Centrality and reaction plane determination at BM@N by new forward hadron calorimeter

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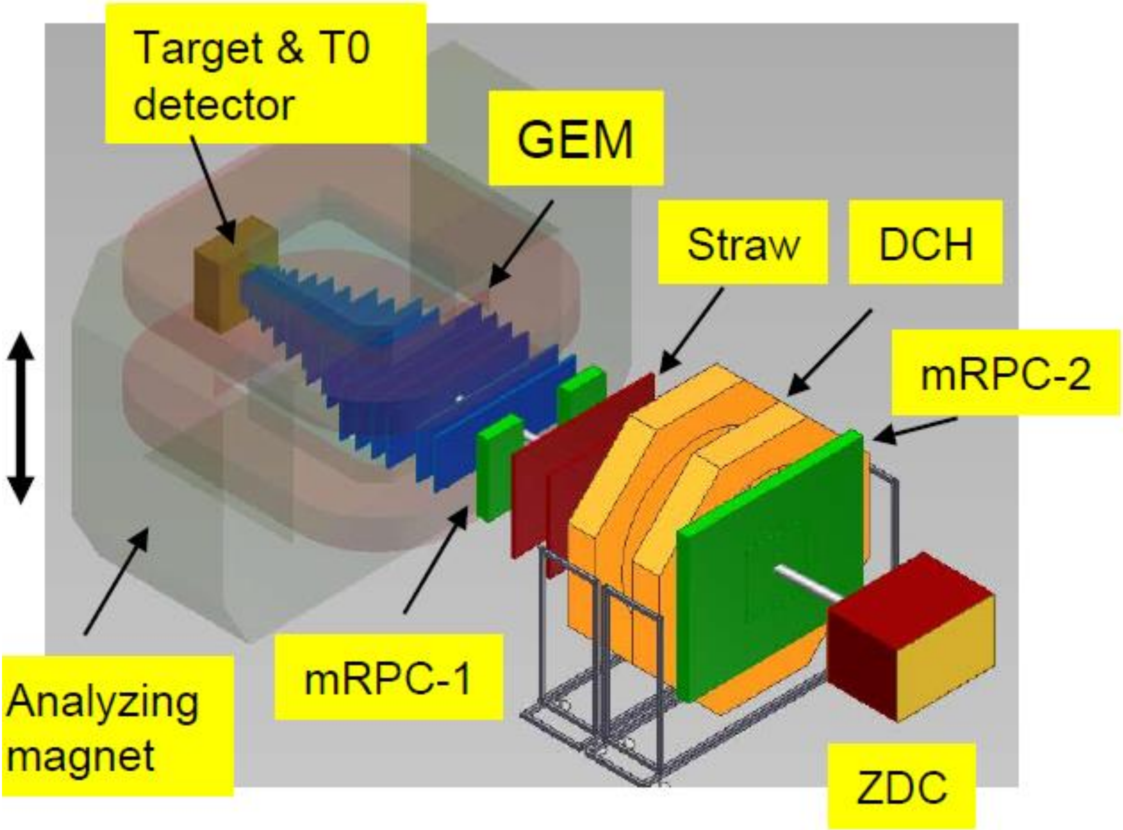
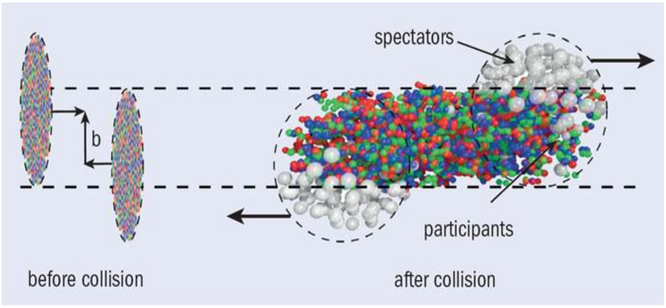
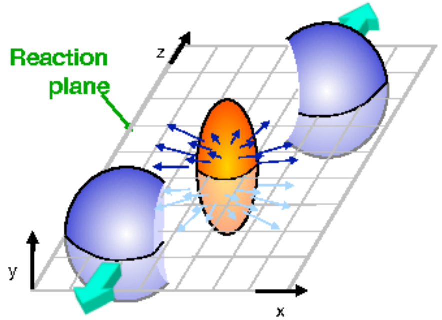
ZDC at BM@N



Main tasks of ZDC at BM@N:

Measurement of centrality and reaction plane orientation in nucleus-nucleus collisions.

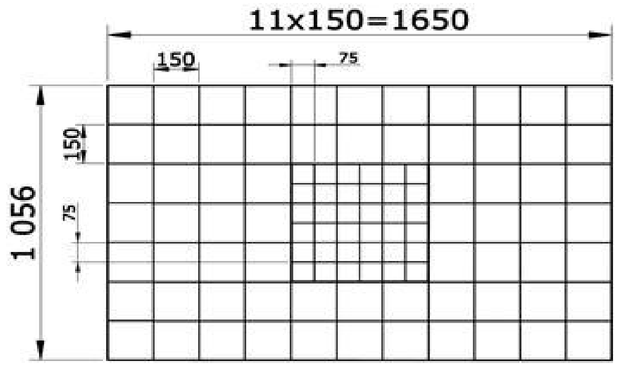




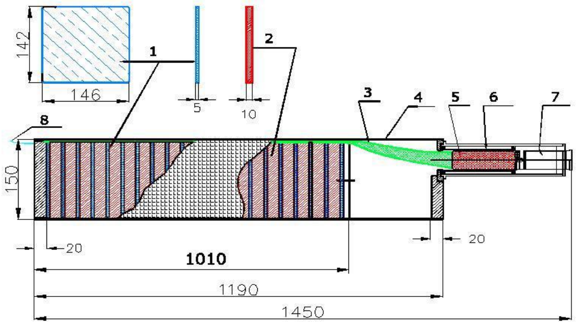
ZDC already used at BM@N experiments with ^{6}C, ^{18}Ar and ^{36}Kr beams.

Since 2020 heavy ion beams are expected and it is planned to replace existing ZDC by new forward hadron calorimeter FHCAL and it should provide also selection of most central events in nucleus-nucleus interactions on trigger level.

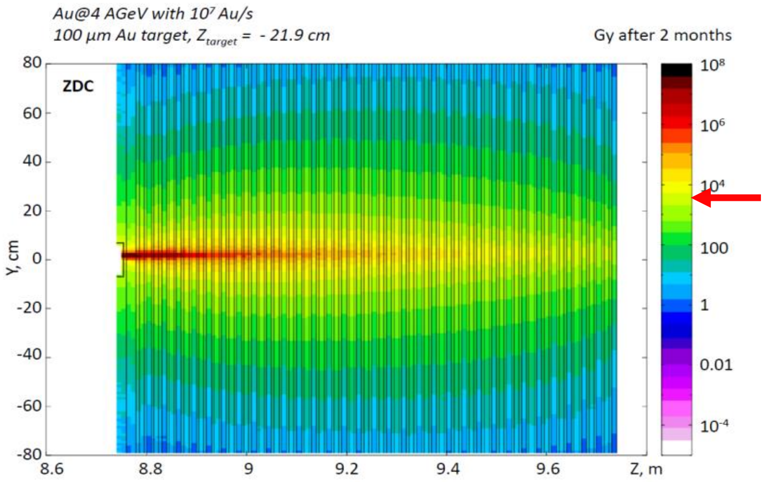
Structure of ZDC and motivation of use new FHCAL



Central part – 36 nodules ($7.5x7.5cm^2$).
Outer part 68 modules ($15x15cm^2$).



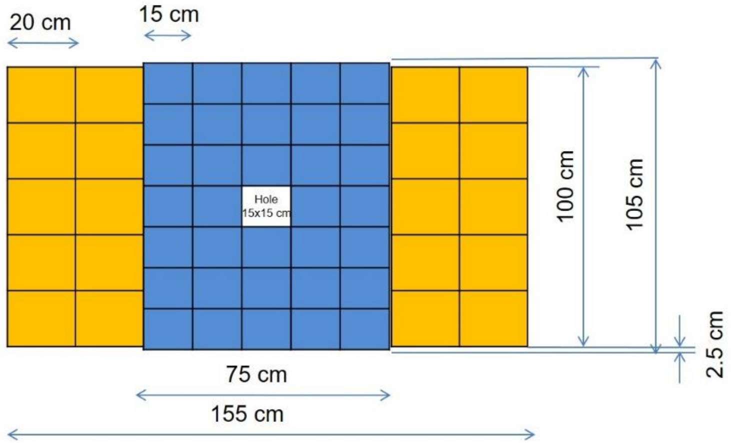
64 layers (5mm (scint.) + 10mm (Pb)

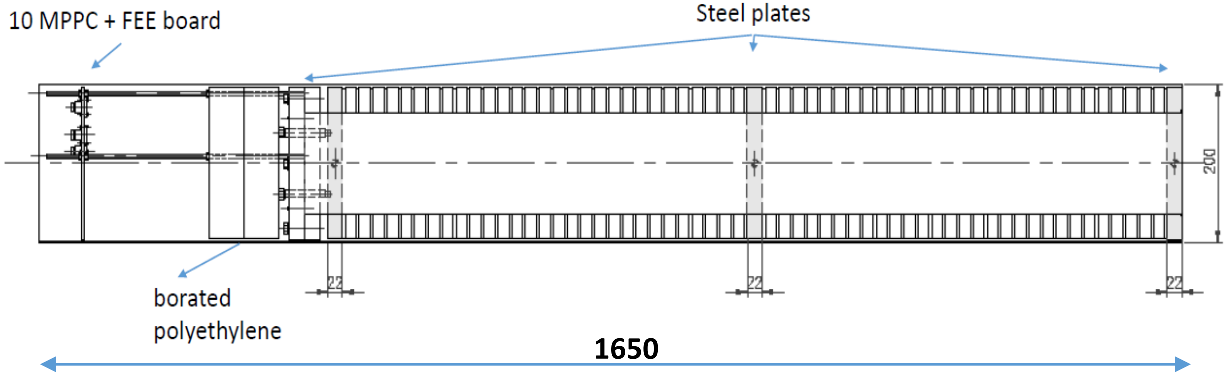


- High radiation doses are expected in ZDC central modules in future experiments with heavy ion beams which will lead to degradation of light transparancy.

- There is significant hadron shower leakage in ZDC due to the such small modules in the ZDC center and use WLS plates for the light collection in modules.
- ZDC has not longitudinal segmentation and longitudinal shower profile can not be measured.

New FHCAL for heavy ions beam runs at BM@N





35 FHCAL MPD modules,
150 x 150 x 1000 mm

20 PSD CBM modules,
200 x 200 x 1650 mm

PSD CBM module - 60 Pb/scint layers
(4mm (scint.) + 16mm (Pb), 4:1 sampling ratio.
Light readout - by 10 MPPCs from 10 longitudinal sections.

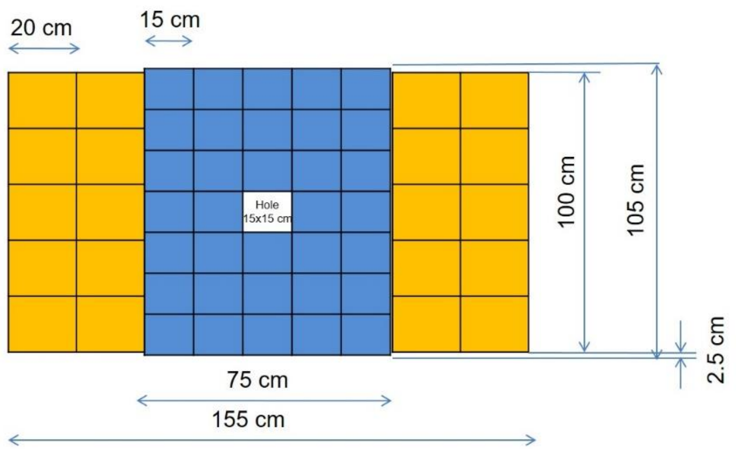
FHCAL MPD module - 42 layers of Pb/scint, the same sampling ratio.
Light readout - by 7 MPPCs from 7 longitudinal sections.

Longitudinal segmentation:

- **provides information about longitudinal shower profile;**
- **possibility to use cosmic muons for calibration without any additional trigger detectors.**

The use of the CBM and MPD modules in FHCAL BM@N will give the possibility to study Its response in real experiment before CBM and MPD experiments starts their operation.

FHCAL BM@N simulation



- **Reaction Au+Au@4.5 AGeV was generated with LAQGSM code, bmnroot framework with FTFP_BERT physics list.**
- **FHCAL - 9 m from the target.**
- **Beam smearing on the target was applied (σ_x = σ_y = 0.3cm).**

Radiation dose simulation by FLUKA:

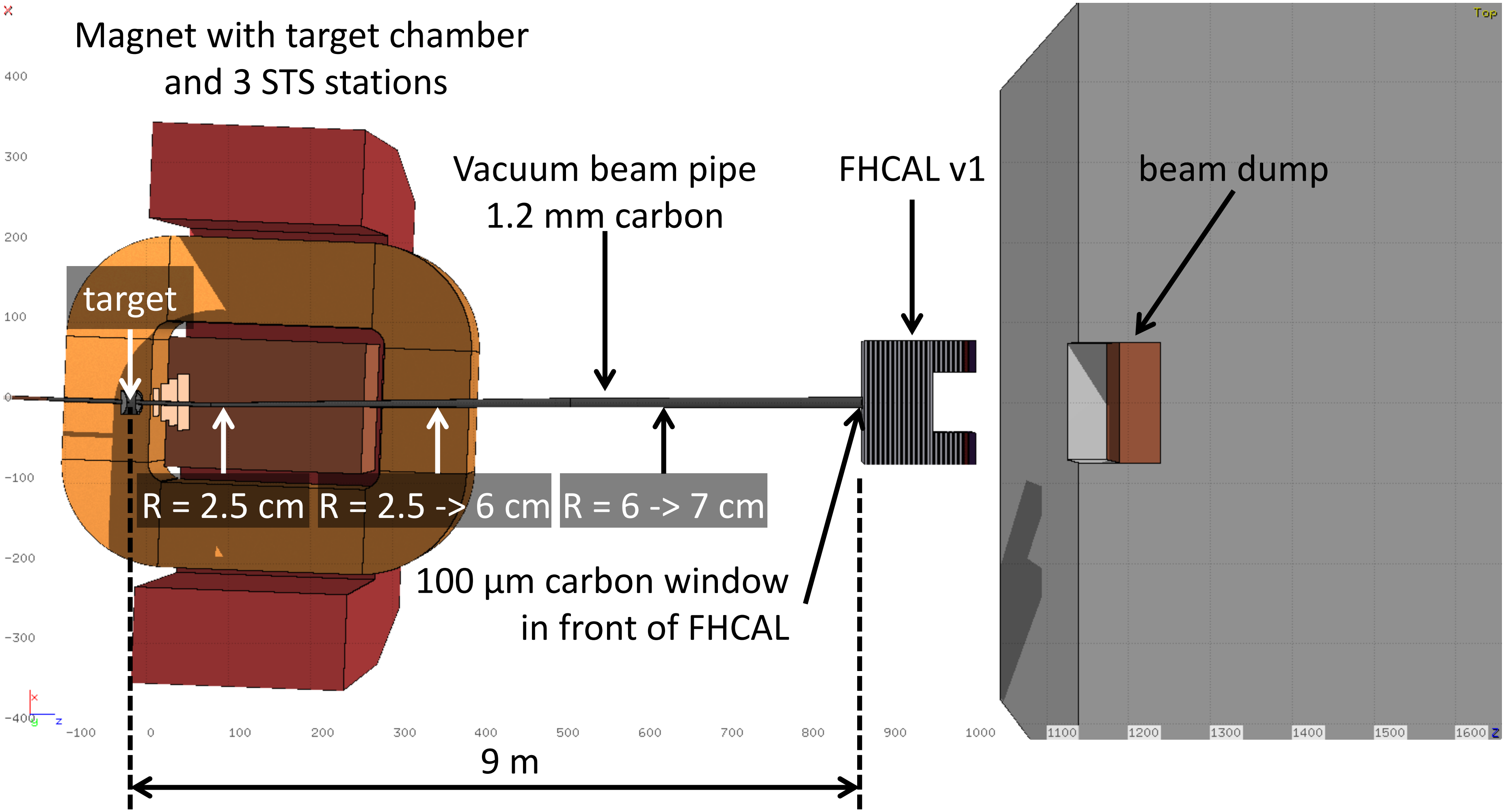
Simulations have been done for 3 versions of new FHCAL BM@N:

V1 – Calorimeter without beam hole;
V2 – Calorimeter with beam hole (15 x15 cm);
V3– Calorimeter with additional quartz detector (15 x15 cm x 0.4 cm) in front of beam hole;

FLUKA simulation of FHCAL radiation condition At BM@N

A.Senger, GSI

FHCAL at BM@N geometry in FLUKA



Used magnetic field corresponds 1200 A current in magnet

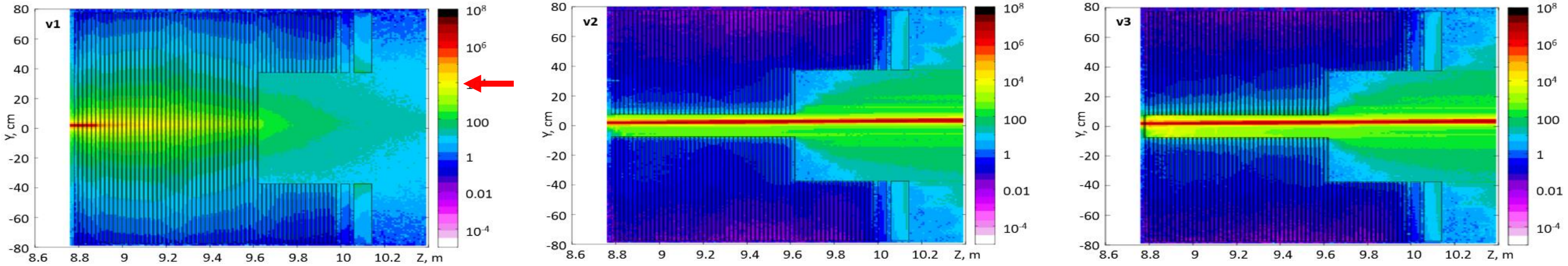
FLUKA simulation results
of the FHCAL radiation conditions at BM@N

A.Senger, GSI

AuAu, 4 AGeV, 100 µm Au target, beam 2×10^6 Au/sec

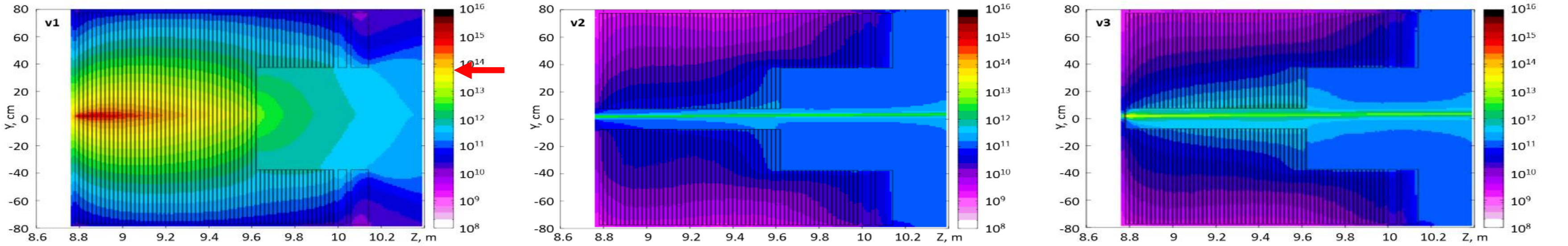
v1 v2 v3

Ionizing doses (Gy, after 2 months of run)



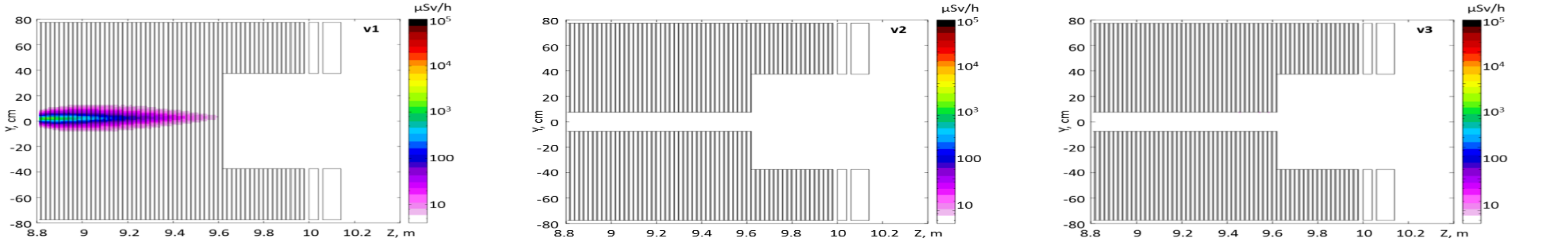
Doses in central modules of V1 version are too high.
⇨ Degradation of light transparency in scintillators.

Non ionizing fluence (n_{eq} /cm^2, after 2 months of run)



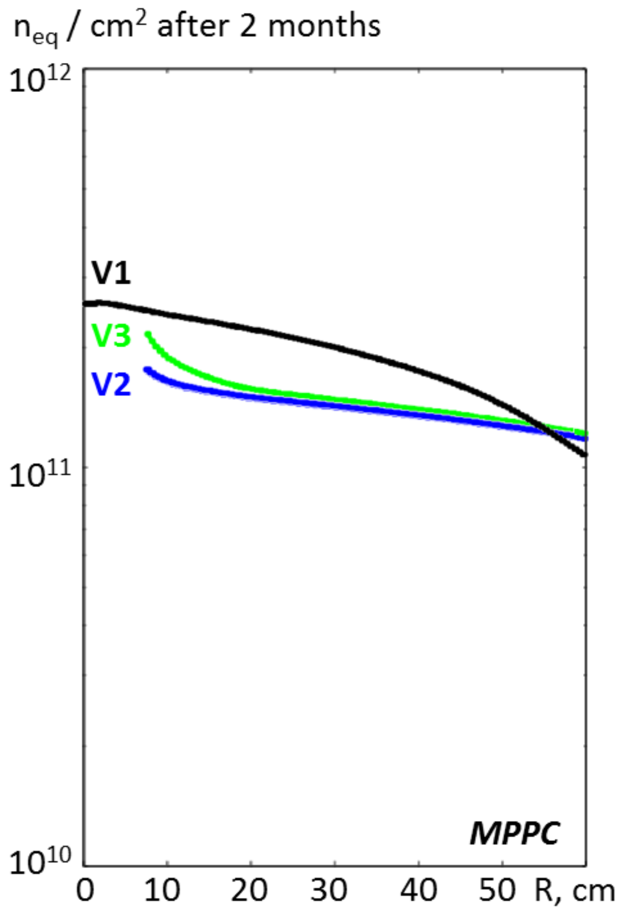
V2 and V3 versions have acceptable doses.

Activation after 2 month of operation with 2×10^6 Au/sec and 1 month after beam shutdown

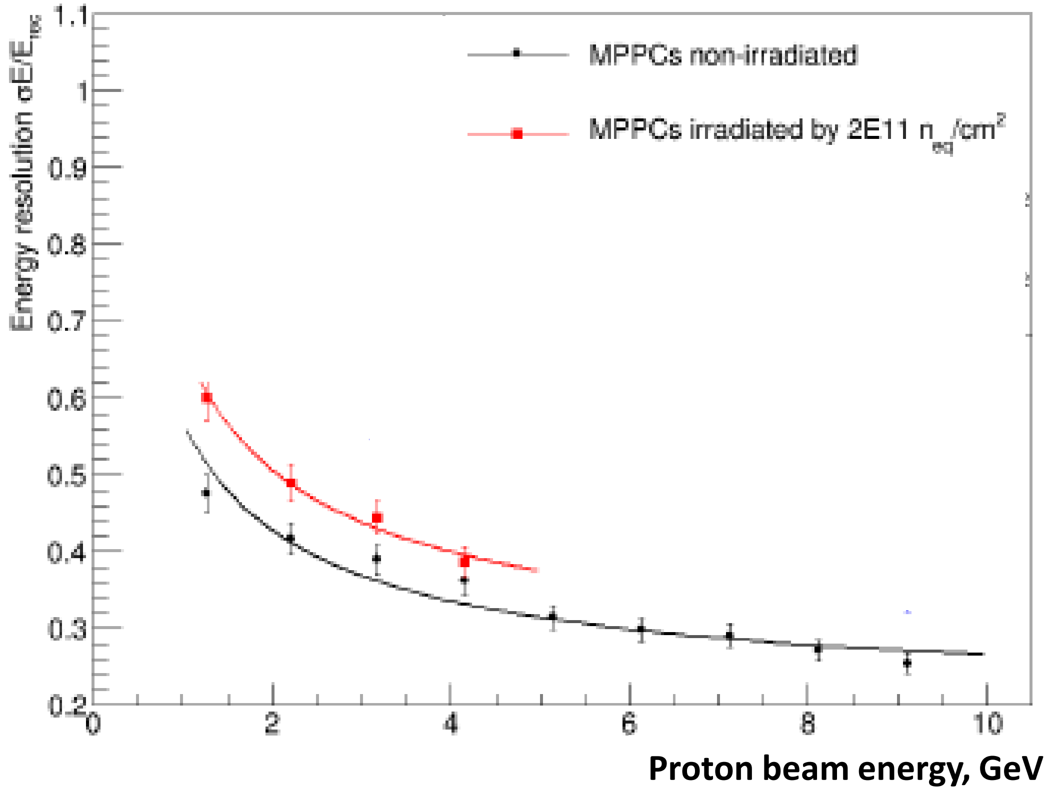


Practically, no activation for all modules in versions V2, V3.

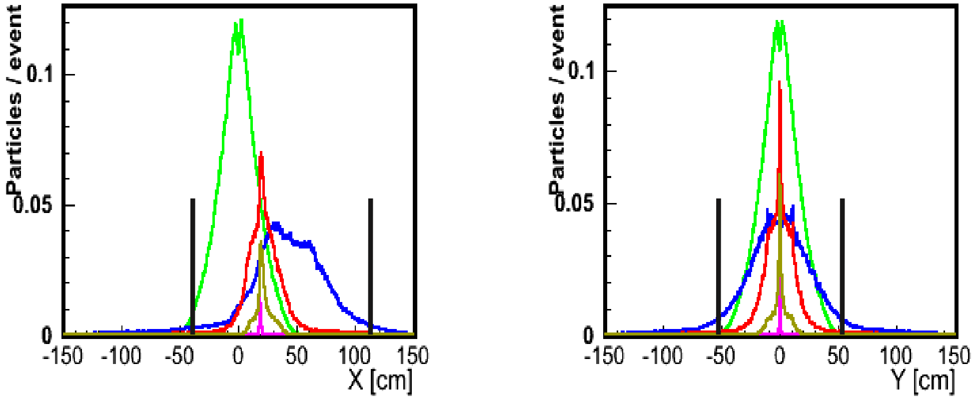
Neutron fluence on the MPPCs position on rear side the FHCAL modules



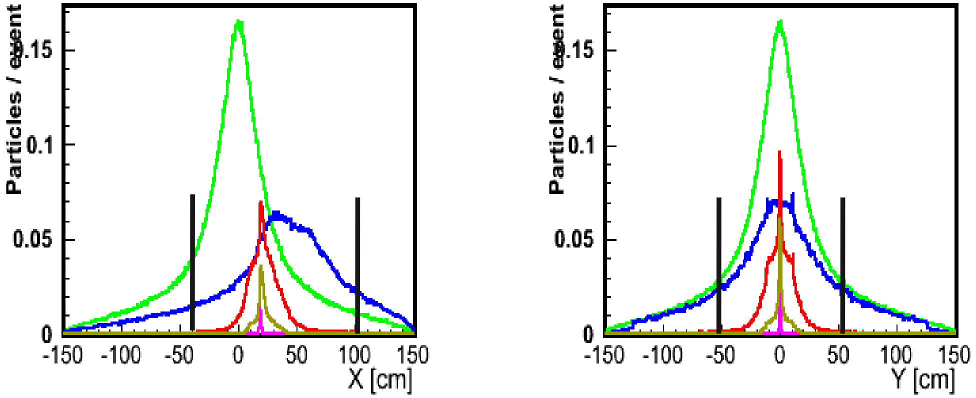
Measured energy resolution of PSD CBM module with irradiated and non irradiated MPPCs



Geometrical acceptance of FHCAL without beam hole



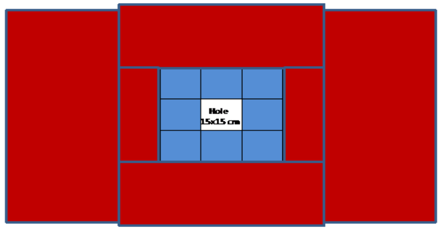
Only spectators transported through BM@N



All particles transported through BM@N

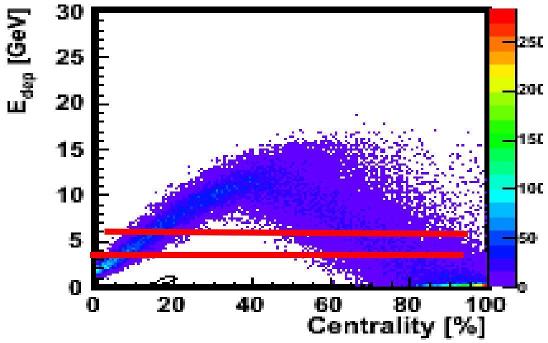
Transverse size of FHCAL is enough to accept practically all spectators.

How to measure centrality with FHCAL?



Calorimeter with beam hole

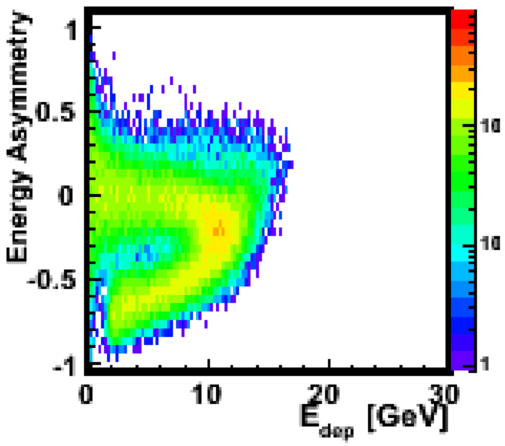
1) Use E_{dep} in FHCAL:



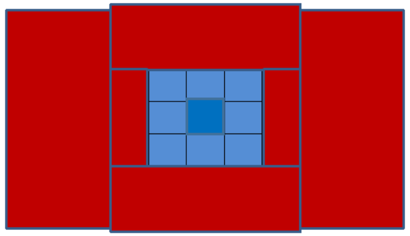
Non monotonic E_{dep} due to beam hole in FHCAL

2) Use energy deposition asymmetry in FHCAL:

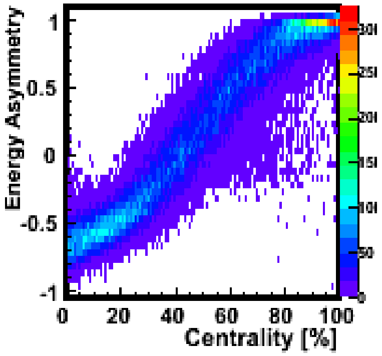
A_s = (E_{dep} (blue) – E_{dep} (red) / E_{dep} (FHCAL)



***A_s* depends on centrality and can be used to define centrality in FHCAL.**



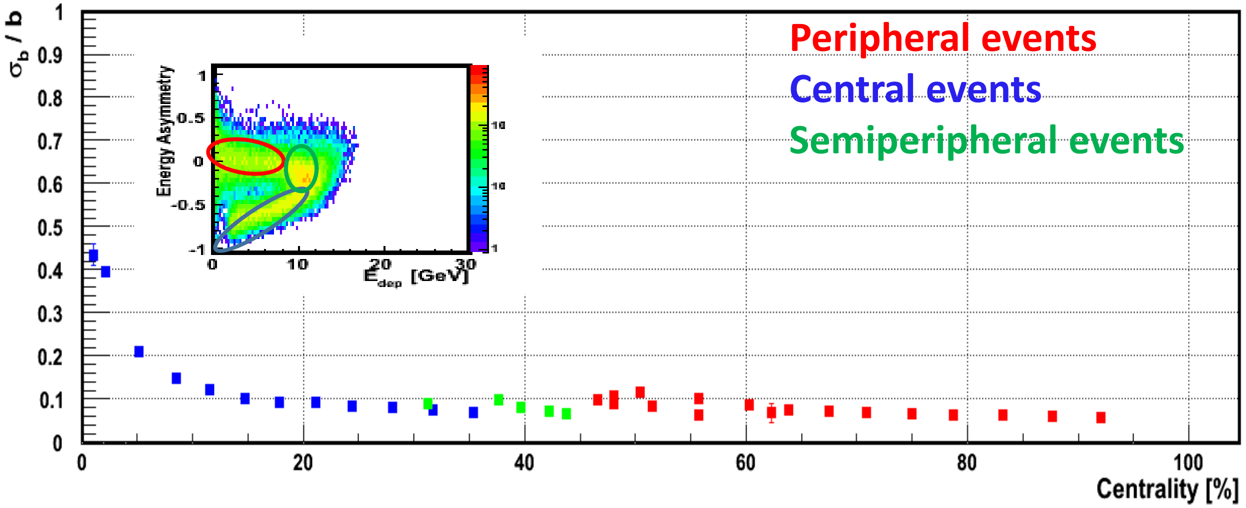
Calorimeter with quartz detector in front of beam hole.



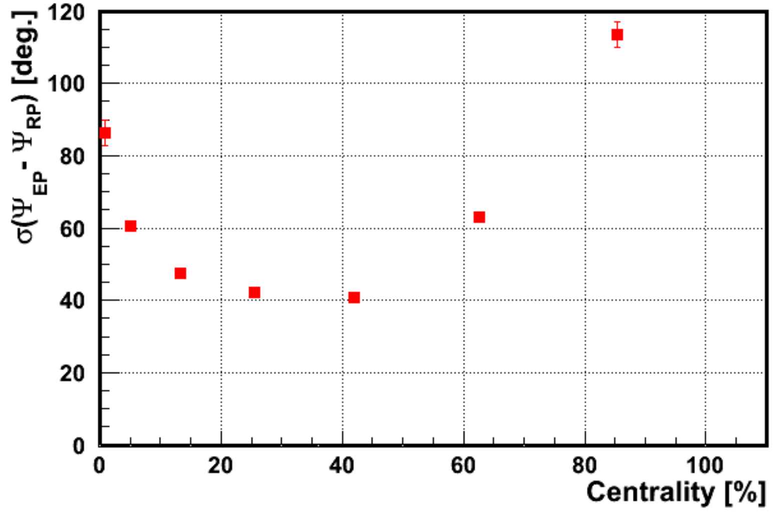
3) At present time, method of energy deposition contribution in FHCAL from charged fragments measured with quartz detector in the beam hole is developed.

Precisions of centrality and reaction plane determination by FHCAL with beam hole

FHCAL centrality resolution vs centrality

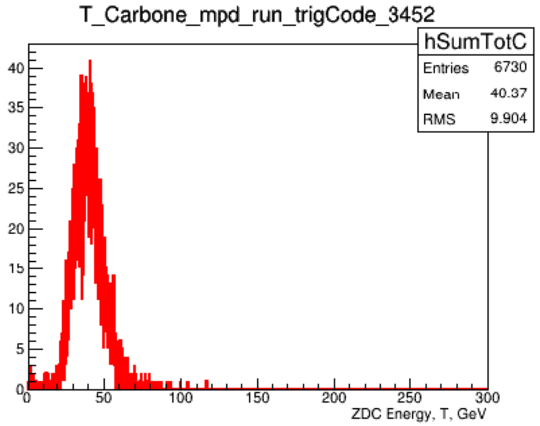


FHCAL reaction plane angle resolution



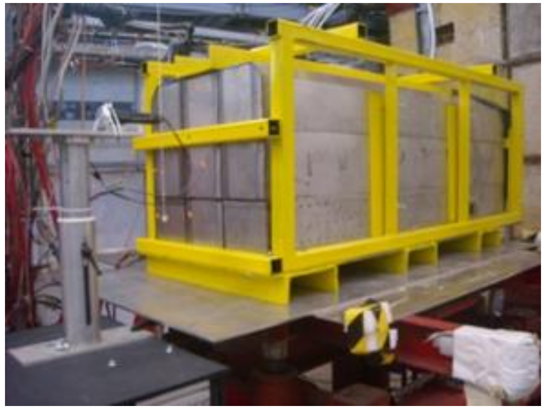
Comparison of measured energy resolution by ZDC BM@N and by new forward hadron calorimeter

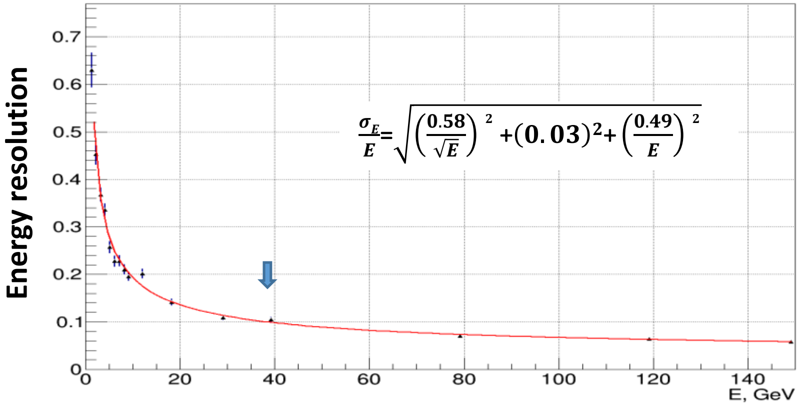
ZDC: energy resolution measured with carbon beam at 3.17 GeV/n



Energy resolution 24.5%
(preliminary)

FHCAL: results of PSD supermodule test at CERN proton beams

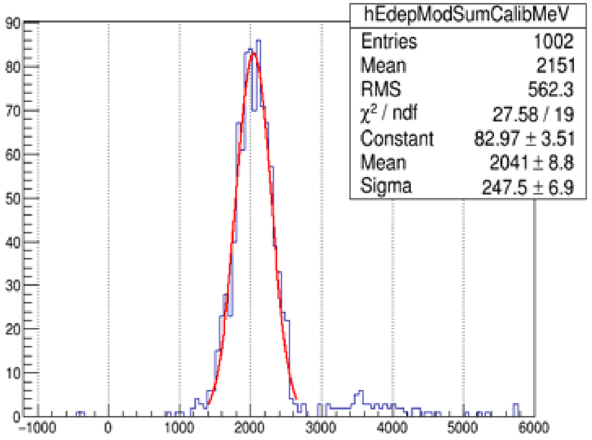




Estimation of energy resolution for carbon 3.17 GeV/n - 10%

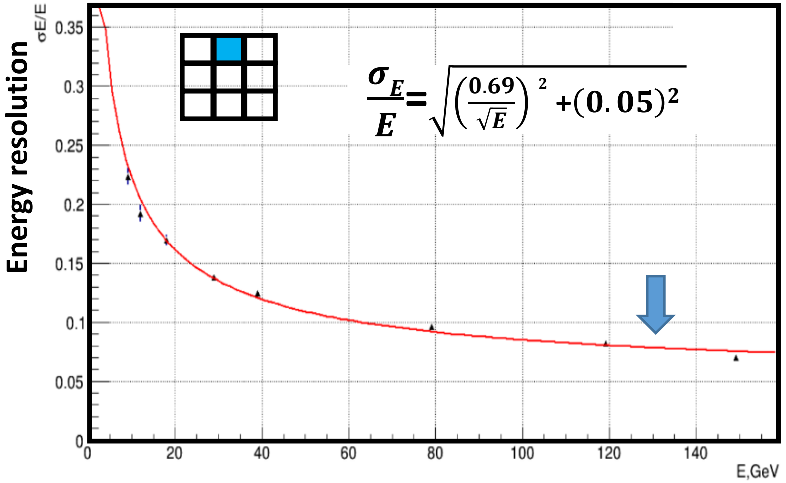
Comparison of PSD CBM single module energy resolution measured on Ar beam (3.3 Gev/n) at BM@N and on proton beam at CERN

BM@N, Ar, March 2018



Energy resolution – 12% (Preliminary)

CERN, protons, May 2018



Energy resolution – 7%

CONCLUSION and OUTLOOK

- New FHCAL for the BM@N heavy ion experiments is proposed. Already constructed modules for MPD/NICA and CBM/FAIR will be used for this calorimeter.

- 2 possible configurations of FHCAL are considered.

- Centrality can be measured with good energy resolution and in full centrality range using asymmetry of energy deposition in FHCAL with proposed geometry. More simulations are needed.

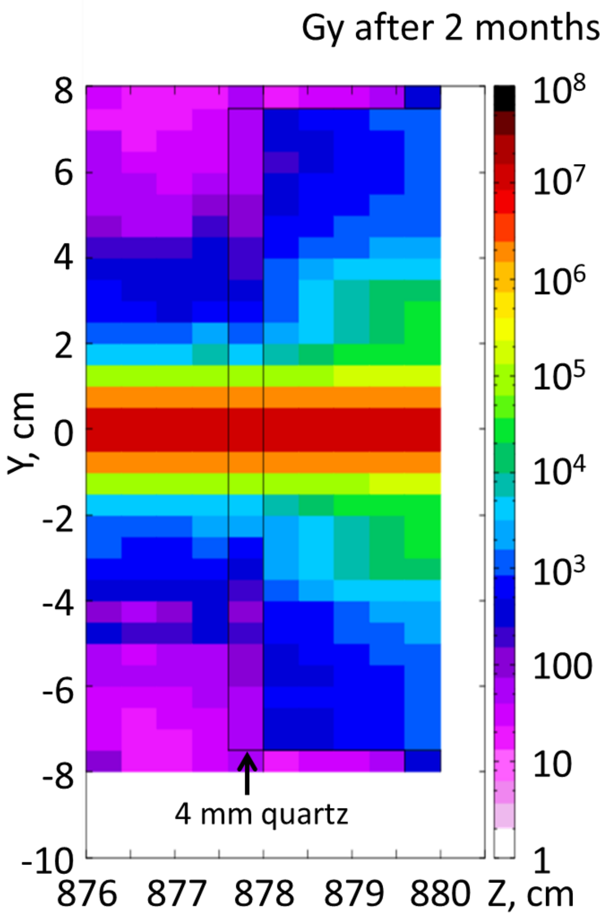
- Radiation condition for all 3 possible FHCAL configurations was simulated by FLUKA. More study of using quartz detector is needed (radiation damages, design of quartz detector, optimization of the position etc.).

All modules for FHCAL are available at INR RAS.

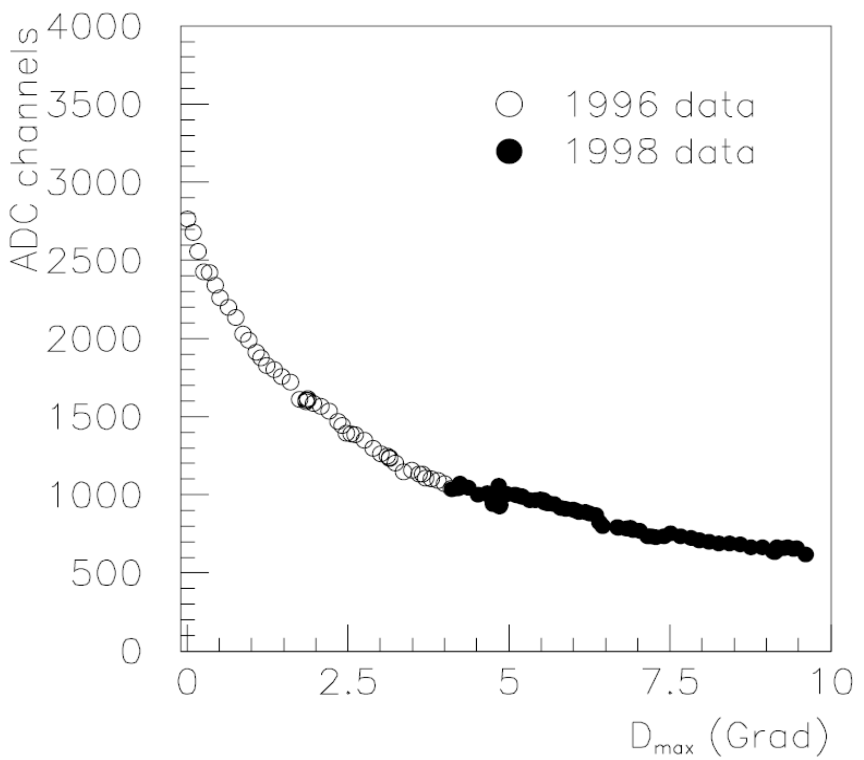
Start of FHCAL assembly at BM@N and tests – beginning of 2019.

Thank you for attention!

Radiation hardness of quartz detector in the FHCAL beam hole



ZDC with quartz fibers at NA50 experiment



The position of the Pb peak as a function of the dose D_{max} absorbed by the ZDC detector (*ALICE ZDC TDR*).

No significant doses in quartz beam detector.
Slight degradation of signal due to radiation dose can be recovered increasing the gain of the PMTs (MPPCs).