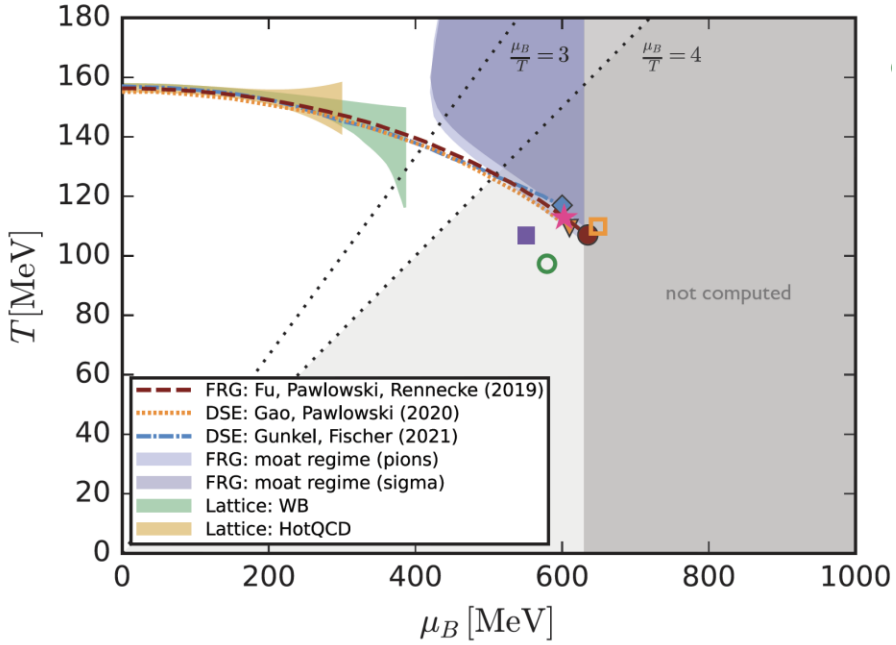
Discussion Session

ECT* Workshop on high μ_B
July 22, 2025

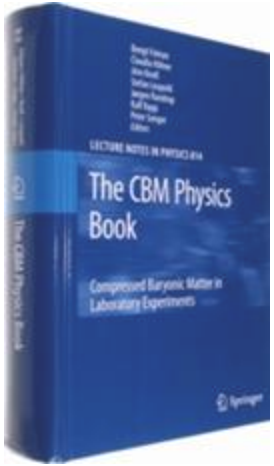
QCD phase structure



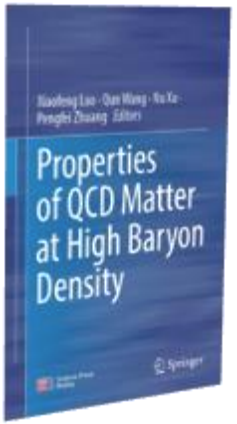
Measure with utmost precision (abundant / rare):

- light flavour hadrons, incl. (multi-)strangeness
  ↦ chemical freeze-out T, μ_B
  flow, vorticity ↦ equation-of-state

- event-by-event fluctuations (criticality)
- dileptons (emissivity)
- charm (transport properties)
- hypernuclei (interaction, production mechanism ↦ EoS)

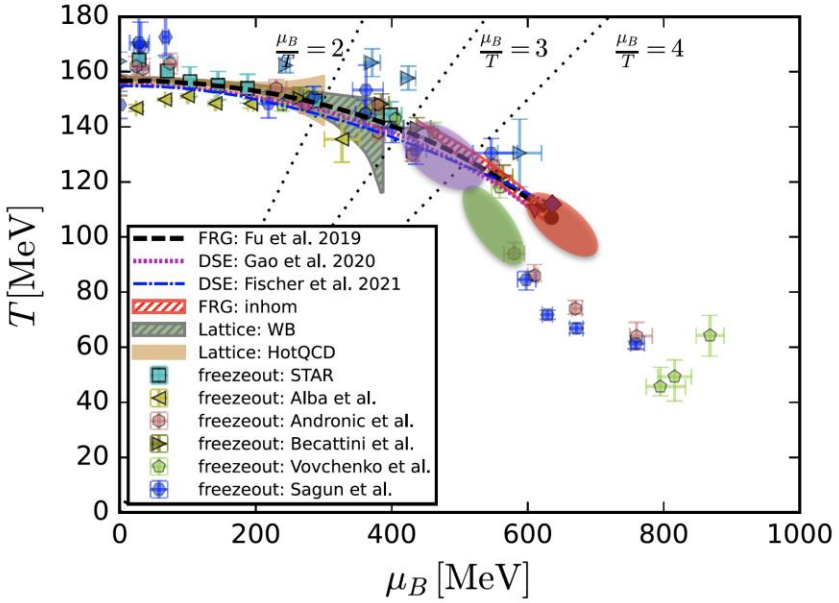


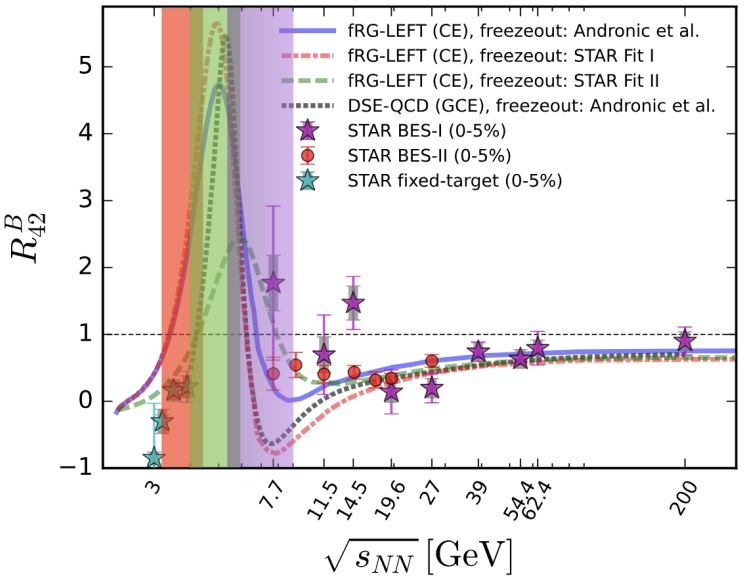
Friman *et al.*, Lect. Notes Phys. 814 (2011)



Chen, *et al.*, doi:10.1007/978-981-19-4441-3_4 (2022)

QCD critical point search





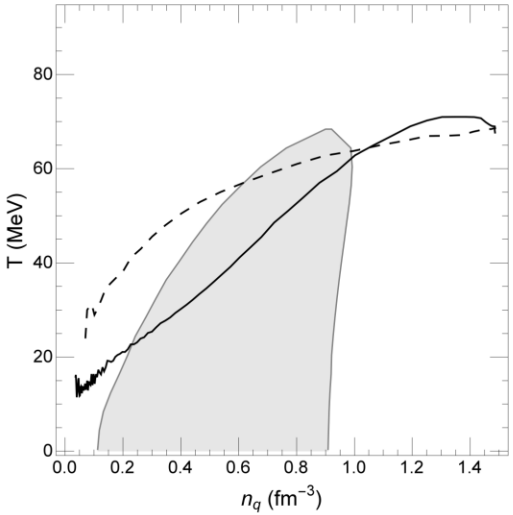
- "Something **non trivial** happens"?
- **Onset of new physics (CEP)**
- Relation chiral and deconfinement phase transition?
- Relevant order parameters?

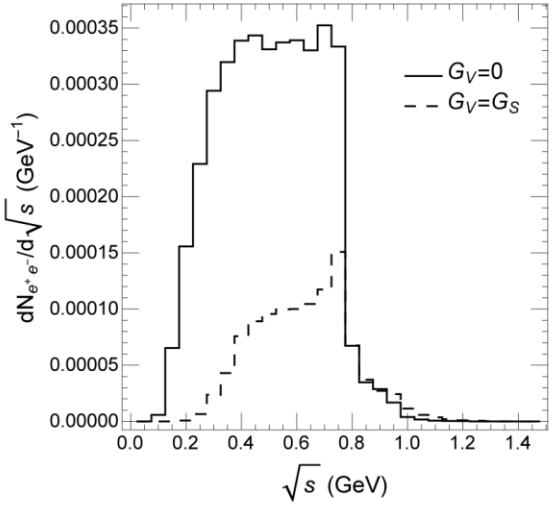
Signal:

- Peak of kurtosis at the freeze-out line
- Does the signal survives?

Dilepton signature of a 1st-order phase transition

Spinodal instabilities of baryon-rich quark matter





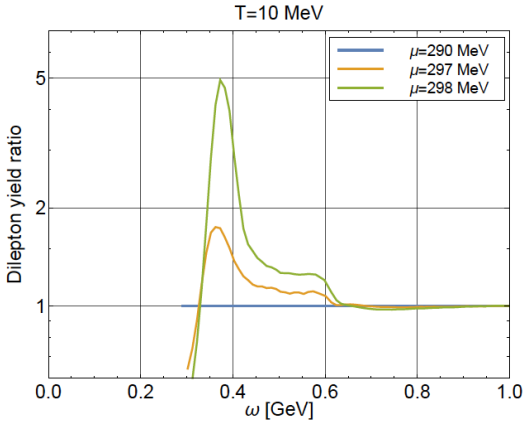
F. Li and C.M. Ko PRC 95 (2017) 5, 055203

Dilepton emission shows a significant effect: factor 2 enhancement of dilepton emission

Dilepton signature of a first-order phase transition

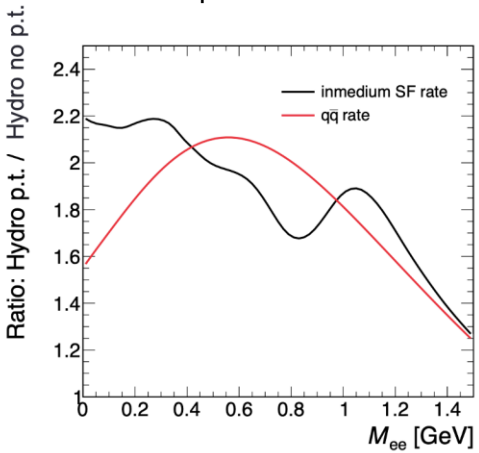
Thermodynamically consistent spectral functions from FRG flows

dilepton rates at critical endpoint



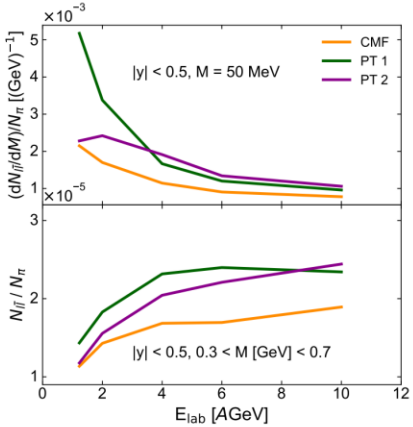
Tripolt, Jung, Tanji, v. Smekal, Wambach, NPA982 (2019) 775

Ideal hydro simulations with and w/o first order nuclear matter – quark matter phase transition

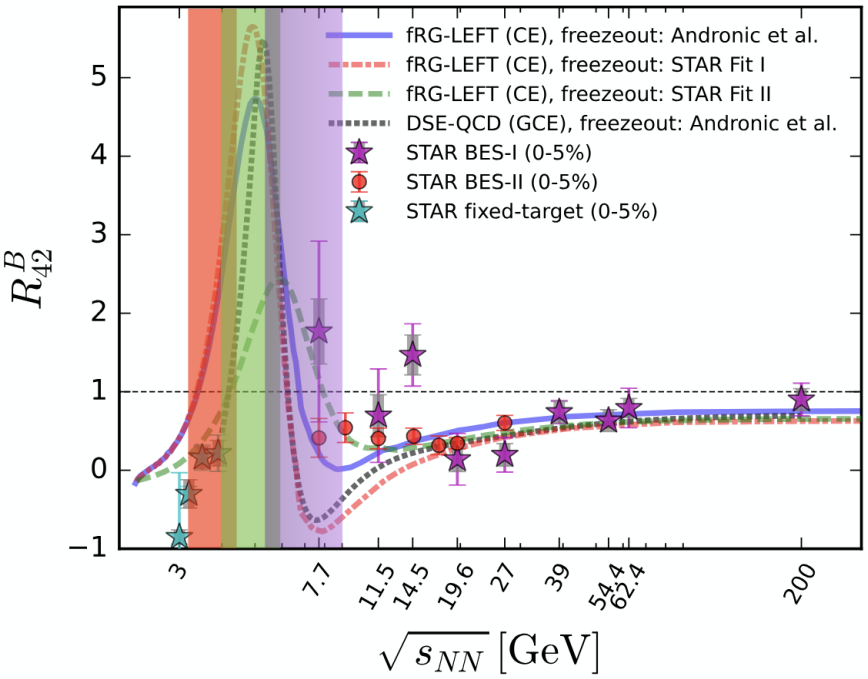


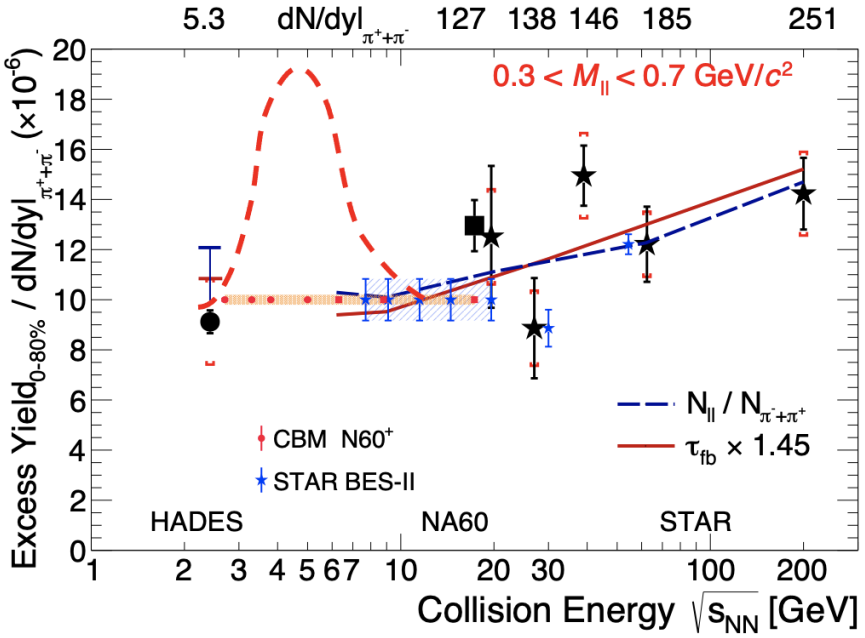
Seck et al., PRC 106, 014904 (2022)

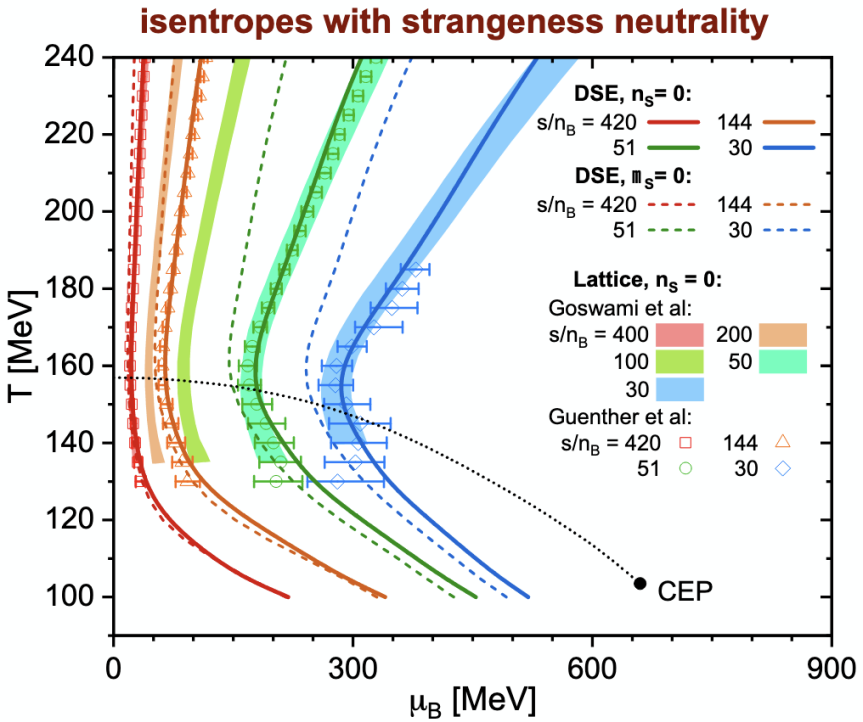
Chiral Mean Field model that matches lattice QCD at low μ_B and neutron-star constraints at high density



Dilepton emission shows a significant effect: factor 2 enhancement of dilepton emission due to extended "cooking"


fRG-LEFT (CE), freezeout: Andronic et al.
fRG-LEFT (CE), freezeout: STAR Fit I
fRG-LEFT (CE), freezeout: STAR Fit II
DSE-QCD (GCE), freezeout: Andronic et al.
STAR BES-I (0-5%)
STAR BES-II (0-5%)
STAR fixed-target (0-5%)
R^B_{42}
$\sqrt{s_{NN}}$ [GeV]

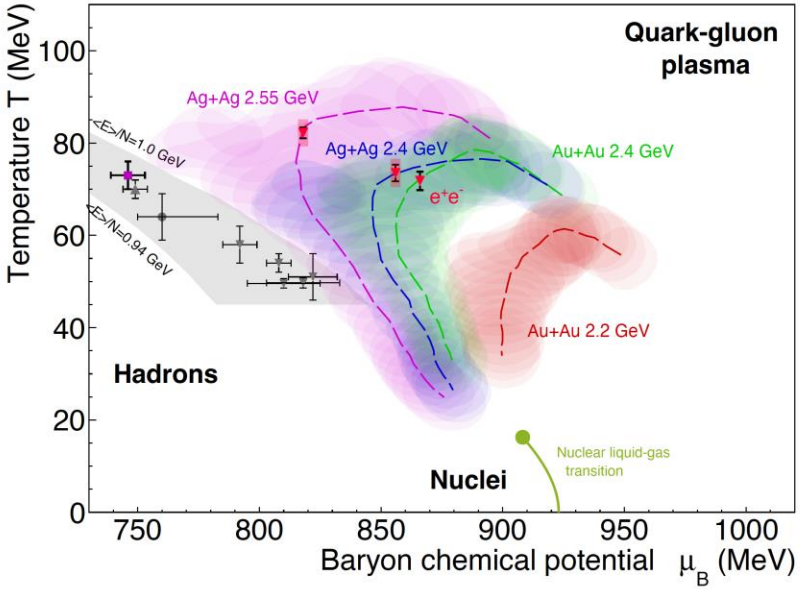

5.3
dN/dy|$_{\pi^+\pi^-}$
127
138
146
185
251
$0.3 < M_{ll} < 0.7$ GeV/c^2
Excess Yield$_{0\text{-}80\%}$ / dN/dy|$_{\pi^+\pi^-}$ (×10^{-6})
N_{ll} / $N_{\pi^-\pi^+}$
τ_{fb} × 1.45
CBM N60$^+$
STAR BES-II
HADES
NA60
STAR
Collision Energy $\sqrt{s_{NN}}$ [GeV]



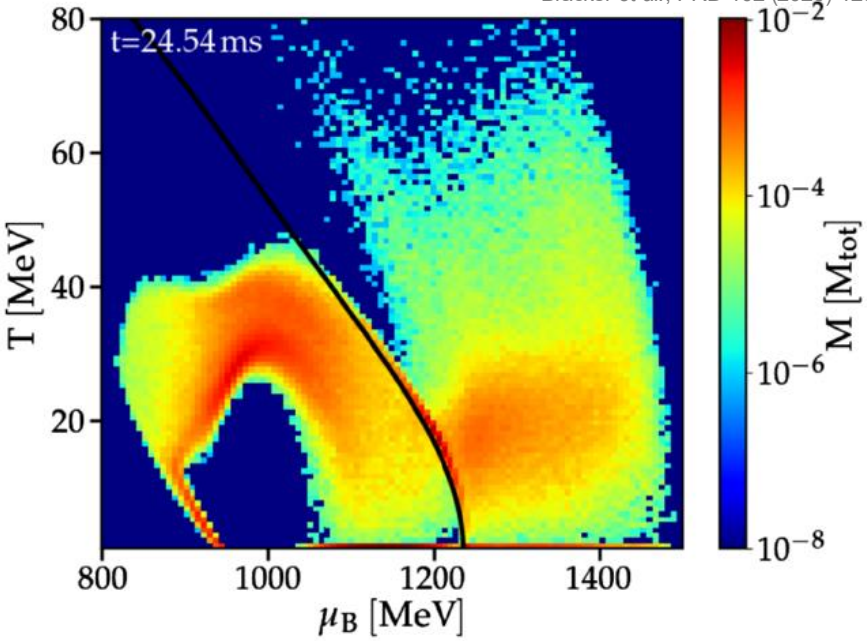
- Calculation of trajectories close to CEP
- Dynamic models

HI and astrophysics

QCD phase transition in **binary neutron star mergers**: study the possible occurrence of the hadron-quark phase transition and its signature in Gravitational Waves



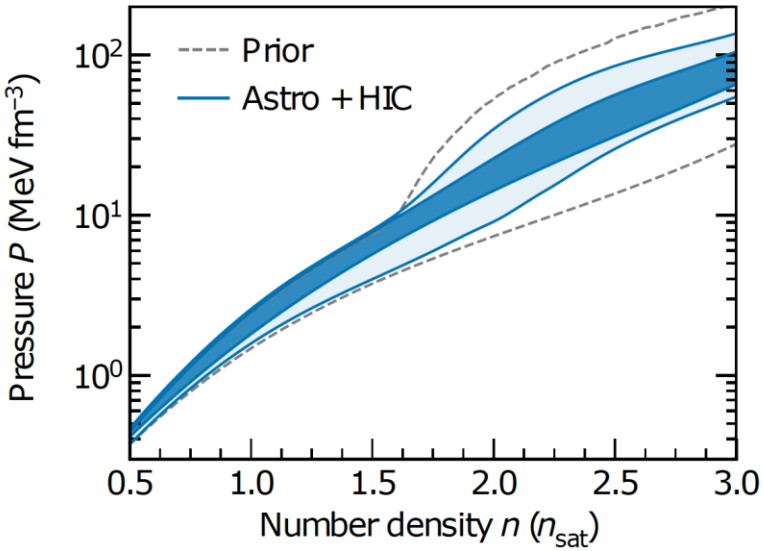
Blacker *et al.*, PRD 102 (2020) 123023

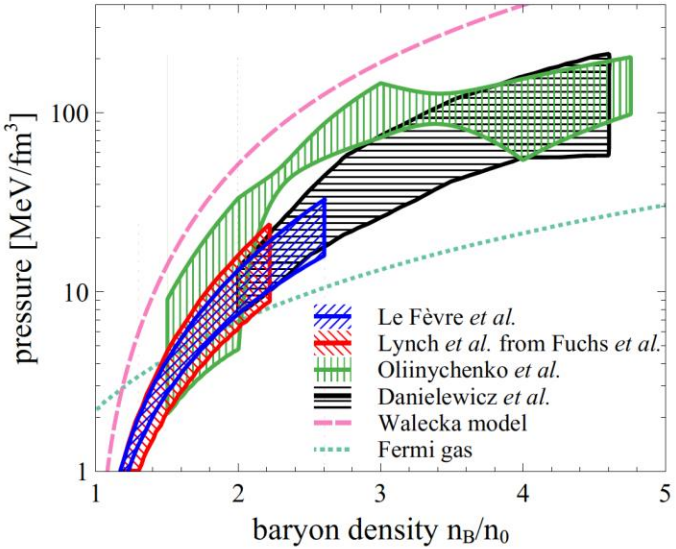


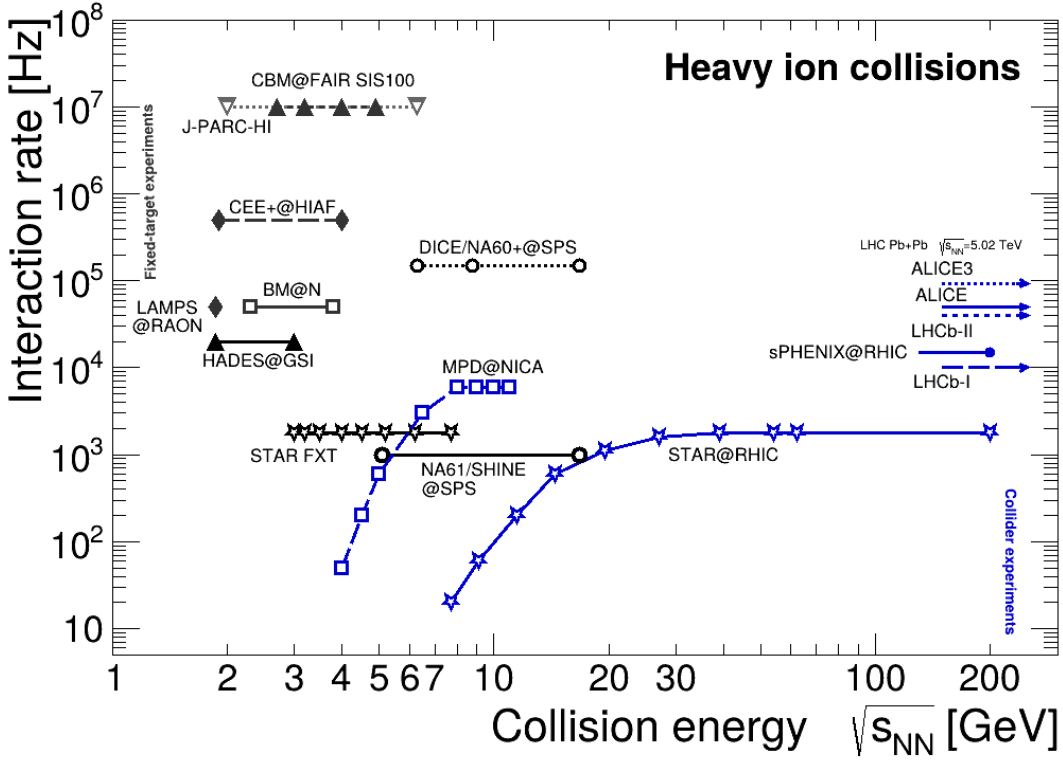
Freeze-out curve:J. Cleymans, K. Redlich, NPA 661 (1999) 379
Au+Au 2.4 GeV: HADES, Nature Phys. 15 (2019) 1040
Ag+Ag 2.4 GeV, 2.55 GeV: HADES in preparation

Connection between the HI and astrophysics

By means of transport model calculations







CBM focus on rare and electromagnetic probes (e-b-e, dileptons, charm, strangeness, hyperons): high rate capability, energy range could be extended with future SIS450 ring

HADES: established thermal radiation at high μ_B, limited to 20 kHz, and SIS18 energies

STAR FXT@RHIC: BES program completed; limited capabilities for rare probes

CEE+@HIAF: construction, no dileptons, focus on e-b-e, hyperons

DiCE/NA60+@SPS: proposal, dimuons, charm, strangeness, hyperons,
e-b-e require detector modification and ToF

NA61/SHINE: e-b-e, limited capabilities for open charm