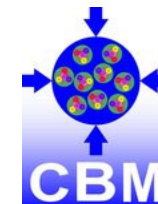
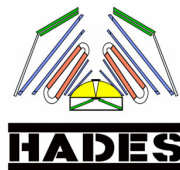


Challenges in QCD matter physics

The scientific programme of the Compressed Baryonic Matter experiments at FAIR

**Claudia Höhne, University Giessen & GSI
HADES & CBM collaboration**





Open QCD questions

.... See e.g. workshop program, white paper(s),

- Phase structure of QCD at finite density
 - EOS at high densities
 - Connection to neutron stars
- Formation of hadrons, hadron spectra
 - Chiral symmetry
 - Hadron masses in vacuum/ dense matter
 - Confinement
- Formation of nuclei
 - Light nuclei in HIC
 - Hypernuclei



QCD phase diagram

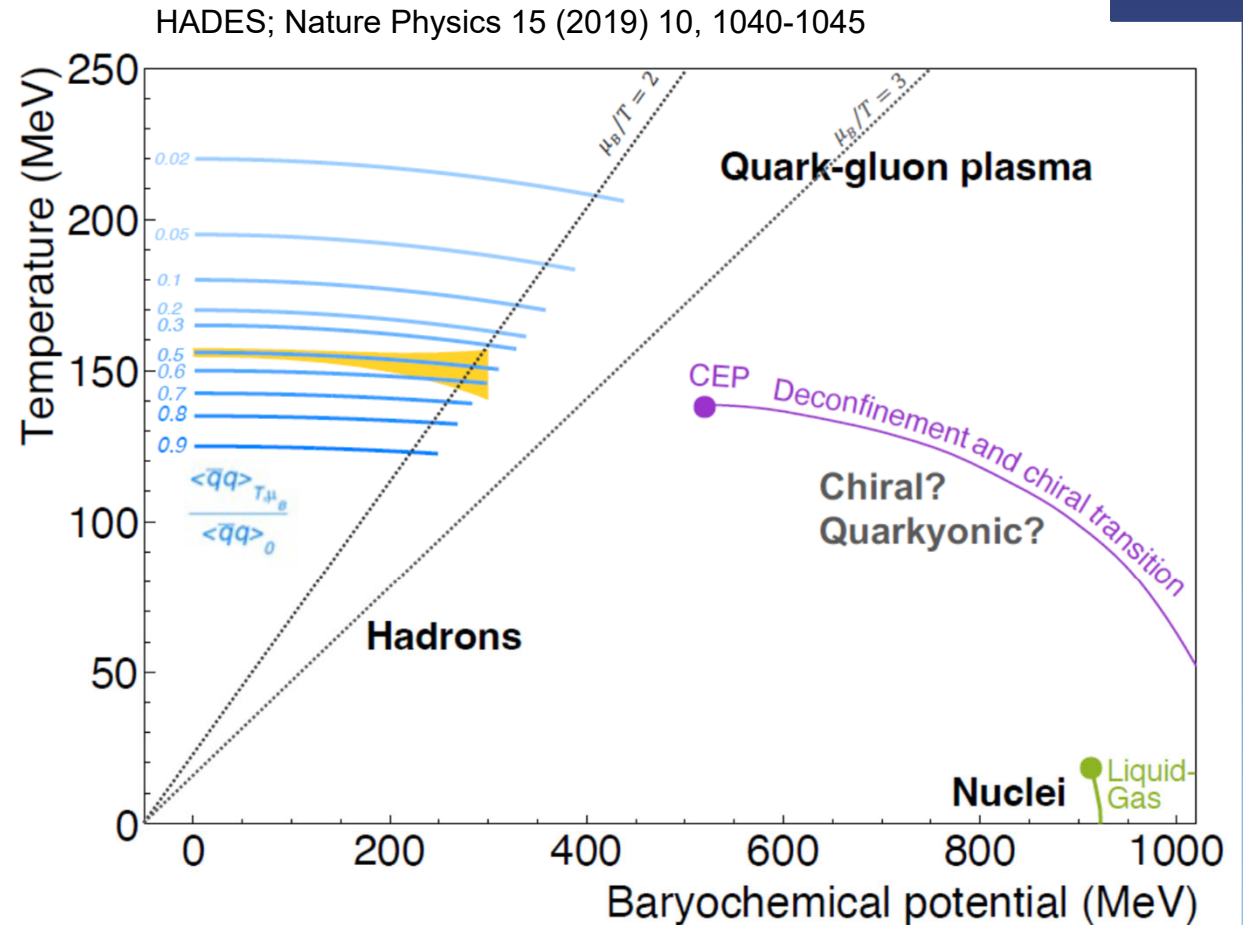


High T , low μ_B

- Crossover
- Consistent in theory & Experiment!

Lower T , high μ_B

- CEP?
- 1st order phase transition?
- EOS?
- Properties of hadrons/ limits of existence?



Borsanyi *et al.* [Wuppertal-Budapest Collab.], JHEP 1009 (2010) 073
Isserstedt, Buballa, Fischer, Gunkel, PRD 100 (2019) 074011
Gao, Pawłowski, PLB 820 (2021) 136584
Cuteri, Philipsen, Sciarra, JHEP 11 (2021) 141

QCD phase diagram



C.B.M. = HADES & CBM

- Experimental investigation of region with $500 \text{ MeV} < \mu_B < 850 \text{ MeV}$

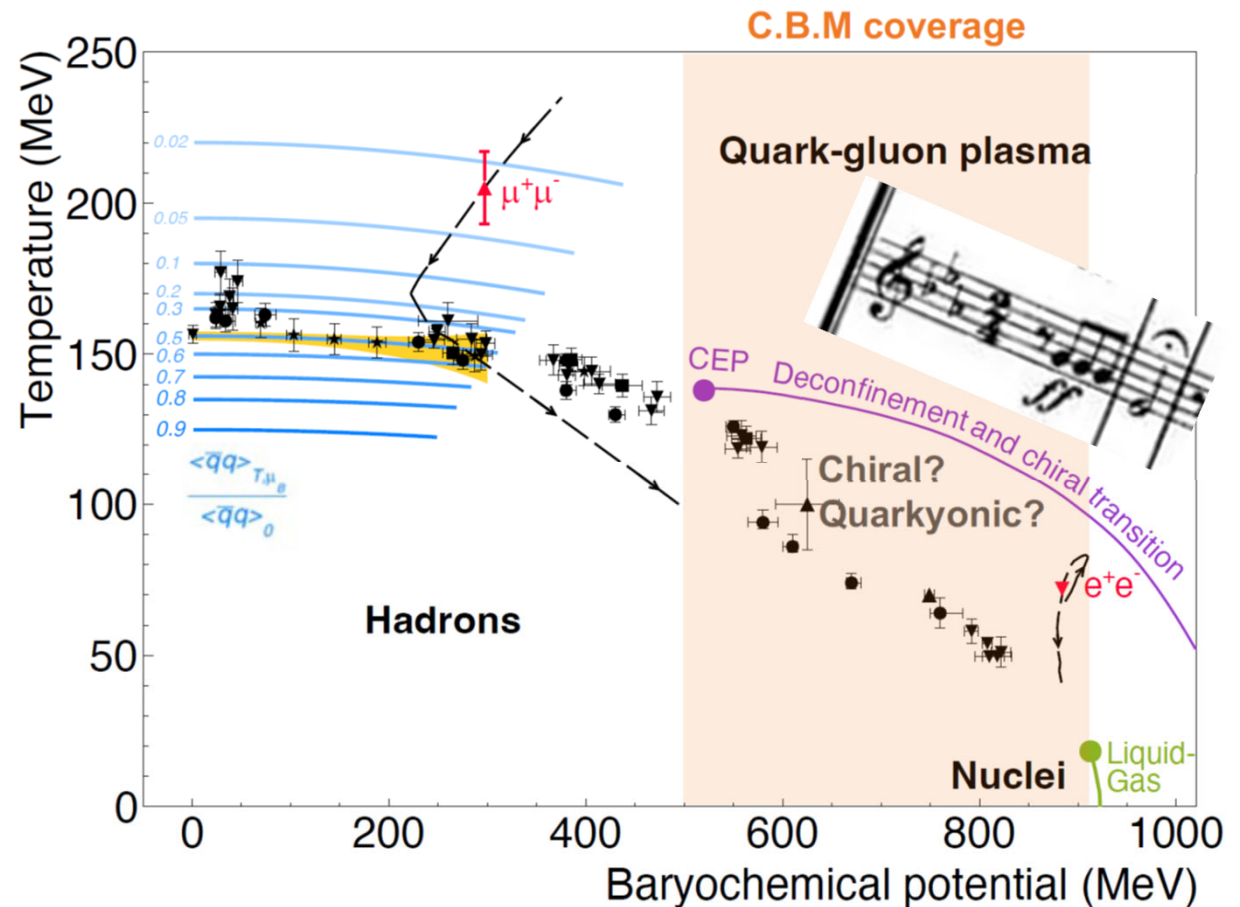
Observables?

- Fluctuations
- Dileptons
- Strangeness
- Hypernuclei
-?

	$\sqrt{s_{NN}}$ [GeV]	μ_B [MeV]
SIS 18	2 – 2.5	830 – 760
SIS 100	2.3 – 5.3	785 – 520
STAR Collider	7.7 – 200	400 – 22
STAR FXT	3 – 13.7	700 – 265

$\mu_B(\sqrt{s_{NN}})$ from A. Andronic, P. Braun-Munzinger, K. Redlich and J. Stachel, Nature 561, no. 7723, 321 (2018)

HADES; Nature Physics 15 (2019) 10, 1040-1045
T. Galatyuk for HADES, Nucl.Phys.A 967 (2017) 680-683



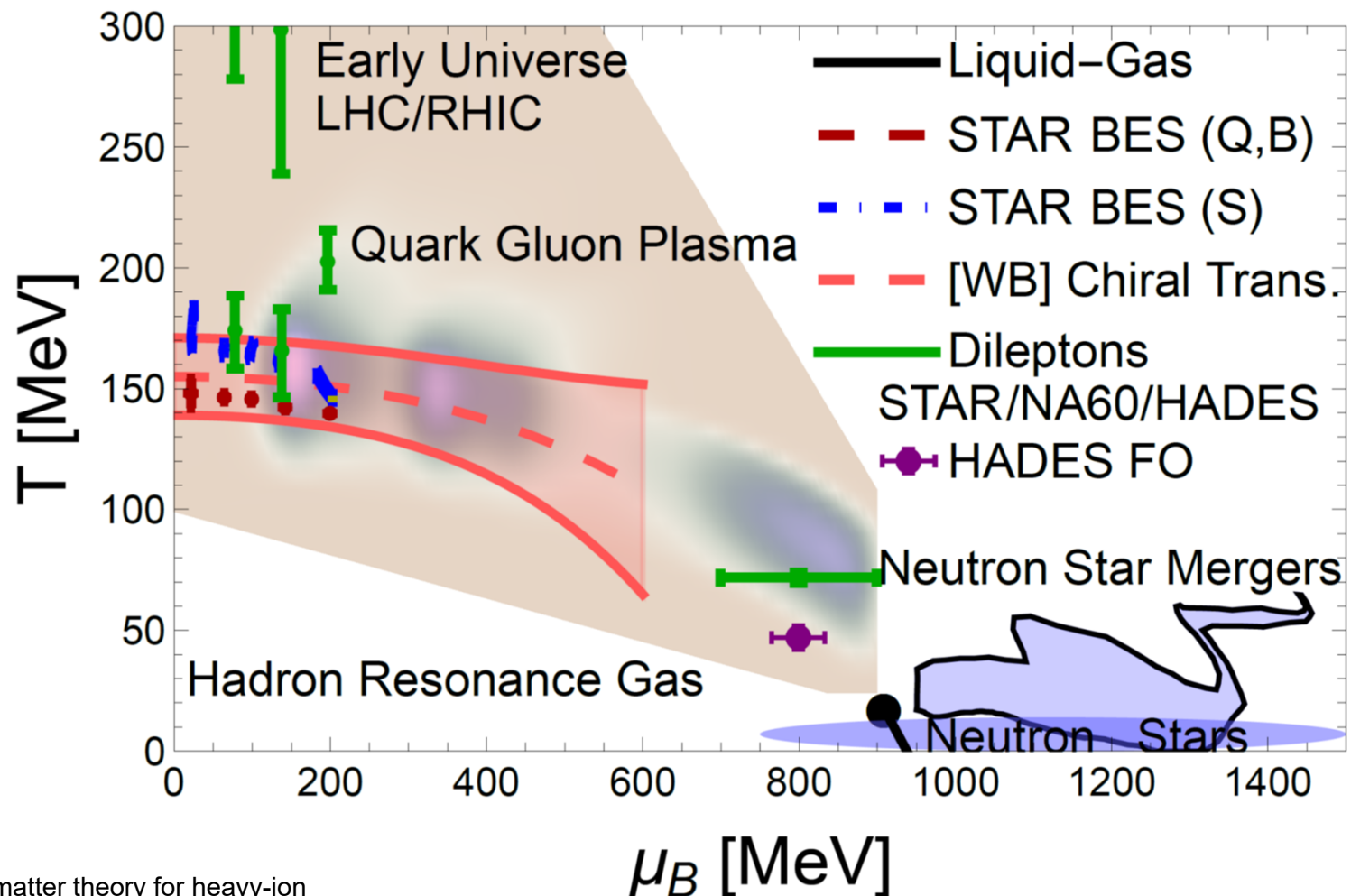
Borsanyi *et al.* [Wuppertal-Budapest Collab.], JHEP 1009 (2010) 073
Isserstedt, Buballa, Fischer, Gunkel, PRD 100 (2019) 074011
Gao, Pawłowski, PLB 820 (2021) 136584
Cuteri, Philipsen, Sciarra, JHEP 11 (2021) 141

Beethoven, 5. Sinfonie

Neutron stars/ Neutron star mergers



With (not any more so new ;-) observation of neutron star mergers revival of combined analysis and cross-disciplinary discussions



[Long Range Plan: Dense matter theory for heavy-ion collisions and neutron stars, nucl-th 2211.02224]

Neutron stars/ Neutron star mergers



With (not any more so new ;-) observation of neutron star mergers revival of combined analysis and cross-disciplinary discussions

$T < 70 \text{ MeV}$, $\rho \approx 3\rho_0$ in both cases

Central Au+Au collisions,
 $\sqrt{S_{NN}} = 2.4 \text{ GeV}$

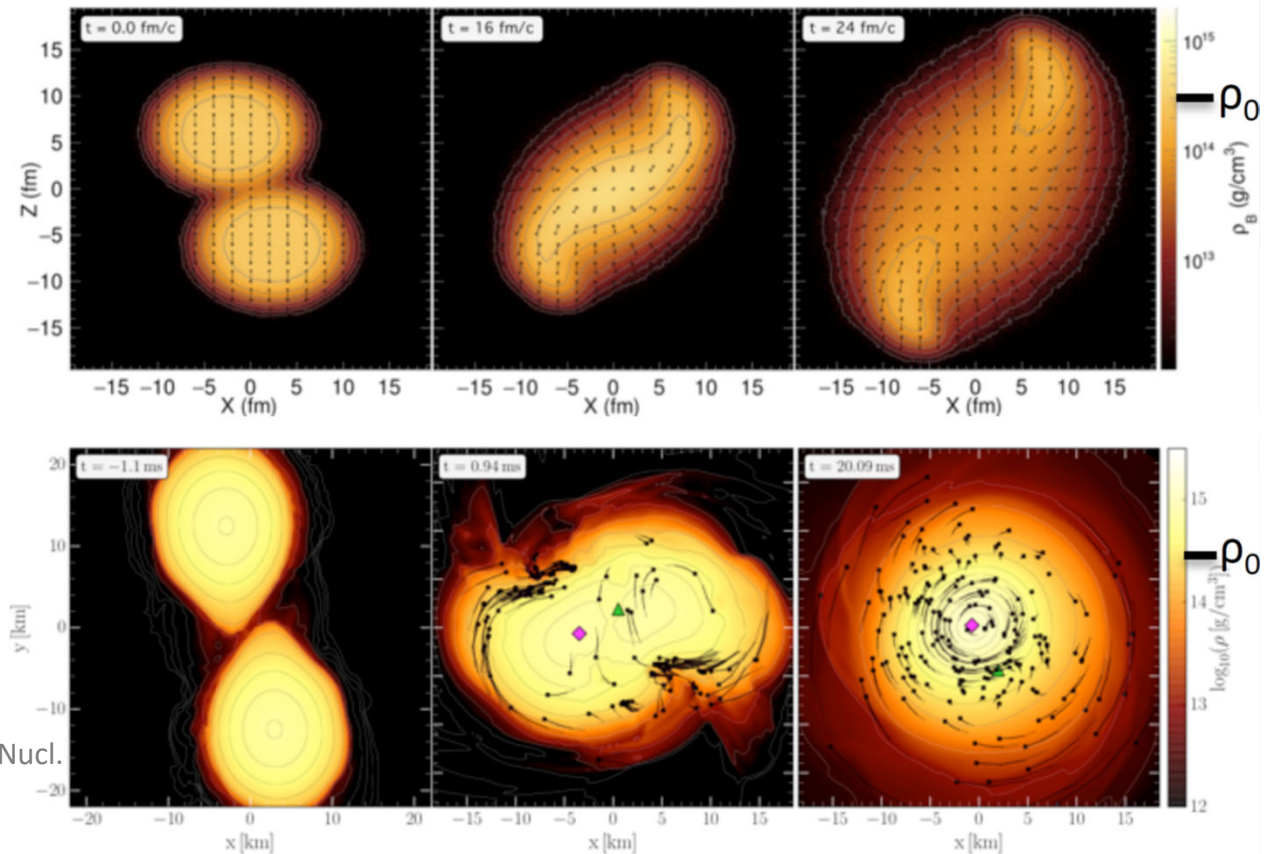
Neutron Star Merger

M. Hanauske, J.Phys.: Conf. Series 878 012031 (2017)

L. Rezzolla et. al. PRL 122, n0.6, 061101 (2019)

Au+Au simulation UrQMD: S. A. Bass et al., Prog. Part. Nucl. Phys. 41, 255 (1998).

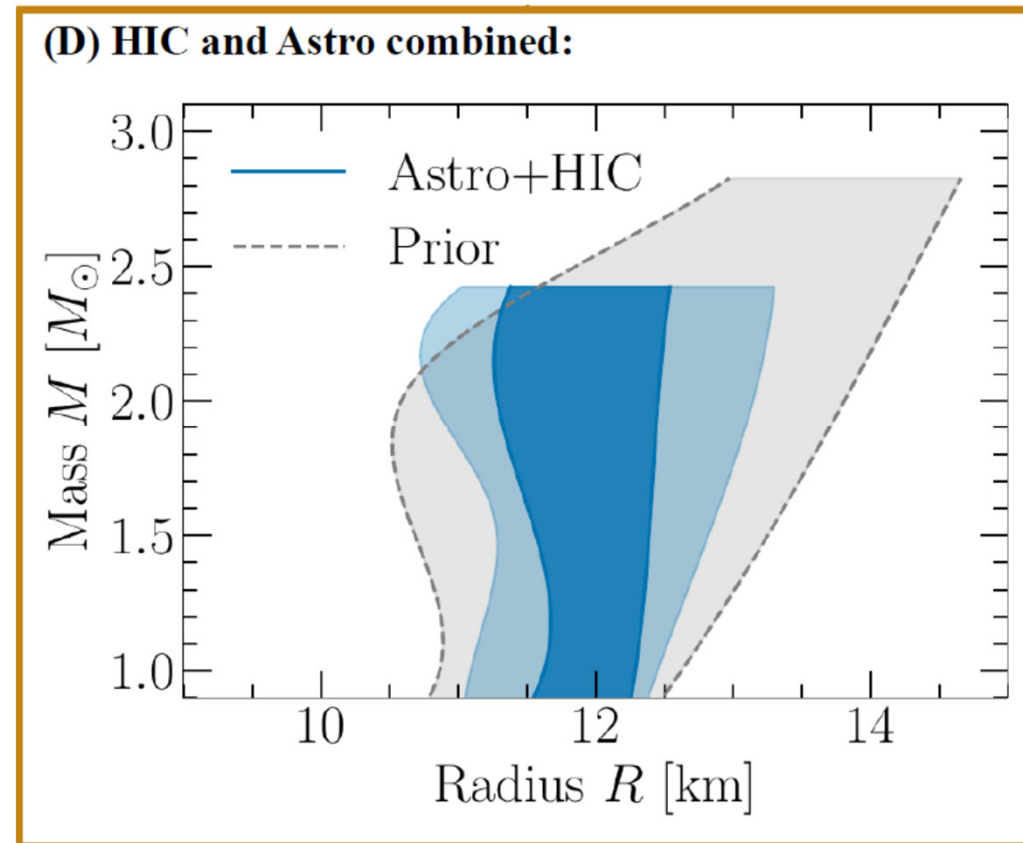
Fig. credit T. Galatyuk & Florian Seck





Example:

Inclusion of HIC shifts NS radii to larger values, consistent with recent results from NICER



Constraining Neutron-Star Matter with Microscopic and Macroscopic collisions
S. Huth, P.T.H. Pang et al., Nature 606 (2022) 276-280



What to measure?

Challenges/ difficulties/ opportunities for high- μ_B facilities?

→ Program needs ever more precise data (statistics!) and sensitivity for rarest signals

Critical phenomena

1st order PT, CEP

EOS

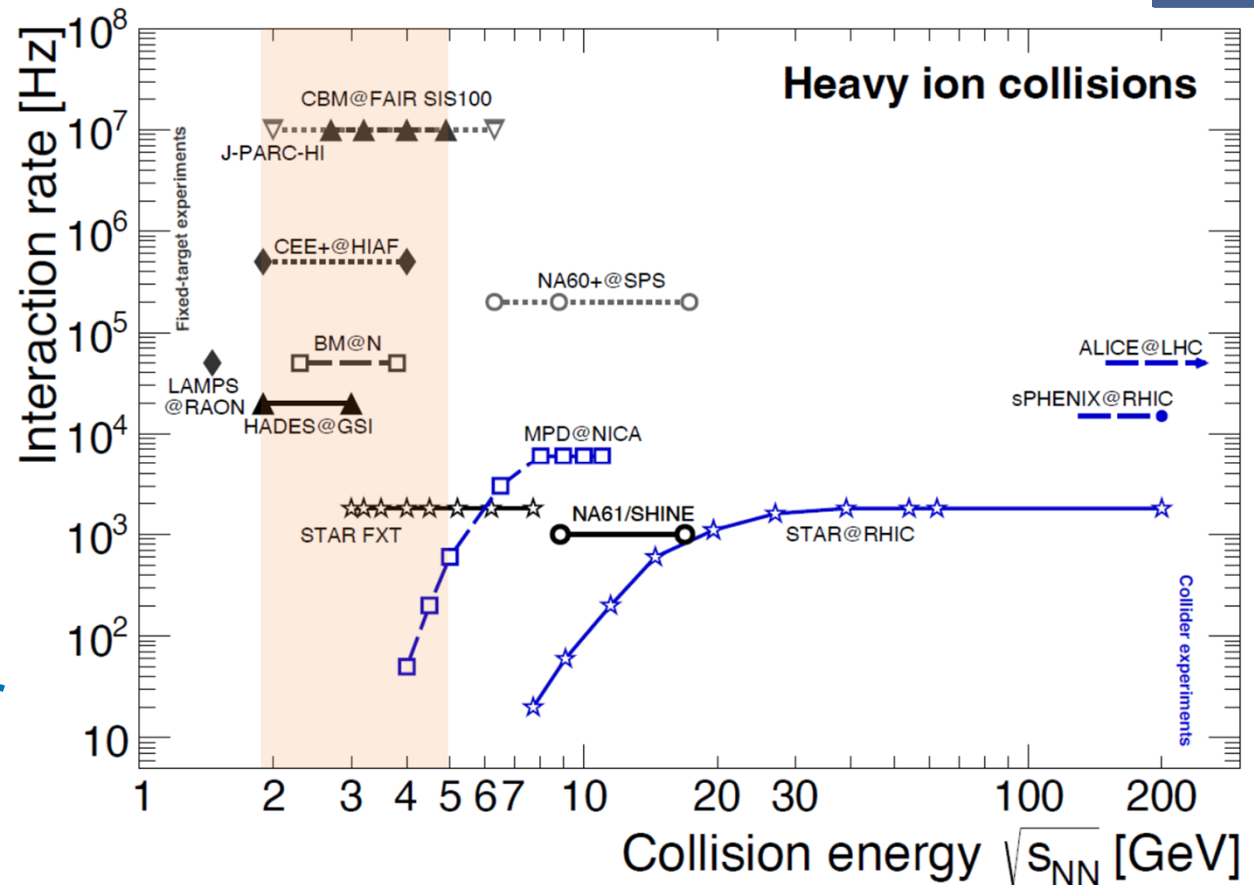
Flow, bulk phenomena

Emissivity

Em probes

Characterization of matter

Hadrons, strangeness,
Hypernuclei, light nuclei
Correlations, vorticity,



T. Galatyuk, NPA 982 (2019), update 2021
CBM, EPJA 53 3 (2017) 60



What to measure?

Challenges/ difficulties/ opportunities for high- μ_B facilities?

→ Program needs ever more precise data (statistics!) and sensitivity for rarest signals

HADES

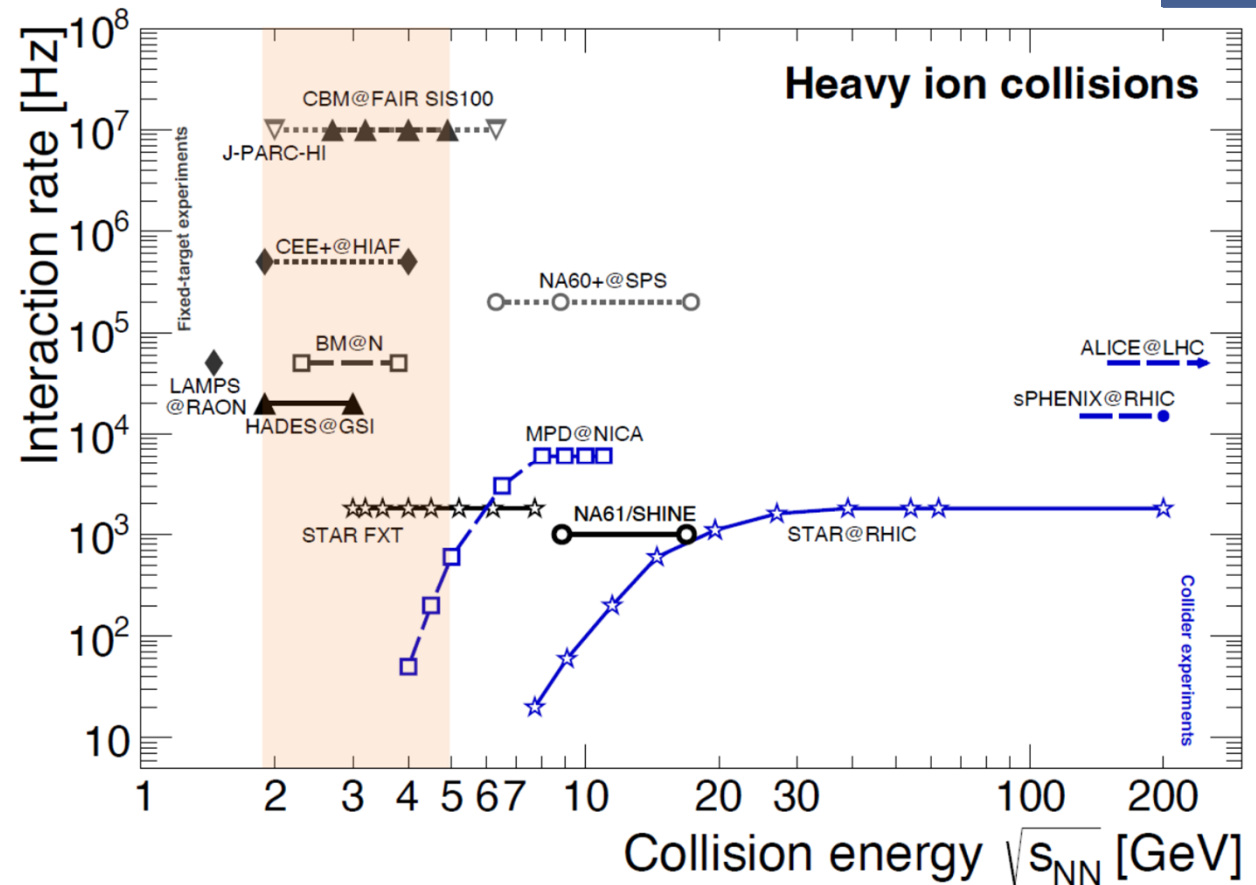
well established exp.
Recent upgrades

STAR

Energy scans completed
Lots of data to come

CBM

Dedicated setup to come



T. Galatyuk, NPA 982 (2019), update 2021
CBM, EPJA 53 3 (2017) 60



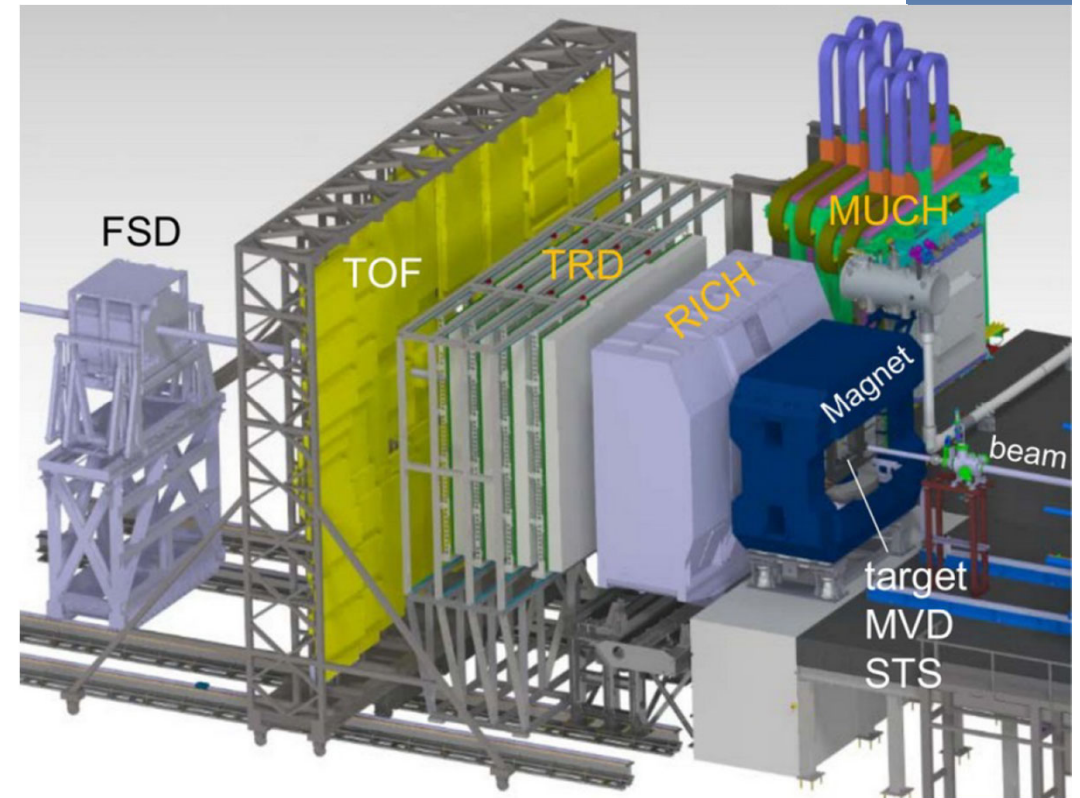
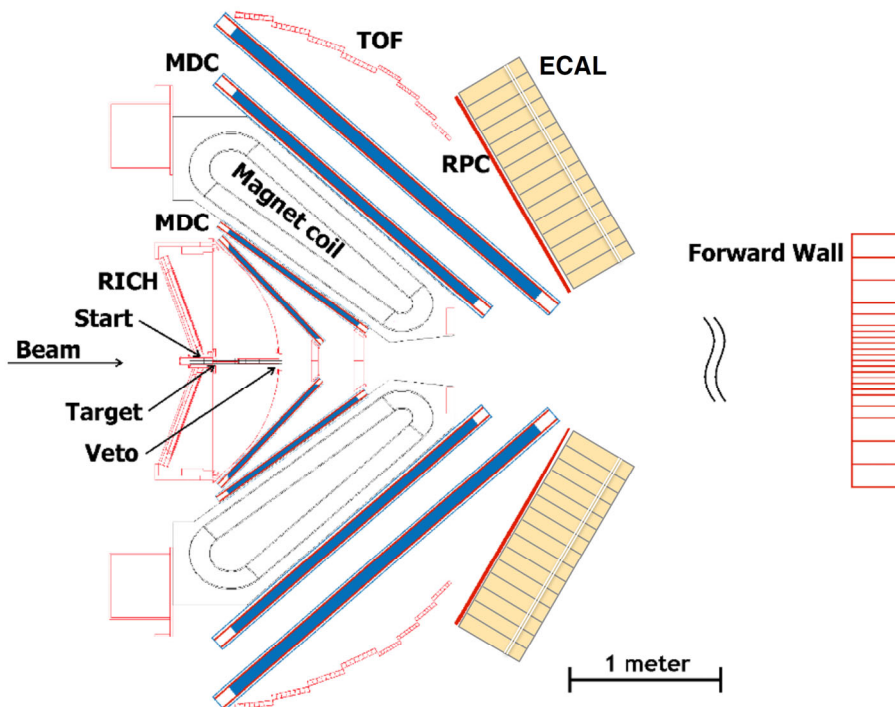


HADES

- $18^\circ - 85^\circ$ polar angle coverage, symmetric in azimuth
- Electron detection in front of magnetic field and most of the material

CBM

- $2.5^\circ - 25^\circ$ polar angle coverage, azimuthal symmetry broken by dipole
- Electron detection behind STS and magnetic field



Fluctuations



When crossing a 1st order phase transition: jump in density
 → Measure derivatives!
 → Cumulants of baryon number measure derivatives of μ_B

$$\chi_n^B \equiv \frac{\partial^n (p/T^4)}{\partial (\mu_B/T)^n} = \frac{\kappa_n [B]}{V T^3}$$

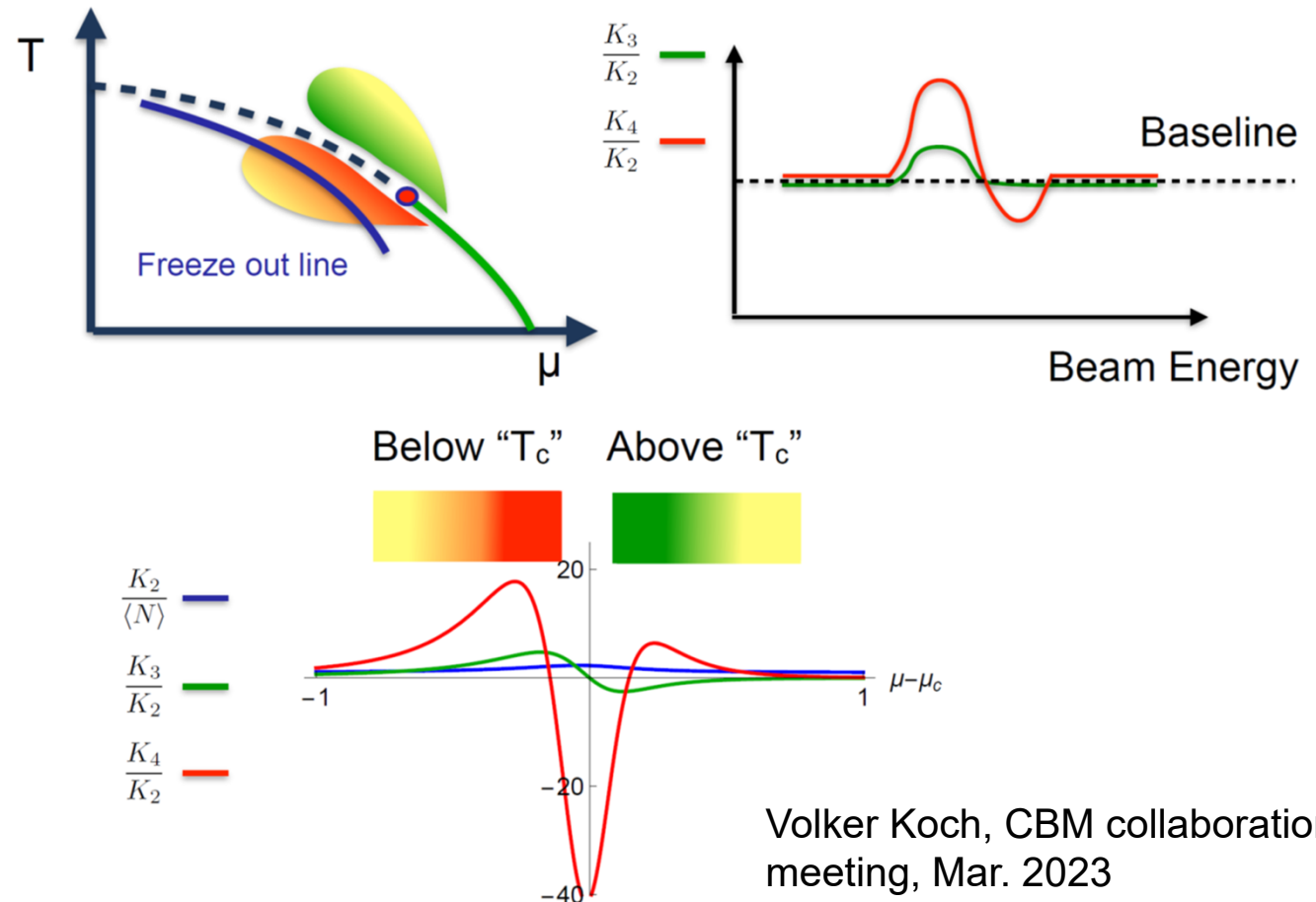
Higher moments more sensitive!

Ratios of cumulants independent on V

$$\frac{\chi_4}{\chi_2} = \frac{K_4}{K_2} = \kappa \sigma^2$$

V. Vovchenko et al.,
Phys.Lett.B 811 (2020) 135868

What to expect from experiment?



Volker Koch, CBM collaboration meeting, Mar. 2023

Net-proton distributions



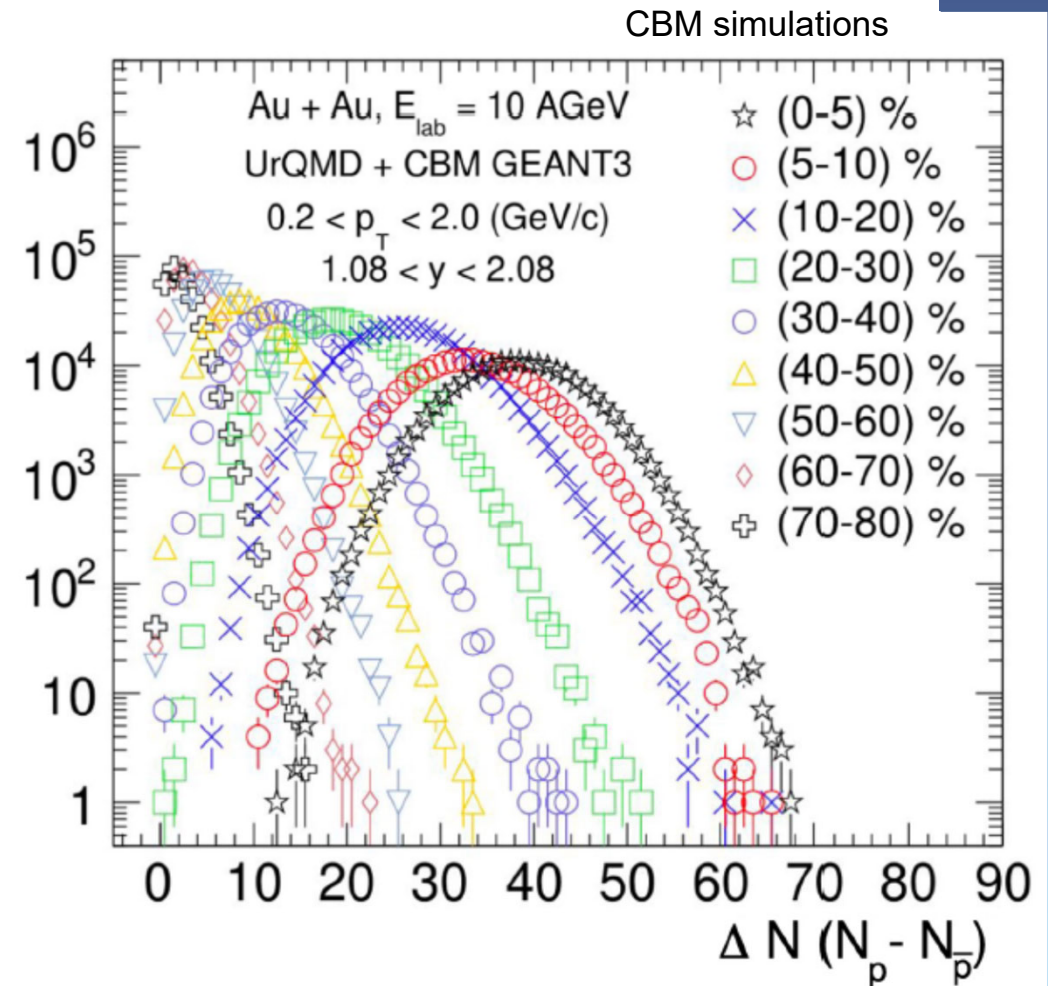
Measure event-by-event net-proton number (protons – antiprotons)
→ Distribution → calculate the moments → higher moments probe the tails!

Challenges:

- Large acceptance in proper (y-pt) bin
- Experimental effects from e-b-e changes of efficiency
Baryon contributions in n,d,...
Volume fluctuations
Conservation laws...
- Higher moments are in the tails!
→ statistics hungry!

$$K_2 = \langle N - \langle N \rangle \rangle^2 \text{ etc.}$$

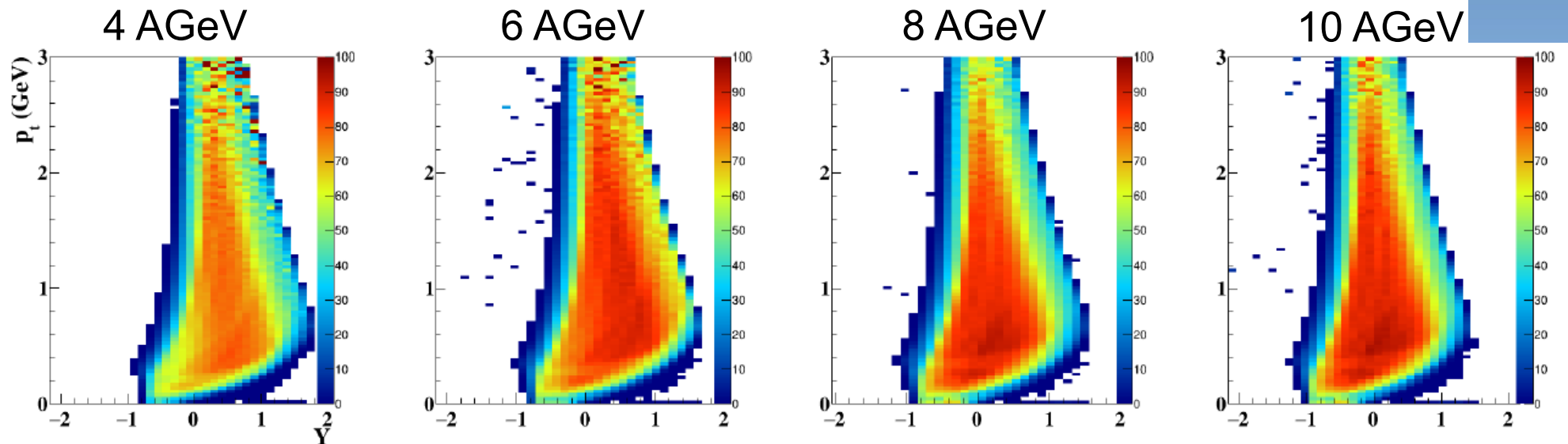
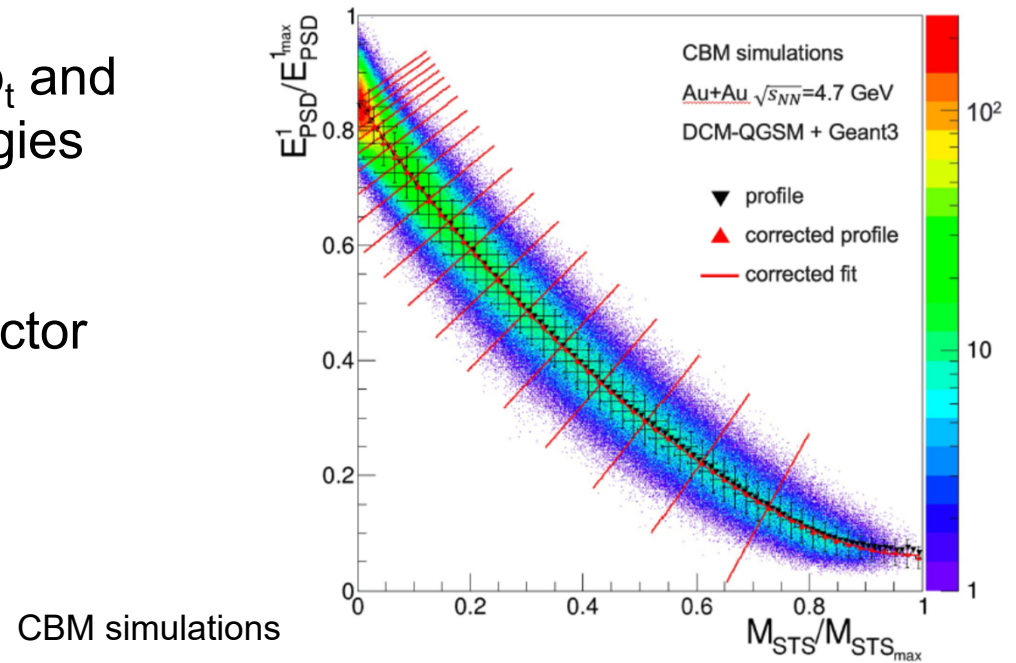
Possible solution to settle volume fluctuations: A.
Rustamov et al., nucl-th 2211.14849



Net-proton distributions



- CBM: Proton acceptance for low p_t and midrapidity for wide range of energies
- Crucial: independent centrality determination with separated detector (PSD \rightarrow FWD)



Critical fluctuations



HADES ✓

... understand volume fluctuations/ acceptance effects of different experiments!

CBM after 3 years – (improve STAR stat. errors by factor of 10):

- measure excitation function (p) for $k\sigma^2 = \frac{\kappa_4}{\kappa_2}$
- First results on $\kappa_6(p)$
- Extension to strangeness?

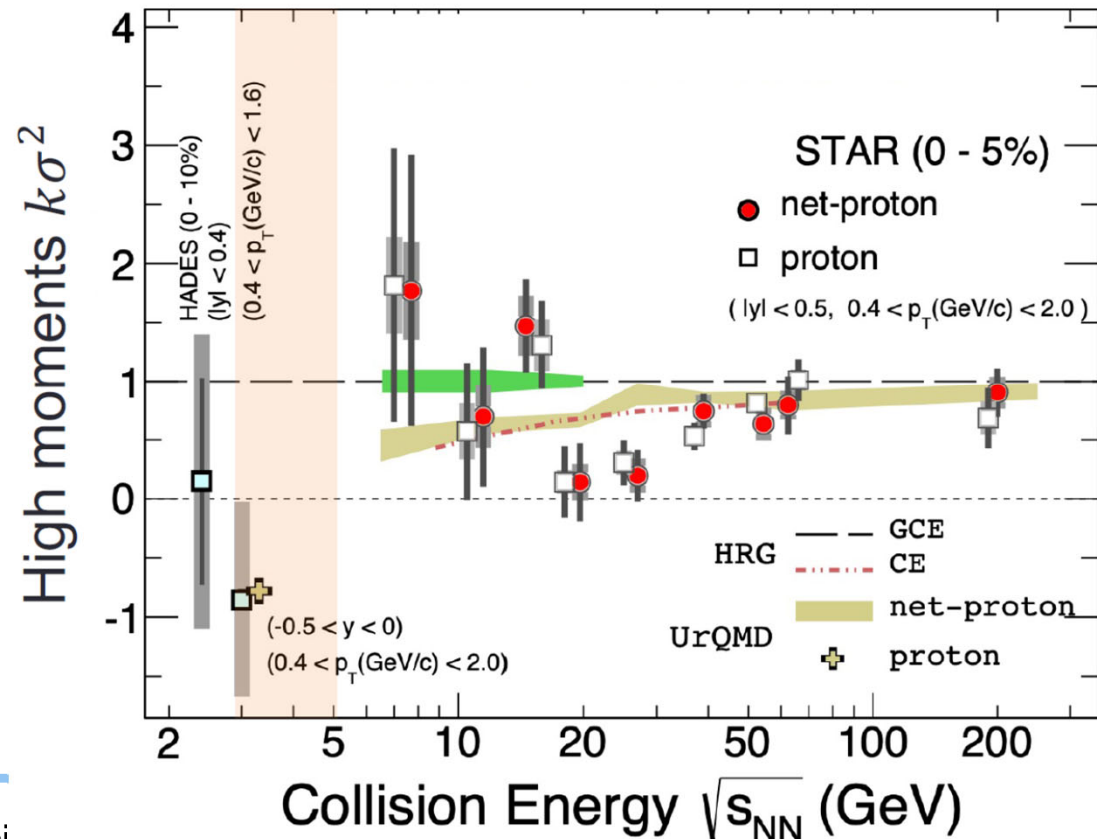
We hope to see:

Discontinuity?!

... that extends to even higher moments?

Understand influence of baryon number conservation at high μ_B

STAR, PRL 128 (2022) 20, 202303
HADES, PRC 102 (2020) 2, 024914



Challenge

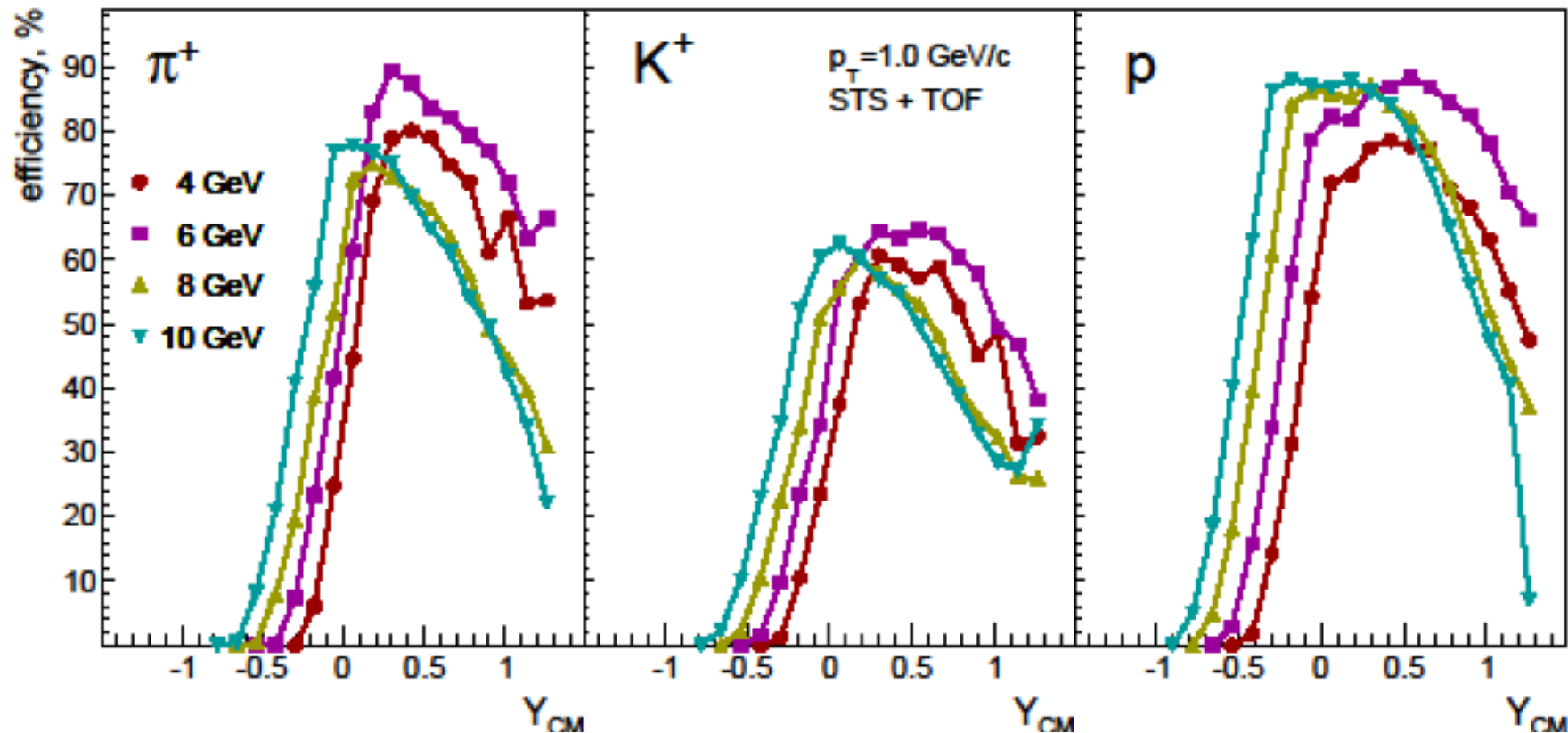


What about further conserved number fluctuations?

Challenge:

CBM acceptance increasingly more forward for lighter particles

CBM simulations

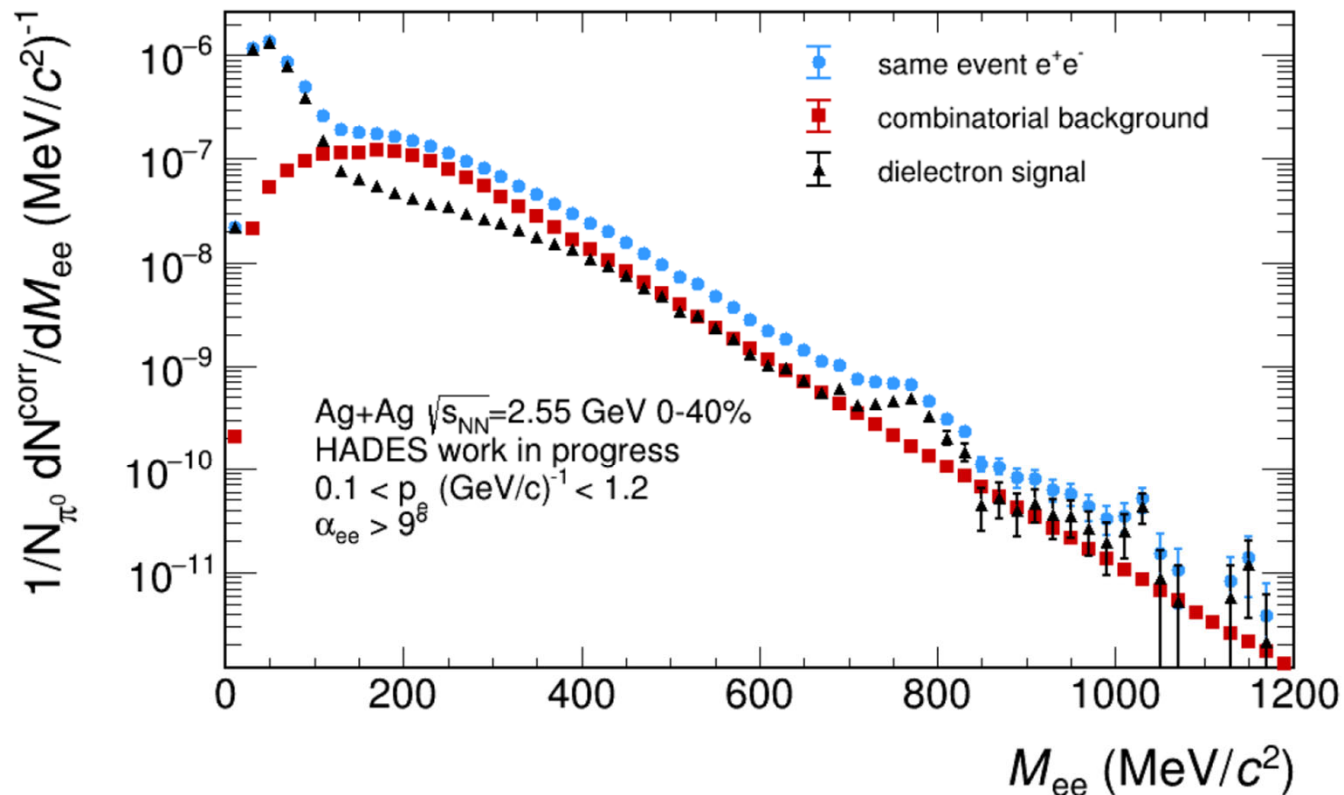
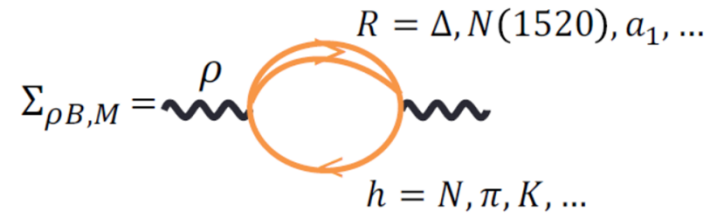


Dileptons



Em probes are sensitive to the full duration/evolution of the collision

- Emission of virtual photons from all stages
- Unique probe of temperature, duration, density, ... of the fireball
- Baryon effects are crucial
→ dedicated program in HADES!



[J. Otto for the HADES collaboration, EPJ Web Conf. 274 (2022), 05002]

Dileptons

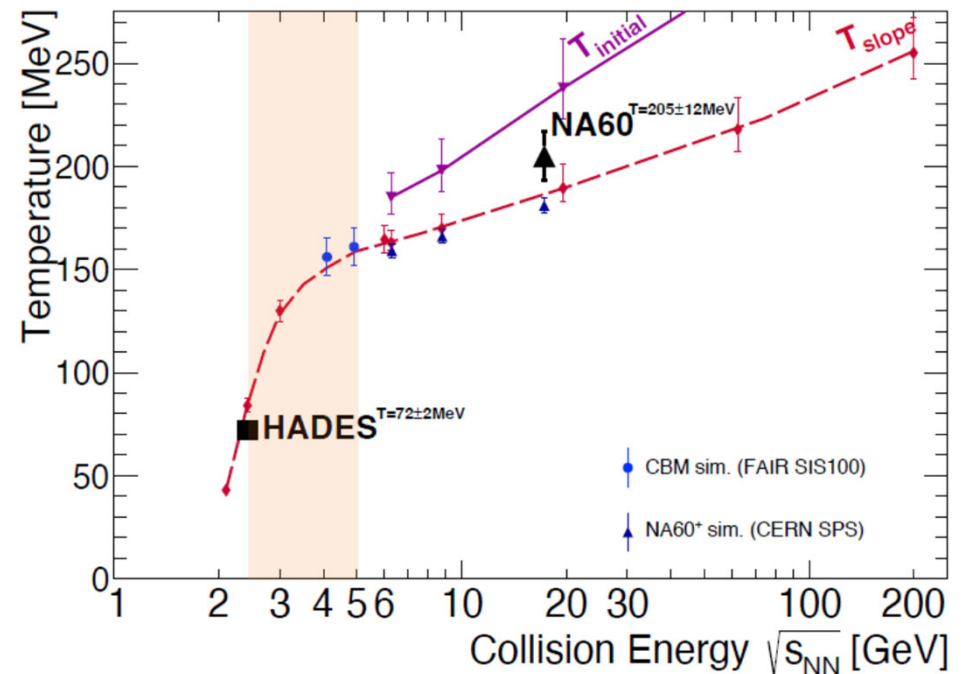
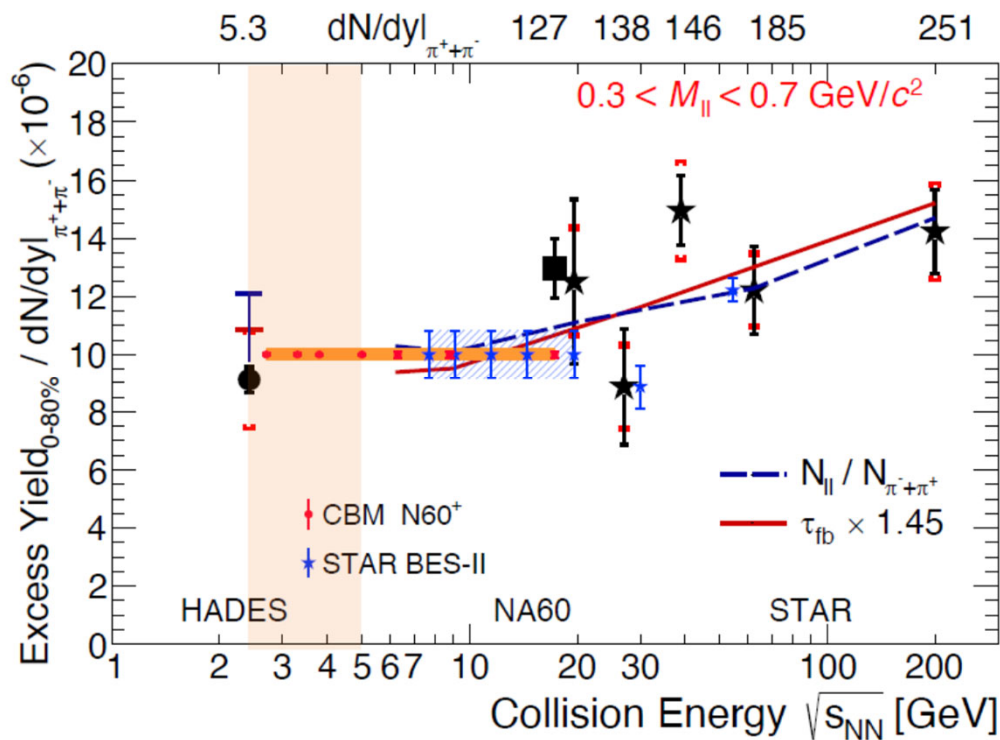


Two key measurements to be made (\rightarrow first year of CBM*, HADES \checkmark)

- Excess yield in LMR \rightarrow fireball lifetime: extra radiation due to latent heat around PT (& CEP?)?
- Invariant mass slope (LMR & IMR) \rightarrow flattening of caloric curve due to PT?

* one year 5 days beam on target, 6 energies Au+Au, $2 \cdot 10^{10}$ ev. each, 100kHz

Tripolt *et al.*, NPA 982 (2019) 775
 Li and Ko, PRC 95 (2017) no.5, 055203
 Seck *et al.*, PRC (2022), arXiv:2010.04614 [nucl-th]



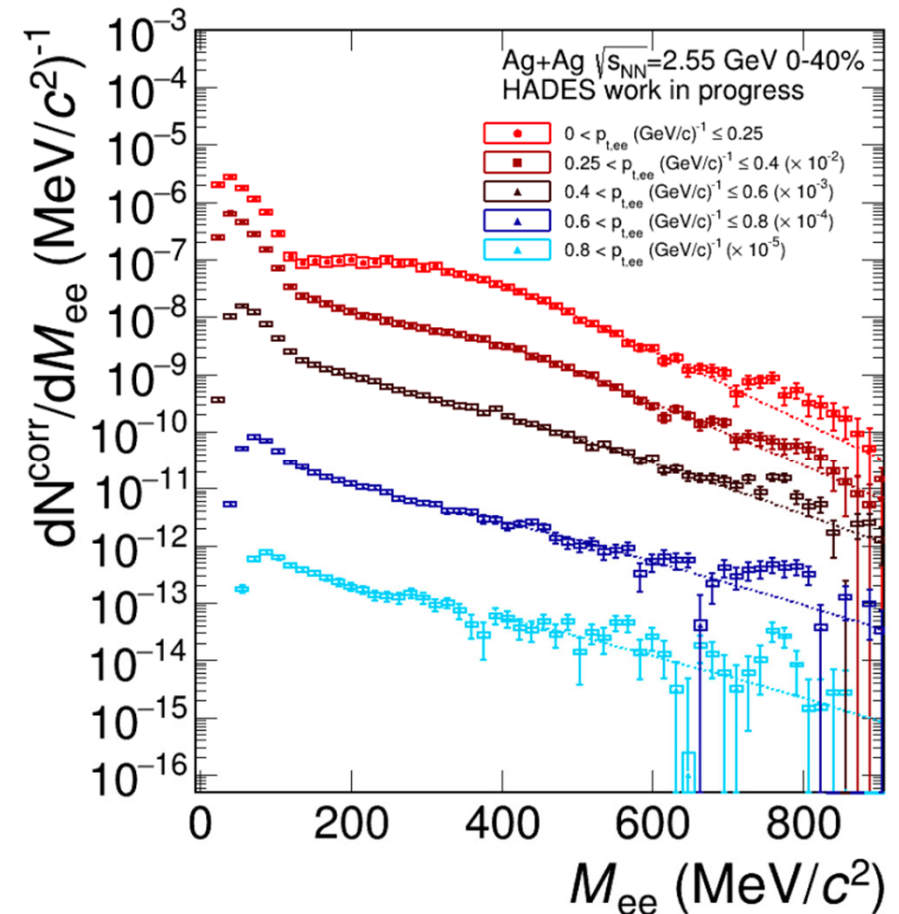
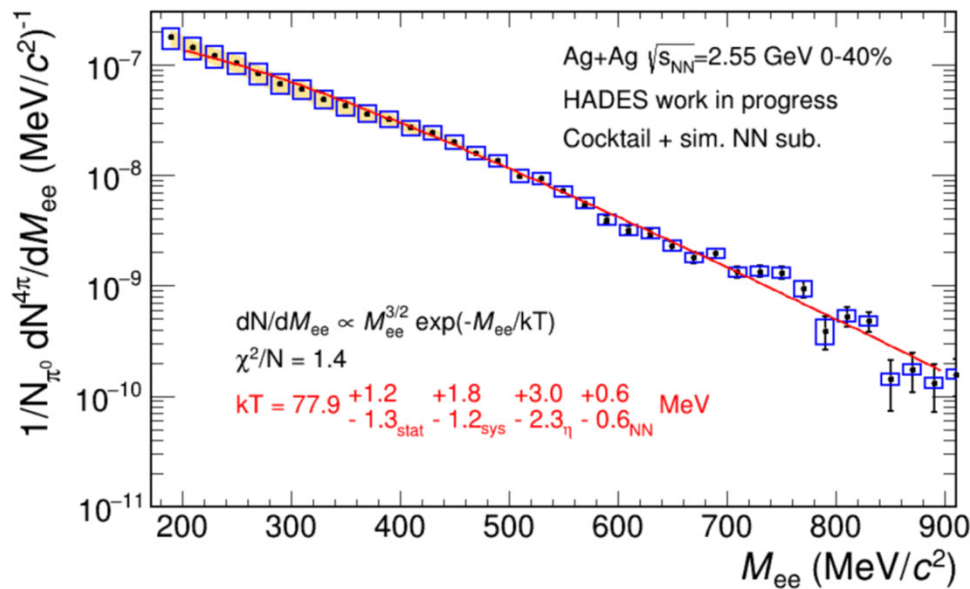
T. Galatyuk, JPS Conf. Proc. 32 (2020) 010079



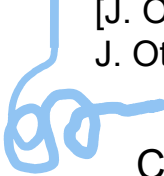


HADES

- New data from Ag+Ag collisions at slightly higher $\sqrt{s_{NN}}$ \rightarrow slightly higher T
- p_t dependence accessible with high statistics
 \rightarrow change in ω/ρ contributions!
- Au+Au energy scan towards lower $\sqrt{s_{NN}}$ to come!



[J. Otto for HADES, EPJ Web Conf. 274 (2022), 05002
 J. Otto, PhD thesis, JLU Giessen]

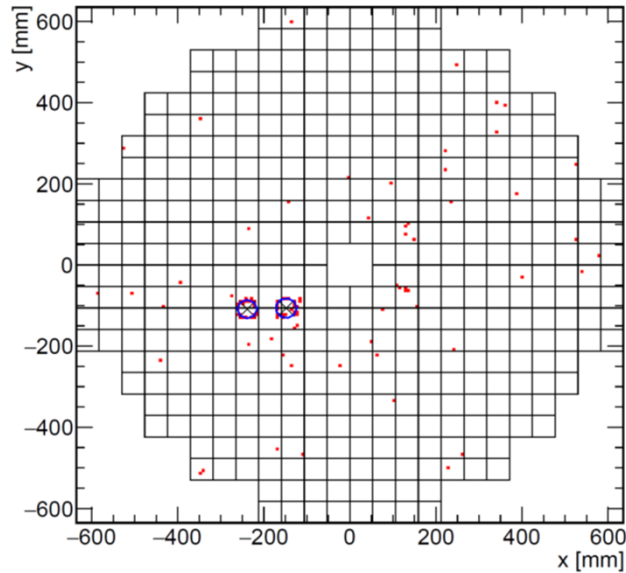


Dileptons



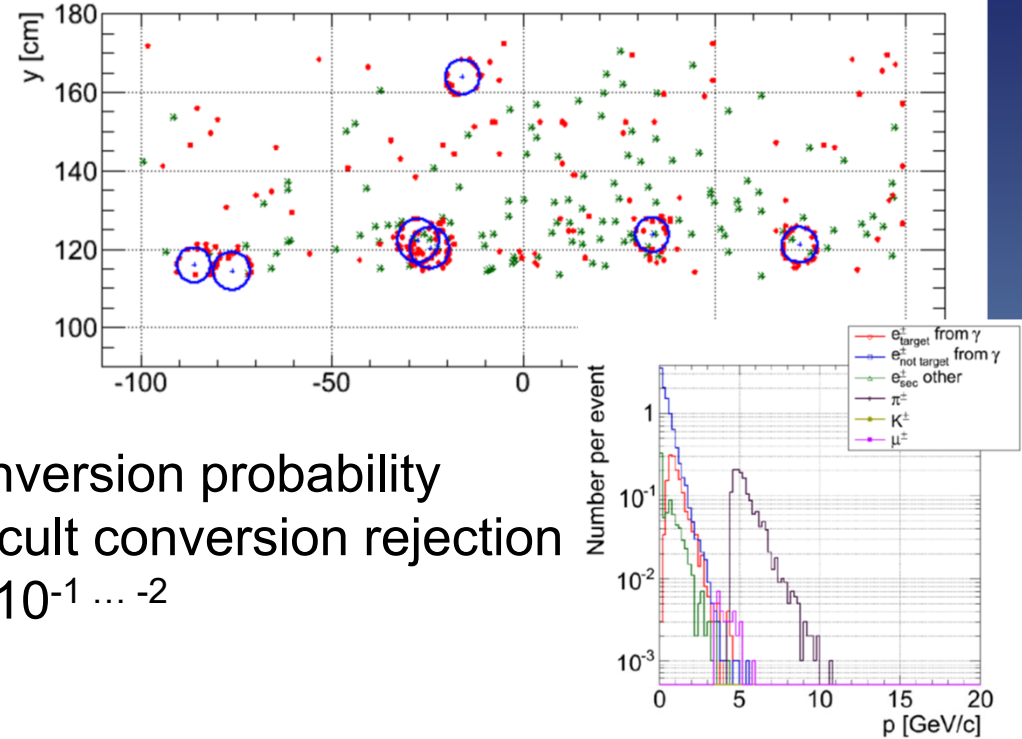
Challenge ?

- Background!!!



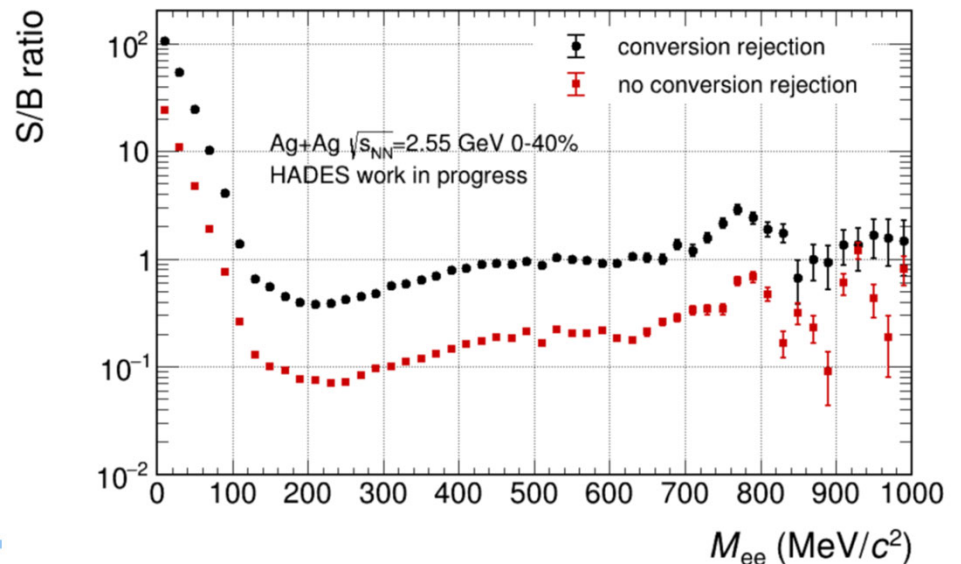
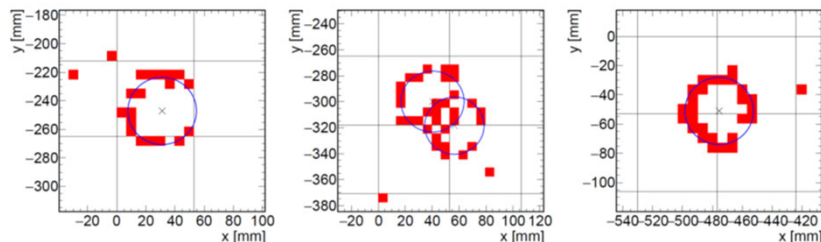
CBM

Large conversion probability
 more difficult conversion rejection
 $\rightarrow S/B \sim 10^{-1} \dots -2$



HADES

Low conversion probability
 Conversion rejection
 $\rightarrow S/B \sim 1$





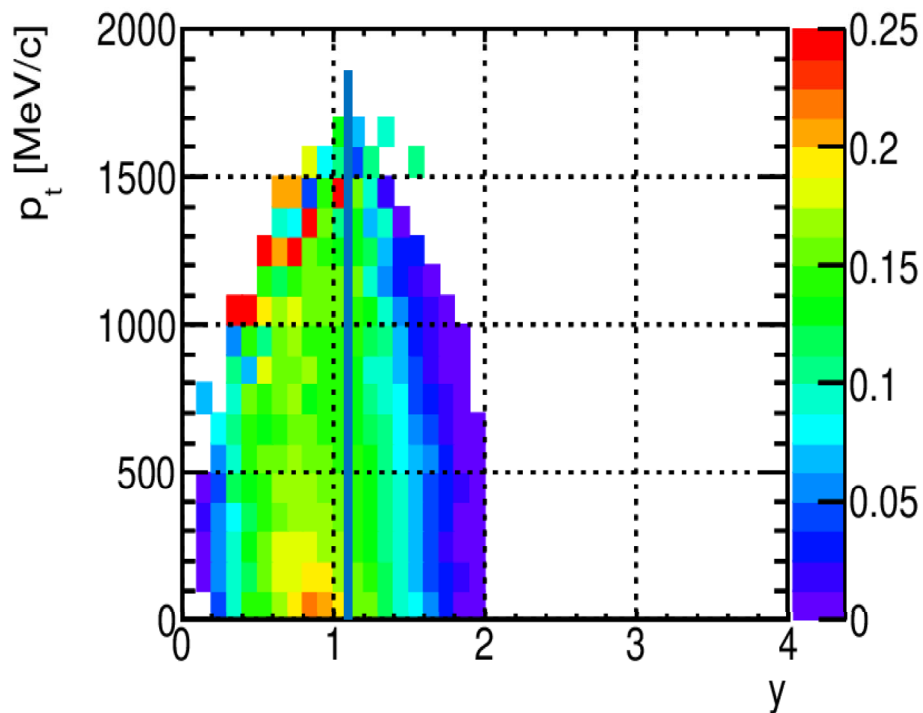
Study dileptons in one common system:

e.g. Ag+Ag collisions at 4.5 GeV beam energy (midrapidity 1.1)

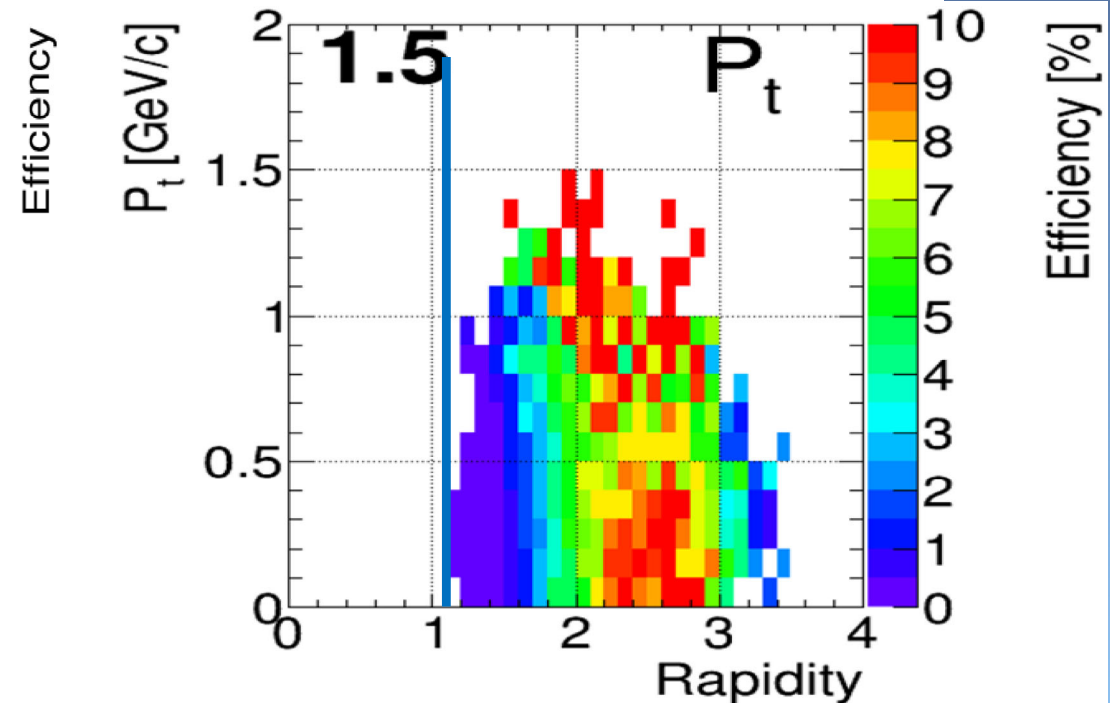
- reconstruction efficiency of ω -meson HADES vs CBM (60% field)

→ Compare spectra in same phase space region!

HADES



CBM

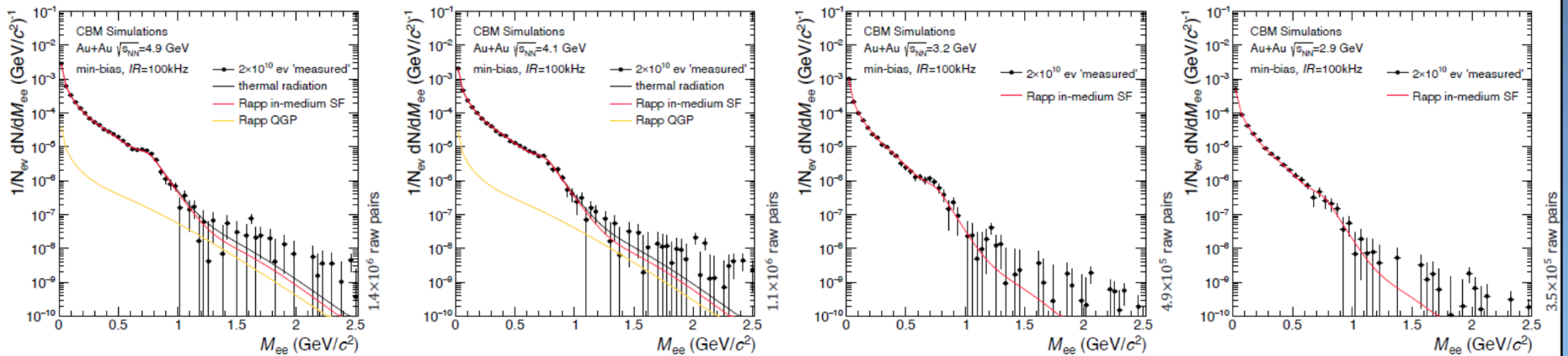


Marten Becker, master thesis, JLU Giessen
Gregor Pitsch, master thesis, JLU Giessen



Expected **CBM** dielectron performance (first year, 5 days/ energy, 2×10^{10} events each)

- LMR ($M_{\parallel} < 1 \text{ GeV}/c^2$) well measured, need to determine background with 0.1% precision for 10% signal precision: excess ratio, T_{LMR}
- IMR ($M_{\parallel} > 1 \text{ GeV}/c^2$) accessible, needs dedicated high statistics runs, measure $\mu^+\mu^-$ channel in addition \rightarrow year „2“



T vs. baryon density effects

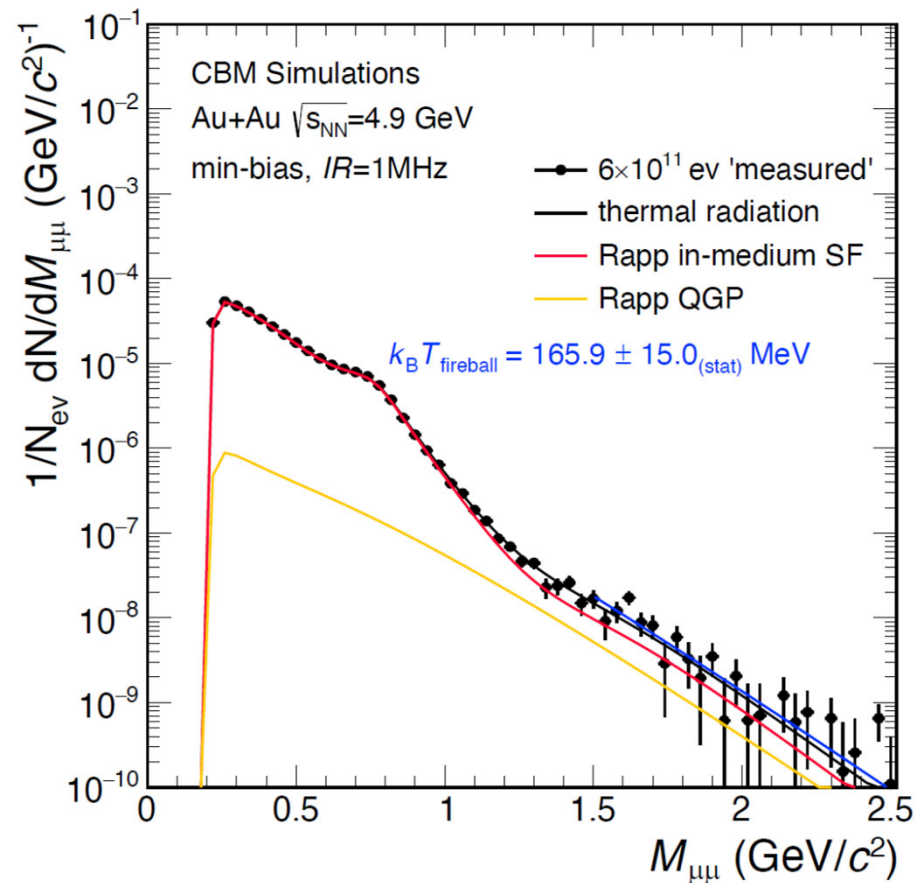
FAIR Review, June 2022, T. Galatyuk for CBM

* one year 5 days beam on target, 6 energies Au+Au, $2 \cdot 10^{10}$ ev. each, 100kHz



Expected **CBM** dielectron performance
(first year, 5 days/ energy, 2×10^{10} events each)

- LMR ($M_{\mu\mu} < 1 \text{ GeV}/c^2$) well measured, need to determine background with 0.1% precision for 10% signal precision: excess ratio, T_{LMR}
- IMR ($M_{\mu\mu} > 1 \text{ GeV}/c^2$) accessible, needs dedicated high statistics runs, measure $\mu^+\mu^-$ channel in addition \rightarrow year „2“



FAIR Review, June 2022, T. Galatyuk for CBM



Dileptons

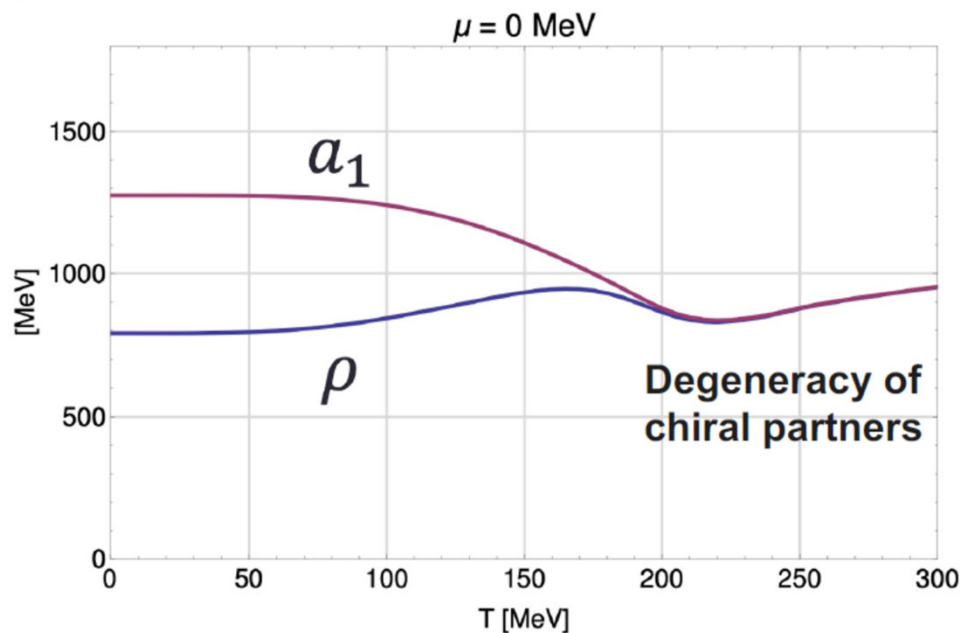


.... more than excess yield and T if you cope with the challenge:

Prediction:

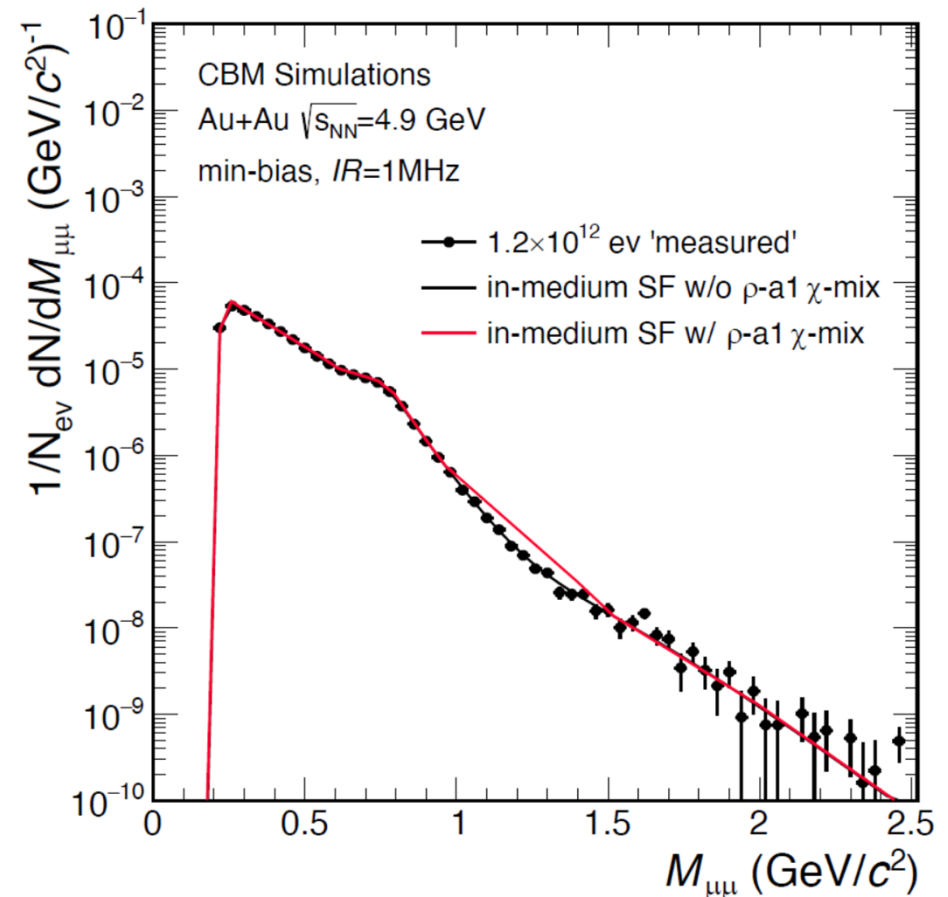
see sign of chiral symmetry restoration in dilepton spectra $M > 1 \text{ GeV}/c^2$

→ Mixing of ρ and a_1 due to restoration of chiral symmetry



Jung *et al.*, PRD 95, 036020 (2017)
Hohler and Rapp, PLB 731 (2014)

FAIR Review, June 2022, T. Galatyuk for CBM



Freeze-out conditions



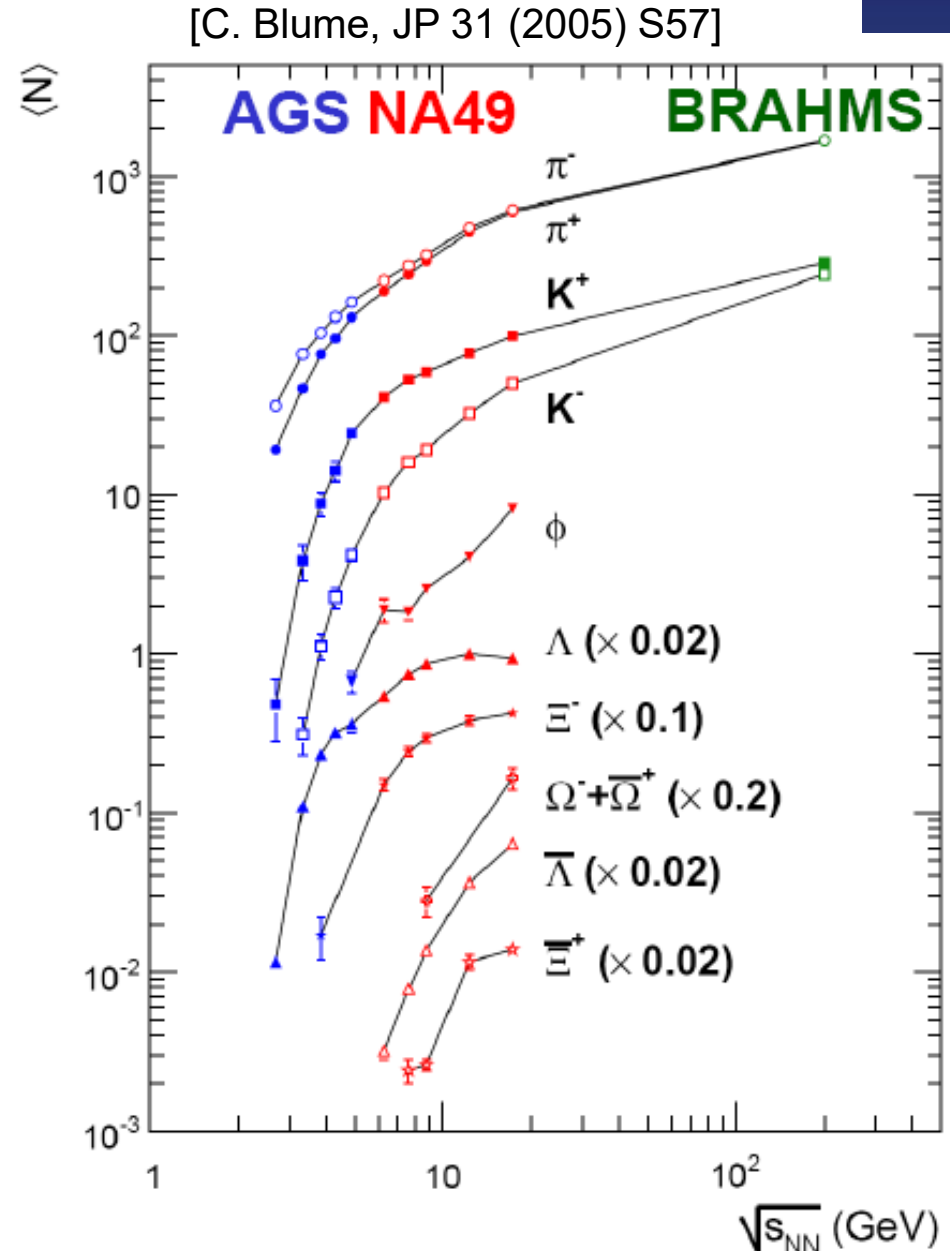
Dileptons offer access to fireball contributions before freeze-out

Conditions at freeze-out?
Pressure during evolution?

Measure yields and phase space distributions of „all“ particles
→ Extract T , μ_B with thermal model
→ System in equilibrium?
→ including multi-s?

Measure correlations
→ size at freeze out!
→ Signs of longer lifetime due to PT?

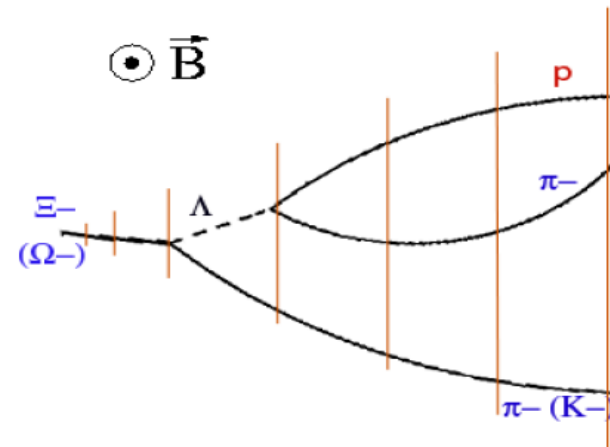
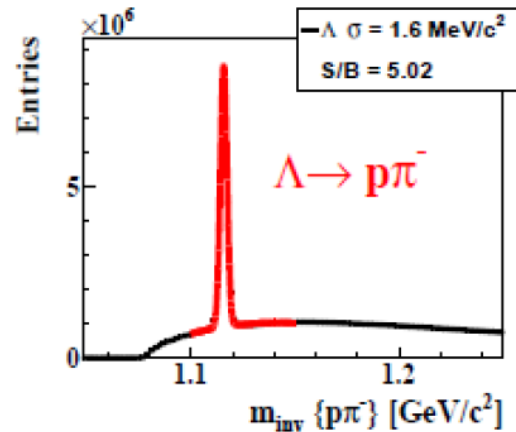
Measure flow
→ EOS



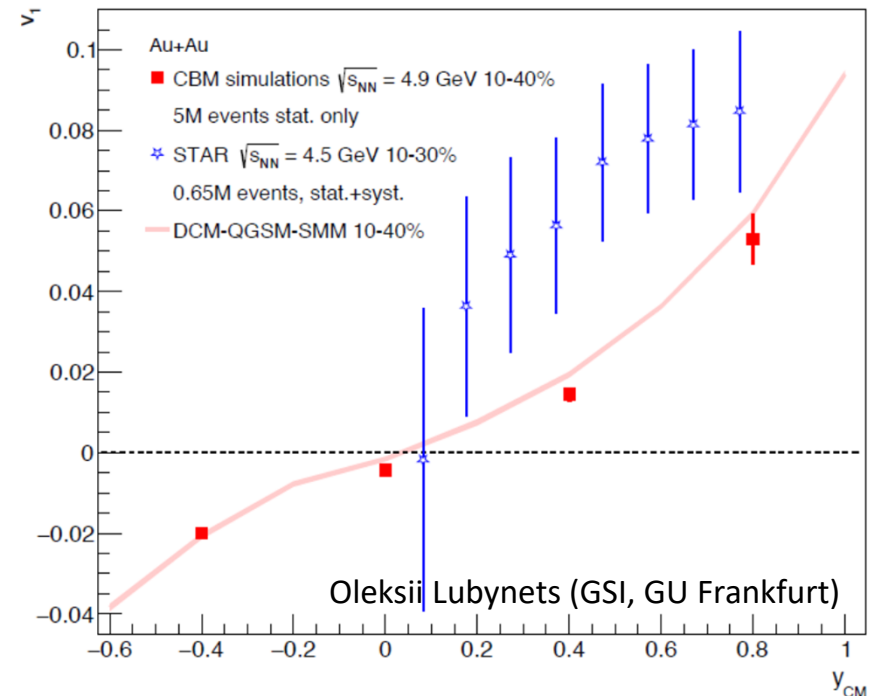
Weak decays in CBM



- Tracking system allows for precise reconstruction
- (also measure flow, correlations, Λ polarization, ...)



CBM simulation, Λ -baryons



Particle (mass MeV/c ²)	Multiplicity at 6 AGeV	Multiplicity at 10 AGeV	decay channel	BR	Efficiency
$\bar{\Lambda}(1115)$	$4.6 \cdot 10^{-4}$	0.034	$\bar{p}\pi^+$	0.64	0.11
$\Xi^-(1321)$	0.054	0.222	$\Lambda\pi^-$	1	0.06
$\Xi^-(1321)$	$3.0 \cdot 10^{-5}$	$5.4 \cdot 10^{-4}$	$\Lambda\pi^+$	1	0.03
$\Omega^-(1672)$	$5.8 \cdot 10^{-4}$	$5.6 \cdot 10^{-3}$	ΛK^-	0.68	0.05
$\Omega^+(1672)$	-	$7.0 \cdot 10^{-5}$	ΛK^+	0.68	0.03

event wise reconstruction by KFPparticle package



Thermal model – low μ_B

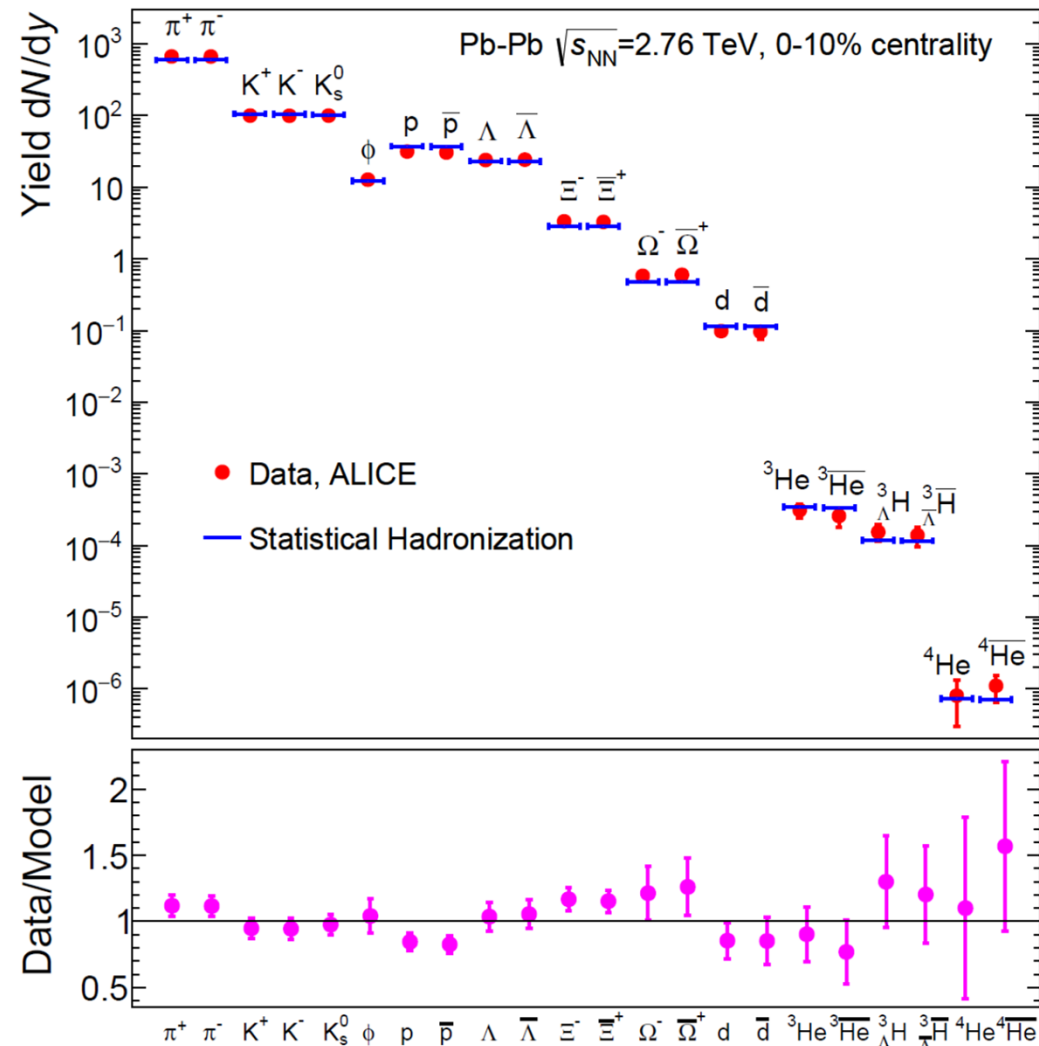


„Any“ model at „any“ low μ_B collision system results in very good description of particle yields in a thermal model

Lower energies/ high μ_B :
production cross-sections
for strangeness decrease
rapidly (below unity)

Implement strangeness
conservation!
Strong effect on multi-s
hadrons!

„Equilibrium“?



A. Andronic, P. Braun-Munzinger, K. Redlich and J. Stachel, Nature 561, no. 7723, 321 (2018)

Thermal model



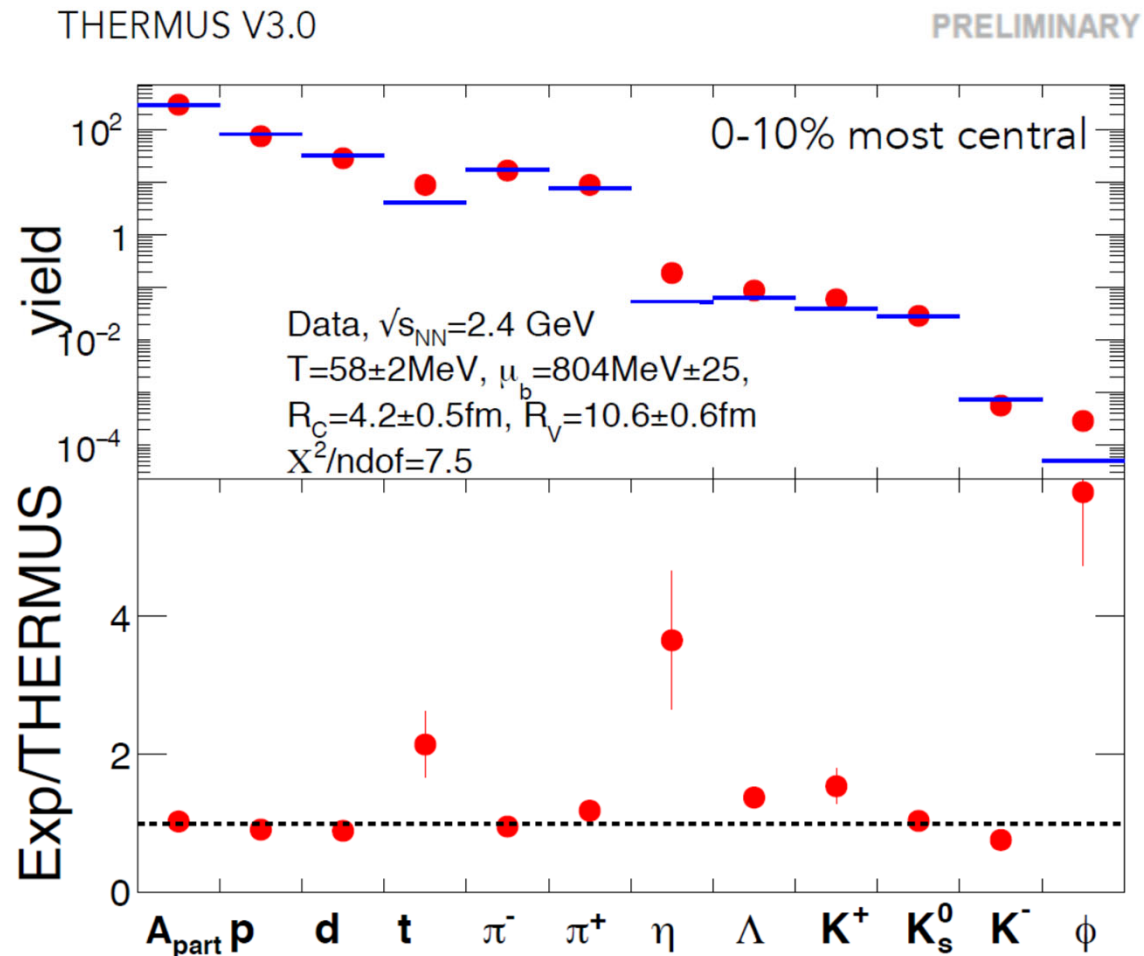
HADES, Au+Au collisions @ $\sqrt{s_{NN}}=2.4$ GeV

- Tensions in description of all hadron yields with thermal model
- All strangeness production below free NN production threshold!

Is there an energy from where on all hadrons can be described as „in thermal equilibrium“?

Or gradual approach?

Hadronization at high μ_B ?



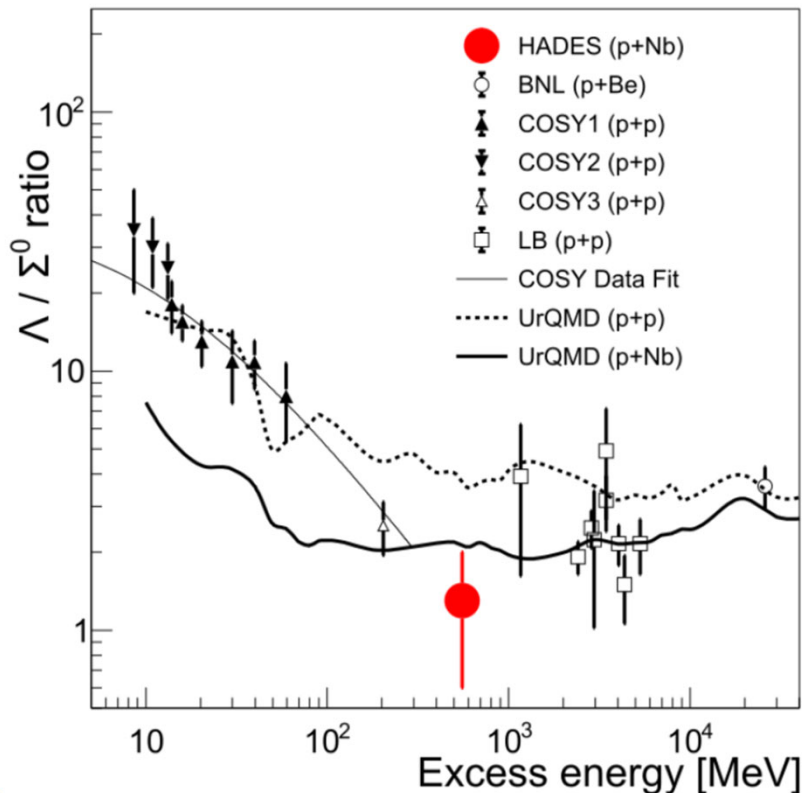
M. Lorenz, SQM 2019



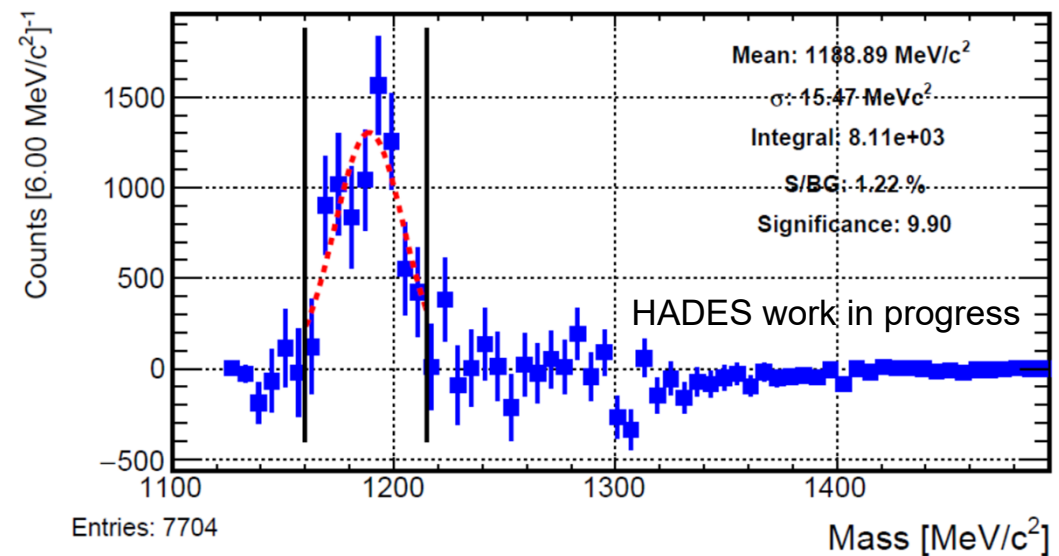


HADES

- Measurement of $\Sigma^0 \rightarrow \Lambda \gamma$ decay in Ag+Ag collisionen at $\sqrt{s_{NN}} = 2.55$ GeV (corresponds to Λ threshold)
- Result of analysis: $(\Lambda + \Sigma^0) / \Sigma^0 = 4.2 \pm 0.9$
- In agreement with expectation from isospin considerations (4)
- No influence of NN threshold



Marten Becker, DPG 2023

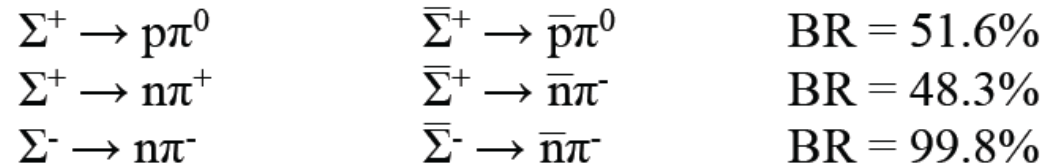


HADES, Phys. Lett. B 781 (2018) 735-740

Σ prospects with CBM



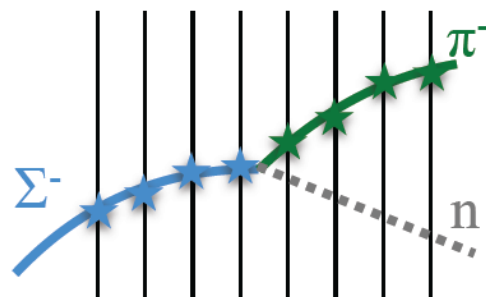
- Identification of Σ^+ and Σ^- via their decay topology



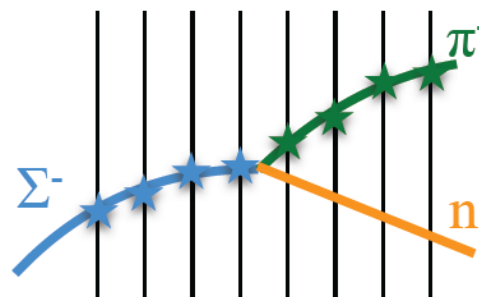
- Method:

- Find all primary and secondary tracks, use TOF PID for sec. track
- Search whether two would fit together with a kink
- From momentum conservation get momentum of neutral particle
- Assume e.g. Σ^- decay, calculate (missing) mass of neutral particle
- Select neutron candidates, recalculate Σ mass

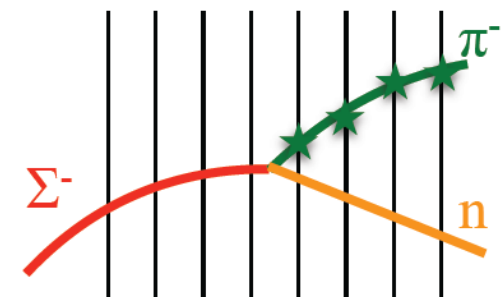
Find tracks of Σ and its charged daughter in STS and MVD



Reconstruct a neutral daughter from the mother and the charged daughter



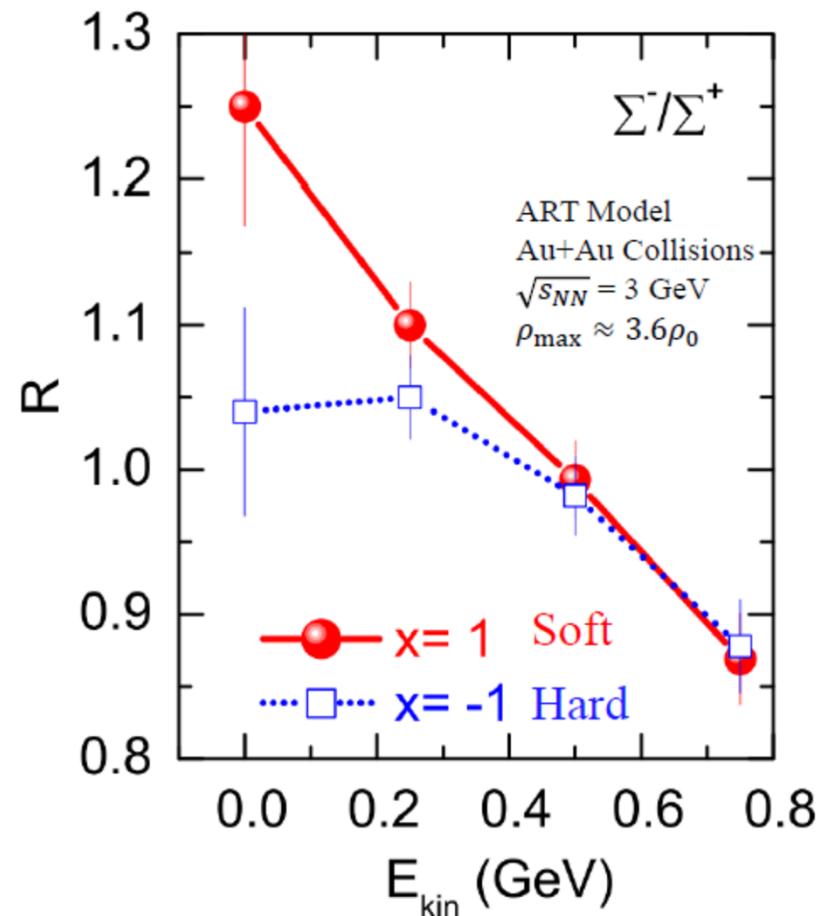
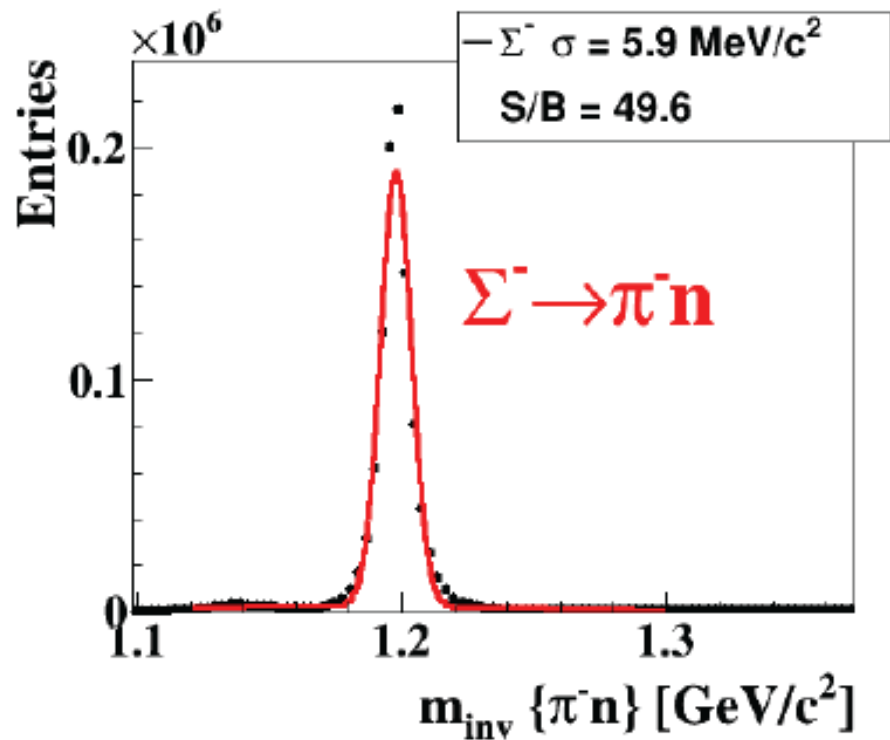
Reconstruct Σ mass spectrum from the charged and obtained neutral daughters



Σ prospects with CBM



- Simulations: UrQMD, 5M central collisions Au+Au, 10 AGeV beam energy
→ (p/n) like ratios! → access to isospin dependence?
→ Σ^-/Σ^+ ratio is expected to carry $E_{\text{sym}}(\rho)$ information (stiff/soft)



G.C. Yong et al,
Phys.Rev.C 106 (2022) 2, 024902

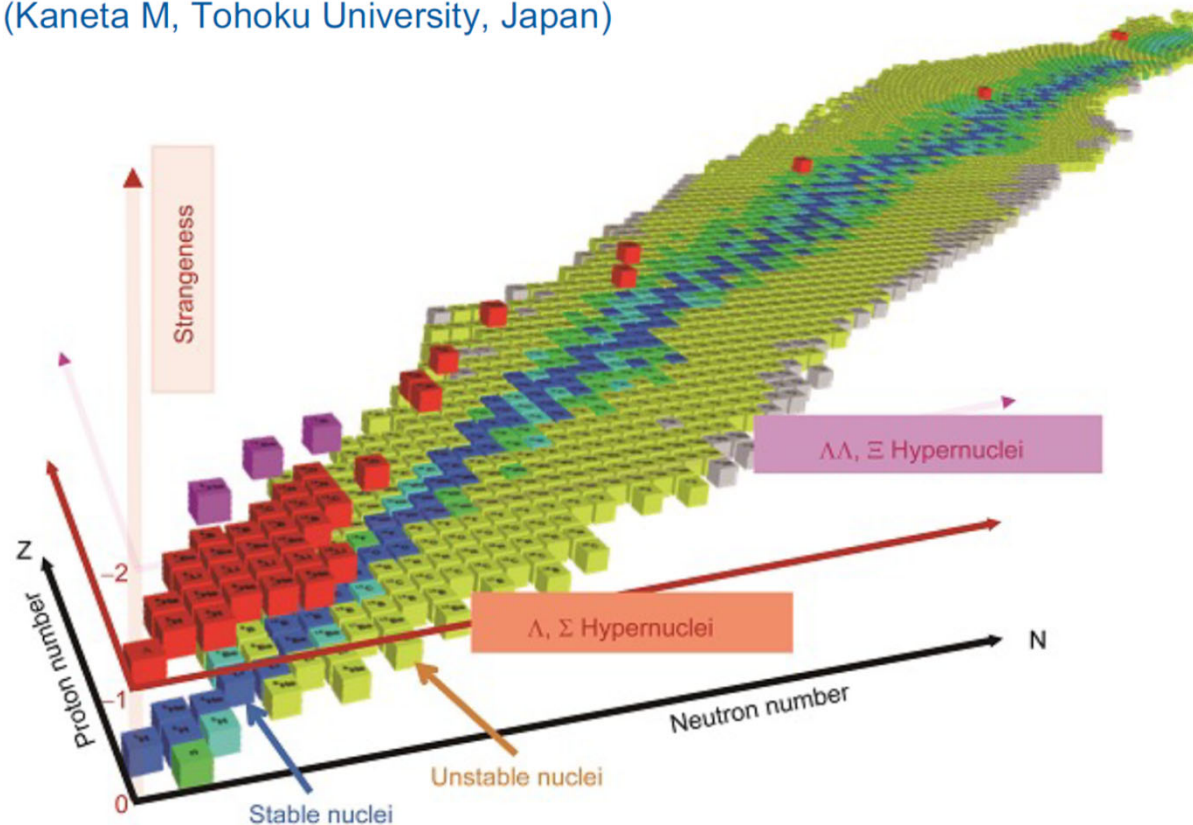
Hypernuclei



- Hypernuclei interesting/ important objects for neutron star descriptions
- Formation? YN and YY interactions? Influence on EOS for high densities?
- CBM energies optimum for production
- Reconstruction routines tested with STAR FXT data

Three-dimensional nuclear chart

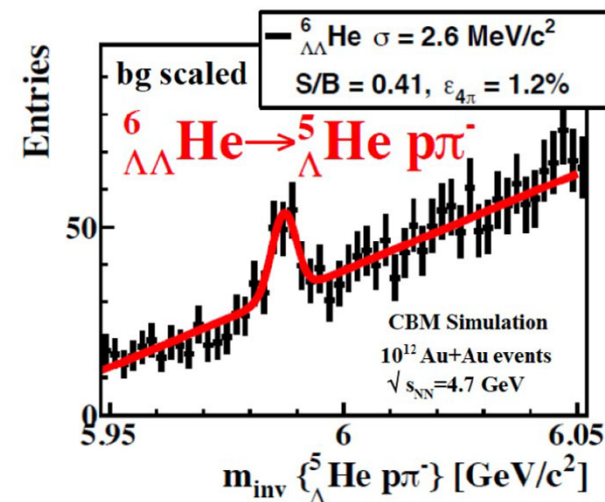
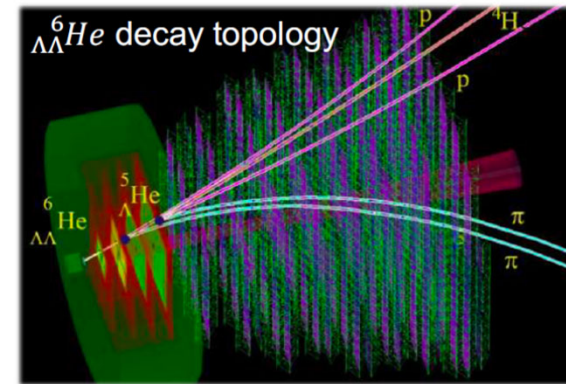
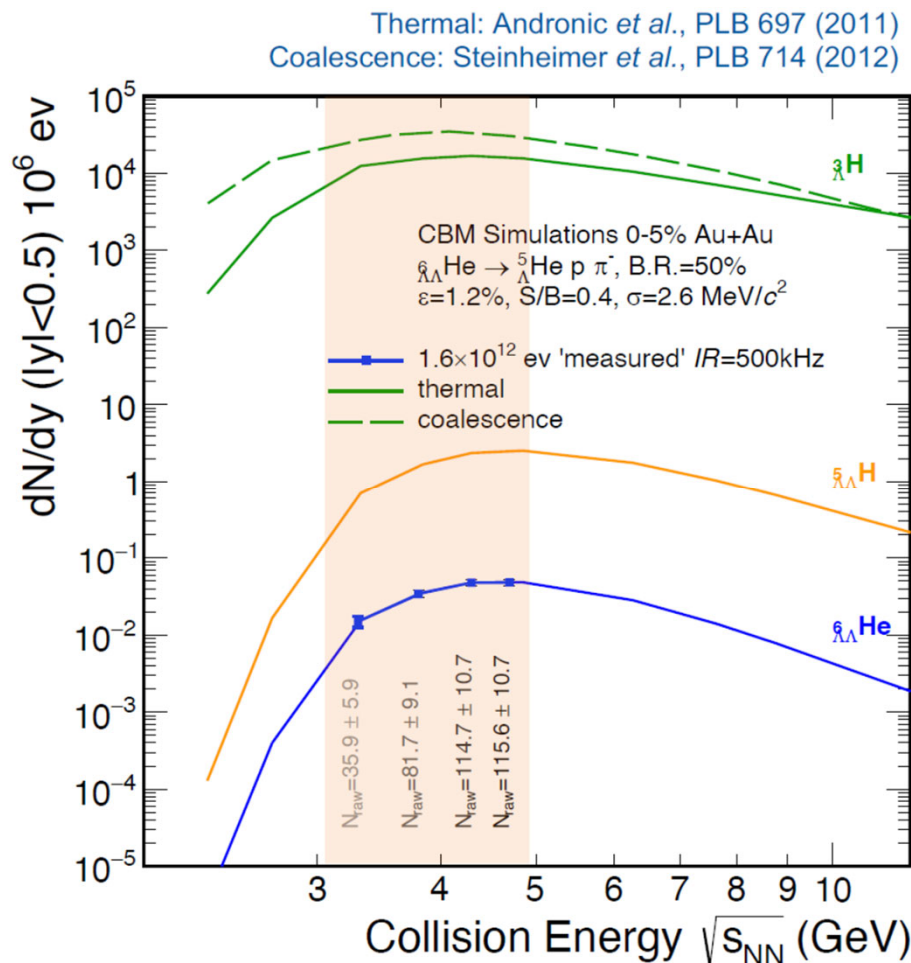
(Kaneta M, Tohoku University, Japan)



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HADES prepared a list of proposals for FAIR phase-0

- Proposed program will take at least until 2026 (one 4-weeks run per year), but likely longer
- Transferring HADES to the new cave is expected to take two years

Au+Au BES < 1 A GeV

SEARCHING FOR CRITICAL BEHAVIOR AND LIMITATIONS OF THE UNIVERSAL FREEZE-OUT LINE
 Au+Au collisions at 0.24-0.81 GeV
 The HADES Collaboration



Spokespersons: J. Streth (j.strath@gsi.de), P. Thury (thury@ufjf.br)
 GSI contact: J. Pietraszkowski (j.pietraszkowski@gsi.de)
 Infrastructure: SIS18 and HADES cave

Beams: slow extraction
 Au at 0.81-0.64-0.4-0.24 GeV, 1.2×10^{10} ions/s (flat top)
 C at 0.61-0.4 GeV, 3×10^9 ions/s (flat top)

Abstract
 We will extend our exploration of the QCD phase diagram towards the location of the nuclear liquid-gas phase transition. Two larger Au+Au runs (30 shifts each) are dedicated to low-mass dilepton and strange-pion production while two shorter Au+Au runs (9 shifts each) will focus on the most abundant (non-strange) particles only, suitable for event-by-event analysis of particle correlations and fluctuations as well as to extract temperature of the system at freeze-out. We also aim to gain insights to enable (i) laboratory studies of the matter properties (Equation-of-State) in compact stellar objects and (ii) detection of remarkable consequences of phase transitions and critical point in the QCD phase diagram. Meson- \bar{C} collisions (9 shifts each) will be investigated to provide reference data. In the following, we describe the proposed studies using the HADES spectrometer.

This is a proposal for a new experiment
 In total we request 94 shifts

re-submission to GPAC 2022

EM transition form factors of hyperons

PRODUCTION AND DECAY OF HYPERONS, AND INCLUSIVE HADRON AND DILEPTON PRODUCTION
 in p-p Reactions at 4.5 GeV
 The HADES and HADES-PANDA Collaborations



Spokespersons: J. Streth (j.strath@gsi.de), P. Thury (thury@ufjf.br)
 GSI contact: J. Pietraszkowski (j.pietraszkowski@gsi.de)
 Infrastructure: SIS18, LH₂ target, HADES cave

Beams: protons at 4.5 GeV, beam intensity 7.5×10^9 p/s, slow extraction

Abstract
 In this FAIR Phase-0 proposal, we request proton beam to perform a group of experiments: (i) inclusive hyperon and baryon strangeness. This new group will make very effective and efficient use of the available beamline since four investigations resolve the same beam trigger conditions and improved detector set-up, that they will be requested concurrently. This proposal addresses the following main physics topics: (1) Hyperon electromagnetic decays $\Sigma^+ \rightarrow n\gamma$ and $\Sigma^0 \rightarrow p\gamma$; (2) Hyperon baryon decays; (3) Production of double-strangeness (Ξ ($\Xi(1321)$, $\Lambda\Lambda$) and baryon strangeness (ϕ); (4) Inclusive hadron and dilepton production as a reference for p-p and heavy-ion data. These new experiments will provide first results in this energy region and an important benchmark for the future physics program at FAIR. The measurements of hyperon production and electromagnetic decay during Phase0 are complementary to the Phase1 studies at PANDA, with antiproton-proton interactions, and will enable some PANDA detector systems to be upgraded and commissioned already now.

Below is a description of the proposed study with proton beam using the HADES spectrometer combined with the new forward detection system.

This is a new experiment proposal.
 We request 84 shifts plus 4 shifts in a separate proposal for commissioning.

Successfully conducted in Feb./March 2022

Cold matter effects including line shapes and SRC

STUDYING MEDIUM EFFECTS IN PROTON INDUCED REACTIONS
 p-Ag reactions at 4.5 GeV
 The HADES Collaboration



Spokespersons: J. Streth (j.strath@gsi.de), P. Thury (thury@ufjf.br)
 GSI contact: J. Pietraszkowski (j.pietraszkowski@gsi.de)
 SRC part: T. Aumann (T.Aumann@gsi.de), O. Ben, E. Piasetzki

Infrastructure: SIS18, HADES cave, and part of the NeuLAND detector to measure the recoil neutron

Beam: p at 4.5 GeV, beam intensity 4×10^8 protons/s, slow extraction


Abstract
 We propose to investigate p-Ag reactions with an improved experimental set-up which enables measurements of charged particle emitted into the very forward hemisphere. Main physics topics are addressed: (i) dilepton production in the low and intermediate mass region; (ii) π production in "cold" nuclear matter; (iii) strange-pion production and propagation in "cold" nuclear matter (comparisons and constraints for thermal and transport models); (iv) $\Lambda \rightarrow p\pi$ scattering parameters and phase shifts; (v) understanding their energy correlations in nuclei; (vi) search for a dark photon in the dilepton channel. These results will provide an important reference for the future program at FAIR.

Below is an executive summary of the proposed study with proton beam using the HADES spectrometer combined with the new forward detection system.

This is a new experiment proposal.
 We request 141 shifts.

Baryon resonances, meson baryon coupling in the 3rd resonance region

BARYON COUPLINGS TO MESONS AND VIRTUAL PHOTONS IN THE THIRD RESONANCE REGION: VACUUM AND COLD MATTER STUDIES
 Pion induced reactions on ^3He and C, Ag targets
 The HADES Collaboration



Spokespersons: J. Streth (j.strath@gsi.de), P. Thury (thury@ufjf.br)
 GSI contact: J. Pietraszkowski (j.pietraszkowski@gsi.de)
 Infrastructure: SIS18, pion production target and HADES cave
 Beams: Nitrogen at 2A GeV, maximum intensity, slow extraction

Abstract
 We propose to use the GSI pion beam to provide information on baryon resonances in the third resonance region which is crucial for the understanding of the universality of dense and hot hadronic matter. This includes their coupling to mesons and virtual photons and their behavior in cold matter. First, differential cross sections for baryon final states will be induced in Partial Wave Analysis to extract various resonance amplitudes, among which are ρ and ω , with unprecedented precision. Second, the measurement of e^+e^- production of the nucleus, which is sensitive to the electromagnetic transition form factors of baryons in the same-like region, will probe the role of vector mesons (ρ , ω) levels. Finally, simultaneous data allow to investigate medium effects on vector mesons in cold nuclear matter. The whole data set constitutes an important input to understanding of the universality of dense and hot hadronic matter.

In 2017, we submitted a request for 91 shifts pion beam and got approved 80 Λ^- shifts, which could not be scheduled. This proposal is an update, and extension of the 2017 proposal motivated by the results of the data analysis of previous experiments.

This is a new experiment proposal.
 We request 141 shifts.

re-submission to GPAC 2022

Iso-spin effects in dilepton production

SCRUTINIZING ISO-SPIN EFFECTS IN N+N BREMSSTRAHLUNG AND DIBARYON $D^*(2380)$ FORMATION IN N+P COLLISIONS
 A Deuteron Energy Scan for proton and neutron induced reactions on protons
 The HADES Collaboration



Spokespersons: J. Streth (j.strath@gsi.de), P. Thury (thury@ufjf.br)
 GSI contact: J. Pietraszkowski (j.pietraszkowski@gsi.de)

Beams: d with kinetic energy of $T_d = 1.0, 1.13, 1, 25, 1.75$ A GeV, beam intensity 2×10^8 deuterons/s, slow extraction

Abstract
 We propose to investigate p-p and quasi-free n-p reactions with deuteron beams in a LED setup with an improved experimental set-up which enables measurements of charged particles emitted into the very forward hemisphere. Quasi-free p-p and n-p reactions will be distinguished by tagging the proton spectator from deuteron break-up in the new Forward Detector which covers almost complete 4π phase space for the spectator nucleon. The main goals of proposal are: (1) measurement of NN reference spectra for interpretation of medium effects in heavy-ion collisions in 1-2 GeV energy range; (2) characterization of dilepton production from baryonic sources in exclusive nucleon-nucleon channels; (3) studies of spin-dependence of baryon ($D^*(2380)$) production close to the threshold and (4) observation $M_{\pi^+\pi^-} = 2380$ MeV ($J = 0, J^{PC} = 2^{-+}$) production in quasi-free n-p reaction. The results will also provide an important reference for the future heavy-ion program at FAIR.

Below is an executive summary of the proposed study with proton beam using the HADES spectrometer combined with the new forward detection system.

This is a new experiment proposal.
 We request 106 shifts.



Status of FAIR & CBM



FAIR (still) under construction

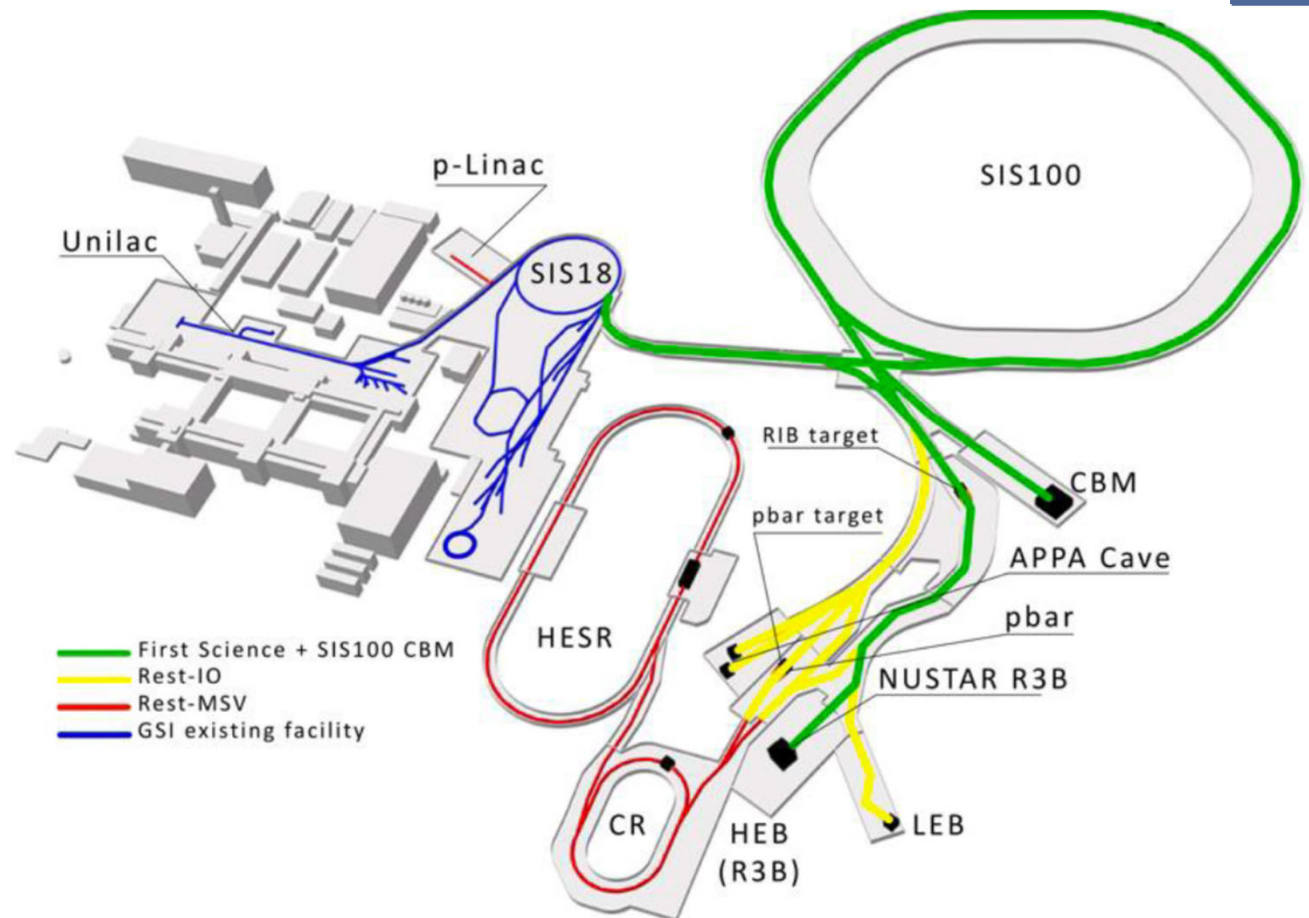
CBM (still) plans for first beams in 2028/2029

After 3 years of running:

- (First) energy scan completed, improved statistical errors of factor 10 with respect to STAR

Years 4-8:

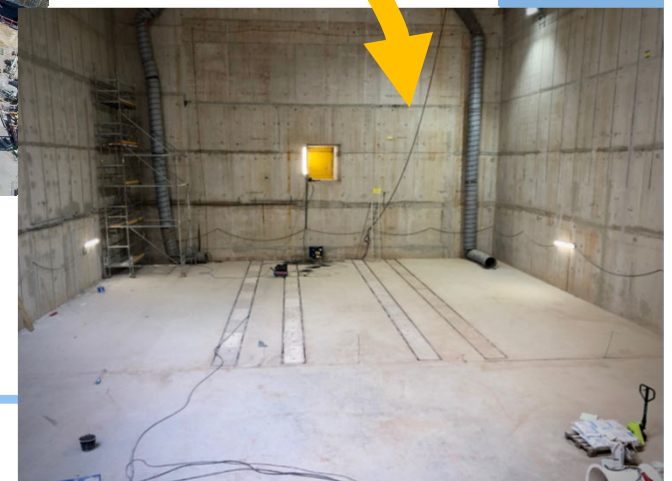
- High statistics measurements
→ dilepton IMR, ultra-rare probes



Status of FAIR & CBM



- FAIR construction progressing
 - ✓ SIS 100 tunnel ready
 - ✓ CBM cave ready
 - ✓ In CBM cave first user installations of FAIR ongoing (upstream platform)



Status of FAIR & CBM



CBM cave



Start of installation of upstream platform!



mCBM @ SIS18 (FAIR phase 0)

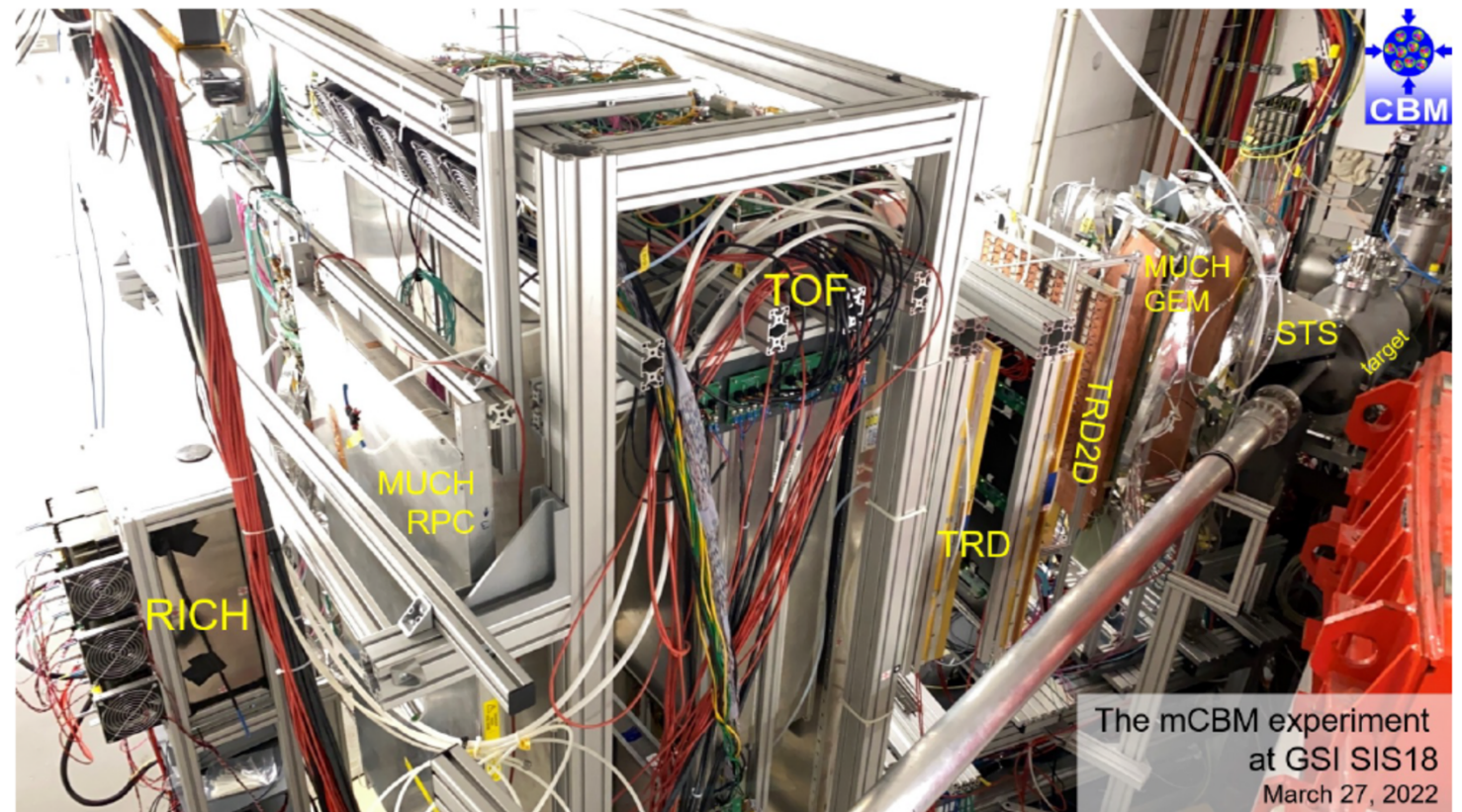


One of the CBM challenges are the high rates:

- Free streaming readout
- Online reconstruction & trigger

Important milestone: mCBM @ SIS 18!

- Full system test, verification of triggerless-free-streaming readout, data transport to CBM, online reconstruction
- High rate detector tests up to 10 MHz collision rates



The mCBM experiment
at GSI SIS18
March 27, 2022

mCBM @ SIS18 (FAIR phase 0)

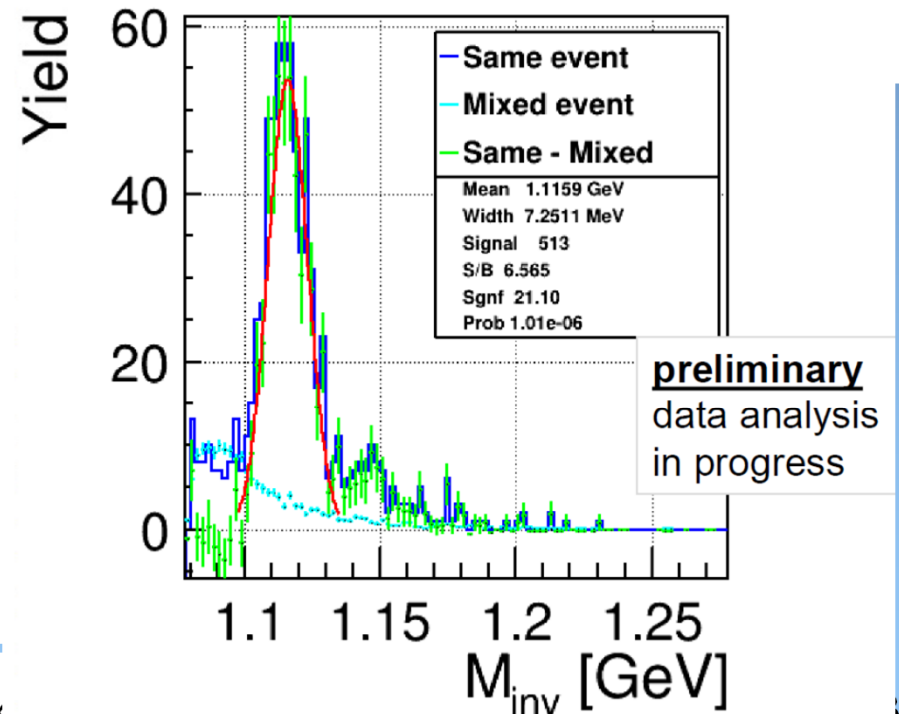


Benchmark run: Ni+Ni collisions at 1.93 AGeV



Full timeslices buffered (build node 0)

Λ reconstruction
 400-500kHz average collision rate
 Offline analysis
 Next step: online reconstruction



Summary & Outlook

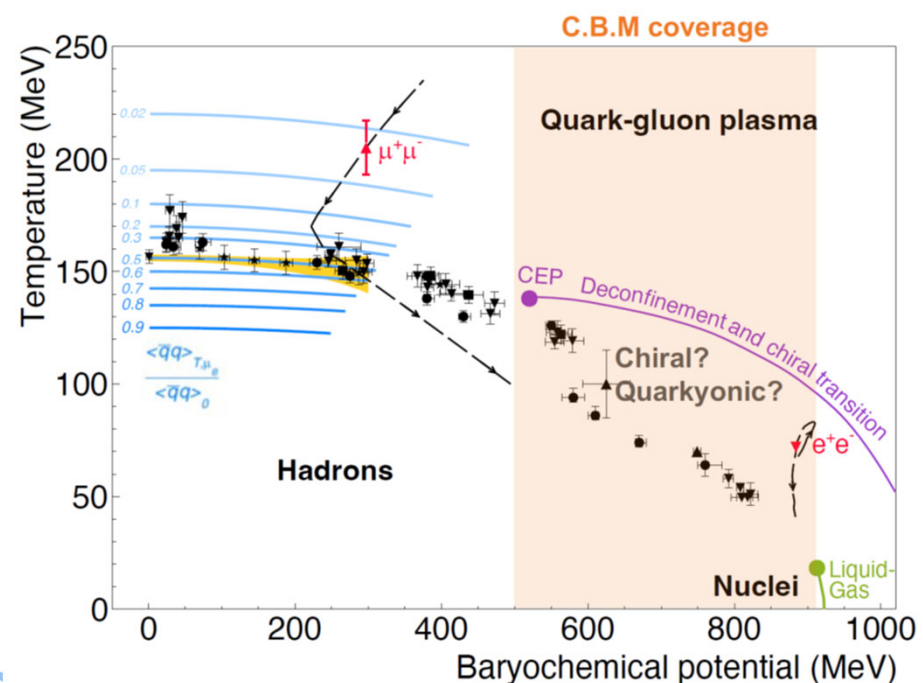


Future is bright!

- Lots of interesting results from HADES – more to come
- Work for timely construction of CBM

→ Experimental data to contribute to open QCD questions:

- Phase structure of QCD at finite density
- Formation of hadrons, hadron spectra
- Formation of nuclei



HADES; Nature Physics 15 (2019) 10, 1040-1045

That's us



XLIV HADES collaboration meeting, Mar. 2023 GSI Darmstadt



41st CBM collaboration meeting, Mar. 2023, TUD, Darmstadt

