ISOBAR RELATIVISTIC NUCLEUS-NUCLEUS COLLISIONS: WHAT CAN WE LEARN?

HADNUCMAT WORKSHOP 2026

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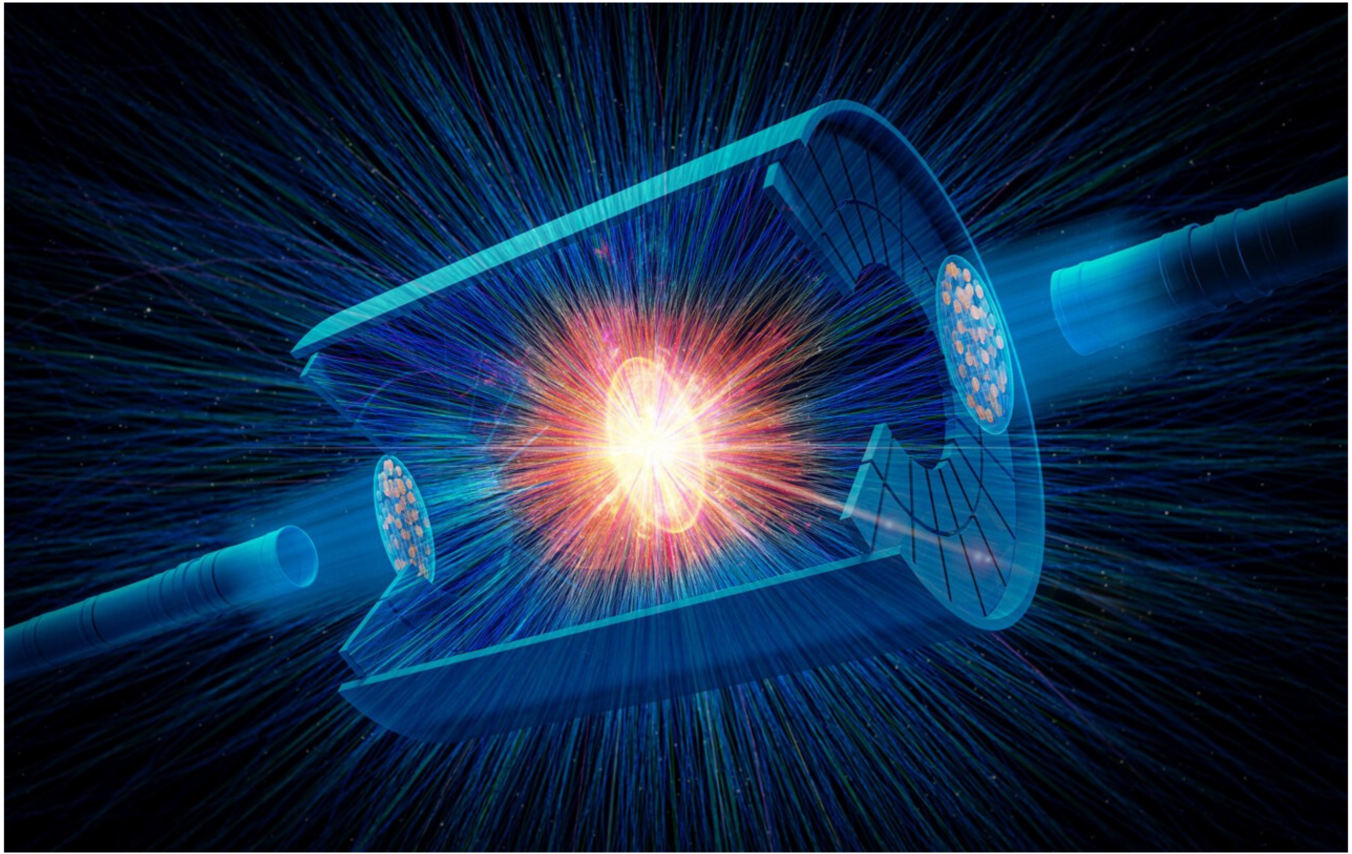
ICCUB

INTRODUCTION

- WHAT ARE RHICs?



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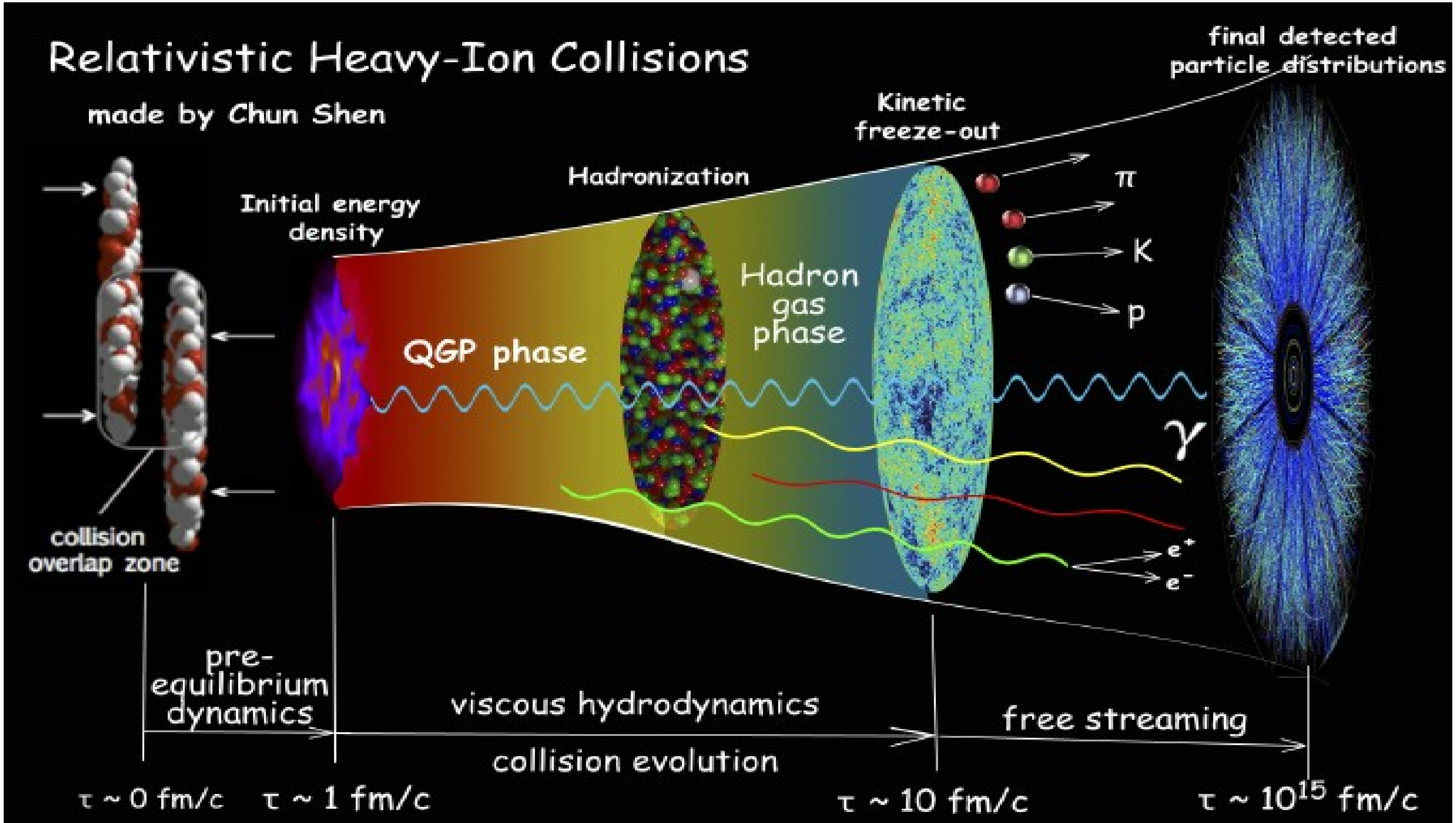

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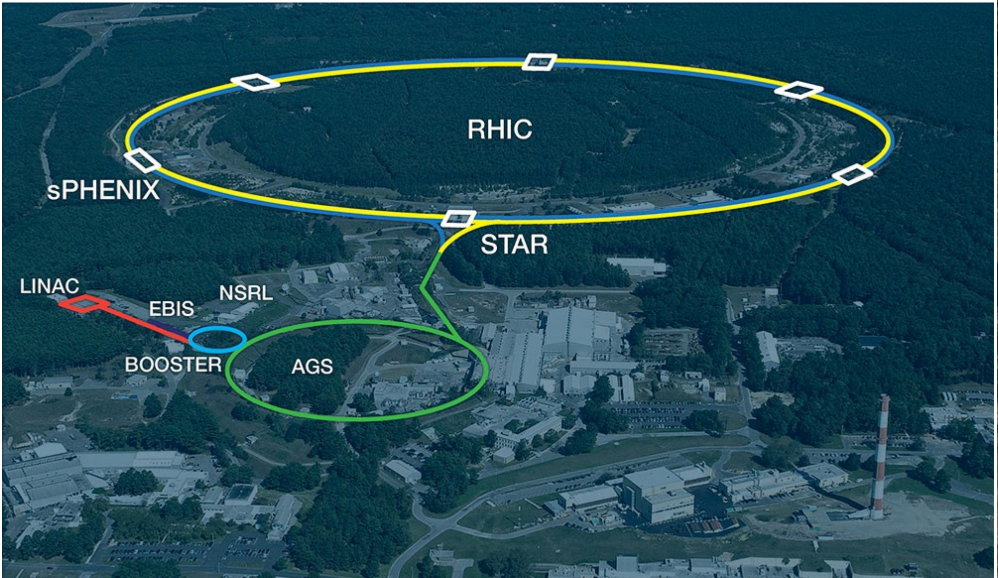
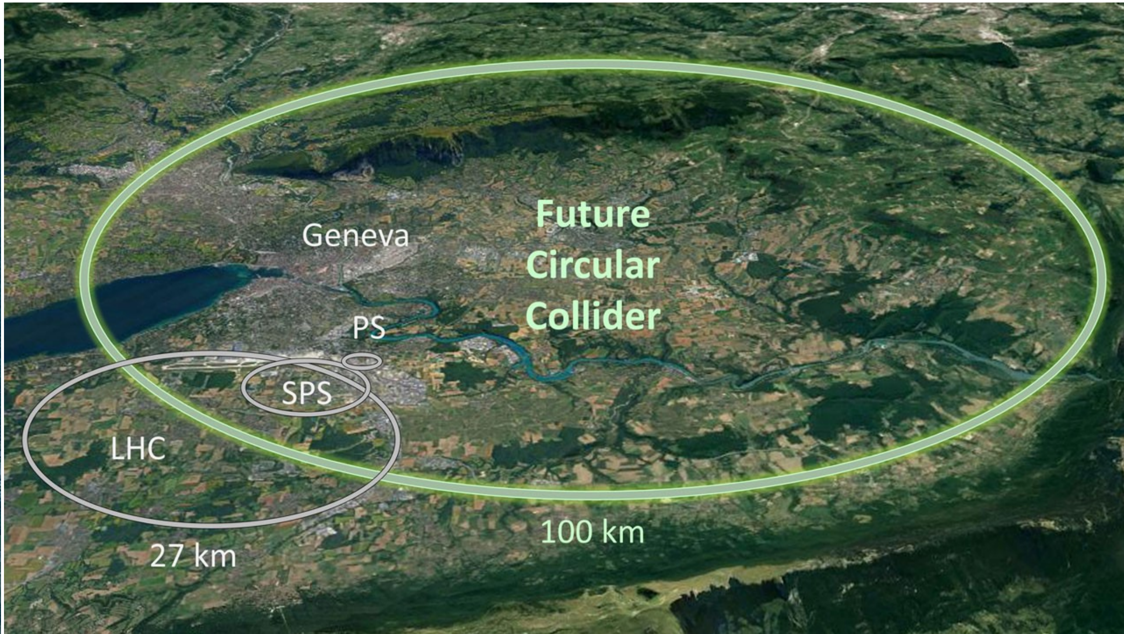
- WHY ARE THEY IMPORTANT?





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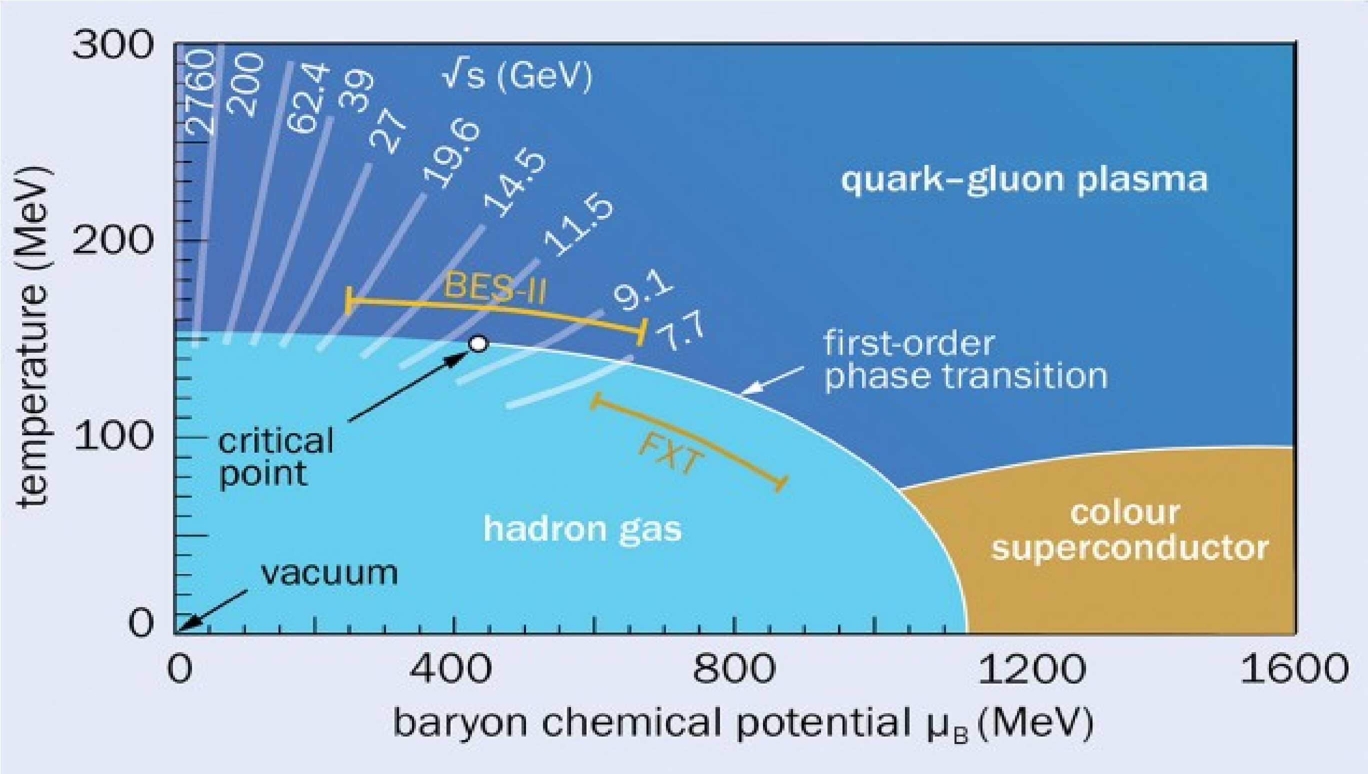

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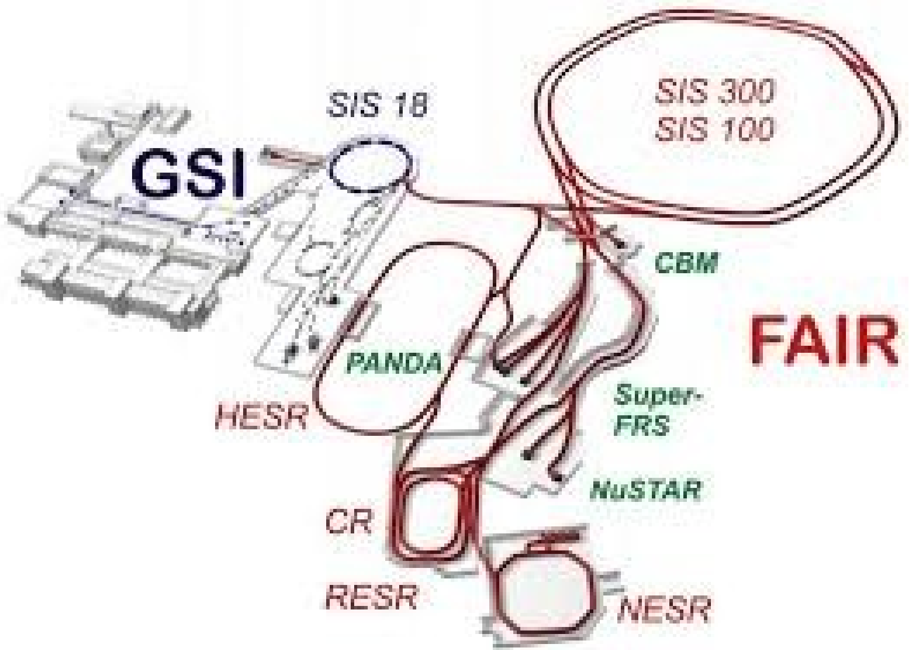

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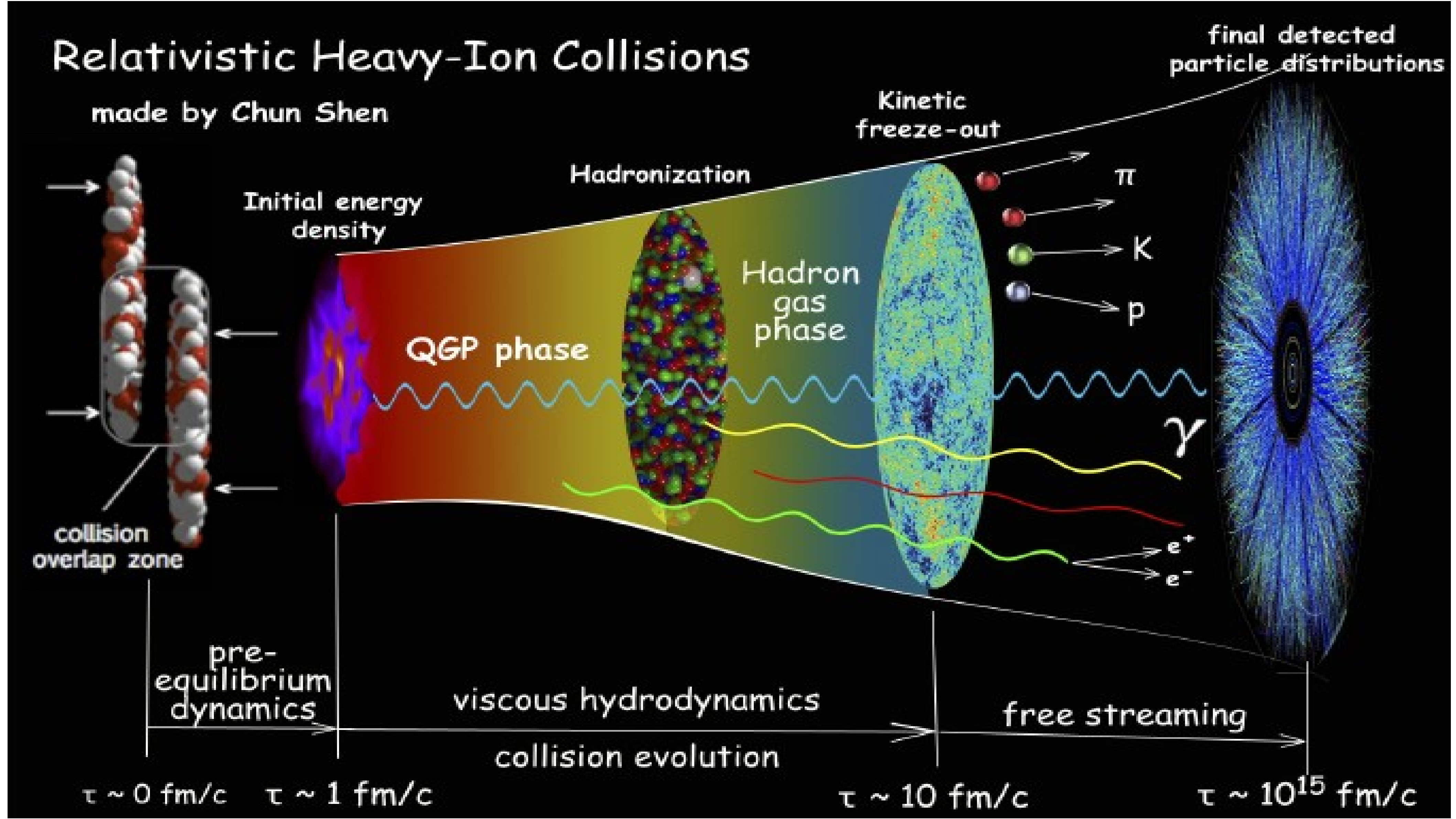
- WHY ARE THEY IMPORTANT?
- HOW TO MODEL RHICs?



Relativistic Heavy-Ion Collisions
made by Chun Shen
final detected particle distributions
Kinetic freeze-out
Hadronization
Initial energy density
Hadron gas phase
QGP phase
π
K
p
γ
e+
e-
collision overlap zone
pre-equilibrium dynamics
viscous hydrodynamics
free streaming
collision evolution
τ ~ 0 fm/c
τ ~ 1 fm/c
τ ~ 10 fm/c
τ ~ 10^15 fm/c

SMASH-vHLLE HYBRID MODEL

https://smash-transport.github.io/

smash

Simulating Many Accelerated Strongly-interacting Hadrons

A relativistic hadronic transport approach

SMASH-vHLLE HYBRID MODEL

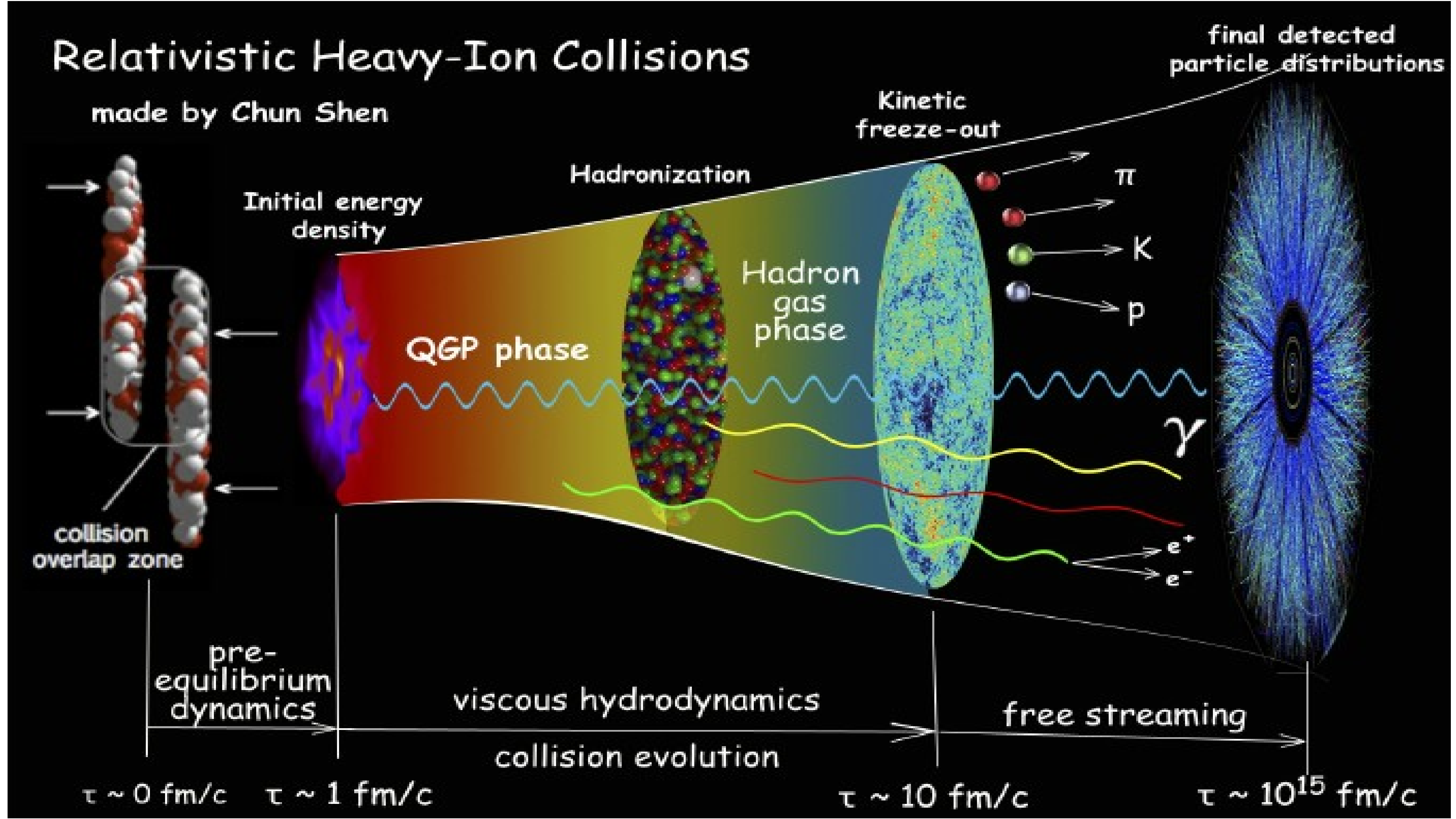
SMASH

Pythia

PRC 94, 054905 (2016)

arXiv:hep-ph/0603175

Comput. Phys. Commun.
178 (2008), 852-867



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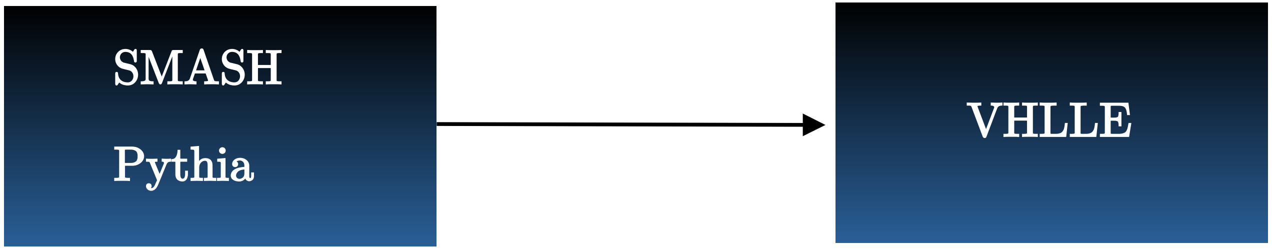
SMASH-vHLLE HYBRID MODEL



PRC 94, 054905 (2016)

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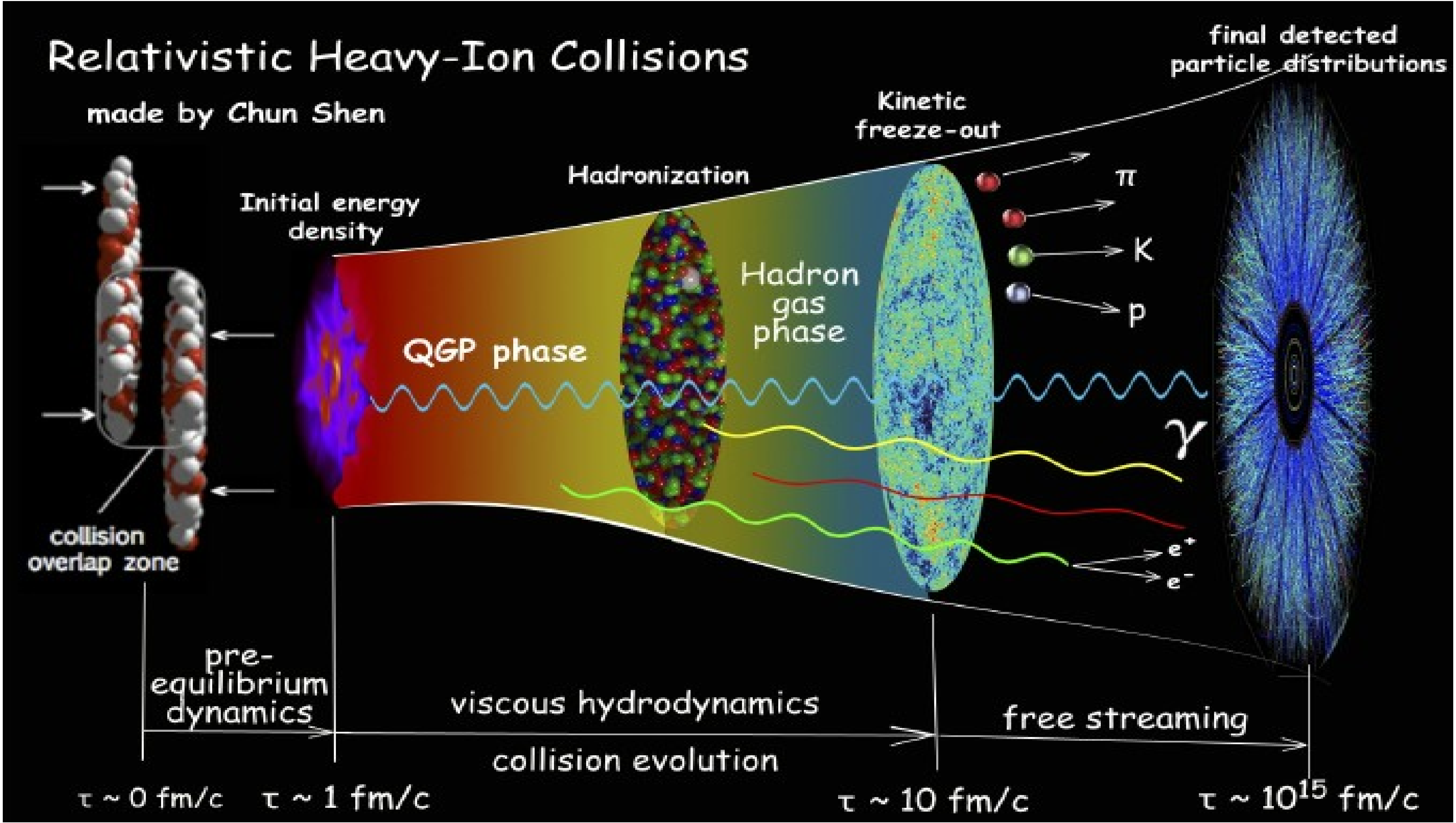
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PRC 94, 054905 (2016)

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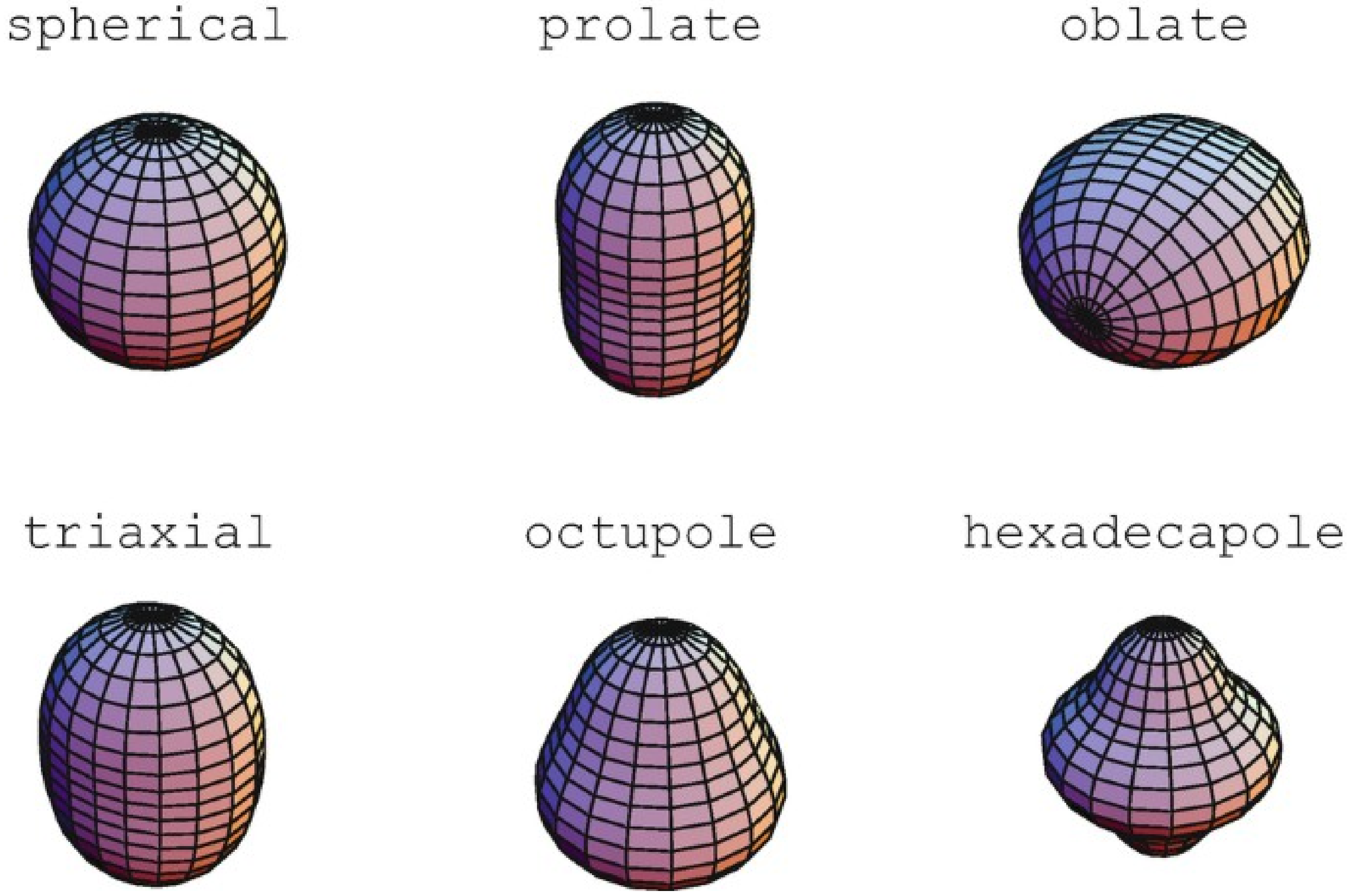
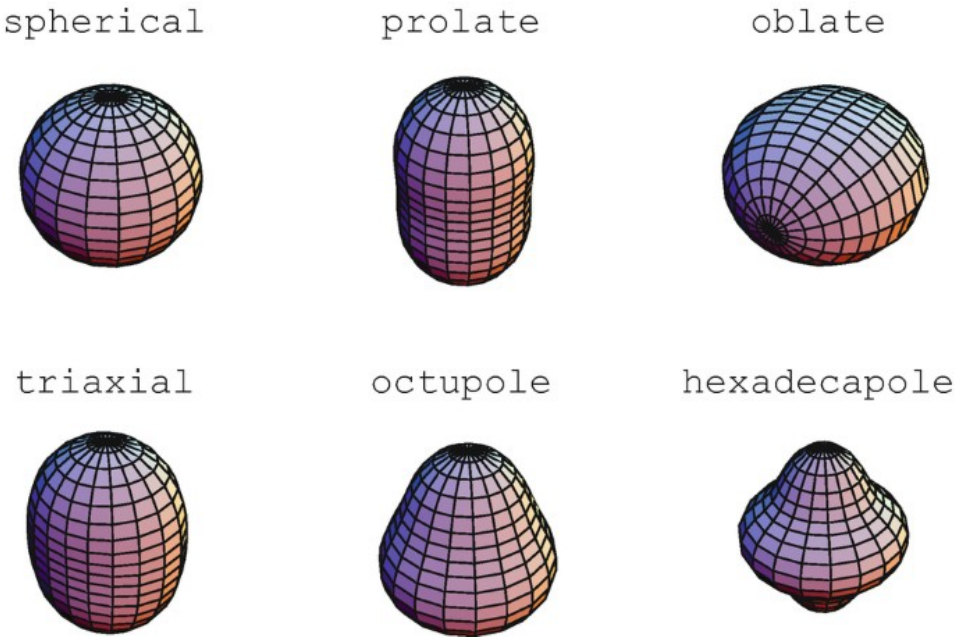
NUCLEAR STRUCTURE OF DEFORMED NUCLEI ON THEIR GROUND STATE

NUCLEAR GROUND STATE DEFORMATIONS



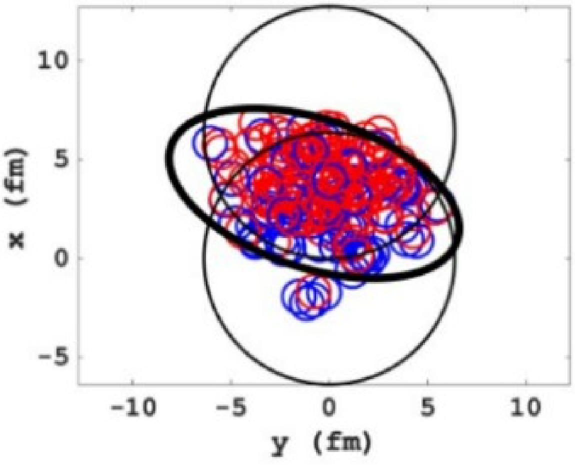
NUCLEAR GROUND STATE DEFORMATIONS

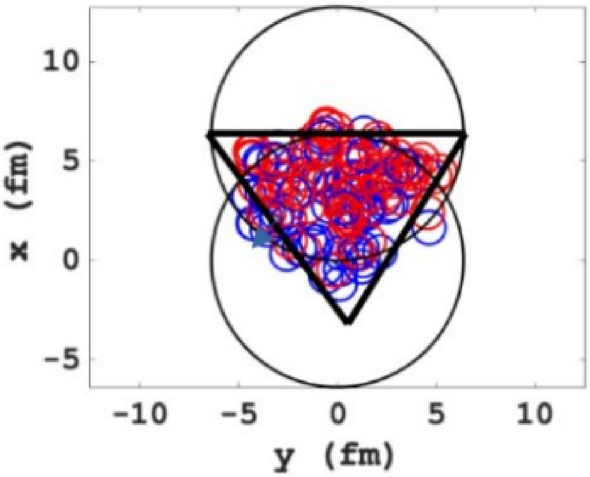
$$\rho(r,\theta,\phi) = \frac{\rho_0}{1 + e^{[r-R(\theta,\phi)]/a}}$$



$$R(\theta,\phi) = R_0(1 + \beta_2(\cos\gamma Y_2^0(\theta,\phi) + \sin\gamma Y_2^2(\theta,\phi)) + \beta_3 Y_3^0(\theta,\phi) + ...)$$

GEOMETRICAL SHAPE OF THE INITIAL STATE





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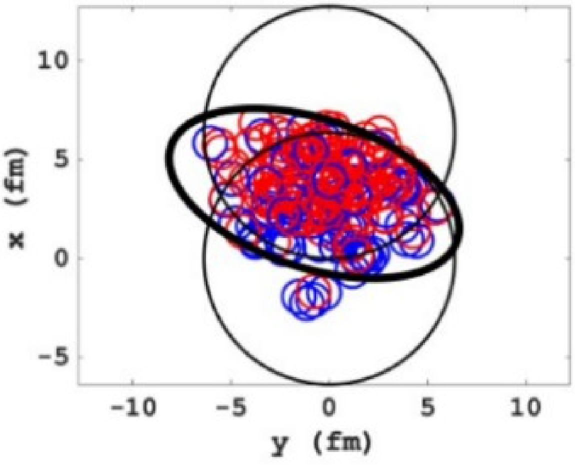

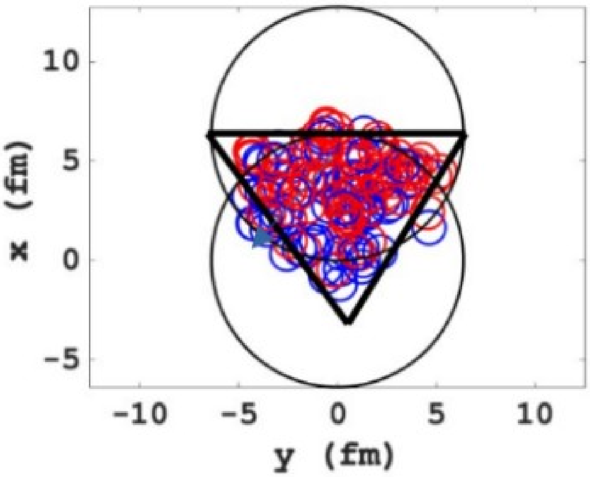

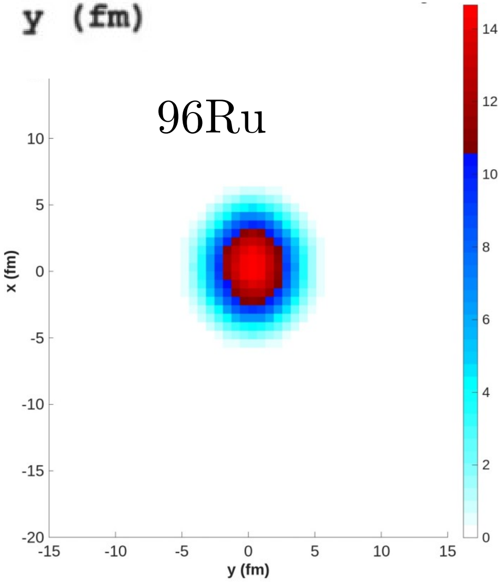

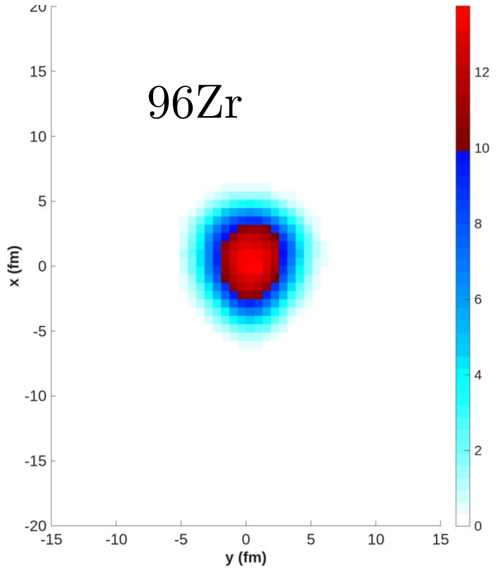

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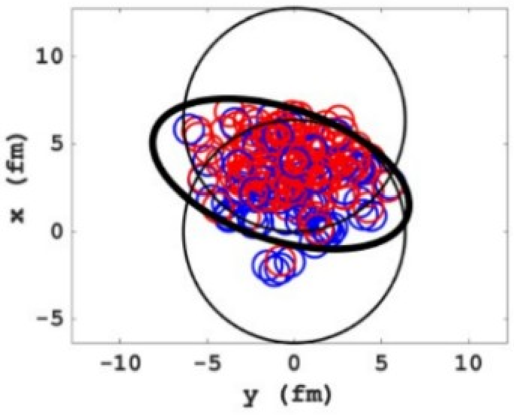
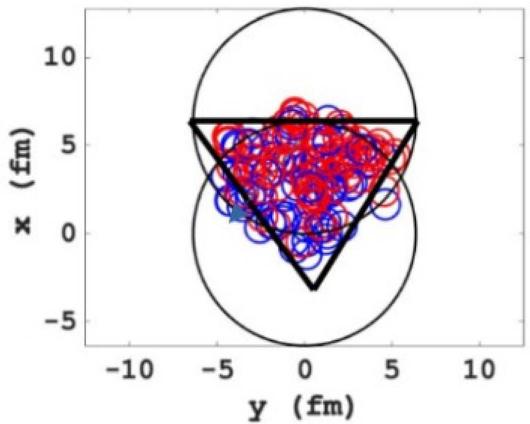
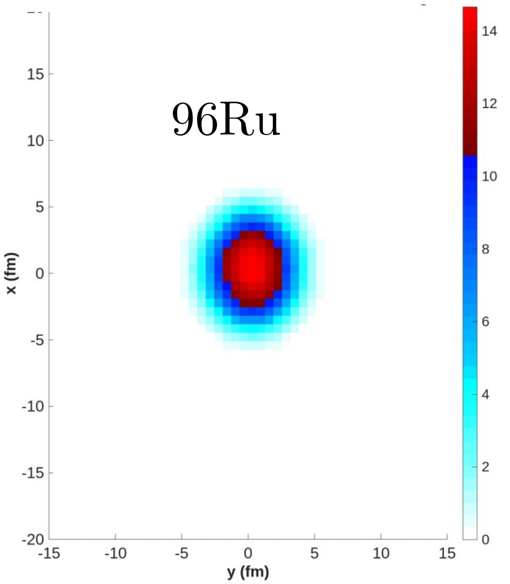
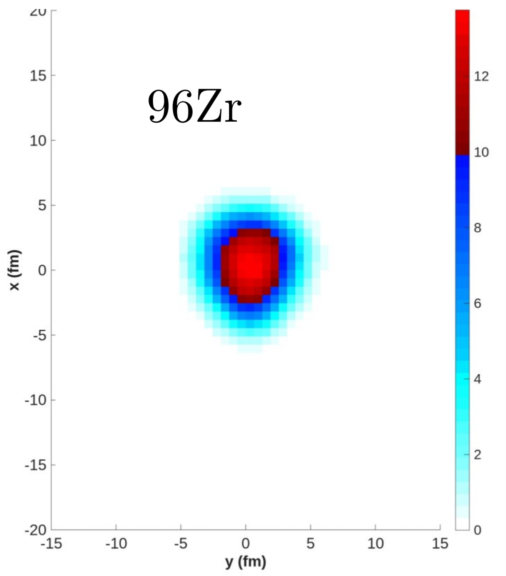




$$\varepsilon_n e^{in\Phi_n} = \frac{\int r_T^n e^{in\phi} w(r_T) d^2 r_T}{\int r_T^n w(r_T) d^2 r_T}$$





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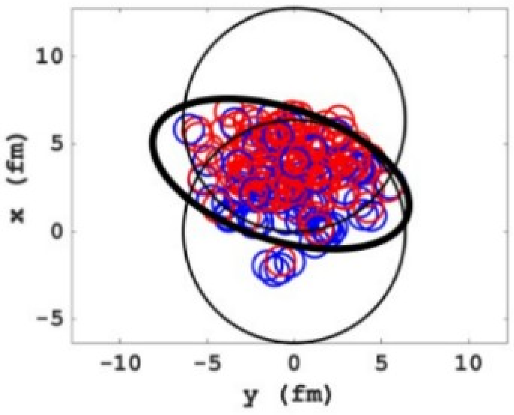
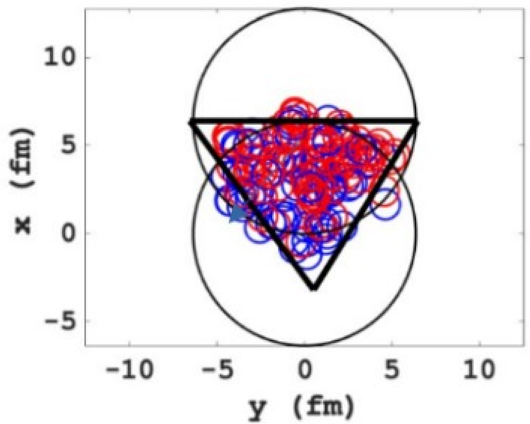




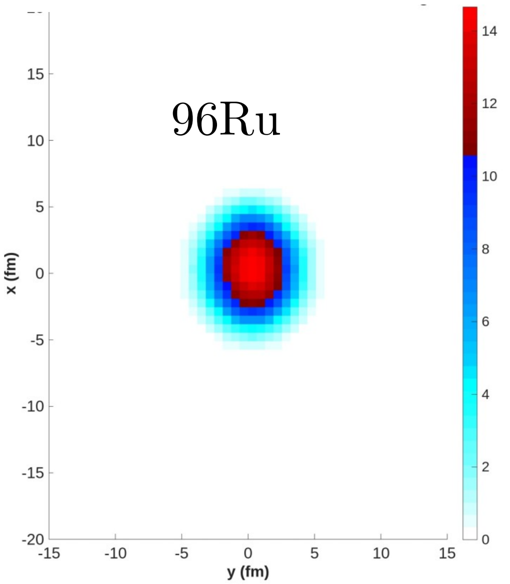
$$\varepsilon_n e^{in\Phi_n} = \frac{\int r_T^n e^{in\phi} w(r_T) d^2 r_T}{\int r_T^n w(r_T) d^2 r_T}$$

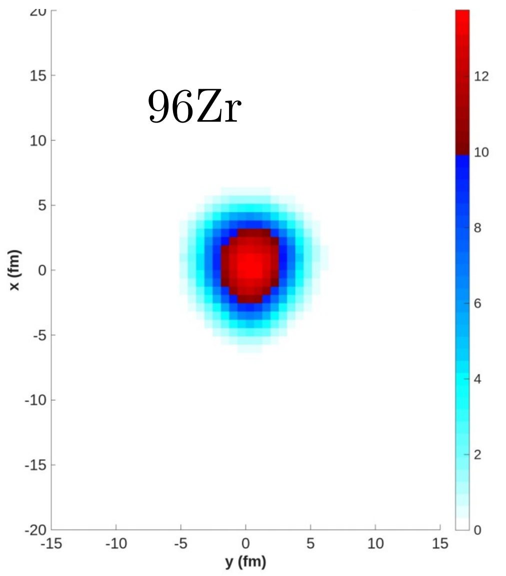
$$\langle \varepsilon_2^2 \rangle \propto a_2 + b_{2,2}\beta_2^2 + b_{2,3}\beta_3^2$$

$$\langle \varepsilon_3^2 \rangle \propto a_3 + b_3\beta_3^2$$

arXiv:2507.01454v1 [nucl-ex]

PRL 128, 022301 (2022)

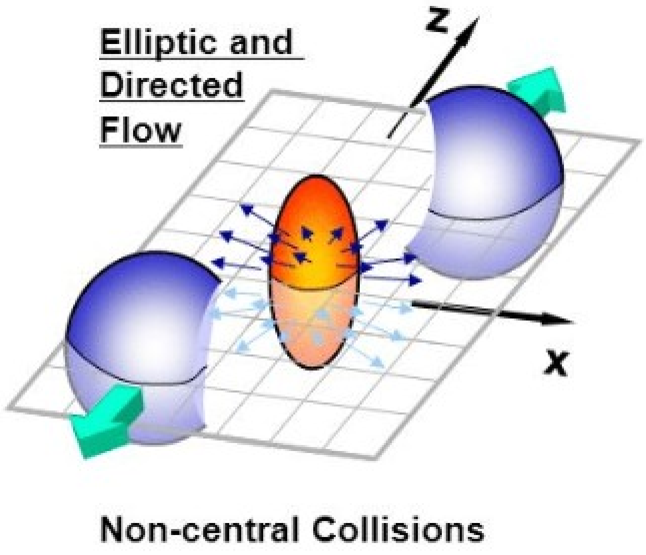




HYDRODYNAMIC RESPONSE OF THE QGP TO ECCENTRICITIES

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left[1 + \sum_{n=1}^{\infty} 2v_n cos\left(n\left(\phi - \psi_n\right)\right)\right]$$

$$v_n = \langle cos\left[n\left(\phi - \psi_n\right)\right]\rangle$$



$$v_2 = \kappa_2 \varepsilon_2 + O(\varepsilon_2^2)$$
$$v_3 = \kappa_3 \varepsilon_3 + O(\varepsilon_3^2)$$

ISOBAR COLLISIONS

$$\rho(r,\theta,\phi) = \frac{\rho_0}{1+e^{[r-R(\theta,\phi)]/a}}$$

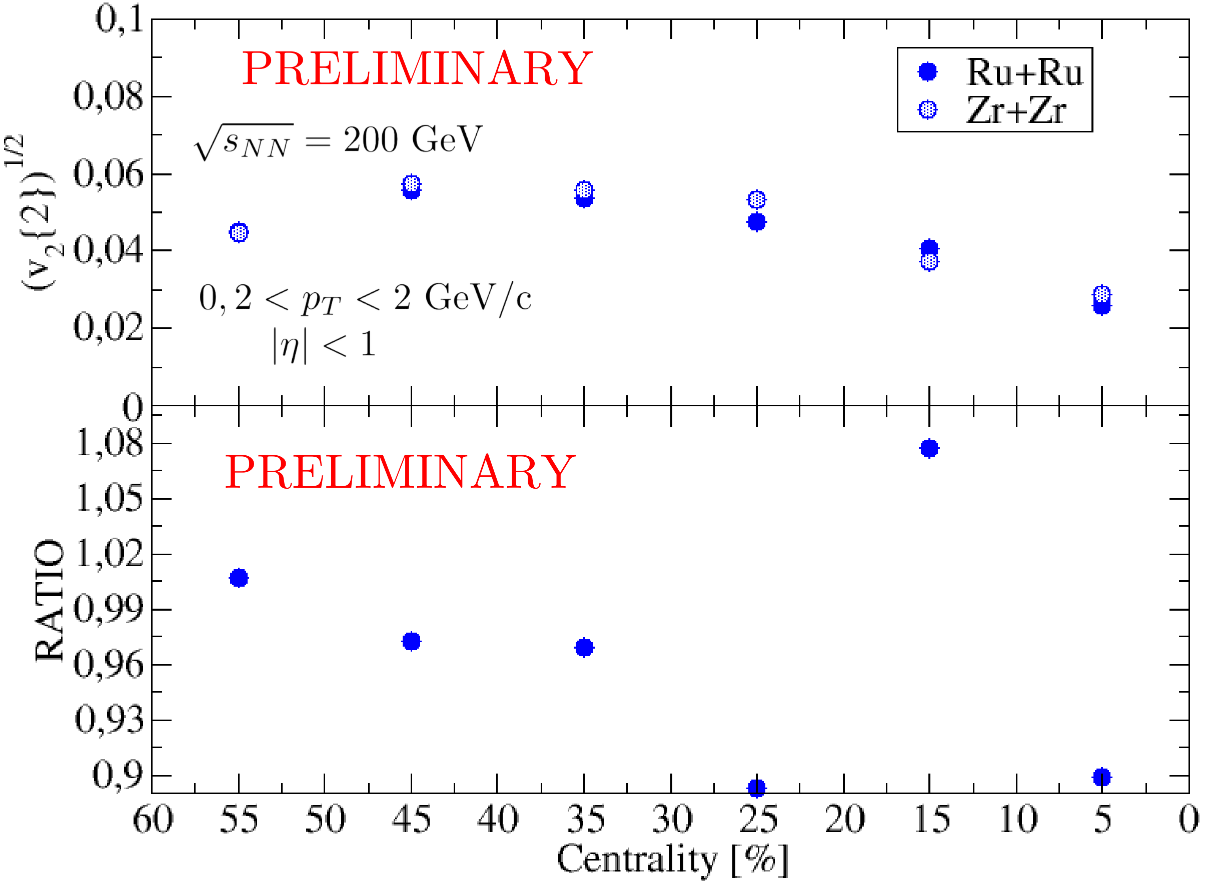
$$R(\theta,\phi) = R_0(1+\beta_2(\cos\gamma Y_2^0(\theta,\phi)+\sin\gamma Y_2^2(\theta,\phi))+\beta_3 Y_3^0(\theta,\phi)+...)$$

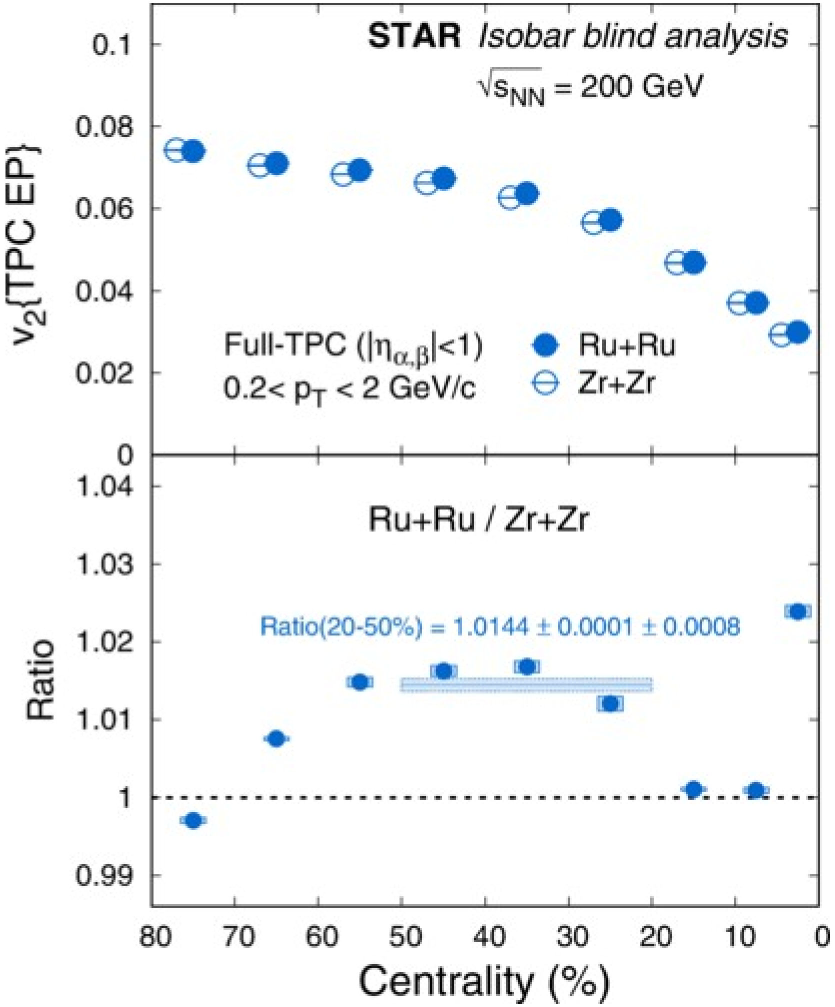
$$\frac{O_{Ru+Ru}}{O_{Zr+Zr}} = 1+c_1\Delta\beta_2^2+c_2\Delta\beta_3^2+c_3\Delta a+c_4\Delta R_0$$

Phys. Rev. C 107 (2023), L021901

PRELIMINARY RESULTS

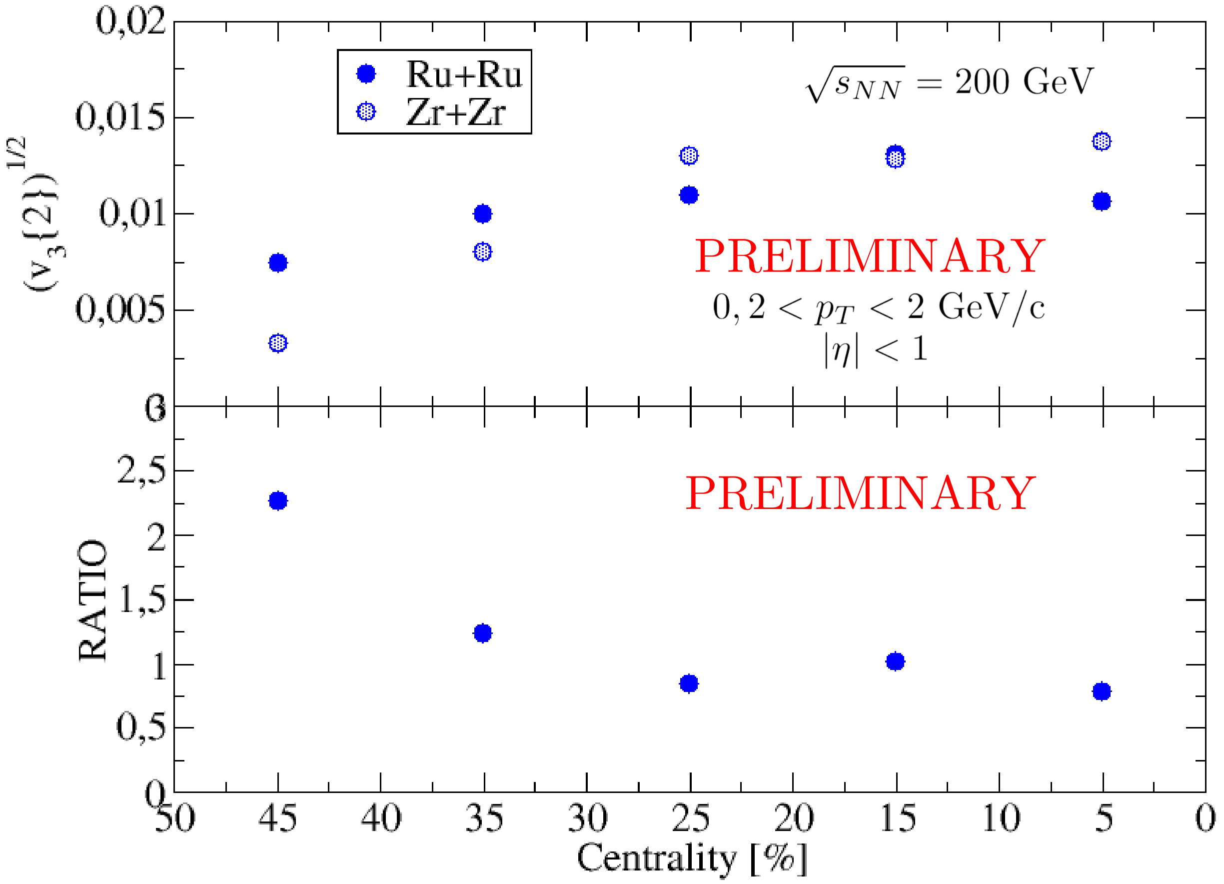
ELLIPTIC FLOW

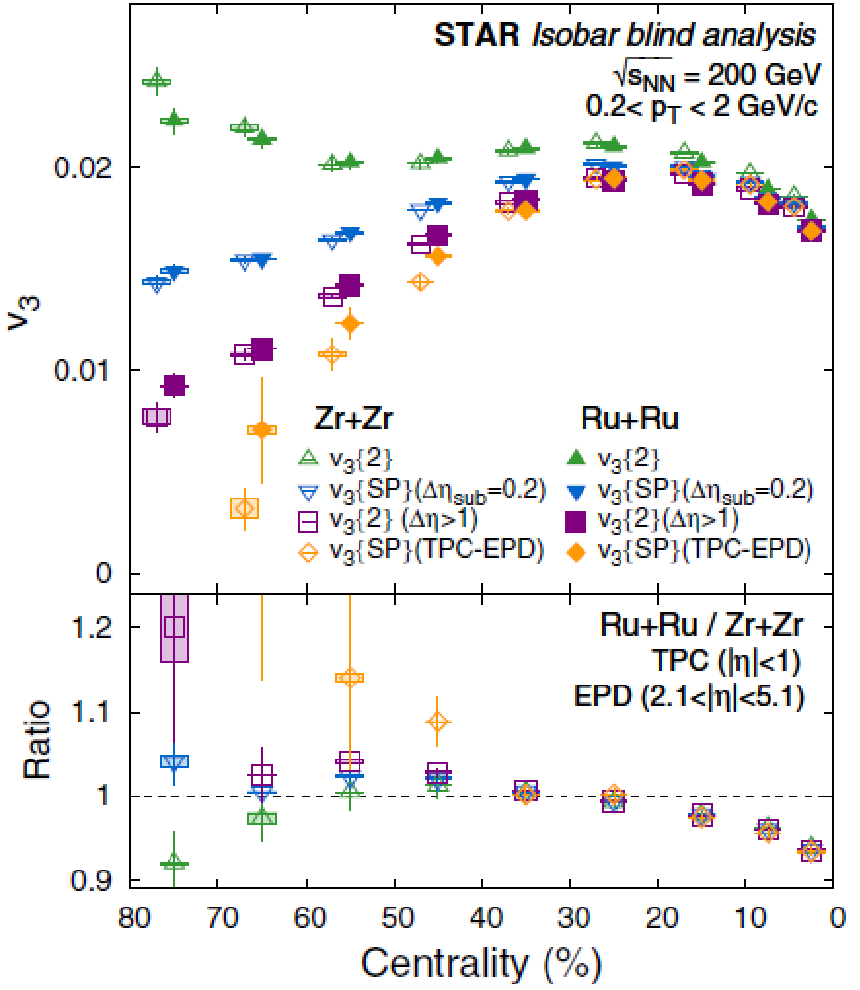




STAR coll.,
Phys. Rev. C 105 (2022) 1, 014901

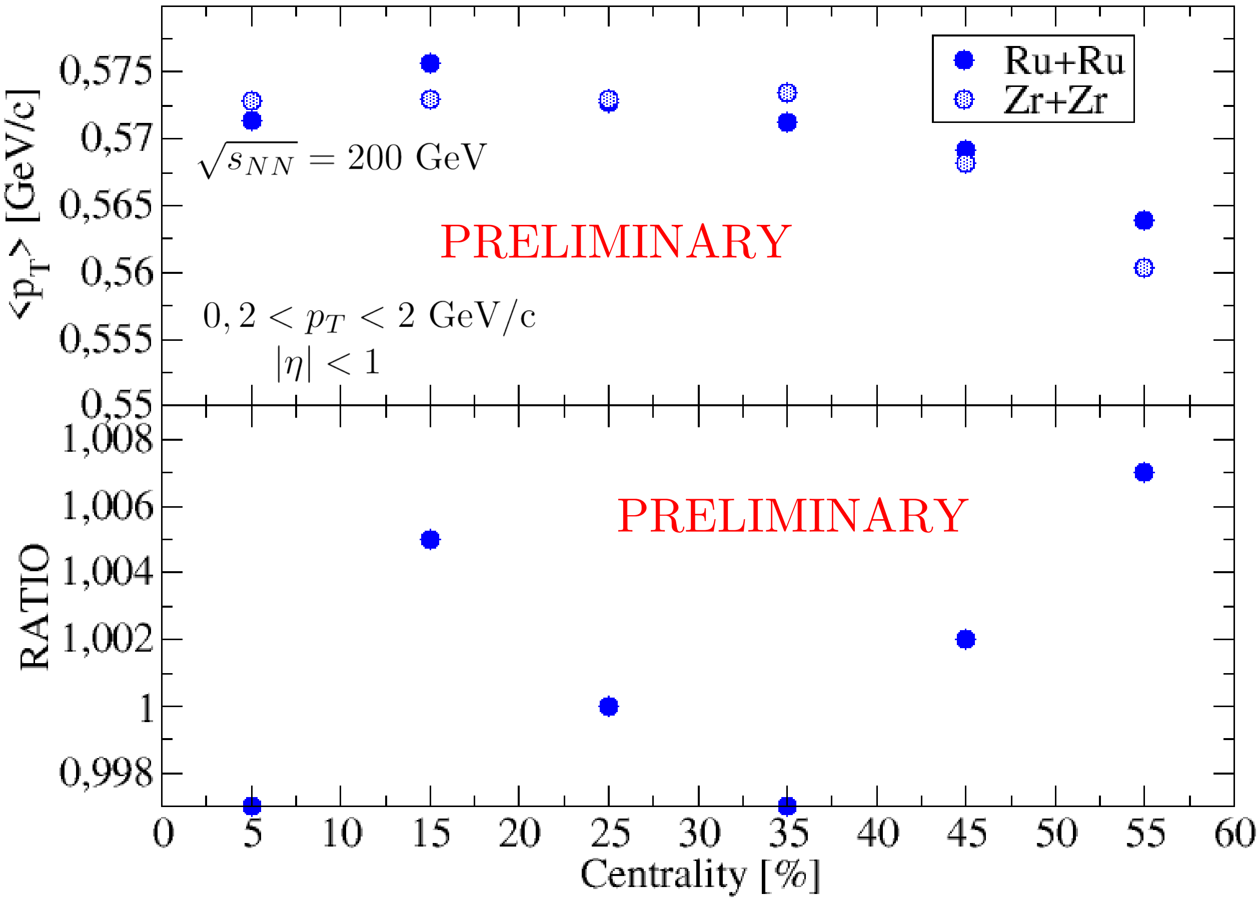
TRIANGULAR FLOW

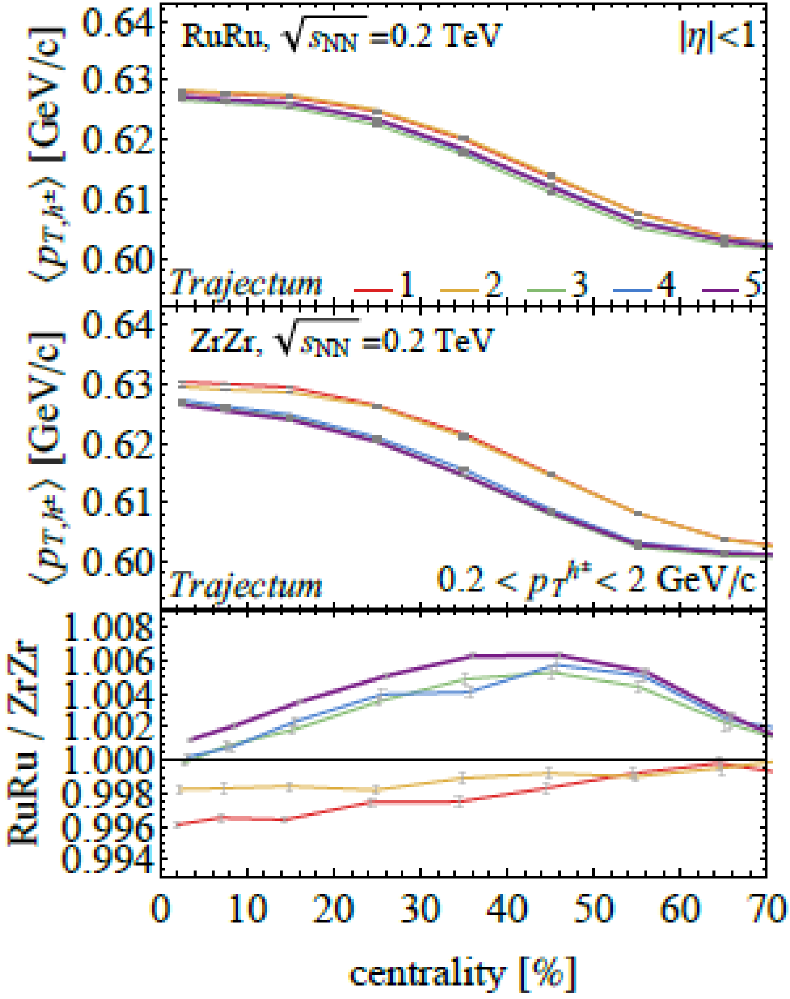




STAR coll.,
Phys. Rev. C 105 (2022) 1, 014901

TRANSVERSE MOMENTUM



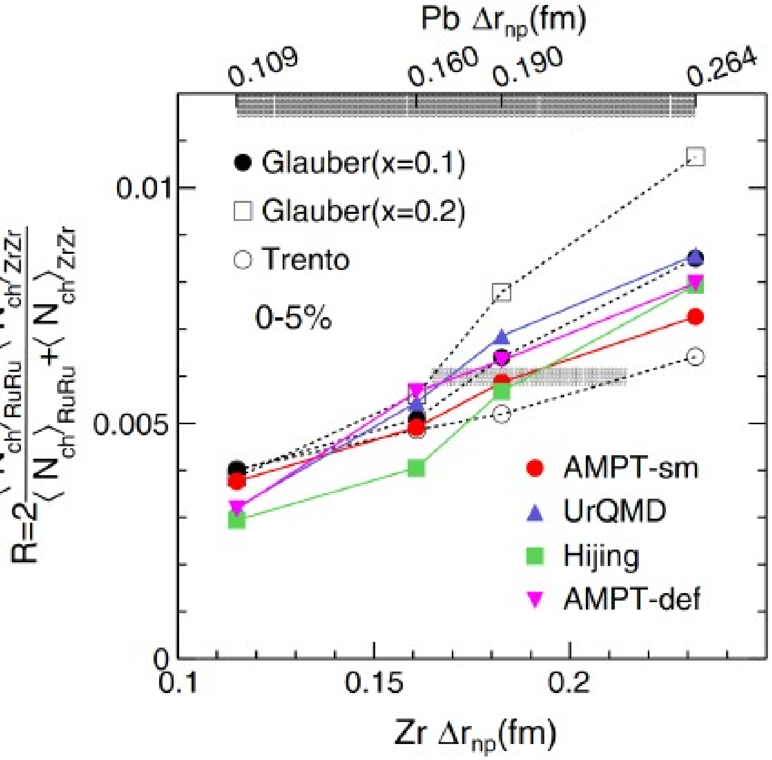


SciPost Phys. 15, 041 (2023)

WORK IN PROGRESS

CHARGE PARTICLE FLUCTUATIONS VS NEUTRON SKIN

Li, Xu, Zhou, PRL **125**, 222301 (2020)



BARYON TO CHARGE TRANSPORT RATIO

STAR coll., 2408.15441 [nucl-ex]

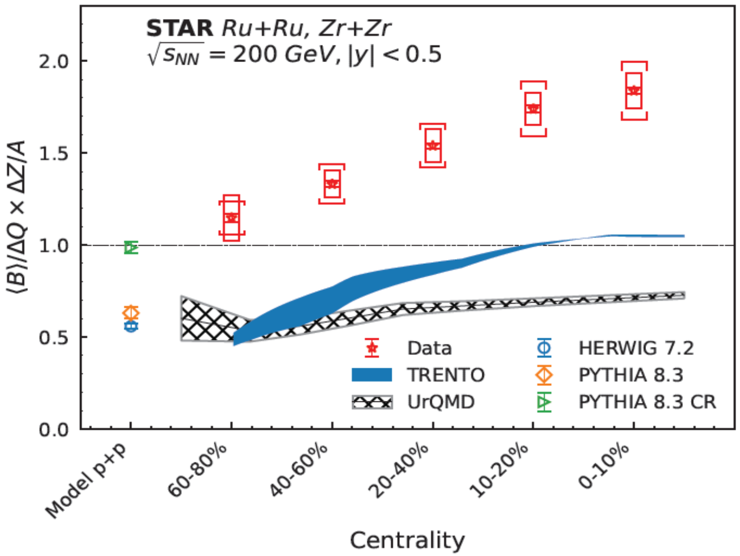


Figure 2: **Baryon to charge transport ratio.** The ratio of the mean net-baryon number ($\langle B \rangle$) to the net-charge difference between Ru+Ru and Zr+Zr collisions (ΔQ), scaled by $\Delta Z/A = 4/96$, as a function of centrality. Red stars represent data with the boxes (vertical bars) around them representing systematic (statistical) uncertainties. Uncertainties arising from estimations of feed-down contributions to neutrons and antineutrons are shown separately as brackets. The horizontal dashed line at 1 shows the naive expectation if the baryon number is carried by valence quarks and all other effects are ignored. Model calculations from UrQMD (hatched band) (*28, 29*), TRENTO (solid band) (*30*), PYTHIA 8.3 (diamond) (*16*), PYTHIA 8.3 with Color Reconnection Mode 2 (triangle), and HERWIG 7.2 (circle) (*19*) are also shown for comparison. See text for details.

THANKS!!!