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EURO-LABS

EUROpean Laboratories for Accelerator Based Science

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MILESTONE REPORT

DESIGN AND CONSTRUCTION OF A BEAM MONITOR BASED ON SCINTILLATING FIBRES

MILESTONE: MS25

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Abstract:

Within the scope of work-package 4.4, subtask 4.4.3 aims to provide a beam monitor for the PSI beam line PiM1 based on scintillating fibres. This document describes the activities towards getting this service improvement ready for the users.

For more information on EURO-LABS, its partners and contributors please see https://web.infn.it/EURO-LABS/

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Executive summary

The Paul Scherrer Institute at Villigen, Switzerland runs several particle accelerators. One of the secondary beam lines at the proton cyclotron called PiM1 is partly used for test beams. In order to improve the service to the test beam users a beam monitor based on scintillating fibres is constructed. This document reports the achievement of milestone MS25, the operation of a prototype of the system.

1. INTRODUCTION

Paul Scherrer Institute (PSI) provides several secondary beam lines grouped around two targets in the main beam of the proton cyclotron. The PiM1, a high-resolution pion beam line is shared between particle physics experiments and hardware tests, the so-called test beams. The beam line is very flexible, and the users have full control over all steering elements of the beam line (magnets, collimators, degraders). The adjustment of the large multitude of parameters can be simplified to a great extent if fast feedback of the beam profile (and, if possible, also its composition) is provided. The aim is to make a system similar to what is presently under development for the MEG (Mu to E Gamma) experiment located at the PSI secondary beam line PiE5 and make it available to test beam users.

2. DESCRIPTION OF THE SYSTEM

The system is a planar 2-layer fibre tracker. The layers are closely spaced and have a stereo angle of 90°. Each layer consists of 21 fibres mounted at a pitch of 5mm with a length of 200mm. So, the region covered is roughly 10 cm by 10 cm, which is much larger than the cross section of the beam when focused. The fibres have a square cross section with an edge length of 500µm and are double cladded for a good light yield. Each fibre is read out by **Si**licon **P**hoto **M**ultipliers (Hamamatsu MPPC S13360-1350CS) on each side to suppress noise counts. The SiPMs can be operated in magnetic field and thus can be placed close to the beam line magnets. The first prototype was read out with MAR-6 pre-amplifiers whose signals were processed by DRS4 chips. The second prototype for operation in vacuum is read out using the PSI WaveDREAM (Drs4 based READout Module) system. The good analogue resolution of the system allows for dE/dx measurements and therefore particle identification for the very low energy "surface muons" in the PiE5 beam line. The test beam users in PiM1 use higher energy particles originating from pion decays in flight. Here a particle identification is possible with a ToF measurement which is also demonstrated (Fig.1).

For the MEG experiment, the fibres are installed in the vacuum of the beam line and then moved out of the beam when beam adjustment is completed. The higher energies of the particles used by a majority of test beam users in PiM1 allow for its operation in air. However, the system provided will be a copy of the system for the MEG experiment which in principle can be connected to a vacuum system.

3. TEST OF THE PROTOTYPE IN AIR

A first prototype of the fibre tracker has been tested in air in the PiE5 beam line using 28 MeV/c positive muons. It was read out with MAR-6 pre-amplifiers whose signals were processed by DRS4 chips. The beam profile could be measured within a few seconds. The result is in agreement with the detector used routinely at the MEG experiment. Particle identification has been demonstrated for both methods as shown in Figure 1. In the upper part the energy deposition of 28 MeV/c particles in the fibre is shown. Here a clear separation between positrons and muons can be seen. These particles originate from pion decay at rest in the production target and don't exhibit the bunch structure of the primary beam. Particles with a higher momentum (115 MeV/c) have an energy deposition in the fibres which is lower and closer to each other. However, as they originate from a decay in flight behind the production target, they conserve the bunch structure. As they have the same momentum selected by the dipole magnets of the beam line but a different mass, their time of flight can be used for particle identification. The system time resolution is sufficient to measure this difference as shown in the lower part of Figure 1.

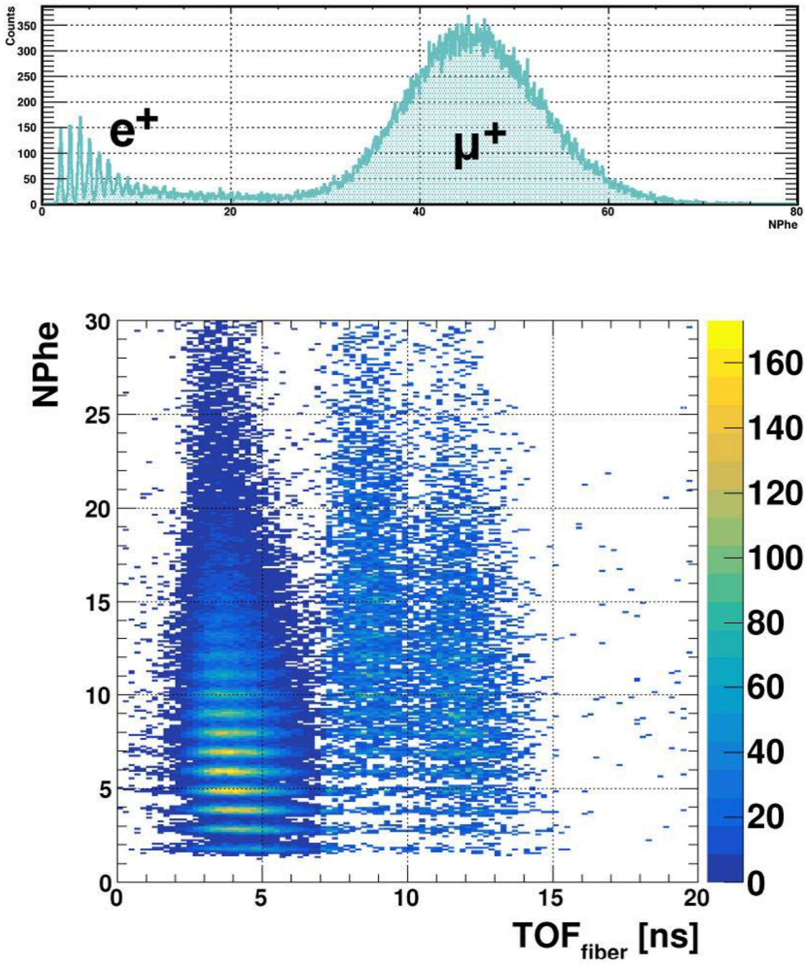

Figure 1: Top: Charge distribution for initial 28 MeV/c positrons and muons. Particles pass through a mylar equivalent thickness of ~300 µm before reaching the active detector. Bottom: The scatter plot of the charge versus the time-of-flight for positrons, pions and muons (left to right) with momentum of 115 MeV/c.

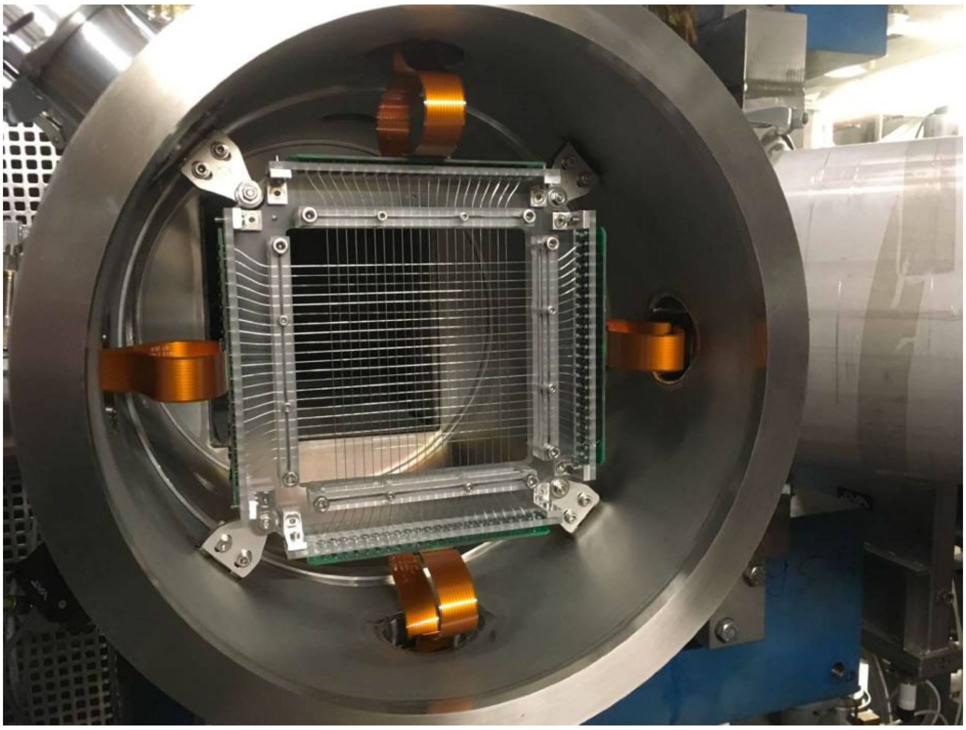

Figure 2: Fibre tracker prototype for operation in vacuum.

4. PROTOTYPE FOR OPERATION IN VACUUM

As the second step a prototype, shown in Figure 2, is constructed for operation in the beam vacuum. The readout system is built based on the PSI WaveDREAM system. It has also been tested in the PiE5 beam line with 28 MeV/c positive muons. A beam profile obtained with a few seconds of beam is shown in Figure 3.

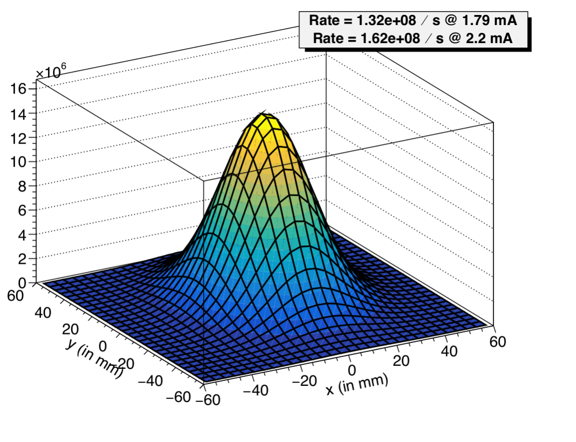

Figure 3: Beam profile measured in the PiE5 beam line with the prototype using 28 MeV/c positive muons.

5. ONGOING DEVELOPMENTS AND OUTLOOK

The final system with the fibre tracker on a movable stage in vacuum is presently under design. The aim is to provide the final system before the accelerator start-up in 2025.