Silicon Tracking System for the CBM experiment at FAIR

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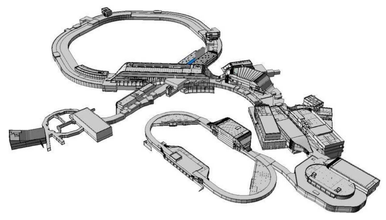
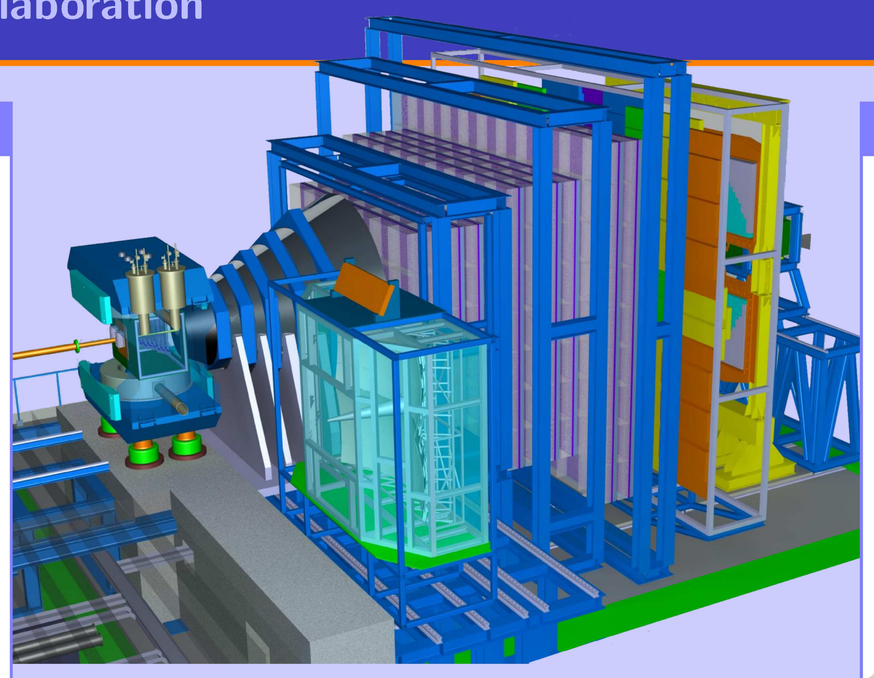
Experimental facilities

FAIR research complex



- Primary beams
  - 10^{12}/s, 1.5 GeV, $^{238}U^{28+}$
  - 10^{10}/s, $\lesssim$ 35 GeV, $^{238}U^{73+}$
- Secondary beams (including radioactive and antiprotons)
- Accelerators:
  - SIS18 *(existing)*
  - SIS100 *(to be constructed, scheduled on early 2020-s)*
  - Total synchrotron length (including beamlines) 1.1 km (3.2 km)
- Experiments:
  - APPA
  - NUSTAR
  - PANDA
  - CBM — dedicated for the Quark-Gluon Plasma studies
    - fixed target (Au-Au collisions)
    - high-rate experiment ($\lesssim$ 10MHz)
    - electron/muon configuration for systematics crosscheck
    - extreme density/temperature
- CBM Technical challenges
  - separation of detached verteces ($\simeq 50\,\mu$m)
  - fast and radiation tolerant detectors
  - free-streaming readout electronics
  - high speed data acquisition
  - 4D event reconstruction

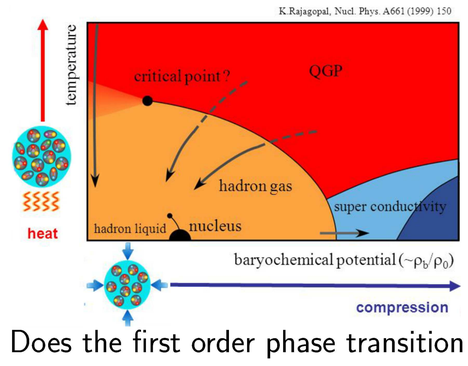


CBM tracking setup:

- Micro Vertex Detector for interaction vertex positioning
- Silicon Tracking System
- Inside 1 Tm dipole magnet (momentum measuring)

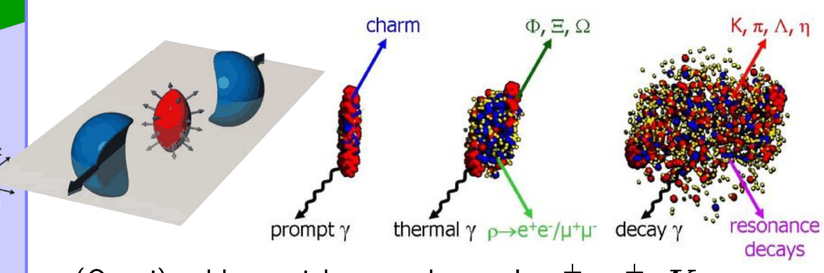
MuCh, RICH, TRD, ToF, PSD and ECAL subdetectors

Physics motivation



- Highest net-baryon densities
  - processes on neutron stars
  - early Universe evolution
- Rare observables
  - created during early expansion of the fireball

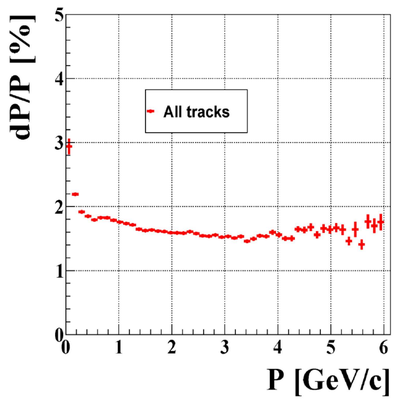
Does the first order phase transition exist?



- (Quasi)stable particles are observed: $e^{\pm}$, $\mu^{\pm}$, K, π, γ,

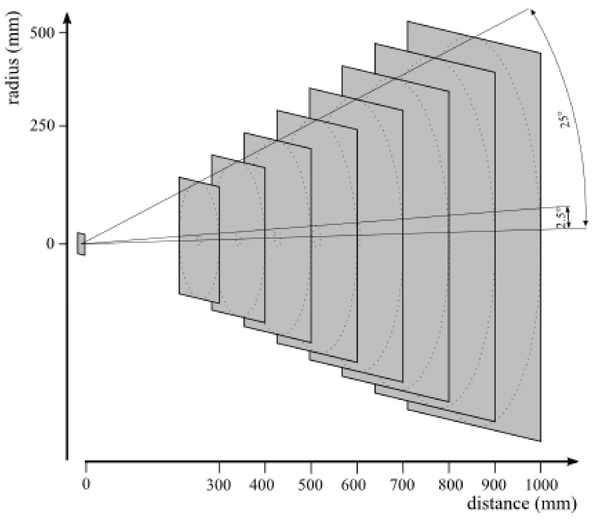
Silicon Tracker System design

- Detector acceptance
  - rapidities from centre-of-mass to beampipe
  - angular coverage $2.5° < \Theta < 25.0°$
- Low mass large area detector
  - readout electronics shifted away from the acceptance region
  - double sided 300 μm thick silicon sensors (8 stations)
  - material budget per station $\simeq 1\% X_0$
  - low scattering, high momentum resolution
  - track matching in MVD and RICH/MUCH
- Momentum resolution
  - $\Delta p/p \simeq 1.5\%$
  - up to $\simeq 25\,\mu$m single hit resolution

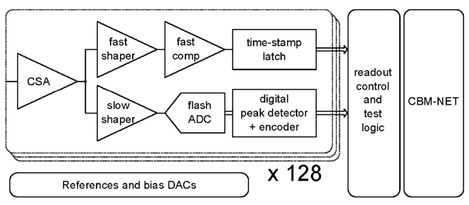


- Efficiency
  - track and single hit reconstruction efficiency $\simeq 100\%$

- STS conceptual scheme:

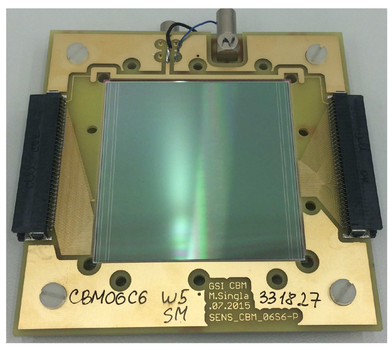


- Read-out electronics
  - self-triggering mode
  - signal shaping time < 20 ns
  - signal to noise ration $\simeq 15$ for non-irradiated sensors
  - block-scheme of the read-out ASIC:

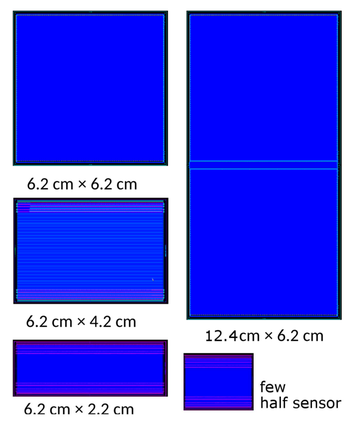


Silicon sensor types

- Double-sided n-type silicon sensors
  - 58 μm pitch
  - 1024 strips per sensor
  - AC-coupling, aluminium strips for r/o
  - 7.5° stereo angle for p-side (suppression of the ghost track rate)
- Sensor inside a sandwich PCB frame for laboratory tests:

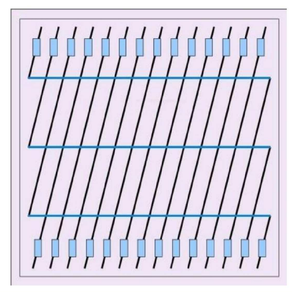


- VI generation of prototypes

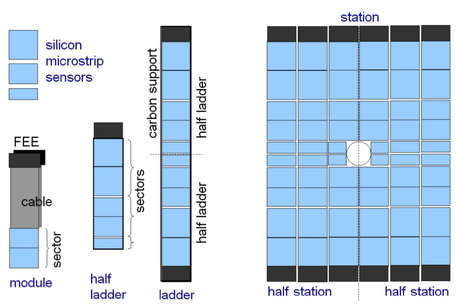


- radiation tolerance up to $10^{14}\,n_{eq}/cm^2$
- signal transfer to r/o electronics by microcable (polyimide 10 μm, aluminium 14 μm thick)

- Variety of silicon sensors to be tested:
  - by vendors:
    - Hamamatsu ($\simeq 320\,\mu$m thick)
    - CiS ($\simeq 290\,\mu$m thick)
  - routing line connection:
    - microcable (40 μm thick polyimide and 20 μm thick Al wires)
    - double metalisation (SiO_2 0.25 μm and Al lines $\sim 20\,\mu$m)

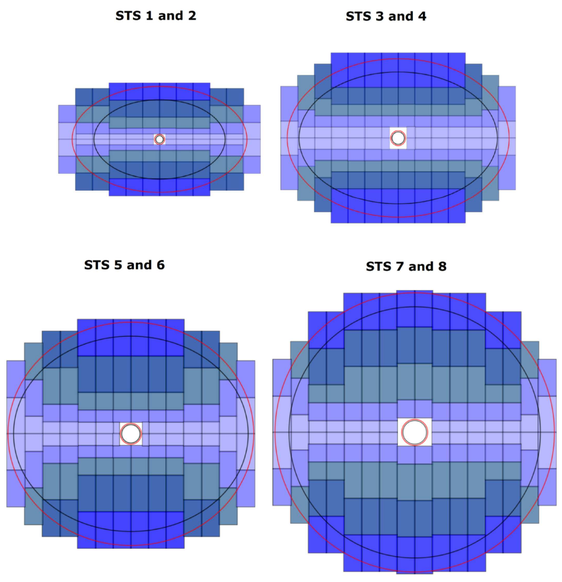


Module and station assemblies



- 8 tracking stations between 0.3 m and 1 m downstream the target
- Strips lengths — 2 cm, 4 cm, 6 cm, 12 cm
- Granularity according to the hit densities
- Components:
  - 160 ladders (17 types)
  - 896 modules
  - 1220 sensors
  - 14144 chips
  - 1.8×10^6 r/o channels

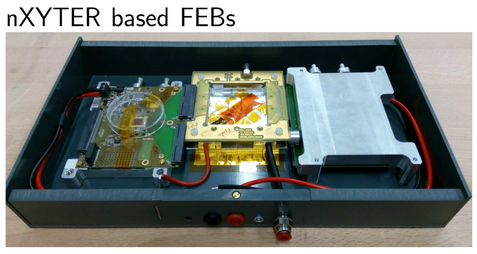
- Stations arranged in 4 duplets
- Cryogenic system, cooled with CO_2 gas



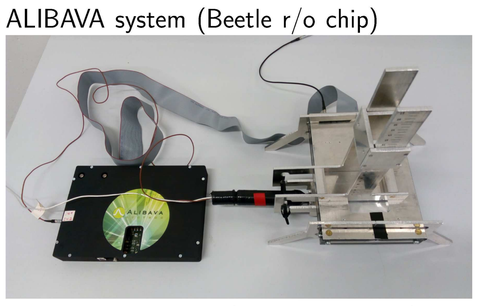
Prototype tests and quality assurance

R&D activities

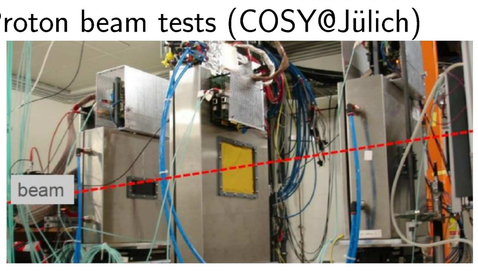
- Signal induction sources for lab tests:
  - β,γ-source radiation
  - infrared 1060 nm lazer radiation
- R/O electronics:
  - nXYTER based FEBs



  - ALIBAVA system (Beetle r/o chip)



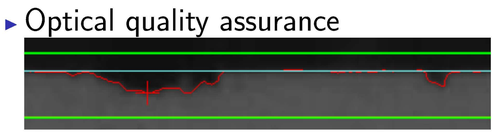
- Proton beam tests (COSY@Jülich)



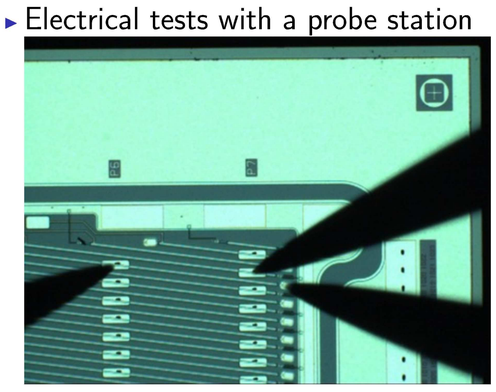
QA for the mass production stage

Workshop on Quality Assurance for the STS at Univ. Tübingen 28-29 January 2016

- Optical quality assurance

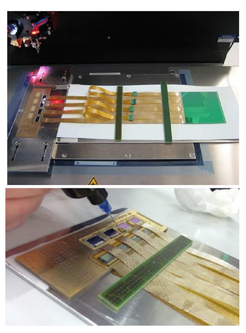


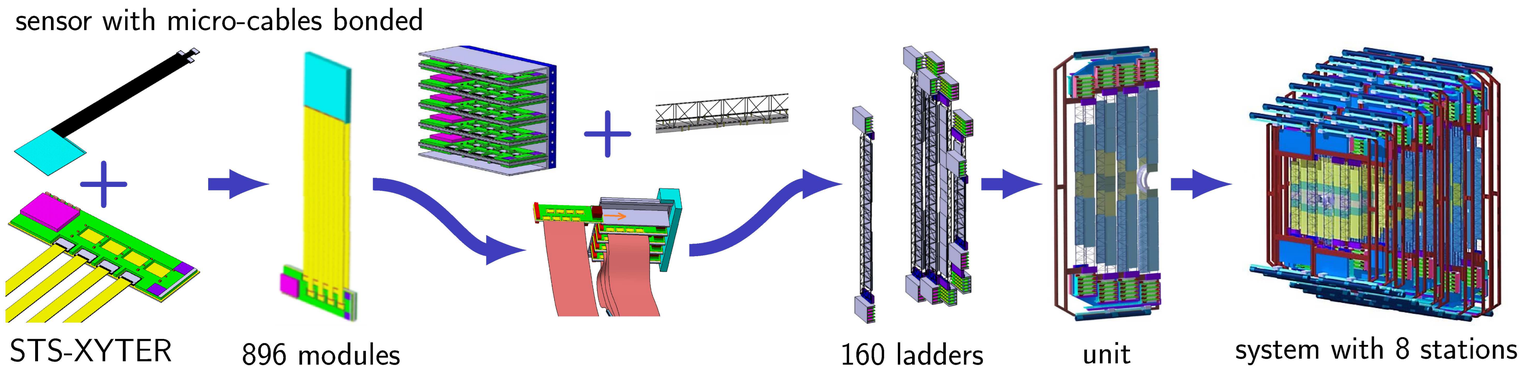
- Electrical tests with a probe station



- Measurements performed by vendors

System integration





- Challenging task of the low-mass tracker
  - severe radiation environment
  - high signal/noise requirements
  - fast detectors/fast electronics
- Studies of preferable sensor types
- Tools for the QA under development

STS project **participants** — about hundred researches from 15 institutes in Germany, Poland, Russia and Ukraine

- 2017 – sensor serial production
- 2020 – STS assembled

WE-Heraeus-Seminar on **"Semiconductor detectors in astronomy, medicine, particle physics and photon science"** 14 – 17 February 2016

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