J / ψ production in d+Au collisions at √s = 200 GeV in STAR

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Why J/ψ? The production of J/ψ and other heavy quarkonia is of particular interest in relativistic heavy ion collisions. The hypothesised quark gluon plasma (QGP) created in these collisions is expected to suppress the yields of quarkonia states due to color screening in the hot, dense matter. Since heavy quarkonia are produced in the initial hard scattering of the collision, they can be used to probe the QGP.

Why d+Au? There are other in-medium effects (recombination, cold nuclear effects, etc.) which can further suppress or enhance the final state yields of J/ψ. To properly understand the effects of the medium on charmonia in heavy systems such as Au+Au and intermediate systems like Cu+Cu, we must first understand the modification of yields due to a nuclear medium where no hot matter is present. Light systems such as p+p, p+A and d+A allow us to investigate the cold nuclear effects on particle production.

We present the analysis of J/ψ production in minimum-bias d+Au collisions at √s = 200 GeV (year 2008) with the STAR detector. Since this run is the first operation of the STAR detector after the removal of the material surrounding the beam pipe, we observe a much cleaner signal and a significant decrease in the number of background electrons, as compared to previous runs.

1. STAR Detector

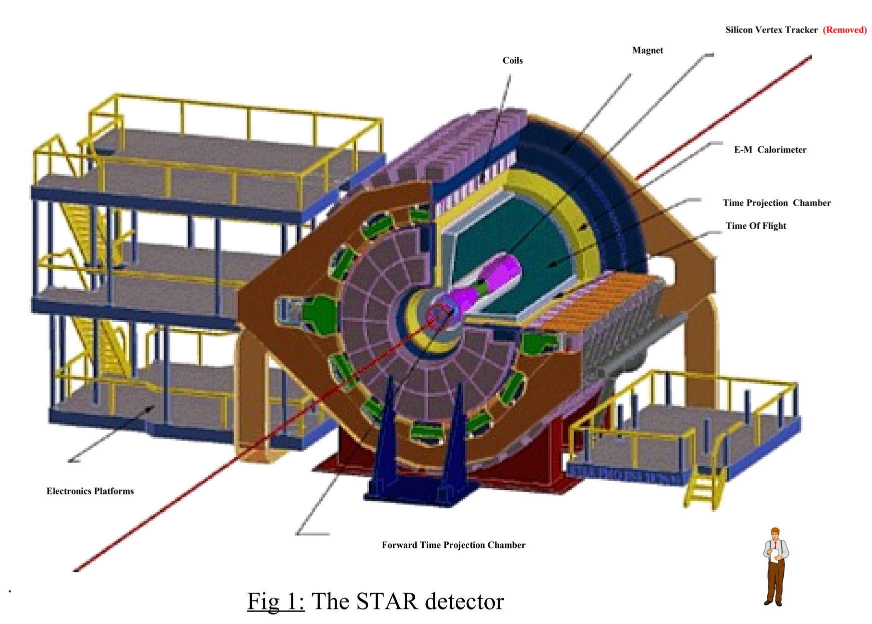

Fig 1: The STAR detector

The **Solenoidal Tracker at RHIC (STAR)** is a large acceptance experiment comprising of several different subdetectors, shown in figure 1. The two subdetectors used in this analysis are the Time Projection Chamber and the Barrel Electromagnetic Calorimeter.

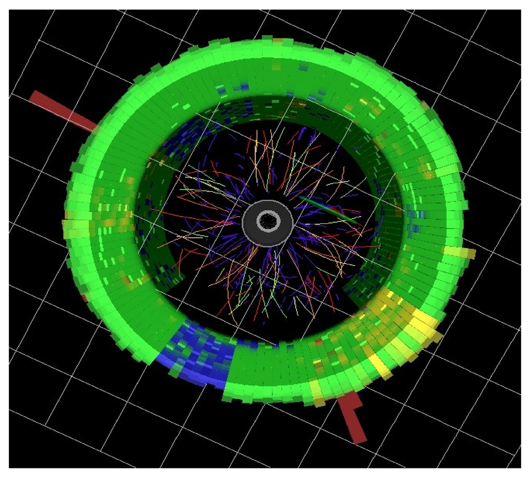

Fig 2: Hits in the Barrel Electromagnetic Calorimeter

Time Projection Chamber (TPC)
The Time Projection Chamber surrounds the beam pipe with full azimuthal coverage and pseudo-rapidity coverage over the range of $-1 < \eta < 1$. The 4m in diameter and 4.2m long chamber is filled with 10% methane 90% argon gas. Particles moving through the TPC lose energy by ionizing atoms in the gas, and electrons from these atoms drift towards the TPC endcaps. The momentum of particles moving through the TPC is calculated from the track curvature with a resolution of **δp/p ~ 2%** at 1 GeV/c in 200 GeV d+Au. Measuring the ionization energy loss allows for particle identification.

Barrel Electromagnetic Calorimeter (BEMC)
The BEMC is a lead-scintillator sampling eletromagnetic calorimeter which surrounds the TPC. It has 120 modules which cover the full 2π in azimuth and pseudorapidity in the range $-1 < \eta < 1$. The energy deposited in the towers can be used to discriminate between hadrons and electrons.

2. J/ψ Reconstruction

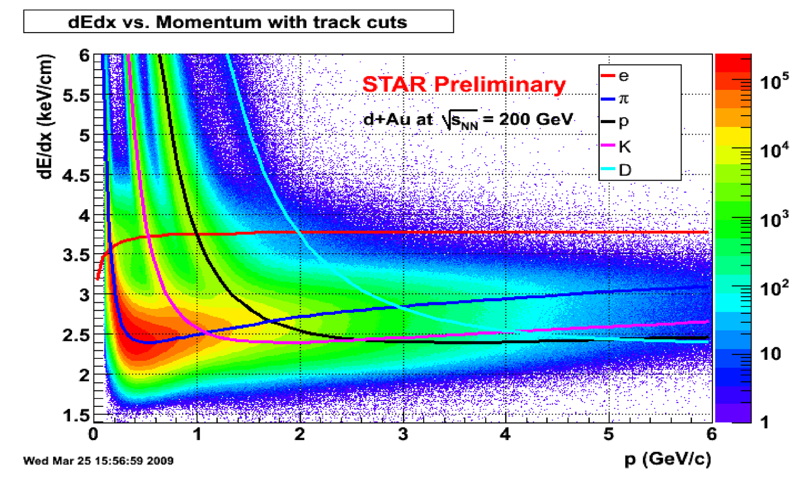

Fig 3: dE/dx vs. momentum for all particles in d+Au at 200 GeV

How do we find J/ψ?
We focus on finding J/ψ via the di-electron decay channel

$$J/\psi \rightarrow e^+e^- \quad (6\%)$$

Electrons have been identified using both the TPC and BEMC. These are then used to reconstruct the mass of the initial parent J/ψ. We will require tracks to have p_T **> 1 Gev/c** to improve on particle identification.

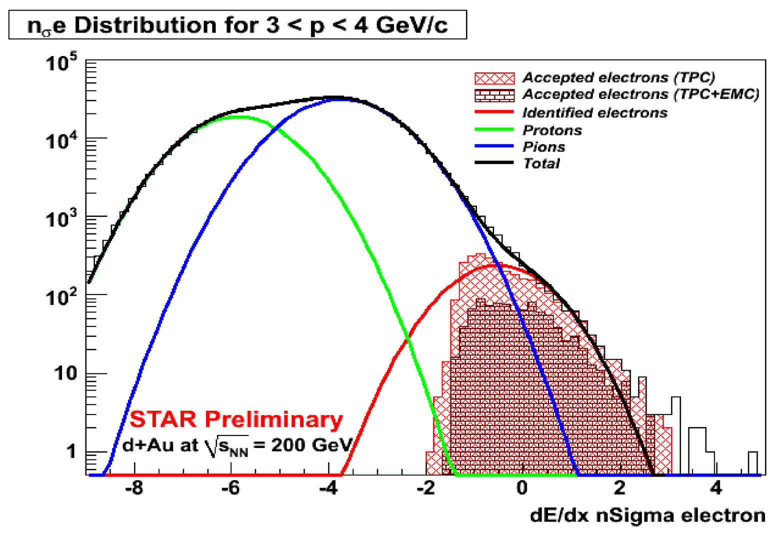

Fig 4: dE/dx for tracks with momentum 3 - 4 GeV/c in d+Au 200 GeV collisions

TPC Electron Identification
Figure 3 shows the dE/dx of particles created in d+Au collision. We define

$$n\sigma_e = \log\left(\frac{dE/dx\,|_{measured}}{dE/dx\,|_{actual}}\right)/\sigma$$

which is shown in figure 4 for tracks with 3 < p < 4 GeV/c. We identify electrons as tracks with:

$|n\sigma_e| < 3$ $\quad |n\sigma_p| > 2.5$
$|n\sigma_\pi| > 2.5$ $\quad |n\sigma_K| > 2.5$

indicated by the shaded light red region in figure 4.

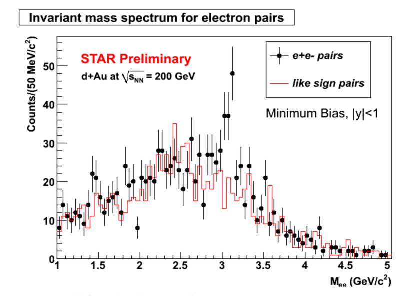

Fig 5: Invariant mass spectrum using TPC PID

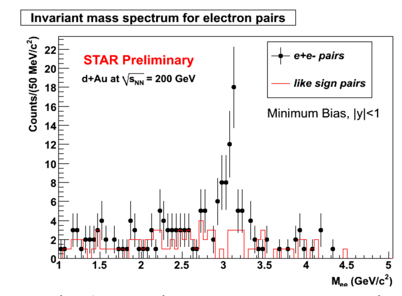

Fig 6: Invariant mass spectrum using TPC + BEMC PID

BEMC Electron Identification
The ratio of an electrons momentum to the energy it deposits in a tower of the BEMC is approximately equal to 1. By requiring that electrons deposit energy in a tower above a threshold, an by further applying the relaxed cut on the p/E ratio:

$$p/E < 2.3$$

we can drastically reduce the background in the invariant mass distribution, indicated by the shaded dark red region in figure 4.

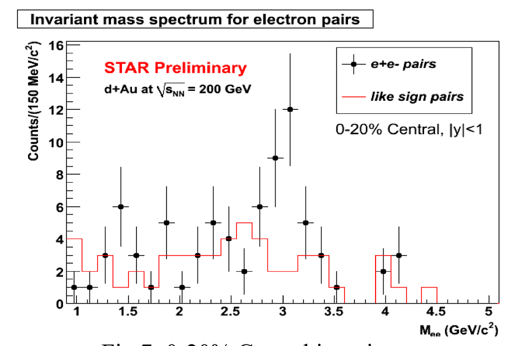

Fig 7: 0-20% Central invariant mass spectrum using TPC + BEMC PID

J/ψ Signal
The uncorrected invariant mass spectrum for e^+e^- pairs is shown in figure 5 (TPC), and figure 6 (TPC + BEMC). The combinatorial background has been calculated using the like-sign technique, and is shown in these plots in red.

By requiring that electrons have valid BEMC information significantly reduces the background. Shown in figure 7 is the invariant mass spectrum for 0-20% central collisions (TPC+BEMC). Analysis of more peripheral events is in progress.

3. Efficiency Corrections

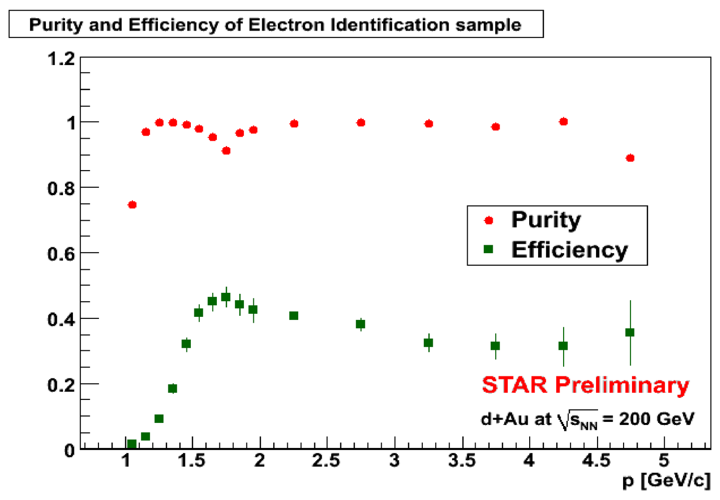

Fig 8: Purity and efficiency of the electron identification cuts

Identification Efficiency Using electron dE/dx projections like figure 4, the total number of electrons has been estimated in the momentum range. This has been compared to the accepted number of electrons after using TPC and BEMC electron identification. The particle identification (PID) efficiency of the electron selection criteria is defined as:

$$\varepsilon_{PID} = \text{electrons}_{Accepted} / \text{electrons}_{Total}$$

The efficiency of identifying a J/ψ is then the product of the individul efficiencies for identifying the daughter electrons. The electron identification efficiency and purity has been plotted, and is shown in figure 8.

Reconstruction Efficiency To determine the track reconstruction efficiency in the TPC, J/ψ particles are simulated and embedded into actual events. The total number of reconstructed J/ψ's is compared to the number of simulated input J/ψ's. The efficiency is defined as:

$$\varepsilon_{REC} = J/\psi_{out} / J/\psi_{in}$$

The J/ψ efficiency (using TPC+BEMC) is defined as the product of the daughters electron identification efficiencies with the J/ψ reconstruction efficiency. The total efficiency and acceptance has been calculated as a function of J/ψ p_T within rapidity |y|<0.5, shown in figure 9.

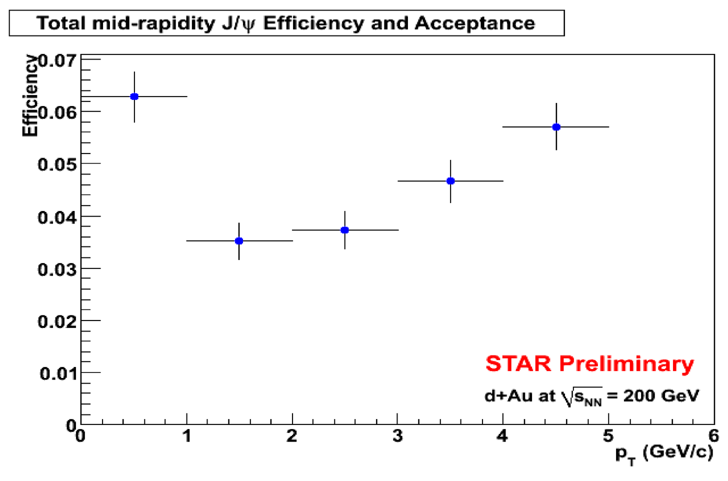

Fig 9: Efficiency for mid-rapidity J/ψ in d+Au

4. J/ψ Yield in d+Au

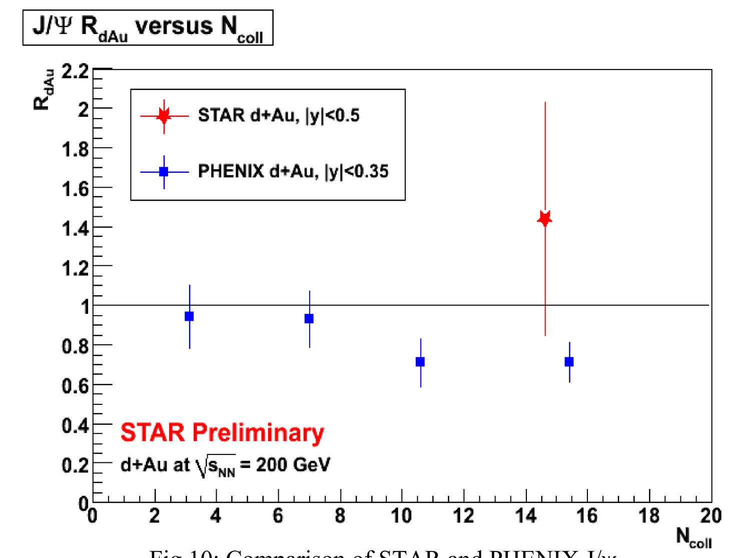

Fig 10: Comparison of STAR and PHENIX J/ψ data with statistical errors only

The corrected yield has been found by applying efficiency calculations to the accepted J/ψ's. The corrected mid-rapidity J/ψ invariant yield in 0-20% central d+Au collisions has been calculated to be:

$$\frac{dN}{dy} = (2.9 \pm 1.2) \times 10^{-5}$$

Using Glauber models, the number of binary collisions for 0-20% collisions in d+Au is found` to be N_{coll} **= 14.6**. The invariant yield has been scaled by N_{coll} and the STAR J/ψ p+p data [1] to obtain R_{dAu} in 0-20%:

$$R_{dAu} = \frac{dN^{dAu}/dy}{N_{coll}\, dN^{pp}/dy} = 1.4 \pm 0.6$$

This is shown in figure 10 in red, and is compared to PHENIX data [2] in blue. Only statistical errors are shown.

5. Conclusion

"Low material" run (after removal of the material surrounding the beam pipe) has resulted in a clear J/ψ signal, visible even before background subtraction (significance ~ 5.7σ).

The preliminary result of the J/ψ nuclear modification factor for central 20% mid-rapidity d+Au collisions is $R_{dAu} = 1.4 \pm 0.6$.

Further analysis of peripheral events is underway. This is a work in progress.

References

[1] *J/Psi Production in pp collisions at √s = 200 GeV in the STAR experiment,* STAR Collaboration, M. Cosentino
[2] *Cold Nuclear Matter Effects on J/Psi as Constrained by Deuteron-Gold Measurements at sqrt(s_NN) = 200 GeV,* PHENIX Collaboration, A. Adare, et al