Forward Hadron Calorimeter for MPD at NICA –Status and Performance

A.Ivashkin, F.Guber and A.Strizhak
Institute for Nuclear Research RAS, Moscow
on behalf of the FHCal group

- **FHCal in MPD/NICA setup;**
- **Tasks of FHCal ;**
- **Status of FHCal modules production;**
- **Front-End-Electronics;**
- **Tests of FHCal modules with cosmic muons;**
- **Integration to MPD;**
- **Summary.**

4rd MPD collaboration meeting, Oct., 2019.
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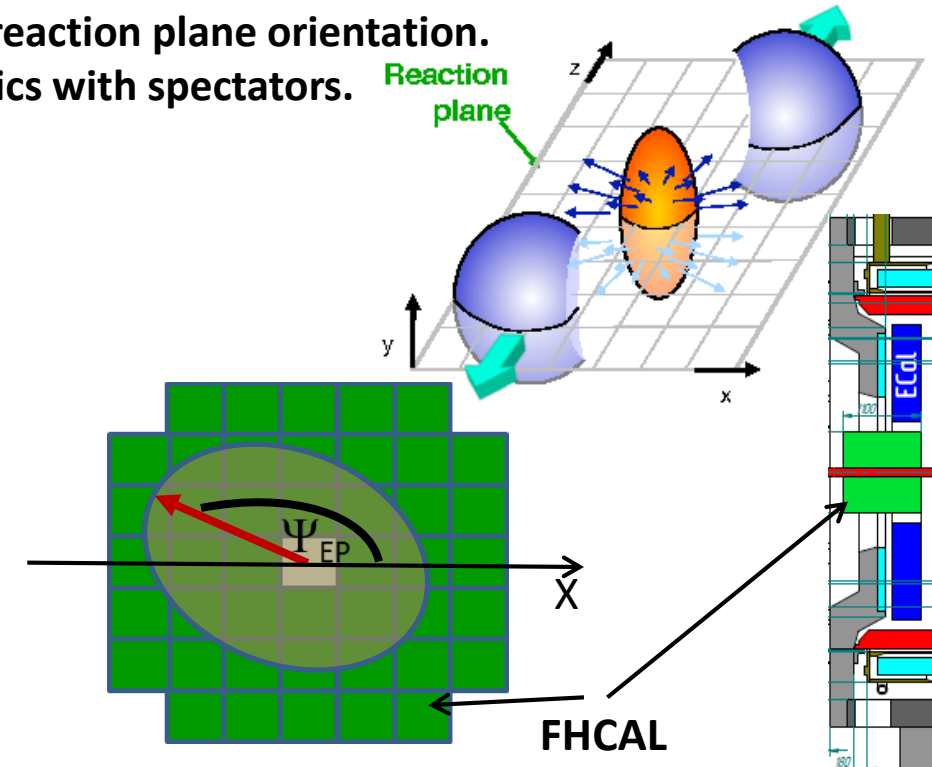
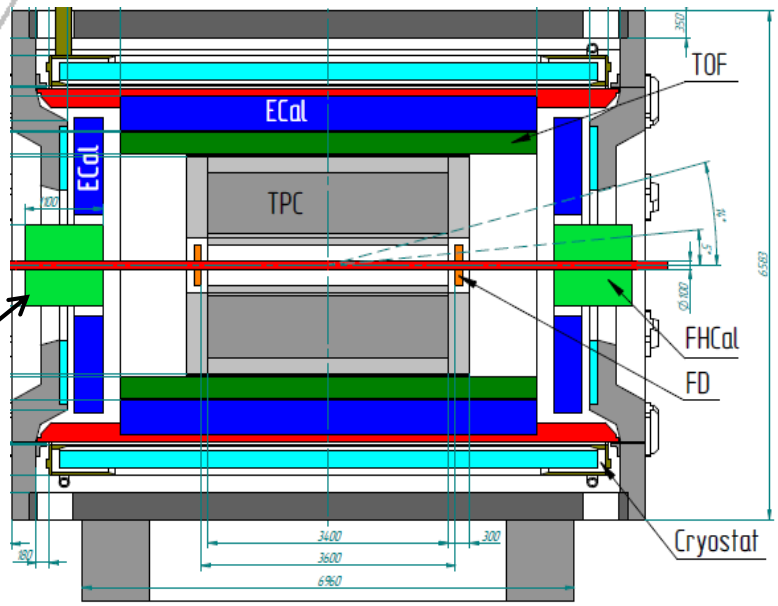
The forward hadron calorimeter in MPD setup

Tasks: detection of spectators to measure:

a) The centrality of the collision;
b) The reaction plane orientation.
c) Physics with spectators.

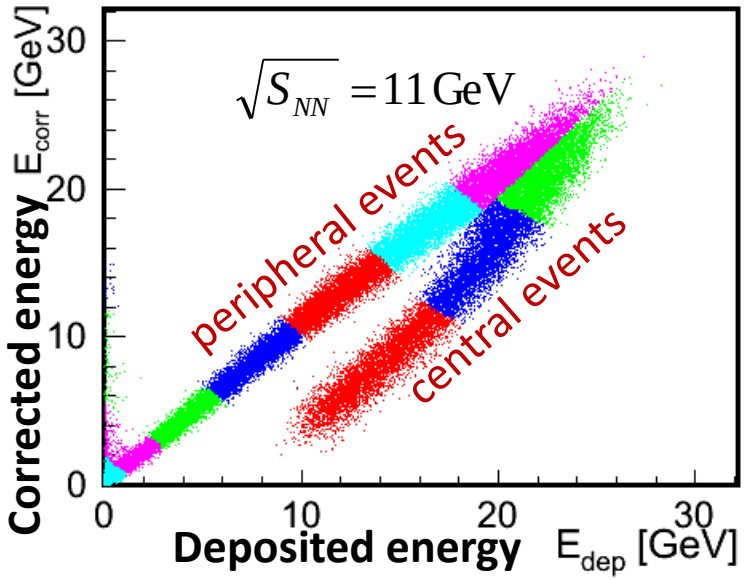




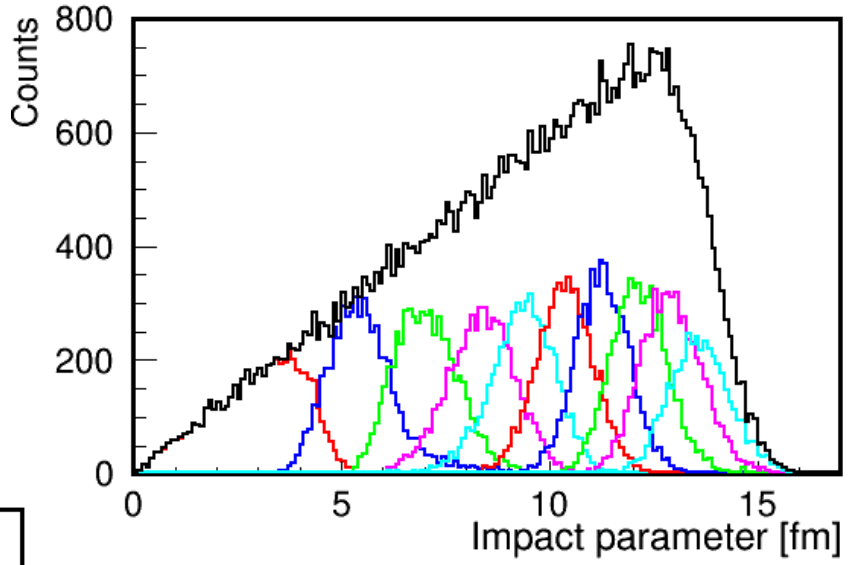
- <u>Two parts of hadron calorimeter</u> at opposite sides in forward regions.
- At the distance 3.2 meters from the interaction point.
- Available acceptance corresponds to pseudorapidity $2.0<\eta<5.0$

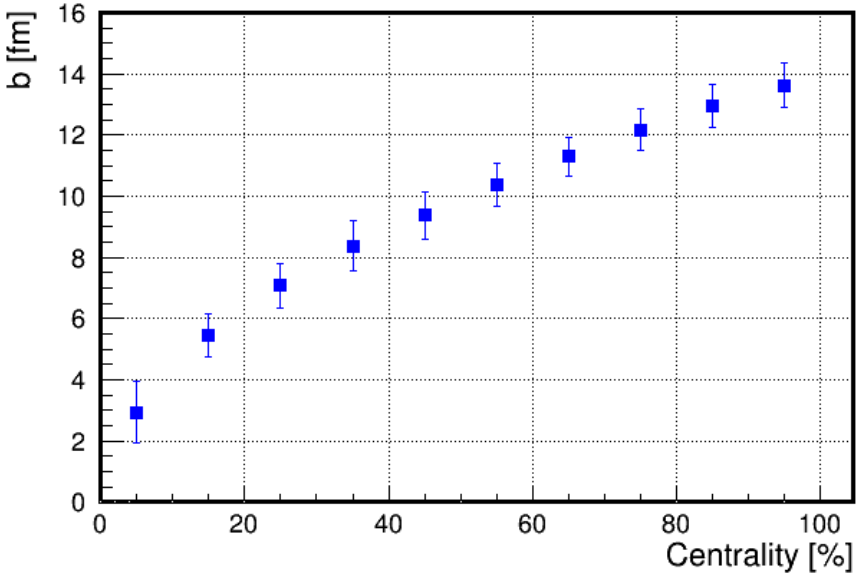
FHCAL consists of 2x44 modules of ~1.1x1.1 m^2 each part.

FHCal physics performance -centrality.



Each color bin is 10% fractions of the total number of events (fraction of the total inelastic nucleus-nucleus cross section).



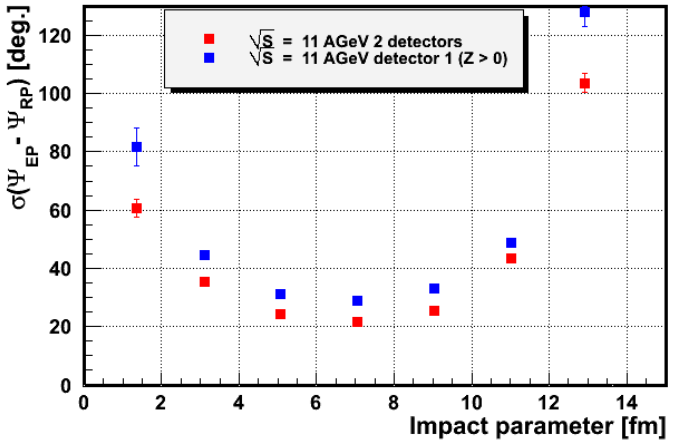


In spectator region the centrality resolution ~5-10% for mid-central events.

FHCal provides the impact parameter resolution practically the same as TPC.

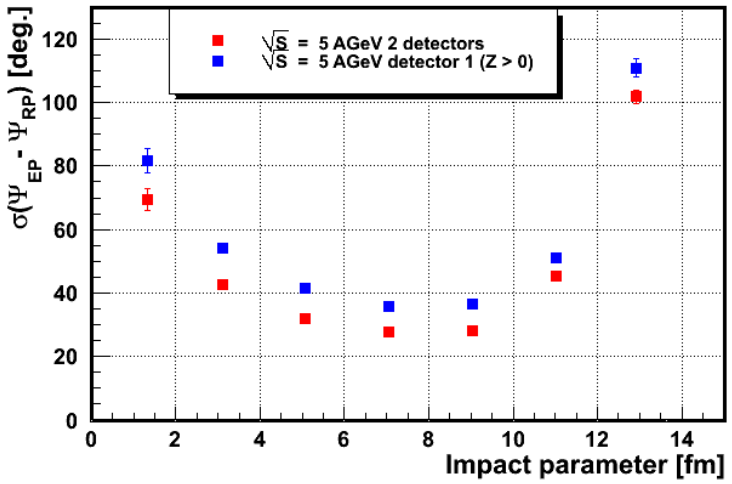
FHCal physics performance – reaction plane.

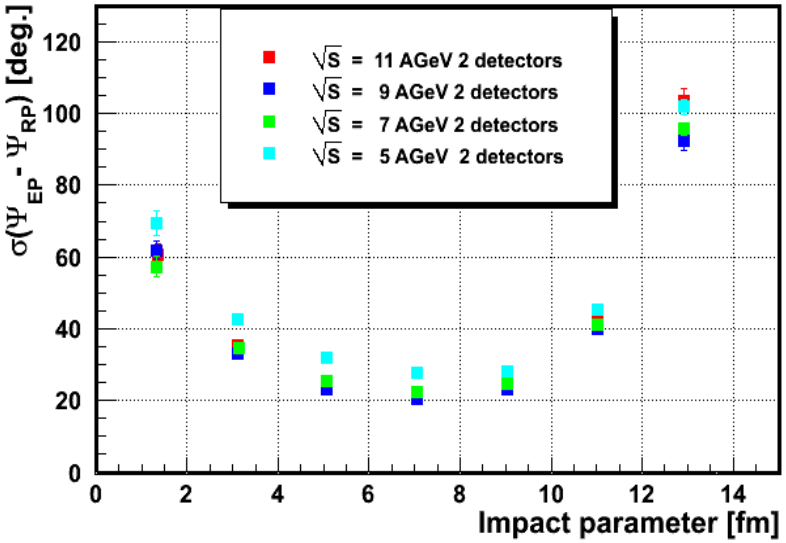
Modules 15x15 cm^2 are optimum choice and fit the transverse size of hadron showers (interaction length of lead+scint. λ_I~20 cm).



The event plane resolution of 20^0-25^0:

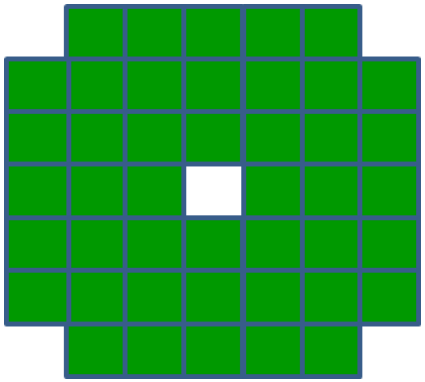
- **L/R parts of FHCal (maximum spectator multiplicity);**
- **no influence of magnet field.**





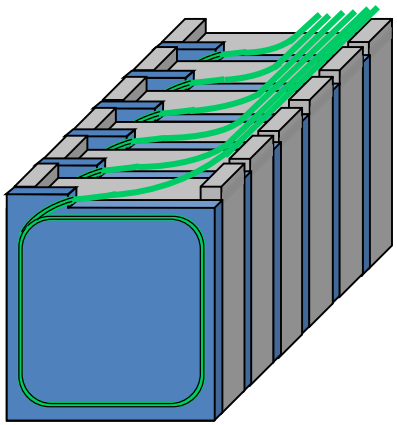
Structure of FHCal – two left/right parts.

Modular Lead/Scintillator sandwich compensating calorimeter.
Sampling ratio Pb:Scint=4:1.



Each part:

- 44 modules;
- Beam hole;
- Weight – 9 tons.

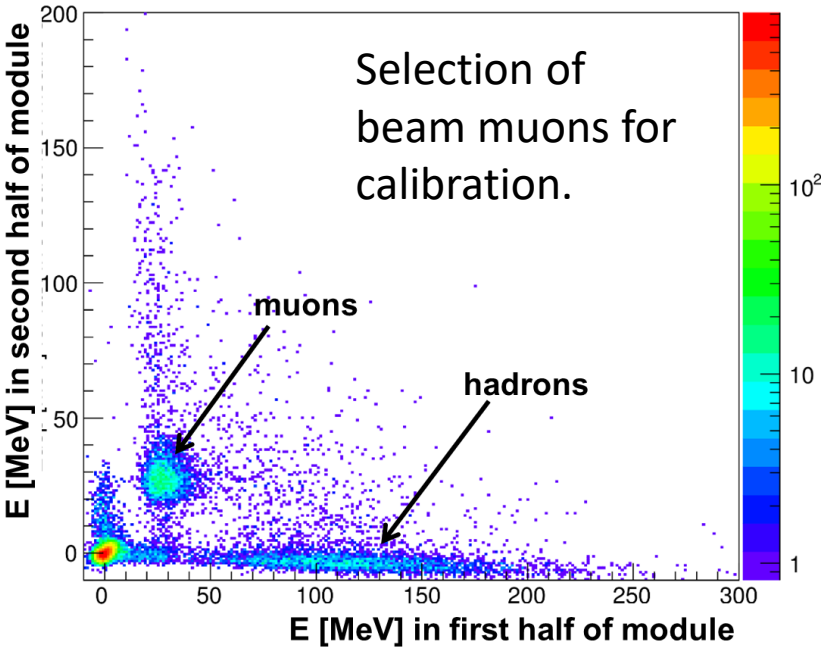


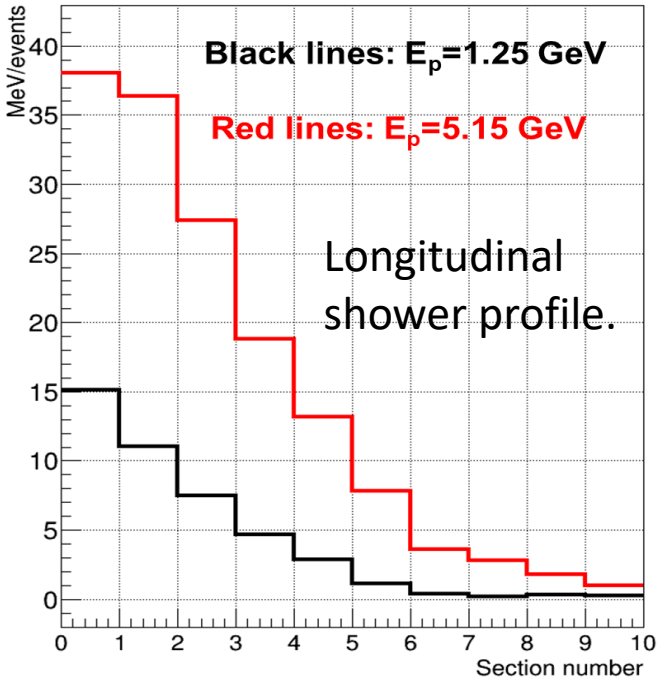
Light from scintillator tiles is captured by WLS-fibers and transported to SiPM.

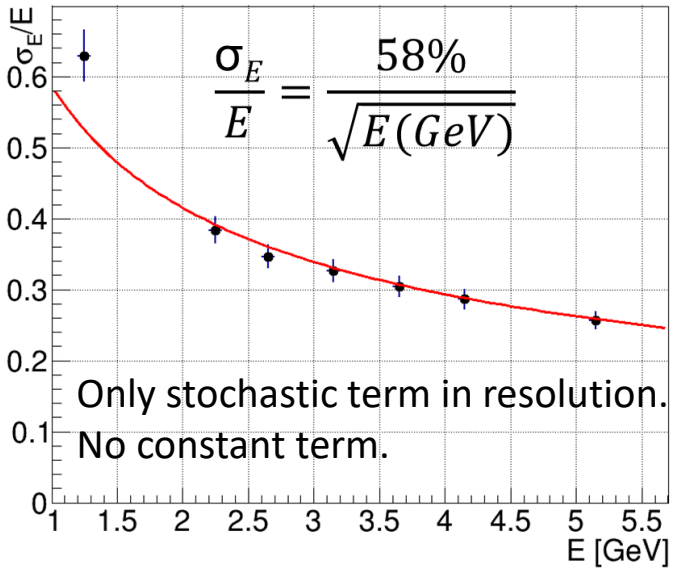
Each module:

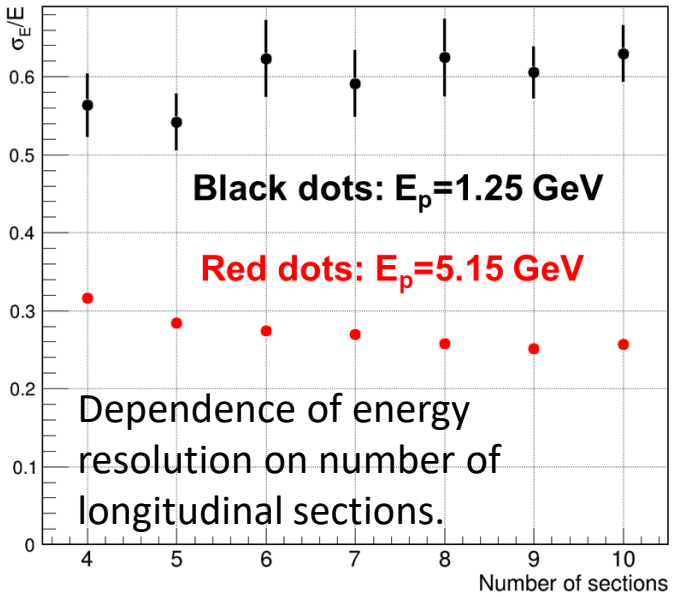
- Transverse size - 15x15cm^2 ;
- Total length - 106 cm.
- Interaction length ~4 λ_{int};
- Longitudinal segmentation – 7 sections;
- 1 section ~ 0.56λ_{int};
- 7 photodetectors/module;
- Photodetectors – silicon photomultipliers (SiPM).

Hadronic showers in FHCal modules (beam tests).

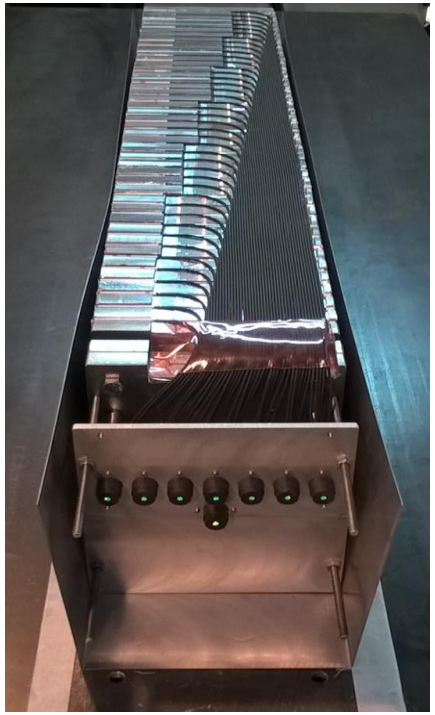


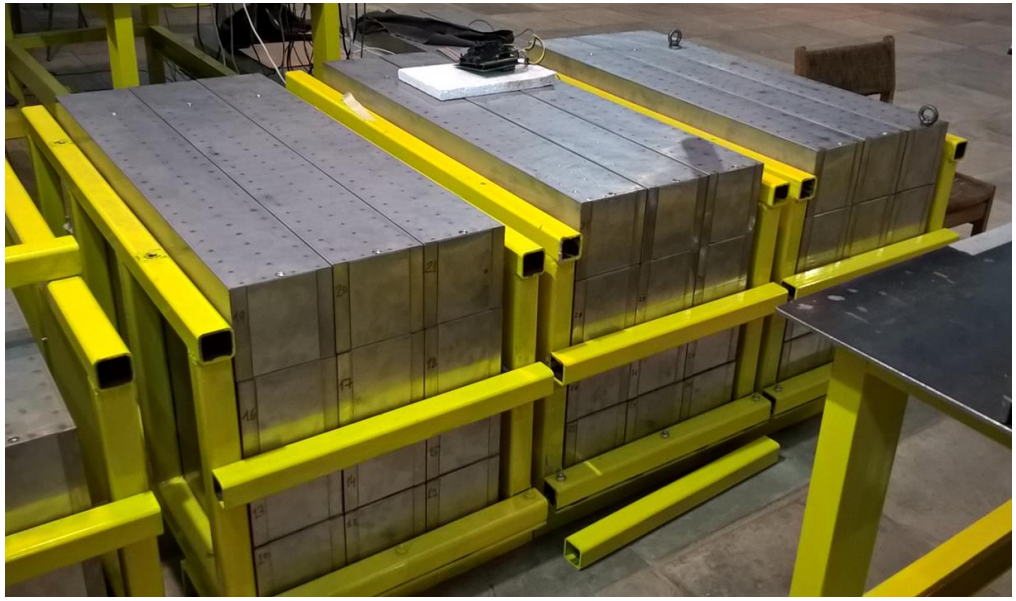


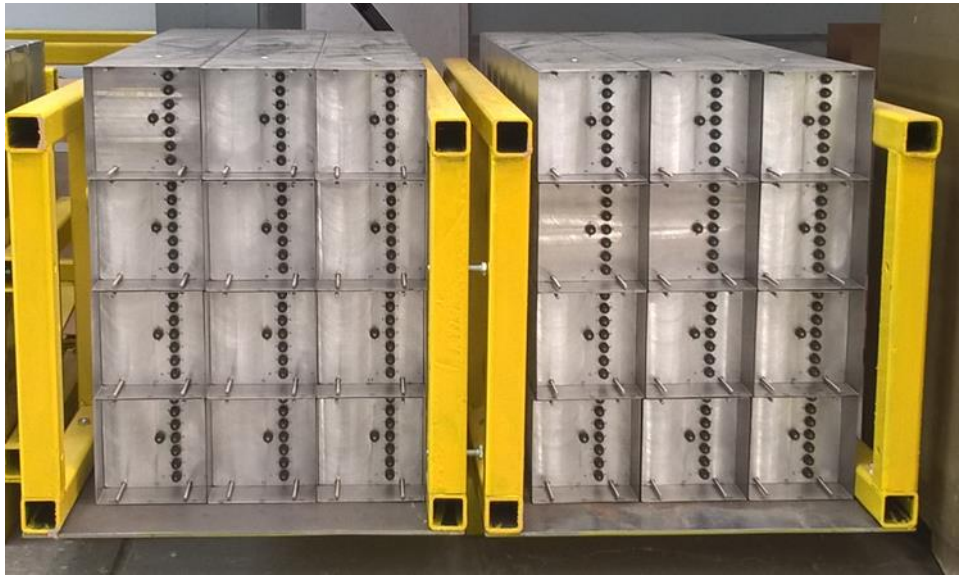




Status of FHCal modules production.







At present, all (90+spare) FHCal modules are produced and ready for the tests.

Tests with cosmic muons are going on.

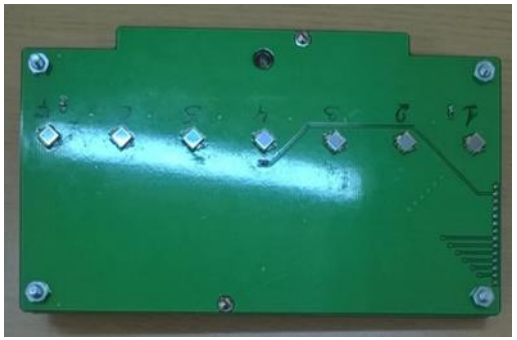
Photodiodes, FEE and readout electronics.

FEE with MPPC photodetectors is developed and under production now.

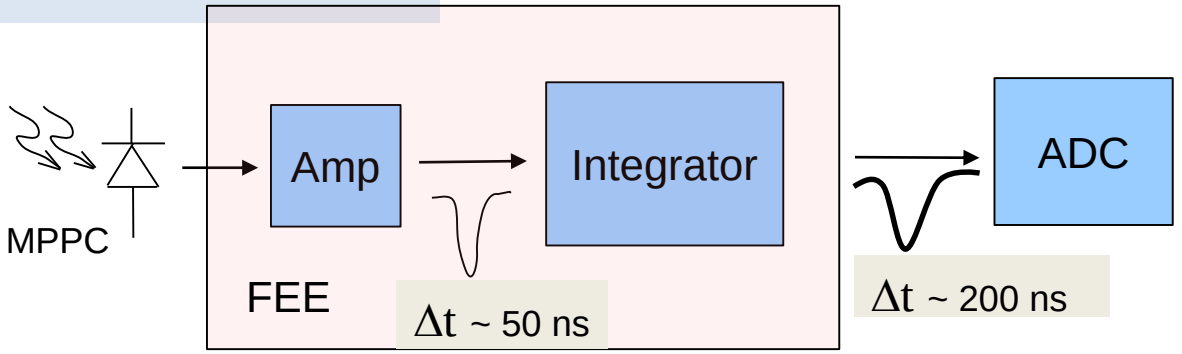
Photodetectors:

Hamamatsu MPPC: New development!
size – 3x3 mm²;
pixel -10x10 μm²;
PDE~18%.

Front-End-Electronics:



7 channels:
two-stage amplifiers;
HV channels;
LED calibration source.



The readout electronics:
FPGA based 64 channel ADC64 board, 62.5MS/s (AFI Electronics, JINR, Dubna).

Full readout chain was tested with cosmic muons and at beam!

Slow control and monitoring system.

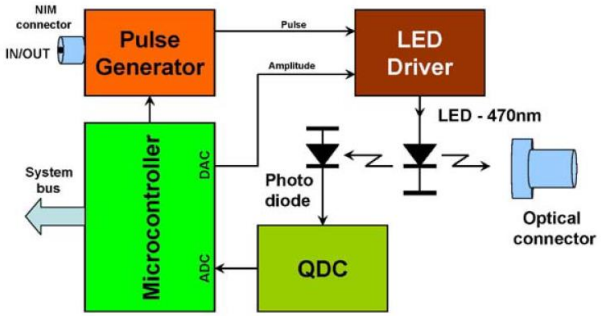
HV system and LED-monitoring is based on the developments of HVSYS Co., Dubna

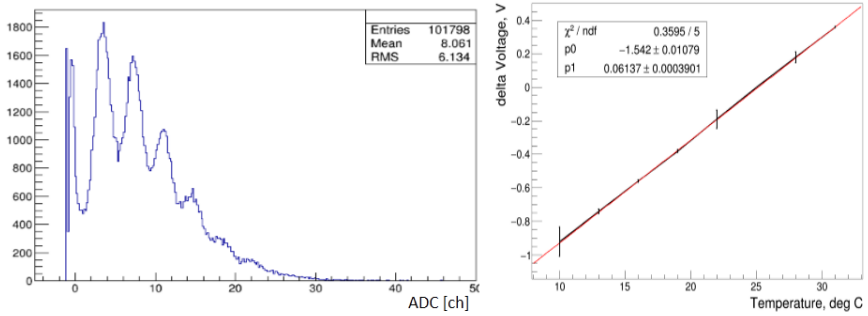
Tasks:

- **Control of HV at photodetectors (MPPC);**
- **Temperature control of photodetectors;**
- **Compensation of temperature drift of MPPC gain;**
- **Monitoring of MPPC gain with stabilized light source.**

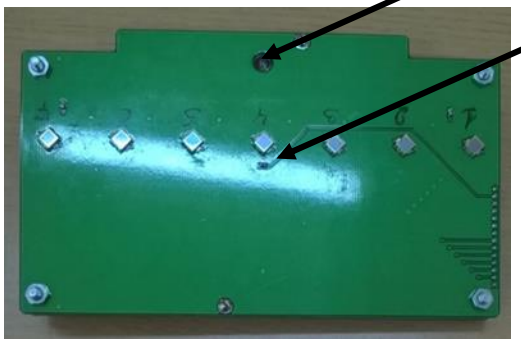
HV and SC system module

LED stabilized source





Dependence of MPPC gain on temperature.



LED

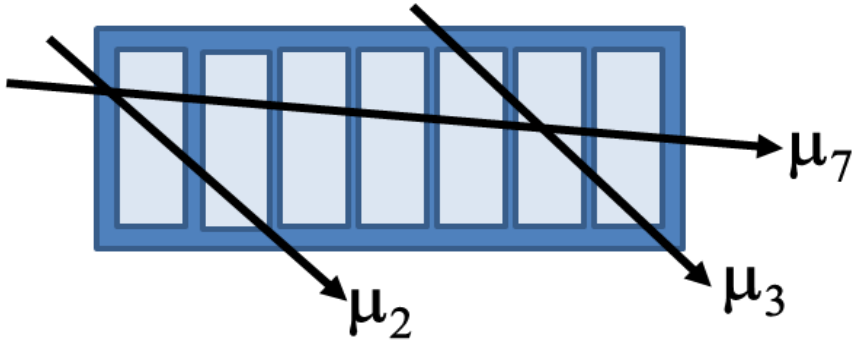
T-sensor

All MPPC are placed on Al-plate.

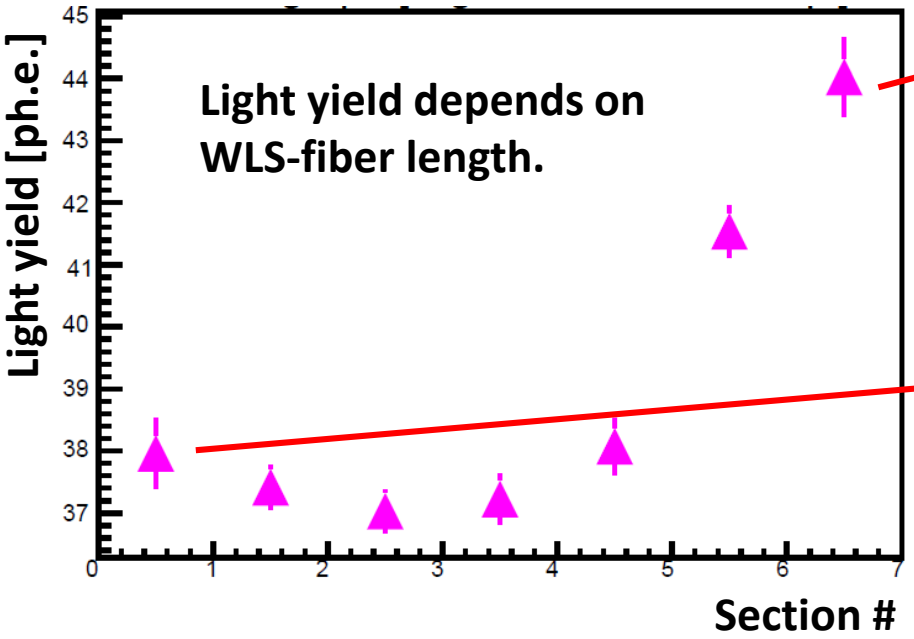
Test of calorimeter modules with cosmic muons.

Geometries of muon tracks in FHCal module.

Tracks passed through 2, 3 or all of 7 sections were studied.

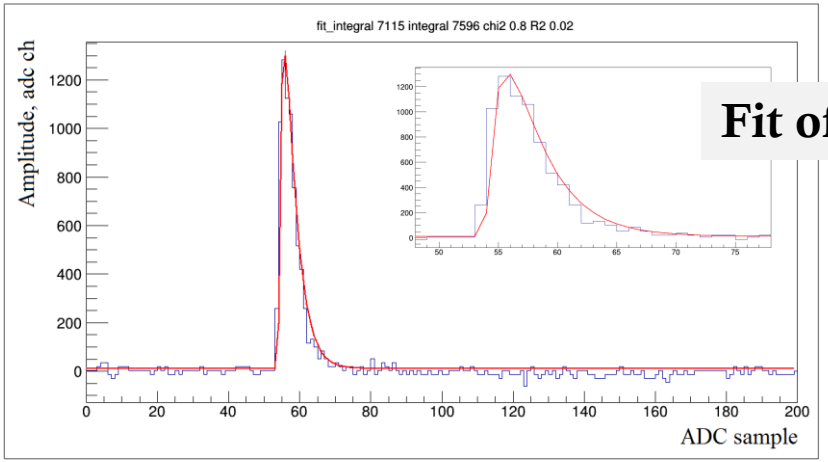


After assembling each module was tested.



Average light yield for 50 modules.

Cosmic muon calibration.

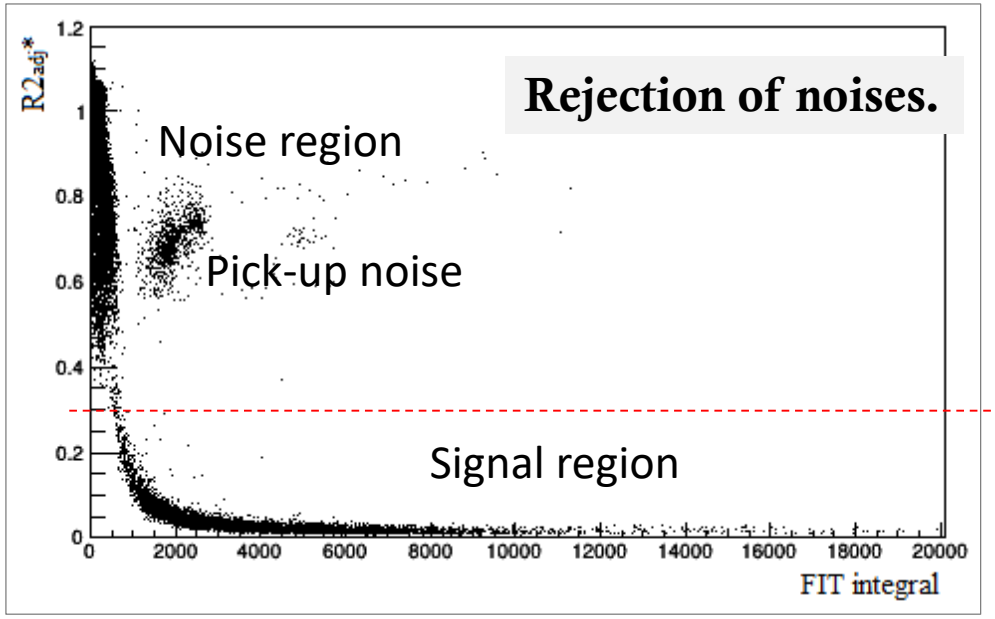


Fit of signals.

Coefficient of determination:

$$R^2 = \frac{\sum_{n=1}^{N}(x[n] - \hat{x}[n])^2}{\sum_{n=1}^{N}(x[n] - \overline{x})^2}$$

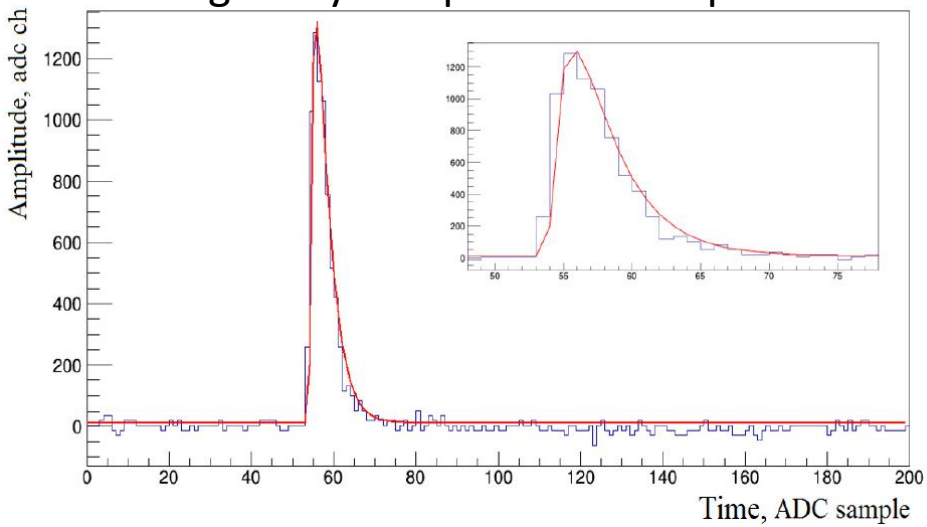
$x[n]$ *and* $\hat{x}[n]$ are the actual and calculated values of the explained variable, $\overline{x}$ is the sample average.



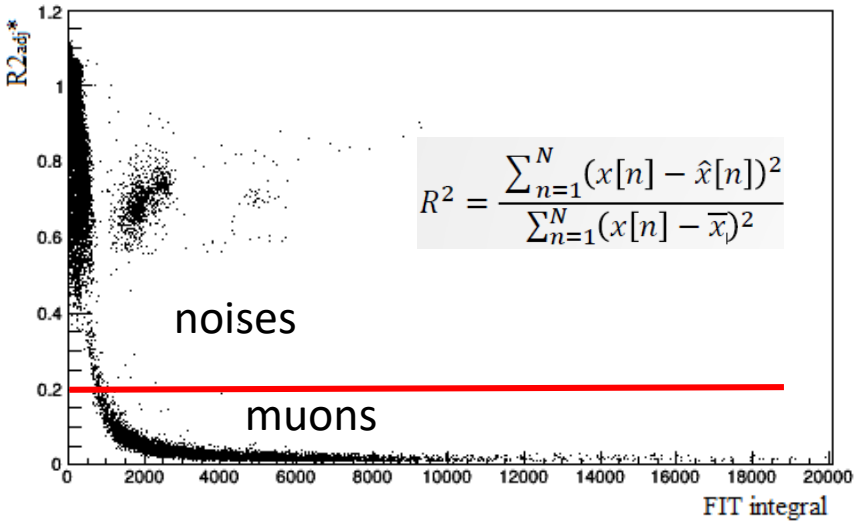
Rejection of noises.

Evaluation of cosmic muon spectrum (4 steps).

1. Fit signal by composition of exponents.

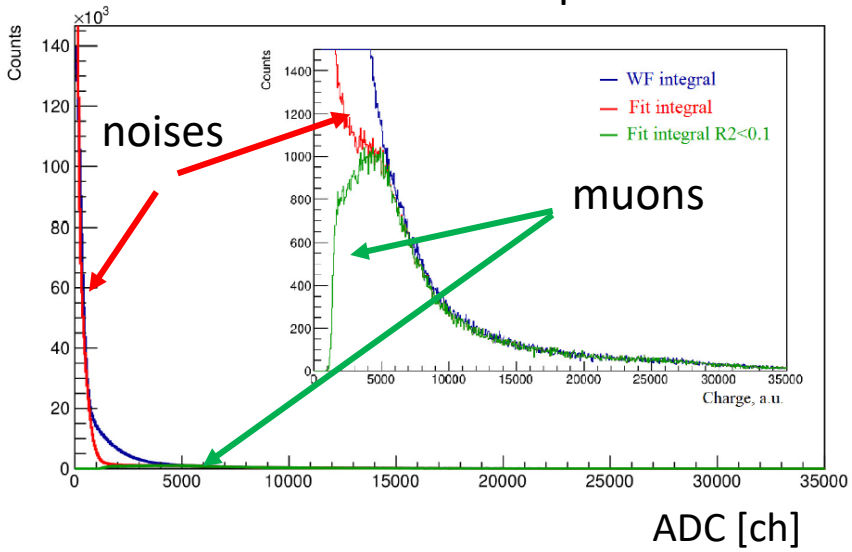


2. Rejection of noises with fit quality par.

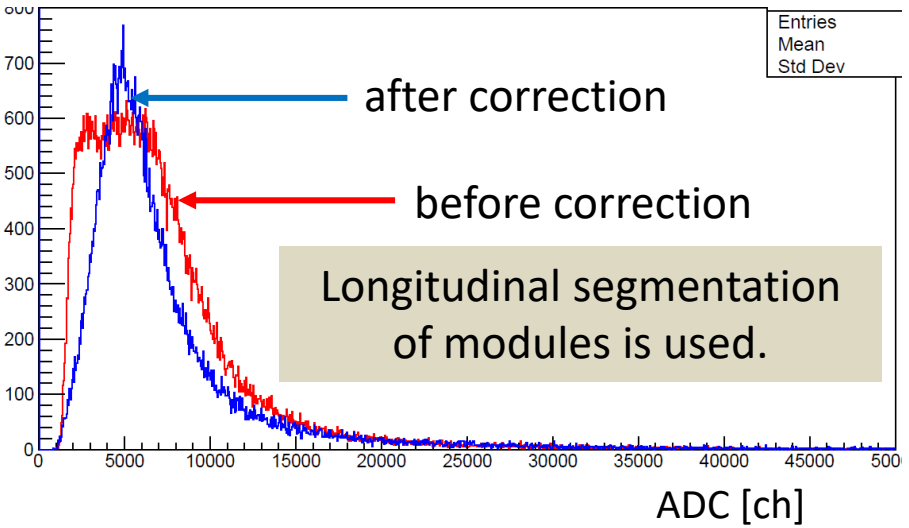


$$R^2 = \frac{\sum_{n=1}^{N}(x[n] - \hat{x}[n])^2}{\sum_{n=1}^{N}(x[n] - \overline{x_i})^2}$$

3. Extraction of muon spectrum

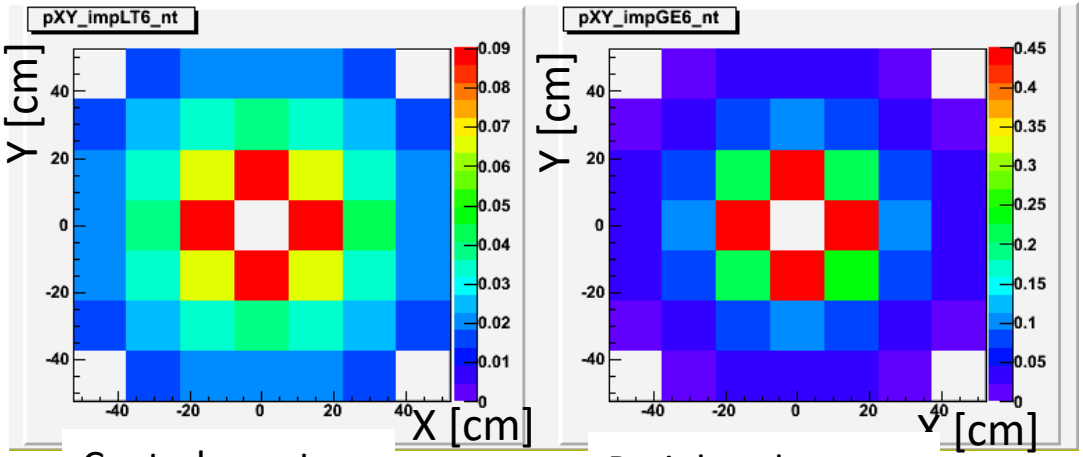


4. Correction for pass length in scintillators.



FHCal in trigger.

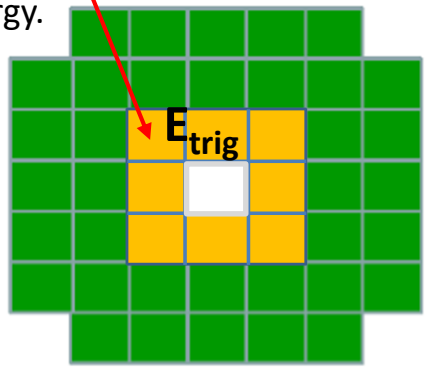
Can FHCal be used in trigger for minimum bias events?

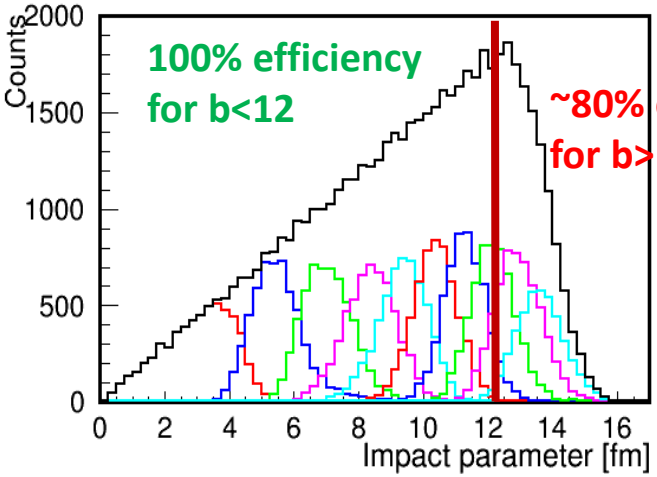


Central events

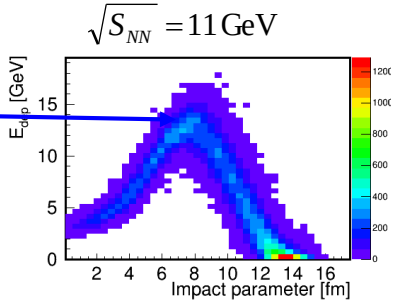
Peripheral events

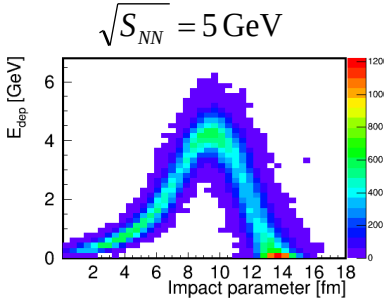
We select **only central** modules, where peripheral events deposit the energy.



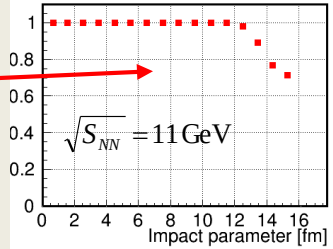


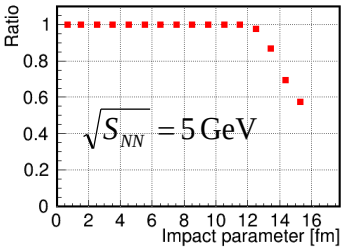
Energy depositions in central modules.





Trigger Efficiency
(Ratio of number of events above the threshold (50-100 MeV) to the number without threshould)



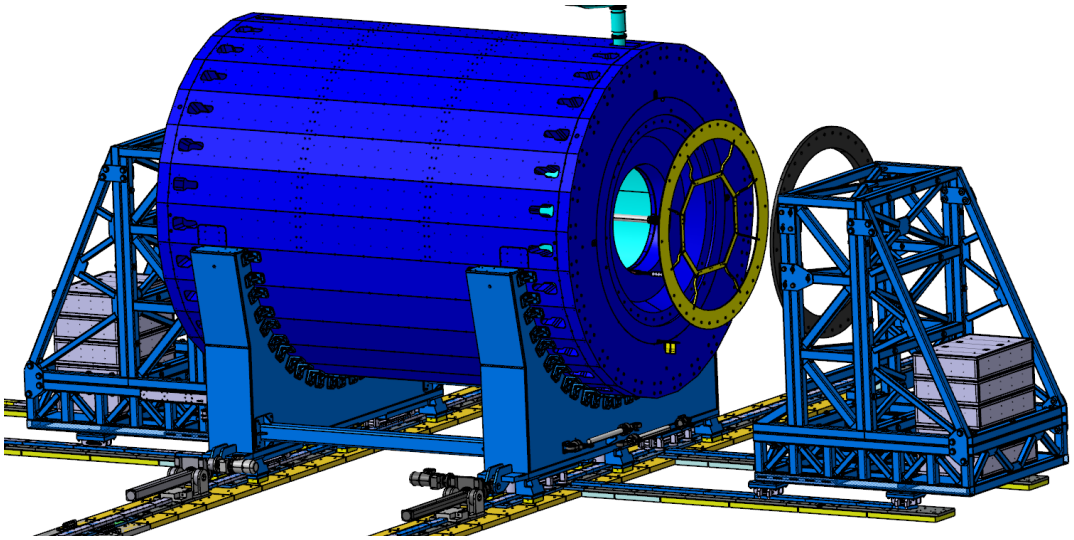


Threshold at the deposited energy larger than 50-100 MeV selects the peripheral events with impact parameter b<12 fm with ~100% efficiency. Trigger efficiency for events with b>12 fm drops significantly.

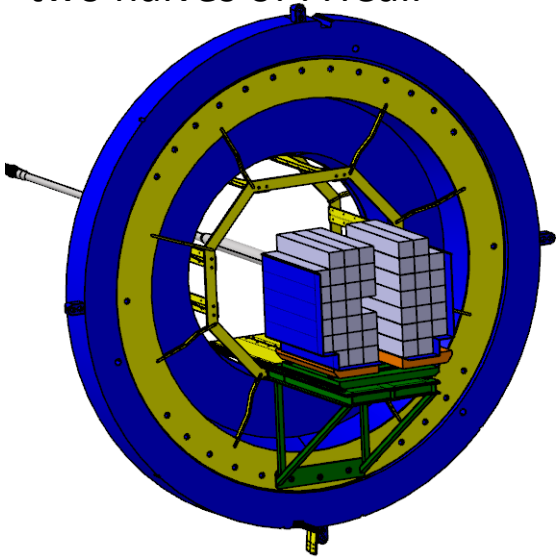
Integration in MPD –Platform.

(preliminary version)

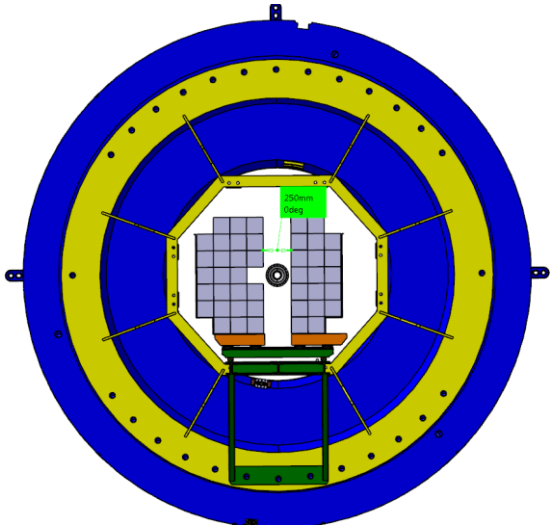
1. Installation of flange

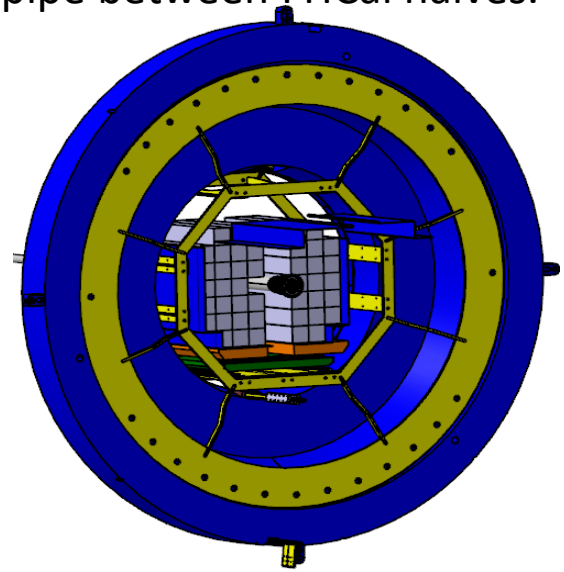


2. Iinstallation of platform and two halves of FHCal.

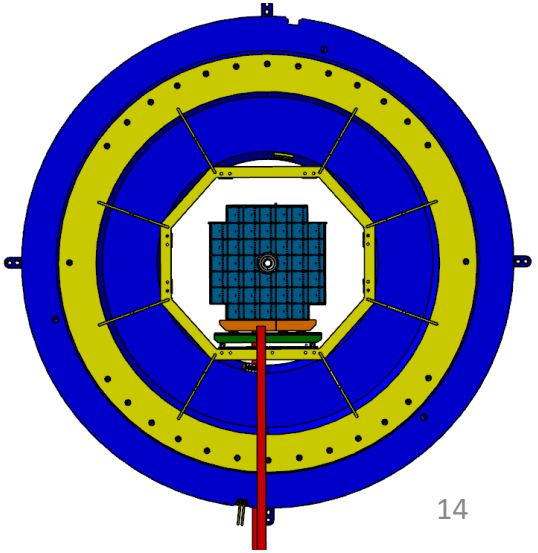


3. Mounting of support. Beam pipe between FHCal halves.



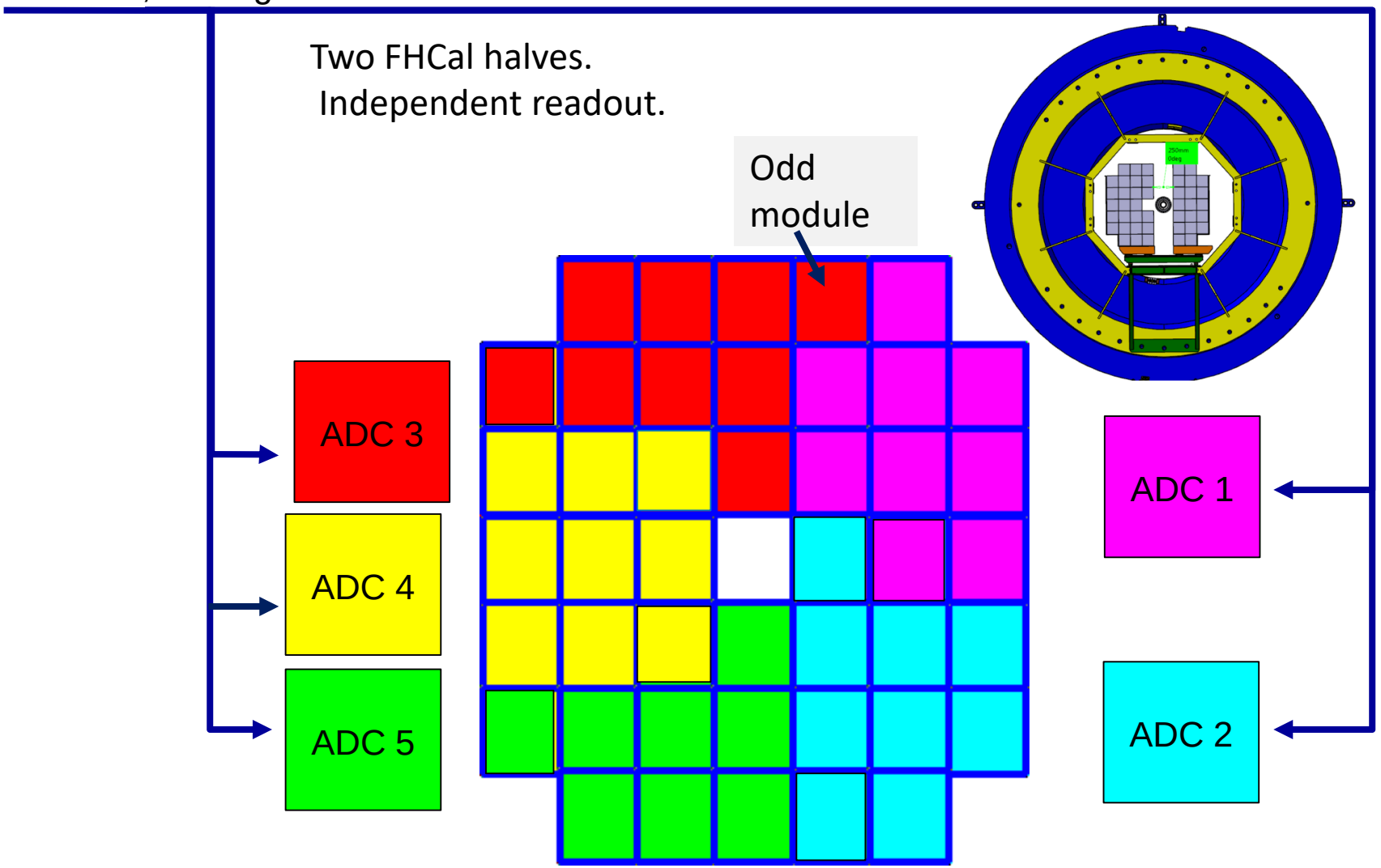


4. FHCal assembled.



Integration - readout. ADC positions.

(preliminary variant)



Summary and Open issues.

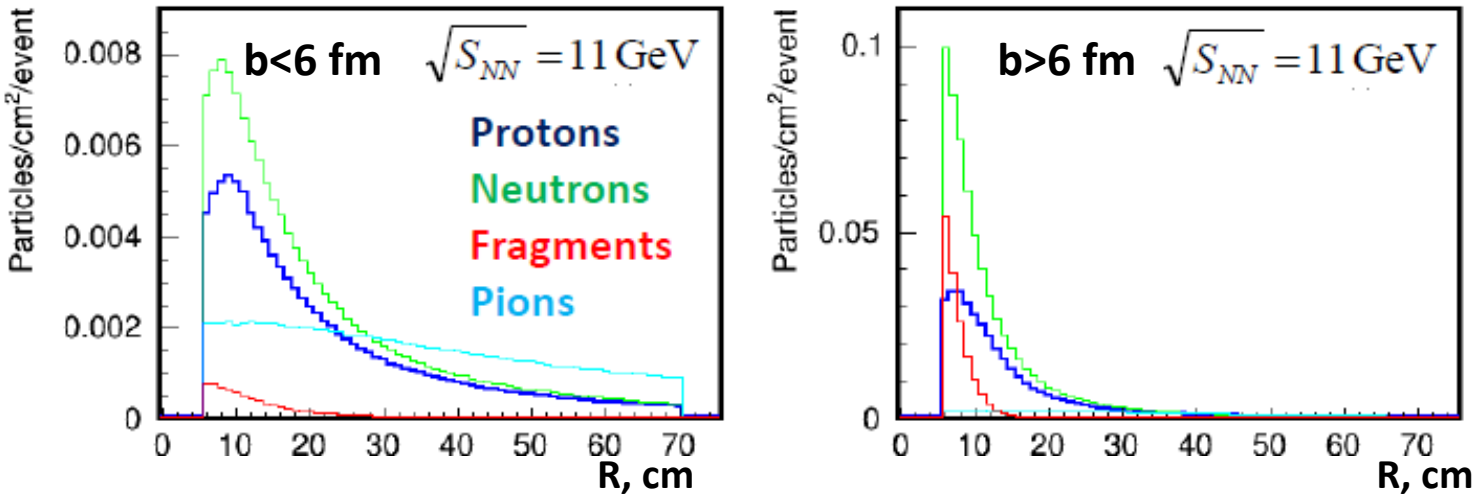
- All FHCal modules are assembled.
- Tests with cosmic muons are going on.
- FEE is in final stage of production.
- Slow control and readout – there are working versions.
- Energy calibration with cosmic muons is under development.

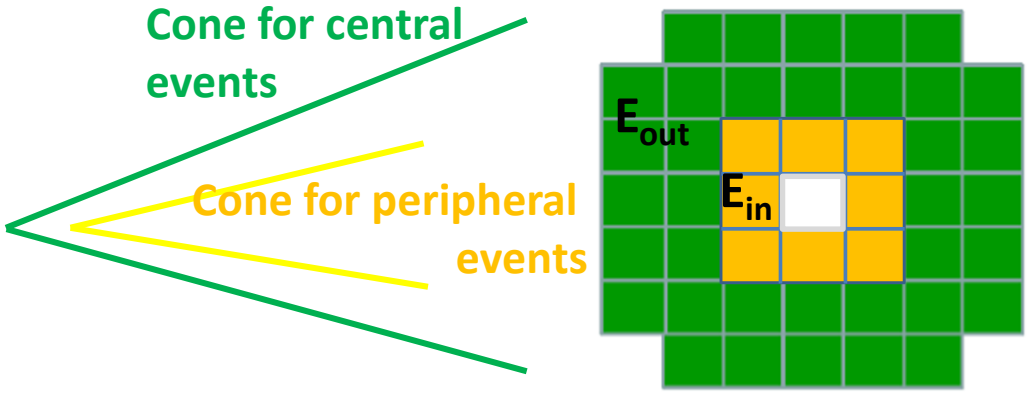
- Mechanical support. The preliminary version is under development.
- Integration with beam pipe.
- Mounting of readout electronics. Full integration to MPD.
- FHCal trigger. Fast adder of signals in central/all modules.
- Software for FHCal data analysis.
- Simulations: physics performance.

Thank you!

Spectators spots at FHCal surface have different sizes for different centralities.

Occupancy of particles at front of FHCal

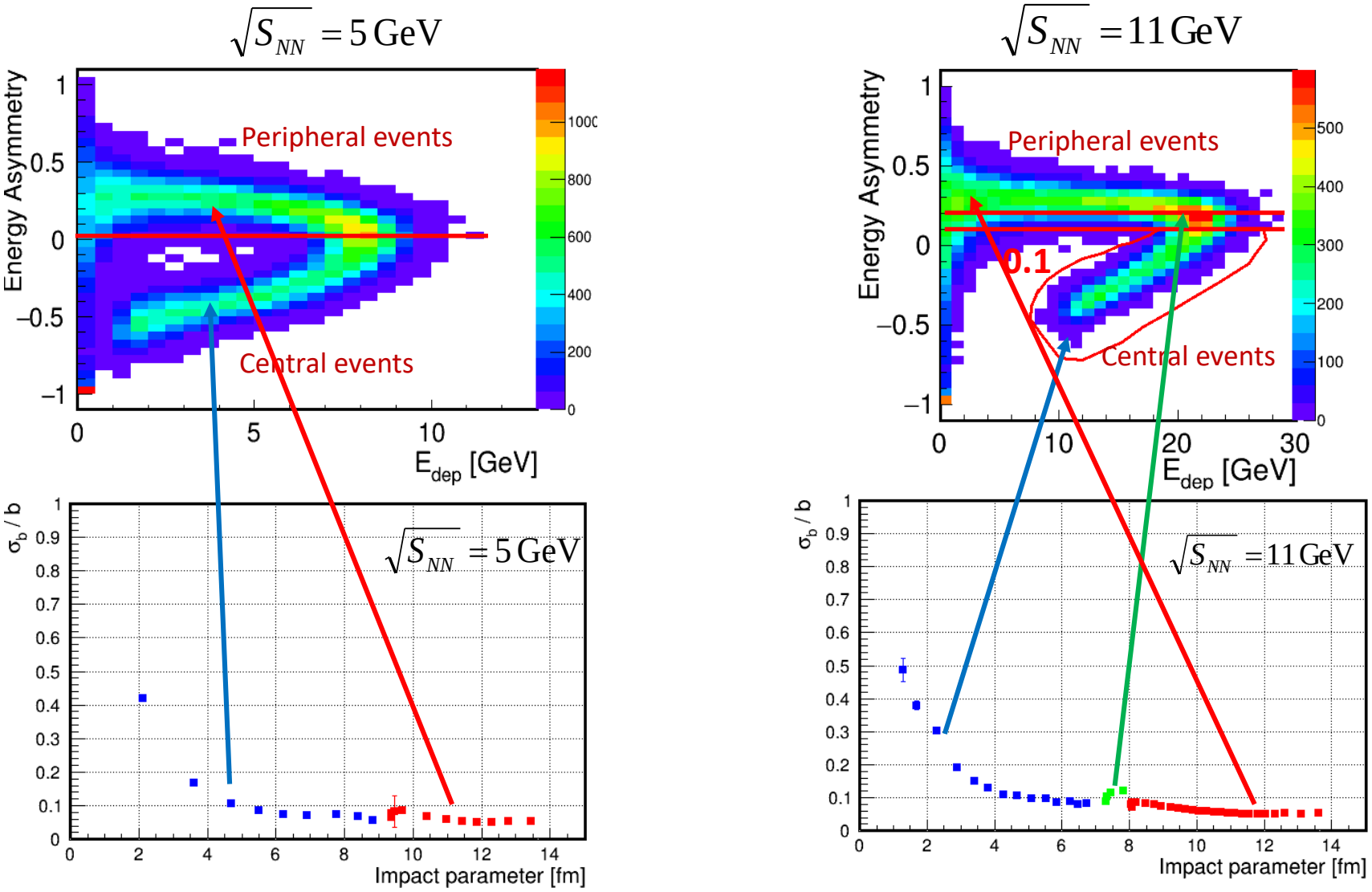




The energy deposition in inner and outer parts of calorimeter must be different for different centralities.

Let's introduce ***energy asymmetry:*** $A_E = \frac{E_{in} - E_{out}}{E_{in} + E_{out}}$

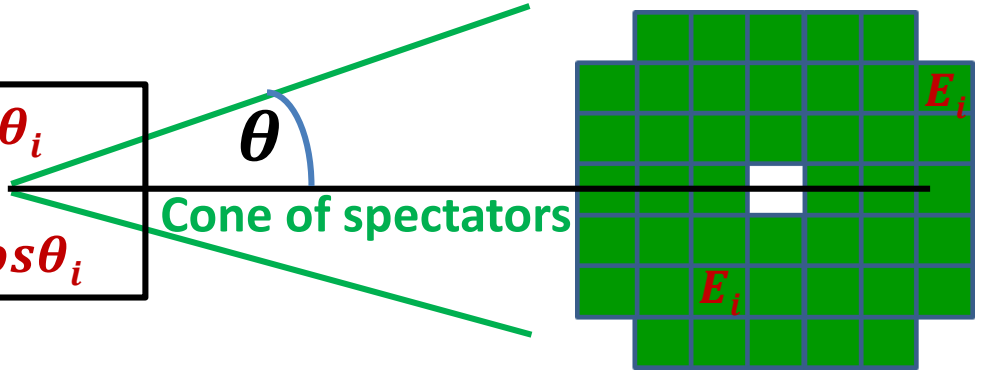
Centrality measurements with two FHCal observables (E_{dep} and A_E).

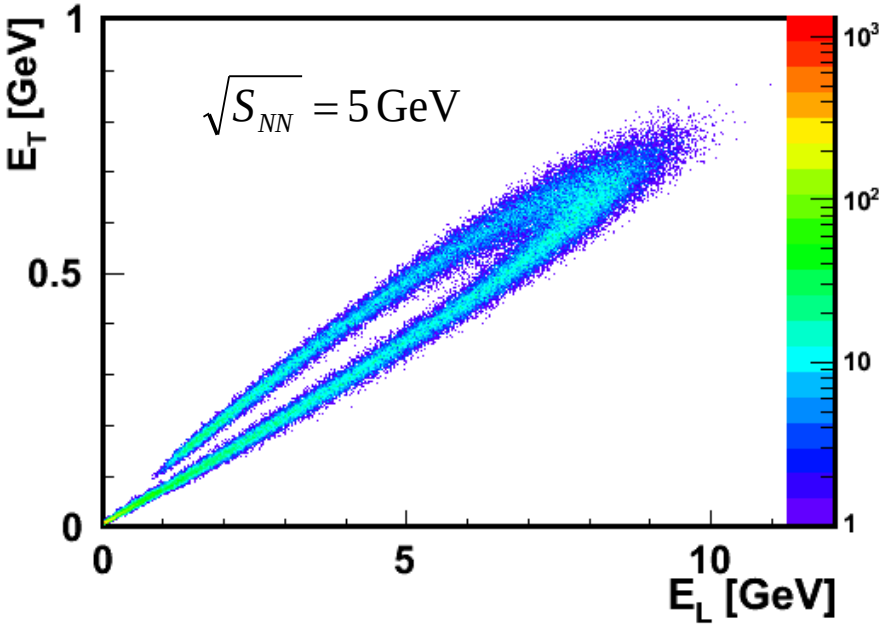


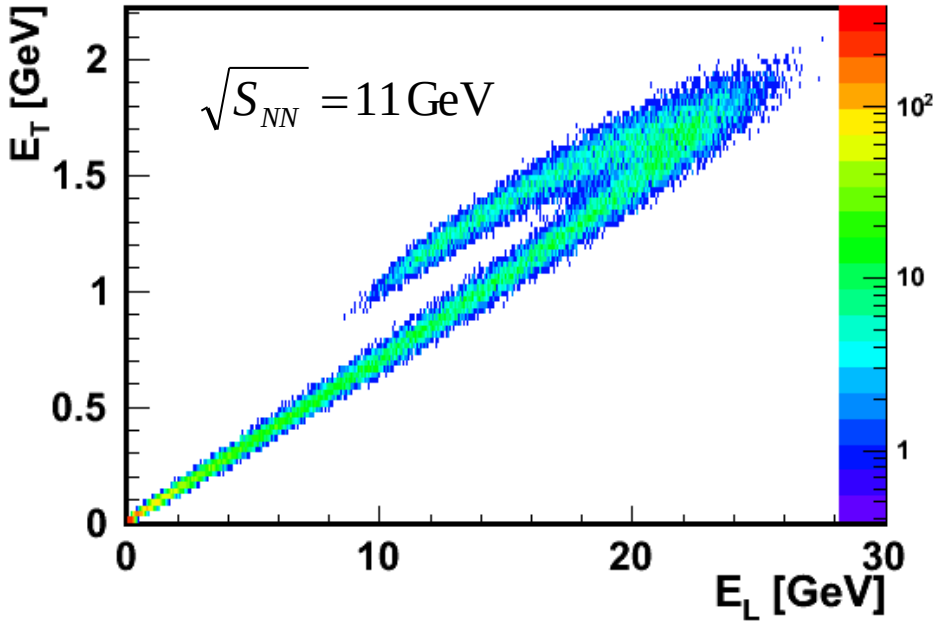
With only FHCal the centrality resolution is below 10% excepting the most central, where the fluctuations of spectator energies dominate.

Construction of other observables in FHCal for the centrality measurement.

Transverse energy: $\mathbf{E_T} = \sum E_i \, sin\theta_i$
and
Longitudinal energy: $\mathbf{E_L} = \sum E_i \, cos\theta_i$

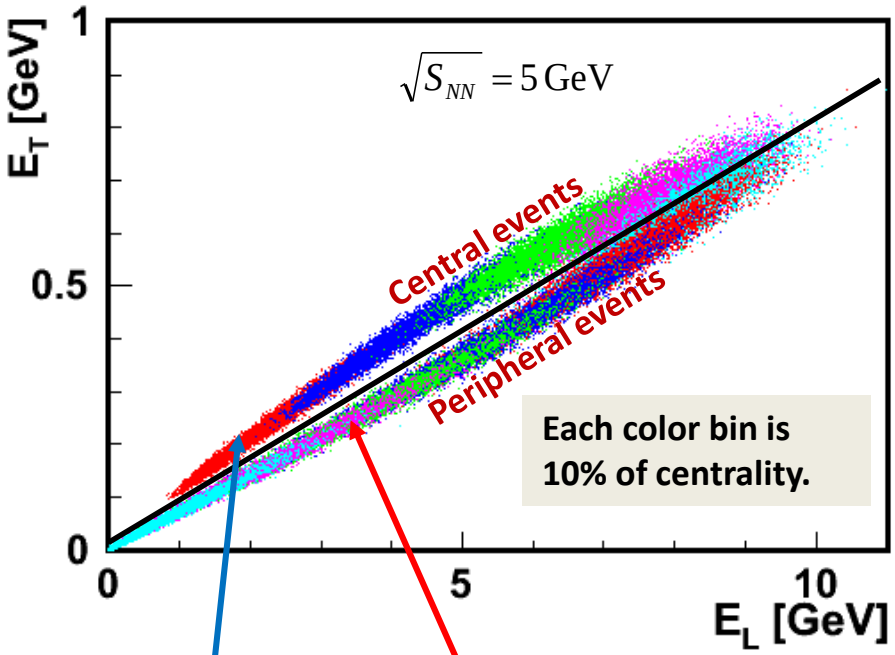


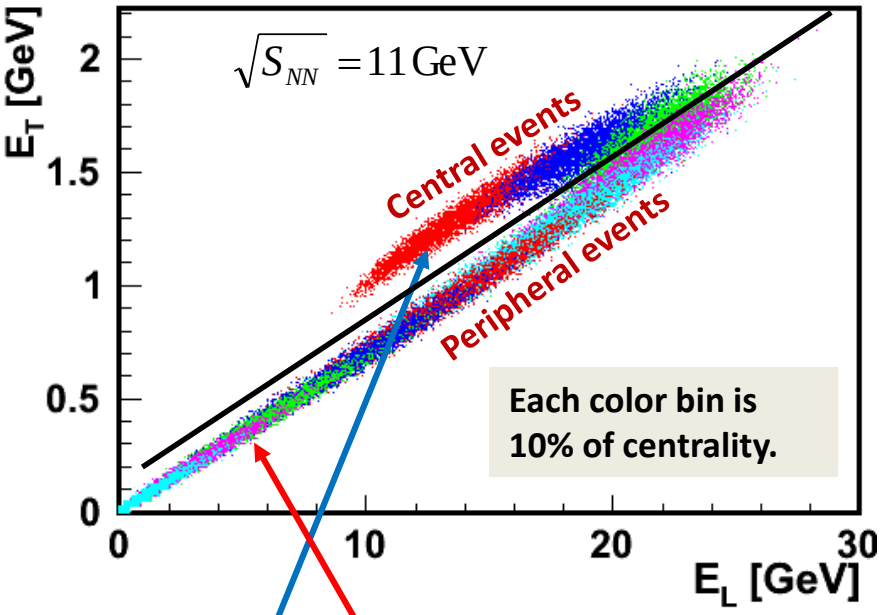


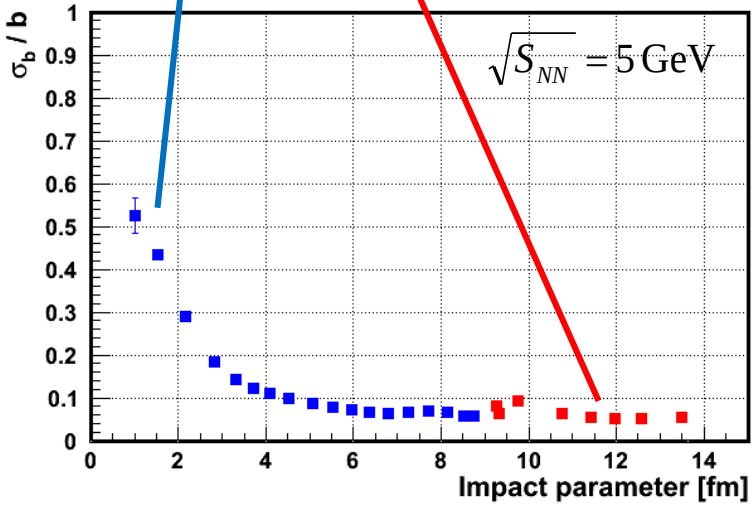


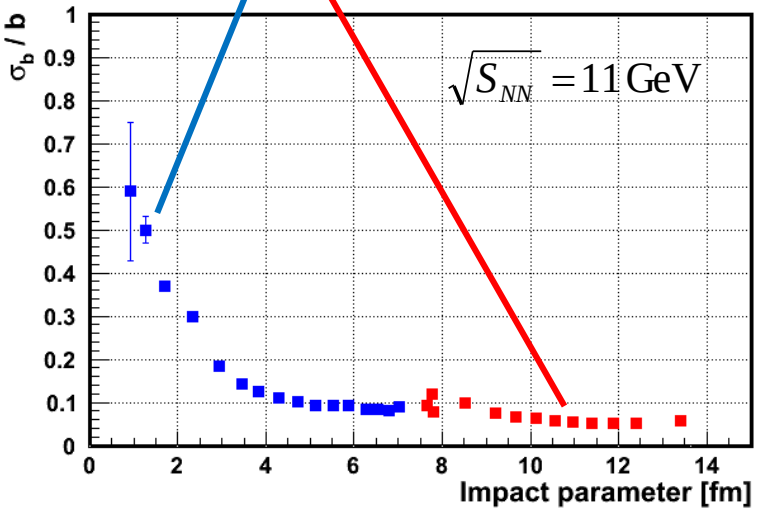
A bagel structure in E_T, E_L correlations.

Centrality measurements with E_T and E_L.





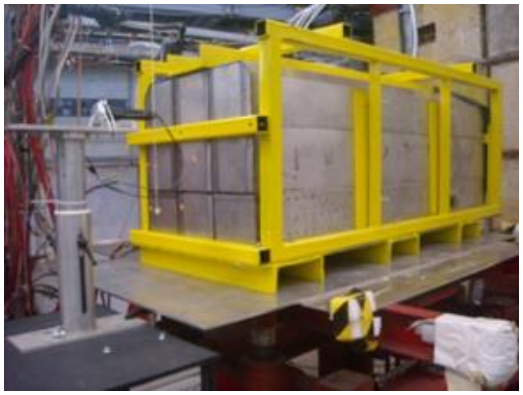




With only FHCal the centrality resolution is below 10% excepting the most central, where the fluctuations of spectator energies dominate.

Test of calorimeter supermodule at CERN T9/T10 line.

- Proton momentum range: 2-10 GeV/c

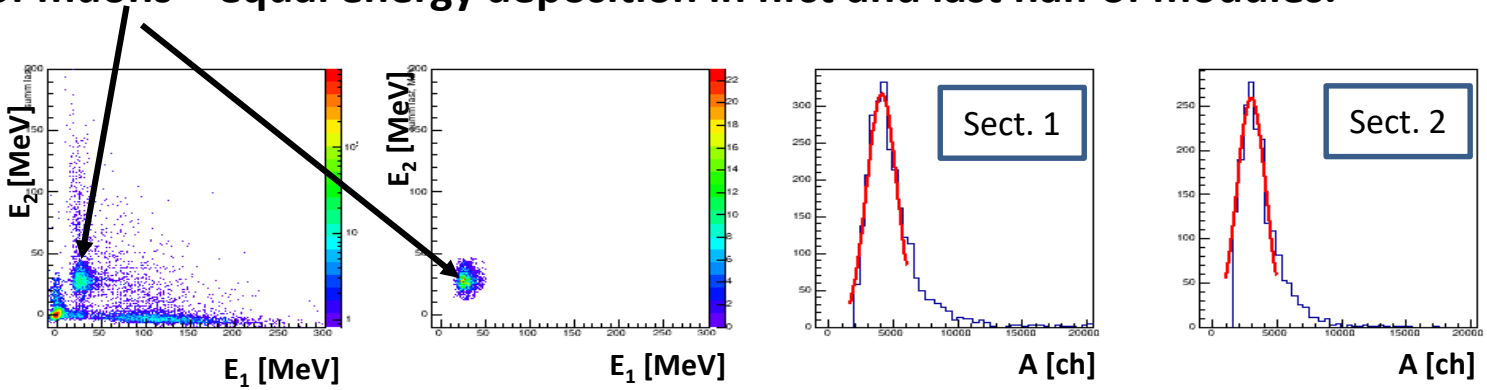


- Each module has 10 longitudinal sections with 10 SiPMs at the end (CBM option).
- Full size 60x60x160 cm^3.
- Readout electronics – for FHCal.

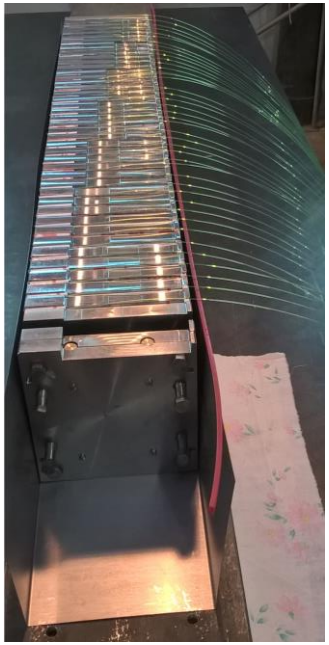
Calibration of longitudinal sections with beam muons, 6 GeV/c

Identification of muons – equal energy deposition in first and last half of modules.

Muons deposit ~5 MeV in each section



FHCal production: modules.



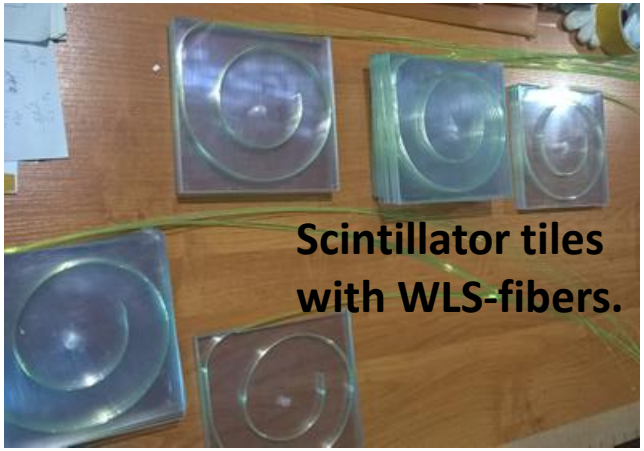
Lead and scintillators sandwiches in box.

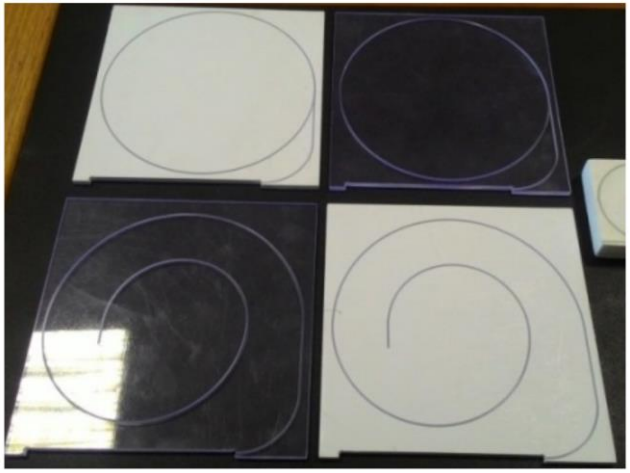
WLS-fibers are aligned.

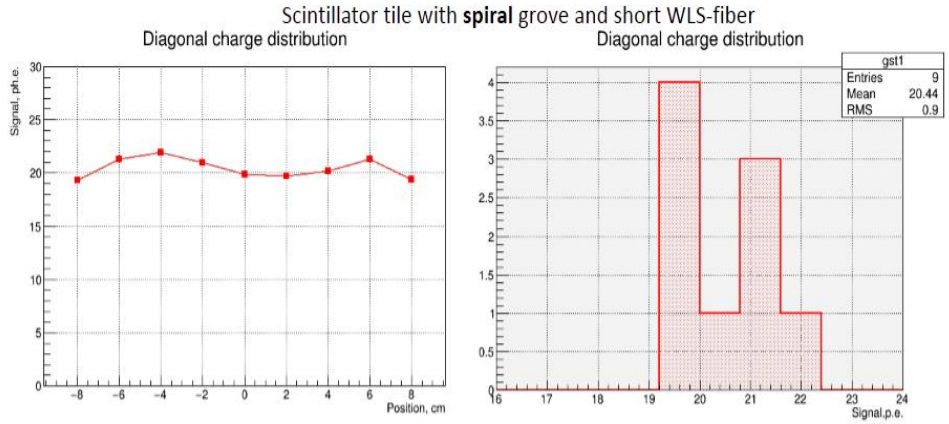
Optical connectors are polished.

Stages of FHCal production: scintillators.

FHCal scintillator tiles and modules are assembled in workshop of INR, Moscow.







Tests of different grooves and reflectors

Permanent quality control of scintillator tiles, WLS-fibers and gluing is performing with ^{90}Sr β-source.