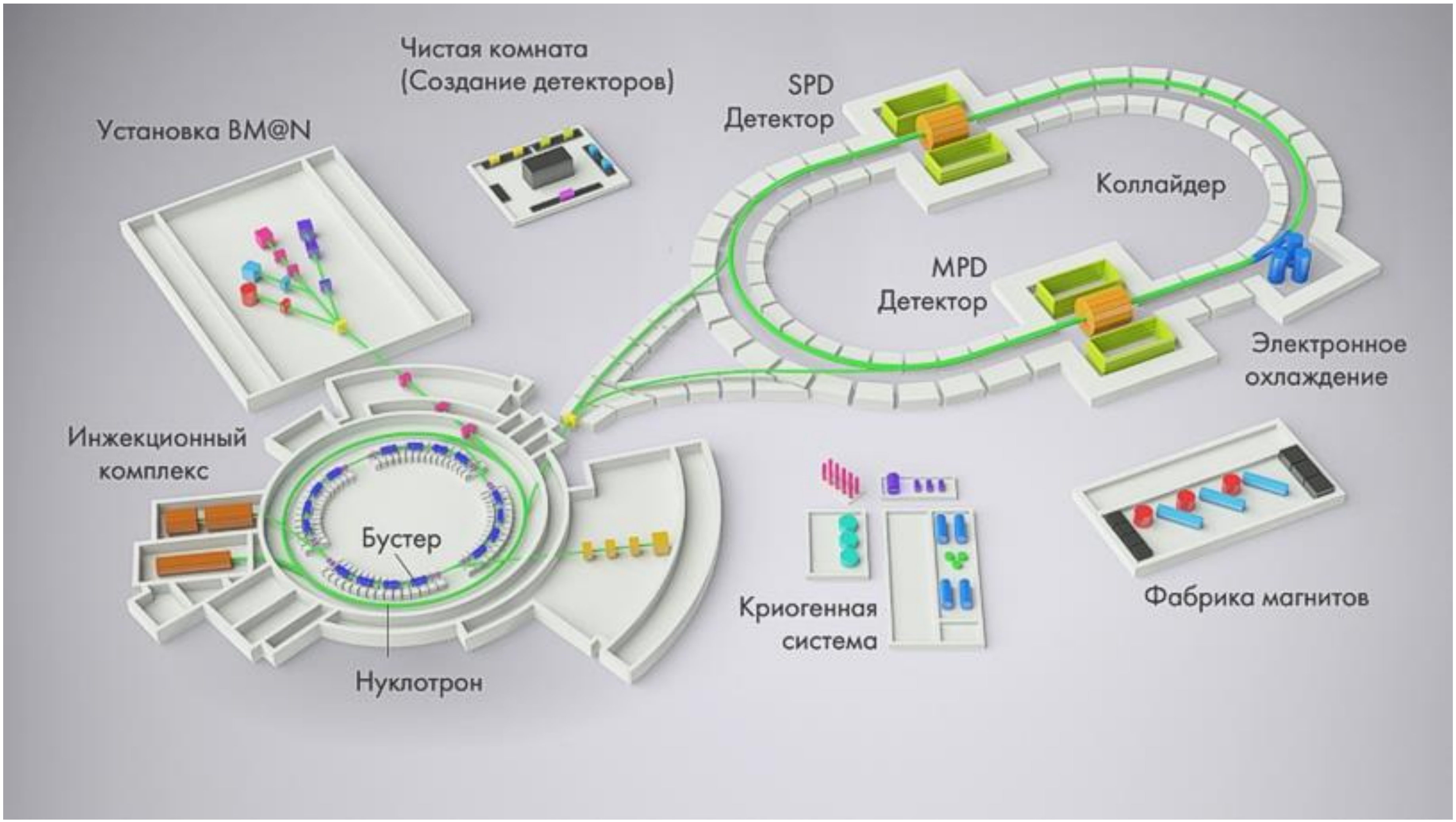
ECAL: status report

O. Gavrishchuk, JINR, Dubna

1. NICA facility : year by year history
2. ECAL integrated inside of Hybrid SPD
3. Cells size and total Cell Number
4. Energy & Space resolution
5. Production – possible option
6. Prototype of 2019 - 36 cells of 55x55 mm^2 are ready
7. Test results in cosmic rays – preliminary results
8. Monte-Carlo simulation for e, mu, pions by Kharkov peoples
9. Longitudinally segmentation – optional solution foe e/pi rejection
10. SiPm readout – PCB for first modules – are designed and ready
11. Cosmic tests with SiPm (Hamamatsu and Sensl) – are in progress
12. ADC and HV , LED control systems – tested with ECAL prototype

NICA facility in Dubna

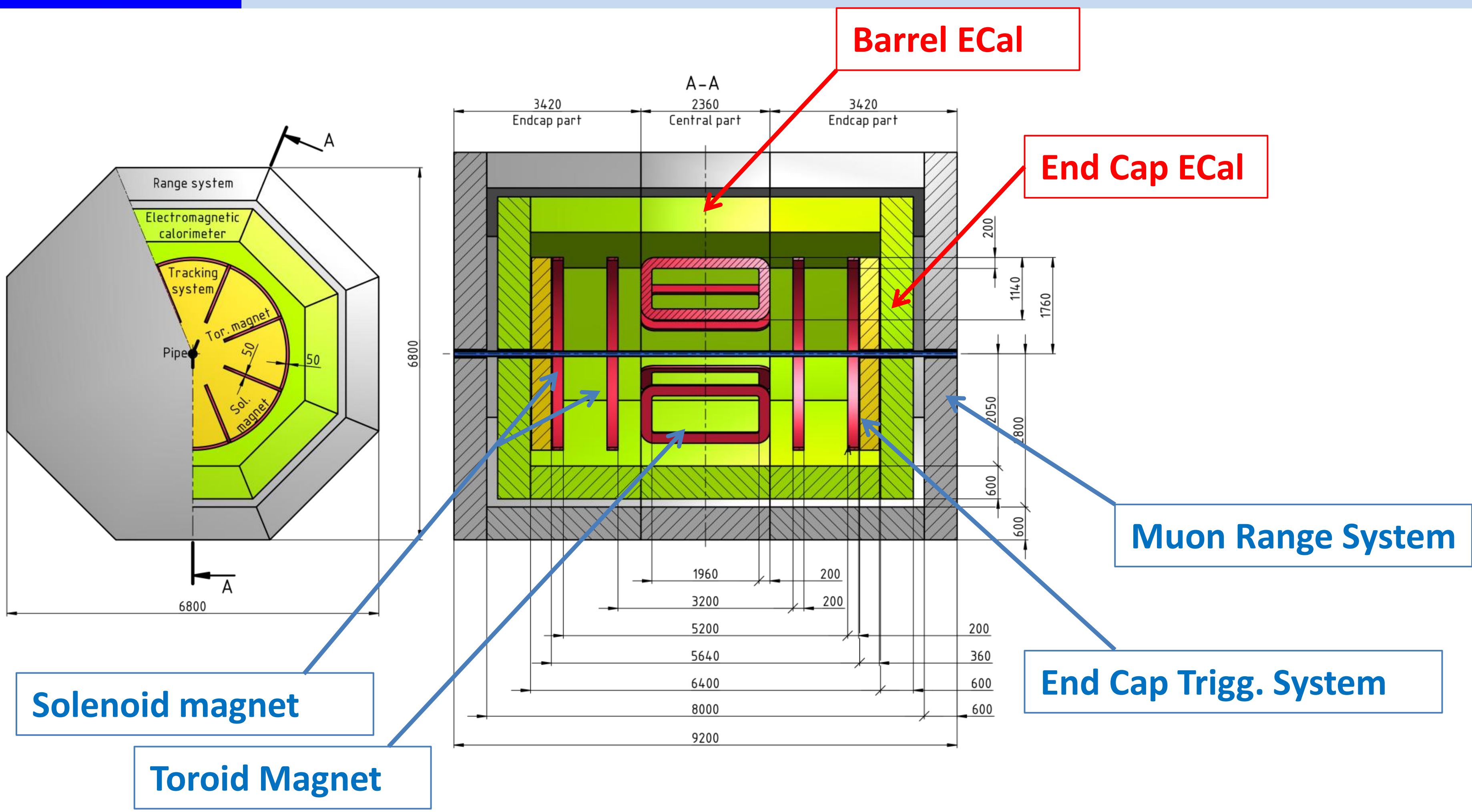


NICA facility in Dubna

NICA facility in Dubna

NICA facility in Dubna today

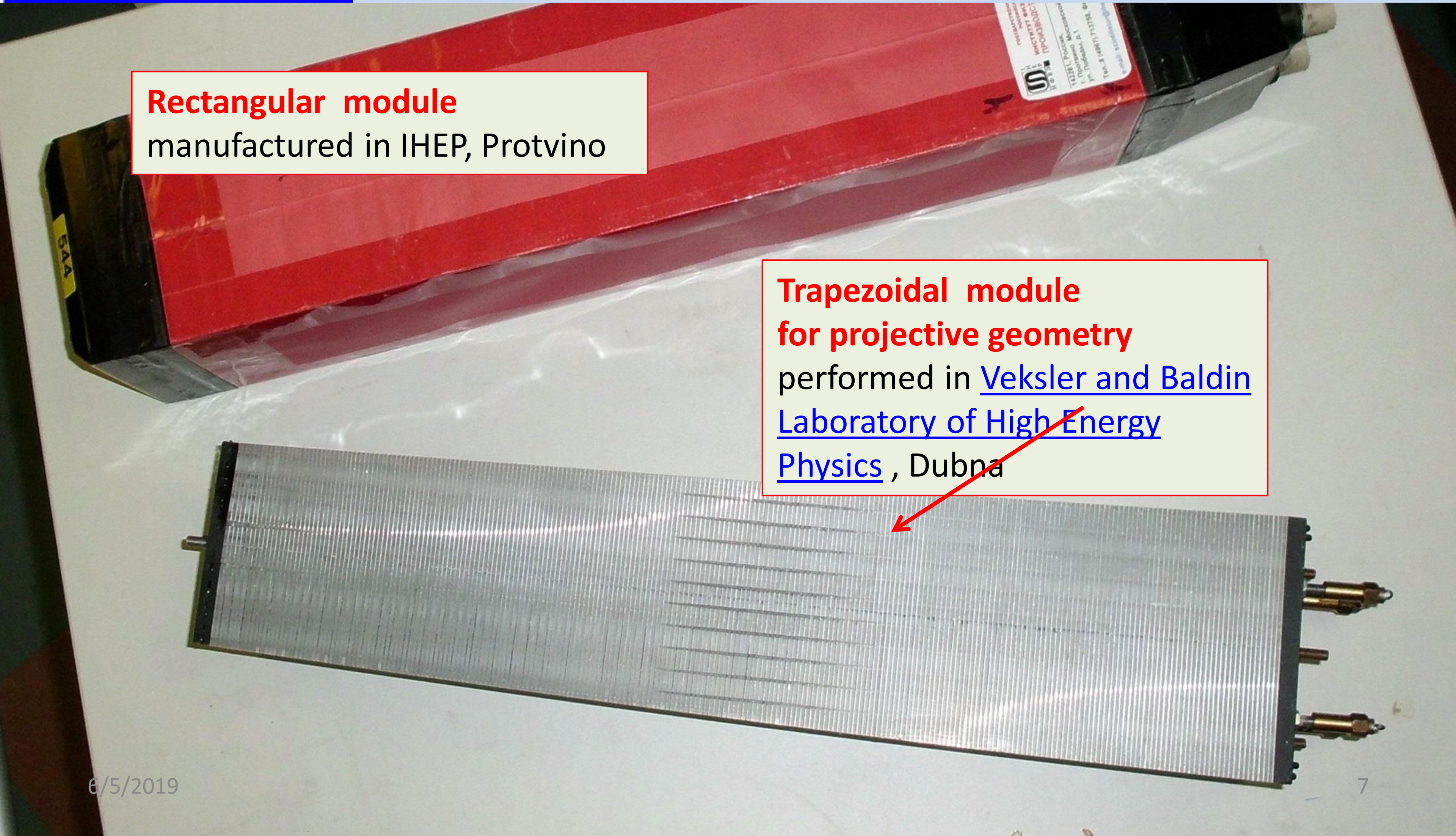
ECAL integrated in to Hybrid SPD



SPD ECAL modules :

Lead (0.3mm)+ Plastic Scintillator(1.5mm) -220 Layers

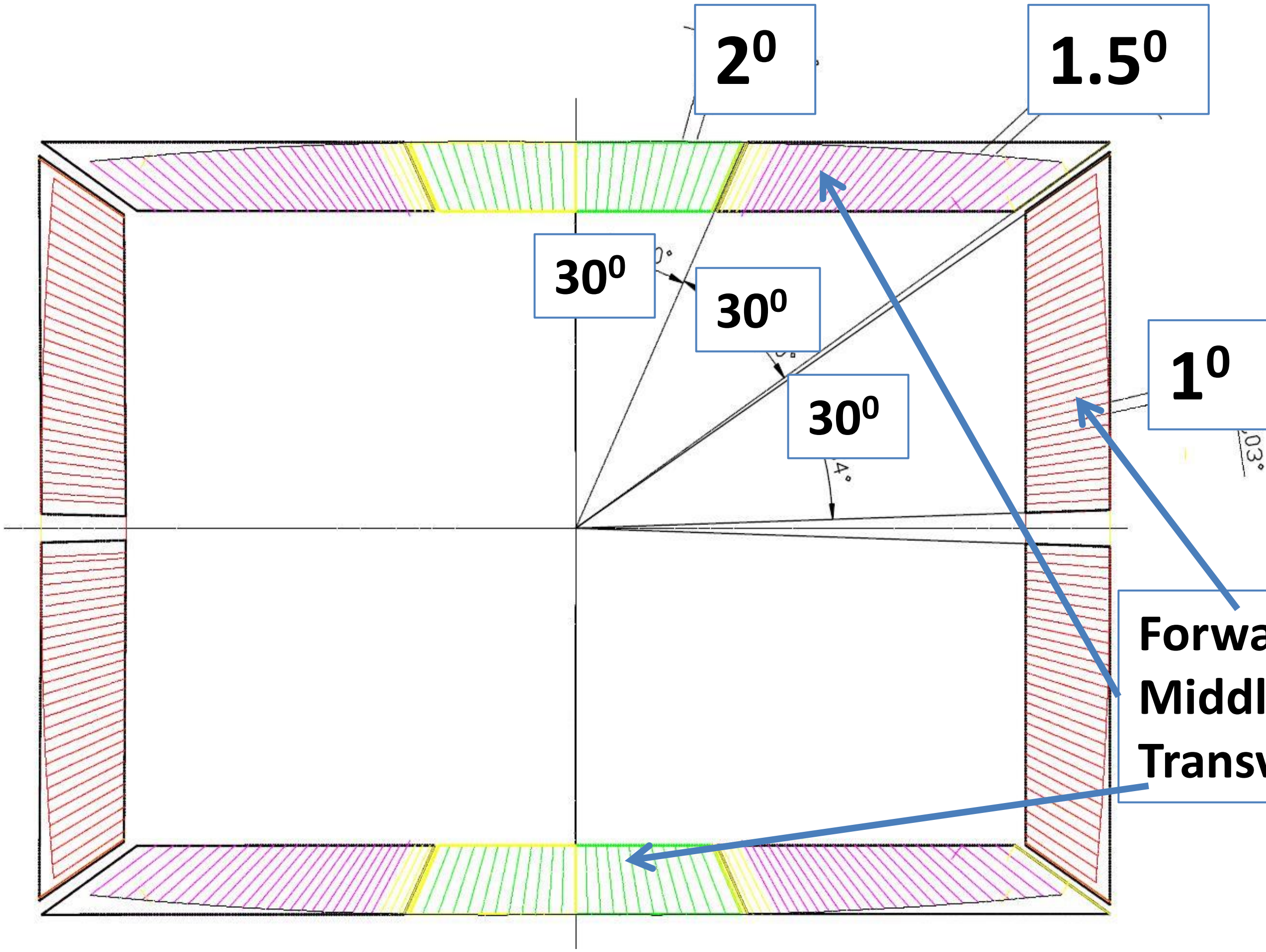
Module consist from 4 cells 55x55mm^2

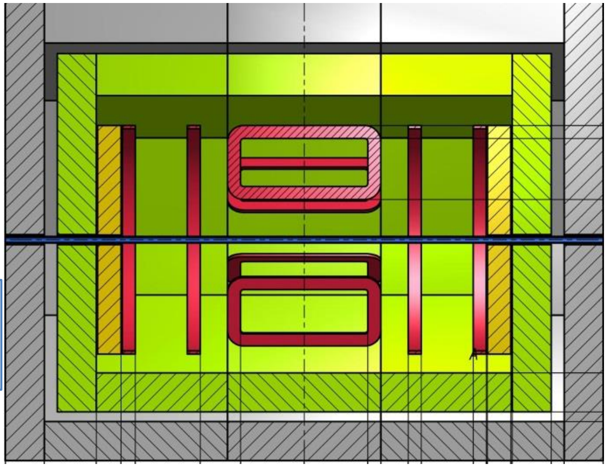


Rectangular module
manufactured in IHEP, Protvino

Trapezoidal module
for projective geometry
performed in Veksler and Baldin Laboratory of High Energy Physics , Dubna

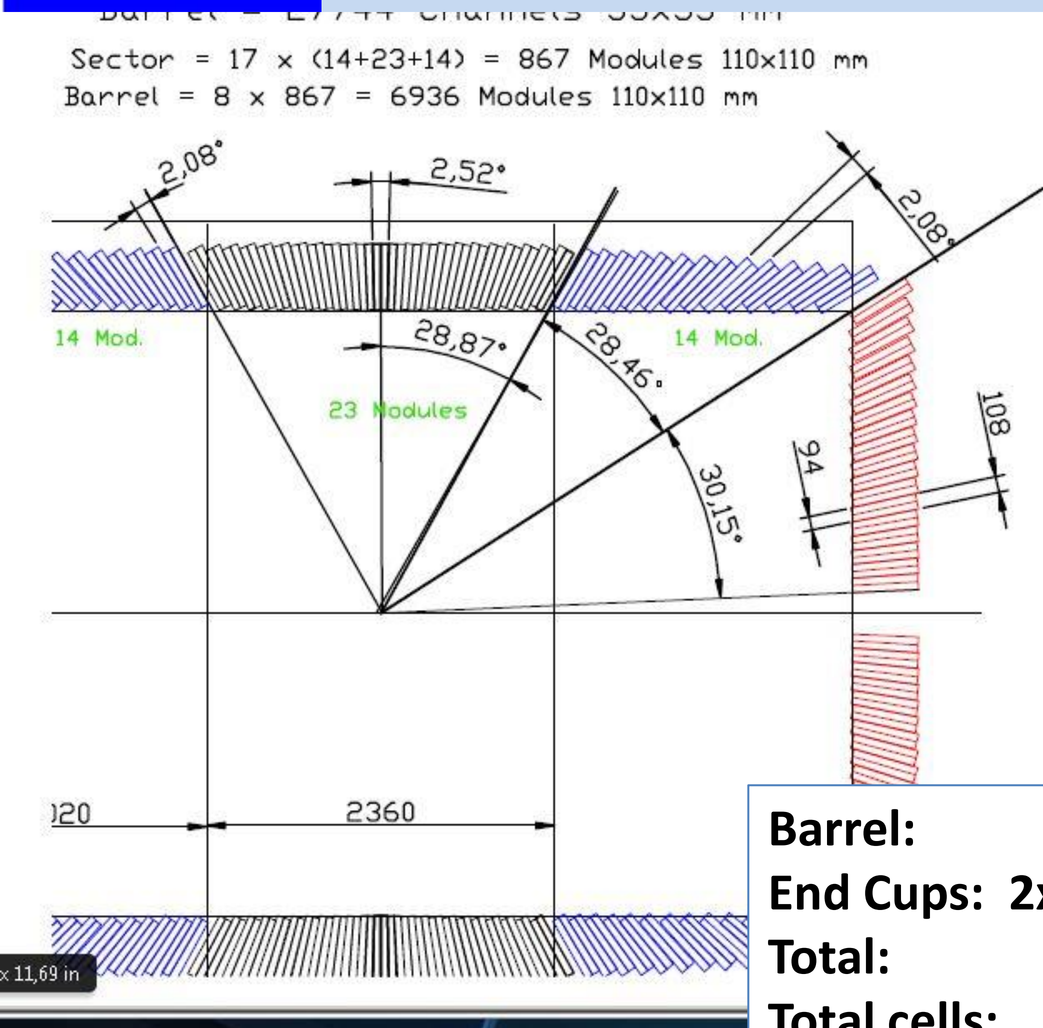
ECAL integrated inside of SPD. Projective geometry option.

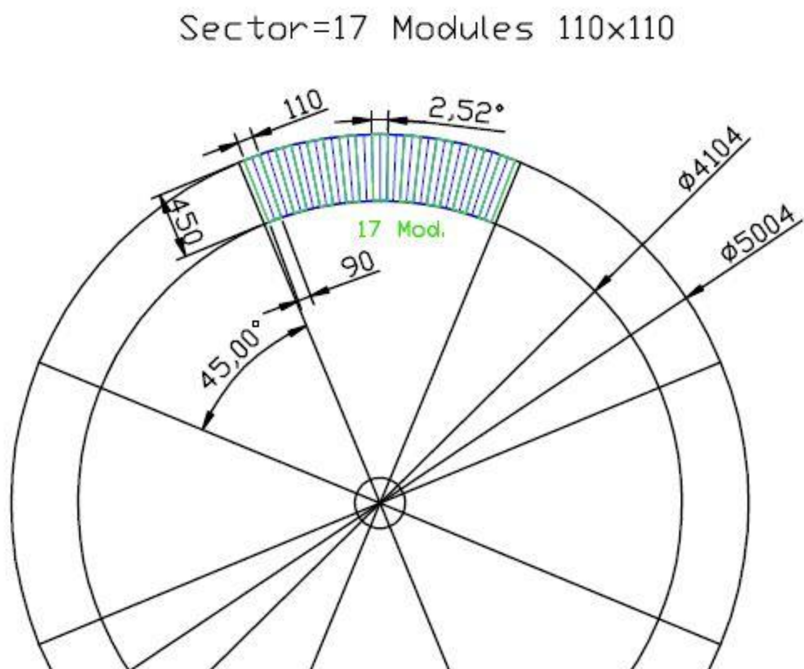




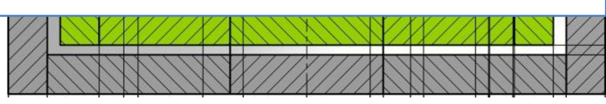
Forward - 3.5 cm Cells size
Middle - 5.5 cm Cell size
Transverse - 7.0 cm Cell size

ECAL integrated inside of SPD. Cell sizes and Cell Number.





Barrel:	**6528 modules**
End Cups:	**2x2268=9097 modules**
Total:	**18144 modules 110x110mm^2**
Total cells:	**44268 cells of 55x55 mm^2**
Total Weight:	**50 tonns**



ECAl – γ - Energy range

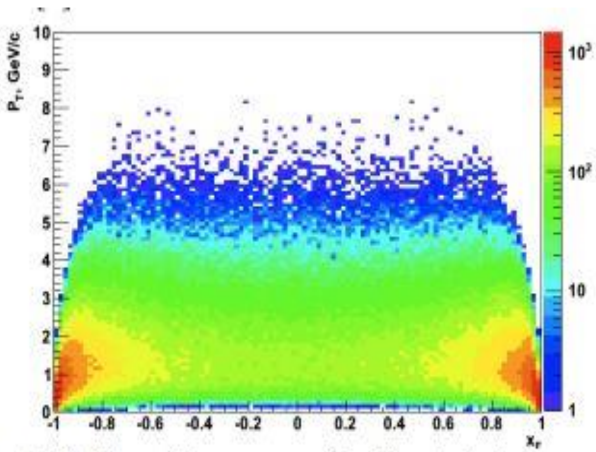


Fig. 5.10: The plot p_T vs. x_F for direct photons.

As follow from SPD LoI (02.06.2014):
The prompt gamma energy range:
Up to 10 GeV in forward (0^0-30^0)
Up to 5 GeV in middle (30^0-60^0)
Up to 3 GeV in transverse (60^0-90^0) angles range.

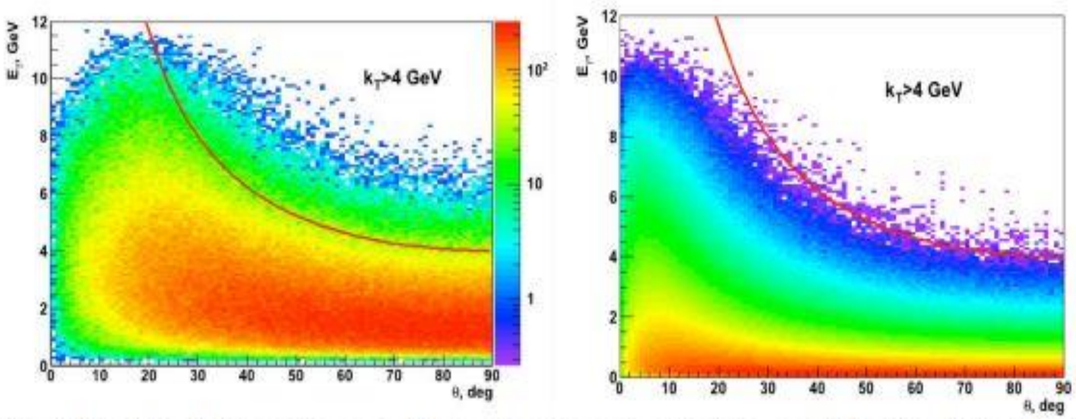
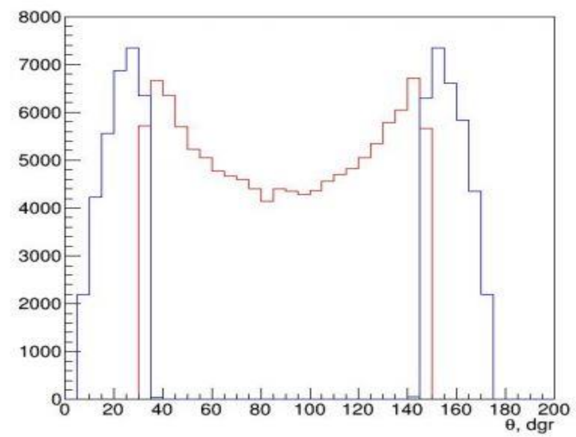


Fig. 5.11: Distribution of energy E_γ as a function of scattering angle θ: left - direct photons, right - minimum bias photons. Red lines correspond to the cut $p_T > 4$ GeV.



The angular occupancy for proton collision at √s ~ 26 GeV

ECAL's requirement for SPD

Take in account the energy range of gamma and electrons SPD
Ecal should be able take energy from 50 MeV up to 10 GeV

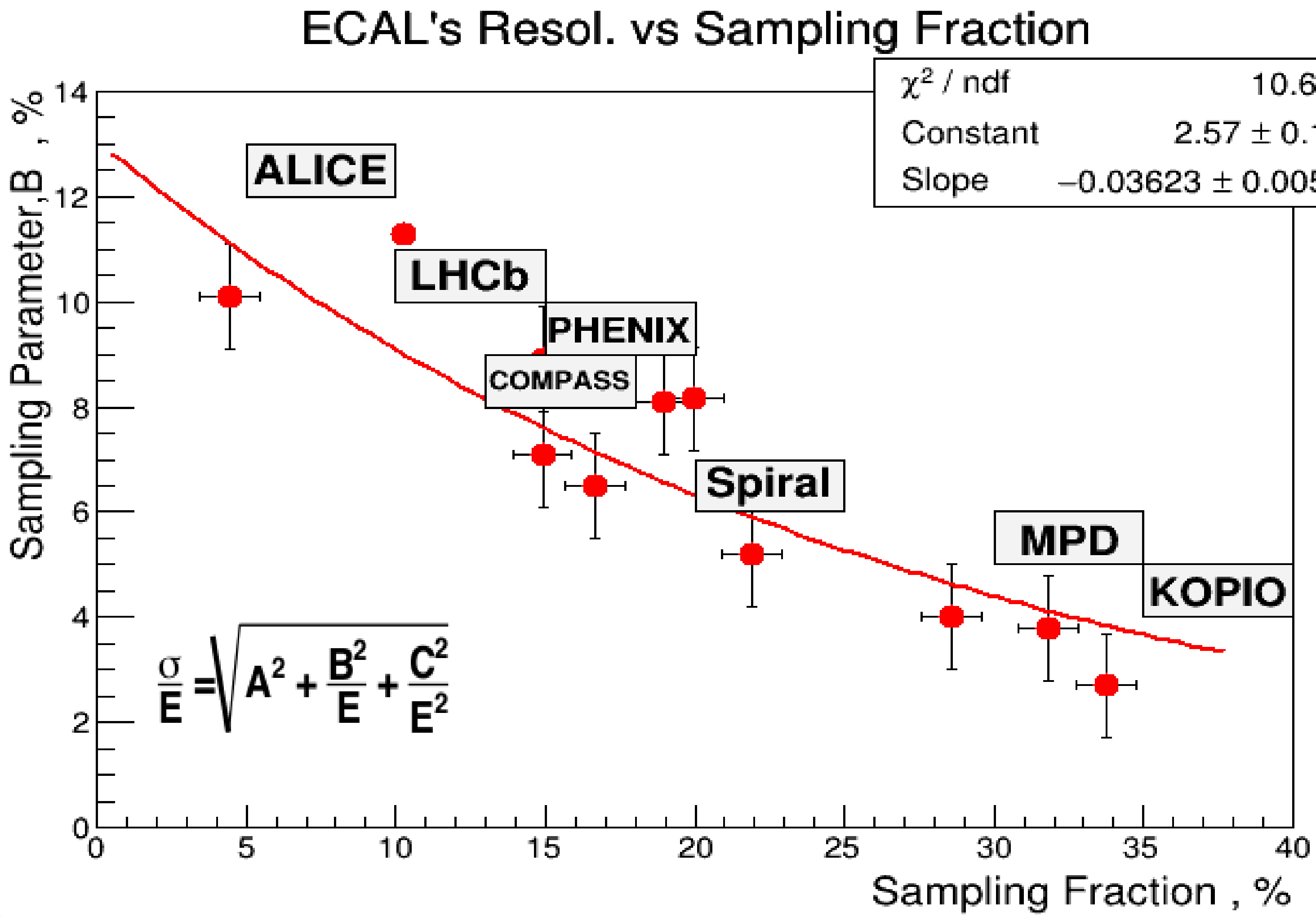
Ecal should have a good E resolution especially an low energy 50- 1000 MeV

$$\sigma_E / E \sim 4\% / \sqrt{E} \text{ (GeV)}$$

This parameter can be reached by :

- Fine granularity (in case of sampling EC) (sampling fraction >20%)
- Radiation length should be about of 15 X_0
- Cells size should be closed to Moliere Radius – 2,5 – 3,5 cm

ECAL's sampling resolution in high energy experiments



KOPIO (BNL)ECAL : Lead + Plastic Scintillator

https://www.worldscientific.com/doi/abs/10.1142/9789812702227_0157

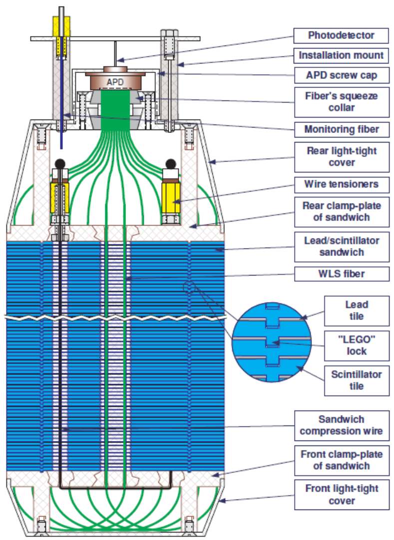
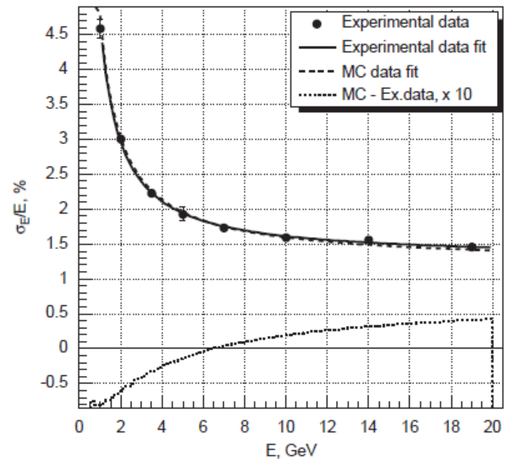


Fig. 1. The Shashlyk module design.



$$\Delta x = \sqrt{a^2 + \frac{b^2}{E}}$$

- Energy resolution $(3 \div 3.5)\% / \sqrt{E(\mathrm{GeV})}$
- Time resolution about 80 ps$/\sqrt{E(\mathrm{GeV})}$
- Calorimeter granularity $\sim 10 \times 10$ cm^2

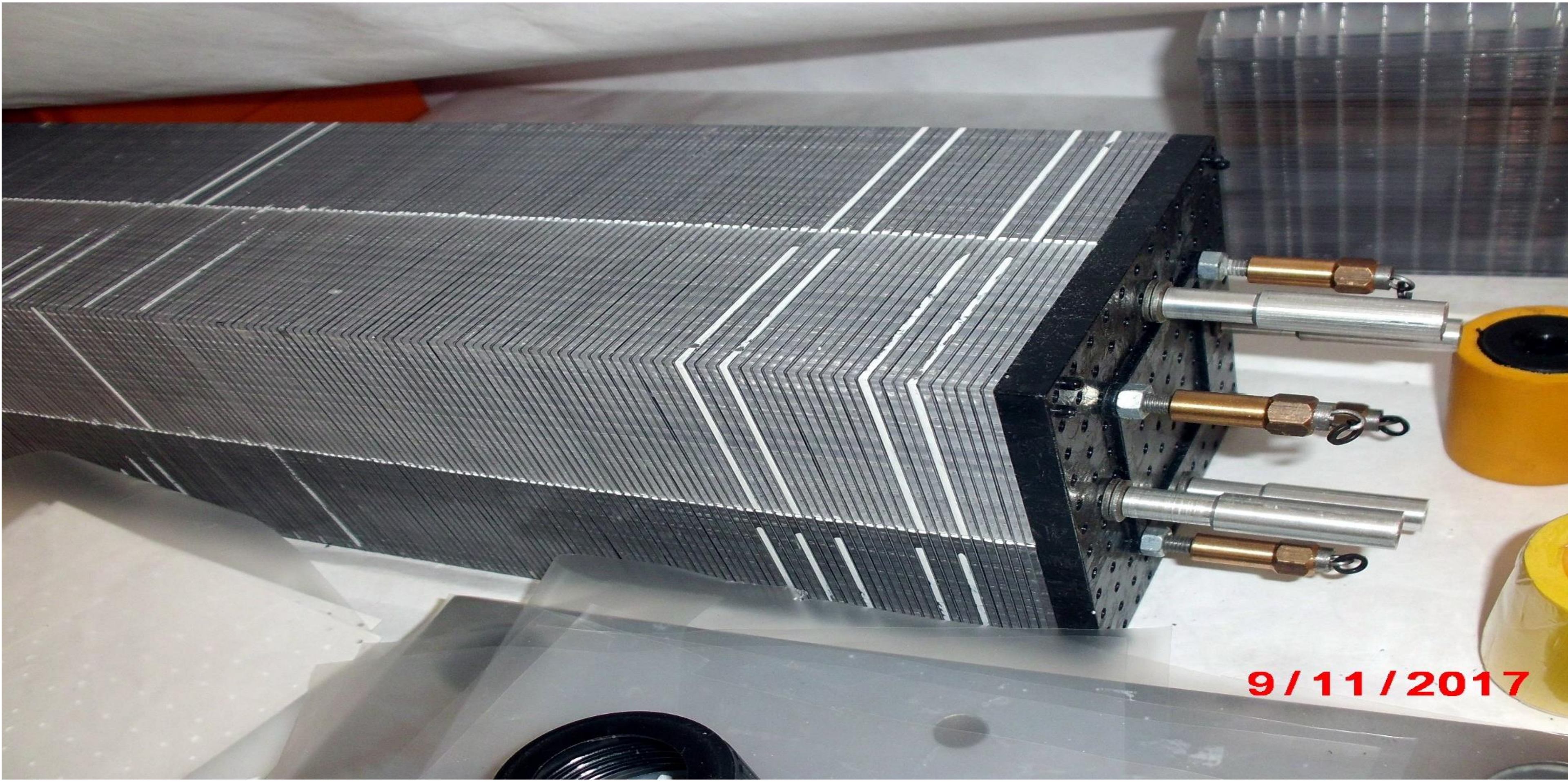
Parameters of the prototype Shashlyk module for KOPIO.

Transverse size	110×110 mm^2
Number of the layers	240
Polystyrene scintillator thickness	1.5 mm
Lead absorber thickness	0.35 mm
Reflective paper (TYVEK) thickness	2×0.06 mm
Number of holes per layer	12×12
Holes spacing	9.5 mm
Holes diameter in Scintillator/Lead	1.4/1.5 mm
WLS fibers per module	72×1.3 m ≈ 92 m
Diameter of WLS fiber	1.0 mm, (1.2 mm)
Diameter of fiber bundle	14 mm, (17 mm)
Effective radiation length X_0	31.5 mm
Effective Molière radius R_M	54.9 mm
Effective density	2.75 g/cm^3
Active length	473 mm ($15.9X_0$)
Total length (without photodetector)	610 mm
Total weight	18.0 kg

SPD ECAL module (110x110mm^2):

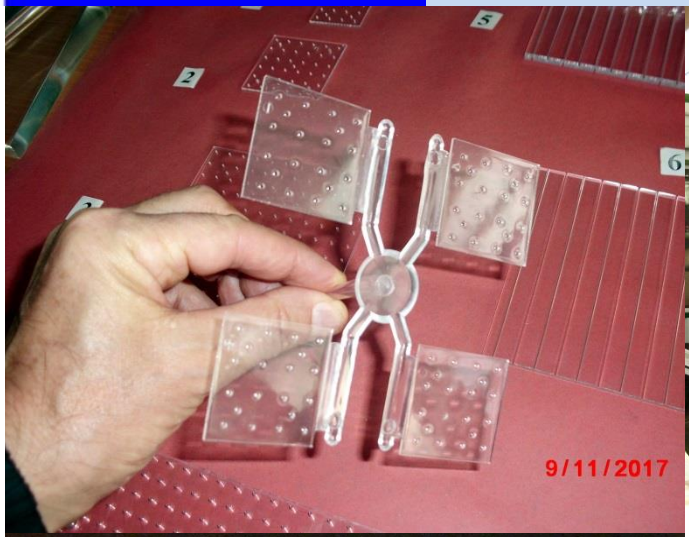
Lead (0.3mm)+ Plastic Scintillator(1.5mm) -220 Layers

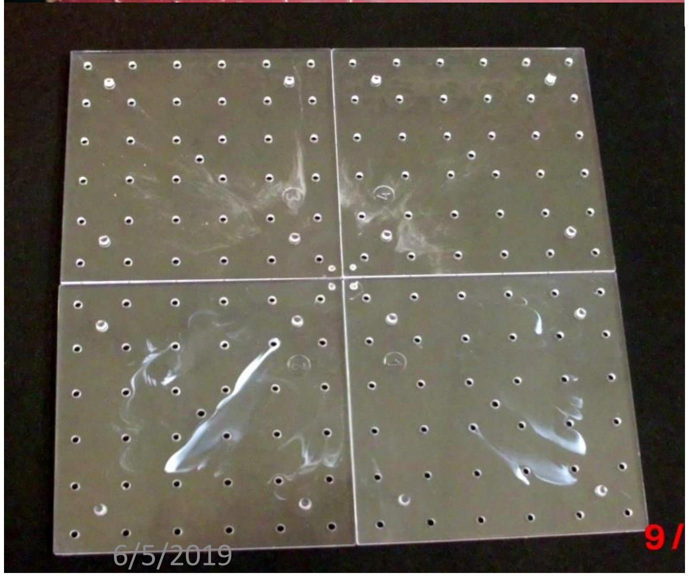
Module consist from 4 cells 55x55mm^2



Scintillator tile production in IHEP , Protvino
Moldings machine general view.

Scintillator tile production molding by pressure technology





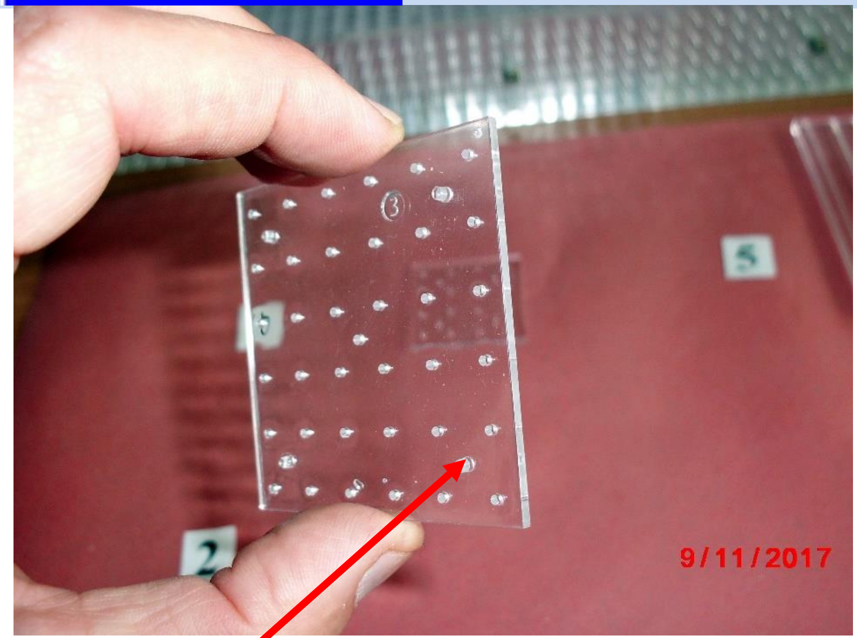
Molding machine used for scintillator production from granulated Polystyrene with dopants: 1.5% Pt-Terphenyle and 0.05% POPOP (420 nm and 2,5 ns decay time).

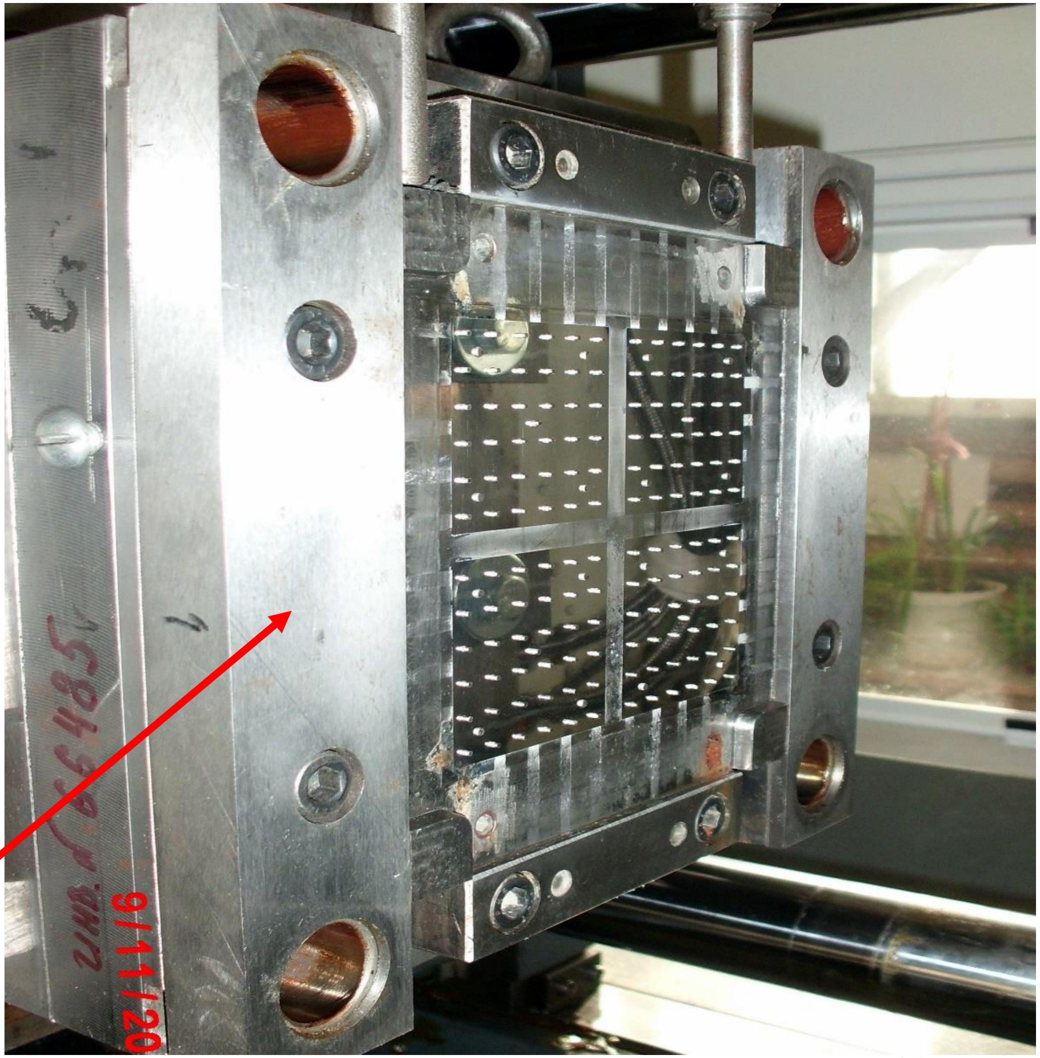
Radiation hardness is about 10^7 Rad (10^5Gy)

The scintillator tiles with different sizes could be made.

The production procedure is automatically and allow one Sycle per minute.

Scintillator tile production
by pressure-molding technology

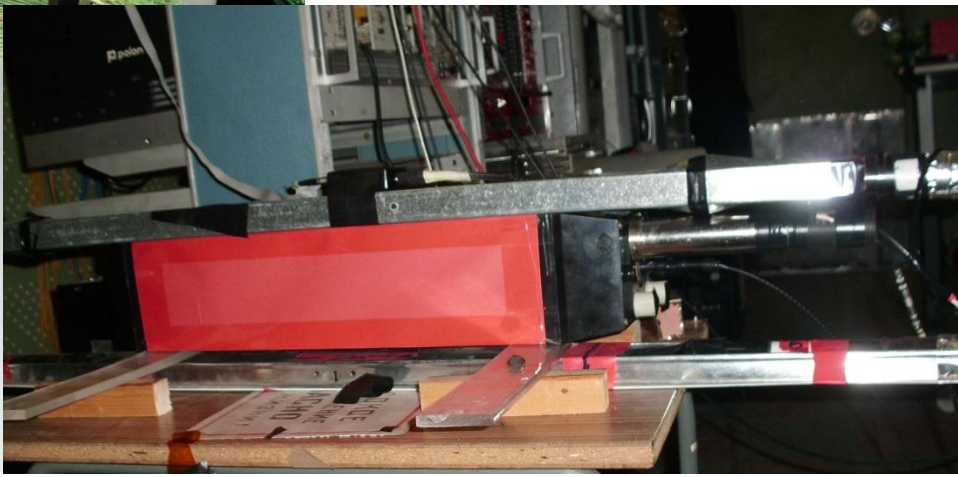




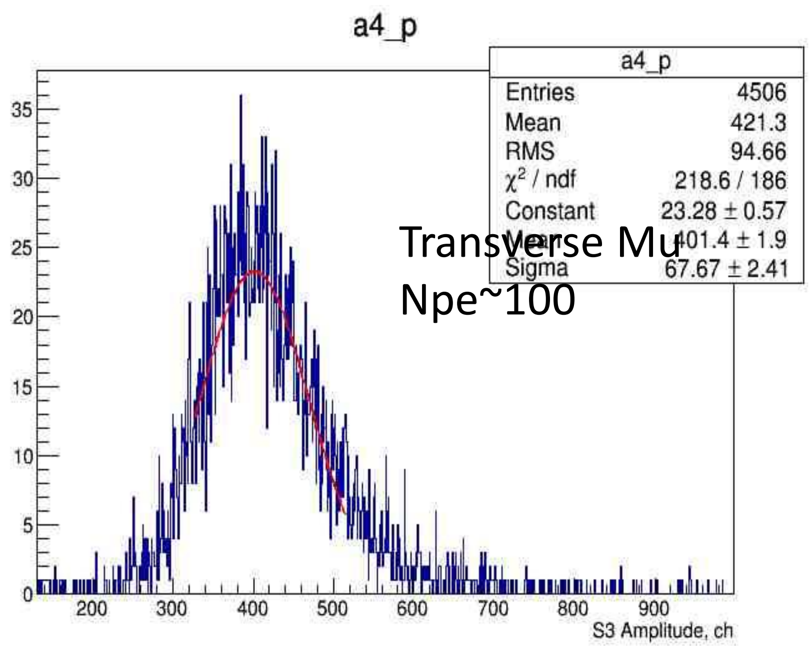
Single tile 1.5 x 55x55 mm^3 with 4 LEGO signs for Lead fixation is shown

4 Sets Matrix Form for this tiles production is presented here

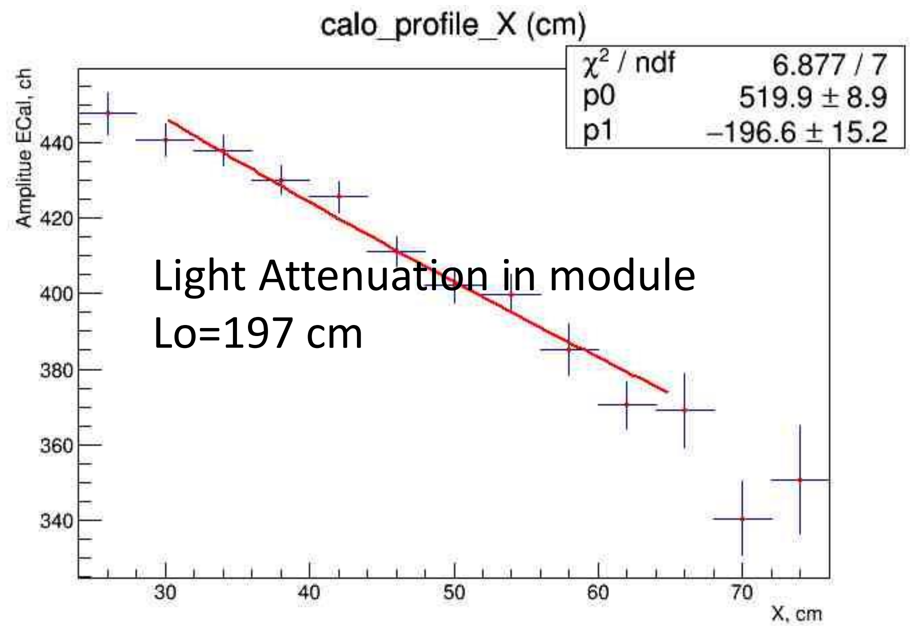
Lead + Plastic Scintillator- 220 Layers
1.5 mm Sc + 0.3 mm Pb + 0.1+0.1 Air
New modules of **2019**



Lead + Plastic Scintillator- 220 Layers
1.5 mm Sc + 0.3 mm Pb + 0.1+0.1 Air
ECAL beam tests: cosmic rays

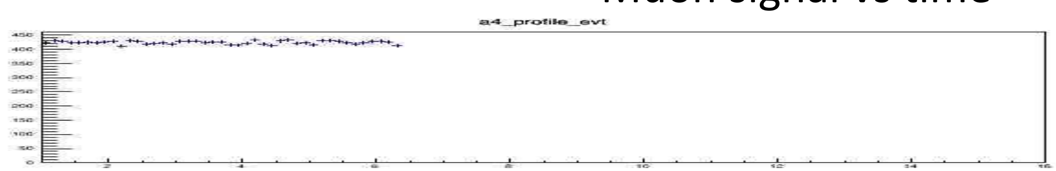


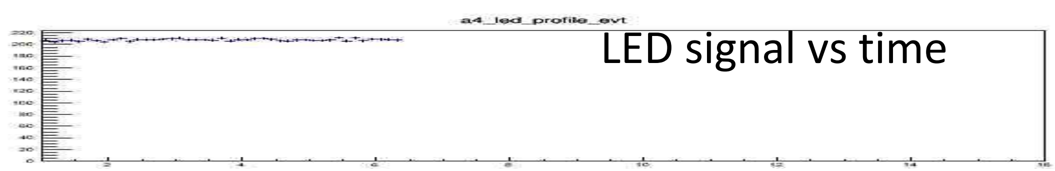
Transverse Mu
Npe~100



Light Attenuation in module
Lo=197 cm

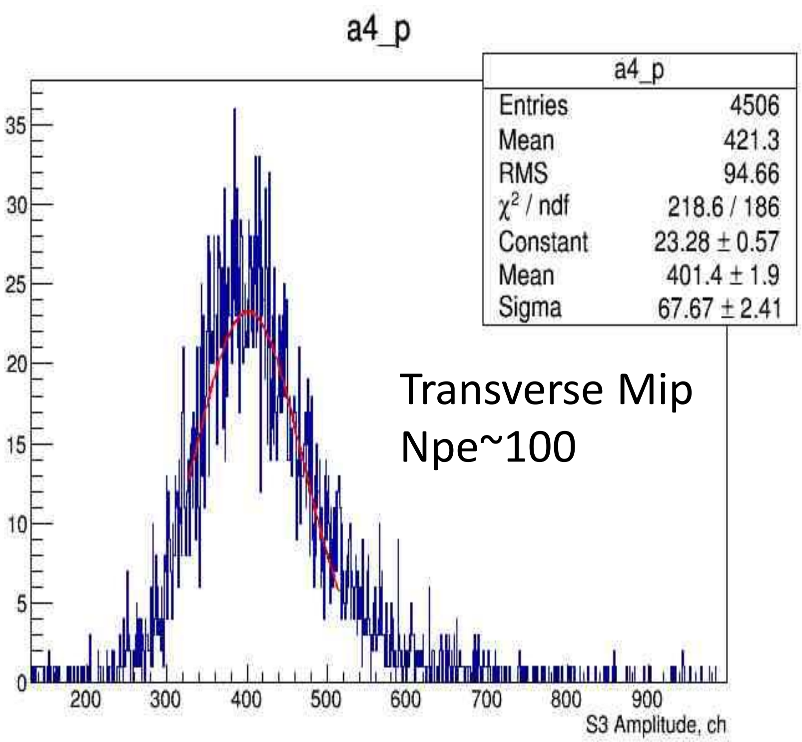
Muon signal vs time





LED signal vs time

Lead + Plastic Scintillator- 220 Layers
1.5 mm Sc + 0.3 mm Pb + 0.1+0.1 Air
ECAL beam tests: cosmic rays



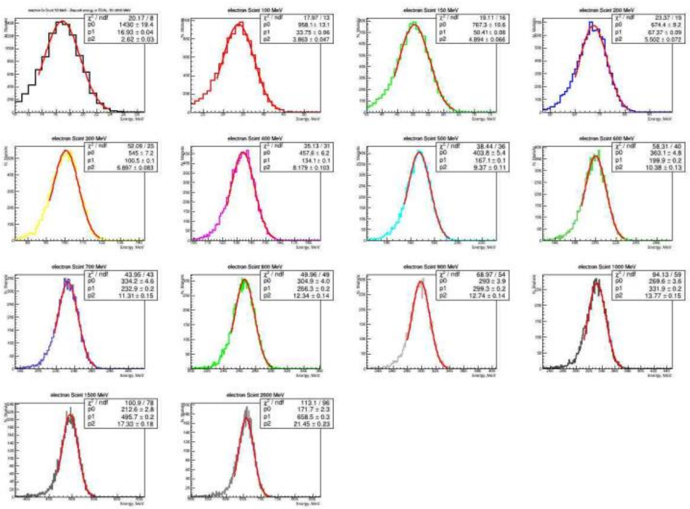
Light output - 100 Phe / transverse (55mm Sc)
Longitudinal Size = 330 mm
NPE = 100 * 330/55 * 2/1.5 = 800 Phe for Mip
1 Mip ~ 200 MeV Electon
1 GeV Electron ~ 800 * 1000/200 = 4000 Phe
Photostat = 100/sqrt(4000)=1.6%
Stochastic = sqrt(3.5**2 + 1.6**2))=3.8% - at 1 GeV

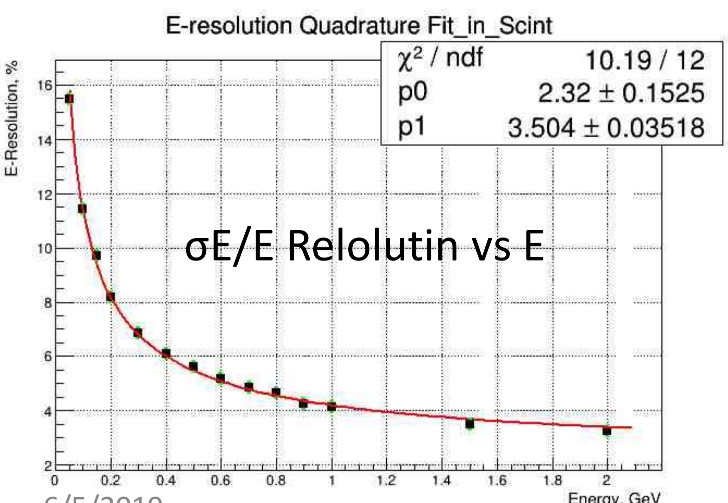
100 MeV Electron ~ 400 Phe
Photo statistic (%) = 100/(sqrt(400)) = 5 %

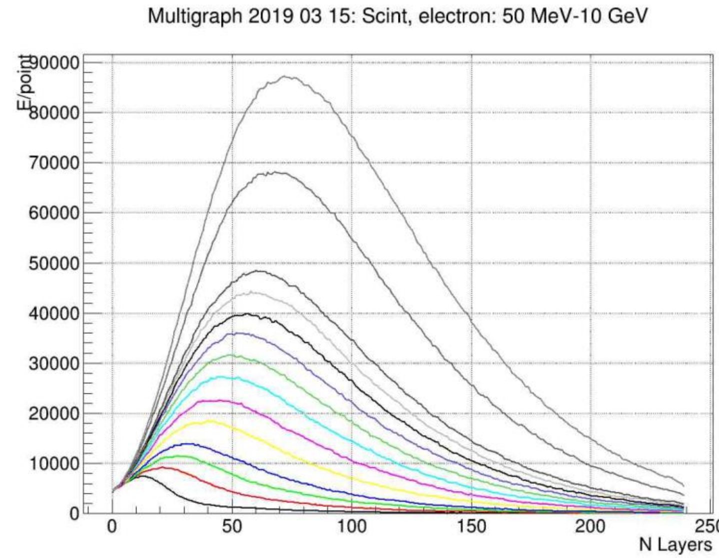
Stochastic = sqrt(3.5**2 + 5**2))=6.1% - at 100 MeV

Lead + Plastic Scintillator- 220 Layers
1.5 mm Sc + 0.3 mm Pb + 0.1+0.1 Air
Monte-Carlo: Electron response 50-2000 MeV

Kovtun Vladimir
Behalf of V.N. Karazin Kharkiv National University (KNU)

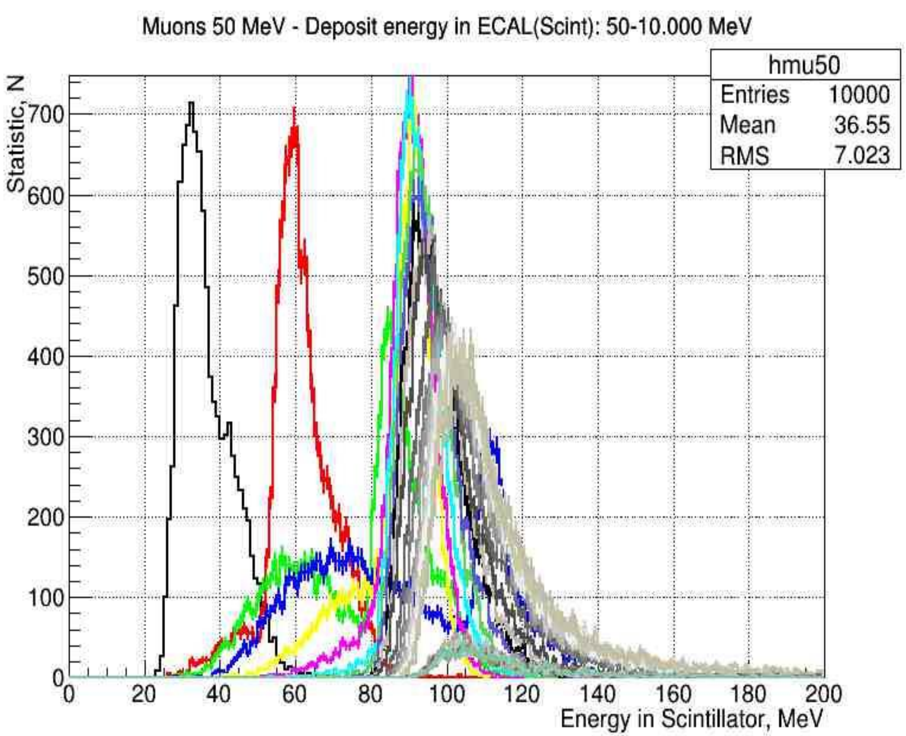


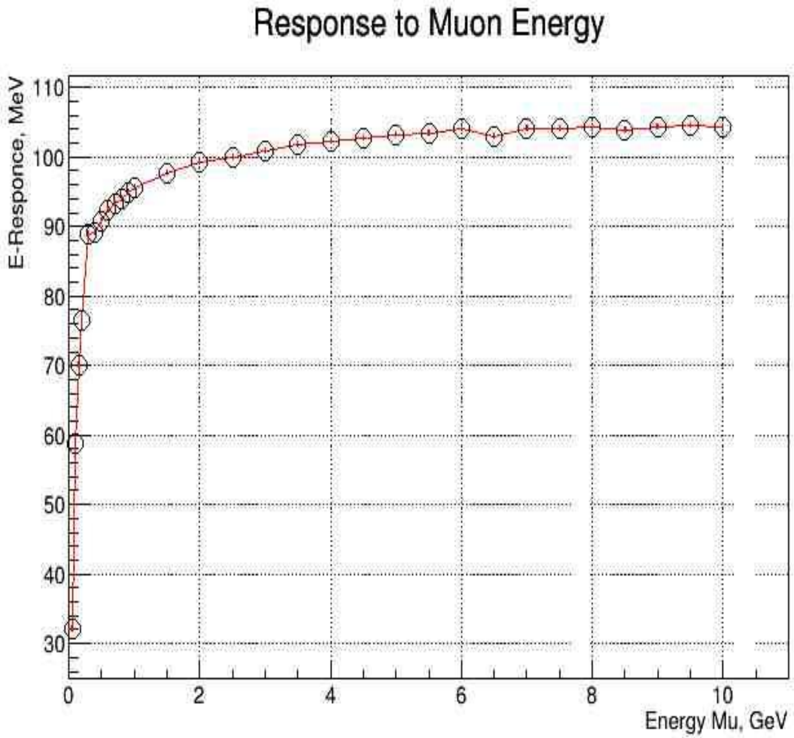




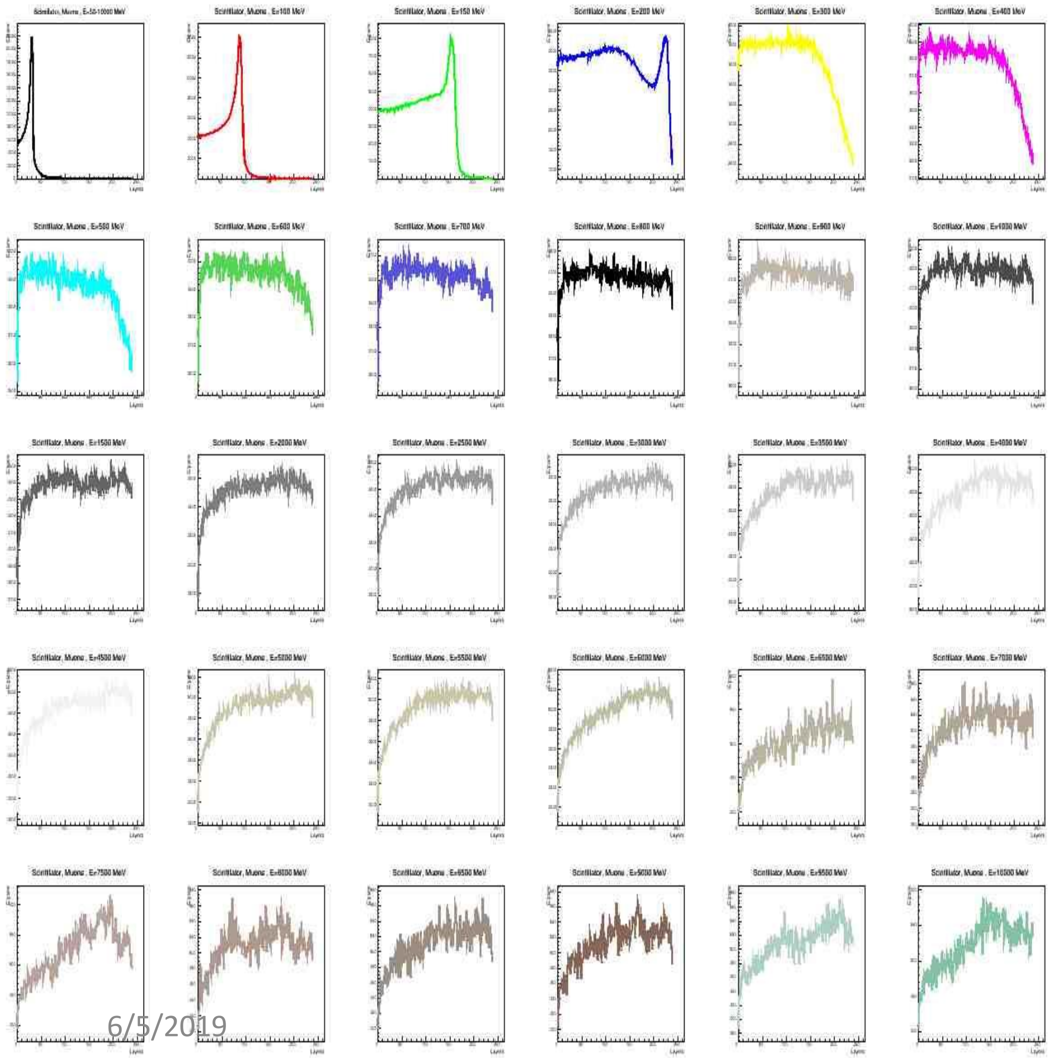
Lead + Plastic Scintillator- 220 Layers
1.5 mm Sc + 0.3 mm Pb + 0.1+0.1 Air
Monte-Carlo: Muon response 50-10000 MeV

Kovtun Vladimir
Behalf of V.N. Karazin Kharkiv National University (KNU)





SPD ECAL : Lead + Plastic Scintillator- 220 Layers
1.5 mm Sc + 0.3 mm Pb + 0.1+0.1 Air
Monte-Carlo: Pions response 50-700 MeV.



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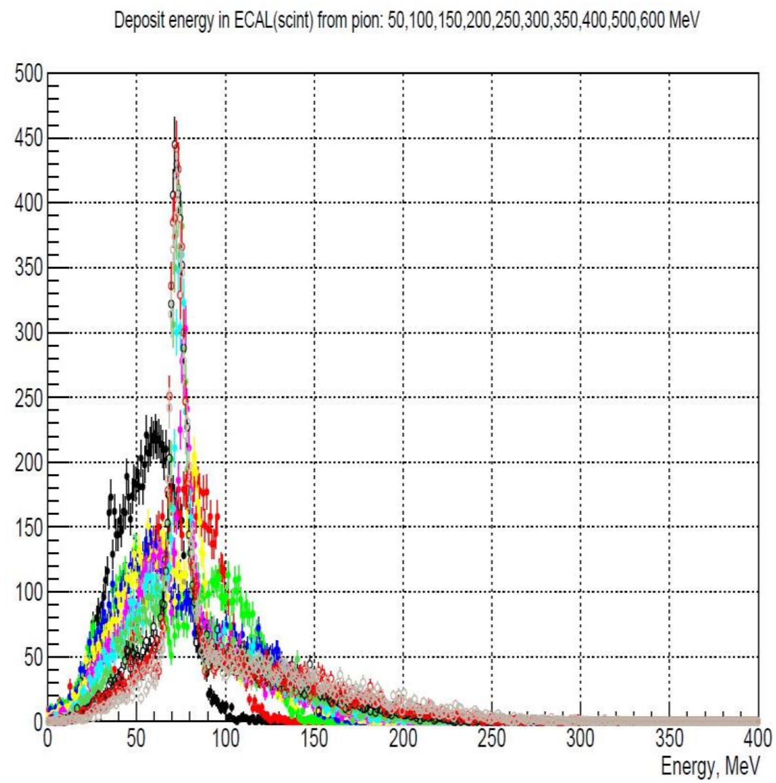


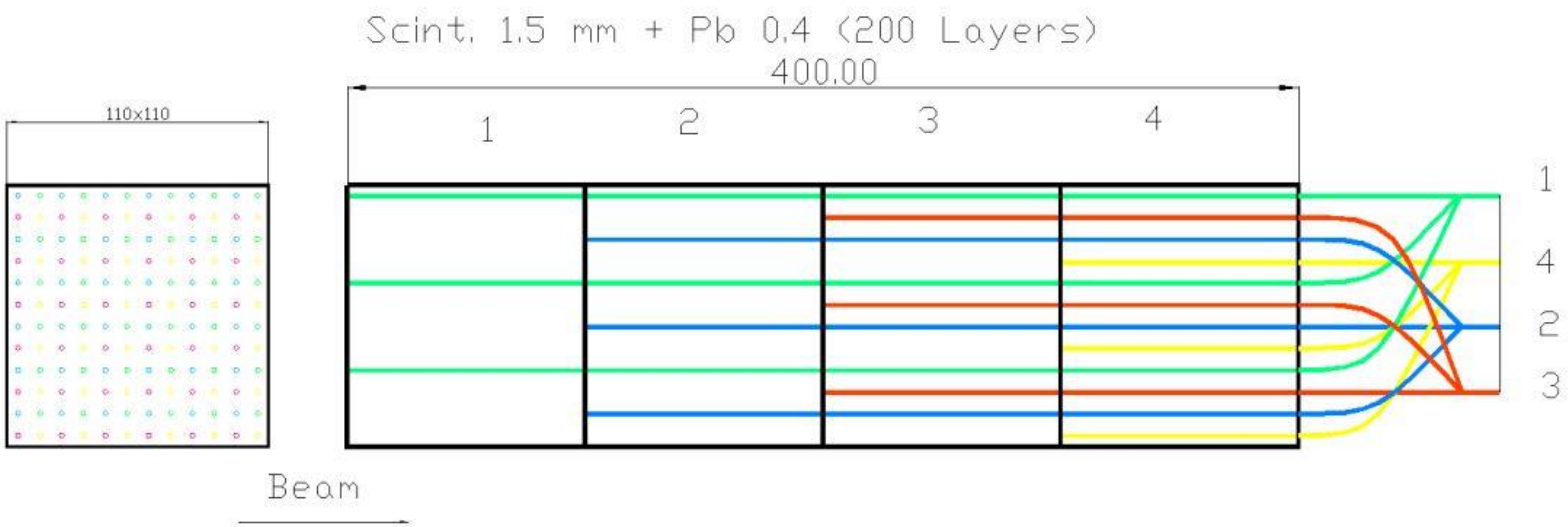
SPD ECAL : Lead + Plastic Scintillator-

220 Layers1.5 mm Sc + 0.3 mm Pb

4 – readout option (shown below)

2 – double readout – simples case

Longitudinal segmentation – Monte-carlo simulation is needed to obtain e/pi rejection factor



SPD ECAL

Printed Board for 4 SiPm’s:

S.Tereshchenko (DLNP)

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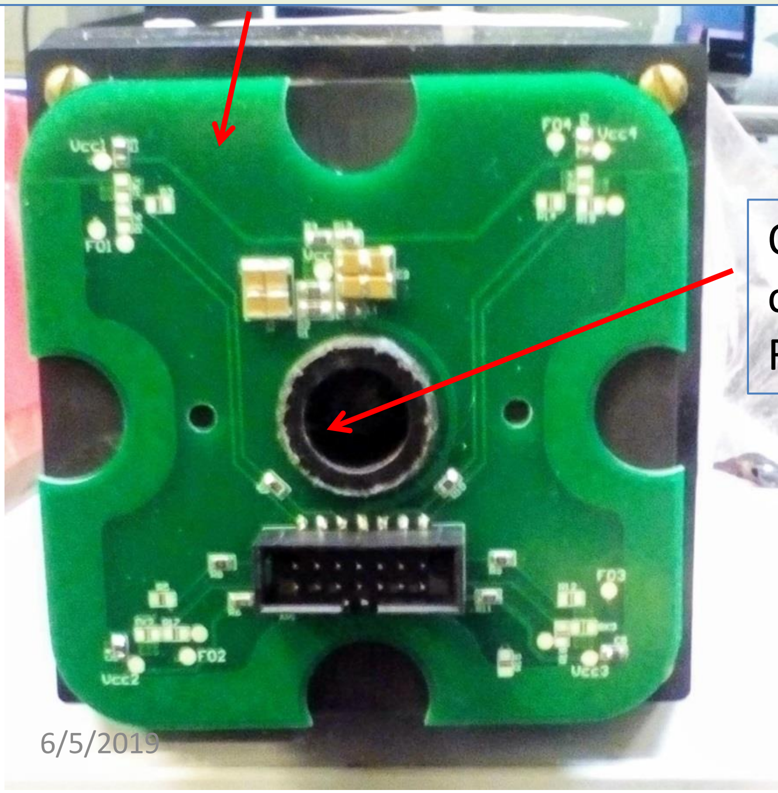
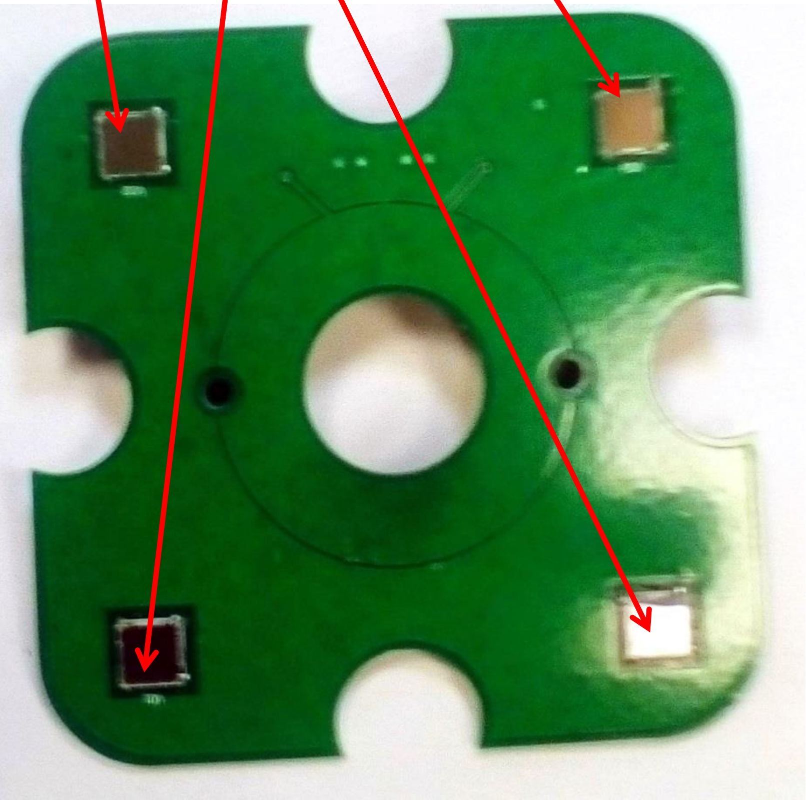
Printed Board with 4 SiPm and one connector for HV. The temperature sensor used for HV control to diode amplitude stabilization.



Optical connector For LED

4 SiPm 6x6 mm^2



SPD ECAL
Printed Board layout for 4 SiPm's
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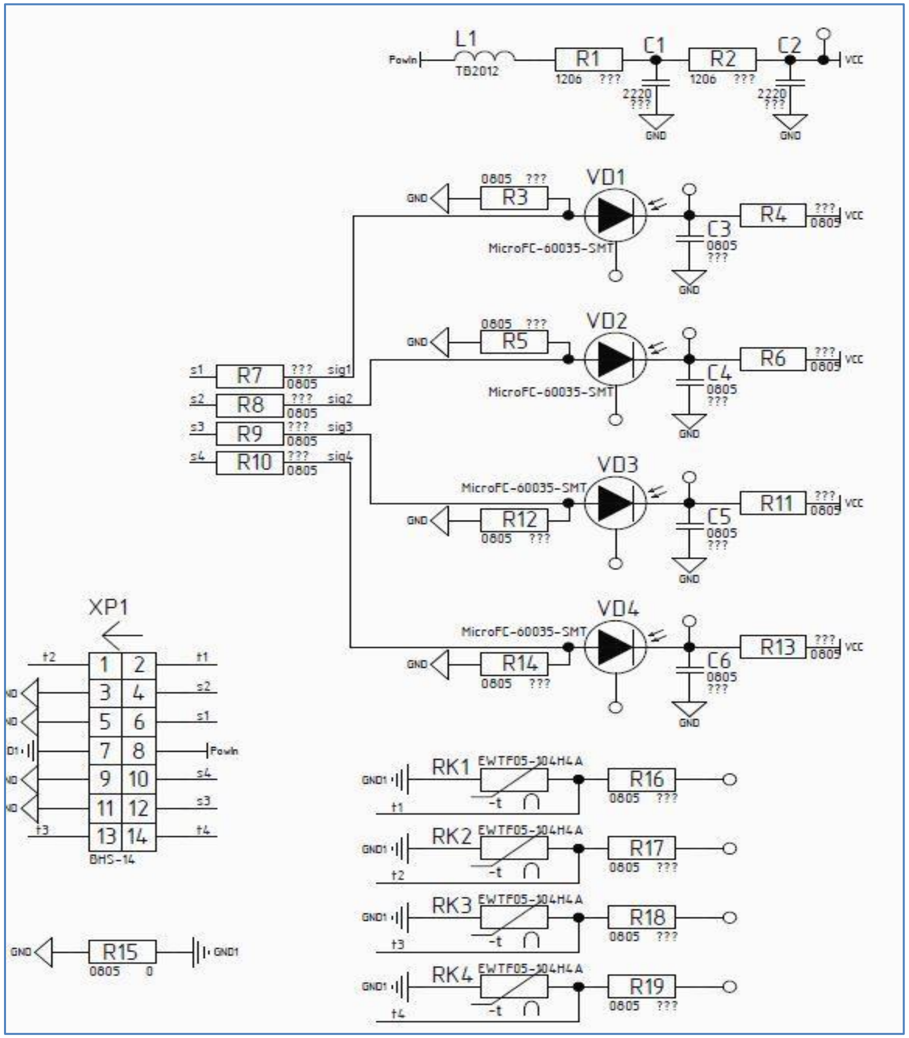
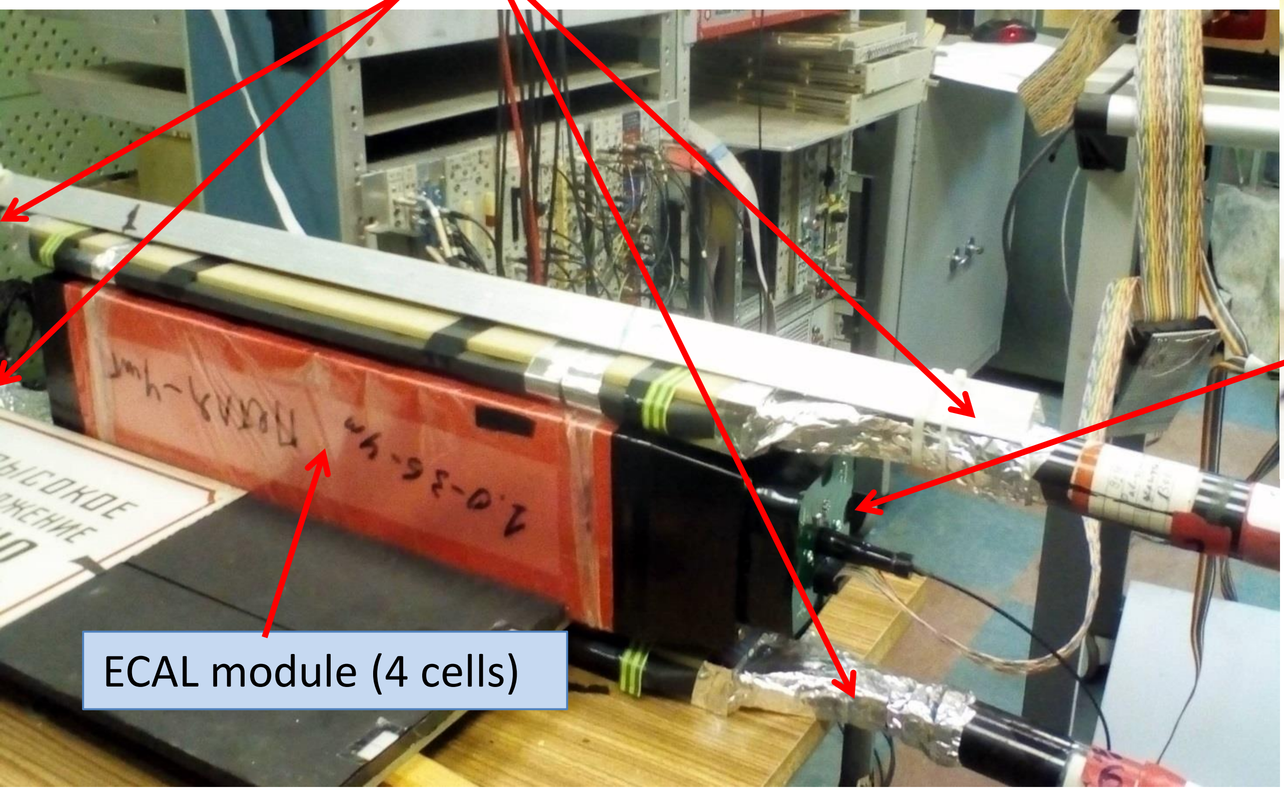
Printed Board layout with 4 SiPm and one connector for HV control is presented. The temperature sensors are used for HV control to diodes amplitude stabilization.



SPD ECAL

The cosmic test Setup for single module consisting from 4 cells 55x55 mm^2.

Two scintillation counters with double side readout and 4 fast PM's (9142) used for cosmic trigger.



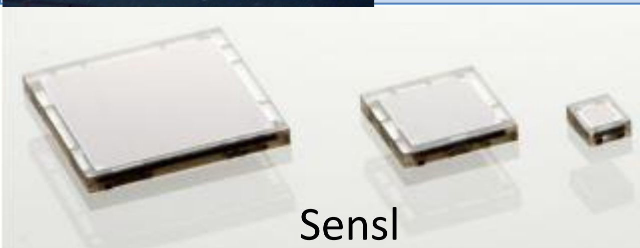
ECAL module (4 cells)

ADC-64 – digitizer unit

Photo sensors

Sensl: MicroFC-60035-SMT

HAMAMATSU: S13360-6025 (50) PE

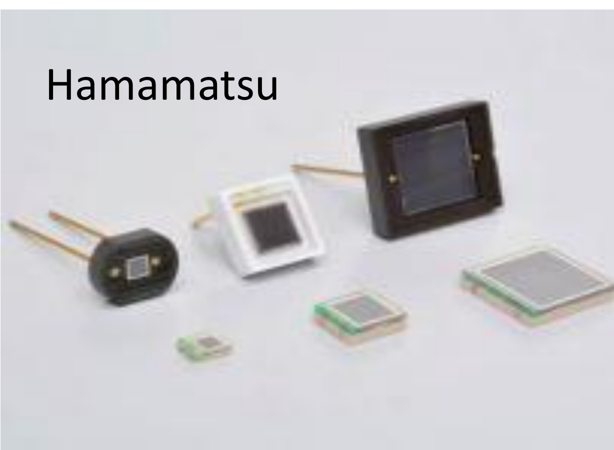


Type no.	Pixel pitch (μm)	Effective photosensitive area (mm)	Number of pixels	Package	Fill factor (%)
S13360-1325CS	25	1.3 × 1.3	2668	Ceramic	47
S13360-1325PE				Surface mount type	
S13360-3025CS		3.0 × 3.0	14400	Ceramic	
S13360-3025PE				Surface mount type	
S13360-6025CS		6.0 × 6.0	57600	Ceramic	
S13360-6025PE				Surface mount type	

http://sensl.com/downloads/ds/DS-MicroCseries.pdf
MicroFC-60035-SMT

Possible Silicon Multy-pixel Photomultiplier (Multy-Pixel Photon Counter) for ECal

https://www.hamamatsu.com/resources/pdf/ssd/s13360_series_kapd1052e.pdf - S13360-6025PE



Sensor Size	Microcell Size	Parameter [1]	Overvoltage	Min.	Typ.	Max.	Units
1mm	10μ, 20μ, 35μ, 50μ	Breakdown Voltage (Vbr) [3]		24.2		24.7	V
3mm	20μ, 35μ, 50μ						
6mm	35μ						
1mm	10μ, 20μ, 35μ, 50μ	Recommended overvoltage Range (Voltage above Vbr) [2]		1.0		5.0	V
3mm	20μ, 35μ, 50μ						
6mm	35μ						
1mm	10μ, 20μ, 35μ, 50μ	Spectral Range [4]		300		950	nm
3mm	20μ, 35μ, 50μ						
6mm	35μ						
1mm	10μ, 20μ, 35μ, 50μ	Peak Wavelength (λp)			420		nm
3mm	20μ, 35μ, 50μ						
6mm	35μ						

HAMAMATSU New Photo sensor S14160

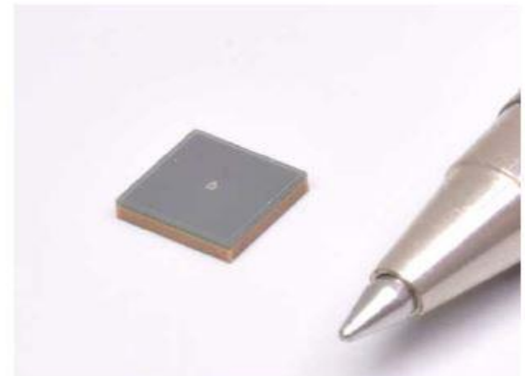
MPPC for scintillation — **S14160 series : 3x3, 4x4, 6x6mm^2**

Low Break down voltage type. — **S14161 series (1x1 icnch array)**

■ Overview

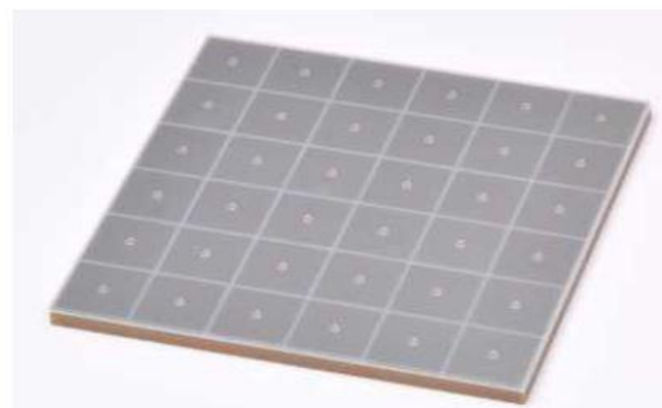
S14160/S14161 series achieve higher PDE and lower operation voltage than other MPPC to adapt for PET and radiation monitor application.

HWB type achieve small dead space in active area with HWB(Hole Wire Bonding) technology**(Patent pending)**. And the gap from active area edge to package edge is only 0.1mm.This package realizes the 4-side tileable arrangement.



■ Features

- Higher PDE (50% at λp, VBR+2.7V)
- Lower voltage (VBR=37V Typ.) operation
- Small active area dead space
- Low after pulse and cross-talk
- High gain: 10^5 ～10^6



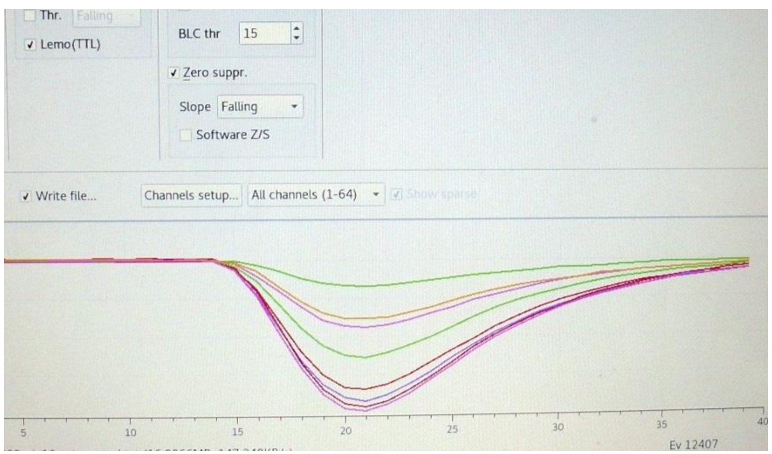
■ Application

- PET
- Radiation monitor

https://www.hamamatsu.com/eu/en/product/type/S14160-3050HS/index.html - S13360-6025PE

ADC_64 for ECAL

https://afi-project.jinr.ru/projects/adc64-sw/files



ADC64 board for signals digitizing

https://afi-project.jinr.ru/projects/adc64-sw/files

As FE electronics unit we have designed and constructed ADC with 64 channels. ADC board is a waveform digitizer. It quantize analogue input signal and samples it at fixed time intervals.

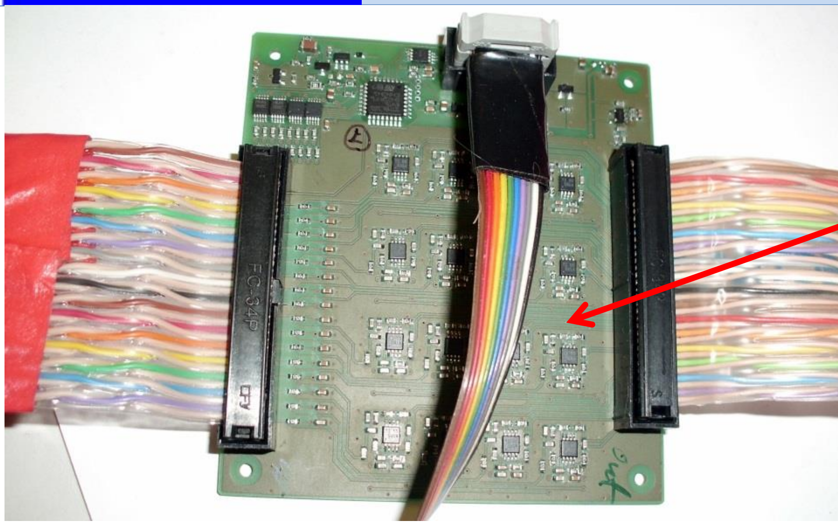
Zero suppression logic is based on baseline estimation and threshold value. Signal shaping is performed in digital form with FIR filters The ring type memory allows the read back of last 30 µs of waveforms.

The sampling rate is 64 MhZ.
Single sample digitizing accuracy is 12 bits

ADC-64 waveform with 30 samples window is shown.
Data taking in nuclear (Argon) Beam
BM&N – JINR – March 2018.

Preamplifier board (16 channels)

http://hvsys.ru./



Preamplifier board for signals shaping and HV control.

The board consist from 16 input-output channels for analogical signal shaping from SiPm, for temperature control and diodes bias power regulation.

These box can take care for 128 preamplifiers boards by flat cable of 5 pairs . Two line RS484 protocol used for HV control.

Control box for diodes bias power supplier.
Controlled by Ethernet (USB , or RS485) ports.

The electronic for slow control:

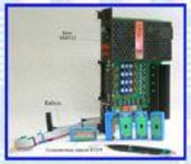
http://hvsys.ru./

1. Источники Высоковольтного питания детекторов от 0,5 до 15kV

Лабораторные блоки Высоковольтного питания;
Многоканальные системы Высоковольтного питания;
Применение: Газовые детекторы ионизирующих излучений; Питание ФЭУ (Фотоэлектронных умножителей); Питание микроканальных пластин (МКП); Нейтронные детекторы; Пьезо-электроника и пьезо-оптика; Ионная оптика.

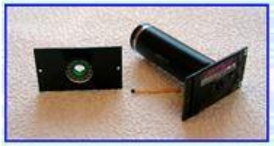
2. Источники питания полупроводниковых детекторов (до 500V).

Многоканальные системы смещения SiPM, APD, Si-детекторов;
Применение: Многоканальные распределенные системы смещения П/П детекторов; Сцинтилляционные детекторы ионизирующих излучений; Кремниевые детекторы ионизирующих излучений; Лавинные фотодиоды.



3. Высоковольтные системы питания ФЭУ

Cockroft-Walton системы питания ФЭУ.
Многоканальные распределенные системы питания ФЭУ.
Применение: Многоканальные детекторы на основе ФЭУ в больших ядерно-физических установках (30 – 10000 каналов).



4. Устройства автономного (батарейного) питания ФЭУ.

Применение: Портативная низкопотребляющая аппаратура с использованием ФЭУ; Портативные дозиметры; UV детекторы пламени; Бортовые приборы с использованием ФЭУ; USB - питание ФЭУ.

5. Светодиодные источники калиброванных вспышек света.

Применение: Системы калибровки в калориметрии ядерно-физической частиц; Многоканальные сцинтилляционные детекторы ядерно-физических установок.

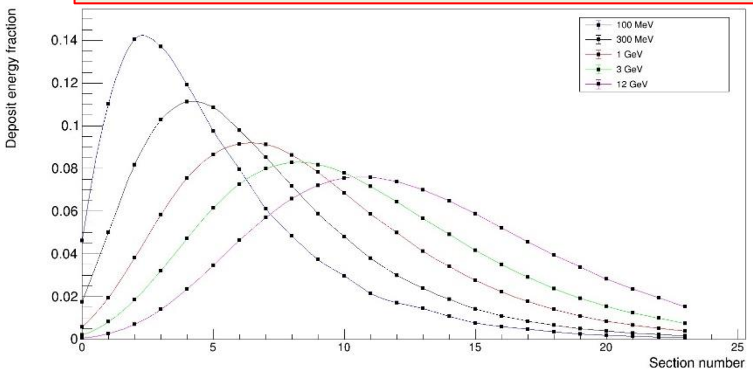
Activity at DLNP (Dzhelepov Laboratory of Nuclear Problems) with electromagnetic calorimeter for SPD

- Simulation – **where performed by Z.Usubov**
- Test zone on the electron beam LUE-200 – **we have plane start in 2019 SPD ECAL prototype test with electrons 50-200 MeV.**
- The measurements with prototype – **will be done soon.**

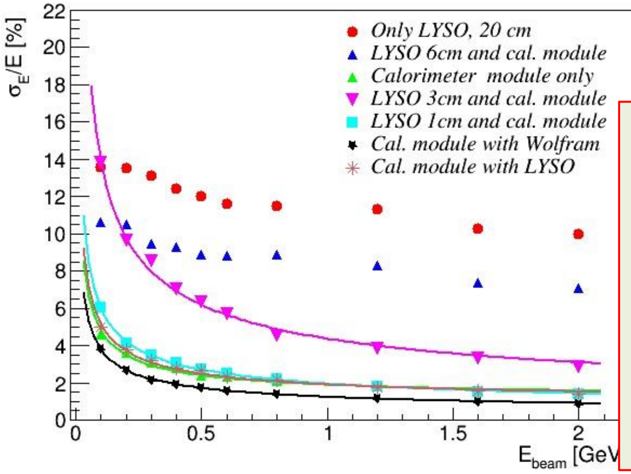
Participants (now) – V. Glagolev, D. Demin, V. Duginov, Z. Tsamalaidze, Z. Usubov, I.Zimin, V.Tkachenko, S.Tereshchenko

Activity at DLNP with electromagnetic calorimeter for SPD

Longitudinal Shower profile in 240 layers (kopio module)



Test zone on the electron beam LUE-200



ECAL Energy resolution:

LYSO – crystal

Pb (Lead)

W (Tungsten)

LYSO & Pb

SPD Electromagnetic Calorimeter

O. Gavrishchuk, JINR, Dubna

Thanks everybody for attention !
Welcome to joint in collaboration.