EMMI Rapid Reaction Task Force

TAMU Approach

Part.2: Equilibrium Limit

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QQ Conservation

- $Q\bar{Q}$ Conservation

$$N_{Q\bar{Q}} = \frac{1}{2}\gamma_Q n_{\mathrm{op}} V_{\mathrm{FB}} \frac{I_1(\gamma_Q n_{\mathrm{op}} V_{\mathrm{corr}})}{I_0(\gamma_Q n_{\mathrm{op}} V_{\mathrm{corr}})} + \gamma_Q^2 n_{\mathrm{hid}} V_{\mathrm{FB}}$$

Open heavy quark   Hidden heavy quark

- Equilibrium Limit and "Relaxation Factor"

$$N_\Psi^{\mathrm{eq}} = V_{\mathrm{FB}} \gamma_Q^2 n_\Psi \qquad \tilde{N}_\Psi^{\mathrm{eq}} = N_\Psi^{\mathrm{eq}} R$$

- $n_{\mathrm{op}}, n_{\mathrm{hid}}$: Open & Hidden heavy flavors: $n_{\mathrm{op}} \gg n_{\mathrm{hid}}$
- QGP/HAD: Different d.o.f for $n_{\mathrm{op}}, n_{\mathrm{hid}}$
- $V_{\mathrm{corr}} = \frac{4}{3}\pi(r_0 + \langle v_Q \rangle t)^3$: Correlation volume.
- γ_Q Fugacity factor

Canonical/Grand Canonical Limit

- Canonical Limit: $x \ll 1$: $\frac{I_1(x)}{I_0(x)} \to \frac{x}{2}$
  - $N_{Q\bar{Q}} \propto \gamma_Q^2 \to N_\Psi^{\rm eq}(T) \propto N_{Q\bar{Q}}$
- Grand Canonical Limit: $x \gg 1$: $\frac{I_1(x)}{I_0(x)} \to 1$
  - $N_{Q\bar{Q}} \propto \gamma_Q \to N_\Psi^{\rm eq}(T) \propto N_{Q\bar{Q}}^2$
  - Charmonium: $N_{c\bar{c}} \simeq 30$ → Grand Canonical Limit
    Large Regeneration
  - Bottomonium: $N_{b\bar{b}} \simeq 1$ → Canonical/Grand Canonical Limit
    Small Regeneration

Open/Hidden Densities Dependence

$n_{\rm op}$, $n_{\rm hid}$

- Open in QGP: Includes heavy/anti-heavy quarks c, b, ..
- Open in HAD: Includes hadronic heavy flavors,
  Mesonic … PDG
  Baryonic … Ebert, Faustov, Galkin PRD84,11'
- Hidden: Quarkonium states, … PDG

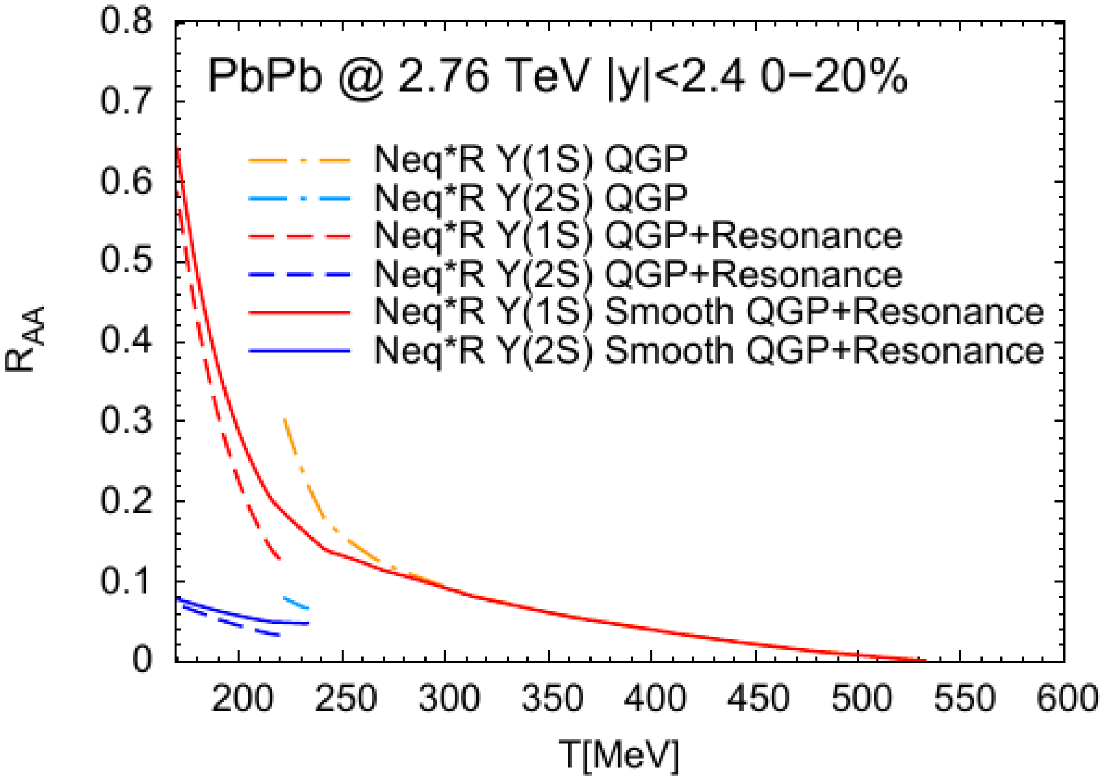
$$n_{\rm op} \gg n_{\rm hid} \;\Rightarrow\; N_{Q\bar{Q}} \propto \gamma_Q^2 n_{\rm op}^2(\gamma_Q n_{\rm op}) \;\Rightarrow\; \gamma_Q \propto \frac{1}{n_{\rm op}}$$

$$\Downarrow$$

$$N_\Psi^{\rm eq}(T) \propto \gamma_Q^2 n_\Psi \propto \frac{n_\Psi}{n_{\rm op}^2}$$

Pre-hadronic Resonance in QGP Phase

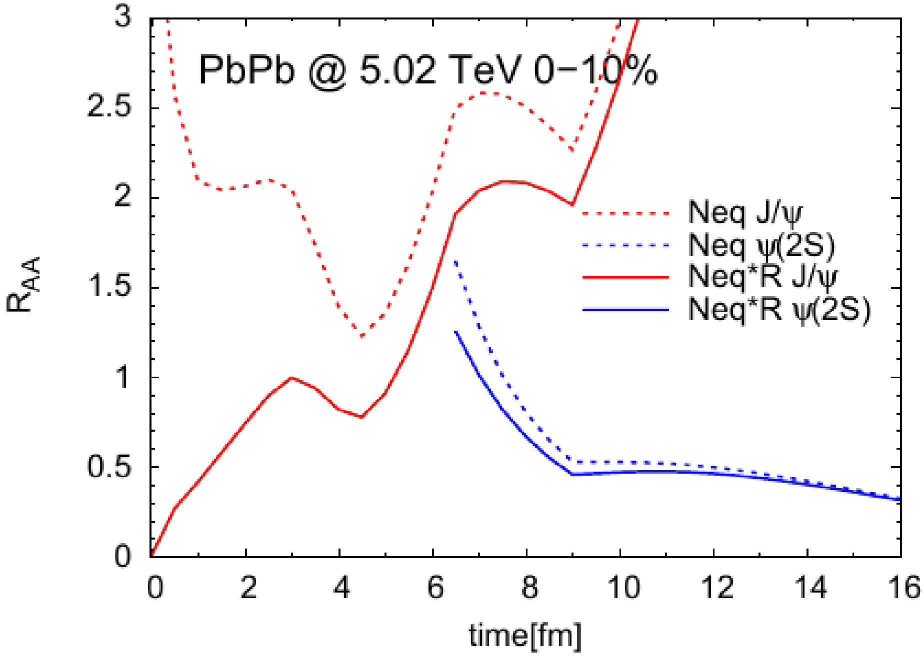
$$N_\Psi^{\rm eq}(T) \propto \gamma_Q^2 n_\Psi \propto \frac{n_\Psi}{n_{\rm op}^2}$$

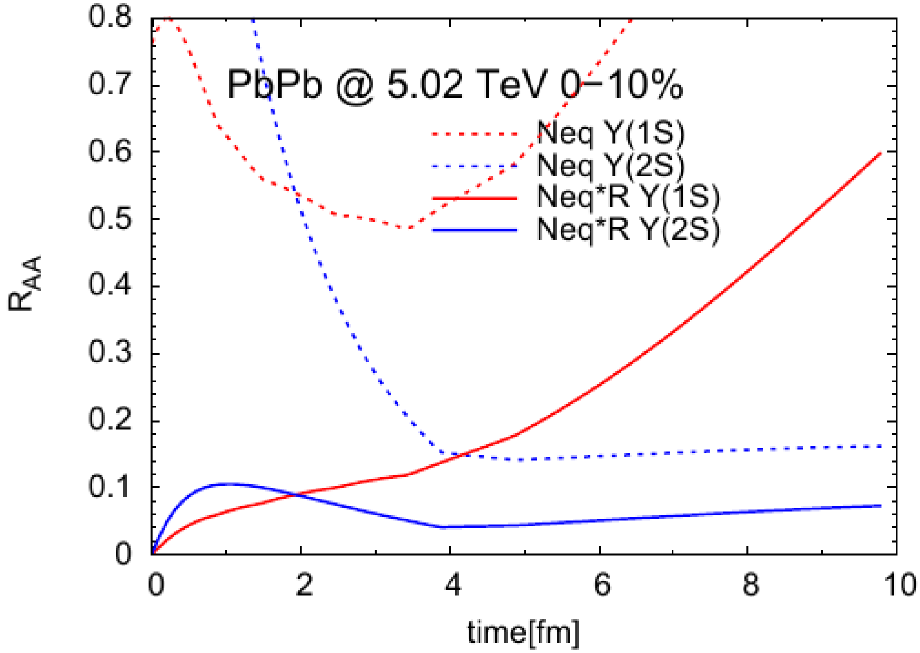


- QGP equilibrium limit also depends on pre-hadronic resonance survived close to Tc:

A few mesonic heavy flavors..

Time Evolution of Equilibrium Limit





- Charmonium
- Bottomonium
- Interplay of increasing binding, decreasing temperature, increasing volume and changing d.o.f. (quark to hadron)
- Relaxation factor R approaches 1 for charm/ remains small for bottom (incomplete thermalization)

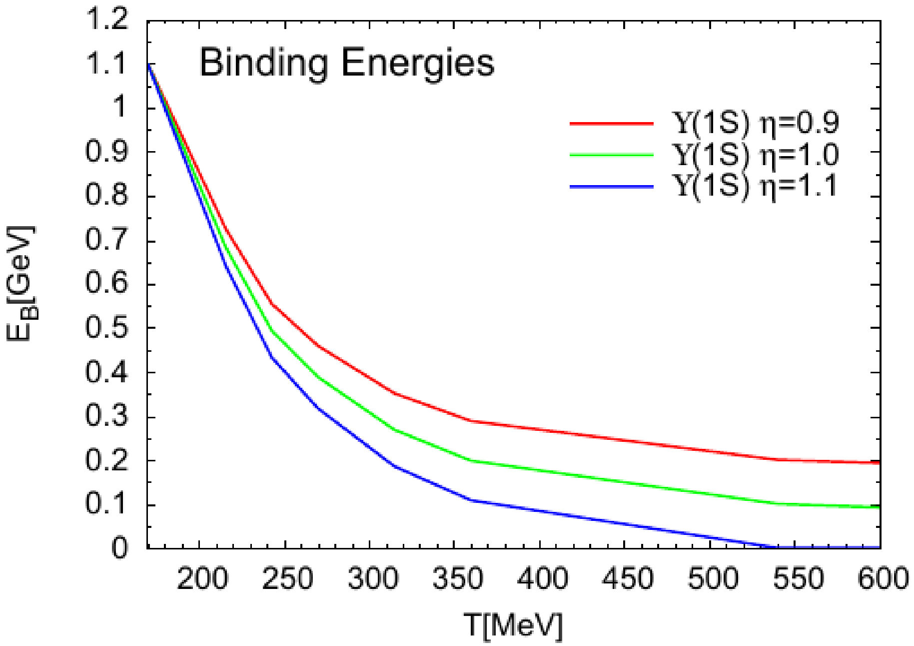
Binding Energy/Mass Dependence

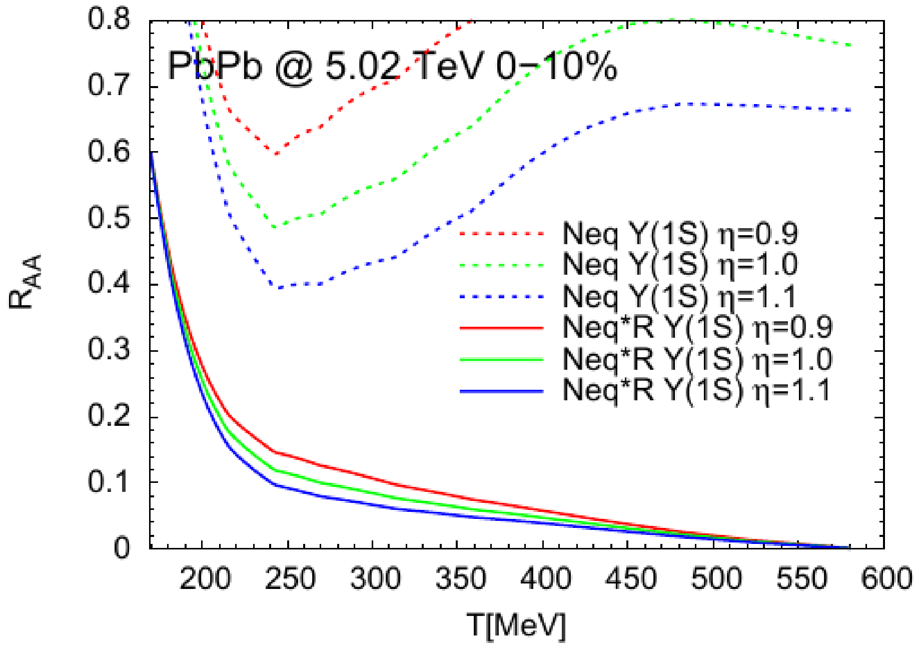
- $n_{\text{op}} \propto m_Q^2 K_2(\frac{m_Q}{T}) \lessapprox m_Q^2 \exp(-\frac{m_Q}{T}) \to \gamma_Q \propto \frac{1}{m_Q^2}\exp(\frac{m_Q}{T})$
- $n_\Psi \propto m_\Psi^2 K_2(\frac{m_\Psi}{T}) \lessapprox m_\Psi^2 \exp(-\frac{m_\Psi}{T})$
- $N_\Psi^{\text{eq}} \propto \gamma_Q^2 n_\Psi \lessapprox \frac{1}{m_Q^4}\exp(\frac{2m_Q}{T}) m_\Psi^2 \exp(-\frac{m_\Psi}{T})$

$$= \frac{m_\Psi^2}{m_Q^4}\exp(\frac{2m_Q - m_\Psi}{T}) = \frac{m_\Psi^2}{m_Q^4}\exp(\frac{E_B}{T})$$

- Weaker binding $\to$ Smaller equilibrium limit

Binding Energy/Mass Dependence





- Weaker binding → Smaller equilibrium limit