Radiation hardness studies of the silicon microstrip sensors for the CBM experiment

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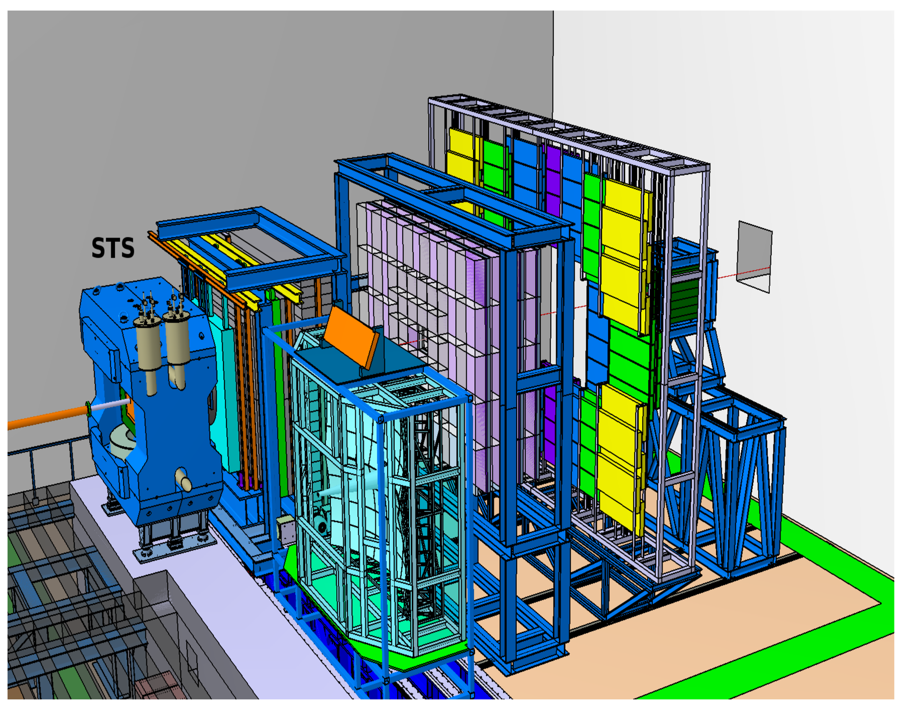
Compressed Baryonic Matter experiment and Silicon Tracking System

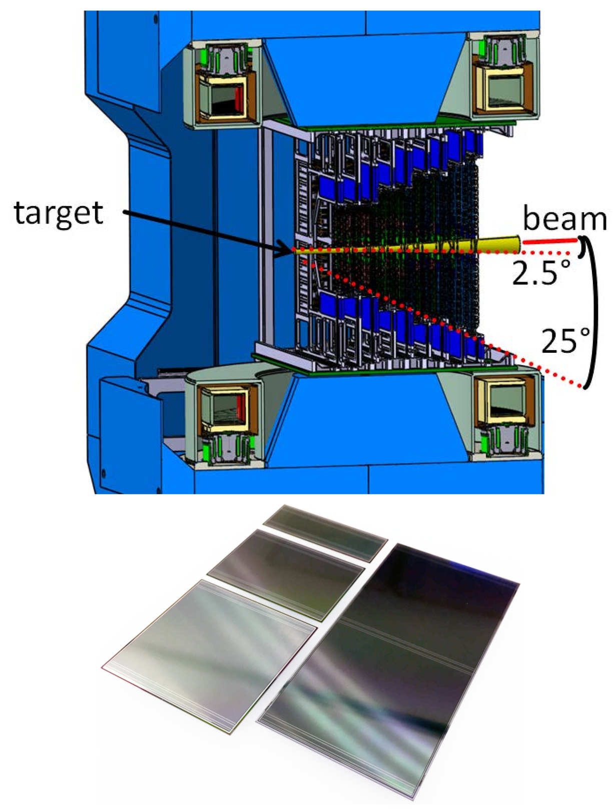


CBM experiment:

- Au+Au collisions @SIS100 2 - 11 AGeV, 10^5-10^7 interactions/s;
- up to 10^3 charged particles per central collision.

physics program @SIS100:

- Strangeness;
- Lepton pairs;
- Collective flow, correlations and fluctuations;
- Hypernuclei and hypermatter;
- Charm-anticharm quark pairs.



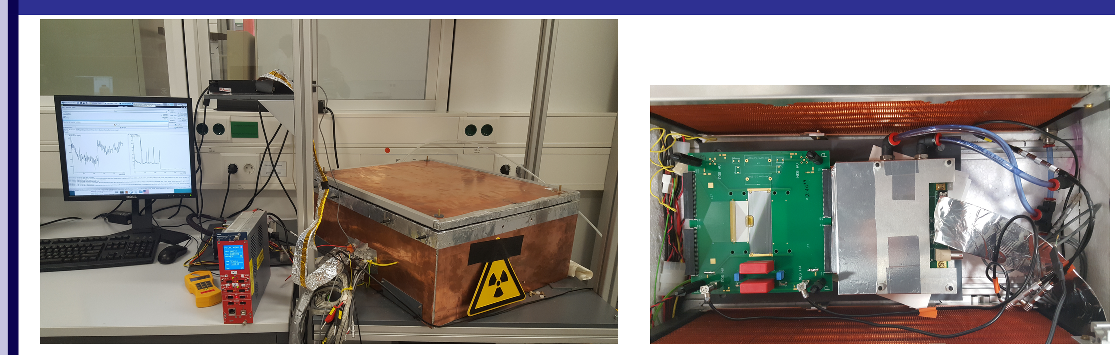
Silicon Tracking System:

- 8 tracking stations;
- hit rates up to 20 MHz/cm^2;
- low material budget $\sim$ 1.5% X_0;
- 25 μm hit spatial resolution;
- S/N>10 for the hit reconstruction efficiency $\sim$ 95 %.

Double-sided micro-strip Si sensors:

- 285/320 μm thick, 58 μm strip pitch;
- sensor sizes 6×2, 6×4, 6×6, 6×12 cm^2;
- 7.5° stereo-angle front-back sides;
- radiation hard: 10^{14} 1 MeV n_{eq}/cm^2.

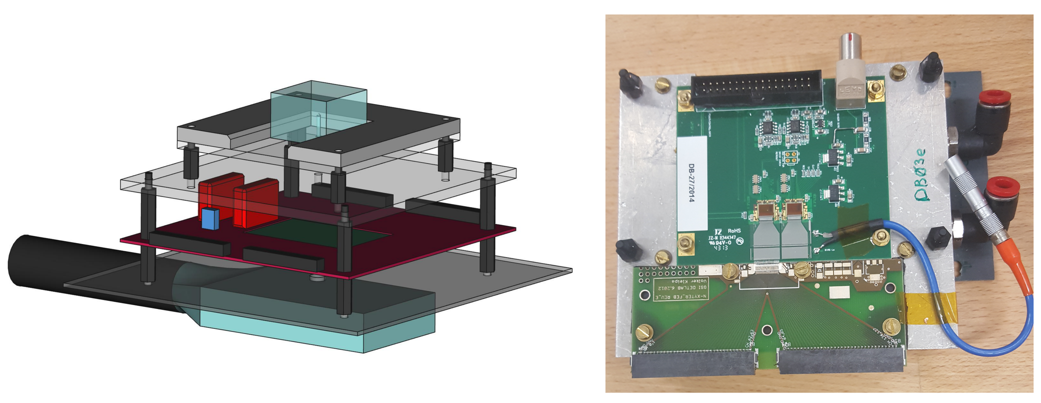
Experimental set-up & program of measurement



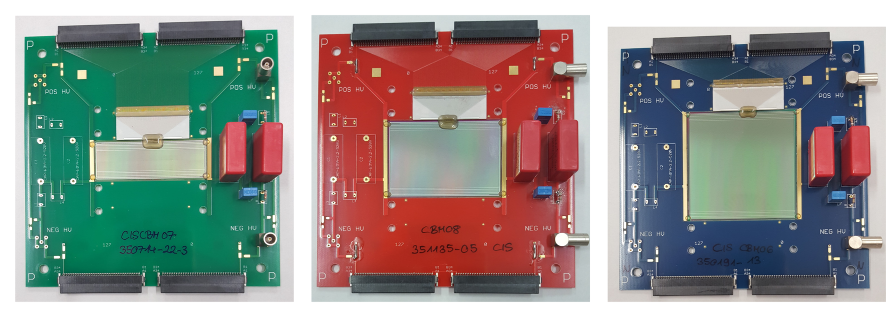
Read out:

ASIC front-end Beetle (according to our needs Daughter Board was customised) and DAQ system (Alibava):
- external trigger mode;
- 2×128 r/o channels;

- Thermal enclosure:
  thermal cycle from 24°C to -11°C $\sim$ 2h;
  colling liquid: H_2O + Glycole;
- collimated β source:
  ^{90}Sr (^{90}Y decay E_{max}= 2.28 MeV);
- Trigger and MIPs selection: Scintillator (2.5 cm thick) + Photomultiplier.



Sensors under test:



- latest prototypes: HPK (Japan) & CiS (Germany);
- three sizes: 2×6, 4×6, 6×6 cm^2;
- irradiated to: 10^{13}, 5×10^{13}, 10^{14}, 2×10^{14} 1 MeV n_{eq}/cm^2.

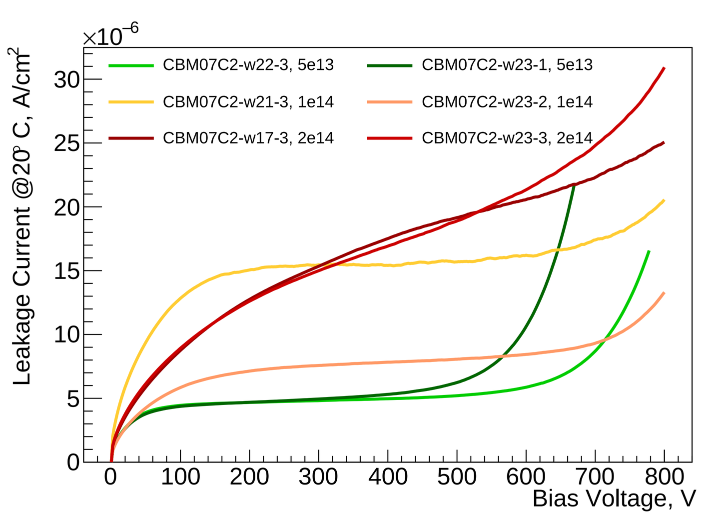
What to measure:

- current (to find breakdown point) & bulk capacitance (to find full depletion voltage) vs. applied voltage;
- signal amplitude before and after irradiation; noise

The aim of this work – to study relative changes of irradiated prototypes of different outer dimensions in terms of charge collection efficiency.

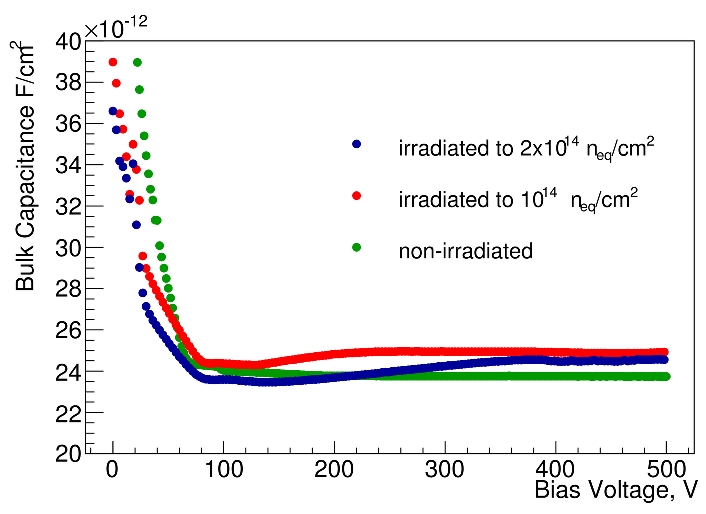
Electrical characteristics

Leakage current dependence on the applied bias voltage.



- Leakage current increases by a factor of 1000 (2×10^{14} n_{eq}/cm^2).

Bulk capacitance as a function of reversed bias



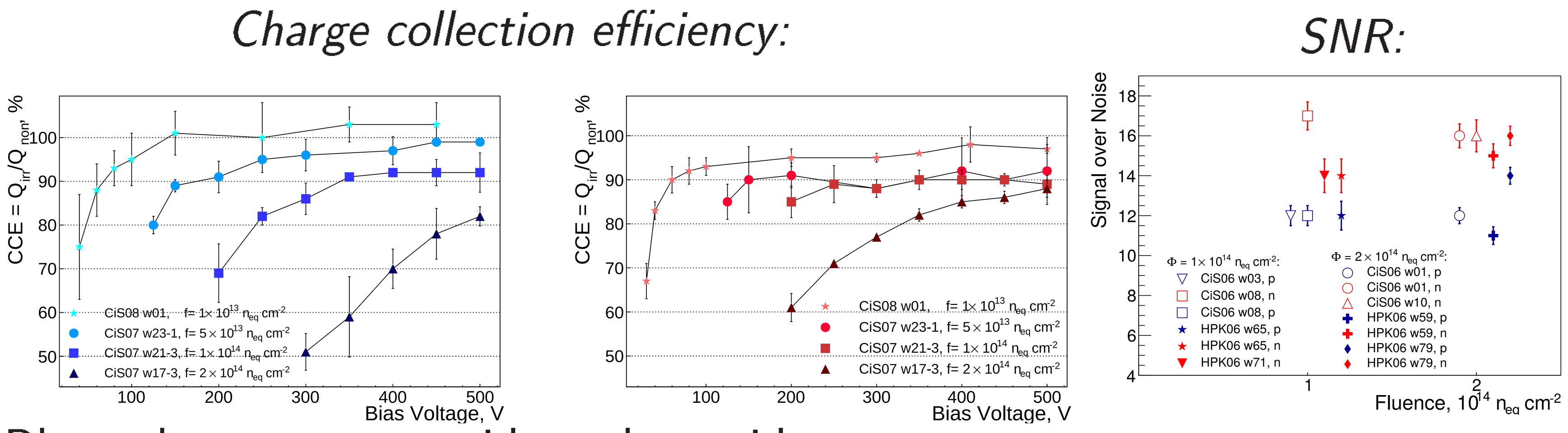
- Sensors are constantly cooled to:
  - suppress current;
  - avoid annealing.

CCE as a function of bias voltage and SNR

CCE was calculated as a ratio of the charge collection measured after irradiation (Q_{irr}) to the value observed before irradiation (Q_{non}): $CCE = \frac{Q_{irr}}{Q_{non}}$.

Charge collection efficiency:

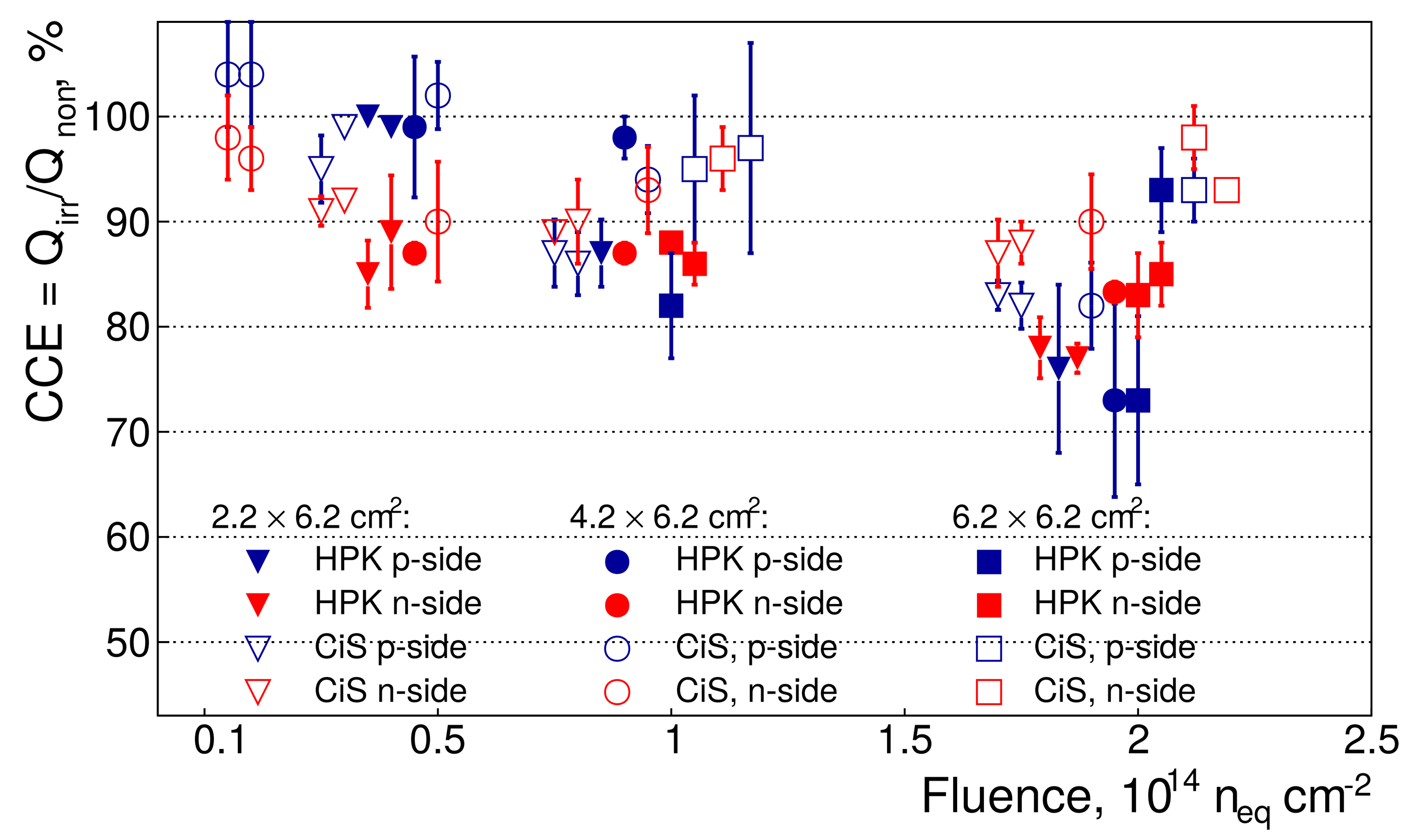
SNR:



Blue color represent p-side, red – n side.

Charge collection as a function of fluence

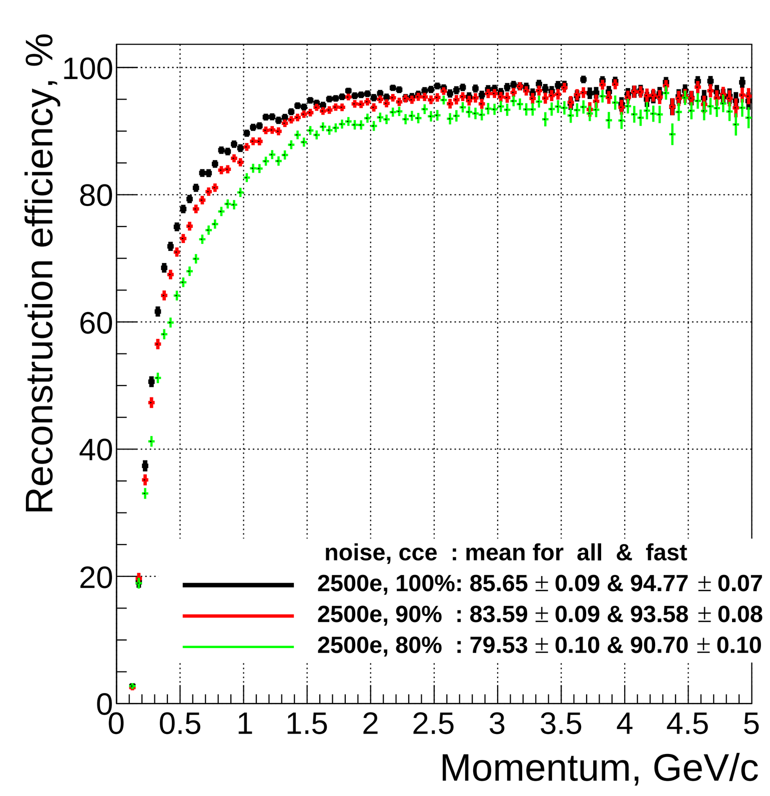
The final picture of all tested sensors is presented. Empty markers are used for sensors produced by CiS, full – by HPK.

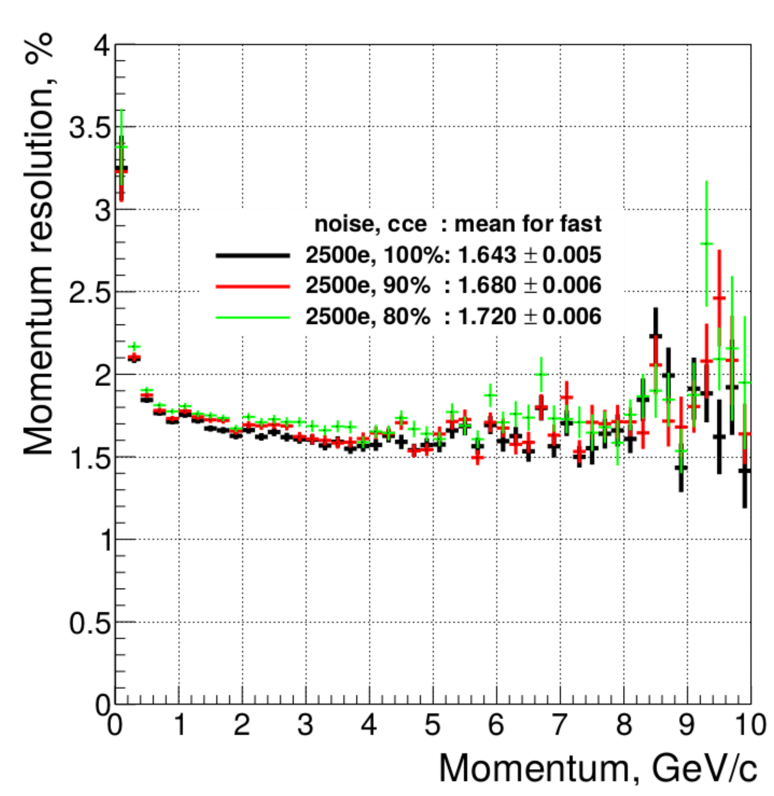


Influence on the STS performance

Simulations involving a realistic detector response model:

- noise of full system based on STS-XYTER (sensor + microcable + r/o)
- deterioration of CCE





Conclusions

Sensor prototypes are found to be radiation hard and will survive CBM fluence:

- 10^{13} n_{eq}/cm^2 – no degradation observed;
- 10^{14} n_{eq}/cm^2 – 90-95% p-side & 85-90% n-side;
- low noise is the main prerequisite to meet STS requirements.