The CAPHRI detector: a fast tool for Mu2e beam normalization

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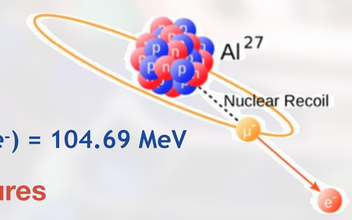
Mu2e: a search for $\mu^- N \rightarrow e^- N$

The Mu2e experiment at Fermilab will search for the CLFV process of coherent neutrinoless muon-to-electron conversion in the field of Aluminum atoms

$$R_{\mu e} = \frac{\Gamma(\mu^- + N(A,Z) \rightarrow e^- + N(A,Z))}{\Gamma(\mu^- + N(A,Z) \rightarrow \nu_\mu + N(A,Z-1))}$$

physics signal

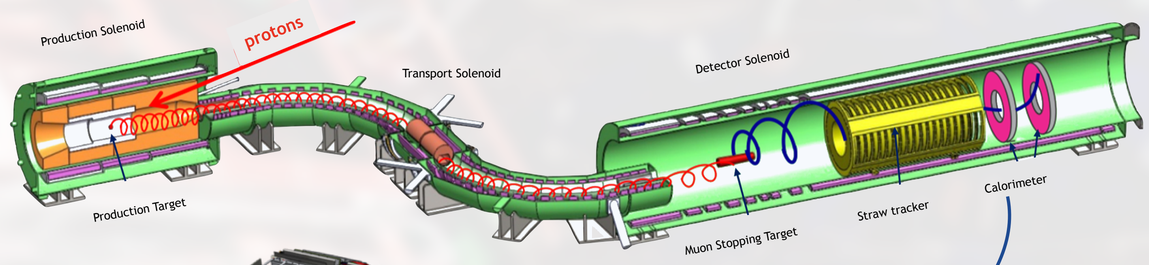
total muon captures

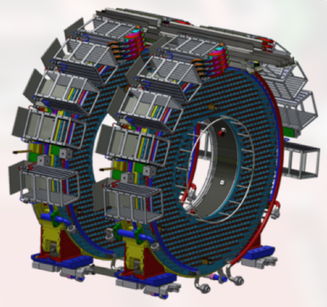


The target sensitivity ($R_{\mu e} \sim 8 \cdot 10^{-17}$ @ 90% CL) requires accurate monitoring of the **muon capture rate (MCR)**

The **Stopping Target Monitor**, located 34 m from the stopping target, provides the absolute scale with 10% precision in few minutes of running

Experiment layout

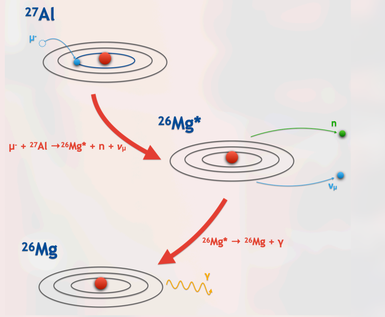


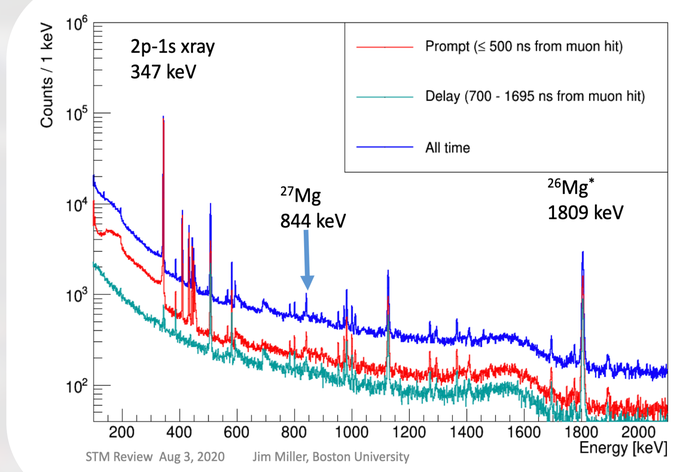


Electromagnetic calorimeter:
- two annular disks
- 674 undoped CsI crystals for each disk
- two read out channels per crystal (custom SiPMs)

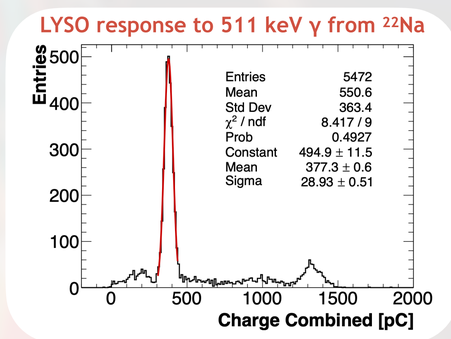
The CAPHRI detector

Goal:
fast measurement of MCR by detecting the **1.8 MeV** gamma emission line of the $^{27}Al(\mu^-, \nu n\gamma)^{26}Mg$ nuclear reaction





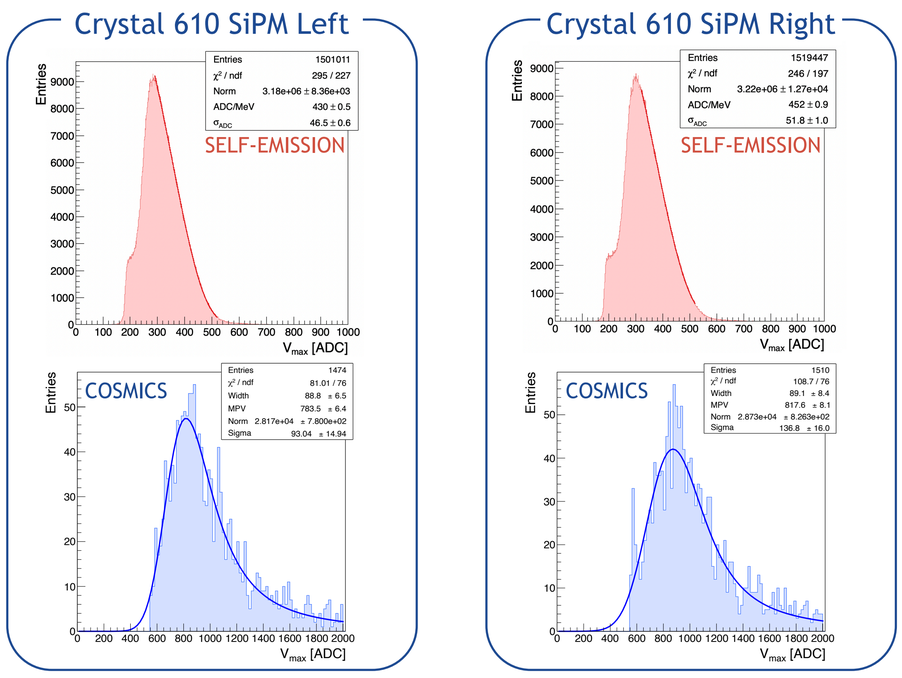
Detector concept:
four LYSO crystals (fast, radiation resistant, high light yield) installed in the upstream calorimeter disk and coupled to the standard readout



- At full beam intensity, a precision of ~3% on **MCR** is achieved for each injection cycle (1.4 s), with response times in the **10 ms** range
- Secondary observables from calorimeter and tracker provide an estimate on the **number of protons on target** for each pulse
  → CAPHRI enables **correlation** of MCR and number of protons on target

In the experimental hall: ROU calibration

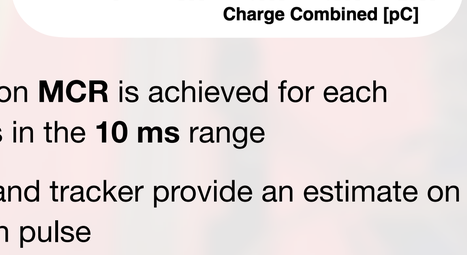
The single channel energy response is calibrated at two SiPM overvoltages:
- **V_{op}:** LYSO **self-emission**, using the β-decay endpoint (1.2 MeV)
- **V_{op} - 8V:** **cosmic ray** spectra fitted with a Langauss function to extract MPV

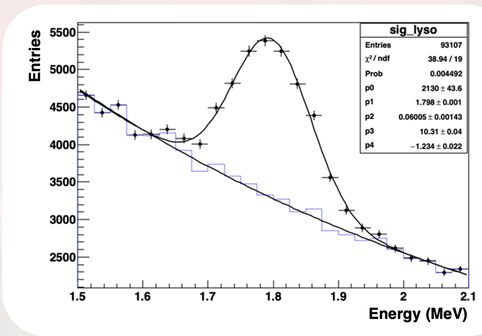


→ Crystal **light yield** consistent with expectations (~500 photoelectrons/MeV)
→ Channel **inter-calibration** at the **2-4% level**

Simulated signal

Monte Carlo simulations used to evaluate the detector **acceptance** and the expected **signal-to-background ratio** under realistic running conditions





The detector acceptance and background rejection satisfy the requirements for physics operations, with about 1000 detected events per beam injection at a beam power of 1.5 kW

Conclusions and outlook

- CAPHRI is operational and calibrated with cosmic rays and LYSO self-emission
- Measured light yield and inter-calibration meet expectations
- Simulations predict adequate signal-to-background separation

→ CAPHRI will be an effective tool for fast signal normalization and beam monitoring

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