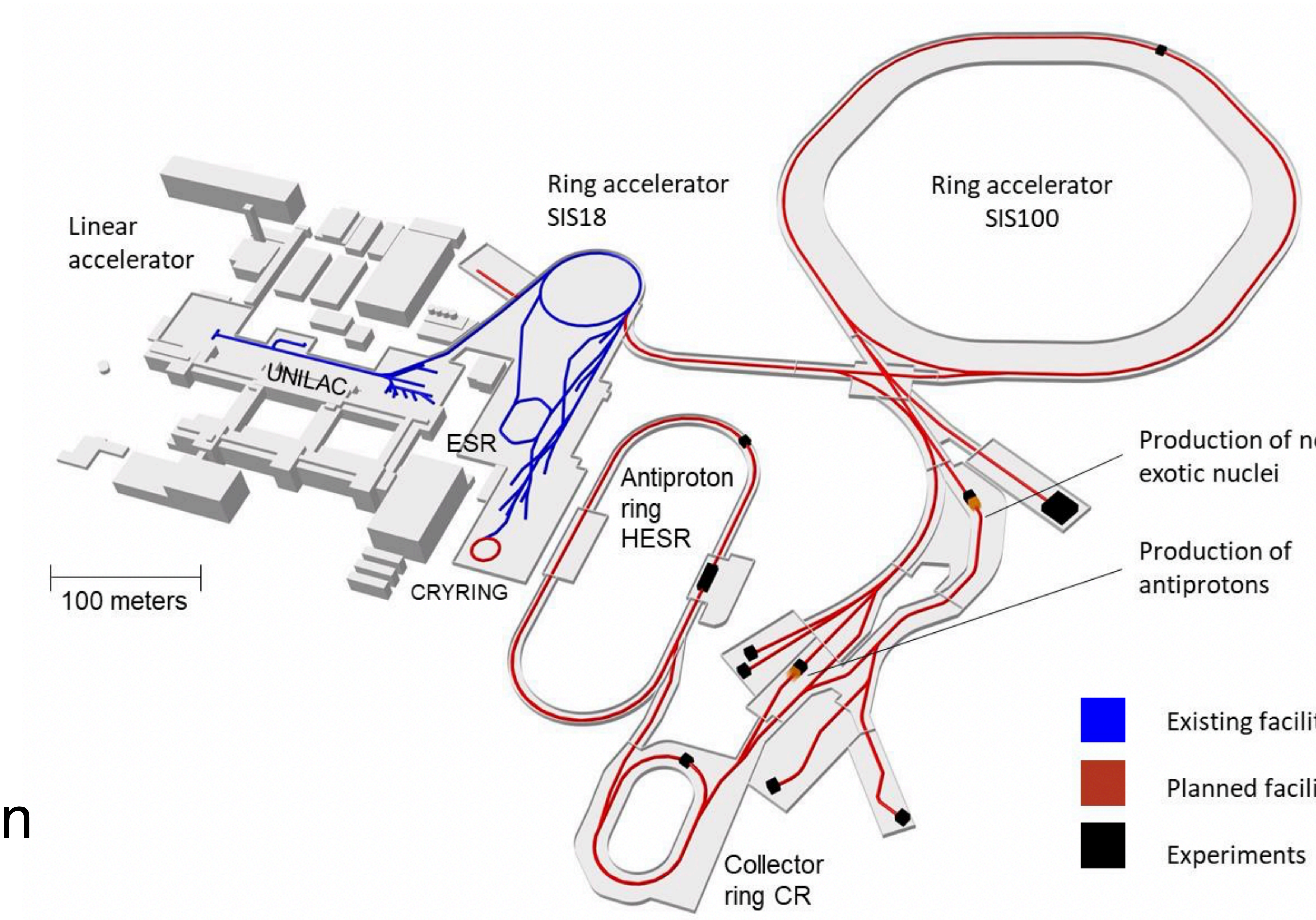
The Silicon Tracking System of the CBM Experiment at FAIR

A. Lymanets for the CBM collaboration

New Trends in High-Energy Physics,
Odessa, 13 May 2019

Facility for Antiproton and Ion Research

- Beam intensities up to 1000x w.r.t. current facility
- Simultaneous operation of different experimental programs:
  - heavy ions
  - antiprotons
  - rare isotopes



<u>SIS-100</u>

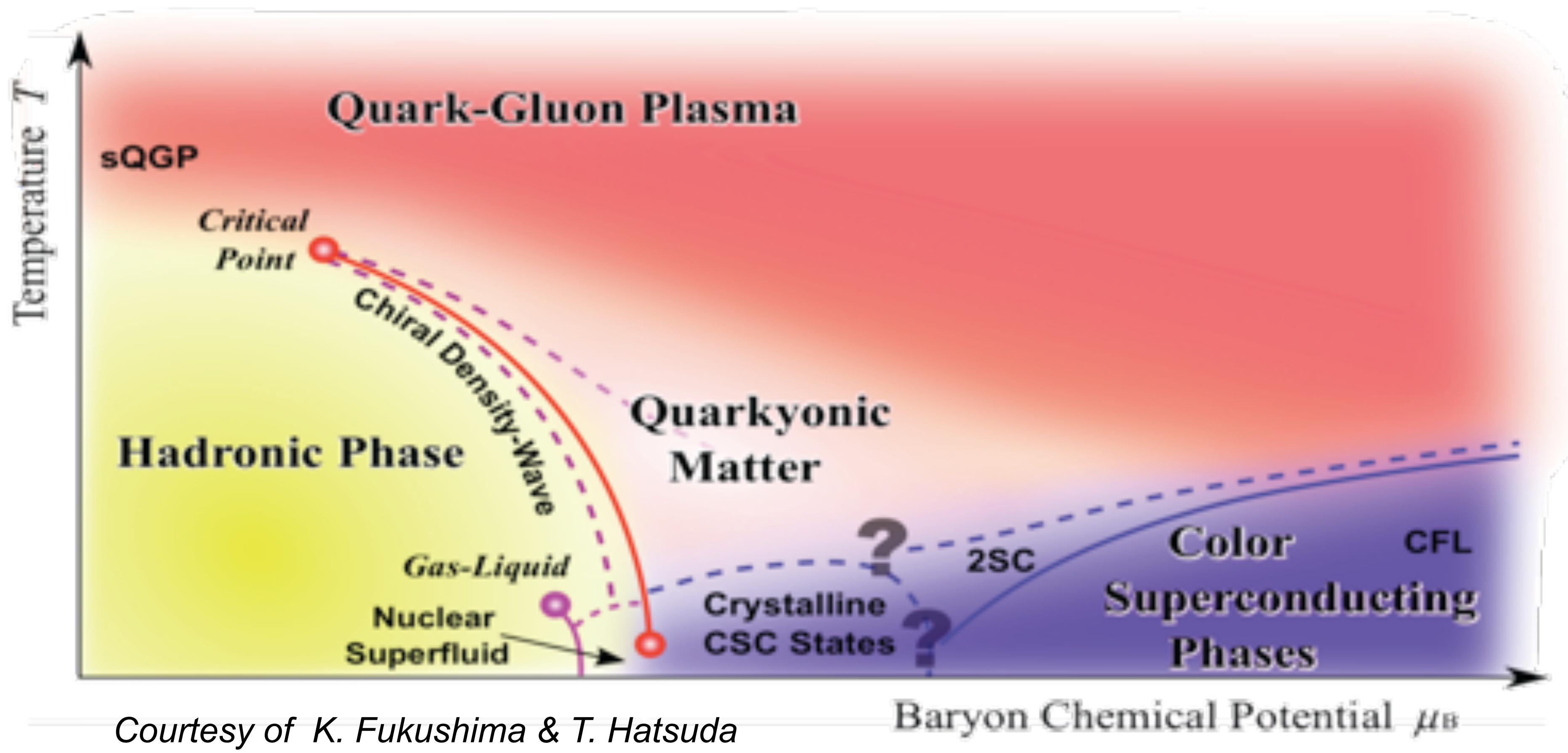
- protons: 30 GeV
- Au: 11 GeV/nucleon

Commissioning start in 2025

FAIR construction status

CBM physics goal

Explore the QCD phase digram of nuclear matter at high baryon densities



Courtesy of K. Fukushima & T. Hatsuda

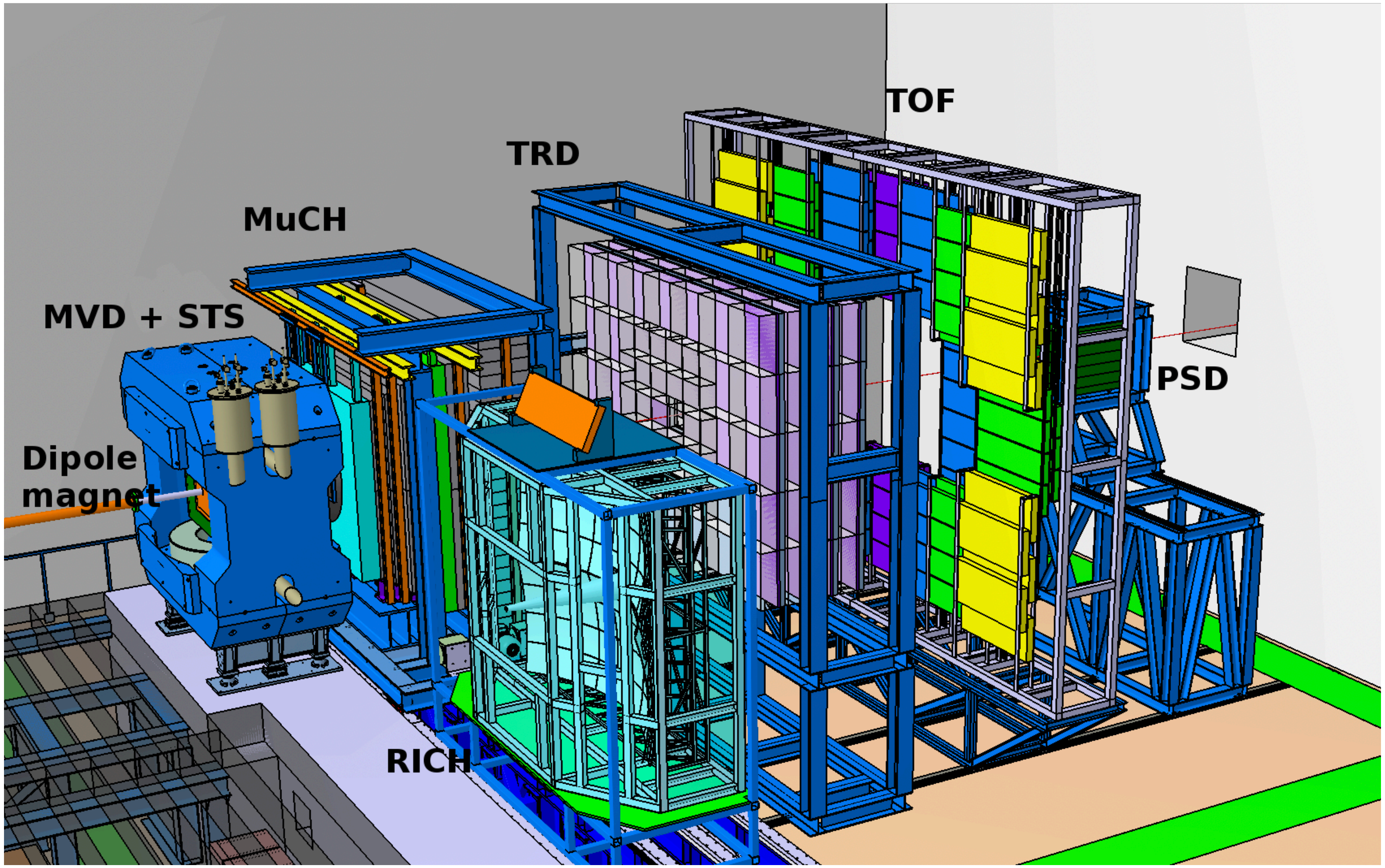
<u>Physics cases</u>

- existence of critical endpoint
- 1st order phase transition and exotic phases
- QCD equation of state
- chiral symmetry restoration at high μ_B

<u>Observables</u>

- strangeness
- charm
- (multi)-strange hypernuclei
- dileptons
- collective flow
- fluctuations and correlations

Compressed Baryonic Matter experiment

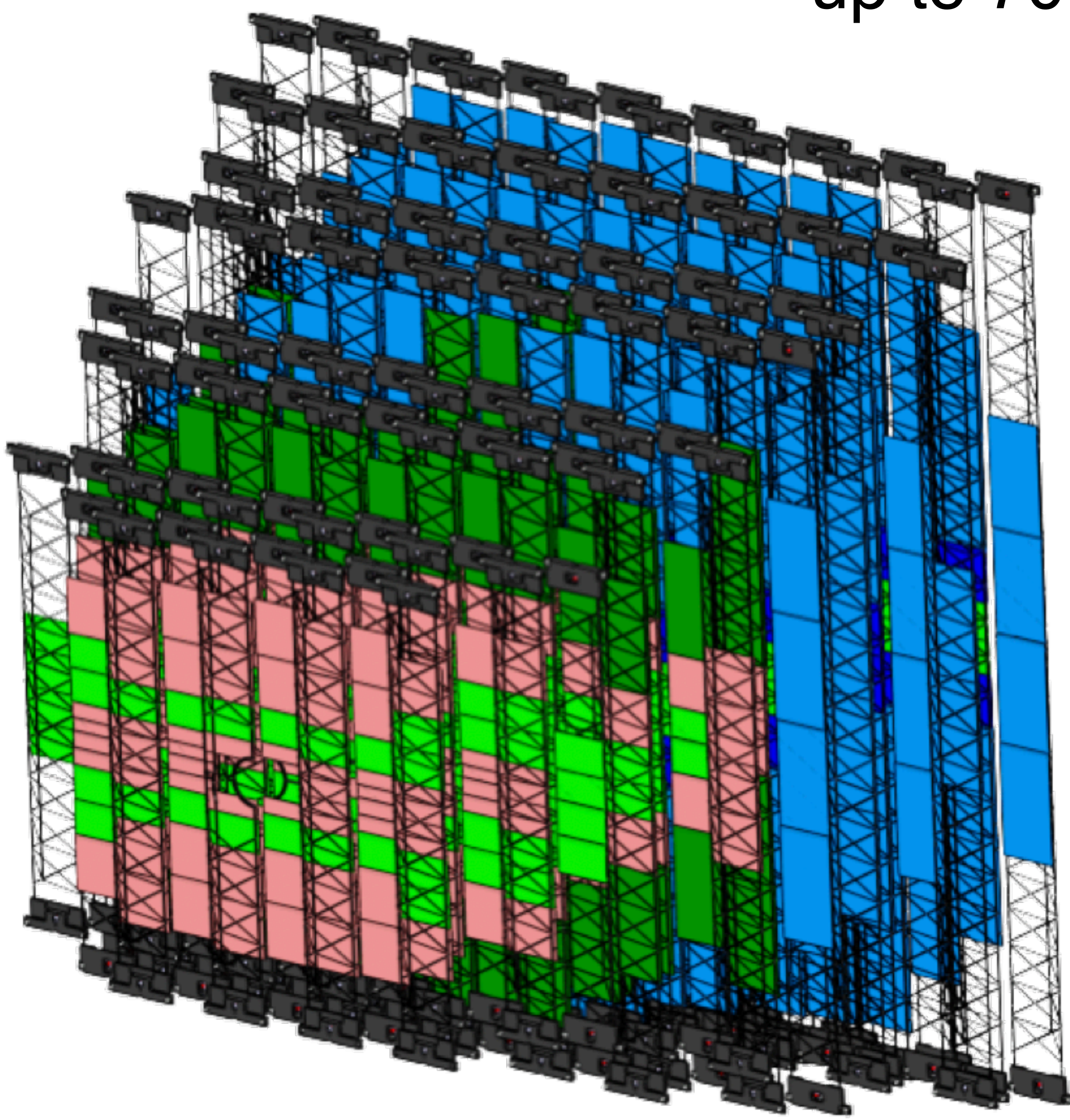


- Vertexing: MVD
- Tracking: STS, MUCH, TRD, ToF
- Particle ID: RICH, TRD, ToF
- Calorimetry: ECAL, PSD

- fixed traget geometry with polar angle coverage [2.5º; 25º]
- electron and muon configuration
- free-streaming DAQ
- online event selection using high level triggers

Silicon Tracking System

STS is a main tracking detector that will reconstruct up to 700 charged particle per collision.



Features:

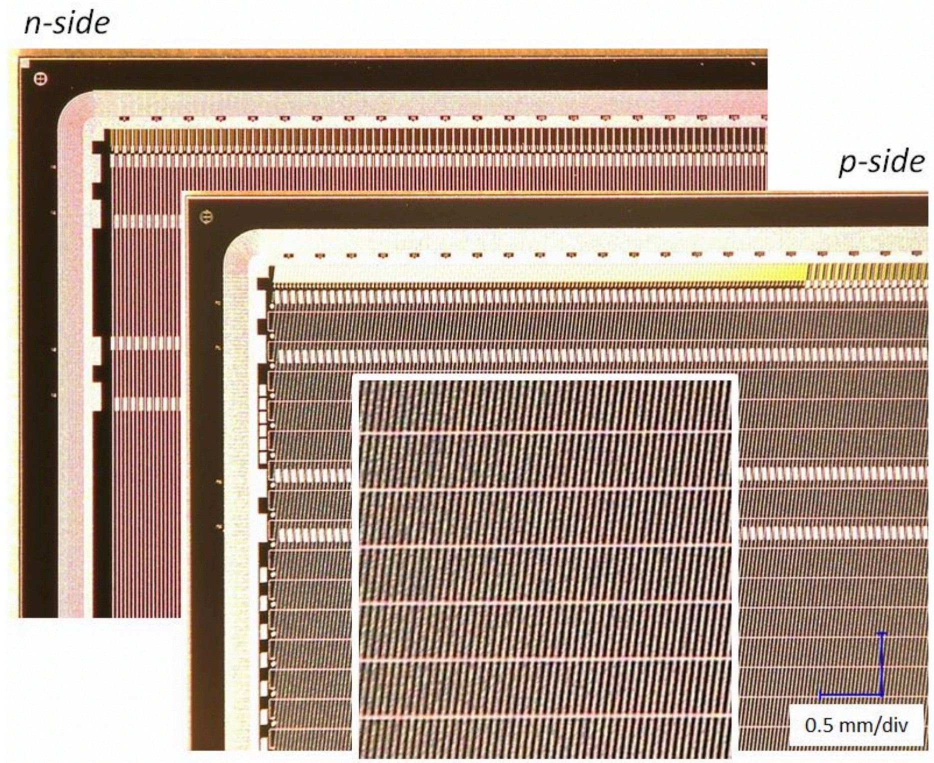
- located inside 1 Tm dipole magnet
- 8 tracking stations
- active area about 4 m^2
- 896 sensors installed onto 106 carbon fibre ladders
- low material budget <1.5% X_0 per station
- fast self-triggering readout
- radiation tolerance up to 10^{14} $n_{eq}cm^{-2}$

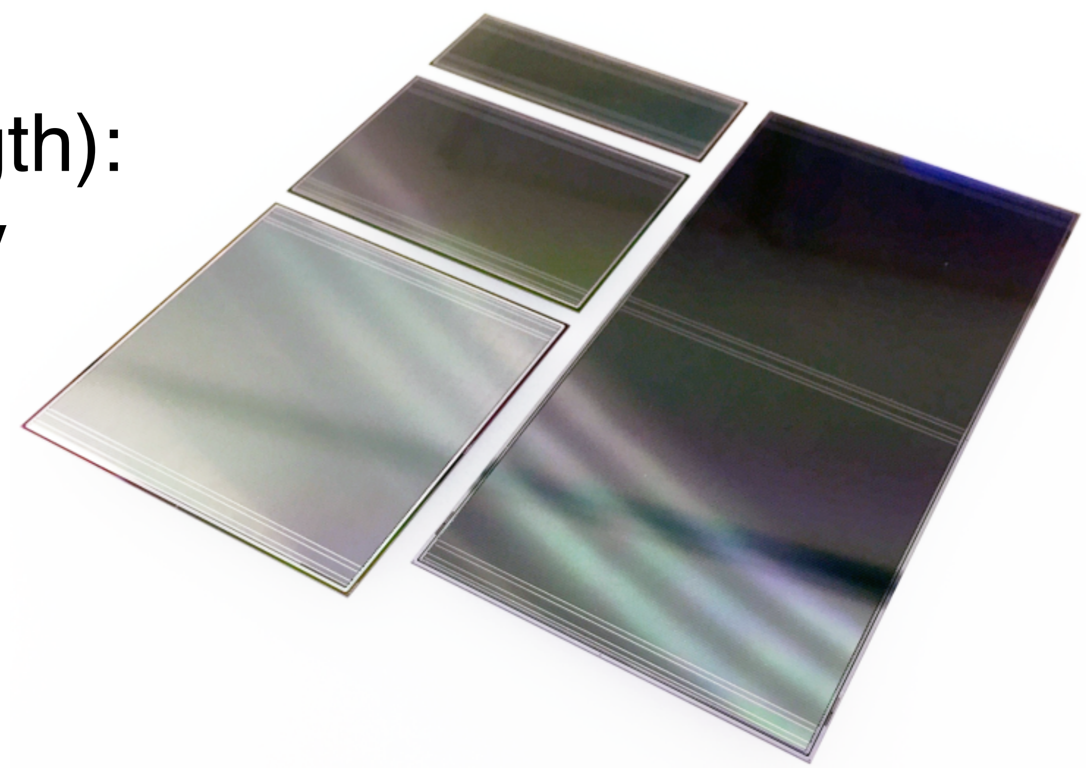
Requirements:

- fast and radiation hard detectors
- self-triggering electronics
- 4D event reconstruction

Double-sided silicon microstrip sensors

- n-type bulk
- 320 ± 15µm thick
- 1024 strips per side
- 58µm strip pitch
- 0/+7.5° stereo angle for n/p side
- second metallisation layer
  to interconnect edge strips
- width: 6.2 cm
- length: 2.2, 4.2, 6.2, 12.4 cm (strip length):
  granularity is matched to the hit density
  in the STS aperture

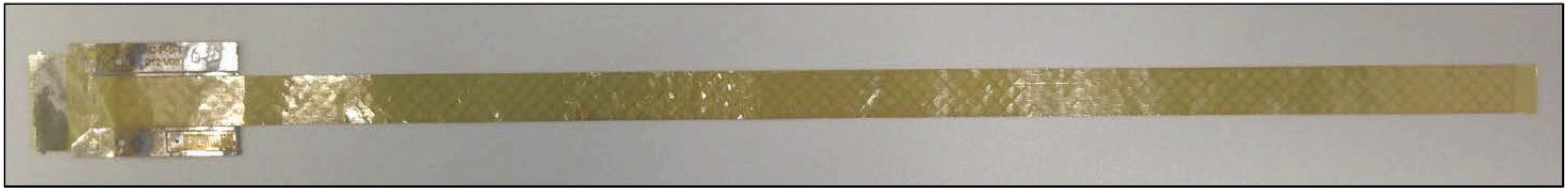




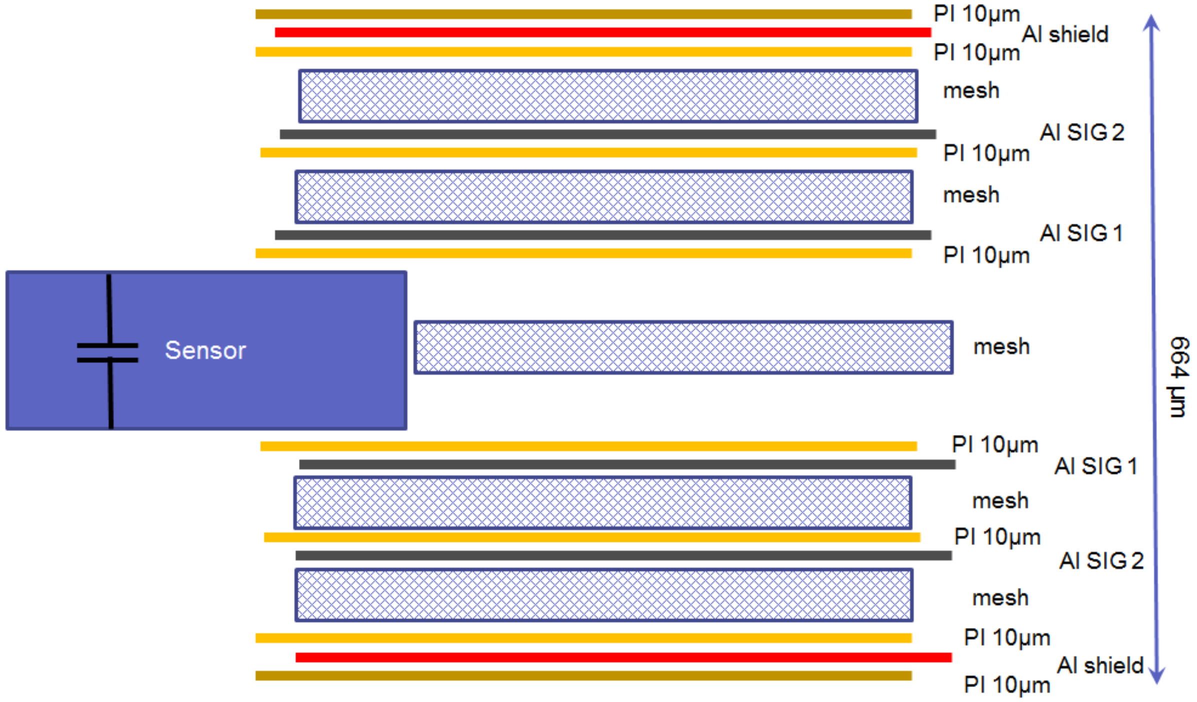
Sensor series production started.

Microcables

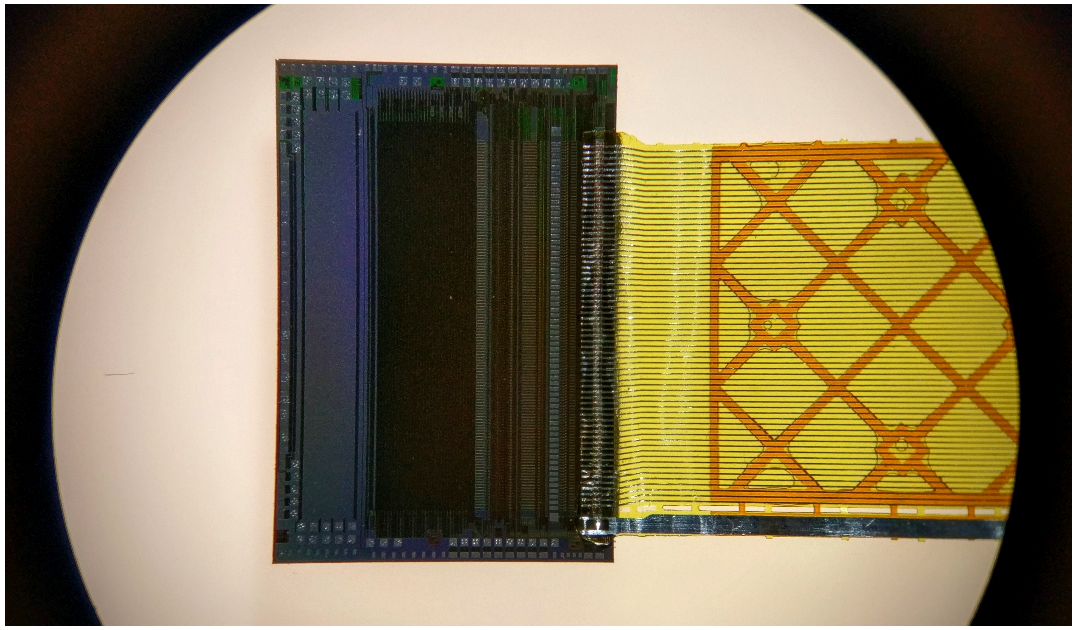
- signal layer: 64 **Al** lines of 116 μm pitch
  Cu alternatively under study
- thickness: 10 μm thick on14 μm polyimide
- length up to 55 cm



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

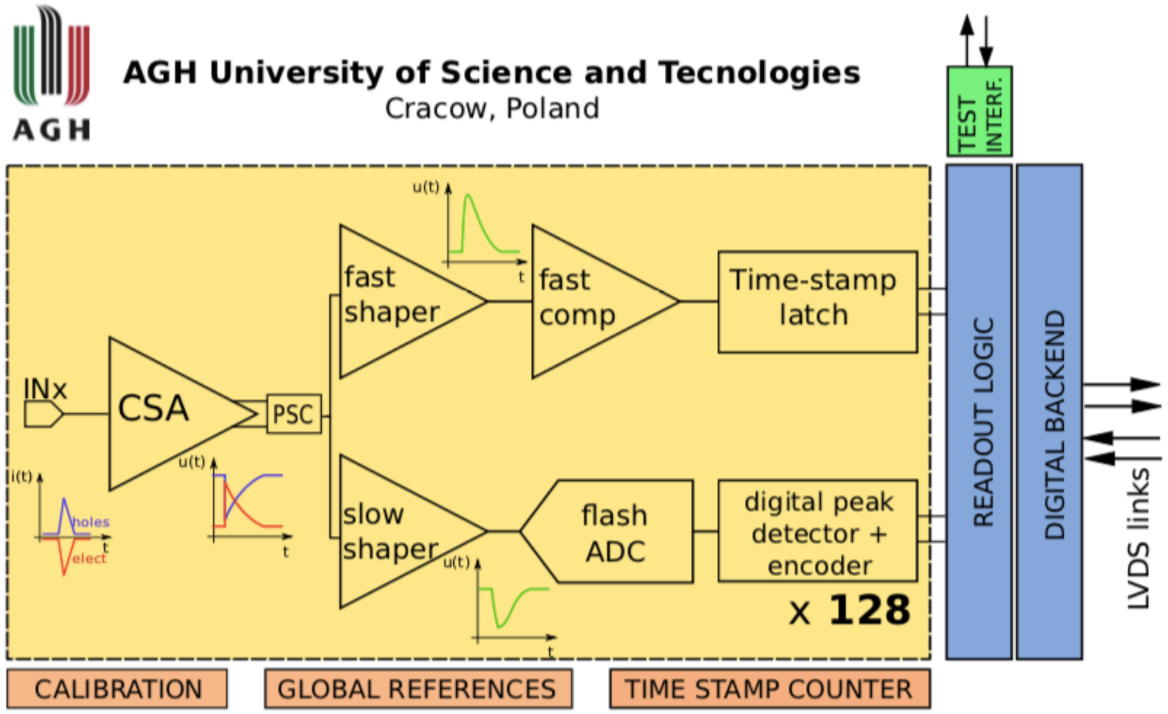


microcable stack structure

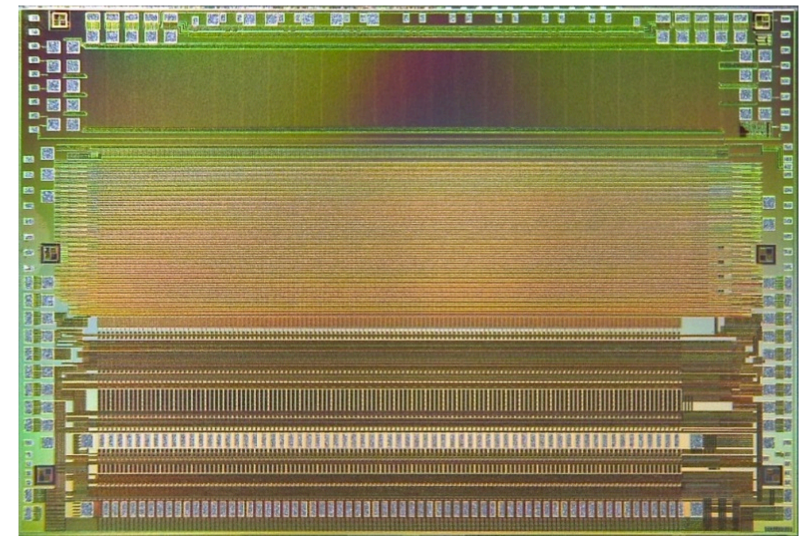


signal layer TAB-bonded to the ASIC

STS-XYTER:
custom ASIC with self-triggering architecture



ASIC architecture

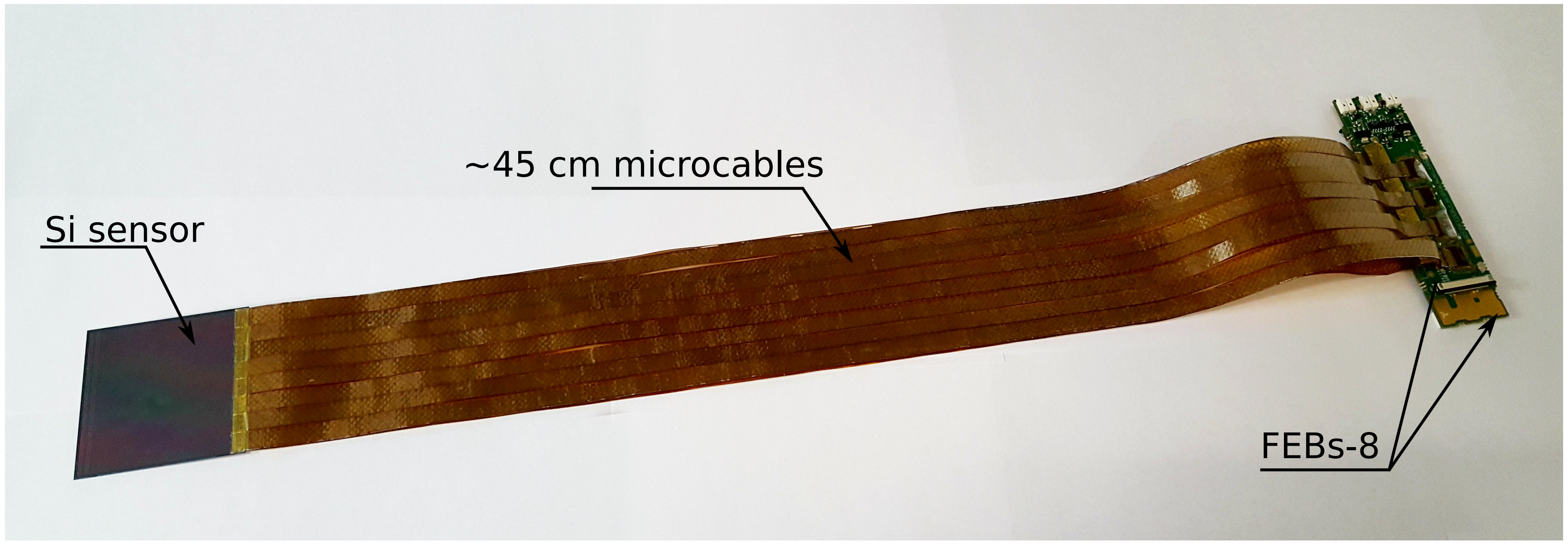


STS-XYTER ASIC

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

- designed for high capacitive load
- fast branch (30 ns rise time): time-stamp latching
- slow branch (80 ns peaking time): signal digitization
- double-threshold discrimination: time stamp is vetoed if ADC produced no signal

Module & ladder assembly

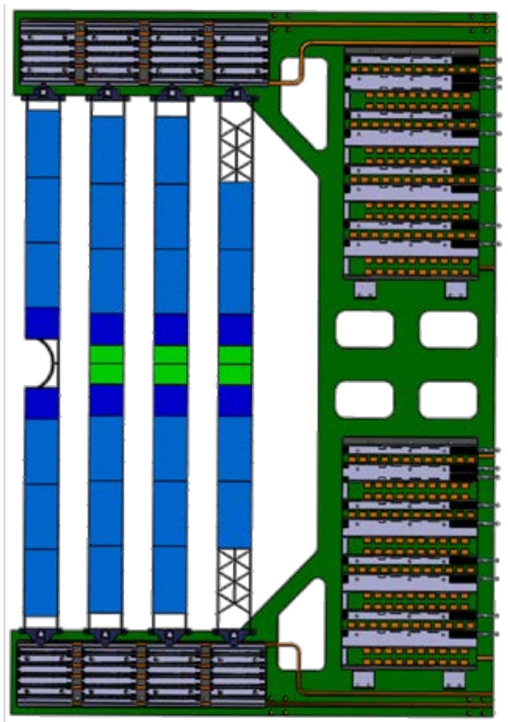


Basic functional unit: double-sided sensor + 2x16 microcable stacks + 2 front-end boards with 8 ASICs each. First full-size modules built.

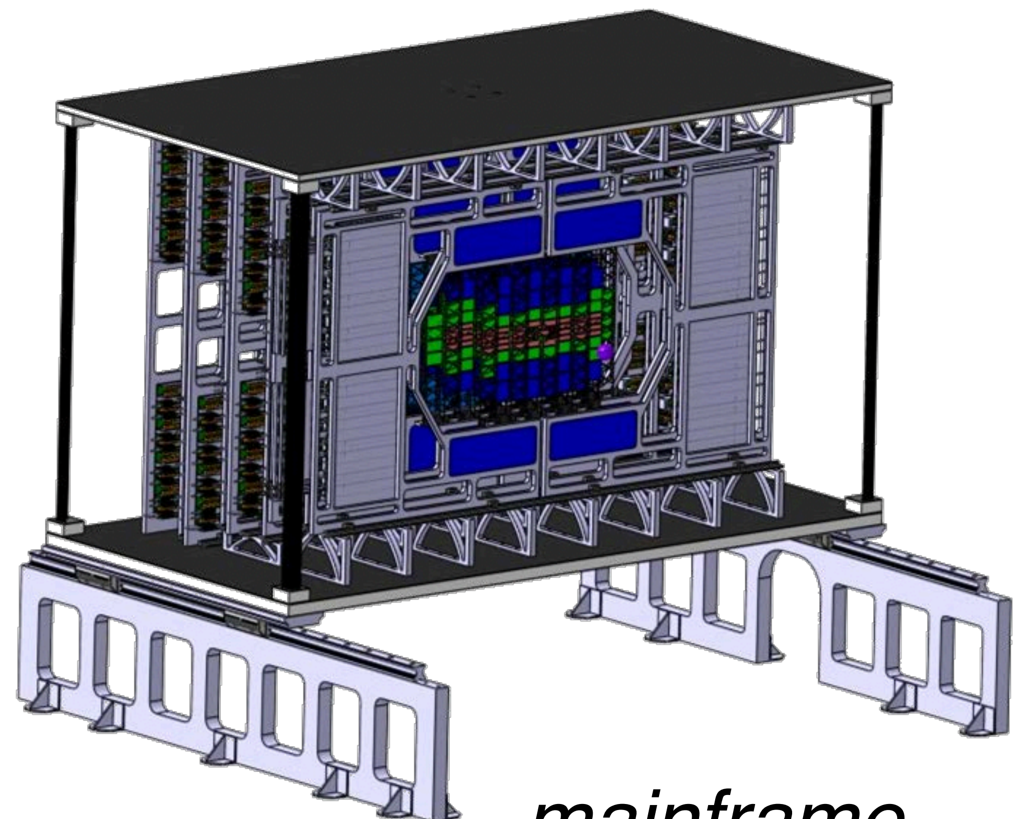
Up to 10 modules are mounted on a carbon fibre ladder using L-legs.

System integration concept

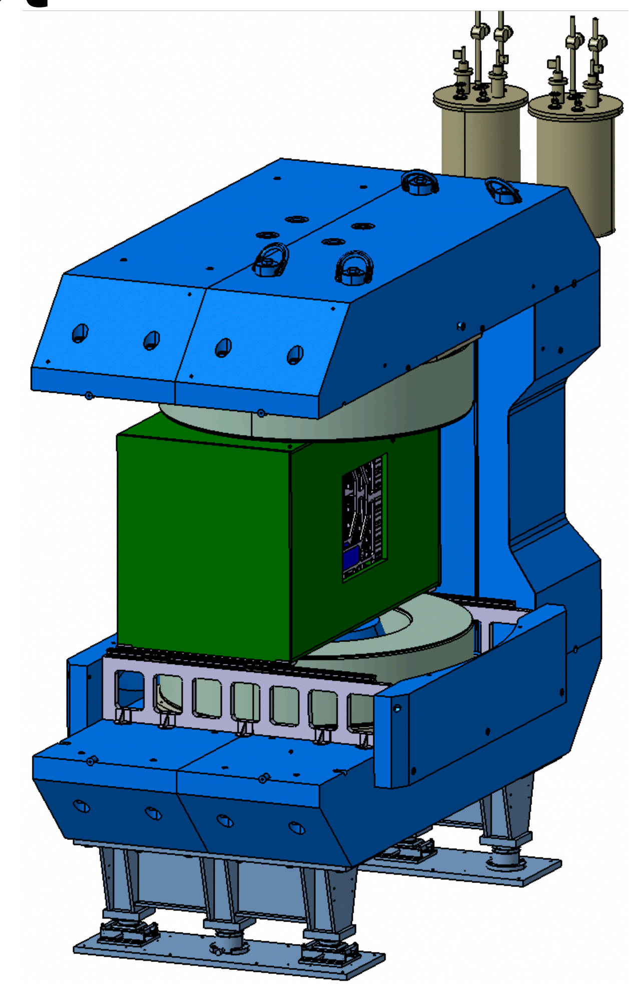
ladder



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

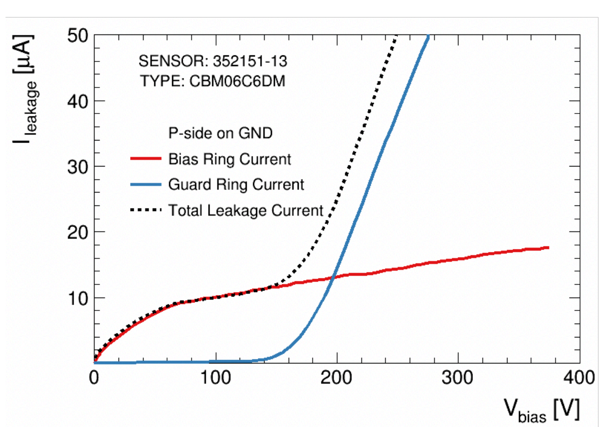
<u>Infrastructure in the STS box:</u>

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

Quality assurance of module/ladder components

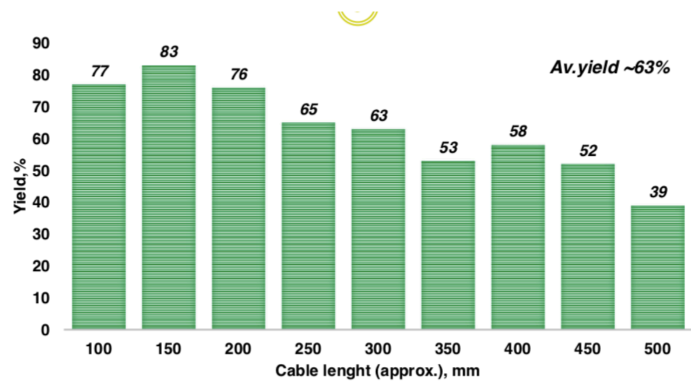
Sensors

Optical inspection



Electrical QA

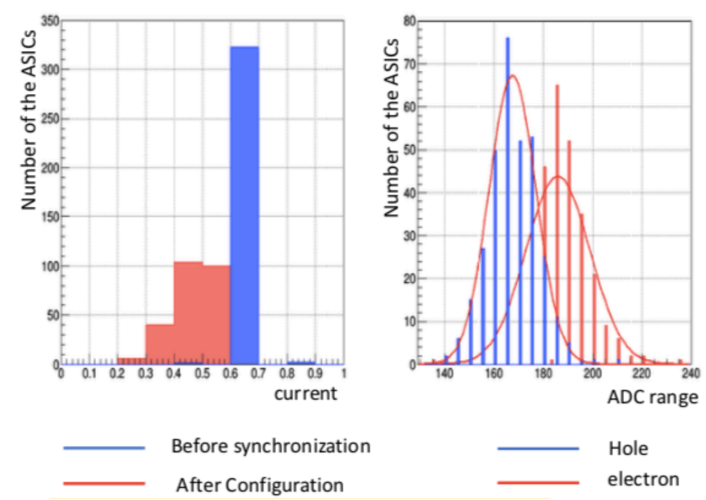
Microcables



Yield determination

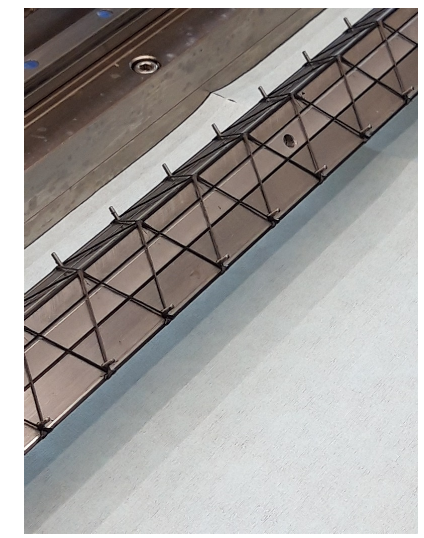
ASICs

ASIC test socket

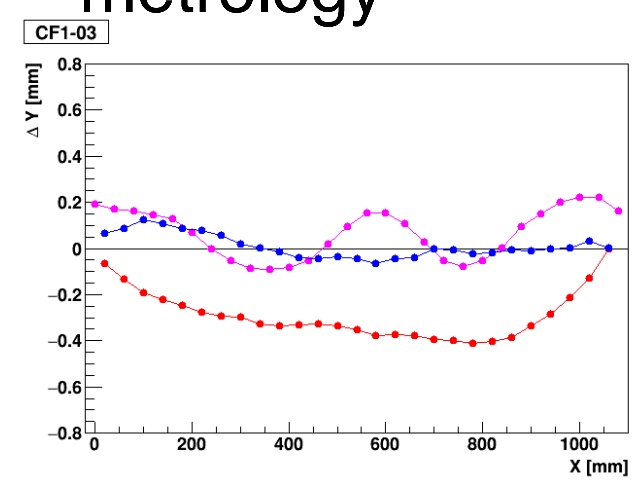


ASIC acceptance results

Ladders

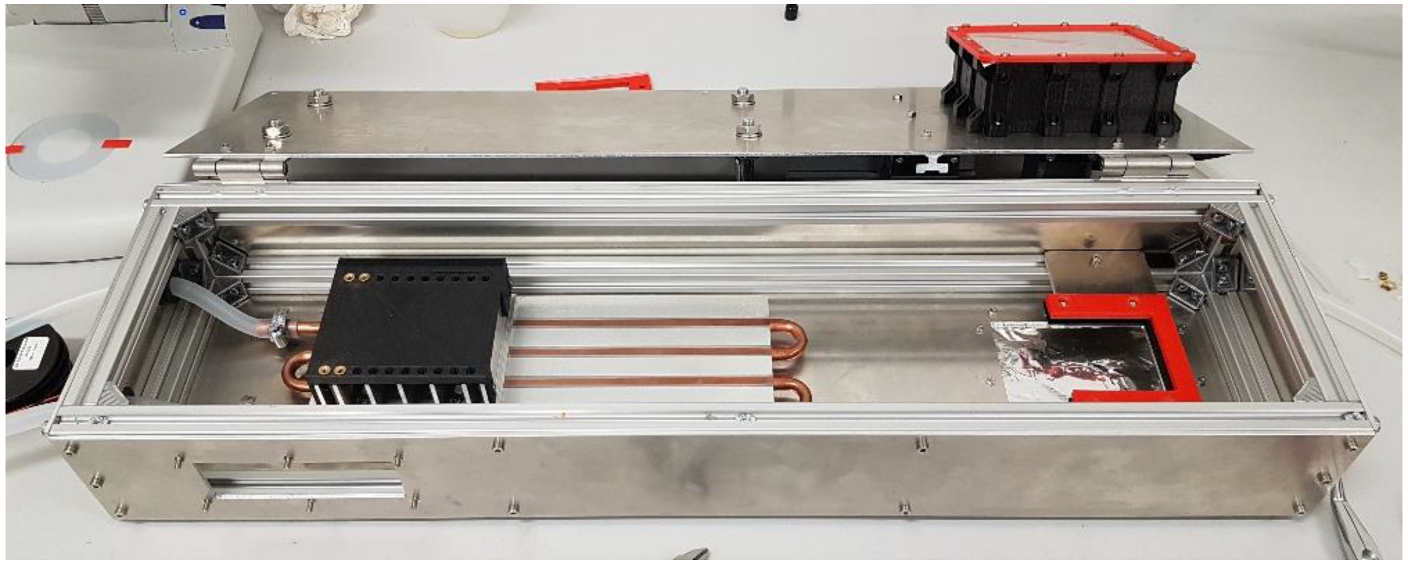


CF ladder metrology

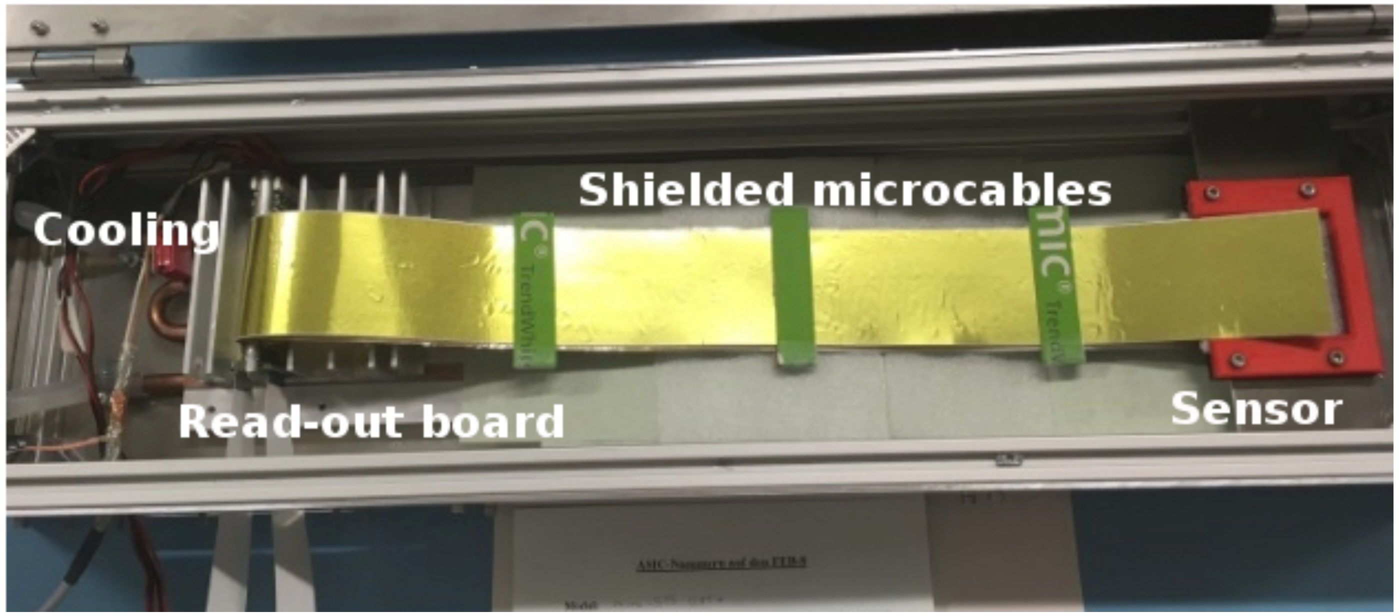


Extract mech. tolerance

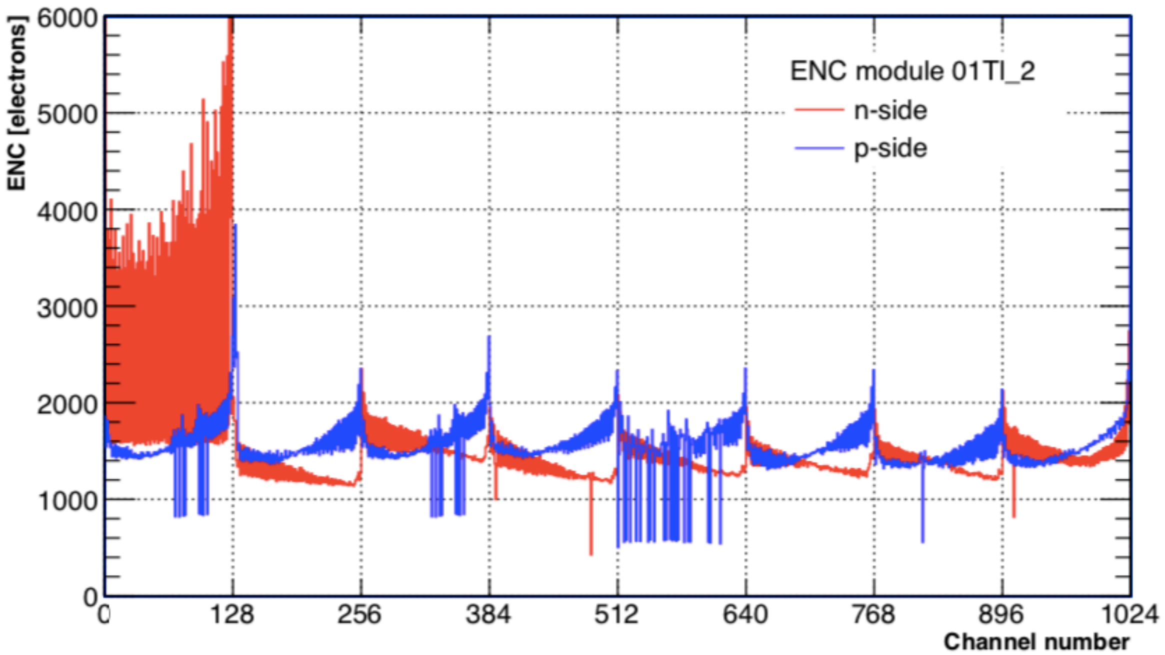
Module testing



Module test stand for S/N determination



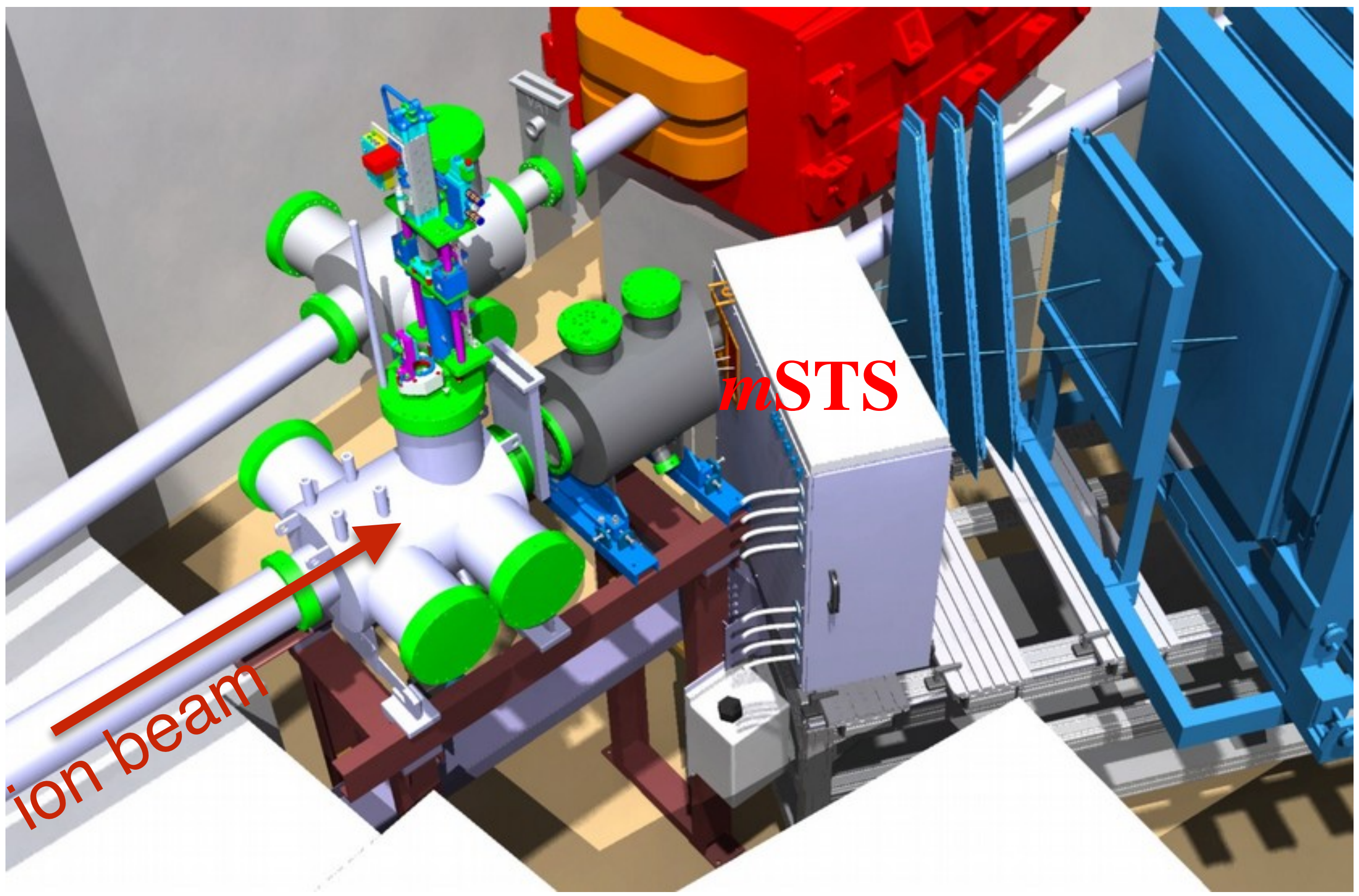
Detector module inside the test stand

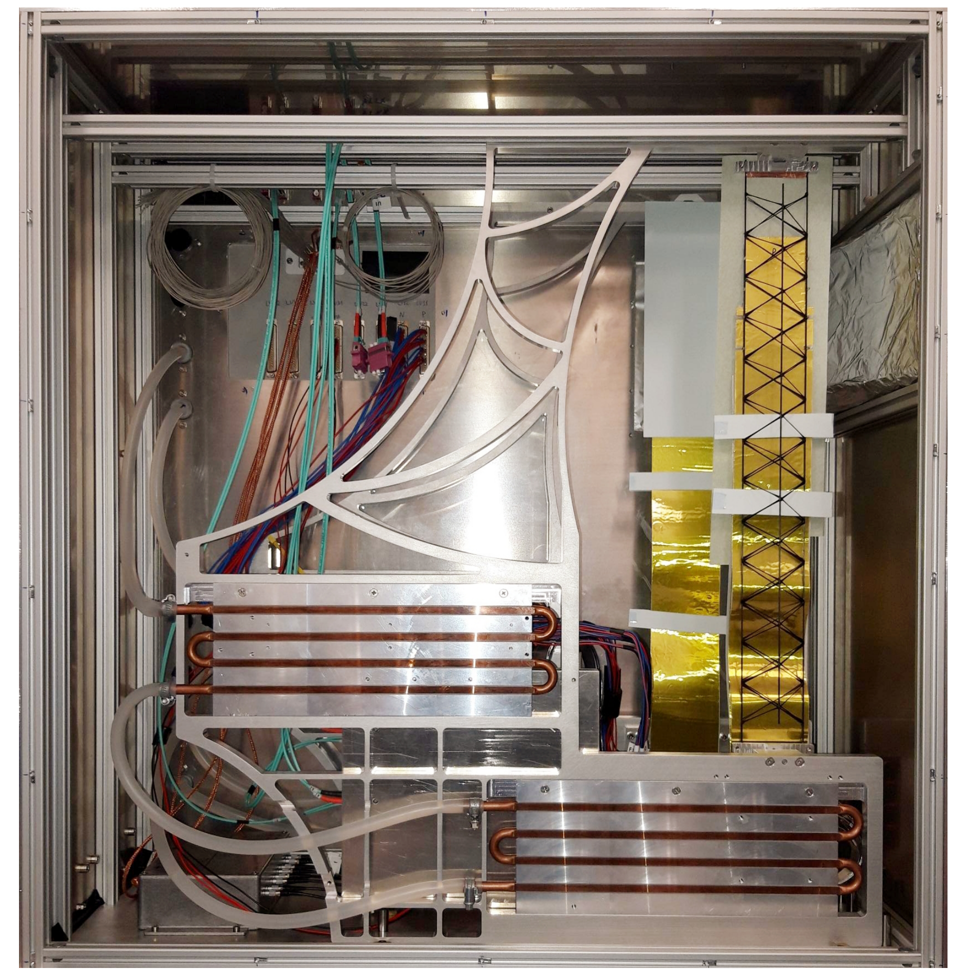


Measured noise performance for a detector module with 6x6 cm^2 sensor and 45 cm long μ-cable is <2000 e.

mSTS at mCBM

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

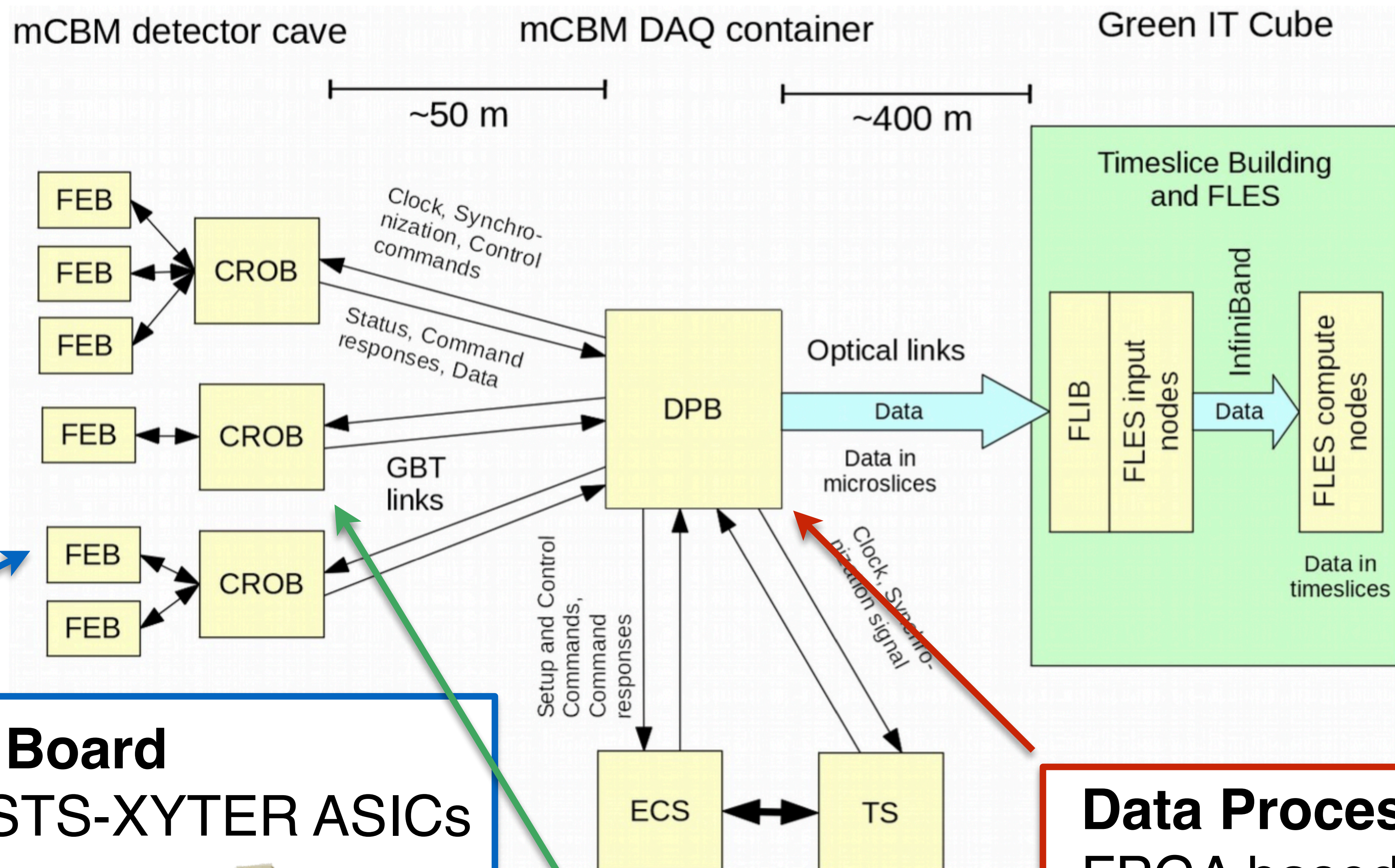




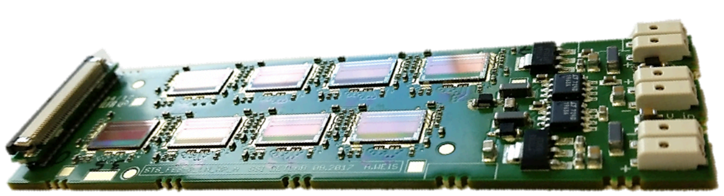
- CBM pre-final detector systems
- free streaming read-out
- data transport to the mFLES (high performance computing farm)
- up to 10 MHz collision rate

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

CBM readout chain Phase I (2019)

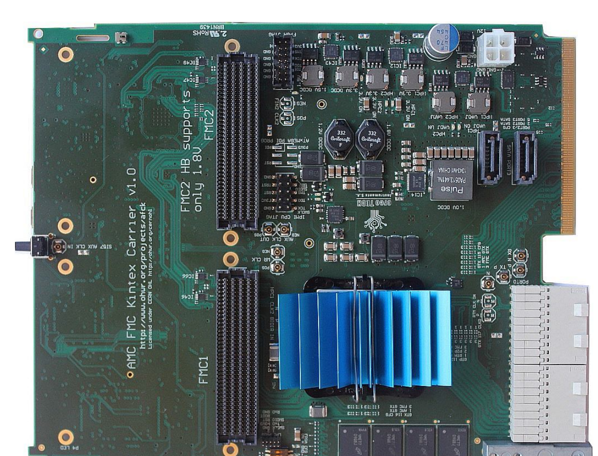


Front End Board
carries 8x STS-XYTER ASICs



Read-Out Board
CERN-GBTx ASIC and
versatile link opto components

Data Processing Board
FPGA based interface for
timing control and data



CBM-STS project

Key Participants of CBM-STS:

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

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

Russia:
- Dubna, Joint Institute for Nuclear Research (JINR)

Project timeline


Technical Design Report for the CBM

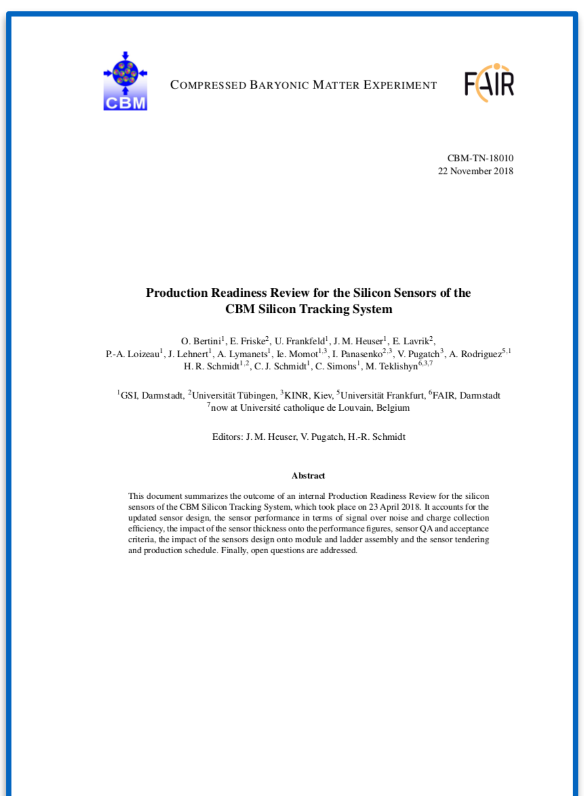
Compressed Baryonic Matter Experiment

Silicon Tracking System (STS)

The CBM Collaboration

GSI Report 2013-4
October 2013

- 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.


Compressed Baryonic Matter Experiment

CBM-TN-18010
22 November 2018

Production Readiness Review for the Silicon Sensors of the CBM Silicon Tracking System

Editors: J. M. Heuser, V. Pugatch, H.-R. Schmidt

Abstract

Sensor production readiness

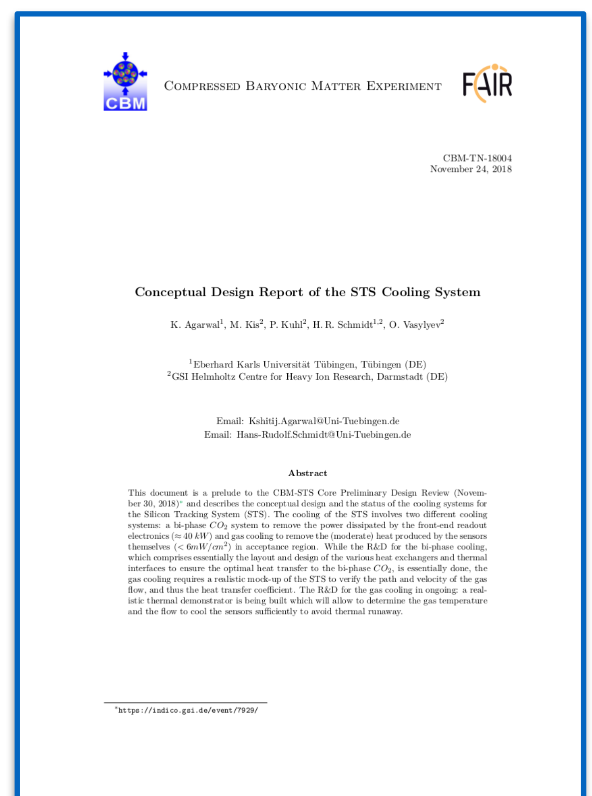

CBM Collaboration

STS Note 2018-1 v1.0
August 22, 2018

Evaluation of the STS sensor prototypes irradiated with 23 MeV proton beam using relativistic β-electrons

CBM-STS

Rad. hardness


Compressed Baryonic Matter Experiment

CBM-TN-18004
November 24, 2018

Conceptual Design Report of the STS Cooling System

Abstract

Cooling


CBM Collaboration

STS Note 2018-02
28 August 2018

Report on the production of prototype STS ladders

CBM-STS team

Editor: Johann M. Heuser, GSI

Abstract

Ladders