The Silicon Tracking System of the CBM experiment at FAIR

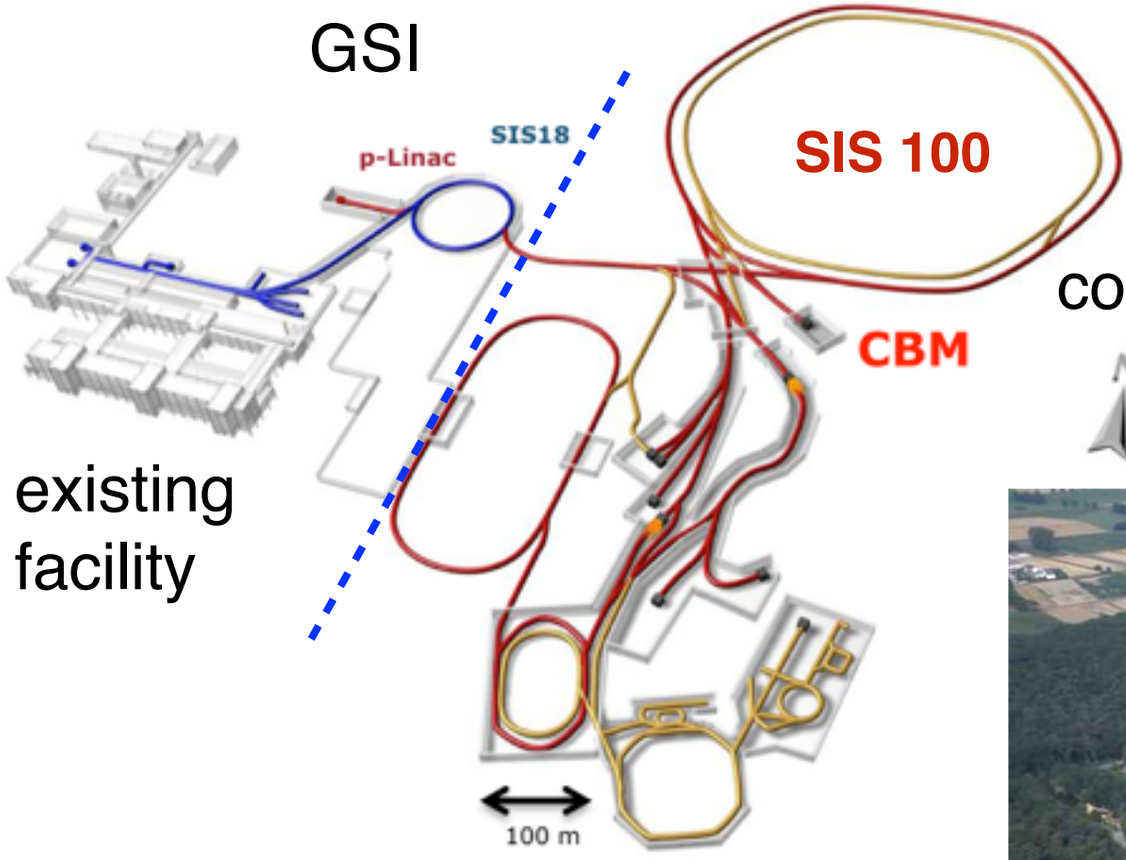
Anton Lymanets[1,2] for the CBM collaboration

14th Vienna Conference on Instrumentation

February 15 - 19, 2016
Vienna University of Technology

[1] GSI, Darmstadt, Germany
[2] Institute for Nuclear Research,
National Academy of Sciences, Ukraine

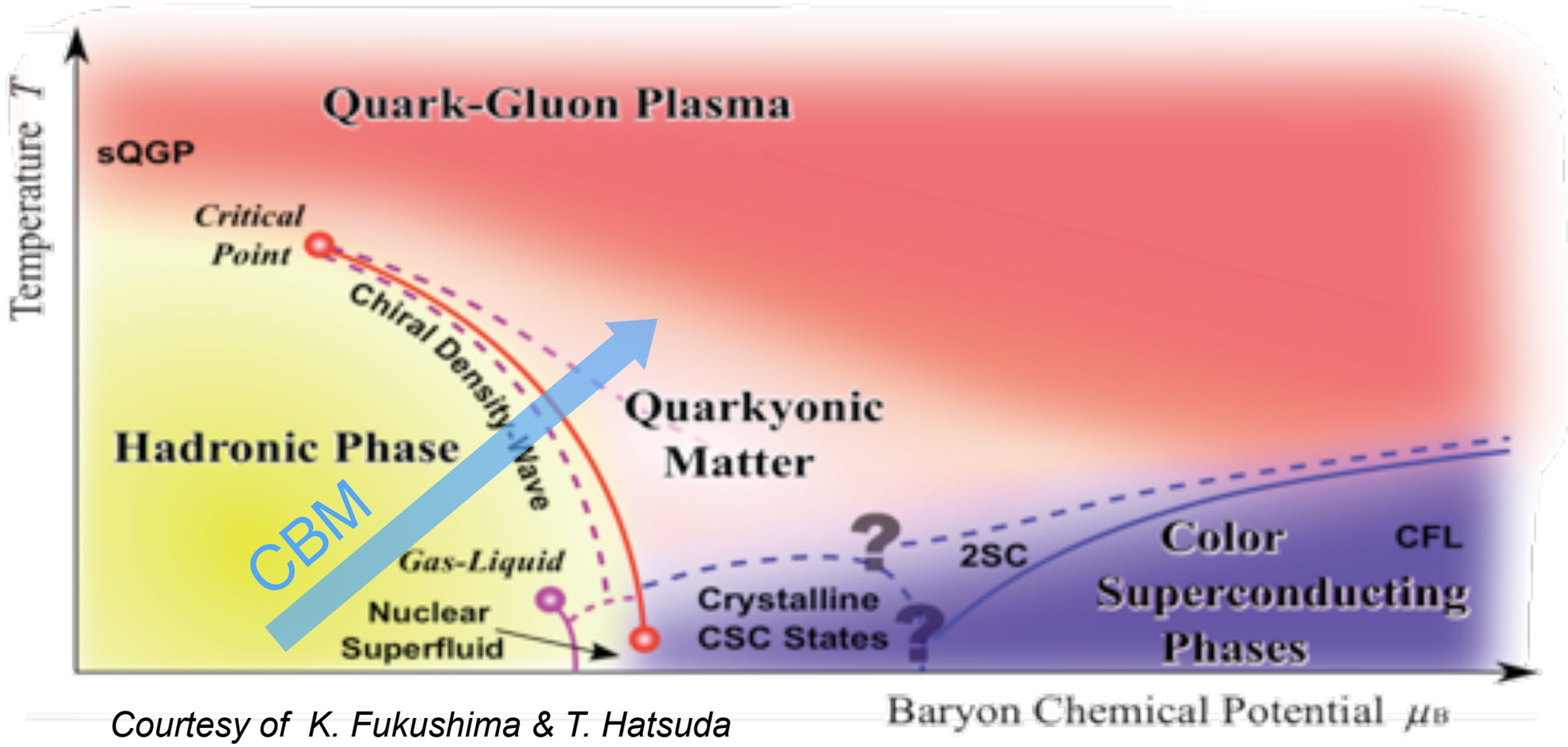
Facility for Antiproton and Ion Research



Aerial photo of the construction site taken on July 27, 2013 (photo: Jan Schäfer for FAIR)

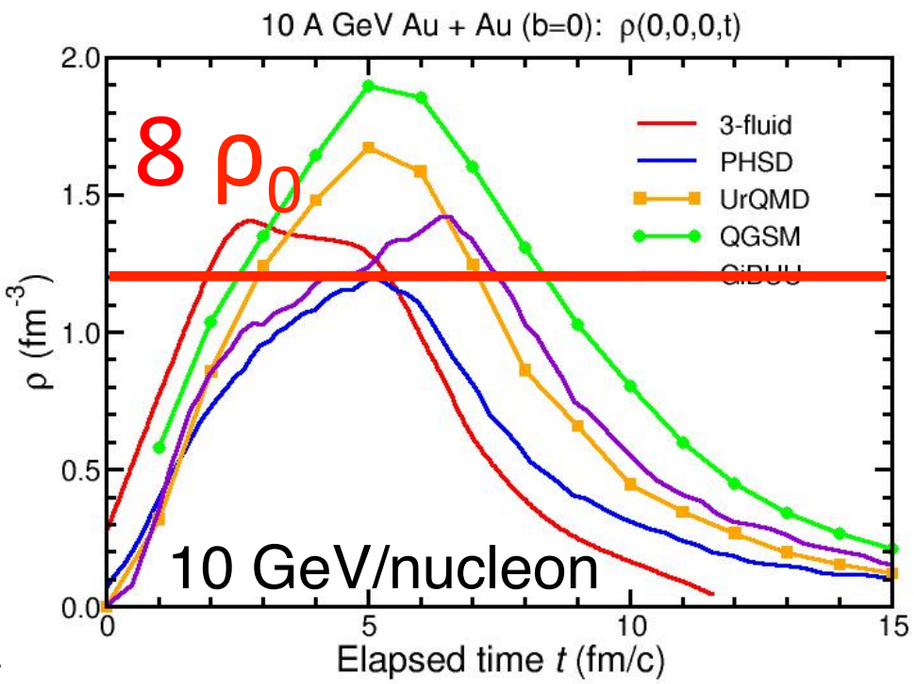
SIS-100
protons: 30 GeV
Au: 8 AGeV

QCD phase diagram



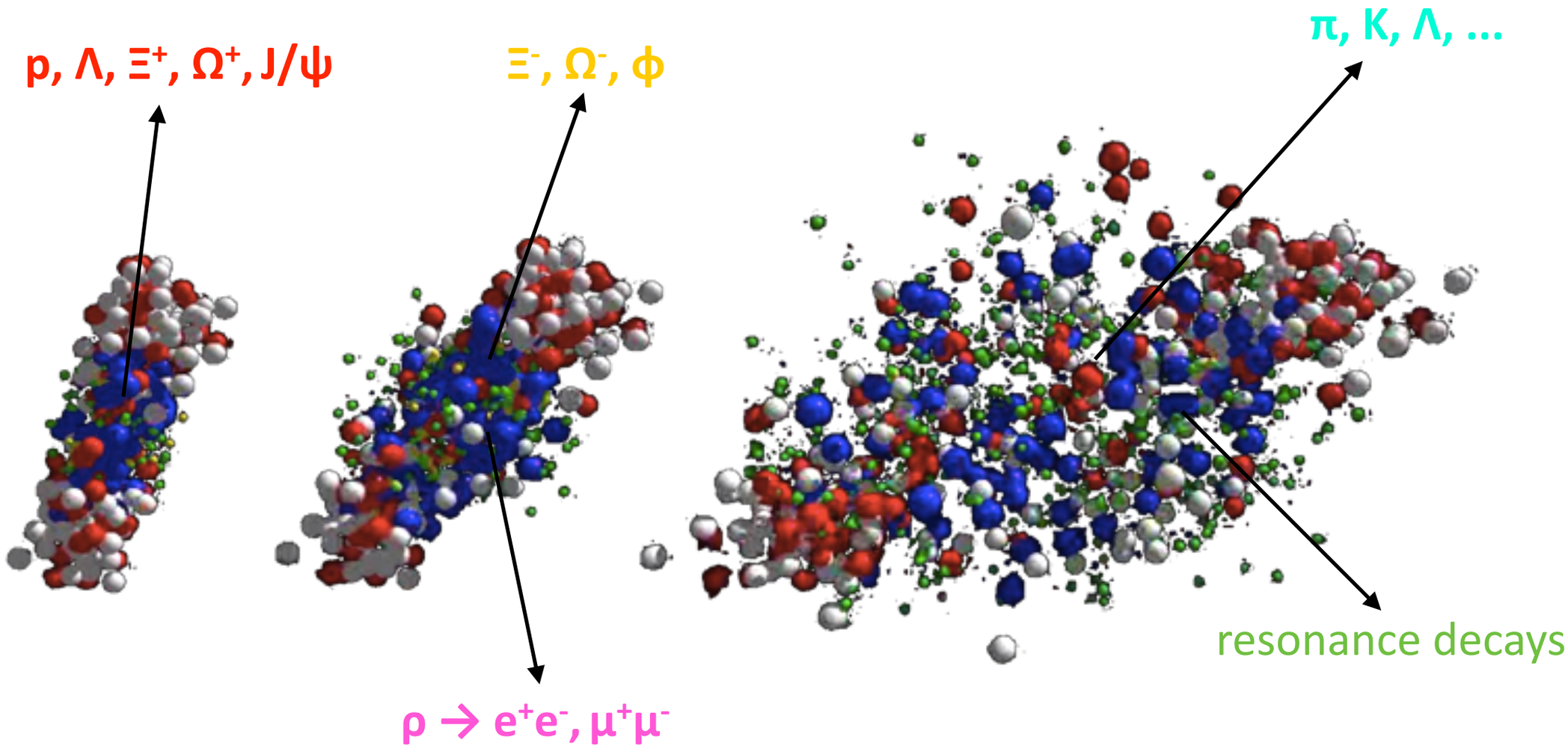
Courtesy of K. Fukushima & T. Hatsuda

- nuclear matter formation at high baryon density and temperature
- models predict 1st oder phase transition with formation of mixed and exotic phases
- existence of critical end-point



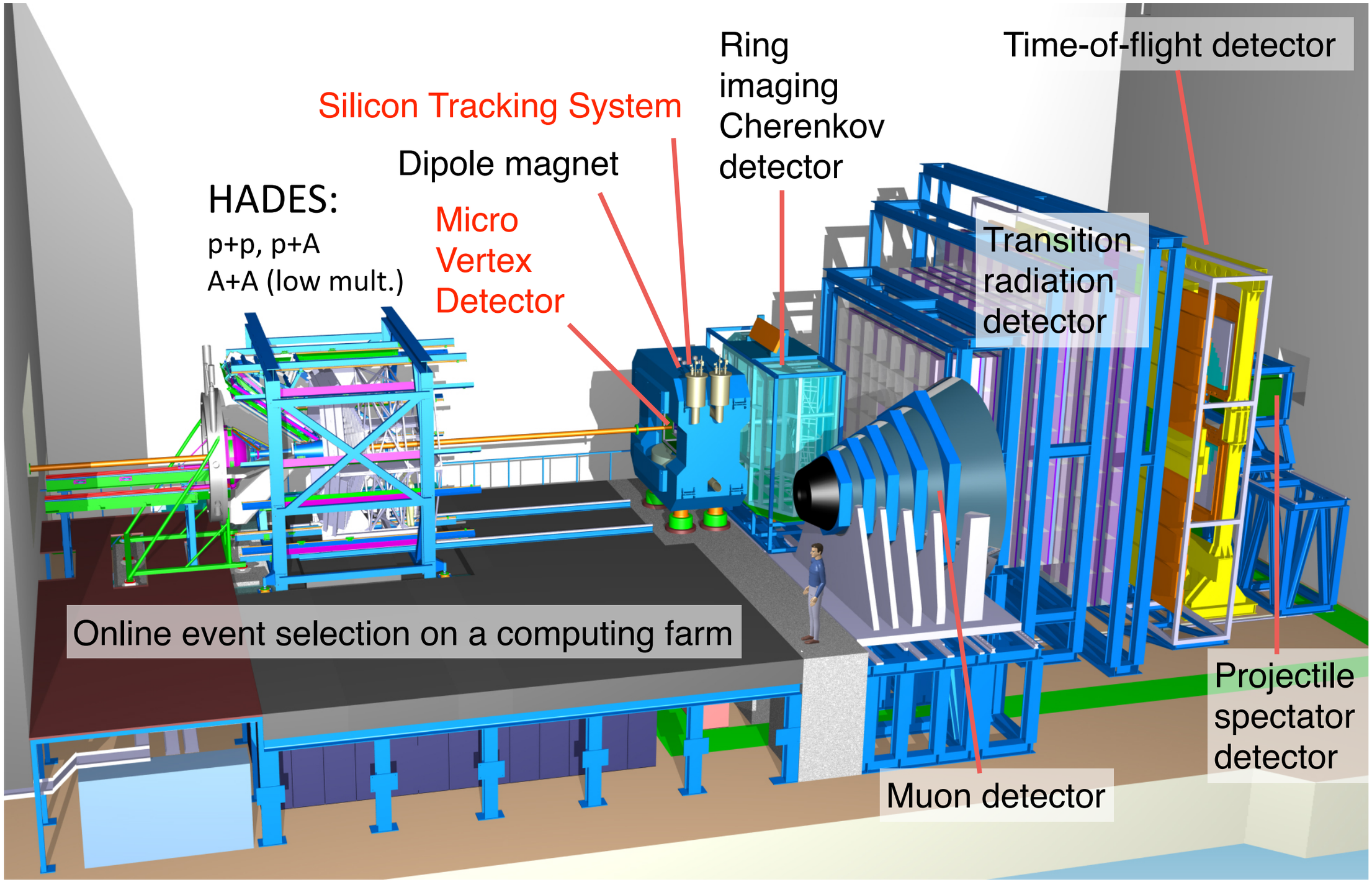
Probing the dense fireball

Au+Au collision at 10.7 GeV/nucleon as simulated in the UrQMD transport code



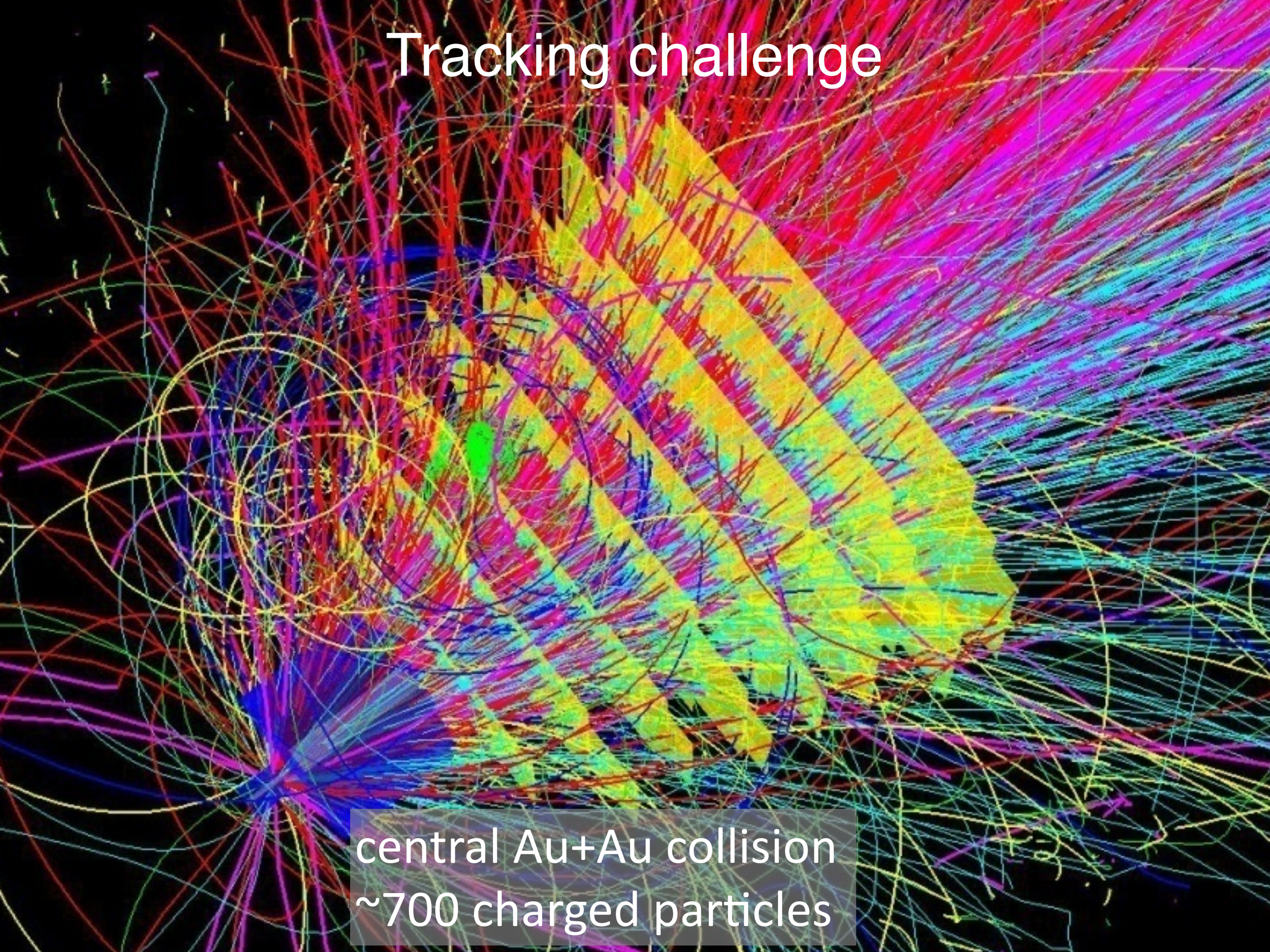
- Leptonic and hadronic signals from all stages of nucleus-nucleus collisions
- Rare probes: multistrange hyperons, low mass vector mesons, charmonium, strange dibaryons, hypernuclei.

CBM experiment



- Vertexing: MVD
- Tracking: STS, MUCH, TRD, ToF
- Particle ID: RICH, TRD, ToF
- Calorimetry: ECAL, PSD

Tracking challenge

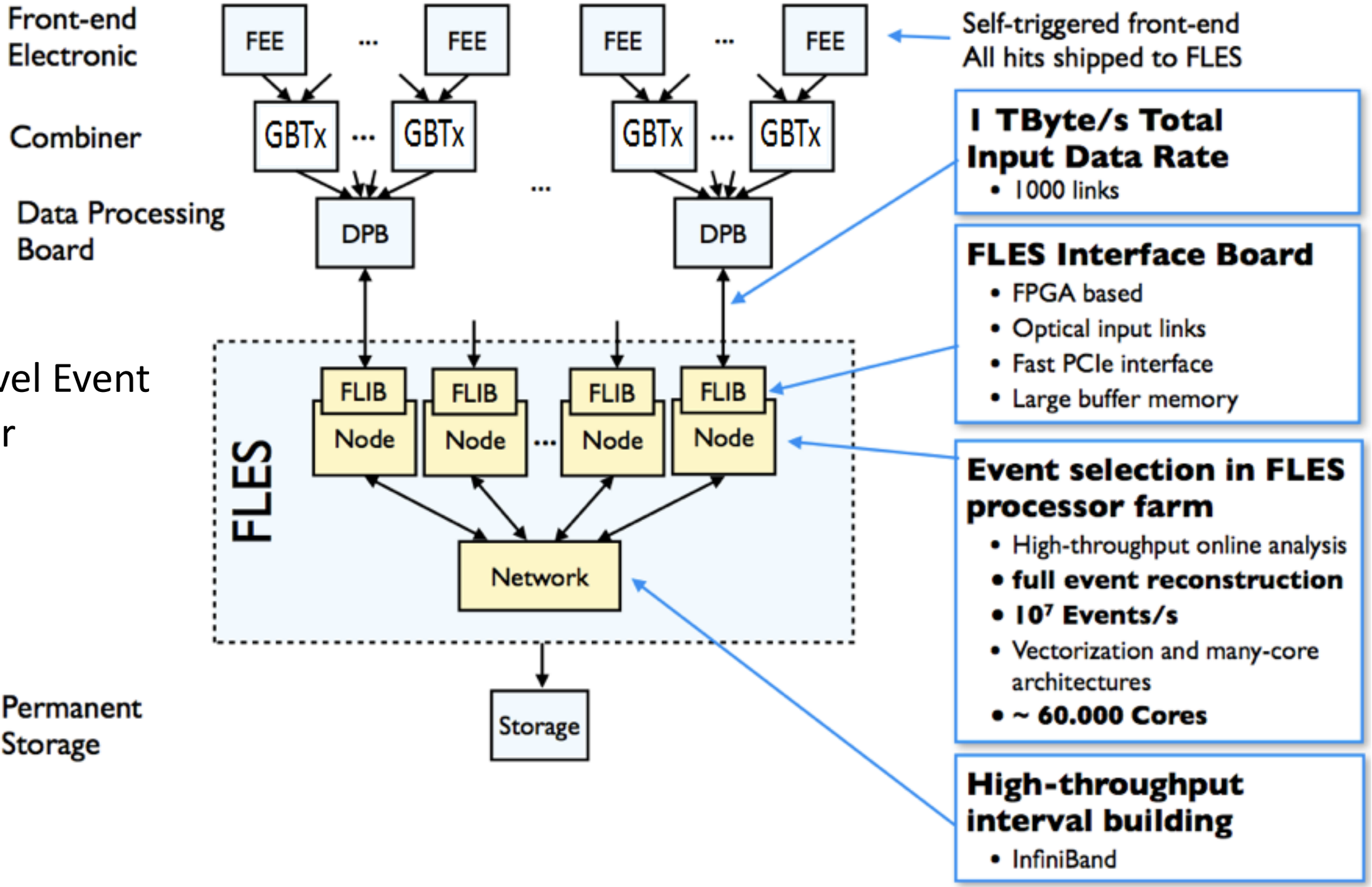


Experimental requirements

- 10^5 - 10^7 Au+Au collisions per second.
- secondary vertex determination (σ≈50 μm)
- track reconstruction from hadron and lepton probes
- fast and radiation tolerant detectors
- self-triggering front-end electronics
- fast data acquisition system + online event selection on a computing farm
- 4D track reconstruction

Online data flow

First-level Event Selector

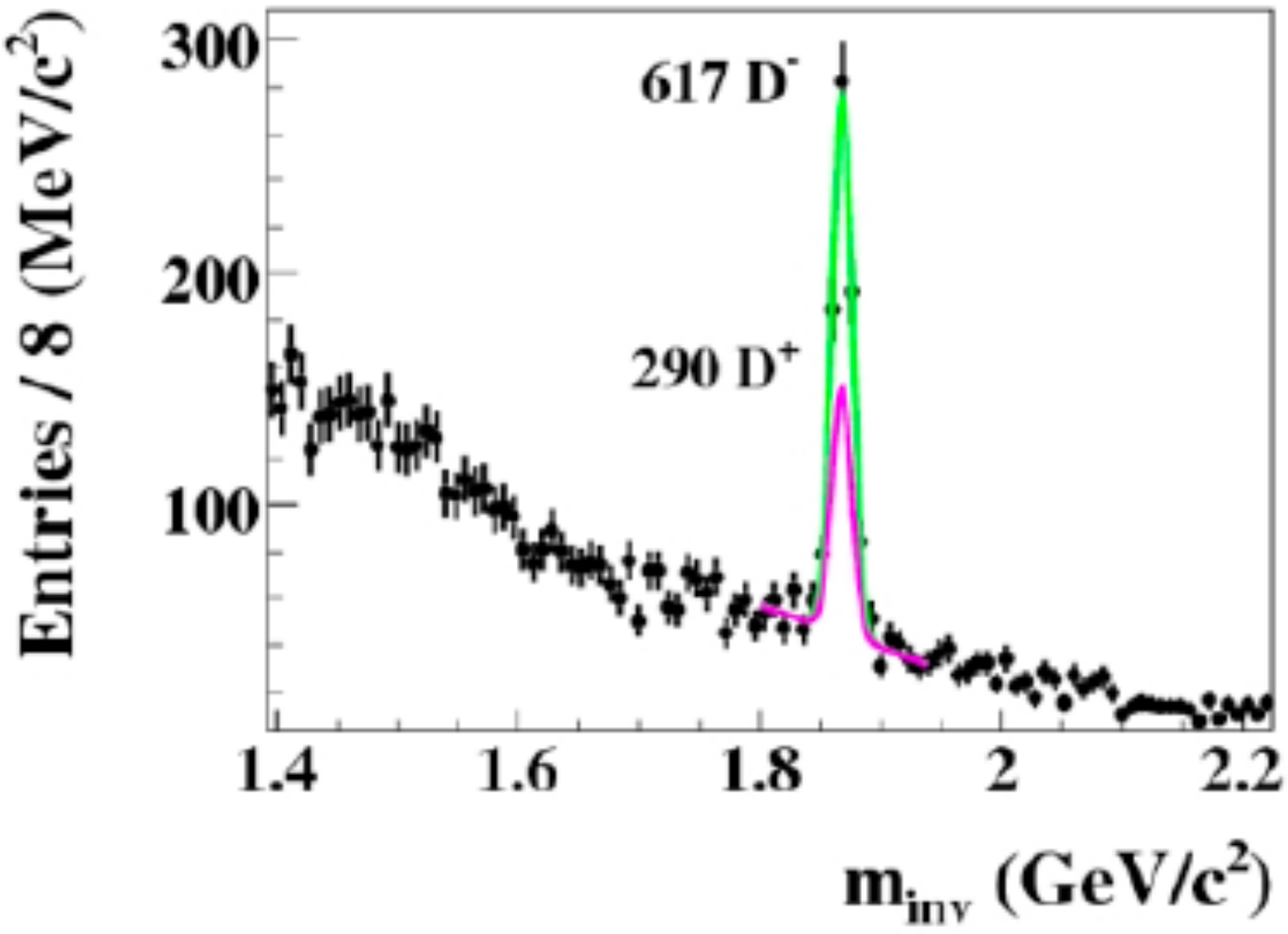


Feasibility studies at SIS-100

Operation scenario: Au+Au, C+C at 4, 6, 8, 10 GeV/nucleon

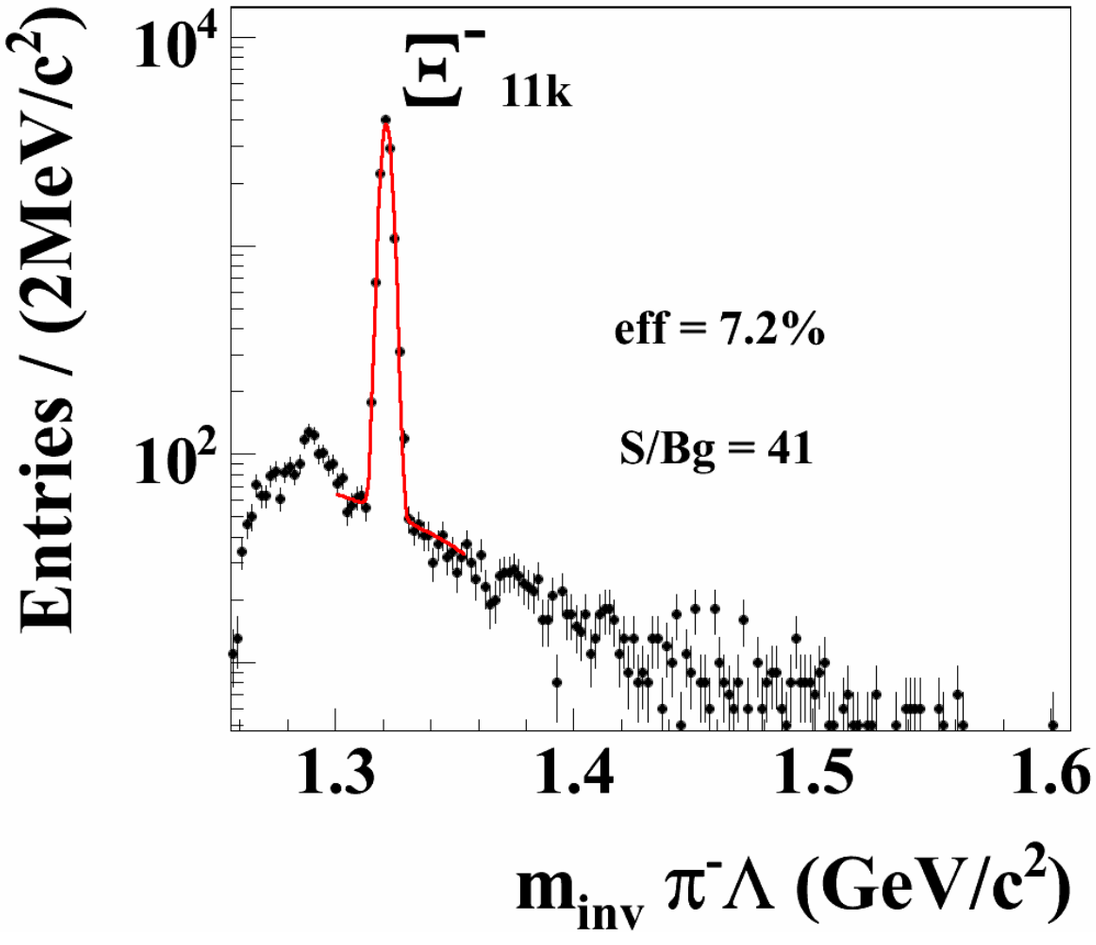
Example: 10^6 central events, interaction rate 100 kHz – 1 MHz

Charmed mesons: $D^{\pm} \rightarrow K\pi\pi$



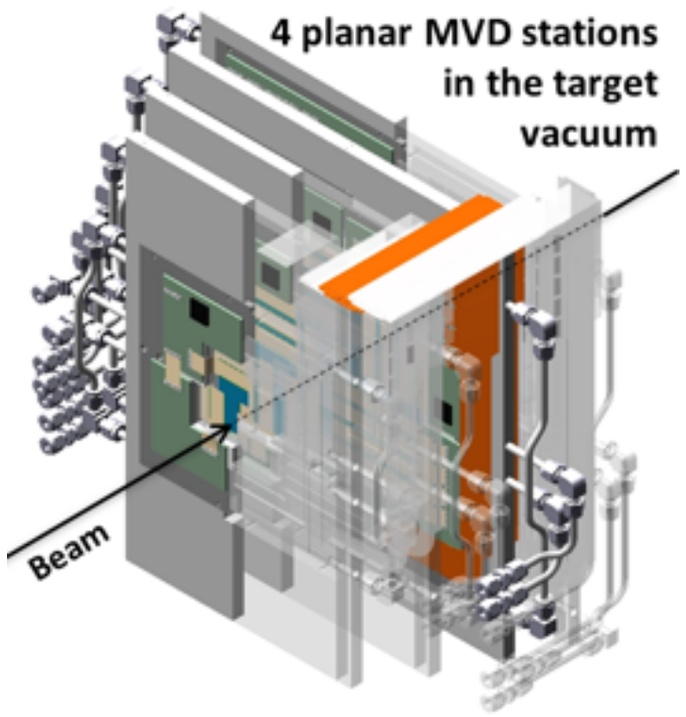
30 GeV p+C

Cascade hyperons

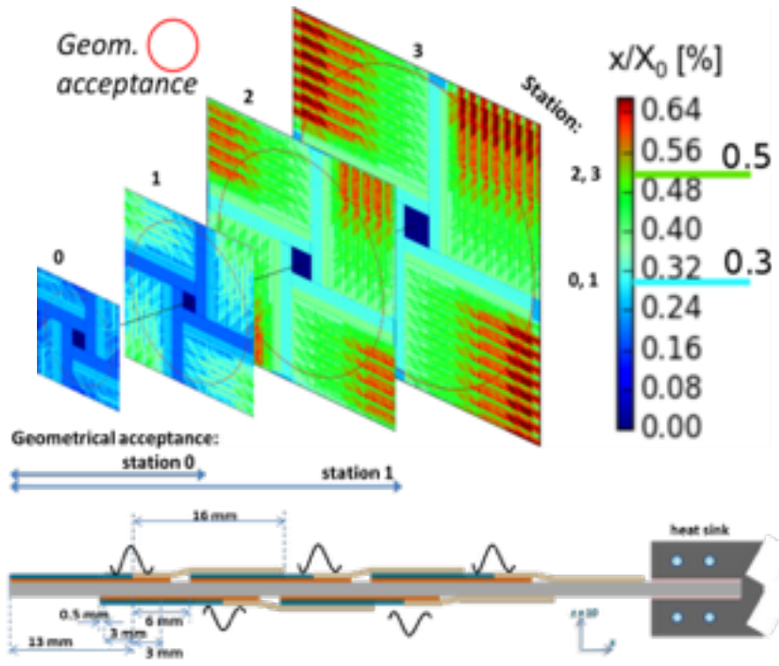


Au+Au, 8 GeV/nucleon

CBM Micro Vertex Detector

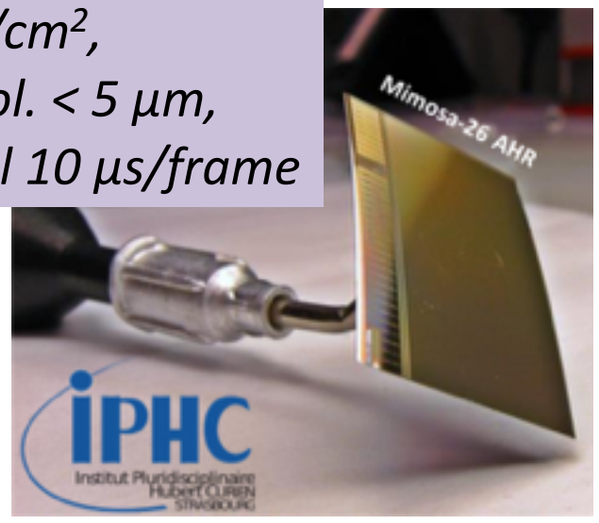


Ultra-thin: CVD diamond, TPG



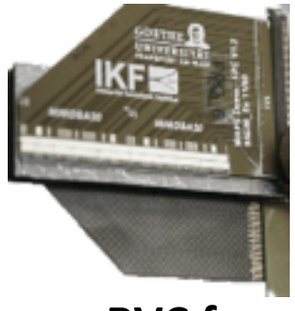
Sensors: CMOS MAPS

- *Radiation hard,*
- *Thinned to 50 µm,*
- *< 150 mW/cm², *
- *spatial resol. < 5 µm,*
- *R/O several 10 µs/frame*

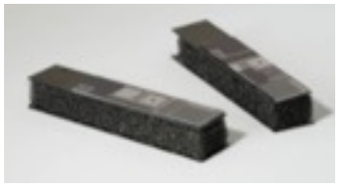


Prototyping & test beam:

MVD demonstrator

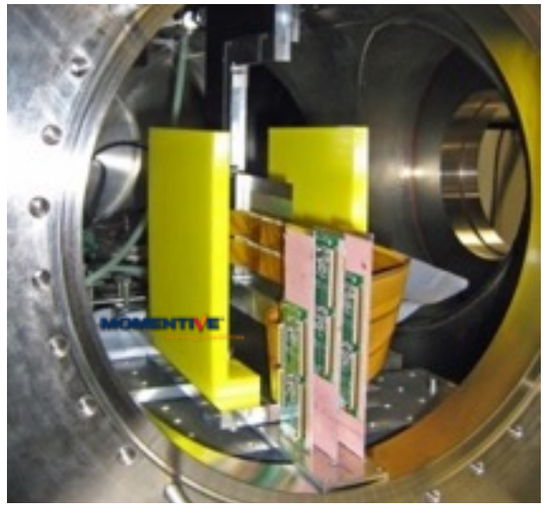


RVC foam

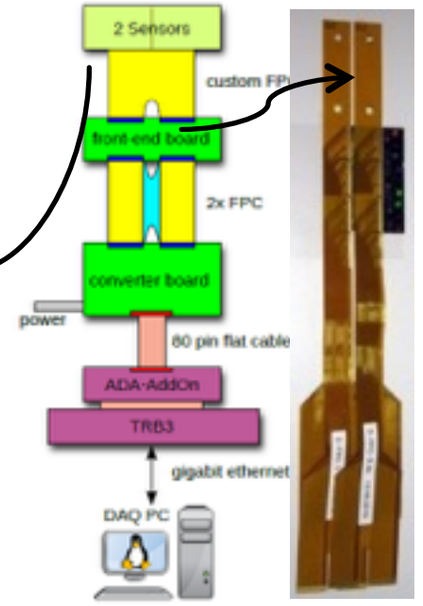


MVD prototype

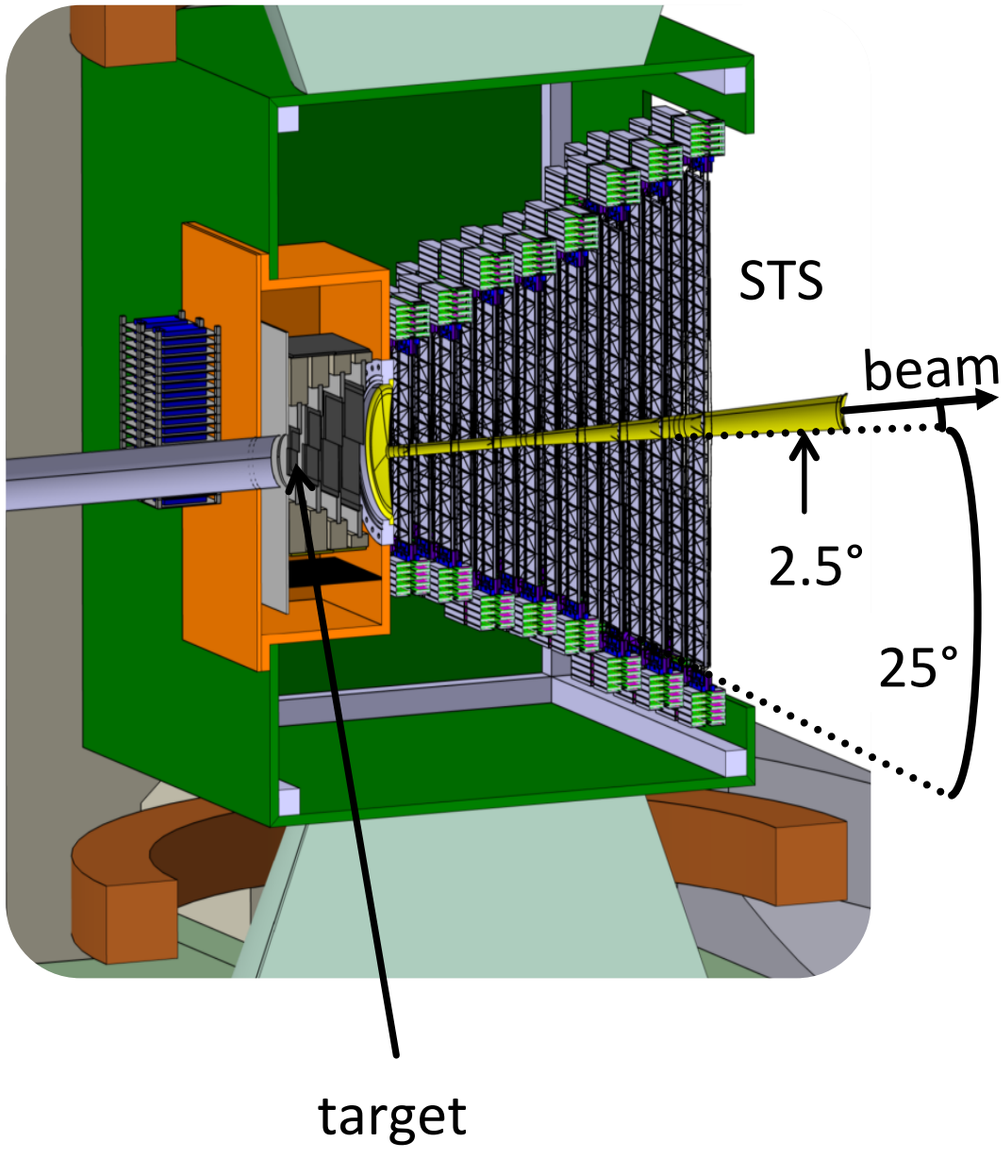
PRESTO

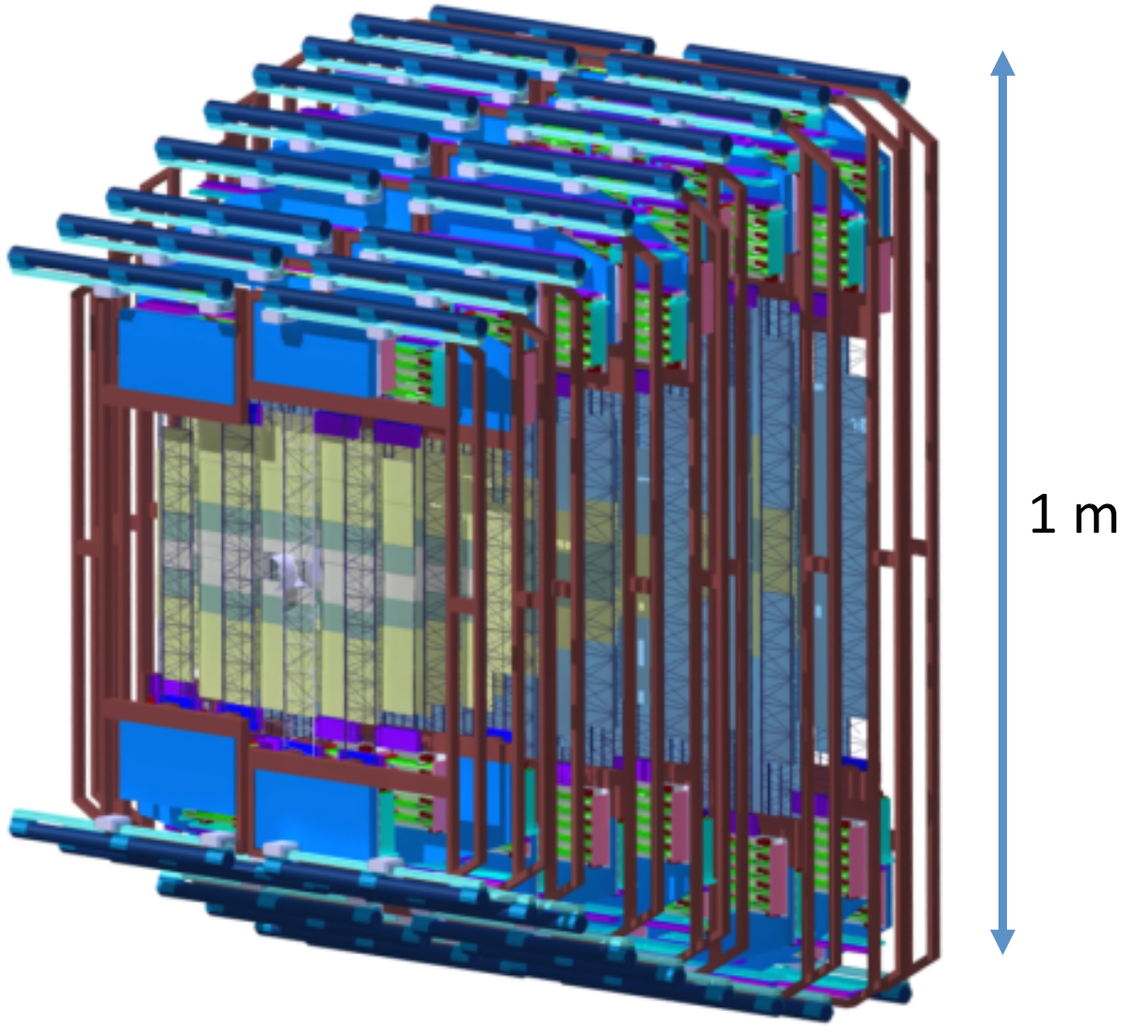


Customized FEE & DAQ: TRB-based



Silicon Tracking System

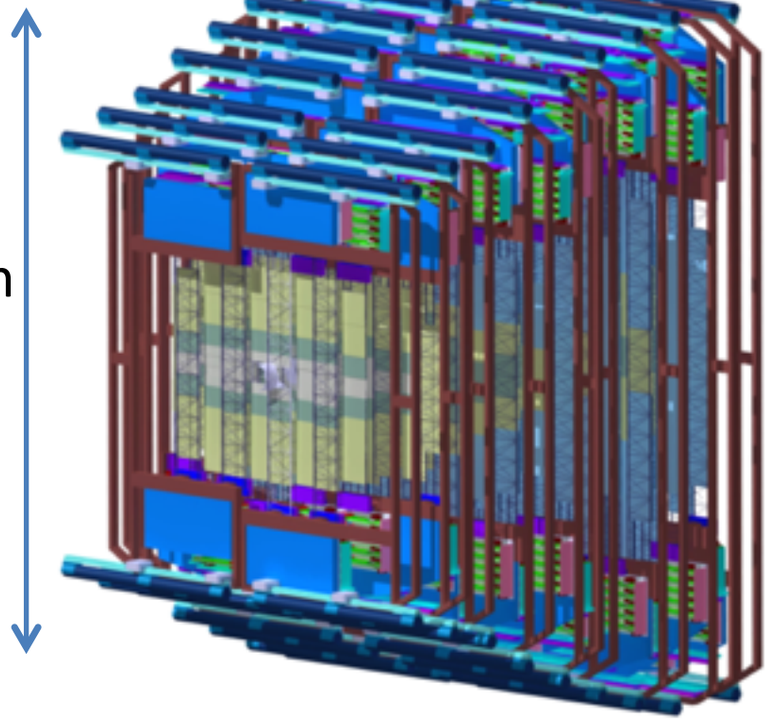




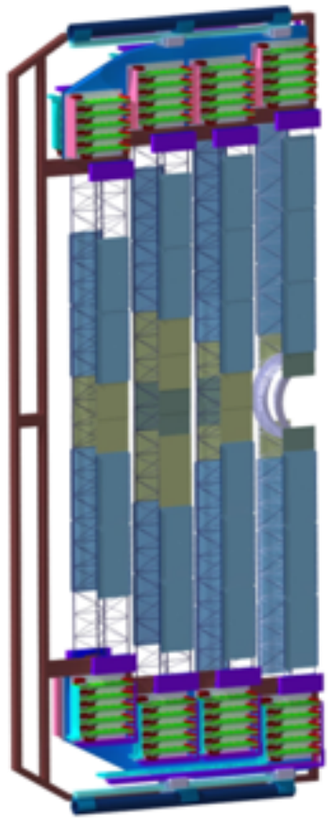
- 8 tracking stations in the magnet aperture
- double-sided silicon microstrip detectors

- Acceptance: $2.5^{\circ} < \theta < 25^{\circ}$
- Active area: 4 m^2

STS integration concept

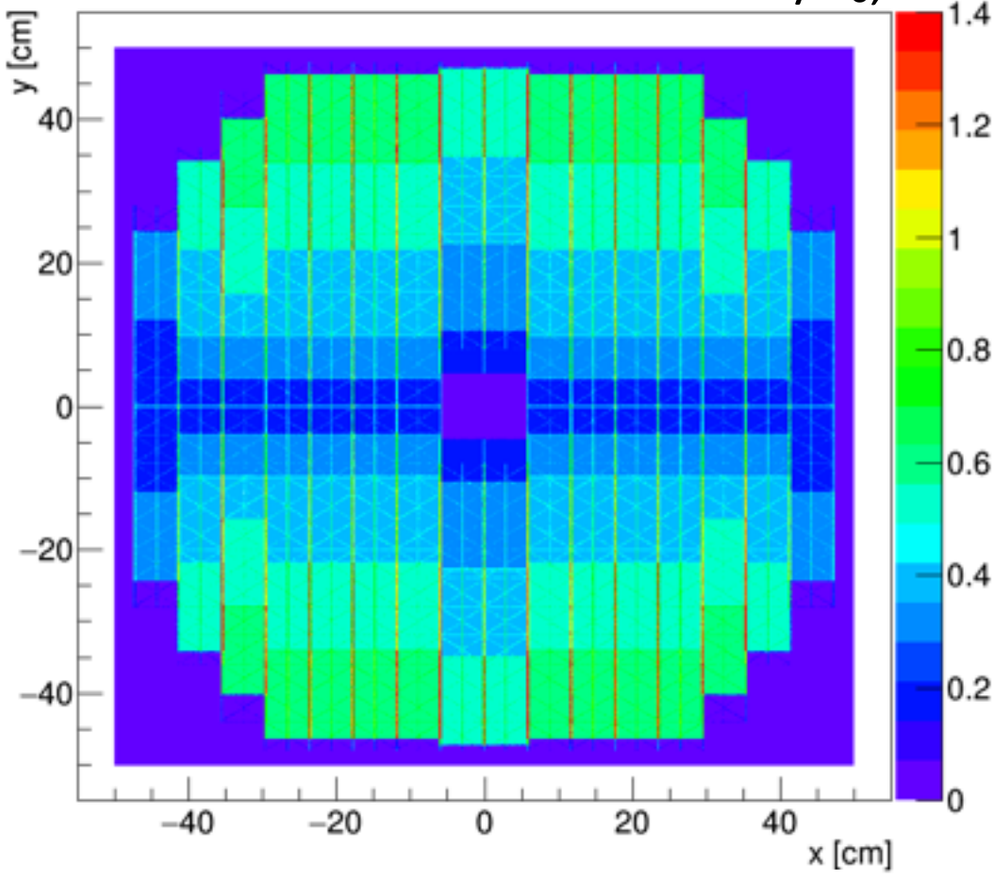


8 tracking stations



mechanical unit

ladder



material budget for station 8

896 detector modules including:

1220 double-sided microstrip sensors

~ 1.8M readout channels

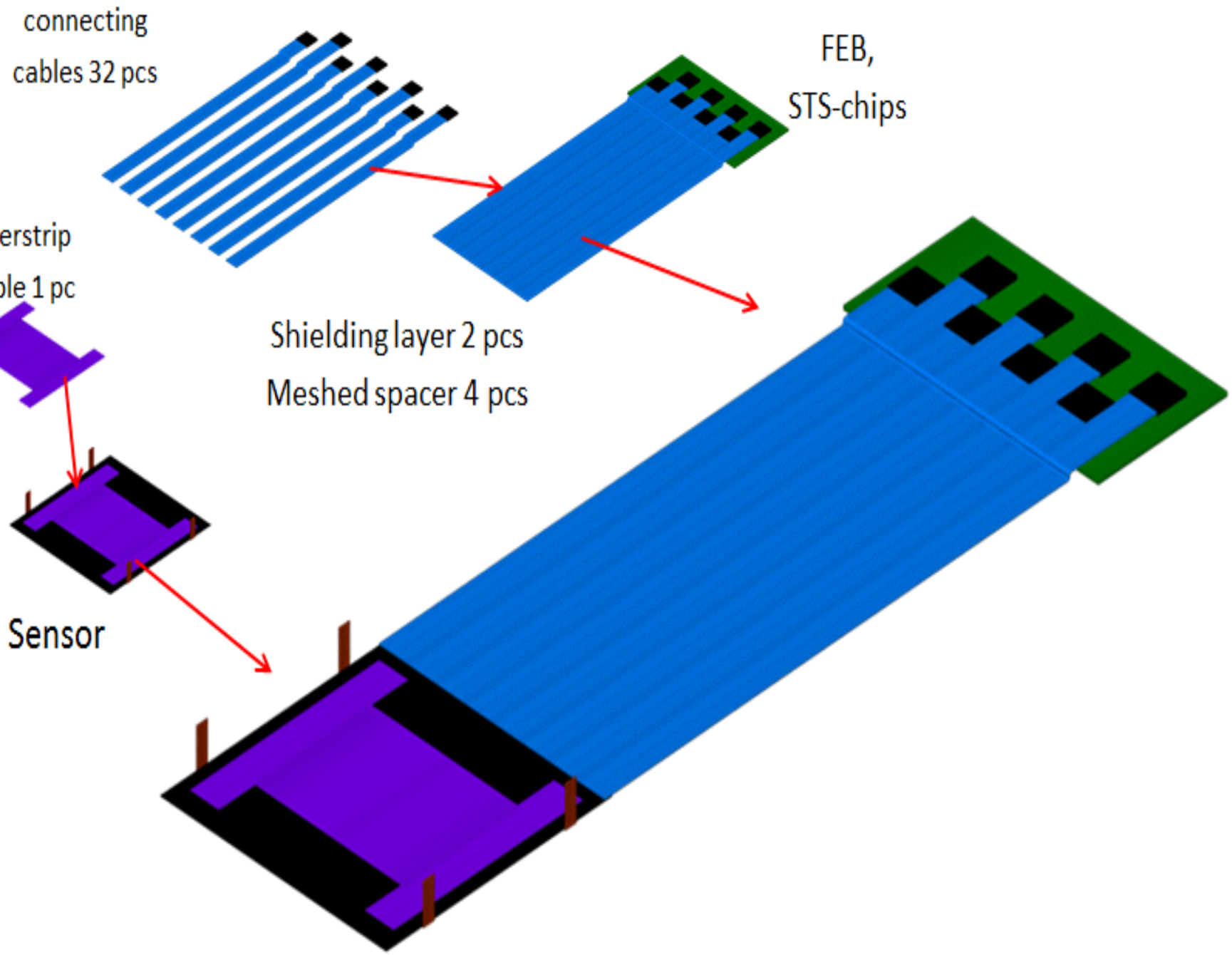
~ 16 000 readout chips

~ 16 000 ultra-thin readout cable stacks

Detector module concept

896 modules required

4-5 modules per ladder

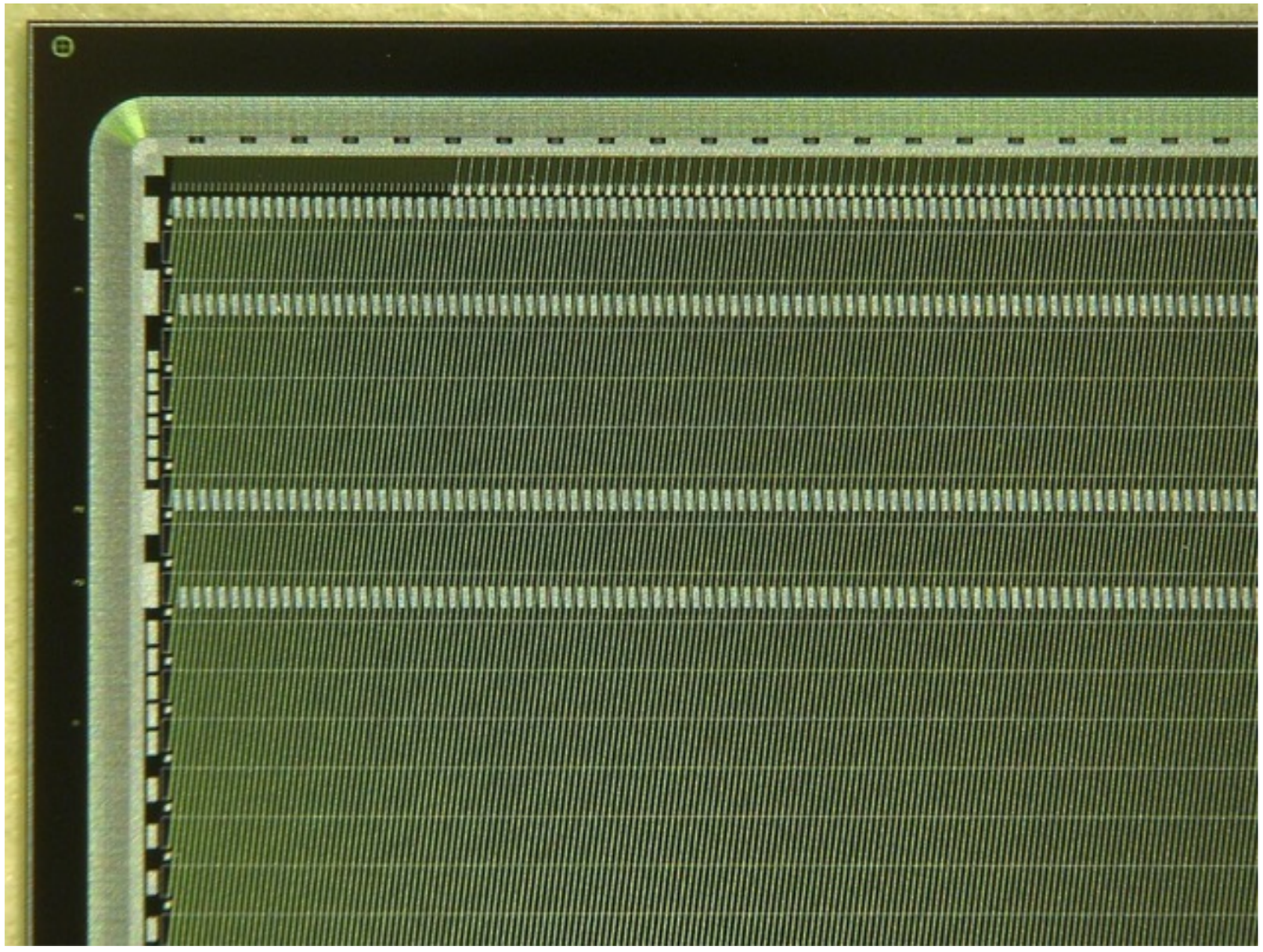


Modules comprises:

- sensor
- analog mirocables
- front-end board

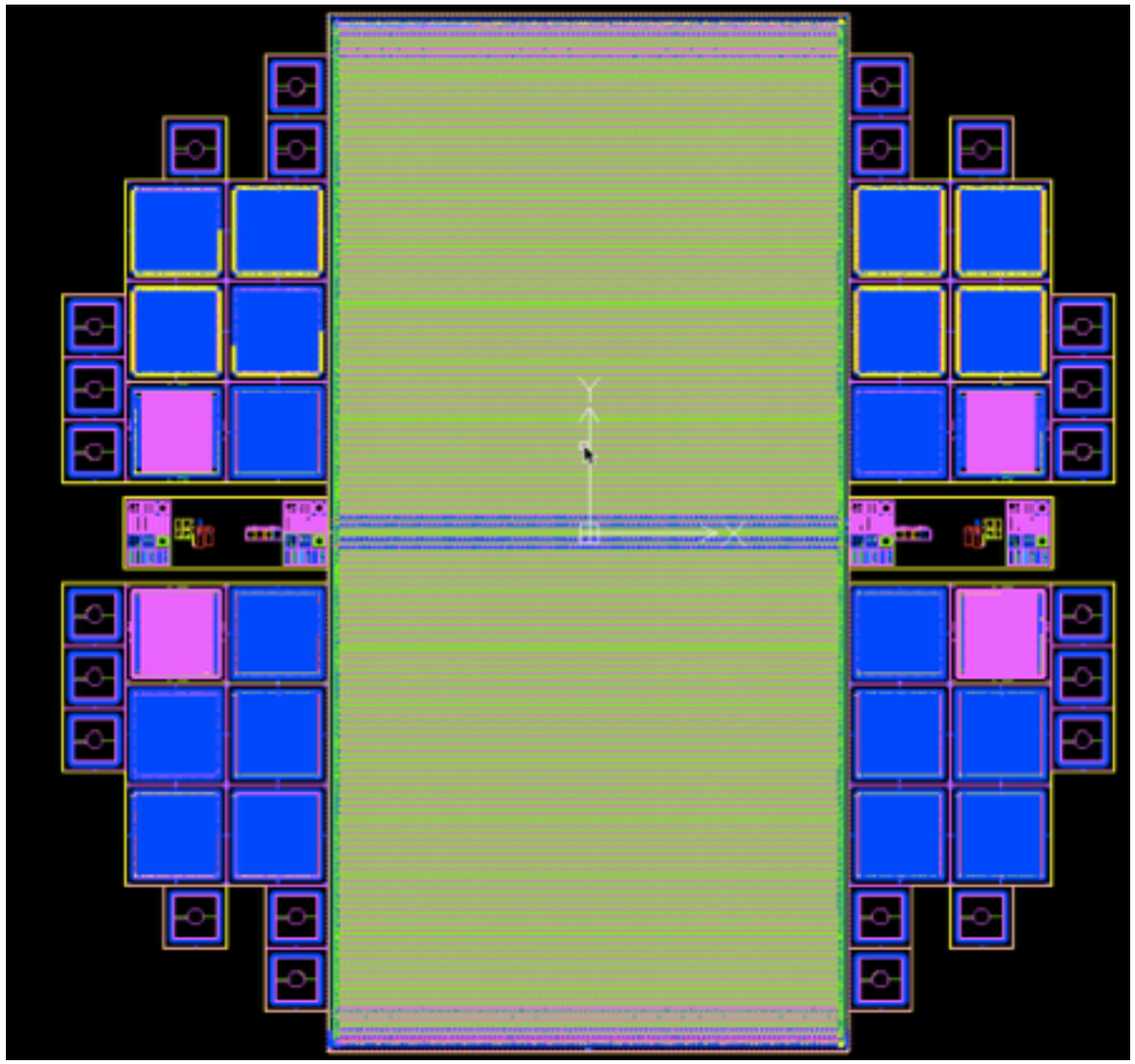
Silicon microstrip sensors

- double-sided
- 1024 channels per side
- 58 μm pitch
- 300 μm thick
- stereo angle 7.5°(p-side)
- dimensions:
  6×2 cm², 6×4 cm²,
  6×6 cm², 6×12 cm²
- 2nd metallization to interconnect short corner strips



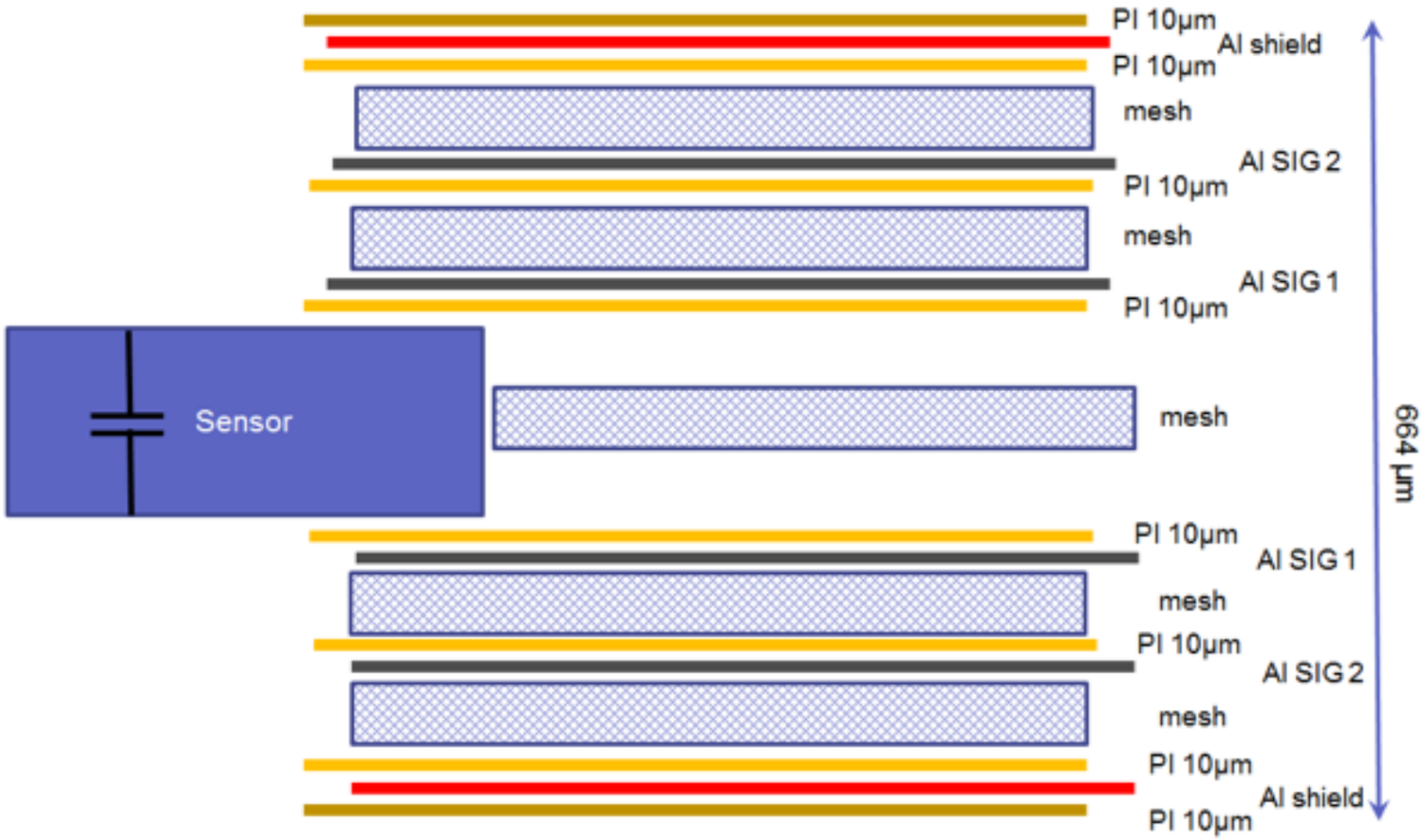
Silicon microstrip sensors

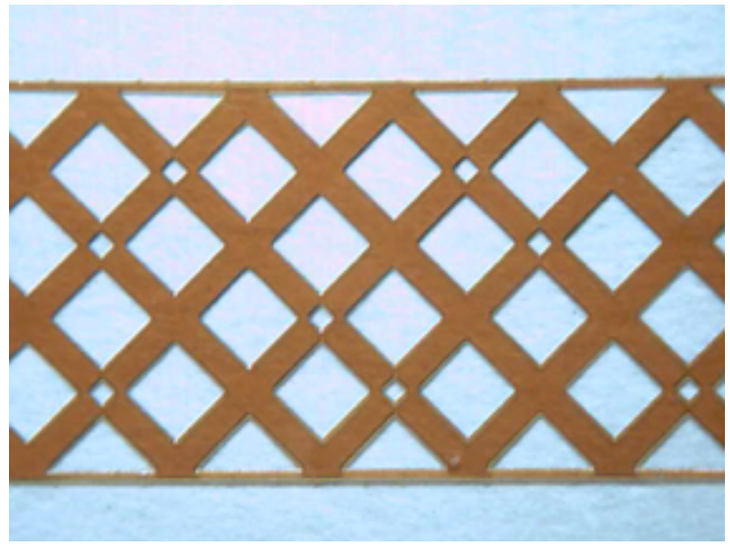
two daisy-chained sensors



6×12 cm^2 sensor design with readout pads in the middle of the sensor (in production by Hamamatsu)

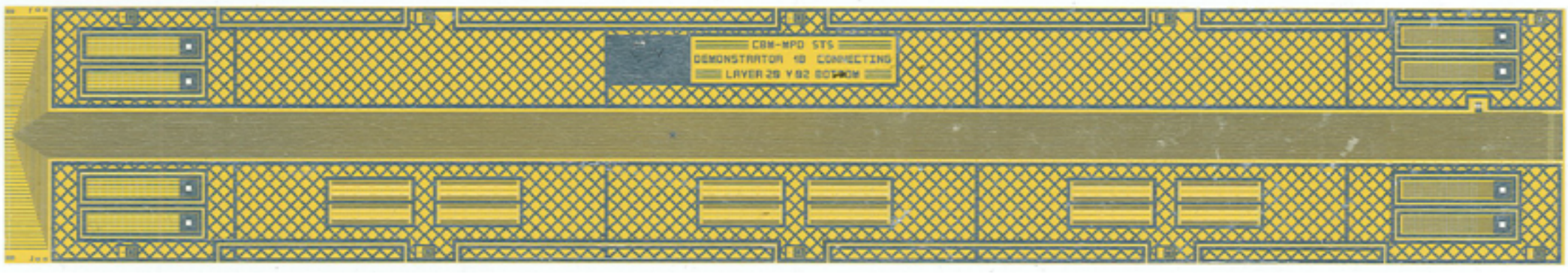
Microcables





meshed spacer

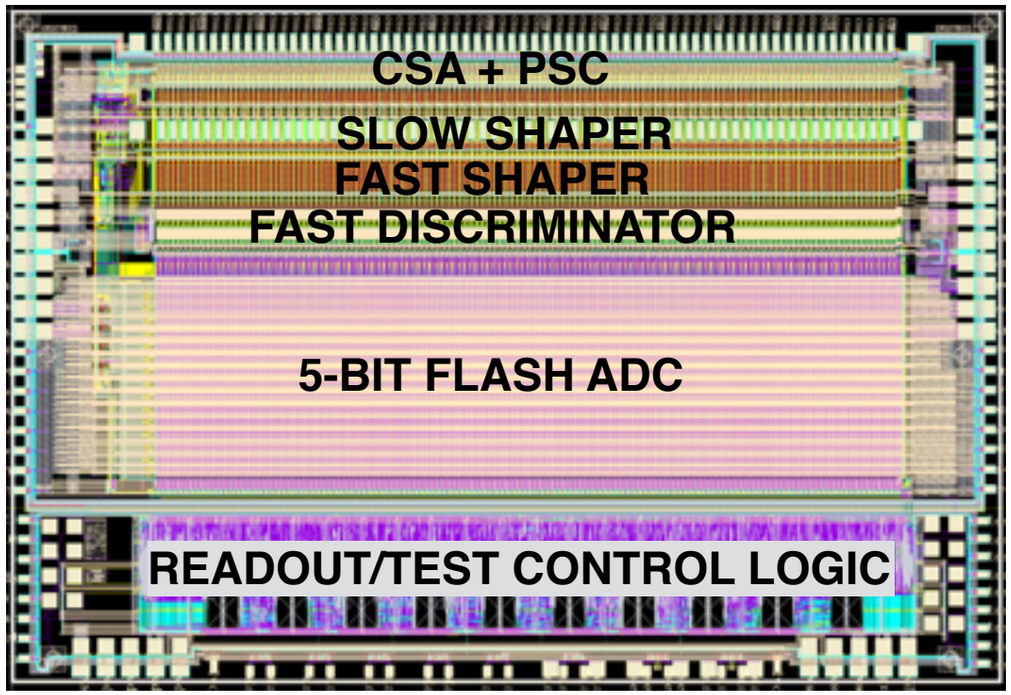
signal layer: *64 Al lines of 116 µm pitch, 10 µm thick on 14 µm polyimide, lengths up to 55 cm*



Material budget: 0.228 X_0 (equivalent to 213 μm Si)

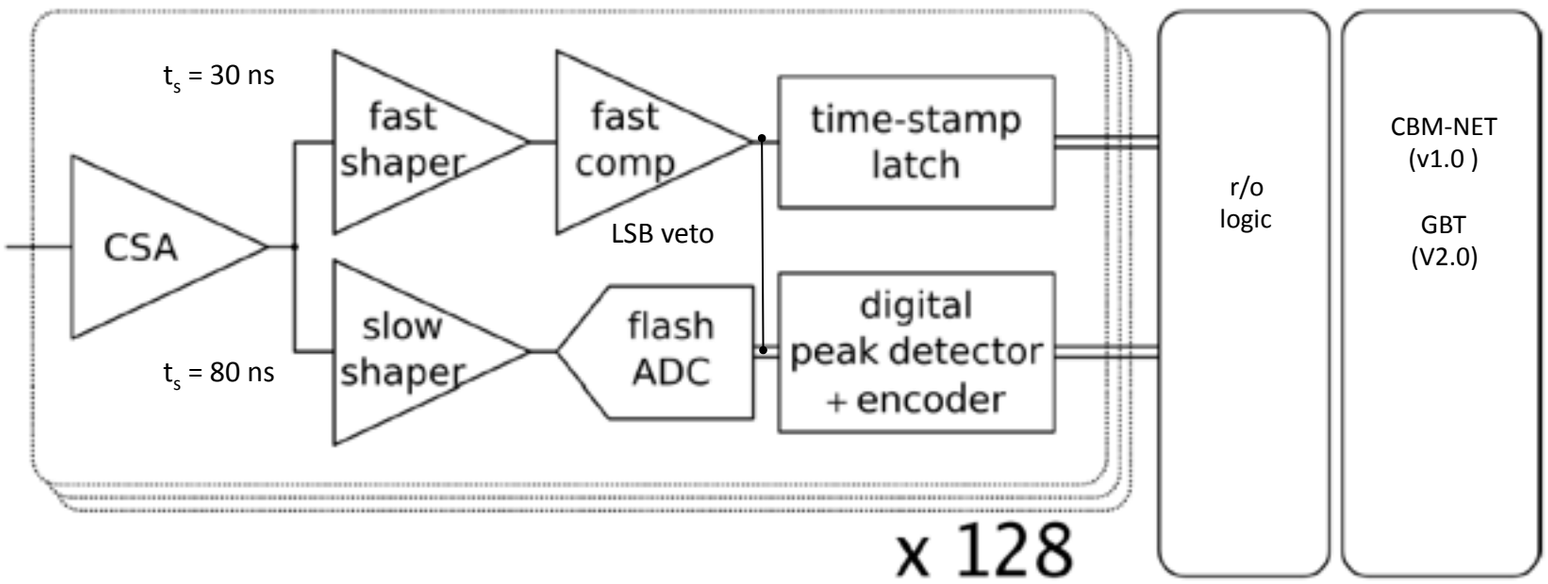
STS-XYTER ASIC

STS-XYTER ASIC

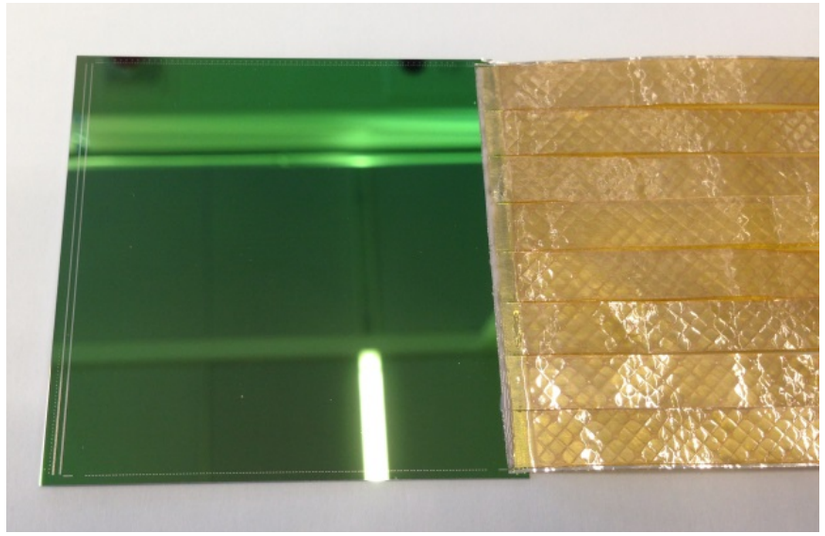


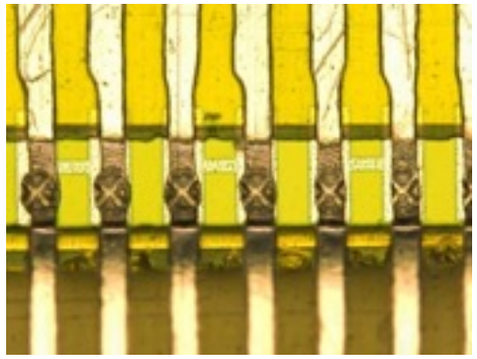
- data driven architecture
- fast branch: time-stamp
- slow branch: signal digitization
- double-threshold discrimination: time stamp is vetoed if ADC produced no signal

channels	128, polarity +/-
noise	1000 e^- at 30 pF load
ADC range	16 fC, 5 bit
clock	250 MHz
power	< 10 mW/channel
timestamp	< 5 ns resolution
out interface	4(5) × 500 Mbit/s LVDS

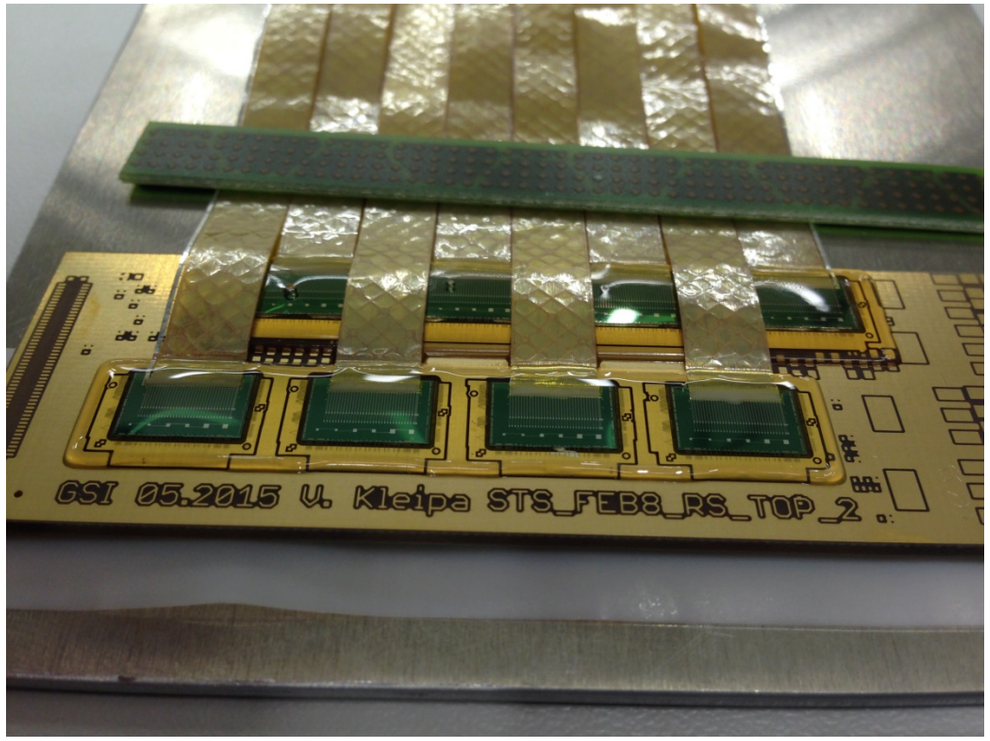


Detector module assembly





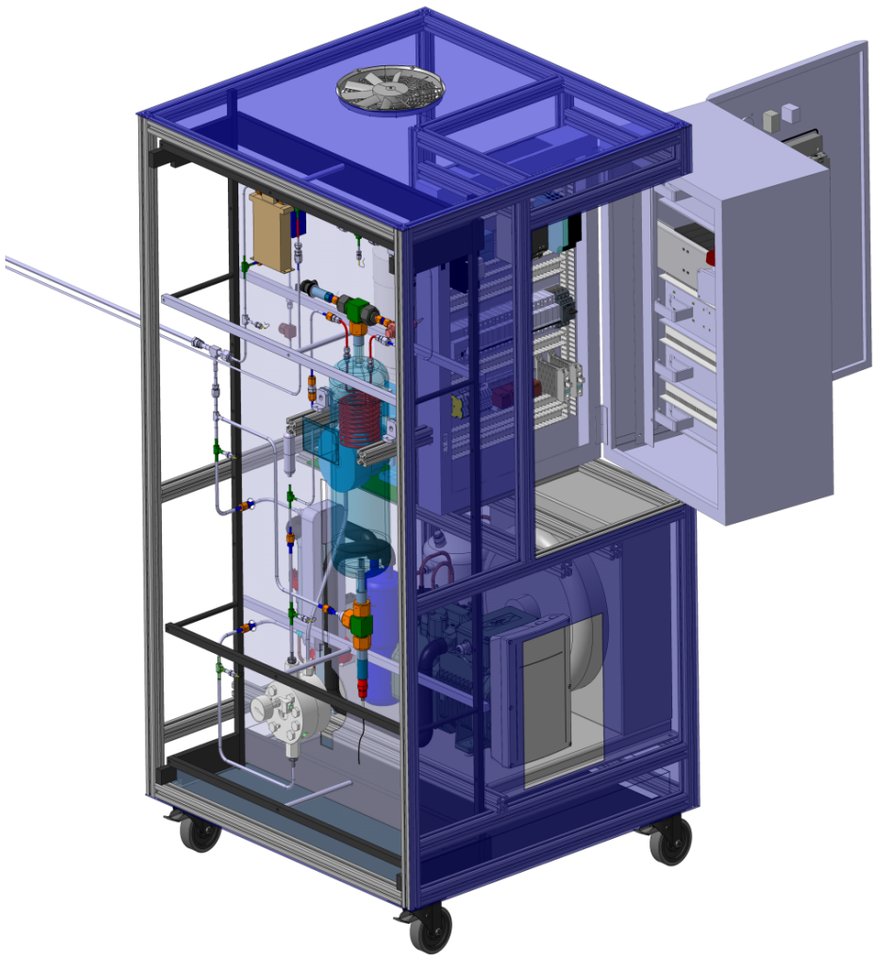
TAB bonding of microcables to ASICs and sensors



Current engineering studies

cooling

TRACI XL: 1 kW cooling prototype

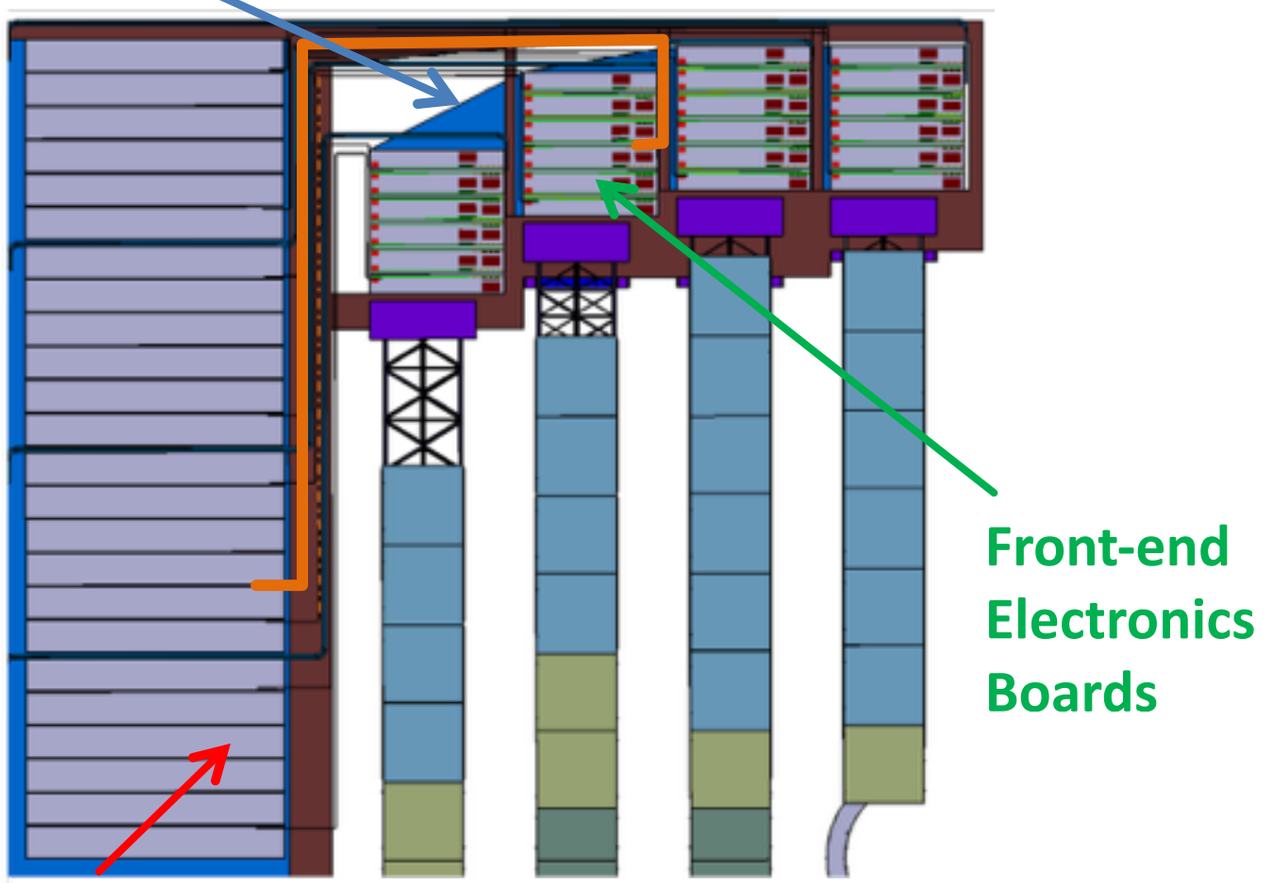


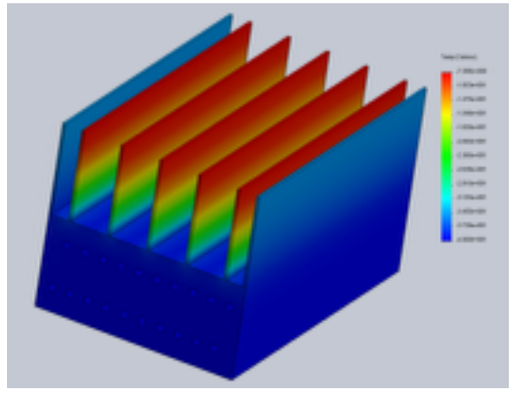
bi-phase CO_2 cooling system

STS electronics total: 42 kW

cooling plate with integrated channels

cabling



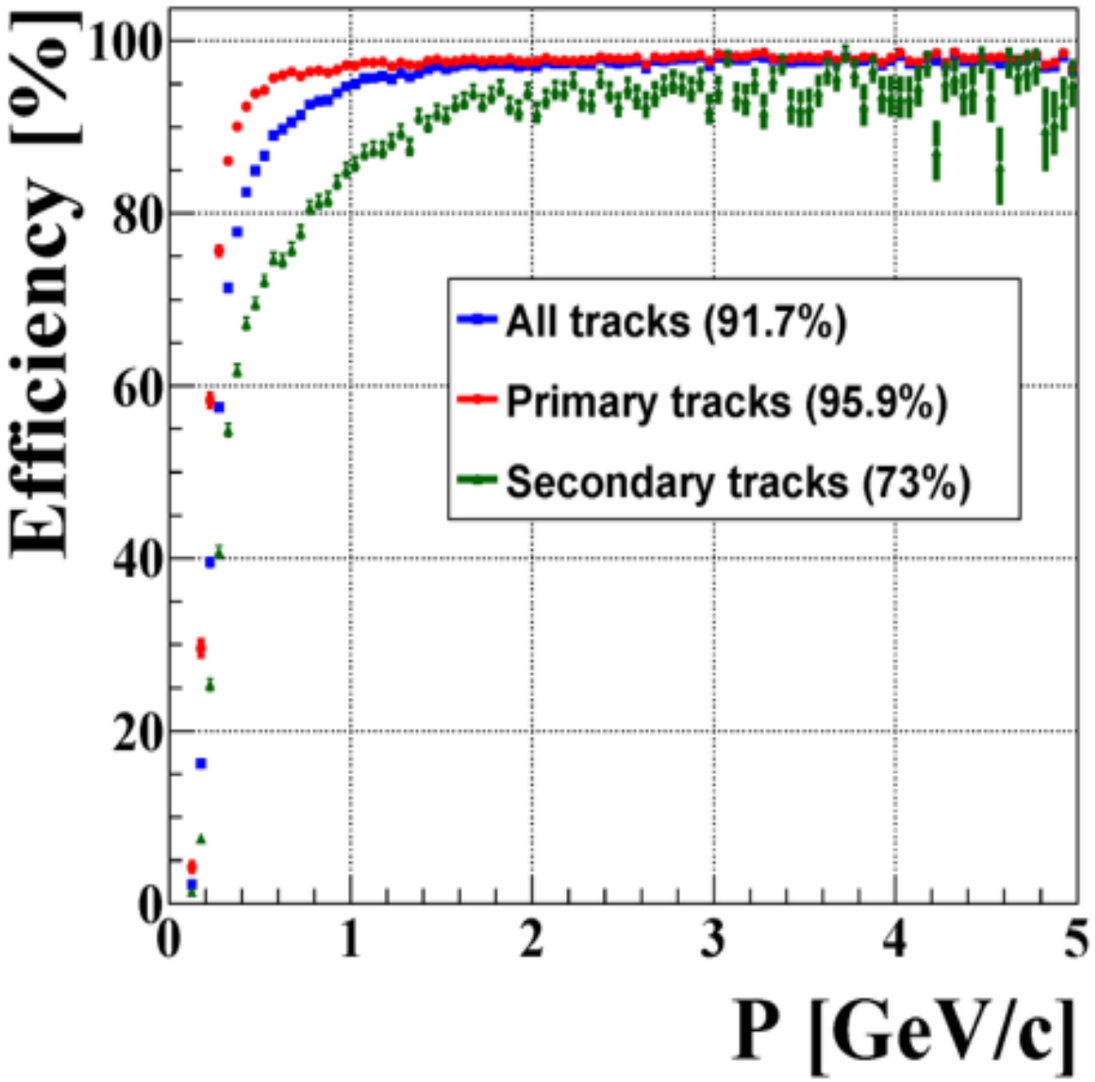


FEB stack

200 W

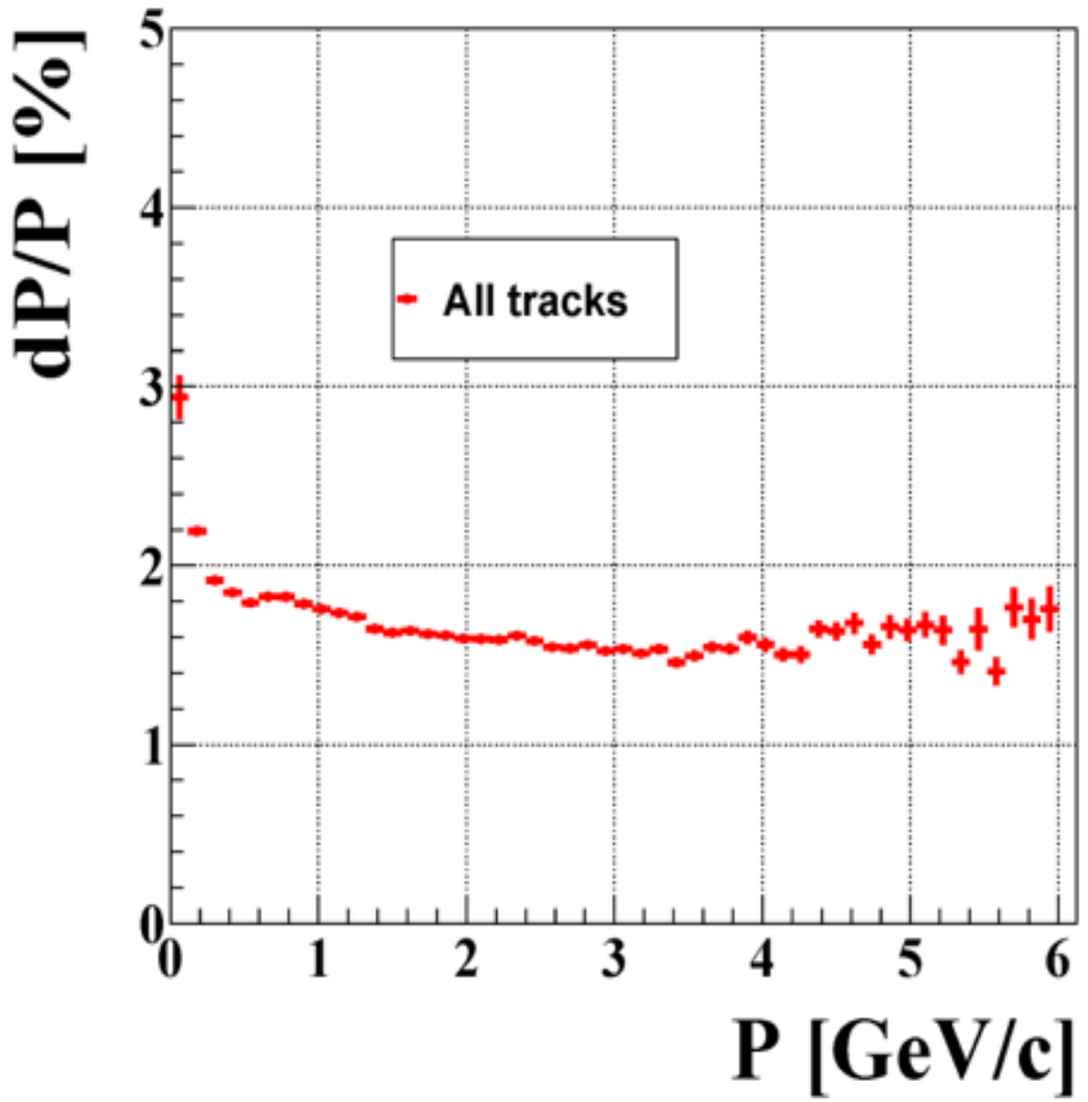
STS performance simulation

Track reconstruction efficiency



- realistic detector model
- CbmRoot simulation framework

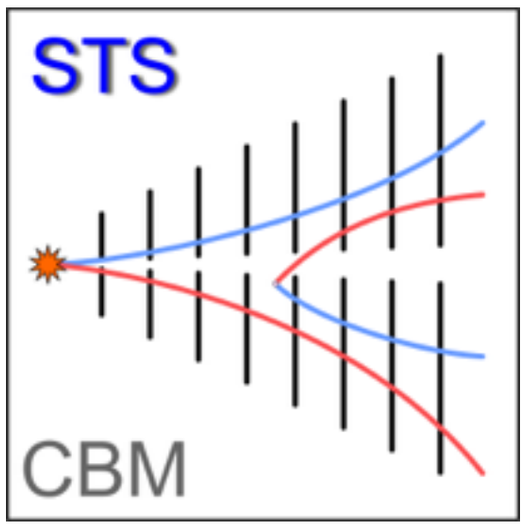
Momentum resolution



- Cellular Automaton track finder
- Kalman Filter track fitting

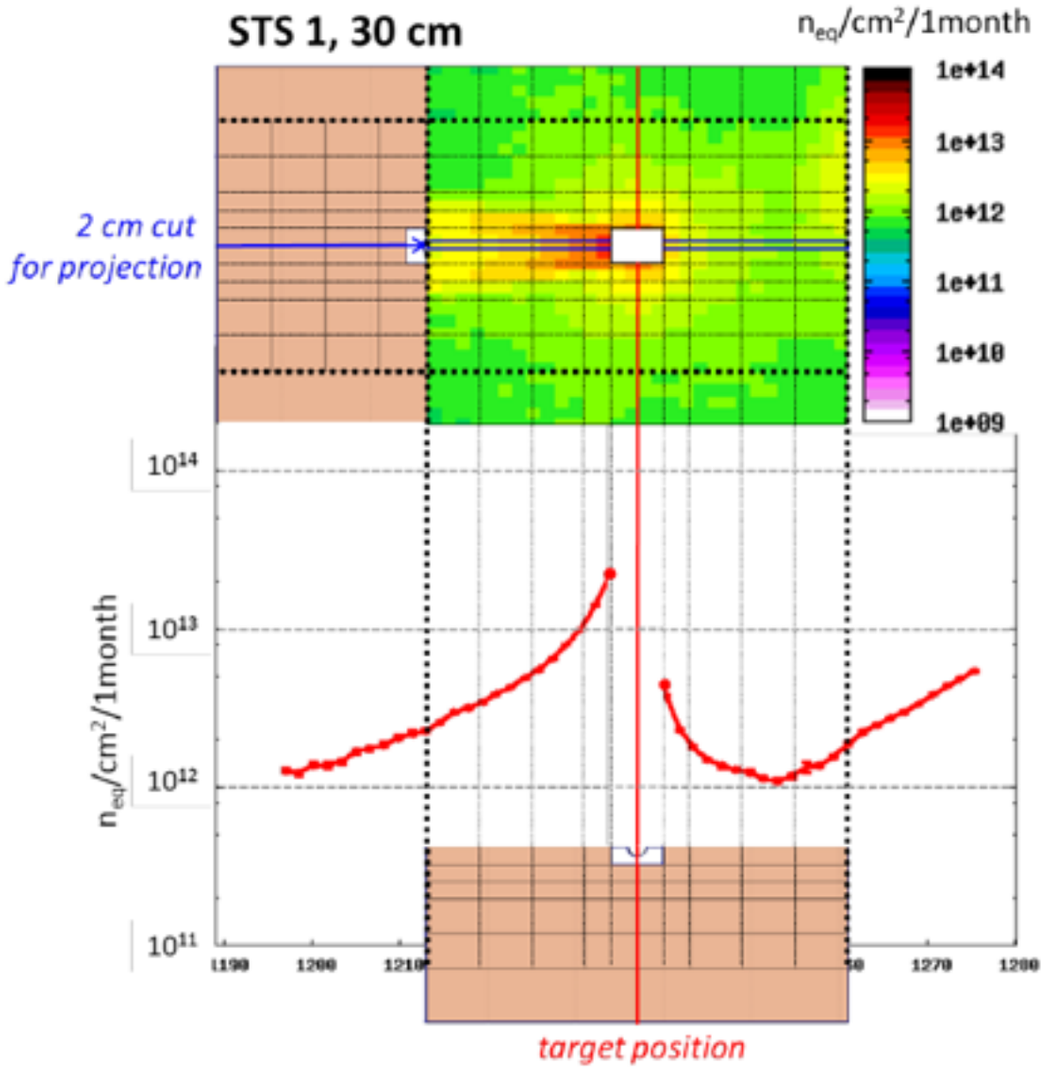
Summary

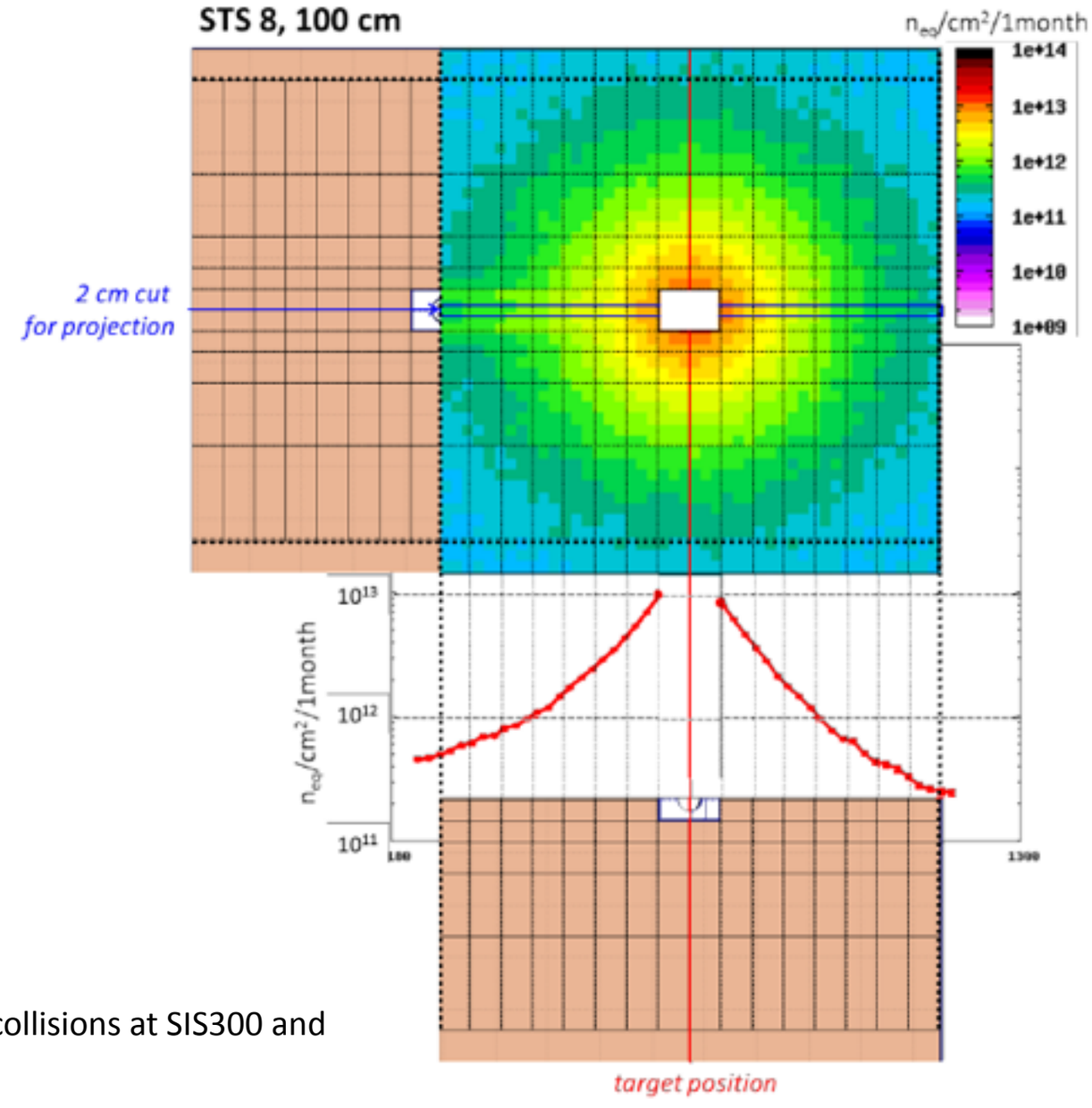
- STS system concept has been presented
- Detailed geometry has been assessed in simulations: performance OK
- Current activity is module assembly and system integration
- Full-size module mockup has been produced
- Production readiness by the end of 2016



BACKUP

Radiation environment





FLUKA calculation of non-ionizing dose for 35 AGeV Au+Au collisions at SIS300 and the CBM experiment in muon configuration.