

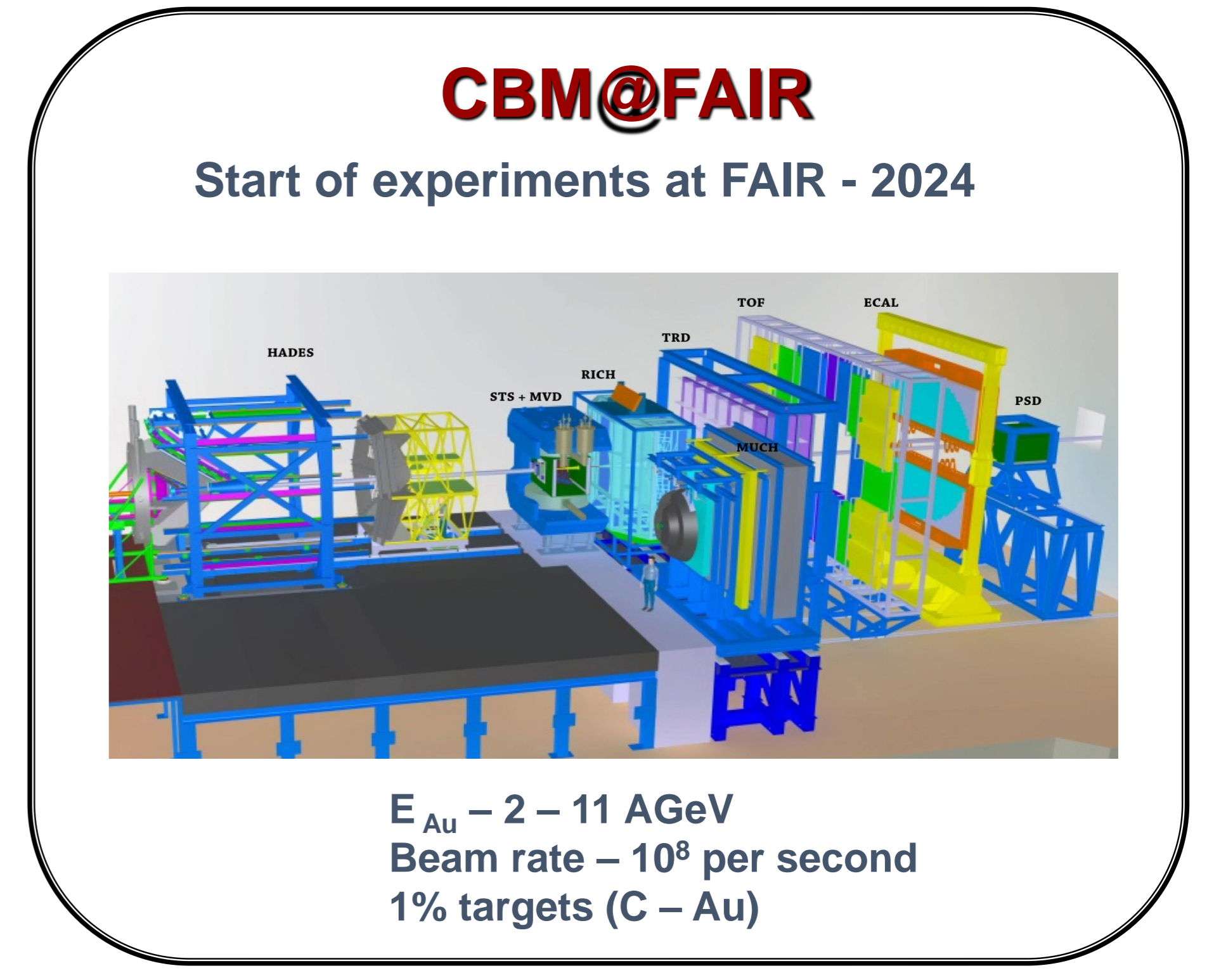
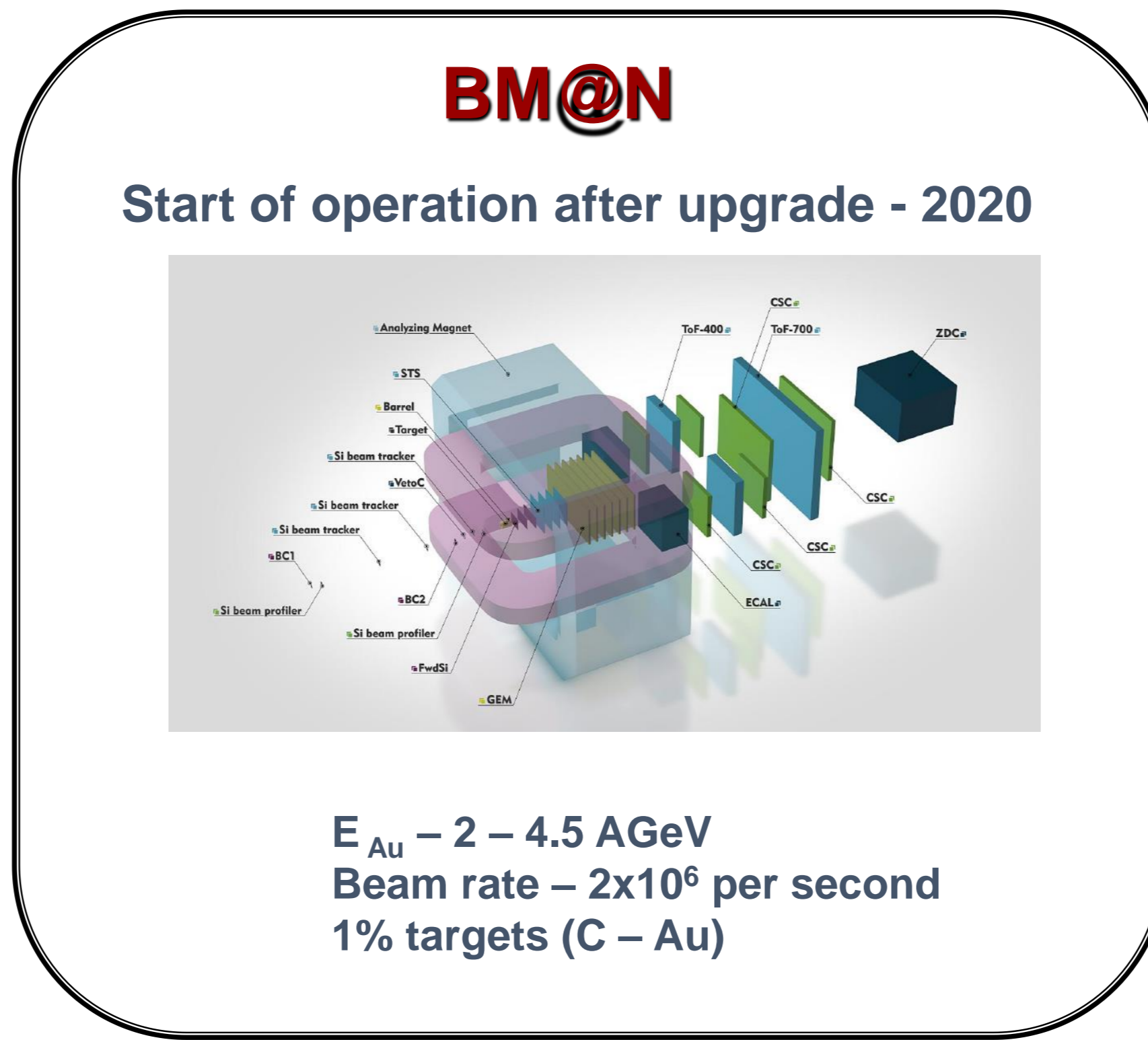
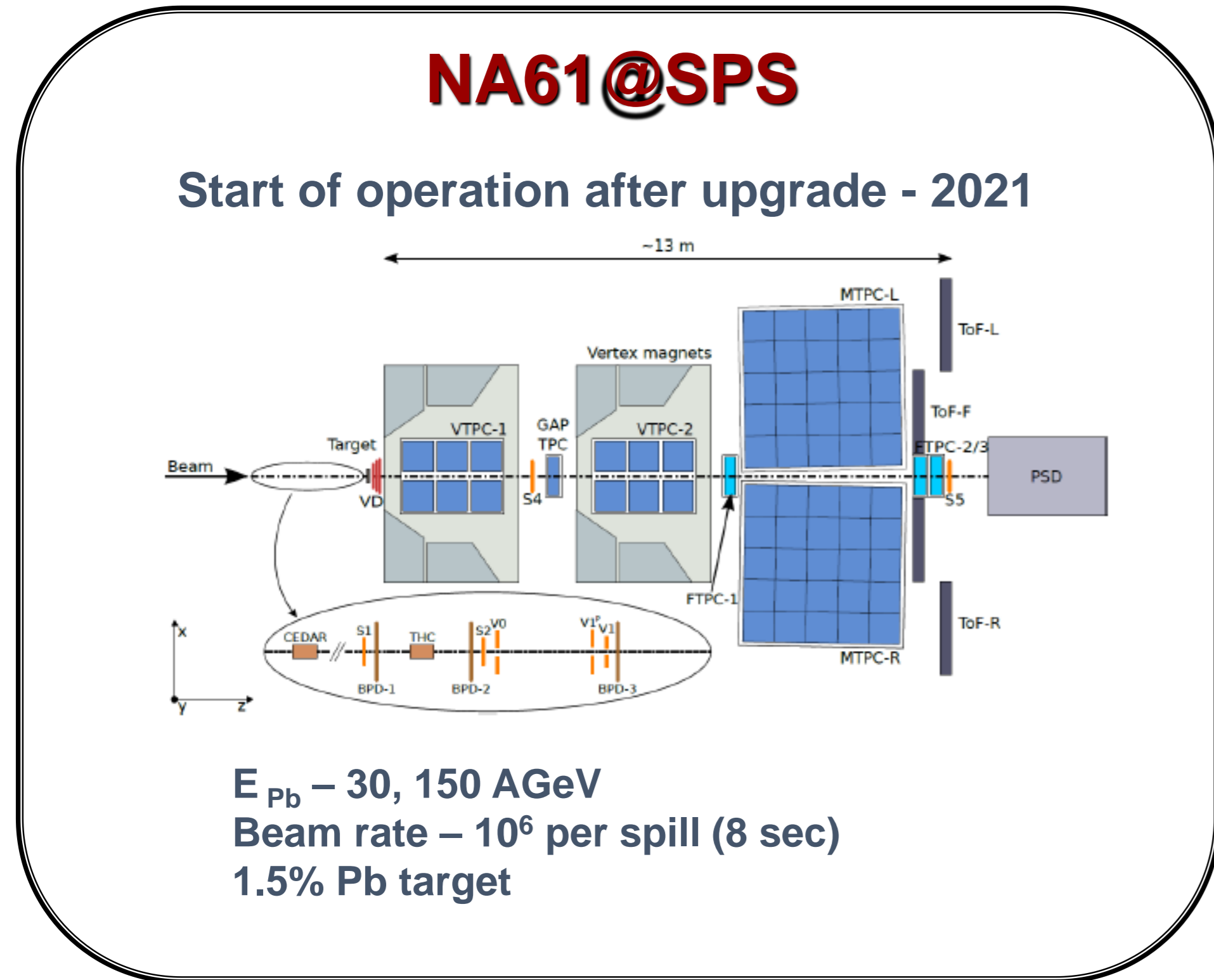


# Transverse and longitudinal segmented forward hadron calorimeters with SiPMs light readout for future fixed target heavy ion experiments



Fedor Guber, INR RAS, Moscow,  
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.



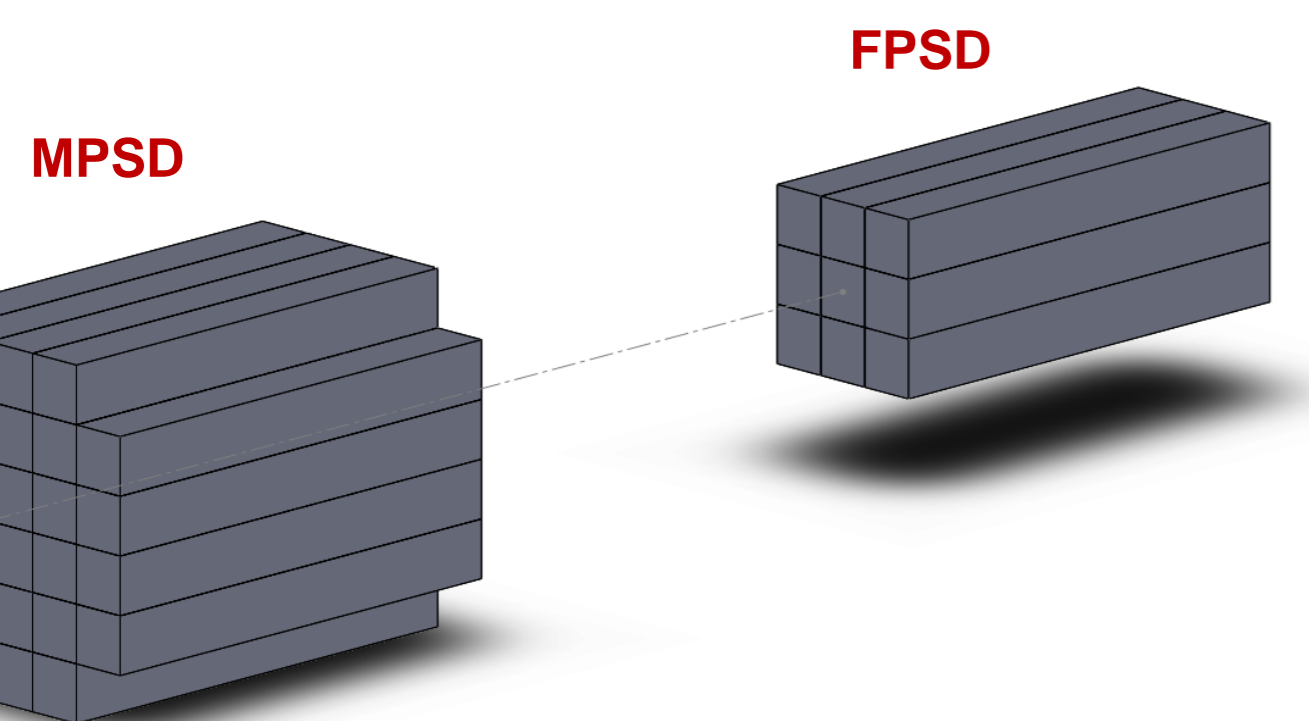
## Structure of modules light and signal readouts

### Present PSD NA61



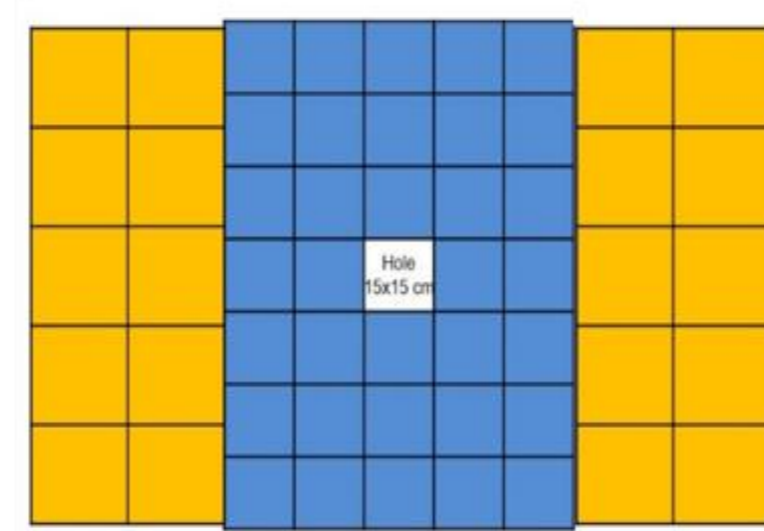
PSD NA61 - 16 inner modules ( $10 \times 10 \text{ cm}$ ,  $5.6 \lambda_{int}$ )  
- 28 outer modules ( $20 \times 20 \text{ cm}$ ,  $5.6 \lambda_{int}$ )  
- 1 small module ( $10 \times 10 \text{ cm}$ ,  $1.2 \lambda_{int}$ )

### Upgraded PSD NA61



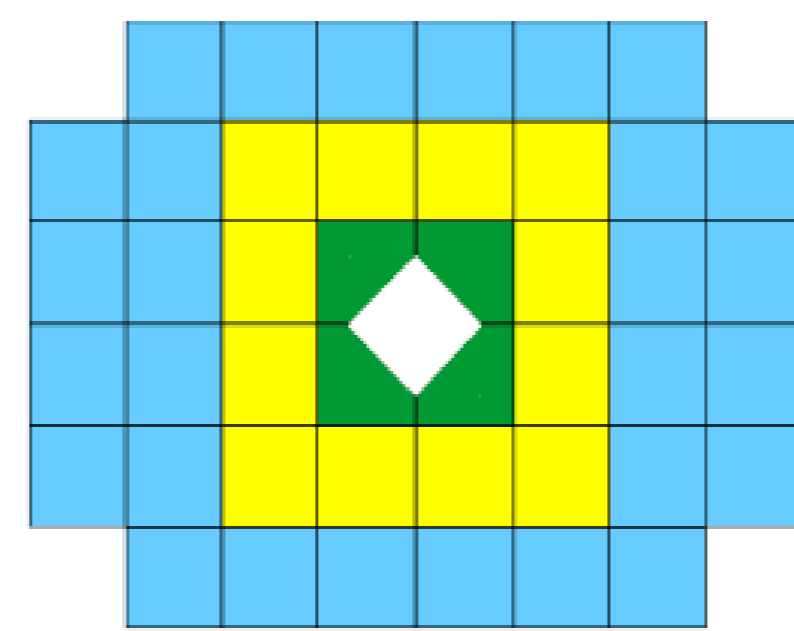
Main PSD (MPSD) - 44 modules ( $20 \times 20 \text{ cm}$ ,  $5.6 \lambda_{int}$ ) with beam hole in the center ( $\varnothing 60 \text{ mm}$ ).  
Forward PSD (FPSD) - 9 modules ( $20 \times 20 \text{ cm}$ ,  $5.6 \lambda_{int}$ ) w/o beam hole.

### FHCAL BM@N



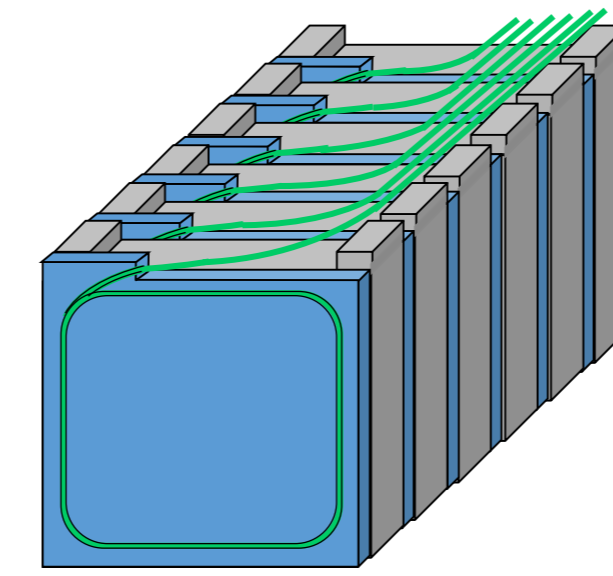
34 inner modules  $15 \times 15 \text{ cm}^2$ ,  $4 \lambda_{int}$   
20 outer modules  $20 \times 20 \text{ cm}^2$ ,  $5.6 \lambda_{int}$   
Beam hole ( $15 \times 15 \text{ cm}^2$ ).  
Total weight - 17t.

### PSD CBM



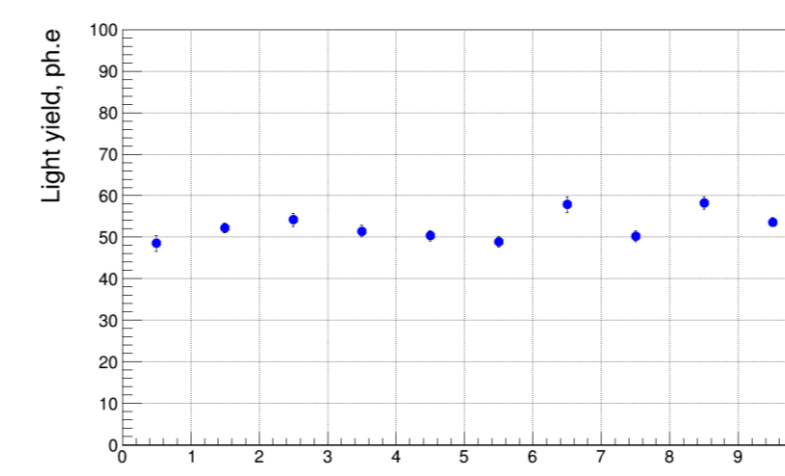
44 modules,  $200 \times 200 \text{ mm}^2$   
Beam hole ( $20 \times 20 \text{ cm}^2$ ).  
Total weight - 22t.

## Structure of modules light and signal readouts



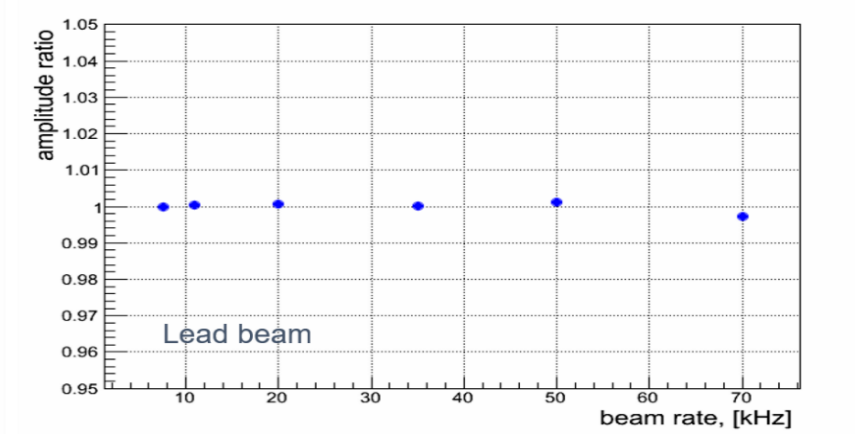
- Module transverse size  $200 \times 200 \text{ mm}^2$
- Total length  $5.6 \lambda_{int}$
- Weight of each module 500 kg.

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



Light yield for MIPs in module sections.

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



Relative MPPC amplitude vs. Pb beam rate.

### Readout electronics

BM@N  
Fast sampling ADC64.  
Trigger rate - 20 kHz.



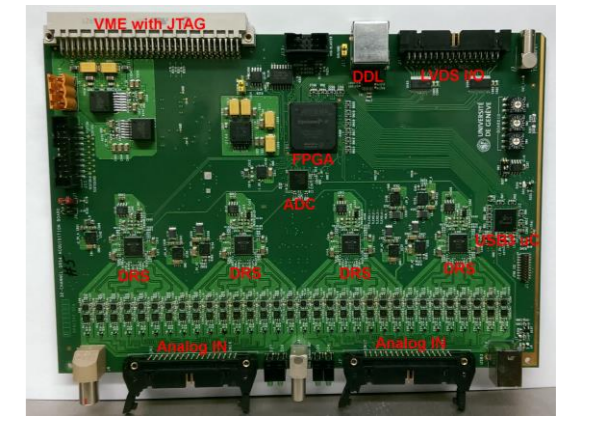
64 readout channels,  
12 bit ADCs  
Analog sample rate 62.5MS/s,

CBM  
Fast sampling PANDA ADC.  
Free streaming DAQ.



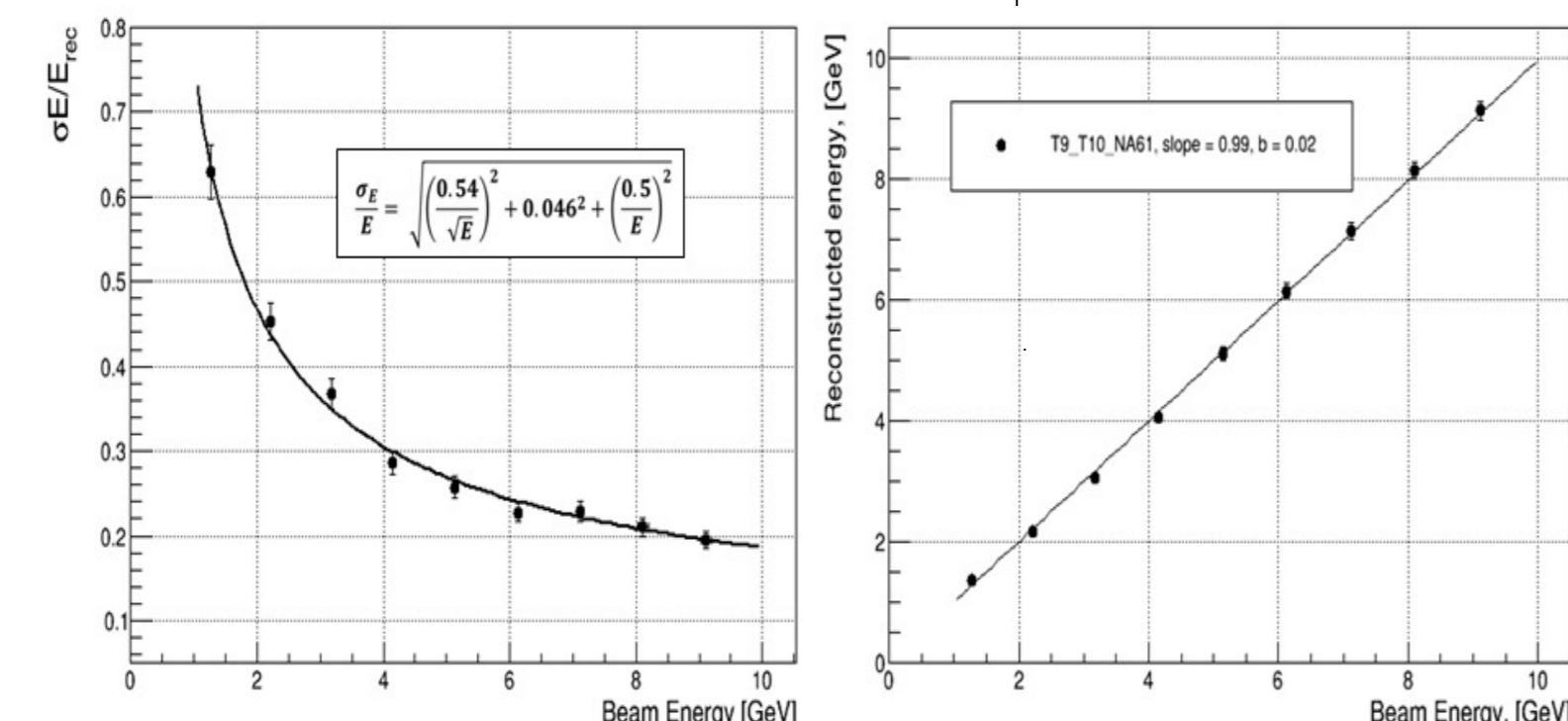
64 readout channels,  
14 bit ADC,  
Analog sample rate 125 MS/s.

NA61  
Fast sampling DRS4.  
Trigger rate - 1 kHz.

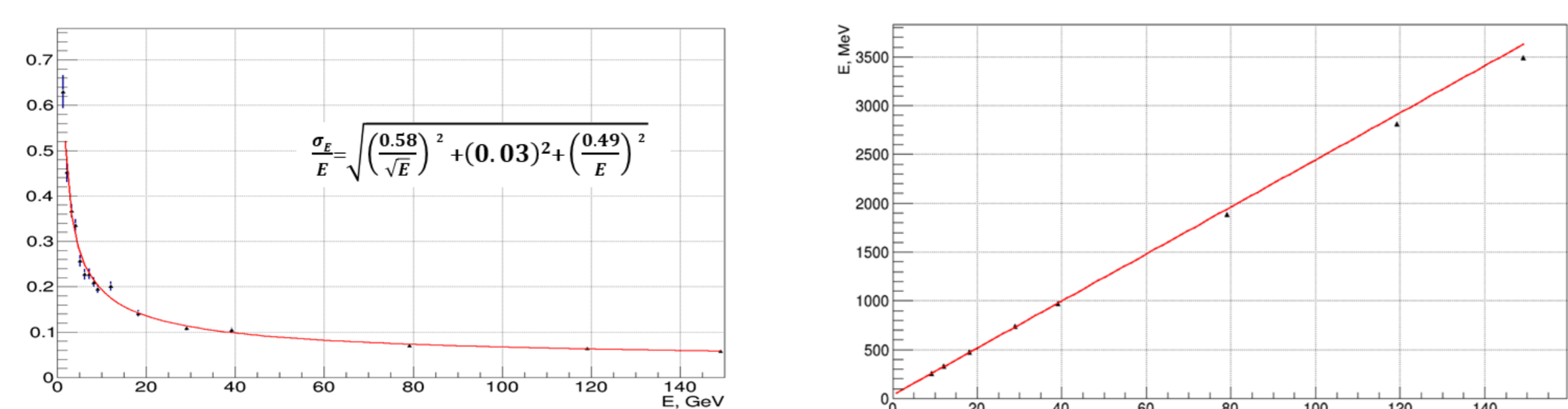


32 readout channels,  
14 bit ADC,  
Analog sample rate up to 5 GS/s.

## 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

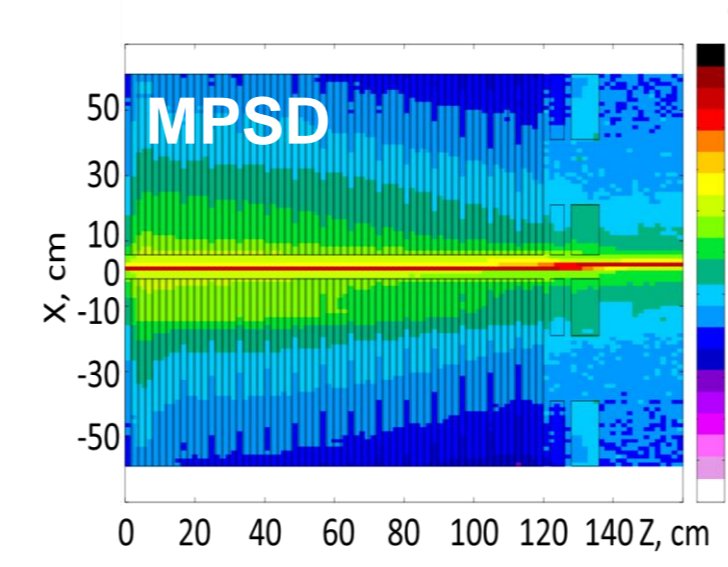


Energy resolution of present PSD NA61 measured at proton beam 20 -150 GeV

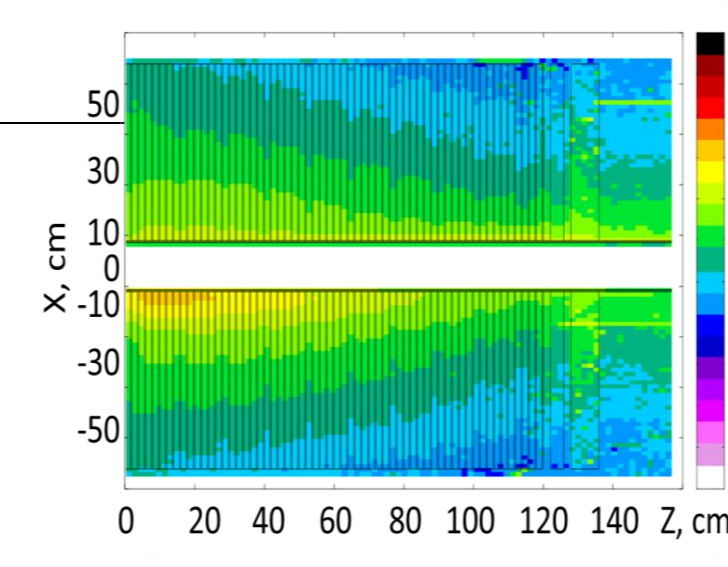
$$\frac{\sigma_E}{E} = \sqrt{\left(\frac{0.66}{\sqrt{E}}\right)^2 + 0.042^2 + \left(\frac{2.7}{E}\right)^2}$$

## Radiation hardness studies (FLUKA simulation results)

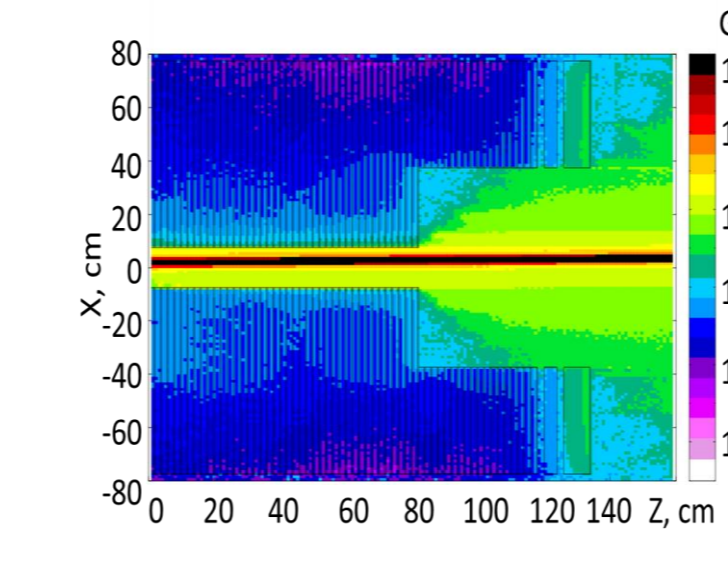
PSD NA61  
Pb, 150 AGeV  
 $2.5 \times 10^4 \text{ Pb/sec}$



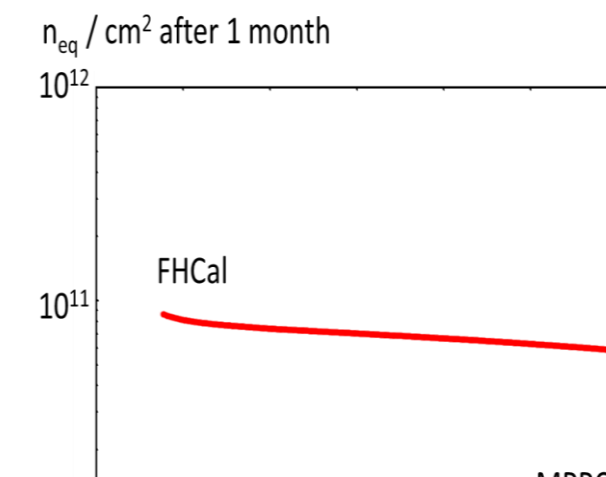
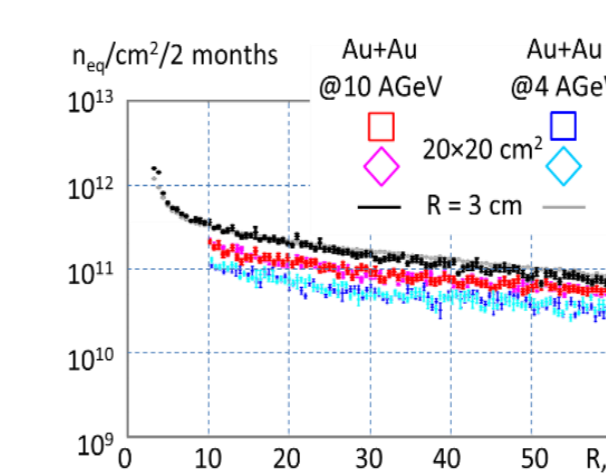
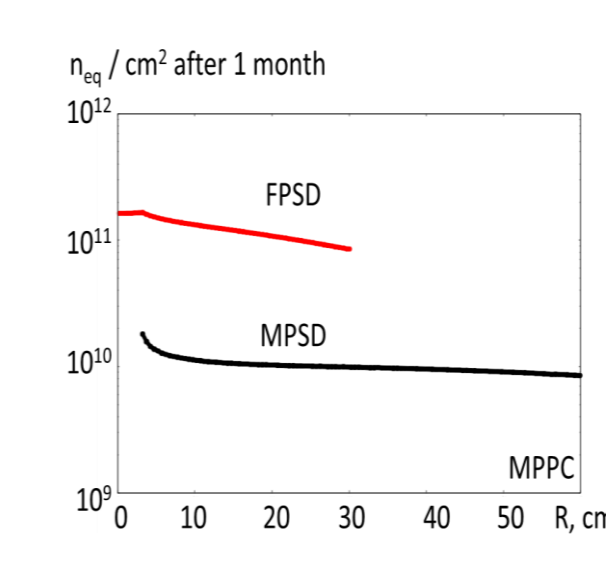
PSD CBM  
Au, 10 AGeV  
 $10^8 \text{ Au/sec}$



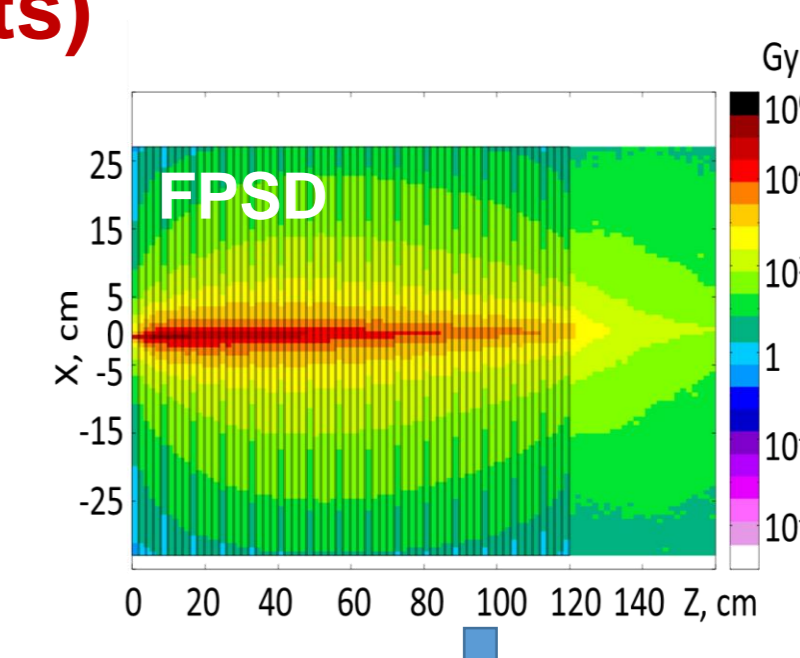
FHCAL BM@N  
Au, 4 AGeV  
 $2 \times 10^6 \text{ Au/sec}$



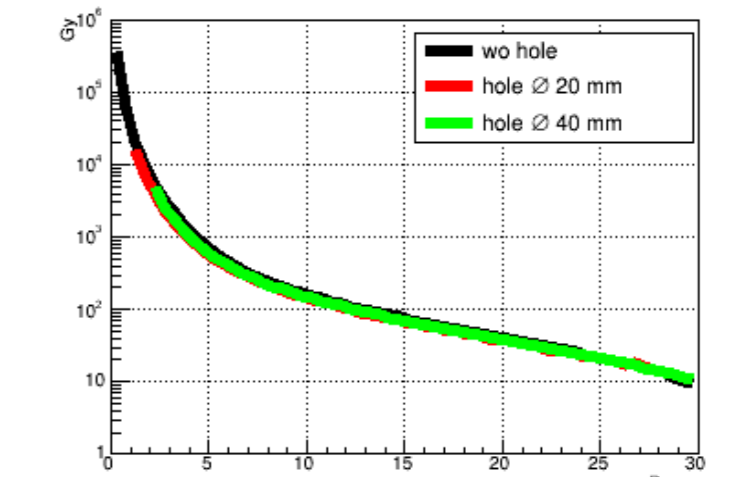
Dose distribution in calorimeters.



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.