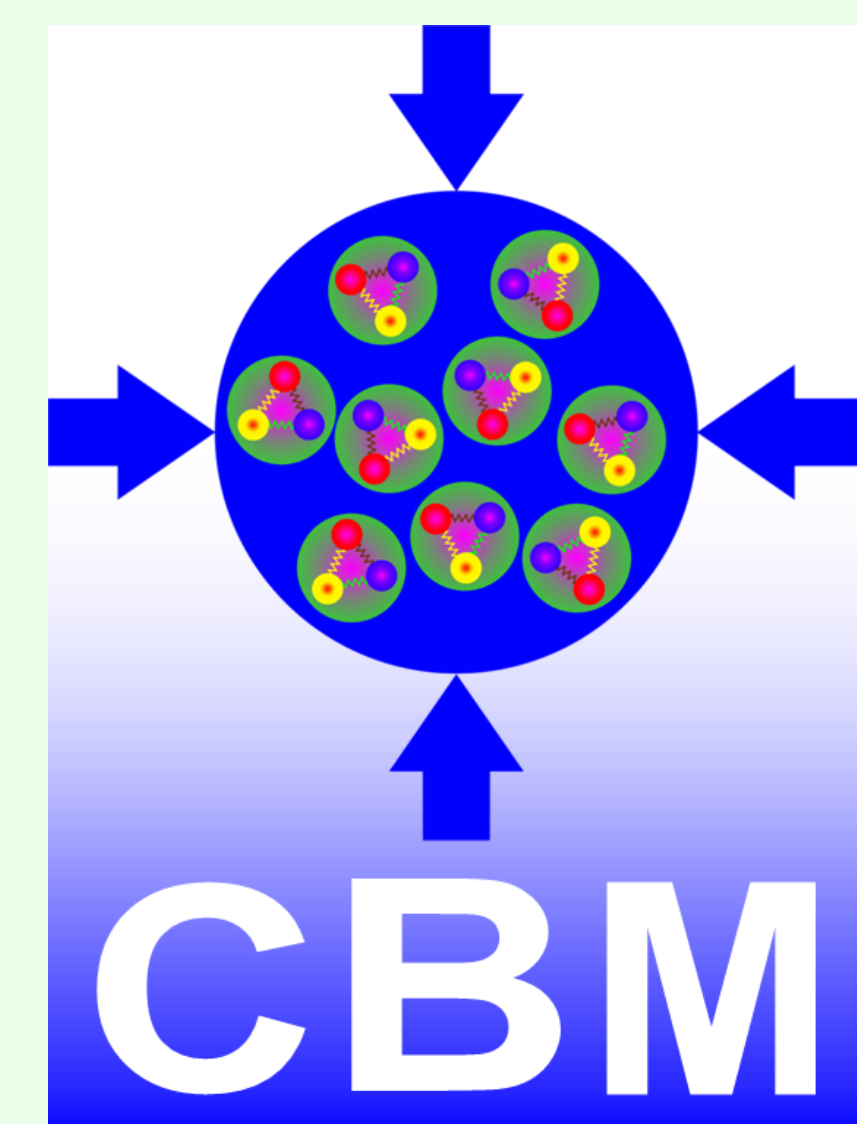


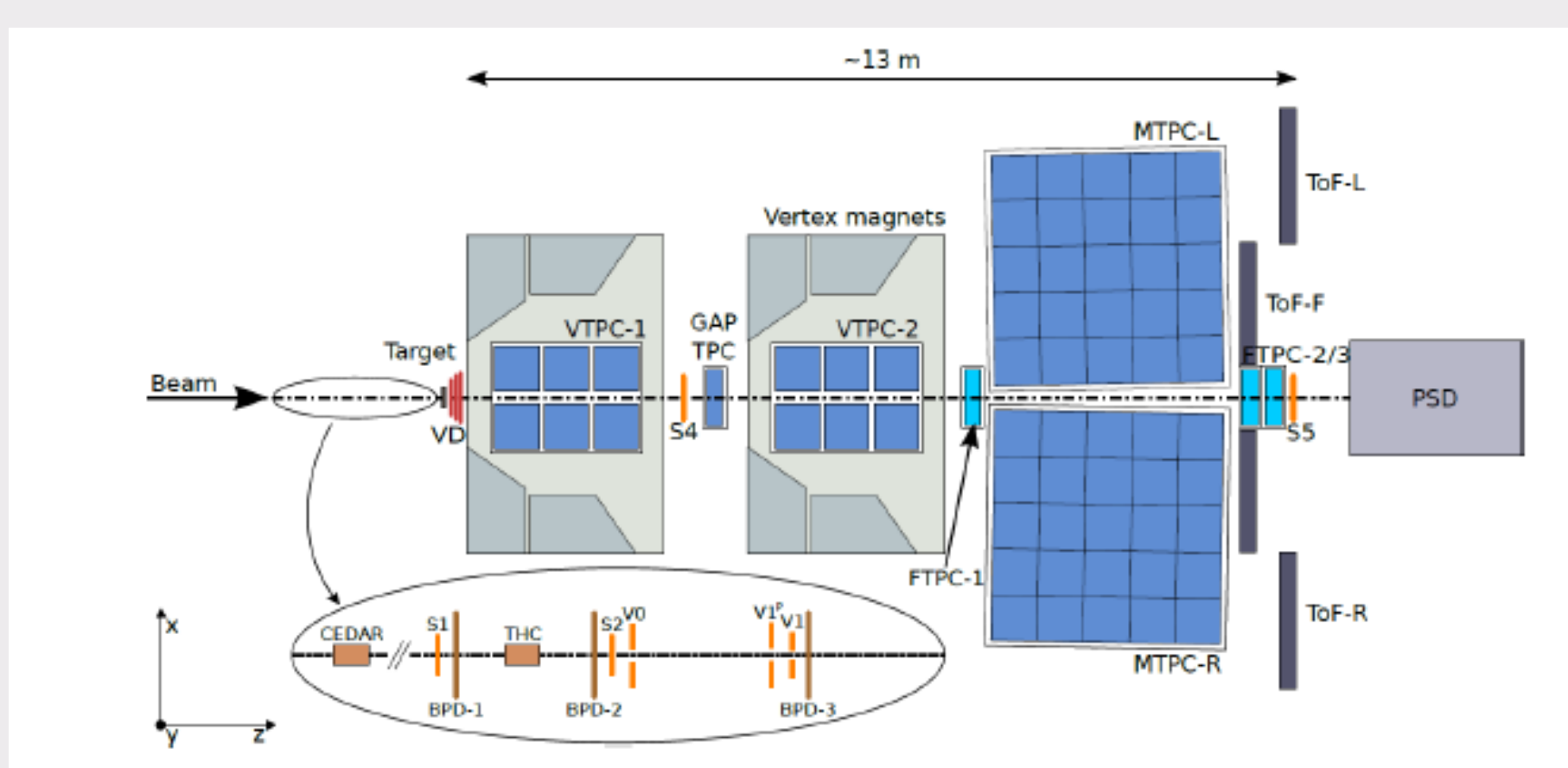
The Projectile Spectator Detectors for the CBM at FAIR and NA61/SHINE at CERN

Fedor Guber, INR RAS, Moscow,
for the CBM and NA61 collaborations



The unique feature of future CBM experiment at FAIR and NA61/SHINE beyond 2020 at CERN SPS is their high-rate capabilities that makes these experiments sensitive to the extremely rare probes. The Projectile Spectator Detector (PSD) is the forward hadron compensating lead/scintillator calorimeter with sampling ratio 4:1. PSD will be used in these fixed target experiments to measure the event centrality and reaction plane orientation in heavy-ion collisions. The PSD at the CBM is designed for the beam energy range 4-10 AGeV and beam rates up to 100 MHz, whereas the PSD at the NA61/SHINE beyond 2020 would operate in the beam energy range 20-150 AGeV and beam rates up to 50 kHz.

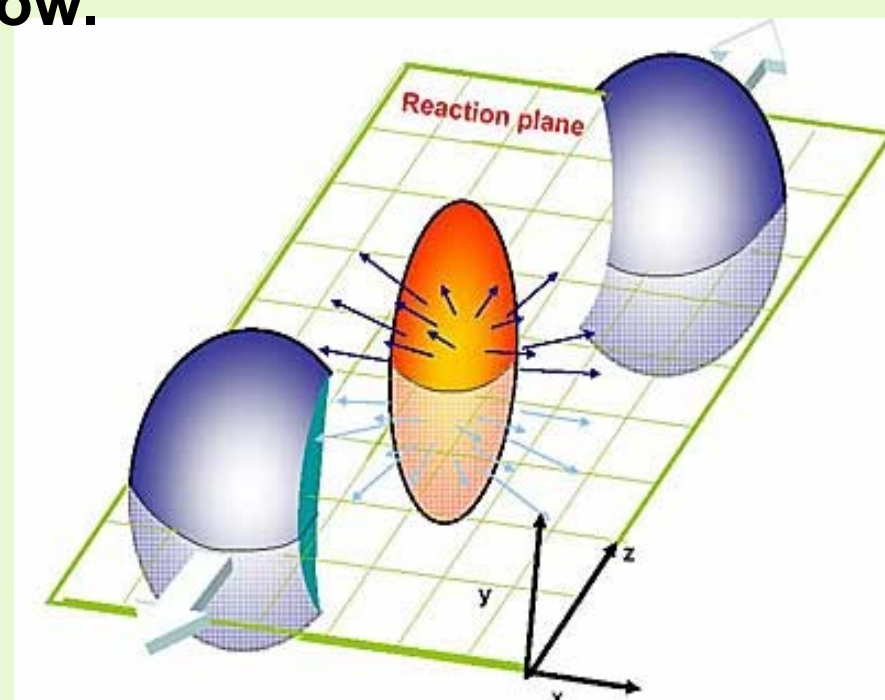
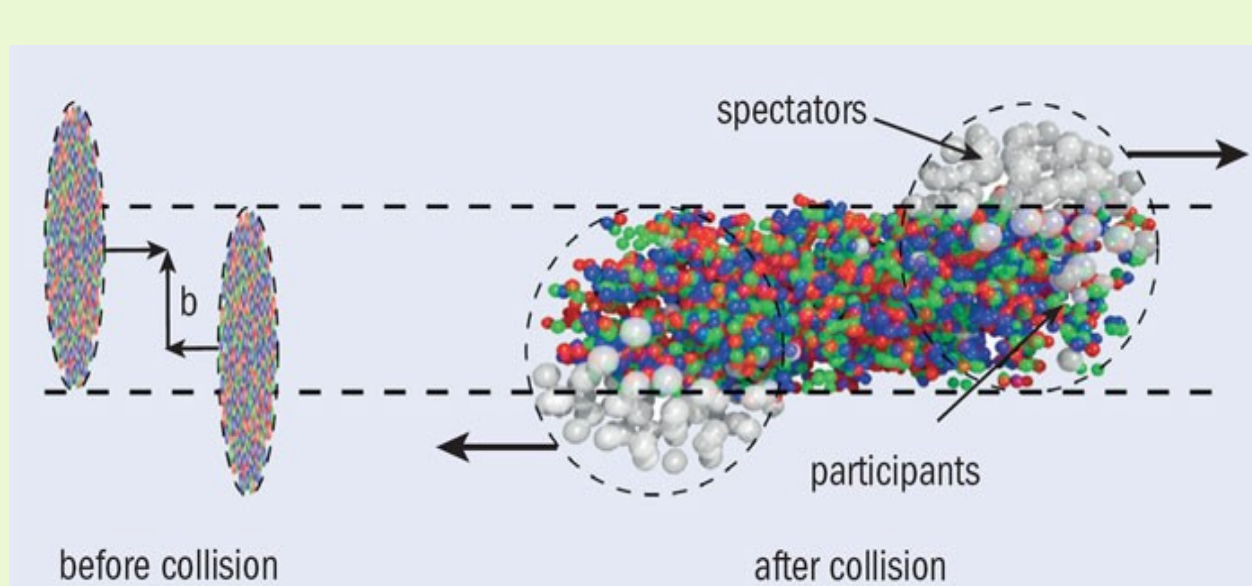
NA61@SPS



Ongoing experiment at SPS (since 2006)

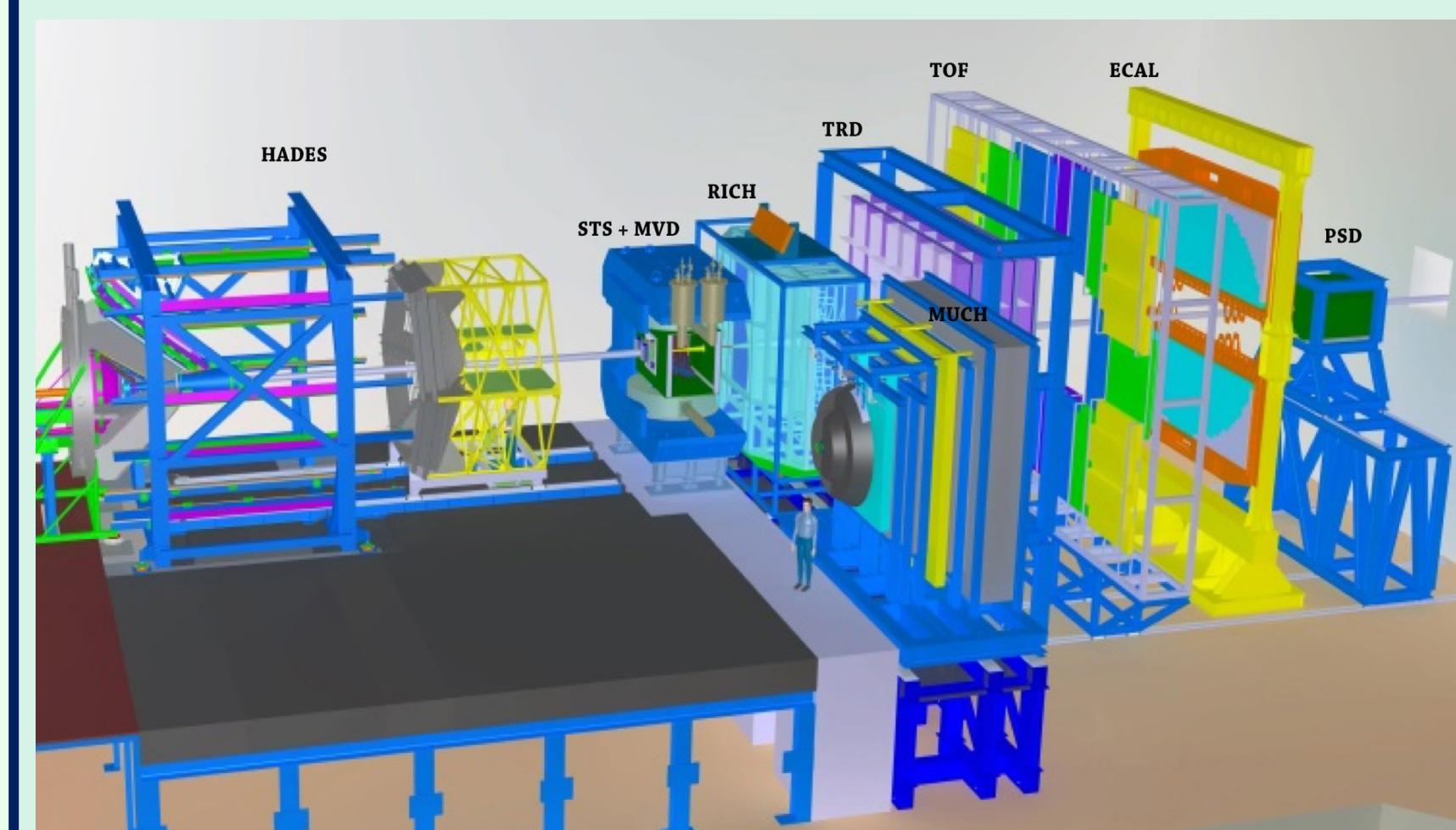
The main PSD tasks in the CBM and NA61 experiments

PSD tasks at the CBM and NA61 experiments are determination of a collision centrality and the orientation of an event plane for precise characterization of the event class. This is of crucial importance for selection of event centrality as well as for the analysis of event-by-event observables, including collective flow.



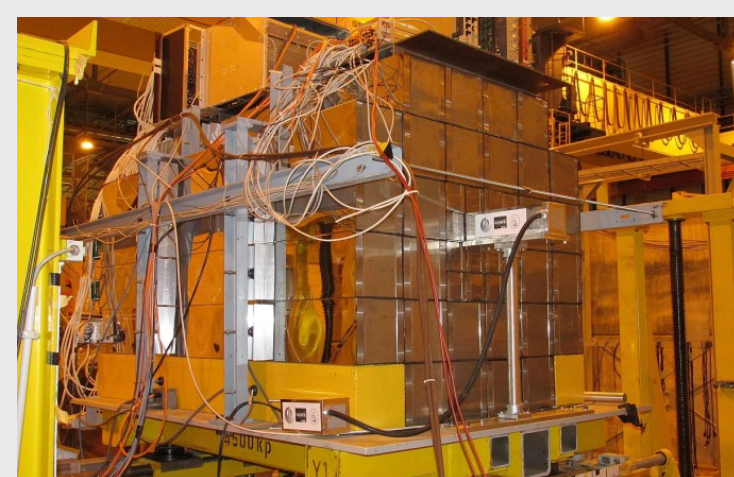
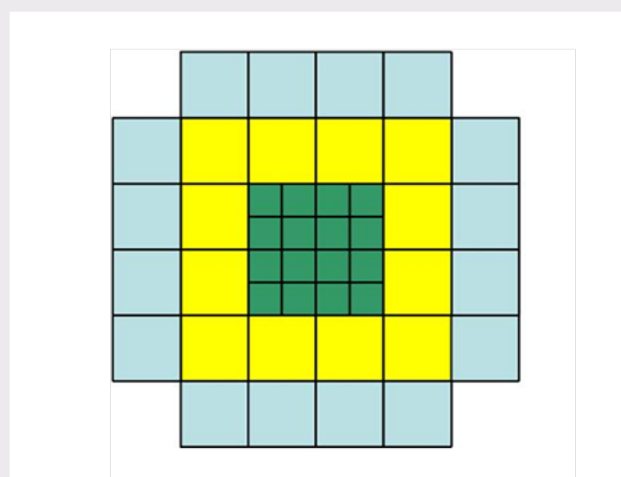
PSD measures energy of spectators in forward direction to determine the centrality of interaction and, in addition, its positions on the entrance face of the calorimeter to determine the reaction plane.

CBM@FAIR



Start of experiments at FAIR - 2024

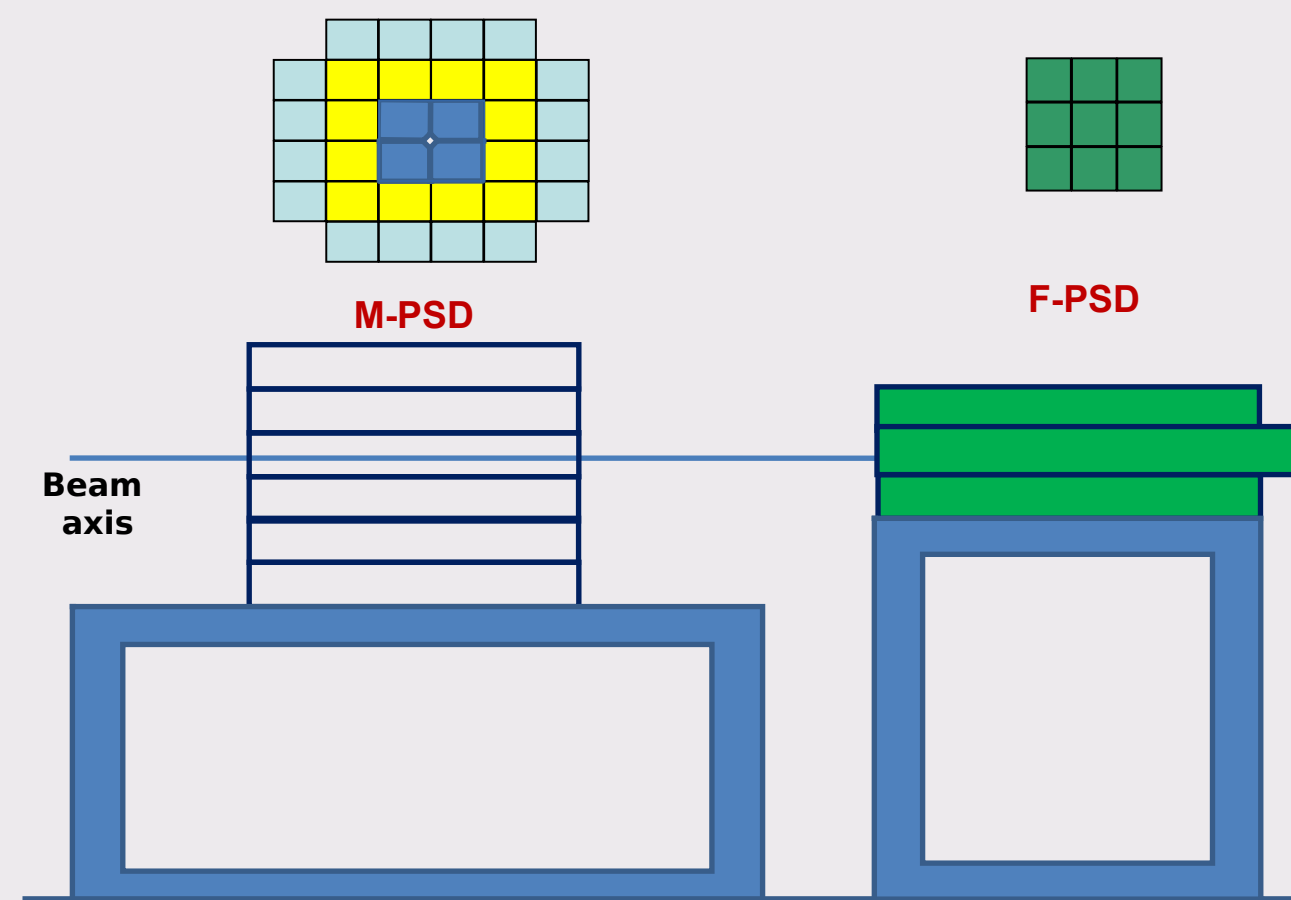
Present structure of PSD NA61



PSD - transverse and longitudinal segmented forward hadron calorimeter (w/o beam hole):

- 16 inner modules ($5.6 \lambda_{int}$), transverse size $100 \times 100 \text{ mm}^2$.
- 28 outer modules ($5.6 \lambda_{int}$), transverse size $200 \times 200 \text{ mm}^2$.
- 1 small modules ($1.2 \lambda_{int}$), transverse size $100 \times 100 \text{ mm}^2$.

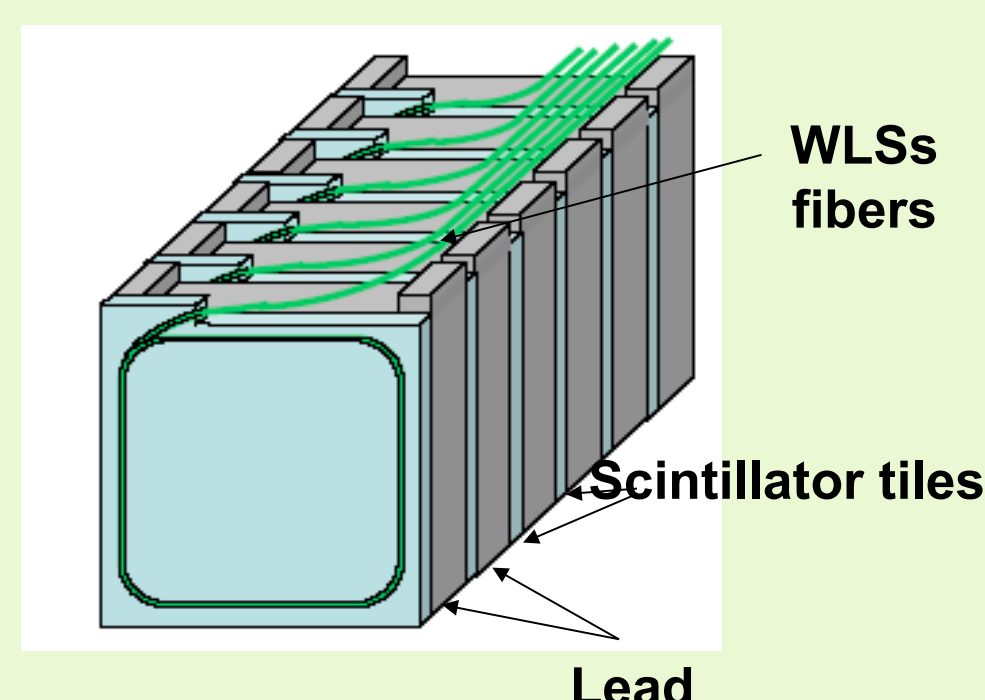
PSD NA61 for experiments beyond 2020



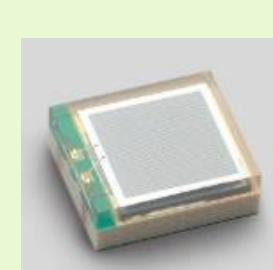
Main PSD (M-PSD) – 44 modules with beam hole in the center ($\phi 60 \text{ mm}$).

Forward PSD (F-PSD) – 9 modules w/o beam hole.

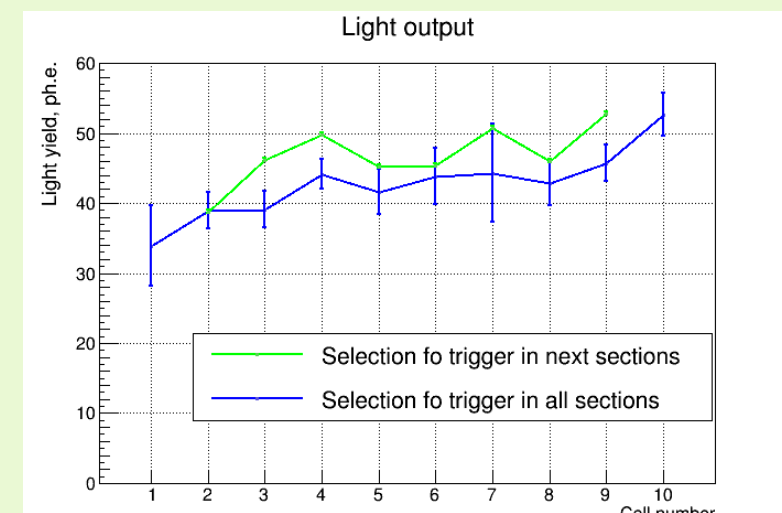
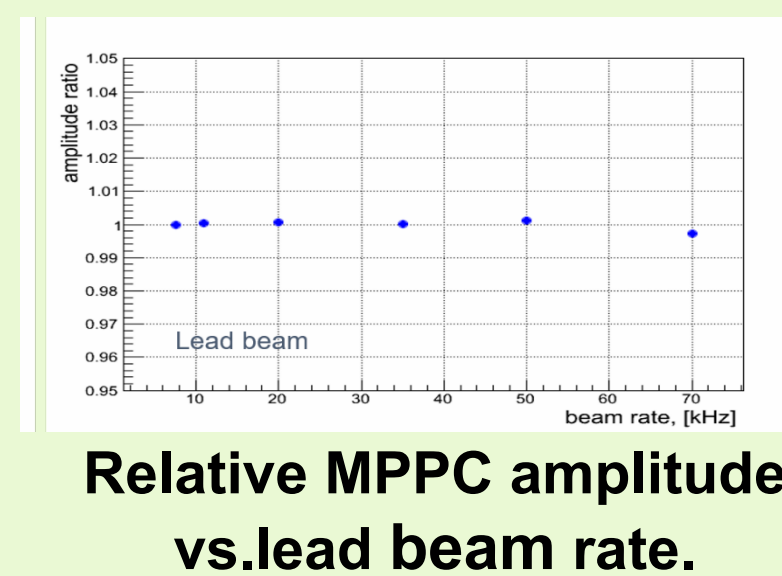
Structure of PSD CBM and PSD NA61 modules



- Module transverse size $200 \times 200 \text{ mm}^2$
- Longitudinal structure of module: 60 Pb/scint. tiles layers: (Pb(16mm), Scint(4mm)) grouped in 10 sections with $\sim 0.6 \text{ int.}$ length each. Total length $5.6 \lambda_{int}$.
- Weight of each module 500 kg.
- Light collections – by WLS fibers from 6 sequentially placed scint. tiles in one section to one optical connector at the end of module.
- Light readout: 10 MPPC ($3 \times 3 \text{ mm}^2$) per module,

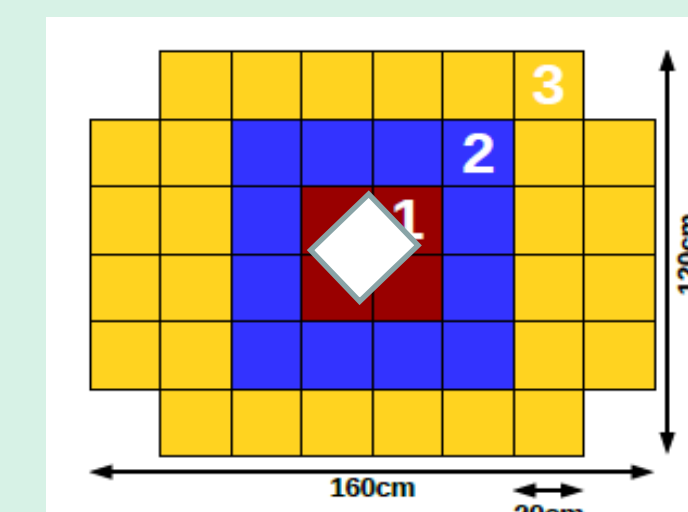


Hamamatsu S12572-010P,
Sensitive area $3 \times 3 \text{ mm}^2$
Number of pixels 90 000
nominal gain 1×10^6 ,
Pixel recovery time - 10 ns



Light yield for MIP vs section number in module.

Structure of PSD CBM



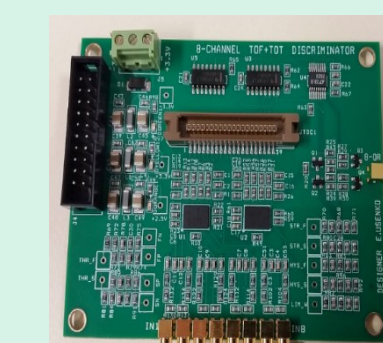
PSD - transverse and longitudinal segmented forward hadron calorimeter:

- 44 modules with transverse size $200 \times 200 \text{ mm}^2$.
- Beam hole ($\phi 200 \text{ mm}$) in the PSD center.
- Total weight – 22t.

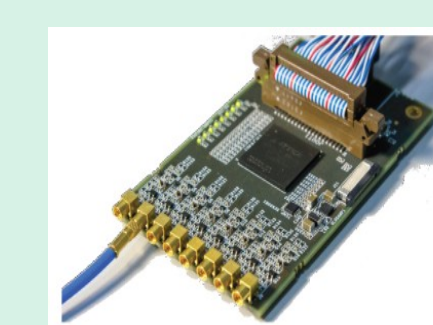
Several versions of PSD FEE and readout electronics are tested now:
-Fast sampling ADC ADC64s, ADC125s boards;
-PaDiWa compatible Time over Threshold +TRB3;
-PaDiWa-Amps + TRB3 board.



ADC ADC64s



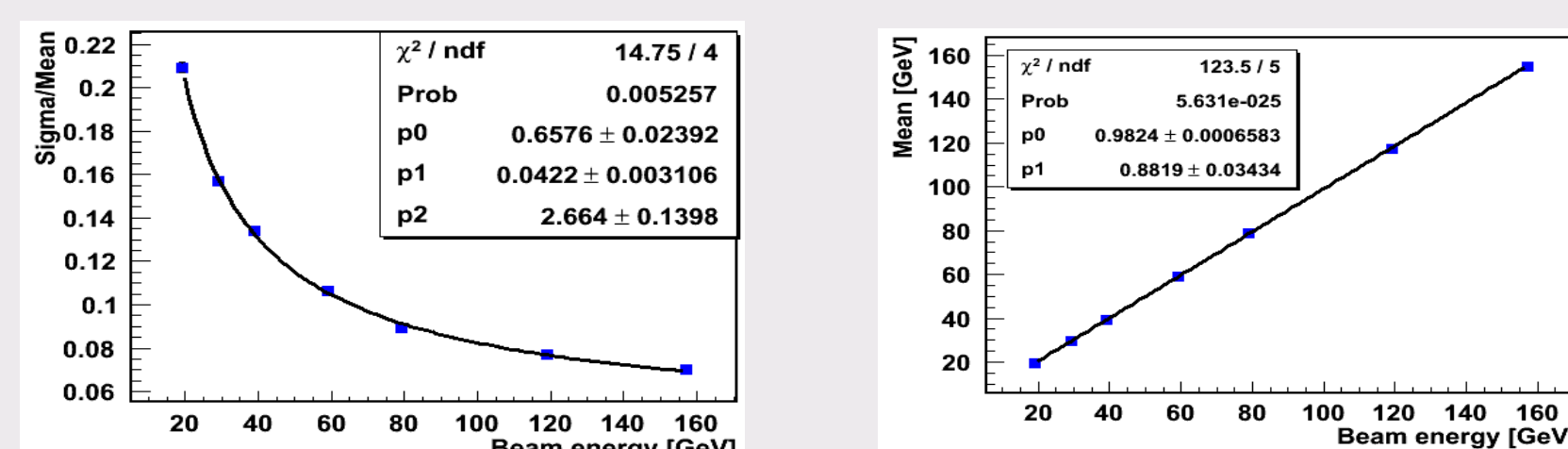
ToT



PaDiWa

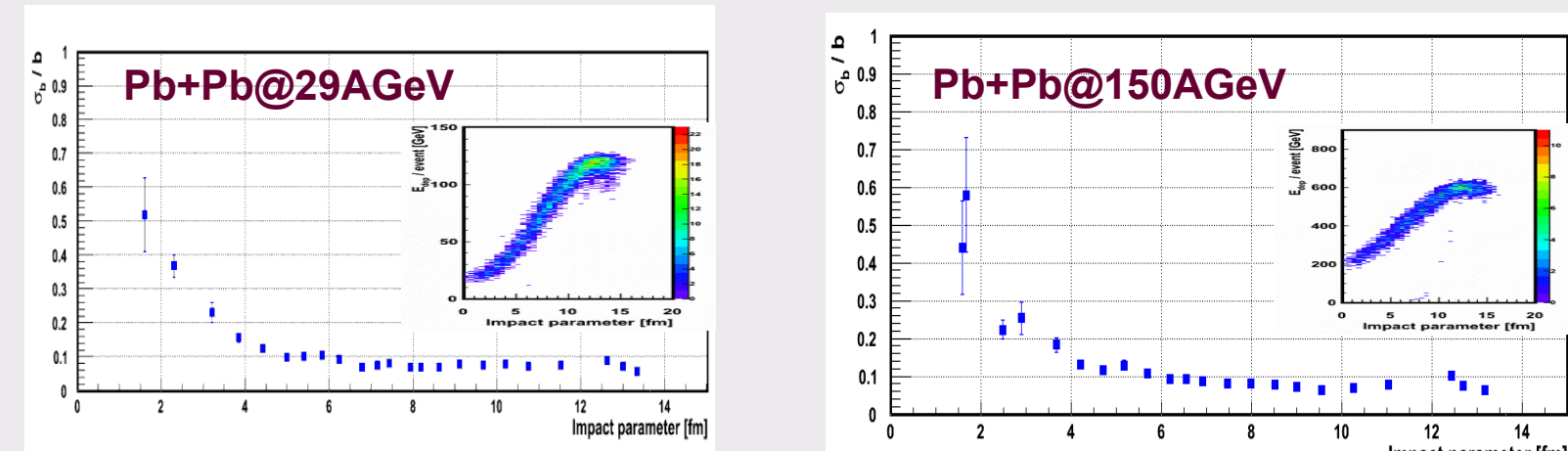
PSD NA61 energy resolution and linearity

Energy resolution and linearity response of present PSD measured at proton beam

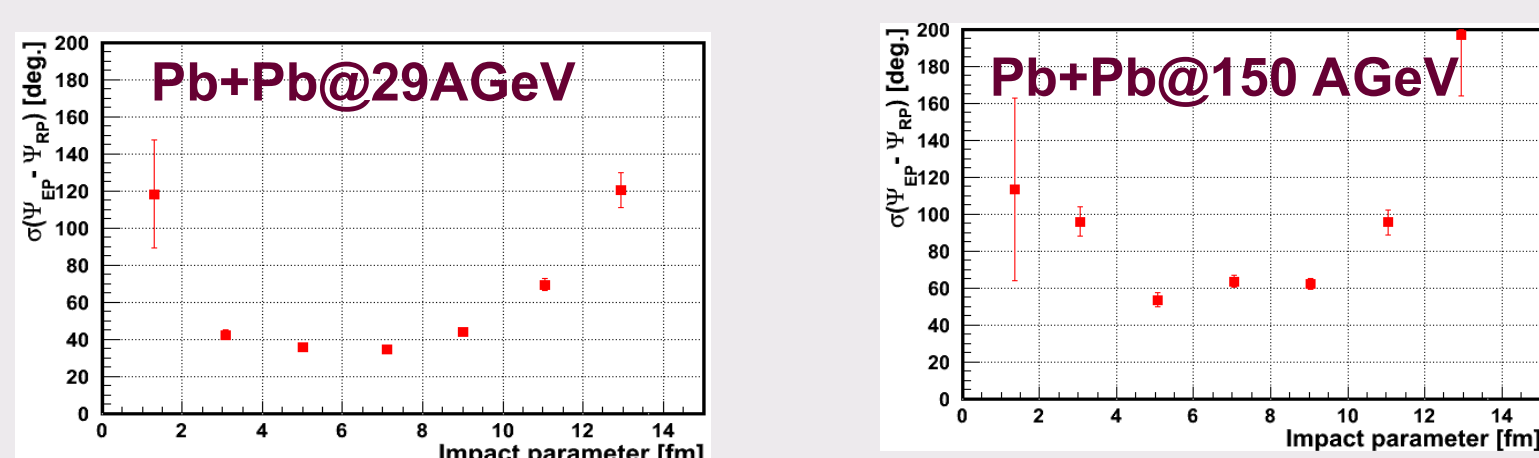


$$\frac{\sigma_E}{E} = \sqrt{\left(\frac{0.66}{\sqrt{E}}\right)^2 + 0.042^2 + \left(\frac{2.7}{E}\right)^2}$$

Simulation of centrality resolution with upgraded PSD NA61

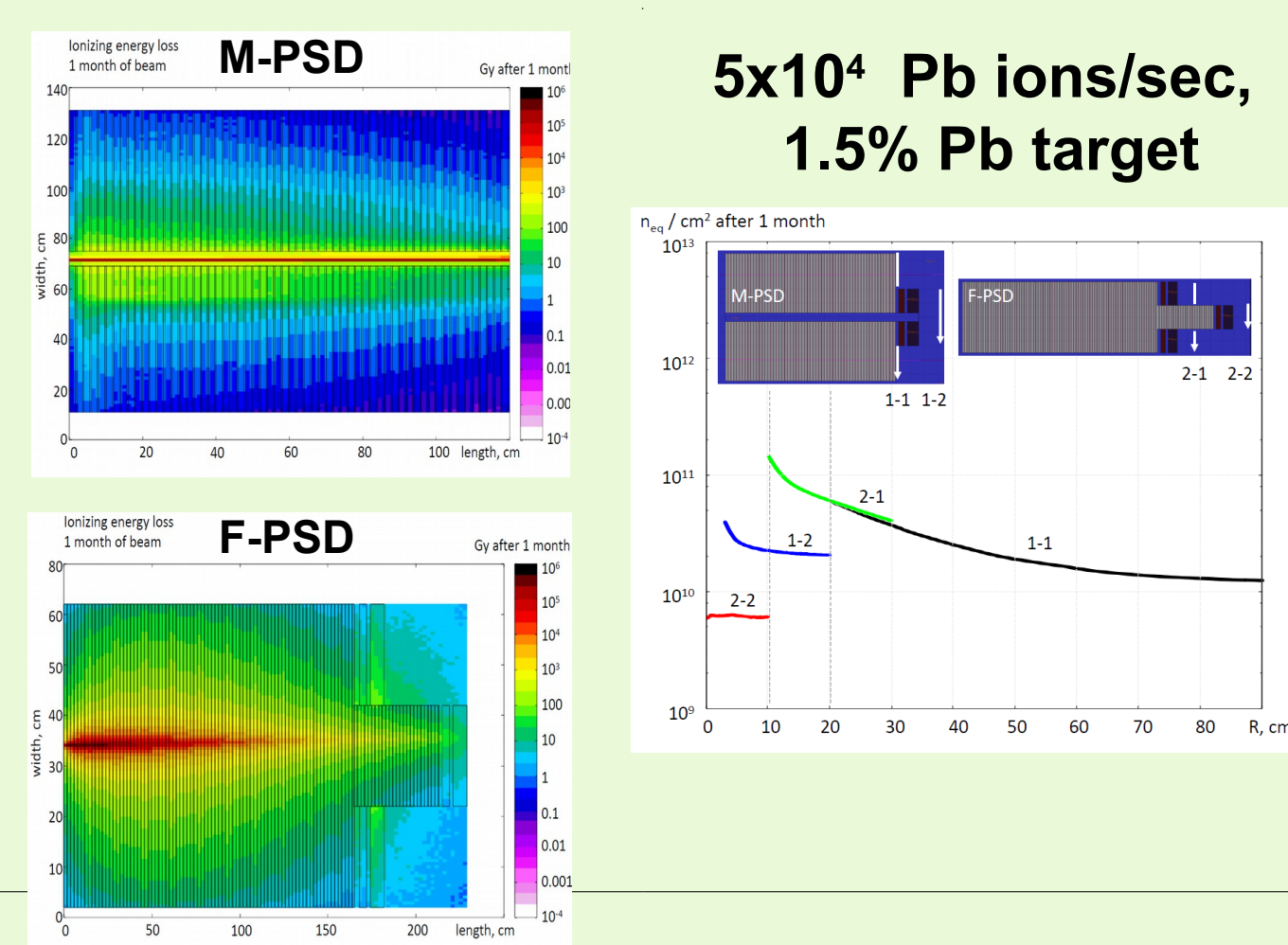


Simulation of the reaction plane angular resolution with upgraded PSD NA61

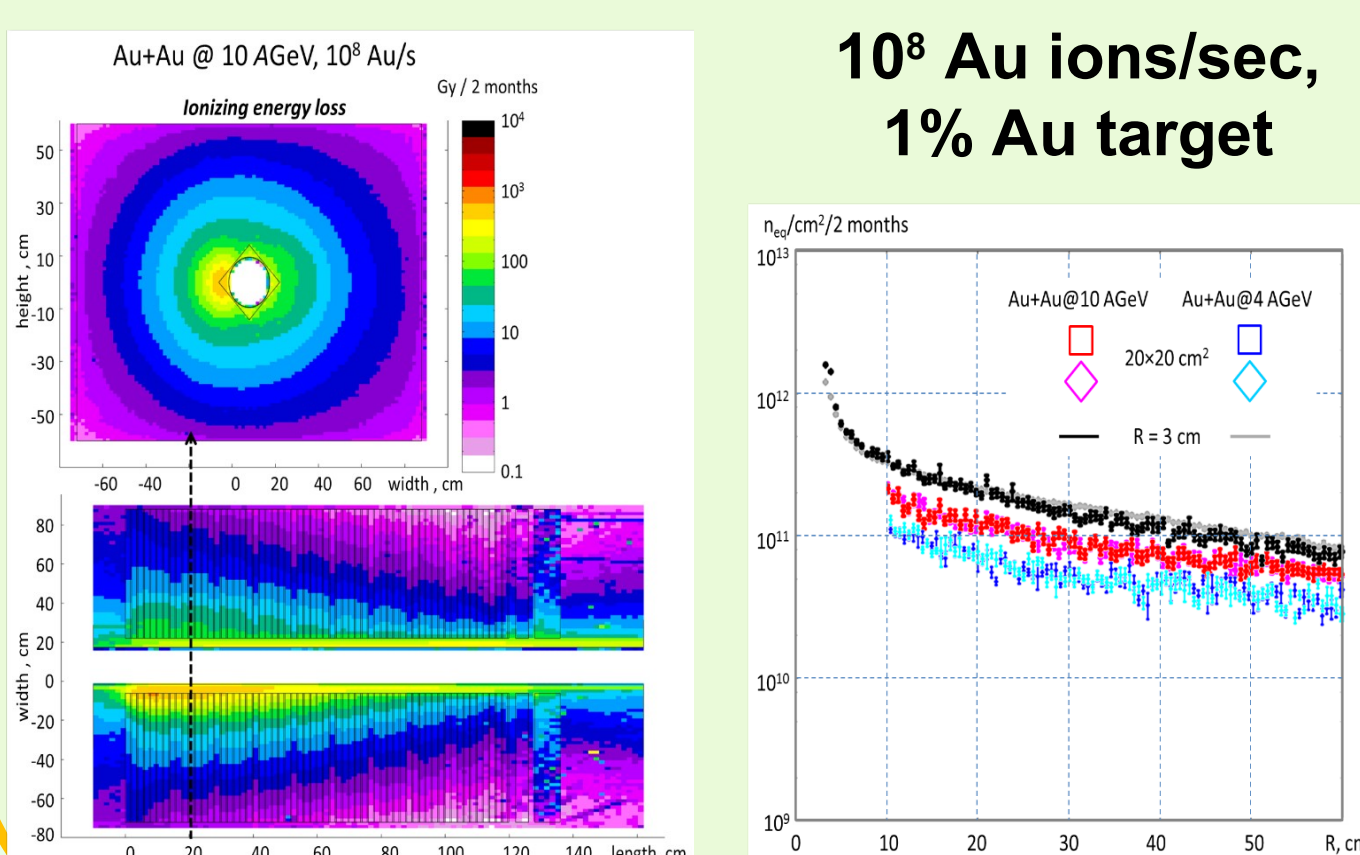


FLUKA simulations of PSD radiation conditions

PSD NA61 beyond 2020



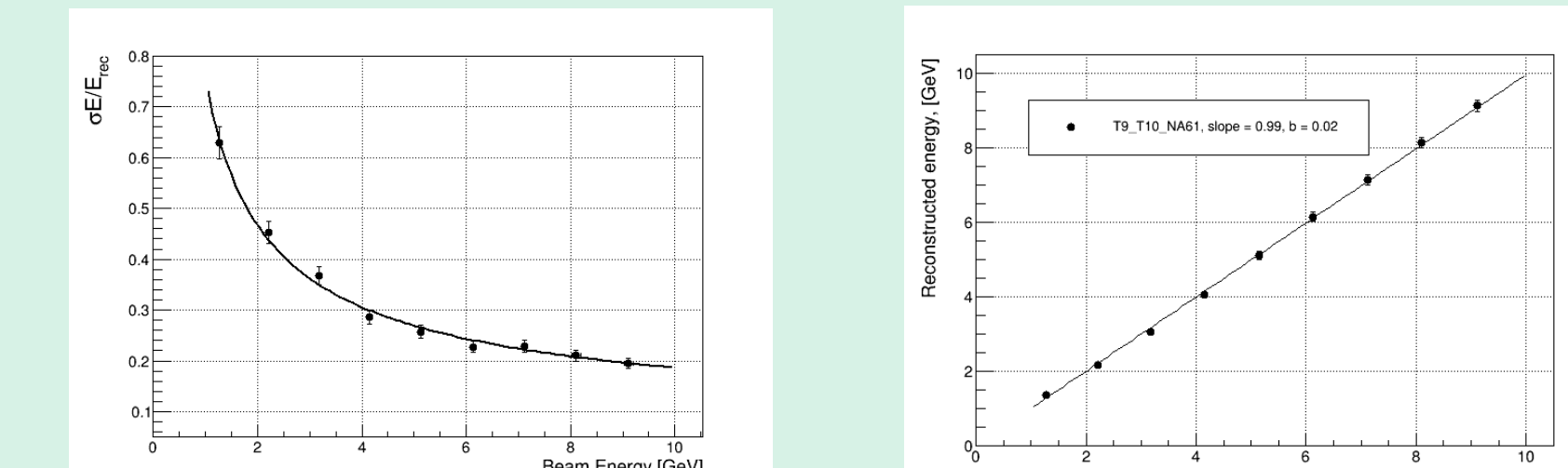
PSD CBM



Test of PSD CBM 3x3 modules array at CERN T9/T10 beam line

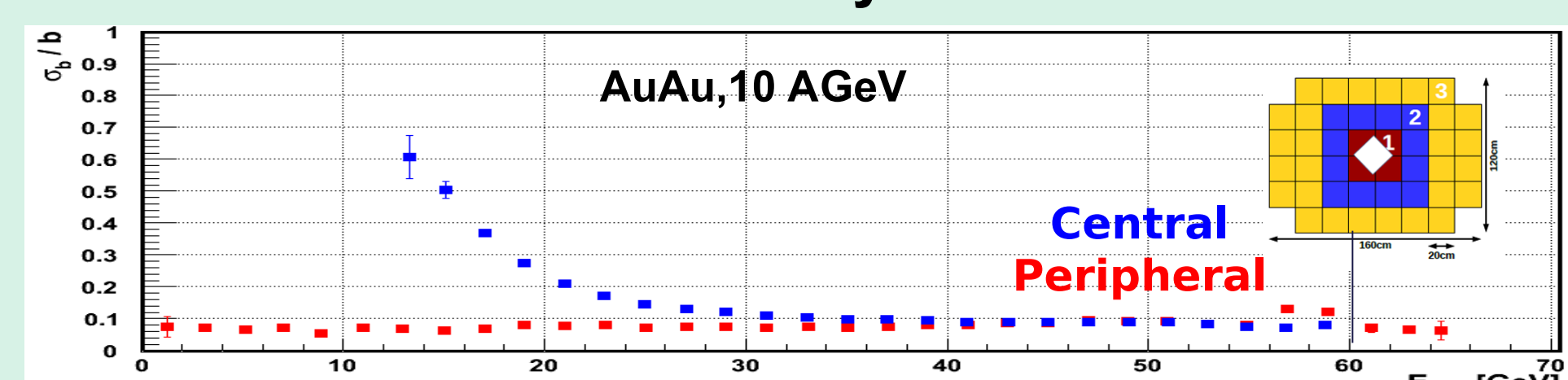


Measured energy resolution and linearity response at proton beam energies 1.5 – 9 GeV



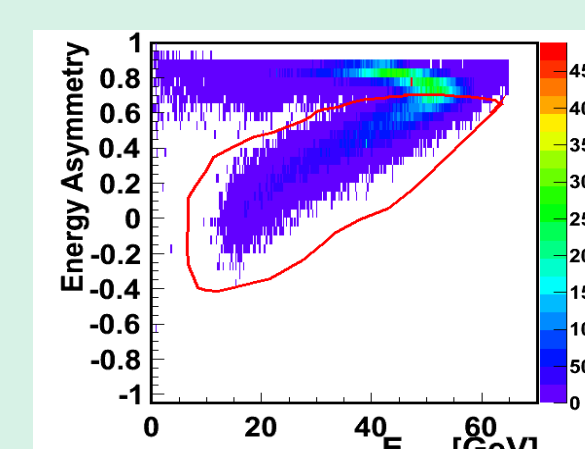
$$\frac{\sigma_E}{E} = \sqrt{\left(\frac{0.54}{\sqrt{E}}\right)^2 + 0.046^2 + \left(\frac{0.5}{E}\right)^2}$$

Simulation of the centrality resolution with PSD CBM

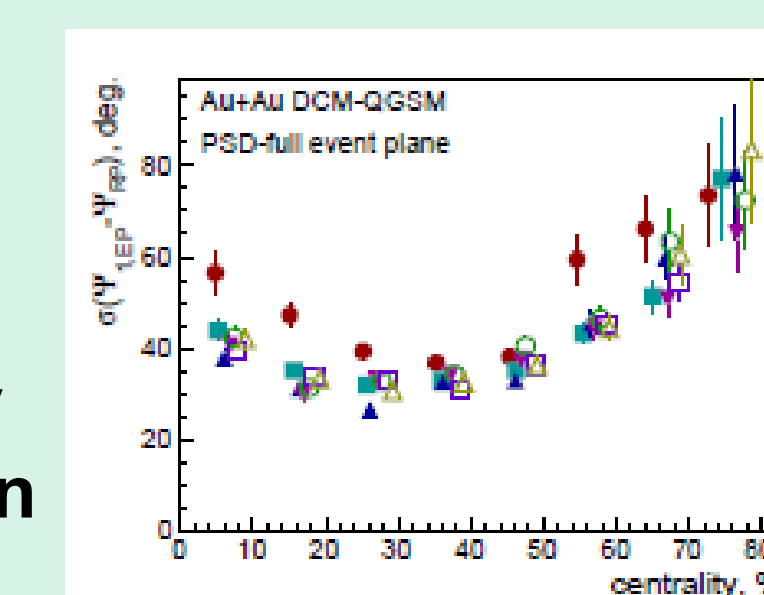


PSD energy asymmetry

$$A_E = \frac{E_{in} - E_{out}}{E_{in} + E_{out}}$$



PSD energy asymmetry vs PSD energy deposition



Simulation of the reaction plane angular resolution with PSD CBM