# The Silicon Tracking System of the CBM experiment at FAIR

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**DPG Frühjahrstagung**

**14 - 18 March 2016**
**Technische Universität Darmstadt**

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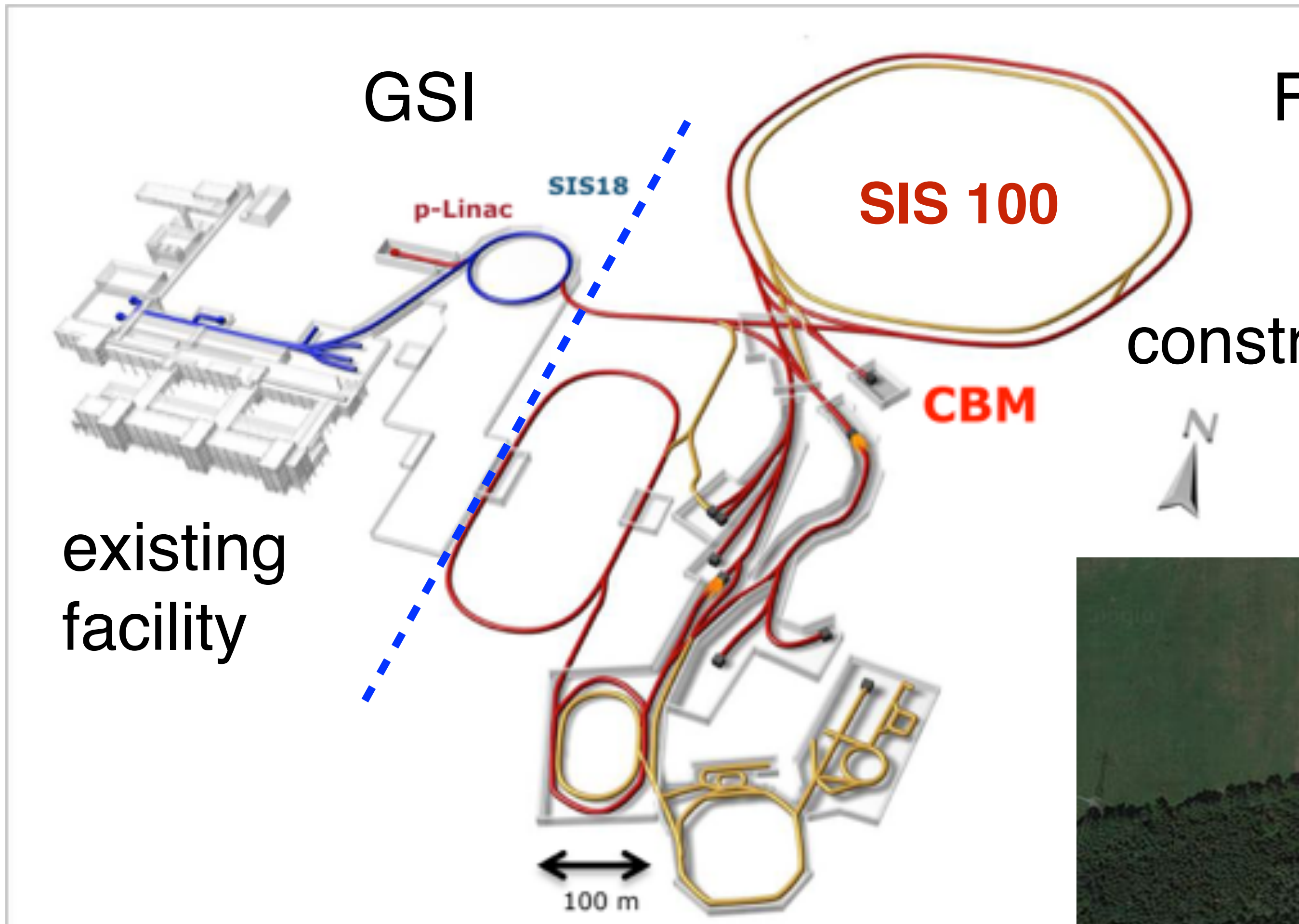
# Facility for Antiproton and Ion Research

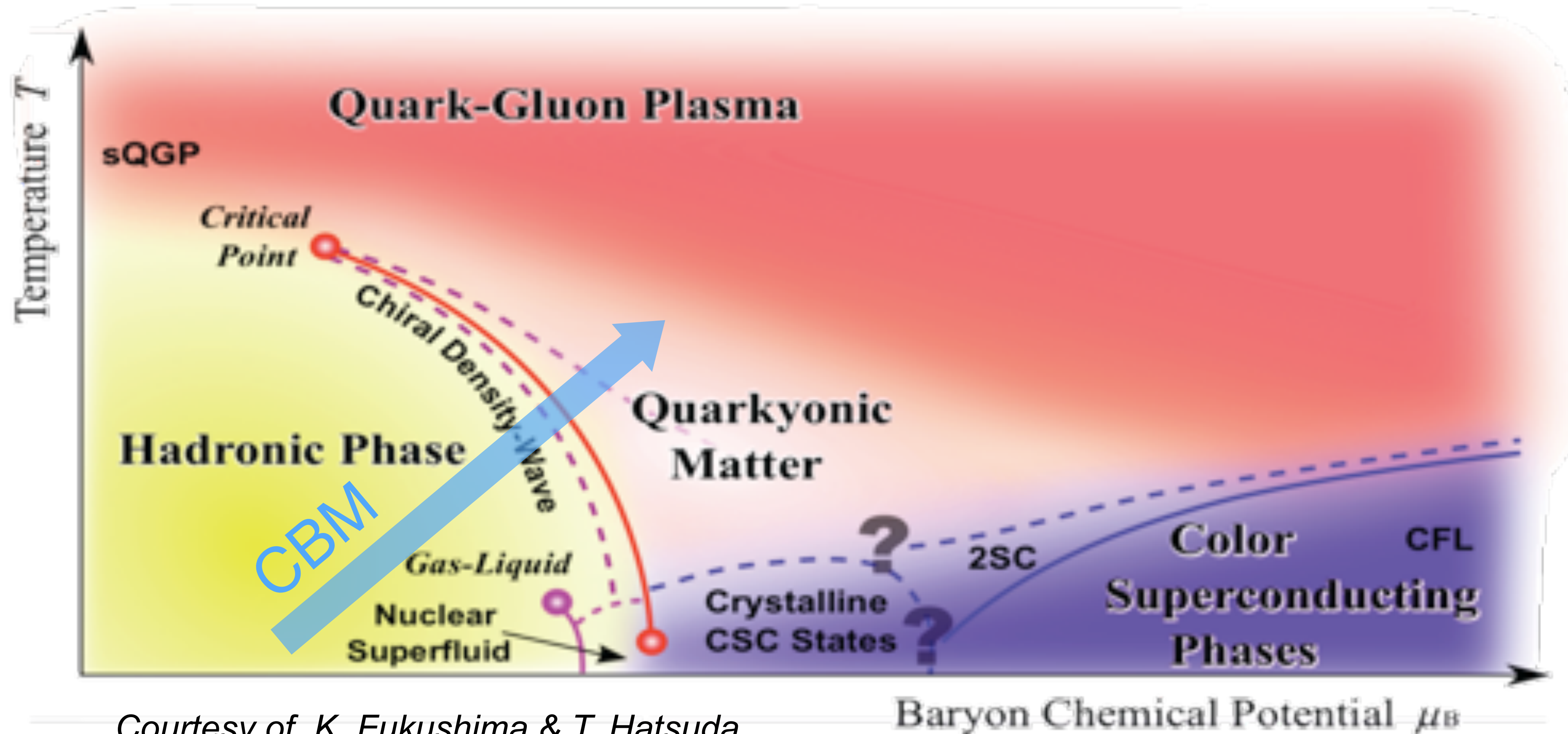



FAIR

under
construction

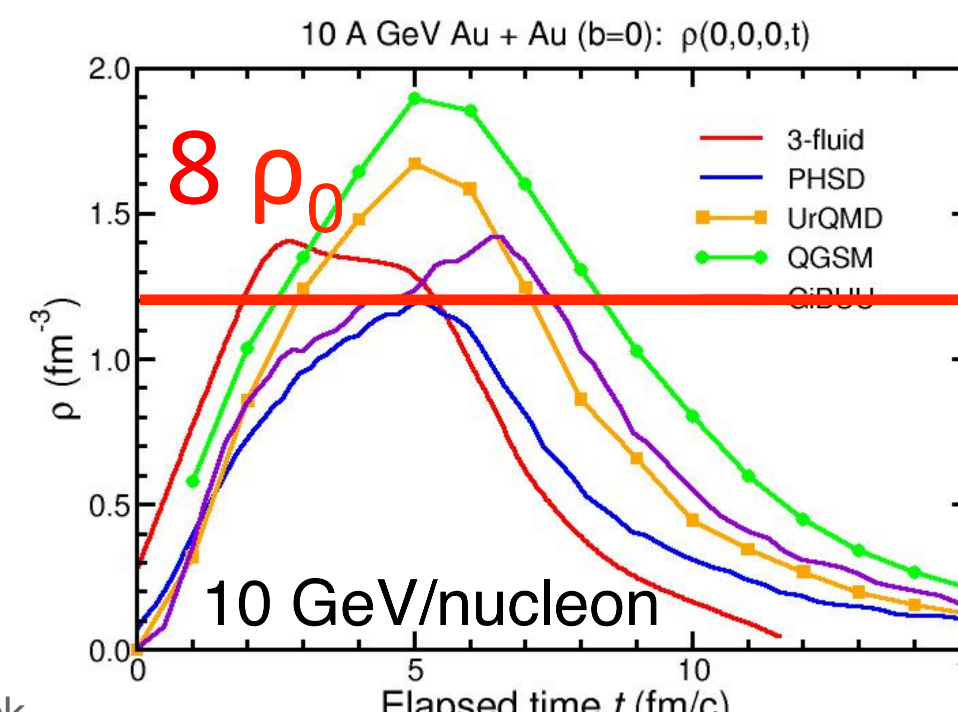
**SIS-100**
protons: 30 GeV
Au: 11 GeV/nucleon

# QCD phase diagram



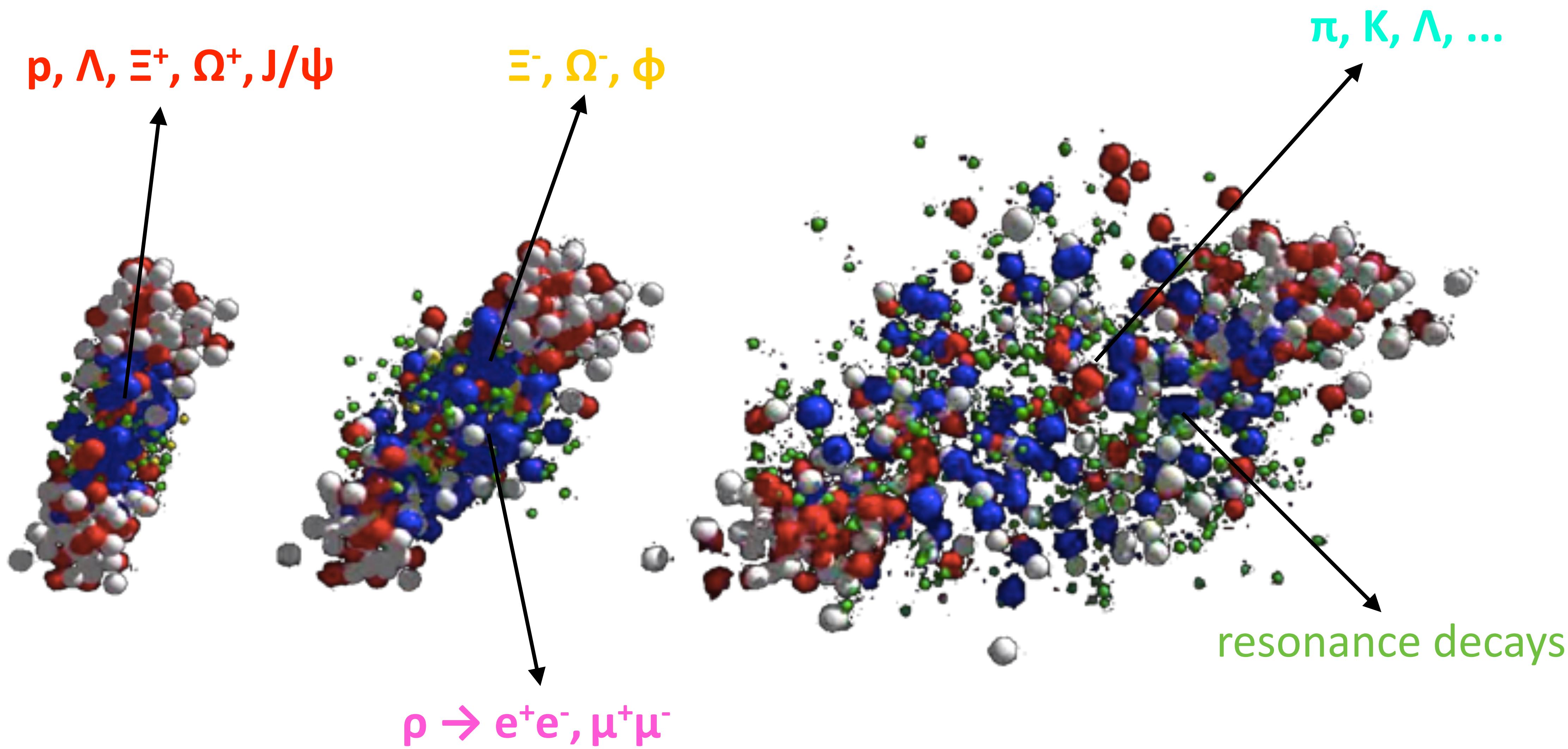

*Courtesy of K. Fukushima & T. Hatsuda*

- 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



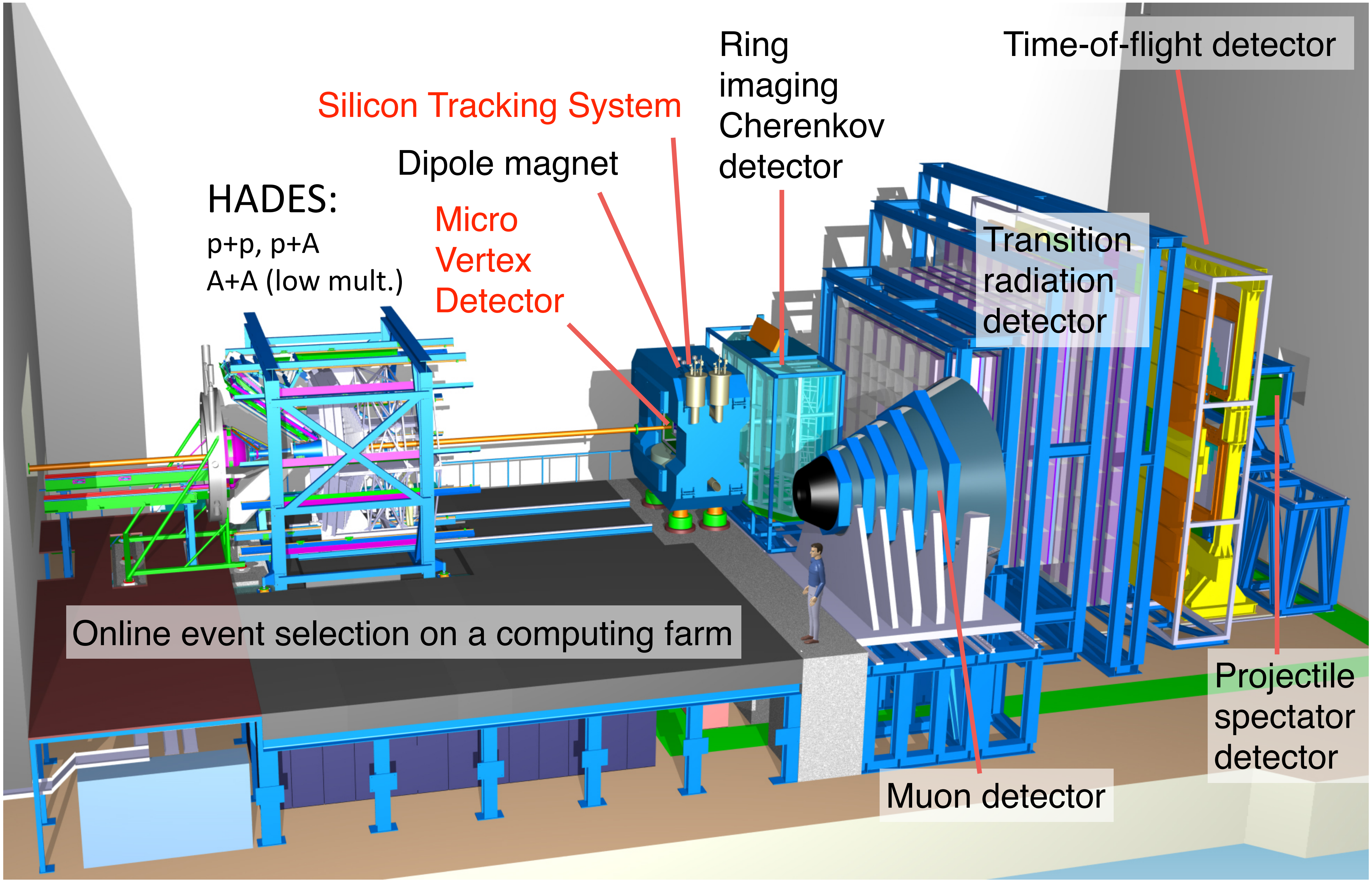
# Probing the dense fireball

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



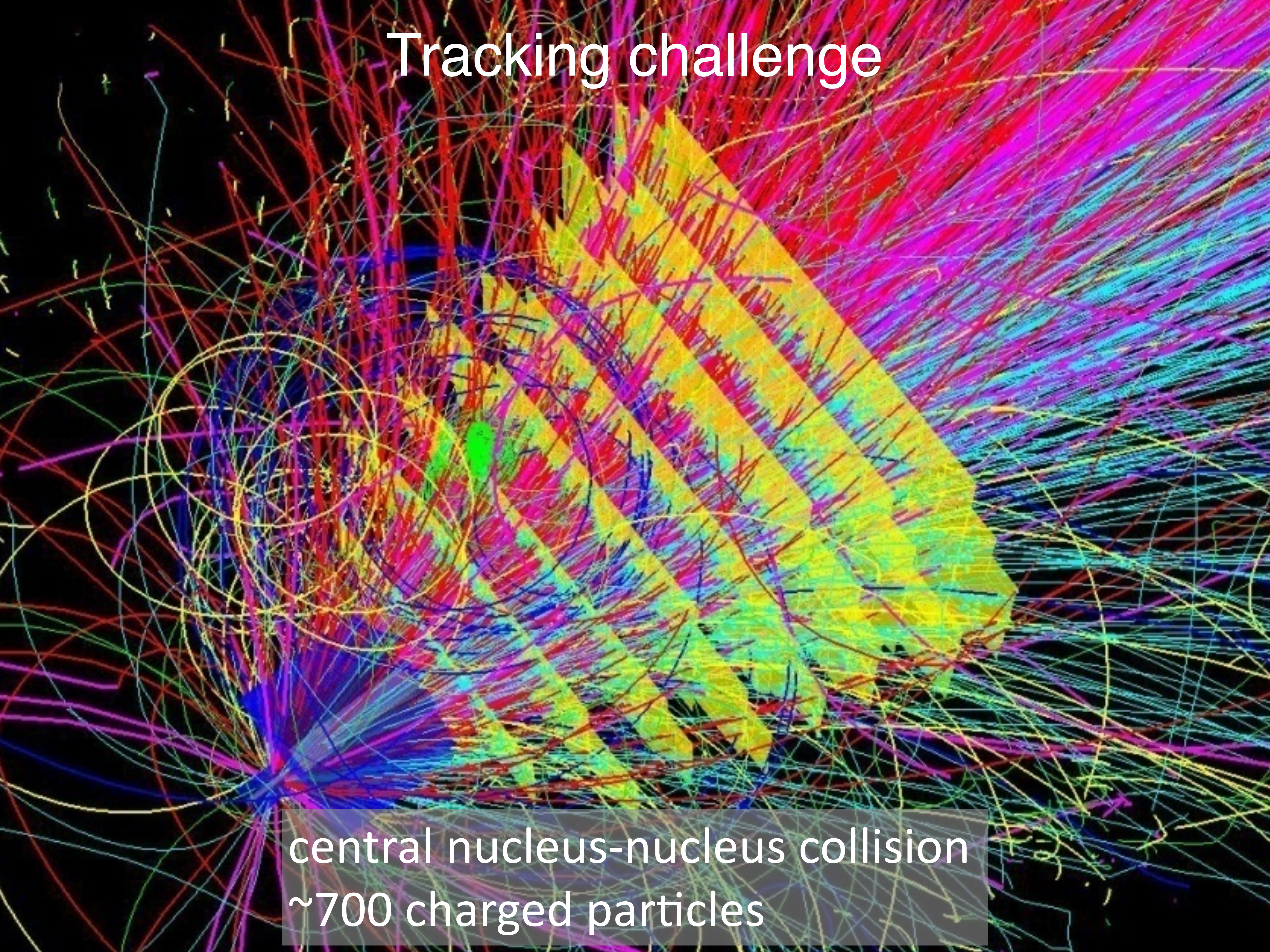

- Leptonic and hadronic signals from all stages of nucleus-nucleus collisions
- Rare probes: multistrange hyperons, low mass vector mesons, charmonium, strange dibaryons, hypernuclei.

# CBM experiment




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

# Tracking challenge



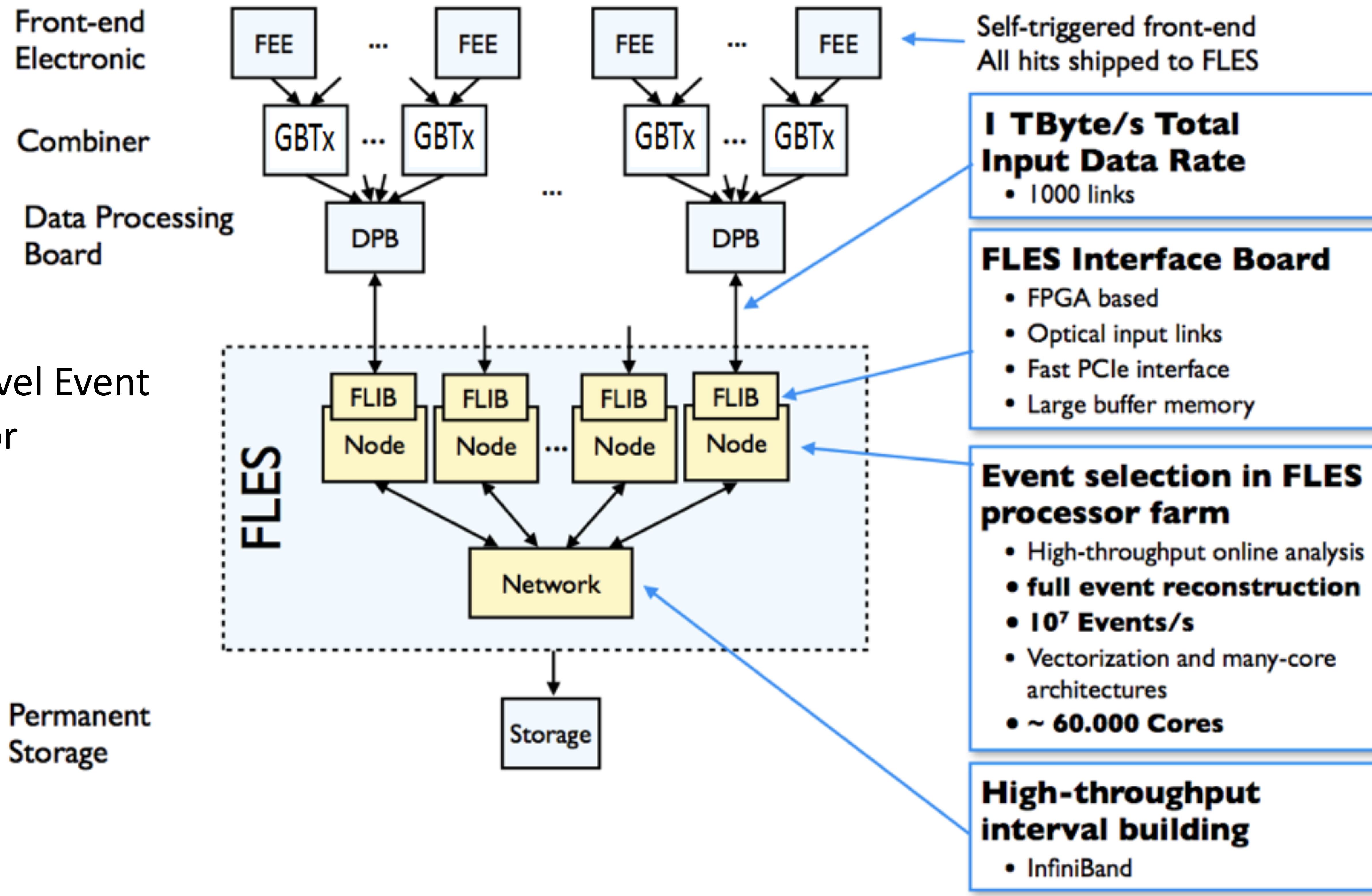
central nucleus-nucleus collision
~700 charged particles

# Experimental requirements

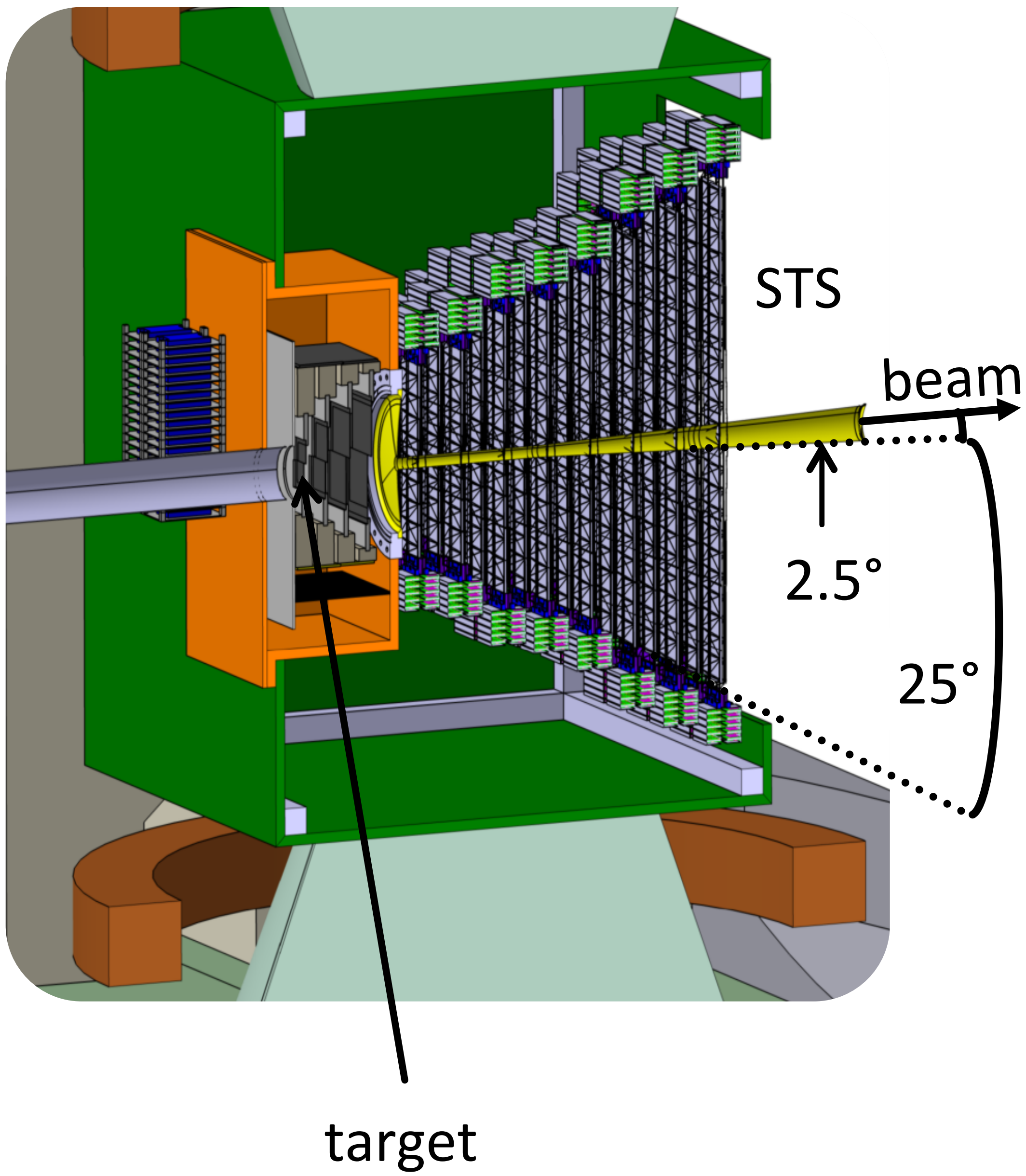
- $10^5$ - $10^7$ Au+Au collisions per second.
- secondary vertex determination (σ≈50 μm)
- track reconstruction from hadron and lepton probes
- fast and radiation tolerant detectors
- self-triggering front-end electronics
- fast data acquisition system + online event selection on a computing farm
-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

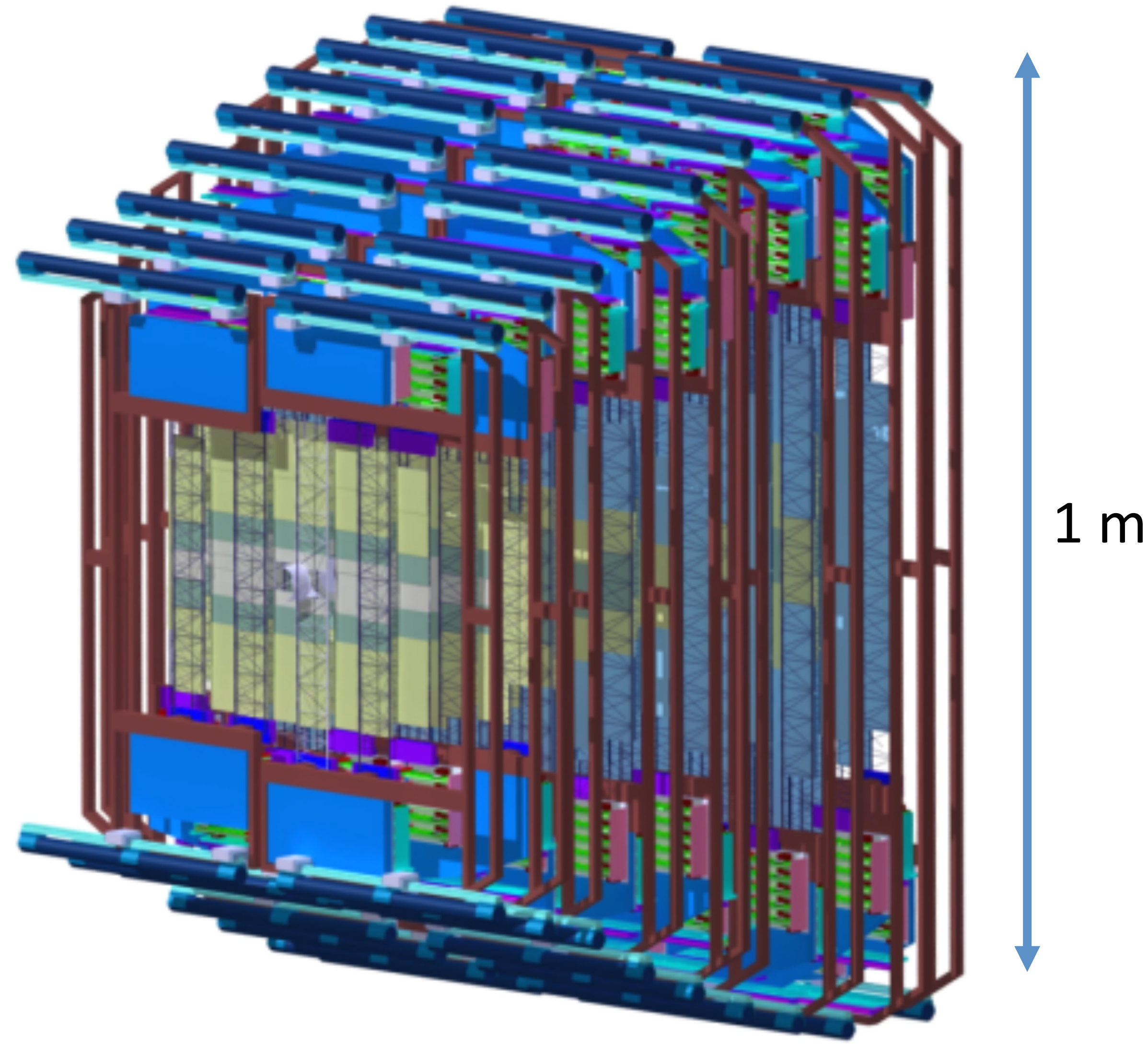
# Online data flow

First-level Event Selector



# Silicon Tracking System

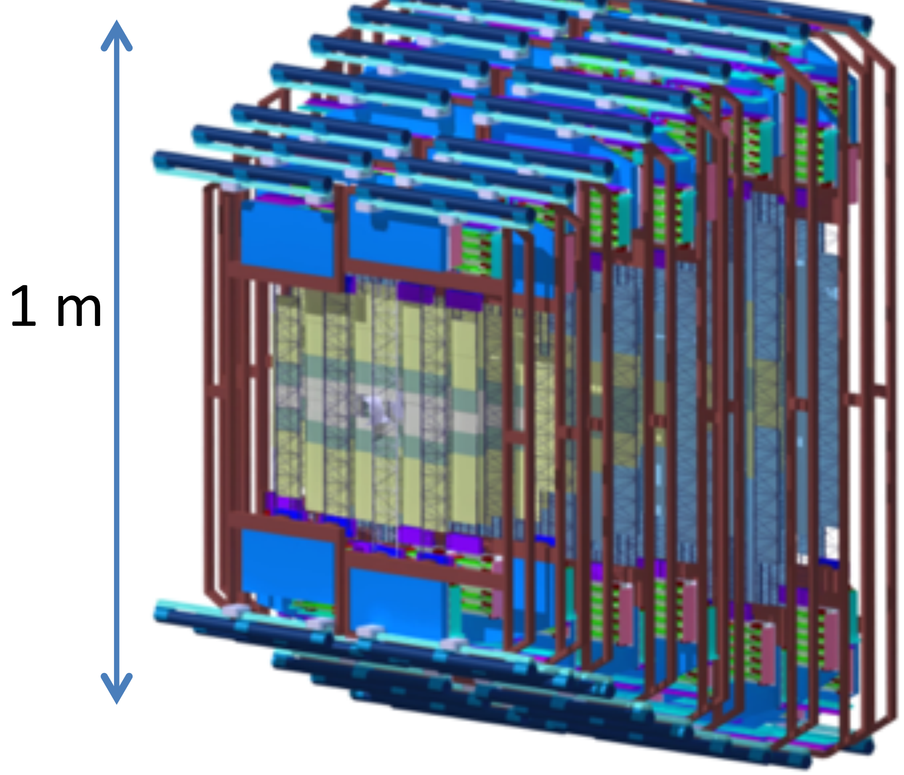


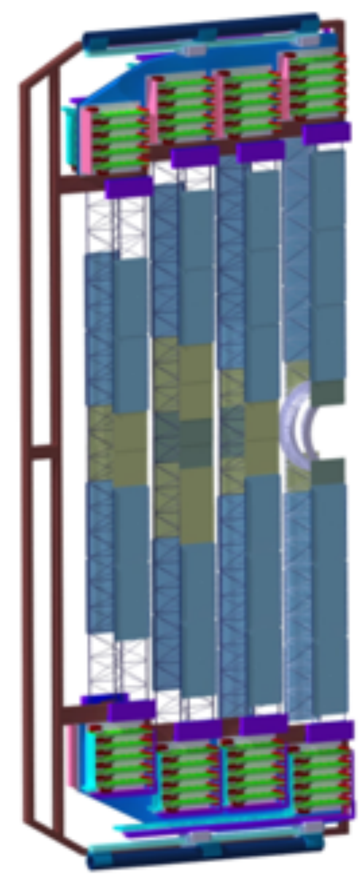

- 8 tracking stations in the magnet aperture
- double-sided silicon microstrip detectors

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

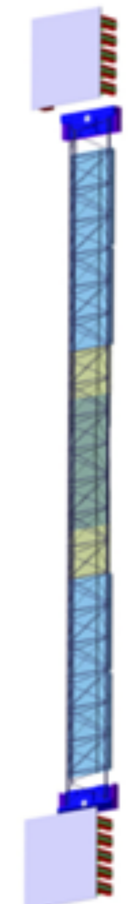
# STS integration concept



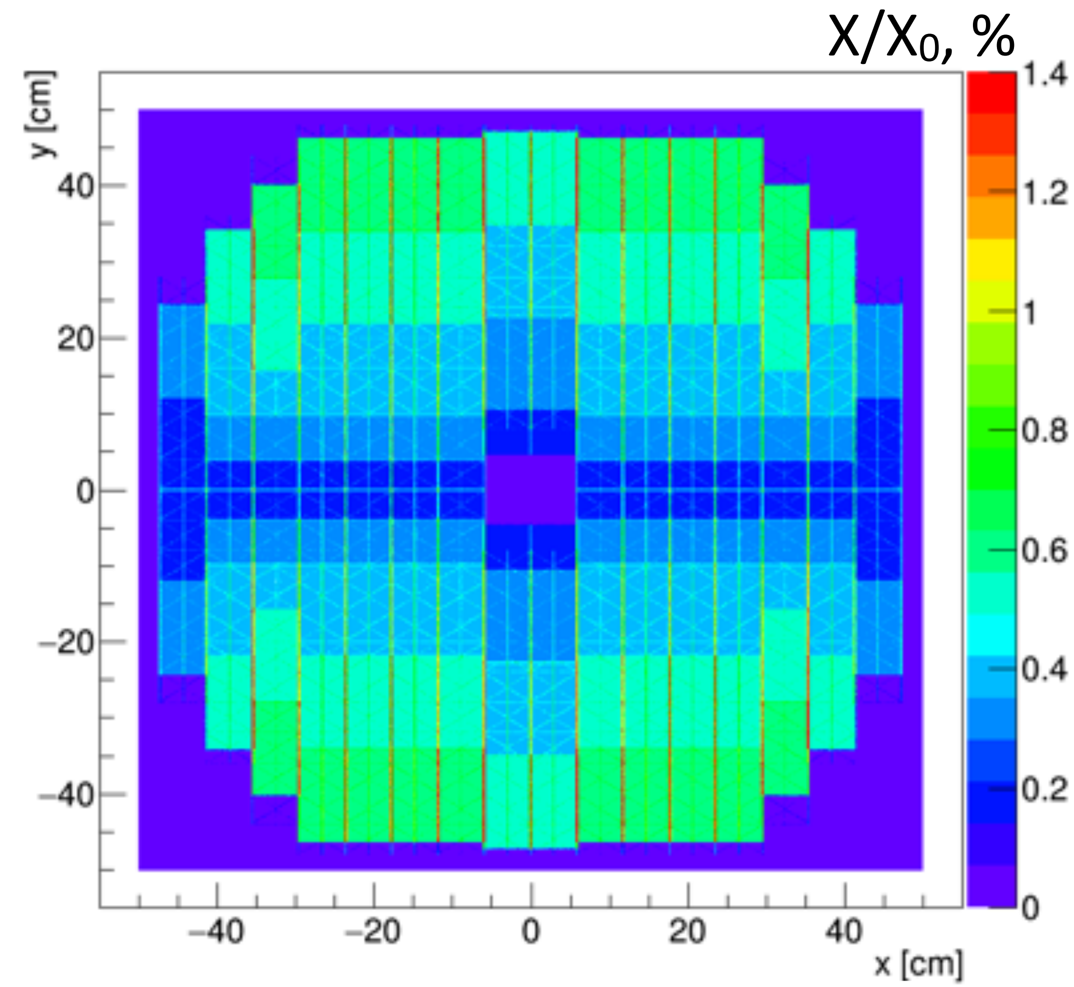

8 tracking stations



mechanical unit



ladder



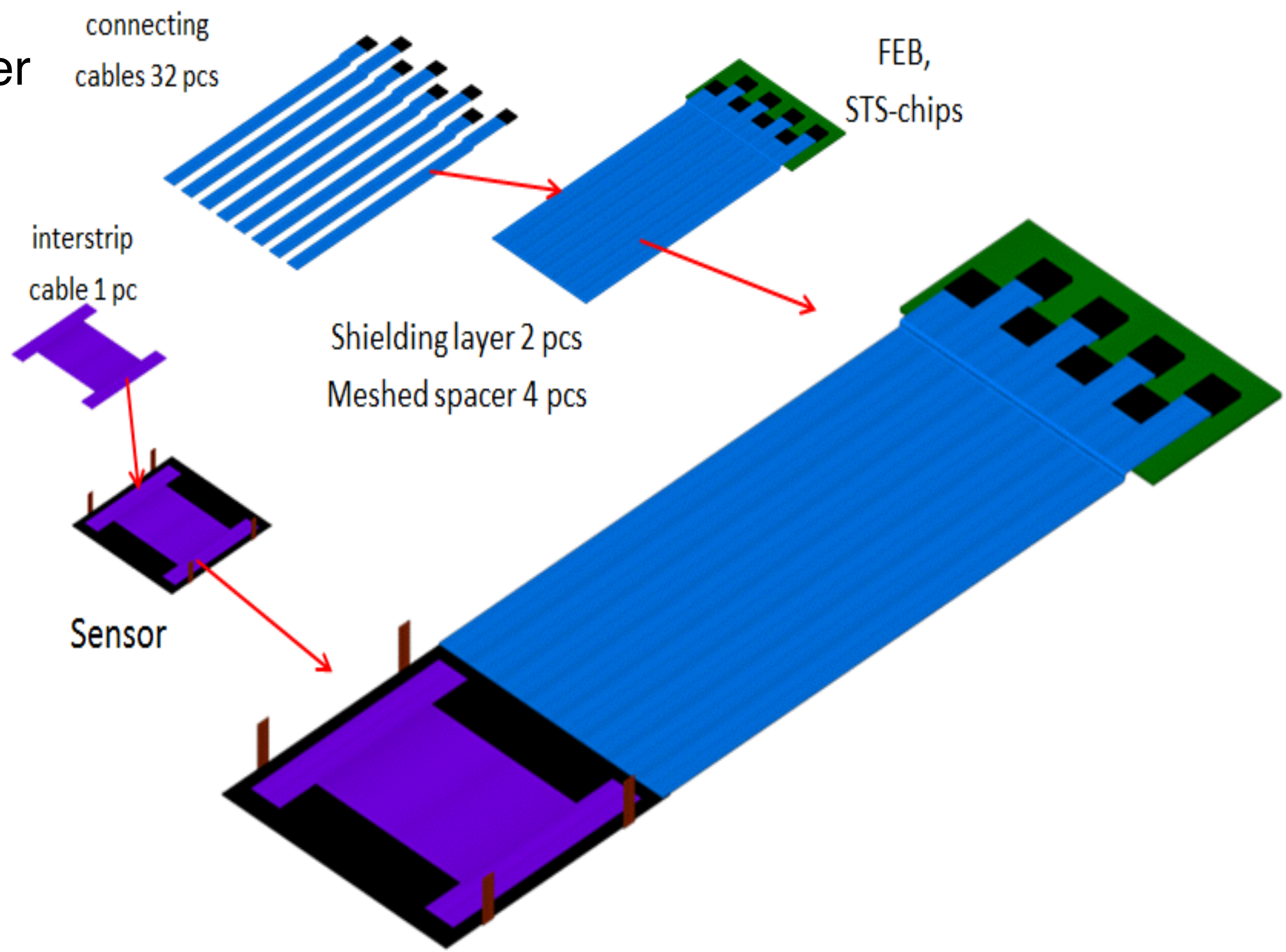

material budget for station 8

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

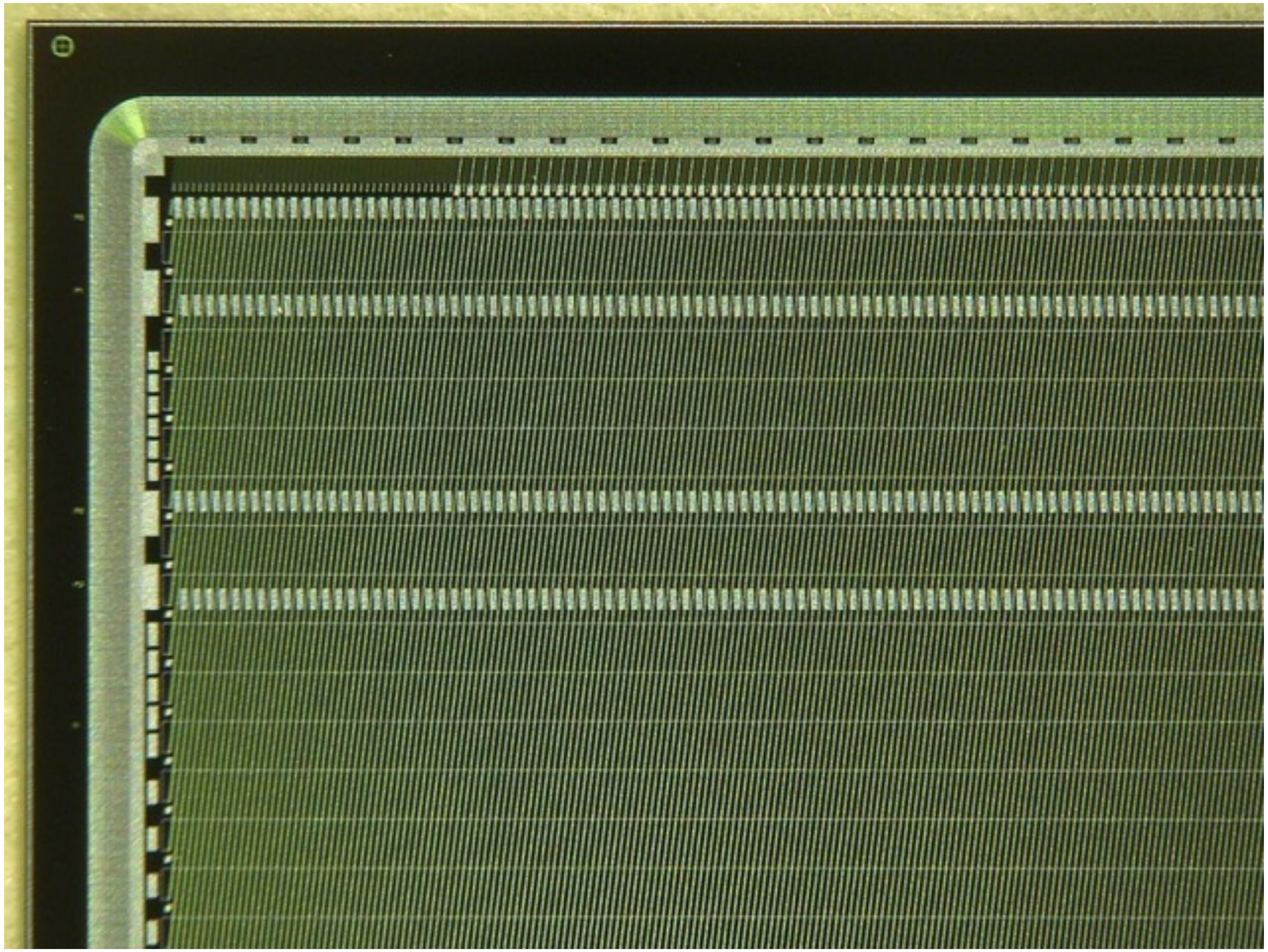


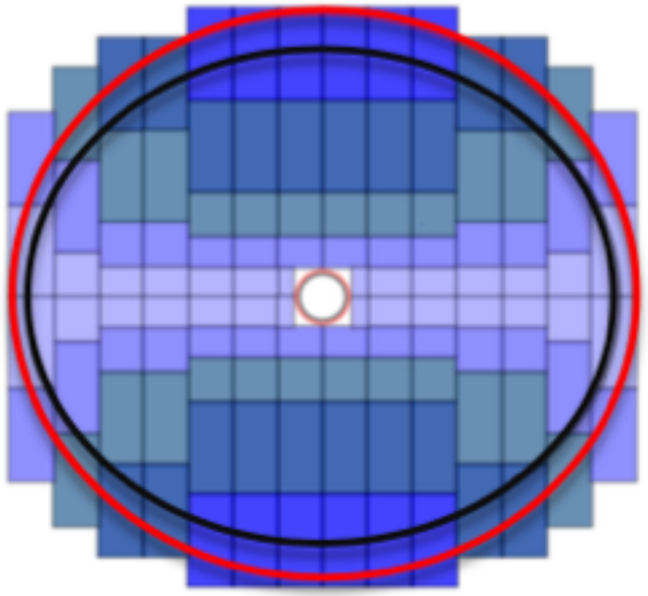

Modules comprises:

- sensor
- ultra-thin mirocables
- front-end board

# Silicon microstrip sensors

- double-sided
- 1024 channels per side
- 58 $\mu$m pitch
- 300 $\mu$m thick
- stereo angle 7.5˚(p-side)
- dimensions:
  6×2 cm$^2$, 6×4 cm$^2$,
  6×6 cm$^2$, 6×12 cm$^2$
- 2$^{nd}$ metallization to interconnect short corner strips

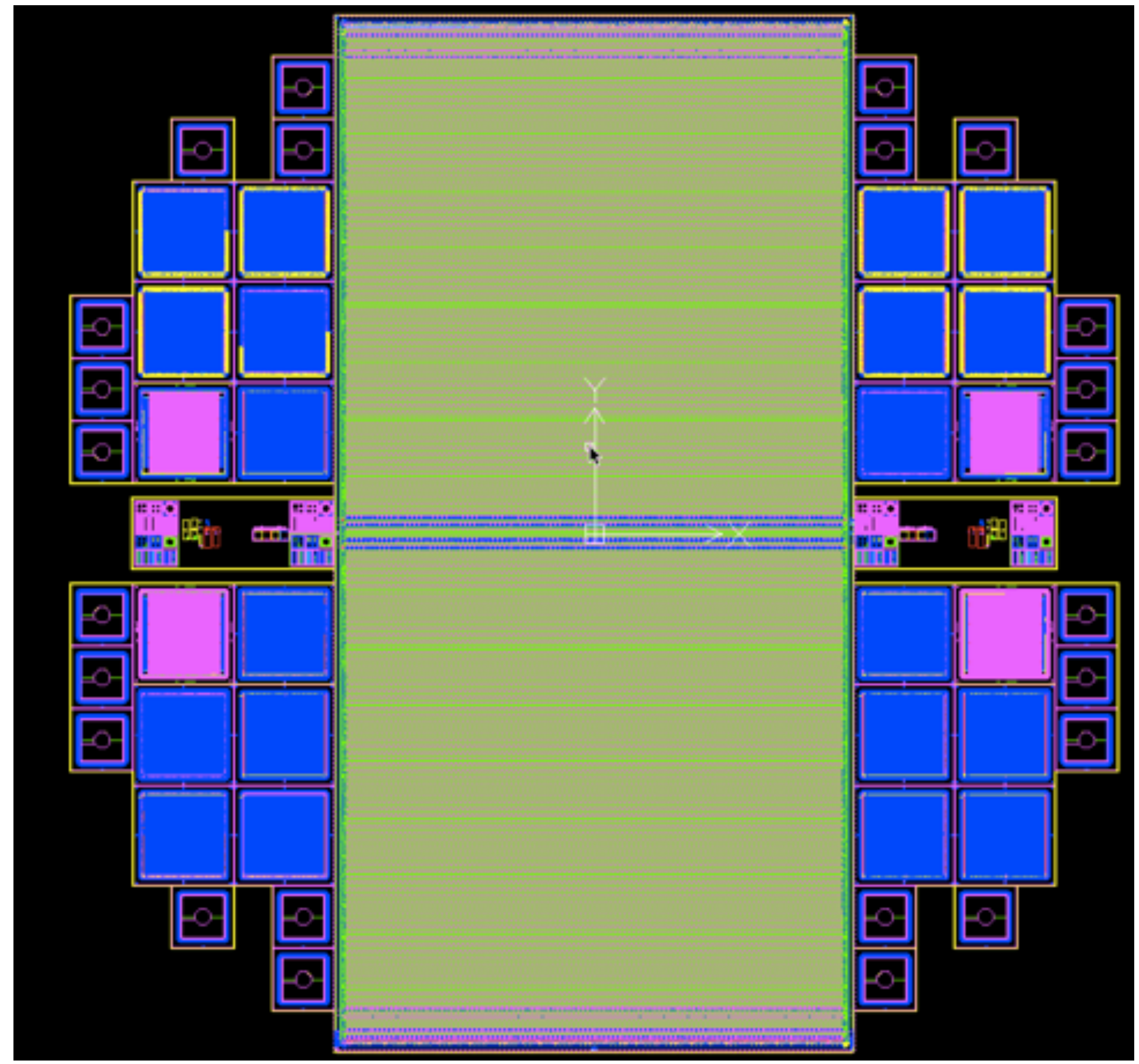




Layout
STS5 and 6

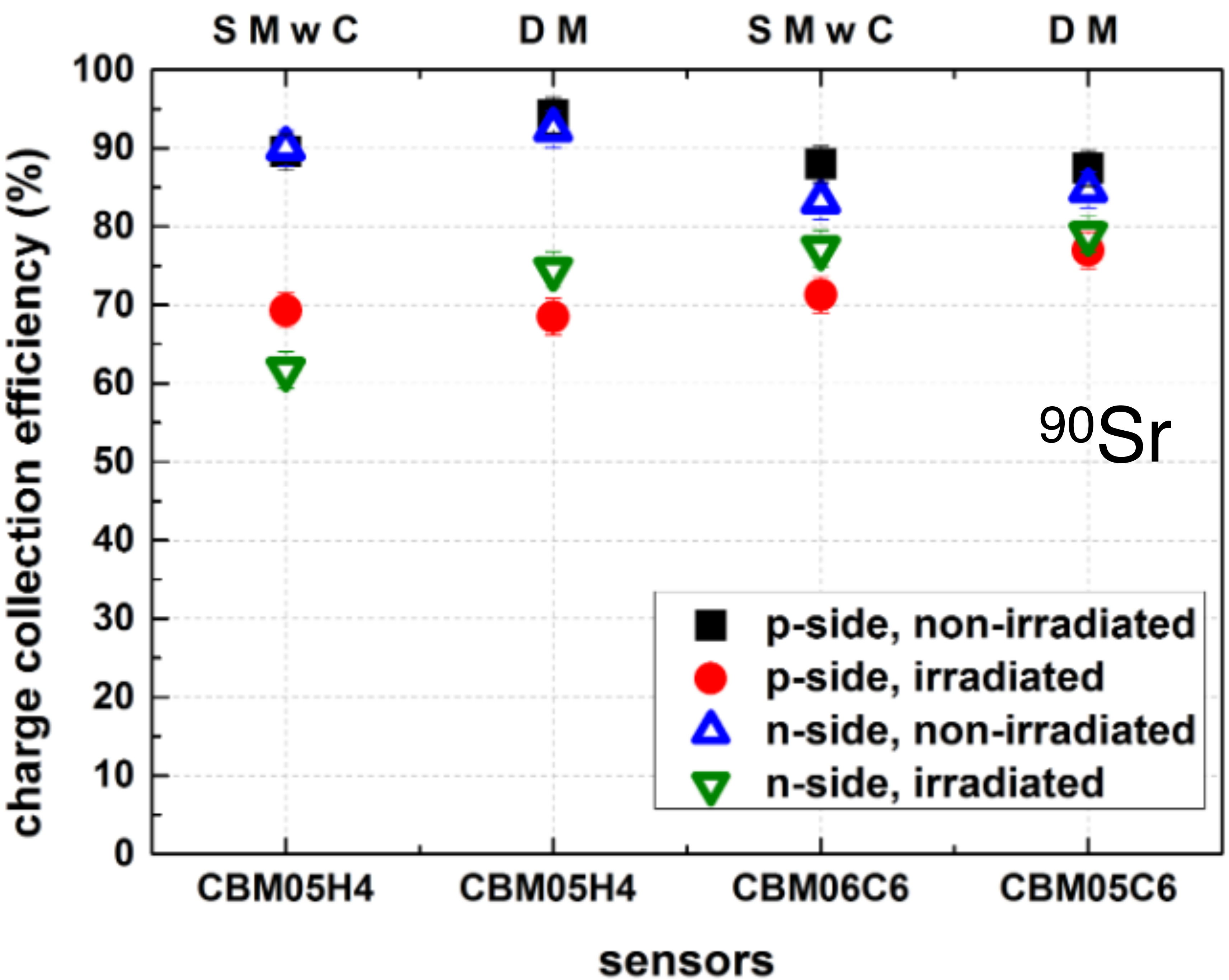
# Silicon microstrip sensors

two daisy-chained sensors with 6×6 cm$^2$ size each



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

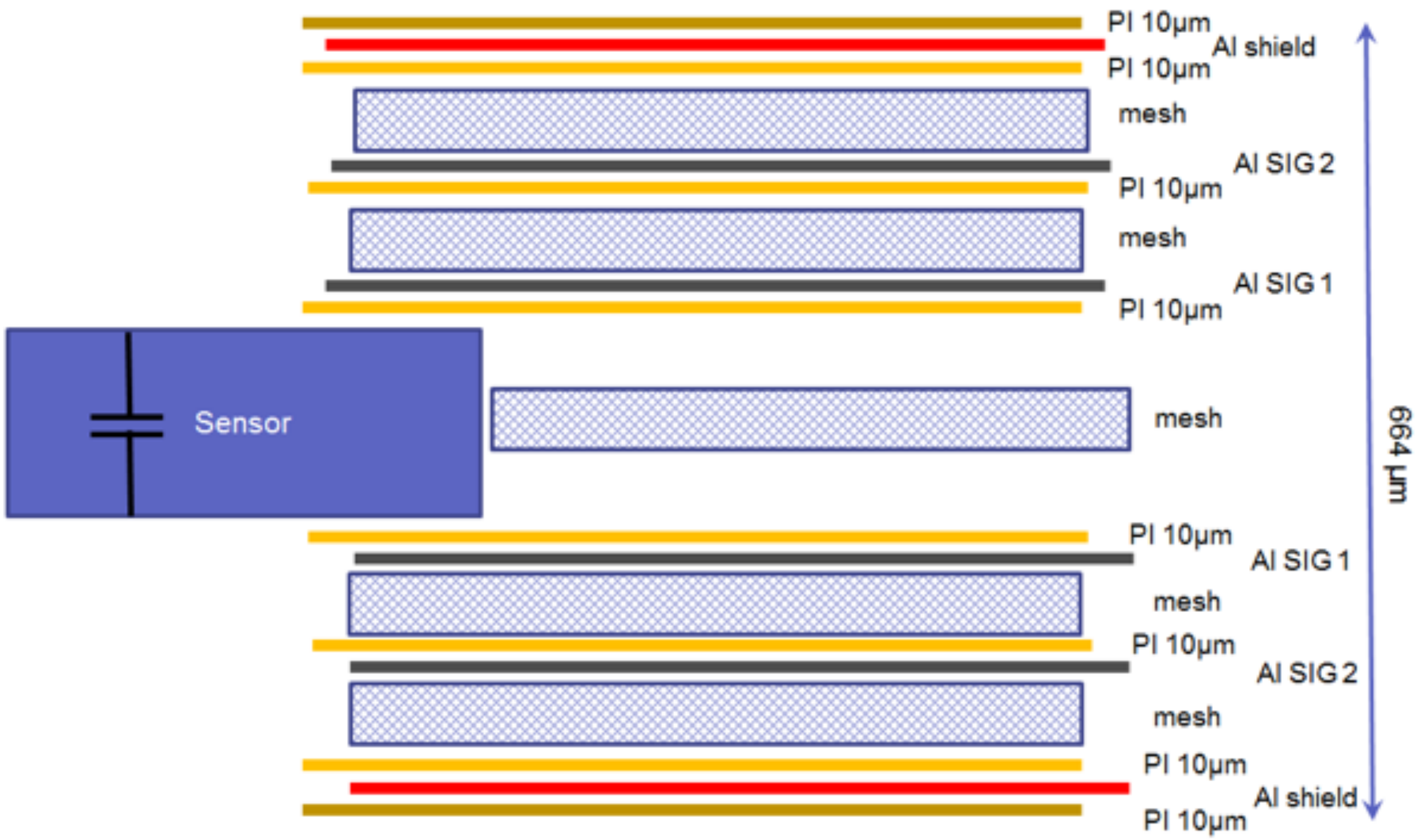
# Charge collection studies

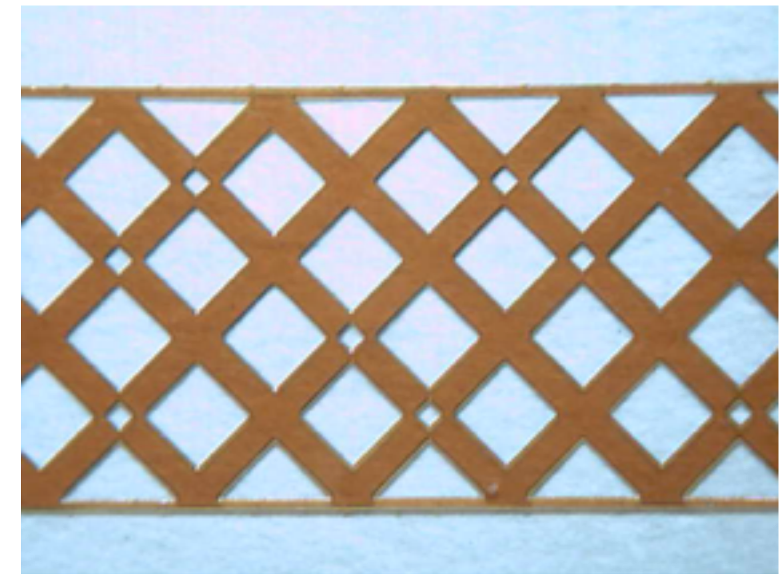



Irradiated sensors: $\Phi$ = 2e14 $n_{eq}/cm^2$ (twice maximum fluence for CBM lifetime)

- Irradiated sensors show reduction in charge collection efficiency of up to 20%
- CCE confirmed in a 2 GeV proton beam test at COSY

# Microcables



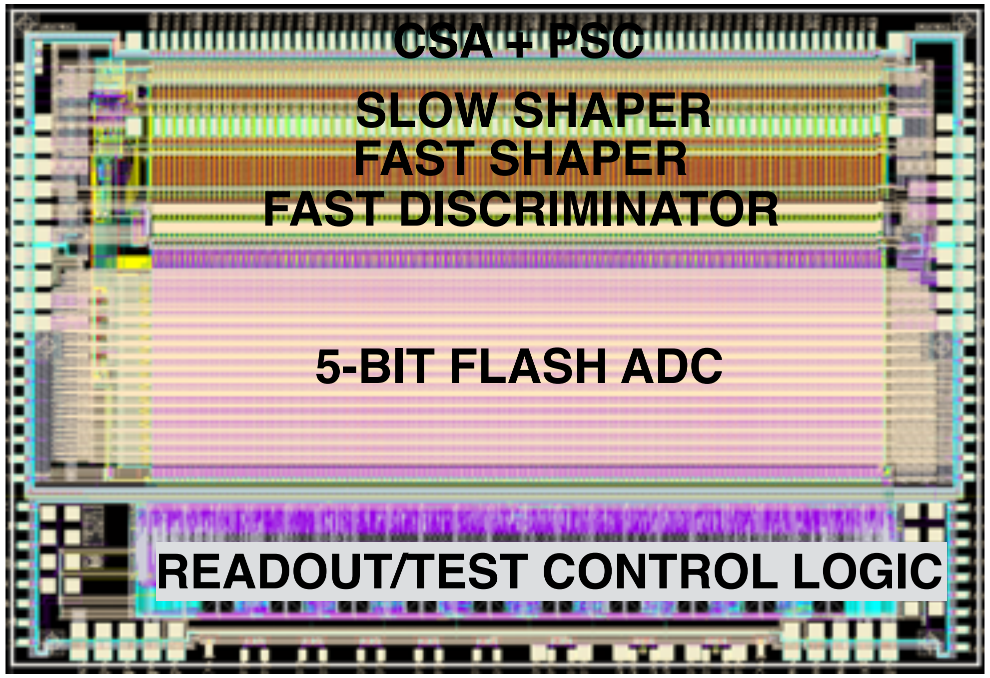
meshed spacer

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

Material budget per cable stack: 0.228 $X_0$ (equivalent to 213 $\mu$m Si)

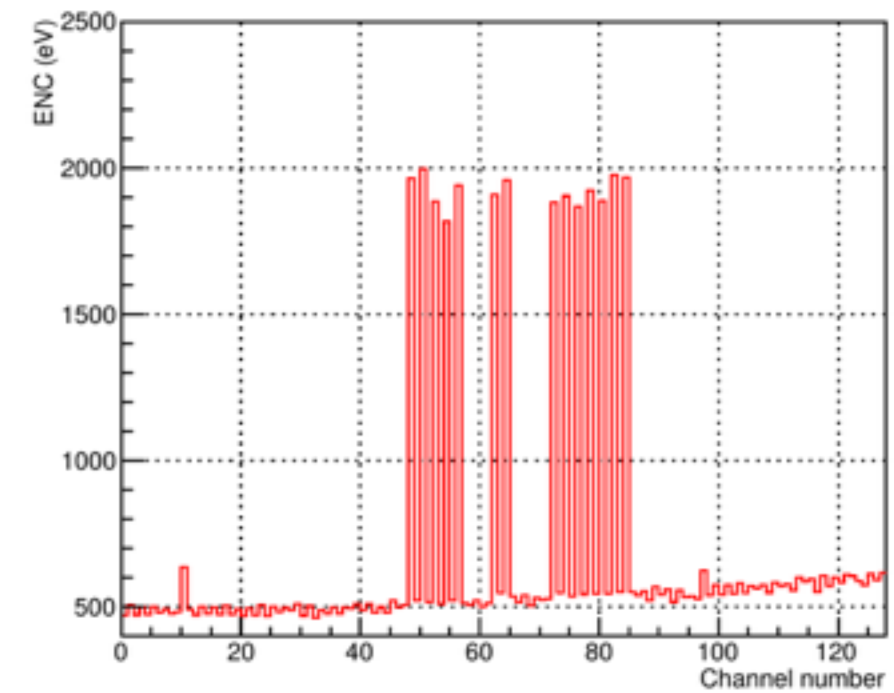
# STS-XYTER ASIC

**STS-XYTER ASIC**



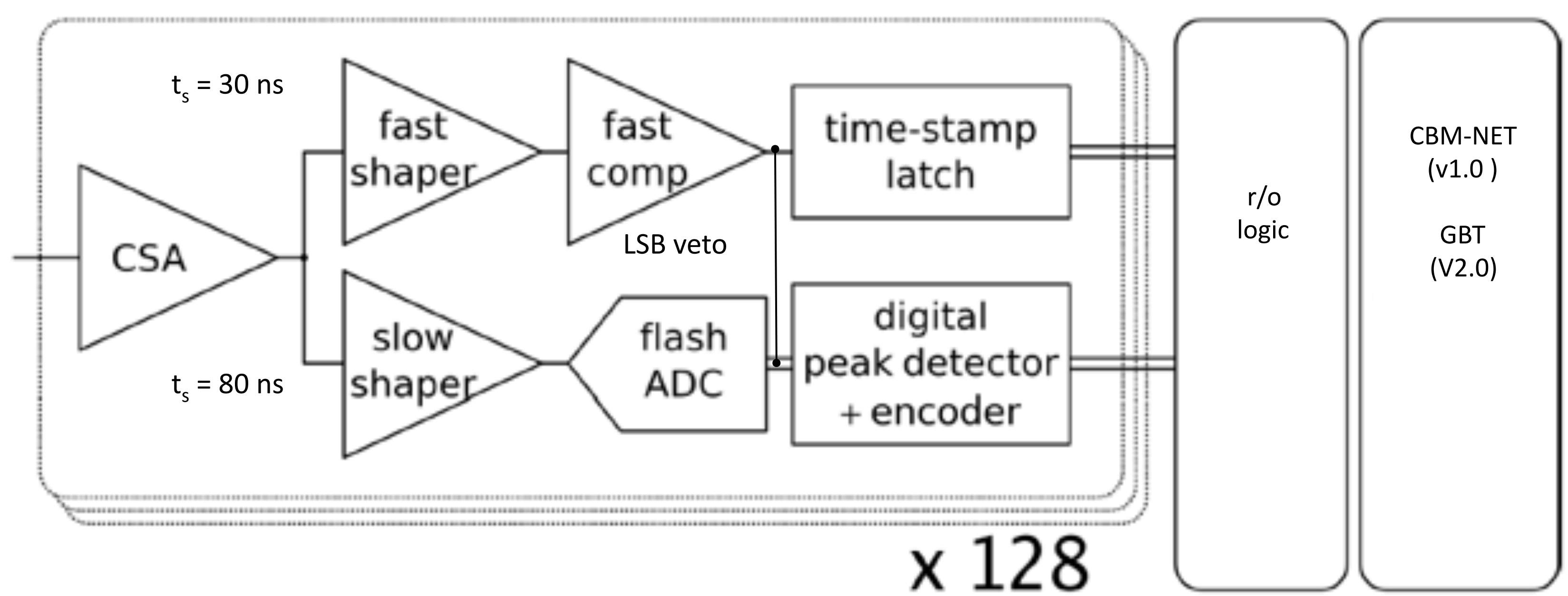

- data driven architecture
- fast branch: time-stamp
- slow branch: signal digitization
- double-threshold discrimination: time stamp is vetoed if ADC produced no signal

**ENC vs channel number**

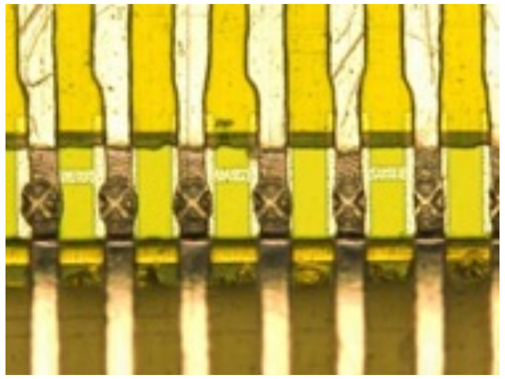



| | |
|---|---|
| channels | 128, polarity +/- |
| noise | 1000 e⁻ at 30 pF load |
| ADC range | 16 fC, 5 bit |
| clock | 160 MHz |
| power | < 10 mW/channel |
| timestamp | < 5 ns resolution |
| out interface | (1..5)×320 Mbit/s LVDS |

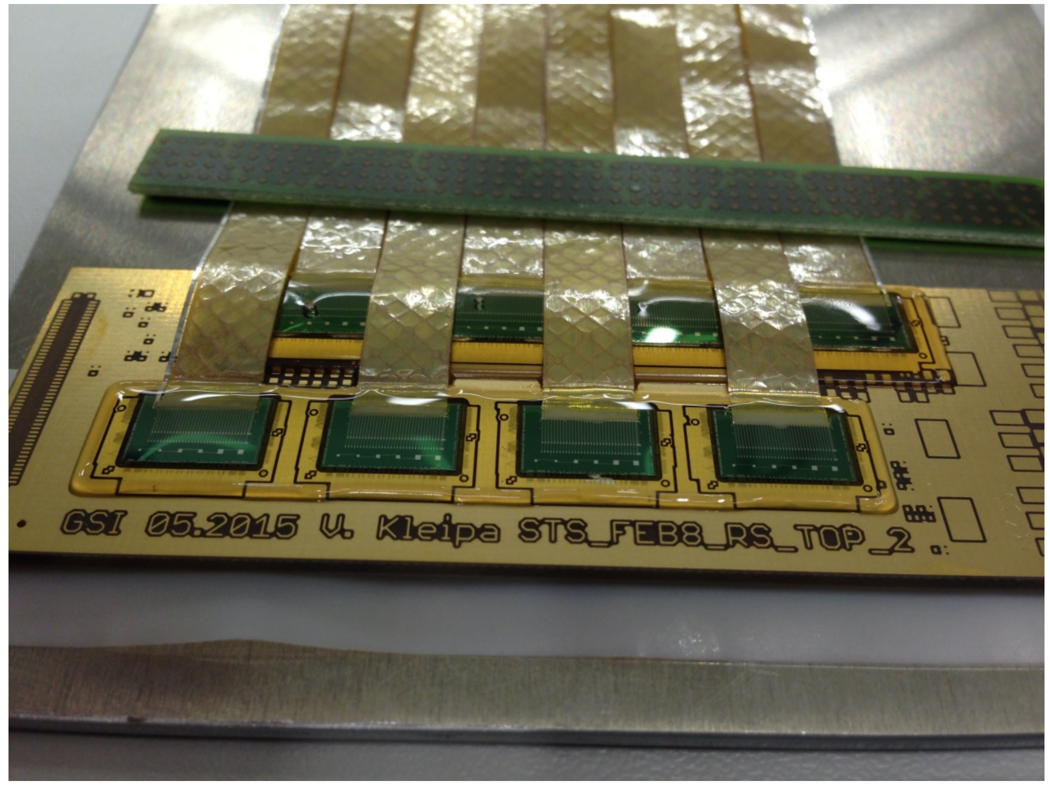
- Noise performance with STS-XYTER v1 is ~1800 $e^-$ (chip + two daisy-chained sensors with 62 mm strips + 30 cm cable)
- Significant improvements expected after redesign



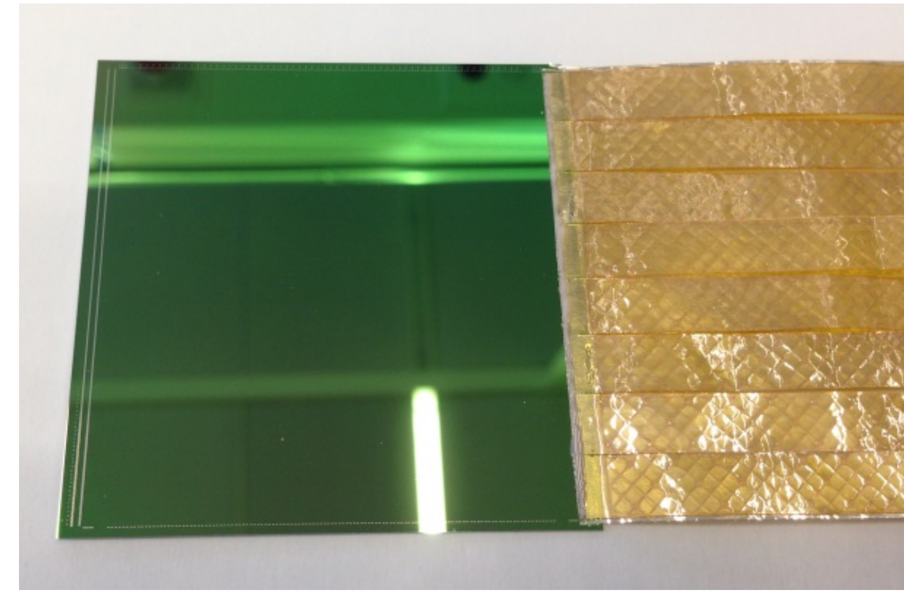
# Detector module assembly



1. TAB bonding of microcables to ASICs




2. Wire bonding ASICs to front-end boards + bond protection (glob top)



3. TAB bonding of microcables to sensors on both sides

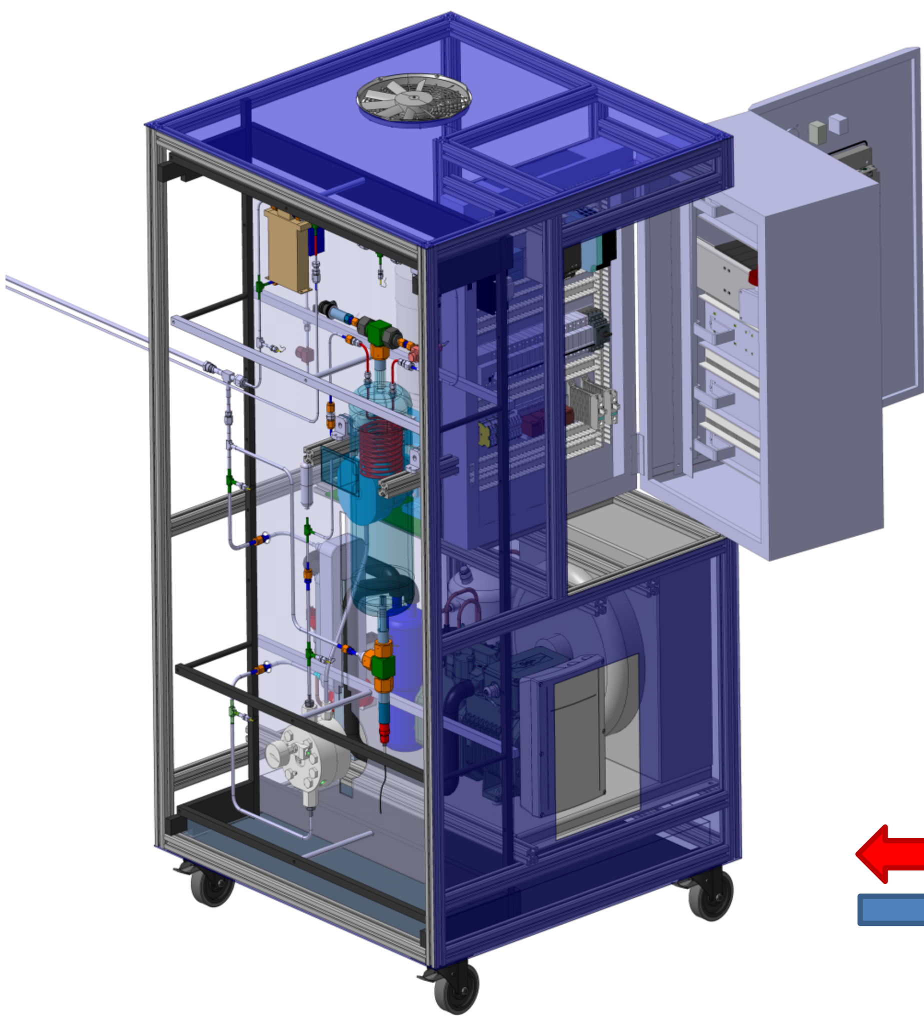
# Current engineering studies

## cooling

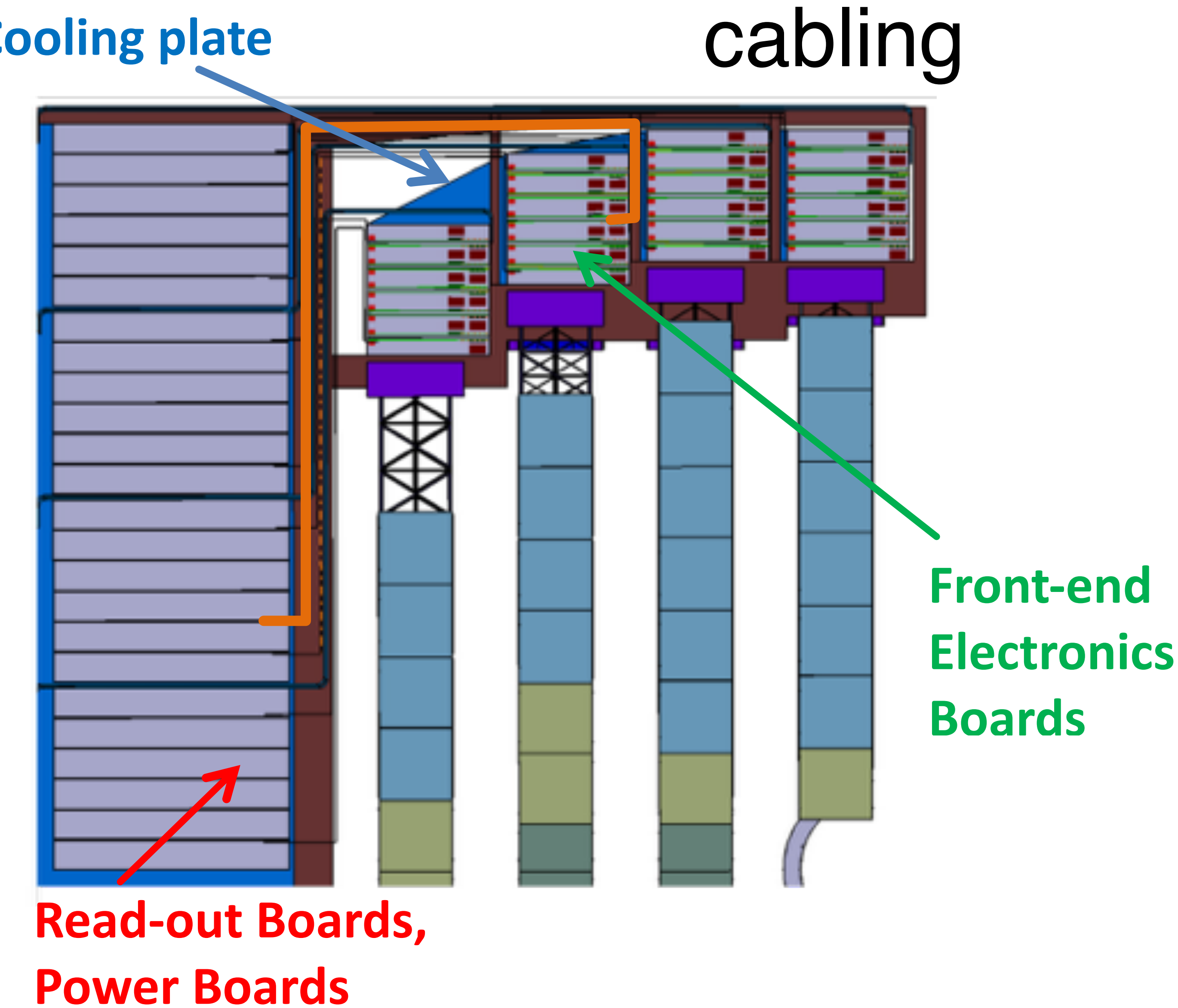
Bi-phase $CO_2$ cooling system

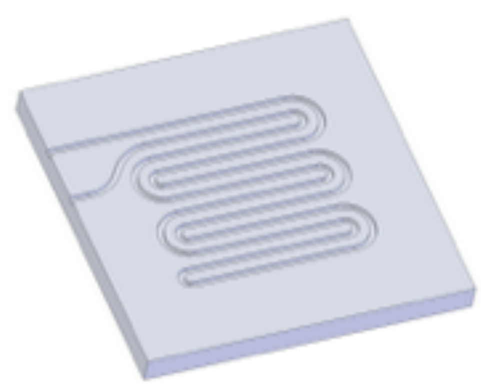
STS electronics total power dissipation: 42 kW

TRACI XL: 1 kW cooling prototype

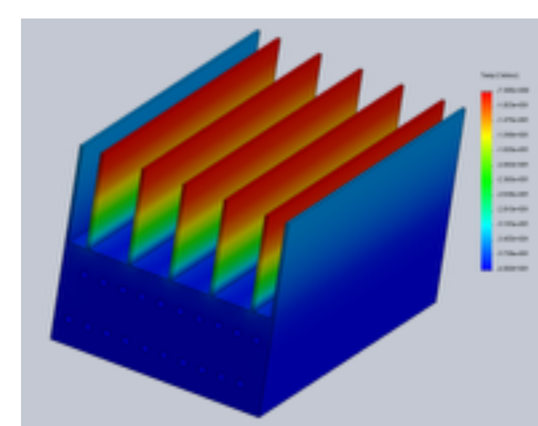


## cabling



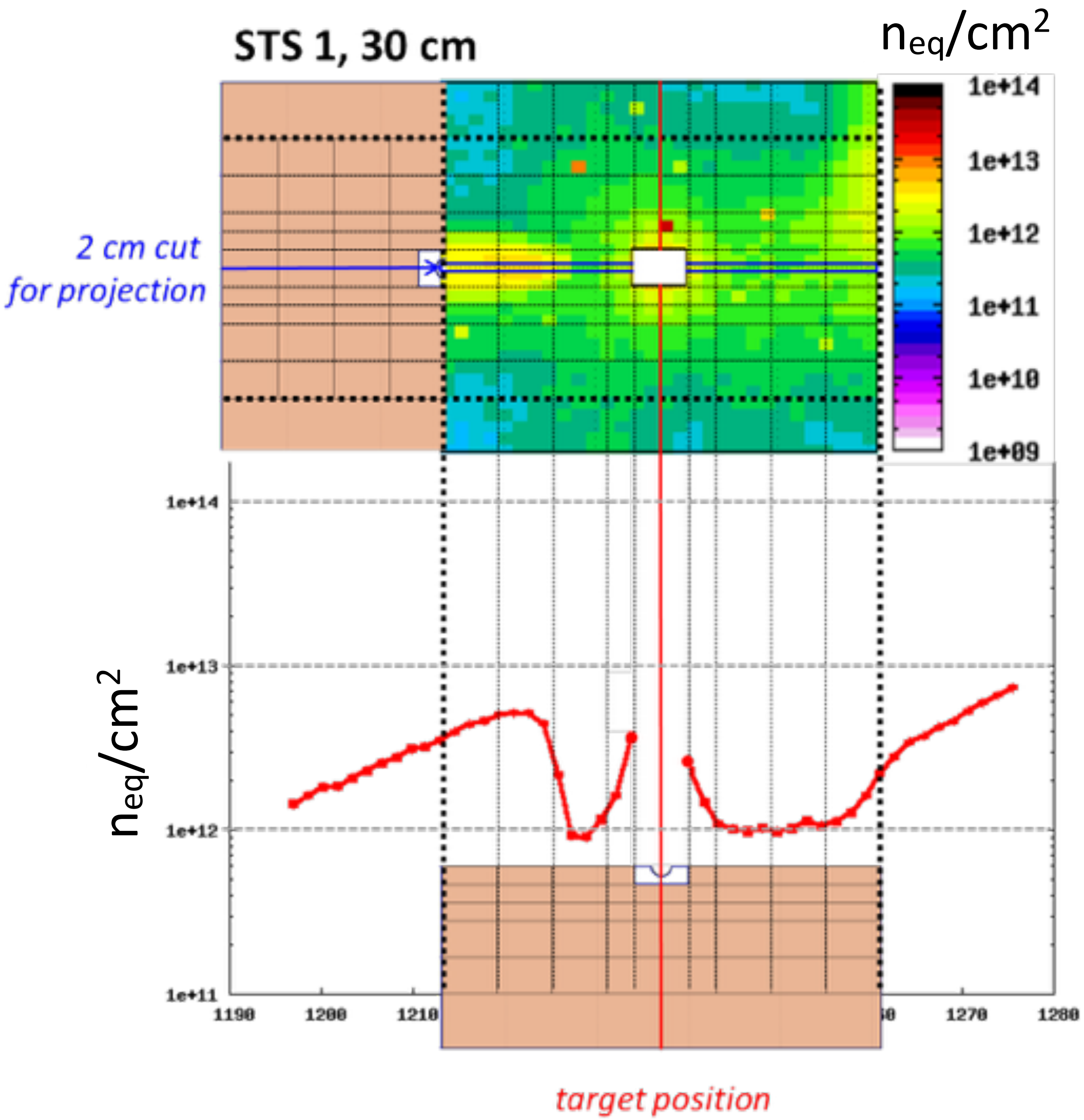



cooling plate with integrated channels



FEB stack 200 W

# Radiation environment




Radiation load per typical operation year

- Non-ionzing dose: $10^{13}$ $n_{eq}/cm^2$ (worst case)
- Ionizing dose: <100 kRad

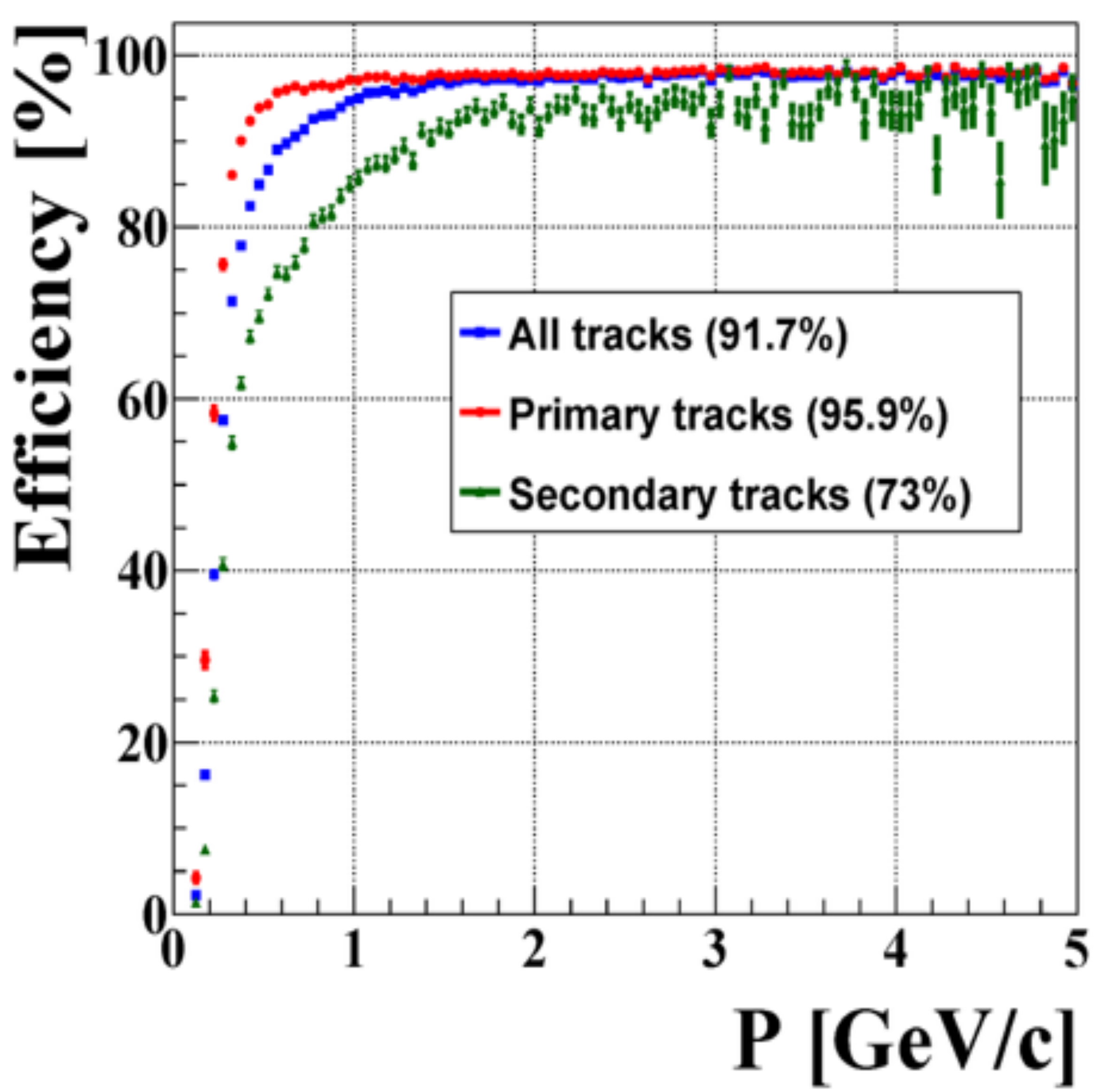
Operation conditions:

1 month of running at $10^9$ ions/s on a 1% $X_0$ target

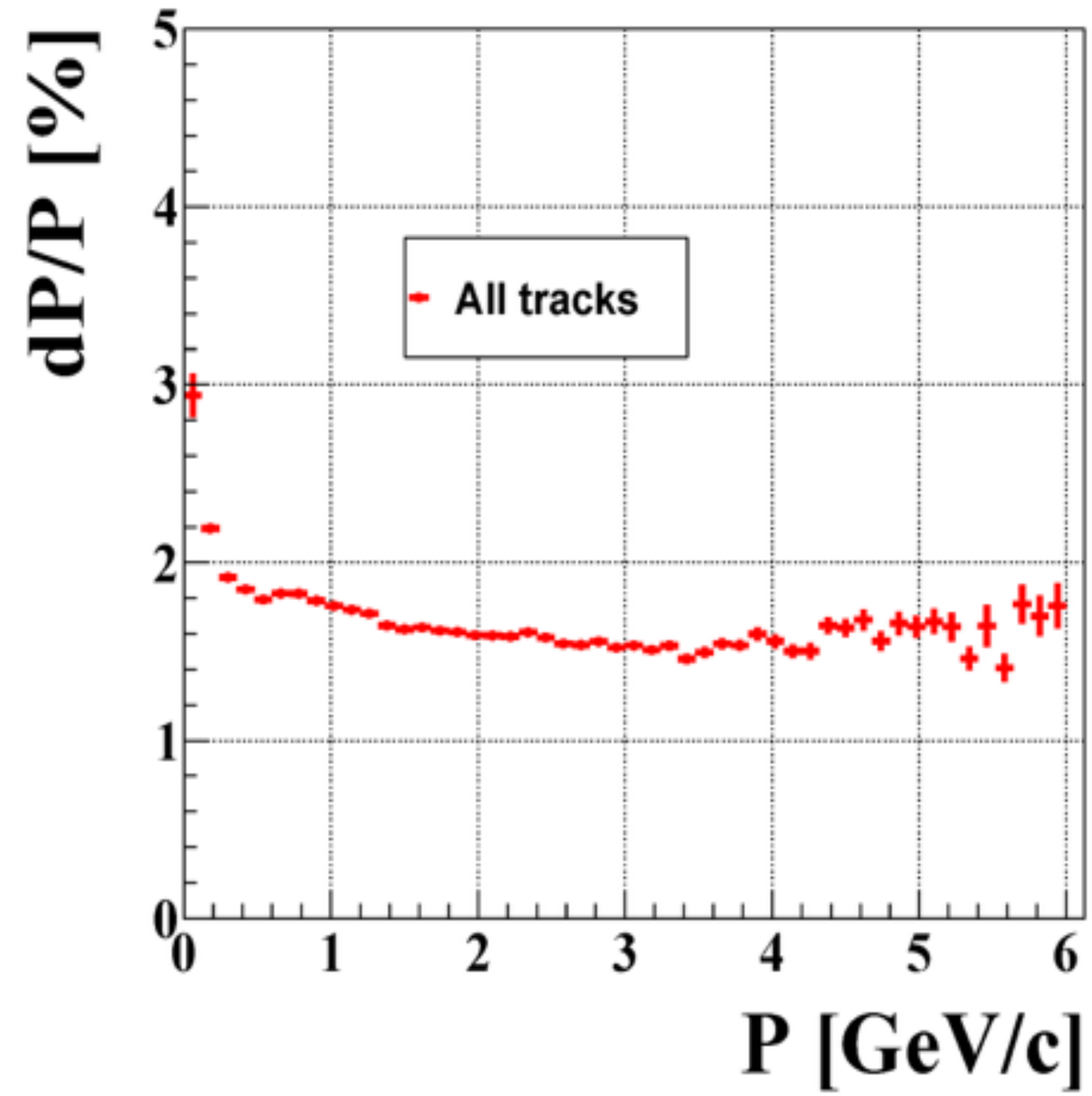
FLUKA calculation of non-ionizing dose for 10 AGeV Au+Au collisions at SIS100 and the CBM experiment in electron-hadron configuration.

# STS performance simulation

Track reconstruction efficiency




Momentum resolution

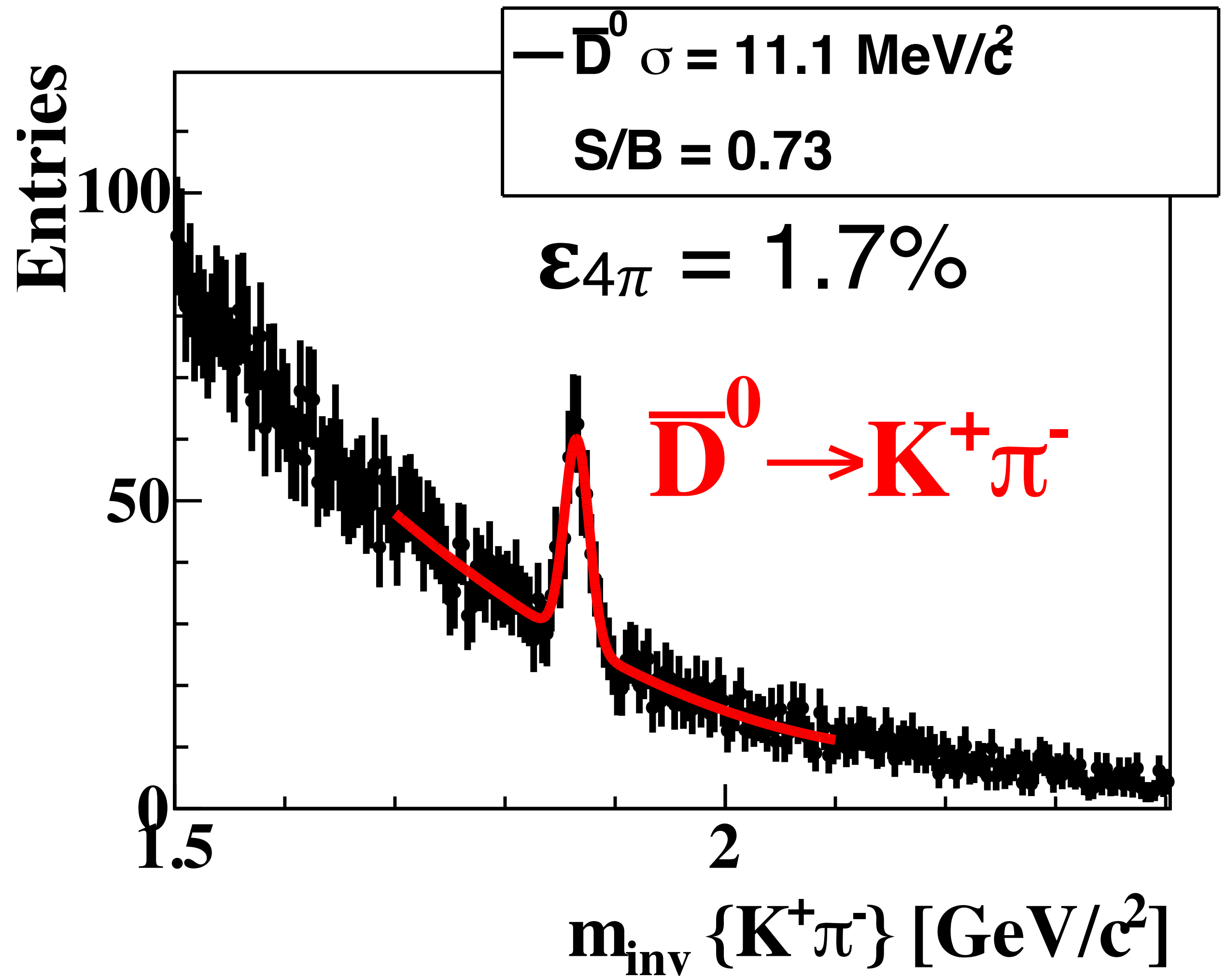


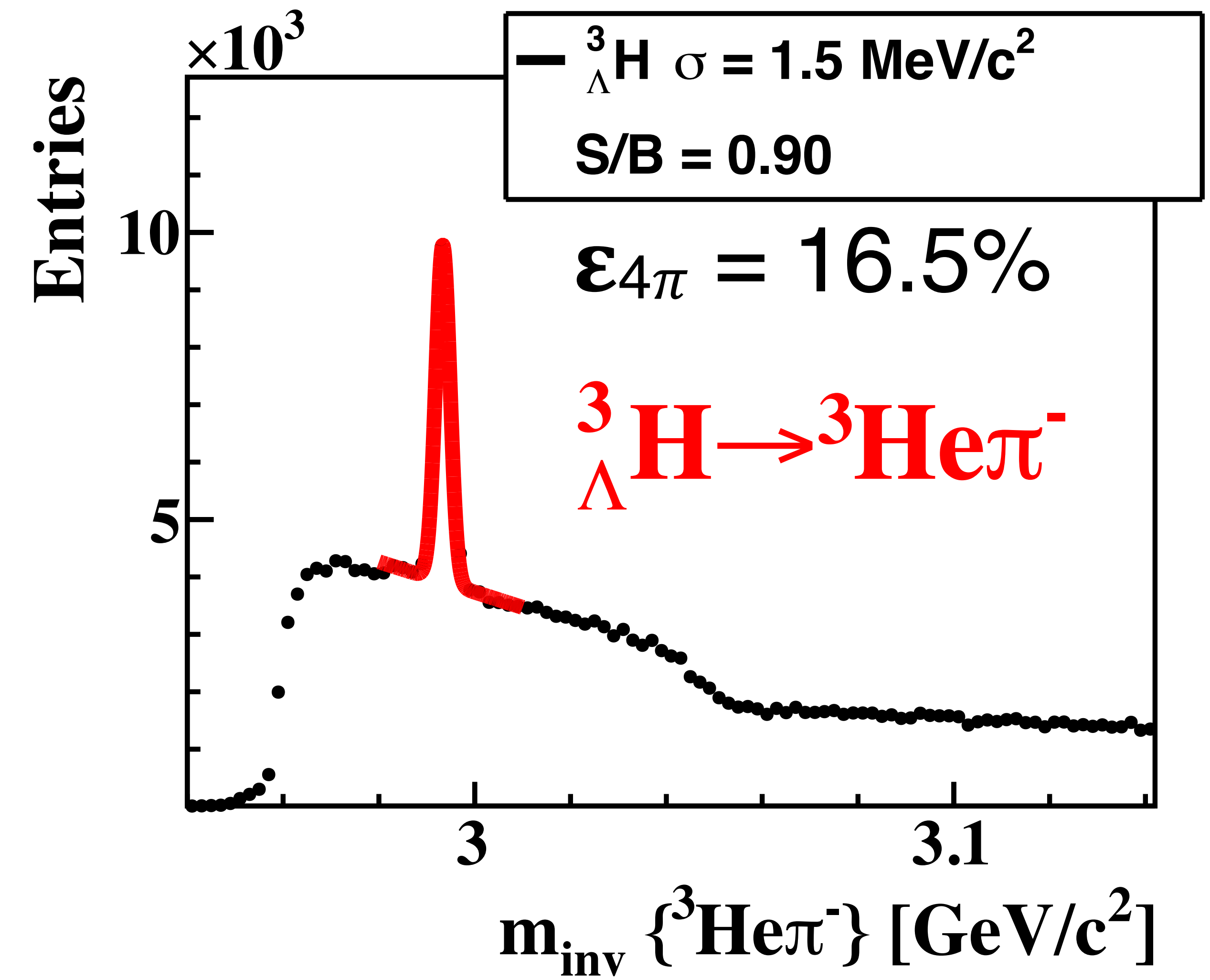

- realistic detector model
- CbmRoot simulation framework
- Cellular Automaton track finder
- Kalman Filter track fitting

# Feasibility studies at SIS-100

Tue, 17:45 HK 25.5
Tue, 16:30 HK 24.1

Operation scenario:
from pA (up to 30 GeV) to AuAu (2–11 GeV/nucleon) systems



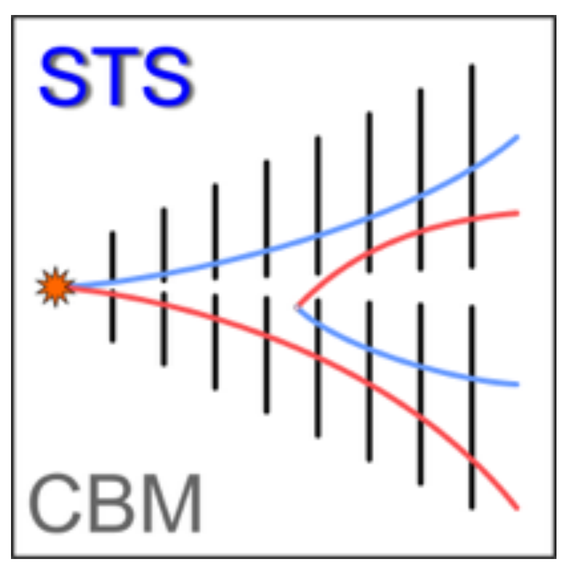




$10^{11}$ central Ni+Ni events
15 GeV/nucleon, using TOF PID

$5{\times}10^6$ central Au+Au events
10 GeV/nucleon, using TOF PID

# Summary

- STS system concept has been presented
- Progress with prototyping and engineering
- Sensor prototypes delivered, radiation hardness is under investigation
- Current activity is module assembly and system integration
- Full-size module mockup has been produced
- System engineering: mechanical structure, mounting of electronics, cabe routing. Close to completion.
- Feasibility for physics measurements demonstrated
- Production readiness in 2017



# Institutions participating in STS

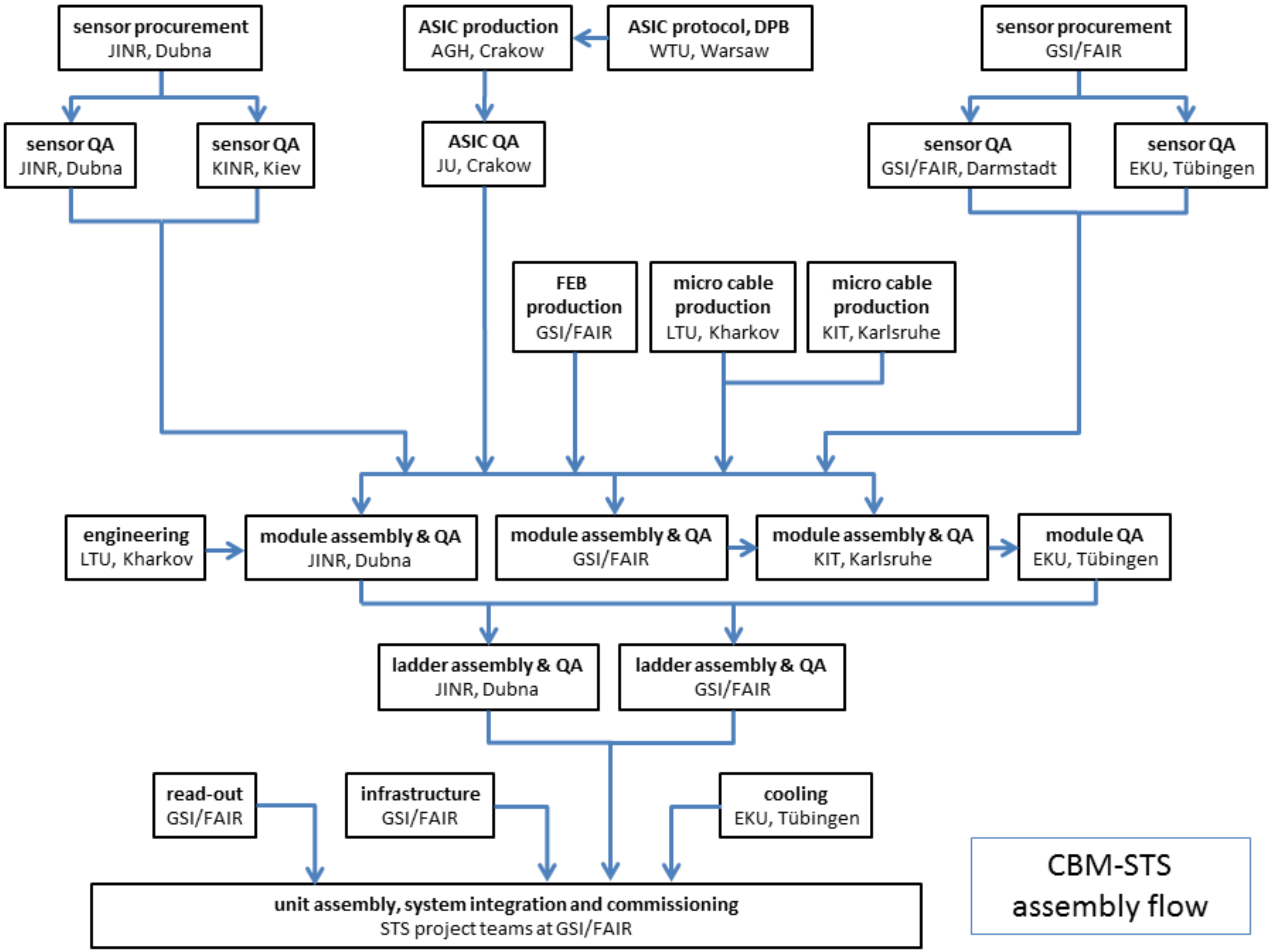
**Germany**
*Darmstadt, Germany, GSI Helmholtz Center (GSI)*
*Karlsruhe, Germany, Karlsruhe Institute of Technology (KIT)*
*Tübingen, Germany, Eberhard Karls University (EKU)*

**Poland**
*Krakow, Poland, AGH University of Science and Technology (AGH)*
*Krakow, Poland, Jagiellonian University (JU)*
*Warsaw, Poland, Warsaw University of Technology (WUT)*

**Russia**
*Dubna, Russia, Joint Institute for Nuclear Research (JINR)*
*Moscow, Russia, Moscow State University (SINP-MSU)*

**Ukraine**
*Kharkov, Ukraine, LED Technologies of Ukraine Ltd (LTU)* * *Partner*
*Kiev, Ukraine, Kiev Institute for Nuclear Research (KINR)*

# CBM STS assembly flow



# STS related presentations at DPG 2016

- **Mon, 14:45 HK 8.3** Grigory Kozlov
  Time-based cluster and hit finding for the STS detector in the CBM experiment at FAIR
- **Mon, 15:00 HK 7.4** Evgeny Lavrik
  Optical quality assurance procedures for the sensors of CBM STS Detector
- **Mon, 15:15 HK 7.5** Maksym Teklishyn
  Quality assurance tests of the CBM Silicon Tracking System sensors with an infrared laser
- **Mon, 16:30 HK 14.1** Hanna Malygina
  The detector response simulation for the CBM Silicon Tracking System as a tool for hit error estimation
- **Group talk Mon, 16:30 HK 15.1** Anton Lymanets
  The Silicon Tracking System of the CBM Experiment at FAIR
- **Mon, 17:00 HK 15.2** Iaroslav Panasenko, Pavel Larionov
  Quality assurance of the silicon microstrip sensors for the CBM experiment
- **Tue, 15:00 HK 21.4** Ievgeniia Momot
  Radiation tolerance of microstrip sensors for the CBM Silicon Tracking System
- **Tue, 18:00 HK 29.7** Adrian Rodriguez Rodriguez
  The CBM-STS front-end electronics
- **Wed, 18:30 HK 45.9** Carmen Simons, Daniel Soyk, and Robert Visinka
  The workflow of CBM-STS silicon strip sensor module-assembly
- **Poster Wed, 18:30 HK 45.20** Evgeny Lavrik
  Bi-Phase $CO_2$ cooling of the CBM STS detector
- **Poster Wed, 18:30 HK 45.63** Oleg Vasylyev, W. Niebur
  Mechanical integration of the detector components for the CBM Silicon Tracking System
- **Thu, 17:45 HK 60.6** Jörg Lehnert, David Emschermann
  The read-out chain of the CBM STS detector