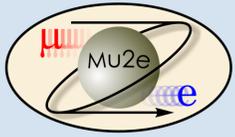


An automated QC station for the calibration of the Mu2e Calorimeter Readout Units



Mu2e Calorimeter Readout Units

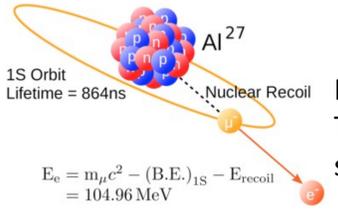


Elisa Sanzani¹ on behalf of the Mu2e Calorimeter group

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The Mu2e Experiment

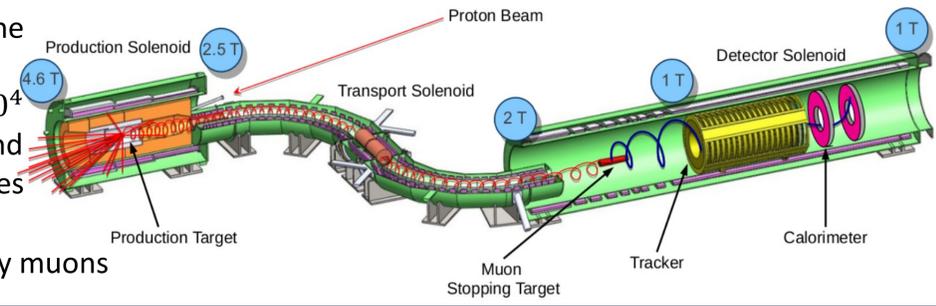
→ For more info about Mu2e see Fabio Happacher's talk!



Mu2e will search for Charged Lepton Flavour Violation (CLFV) in the muon sector via the conversion process: $\mu^- N \rightarrow e^- N$. The candidate signature is provided by a 104.96 MeV monoenergetic electron. The goal of the experiment is to improve the current sensitivity on the ratio between the conversion and capture rates by four orders of magnitude, reaching a sensitivity of $3 \cdot 10^{-17}$.

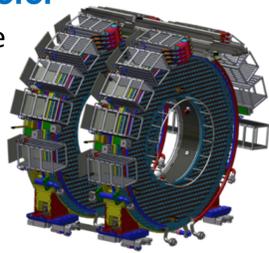
A high intensity pulsed muon beam at 10 GHz is stopped on the Al target and the interaction products are analysed by the Mu2e detectors:

- ✓ A high momentum resolution 3 meter long Straw Tube Tracker, made of $\sim 2 \cdot 10^4$ straws arranged in 36 planes, suppresses the irreducible decay in orbit background
- ✓ A pure CsI Crystal Calorimeter complements the tracker information and provides excellent energy and time resolution
- ✓ A Cosmic Ray Veto surrounds the detector regions to identify incoming cosmic ray muons



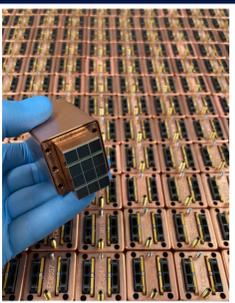
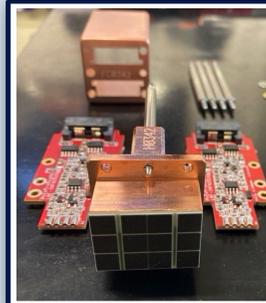
The Mu2e Electromagnetic Calorimeter

- Two annular disks, each one filled with 674 pure CsI crystals + 2 large area UV-extended SiPMs
- Work in a 10^{-4} Torr vacuum, 1T magnetic field and in a harsh radiation environment while providing:
 - ✓ $\sigma_t < 500$ ps @ 100 MeV
 - ✓ $\sigma_E/E < 10\%$ @ 100 MeV
 - ✓ $\sigma_x < 1$ cm

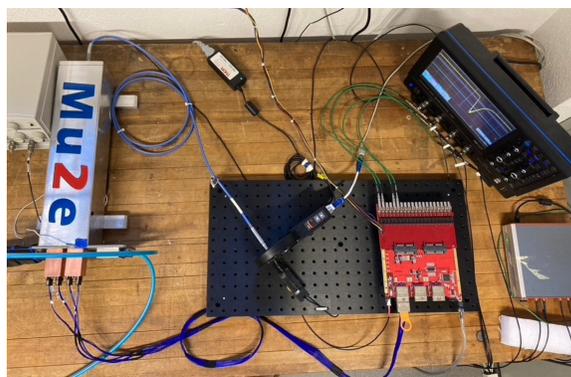


Calorimeter Readout Units

- ✓ Two Hamamatsu UV-extended 2x3 matrices of 6x6 mm² SiPMs, 50 μ px
- ✓ Two Front End Electronics Boards (FEE), one per SiPM
- ✓ One copper holder to cool down SiPMs and one Faraday cage

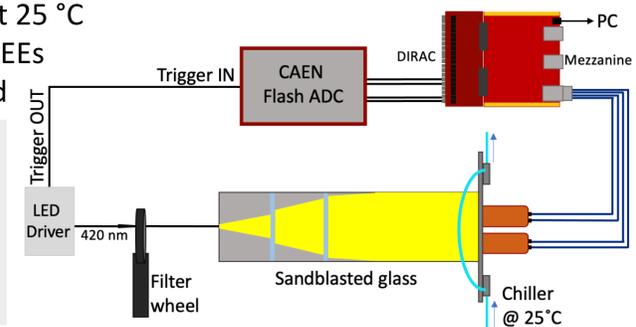


The LNF Quality Control Station for the Calorimeter Readout Units

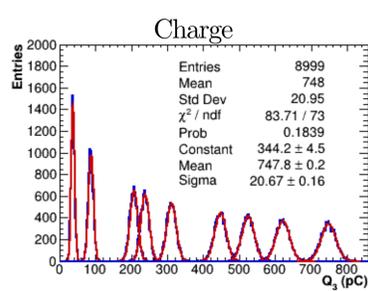
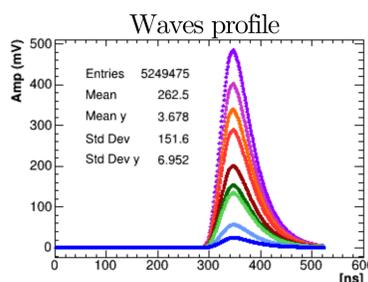
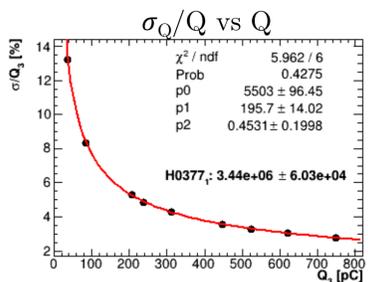


- ✓ A 420 nm Blu LED goes through a 9 position filter to attenuate the light intensity
- ✓ Sandblasted glass layers ensure uniform light diffusion on the SiPMs faces inside a box for light tightness
- ✓ 2 ROUs are mounted on an Al cooling plate and stabilized at 25 °C
- ✓ Mezzanine and DIRAC boards collect the signals from the FEEs
- ✓ The signal is acquired via USB through the Mezzanine board

- Bias voltage scan : $V_{op} - 4V$ to $V_{op} + 2V$.
- 10^4 events acquired/HV point for each filter position
- Study of SiPM Gain, Photon Detection Efficiency and total charge for every light intensity and bias voltage
- Parallelized live analysis of the data, 7' / scan



Calibration and QC results



- **Gain measurement** \Rightarrow study of the ROU response at V_{op}

$$\frac{\sigma_Q}{Q}(Q) = \sqrt{\frac{p_0}{Q} + \frac{p_1^2}{Q^2} + p_2^2} \Rightarrow G = p_0/q_{e[pC]}$$

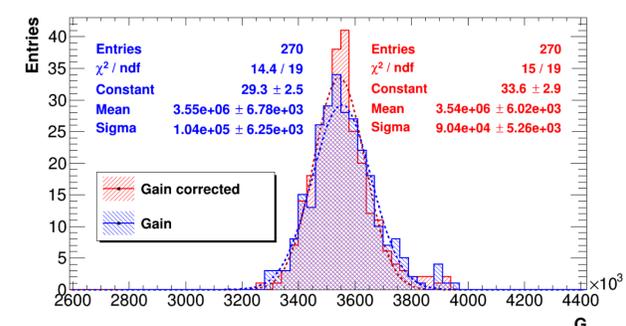
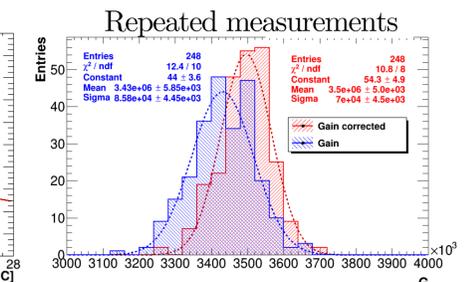
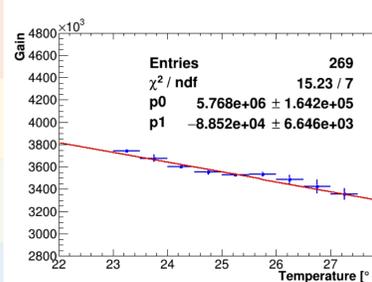
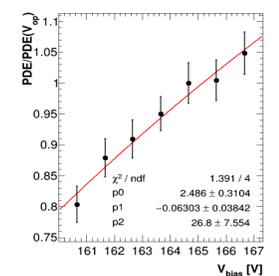
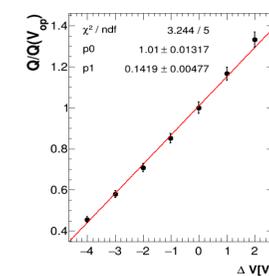
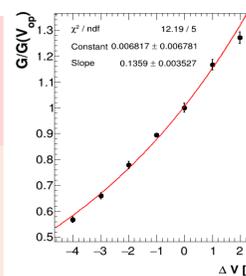
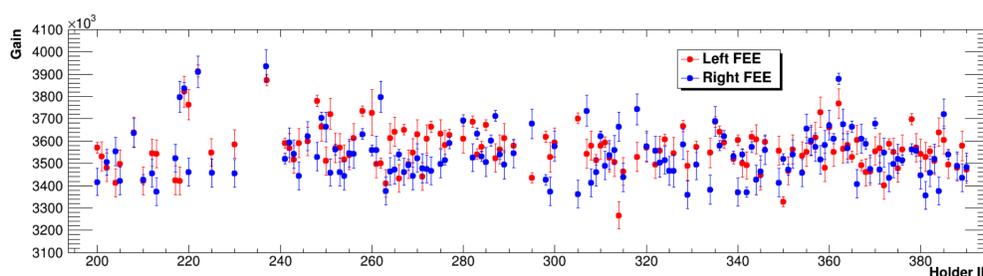
- **Dependence of G, Q, PDE on V_{bias}** \Rightarrow 7 HV points scan

$$G(V) = \exp[\text{slope} \cdot V + \text{const}]$$

$$Q(V) = p_0 \cdot V + p_1$$

$$PDE(V) = p_0 \cdot \left[1 - \left(p_1 \cdot V \cdot \exp(-p_2/\sqrt{V}) \right)^{-2} \right]$$

- **QC Station's measurement reproducibility** \Rightarrow 2% gain spread on repeated measurements
- **Gain temperature dependence** \Rightarrow correction in T
Correct to 25°C : $G_{corr} = G (1 + 0.016 \cdot (T - 25))$
- **ROUs consistency** \Rightarrow 2.5% gain spread after correction



Conclusions

The Mu2e Calorimeter has strict requirements in terms of performance and stability. To ensure these requirements are met, a full characterization of the Readout Unit parameters is needed. The QC Station allows to perform a HV scan of 2 ROUs at the time in 7', with a reproducibility better than 2% on the final gain. The dependence of gain, charge and PDE on the SiPM overvoltage and on temperature can be also studied. The average gain value at operational voltage is $3.6 \cdot 10^6$, with a spread along production of O(3%) that well satisfies the Mu2e calorimeter requirements.