Selection of body-tip configuration in U+U collisions at $\sqrt{s_{NN}}$ = 193 GeV using spectator neutrons

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Introduction

In central heavy-ion collisions with spherical nuclei such as Au or Pb, the initial overlap region is always circular. Due to the deformed shape, the initial overlap region in U+U collisions can have unique orientations in which the magnetic field is very high in central collisions and the azimuthal anisotropy v_2 is very low [1]. Therefore, U+U collisions may provide a unique opportunity to study these exotic effects in relativistic heavy-ion collisions. However, it has not been experimentally possible so far to unambiguously select specific configurations in U+U collisions.

In this work, we propose a methodology to select a body-tip configuration from unbiased events in U+U collisions. The body-tip configuration is pictorially shown in Fig.1(a), where the impact parameter b is along x axis and the beam direction is along z axis. In this configuration, the right-going uranium nuclei whose major axis is perpendicular to the beam is called the body and other one (left-going) whose major axis is along the beam is called the tip [2]. As seen in Fig. 1(b), the overlap region in such a body-tip collision is circular (shown by mesh). The nucleons which lie in the overlap region are called participants and those which lie outside the overlap region and do not take part in the collisions are called spectators. It is visible from Fig.1(b) that one uranium nucleus gets completely occluded into the other, leaving almost no spectators, whereas the other one will always have some spectators from the non-overlapping regions. This gives rise to asymmetry in the spectator counts in the two opposite directions. We use this particular feature of this body-tip event configuration to separate it out from the rest of the random configurations possible.

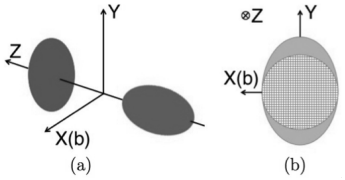

FIG. 1: (a) Schematic diagram of a body-tip configuration in U+U collision. The beam direction is along z axis and impact parameter is along the x axis. (b) The cross sectional view of a central (b = 0) body-tip collision.

Analysis and Results

In the experiments, it is possible to get the measure of spectators using a zero degree calorimeter (ZDC) detector. The ZDC detector gives an electrical signal which is proportional to the number of spectator neutrons. Therefore, we use only the neutrons from the spectators for our study. In Fig. 2(a) we show the spectator neutron correlation for both body and tip oriented uranium nuclei in body-tip collisions. As seen from the figure, the spectator neutron counts are not symmetric for body-tip collisions. The energy deposited by the spectator neutrons in the ZDC is shown in Fig. 2(b). We can select the body-tip events from all the other configurations using this correlation. The two dotted lines show the selection ranges for the possi-

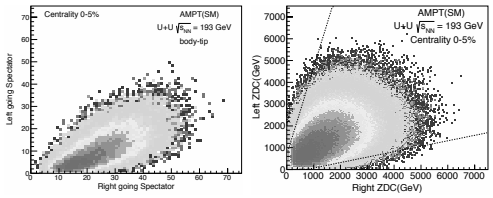

FIG. 2: (a) Distribution of spectator neutrons in body-tip configuration for central($0 - 5\%$) U+U collisions. (b) Energy deposition in ZDC by spectator neutrons for all configurations in U+U collisions. Selection of body-tip events is shown by the dotted lines.

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ble body-tip events. We select all the events which lie below these lines, therefore selecting the events with asymmetric spectator neutrons. Since both left-going and right-going nuclei can be in either body or tip orientation, we select these events along both (left and right) axes.

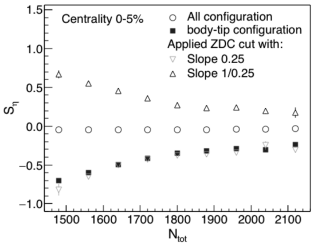

FIG. 3: S_η as function of total multiplicity for minimum bias, pure body-tip events, and selected body-tip events from minimum bias.

One way to differentiate between all possible configurations and the body-tip configurations is to look at the variable S_η which is defined as $S_\eta = \sum \eta(dN/d\eta)/N_{tot}$, where N_{tot} is the number of particles within the pseudo-rapidity range -1.0 < η < 1.0, and the summation is over all particles in the event. Figure 3 shows the variable S_η as a function of N_{tot}. The S_η for minimum bias configurations lies close to zero, suggesting symmetry in particle production. The particle production in body-tip events is asymmetric in η as shown by solid squares in Fig. 3. The difference observed in S_η of selected events and all possible configurations enhances the possibility of our method to select the body-tip events in real experiments.

Now that we have selected body-tip events from all the configurations, we can look at v_2 of selected events. As the overlap region in a central body-tip collision is circular, therefore we expect that the magnitude of the v_2 for selected events should be less compared to minimum bias configuration in U+U collisions. Figure 4 shows the v_2 of charged particles in midrapidity (-1.0 < η < 1.0), measured with respect to the participant plane (ψ_{pp}) for $0-5\%$ central events in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV. The magnitude of charged particle $v_2(p_T)$ in the selected body-tip events are systematically 25% lower than that in all configurations as expected. We also calculated the purity of the selected event sample. More than 70% purity can be achieved using a low slope value (i.e., higher order of spectator neutron asymmetry).

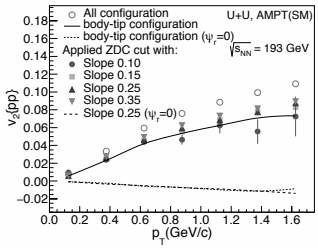

FIG. 4: v_2 as function of p_T for most central($0-5\%$) U+U collisions at $\sqrt{s_{NN}} = 193$ GeV without ZDC cut (open markers) and with ZDC cut (solid markers).

Conclusions

We present an experimental procedure to select the body-tip configuration among all possible configurations in $0-5\%$ central U+U collisions at $\sqrt{s_{NN}} = 193$ GeV. We found that the spectator neutron energy deposited in the zero degree calorimeter is a useful tool to select body-tip oriented events in central U+U collisions. We are able to select a body-tip configuration with conditions applied on spectator neutron asymmetry simulated with the ZDC. We have used a new variable S_η to differentiate between the body-tip and the minimum bias configurations. As expected, elliptic flow, v_2 of selected events is found to be systematically lower than that in all configurations in U+U collisions. The ZDC selection cut (slope) was varied and it was found that selecting events with higher spectator neutron asymmetry results in lower v_2 values which tends to match with v_2 of pure body-tip events. We observed that purity of selected body-tip events increases for decreasing slope parameter.

Acknowledgments

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References

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[2] S. Chatterjee and P. Tribedy, Phys. Rev. C **92** (2015) 1, 011902.