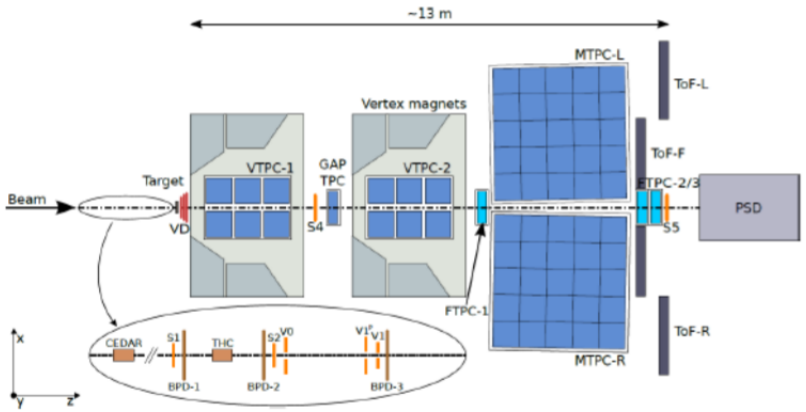
Forward hadron calorimeters for fixed target heavy ion experiments

Sergey Morozov on behalf of INR RAS

ICNFP-2019, Crete, Greece 21-29 Aug 2019

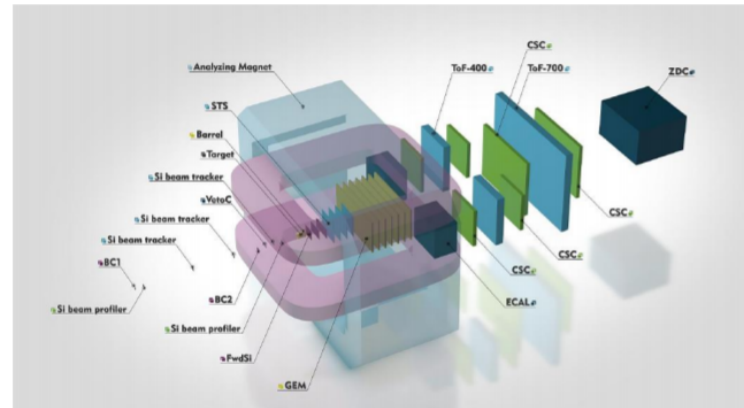
NA61@SPS

Start of operation after upgrade - 2021



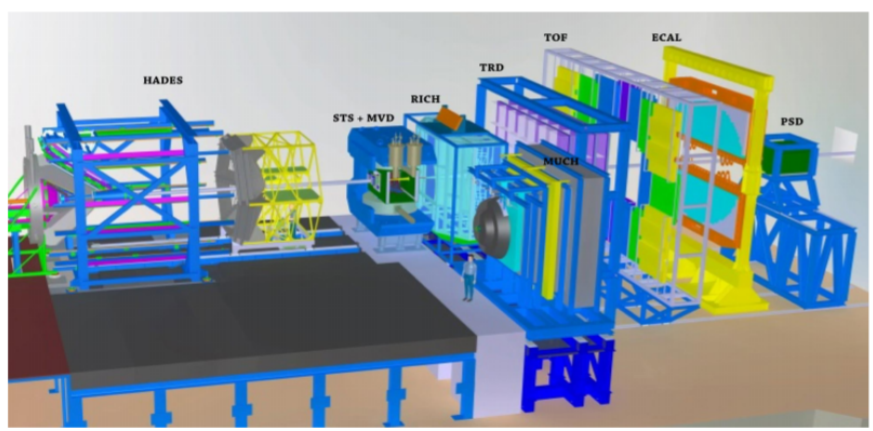
BM@N

Start of operation after upgrade - 2020

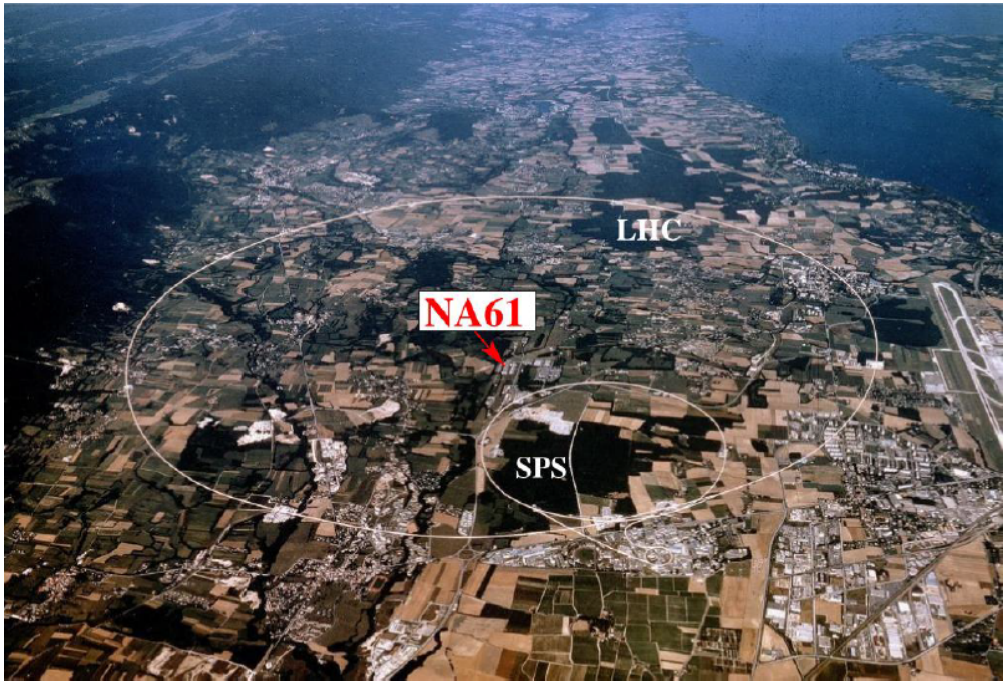


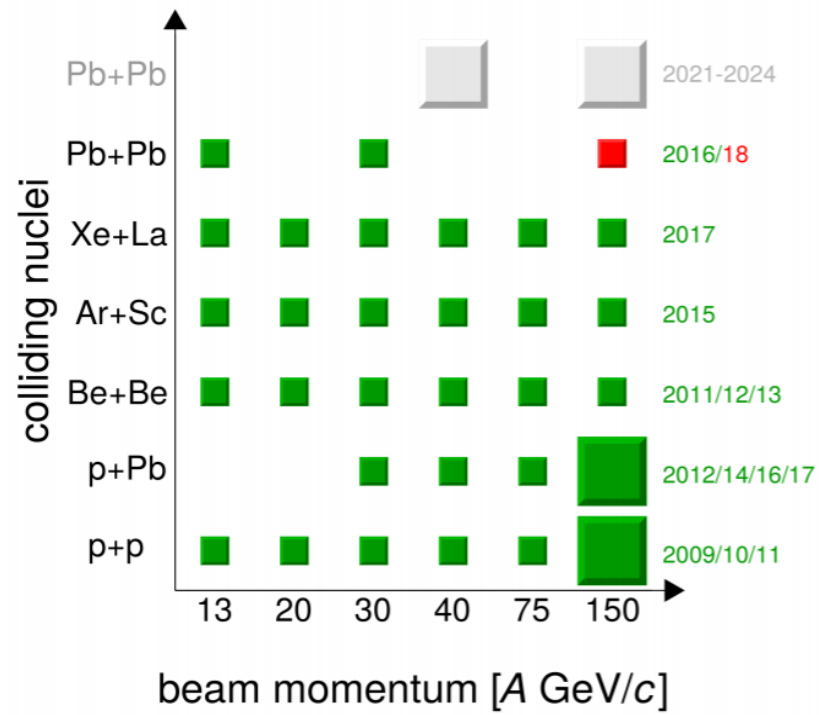
CBM@FAIR

Start of experiments at FAIR - 2024



NA61/SHINE strong interactions program





- wide range of system size in ion collisions: from Be+Be to Pb+Pb

- large range of beam momentum: 13 – 150 AGeV/c (GeV/c per nucleon)

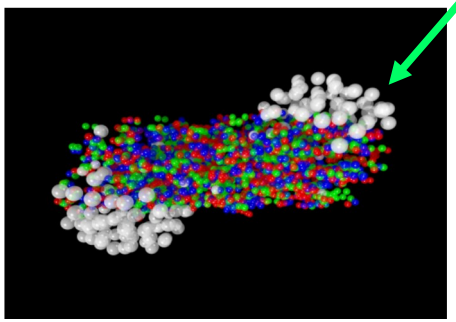
Forward hadron calorimeters for fixed target heavy ion experiments

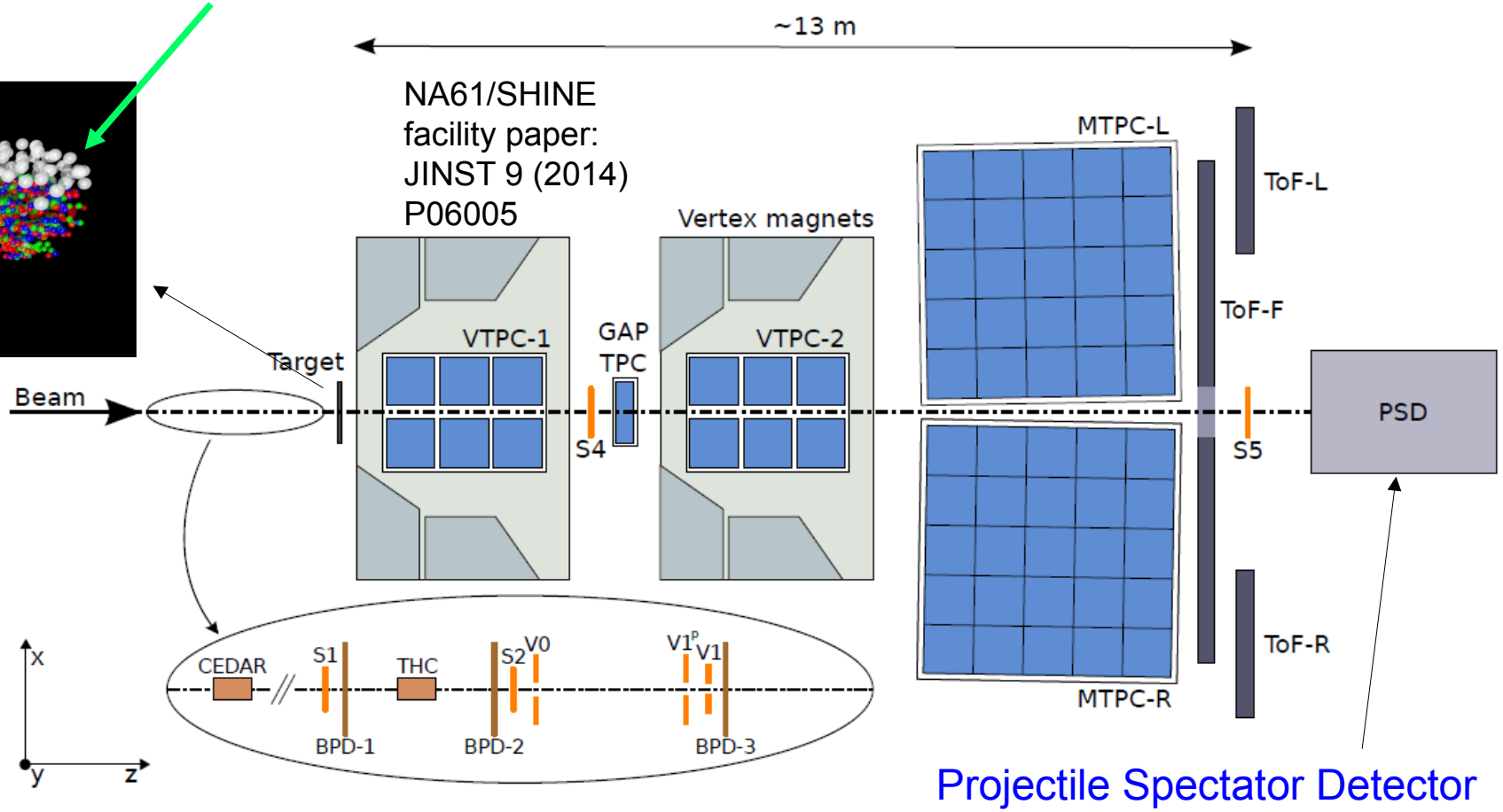
Number of interacting participants:

A – mass number of ion

E_a – beam energy per nucleon

E_s – energy carried by the non-interacting nucleons (projectile spectators) - measured with PSD





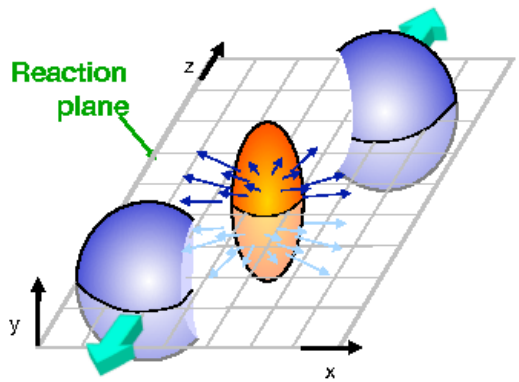
Projectile Spectator Detector

Forward hadron calorimeters for fixed target heavy ion experiments

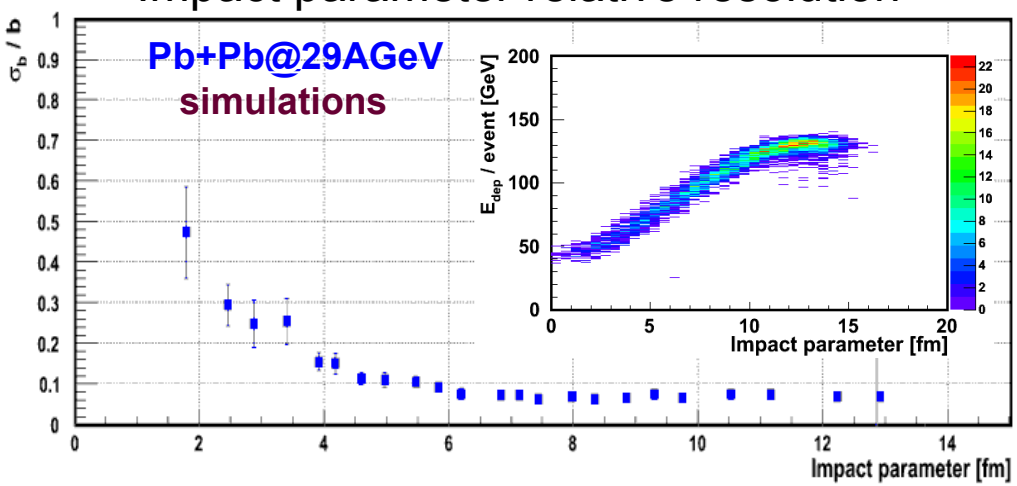
Projectile Spectator Detector (PSD) gives a very important informations:

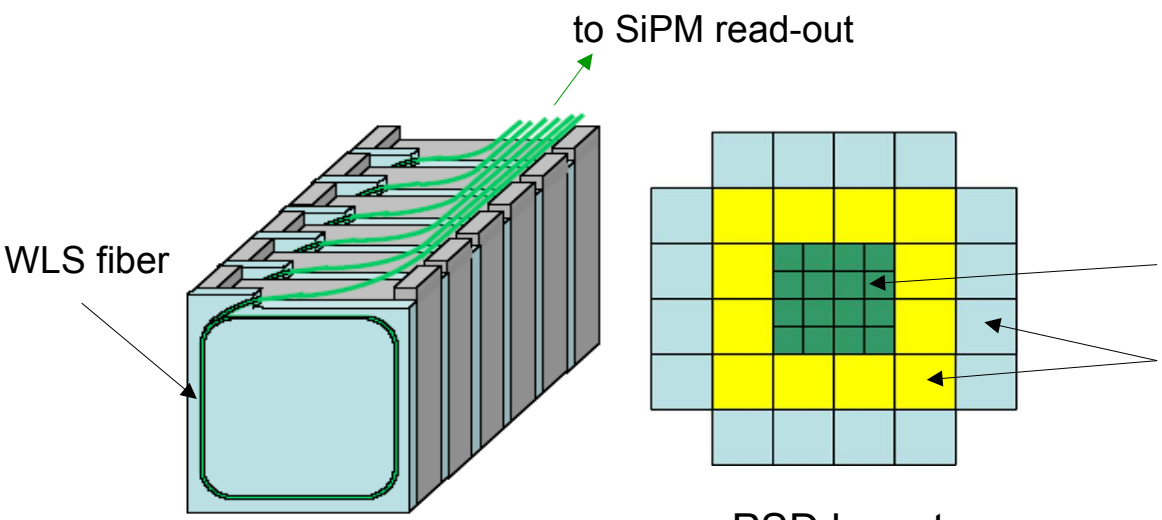
- centrality of nucleus-nucleus collisions:

- reaction plane orientation



Impact parameter relative resolution





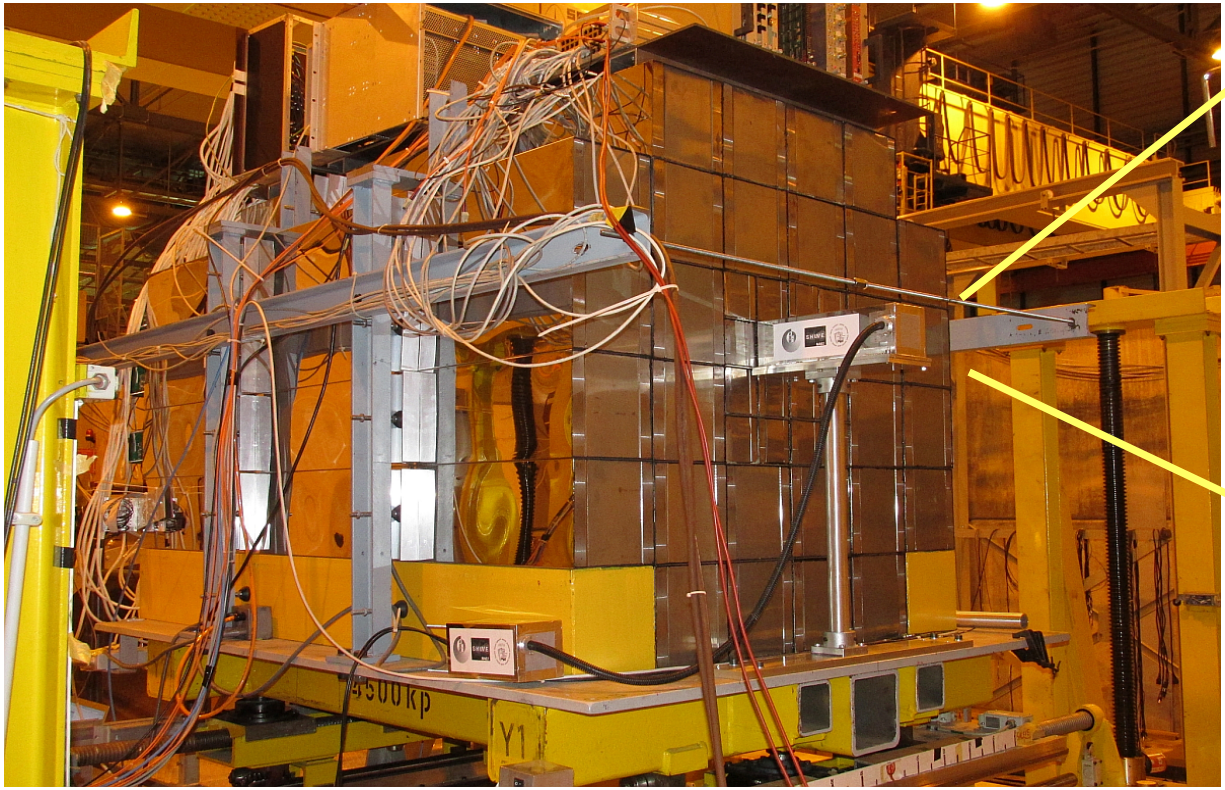
one PSD section view

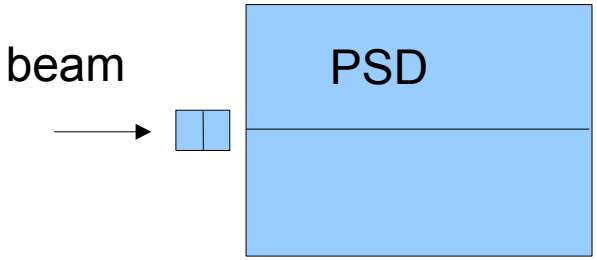
PSD layout

PSD is a hadron sampling compensating calorimeter

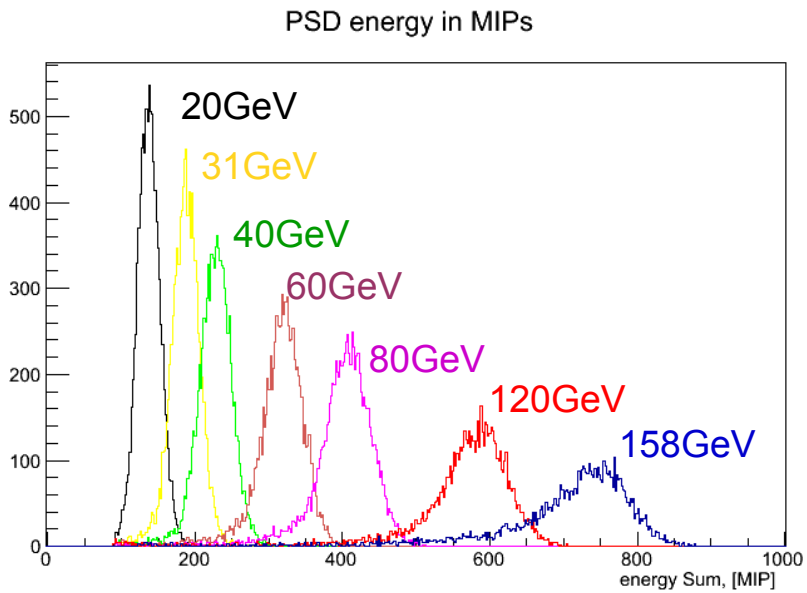
- Pb/scintillator (4/1) 60 sandwiches in one module
- Modules 10 x 10 x 120 cm^3 – central part
- Modules 20 x 20 x 120 cm^3- outer part
- 10 longitudinal sections with 10 SiPM readout

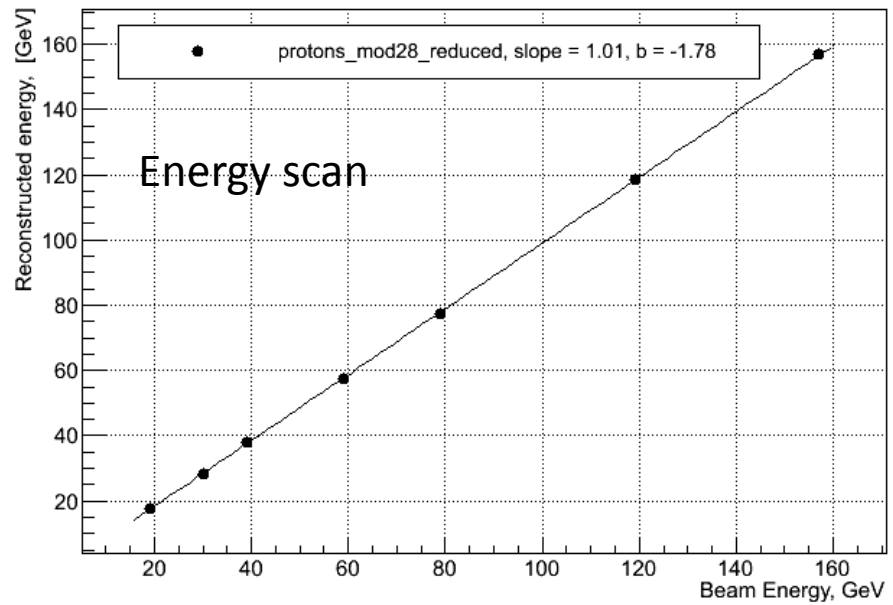
PSD on NA61 beam line

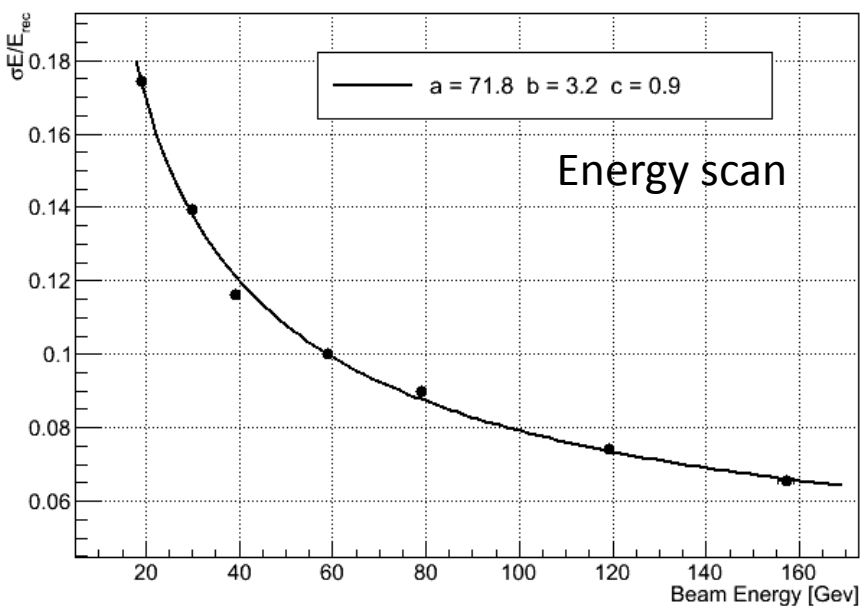




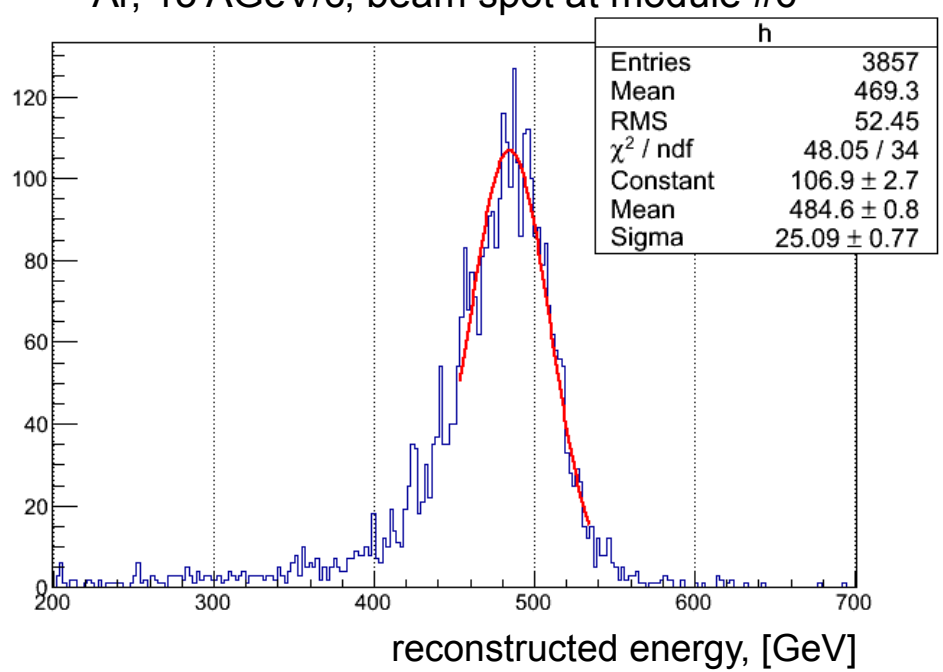
NA61/SHINE PSD performance



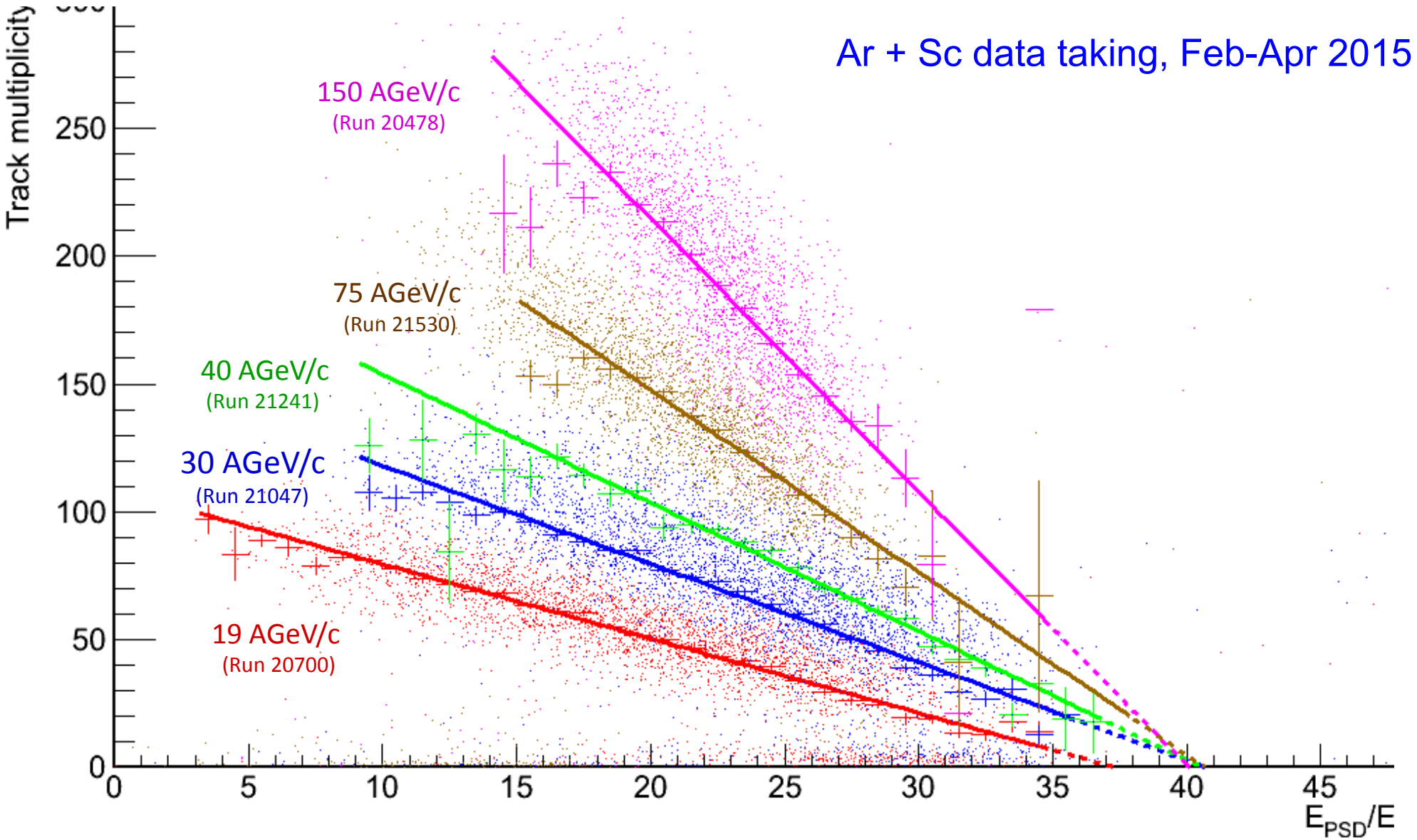




Ar, 13 AGeV/c, beam spot at module #6

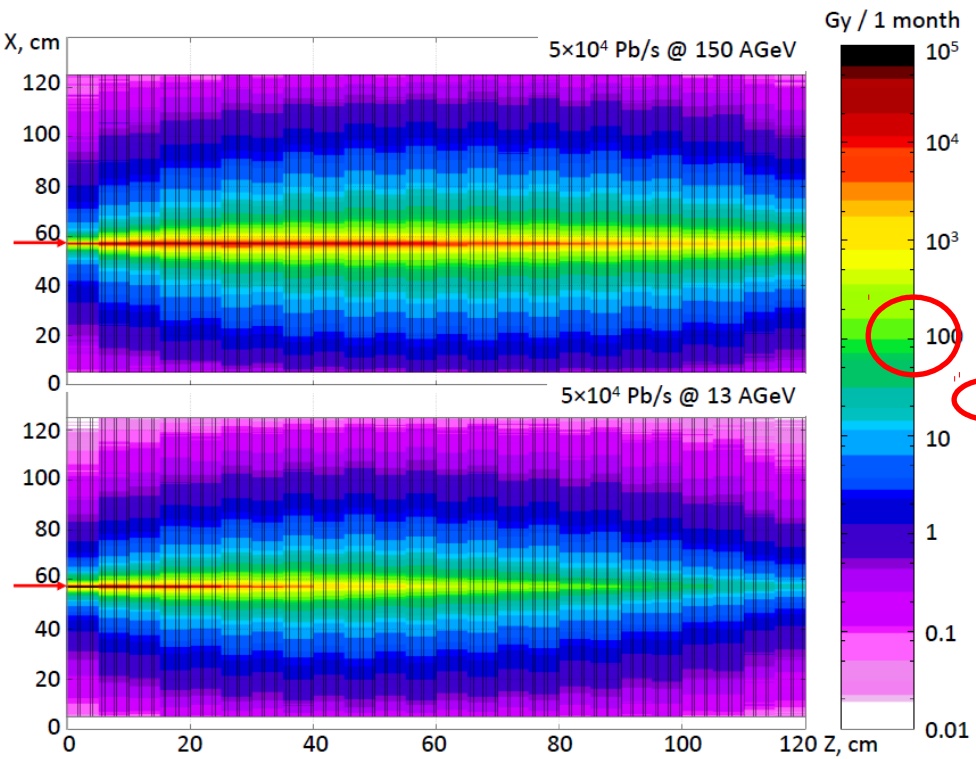


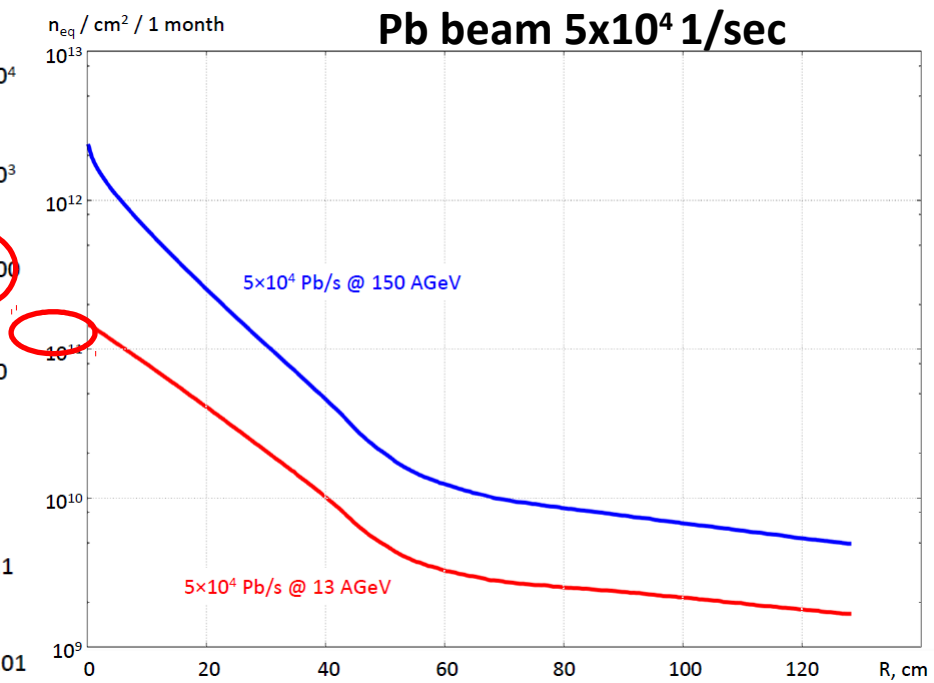
Track multiplicity vs PSD reconstructed energy: Ar+Sc, T2 trigger



Forward hadron calorimeters for fixed target heavy ion experiments

A.Senger simulation with FLUKA





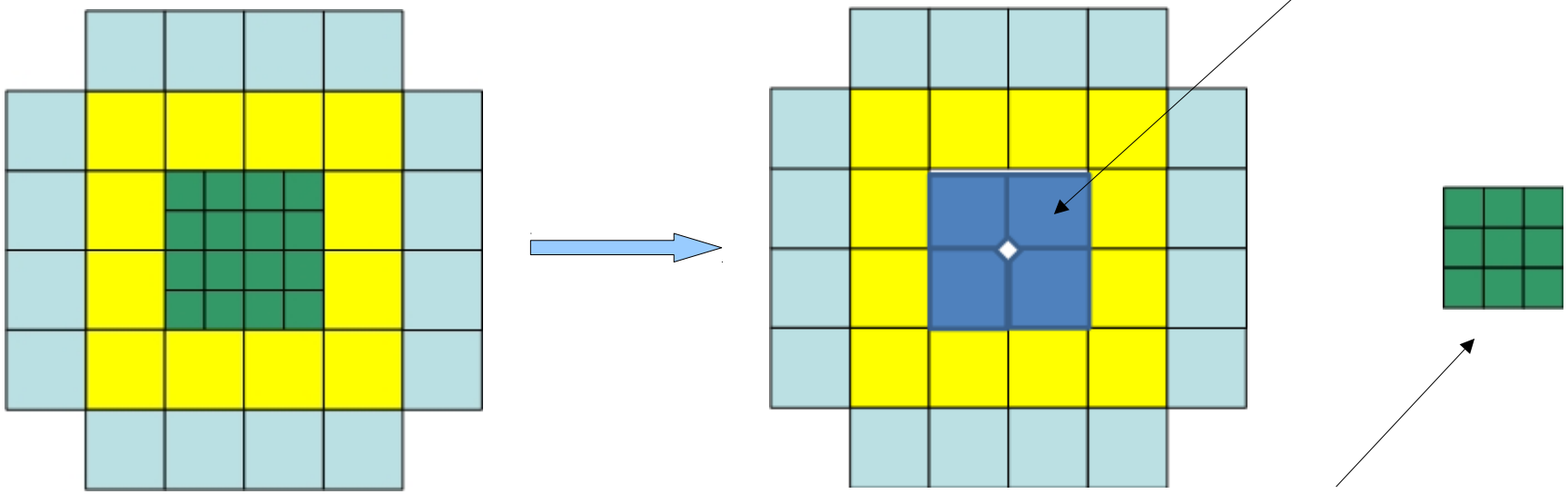
Radiation effects:
- scintillators (ageing effects, reduction of light yield);
- photo-diodes (higher noise, drop of gain)

→ Affects the calorimeter performance

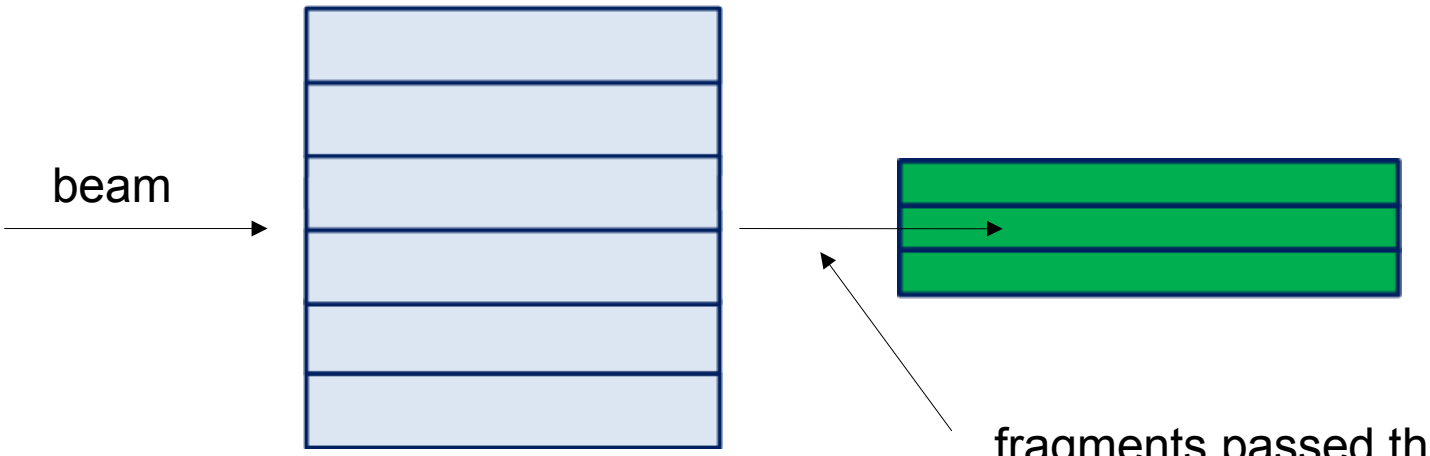
The relative light yield of the scintillators degrades by 25% after 2.5 kGy irradiation, and then slowly decreases by a further 20% with irradiation up to 14 kGy.

NA61 beyound 2020: 10x more beam intensity → high radiation doses for PSD

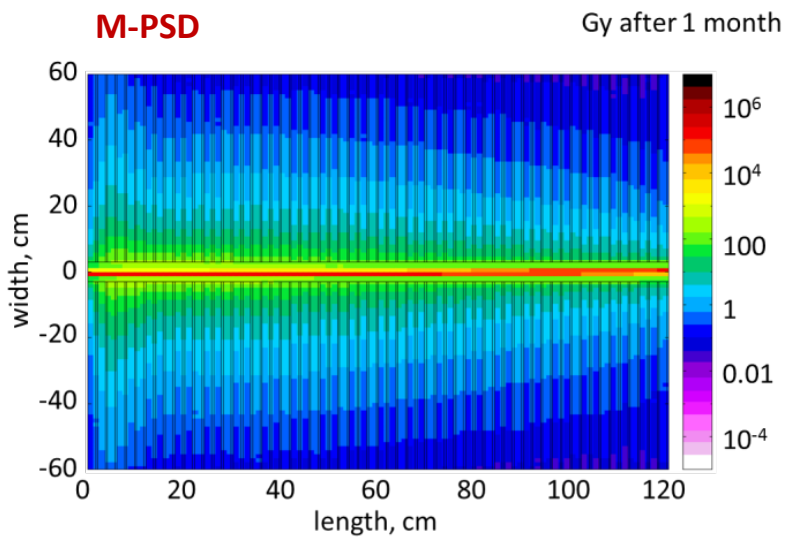
Proposal: replace central part of PSD with new modules designed for CBM experiment:

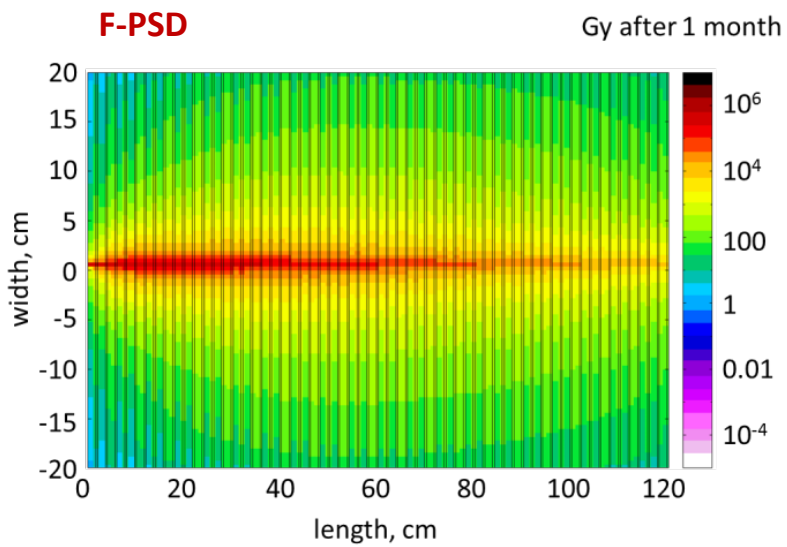


Use small modules of PSD as “tail catcher”

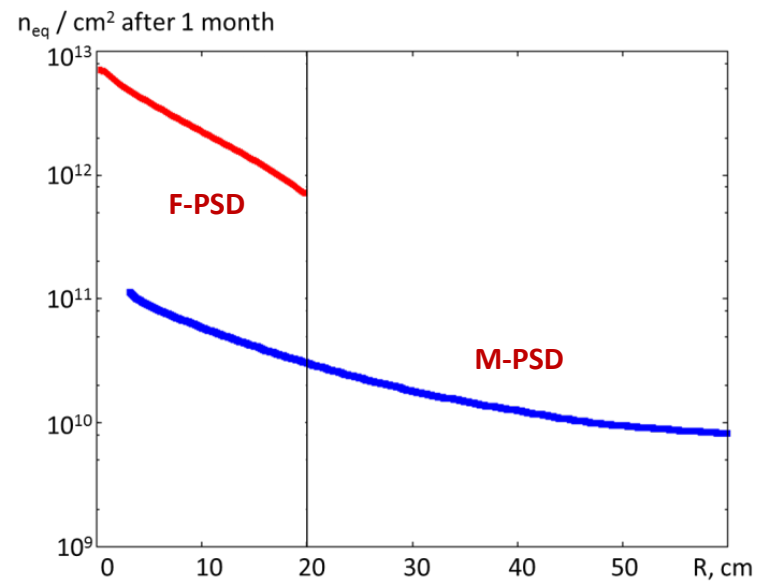


fragments passed the hole





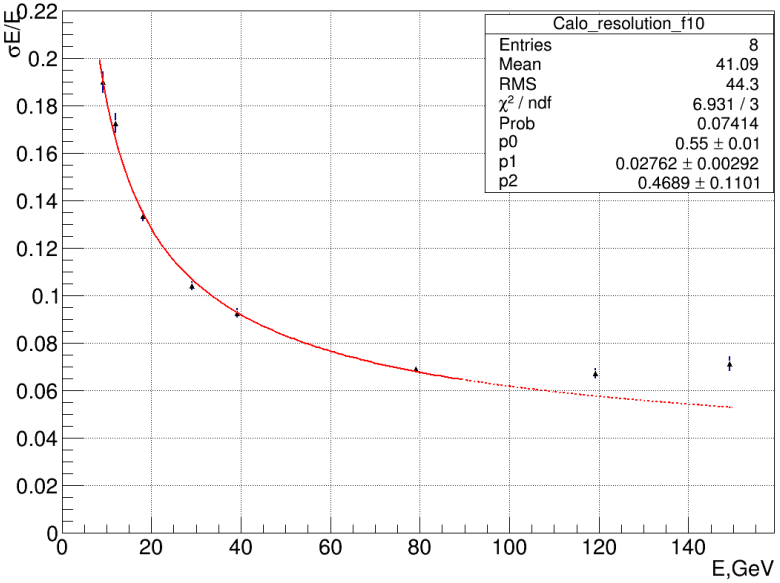
A.Senger
Fluka simulation for
Pb beam at rate $5x10^4$ ions /sec



Radiation and activation problems are now localized only in F-PSD which can be shielded by concrete blocks.

Forward PSD (FPSD) construction and test on NA61 beam line

Energy resolution of FPSD



PSD supermodule tests on CERN test beams

CERN PS T9 beamline

Beam momenta: 1-10 GeV/c
Particle ID: Cherenkov gas counter
Position of PSD: fixed

CERN PS T10 beamline

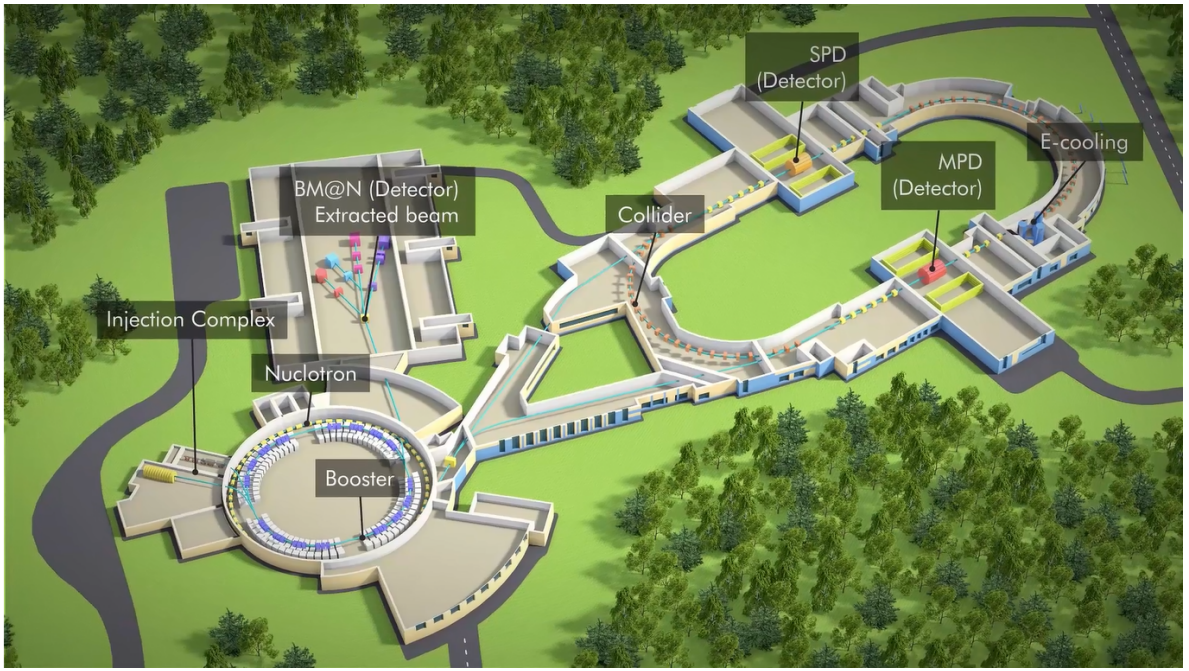
Beam momenta: 1-6 GeV/c
Particle ID: TOF system installed
Position of PSD: movable platform

NA61/SHINE PSD upgrade to have
a beam hole in the center

..to be continued in 2019

Forward hadron calorimeters for fixed target heavy ion experiments

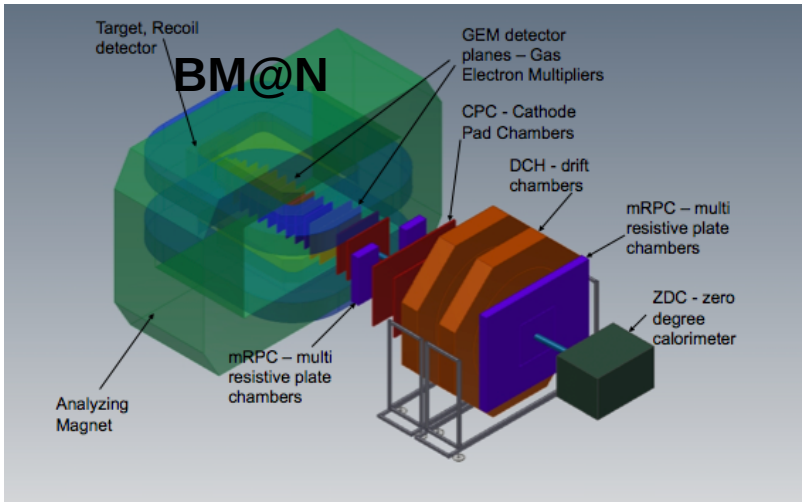
BM@N experiment



NICA-Nuclotron acceleration complex (JINR, Dubna)

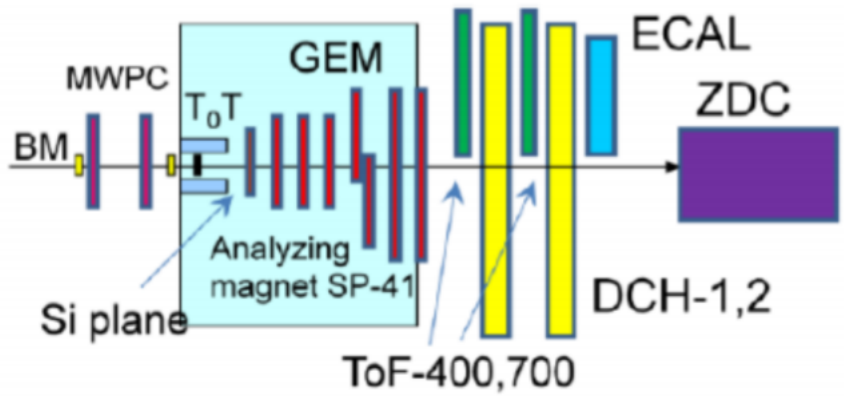
BM@N Zero Degree Calorimeter

Year	2016	2017 spring	2018 spring	2021	2022 and later
Beam	d(↑)	C	Ar,Kr, C(SRC)	Kr,Xe	up to Au
Max.intensity, Hz	0.5M	0.5M	0.5M	0.5M	2-5M
Trigger rate, Hz	5k	5k	10k	10k	20k→50k

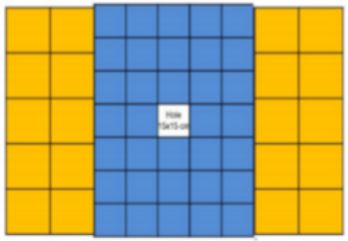


Forward hadron calorimeters for fixed target heavy ion experiments

BM@N forward calorimeter upgrade

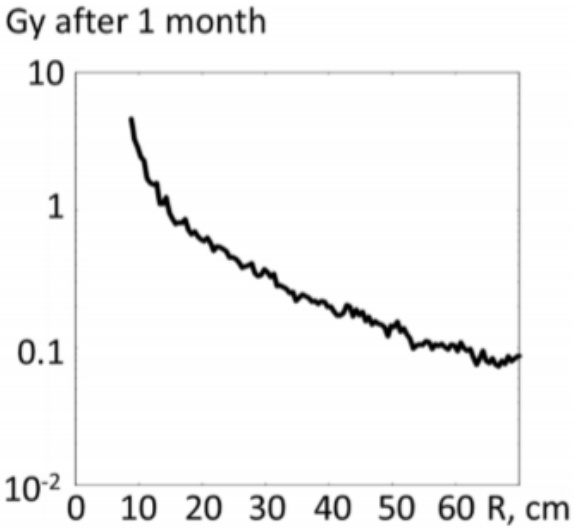


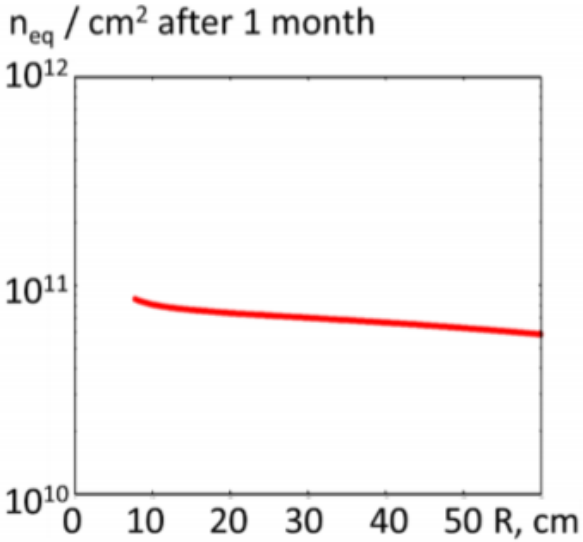
new FHCAL with beam hole



CBM modules
MPD modules

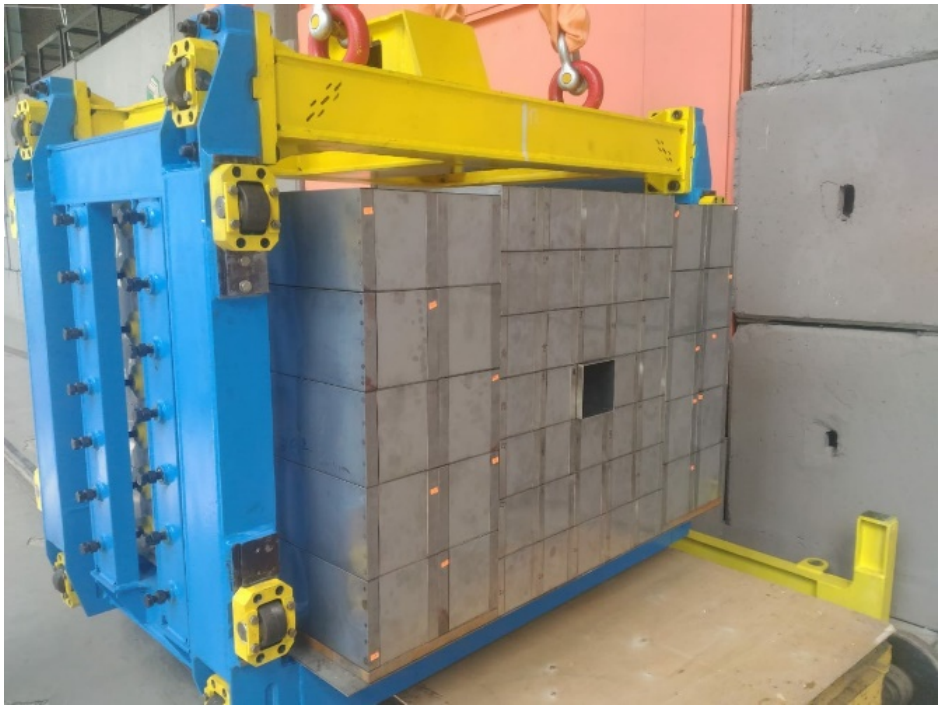
Eexpected high beam rate of gold ions: up to 2×10^6 Au/sec with energies up to 4.5 AGeV.





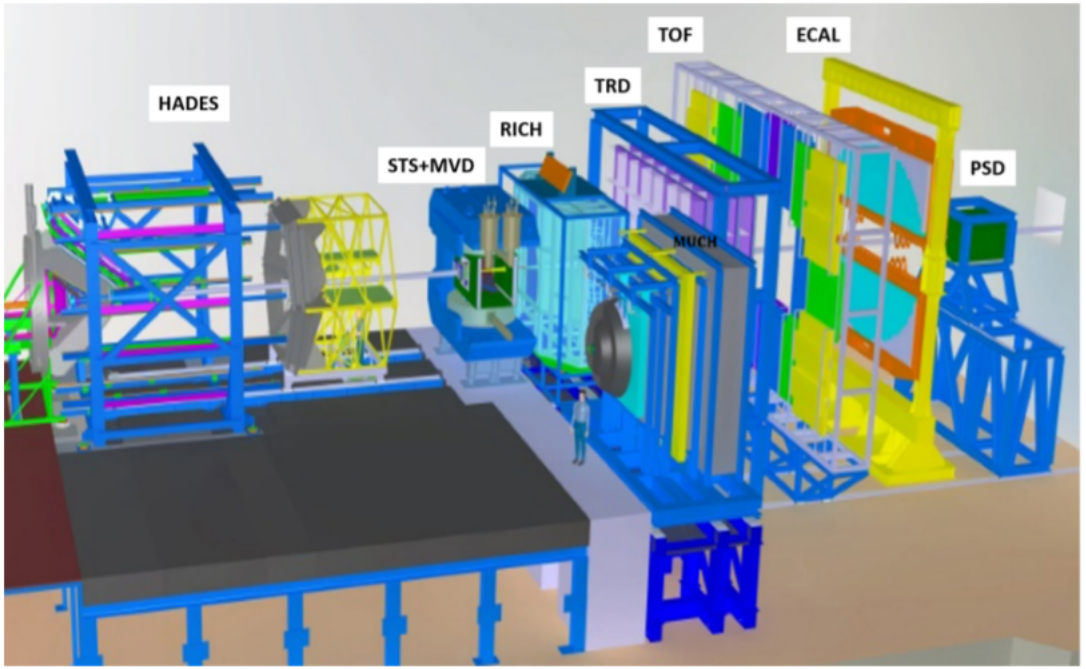
Doses from ionizing particles (left) and neutron fluence at the plane of MPPCs (right) in FHCal at depth of 10 cm from the forward face (A. Senger simulation with FLUKA).

BM@N forward calorimeter upgrade

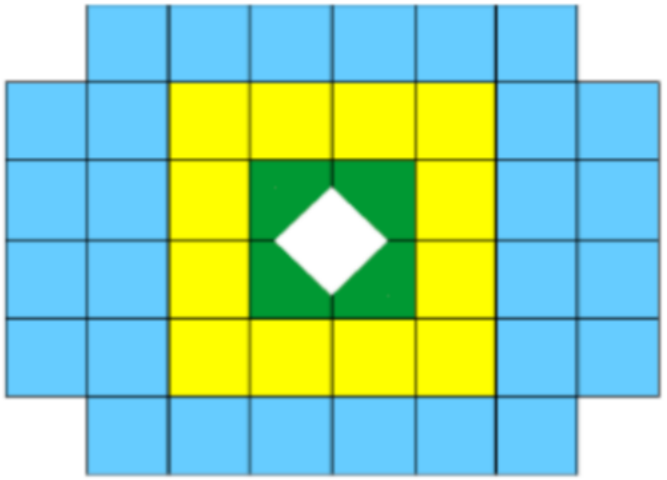


Forward hadron calorimeters for fixed target heavy ion experiments

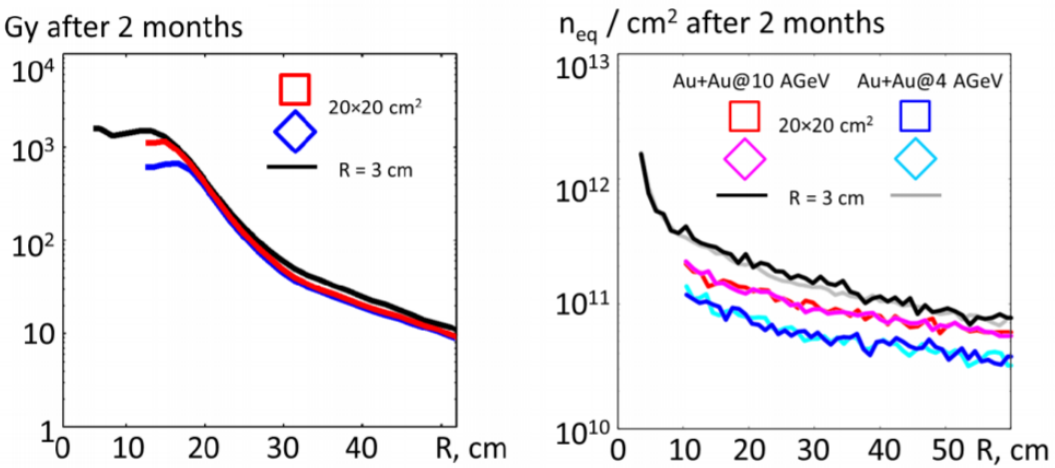
CBM experiment (GSI, Germany)



PSD calorimeter for CBM



Beam rate: up to 10^8 ions/sec (Au)
Reaction rate: up to 10^6 /sec
(free streaming DAQ)
Energies: 2 – 11 AGeV

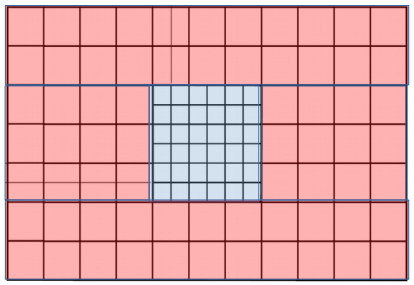


Doses at depth of 10 cm from the forward face of the PSD for Au+Au (A. Senger simulation with FLUKA)

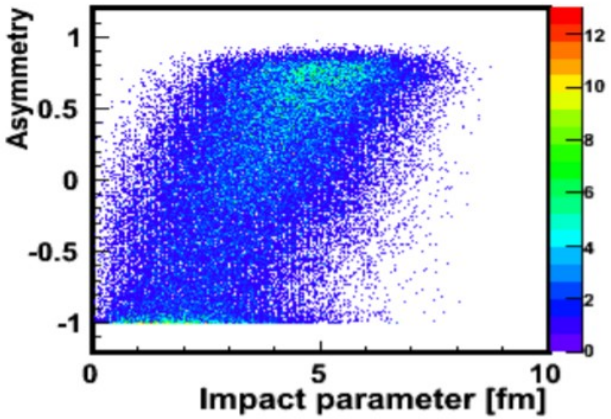
Forward hadron calorimeters for fixed target heavy ion experiments

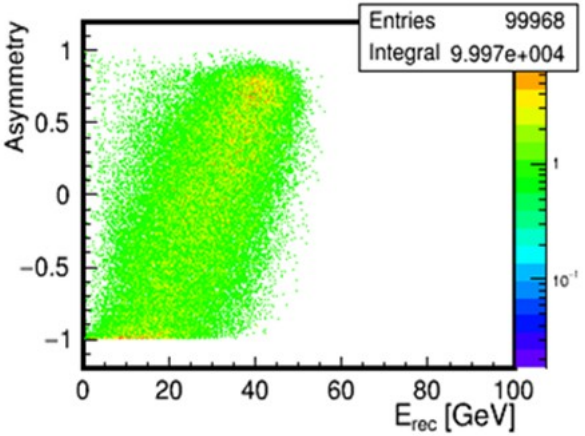
Energy asymmetry:

$$\frac{(E\_ZDC\_inner - E\_ZDC\_outer)}{(E\_ZDC\_inner + E\_ZDC\_outer)}$$

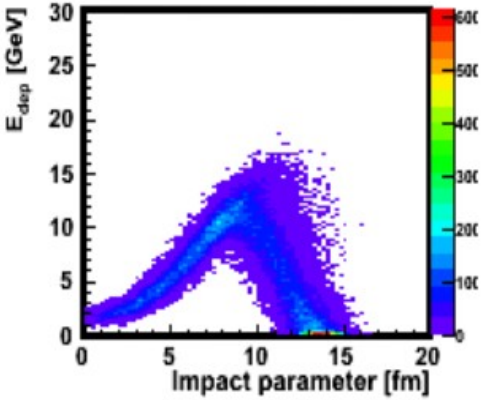


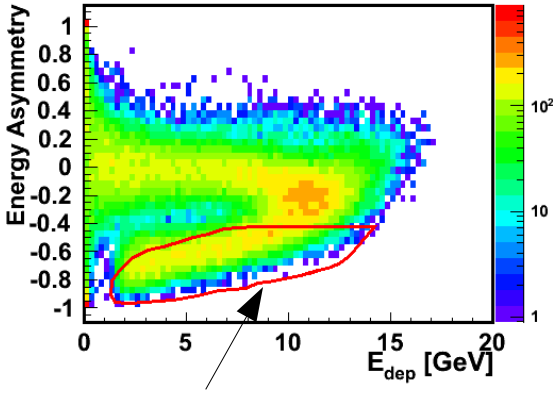
C+C, 4AGeV





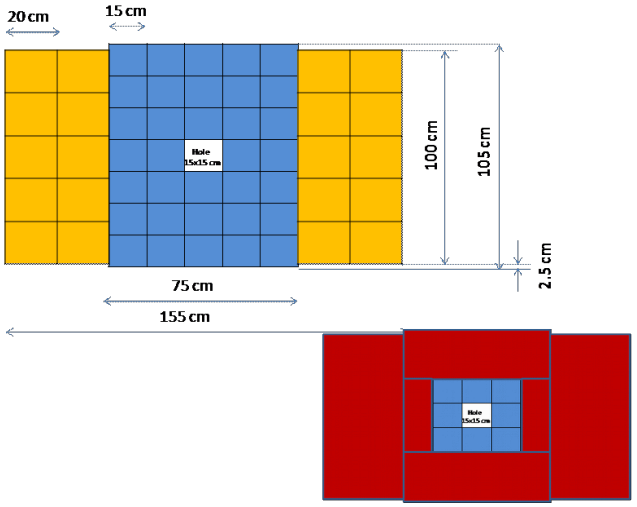
Au+Au, 4.5AGeV





central events

ZDC with hole (54 modules)



Summary:

Forward hadron calorimeters with Pb+Scint sampling structure and SiPM readout have been developed and widely used in heavy ion fixed target experiments:

- NA61/SHINE experiment: ion-ion data taking are done from Be+Be (light system) to Pb+Pb (most challenging) during 2011-2018 data taking periods

  - upgrade of NA61/SHINE experiment will be prepared for 2020, new PSD calorimeter system will be used, beam hole in the main calorimeter

- BM@N experiment with ZDC: C, Ar, Kr beams with wide range of targets

  - new FHCAL with beam hole will be operated on BM@N experiment (modules for CBM and MPD will be used)

- CMB experiment is planned at GSI, PSD calorimeter with beam hole will be used

- energy asymmetry is a good method to estimate event centrality for calorimeter with beam hole in a center