Transverse and longitudinal segmented forward hadron calorimeters with SiPMs light readout for future fixed target heavy ion experiments

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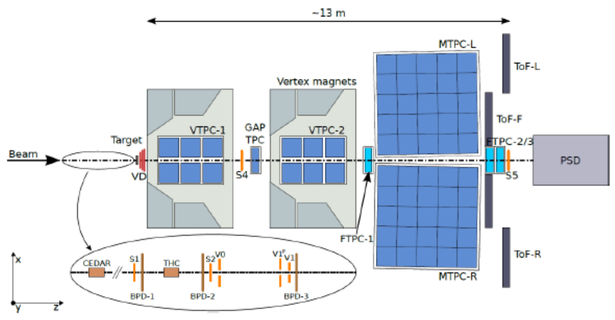
for the CBM, BM@N and NA61 collaborations

Forward hadron calorimeters with transverse and longitudinal segmentation are developed for upgraded heavy ion NA61 and BM@N experiments and future CBM experiment at FAIR. The main purpose of these calorimeters is to provide an experimental event-by-event measurements of centrality and orientation of reaction plane in heavy-ion collisions at high beam rates. Hadron calorimeters in all these experiments are composed of sampling lead/scintillator modules. The light collection in modules is provided by WLS fibers and SiPMs are used for light detection.

NA61@SPS

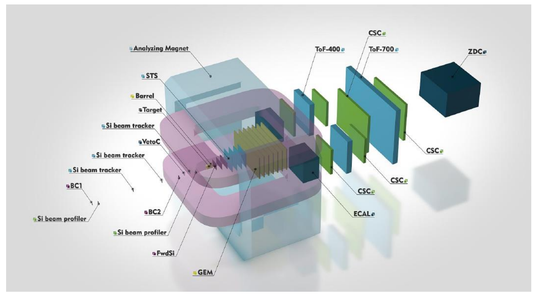
Start of operation after upgrade - 2021



E_{Pb} – 30, 150 AGeV
Beam rate – 10^6 per spill (8 sec)
1.5% Pb target

BM@N

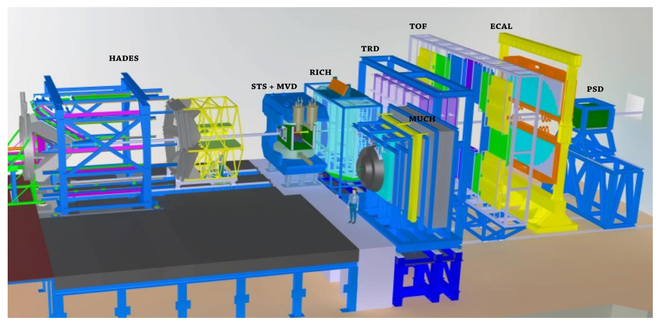
Start of operation after upgrade - 2020



E_{Au} – 2 – 4.5 AGeV
Beam rate – $2x10^6$ per second
1% targets (C – Au)

CBM@FAIR

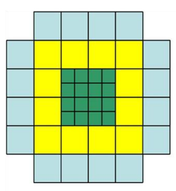
Start of experiments at FAIR - 2024

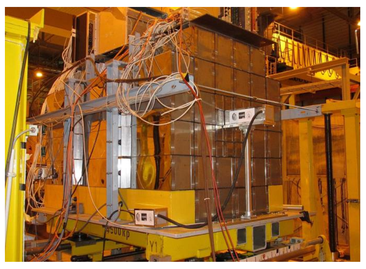


E_{Au} – 2 – 11 AGeV
Beam rate – 10^8 per second
1% targets (C – Au)

Structure of modules light and signal readouts

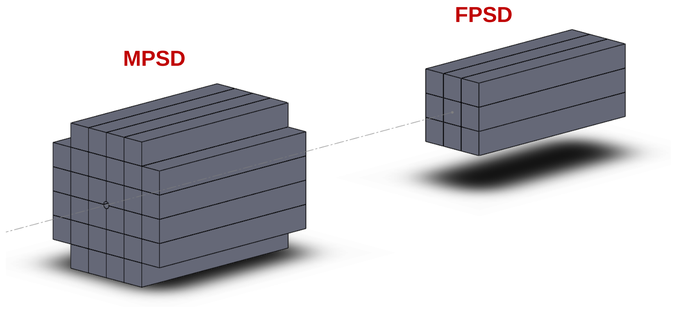
Present PSD NA61





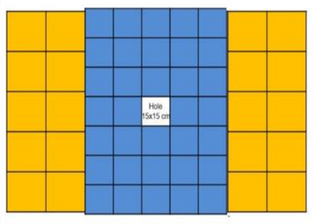
PSD NA61 – 16 inner modules (10x10cm, 5.6 λ_{int})
- 28 outer modules (20x20cm, 5.6 λ_{int})
- 1 small module (10x10cm, 1.2 λ_{int})

Upgraded PSD NA61



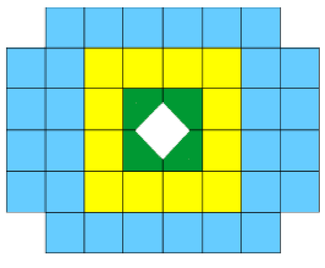
Main PSD (MPSD) – 44 modules (20x20cm, 5.6 λ_{int}) with beam hole In the center (⌀ 60mm).
Forward PSD (FPSD) – 9 modules (20x20cm, 5.6 λ_{int}) w/o beam hole.

FHCAL BM@N



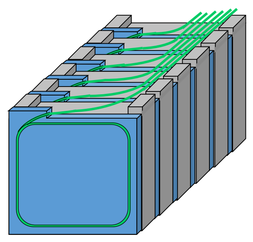
34 inner modules 15x15 cm^2, 4 λ_{int}
20 outer modules 20x20 cm^2, 5.6 λ_{int}
Beam hole (15x15 cm^2) .
Total weight – 17t.

PSD CBM



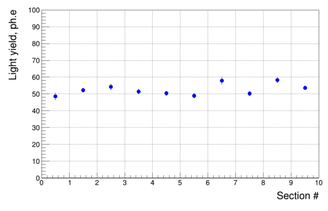
44 modules, 200x200mm^2
Beam hole (20 x 20 cm^2).
Total weight – 22t.

Structure of modules light and signal readouts



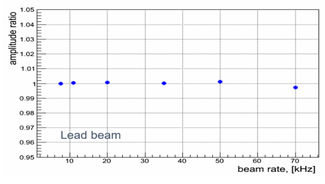
- Module transverse size 200x200 mm^2
- Total length 5.6 λ_{int}.
- Weight of each module 500 kg.

- Longitudinal structure of module: 60 Pb/scint. samples - (Pb(16mm), Scint(4mm)
- Light collections – by WLS fibers from 6 sequentially scunt. tiles (one section) to one optical connector at the end of module.
- Light readout: 10 MPPC (3x3 mm^2) per module.



Light yield for MIPs in module sections.

Hamamatsu S12572-010P,
Sensitive area 3 x 3 mm^2
Number of pixels 90 000
nominal gain 1 x 10^5,
Pixel recovery time - 10 ns
PDE -12%



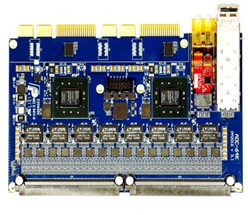
Relative MPPC amplitude vs.Pb beam rate.

Readout electronics

BM@N
Fast sampling ADC64.
Trigger rate – 50 kHz.

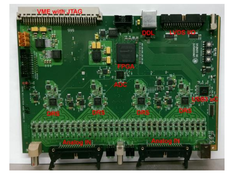
64 readout channels,
12 bit ADCs
Analog sample rate 62.5MS/s,

CBM
Fast sampling PANDA ADC.
Free streaming DAQ.



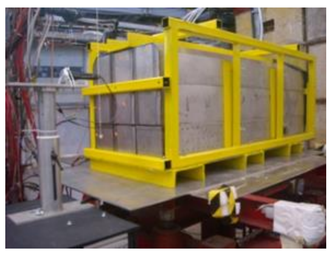
64 readout channels,
14 bit ADC,
Analog sample rate125 MS/s.

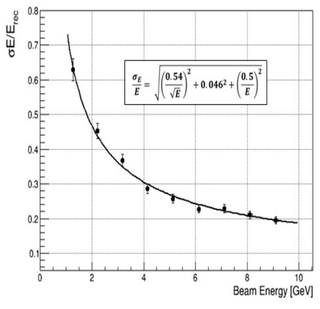
NA61
Fast sampling DRS4.
Trigger rate – 1 kHz.

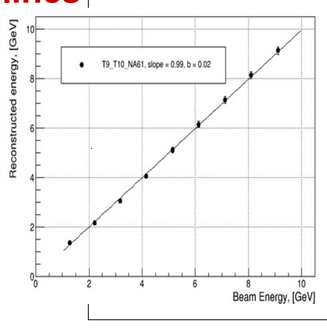


32 readout channels,
14 bit ADC,
Analog sample rate up to 5 GS/s.

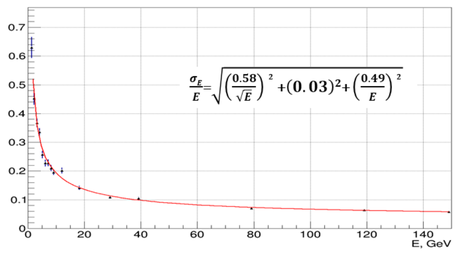
Results of PSD CBM supermodule tests at CERN T9/T10 beam lines

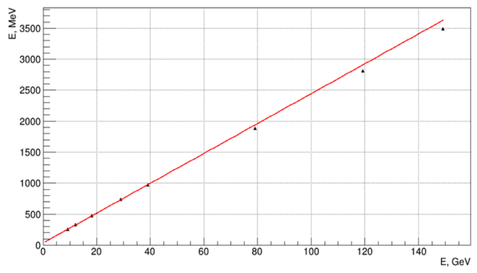






Results of PSD CBM supermodule tests at CERN T9/T10 and NA61 beam lines





Energy resolution of present PSD NA61 measured at proton beam 20 -150 GeV

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

Radiation hardness studies (FLUKA simulation results)

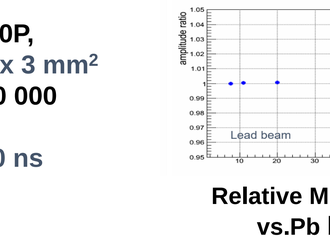
PSD NA61
Pb, 150 AGeV
$2.5x10^4$ Pb/sec

PSD CBM
Au, 10AGeV
10^8 Au/sec

FHCal BM@N
Au, 4 AGeV
$2x10^6$ Au/sec

Dose distribution in calorimeters.

Neutron fluences distribution in MPPCs positions.



To solve the problem of large dose in central FPSD module it is proposed to do holes in centers of all 60 scint. plates of central FPSD module.

Comparison of dose distribution in scintillator plate at second section of FPSD without beam hole in scint. center and with holes with diameters 20 and 40 mm.

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