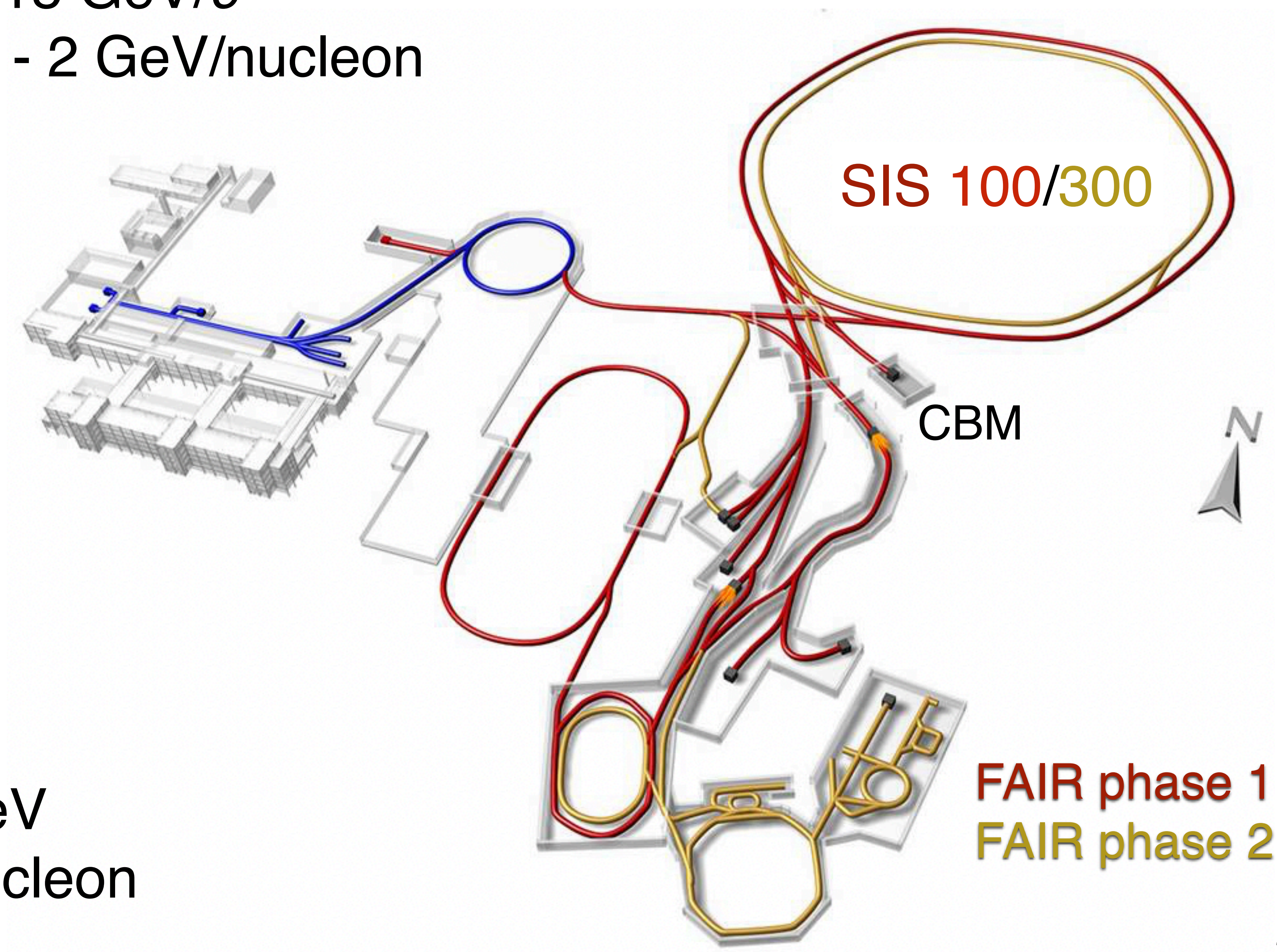
Silicon Tracking System of the CBM experiment

Anton Lymanets
for the CBM collaboration

Arbeitstreffen Kernphysik, Schleching, 29 Feb 2020

Facility for Antiproton & Ion Research

- Beam intensities up to 1000x w.r.t. current facility
- Simultaneous operation of different experimental programs:
  - heavy ions
  - antiprotons 1.5 - 15 GeV/*c*
  - rare isotopes 1.5 - 2 GeV/nucleon



SIS-100 (300)

- protons: 30 (90) GeV
- Au: 11 (35) GeV/nucleon

FAIR Project status

Construction timeline:

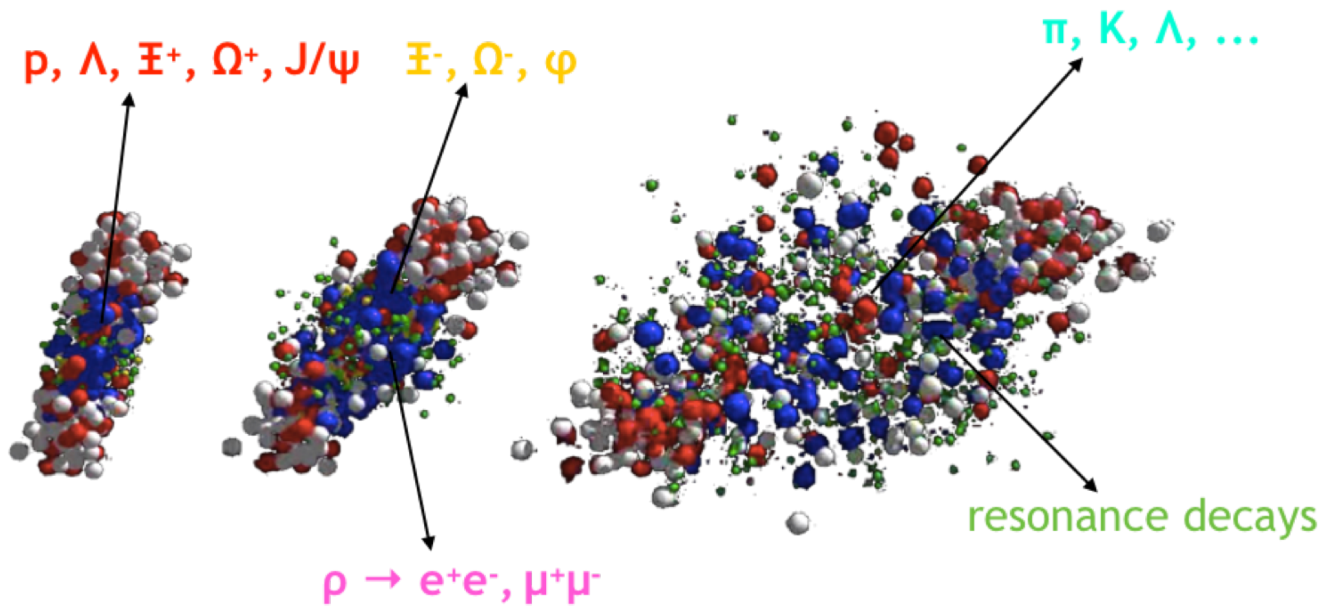
- civil construction completed in 2023
- installation of accelerators and experiments 2022 - 2024
- start of pilot beams in 2025

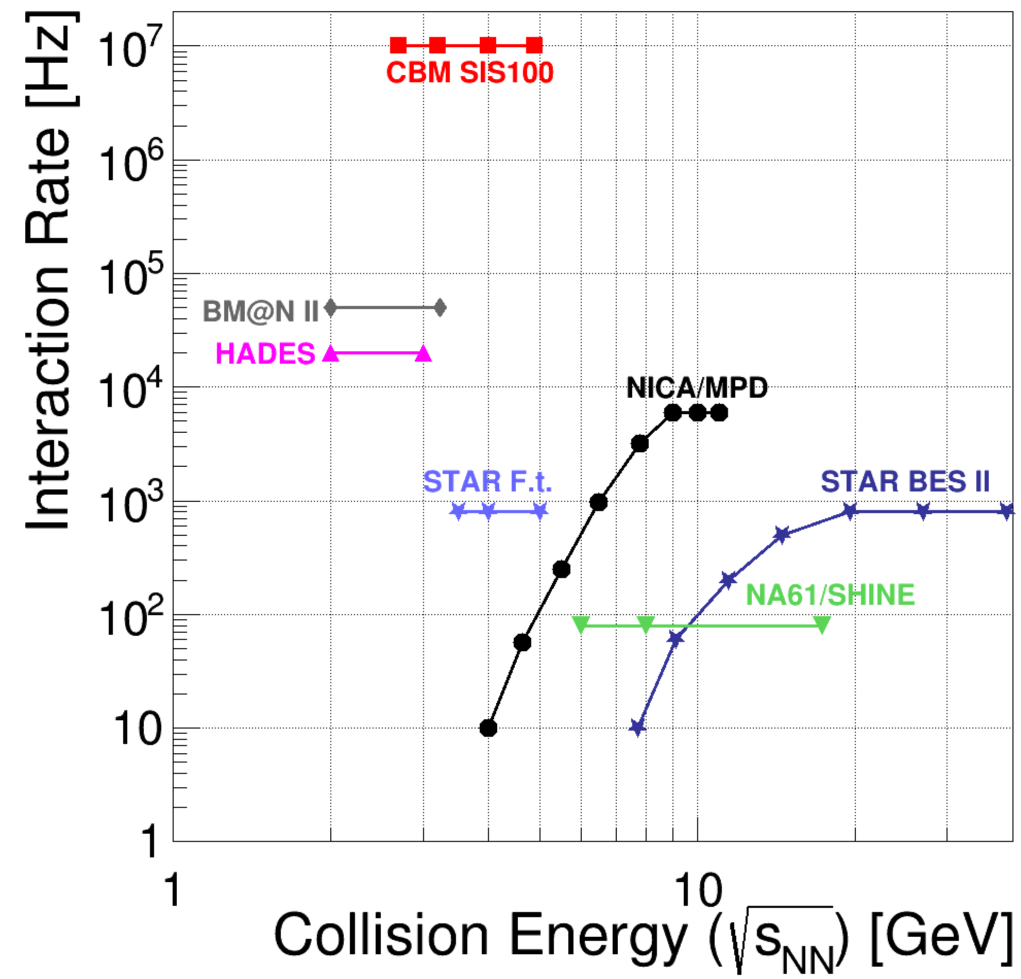
CBM cave (July 2019)

Compressed baryonic matter experiment at FAIR

Probing the dense fireball

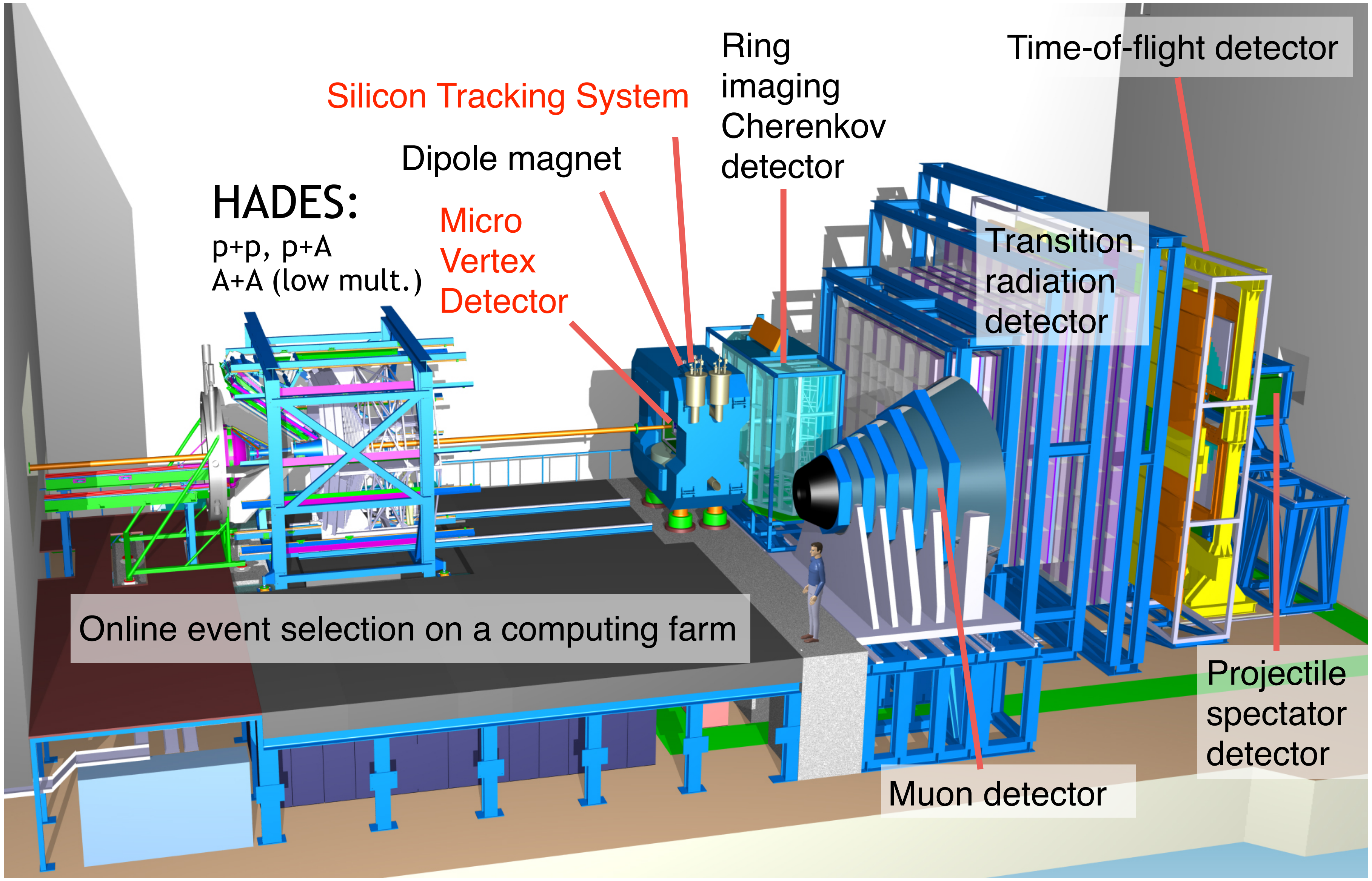
UrQMD transport calculation: Au+Au collision at 10.7 GeV/nucleon



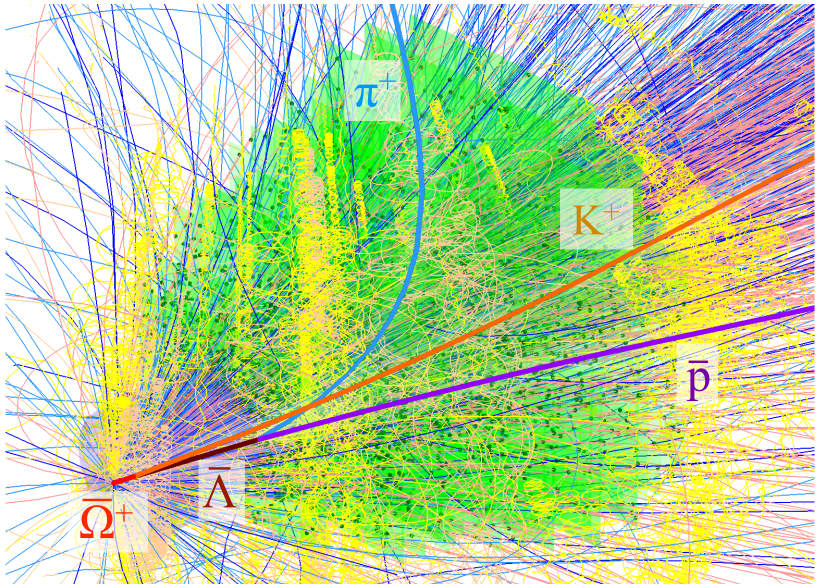


Systematic study of nuclear matter at high net baryon densities and highest interaction rates: high-accuracy measurements and rare probes

Compressed Baryonic Matter experiment



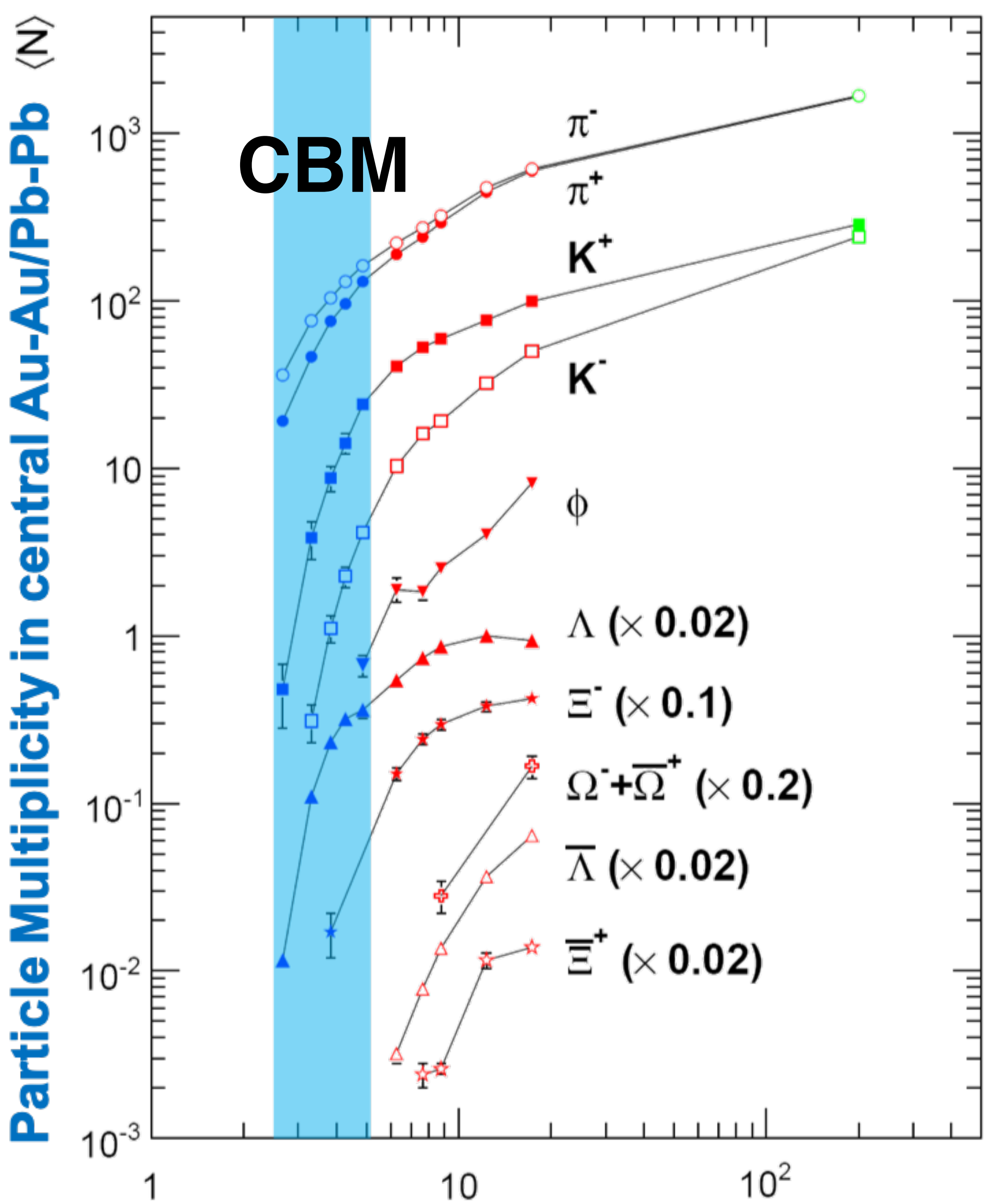
Typical operation:
Au+Au @ 4 – 11 AGeV (SIS100)
Day 1: interaction rate 0.5 MHz



- 10^5-10^7 collisions per second
- Up to 1000 charged particles/collision
- Free streaming data
- No hardware triggers (HLT only)
- On-line event reconstruction and selection is required in the first trigger level

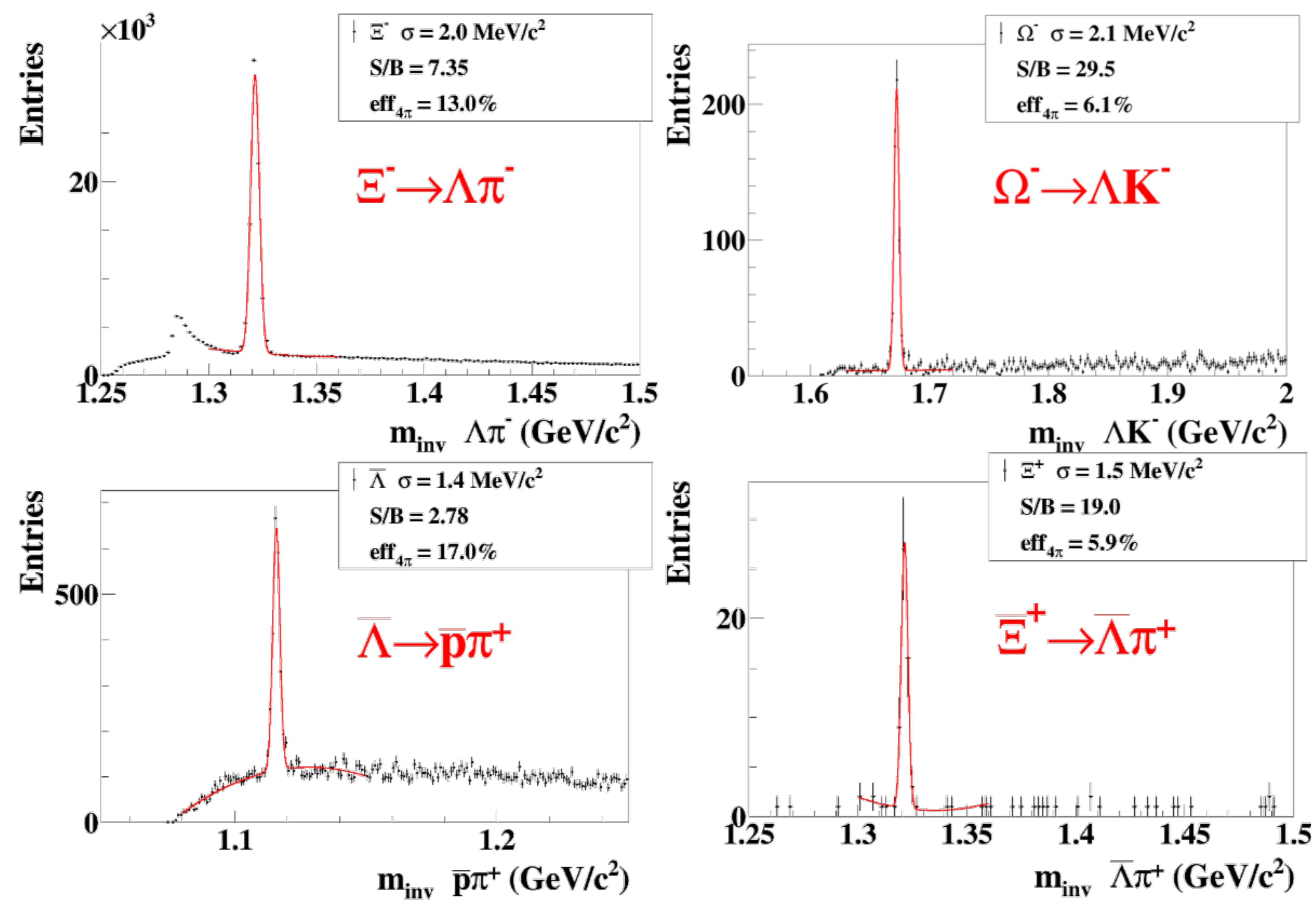
- Fast and efficient reconstruction algorithms have to be highly parallelised and scalable
- CBM event reconstruction: Kalman Filter and Cellular Automaton.
- On-line reconstruction with 60000 CPU equivalent cores

Hyperon reconstruction capability in CBM



C. Blume, J. Phys. G 31, S57 (2005) $\sqrt{s_{NN}}$ (GeV)

CBM performance using UrQMD Au+Au centr. collisions at 10 AGeV (5M evt.)



I. Vassiliev, 34th CBM Collaboration Meeting (2019)

For neutral daughter particles, missing mass method added to the particle finding algorithm: additional channels for hyperons and hyper-nuclei reconstruction.

Silicon strip detectors: operation principle

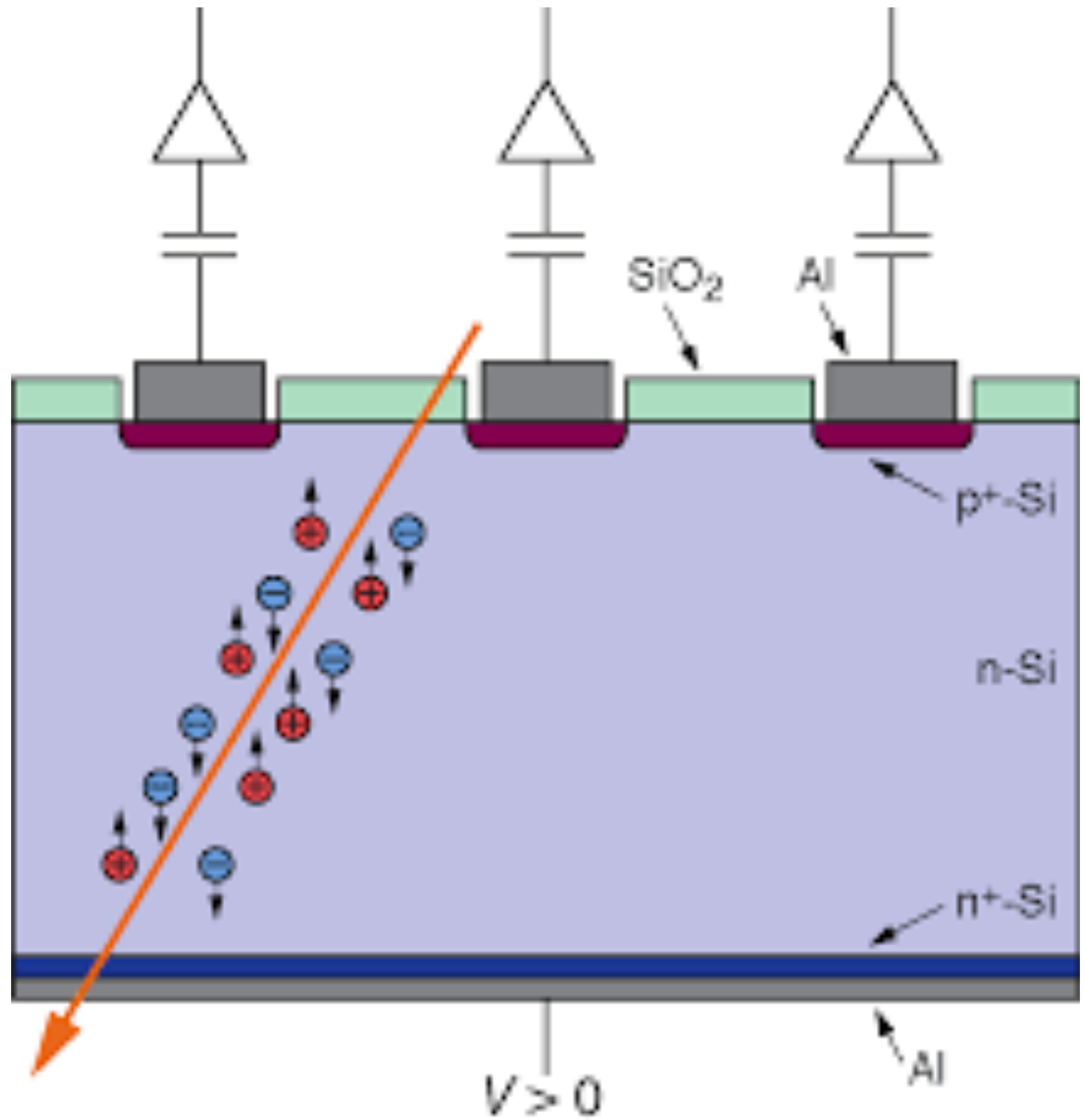


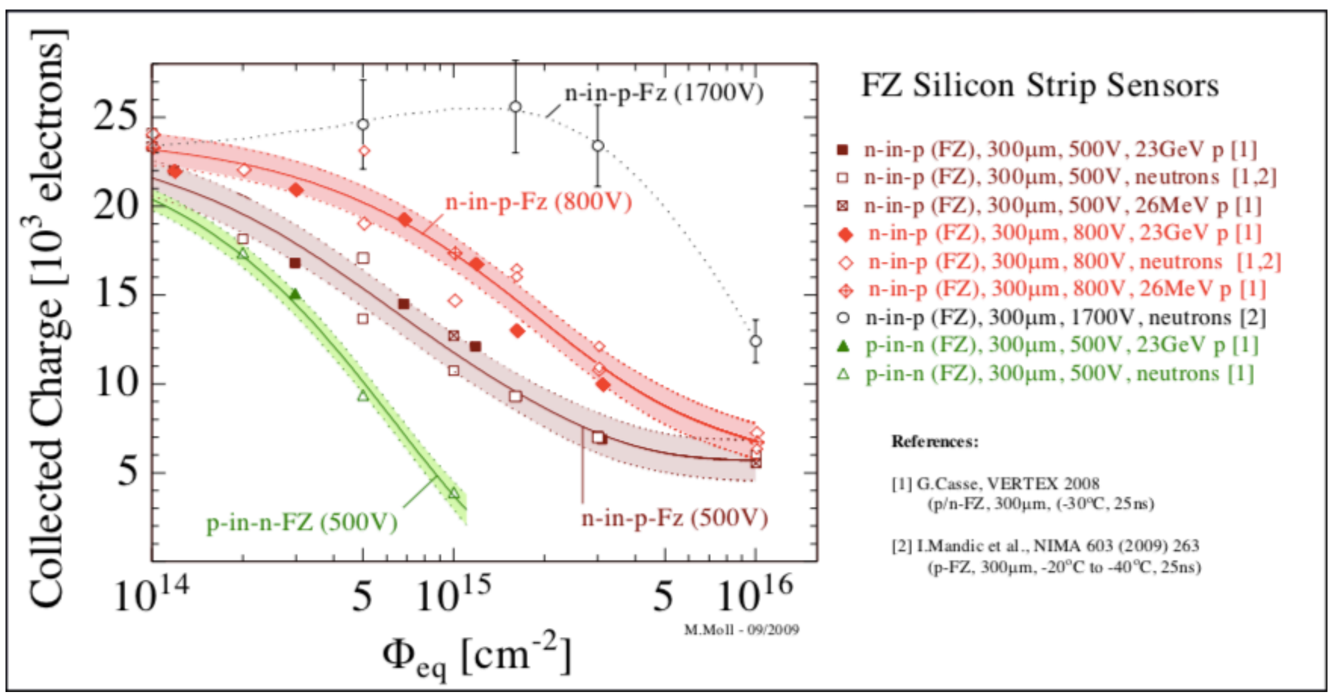
Image: hephy.at

- Drift of charge clouds of both signs induce signal in the readout electrodes
- E-field in the Si bulk is formed by the voltage applied to the electrodes and doping profile.
- Signal spread over several strips, charge deflection in the B-field: task of the hit finding algorithm
- Radiation effects in Si detectors: decrease of signal, increase of noise.

Radiation effects

<u>Non-ionising radiation</u>:

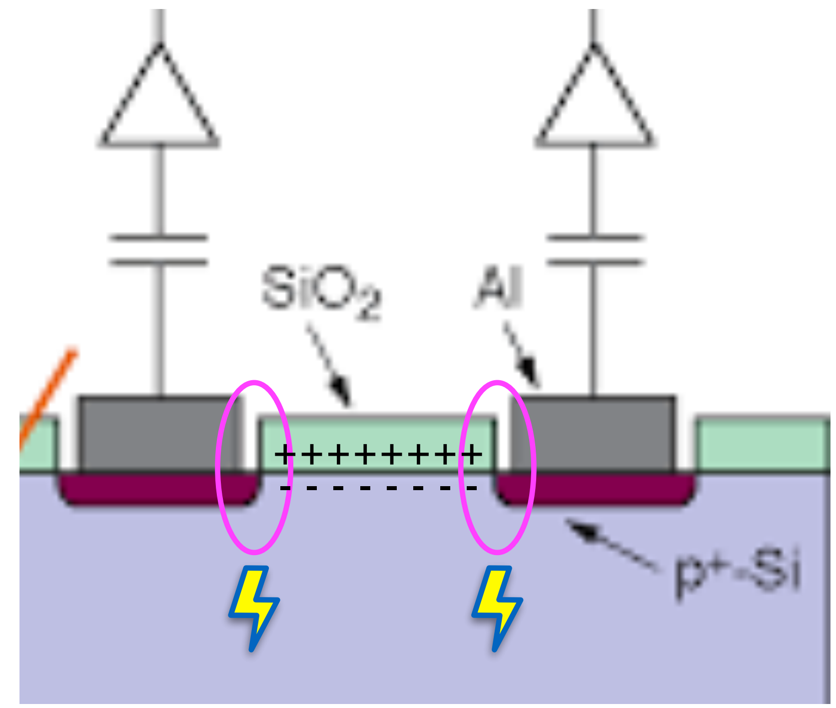
- Change of depletion voltage
- Increase of leakage current
- Increase of charge trapping



M. Moll, Si Workshop: Calorimetry with silicon (2016)

<u>Ionising radiation</u>:

- Formation of high-field regions close to strip edges (junction curvature effect)

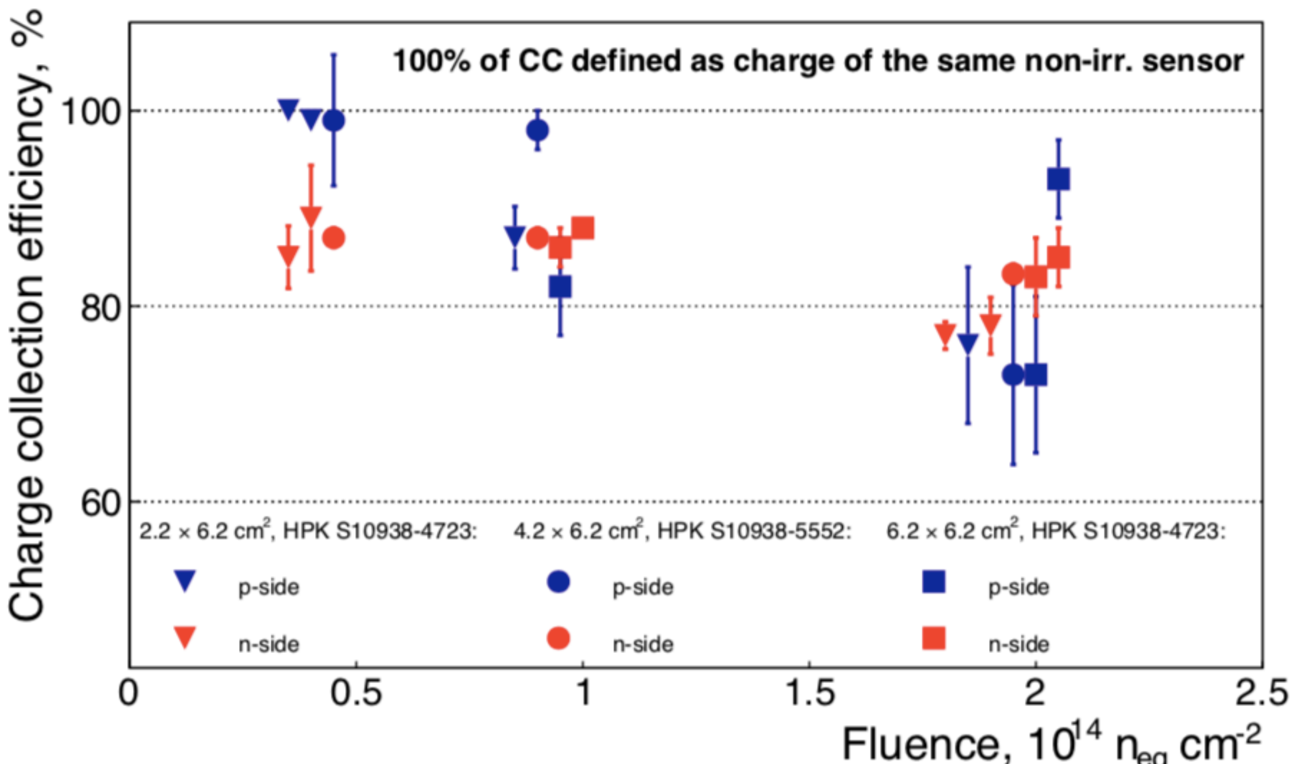


Non-ionising damage is subject to (beneficial) annealing and (detrimental) reverse annealing → Temperature exposure plan may be required between the detector runs.

Sensor breakdown behaviour must be addressed at the design stage and tested in irradiation campaigns.

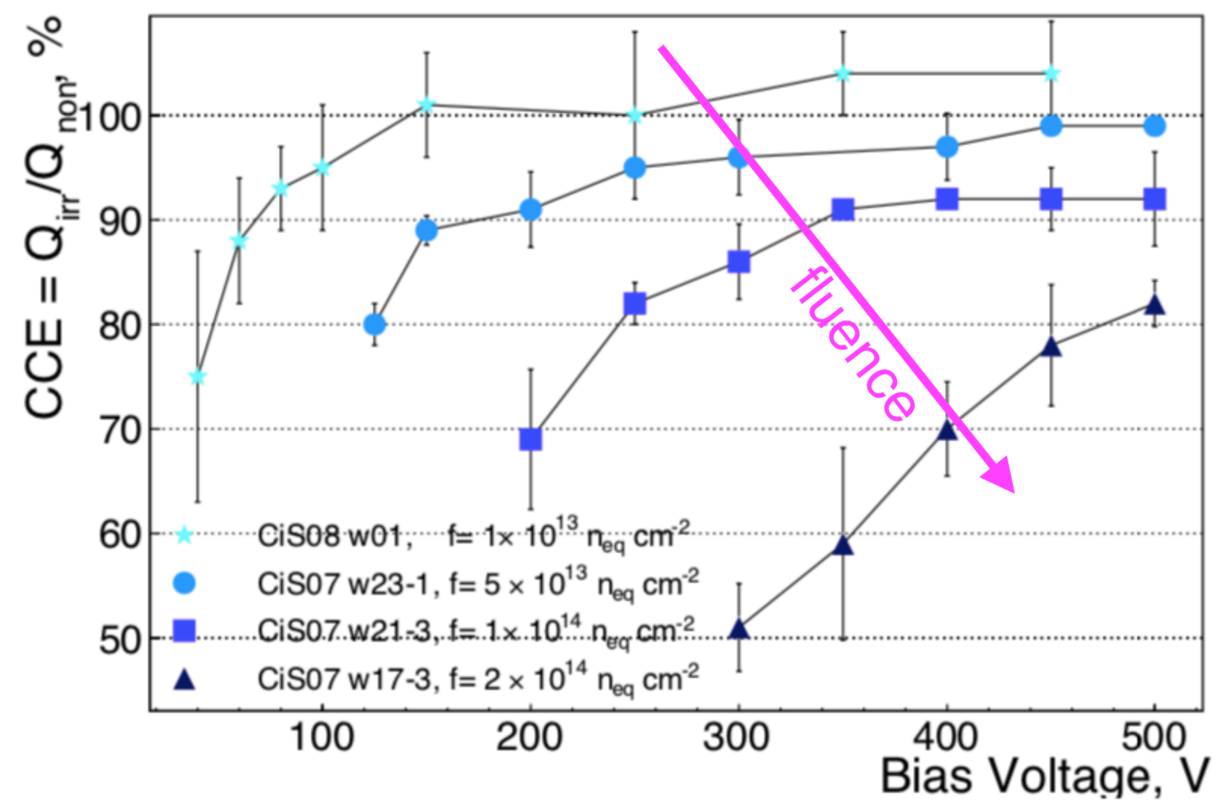
Irradiation tests for STS silicon sensors

Charge collection efficiency for proton irradiated STS sensors



2x lifetime fluence

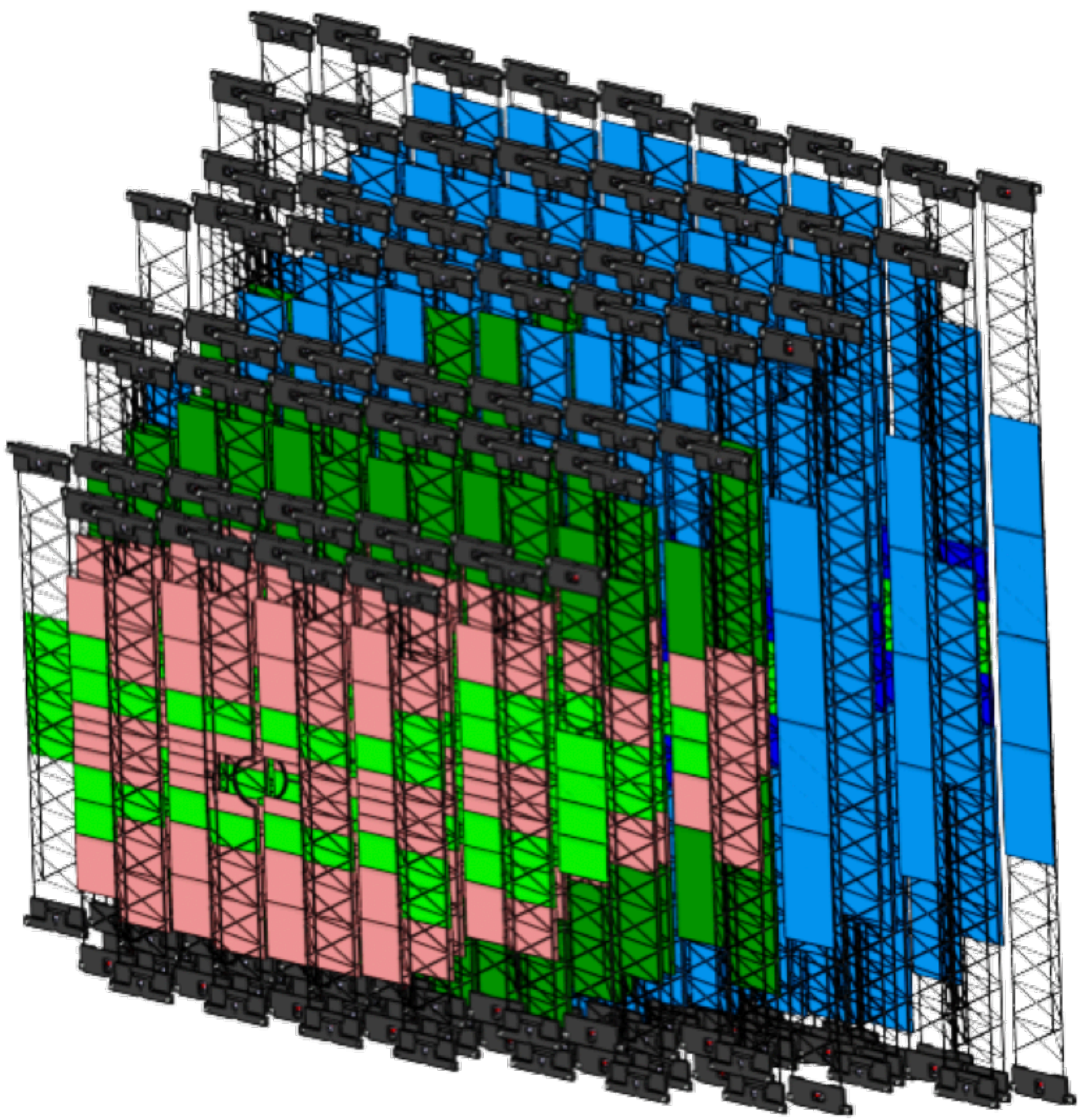
Charge collection efficiency vs. bias voltage for diff. fluences (p-side)



I. Momot, PhD thesis

- Radiation hardness of Si microstrip detectors is strongly related to their HV stability (implications for detector module design and operation).
- Detector cooling is crucial to reduce the sensor leakage current at high fluences (see next talk by K. Agarwal).

Silicon Tracking System



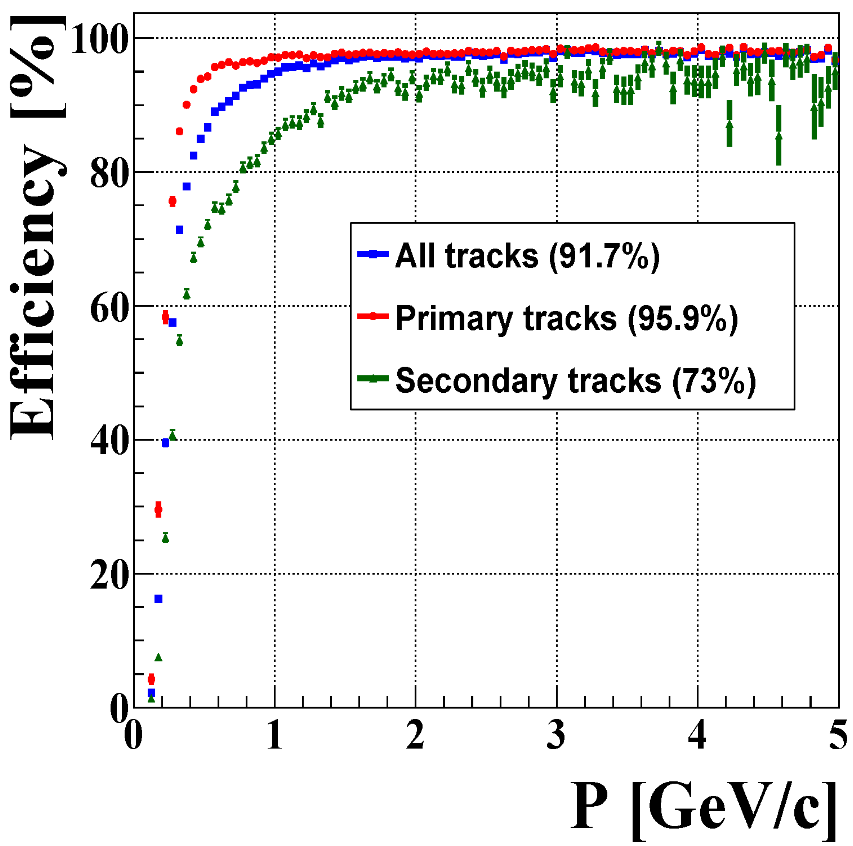
Features:

- located inside 1 Tm dipole magnet
- 8 tracking stations
- active area about 4 m^2
- 896 sensors installed onto 106 carbon fibre ladders
- low material budget <1.5% X_0 per station
- fast self-triggering readout
- radiation tolerance up to 10^{14} $n_{eq}cm^{-2}$

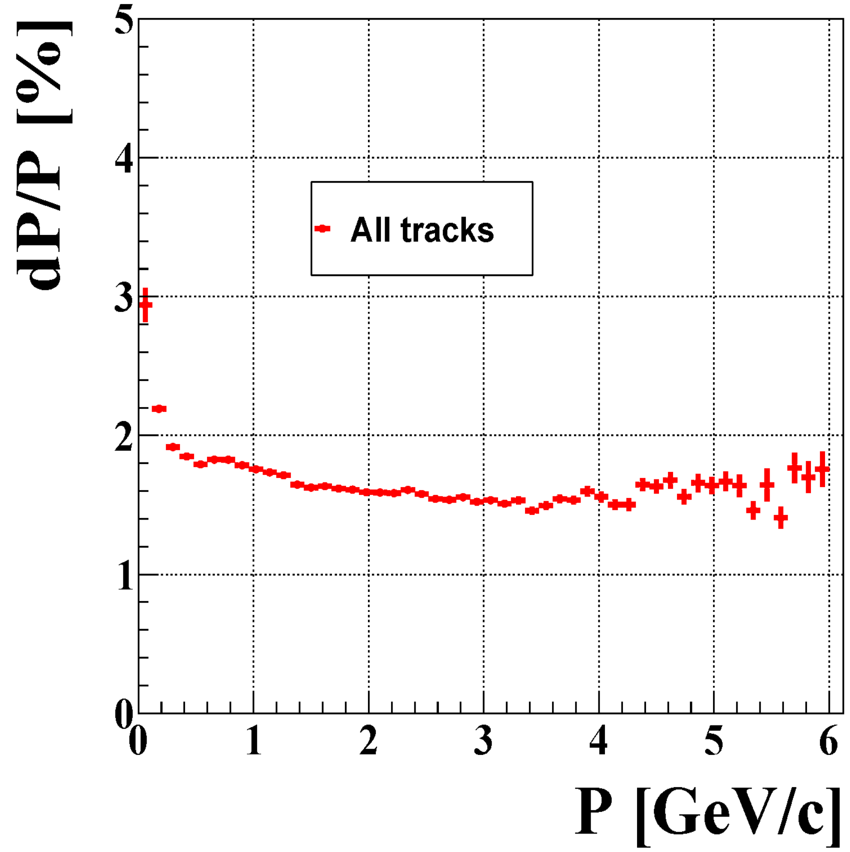
System design is driven by the minimal material budget requirement.

Simulation performance and material budget

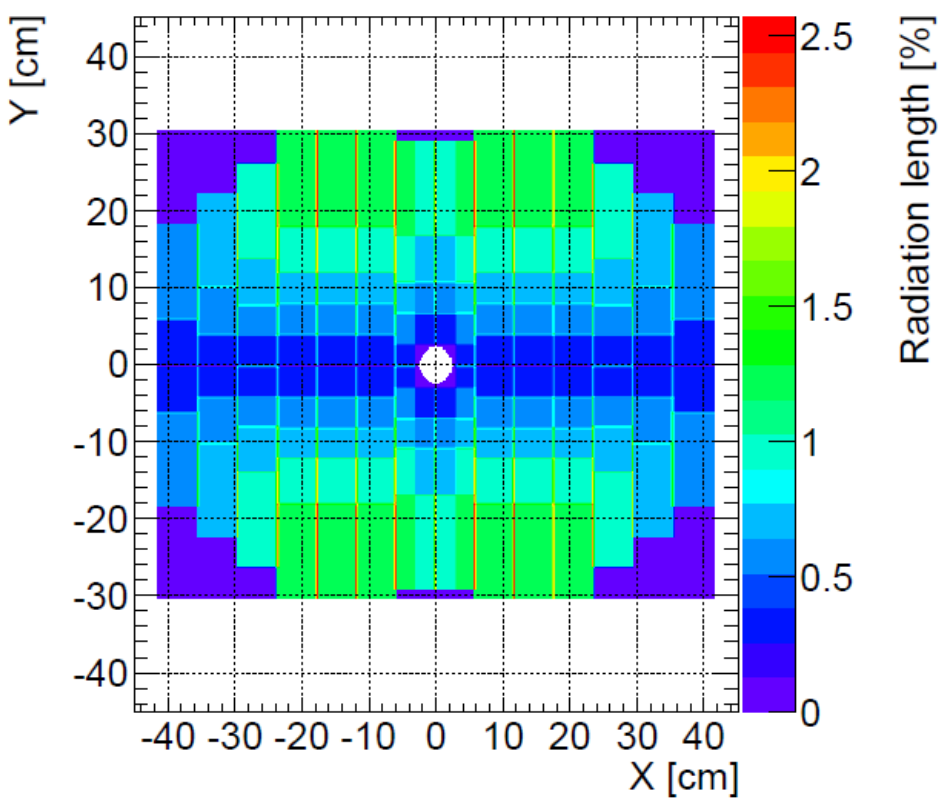
Track reconstruction efficiency



Momentum resolution

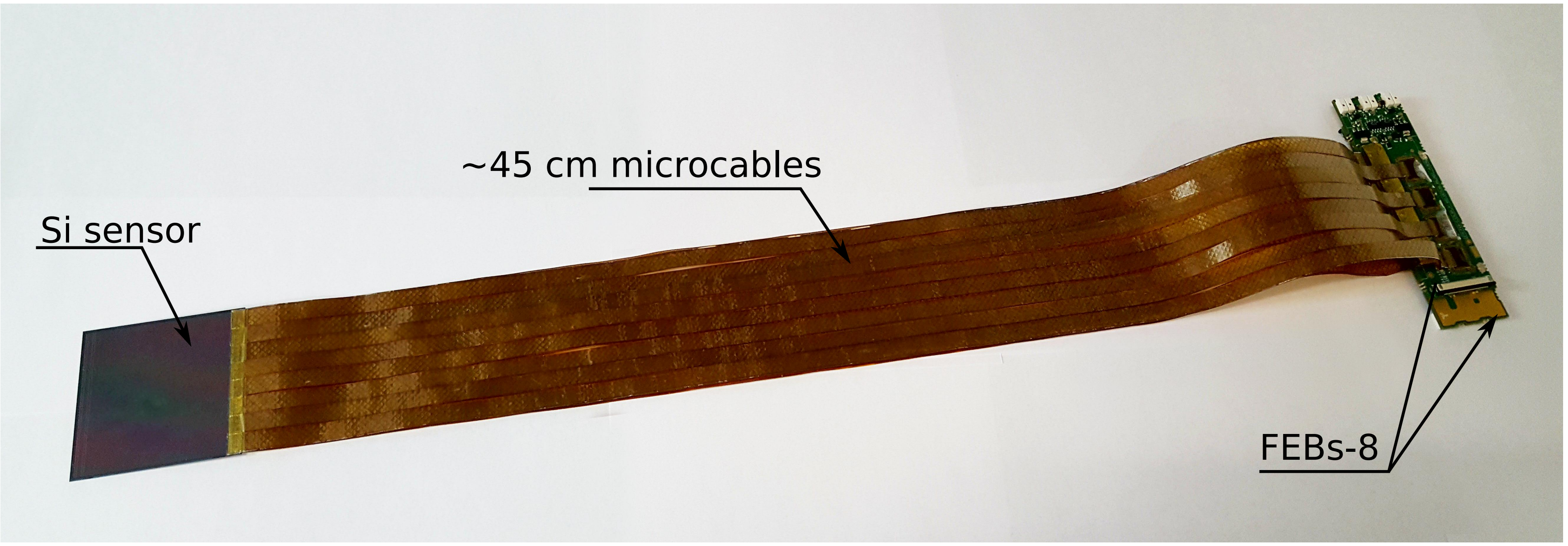


Material budget



- Track reconstruction efficiency: 98% (p>1GeV)
- Momentum resolution: 1.5 — 2%
- Material budget: 0.3 — 1.5 $\%X_0$ (sensor — periphery)

Detector module & ladder assembly

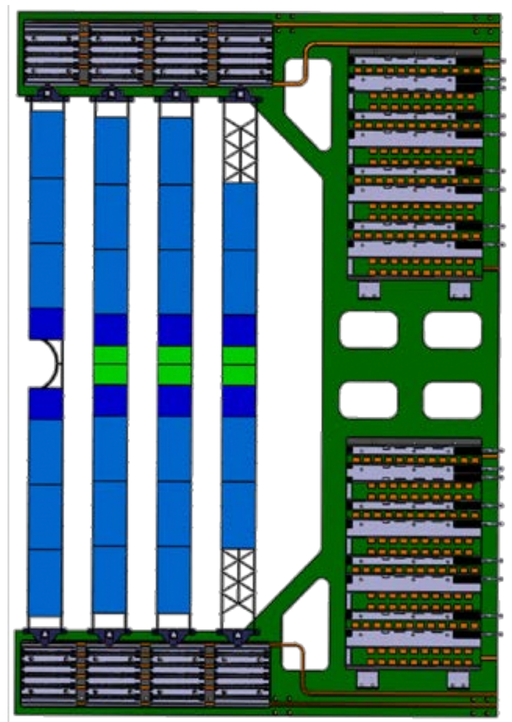


Basic functional unit: double-sided sensor + 2x16 microcable stacks + 2 front-end boards with 8 ASICs each. First full-size modules built.

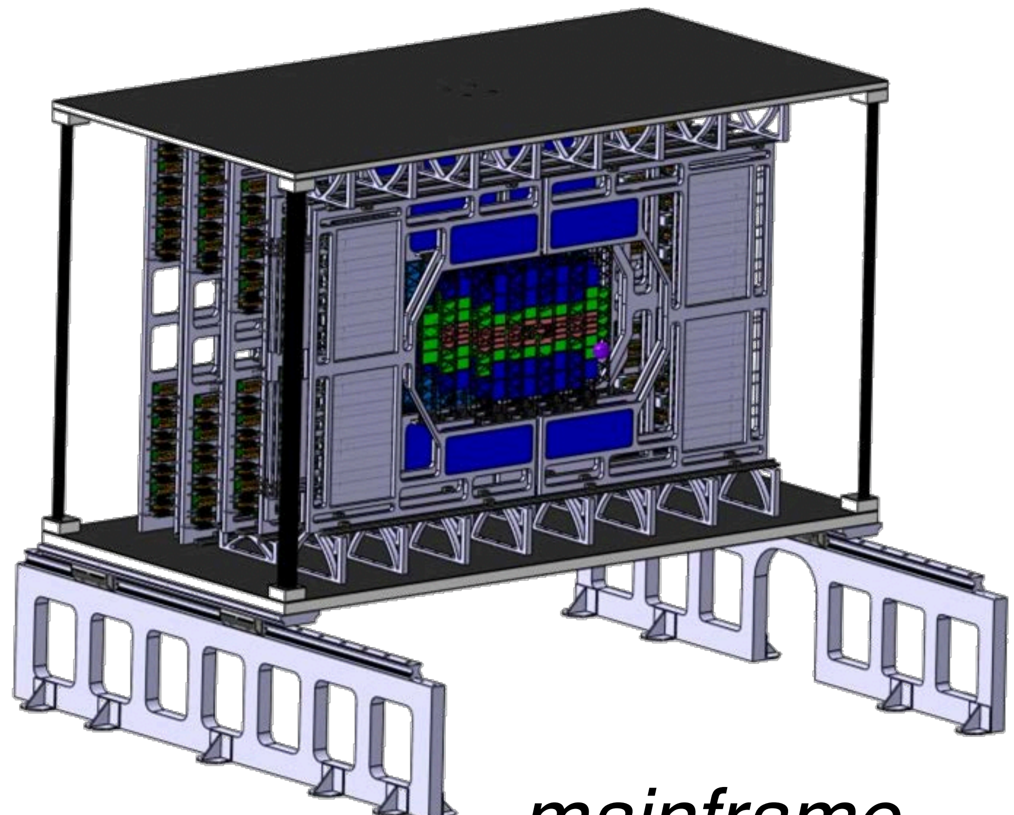
Up to 10 modules are mounted on a carbon fibre ladder using L-legs.

System integration concept

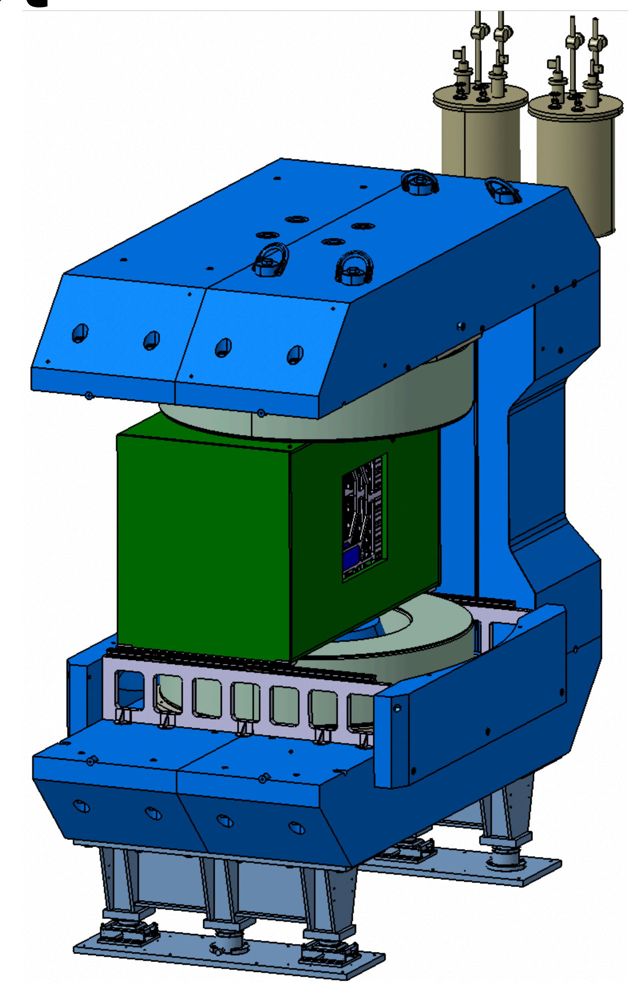
ladder



half-unit



mainframe



STS in the aperture of a dipole magnet

<u>896 detector modules including:</u>

- 1.8M readout channels
- 14.3k readout chips
- 28.6k ultra-thin readout cable stacks
- 106 ladders
- 18 half-units

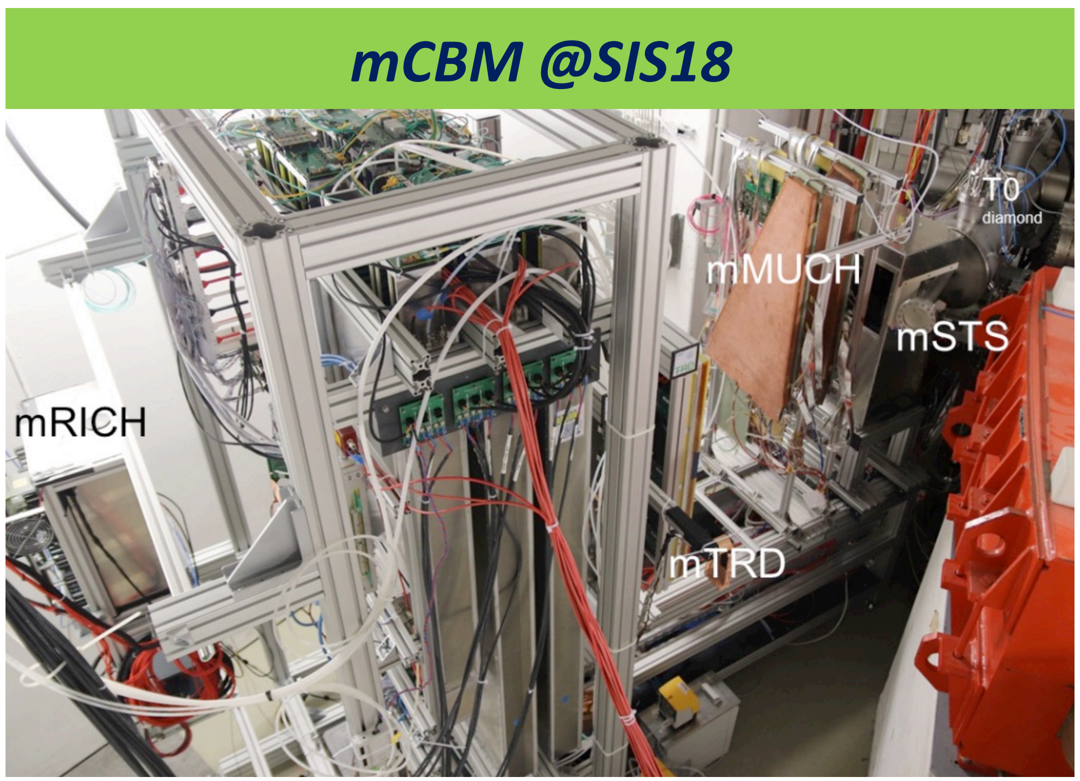
<u>Infrastructure in the STS box:</u>

- power distribution boards
- interface boards
  (electr. + opto)
- cooling (electronics + sensors)
- feedthroughs for services

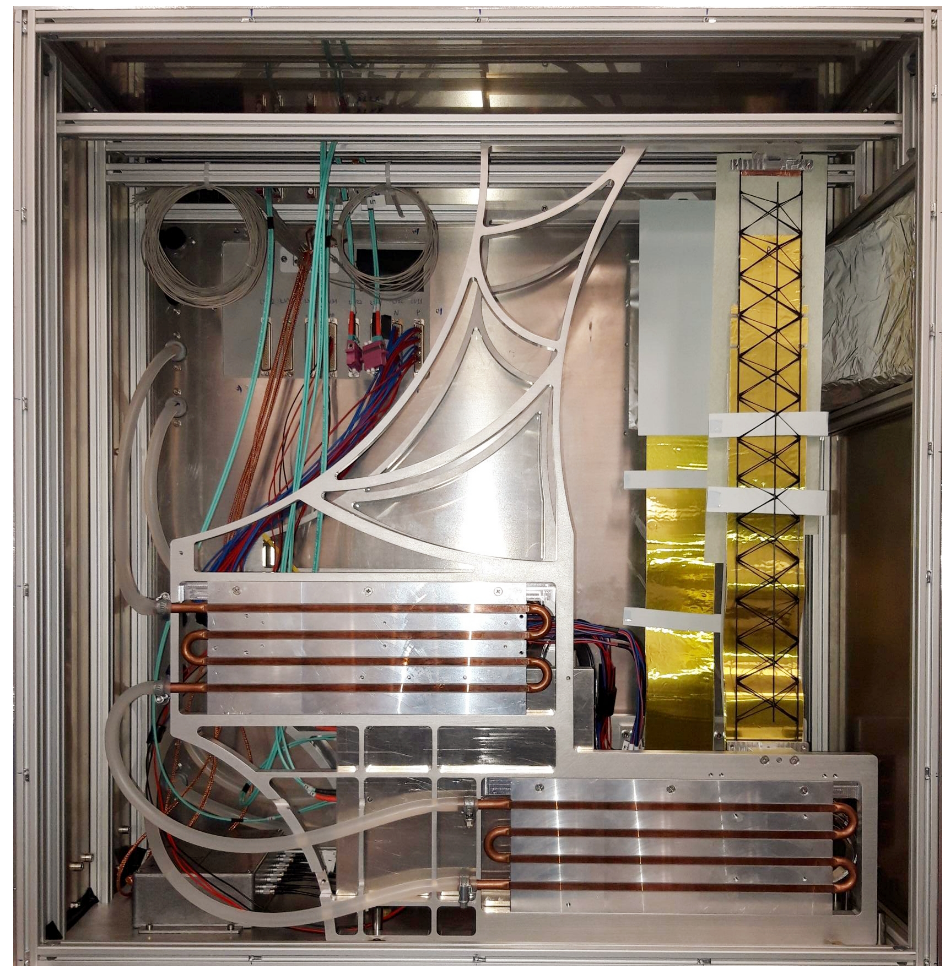
mSTS at mCBM

FAIR Phase 0

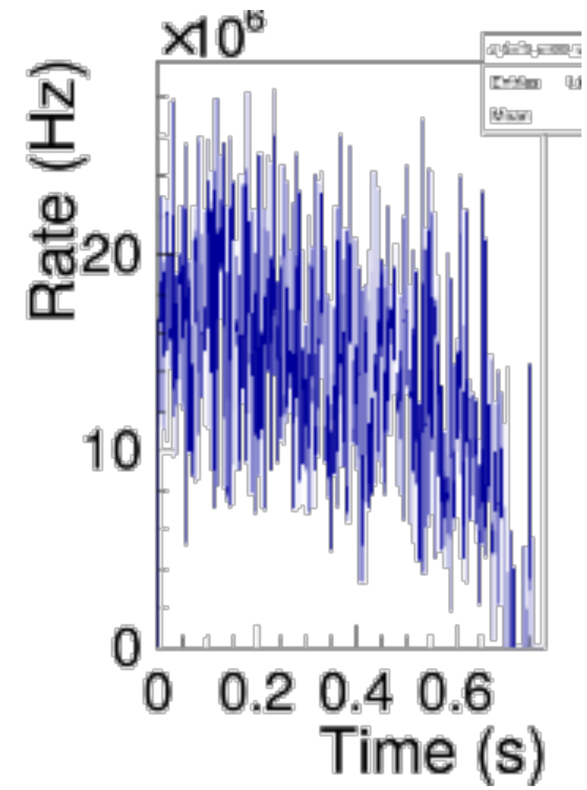
Long term campaign at SIS18: full system test with high-rate AA collisions at GSI/FAIR



- CBM pre-final detector systems
- free streaming read-out
- data transport to the mFLES (high performance computing farm)
- up to 10 MHz collision rate



mSTS box with C-frames holding carbon ladders with silicon strip detectors
4 modules (Feb' 2019)



20 MHz beam rate @10% target
R_{int}=2 MHz

Noise performance of a mSTS module

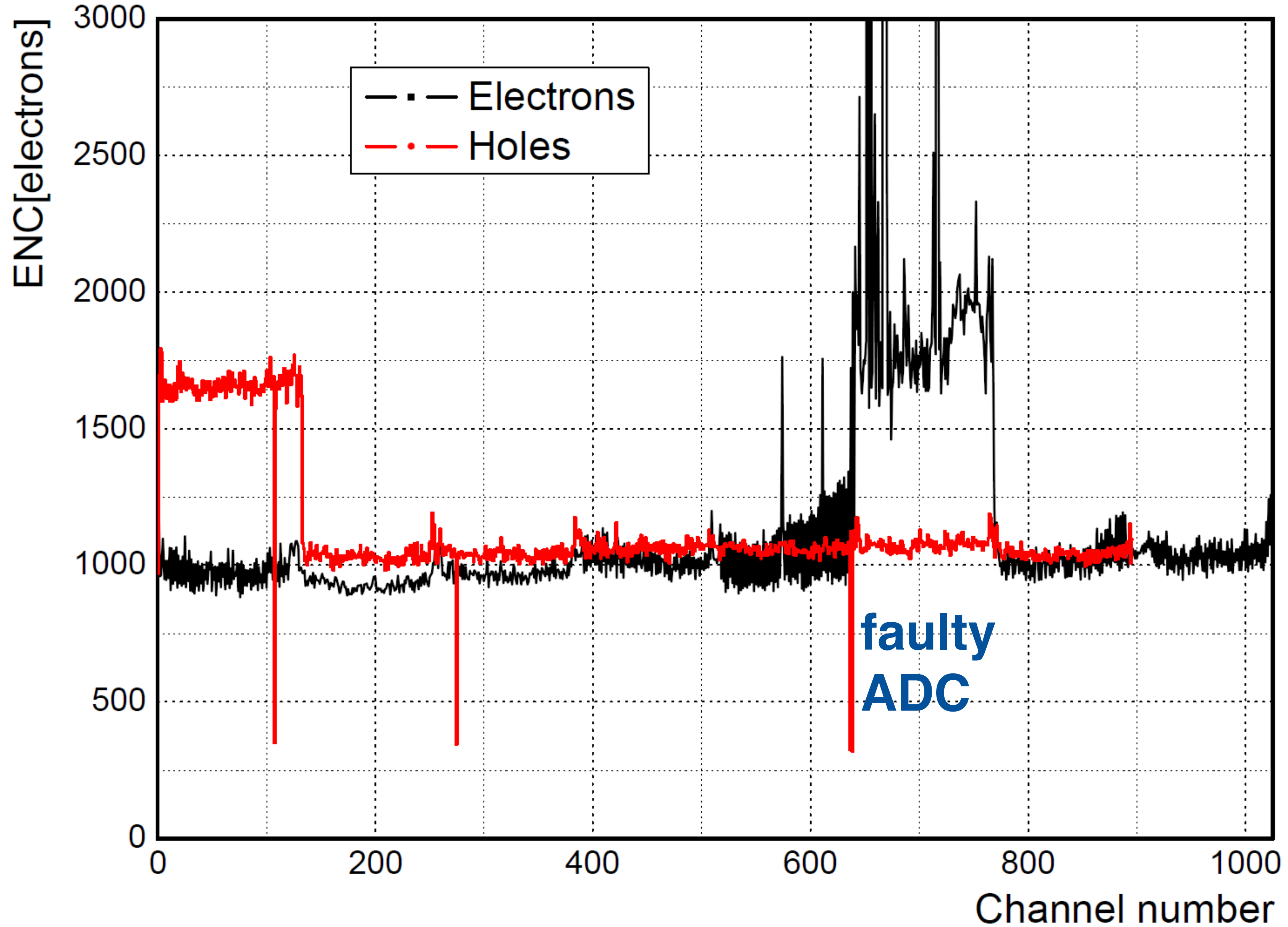
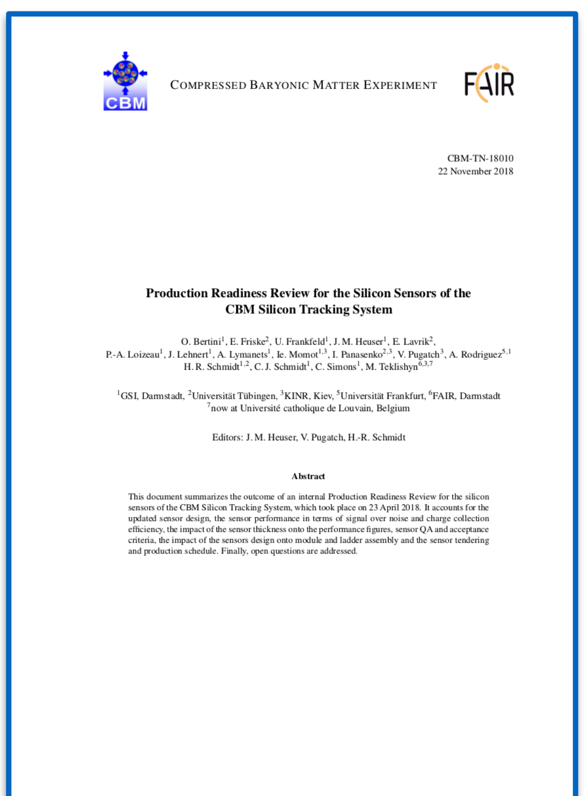


Image: O. Maragoto Rodriguez

- Noise level on both sides comprises ca. 1000 e
- Expected signal level for 300 μm thick sensor: 23 ke

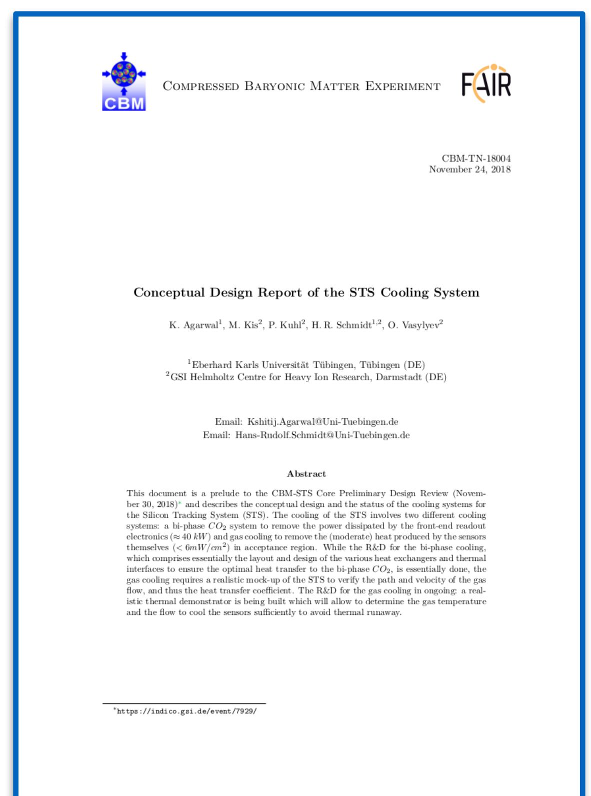
Project timeline

- Technical Design Report approved in 2013
- Production readiness of silicon sensors in 2018
- mCBM run 2018-2022
- Production of components 2019 - 2024
- STS system assembly and commissioning in 2020 - 2023
- Installation in CBM cave in 2025. Commissioning with beam.



Sensor production readiness

Rad. hardness



Cooling

Ladders