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

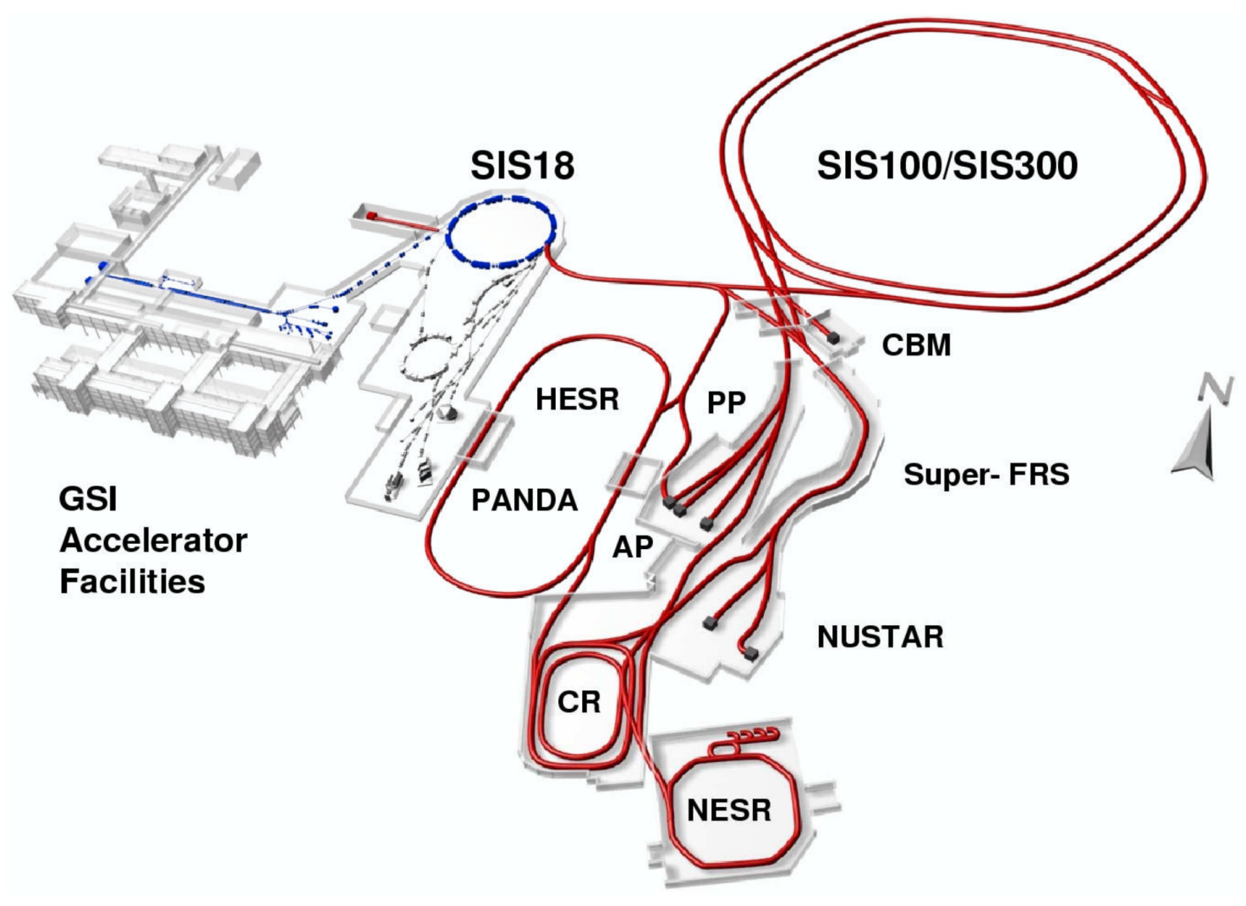

Fig. 1: Schematic view of the FAIR complex [1]

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

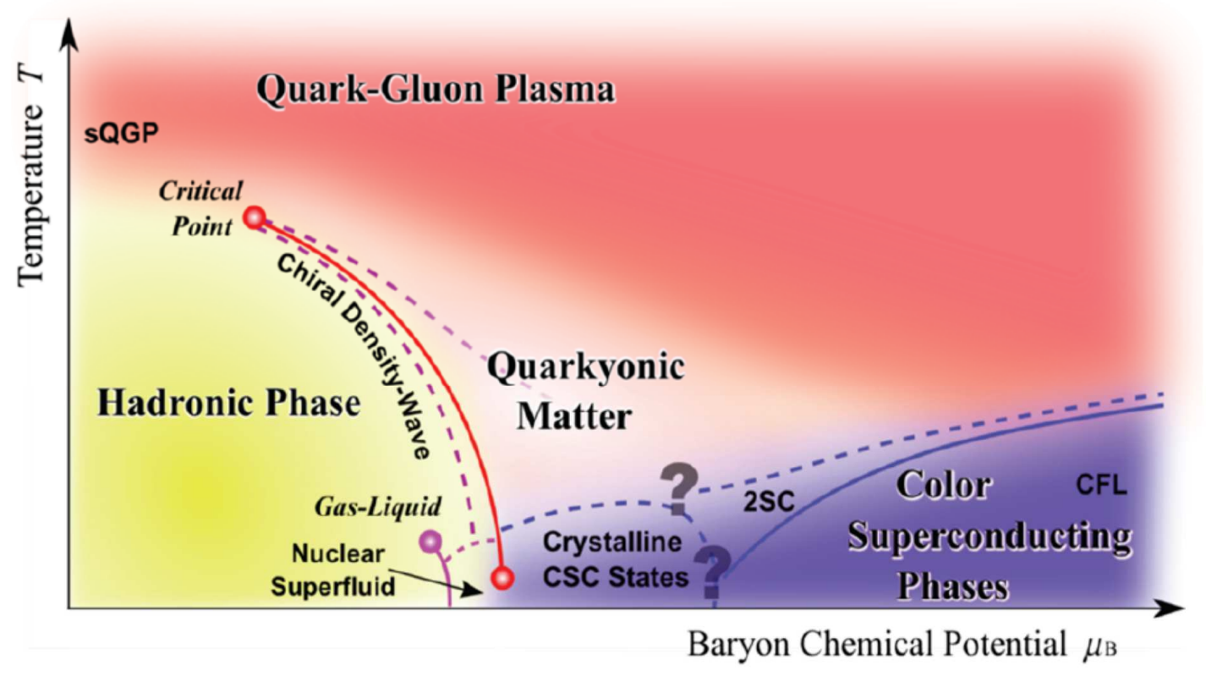

Fig. 2: Predicted nuclear phase diagram with hypothetical phase transitions [1]

Silicon Tracking System (STS)

- 8 layers of double-sided silicon strip detectors
- particle momentum measurement inside 1 T dipole magnet
- triggerless continuous readout of ∼900 sensors

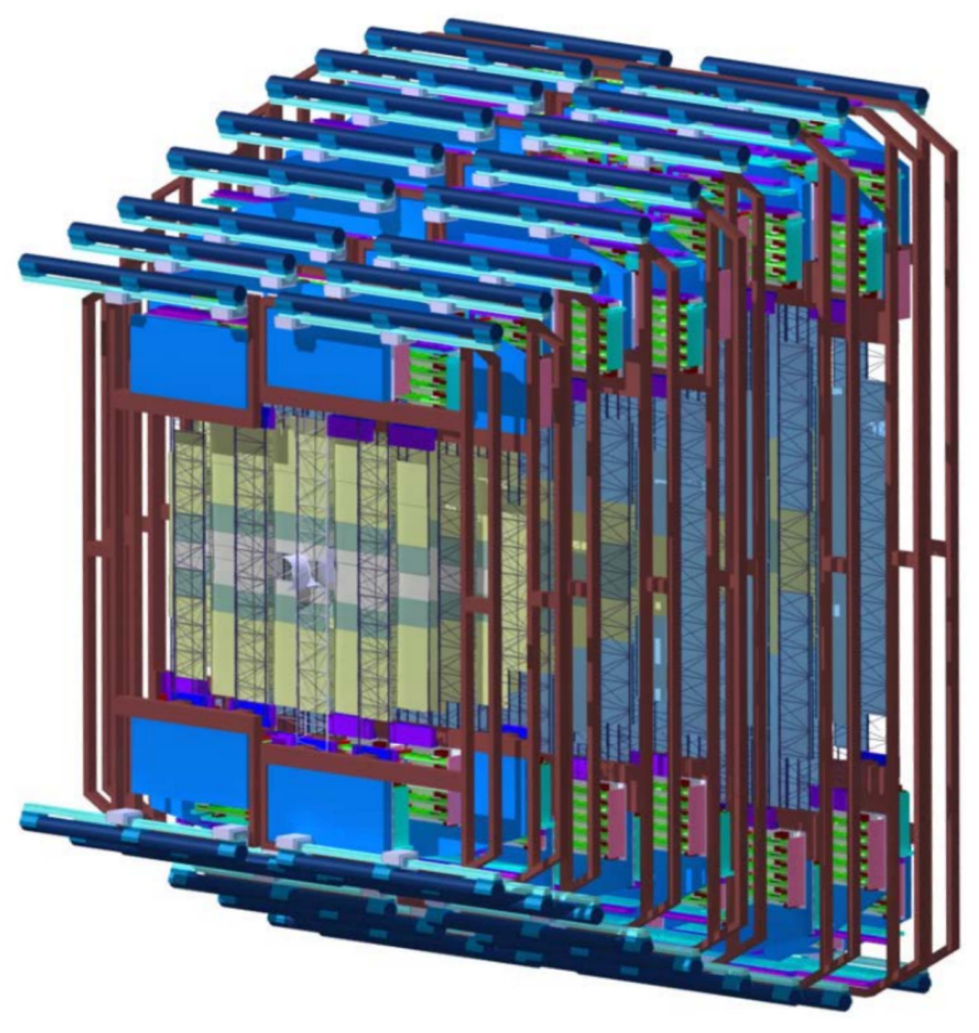

Fig. 3: Engineering study of the STS station [1]

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

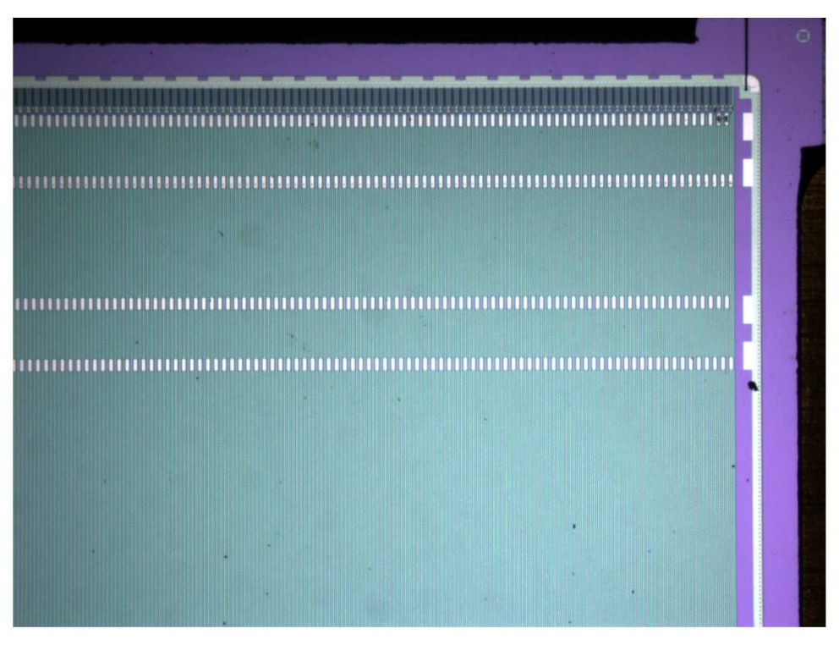

Fig. 4: Image of the n-layer side [2]

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
- free-streaming readout chain without external trigger ⇒ high signal/noise ratio crucial for detector performance
- lattice defects emulate additional doping ⇒ change in electrical properties ⇒ increase in noise and decrease in signal strength
- common irradiation tests procedures on very short time scale (few minutes)
- cross-check of simulations and measurements needed with long-term iradiation and live monitoring

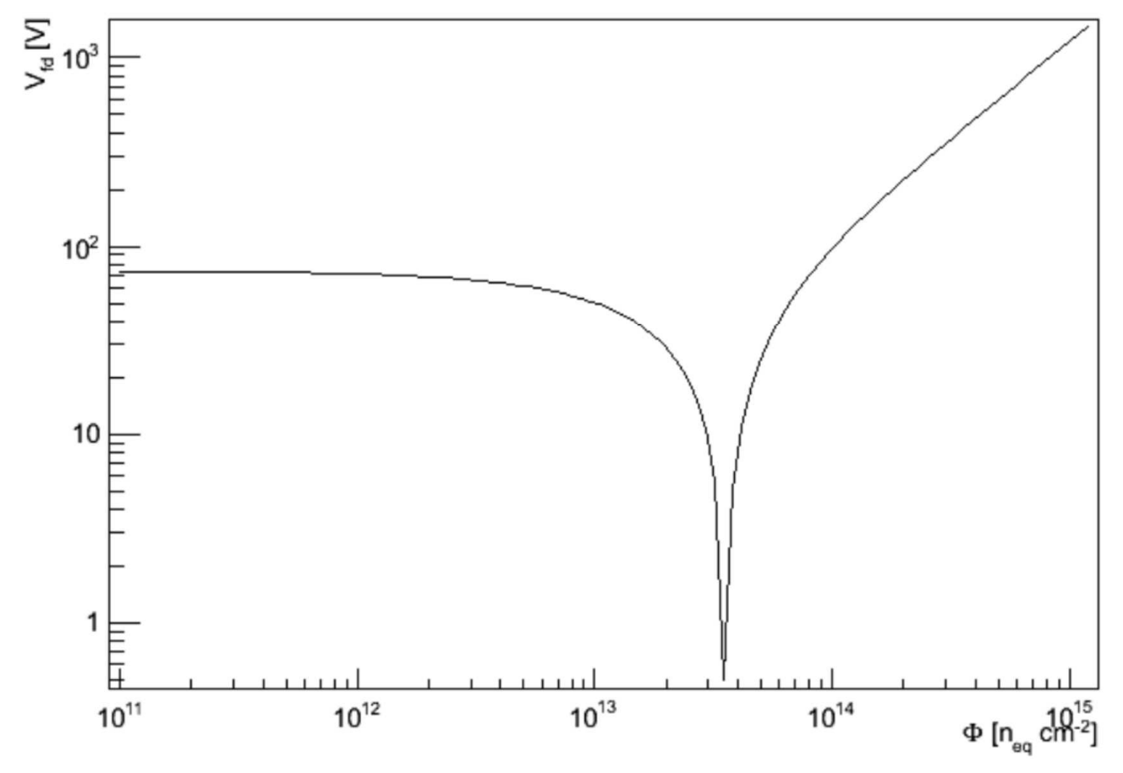

Fig. 5: Bias voltage graph showing type inversion of the detector material [1]

Irradiation setup

Neutron generation

General design

- accelerator provides 2.4 MeV deuteron beam
- deuterium gas target with high density
- D-D fusion produces uncollimated neutrons

Setup features

- 2.5 μm Ti entrance window reduces beam energy losses (≈ 0.14 MeV)
- high gas density and improved window cooling by liquid nitrogen
- compact source ⇒ large solid angle coverage possible
- thermal insulation via beampipe vacuum and additional foam layer
- cell sealed with In wire for low temperature capabilities

Monitoring capabilities

- live beam current and position measurement
- neutron rate and spectrum monitoring via scintillation detector
- temperature and pressure logging

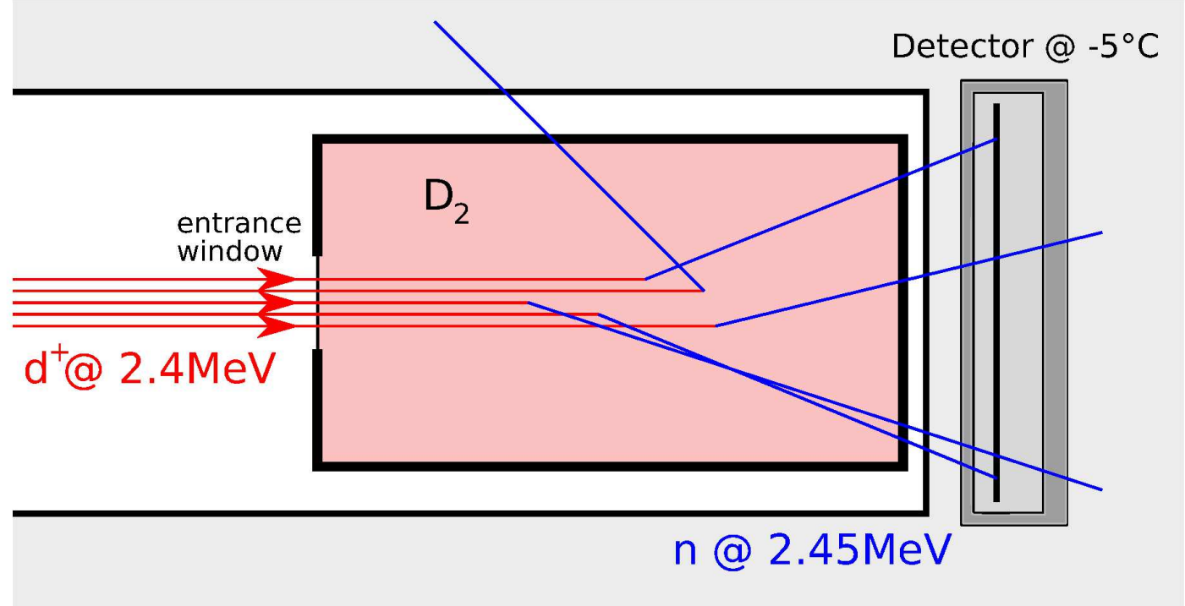

Fig. 6: Schematic view of the irradiation setup at the end of the accelerator beampipe

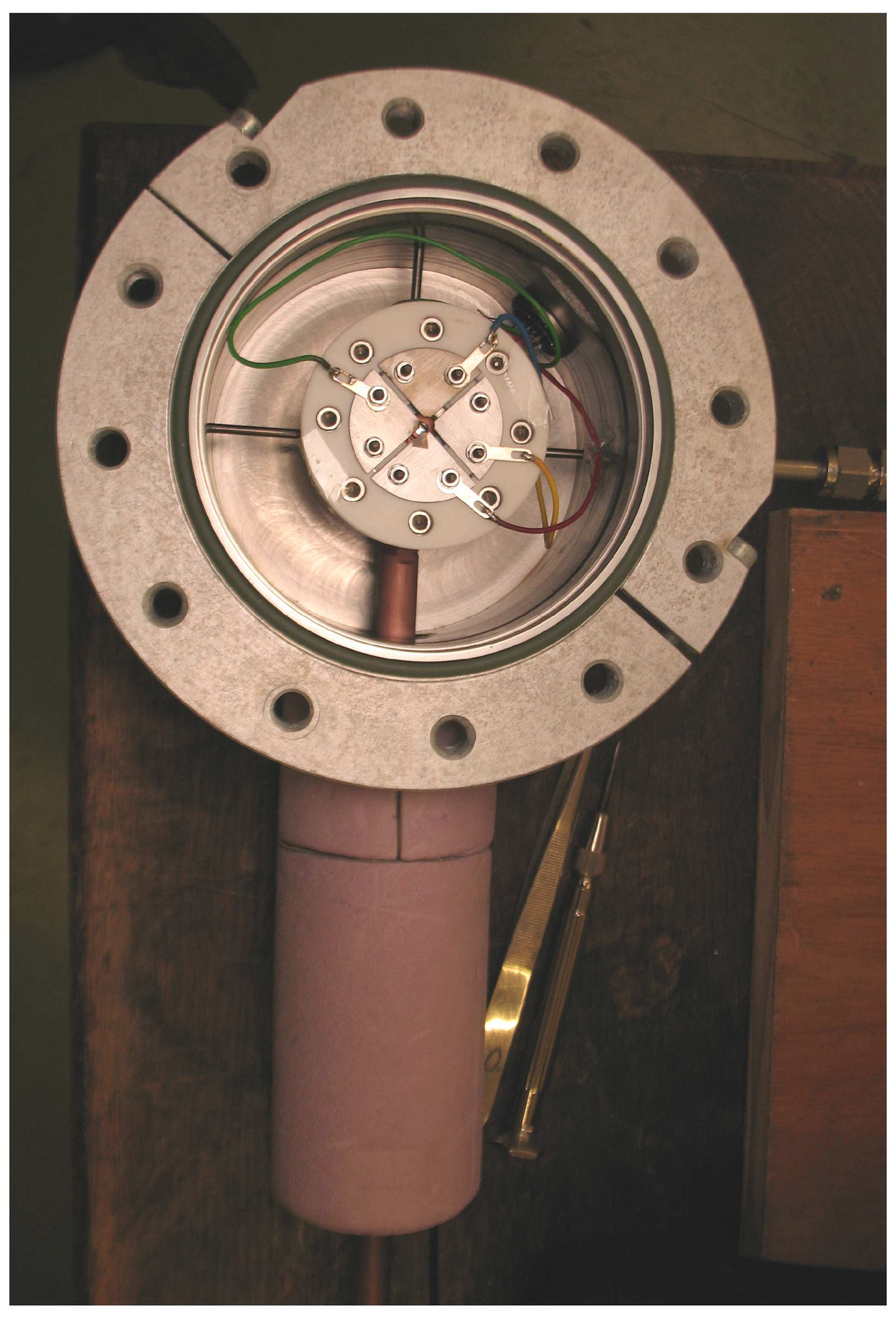

Fig. 7: Image of the finished gas cell with the entrance window and beam position plates attached

Readout system

Detector housing and holder

- stainless steel housing, electromagnetic shielding (see Fig. 8)
- light tight PTFE seal to enable PMT readout trigger
- ^{36}Cl source to generate detector pulses, 5 collimated sources
- Peltier cooling to −5°C (STS specification)
- temperature control with PT1000 thermometers
- fixed connection between Alibava daughter board and detector

Readout via Alibava® system

- 2 beetle chips, 256 channel parallel readout (see Fig. 9)
- 5 sensor areas connected to readout board, covering center to edge
- trigger signal provided by plastic scintillator + PMT, reduces noise issues
- basic software functionality tested via built-in functions

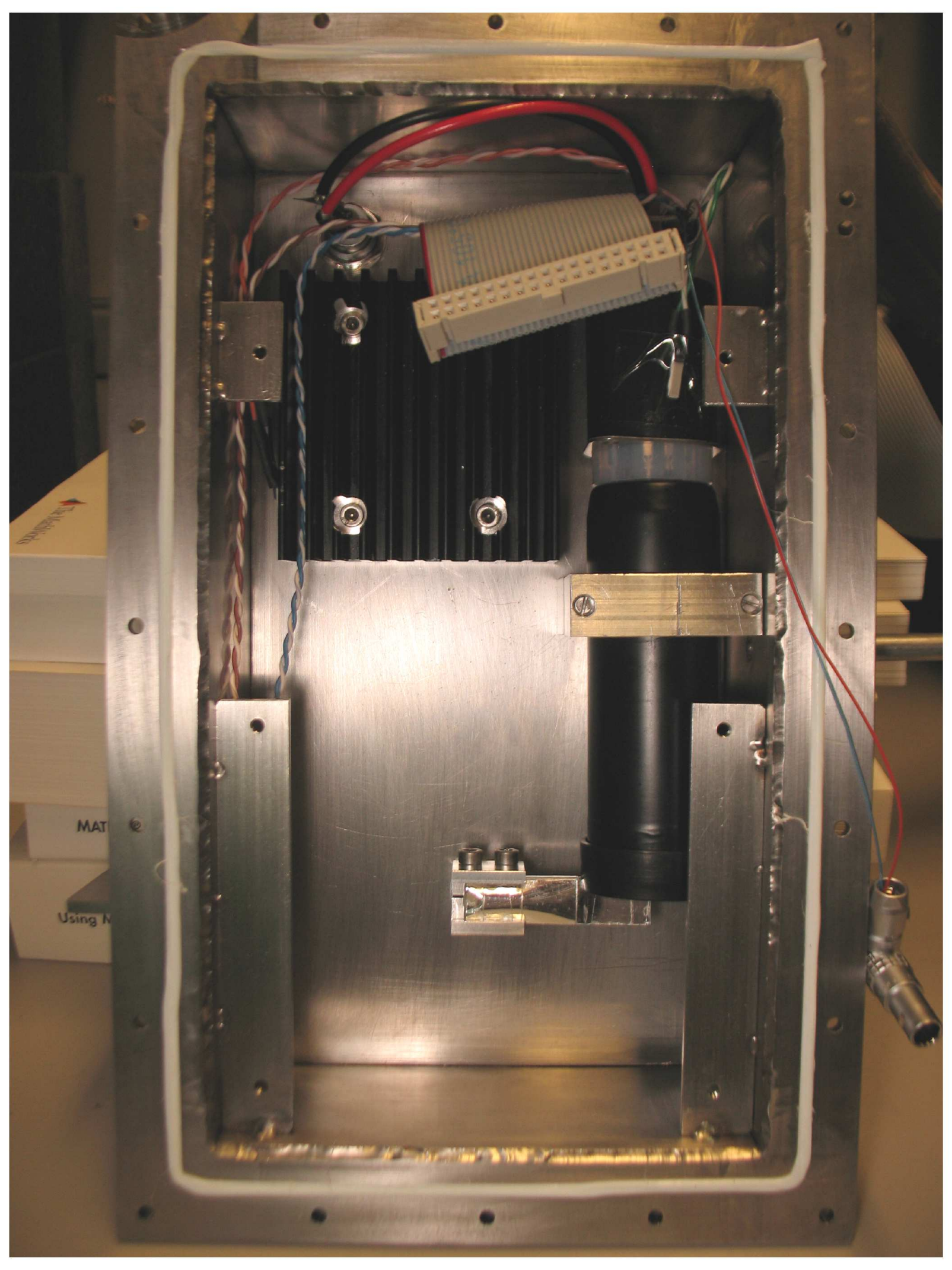

Fig. 8: Detector housing with cooling fins and PMT

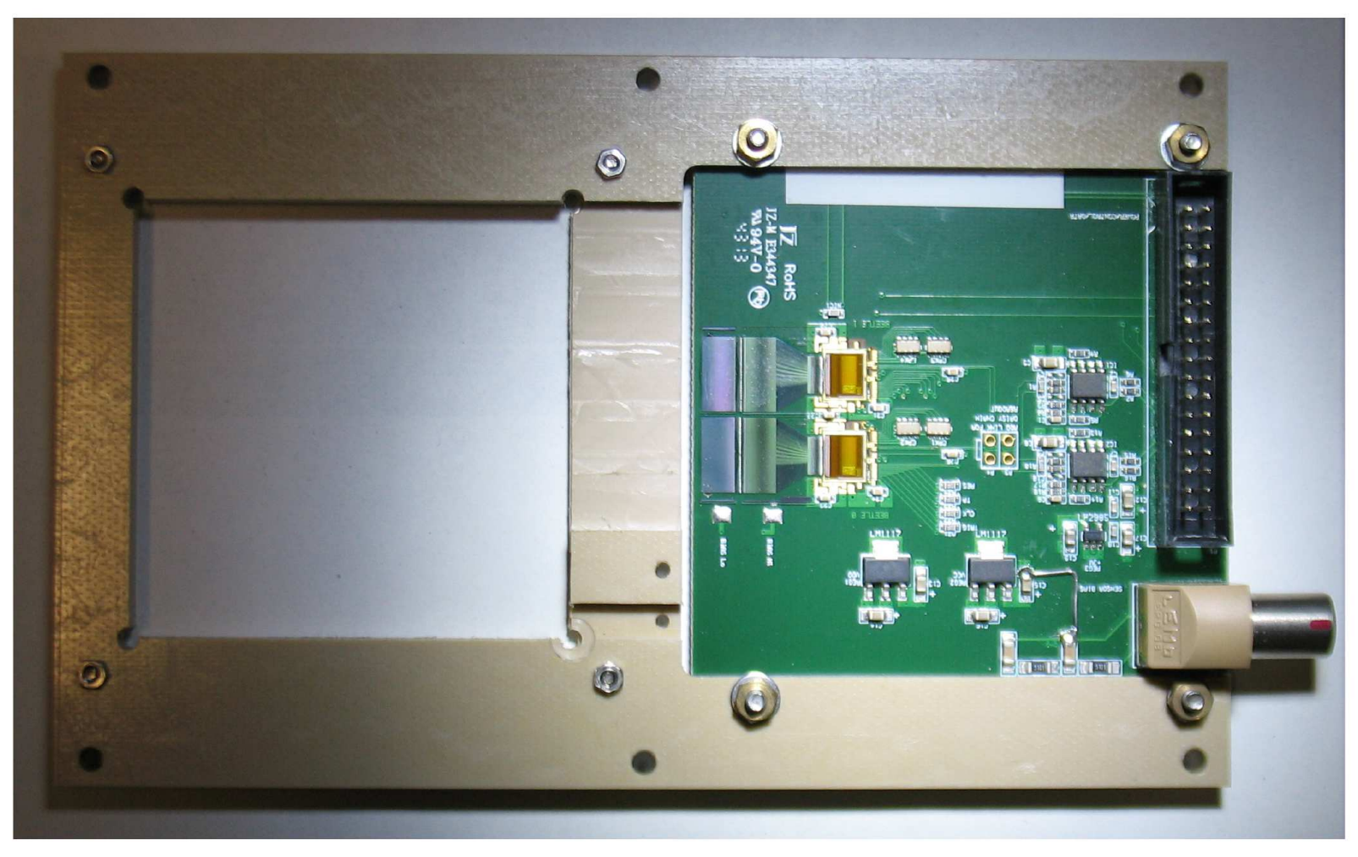

Fig. 9: STS sensor holder with attached Alibava readout board

References

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

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