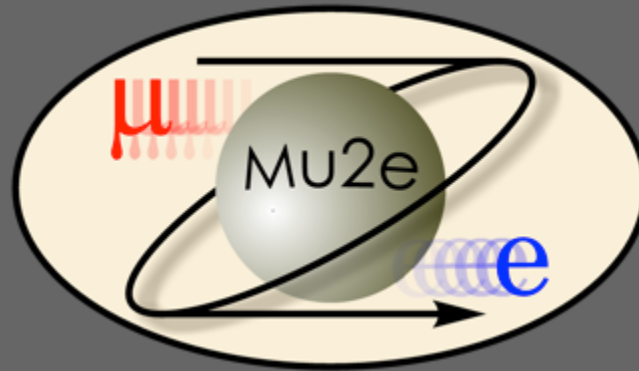


Preparation for the final calorimeter vertical slice test @ Module-0

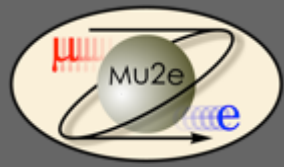


Raffaella Donghia

LNF-INFN

On behalf of the Mu2e calorimeter group

September 3, 2020



Talk overview



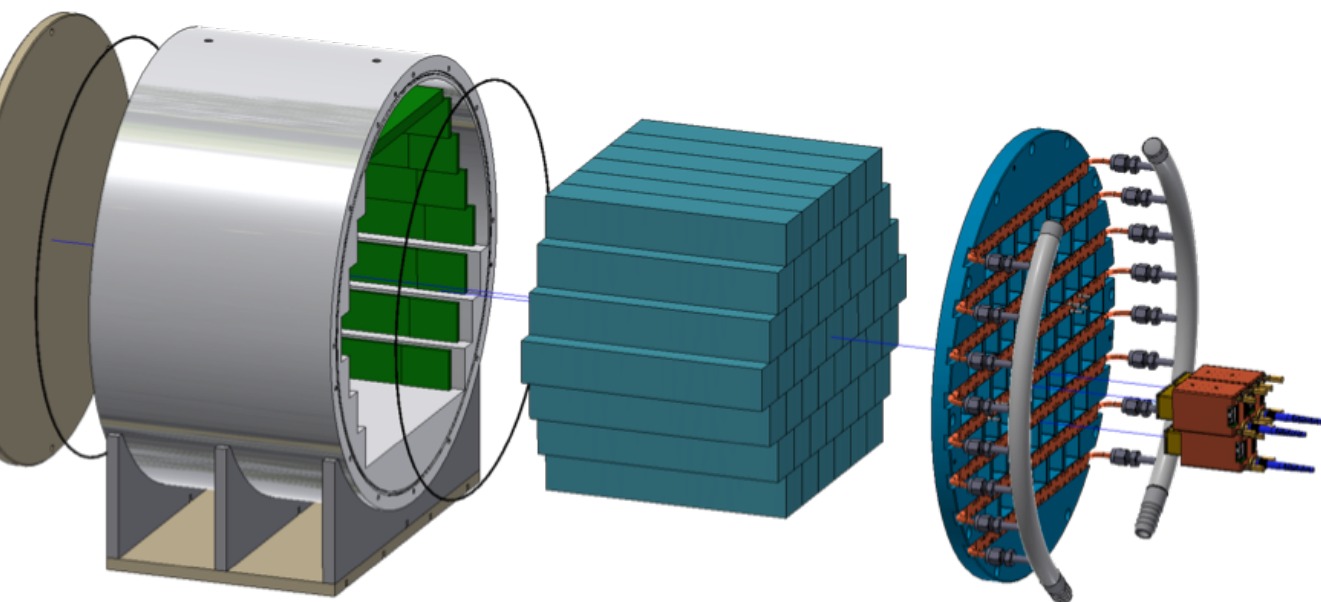
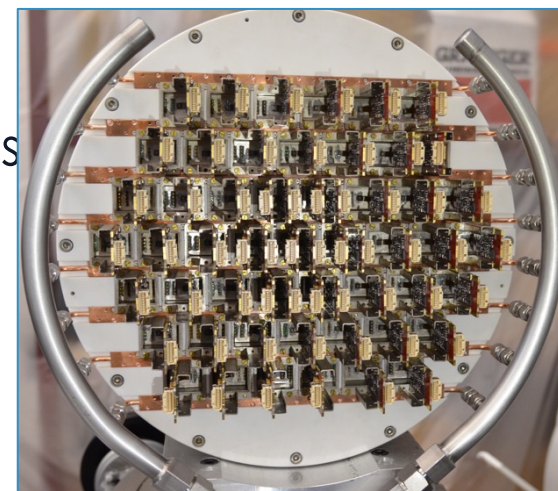
Preparing Module-0 for final slice test

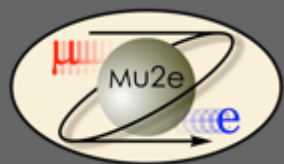
- Crystals preparation
- SiPMs and copper holders
- FEE v_6 and cables
- MB
- Readout (?)
- Laser calibration system
- CRT

Plans

51-channel calorimeter prototype

- Constructed and tested during 2017-18 with CRs and e-beam
- Prototype structure (Mechanics and cooling system) similar to the final ones



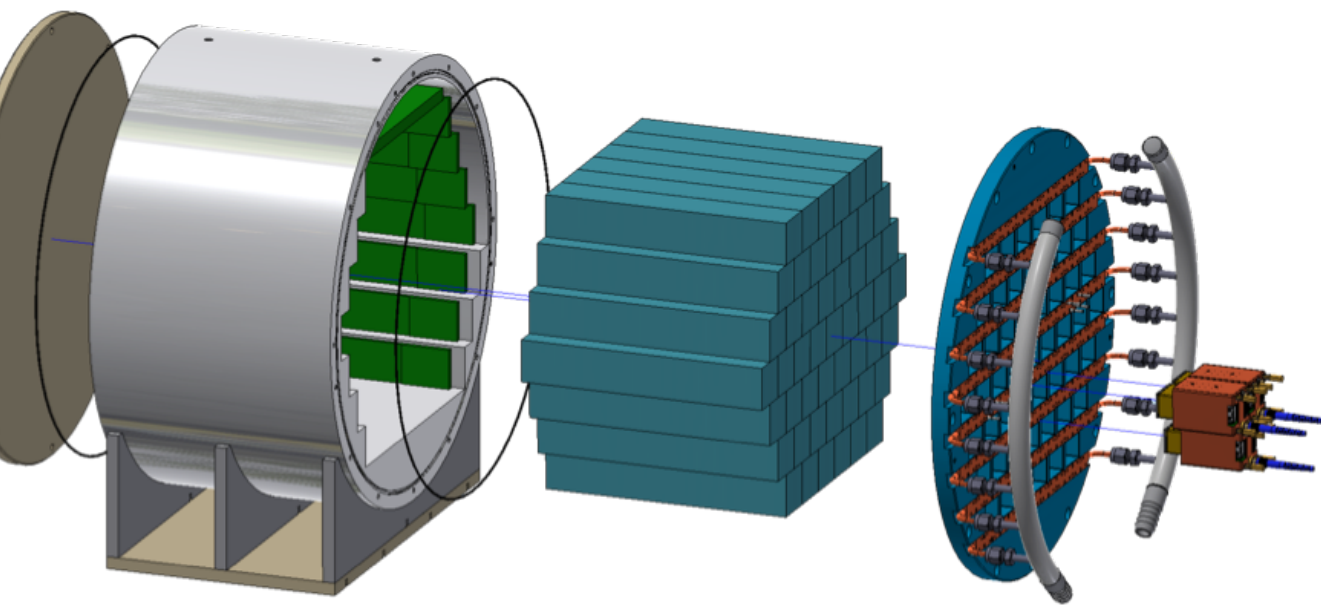


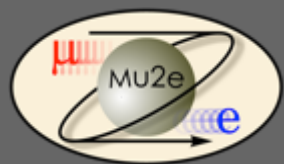
Module-0

2020

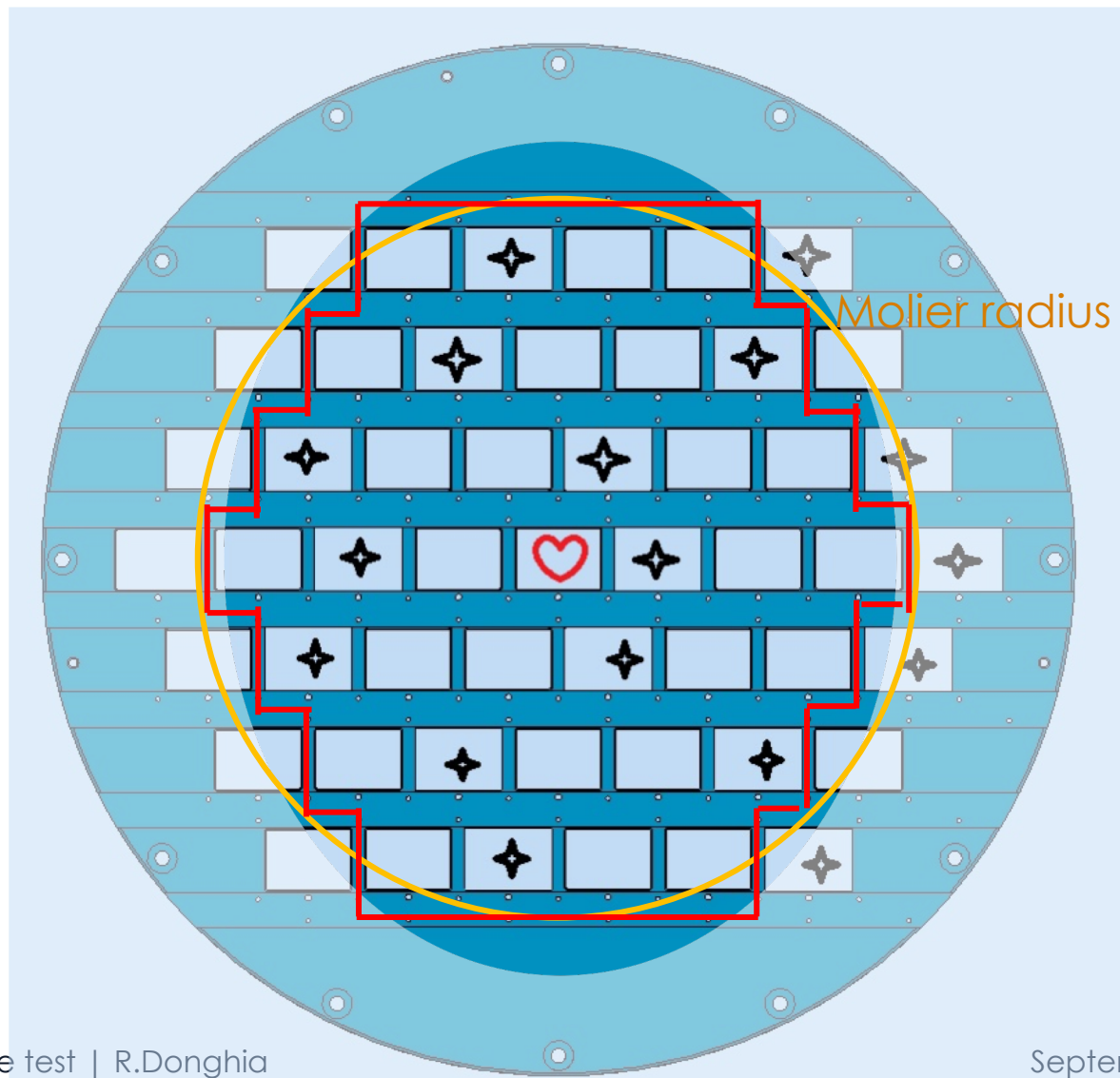


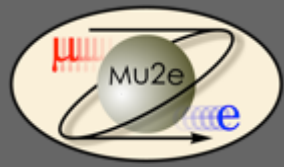
- We are equipping 37 Module-0 crystals with the very final components, in order to
 - Test the final assembly procedure
 - Validate the electronic readout chain
 - Test the prototype performances with CRs
 - Check crystals performance/deterioration in 3 years





"New" Module-0 map

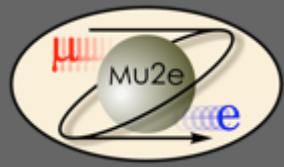




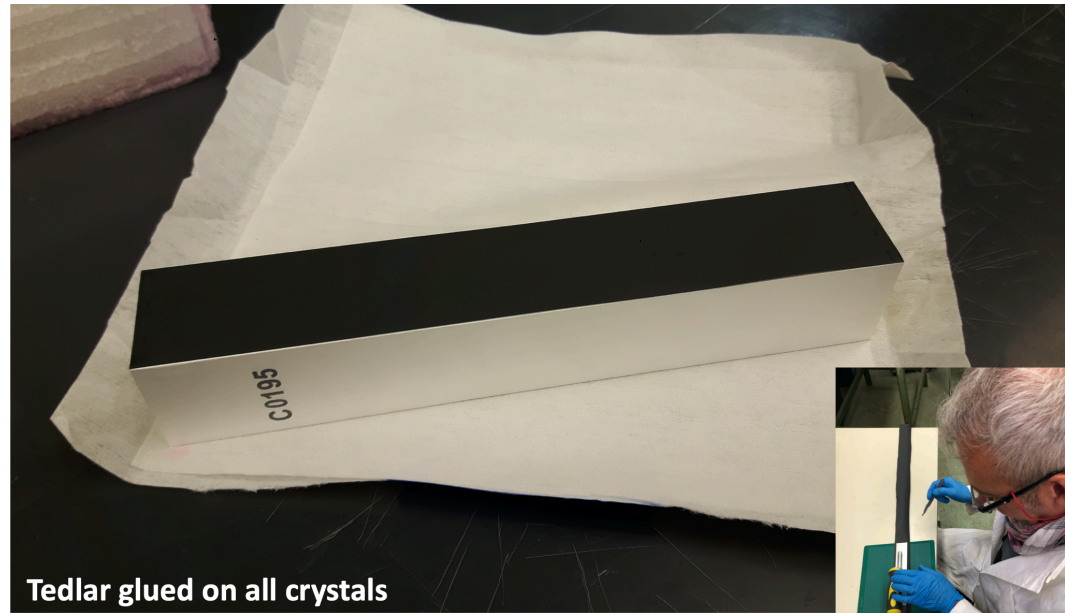
Measurements already done and planned



- Complete test of irradiated SiPMs and irradiated FEE
- Study of Calo response at different temperatures
- Calibration methods with MIPs and Laser
- Stability of response and calibration along time
- Work with template method and comparison with standard reconstruction method
- Study of response, resolution vs Z (CRT)



Crystals

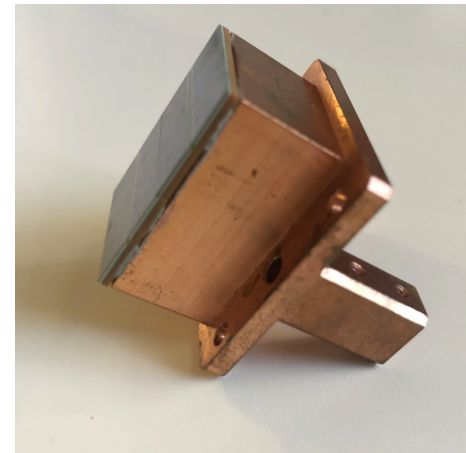


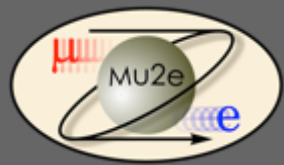
Tedlar glued on all crystals

37 preproduction crystals:

- Final dimensions
- All samples will be reinserted and integrated in the mechanical structure adding Tedlar foils to avoid cross talk effects
 - w/o tedlar we estimated a cross talk effect of about 3%
 - Tedlar sheet will cover one longitudinal crystal side as in picture. Longer Tedlar sheet among crystal rows.

- 74 production SiPMs have been randomly selected (2 SiPMs/crystal)
 - Completely characterized at FNAL during production QC phase (Vbr, Id, GainXPDE ...)
- SiPM glued on a copper holder, to guarantee the thermal coupling with the cooling system
 - Procedure tested before lockdown
 - 37 copper holders in preparation

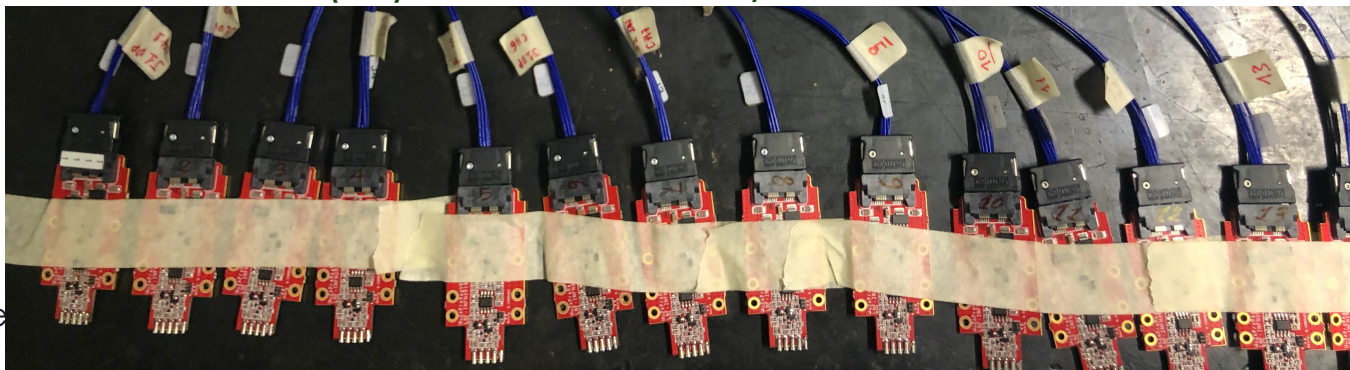


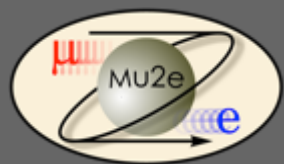


FEE boards and cables



- In June 2020 the last irradiation test on ADC and DAC have been carried out at Calliope Facility (ENEA-Casaccia)
 - Test results satisfy the experimental requirements, guaranteeing a FEE radiation hardness up to 100 krad
 - A maximum variation of 4 bit has been observed
 - This test **concluded the FEE R&D phase**
- **80 preproduction FEE_v6 at LNF**
 - HV scale and current response calibrated
- FEE **cables ready**, no damages observed during irradiation and vacuum tests. Production phase has started.
 - At the moment 10 (x4) cables already at LNF for test

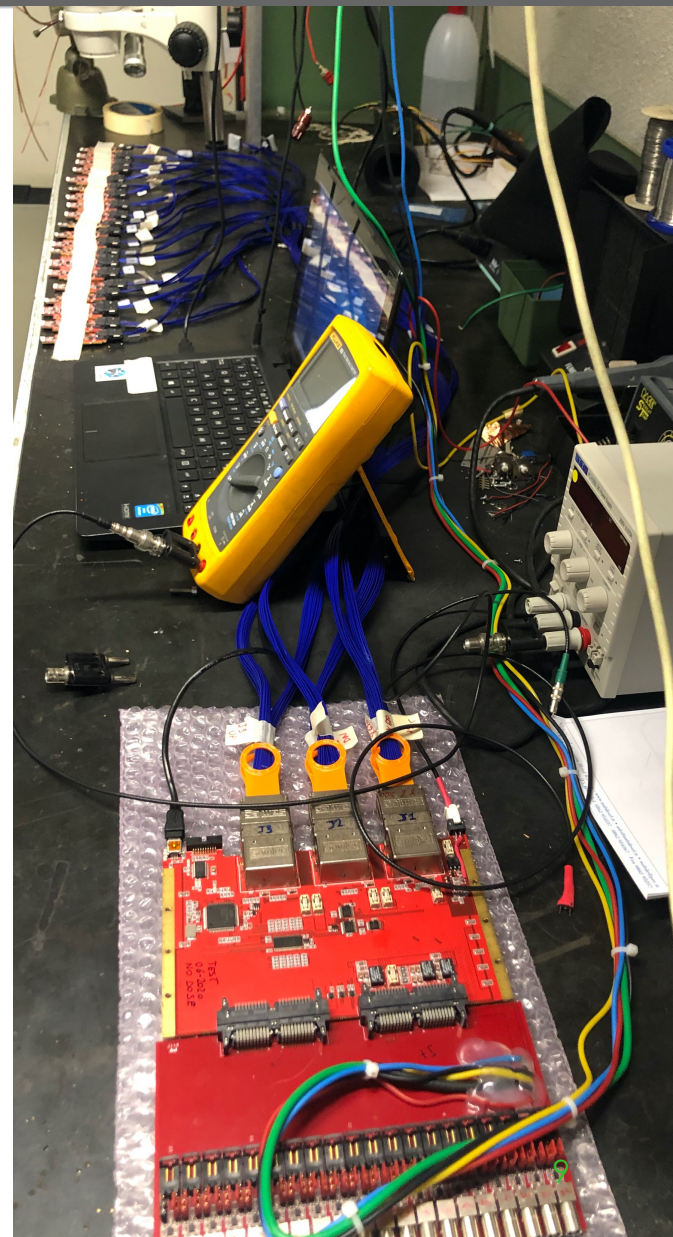


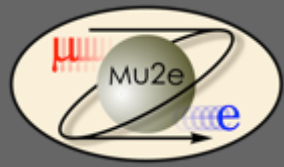


Mezzanine boards



- 20 FEE are managed by a MB, which is used to provide HV and handle the I and T readout
 - custom board designed by the SEA facility of LNF
- In June also a MB has been tested at Calliope up to 20 krad, no damage/variation observed (in particular on switching regulators)
 - **MB R&D phase concluded**
 - **5 pre-production MB** at LNF next week





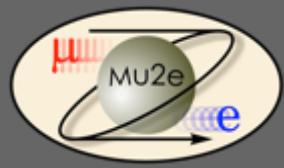
Single readout channel test



Before installation on Module-0, each holder will be tested to check gain and linearity

- 2 SiPMs + 2 FEE + MB + Caen Digitizer readout
- Intensity scan with Laser/LED light uniformly distributed on SiPMs surface

See Ivano's pres



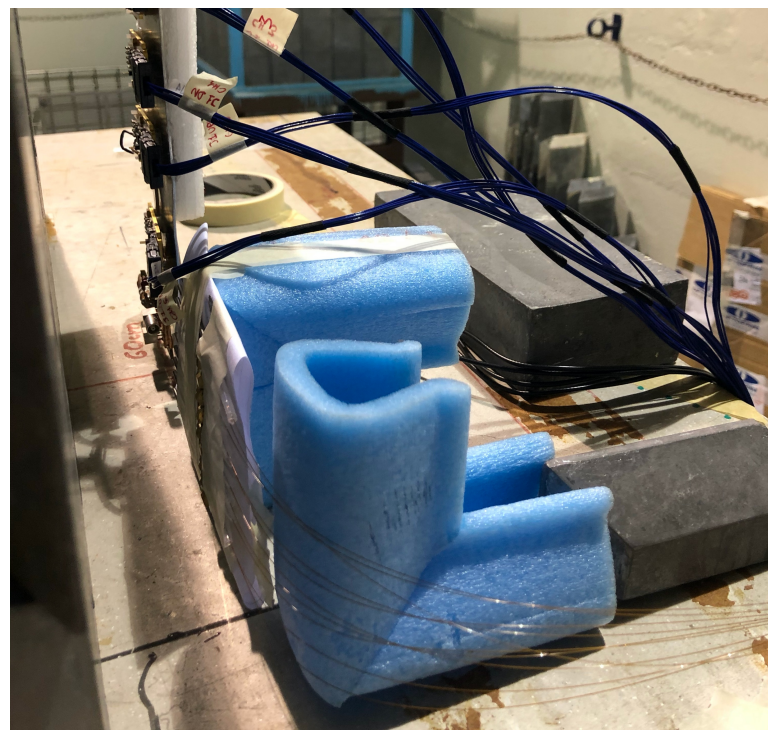
A DIRAC readout is needed, to perform a very final vertical slice test

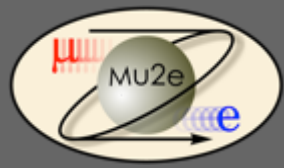
→ Information about pre-production boards from Pisa group

→ Is it reasonable within the end of 2020?

As for the final calorimeter disk, we will mount the laser system to calibrate and monitor SiPMs gain

- 110 fibers bundle already at FNAL
 - radiation hardness and vacuum test OK
- New Green Laser and diffusive sphere will be used



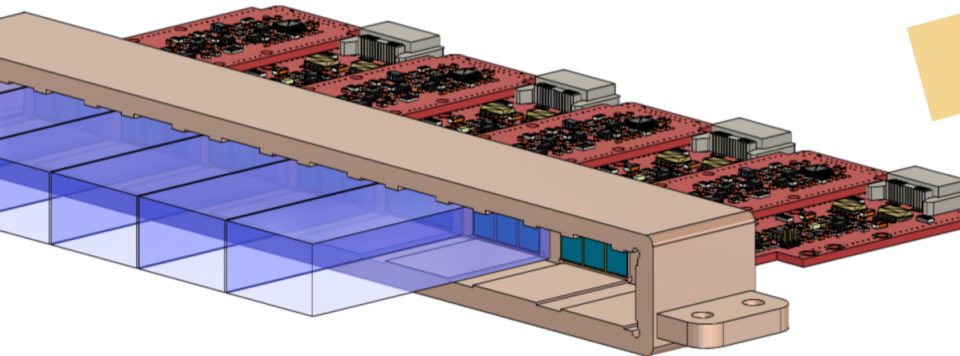


Cosmic Rays tagger- CRT

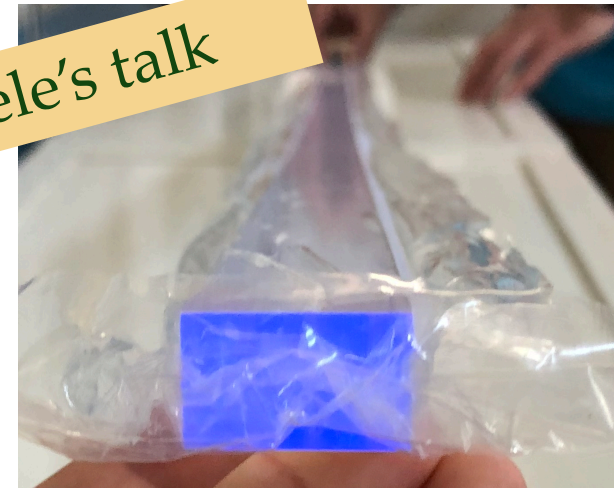
Each calorimeter disk will be tested at SiDET before installation, w CR MIPs

A dedicated CR tagger system have been designed and produced:

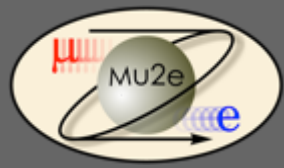
- Two layers of plastic scintillators will be placed above and below the disk
- These EJ200 scintillators are already shipped and tested at LNF



See Daniele's talk

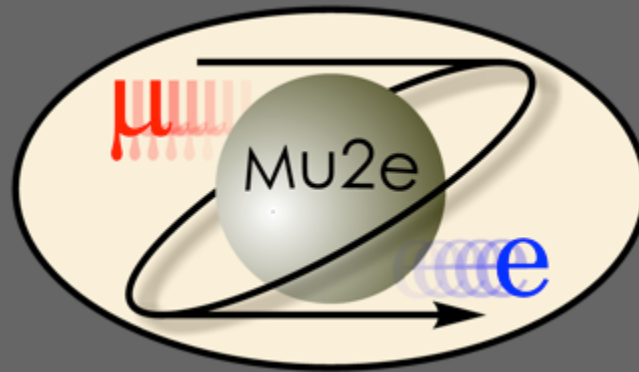


The CRT mechanical structure is in construction, the system will be used also for the vertical slice test w Module-0



- Despite the Covid delay, almost all the calorimeter components are ready
- A complete vertical slice test will be performed within the end of the year
 - All components are practically ready
 - Planning to integrate few DIRAC boards asap

Thanks



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LNF-INFN

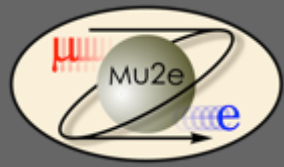
On behalf of the Mu2e calorimeter group

September 3, 2020



Istituto Nazionale di Fisica Nucleare





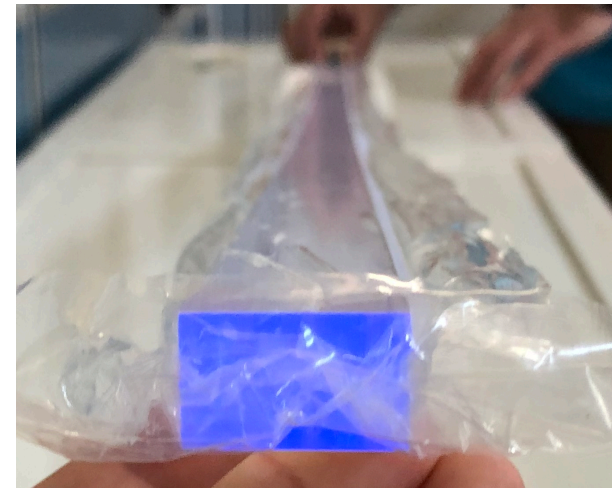
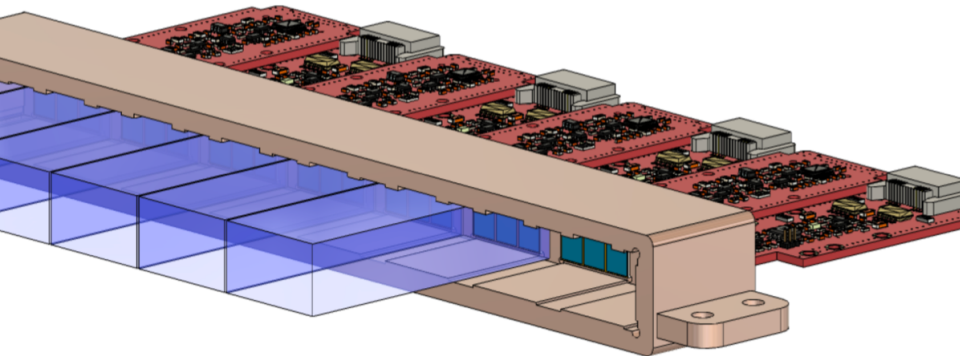
CRT



Each calorimeter disk will be tested at SiDET before installation, w CR MIPs

A dedicated CR tagger system have been designed and produced:

- Two layers of 8 plastic scintillators ($1,5 \times 1 \times 160 \text{ cm}^3$) will be placed above and below the disk
- These EJ200 scintillators are already shipped and tested at LNF
 - Longitudinal Spatial resolution $< 7\text{mm}$

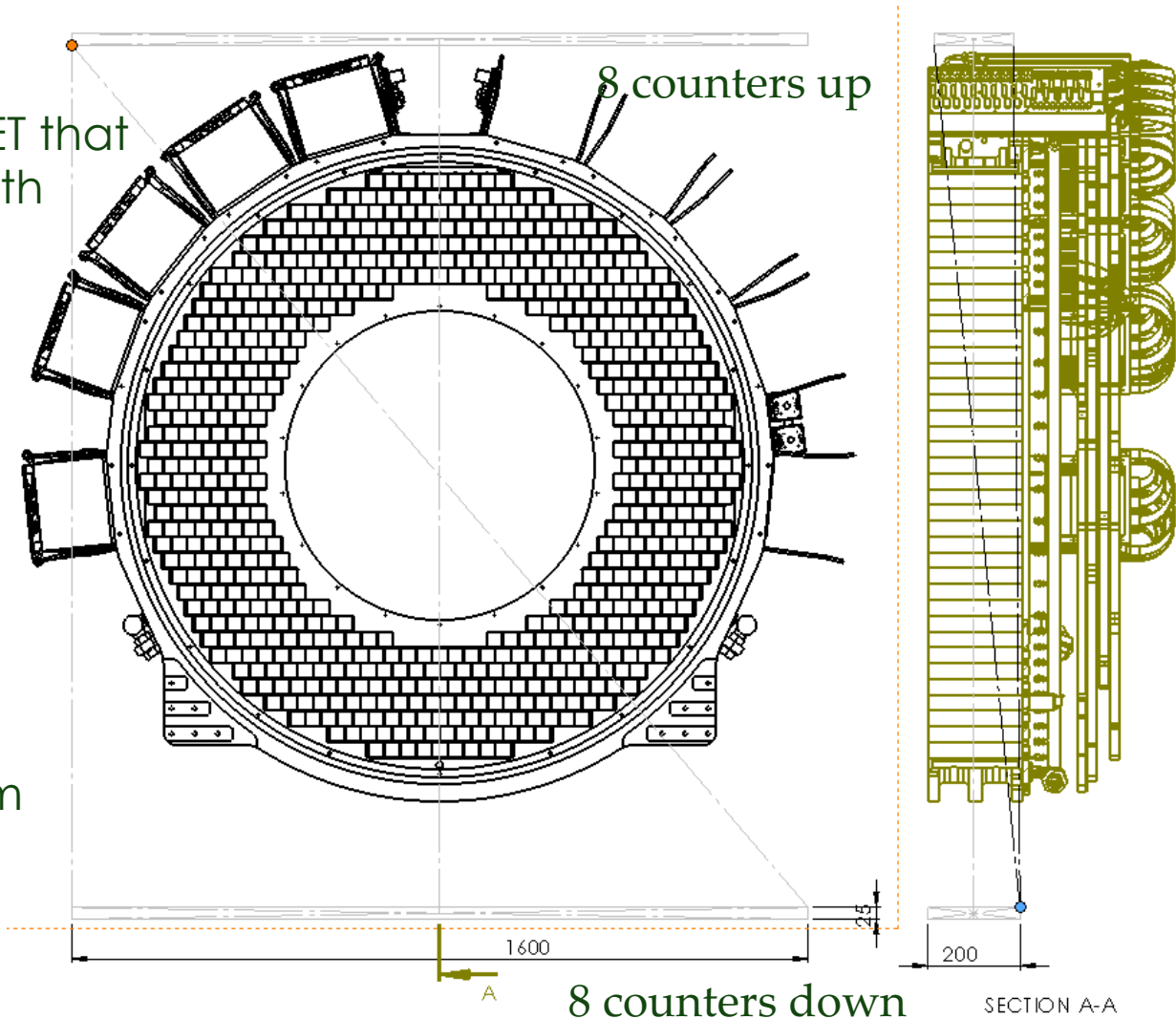


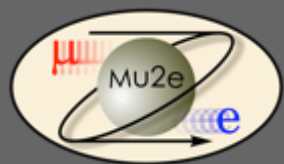
The CRT mechanical structure is in construction, the system will be used also for the vertical slice test w Module-0

We want to confirm at SIDET that LRU with photons == LRU with MIPs

Check of time resolution dependence w crystal long. axis

Crystal length = 20 cm
 → 8 scintillator bars → 2.5 cm granularity → $\sigma_Z = 7$ mm





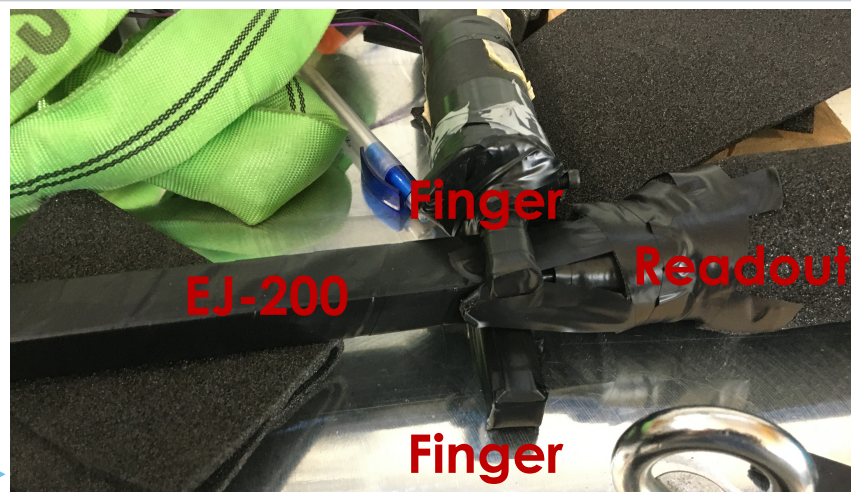
CRT – single channel measurements



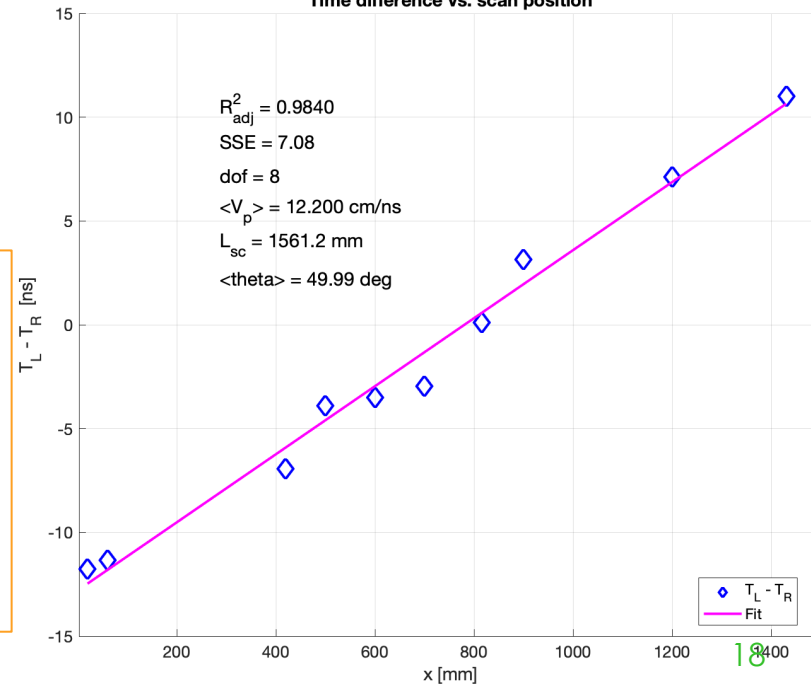
- Readout: Mu2e-SiPM + FEE
- Optical grease coupling
- Tyvek inner wrapping + black tape darkening

First test done two (parallel) fingers coincidence trigger

- TRG moved along the scintillator longitudinal axis



Time difference vs. scan position



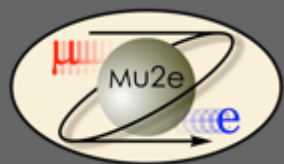
$$TL - TR = 2*x/V - L/V$$

Fitted light propagation speed $\rightarrow V = 12.2 \text{ cm/ns}$

Fitted scintillator length $\rightarrow L = 156.1 \text{ cm}$
(vs 160 cm actual)

Avg. propagation angle:

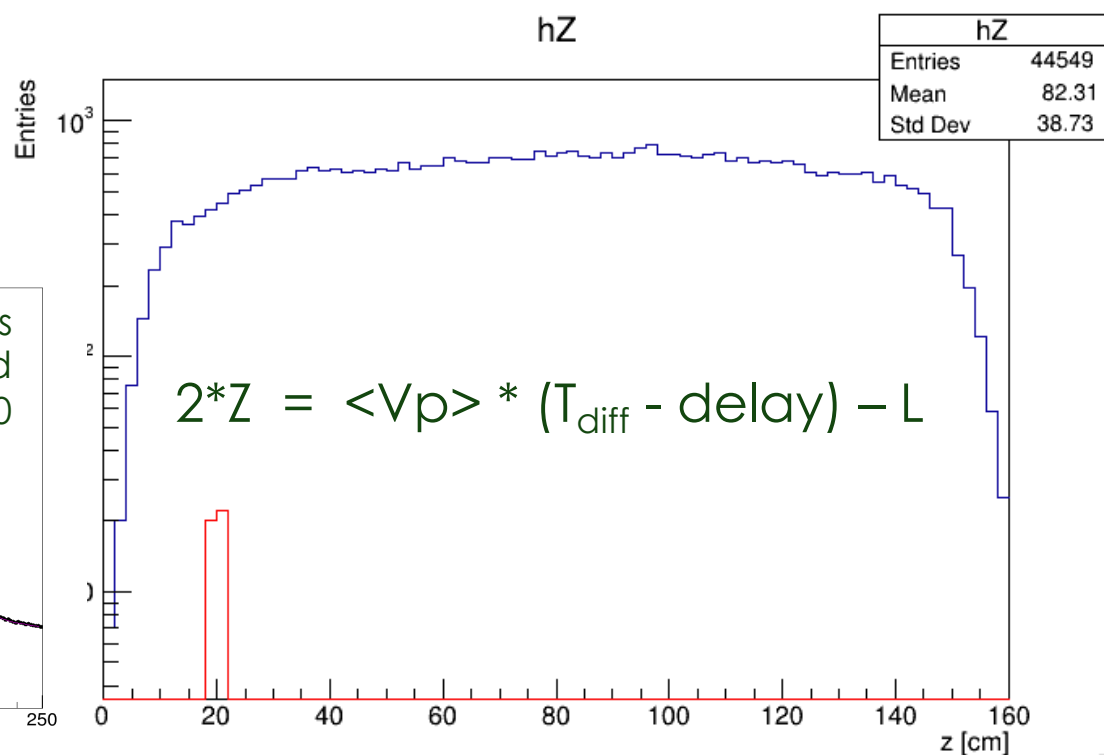
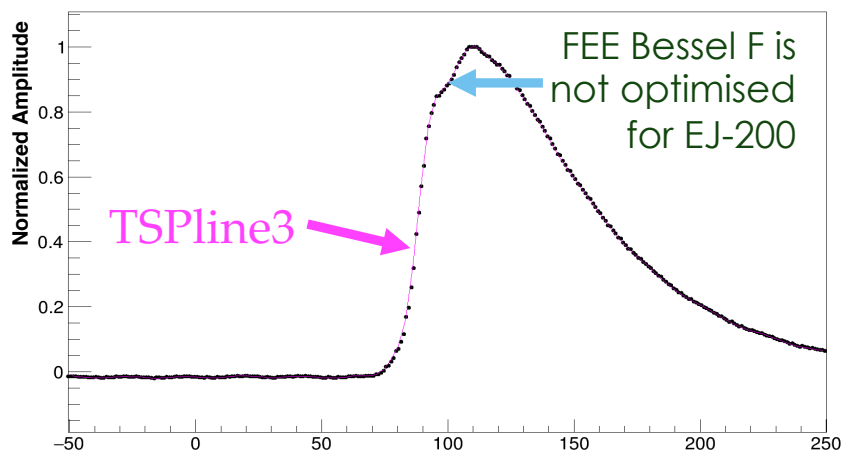
$$\langle \theta \rangle = \arccos(n*V/c) = 49.99 \text{ deg}$$

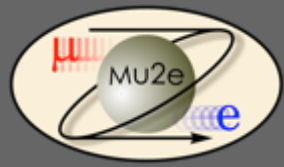


CRT – single channel measurements (2)



- Template fit constructed and applied to evaluate SiPMs time
- TRG on SiPMs coincidence
 - Time difference used to evaluate impact position:

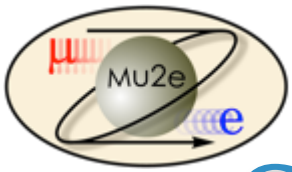




CRT – status



- Holder already designed by D.Paesani
 - First version printed
 - Tomorrow we are going to test assembly procedure
- Dedicated FEE boards already at LNF
 - Under calibration and test

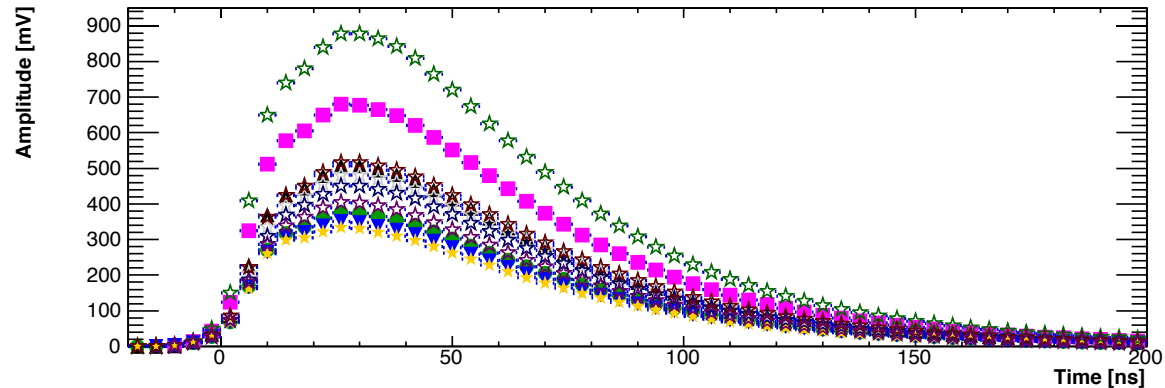


Waveform profiles

Scan over 10 positions

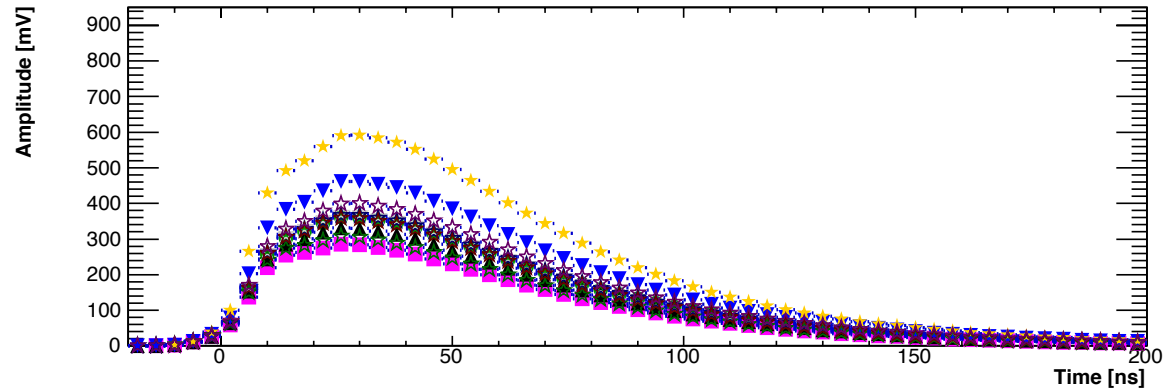
Trg – SiPM distance from side L

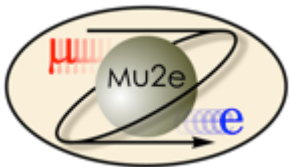
- 0 mm
- 400 mm
- 800 mm



Trg – SiPM distance from side R

- 1600 mm
- 1200 mm
- 800 mm

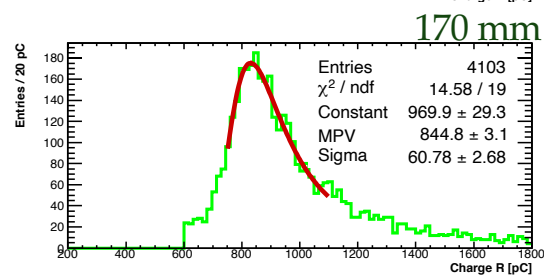
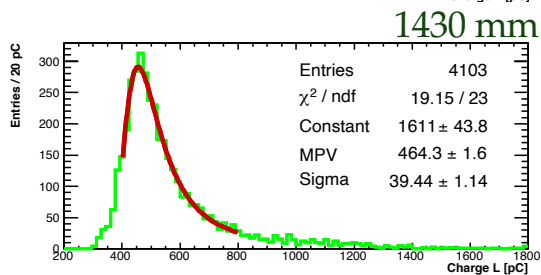
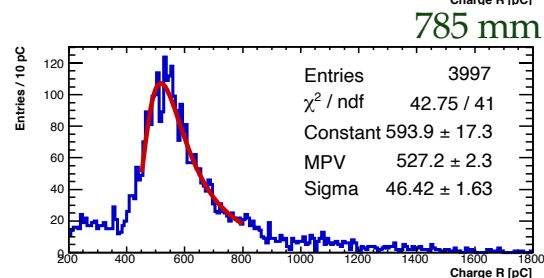
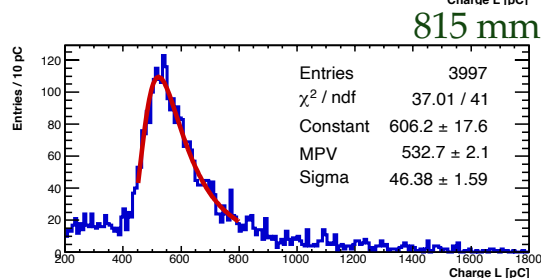
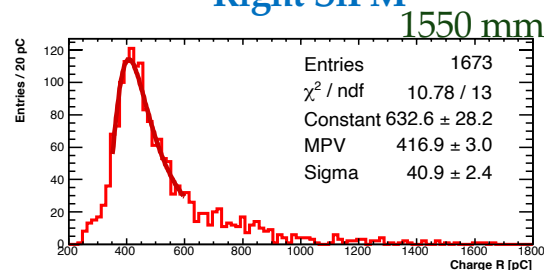
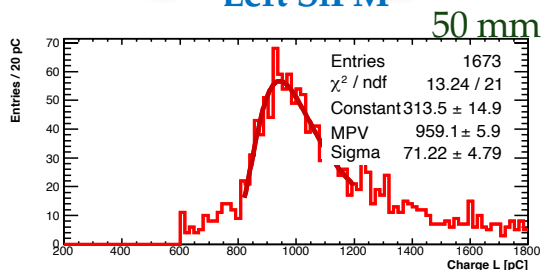


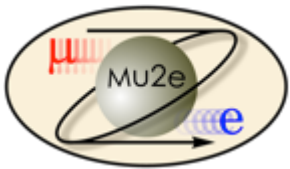


Charge spectra examples

Left SiPM

Right SiPM



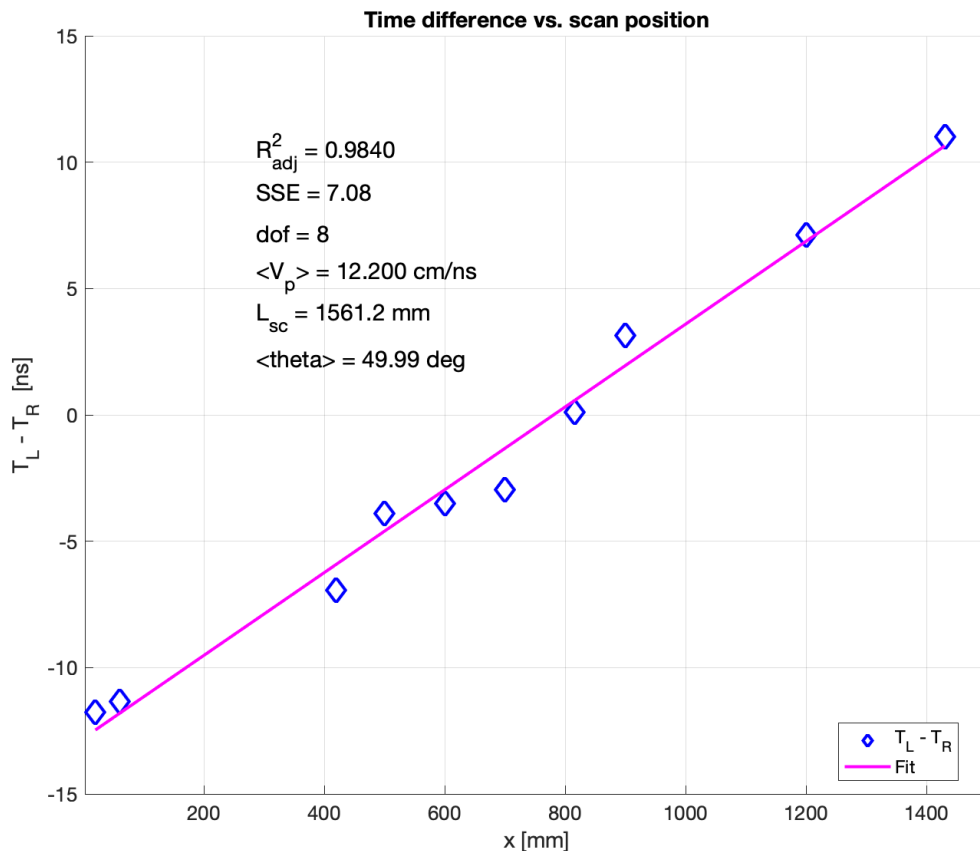


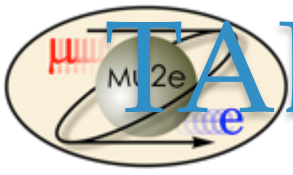
TOF, propagation speed

- Signal time has been obtained w a Logn fit on wf leading edge and w a CF at 20%

$$TL - TR = 2*x/V - L/V$$

- Fitted light propagation speed $\rightarrow V = 12.2 \text{ cm/ns}$
- Fitted scintillator length $\rightarrow L = 156.1 \text{ cm}$
(vs 160 cm actual)
- Avg. propagation angle $\langle \theta \rangle = \text{acos}(n*V/c) = 49.99 \text{ deg}$
- Sigma (TL-TR) $\sim 100 \text{ ps}$
- Time resolution $\sim 100 \text{ ps} / \text{sqrt}(2) \sim 70 \text{ ps}$
- Longitudinal resolution = $Vf*\text{sigma}/2 \sim 6 \text{ mm}$**

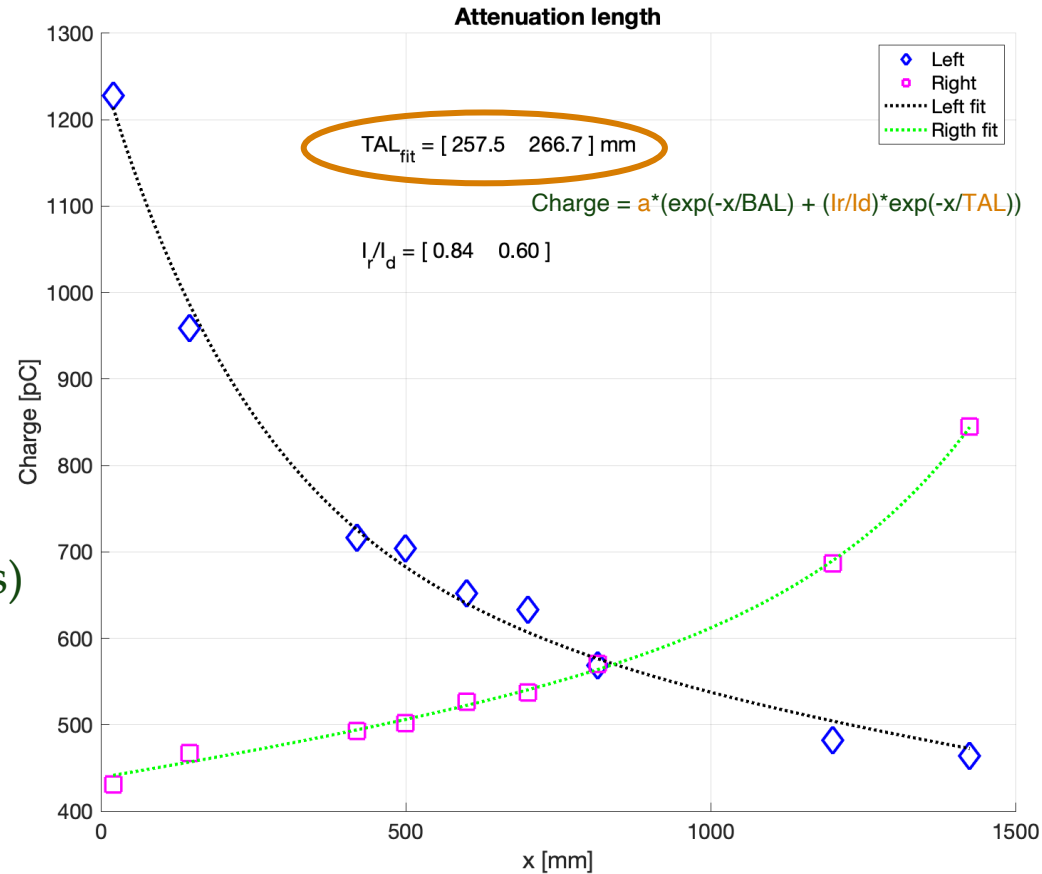




TAL (technical att. length) estimation

Considering

- Reflection efficiency = 0.95
- $V_f = 12.2$
- $\langle \theta \rangle = 49.9$ deg
- cross sectional dimension:
 $h = \frac{2 \cdot h_1 \cdot h_2}{h_1 + h_2}$
 ($h_1 = 25$ mm , $h_2 = 15$ mm)
- $d \cdot \cos \theta = x$, $d \cdot \sin \theta = m \cdot h$,
 (d = average light path, m reflections)
- BAL = 3800 mm (bulk attenuation length)
- $h / BAL + \log(1/R) \cdot \sin \theta = h \cdot \cos \theta / TAL$



We expect a TAL ~ 273.5 mm