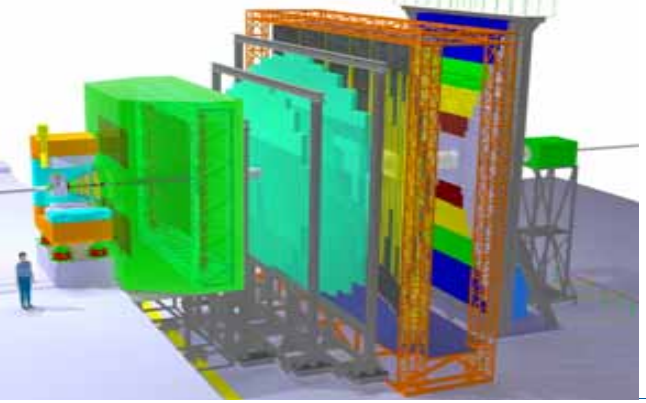
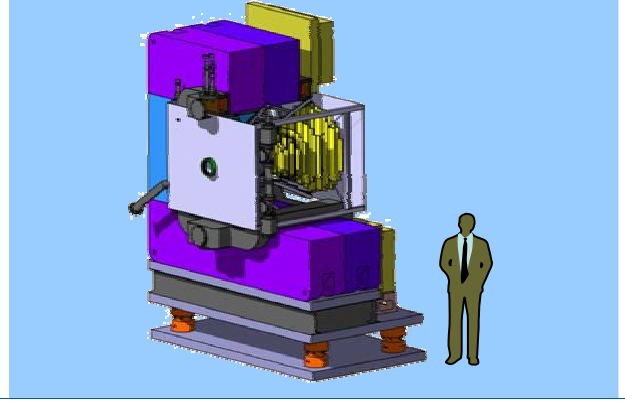
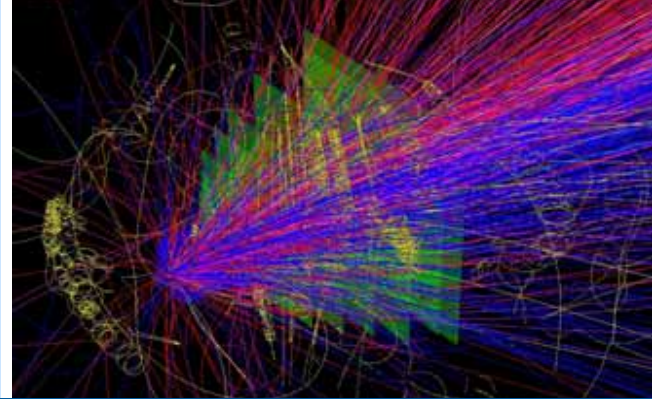
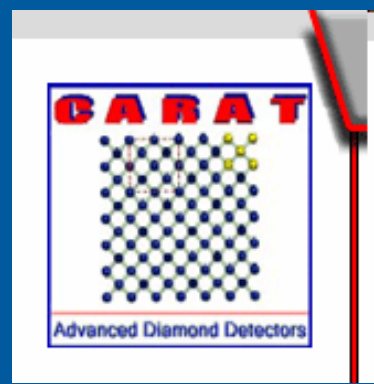




Development of the **CBM** Silicon Detector Systems

- Compressed Baryonic Matter experiment
- Silicon Tracking System
- Micro Vertex Detector

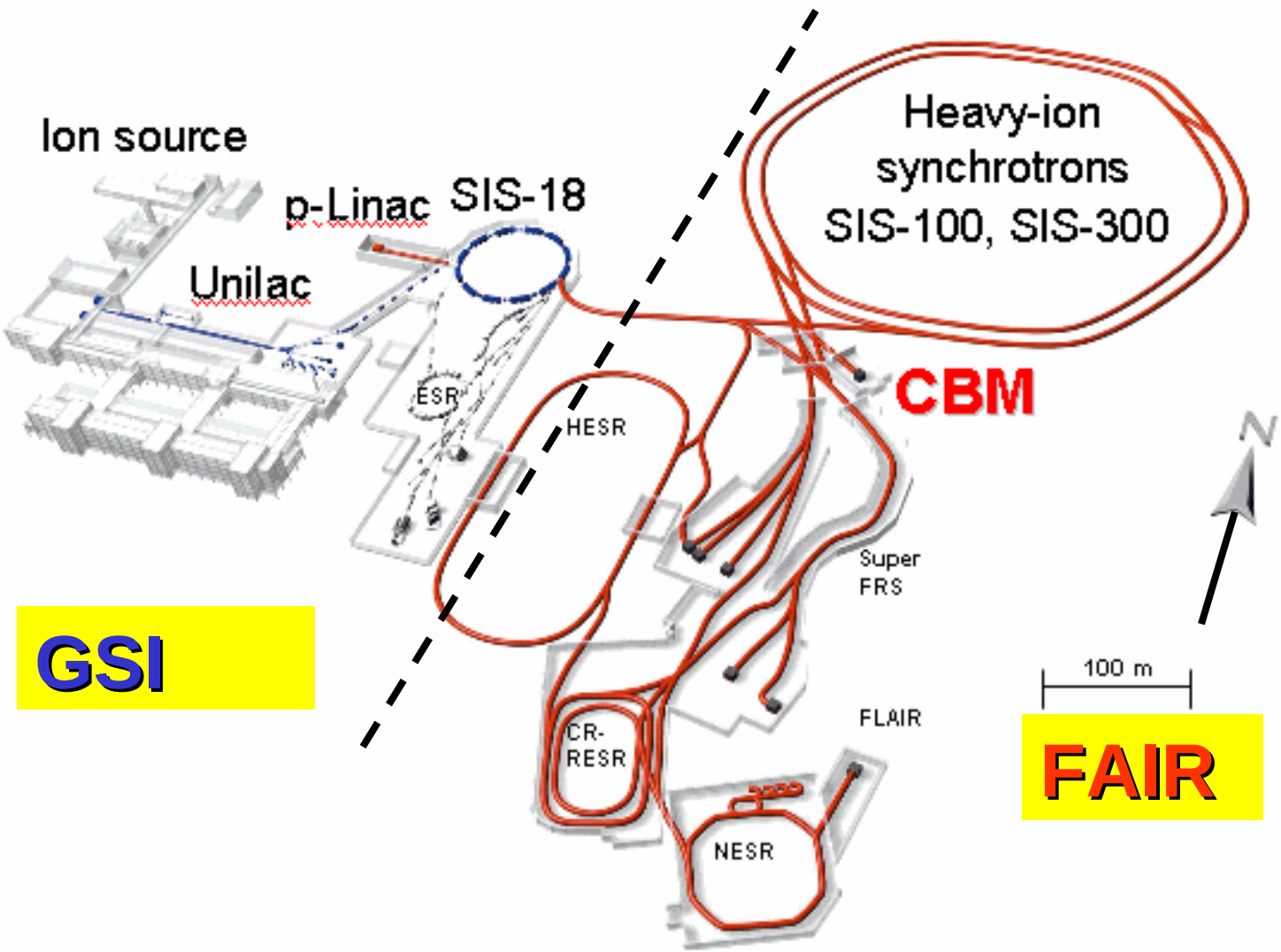


Johann M. Heuser
GSI Darmstadt

HadronPhysics2 – 1st CARAT Workshop
GSI, 14 December 2009

CBM FAIR GSI

Facility for Antiproton and Ion Research



High-intensity primary and secondary beams

Efficient parallel operation of up to 5 programs

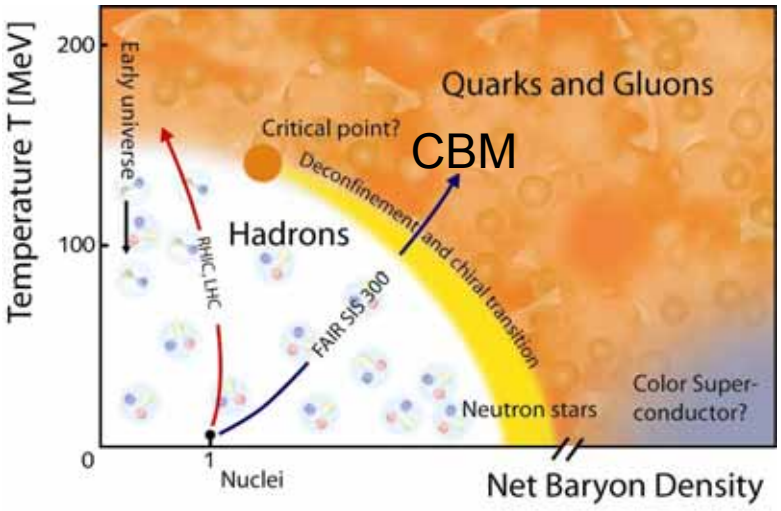
SIS-100/300:

protons:
max: 90 GeV

ions:
max. 45 GeV
up to Z/A=0.5

intensities:
up to 10^9 ions per second at CBM

QCD phase diagram & High-density nuclear matter



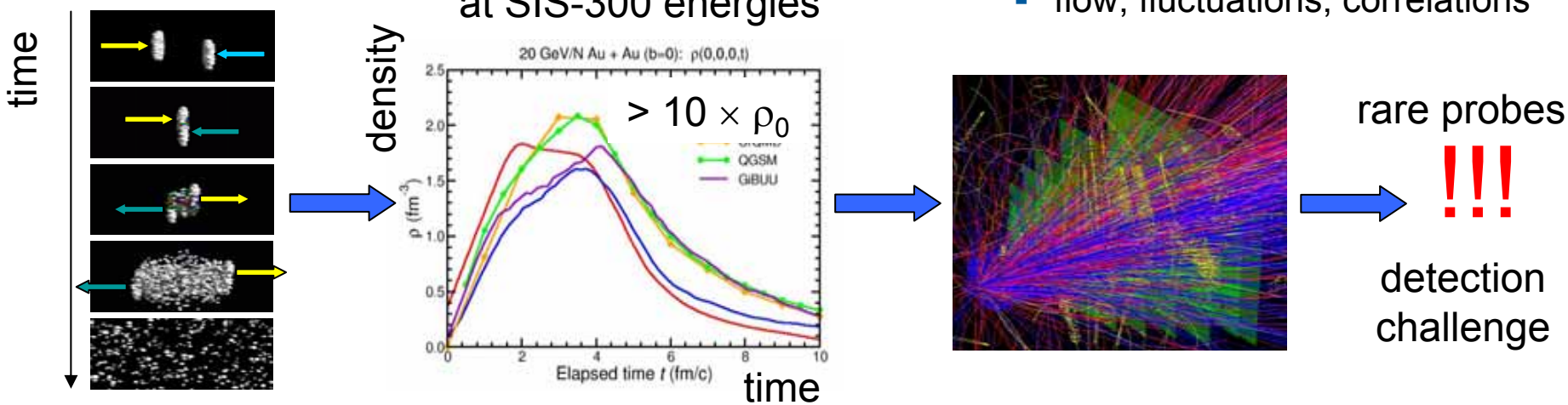
CBM physics program:

- Equation-of-state at high ρ_B
- Deconfinement phase transition
- QCD critical endpoint
- Chiral symmetry restoration

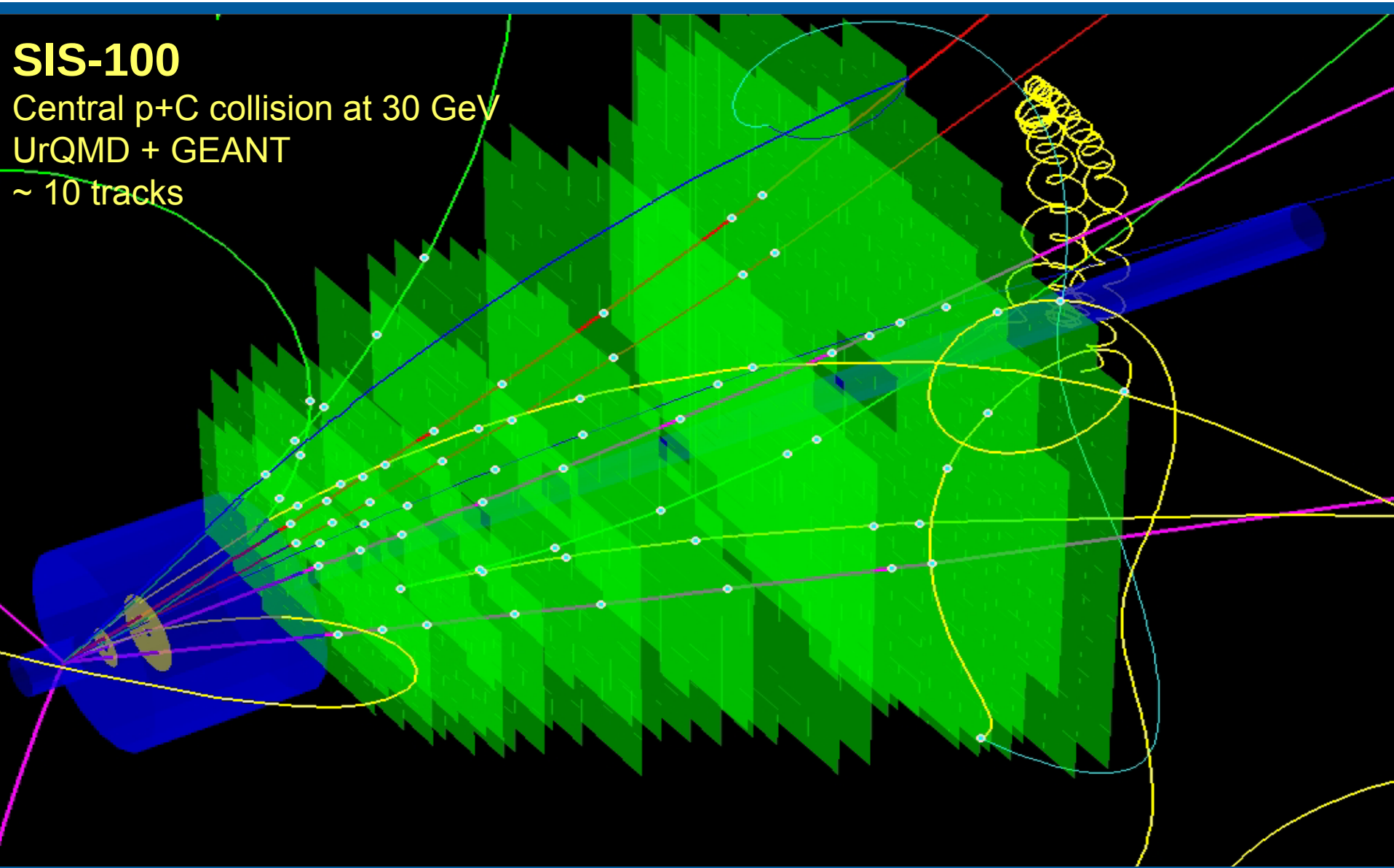
Diagnostic probes of the high-density phase:

- open charm, charmonia
- low-mass vector mesons
- multistrange hyperons
- flow, fluctuations, correlations

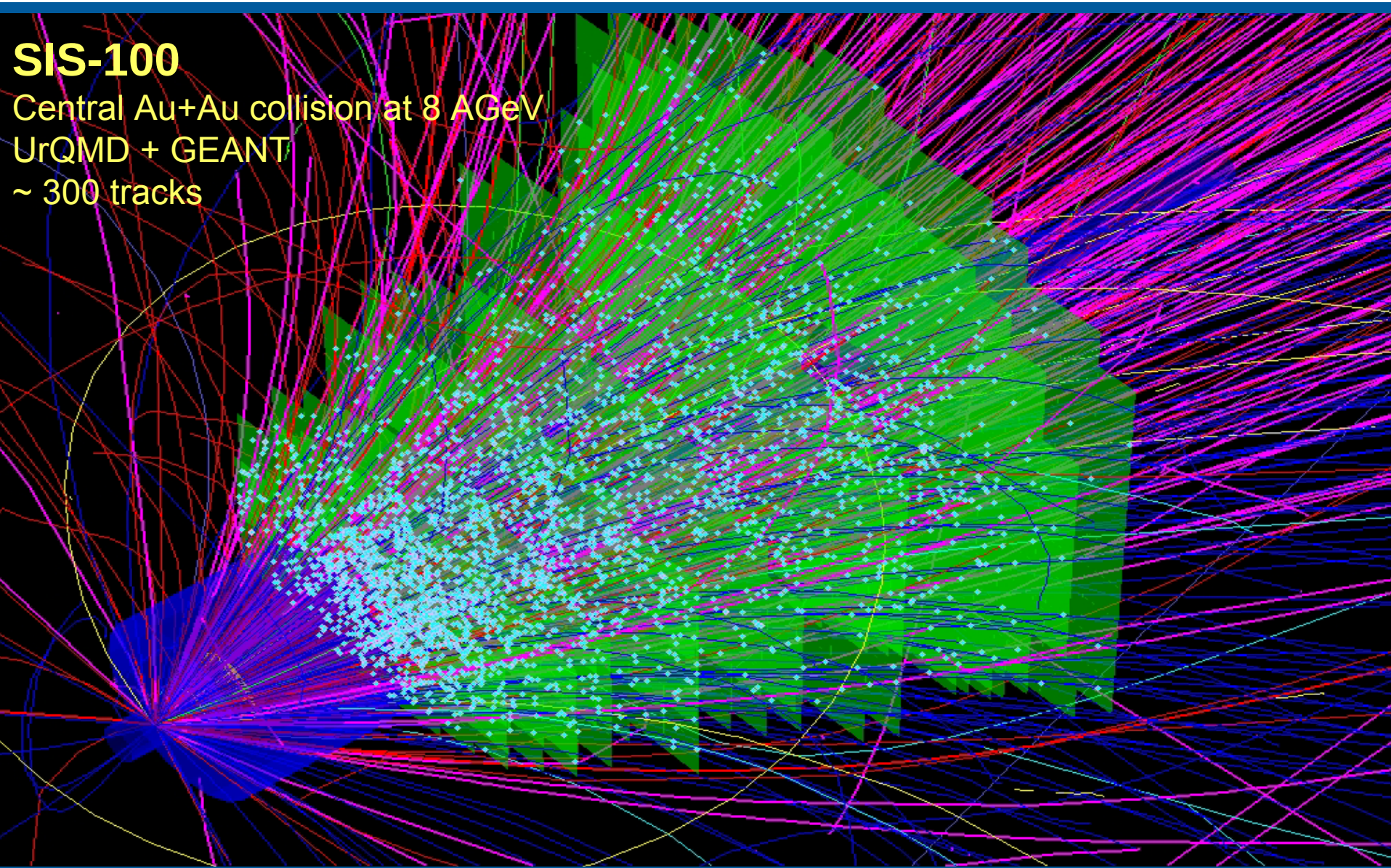
AA collisions at SIS-300 energies



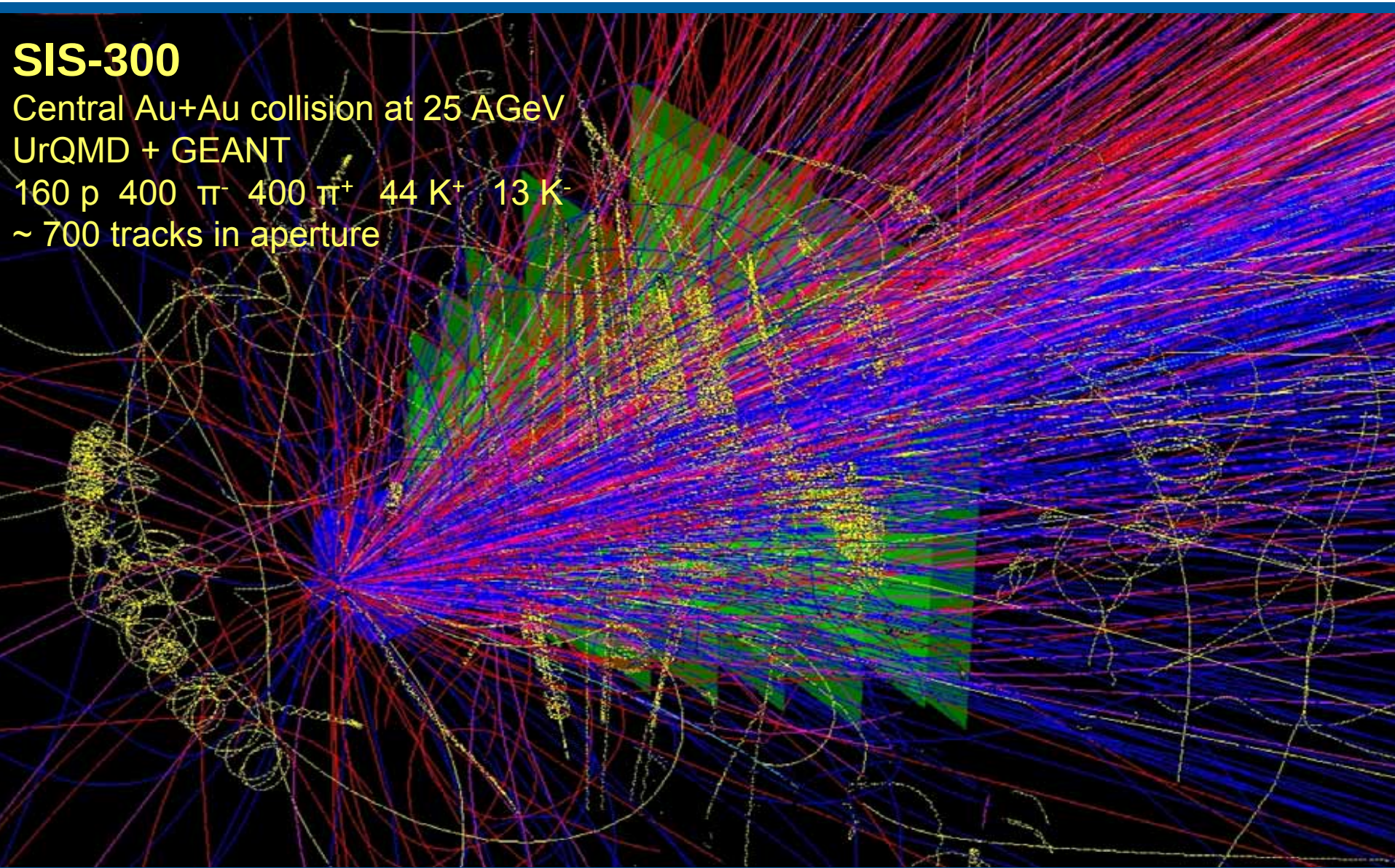
Experimental challenges



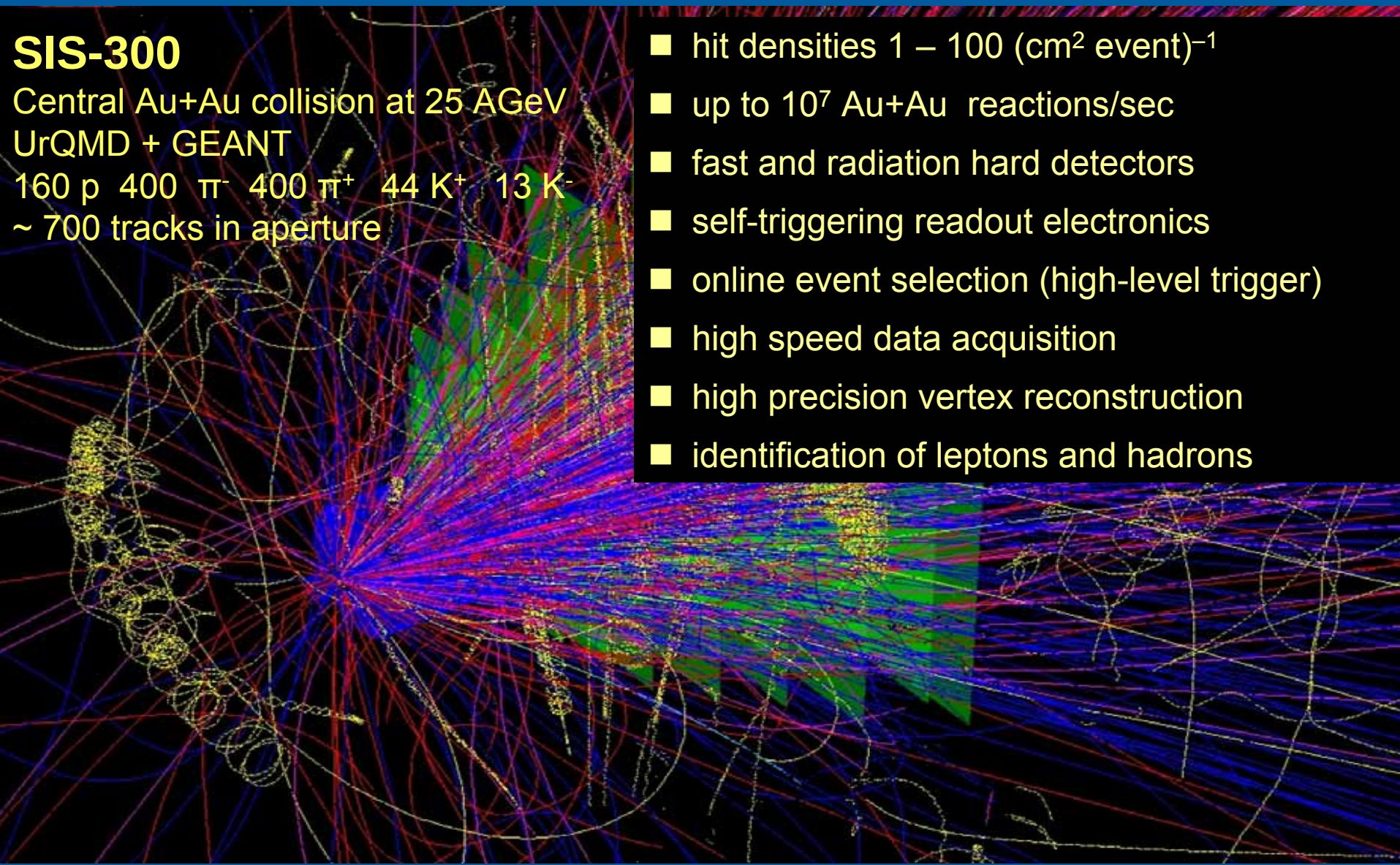
Experimental challenges



Experimental challenges



Experimental challenges

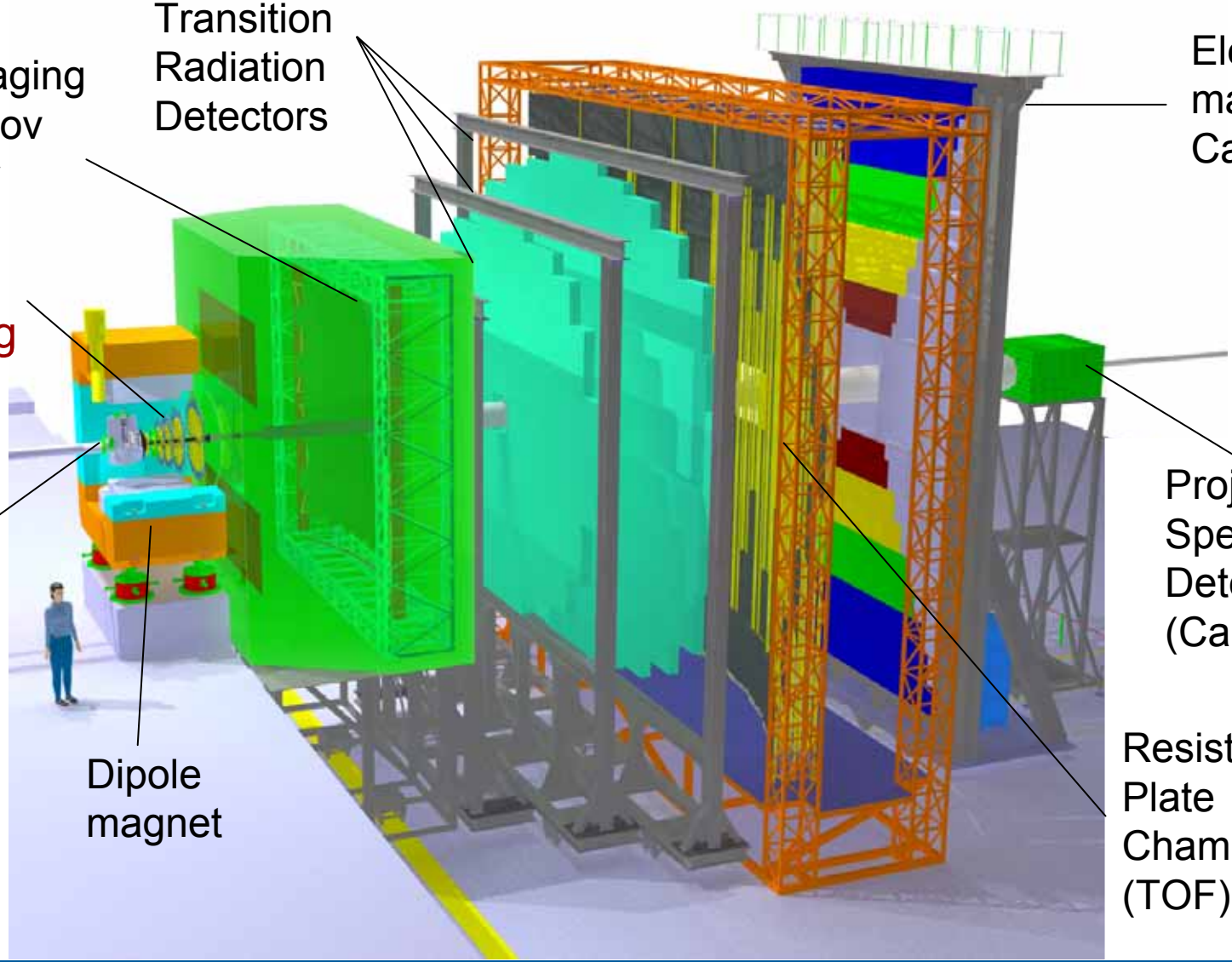


SIS-300

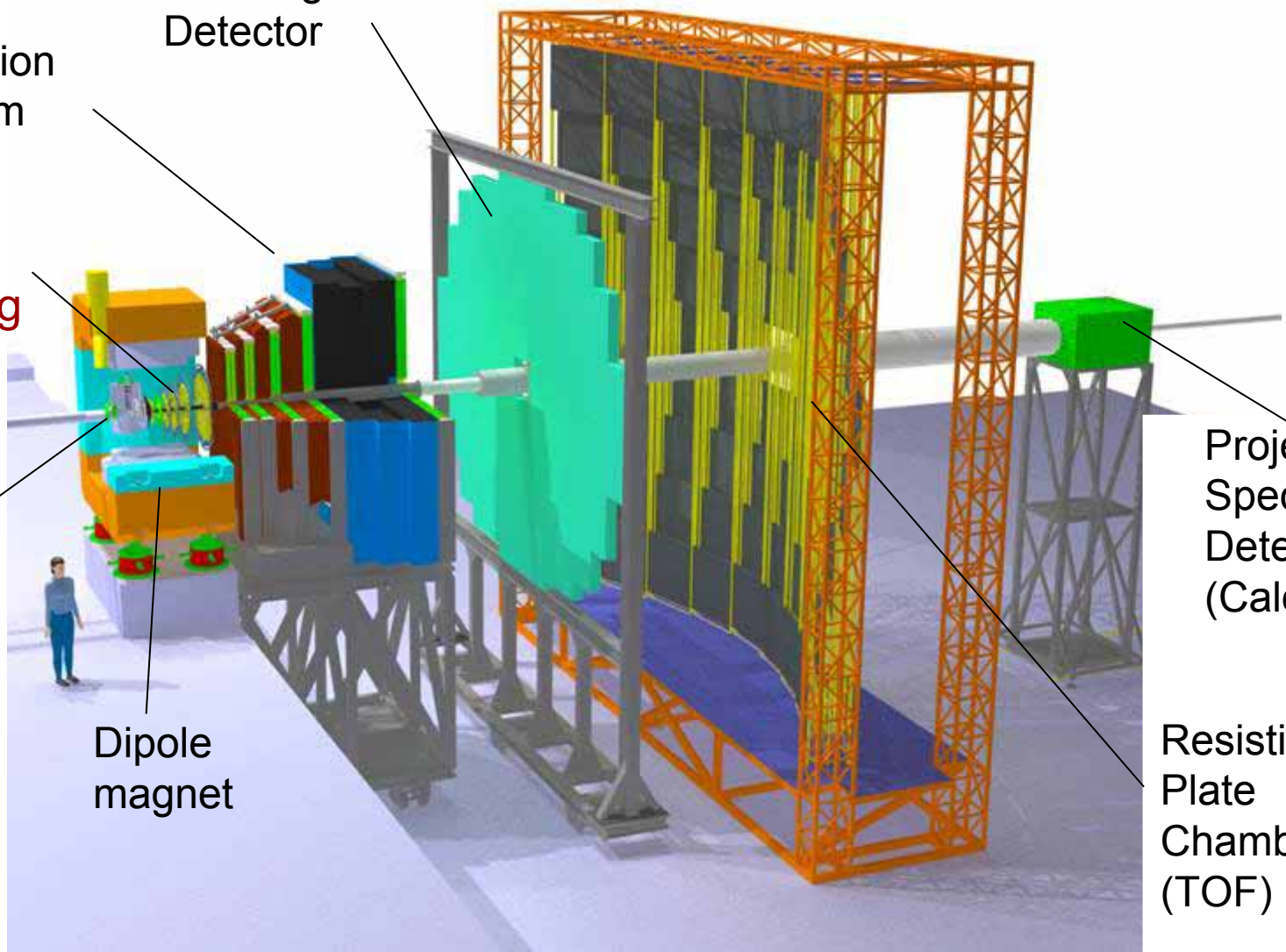
Central Au+Au collision at 25 AGeV
UrQMD + GEANT
160 p 400 π^- 400 π^+ 44 K^+ 13 K^-
~ 700 tracks in aperture

- hit densities 1 – 100 $(cm^2\ event)^{-1}$
- up to 10^7 Au+Au reactions/sec
- fast and radiation hard detectors
- self-triggering readout electronics
- online event selection (high-level trigger)
- high speed data acquisition
- high precision vertex reconstruction
- identification of leptons and hadrons

The CBM experiment – electron-hadron setup

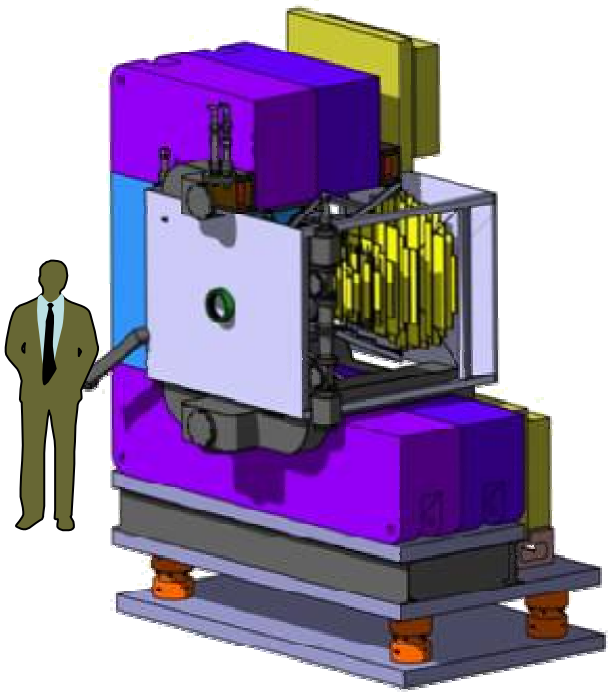


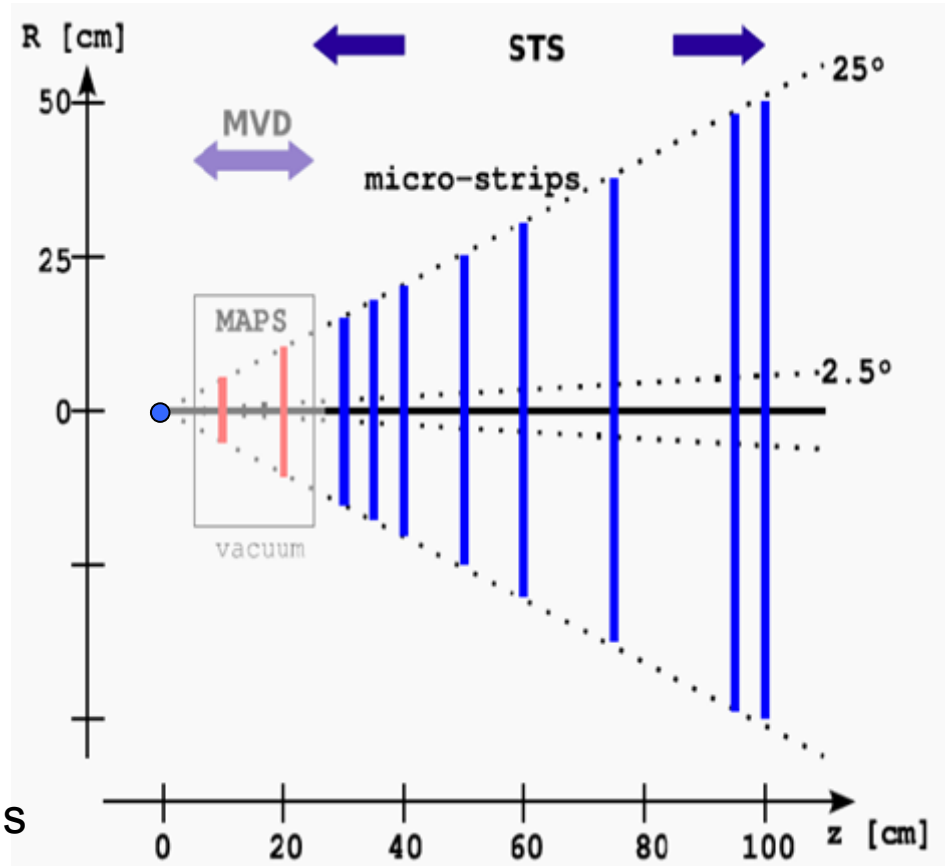
The CBM experiment – muon setup



CBM target region

Silicon Tracking System, Micro Vertex Detector,
Target, Beam pipe, Superconducting Dipole Magnet



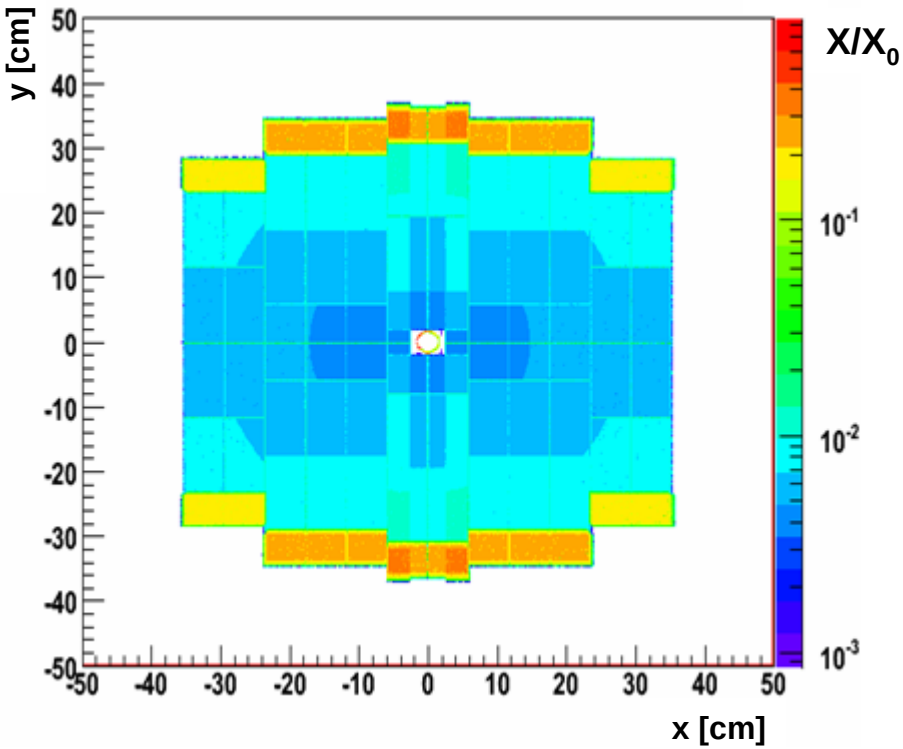


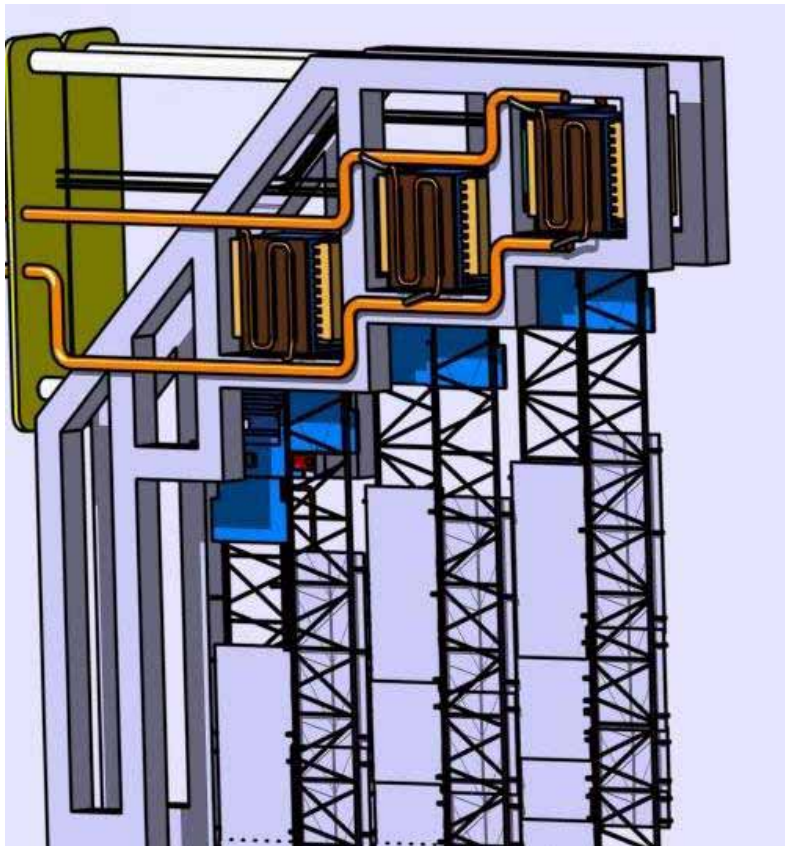
STS:
8 detectors stations
in thermal enclosure

MVD:
2 detectors stations
in vacuum vessel

Silicon Tracking System

R&D challenge: *detector stations with ultra-low material budget*

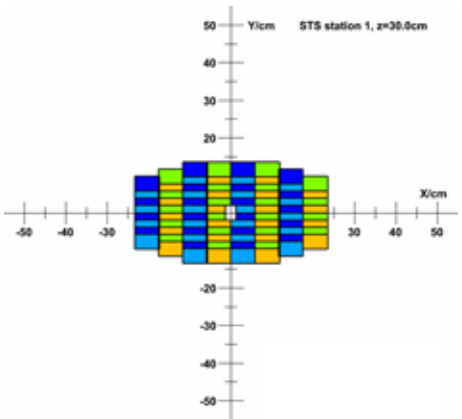


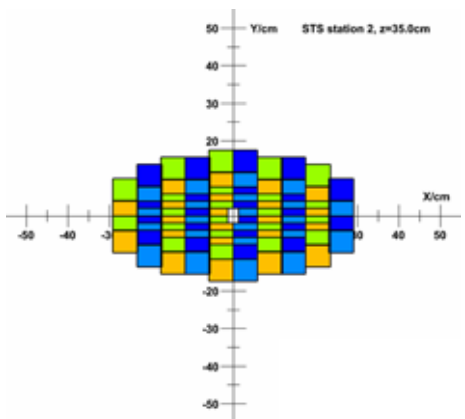


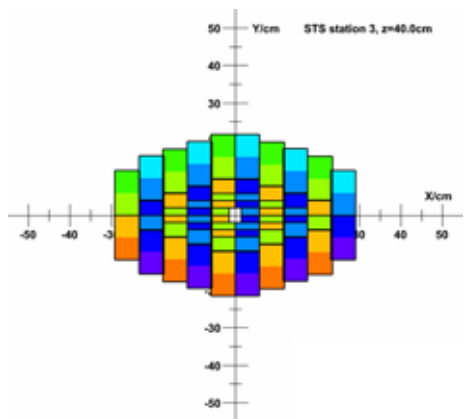
- μ-strip detectors, 300 μm Si: **0.3% X_0**
- station incl. cables and support structure: **≤ 1% X_0**

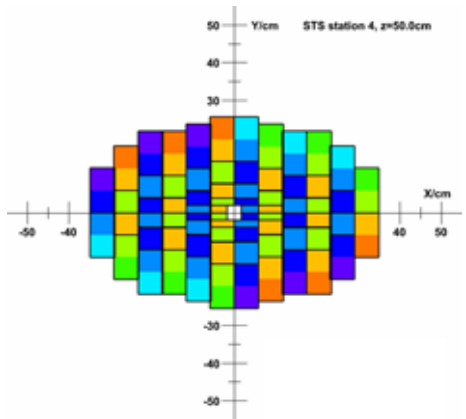
thin carbon enforced ladder structures with peripheral read-out

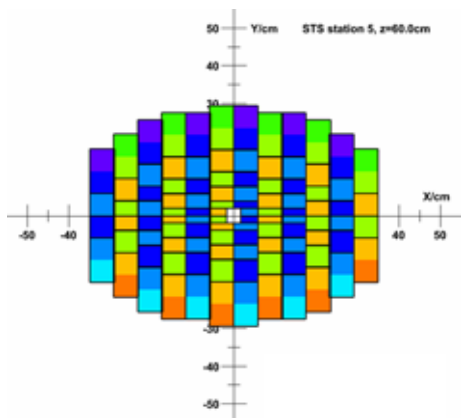
Silicon Tracking Stations

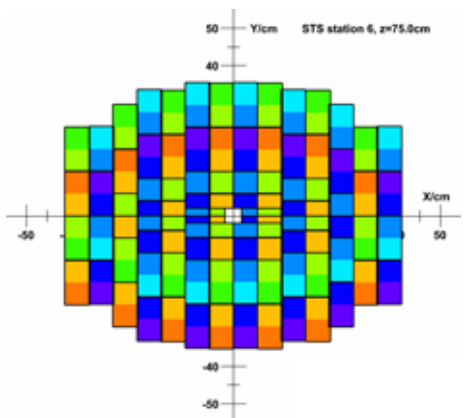


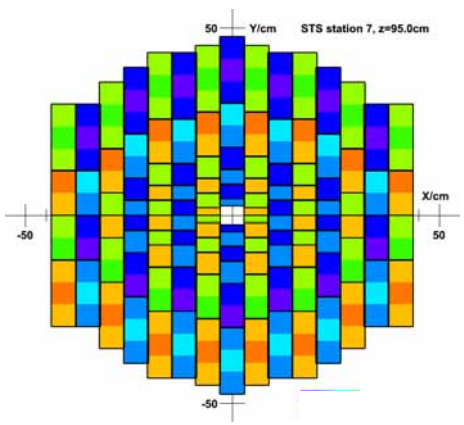


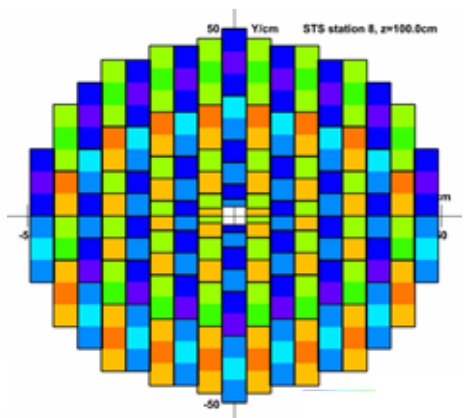




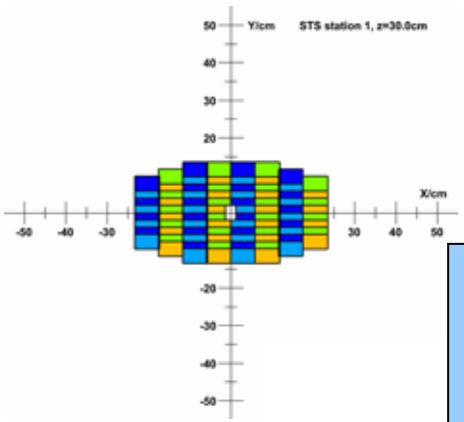


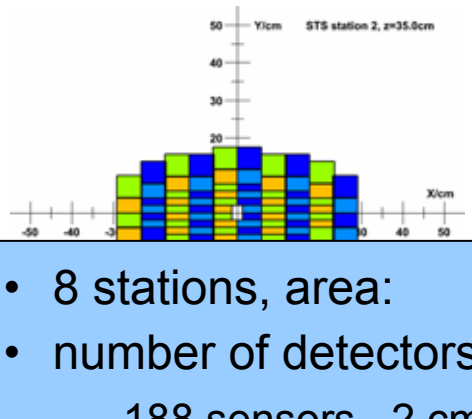


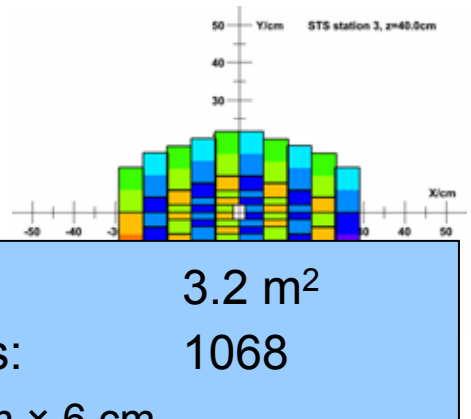


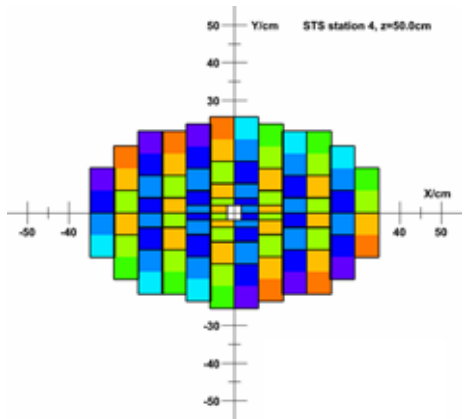


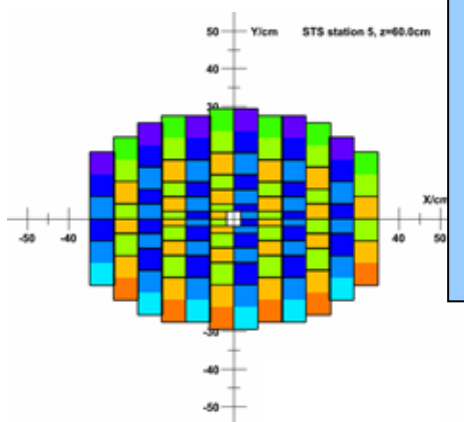
Silicon Tracking Stations

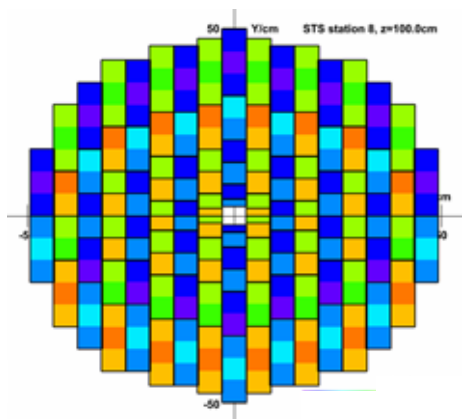






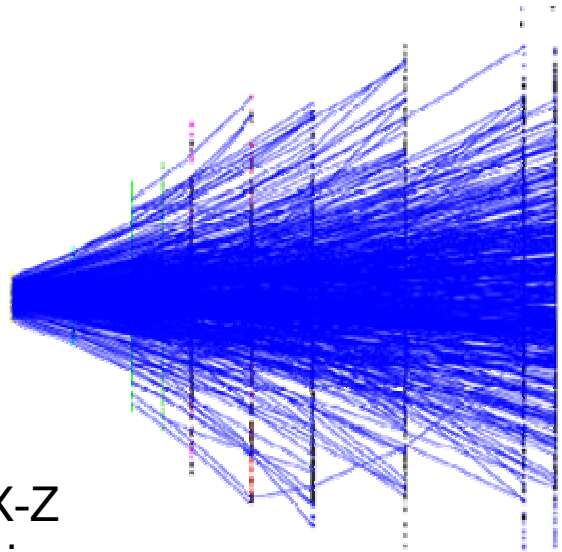






- 8 stations, area: 3.2 m^2
- number of detectors: 1068
  - 188 sensors, 2 cm × 6 cm
  - 166 sensors, 4 cm × 6 cm
  - 714 sensors, 6 cm × 6 cm
- number of modules: 756
- number of super modules: 200
- number of r/o channels: 1.5×10^6
- number of FE chips: 1.2×10^4

Silicon Tracking Performance



X-Z view

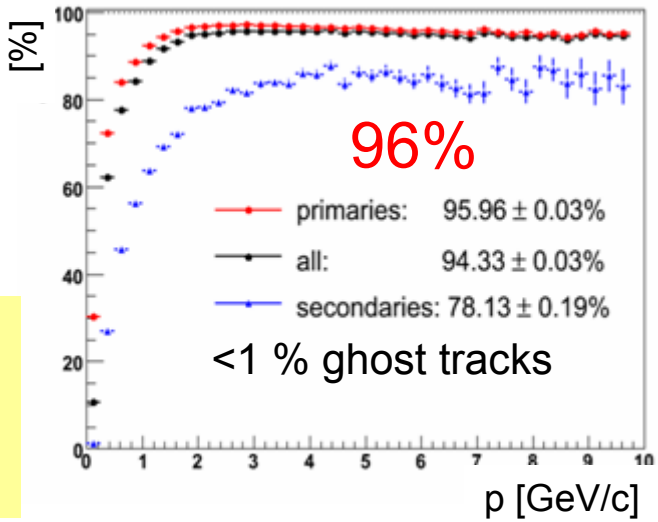
central Au+Au
25 AGeV
(UrQMD)

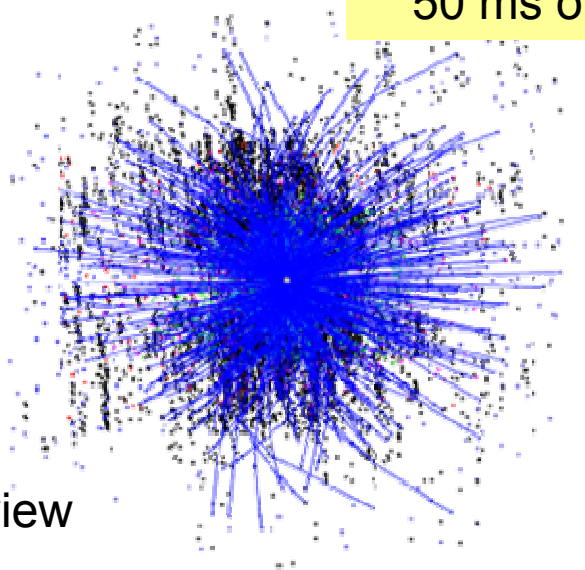
700 reconstructed tracks

Cellular Automaton and Kalman Filter

50 ms on Pentium 4

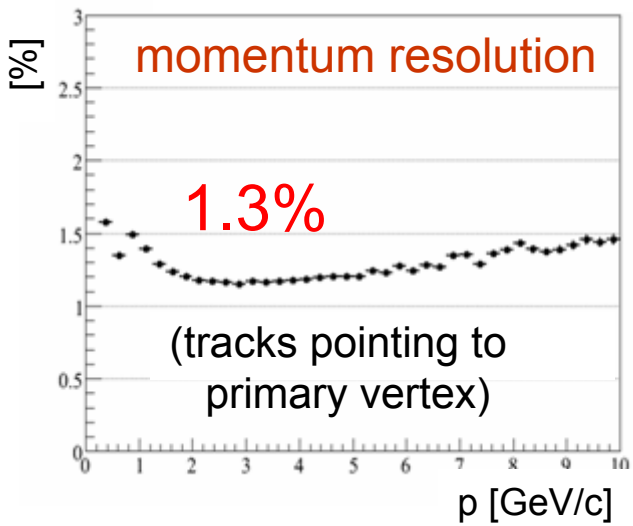
reconstruction efficiency





Y-X view

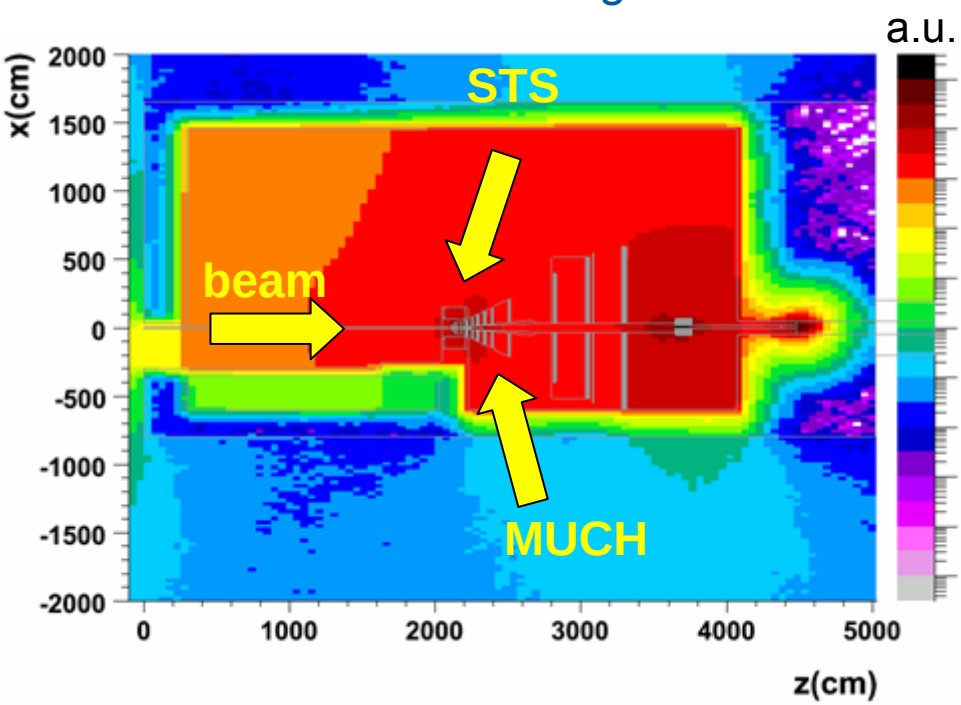
momentum resolution



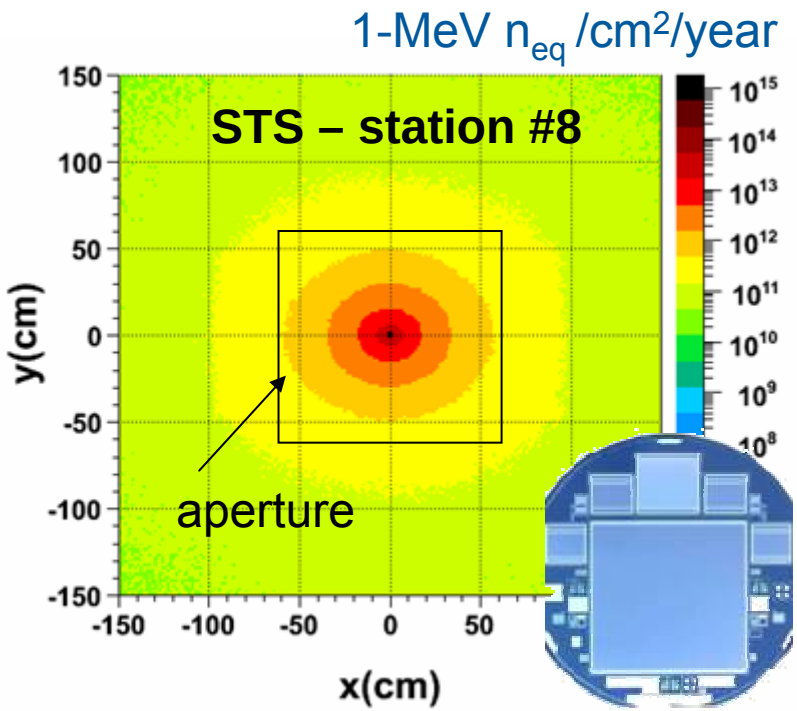
CBM – Radiation environment

Neutron fluence in CBM cave

UrQMD + FLUKA simulation,
25 GeV Au beam on Au target



Neutron fluence through Silicon Tracking System

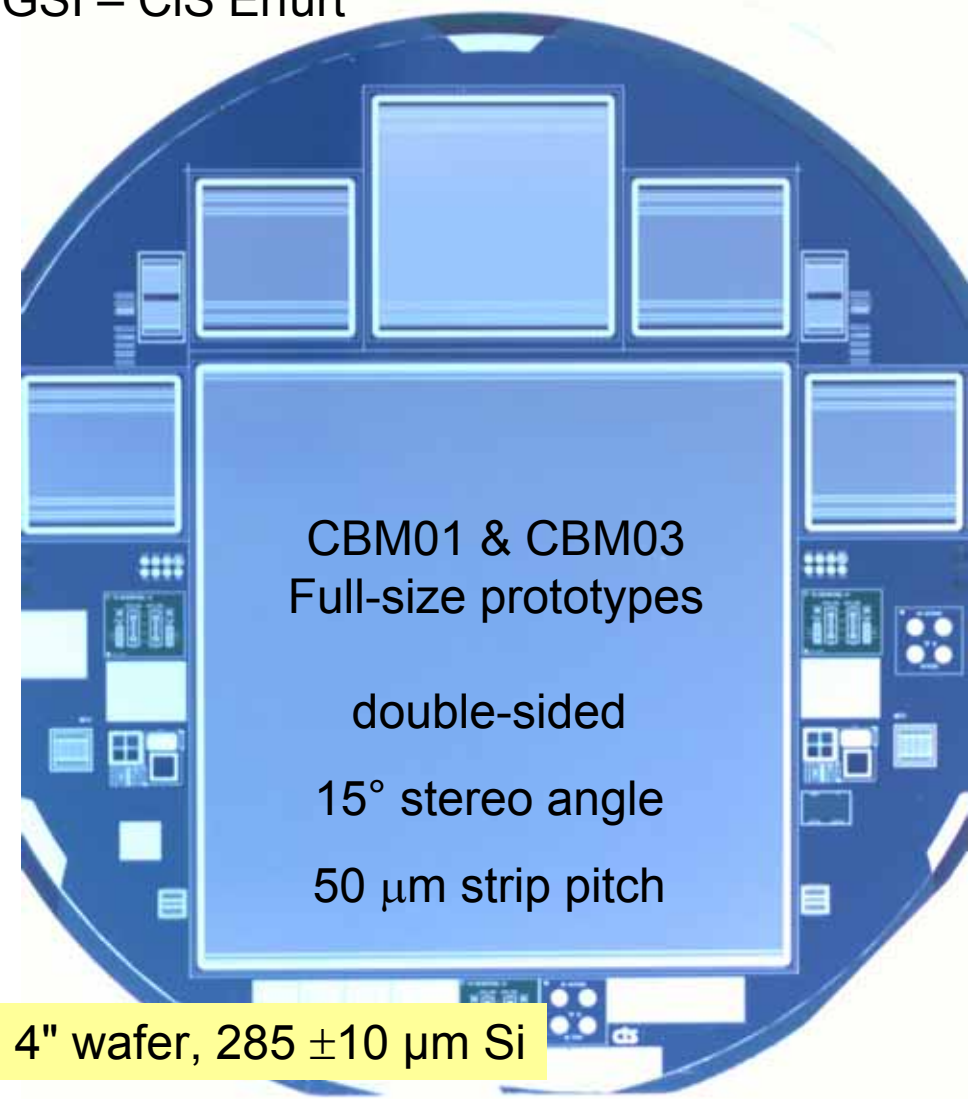


Typical operation scenario: 6 years $\Rightarrow$ 10^{13} - 10^{15} n_{eq}/cm²

$\Rightarrow$ radiation hardness regime of LHC experiments

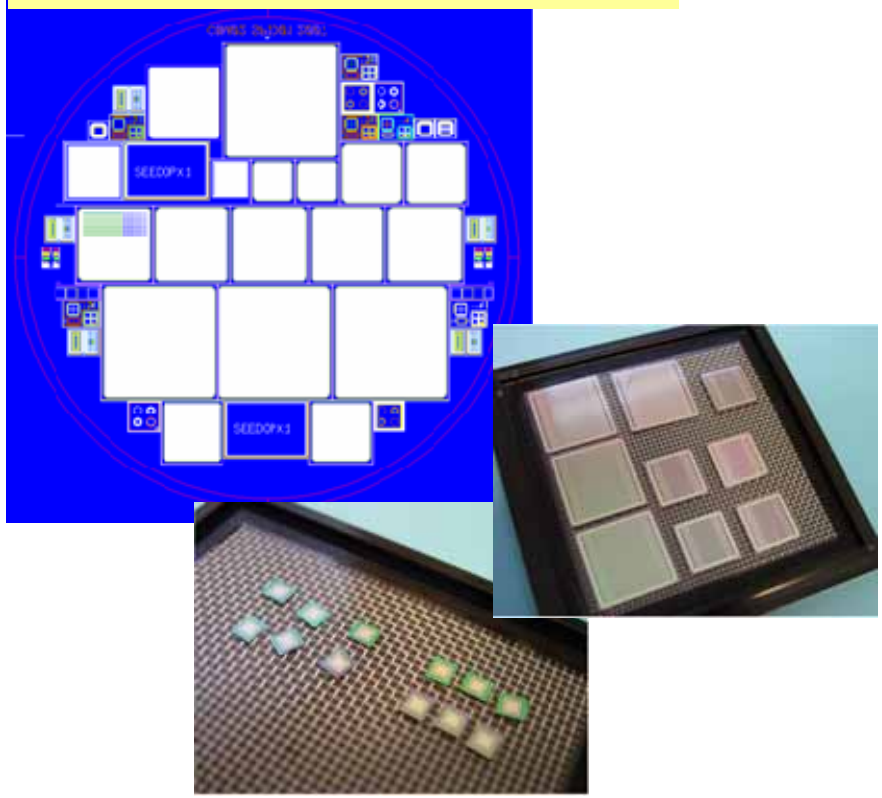
Development of Silicon Microstrip Sensors

GSI – CiS Erfurt



4" wafer, 285 ±10 µm Si

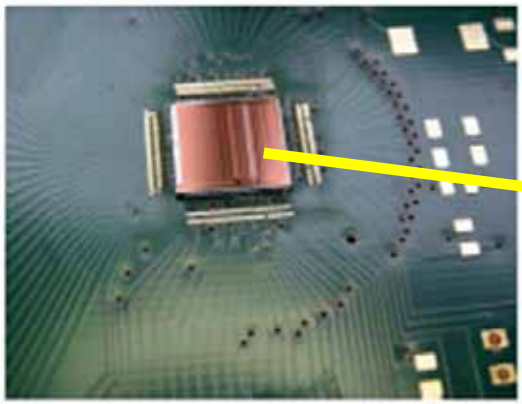
CBM02 & CBM04 –
double-sided prototypes with
radiation tolerant design



- irradiation experiments
- device and process simulations

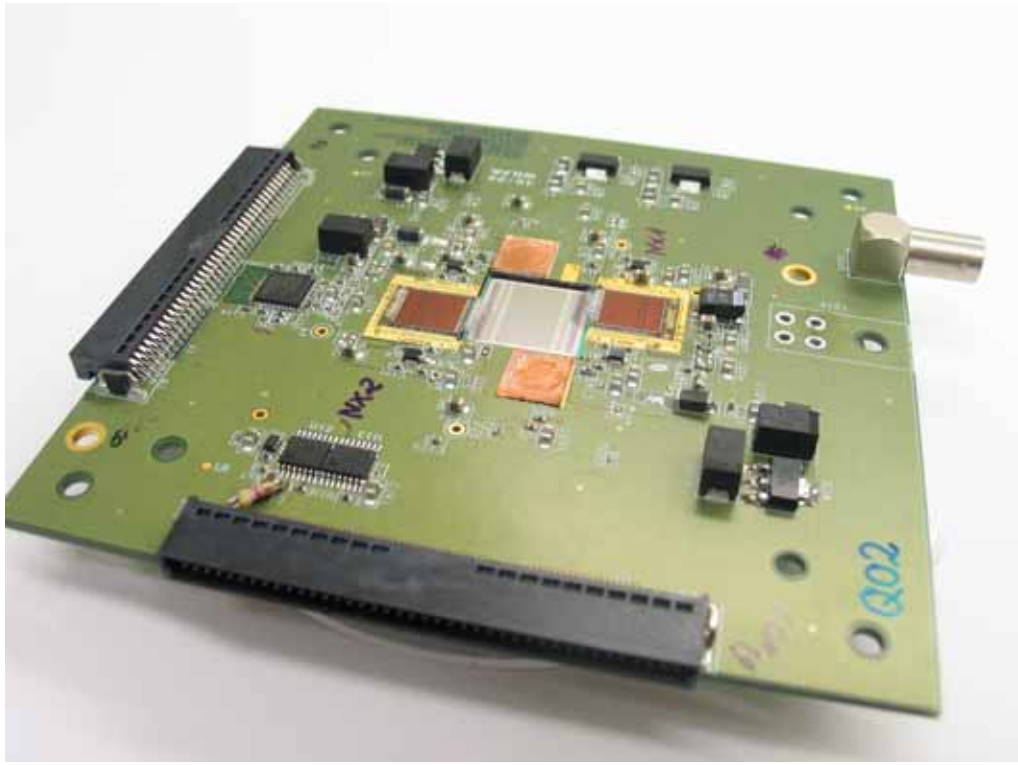
Readout Electronics & Front-end boards

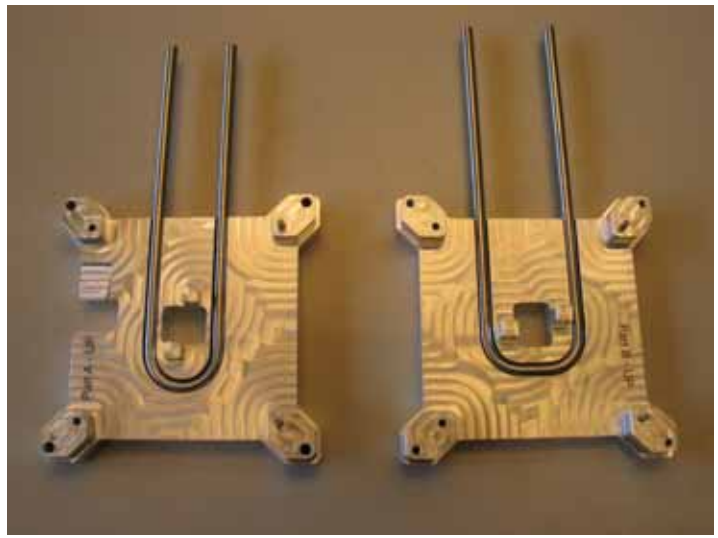
based on self-triggering n-XYTER chip (EU-FP6 project *DETNI*)

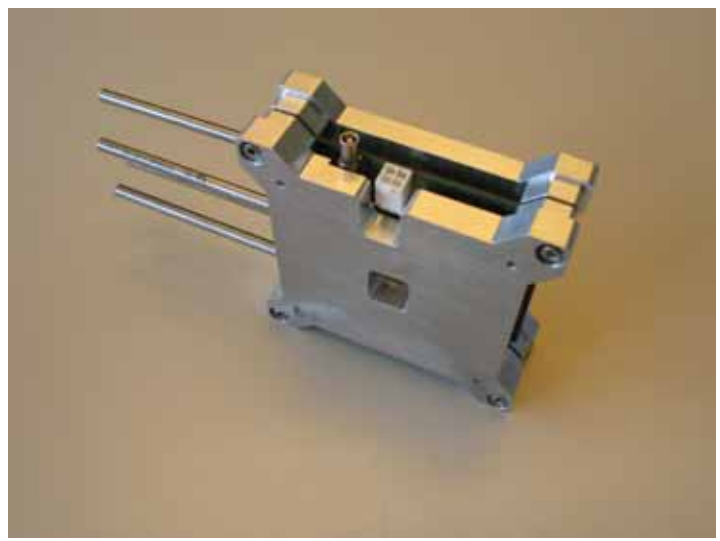


CBM-STS XYTER chip under development

STS reference tracking station



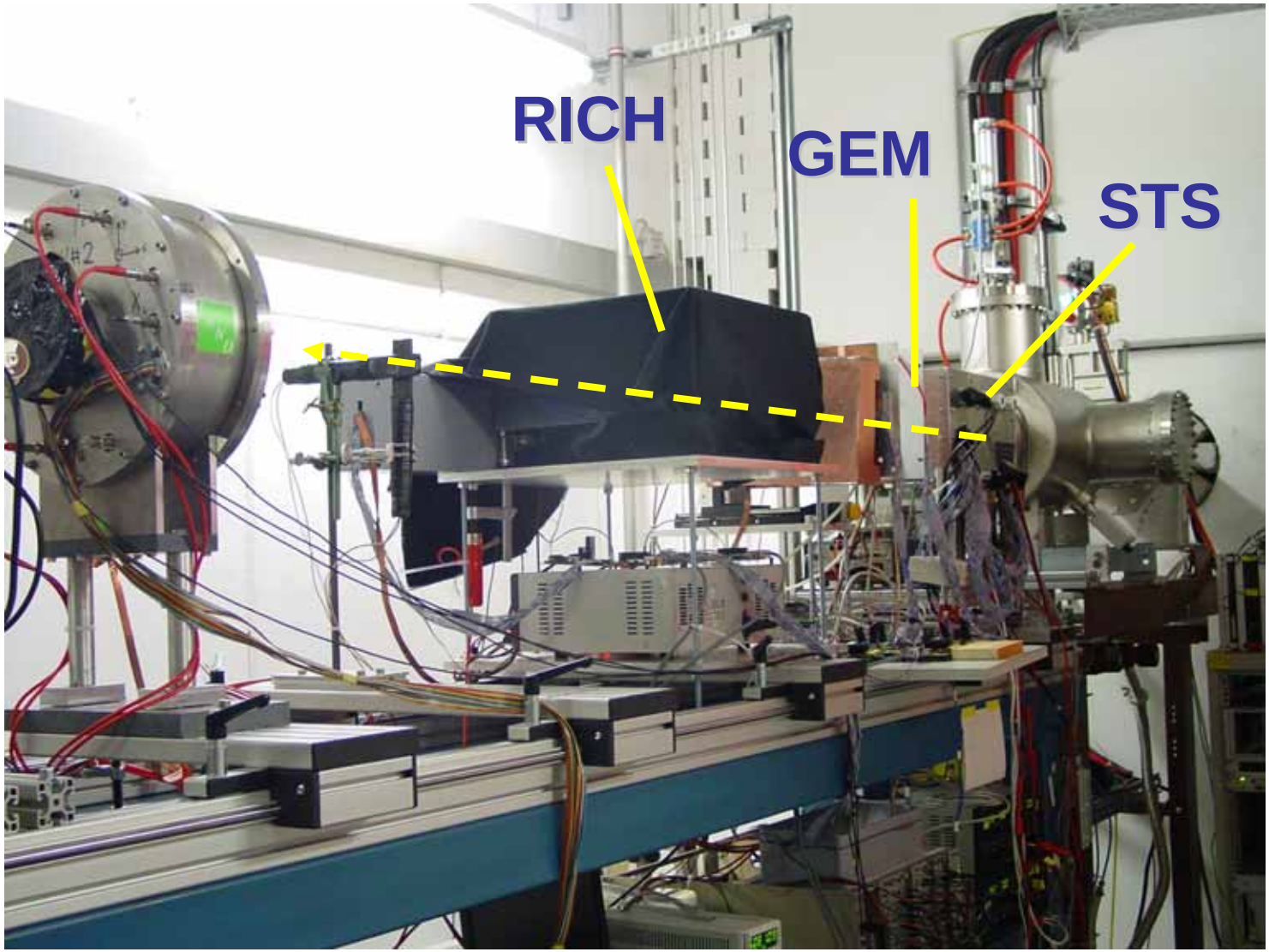




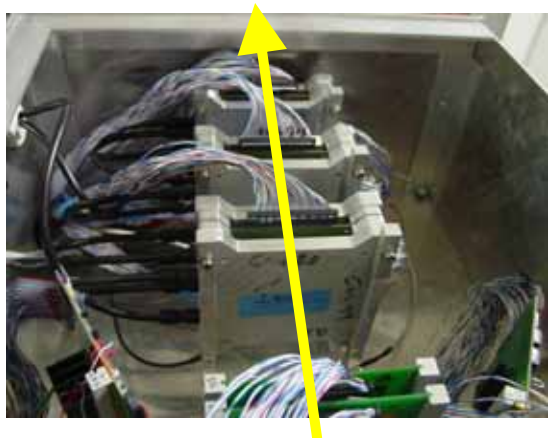
- double-sided CBM test detector
- 2 × 256 orthogonal strips of 50 μm pitch
- 4 n-XYTER chips

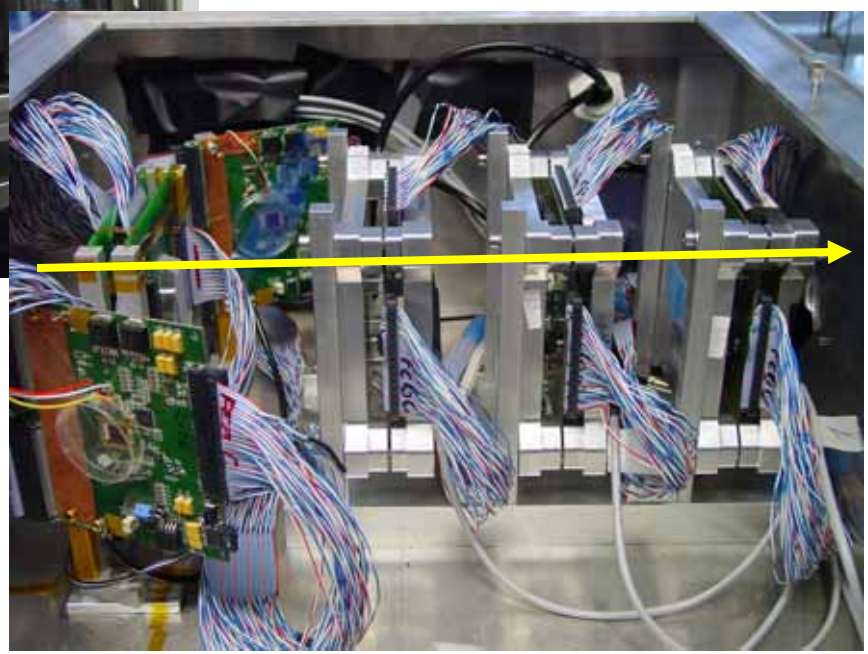
CBM-GSI detector lab

Beam test 9/2009 at GSI with 2 GeV proton beam

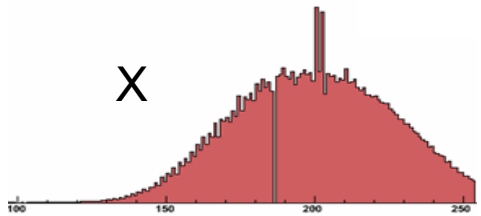


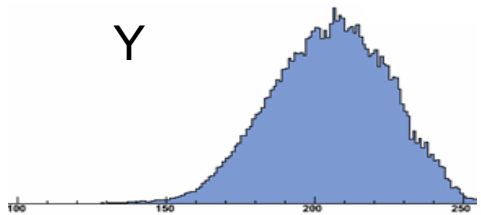
Beam test 9/2009 at GSI with 2 GeV proton beam

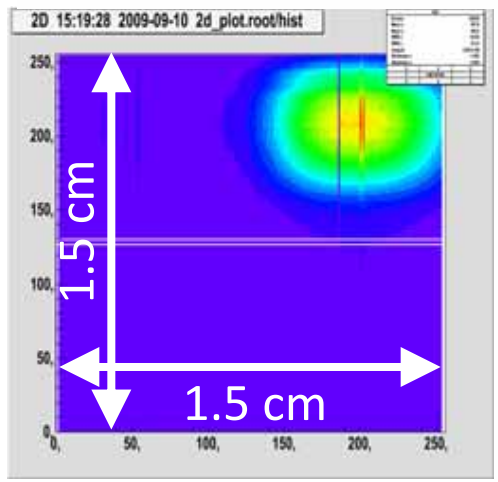




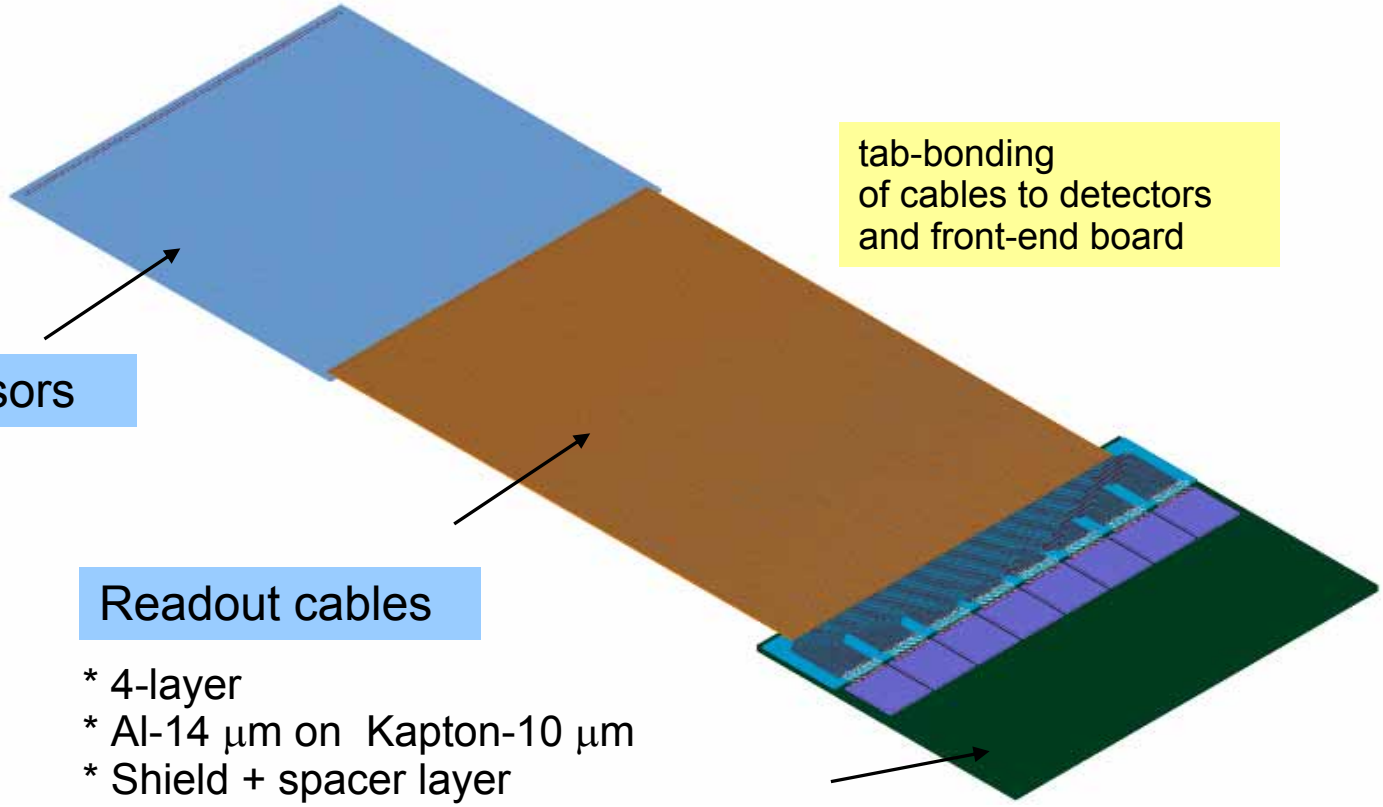
beam spot in STS







Development of tracking modules



tab-bonding
of cables to detectors
and front-end board

Microstrip sensors

double sided,
CBM01/CBM03

Readout cables

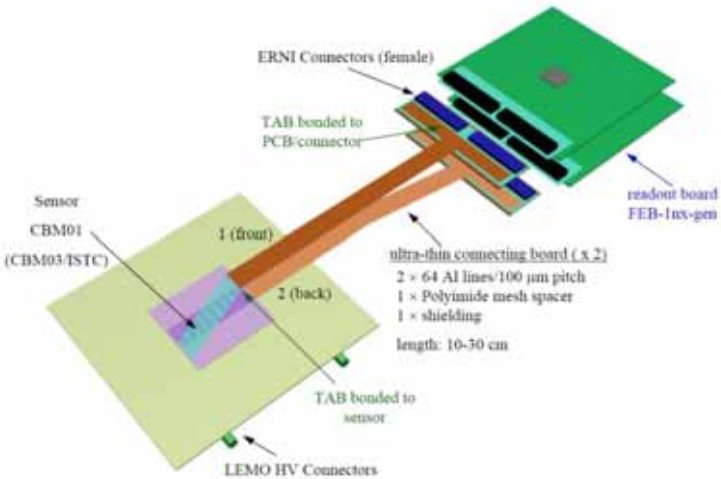
* 4-layer
* Al-14 μm on Kapton-10 μm
* Shield + spacer layer
* 1024 lines, 100-120 μm pitch
* up to 60 cm long

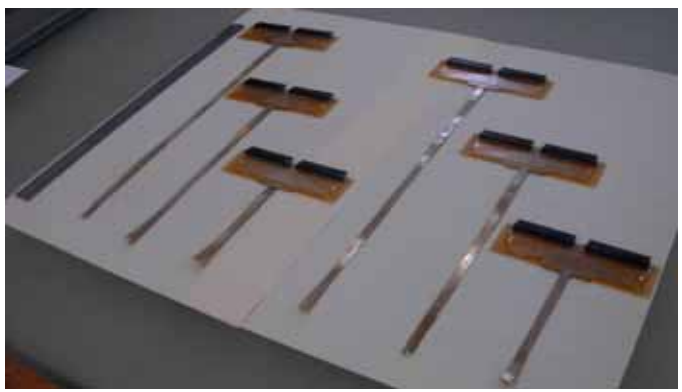
Front-end board

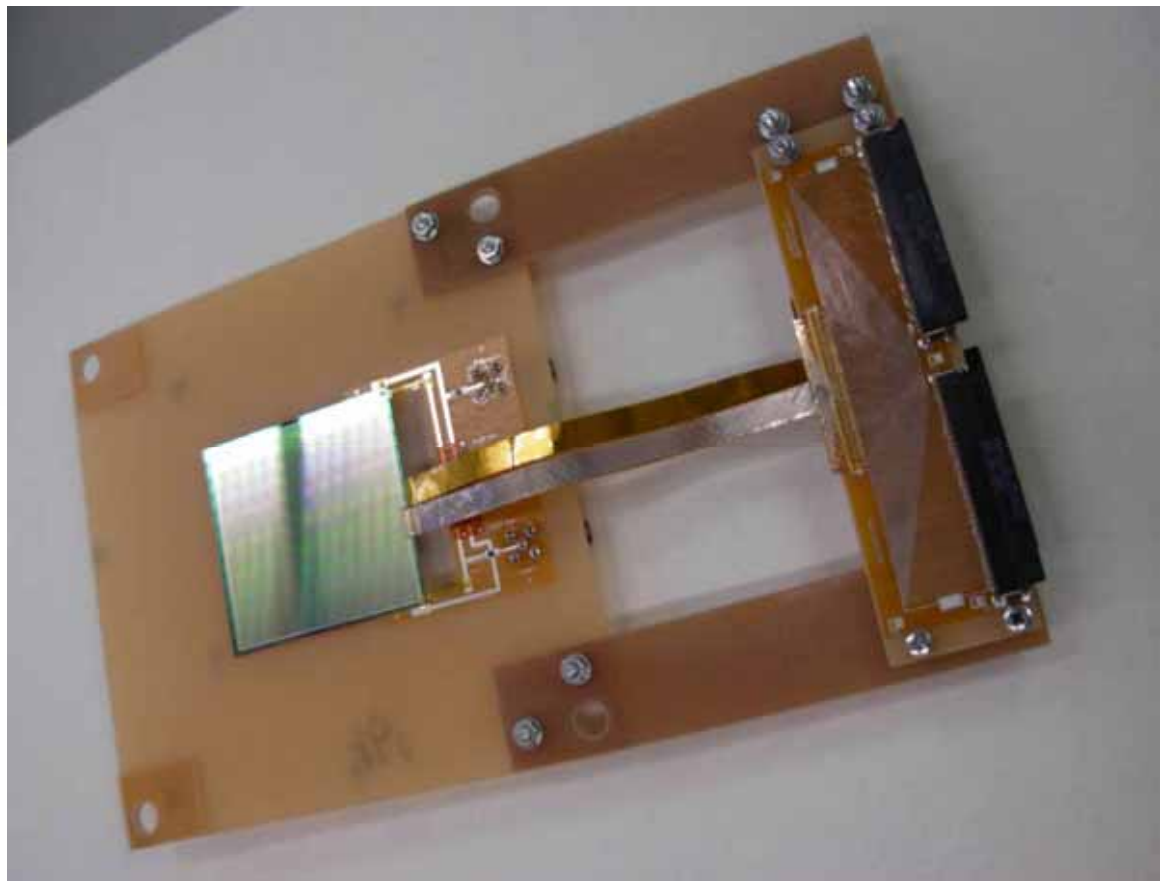
bump-bonded low-power FE
chip on a high-density circuit

Module demonstrator # 1

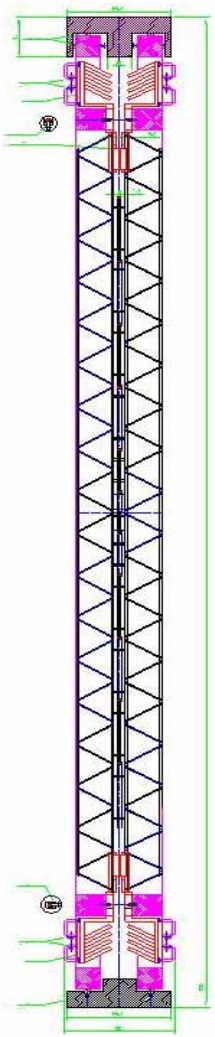
CBM-MPD STS Consortium



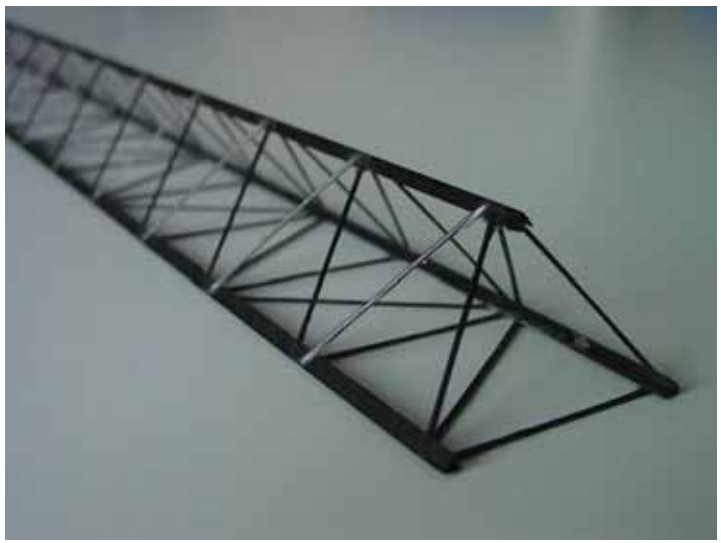




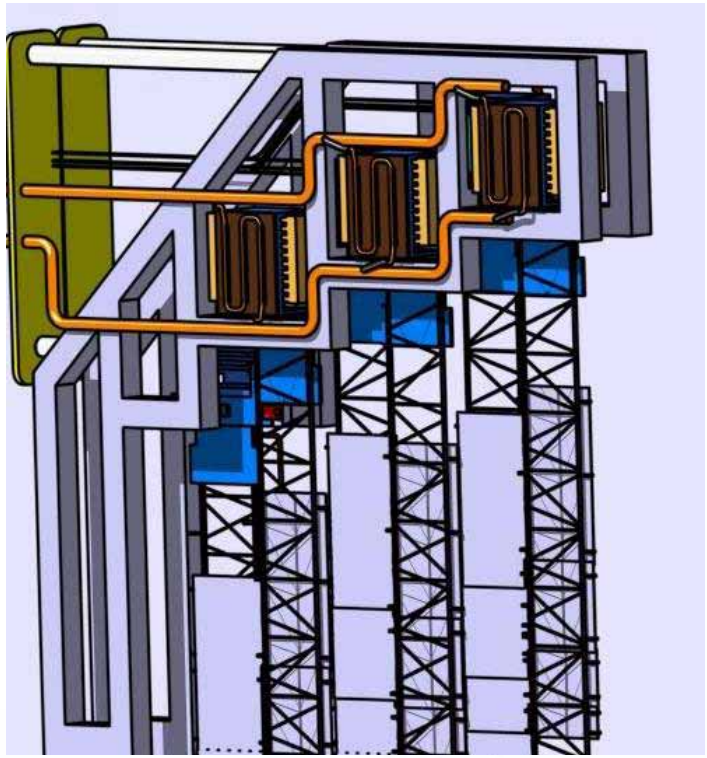
Silicon Tracking System – mechanical support



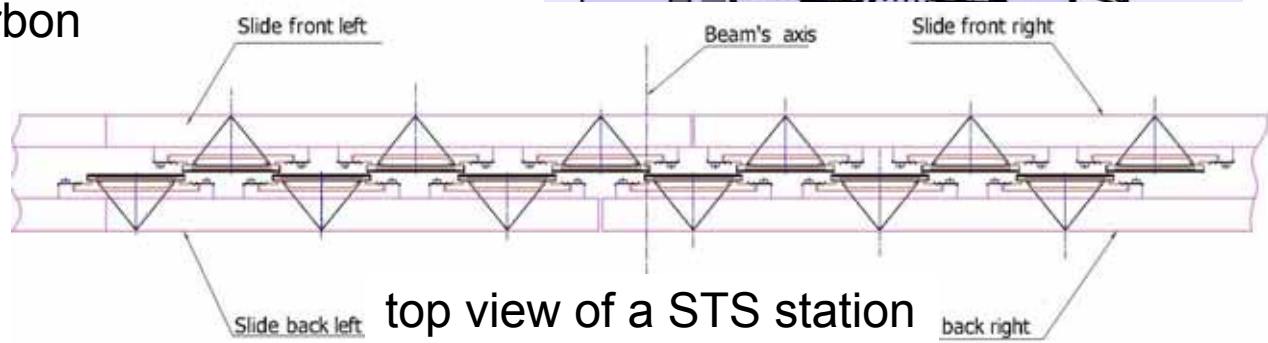
Building on technology developed for the ALICE Strip Tracker



ALICE ITS carbon fiber structure



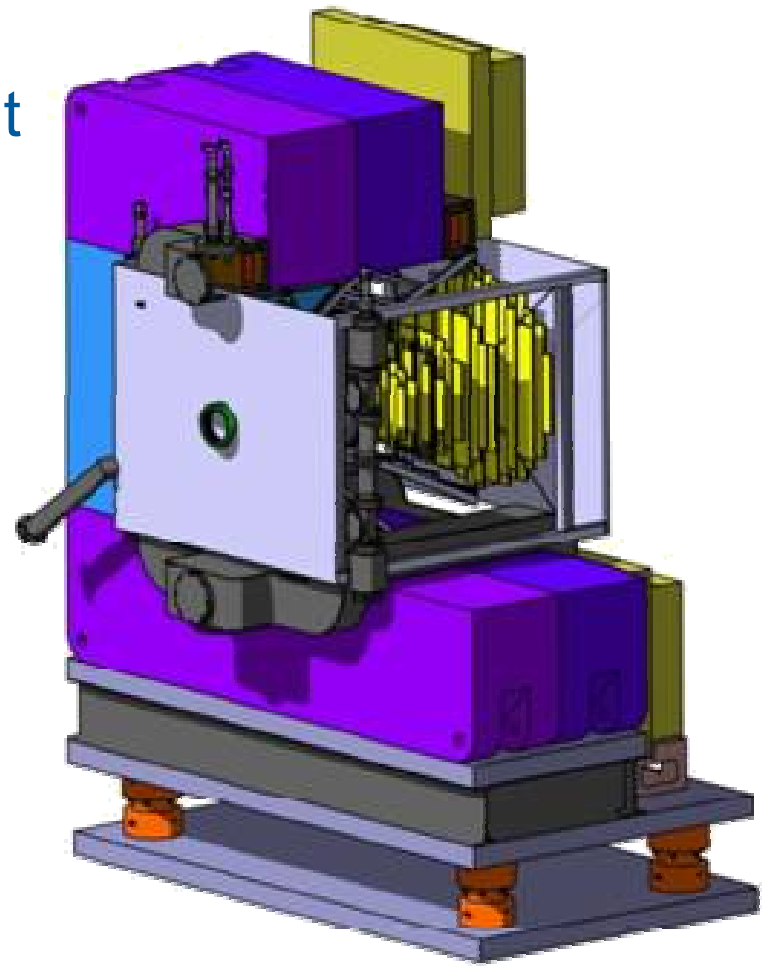
CBM-STS module



top view of a STS station

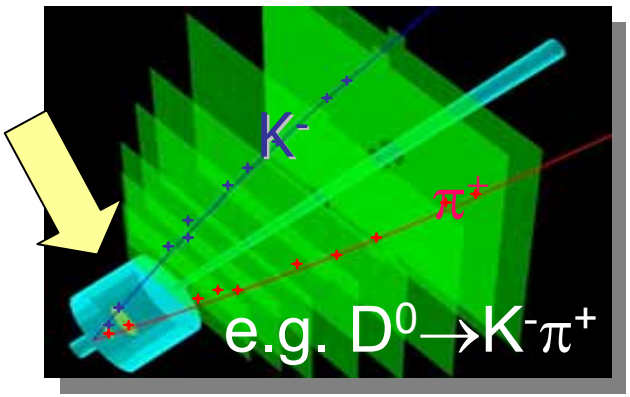
Summary on Silicon Tracking System

- STS = central CBM detector system
- Tracking + momentum measurement
- Challenges:
  high-speed, low-mass system,
  radiation hard Si detectors
- Detailed conceptual studies
- Detector R&D has started
  - microstrip sensors
  - r/o electronics
  - modular detector structures
  - system engineering



Micro Vertex Detector

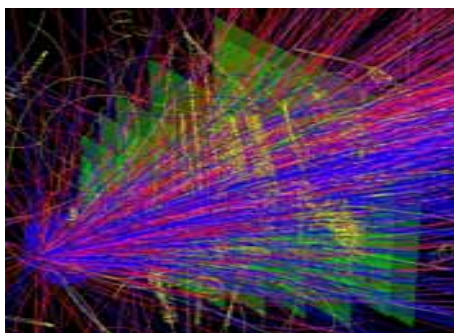
R&D challenge: *novel ultra-thin system of MAPS-CMOS detectors*



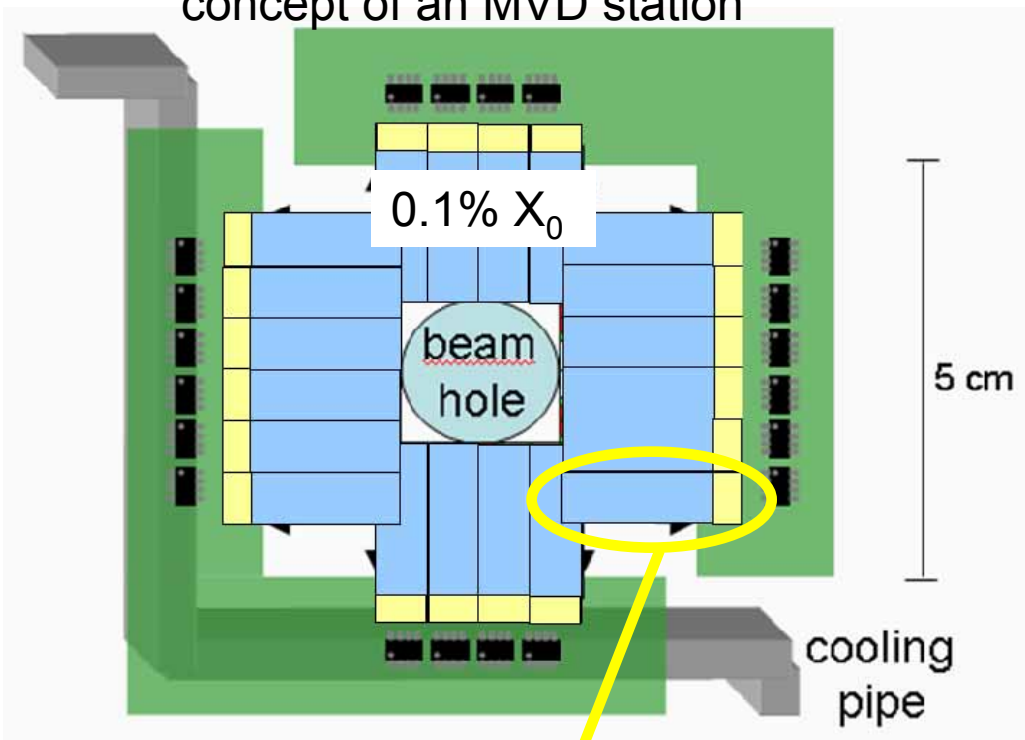
decay vertex detection

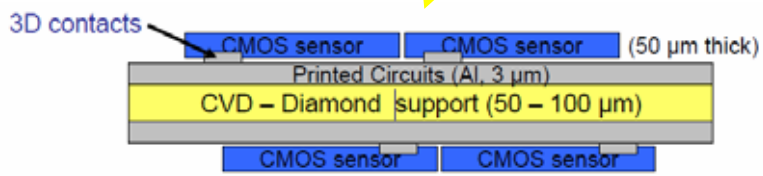
"open charm"
$c\tau \approx 100\mu m$

in high-multiplicity events

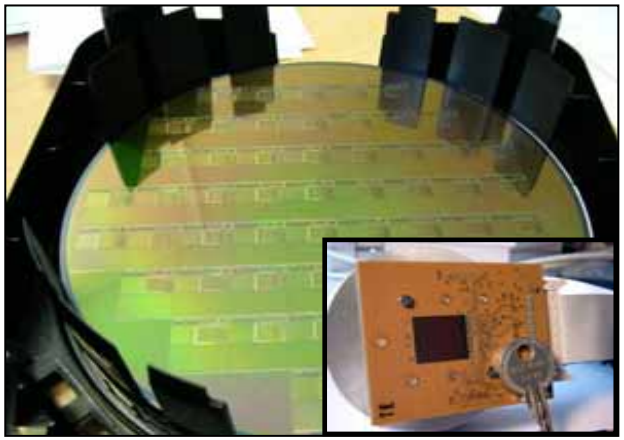


concept of an MVD station





Monolithic Active Pixel Sensors

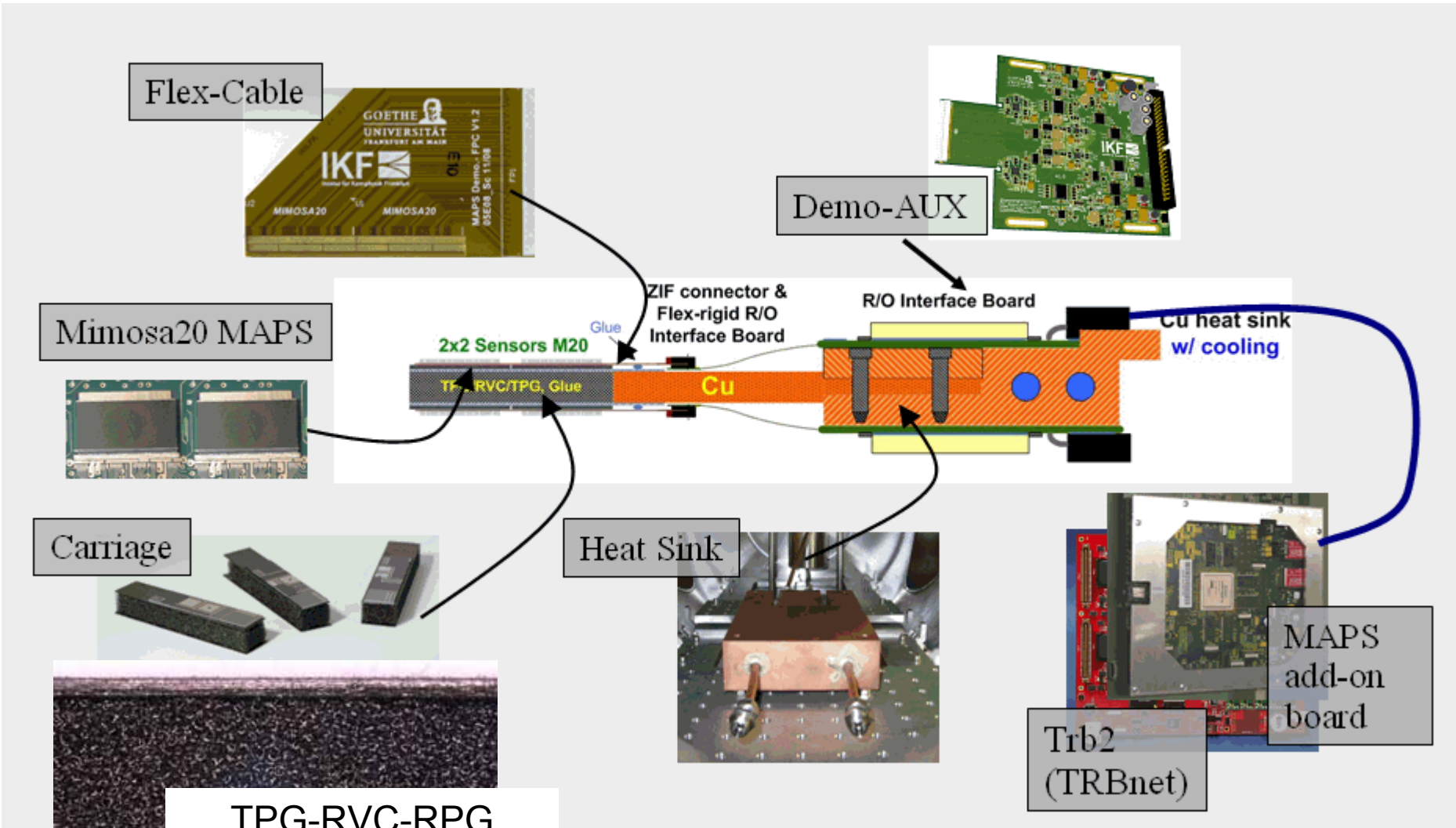


(MAPS, also CMOS-Sensors)

- Invented by industry (digital camera)
- Modified for charged particle detection since 1999 by IPHC Strasbourg
- Also foreseen for ILC, STAR …

Topic	CBM wish list	MAPS (2003)	MAPS (2009)
Single point resolution	~ 5µm	1.5µm	~ 1 µm
Material budget	few 0.1% X_0	~ 0.1% X_0	~ 0.05% X_0
Rad. hard. non-ionizing	>10^{13} n_{eq}/cm^2	~10^{12} n_{eq}/cm^2	> 3x10^{13} n_{eq}/cm^2
Rad. hard. ionizing	> 3 Mrad	200 kRad	> 1 MRad
Time resolution	< 30 µs	~ 1 ms	~ 50 µs

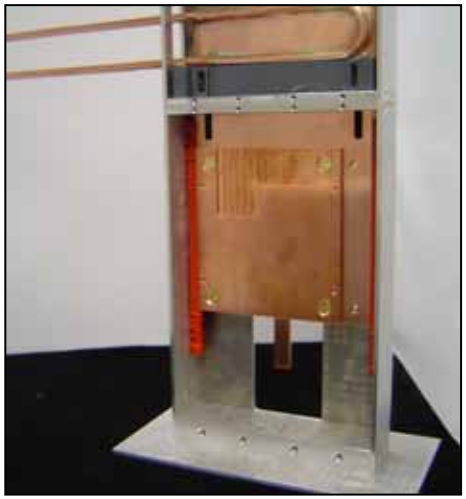
MVD demonstrator



TPG-RVC-RPG
0.46% X_0, d=6.6mm

IKF Univ. Frankfurt, synergy with HADES experiment

The MVD-demonstrator, Beam-test at CERN 11/2009



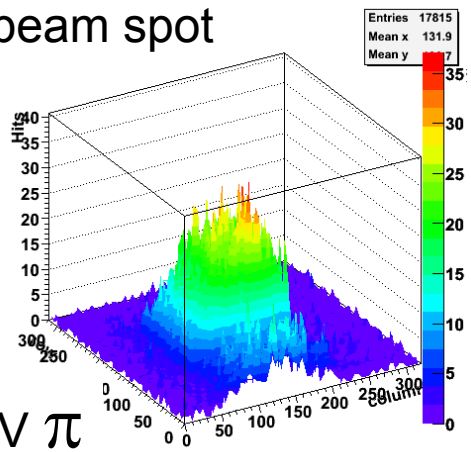
MVD demonstrator module

+

TAPI-Teleskop (IPHC)

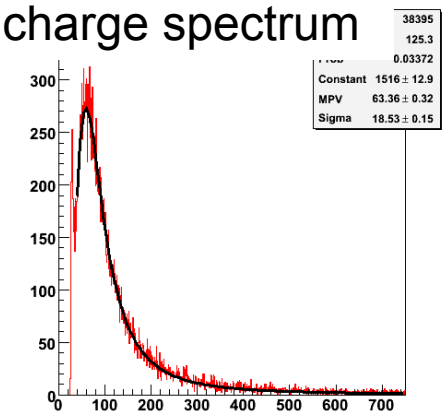
4 x MIMOSA-20
- 4 x 640 x 320 pixel
- 30 x 30 µm² pixel
- Serial analog readout
- Vacuum compatible cooling

beam spot



120 GeV π

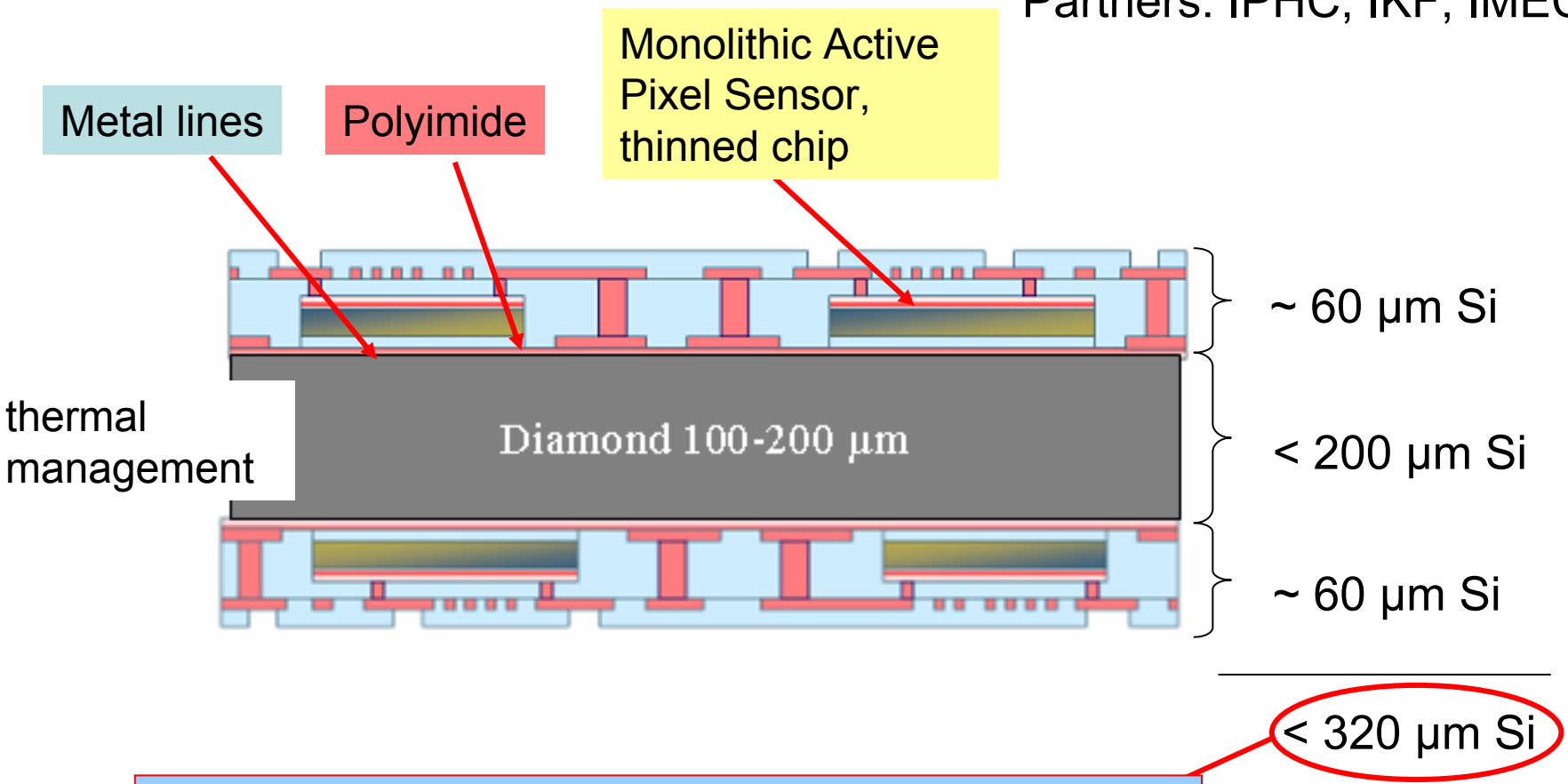
charge spectrum



some on-line results

Development of an ultra-thin ladder

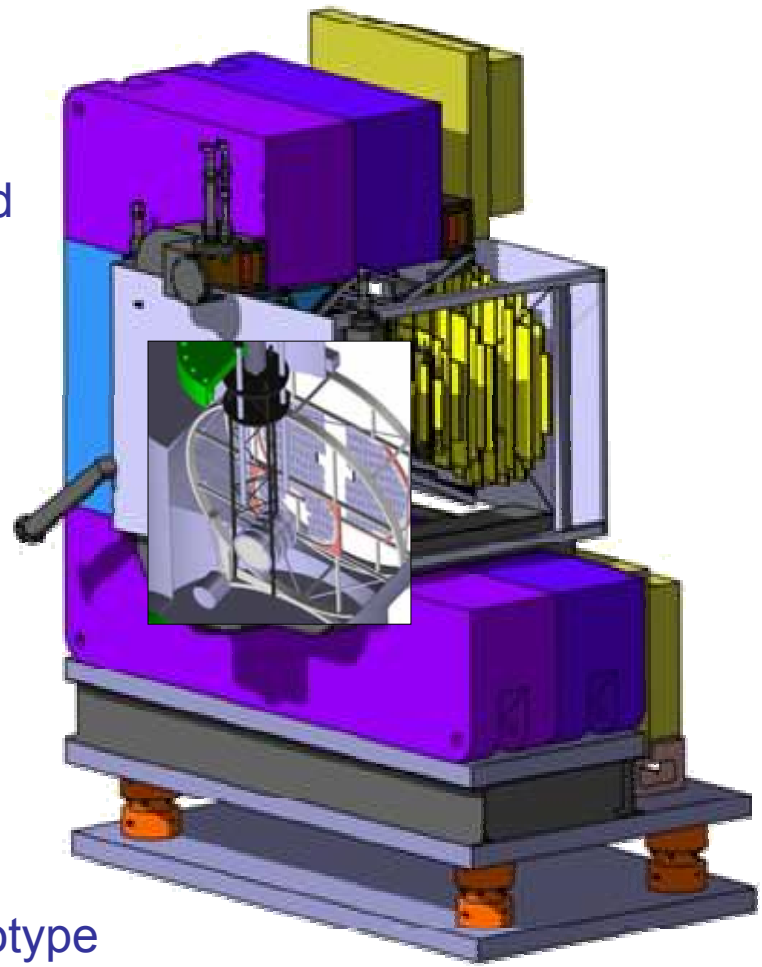
HP-2 Project - WP26 (ULISI)
Partners: IPHC, IKF, IMEC



Factor 4-5 thinner than conventional solution

Summary on Micro Vertex Detector

- The tool for "open charm" detection
- Challenges:
  - Radiation hardness: > 10^{13} n_{eq}/cm² + 3 Mrad
  - Frame readout time: < 40 µs
  - Material budget: ultra thin, few 0.1% X_0
  - Spatial resolution: < 5 µm
  - Vacuum compatible cooling of ~ 1W/cm²
- Current choice of technology:
  - Monolithic Active Pixel Sensors (by IPHC): R&D towards CBM chip *MIMOSIS*
- Status:
  - Demonstrator accomplished, aiming for prototype
  - System engineering together with STS



Networking

http://ulisi-wiki.gsi.de/

Joint Research Activity ULISI:

Ultra-light silicon tracking and vertex detection systems for frontier precision experiments

Spokesperson: J. Heuser, GSI

1. An innovative thin microstrip tracking detector system for large-area coverage
2. A thin fast hybrid pixel detector system for tracking in high particle densities
3. An ultra-thin monolithic pixel detector system for decay vertex identification

Participants: FAIR (CBM, PANDA), ILC communities

GSI, INFN Torino, FZJ Jülich, Univ. Bonn, Univ. Frankfurt, IPHC Strasbourg, IMEC Leuven, KINR Kiev, SE SRTIIE Kharkov