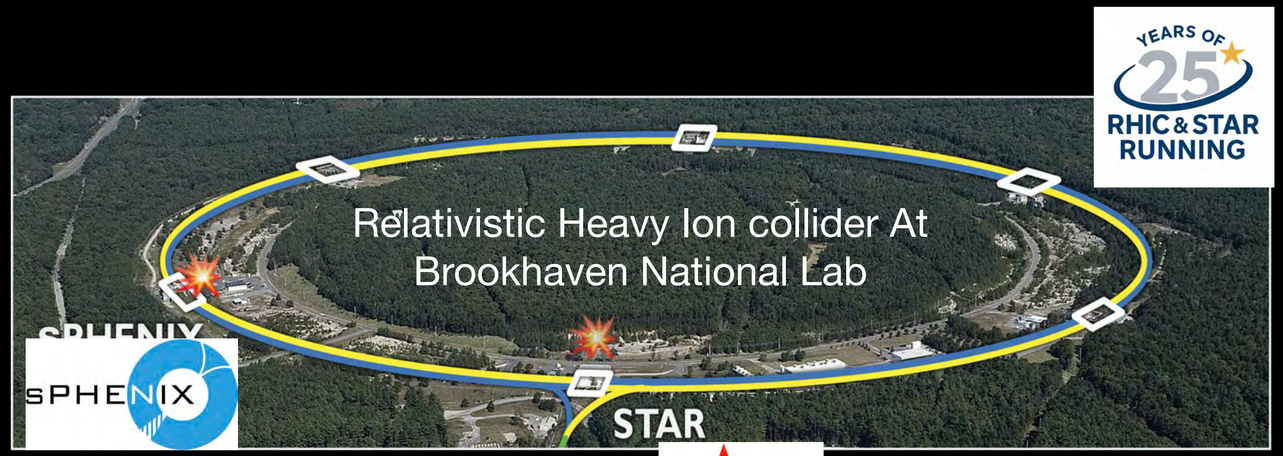
Heavy Ion Summary

Conveners: Xin Dong (LBNL), Olga Evdokimov (UIC), Jean-Francois Paquet (Vanderbilt Univ.), Prithwish Tribedy (BNL)

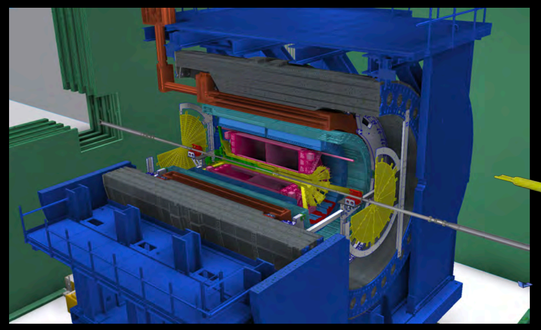
15th Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2025)

University of Wisconsin, Madison, June 9-13, 2025

Facilities & detectors: running right now!

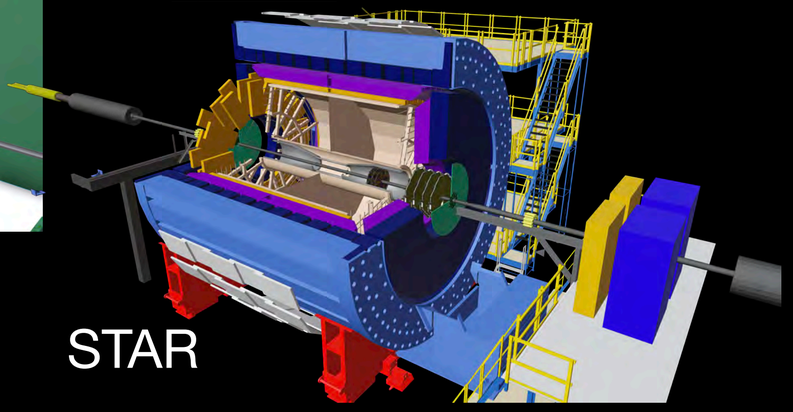


YEARS OF 25 RHIC & STAR RUNNING



sPHENIX

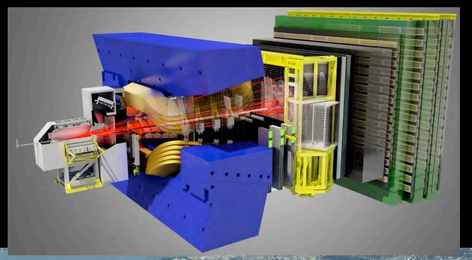
STAR



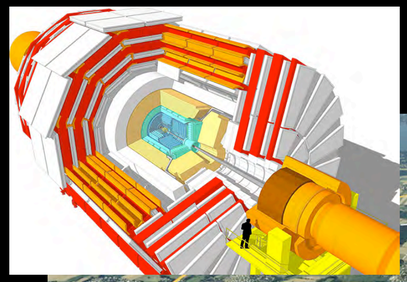
RHIC (versatility, dedicated facility)

U+U, Au+Au, Cu+Au Cu+Cu, Ru+Ru, Zr+Zr, O+O,
p+Au, d+Au, He+Au, p+Al, (E_{cms}=7.7-200 GeV)
Polarized p+p (E_cms=500 GeV)

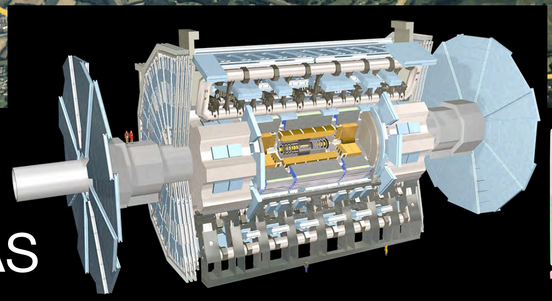
LHCb

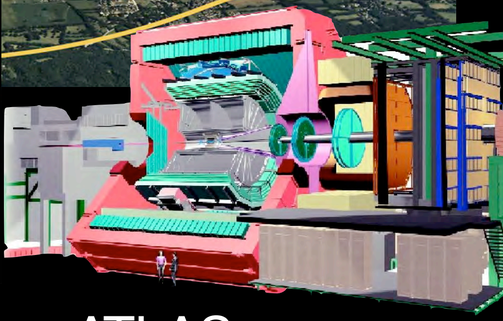


CMS



ATLAS





LHC (energy champion):

Pb+Pb, Xe+Xe, (E_{cms}=2760-5000 GeV)
p+p (E_{cms}=900-13600 GeV)

ATLAS

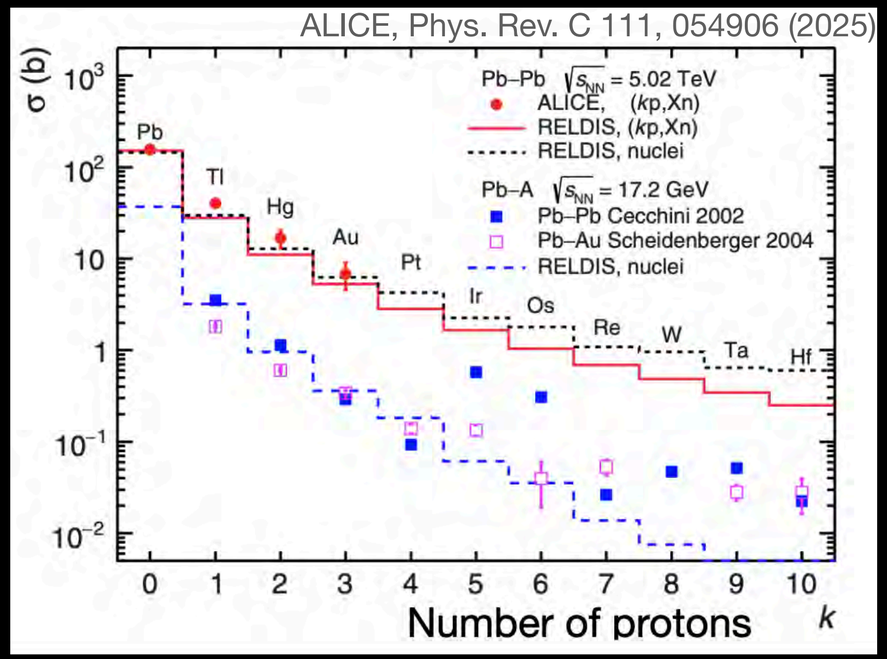
Also operating (fixed-target/near-future):
- **HADES, NA61/SHINE, CBM, NICA**

While you listen to me RHIC is colliding Au on Au at 200 GeV

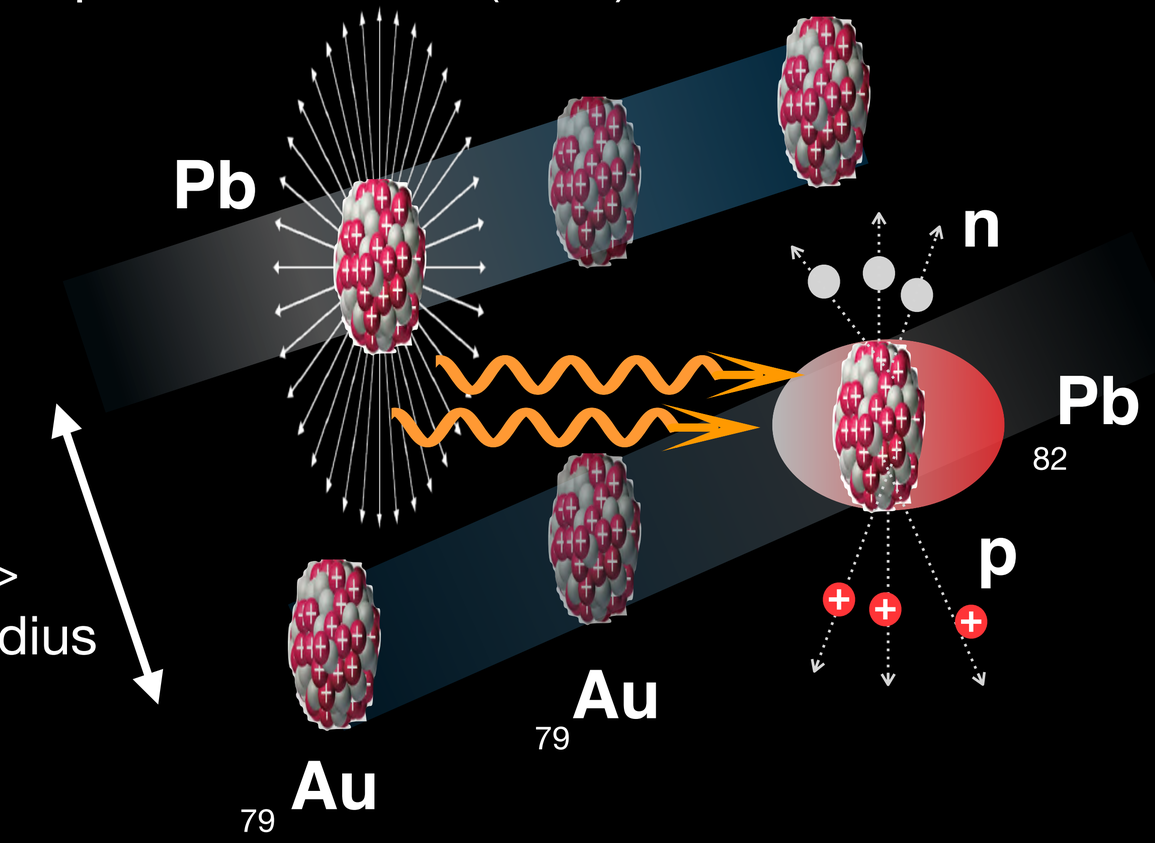
Your Free Photon Collider

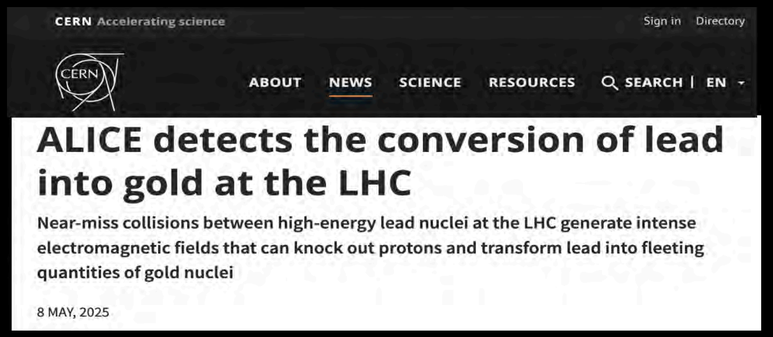
Talk: A. Ikbal (Mon)

Relativistic heavy-ion beams = built-in photon colliders, strongest EM-field (10^{18} T)



Giant Dipole Resonance (GDR) in Ultra-Peripheral Collisions (UPC)

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ALICE detects the conversion of lead into gold at the LHC

Near-miss collisions between high-energy lead nuclei at the LHC generate intense electromagnetic fields that can knock out protons and transform lead into fleeting quantities of gold nuclei

8 MAY, 2025

Ion-1's photons drive Ion-2 into its GDR → EM dissociation, nucleon emission & transmutation

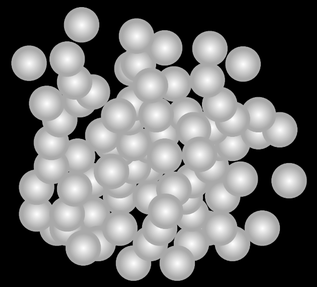
Initial conditions: Color Glass Condensates

Talk: S.Tiwari
A.Ikbal, L. Kosarzewski (Mon)

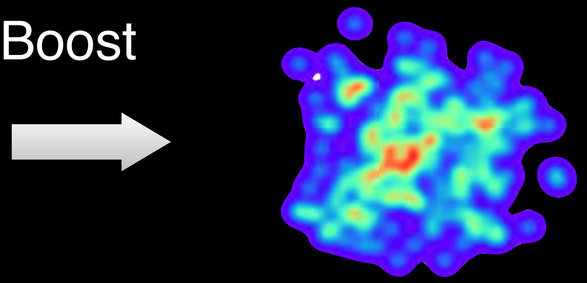
Strongest color field in the nature: $\rho \sim 1/\alpha_S$

Gluon density grows and saturate

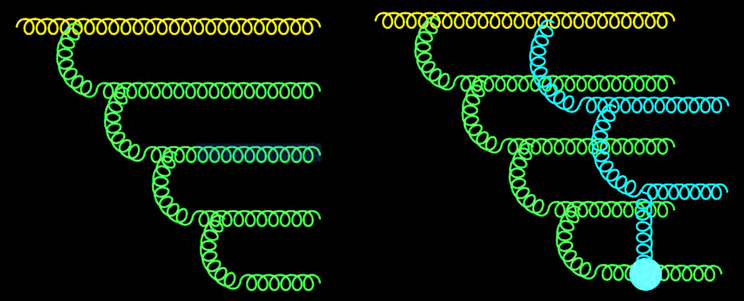
Nuclei at rest

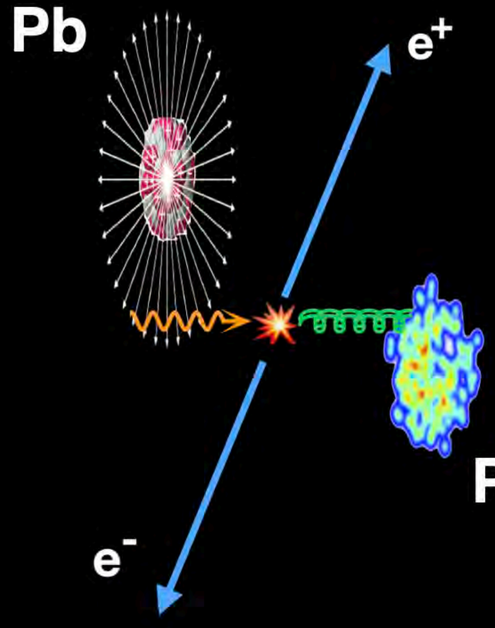


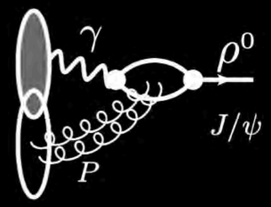
Boost



Color-Glass-Condensate (CGC)

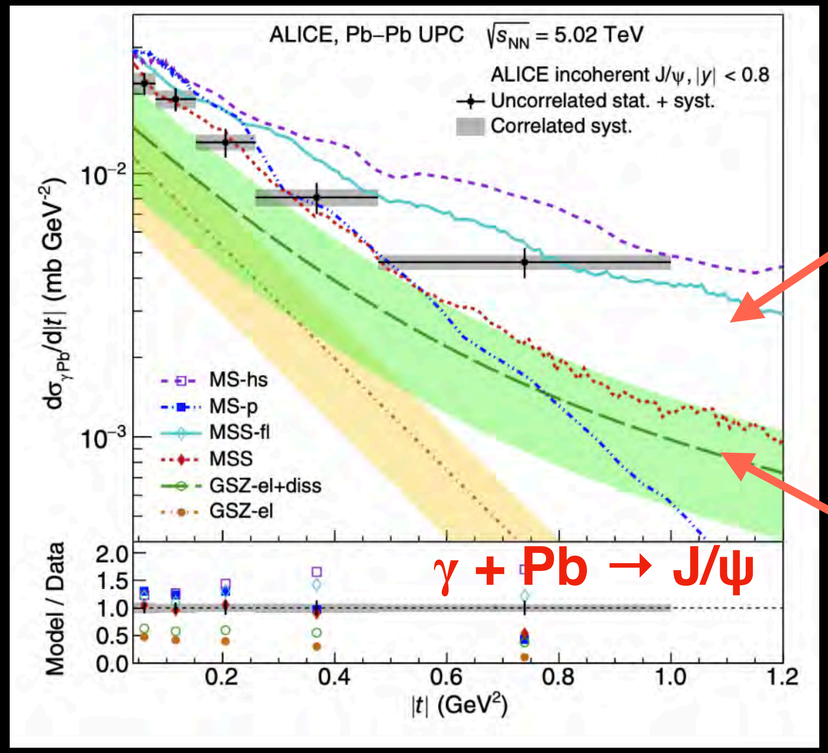


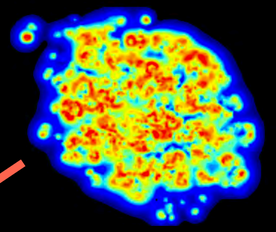




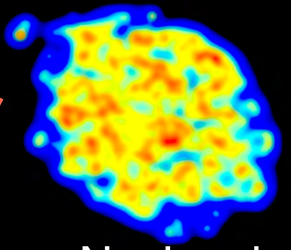
γ + A → J/ψ

Ultra-peripheral heavy-ion & electron-ion collider





Sub-nucleonic fluctuations

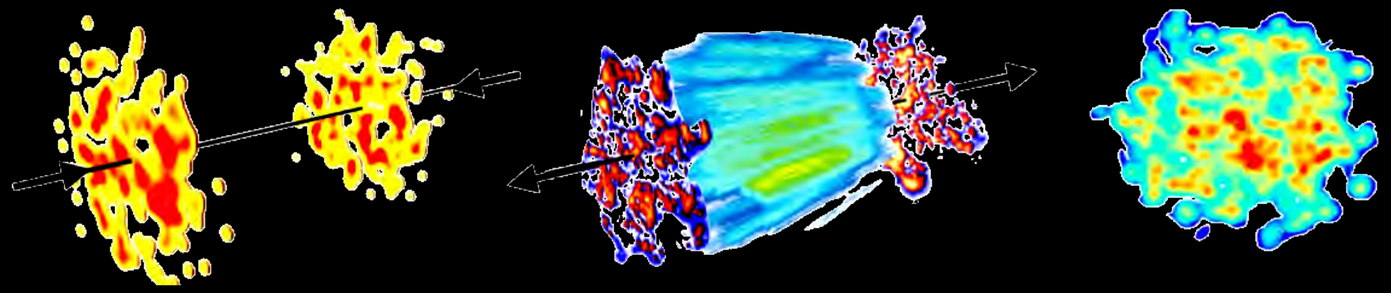


Nucleonic fluctuations

Photon-induced J/ψ production: probes nuclear gluons down to sub-nucleon scales

Conventional model of relativistic heavy-ion collisions

Talk: D. Almaalol



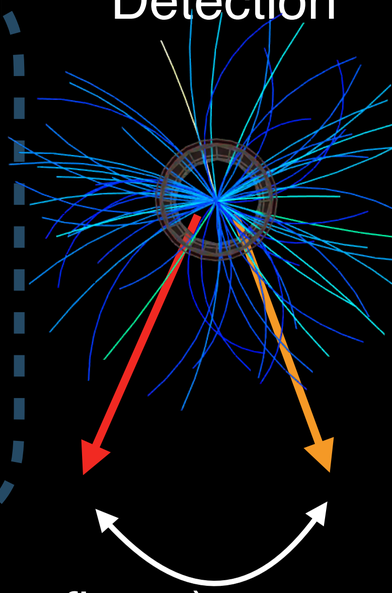
Color Glass Condensate (CGC)

Gluon Condensate Plasma (Glasma)

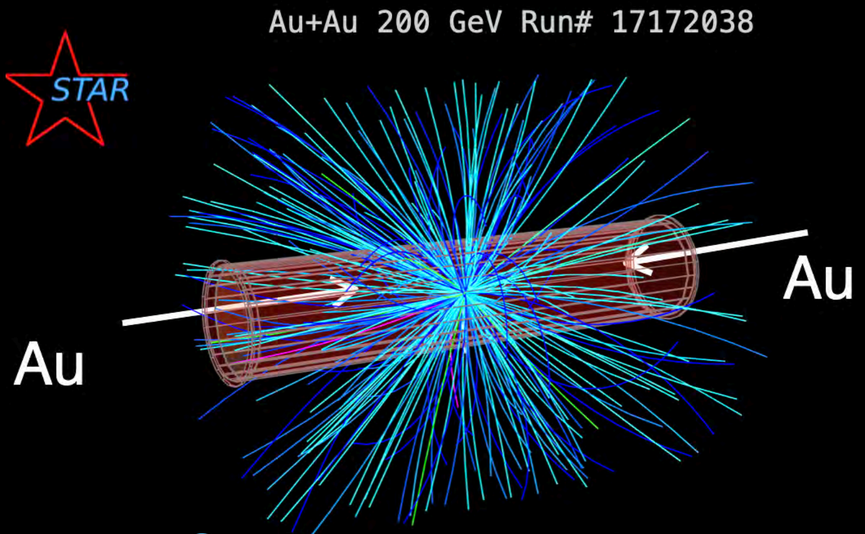
Hadronization

Quark-Gluon Plasma (QGP)

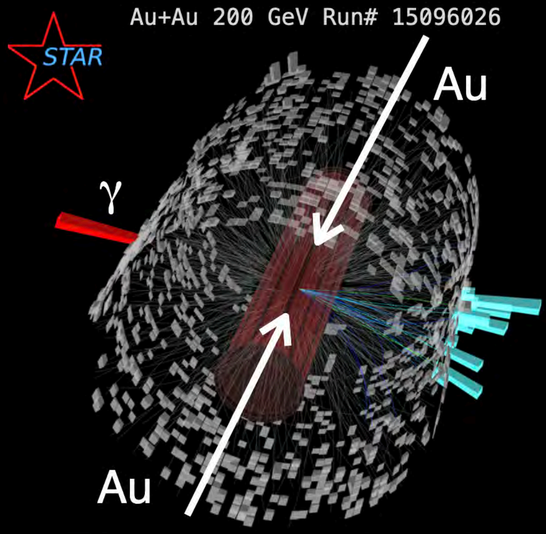
Detection



Bulk inclusive probes (particle correlations)



Exclusive & hard probes (Jets - heavy-flavor)

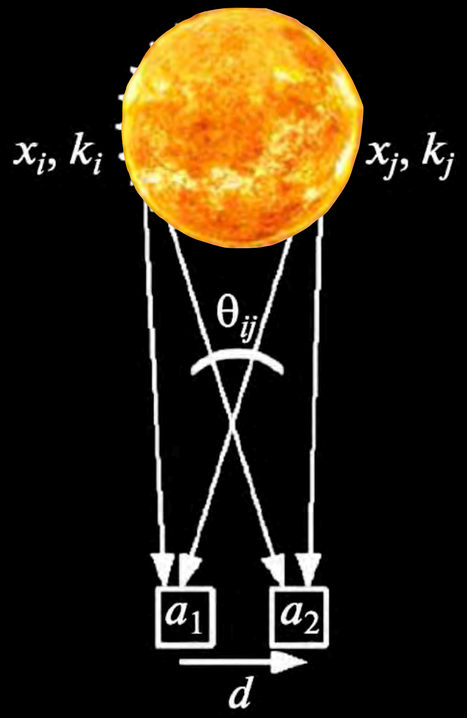


Goal: probe the microstructure of the Quark-Gluon-Plasma medium in heavy-ion collisions

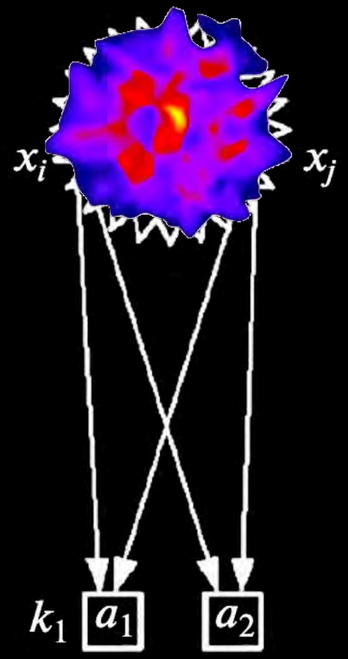
Femtoscopy: Measuring the Fireball's Size

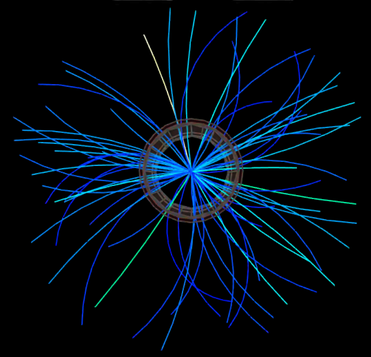
Talk: Y. Khyzhniak

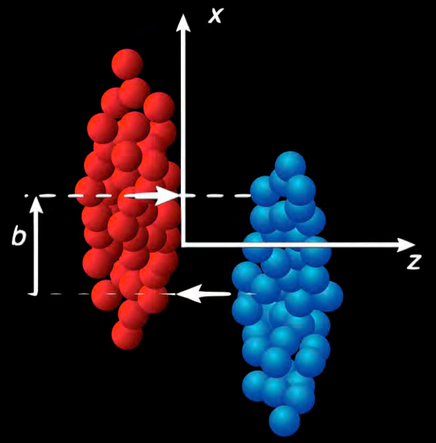
Hanbury Brown–Twiss (steller diameter)

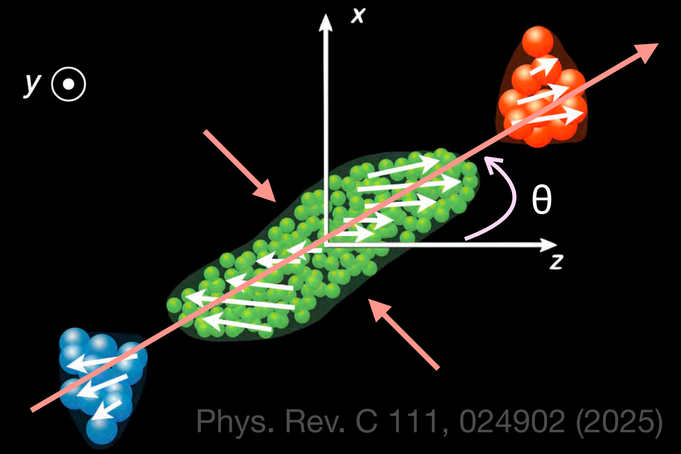


Heavy-Ion Femtoscopy (size, shape, lifetime of fireball)

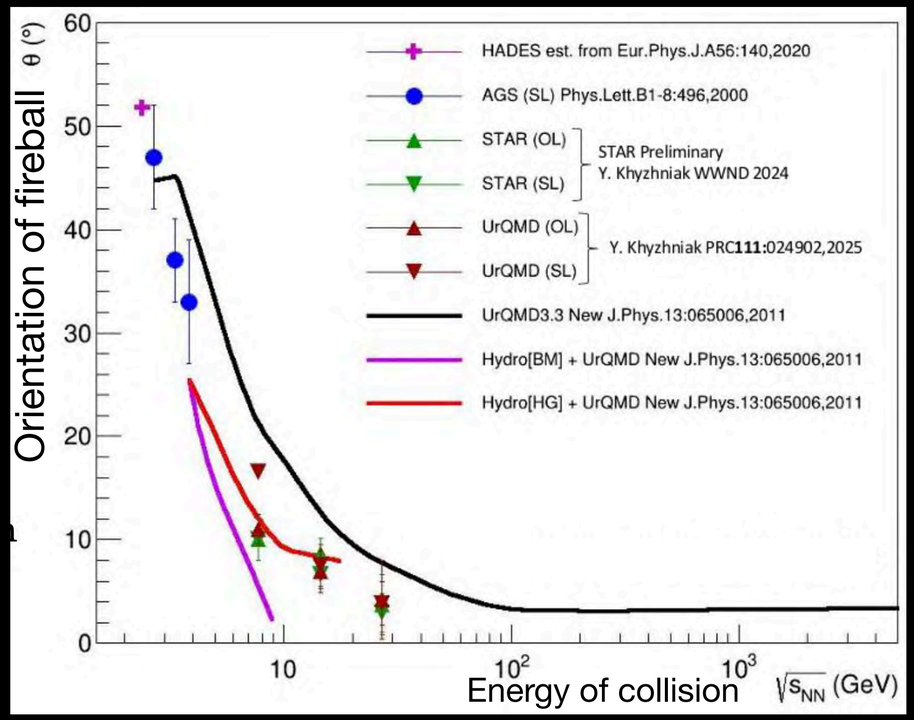








Phys. Rev. C 111, 024902 (2025)



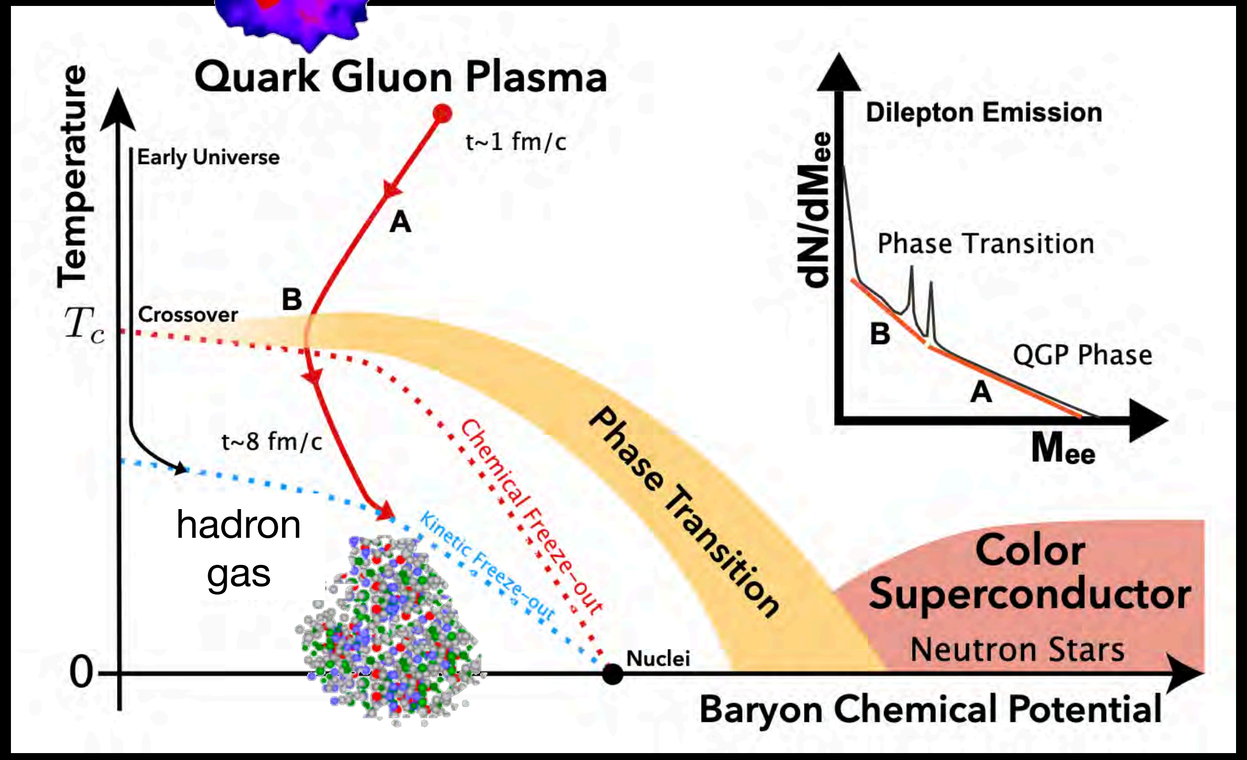
New RHIC data: femptoscopic method inspired by HBT technique is used to measure the orientation of the fireball created in heavy-ion collisions

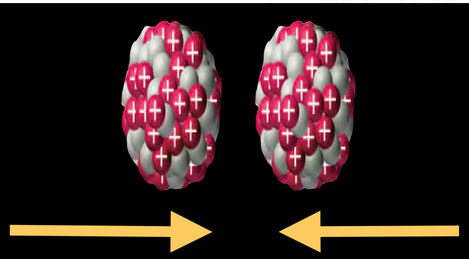
Thermodynamic property: how hot is the medium?

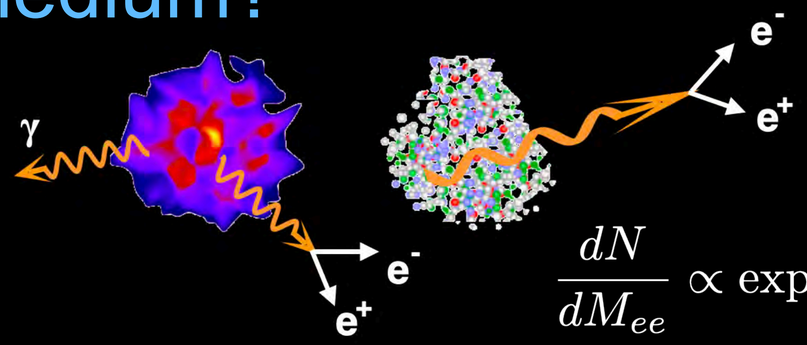
Talk: C. Jin

STAR collaboration, arXiv: 2402.01998

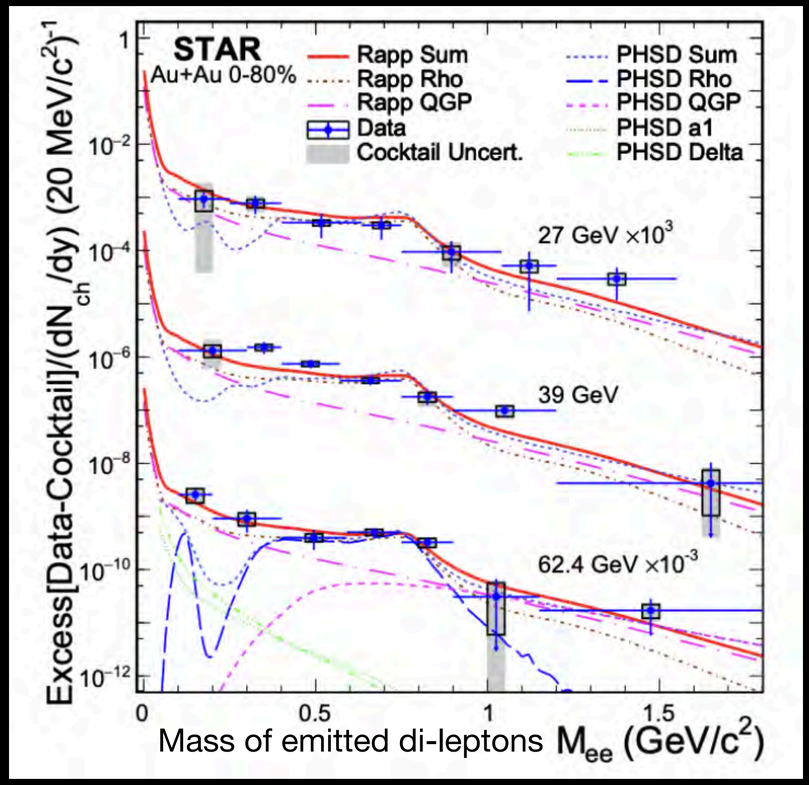
QCD Phase diagram (conjectured)

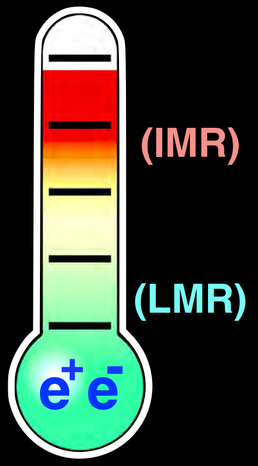






$$\frac{dN}{dM_{ee}} \propto \exp(-M_{ee}/T)$$





Hadron-Gas Quark-gluon-plasma

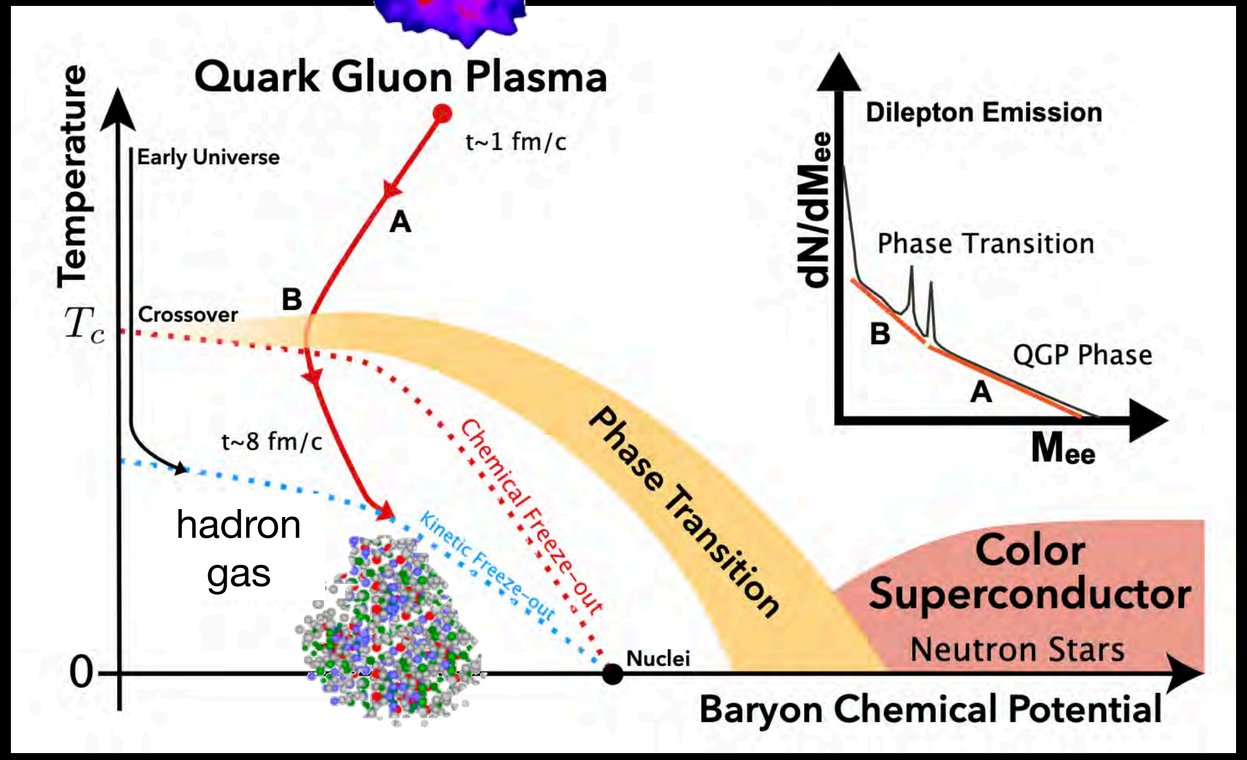
Thermally radiated (blackbody) of di-lepton can be thermometer of the medium

Thermodynamic property: how hot is the medium?

Talk: C. Jin

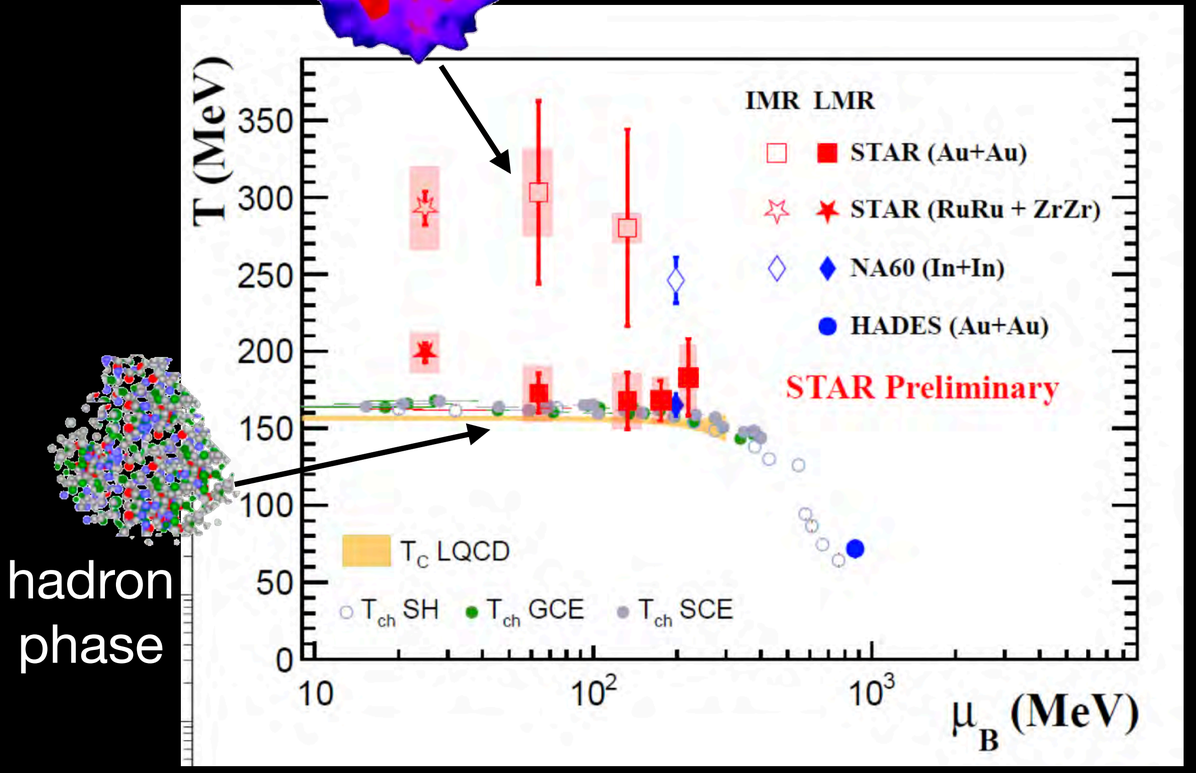
STAR collaboration, arXiv: 2402.01998

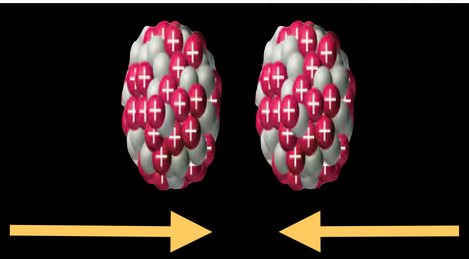
QCD Phase diagram (conjectured)



QGP phase

Mapped phase diagram



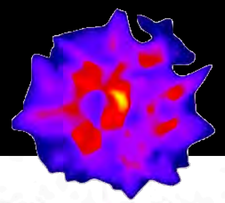


Temp of the Quark-Gluon-Plasma @RHIC ~ 300 MeV ~ 3x10^{12} K

First steps towards blue-shift free temperature of QGP medium & mapping the QCD phase diagram

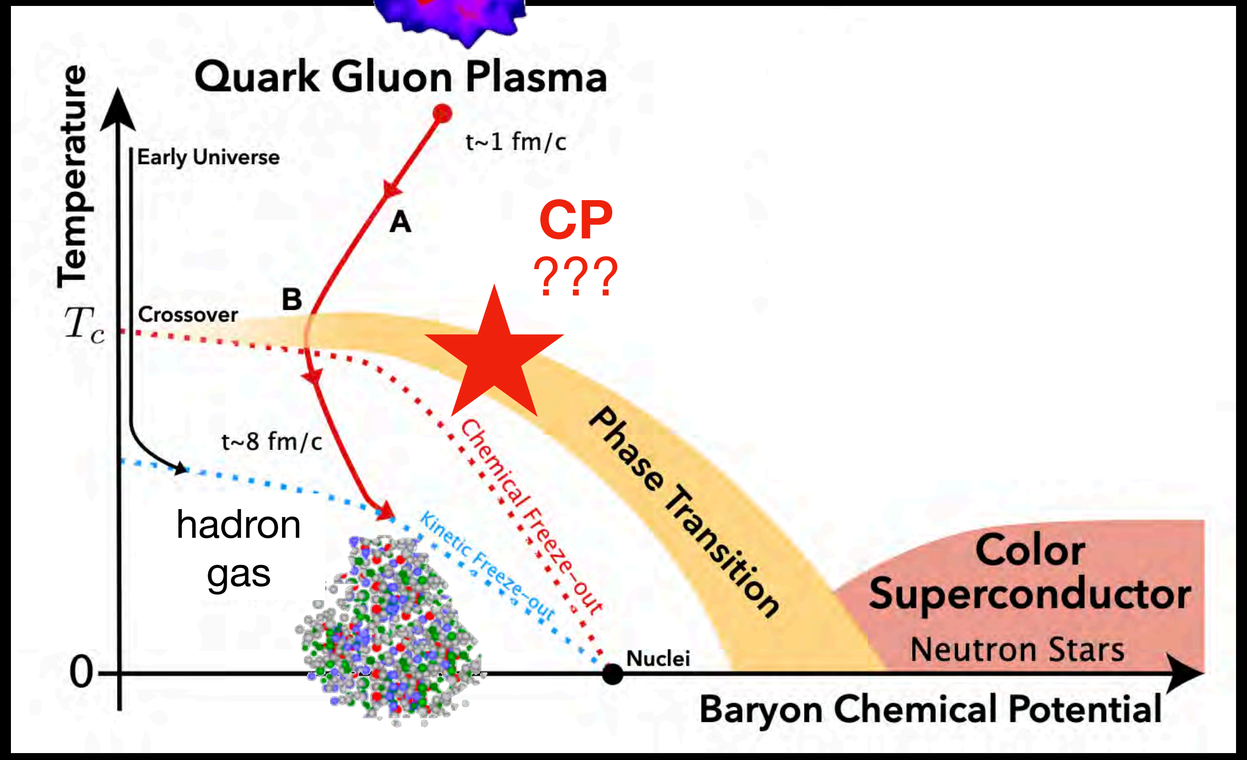
Critical point search on QCD phase diagram: Theory

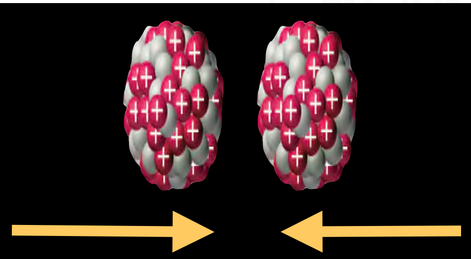
Talk: T. Restrepo, J. Grefa



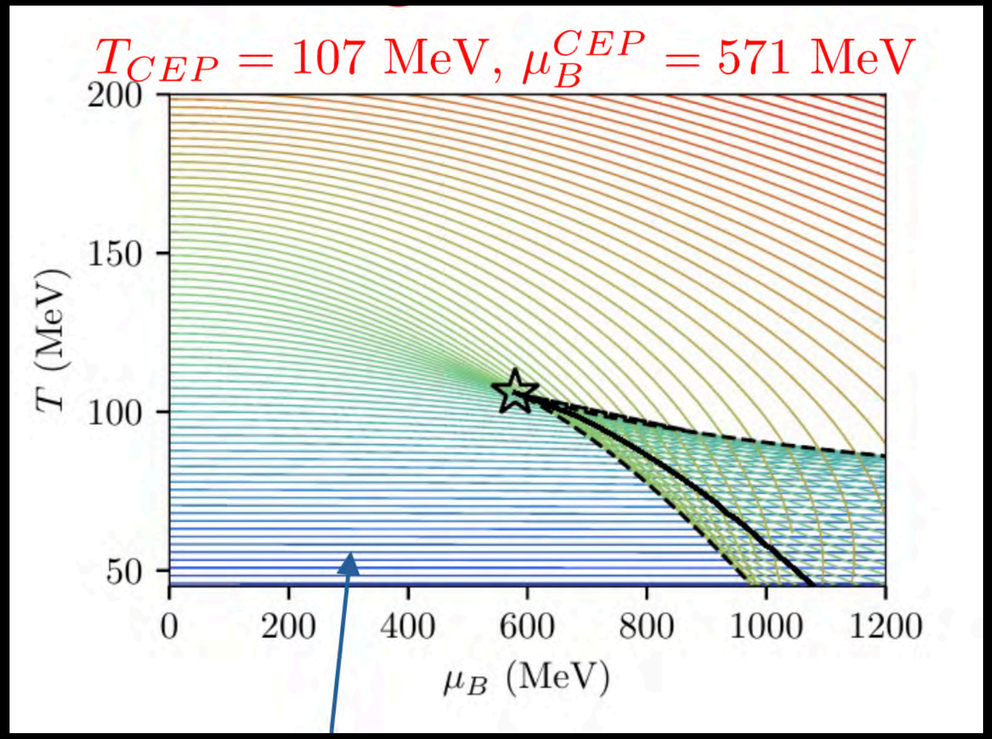
STAR collaboration, arXiv: 2402.01998

QCD Phase diagram (conjectured)





$$S = \frac{1}{2\kappa_5^2}\int_{M_5} d^5x\sqrt{-g}\left[R - \frac{(\partial_\mu\phi)^2}{2} - \underbrace{V(\phi)}_{\text{nonconformal}} - \underbrace{\frac{f(\phi)F_{\mu\nu}^2}{4}}_{\mu_B\neq 0}\right]$$

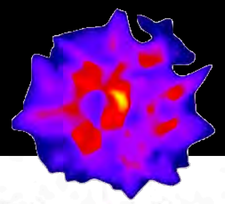


The holographic model predicts a critical point!!

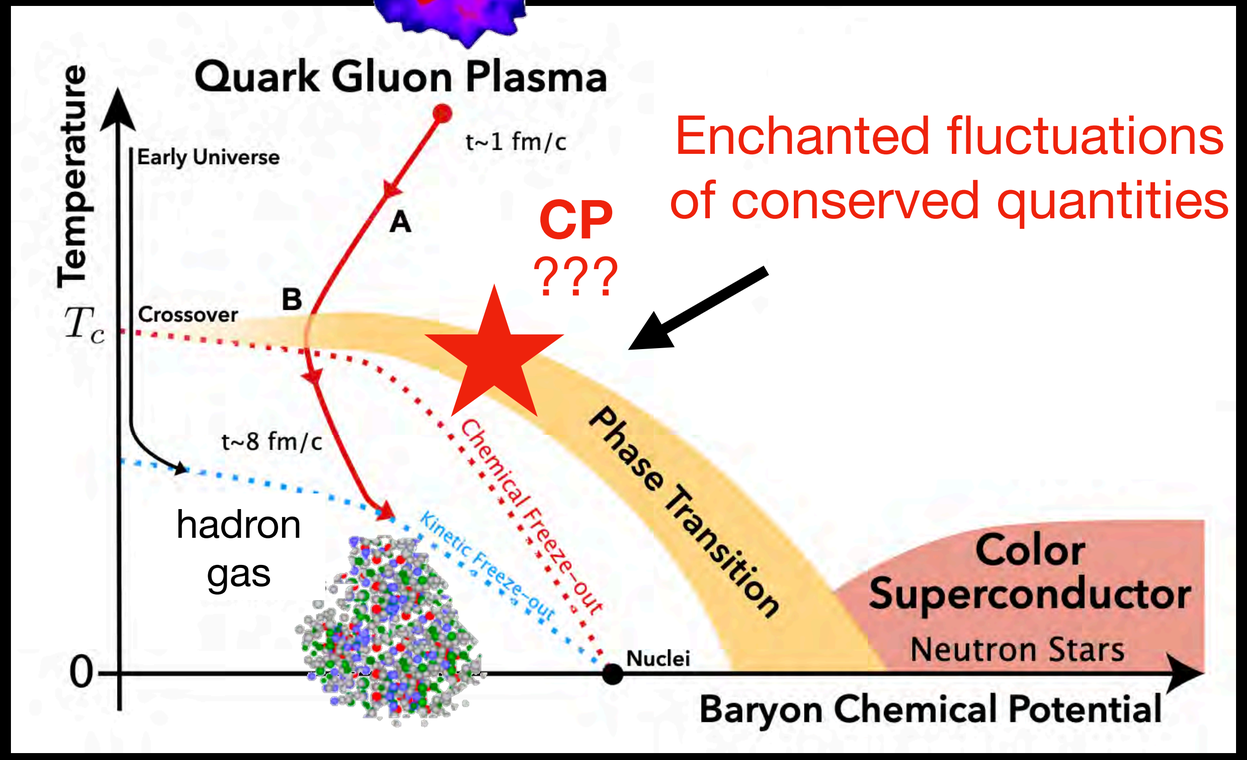
Critical point search on QCD phase diagram: Experiment

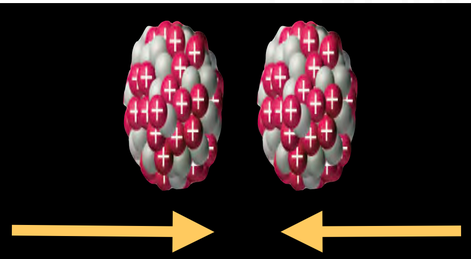
Talk: O. Savchuk
R. Poberezhniuk

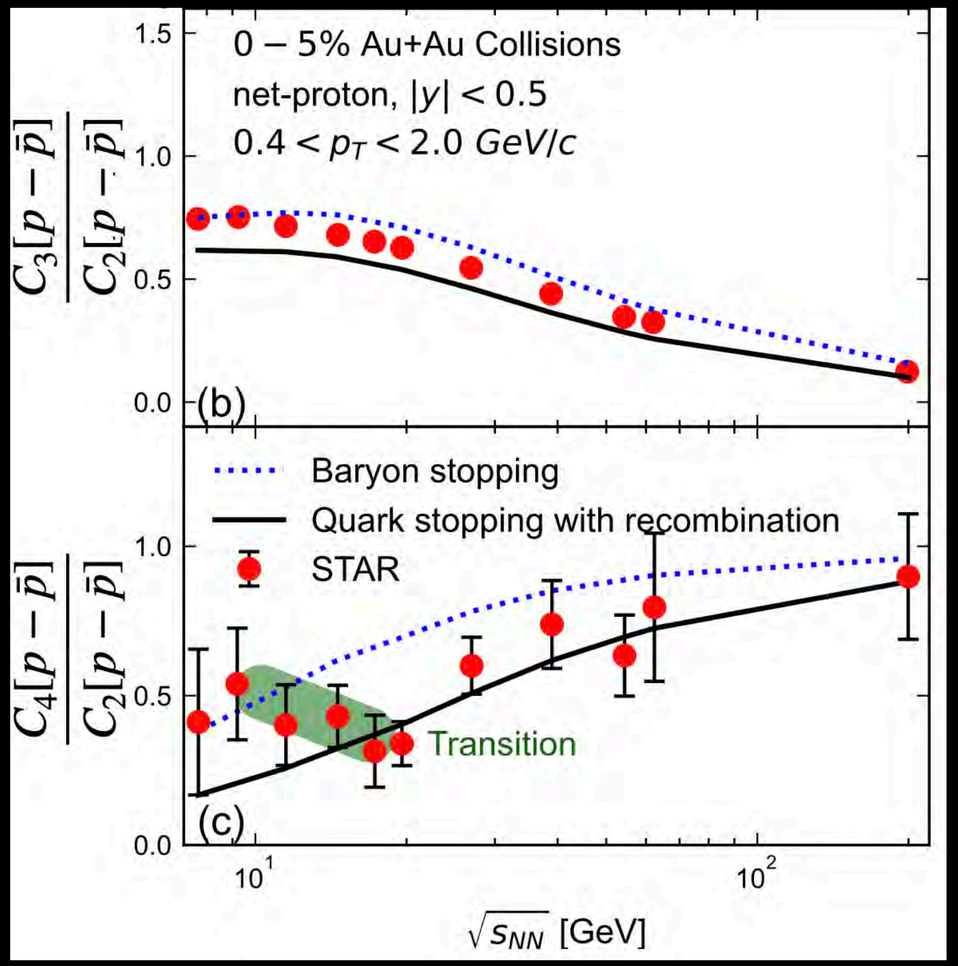
STAR collaboration, arXiv: 2402.01998



QCD Phase diagram (conjectured)





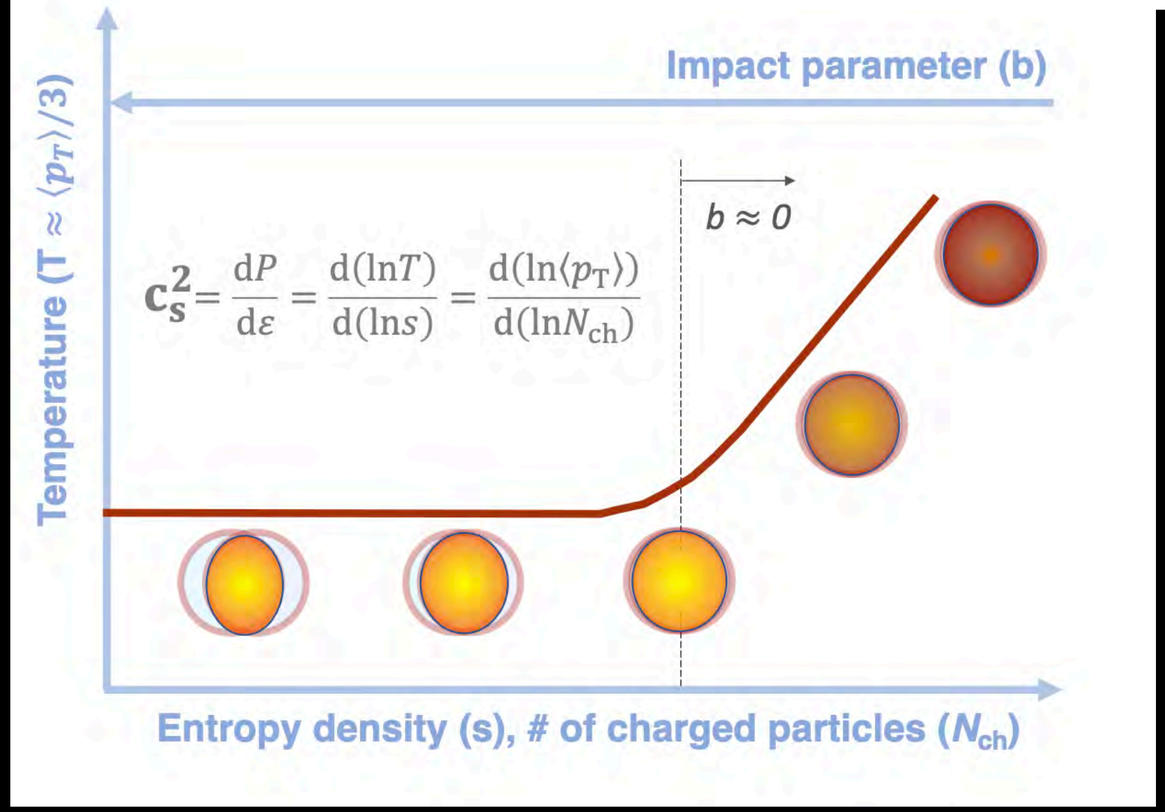


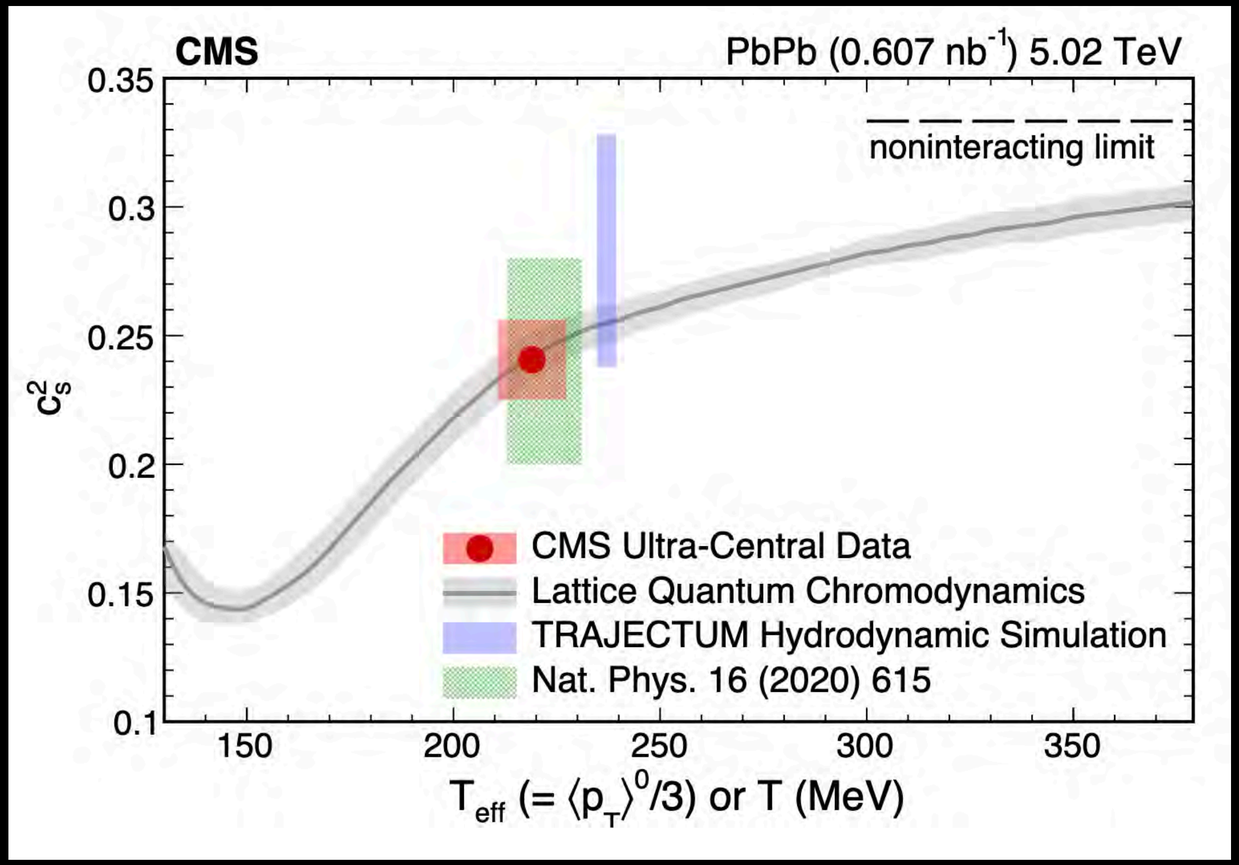
Transport model claims to explain experimental baryon-number fluctuations without CP

Speed of sound in Quark-Gluon-Plasma

Talk: M. Stojanovic

$c_s^2 = \frac{dP}{d\varepsilon} \Longrightarrow$ a direct probe of equation of state

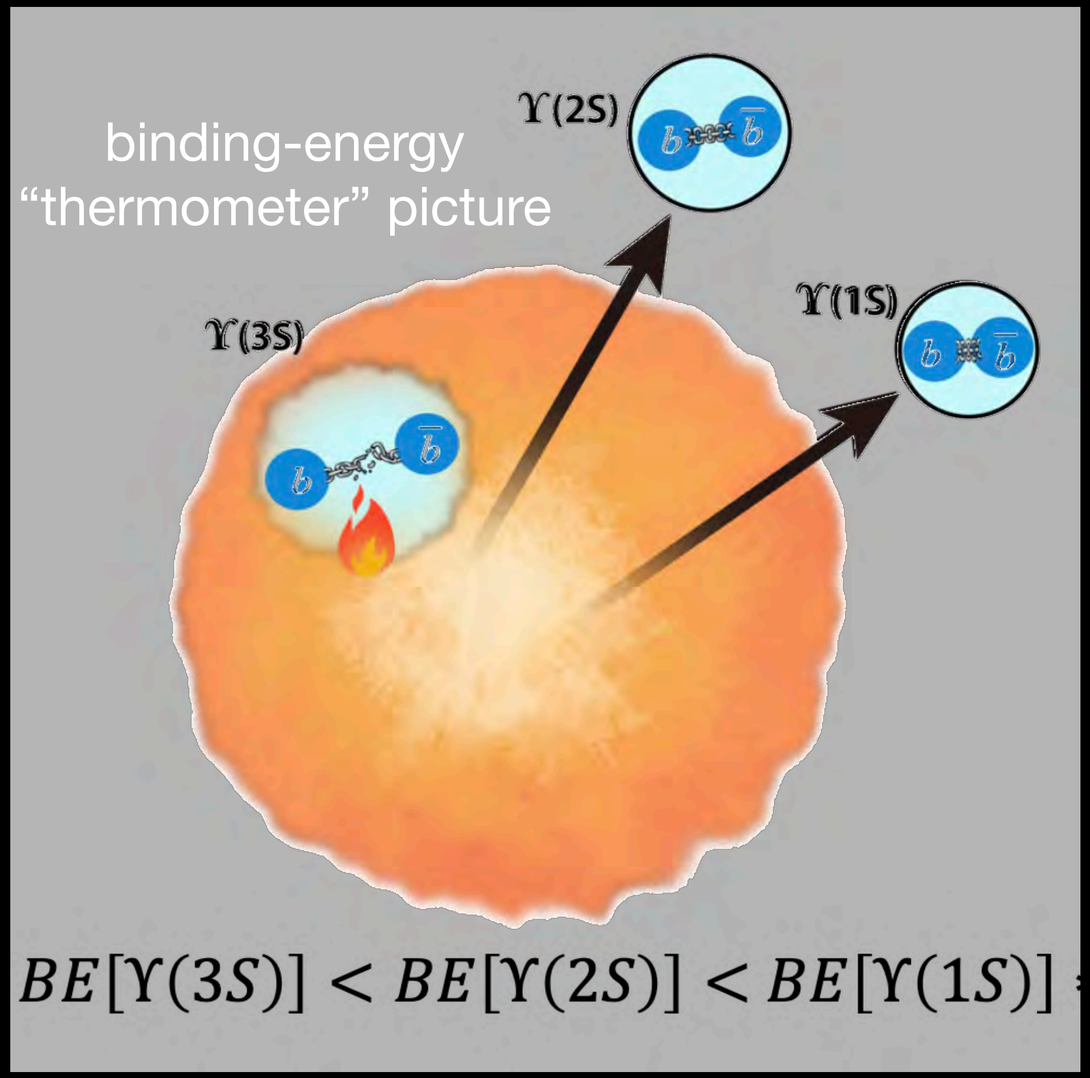


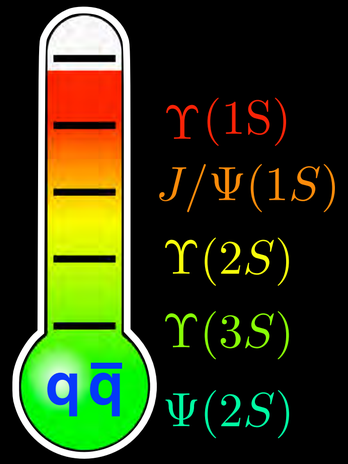


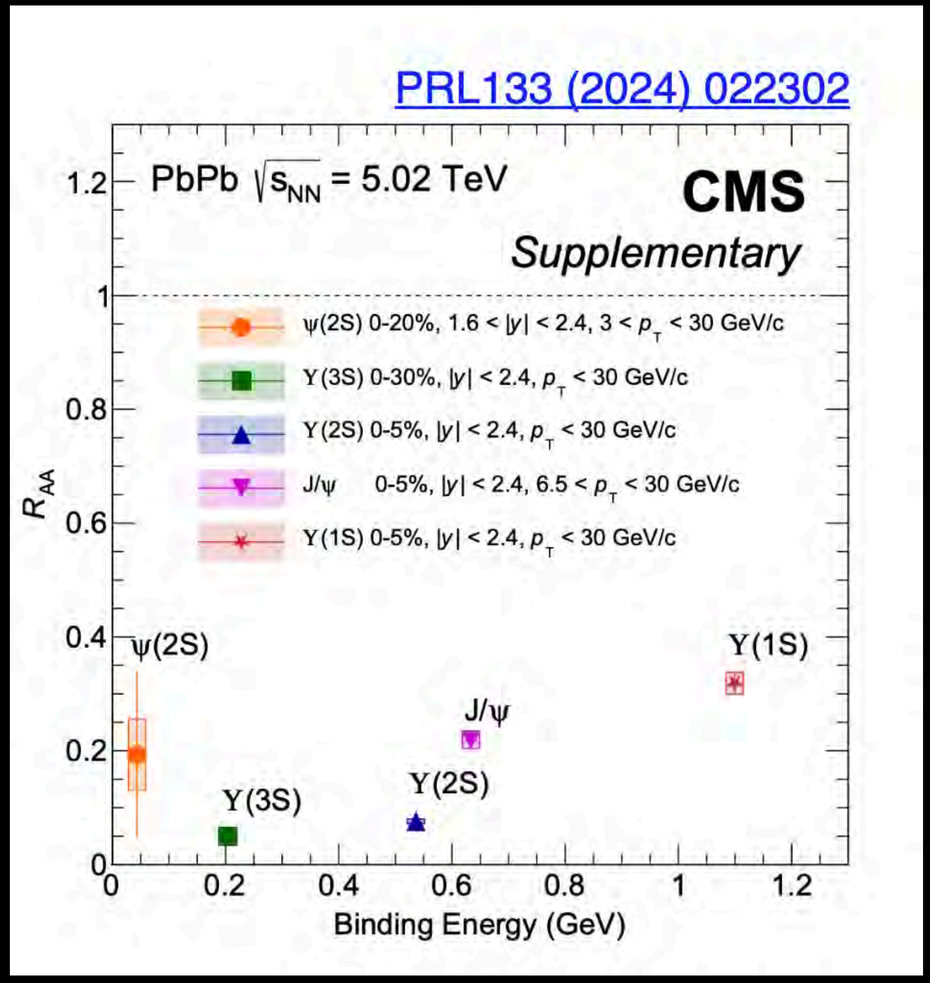
First direct measurements of speed of sound assuming QGP medium under thermodynamic assumptions

Another thermometer: melting of quarkonia

Talk: C. Dean,
S. Nanada,
K. Shen, S. Chandra



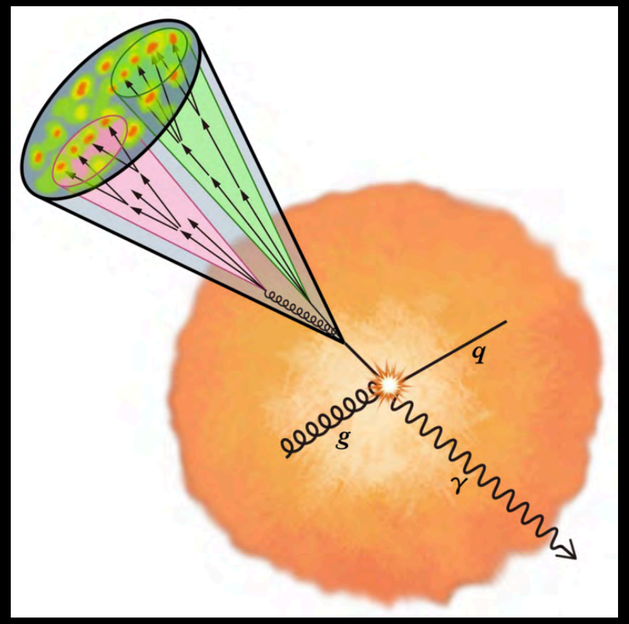


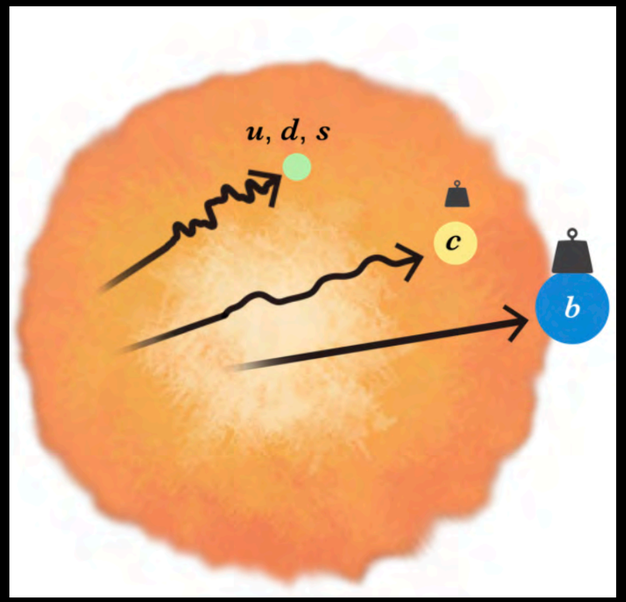


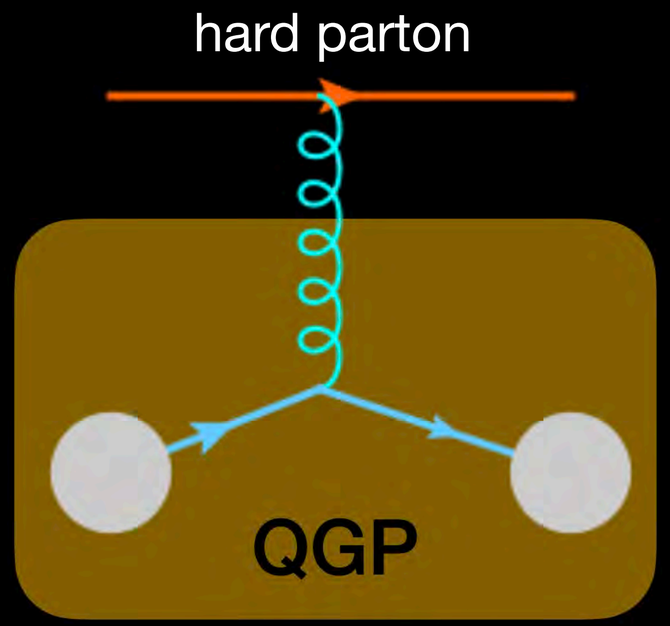
Sequential suppression of heavy quarkonia seen that probes the medium temperature and properties

QGP properties at smaller scales: hard probes

Talk: C. Dean, A. Majumber







Jet quenching and heavy-flavor suppression — fundamental transport coefficients that reveal the QGP's microscopic properties

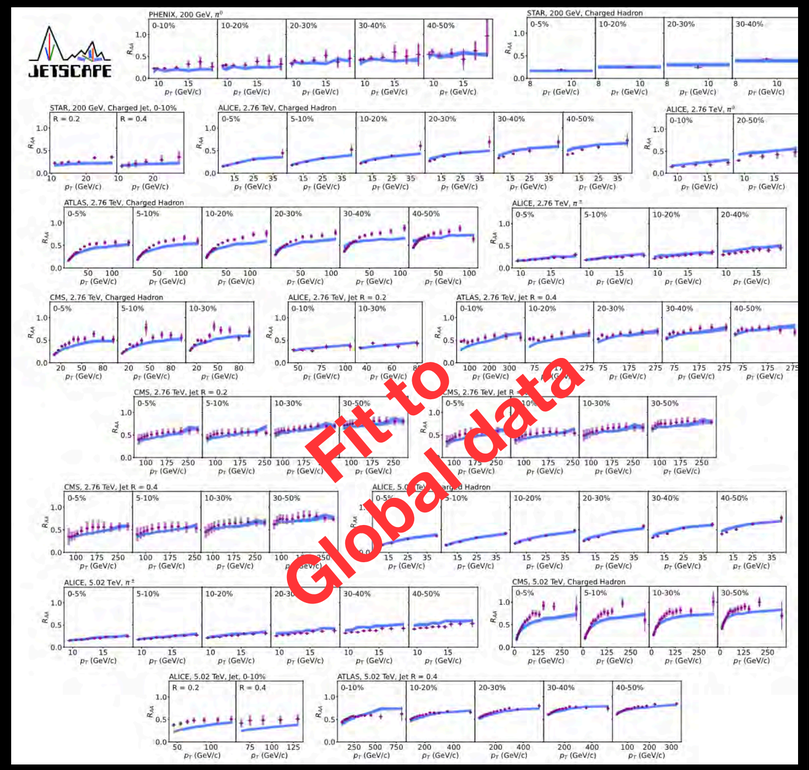
$$\hat{q} = \frac{\langle p_\perp^2 \rangle_L}{L}$$

Transverse momentum diffusion rate

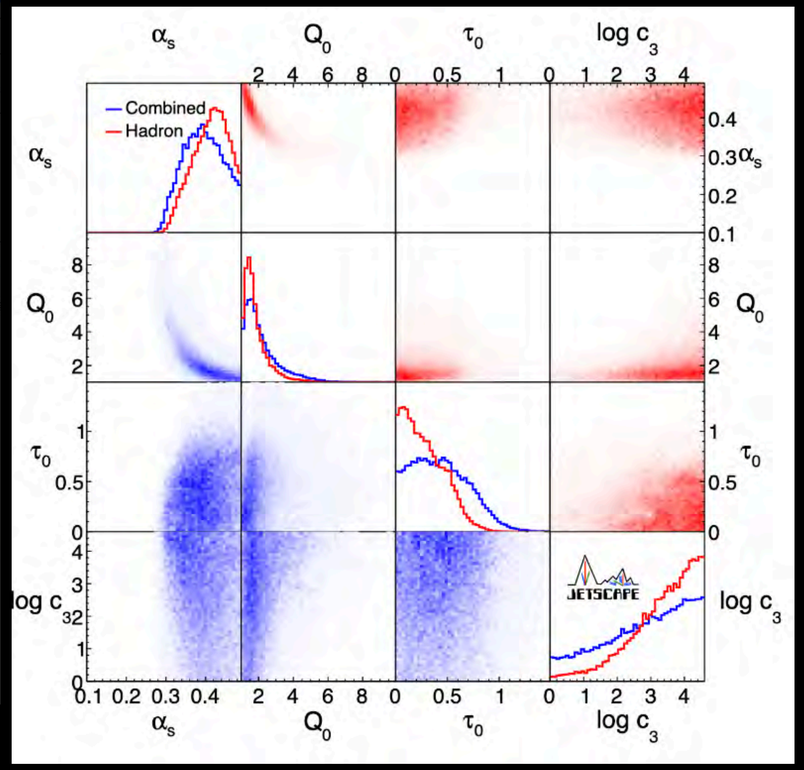
QGP properties at smaller scales: hard probes

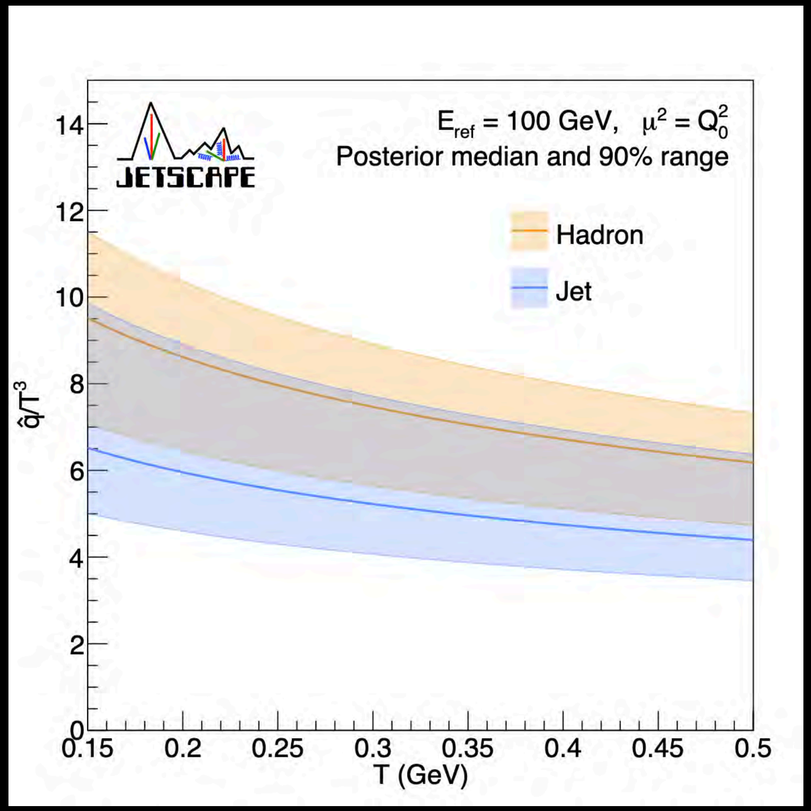
Talk: C. Dean, A. Majumber

R. Ehlers et al., e-Print:2408.08247 [hep-ph]



Bayesian analysis





Jet-quenching and suppression of hadron data gives latest constraints on QGP microscopic transport coefficients

Summary

QMHEHIC Session Focus:

- Ultr-peripheral collisions, d**iffractive VM tomography** (J/ψ/Y in UPCs & at the EIC → sub-nucleon gluon imaging)
- **Femtoscopy (HBT-inspired)** (fireball size, shape & orientation)
- **Thermometry** (thermal di-leptons & quarkonium melting)
- QGP properties & Phase diagram (speed of sound, QCD critical points)
- **Hard probes & jet quenching** (microscopic transport coefficients)

Topics I couldn't cover in details:

Search for polarization of hyperon (M. Stefaniak)

Search for chiral properties of the medium (K. Tuchin)

Readiness & run plan of the sPHENIX detector (C. Dean)

Hadronic Calorimeter and diffractive physics at EIC (L. Kosarzewski)

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BROOKHAVEN NATIONAL LABORATORY

RHIC Begins World's Highest Energy Heavy-Ion Collisions

On the evening of Monday, June 12, operators in the main control room of the Relativistic Heavy Ion Collider (RHIC) watched control displays anxiously as the beams circulating in the collider's twin rings appeared to be colliding.

Thanks