Hyperon production and Polarization studies

UrQMD vs PHSD

Ivonne Maldonado*, for MeXNICA Collaboration

*Facultad de Ciencias Físico Matemáticas, Universidad Autónoma de Sinaloa
ivonne.alicia.maldonado@gmail.com

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Outline

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3. Event Plane Angle
4. Hyperon Identification
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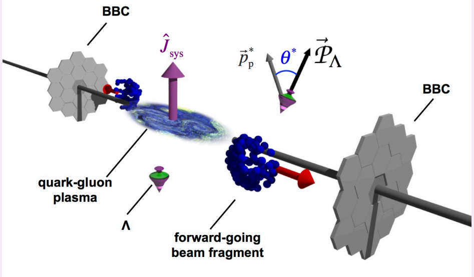
5. Preliminary distributions
6. Summary

Section 1

Motivation

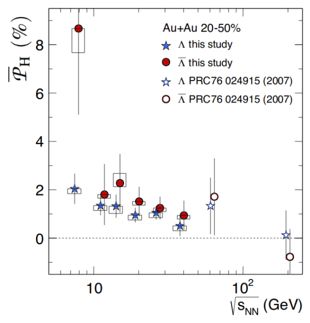
Motivation: Hyperon Global Polarization

Due the spin-orbit coupling, particles produced in heavy ion collisions, acquire polarization in the direction of the orbital angular momenta of the system



The induced polarization should be the same for particles and antiparticles.

STAR BES measured it, as a function of $\sqrt{s_{NN}}$.

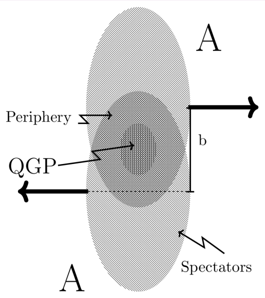


They found that polarization increases as the energy decreases, but is larger for the $\bar{\Lambda}$.

Nature 548, 62-65(2017)

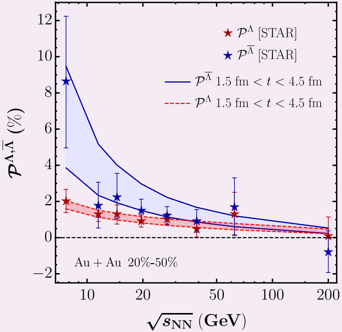
Motivation: Core meets Corona

Differences in Λ and $\bar{\Lambda}$ global polarization in semi-central heavy-ion collisions, can be explained in terms of two component source. J.Phys.Conf.Ser. V. 1602 no 1 (2020) 012032, Phys.Lett.B. V810 (2020)135818



$$\mathcal{P}^{\Lambda} = \frac{z\frac{N_{\Lambda_{QGP}}}{N_{\Lambda_{REC}}}}{\left(1+\frac{N_{\Lambda_{QGP}}}{N_{\Lambda_{REC}}}\right)}$$

$$\mathcal{P}^{\bar{\Lambda}} = \frac{\left(\frac{\bar{z}}{w}\right)\frac{N_{\Lambda_{QGP}}}{N_{\Lambda_{REC}}}}{\left(1+\left(\frac{1}{w}\right)\frac{N_{\Lambda_{QGP}}}{N_{\Lambda_{REC}}}\right)}$$



If $w < 1$ and $N_{\Lambda_{REC}} > N_{\Lambda_{QGP}}$ data can be described.

- $N_{\Lambda_{QGP}} \rightarrow$ central region
- $N_{\Lambda_{REC}} \rightarrow$ periphery region
- $z(\bar{z})$ intrinsic polarization
- $w \rightarrow \bar{\Lambda}/\Lambda$ ratio in periphery

Section 2

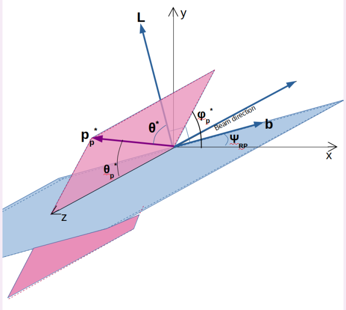
Measurement procedure of Hyperon Global Polarization

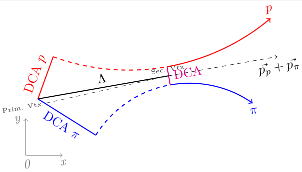
Measurement procedure of Hyperon Global Polarization

1. Measurement of the Event Plane angle Ψ_{EP} and its Resolution R_{EP}
2. Λ and $\bar{\Lambda}$ identification through their decay products and measurement of the azimuthal angle of the decay baryon ϕ_p^*
3. Polarization as a function of the difference of these angles

$$\boxed{\mathcal{P}_H = \frac{8}{\pi \alpha_H} \frac{\left\langle \sin\left(\phi_p^* - \Psi_{EP}^{(n)}\right)\right\rangle}{R_{EP}^{(n)}}}$$

$\alpha_H = 0.642 \pm 0.013$ – hyperon decay parameter





Analyzed data: Au + Au at $\sqrt{s_{NN}} = 7.7$ GeV/c

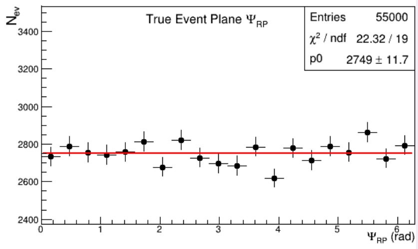
- PHSD dataset $\approx$ 55000 Minimum Bias events reconstructed and corrected
- UrQMD dataset $\approx$ 90000 Minimum Bias events reconstructed and corrected
- ZDC and TPC detectors for event plane angle measurement
- TPC detector for Hyperon identification

Section 3

Event Plane Angle

Event Plane Angle

MC $\rightarrow \Psi_{RP}$ isotropic distribution randomly in $(0^o, 360^o)$ for PHSD and $(-180^o, 180^o)$ for UrQMD.



For reconstructed data we get the Event plane angle $\Psi_{EP}^{(n)}$:

$$\Psi_{EP}^{(n)} = \frac{1}{n} \arctan \frac{Q_y}{Q_x}$$

where:

$$Q_x = \sum_i w_i \cos(n\phi_i)$$

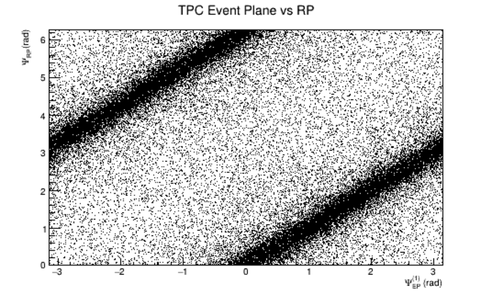
$$Q_y = \sum_i w_i \sin(n\phi_i)$$

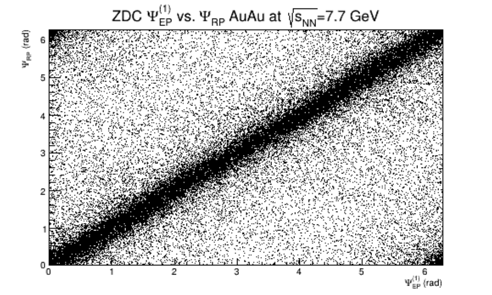
Where w_i is p_T for TPC and E_{Loss} for ZDC and ϕ_i is the angle of the track or the module respectively.
Resolution is given by

$$R_{EP}^{(n)} = \left\langle \cos n(\Psi_{EP}^{(n)} - \Psi_{RP}) \right\rangle$$

Event Plane Angle ZDC vs MC - Phase Shift

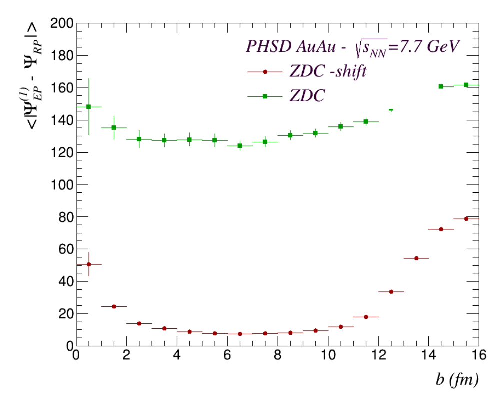
MC is asigned from $\rightarrow (0, 2\pi)$, from reconstruction $\Psi_{EP}^{(n)} \rightarrow (-\pi, \pi)$

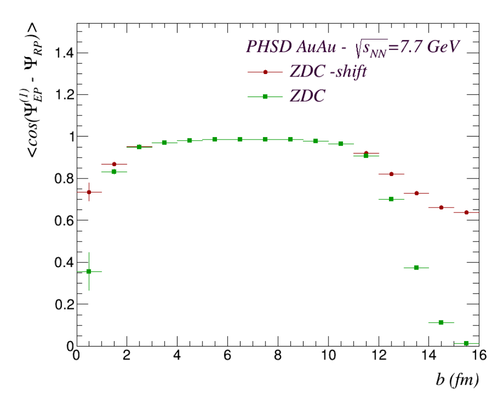




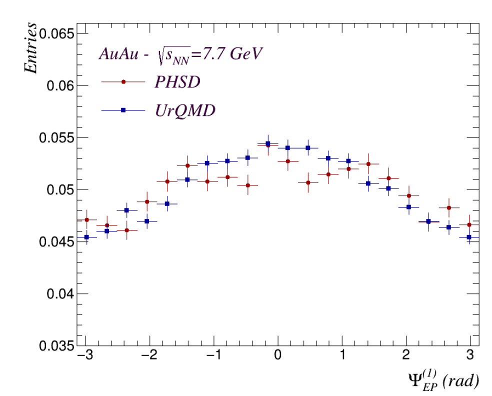
Resolution ZDC - Phase Shift

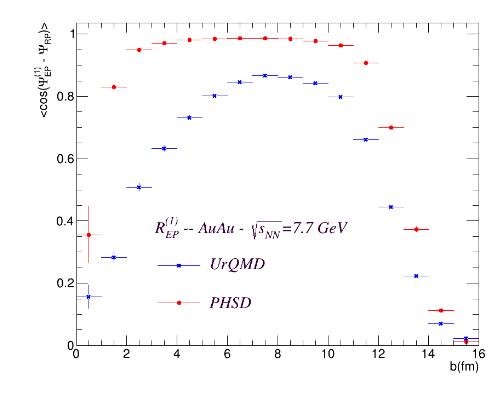
Change the angle gives different resolution for central and peripheral collisions





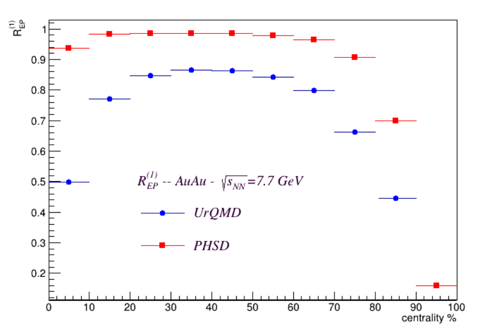
Event Plane Angle with ZDC, PHSD and UrQMD comparis





The distribution should be given in terms of centrality. Classes to get it in physical_analysis/Flow directory in mpdroot

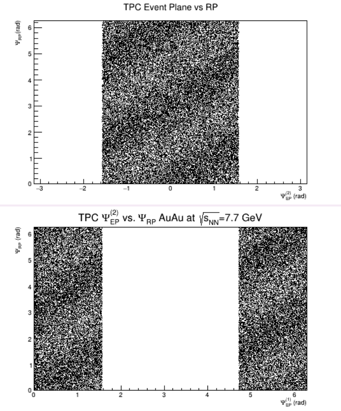
Event Plane Angle with ZDC, PHSD and UrQMD comparis

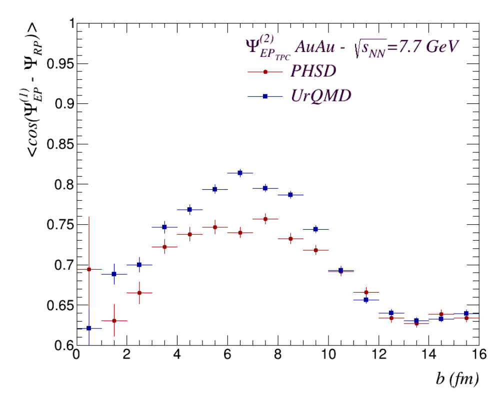


a very rough centrality-bin selection

Event Plane Angle with TPC, PHSD and UrQMD comparis

For PHSD, we need to change the angle interval





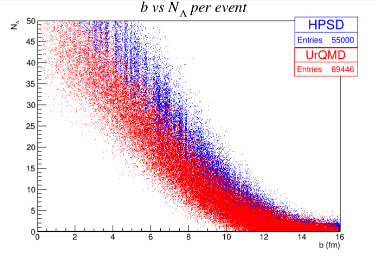
PHSD gives a smaller resolution for central and semicentral collisions

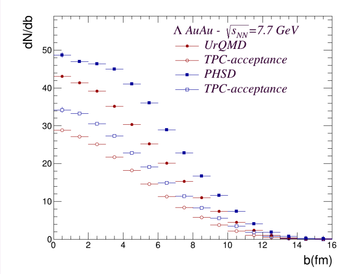
Section 4

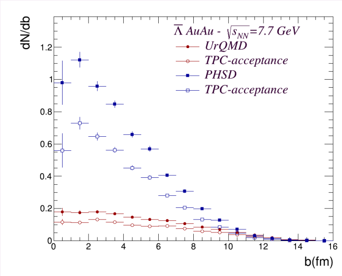
Hyperon Identification

Generation of Λ and $\bar{\Lambda}$

MC data $\rightarrow$ Λ and $\bar{\Lambda}$ generated by PHSD or UrQMD + particle decays, secondary interactions by GEANT3 transport package





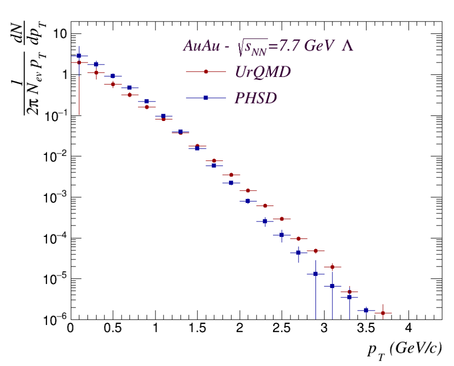


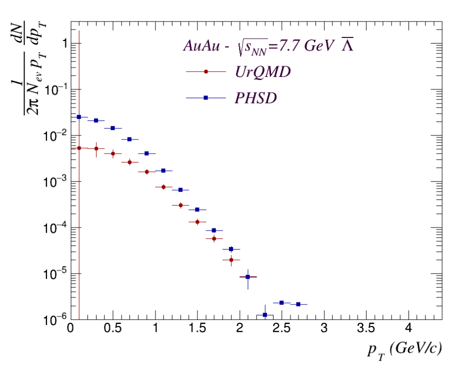
PHSD produces more Λs than UrQMD

Similar for $\bar{\Lambda}$

p_T distribution

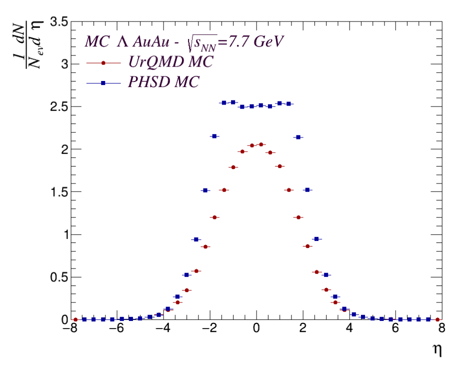
Less number of hyperons for UrQMD at low p_T

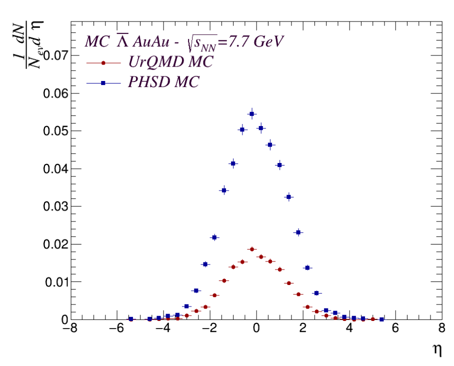




$|\eta|$ distribution

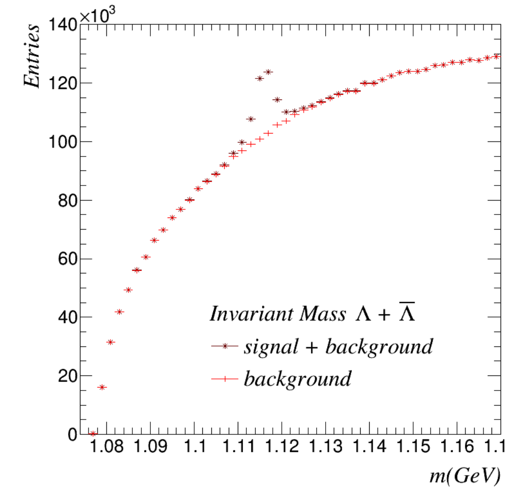
Pseudorapidity distribution for Λ changes for PHSD with respect to UrQMD

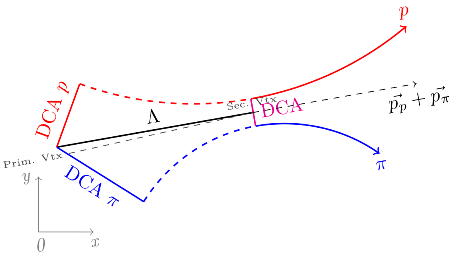




Normalized to the number of events and bin width

Reconstruction: Kinematic and topological variables

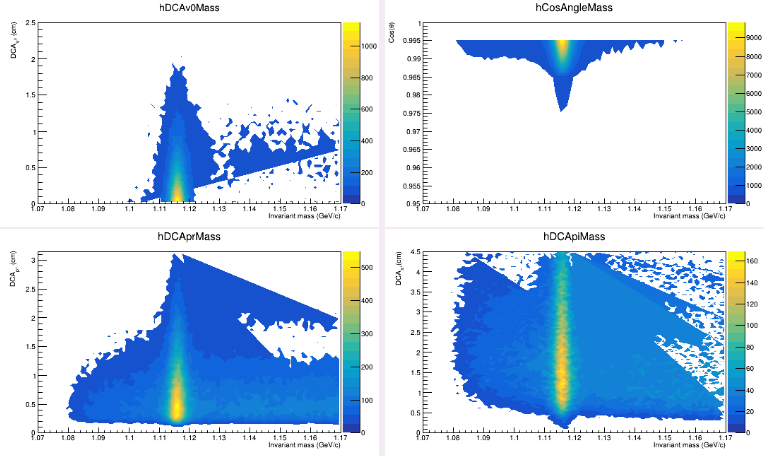




Variable	Cut
Cos of Angle	?
DCA V^0	? cm
DCA $p-$track	? cm
DCA $\pi-$track	? cm

Cuts on Kinematical variables

Daughter tracks with MC association



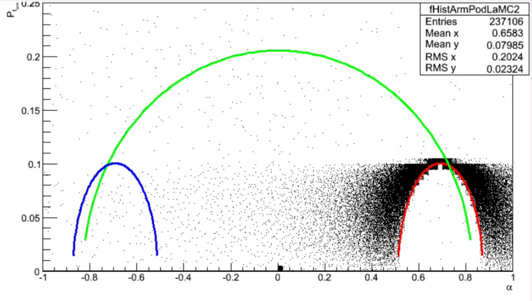
- DCA $V^0 < 0.5$ cm
- $\cos(\theta) > 0.98$
- DCA $p > 0.1$ cm
- DCA $\pi > 0.3$ cm

Distinguish between Λ and $\bar{\Lambda}$

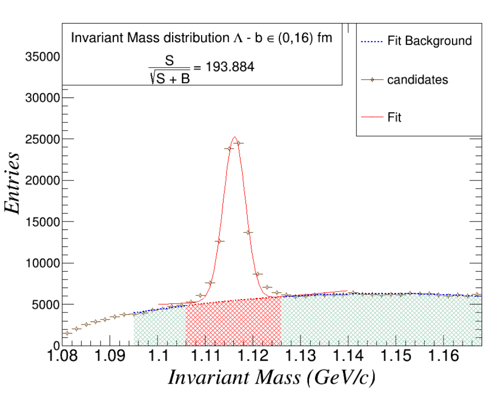
Armenteros-Podolanski plot, each V^o particle describes a semiellipse in the α vs. p_T graph

$$\boxed{\alpha = \frac{p_L^+ - p_L^-}{p_L^+ + p_L^-}} \quad vs. \quad \boxed{p_T^{(\pm)}}$$

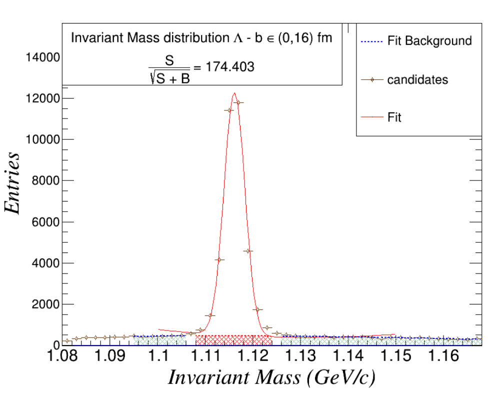
We select $\alpha > 0$ for Λ and $\alpha < 0$ for $\bar{\Lambda}$. In the drawing Λ **is in red**, $\bar{\Lambda}$ **in blue** and K_s^o **in green**



Λ Invariant Mass Distribution - PHSD

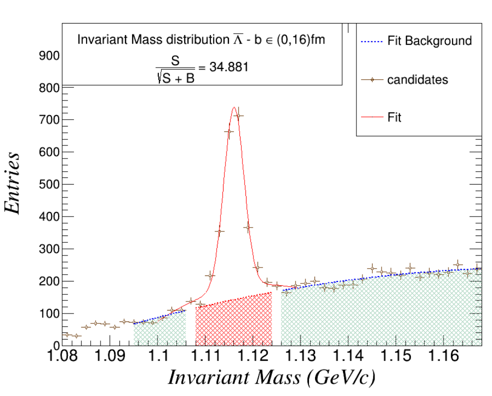


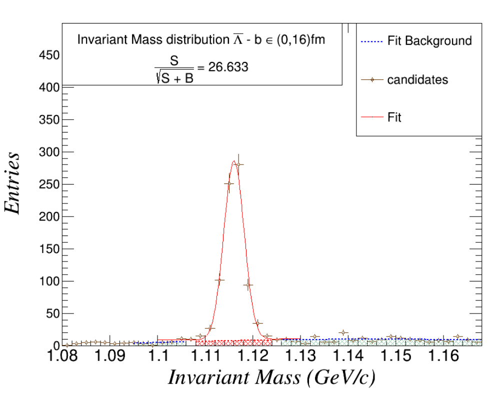
cuts



Daughter tracks identified as p and π by MC association

$\bar{\Lambda}$ Invariant Mass Distribution - PHSD





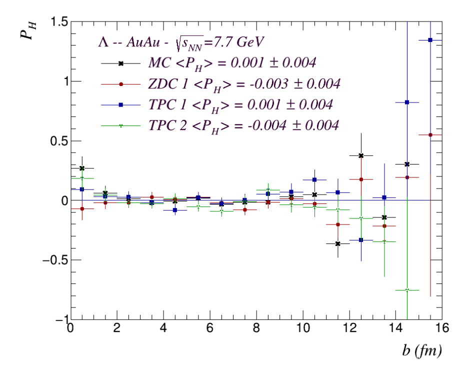
Daughter tracks identified as p and π by MC association

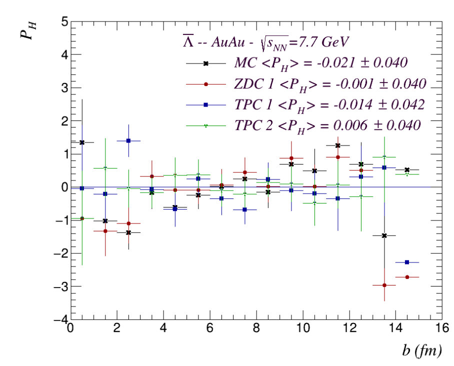
Section 5

Preliminary distributions

Preliminary distribution with $\Psi_{EP}^{(n)}$ UrQMD

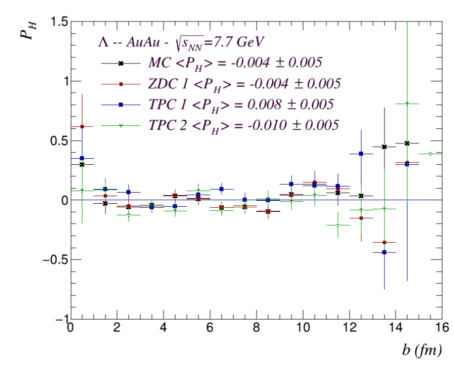
$$\mathcal{P}_H = \frac{8}{\pi\alpha_H}\left\langle \sin\left(\phi_p^* - \Psi_{EP}^{(n)}\right)\right\rangle$$

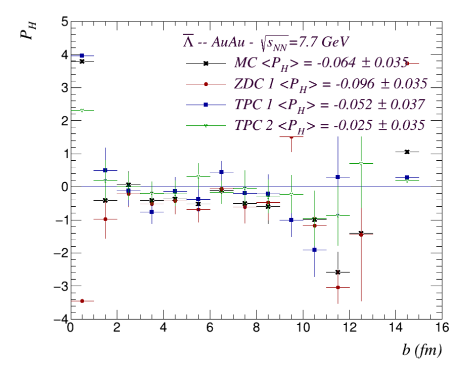




Preliminary distribution with $\Psi_{EP}^{(n)}$ PHSD

$$\mathcal{P}_H = \frac{8}{\pi \alpha_H} \left\langle \sin\left(\phi_p^* - \Psi_{EP}^{(n)}\right) \right\rangle$$





Section 6

Summary

Summary

- We have presented a preliminary Event Plane angle measurement as a function of impact parameter for AuAu collisions at $\sqrt{s_{NN}} = 7.7$ GeV/c with data from UrQMD and PHSD.
- We compare Λ and $\bar{\Lambda}$ production with UrQMD and PHSD, founding discrepancies which affects Event Plane angle resolution and hyperon global polarization.
- We plan to get the polarization with the measured event plane and to improve the selection of Λ and $\bar{\Lambda}$ considering the particle identification for the decay product tracks and improving the topological cuts to increase the significance.
- We plan to compare these results with previous analysis at BiBi collisions.

¡GRACIAS!