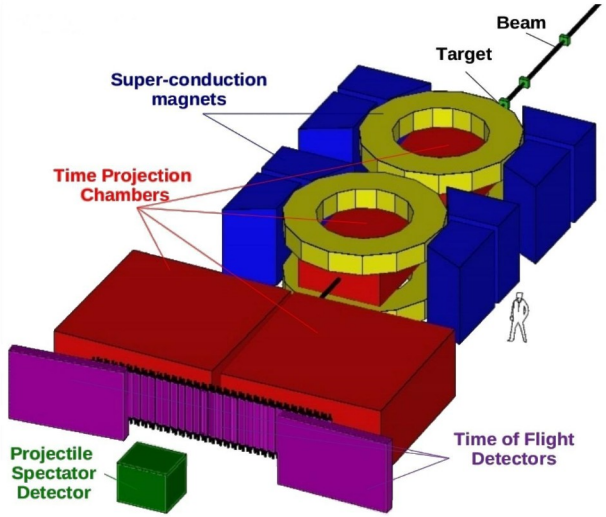
Upgrade of Projectile Spectator Detector at NA61/SHINE experiment

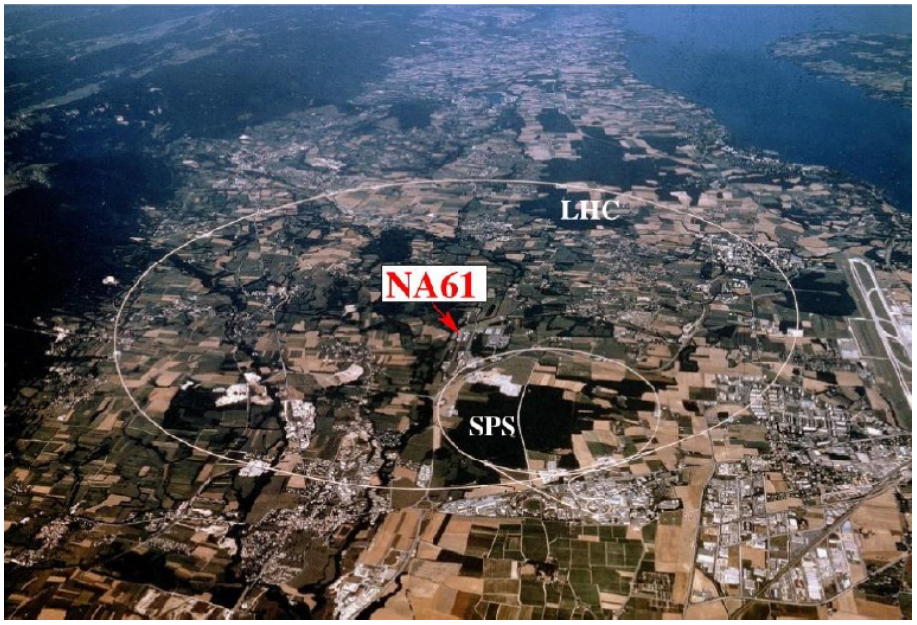
Sergey Morozov on behalf of INR RAS, Moscow



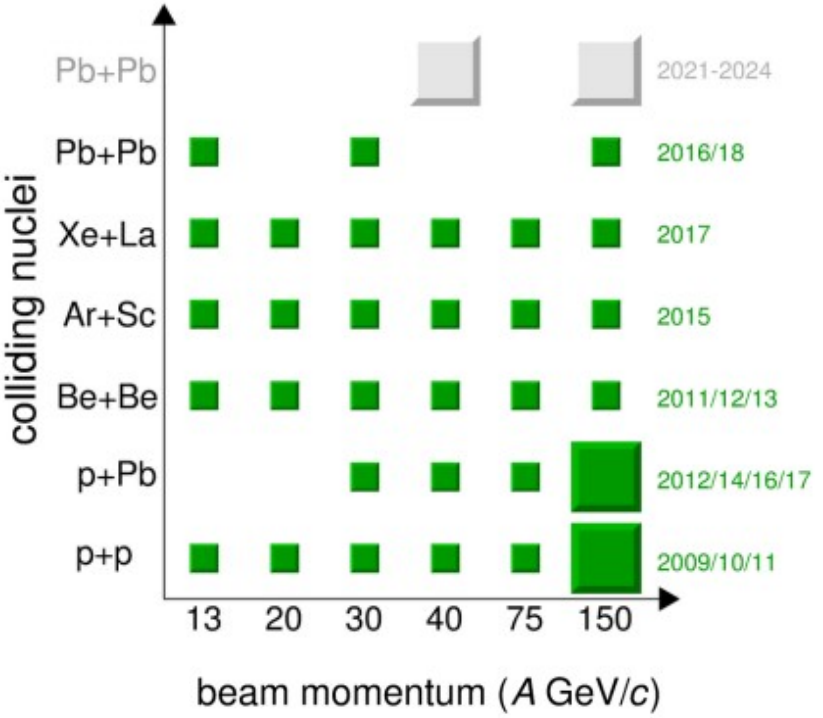
LXX International conference "NUCLEUS – 2022:
Fundamental problems and applications"

11-16 July 2022
Moscow State University, Russia

NA61/SHINE experiment at CERN SPS

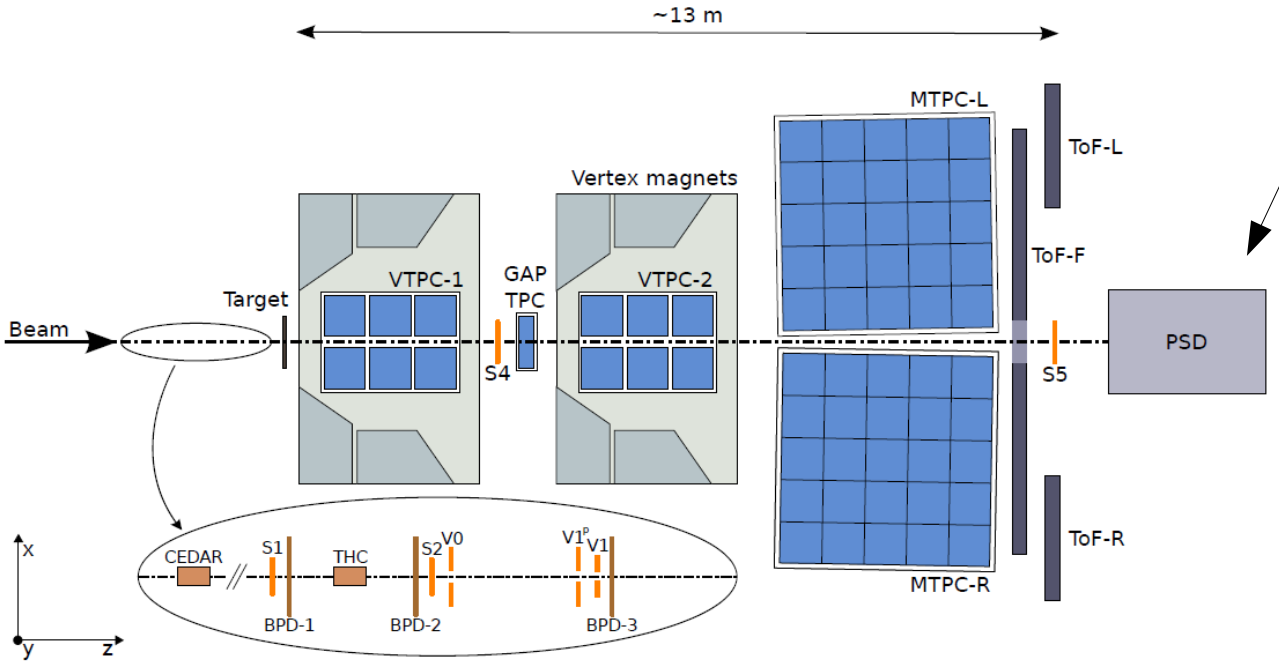


Physics program at NA61



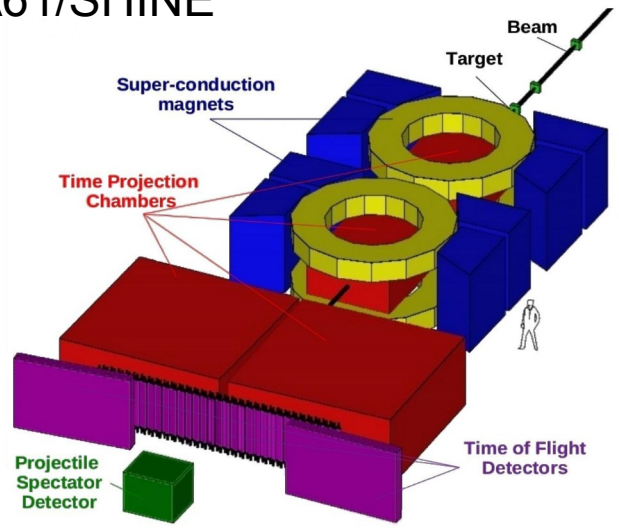
NA61/SHINE facility:

- accelerator chain, beam line and detectors
- hadron production spectrometer for h+p, h+A, A+A
- energies: 13 – 150 AGeV/c (400)
- precise measurements of produced particles (charge, mass, momentum)

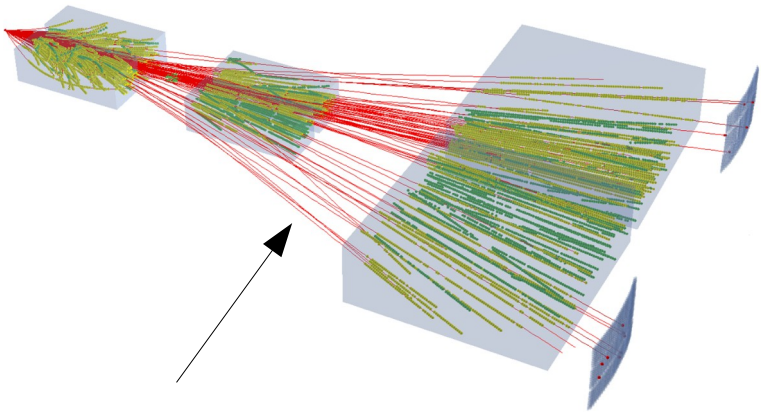


Projectile Stectator Detector

NA61/SHINE

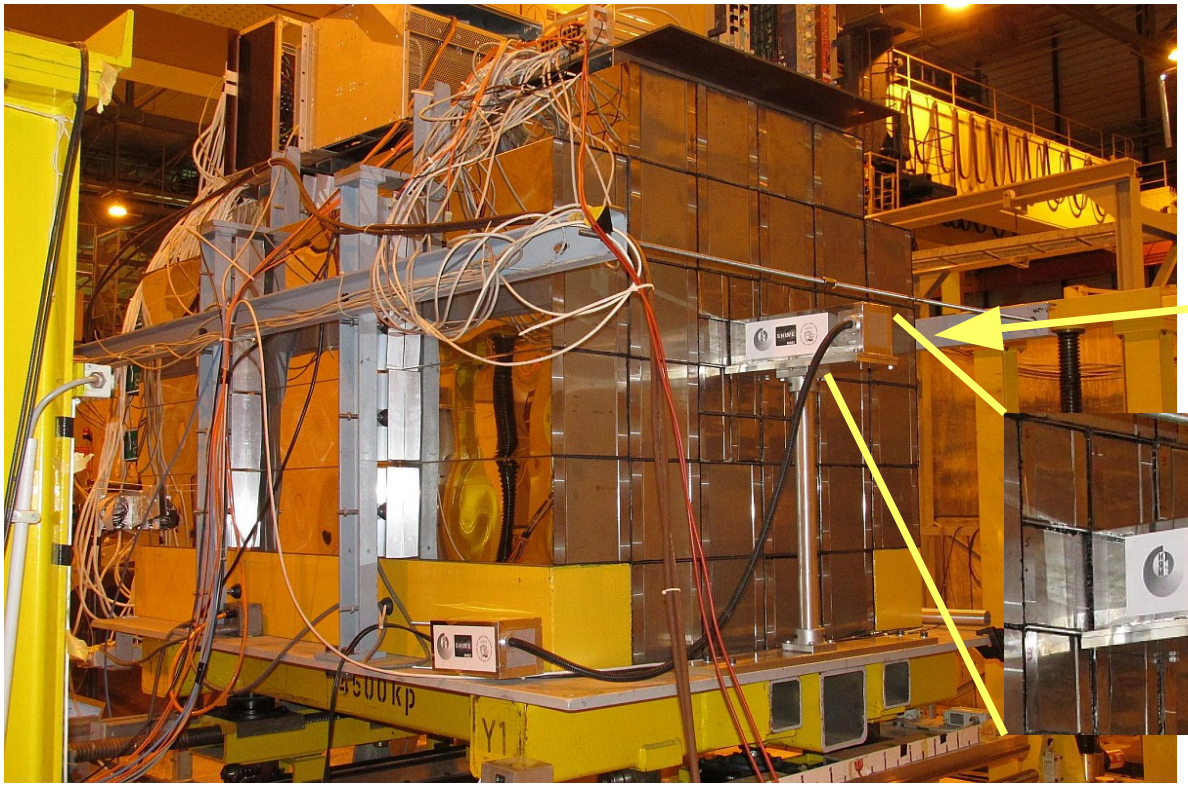


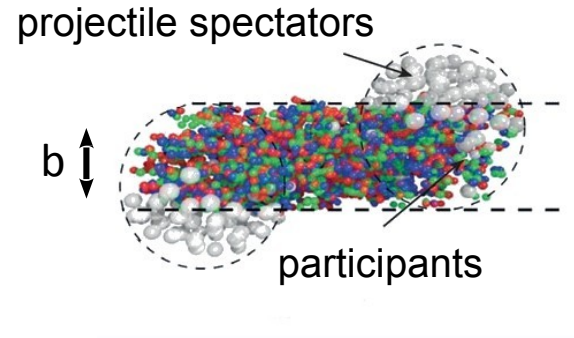
Ar + Sc @ 150 AGeV/c

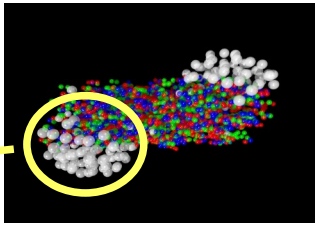


tracks reconstructed

Hadron calorimeter PSD at NA61/SHINE

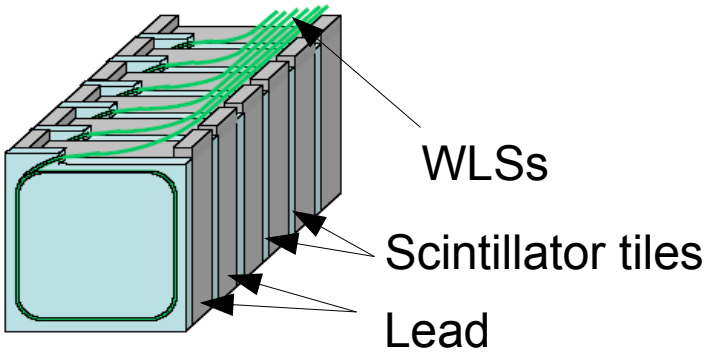




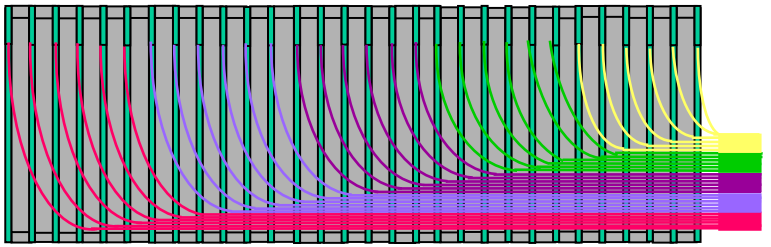


Main goals of PSD:

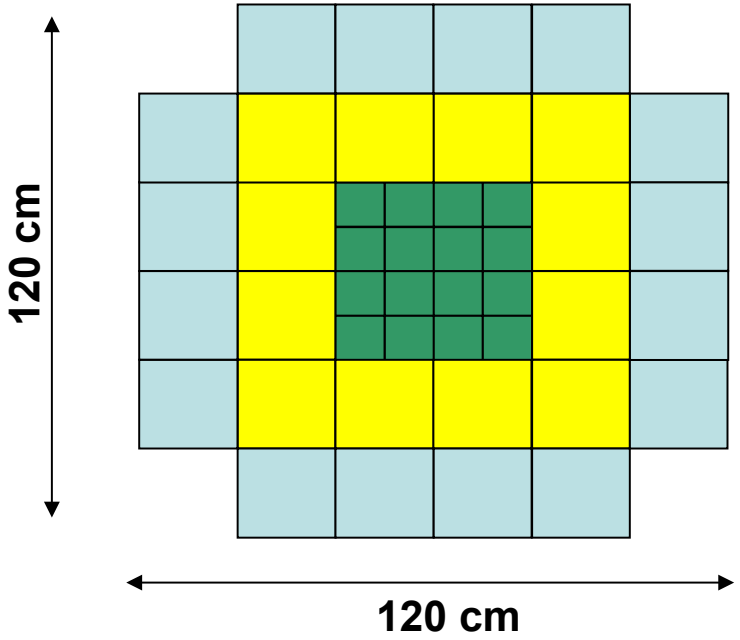
- event selection with collision centrality classes
- event plane reconstruction (with transverse granularity)



PSD section schematic



Module schematic



44 modules + 1:

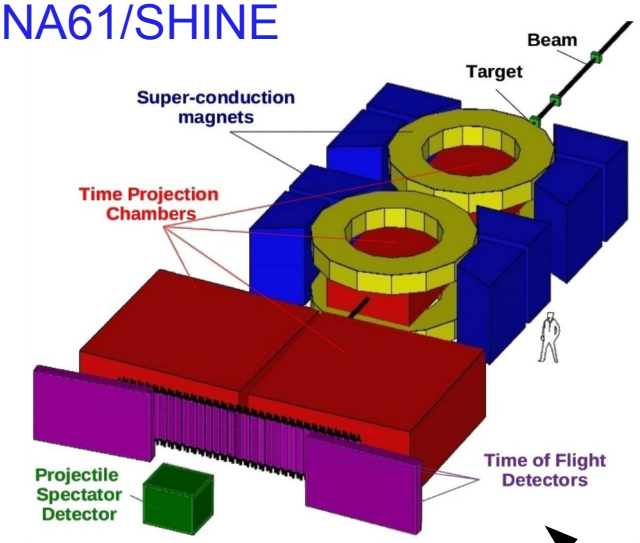
16 small: 10cm x 10cm size
28 large: 20cm x 20 cm size

(10 sections in 1 module) => ~5.6 int. length

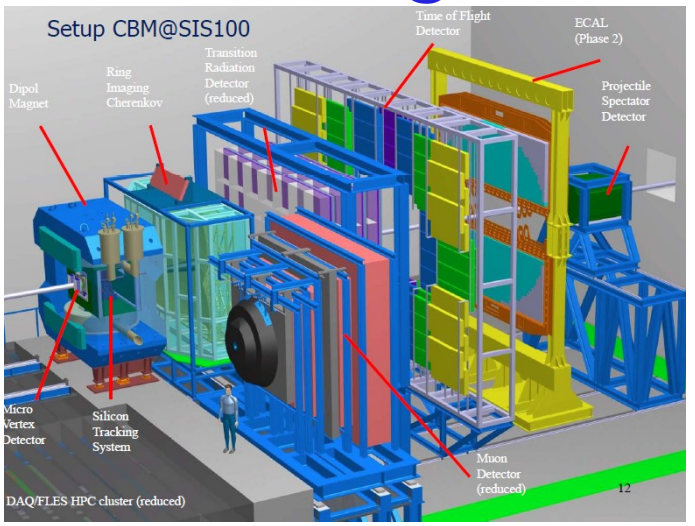
1 short module of 2 sections

450 channels to read-out

NA61/SHINE

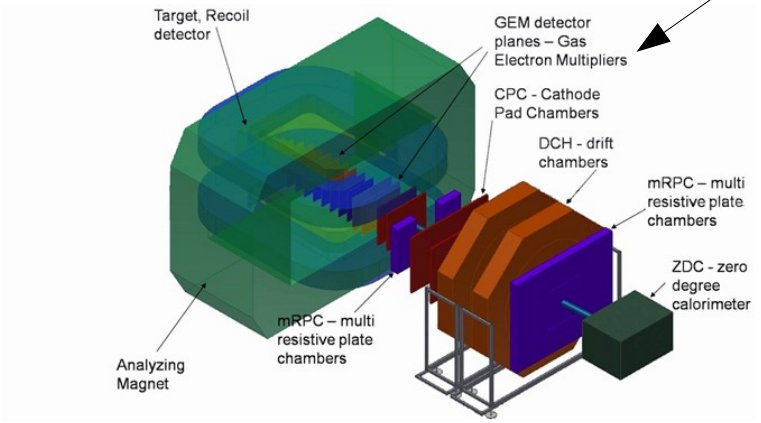


CBM @ FAIR

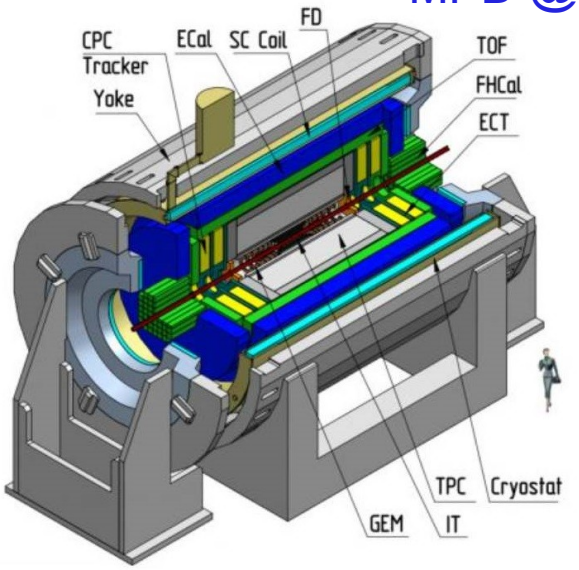


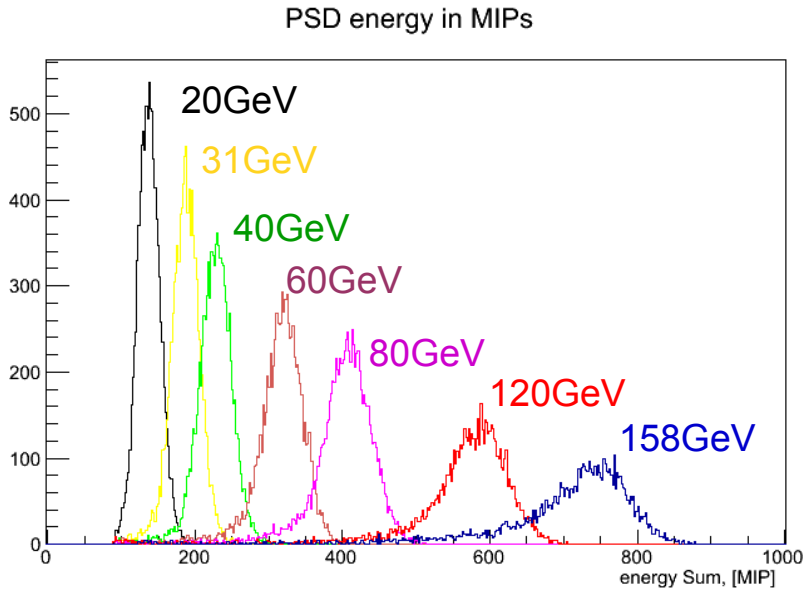
Forward Hadron Calorimeters

BM @ Nuclotron



MPD @ NICA

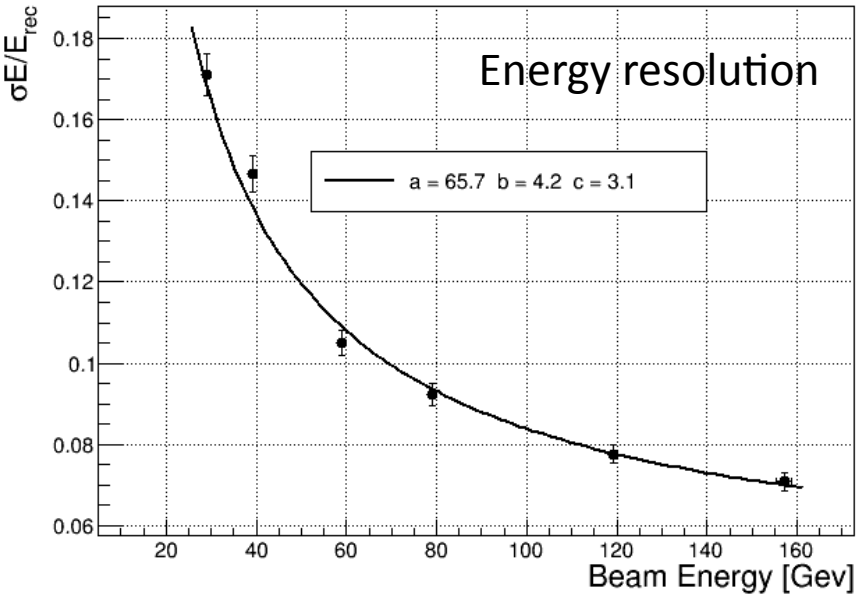


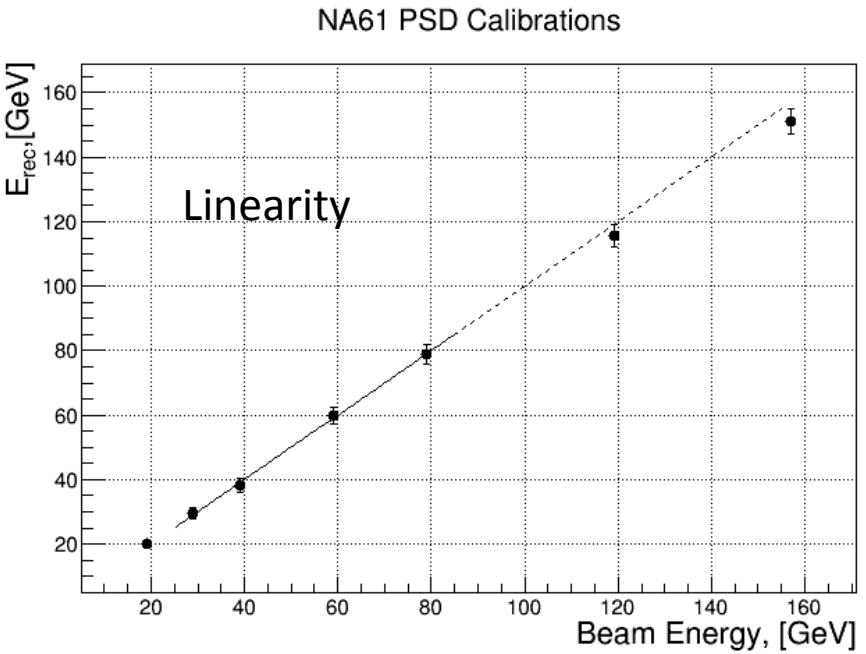


Forward hadron calorimeter at NA61/SHINE (calibration and performance):

- good linearity with slight longitudinal shower leakage effect starting from 120GeV

- good energy resolution with about 65% stochastic term

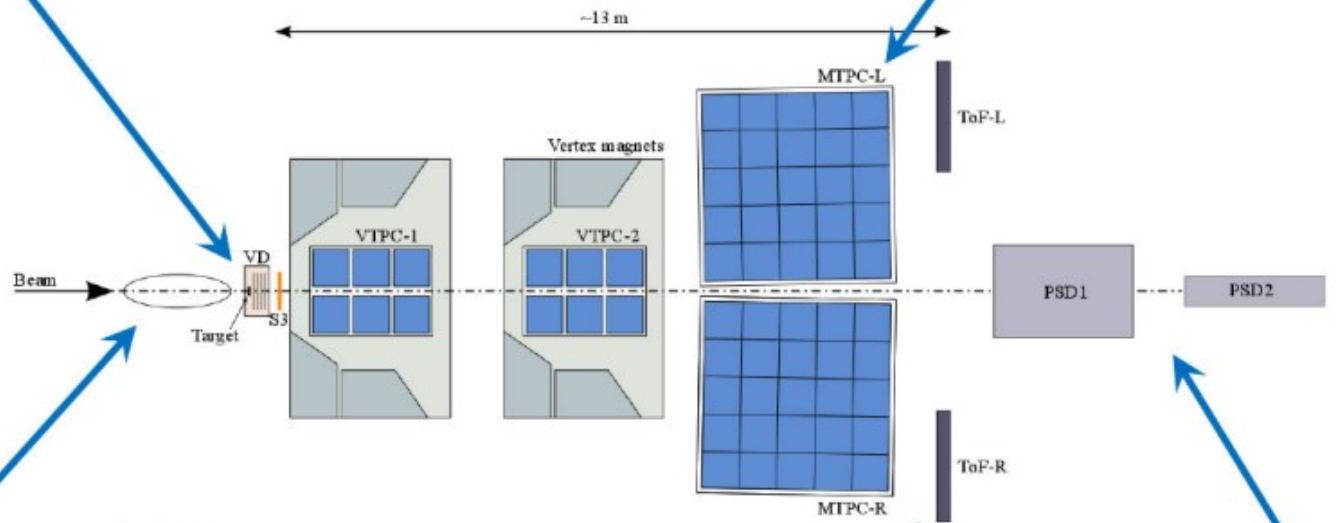




Upgrade of NA61/SHINE experiment

Construction of Vertex Detector (VD)
for D^0, $\overline{D^0}$ decay reconstruction

Replacement of the TPC
read-out electronics
to increase data rate to 1 kHz



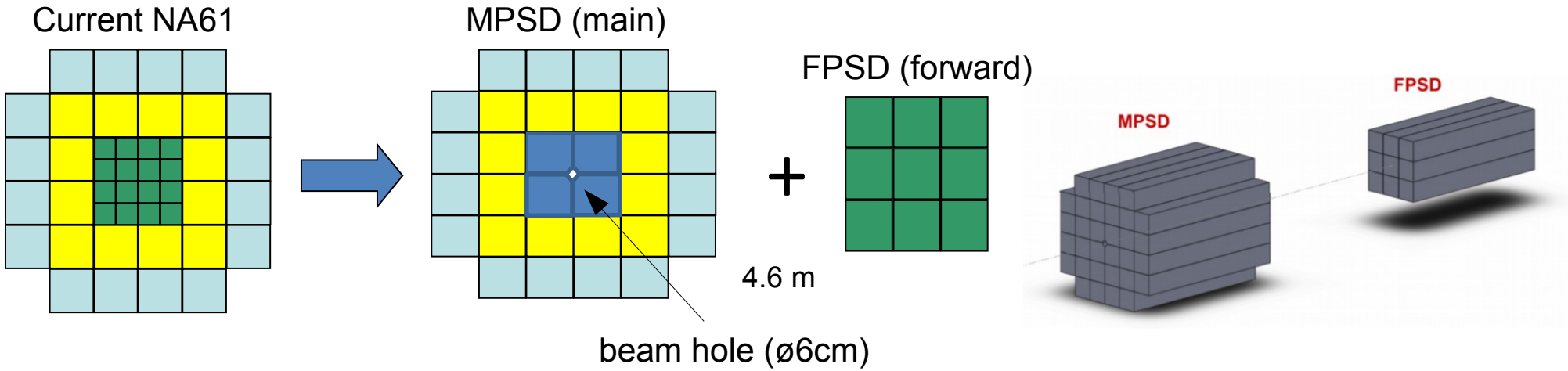
New trigger and data
acquisition system

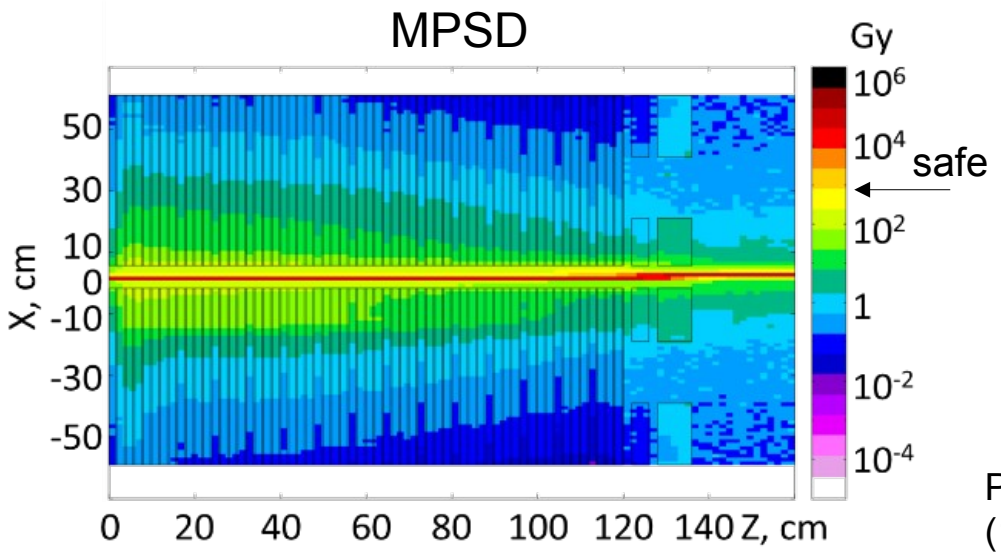
New Time-of-Flight
detectors

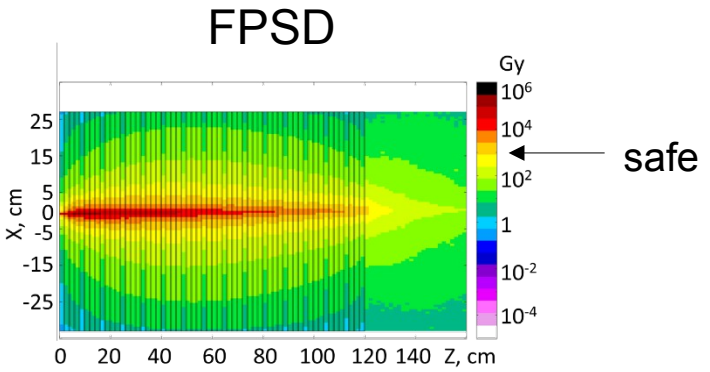
Upgrade of Projectile
Spectator Detector

PSD upgrade motivations:

- radiation damage of central modules of PSD with expected high beam intensity
- decouple the detection of single spectators and heavy fragments
- problems with radiation alarm (PSD is now an active beam dump!)

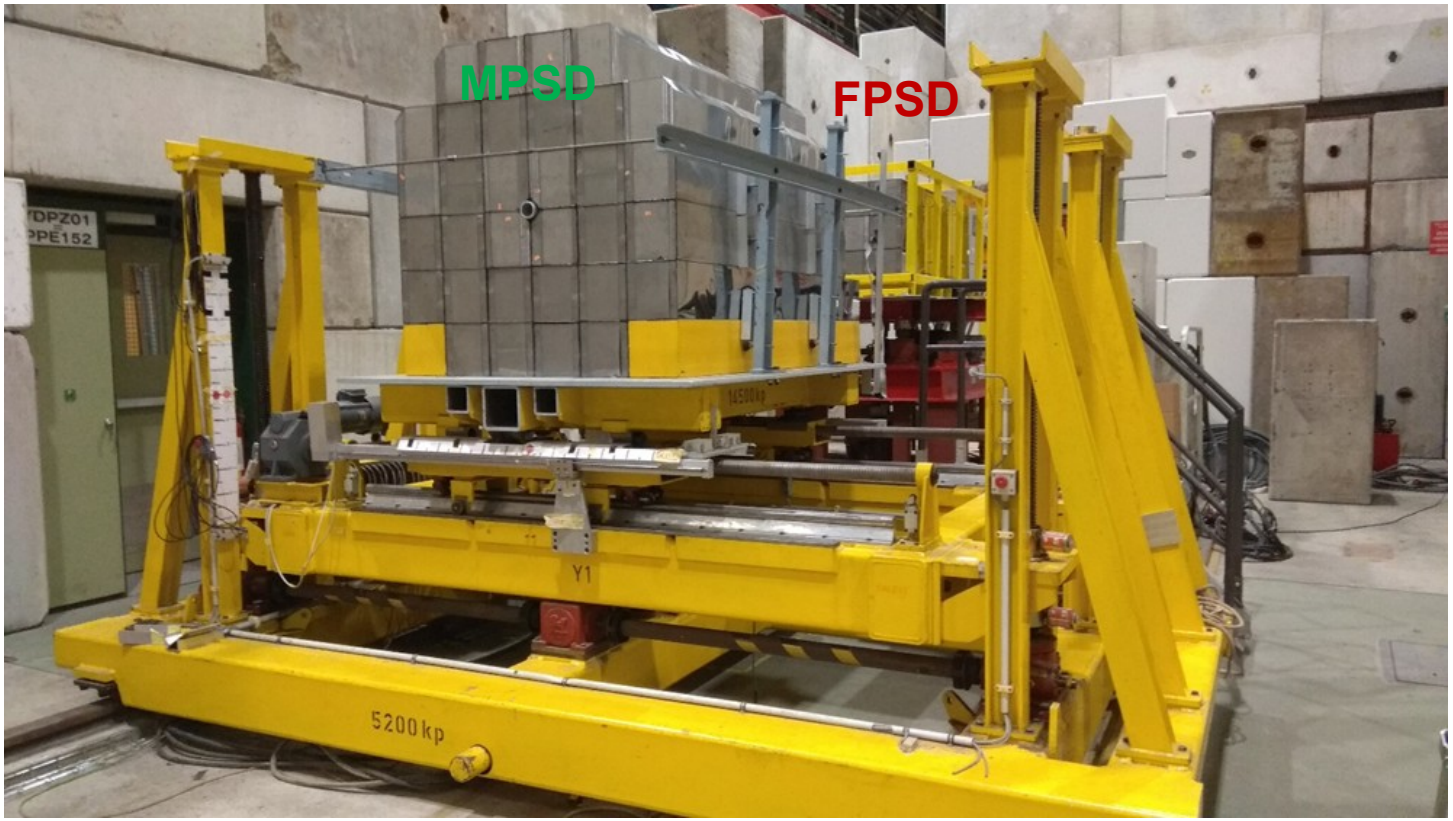






Pb150 beam 2.5×10^4 1/sec
(10^6 per spill), 1 month run

FPSD + MPSD on NA61/SHINE beam line

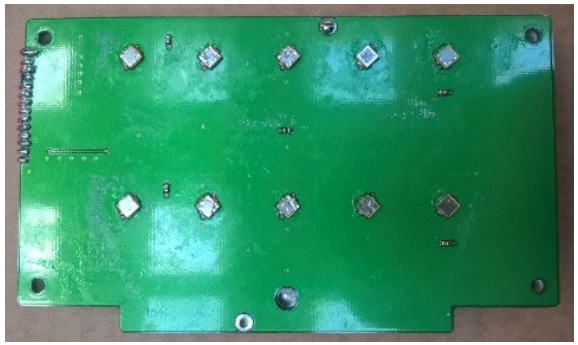


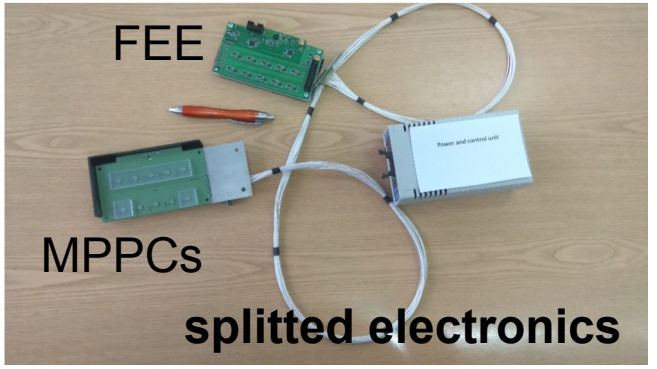
- 13 new modules in MPSD (borrowed at CBM experiment)
- 1 new (central) FPSD module with 4 cm hole in scintillators to avoide degradation of response with time due to high radiation doses

MPSD upgrade status:

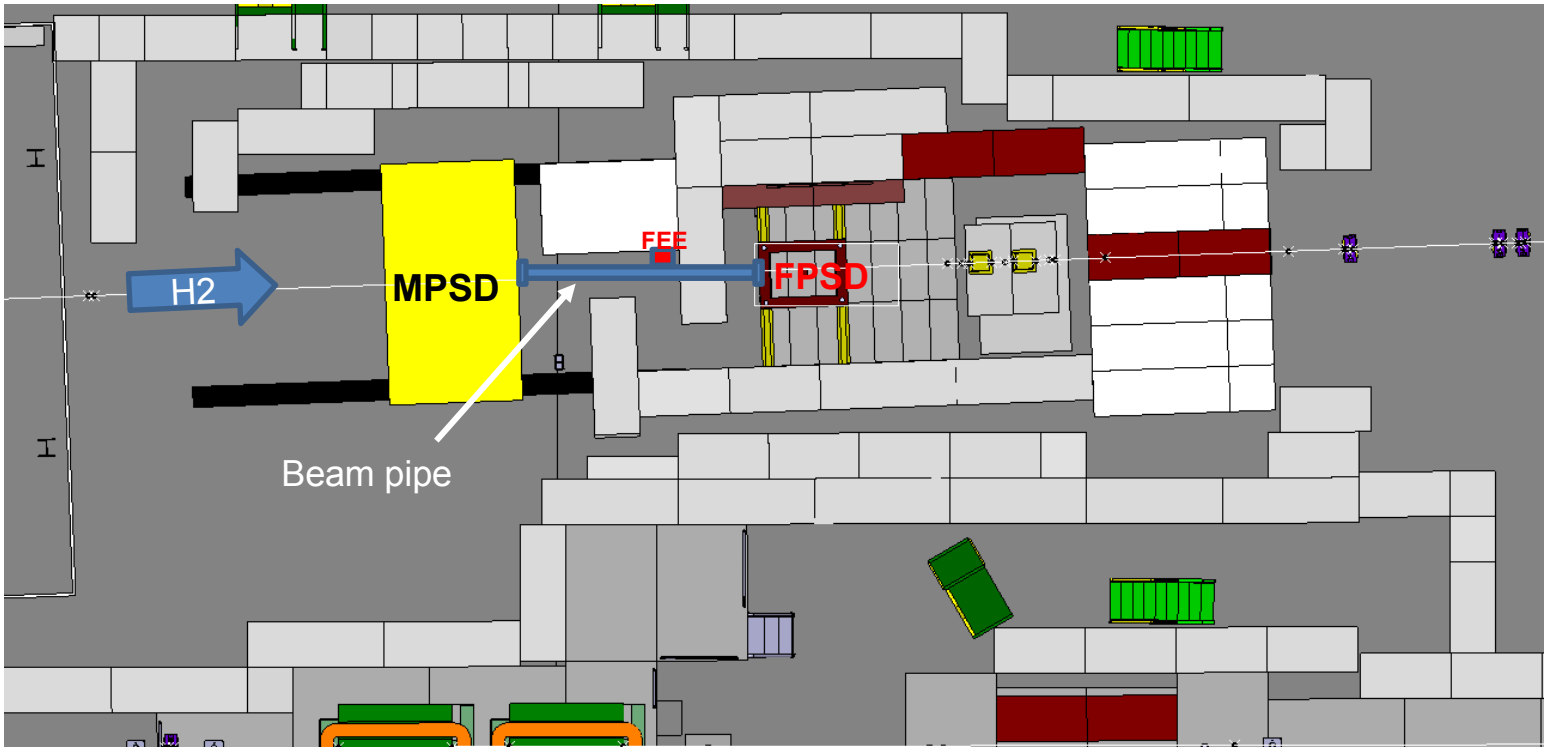
- new fast Hamamatsu MPPCs in all modules – no more saturation effect due to long pixel recovery time

FEE for FPSD (based on developments for CBM experiment)

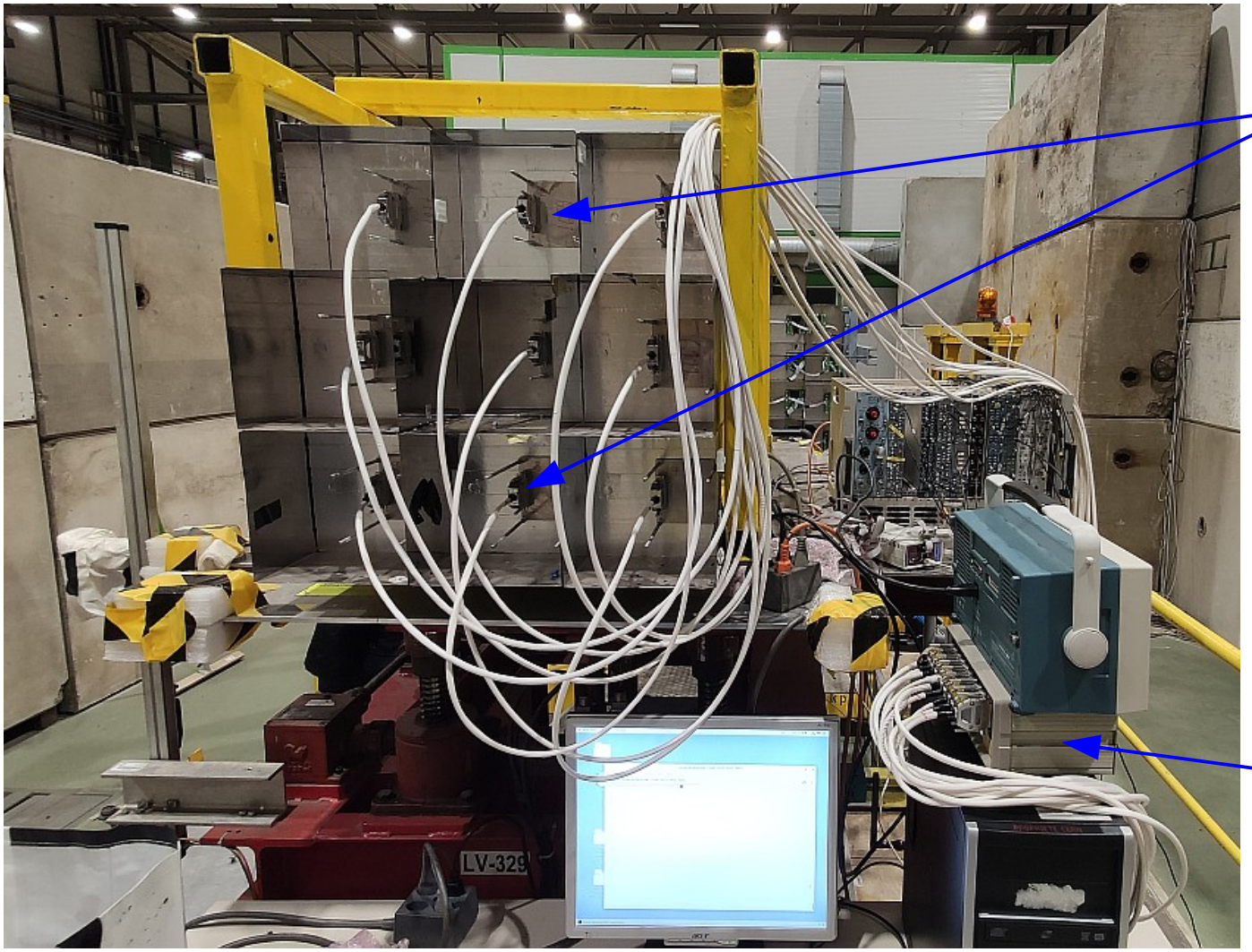




FPSD shielding structure



FPSD radiation safe FEE and slow control has been installed



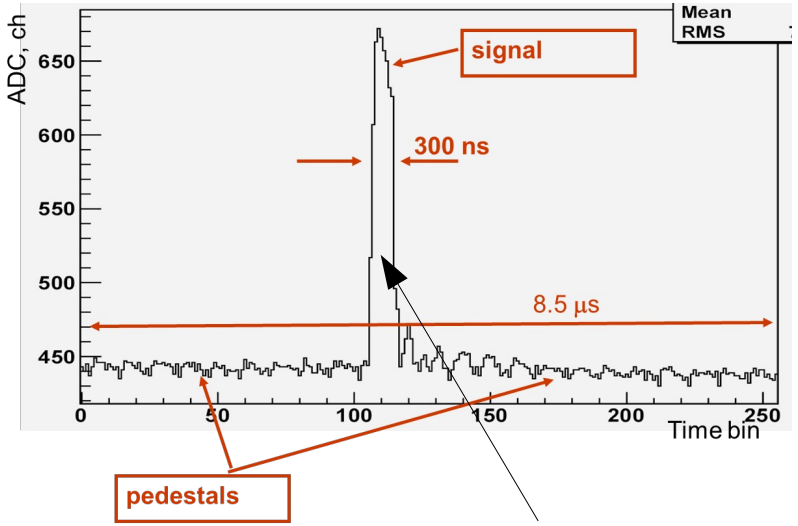
PCB with MPPCs

slow control
HV control box
with 9 boards

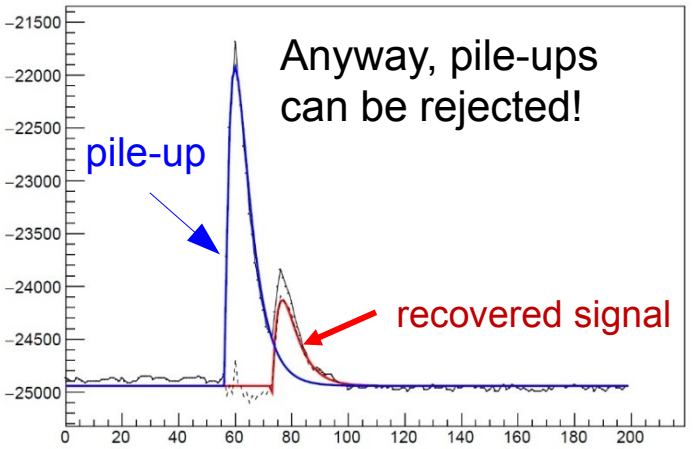
FPSD + MPSD on NA61/SHINE beam line

New DRS4 read-out system for MPSD + FPSD

Old PSD: shape of digitized signal (after integrator).



DRS4 signal is ~ order shorter.
No problem with pile-ups!

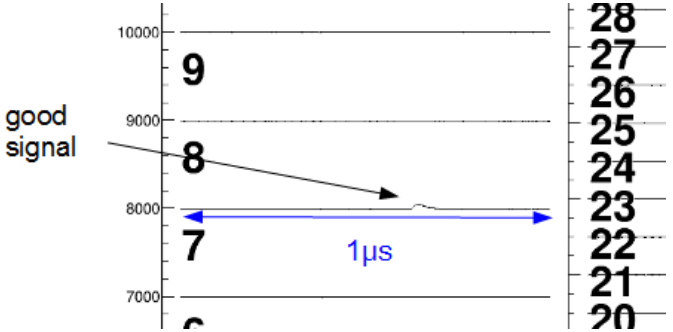


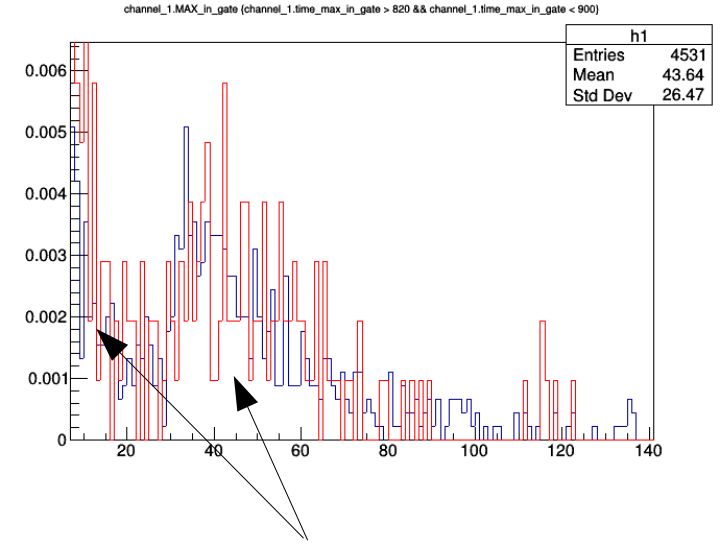
possible pile-ups are inside

DRS4 board time window:

~200 ns, ~500ns or ~1000ns
(with clock set)

FPSD with DRS4 boards at cosmic tests in November 2019

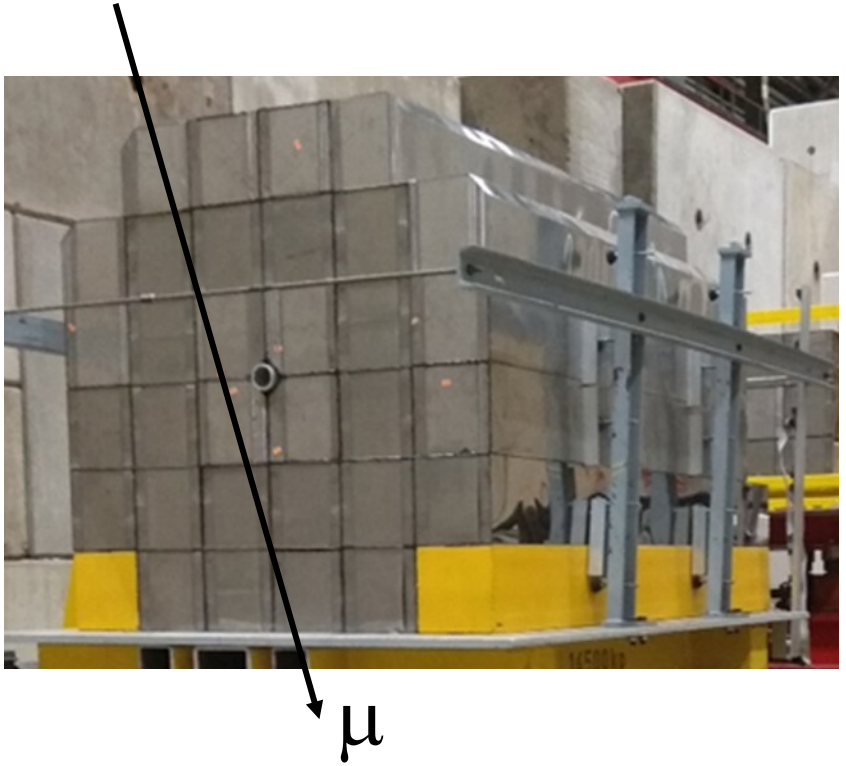


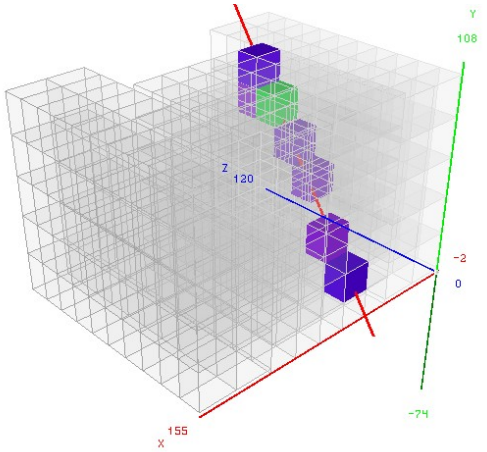


good signal/noise ratio

..cosmic data on upgraded PSD has been taken

New approach for PSD calibration with cosmic muons





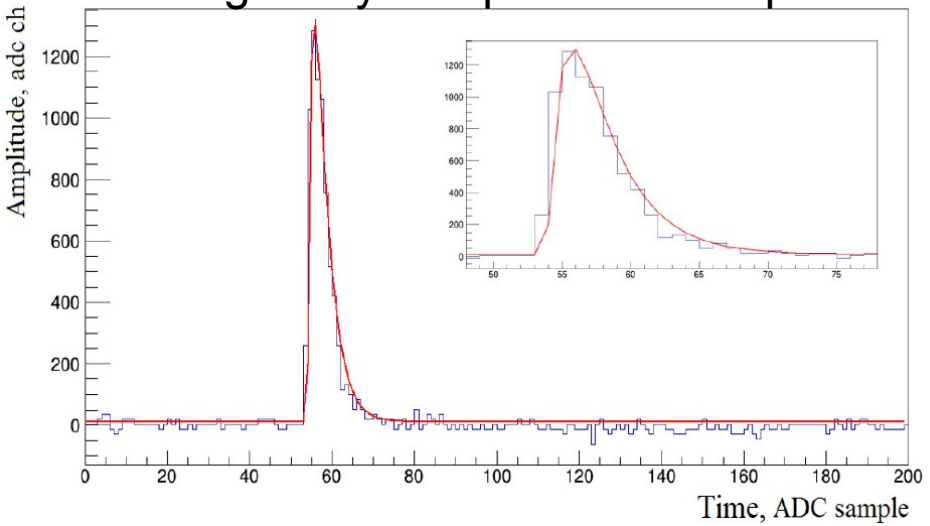
example of 3D muon track reconstruction

- Amplitudes of muon signals are comparable with electronic noise.
- The procedure of muon signal evaluation has been developed.
- The correction for pass length in scintillators is applied.

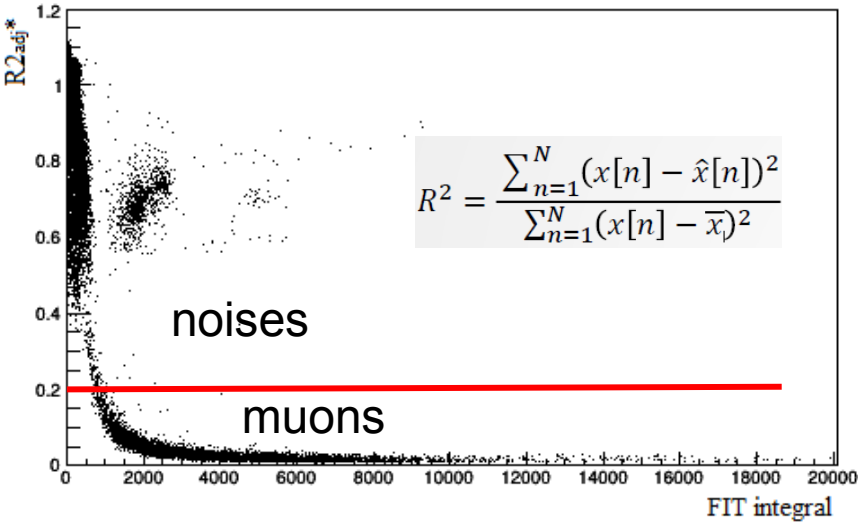
Published in: S. Morozov et al 2020 JINST 15 C05050

New approach for PSD calibration with cosmic muons

1. Fit signal by composition of exponents.

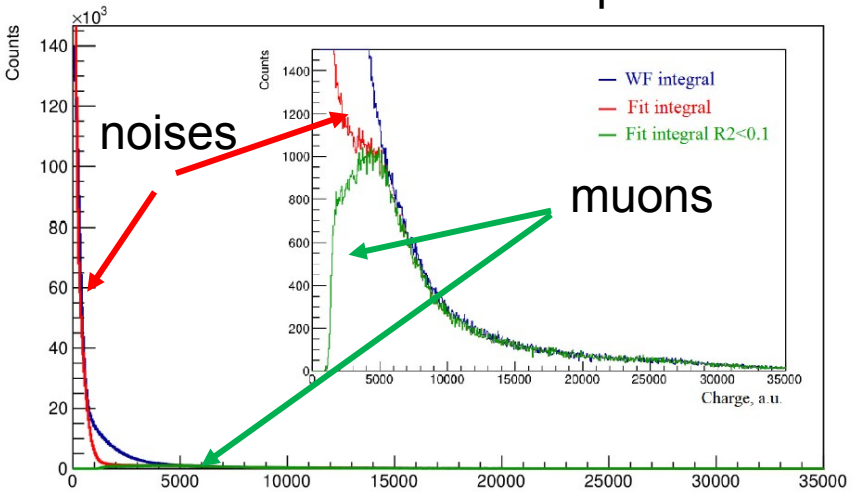


2. Rejection of noises with fit quality par.

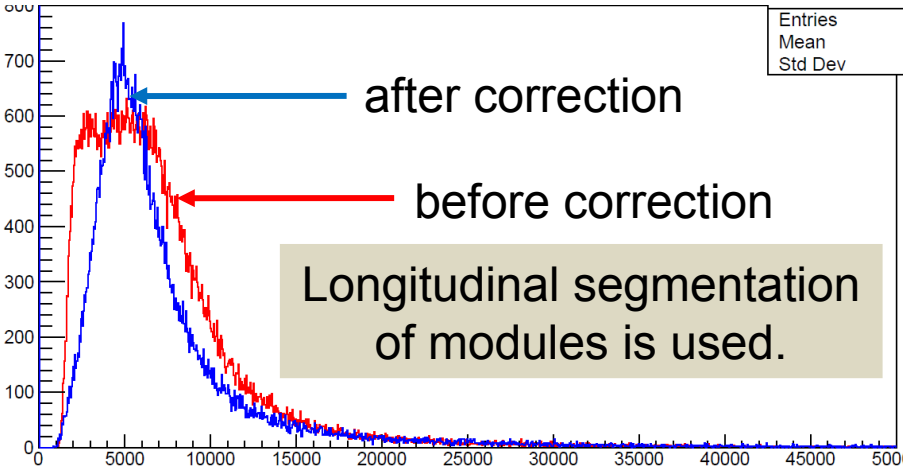


$$R^2 = \frac{\sum_{n=1}^{N}(x[n] - \hat{x}[n])^2}{\sum_{n=1}^{N}(x[n] - \overline{x_i})^2}$$

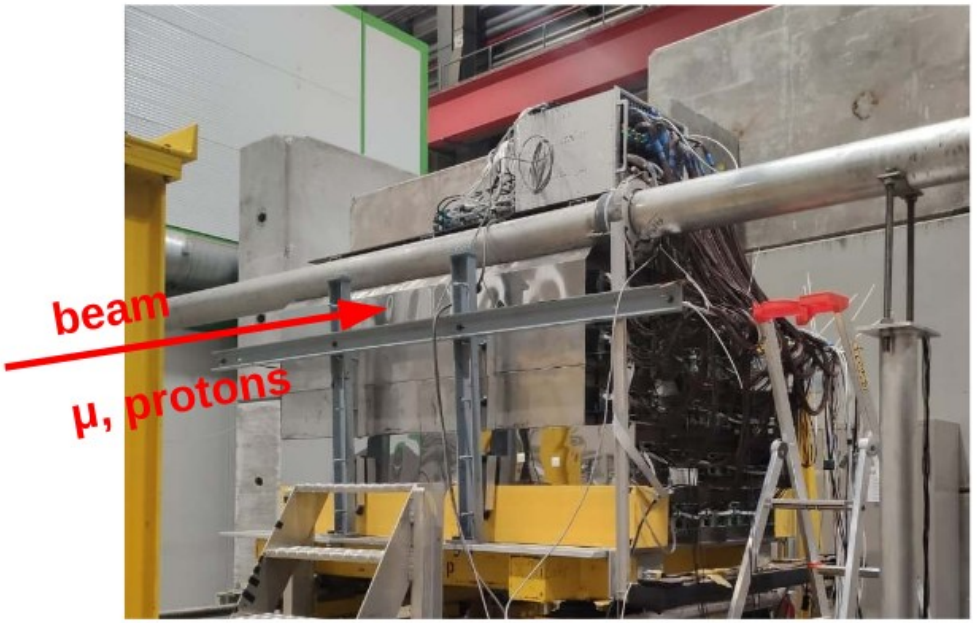
3. Extraction of muon spectrum

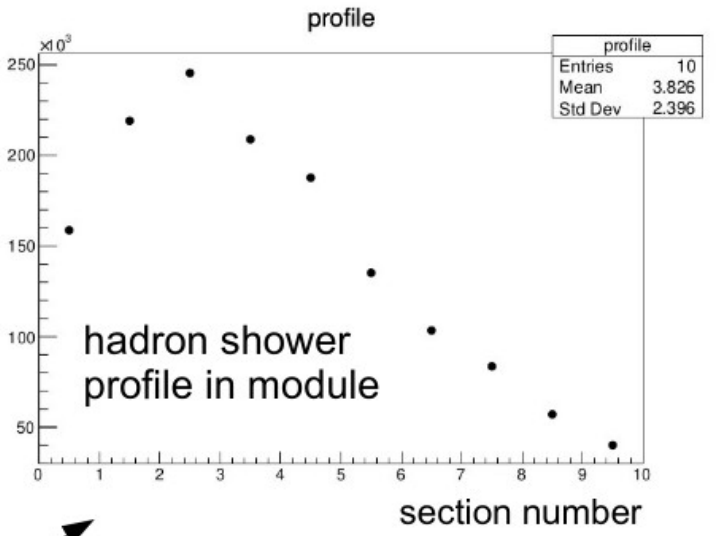


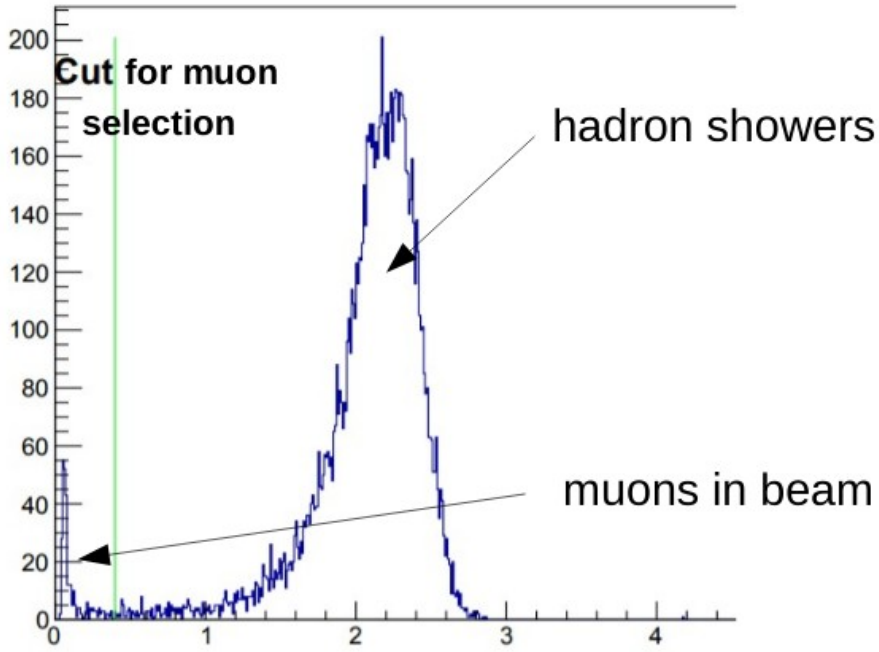
4. Correction for pass length in scintillators.

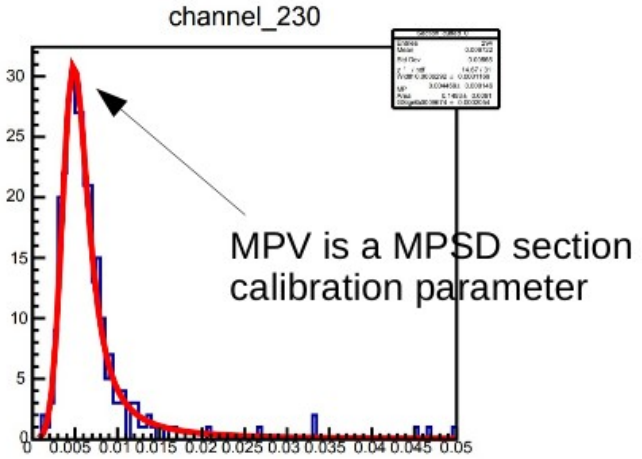


MPSD module scan, p 158GeV/c, 2021









The muon spectrum in one MPSD section with Landau+Gauss convoluted fit

Conclusions:

- forward hadron calorimeters (PSD) are widely used in many heavy ion experiments

- new challenging conditions (high beam rate) will require PSD upgrade

- NA61/SHINE PSD detector has been updated with MPSD+FPSD calorimeter system

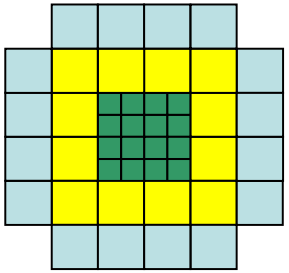
- cosmic muon calibration procedure has been developed for current and future segmented hadron calorimeters

Thank you for your attention!

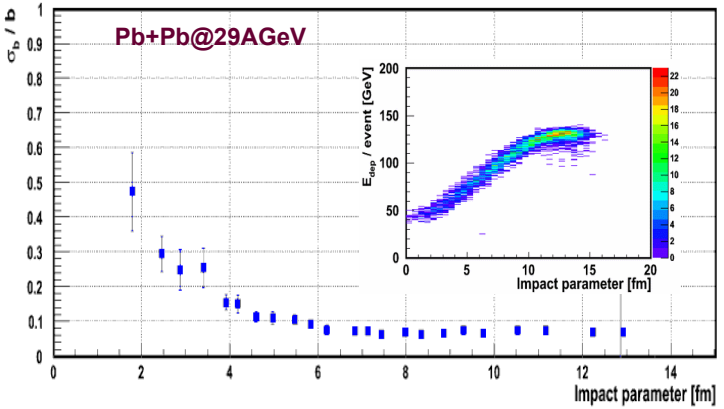
Backup slides

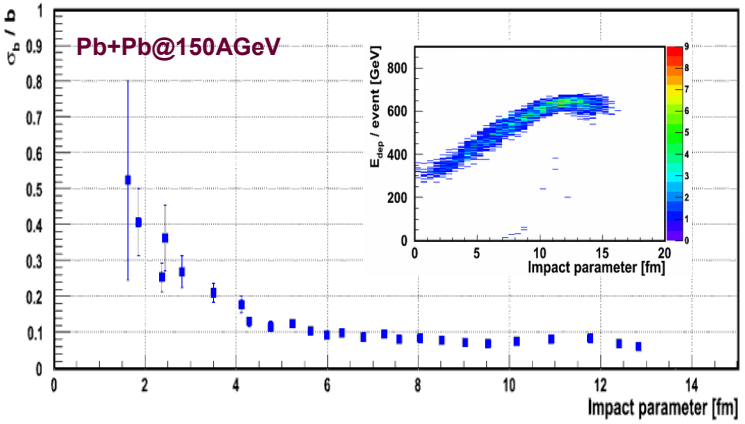
Centrality determination with PSD schematics:

old NA61/SHINE PSD

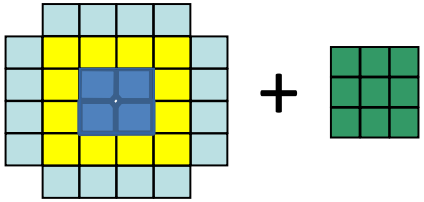


simulated impact parameter resolution

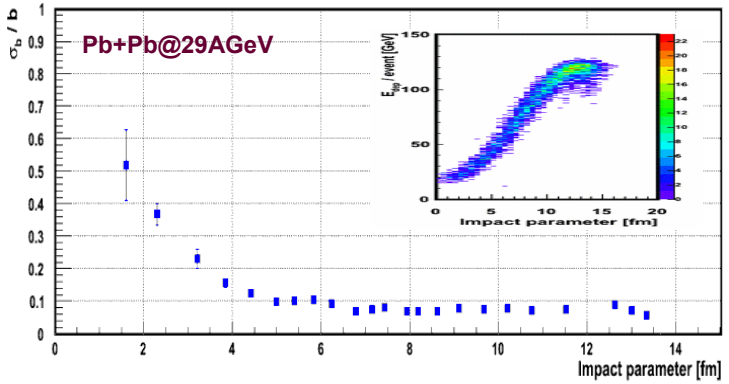


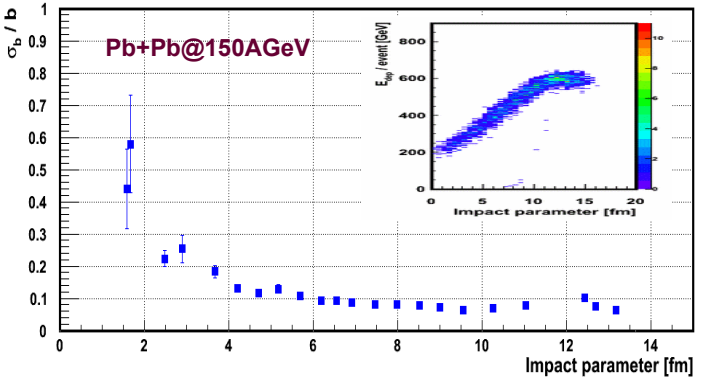


New MPSD+FPSD

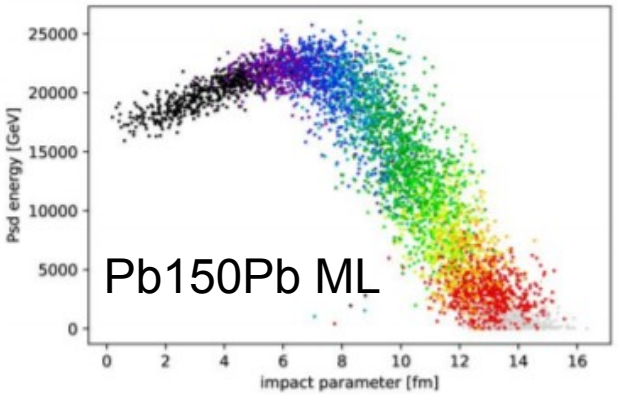


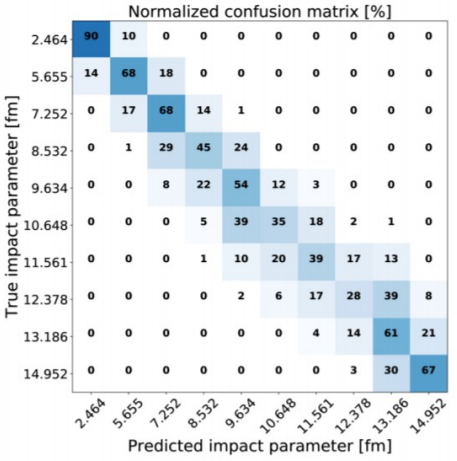
simulated impact parameter resolution

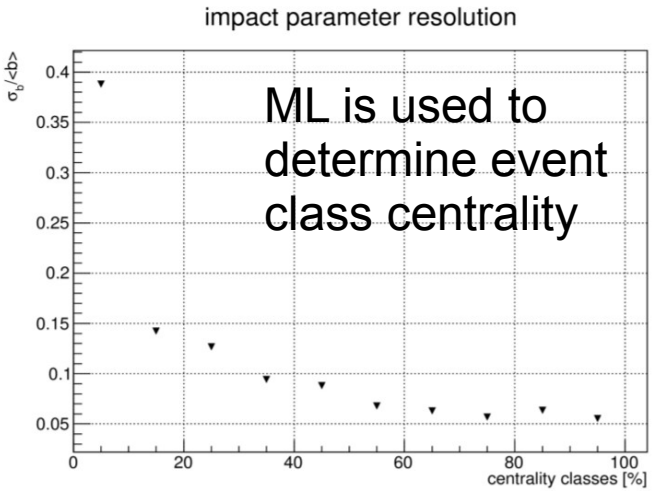




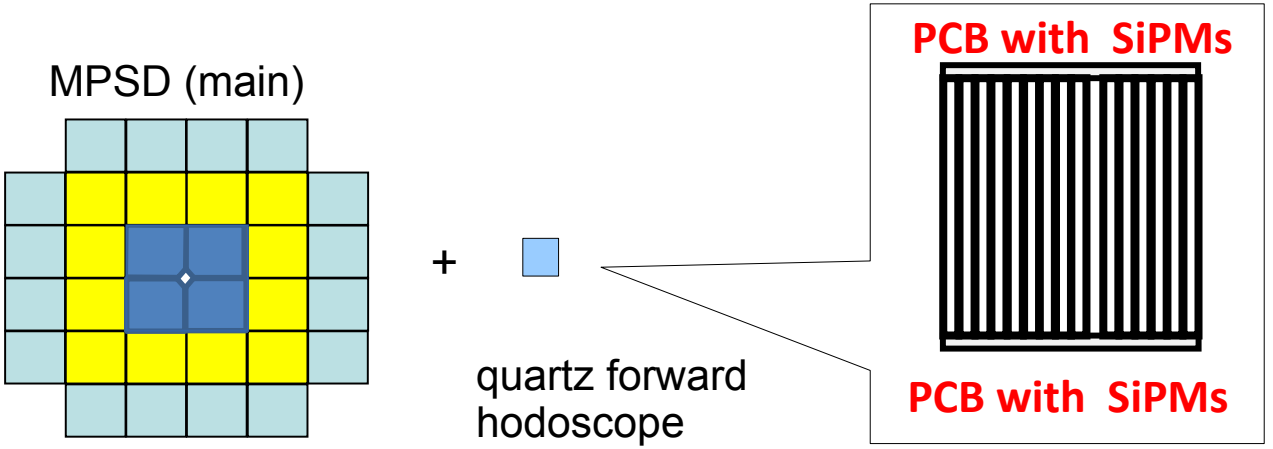
New approach with Machine Learning technique for event selection with MPSD only







..and an alternative to the FPSD to help with event centrality estimation



Quartz forward hodoscope is under development at INR (planned to be used with BM@N and CBM calorimeters)