Partonic J/ψ production in the Statistical Hadronization Model

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Outline

Outline

Basic Formulation

Assumptions

- Perfect thermal and chemical equilibrium
- Hadron production governed by parameters T, μ_B
- Production is instantaneous, same for all species

Basic Formulation

Expressions

Partition Function

$$\ln Z_i^{\mathrm{GC}} = \pm \frac{V g_i}{2\pi^2} \int_0^\infty \mathrm{d}p\, p^2 \ln\left(1 \pm \exp\left(-\frac{E_i - \mu_i}{T}\right)\right)$$

Multiplicity

$$N_i^{\mathrm{th}} = \frac{V g_i}{2\pi^2} \int_0^\infty \mathrm{d}p\, \frac{p^2}{\exp\left(\frac{E_i - \mu_i}{T}\right) \pm 1}$$

Basic Formulation

Expressions

Partition Function

$$\ln Z_i^{\mathrm{GC}} = \frac{VTg_i}{2\pi^2} \sum_{n=1}^{\infty} \frac{(\pm 1)^{n+1}}{n^2} \lambda_i^n m_i^2 K_2 \left(\frac{nm_i}{T} \right)$$

Multiplicity

$$N_i^{\mathrm{th}} = \frac{VTg_i}{2\pi^2} \sum_{n=1}^{\infty} \frac{(\pm 1)^{n+1}}{n} \lambda_i^n m_i^2 K_2 \left(\frac{nm_i}{T} \right)$$

Corrections
Excluded Volume

- Include finite hadron volumes
- $V^{\mathrm{excl}} = 4\frac{4}{3}\pi R^3$, $R = 0.3\,\mathrm{fm}$
- Includes ~ 500 particle species

Iteration

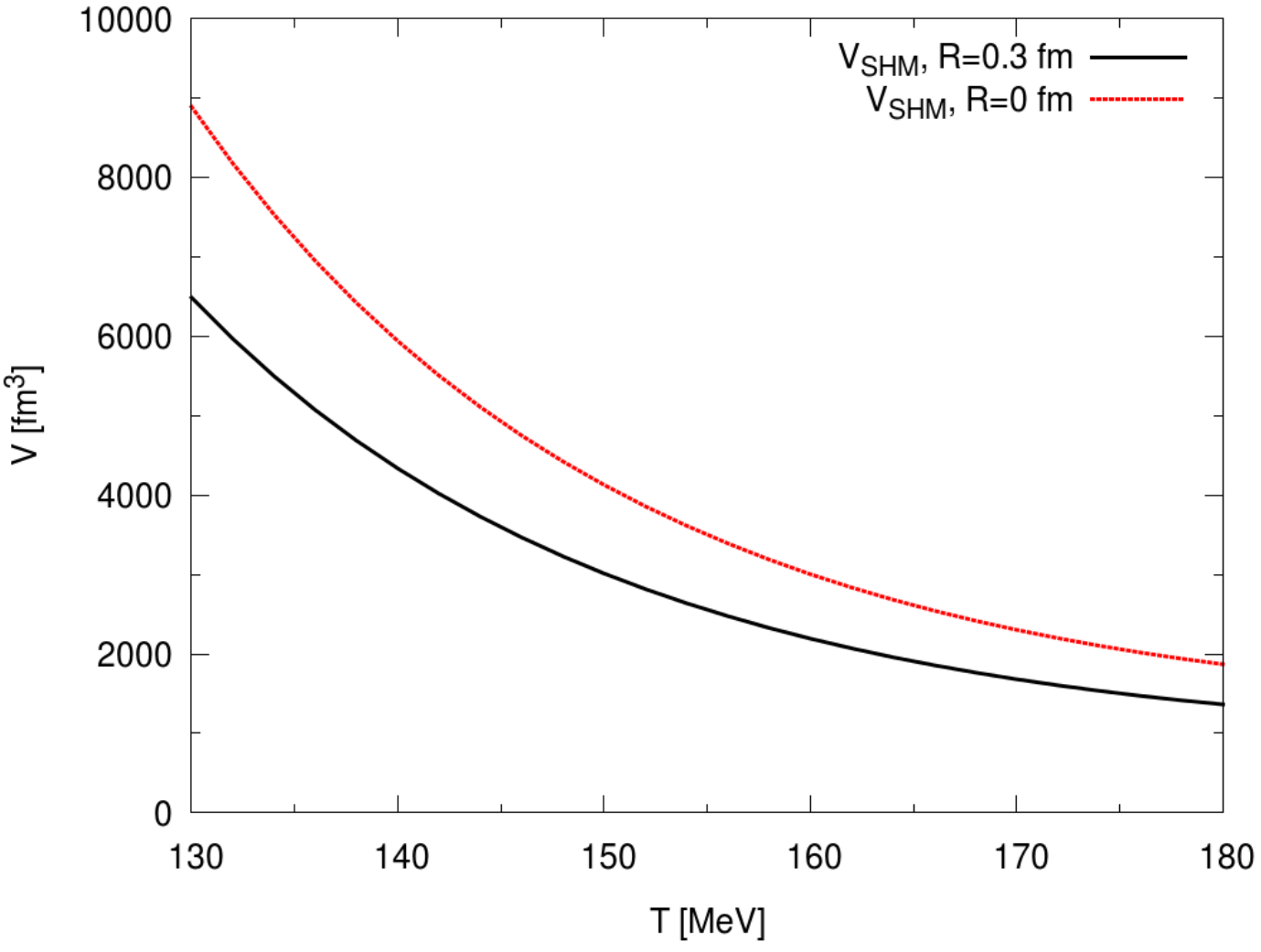
$$\hat{p}\left(T,\mu\right) = p^{\mathrm{id}}\left(T,\hat{\mu}_1,\ldots,\hat{\mu}_k\right)$$
$$\hat{\mu}_i = \mu_i - v_i \cdot \hat{p}\left(T,\mu_1,\ldots,\mu_k\right)$$

Volume

$$V^{\mathrm{SHM}} = \frac{N_{\mathrm{ch}}}{n_{\mathrm{ch}}^{\mathrm{th}}\left(T,\hat{\mu}_B\right)}$$

Corrections

Excluded Volume Effect



Corrections
Charm Quarks

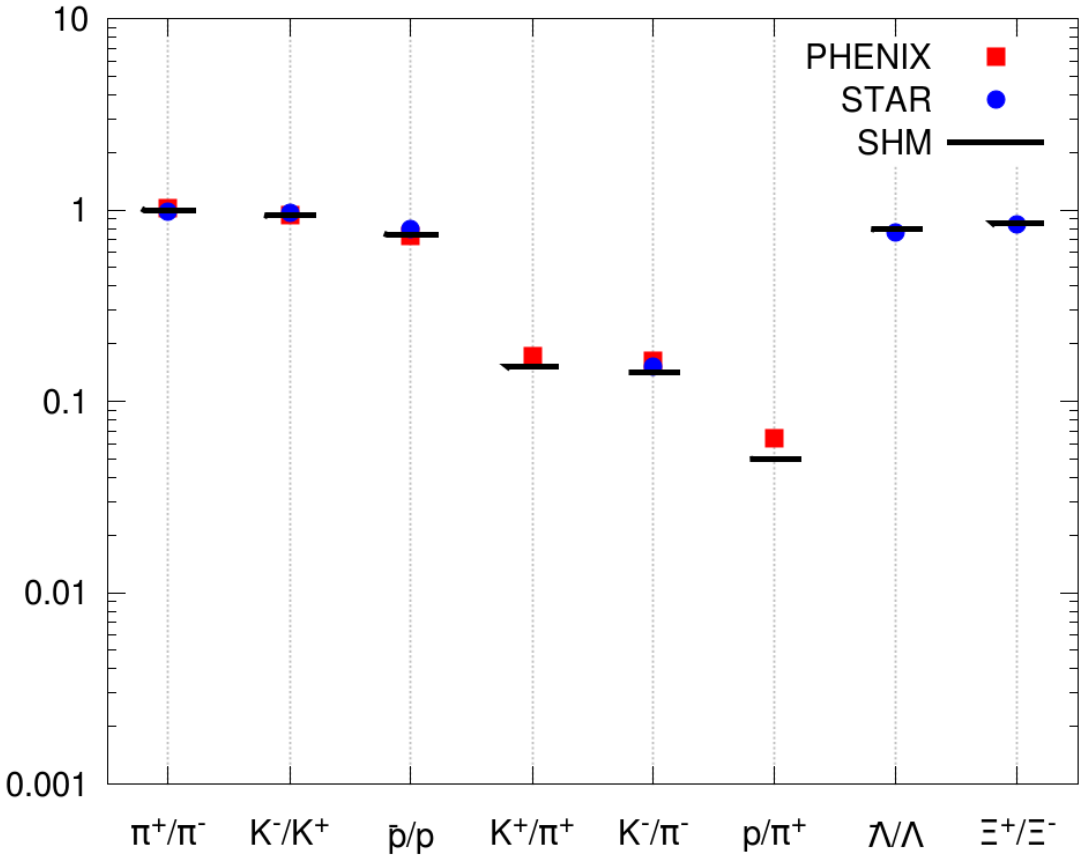
- $m_c \gg T$
- Charm far away from chemical equilibrium

Balance Equation

$$N_{c\bar{c}}^{\mathrm{dir}} = \frac{1}{2} g_c N_{\mathrm{oc}}^{\mathrm{th}} \frac{I_1\left(g_c N_{\mathrm{oc}}^{\mathrm{th}}\right)}{I_0\left(g_c N_{\mathrm{oc}}^{\mathrm{th}}\right)} + g_c^2 N_{c\bar{c}}^{\mathrm{th}}$$

Model Results

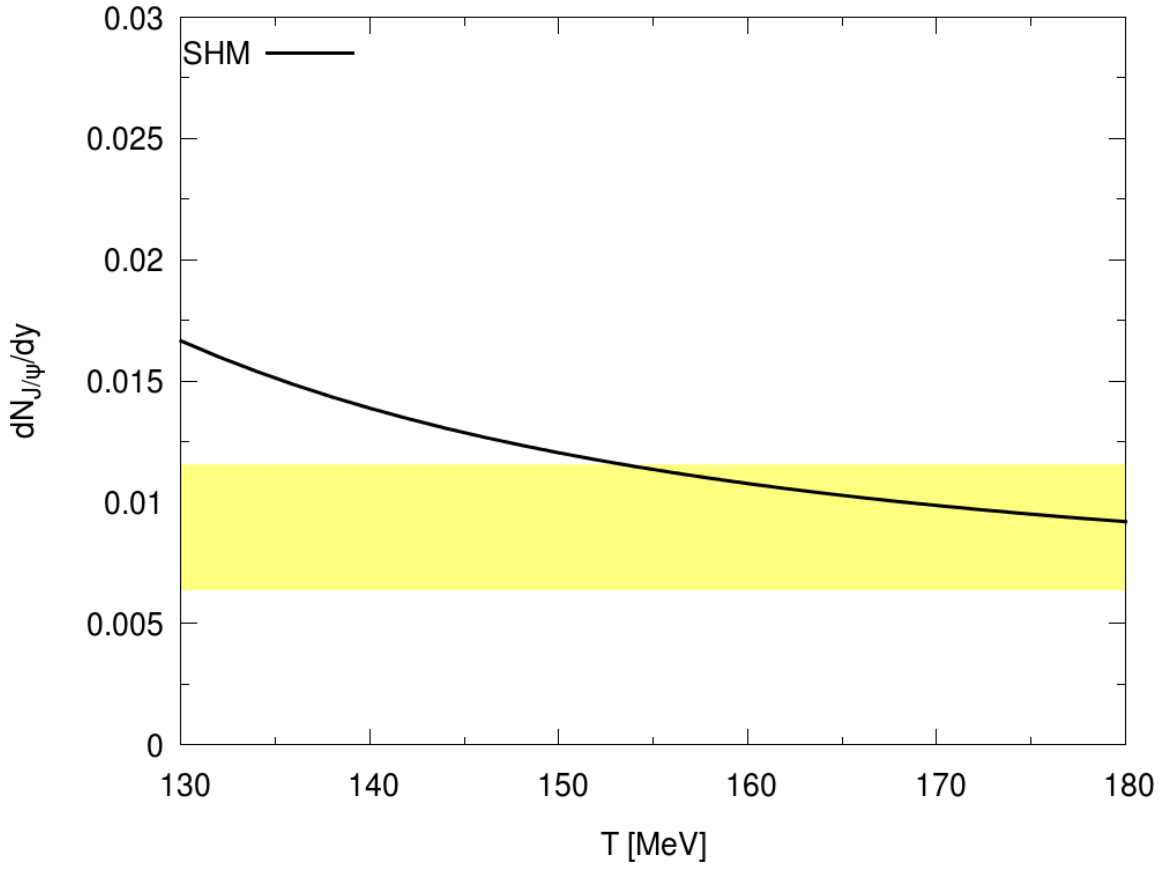
Ratio Fit



- 200 GeV, Au+Au
- $T = 162\,\mathrm{MeV}$, $\mu_b = 24\,\mathrm{MeV}$

Model Results

J/ψ yield



- 200 GeV, Au+Au
- $\mu_b = 24\,\mathrm{MeV}$
- $N_{\mathrm{ch}} = 730$
- $N_{c\bar{c}}^{\mathrm{dir}} = 1.92$

Outline

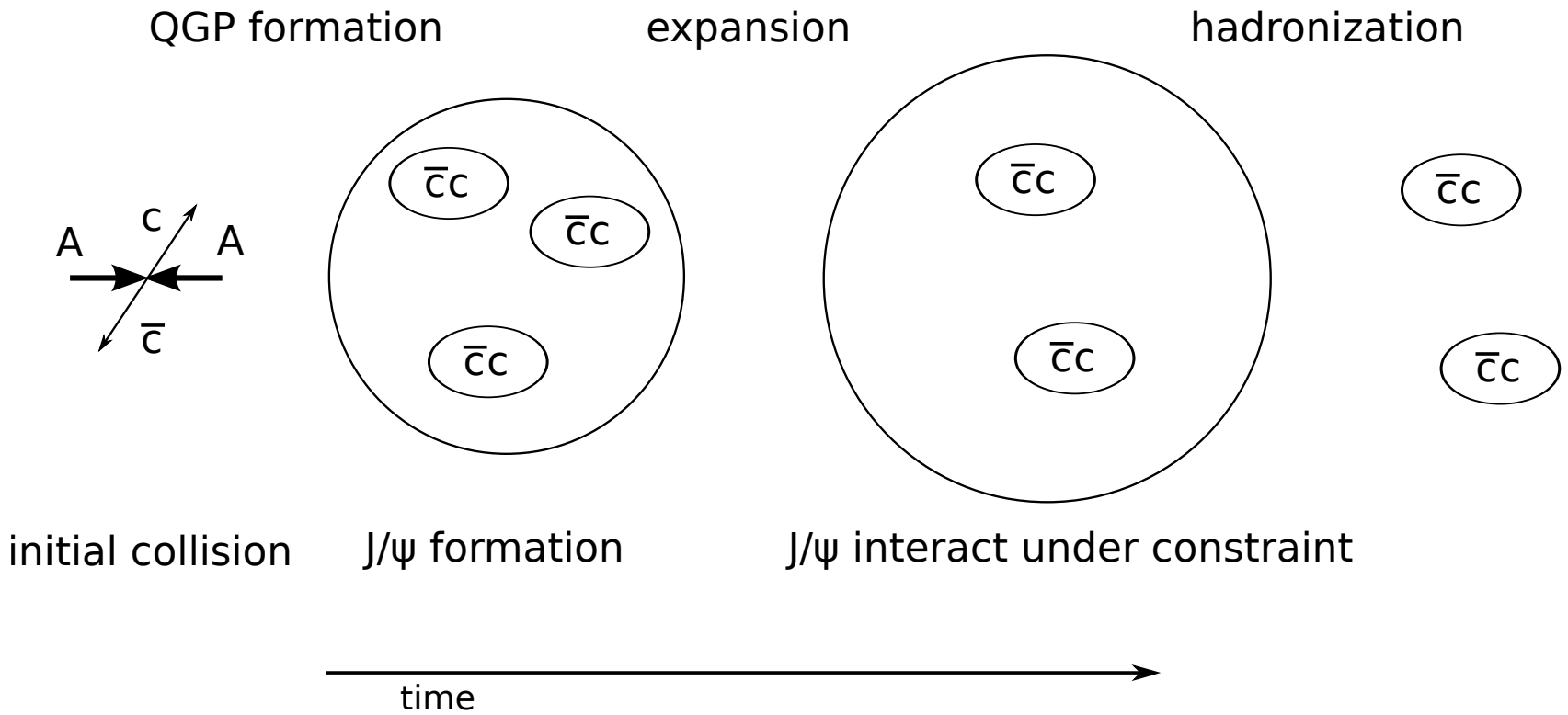
Motivation

J/ψ at high Temperatures

- Lattice results: J/ψ dissociate at 1.5-1.9 T_c
- Production in the QGP describable in SHM?
- Sensitive quantities of description?

Motivation

Progression of J/ψ Formation



Formulation
Assumptions

- Exact charm conservation
- J/ψ are in constrained equilibrium
- No J/ψ formed or destroyed during hadronization
- Equal entropy in QGP and hadronic fireball at hadronization

Formulation
Analogous Quantities

- $V^{\mathrm{SHM}} \rightarrow V^{\mathrm{QGP}}$ by entropy conservation
- $g_c \rightarrow \lambda_c$ by exact charm conservation

Formulation

QGP Volume V^{QGP}

Fireball Entropy

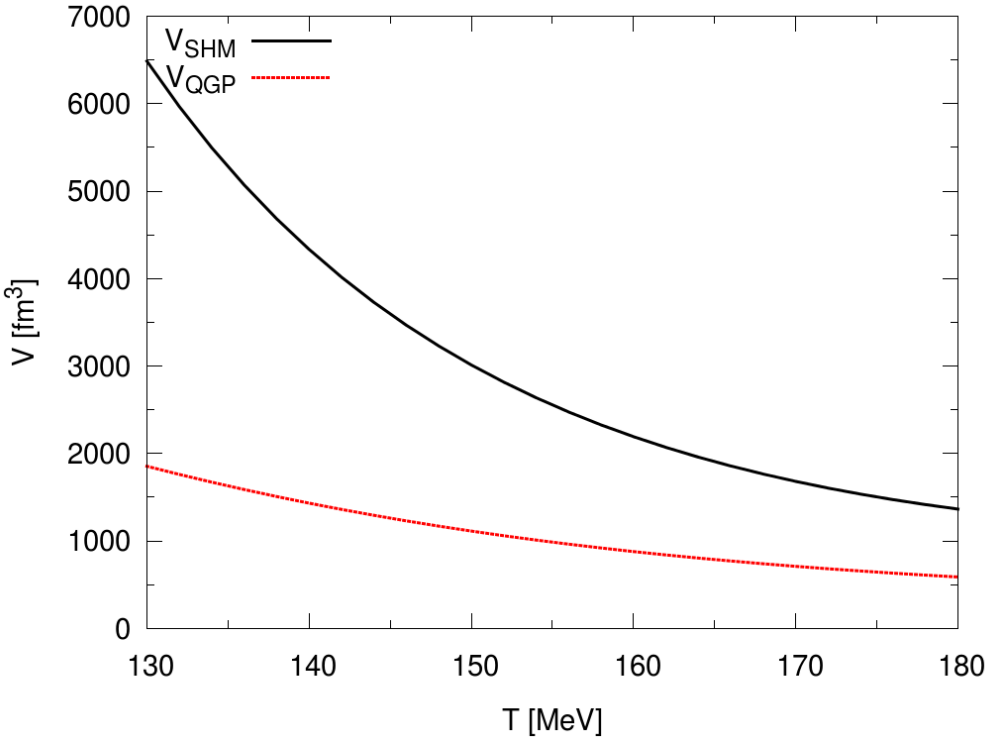
$$S_i^{\mathrm{SHM}} = \frac{g_i V^{\mathrm{SHM}}}{2\pi^2} m_i^2 \sum_{n=1}^{\infty} (\pm 1)^{n+1} \frac{\lambda_i^n}{n^2} (2T - \mu n) K_2\left(\frac{n m_i}{T}\right) + \frac{n m_i}{2}\left[K_1\left(\frac{n m_i}{T}\right) + K_3\left(\frac{n m_i}{T}\right)\right]$$

QGP Entropy Density

$$s^{\mathrm{QGP}} = 4\left(16 + \frac{21}{2} N_f\right) \frac{\pi^2}{90} T^3$$

Formulation

QGP Volume V^{QGP}



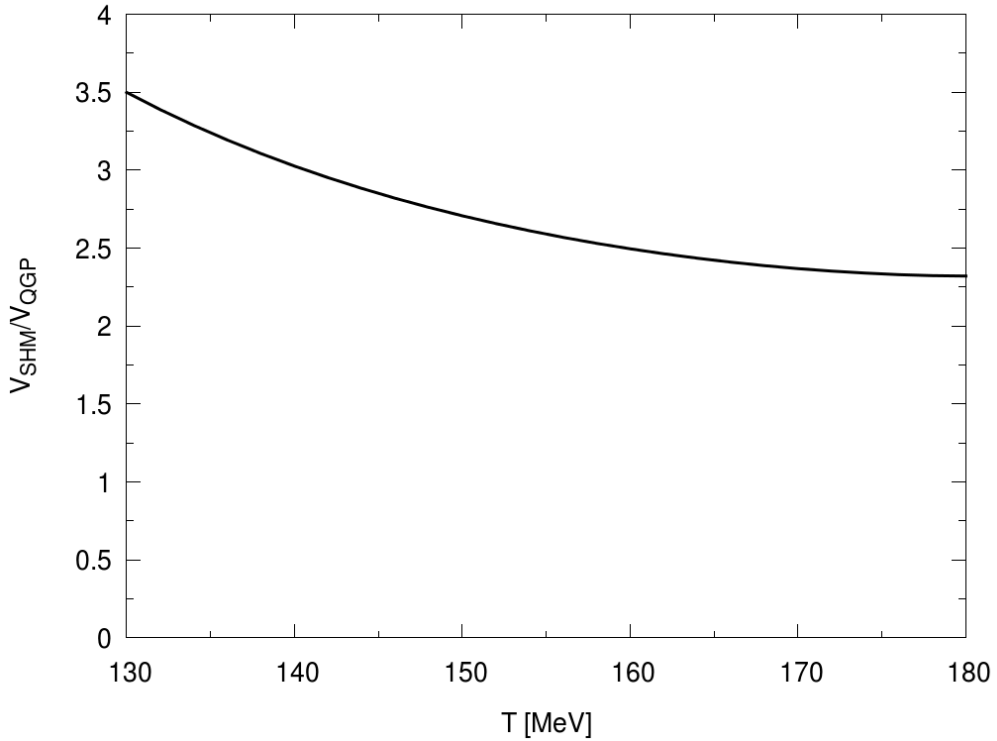
Volume Calculation

$$S^{\mathrm{SHM}} \stackrel{!}{=} S^{\mathrm{QGP}} :$$

$$V^{\mathrm{QGP}} = \frac{S^{SHM}}{s^{\mathrm{QGP}}}$$

Formulation

QGP Volume V^{QGP}



Volume Calculation

$$S^{\mathrm{SHM}} \stackrel{!}{=} S^{\mathrm{QGP}} :$$

$$V^{\mathrm{QGP}} = \frac{S^{SHM}}{s^{\mathrm{QGP}}}$$

Formulation

Charm Fugacity λ_c

Hadronic Charm Balance

$$N_{c\bar{c}}^{\mathrm{dir}} = \frac{1}{2} g_c N_{\mathrm{oc}}^{\mathrm{th}} \frac{I_1\left(g_c N_{\mathrm{oc}}^{\mathrm{th}}\right)}{I_0\left(g_c N_{\mathrm{oc}}^{\mathrm{th}}\right)} + g_c^2 N_{c\bar{c}}^{\mathrm{th}}$$

Partonic Charm Balance

$$N_{c\bar{c}}^{\mathrm{dir}} = \lambda_c \frac{2V^{\mathrm{QGP}}}{2\pi^2} \left(m_c T\right)^{\frac{3}{2}} e^{-\frac{m_c}{T}}$$

$\Rightarrow \lambda_c$ strongly depends on m_c!

Outline

J/ψ Multiplicity

Hadronic vs. Partonic Formulation

Hadronic Picture

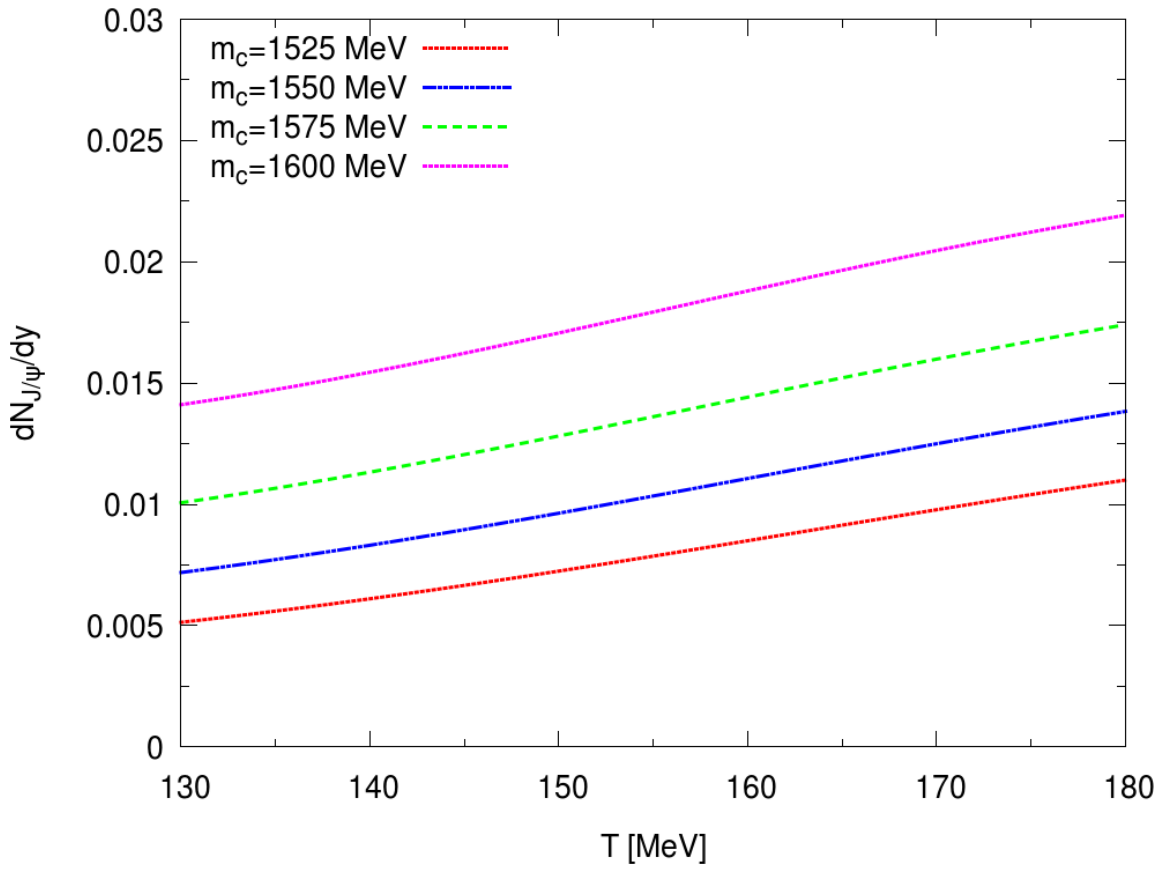
$$N_{J/\psi}^{\mathrm{SHM}} = \frac{3V^{\mathrm{SHM}}}{2\pi^2} g_c^2 \int_0^\infty \mathrm{d}p \frac{p^2}{\exp\left(\frac{E_{J/\psi}-\mu_{J/\psi}}{T}\right) - 1}$$

Partonic Picture

$$N_{J/\psi}^{\mathrm{QGP}} = \frac{3V^{\mathrm{QGP}}}{2\pi^2} \lambda_c^2 \int_0^\infty \mathrm{d}p \frac{p^2}{\exp\left(\frac{E_{J/\psi}-\mu_{J/\psi}}{T}\right) - 1}$$

J/ψ Multiplicity

Effect of m_c

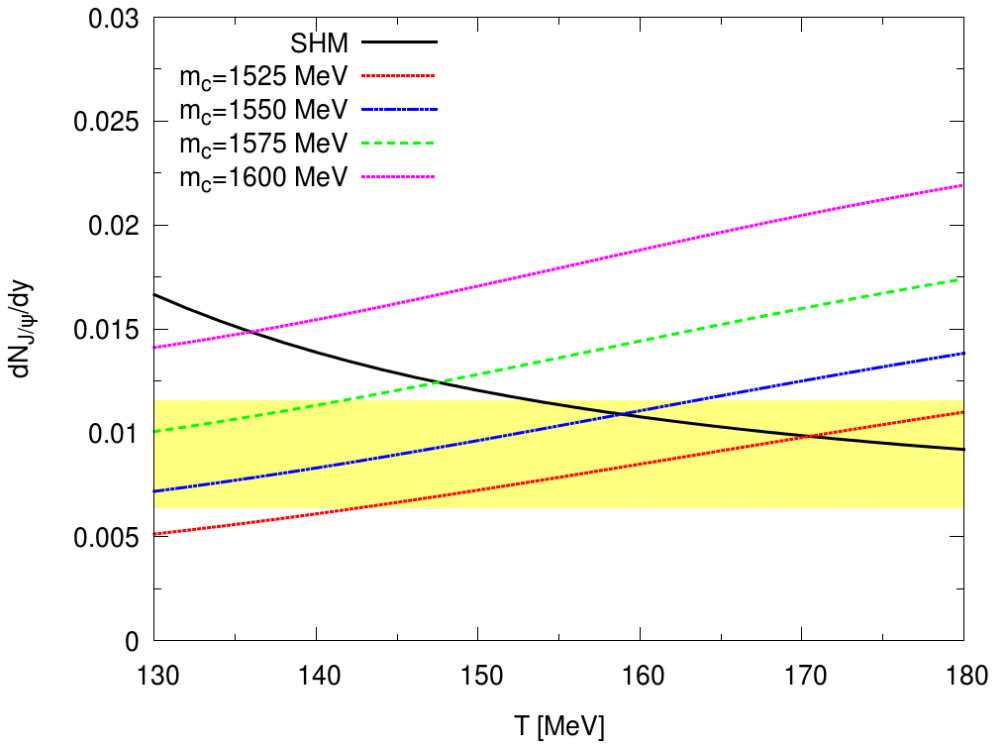


- $\mu_b = 24\,\mathrm{MeV}$
- $N_{\mathrm{ch}} = 730$
- $N_{c\bar{c}}^{\mathrm{dir}} = 1.92$

J/ψ Multiplicity

Comparison

No J/ψ formed or destroyed during crossover $\Rightarrow N_{J/\psi}^{SHM} = N_{J/\psi}^{QGP}$



- Intersections for (T, m_c) pairs
- $T \simeq 160\,\mathrm{MeV}$
  $\Rightarrow m_c \simeq 1550\,\mathrm{MeV}$

Summary

- In-medium J/ψ treated
- Compatible with established model and experiment
- Charm mass constrained, $m_c \simeq 1550\,\mathrm{MeV}$