Status of Forward Hadron Calorimeter (FHCal)

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

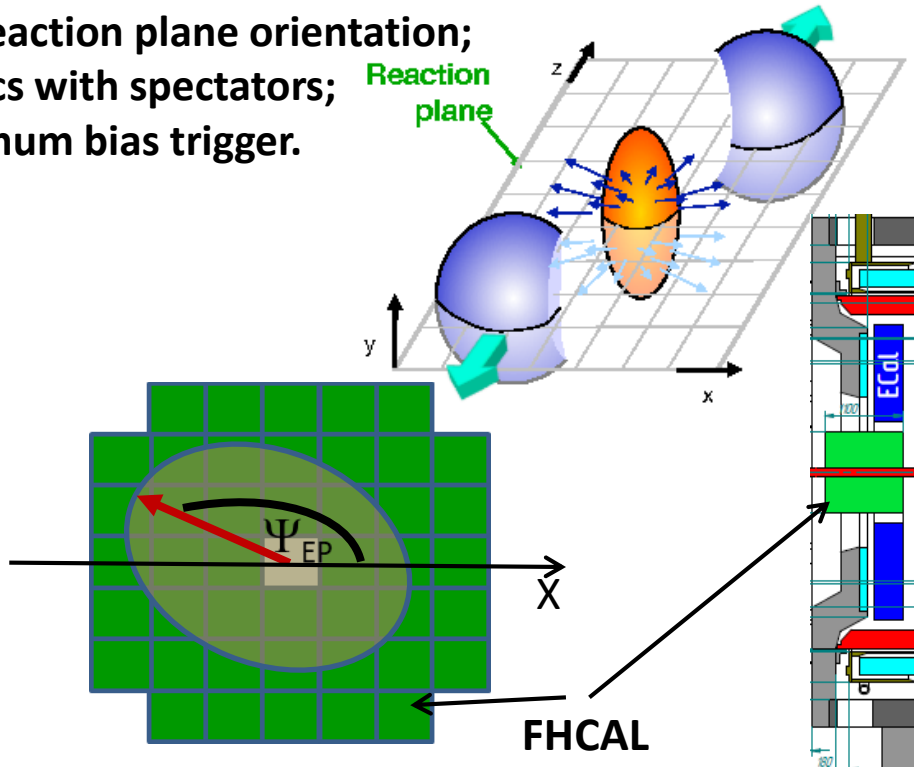
- **FHCal in MPD/NICA setup;**
- **FHCal modules;**
- **Front-End-Electronics;**
- **Slow control;**
- **Tests of FHCal modules with cosmic muons;**
- **Integration to MPD;**
- **Summary.**

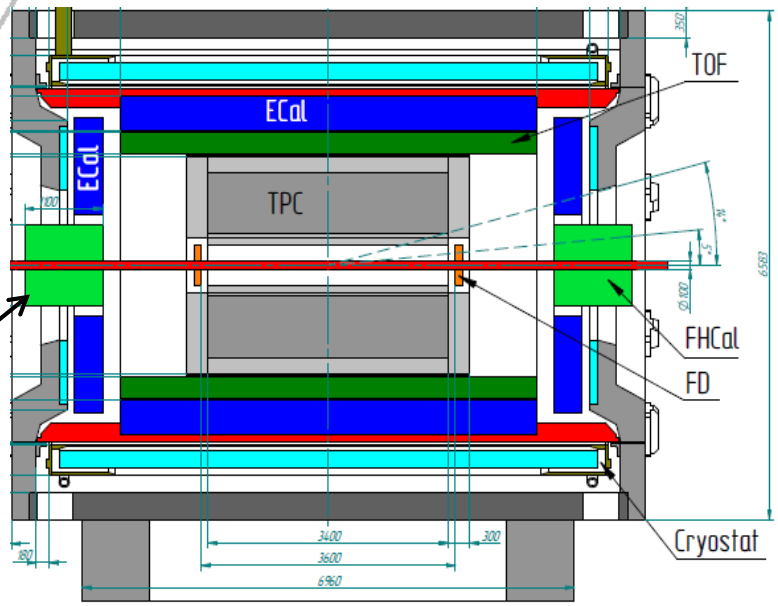
5th MPD collaboration meeting, Apr., 2020.
This work was supported by RFBR according to the research project No 18-02-40065

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;
d) Minimum bias trigger.



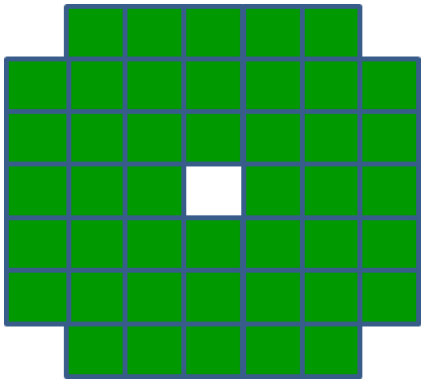


- Two parts of hadron calorimeter at opposite sides in forward regions.
- At the distance 3.2 meters from the interaction point.
- Available acceptance corresponds to pseudorapidity $2.0<\eta<5.0$

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

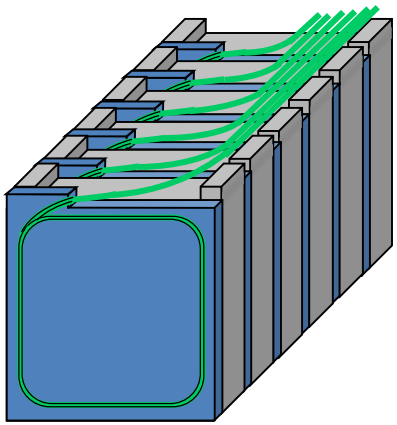
Structure of FHCal – two left/right parts

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:

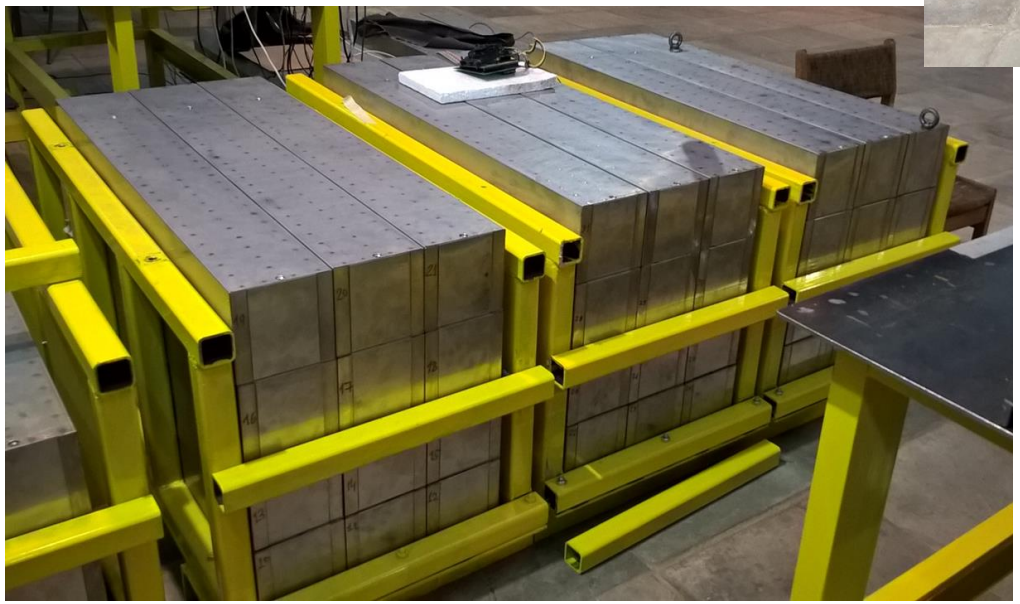
- Transverse size - 15x15cm^2 ;
- Total length - 106 cm.
- Interaction length ~4 λ_{int};
- Longitudinal segmentation – 7 sections;
- 1 section ~ 0.56λ_{int};
- 7 photodetectors/module;
- Photodetectors – silicon photomultipliers (SiPM).

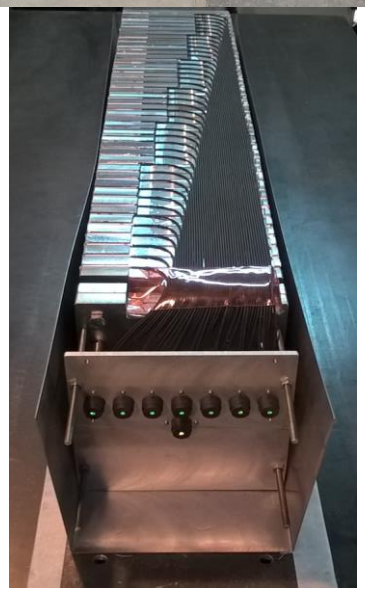
Status of FHCal modules

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

The activities with modules:

- **Tests with cosmic muons;**
- **Tests of photodetectors;**
- **Tests of Front-End-Electronics (FEE);**
- **Development of Slow Control.**





Front-End-Electronics

100 units of FEE were produced and are under the tests now.

Similar FFE will be tested in FHCal at BM@N first.

Two PCBs in each module with:

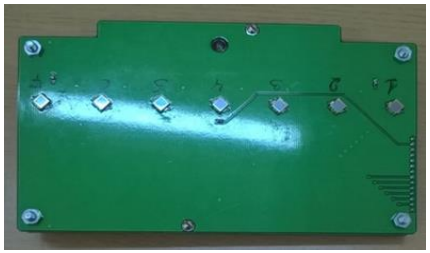
7 photodetectors ;

Photodetectors – MPPCs;

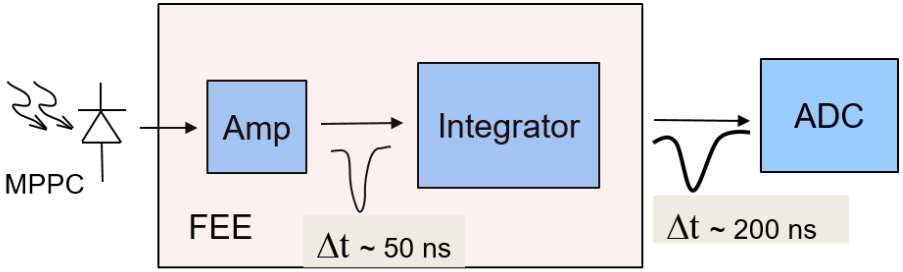
two-stage amplifiers;

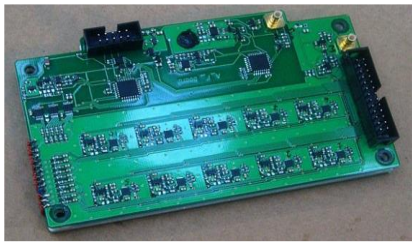
HV channels;

LED calibration source.

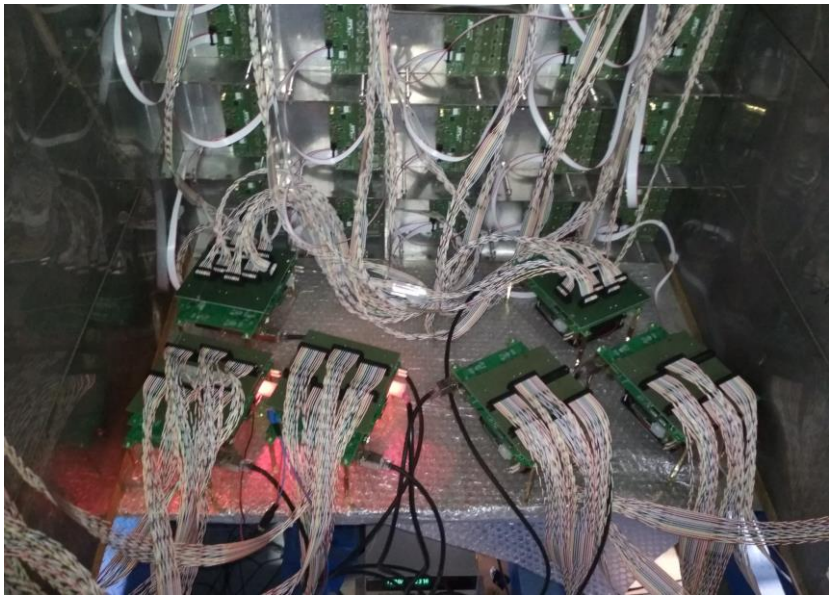


MPPC: new type S14160-3010PS size – 3x3 mm^2; pixel -10x10 µm^2; PDE~18%.

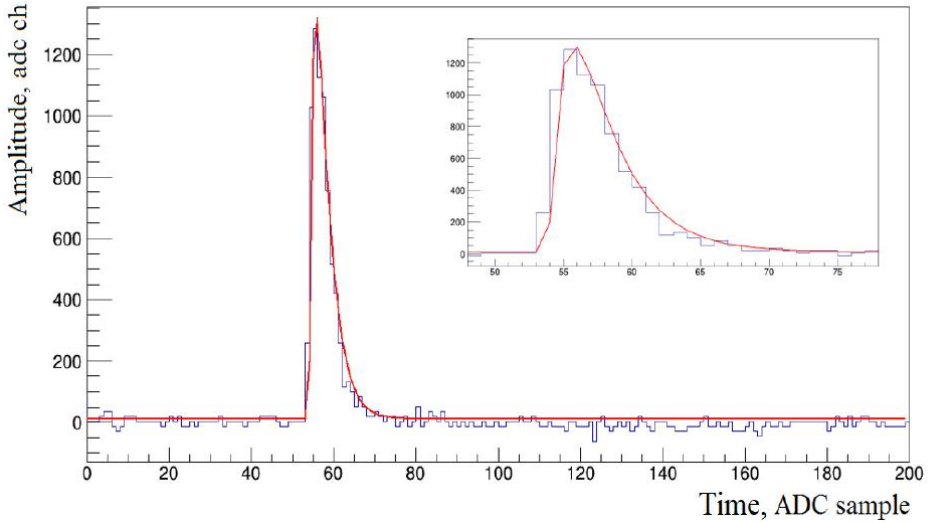




Readout of FHCal



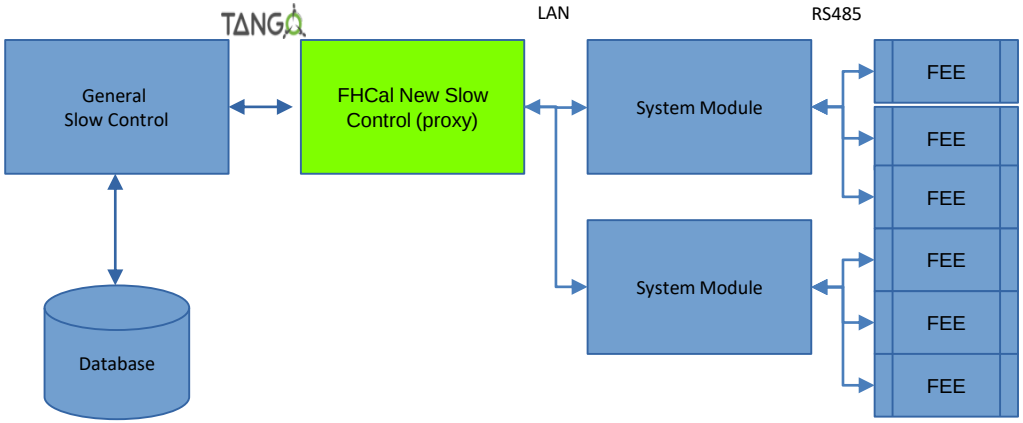
Shape of digitized signal.



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

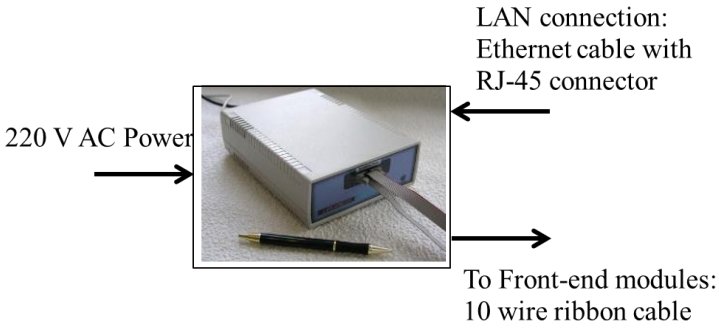
- **At present (in cosmic muon tests) the ADC's are placed at horizontal support.**
- **One needs to develop the dedicated support structure for ADC's around FHCal.**

Slow Control of FHCal



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

Hardware:
System Module (HV sys. Co.)



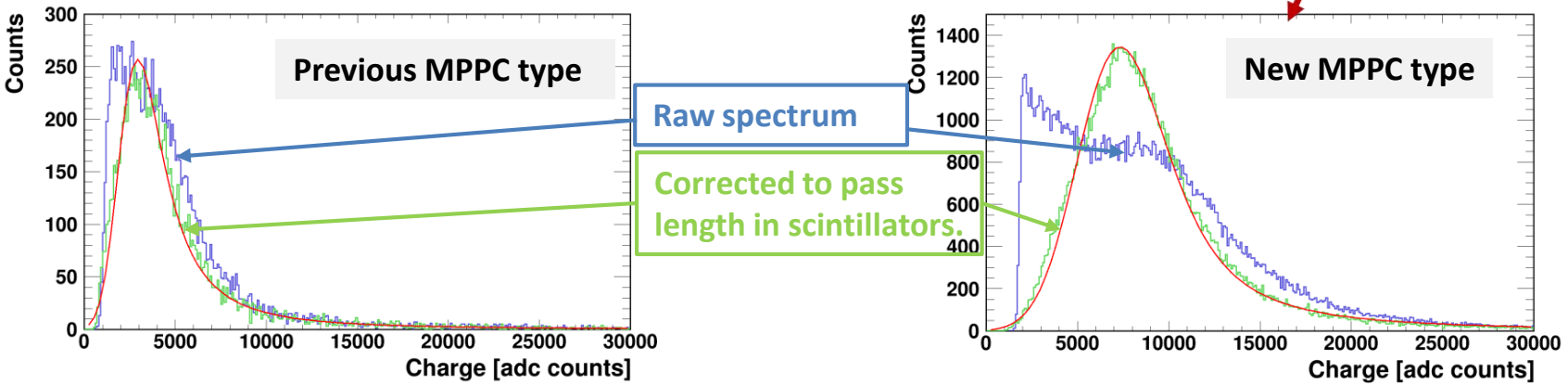
Software:

- Test version (full functionality) is **ready**.
- New (advanced) python version **in development** (ETA: June 2020)
  - Proxy mode: let other software read FHCal transparently
  - Provide TANGO bindings
  - Faster operation with multiple System Modules

Test of calorimeter modules with cosmic muons

- Tasks:
- Tests of different SiPM's;
- Tests of FEE;
- Development of methods of the energy calibration;
- Control of the light yield of the modules;
- Energy threshold for the FHCal trigger.

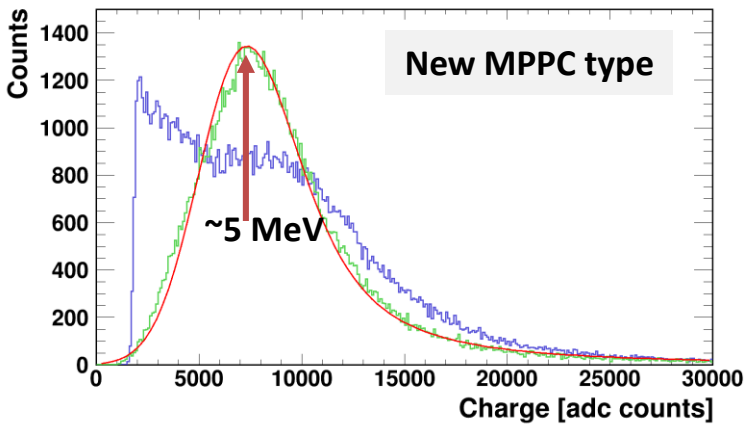
Response of FHCal modules to cosmic muons with different types of MPPC.



MPPC: S12572-010P
pixel -10x10 μm^2;
PDE~12%;
G~10^5.

MPPC: S14160-3010PS
pixel -10x10 μm^2;
PDE~18%;
G~1.8x10^5.

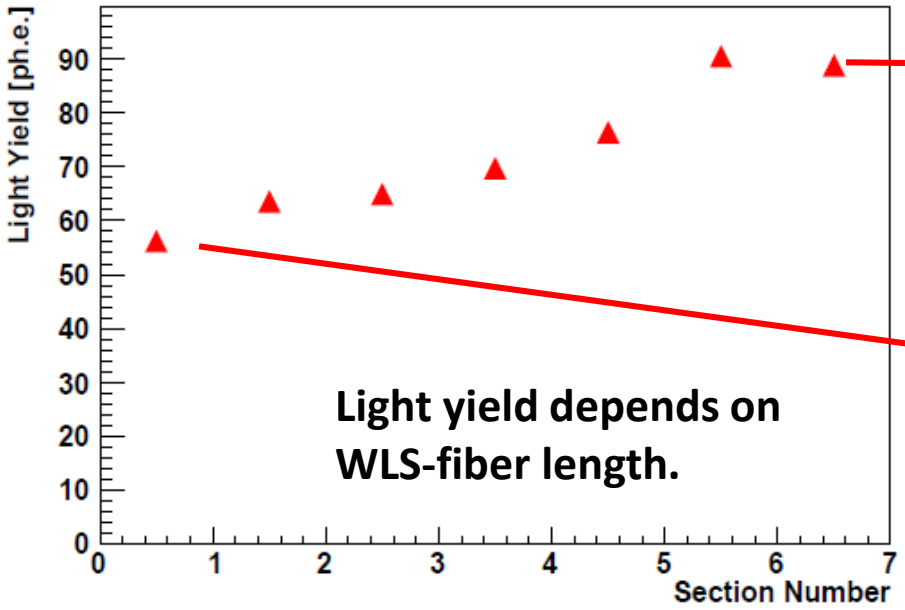
Calibration and light yield of FHCal modules



Clear amplitude spectra from cosmic muons allow the energy calibration in self-triggering mode (without external muon trigger).

This is due to high light yield in the longitudinal sections in modules.

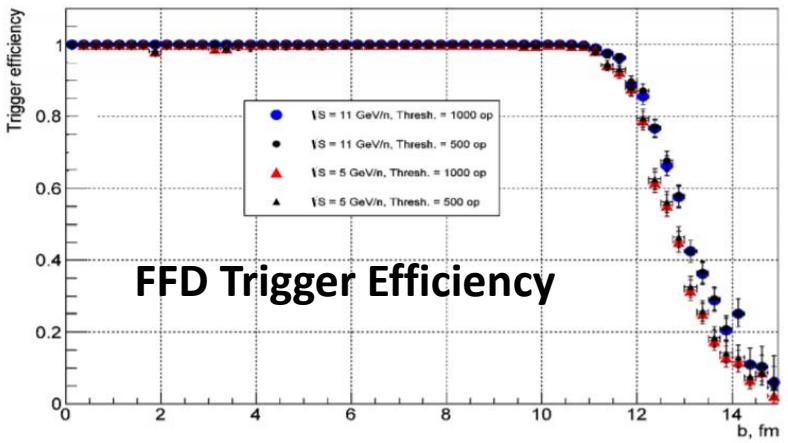
Average light yield for MIP's in longitudinal sections.



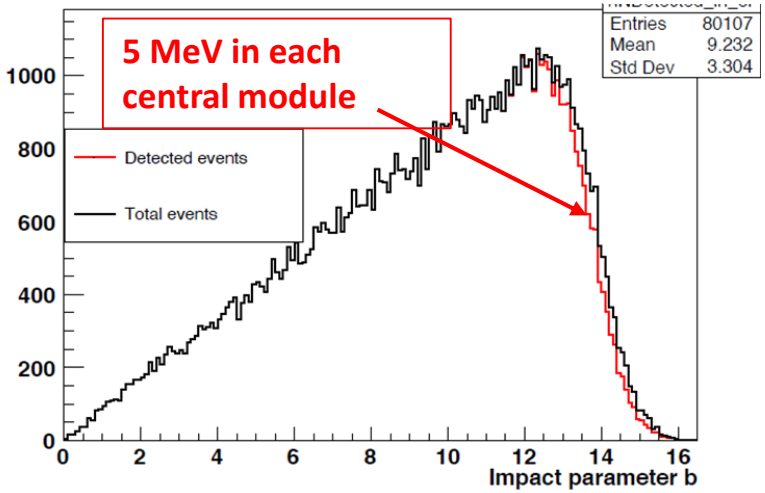
Light drops for ~40% for 1m fiber.

FHCal in trigger

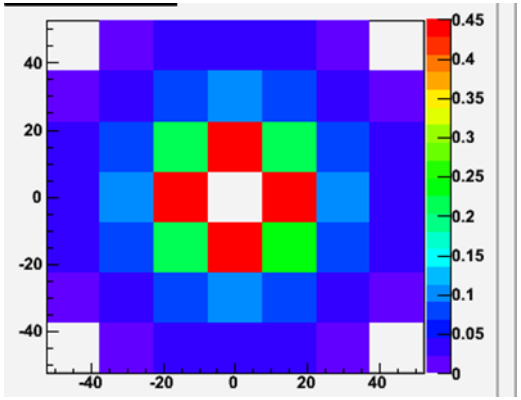
- **Problem: FFD trigger efficiency drops for peripheral collisions.**
- **Is it possible to arrange minimum bias trigger?**



- **FHCal detects the energies practically from all events, including the most peripheral ones.**
- **Detected events – if the energy deposition in each central module exceeds 5 MeV.**

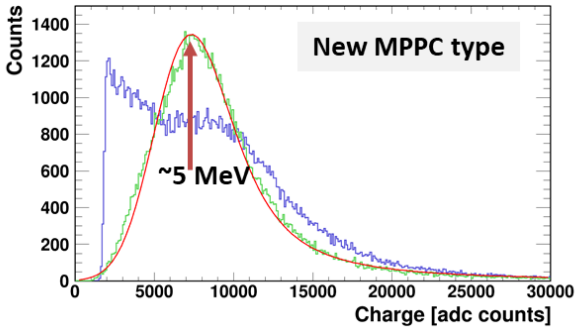


In peripheral collision the energies are mainly deposited in central modules.



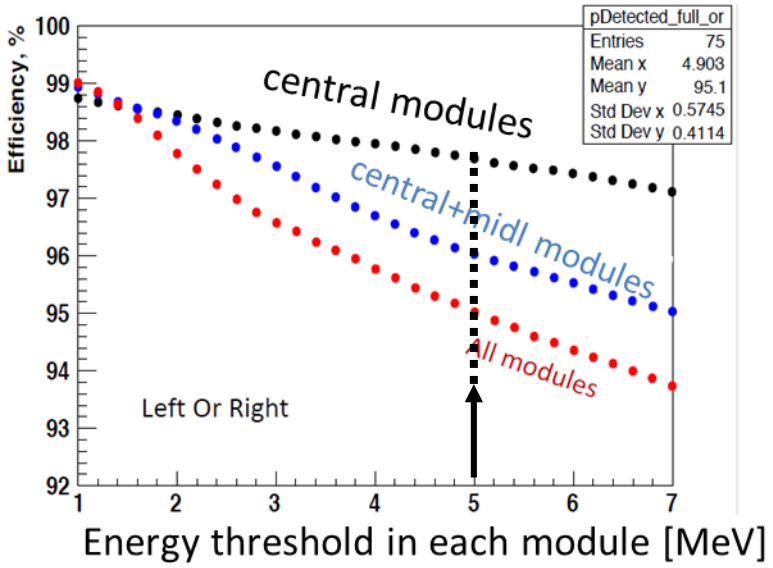
FHCal in trigger - 2

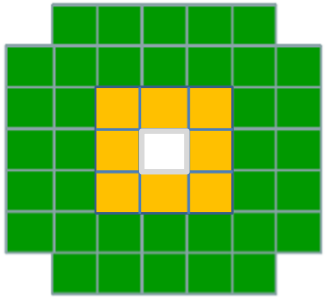
Spectrum from cosmic muons.

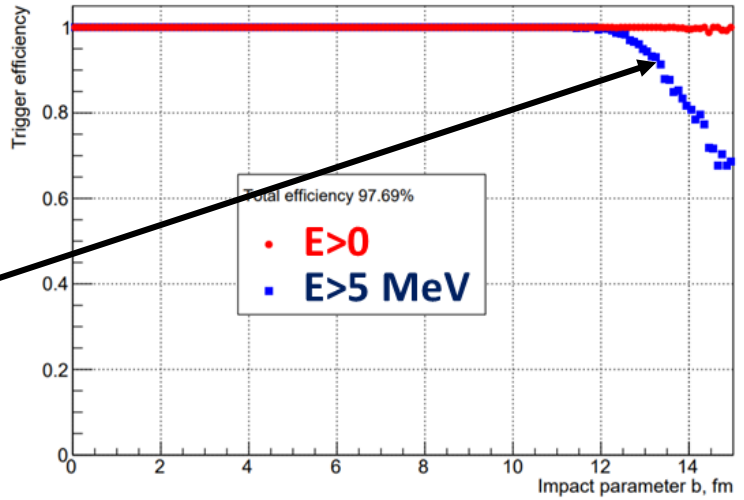


5 MeV is rather reasonable threshold for a single FHCal module with new photodiodes.

Dependence of trigger efficiency on the energy threshold and on the number of modules.







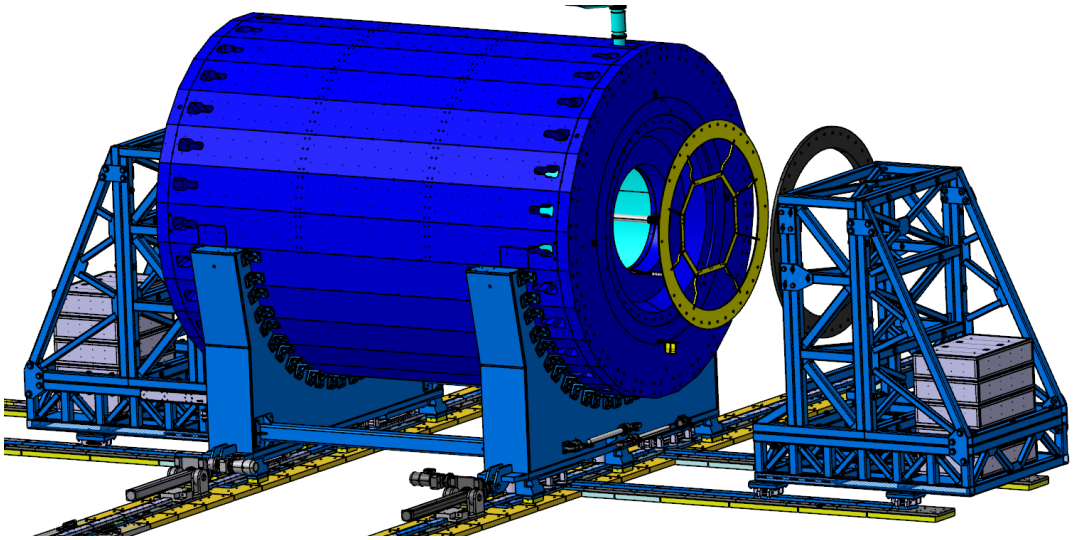
Events with energy deposition in each central module > 5 MeV.

Total trigger efficiency ~97.7%.

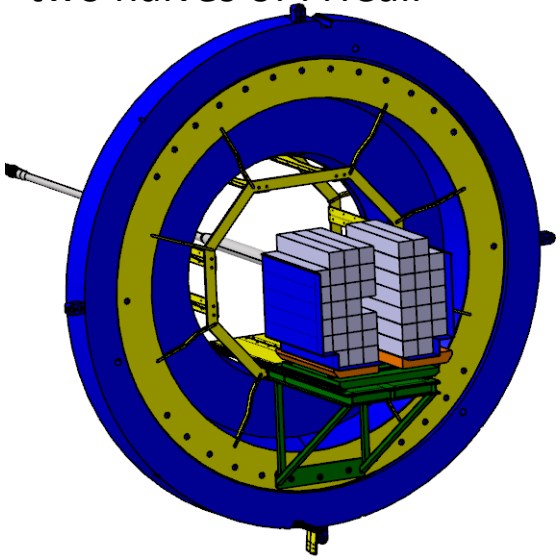
FHCal integration in MPD

(Concept of installation)

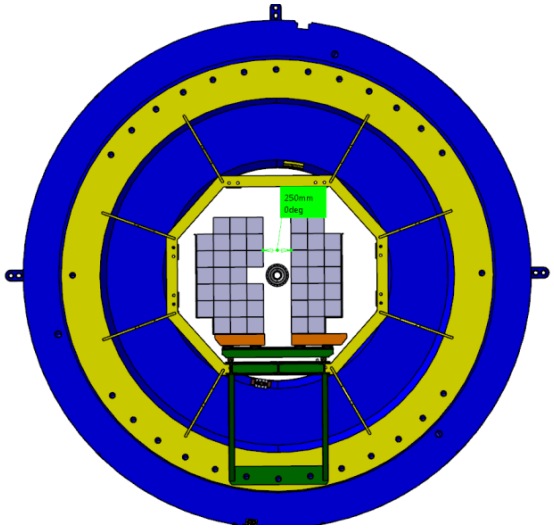
1. Installation of flange

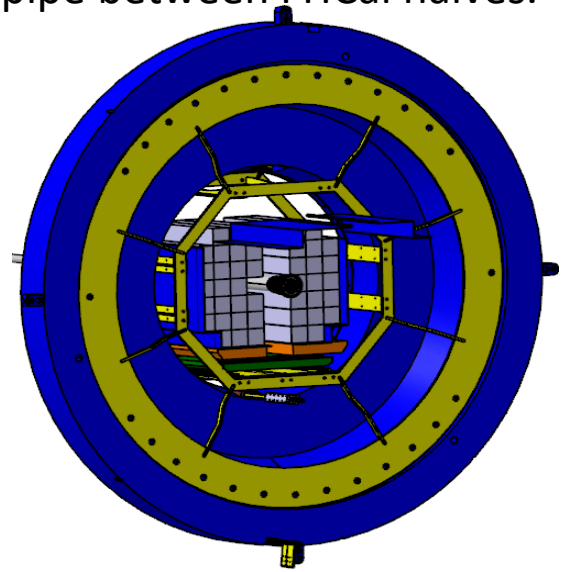


2. Iinstallation of platform and two halves of FHCal.

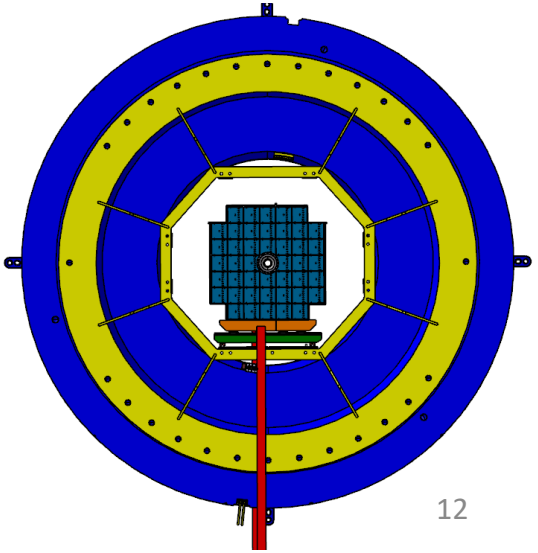


3. Mounting of support. Beam pipe between FHCal halves.

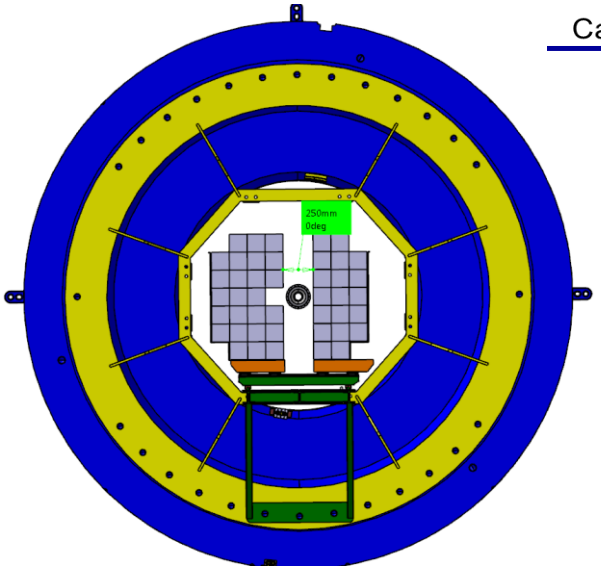


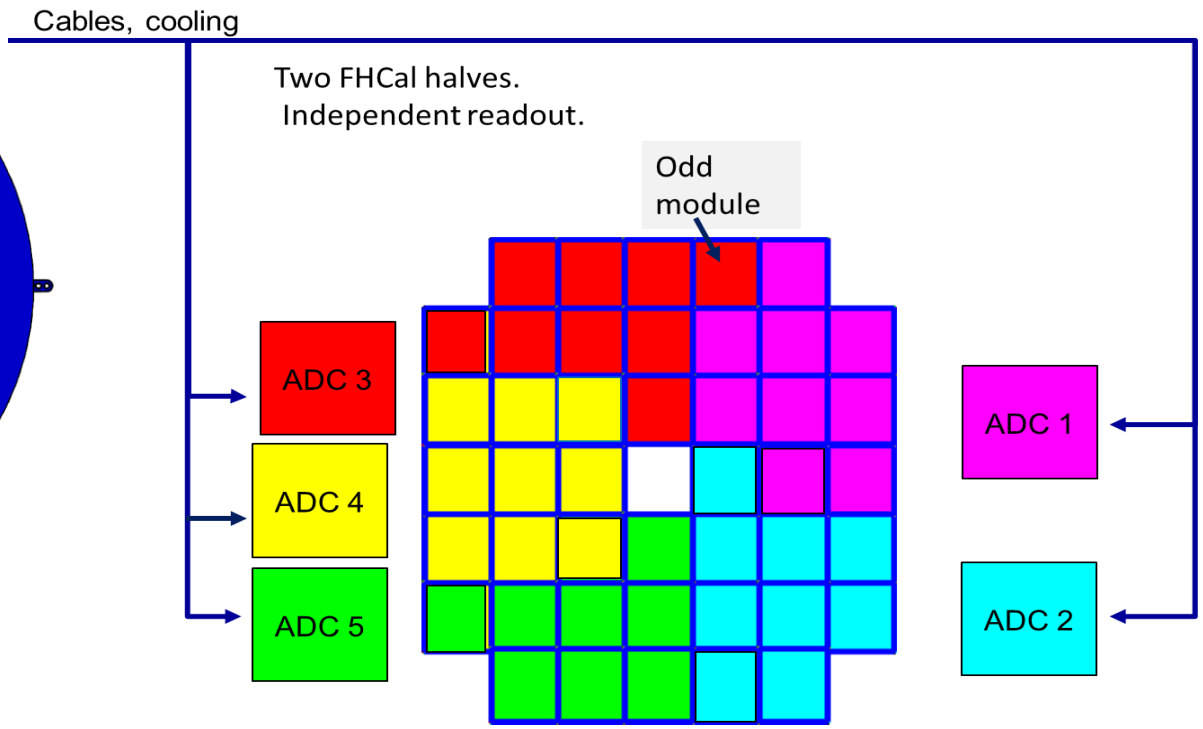


4. FHCal assembled.



FHCal integration - readout





Questions:

- **Mechanical support for ADC's?**
- **Where to put the power supplies for ADC? synchronization modules (WR)?**
- **Crate at top of FHCal?**
- **What cooling? Air flow is good enough!**

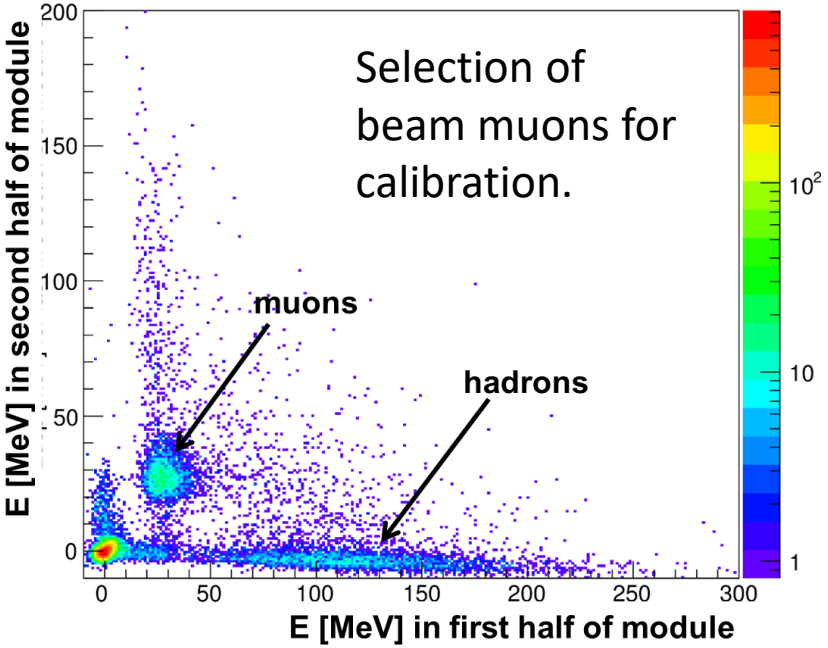
Summary and Open issues.

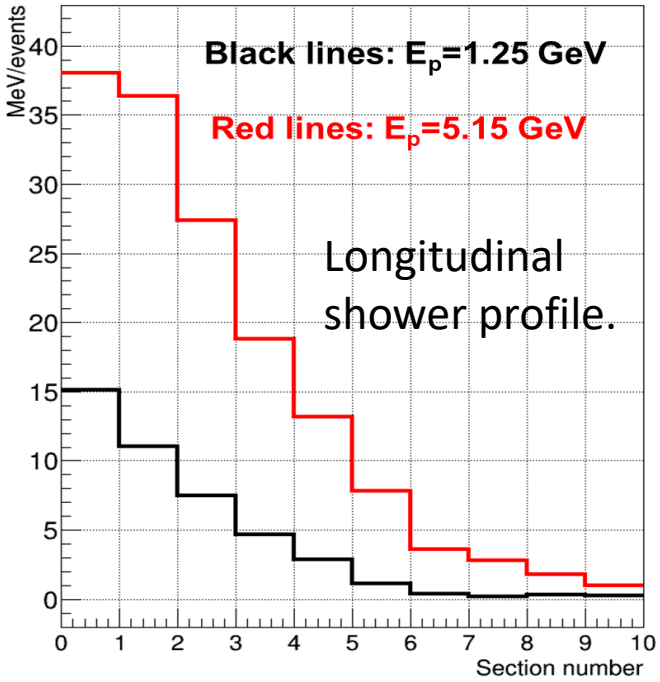
- All FHCal modules are assembled.
- Tests with cosmic muons are going on.
- FEE was produced and is tested now.
- Slow control – advanced software is in development.
- Energy calibration – method of calibration with cosmic muons is well developed.
- FHCal minimum bias trigger is under development. Tests with cosmic muons are planned.

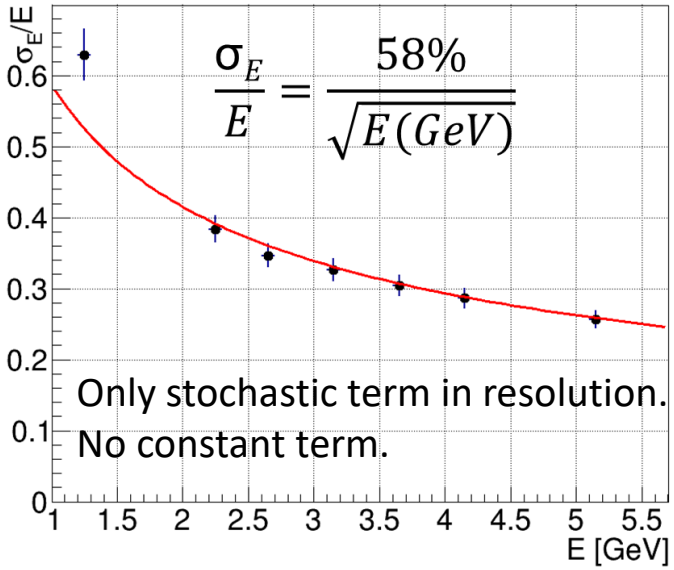
- FHCal integration.
- Mechanical support.
- Mounting of readout electronics and power supplies near FHCal.
- FHCal trigger. Tests in realistic conditions.

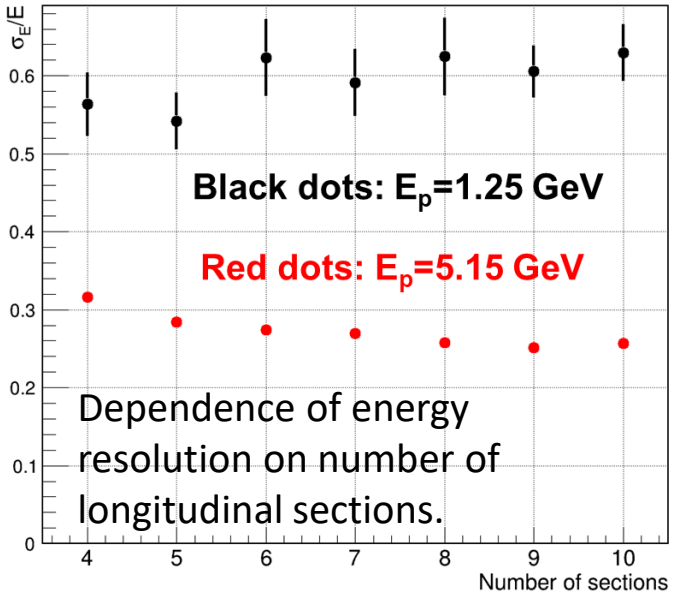
Thank you!

Hadronic showers in FHCal modules (beam tests).



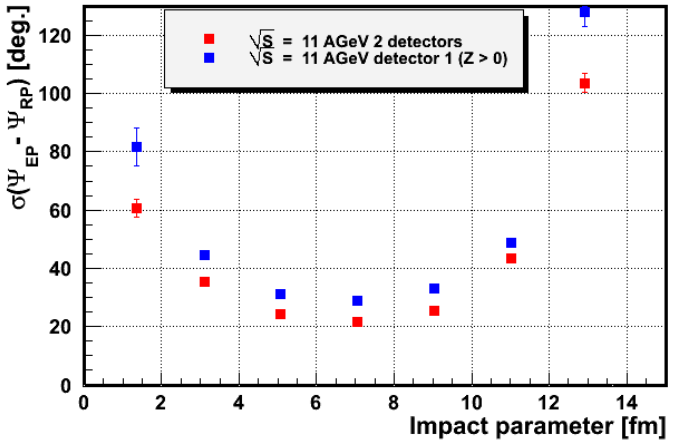






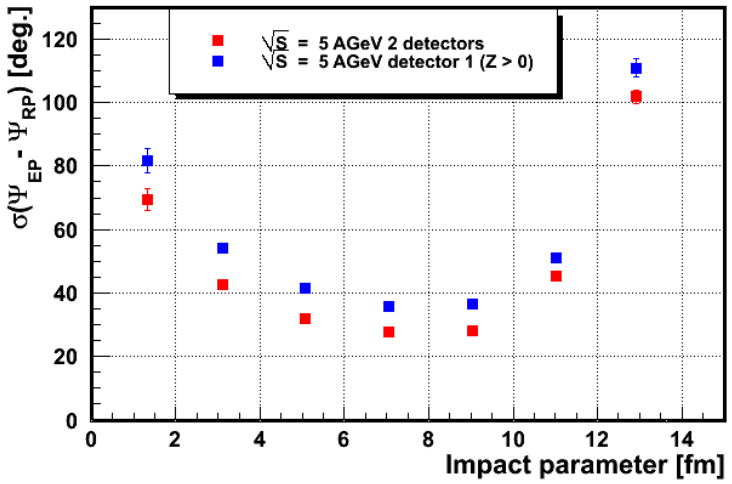
FHCal physics performance – reaction plane.

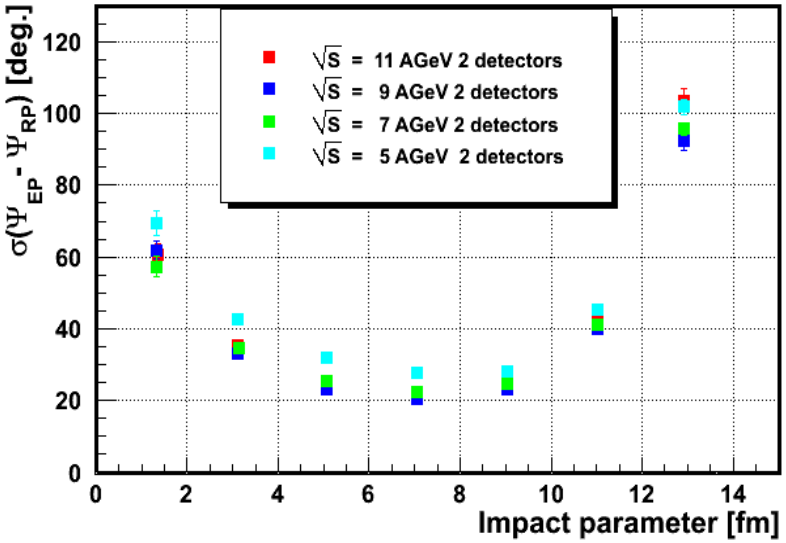
Modules 15x15 cm^2 are optimum choice and fit the transverse size of hadron showers (interaction length of lead+scint. λ_I~20 cm).



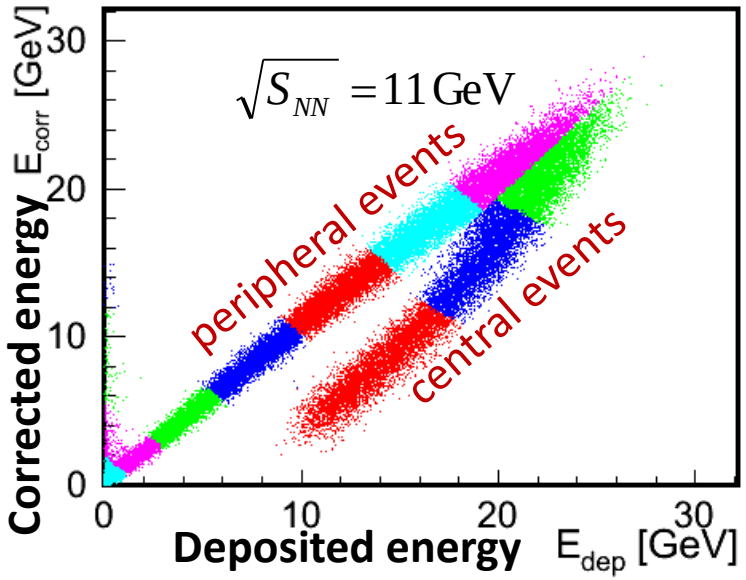
The event plane resolution of 20^0-25^0:

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

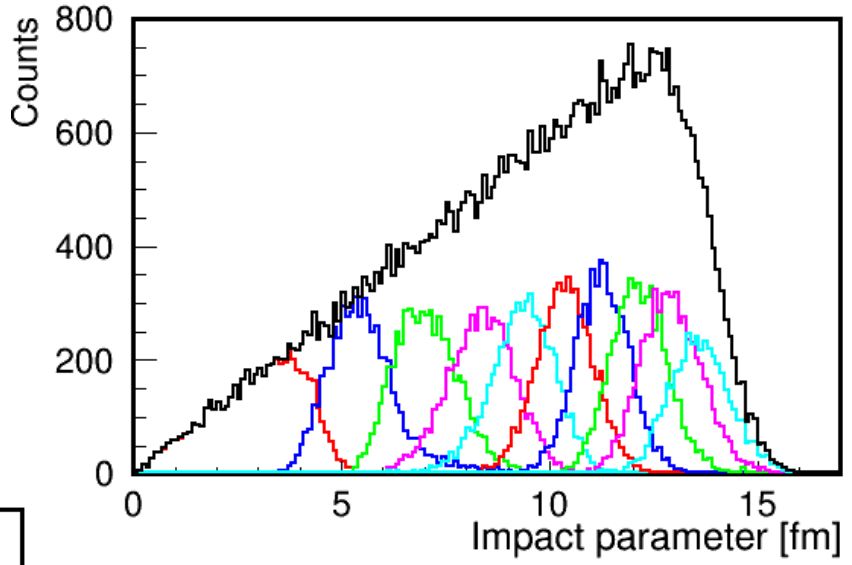


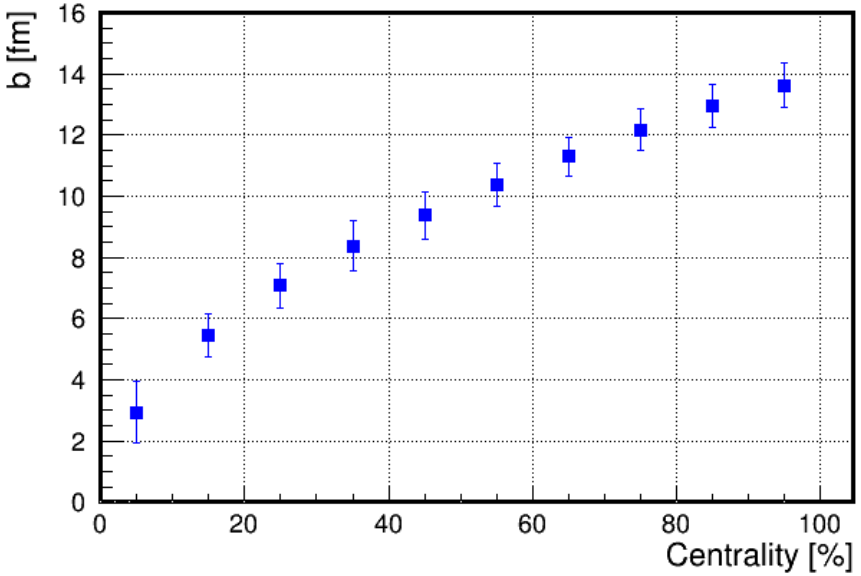


FHCal physics performance -centrality.



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

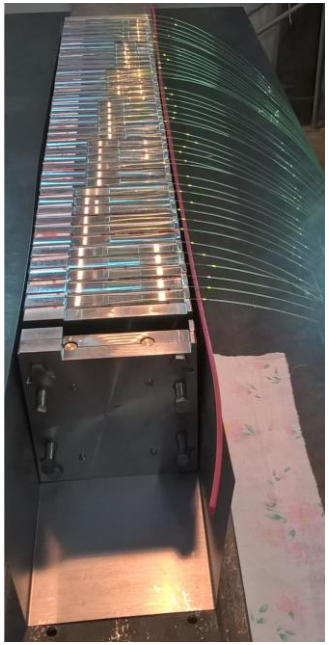




In spectator region the centrality resolution ~5-10% for mid-central events.

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

FHCal production: modules.



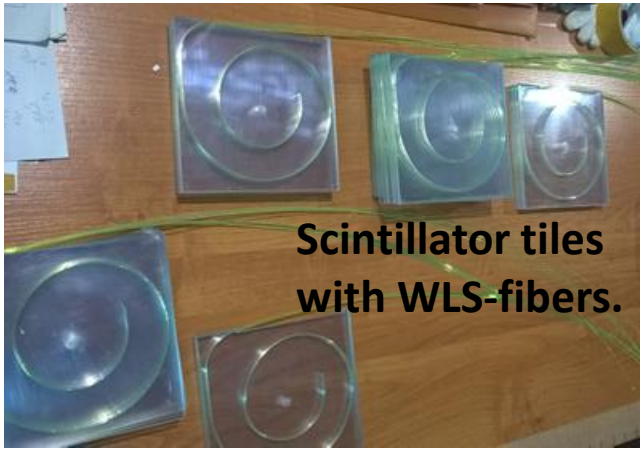
Lead and scintillators sandwiches in box.

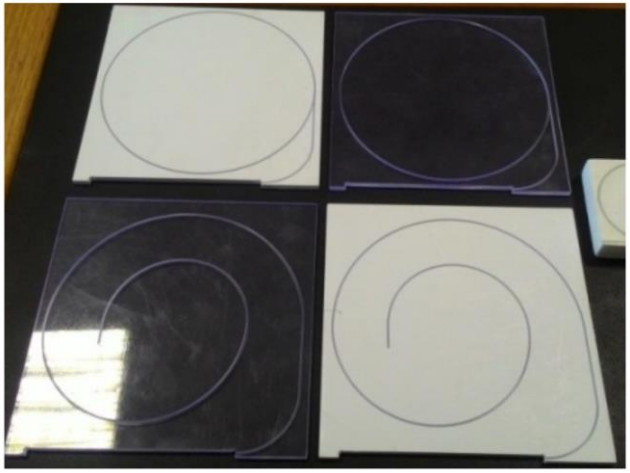
WLS-fibers are aligned.

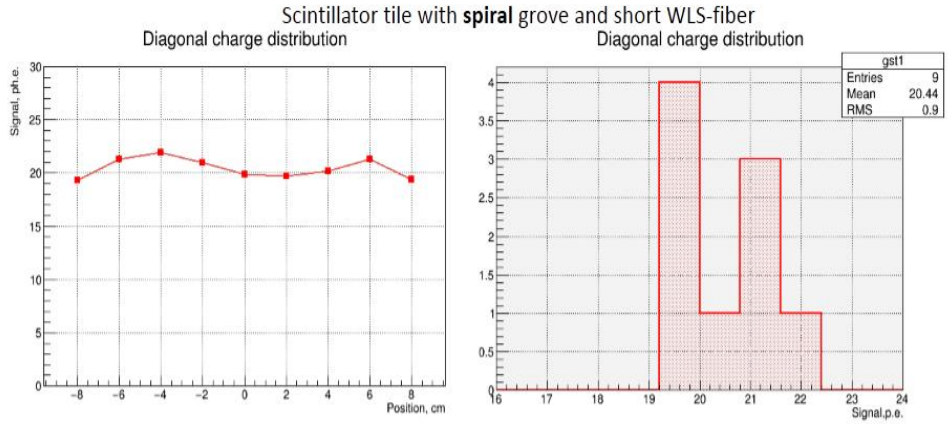
Optical connectors are polished.

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.

$$Au + Au, \sqrt{S_{NN}} = 5\ GeV$$