Radiation Hardness tests of Silicon Strip Detectors

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Facility for Antiproton and Ion Research (FAIR)

- under construction at GSI, Darmstadt
- provides high intensity beams from protons to uranium ions for several associated experiemnts
- 29 GeV proton and 11 AGeV Au beams

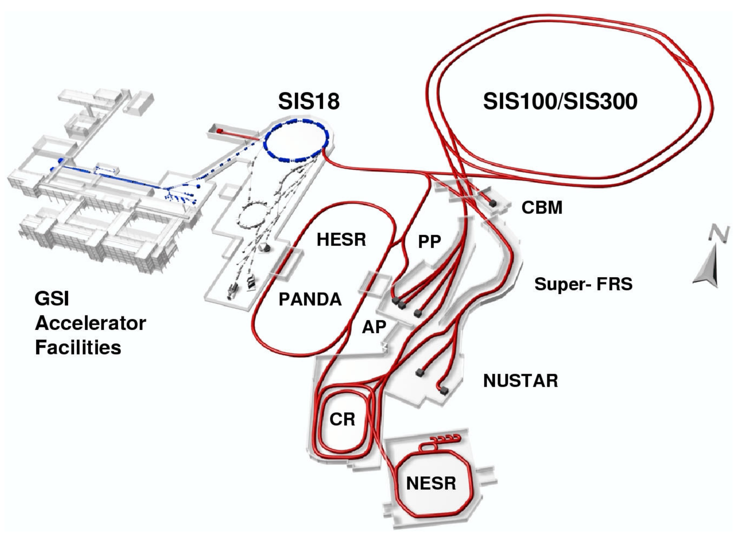

Fig. 1: Schematic view of the FAIR complex [1]

Compressed Baryonic Matter (CBM)

- probing the nuclear equation of state in the baryon-rich region
- investigation of dense nuclear matter through heavy ion collisions
- high beam intensity, fixed target ⇒ high collision rate, large statistics

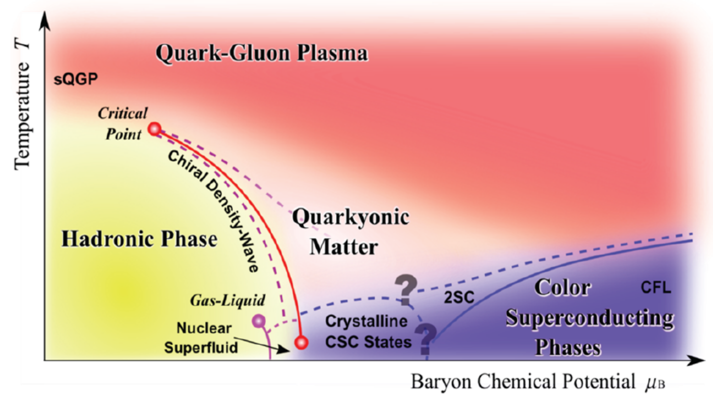

Fig. 2: Predicted nuclear phase diagram with hypothetical phase transitions [1]

Silicon Tracking System (STS)

- 8 layers of double-sided silicon strip detectors
- particle momentum measurement inside 1 T dipole magnet
- triggerless continuous readout of ∼1300 sensors

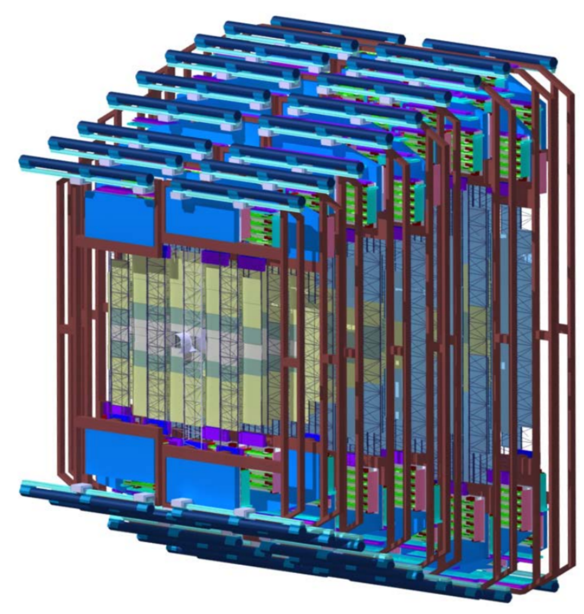

Fig. 3: Engineering study of the STS station [1]

Silicon Strip Detectors

- reverse biased silicon detectors
- 1024 strips per side
- 58 μm pitch, ∼290 μm thickness
- strips on p-side inclined at an angle of 7.5°
- several formfactors depending on position within the STS: 6 × 12 cm, 6 × 6 cm, 6 × 4 cm and 6 × 2 cm

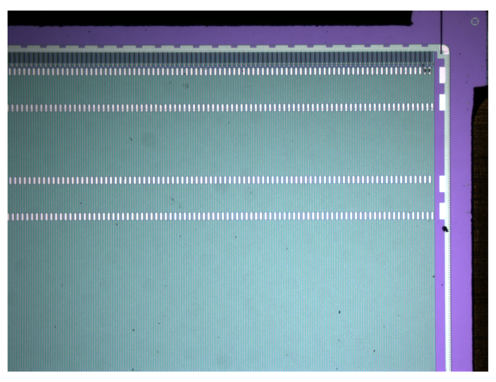

Fig. 4: Image of the n-layer side [2]

Radiation Damage

- interaction rates of 10^7 Hz cause high doses of ionizing and non-ionizing radiation (10^{14} n_{eq}/cm^2 over several years, depending on on running conditions, need to be replaced after that)
- lattice defects emulate additional doping ⇒ change in electrical properties → detector failure
- common irradiation methods very short (few minutes)
- cross-check of simulations and measurements needed with long-term irradiation and live monitoring

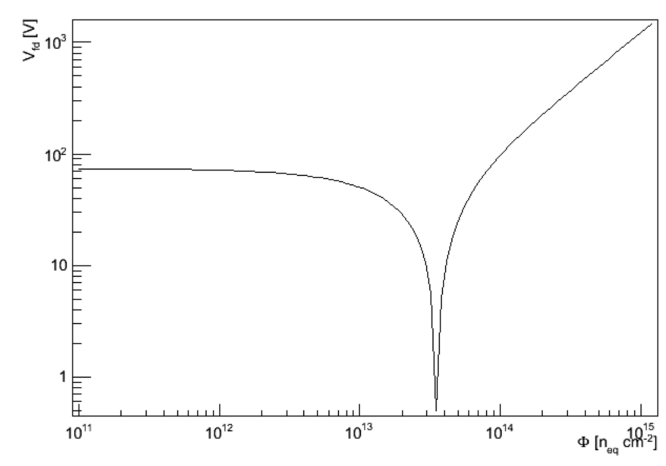

Fig. 5: Bias voltage graph showing type inversion of the detector material [1]

Irradiation setup

Neutron generation

- Rosenau Van-de-Graaf accelerator provides primary deuteron beam
- deuterium gas target installed into beamline (see Fig. 6)
- generated neutrons emerge uncollimated, but with boost in beam direction
- detector mounted close to the gas target to maximize solid angle coverage

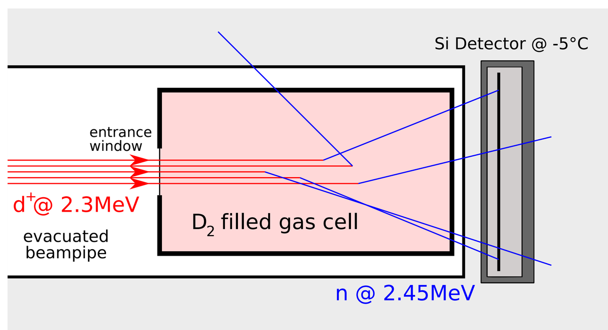

Fig. 6: Schematic view of the irradiation setup at the end of the accelerator beampipe

Challenges and gas target design

Issues of previous designs

- low deuteron energies (∼ 2.5MeV) ⇒ thin entrance window with low Z required
- high gas density necessary to maximize collision probability
- high target gas pressure (∼ 4 bar) causes large sresses on entrance window
- beam energy deposition heats up and weakens entrance window ⇒ reduced lifetime

Improvements

- 1μm thin window from Si or SiN
- cooling by liquid nitrogen(via copper rod)
- beampipe vacuum provides thermal insulation
- small gas target length improves solid angle coverage of detector

⇒ increased gas density without increasing pressure, increased window lifetime due to lower temperature and pressure

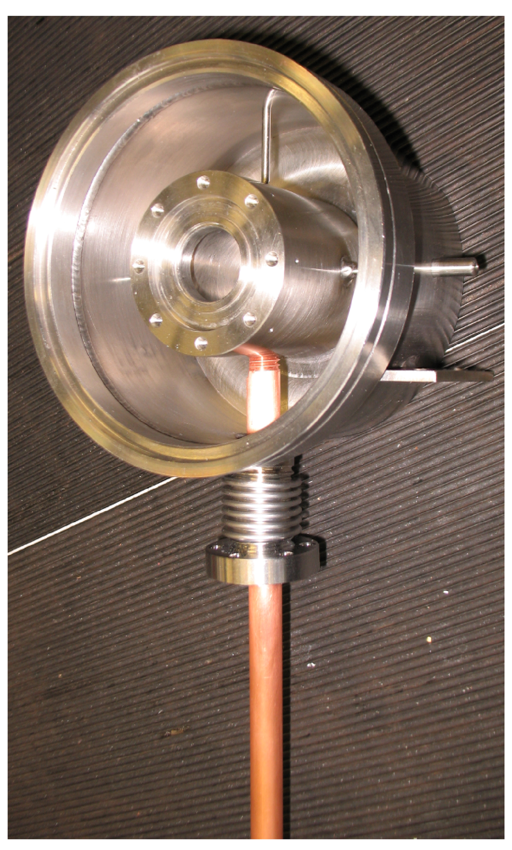

Fig. 7: Image of the finished gas cell without the entrance window

Readout system

Detector holder

- stainless steel housing, electromagnetic shielding
- Peltier cooling to −5°C (STS specification)
- light-tight setup for PMT
- fixed connection between Alibava daughter board and detector, necessary for bonding wires

Readout via Alibava® system

- parallel readout of up to 256 channels via 2 beetle chips
- software for testing, calibration and readout
- daughter board directly connected to sensor (see Fig. 8)
- ^{90}Sr source to generate detector pulses
- trigger signal provided by plastic scintillator + PMT, reduces noise issues

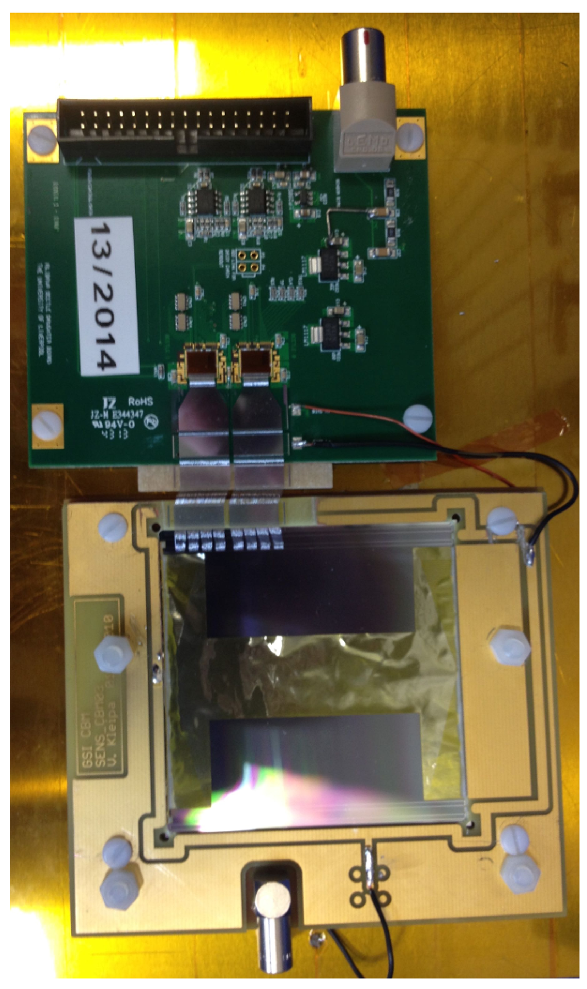

Fig. 8: Detector connected to the Alibava daughter board at GSI

Current status

Irradiation setup

- gas target operational
- liquid nitrogen dewar provides ∼1 week cooling time
- additional insulation necessary to account for beam heating

Detector housing and readout

- housing and holding structures in construction
- readout software tested via built-in simulation functions, final setup to be tested
- slow control and live monitoring in development

References

[1] (eds.) Friese, V. and Sturm, C. [CBM], "CBM Progress Report 2013", GSI Darmstadt, April 2013

[2] Panasenko, I., Universität Tübingen, 2015