Overview of the Silicon Tracking System for the CBM experiment

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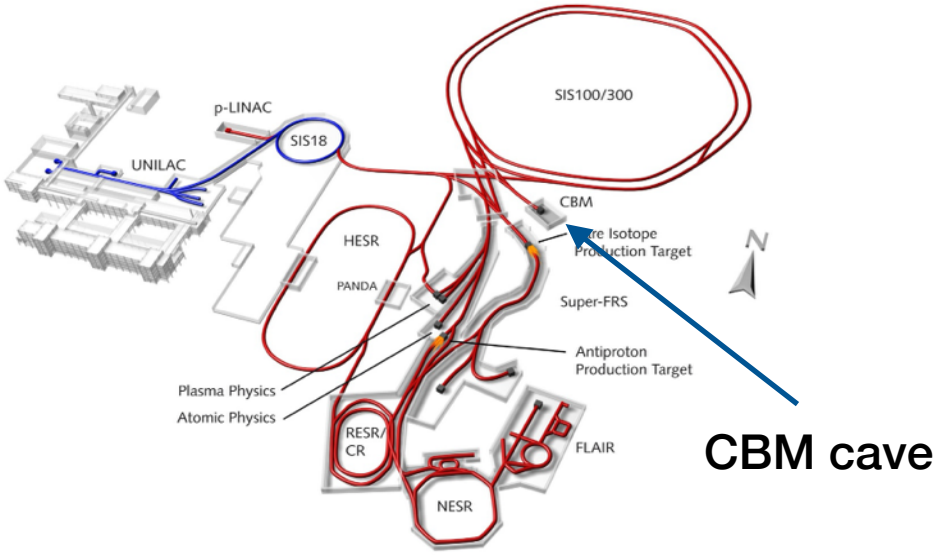
FAIRNESS 2014
22-27 September, Vietri sul Mare, Italy

The CBM experiment

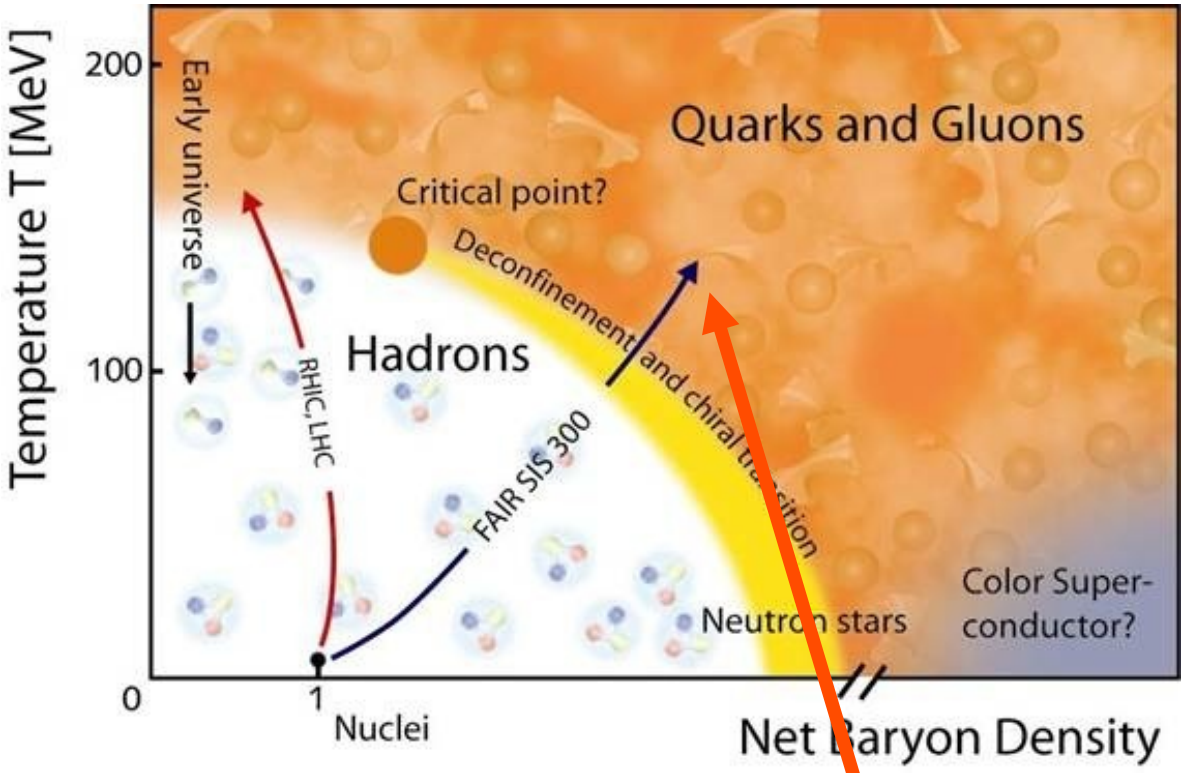
- comprehensive program to explore the phase diagram of strongly interacting matter at highest net baryon densities and moderate temperatures:

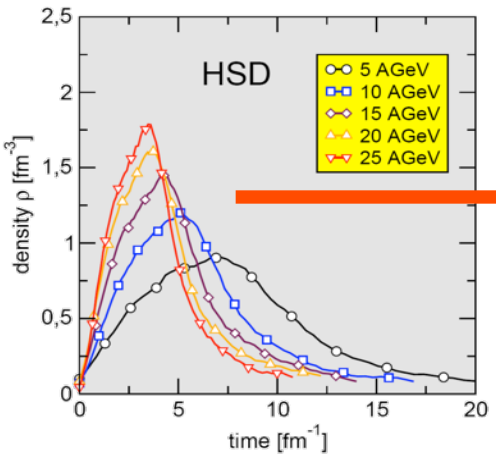
“Compressed Baryonic Matter”

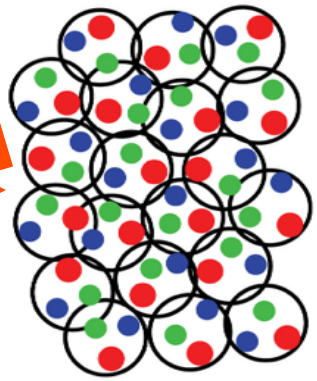
- heavy-ion collisions from 2 – 45 GeV/nucleon at FAIR;
  - SIS100
    - 2 to 14 GeV/nucleon for nuclei;
    - up to 29 GeV for protons;
  - SIS300:
    - up to 45 GeV/nucleon for nuclei;
    - up to 90 GeV for protons;
  - beam extracted from SIS100/300 to the CBM experimental hall



Explore the QCD phase diagram







How to probe dense matter?

- Need penetrating probes sensitive to the early, high-density phase of fire ball evolution;
- CBM: di-lepton decays of light vector mesons and charm
  - light vector mesons

$$\rho, \omega, \Phi \rightarrow e^+ e^- / \mu^+ \mu^-$$

  - charmonium

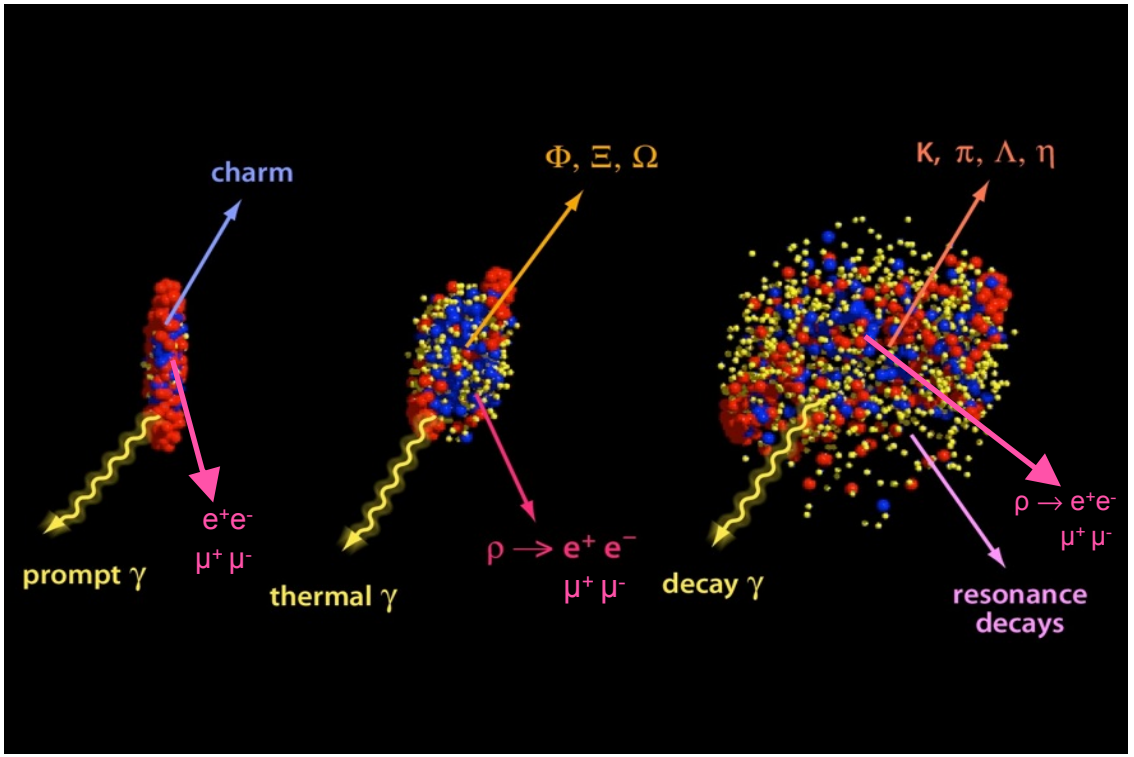
$$J/\Psi, \Psi' \rightarrow e^+ e^- / \mu^+ \mu^-$$

  - open charm

$$D^{+-}, D^0 \rightarrow K+\pi$$

$$K+\pi\,\pi$$

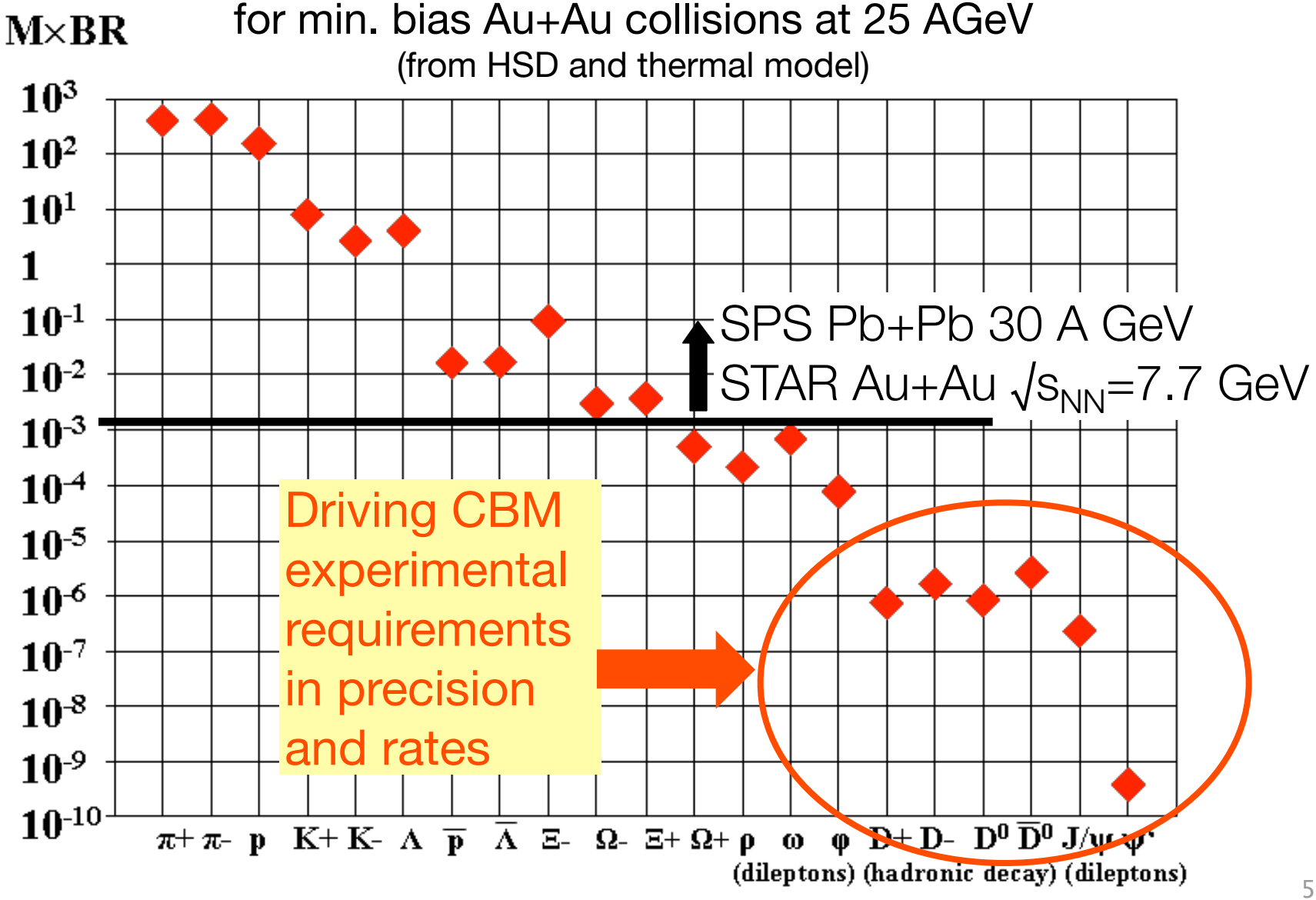
  - Strangeness;



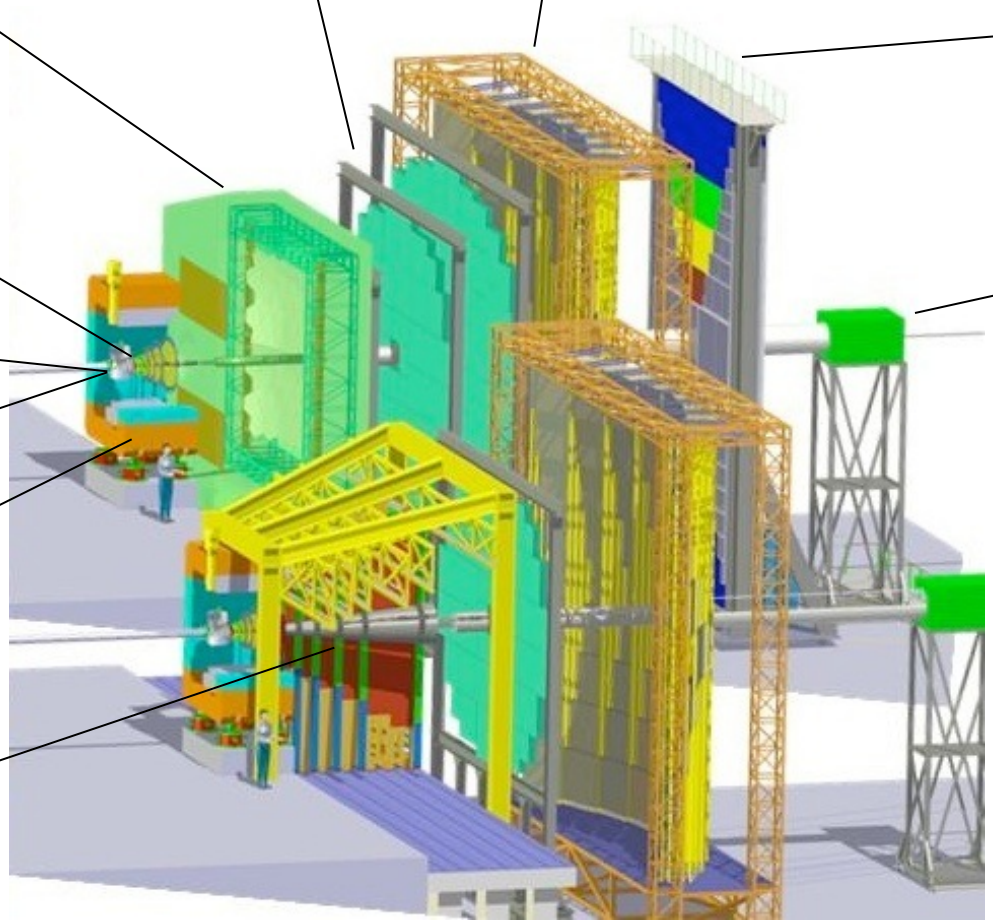
- Rare probes! Require:
  - ➠ Reaction rate up to 10 MHz (J/Psi)
  - ➠ Good particle ID

Experimental challenges

Particle multiplicity x branching ratio
for min. bias Au+Au collisions at 25 AGeV
(from HSD and thermal model)



The CBM experimental setup



two configurations:
- electron-hadron
- muon setup

STS design constrains

High interaction rates

- 10^5 – 10^7 Au+Au collisions/ sec.

Fast and radiation hard detectors

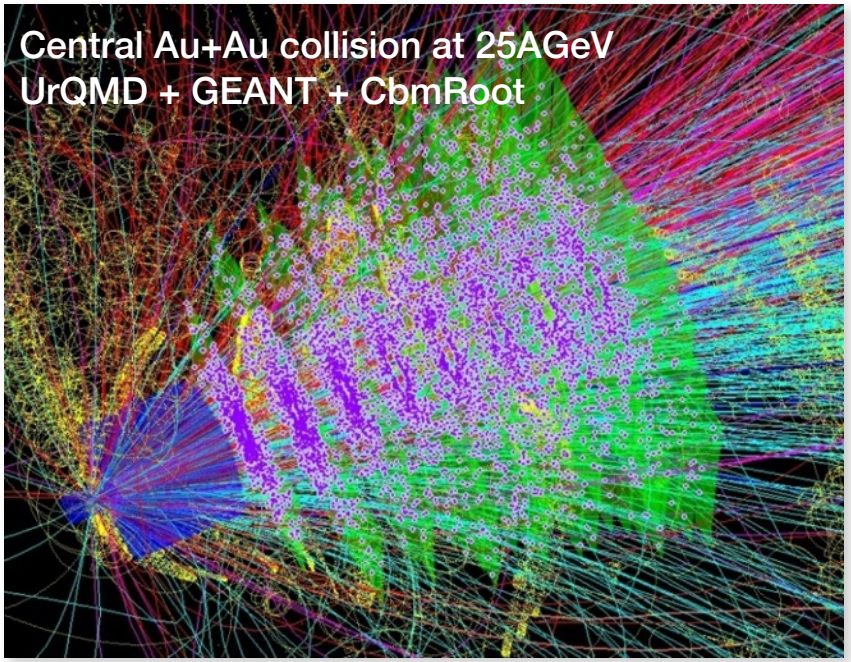
- up to 10^{14} n_{eq}/cm^2

Free streaming read-out

- time-stamped detector data
- high speed data acquisition

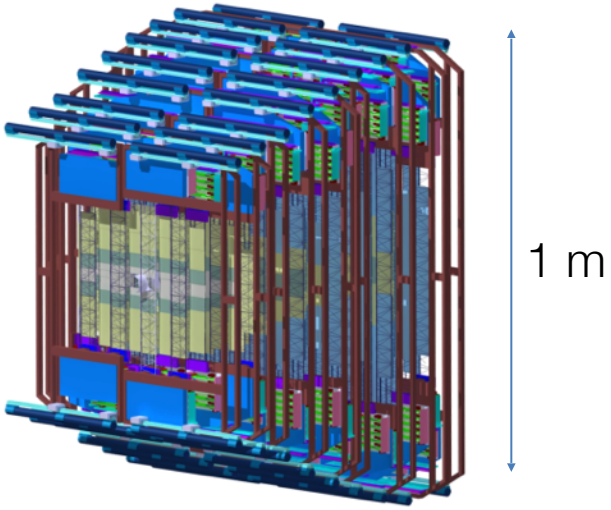
On-line event reconstruction

- powerful computing farm
- 4-dimensional tracking
- software triggers

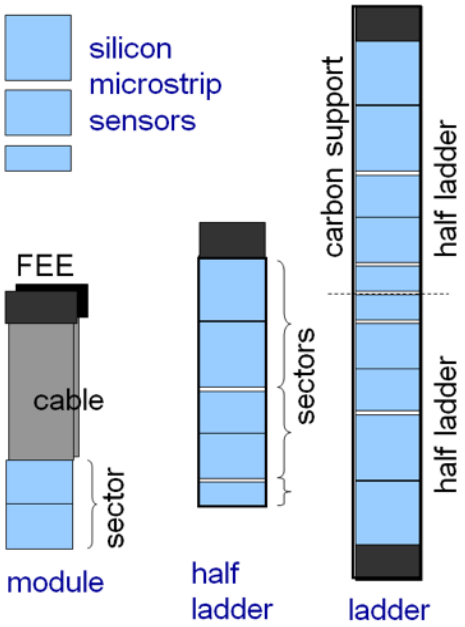


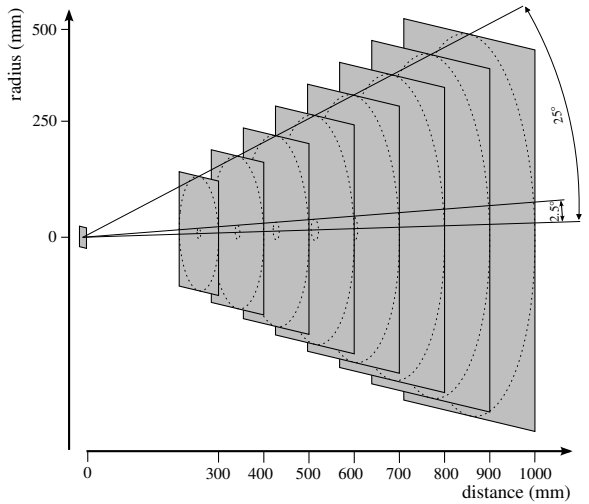
~700 charged particles per event

The Silicon Tracking System



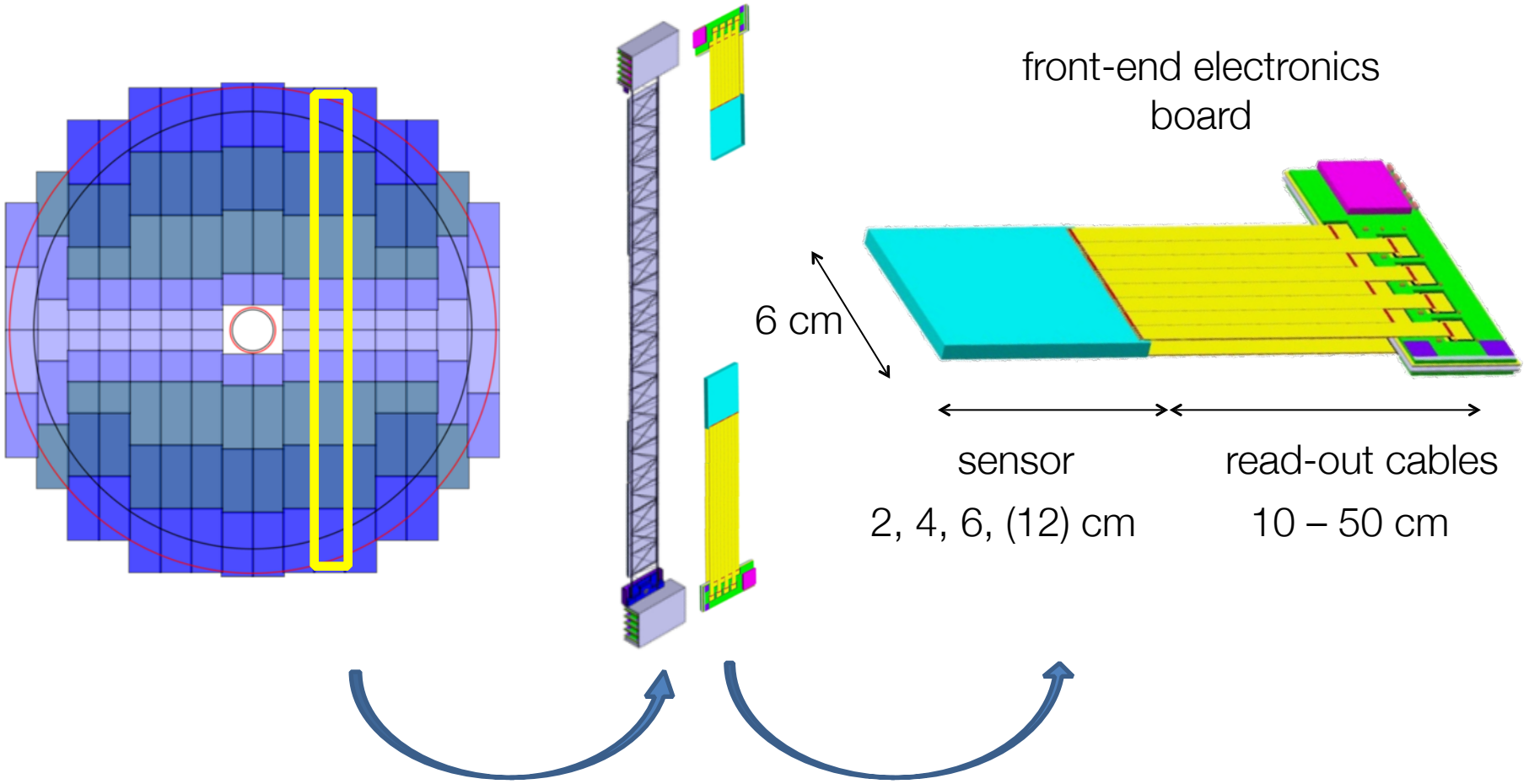
- 8 tracking stations between 30 cm and 1m;
- Located in 1 Tm dipole magnet;
- Built from double-sided silicon micros trip sensors in 3 sizes;
- Arranged in modules on a small number of different detector ladders;
- Readout electronics outside of the physics aperture;
- Momentum resolution $\Delta p/p=1\%$;
- Track reconstruction efficiency ~95%.





STS Module

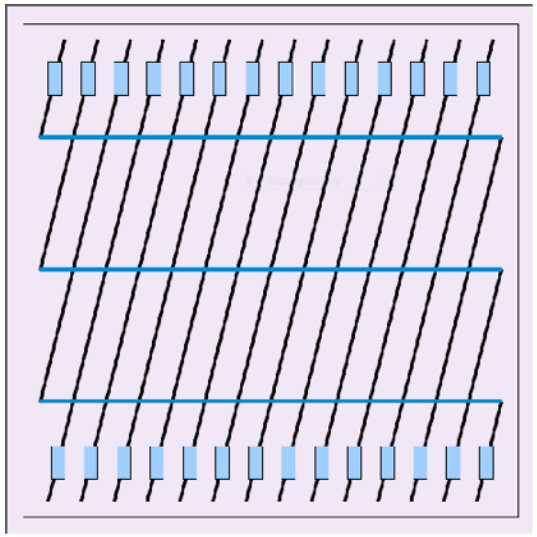
Module := building block of ladders, smallest assembled functional unit

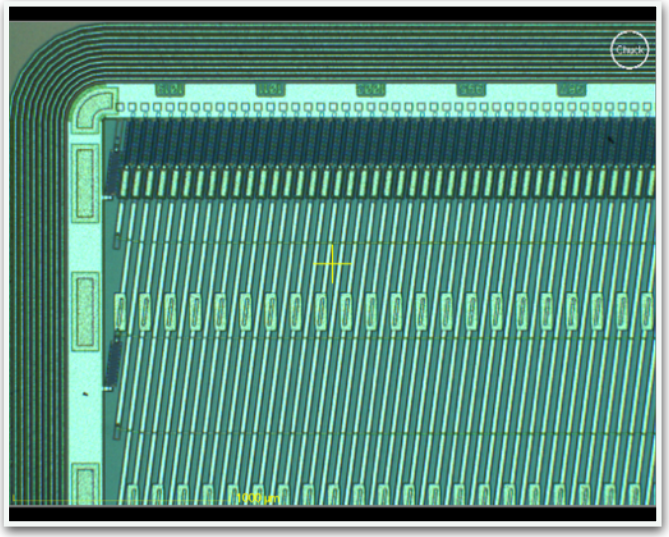


896 modules in 25 types, differing in numbers and size of sensors, and cable lengths

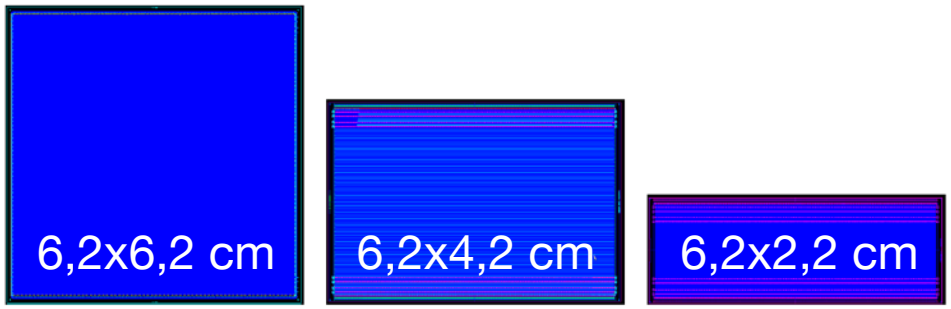
Double-sided silicon strip sensors

- Double-sided structure;
- 1024 strips per side;
- 58 μm pitch (distance b/w two strips);
- Stereo angle front-back side 7.5°;
- Integrated AC-coupled readout;
- Radiation tolerant up to 1×10^{14} n_{eq}/cm^2;
- Three different sizes;
- Around 1200 will be produced





edge of the sensor under microscope

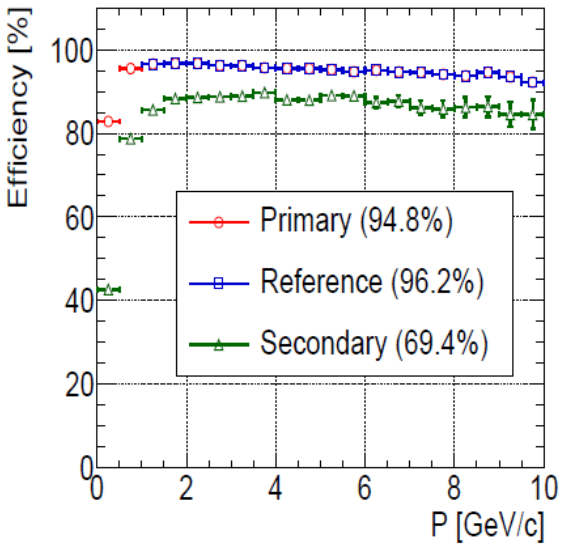


CBM05 CBM05H4 CBM05H2

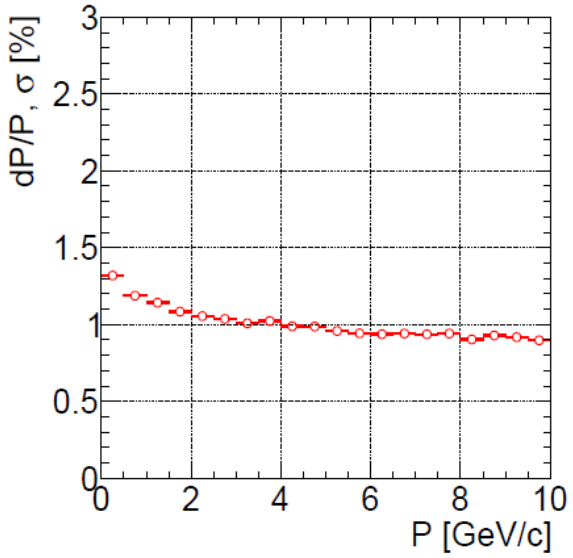
Detector performance simulation

- Detailed, realistic detector model based on tested prototype components;
- CbmRoot simulation framework;
- Using Cellular Automaton / Kalman Filter algorithms.

track reconstruction efficiency

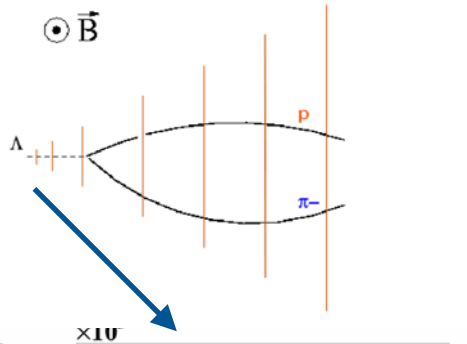


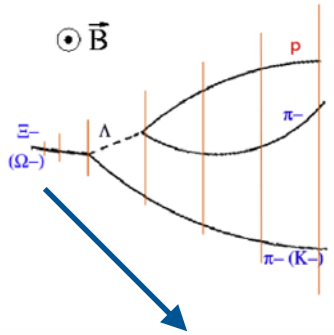
momentum resolution



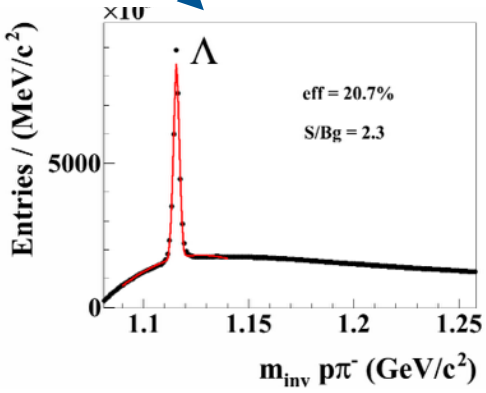
Au+Au @ 25 AGeV (SIS 300)

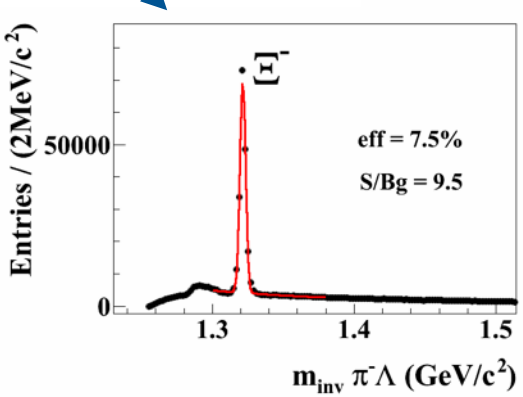
STS Perfomance: (multi strange) hyperon production

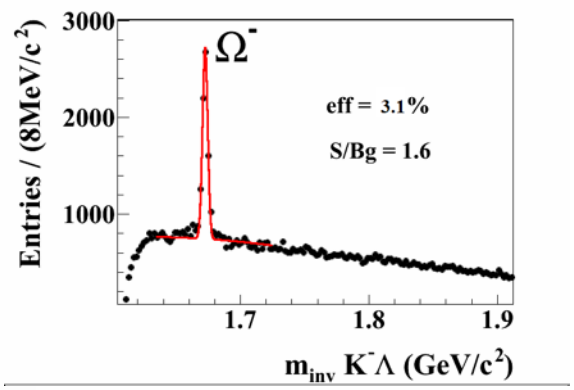


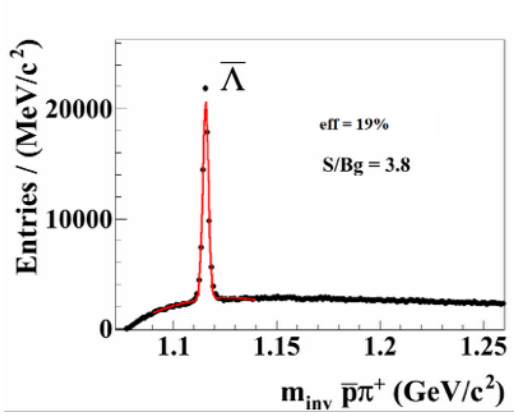


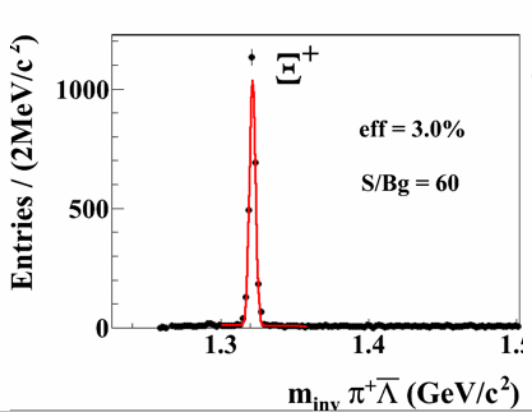
Au+Au @ 25 AGeV (SIS 300)

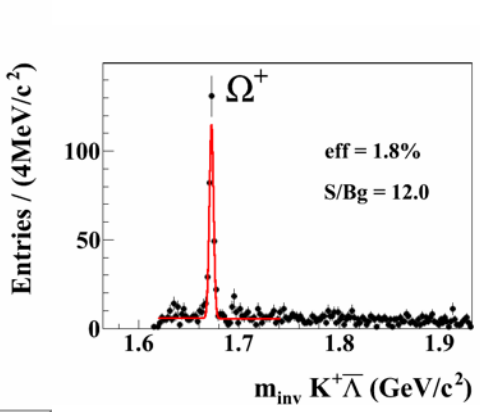




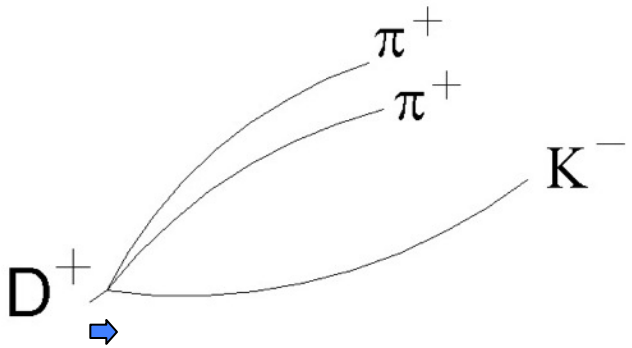




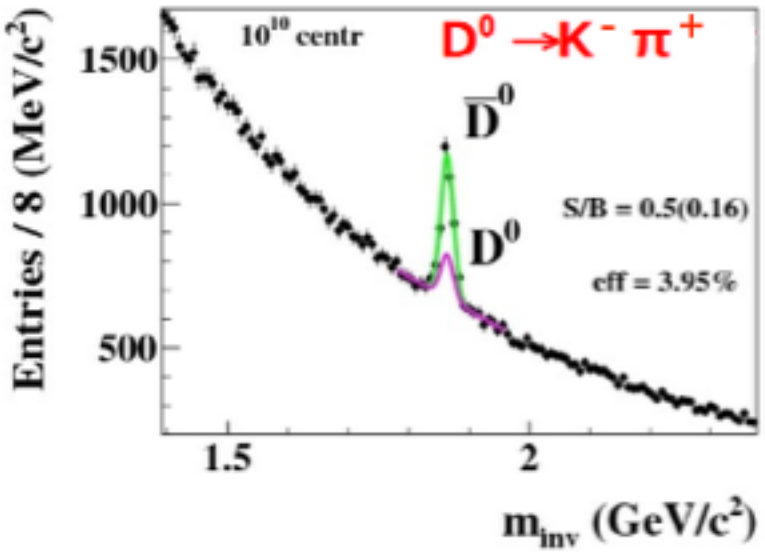


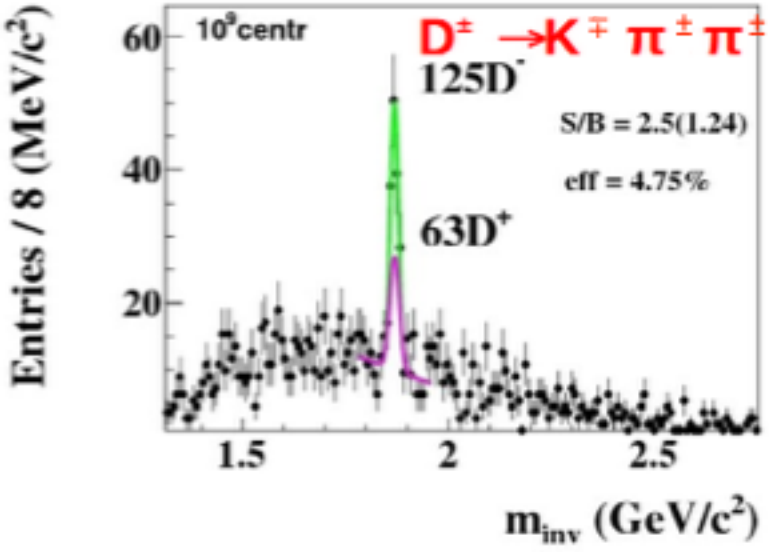


STS Perfomance: open charm

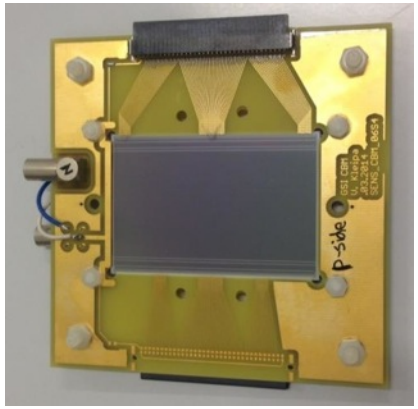


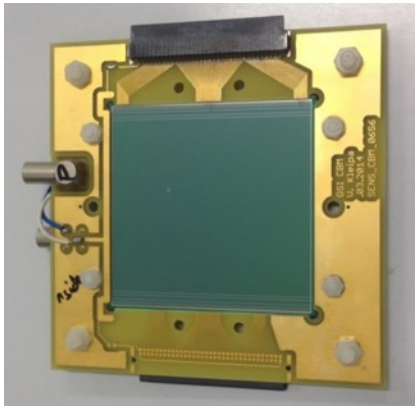
cτ few hundred μm,
decay just downstream of target,
in front of MVD and STS

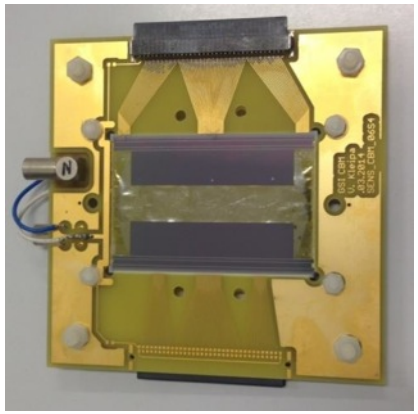


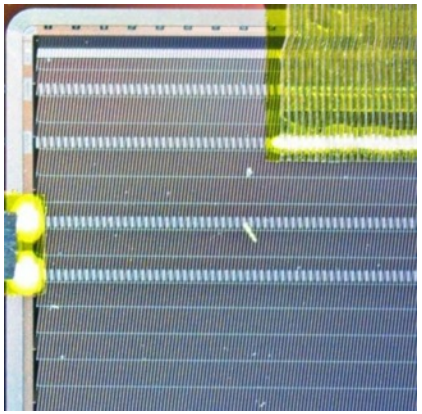


Sensor related projects, in which I’m involved in





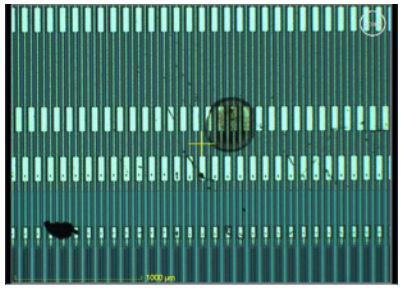


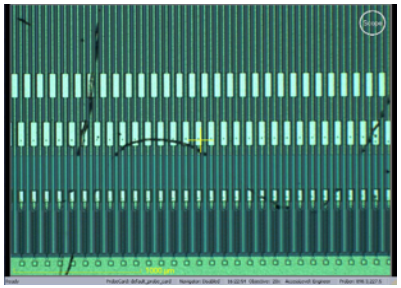


Sensor characterization and quality assurance

Bulk tests:

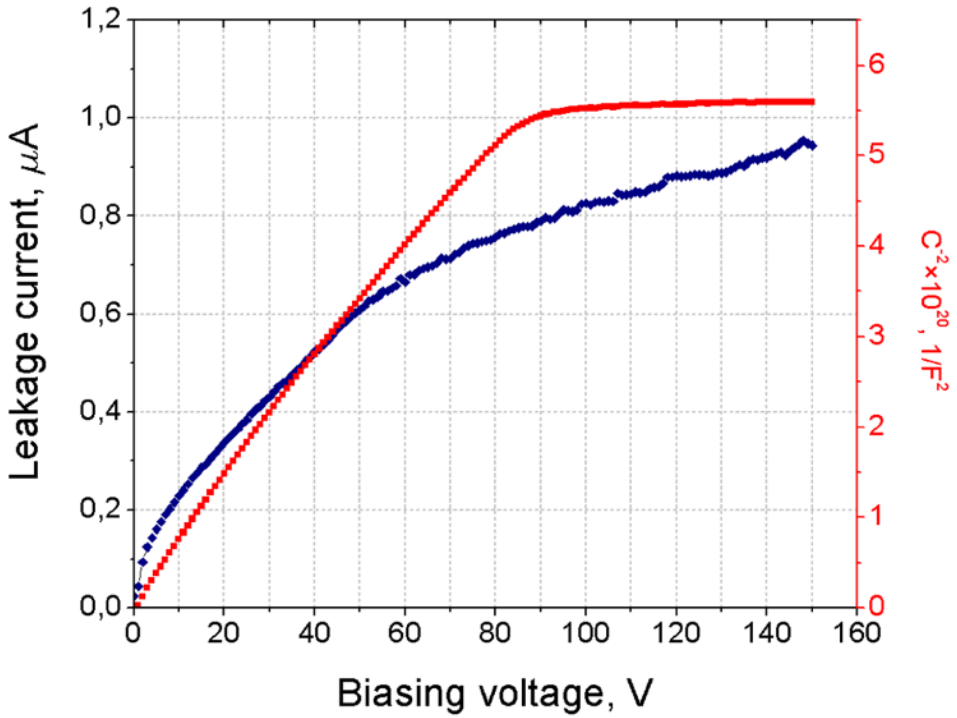
1) Visual inspection
- to check scratches and defects;





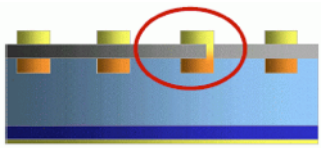
2) IV-scan
- to check overall sensor health;

3) CV-scan
- to determine the depletion voltage;

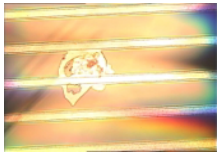


Detailed sensor quality assurance

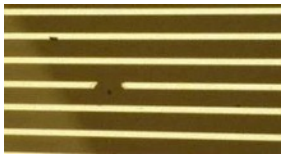
Strip defects:



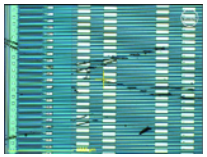
“Pinhole”



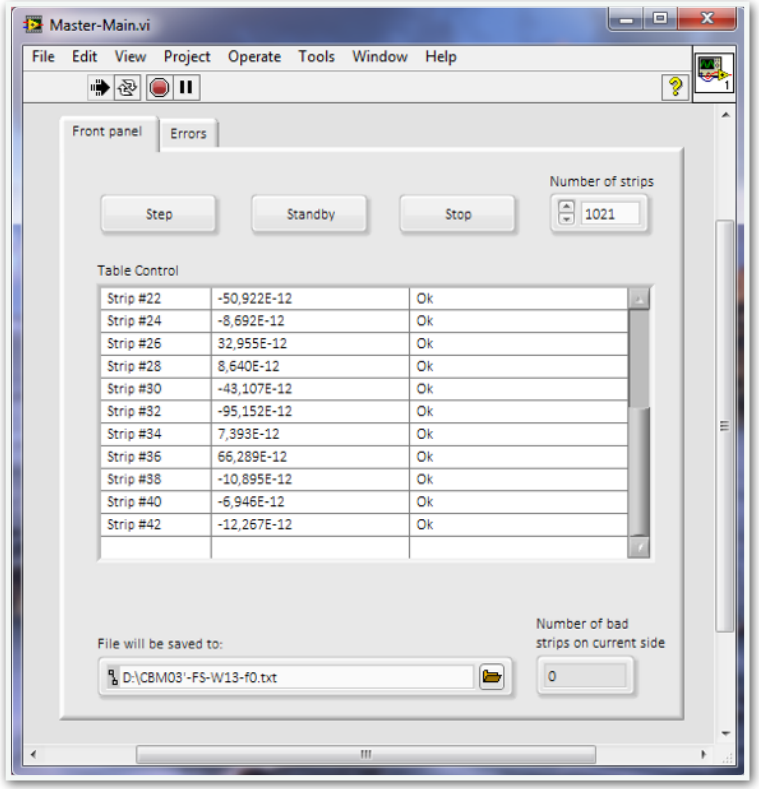
Metal short



Metal brake

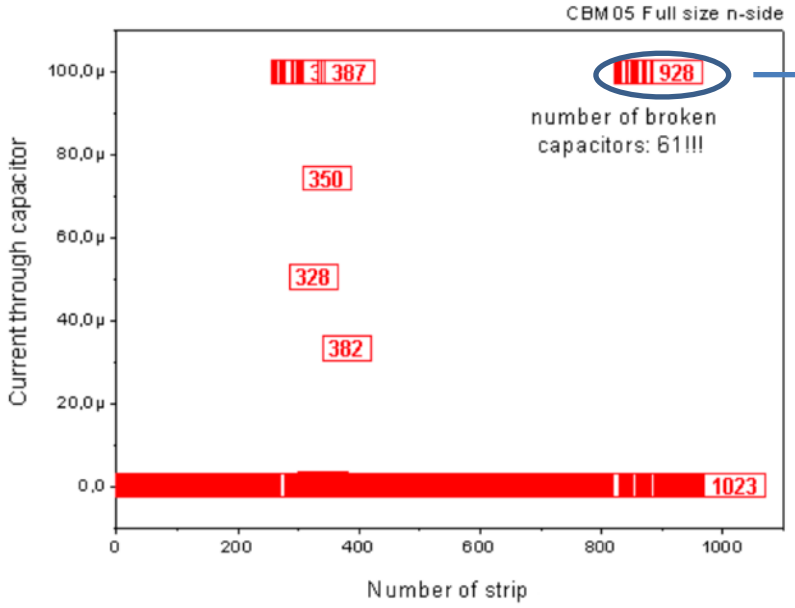


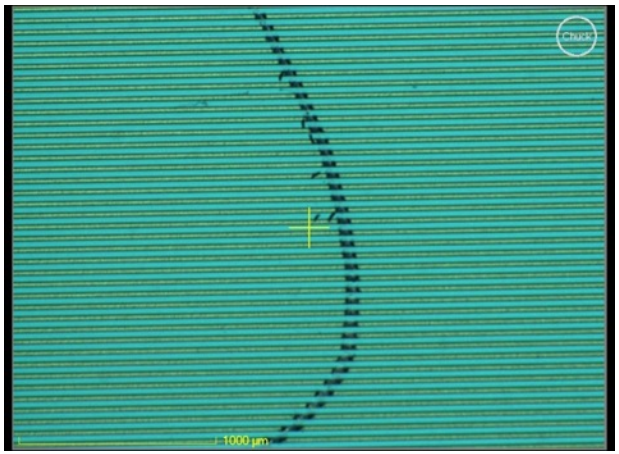
Scratches



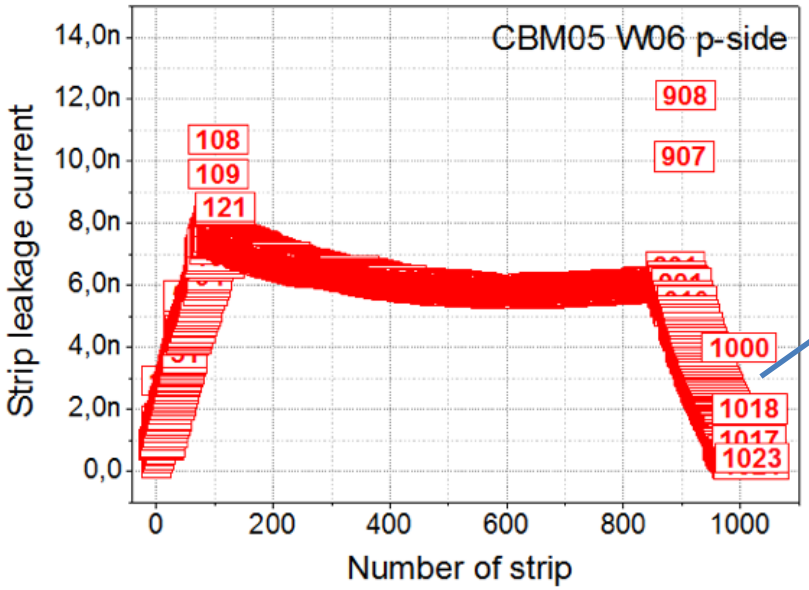
- **Automated testing procedure**;
- LabView program;
- Check for pinholes, metal shorts, strip current, coupling capacitance;
- Shows result online and also saves ASCII file.

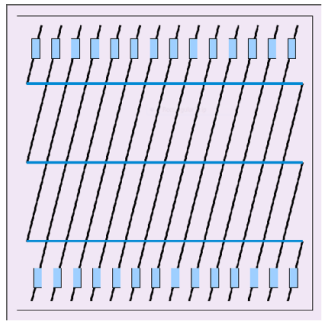
Detailed sensor quality assurance





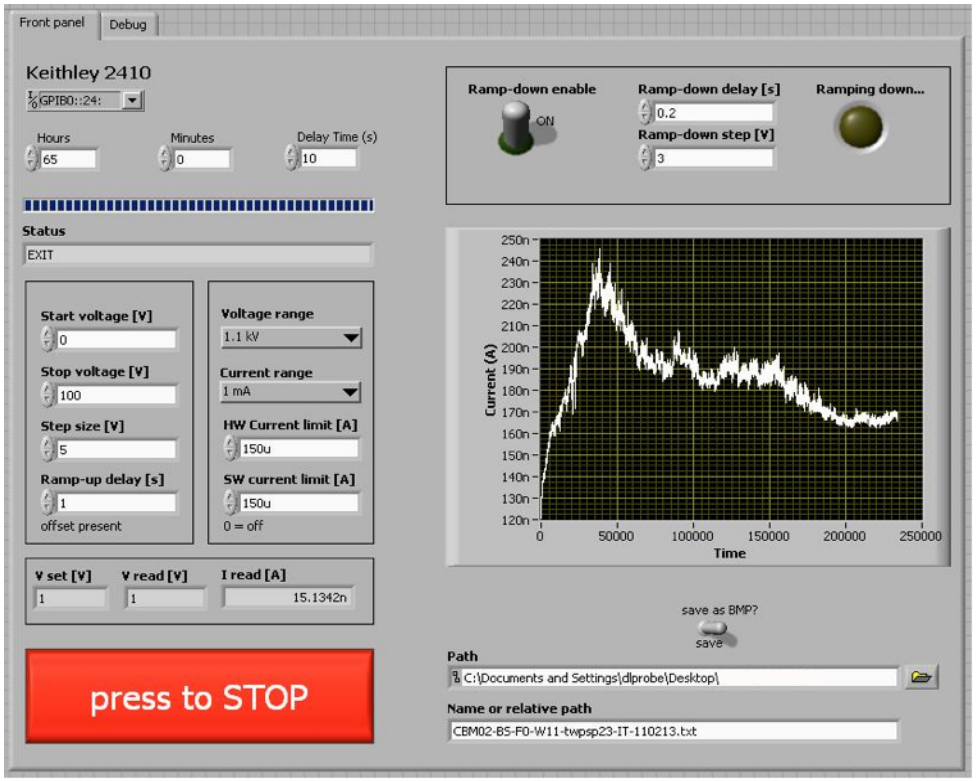
scratch caused huge number of pinholes

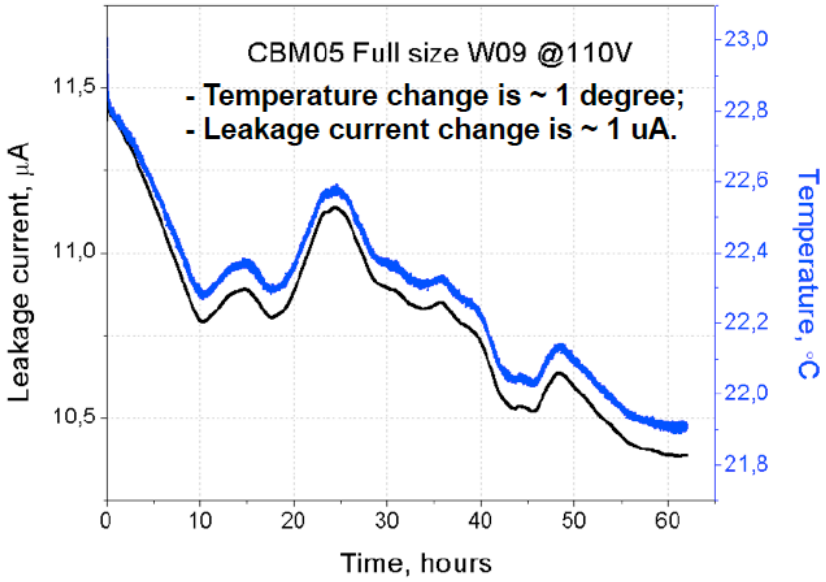


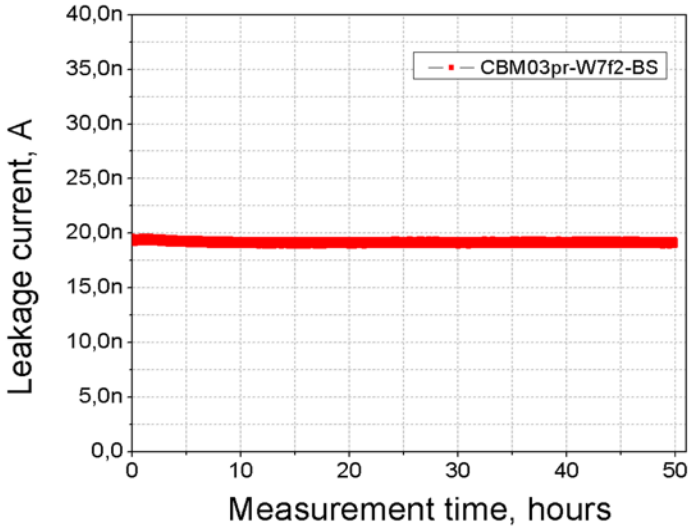


Strip leakage current distribution

Sensor Quality Assurance - Current Stability







- Labview program
- Measuring temperature and humidity
- Automized measurements (65 hours)
- Excluding the temperature effect

Radiation tolerance of our sensor prototypes

- 12 baby sensors selected: 4 sensors per neutron fluence
- exposed to neutrons: IJS, Ljubljana, Slovenia
- neutron fluences: 1×10^{13}, 5×10^{13}, 1×10^{14} n_{eq} cm^{-2}

4 × CBM05 → **1×10^{13} $n_{eq}cm^{-2}$**

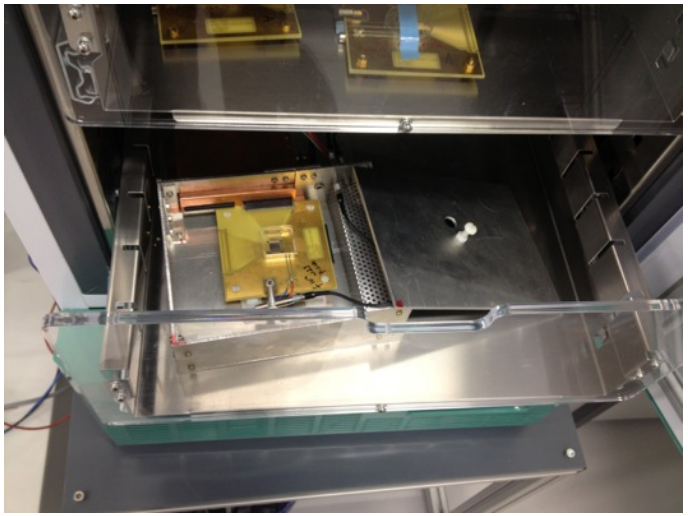
4 × CBM05 → **5×10^{13} $n_{eq}cm^{-2}$**

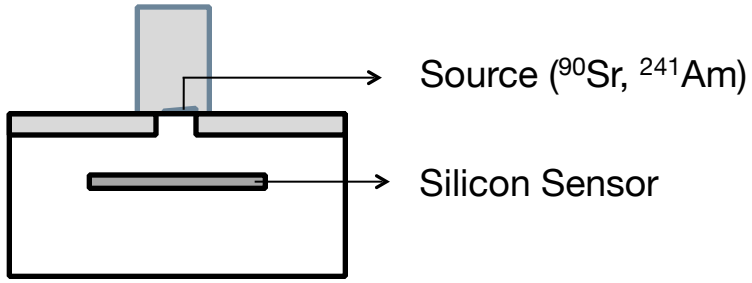
4 × CBM05 → **1×10^{14} $n_{eq}cm^{-2}$**

baby sensor properties:

- 1 × 1 cm^2 size
- n-type substrate
- 285±15 μm thickness
- 2-5 kΩ cm
- 128 strips per side
- 50μm strip pitch
- stereo angle 90^0

Radiation tolerance of our sensor prototypes



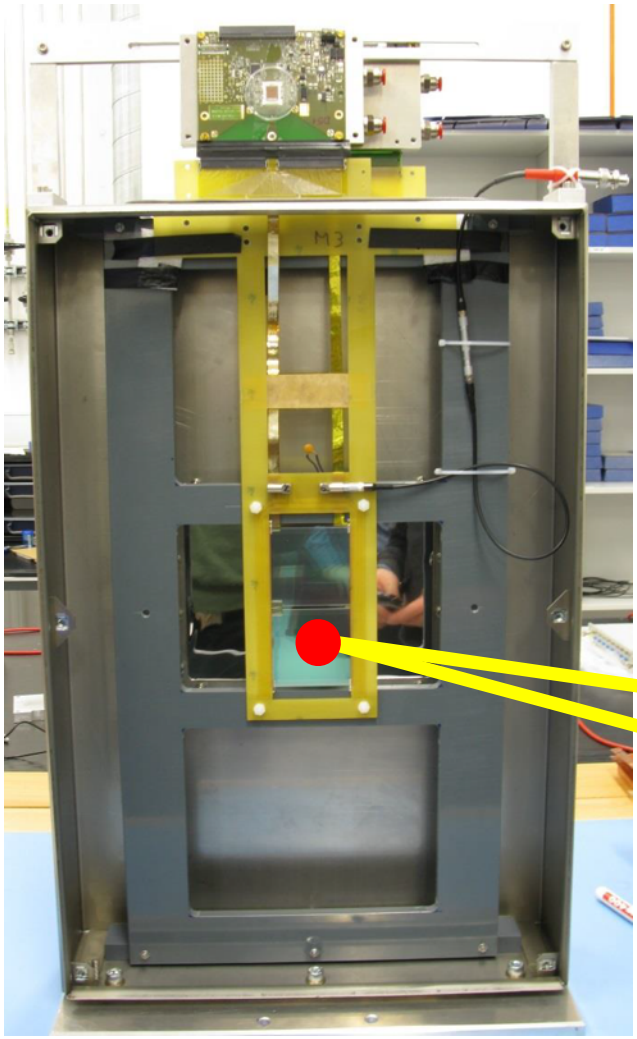


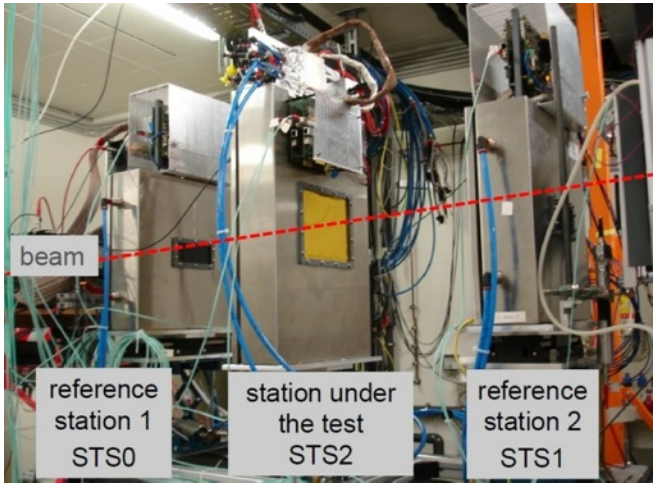
- Operated at -5 degrees in a shielded box

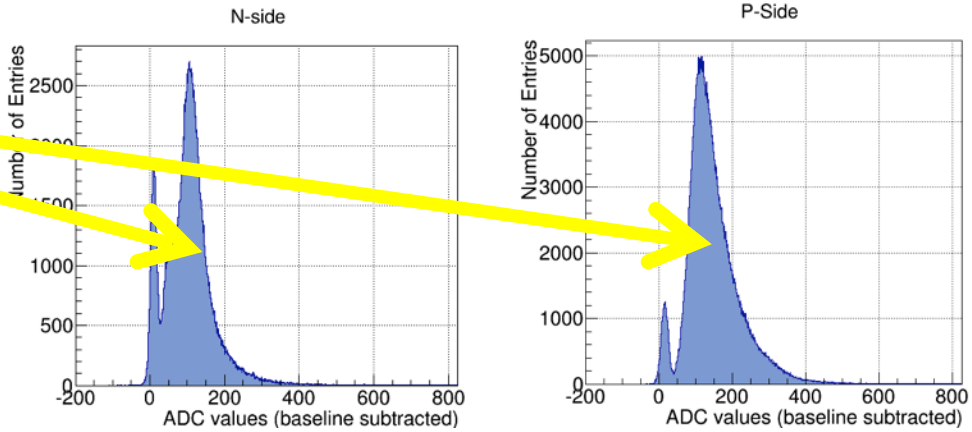
fluence (n	full depletion, V	bias , V ± 1	charge collected (ke		charge collection efficiency (%) ±4	
			p-side	n-side	p-side	n-side
0	80 ± 2	160	16	14	100	90
1 × 10	35 ± 5	150	14.6	14.4	90	91
5 × 10	45 ± 5	250	13	13.2	80	84
1 × 10	120 ± 2	400	13	12.2	80	77

Beam test at COSY, December 2013

- Second module prototype with CBM05 sensor prototype and second batch of the low-mass micro-cables and n-XYTER FEB, proton beam, 2.8 GeV/c

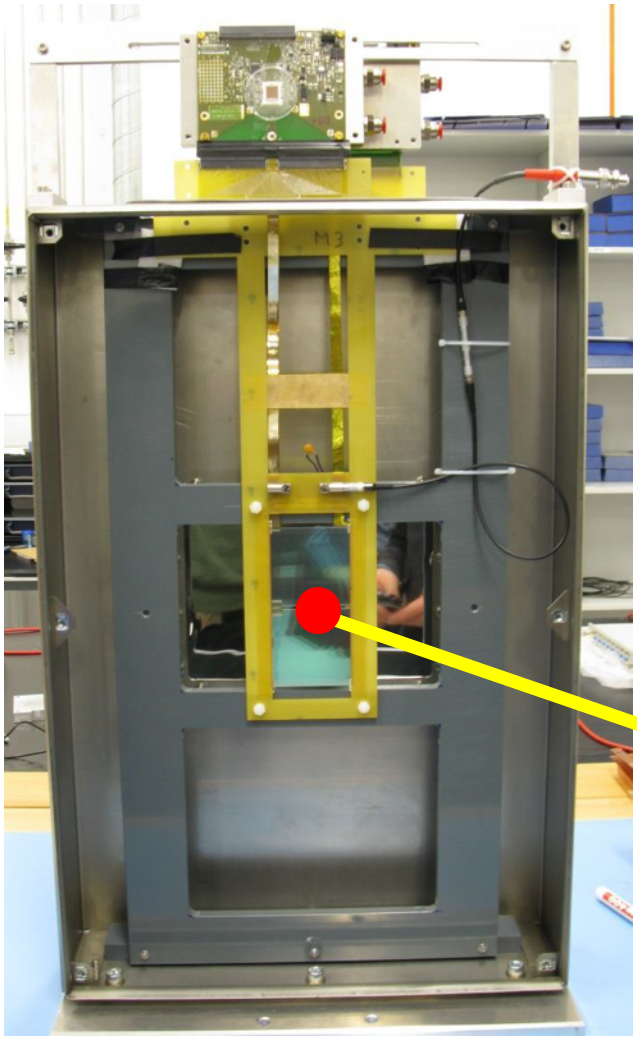


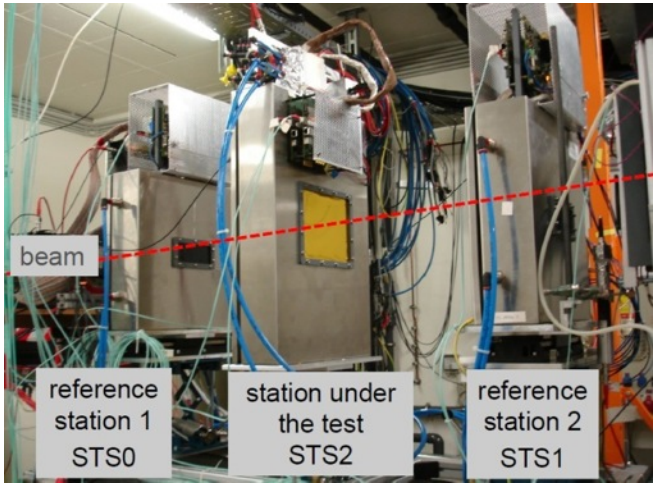




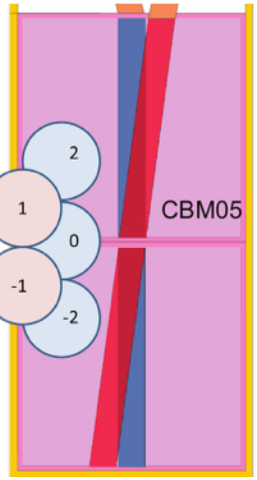
Beam test at COSY, December 2013

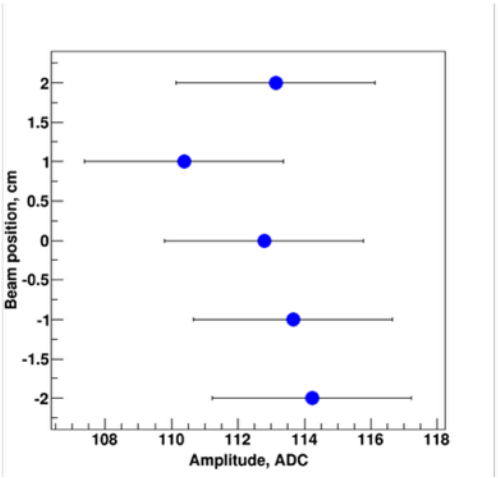
- Second module prototype with CBM05 sensor prototype and second batch of the low-mass micro-cables and n-XYTER FEB, proton beam, 2.8 GeV/c





Daisy-Chained Sensor (M3), Y-scan





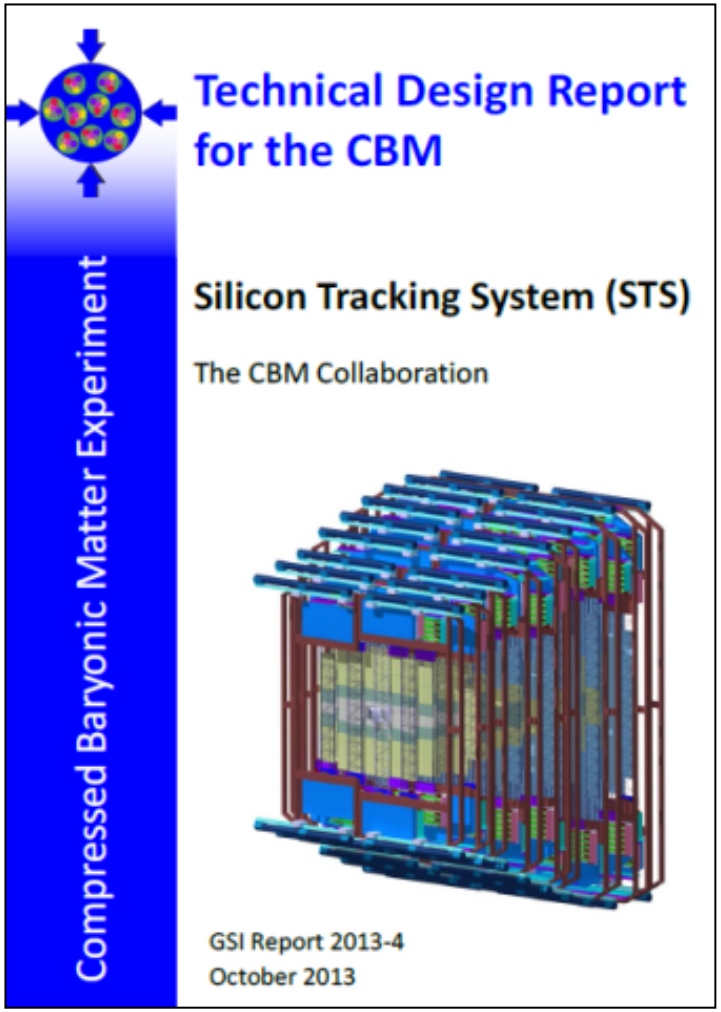
Summary

- CBM experiment aims to explore the QCD phase diagram in the region of high net baryonic densities and moderate temperatures using particular rare, penetrating probes;
- Silicon Tracking System is the will be used for particle tracking and determination of momentum of charged particles;
- STS will be built of large amount of silicon sensors, read-out cables and read-out electronics;
- For sensor characterization a lot of different procedures are being done with our sensor prototypes;
- Radiation tolerance study showed that the sensors survived even after being exposed to 10^{14} $n_{eq}cm^{-2}$ resulting in expected decrease of charge collection efficiency;
- Simulated results for track reconstruction efficiency, momentum resolution and particle identification are in good agreement with our expectations.

Summary

- Technical Design Report approved in 2013
- production of components to start in 2016
- commissioning in CBM cave planned in 2019

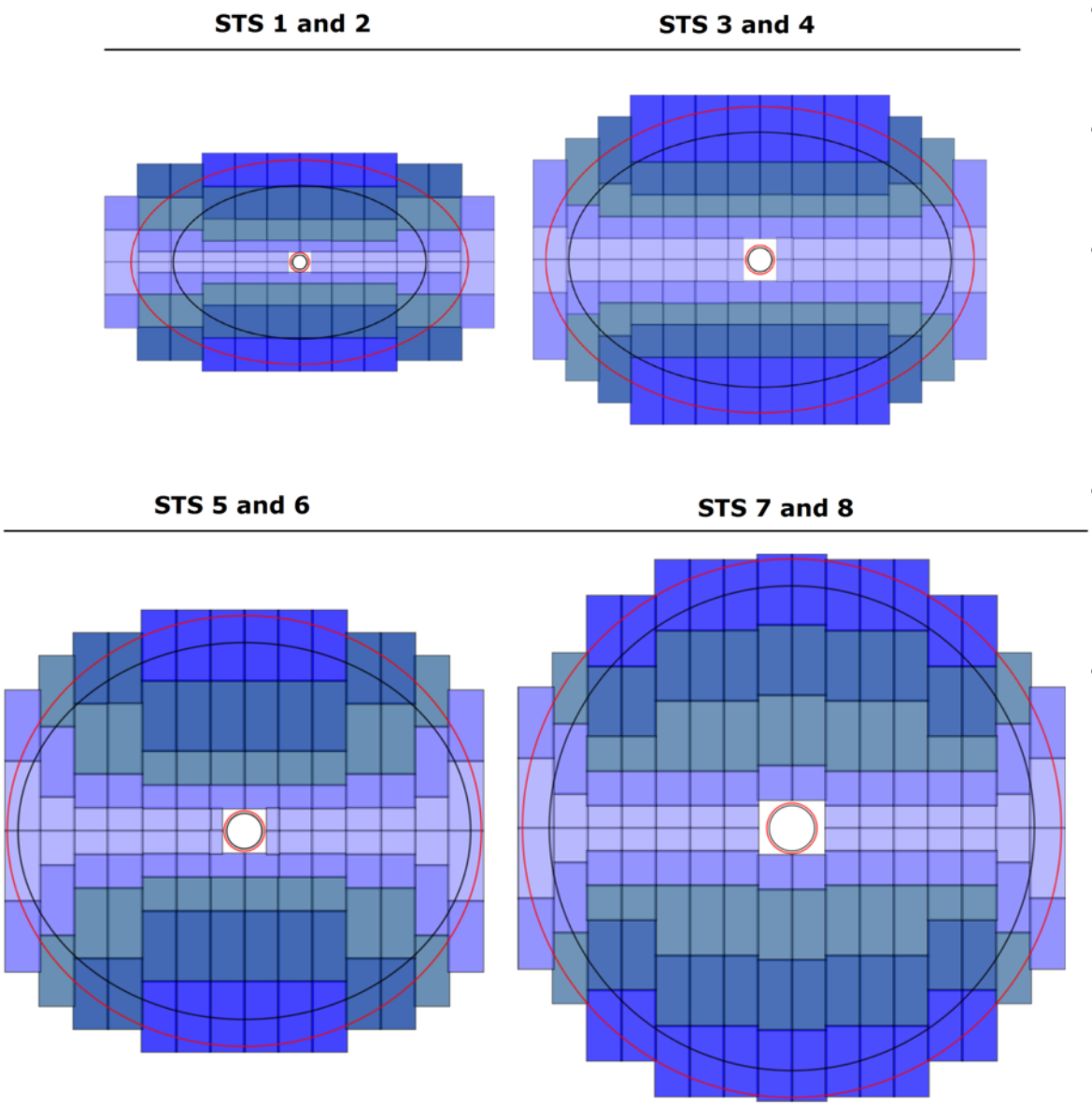
STS project team:
participants from 15 institutes in Germany, Poland, Russia, Ukraine



http://repository.gsi.de/record/54798

Thank you for attention!

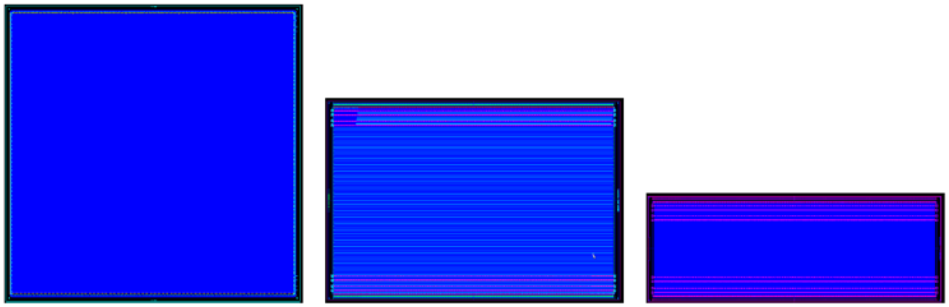
STS Layout



- Stations arranged in 4 duplets
- Minimizing amount of modules
- Strips lengths – 2 cm, 4 cm, 6 cm and in case of daisy chained sensors 12 cm
- Granularity according to the hit densities
- Components breakdown:
  - ✓ 106 ladders (17 types)
  - ✓ 896 modules
  - ✓ 1220 sensors
  - ✓ 14144 chips
  - ✓ 1.8 Mio channels

STS sensor prototypes

Prototype	Year	Vendor	Processing	Size [cm	Description
CBM01	2007	CiS	double-sided	5.5 × 5.5	±7.5 deg
CBM03	2010	CiS	double-sided	6.2 × 6.2	±7.5 deg
CBM03’	2011	CiS	Single/CBM03	6.2 × 6.2	test for CBM05
CBM05	2013	CiS	double-sided	6.2 × 6.2	7.5/0 deg, full-size
CBM05H4	2013	Hamamatsu	double-sided	6.2 × 4.2	7.5/0 deg, full-size
CBM05H2	2013	Hamamatsu	single-sided	6.2 × 2.2	7.5/0 deg, full-size
CBM06	2014	Hamamatsu, CiS	double-sided	6.2 × 6.2	7.5/0 deg, full-size



CBM05 CBM05H4 CBM05H2

under study: replacement for integrated 2nd metal layer

external on-sensor cable