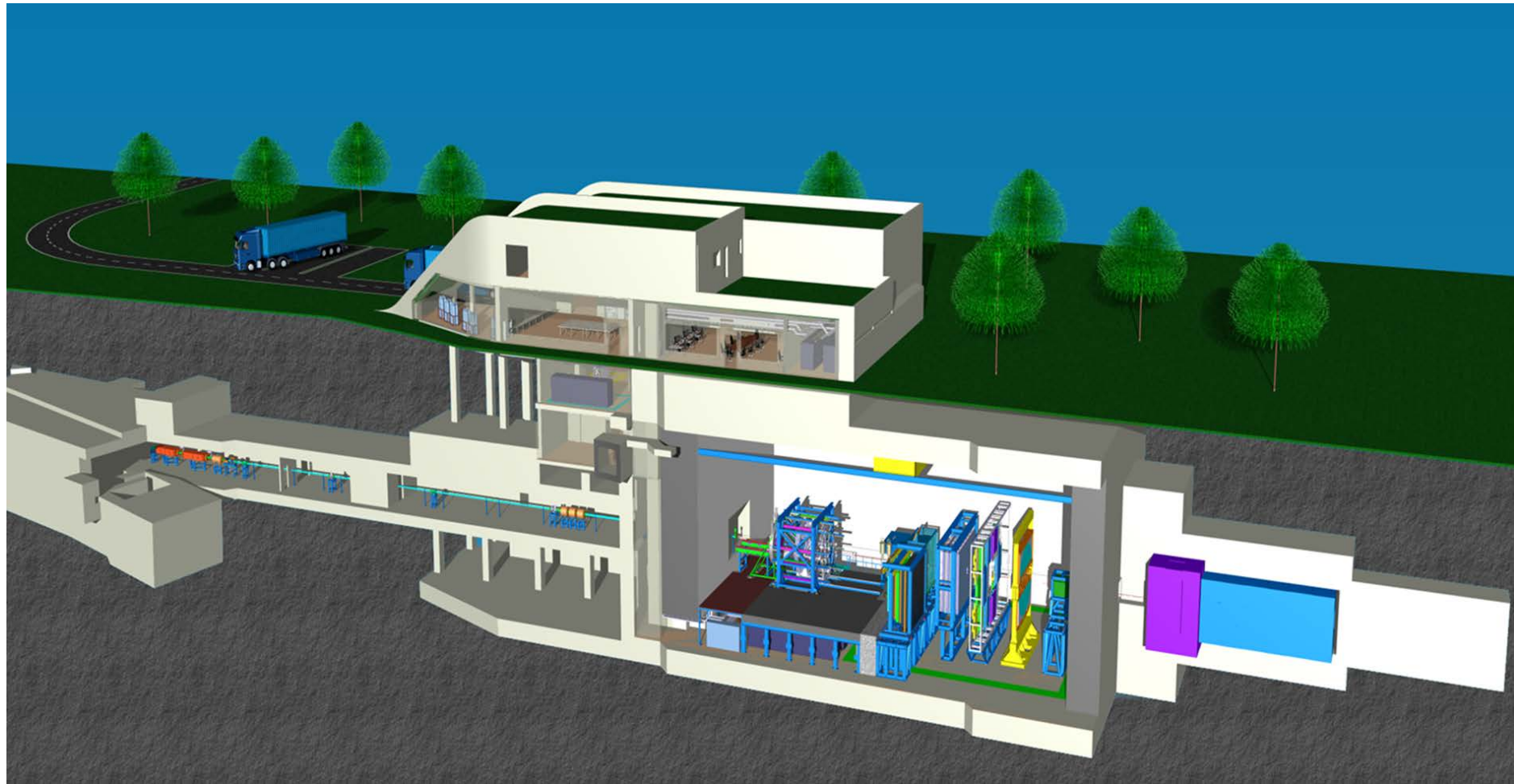
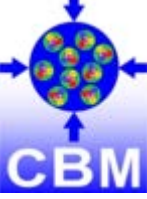
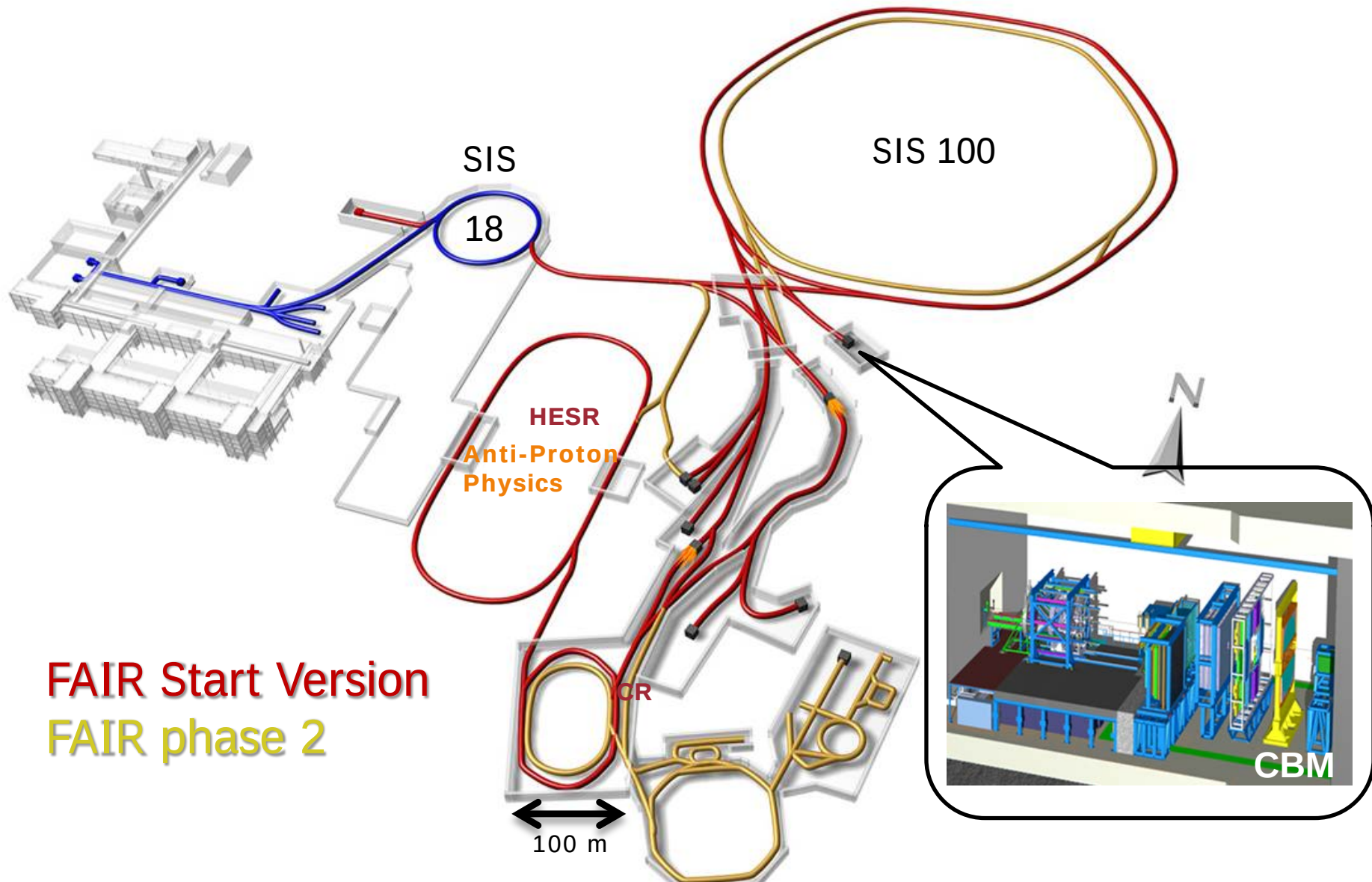
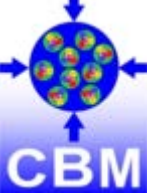


The CBM experiment at FAIR

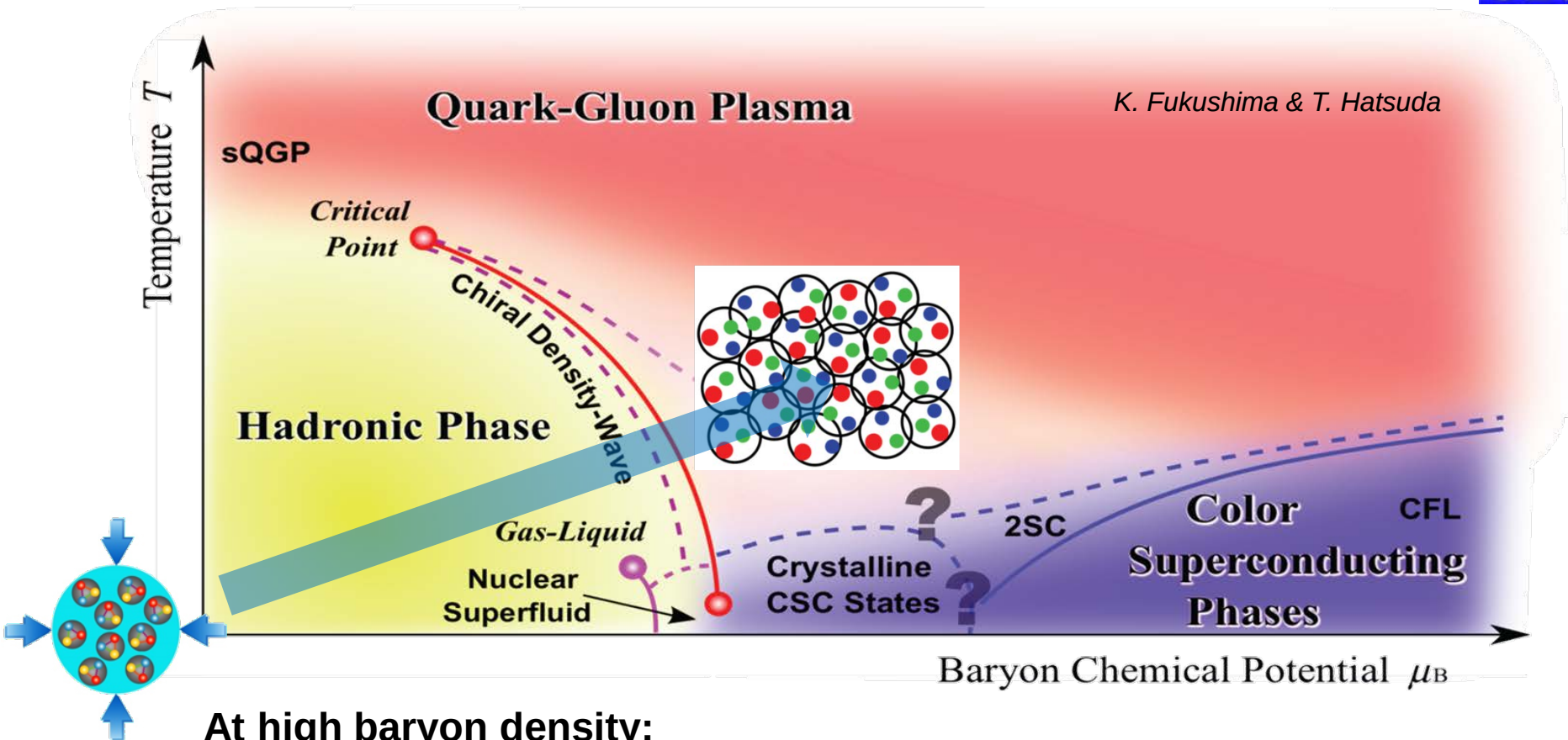
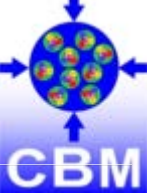


David Emschermann - GSI - DPG Darmstadt - 18/03/2016

Facility for Antiproton and Ion Research



Exploring the QCD phase diagram



At high baryon density:

- N of baryons $\gg$ N of antibaryons, densities like in neutron star cores
- L-QCD not (yet) applicable
- Models predict first order phase transition with mixed or exotic phases

Experiments:

BES at RHIC, NA61 at CERN SPS, NICA at JINR and **CBM at FAIR**

Crab-Nebula (Supernova 1054)

pseudo-color
image

infrared – Spitzer
optical – Hubble
x-ray – Chandra

Example: Crab pulsar

Rotation period $T = 33.4 \text{ ms}$

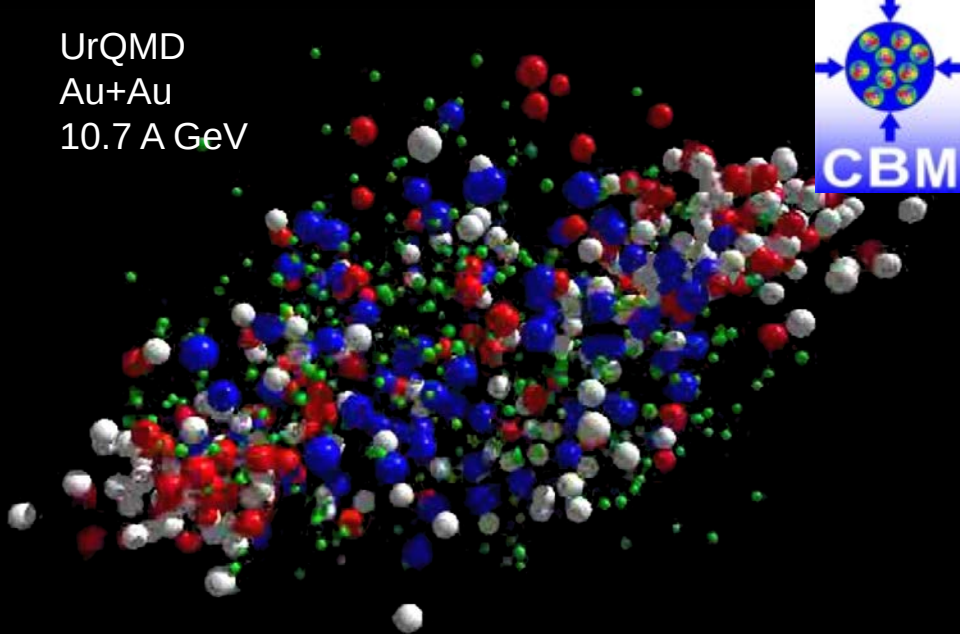
Slowing down rate $\Delta T/\Delta t = 3 \cdot 10^{-8} \text{ s/a}$

Mass $\sim 1.5 M_{\odot}$

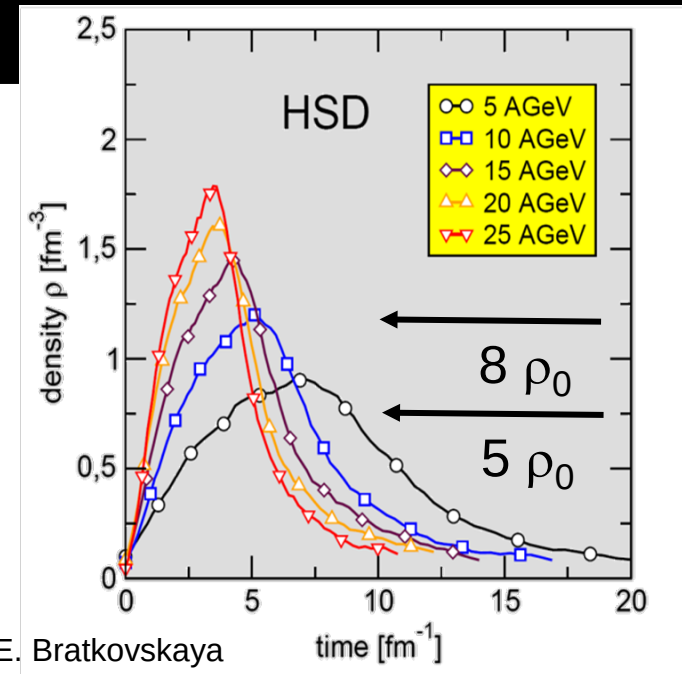
Radius $\sim 15 \text{ km}$

Density $3 - 10 \rho_0$

UrQMD
Au+Au
10.7 A GeV



central
Au + Au
collisions



W.Cassing, E. Bratkovskaya

The CBM physics program

Physics case

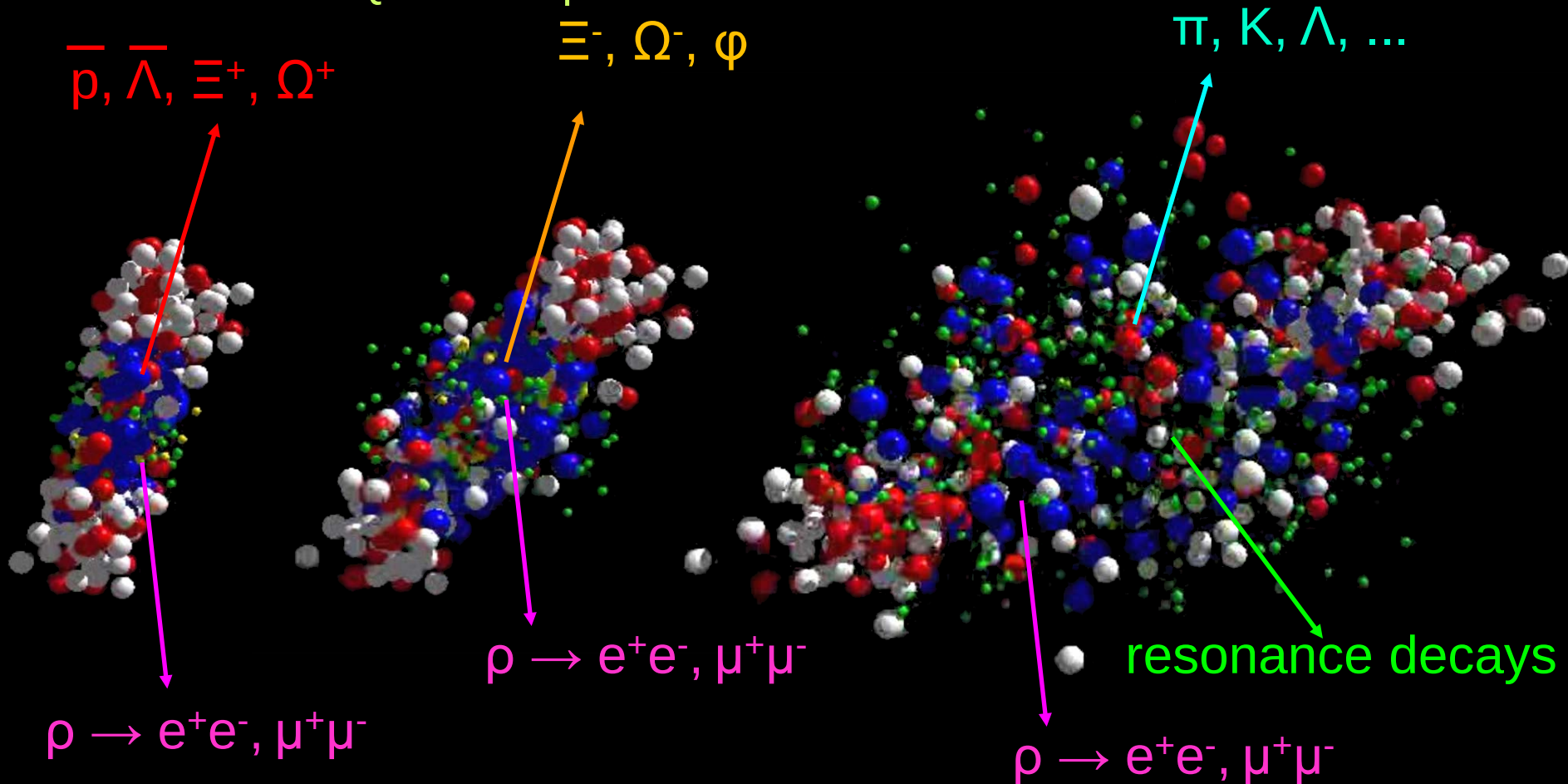
- Nuclear matter equation-of-state at high net-baryon densities
- Search for quarkyonic matter or for phase coexistence
- In-medium modifications of hadrons
- Exploring chiral symmetry restoration
- Hypernuclei and (multi-) strange objects
- Charm production and propagation in cold nuclear matter

Observables

- Strangeness
- Hypernuclei
- Collective flow, correlations, fluctuations
- Dileptons
- Charm

Messengers from the dense fireball: CBM at FAIR

UrQMD transport calculation Au+Au 10.7 A GeV



Experimental observables:

Strangeness, dileptons, flow, fluctuations, hypernuclei, charm, ...

Strangeness – data situation

Particle yields

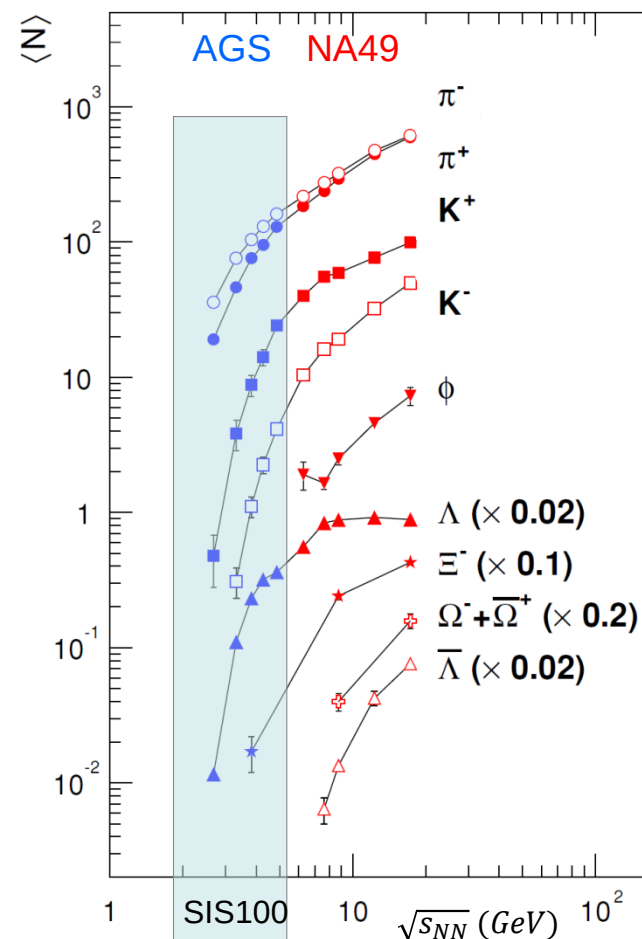
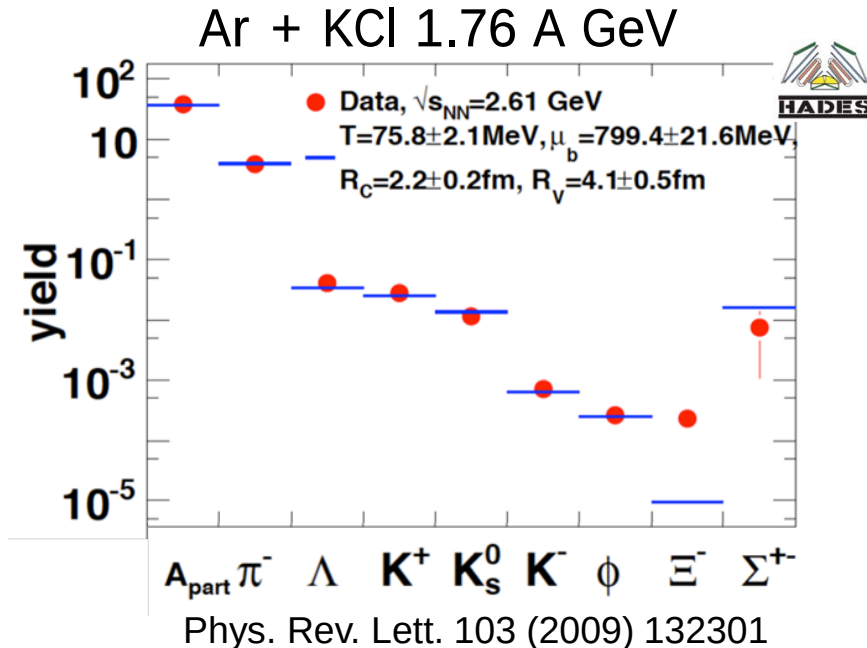


Observables

Excitation function of yields, spectra, and collective flow of (multi-) strange baryons in heavy-ion collisions

Physics case

- Nuclear matter equation-of-state at high net-baryon densities
- Search for quarkyonic matter or for phase coexistence



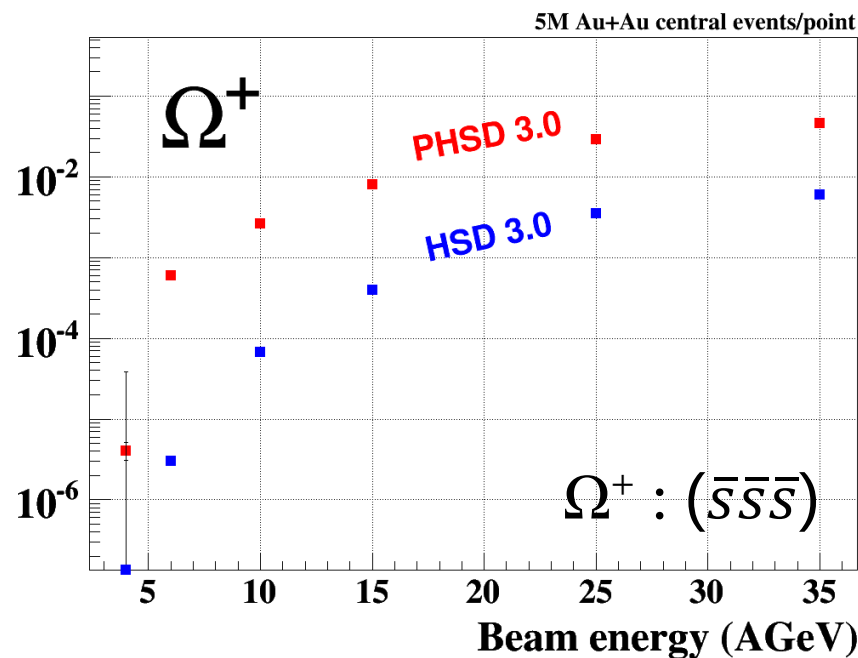
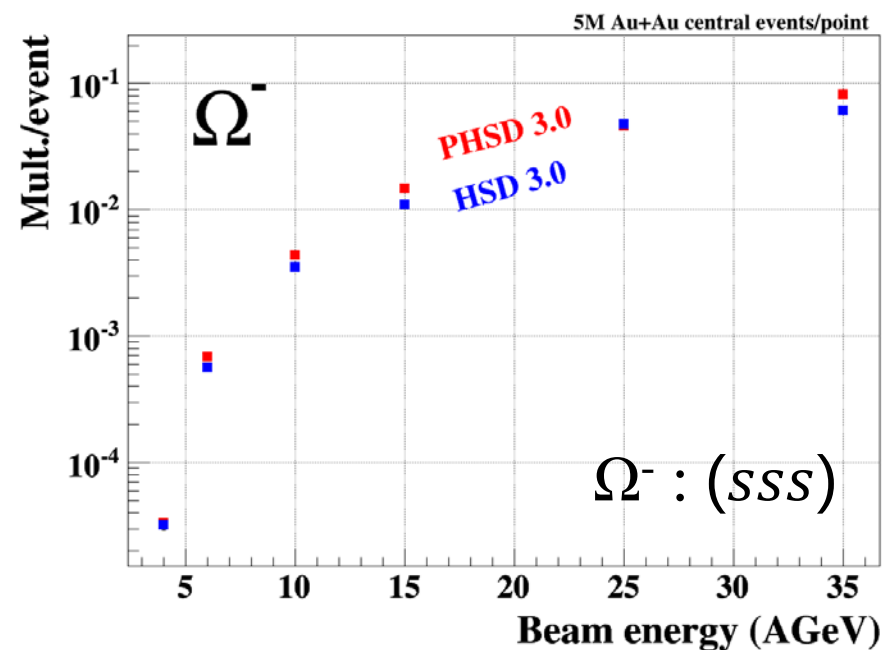
Strangeness

Multi-strange (anti-) hyperons at FAIR energies



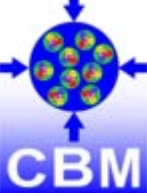
PHSD: Hadronic transport code with partonic phase ($\epsilon > 1 \text{ GeV/fm}^3$)

HSD: Hadronic transport code



I. Vassiliev, E. Bratkovskaya, preliminary results

Strange Matter



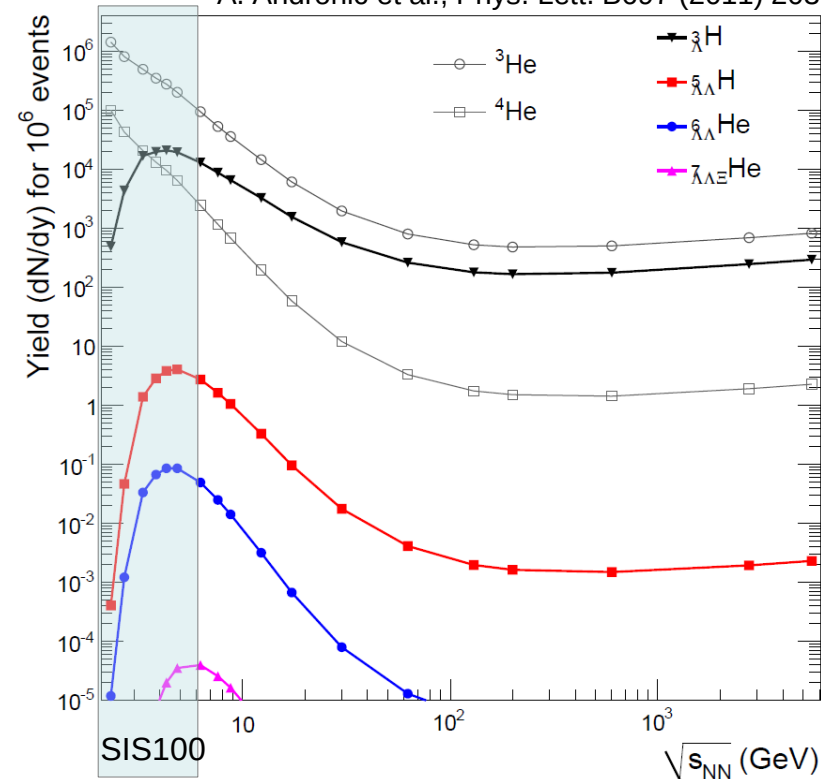
Observables

Hypernuclei, strange dibaryons and massive strange objects

no data at FAIR energies

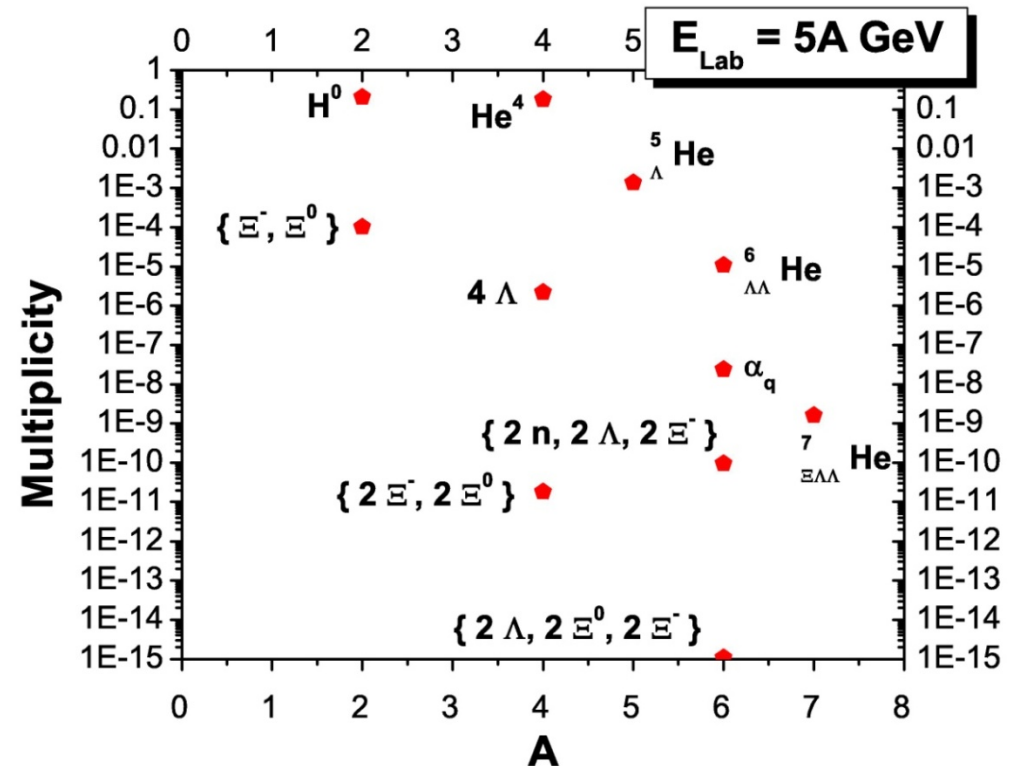
Thermal model calculation

A. Andronic et al., Phys. Lett. B697 (2011) 203



Some Hypernuclei crosssections in reach of CBM UrQMD + HSD

H. Stöcker et al., Nucl. Phys. A 827 (2009) 624c



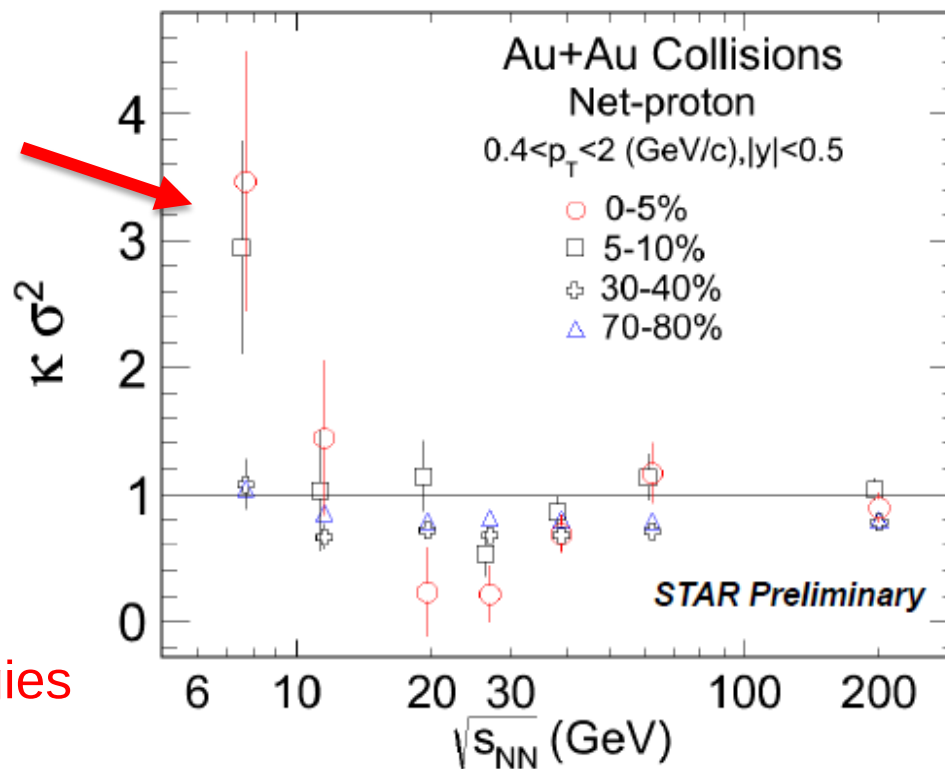
Observables

- Excitation function of flow of identified particles
- Higher moments of net-baryon, net-strangeness and net-charge multiplicity distributions

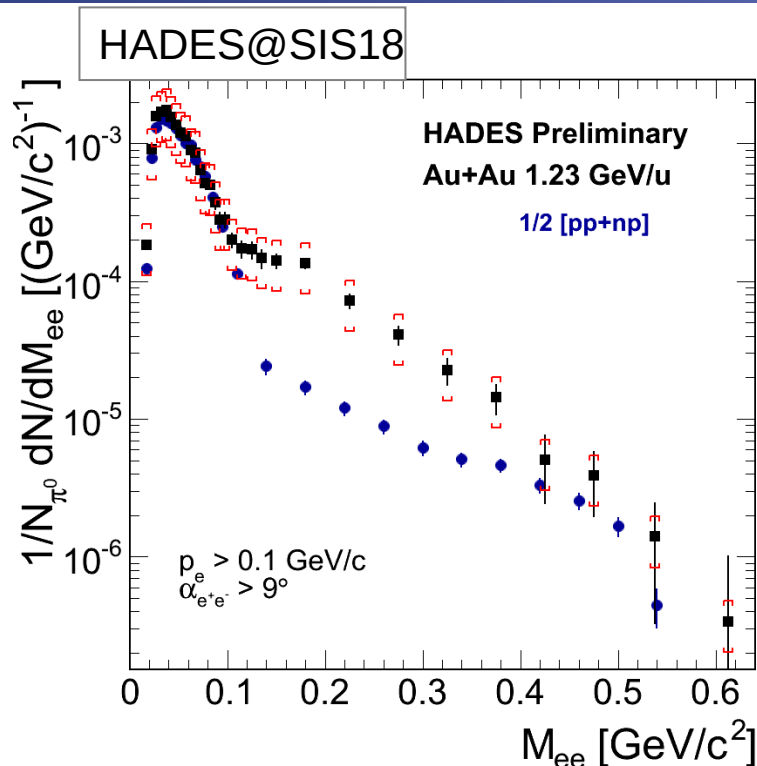
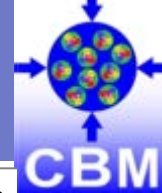
Physics case

- Equation-of-state
- Phase coexistence
- Phase transition
- Critical endpoint

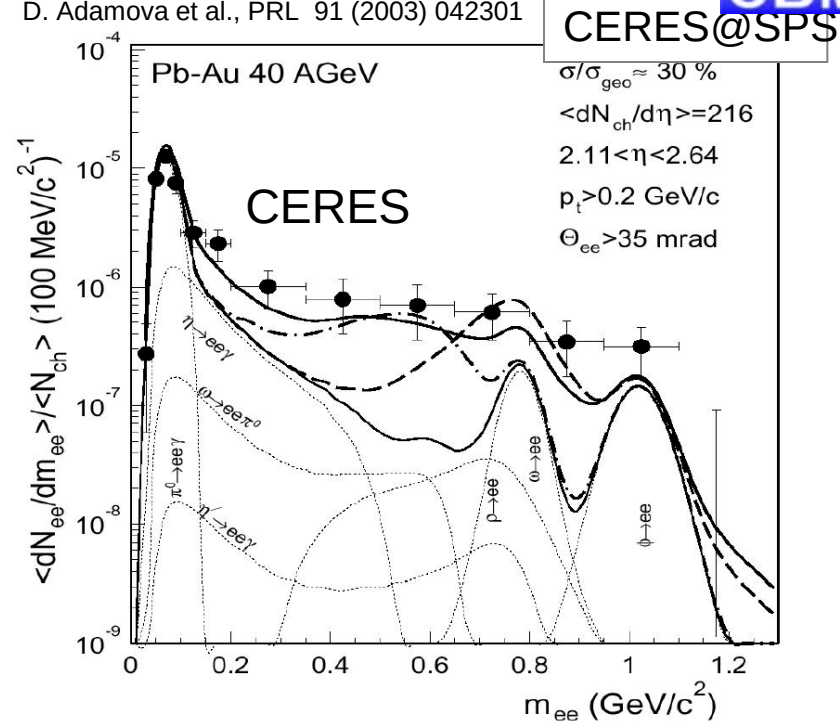
few data
at FAIR energies



Dileptons – data situation



D. Adamova et al., PRL 91 (2003) 042301



No data available in SIS100 / SIS300 energy range !

Excitation function of lepton pair production (2 – 45 A GeV)

→ excess ?

In-medium mass distributions of light vector mesons (2 – 45 A GeV)

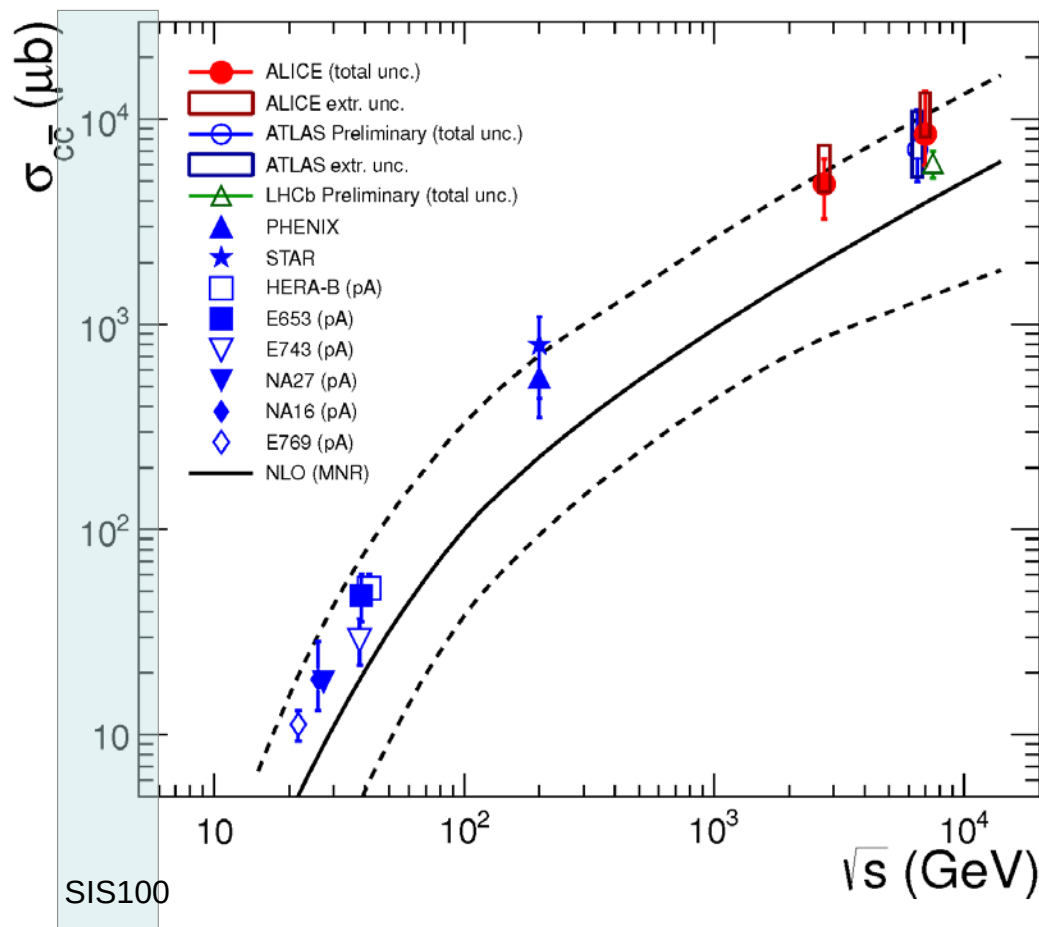
→ in-medium modification of light vector mesons ?

Observables

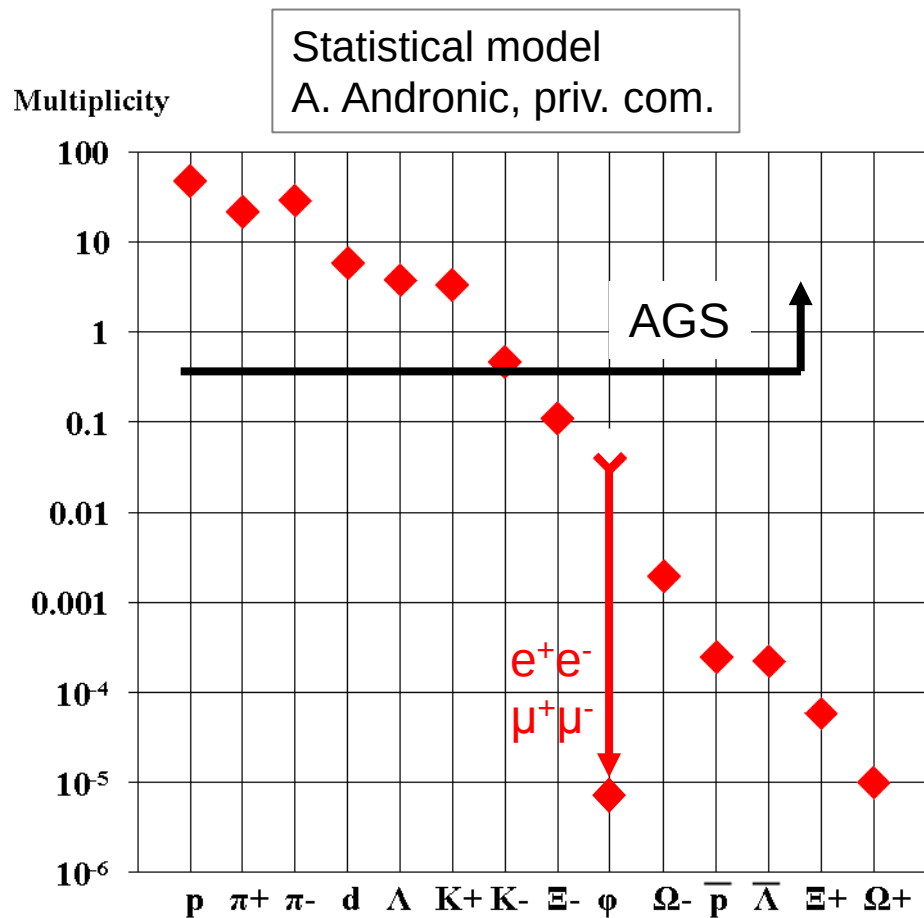
Cross sections and phase-space distributions in p+p , p+A , A+A collisions

Physics case

- Charm production at threshold energies
- Charm production in cold nuclear matter
- Charm propagation in dense QCD matter



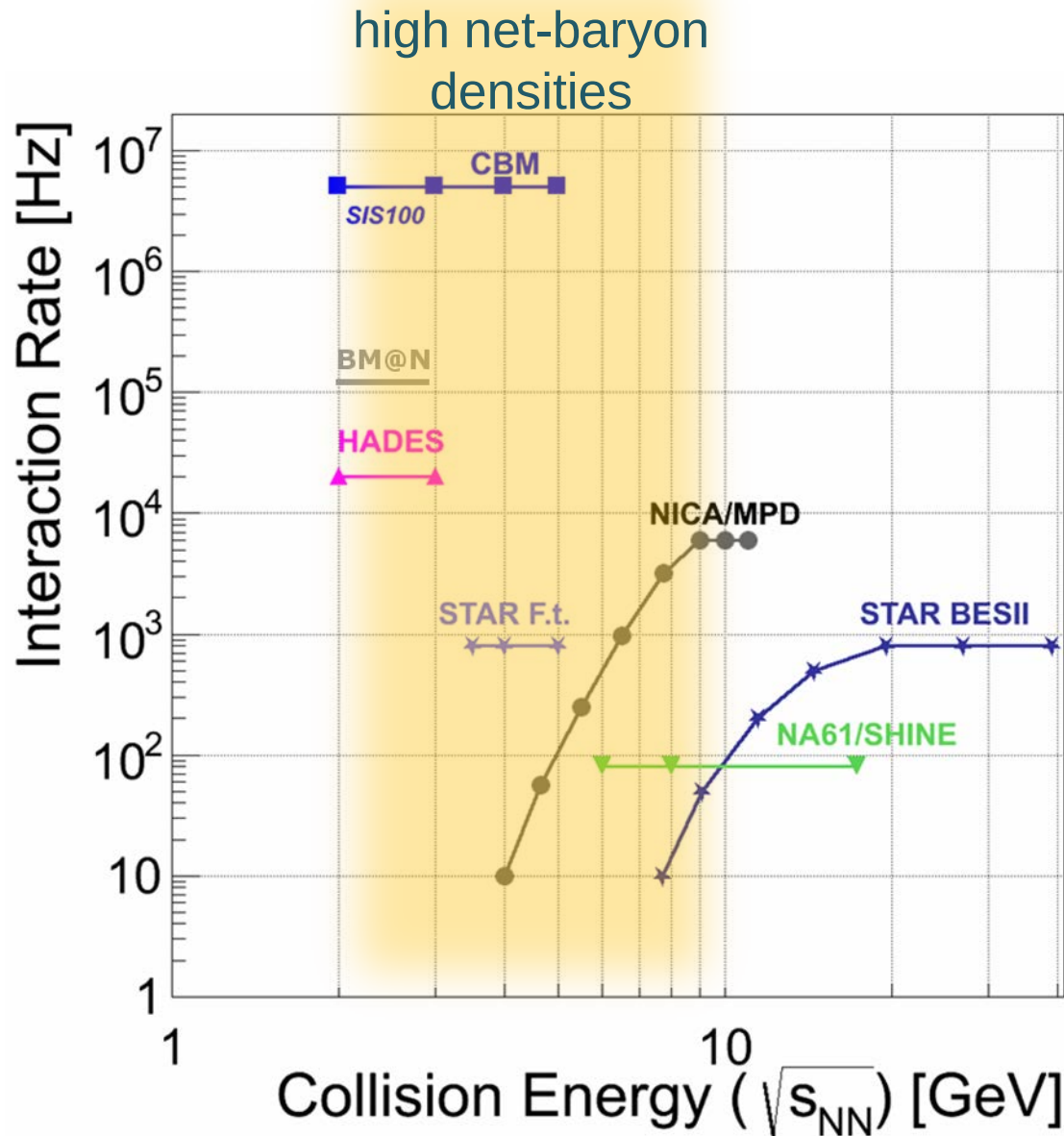
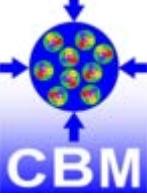
Particle yields in central Au+Au 4 A GeV



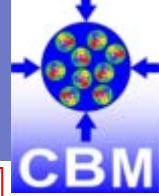
rare probes $\rightarrow$ extremely high interaction rates required !

Experiments exploring dense QCD matter

Rate capabilities



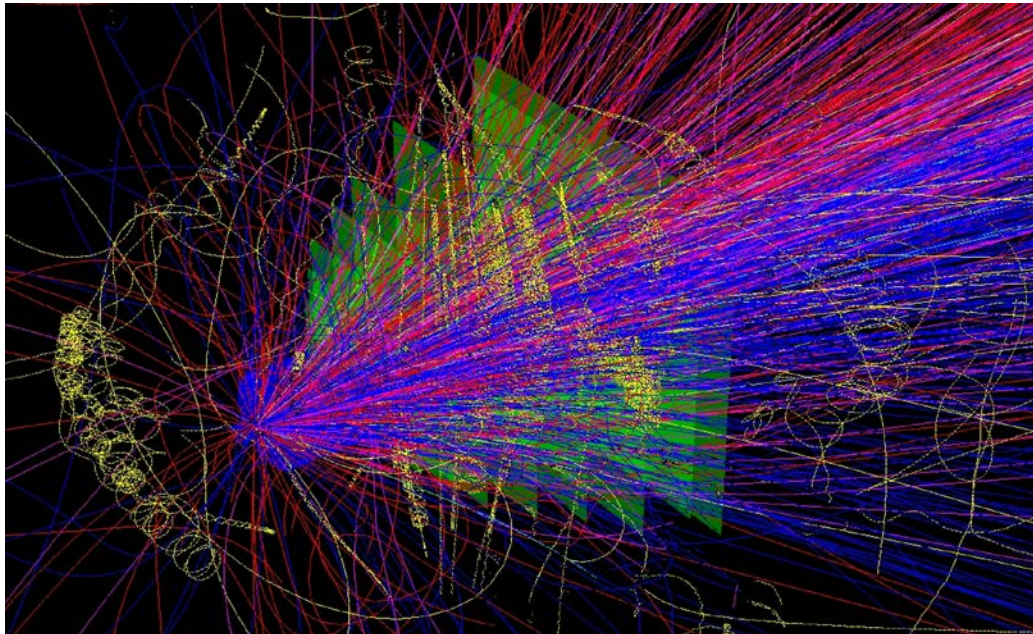
Experimental challenges



Perform measurements at unprecedented reaction rates

$10^5 - 10^7$ Au+Au reactions/sec

- fast and radiation tolerant detectors
- free-streaming read-out electronics
- high speed data acquisition and high performance computer farm for online event selection



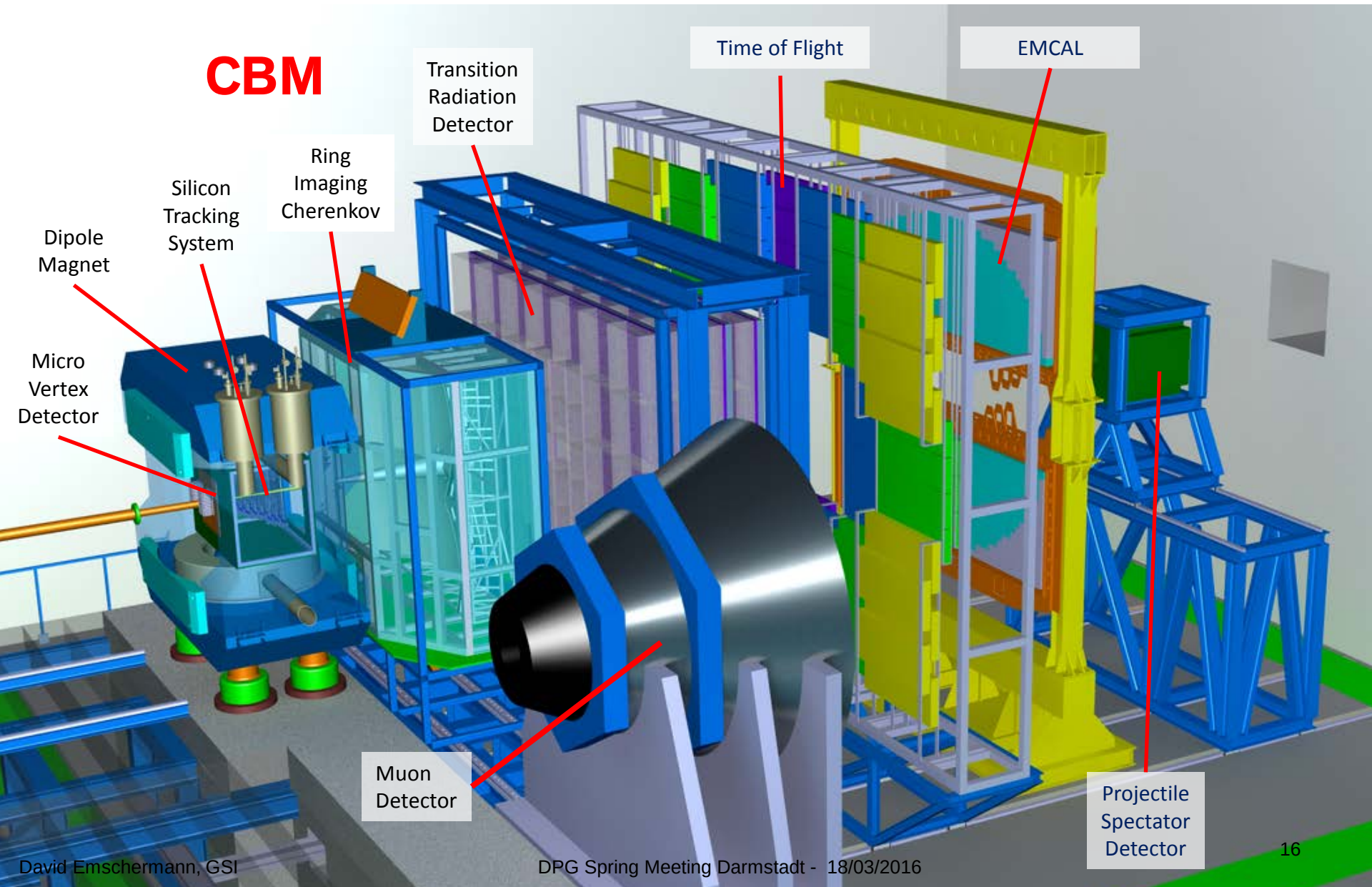
Identification
of leptons and hadrons

Determination of
(displaced) vertices ($\sigma \approx 50 \mu\text{m}$)

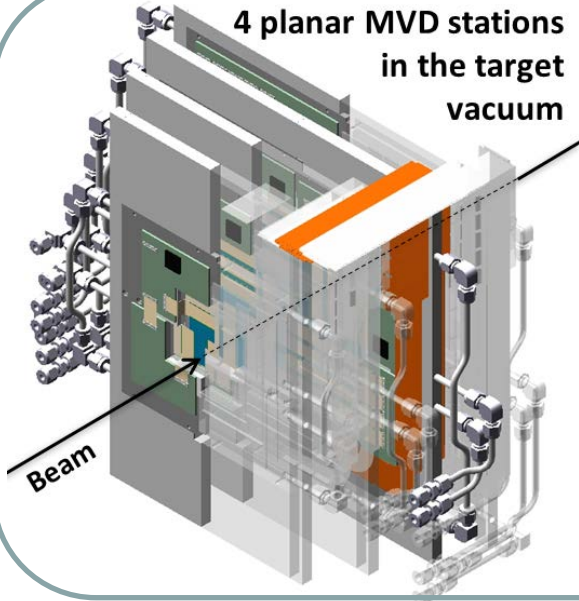
momentum resolution
 $\delta p / p \cong 1\%$

Central Au+Au at 25 A GeV / UrQMD+GEANT4
160 p, 450 $\pi^+ + \pi^-$, 44 K^+ , 13 K^-

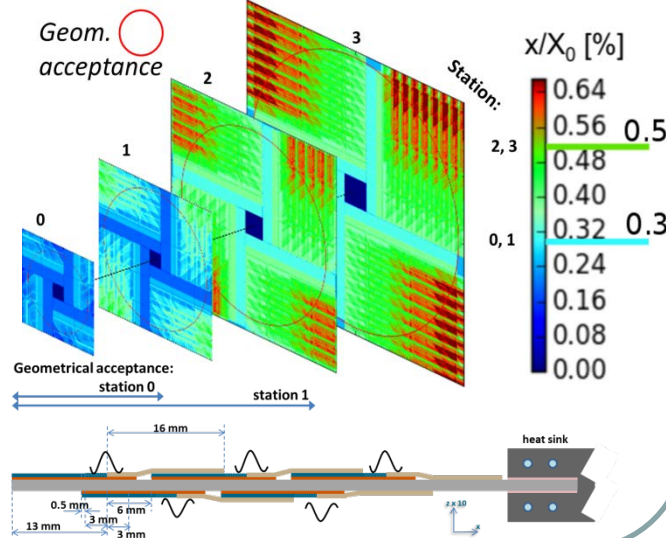
The CBM SIS 100 setup in the cave



Micro-Vertex Detector for CBM

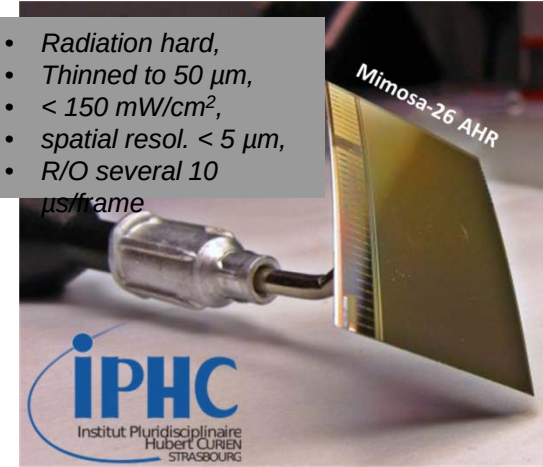


Ultra-thin: CVD diamond, TPG



Sensors: CMOS MAPS

- Radiation hard,
- Thinned to 50 μm ,
- $< 150 \text{ mW/cm}^2$,
- spatial resol. $< 5 \mu\text{m}$,
- R/O several 10 $\mu\text{s/frame}$

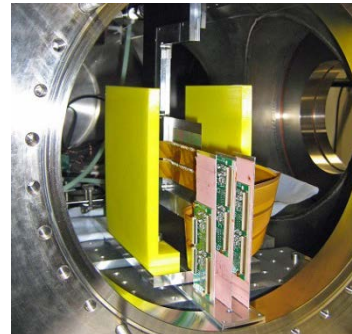
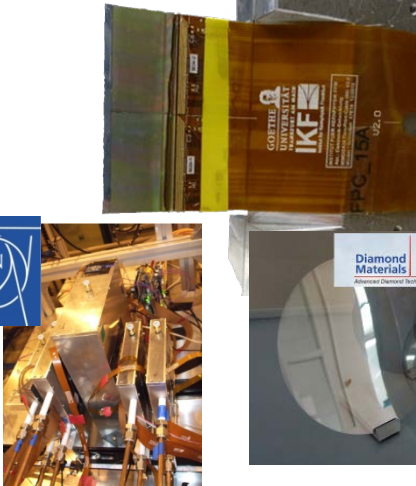
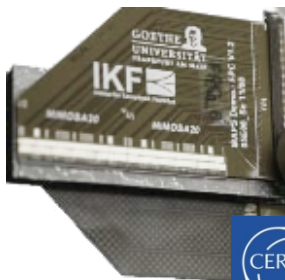


Prototyping & test

MVD demonstrator

MVD prototype

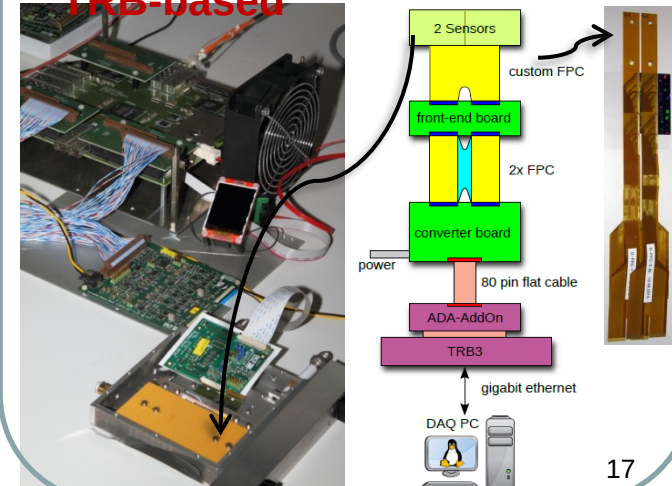
PRESTO



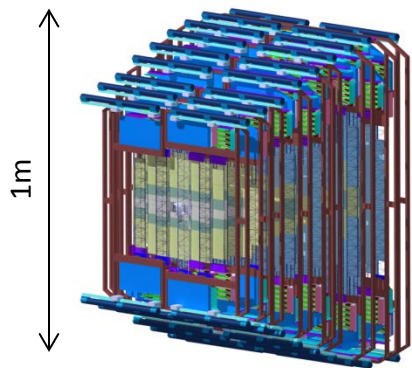
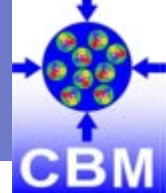
Thermal
Pyrolytic
Graphite

MOMENTIVE
inventing possibilities

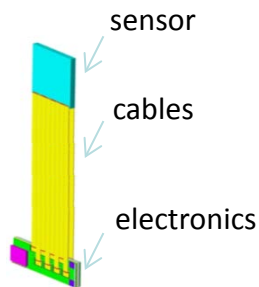
Customized FEE & DAQ: TRB-based



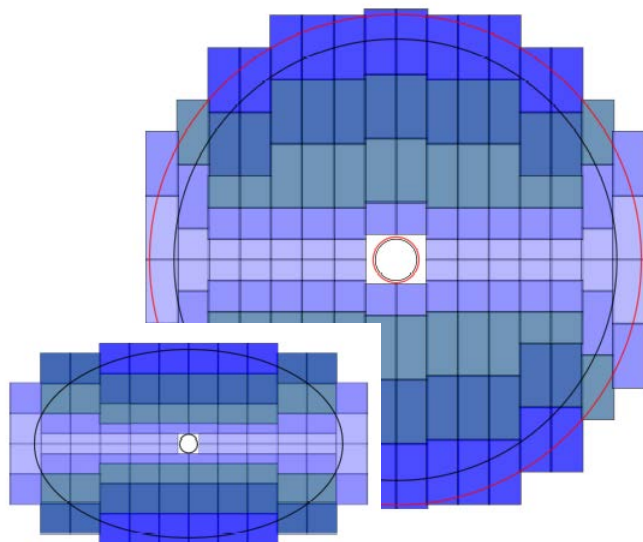
Highlight STS: silicon microstrip sensors



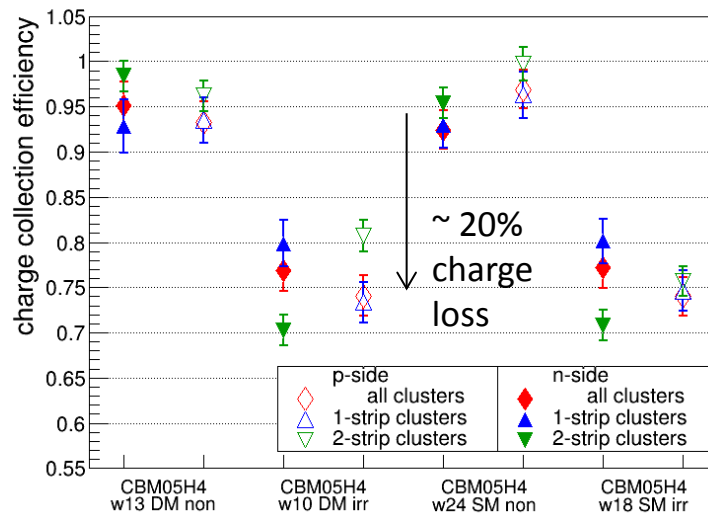
8 tracking stations
106 ladders



STS v16c:
876 modules



Charge collection efficiency of prototype sensors
verified in 2.4 GeV proton beam at COSY, $T_{op} = -5^\circ\text{C}$



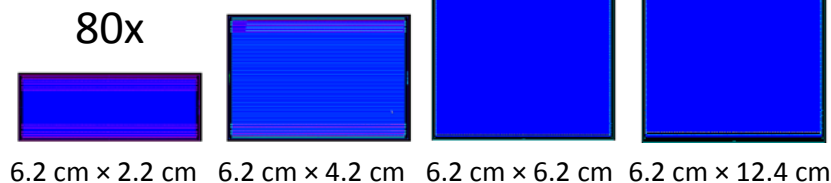
← new

← irradiated to $2 \times 10^{14} \text{ n}_{eq} \text{ cm}^{-2}$
(2 × STS “lifetime”)

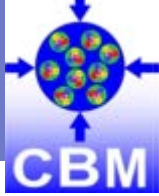
double-metal
technology

single-metal
technology

double-sided, 300 μm thick,
1024 strips per side at 58 μm
pitch, 7.5 deg angle front/back

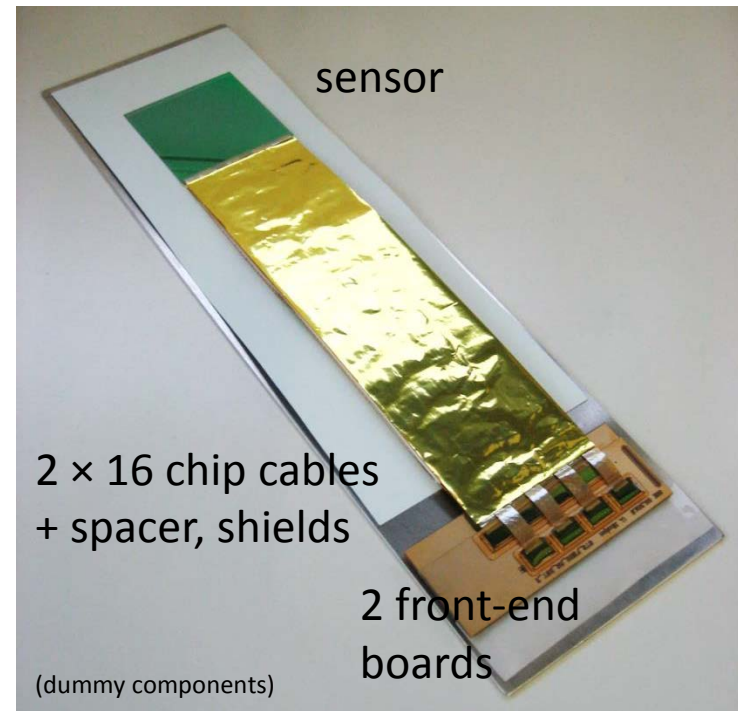
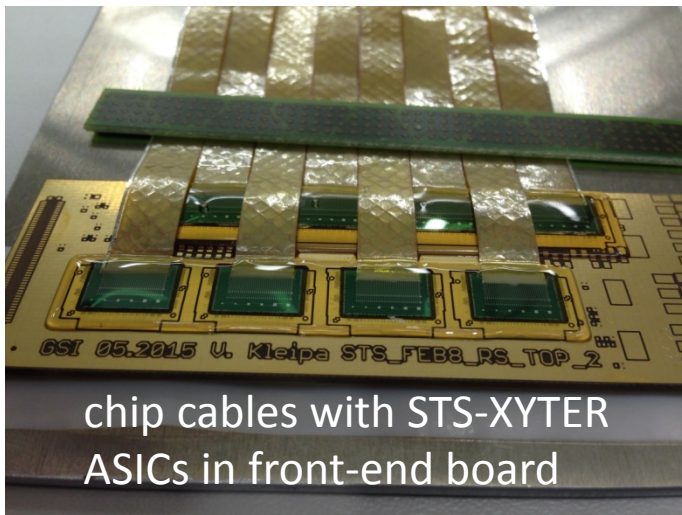


Highlight STS: module assembly

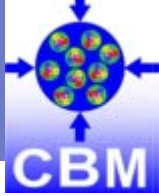


Workflow and tooling for double-sided module-assembly has been developed:

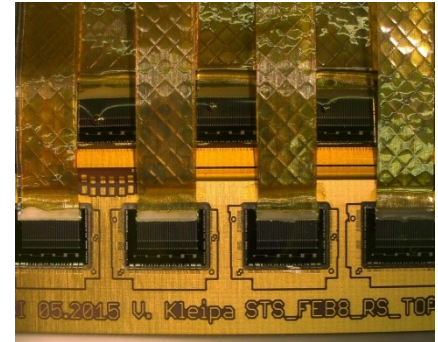
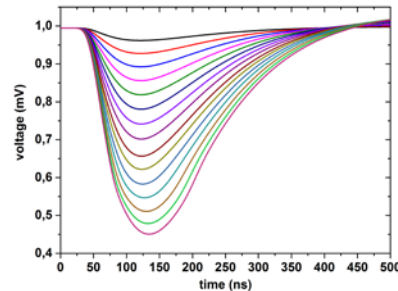
- assembly of 16 *chip cables* via TAB bonding (2 work steps each)
- install 8 *chip cables* and *spacer/shield layers* on *p* side of module (7 work steps each)
- install 8 *chip cables* and *spacer/shield layers* on *n* side of module (7 work steps each)



STS-XYTER 2.0: Front-end readout ASIC

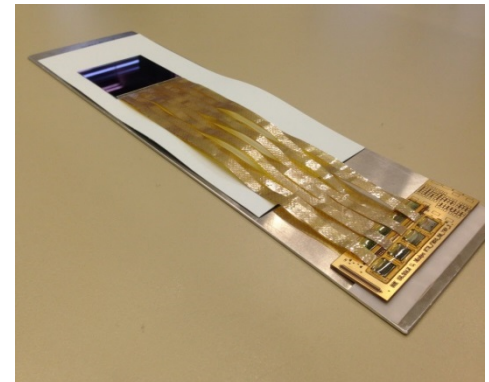
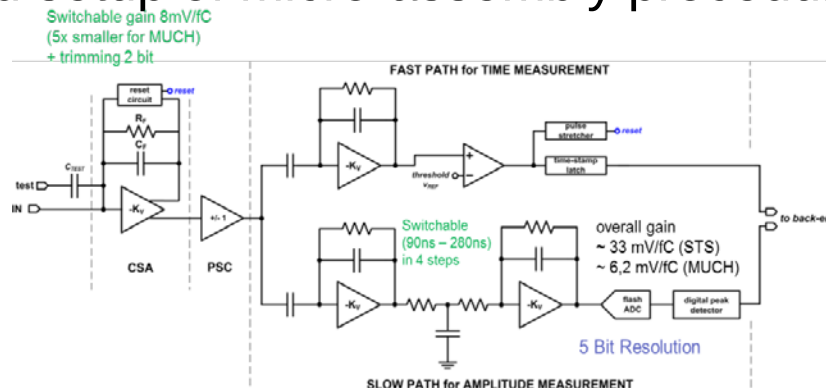
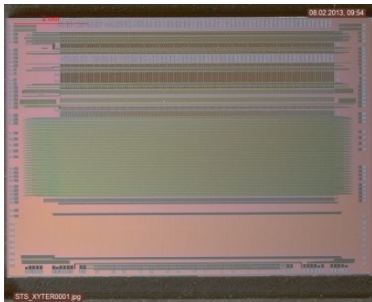


- Thorough complete-system simulations result in S/N and power optimizations with consequences to
 - sensor design
 - micro-cable design
 - front-end architecture
 - floating power-networks

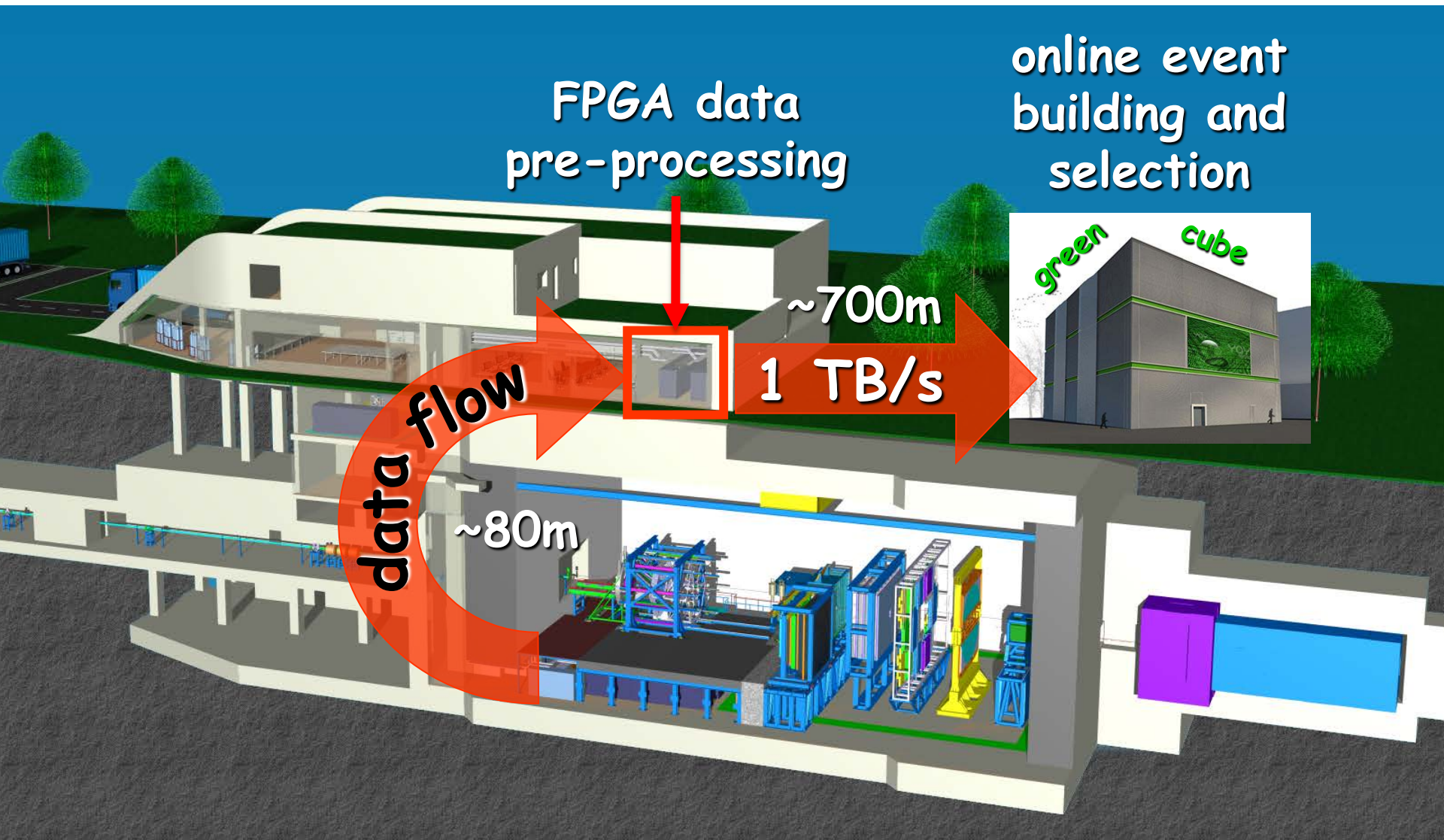


→ S/N noise target feasible on system level over life-time!

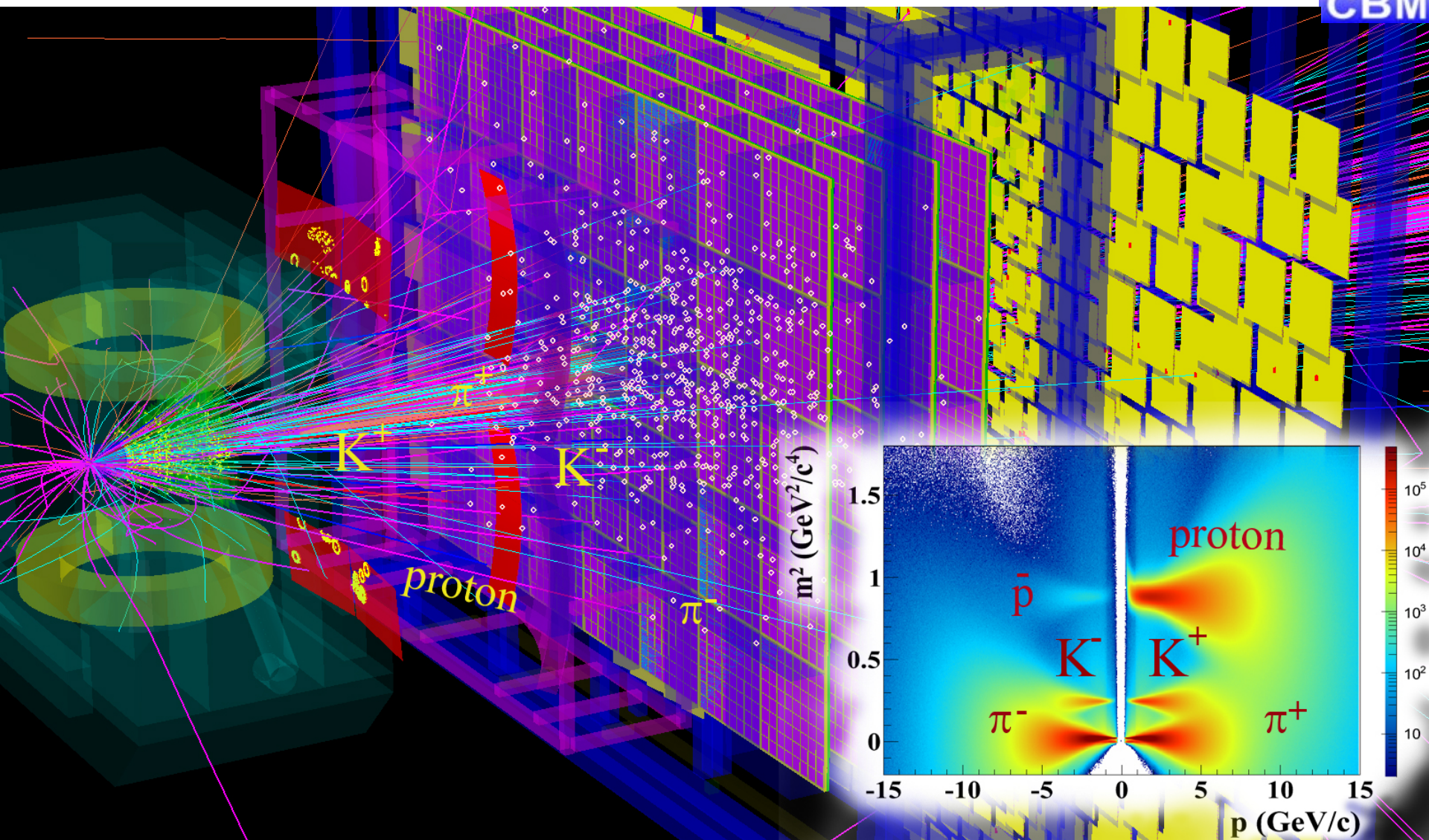
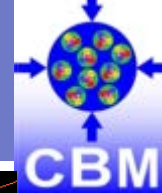
- Full back-end integration of GBTx (CERN) data aggregation solution
- Engineering run in April 2016 will supply enough dies for STS/MUCH
- prototyping and setup of micro-assembly procedures.



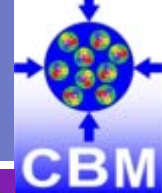
DAQ/FLES (First Level Event Selection)



Particle identification



Anti-hyperon reconstruction



Input:
UrQMD 3.2
Au+Au 10 AGeV
central collision

π^+

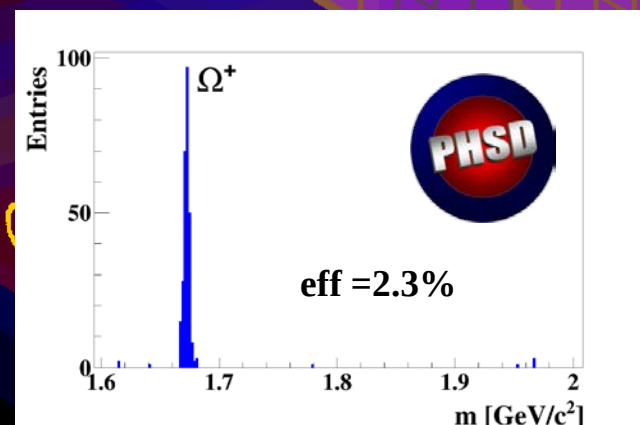
K^+

$\bar{p}$

$\Omega^+ \rightarrow \bar{\Lambda} K^+$

$\Omega^+(\bar{s}\bar{s}\bar{s})$

hits in STS stations

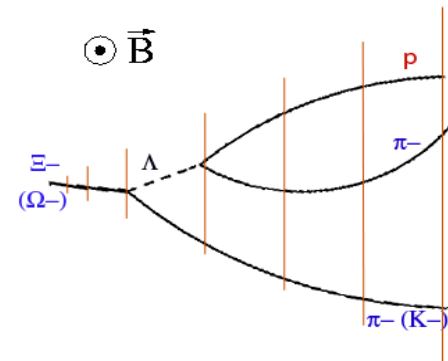
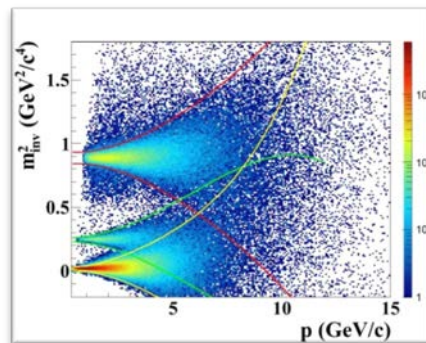


Performance of hyperon identification

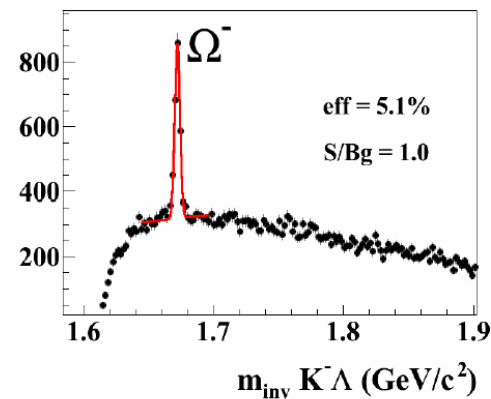
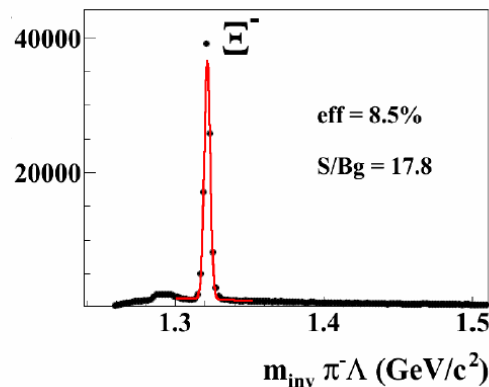
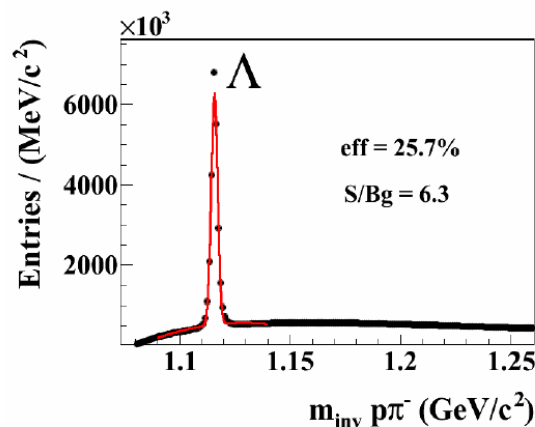


Simulations:

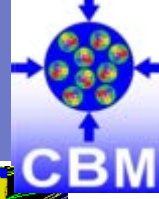
- STS with realistic geometry, material budget, and detector response
- TOF at 10 m, time resolution 80 ps



$5 \cdot 10^6$ Au+Au
central
10 AGeV



Di-electron reconstruction



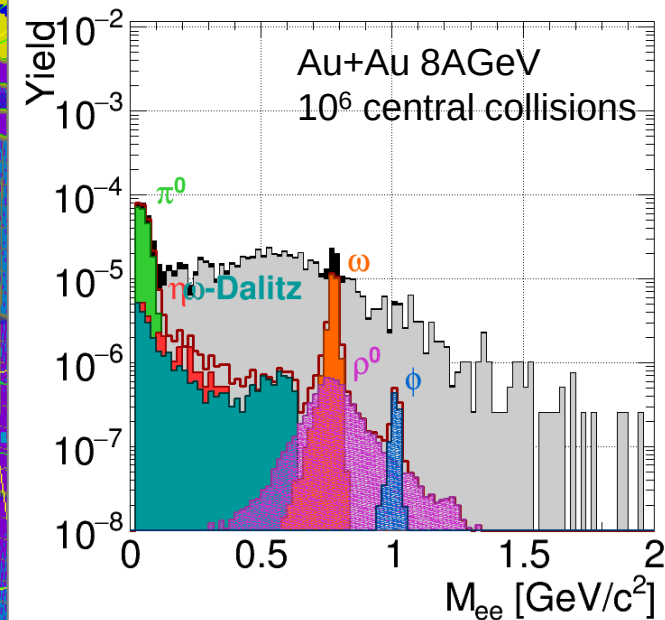
Input:
UrQMD 3.2
Au+Au 8 AGeV
central collision

e^+

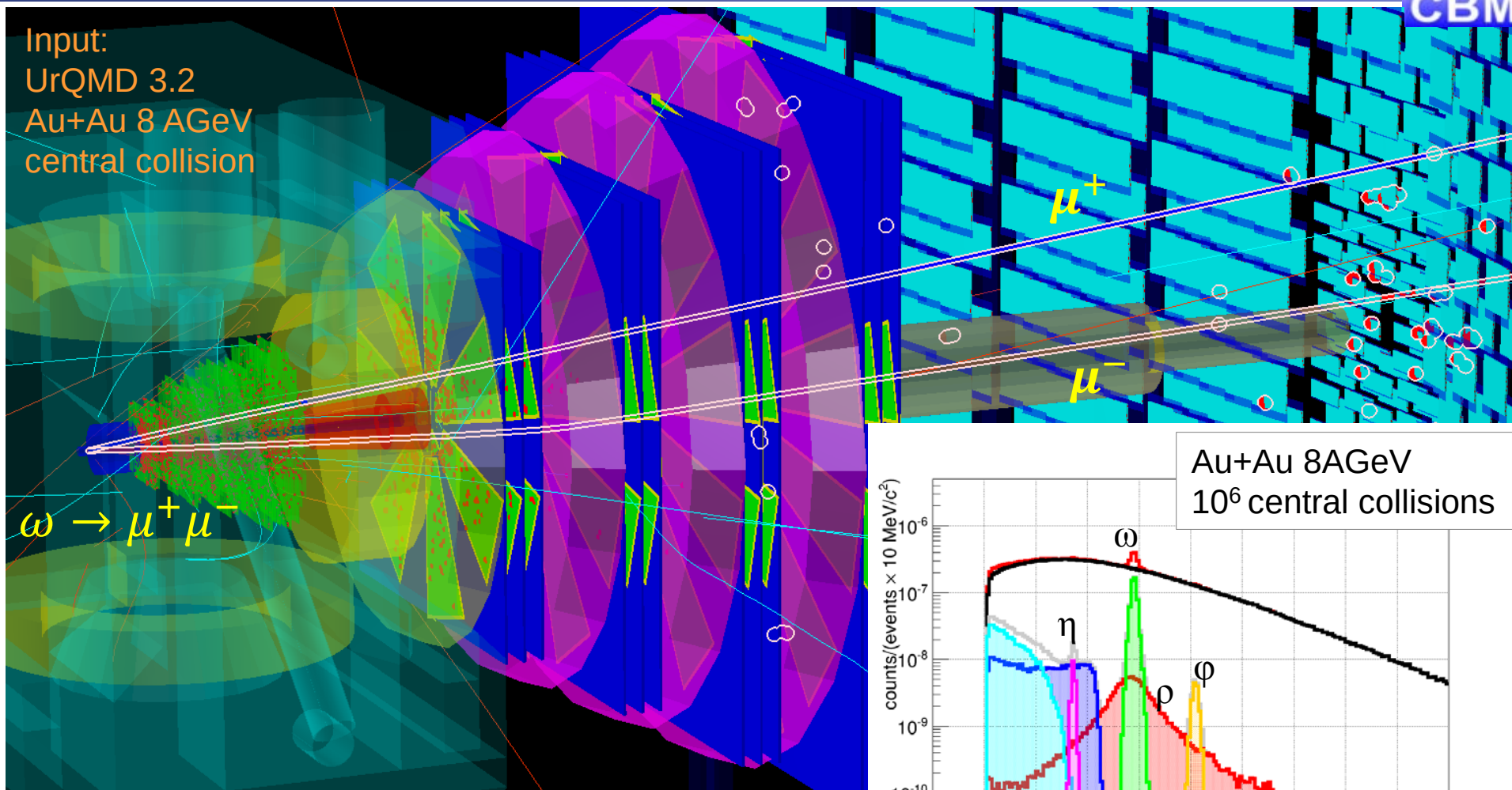
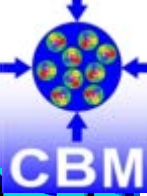
e^-

$\rho \rightarrow e^+ e^-$

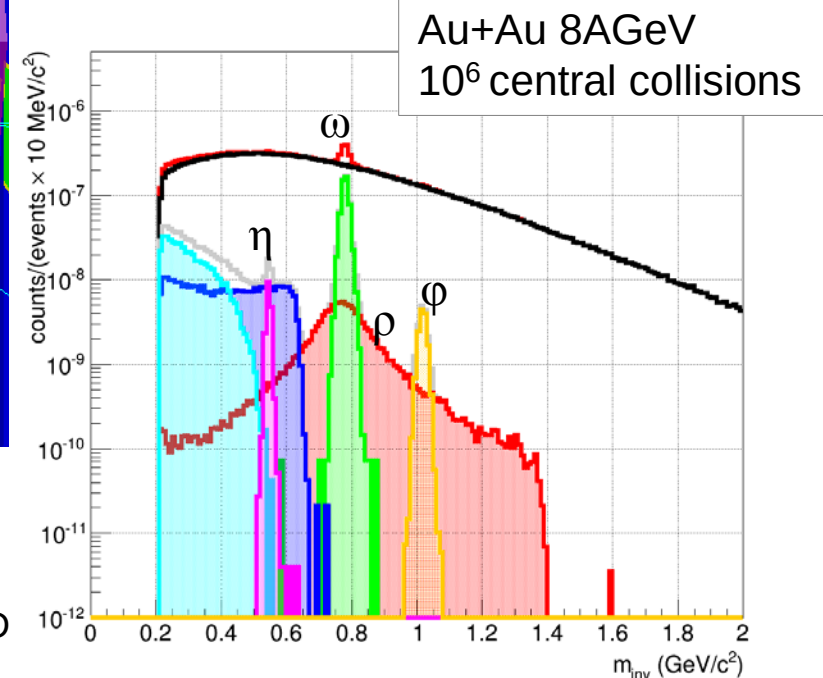
mc lepton tracks



Di-muon reconstruction



Simulation: signal yields from HSD
background from UrQMD



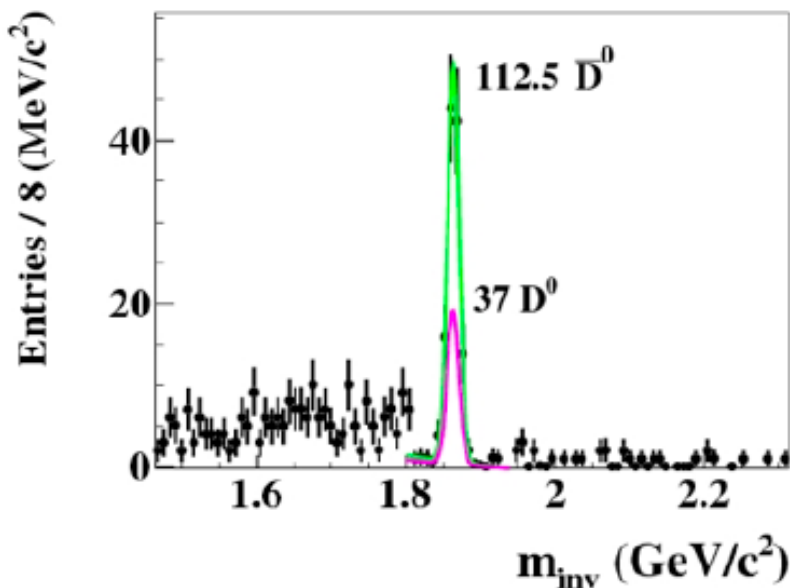
Open charm in CBM at SIS100



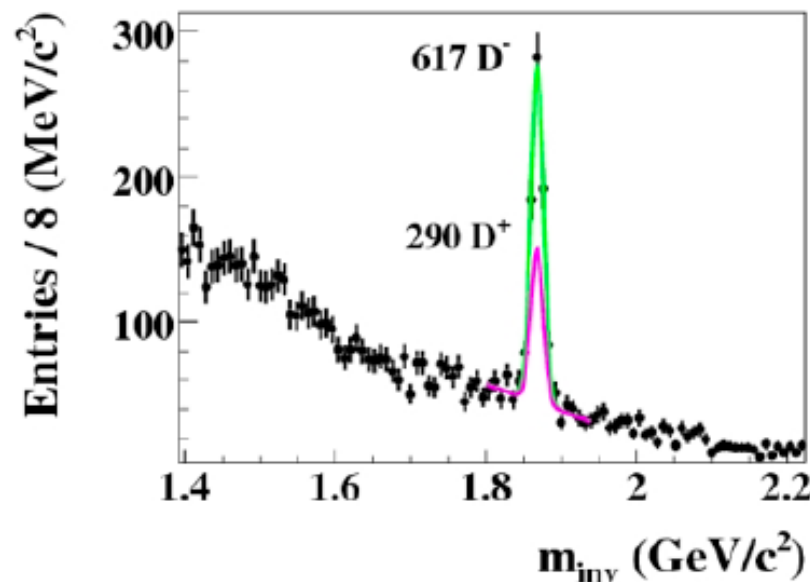
- Charm production cross sections at threshold energies
- Charm production in cold nuclear matter

Open charm reconstruction in p+C 30GeV :

$D^0 \rightarrow K\pi\pi\pi$



$D^\pm \rightarrow K\pi\pi$



Status of the experiment preparation

Technical Design Reports



#	Project	TDR Status	Technical Design Report for the CBM
1	Magnet	approved	Technical Design Report for the CBM Superconducting Dipole Magnet The CBM Collaboration November 2012
2	STS	approved	Technical Design Report for the CBM Silicon Tracking System (STS) The CBM Collaboration GSI Report 2013-4 October 2013
3	RICH	approved	Technical Design Report for the CBM Ring Imaging Cherenkov (RICH) Detector The CBM Collaboration April 2013
4	TOF	approved	Technical Design Report for the CBM Time - of - Flight System (TOF) The CBM Collaboration March 2013
5	MuCh	approved	Technical Design Report for the CBM Muon Chamber (MUCH) The CBM Collaboration December 2013
6	HADES ECAL	approved	Technical Design Report for the CBM Projectile Spectator Detector (PSD) The CBM Collaboration March 2013
7	PSD	approved	
8	MVD	submission in Oct 2016	
9	DAQ/FLES	submission in Jun 2017	
10	TRD	submission in Oct 2016	
11	ECAL	submission t.b.d.	

63% of TDRs approved

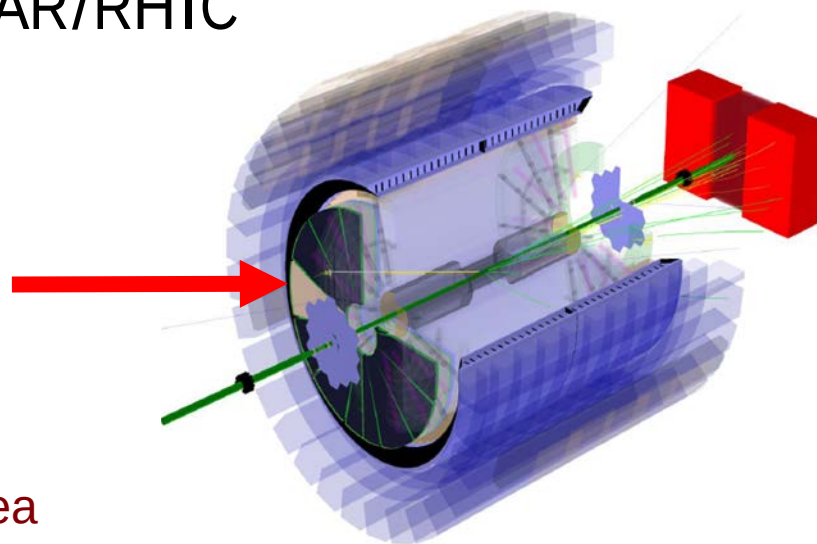
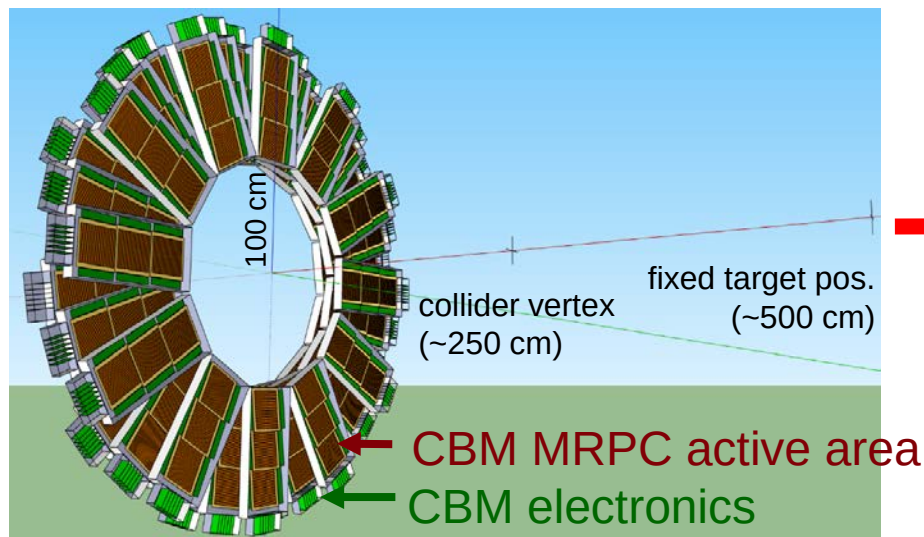
Ongoing R&D:

Development of CMOS sensors (MVD), read-out ASIC for STS, and DAQ/FLES

CBM TOF participation in STAR



Install, commission and use 10% of the CBM TOF modules including read-out chain at STAR/RHIC



Participation in STAR Beam Energy Scan (BES II) in 2019/2020

Operation of ~30 CBM TOF modules and electronics ($A \sim 10 \text{ m}^2$, ~10.000 channels)

Benefits

- Get experience with detector system, develop online calibration and monitoring tools
- Coverage of complementary part of CBM's physics program (low rate, high energy, $7.7 \text{ GeV} < \sqrt{s_{NN}} < 20 \text{ GeV}$)
- Develop TOF analysis strategies for particle ID under experimental conditions
- Participate visibly in physics analysis (e.g. baryon and strangeness fluctuations)

Joint CBM & HADES RICH Setup



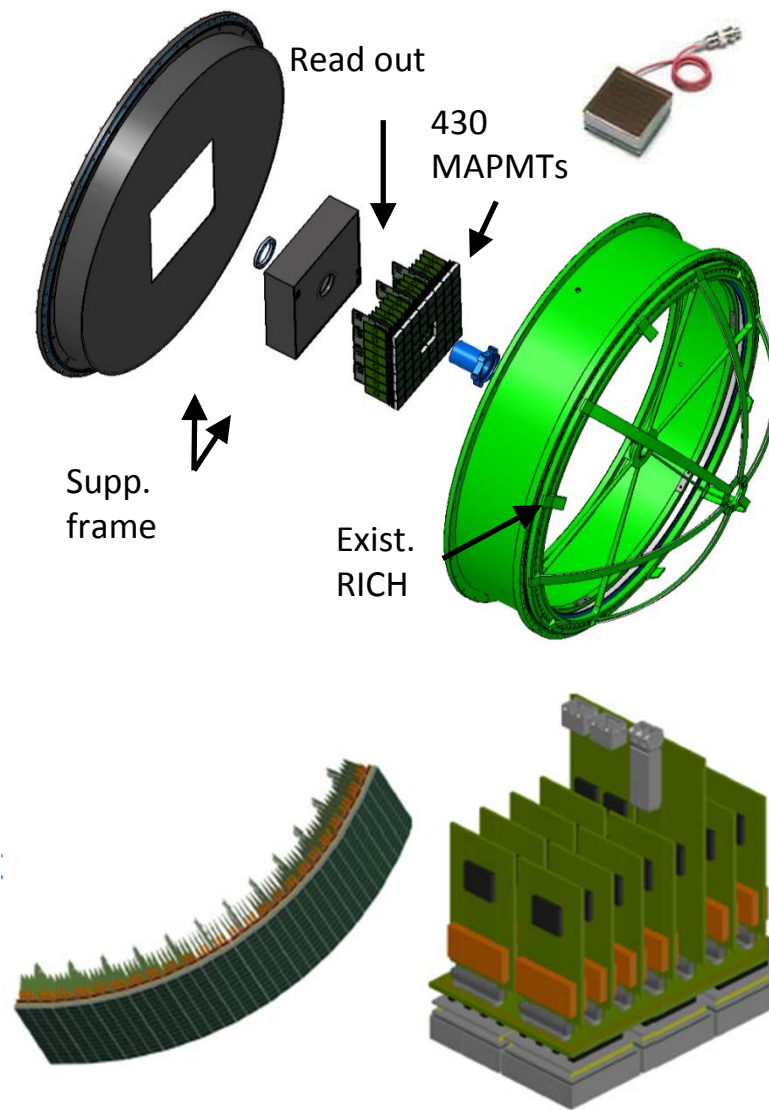
Setup

Install, commission and use part of CBM RICH multi-anode photon multipliers (MAPMT) in HADES RICH.

- Gain experience in detector set-up, calibration, data analysis
- Participation in research program at GSI from 2018-2020 (π , p, HI induced reactions)
Reference measurements for CBM
- Joint development of read-out electronics (DiRICH FE, TRB3)
- Part. Inst.: U. Gießen, GSI, U. Wuppertal, TU München

Status

- MAPMT delivery: 11.2015
- Support & test chamber: delivered to GSI
- FE Electronics design: started



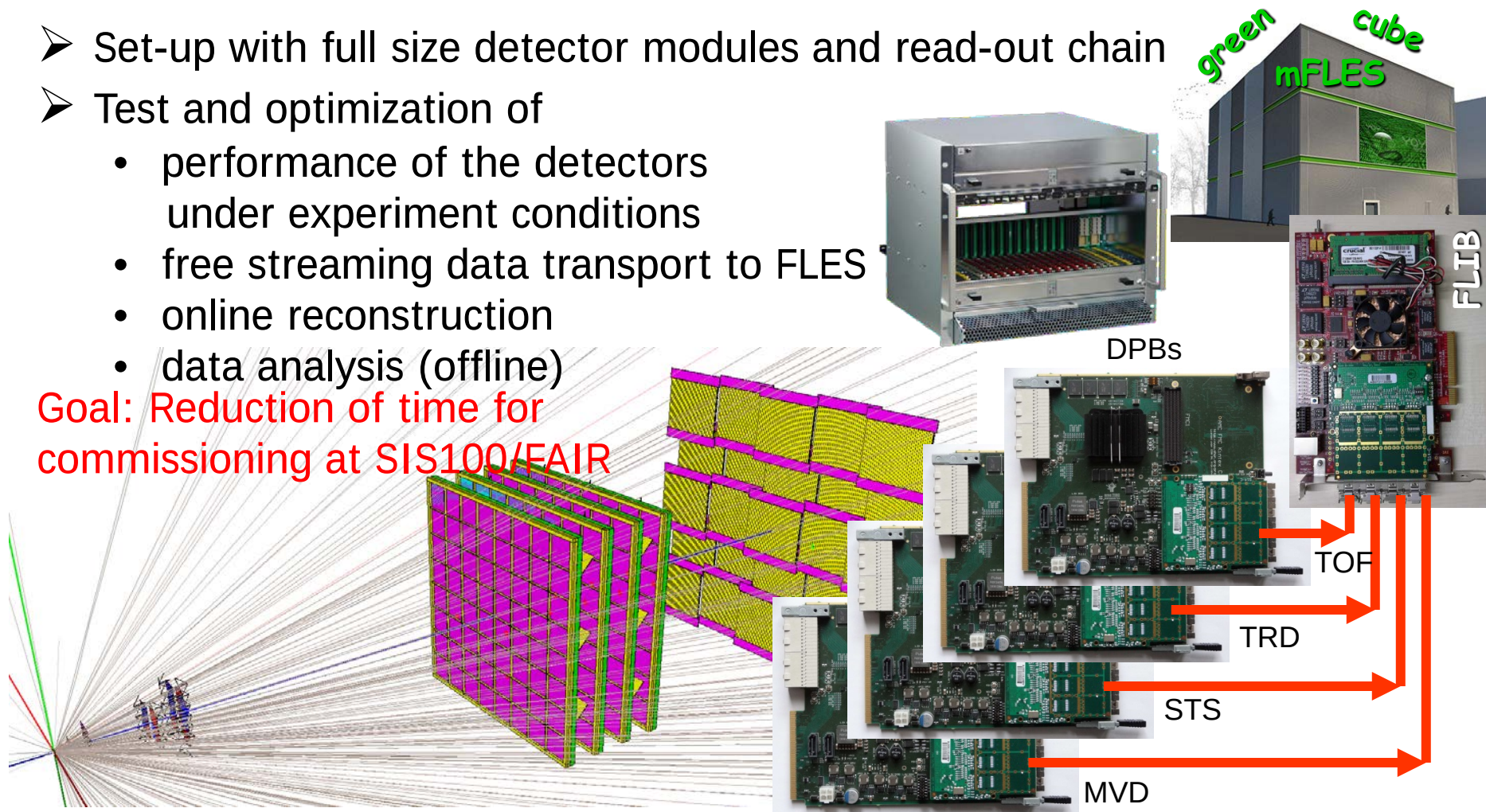
CBM commissioning test stand



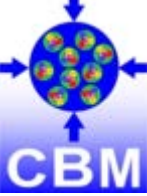
Build mCBM at GSI/SIS18 for a full system integration and commissioning test with high-rate A-A collisions from 2018-19

- Set-up with full size detector modules and read-out chain
- Test and optimization of
 - performance of the detectors under experiment conditions
 - free streaming data transport to FLES
 - online reconstruction
 - data analysis (offline)

Goal: Reduction of time for commissioning at SIS100/FAIR



The CBM Collaboration



60 institutions

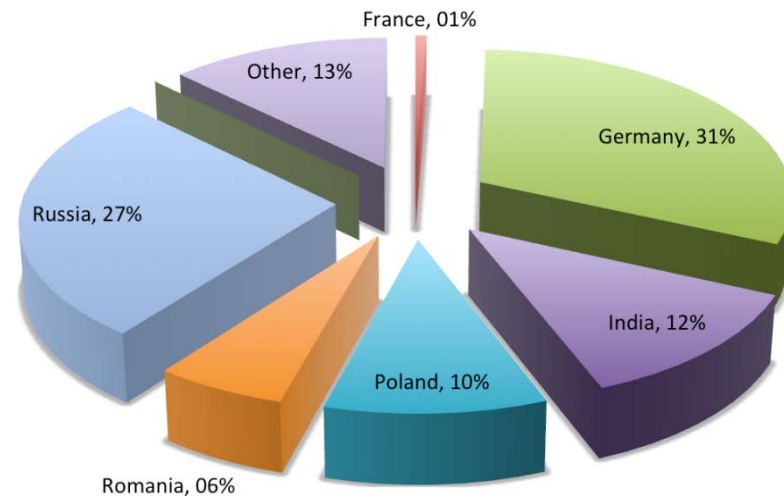
> 500 members

48 contributions to this DPG conference

26th CBM Collaboration meeting in Prague, CZ
14. -18. Sept. 2015

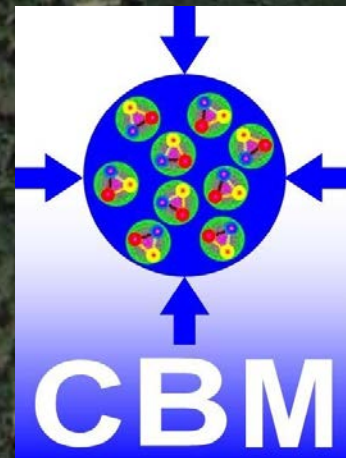


Scientist fraction, CBM



Summary

- CBM scientific program at SIS100:
Exploration of the QCD phase diagram in the region of neutron star core densities → large discovery potential
- First measurements with CBM:
High-precision multi-differential measurements of hadrons incl. multistrange hyperons, hypernuclei and dileptons for different beam energies and collision systems → terra incognita
- Status of experiment preparation:
Prototype detector performances fulfill CBM requirements
7 TDRs approved, 4 TDRs in preparation
- Timeline: According to actual schedule, CBM start version will be ready to take the first beam from SIS100 in 2022.
- FAIR phase 0 experiments:
CBM detectors will be used in HADES at GSI, STAR at RHIC, BM@N at JINR, mCBM at SIS18



Thank you