Electromagnetic calorimeter for the SPD experiment.

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A prototype of Shashlyk-type electromagnetic calorimeter for reconstruction of photons and electrons in the SPD experiment was suggested. Energy and time resolution of the calorimeter, obtained from cosmic ray testing are presented. Long time LED and MIP signal amplitude stability was tested and don't exceeded 0.5% during one week.

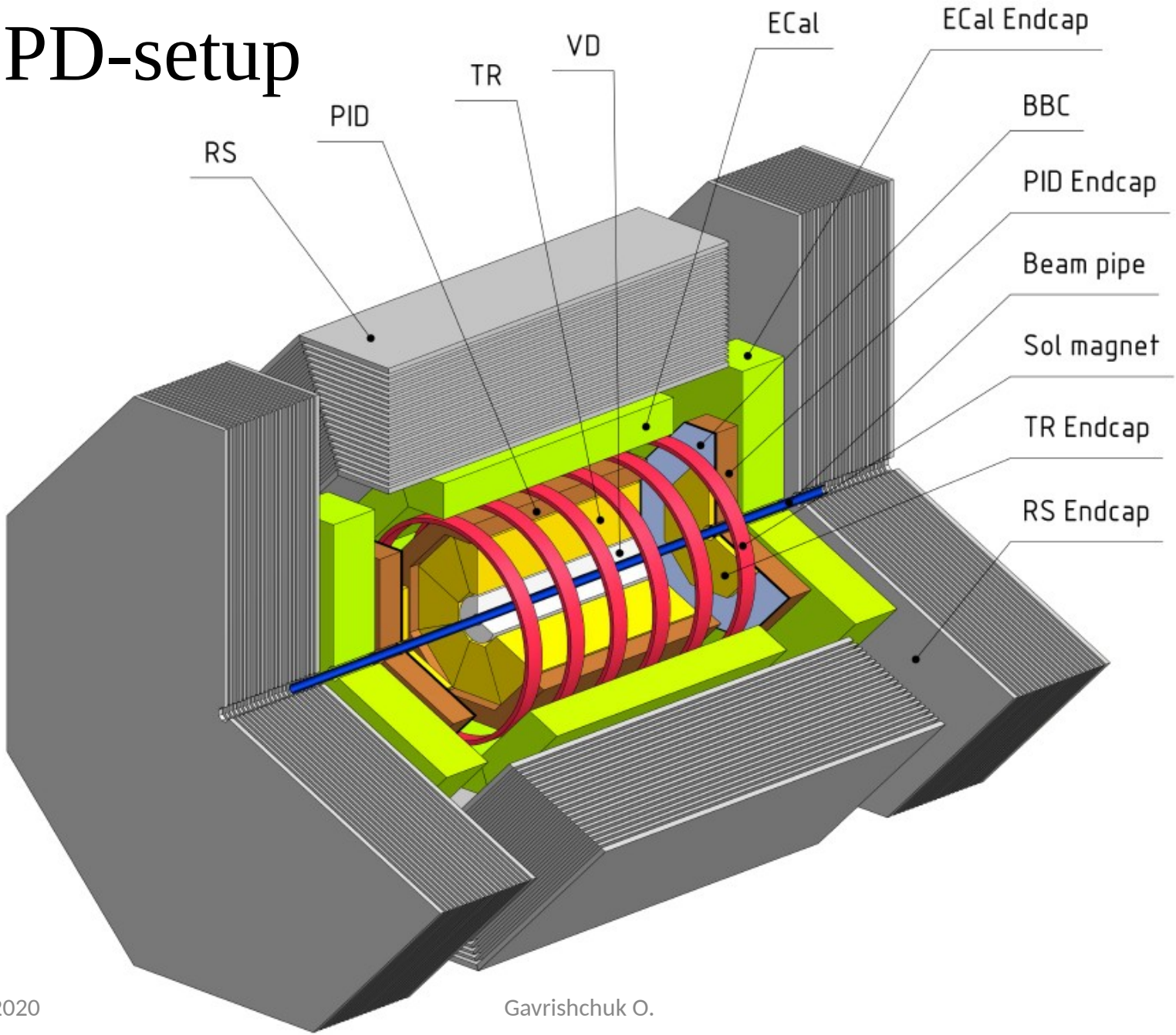
Electromagnetic calorimeter for the SPD experiment.

- The calorimeter design should meet the criteria imposed by the physics goals of the SPD experiment:
  1. Energy range of photons and electrons: 50 MeV - 10 GeV.
  2. Energy resolution for the above-mentioned particles: ~ 5% / √E [GeV]
  3. Spatial resolution that ensures separation of two-particle showers.
  4. Time resolution: ~ 500 ps.
  5. Long-term stability: 2-3% in a six month period.

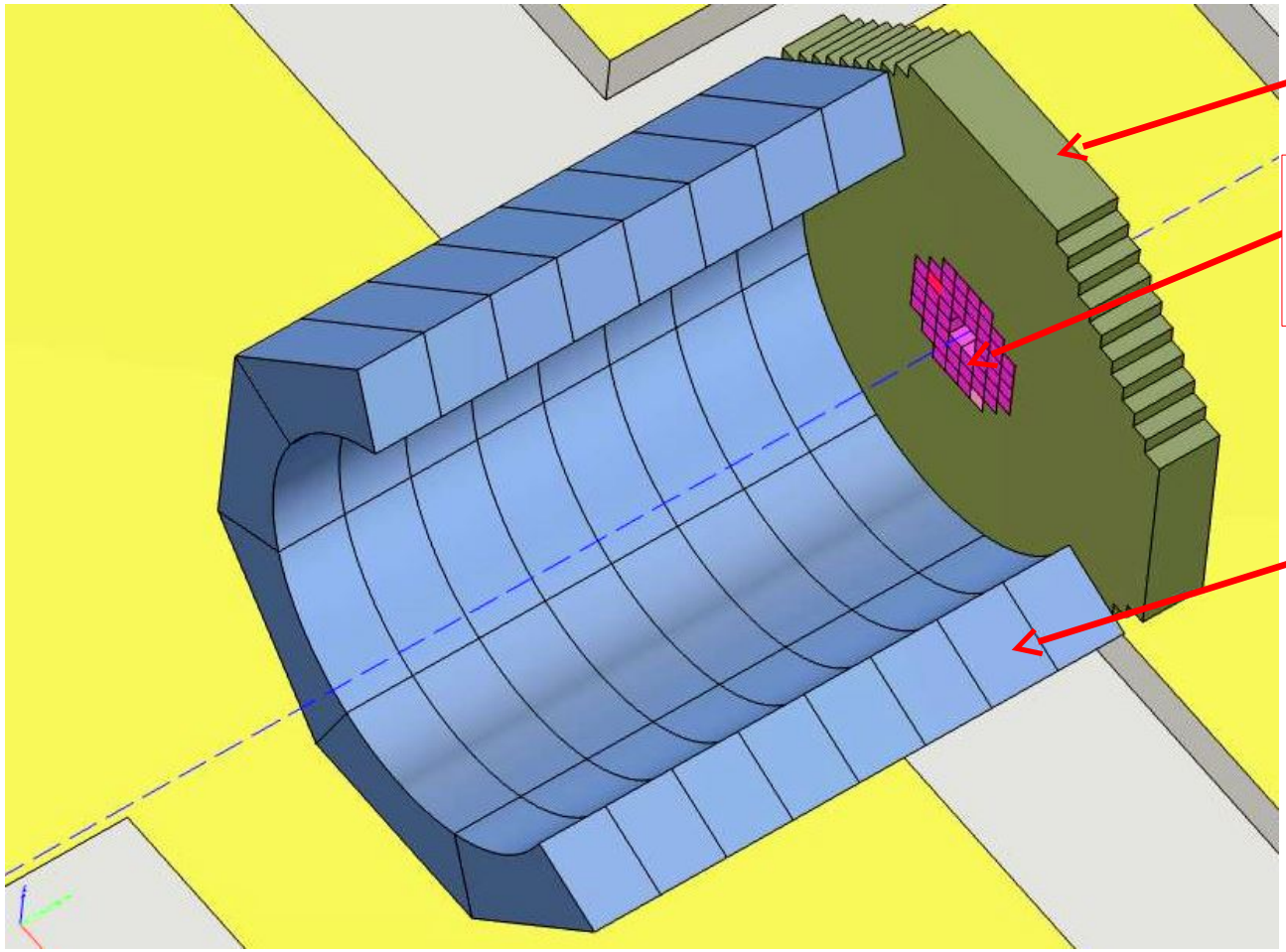
- The energy range requirement follows from the kinematic range of secondary particles, which are produced in the interaction of two colliding protons with energy of 10 GeV and emitted into 4π sr.
- Good energy resolution is required for identification and qualitative measurement of energies of neutral pions. Required ~ 5%/ √E [GeV].
- The spatial resolution is defined by the efficiency of separation of two photon showers from π^0 decay. It is needed to suppress background events in measurements with prompt photons.
- Time resolution is an auxiliary requirement that could allow to use information from calorimeter for fast trigger to improve pileup.
- Long-term stability is an important parameter that is necessary for polarization measurements featuring π^0 reconstruction in the calorimeter endcaps. Calorimeter instability may result in false asymmetry values.

SPD Hall in end of September 2020

SPD-setup


ECal
ECal Endcap
VD
TR
BBC
PID
RS
PID Endcap
Beam pipe
Sol magnet
TR Endcap
RS Endcap

Preliminary ECAL-3D

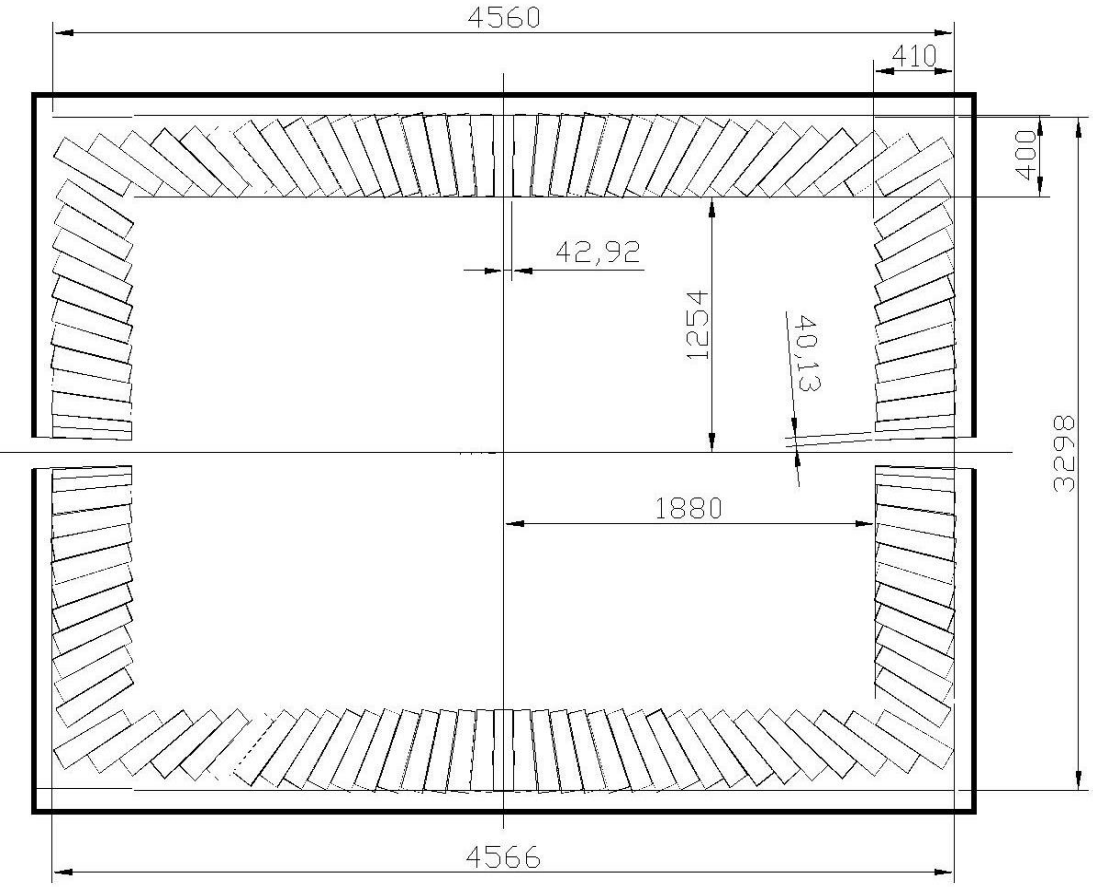


End Cap
peripheral part

End Cap Center (optionally)
with fine granularity
or Crystals type

Barel ECAL
8 sectors and
8 baskets each

Projective SPD Barrel & End Cap - preliminary design to estimate cell number and total weight.



ECAL consists of trapezoidal (~2^0) cells:
40x40 mm^2 – face, 52x52 mm^2 – back.

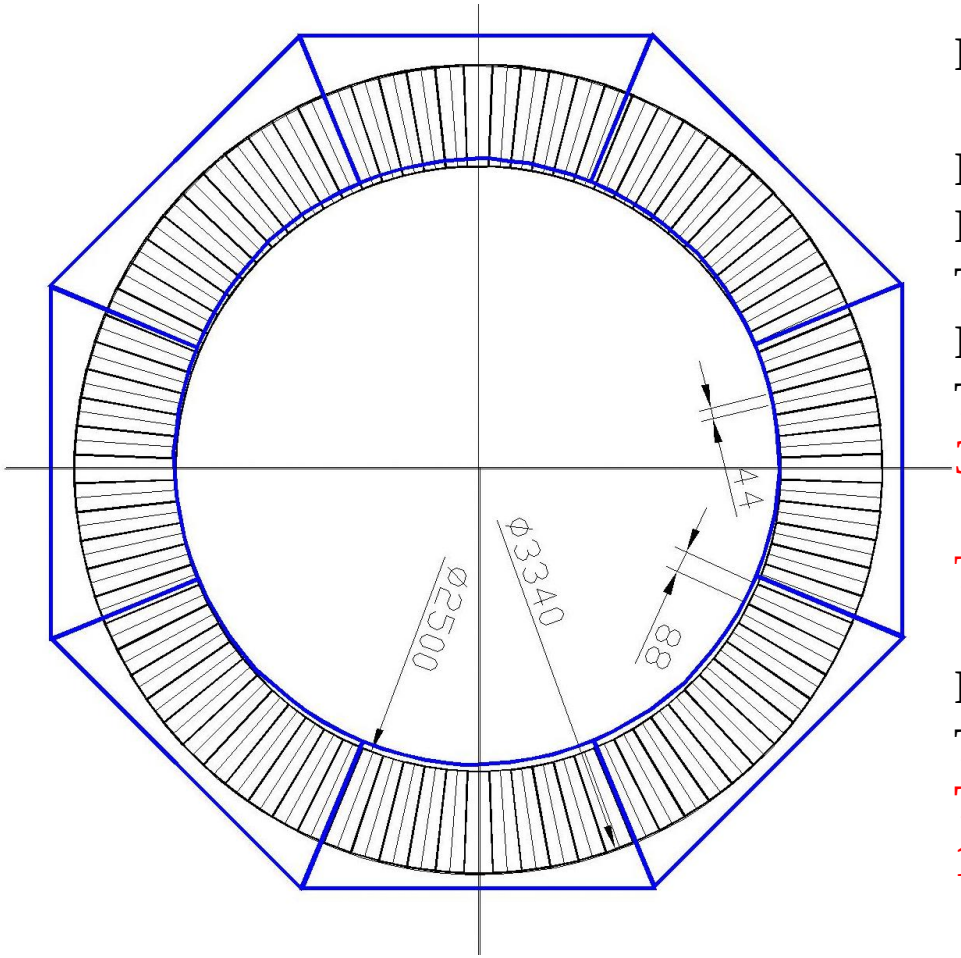
4 cells are combined into a module ~10x10 cm^2 using common Lead plate 10x10 cm^2

One End-Cap consists of:
720 - modules ~11x11 cm^2
1440 – modules for 2 End Cup's

Total weight = 8.5 tons – 1 end cup

Total weight of 2 end cups is 17 tons

ECAL Barrel layout - preliminary design to estimate cell number and total weight.



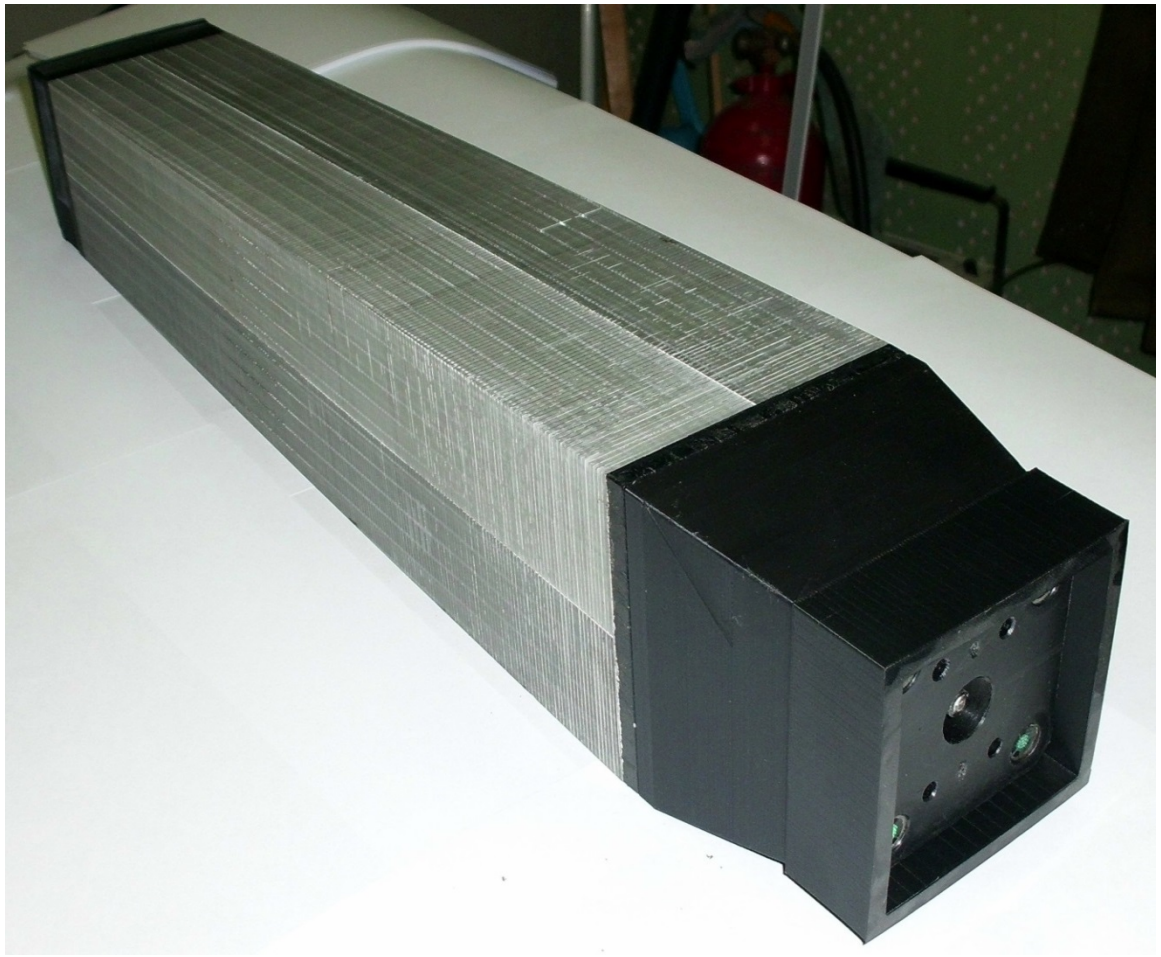
Barrel part is divided into 8 sectors of 45^0

Each sector consists of : 11 Modules 10x10 cm^2
Each sector consists of : 22 cells – 42x44 mm^2
Totally in ring – 88 modules (176 cells)
Module weight is 12 kg
Totally there are
3080 10x10 cm^2 barrel modules

Total barrel weight is 37 tons

ECAL weight = 37 + 17 = 54 tons
Total number of modules is 3080+1440=4520
Total number in Barrel and End Caps is 18080 cells

Possible option for ECAL module design

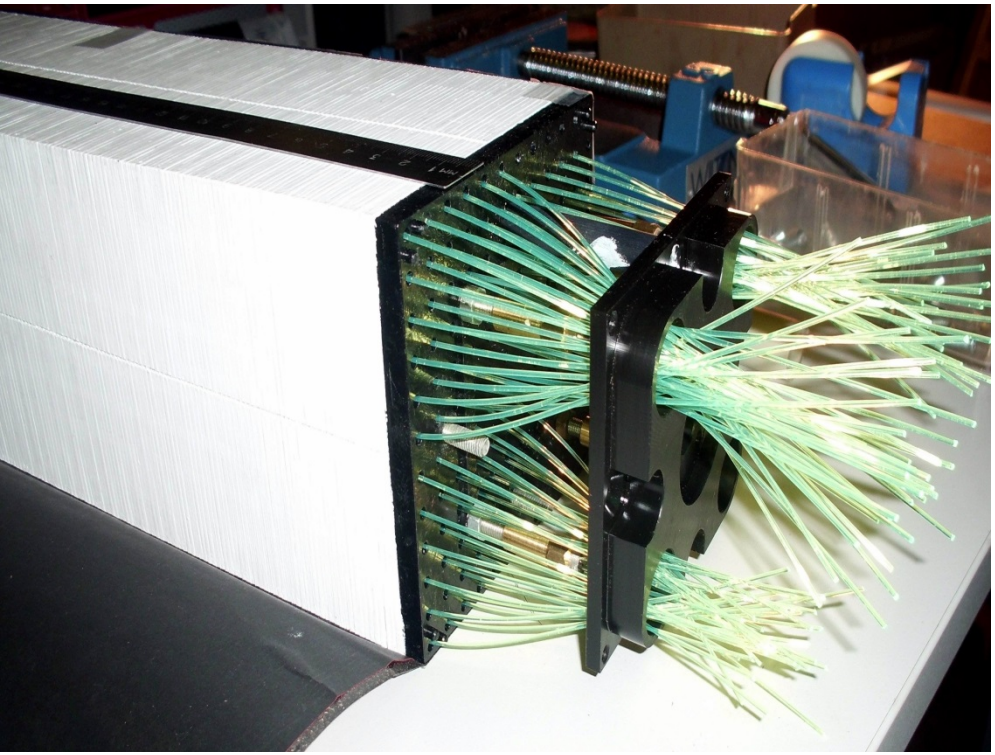


Module has trapezoidal shape with angles of about 2^0 and consists of 4 cells ~50x50mm^2.

Module length is equal to 440 mm – an active part consists of:
220 layers (lead and scintillator)
1.5 mm – scintillator ~42x42mm^2
0.3 mm - lead ~10x10 cm^2 plate

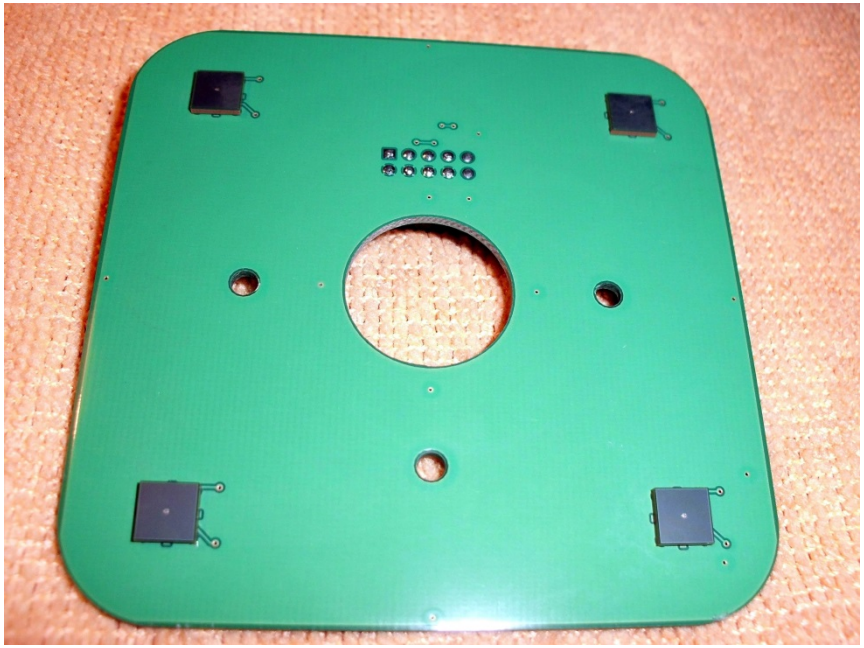
Total thickness is $12.6X_0$

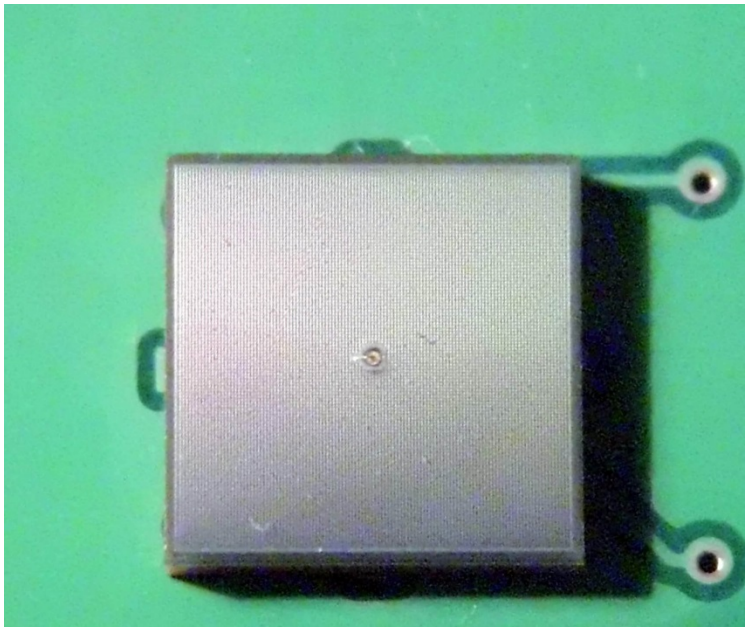
WLS pulled through module have an U-loop edge.
4 bundles of 36 fibers each are used for light collection to MPPC



We used Y11-200 WLS fibers with multi-cladding of 1 mm in diameter.
Totally about 80 meters of WLS fiber was used for assembling of one module (144 WLS fibers per module).

PCB board with 4 MPPC 6x6 mm2 (left) Single MPPS type S14160-6050



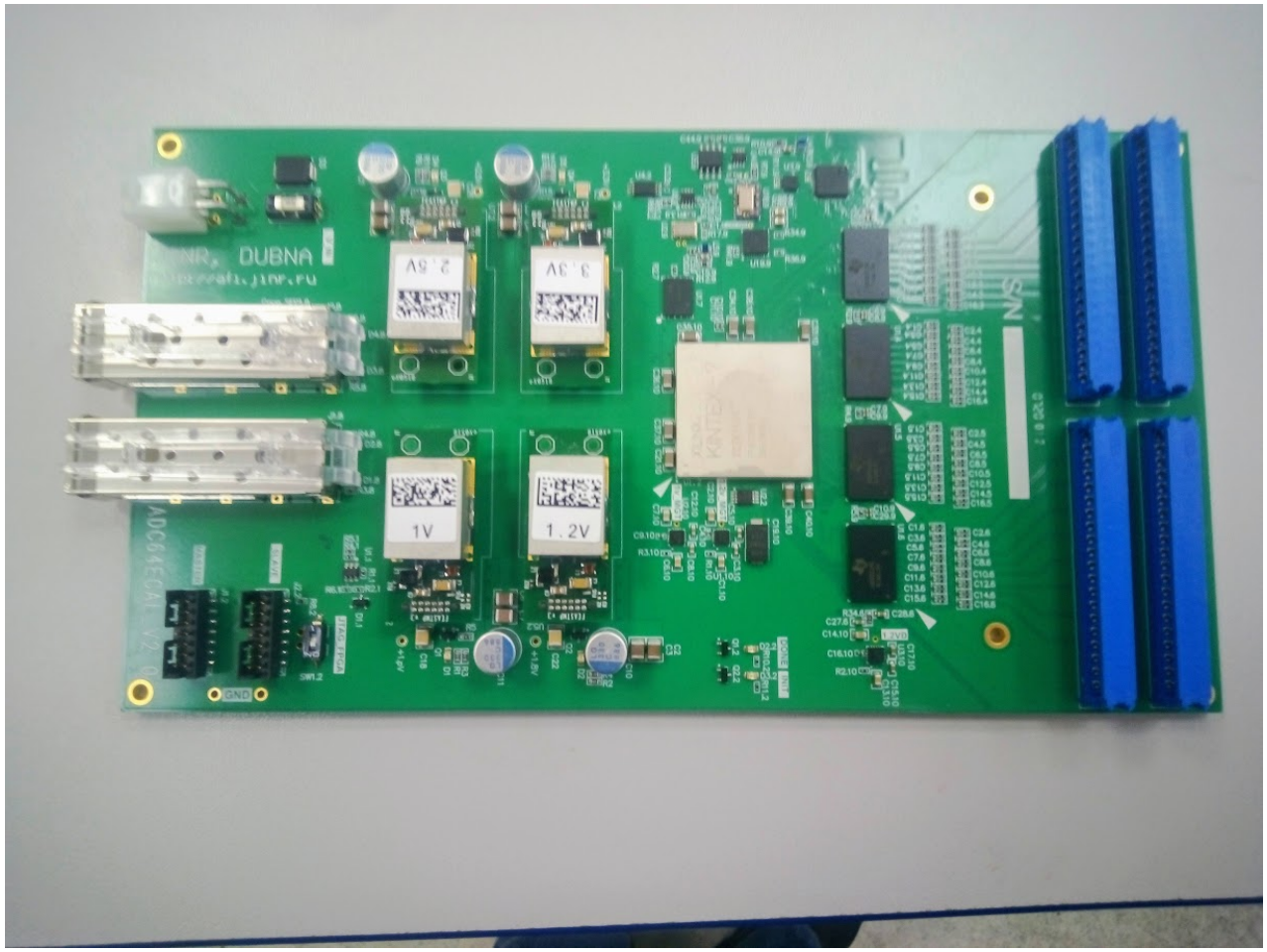


MPPC series of S14160-6050:

- Low operation power: ~40 V
- Low temperature dependencies : 0.034 V/^{0}C
- High PDE : 50% for 480 nm
- Pixel pitch = 50 mc
- Pixel Number =14400

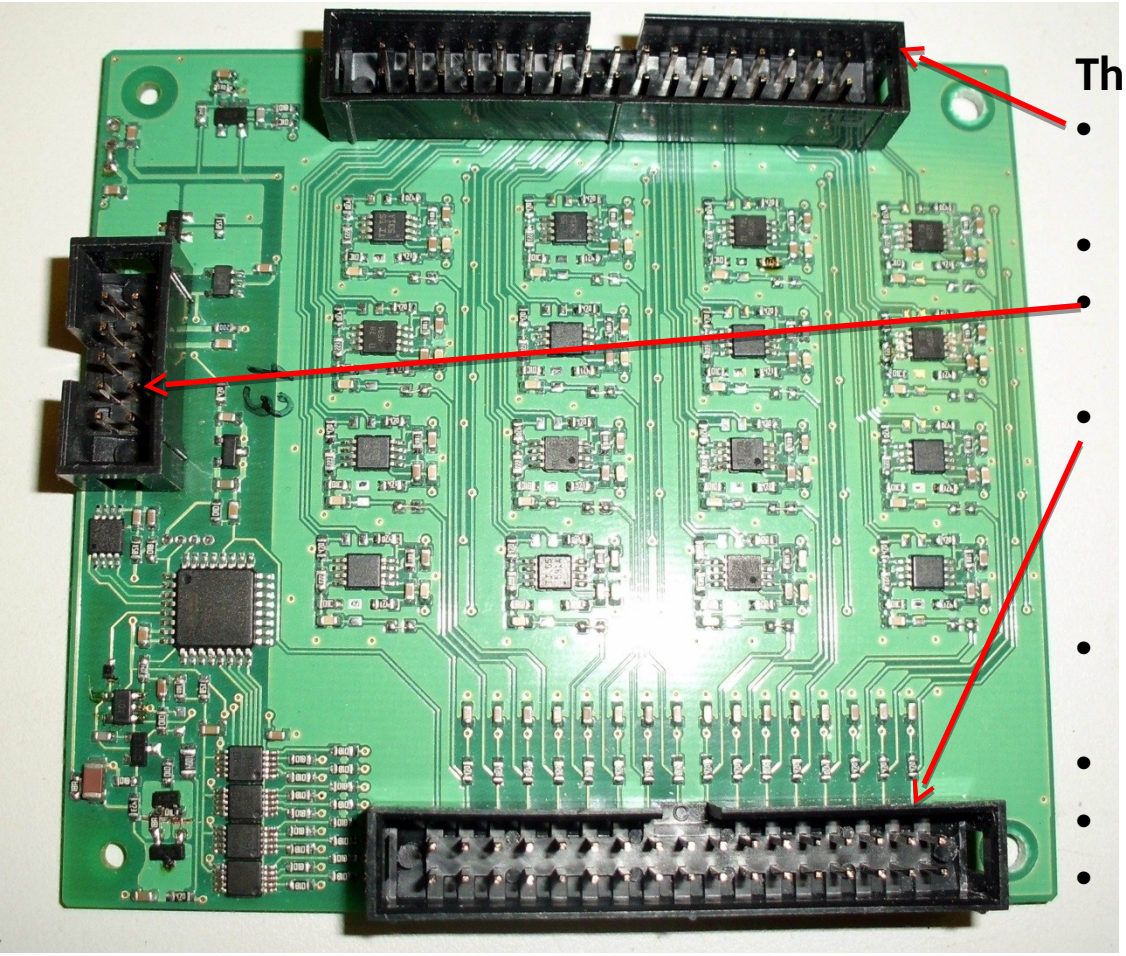
Hamamatsu promise produce **New** MPPC series of S14160
with 15 mc Pitch and
Pixel Number = 160000

64 channel waveform digitizer
ADC_64 Ecal – produced by AFI electronics (https://afi.jinr.ru)



1. 64 MHz – sampling frequency
2. 14 – bit per sample
3. White Rabbit provides sub-nanosecond synchronization accuracy.
4. Can operate in Streamer mode – Trigger less DAQ
5. Can operate in Magnet
6. Power concept:
   10 Watt/64 ch
7. Total Power: 2.8 kWt for ECAL SPD

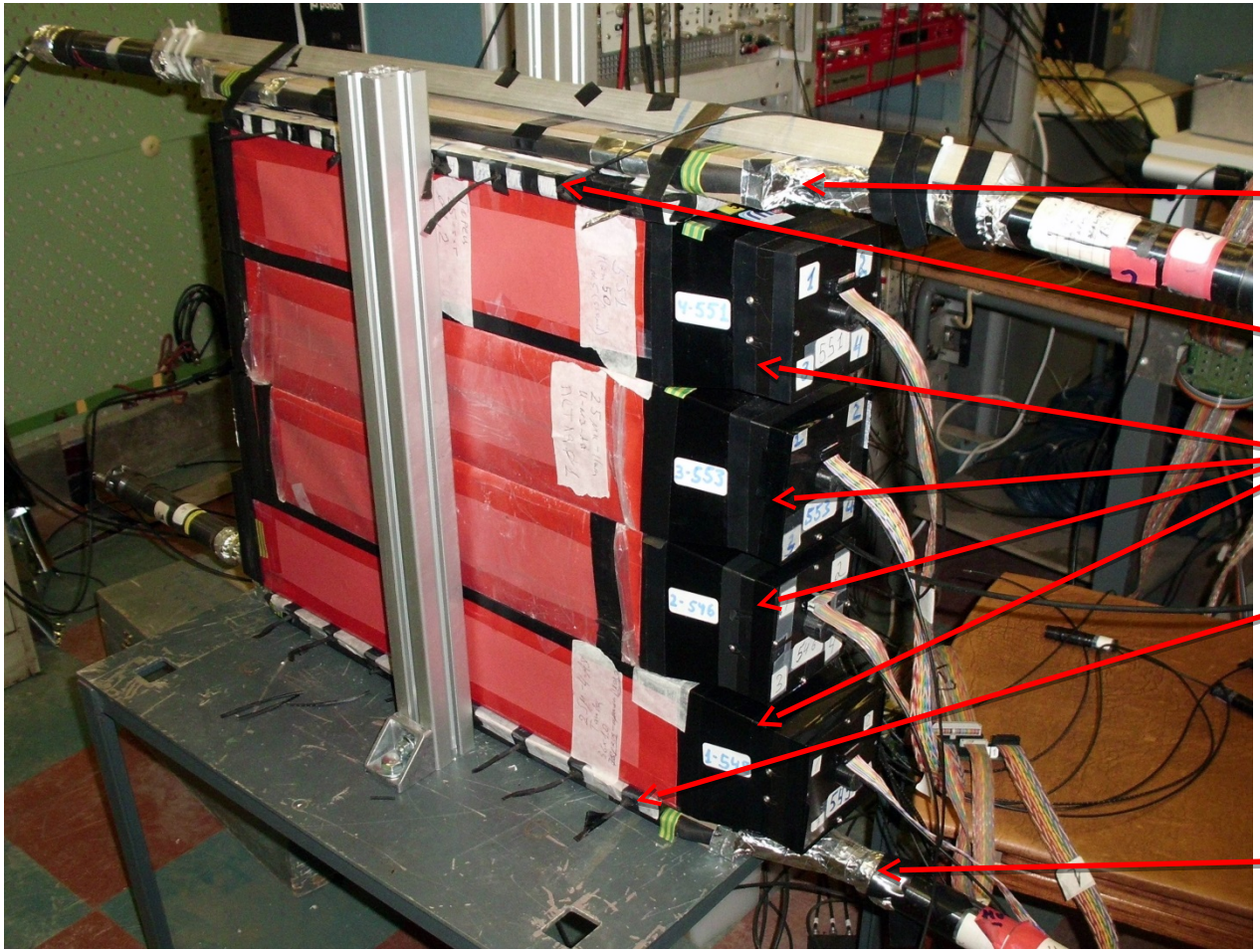
16 channels front-end – card
Produced by HVSys (http://hvsys.ru/en)



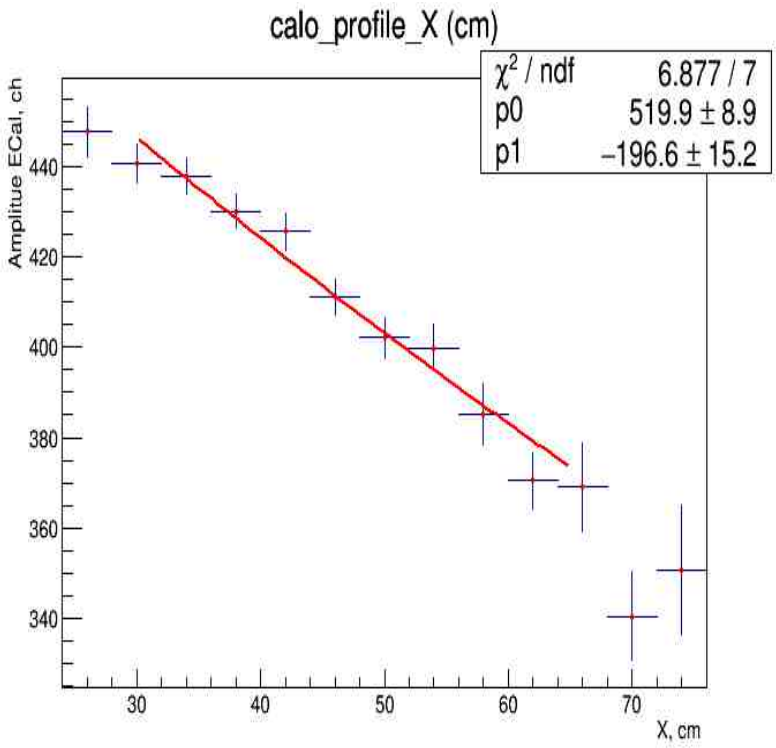
This board controlled of 16 MPPC H/V :

- **Output** connector of 34 pins to ADC – with differential input by flat cable
- Control: using RS485 protocol
- 10-pins connector with flat cables up to 100 m
- **Input** connector of 34 pins to MPPC with input by flat cable:
  - H/V distribute to 16 ch
  - Temperature measurement
- H/V temperature compensation done with software
- Voltage for diode supplies = 36 – 44 V
- Power concept - 100 mWt/16 ch
- Total Power – 2.0 kWt – for ECAL SPD

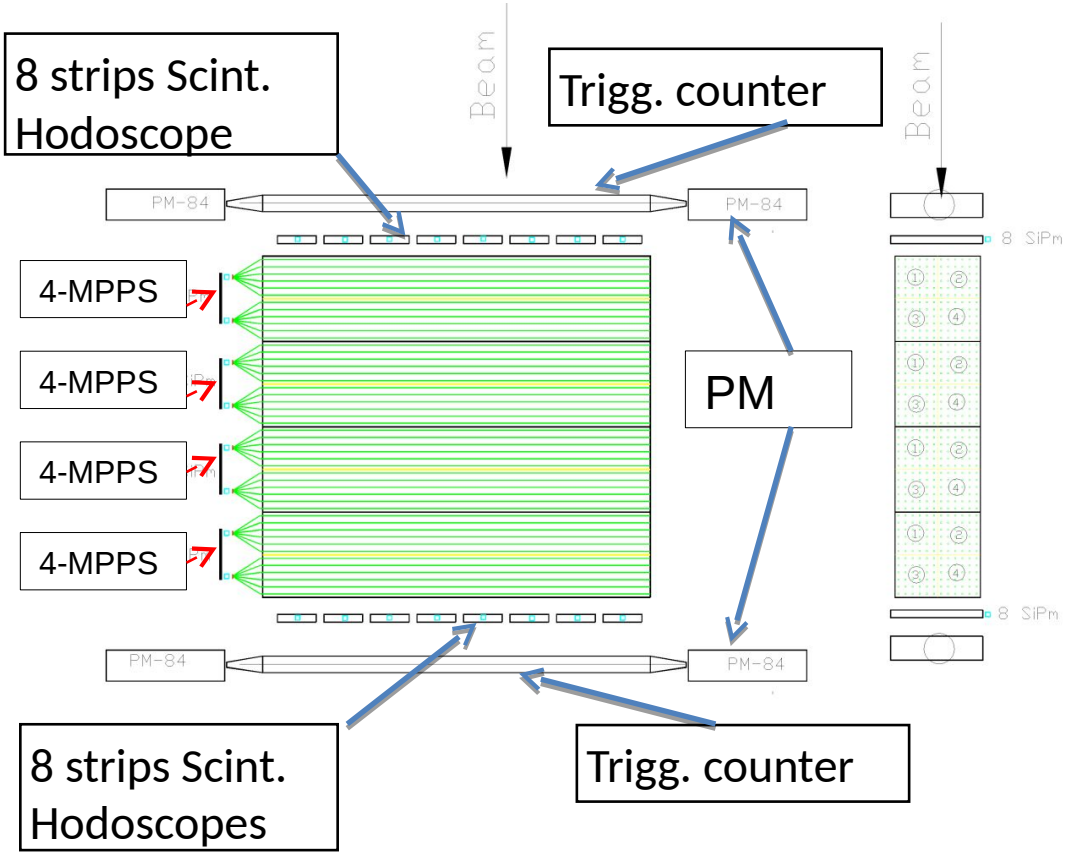
ECAL setup for horizontal cosmic test of 4 (16 cells)



Horizontal cosmic test for measurement the attenuation length

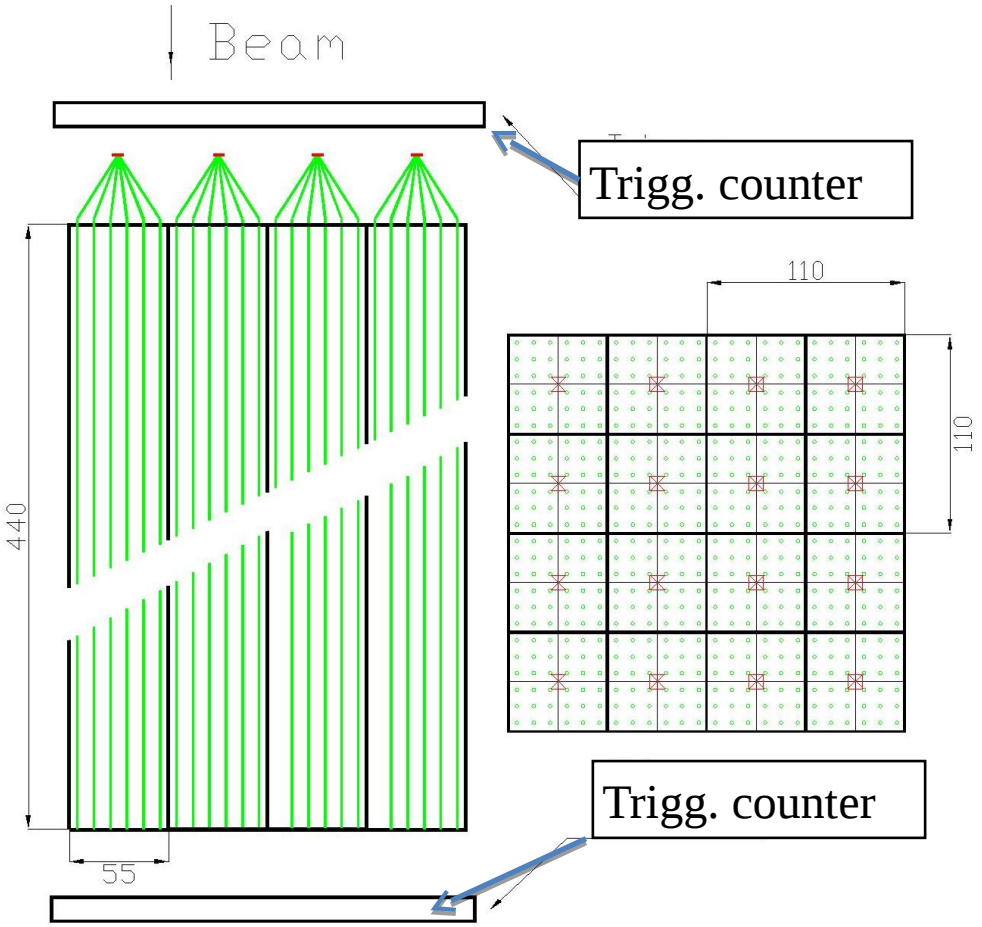


Attenuation Lengt = 198 cm

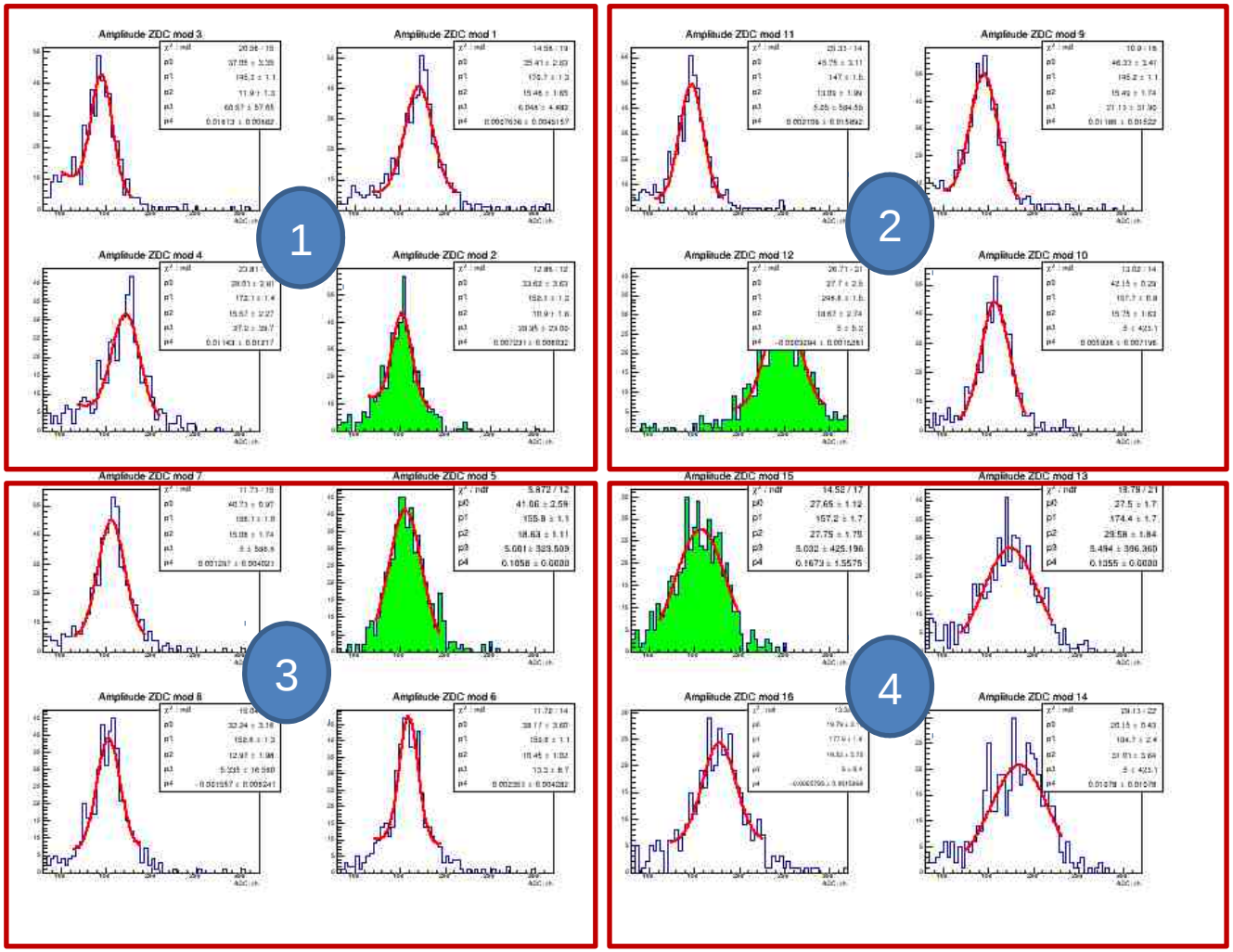


ECAL setup for vertical cosmic test of 4 Modules - Photo

ECAL setup for vertical cosmic test of 4 Modules (16 cells) Schematic Layout

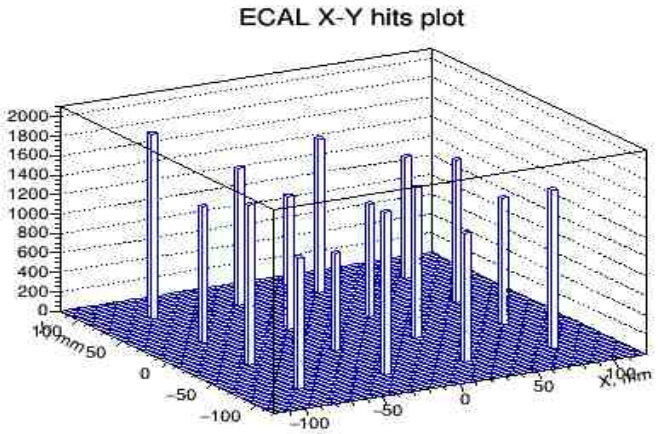


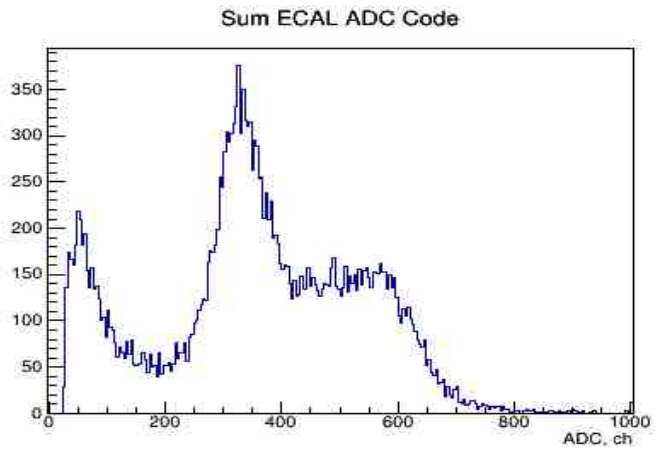
16 MIP ADC spectra with a requirement of one hit per track

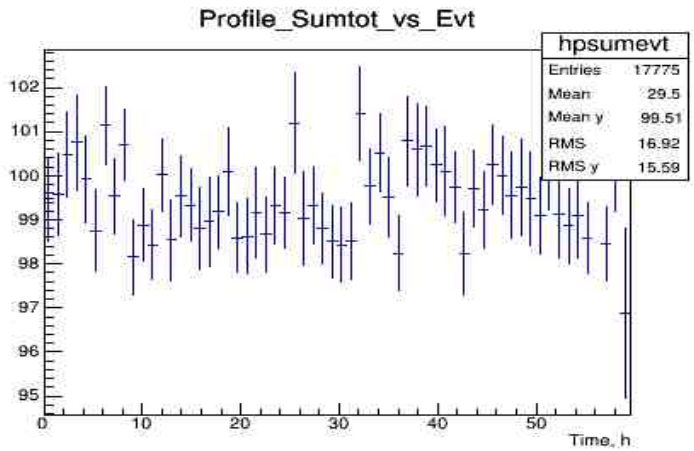


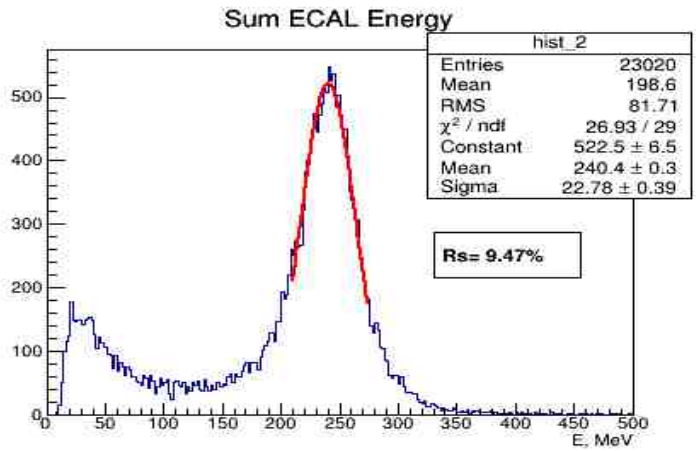
4 Modules top view

Applied selection: one hit per event
Calibration was done in cosmic muons.
Energy resolution is **9.4%** per MIP for 16 cells setup

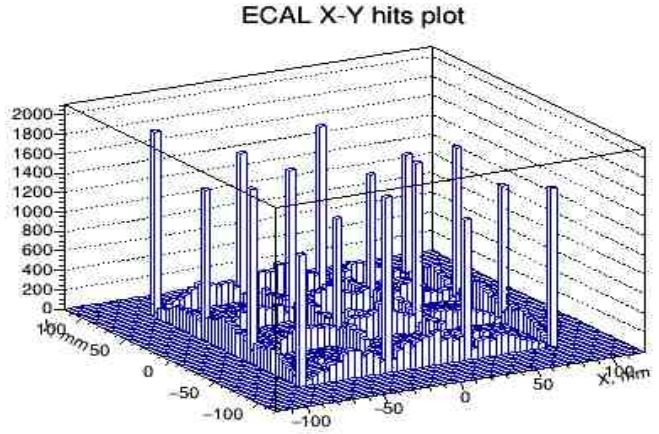


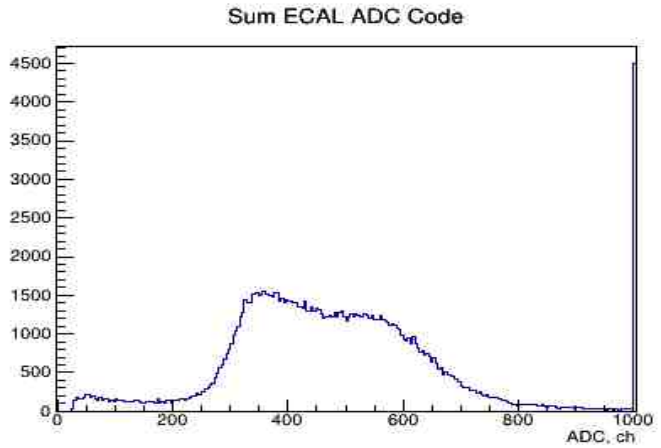


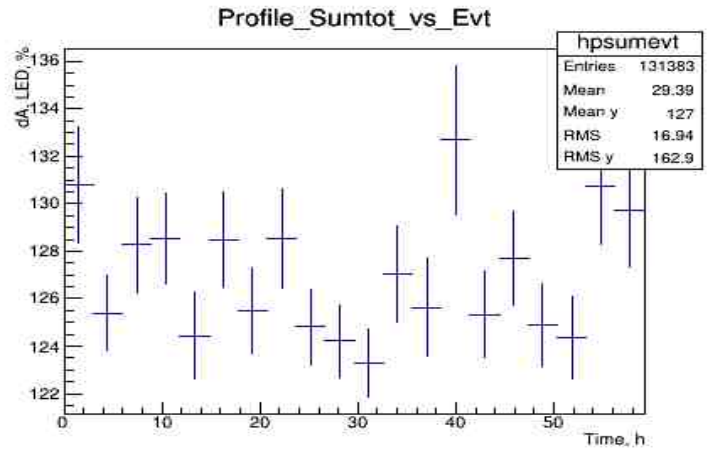


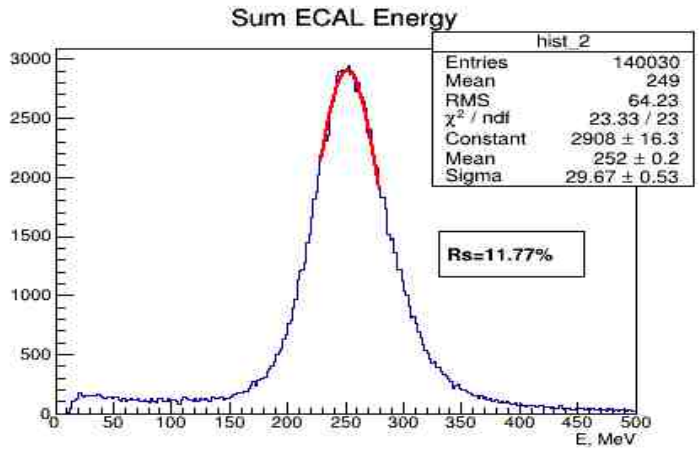


Applied selection: all hits are accepted
Calibration was done in cosmic muons.
Energy resolution is **11.7%** per MIP for 16 cells setup

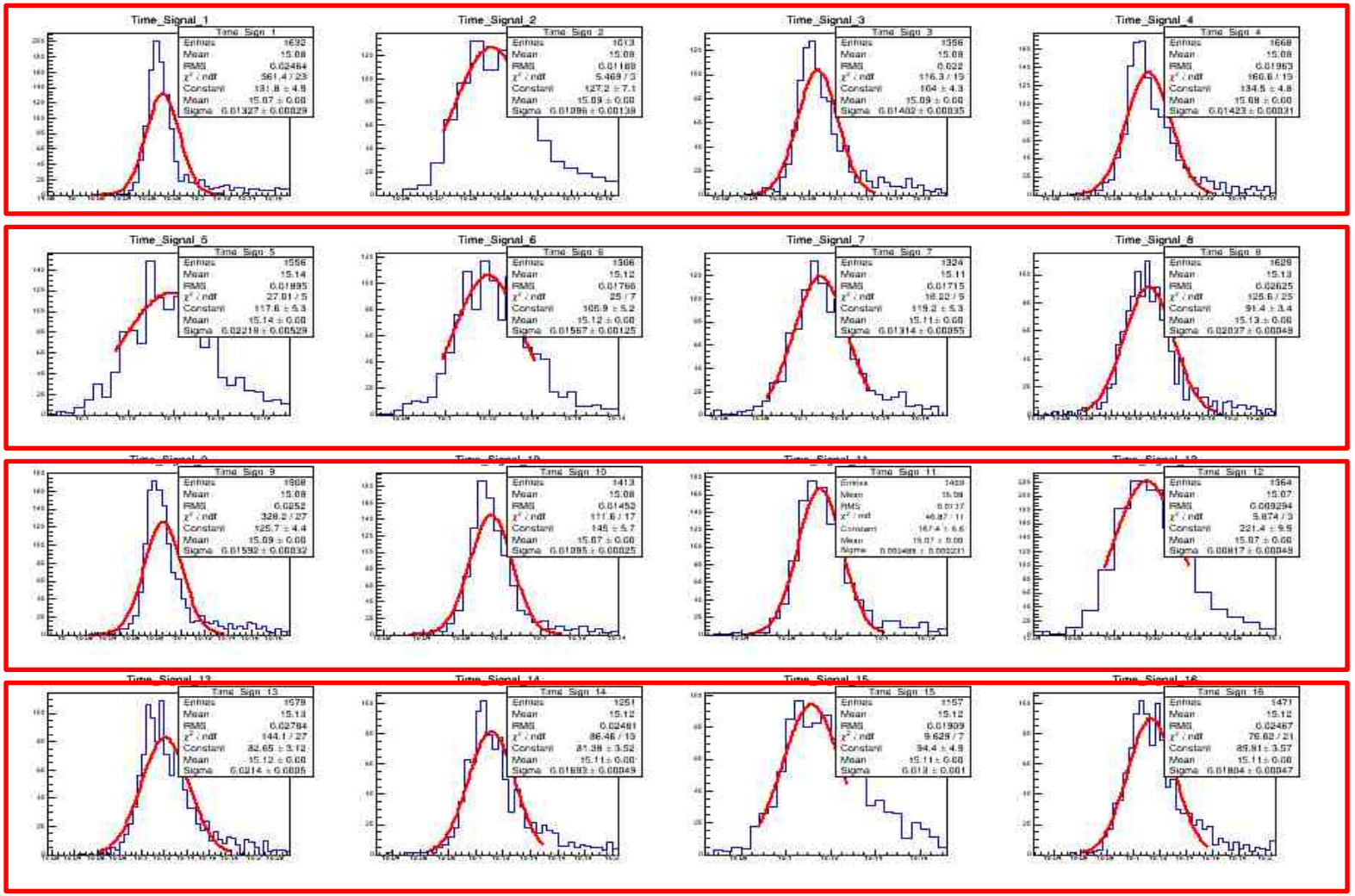








Time signal from 16 ECAL cells for MIP signals with 1 hit per event



4 Modules

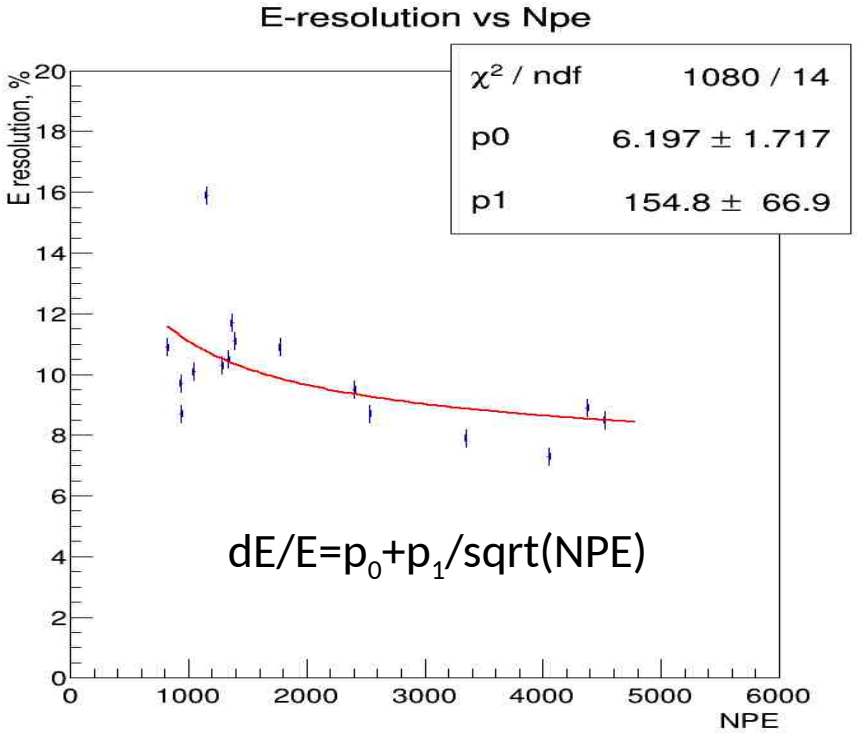
1

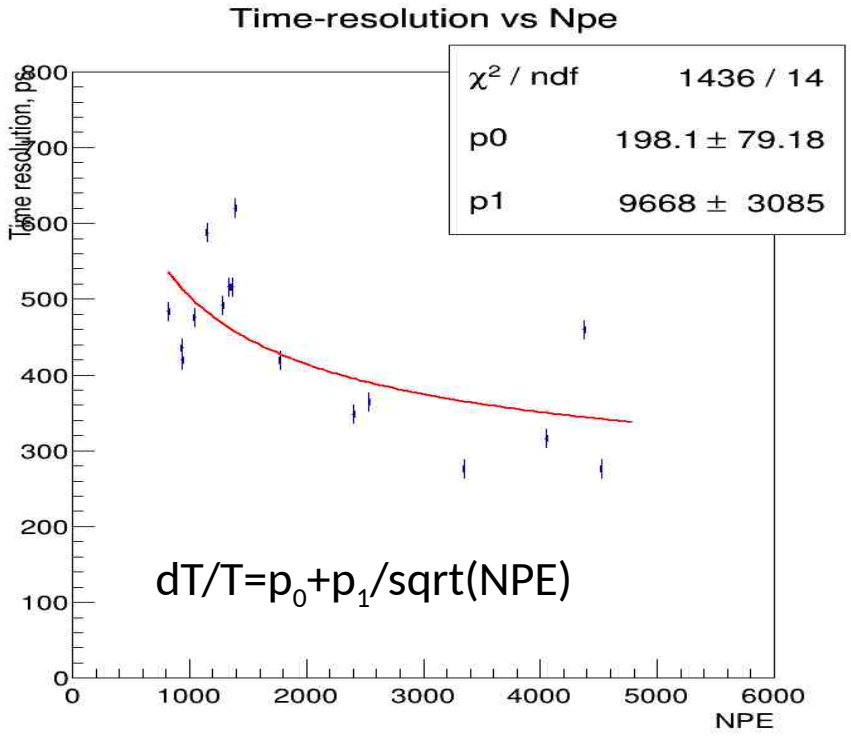
2

3

4

Energy & Time resolution as a function of NPE in cosmic tests

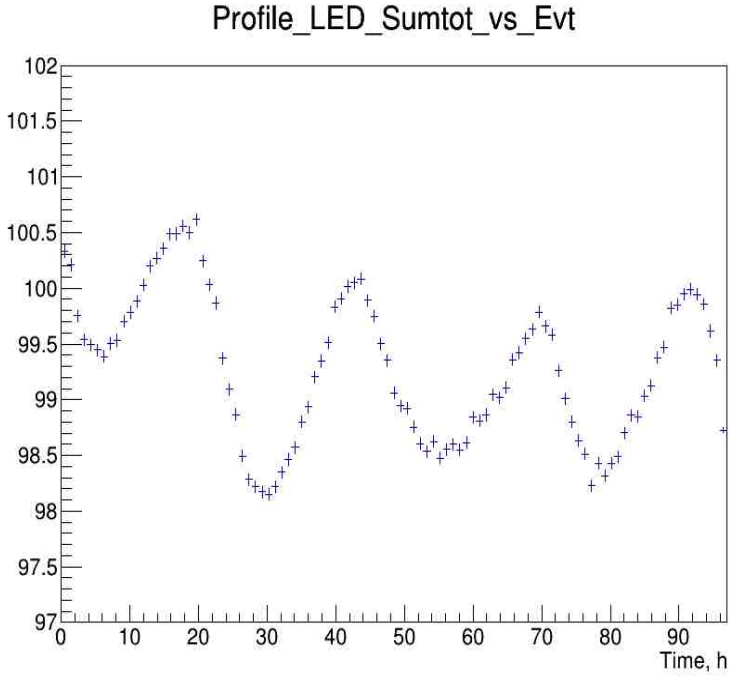


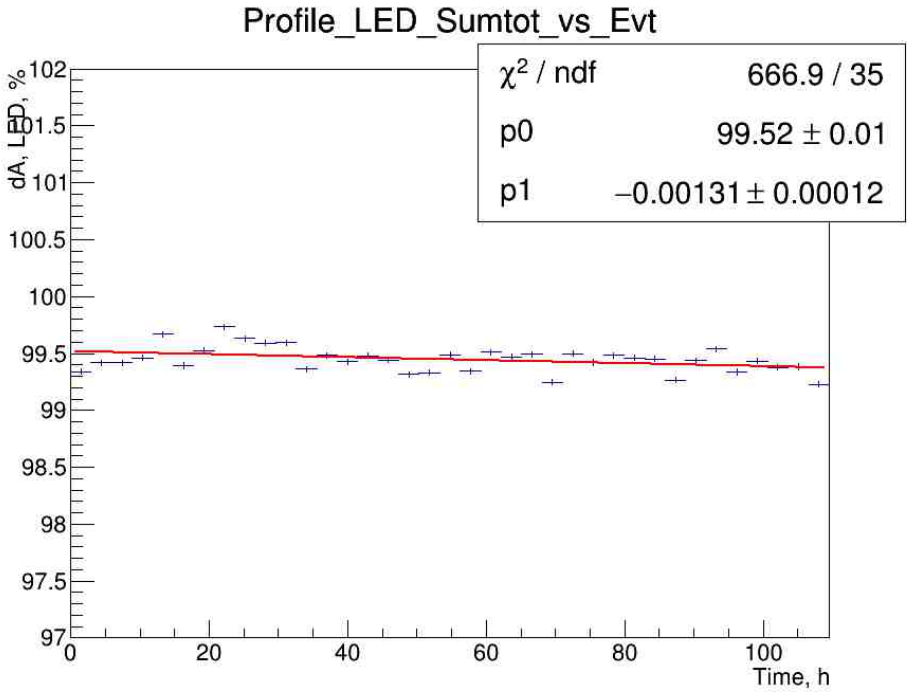


E – resolution: limit is equal to 6.2% for MIP as function of Light Yield

Time – resolution: limit is equal to 198 ps for MIP as function of Light Yield

LED amplitude stability in time (hours)





Without Voltage temperature compensation

With Voltage temperature compensation

Summary

- Preliminary geometry for SPD ECAL was developed.
- 9 prototype module were produced (with $12.6X_0$) and 16 are under production (with $17X_0$).
- Energy resolution of the calorimeter prototype was measured to be ~10% for MIP.
- Time resolution for a single cell to be 215 ps for MIP.
- Fluctuation of the signal amplitude are within 0.5%.
- The obtained results will be taken into account for the final choice of the calorimeter construction.
- ECAL was implemented to Mini SPD setup for testing the Straw, Silicon and RS detectors with cosmic muons.

End of Talk

Thanks All for your attention