Quality Assurance and radiation tolerance tests of double-sided silicon sensors for the CBM Silicon Tracking System

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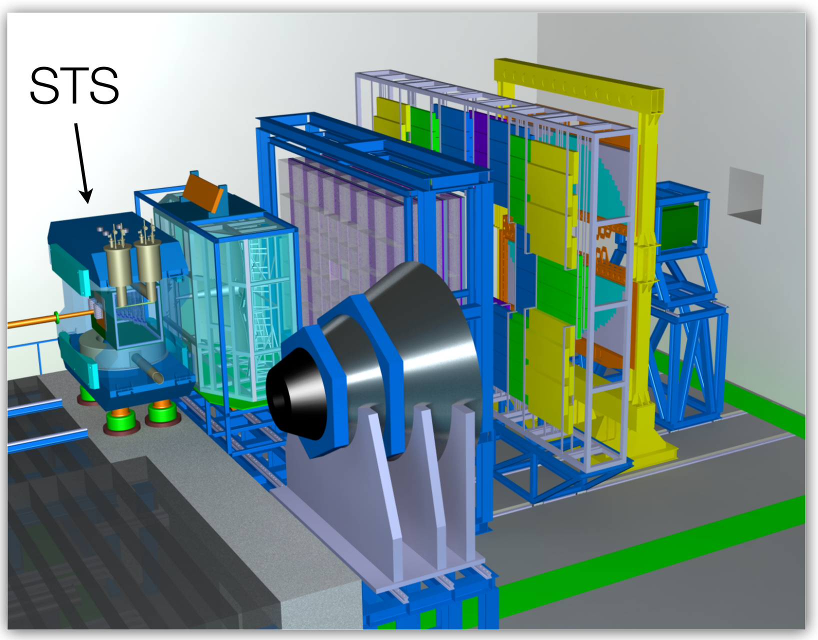
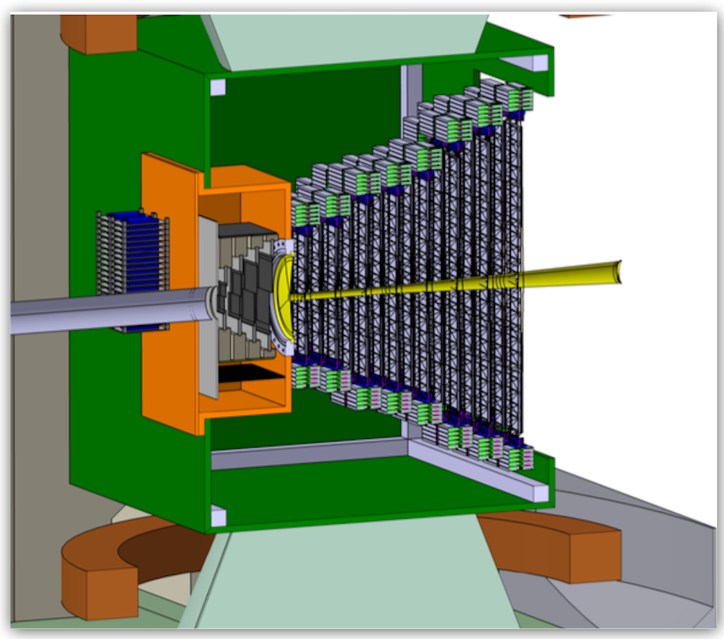
The Compressed Baryonic Matter experiment at FAIR



3D view of CBM set-up

- Explore the QCD phase diagram (high net-baryonic densities and mid temperatures region);
- Fixed target experiment, collision energies 2-45 AGeV;
- Measuring rare (J/ψ), penetrating probes (ρ, ω, ϕ) and multi-strange hyperons.



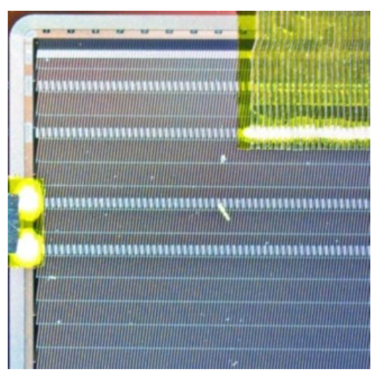
Silicon Tracking System (STS)

- 8 tracking stations 30 cm downstream the target;
- Reconstruct tracks of charged particles, determine their momenta;
- Constructed with double-sided silicon strip sensors;
- Readout electronics outside of the physics aperture $2.5^o < \theta < 25^o$.

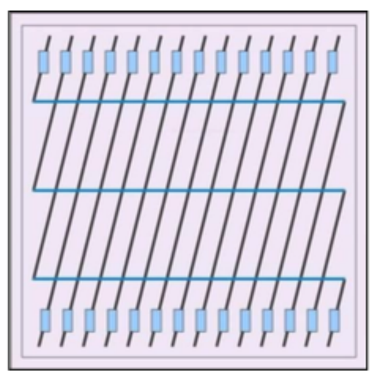
STS Module

A building block of the STS

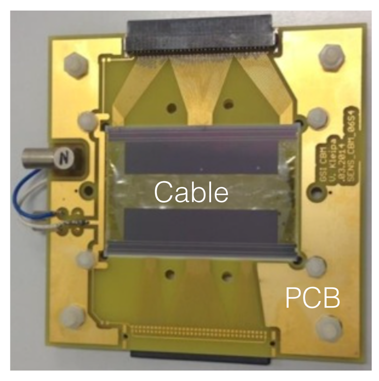
Double-sided microstrip sensors



CBM prototype sensor corner view

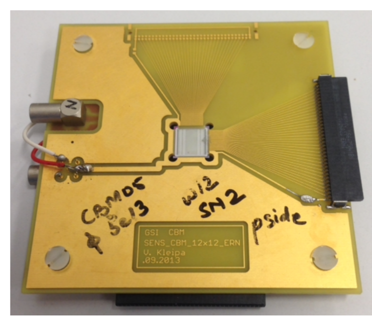


Double-metal interconnection



External microcable interconnection

- p^+-n^--n^+ silicon structure,
- 58 µm strip pitch;
- 1024 strips per side;
- Stereo angle front-back side 7.5º;
- Poly-Si biasing structure;
- Integrated AC-coupled readout;
- ~ 1200 will be produced in four sizes;
- baby sensors: orthogonal strips, 50 µm strip pitch, same wafer.



Baby sensor

Sensor Quality Assurance

Sensor requirements

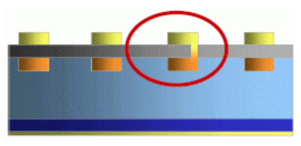
- Provide track reconstruction efficiency ~95% for fast primary tracks;
- ~99% hit efficiency;
- Radiation tolerant up to 1×10^{14} n_{eq}/cm^2;
- Full depletion voltage < 100 V;
- Leakage current < 8 nA /strip/cm at 300V;
- Number of defected strips < 1% per sensor.

Quality Assurance (QA)

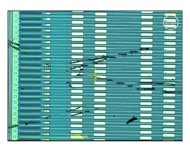
Macroscopic QA: I-V and C-V tests.

Microscopic QA: Optical inspection; Strip quality tests.

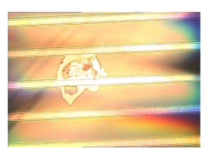
Strip defects



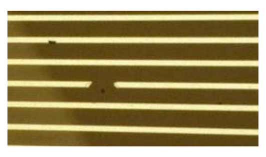
"Pinhole" [1]



Scratches

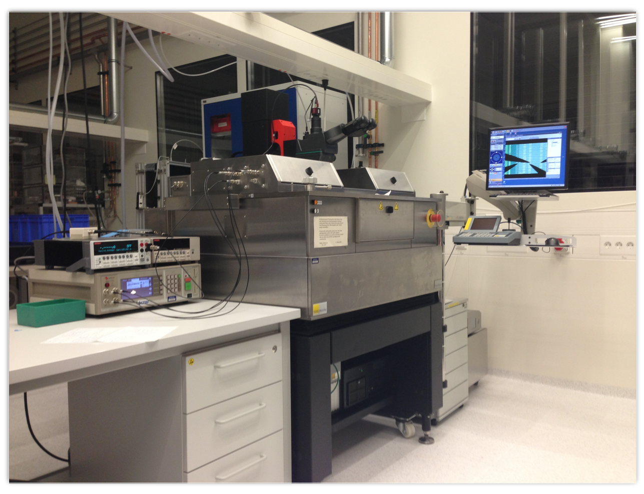


Metal short [1]



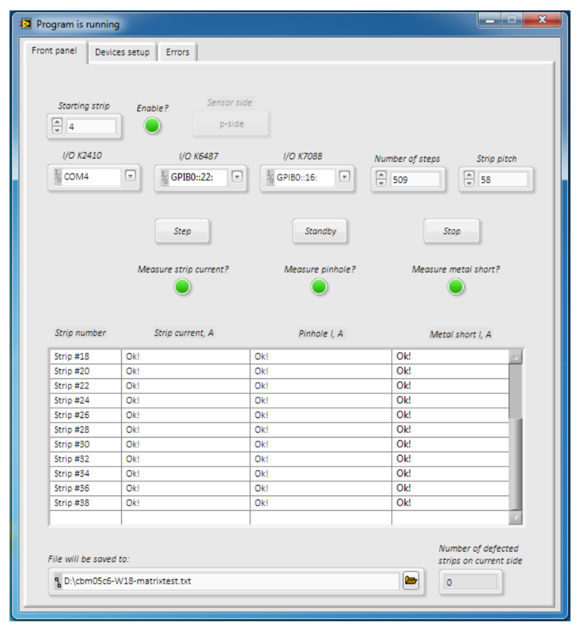
Metal brake [1]

Setup for Microscopic QA

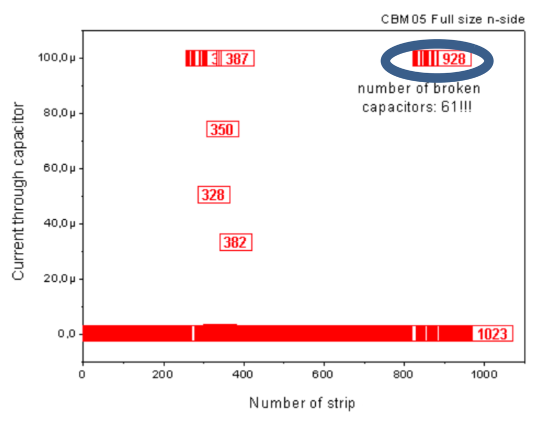


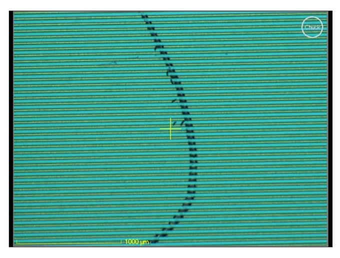
- Cleanroom environment with temperature and humidity control;
- Probe station Süss PA300PS equipped for detailed sensor tests;
- Instruments for the measurement of strip parameters;
- Switching matrix (multiplexer);
- Automated measurements.

Software and results

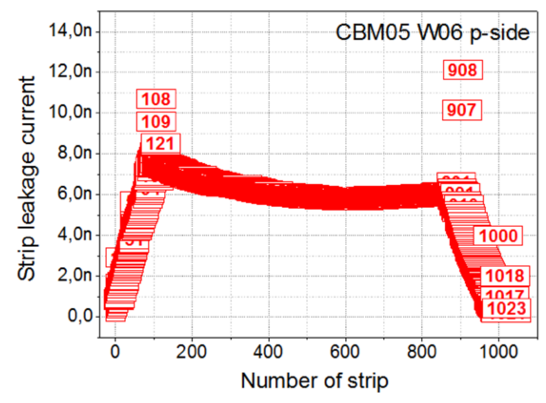


- LabView based software;
- Perform multiple or single tests;
- Check for pinholes, metal shorts, strip current;
- Results shown online and also saved ASCII file;
- 6 seconds per strip (measuring three parameters).

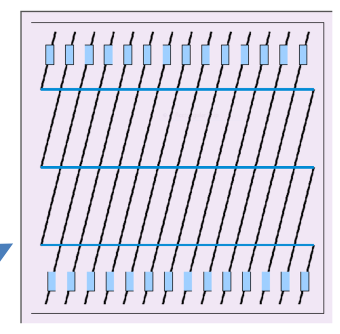




Scratch resulted in large number of pinholes



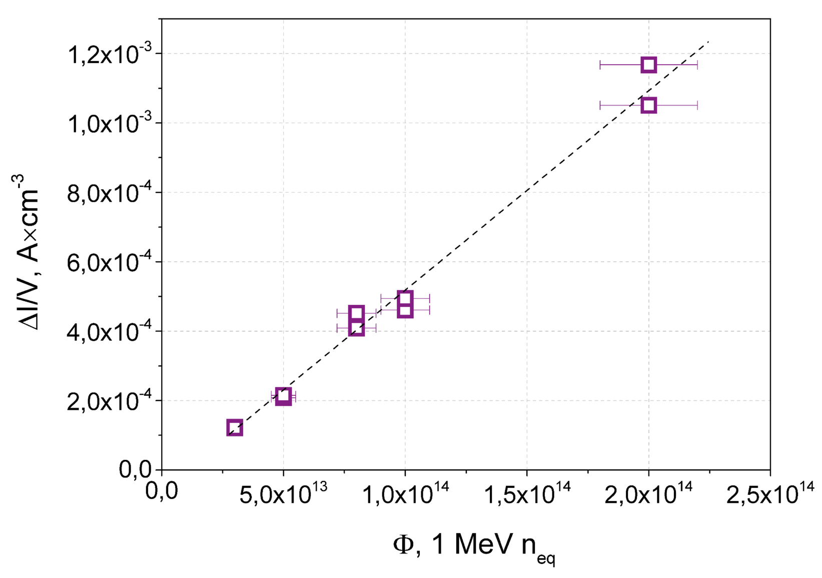
Strip leakage current distribution vs strip's length



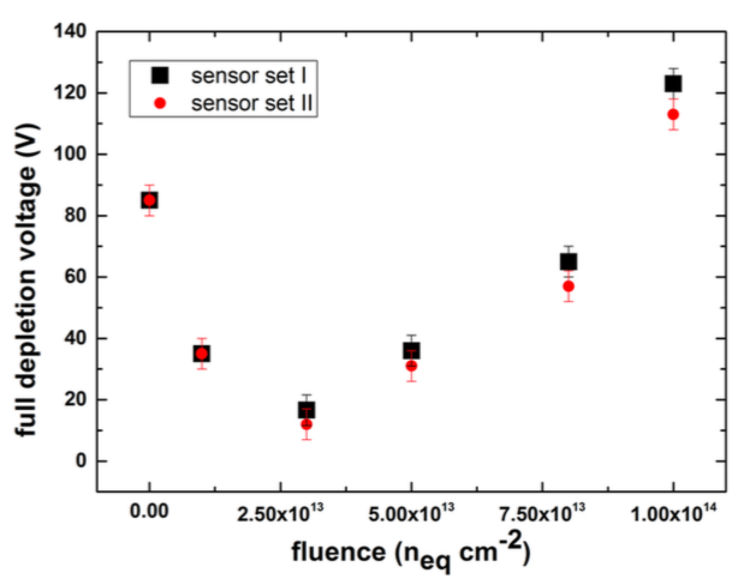
Sensor radiation tolerance tests

Aim of the work

- STS's TDR: 1×10^{14} 1 MeV n_{eq}/cm^2 is the harshest scenario for CBM sensors;
- Baby sensors irradiated: 1×10^{13}, 3×10^{13}, 5×10^{13}, 8×10^{13}, 1×10^{14}, 2×10^{14} in TRIGA reactor, IJS, Slovenia;
- Full-size prototypes irradiated: 2×10^{14} at KIT, Germany;
- Monitor parameters:
  1. charge collection;
  2. Full depletion voltage V_{fd};
  3. Leakage current I_{leak} stability;
  4. charge collection vs annealing;
  5. charge collection for different interconnecting schemes (full-size sensors).

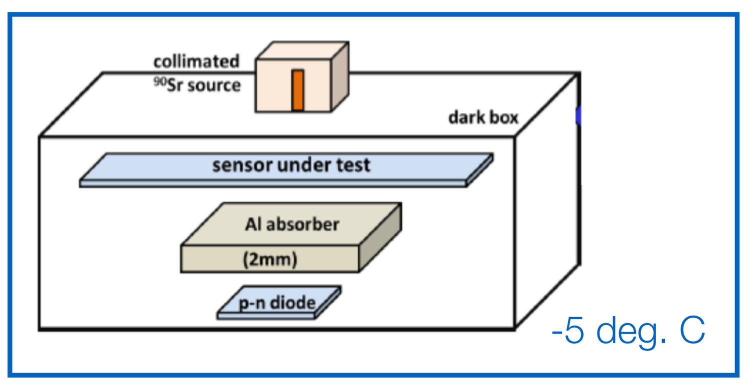


Sensor current over volume scaling with fluence

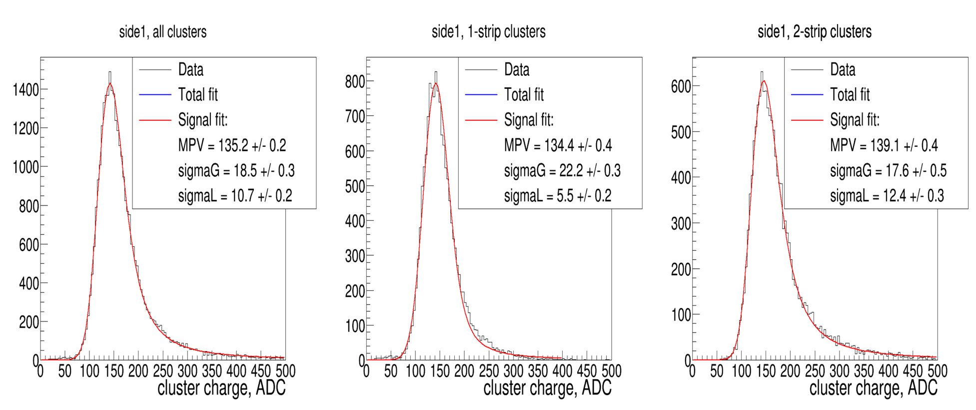


Full depletion voltage vs fluence: type inversion ~ 2×10^{13}

Setup for charge collection tests

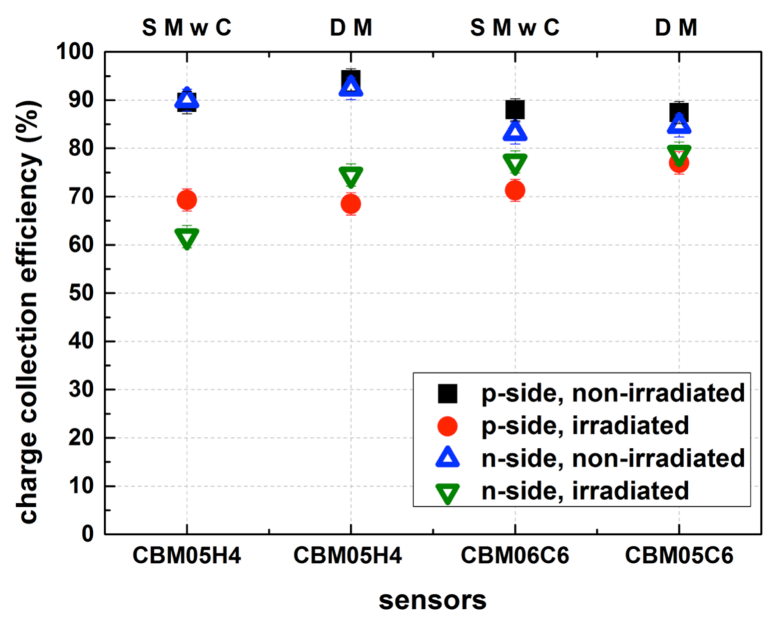


Charge collection analysis



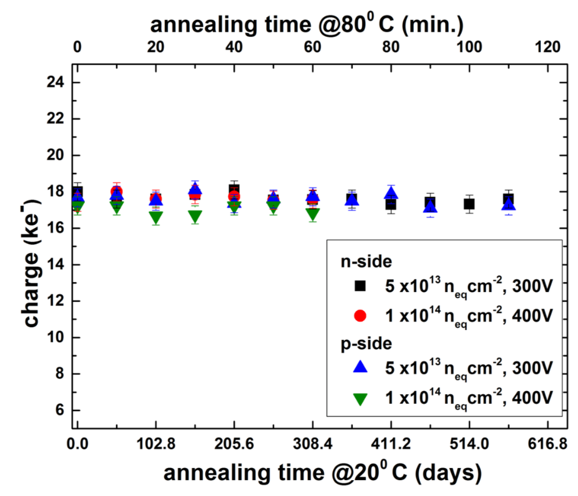
fitting: Landau - Gaussian convolution

Charge collection vs strip interconnection schemes



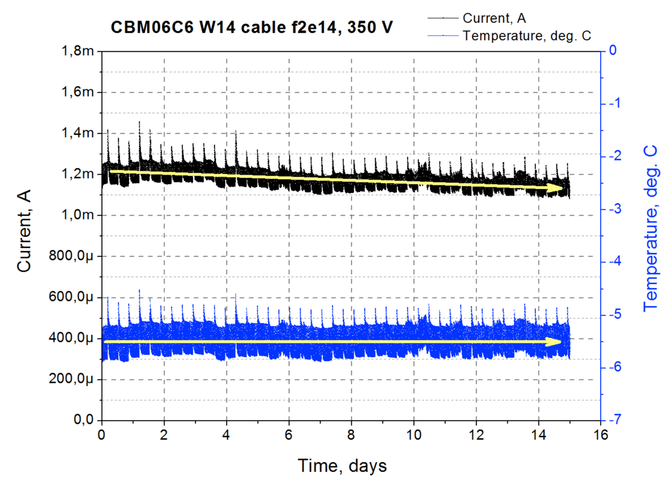
- Full size prototype sensors: 6×4 cm (Hamamatsu), 6×6 cm (CiS);
- Strip interconnection schemes: 2nd metal layer (DM), external cable (SMwC);
- Irradiated with protons (2×10^{14} n_{eq}/cm^2);
- Thickness: ~290 µm (CiS), ~330 µm (Hamamatsu);
- CiS senors show less charge collection losses after irradiation;
- DM vs SMwC interconnection: no significant difference.

Charge collection vs annealing at 80 deg. C

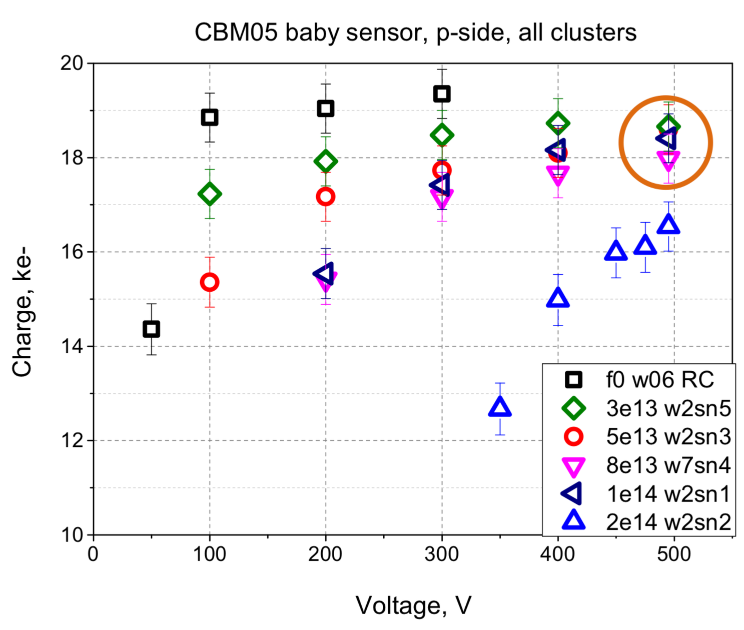


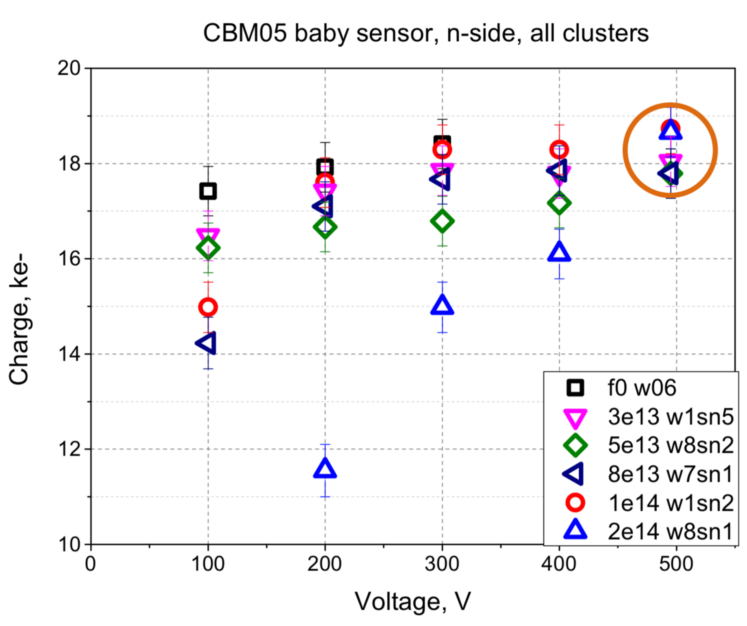
No major changes seen after 120 mins

Leakage current stability: 15 days



Baby sensors charge collection results: p-side (left) and n-side (right)





At 500 V bias applied the collected charge becomes close for most of the sensors

Summary

- The developed automated Quality Assurance system allows to identify several strip defects of sensors including pinholes, metal shorts and leaky strips;
- The charge collection of sensors irradiated to fluences from 1×10^{13} to 2×10^{14} n_{eq}/cm^2 degrade with fluence but show similar values at high voltages for both p- and n-sides;
- Charge collected vs annealing time for 120 minutes at 80 deg. C showed close to stable behaviour;
- The stability of the leakage current of irradiated sensors has been monitored for more than 2 weeks showing minor suppression over a long-term period.

[1] Thomas Bergauer, Quality Assurance of the Silicon Strip Sensors for the CMS Tracker, QA Workshop, CERN, 2011.