

The centrality dependence of high p_T π^0 production in d-Au collisions



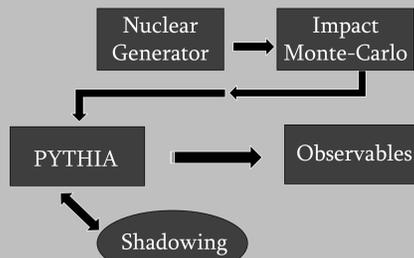
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Abstract

We study the correlation between jet production in d -Au collisions and the number of charged particles produced (N_{chg}), which allows collisions to be binned in centrality. The Hulthén distribution is used to sample the spatial distribution of nucleons in deuteron, Woods-Saxon distribution with excluded volume are used for the nucleus. Collisions are carried out by modifying the PYTHIA event generator for p/n - p/n collisions. Exact energy conservation, in a collision of one nucleon (from the d) with a column of N nucleons (from Au), is incorporated by elevating one nucleon in a p - p collision to a “super” nucleon, enhancing the parton distribution functions by N . We include a new implementation of a transverse density dependent event-by-event shadowing. The results for high p_T π^0 production, binned in centrality by the number of charged particles produced, is compared with data from PHENIX [1]. Due to less energy available for particle production after the production of a hard jet pair, central events (in terms of N_{bin}) produce fewer particles and are identified as peripheral events based on number of charged particles produced. This “mis-binning” leads to the observed enhancement in peripheral events.

Code Flow



Method

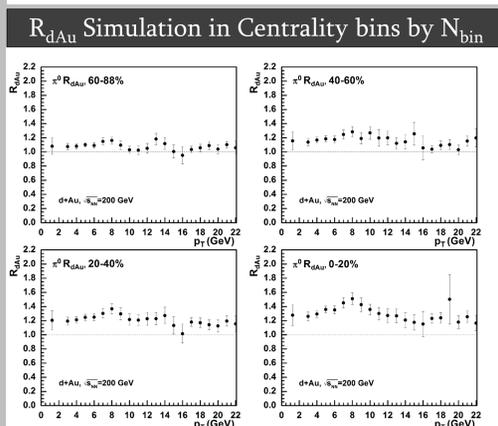
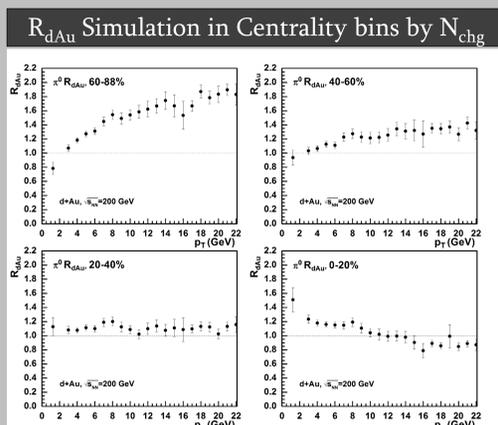
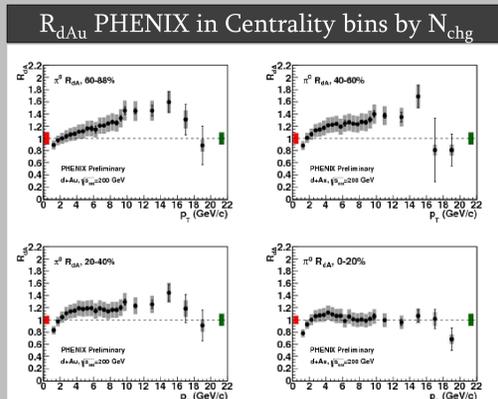
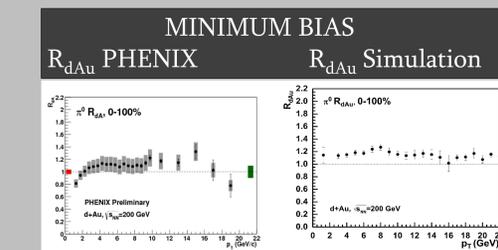
- 1) Generate the heavy nucleus (Au) and deuteron (d) by sampling a Woods-Saxon distribution for Au and a probability distribution based on the Hulthén wavefunction for deuteron. In addition, a nucleon exclusion volume was implemented in the generation for both nuclei.
- 2) After generation, nuclei are flattened along the z -direction and an impact parameter is chosen. The center-of-mass (CM) of the deuteron is shifted relative to the position of the CM of the Au nucleus.
- 3) The number of binary collisions (N) is counted for each nucleon in d (and in addition, other preliminary data can be recorded, such as the event's impact parameter or the average number of collisions per nucleon).
- 4) From here, the code is integrated with a modified version of PYTHIA. This allows experimental observables to be generated and analyzed. The Parton Distribution Function (PDF) calls within PYTHIA were modified with an E-by-E implementation of shadowing based on the function $[S(x)]$ of Li and Wang [2], as well as a factor to allow the PDF calls to be enhanced.

$$F_N(x) = N \times S(x) f(x)$$

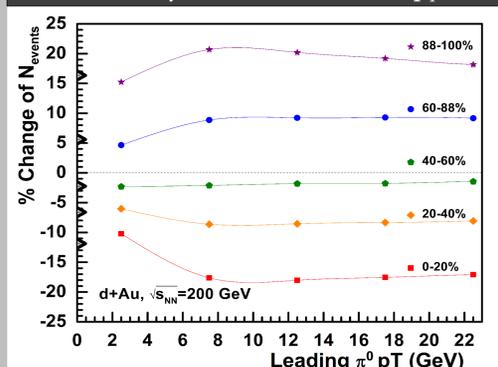
This allows for event-by-event shadowing to be implemented as well as multiple nucleon collisions. In addition, these modifications allow for both the number of protons and neutrons to be accounted for.

- 5) For the purposes of experimental comparison, the number of charged particles and the p_T of produced π^0 's were recorded for each event. Phase space cuts within PYTHIA were invoked to force the allowable hard p_T of one of the p -(*super*) p collisions into a number of ranges (e.g. 3-5, 5-10 GeV). The corresponding p - p cross-section for that range were used to calculate the R_{dAu} .

Plots



Event Shifting Percentages for different centrality bins as a function of p_T



Analysis

For the generated events, the number of binary collisions, the number of charged particles and the p_T of produced π^0 's were recorded. Over all events, binning was performed by sorting the π^0 's into bins of 0-20%, 20-40%, 40-60% and 60-88% in both N_{bin} and N_{chg} (each performed separately). The bins were constructed by integrating from the upper end of each distribution. Once events were binned, a histogram of π^0 p_T 's was generated for each hard p_T phase space cut. $dN/dp_T d\eta$ was calculated from each of these histograms after scaling each by the corresponding p - p cross-section; these were then summed in order to produce a “full” $dN/dp_T d\eta$ for each centrality bin. R_{dAu} was then calculated for each by dividing by the p - p π^0 p_T spectrum generated from PYTHIA. These results can then be directly compared with PHENIX's results.

To quantify effects of events shifting between centrality bins, events were tracked by which bin they were in by N_{bin} and N_{chg} , then a percent change in the events for each bin (using N_{bin} as the “original” bin for an event), was calculated for different leading π^0 p_T ranges (e.g. 3-5, 5-10 GeV ...).

Results

Binning the d -Au events by N_{chg} reproduces the experimental data for R_{dAu} of π^0 's. However, binning by N_{bin} gives a different result, one that matches the more naïve expectation that nuclear effects should have a greater impact for central collisions compared to peripheral. The minimum bias R_{dAu} also matches the experimental data.

Examining the plot of event shifting in and out of each bin as a function of the p_T of the leading π^0 shows that all events have a tendency to drift from more central bins to more peripheral ones, however the effect also depends on p_T . Events with a low p_T (approx. 4 GeV and less) leading π^0 do not shift as much as events with a higher p_T π^0 . This would appear to be the effect driving the enhancement of R_{dAu} for the peripheral bin, as well as the suppression for the central bin.

In essence, the production of a jet in d -Au causes a depletion in charged particle production in that particular event.

Future Plans

- 1) Complete the analysis for PHENIX d -Au, by considering the effect on full jets.
- 2) Extend to p -Pb collisions at LHC energies, and compare with the results from ATLAS [3].
- 3) Extend this simulation into a full A - A event generator:
 - >Extend the nuclear generator to use the Shell Model (with a short-distance repulsion implemented as a perturbation)
 - >Incorporate Hydrodynamic evolution of the same medium.
 - >Incorporate final state jet energy loss within this medium

References

- [1] B. Sahlmueller [PHENIX], “Cold Nuclear Matter Effects in d -Au Collisions at PHENIX,” Nucl. Phys. A904-905, 795c (2013) [arXiv:1210.5547 [nucl-ex]].
- [2] S.-y. Li and X.-N. Wang, “Gluon shadowing and hadron production at RHIC,” Phys. Lett. B 527, 85 (2002) [nucl-th/0110075].
- [3] The ATLAS collaboration, “Measurement of the centrality-dependence of inclusive jet production in p +Pb data at $\sqrt{s_{NN}} = 5.02$ TeV with the ATLAS detector,” ATLAS-CONF-2013-105.
- [4] M. Kordell and A. Majumder, to appear (2014).