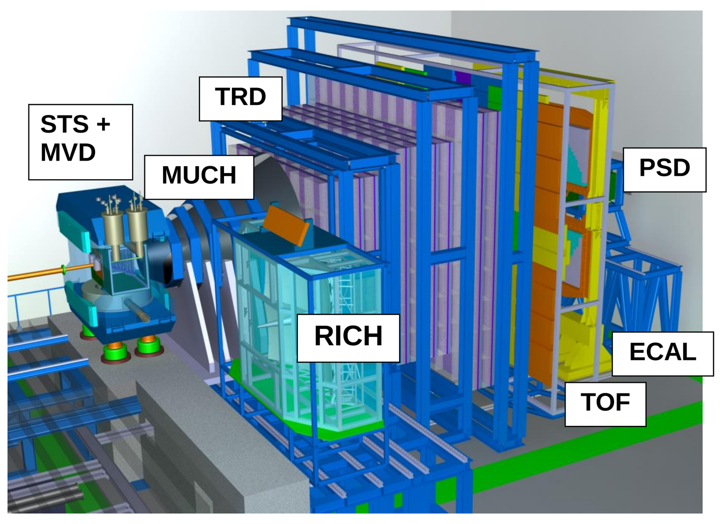
Charge collection studies of neutron irradiated double sided silicon microstrip sensors

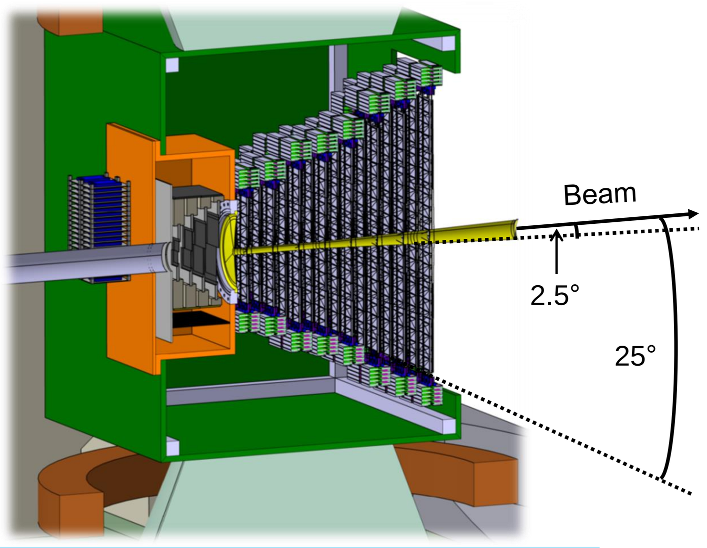
M. Singla & P. Larionov, for the CBM Collaboration- GSI Darmstadt

The CBM experiment



Compressed Baryonic Matter (CBM) experiment

- at FAIR, Darmstadt, Germany
- 2-45 AGeV nucleus-nucleus collision
- up to 10 MHz interaction rate
- explore QCD phase diagram the region of high net baryon densities and moderate temperatures



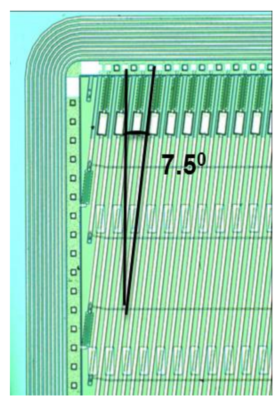
Silicon Tracking System (STS)

- 8 tracking stations
- double sided silicon microstrip sensors
- minimized number of channels
- minimized material budget
- read-out electronics outside the physics aperture

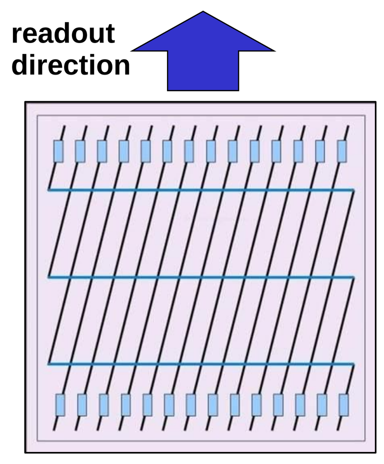
sensor module

Aim of the study

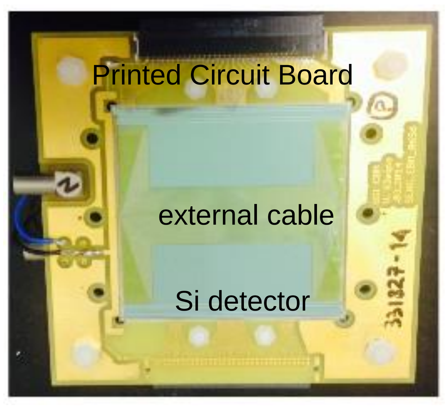
- compare interstrip connection schemes for strips with stereo angle
  - double metallization **(DM)**
  - single metal with external microstrip cable **(SMwC)**
- test radiation tolerance up to 2 ×10^14^ $n_{eq}cm^{-2}$ (max. lifetime fluence for STS)
- annealing studies on baby sensors



microscopic view of sensor edge



integrated routing lines, **"DM"**



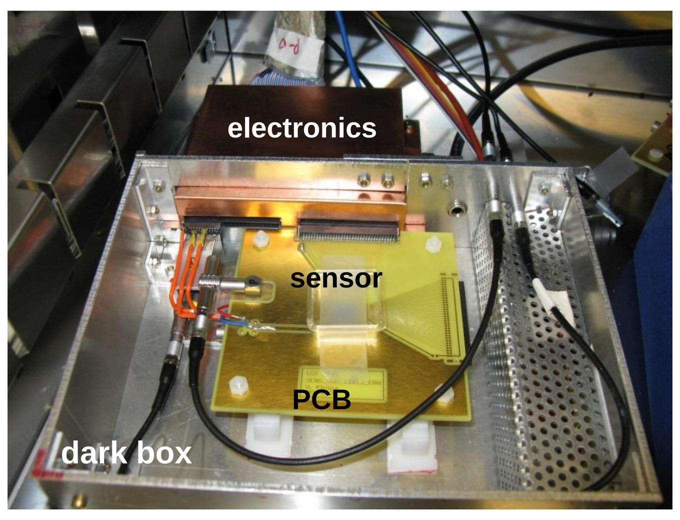
external routing lines, **"SMwC"**

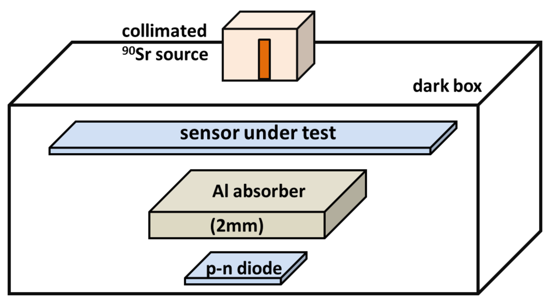
DUT & experimental set-up

- Four sensors selected as device under test (DUT) from two vendors:

name CBM0-	size cm × cm	vendor	inter connection	total sensor thickness (± 2 µm)
5H4-W18	6 × 4	Hamamatsu	SMwC	327
5H4-W10	6 × 4	Hamamatsu	DM	331
6C6-W14	6 × 6	CiS	SMwC	293
5C6-W6	6 × 6	CiS	DM	291

- small sensors (1 × 1 cm^2) tested for annealing studies
- measurements performed in light-tight set-up at -5 ± 3^{0}C
- sensors tested for
  - leakage current versus bias voltage
  - current stability test
  - capacitance versus bias voltage
  - charge collection with ^{90}Sr source

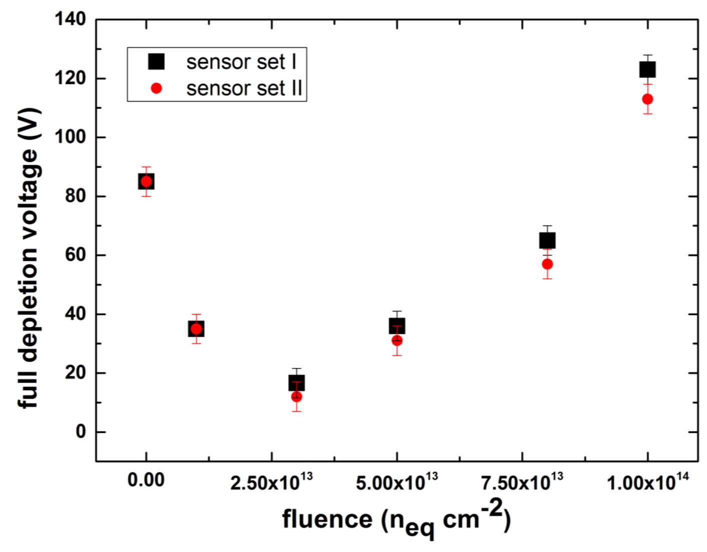




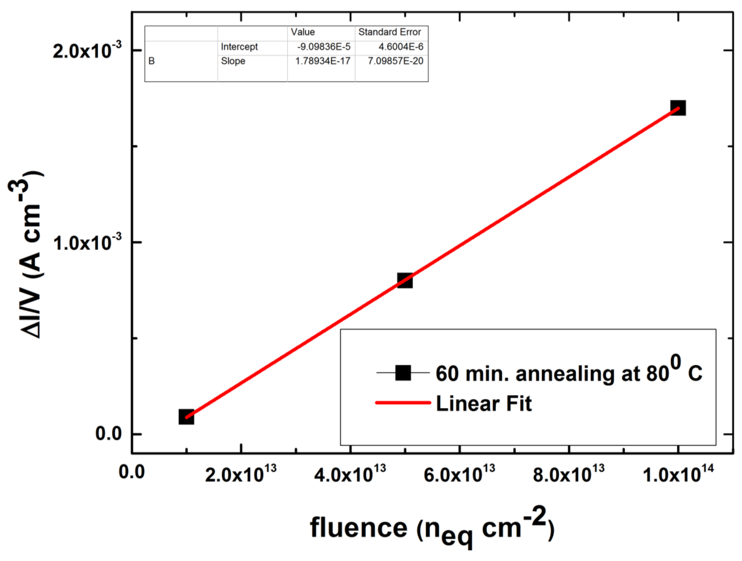
Annealing studies

sensor specifications:

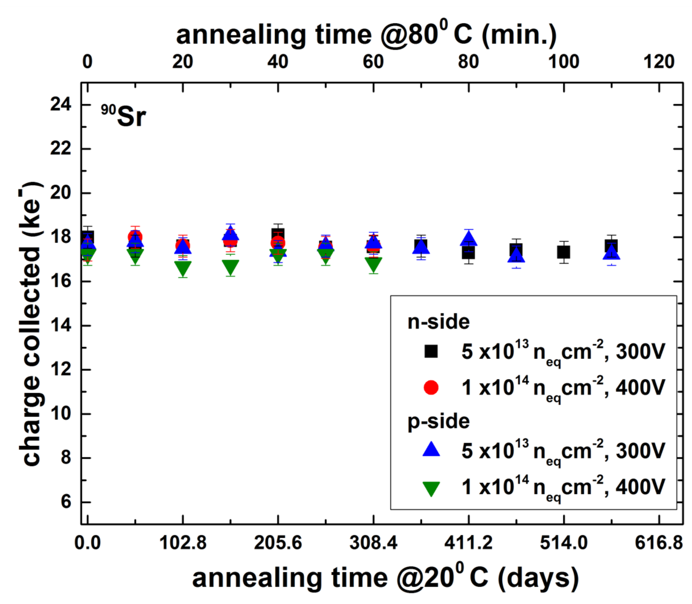
- double-sided sensors, p-n-n structure
- 192 strips per side with 50 µm pitch
- integrated AC-coupled read-out
- stereo angle front-back sides 90°
- no routing lines
- neutron irradiation to 10^{13}, 3×10^{13}, 5×10^{13}, 8×10^{13} and 10^{14} $n_{eq}cm^{-2}$
- annealed at 80^0 C with steps of 10 min
- measurement temperature -5° C



full depletion voltage vs. fluence (n_{eq} cm^{-2})
✓ **type inversion point lies at ~ 3×10^13^ $n_{eq}cm^{-2}$**

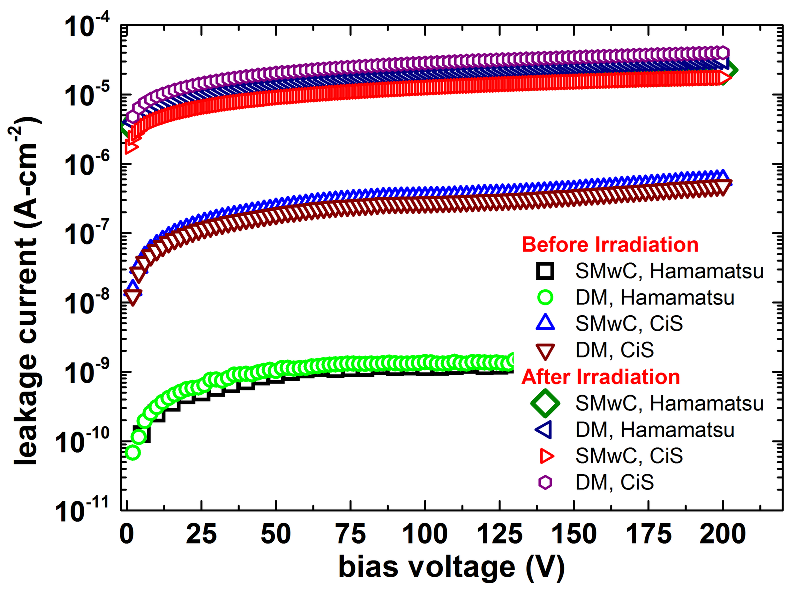


change in leakage current per unit volume vs. fluence
✓ **current damage rate (α) is ~1.8×10^-17^ A cm^-1^**



charge collection with vs. annealing time
✓ **almost no change in charge collection till 1 year at room temperature for both 5×10^13^ and 10^14^ $n_{eq}cm^{-2}$ due to high operating voltage**

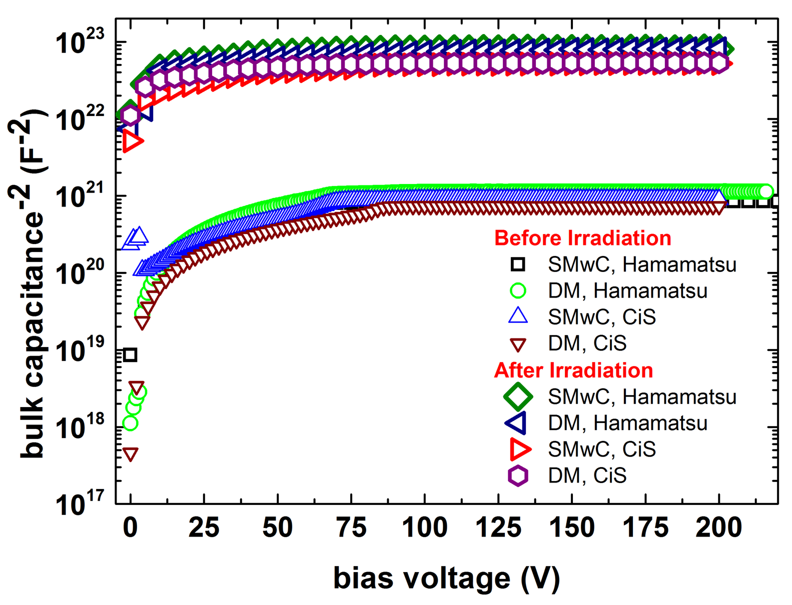
Test results: electrical parameters & charge collection



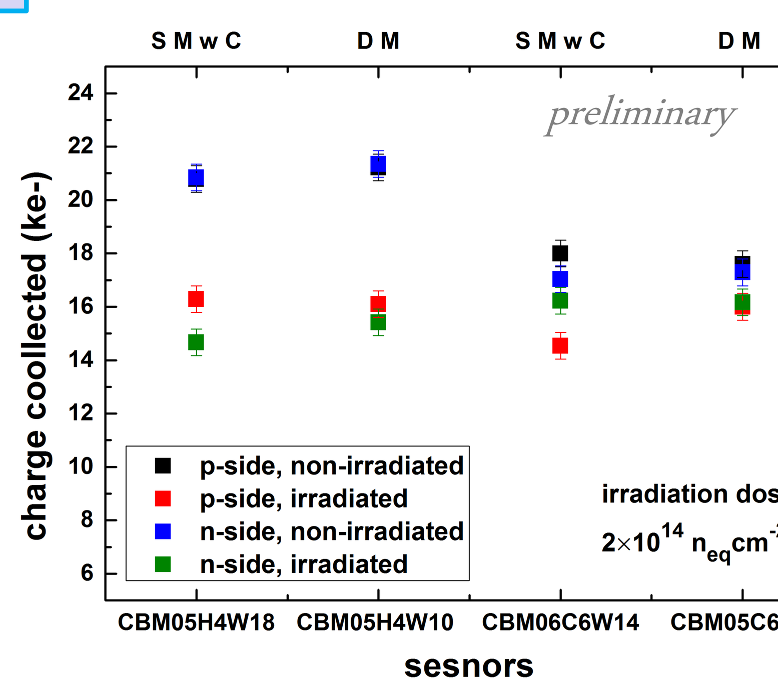
leakage current vs. bias voltage
✓ **current increases after irradiation**
✓ **current per unit are from all sensors is much less than 1 nA/cm per strip (before irradiation) which is acceptable**

sensor specifications:

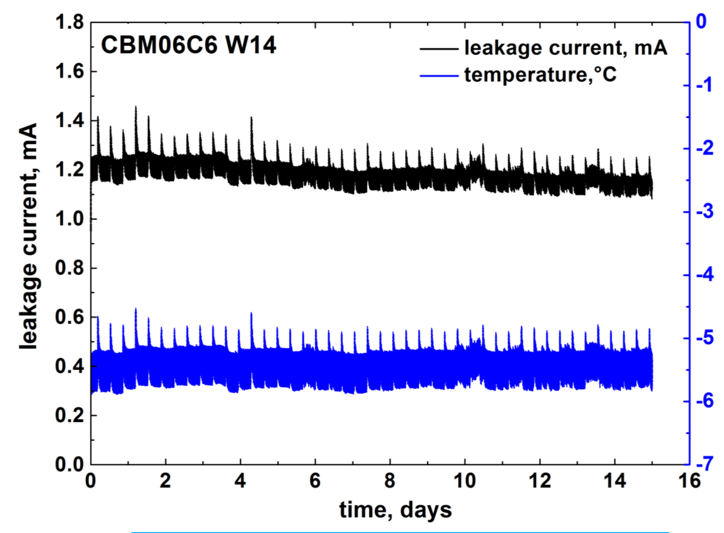
- double-sided sensors, p-n-n structure
- 1024 strips per side with 58 µm pitch
- integrated AC-coupled read-out
- stereo angle front-back sides 7.5°
- n side: straight strips (0^0)
- p side: stereo angle (7.5°)
- routing lines on 2nd metal layer or replacement with an external micro cable on the stereo angle side
- neutron irradiation to 2×10^14^ $n_{eq}cm^{-2}$
- measurement temperature -5 ± 3^{0}C



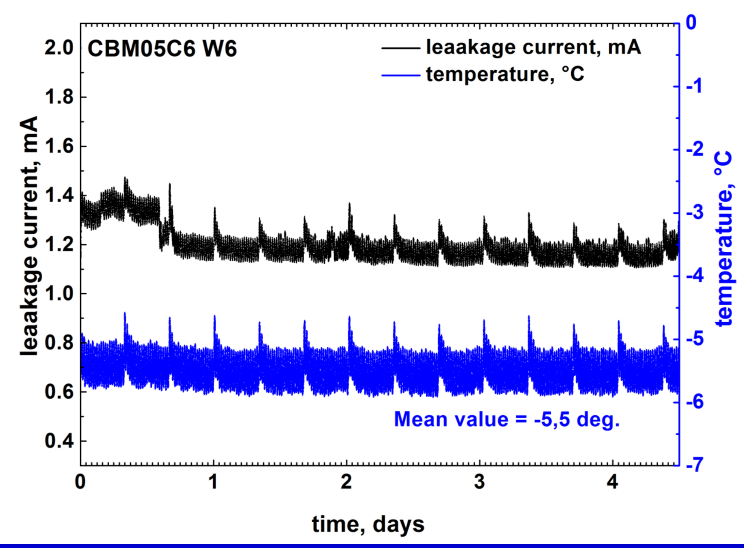
bulk capacitance vs. bias voltage
✓ **capacitance increases after irradiation**
✓ **bulk capacitance for all the sensors (before irradiation) is 0.16 pF/strip/cm which is small compared to interstrip capacitance (~2×1(+0.5) pF/cm/strip)**



charge collection for sensors under test
✓ **CiS sensors have less charge collection losses than Hamamatsu sensors after irradiation**
✓ **similar charge collection from DM and SMwC sensors**



leakage current stability with time
2×10^14^ $n_{eq}cm^{-2}$, @ 470V



Conclusions

Annealing studies performed on small sensors

- no loss in charge collection seen till 1 year at 20^0 C because of high operating voltage
- current damage rate (α) is ~1.8×10^-17^ A cm^-1^
- type inversion point lies at ~ 3×10^13^ $n_{eq}cm^{-2}$

Sensors from two vendors with two different technologies tested before and after irradiations:

- sensors with double metallization or single metal with

external cable shows same charge collection (both before and after irradiation)

- sensors procured by **CiS**, Germany shows **~10% charge losses** after irradiation to 2×10^14^ $n_{eq}cm^{-2}$
- sensors fabricated by **Hamamatsu**, Japan shows **~25% charge losses** after irradiation to 2×10^14^ $n_{eq}cm^{-2}$
- leakage current does not vary with time

FAIR · GSI · HIC for FAIR Helmholtz International Center · HELMHOLTZ ASSOCIATION · H-QM Helmholtz Research School Quark Matter Studies · HGS-HIRe for FAIR Helmholtz Graduate School for Hadron and Ion Research