Strongly interacting QGP and quarkonium suppression at RHIC and LHC energies

Binoy Krishna Patra
Department of Physics,
Indian Institute of Technology Roorkee

Outline of talk

- Why do we think QGP is strongly-coupled?
- Equation of state for strongly-coupled e/m plasma
- Equation of state for strongly-coupled QGP
  - ⇨ Results on thermodynamic variables, pressure, energy density etc.
- Journey and dissociation of c-cbar pair in nucleus-nucleus collisions

- Longitudinal expansion in presence of shear viscosity

- Suppression in a longitudinally expanding QGP

- Results and conclusions

- Future scope

Evidences of sQGP

Shuryak. Pro. Part. Nu. Phy.53’04

1. a) Collective phenomena observed at RHIC: QGP as a “near perfect liquid” with *ratio* η/s=.1-.2 in contrast to pQCD

   b) Not only light jets, charmed ones are strongly quenched

   STAR, PHENIX, PHOBOS,BRAHMS, NPA 757’05

   b) Charm diff const D_c from charm flow is much lower than pQCD estimates

   Teaney PRC 68’03.Moore and Teaney, PRC71’05

2. η_c, J/ Ψ remains bound till near $3T_c$ S Datta et al. PRD’04, M Asakawa et al NPSA 715’03 resonance enhance transport cross section ⇒ liquid-like behavior

⇒ Similar thing does happen for ultracold trapped atoms: Feshbach resonance

3. $\Gamma = \langle K.E.\rangle/\langle P.E.\rangle$ in sQGP is not small. e/m plasmas at comparable coupling $\Gamma \sim 1$-10 are good liquids too.

4. Exact correspondence N =4 SYM ⟺ type IIB string theory in AdS space. The results in CFT plasma are close to what we know about sQGP

Maldacena, In. J. Th.Ph.38’99

Various equation of states for QGP

- Bag model: QGP is treated as a big hadron with large number of partons interacting weakly but confined by the bag wall.
  Further inclusions of glue balls or hadrons improve the predictions.
  Rischke et al. PLB 278’92; ZPC56’92, Bannur PLB362’95,Khadkikar et al Mod PLA8’93

- Confinement model: Extension of bag model with smooth potential like Cornell potential, harmonic oscillator potential using Mayer’s cluster expansion method

- Quasi-particle models: Peshier et al. PLB 337’94; PRD 54’96, Levai, Heinz PRC 57’98
  a) constant parton masses and bag constant Schneider &Weise, PRC 64’01
  b) temperature dependent parton masses and bag constant
  c) effective degrees of freedom d(T) to take account of the changes in dof near T_c

➡ All of them claim to explain lattice results, either by adjusting free parameters in the model or by taking lattice data on one of the thermodynamic quantity as an input and predicting other quantities. Rischke Prog Part Nucl Phys 52’04

<u>physical picture of quaiparticle model and the origin of various temperature dependent quanties are not clear yet</u>

- EoS of interacting quarks and gluons up to O (g^5) and has been further improved upon by incorporating the contributions from the non-perturbative scales : gT, g^2T up to O(g^6 ln(1/g)) with poor convergence except for very low coupling
  Arnold & Zhai, PRD 50'94, 51'95, Pisarski, PRL 63'89, Braaten &Pisarski, NPB337'90
  Kajantie et al., PRD67'03,Arnold & Yaffe, PRD52'95,Zhai &Kastening, PRD52'95

- Semi-classical approach incorporate HTL effects where the non-perturbative features manifested as effective mean color fields having the dual role of producing the soft and semi-soft partons. Kelly et al.PRL72'94, Nayak & Ravishankar, PRC 58'98, Bhalerao & Ravishnakar, PLB409'97

  ⇨ emergence of a classical transport theory with effective field dof Blazoit & Iancu, PRL70'93

- Strongly interacting QGP models (sQGP), one considers various binary color bound states even at T > T_c and try to explain non-ideal behavior of QGP near T_c
  Shuryak & Zahed, PRD 70'04

- PNJL Model: NJL Model (chiral symmetry) with a Polyakov loop (confinement)
  Ghosh et al. PRD 73'06, Ratti, Roessner, Thaler, Weise Eur Phy JC49'07

- one can either abandon field-theoretical models like perturbative in favor of quasi particle models with many fitting parameters to reproduce the lattice data or turn to a less intuitive Polyakov-loop model which also contains more than two parameters.

Equation of State for e/m plasma

• Plasma is a quasi-neutral gas of charged and neutral particles which exhibits collective behavior.

At sufficiently high temperature neutral particles will be negligibly small so that one can see collective effects of plasma otherwise it will be just ordinary neutral gas and not plasma.

Interaction parameter in plasma : ratio of average potential energy to average kinetic energy

$$\Gamma = \frac{\langle PE \rangle}{\langle KE \rangle}$$

For classical e/m plasma

$$\Gamma = \frac{e^2}{a_e k_B T}$$

$$a_e = \left(3/4\pi n_e\right)^{1/3}$$

Wigner-Seitz radius

Strongly-coupled plasma (SCP) is a plasma where the plasma parameter, is of the order of 1 or larger.

Equation of state for a strongly coupled (non-relativistic) plasma where the internal energy of a classical one-component plasma: a sum of ideal-gas part and the excess as a function of plasma parameter

$$u = \left(3/2 + u_{ex}(\Gamma)\right) n T$$

Excess part $u_{ex}(\Gamma)$ is calculated from the interaction energy per unit volume

$$E_{\text{int}} = \sum_{\sigma,\tau} \frac{dk}{(2\pi)^3} \frac{2\pi Z_\sigma Z_\tau e^2 \sqrt{n_\sigma n_\tau}}{k^2} \left[S_{\sigma\tau} - \delta_{\sigma\tau} \right]$$

Dynamic structure factor $$S_{\sigma\tau}(k,\omega) = -\frac{\hbar}{2\pi} \coth\left(\frac{\hbar\omega}{2k_B T} \right) \text{Im}\,\chi_{\sigma\tau}(k,\omega)$$

Static structure factors $$S_{\sigma\tau}(k) = \frac{1}{\sqrt{n_\sigma n_\tau}} \int_{-\infty}^{\infty} d\omega S_{\sigma\tau}(k,\omega)$$

RPA: An approximation that goes beyond Hartree-Fock approximation where one takes account of the Coulomb interaction through mean field term (nonlinear coupling term between the density-fluctuation excitation remains neglected)

Since mean field term is linear in the fluctuations, the RPA density-density response functions

$$\chi^{RPA}_{\sigma\tau}(k,\omega) = \sum_{\rho} \delta_{\sigma\rho}\delta_{\tau\rho}\chi^{(0)}_{\rho}(k,\omega) + \frac{Z_\sigma Z_\tau v(k)\chi^{(0)}_{\sigma}(k,\omega)\chi^{(0)}_{\tau}(k,\omega)}{\varepsilon_0(k,\omega)}$$

RPA dielectric function:

$$\varepsilon_0(k,\omega) = 1 - \sum_{\sigma} Z_\sigma^2 v(k)\chi^{(0)}_{\sigma}(k,\omega)$$

For a high T and low density plasma, static values of Vlasov polarizability are:

$$\chi^{(0)}_{\sigma}(k,0) = -\frac{n_\sigma}{k_B T}$$

give the Debye-Huckel value for the excess internal energy

$$u^{DH}_{ex}(\Gamma) = -\frac{\sqrt{3}}{2}\Gamma^{3/2}$$

The next terms in the coupling-constant expansion of $u_{ex}(\Gamma)$ were calculated by Abe exactly in the giant cluster expansion theory for $\Gamma<0.1$

$$u_{ex}^{Abe}(\Gamma) = -\frac{\sqrt{3}}{2}\Gamma^{3/2} - 3\Gamma^{3}\left[\frac{3}{8}\ln(3\Gamma) + \frac{\gamma}{2} - \frac{1}{3}\right]$$

O'Neil & Rostoker '65 : analyzed the triple correlation in a plasma by expanding BBGKY hierarchy in powers of plasma parameter

Totsuji and Ichimaru'73 calculated structure factor in the convolution approx through a split of the k-integration into long and short wavelength domains

- Abe's formula accurately give the values of excess internal energy for $\Gamma<0.1$

Strong coupling regime 1<Γ<180, the excess internal energy has been evaluated by computer simulations: Saltery, Doolen and DeWitt' 82; Ogatta & Ichimaru' 87

$$u_{ex}^{OCP}(\Gamma) = -0.898004\Gamma + 0.96786\Gamma^{1/4} + 0.220703\Gamma^{-1/4} - 0.86097$$

Intermediate-coupling regime 0.<Γ<1,

Excess internal energy has been calculated through a solution to the hypernetted-chain scheme (HNC) integral equations. Using these HNC values, one finds a formula connecting the above weakly-coupled & strongly-coupled results:

$$u_{ex}(\Gamma) = \frac{u^{Abe}{}_{ex}(\Gamma) + 3\times10^{3}\Gamma^{5.7}u_{ex}{}^{OCP}(\Gamma)}{1+3\times10^{3}\Gamma^{5.7}}$$

- This formula is applicable for a classical OCP fluid in the range Γ<180 with the accuracy better than 0.1%

Equation of state for SCQGP in analogy to e/m plasma

- QGP is a quasi-color-neutral gas of colored particles like quarks and gluons which exhibits collective behavior.

To see the collective behavior , color neutral objects like hadrons and glue balls must be negligibly small in number. Otherwise, it is just a hadron gas and not QGP.

Equation of state for SCQGP has been inferred by utilizing the understanding from strongly coupled plasma where hadrons are assumed to exist only for $T<T_c$ and undergo to plasma of quarks and gluons for $T>T_c$,

no hadrons or glue balls because the confinement interactions in vacuum vanish due to the melting of string at the deconfinement (critical) temperature

color Coulombic interactions due to one gluon exchange with proper quantum effects like running coupling constant

Interaction parameter in QGP

$$\Gamma_{QGP}^{Bannur} = \frac{4}{3}\frac{\alpha_s}{a_e k_B T}$$

Bannur, J Phy G 32'06

- Deviation of equation of state from ideal gas behavior even at $T>>T_c$
- Phase transition ($\mu=0$) is smooth cross-over,

➡ String tension should not vanish sharply at T_c

Effective potential by correcting the full (linear+Coulomb) Cornell potential with a dielectric function embodying the effects of deconfined medium and not its Coulomb part alone gives

➡ a non-vanishing confining (string) term, in addition to the screened-Coulomb term Agotiya, Chandra, BKP, PRC 80'09

$$V(r,T)=\left(\frac{2\sigma}{m_D{}^2(T)}-\alpha\right)\frac{\exp(-m_D(T)r)}{r}-\frac{2\sigma}{m_D{}^2(T)r}+\frac{2\sigma}{m_D(T)}-\alpha m_D(T)$$

A gauge-invariant, non-perturbative form where non-perturbative corrections, $O(g^2T)$ and $O(g^3T)$ to the leading-order from the effective field theory approach to finite temperature QCD by 3-D lattice simulations Kajantie et al. PRL 79'97

$$m_D = m_D^{LO} + \frac{n_c g^2 T}{4\pi}\ln\left(\frac{m_D^{LO}}{g^2 T}\right) + C_{n_c} g^2 T + d_{n_c n_f} g^3 T + ..$$

Energy density for the relativistic QGP:

$$\varepsilon = \left(2.7 + u_{ex}(\Gamma)\right) n T$$

$$\Gamma_{QGP}^{Our} = \frac{V(r = a_{e,} T)}{k_B T}$$

F
irst term corresponds to ideal EoS

$$\varepsilon = 3 a_f T^4$$

a_f is constant which depends on degree of freedom.

$$a_f = (16 + 21 n_f / 2) \pi^2 / 90$$

Scaled energy density $$e(\Gamma) \equiv \frac{\varepsilon}{\varepsilon_{SB}} = 1 + \frac{1}{2.7} u_{ex}(\Gamma)$$

Pressure by using the relation (for μ=0)

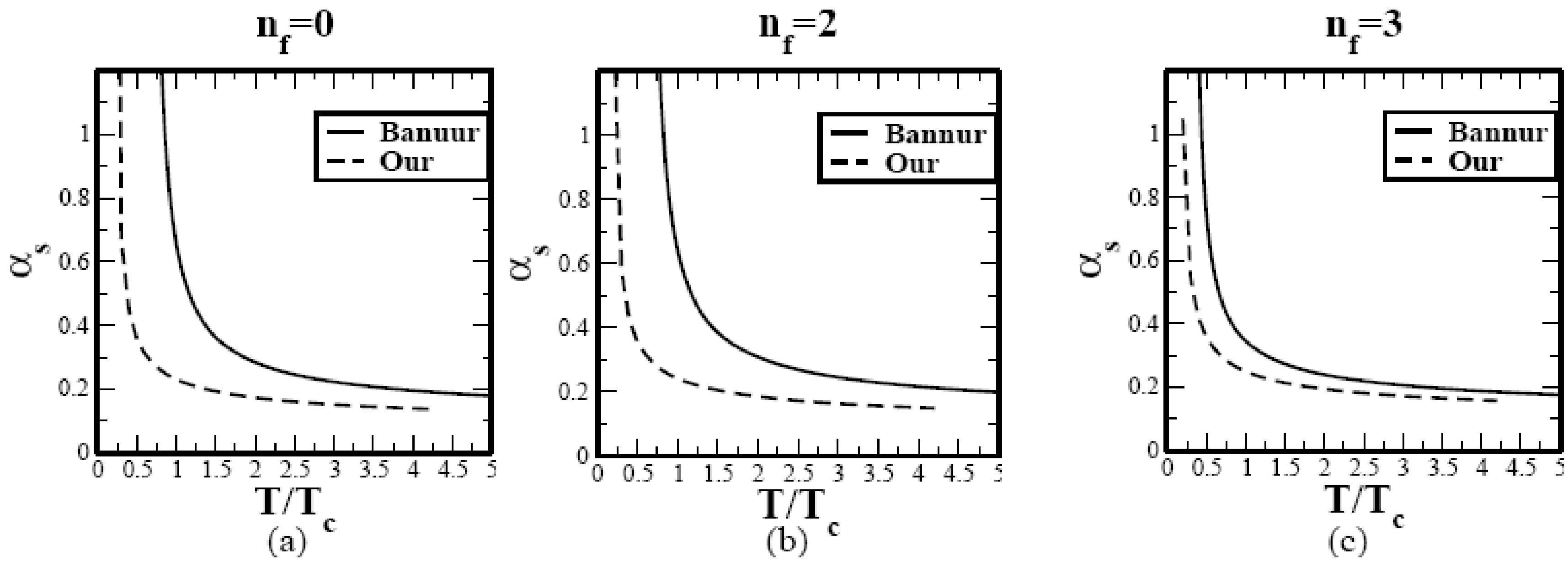
$$\varepsilon = T\frac{dp}{dT} - p$$

$$\frac{p}{T^4} = \left(\frac{p_0}{T_0} + 3a_f T^4 \int_T^{T_0} d\tau \tau^2 e(\Gamma(\tau)) \right) / T^3$$

P_0 is determined by the pressure at some reference temperature T_0 and has been fixed with the pressure at the critical temperature for a particular system, such as, gluon plasma, 2-flavor plasma etc.

Speed of Sound: $$C_s^2 = \frac{\partial P}{\partial \varepsilon}$$

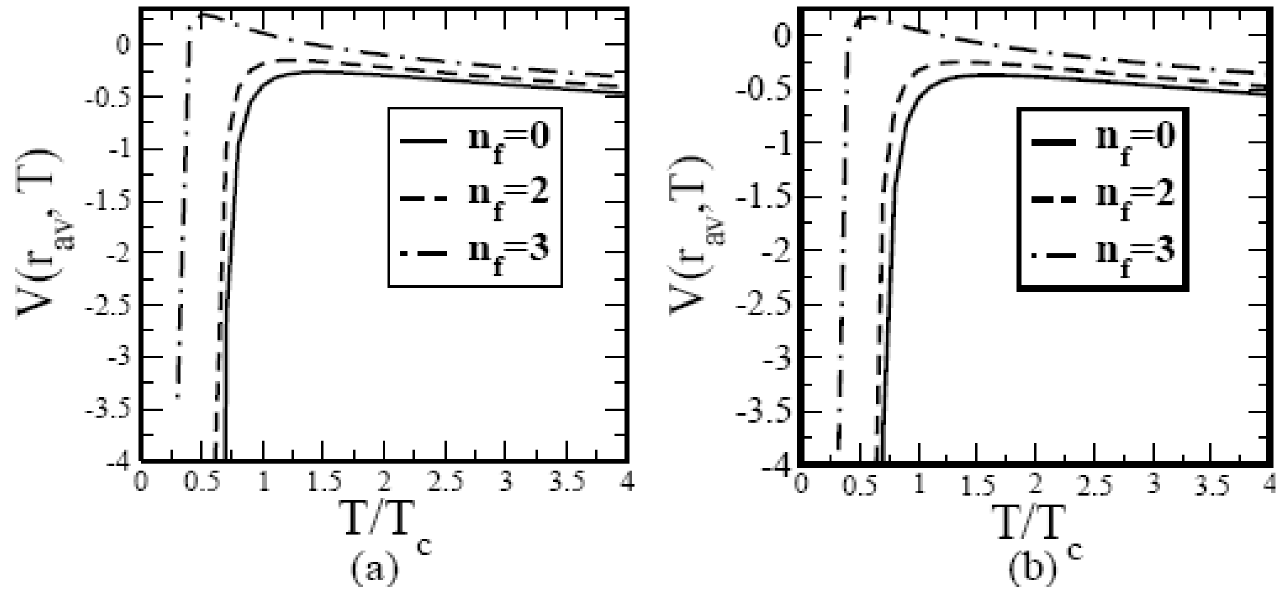
Once we know the pressure P and the energy density ε as a function of temperature, the speed of sound can be evaluated immediately



Coupling constant, αs as a function of T/Tc for pure, 2-flavor and 3-flavor QCD.

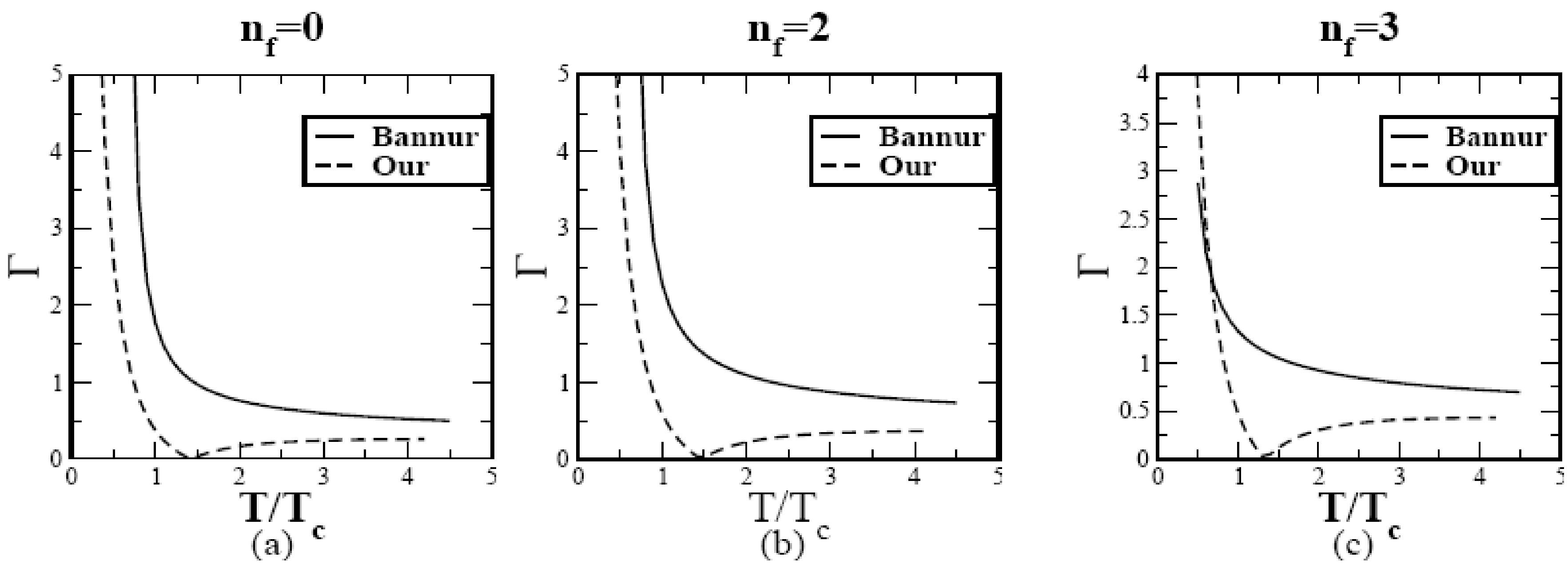
QCD coupling up to two loop:

$$\alpha_s(T) = \frac{6\pi}{\left(33-2n_f\right)\ln\frac{\bar{\mu}}{\Lambda_{\overline{MS}}}}\left(1+\frac{3(153-19n_f)}{(33-2n_f)^2}\frac{\ln(2\ln\frac{\bar{\mu}}{\Lambda_{\overline{MS}}})}{\ln\frac{\mu}{\Lambda_{MS}}}\right)^{-1}$$

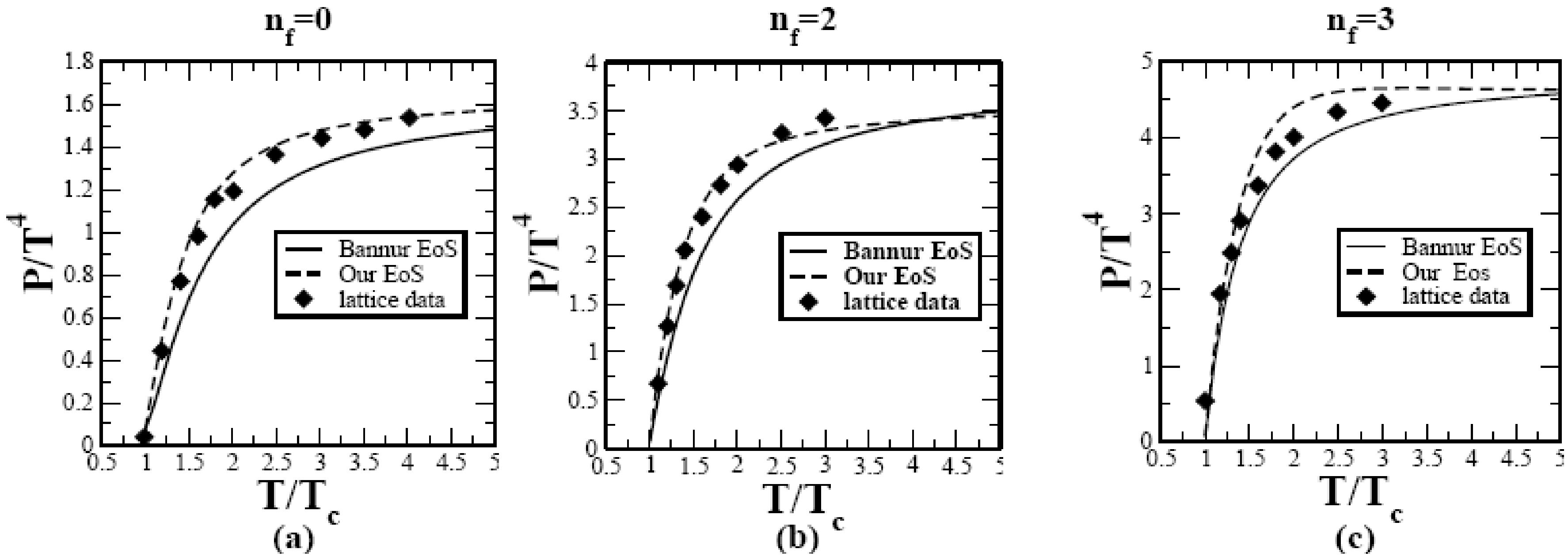


V (r_{av} ,T) as a function of T/Tc for pure gauge, 2-flavor QGP and 3-flavor QGP using the Debye masses a) in leading-order and b) lattice parametrized form (m^L)

$$m_D^{LO} = \left(\frac{n_c}{3} + \frac{n_f}{6}\right) gT \qquad F(r,T) - F(\infty,T) \approx -\frac{4}{3}\frac{\alpha_s(T)}{r}\exp\left(-m_D^L(T) r\right)$$



Plasma parameter as a function of T/Tc from Bannur model (solid-line) and our model (dashed line) for pure, 2-flavor and 3-flavor QGP using leading-order Debye mass, respectively

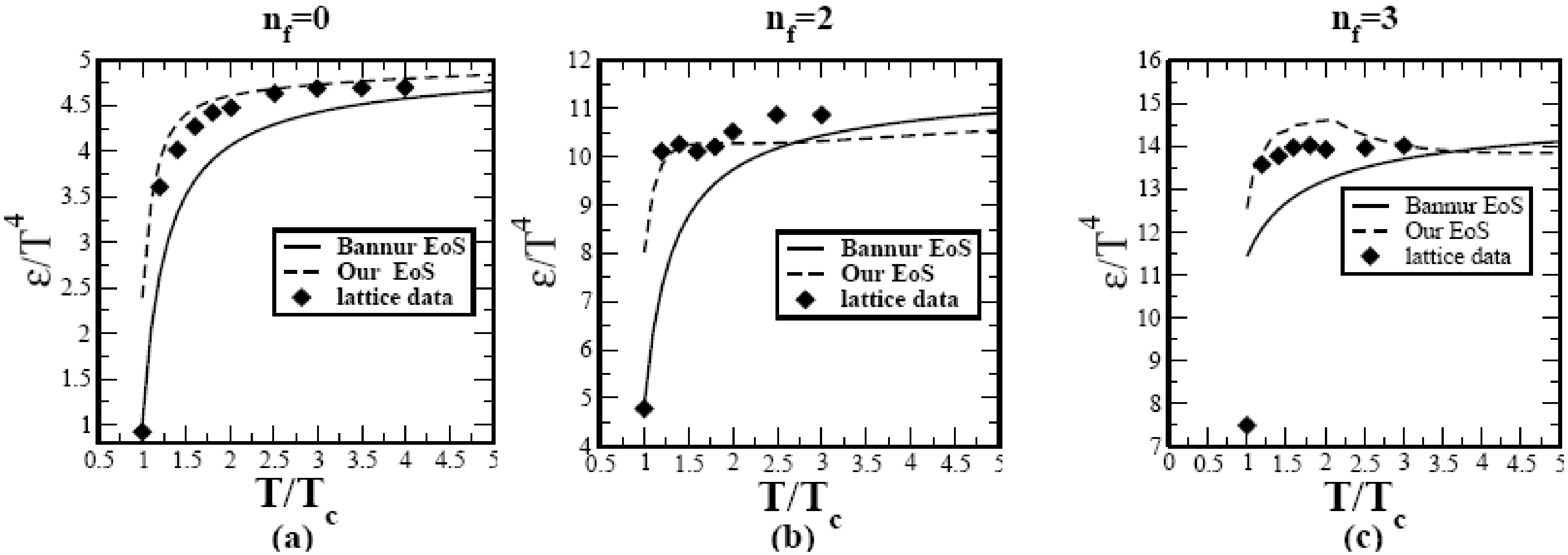


P/T^4 as a function of T/T_C from our model and Bannur model and lattice results (symbols) for N_f=0, 2 and 3-flavor QGP.

G. Boyd et al., Phys. Rev. Lett. 75, 4169 (1995); Nucl. Phys. B 469, 419 (1996);

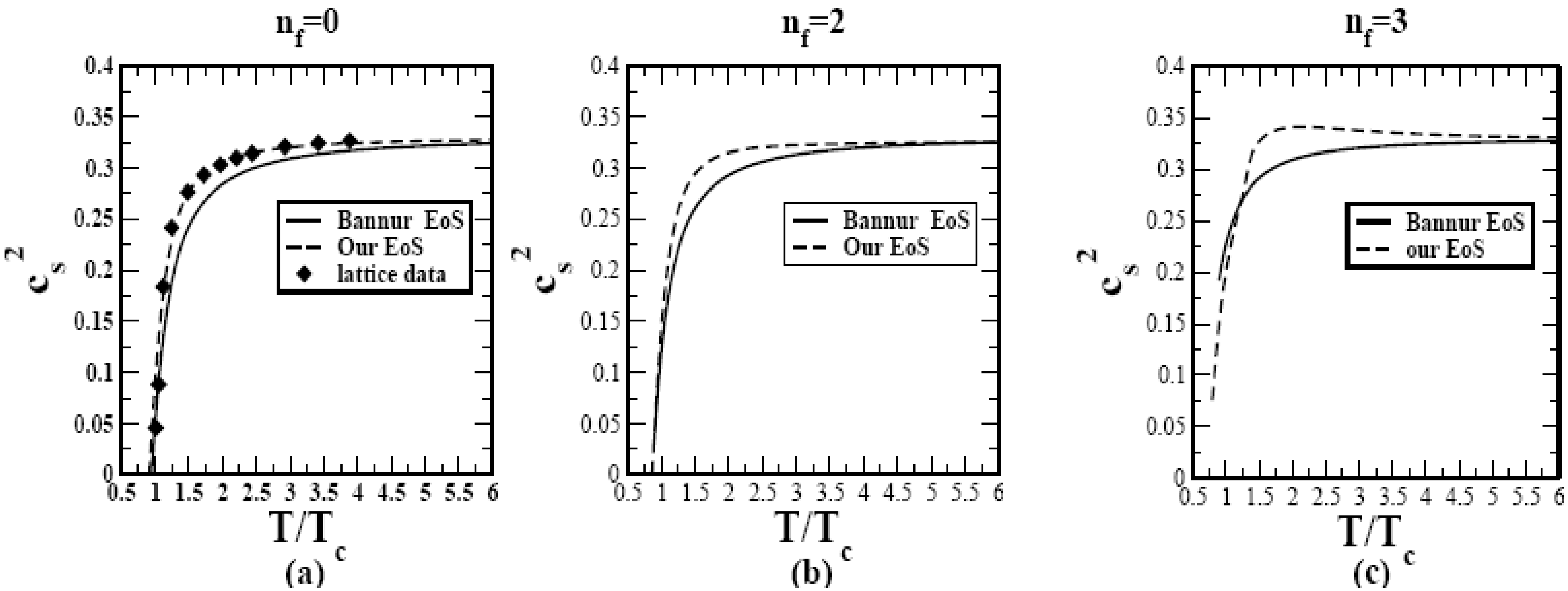
A. Bazavov et al., Phys. Rev. D 80, 014504 (2009).

M. Cheng et al., Phys. Rev. D 77, 014511 (2008



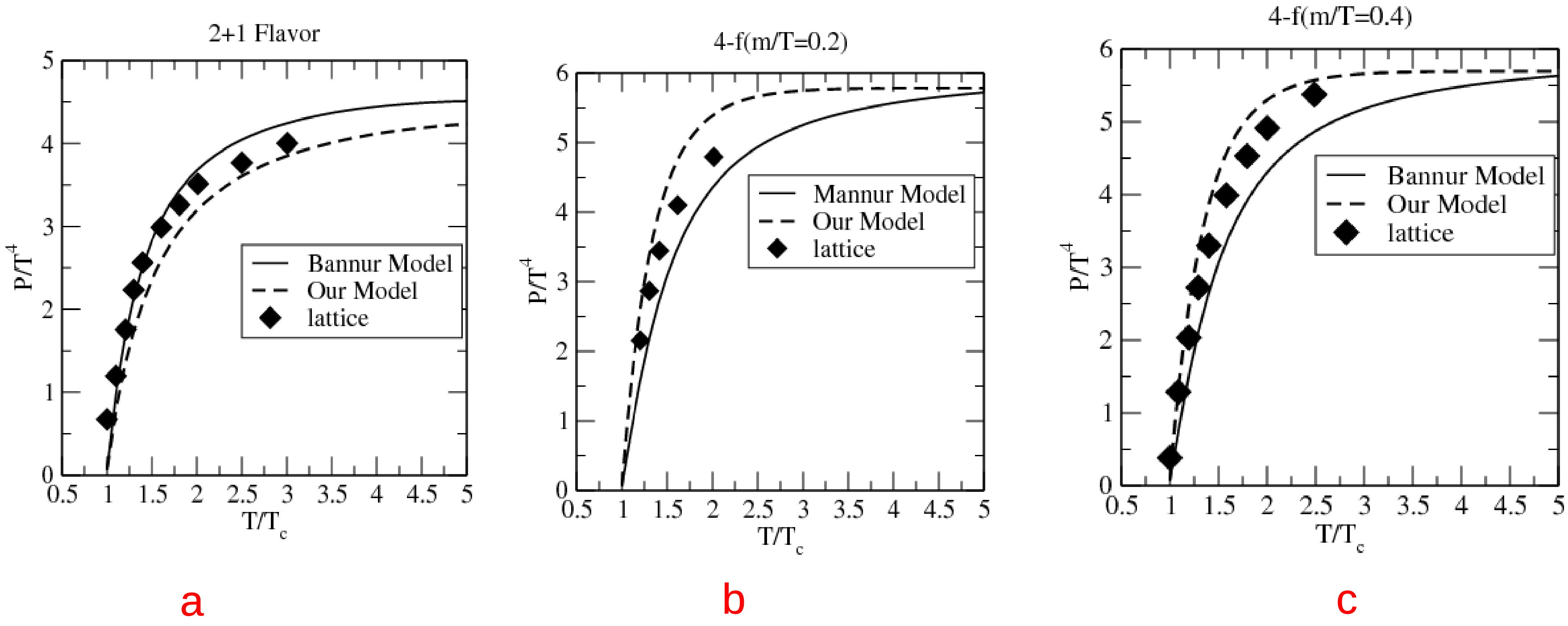
ε/T^4 as a function of T/Tc from our model and Bannur model for N_f=0, 2 and 3-flavor QGP with lattice data.

G. Boyd et al., Phys. Rev. Lett. 75, 4169 (1995); Nucl. Phys. B 469, 419 (1996);
A. Bazavov et al., Phys. Rev. D 80, 014504 (2009).
M. Cheng et al., Phys. Rev. D 77, 014511 (2008)



Speed of sound as a function of T/T_C from our model and Bannur model and lattice results (symbols) for N_f=0, 2 and 3 flavor QGP.

G. Boyd et al., Phys. Rev. Lett. 75, 4169 (1995); Nucl. Phys. B 469, 419 (1996);
A. Bazavov et al., Phys. Rev. D 80, 014504 (2009).
M. Cheng et al., Phys. Rev. D 77, 014511 (2008)



Plots of P/T^4 as a function of T/Tc for a) two massless and one massive (2+1) and b) and c) 4-flavour QGP for two different masses.

G. Boyd et al., Phys. Rev. Lett. 75, 4169 (1995); Nucl. Phys. B 469, 419 (1996);
A. Bazavov et al., Phys. Rev. D 80, 014504 (2009).
M. Cheng et al., Phys. Rev. D 77, 014511 (2008)

Journey of J/ψ

Heavy quark pair leading to J/Ψ mesons are produced on a very short time-scale

T. Matsui, H. Satz, PLB178'86

↓

The pair develops into physical resonance over a τ_{Ψ} and traverses the plasma

↓

Hadronic matter before leaving the interacting system to decay into a dilepton

Different stages of dissociation

Even before J/ Ψ is formed it may be absorbed by the nucleons streaming past it

C. Gerschel et al, PLB207'88

↓

By the time the resonance is formed, the screening of color forces in plasma may be sufficient to inhibit a binding of the c $\bar{c}$

B.K.P. et al, PLB505'05

↓

The resonance could either be dissociated by energetic gluons in plasma

X.M. Xu. et al, PRC53'96,
B.K.P , EPJC37'04; C44'05; C48'06

↓

A comoving hadron could also dissociate J/ψ

Suppression of J/ψ in a longitudinally expanding plasma

Hydrodynamic boost-invariant Bjorken expansion in (1 + 1) dimension in first-order dissipative term Binoy, Agotiya & Chandra, Eur Phy C 67' 10

$$\varepsilon(\tau)\tau^{1+C_S^2} + \frac{4a}{3\tilde{\tau}^2}\tau^{1+C_S^2} = \varepsilon(\tau_i)\tau_i^{1+C_S^2} + \frac{4a}{3\tilde{\tau}_i^2} = const.$$

Where

$$a = \left(\frac{\eta}{s}\right)T_i^3\tau_i \qquad \tilde{\tau}^2 = \left(1 - C_s^2\right)\tau^2$$

First term for the contributions coming from the zeroth-order expansion and the second term is the first-order viscous corrections

Initial energy-density profile on any transverse plane :

$$\varepsilon(\tau_i, r) = \varepsilon_i A_T(r);\; A_T(r) = \left(1 - \frac{r^2}{R_T^2}\right)^\beta \theta(R_T - r)$$

r is transverse co-ordinate R_T is the transverse radius of the nucleus

Average energy density ε_i $$\pi R_T^2 \langle \varepsilon_i \rangle = \int 2\pi r dr \varepsilon(r)$$

Initial energy density ε_i $$\varepsilon_i = (1+\beta)\langle \varepsilon_i \rangle$$

Average Energy density : Bjorken Formula

$$\langle \varepsilon_i \rangle = \frac{1}{\pi R_T^2 \tau_i} \frac{dE_T}{dy}$$

E_T : Transverse energy deposited in the collision

where $A_T = \pi R_T^2$ is the transverse overlap area of the colliding nuclei and $(dE_T/dy_h)y_h=0$ is the transverse energy deposited per unit rapidity of outgoing hadrons.

Both depend on the number of participants N_{part} and thus provide centrality dependent initial average energy density in the transverse plane

Initial Conditions at RHIC & LHC

N_{part}	R_T (fm)	**RHIC** $\langle \varepsilon_i \rangle$ (GeV/fm^3)	**LHC** $\langle \varepsilon_i \rangle$ (GeV/fm^3)
22.0	3.45	5.86	217.97
30.2	3.61	7.92	236.12
40.2	3.79	10.14	253.15
52.2	3.96	12.76	269.11
66.7	4.16	15.69	291.45
83.3	4.37	18.58	315.55
103	4.61	21.36	341.05
125	4.85	24.38	370.49
151	5.12	27.37	400.42
181	5.38	30.52	433.18
215	5.64	34.17	463.66
254	5.97	37.39	507.04
300	6.31	41.08	550.88
353	6.68	45.09	600.39

Parton Saturation model

$$\varepsilon_i = 0.103 GeV fm^{-3} A^{0.504} (\sqrt{s})^{0.786}$$

$$n_i = 0.103 GeV\, 0.370\, fm^{-3} A(\sqrt{s})^{0.574}$$

$$T_i = 0.111 GeV A^{0.126} (\sqrt{s})^{0.197}$$

Energy density drops to screening energy density ε_s : $\varepsilon(\tau, r) = \varepsilon_s$

Secreening time τ_s

Binoy, Agotiya & Chandra, Eur Phy C 67' 10

$$\tau_s(r) = \tau_i \left[\frac{\varepsilon_i(r) - \dfrac{4a}{3\tilde{\tau}_i^2}}{\varepsilon_s(r) - \dfrac{4a}{3\tilde{\tau}_s^2}} \right]^{1/(1+C_s^2)} \qquad \tilde{\tau}_s^2 = \left(1 - C_s^2\right)\tau_s^2$$

Screening time depends:

•The difference between the initial energy density and the screening energy density ⇒ more will be the difference more will be the suppression.

•Speed of sound : ⇒ if the rate of cooling will be slower i.e. screening time large for a fixed difference leading to more suppression

•The η / s ratio : If ratio is larger then cooling will be slower

Critical radius r_s : Duration of screening $\tau_s(r)$ = Formation time $t_F = \gamma\tau_F$
for the quarkonium in the plasma frame

$$r_s = R_T \left(1 - A\right)^{1/2} \theta\left(1 - A\right)$$

Where A is given by

$$A = \left[\left(\frac{\varepsilon_s}{\varepsilon_i} \right) \left(\frac{t_F}{\tau_i} \right)^{1+c_s^2} + \frac{1}{\varepsilon_i} \left(\frac{t_F}{\tau_i} \right)^{1+c_s^2} \frac{4a}{3\tilde{t}_F^{\,2}} + \frac{1}{\varepsilon_i} \frac{4a}{3\tilde{\tau}_i^{\,2}} \right]^{1/\beta}$$

Condition of survival:

$$| r + \tau_F \, p_T \; / \; M \; | \geq r_s$$

r :position , p_T: transverse momentum

$$\cos\phi \geq \left[\left(r_s^2 - r^2 \right) M - \tau_F^2 \, p_T^2 \, / \, M \right] / \left[2 r \tau_F \, p_T \right],$$

ϕ: angle between vectors **r** and $\mathbf{p_T}$

Survival probability of the quarkonium:

Chu & Matsui, PRD 37'88
DP, BKP and DKS, EPJC17(2000)

$$S(p_T) = \left[\int_0^{R_T} r dr \int_{-\phi_{max}}^{+\phi_{max}} d\phi P(r, P_T) \right] / 2\pi \left[\int_0^{R_T} r dr P(r, P_T) \right]$$

Where Φ_{max} is the maximum positive angle

$$\phi_{max} = \begin{cases} \pi & \text{if } y \leq -1 \\ \cos^{-1}|y| & \text{if } -1 < y < 1 \\ 0 & \text{if } y \geq 1 \end{cases}$$

where

$$y \geq \left[\left(r_s^2 - r^2 \right) M - \tau_F^2 p_T^2 / M \right] / \left[2 r \tau_F p_T \right]$$

And P is the probability for the quark pair production at (r, P_T) in a hard collision which may be factored out as

P(**r, P$_T$**) =f(r) g(P_T)

profile function f(r) ;

$$f(r)\alpha\left(1-\frac{r^2}{R_T^2}\right)^{\alpha}\theta(R_T-r)$$

Experimental measurement of survival probability at a given number of participants N_{part} or rapidity y is reported in terms of the p_T integrated yield ratio whose theoretical expression would be

$$\langle S(p_T)\rangle=\frac{\int_{p_T^{min}}^{p_T^{max}} dP_T\, S(P_T)}{\int_{p_T^{min}}^{p_T^{max}} dP_T}$$

$<P_T>$ -integrated inclusive survival probability of J/ψ : H. Satz, NPA783'07

$$\langle S^{incl}\rangle = 0.6\langle S^{dir}\rangle_{\psi} + 0.3\langle S^{dir}\rangle_{\chi_c} + 0.1\langle S^{dir}\rangle_{\psi'}$$

States	τ_f	T_D	C_S^2 (SIQGP)	ε_S (SIQGP)	C_S^2 (Bannur)	ε_S (Bannur)
J/Ψ	0.89	2.10	0.308	29.33	0.275	32.05
Ψ'	1.50	1.12	0.255	01.94	0.214	02.36
χ_C	2.00	1.16	0.261	02.28	0.220	02.74

Formation time (fm), dissociation temperature T_D (in units of Tc=197 MeV for a 3-flavor QGP) with the Debye mass in the leading-order, the speed of sound and the screening energy density (GeV/fm3) calculated in SIQGP EoS for J/ψ, ψ', χ_c states respectively

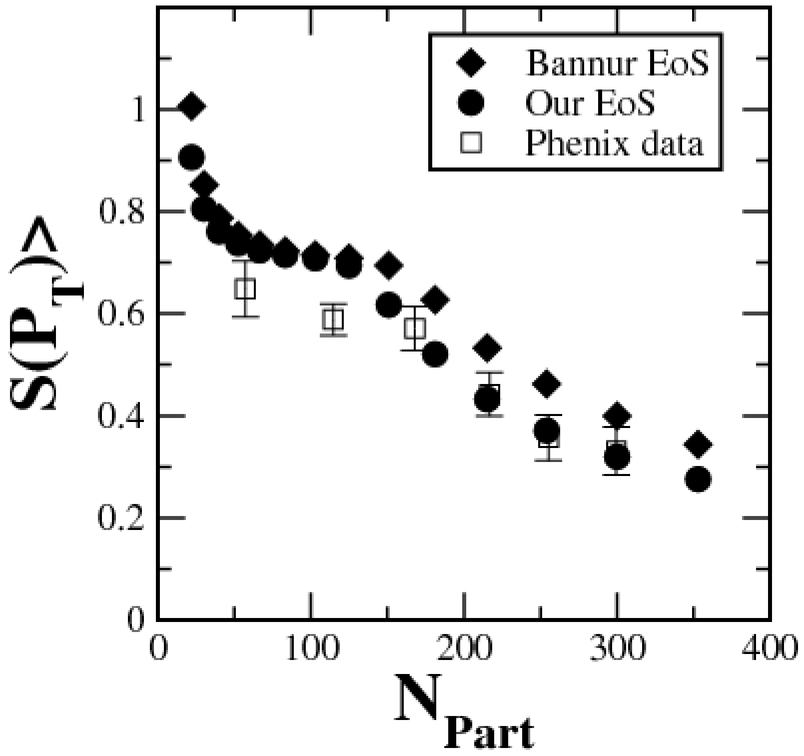


Fig. Variation of P_T integrated survival probability versus number of participants using Debye mass in leading-order.

States	τ_f	T_D	C_S^2 (our)	ε_S (our)
γ	0.76	4.18	0.322	496.86
γ'	1.90	1.47	0.287	06.31
χ_b	2.60	1.61	0.294	09.38

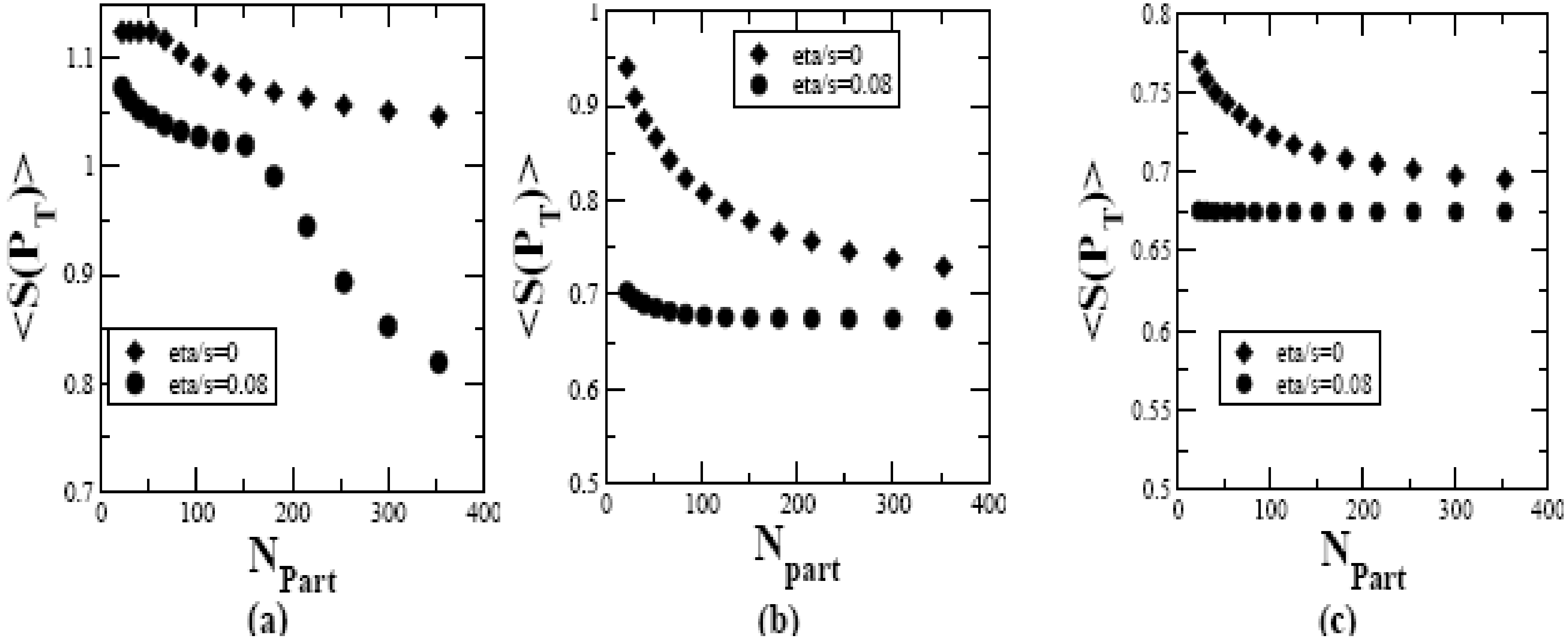
Formation time (fm), dissociation temperature T_D with the Debye mass in the leading-order, the speed of sound and the screening energy density (GeV/fm^3) calculated in our EoS for bottomonium states respectively

States	τ_f	T_D	C_S^2 (our)	ε_S (our)
γ	0.76	3.40	0.320	213.14
γ'	1.90	1.18	0.263	02.44
χ_b	2.60	1.22	0.267	02.82

Formation time (fm), dissociation temperature T_D with the Debye mass in the leading-order, the speed of sound and the screening energy density (GeV/fm^3) calculated in our EoS for bottomonium states respectively

States	τ_f	T_D	C_S^2 (our)	ε_S (our)
γ	0.76	2.90	0.317	111.29
γ'	1.90	1.06	0.244	01.47
χ_b	2.60	1.07	0.247	01.58

Formation time (fm), dissociation temperature T_D with the Debye mass in the leading-order, the speed of sound and the screening energy density (GeV/fm^3) calculated in our EoS for bottomonium states respectively



p_T integrated survival probability versus number of participants for γ.The circles and diamonds represent sequential melting for $\eta/s = 1/4\pi$ and $\eta/s = 0$. The parameters for the figures (a), (b) and (c) are given in the Table(s) given in the next slide respectively.

Conclusions

- EoS for strongly interacting quark-gluon plasma in the framework of SCP with appropriate modifications to take account of color and flavor dof and QCD running coupling.

- improve r upon the existing one by correcting the full Cornell potential with a dielectric function embodying the effects of the deconfined medium and not its Coulomb part alone.

- nicely fit with the lattice EoS for gluon, massless and as well massive flavored plasma.

- apply our equation of state to estimate the centrality dependence of J/ψ suppression in an expanding, dissipative strongly interacting QGP

- very good agreement with the PHENIX results on J/ψ suppression at RHIC

- Predicted the upsilon suppression which is yet to be verified at CERN LHC.

Future Scope

To extend the present study by incorporating the higher-order contributions coming from the viscous forces including contributions of the bulk viscosity

To incorporate transverse expansion, variations in initial conditions, finite dissociation widths beyond the theta-function suppression, suppression effects during the formation time, coalescence effects etc

Thank you