Study of J/ψ Reconstruction and Analysis for 15 AGeV Ni+Ni Collisions

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Outline

Motivation

- J/ψ suppression in relativistic nuclear collision is a signal of QGP(T. Matsui,H.Satz. PLB,1986).
- Inside a plasma ,debye screening hinders binding of $c\bar{c}$ quarks to resonance states leading to J/ψ suppression.
- Many non-QGP effect also lead to significant J/ψ suppression such as Colde Nuclear Matter(CNM).
- Kinematic threshold for J/ψ suppression production in elementary p+N collision: $p + N \rightarrow p + N + J/\psi$ ($\sqrt{s}_{\text{th}} = 4.9$ GeV ,E_{b}=12.5 AGeV) .

Motivation

- Maximum energy of the heavy ion beam at FAIR SIS-100: E_b=11A GeV.
- J/ψ production in heavy ion collision kinematically forbidden at FAIR.
- Light ion collisions(Z/A =0.5),E_b may go up to 15 A GeV. J/ψ production(close to threshold energy) are allowed.
- Possibly no QGP effect: useful to probe effects of CNM and hot dense matter

Simulation Setup

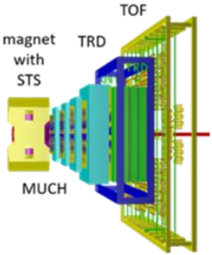


Figure: Geometry of sis100-jpsi setup.

Simulation Details:

- Event Generator:UrQMD(Background)and Pluto($J/\psi \rightarrow \mu^+ + \mu^-$)
- Setup:sis100-muon-jpsi
  Sub dectectors:STS(**v22d**), MuCh(**v22a-jpsi**).TRD(**v24c-1m**), TOF(**v21a-1m**).
- System:Ni+Ni 15AGeV Central
- Events:1M
- Transport engine:GEANT3
- Beam energy:15A GeV.

Pluto: `/lustre/cbm/prod/gen/pluto/nini/charm/15gev/jpsi/mpmm`

UrQMD: `/lustre/cbm/prod/gen/urqmd/nini/15gev/centr`

Muon Chamber for J/ψ Detection

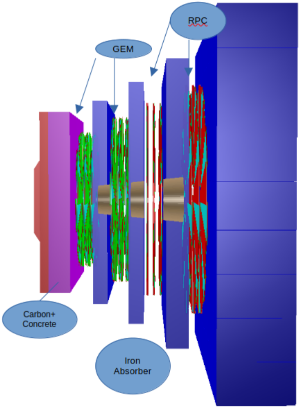


Figure: Schematic of the Muon Chamber setup

- The Muon Chamber (MUCH) is designed to detect muons from $J/\psi \rightarrow \mu^+\mu^-$ decays.
- First two station made by GEM and 3rd and 4th sation made by RPC .
- First absorber made with (Carbon(28cm)+Concrete(30cm)) and remaining are made with Iron(20cm,20cm,30cm,100cm)
- We used segmented absorber for momentum dependent muon measurement.

Input Distribution from Pluto

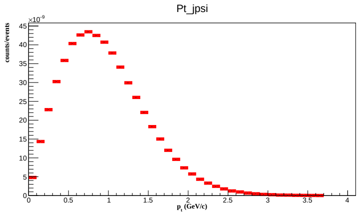


Figure: p_T distribution.

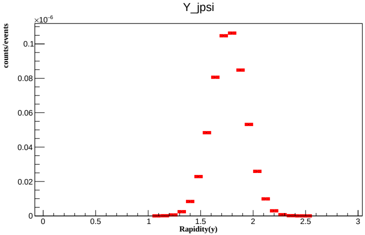


Figure: Rapidity distribution.

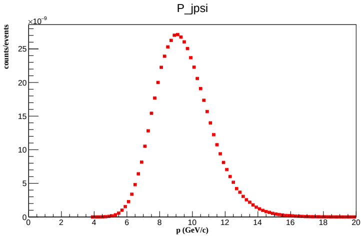


Figure: P distribution.

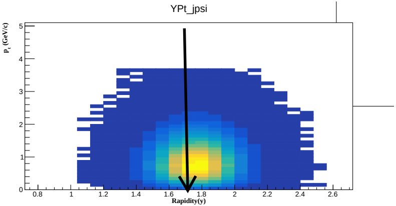


Figure: Y-p_T distribution.

Accepted Monte Carlo Track Kinematics

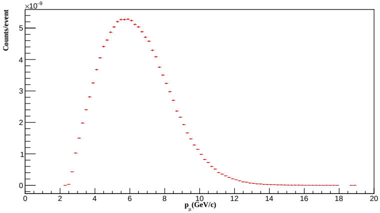


Figure: P_{μ} distribution of single muon.

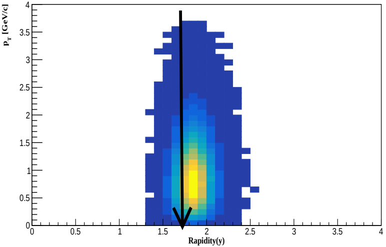


Figure: Y-p_T distribution of accepted muon pair.

- **Accepted MC track:** with MC truth, at least `7 STS points`, `11 MuCh points`, `1 TRD point`, and `1 TOF point`.
- A small shift in rapidity $\delta y \approx 0.1$ has been observed in forward direction due to absorber.

Estimation of J/ψ Multiplicity

- At FAIR energies, J/ψ production is dominated by hard scatterings. The J/ψ yield at an impact parameter b is given by:

$$N_{J/\psi}^{Ni+Ni}(b) = T_{NiNi}(b) \times \sigma_{NN}^{J/\psi}$$

- The nuclear overlap function $T_{NiNi}(b)$ is calculated using the Glauber model.

$$p_{\text{inel}}(b) = 1 - e^{-N_{\text{coll}}(b)}, \qquad N_{\text{coll}}(b) = \sigma_{NN}^{\text{inel}} \times T_{NiNi}(b)$$

$$\sigma_{NN}^{\text{inel}} \approx 30 \text{ mb}$$

$$\langle N_{J/\psi} \rangle_{Ni+Ni} = \frac{\int d^2b \; p_{\text{inel}}(b) \; N_{J/\psi}(b)}{\int d^2b \; p_{\text{inel}}(b)}$$

$$\Rightarrow \langle N_{J/\psi} \rangle_{Ni+Ni} = \sigma_{NN}^{J/\psi} \times \langle T_{NiNi} \rangle$$

Estimation of J/ψ Multiplicity

Similarly

$$\langle N_{J/\psi} \rangle_{Au+Au} = \sigma_{NN}^{J/\psi} \times \langle T_{AuAu} \rangle$$

$$\Rightarrow \langle N_{J/\psi} \rangle_{Ni+Ni} = \frac{\langle N_{J/\psi} \rangle_{Au+Au}}{\langle T_{Au+Au} \rangle} \times \langle T_{NiNi} \rangle$$

From Glauber model:

$$\langle T_{NiNi} \rangle = 18.63 \text{ fm}^{-2}, \langle T_{AuAu} \rangle = 82.37 \text{ fm}^{-2}$$

From HSD model:

$$\boxed{\langle N_{J/\psi} \rangle_{Au+Au} \approx 2.44 \times 10^{-6}}$$

Finally:

$$\boxed{\langle N_{J/\psi} \rangle_{Ni+Ni} \approx 5.518707 \times 10^{-7}}$$

Interpretation: Predicted average J/ψ multiplicity in Ni+Ni collisions at 15A GeV.

Input Accepted Reconstructed Track(Single Muon)

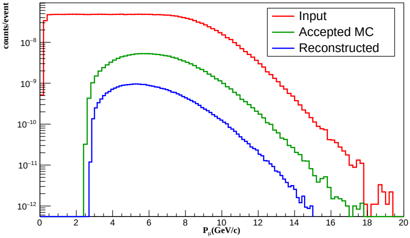


Figure: Input and Accepted, Reconstructed distribution of P_μ.

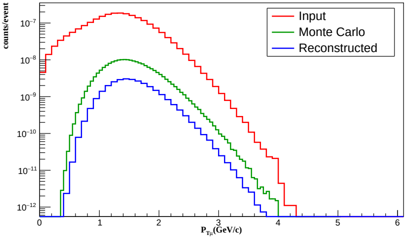


Figure: Input and Accepted,Reconstructed p_T distribution of single muon.

Input Accepted Reconstructed Track(Pair Muon)

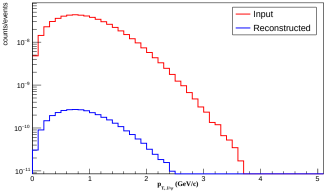


Figure: Input and Reconstructed p_T distribution of J/ψ.

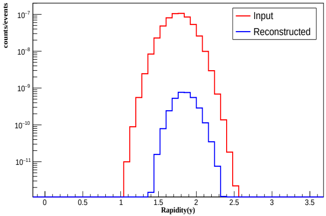


Figure: Input and Reconstructed Y distribution of J/ψ.

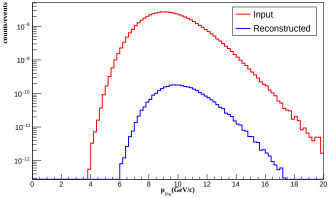
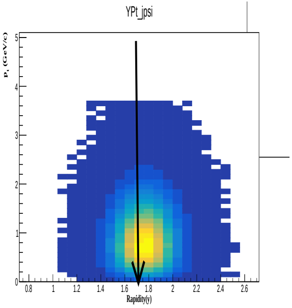
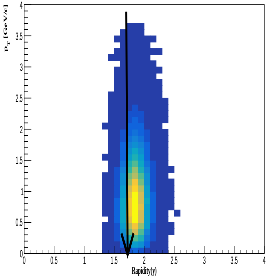
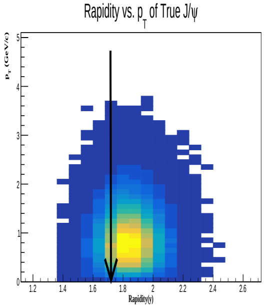


Figure: Input and Reconstructed P_J/ψ distribution.

y-p_T Phase Space Distribution(Pair Muon)







Input **Accepted MC Track** **Reconstructed**

$$E = m_T \cosh(y) \quad \Rightarrow \quad \text{For beam: } p_T = 0 \Rightarrow E_b = m_N \cosh(y_b)$$

$$\Rightarrow \quad y_b = \cosh^{-1}\left(\frac{15}{0.94}\right) \approx 3.46, \quad y_m = \frac{y_b}{2} \approx 1.73$$

A small shift in rapidity $\delta y \approx 0.1$ has been observed in forward direction due to absorber.

Invariant Mass Distribution (Signal)

- Invariant mass of reconstructed $\mu^+\mu^-$ pairs:

$$M_{\mu^+\mu^-} = \sqrt{(E_{\mu^+} + E_{\mu^-})^2 - (\vec{p}_{\mu^+} + \vec{p}_{\mu^-})^2}$$

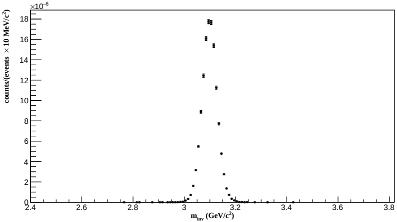


Figure: Invariant mass distribution of pure signal(MC Truth).

- **Reconstructed muon track candidate:** A global track with associated at least 7 STS hits, 11 MuCh hits, 1 TRD hit, and 1 TOF hit. Additional quality cuts applied: $\chi^2_{\text{vertex}} \leq 3$, $\chi^2_{\text{MuCh}} \leq 3$, $\chi^2_{\text{STS}} \leq 3$.

- Background estimated using:
  - Superevent(SE) method .
- Signal extracted via Gaussian + polynomial fit(pol2).

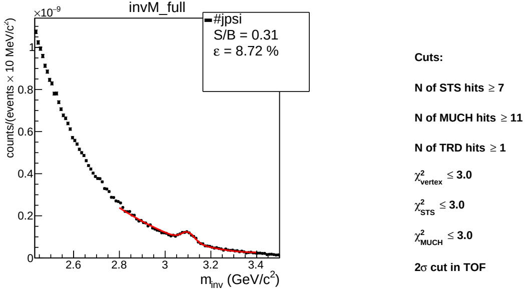


Figure: Invariant mass with signal+background.

Efficiency vs p_T and Rapidity

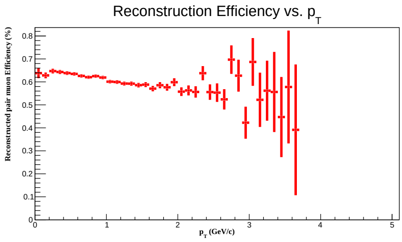


Figure: Efficiency vs p_T distribution

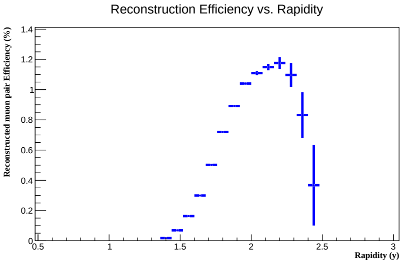


Figure: Efficiency vs Rapidity distribution

- Left: Efficiency as a function of transverse momentum (p_T).
- Right: Efficiency as a function of rapidity (y).
- Both obtained from reconstructed J/ψ candidates.

Summary and Conclusion

- Preliminary result for reconstruction of J/ψ in light ion collision at FAIR SIS-100 .
- Estimation of J/ψ yield..
- Repeat the simulation with realistic MuCh setup(2 GEM +2 Straw Tube(STT)) for:
    1. Higher statistics
    2. Different p+A system
    3. Different background estimation technique

Thank You!