Bottomonia suppression in 2.76 TeV Pb-Pb collisions

Brandon Krouppa[1], Radoslaw Ryblewski[2], and Michael Strickland[1]

[1] *Department of Physics, Kent State University, Kent, OH 44242 United States*
[2] *The H. Niewodniczański Institute of Nuclear Physics,Polish Academy of Sciences, PL-31342 Kraków, Poland*

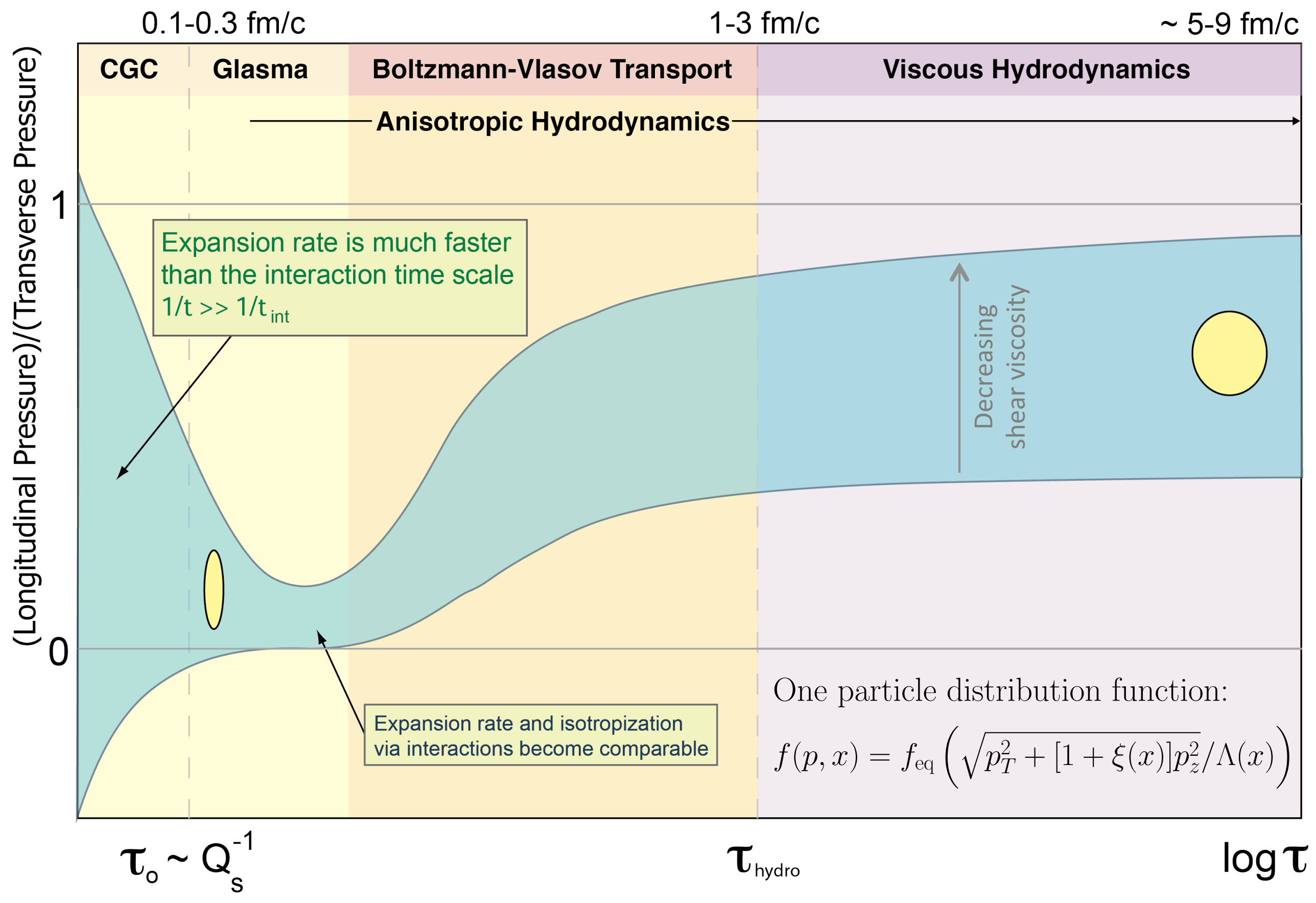
Introduction

We extend our previous work to:

- Extend the background evolution to full (3+1)D anisotropic hydrodynamics (aHydro) with a rapidity profile consistent with experimentally-observed particle multiplicity distributions;
- Update the mixing fractions to recent updated values determined via fits to ATLAS, CMS, and LHCb results for Υ and χ_b production in p-p collisions;
- Correct the probability weight-function used for centrality averaging in order to match the experimental procedure.

We find that, with the improvements listed above, the original model gives a reasonable description of the $N_{part}-$, $y-$, and p_T-dependence of $\Upsilon(1s)$ and $\Upsilon(2s)$ suppression.

Anisotropic QGP



Expansion rate is much faster than the interaction time scale $1/t >> 1/t_{int}$

Expansion rate and isotropization via interactions become comparable

One particle distribution function:

$$f(p,x) = f_{\rm eq}\left(\sqrt{p_T^2 + [1+\xi(x)]p_z^2}/\Lambda(x)\right)$$

- Finite shear viscosity results in momentum space anisotropies
- Anisotropies, ξ, can be quite large
- Anisotropies present in both weak and strong coupling approaches
- Anisotropies modify the heavy quark potential

Potential Model and R_{AA}

- The heavy quark potential in the QGP has both real and imaginary parts, $V = \Re[V] + i\Im[V]$.

$$\Re[V] = -\frac{a}{r}(1+\mu r)e^{-\mu r} + \frac{2\sigma}{\mu}[1-e^{-\mu r}] - \sigma r e^{-\mu r} - \frac{0.8\sigma}{m_b^2 r}$$

$a = 0.385$, μ is the anisotropic Debye mass, $\sigma = 0.223$ GeV^2

- Solve Schrödinger equation with complex potential

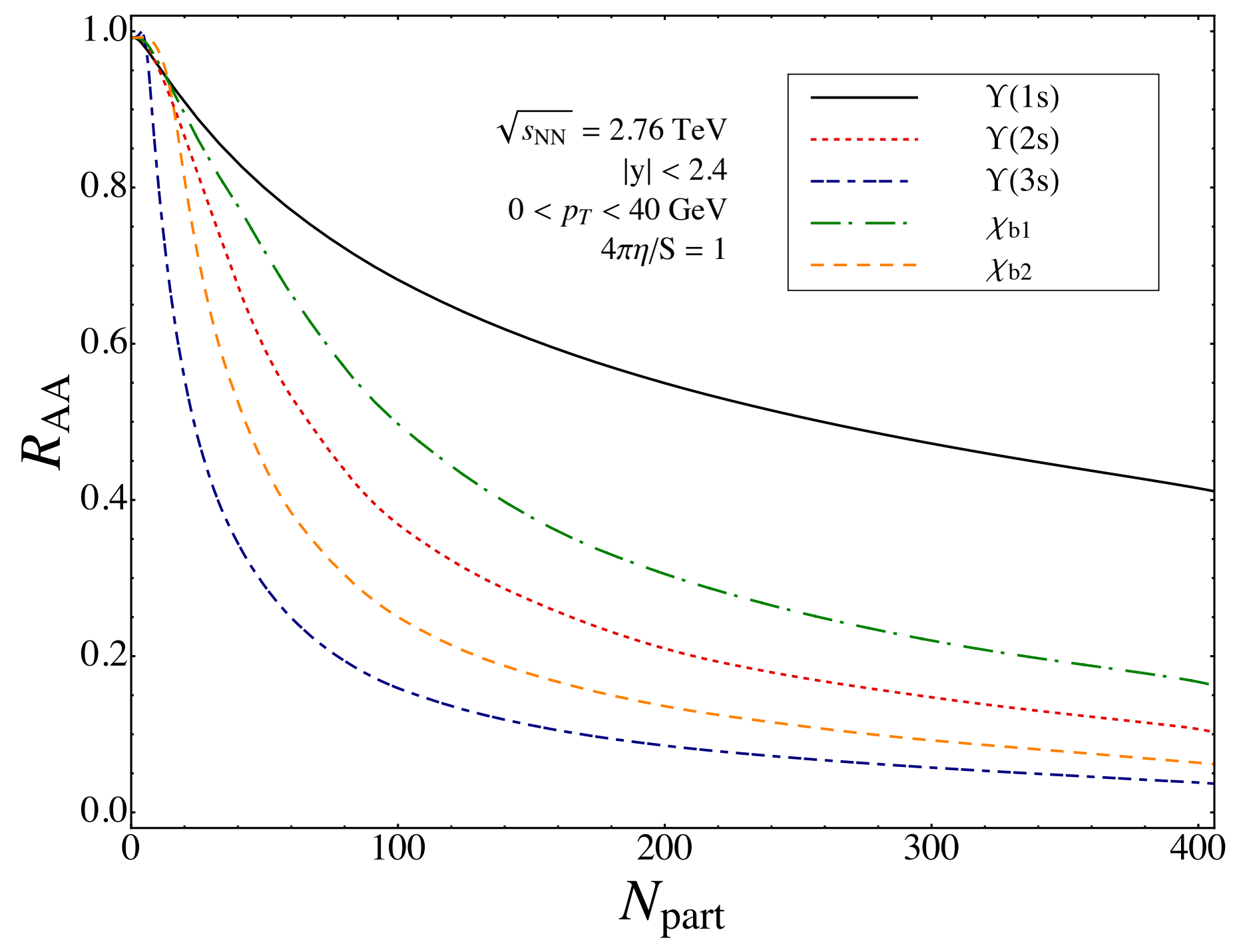
$$\Im[V] = -\alpha_s C_F T\left\{\phi(r/m_D) - \xi[\psi_1(r/m_D,\theta) + \psi_2(r/m_D,\theta)]\right\}$$

- The imaginary part gives the decay rate.

$$\Gamma(\tau,\mathbf{x}_\perp,\varsigma) = \begin{cases} 2\Im[E_{\rm bind}(\tau,\mathbf{x}_\perp,\varsigma)] & \Re[E_{\rm bind}(\tau,\mathbf{x}_\perp,\varsigma)] > 0 \\ \gamma_{\rm dis} & \Re[E_{\rm bind}(\tau,\mathbf{x}_\perp,\varsigma)] \leq 0. \end{cases}$$

- We use (3+1)D anisotropic hydrodynamics for background evolution

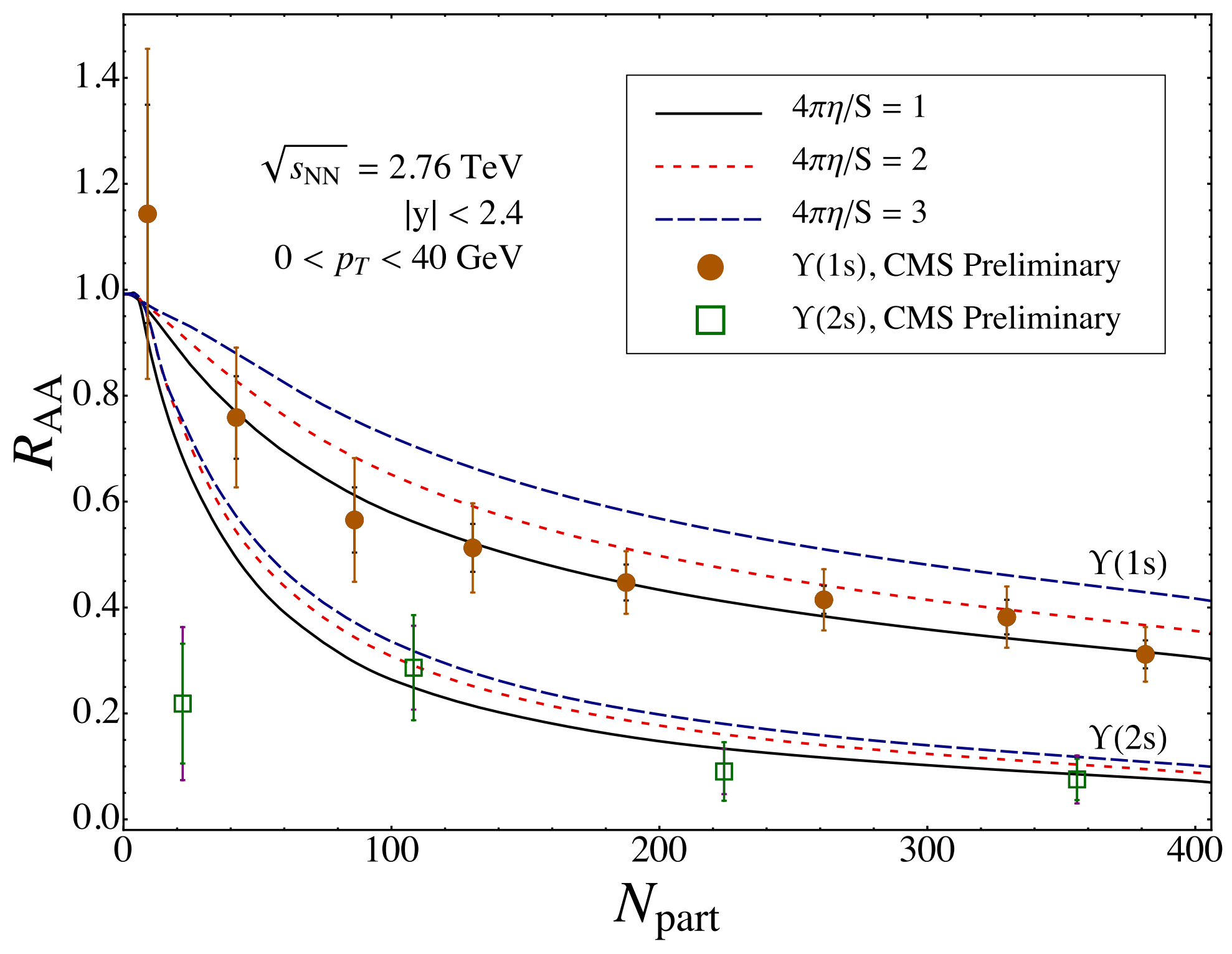
Raw Suppression and Feed Down



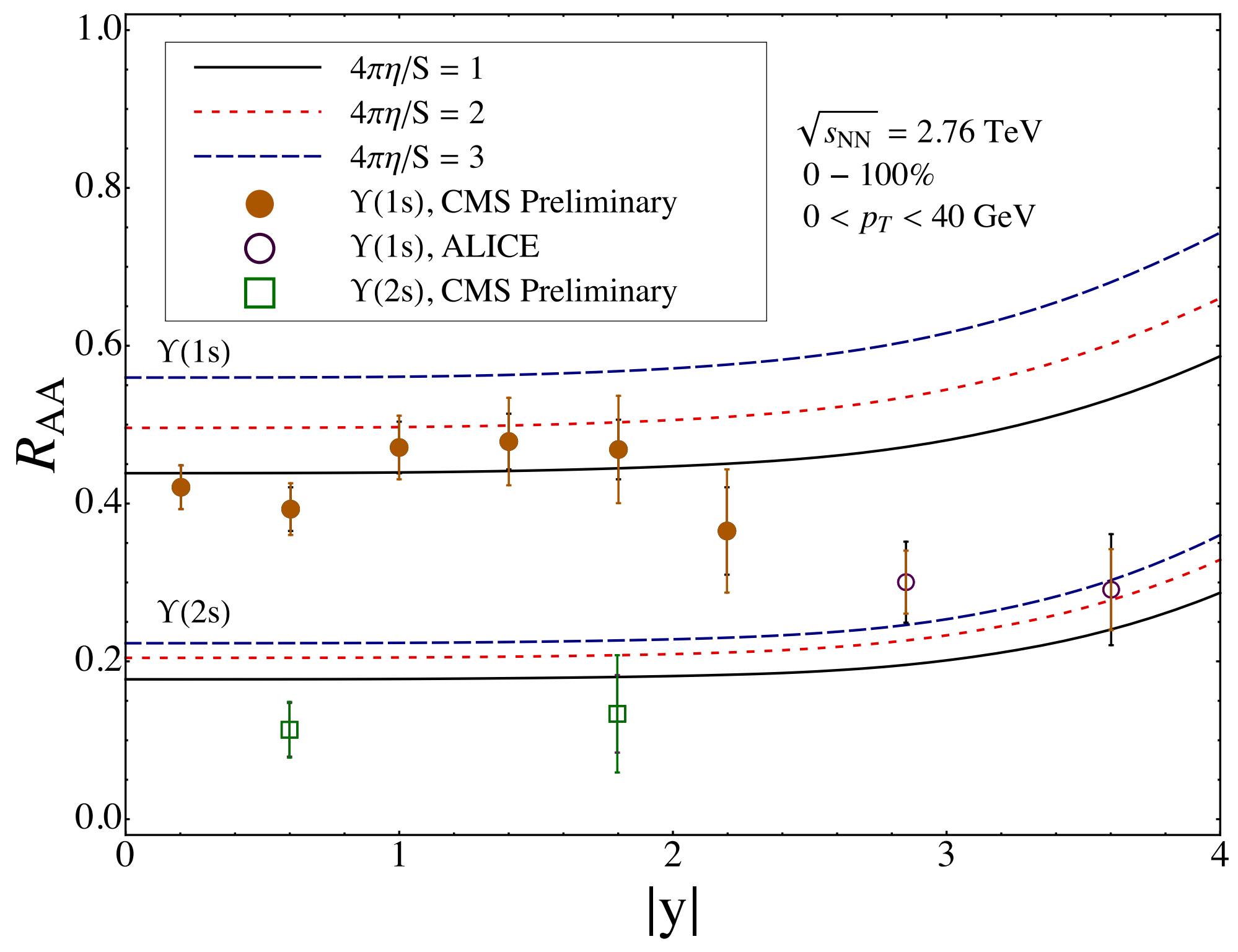
- Pattern of sequential suppression seen
- No visible thresholds due to continuous decays

$\Upsilon(1s)$ Production Fractions	
$\Upsilon(1s)$	0.618
$\Upsilon(2s)$	0.105
$\Upsilon(3s)$	0.02
χ_{b1}	0.207
χ_{b2}	0.05
$\Upsilon(2s)$ Production Fractions	
$\Upsilon(2s)$	0.5
$\Upsilon(3s)$	0.5

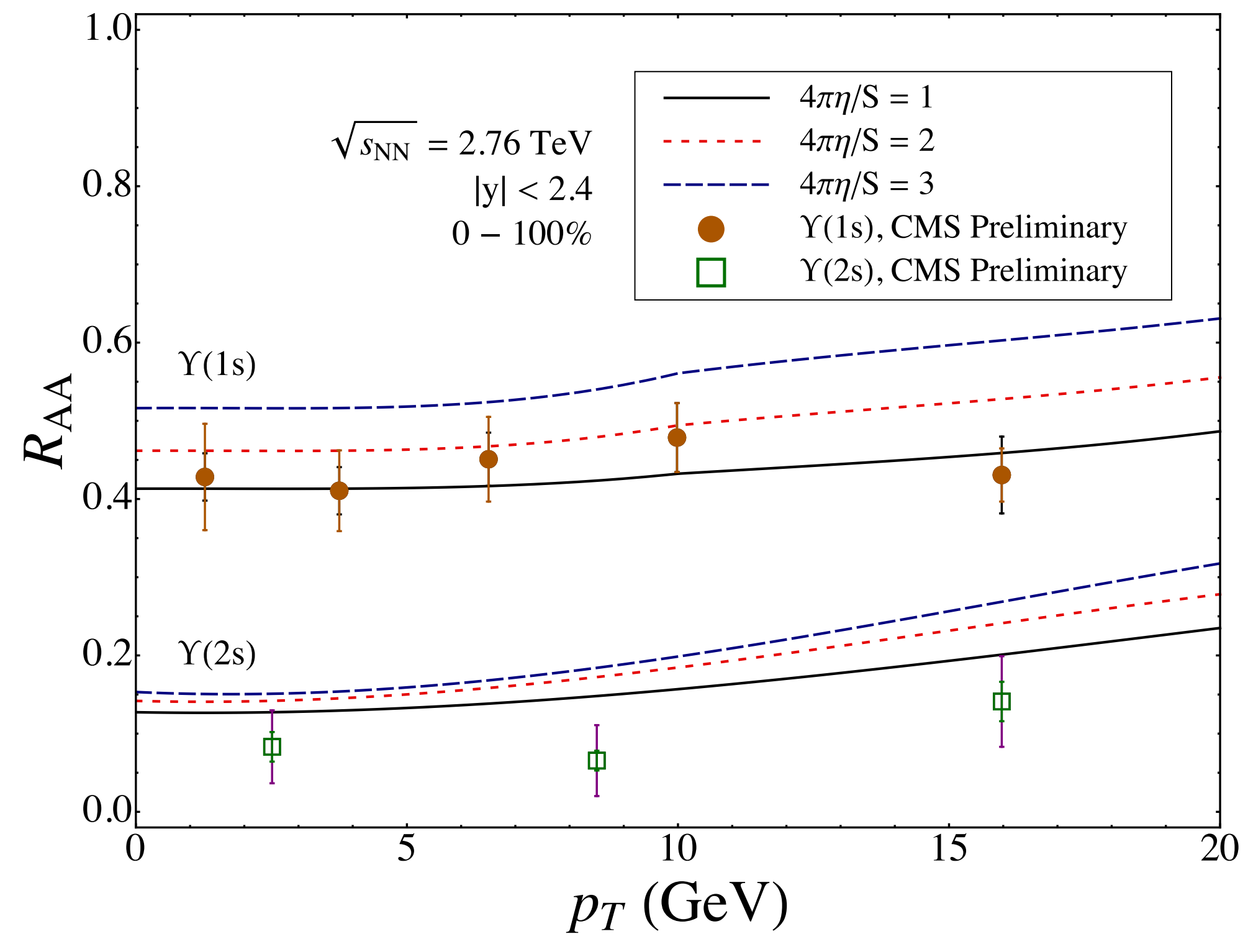
Final Results



- Some tension with the lowest $N_{\rm part}$ point for $R_{AA}^{\Upsilon(2s)}$
- $R_{AA}^{\Upsilon(1s)}$ data prefers small shear viscosities $1 \simeq 4\pi\eta/S \simeq 2$
- $R_{AA}^{\Upsilon(2s)}$ data does not provide a tight constraint on η/S at this point in time



- Model does a reasonable job in reproducing the trends seen in the CMS preliminary data
- Change in the way we perform centrality averaging
- Still some lingering tension with the ALICE forward results



- Slow increase in R_{AA} is due to the effect of time-dilation of the formation times of the states
- The data prefers small values of η/S for $R_{AA}^{\Upsilon(1s)}$
- For the $R_{AA}^{\Upsilon(2s)}$, the model seems to under predict the amount of suppression seen in CMS preliminary data

Conclusions

- At central rapidities ($y \simeq 2$) the data are consistent with bottomonia suppression due to the creation of a deconfined QGP with a shear viscosity to entropy density ratio roughly between $1/(4\pi)$ and $2/(4\pi)$.
- These values are consistent with those obtained via analysis of the collective flow coefficients, thereby providing further evidence that the QGP created in relativistic heavy ion collisions behaves like a nearly perfect fluid.

Acknowledgements/References

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