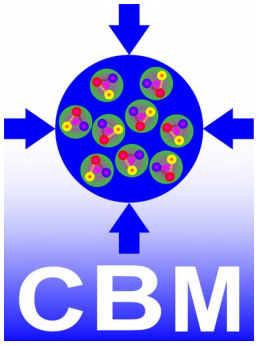
Status of the CBM experiment at FAIR

Ilya Selyuzhenkov

(GSI / EMMI / MEPhI)

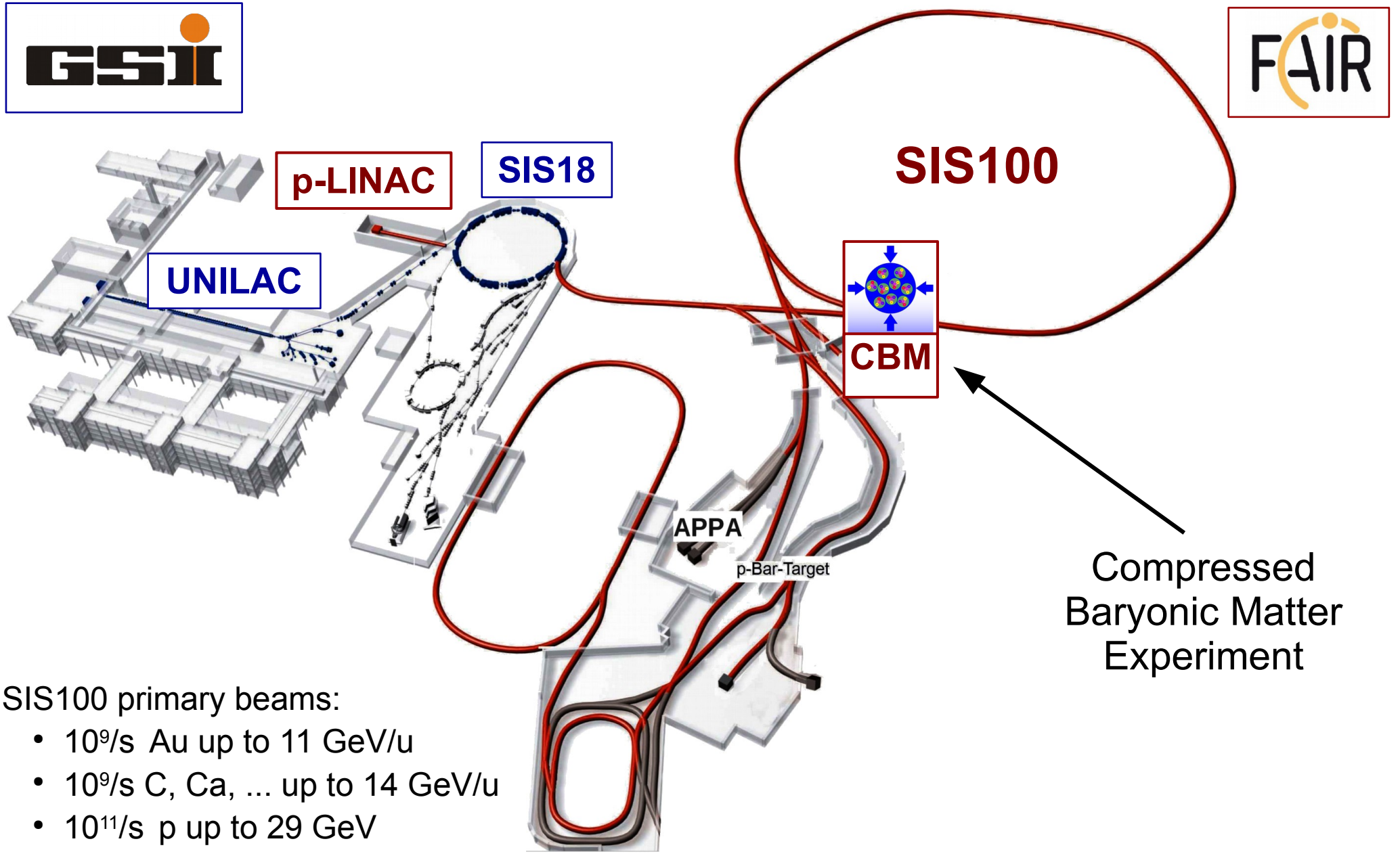
for the CBM Collaboration



SQM2019 (Bari, Italy)

June 15, 2019

Facility for Antiproton and Ion Research



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

Start of excavation (less than 2 years ago)

Current schedule landmarks:

2017 Start of excavation
2018 Finished SIS18 tunnel upgrade
2022 CBM cave ready
2025 SIS100 commissioning with beams

FAIR construction site (April 2019)

Drone video as of 03/2019 on youtube: https://youtu.be/ayrjkV8kr48

CBM at FAIR

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 cave ready → 2022

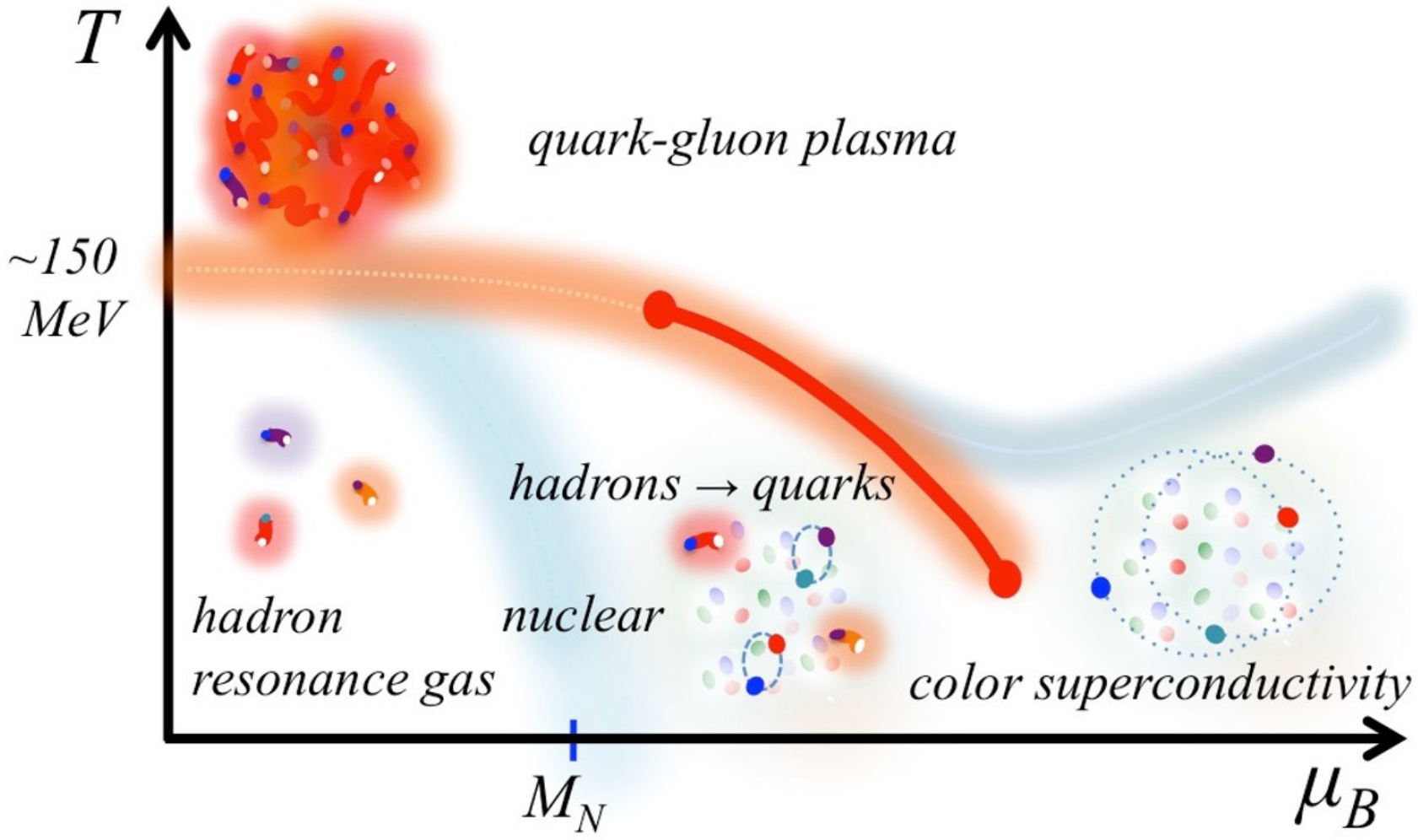
CBM physics and observables

CBM Collaboration
Eur.Phys.J. A53 (2017) no.3, 60

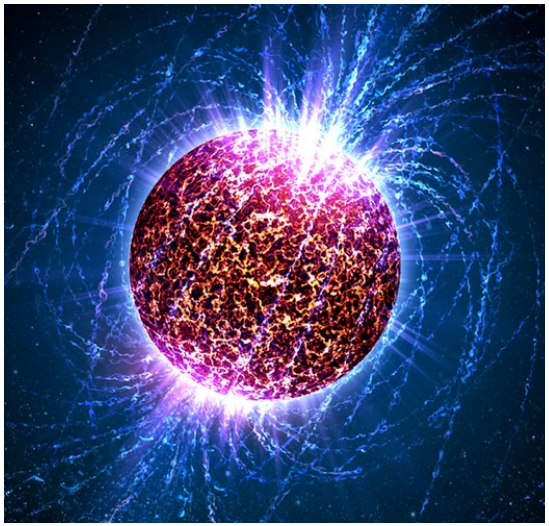
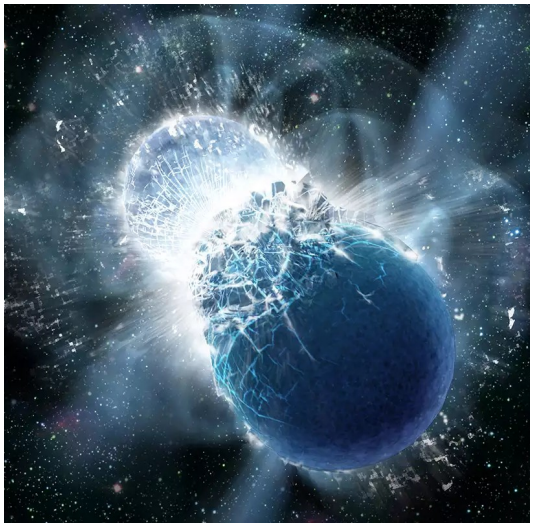
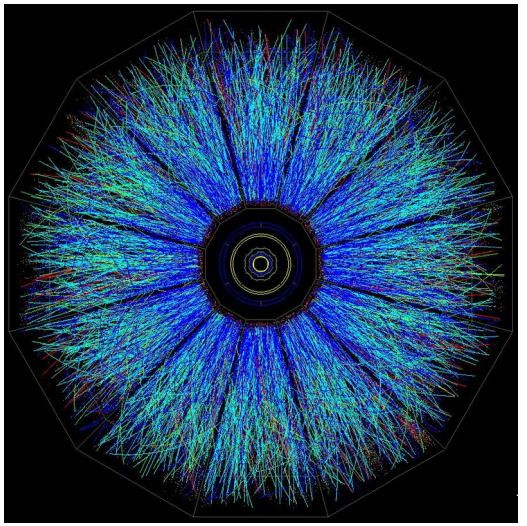
https://inspirehep.net/record/1474181

Rich structure of the QCD matter phase diagram

Gordon Baym et al., RPP81 (2018) 056902



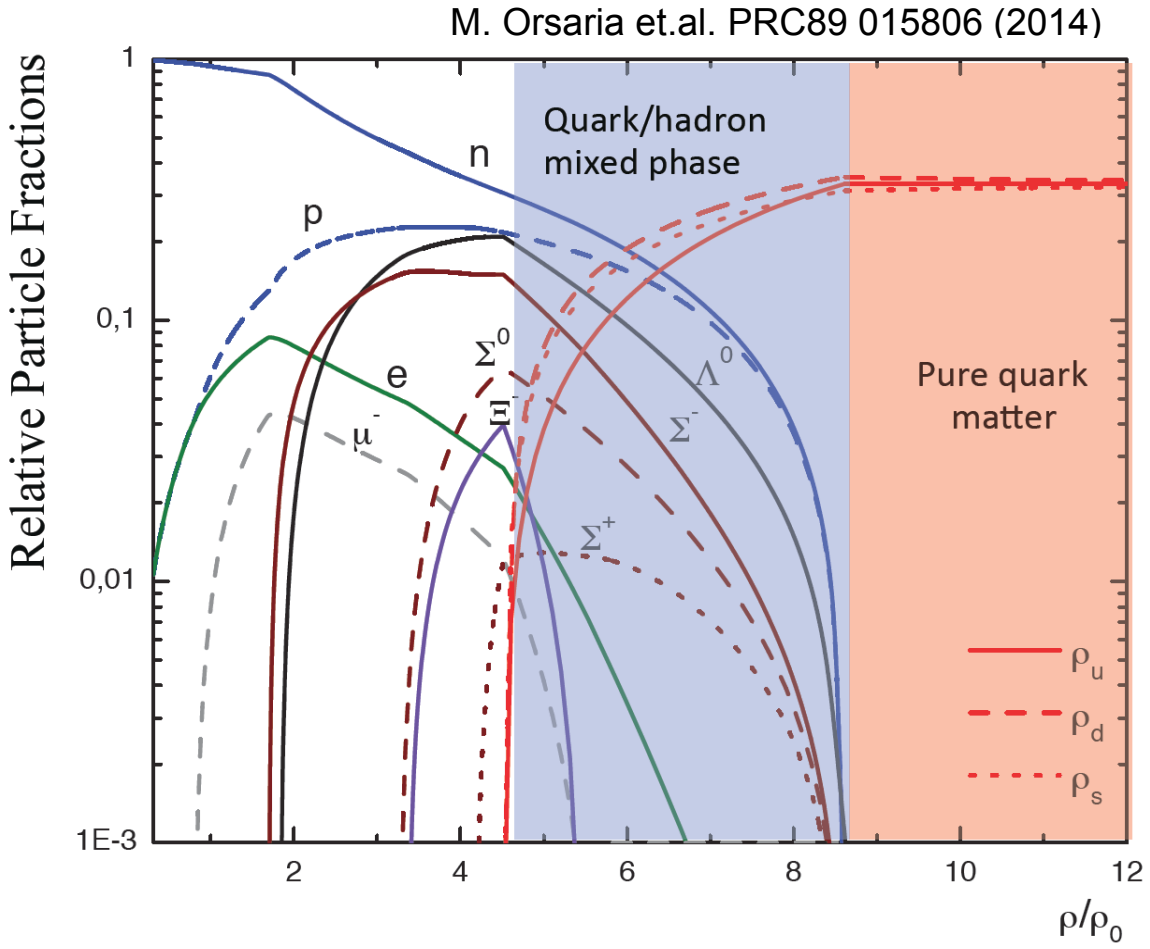
Dense Baryonic Matter

	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	t ~ infinity	t ~ 10 ms	$t \sim 10^{-23}$ s

CBM physics and observables

QCD 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

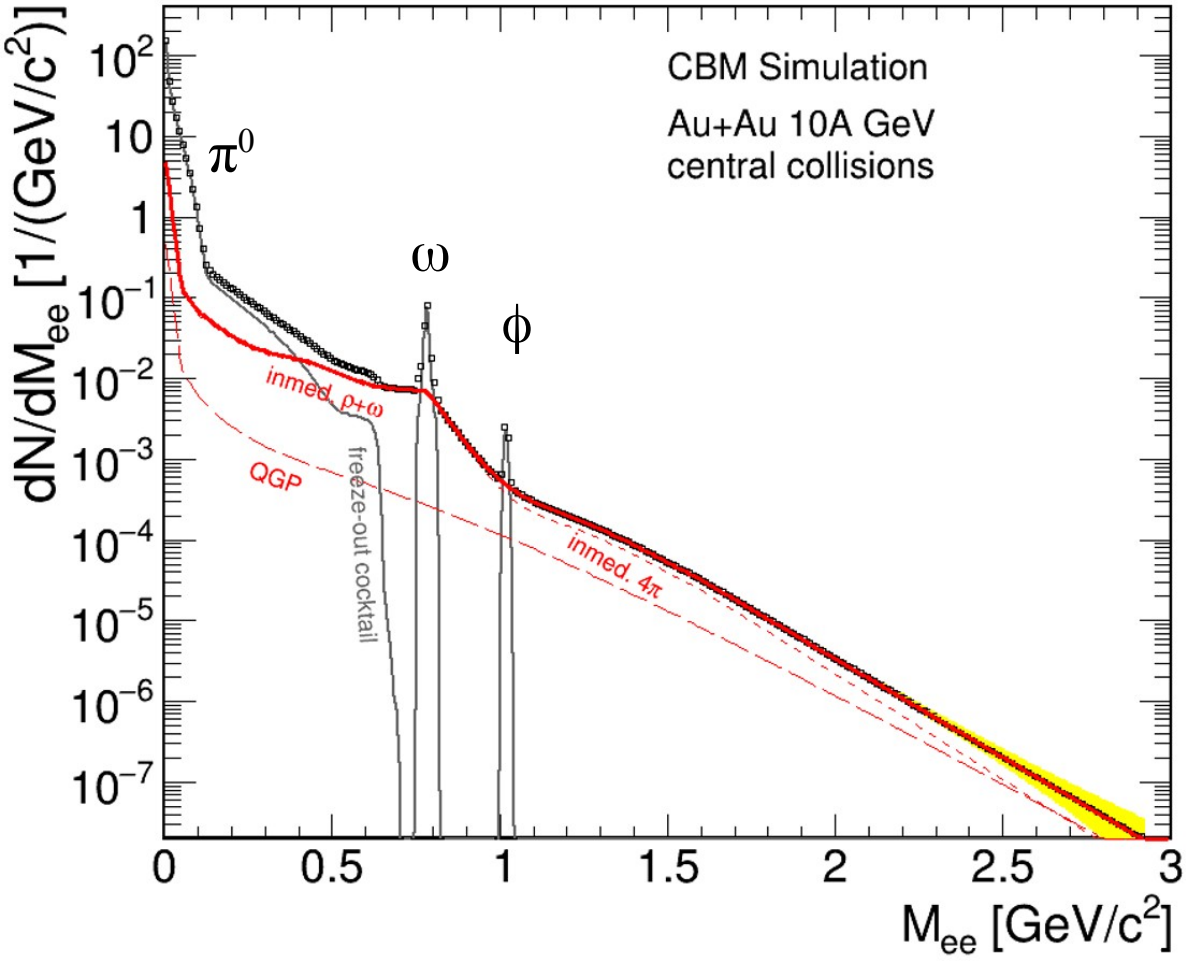


CBM physics and observables

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



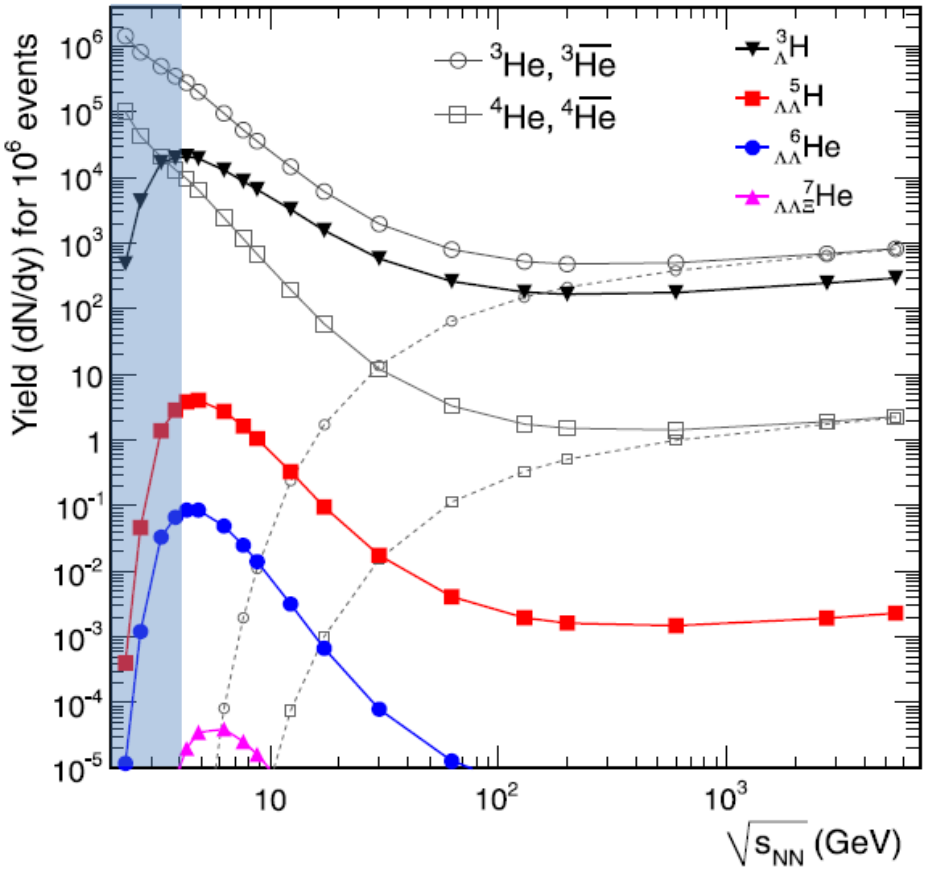
CBM physics and observables

Strange nuclear matter:

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

SIS100

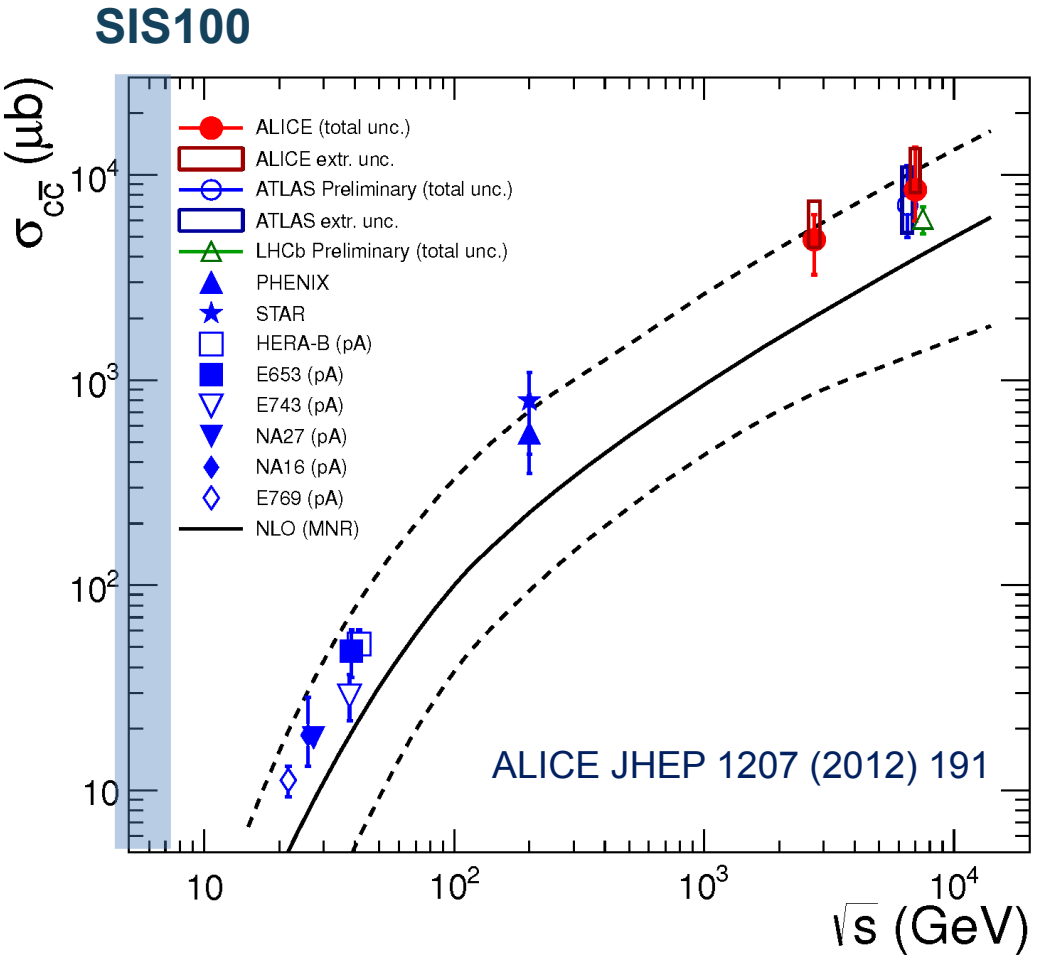
A. Andronic, PLB697 203 (2011)



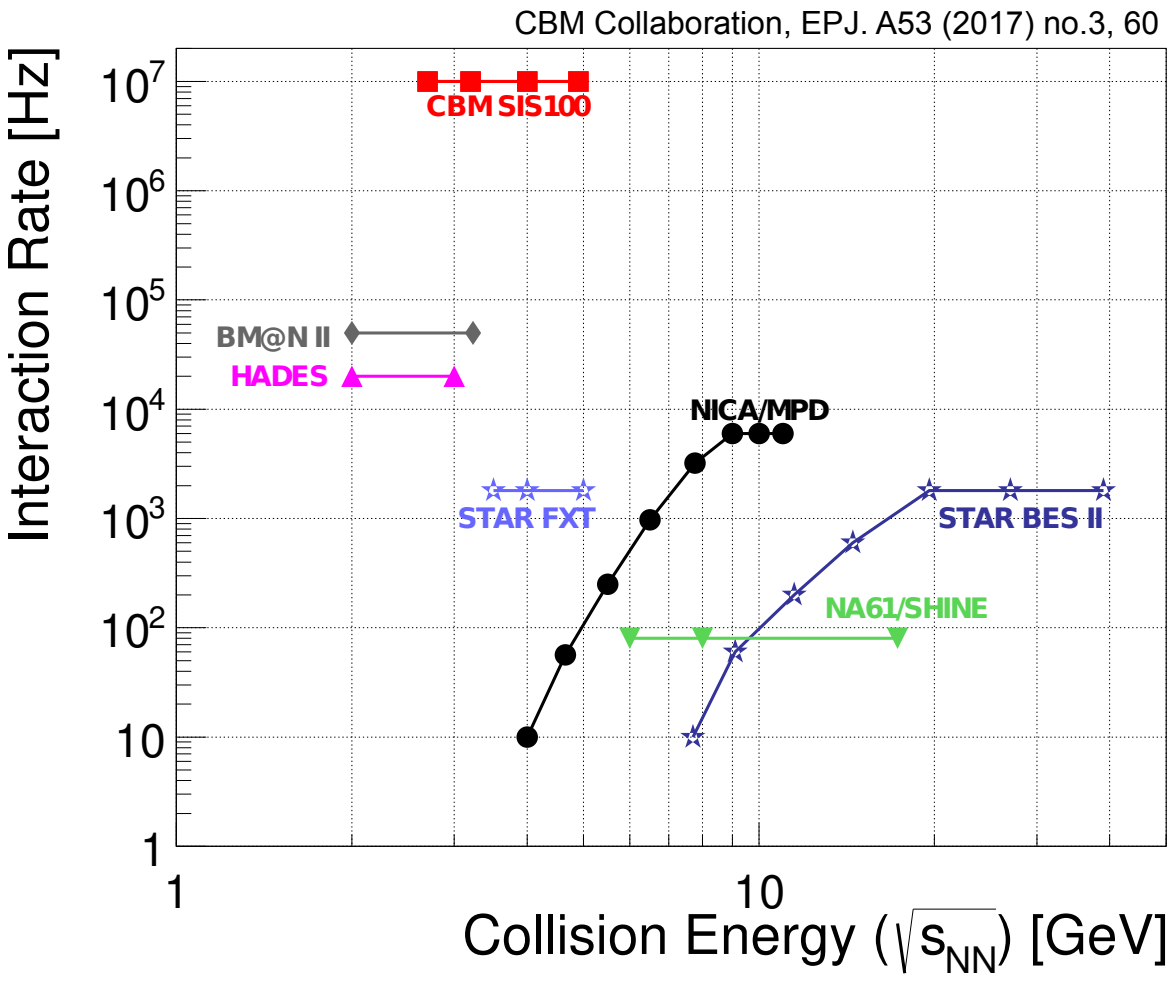
CBM physics and observables

Charm production and propagation at threshold energies

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



Experiments in the high net-baryon density



CBM will operate at high reaction rates:

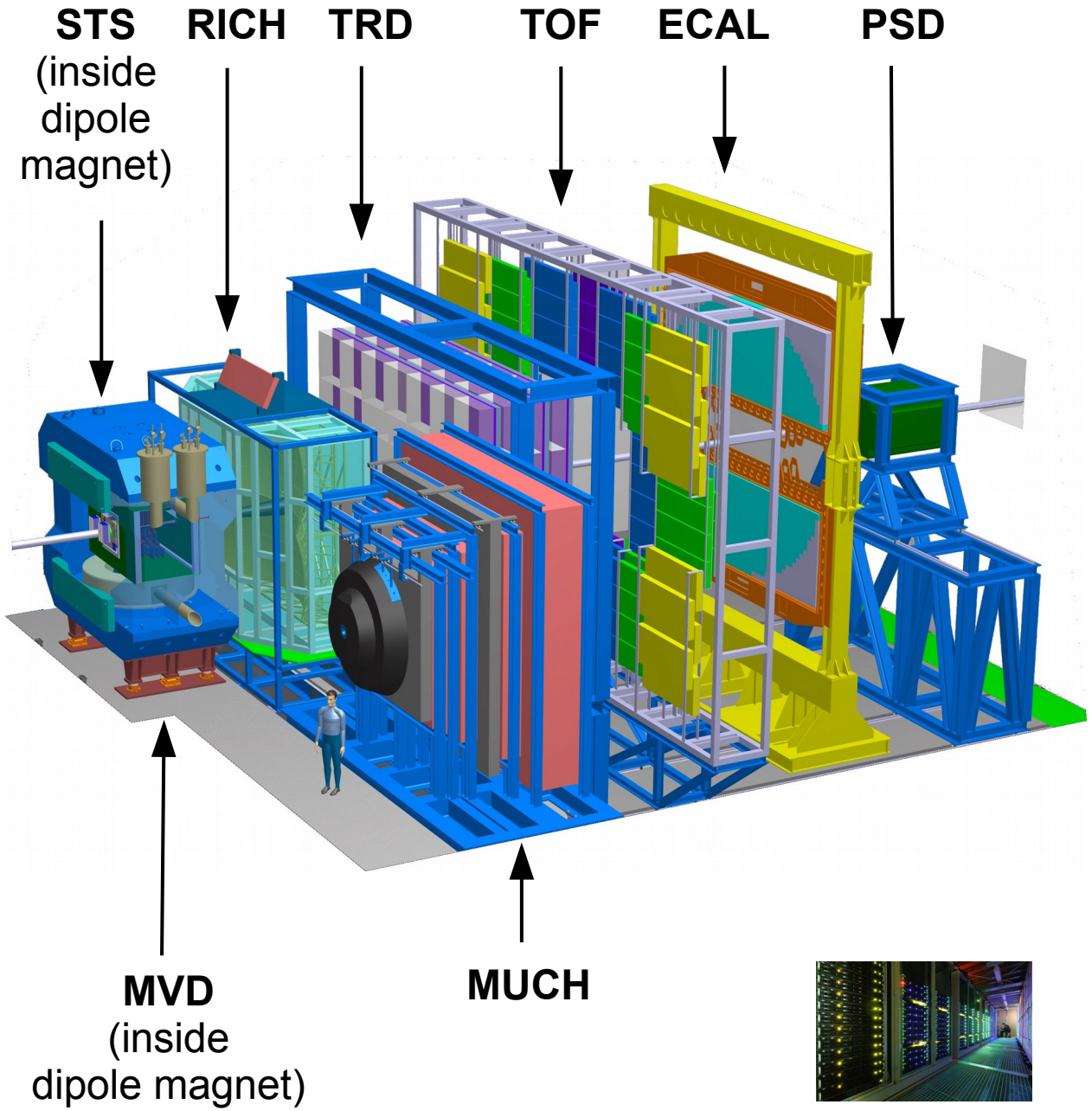
10^5 - 10^7 Au+Au reactions/sec

Main experimental requirements

- High statistics needs high event rates:
  10^5 - 10^7 Au+Au reactions/sec
- Particle identification: hadrons and leptons,
  displaced ($\sigma \approx 50$ μm) 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

CBM detectors

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)

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

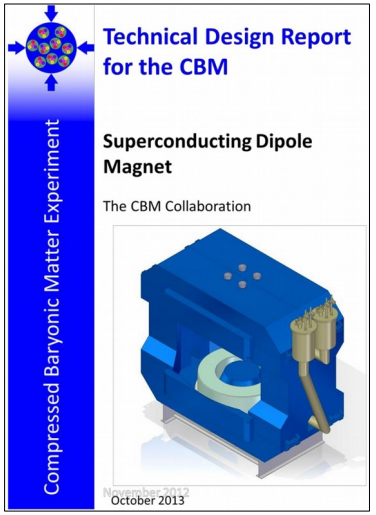
PSD (Projectile Spectator Detector)
collision centrality and
reaction plane determination

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

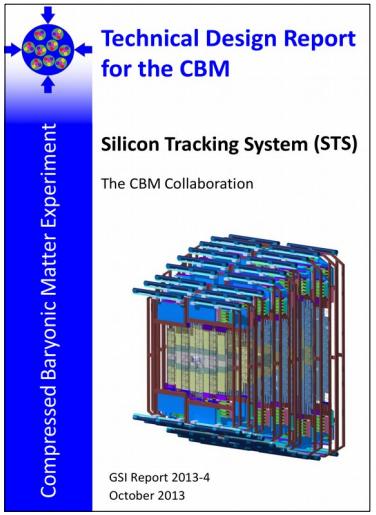
Subsystems preparation status

TDRs approved by FAIR

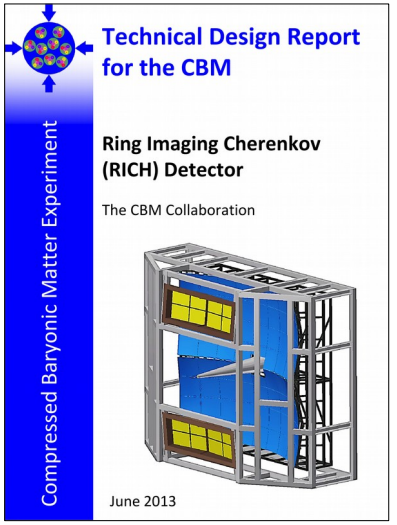
Dipole Magnet



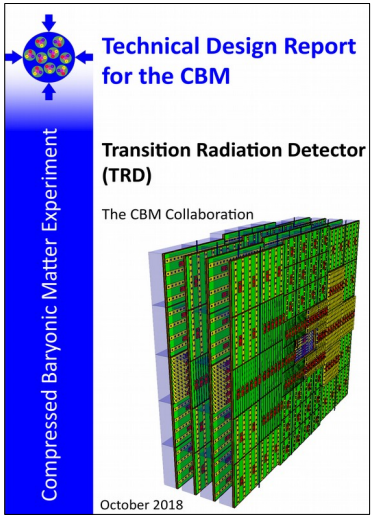
STS



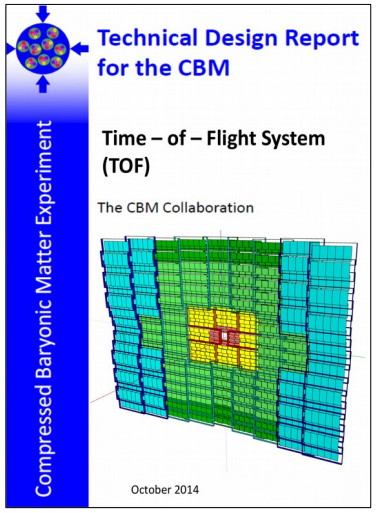
RICH



TRD



TOF

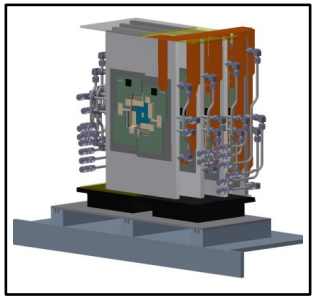


MUCH

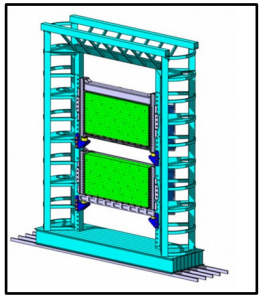
PSD

TDRs in preparation

MVD



ECAL

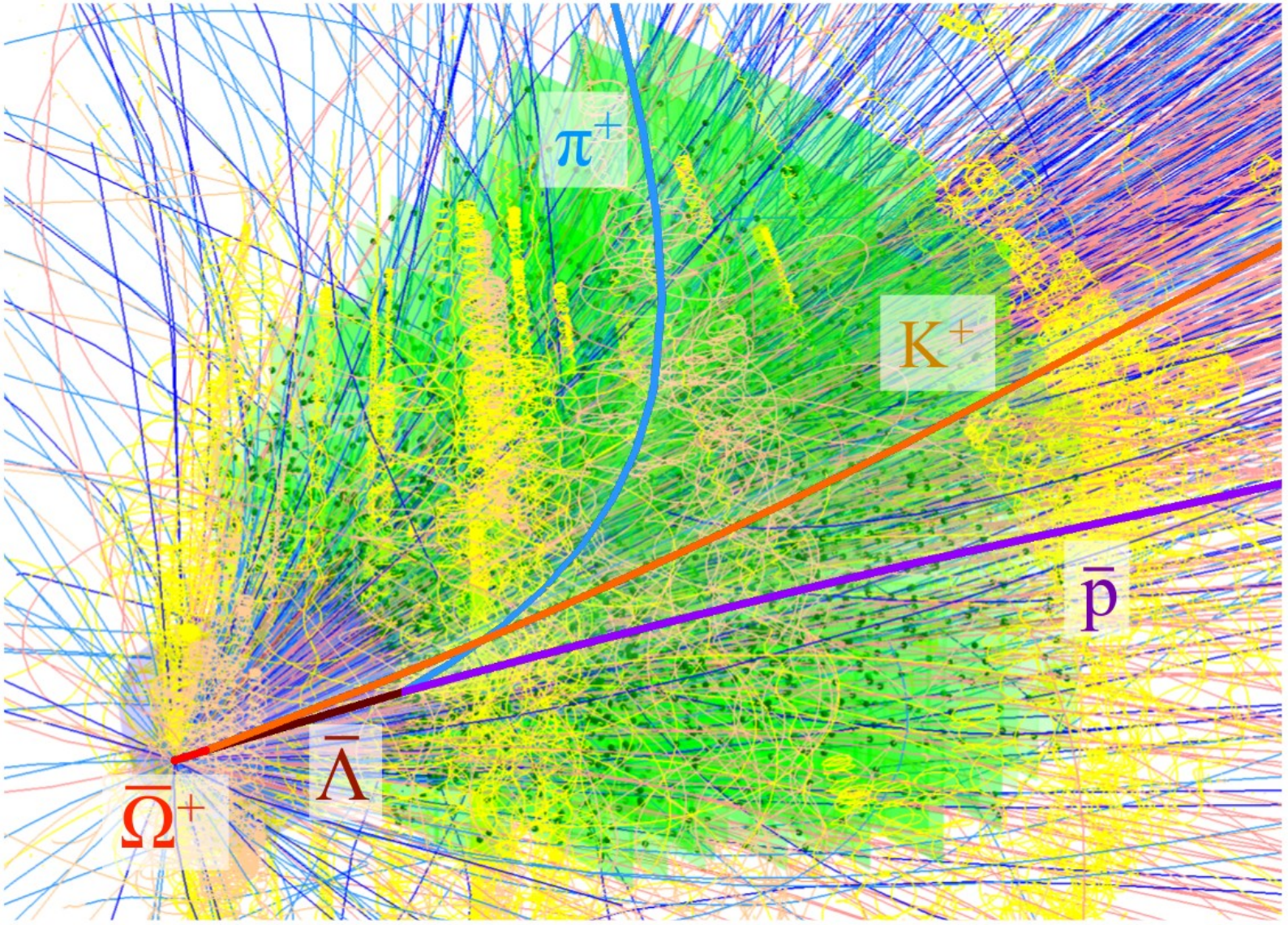


DAQ & FLES

Performance studies

CBM event and track reconstruction

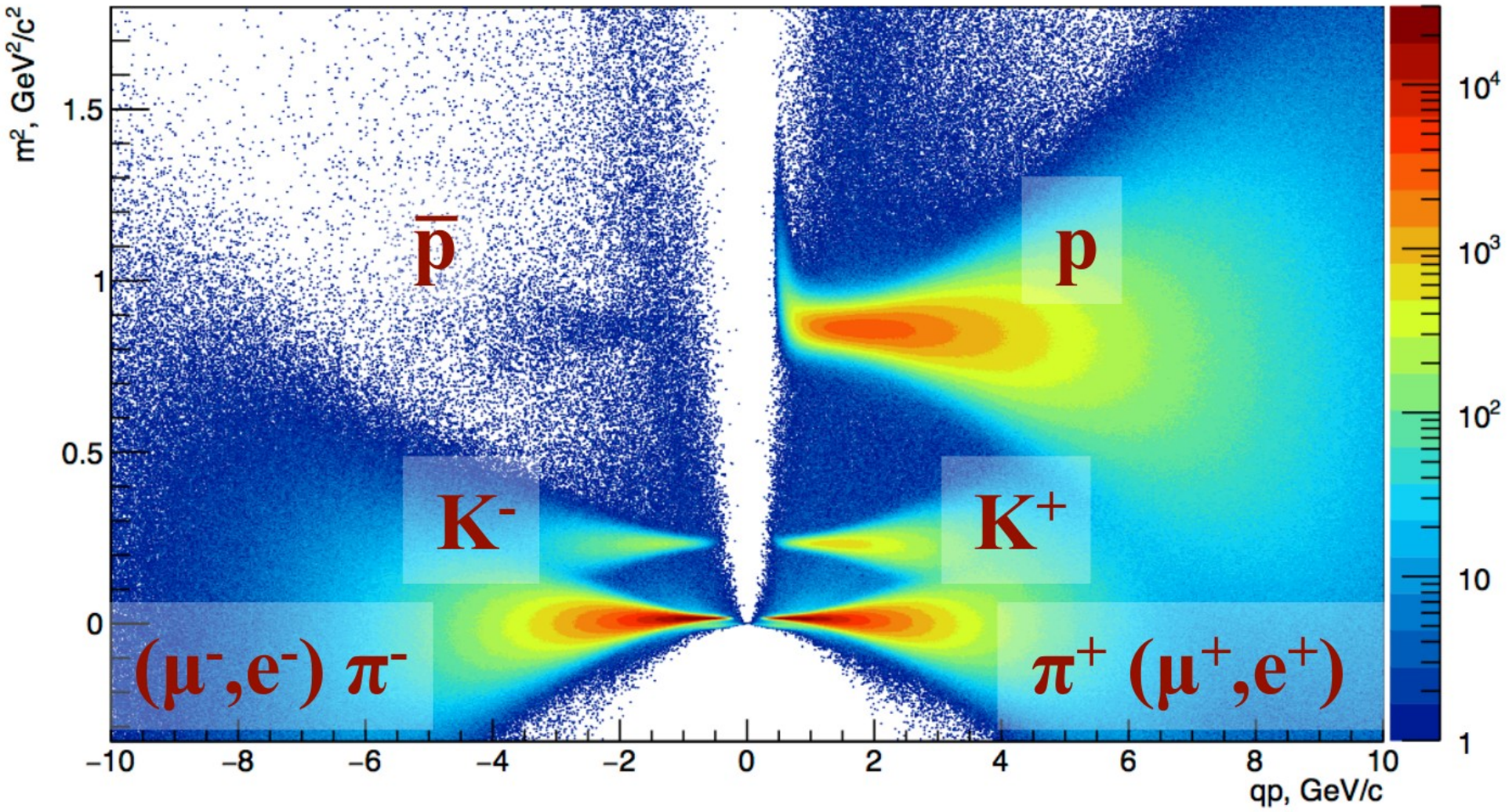
CBM Simulations, central AuAu@10AGeV



4D (space+time) reconstruction: Talk by I. Vassiliev (13/06)

Particle identification: light hadrons

CBM Simulations, central AuAu@10AGeV

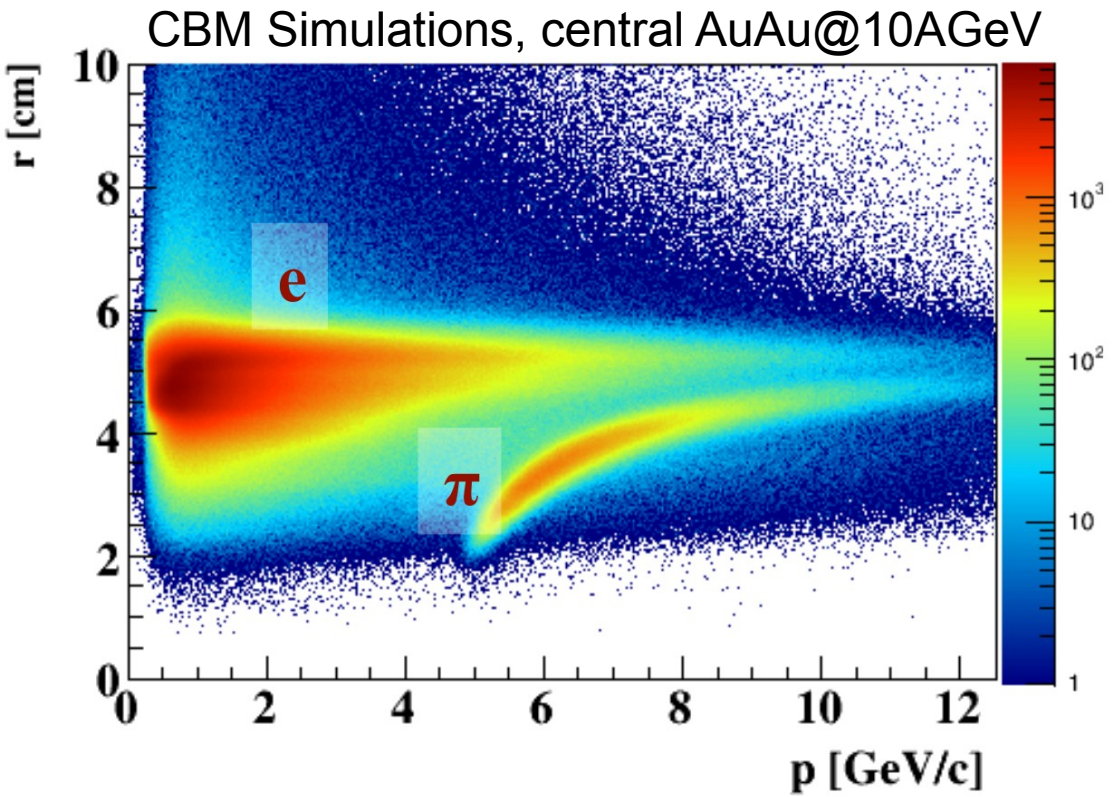


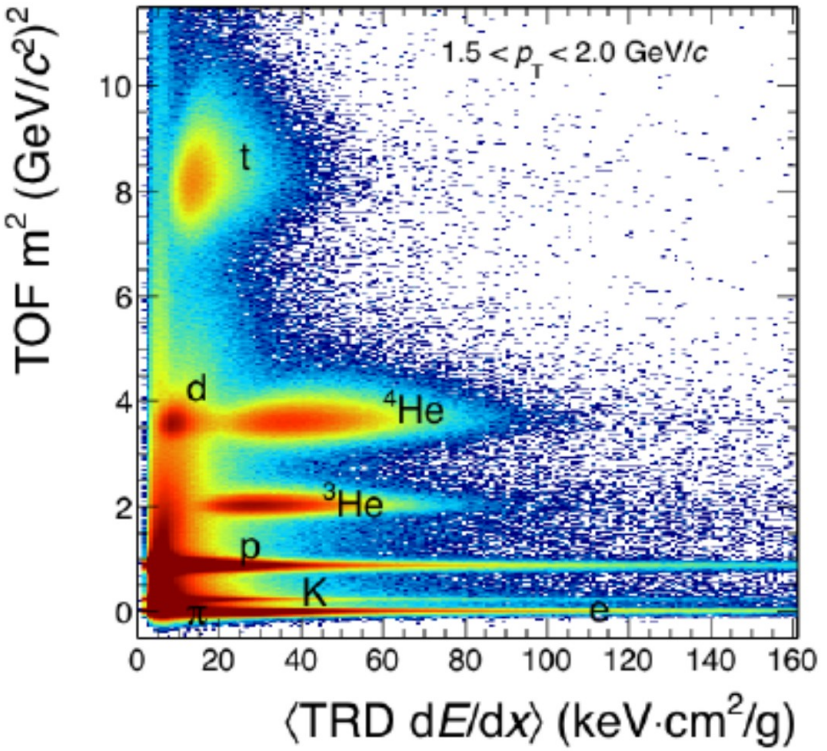
Clear separation between charged protons, pions and kaon

Particle identification: electrons and light nuclei

RICH (electrons)

TRD+TOF

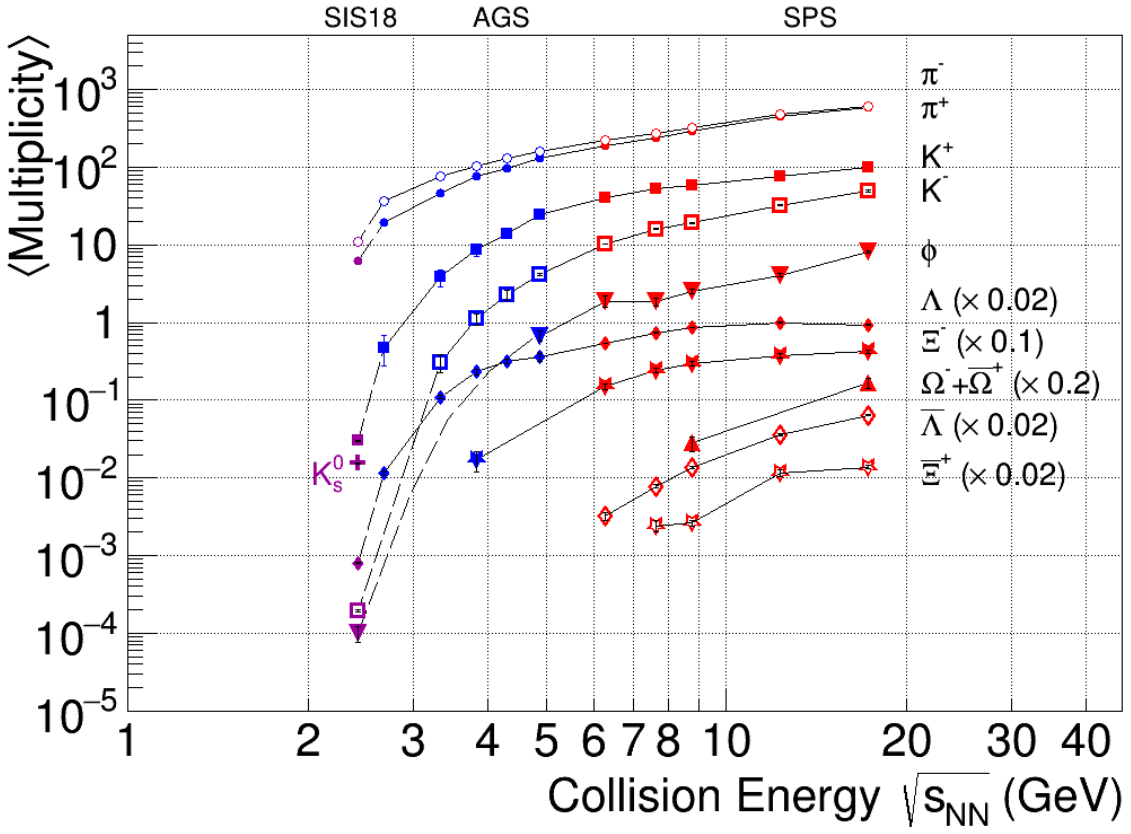


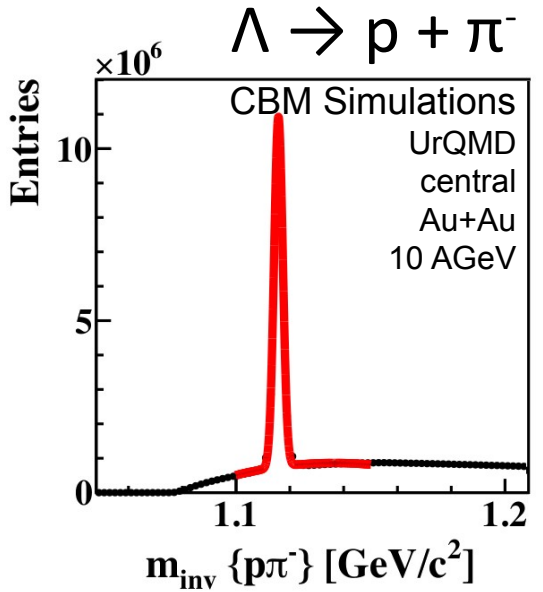


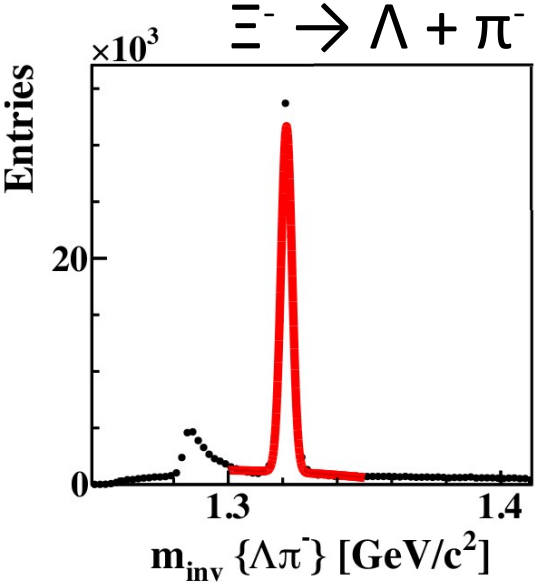
Clear separation between pions and electrons, and light nuclei

Multi-strange reconstruction

Blume/Markert PPNP66 (2011)
HADES PLB778 (2018); PLB793 (2019)





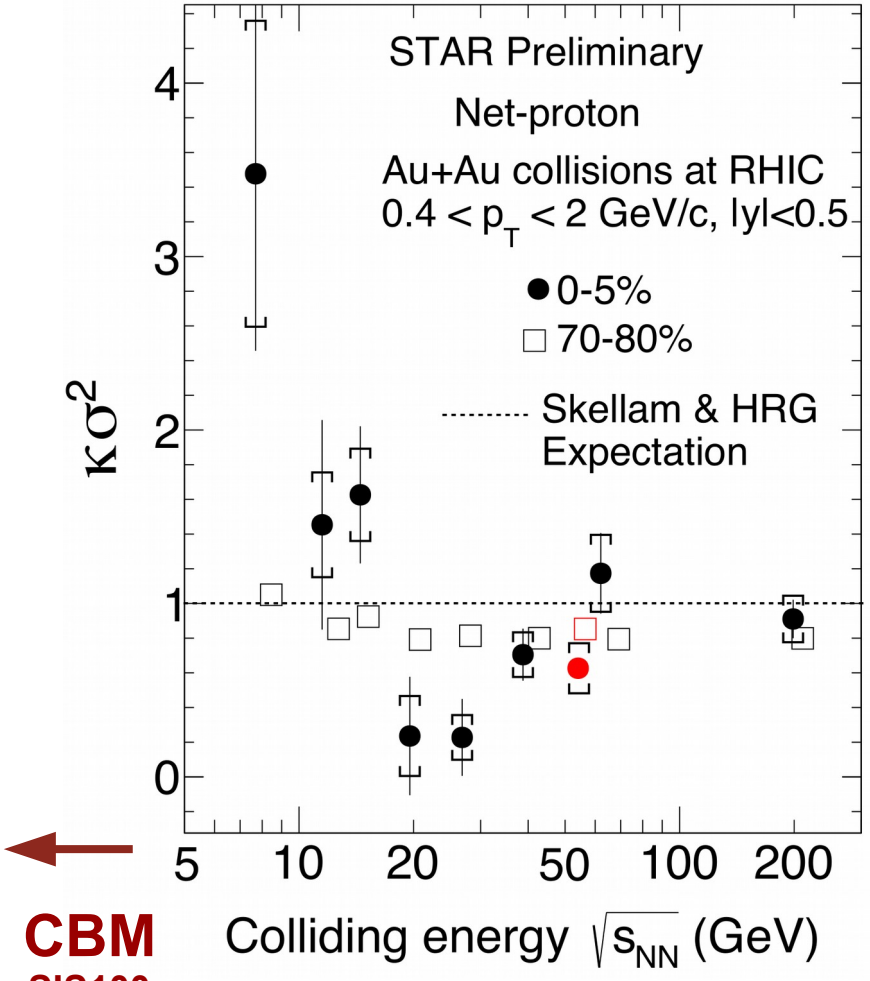


Decay topology reconstruction with KFParticleFinder package

Talk by I. Vassiliev (13/06)

Fluctuations of conserved quantities: net-protons

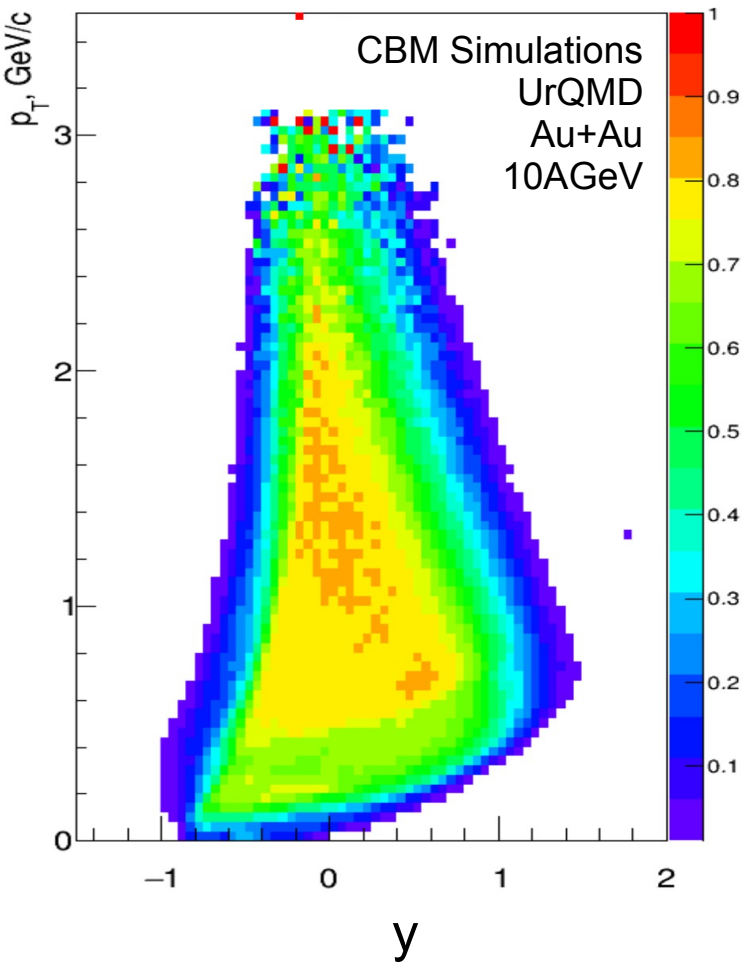
Moments:
1st - mean, 2nd - variance (σ)
3rd - skewness (s), 4th - kurtosis (κ)



CBM
SIS100

STAR Collab. [Jie Zhao] (11/06)

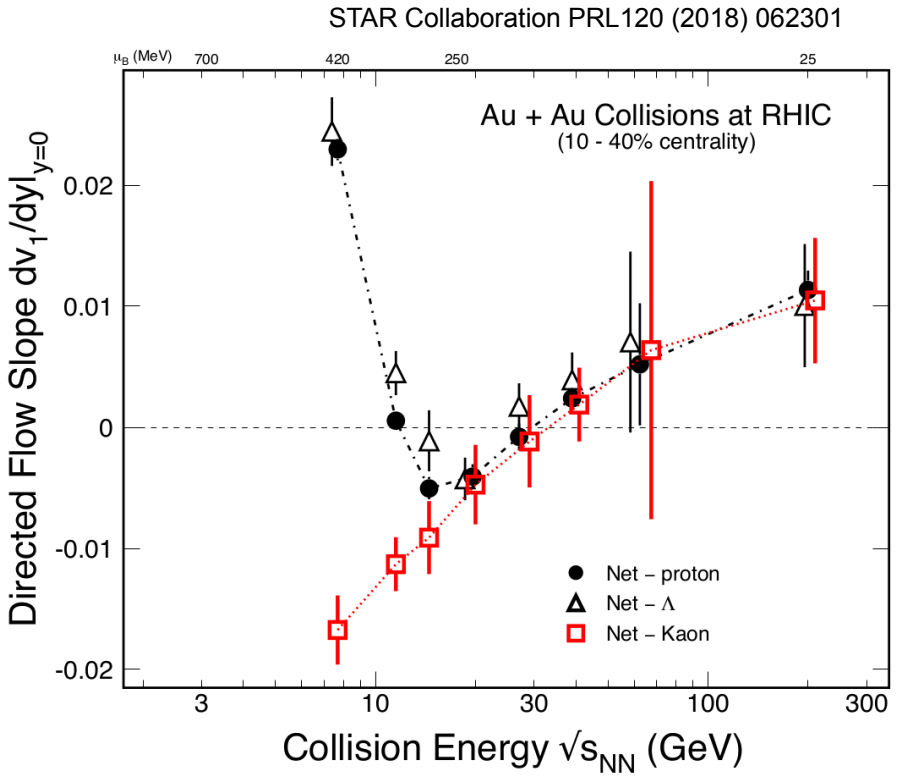
proton reconstruction efficiency

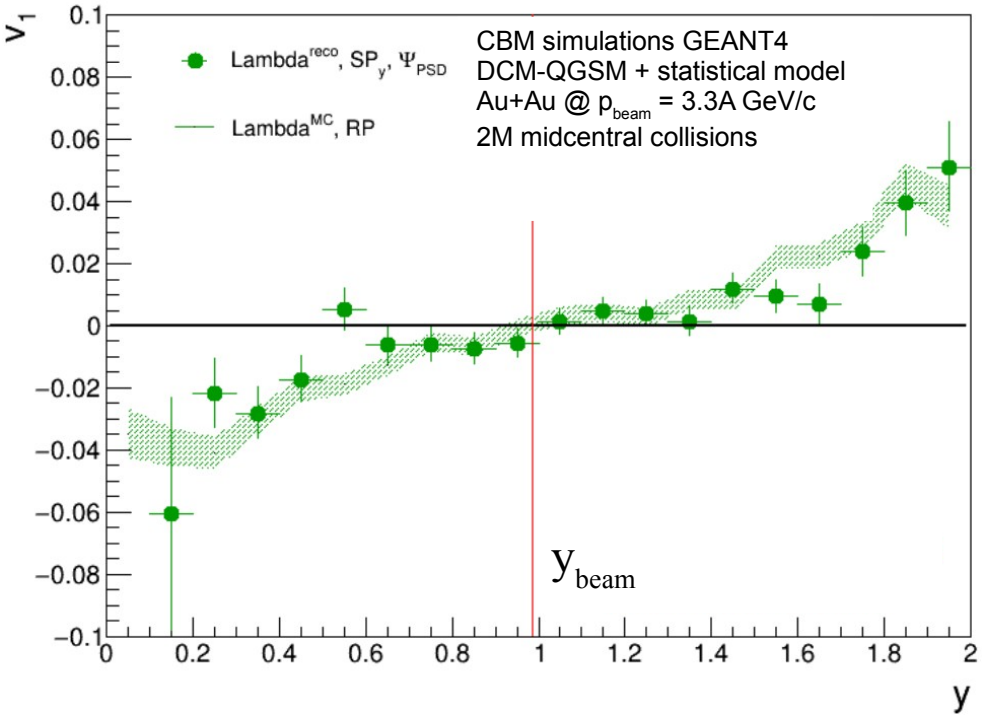


sufficient proton coverage at midrapidity

Studes by HADES: see EMMI workshop 2019
https://indico.gsi.de/event/7994/timetable/#20190325

Performance for directed flow (v_1) of strange hyperons

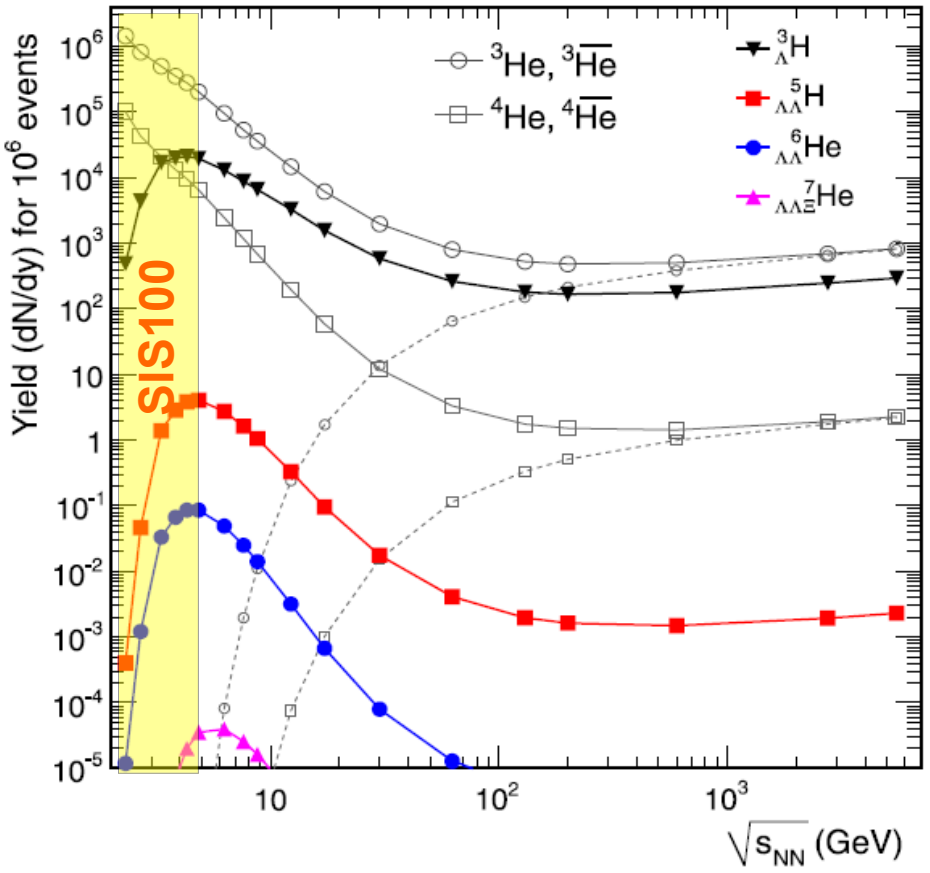




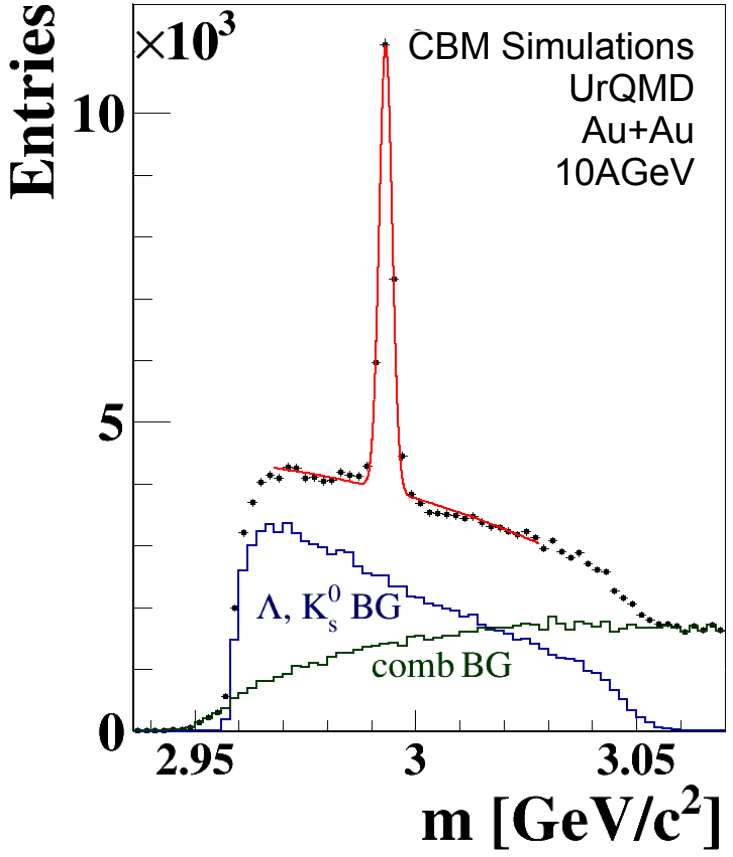
"input" model v_1 is recovered using "data-driven" method with reaction plane from projectile spectators

Strange nuclear matter

A. Andronic, PLB697 203 (2011)



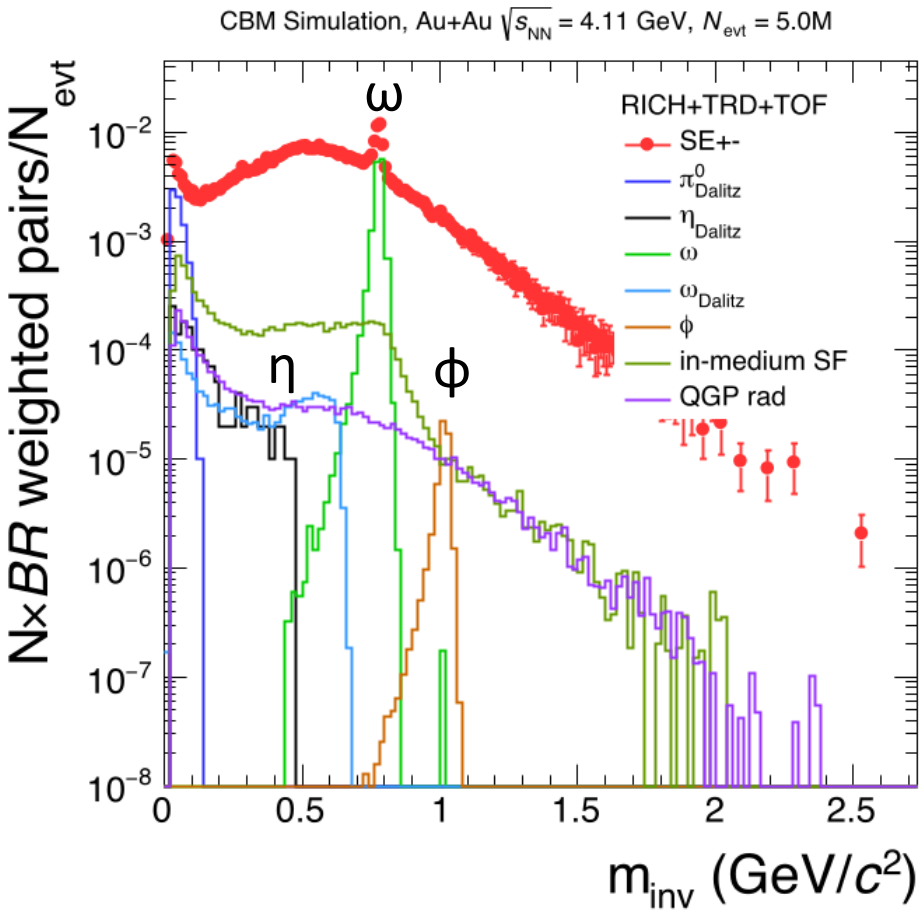
$^3_\Lambda\text{H} \rightarrow {}^3\text{He} + \pi^-$



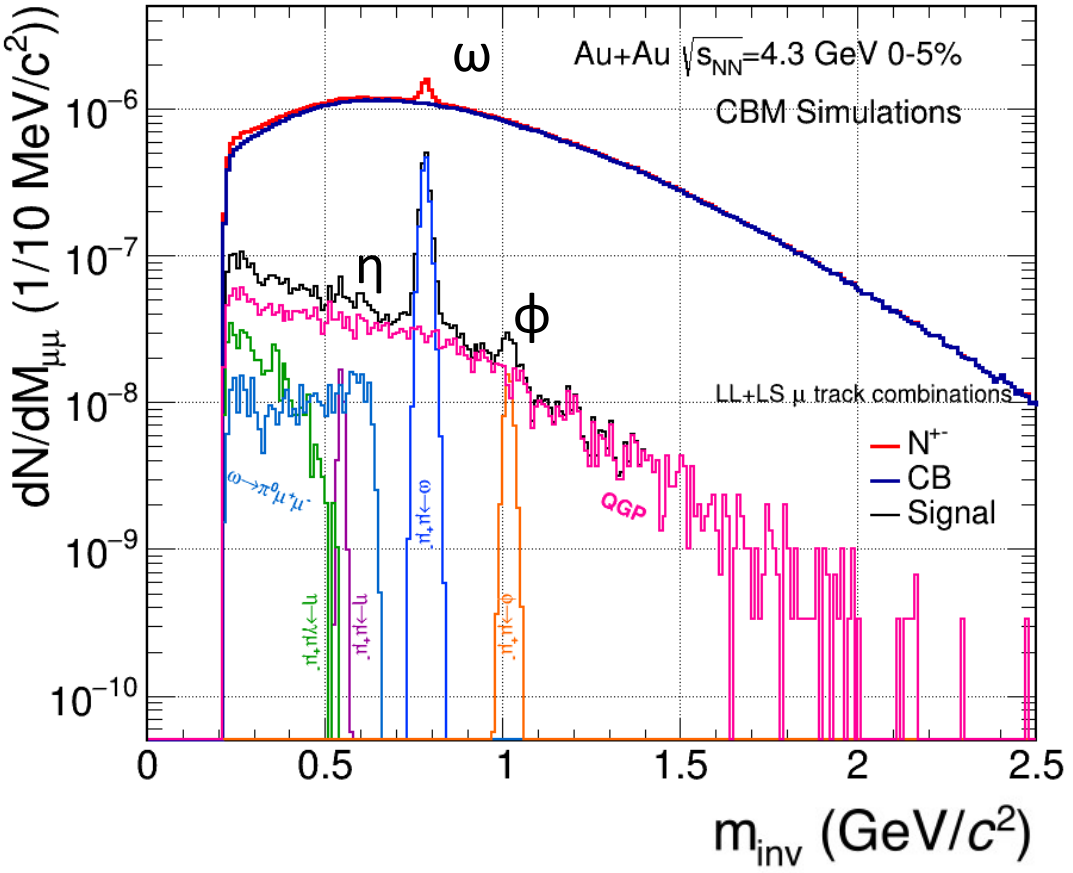
Talk by I. Vassiliev (13/06)

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

di-electrons



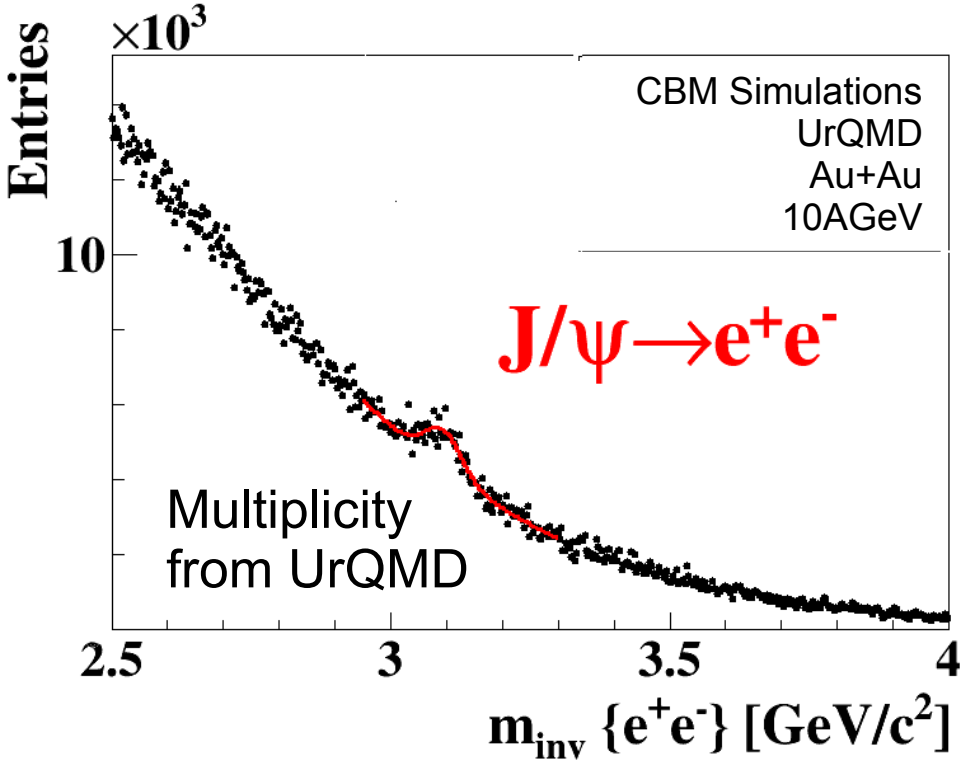
di-muons



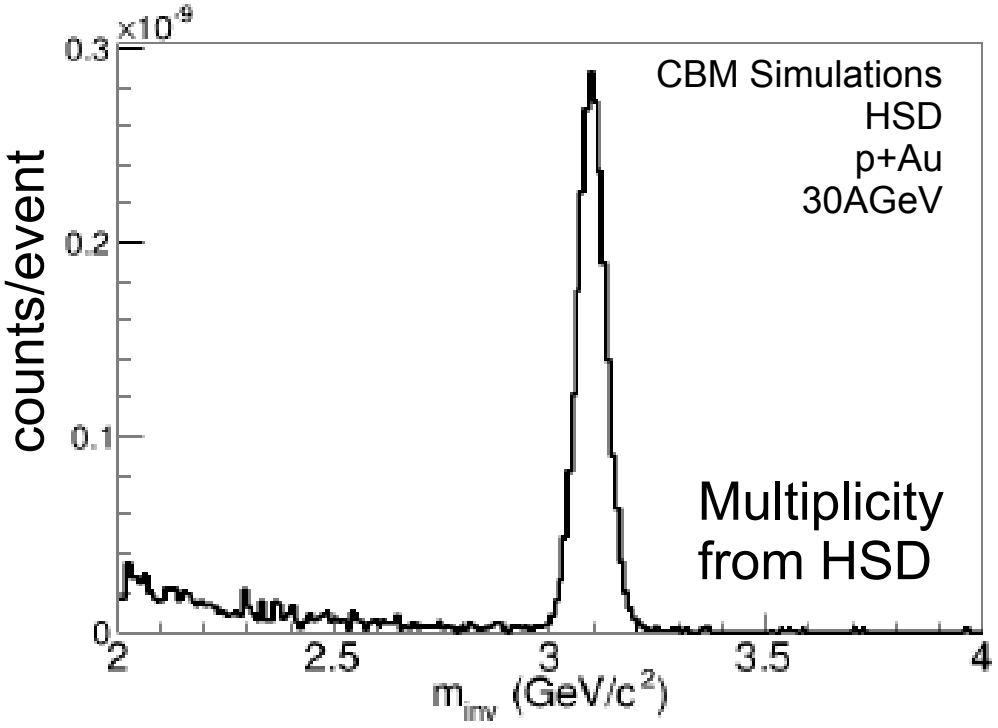
Poster by Etienne Bechtel

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

central Au+Au 10 A GeV



p+Au 30GeV



Also investigating: open charm reconstructed

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)
  → talk by Manuel Lorenz (10/06)

- Use 10% of the CBM TOF modules including read-out chain at STAR/RHIC (BES II 2019/2020)
  → talk by Florian Seck (11/06)

- 4 Silicon Tracking Stations in the BM@N in JINR/Dubna (start 2020 with Au-beams up to 4.5 A GeV)
  → talk by Mikhail Kapishin (10/06)

- Project Spectator Detector at the BM@N experiment (2020). Tests and performance studies at the NA61/SHINE SPS experiment
  → talk by Szymon Pulawski (10/06)

- mini CBM at GSI/SIS18
  full system test with high-rate A-A collisions (2018-2021)
  → 1st data taking in 12/2018 - 03/2019 – ongoing analysis of the collected data

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: 7 approved, 4 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, 413 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
MEPHI Moscow
PNPI Gatchina
SINP MSU, Moscow

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

JINR
VBLHEP, Dubna
LIT, Dubna

30th CBM Collaboration Meeting, 24-28 September 2017, Wuhan, China