# The tile type electromagnetic calorimeter for SPD setup

- The electromagnetic calorimeter has divided on 4 tiles along beam line. The idea is to improve particles identification take in account longitudinal shower profile for electrons, muons and hadrons.
- The prototype of such calorimeter was tested at IHEP U-70 and CERN PS in 2007. The experimental results presented to particles identification in 5 GeV beam with 80% pions, 15% positrons and 5% muons.
- The design and results of studies on a beam of particles with an energy of 5 GeV of electromagnetic sampling calorimeters are presented.
- New idea proposed to crate such calorimeter type based on ‘shashlik’ option with longitudinal segmentation.

Principal calorimeter design. The sampling structure of the calorimeter consists of 20 alternating layers of a 5mm thick scintillator and 5mm thickness of lead. A scintillator was produced by injection molding method from PSM-115 polystyrene with dopants : 1.5% PTP and 0.05% POPOR . BCF-92 (4 optic fiber) 1mm in diameter and 80 cm in length, transmits light from 5 scintillator plates to the silicone 1mm diode of 30 µm pitch (AMPD of 900 pixels).

The fiber pools in scintillation plate along the groove of 3 mm in depth and 67 mm in diameter.

4 WLS fibers used for light collection on 4 AMPD

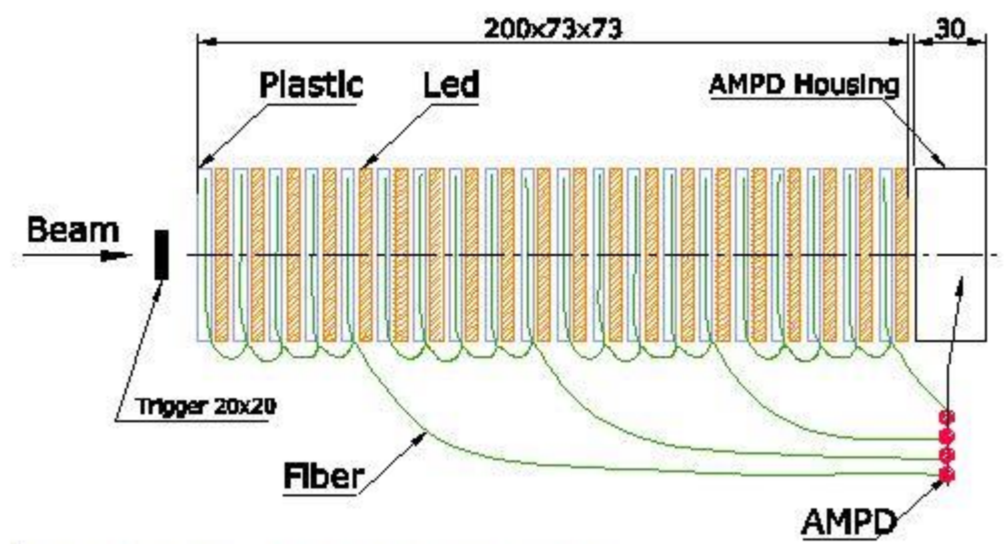



Fig.2. The scheme of the calorimeter module.

One fiber passes in a spiral through 5 layers of the scintillator, thus combining them into one group. In each of the 5 scintillators there are several turns of wolf. The number of turns is increasing in proportion to the removal of the scintillator from the photodetector. For example, in the first scintillator - 3 turns. In the second -2 turns, in 3,4,5 - on one turn. The center of the circumference of the groove is shifted to the corner of the square by 3 mm in order to ensure the exit of the fiber through the side face of the scintillator. When creating such a spiral, each scintillator plate is rotated by $90^0$ to avoid an overlapping of all turns along the particle beam.

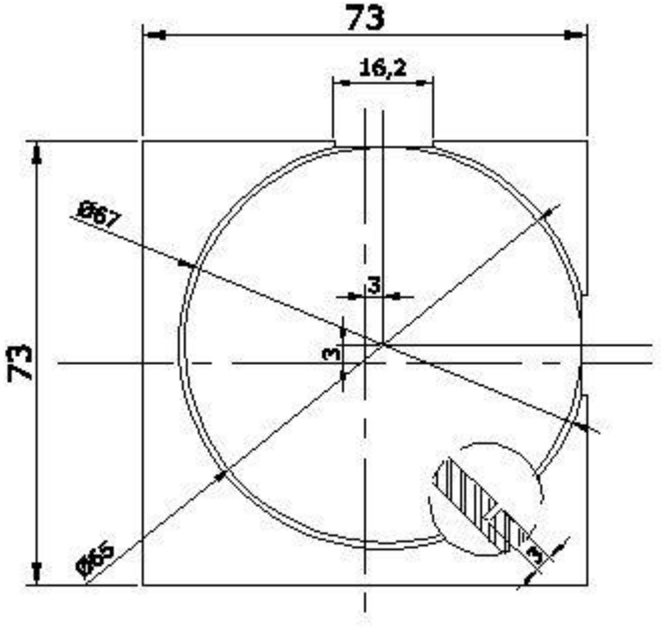
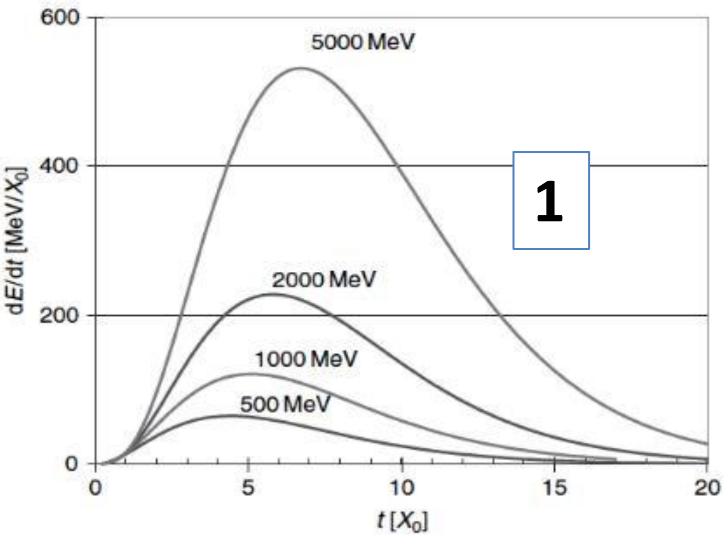
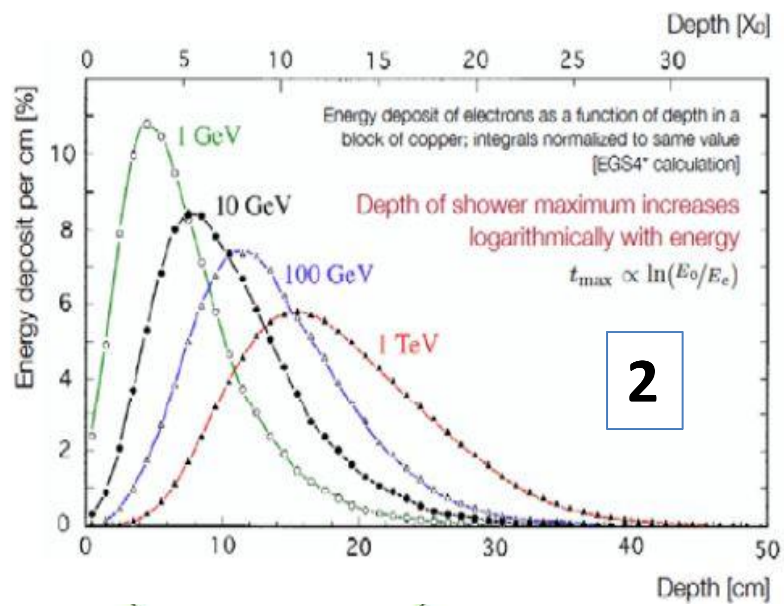
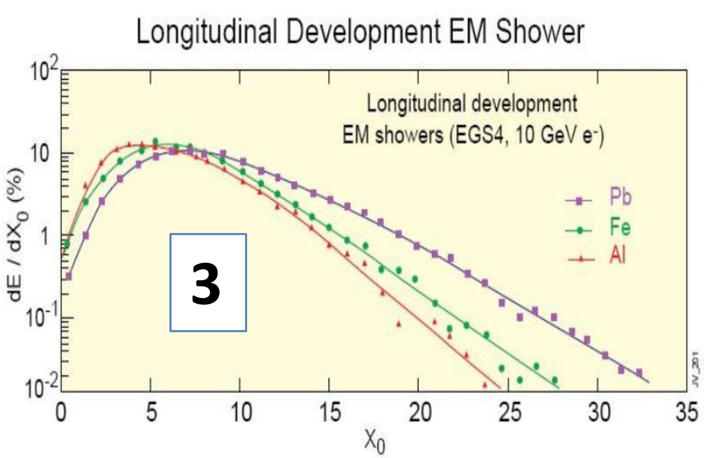


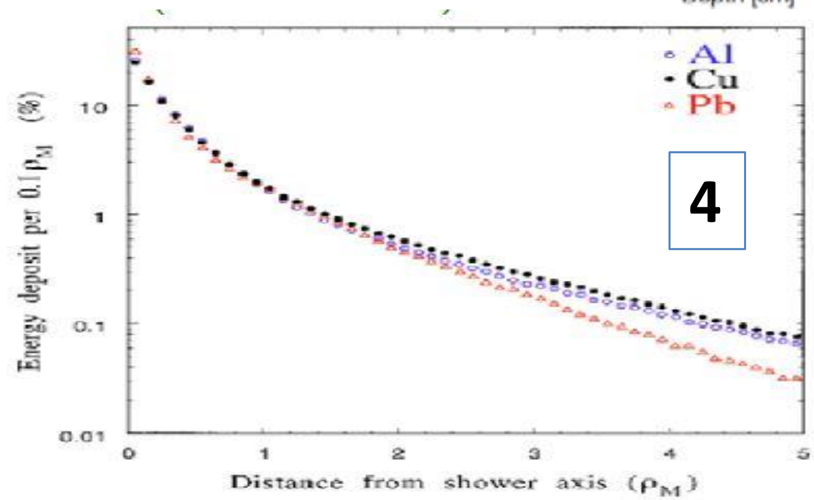

Fig.1. Scintillation plate 5mm thick with a groove for fiber.

1,2 -Theoretical longitudinal Shower shape for electrons with different energies
2 - The longitudinal Shower shape in dependences from material density
4 – Lateral Shower shape in dependences from material density



Measurement of the present electromagnetic calorimeter was fulfilled in positive beam of charged particles with an energy of 5.0 ± 0.2GeV. The beam size was set by a scintillation counter 4x4 cm2, installed in front of the calorimeter. The energy spectra in individual groups are shown in Fig. left. The equalization of signals was done take in account signals from **μ.**

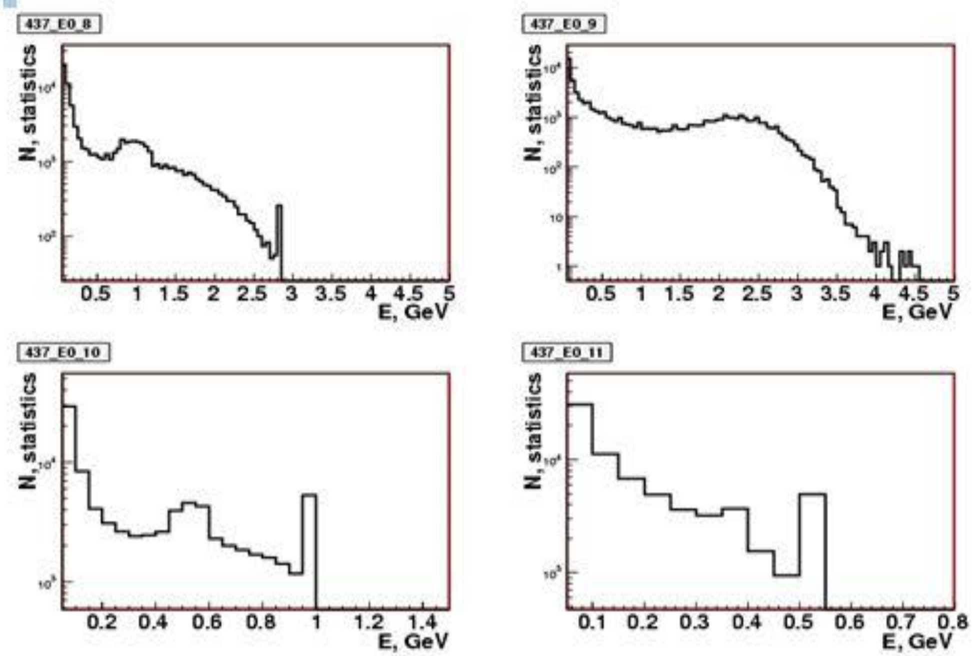
Beam composition:

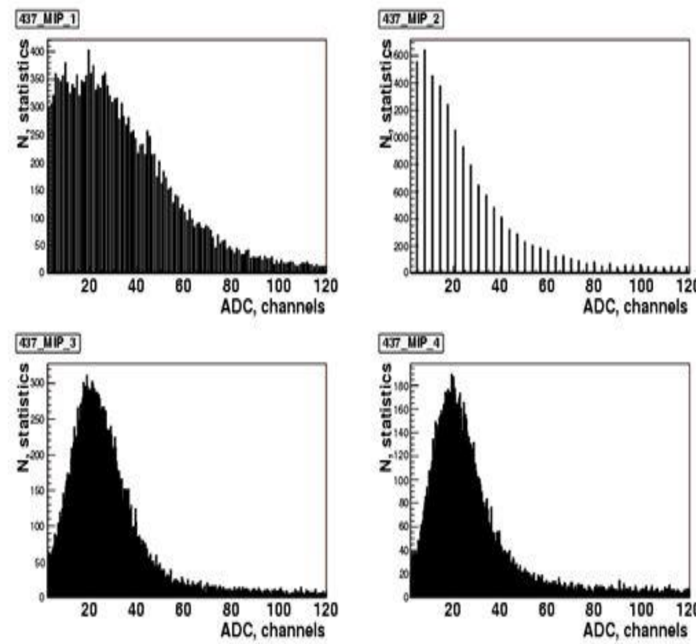
hadron (pi+) - 80%,

positrons (e +) - 15-17%,

**μ** -mesons (**μ**) - 3-5%.

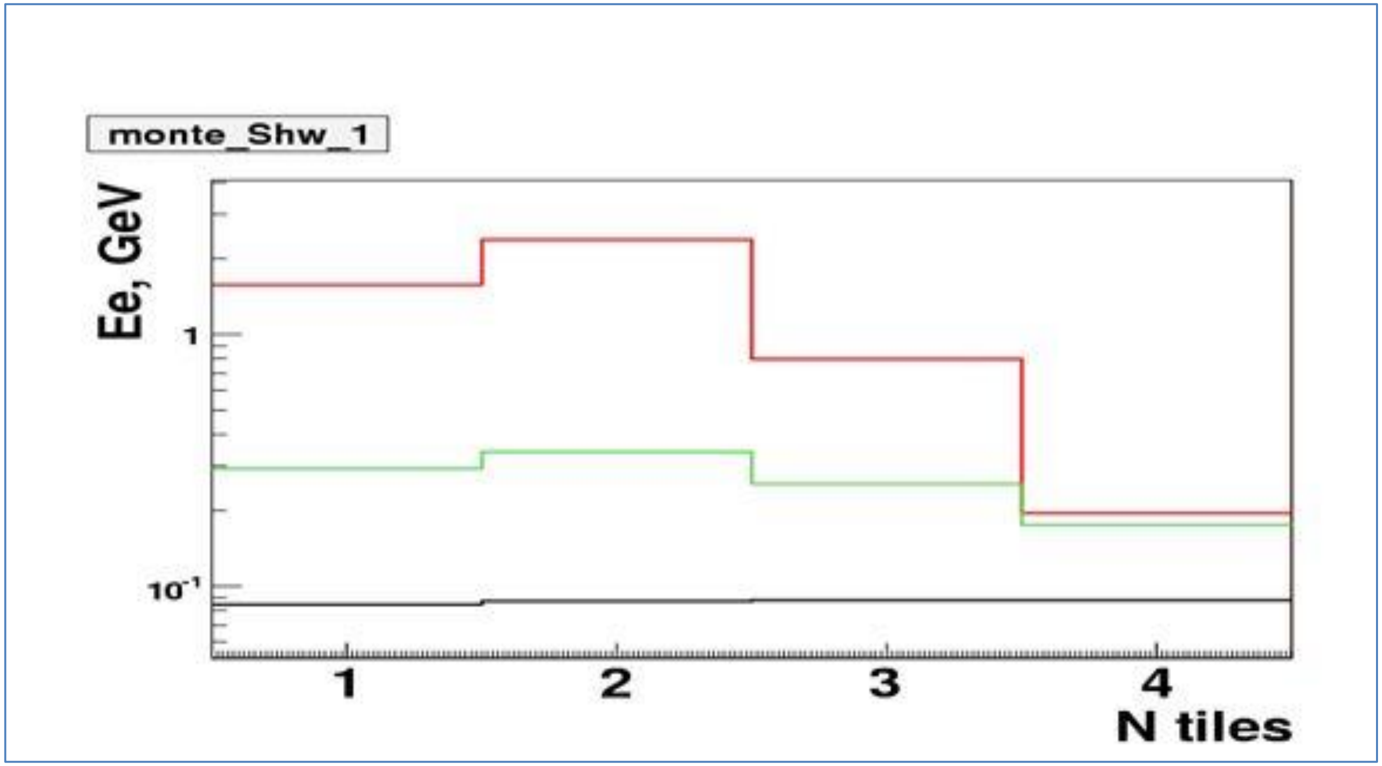
Particles with minimal ionization **μ**) , non-interacting hadrons - were used to equalize the signals um of individual groups of the calorimeter (right).



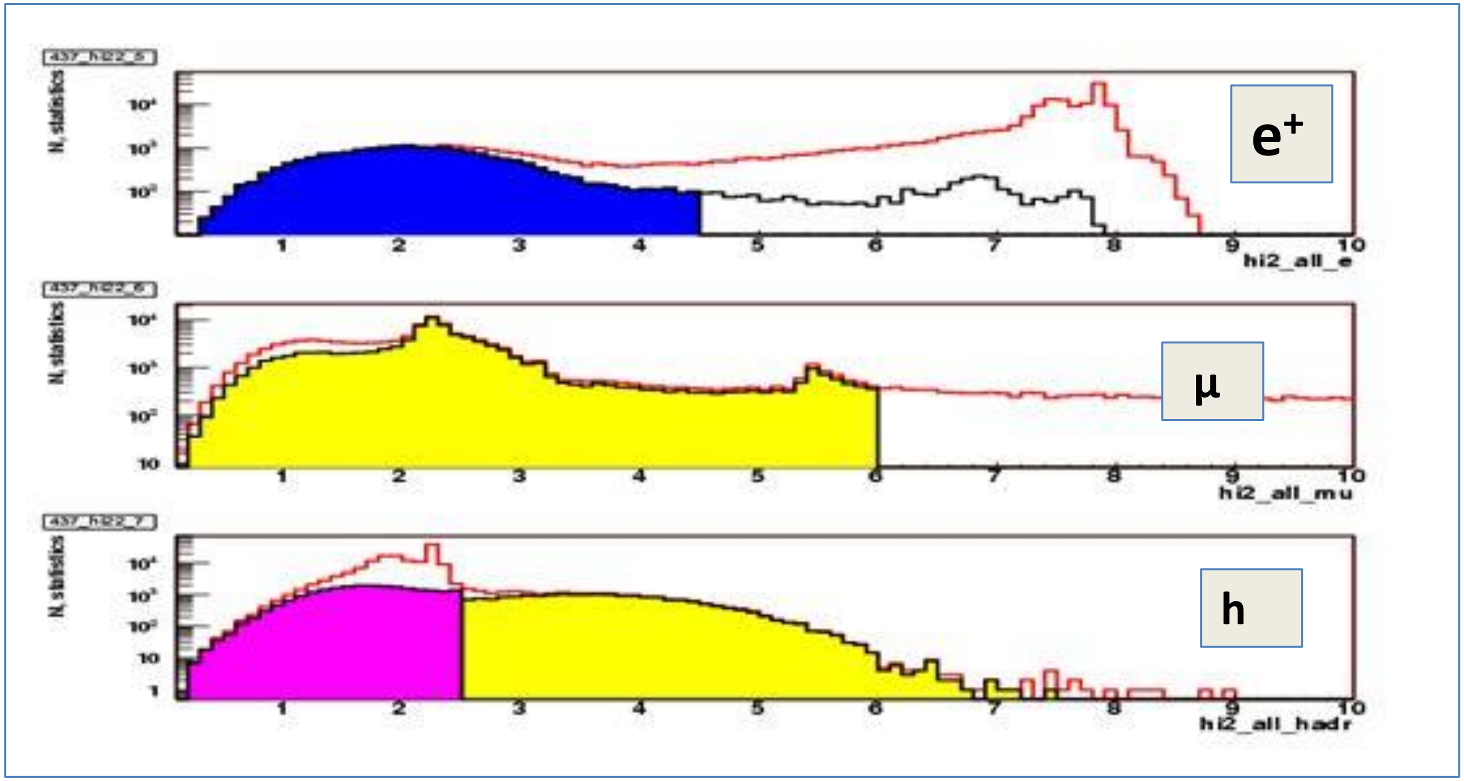
The estimated by MC energy distribution in tiles for hadrons (black), muons (green) , $e^+$ - positrons (red).

A significant difference in the average energy distribution over tiles is for different particle type.

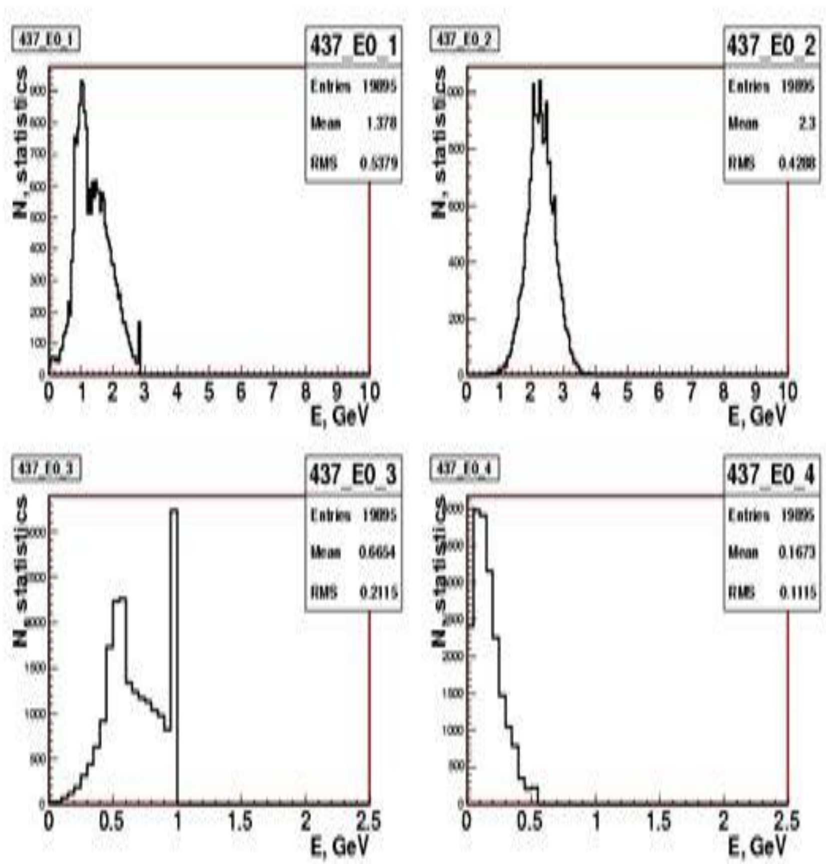


We can define the $\chi^2$ distributions as the square deviation of the Monte Carlo values and experimental results normalized to the corresponding RMS - red lines.

The $\chi^2$ cuts corresponded to $\chi^2 < 6$ (for muon - yellow), $\chi^2 < 2.5$ (for hadron - magenta) and $\chi^2 < 4.5$ (for $e^+$ - blue) are shown in shaded zones.



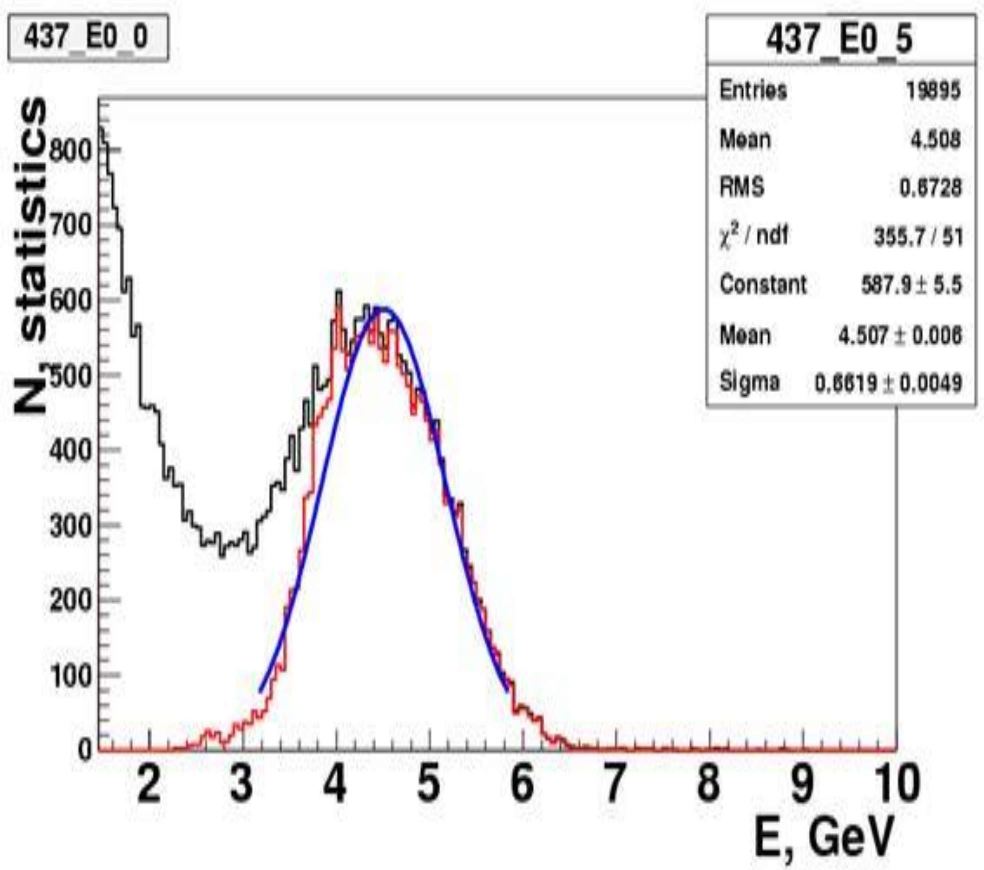
The energy spectra of 5 GeV positions separated from combined beam (~85% hadrons, ~5% muons and ~10% positrons)




The $e^+$ energy spectra in 4 calorimeters tiles are shown after $\chi^2$ rejection.

The background from scattered positrons on the beam pipe is particularly visible on the spectra in individual groups.

# The energy spectra of 5 GeV positions separated from combined beam (~85% hadrons, ~5% muons and ~10% positrons)




The total energy in calorimeter.

Black and red histograms - the spectra before and after the $\chi^2$ rejection. The blue line – the Gaussian fit for $e^+$.

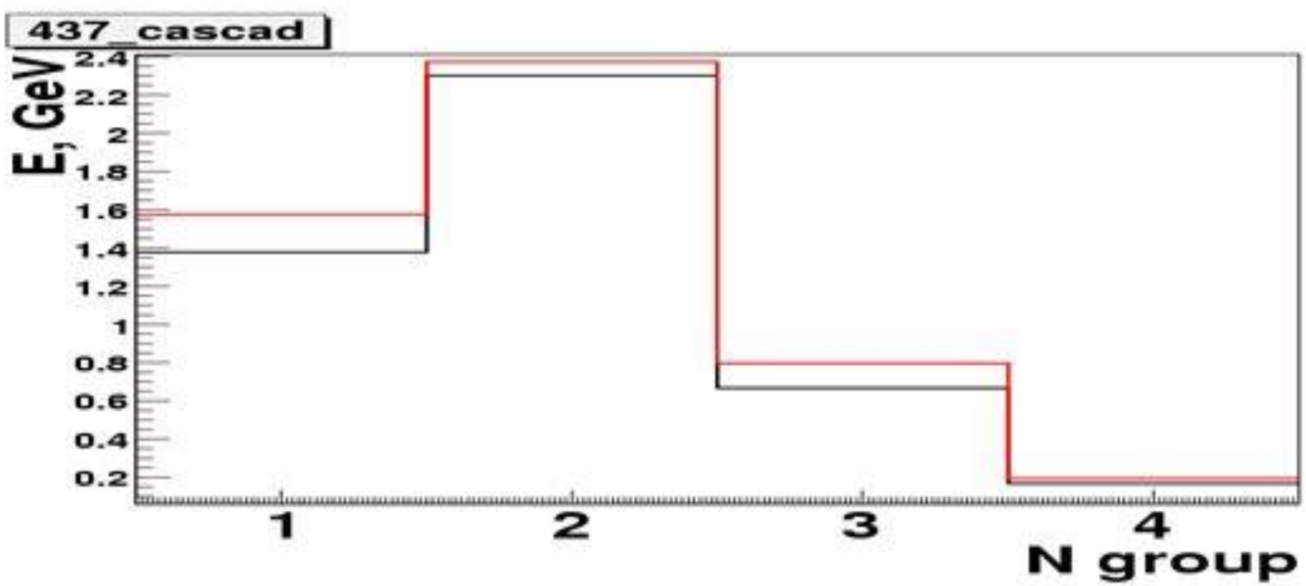
Background signal is integrated and slightly visible as a small burst at 4 GeV.

The average energy response in calorimeters tiles corresponded to cascade curve – Shower shape.

Red line - Monte Carlo calculation for $e^+$ of 5 GeV.

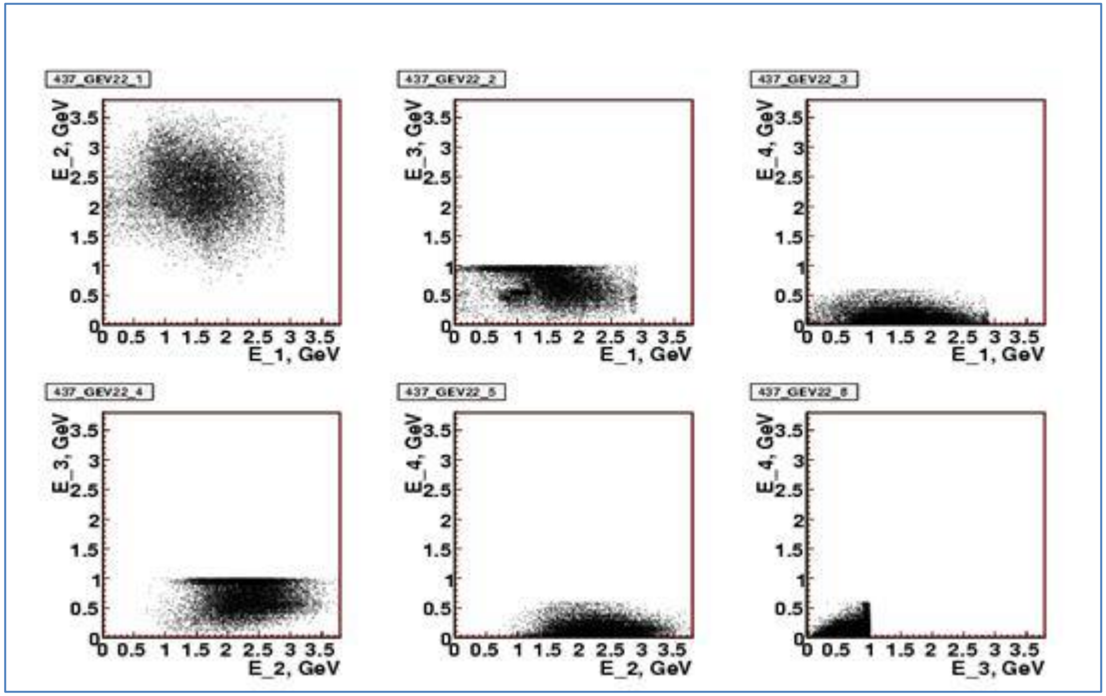
Black line - e+ energy take in account $\chi^2$ cut.

It is good agreement for experimental and MC results.



# Correlation of 5 GeV positron energy in 4 calorimeters groups.

# Correlation matrix for positrons



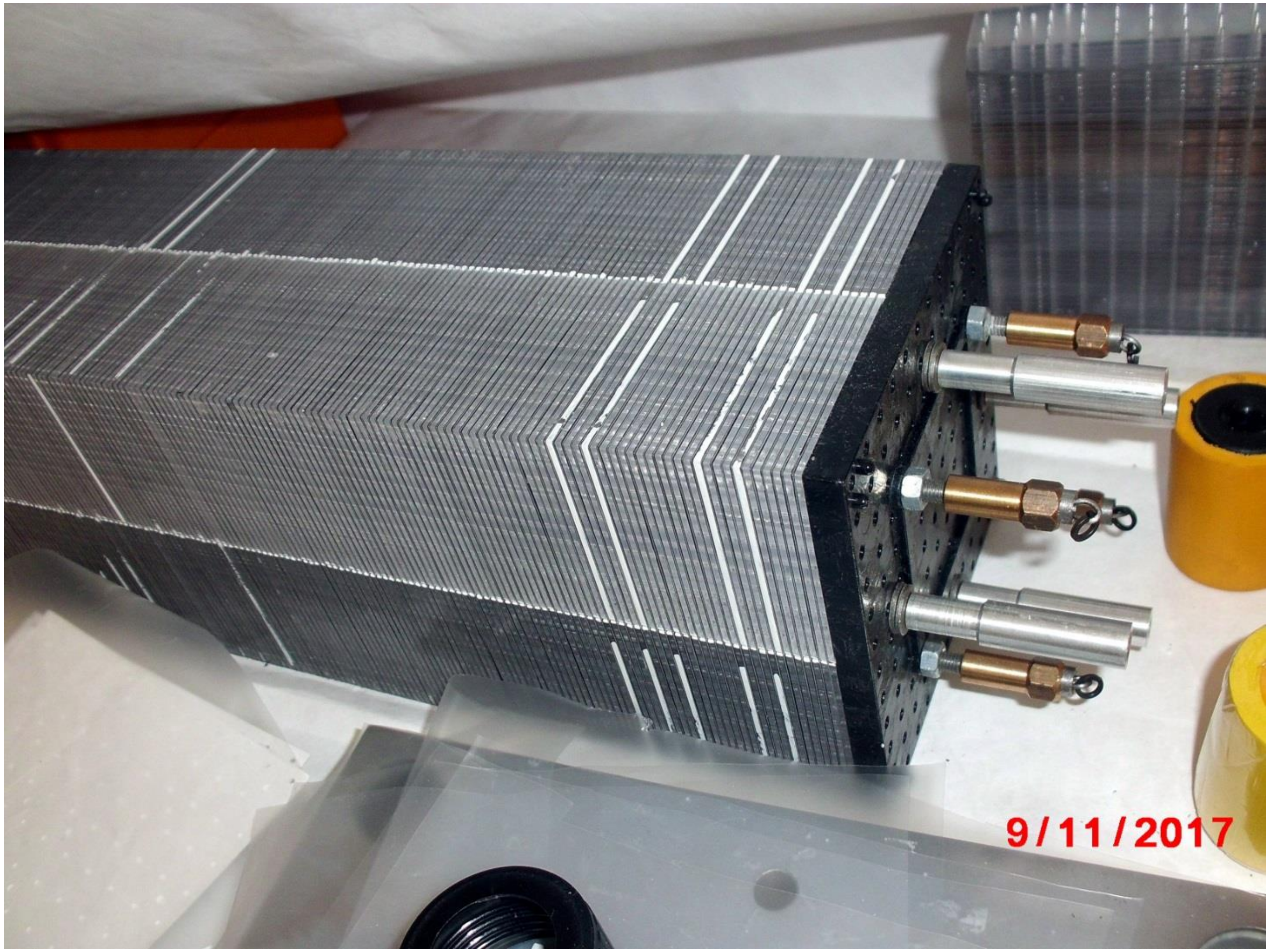

**Correlation matrix for positrons:**

| | | | |
|---|---|---|---|
| **1.0000** | **-0.1362** | **-0.2756** | **-0.0248** |
| 000000 | **1.0000** | **0.1860** | **0.0461** |
| 000000 | 00000 | **1.0000** | **0.4634** |
| 000000 | 00000 | 000000 | **1.0000** |

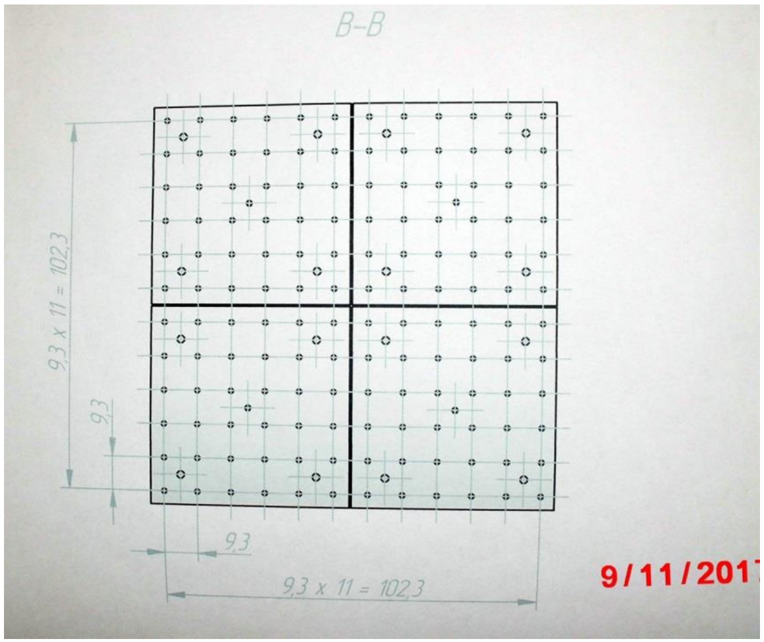
# SPD Ecal segmented by deep

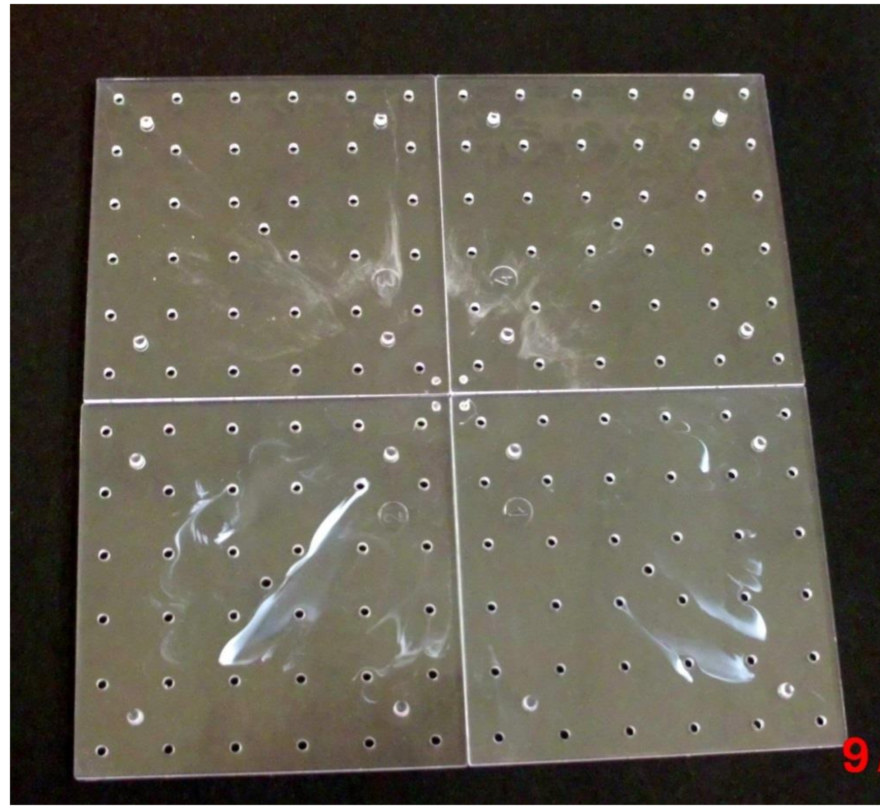
- How to do it ?
- There are 2 ways:
  - Shashlik calorimeter type
  - Tiles with WLS in grows  combined in 4 groups
- The possible Photo sensor – AMPD 6 mm
  - S13360-6025PE (25 μm ) 5760 pixels
  - https://www.hamamatsu.com/resources/pdf/ssd/s13360_series_kapd1052e.pdf
- WLS – Y11 diameter 1 mm http://kuraraypsf.jp/pdf/all.pdf

# Kopio 4-towers module front view without WLS fibers

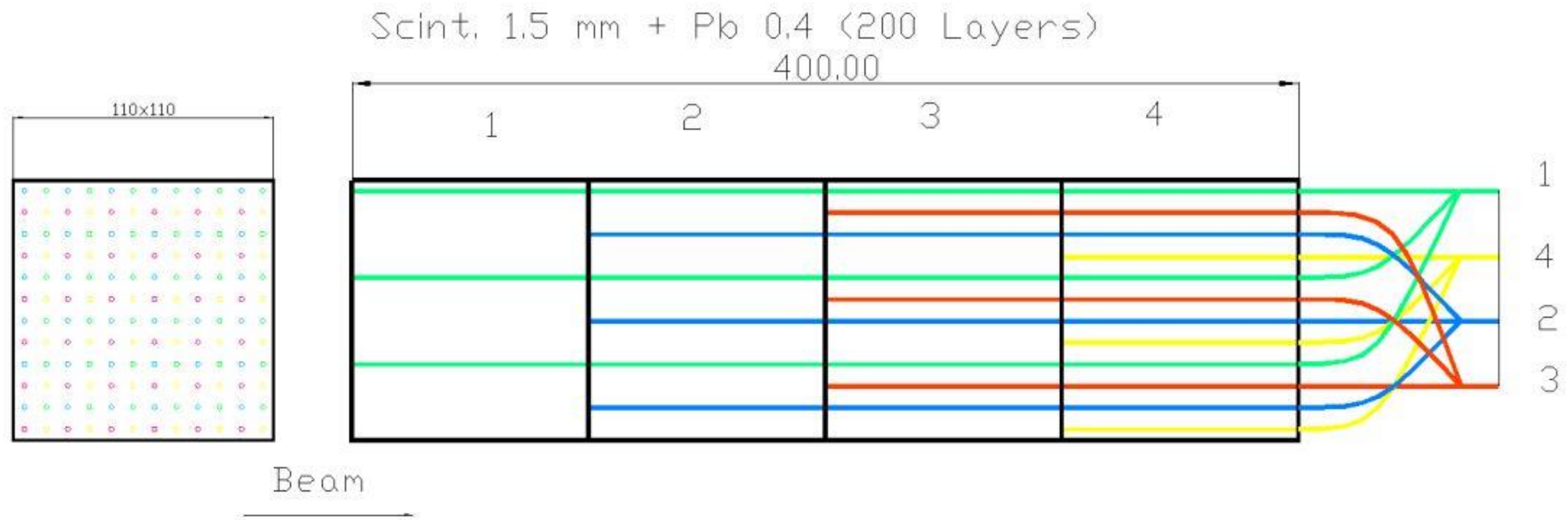


# Scintillation tiles
# Drawing (left) and photo (right)



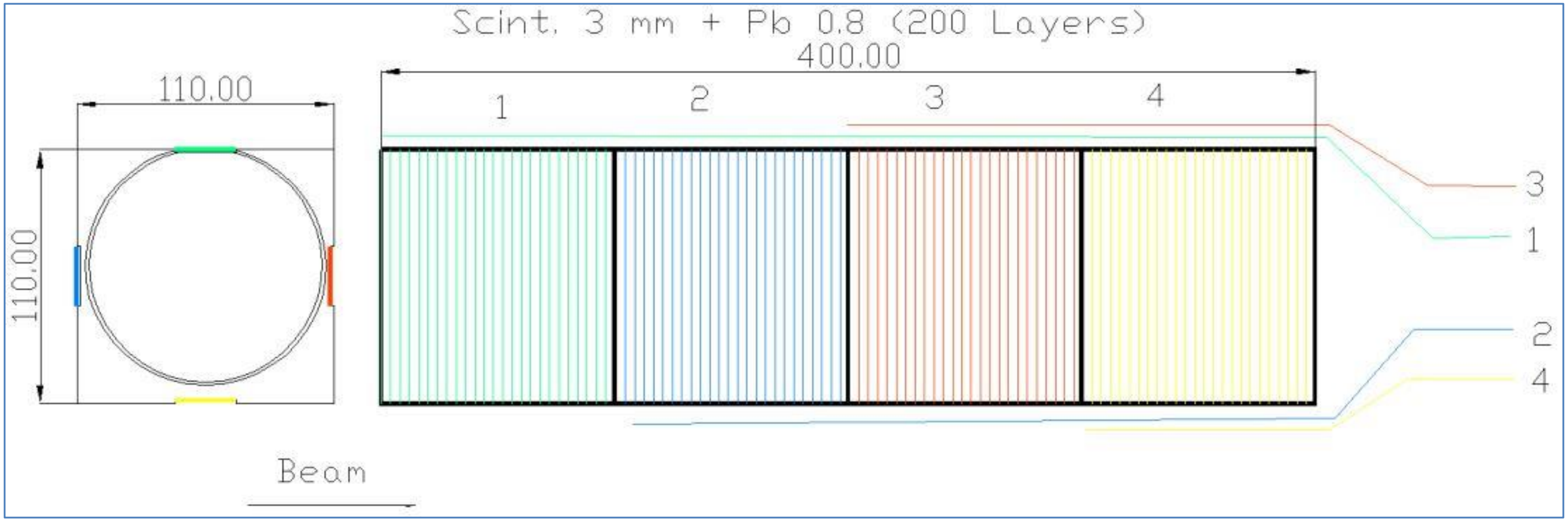



# Integral SPD Ecal option



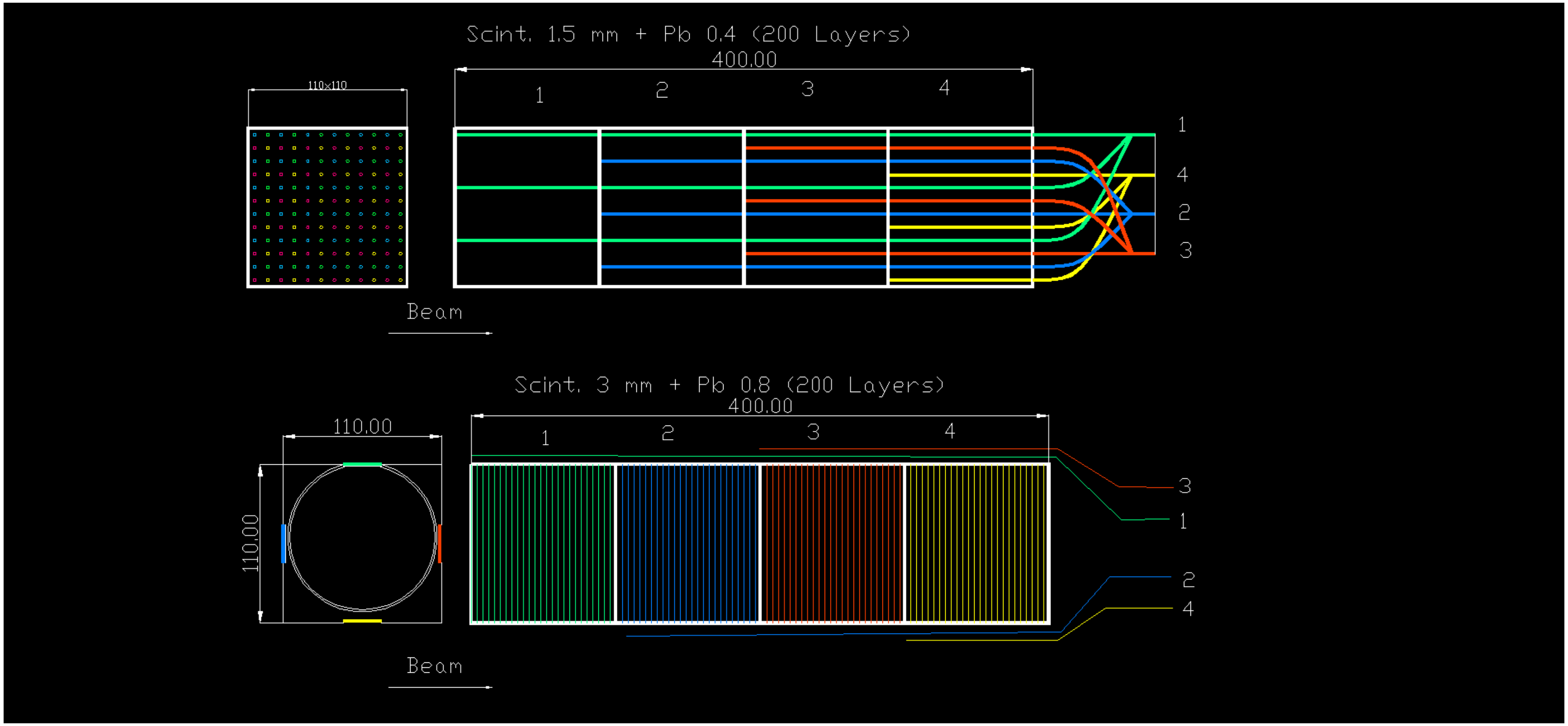

- Cell size – ~100x100 mm$^2$
- 50 Scintillators + Lead (1.5 +0.4 mm) layers per group – more fine granularity
- Possible projective geometry
- 15 $X_0$ – radiation length

# Differential SPD ECAL option




- Cell size – not limited – could be from 55 to 100 mm
- 25 Scintillators + Lead (3 +0.8 mm) layers per group
- Difficult create projective geometry
- 20 $X_0$ – radiation length

# Integral and differential SPD Ecal options



# Monte Carlo simulation ongoing

- Preliminary results for e, pi, mu  particles
- Differential and integral option are compared
- Energy range – around  of 1 GeV
- Shower shape should taken in account to particles identification

# Rough estimation for longitudinal shower shape

$$\frac{dE}{dt} = E_0\, t^{\alpha} e^{-\beta t}$$

$\alpha, \beta$ : free parameters

$t^{\alpha}$ : at small depth number of secondaries increases ...

$e^{-\beta t}$ : at larger depth absorption dominates ...

Numbers for E = 2 GeV (approximate):
$\alpha = 2,\ \beta = 0.5,\ t_{max} = \alpha/\beta$

where t = shower depth in units of $X_0$

$t_{max}$ = depths where the energy deposition is maximal

# More exact longitudinal shower shape

## *The longitudinal shower shape*

More exact (EGS simulation and measurements)
[Longo 1985]

$$\frac{dE}{dt} = E_0 \cdot \beta \cdot \frac{(\beta t)^{\alpha-1} e^{-\beta t}}{\Gamma(\alpha)}$$

[Γ: Gamma function]

where t = shower depth in units of $X_0$

# End of Report

- **Thanks everybody** for attention