Status and physics program of the CBM experiment at FAIR

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(GSI / EMMI / MEPhI)

for the CBM Collaboration

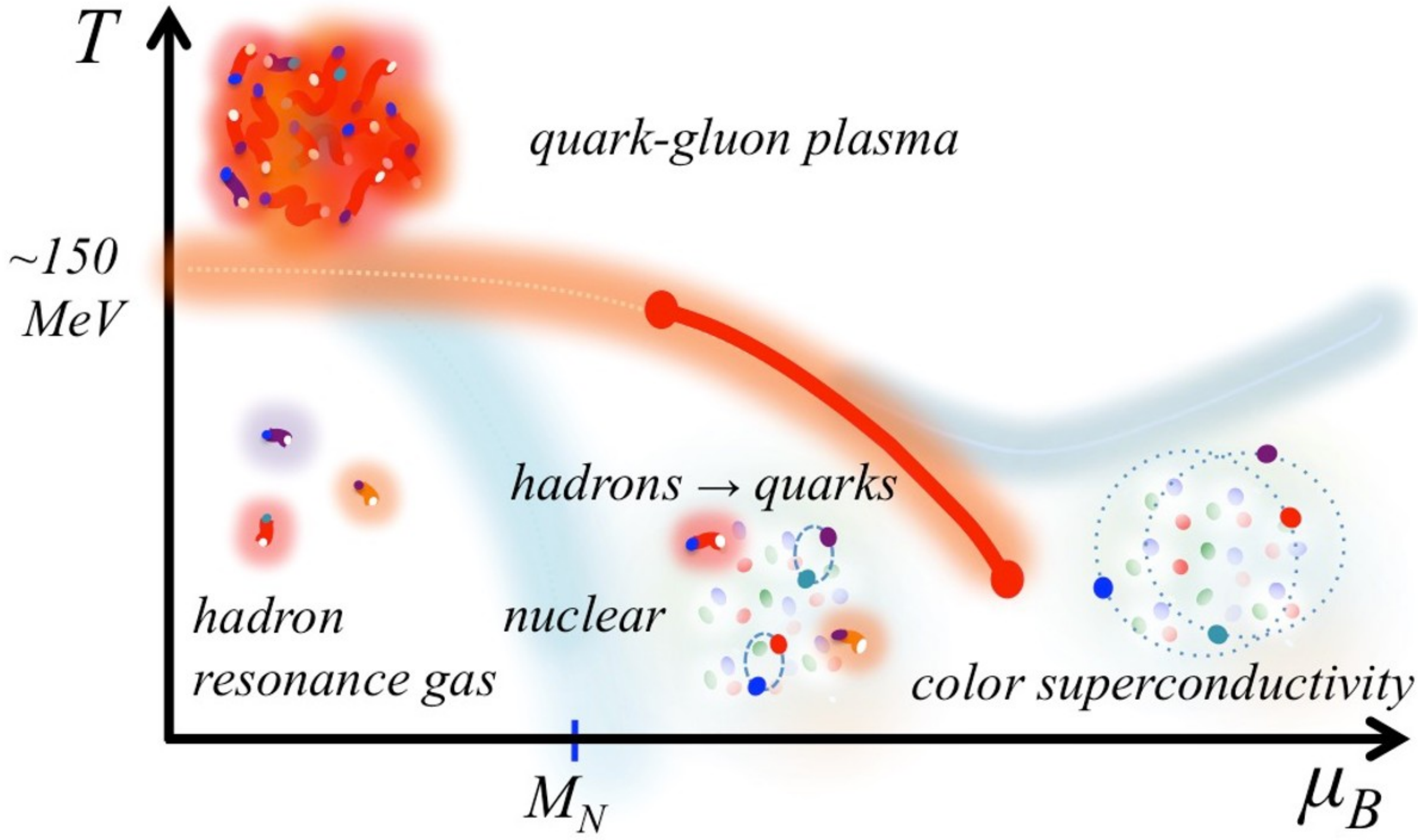
CBM physics symposium

GSI, Darmstadt

October 3, 2018

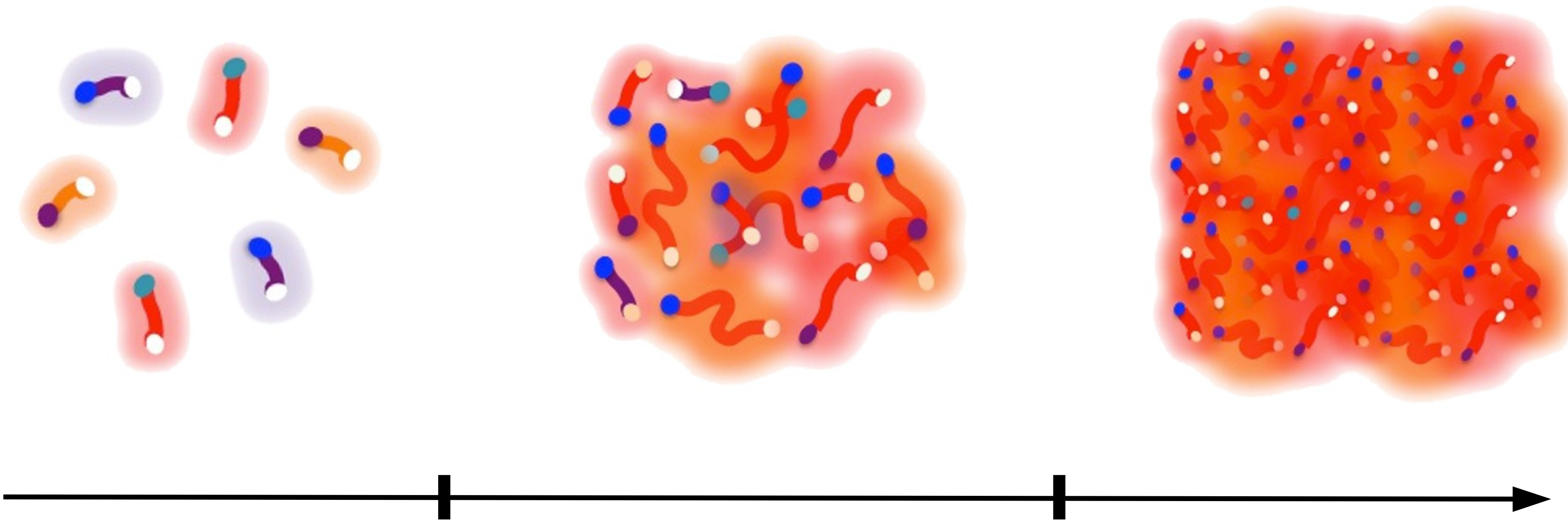
Rich structure of the QCD matter phase diagram

Gordon Baym et al., RPP81 (2018) 056902



Crossover phase transition at high T and small μ_b

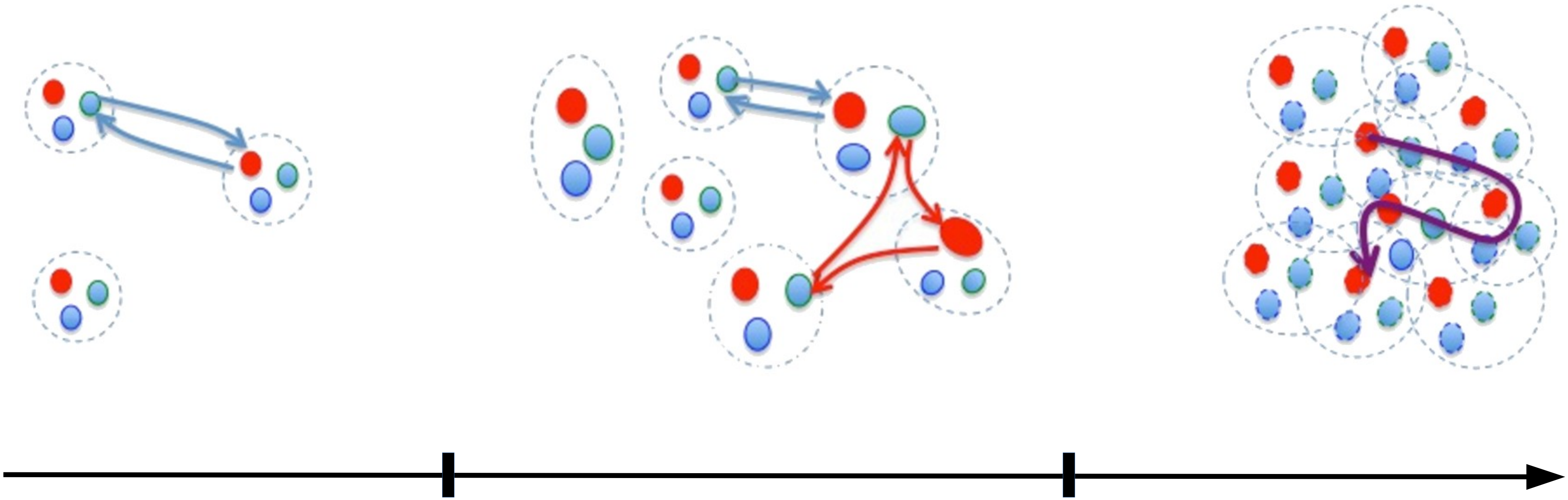
Hadron resonance gas | “semi” quark-gluon plasma | quark-gluon plasma



T_c ~ 150 MeV | ~ (2-3)T_c

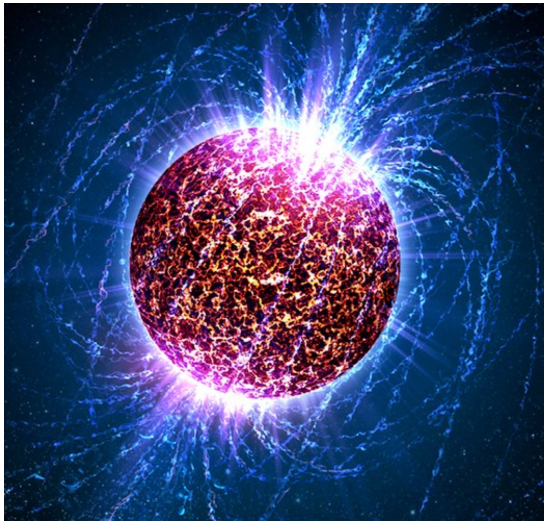
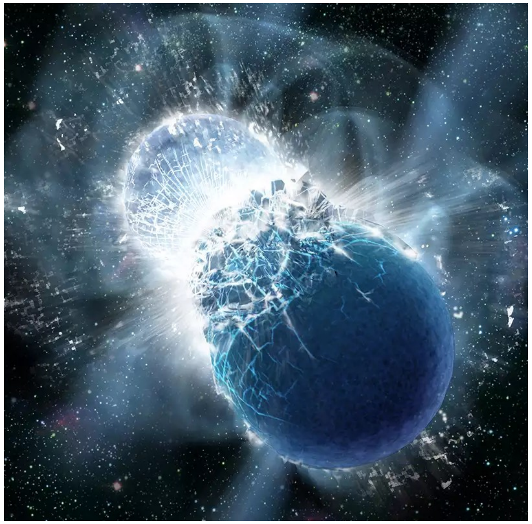
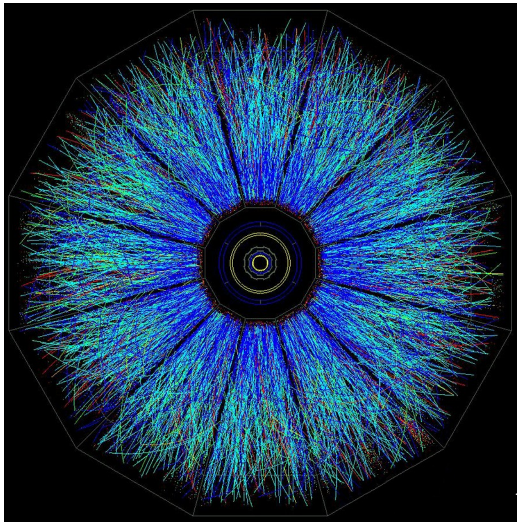
Phase transition with increasing density at high μ_b

Nuclear matter | Matter compression | Quarkyonic matter

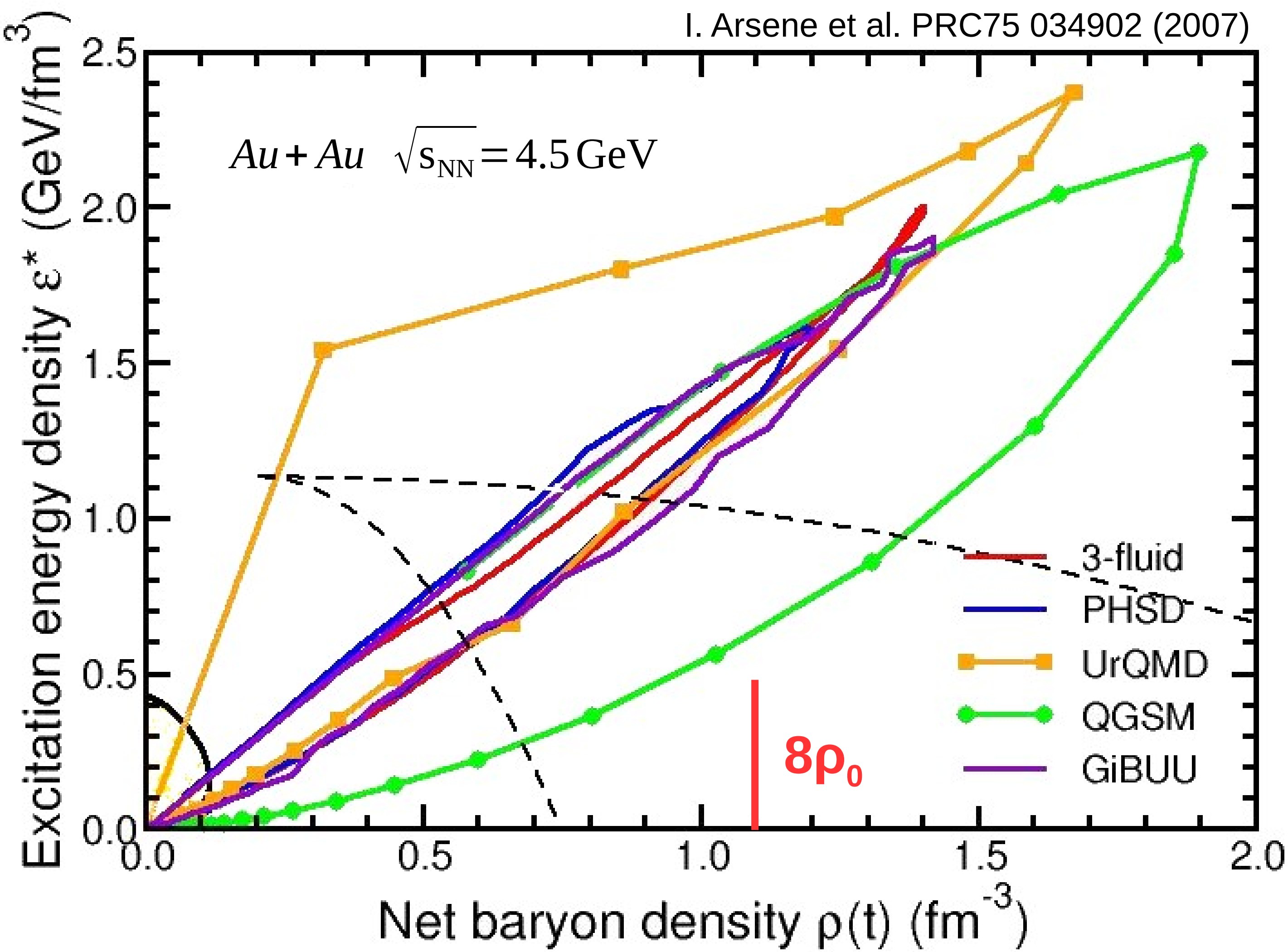


$\sim 2n_0 = 2 \times 0.16\ \mathrm{fm}^{-3}$ $\sim (4\text{-}7)n_0$

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



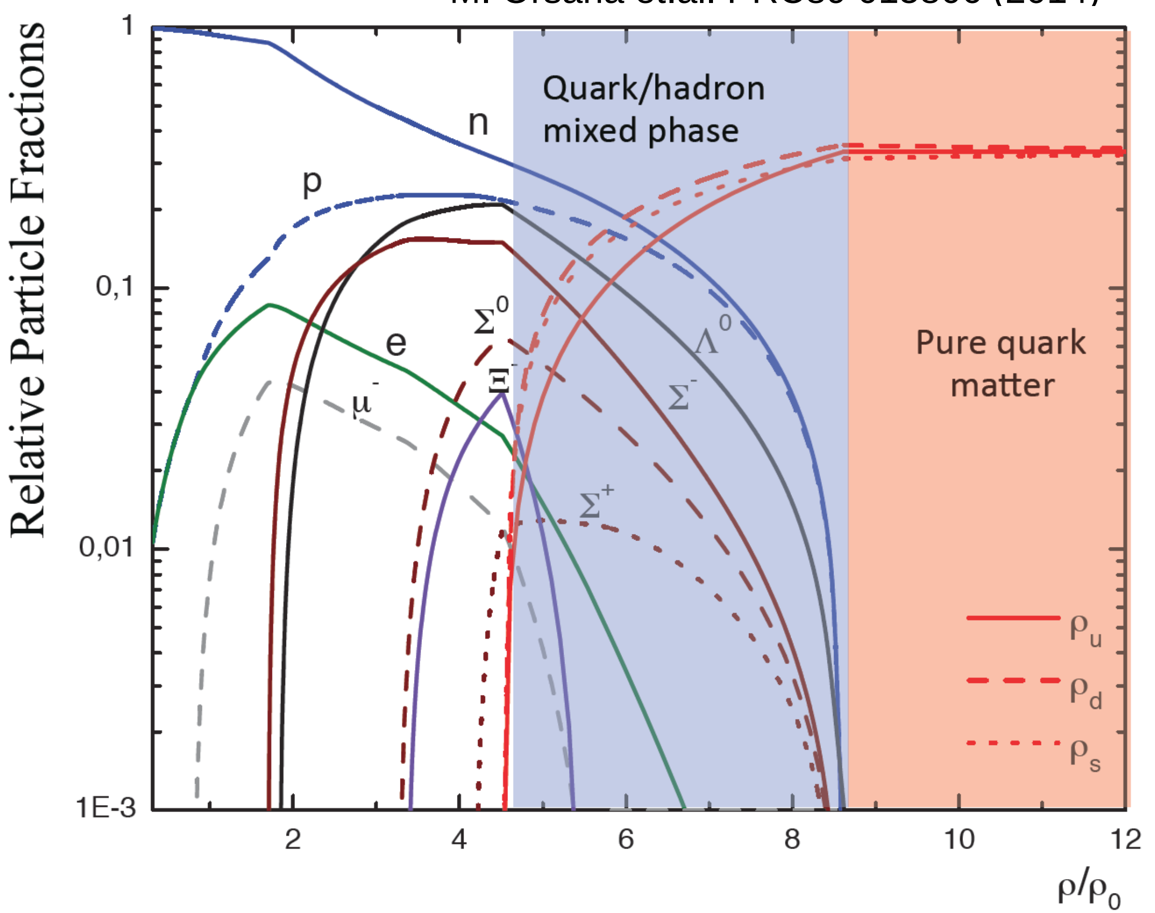
Net-baryon density reaches a value 5-15 times of the normal matter:
- experimentally access the region of mixed / quarkyonic phase

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

M. Orsaria et.al. PRC89 015806 (2014)

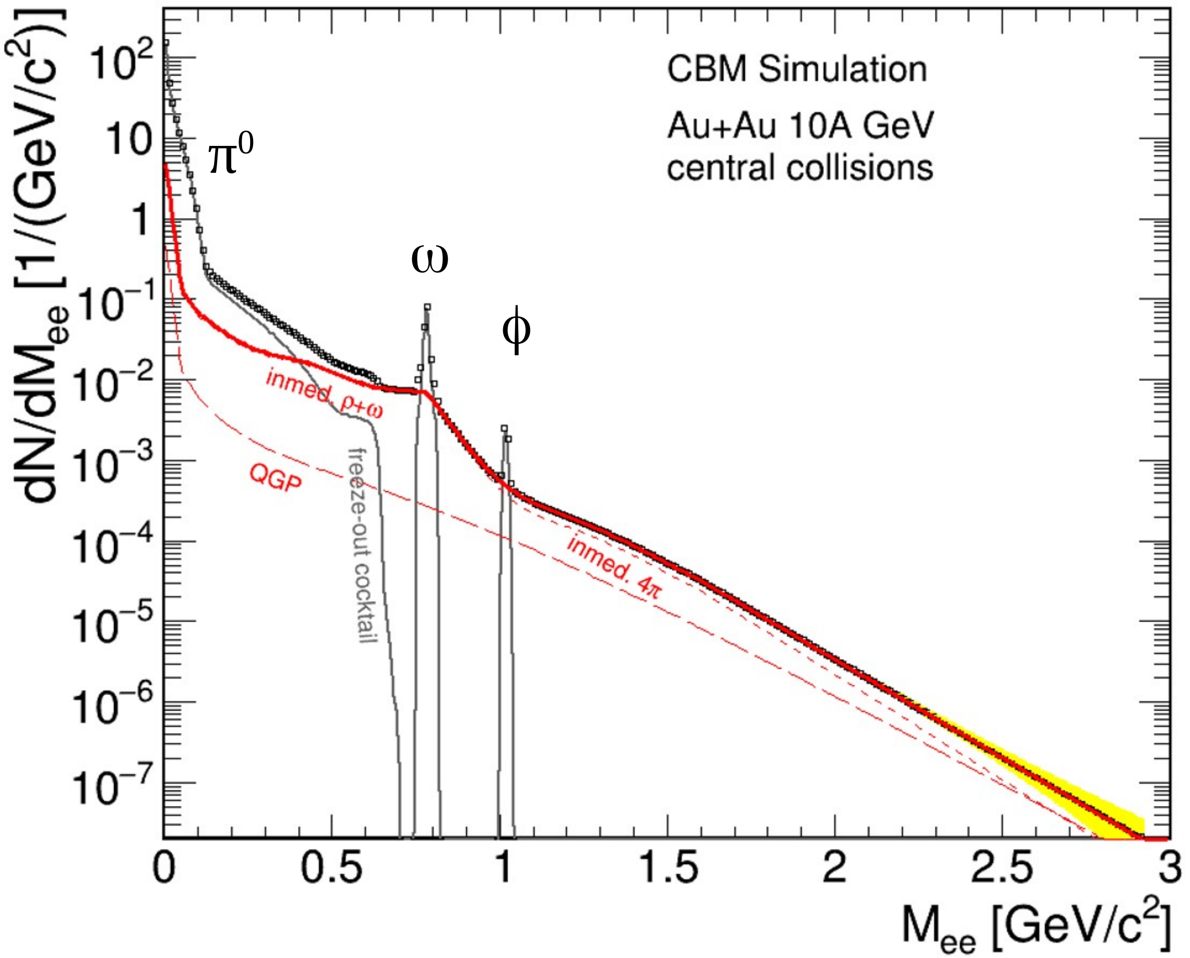


CBM physics and observables

Chiral symmetry at large baryon densities:

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

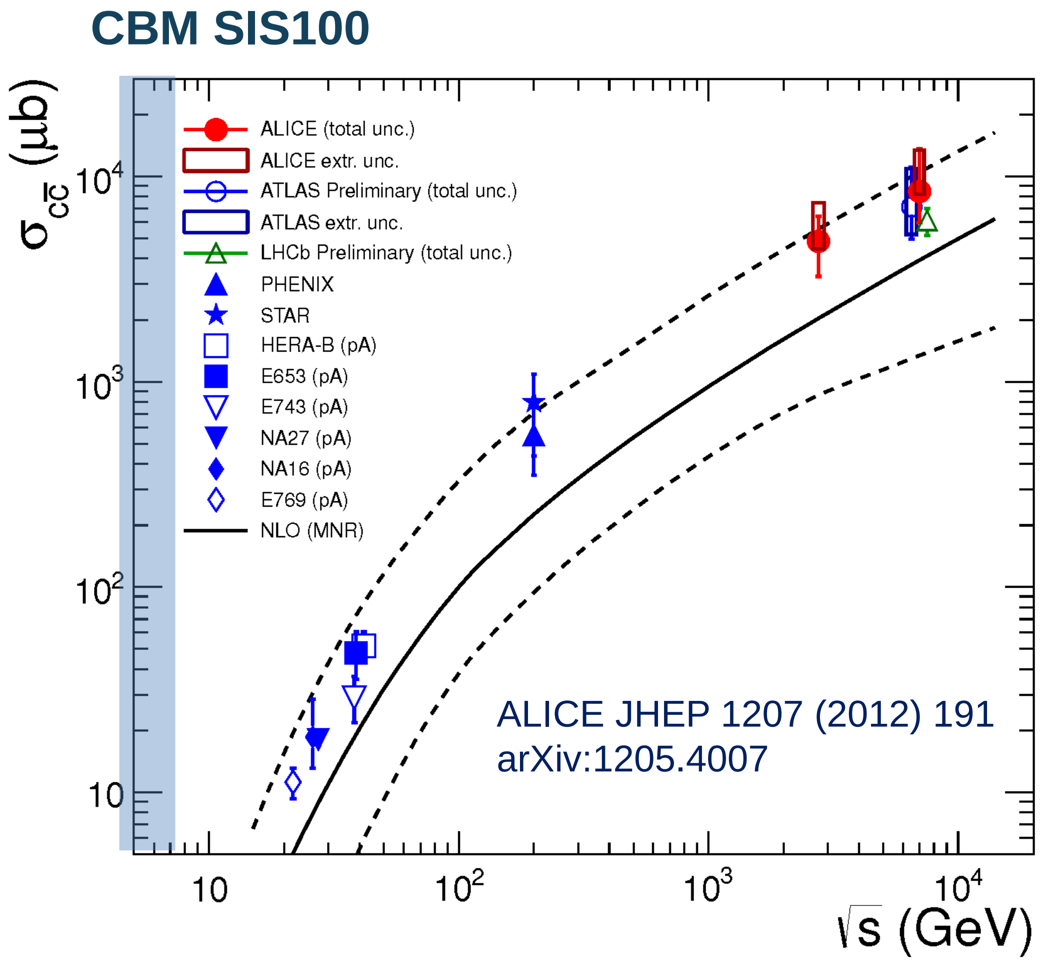
Electromagnetic radiation of produced matter



CBM physics and observables

Charm production and propagation at threshold energies

- Excitation function in p+A collisions (J/ψ, ψ', D^0, $D^{\pm}$)
- Charmonium suppression in cold nuclear matter

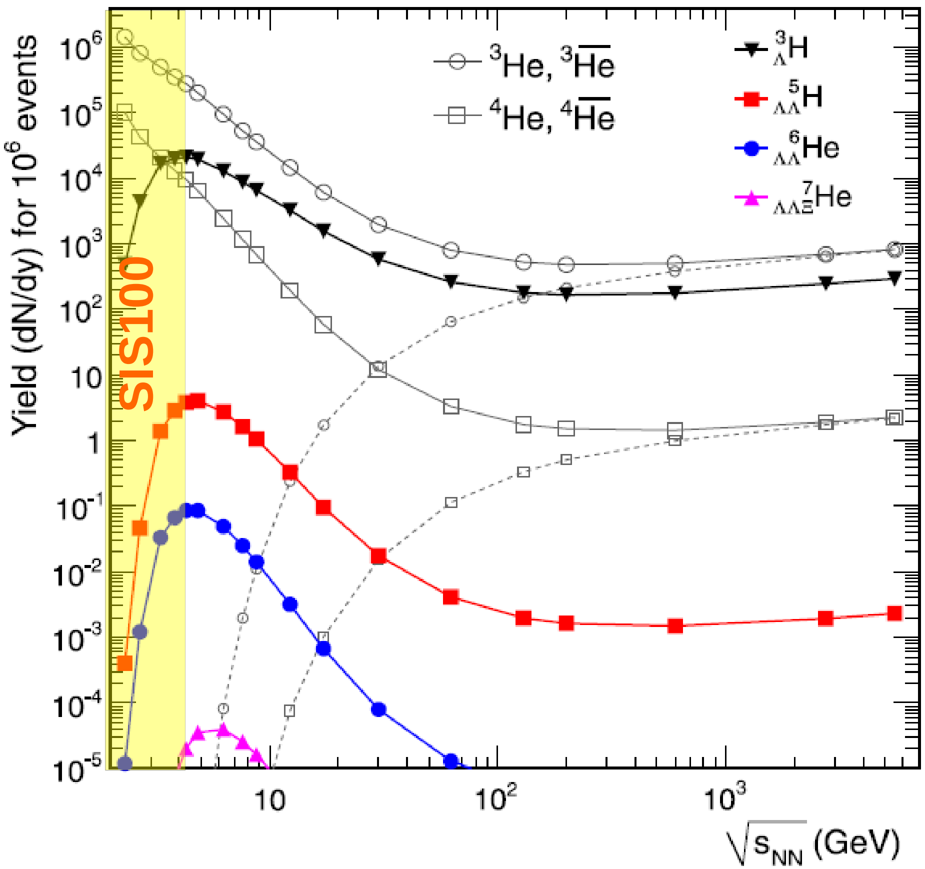


CBM physics and observables

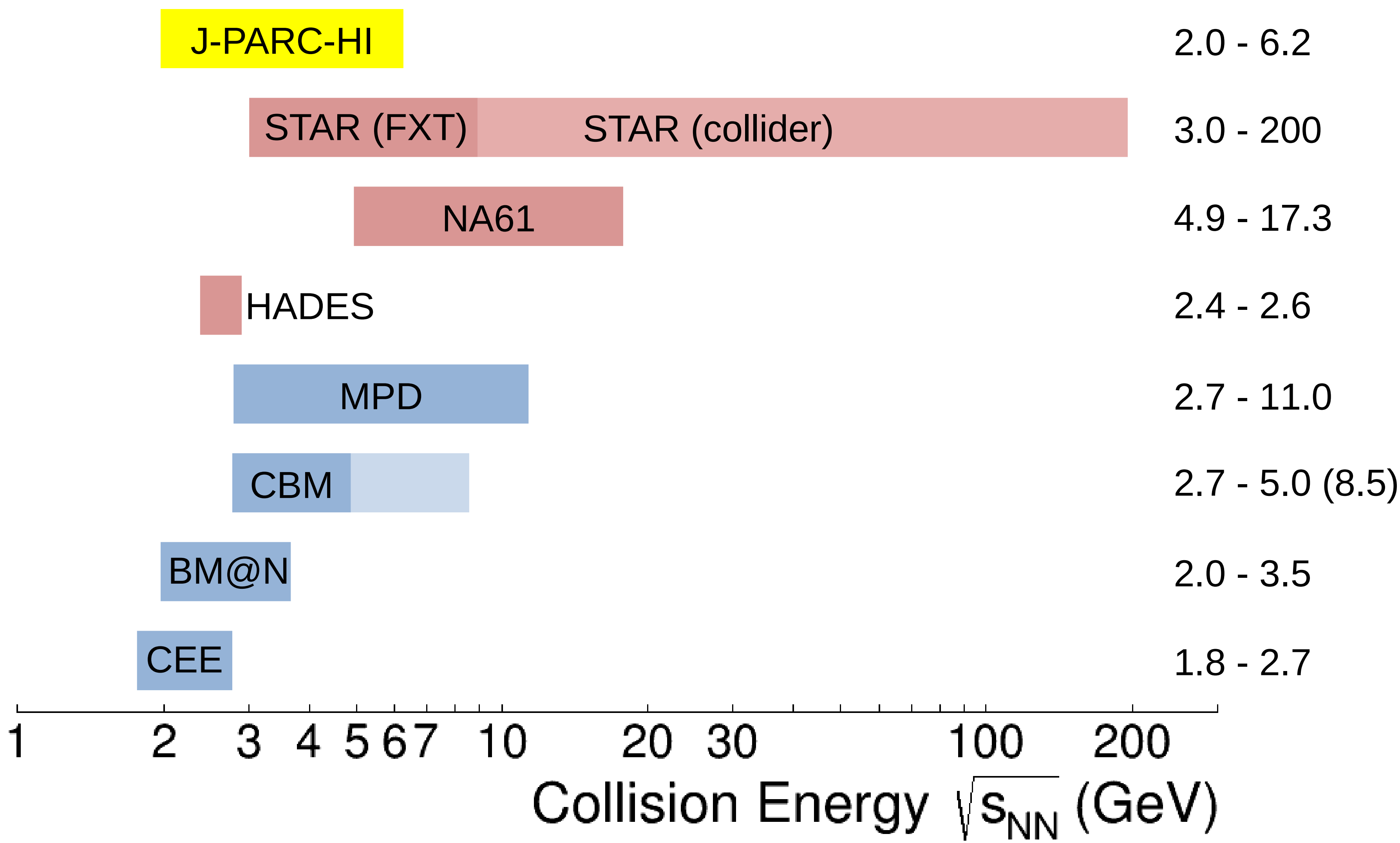
Strange nuclear matter:

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

A. Andronic, PLB697 203 (2011)

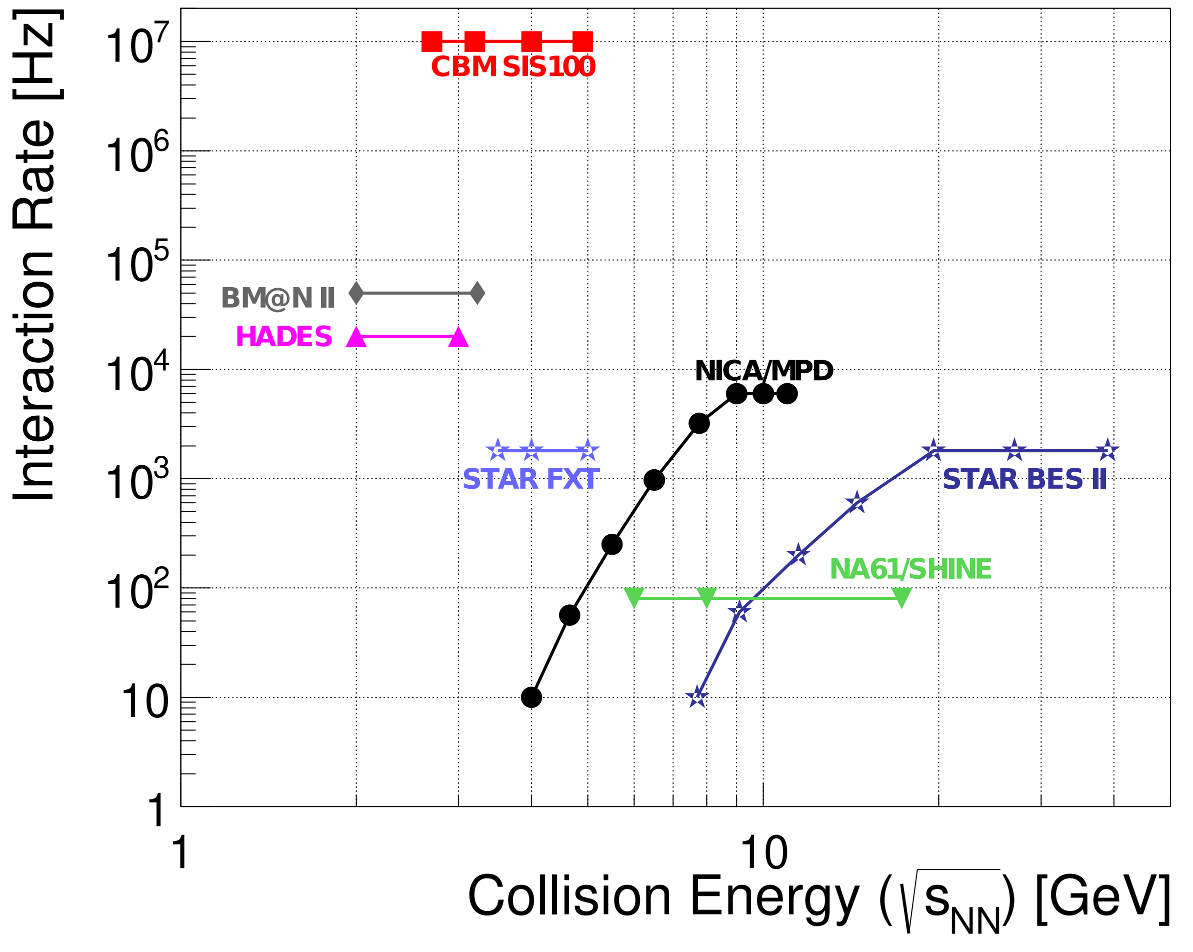


Experiments in the high net-baryon density



Experiments in the high net-baryon density

CBM Collaboration, EPJ. A53 (2017) no.3, 60



CBM will operate at high reaction rates:

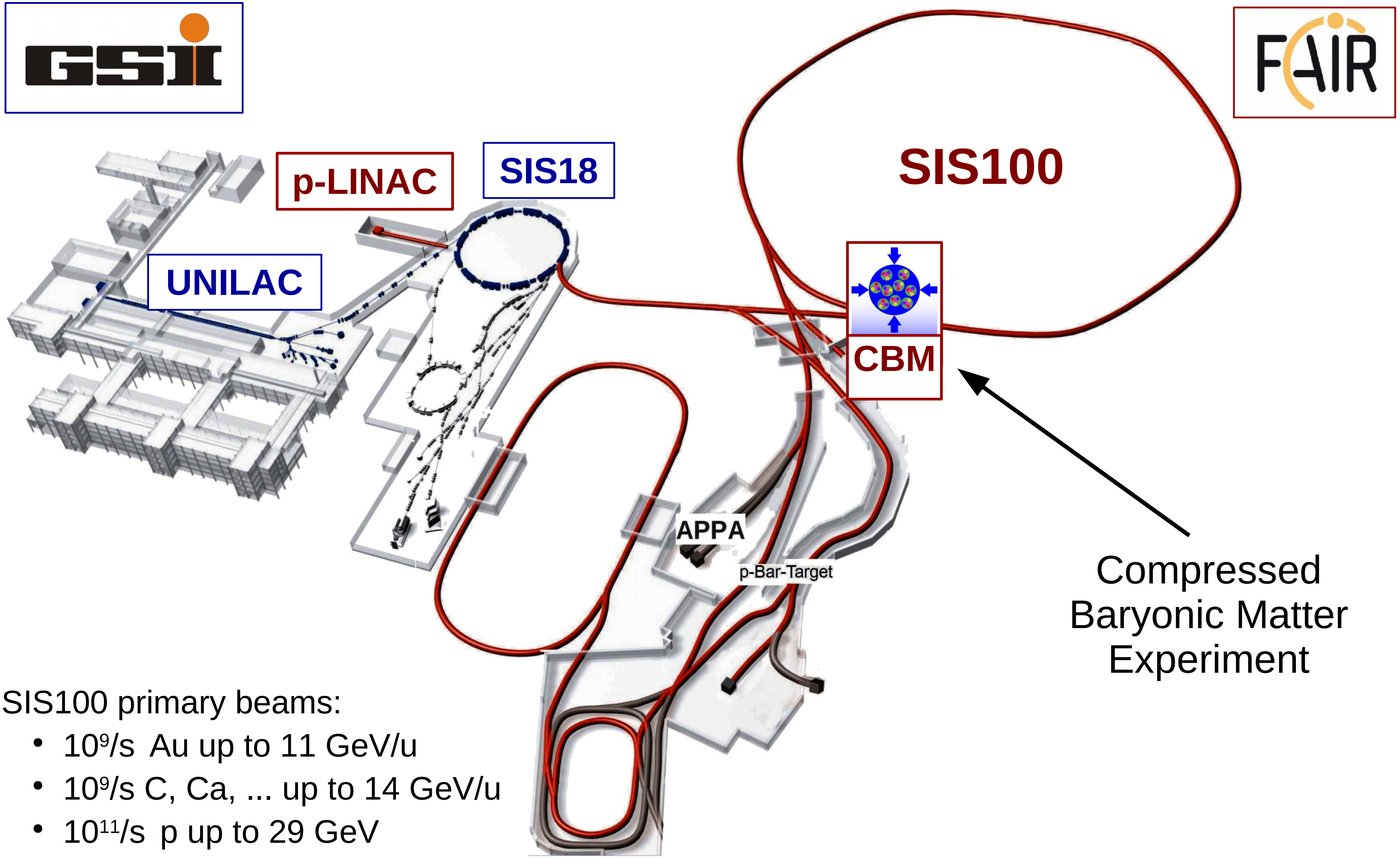
10^5 - 10^7 Au+Au reactions/sec

Main experimental requirements

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

Compressed Baryonic Matter (CBM) experiment at FAIR

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

CBM building layout

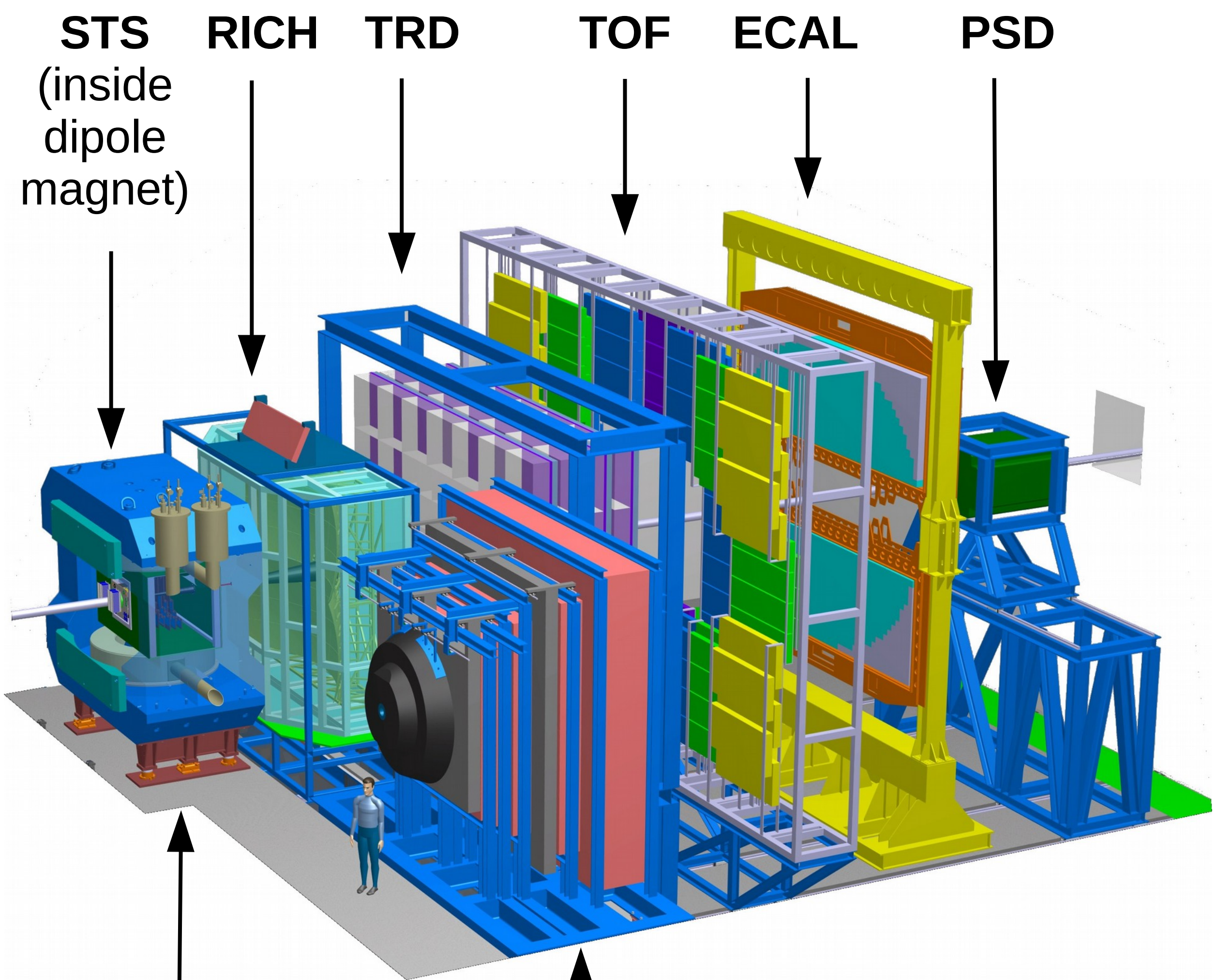
HADES: p+p, p+A, A+A
limited to low multiplicity A+A
optimized for dileptons

CBM: p+p, p+A, A+A
designed for high multiplicity
general purpose detector

Complementary operation of HADES and CBM at FAIR

CBM area excavation

CBM detector subsystems



Dipole Magnet
bends charged particle's trajectories

STS (Silicon Tracking System)
charged particle tracking

MVD (Micro-Vertex Detector)
secondary vertex reconstruction

RICH (Ring Imaging Cherenkov)
electron identification

TRD (Transition Radiation Detector)
electron identification

TOF (Time of Flight detector)
hadron identification

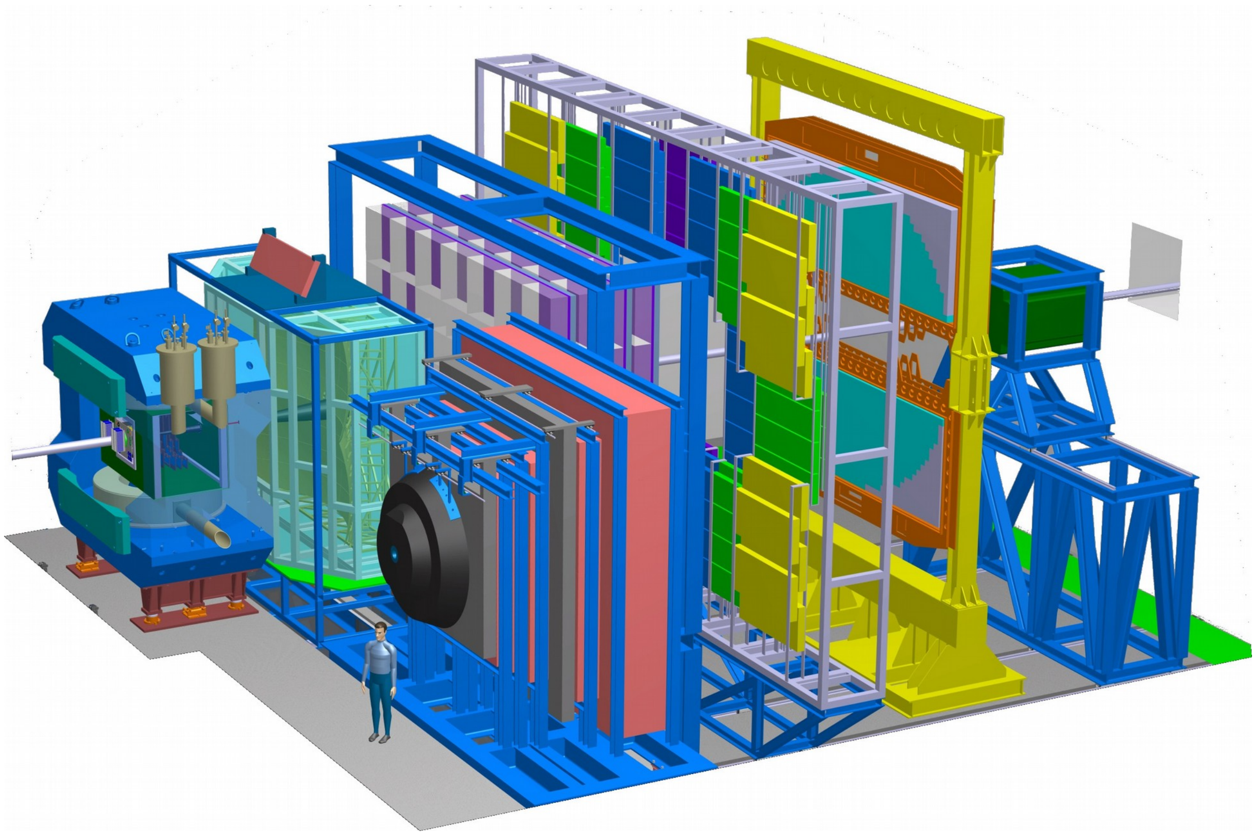
MUCH (MUon CHambers)
muon tracking & identification

ECAL (Electromagnetic Calorimeter)
electron/photon identification

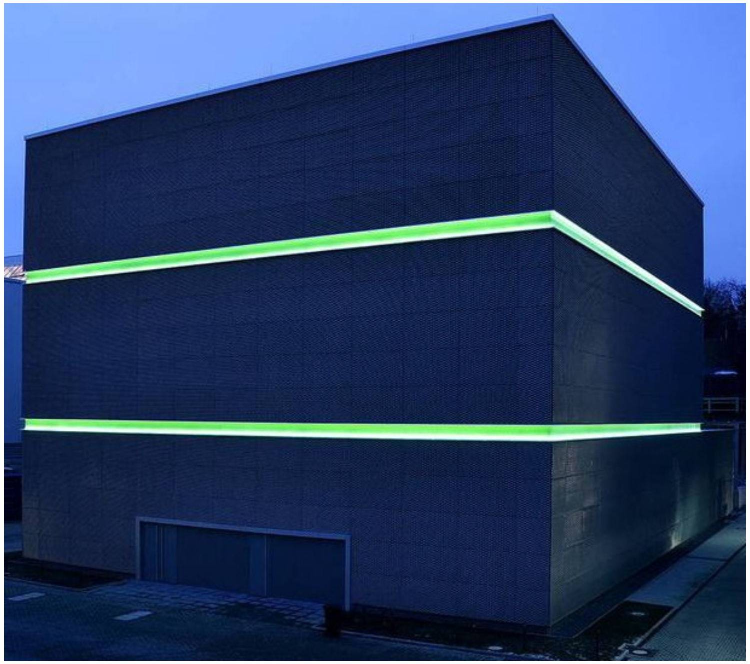
PSD (Projectile Spectator Detector)
collision centrality and
reaction plane determination

FLES (First-level Event Selector)
online reconstruction / event selection

CBM subsystems: high performance computing



FAIR/GSI Green cube

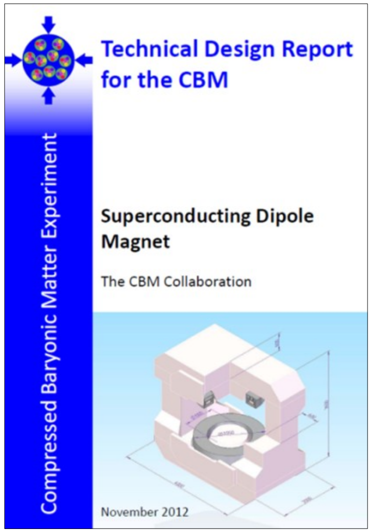


DAQ / FLES (First-level Event Selector)
online reconstruction / event selection

Subsystems preparation status

TDRs approved by FAIR

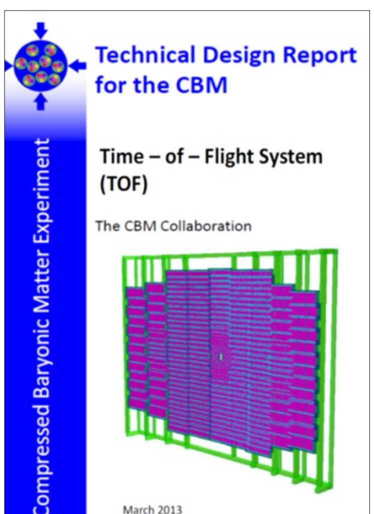
Dipole Magnet



STS

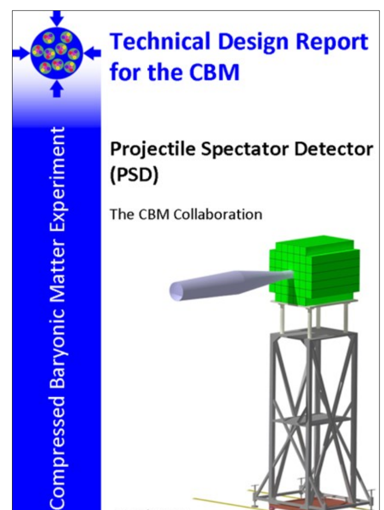
RICH

TOF



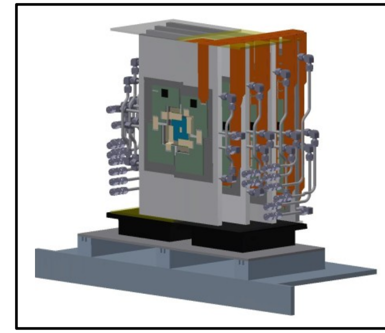
MUCH

PSD

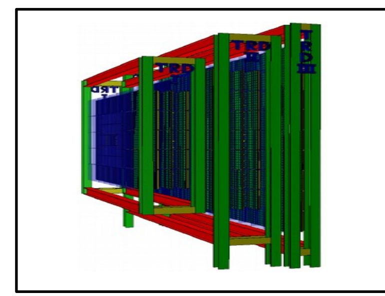


TDR in preparation

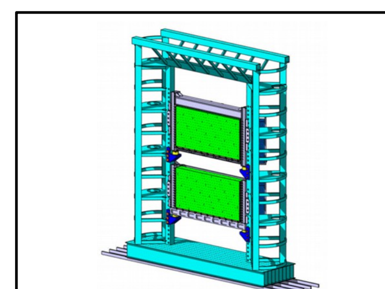
MVD



TRD



ECAL

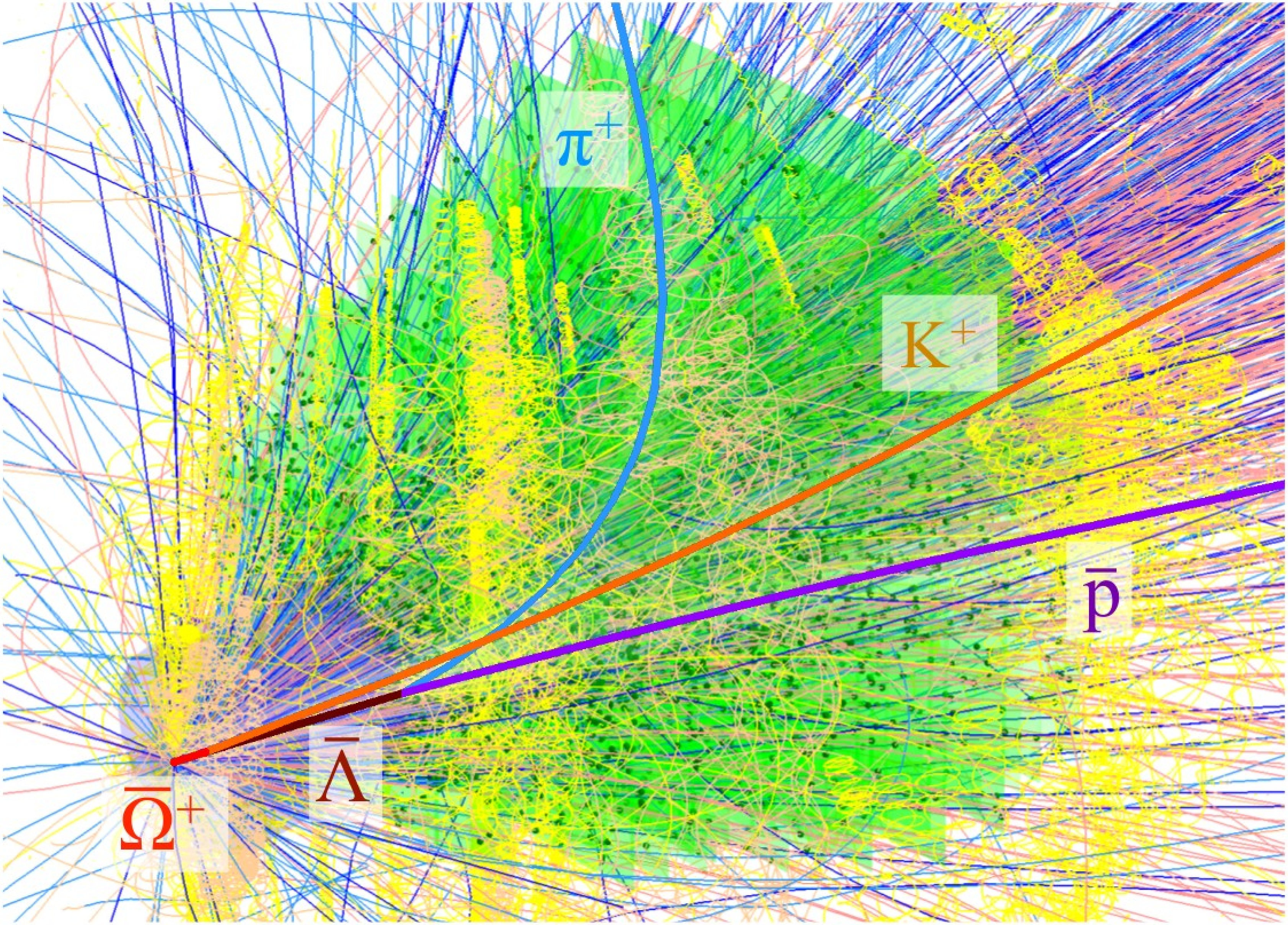


DAQ / FLES

Performance studies

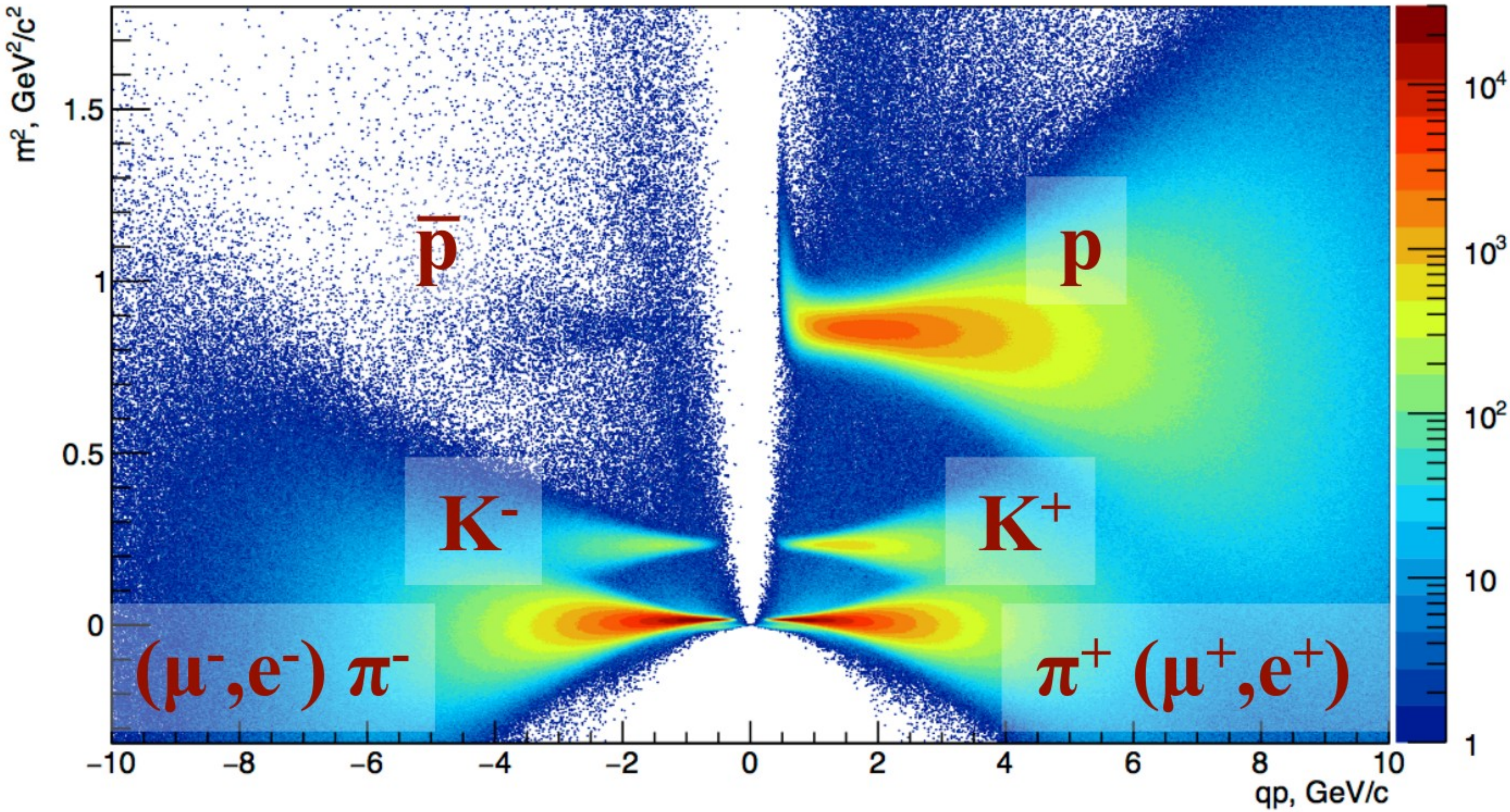
CBM event and track reconstruction

central AuAu@10AGeV



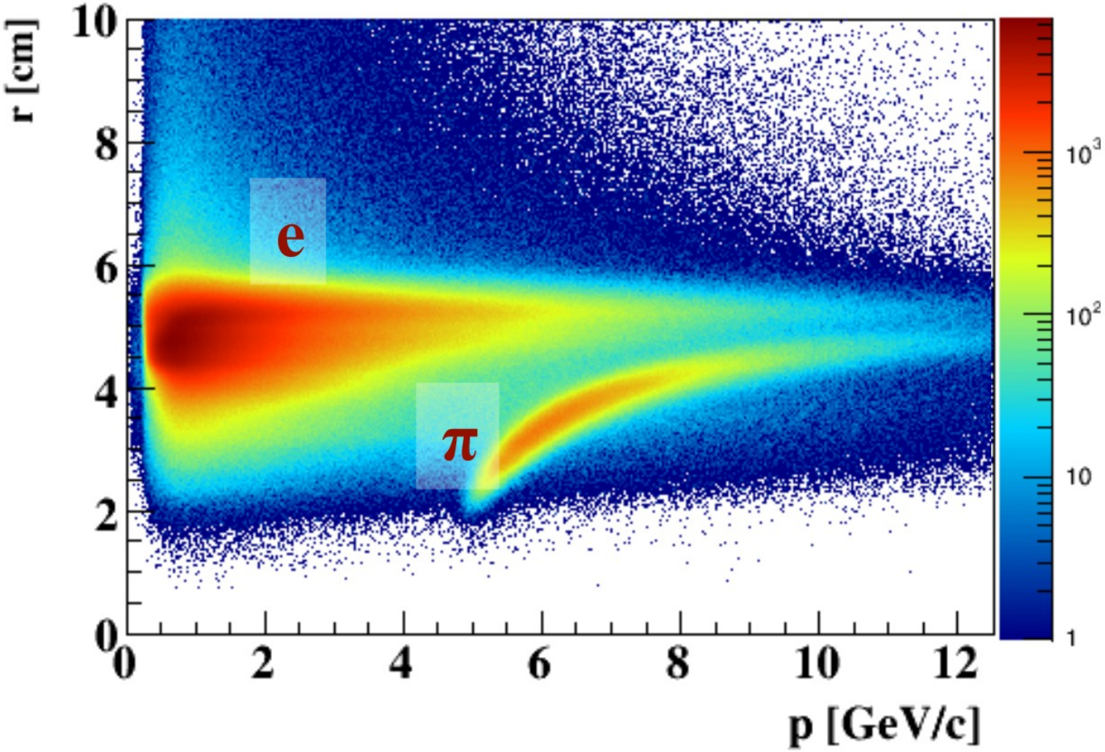
Particle identification: light hadrons

Beta (TOF detector) vs. charge*momentum (STS detector)

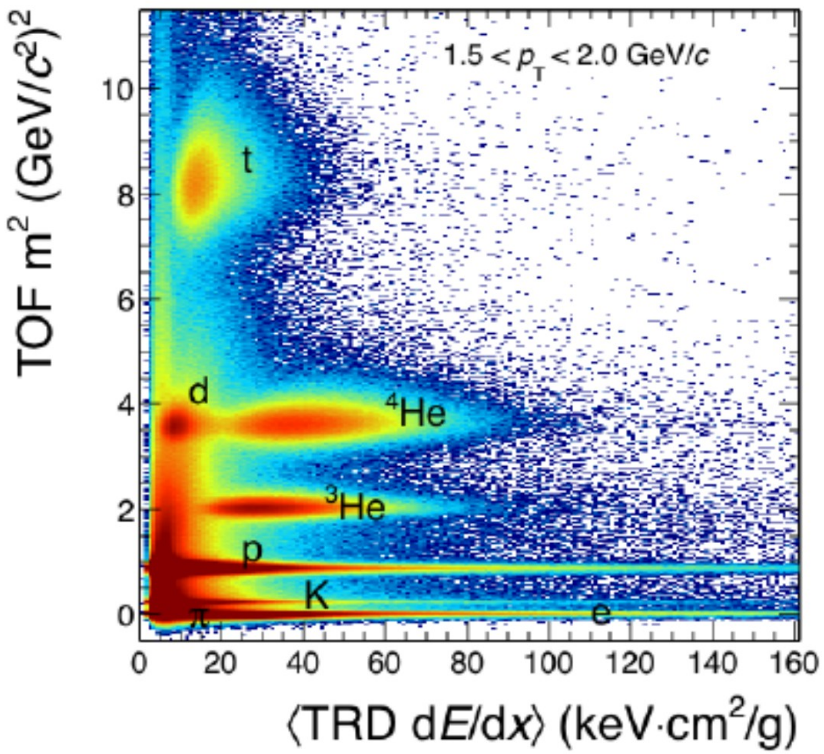


Particle identification: electrons and light nuclei

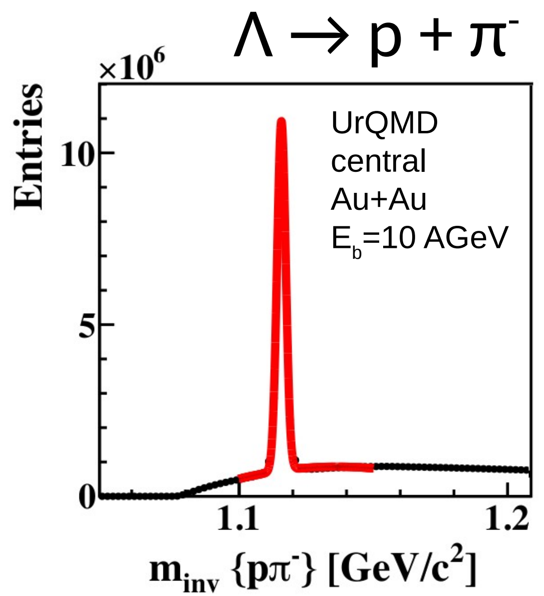
RICH (electrons)

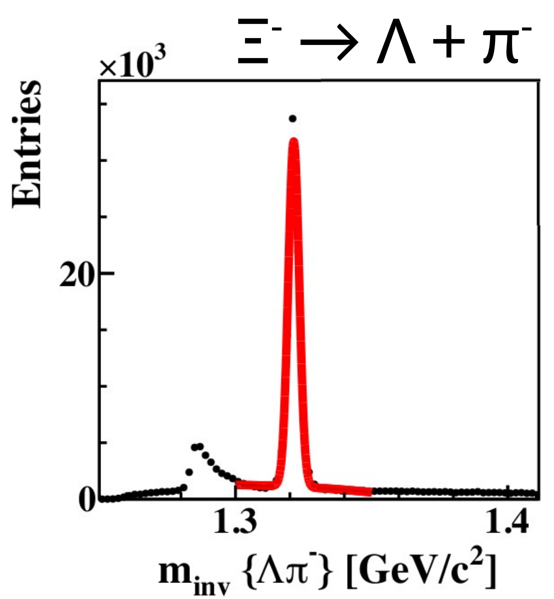


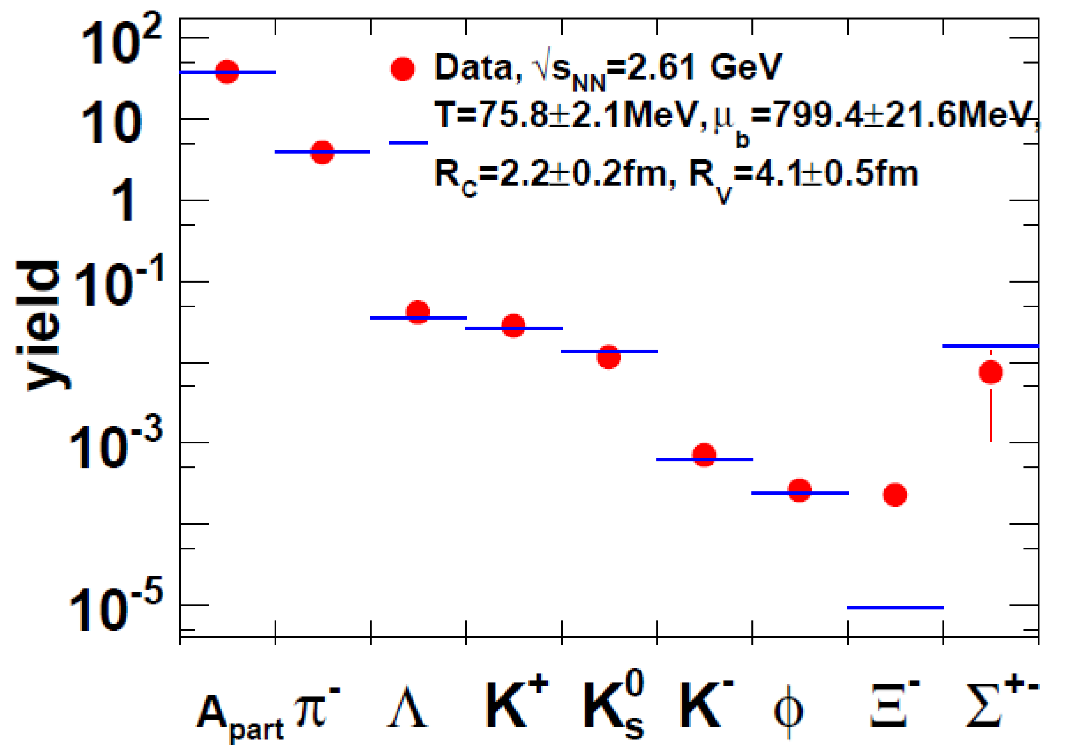
TRD+TOF



Multi-strange reconstruction





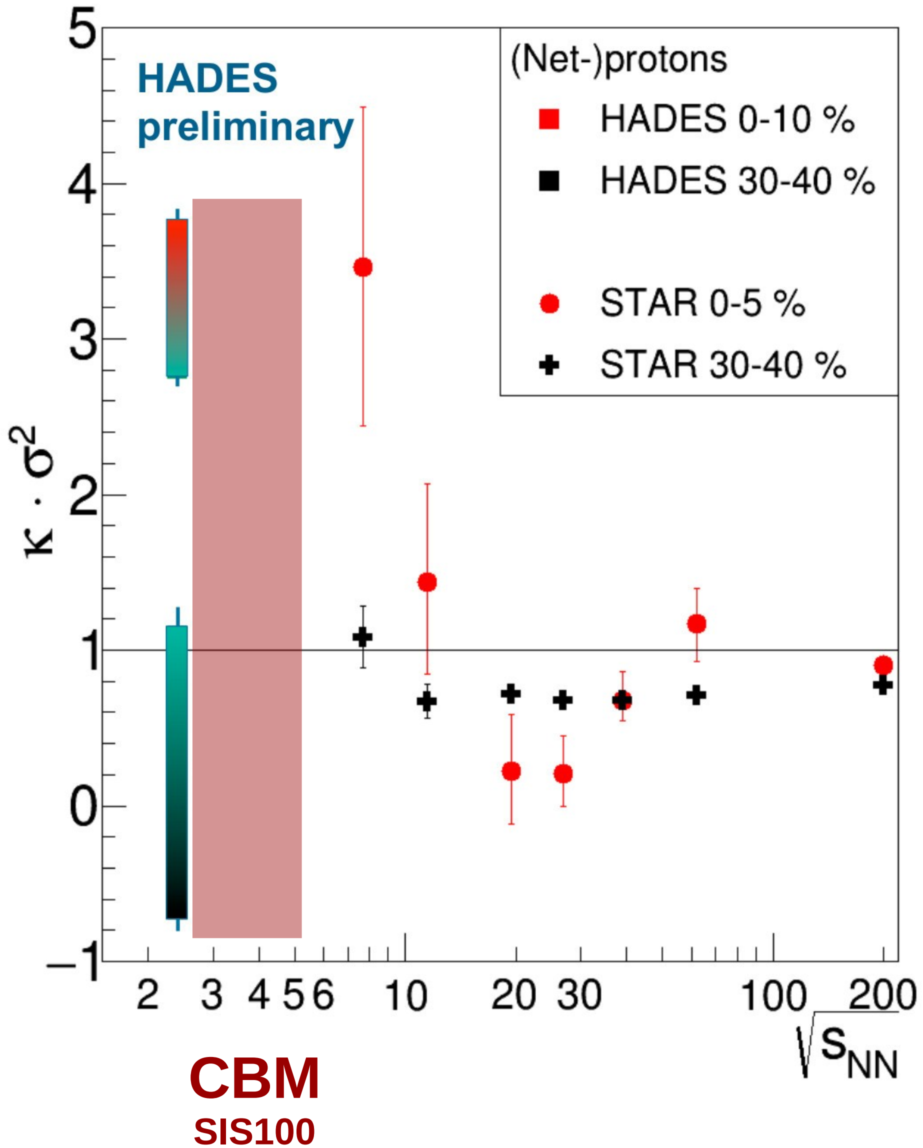


Decay topology reconstruction
using the KFParticleFinder package

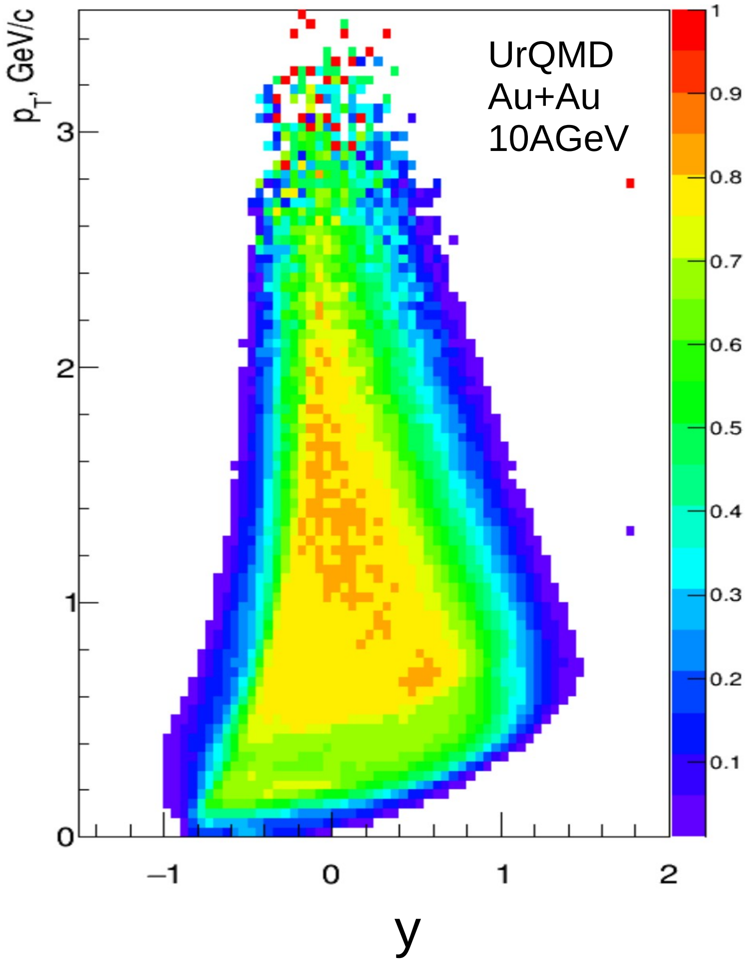
See talk by I. Vassiliev

Fluctuations of conserved quantities: net-protons

Moments:
1st - mean, 2nd - variance (σ)
3rd - skewness (s), 4th - kurtosis (κ)

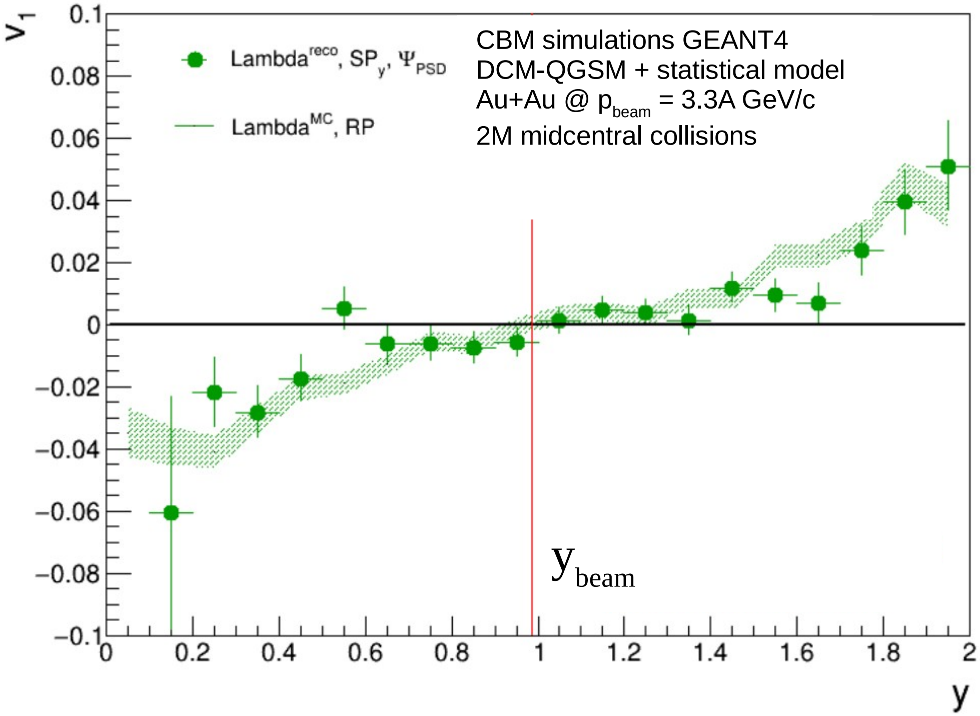


proton reconstruction efficiency

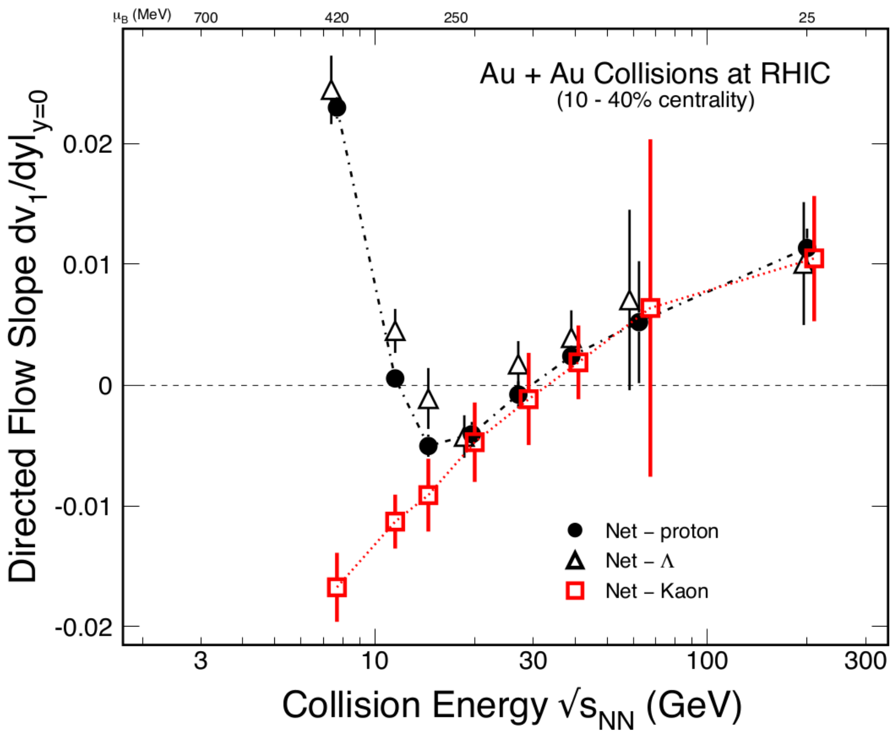


sufficient proton coverage at midrapidity

Performance for directed flow (v_1) of strange hyperons



STAR Collaboration PRL120 (2018) 062301

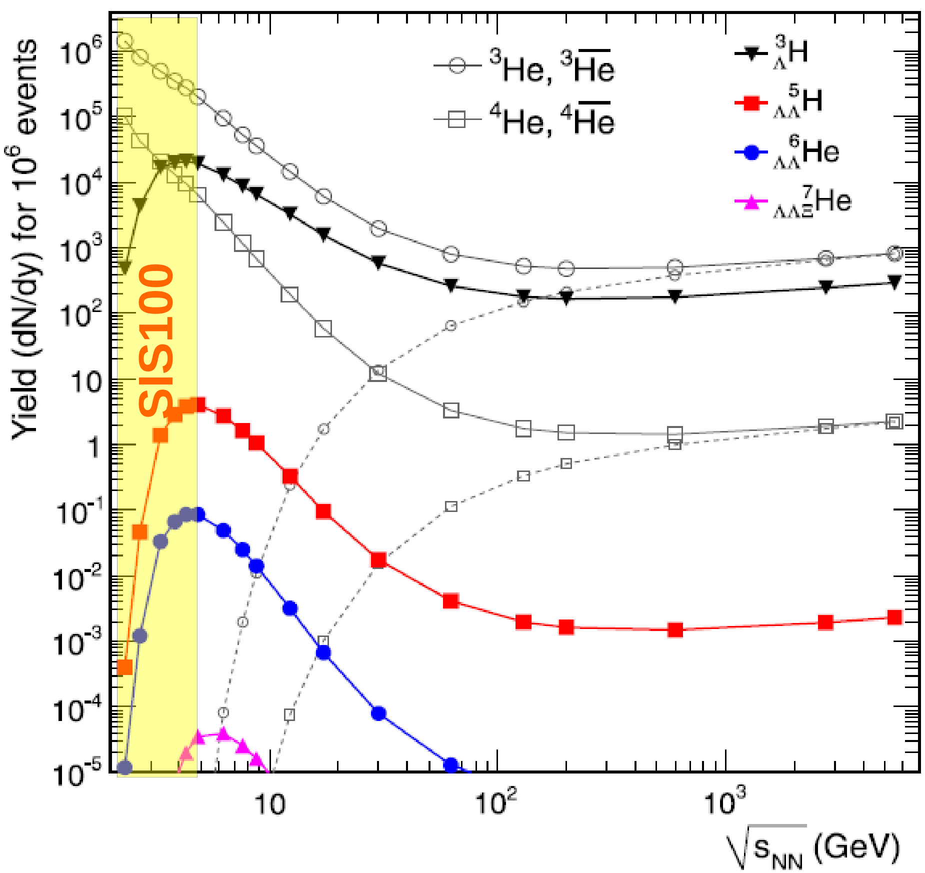


"input" model v_1 is recovered using "data-driven" method

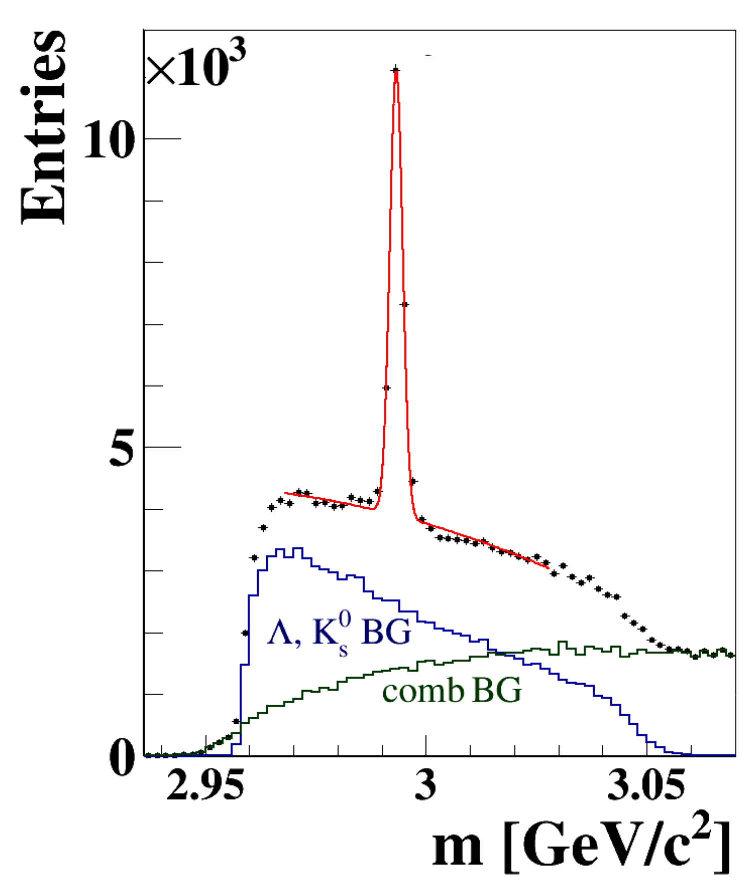
Strange nuclear matter

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

A. Andronic, PLB697 203 (2011)



$^3_\Lambda H \rightarrow {}^3He + \pi^-$

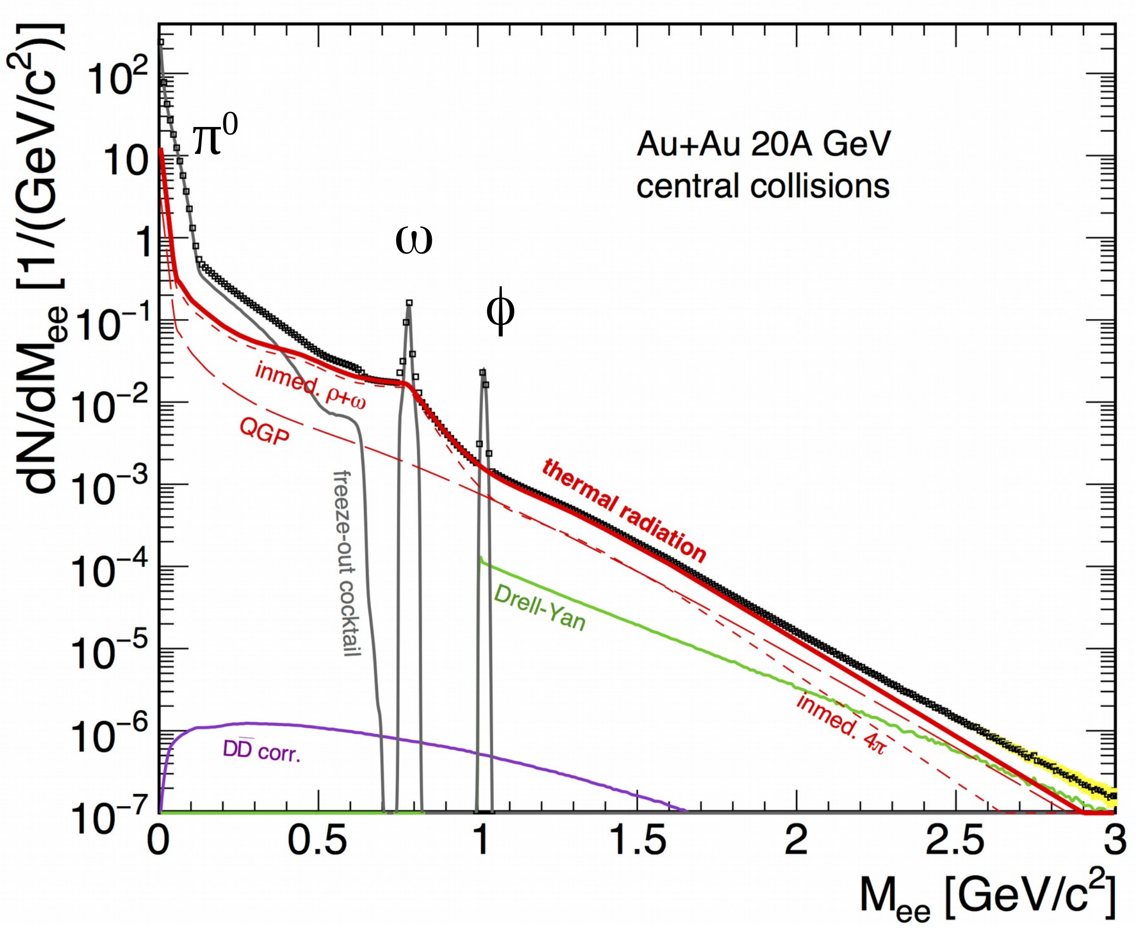


Dilepton measurements

Chiral symmetry at large baryon densities:

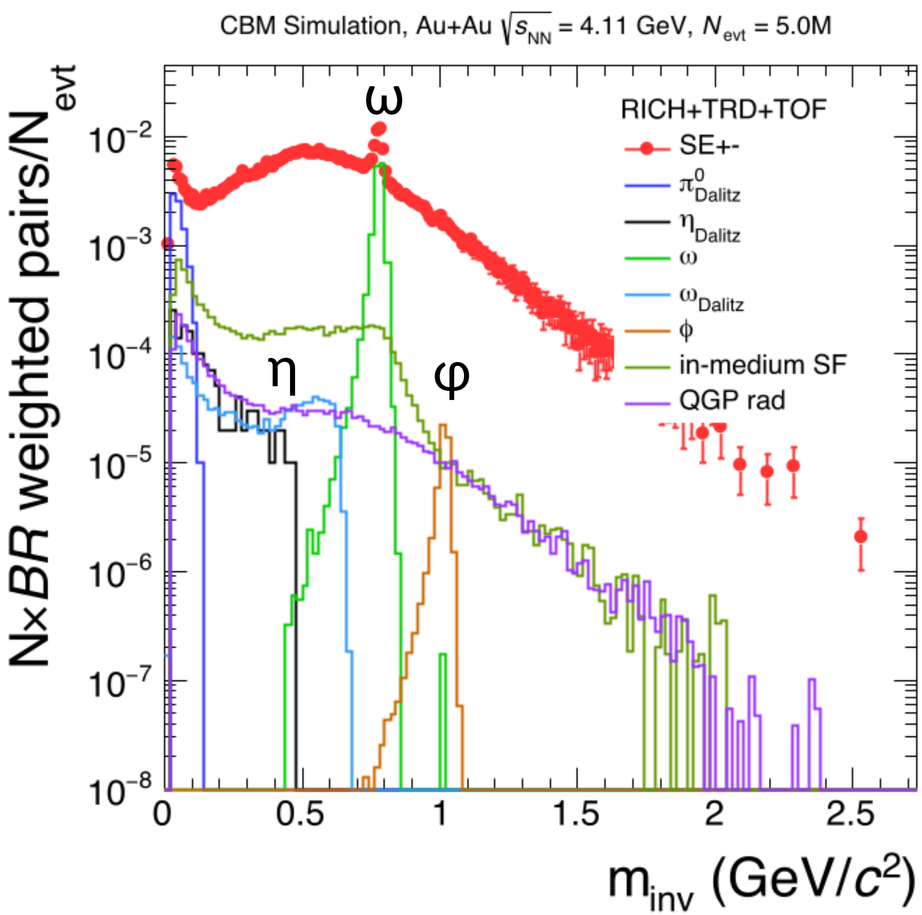
- In-medium modifications of light vector mesons
  $\rho, \omega, \phi \rightarrow e^+e^-$ $(\mu^+\mu^-)$ via dilepton measurements

Electromagnetic radiation of produced matter

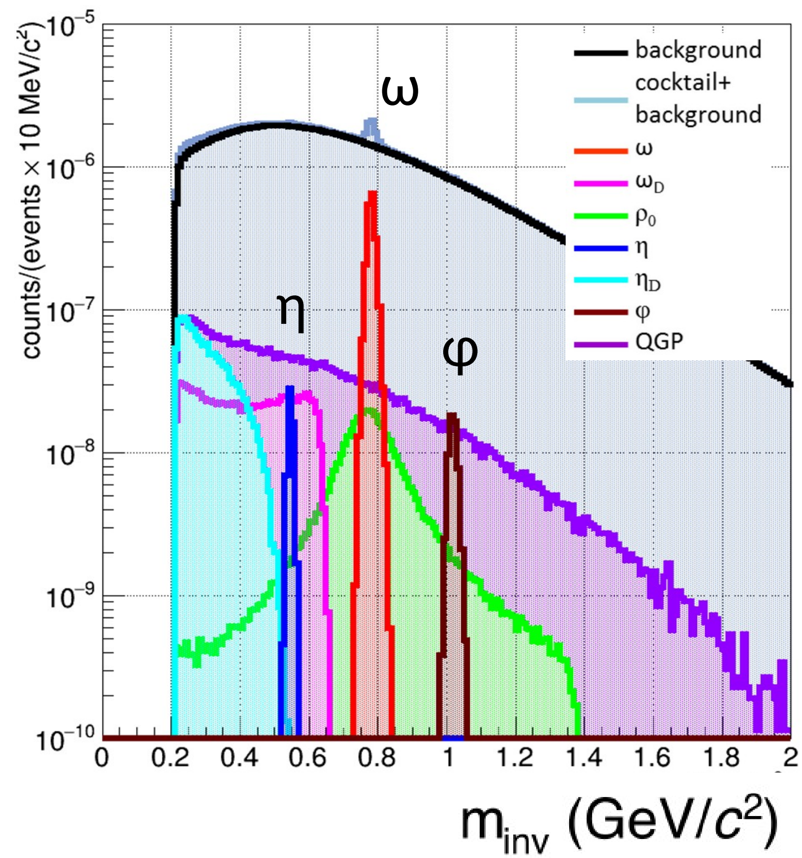


Dilepton measurements: e^+e^- and $\mu^+\mu^-$

di-electrons



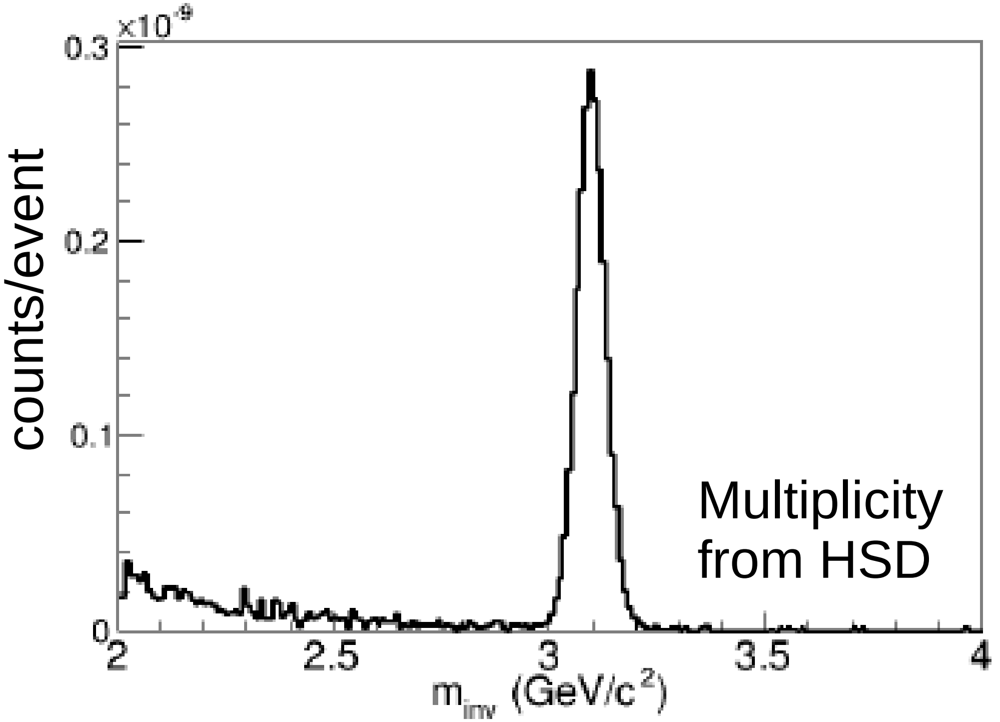
di-muons



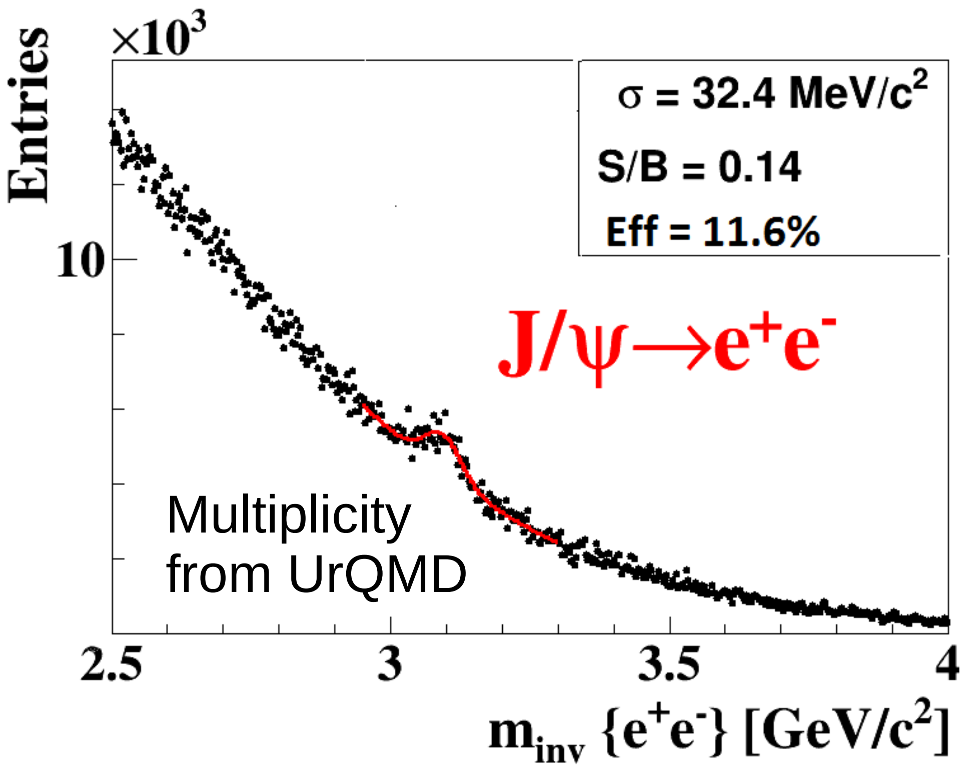
See talk by T. Galatyuk

Charm performance: J/ψ → $\mu^+\mu^-$ / e^+e^- reconstruction

p+Au 30GeV



central Au+Au 10 A GeV



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

- Use 430 out of 1100 CBM RICH multi-anode photo-multipliers (MAPMT) in HADES RICH photon detector (2019)

- Use 10% of the CBM TOF modules including read-out chain at STAR/RHIC (BES II 2019/2020)

- 4 Silicon Tracking Stations in the BM@N in JINR/Dubna (start 2020 with Au-beams up to 4.5 A GeV)

- Project Spectator Detector at the BM@N experiment (2020). Tests and performance studies at the NA61/SHINE SPS experiment.

- mini CBM at GSI/SIS18 full system test with high-rate A-A collisions (2019-2021)

Summary

CBM physics program at SIS100:
- Precision study of the QCD phase diagram in the region of extreme high net-baryon densities.

Unique measurements of rare diagnostic probes with CBM:
- High-precision multi-differential measurements of hadrons incl. multistrange hyperons and dileptons for different beam energies and collision systems.

Key experimental requirements:
- high-rate capability of detectors and DAQ
- online event reconstruction and selection

Status of CBM experiment preparation:
- Technical Design Reports: 6 approved, 3 in preparation
- Extensive performance studies for many physics observables
- FAIR phase-0 program targeted towards usage and understanding of major components

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

30th CBM Collaboration Meeting, 24-28 September 2018, Wuhan, China

Information | References (67) | Citations (11) | Files | Plots

Challenges in QCD matter physics --The scientific programme of the Compressed Baryonic Matter experiment at FAIR

CBM Collaboration (T. Ablyazimov (Dubna, JINR) *et al.*) Show all 587 authors

Jul 6, 2016 - 11 pages

Eur.Phys.J. A53 (2017) no.3, 60
(2017-03-23)
DOI: 10.1140/epja/i2017-12248-y
e-Print: arXiv:1607.01487 [nucl-ex] | PDF
Experiment: GSI-FAIR-CBM

Abstract (Springer)
Substantial experimental and theoretical efforts worldwide are devoted to explore the phase diagram of strongly interacting matter. At LHC and top RHIC energies, QCD matter is studied at very high temperatures and nearly vanishing net-baryon densities. There is evidence that a Quark-Gluon-Plasma (QGP) was created at experiments at RHIC and LHC. The transition from the QGP back to the hadron gas is found to be a smooth cross over. For larger net-baryon densities and lower temperatures, it is expected that the QCD phase diagram exhibits a rich structure, such as a first-order phase transition between hadronic and partonic matter which terminates in a critical point, or exotic phases like quarkyonic matter. The discovery of these landmarks would be a breakthrough in our understanding of the strong interaction and is therefore in the focus of various high-energy heavy-ion research programs. The Compressed Baryonic Matter (CBM) experiment at FAIR will play a unique role in the exploration of the QCD phase diagram in the region of high net-baryon densities, because it is designed to run at unprecedented interaction rates. High-rate operation is the key prerequisite for high-precision measurements of multi-differential observables and of rare diagnostic probes which are sensitive to the dense phase of the nuclear fireball. The goal of the CBM experiment at SIS100 ($\sqrt{s_{NN}} =$ 2.7--4.9 GeV) is to discover fundamental properties of QCD matter: the phase structure at large baryon-chemical potentials ($\mu_B > 500$ MeV), effects of chiral symmetry, and the equation of state at high density as it is expected to occur in the core of neutron stars. In this article, we review the motivation for and the physics programme of CBM, including activities before the start of data taking in 2024, in the context of the worldwide efforts to explore high-density QCD matter.
Abstract (arXiv)

https://inspirehep.net/record/1474181