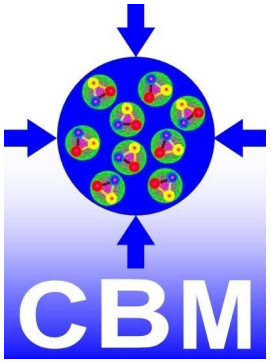
Overview of the Compressed Baryonic Matter experiment at FAIR

Viktor Klochkov

(GSI, Frankfurt University)

for the CBM Collaboration



GOETHE UNIVERSITÄT FRANKFURT AM MAIN

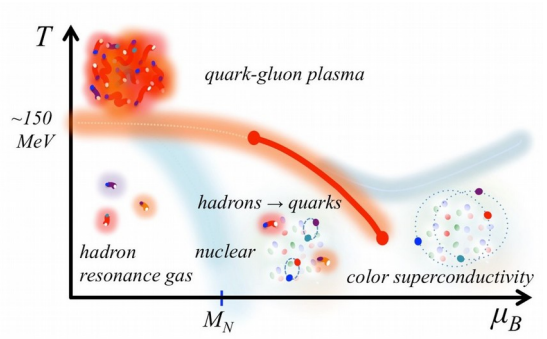
FAIR

GSI

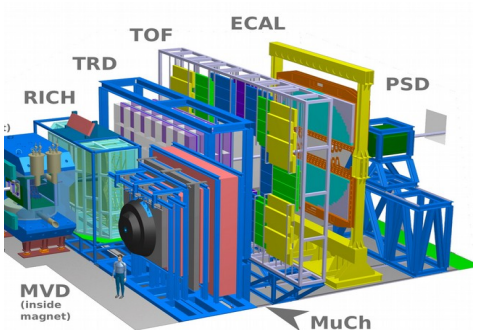
HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

Outline

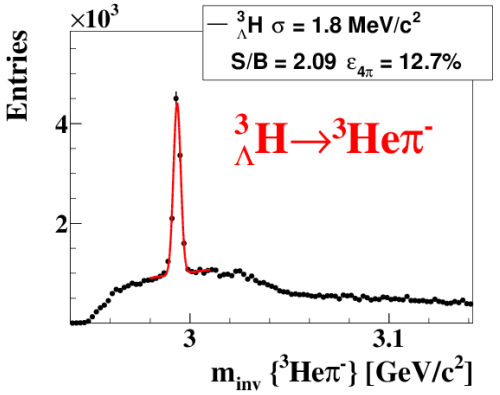
- Physics motivation



- CBM experimental setup

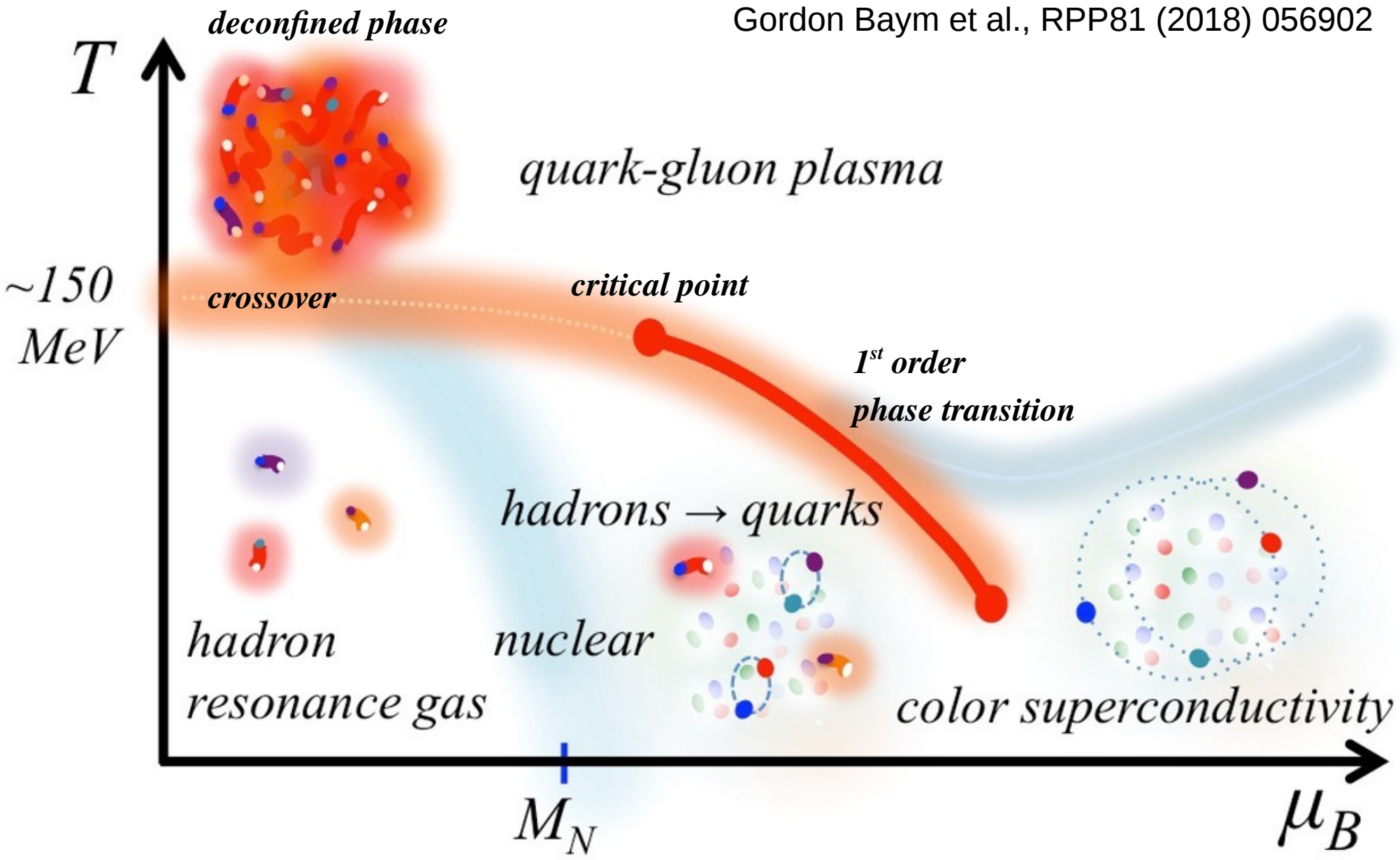


- Physics performance studies



Rich structure of the QCD matter phase diagram

Gordon Baym et al., RPP81 (2018) 056902



Rich structure of the QCD matter phase diagram

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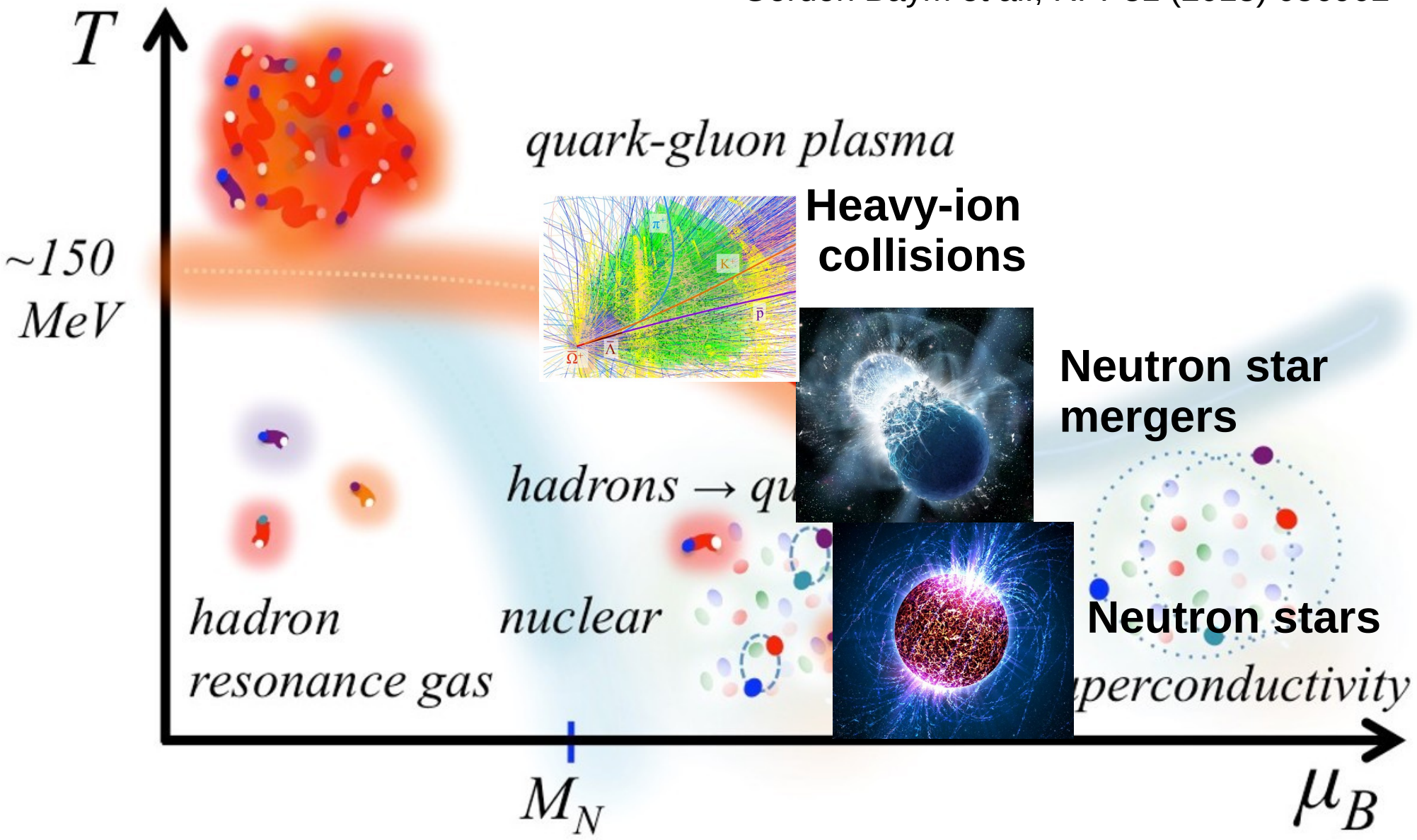
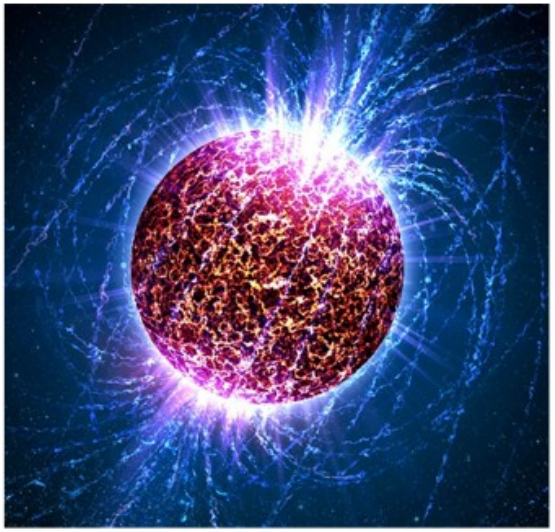
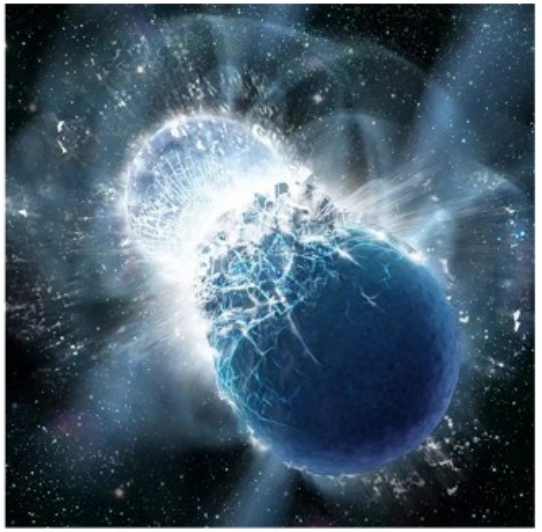
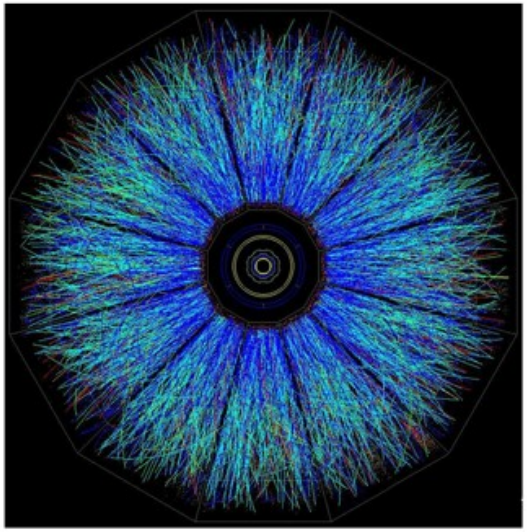
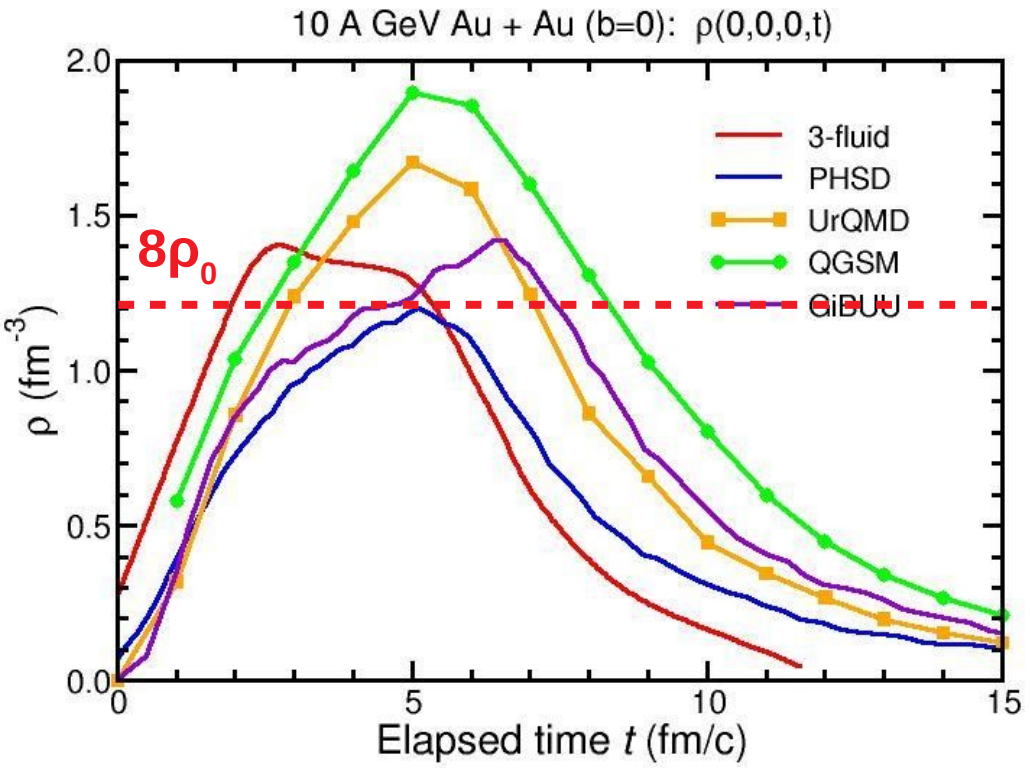


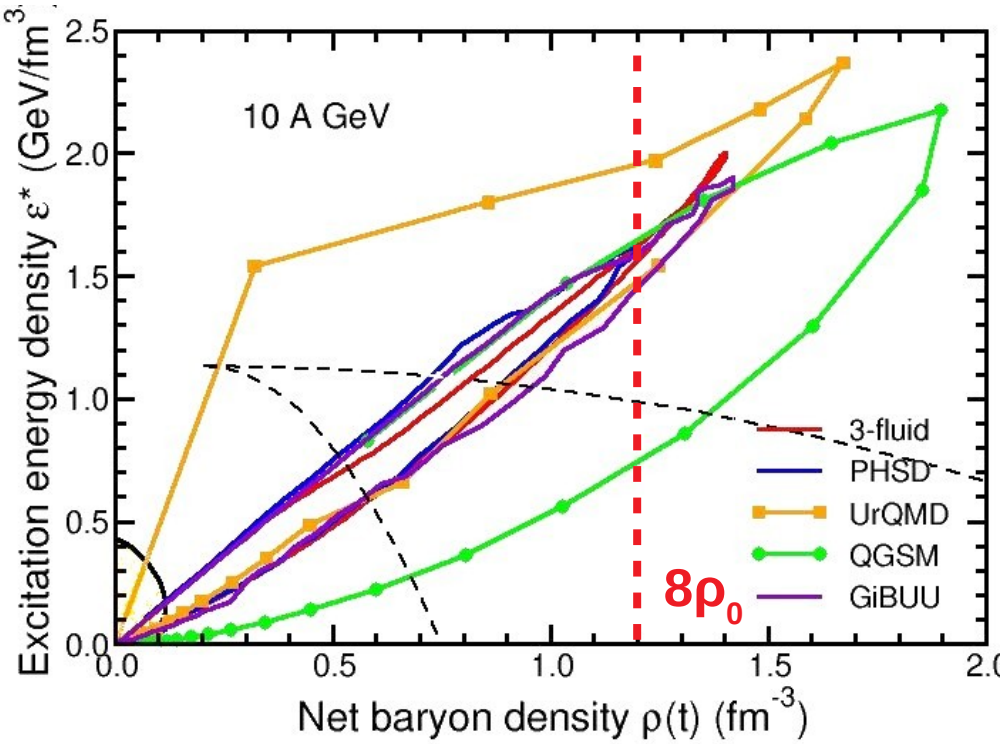
Dense Baryonic Matter

	Neutron stars	Neutron star merger	Heavy ion collisions
			
		GW170817	SIS100 energies
Temperature	T < 10 MeV	T ~ 10-100 MeV	T < 120 MeV
Density	$\rho < 10\ \rho_0$	$\rho < 2 – 6\ \rho_0$	$\rho < 5 – 15\ \rho_0$
Lifetime / Reaction time	~ infinity	T ~ 10 ms	$t \sim 10^{-23}$ s

Net-baryon density at SIS100 FAIR energies

I. Arsene et al. PRC75 034902 (2007)

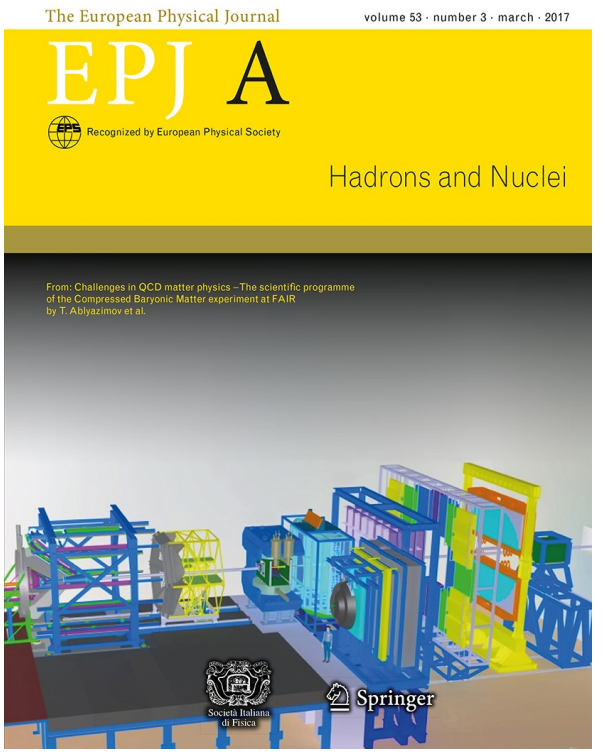




High baryon densities during system evolution!

CBM physics and observables

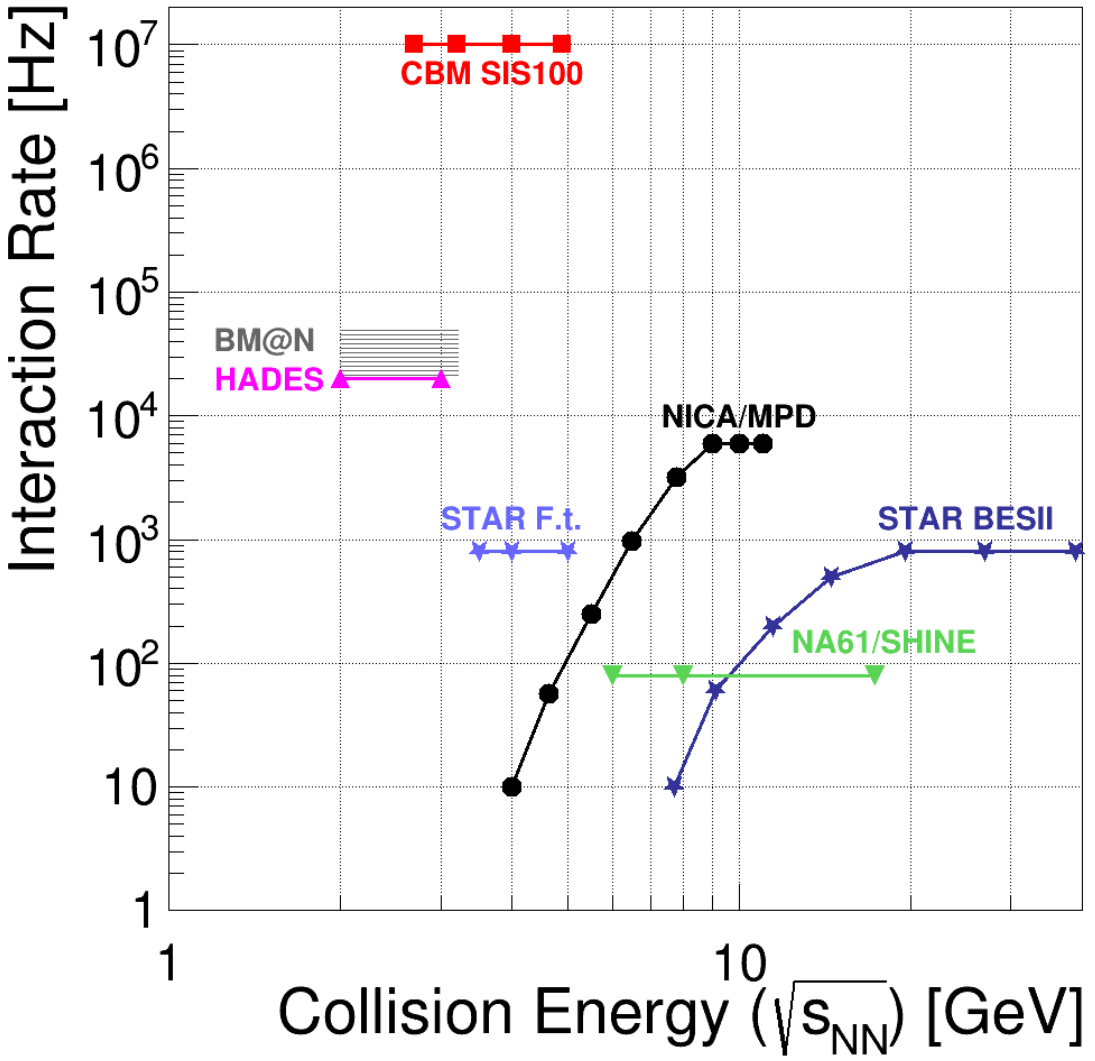
- Quark matter equation-of-state at large baryon densities, coexistence (quarkyonic) & partonic phases:
  - Hadron yields, collective flow, correlations, fluctuations
  - (Multi-)strange hyperons (K, Λ, Σ, Ξ, Ω)
  - production at (sub)threshold energies
- Chiral symmetry at large baryon densities
  - In-medium modifications of light vector mesons
  - ρ, ω, φ → $e^+ + e^-$ ($\mu^+ + \mu^-$) via dilepton measurements
- Hypernuclei
- Charm production and propagation at threshold energies
  - Excitation function in p+A collisions (J/ψ, D^0 , D^{+-})
  - Charmonium suppression in cold nuclear matter



https://inspirehep.net/record/1474181

Experiments in the high net-baryon density

CBM collab., EPJA 53 (2018) 60

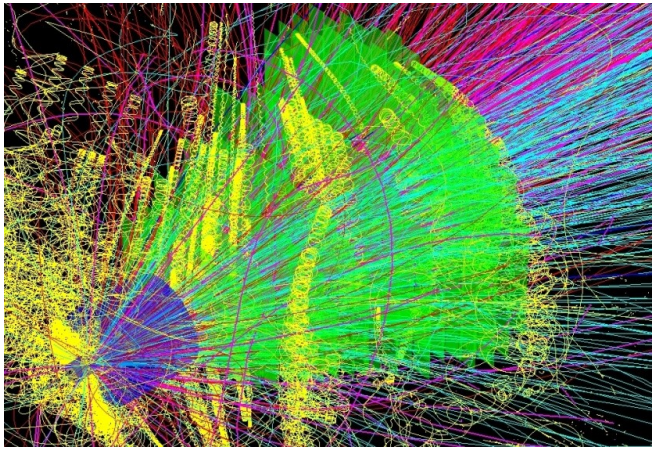


CBM will operate at high reaction rates: 10^5 - 10^7 Au+Au collisions/sec!

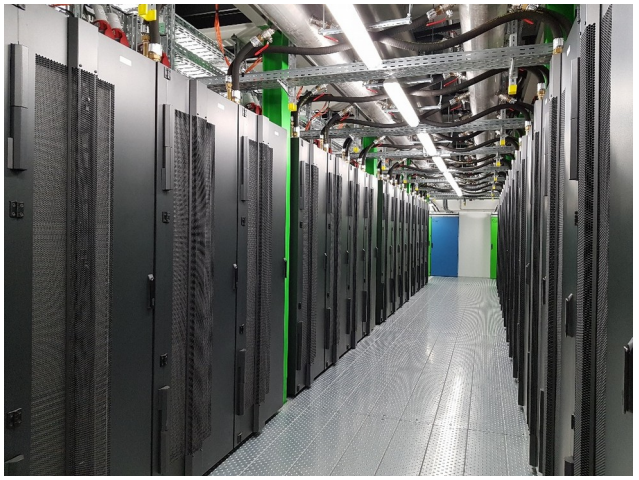
Main experimental requirements

- High statistics needs high event rates:
  10^5 - 10^7 Au+Au collisions/sec
- Fast, radiation hard detectors
  & front-end electronics
- Free-streaming readout & 4 dimensional (space+time) event reconstruction
- Particle identification: hadrons and leptons, displaced (~50 μm) vertex reconstruction for charm measurements
- High speed data acquisition & performance computing farm for online event selection

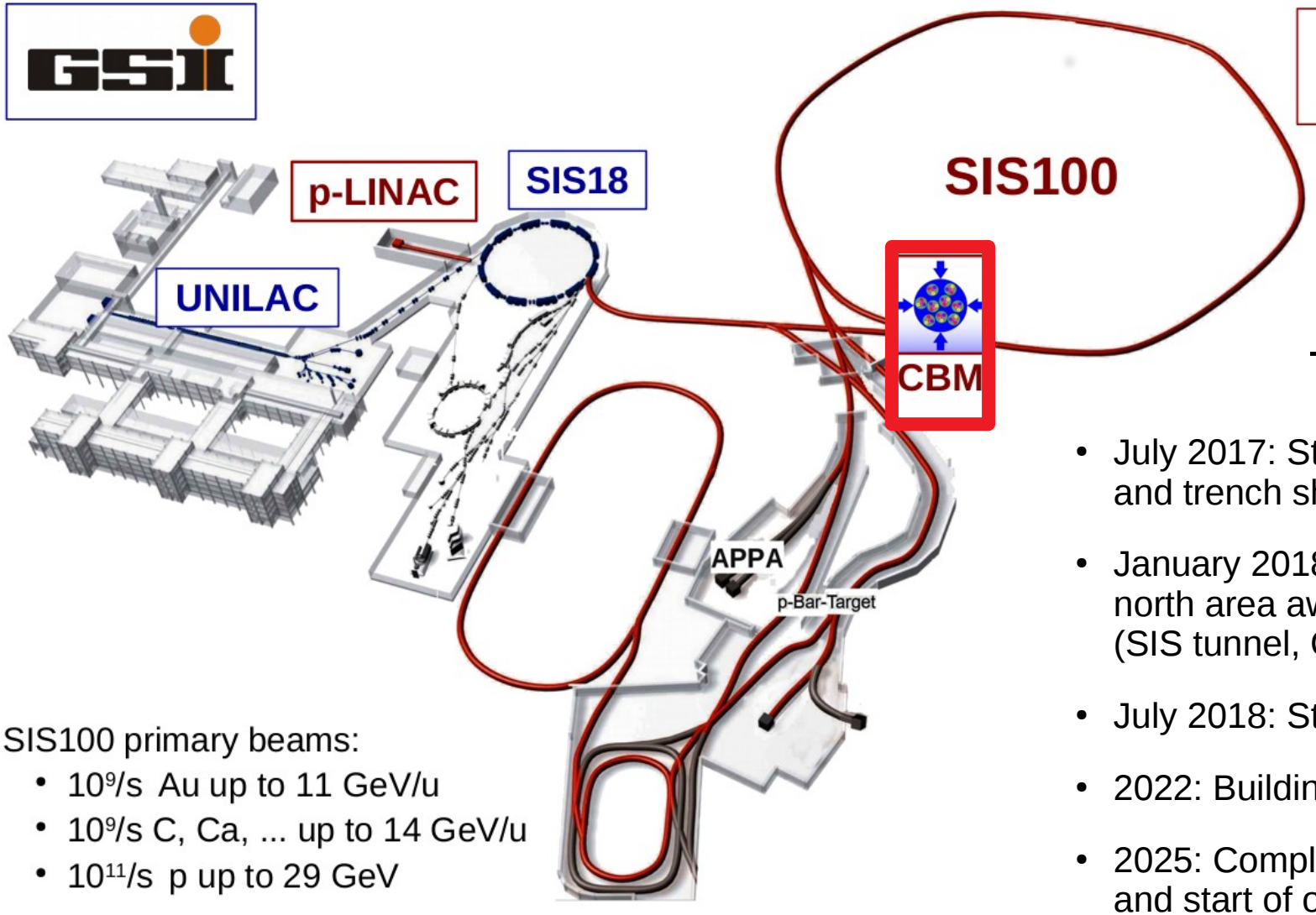
central Au+Au collision @ 10*A* GeV/*c*



GSI IT Center



CBM at FAIR, Darmstadt



SIS100 primary beams:

- 10^9/s Au up to 11 GeV/u
- 10^9/s C, Ca, ... up to 14 GeV/u
- 10^{11}/s p up to 29 GeV

Timeline

- July 2017: Start of excavation and trench sheeting
- January 2018: Civil construction north area awarded (SIS tunnel, CBM building)
- July 2018: Start of shell construction
- 2022: Buildings completed
- 2025: Completion of full facility and start of operations

More details: P. Giubellino, “FAIR Scientific Program”, today 14:00

CBM area excavation

CBM detector subsystems

STS

Silicon Tracking System*

MVD

Micro Vertex Detector*

* magnetic field

MuCh or RICH

MuonChamber System/
Ring Imaging Cherenkov
Detector

TRD

Transition Radiation
Detector

ToF

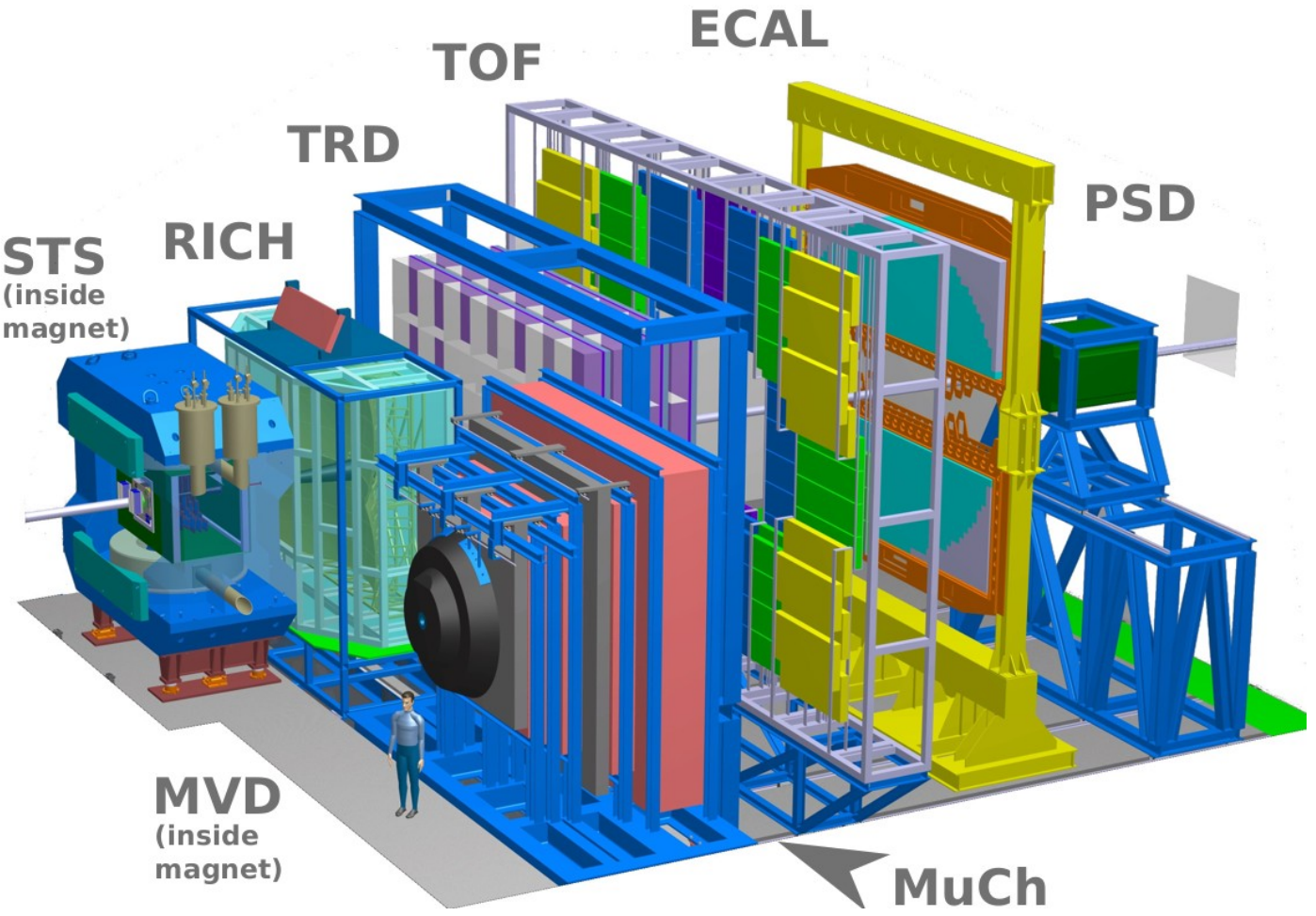
Time-of-Flight Detector

ECAL

Electromagnetic
Calorimeter

PSD

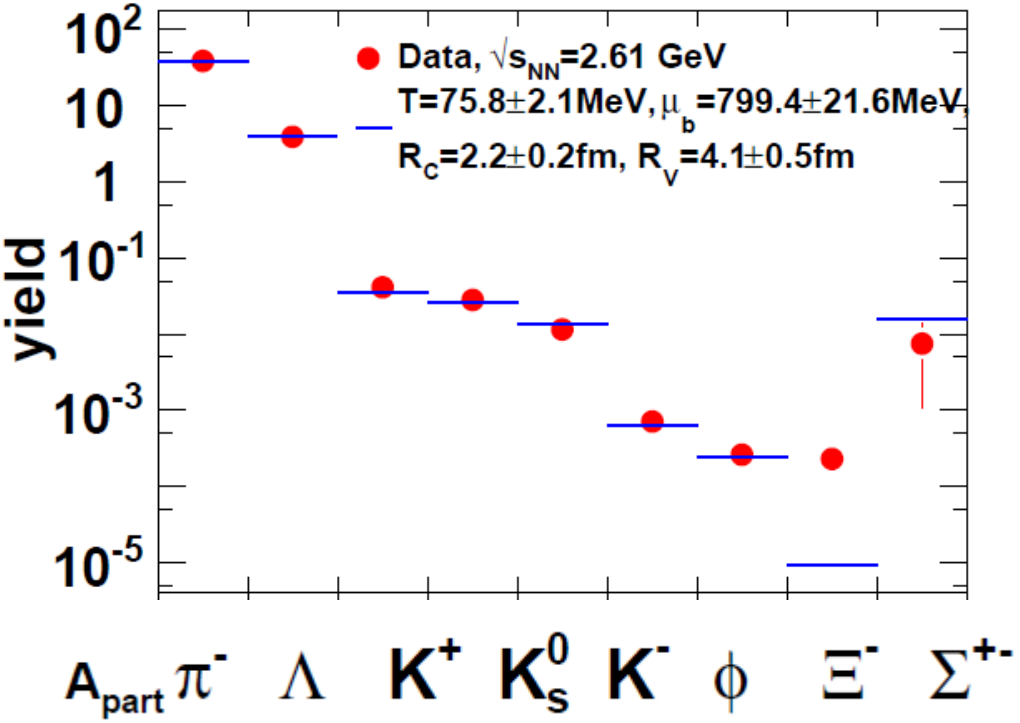
Projectile Spectator
Detector



More details about STS:
E. Lavrik, “The Silicon Tracking System of the CBM Experiment at FAIR”, today 17:05

Needed components for physics analysis

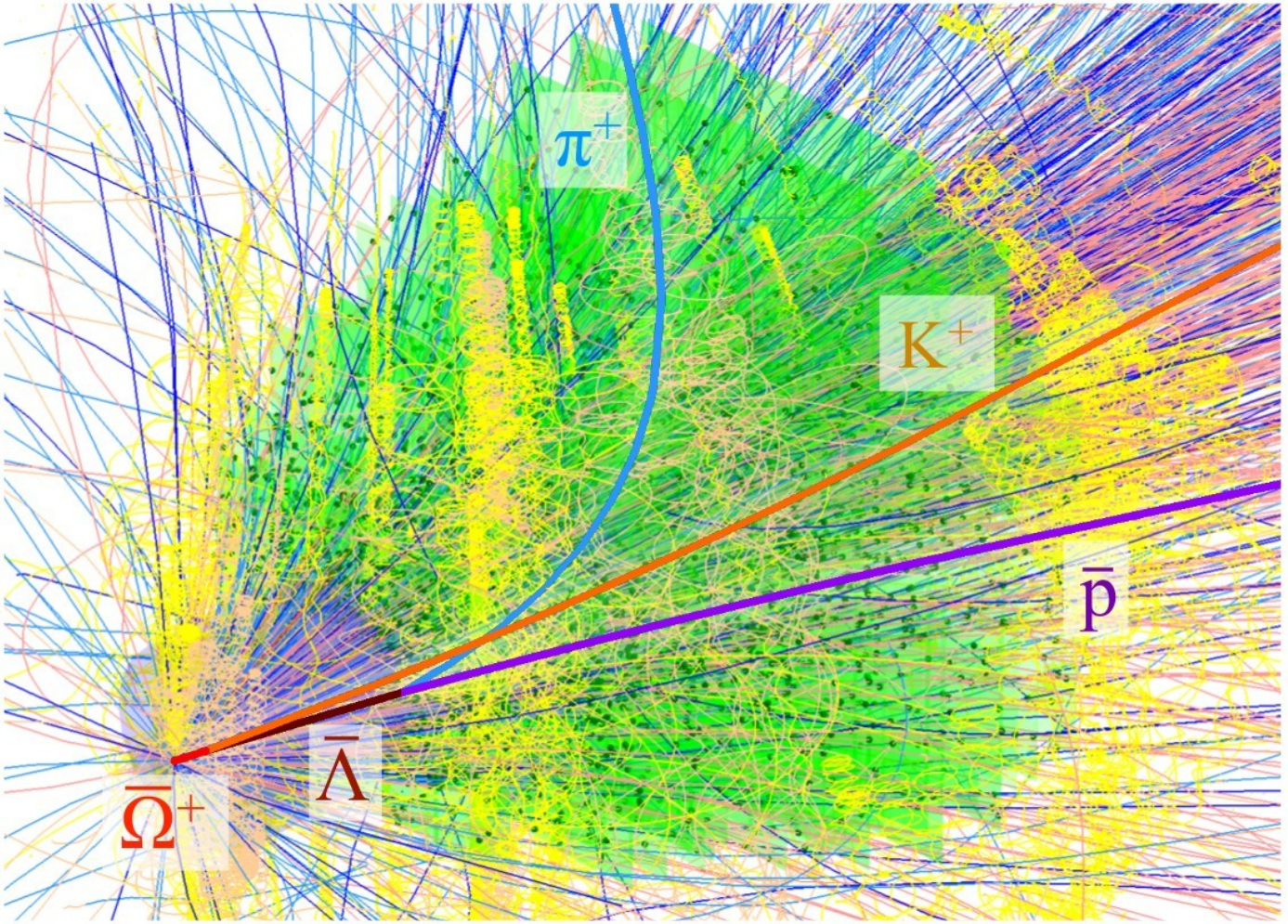
HADES data



- Displaced vertex reconstruction
- Particle identification
  - charged hadrons
  - electrons / muons
- Collision centrality

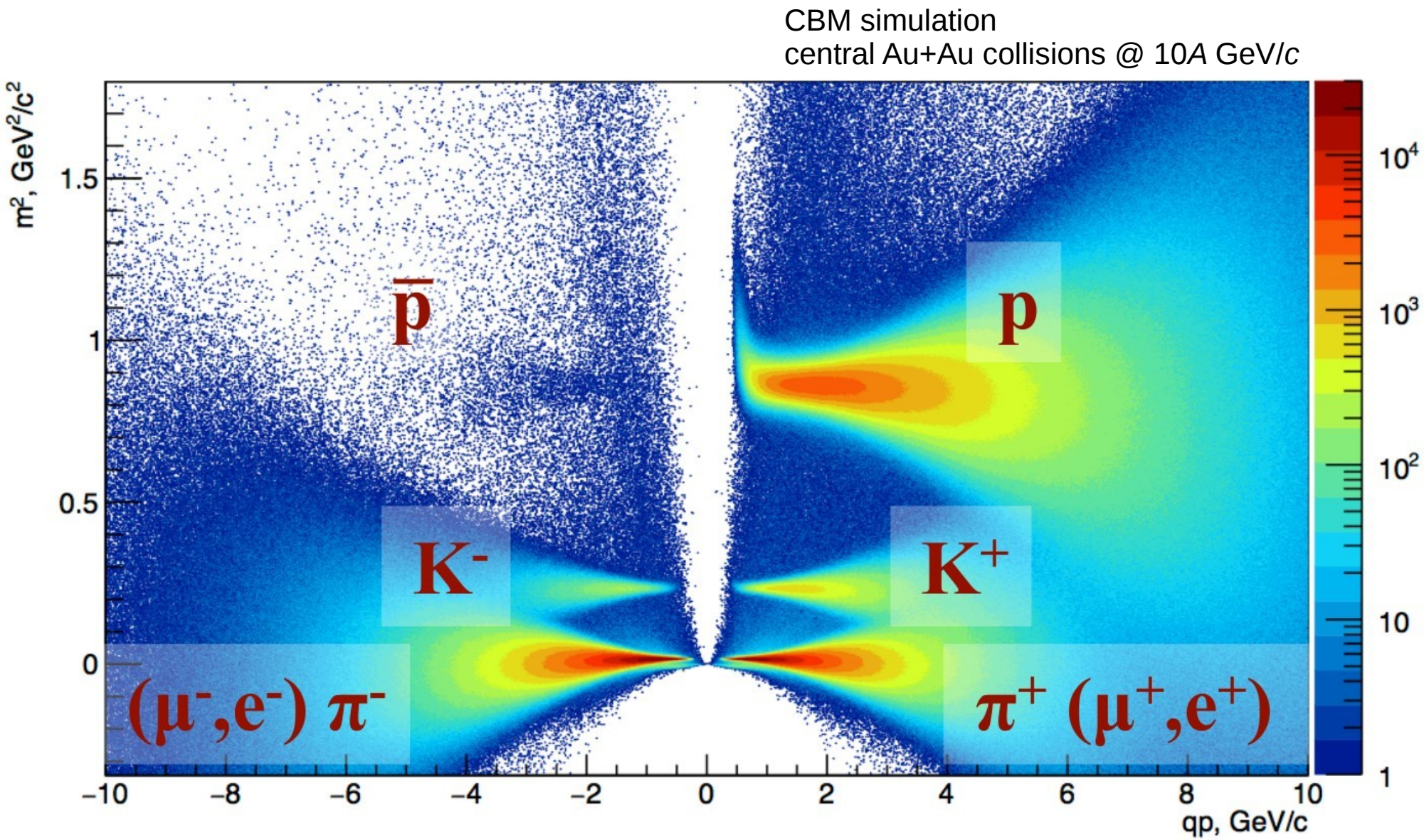
Challenges of event and track reconstruction in CBM

CBM simulation
central Au+Au collision @ 10*A* GeV/*c*



- High multiplicity collisions
- Events in the selected time window (time slice) will overlap in time
- High interaction rate → reconstruction will be in 4D (space, time)
- Decay topology reconstruction

Particle identification: light hadrons

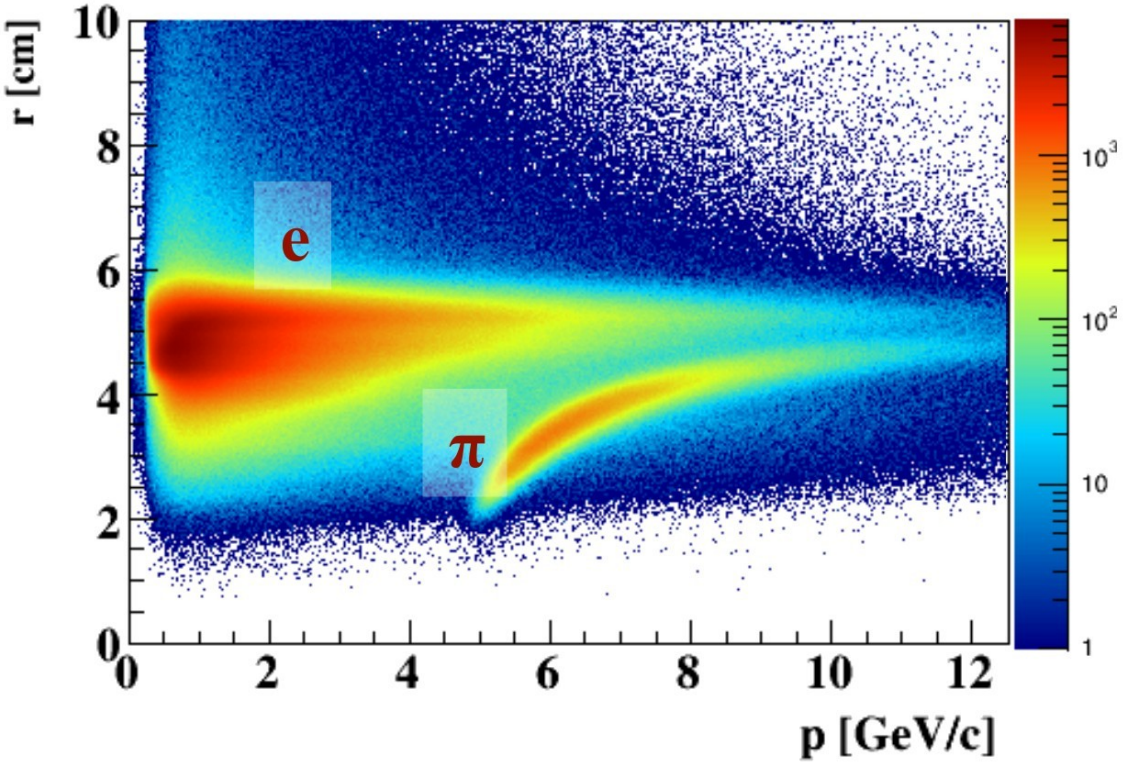


Clear separation between charged protons, pions and kaon

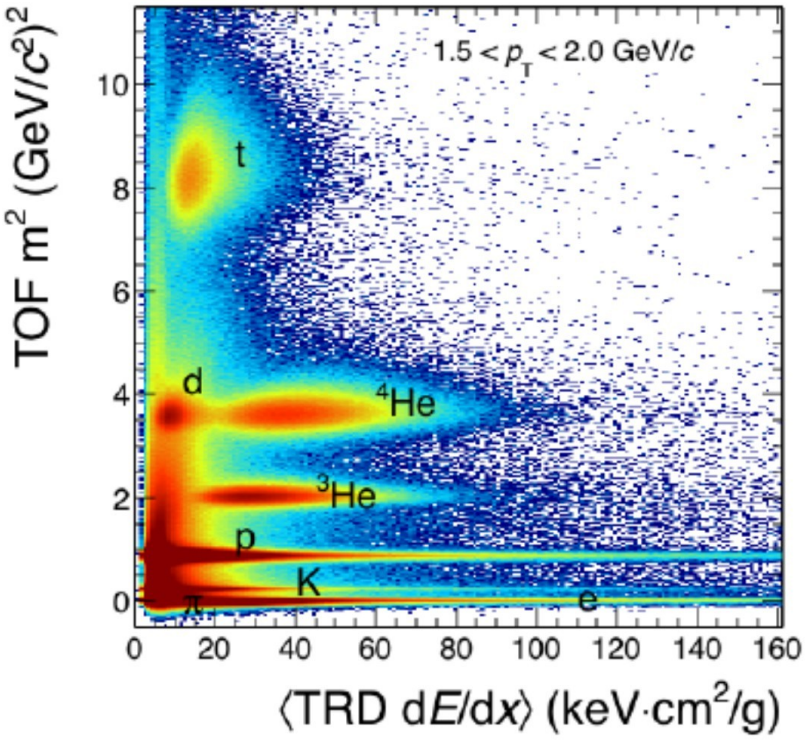
Particle identification: electrons and light nuclei

CBM simulation
central Au+Au collision
10*A* GeV/*c*

RICH (electrons)



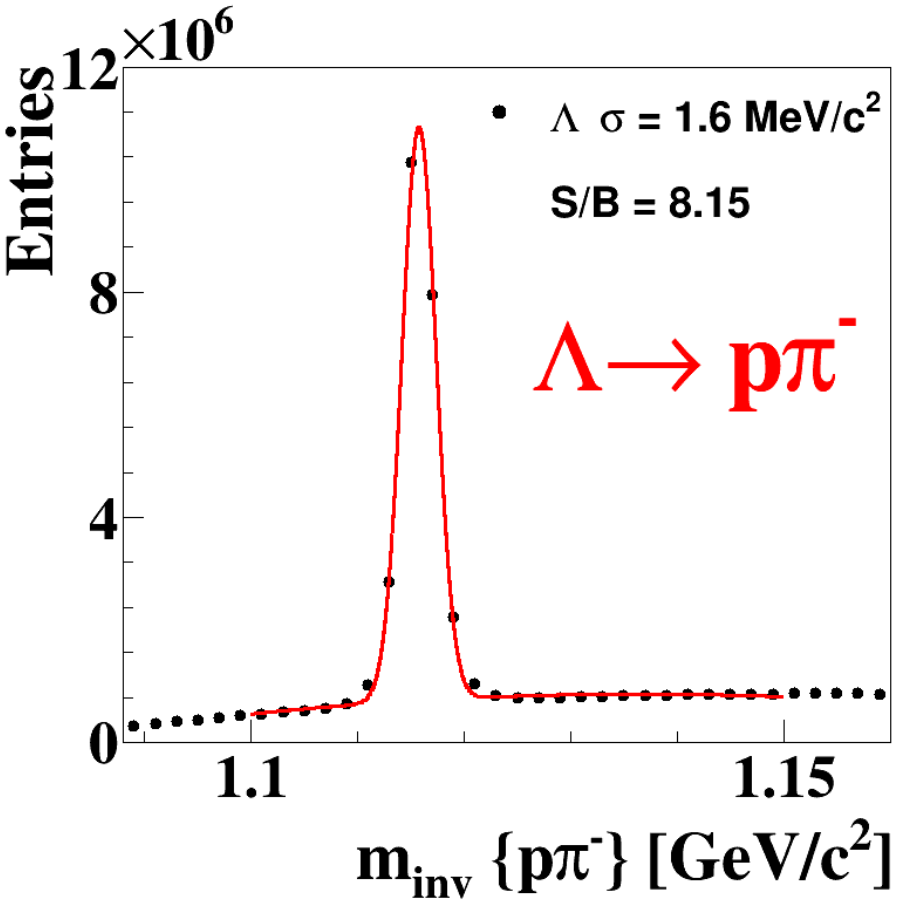
TRD+TOF

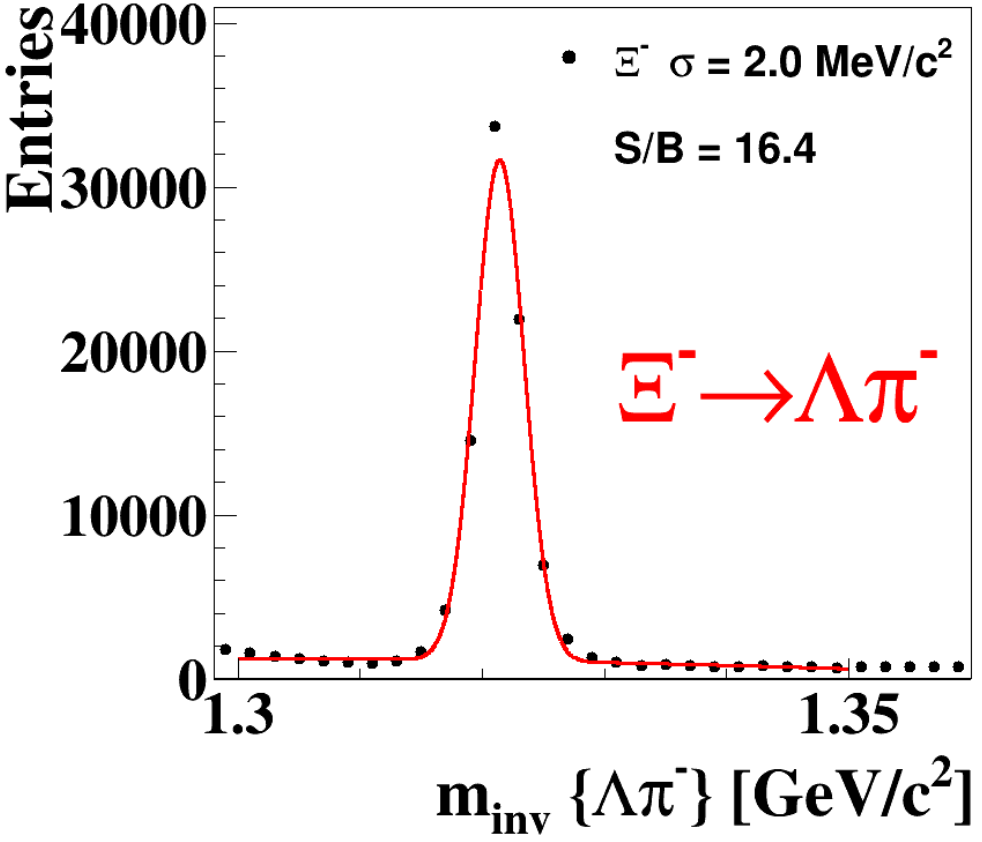


Clear separation between pions and electrons, and light nuclei

Multi-strange reconstruction

CBM simulation
UrQMD, Au+Au @ 10*A* GeV/*c*, central, 5M events

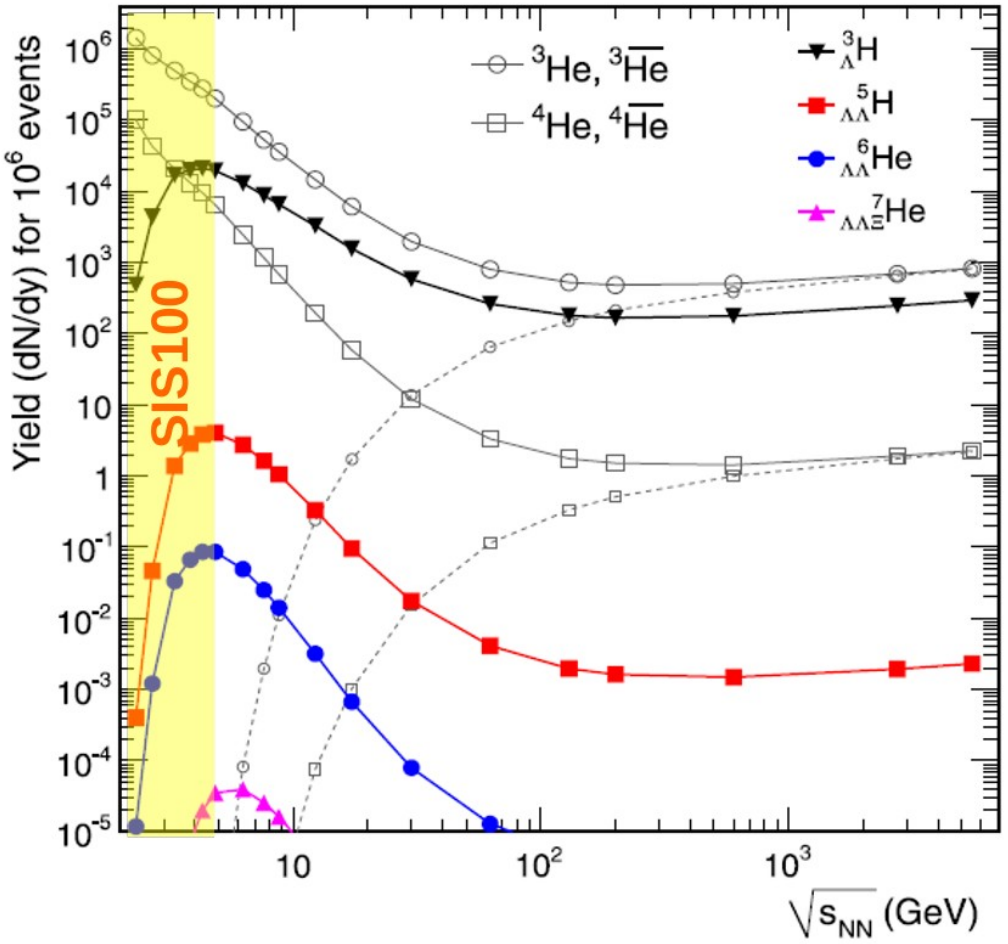




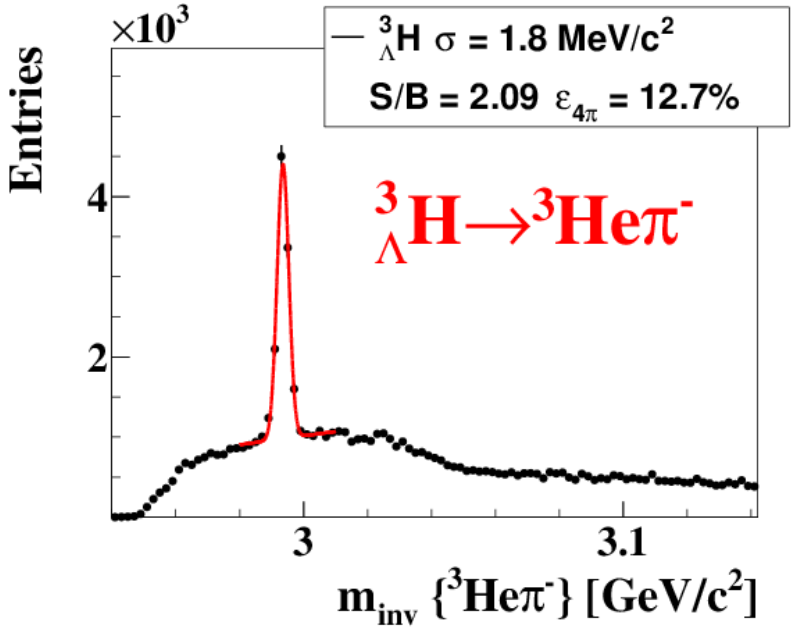
Decay topology reconstruction
using the KFParticleFinder package

Hypernuclei

A. Andronic, PLB697 203 (2011)



CBM simulation
Au+Au 10*A* GeV/*c*
minbias
5M events

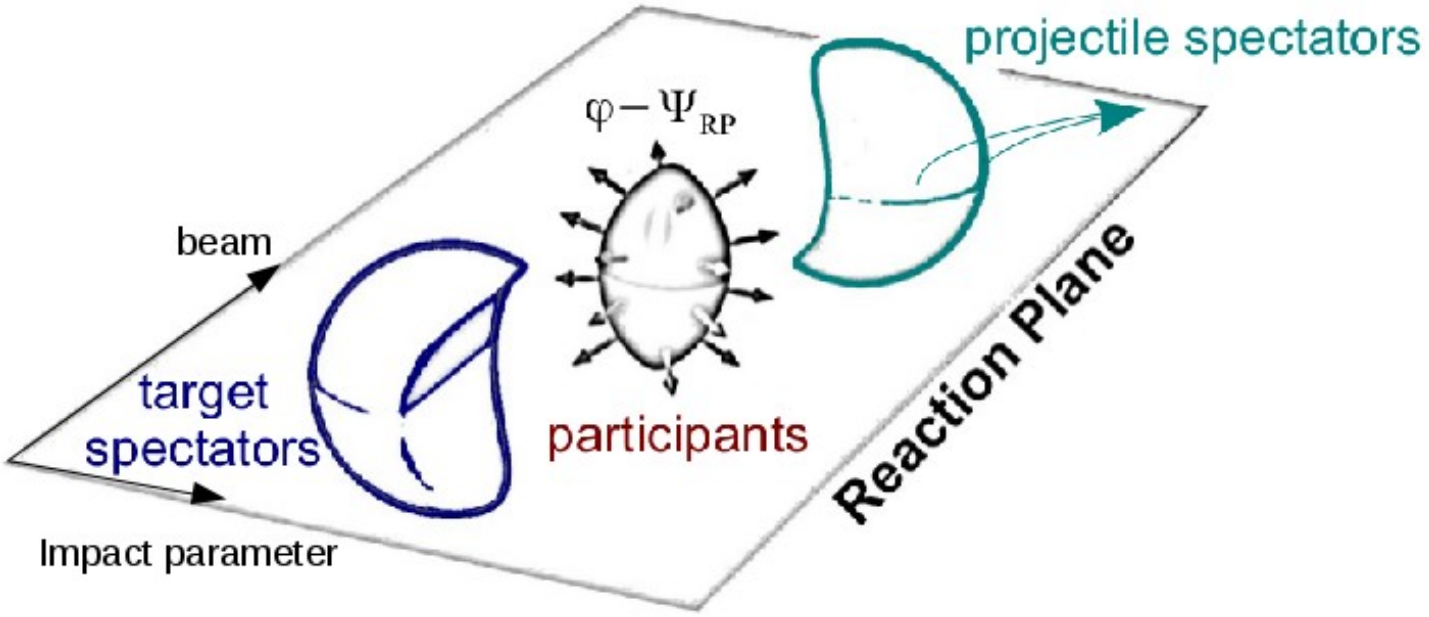


CBM physics cases

- Λ-N, Λ-Λ interaction
- (Double-)lambda hypernuclei
- Meta-stable strange states

Anisotropic flow

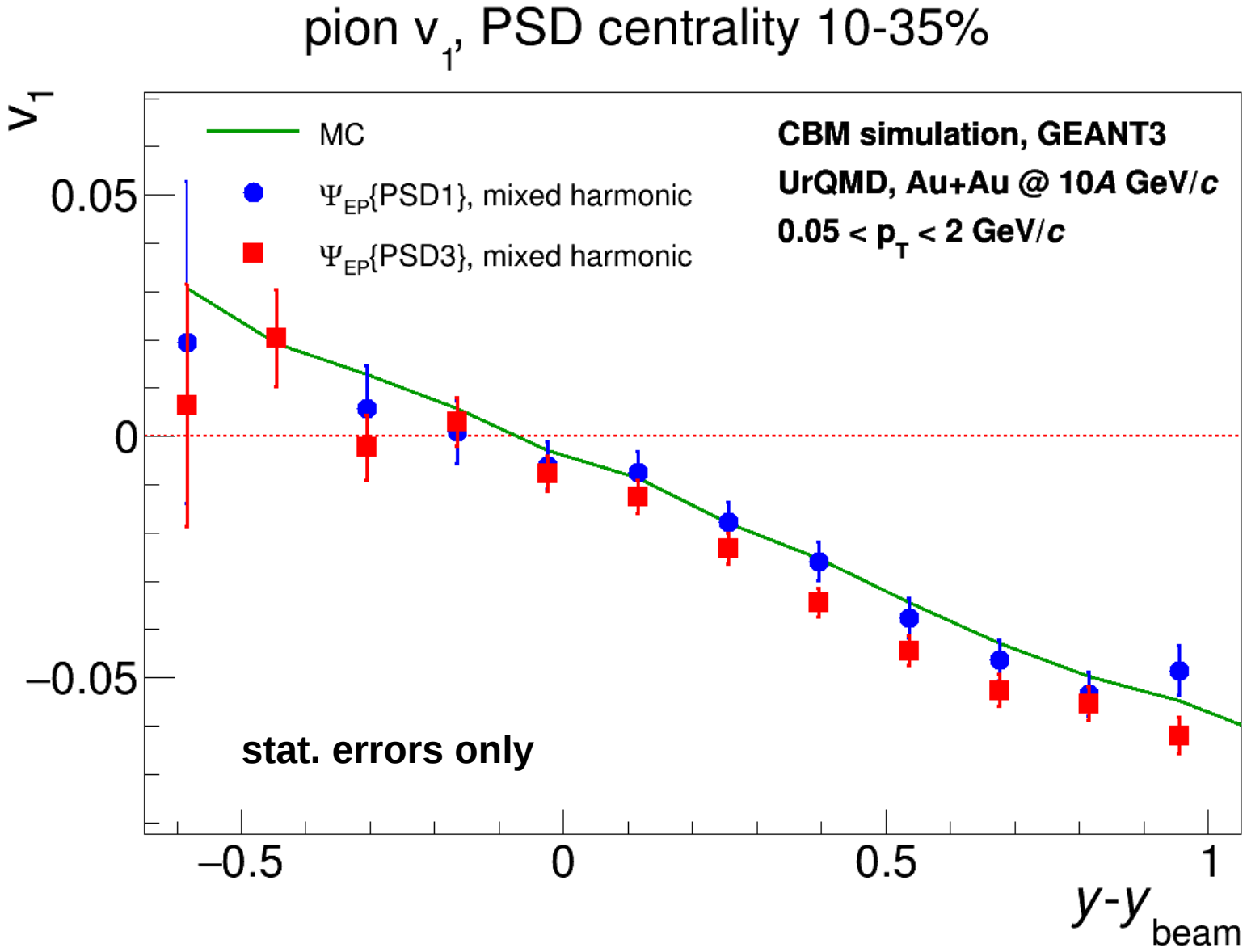
Asymmetry in coordinate space converts due to interaction into momentum asymmetry with respect to the symmetry plane (reaction plane - RP)



$$\rho(\varphi - \Psi_{RP}) = \frac{1}{2\pi}\left(1 + 2\sum_{n=1}^{\infty} v_n \cos\left(n(\varphi - \Psi_{RP})\right)\right)$$

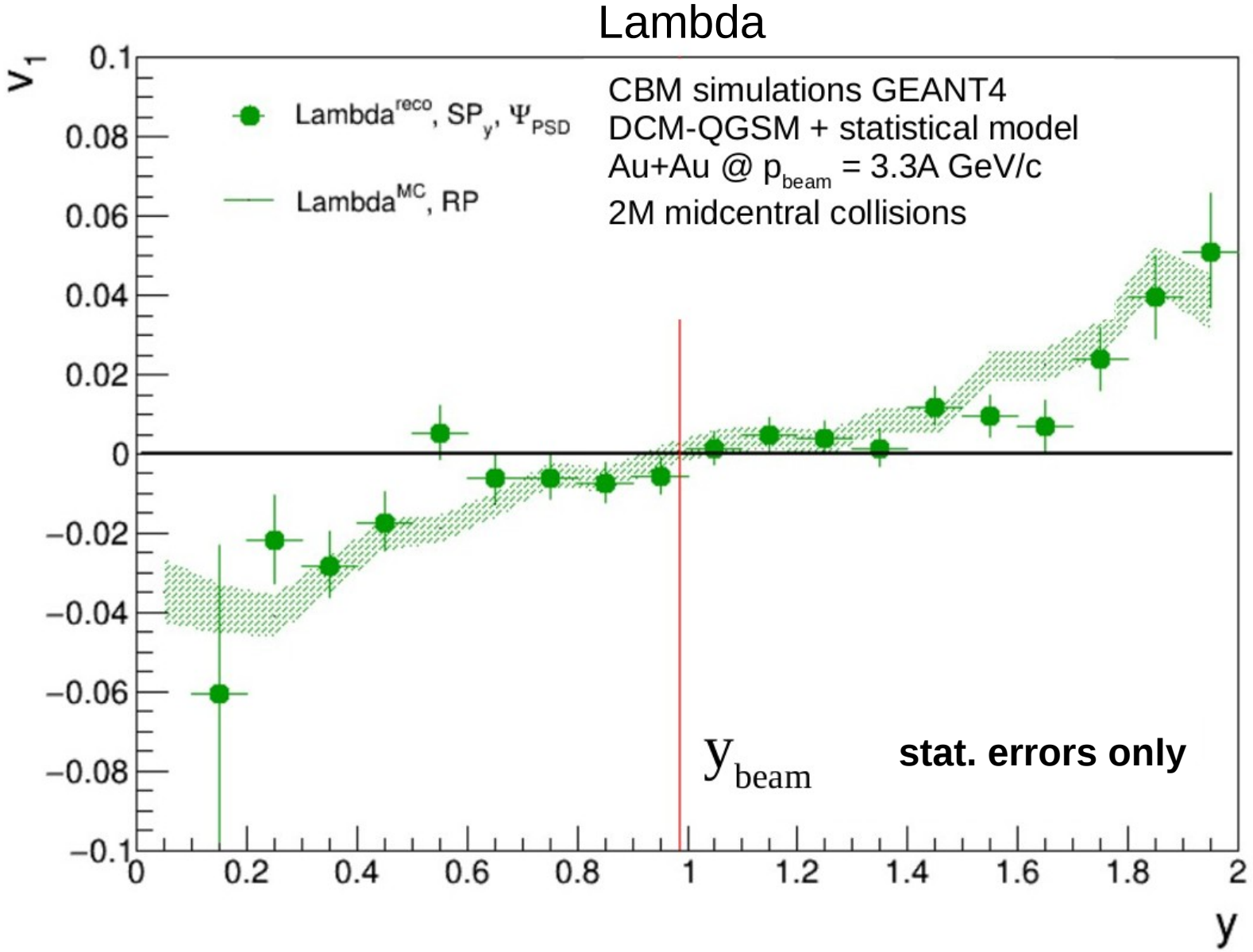
$$v_n = \langle \cos[n(\varphi - \Psi_{RP})] \rangle$$

Performance for directed flow (v_1)



"input" model v_1 is recovered using "data-driven" method

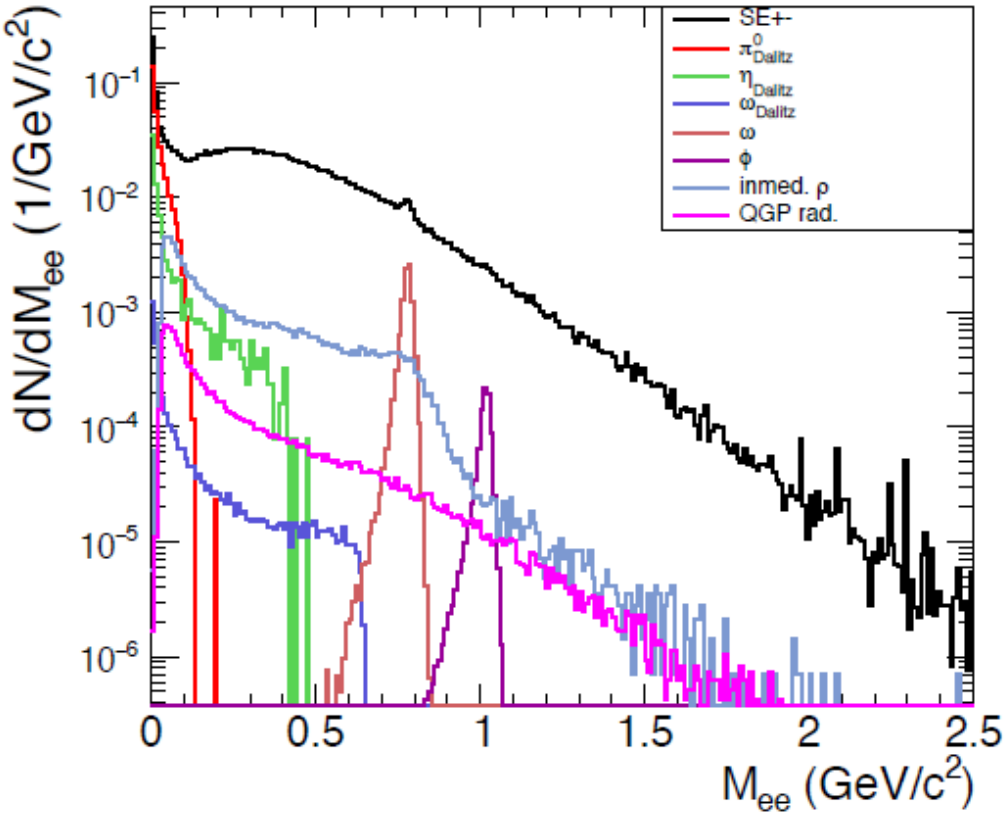
Performance for directed flow (v_1)



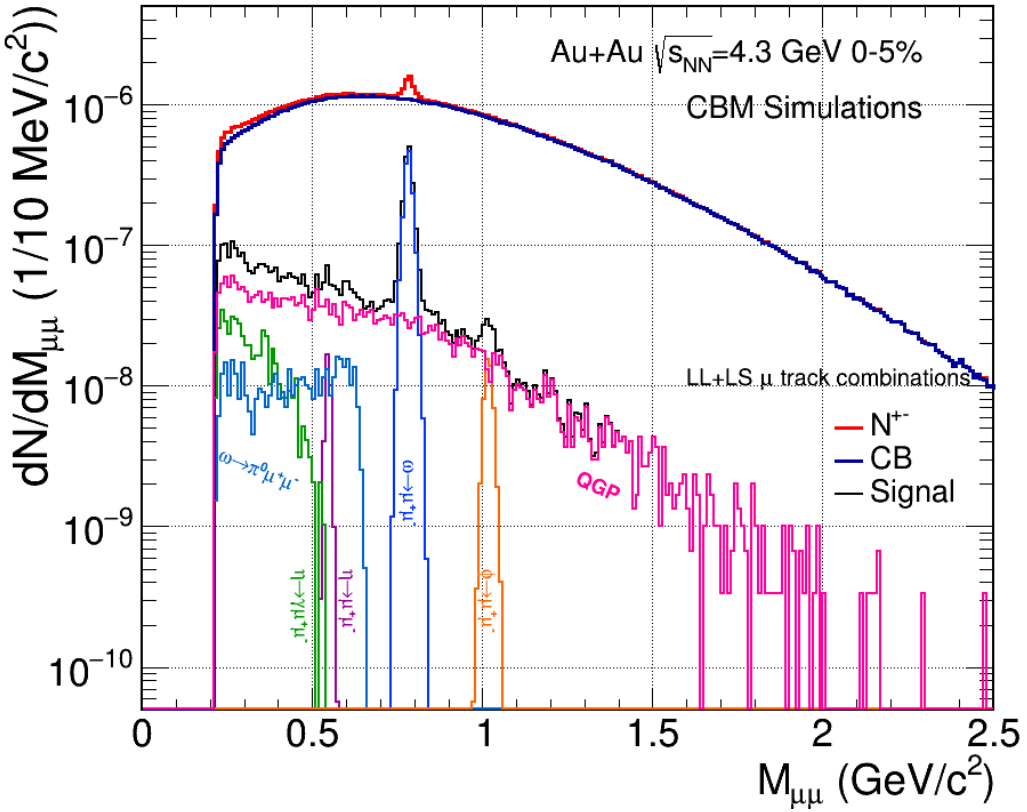
"input" model v_1 is recovered using "data-driven" method

Dilepton measurements: e^+e^- and $\mu^+\mu^-$

di-electrons



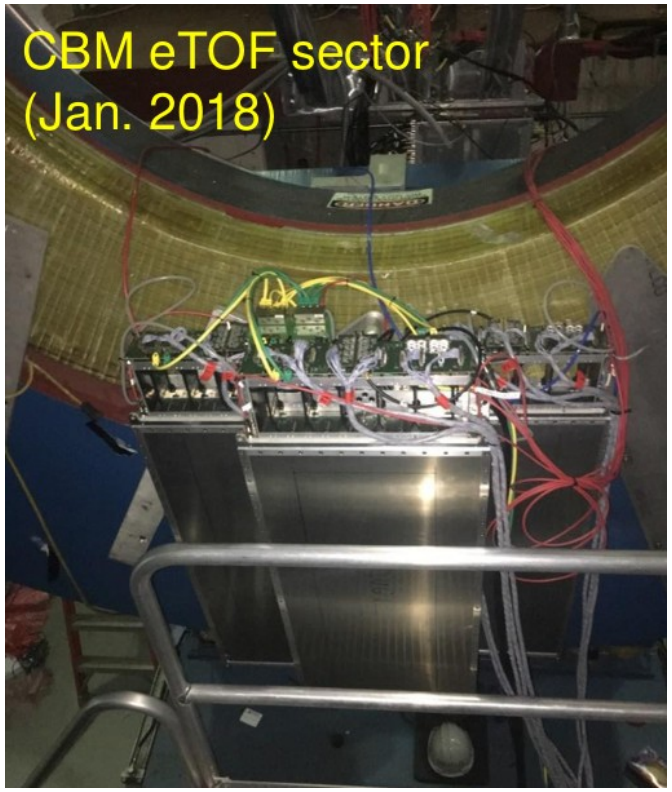
di-muons



- In-medium modifications of light vector mesons
- ρ, ω, φ → $e^+ + e^-$ ($\mu^+ + \mu^-$) via dilepton measurements

CBM FAIR phase-0 program
(before the start of operation in 2025)

CBM TOF modules @ STAR



PSD at BM@N

mini CBM @ GSI/SIS18

- Use 430 out of 1100 CBM RICH multi-anode photo-multipliers (MAPMT) in HADES
- 4 Silicon Tracking Stations in the BM@N in JINR (start 2020 with Au-beams up to 4.5*A* GeV)
- Tests and performance studies at the NA61/SHINE experiment @ CERN SPS

Summary

- CBM physics program at SIS100:
  - Precision study of the QCD phase diagram in the region of extremly high net-baryon densities
- Key experimental requirements:
  - high-rate capability of detectors and DAQ
  - online event reconstruction and selection
- Unique measurements of bulk & rare probes with CBM:
  - collective effects
  - event-by-event fluctuations
  - strangeness
  - lepton pairs
  - charm
  - hypernuclei and strange objects

The CBM Collaboration: 55 institutions, 470 members

China
CCNU Wuhan
Tsinghua Univ.
USTC Hefei
CTGU Yichang

Czech Republic
CAS, Rez
Techn. Univ.Prague

France
IPHC Strasbourg

Hungary
KFKI Budapest
Budapest Univ.

Germany
Darmstadt TU
FAIR
Frankfurt Univ. IKF
Frankfurt Univ. FIAS
Frankfurt Univ. ICS
GSI Darmstadt
Giessen Univ.
Heidelberg Univ. P.I.
Heidelberg Univ. ZITI
HZ Dresden-Rossendorf
KIT Karlsruhe
Münster Univ.
Tübingen Univ.
Wuppertal Univ.
ZIB Berlin

India
Aligarh Muslim Univ.
Bose Inst. Kolkata
Panjab Univ.
Univ. of Jammu
Univ. of Kashmir
Univ. of Calcutta
B.H. Univ. Varanasi
VECC Kolkata
IOP Bhubaneswar
IIT Kharagpur
IIT Indore
Gauhati Univ.

Korea
Pusan Nat. Univ.

Romania
NIPNE Bucharest
Univ. Bucharest

Poland
AGH Krakow
Jag. Univ. Krakow
Warsaw Univ.
Warsaw TU

Russia
IHEP Protvino
INR Troitzk
ITEP Moscow
Kurchatov Inst., Moscow
VBLHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
PNPI Gatchina
SINP MSU, Moscow

Ukraine
T. Shevchenko Univ. Kiev
Kiev Inst. Nucl. Research

32th CBM Collaboration Meeting, 1-5 October 2018, GSI, Darmstadt