START PAGE

Marie Skłodowska-Curie Actions

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PART B

JENNIFER2

Table of Contents

2. Excellence

2.1 Quality and credibility of the research/innovation action; level of novelty and appropriate consideration of inter/multidisciplinary, intersectoral and gender aspects

The JENNIFER2 project aims to produce synergy and knowledge sharing among experimental particle physics groups searching for signal of new physics in neutrino and flavour physics, exploiting the discovery potentialities of experimental facilities located in Japan.

The Standard Model of elementary particles has been very successful in explaining a wide variety of existing experimental data. However, in spite of its tremendous success, the SM does not answer several fundamental questions, which require to be investigated with various complementary approaches, using different "messenger" particles. The flavour sector of quarks and leptons is a privileged field to look for the presence of new physics effects, by profiting from a closer collaboration among different experimental communities. Moreover, neutrino physics requires the use of very large volume detectors, which can both be used for accelerator produced neutrinos and for cosmic one, creating another stimulating synergy.

In the first place, SM currently does not provide any candidate for the dark matter that is responsible for about 90% of the gravitationally interacting mass of the universe in the Standard Cosmological Model, but that we have not directly detected so far. Secondly, from a cosmological viewpoint, there is a serious problem with the matter-antimatter asymmetry in the universe. While CP violation is one of the conditions for the evolution of a matter dominated universe [1], according to baryogenesis models (for a review, see [2]), the magnitude of the asymmetry cannot be explained solely by the CP violation within the Standard Model, which originates from the quark mixing. However, experimental data have already shown that neutrinos are not massless, as assumed in the SM, and that they mix as suggested in the Pontecorvo-Maki-Nakagawa-Sakata (PMNS) model [3,4]. They should then have at least one CP violating phase, expected on general grounds different from zero, which may help explaining matter-antimatter asymmetry.

Moreover, the SM does not explain the characteristic pattern of the mass spectrum of quarks and leptons. The second generation of quarks and leptons is several orders of magnitude heavier than the corresponding first generation particles, and the third generation is even heavier by another order of magnitude. The quark flavour mixing matrix - the Cabibbo-Kobayashi-Maskawa (CKM) matrix - also has a striking hierarchical structure, i.e. the diagonal terms are close to unity and $1 \ll \theta_{12} \ll \theta_{23} \ll \theta_{13}$, where θ_{ij} denotes a mixing angle between the i-th and j-th generation. Interestingly, the observation of neutrino oscillations implies that the neutrino sectors has a very different structure, $\theta_{13} \ll \theta_{12} \approx \theta_{23} \approx 1$. All of these masses and mixings are free parameters in the Standard Model, but ideally they should be explained by higher scale theories.

JENNIFER2 project aims to investigate such fascinating scenarios, both by an aggressive program of data mining at Belle II and T2K and by developing innovative particle detectors to meet even more challenging performance requirements for present and future experiments. The knowledge exchange among the Belle II, T2K and HyperK scientific communities, started by the JENNIFER project, already produced some new ideas towards more performant detectors and techniques. JENNIFER2 will allow to realize part of them, via the upgrade of T2K experiment with a new near detector, and to continue developing many other techniques in a very synergic way. Photon detection plays a special role in all experimental applications and JENNIFER2 will provide an invaluable space to coordinate and contaminate few challenging developments in this field, while techniques related to computing, data acquisition, statistical methods and theory-experiment interface will be for the first time jointly addressed by the collider and neutrino communities.

2.1.1 Physics at Belle II

a) The Belle II detector optimization at SuperKEKB collider

The Belle II detector at the KEK laboratory in Tsukuba, Japan, is a major upgrade of Belle, built by a multi-national collaboration of about 800 physicists and engineers from about 100 institutions worldwide. Compared to Belle, the Belle II detector will record data at SuperKEKB with a 40 times higher luminosity, and thus has to operate at 40 times higher event rates, as well as background rates higher by a factor of 10 to 20 [6]. To meet these challenges, Belle II detector has a new silicon vertex detector (VXD), a new central tracking chamber (CDC), a completely new particle identification detector in barrel (TOP) and forward (ARICH) regions, upgraded electromagnetic (ECL) and hadron (KLM) calorimeters and a new trigger and data acquisition system. Data reconstruction software has been also upgraded. Such beautiful detector will be exposed to SuperKEKB collisions for the first time in April 2018 and physics data taking is scheduled to start in early 2019. A major effort is required to study and optimize the performance of the new device on real data in terms of track and vertex resolution, energy resolution, photon detection efficiency, particle identification power. Each sub-detector has to be studied both by itself and in combination with the others, thus requiring the collaboration of all sub-detector experts from different groups. A large number of Belle II collaborators will spend significant time at the KEK lab in Japan to operate Belle II and its sub-detectors, debug hard- and software problems and understand the performance of the devices. This is a prerequisite for any physics research with the Belle II data.

b) Measurement of CP violating processes and rare decays

We measure the angles and sides in the CKM unitarity triangle, still statistically limited. Only four real parameters describe all quark flavor and CP violating phenomena in the SM. This is thus a natural place for searching for New Physics contributions. One important goal of Belle II is to resolve the experimental status of the CKM matrix element magnitude |Vub|, which measures one side of the unitarity triangle. Existing B factory measurements using semileptonic B decays lead to |Vub| determinations which are at odds by about three standard deviations [7]. Another important parameter is the CKM angle gamma, which is cleanly determined from the interference of different weak and strong phases contributing to $B \to D(*) K(*)$.

Beyond CKM physics, flavor-changing neutral current (FCNC) processes $b \to s$ and $b \to d$ are of great importance for the search for physics beyond the SM. The FCNC processes are sensitive to physics beyond the SM via higher order contributions. The Belle II physics program in this area will encompass the study of processes such as inclusive $B \to X_{s,d}\, \gamma$ and $B \to X_{s,d}\, l^+ l^-$ channels, as well as rare decays involving photons or neutrinos like $B_{d,s} \to \gamma\gamma$, $B \to K(*)\nu\nu$, $B_{d,s} \to \tau^+\tau^-$ and $B \to K(*)\tau^+\tau^-$. In particular, Belle II can perform fully inclusive measurements of these decays which are less affected by theoretical uncertainties like exclusive ones.

c) Search for violations of lepton universality and lepton flavour number

Large rates of $B \to D^{(*)}\tau\nu$ have been observed by the BaBar, Belle and LHCb experiments [7]: The combined deviation of the parameters R_D and R_{D*} (where $R_{D(*)}$ is the ratio of the rates of the semitauonic decay to the corresponding semileptonic decay) with respect to the SM expectation is larger than three standard deviations, make this one of the most intriguing anomalies in flavor physics today. Belle II, using its large data sample, will be able to confirm current indications for lepton non-universality by improving the $B \to D^{(*)}\tau\nu$ rate measurement (R_D, R_{D*}), and by measuring the τ and D^* polarizations and the di-lepton q^2 distribution. A similar experimental techniques can be used to search for flavor universality on missing energy modes like leptonic decays and exclusive $b \to u$ semileptonic decay such as $B \to \pi\tau\nu$ or inclusive $B \to X_c\tau\nu$.

Belle II allow also to follow up hints for lepton non-universality observed by the LHCb experiment in the FCNC decay $B \to K^{(*)} l^+ l^-$ in the parameter $R_{K(*)} = Br(B \to K^{(*)}\mu^+\mu^-)/Br(B \to K^{(*)}e^+e^-)$ and probe the full $q^2 = (p_{l+} + p_{l-})^2$ region. Belle II also allows to study lepton universality in the inclusive mode $B \to X_s\, l^+ l^-$. Lepton Flavour Violation can be tested in Belle II with a variety of experimentally decay modes like $\tau \to e/\mu\,\gamma$, $3e$, 3μ. Current limits are statistically limited and could be improved up to two orders of magnitude.

d) Dark photon searches

In recent years the possibility that both DM and the particles mediating its interactions to the SM have a mass at or below the GeV-scale has gained much attraction among theorists. The direct detection of sub-GeV DM particles is hampered by small energy depositions and finite detector thresholds, making high intensity, low-energy colliders such as SuperKEKB a competitive environment to explore sub-GeV DM physics.

DM scenarios involving a so called “dark photon” and including a number of other Z-like or Higgs-like particles, can be probed by searching for the production of such particles either in scattering processes or in the decays of Y mesons. Limits on exotic processes including axions and WIMPS can also be improved. All such events require hermeticity and excellent control of machine and accidental backgrounds. Dedicated triggers will be available already during the early running of Belle II that will allow to collect events with a single photon in the final state. The better hermeticity of the Belle II detector compared to previous experiments makes these searches competitive even on smaller datasets. With the final dataset the sensitivity of existing limits can be improved by an order of magnitude since these searches are generally not limited by systematics.

e) Quarkonium spectroscopy

Quarkonium is a bound state of a heavy quark and a heavy antiquark, *i.e.*, a bound state of the type cc, bb or bc. At Belle and other experiments “quarkonium-like” bound states, referred to as X, Y and Z, have been observed which likely involve more degrees of freedom besides the heavy quark and the heavy antiquark. While some of these new states could clearly be linked to charmonium or bottomonium, for others an exotic explanation is most likely. For others still the nature and the experimental evidence is still unclear and more data is desperately needed to settle the experimental situation. Quarkonium is a system of great physical interest in general and of great interest for the Belle experiment in particular: the most cited paper of the Belle collaboration reports the first observation of an exotic quarkonium candidate (the famous X(3872)).

Belle II will perform quarkonium spectroscopy and search for quarkonium-like states by searching for missing quarkonia and for expected partners of exotic states, by looking for new decay channels of known states, and by detailed measurements of all accessible properties, including spin-parities, absolute branching fractions, line-shapes, and so on. Experimentally, quarkonium spectroscopy can be performed in B decays as well as in ISR and two-photon processes.

2.1.2 Neutrino Physics at T2K

In 1998 the Super-Kamiokande (SK) experiment, analysing atmospheric neutrino data, for the first time gave experimental evidence to the oscillation phenomena postulated by Pontecorvo, Maki, Nakagawa, and Sakata [8]. The same result was confirmed a few years later by the first LBL (Long BaseLine) experiment in the world, named K2K [9] (KEK-to-Kamioka), comparing the "un-oscillated" beam close the source with a Near Detector to the "oscillated" one 300 kilometres away with SK. T2K [10] (Tokai-to-Kamioka) is a second generation LBL neutrino oscillation experiment where a much larger statistic is insured by producing the beam from a MW-class proton synchrotron at the J-PARC-KEK complex in Tokai. In addition, it is the first LBL experiment using the off-axis technique: the near detector complex, at 280 meters from the target (ND280), and the far detector (SK) intercept the beam at 2.5 degrees with respect to its axis; this angle is tuned for a beam energy peaked at 600 MeV, where effect of neutrino oscillation is maximal for the given SK-Tokai distance.

T2K started taking data in 2010. Already in summer 2013 T2K announced the discovery of $\nu_\mu \rightarrow \nu_e$ appearance with a significance of $7.3\boldsymbol{\sigma}$ [11]. This historical result, awarded with the "Breakthrough Prize" in 2015, opened the possibility for T2K to measure the CP-violating phase by comparing oscillations of neutrinos to those of antineutrinos. Observing CP-violation in the lepton sector would be a crucial input towards understanding the matter-antimatter asymmetry of the universe.

A joint analysis of the $\nu_\mu \rightarrow \nu_e$ appearance and ν_μ disappearance channels allowed to place the first significant constraints on δ_{CP} in 2015 [12][13]: combined with information from other experiments, the relatively large signal of $\nu_\mu \rightarrow \nu_e$ observed at T2K may be a hint of pronounced CP-violating effects that enhance this transition while suppressing the corresponding process in antineutrinos. T2K is now strengthening these first indications by planning for an extended running to collect a total statistic of 20 × 1021 POT [14], and for a dedicated upgrade of the ND280 detector complex [15] to achieve a sizeable reduction of the systematic errors.

T2K Analysis: neutrino cross sections and oscillations

After the discovery of the $\nu_\mu \rightarrow \nu_e$ transition and the hints of leptonic CP violation, the ultimate goal of the T2K neutrino oscillation analysis is to achieve $3\boldsymbol{\sigma}$ significance on the evidence of CP violation. To exploit the full potential of T2K at the expected larger statistics, the budget of systematic errors has to be tightened. Through the addition of new samples and a better understanding of neutrino cross-sections, the constraint given by the near detector measurements will reduce the uncertainty on the expected number of events at the far detector, which is the largest contribution to the present systematic error.

T2K is pursuing a complete program of cross-section measurements of different interaction channels, on different targets (C, O, Fe), for different neutrino species and at different energies (on-axis and off-axis fluxes) with the Near Detector complex. The collaboration is focused on producing cross-section measurements in an as model-independent way as possible and is working closely with theorists and the neutrino interaction Monte Carlo generator groups to ensure these data can be used effectively. One typical example is the so called 2 particle - 2 holes (2p-2h) effect, dominated by the meson exchange current (MEC) where 2 nucleons of relatively low momentum are emitted in a compact volume around the interaction vertex, and are typically difficult to identify. The experimental evidence collected so far for these nuclear effects does not allow yet to distinguish between different theoretical models. This requires higher statistic data with increased acceptance in order to extract cross-sections, to be compared with Monte Carlo implementation of the models.

The availability of additional data in the next years will help reducing uncertainties on the cross-section ratio ν_e/ν_μ and the anti-neutrino ones are a primary source of systematics on the measurement of CP violation.

At the same time, the event selection and the evaluation of the detector systematics at the far SK detector is undergoing important optimizations. In future analyses, many of the signal ν_e events can be recovered by including pion production channels, and additional ones can be selected by extending the current fiducial volume definition. Some of these developments will be enabled by a new reconstruction algorithm with better vertex and kinematics resolution and enhanced multi-ring identification capabilities. The combined impact of all the improvements can increase the efficiency of the T2K CCν_e event selection by as much as 40%.

The evolution will further accelerate starting with the year 2019 when Gd salts will be gradually added to the water target. Dissolving $Gd_2(SO4)_3$ into the SK water to improve its ability to detect neutrons is the focus of the SK-Gd. From the point of view of the oscillation analysis, the increased neutron sensitivity will enable better separation of neutrino from antineutrino interactions, since the latter produce more neutrons on average, and can therefore be utilized to improve T2K's sensitivity to CP violation. The impact on detector systematic uncertainties and, therefore, on the oscillation analysis cannot be underestimated and will require a considerable effort to extract the maximum benefit.

T2K upgrades: detector design and construction

Facing the potential increase of statistics by two orders of magnitude, the near detector upgrades aim at reducing the statistical and systematic uncertainties at the appropriate level of 3-4% or less on the prediction of appearance signals in the far detector.

The current Near Detector [10] has two main limitations. First, the acceptance for events selected by requiring a lepton in the TPC [16] downstream of an FGD [17] is peaked in the forward region and drops considerably at an angle above ~40 degrees w.r.t. the beam direction. At the far Super-Kamiokande [18] detector instead, the efficiency is completely flat due to the uniformity of the large water Cherenkov. This acceptance mismatch increases the dependency from nuclear cross-section models when extrapolating the spectra from the near to the far detector. The second limitation lies in the poor efficiency of the present Near Detector in selecting electron neutrino interactions below 1 GeV.

The design goals for the upgraded Near Detector are therefore: extend to the full polar angle the momentum resolution, dE/dx and charge identification capabilities of the current ND280; increase the efficiency of the active target to identify specific topologies, with high-efficiency tracking in the full solid angle for low-energy pions and protons contained in the target itself.

The main modification of ND280 is the planned removal of the current P0D detector, replaced by a sandwich of ~ 2t high-granularity scintillator target in between two high-angle TPCs, one above and one below. The new active target will provide better efficiency for topologies with low-energy secondaries, while the new TPCs will provide the required acceptance, particle identification and spectrum measurement for large-angle tracks.

The performance of the present TPCs is deemed sufficient in terms of position (800µm), dP/p (10%) and dE/dx (8%) resolution, but their acceptance not. Two modification will be introduced for the new ones: to maximize the acceptance the field-cage will have a single-wall configuration, very much like the design of the ILC-TPC [19], and the MicroMegas (MM) detectors will be constructed with the "resistive bulk" technique [21].

The main challenge of the field-cage is combining in one single envelope the contrasting requirements of low material budget (a few % of a radiation length), extreme rigidity (needed to limit electric field distortions at the level of 10-4), with gas tightness to limit contaminants to a few ppm. The most promising design option is the use of a composite structure of honeycomb panels and G10 or Carbon Fiber skins, which according to simulations will guarantee a deformation < 100µm under the action of gravity and at a few mbar overpressure.

In the new MMs a resistive layer covering the pads acts like a 2D RC network, spreading the avalanche charge between pads, so to obtain a wider Pad Response Function. In addition, it has quenching properties against sparking, therefore no protection diodes will be necessary.

The digitization electronics will still be based on the original AFTER chip [22]. With resistive MMs the readout will be simplified: the number of channels per MM module will be reduced compared to the present TPC thanks to the wider Pad Response function, and the absence of protection diodes will reduce the number of passive components.

The Super-FGD (Fine Grained Detector) is a next-generation active scintillator neutrino target, able to determine the topology around the interaction vertex. Its acceptance will match the one of the new TPCs, and it has a much better capability compared to present FGDs to reconstruct low energy hadrons emerging from the vertex. The dimensions will 1.8m (width) x 2.0m (length) x 0.6m (height).

The SuperFGD will be composed by small cubes of extruded plastic scintillator, read out along the 3 orthogonal directions by WLS fibers [23]. the cube size is 1x1x1 cm^3, for a total of more than 2 million cubes. Cross-talk between cubes is avoided by a ~50µm-thick reflector, obtained by chemically etching the surface. Each cube is drilled by 3 orthogonal holes where WLS fibers are inserted. Each fiber is read out by a Multi-Pixel Photon Counter (MPPC) located on the outer surfaces of the detector. The small size of the individual active cells and the 3D projective geometry of the readout promise better efficiency in locating the vertex and detecting short low-energy tracks.

The mechanics and integration will be a challenge for the SuperFGD. To avoid surface damage to the thin reflector of the cubes and mechanical stresses to the fibers running through them, no glue will be used. In addition, it is mandatory to minimize the amount of material and power dissipation of the front-end electronics sitting in the tiny volume available between the SuperFGD and the TPCs.

2.1.3 Towards the Hyper-Kamiokande Detector

The Hyper-Kamiokande [24] experiment is the next generation, state-of-the-art flagship experiment targeting a broad physics program consisting of neutrino oscillations, nucleon decays, and astrophysical neutrinos with unprecedented precision. Hyper-Kamiokande will be the third-generation underground water Cherenkov detector in Japan following on from the Kamiokande and Super-Kamiokande experiments whose discoveries were awarded the 2002 and 2015 Nobel Prize, respectively. This project is also perfectly aligned with the European Strategy [25] which recognises the importance of Hyper-Kamiokande.

Recently, we were invited to join the Super-Kamiokande collaboration. This allows the European institutions to gain direct expertise on a system that serves as an underlying base for the Hyper-Kamiokande detector, as well as gain access to all the data collected by Super-Kamiokande. This includes non-beam data, like atmospherics, solar and supernova neutrinos and proton decays events, as well as the calibration dataset. Furthermore, we will test our calibration prototypes in a realistic environment.

Furthermore, in Summer 2018 the Super-Kamiokande detector will be refurbished and subsequently doped with gadolinium. This will open up new opportunities for the experiment to which we aim to contribute as well as will new operational challenges as the water properties need to be monitored very closely and must not degrade. The tank opening also offers a unique opportunity to install new calibration sources.

Within Hyper-Kamiokande we are working in several crucial areas: the calibration, Outer Detector (OD), electronics and simulation all described in this workpackage. Furthermore, we are also working on a multi-photosensor system (WP4), DAQ and computing (WP5) in synergy with Belle II.

a) Study of a gadolinium-doped water Cherenkov detector

Our groups started working on the refurbishment of Super-Kamiokande. With JENNIFER2 we will focus on the operations of the Gd-doped detector. A detailed monitoring and analysis of the data is required to check the water properties once the gadolinium has been added, as well as checking that the performance of the detector improved for the analyses.

We are working on an optical method using hard ultraviolet light (UV) to measure the gadolinium concentration in water. Initial coarse testing on water samples containing various concentrations of Gd have been undertaken and have shown that an optical method can be used to determine the concentration to ~50% in 1cm water sample. A confirmation of this result with higher accuracy is planned, with the intention to scale up the apparatus using ~1m of water length if successful. This scaled version aims to measure the concentration to the desired 1% level. This new method will be tested in Kamioka before being deployed in the Super-Kamiokande detector. The development of this new device will provide a new automatic way to test the gadolinium concentration now being based on a test of collected water samples from the tank. A close coordination with the Japanese team is required for the development, construction, testing and deployment.

Furthemore, 50 new PMTs of the same type planned for Hyper-Kamiokande will be installed in Super-Kamiokande. We plan to work on the characterization of these new PMTs. This is particularly crucial for Hyper-Kamiokande for a test of the proposed PMTs in real conditions.

b) Development of a calibration system for a water Cherenkov detector

In T2K uncertainties in the understanding of the detector response contribute to up to 4% to the ν_e appearance and ν_μ disappearance overall systematic uncertainty. To meet the Hyper-Kamiokande physics goals, it is necessary to significantly reduce these uncertainties to the sub 2% level. Additionally, with recent progress made with the addition of Gd to water Cherenkov detectors the possibility of Gd loading of Hyper-Kamiokande will require further effort to maintain systematic uncertainties. The baseline design of Hyper-Kamiokande [26] foresees implementation of a calibration system based on Super-Kamiokande with improvements in both hardware and analysis to meet the systematic requirements.

We are developing a calibration system that injects light pulses of known emission time and intensity at several visible wavelengths into the detector using fibre coupled solid state devices such as LEDs or laser diodes as a light source. This allows us to calibrate and monitor the photodetector response and the detector medium properties. The light pulses are propagated through optical fibres from easily accessible electronics racks to fixed injection points on the detector's inside surfaces. The same system can also monitor the optical properties of the water, both attenuation and scattering. To improve calibration techniques and analysis developed for Hyper-Kamiokande we have joined the Super-Kamiokande calibration group and are now working on a prototype to be installed in Summer 2018. Thereafter, we will commission and analyse the data and make improvements towards the design of the Hyper-Kamiokande system..

The deployment of Gd to the detectors provides further analysis power via neutron detection, however this then requires that the neutron response of the detector be measured and monitored. Encapsulated neutron sources can be used to do this. We propose to examine this option and assess its feasibility, based on the required precision for Hyper-Kamiokande and the intermediate detectors.

c) Hyper-Kamiokande outer detector

The Hyper-Kamiokande Outer Detector (OD) consists of PMTs lying in the crown of the detector, but facing outwards. The OD is an essential element of Hyper-Kamiokande that will serve as a highly granular instrument for identifying and removing background events. Its aim is to reject the external background, i.e. to detect interactions originating from particles outside of the detector. The external background includes low radioactive events and low energy gamma as well as cosmic muons. The radioactive background comes from several sources including the rock surrounding the detector. The cosmic muons can pass through the detector, leaving a signal in the OD at their entry and exit point, or decay during their journey, and then leave only one signature in the OD. The dimension of the water thickness of the OD takes into account the size of the gamma-induced electromagnetic showers to reduce the contamination inside the inner-segment part. This work requires close coordination between the PMT, tank design and physics work. The tank design is specifically a Japanese responsibility and with whom we need to be in constant contact.

The OD's design and PMTs are subject to an optimization that takes into account the required signal identification efficiencies, background rejection power, and cost. The project described in this proposal aims at achieving the best design for the OD by addressing three main items: an original geometrical setup, improved PMT performance and the best trigger system to reject external background.

d) Design of a low noise front end electronics for large area photodetectors

Among key aspects of the studies towards Hyper-K is development of reliable readout electronics for acquiring signals from more than 20,000 Hyper-K photomultipliers. One of considered options is based on the established waveform digitizing technology (WFD), which consists in recording full the pulses from various detectors and later on applying algorithms for timing and charge estimation.

We are currently considering two options for waveform digitization – one based on a Flash-ADCs coupled with anti-aliasing filters (A.Rychter, NCBJ/WUT), the other on switched capacitor arrays (A. Bravar, Uni Geneva). A third option is based on more conventional electronics, based on a further developments of existing Super-K readout electronics (U. of Tokyo).

The major requirement of the acquisition electronics is limitation of dissipated power, which is necessary in order to ensure proper circulation of water within the tank. Initial studies showed that we may be able to achieve required performance by using a 100 MSPS ADC coupled with proper anti-aliasing filter. Another way of lowering power consumption is by using circular switched capacitor arrays (SCA). Since they store sampled waveforms in analog form, fast sampling can be achieved and then a slower and less power hungry ADC can be used for digitizing them.

While it is envisaged that the prototypes of both types of waveform digitizing electronics will be developed in Europe (both UGE and NCBJ/WUT have significant experience in front-end electronics), it will be necessary to test them with actual photosensors, in close to final conditions. Both the photosensors and the infrastructure is in Japan, so it will be necessary to make these tests there.

e) Hyper-Kamiokande simulation

The simulation of the detector needs to follow the development of the design to provide a tool to describe the impact of the design on the physics. Accurate and detailed simulations of the detector response are also essential in optimising the physics reach of Hyper-K, and we propose to provide key elements to the Monte Carlo package for low energy event simulation and analysis. We will use our existing experience and expertise to make a series of improvements to the accuracy of existing simulation software and to increase the accuracy and efficiency of reconstruction algorithms. The main improvements envisaged are a full implementation of the trigger algorithms, and improved simulation of Gd neutron captures in the Hyper-Kamiokande simulation package, WCSim, developed by the Hyper-Kamiokande collaboration. Recently, the handling of Gd within the simulation has been upgraded, but further data driven improvements are envisaged. Building on this work, we will also optimise the reconstruction capabilities for neutrons, within the WCSim. Existing reconstruction algorithms will be investigated and adapted as required and new tagging algorithms will be developed.

2.1.4 Development of innovative photodetectors

Photon detection is a key element in experimental particle physics, in particular is essential to detect light produced by the Cherenkov effect, which can be used either for particle identification at colliders, either for large volume neutrino detectors. Specialized photosensors and electronics allow to deal with high radiation environments, low threshold application and wide energy range requirements. Such devices are continuously evolving and their performances are continuously improving to meet the application requirements. JENNIFER2 activities in this field will cover the following lines:

a) Silicon photomultipliers (SiPMs) as single photon counters in neutron irradiated areas

In Cherenkov Ring Imaging detectors (RICH), it is crucial to detect single photons with high efficiency and with a good position resolution. State of the art vacuum based single photon sensors are still both expensive and complex to operate, and have limited use in the high magnetic fields of high energy particle spectrometers. We have demonstrated that SiPMs can replace them. Their use is however limited due to their sensitivity to neutron irradiation. To use them in such environments several measures will be implemented: we will use smaller SiPMs to reduce the radiation sensitive volumeand light collectors to adjust the collection and detection area employed. NUV-HD SiPM technology with reduced optical crosstalk will be used to build a SiPM photo sensor module for aerogel Ring Imaging Detector of Belle II and test it in an operational environment. The task requires close collaboration and knowledge transfer between different partners: FBK has the expertise in simulation, design, fabrication and characterization of single SiPMs, JSI as one of the leading European centers for the development of the Cherenkov detectors and our Japanese partner KEK with expertise in integration of the detectors in the operational environment and data analysis.

b) Development of long-lived microchannel-plate photomultiplierss (MCP-PMT)

The Time-Of-Propagation (TOP) detector of the Belle II spectrometer separates charged hadrons by measuring the arrival time of Cherenkov photons emitted in the quartz plate with a time resolution better than 50ps. Single photons are detected by state of the art MCP-PMTs with excellent single photon timing resolution. Unfortunately, their lifetime is limited due to photocathode quantum efficiency degradation by gas or positive ions desorbed from the MCP layer. The collaboration with Hamamatsu Photonics has increased the lifetime from a fraction of C/cm2 to more than 10 C/cm2 in three steps: by protecting the photocathode from the ion return by using ceramic and aluminum layers, by reducing the gas emission from MCP with an atomic layer deposition (ALD) on the surface of each micro channels and by improving the production processes to reduce the quantity of the residual gas and ions inside MCP's. Further increase of the lifetime is planned by identifying the ions mainly responsible for the photocathode degradation to obtain a new generation of ALD MCP-PMT with a more uniform and higher lifetime. Different ions can be discriminated with the delay time of secondary electronic signals. The objective of this task is a further improvement of the production processes targeted to specific ions with the aim to obtain a new generation of ALD MCP-PMT with a more uniform and higher lifetime. All the parties involved in this task have long and complementary expertise required to achieve the proposed objectives.

c) Development of multi PMTs for a large water Cherenkov detector

The concept of an optical module with a 20 to 40cm PMT housed in a vessel has been developed the past decades for neutrino telescopes in water and ice (DUMAND, Baikal, NESTOR@, ANTARES, AMANDA and IceCube). However KM3Net experiment, the km3 neutrino observatory in the Mediterranean, has explored the idea of replacing a single large area phototube by several PMTs packed in a glass pressure vessel. This helps to distinguish single from multi-photon hits in coincident signals from neighbouring PMTs. The increased granularity and directionality could also improve the reconstruction performance and the much lower sensitivity of the smaller pmT to the Earth's magnetic field makes magnetic shielding unnecessary. The baseline design of a Hyper-K mPMT would replace each 50 cm PMT by 33 7.7 cm PMTs in a half sphere with a radius of about 26 cm. The front-end electronics will be situated inside the modules near the PMTs which need to be pressure tolerant, water-tight and use water-tight connectors. The vessel will be fabricated in acrylic, due the unwanted contamination from K40 present in glass and quartz. This will require a deep study of the acrylic performances in terms of pressure resistance and stability against water absorption.

d) Organic photodetectors

The materials used for radiation detection today are mainly semiconductors and scintillators. In the early 1980s conjugated polymers were first suggested for radiation detection. During the last years within the EOS project (funded by Italian Ministry for Research in 2014) already organic transistors have been developed and used in elementary digital and analog cells, exploiting different conjugated perilene-based polymers. Recently also phototransistors have been developed [27], based on organic photoactive materials, combining tunable light absorption with low-temperature processability over large areas on flexible substrates. These devices have a typical sandwich structure, where the organic polymers play the role of the semi-conductor, and they are good potential candidates for dosimetry and scintillation detectors. Through studying photo-absorption and luminescence of organic semiconductors and enhancing the photon sensitivity of such devices through: (i) the use the phototransistor in an indirect detector where an element of the sandwich-like structure can be a photo-sensitive material; (ii) direct light detection where the organic polymer used is blended with a different material; an integration of front-end organic electronic circuits on the detector to process the information can be achieved, leading us towards break-through inventions of unique devices with detection and processing properties. Such long term R&D activity started from the expertise developed inside the on-going JENNIFER project, and is strongly supported by our Japanese partners which will implement 2 secondments of Japanese expert in European labs.

The networking between all the above photon detection tasks will be organized via a common workshop and during common session during the project annual meeting. In addition we will organize a training activity for PhD students and postdocs on the conference New developments in Photodetection (NPID) 2020.

2.1.5 Computing and other common tools

a) Cloud computing and data handling

The computing models of Belle II, T2K and HK experiments are at different design and operational stages but they have to face a variety of common problems to manage computational and storage resources, monitor the network and develop software. Each of the three collaborations has to manage a huge amount of data, which have to be made available to scientific communities spread worldwide. Moreover, large computing power is needed to reconstruct physics events in large detectors, with millions of readout channels, and to look for rare signals in a background dominated environment.
For each topic a set of technologies will be examined together.
Computing: DIRAC is a general framework for the management of jobs and resources over distributed heterogeneous computing environments. It will be one of the main common component used by the three experiments. During our activities want to share information and idea about the usage of this framework for production and analysis, in particular we want converge on a set of common technologies to take advantage from resources provided via Cloud interface.
Storage: Data Management represent a hot topic for the three experiments. We plan to converge on a set of common interfaces for data access and data replication, even doing joint test of data access and data transfer. Grid storage with SRM, Http and S3 are three of the candidate protocols, while FTS will be exanimate as possible common tools for data transfer and data replication.
Software: Code development and distribution overs sites are two common topics. We plan to share know how, best practise and procedure for the usage of distributed version control system for software development like GIT. Then we will share idea about directory organization and general usage of CVMFS, a software to replicate code in Grid and Cloud resources.
Network: The three experiments will run over a high latency network-connecting sites from three different continents. We want to define a common way to monitor the main parameters of the network infrastructure, measure performances and increase reliability via the early identification of fault and network degradation.
We plan to evaluate the possibility to share a mesh of servers based of PERFSONAR Tool kit, sharing the ones implemented in the common sites, and creating the respective maps of the network of different experiments.

b) Online data acquisition and remote controls

Both Belle II and HyperK Data Acquisition requirements are very similar to those of other leading experiments at the intensity frontier. In particular the search for rare processes require very high trigger rates.
Belle II data taking is designed for trigger rates of 30 kHz, which is a factor >50 larger than in the former Belle experiment. The High Level Trigger acceptance rate is planned to be 10 kHz. A DAQ upgrade at Belle II is now being discussed, with the aim of increasing the HLT accept rate to open up the window for possible detection of new physics.
The HyperK DAQ and trigger system, presently under construction using ToolDAQ, has single rates of photomultiplier tube (PMT) dark noise of more than 10 kHz for each of the 40,000 PMTs. The use of sophisticated algorithms will lower this to trigger rate of between ~10-40kHz depending on the algorithm, where low energy running (e.g. solar neutrinos, supernovae), will dominate these random coincidences.
These systems and possible upgrades, require:
(i) new hardware technologies for high bandwidth data transfer, in particular optical technologies up to 16.3 Gbps on newest generation FPGAs, or 10 Gbps ethernet.
(ii) precise timing distribution in the sub-nanosecond regime. Possibly the inclusion of White Rabbit.
(iii) intelligent realtime algorithms for online data reduction.
Belle II uses online tracking on an FPGA for background rejection. Background means on the one hand beam background and physics background e.g. from QED processes. HyperK plans to multiple trigger algorithms including vertexing on trigger level ($t < 10$ ns) on GPUs and large data buffers for supernovas.
(iv) novel programming and DAQ software techniques, such as methods of parallelisation on both FPGAs or GPUs, methods of artificial intelligence for trigger decisions with multiple input parameters, integrated dynamic service discovery, monitoring, fault tolerance, dynamic routing and remote control.
We foresee an active knowledge exchange between the two experiments, in form of combined DAQ technology and trigger workshops, which will be organized either jointly with annual JENNIFER2 general meetings, either in collaboration with Belle II or HyperK DAQ workshops, and at least once in an independent way, during the second half of the project, involving also private sector technology partners.

c) Statistical methods for combinations of experimental results

The reach of many crucial measurements of the T2K and Belle2 programs is severely limited by the small size of the event samples used. In this scenario, completely common for neutrino and quark flavour experiments, the combination of the statistical information from multiple measurements has significant potential to enhance the physics reach over the bare combination of the final results. Past results combination attempts have typically been conducted on an ad-hoc basis and after the individual measurements and their methodological choices and approximations had been consolidated. This results in suboptimal combinations limiting the statistical power of the outcomes.

Each individual measurement typically involves a large number of estimated parameters: the physics parameters of interest and many nuisance parameters correlated with them. While the former can be reasonably cast in an universal experiment-independent format and treated consistently in combinations, the latter are partly universal and partly experiment-dependent. This leads to a variety of possible options for the approximations and approaches needed to include their effect in the combination.

We propose a systematic and consistent plan for obviating the above pitfalls that consists in:

- A survey of the Belle2 and T2K physics topics and specific measurements where inter-experiment combinations (with NOvA, LHCb, etc.) have the potential to lead to significant reach enhancements.
- A survey of past and present combination efforts aimed at forming a global picture of the variance of the approaches adopted, the approximations made, and the possible pitfalls/inconsistencies encountered.
- A unified proposal for: (i) restricting the definition of the relevant physics and nuisance parameters for each measurement to one or few variants; (ii) restricting the approximations associated with the modelling of the interplay between nuisance and physics parameters to a few consistent variants. The proposal will be documented in a report that will serve as a reference for experimental groups willing to combine their results, which will be invited to conform to the selected prescriptions.

A possible development of such work could be the set up a software framework (e.g., a data base) explicitly suited and optimized for (i) accepting as inputs the values of multivariate likelihoods from each individual measurement and (ii) operating consistently the combination (likelihood multiplication) taking properly into account the commonalities between physics and global nuisance parameters and treating coherently experiment-dependent nuisance parameters. If successful, this work will enhance the physics reach of the single experiments both in neutrino and quark flavour physics.

d) Event generators and phenomenology

The SuperKEKB will start the operation in early March 2018 and a large amount of new data will be available. In 2018, also Belle II is expected to start operating. The B2TiP report, produced during the JENNIFER project, has proposed various new measurements in order to deepen our understanding of the SM and the beyond. To further clarify their theoretical meaning and their proper implementation, a new series of B2TiP workshops will start in 2019, providing lectures by theorists and open discussions with experimentalists. Moreover, the first workshop is going to be integrated in the Belle II Physics Week where tutorials of statistical tools and data-challenges (to search for hidden “odd” event in the Monte Carlo data) will happen. In this context, JENNIFER2 secondments will allow close collaborations between the different Belle II physics analysis groups and theorists, allowing to improve the tools and the Monte Carlo generators for specific channels.

In parallel, the same theoretical physicists will collaborate with T2K experiment to extend its physics case, to clarify the complete reach of the upgraded experiment and to define in details the experimental program of the HyperK project. The KEK theory group will actively participate to this process and will host lectures, discussions, Q&A, tutorials. Specific care will be dedicated to identify and discuss the various physics issues and analysis problems, which are common to Belle II and T2K.

In the second half of the JENNIFER2 project a large workshop will be organized, involving Belle II, T2K and HyperK physicists together with theoretical physicists to address and clarify all such common issues and problems. Proceeding of the workshop will be a reference document for future data analysis. Moreover, the same subjects will be an essential part of the training program of the Summer School that JENNIFER2 will organize at KEK for European master students in physics (see section 3.4). Communication of such physics via JENNIFER2 outreach activities will be also implemented.

Table B1 – Work Package (WP) List

Work Package No	Work Package Title	Activity Type	Number of person-months involved	Beneficiary leading	Start Month	End month
1	Search for New Physics signals at Belle II	Research, Training, Dissemination, Management	220	OEAW-HEPHY	1	48

2	T2K physics and upgrade	Research, Training, Dissemination	137	INFN	1	48
3	Towards Hyper-Kamiokande detector	Research, Training, Dissemination	85	QMUL	1	48
4	New Photodetectors development	Research, Training, Dissemination	34	JSI	1	48
5	Computing and common techniques	Research, Training, Dissemination	56	CEA	1	48
6	Communication and Outreach	Communication, Training	0	UKP	1	48
7	Management of the Project	Management	0	INFN	1	48

2.1.6 Summary of the multi-disciplinary and inter-sectorial aspects

Many of the JENNIFER2 research activities imply interactions with different disciplines and/or with industrial applications, due to the fact that particle physics research often requires to use frontier technologies to improve the experimental sensitivity. Direct collaboration with scientists and technology experts from different disciplines is a standard practice to develop best detector design and implementation.

The upgrade of the T2K near detector requires to apply advanced techniques and original solutions in mechanical and electronic engineers, to guarantee rigidity, stability and low power dissipation for a very light material detector.

Physics data analysis often implies the development of efficient algorithms which implement computational science expertise and sometime exploit machine learning techniques.

Gadolinium doping of the SuperKamiokande water Cherenkov requires advanced competences in nuclear chemistry to check the purity and reduce contamination of the compound. Precise measurements will be performed in some European underground laboratories (Gran Sasso, Canfranc, Boulby), where environmental and cosmic background are very low.

Optimization of hybrid photodetectors requires a strict interplay with solid state physicists and electronics engineers, to develop new production techniques and shapes which may reduce unwanted degradation effects on the devices. On the other hand, the study of organic photo-sensors involves chemists, physicists and engineers: solid state physicists design and simulate the conductivity and light sensing properties of different polymers, chemists synthetize and deliver the selected polymers with the proper purity, physicists and engineers build the final device and characterize it for photon-detection, noise properties and conductivity.

The whole computing activity in JENNIFER2 implements several information technology advanced techniques for farming, networking, data and code management.

Data acquisition and remote controls of the detectors parameters imply collaboration with electronics engineering to develop challenging real time applications and efficient slow control protocols, which often can be considered also for applications in smart devices for health or environment monitoring.

Inter-sectorial aspects come naturally from the above listed connections, which in some cases are already involving collaboration with technology producers. CAEN firm, as member of JENNIFER2, has a privileged role for what concerns electronic engineering applications, in particular for radiation detectors readout and control. On the other hand FBK provides access to key enabling technologies in the field of solid state detectors, which will enhance the innovation capacity of the project.

2.1.7 Gender balanced approach to research activity

The JENNIFER2 consortium is deeply aware of and actively involved in promoting gender balance and equal opportunity policies in the context of its research activities. The still running JENNIFER project during its first 2 years moved from Europe to Japan about 140 researchers, out of which 25% were women, the unbalance being due only to staff composition and not to selection of researchers to be seconded. JENNIFER2 will pay special attention to offer training and research opportunities to women, aiming to reduce in the future such basic staff unbalance. Moreover the proposed exchanges between European and Japanese researchers are of special relevance in this context, in particular to share useful experience and appropriate role models. JENNIFER2 is based on experimental collaborations, Belle II and T2K, where a Diversity Committee is in place, and some of the members are European physicists participating in JENNIFER2. Such Committees aim to monitor diversity in positions of responsibility and career advancement within the collaboration, keeping track of talk demographics, particularly for under-represented minorities and women, with the aim also of mentoring and grooming young researchers from under-represented communities to step into leadership tasks through appointments as sub-group leaders or nominations as deputies. JENNIFER2 will extend these good practices to its activities and coordination roles.

Regular reports on gender balance in JENNIFER2 research activities will be presented at the annual project meetings, where discussions and proposals on specific measures which may guarantee equal opportunities to female researchers will be coordinated. Support to their implementation will be also provided.

2.2 Quality and appropriateness of knowledge sharing among the participating organisations in light of the research and innovation objectives

JENNIFER2 aims at building up a highly efficient network for knowledge sharing, to connect groups and activities across countries, sectors and different kinds of experiments. The main way by which significant two-way transfer of knowledge between the partners of the project will be achieved are the periods of secondments in Japan, which will put both junior and experienced staff from European institutes in excellent position to exchange knowledge and skills, not only with their counterparts in Japan, but also with the other researchers and engineers of the two collaborations.

JENNIFER2 will foster and enhance some of the already existing exchange of information between research teams, both European and Japanese ones, which are holders of very complementary knowledge and technical knowhow. Here is some example:

- Silicon detectors: collaboration between DESY, INFN, HEPHY, UKP, IFJ-PAN and KEK allowed construction of Belle II vertex detector, which will be soon installed and commissioned.
- Particle ID: the collaboration between experts in Cherenkov detectors at KEK, JSI and CNRS has allowed to achieve critical technical progress at Belle II.
- Beam background: the complementary knowledge of KEK, DESY, INFN and CNRS teams in the handling of the SuperKEKB collider environment, has proven to be essential for the success of the project.
- Water Cherenkov: collaboration of INFN, QMUL, NCBJ, IFAE, UGE groups with U-Tokyo for the operation and reconstruction of the large SuperK water Cherenkov has allowed European groups to gain specific experience and to provide important contributions to the R&D for HyperK.
- Photodetectors: strong collaboration with Japanese photodetectors developers and producers is going on for various detector applications, in particular those implemented in Belle II and T2K detectors.
- Computing: data management and reconstruction of both Belle II and T2K data already requires a close collaboration among all Japanese and European involved institutions.
- Data Acquisition: complementary knowledges of experimental environment, trigger and electronics allowed to implement running acquisition systems on Belle II and T2K, which are still continuously updated and monitored.

In this context, WP1, WP2 and WP3, where most of the secondments are planned, will strongly enhance the scientific and technical knowledge sharing among the different groups of each of the two experiments, beyond what can normally be achieved in large international collaborations, especially with the Japanese institutions, including in terms of training for our Early Stage Researchers and junior staff.

At the same time, WP4 and WP5 will enable sharing of important specific knowhow and skills between the two different experimental communities involved in the project. For the latter, existing synergies will be exploited, and new ones will be enabled, to achieve significant cross-fertilization between the involved heavy flavour and neutrino physics communities. This can be expected to stimulate important innovation in the new photodetectors developed as part of the planned upgrades of the detector apparatus, as well as for the state-of-the-art tools for computing, data acquisition, statistics and theory needed by both experimental programmes. Drawing upon the experience with our previous JENNIFER RISE project, pursuing these activities in common in WP4 and WP5 will be an important new dimension of our proposed JENNIFER2 project, significantly boosting the exchanges and knowledge sharing between our two communities, both in Europe and in Japan, beyond what was possible previously.

It is also noteworthy that CAEN, a leading European company, renowned worldwide for its state of the art electronics, has agreed to join our consortium of European and Japanese research institutes and universities, as important contributor to both WP3 and WP4, in the context of the strong competition which exists between the European and Japanese private sector technological companies in this area. Equally noteworthy also the Fondazione Bruno Kessler (FBK), a public research organization with remarkable experience in innovation,

joined the JENNIFER2 consortium to collaborate in photodetectors development. The presence of such qualified members will provide our consortium with rich inter-sectoral knowledge transfer opportunities, at the fore-front of our field, thus enhancing the innovation capability of the project.
Sharing the experiences and approaches of the two experimental communities with respect to communication and outreach is also foreseen through WP6, in the European institutes, and also in Japan, where JENNIFER2 will have the opportunity to contribute to specific actions organised each year by our Japanese partners for the local communities surrounding the KEK and J-PARC laboratories. Moreover, co-supervised PhD students will benefit from an invaluable mixture of competences and approaches which will put them in the condition of making other high quality experiences and boosting their careers.
On the practical side, Belle II, T2K and HyperK collaborations hold several general meetings per year, as well as a few smaller ones focused on technical topics, to review and exchange the achieved scientific and technical progress. We plan to systematically exploit these meetings, by adding dedicated sessions to review and promote the specific activities and goals of JENNIFER2 within each experiment. In addition, once per year, an annual meeting of JENNIFER2 will be organised, with attendance from both communities. These meetings will be important for direct discussions of the progress in the common work packages WP4, WP5 and WP6, complementing the regular exchanges planned within these work packages.

2.3 Quality of the proposed interaction between the participating organisations

The JENNIFER2 consortium is very large compared to the expected size of a RISE project but, as we experienced in the former JENNIFER project, this is a natural consequence of the large variety of problems which have to be afforded in large particle physics experiments. Only by merging the contributions of many different groups, each bringing its own competences with its own background, it is possible to face deeply interconnected issues. Moreover data analysis requires to study a large number of different channels, which needs dedicated studies by many collaborators. Each single partner in the JENNIFER2 consortium is contributing with special competences and, by converse, will profit of the project activities in term of increasing scientific expertise, personnel skills and number of collaborating groups. Here is a non-exhaustive summary of the contributed expertise. Additional description of each partner is given in section 6.
INFN: will participate to all WPs with a wide range of expertise: data reconstruction, simulation, physics analysis, phenomenology, Detector R&D, construction and testing, innovative photon detectors development, computing, remote controls, outreach expertise.
DESY: involved in WP1 and WP5, contributes with silicon detector operation and data reconstruction, data acquisition, reconstruction software, physics analysis and computing.
HEPHY coordinates WP1 where it provides physics analysis and tracking expertise.
CNRS is involved in WP1,WP2,WP5 and provides contribution on particle identification, luminosity measurement, physics analysis, Computing.
JSI is in WP1,WP4 (coordinator) and WP5. Expertise in particle-id, spectroscopy, γ detection, computing.
IFJ-PAN is involved in WP1 and WP2 and contributes to tracking, physics analysis and ND280 construction.
NCBJ is involved in WP2,WP3 and WP4. Expertise in neutrino analysis, electronics and photodetectors.
UKP, TAU and METU are involved in WP1 and will work on physics analysis and data reconstruction.
IFAE is involved in WP2 and WP3. Provides expertise in neutrino analysis and gaseous detector construction.
UGE is involved in WP2,WP3 and WP4. Provide expertise in detector electronics and neutrino analysis.
CEA is involved in WP2 and WP5 (coordinator). Provides expertise in advanced data analysis techniques.
QMUL is involved in WP2, WP3 (coordinator) and WP5. Provides expertise in detector calibration systems, data acquisition, computing, photodetectors.
STFC-RAL is involved in WP2,WP3 and WP5. Provides expertise in data acquisition and readout electronics.
CAEN is involved in WP3 and WP4. Provides technical expertise in electronic engineering.
FBK is involved in WP4 and hold expertise in photodetector design and construction.
KEK is involved in all WP and holds top level competences in all fields addressed by JENNIFER2.
U-Tokyo is involved in WP3 and WP4. Holds profound knowledge of the SuperK detector.

2.3.2 Networking activities

First, natural, networking events will be the Belle II, T2K and HyperK collaboration meetings, where also JENNIFER2 activities will be discussed. However, to promote full knowledge sharing among different experimental communities, yearly consortium general meeting will be organized, to be held at KEK or at U-Tokyo with the participation of the largest possible community of researchers involved in the project activities. Participation of Japanese researchers will be supported. Such Meetings will aim to maximize the transfer of knowledge between its different components: focused plenary talks and discussions will be integrated with specific WP parallel sessions where technical problems will be discussed in details, and possible solutions proposed.

Specific networking activity will be supported in the framework of WP4 and WP5 activities:

- the next NDIP conference on photodetectors, which will be held in 2020, will be supported, and JENNIFER2 researchers will participate to the organization of the scientific and training program.
- Organization of a common physics workshop bridging both experimental communities to the theory community, and addressing common physics and analysis issues.
- A joint Real Time and Remote Control workshop will be organized, to share and compare different solutions for technical challenges arising both in collider experiments and in large volume ones.
- Computing workshops regularly organized by the Belle II and T2K communities will be opened to both experiment audience, to share solutions for distributed computing architectures and large data sharing implementation.

3. Impact

3.1 Enhancing the potential and future career prospects of the staff members

The numerous European personnel who will participate in the JENNIFER2 network will have the opportunity to collaborate into high-level research and technological activities in an international framework. In such context it will be possible to enhance individual knowledge and skills in the different fields covered in section 2, with the advantage of mixing expertise from different experiments using different techniques and collaborateing with scientific communities based and operating far from Europe. This invaluable experience will not only open multiple different career perspectives to European research staff, but will also allow to develop a deep and durable relation with Japanese scientific and technological environment, which is rare in European research area. The validity of this investment has already been demonstrated by the former JENNIFER project, which is now allowing many European researchers to improve their career thanks to the expertise and relations established during secondments (including ERC grant award, academic positions in Japan, intersectorial career developments).

In particular JENNIFER2 work packages 1-5 involve the training of significant numbers of doctoral students (ESRs), in both the European and Japanese universities associated to the project. In many cases, the European ESRs will be seconded to KEK or J-PARC for extended research visits, as part of their doctoral studies, through the JENNIFER2 project. As part of WP6, a task is defined to manage these exchanges, in particular to ensure proper supervision and support of the ESRs during their extended stays. The host lab (KEK or J-PARC) will provide a scientific or technical co-supervisor, as well as administrative support and hosting arrangements. The task within WP6 will consist in preparing the visits, by reviewing its work, by ensuring that a Japanese co-supervisor is nominated, and by monitoring the progress during the visit. Where permitted by individual university regulations, the co-supervision will be officialised in the PhD title. Moreover, JENNIFER2 management will foster the conclusion of inter-university agreement which recognize double PhD to co-supervised students.

Another valuable training opportunity will be offered to PhD students by supporting their participation to next NDIP conference on photodetectors, where focused training mini courses will be organized with important contribution from JENNIFER2 groups. Young researchers profiting of such an advanced training in photon detection will be in the best position to explore innovative approaches and to develop their career in a challenging field where strong connections with industry are already present.

3.2 Developing new and lasting research collaborations, achieving transfer of knowledge between participating organisations and contribution to improving research and innovation potential at the European and global levels

Scientific collaboration with Japan is strategic for Europe, not only because Japan is one of the most developed countries in the world, holding excellent industries and universities, but most of all because Japan has been since long time a knowledge-based society, exactly as Europe wants also to be. European groups working in JENNIFER2 will develop, and in some cases reinforce, a very strong research collaboration with the Japanese scientific community on the one side and on the other side between European members of the project. Belle-II and T2K experiments, whose lifetimes will exceed the project duration by many years, are the ideal environments for merging expertise on state of the art technologies in many different fields and for starting new collaborations for their future development. Scientific collaborations which will start inside our project will profit of such fertile and stable environment, where many opportunities and infrastructures are available to develop ideas and applications also with a medium and long term timescale. Moreover, research developments are not confined inside the existing experimental collaborations, but are allowed and supported to start new

scientific or technological initiatives, as it already happened in the former JENNIFER project. Two different examples are: the ENUBET ERC project, and the organic photodetector R&D. Both ideas started inside an European-Japanese collaboration supported and fostered by the RISE program, and are now continuing, one with another funding instrument, the other one still included into a RISE activity.
Cross fertilization between two different particle physics experiments produces also a high quality European knowledge exchange as both communities need frontier technology to achieve their results. JENNIFER2 project organization is designed to foster collaboration on specific items where synergies and common solutions are envisaged.
Europe will benefit of these close collaborations, in different fields, in terms of innovative ideas and cultural opening, both in fundamental physics and in technology applications. On one hand, JENNIFER2 will provide in itself strong connections with the industrial sector, both by direct collaboration and by commercial relations, assuring the availability of technology transfer communication channels for all interesting developments. On the other hand the JENNIFER2 outreach program will improve societal awareness of particle physics fundamental research and its technology by products.
Finally, European scientific community will be allowed to keep and develop expertise on physics at electron-positron colliders and on long baseline neutrino experiments, which are both unavailable in Europe. Not only European particle physics groups will give an important contribution to achieve challenging new results (possibly discoveries), but also they will hold essential competences for driving future particle physics challenges based on the same approach, such as FCC or DUNE projects.

3.3 Quality of the proposed measures to exploit and disseminate the action results

JENNIFER2 dissemination strategy is first of all based on the best practices of the particle physics community, which imply regular presentation of the results at international conferences, also in preliminary status, and subsequent publication of peer reviewed papers on specialized journals. Results from all JENNIFER2 activities will follow the same procedure, in particular early conference presentation will be encouraged, not only in particle physics ones, but particularly in the technology dedicated workshops and international conferences (like IEEE, CHEP, NDIP…) where mixed academic and industrial audience is present.
Purpose of JENNIFER2 dissemination is both to share its findings with all the scientific community for further use and development, and to trigger possible technology transfer processes where applicable. For this reasons the audiences to which we aim are the specialized research communities and their industrial partners. International Conferences and specialized journals are the main tools to reach them, together with the project website, which will be kept up to date with the list of public presentations and papers produced. News about the most relevant ones will be spread also via communications to specialized newsletters.
JENNIFER2 dissemination will happen with two different timings and correspondingly different objectives: first dissemination will happen when results are considered enough reliable but still deserve testing and investigations, while a second dissemination will happen when results are considered solid a fully documented. The first one aims to trigger other works from the scientific and technology community to confirm or contradict the results, and possibly develop them, the second one aims to publish all the tools needed to understand and implement the results.
As a large part of the JENNIFER2 results will be property of international experimental collaborations, the project members will play an active role inside such collaborations both to promote a dissemination strategy coherent with the JENNIFER2 one, and to push for the wider possible implementation of open access to scientific results. Open access journals will be always preferred for paper submission, and activities to make also experimental data available to the wider community in the future will be started.
Impact of particle physics results dissemination will be very important on scientific community, as it will provide insights on CP violating processes both in quarks and neutrinos, and reveal the appearance of possible new physics processes. Detector and technological developments will on the other hand drive innovation and stimulate new application ideas.
JENNIFER2 research activities aim to general progress of science and should not imply commercial use. In case of necessity, the Consortium Council will take decision about internal IPR issues, taking into account the national regulations of the different beneficiaries. Consortium Agreement will address thispoint.

3.4 Quality of the proposed measures to communicate the action activities to different target audiences

Communication activities are central in the JENNIFER2 project, not only from the point of view of science outreach, but also aiming to bridge the gap between European and Japanese society. Japan is considered, often also by the scientific community, as a far and hard to communicate research world. While Japanese technology is widely used, little effort of joint developments has been tried up to now. We are engaged to change this approach starting from fundamental sciences, wide initiatives in communication and dissemination of the research and technology achievements jointly obtained with Japanese scientists. This strategy will also be enhanced by merging the specific knowledge of different experiments testing fundamental physics from different perspectives. The JENNIFER2 communication and outreach program is included in WP6 and is organized in three main directions:

General Public. Outreach activities aimed to general public are a routine part of a communication strategy of each JENNIFER2 institution. However, they are not always known to broader audience. To coordinate the communication strategy and gain more visibility, JENNIFER2 will prepare an outreach web portal where links to initiatives of Belle II, T2K, individual institutions as well as other players as IPPOG, interactions.org, etc. will be available. Events will be advertised on social media and using local communication offices. An important aspect of the outreach comes with visits of public in the institutions and experimental facilities. While it is not easy to bring people to visit the Japanese facilities physically, all effort is planned to be made to utilize the communication technology to enable virtual visits. Here the existing Belle II virtual reality application will be used as well as remote access to KEK and T2K via Webcams, live broadcasts and remote live guided tours.

High school students. The Masterclasses/Hands on Particle Physics is an extremely successful world-wide initiative run by the International Particle Physics Outreach Collaboration (IPPOG). Here high school students are invited to analyse the real data from particle physics experiments. The on going JENNIFER project allowed Belle II community to develop their own exercises for Masterclasses using the Belle data and achieved the key milestone of running the first Belle II masterclasses. In parallel, Belle II experiment has officially become member of IPPOG, where it is represented by Zdenek Dolezal (UKP) who also coordinates the whole JENNIFER2 WP6. Belle II collaboration will support specific Masterclasses in Europe, Japan and elsewhere, and JENNIFER2 project will provide most people implementing and organizing them.

Unfortunately until now no similar events have been organized for neutrino physics and no exercises on real neutrino data have been designed and made available. JENNIFER2 aims to achieve also this important step forward, by working on real T2K and SuperK data and obtaining the support from the collaborations to use them in first pioneering neutrino masterclasses in Europe.

University students. It is important to promote the European-Japanese scientific collaboration on many levels. The university physics students represent a key target audience as they will lead the science and innovation of the coming years in Europe and worldwide. We propose to organize 2 two-week long summer schools at KEK aimed to the physics master students. Each school will host 20 European students and a similar number of the Japanese ones (the Japanese paid by Japan) with lectures given both by European and Japanese physicists and practical labs in KEK. This initiative intends to broaden the view of the students and motivate them to consider choosing Belle II and T2K for their PhD studies or postdoc positions. Moreover the schools will include complementary skills training, such as science communication ability, project writing, outreach to general public, aiming to give common grounds to European and Japanese young researchers thus easing their collaboration attitude.

Such multi target communication will spread into EU society the idea that fundamental research and international scientific collaboration is not only fascinating, but also produces ideas and innovation on the medium and long term timescale.

As described in section 3.1, JENNIFER2 WP6 includes also a training activity aimed to PhD students, based on medium and long duration stays in Japan and providing a co-tutorship program.

It is very important to underline that the JENNIFER2 Consortium considers the outreach and communication as a part of the research activity. No good research can be realized if it does not include the appropriate communication strategy. For this reason we are not requiring any secondment budget for the communication activities which will take place in Japan or which require preparation work to be done with our Japanese partners: all communication activity will be included into the research, and when needed will be carried on also during secondments associated to any other JENNIFER2 work package.

4. Quality and efficiency of the implementation

The JENNIFER2 Consortium endorses the principles and best practices stated in the European Charter of Research for Researchers and Code of Conduct for the Recruitment of Researchers, will implement them in all its activities and decisions, and will push its beneficiaries and partners to provide open recruitment and attractive working conditions for researchers in Europe and possibly in Japan.

4.1 Coherence and effectiveness of the work plan, including appropriateness of the allocation of tasks and resources

JENNIFER2 project is organized in 7 work packages which complements each other and are designed to reach the various project objectives.

The first 3 WPs are built up on the core activities of the three experiments on which JENNIFER2 is based. Such activities need to be developed in parallel and involve separately the three experimental communities with their Japanese partners, but cross communication between them will be assured by the regular networking activity described in section 2.

Work packages 4 and 5 are designed to involve in common and focused research activities the two experimental communities forming the JENNIFER2 consortium. These two WPs are ideal tools to build up synergies and exchange specific knowledge.

Work Package 6 includes all the outreach activities of the project and part of the training, but such activities are considered part of the research process and are actually developed in close connection with it. Management activity is included in WP7.

Each work package has a very clear work plan, depending on the agreed schedules and reasonable expectations in each of the quickly evolving fields, as listed below:

<u>WP1</u>: Belle II data taking with full detector in place will start in February 2019 and will last several years to accumulate the required statistics. WP1 includes study and optimization of detector performances in real conditions, which will start immediately, and are essential to perform accurate data analysis. WP1 also includes the data analysis of the various physics channels, which will also start in parallel, getting more and more refined with time.

<u>WP2</u>: T2K experiment has approved an upgrade of the near detector ND280, which includes 2 new TPCs and a new Fine Grade Detector. Design and construction of such detector is starting and JENNIFER2 groups will provide a very important contribution. Prototyping, testing, TDR writing, installation will be followed during the project life. In parallel, T2K data taking will continue as well as physics analysis, which will be refined with more statistics, dedicated runs and improved algorithm, both for neutrino cross sections and for oscillation parameters measurements.

<u>WP3</u>: HyperK detector development is in a crucial phase and JENNIFER2 groups are deeply involved in it. Various different detectors aspects have to be now studied separately in close collaboration with Japanese laboratories. Water Cherenkov test with Gd doped water, calibration, external detector for background rejection, front end electronics design deserves dedicated tasks, together with a general simulation task. SuperK detector is used as a test facility for such tasks, and a clear time scale is now defined for them, which coincides with JENNIFER2 project expected lifetime.

<u>WP4</u>: This WP includes most of the photodetector R&Ds which are going on in the JENNIFER2 groups, with the aim of compare and exchange problems, ideas and solutions. Some of these R&Ds have timescales connected to detector upgrades or construction, and they need to be completed and produce reports in e or 3 years at most. For organic photo-sensors study the timescale is anyway important to compare to other frontier research in the same field.

<u>WP5</u>: This WP address Computing, data acquisition, Statistical methods and theory interface, which are common issues for neutrino and flavour physics experiments. In each of the WP tasks, solutions are required timely, and comparison with state of the art techniques is essential to be competitive.

<u>WP6</u>: This WP includes outreach and communication activities, which will happen regularly during the project life. This is specially true for general public events and for Masterclasses, while the Summer school Organization is planned for the second and fourth year of the project.

<u>WP7</u>: includes the management activities, which will constantly monitor and coordinate the project implementation, the activity evolution, the dissemination, the accounting and reporting.

Credibility of the JENNIFER2 project research activities is first ensured by the fact that they are all part of well defined research programs, and they are carried on by experienced and reputed research groups, as documented in section 6. Moreover, well reputed and experienced researchers are in charge to coordinate the WP and for the accomplishment of each task, as described in the various WP summary tables. Finally, none of the project objectives and deliverable is manifestly not reachable on the basis of the present activity status, nor it is missing the essential infrastructure and instrumentation. Few risks connected to external factors are detailed in section 4.2 and mitigation measures are discussed.

Feasibility of the networking and transfer of knowledge activities is ensured first of all by the previous experiences of the Consortium members, used to collaborate already inside their experimental collaborations, and trained also to cross collaborate and fertilize each other thanks to the former JENNIFER RISE project. The problem of merging and comparing different approaches and the compensation of different needs have already

been faced by these groups. On such basis the JENNIFER2 project has been designed to ease this process and to foster cooperation at all levels.
The scientific coordination of the project is leaded by very experienced researchers:
Dr. Antonio Passeri, scientific coordinator, is INFN senior researcher and has long term research experience in international collaborations (DELPHI, KLOE, ATLAS, SuperB, Belle-II), is the coordinator of the on-going JENNIFER MSCA-RISE project, has served in several INFN committees and has been elected to represent INFN researchers in the institution Directive Council.
Prof. Christoph Schwanda (HEPHY), WP1 coordinator, is the leader of HEPHY Belle II group, the SVD project leader, the Belle II semileptonic physics group coordinator, the Belle Physics Coordinator, WP1 coordinator in JENNIFER project and ECFA member.
Dr. Emilio Radicioni (INFN), WP2 coordinator, is the convener of the ND280 detector, TPC coordinator and Resource manager of the TOTEM experiment at CERN.
Prof. Francesca Di Lodovico (QMUL), WP3 coordinator, is the Hyper-Kamiokande co-project leader and the UK country representative in Super-Kamiokande.
Dr. Rok Pestotnik (JSI), senior researcher, has 22 years of experience in HEP instrumentation, member of international collaborations (HERA-B, ALICE, Belle, Belle II), is the leader of the Photon Detector Laboratory at JSI.
Dr. Sara Bolognesi (CEA), previously worked in CMS, is responsible of the T2K Neutrino Interaction Work Group, member of the CEA Scientific Council
Prof. Zdenek Dolezal (UKP), leader of the Prague group in Belle II, former chair of the Belle II Institution Board, Belle II representative in IPPOG.

Table B2: Work Package Description

<table>
<tr><td>Work Package Number</td><td colspan="5">1</td><td colspan="2">Start/End Month</td><td colspan="3">1 / 48</td></tr>
<tr><td>Work Package Title</td><td colspan="10">Search for new physics signals at Belle II</td></tr>
<tr><td>Lead Beneficiary</td><td colspan="10">OEAW-HEPHY</td></tr>
<tr><td>Participating organisation Short Name</td><td>INFN</td><td>DESY</td><td>OEAW-HEPHY</td><td>CNRS</td><td>JSI</td><td>IFJ-PAN</td><td>UKP</td><td>METU</td><td>TAU</td><td>KEK</td></tr>
<tr><td>Total Person Months per Participating organisation:</td><td>56</td><td>70</td><td>22</td><td>25</td><td>15</td><td>11</td><td>9</td><td>6</td><td>6</td><td>0</td></tr>
</table>

Objectives:

- Study and optimize the Belle II detector performance on real data in terms of track and vertex resolution, energy resolution, photon detection efficiency, particle identification power, which are key items for the data analysis.
- Perform physics measurements with the data sample that Belle II will collect in the first 4 years of data taking, which will exceed by a factor of 5÷8 the existing B-factories data set.

Description of Work and Role of Specific Beneficiaries / Partner Organisations
The search for new physics requires to perform precision measurements of a large variety of channels, which in turn requires excellent control of all detector performances. The two activities have to be developed in parallel and in close collaboration. For this reason, the task dedicated to detector performances is by far the largest one, as it is connected to all the others.
This work package is coordinated by prof. Christoph Schwanda (OEAW-HEPHY) leader of HEPHY Belle II group, the SVD project leader, WP1 coordinator in JENNIFER and member of the ECFA.
Task 1.1: Detector performances assessment [INFN,DESY,HEPHY,JSI,CNRS,UKP,KEK]

- Total number of Person Months allocated: 100
- Determine and optimize detector resolutions and efficiencies using real data, in order to provide precise inputs to physics analyses. Each sub-detector has to be studied both by itself and in combination with the others, thus requiring the collaboration of all sub-detector experts from different groups. The leading organization is INFN, which holds expertise in tracking, calorimetry and particle identification, other specific detector expertise: DESY for PXD, HEPHY, INFN and UKP for SVD, JSI and CNRS for ARICH, INFN for TOP, ECL and KLM, CNRS for luminosity evaluation.
- The main involved staff are: G.Finocchiaro (INFN), leader of the Belle II INFN group, C.Marinas (DESY), deputy run Belle II coordinator.

Task 1.2: Study of CP violation and search for new phenomena in rare decays

[INFN,DESY,HEPHY,CNRS,JSI,KEK] person Months allocated: 40

- Physics analyses to test CKM matrix unitarity (measurement of $|V_{cb}|$ and $|V_{ub}|$ using leptonic and semileptonic decays; measurement of the angles of the CKM unitarity triangle, in particular the γ angle), studies of rare B decays ($B \rightarrow X_s\gamma$; charmless hadronic B decays) and of rare charm decays are developed in this task. The leading organization is HEPHY which holds specific experience on leptonic and semileptonic B decays, DESY and JSI will mostly work on unitarity triangle angles, CNRS on $B \rightarrow X_s\gamma$ channel, INFN on charm physics and KEK on charmless hadronic decays.
- Main involved staff: C.Schwanda (HEPHY), F. Bernlochner (DESY).

Task 1.3: Lepton flavour and lepton universality violations [INFN,DESY,HEPHY,IFJ-PAN,UKP,TAU,KEK]

- Total number of person Months allocated: 40
- Hints for lepton flavour non-universality are currently seen in the $B \rightarrow D^* \tau \nu$ and $B \rightarrow X_s l^+l^-$ channels by the BaBar, Belle and LHCb experiments. These anomalies can be interpreted within various new physics models but require final experimental confirmation, for which Belle II measurements are essential. Lepton flavour violation is best tested in tau decays, where many channels can also be studied. Missing energy due to neutrinos requires in turn full event reconstruction to reject backgrounds. The leading organization is DESY, but the variety of possible channels requires the collaboration of many analysis groups.
- Main involved staff: G.De Nardo (INFN), F. Bernlochner (DESY).

Task 1.4: Dark sector and exotics [INFN,HEPHY,METU,KEK] person Months allocated: 20

- Production of the so called “dark photon” and of other Z-like or Higgs-like particles will be searched for. Limits on exotic processes including axions and WIMPS can also be improved. All such events require hermeticity and excellent control of machine and accidental backgrounds. The leading organization is HEPHY where a specific competence on such physics is present, in strict collaboration with INFN for what concerns processes involving muons, METU for the channels with large missing energy and KEK for the machine background measurements.
- Main involved staff are: G.Inguglia (HEPHY), E.Graziani (INFN).

Task 1.5: Quarkonium Spectroscopy [INFN,DESY,JSI,METU,KEK] person Months allocated: 20

- This task aims at performing quarkonium spectroscopy in B decays, ISR and two-photon processes. The leading organization is JSI where experts from Belle experiment are present.
- Main involved people are: Marko Bracko (JSI), R.Mussa (INFN).

Description of Deliverables (D) and Milestones (M)

Task 1.1 Belle II internal report(s) on detector performance and calibration (**M**, month 24).
Journal publication(s) on detector performance and calibration (**D**, month 48).
Task 1.2 International conference presentation(s) of task 1.2 physics results (**M**, month 24).
Journal publication(s) of task 1.2 physics results (**D**, month 48)
Task 1.3 International conference presentation(s) of task 1.3 physics results (**M**, month 24).
Jjournal publication(s) of task 1.3 physics results (**D**, month 48).
Task 1.4 International conference presentation(s) of task 1.4 physics results (**M,** month 24).
Journal publication(s) of task 1.4 physics results (**D**, month 48).
Task 1.5 International conference presentation(s) of task 1.5 physics results (**M**, month 24).
Journal publication of task 1.5 physics results (**D**, month 48).

Work Package Number	2				**Start/End Month**			1 / 48	
Work Package Title	T2K detector upgrade and Neutrino Physics								
Lead Beneficiary	INFN								
Participating organisation Short Name	INFN	CEA	CNRS	NCBJ	IFJ-PAN	IFAE	UGE	QMUL	RAL	KEK
Total Person Months per Participating organisation:	49	16	9	17	7	12	18	3	6	0

Objectives:

- Design, build, test and commission the upgrades for the T2K near detector (ND280), consisting of two TPCs and a scintillator based 3D Fine Grained Detector (Super-FGD).
- Deploy a strategy of measurements of neutrino cross-sections, in particular to pin down nuclear effects and improve the neutrinos-nucleus cross section modelling.
- Perform oscillation measurements with neutrinos and anti-neutrinos, both in appearance and disappearance, to maximize the sensitivity to leptonic CP violation.

Description of Work and Role of Specific Beneficiaries / Partner Organisations

This WP will be coordinated by Dr.Emilio Radicioni (INFN), ND280 detector convener.

Task 2.1: Construction and commissioning of the ND280 TPC [INFN,CNRS,CEA,NCBJ,IFJ-PAN,IFAE,KEK]

The four main areas of activity are the design and production of the field-cages (INFN, IFAE), MM modules and its on-detector electronics (CEA), the mechanical structure interfacing the MM with the field-cages (CEA, NCBJ, IFJ-PAN), and the back-end electronics (CNRS). The conceptual design will be performed by European groups and will be supported by prototyping activities for the field-cages, the resistive MMs and the readout electronics. The tight mechanical requirements for integration of the new detector into the existing experimental layout in J-PARC call for a high level of coordination between the involved European groups and the Japanese partners. After prototyping, the construction will be performed in Europe, where the final detector will be fully assembled and tested, prior to shipping to J-PARC for installation, integration and commissioning. • Total number of Person Months allocated = 54 • key people profile: T. Lux, staff researcher (IFAE), expert in field-cage design and MPGD readout. A. Delbart, Staff detector physicist (CEA), expert of MPGD detectors **Task 2.2: Construction and commissioning of the Super FGD** [UGE,KEK,U-Tokyo] The challenging aspects of this detector are the assembly of the ~ 2 million cubes with their readout fibers, and the integration of MPPCs and front-end electronics in the limited space available between the Super-FGD and the neighboring TPCs. The design and construction will be performed by European and Japanese groups and, as for Task 2.1, requires a close collaboration between the involved partners. Construction will be conducted at CERN, from where the detector will be shipped to J-PARC for installation, integration and commissioning. • Total number of Person Months allocated = 10 • key people profile*:* E. Noah Messomo, researcher (UGE), project leader of the BabyMIND muon spectrometer for the Wagashi experiment **Task 2.3: Neutrinos cross section measurement** [INFN,CNRS,CEA,NCBJ,IFJ-PAN,IFAE,UGE,QMUL,KEK,U-Tokyo] Person Months allocated = 38 This task is an excellent playground for a broad community of theoreticians and experimentalists, mixing different skills and backgrounds. It is also a valuable environment for students, where they can enrich the foundations of their career. Cross-section of the different neutrino types on different targets (C, O, Fe) will be published open access and will be accompanied by public data releases in order to allow a broader community to interpret and study them. • key people profile: F. Sanchez, senior researcher (IFAE), member of the T2K Executive Committee A. Longhin, associate professor (INFN), cross-section study coordinator in T2K **Task 2.4: Neutrino oscillation analysis** [INFN,CNRS,CEA,NCBJ,IFJ-PAN,IFAE,UGE,QMUL,KEK,U-Tokyo] The first step of the oscillation analysis is the selection of different event samples, each corresponding to a different final state topology and coming with its own efficiency and systematic errors, and it is the result of a coordinated teamwork. The combination of all these samples in a coherent framework requires an even higher level of coordination between different groups. The last step of the oscillation analysis is a simultaneous fit of the different appearance and disappearance samples to extract the oscillation parameters. This is done independently by three different groups, using complementary approaches, both Bayesian and frequentist. • Total number of Person Months allocated = 35 • key people profile: C. Giganti, Chargé de recherche (CNRS), coordinator of the T2K oscillation working group. L. Ludovici, senior researcher (INFN), expert in oscillation analysis, T2K Publication Board chair. J. Lagoda, associate professor (NCBJ), coordinator of the ND280 ν_μ analysis group
Description of Deliverables and Milestones: **Task 2.1 and 2.2** • Deliverable: Technical Design Report of the upgraded ND280; EMD: 12 • Milestone: production and test of first prototypes with front-end electronics; EMD: 24 • Deliverable: report paper on the new detectors; EMD: 48 **Task 2.3** • Milestones: improved selection acceptance for cross-section measurements, EMD 24; neutrino energy reconstruction using detectors at different off-axis angles, EMD 36 • Deliverables: report on cross-sections on C and O and reduction of uncertainties, EMD 48; report on electron neutrino cross-section and reduction of uncertainties, EMD 48 **Task 2.4** • Milestone: inclusion of multi-ring topologies in the event selection; EMD: 24 • Deliverable: report on δ_{CP} sensitivity; EMD: 48

Work Package Number	3		**Start/End Month**		1 / 48	
Work Package Title	Towards the Hyper-Kamiokande detector					
Lead Beneficiary	QMUL					
Participating organisation Short Name	INFN	QMUL	RAL	NCBJ	UGE	CAEN	U-Tokyo

Total Person Months per Participating organisation:	21	30	23	5	4	2	0

Objectives:
- Test a Gd-doped water Cherenkov using the existing Super-Kamiokande detector
- Accurate optical calibration of a large tank Cherenkov detector.
- Design the Outer Detector for the Hyper-Kamiokande experiment.
- Design specific low-threshold, low-noise, large dynamics front-end electronics.
- Develop realistic simulation of the Hyper-Kamiokande detector.

Description of Work and Role of Specific Beneficiaries / Partner Organisations
Hyper-Kamiokande is the third generation water Cherenkov detector in Kamioka. Many different aspects are being developed in parallel towards finalizing the design and starting the construction of the Hyper-Kamiokande detector.
This WP will be coordinated by QMUL.. Prof. Francesca Di Lodovico (QMUL), Hyper-Kamiokande co-project leader and the UK country representative in Super-Kamiokande, is the WP coordinator.

Task 3.1: Study of a gadolinium-doped water Cherenkov detector [INFN,NCBJ,QMUL,RAL,U-Tokyo]
- Total number of Person Months allocated = 20
- Institutions' roles: QMUL and RAL are working on the analysis of the data as well the gadolinium concentration measurement. INFN will focus on the analysis of data and will characterise the new PMTs in the detector.
- Key people profile: Vincenzo Berardi (INFN) has extensive experience on the photosensor system and will contribute to the installation of the new PMTs.

Task 3.2: Development of a calibration system for a water Cherenkov detector [INFN,QMUL,RAL,U-Tokyo]
- Total number of Person Months allocated = 20
- Institutions' roles RAL and QMUL will concentrate on the light pulse system that have developed, built and will install at Super-Kamiokande as well as other optical and neutron calibrations. INFN will focus on the neutron calibration.
- Key people profile: Dr Neil McCauley (Liverpool), coordinator of the Hyper-Kamiokande calibration working group; Prof Lee Thompson (Sheffield), who is working on the calibration system being deployed in Super-Kamiokande; Dr Gianmaria Collazuol (Padua), who has extensive experience in detector construction.

Task 3.3: Hyper-Kamiokande Outer Detector [QMUL, U-Tokyo] Person Months allocated = 20
- Institutions' roles: QMUL is already leading the work on the outer detector from the hardware to the simulation of the system. RAL is working together with QMUL in optimizing and designing the system.
- Key people profile: Dr Stephane Zoldos (QMUL), coordinator of the OD photosensor; Prof. Steve Playfer (Edinburgh) who has extensive experience in the design of experiments.

Task 3.4: Design of a low noise front end electronics for large area photodetectors [NCBJ,UGE,CAEN,U-Tokyo]
- Total number of Peson Months allocated = 10
- Institutions' roles: UGE has significant prior experience with data acquisition systems and the development and implementation of fast WFD systems (NA61 experiment at CERN, MICE at RAL). NCBJ has significant prior experience in both hardware design of front-end electronics (COMPASS experiment at CERN) as well as estimating impact of hardware on physics capabilities of the detector.
- Key people profile: Prof. A. Bravar (UGE), he has extensive experience in the electronics having designed the electronics for several experiments. Dr. A. Rychter (NCBJ) is working the waveform digitization based on a Flash-ADCs coupled with anti-aliasing filters.

Task 3.5: Hyper-Kamiokande simulation [INFN,QMUL,RAL,U-Tokyo] Person Months allocated = 10
- Institutions' roles: QMUL and RAL already gave leading contributions to the simulation programme for Hyper-Kamiokande implementing the outer detector as well as the triggering system. They will continue to develop the realistic design of the experiment in the simulation as well as analysing the simulated data. The INFN will focus on implementing its calibration systems in the simulation and the analysis of the simulated data.
- Key people profile: T. Dealtry () he developed the trigger simulation.

Description of Deliverables and Milestones:
Task 3.1: decision of the feasibility of the UV system to measure Gd concentration in Super-Kamiokande (month 30).
Task 3.2: data taking and analysis of the light pulse calibration prototype after the first year of data taking (month 24).
Task 3.3: technical note on the proposed Outer Detector system (month 36)
Task 3.4: Milestone**:**test report on waveform digitizer(s) performance (month 30)**.** Deliverable**:** Final report on front-end activities (month 48)
Task 3.5: simulation data analysis with the final photosensor configuration (month 48)

Work Package Number	4	**Start/End Month**	1 / 48
Work Package Title	New Photodetectors Development		

Lead Beneficiary	JSI						
Participating organisation Short Name	INFN	JSI	NCBJ	CAEN	FBK	U-Tokyo	KEK
Total Person Months per Participating organisation:	19	8	3	1	1	0	2

Objectives:

- Develop and test few types of new photodetectors aiming to different applications in particle physics, while building an high level of knowledge exchange among the developers.
- Explore a very innovative and interdisciplinary technique to detect photons, based on organic substrates, through a strong partnership with Japanese institutions.
- Provide high quality training opportunities in the field of photon detection both for ERs and for ESRs, including contacts with technology industries operating in this field.

Description of Work and Role of Specific Beneficiaries / Partner Organisations

The work is divided into 4 well defined tasks. Coordination of the activities, will be Dr. Rok Pestotnik (JSI), senior researcher: 22 years of experience in HEP instrumentation, member of international collaborations (HERA-B, ALICE, Belle, Belle II), lead of the Photon Detector Laboratory at JSI.

Task 4.1: R&D of Silicon-PMs as single photon counters in neutron irradiated areas [JSI,FBK,KEK]

- Total number of Person Months allocated = 9
- Study of silicon PM samples before and after irradiation with neutrons: time and pulse height distribution, waveform analysis, background noise counts, effect of annealing . Design requirements, selection of SiPM, design and fabrication of readout electronics. Development of light concentrator to increase signal to noise. Integration of the module and study of the module in the relevant environment .
- Institutions' roles: JSI – leading partner – technology design and validation in the lab, optimization of the module, KEK – technology demonstration in the test beam, system prototype demonstration in operational environment.
  - Key people involved: Rok Pestotnik (JSI), Prof. Samo Korpar (JSI), prof. Nishida Shohei (KEK), Alberto Gola (FBK) custom technology team leader.

Task 4.2: Development of long-lived MCP photomultipliers [INFN,KEK] Person Months allocated = 7

- The main objective is reduction of residual gas components, responsible for lifetime reduction in the MPC production procedure. Study of MCP-PMT samples: time and pulse height, photocathode lifetime analysis. Identification of ions responsible for lifetime reduction.
- Institutions' roles: INFN – leading partner, sample characterization, Hamamatsu Photonics – sample provider, KEK – integration of components.
- Key people: Ezio Torassa (INFN), senior researcher. Prof. Kenji Inami (KEK),

Task 4.3: Development of multi PMTs for a large water Cherenkov detector [INFN,NCBJ,CAEN,U-Tokyo]

- Total number of Person Months allocated = 9
- Study of optical module components (time and pulse height distribution, waveform analysis, background rates). Design, fabrication end test of multi-PMT optical module.
- Institutions' roles: INFN – design, construction and study of the module, CAEN – design of electronics, NCBJ - study and construction of the module.
- Key People: G. De Rosa (INFN), prof. Vincenzo Berardi (INFN). Both with wide expertise in photodetectors.

Task 4.4: Study of innovative organic photosensors [INFN,KEK] Person Months allocated = 6

- Study of Organic FET (IV and in CV characteristic, response to light). Study of photo-absorption and luminescence of organic semiconductors. Characterization of charge transport, signal formation and timing response
- Institutions' roles: INFN - development of organic FETs samples, characterization of samples, simulation studies, KEK, development of new OFET
- The main involved staff are: Prof. Alberto Aloisio (Naples University and INFN), full Professor, Dr. Paolo Branchini (INFN), senior researcher. Both have wide experience in detector design and readout electronics.

Description of Deliverables:

Task 4.1: Report on the design and performance of the prototype module (month 35)

Task 4.2: Report on the lifetime properties of the MCP PMTs (month 24)

Task 4.3: Milestone: Report on the Acrylic properties for the external vessel of the mPMT module (month 12)

Deliverable: Realisation of the mPMT module prototype (month 24).

Task 4.4: Milestone: Report on electrical characterization of photo-transistors (month 24)

Deliverable: Final R&D report on organic light detection (month 48)

Common deliverable: Support organization and participation to photon detectors training sessions for PhD students at NDIP 2020 conference (month 18)

Work Package Number	5			**Start/End Month**			1 / 48	
Work Package Title	Computing and Common Techniques							
Lead Beneficiary	CEA							
Participating organisation Short Name	INFN	DESY	JSI	QMUL	RAL	CNRS	UGE	CEA	KEK
Total Person Months per Participating organisation:	14	11	5	12	4	4	2	4	0

Objectives:

- Jointly face Belle II and HyperK common problems in computing and big data handling.
- Exchange data acquisition schemes and remote control techniques developed for different environments and standards.
- Share statistical methods to treat rare signals and provide easy-to-combine results.
- Support collaboration of theory experts to improve precision of flavour processes prediction and update corresponding generators.

Description of Work and Role of Specific Beneficiaries / Partner Organisations

Neutrino and flavour physics experiments have to manage a number of similar problems, for which large synergies can be obtained. This is the case for all computing issues, for real time applications, for data mining algorithms and for theoretical calculations. Close collaboration on such items is unprecedented in our community and it could produce benefits for the whole particle physics experimental effort.

This WP is coordinated by Sara Bolognesi (CEA), physics analysis expert of the T2K experiment.

Task 5.1: Computing and data handling for Belle II and HyperK [INFN,DESY,JSI,CNRS,QMUL,KEK]

- Total number of Person Months allocated = 16
- To study a set of common tools for the computing model of Belle2-T2K-HK experiments, which users from Japanese and European Research centres can use in a transparent way. The activity will focus on the following technologies: a) Computing. Workload Management System based of DIRAC Framework; Data distribution software like CVMFS and Technologies to use Grid and Cloud Resources. b) Storage: Data Access protocol (Grid and Cloud) and Data Transfer system FTS. c) Software: Tools for software development and versioning. d) Network: Common tools for Network Monitoring
- Key people involved: S.Pardi (INFN), M.Bracko (JSI), T.Kuhr (DESY), S.King (QMUL)

Task 5.2: Data Acquisition and remote controls [INFN,DESY,QMUL,RAL,CNRS,KEK]

- Total number of Person Months allocated = 8
- To develop and share hardware and software techniques/knowledge for dealing with the challenges of high trigger rate next generation experiments. These include techniques for high data bandwidth optical data transfer, sub nanosecond timing distribution, intelligent real time algorithms for online data reduction run in parallel on multiple GPUs or FPGAs, as well as novel software solutions for scalable modular DAQ frameworks featuring integrated dynamic service discovery, monitoring, fault tolerance, dynamic routing and remote control.
- Key involved staff: Ben Richards (QMUL), Soeren Lange (DESY), Igor Konorov (DESY)

Task 5.3: Statistical methods and analysis algorithms [INFN,DESY,JSI,CEA,CNRS,UGE,KEK]

- Total number of Person Months allocated = 7
- To develop and document sound statistical methods which allow straightforward combination of results from different experiments, thus extending their individual experimental reach. Study and document the most suited observables to be used in experimental likelihood functions to allow easy combination. Define and documents analysis implementation methods that facilitate combination of results. Leading organizations are CEA and INFN, all the other organizations contribute with specific physics analysis expertise.
- Main involved staff: Sara Bolognesi (CEA), Diego Tonelli (INFN)

Task 5.4: Generators and Phenomenology [INFN,CNRS,DESY,KEK] Person Months allocated = 4

- Develop a coherent theoretical framework from CP violation analyses in both quark and lepton sector, lepton flavour violation analyses, searches for sterile neutrinos. Study possible common techniques (ex. fitting procedures) to determine CKM and PMNS matrix parameters with high precision. Theoretical support to flavour and lepton analyses in WP1-WP4, including neutrino-nucleus cross section analyses.
- Key people involved: Emi Kou (CNRS), Giulia Ricciardi (University of Naples and INFN)

Description of Deliverables:

Task 5.1 : A common Belle II – HyperK Cloud Computing demonstrator (month 36)

Task 5.2: Joint real time and remote control workshop (month 36)

Task 5.3: Reference report on statistical treatment of rare signal searches for future combination (month 36)

Task 5.4 Organization of a common physics workshop with all activities in WP1 and WP2 (month 48). Single

workshops for WP1 and WP2 are an intermediate milestone (month 36)

Work Package Number	6	**Start/End Month**	1 / 48
Work Package Title	Communication and Outreach		
Lead Beneficiary	UKP		
Participating organisation Short Name	All Beneficiaries and Third Country Partners		
Total Person Months per Participating organisation:	0 (zero). Outreach and Communication is fully integrated into research activities.		
Objectives: - Promote and spread in all Europe the Masterclasses in particle physics including Belle II and neutrino physics exercises with real data. - Organize every second year a summer school on flavour and neutrino physics at KEK, where European and Japanese students can meet and get in touch with KEK research facilities. - Coordinate the various general public communication events related to JENNIFER2 activities, organized by the participating organizations. - Provide joint European and Japanese supervision for a number of PhD students in flavour and neutrino physics during their secondments to JENNIFER2 partner institutions.			
Description of Work and Role of Specific Beneficiaries / Partner Organisations Outreach and communication is an essential part of the research work. Besides regular communication of research activities, performed by experimental collaborations, JENNIFER2 will provide few larger scope initiatives, aimed at different targets: high school students, physics students and general public. Moreover PhD students involved in JENNIFER2 activities will benefit from common supervision by a European and a Japanese scientist. This WP will be coordinated by prof. Zdenek Dolezal (UKP), leader of the Prague group in Belle II, former chair of the Belle II Institution Board, Belle II representative in IPPOG. **Task 6.1: Masterclasses on flavour and neutrino physics** [all] Organization of Masterclasses focused on Belle II physics. Development of Masterclasses exercises on neutrino physics and first test with T2K data. Coordinating organizations are UKP and INFN. Key people involved: Zdenek Dolezal (UKP), and L.Ludovici (INFN) **Task 6.2: Summer School for physics students at KEK** [all] Organization of 2 summer schools at KEK aimed to physics master students. Each school lasting 2 weeks, for 20 European students and a similar number of Japanese ones (the last ones paid by Japan), with lectures given both by European and Japanese physicists and practical labs. Coordinating organization is TAU. Key people involved: Abner Soffer (TAU), Federco Sanchez (IFAE) **Task 6.3: General public science communication** [all] Coordination and monitoring on a dedicated website of all outreach events involving JENNIFER2 physics organized (or participated) by local JENNIFER2 groups. Coordinating Organization is INFN. Key people involved: A.Passeri (INFN). **Task 6.4: PhD thesis co-supervision** [all] Training activity for PhD students involved in the project. A number of 3 or more months secondments are reserved for European PhD students working in one of the beneficiary institutions. They will allowed to develop their research program through a medium duration stay in the partner organizations, where a co-tutorship will be provided. The hosting lab will provide also assistance for accommodation and for cultural integration in Japan. Coordinating organization is CNRS. Key person is Philip Bambade (CNRS).			
Description of Deliverables: **Task 6.1:** Belle II masterclasses organization in JENNIFER2 Belle II institutions (month 36); Design and first test of T2K masterclasses (month 48) **Task 6.2**: Organization of 2 summer student institutes at KEK (month 24 and 48) **Task 6.3**: Setting up an outreach web portal with links to outreach events of JENNIFER2 institutions (month 24) **Task 6.4**: co-supervision of PhD students seconded for longer periods (month 48)			

Work Package Number	7	**Start/End Month**	1 / 48

Work Package Title	Management of the Project
Lead Beneficiary	INFN
Participating organisation Short Name	All
Total Person Months per Participating organisation:	No person months are required for this WP
Objectives: - Manage secondments and their accounting - Guarantee communication and decision making among beneficiaries and partners - Manage risks which can delay or stop the project activities.	
Task 7.1 Secondments management Implementation of an internal procedure for secondments monitoring and documentation, including a dedicated Database. Secondment Reporting on Participant Portal. Key People: Dr. Filomena Foglietta, INFN financial officer. **Task 7.2 Internal communication and decision making** Hold regular management meetings of the project governing bodies. Organize annual project meetings. **Task 7.3 Continous Reporting** Keep communication with Project Officer. Regularly Update Project progress on participant portal.	
Description of Deliverables: **Task 7.1:** Start Internal DB (month 3) **Task 7.2**: (i) Kickoff meeting (month 6) (ii) Election of CC chair. (iii) Annual Project meetings **Task 7.3**: Progress reports on month 12 and 36. Activity report on months 24 and 48.	

Table B3a – Deliverables list

Scientific Deliverables						
Deliverable Number	**Deliverable Title**	**WP No.**	**Lead Beneficiary Short Name**	**Type**	**Dissemination Level**	**Due Date**
1.1	Publication on detector performance	1	INFN	PDE	PU	48
1.2	Publication on CPV	1	HEPHY	PDE	PU	48
1.3	Publication on LFV and LFUV search	1	DESY	PDE	PU	48
1.4	Publication on dark sector	1	HEPHY	PDE	PU	48
1.5	Publication on spectroscopy	1	JSI	PDE	PU	48
2.1	TDR of ND280 upgrade	2	IFAE	R	PU	12
2.2	Paper on upgraded ND280	2	INFN	PDE	PU	48
2.3	Paper on cross sections on C and O	2	IFAE	R	PU	48
2.4	Paper on ν_e cross section	2	INFN	R	PU	48

2.5	Paper on δ_{CP} sensitivity	2	CNRS	R	PU	48
3.1	First calibration analysis	3	RAL	R	PU	24
3.2	Decision on UV system	3	RAL	R	CO	30
3.3	Technical note on Outer Detector	3	QMUL	R	PU	36
3.4	Final Report on front-end	3	UGE	R	PU	48
3.5	Full simulation analysis	3	QMUL	R	CO	48
4.2	Report on MCP-PMT lifetime	4	INFN	R	PU	24
4.3	mPMT prototype module	4	INFN	Other	PU	24
4.4	Report on SiPM prototypes	4	JSI	R	PU	35
4.5	Organic R&D Report	4	INFN	R	CO	48
5.1	Common Cloud Computing Demonstrator	5	DESY	Other	CO	36
5.2	Real Time Workshop	5	QMUL	Other	PU	36
5.3	Reference Statistical Report	5	CEA	R	PU	36
5.4	Physics Workshop	5	CNRS	Other	PU	48

Management, Training, and Dissemination Deliverables

Deliverable Number	Deliverable Title	WP No.	Lead Beneficiary Short Name	Type	Dissemination Level	Due Date
4.1	Photodetector Training at NDIP	4	JSI	PDE	PU	18
6.1	Belle II Masterclasses	6	UKP	PDE	PU	36
6.2	Summer School	6	TAU	PDE	PU	24,48
6.3	Outreach Portal	6	INFN	Other	PU	24
6.4	T2K Masterclasses	6	INFN	PDE	PU	48
6.5	Co-Supervision	6	CNRS	Other	PU	48

7.1	Secondments DB	7	INFN	ADM	CO	3
7.2	Kickoff meeting	7	INFN	Other	PU	6
7.3	Election of CC chair	7	INFN	Other	PU	6
7.4	Annual meetings	7	INFN	Other	PU	12,24,36,48
7.5	Progress Reports	7	INFN	ADM	CO	12,36
7.6	Actitivy Reports	7	INFN	ADM	CO	24,28

Table B3b – Milestones list

Number	Title	Related WPs	Lead Beneficiary	Due Date	Means of Verification
1.1	Report on detector performance	1	INFN	24	Document
1.2	Conference Presentation on CPV	1	HEPHY	24	PublicTalk
1.3	Conference Presentation on LFV and LFUV search	1	DESY	24	PublicTalk
1.4	Conference Presentation on dark sector search	1	HEPHY	24	Public Talk
1.5	Conference Presentation on Spectroscopy	1	JSI	24	Public Talk
2.1	Production and test of ND280 prototypes	2	INFN	24	Prototype
2.2	Improved acceptance for cross section	2	IFAE	24	Internal Report
2.3	Off axis neutrino energy reconstruction	2	INFN	36	Internal Report
2.4	Inclusion of multi-ring topologies	2	CNRS	24	Internal Report
3.1	Report on waveform digitizers	3	UGE	30	Internal Report
4.1	Report on acrylic vessel	4	INFN	12	Internal Report
4.2	Photo-transistor electrical characterizatiom	4	INFN	24	Internal Report
5.1	Flavour and neutrino internal physics workshops	5	CNRS	36	Workshops

4.2 Appropriateness of the management structures and procedures, including quality management and risk management

4.2.1 Project organisation and management structure

Due to the considerable size of JENNIFER2, a careful management structure has been prepared, effective at each step of the project and engaging the entire consortium, while avoiding dispersion of resources. The Executive Committee, consisting of the 7 WP leaders (listed in 4.1), chaired by the Scientific Coordinator (SC), will handle the project management, including quality monitoring and risk management. A Consortium Council (CC), composed of one representative for each beneficiary and partner, will act as supervisory body. The EC and SC will be assisted by a Financial Officer (FO), responsible for the continuous accounting of secondments and financial resources, and assisting also with administrative tasks. The management tasks are planned in a dedicated work package, led by the SC, with help from the FO. Dr. Antonio Passeri, senior staff physicist at INFN, coordinator of the currently on-going JENNIFER project, with broad experience managing European projects, will be the SC. Dr. Filomena Foglietta, administrative staff at INFN, with specific long term experience in administration and accounting of European projects, will be the FO. At the start of the project the CC will elect its chairperson, for a two years term. The EC and SC will directly interface with the project managements of Belle II, T2K and HK, and through the CC representatives for the participating institutions. The detailed work plan and schedule of the staff exchange programme will be presented and validated during the kick-off meeting. The tasks with associated milestones and deliverables will be monitored during the project. WP leaders will inform the SC and FO of any changes in objectives. Role and responsibilities of each body are described below.

Body	Membership and organisation	Role
Executive Committee	The Scientific Coordinator The Financial Officer The WP leaders	Communicate with the partners Organize and prepare documentation for the CC meetings, incl. scientific reports on achievements Communicate and report to the European Commission Coordinate the staff exchange programme, incl. monitoring of secondments Prepare the research plan, incl. milestones and deliverables, and the exploitation plan
Consortium Committee	The Scientific Coordinator One representative from each beneficiary and partner organisation The chairperson of the CC The CC will meet at the kick-off meeting and in follow-up meetings every year (four meetings in total)	Approve and oversee implementation of staff exchange programme for scientific, technical and complementary skills and knowledge Monitor and evaluate overall progress of the research and innovation project Ensure best Transfer of Knowledge practice among the partners Approve the work plan and the exploitation plan
Work Packages	Individual WP Leaders Each WP will have regular meetings every 6 months, or more frequently is needed	Manage activities of each WP Manage and follow-up the progress of individual WP tasks Oversee the integration of the seconded researchers into the host organisations Disseminate best practices and results

Financial management: The coordinator (INFN) has the overall responsibility for financial management. INFN has longstanding experience in management of European projects under FP6, FP7 and H2020. A specialized unit at INFN will assist the SC and FO with the coordination of all administrative and financial processes involved, including recruitment and production of annual reports, in close liaison with the Finance Department, Internal Audit and INFN EU office, in order to strictly comply with EC reporting standards. INFN also has a Legal Service which is available to give advice as required. The FO will prepare a consolidated overview of the budgetary situation on the basis of the input of the partners.

Decision-making procedure: Executive decisions will be taken by the SC, in close consultation with the EC. Any changes in the staff exchange programme will need approval by the CC. Where such changes may have impact on the contractual obligations of the project, the prior agreement of the EC Project Officer in charge will be sought. Should disputes arise, the person in charge of the specific project, with input from the seconded researcher and the supervisor will intervene to try to find an amicable settlement. For cases where that would fail, disputes will be settled by the EC whenever possible. When such resolution is not possible the matter will be raised to the CC. Gender balance will be closely considered at the level of all decisions within the project.

Consortium Agreement and communication strategy: A Consortium Agreement (CA) will be signed at the same time as the Grant Agreement, specifying the management structure and the administration of the budget.

The rules for internal communication will be considered an integral part of the CA and the SC will be responsible for making all necessary arrangements for review and/or amendments to it. The objective of the organisation and communication structure is to obtain maximum transparency for all the partners regarding the technical and overall project status. All information (meeting minutes, progress reports, financial reports, relevant publications, etc.) will be communicated to the SC and FO, who assume the responsibility for directing this information to the associated partners as appropriate. Communication between the seconded researchers and the partners in each work package will be coordinated by the WP leader, in consultation with the team leaders of the sending and hosting groups. Frequent online meetings will be encouraged.

Intellectual Property and Exploitation: The innovation activities of JENNIFER2, especially the participation of one private sector companies, requires consideration of both the exploitation potential of some of the developments, and a suitable level of protection of the related intellectual property (IP). The CA will moreover specify the handling of the shared IP during the course of the project, following discussion and agreement with the parties involved. The INFN Legal Office in charge of IP protection arrangements is available for advice.

4.2.2 Quality management and availability of resources of the coordinating organisation

The CA will specify a fraction of the management and indirect costs associated to each secondment to be retained by the coordinating organisation in the form of a common fund to help cover the salary of the FO at INFN, and to support common communication activities across the consortium. For the latter, resources to be allocated will be managed by the FO, under supervision by the EC. Quality management will be ensured by a careful planning of the tasks in WP7, and by the necessary reporting to the CC. Another important aspect of maximising the quality of the activities of such a large consortium will be the capacity to engage its members in the activities and goals of JENNIFER2, on top of their normal involvement in Belle II or in neutrino experiments. The specific JENNIFER2 activities promoting knowledge sharing and cooperation across experiments and sectors will play an important role here. The EC and SC will pay special attention to ensure that yearly consortium meetings and regular WP meetings where all such activities are discussed are carefully prepared and organised.

4.2.3 Risks and the contingency plans

Risk management will be monitored throughout the project by each WP leader. The mitigation of technical and scientific risks is based on proven methodologies, the involvement of participants with the relevant expertise, and the setting of well-defined goals and deliverables on a realistic timescale. Failures or delays in one WP or task must not jeopardize the entire project. The WP leaders will lead risk resolution attempts and will be responsible for consulting the EC, and if needed the CC and the EU Project Officer, if any significant changes to the project are likely.

The risk analysis of JENNIFER2 distinguishes between overall risks associated with the experimental program (R1, R2 and R2 in the table below) and risks of administrative nature (R4, R% and R&) both of which could delay the secondment program.

Table B3c – Risk List

Risk No	Description of Risk	WP Number	Proposed mitigation measures
R1	SuperKEKB integrated luminosity and backgrounds	1	Medium level technical/financial risk. Refocus part of resources on less sensitive channels and on background investigations
R2	Handling differences in administrative rules across the consortium	All	Low level administrative risk. The experience from the current JENNIFER project is used.
R3	Delay in Japan neutrino program	WP2 and WP3	Medium level technical risk. Refocus activity on present data analysis and detector R&D.
R4	Key staff leaving	All	Low level risk. Find replacement within their institute.
R5	Difficulties in hiring suitable postdocs and doctoral students	WP1-4	Low level risk. Positions will be advertised through suitable channels in Europe and Japan.
R6	Availability of staff from Belle II and Neutrino communities for joint activities	WP4-6	Medium/low level risk. Emphasize careful preparation of general and WP meetings

4.3 Appropriateness of the institutional environment (hosting arrangements, infrastructure)

All the members of the JENNIFER2 consortium are well-known and reputed research institutions in particle and nuclear physics. They all hold several high level technological infrastructures and top level competences in detector technology and data analysis, as described for each of them in the relevant capacity table in section 6. There are no doubts that such a consortium holds the appropriate environment to accomplish the activities proposed. However we will here briefly summarize few key points:

KEK laboratory provides excellent particle accelerating and colliding infrastructures and one of the best accelerator physics groups, whose past achievements have made the history of particle physics. Both electron positron collider and neutrino beams are Such golden class infrastructure implies also the availability of very efficient mechanical and electronic workshops, cooling infrastructures, particle detector expertise together with excellent links to Japanese industrial partners.

Larger groups, like INFN, DESY, RAL, CNRS holds large laboratories infrastructures, with wide installation spaces, mechanical and electronic support and test beam facilities. Moreover several groups (INFN, JSI, RAL, NCBJ, FBK) have valuable competences in photon detection devices test and readout, and holds dedicated laboratories. Some groups (INFN, CEA) have specific experience in building gaseous detectors and holds clean rooms and mechanical and electronic know how. Multiple groups (INFN, DESY, JSI, CNRS, QMUL) hold important computing infrastructures which are part of a worldwide distributed computing and storage network. The CAEN company is a reputed detector electronics producer, holding top class laboratories for R&D, but also various public groups hold excellent electronics design and testing workshops.

All partners have excellent outreach and communication expertise, and they organize many initiatives and events, both toward the general public and toward the scientific community. Moreover they have professional and experienced administrative support for European research projects participation and management.

Four JENNIFER2 beneficiaries are connected by pre-existing legal links with other national institutions, with which they share a close scientific collaboration on the activities included in the project:

<u>DESY</u>: a *Kooperationsvereinbarung* was signed in February 2016 among DESY and other 10 German institutions, covering the legal aspects of their cooperation in the Belle II experiment. The entities list and acronyms are listed in the DESY description table in section 6. The affiliated institutions in JENNIFER2 take responsibilities are: HLL and MPP for PXD detector operation and monitor; LMU for PXD operation and Belle II software coordination; BN for PXD detector data concentrator; TUM and GIE for data acquisition; GOE for detector simulation and calibration; MZ for Slow Control and Data Quality Monitoring; JUL for tracking software; KIT for full event interpretation software; DESY for PXD project responsibility.

<u>NCBJ</u>: Warsaw University of Technology (WUT, Faculty of Electronics and Information Technology) collaborate closely since many years. Both institutions belong to "NEUTRINA-T2K" consortium formed on May 11 2011 by six Polish institutions being members of T2K and Hyper-Kamiokande projects. NCBJ is currently leader of the consortium. In JENNIFER2 WUT will work on task 3.4 and 4.3.

<u>QMUL</u>: five UK institutions are affiliated to QMUL in the same UK grant for HyperKamiokande project. QMUL is the grant coordinator and holds the funds. The member of the affiliated institutes are considered personnel of QMUL subject to its staff rules and regulations and associated with the Particle Physics Research Centre at QMUL. Affiliated institutes will work with QMUL on calibration (Imperial, Sheffield and Warwick) and outer detector (Edinburgh), described in WP3, and DAQ (Lancaster), described in WP5.

<u>STFC-RAL</u>: three UK institutions are affiliated to RAL in the same UK grant for SuperKamiokande project. RAL is the grant coordinator and holds the funds. The member of the affiliated institutes are considered personnel of RAL subject to its staff rules and regulations and associated with the Particle Physics Department at RAL. Affiliated institutes will work with RAL on Super-Kamiokande (Liverpool, Oxford) described in WP3, and the T2K upgrade (Glasgow), described in WP2.

Table B3d – Secondments allocated to affiliated entities

WP	Task name	Staff member profile (ER/ESR/MNG/ADM/TECH)	Beneficiary /partner short name	Affiliated entity short name	Country of the affiliated entity	Person-months allocated
1	1.1, 1.2	ER/ESR	DESY	BN	Germany	8
1	1.1, 1.5	ER/ESR	DESY	GIE	Germany	4
1	1.1, 1.2	ER/ESR	DESY	GOE	Germany	7
1	1.1	ER/ESR/TECH	DESY	HLL	Germany	5

1	1.5	ER/ESR	DESY	JUL	Germany	4
1	1.3	ER/ESR	DESY	KIT	Germany	7
1	1.1, 1.3	ER	DESY	LMU	Germany	2
1	1.1, 1.2	ER/ESR/TECH	DESY	MPP	Germany	12
1	1.1, 1.4	ER/ESR	DESY	MZ	Germany	6
1	1.1, 1.5	ESR	DESY	TUM	Germany	4
5	5.2	ER/TECH	DESY	GIE	Germany	2
5	5.3	TECH	DESY	KIT	Germany	1
5	5.1	ER/ESR/TECH	DESY	LMU	Germany	4
5	5.2, 5.4	ER/ESR	DESY	TUM	Germany	3
3	3.4	ER/ESR	NCBJ	WUT	Poland	5
4	4.3	ER/ESR	NCBJ	WUT	Poland	3
3	3.1/3.3/3.5	ER	QMUL	Edinburgh	UK	12
3	3.1/3.2	ER	QMUL	Imperial	UK	2
5	5.2	ER	QMUL	Lancaster	UK	2
3	3.1/3.2	ER	QMUL	Sheffield	UK	3
3	3.2	ER	QMUL	Warwick	UK	3
3	3.1/3.2	ER	STFC-RAL	Liverpool	UK	9
3	3.2/3.5	ERS	STFC-RAL	Liverpool	UK	5
3	3.2/3.5	ERS	STFC-RAL	Oxford	UK	9
5	5.2	ERS	STFC-RAL	Oxford	UK	3
2	2.3	ERS	STFC-RAL	Glasgow	UK	6

4.4 Competences, experience and complementarity of the participating organisations and their commitment to the action

The JENNIFER2 project exploits complementary knowledge of its members at various levels:

- the first, most evident, complementarity relies between the European institutions detector competences and the KEK laboratory infrastructures and expertise in particle accelerator technology.
- Unique complementarity exists between Belle-II, an electron-positron collider experiment, and T2K, a long baseline neutrino experiment. Synergy between two such research communities will produce advances and new ideas in particle detector design and electronics, in physics data analysis techniques and in outreach initiatives. The JENNIFER2 networking activity will be crucial to this aim, in particular the two WP where the neutrino and collider communities will actually work together on specific technology items.
- Intersectorial complementarity will also be exploited in the JENNIFER2 activities, first of all thanks to the presence of CAEN as a consortium member, whose role will be to provide advice and engineering skills for detector electronics design and maintenance to all members. But collaboration with industrial sector is present in many of the JENNIFER2 R&Ds, and technology transfer opportunities are carefully considered.
- A more general complementarity is actually a cultural one, between European and Japanese scientific and technological communities. Bridging different approaches and putting them in synergy at various levels is the real challenge of the JENNIFER2 consortium. Participation of Japanese colleagues to all the networking activities will be crucial and will be supported by the consortium budget.

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