Compton Polarimetry for Future Linear Colliders

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Polarimetry at Future Linear Colliders

- Upstream polarimeter to measure the undisturbed beam before collisions.

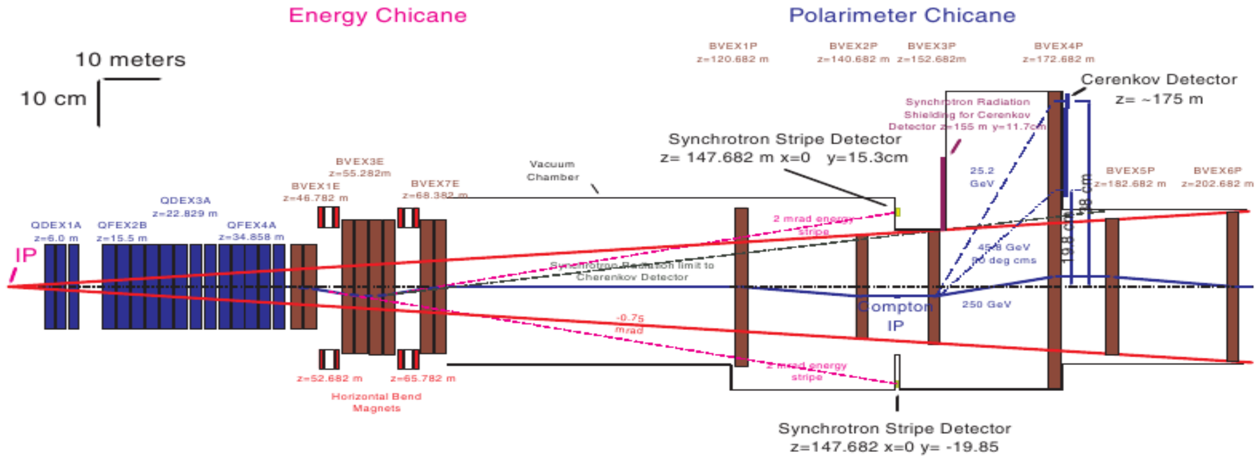
- Physics measurements (A. Rosca, G. Wilson)

- Compton polarimetry

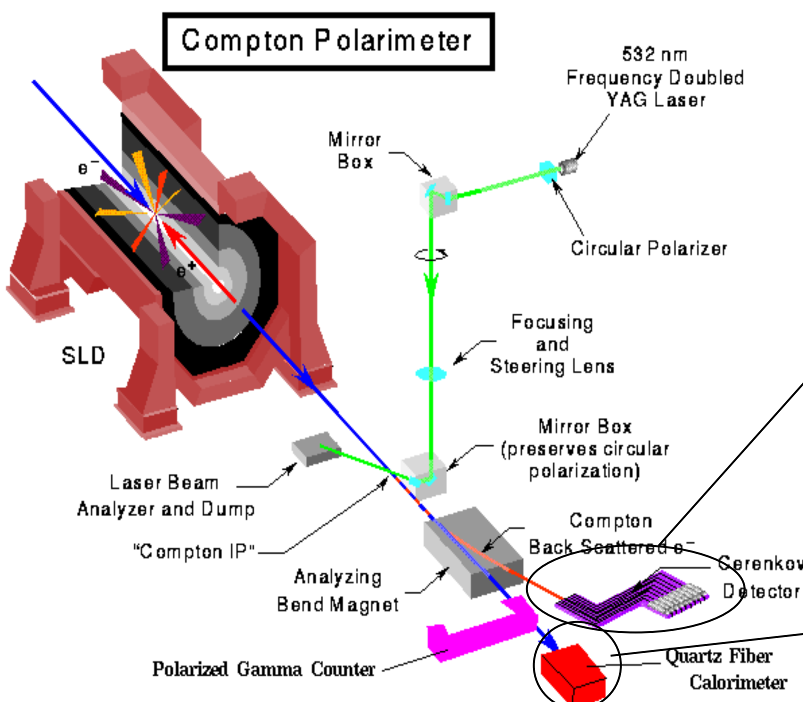
    - Necessary to obtain a sub-1% (~0.25%) polarimetry accuracy.

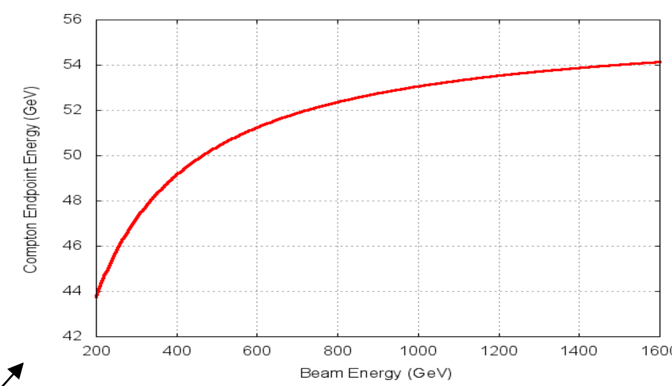
    - Accurately measure depolarization effects.

Compton Polarimetry Baseline

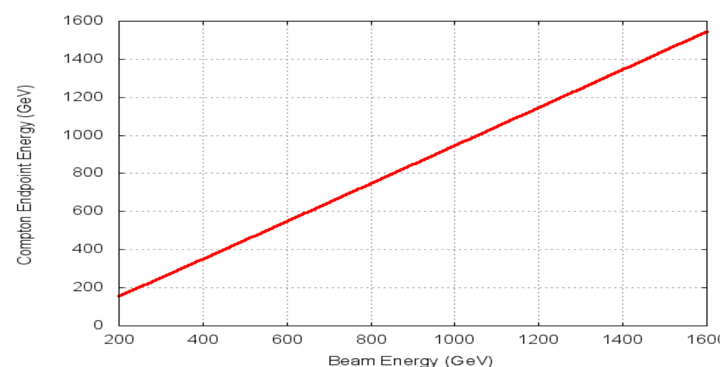


ILC RDR

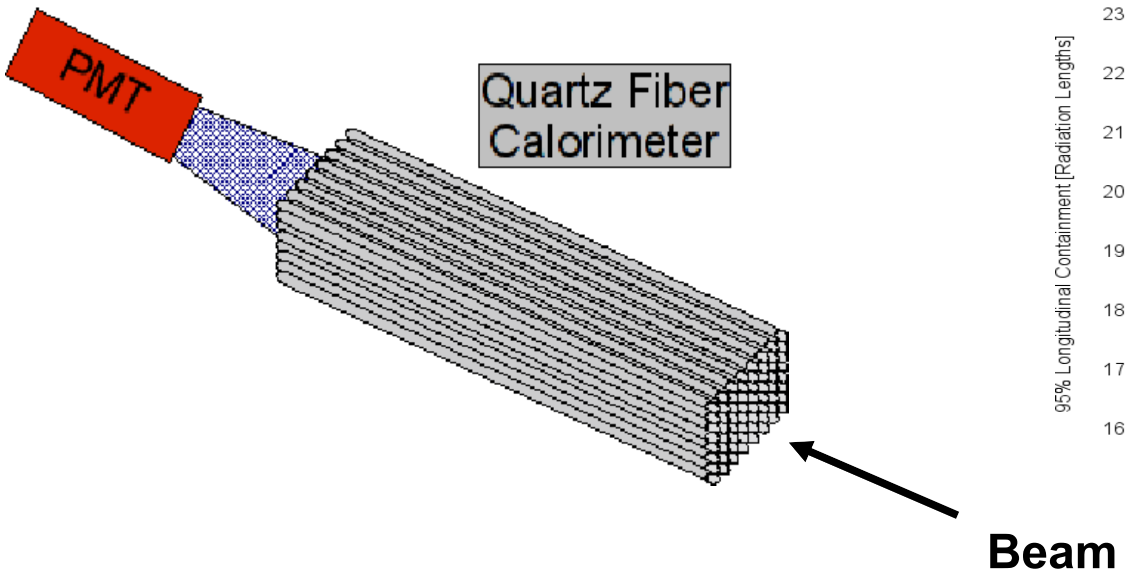


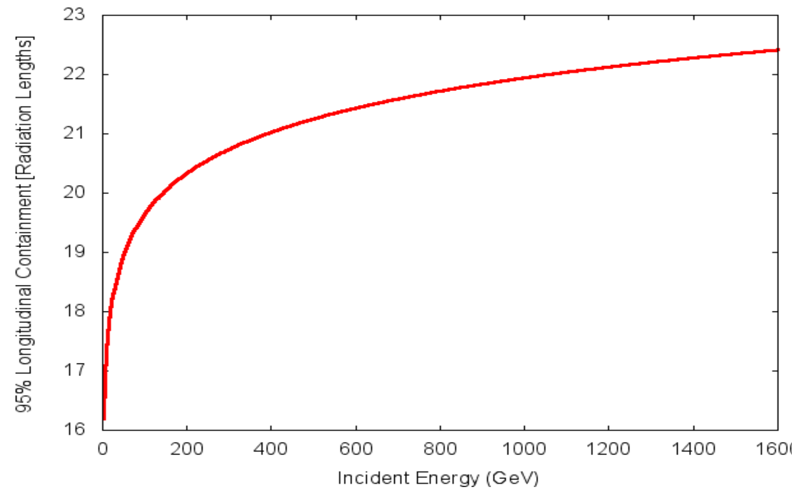


1064 nm Nd:YAG



Quartz Fiber Calorimeter

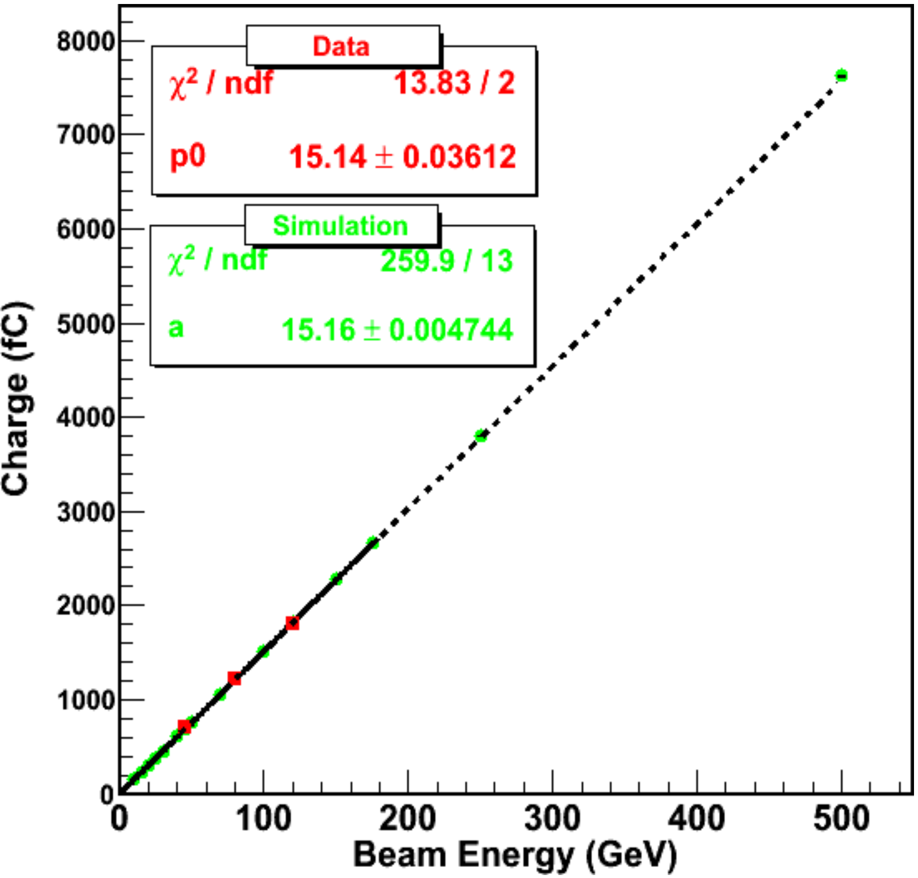


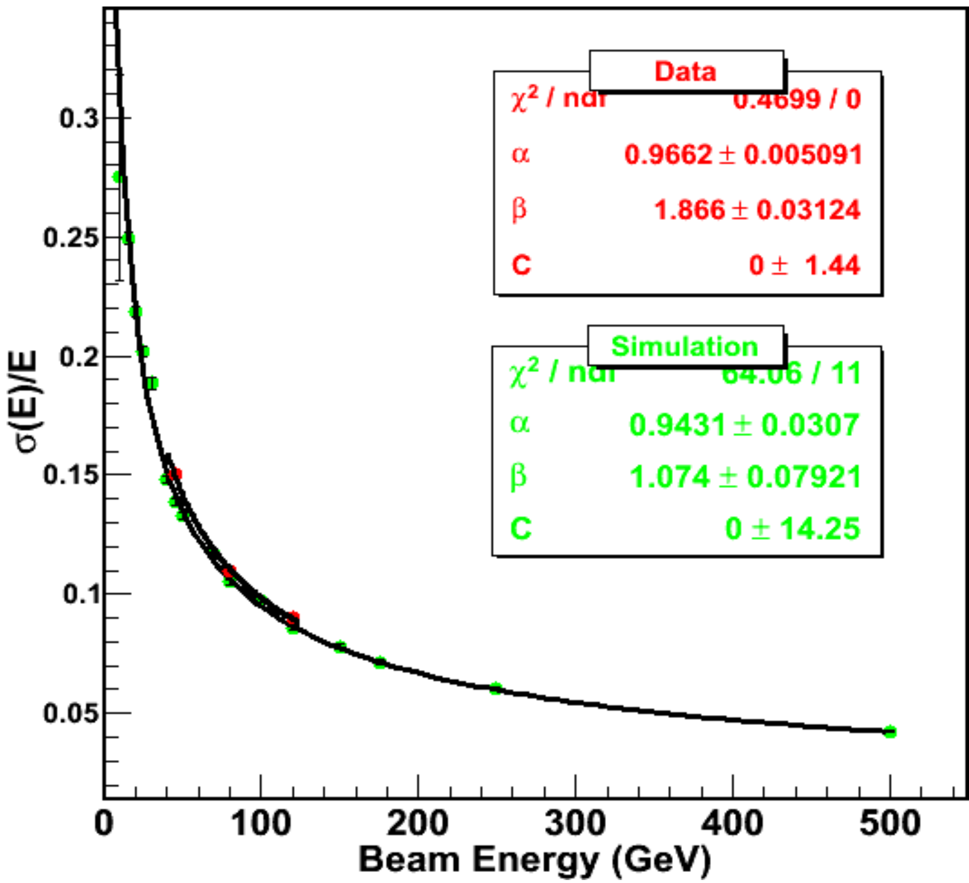


- Iron rods of 6 mm diameter, 45 cm length (~25X_0).
- Quartz fibers in between the rods (0.3 mm core diameter).
- 20 cm x 20 cm lateral size.
- Single readout of the bundled fibers.

Tested with 45, 80 and 120 GeV/c electron beams.

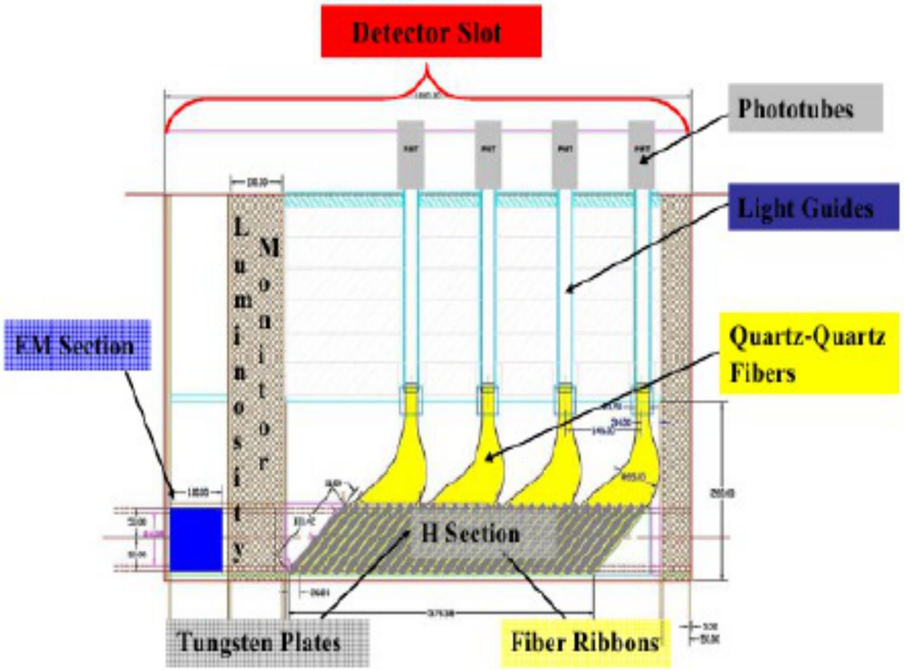
Quartz Fiber Calorimeter

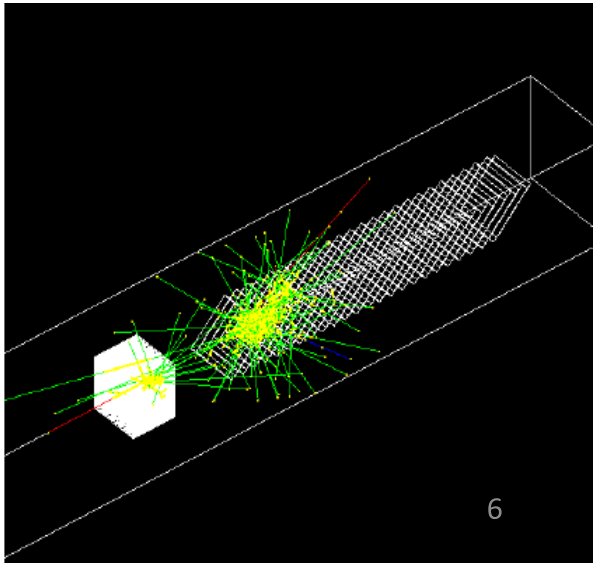




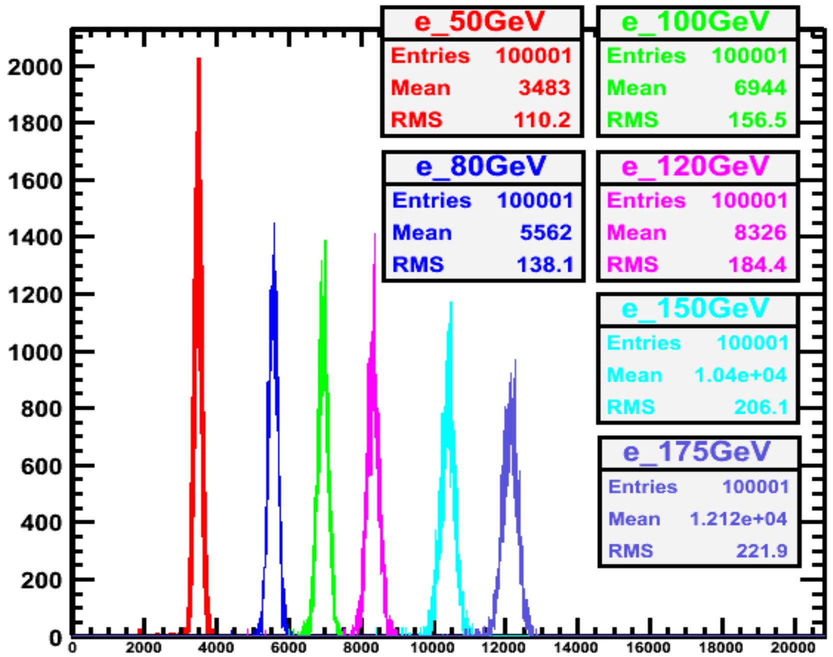
$$\frac{\sigma}{E} = \frac{\alpha}{\sqrt{E}} \oplus \frac{\beta}{E} \oplus C$$

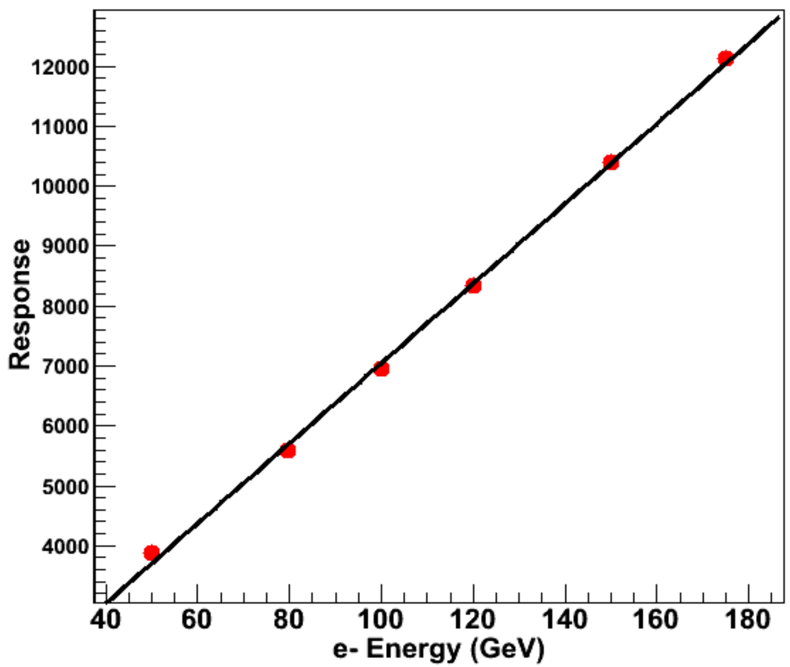
Quartz Fiber Calorimeter Alternative – CMS ZDC





Quartz Fiber Calorimeter Alternative – CMS ZDC





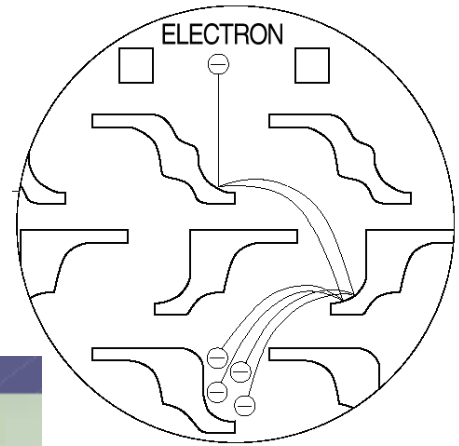
Secondary Emission Ionization Calorimeter

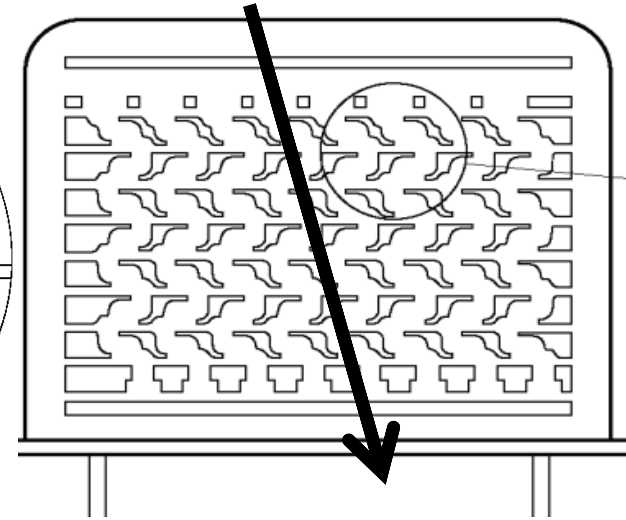
- **Secondary Emission (SE) signal:** SE surfaces inside em/had showers:
  - SE yield δ: Scales with particle momentum
  - e^-: $3 < \delta < 100$, per $0.05 < e^- < 100$ keV (material dependent)
  - $\delta \sim 0.05 - 0.1$ SEe^- per MIP
- **SE is:** Rad-Hard + Fast
  - a) Metal-Oxide SE PMT Dynodes survive > 100 GigaRad
  - b) SE Beam Monitors survive 10^{20} MIPs/cm^2

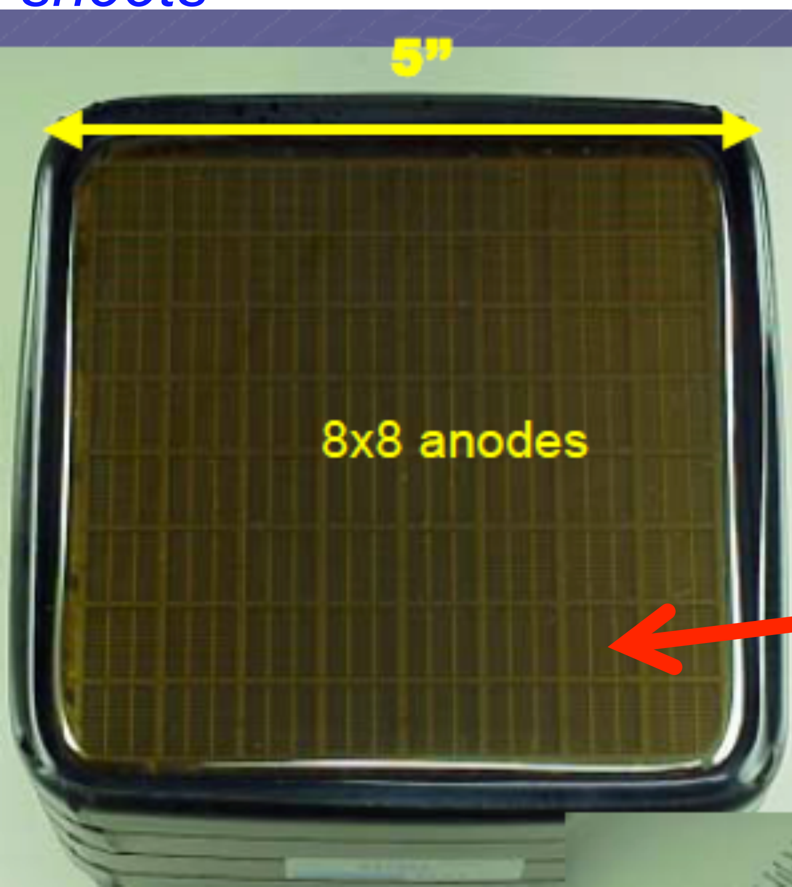
Ex: ~60-240 SEe^- per 100 GeV pion shower w/ MIPs alone
BUT SEe^- Must be Amplified! Exactly like photoelectrons (p.e.)!

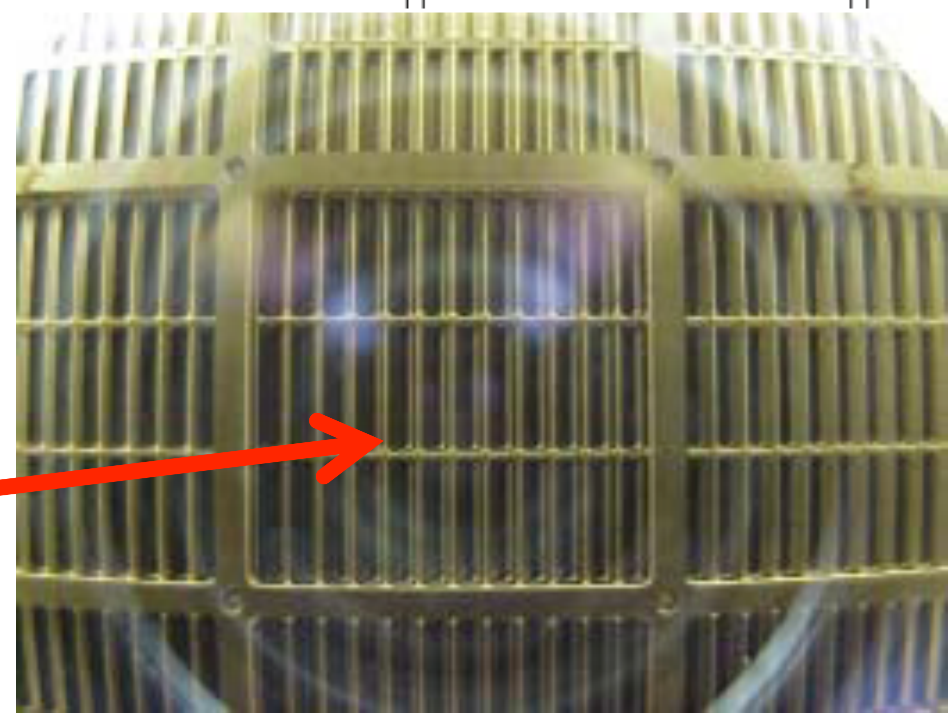
SEe Dynodes: a) Etched Metal Sheets

Hamamatsu Dynodes
15 cm now → ~50 cm
Already diced from large sheets



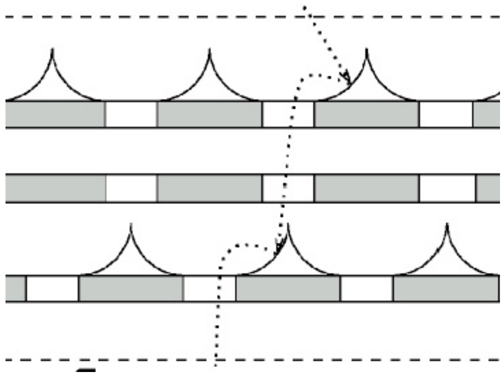


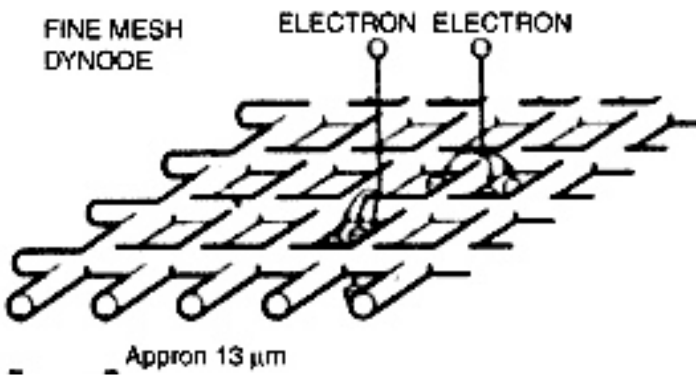


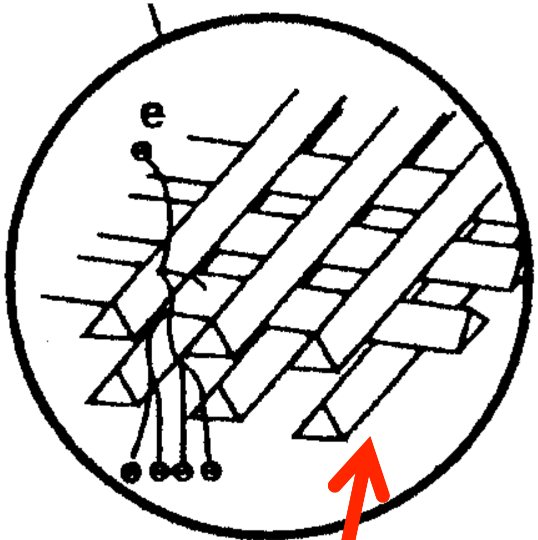


SEe Dynodes: b) Metal Screen Dynodes: 15D - g~10^5

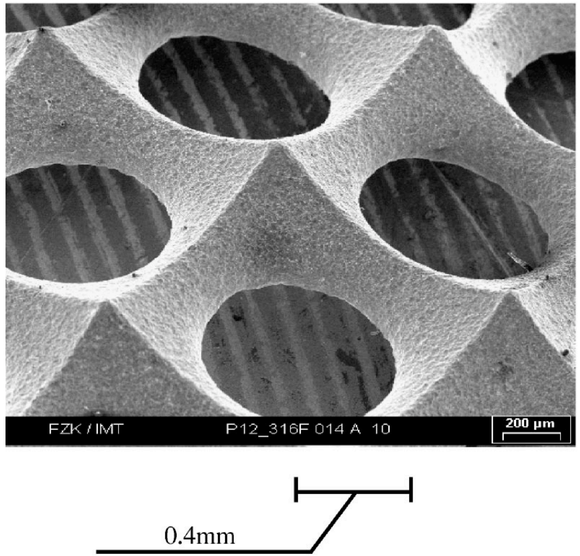
MESH DYNODE VARIANTS

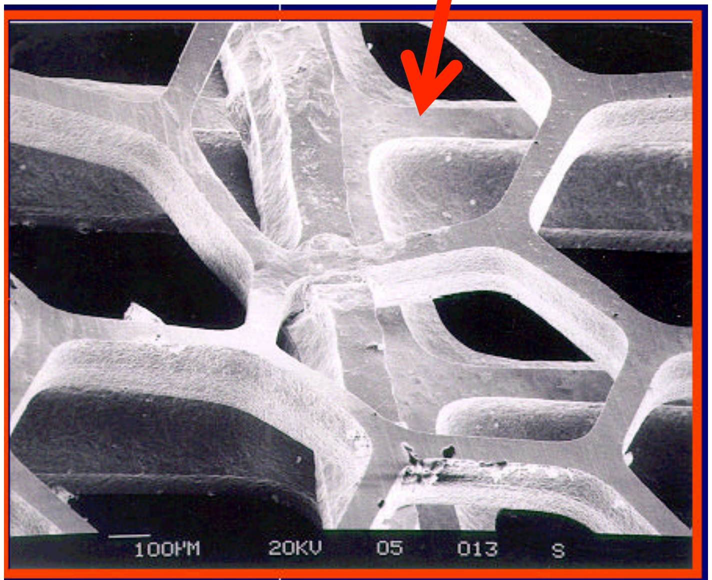






D_n-D_{n+1}: 0.9 mm
C-C mesh: 13 µm
Wire diameter: 5 µm





SE Module Beam Test

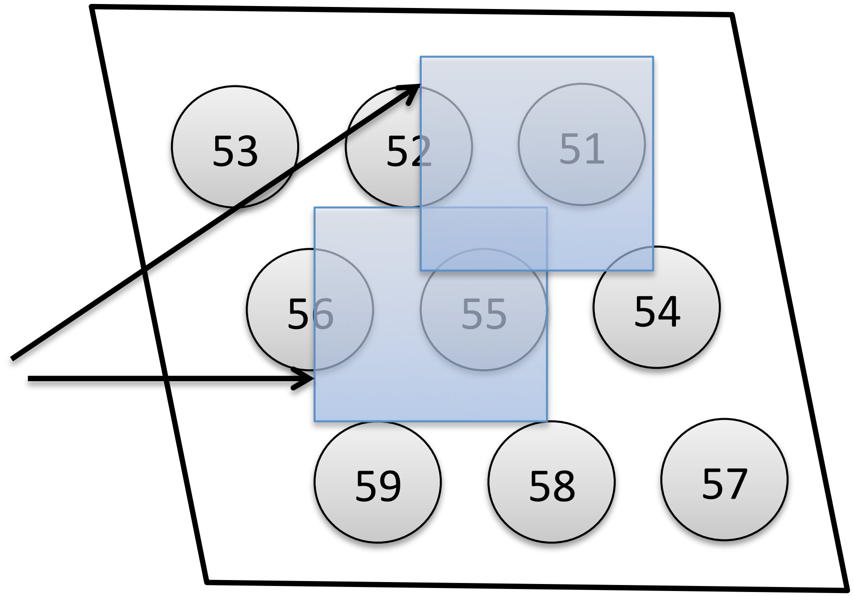
Using mesh dynodes from PMTs

CERN SPS, Nov. 2012

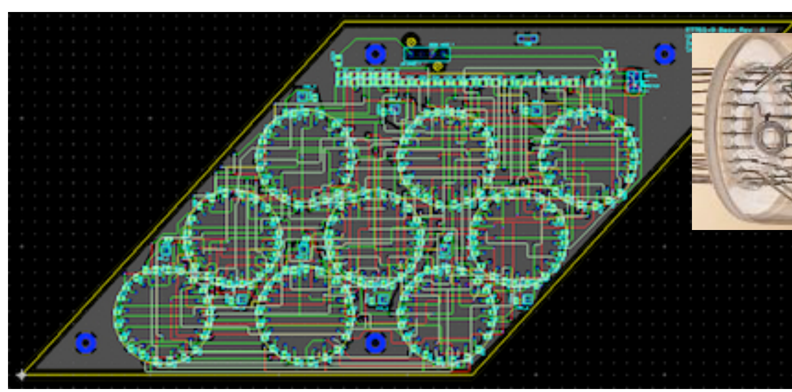
Beam position
(into the page)

2 datasets

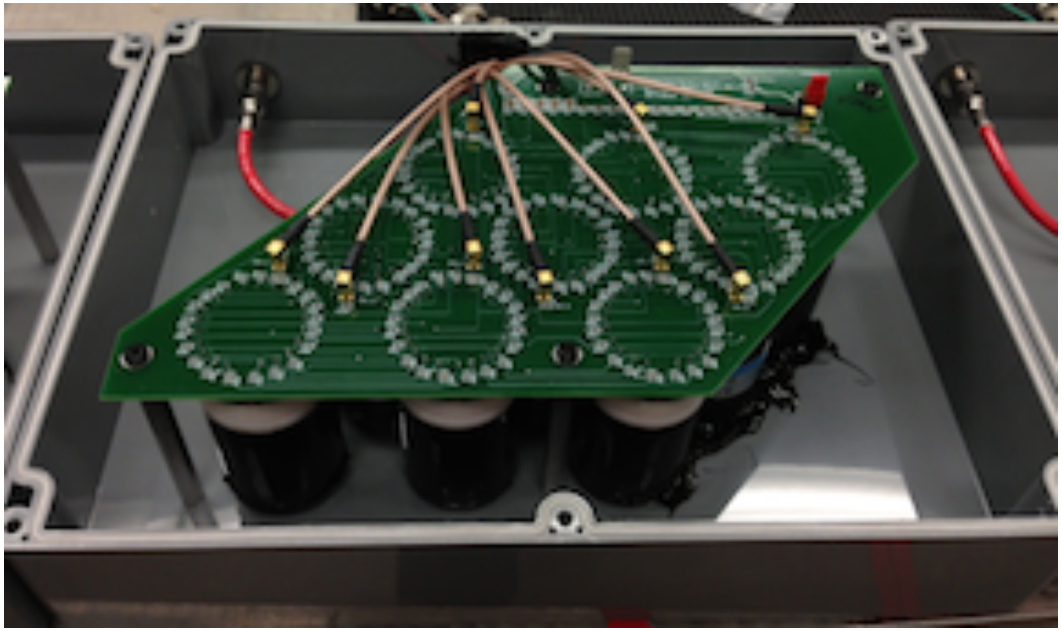
Selected with
Wire Chamber



51, … , 59: PMT IDs

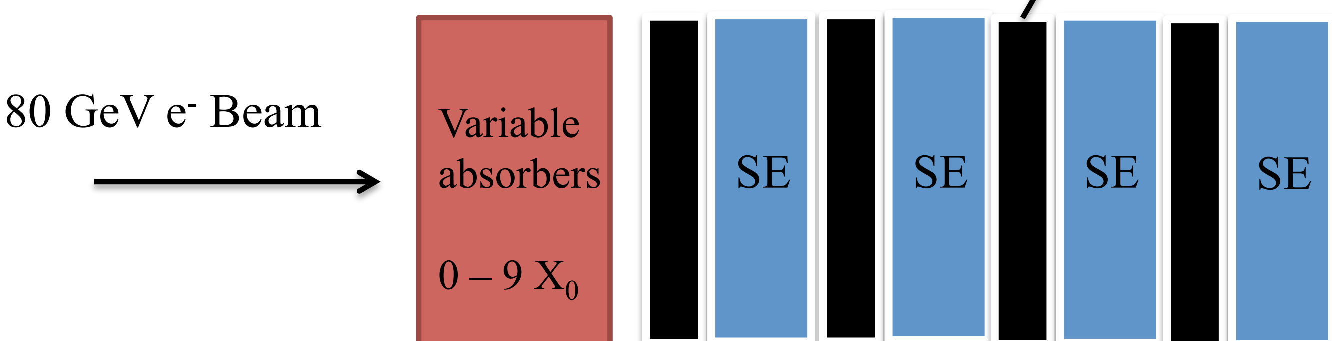


SE Module Beam Test



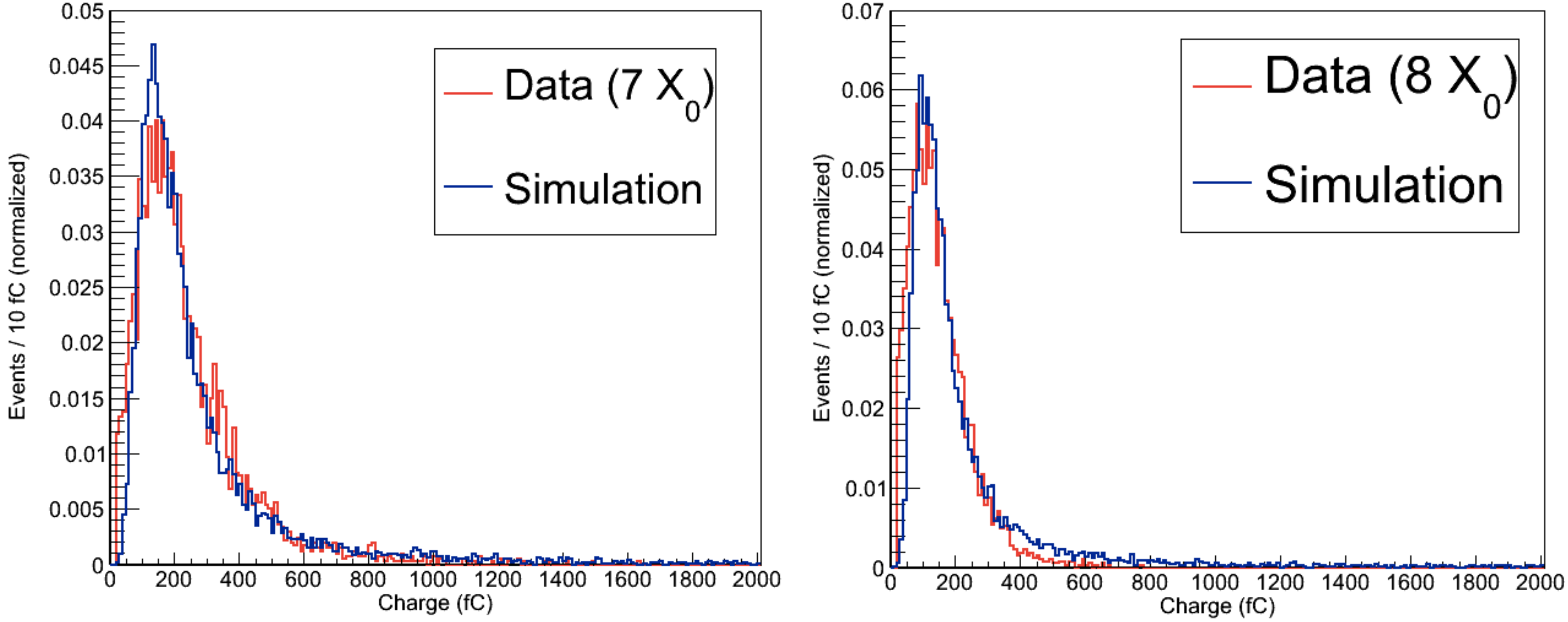
2-cm iron absorbers:

X_0 = 1.75 cm
Molière Radius: 1.72 cm



Shower not contained laterally or longitudinally
→ Results require estimates and approximations

SE Module Simulation



Geant4 simulation of the SE module test beam setup:

80 GeV e^- beam

19 stage mesh dynodes generate SE electrons (dynodes ~ sheets)

Gain is simulated offline (10^6)

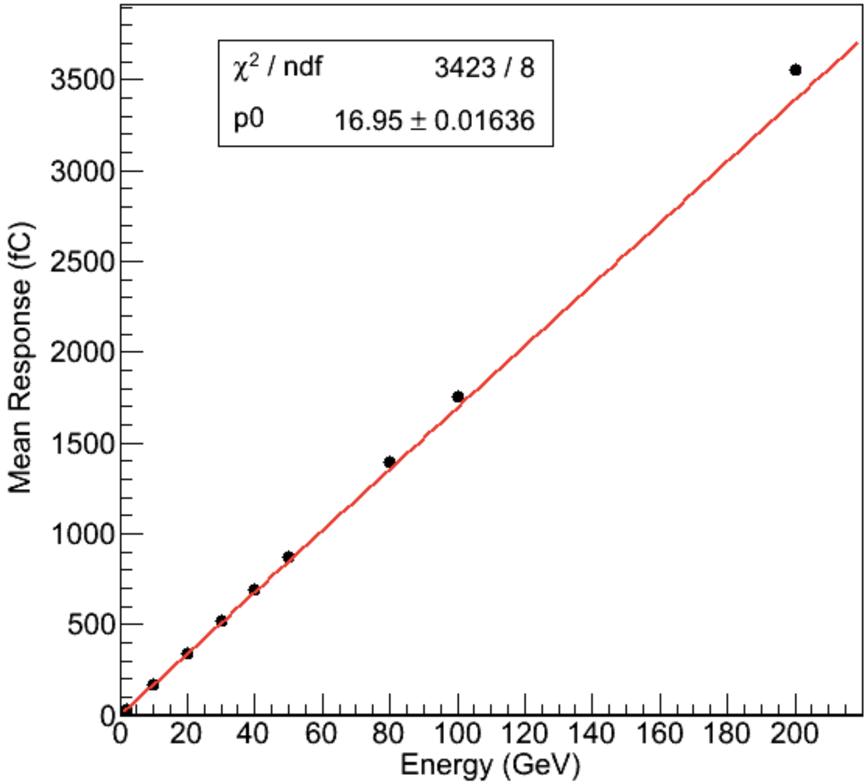
Landau fluctuations are implemented offline

Single parameter to tune: Efficiency of SEe production (mesh dynodes are simulated as solid sheets) → 0 - 0.35% flat random

SE Calorimeter Simulation

Using SE module MC tune

25 X_0 sampling calorimeter
1.75 cm Fe absorbers
19-stage SE sensor ~ 2 cm
Lateral size 30 cm x 30 cm

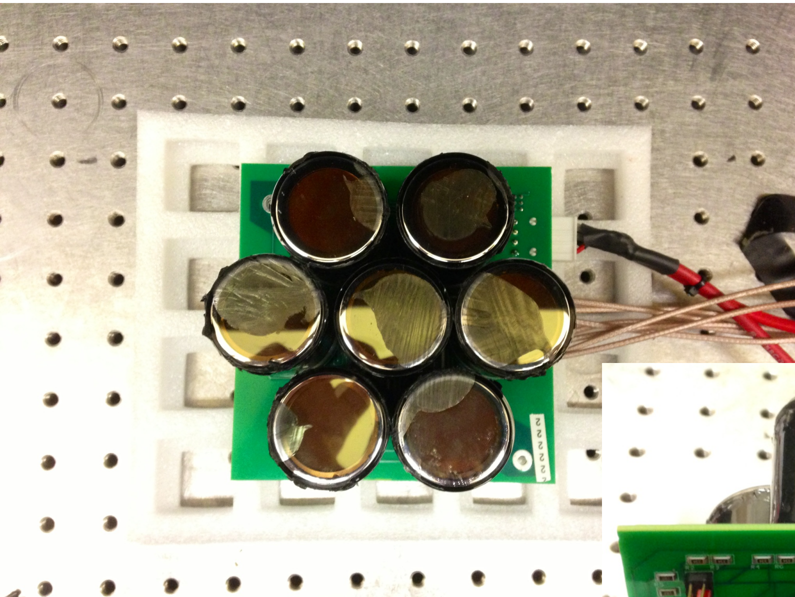


Advantages:

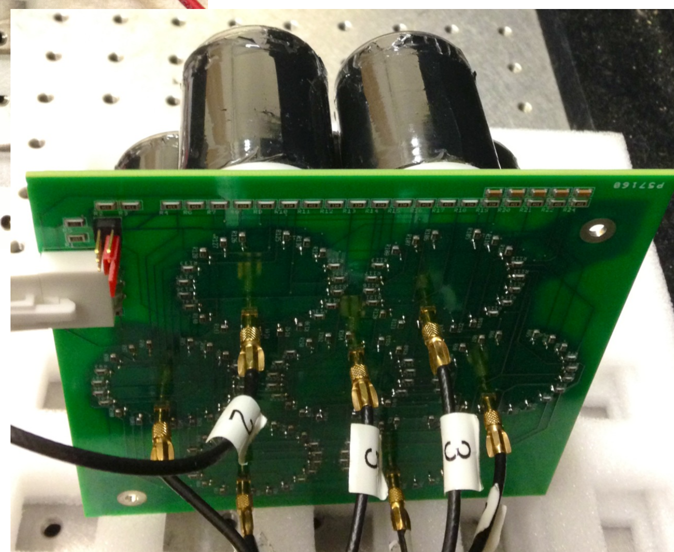
Could be laterally segmented

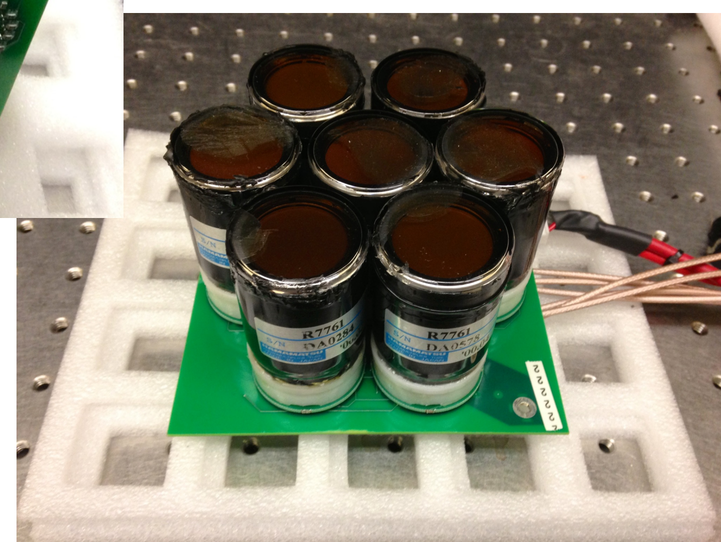
➔ Additional handle for angular measurements

SE Calorimeter 2nd Generation Prototype



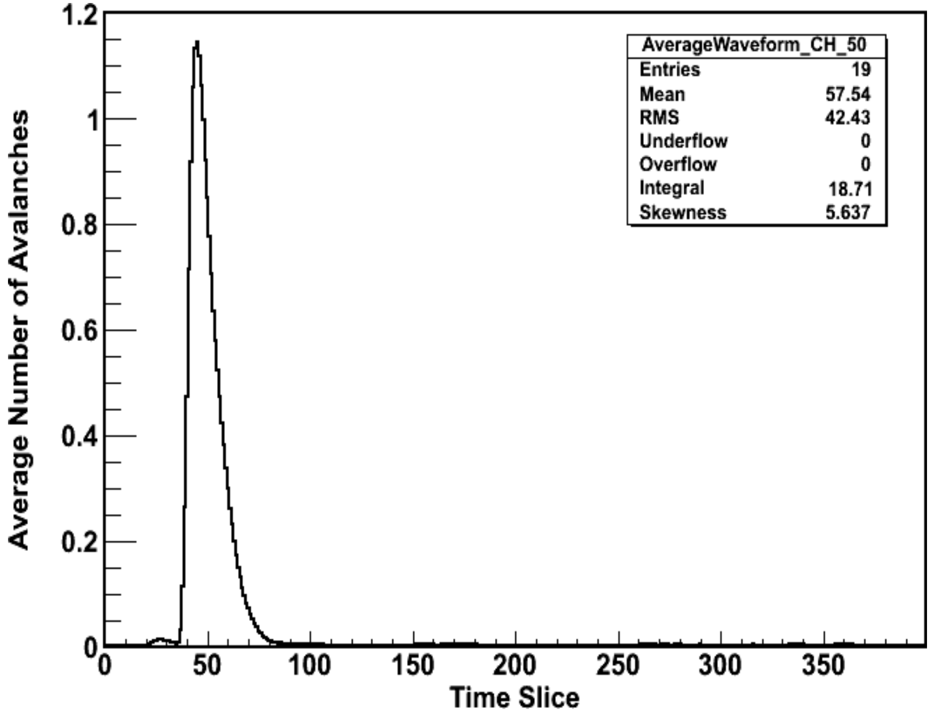
Laboratory tests completed,
ready for beam!





Čerenkov Detector

We have shown in TIPP2011 that the Čerenkov light produced in PbF_2 crystals can be read out by SiPMs directly coupled to the crystal.

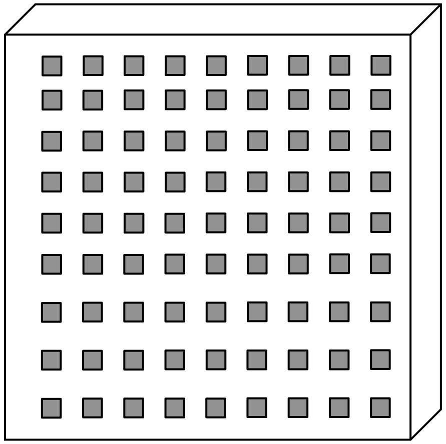


2 cm x 2 cm x 5 cm PbF2

3 mm Hamamatsu SiPM

http://indico.cern.ch/contributionDisplay.py?contribId=225&confId=102998

Čerenkov Detector First Approach



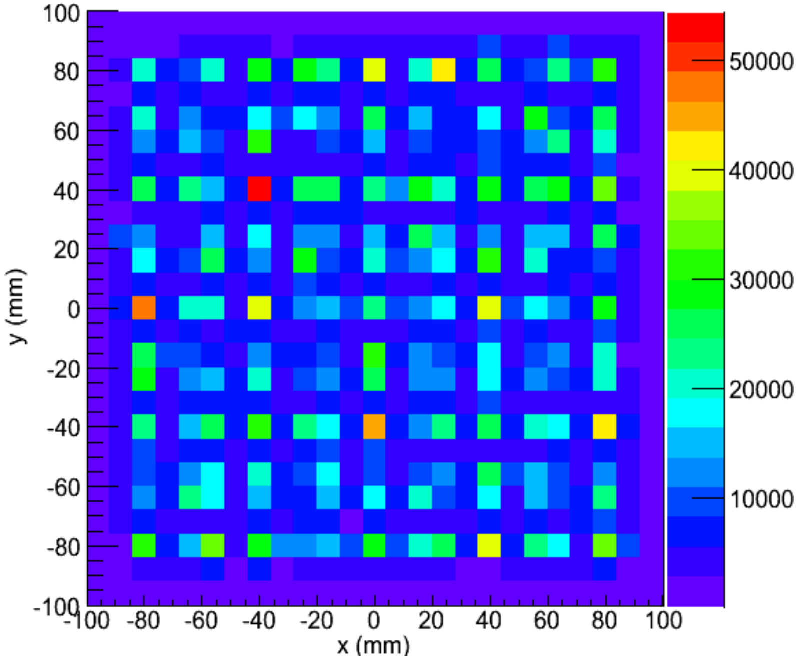
20 cm x 20 cm x 1 cm PbF_2

n=1.78 → Čerenkov angle ~ 57^{o}

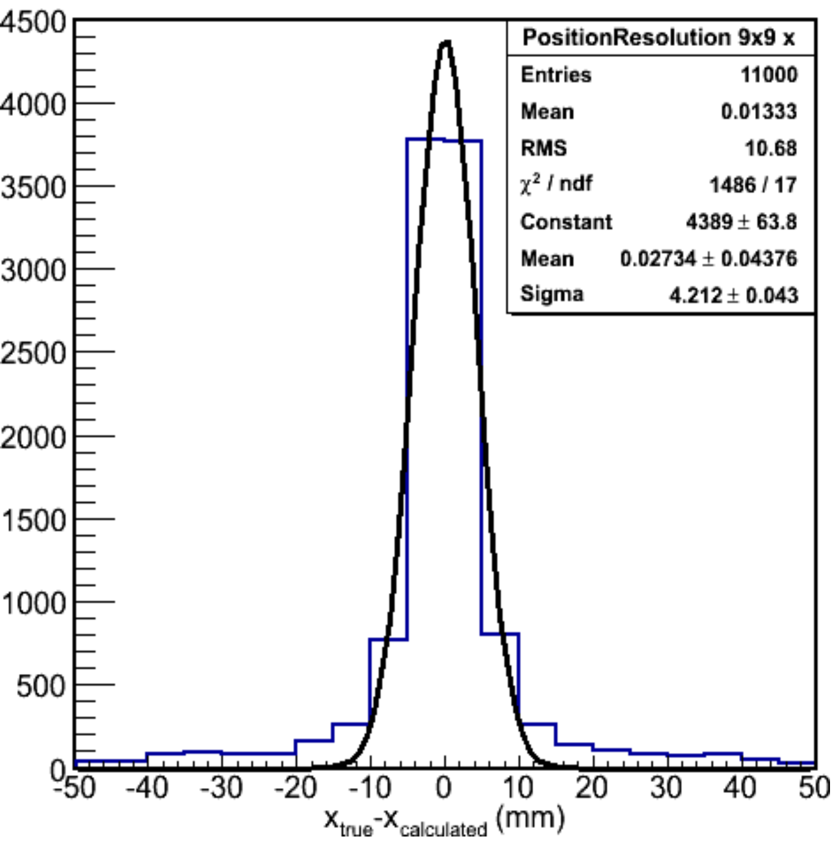
2 cm SiPM seperation

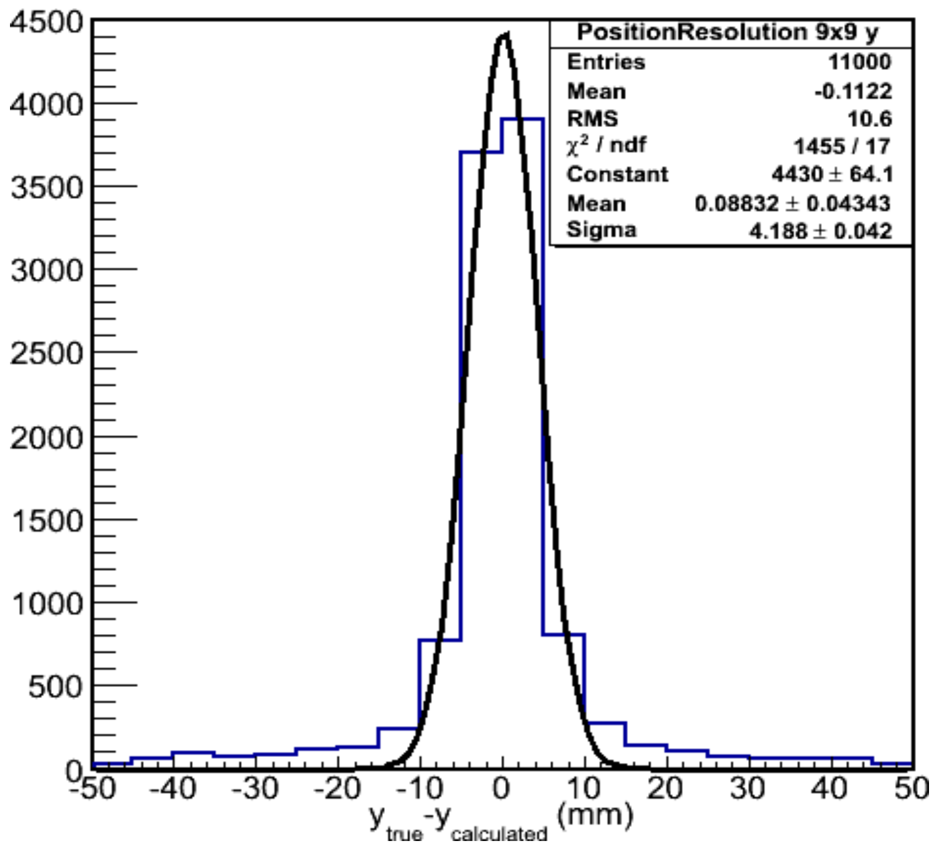
SiPM response ↔ number of photons

50 GeV e- beam ~ Compton edge @ 500 GeV



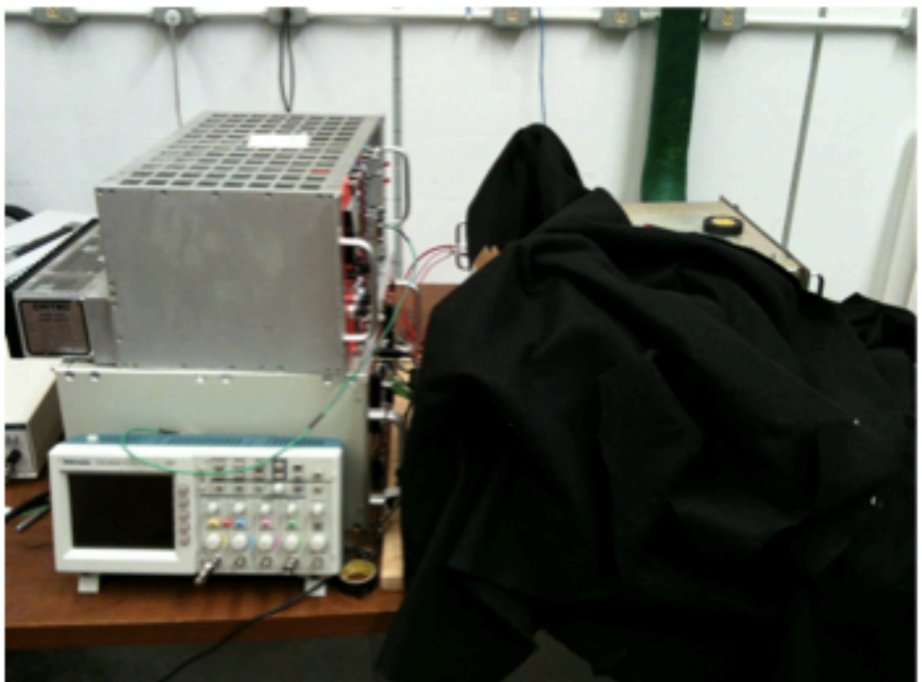
Čerenkov Detector
First Approach

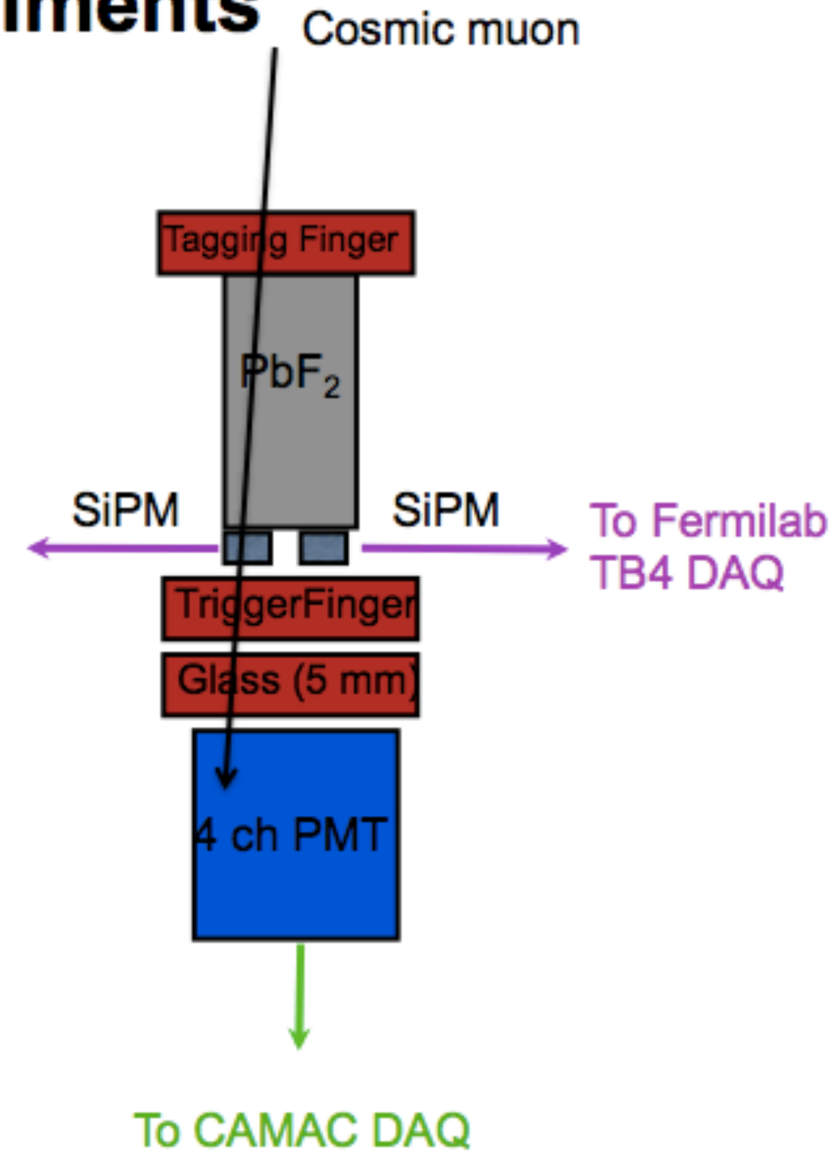




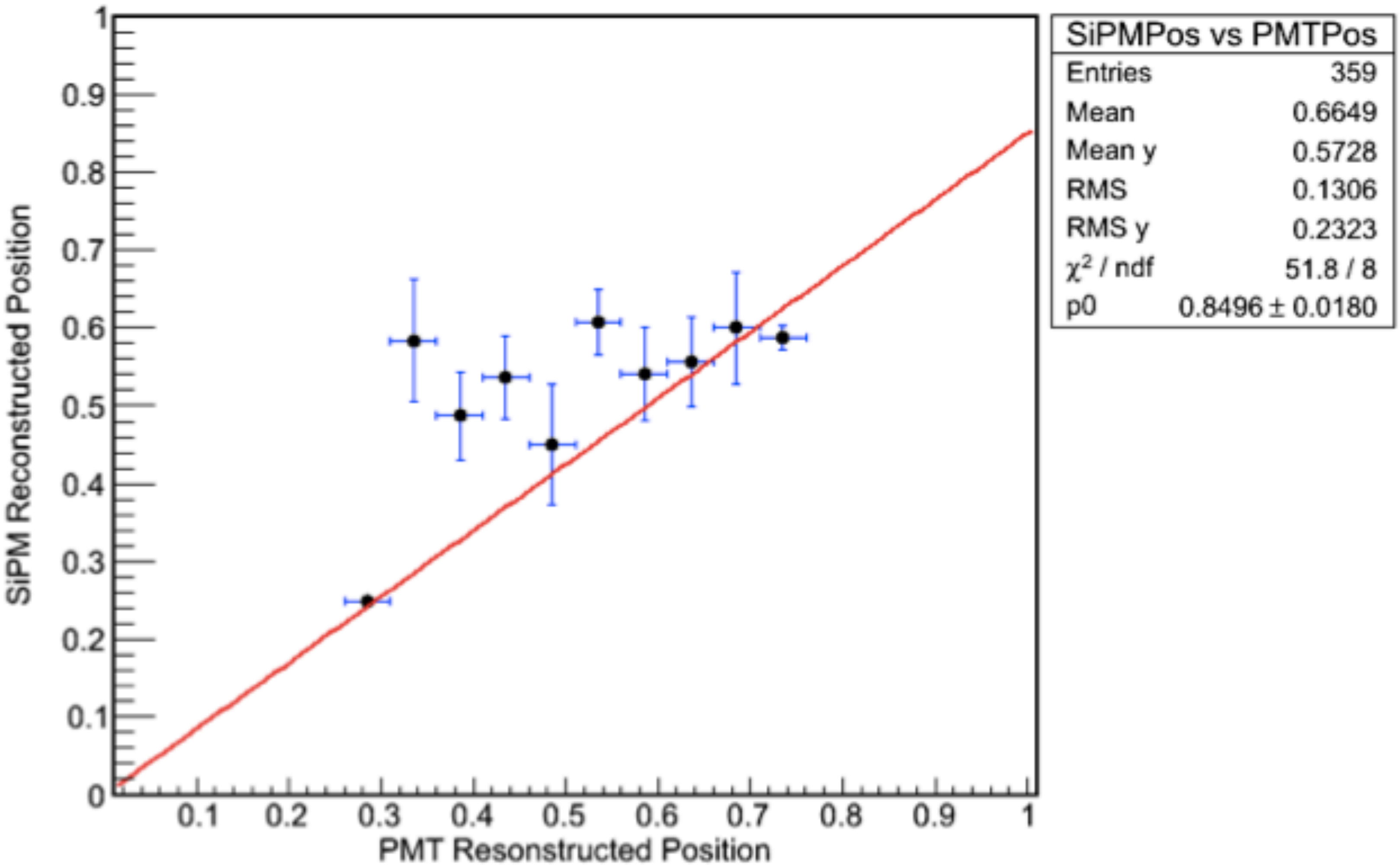
Čerenkov Detector Further Experiments

Test station at University Of Iowa





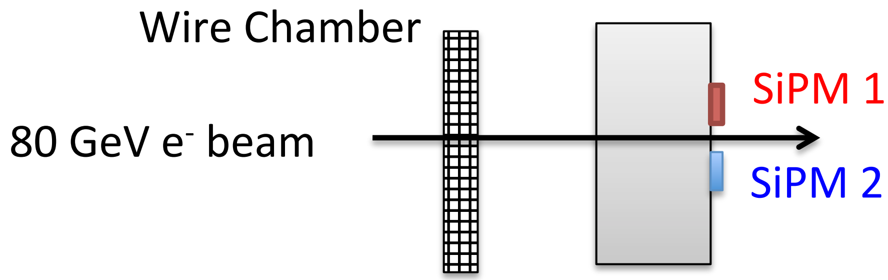
Čerenkov Detector
Further Experiments



PMT Position = $((PMT_0+PMT_1)x0.25 + (PMT_2+PMT_3)x0.75)/(PMT_0+PMT_1+PMT_2+PMT_3)$

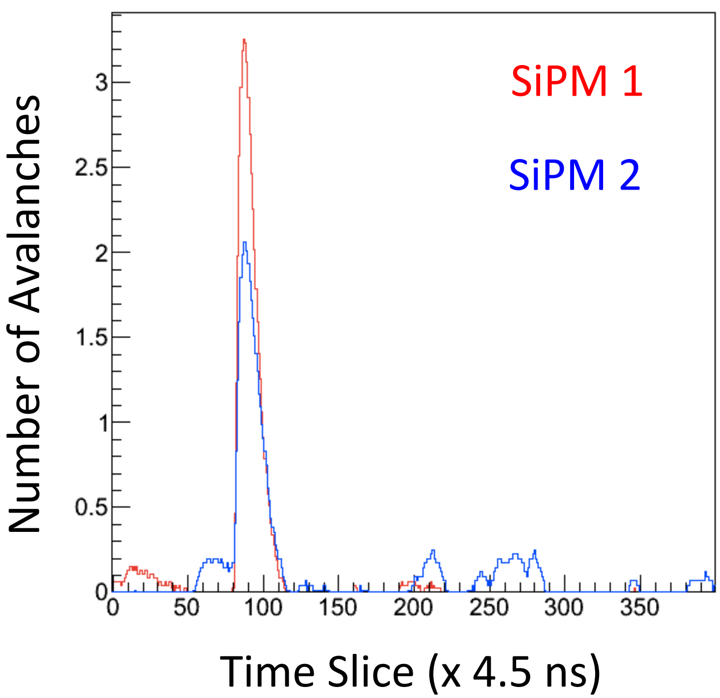
SiPM Position = $(SiPM_0 \text{ x } 0.25 + SiPM_1x0.75)/(SiPM_0+SiPM_1)$

Čerenkov light readout with SiPMs directly coupled to PbF_2

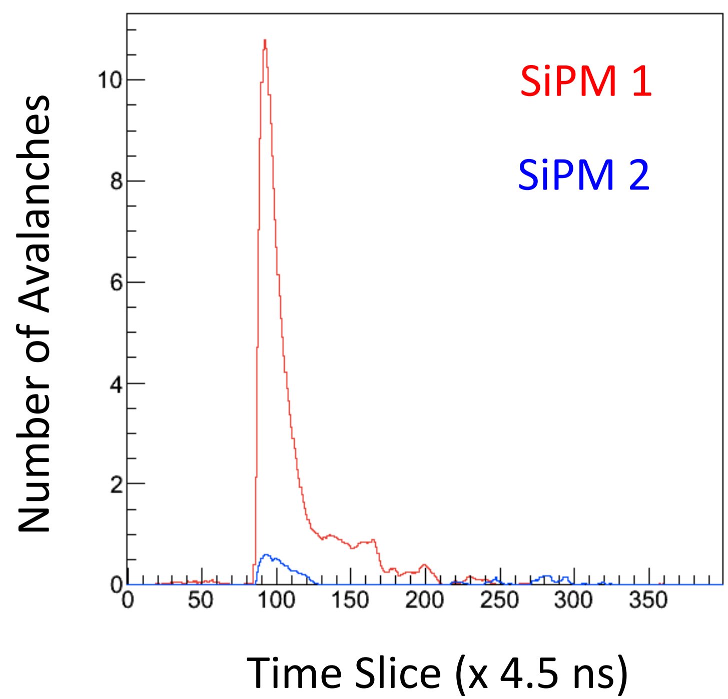


PbF_2 2 x 2 x 5 cm^3

Electron passing between SiPMs



Electron passing closer to SiPM 1

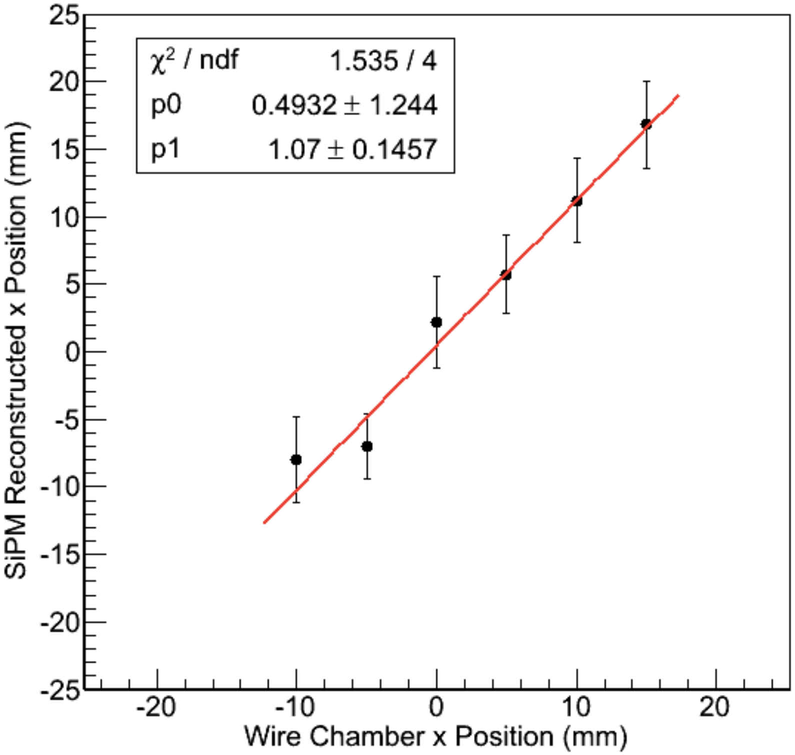


SiPM 1: 47 avalanches
SiPM 2: 35 avalanches

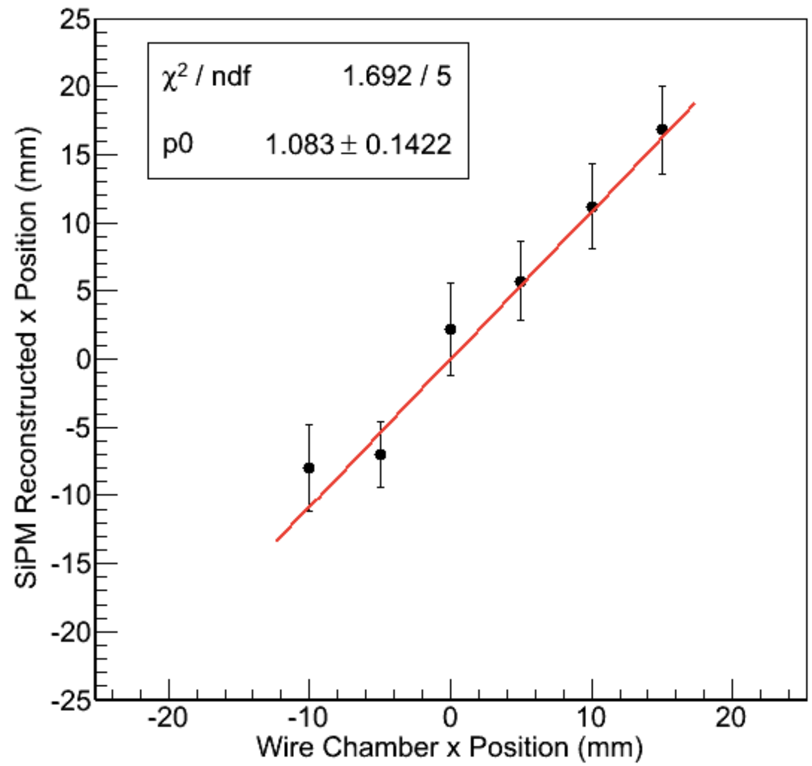
Integrate from 80 to 130 (many reflections)

SiPM 1: 200 avalanches
SiPM 2: 14 avalanches

Čerenkov light readout with SiPMs directly coupled to PbF_2



More data exists but not analyzed yet.



Summary

- We have existing calorimeters that have required properties.

- A novel Secondary Emission calorimeter would provide additional information (requires the proof of principle).

- The concept of Čerenkov light readout with SiPMs directly coupled to the crystals is validated. Ready for implementations.