Test Beam of the calibration system for the Muon g-2 experiment performed with 500 MeV e^- beam at the Beam Test Facility in Frascati

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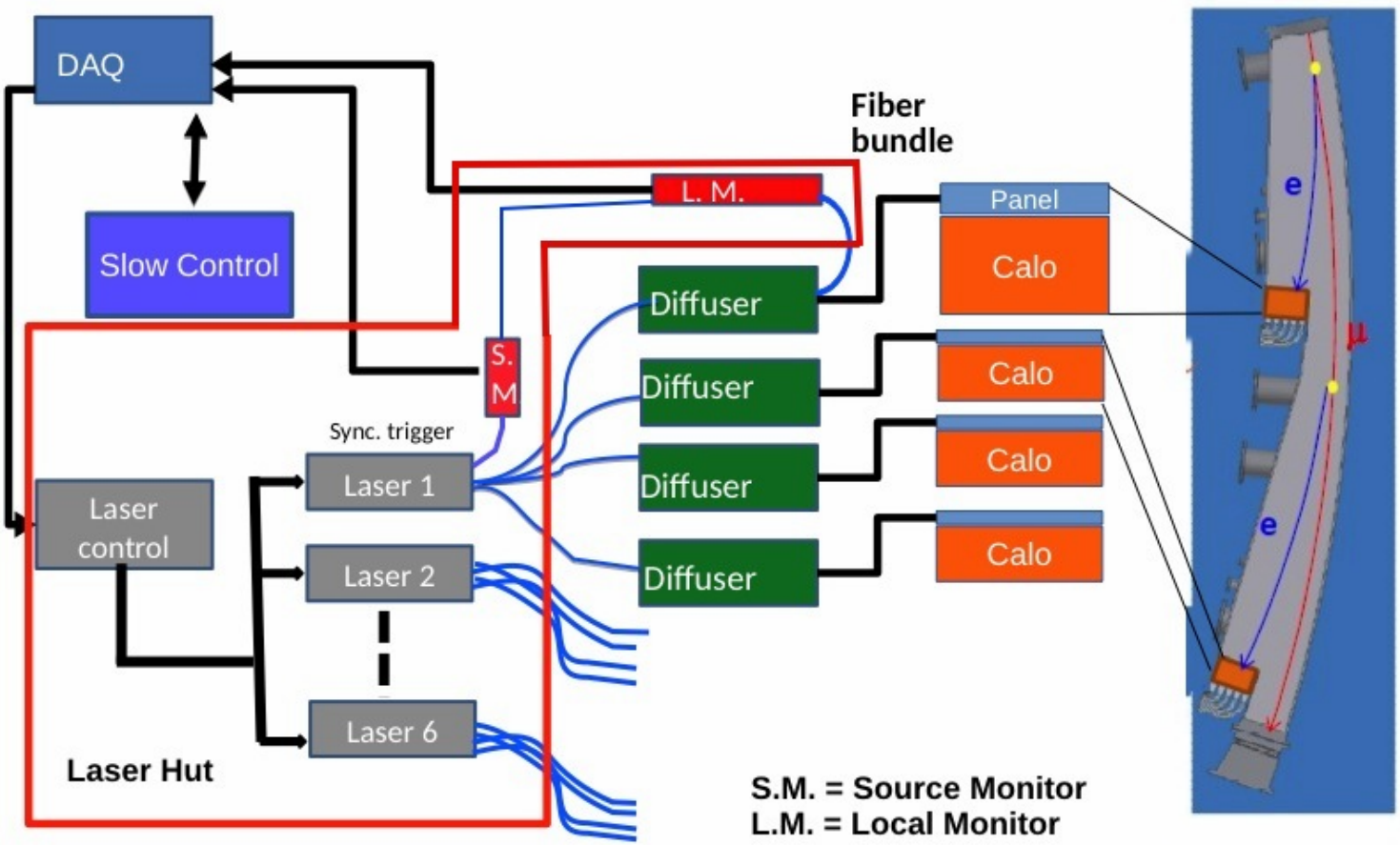
Outline

Laser-based calibration system for the muon *g*-2 experiment

- Objectives:
  - calibration of the detection time;
  - equalization of the crystal response and light intensity;
  - calibration of the positron energy measurements;
- Key elements:



The Test Beam

Purpose:

- test the complete calibration system chain;
- calibrate the equivalent luminous energy of the laser.

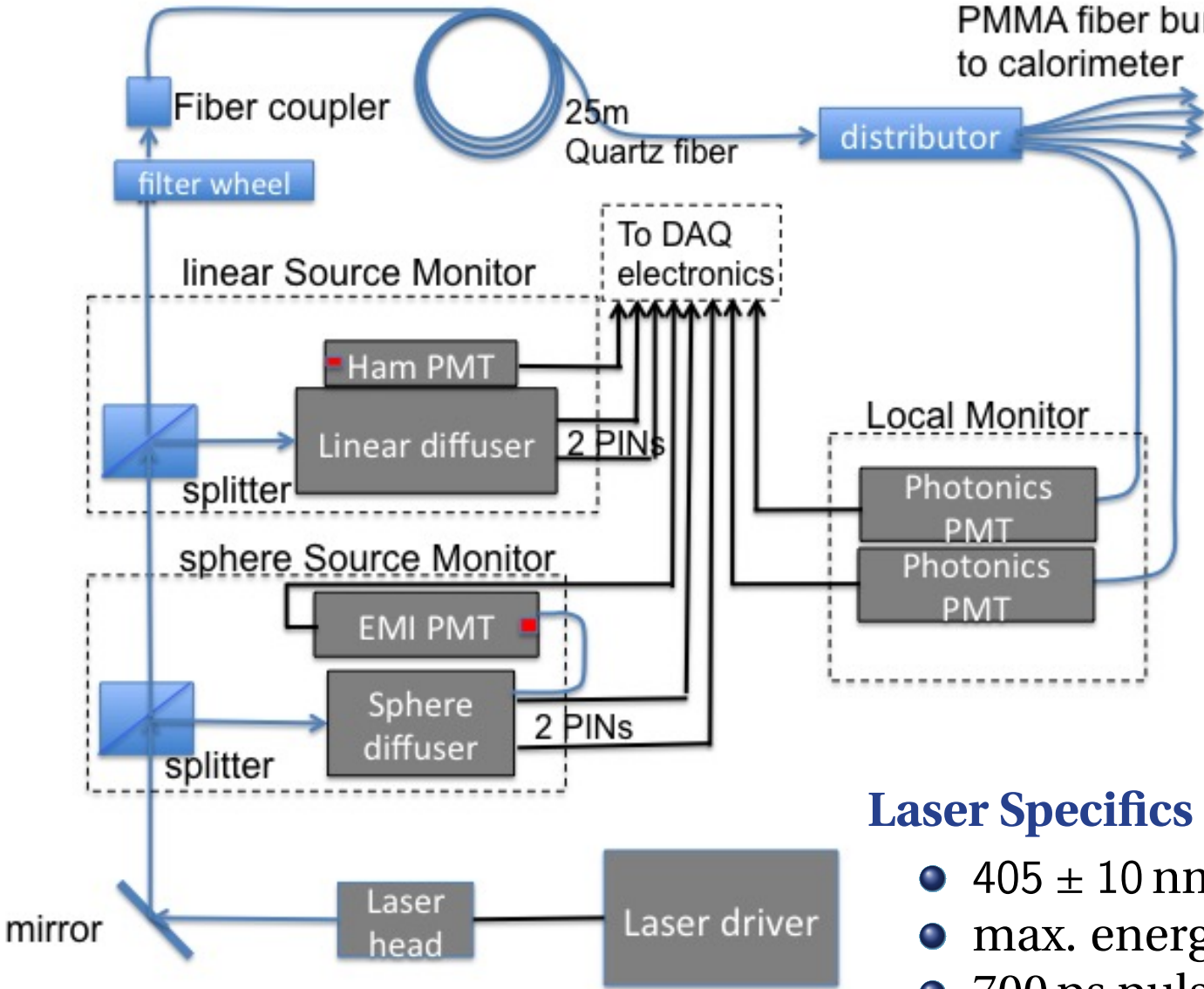
Beam Test Facility (BTF) @ Laboratori Nazionali Frascati (LNF)

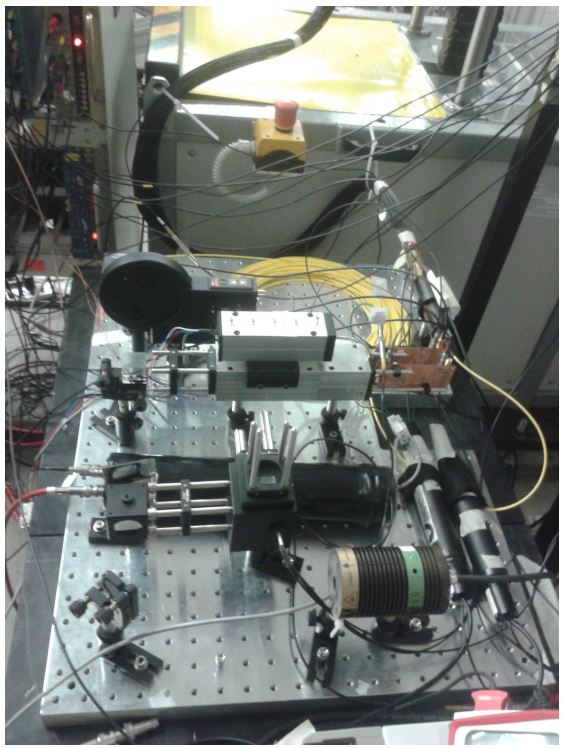
- BTF is part of the DAΦNE accelerator complex
- 100 m^2 instrumented experimental hall

The Electron Beam

- highly collimated;
- 450 MeV ±1% monoenergetic;
- 10 ns spill @ 50 Hz repetition rate;
- average of 1-3 electrons per pulse;
- 250 μm of transverse dimension.

Experimental Setup: Laser Distribution System





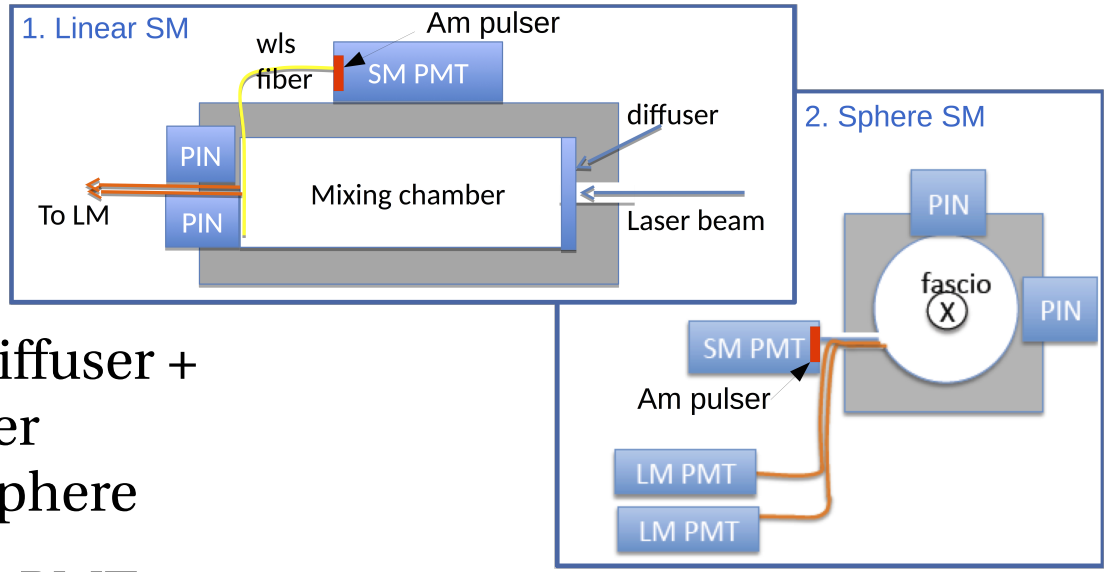
Laser Specifics

- 405 ± 10 nm laser by PicoQuant;
- max. energy pulse 1 nJ;
- 700 ps pulse width;
- up to 40 MHz of repetition rate.

Experimental Setup: Monitoring system and Calorimeter

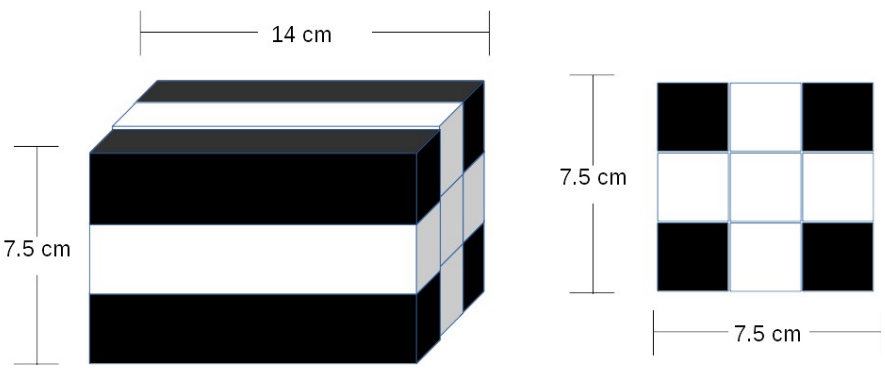
Monitoring System:

- two Source Monitor designs:
  1. Linear SM: engineered diffuser + reflective mixing chamber
  2. Sphere SM: integrating sphere
- Local Monitor: two Photonics PMTs;
- custom PIN frontend electronics;



Calorimeter:

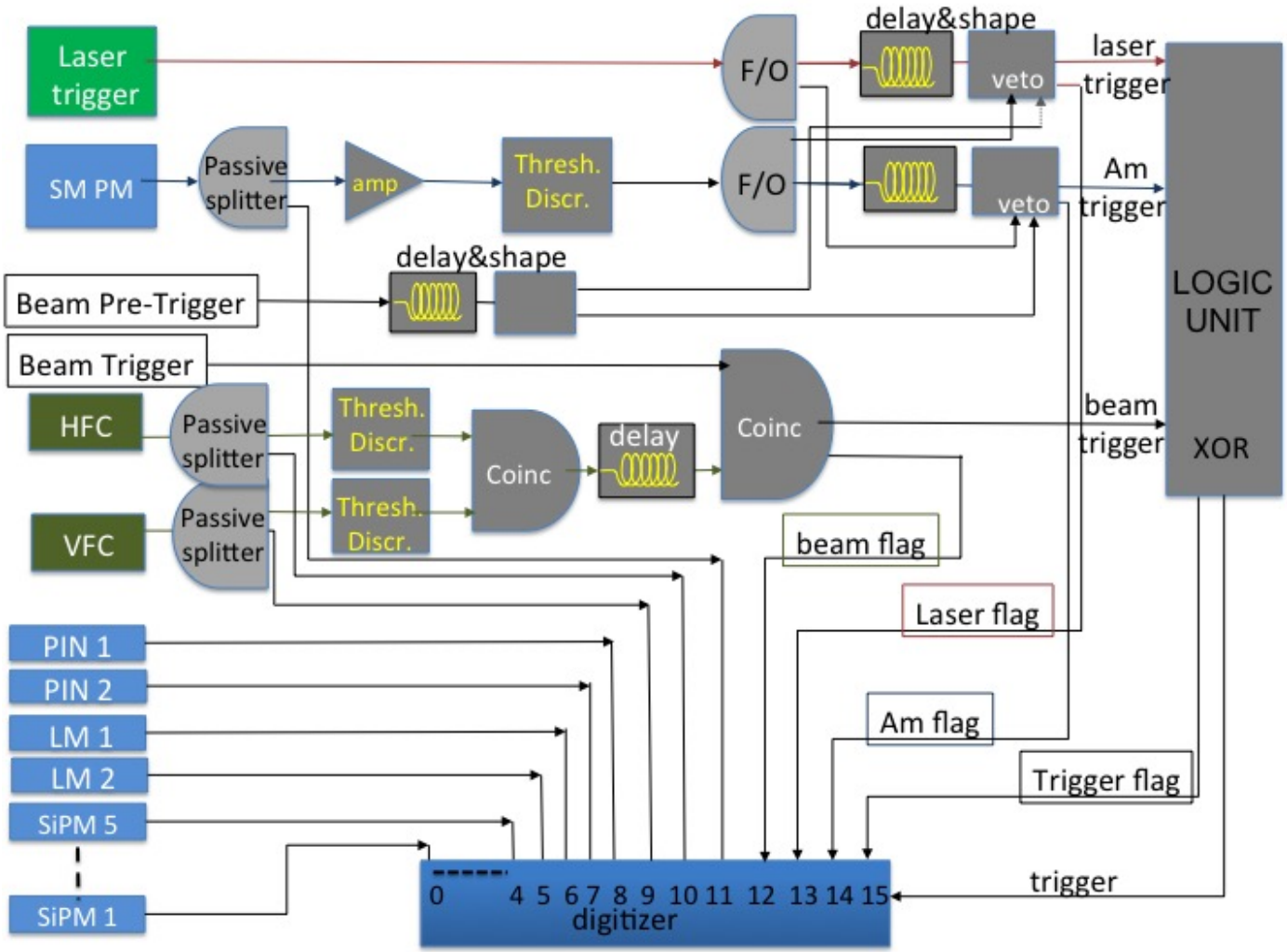
- final detector's subset of 5 elements;
- element = $2.5 \times 2.5 \times 14\ \mathrm{cm}^3$ PbF_2 crystal + 16 ch. Hamamatsu SiPM;
- 4 mock Plexiglass crystals.



Experimental Setup: Acquisition System

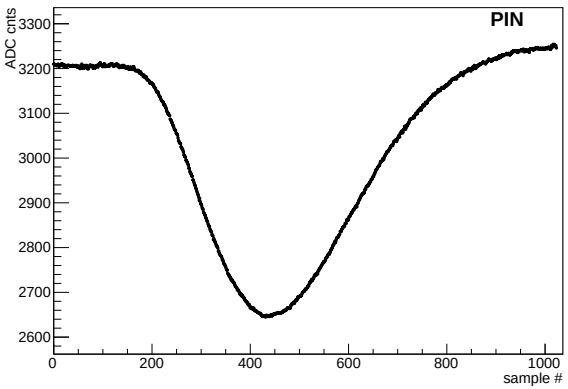
DAQ included:

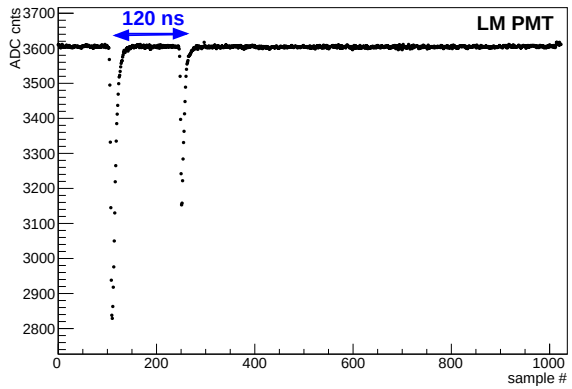
- two CAEN digitizer (5742, 5 GS/s);
- 3 triggers (beam, laser, Am) using NIM electronics;
- ambient and SiPMs temperatures.

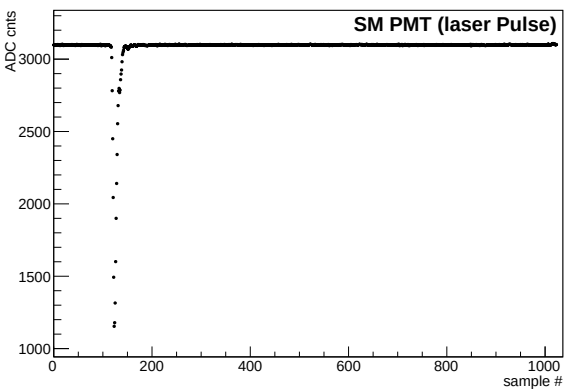


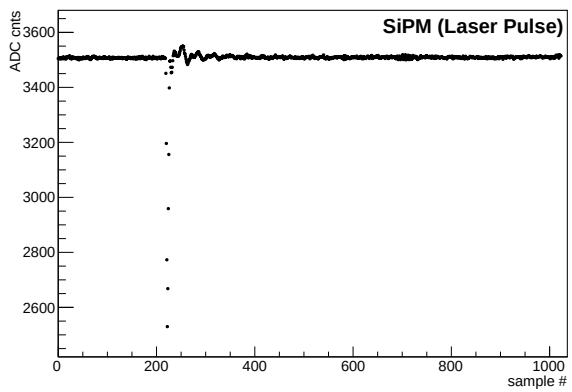
Experimental Setup: Typical Events

Laser Events

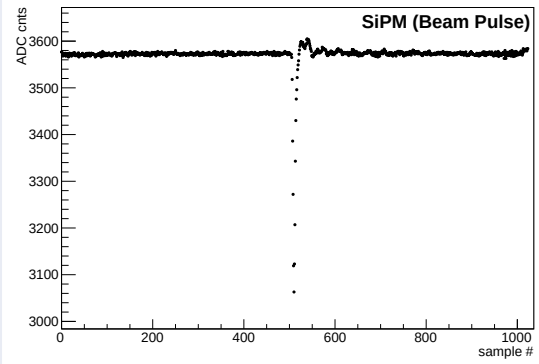




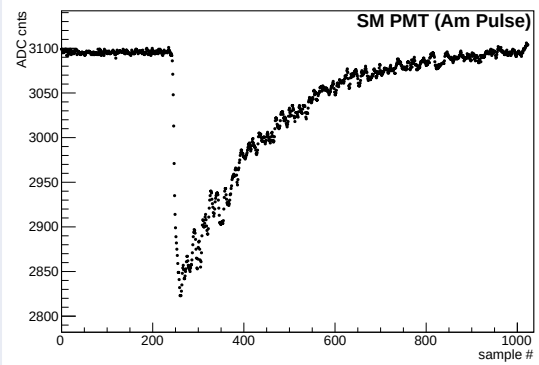




Beam Events



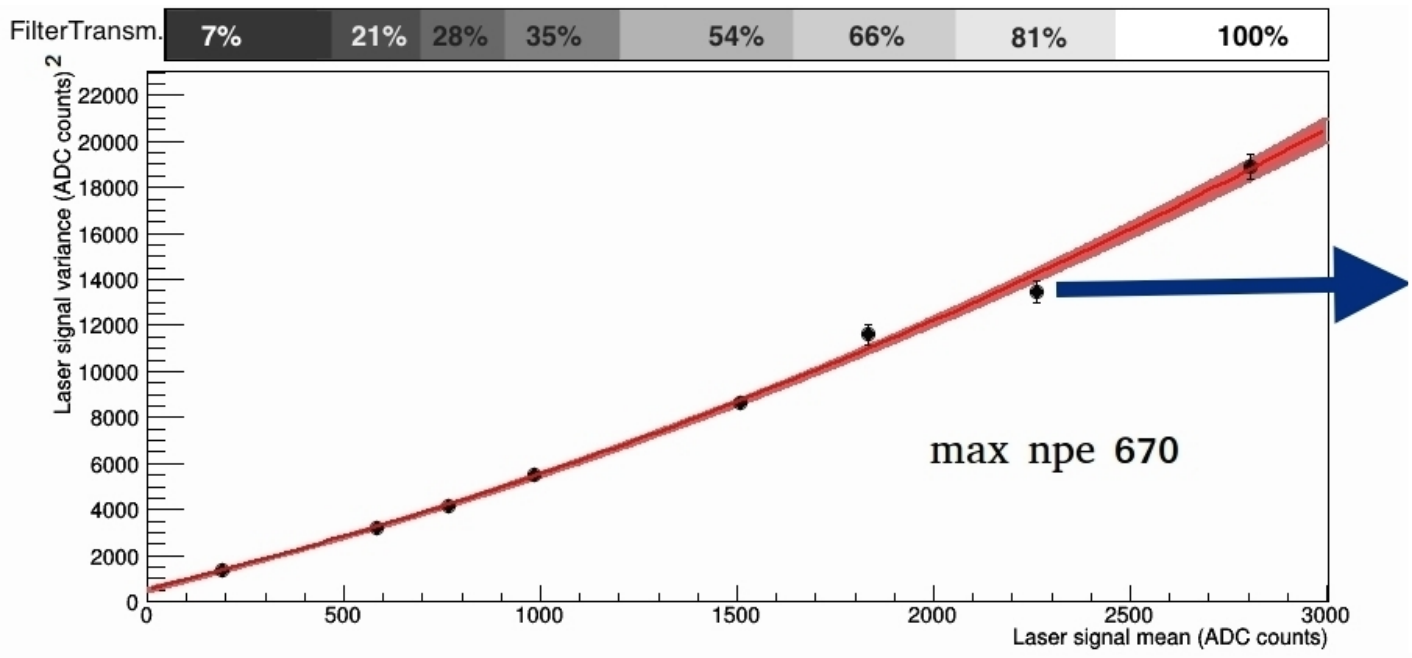
Americium Events

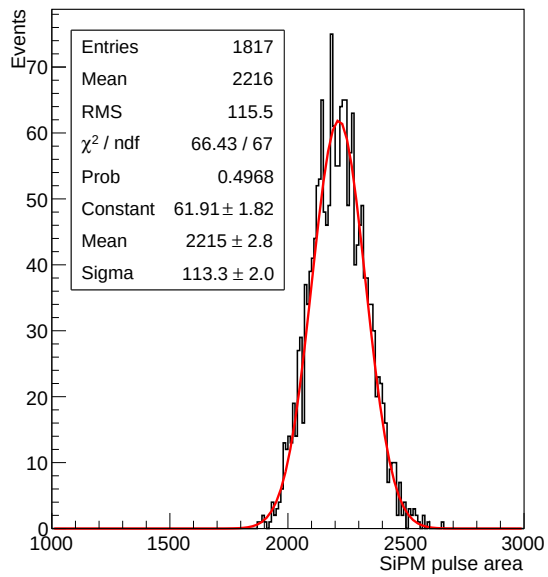


Results: Calibration trough photostatistics

- Using laser data with different intensities obtained with filter wheel;
- measure laser-pulse area mean (μ_L) & variance (σ_L^2):

$$\mu_L = k n_{p.e.} \qquad \sigma_L^2 = \underbrace{\sigma_{noise}^2}_{\text{electronic noise}} + \underbrace{(k\sqrt{n_{p.e.}})^2}_{\text{Possion statistic}} + \underbrace{\alpha(k n_{p.e.})^2}_{\text{intrinsic fluctuations}} = \sigma_{noise}^2 + k\mu_L + \beta\mu_L^2$$





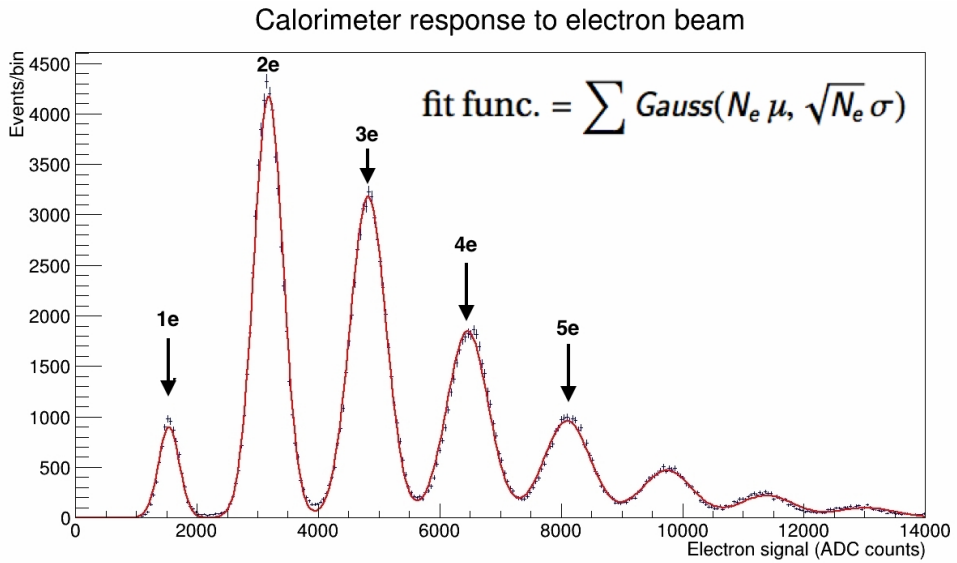
- from fit identify k as $p1$ the pulse area/p.e.
- measured 600-800 p.e. depending on SiPM, bias voltage and temperature.

Results: Equivalent light Calibration

Photoelectron yield from beam:

$$(\mu_{1e}/k) \,/\, 450\,\text{MeV} = 0.9\,\text{p.e./MeV}$$

- μ_{1e} single electron peak mean from fit.
- k from photoelectron calibration;
- 450 MeV e-beam energy;



Laser Equivalent Energy:

- μ_L mean laser-pulse area on SiPMs (filter 100% trasm.)
- $\mu_L/\mu_{1e} \sim 1.8 \Rightarrow$ Laser Equivalent Energy @ TB $\sim$ 800 MeV

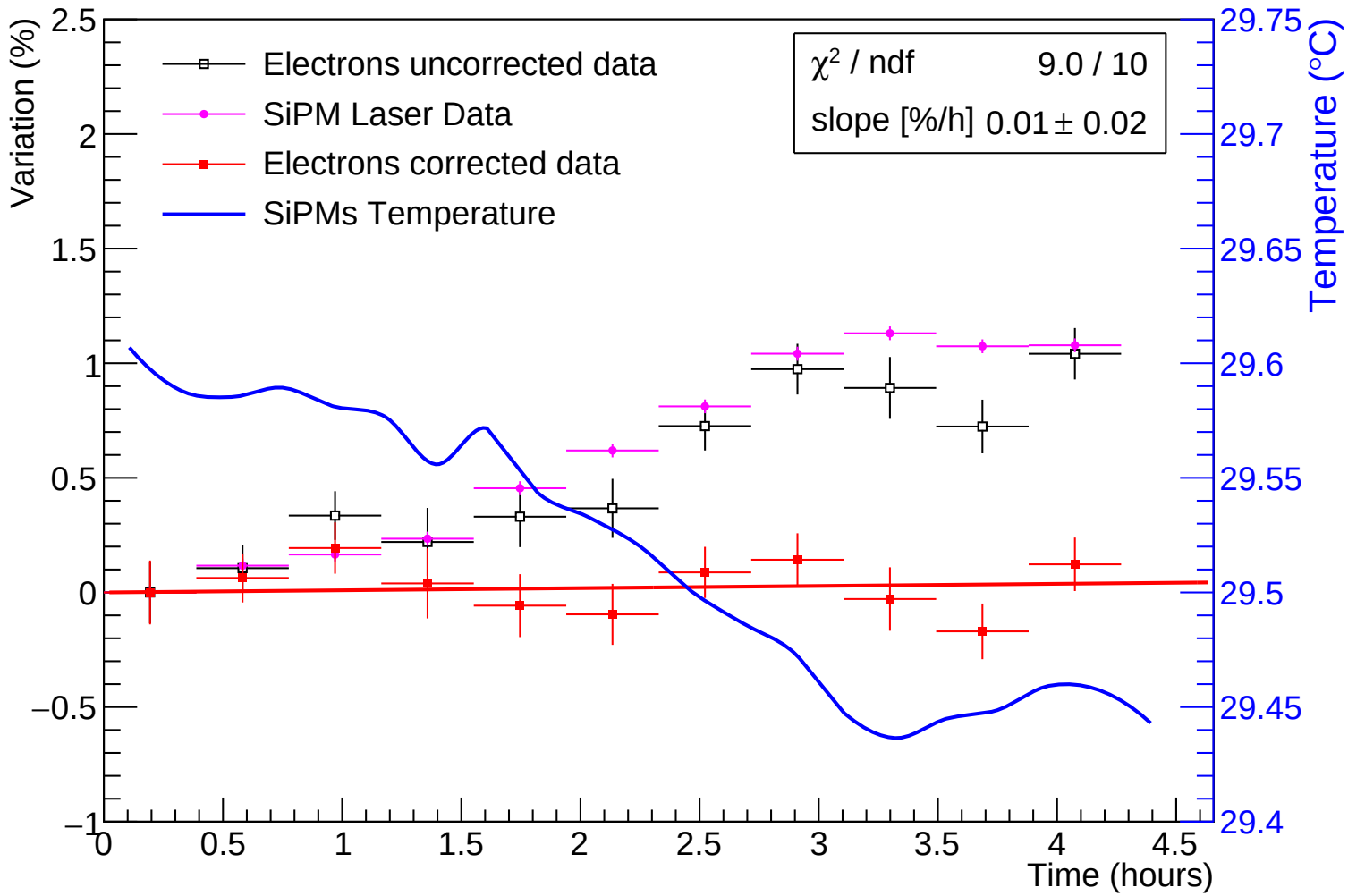
Scale to experiment:

- light power before calorimeter:

  11.2 pJ measured @ TB *vs* 141 pJ expected @ experiment

- Equivalent Maximum Energy: $800\,\text{MeV}/11.2\,\text{pJ} \cdot 141\,\text{pJ} = 10\,\text{GeV}$

Results: Stability monitoring and corrections



$$\text{Electron corrected data} = \frac{\text{Electron uncorrected data}}{\text{SiPM laser data/Monitors data}}$$

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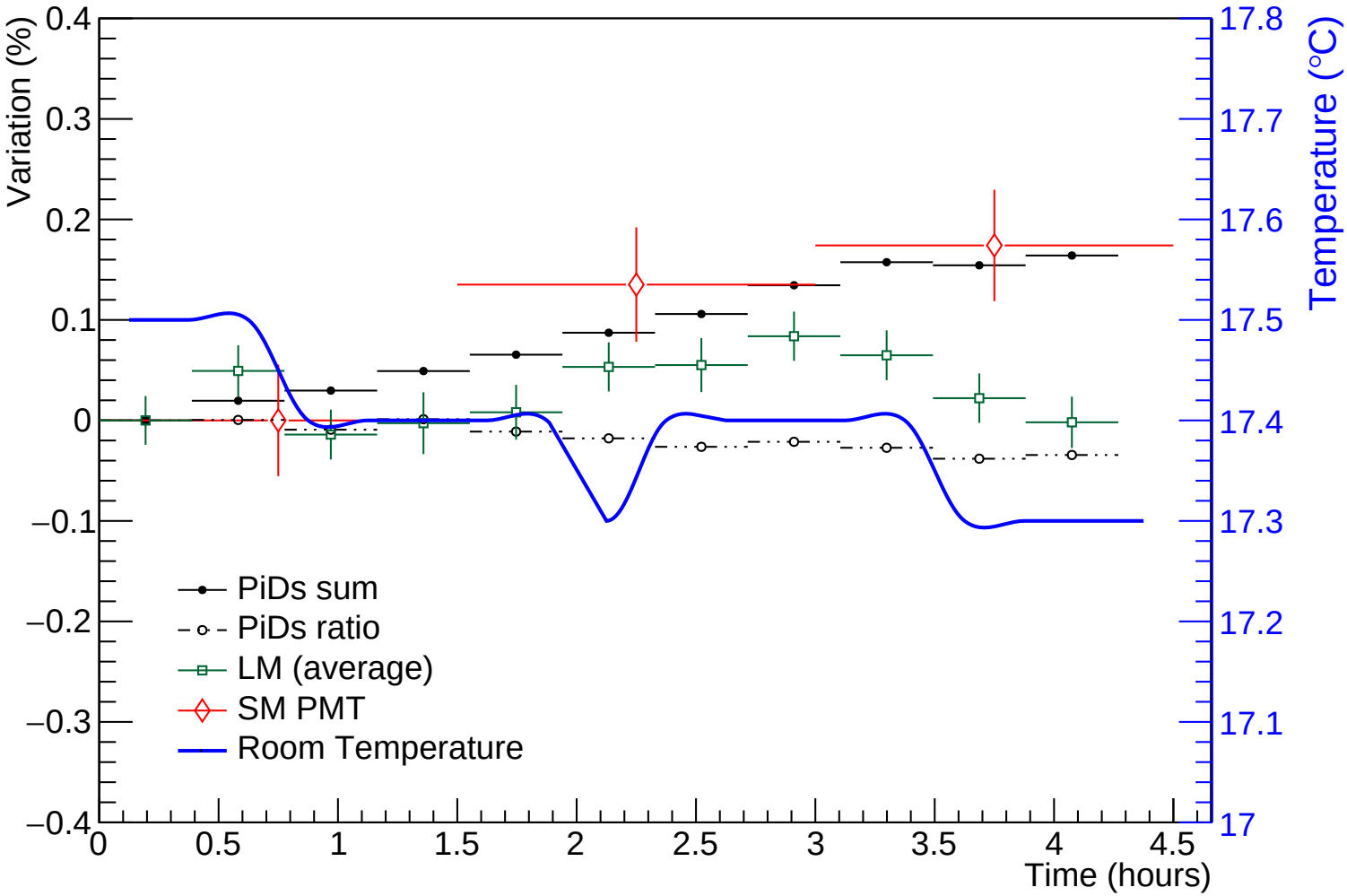
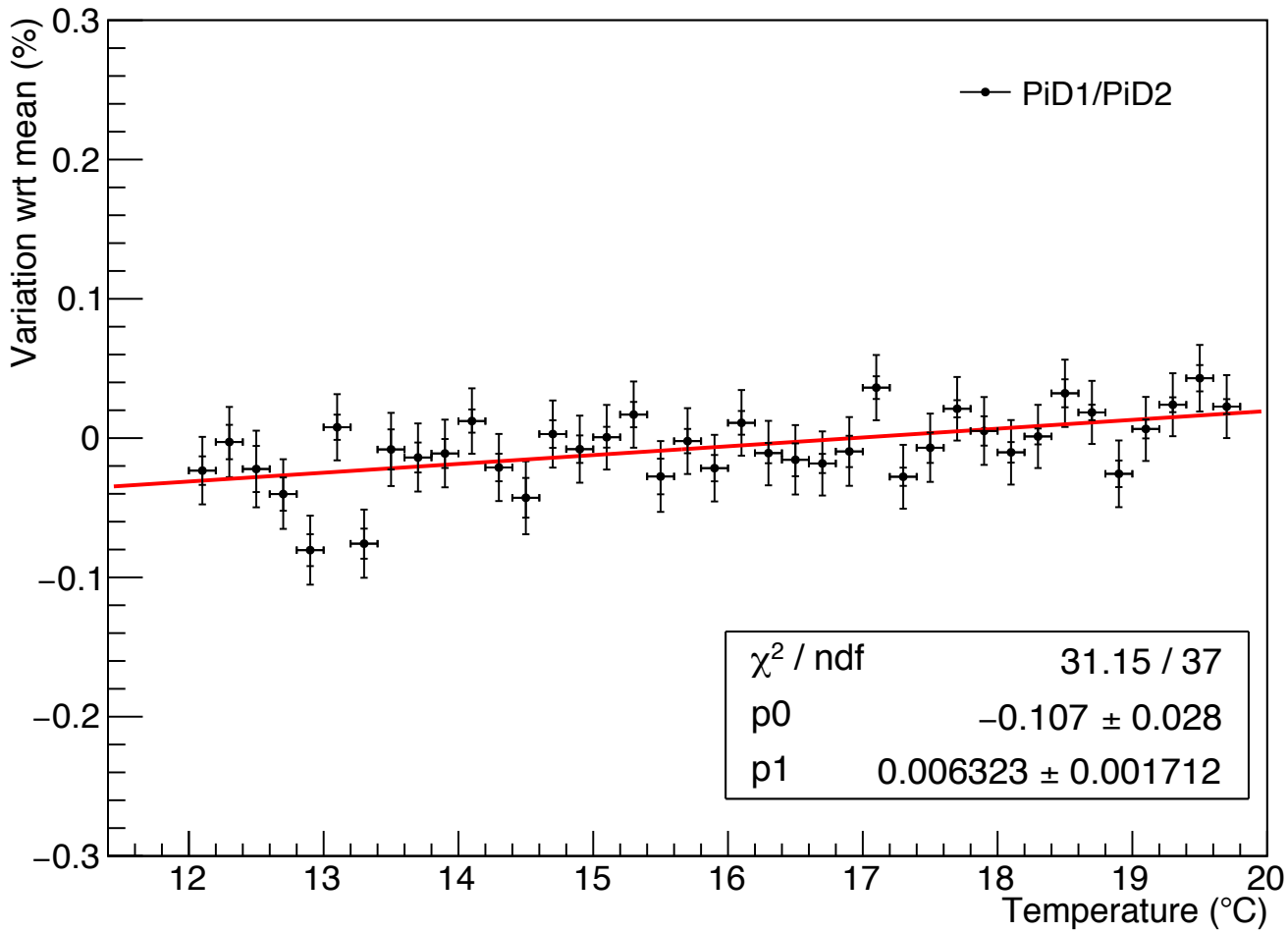


Monitors data = PiDs Sum · LM (2nd pulse / 1st pulse)

Results: Temperature-dependence of PiDs response

- measured after TB with a temperature controlled chamber:
  - PiD1 inside the chamber
  - PiD2 outside the chamber (reference diode)
- PiDs coupled with their frontend electronics



Conclusions & Acknowledgements

- **Successful** test of the laser-based calibration system for the g-2 experiment:
  - tested all the key elements of the system;
  - measured electron-energy equivalent of the laser intensity up to 10 GeV;
  - guaranteed light stability at sub-per-mill level (thanks to corrections with Monitors data);
- A **paper** is ready to be submitted on Nuclear Instruments and Methods in Physics Research Sec. A (**NIM**) journal:

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