Test beam - Calorimeter(s)

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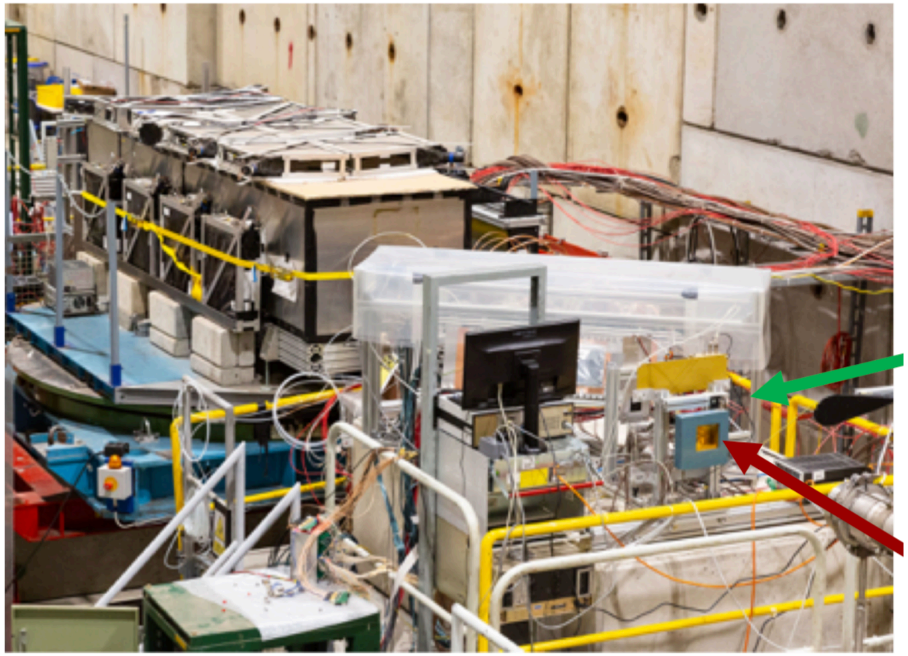
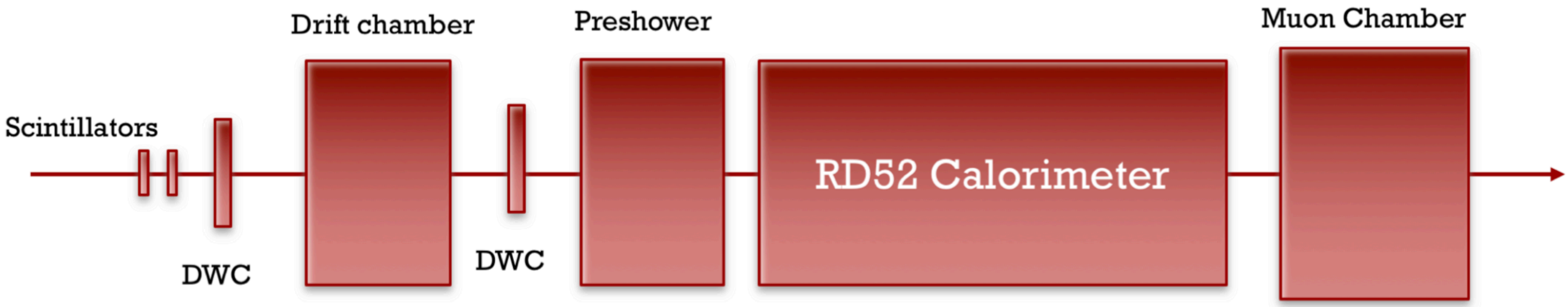
IDEA slice on beam (2018)

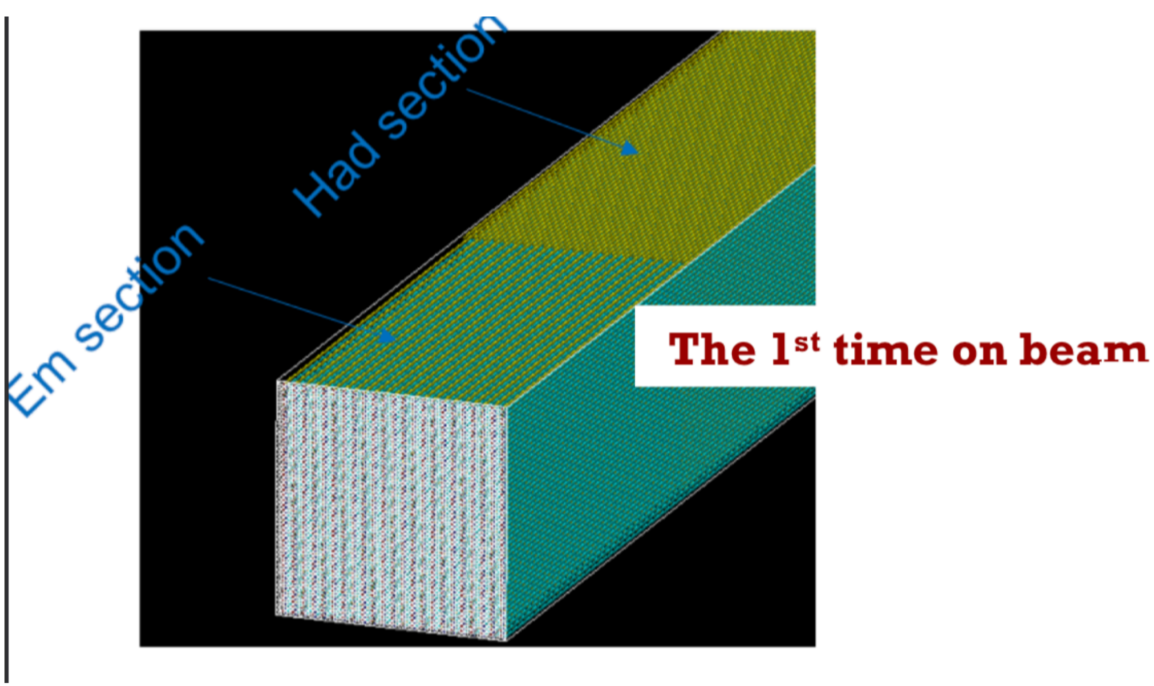
- A full **combined test** of IDEA:
  - Drift chamber prototype
  - GEM as preshower + µRWell for µ de
  - Several calorimeter options tested c
  - See, e.g., talk from R. Santoro <u>here</u>

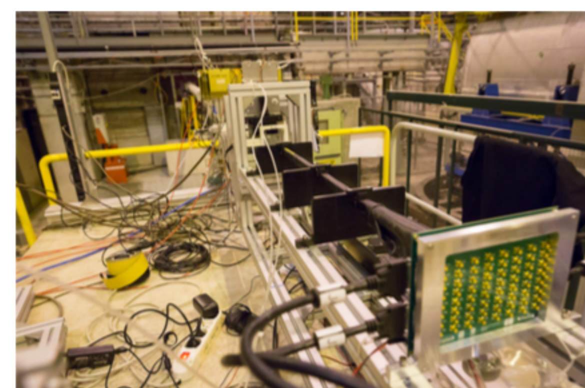




Calorimeter options used during TB 2018

- **RD52 module** (combined data tak o detectors)
- **SiPM-based** readout (standalone)
- **"Staggered"** module (standalone)

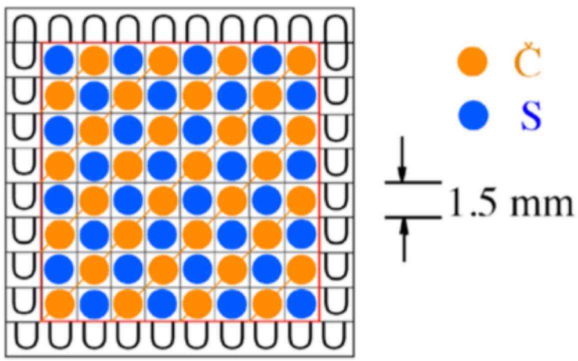


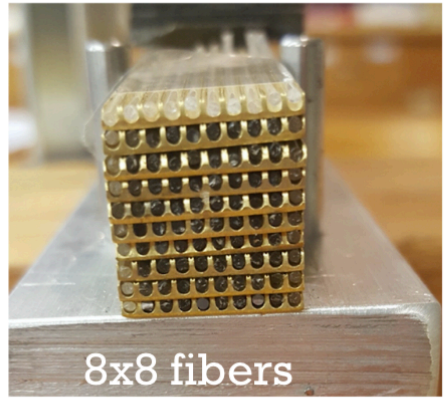


SiPM Readout

Como - analysis from M. Antonello - here

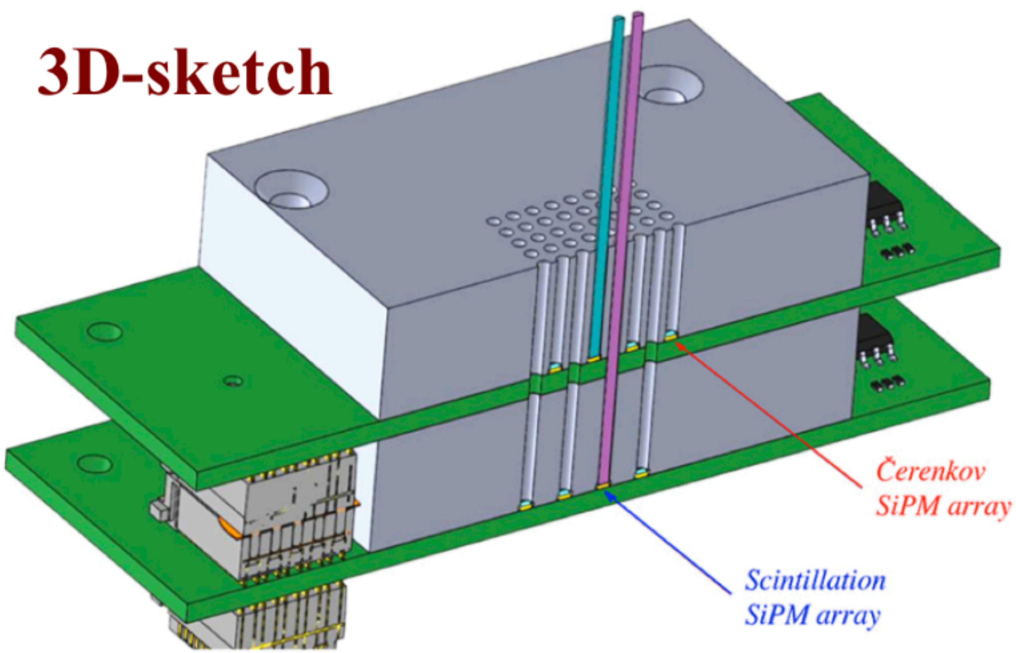
SiPM dual readout (standalone test)

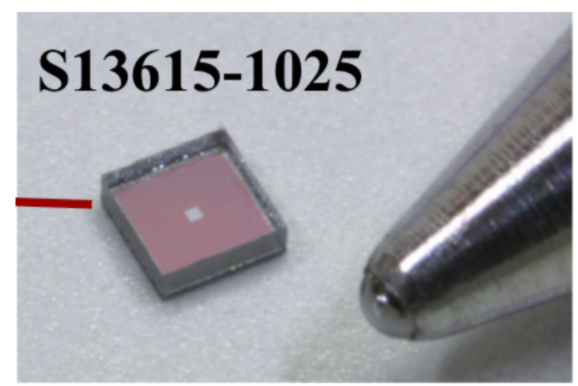




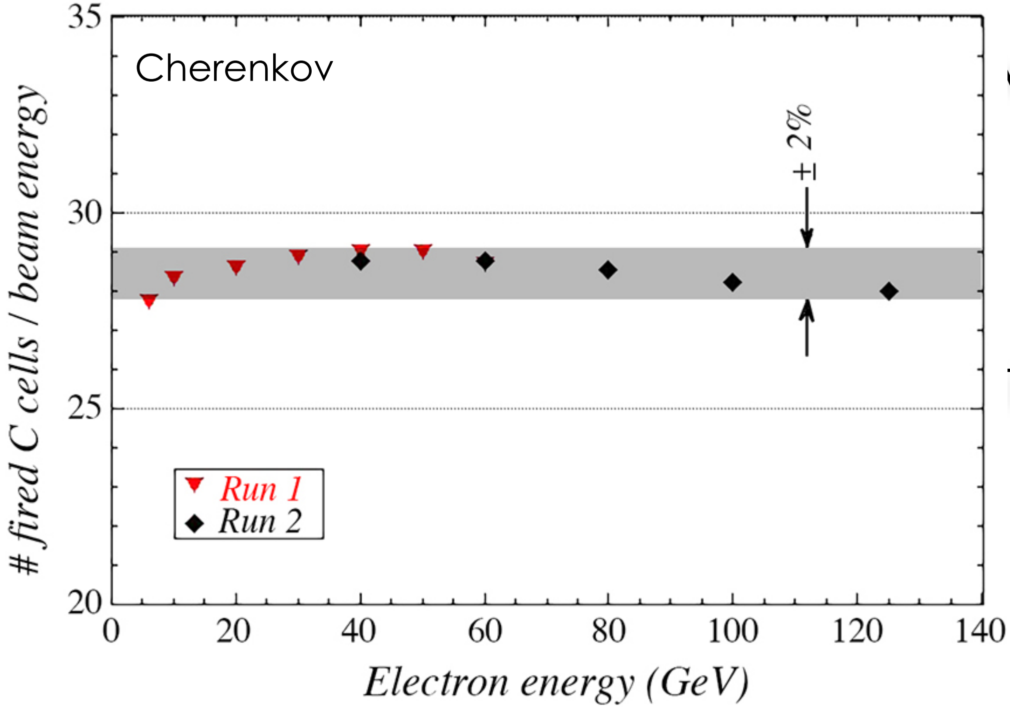
TSU SiPM

illation light separated to
pected to be ~ 50 times



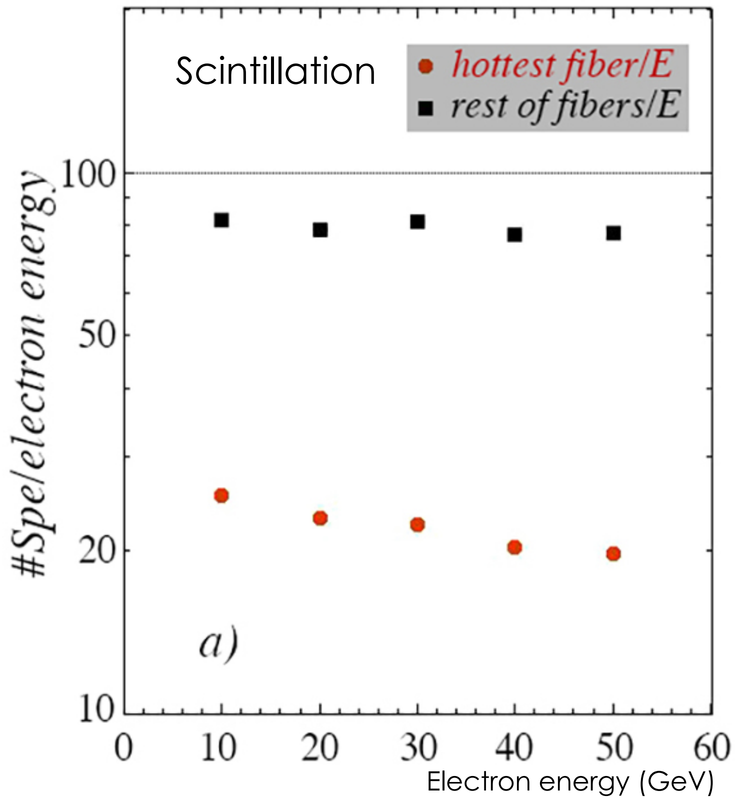


SiPM readout - previous results (TB2017)



vith beam energy over a wide

t ~ 55 Spe/GeV.

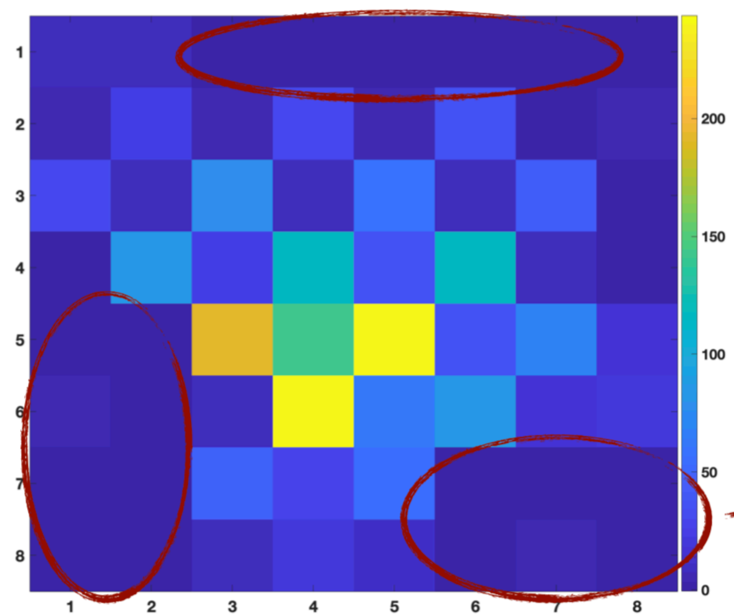


- Scintillation response showing evidence of saturation

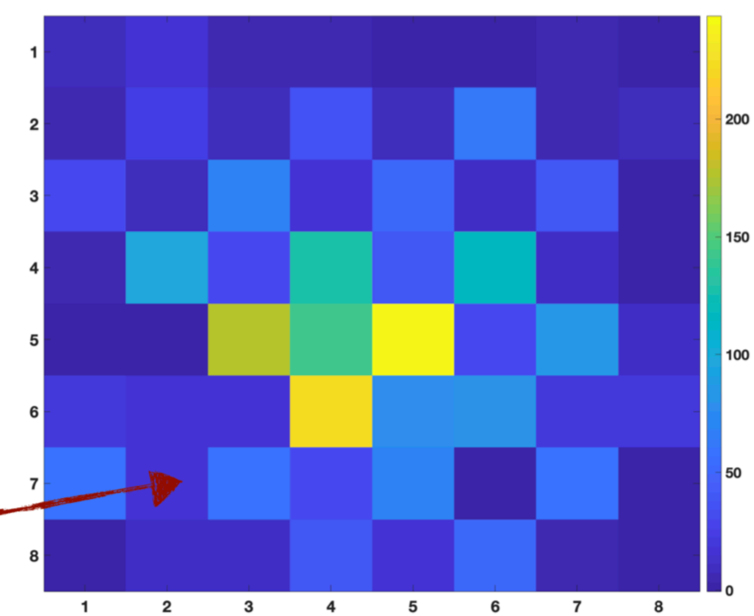
2018 - aims and issues

- Aim: verify that
  - **Cross talk** is under control
  - **Linearity is fully recovered** after attenuation of scintillation light
- Issues:
  - Slightly **degraded uniformity** of SiPM + fiber response
  - Dedicated **correction factors** extracted with optical measurements in the lab

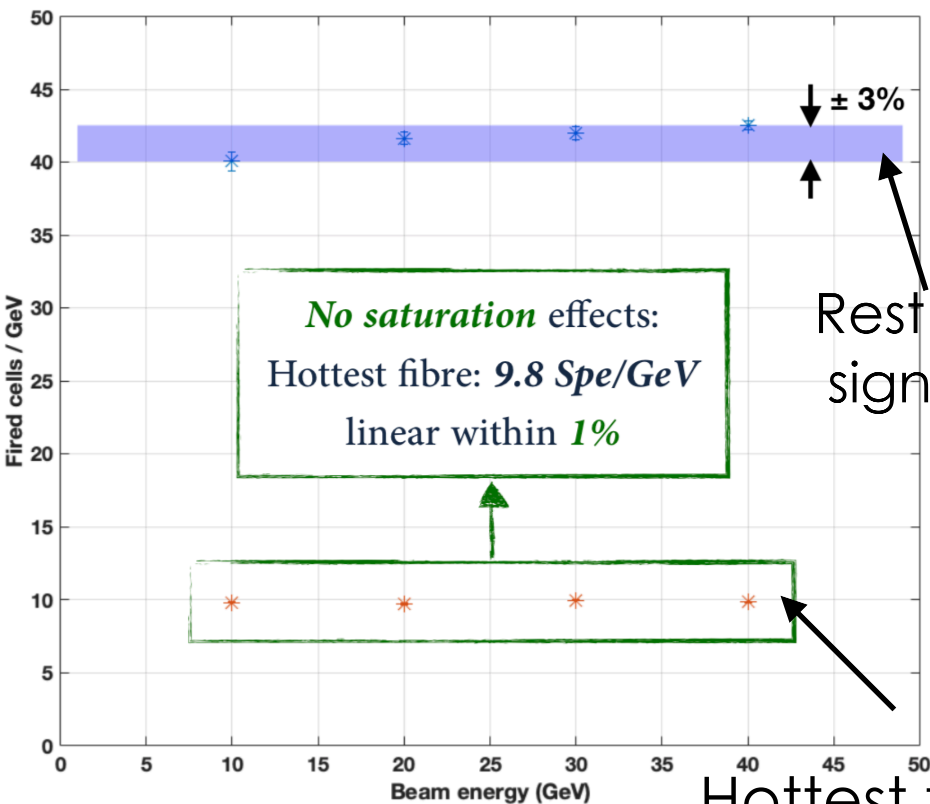
Before correction



After correction



SiPM dual readout (linearity)



Rest of signal

Hottest fiber

Operating with 5.5 V_{OV} - PDE ~ 22%

Cherenkov light yield (70 Spe/GeV) ~ a factor 2 larger than what measured with PMT

(Filtered) scintillation light yield under control (~95 Spe/GeV).

EM stochastic term ~ 10% is achievable

Result could still be improved with SiPM with larger dynamic range

See here for more material

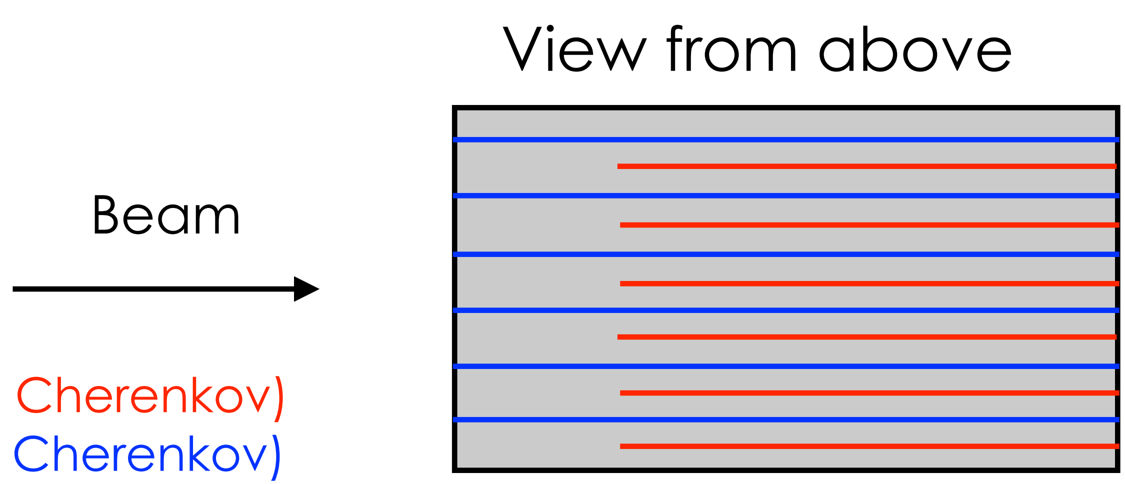
Staggered module

Pavia - analysis from L. Pezzotti

Longitudinal segmentation (standalone test)

- Particle identification (e.g. hadronic tau decay) may benefit from **longitudinal segmentation**.
- “Staggered” option tested on beam

“HAD” section: E(short fibres)
“EM” section: E (long fibres) - E (short fibres)



Red: short fibres (scintillation and Cherenkov)
Blue: long fibres (scintillation and Cherenkov)

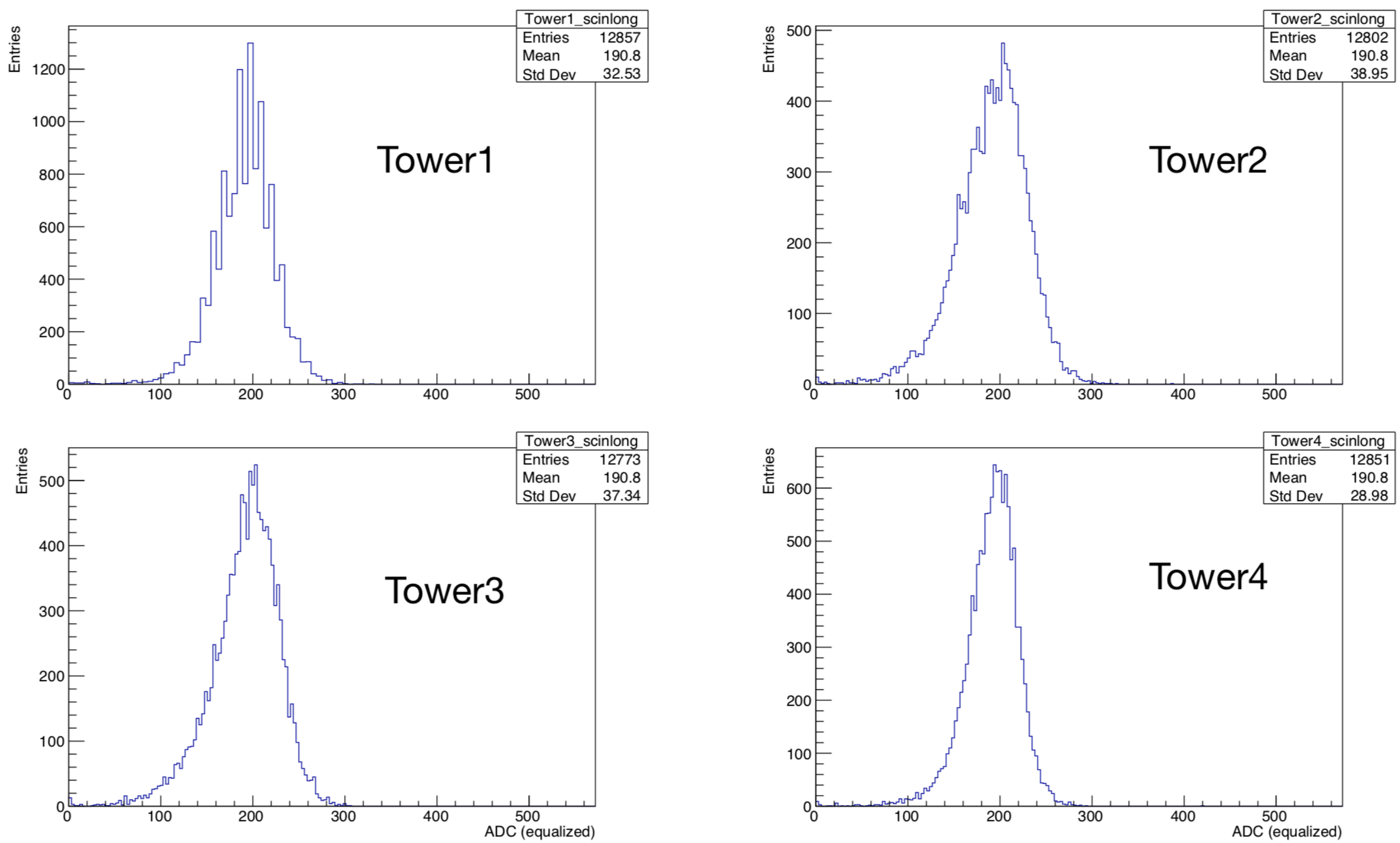
Staggered modules - the good and the bad

- Good:
  - **Coarse radial information** of the energy deposit (tau decay, e/pi separation)
- Bad:
  - **Half sampling fraction** for the same number of channels
  - Loss of EM resolution from subtracting **two independent energy measurements** (long-short)
- Challenging:
  - How to propagate calibration to the short section?
    - With some calibration system
    - With particles (see next slides)

Long sector calibration with electrons

- Equalisation of electron channels after pedestal subtraction (similar plots for Cherenkov channels)

Scintillating long fibers 20 GeV electrons

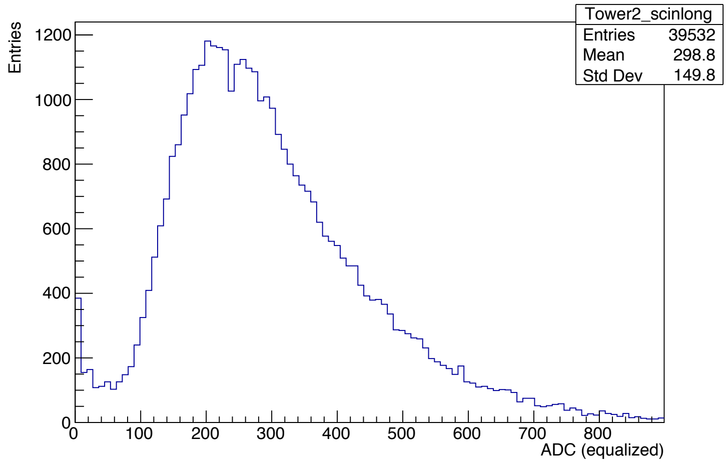


Longitudinal segmentation

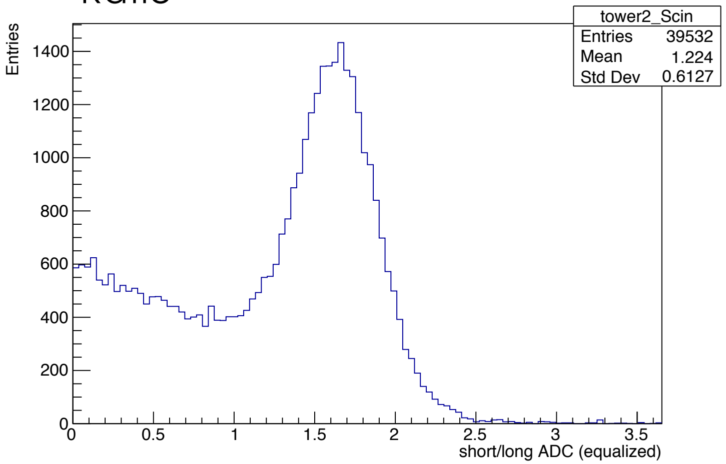
See also L. Pezzotti - here

- Calibration of the short:
  - Propagate the long section calibration using pions.

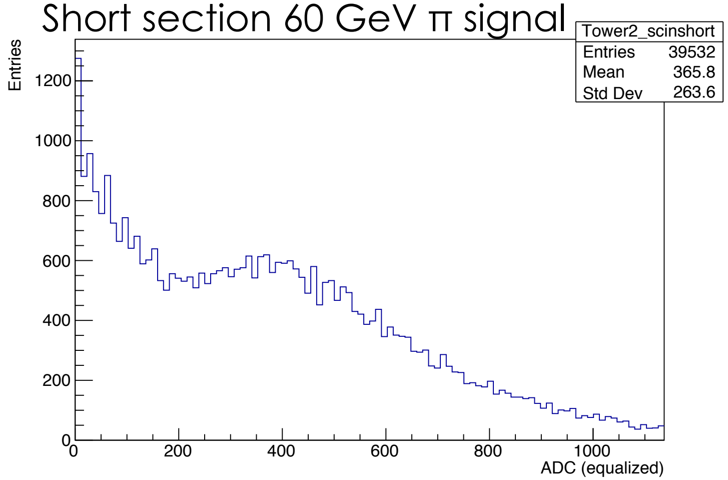
Long section 60 GeV π signal

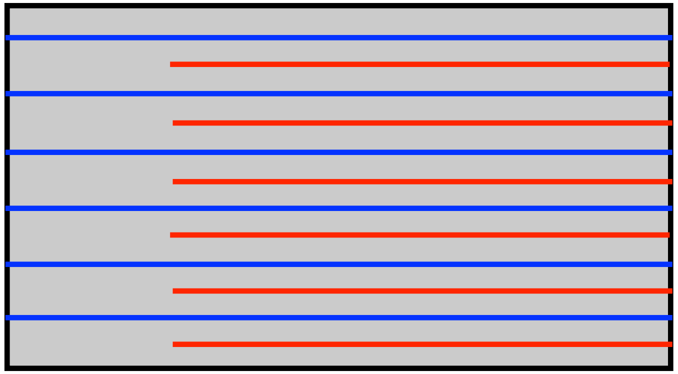


Ratio



Short section 60 GeV π signal





Scintillation fibers

Longitudinal segmentation

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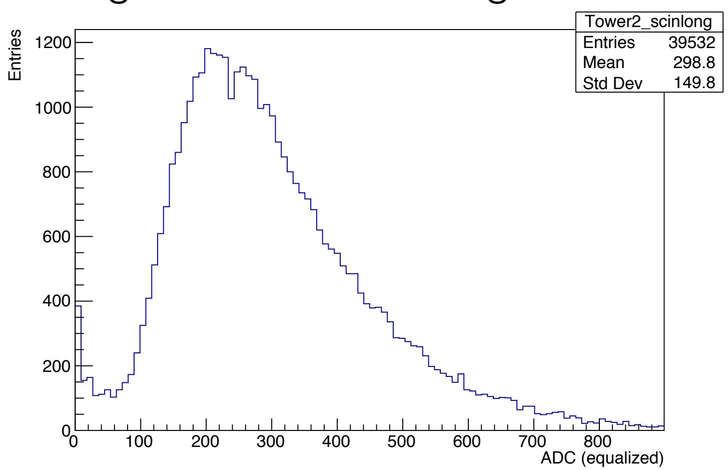

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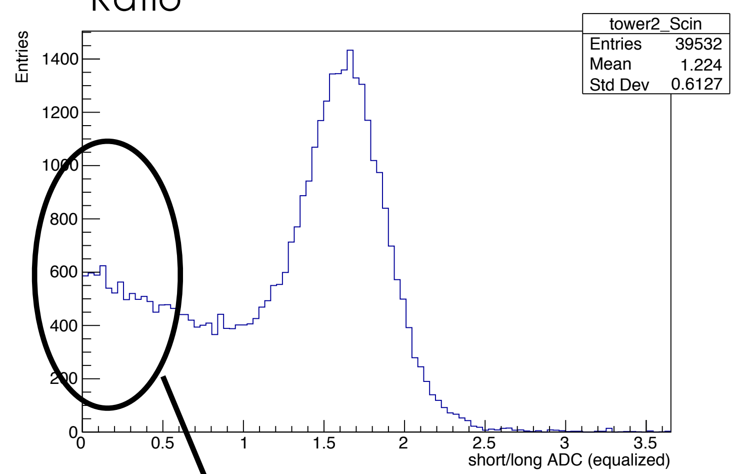

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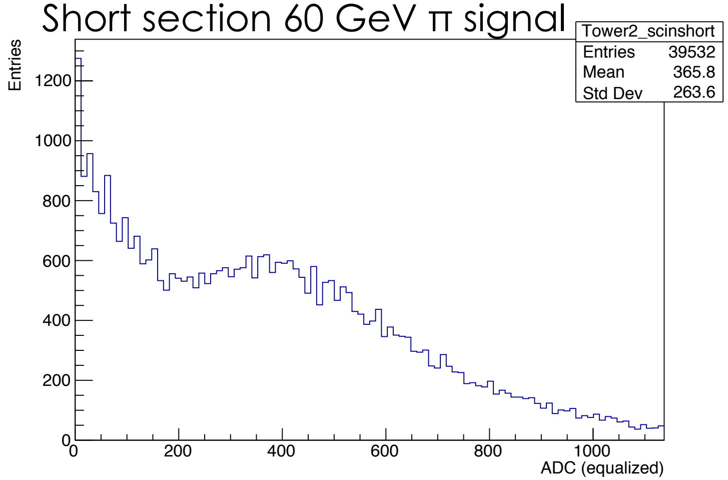

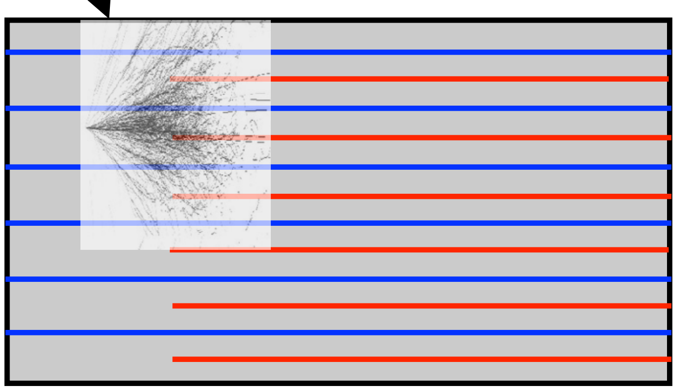

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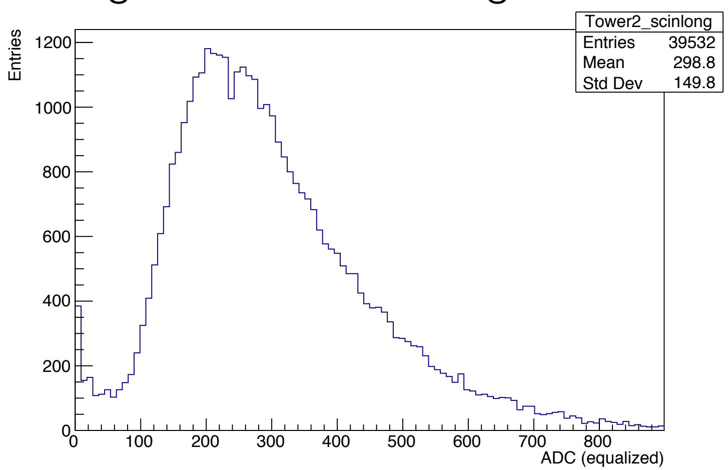
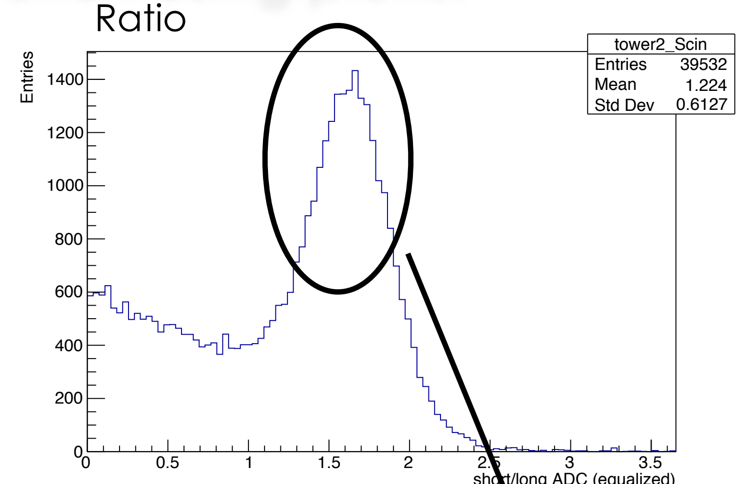
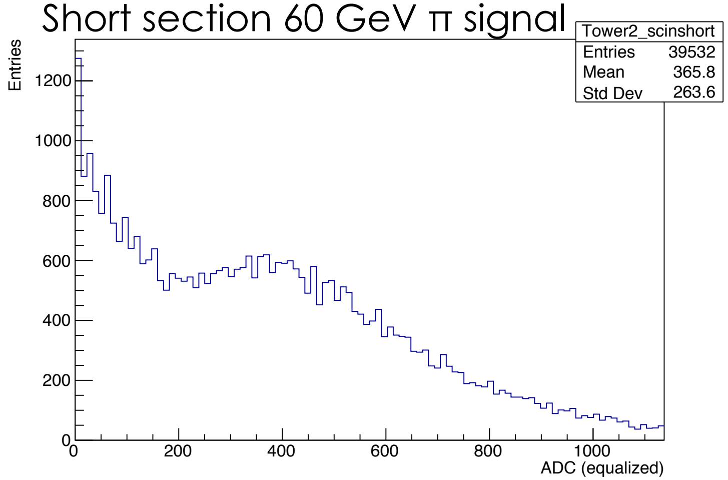
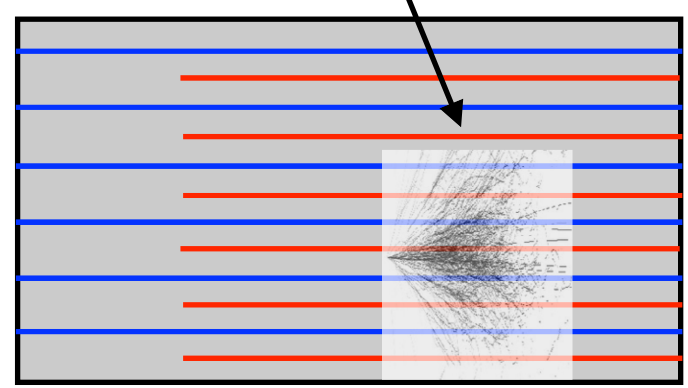


Ratio



Short section 60 GeV π signal

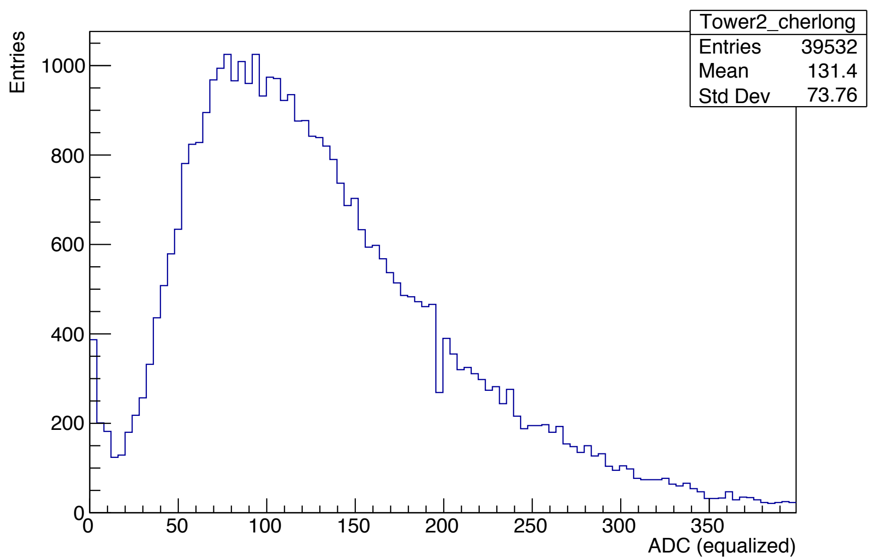




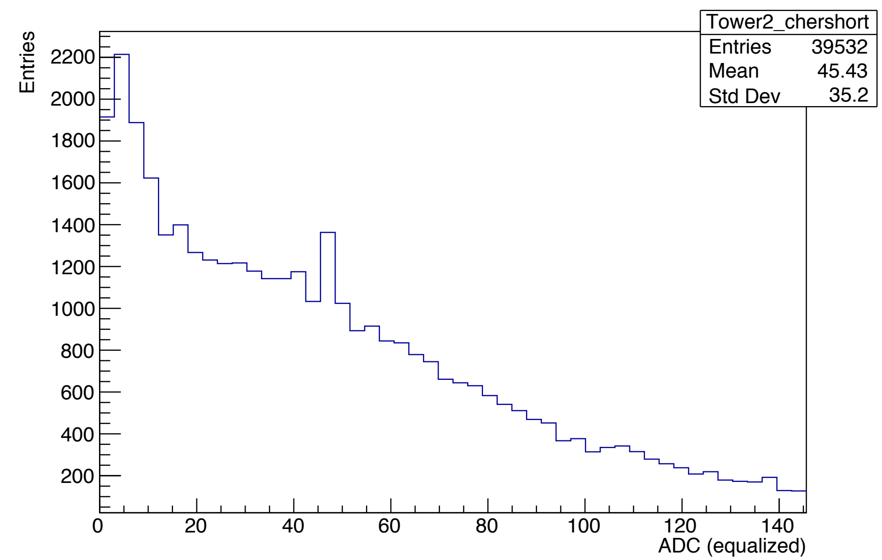
Scintillation fibers

Longitudinal segmentation

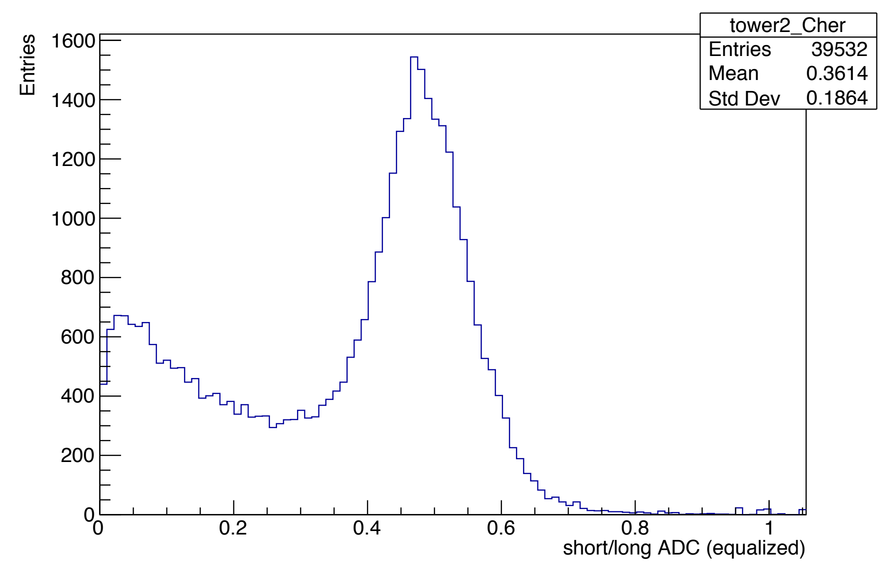
Long section 60 GeV π signal



Short section 60 GeV π signal



Cherenkov signal
60 GeV pions

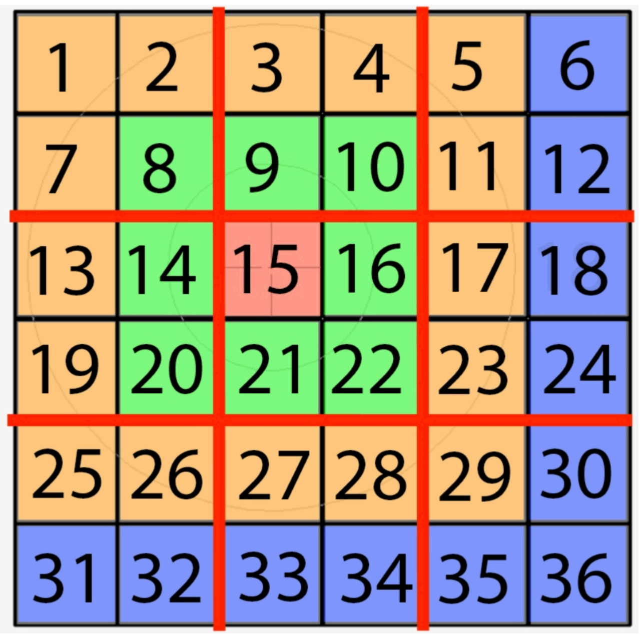


RD52

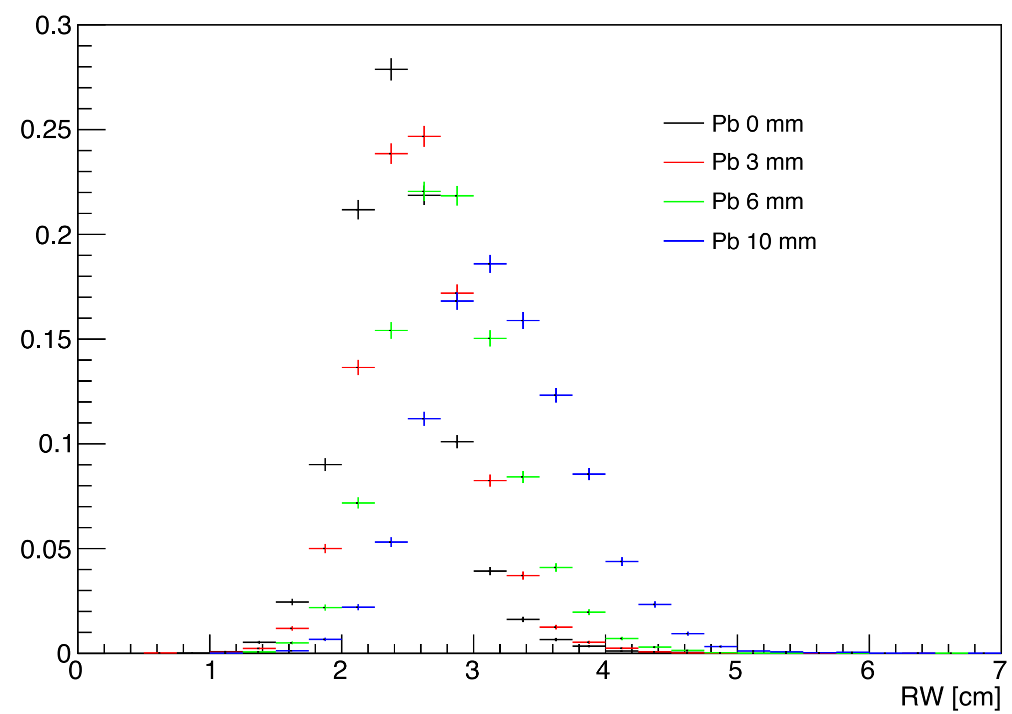
Shower shape

- Prototype tested on beam in the past.
  - Focus on combined running
  - Studies of electron shower shape as a function of dead material in front of the calorimeter.

$$R_W = \frac{\sum_{ch} E_{ch} \cdot \sqrt{x_{ch}^2 + y_{ch}^2}}{\sum_{ch} E_{ch}}$$



Each tower is 4.6 cm side - Moliere radius 1.6 cm

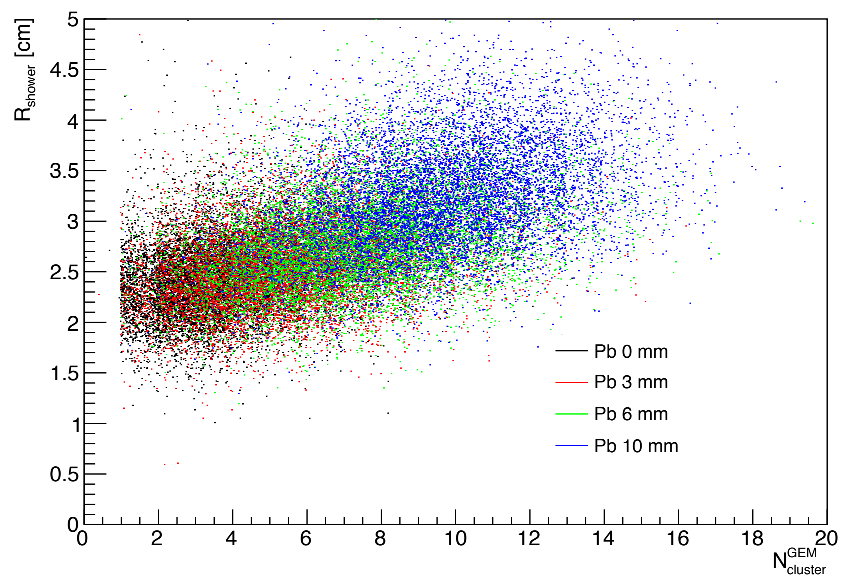


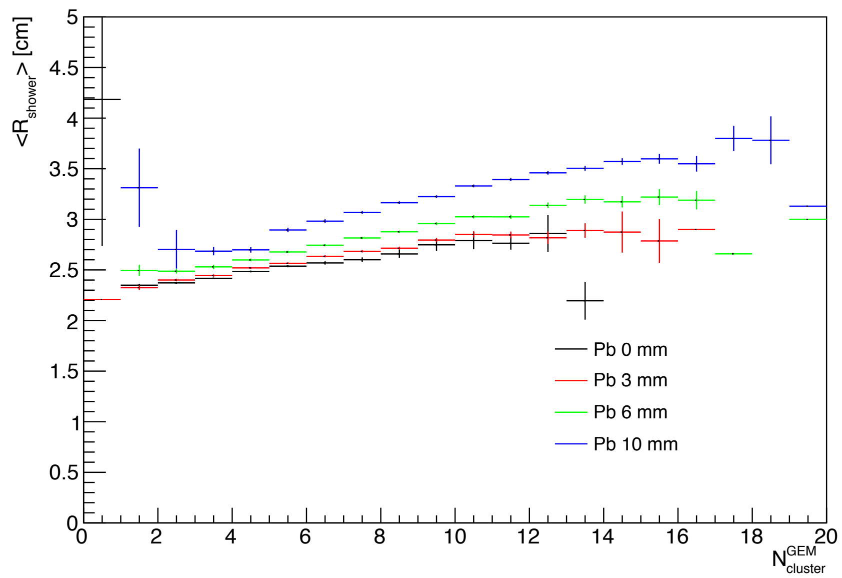
Combined measurements (RD52)

- Focus on DAQ combination and combined runs with GEM-based preshower

$$R_{\text{shower}} = \frac{\sum_{\text{ch}} E_{\text{ch}} \cdot \sqrt{x_{\text{ch}}^2 + y_{\text{ch}}^2}}{\sum_{\text{ch}} E_{\text{ch}}}$$

Shower width from 5 mm Pb + additional material correlates with number of clusters in GEM preshower

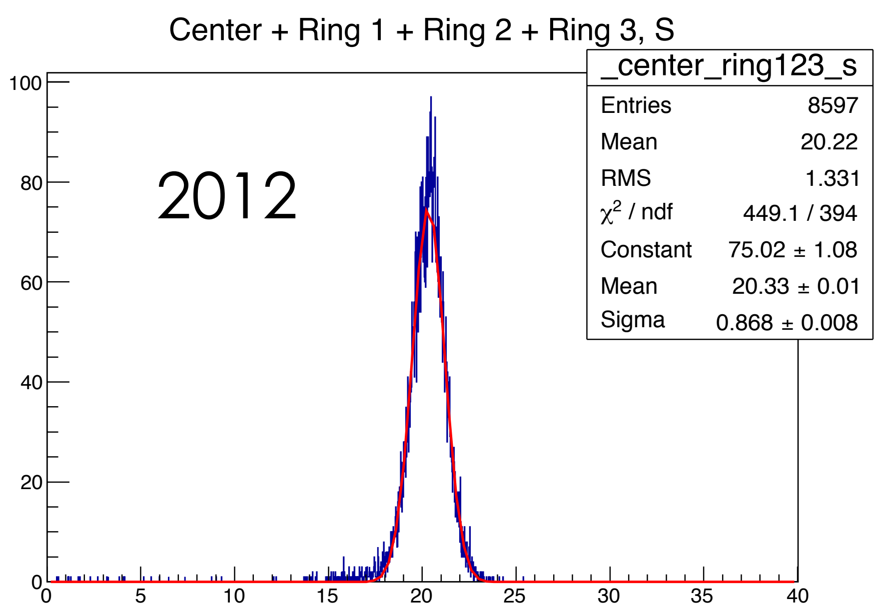


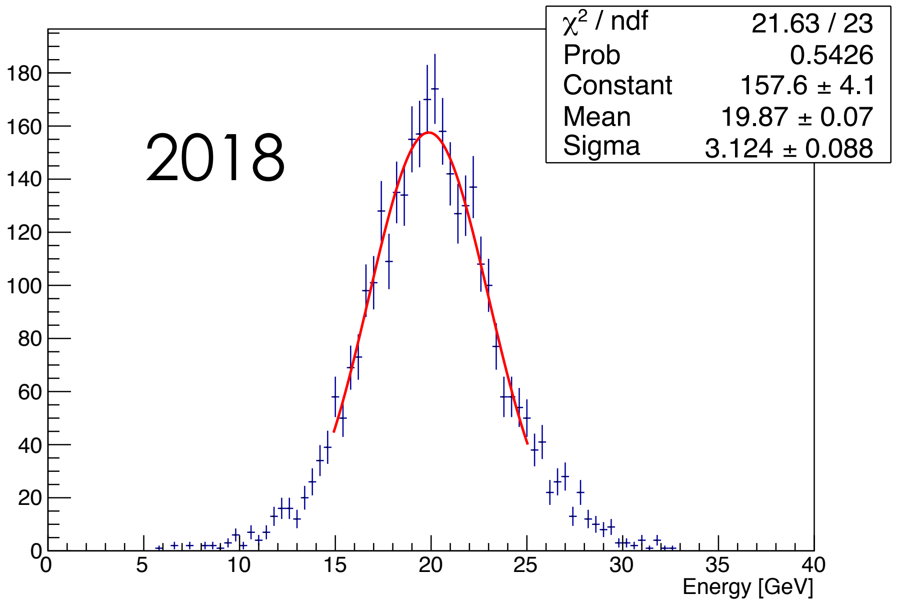


Issues and possible immediate steps

- Electron resolution not proven to be the same as in the past (see talk here)
- Investigated:
  - Beam position and divergency
  - Pedestals
  - Shower shape
  - Electron selection
  - Equalisation

- To be investigated:
  - Role of upstream material - nice chance to use the GEM preshower as illustrated yesterday





What we have learnt

- Main lessons from 2018 TB:
  - **Linearity can be achieved** with SiPM while **keeping cross talk under control**
  - It is **in principle** possible to **calibrate a staggered module** using single electrons and single pions at the test beam.
    - Probably this would extend easily to in-situ calibration measurements
  - **Combined data taking** at the TB **worked**, nice results from combined GEM/Calo runs.

Things we should consider for future tests

- Containment is **nice, but expensive** - and maybe not the highest priority
- My personal **priority list**:
  - Cost reduction - explore new layout ideas
  - Readout chain (SiPM + ASIC? + ?)
  - Calibration system - **stability monitoring** - do we solely rely on in-situ Z->ee? Need to decouple **electronics linearity** from **optical readout efficiency/gain**.
  - **Simulation validation** - G4 is not perfect, but often good enough - especially after TB tuning.
  - Any **hardware/layout** solution to **improve timing resolution**? Note it is maybe enough to **do it on scintillation signal** where light yield not an issue
    - Reflect light on the inner fiber end
    - Reduced granularity SiPM on the inner side? (Feasible at all?)
    - Fibers mutually at an angle? (Reconstruction nightmare….)