Radiation tolerance of microstrip sensors for the CBM Silicon Tracking System

Ie. Momot [1,3] H. Malygina [1,3] J. Heuser [2] for CBM collaboration

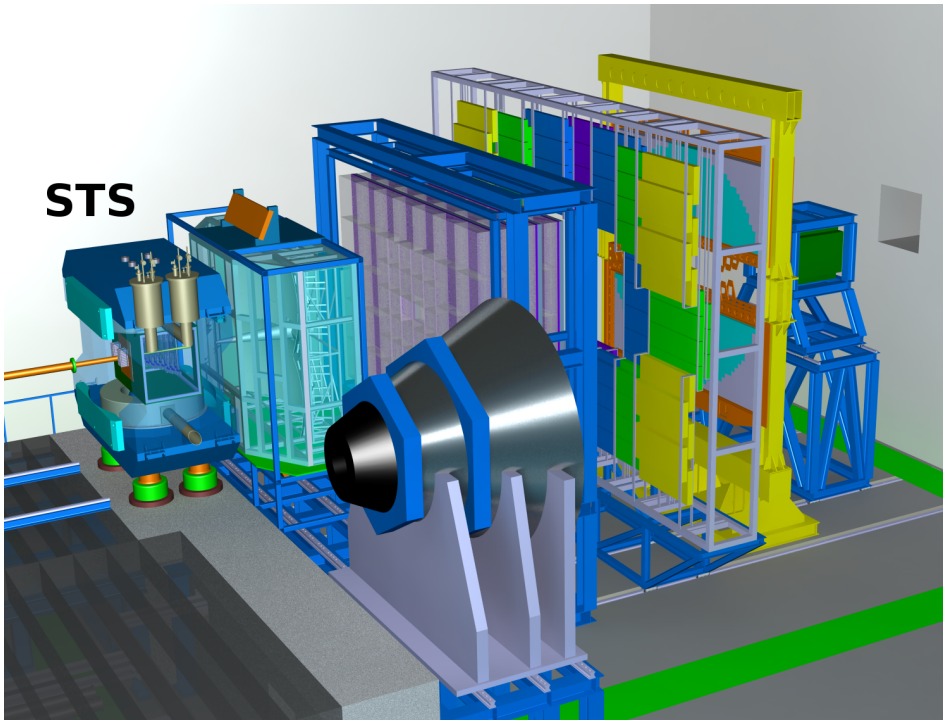
[1] Goethe University, Frankfurt, Germany

[2] GSI, Darmstadt, Germany

[3] KINR, Kyiv, Ukraine

DPG 2016
Darmstadt
15.03.2016

The CBM experiment [Fri, 14:00, HK 66.1 D.Emschermann]



Goal:
To study the QCD phase diagram at high net baryon densities and moderate temperatures

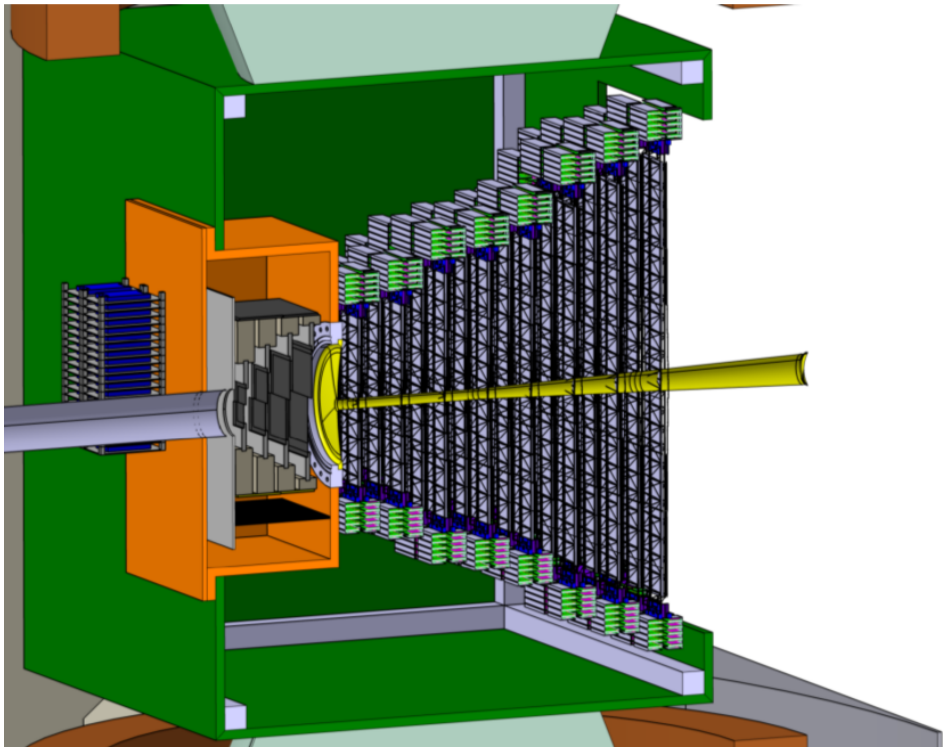
SIS100 collision energies 2÷11 A GeV

Physics observables:

- Differential cross-sections
- Rare diagnostic probes
  - Strange mesons
  - Light vector mesons (ρ, ϖ, φ)

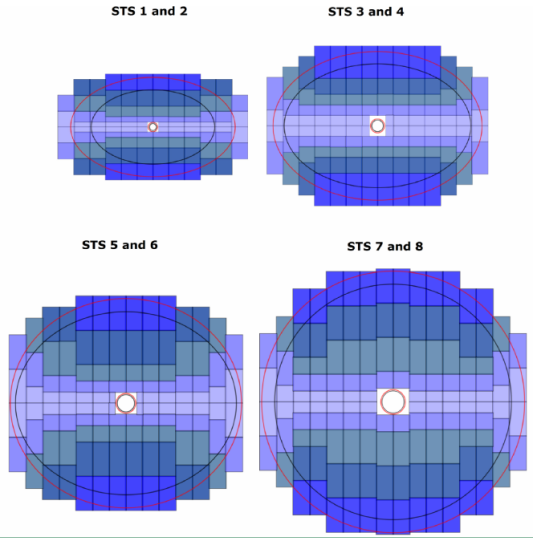
STS layout

[Mon, 16:30, HK 15.1, A.Lymanets]



- Momentum resolution $\Delta p/p \sim 1\%$
- Hit spatial resolution ~ 25 μm
- Material budget $\sim 1\%$ X_0/station

- 8 tracking stations
- double-sided sensors, p-n-n structure
- sensor sizes 6×2, 6×4, 6×6, 6×12 cm^2
- 1024 strips per side (58 μm pitch)
- stereo angle front-back sides 7.5 deg
- radiation tolerance up to 1×10^{14} 1 MeV n_{eq}/cm^2
- S/N >10 for the hit reconstruction efficiency $\sim$ 98%



Motivation

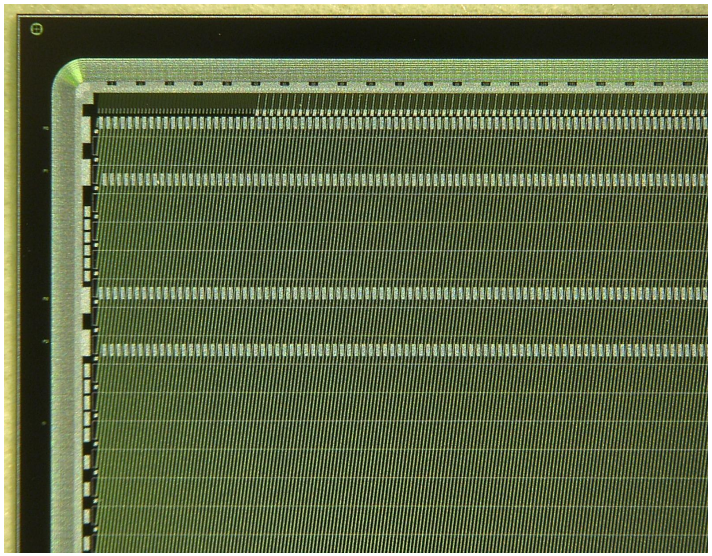
Double metalization (DM) each strip is connected to its partner on the opposite end with a second metal layer

Interstrip cables on the top of the sensor (SMwC) routing lines are made by the microcables on the top of the sensor

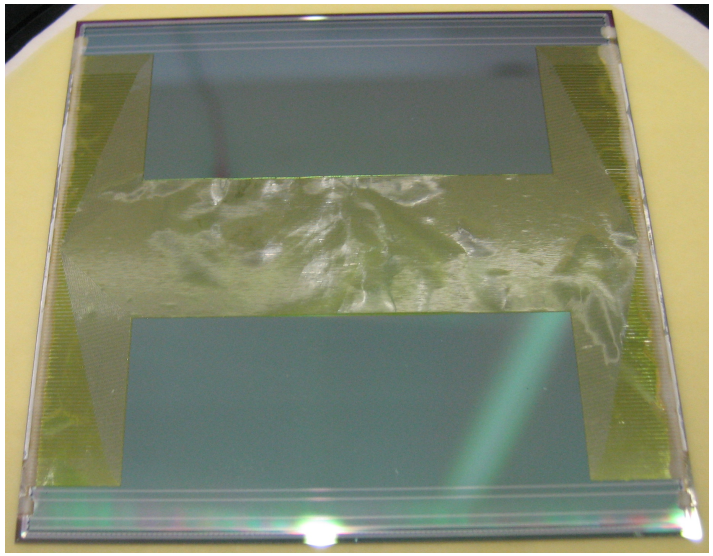
The main aim of the studies:

I Compare sensors from two vendors

II Choose the appropriate technology for the routing lines



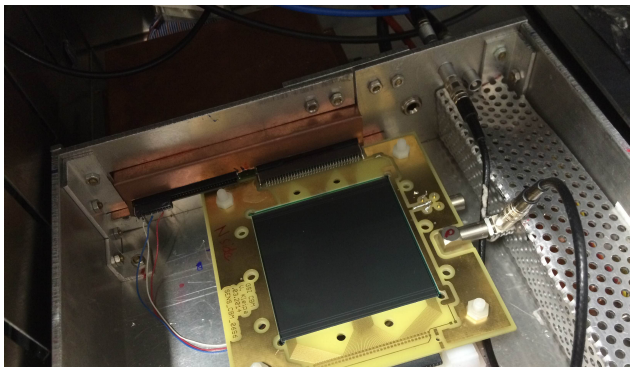
double metal sensor (DM)

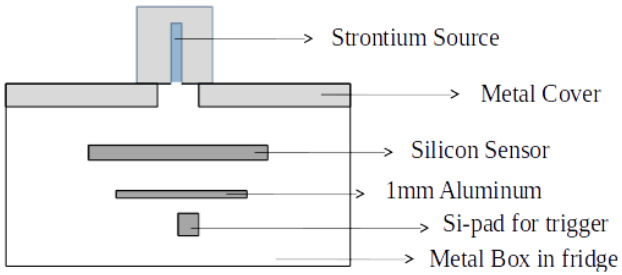


single metal with cable (SMwC)

Charge collection measurements

- 4 sensors were selected for charge collection test before and after irradiation (KIT, 2×10^{14} 1 MeV n_{eq}/cm^2 – twice the maximum neutron fluence expected in the CBM)
- measurements in light tight metal box
- air was dried by N_2 flow
- measurements inside fridge (temperature and humidity monitored)
- after irradiation the measurement temperature: -10 ($\pm$2) °C

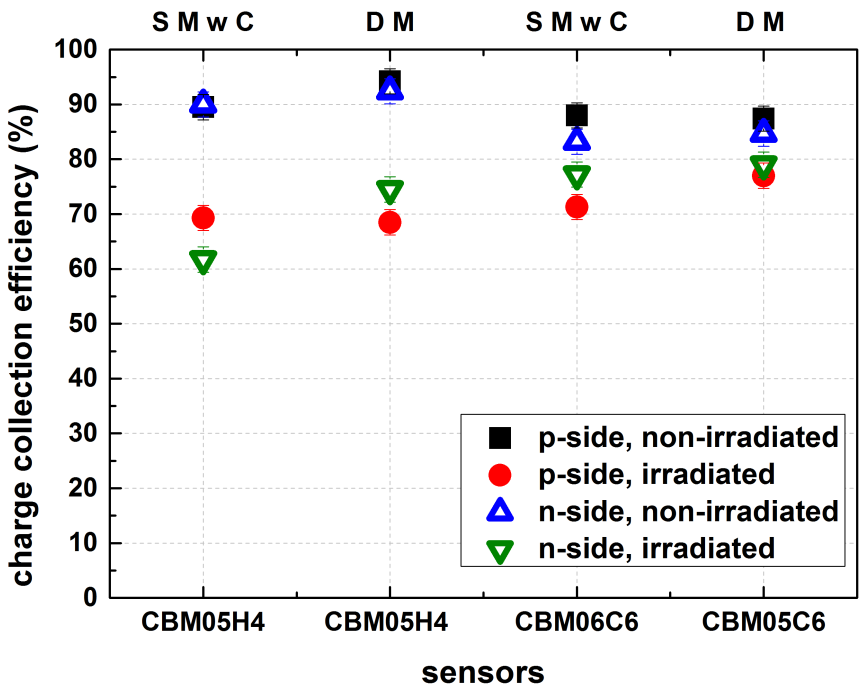




name CBM0-	size cm × cm	thickness μm	inter-connection
5H4-W18	6 × 4	327	SMwC
5H4-W10	6 × 4	331	DM
6C6-W14	6 × 6	293	SMwC
5C6-W6	6 × 6	291	DM

5 or 6 – prototype generation,
H = Hamamatsu, C = CiS – manufacturer,
4 or 6 – sensor height/strip length in cm,
W – wafer number

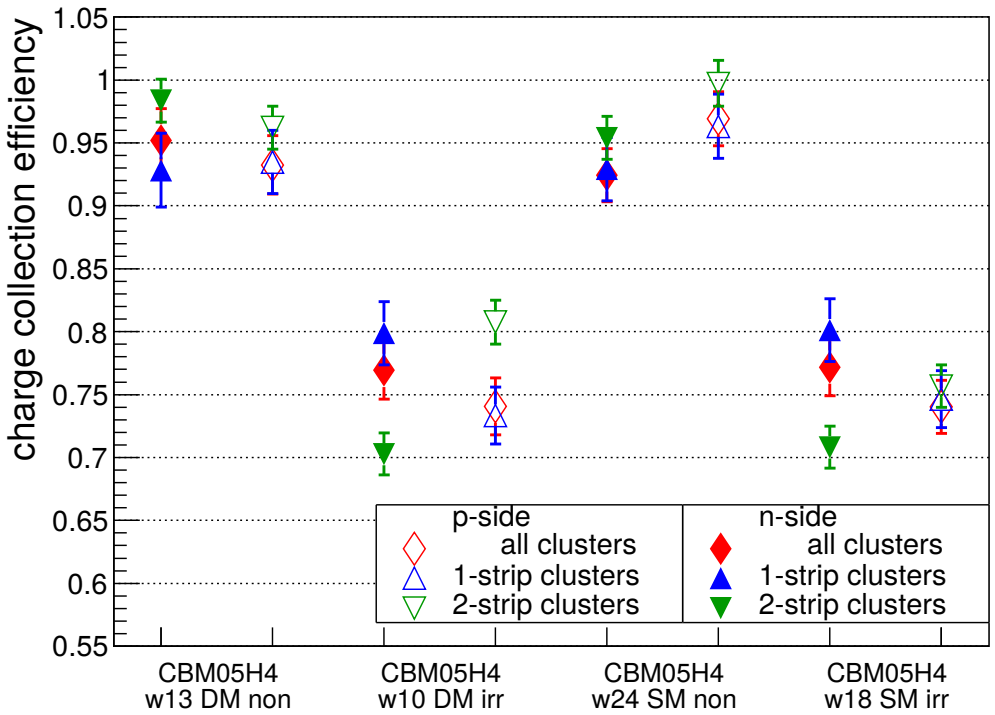
Charge collection with radioactive source ^{90}Sr



100% of collected charge was estimated for the given thickness.

- **CiS & Hamamatsu sensors:** difference of charge collection efficiency is negligible within error bars
- **DM & SMwC:** sensors from the same vendor shows the same result
- **after irradiation:** charge collection efficiency drop about 20% at fluence 2×10^{14} 1 MeV n_{eq}/cm^2

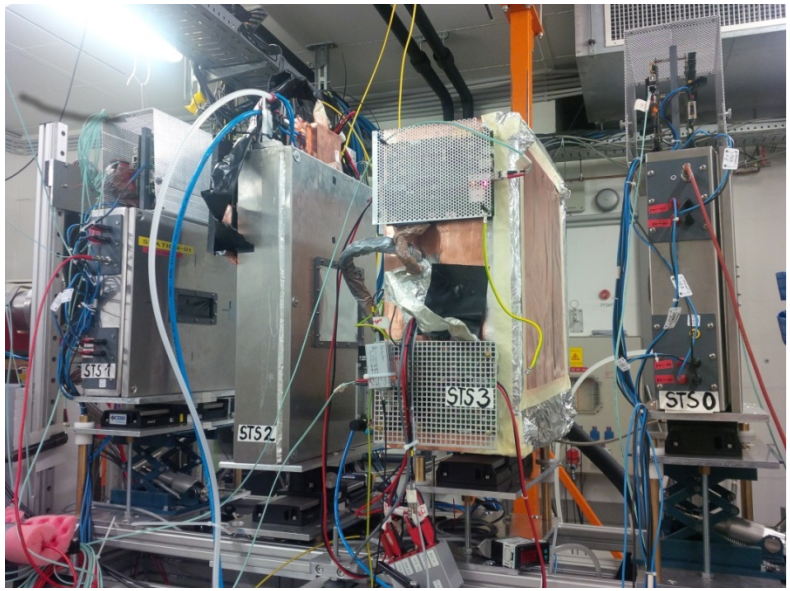
Charge collection with proton beam 2.4 GeV @COSY, Julich



100% collected charge was calculated taking into account interstrip and coupling capacitance.

STS test system:

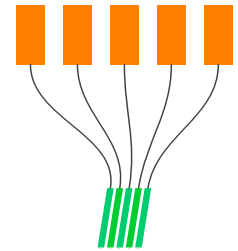
- STS0, STS1: reference stations
- STS2: module: sensor + 20 cm microcable
- STS3: irradiated sensors operated at -8° C



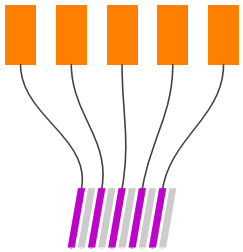
After irradiation signal dropped down by ~ 20 %

Charge collection studies with different read-out bonding configurations

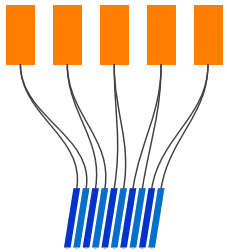
- At the outer part of detector where occupancy of particles is low → possibility to cut signal with threshold
- To get signal higher → to read not every strip, but from two or every second strip
- First approach: only perpendicular tracks



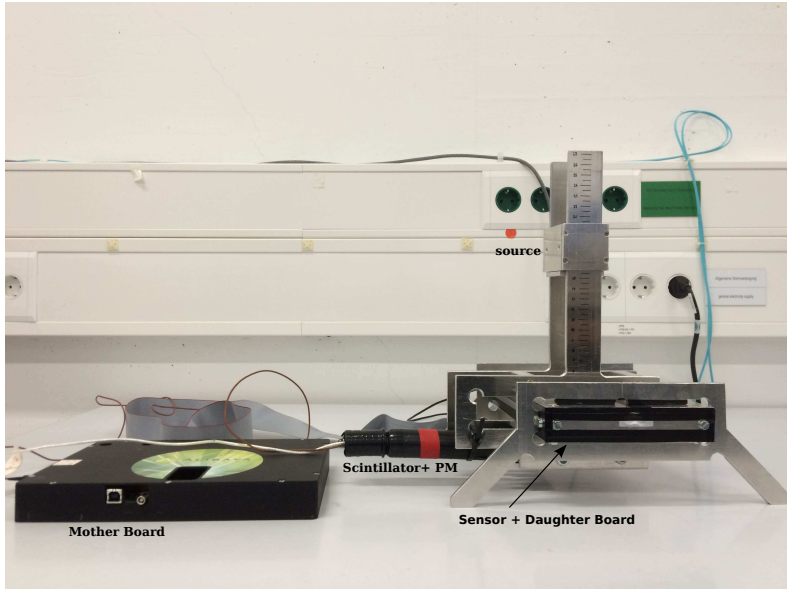
1 → 1
one strip correspond to one r/o



every second strip is r/o



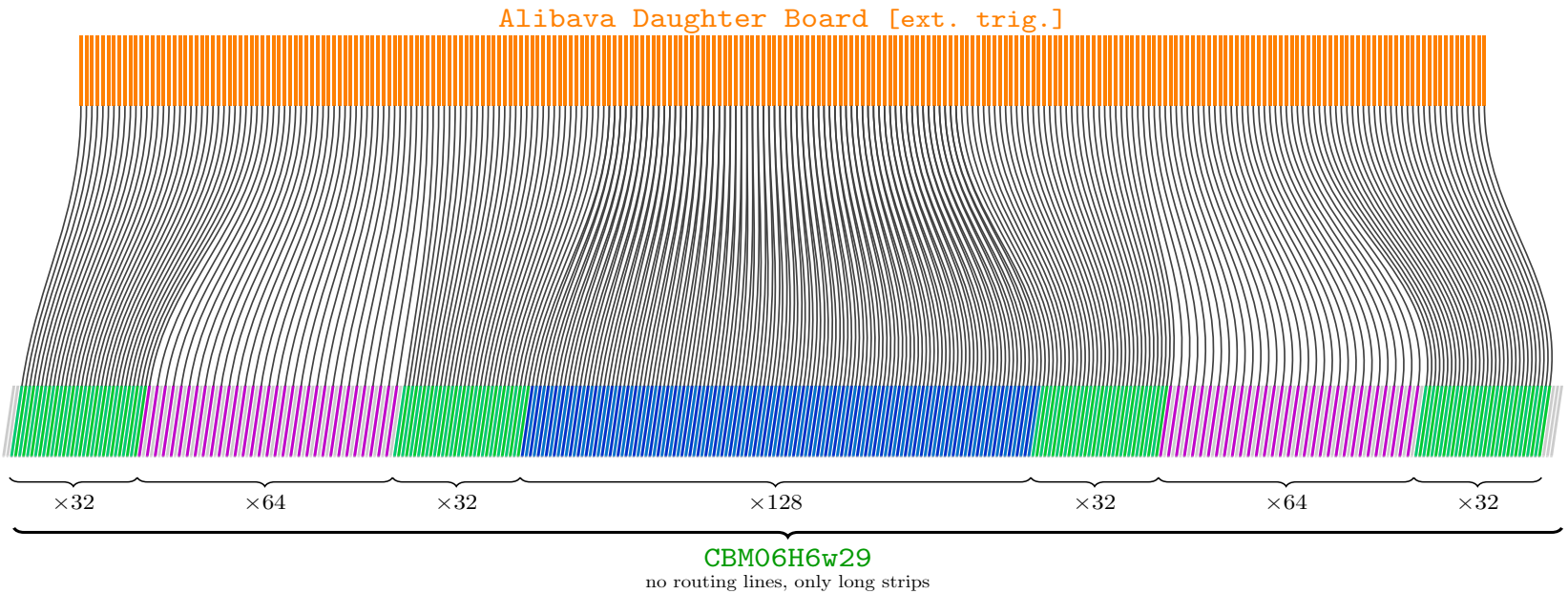
2 → 1
two strips connected to one r/o



Charge collection studies with different read-out bonding configurations

To reduce number of r/o channels in outer aperture of STS detector three different configurations of connection were tested:

- each strip corresponds to one r/o channel
- every second strip is read-out
- two strips connected to one r/o channel

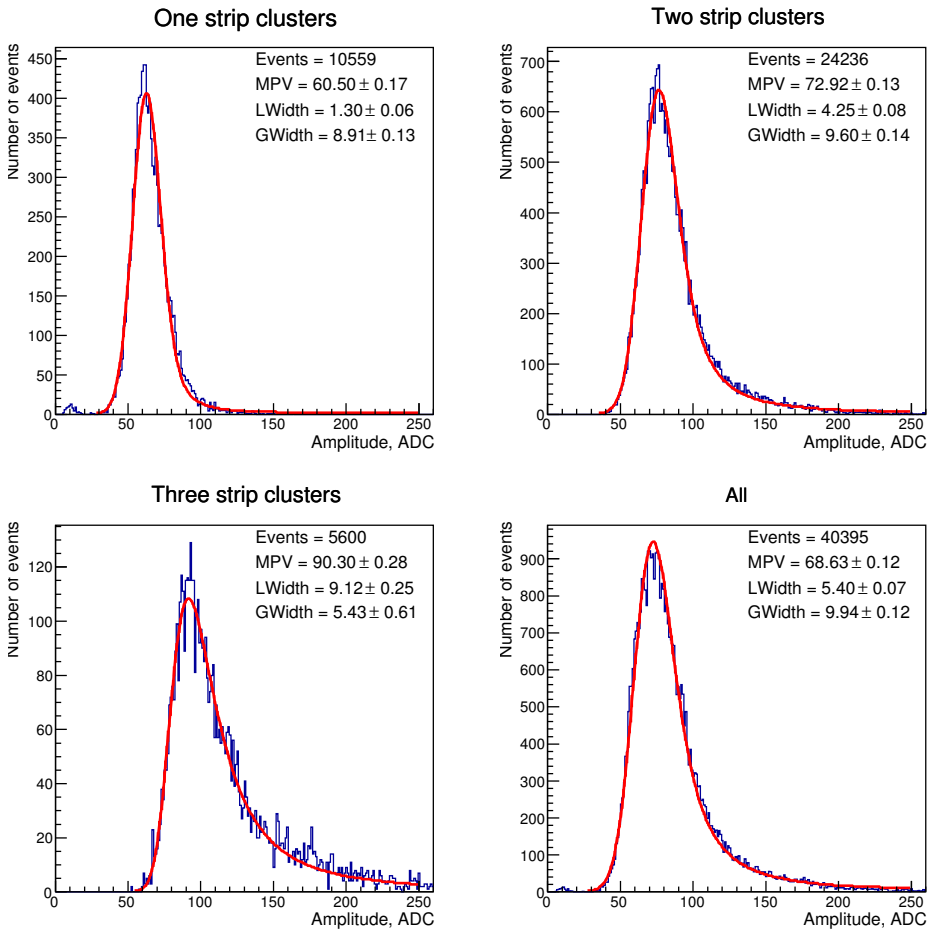


Advantages:

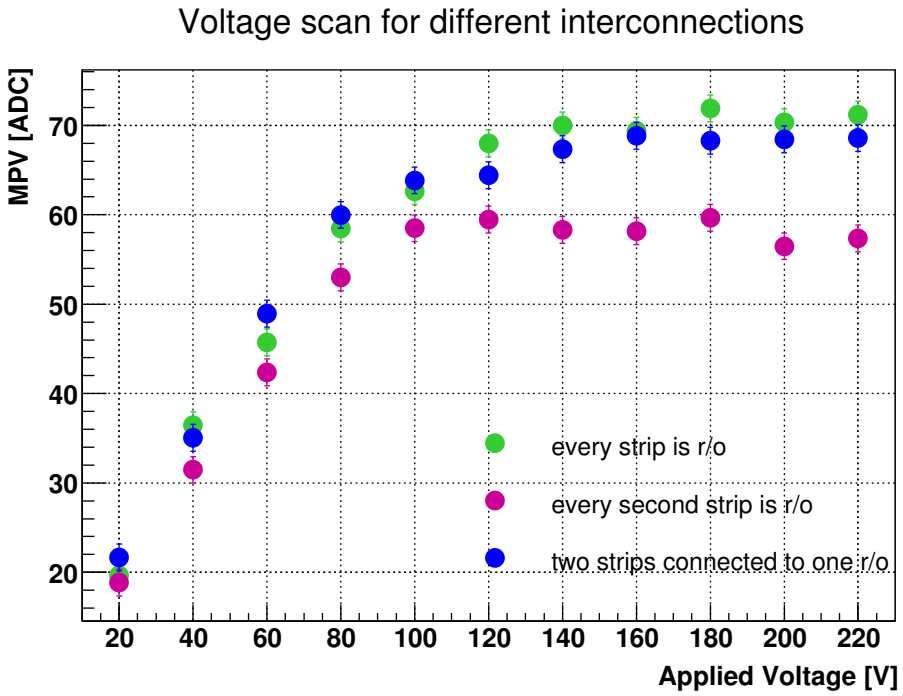
* possible S/N improvement

* less read-out electronics

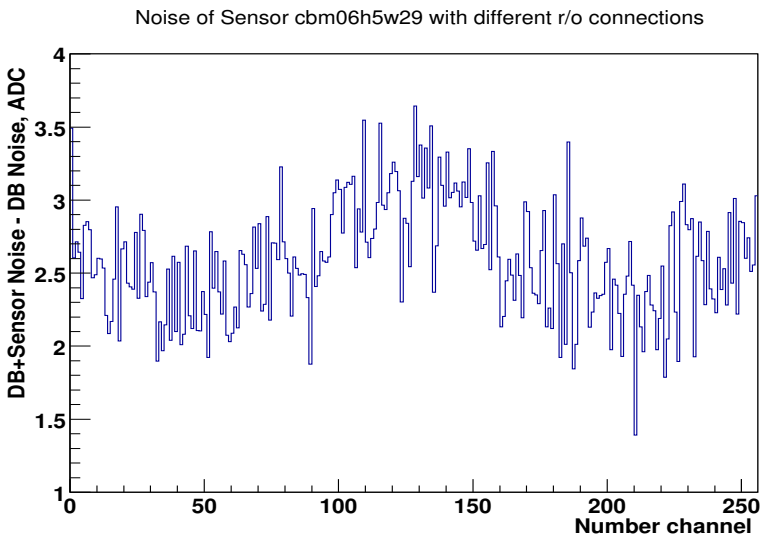
Charge collection studies with different read-out bonding configurations



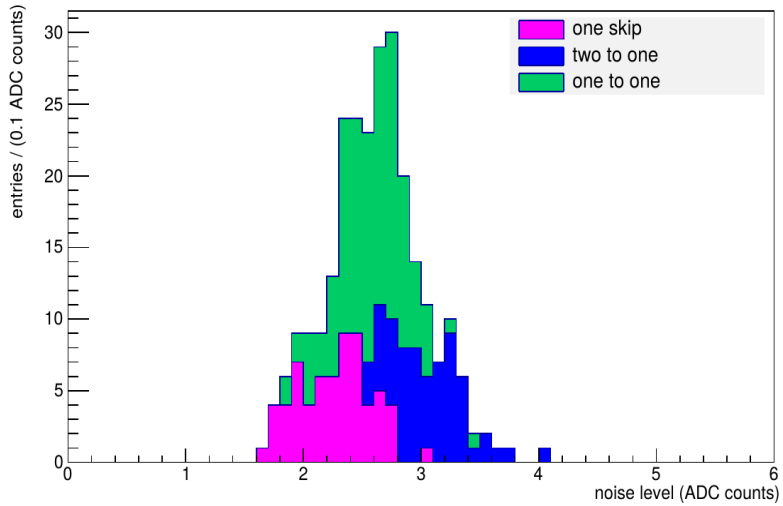
- Cluster charge spectrum was fitted by the Landau-Gaussian convolution
- MPV interpreted as collected charge

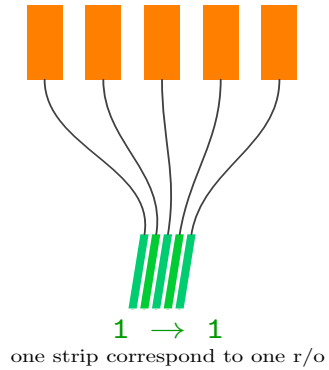


Noise

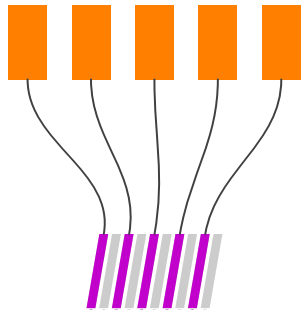


Edge&noisy channels were removed from analysis



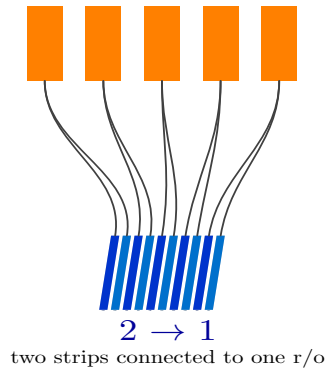


I case
2.58±0.02 ADC
S/N ≈ 26



II case
2.27±0.04 ADC
S/N ≈ 25

every second strip is r/o



III case
3.05±0.05 ADC
S/N ≈ 22

Conclusion

* The prototype sensors from two vendors, in two technological configurations, show a reduction of charge collection by 15% to 25% after irradiation to twice the maximum neutron fluence expected in the CBM experiment.
* Double Metal and Single Metal with Cable sensors shows similar charge collection result.
* Three types of connection schemes with perpendicular penetrated particles were analysed:
  - For each group $\mathbf{S/N > 20}$;
  - Cases when two strips and every strip connected to one read-out has shown the same charge collection;
  - In case of every second strip is read-out collected charge is $\approx 15\%$ less;
  - Study will be continued with inclined beam.
* New series of sensors are under preparation to forthcoming irradiation studies.

Thank you for attention!