Synergy in the development of Forward Hadron Calorimeters for NA61/SHINE, BM@N, MPD and CBM experiments

F. Guber
INR, Moscow

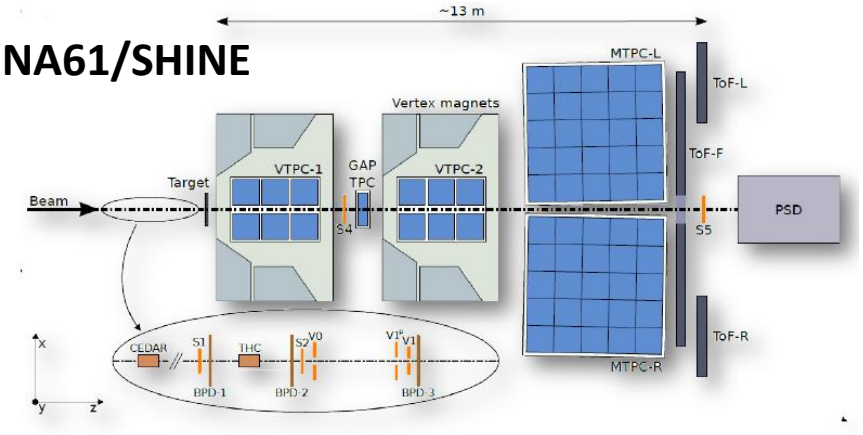


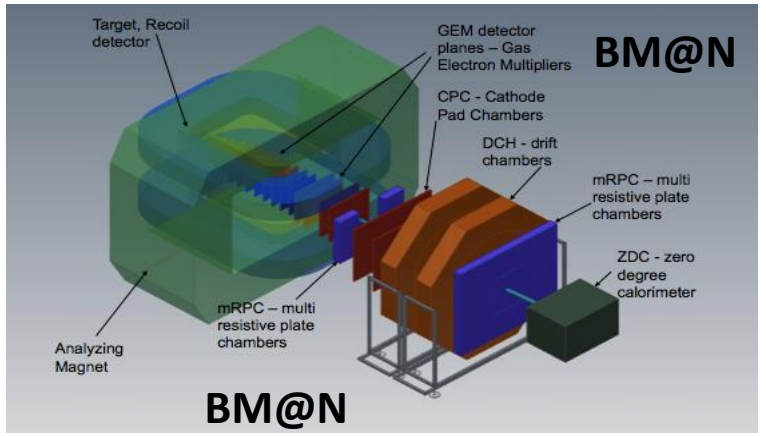
NICA days 2019, October 21-25, 2019

Mutual cooperation between NA61/SHINE, BM@N, MPD and CBM collaborations in Forward Hadron Calorimeters developments

Existing experiments

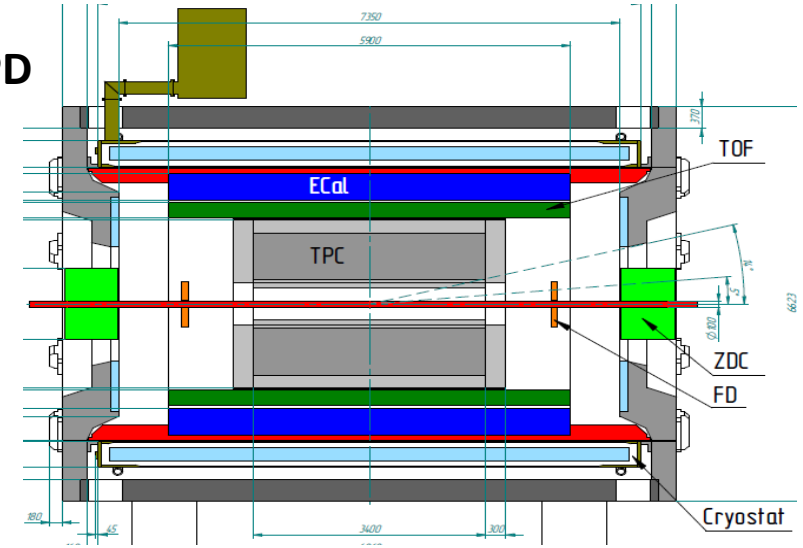
NA61/SHINE

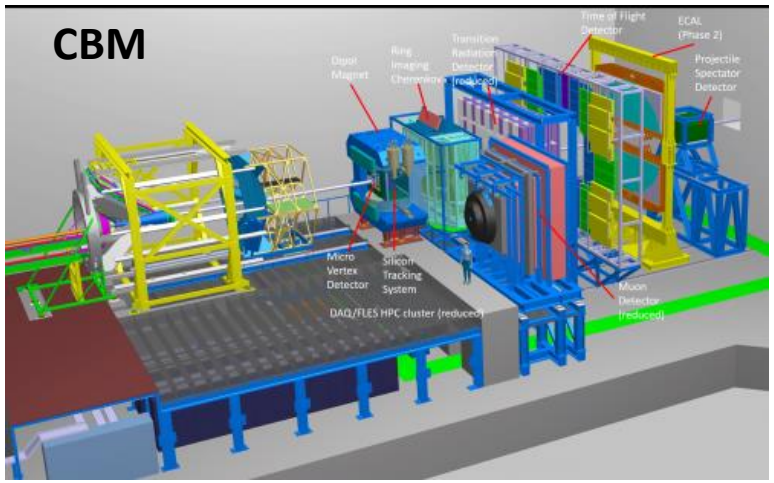




Future experiments

MPD





All 4 experiments are used Forward hadron calorimeters for centrality the reaction plane measurements.

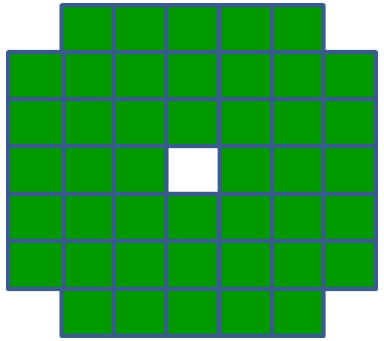
The feature of these calorimeters – Lead/scintillator sampling calorimeters with transverse and longitudinal segmentations.

All calorimeters are developed and constructed at INR RAS (Moscow).

Cooperation between collaborations is needed in commissioning of the calorimeters

Structure and status of calorimeters at the MPD, BM@N and CBM experiments

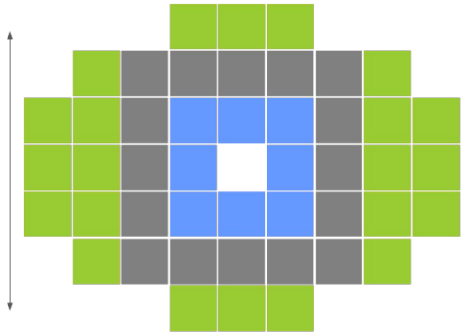
FHCAL@MPD



2 x 44 modules, 150x150mm^2
Beam hole (15 x 15 cm^2).
Total weight – 18t.

Construction of modules will be finished at the end 2019.

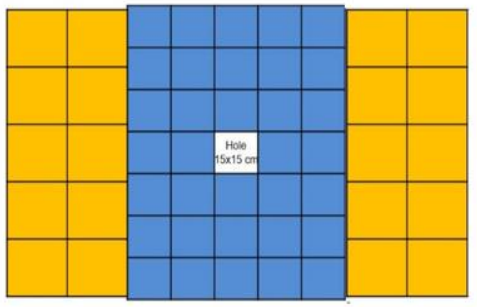
PSD@CBM



44 modules,200x200mm^2
Beam hole (20 x 20 cm^2).
Total weight – 22t.

All modules already constructed at the end of 2017.

FHCAL@BM@N



34 inner MPD type modules
20 outer CBM modules
Total weight – 17t.

New FHCAL is already assembled at BM@N

Sep. 2019

Memorandum of Understanding

between Institute for Nuclear Research of the Russian Academy of Science

and Joint Institute for Nuclear Research

and CBM Collaboration

for the use of Projectile Spectator Detector (PSD) modules for Zero Degree Calorimeter (ZDC) at BM@N experiment at Nuclotron

Authorised to sign on behalf of INR

Name: Prof. Dr. L. V. Kravchuk

Position: Director

Date: 23.12.2016

Signature:

Authorised to sign on behalf of JINR

Name: Academician V.A.Matveev

Position: Director

Date: 29.12.2016

Signature:

Name: Prof.Dr. V.D.Kekelidze

Position: Director of Veksler and Baldin Laboratory of High Energy Physics

Date:

Signature:

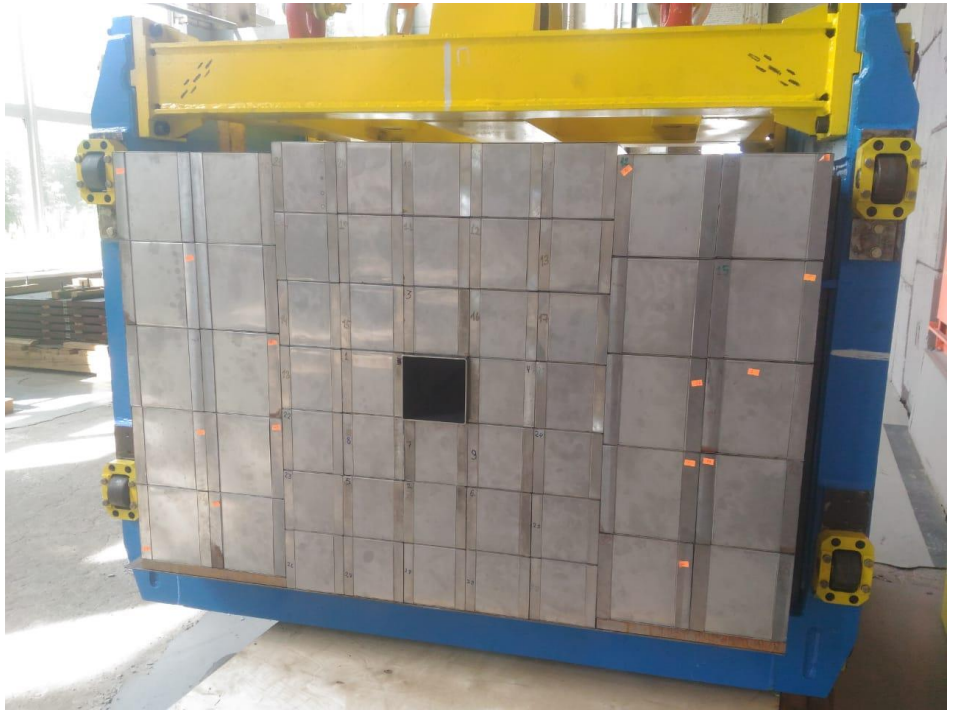
Authorised to sign on behalf of CBM ollaboration

Name: Prof.Dr. P.Senger

Position: The CBM Spokesperson

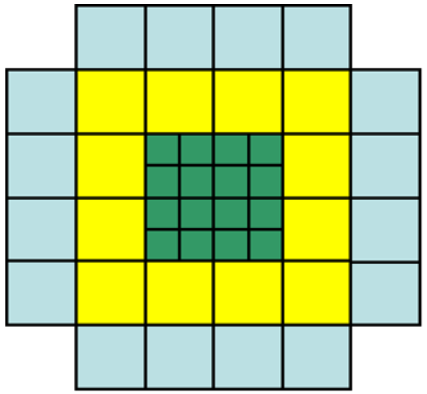
Date: 15.12.2016

Signature:

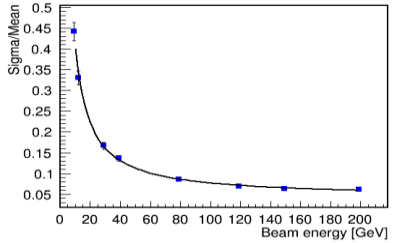


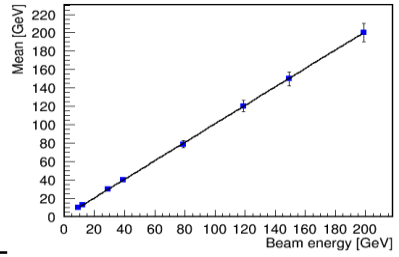
PSD@NA61/SHINE

First Forward hadron lead scintillator calorimeter with SiPMs readout has been developed and constructed for NA61/SHINE and used in heavy ion experiments during 2010-2018.



NA61/SHINE PSD energy resolution and linearity response



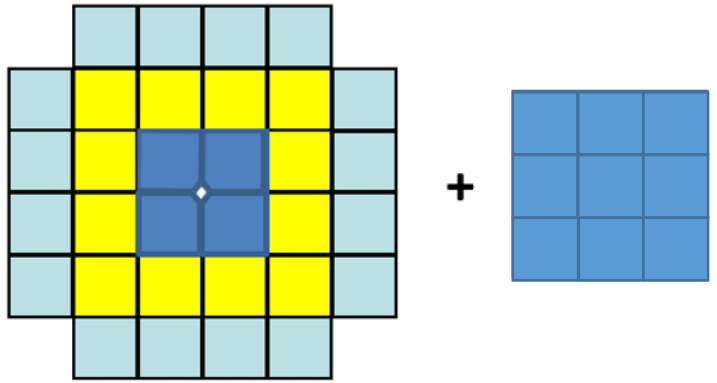


$$\frac{\sigma_E}{E} = \sqrt{\left(\frac{0.54}{\sqrt{E}}\right)^2 + (0.041)^2 + \left(\frac{3.6}{E}\right)^2}$$

Upgraded in May 2019

Upgraded calorimeter for NA61/SHINE experiments after 2020 has been assembled in May 2019.

12 CBM PSD modules has been used in the upgraded PSD



Addendum
to Memorandum of Understanding between
CBM Collaboration at FAIR
and NA61/SHINE Collaboration at CERN

Transfer of 12 modules CBM PSD modules for the NA61/SHINE PSD upgrade. These modules will be used until start of the the PSD assembly at the CBM (~2024).

On behalf of NA61/SHINE

Marek Gazdzicki
NA61/SHINE Spokesperson

Date: 25.05.2018

On behalf of CBM

Norbert Hermann
CBM Spokesperson

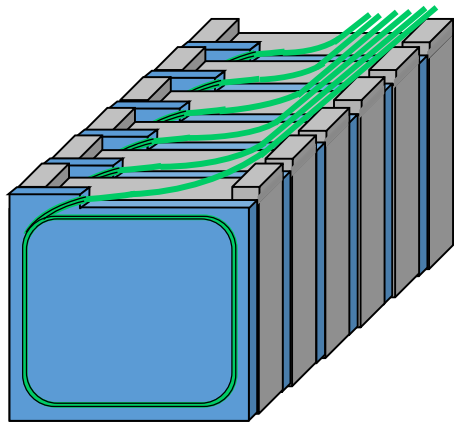
Date: 17.05.2018

Fedor Guber
INR Project leader at CBM and NA61/SHINE

Date: 16.05.2018

Structure of FHCAL modules

The FHCAL has transverse and longitudinal segmented structure and consists of separate modules.

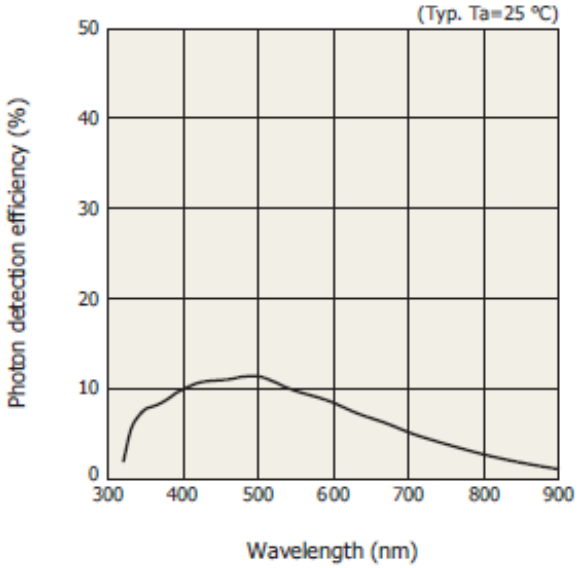


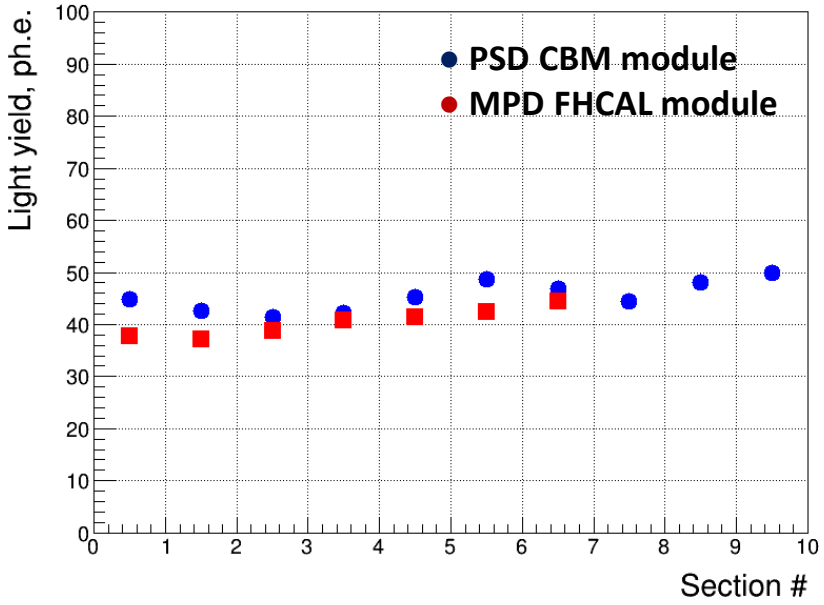
- CBM PSD module - 60 Pb/scint. samples. - (Pb(16mm), Scint(4mm)
  MPD FHCAL module - 42 Pb/scint. samples - (Pb(16mm), Scint(4mm)
- Length pf the MPD module – 4 λ_{int}, CBM module – 5.6 λ_{int}
- Light collections – 6 WLS fibers from 6 sequentially scint. tiles (one section) are combined in one optical connector at the end of module.
- Light readout: 10 MPPC (3x3 mm^2) per CBM module and 7 MPPC per MPD module.
- Weight of the CBM PSD module – 500 kg.
  Weight of the MPD FHCAL module – 200 kg.

Photodetectors

SiPMs for light detection

Hamamatsu S12572-010P
Sensitive area - 3 x 3 mm²
Number of pixels - 90 000
nominal gain - 1 x 10^5,
Gain ~1% /1°C
Pixel recovery time - 10 ns
PDE -12%

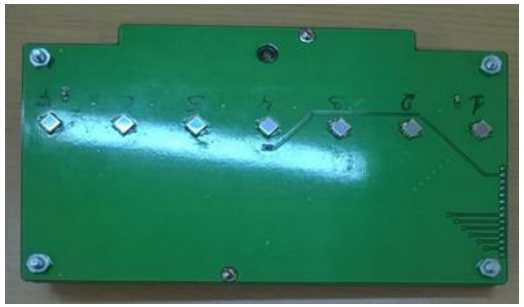


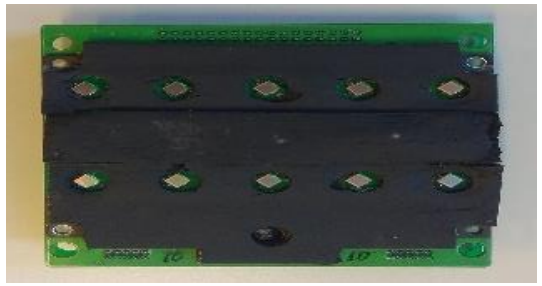


Light yield in the PSD CBM and MPD FHCAL modules sections

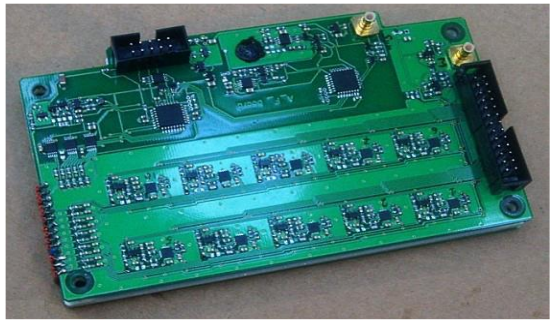
FEE and readout electronics

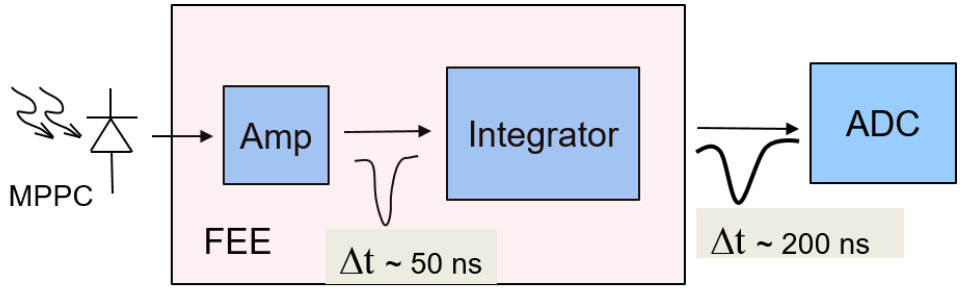
MPD
FHCAL
FEE





NA61/SHINE
and CBM
FEE





Front-End-Electronics:

two-stage amplifiers; HV channels; LED calibration source;
MPD module - 7 channels; CBM module – 10 channels.

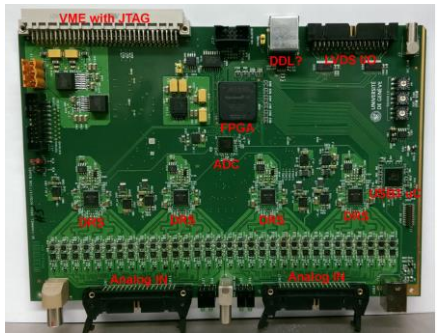
The readout electronics

Readout in all hadron calorimeters are based sampling ADC

BM@N and MPD

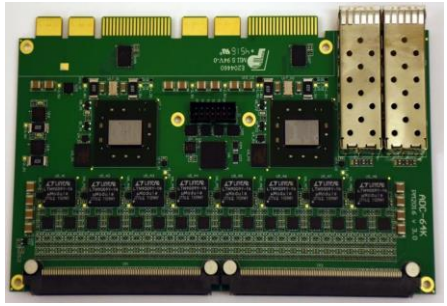
64 channel 62.5 MS/s
ADC64 board,

NA61/SHINE



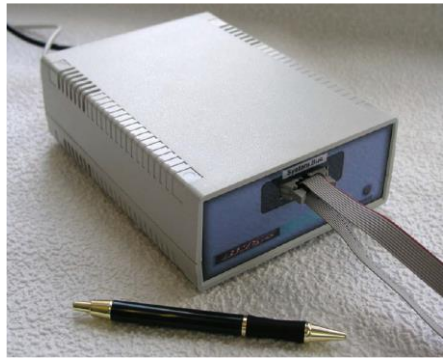
32 channel 1GS/s
ADC DRS4

CBM



32 channel 125 MS/s
ADC ECAL@PANDA

FHCAL Slow Control at BM@N, MPD and NA61/SHINE



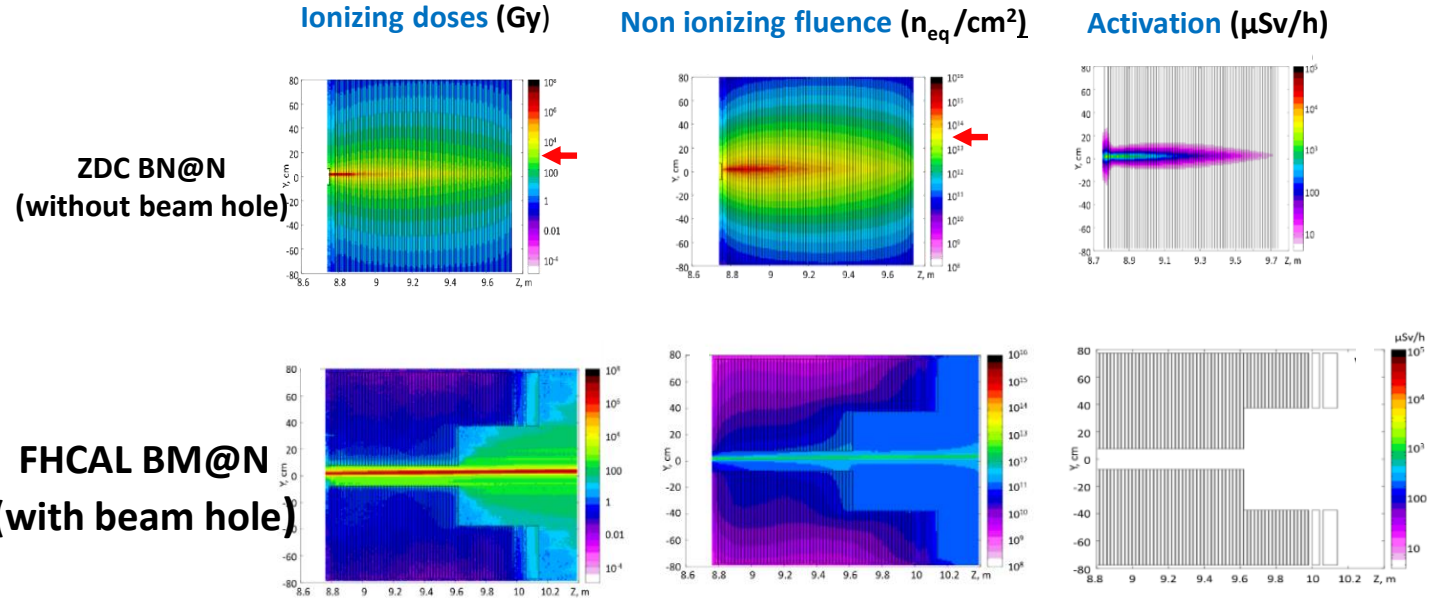
SC at BM@N, MPD and NA61/SHINE Forward Hadron Calorimeters is based on system module developed at Dubna.

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

Features of the Forward Hadron Calorimeters

- All calorimeters have the beam hole in the center.

Reasons for FHCAL@BM@N, PSD@CBM and PSD@NA61/SHINE: High radiation level at expected beam rates.

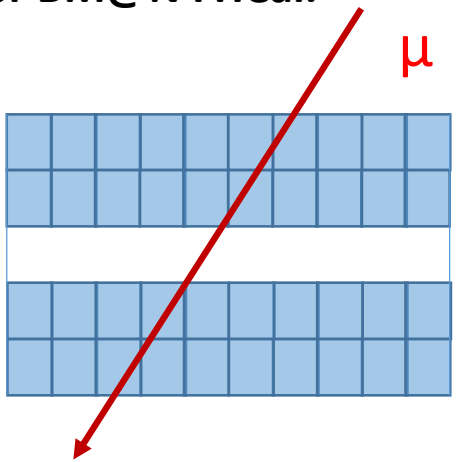


Cooperation with GSI (A.Senger) – FLUKA simulation.

Cooperation with A.Kugler group (NPI (Rez)) – MPPCs radiation hardness study.

- Longitudinal segmentation of FHCAL modules provides uniformity of light collection along the module and gives possibility to do energy calibration on cosmic muons.

Corresponding procedure is developed now at INR RAS for BM@N FHCal.

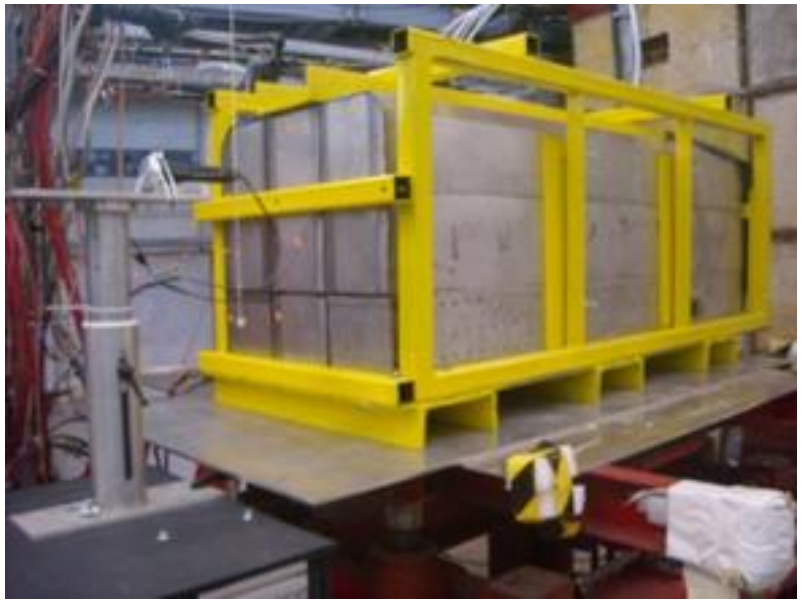


The mutual interest is to use the developed method of calibration at the BM@N FHCal, MPD, CBM and NA61/SHINE experiments.

Construction and cosmic tests of FHCALs modules at INR (Moscow)

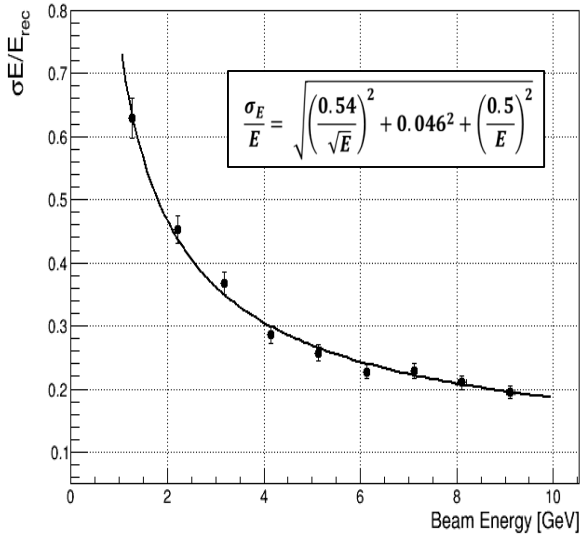
At first time the modules for NA61/SHINE hadron calorimeter were assembled at INR in 2010.
2015 – 2019 construction of modules for CBM, BM@N и MPD hadron calorimeters.

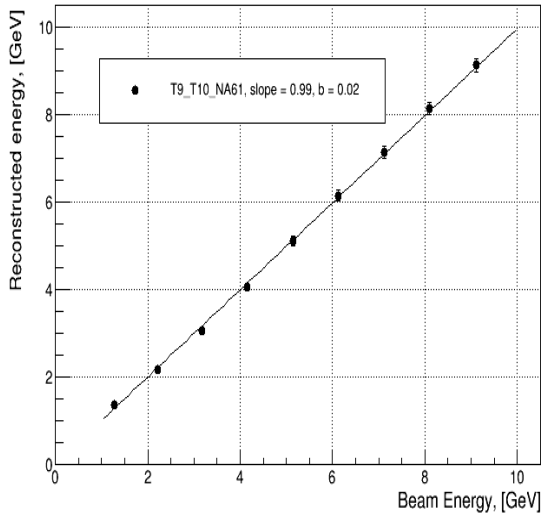
Study of PSD CBM supermodule performance on T9/T10 beams at CERN



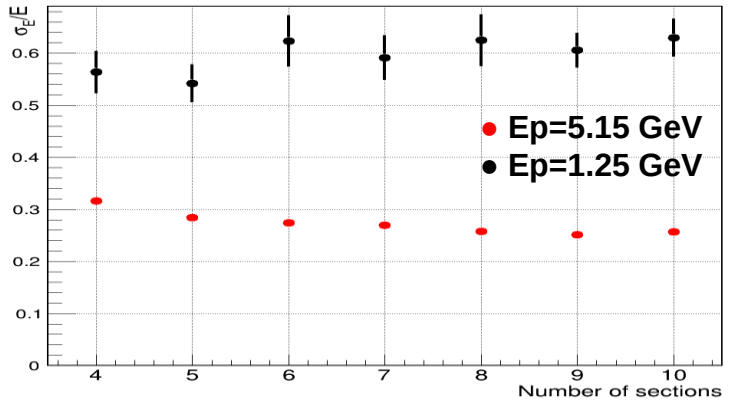
PSD CBM supermodule
on T9/T10/NA61/SHINE test beams at CERN

Energy resolution and linearity response

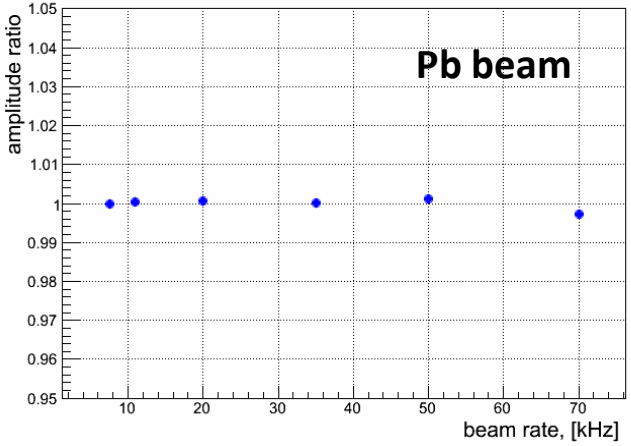




Energy resolution vs number of sections

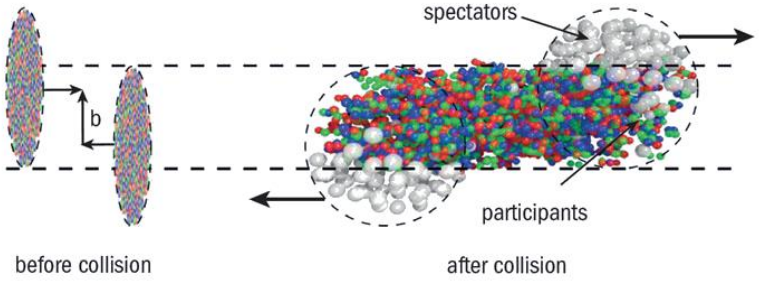


Module response vs beam rate



Centrality and reaction plane determination with FHCAL

➢ Centrality determination

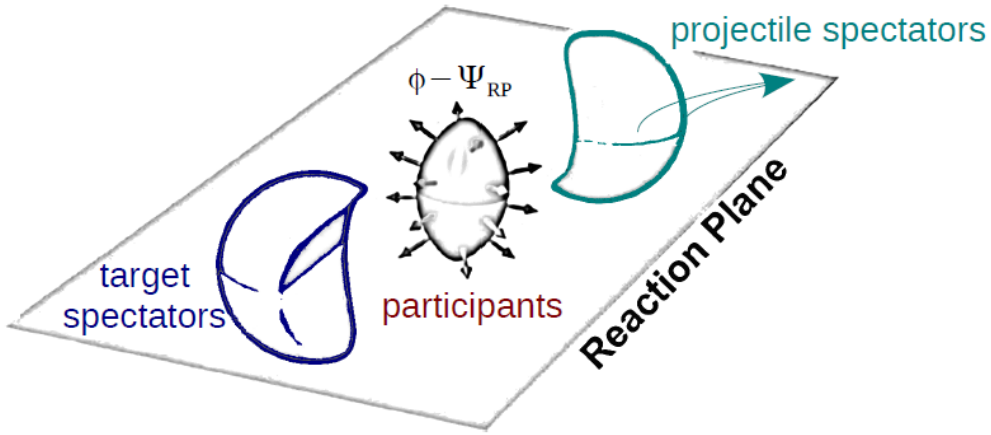


FHCAL measures fragment energy deposition on e-by-e basis. Centrality classes have been created from the energy deposition in calorimeters without beam hole ZDC (BM@N) and PSD (NA61/SHINE) experiments.

How to get centrality from energy deposition in calorimeters with beam hole?

Cooperation between INR, MEPHI, GSI group is needed for development the methods and models for the centrality determination with FHAL at future NA61/SHINE, BM@N, MPD and CBM experiments.

➢ Reaction plane determination

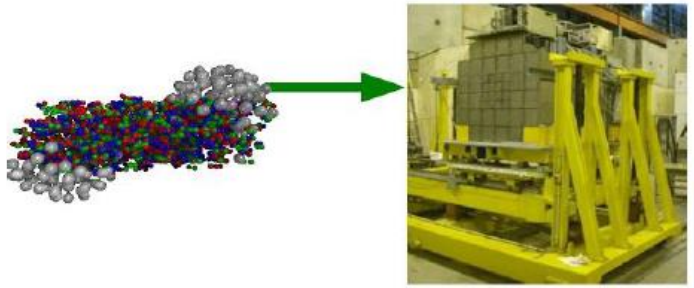


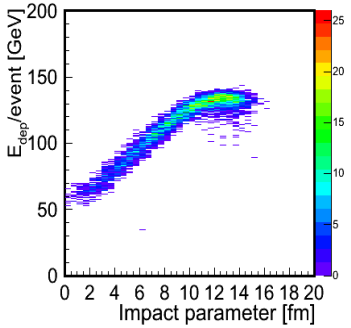
GSI group (I.Selyuzhenkov) already developed RPA methods which is successfully used for NA61/SHINE data analysis.

Cooperation between MEPHI, GSI and INR is necessary for implementation of these methods for BM@N. MPD and CBM experiments.

Problems with centrality measurement by FHCAL with beam hole

Centrality measurement at NA61 by PSD without beam hole



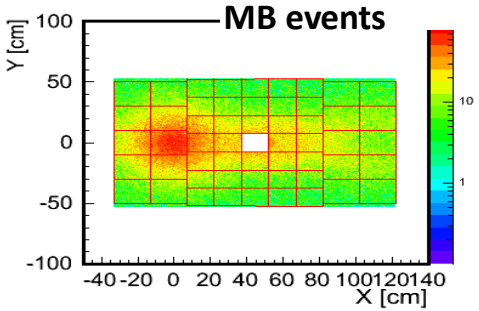


Pb+Pb@29 AGeV QGSM (SHIELD code), FTFP_BERT

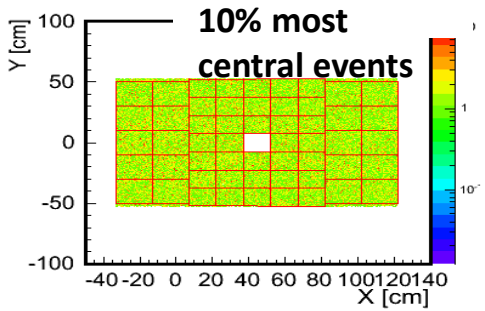
Intervals in E_F allow to select different centrality classes

Problems with centrality measurement at BM@N by FHCAL with beam hole

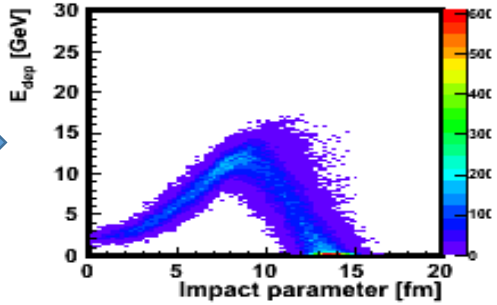
FHCAL BM@N
Reaction Au+Au@4.5 AGeV
Simulation - LAQGSM code



50% of particles energy goes through the hole



2% of particles energy goes through the hole



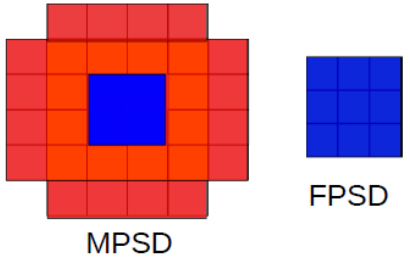
The same problem at NA61/SHINE, MPD and CBM experiments

How to resolve the ambiguity in centrality measurements?

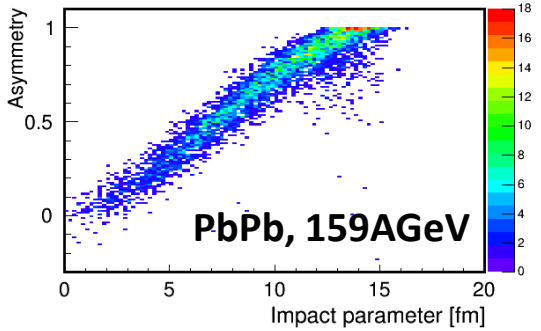
Development of methods for centrality measurements for calorimeters with beam hole

NA61

Asymmetry of energy distribution in the calorimeters

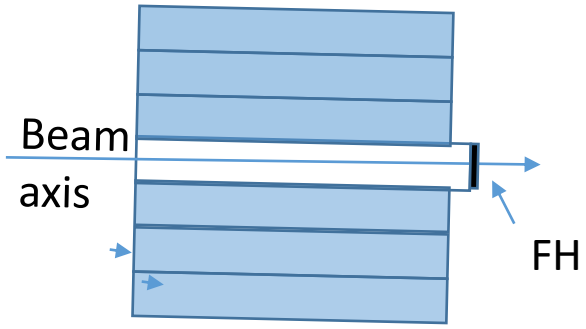


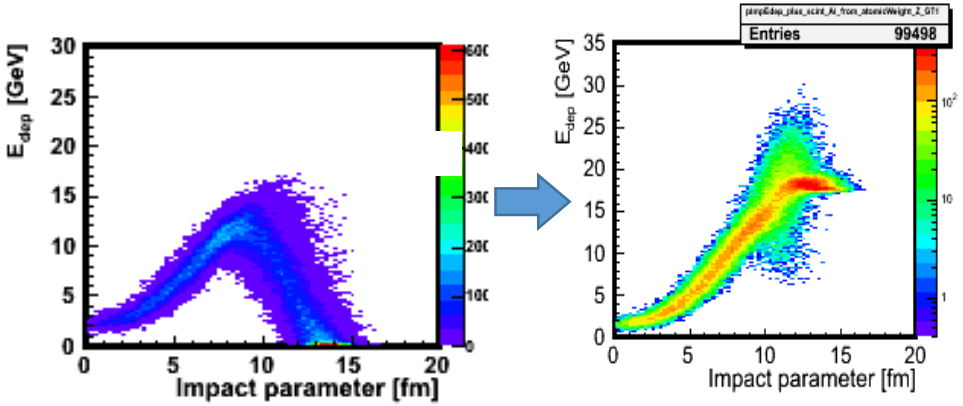
$$A_E = \frac{E_{dep}\ (blue) - E_{dep}\ (red)}{E_{dep}\ (blue) + E_{dep}\ (red)}$$



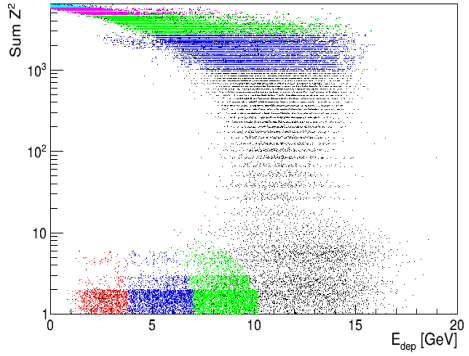
BM@N

The use of quartz hodoscope to measure fragments charge in the beam hole





or



OUTLOOK

➢ **There is mutual interest of BM@N, NA61/SHINE, MPD and CBM collaboration in development of Forward Hadron Calorimeters:**

- **Development of signal treatment methods from sampling ADCs;**
- **Development of cosmic calibration procedure for transverse and longitudinal segmented calorimeters;**
- **Radiation hardness study of MPPCs, simulation of radiation conditions at heavy ion experiments;**
- **Development of slow control;**
- **Development the methods and models for the centrality and reaction plane for FHCALs with beam hole;**

➢ **Participation of young researches and students in the calorimeters developments in the BM@N and NA61/SHINE experiments will give them good experience to continue their researches at the MPD and CBM experiments.**

Young researches and students involved in the calorimeters developments for NA61/SHINE/SHINE, BM@N, MPD and CBM experiments

INR

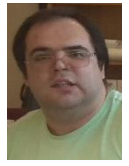
Nikolay Karpushkin
Graduate student, INR

Dmitry Borisenko
Researcher, INR

Dmitry Finogeev
Researcher, INR

Oleg Petukhov
Researcher, INR

Alexander Izvestnii
Researcher, INR



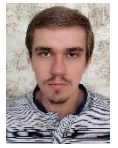
Elizaveta Zherebzova
Graduate student
MEPHI, INR

Alexey Makarov
Student, MEPHI, INR

MIPT - INR

Dmitry Gerasimov
Student, MIPT

Alexander Strizhak
Student, MIPT



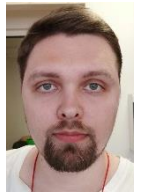
Vadim Volkov
Graduate student, MIPT

MEPHI

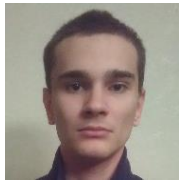
Oleg Golosov
Student, MEPHI

Evgeny Kashirin
Graduate student,
MEPHI

Piotr Parfenov
Graduate student,
MEPHI, INR



Alexander Baranov
Graduate student,
MEPHI



INP, Rez, Czech

Vasily Mikhaylov

Petr Chudoba

Thanks for your attention