

Summary: Quark Matter and High Energy Heavy Ion Collisions

Rongrong Ma

Brookhaven National Laboratory

14th Conference on the Intersections of Particle and Nuclear Physics
(CIPANP 2022)

Heavy-ion sessions

- Conveners:
 - Alexei Bazavov (MSU)
 - Anne Sickles (UIUC)
 - Rongrong Ma (BNL)

< Thu 01/09	Fri 02/09	Sat 03/09	All days	>
Print PDF Full screen Detailed view Filter				
13:00	Recent heavy-ion results from ALICE			Nicole Apadula
	Poinsettia/Quince			13:00 - 13:30
	CMS Heavy-ion Physics Results			Olga Evdokimov
	Poinsettia/Quince			13:30 - 14:00
14:00	Recent heavy ion results from LHCb			Thomas Boettcher
	Poinsettia/Quince			14:00 - 14:30
	Lattice QCD thermodynamics from cumulants of conserved charge fluctuations			Dennis Boalweg
	Poinsettia/Quince			14:30 - 15:00
15:00	STAR highlights			Dr Nissem Abdelrahman
	Poinsettia/Quince			15:30 - 16:00
16:00	Results from PHENIX			Christine Nattrass
	Poinsettia/Quince			16:00 - 16:30
	The Status and Anticipated Physics of sPHENIX			Megan Connors
	Poinsettia/Quince			16:30 - 17:00
17:00	Studying the Quark Gluon Plasma with JETSCAPE			Abhijit Majumder
	Poinsettia/Quince			17:00 - 17:30

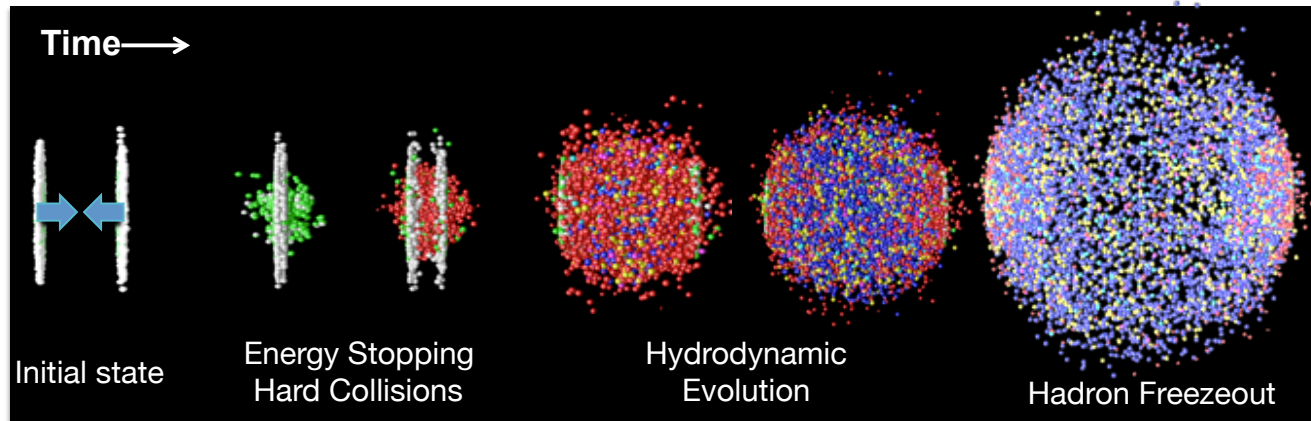
< Thu 01/09	Fri 02/09	Sat 03/09	All days	>
Print PDF Full screen Detailed view Filter				
10:00	Lattice QCD and heavy flavor probes of QGP			Peter Petreczky
	Poinsettia/Quince			10:30 - 11:00
11:00	Measurements of heavy flavor production and what we have learnt from them			Deepa Thomas
	Poinsettia/Quince			11:00 - 11:30
	Measurements of J/ψ production vs event multiplicity in $p+p$ and $p+A$ collisions in the PHENIX e...			Ming Liu
	Collectivity of quarkonium in PbPb with CMS			Dong Ho Moon
	Poinsettia/Quince			11:50 - 12:10
12:00	Recent results on ultra-peripheral heavy ion collisions with ALICE at the LHC			Valerii Pozdniakov
	Poinsettia/Quince			12:10 - 12:30

< Thu 01/09	Fri 02/09	Sat 03/09	All days	>
Print PDF Full screen Detailed view Filter				
13:00	Jet substructure measurements in heavy-ion collisions			Dhanush Hangal
	Poinsettia/Quince			13:00 - 13:30
	Measurements of dijets in heavy-ion collisions			Timothy Rin
	Poinsettia/Quince			13:30 - 14:00
14:00	Measuring Jet Constituent Yields in 5.02 TeV Pb–Pb Collisions Using Jet-Hadron Correlations with ALICE			Charles Hughes
	Poinsettia/Quince			14:00 - 14:20
	Dilepton production in heavy ion collisions			Lijuan Ruan
	Poinsettia/Quince			14:20 - 14:50
15:00	Dense Nuclear Matter in a Magnetic Field via the Skyrme Model			Zebin Qiu
	Poinsettia/Quince			14:50 - 15:10
16:00	Investigating the Quark Gluon Plasma with Multi-system Bayesian Analysis in the JETSCAPE framework			Wenbin Zhao
	Poinsettia/Quince			15:30 - 15:50
	Studying small systems using a multi-stage approach			ismal soufi
	Poinsettia/Quince			15:50 - 16:10
	Systematic study of flow harmonics via di-hadron correlations at mid-rapidity in pAu, AuAu and heavy collisions at 200GeV			Shengli Huang
17:00	Recent results on collectivity in small collision systems			Dr Shengquan Tuo
	Poinsettia/Quince			16:40 - 17:10
	Search for the chiral magnetic effect in heavy ion collisions			Yu Hu
	Poinsettia/Quince			17:10 - 17:40

5 sessions, 22 talks

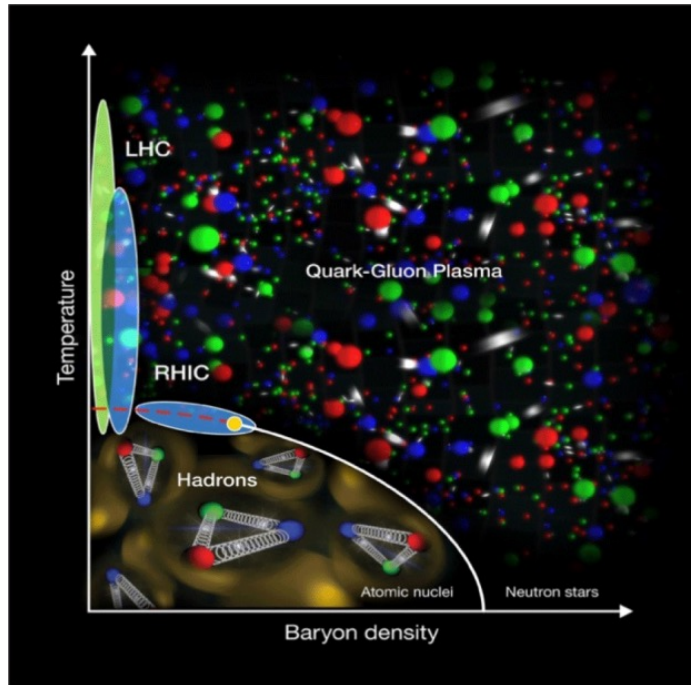
Heavy-ion collisions & QGP

- Quark gluon plasma (QGP): a state of matter consisting of **deconfined quarks and gluons**
 - Believed to have existed momentarily after the Big Bang
- Can be created in relativistic heavy-ion collisions.



T. Nayak, arXiv:1201.4264

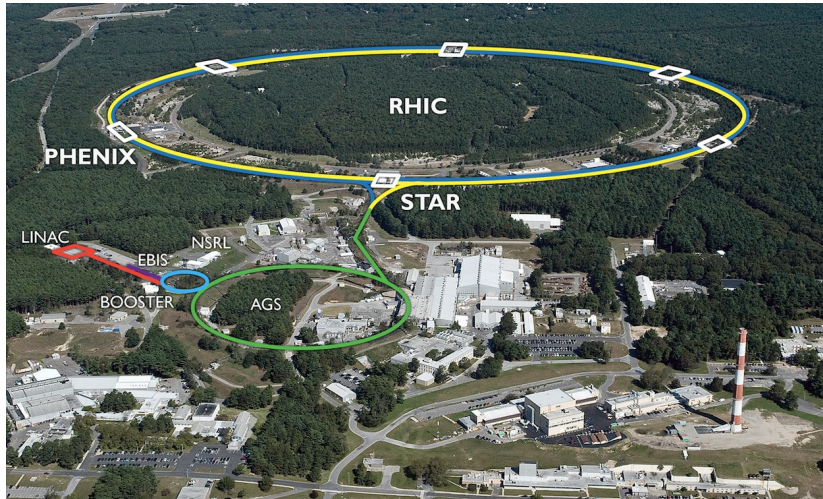
Main goals of heavy-ion physics



- Characterize and understand the properties of the QGP
 - How do they come about?
- Map out the phase diagram and search for the possible critical endpoint
- Multi-messenger approach

Major facilities

RHIC
(2000 -)



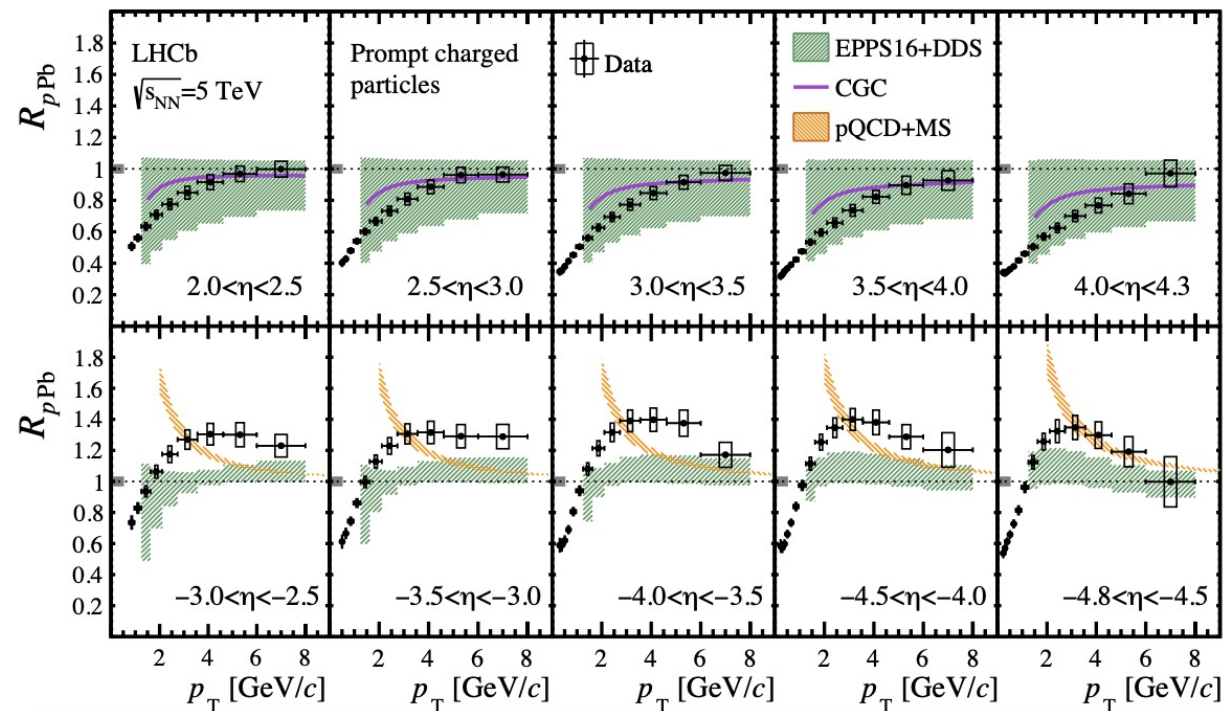
**PHENIX completed operation in 2016*

LHC
(2009 -)



Charged particle production in p+Pb

T. Boettcher (Thu. 14:00)



- $x < \sim 10^{-5}$, $Q^2 < \sim 1 \text{ GeV}^2$
- Significant suppression at forward rapidity
- Enhancement at backward rapidity, not explained by nPDF
- Good precision to constrain nPDF

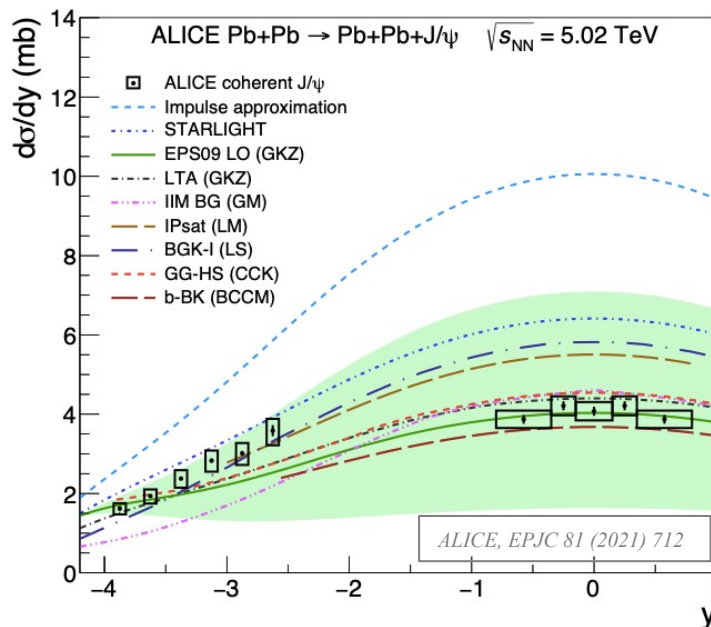
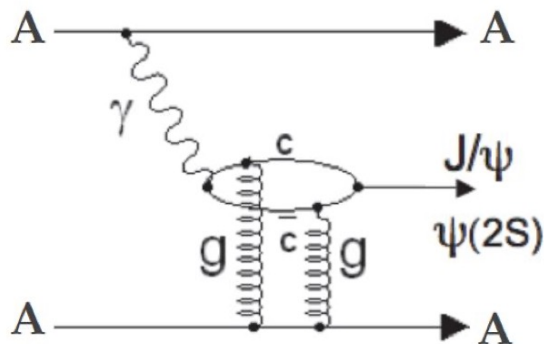
LHCb, PRL 128 (2022) 14

Coherent J/ψ production in UPC

V. Pozdnyakov (Fri. 12:10)

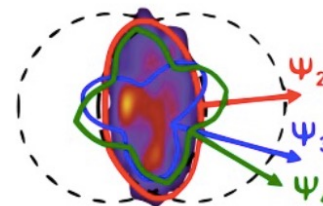
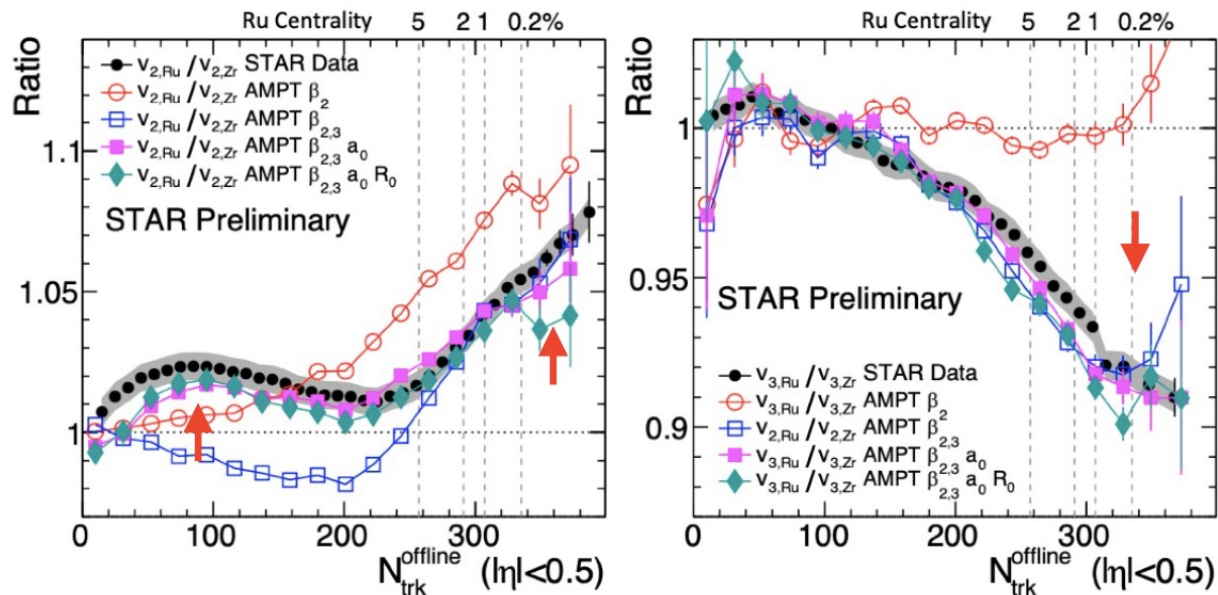
Ultra Peripheral Collisions

$$b > 2R$$



- The nuclear gluon shadowing factor is found to be ~ 0.65 at x values $\sim 10^{-3}$

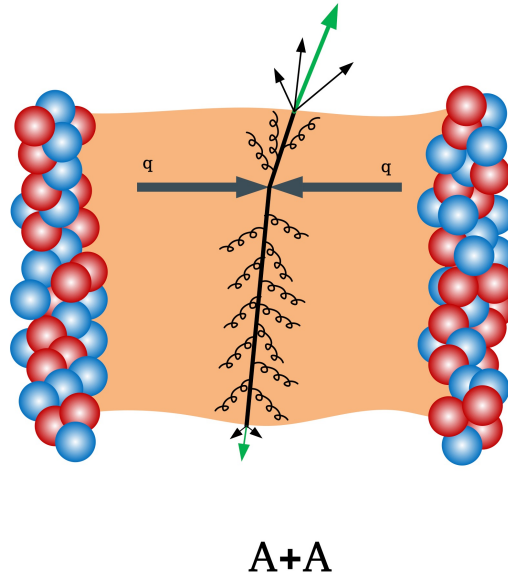
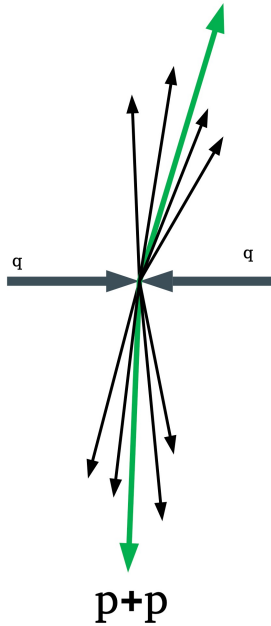
Probe nuclear deformation at high energy



N. Abdelrahman
(Thu. 15:30)

- Ratios show non-monotonic trends
- Based on AMPT model, one extract $\beta_{2,Ru} = 0.16 \pm 0.02$, $\beta_{3,Zr} = 0.20 \pm 0.02$

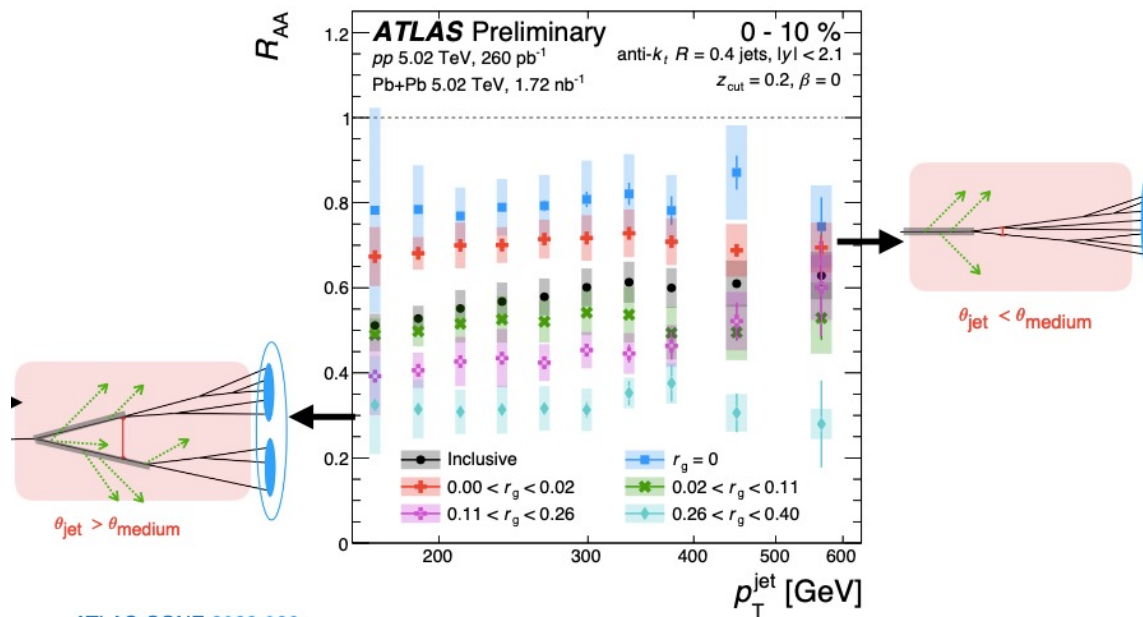
Jet quenching



$$R_{AA} = \frac{1}{\langle N_{\text{coll}} \rangle} \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$$

- ✓ $R_{AA} = 1$: no medium effect
- ✓ $R_{AA} < 1$: energy loss

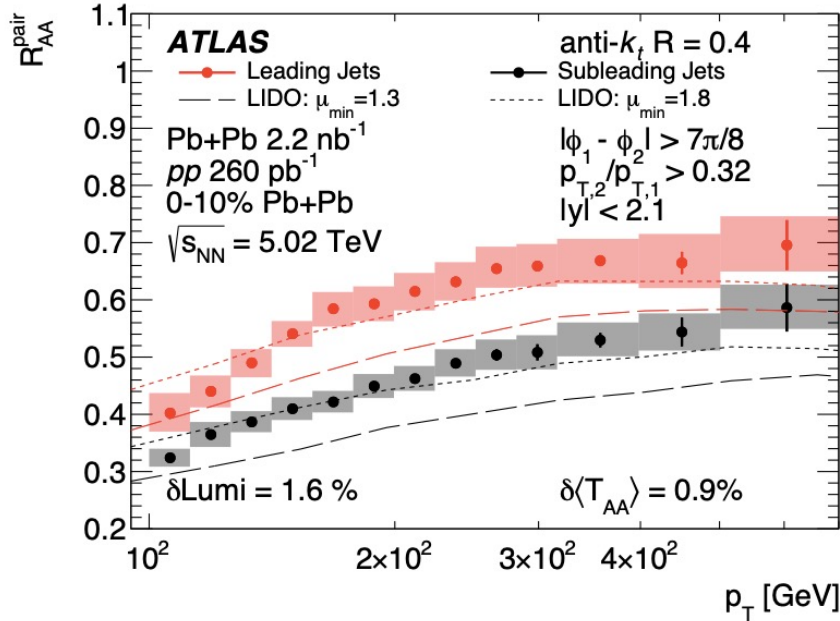
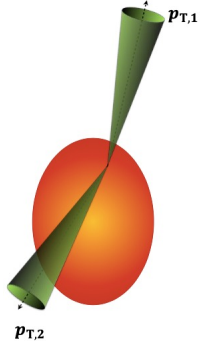
Coherence dependence of jet energy loss



D. Hangel (Sat. 13:00)

- Jets that can be resolved by the QGP lose more energy

Pathlength dependence



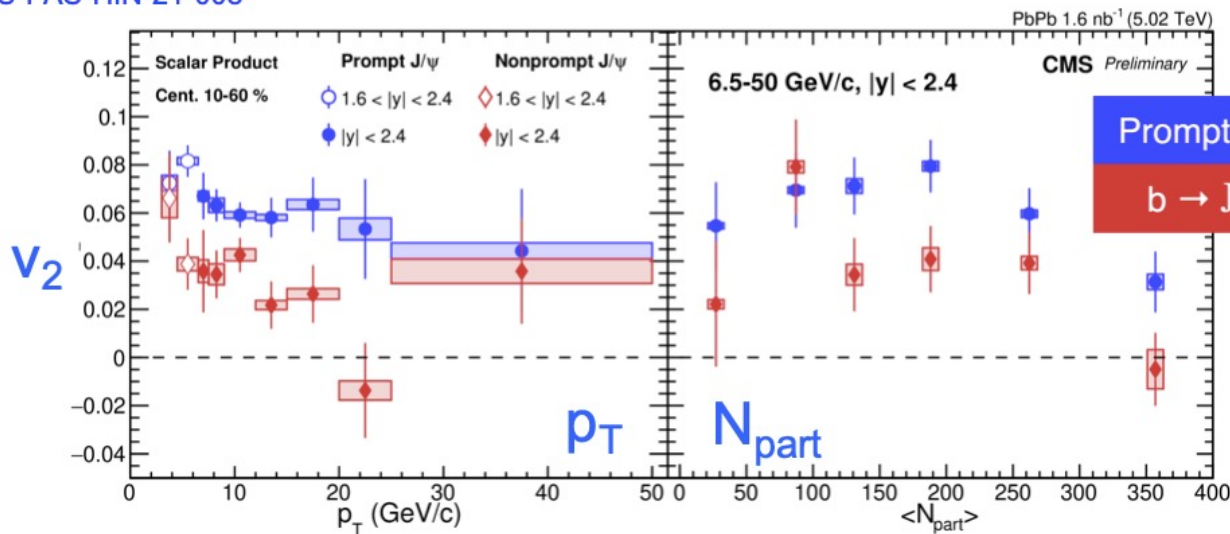
T. Rinn (Sat. 13:30)

- Jets traversing longer pathlength lose more energy

Prompt and non-prompt J/ψ v_2

D. Moon (Fri. 11:50)

CMS-PAS-HIN-21-008

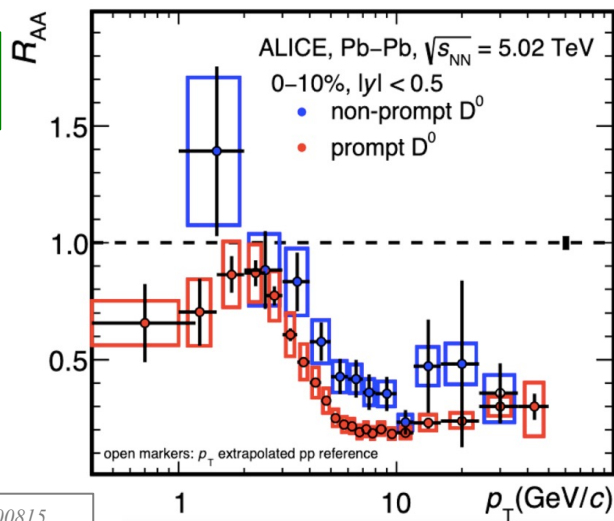


- Sizable v_2 up to $50 \text{ GeV}/c$, due to pathlength dependence of parton energy loss
- Large fraction of prompt J/ψ coming from gluon fragmentation, which loses energy before fragmenting

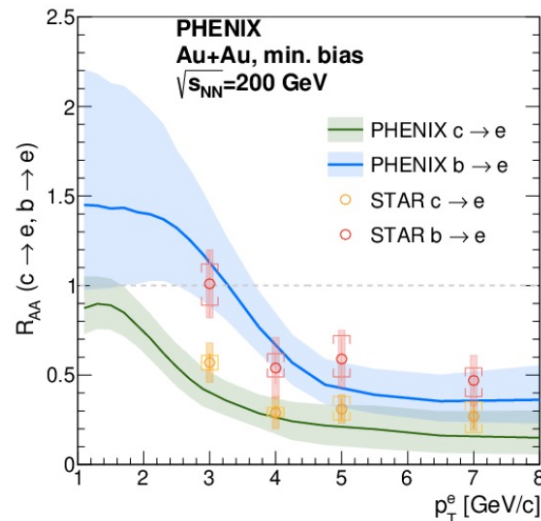
Mass dependent energy loss

- Expectation: $\Delta E_c > \Delta E_b$

N. Apadula
(Thu. 13:00)



ALICE, arXiv:2202.00815



C. Nattrass
(Thu. 16:00)

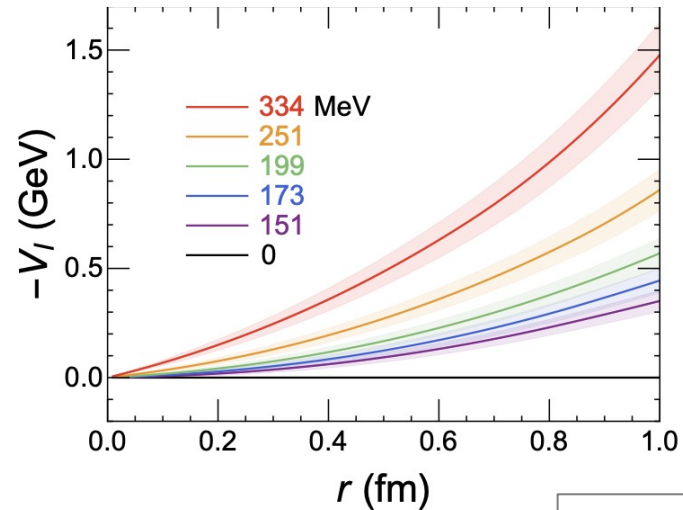
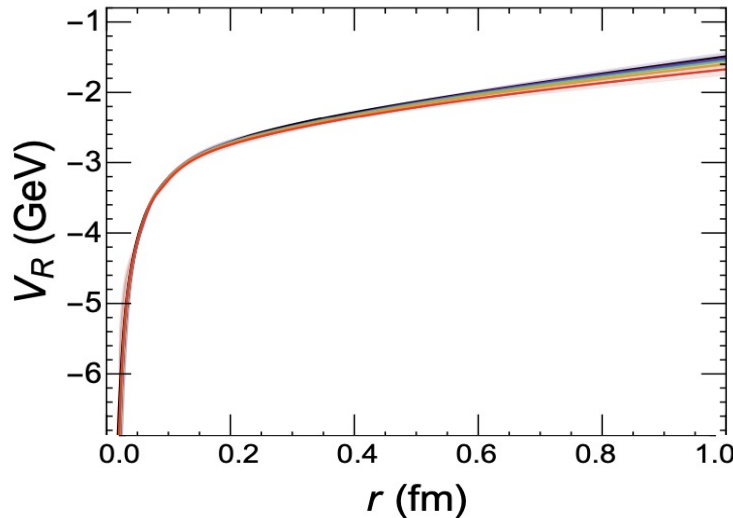
PHENIX, arXiv:2203.17058

- Charm quarks lose more energy than bottom quarks

Quarkonia - QGP “thermometer”

- Quarkonia of different binding energies melt at different temperatures in the QGP

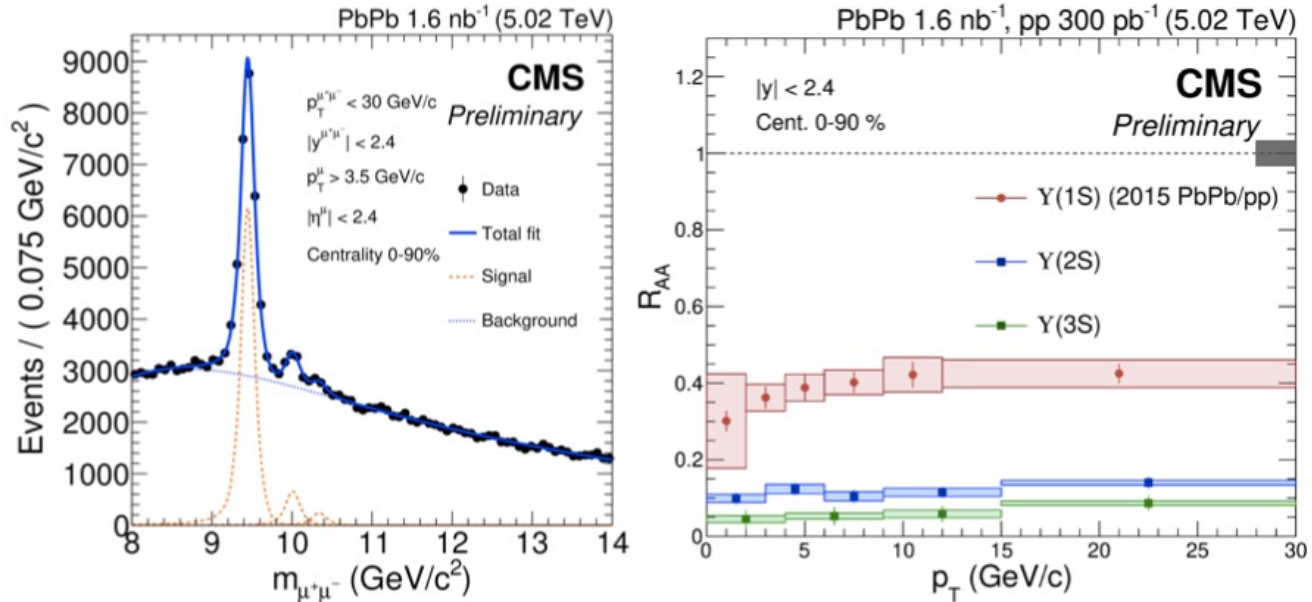
P. Petreczky (Fri. 10:30)



Shi et al, PRD 105 (2022) 014017

- Imaginary part of potential lead to melting
- $T_{\text{melt}}(\Upsilon(1S)) > 500$ MeV, $T_{\text{melt}}(\Upsilon(2S)) \sim 360$ MeV, $T_{\text{melt}}(\Upsilon(3S)) \sim 220$ MeV

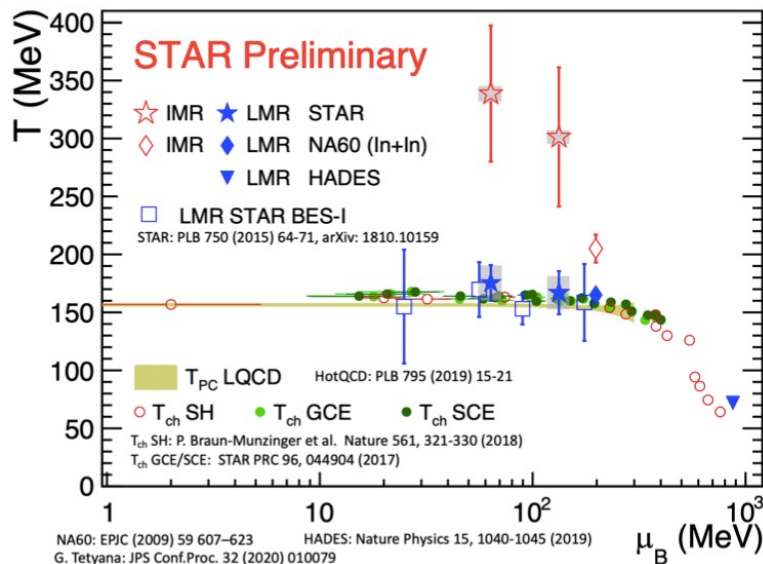
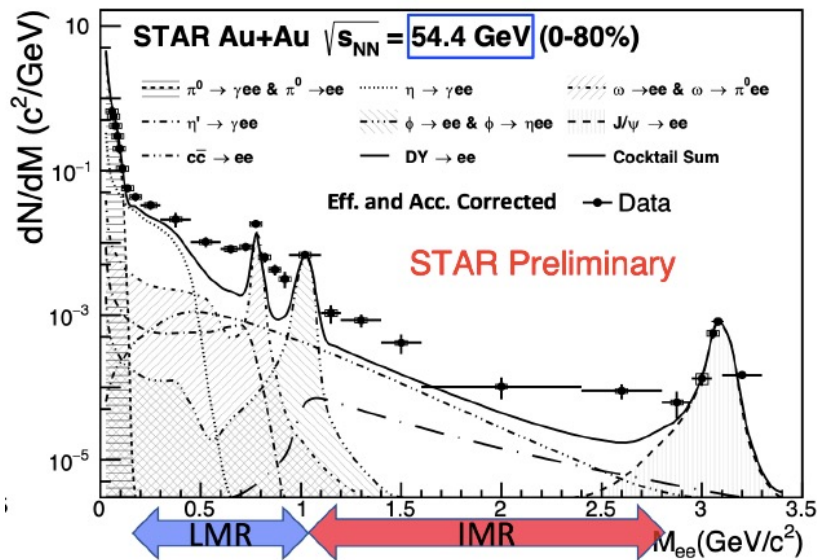
Υ sequential melting



- First observation of $\Upsilon(3S)$ in heavy-ion collisions
- **More loosely bound states are more suppressed**

O. Evdokimov (Thu. 13:30)

True thermometer: di-leptons

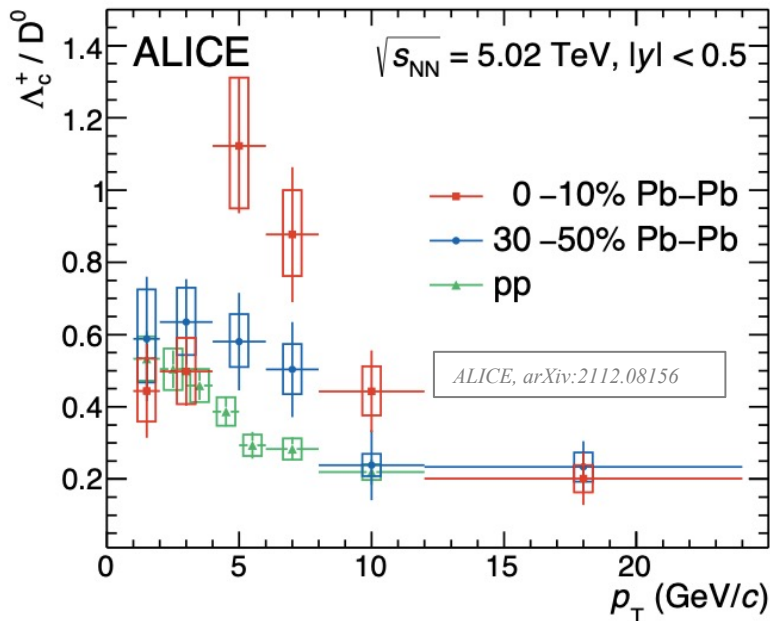


- QGP radiation within $1 < M < 2.8 \text{ GeV}/c^2$
- Slope directly related to system temperature

L. Ruan (Sat. 14:20)

Charm quark hadronization

D. Thomas (Fri. 11:00)



Λ_c baryon



D^0 meson



- Significant enhancement in Pb+Pb than p+p around 5 GeV/c
- Can be described by coalescence+fragmentation hadronization

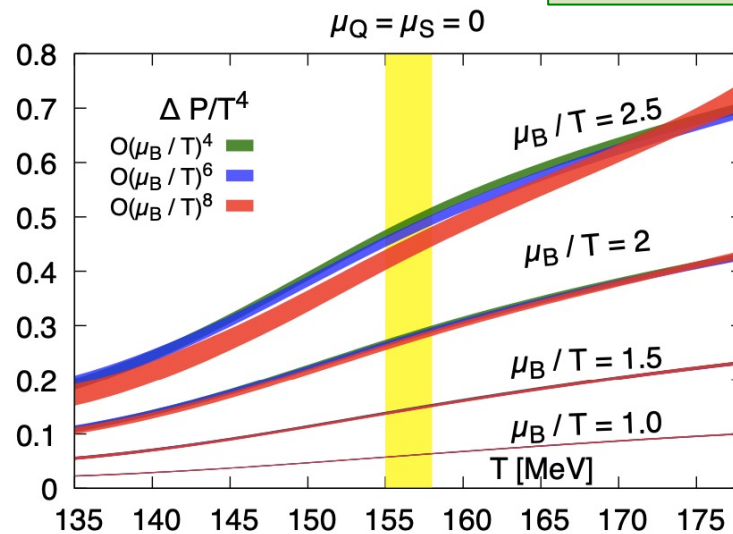
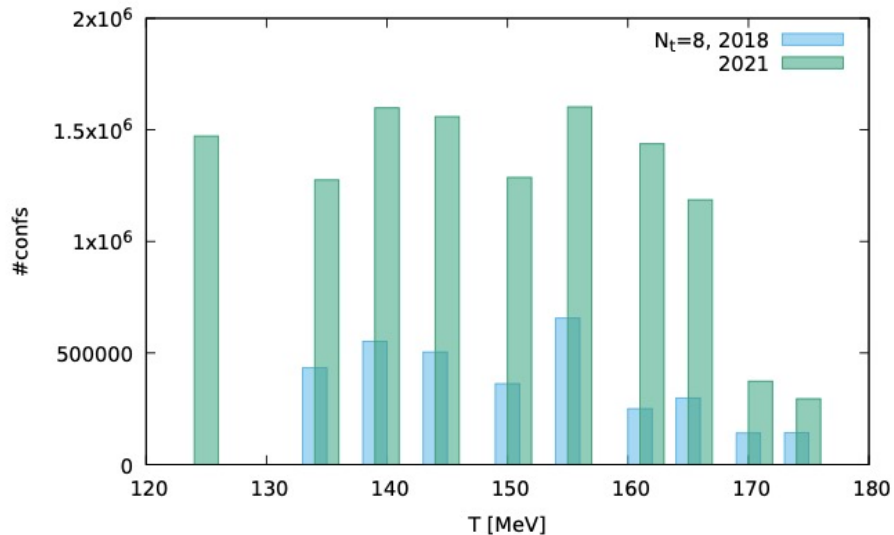
Theory collaborations



More lattice-QCD statistics

D. Bollweg (Thu. 14:30)

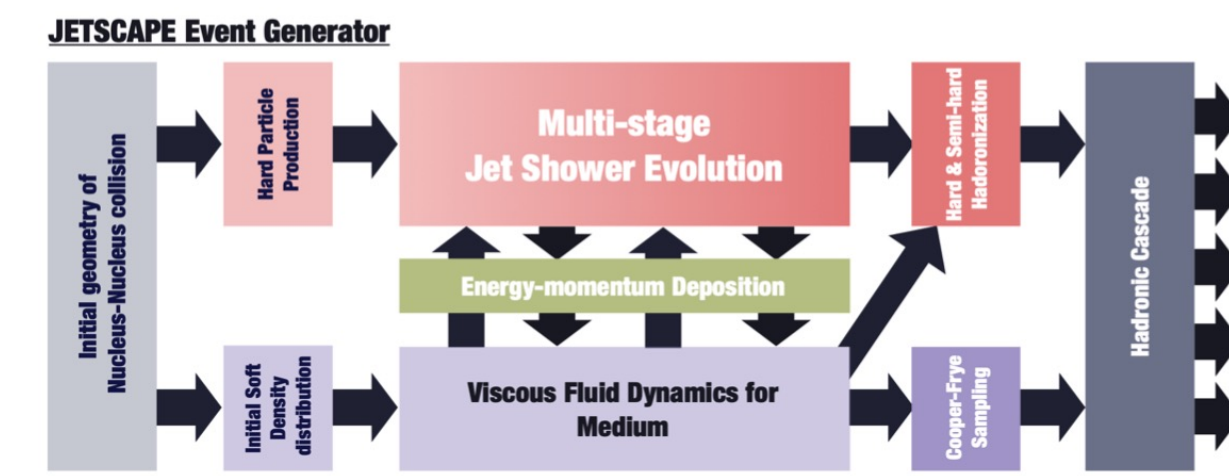
HotQCD, arXiv:2202.09184



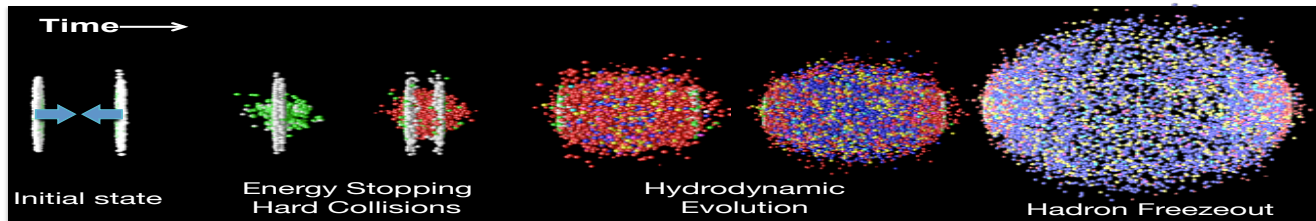
- Multi-year campaign generates large statistics
- Equation of state up to 8th order

JETSCAPE framework

- A modular framework one can swap out different components



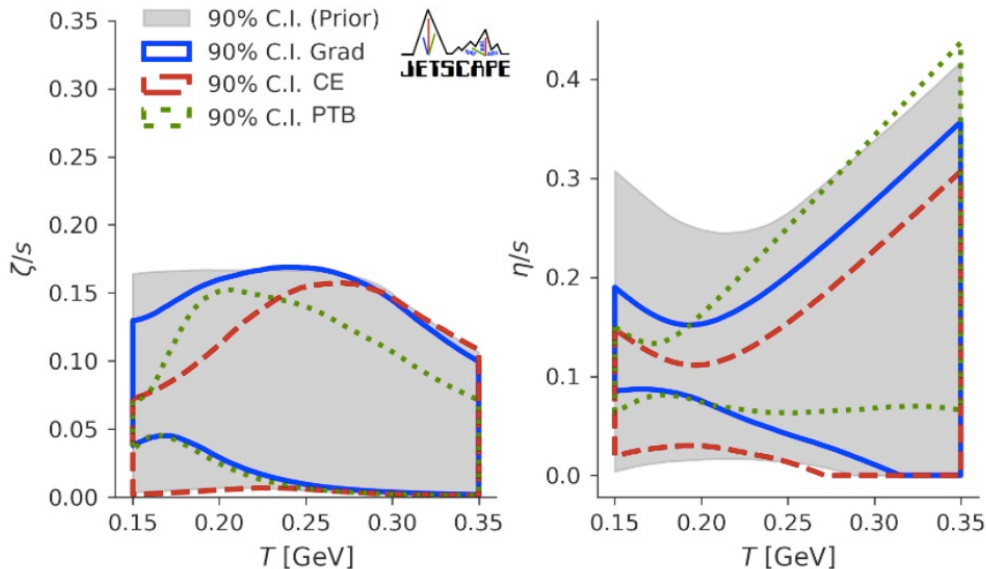
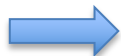
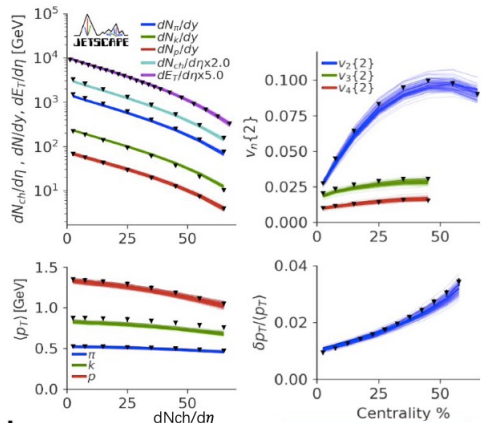
A. Majumder (Thu. 17:00)



Shear and bulk viscosities

W. Zhao (Sat. 15:30)

JETSCAPE, arXiv: 2022.01430, 2010.03928



- Bayesian analysis to extract medium viscosities

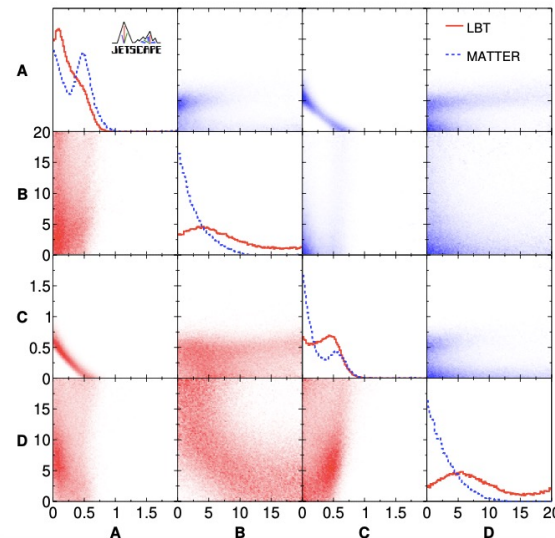
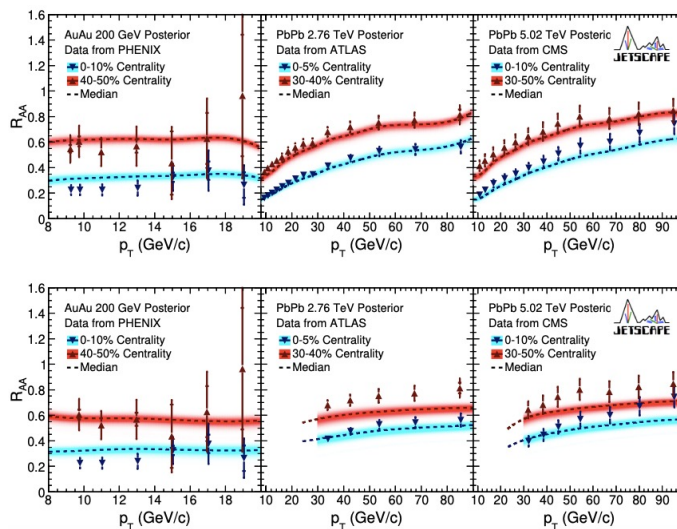
Constrain transport coefficient

- We parametrize with

$$\frac{\hat{q}(E, T)|_{A,B,C,D}}{T^3} = 42C_R \frac{\zeta(3)}{\pi} \left(\frac{4\pi}{9}\right)^2 \left\{ \frac{A \left[\ln\left(\frac{E}{\Lambda}\right) - \ln(B) \right]}{\left[\ln\left(\frac{E}{\Lambda}\right) \right]^2} + \frac{C \left[\ln\left(\frac{E}{T}\right) - \ln(D) \right]}{\left[\ln\left(\frac{ET}{\Lambda^2}\right) \right]^2} \right\}$$

A. Majumder (Thu. 17:00)

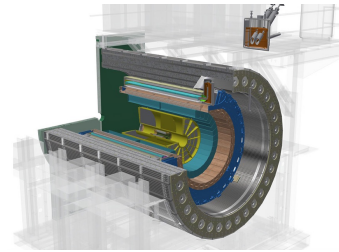
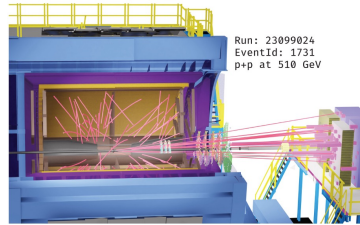
- Bayesian analysis to extract jet transport coefficient



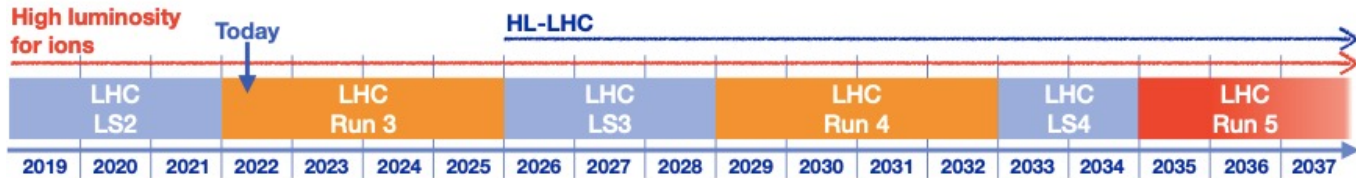
The future is bright

High-statistics data taking (Au+Au @ 200 GeV) through 2025

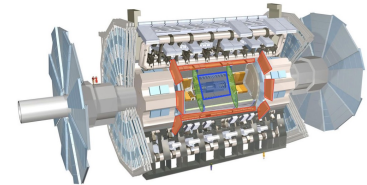
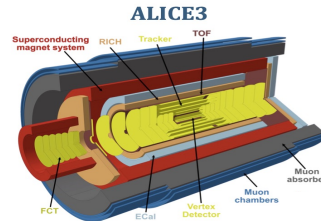
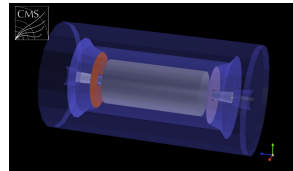
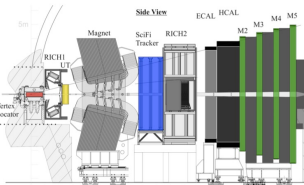
RHIC



M. Connors (Thu. 16:30)



LHC

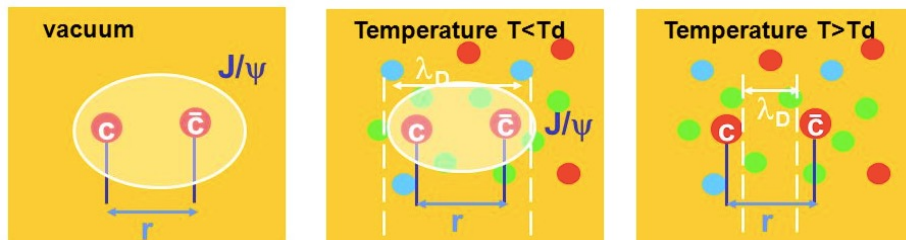


Backup

QGP “thermometer”

- Quark-antiquark potential color-screened by surrounding partons \rightarrow (*static*) *dissociation*

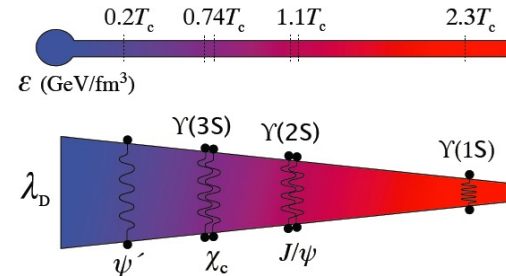
T. Matsui and H. Satz, PLB 178 (1986) 416



$$r_{q\bar{q}} \sim 1 / E_{binding} > r_D \sim 1 / T$$

- “**Thermometer**”: different states dissociate at different temperatures \rightarrow *sequential suppression*

	J/ψ	ψ(2S)	Υ(1S)	Υ(2S)	Υ(3S)
E_b (MeV)	~ 640	~ 60	~ 1100	~ 500	~ 200



Charm quark diffusion coefficient

D. Thomas (Fri. 11:00)

ALICE, JHEP 01 (2022) 174

