# the Distribution of low-pT J/ψ under the Influence of Quark-gluon Plasma

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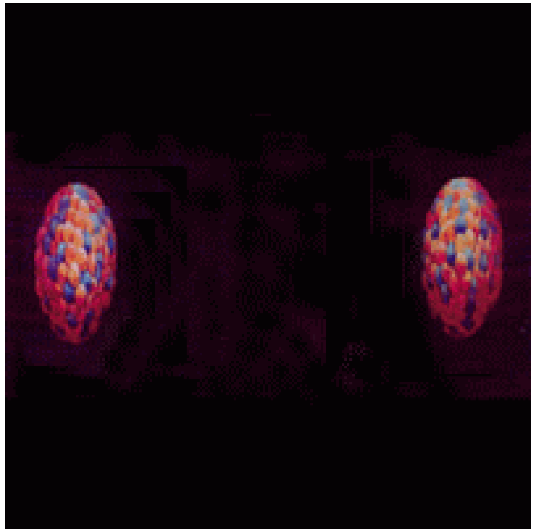
# Background

## 1. Quark-gluon Plasma



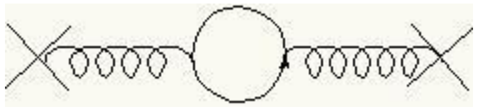
New form of hot deconfined matter

## 2. Research of J/ψ

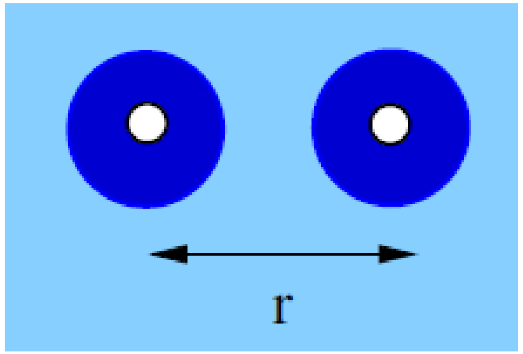
Important Tool to understand Quark-gluon Plasma

# Influence of hot medium on J/ψ

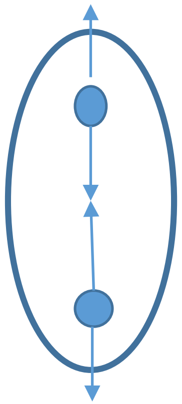
1. Hot medium influence gluon propagator



2. Hot medium influence gluon propagator

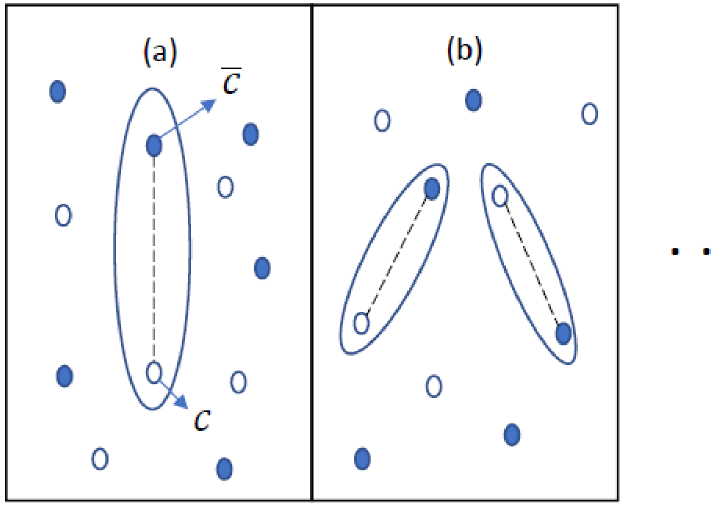



3. medium effect on c quark and cbar



# Motivation

**How to study the three aspects together?**

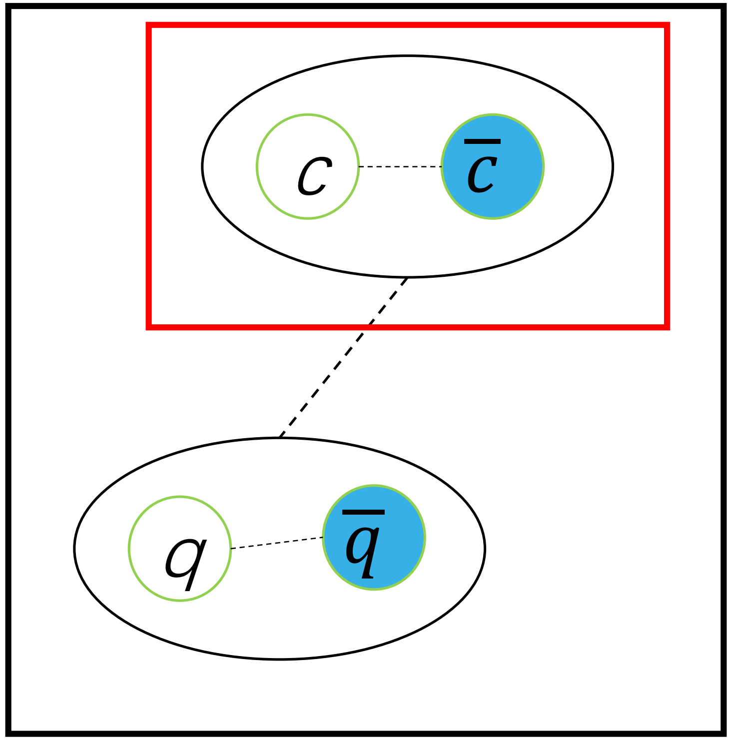



**Collective flow**

**two-body resonance system**

**self-similarity structure**

# Charmonium Aspect




## Assume free in the vacuum

$$P1_0 = \frac{\langle \psi_{J/\psi} | e^{-\beta \hat{H}} | \psi_{J/\psi} \rangle}{\sum_i \langle \psi_i | e^{-\beta \hat{H}} | \psi_i \rangle}$$

## Partition function

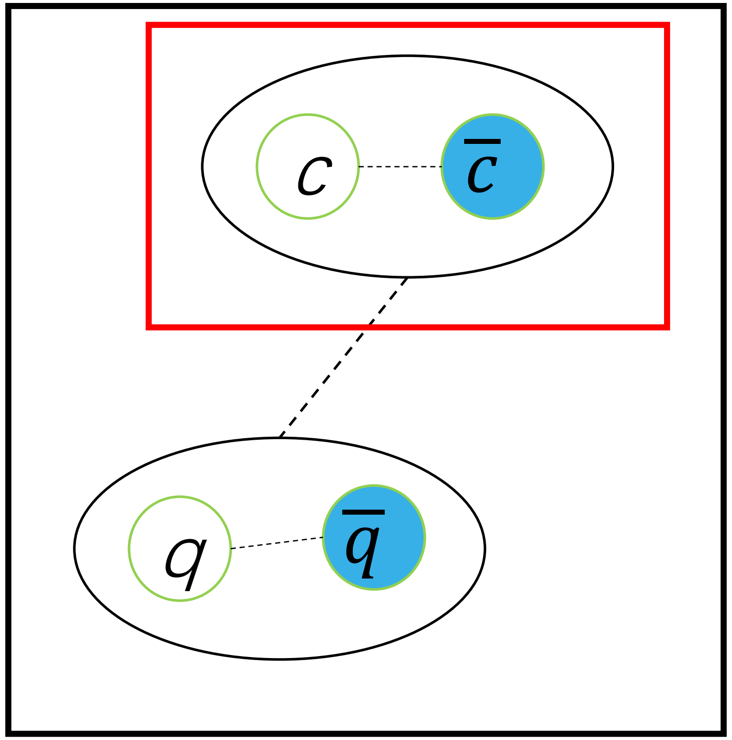
$$\sum_i \langle \psi_i | e^{-\beta \hat{H}} | \psi_i \rangle = e^{-\beta E_0} + e^{-\beta E_1} + ... + e^{-\beta E_7}$$

$$+ V \int_{|\vec{p}_{Q1}| \geq p_{\min}}^{\infty} \int_{|\vec{p}_{Q2}| \geq p_{\min}}^{\infty} \int_{r_{\min}}^{r_{\max}} e^{-\beta(\frac{p_{Q1}^2}{2m_Q} + \frac{p_{Q2}^2}{2m_Q} + V_{\mathrm{vac}}(r))} 4\pi r^2 \frac{d^3\vec{p}_{Q1} d^3\vec{p}_{Q2} dr}{(2\pi)^6},$$

**where** $V_{\mathrm{vac}}(r) = -\frac{\alpha_s}{r} + \sigma r - \frac{0.8\sigma}{m_Q^2 r}$

$$r_{\max}(T) = 41480 \cdot \mathrm{e}^{-62.88 \cdot T} + 1.346 \cdot \mathrm{e}^{-2.52 \cdot T}$$

# Charmonium Aspect




**Introduce medium influencing factor** $q_{gpQ}$

## Probability in the medium

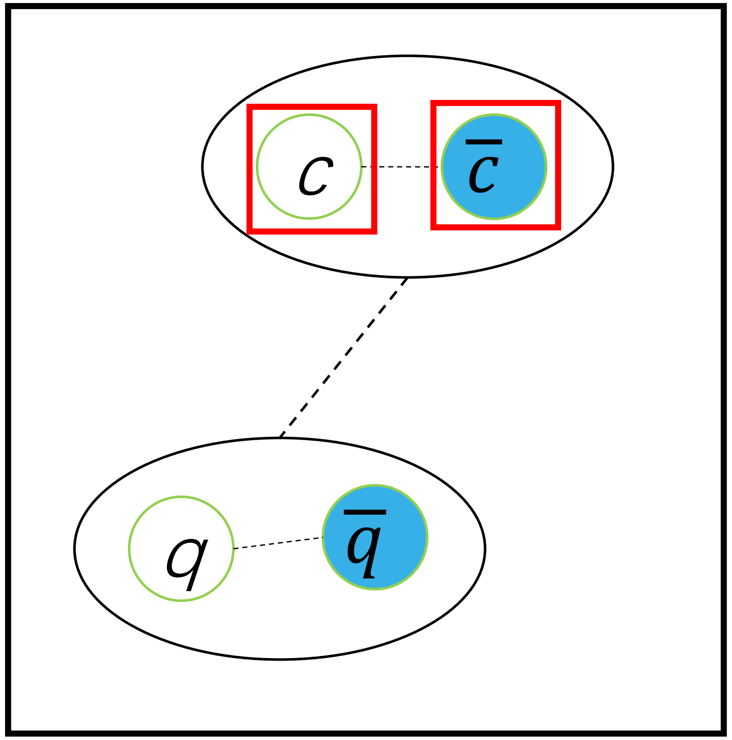
$$P1_{gpQ} = \frac{P1_0^{q_{gpQ}}}{\sum_i P1_i^{q_{gpQ}}} = \frac{\langle \psi_{J/\psi} | e^{-\beta q_{gpQ} \hat{H}} | \psi_{J/\psi} \rangle}{\sum_i \langle \psi_i | e^{-\beta q_{gpQ} \hat{H}} | \psi_i \rangle}$$

## Entropy

$$S1_{gpQ} = \frac{1 - \sum_i P1_i^{q_{gpQ}}}{q_{gpQ} - 1}$$

$$= \left(1 - \frac{\sum_i \langle \psi_i | e^{-\beta q_{gpQ} \hat{H}} | \psi_i \rangle}{\left(\sum_i \langle \psi_i | e^{-\beta \hat{H}} | \psi_i \rangle\right)^{q_{gpQ}}}\right) / (q_{gpQ} - 1)$$

# Quark Aspect




## Assume free in the vacuum

$$P2_0 = \frac{\langle \phi_{J/\psi} | e^{-\beta \hat{H}_0} | \phi_{J/\psi} \rangle}{\sum_i \langle \phi_i | e^{-\beta \hat{H}_0} | \phi_i \rangle}$$

$$\hat{H}_0 = \frac{\hat{P}^2_{Q1}}{2m_Q} + \frac{\hat{P}^2_{Q2}}{2m_Q}$$

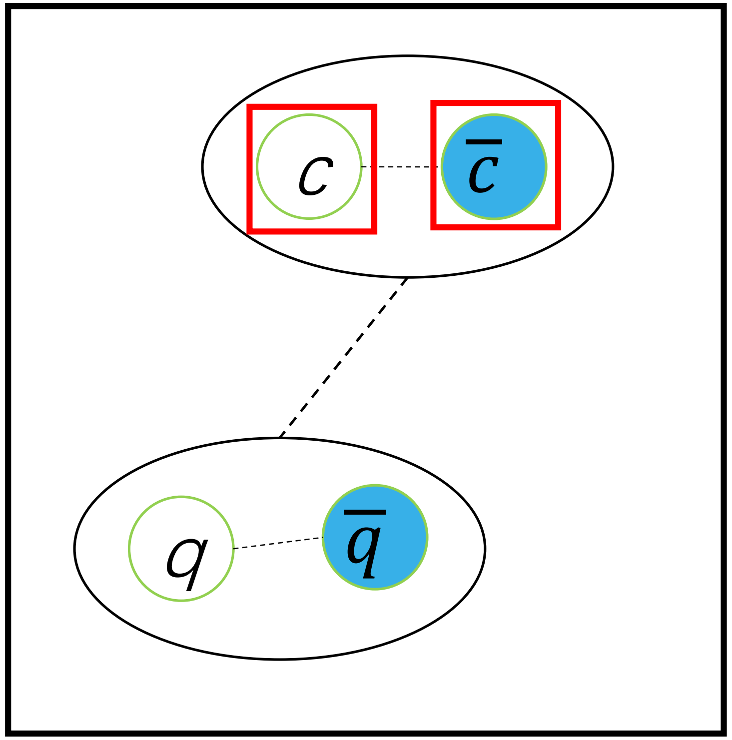
## Partition function

$$\sum_i \langle \phi_i | e^{-\beta \hat{H}_0} | \phi_i \rangle = e^{-\beta E_{k0}} + e^{-\beta E_{k1}} + \ldots + e^{-\beta E_{k7}}$$

$$+ V^2 \int_{|\vec{p}_{Q1}| \geq p_{\min}}^{\infty} \int_{|\vec{p}_{Q2}| \geq p_{\min}}^{\infty} e^{-\beta \left( \frac{\vec{p}^2_{Q1}}{2m_Q} + \frac{\vec{p}^2_{Q2}}{2m_Q} \right)} \frac{d^3 \vec{p}_{Q1} d^3 \vec{p}_{Q2}}{(2\pi)^6}.$$

Schrödinger equation $\hat{H} \psi_i(r) = E_i \psi_i(r)$,

# Quark Aspect




## Escort probability in the medium

$$P2_{q_2} = \frac{P2_0^{q_2}}{\sum_i P2_i^{q_2}} = \frac{\langle \phi_{J/\psi} | e^{-\beta q_2 \hat{H}_0} | \phi_{J/\psi} \rangle}{\sum_i \langle \phi_i | e^{-\beta q_2 \hat{H}_0} | \phi_i \rangle}$$

## Entropy

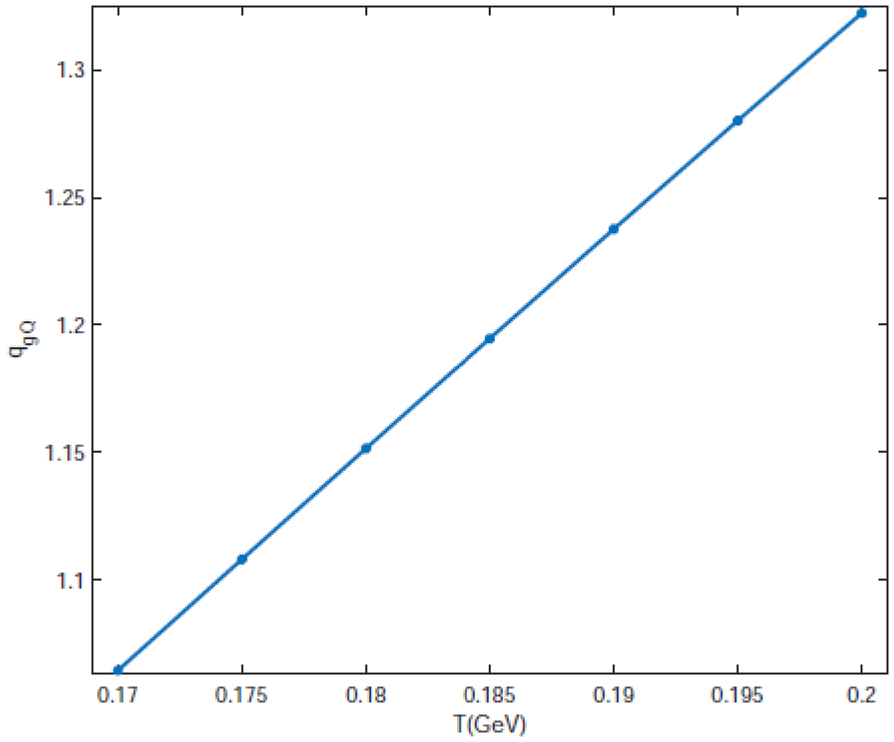
$$S2_{q_2} = \frac{1 - \sum_i P2_i^{q_2}}{q_2 - 1}$$

$$= (1 - \frac{\sum_i \langle \phi_i | e^{-\beta q_2 \hat{H}_0} | \phi_i \rangle}{(\sum_i \langle \phi_i | e^{-\beta \hat{H}_0} | \phi_i \rangle)^{q_2}})/(q_2 - 1)$$

# Medium Influencing Factor

## Same Physics

$$P1_{gpQ} = P2_{q_2} \qquad S1_{gpQ} = S2_{q_2}$$



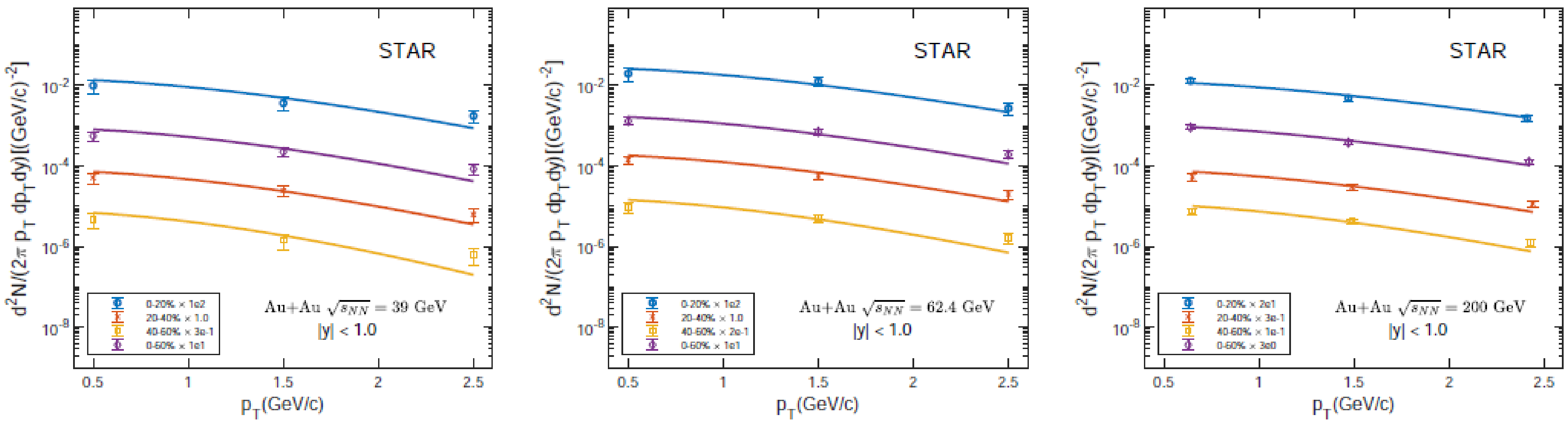
# Transverse Momentum Spectrum

**Distribution of Particle Number**

$$\frac{d^2N}{2\pi p_T dp_T dy} = V \frac{m_T \cosh y}{(2\pi)^3} f_i$$

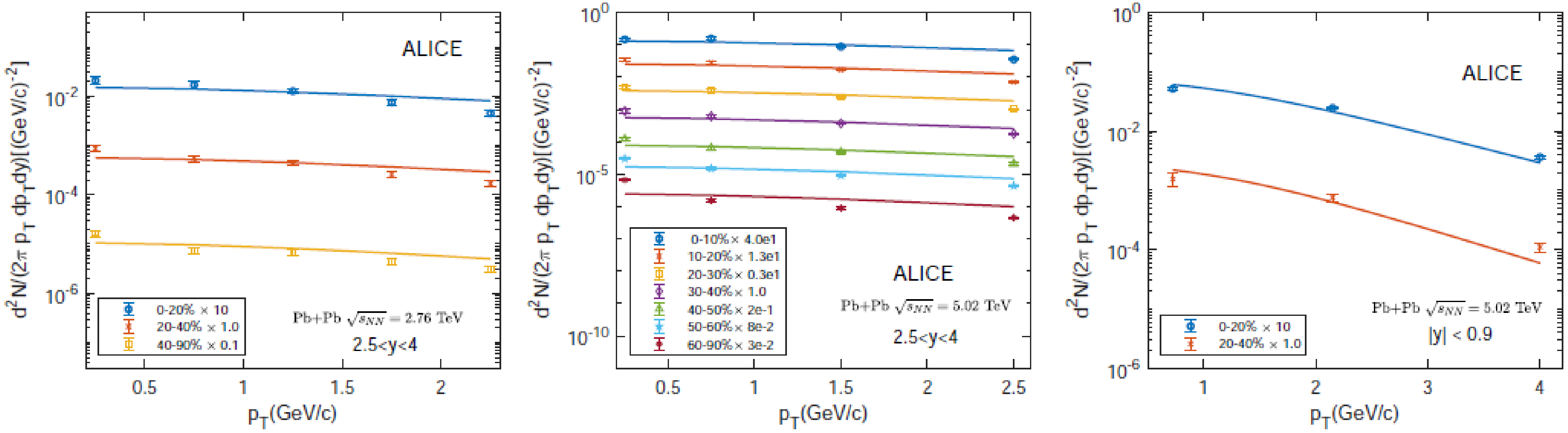
**Distribution function**

$$f_i = [(1 + (q-1)\beta m_T \cosh y)^{q/(q-1)} - 1]^{-1}$$




Transverse momentum spectrum of $J/\psi$ in Au-Au collisions at $\sqrt{s_{\rm NN}} = 39\,\text{GeV}, 62.4\,\text{GeV}, 200\,\text{GeV}$ for different centrality classes, in mid-rapidity region $|y| < 1.0$. The experimental data are taken from STAR[42, 43].

# Transverse Momentum Spectrum




Transverse momentum spectrum of $J/\psi$ in Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 2.76\,\text{TeV}, 5.02\,\text{TeV}$ for different centrality classes, in rapidity region $2.5 < y < 4$ and $|y| < 0.9$. The experimental data are taken from ALICE[44, 45, 46].

**Good Agreement with Experimental Data**

# Conclusion

- Three aspects 1. gluon propagator

  2. polarization

  3.medium influence on c and cbar

- Introducing medium influencing factor $q_{gpQ}$

- Good agreement with experimental data

Thank you!