Production of charmed hadron

1. Charm SPD & FF
2. Production of charmed meson
3. J/ψ production in Au+Au @200GeV
4. Two jets contribution
5. Apply SPD to calculate the di-hadron correlation of J/ψ on near and away sides

The fragmentation function (FF) $D_i^H(x)$

$$xD(x) = \int_0^x \frac{dx_1}{x_1} \int_0^x \frac{dx_2}{x_2} \{S_i^q(x_1), S_i^{\overline{q'}}(x_2)\} R(x_1, x_2, x)$$

where
$$\{S_i^q(x_1), S_i^{\overline{q'}}(x_2)\} \equiv \frac{1}{2}\left[S_i^q(x_1) S_i^{\overline{q'}}\left(\frac{x_2}{1-x_1}\right) + S_i^q\left(\frac{x_1}{1-x_2}\right) S_i^{\overline{q'}}(x_2)\right]$$

Parametrized SPD
$$S_i^j(z) = Az^a(1-z)^b\left(1+cz^d\right)$$
$i = c,\ g$ and $j = c,\ \bar{c},\ u(\bar{u})$ or $d(\bar{d})$

Q=3GeV/c

RF
$$R_M(x_1, x_2, x) = \frac{1}{B(a,b)}\left(\frac{x_1}{x}\right)^a \left(\frac{x_2}{x}\right)^b \delta\left(\frac{x_1}{x} + \frac{x_2}{x} - 1\right)$$

1.Charm SPD & FF

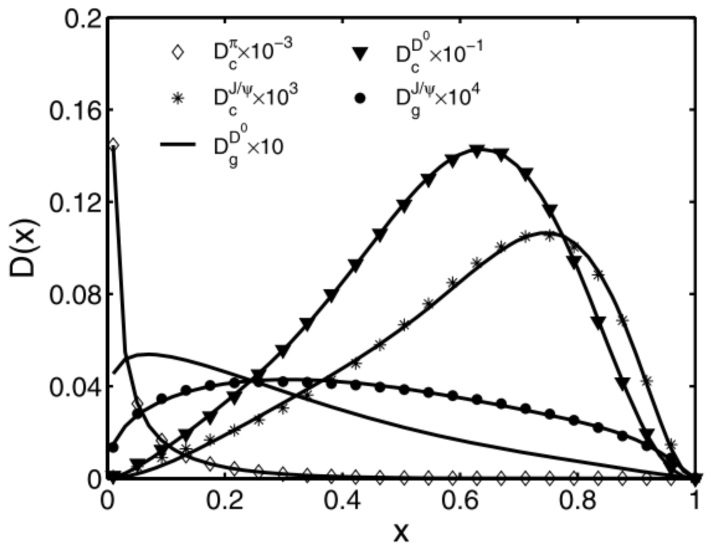

Fig. 1. Fragmentation functions of $D_g^{J/\psi}$ [19], D_c^{π} [20], $D_c^{D^0}$ [21] and $D_c^{J/\psi}$ [22] are shown in symbols, and the calculated results from the recombination model are shown by the solid curves. The curve without any symbol stands for the predicted result of $D_g^{D^0}$.

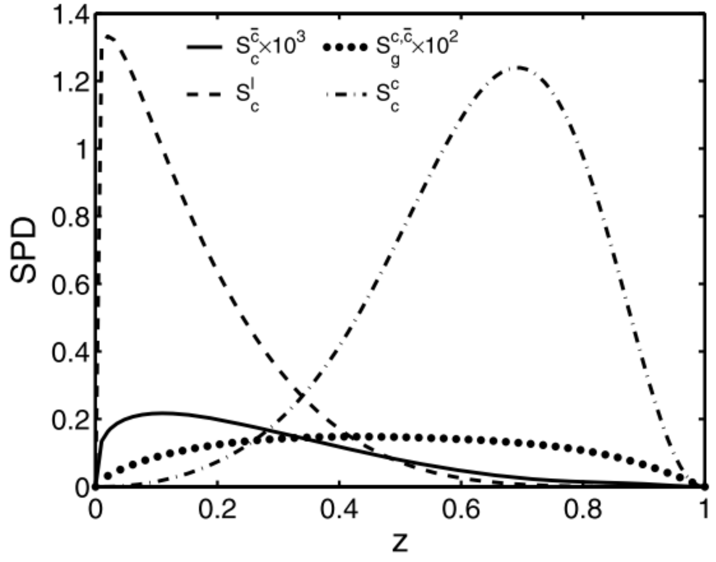

Fig. 2. Shower parton distributions determined from the recombination model, represented with the parameters given in Table 1.

2.Production of charmed meson

Meson production
$$\frac{dN_M}{d^2p}=\frac{d(N_M^{\mathcal{TT}}+N_M^{\mathcal{TS}}+N_M^{\mathcal{SS}})}{d^2p}.$$

Q1:通过FF*RF得到？

$$\frac{dN_M^{\mathcal{TT}}}{d^2p}=C_M M_T\frac{\tau A_T}{(2\pi)^3}2\gamma_a\gamma_b I_0[\frac{\mathrm{psinh}\eta_T}{T}]\int_0^1 dx|\phi_M(x)|^2 k_M(x,p).$$

$$\frac{dN_M^{\mathcal{TS}}}{d^2p}=C_M\int_\Sigma d\sigma_R\frac{p^\mu u_\mu(R)}{(2\pi)^3}\int_0^1 dx|\phi_M(x)|^2$$
$$[\omega_a(R,p_1)\mathcal{S}_b(R,p_2)+\mathcal{S}_a(R,p_1)\omega_b(R,p_2)]$$

$$\frac{dN_M^{\mathcal{SS}}}{pdp}=\frac{1}{p^0p}\sum_i\int\frac{dq}{q}F_i'(q)\frac{p}{q}D_i^M(\frac{p}{q})$$

2.Production of charmed meson

第一项 $$\frac{dN_M^{TT}}{d^2p}=C_M M_T\frac{\tau A_T}{(2\pi)^3}2\gamma_a\gamma_b I_0[\frac{p\sinh\eta_T}{T}]\int_0^1 dx|\phi_M(x)|^2 k_M(x,p).$$

$$k_M(x,p)=K_1[\frac{\cosh\eta_T}{T}(\sqrt{m_a^2+p_1^2}+\sqrt{m_b^2+p_2^2})]$$

Wave function $$|\phi_M(y_1)|^2=\frac{1}{B(a,b)}y_1^{a-1}(1-y_1)^{b-1}.$$

2 fitted parameters

J/ψ $\quad v_T=0.3c,\quad \gamma_c=0.260.$

$$v_T=\tanh\eta_T$$

D^0 $\quad v_T=0.42c$

2.Production of charmed meson

第二项

$$\frac{dN_M^{\mathcal{TS}}}{d^2p} = C_M \int_\Sigma d\sigma_R \frac{p^\mu u_\mu(R)}{(2\pi)^3} \int_0^1 dx |\phi_M(x)|^2 [\omega_a(R,p_1)\mathcal{S}_b(R,p_2) + \mathcal{S}_a(R,p_1)\omega_b(R,p_2)]$$

$$\frac{dN_M^{\mathcal{TS}}}{d^2p} = C_M \int_0^1 dx |\phi_M(x)|^2 [\frac{\mathcal{T}_a(p_1)\mathcal{S}_b(p_2)}{g\gamma_a x} + \frac{\mathcal{S}_a(p_1)\mathcal{T}_b(p_2)}{g\gamma_b(1-x)}].$$

$$\mathcal{T}(p) = \frac{g\gamma}{\tau A_T} \int_\Sigma d\sigma_R \frac{p^\mu u_\mu(R)}{(2\pi)^3} \omega(R,p)$$

Q2:formula of thermal ?

SPD in central collision

$$\mathcal{S}(p) = \sum_i \int \frac{dq}{q} F_i(q) S_i^j(p/q)$$

$$F_i(q) = \frac{1}{\beta L} \int_q^{qe^{\beta L}} \frac{dk}{k} f_i'(k)$$

Distribution from fi to Fi

$$F_i(q,\phi,c) = \int d\xi P(\xi,\phi,c) F_i(q,\xi).$$

2.Production of charmed meson

第三项

$$\frac{dN_M^{SS}}{pdp} = \frac{1}{p^0 p} \sum_i \int \frac{dq}{q} F_i'(q) \frac{p}{q} D_i^M(\frac{p}{q})$$

$$F_i'(q) = \frac{1}{\beta L} \int_q^{qe^{\beta L}} dk k f_i(k)$$

3.J/ψ production in Au+Au @200GeV

$$\frac{dN_{J/\psi}^{\mathcal{TT}}}{d^2p} = C_{J/\psi} M_T \frac{\tau A_T}{(2\pi)^3} 2\gamma_c^2 I_0\left[\frac{p\sinh\eta_T}{T}\right]\int_0^1 dx\left|\phi_{J/\psi}(x)\right|^2 k_M(x,p)$$

$$v_T = 0.3c, \qquad \gamma_c = 0.260.$$

$$\frac{dN_{J/\psi}^{\mathcal{TS}}}{d^2p} = \frac{C_{J/\psi}}{g\gamma_c}\left[\mathcal{T}_c(p/2)\mathcal{S}_{\bar{c}}(p/2) + \mathcal{S}_c(p/2)\mathcal{T}_{\bar{c}}(p/2)\right].$$

$$\frac{dN_{J/\psi}^{\mathcal{SS}}}{p\,dp} = \frac{1}{p^0 p}\sum_i \int \frac{dq}{q} F_i'(q)\frac{p}{q} D_i^{J/\psi}\left(\frac{p}{q}\right)$$

3.J/ψ production in Au+Au @200GeV

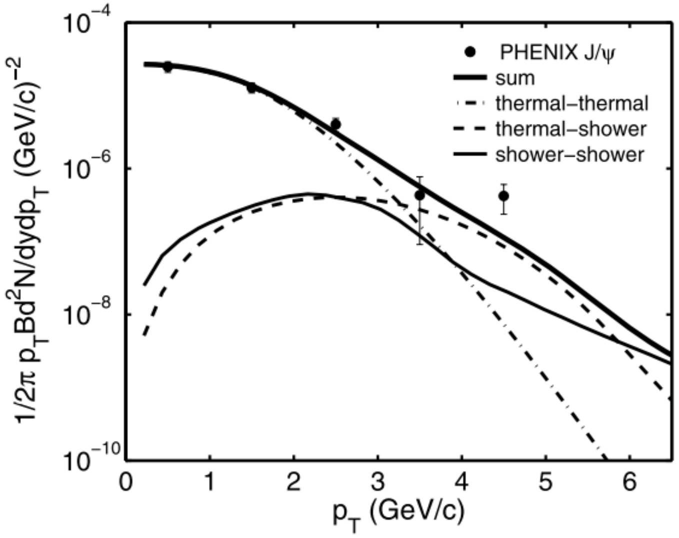

Fig. 4. The transverse momentum spectrum of J/ψ in central Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV (solid) for mid rapidity $|y| < 0.35$. The results are calculated with $T = 175$ MeV. The experimental data are from Ref. [6].

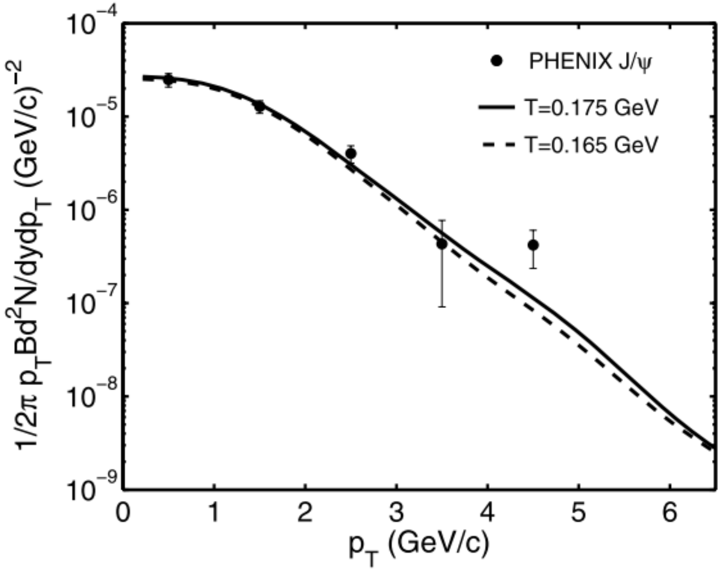

Fig. 5. The transverse momentum spectra of J/ψ in central Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV with $T = 175$ MeV (solid) and $T = 165$ MeV (dashed). The experimental data are from Ref. [6].

4.Two jets contribution

At higher energy or higher jet density, such as LHC, the contribution $\mathcal{SS}(2)$ should be taken into account.

$$\frac{dN^{\mathcal{SS}(2)}}{pdpd\phi} = \frac{1}{p^0 p} \sum_{i,i'} \int \frac{dq}{q} \frac{dq'}{q'} F_i(q,\phi,c) F_{i'}(q',\phi,c) \Gamma(q,q') \times \int \frac{dp_1}{p_1} \frac{dp_2}{p_2} F_{ii'}(q,q';p_1,p_2) R_M(p_1,p_2,p).$$

$$F_{ii'}(q,q';p_1,p_2) = S_i^j\left(\frac{p_1}{q}\right) S_{i'}^{j'}\left(\frac{p_2}{q'}\right)$$

The overlap function $\Gamma(q,q')$ between the two neighboring jets, reflects the probability for the overlap of the two shower partons, relating to $\sqrt{s_{NN}}$.

$$\Gamma = 10^{-n} \text{ with } n = 1, 2, 3 \text{ and } 4.$$

4.Two jets contribution

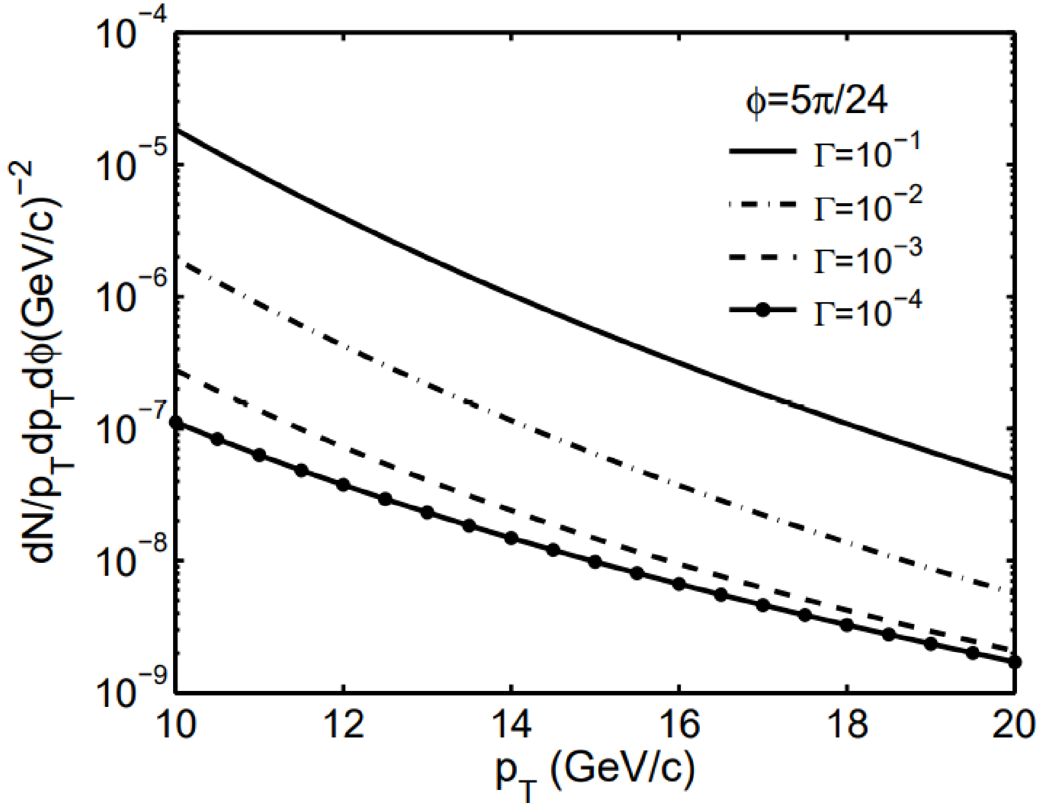

Figure 1. J/ψ distribution as functions of the transverse momentum p_T for the fou different values of Γ.

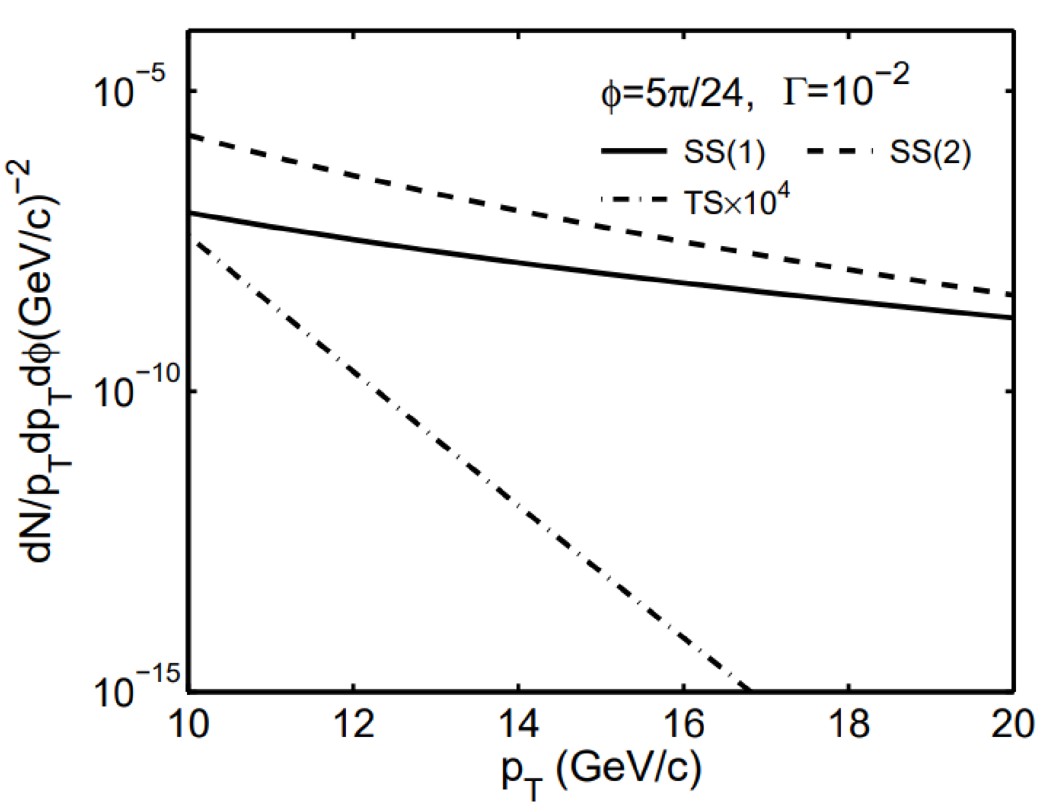

Figure 2. The comparison of three terms for J/ψ with $\Gamma = 10^{-2}$.

4.Two jets contribution

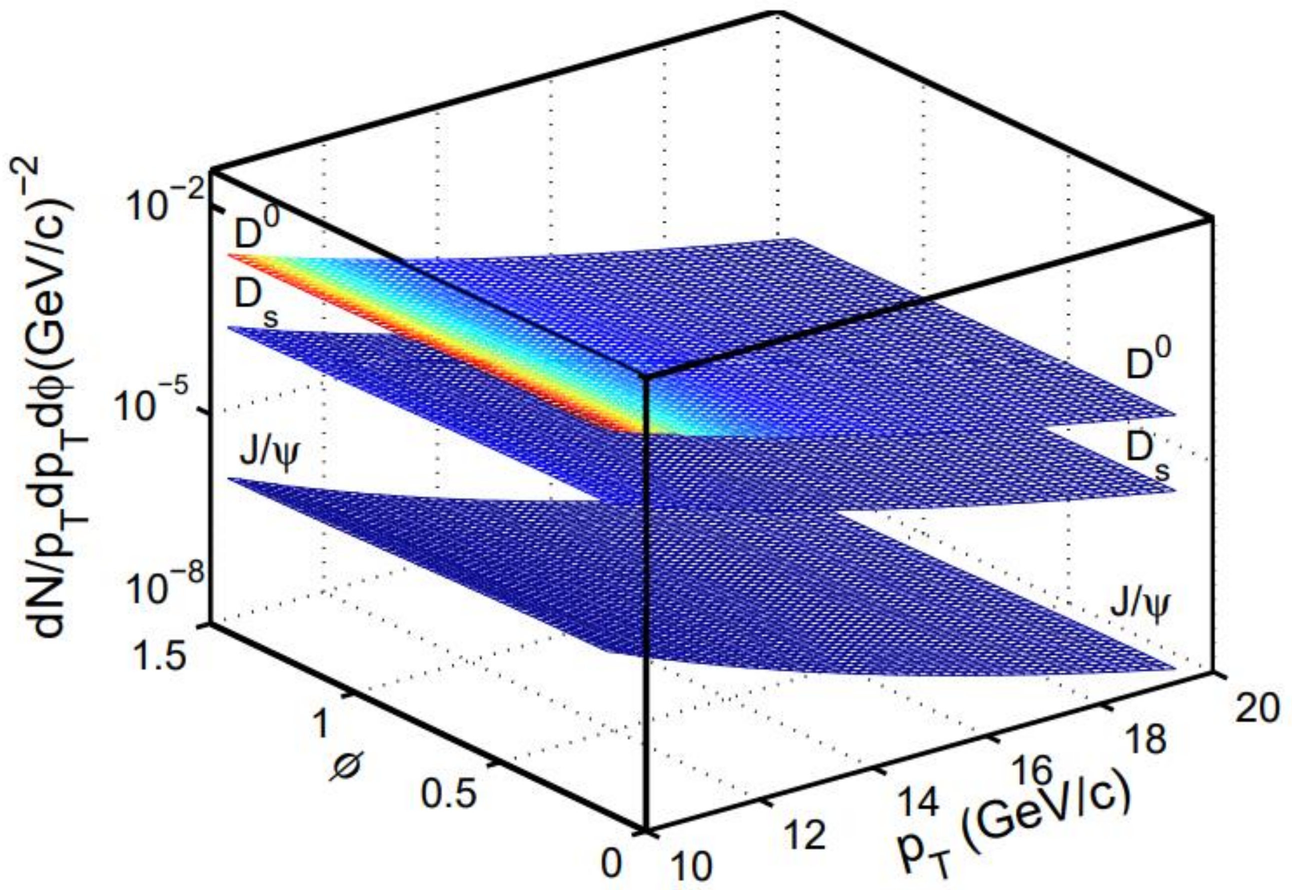

Figure 6. The distribution of J/ψ, D^0 and D_s as functions of the transverse momentum p_T and the azimuthal angle ϕ with $\Gamma = 10^{-2}$.

5.Apply SPD to calculate the di-hadron correlation of J/ψ on near and away sides

Q3: Trigger particle (pi) ? Associated particle (J/ψ) ?
Near side? Away side?

In particle physics, a **diquark**, or **diquark correlation/clustering**, is a hypothetical state of two quarks grouped inside a baryon (that consists of three quarks) (Lichtenberg 1982). Corresponding models of baryons are referred to as **quark–diquark models**. The diquark is often treated as a single subatomic particle with which the third quark interacts via the strong interaction. The existence of diquarks inside the nucleons is a disputed issue, but it helps to explain some nucleon properties and to reproduce experimental data sensitive to the nucleon structure. Diquark–antidiquark pairs have also been advanced for anomalous particles such as the X(3872).[1][2]

can be neglected. Then the correlation of the particle J/ψ with p_a associated with the trigger particle π with p_t on the near side is

$$\frac{dN^{\text{near}}_{\pi,J/\psi}}{p_t dp_t p_a dp_a} = \sum_i \int \frac{dq}{q} F_i(q)\{[\widehat{TS}^{\pi}(q,p_t) + \frac{1}{p_t^0 q} D_i^{\pi}(\frac{p_t}{q})]\widehat{TS}^{J/\psi}(q-p_t,p_a)$$
$$+\widehat{TS}^{\pi}(q-p_a,p_t)\frac{1}{p_a^0 q} D_i^{J/\psi}(\frac{p_a}{q}) + \frac{1}{p_t^0 p_a^0 q^2} D_2(\frac{p_t}{q},\frac{p_a}{q})\}, \quad (9)$$

where the di-hadron FF $D_2(z_1,z_2)$ is assumed as [10]

$$D_2(z_1,z_2) = \frac{1}{2}[D^{\pi}(z_1)D^{J/\psi}(\frac{z_2}{1-z_1}) + D^{\pi}(\frac{z_1}{1-z_2})D^{J/\psi}(z_2)]. \quad (10)$$

The di-hadron distribution of the trigger π and the associated J/ψ with p_b on the away side is calculated in Ref.[10] as

$$\frac{dN^{\text{away}}_{\pi,J/\psi}}{p_t dp_t p_b dp_b} = \frac{e^{\beta L}}{2\beta L}\sum_i \int_{p_t} dq \int_{q_0'}^{qe^{\beta L}} dq' f_i(\sqrt{qq'e^{\beta L}})[\widehat{TS}^{\pi}(q,p_t) + \frac{1}{p_t^0 q} D_i^{\pi}(\frac{p_t}{q})]$$
$$\times[\widehat{TS}^{J/\psi}(q',p_b) + \frac{1}{p_b^0 q'} D_i^{J/\psi}(\frac{p_b}{q'})] \quad (11)$$

with $q_0' = \text{Max}(qe^{-\beta L}, p_b)$. Here, q' is the momentum of the recoil parton in the trigger jet.

5.Apply SPD to calculate the di-hadron correlation of J/ψ on near and away sides

Q4: Yield function?

Then the near-side (away-side) yield per trigger for the trigger momentum in a narrow range Δp_t ($\Delta p_t \to 0$) around p_t is

$$Y_{\pi,J/\psi}^{\text{near(away)}} = \int_{\Delta p_t} dp_t \frac{dN_{\pi,J/\psi}^{\text{near(away)}}}{p_a(p_b)dp_t dp_a(p_b)} \Big/ \int_{\Delta p_t} dp_t \frac{dN_\pi}{dp_t}$$

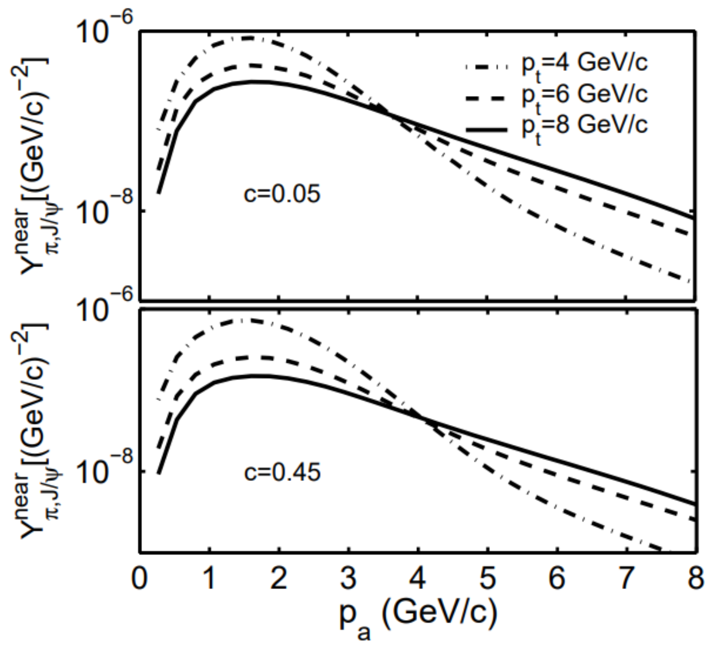

Figure 1: Distribution of associated J/ψ (p_a) on the near side of a jet triggered by a pion with three momenta (p_t) for $c = 0.05$ and $c = 0.45$.

5.Apply SPD to calculate the di-hadron correlation of J/ψ on near and away sides

Elliptic flow v2 ?

$$\frac{dN}{p_T dp_T d\phi} = A(p_T)[1 + 2v_2(p_T)\cos(2\phi)].$$

Relativistic heavy-ion collisions produce very large numbers of subatomic particles in all directions. In such collisions, *flow* refers to how energy, momentum, and number of these particles varies with direction,[1] and **elliptic flow** is a measure of how the flow is not uniform in all directions when viewed along the beam-line. Elliptic flow is strong evidence for the existence of quark–gluon plasma, and has been described as one of the most important observations measured at the Relativistic Heavy Ion Collider (RHIC).[2][3]

Elliptic flow describes the azimuthal momentum space anisotropy of particle emission from non-central heavy-ion collisions in the plane transverse to the beam direction, and is defined as the second harmonic coefficient of the azimuthal Fourier decomposition of the momentum distribution.[4] Elliptic flow is a fundamental observable since it directly reflects the initial spatial anisotropy, of the nuclear overlap region in the transverse plane, directly translated into the observed momentum distribution of identified particles. Since the spatial anisotropy is largest at the beginning of the evolution, elliptic flow is especially sensitive to the early stages of system evolution.[5] A measurement of elliptic flow thus provides access to the fundamental thermalization time scale and many more things in the early stages of a relativistic heavy-ion collision.[4]

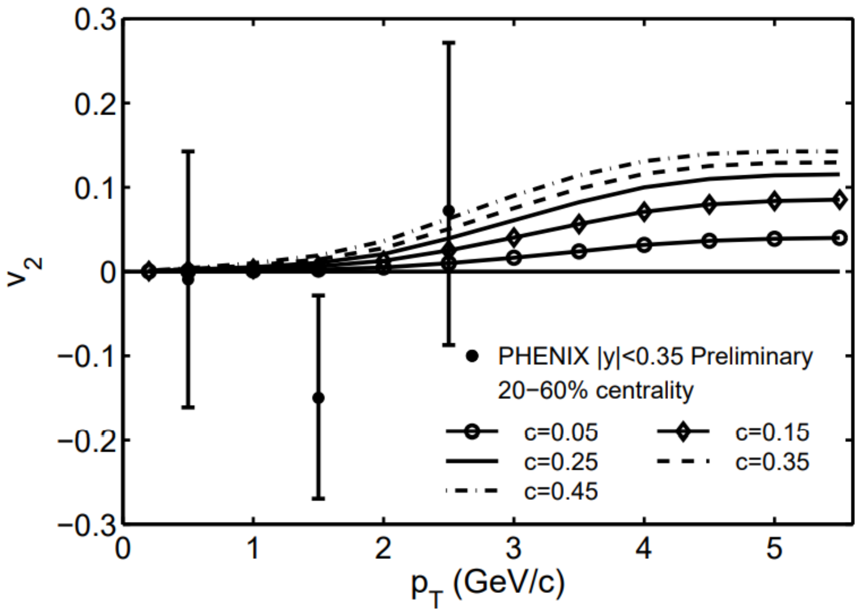

Figure 5: v_2 for J/ψ as a function of p_T in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV for different centralities. The data shown for three p_T's are from [11].

References

[1] J/ψ production and elliptic flow parameter v2 at LHC energy.

[2] J/ψ production in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV in the recombination model.

[3] Productions of Heavy Flavored Mesons in Relativistic Heavy Ion Collisions in the Recombination Model.

[4] π-J/ψ Correlation and Elliptic Flow Parameter v2 of Charmed Mesons at RHIC Energy.

[5] Hadron production in heavy ion collisions: Fragmentation and recombination from a dense parton phase.