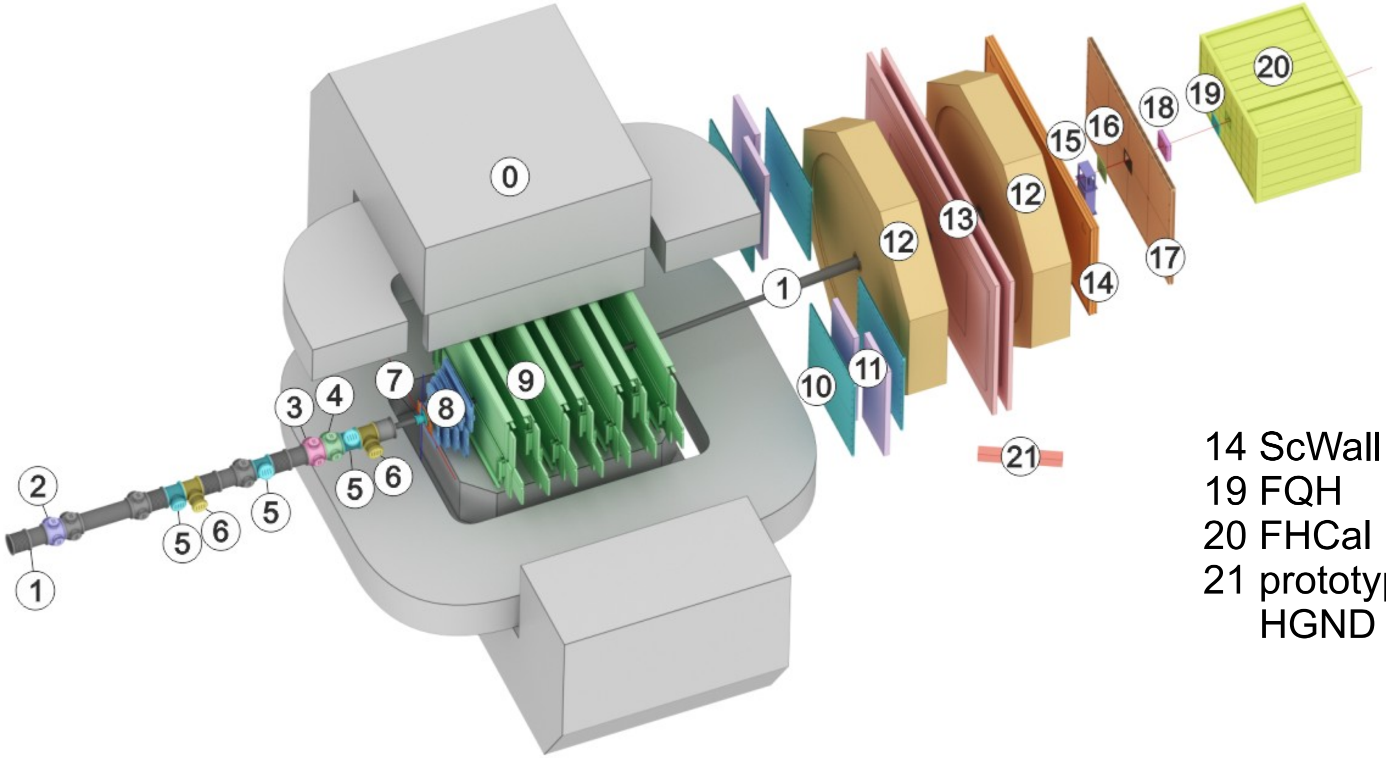
Status of forward detectors readiness to the next run. Status of new HGND detector development.

Sergey Morozov
on behalf of INR RAS, Moscow and HGND team



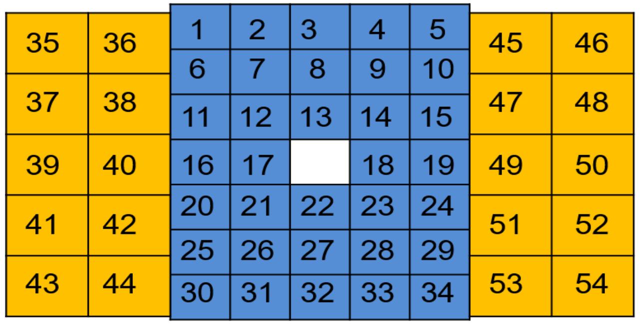
14 ScWall
19 FQH
20 FHCal
21 prototype of HGND

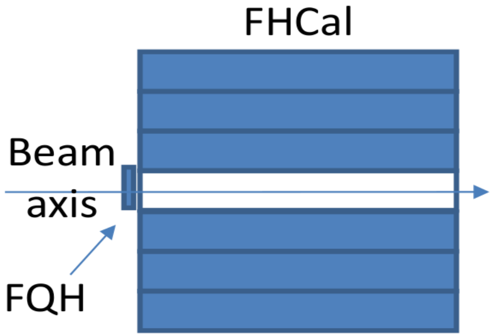
Forward detectors:

- **FQH** (**F**orward **Q**uarz **Hodo**scope)
- **FHCal (F**orward **H**adron **Cal**orimeter)
- **ScWall** (**Sc**intillation **W**all)

Can measure:

- charge distributions of spectator fragments
- centrality determination
- reaction plane orientation





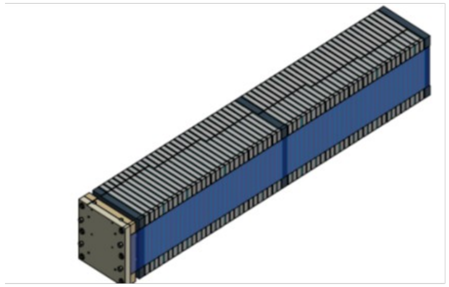
FHCal - (Forward Hadron Calorimeter):

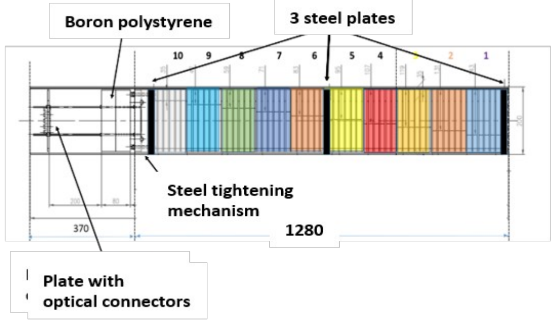
20 modules with 10 longitudinal sections (PSD CBM), transverse size 20x20cm^2, length – 5.6 λ_{int}.

34 modules with 7 longitudinal sections (FHCal MPD like) – 15x15cm^2 (– 4.0 λ_{int}).

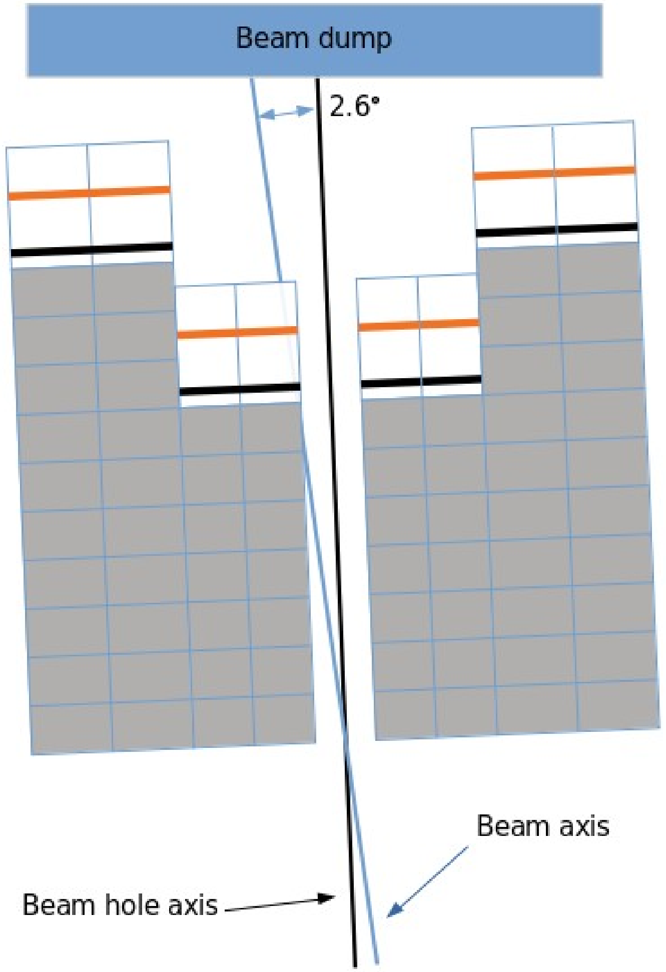
Hamamatsu MPPC S12572-010P, 3 x 3 мм^2.

434 readout channels.



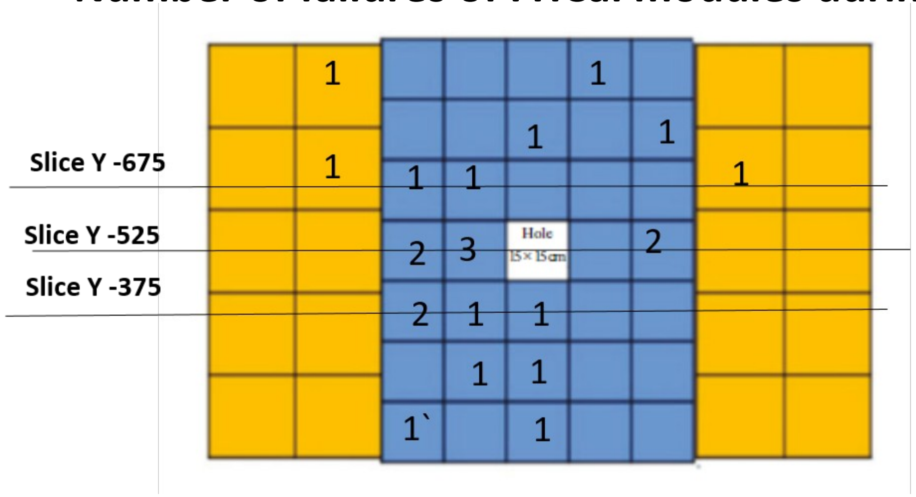


FHCal alingment relative to the beam axis

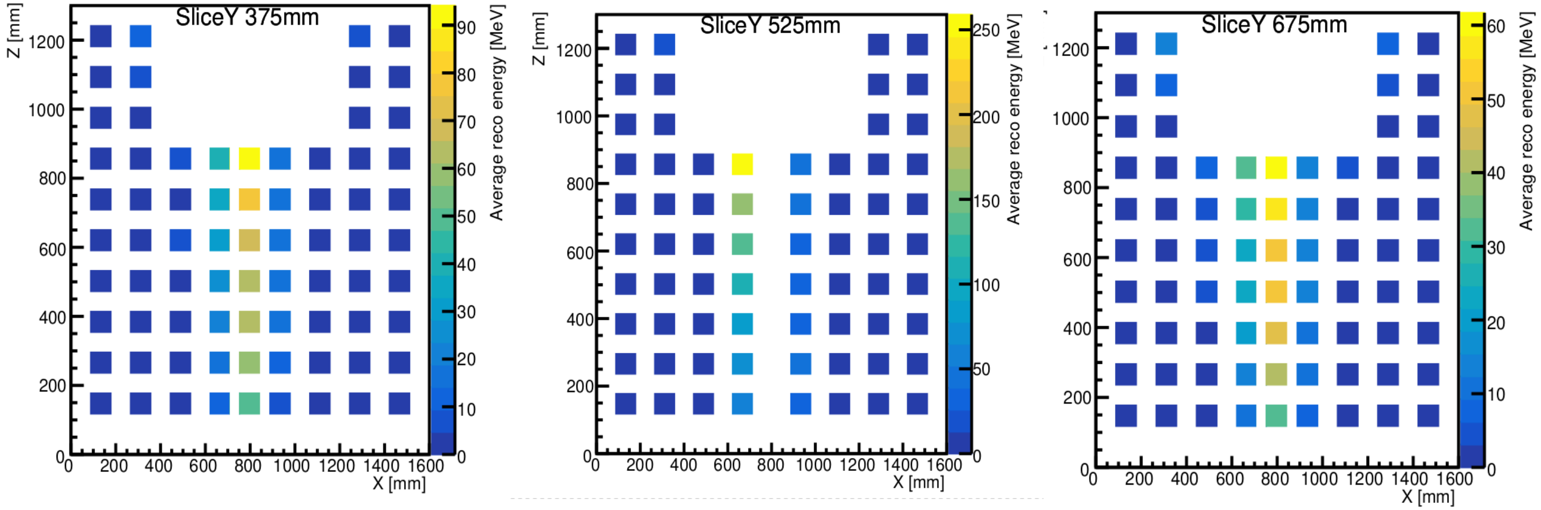


1) after run 8 FHCal was rotated and is now aligned to beam axis
2) beam dump upgrade is planned

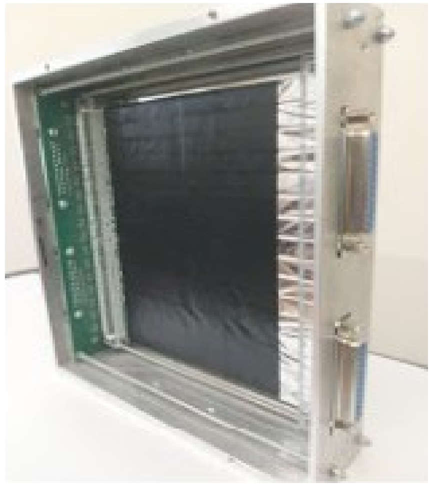
Number of failures of FHCal modules during Run8

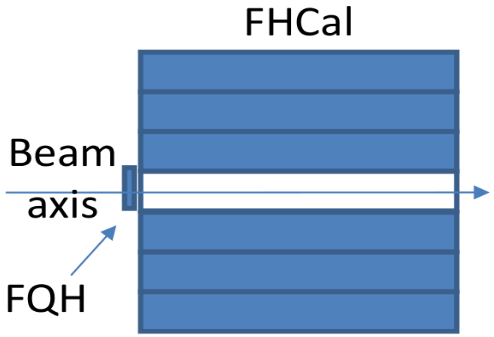


Energy distribution in calorimeter sections. Beam trigger BT

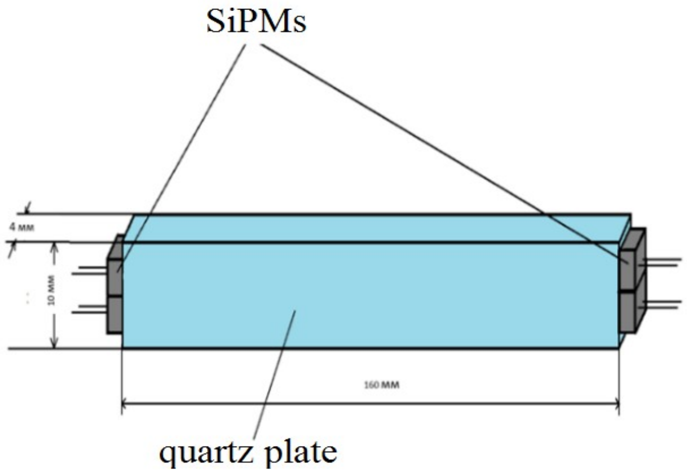


Forward Quartz Hodoscope (FQH)



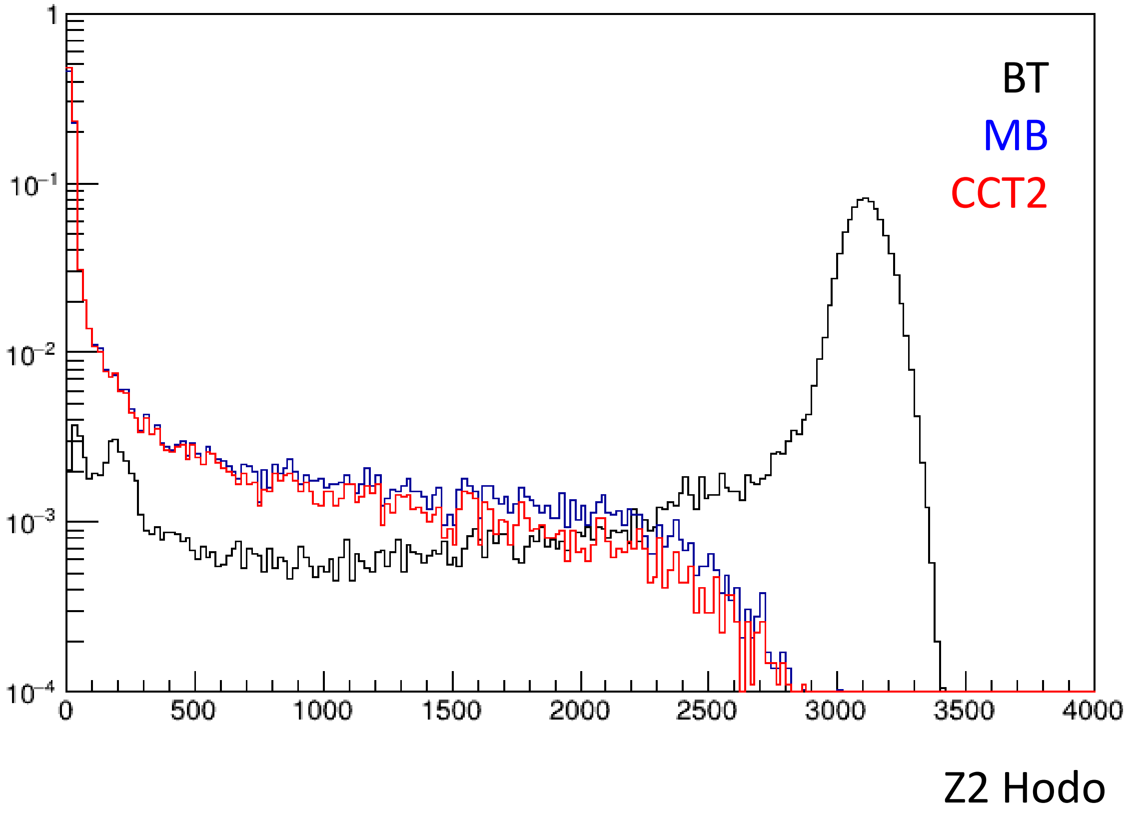


FQH - (Forward Quartz hodoscope):
16 quartz strips 160x10x4mm^3,
2+2 MPPCs per strip,
Hamamatsu MPPC S14160-3015PS, 3 x 3 мм^2,
64 readout channels (low gain, high gain)



FHCal + FQH → collision centrality estimation, reaction plane

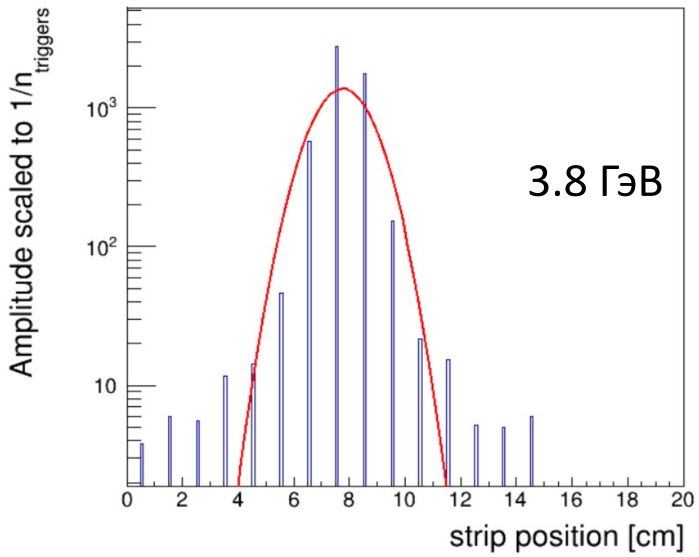
Fragments charge distribution in FQH

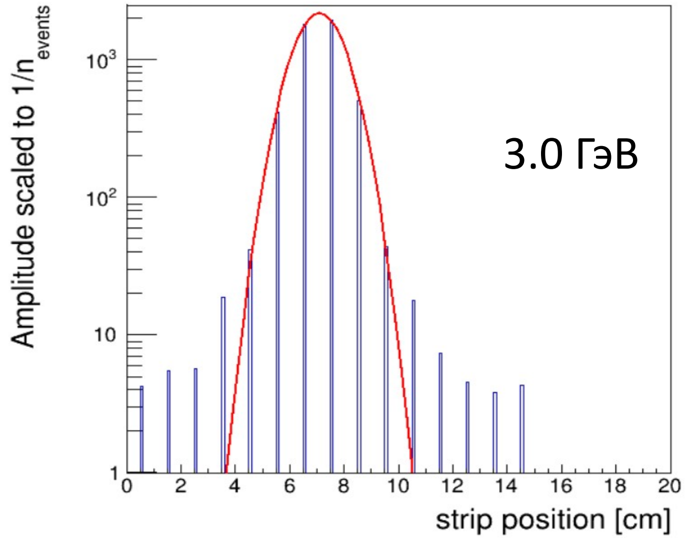


- beam ion peak is clearly visible

- probably we can use different HV for upper and lower sides of SiPM read-out to increase signal dynamic range

Beam profile. BT





Scintillating Wall (ScWall)

ScWall view inside during production

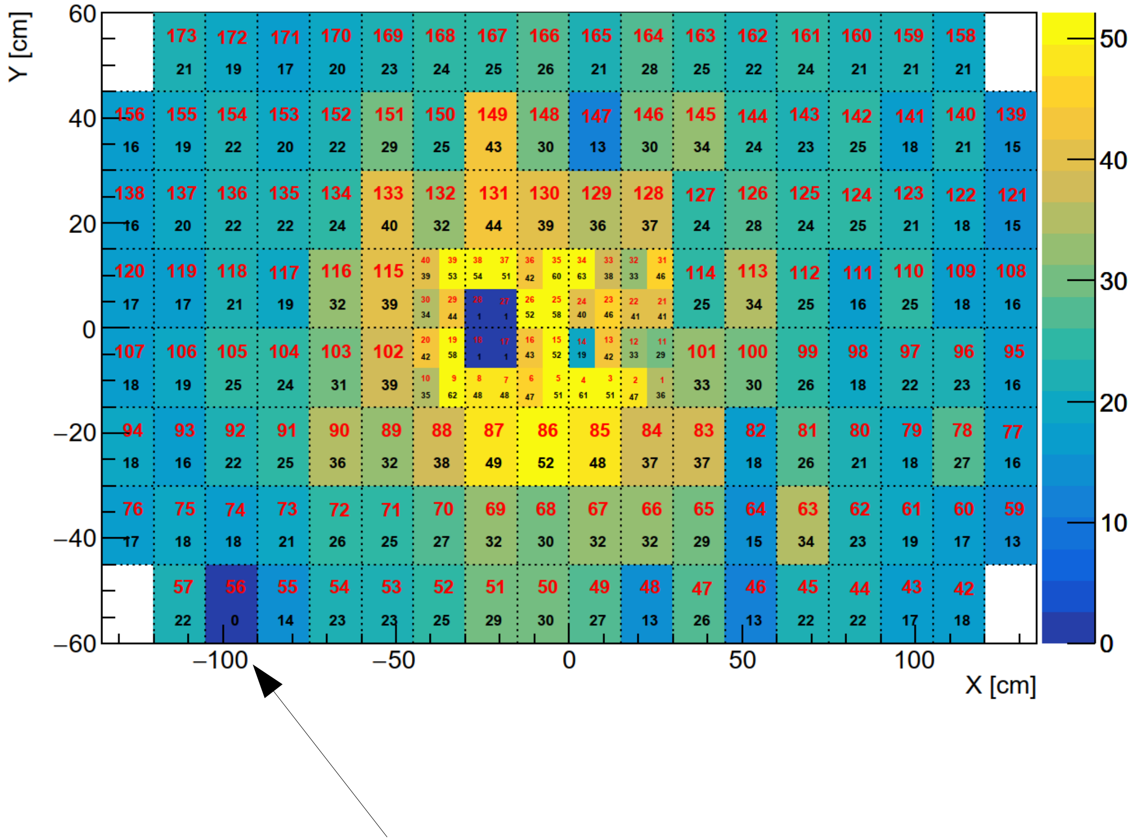
ScWall mounted on the frame during Run8 run

Charge spectators detection
→ fragmentation model parameters

+ collision centrality
+ reaction plane

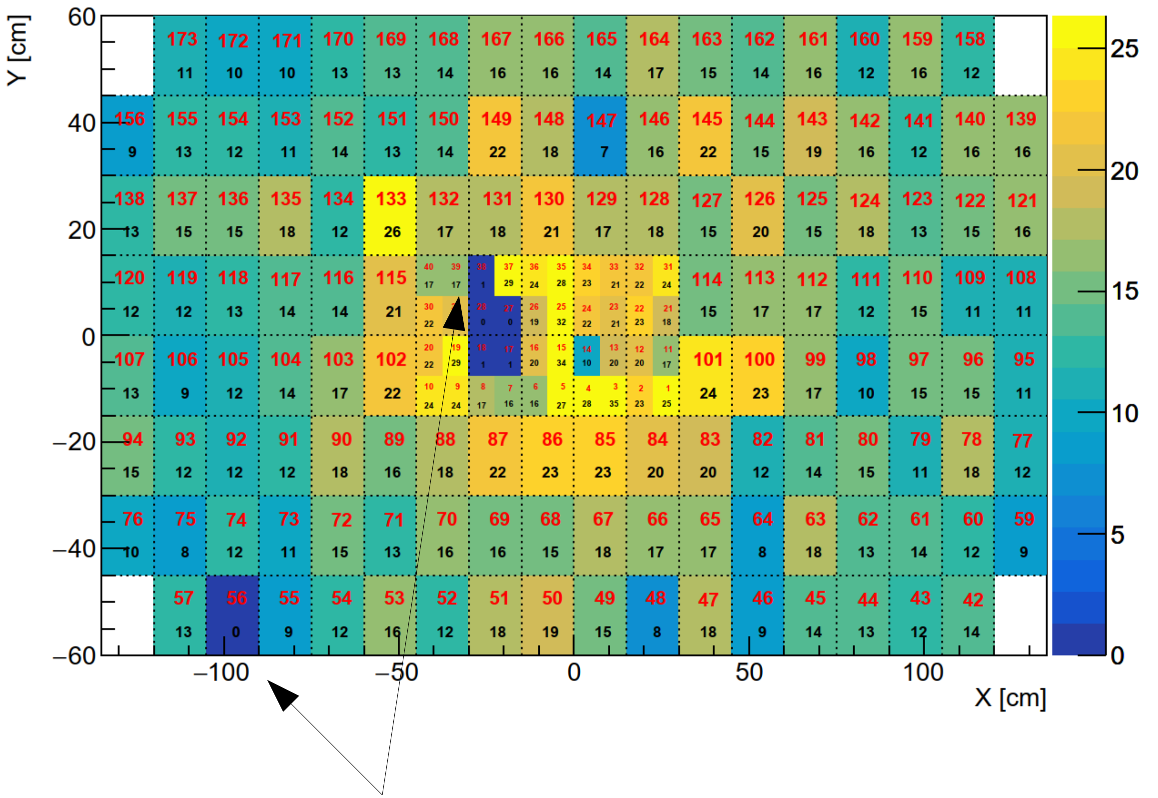
ScWall average Z2 distribution with CsI(2%) target, Xe, CCT2

3A GeV



no signal

3.8A GeV

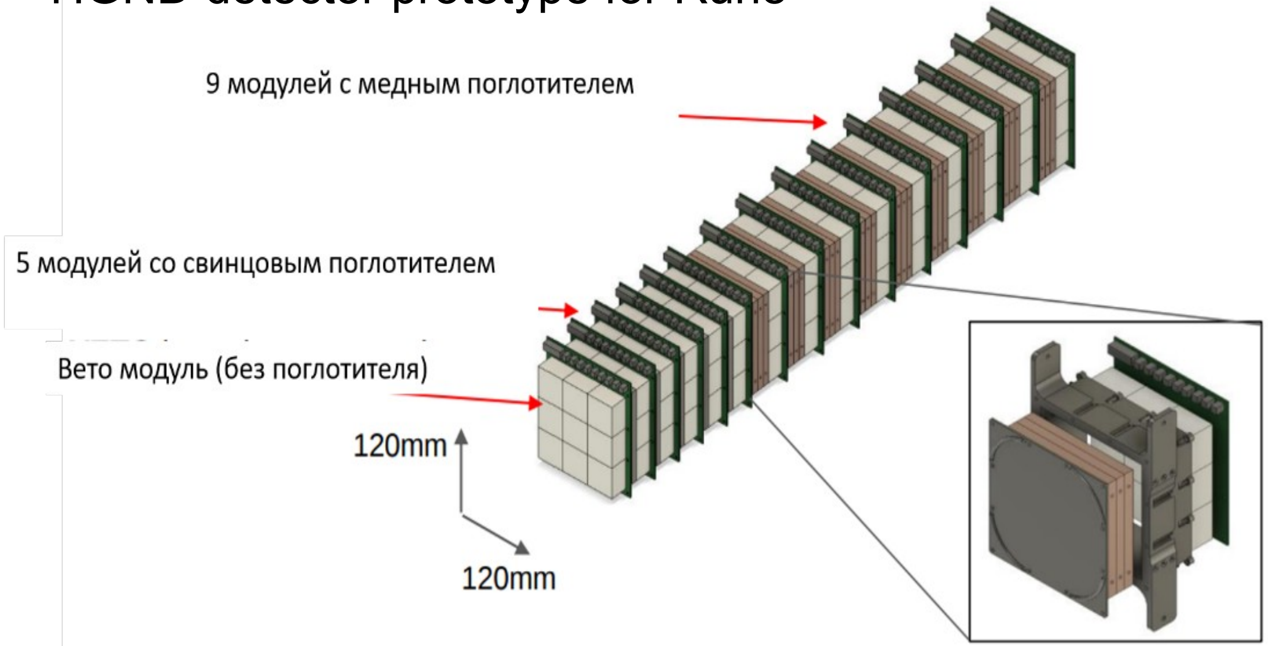


no signal

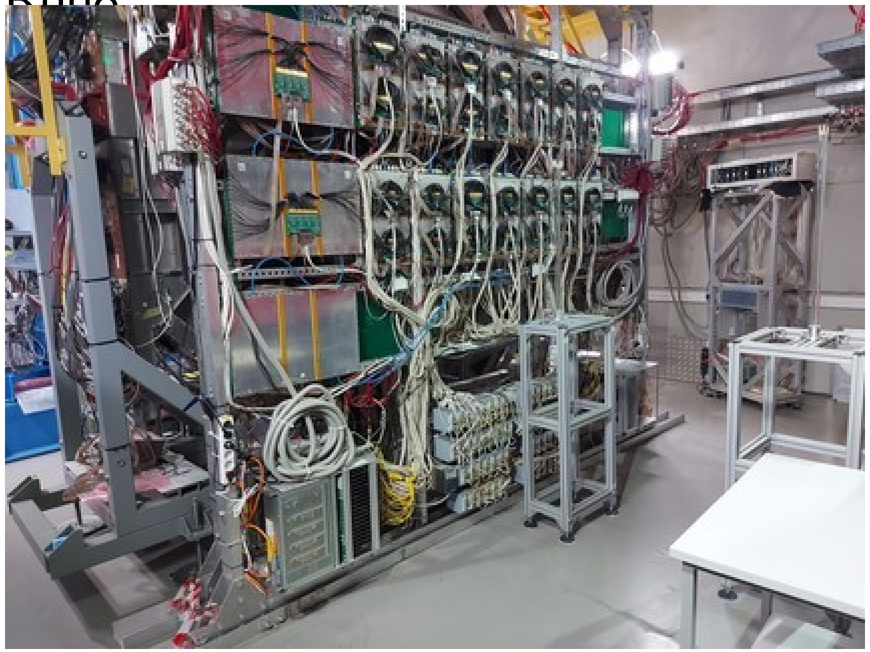
1) No signal: bad contacts in connectors, fixed after the Run8

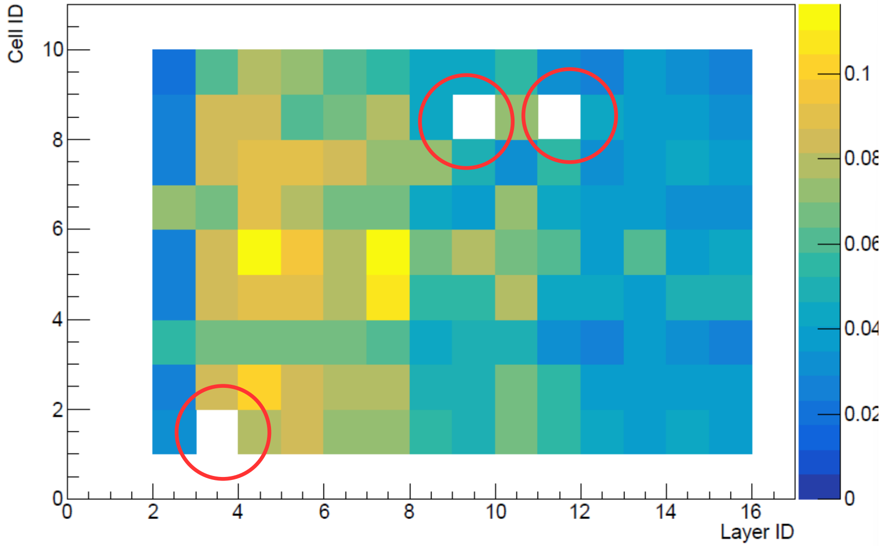
2) ScWall is now moving to new place, after the movement all cells will be checked again

HGND detector prototype for Run8



HGND neutron detector prototype in Run8

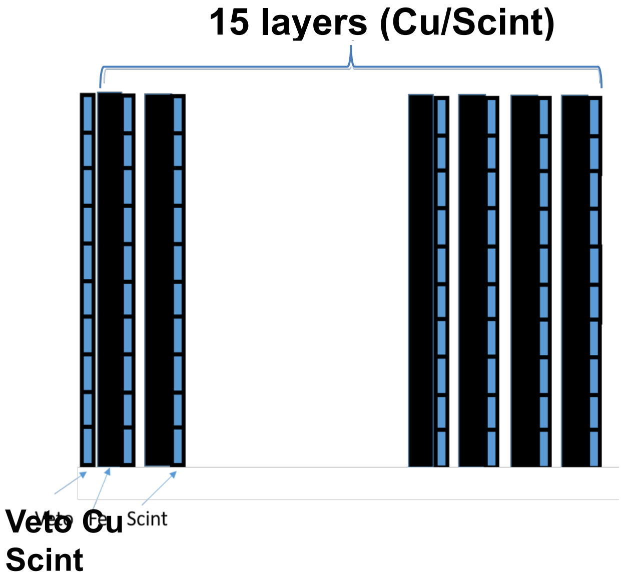


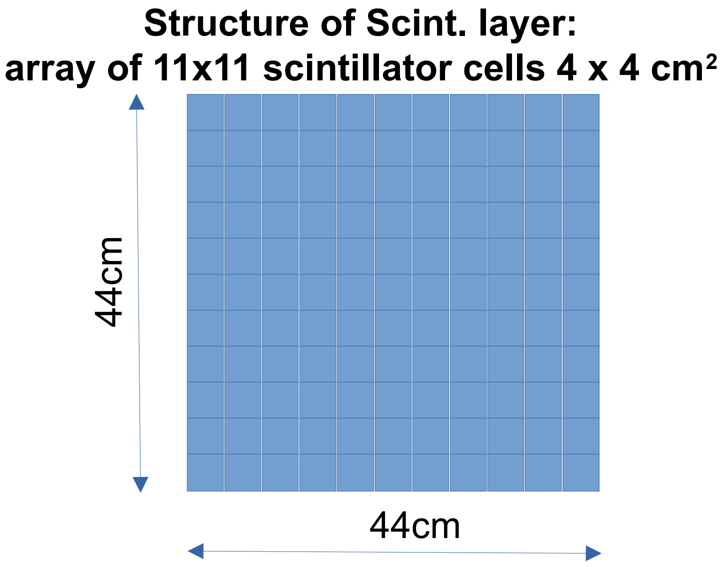


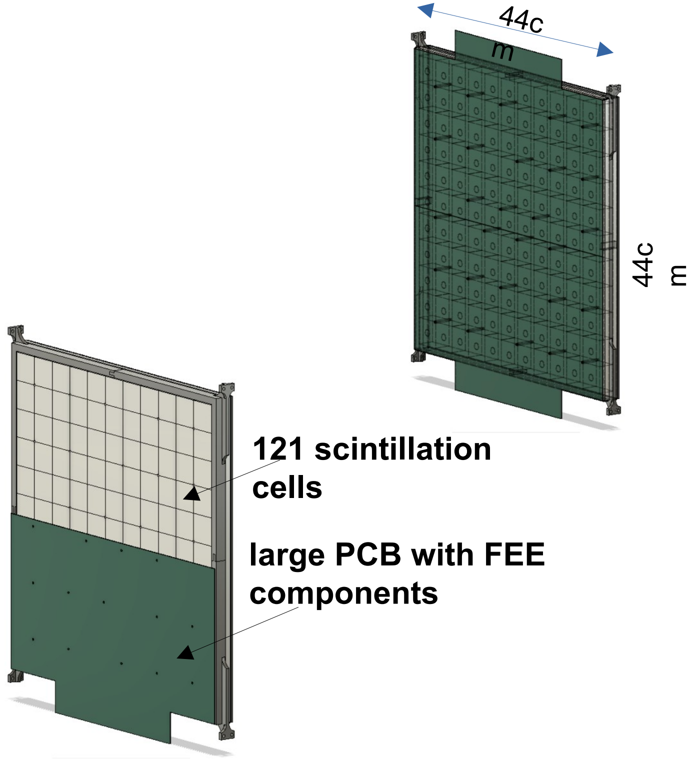
- no signal in several channels:
  fixed after Run8

- new LED flash calibration system:
  is under development (INR RAS, ITEP, JINR)

Status of new neutron detector for the BM@N: High Granular Neutron time-of-flight Detector (HGND) with SiPM readout





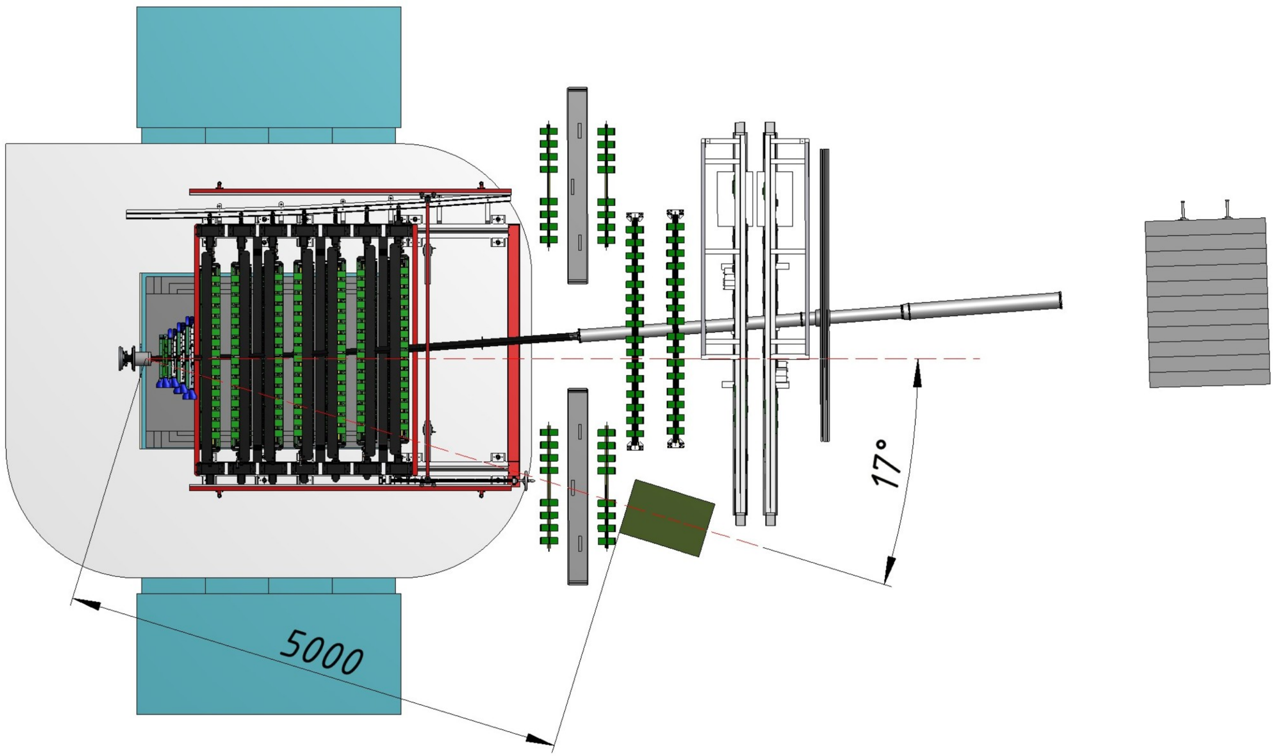


- Transverse size of one layer: 44 x 44 cm^2,
- number of layers: – 15 + Veto,
- structure of layer: 3 cm Cu (absorber) + 2.5cm Scint. + 0.5cm (SiPM+FEE)
- size of scintillation detectors (cells): 4x4x2.5 cm^3, total number of cells: 1936
- light readout: one SiPM with sensitive are 6 x 6 mm^2 per cell
- total length of the HGN: ~ 95 cm (~3 λ_{in})

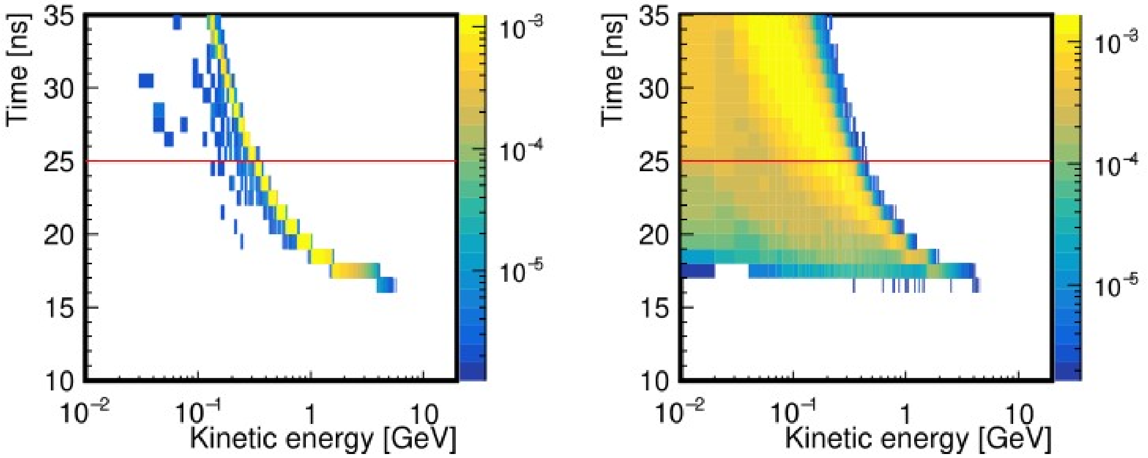
See presentation of Alexander Makhnev for details

Dependence of neutrons time-of-flight on the entrance of the HGN detector on its kinetic energy

Option1: one HGND with 16 layers



DCM-QGSM-SMM, the HGND is at 17 degree

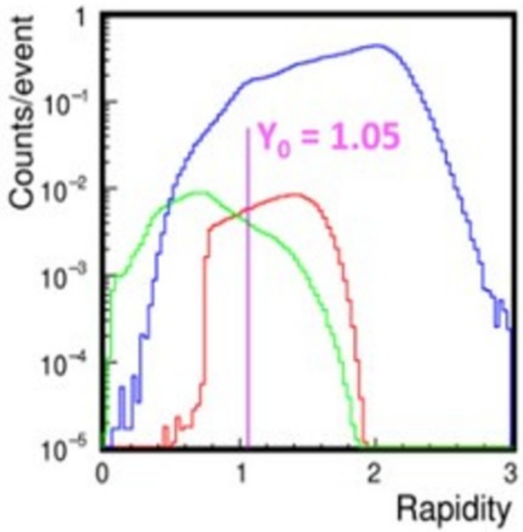


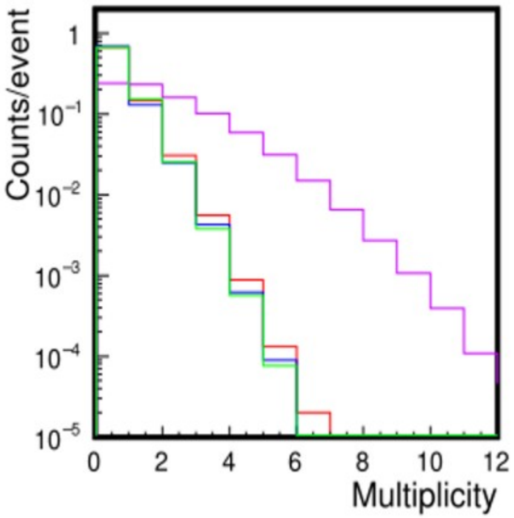
- at neutron time-of-flight cut < 25 ns the number of background neutrons will be reduced as factor of 6

- at this time cut only primary neutrons with kinetic energy more than about 300 MeV will be analyzed

Estimation of the HGND acceptance at 17 degree

DCM-QGSM-SMM, Bi+Bi @ 3A GeV, time cut 25ns applied





primary neutrons
background neutrons
for comparison: protons in BM@N acceptance

- about 5% probability of events with number of primary neutrons > 1

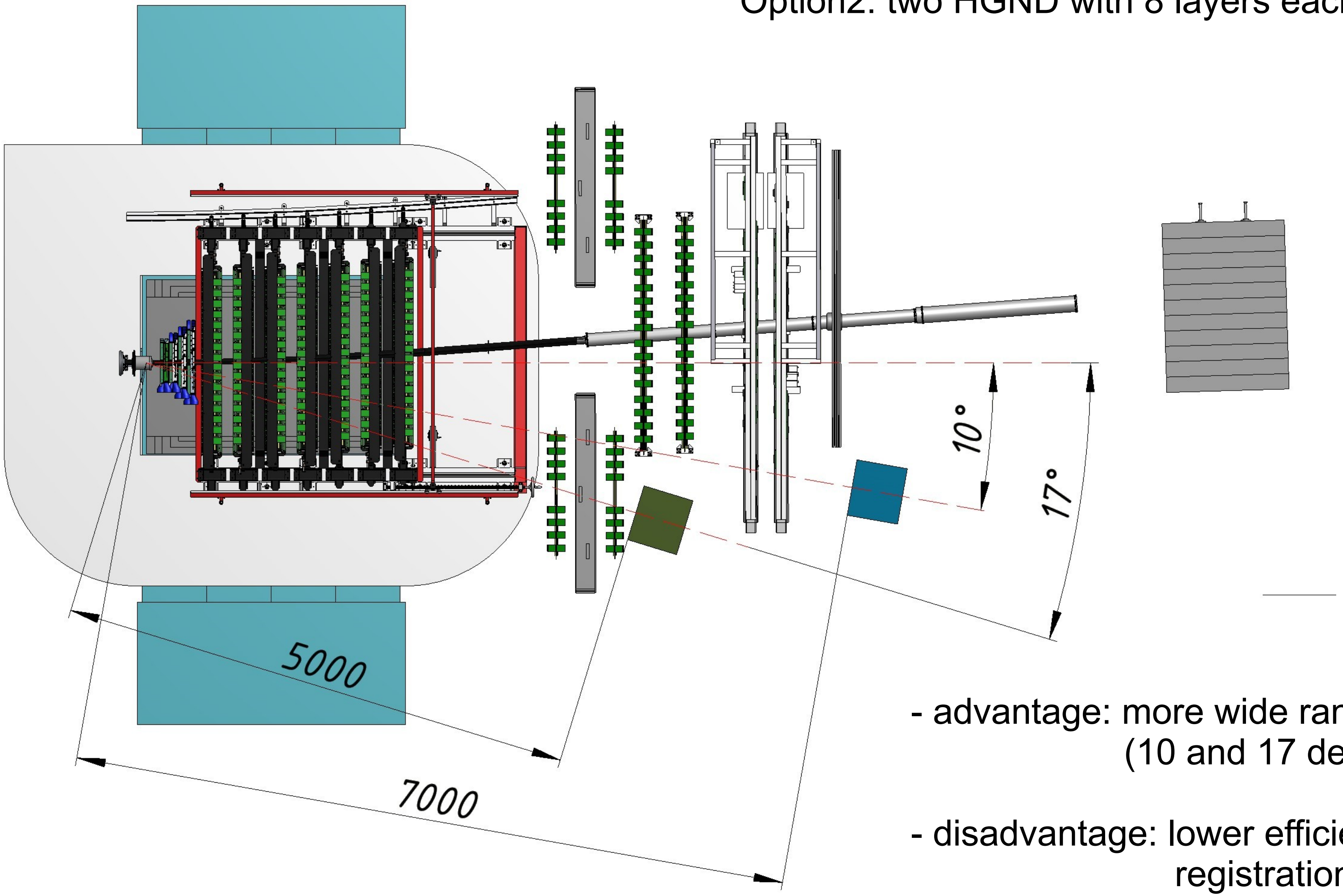
Estimation of primary neutrons count rate at the BM@N run

Beam rate - 10^6 per spill,
Duty factor of the beam - 50%
Efficiency of accelerator operation – 70%

Target interaction length - 2%,
Mean primary neutron yield - 0.1 neutron / interaction
Mean efficiency of the HGND detector - 50%

During 1 month of the BM@N run ~ 10^9 primary neutrons with kinetic energy > 300 MeV can be collected

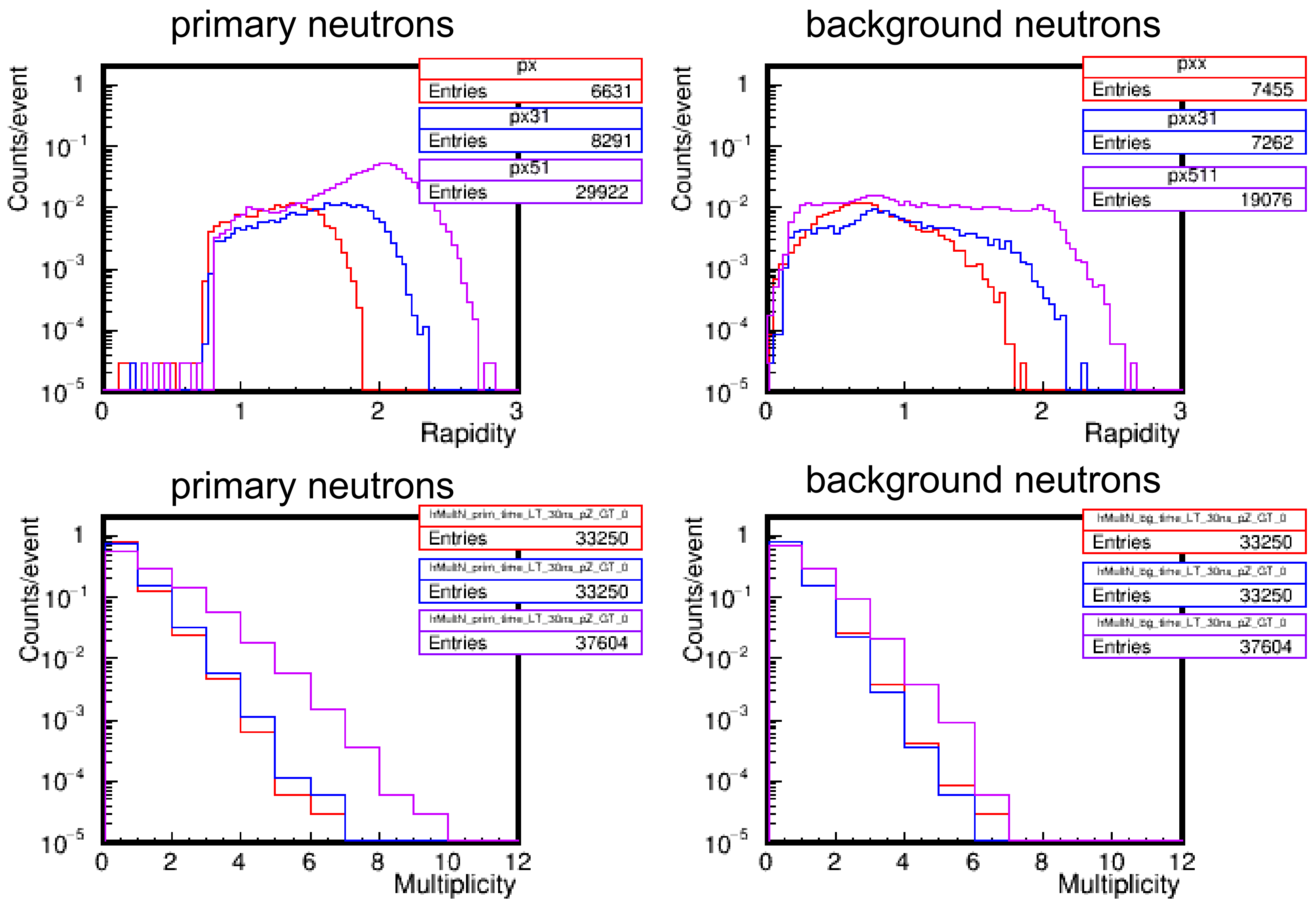
Option2: two HGND with 8 layers each



- advantage: more wide range in rapidity (10 and 17 deg overlapped)

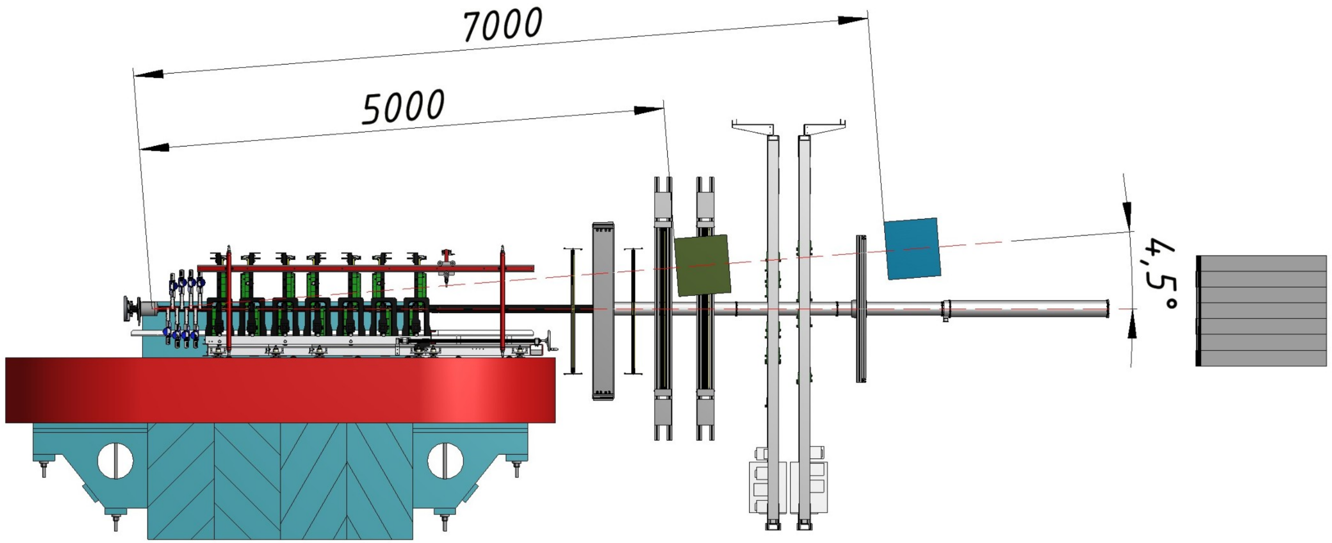
- disadvantage: lower efficiency of neutron’s registration

Status of forward spectator detectors readiness to the next run



HGND at:
17 deg
10 deg
4.7 deg

Option2: two HGND with 8 layers each



Rotation in Y-Z plane will help to minimize of material budget on the way of neutrons from the target to the HGND

plastic holders of GEMs

Conclusions:

- forward spectator detectors (FHCal, FQH, ScWall) are ready for the next runs at the BM@N

- the new HGND is under development:
  mechanics and FEE have been developed (see talk of Alexander Makhnev)
  read-out electronics is being developed now (see talk of Dmitry Serebryakov)
  methods for neutron registration are under discussions (see talks of Arseny Shabanov and Vladimir Bocharnikov)

- small HGND prototype was used in Run8 and will be ready for the next runs (+ LED calibration)
  see details of tests for neutron reconstruction in talk of Alexander Zubankov

Outlook:

- we are looking for the d beam in Summer 2024 to cross-check FHCal cosmics calibrations

- new LED calibration system for small HGND prototype is under construction

Thank you for your attention!

The development of HGN is supported by RSF grant No. 22-12-00132

Backup

Measurements of time resolution of scintillation detectors (scint + SiPM)

F.Guber et.al., Instruments and Experimental Techniques, 2023, Vol. 66, No. 4, pp. 553–557
(JINR. ИФТП scint. + Hamamatsu, SensL photodetectors)
F.Guber et.al., arXiv:2309.03614v1 [hep-ex] 7 Sep 2023
(JINR, EJ230 scint. + EQR photodetector)

Photodetector:
EQR15 11-6060D-S
(sensitive area - 6x6 mm^2, 15mkm pixel pitch, 160 000 pixels, PDE - 45%, gain - $4x10^5$)

Test results on e-beam at LPI

Scintillator:

1) JINR produced (40x40x25mm^3), 1.5% paraterphenyl and 0.01% POPOP) with light time decay of 3.9 ± 0.7 ns → σ ~117 ps, N ph.el. = 158 ± 9

2) EJ230 with light time decay of 2.8 ± 0.5 ns → σ ~ 74 ps, N ph.el. = 292 ± 2

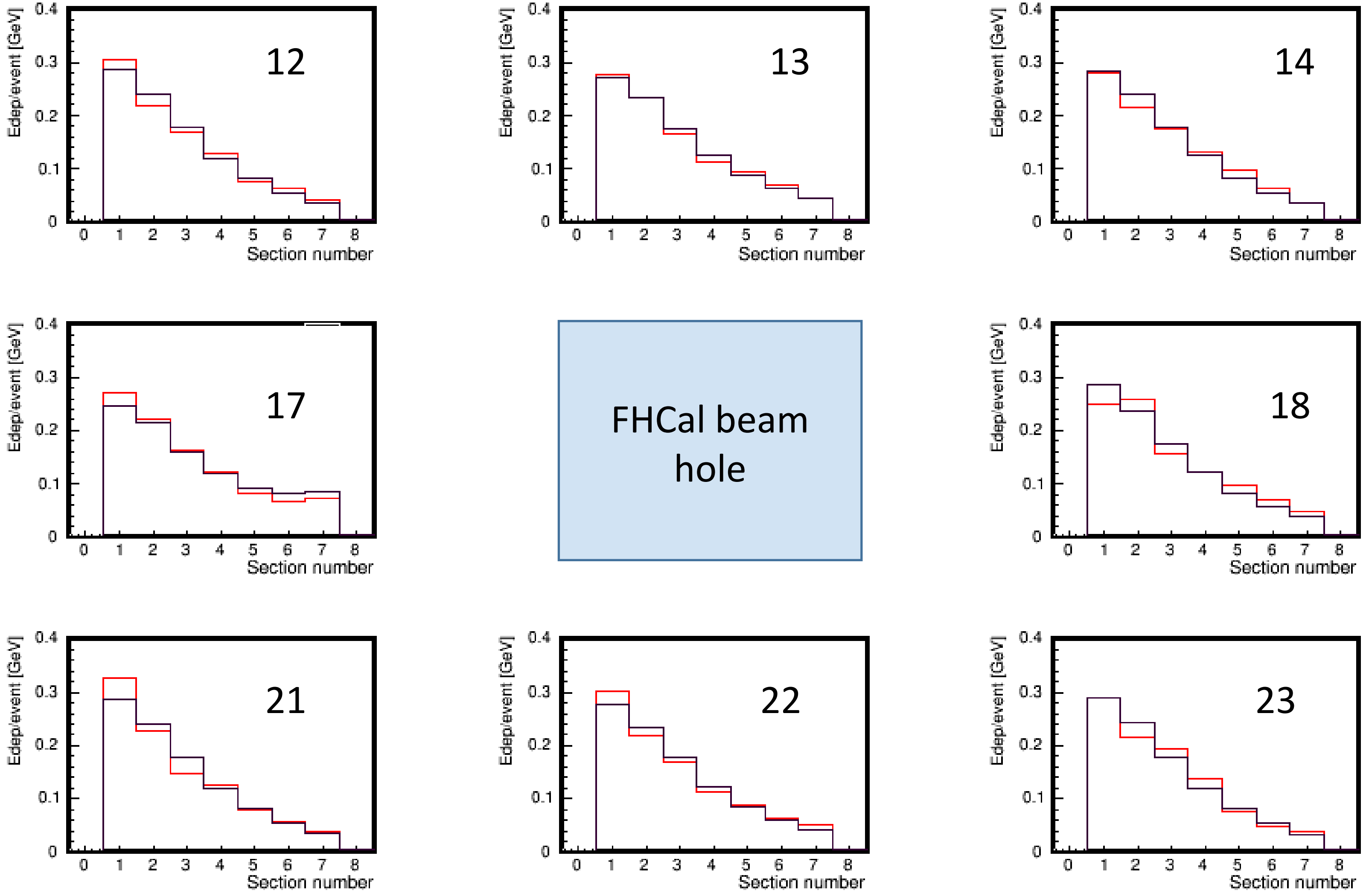
FEE: LMH6629MF preamp (20 dB gain, bandwidth of 600 MHz at a 3 dB level, and noise of <2.2 nV/√Hz) + rapid discriminator (ADCMP553) with a fixed threshold.

Readout: CAEN DT5742

JINR scintillators will be used for the HGN detector because they are available and significantly cheaper than EJ230.

Energy profiles in FHCal modules around the beam hole: comparison with simulation

Modules



Run 7821 MBT trigger 3.8 AGeV

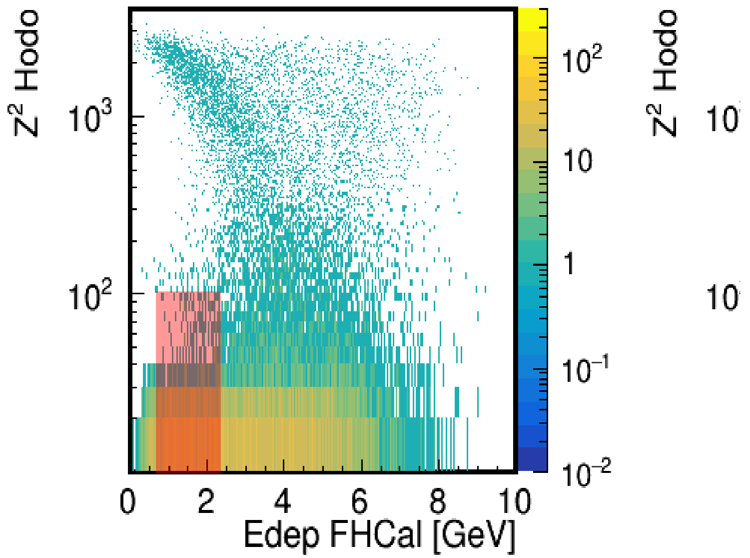
Central events:

FHCal Edep < 1.4 GeV && Z^2 < 100

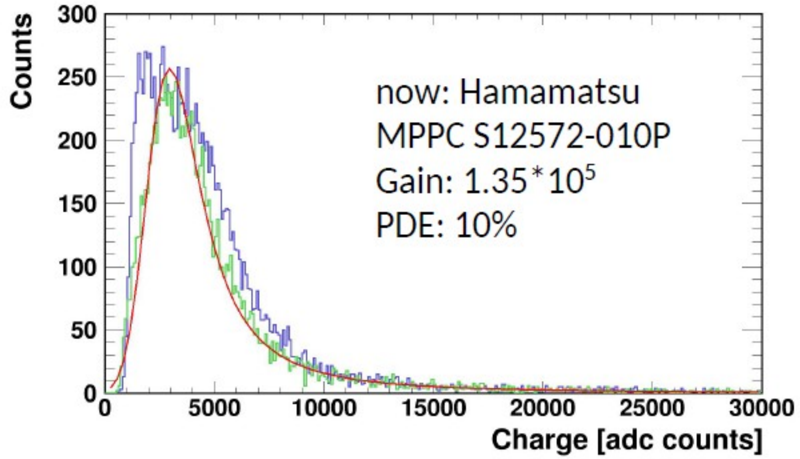
Simulation Xe+CsI@3.26 AGeV cms
DCM-QGSM-SMM (UNIGEN)
all BMN detectors

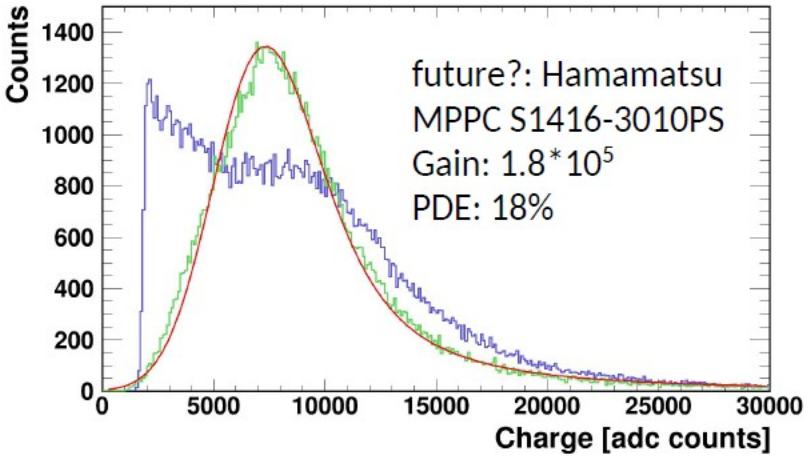
Central events:

FHCal Edep < 1.4 GeV && Z^2 < 100



- Do we need to exchange photodiodes in FHCal?

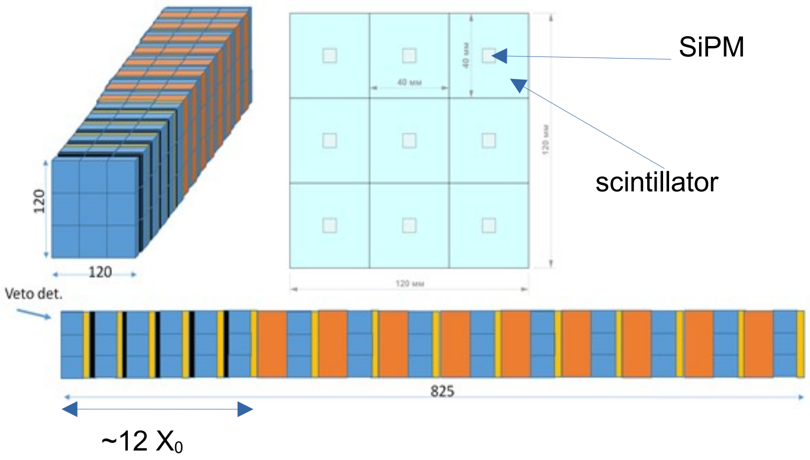


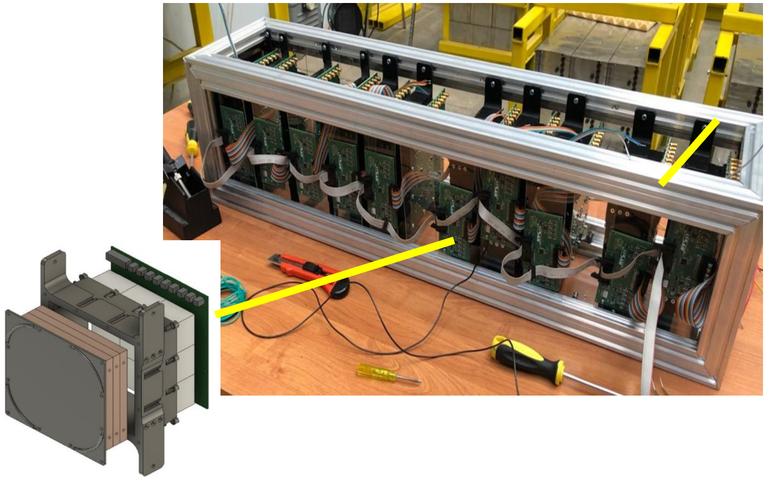


Pro: more visible MIP peak → more accurate calibrations (?)
Contra: less dynamic range with ADC64 board

These points need to be discussed and cross-checked with new cosmic calibrations + MC

- we are looking for the d beam in summer to check FHCal calibrations with pure beam of particles





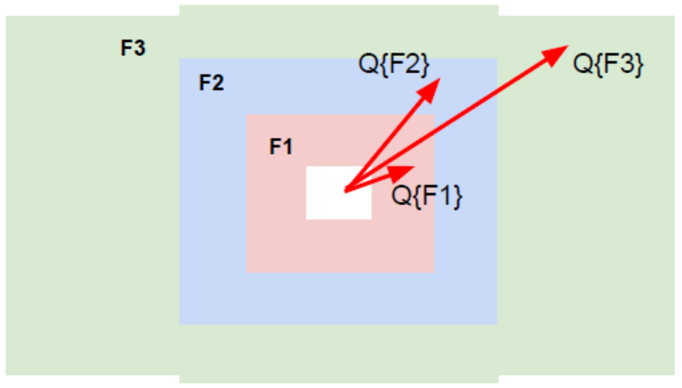
HGN prototype (15 layers, thickness ~ 2 λ_{int}):
- **1-st layer – VETO**
- **2-6 layers – E/M) part (Pb/Scint.)**
- **7-15 layer – hadron part (Cu/Scint.)**

Absorbers – Pb (8mm), (Cu 30mm),
145 scintillator cells (40x40x25mm)
SiPM - Hamamatsu MPPCs
Readout – TQDC (JINR)

Main goals:
- **Study of the design of the HGN detector mechanics and FEE design**
- **developments of neutrons identification and energy reconstruction methods**
- **measured time resolution of cell ~ 140 ps**

- Do we need to re-arrange modules of FHCal?

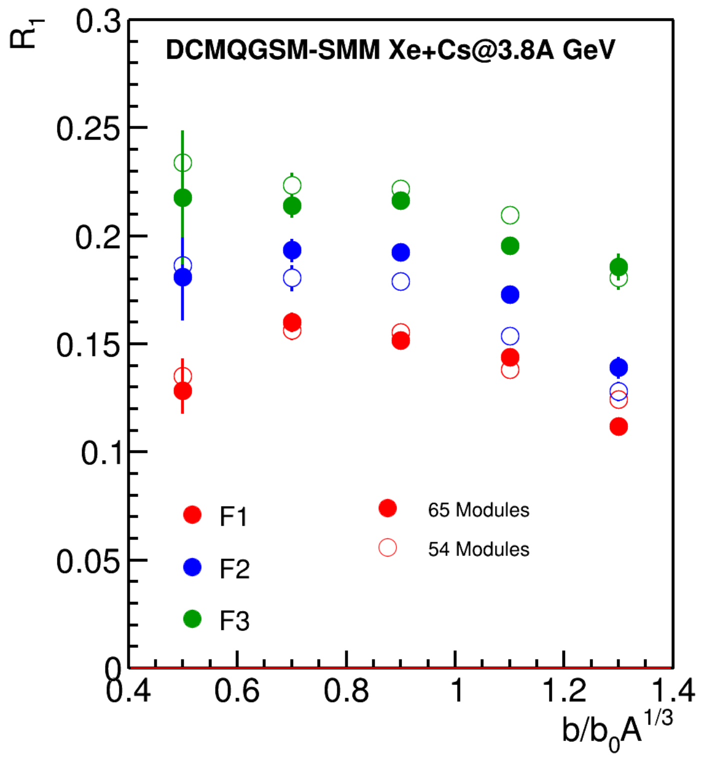
54 modules



The idea: 64 small (15x15) modules in total.

Check: do we have any improvements in flow analysis?

MC results:



65 modules (only small 15x15)

Conclusion: keep the current 54 “small + large” configuration.