NEUTRON SKIN

Insight from the conserved charges in heavy-ion collisions

Buenas Ideas on the QCD Phase diagram - YITP 2026

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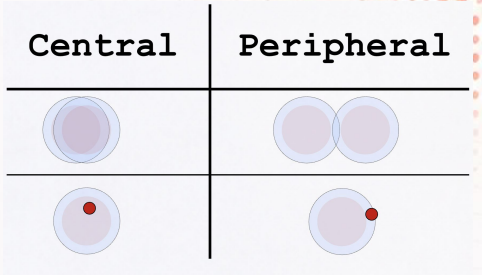
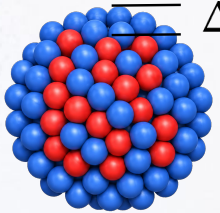


What is the neutron skin

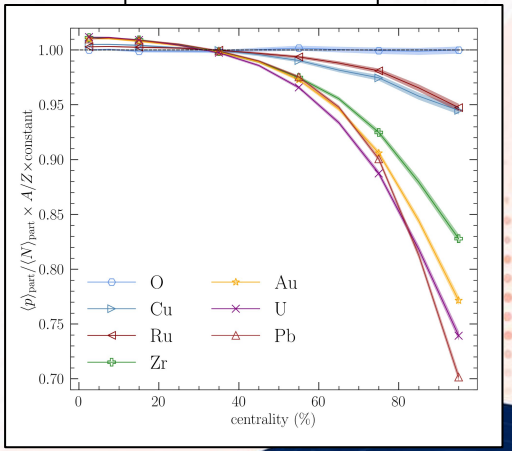


ΔR_{np}

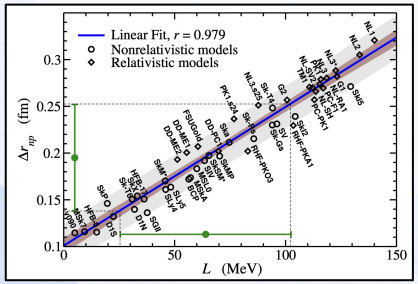
$$\rho_{p,n}(r) = \frac{1}{1+e^{(r-R_{p,n}^{WS})/a_{p,n}}}$$

The deposited proton fraction

$$\frac{\langle p \rangle}{\langle N_{\text{part}} \rangle} \times \frac{A}{Z}$$



Connection to neutron stars



Conserved charges ratios

Single system

Cancellation: centrality

$$\mathcal{R}^{X,Y}_{c_1,c_2}(y_1,y_2) = \frac{N_X(y_1,y_2,c_1)}{N_Y(y_1,y_2,c_1)} \Big/ \frac{N_X(y_1,y_2,c_2)}{N_Y(y_1,y_2,c_2)}$$

$$N_X(y_1,y_2,c) = \left\langle \int_{y_1}^{y_2} \mathrm{d}y \, \frac{dN_X}{dy}(y,c) \right\rangle_{\mathrm{ev}}$$

Two systems

Cancellation: systems+cent

$$r^{XY} = \alpha_Y \frac{\Delta\tilde{B}}{\Delta\tilde{Q}} + \Gamma_{XY} \frac{\tilde{B}^X}{\Delta\tilde{Q}}$$

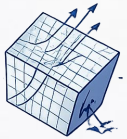
$$\alpha_Y = \frac{Z_Y}{A_Y}, \qquad \Gamma_{XY} = \frac{\Delta Z}{A_X} - \frac{Z_Y}{A_X}\frac{\Delta A}{A_Y}$$

$$\Delta\tilde{Q} \equiv \tilde{Q}^X - \tilde{Q}^Y \qquad \Delta\tilde{B} \equiv \tilde{B}^X - \tilde{B}^Y$$

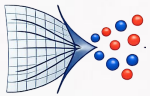
Simulations pipeline

The iEBE-MUSIC Framework

Initial conditions: 3D MC Glauber model



Hydrodynamics: MUSIC



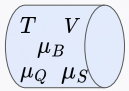
Particlization: ISS

Afterburner: UrQMD

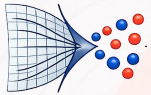
https://github.com/chunshen1987/iEBE-MUSIC

The Thermal-FIST

Initial conditions: 3D MC Glauber model



Fireball at equilibrium: Thermal-FIST

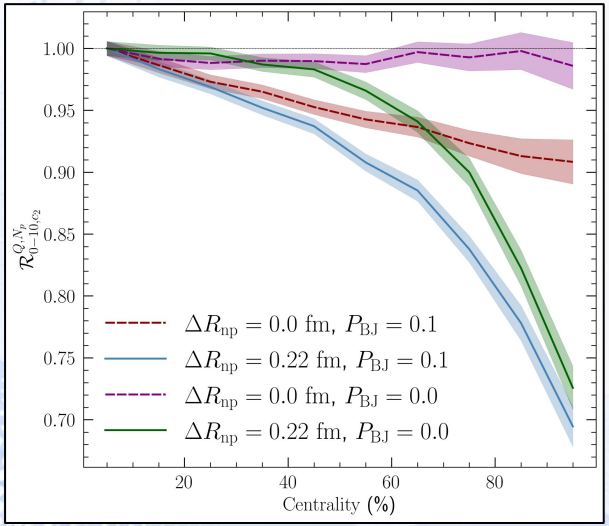


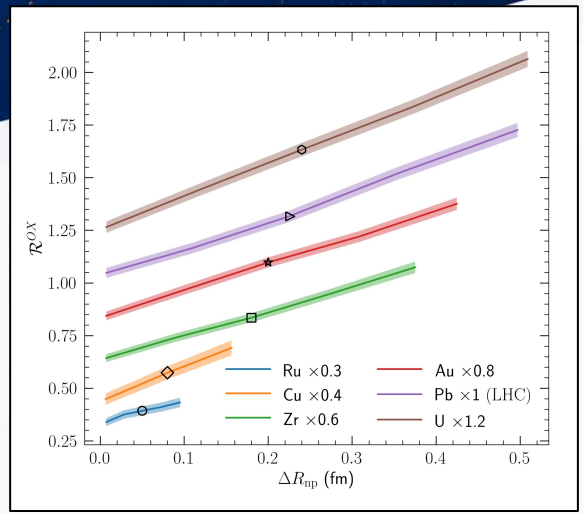
Particlization: Thermal-FIST

Results

Pb+Pb, $\sqrt{s_{\rm NN}} = 5.02$ TeV

The peripheral centrality dependence of the double Q/B ratio. We see a strong centrality dependence for finite neutron skin thickness. Varying the baryon stopping (with the junction mechanism) leads to different slope in the most central collision limit.





The neutron skin thickness dependence on the central to peripheral two systems double ratio. The baseline nucleus is oxygen (negligible neutron skin). We observe a linear dependence of this ratio with the neutron skin thickness. This method can in principle be used to extract the thickness of all nucleus but require a strict control on the systematics

O+O, X+X $\sqrt{s_{\rm NN}} = 200$ GeV, $\sqrt{s_{\rm NN}} = 5.02$ TeV

p+Pb, $\sqrt{s_{\rm NN}} = 5.02$ TeV

The neutron skin thickness dependence on the central to peripheral one system double ratio for proton lead. We see a clear dependence with the neutron skin thickness. The curves depends strongly on the choice of rapidity window. Very forward windows give the best results.