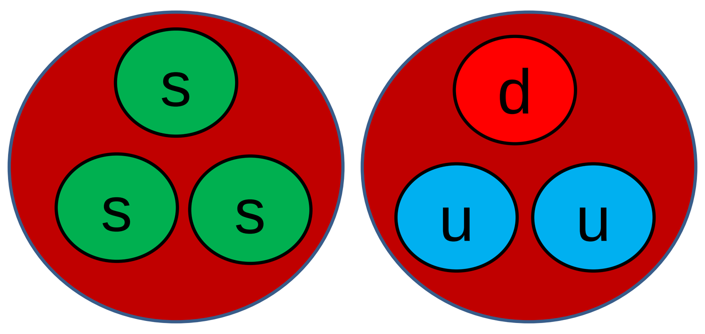
Study of Omega-Proton Correlations in Heavy-Ion Collisions

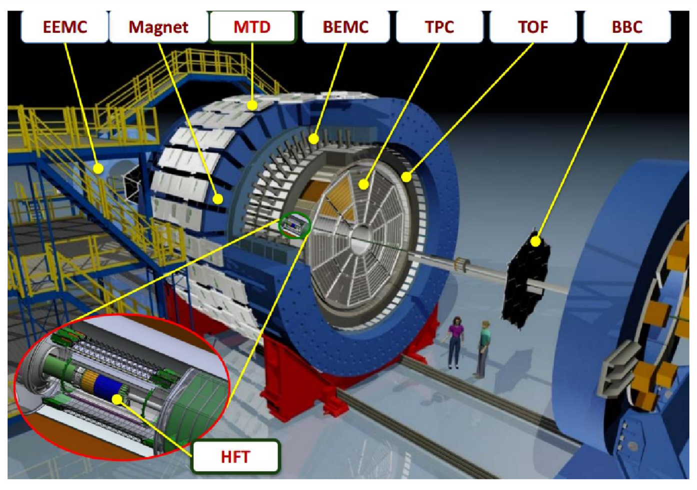
Yifei Han(UCLA), *for the STAR Collaboration*

Abstract

Recently the STAR experiment at RHIC measured ΛΛ correlations from Au+Au collisions at $\sqrt{s_{NN}}$ = 200GeV to search for the H particle (uuddss)[1]. The correlation strength indicated that the Λ-Λ interaction is weak and is unlikely to be attractive enough to form a bound state. A recent lattice QCD calculation predicted a possible di-baryon bound state with ΩN [2]. Thus, we will extend the correlation measurements to $\Omega - p$, which could potentially be a sensitive approach to search for such a state. We will present the Omega-proton correlations based on data collected by STAR in Au+Au collisions at $\sqrt{s_{NN}}$ = 200GeV, and discuss the physics implications.

Introduction





- Hal Lattice QCD result predicts stable $\Omega^- p$ state with 18.9 (±5.0) MeV binding energy with $a_0 = -1.28\ (\pm 0.13)$ fm, $r_e = 0.499(\pm 0.026)$fm
- Correlation study serves as a compliment to invariant mass search.
- In another study by J. Ping, spin -3 bound state was predicted by different models, and shows that the bound state is "model independent." [3]

	$a_0(fm)$	$r_e\ (fm)$	$E_{binding}\ (MeV)$
QDSCM	2.8007	0.5770	-5.2
SU (2) ChQM1	0.8103	0.3609	-110.3
SU (2) ChQM2	1.3808	0.6018	-37.3
SU (3) ChQM	1.9870	0.7064	-13.7

- For this study we use Data from 200GeV Au+Au collisions at RHIC run 2011.

Particle Identification

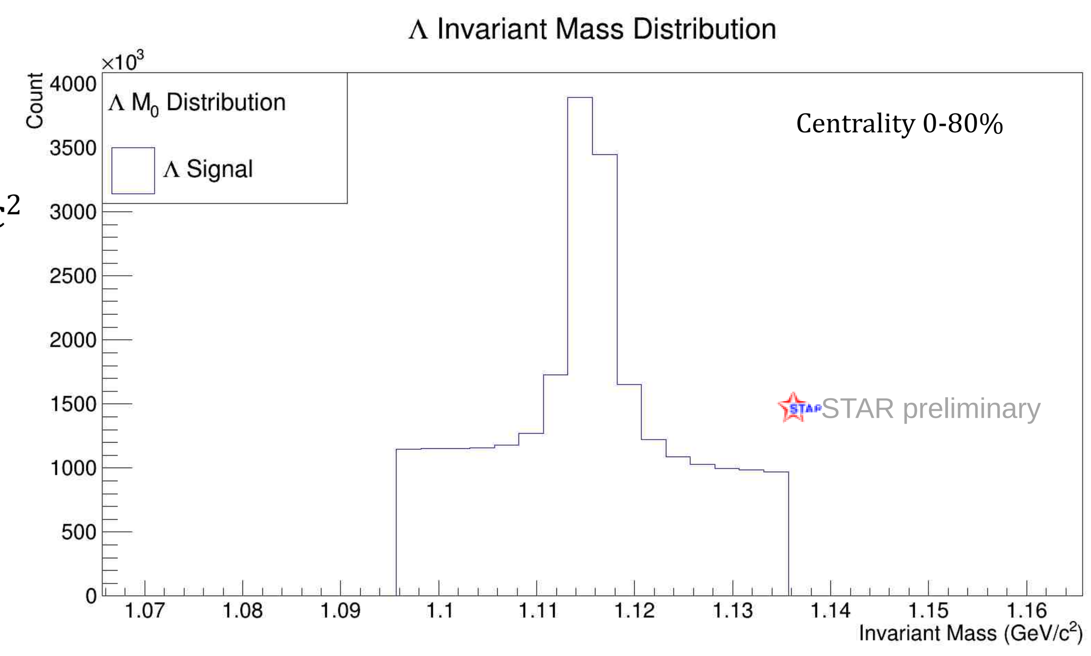
Event Selection

- 1.03×10^8 Events
- $|vertex_z| < 40$ cm
- $|\vec{r}_{TPC} - \vec{r}_{VPD}| < 4$ cm
- Centrality 0-80%

Ω^- Decay Mode:
$\Omega^- \to \Lambda^0 K^-$ (67.8 ± 0.7)%
$\Lambda^0 \to p\pi^-$ (63.9 ± 0.5)%

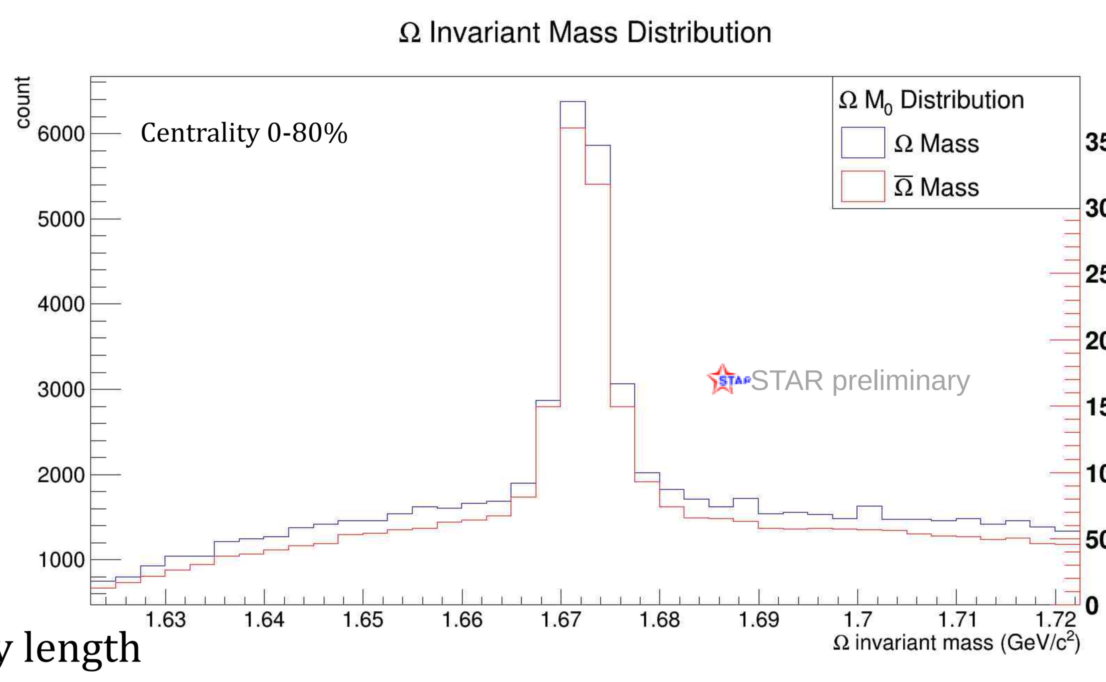
Proton Identification

- Proton $n_\sigma < 1.5$
- Proton dca < 3 cm
- 0.8GeV/c²< m_{proton}<1.1GeV/c²
- 0.5GeV/c< $p_{t,proton}$<2.5GeV/c



Lambda Identification

- Λ^0 dca > 0.4 cm
- Λ^0decay length > 5.0 cm
- p dca > 0.6 cm
- π^- dca > 2.0 cm
- p to π^- dca < 0.7cm



Omega Identification

- Ω^- dca < 0.4 cm
- Ω^- decay length > 3.0 cm
- Ω^- rapidity < 0.5
- dca Λ^0 to K^- < 0.7 cm
- Λ^0 decay length > Ω^- decay length
- $|\Lambda^0 - m_{\Lambda^0\,peak}| < 6$ MeV/c²
- Additional cut: replace K^- mass with π^- mass and if resulting parent mass is within 100 MeV of Ξ^- mass then reject. This cut will reject Cascade particles misidentified as Omega particles due to a misidentification of Pions as Kaons.

Omega Background

Omega particle background is done using rotational background method. Each of the two daughters of Omega are rotated by π/3, 2π/3, π, 4π/3, 5π/3, and invariant mass with the other daughter's original momenta is calculated. The invariant mass signal is scaled down by 10 to preserve the scaling.

Correlation Function

- Calculate relative momentum between $\Omega^-$and p using:

$$Q^2 = |(\vec{P}_\Omega - \vec{P}_p)^2 - (E_\Omega - E_p)^2|$$

- In the interest of statistics we take Ω^- particles within 2 standard deviations of the mass peak. Then we have

$$CF(Q) = \frac{A(Q)}{B(Q)}$$

where $A(Q)$ is relative momentum distribution for same event Ω^- and p, and $B(Q)$ is reference distribution obtained with rotational background by rotating proton azimuthal angle by π.

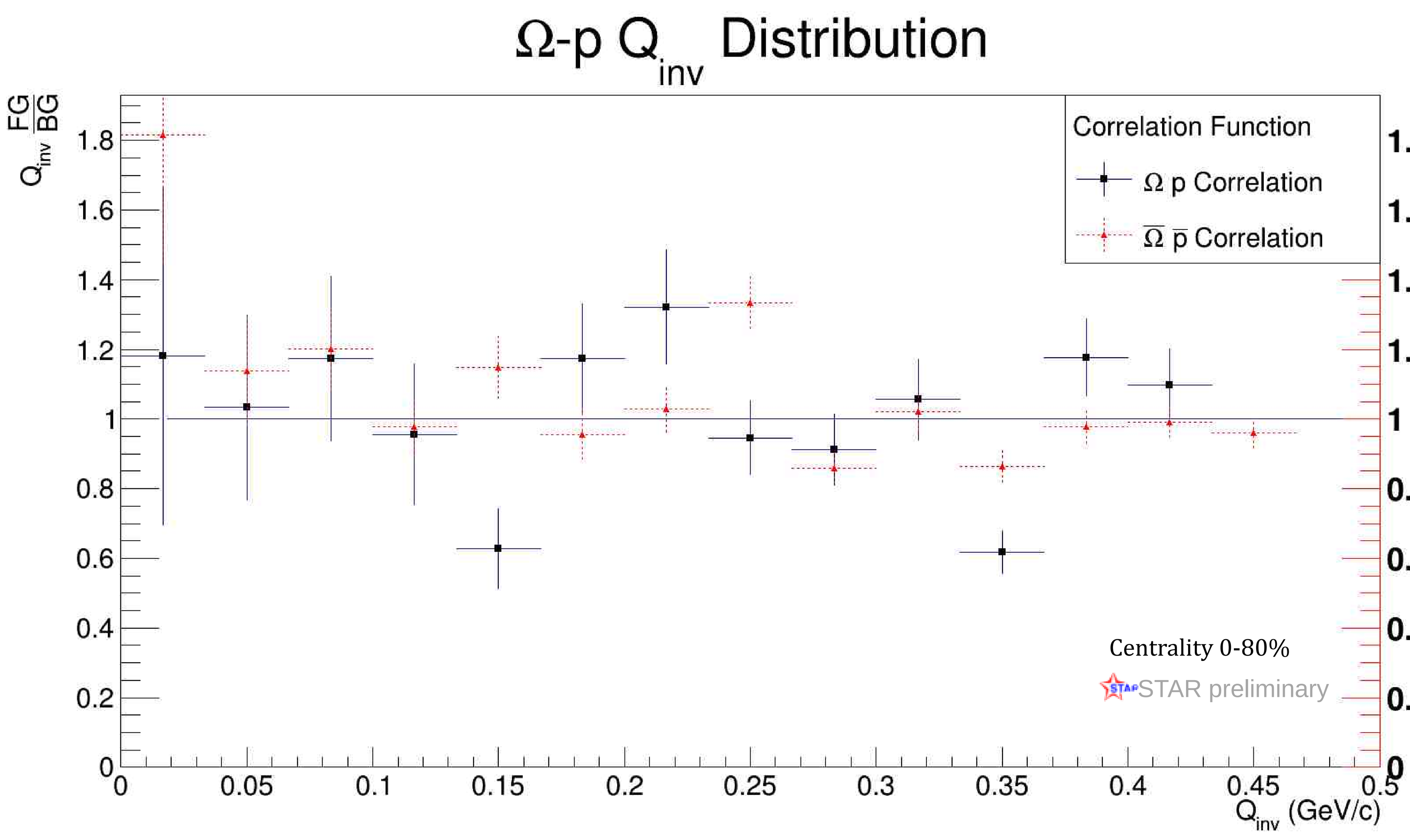
- To account for purity, we have

$$CF_{corrected} = \frac{A(Q) - A_{background}(Q)}{B(Q) - B_{background}(Q)}$$

where $A_{background}(Q)$ and $B_{background}(Q)$ are obtained by taking the same number of Ω^- proton pairs outside of 2 standard deviations as the number of background Ω^- proton pairs within 2 standard deviations and calculating Q distribution. The number of pairs to include is decided by taking rotational background Ω^- particles within 2 standard deviations of the peak and pairing them with same event protons. Then the same number of pairs are taken from Ω^- particles outside of the 2 standard deviation interval . $B_{background}(Q)$ is obtained by taking the same pairs with rotated proton.

Results

Correlation



At the time of this study the fitting function appropriate for this correlation function has yet to be determined. Also note that this correlation function did not account for the effects of Coulomb interactions, which are not present for Λ-Λ correlation. Statistics around Q_{inv} = 0 GeV/c are very low, at less than 20 events per foreground and background bin. More statistics are needed to improve measurements at low Q_{inv}.

Summary and Future Work

Summary:
- Reconstructed Λ^0 and Ω^- particles
- Obtained a preliminary result for $\Omega^- p$ correlation

To do:
- Apply fitting function to obtained correlation function
- Use more data from STAR experiments to increase the statistics
- Study systematic uncertainties in cuts used
- Include the effect of Coulomb Interactions to the correlation function

Reference

[1] L. Adamczyk et al (STAR Collaboration). ΛΛ Correlation Function in Au+Au Collisions at $\sqrt{s_{NN}}$=200 GeV. *Phys. Rev. Lett.* **114**, 022301 (2015).
[2] F. Etminan et al (HAL QCD Collaboration). Spin-2 $N\Omega$ dibaryon from lattice QCD. arXiv:1403.7284.
[3] Hongxia Huang, Jialun Ping, Fan Wang. Further study of the NΩ dibaryon within constituent quark models. arXiv:1507.07124.

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