M. Gyulassy 7/14/15 Tihany Workshop Hungary

Consistency of Perfect Fluidity and Jet Quenching in semi-Quark-Gluon Monopole Plasmas

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(Dated: March 10, 2015)

We utilize a new framework, CUJET3.0, to deduce the energy and temperature dependence of jet transport parameter, $\hat{q}(E > 10\ GeV, T)$, from a combined analysis of available data on nuclear modification factor and azimuthal asymmetries from RHIC/BNL and LHC/CERN on high energy nuclear collisions. Extending a previous perturbative-QCD based jet energy loss model (known as CUJET2.0) with (2+1)D viscous hydrodynamic bulk evolution, this new framework includes three novel features of nonperturbative physics origin: (1) the Polyakov loop suppression of color-electric scattering (aka "semi-QGP" of Pisarski et al) and (2) the enhancement of jet scattering due to emergent magnetic monopoles near T_c (aka "magnetic scenario" of Liao and Shuryak) and (3) thermodynamic properties constrained by lattice QCD data. CUJET3.0 reduces to v2.0 at high temperatures $T > 400$ MeV, but greatly enhances $\hat{q}$ near the QCD deconfinement transition temperature range. This enhancement accounts well for the observed elliptic harmonics of jets with $p_T > 10$ GeV. Extrapolating our data-constrained $\hat{q}$ down to thermal energy scales, $E \sim 2$ GeV, we find for the first time a remarkable consistency between high energy jet quenching and bulk perfect fluidity with $\eta/s \sim T^3/\hat{q} \sim 0.1$ near T_c.

CUJET3: Jiechen Xu, Jinfeng Liao, MG arXiv:1411.3673 [hep-ph]; version 2
CUJET2: Jiechen Xu, A. Buzzatti, MG, JHEP 1408 (2014) 063 , arXiv:1402.2956

My ride to the top of Mt. RHIC and Mt. LHC with friends Jiechen and Jinfeng

sQGP is a novel form of QCD matter discovered at RHIC in Au+Au @200 AGeV

(and now probed at higher temp at LHC in Pb+Pb @2760 AGeV)

But what is it really ?

Theoretical interpretations of sQGP include

1) s̲trongly coupled – Q̲uark - G̲luon chromo-electric *Fluid*

2) 10D *Black Hole* in deformed AdS_5 X S_5 with stringy jets

3) C̲olor G̲lass C̲ondensate (*Color Field* Interference GLVB14)

4) Pseudo-Thermal Unruh *Radiation* *Fields* Sourced by Accelerating SU(N) charges

In this talk I explore our recent proposal :

5) semi-Quark-Gluon-Monopole Plasmas (sQGMP)

Jiechen Xu, Jinfeng Liao, MG arXiv:1411.3673 [hep-ph] and in preparation

Kinetic theory => inverse connection between eta/s = shear viscosity/entropy and the jet transport qhat(T,E)/T^3 coefficients

estimate of shear viscosity per entropy density η/s can be derived from kinetic theory in the weak coupling limit:

$$\eta/s = \frac{1}{s}\frac{4}{15}\sum_a \rho_a \langle p\rangle_a \lambda_a^{tr}$$

$$= \frac{4T}{5s}\sum_a \rho_a \left(\sum_b \rho_b \int_0^{\langle S_{ab}\rangle/2} dq^2 \frac{4q^2}{\langle S_{ab}\rangle}\frac{d\sigma_{ab}}{dq^2}\right)^{-1}$$

$$= \frac{18T^3}{5s}\sum_a \rho_a/\hat{q}_a(T,E=3T) \ .$$

We must specify composition and m.f.p. paths of all quasi-particles a=1, …, N

[4] P. Danielewicz and M. Gyulassy, Phys. Rev. D **31**, 53 (1985).

[5] T. Hirano and M. Gyulassy, Nucl. Phys. A **769**, 71 (2006).

[6] A. Majumder, B. Muller, and X. N. Wang, Phys. Rev. Lett. **99**, 192301 (2007).

Jiechen Xu, Jinfeng Liao, MG arXiv:1411.3673 [hep-ph]

Jet quenching vs. η/s

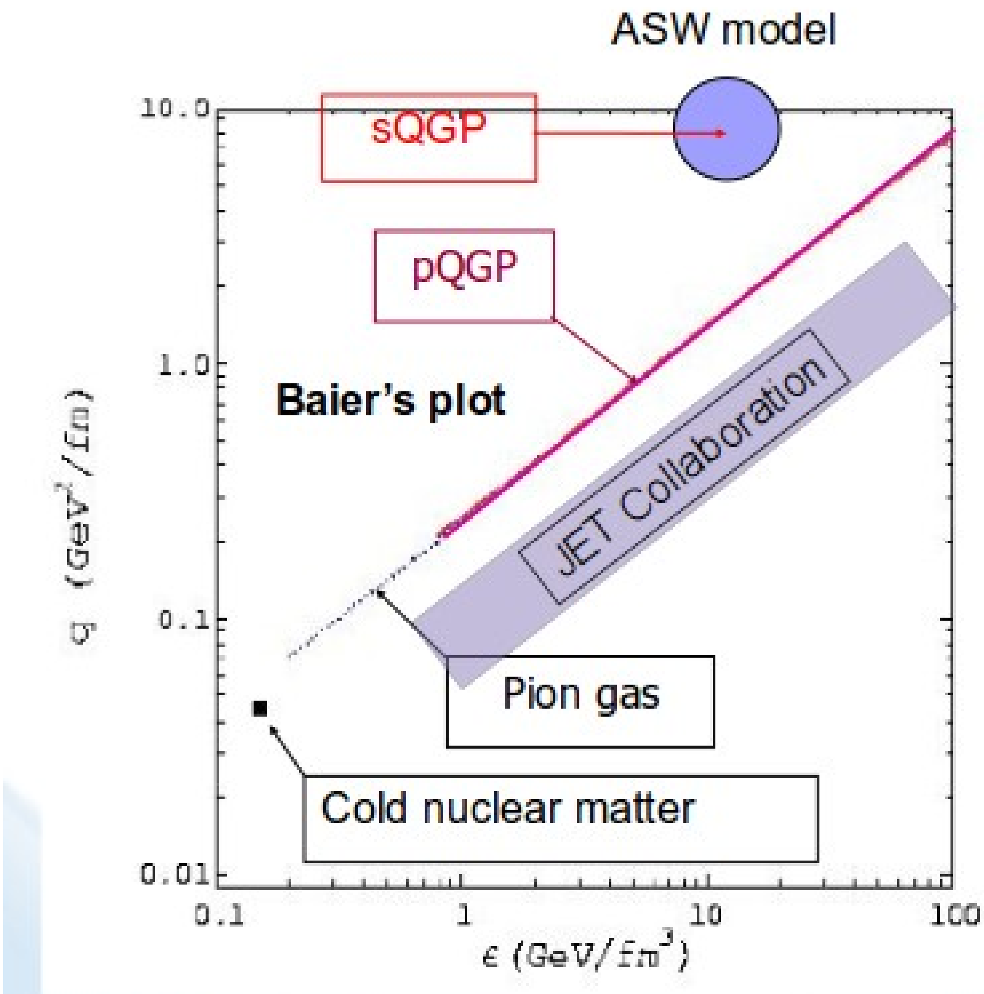
From B. Mueller's talk 12/2/13

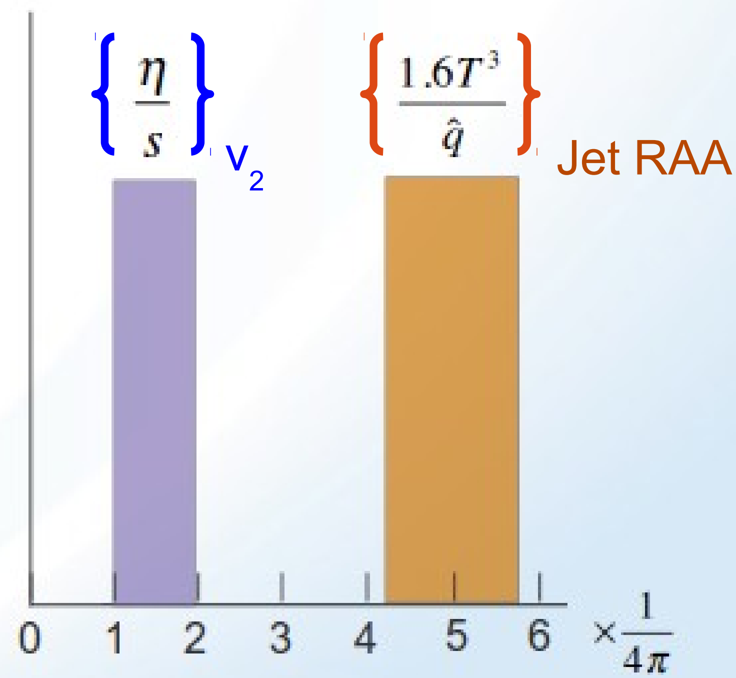
Majumder, BM, Wang

$$\eta / s \approx \frac{0.065}{\alpha_s^2 \ln(q_{\max}^2 / m_D^2)}$$

$$T^3 / \hat{q} \approx \frac{0.04}{\alpha_s^2 \ln(q_{\max}^2 / m_D^2)}$$

HTL Weakly Coupled





Bulk Flow suggests strongly coupled "perfect fluidity" for pT<2 GeV

But Hard Jet probes suggest perturbative jet medium interactions pT>10.

What is the missing physics that could resolve this Puzzle?

JET Collab 2013 pQCD Tomography summary
5 models extraction of qhat/T^3 jet transport coef

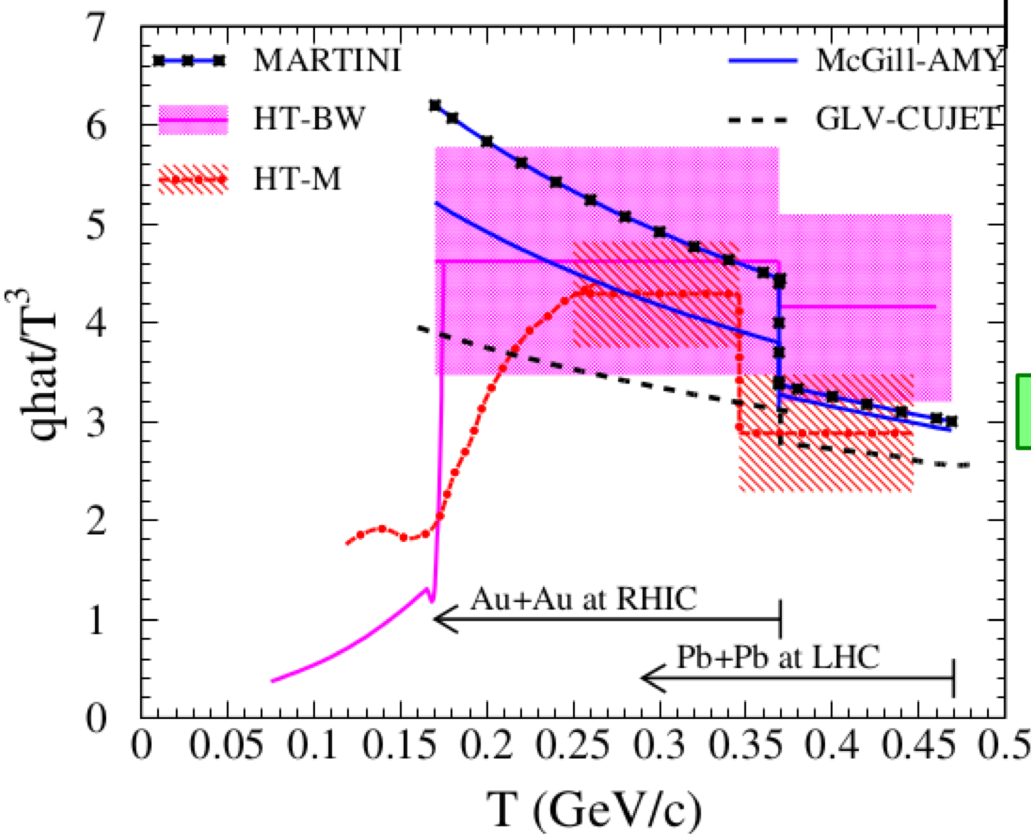


FIG. 10. (Color online) The assumed temperature dependence of the scaled jet transport parameter $\hat{q}/T^3$ in different jet quenching models for an initial quark jet with energy $E = 10$ GeV. Values of $\hat{q}$ at the center of the most central A+A collisions at an initial time $\tau_0 = 0.6$ fm/c in HT-BW

Contrast to AdS Holography

LO=AdS+BH+NambuGoto $\lambda^{1/2}$

Over quenches jet RAA

NLO_1=LO+WS $\lambda^{1/2}+\lambda^0$

AdS qualitatively consistent with RAA
versus quantitative low Chi^2
pQCD tomography

In 2013:

The main problem with pQCD HTL and E>10 GeV data constrained qhat Is that it predicts way too large viscosity eta/s ~ 1.6 T^3/qhat >> 0.1

PQCD based Jet quenching tomography thus appears Inconsistent with Bulk hydro flow

Also pQCD based tomography Is inconsistent with jet v2 !

Part 1: Open problems

1) Some crucial degree of freedom is missing in the old sQGP picture.

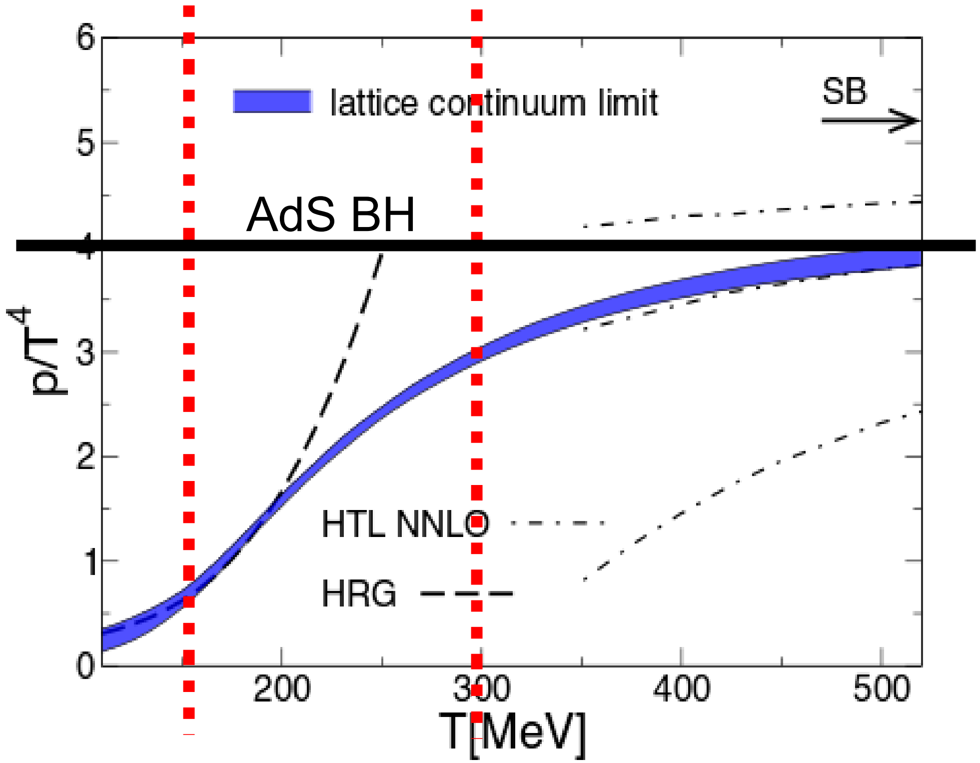
2) Jet Quenching $pT>10$ GeV in AA can be well understood
In a perturbative QCD paradigm with only with modest
$Qhat(pT>10,T)/T^3 \sim 4$ but pQCD $Qhat \rightarrow 0$ near Tc !
which is inconsistent with (3)

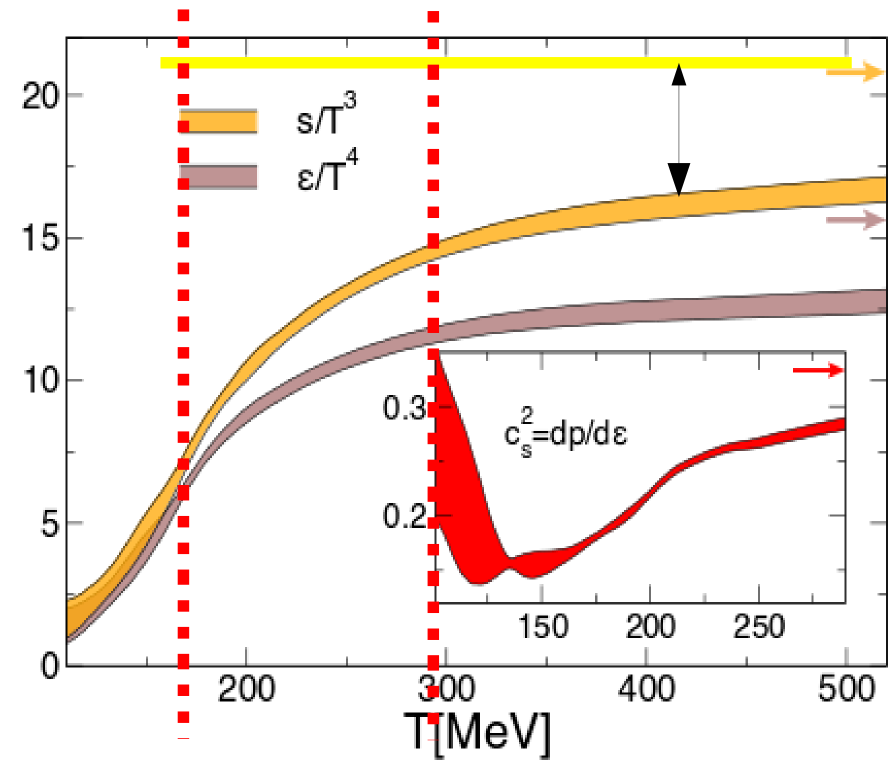
3) Bulk collective low $pT< 2$ GeV flow v2(pT) that requires
$eta/s \sim T^3/Qhat(pT\sim 3T, T) \sim 0.1\text{-}0.2$
Inconsistent with jet quenching (2)

Part 2 Next: Our proposed sQGMP solution to Part 1 puzzles

Szabolcs Borsányi[a], Zoltán Fodor[a,b,c], Christian Hoelbling[a], Sándor D. Katz[c,d], Stefan Krieg[a,b*], Kálmán K. Szabó[a,e] LATTICE2013 (2014) 155

. Continuum EoS for QCD with Nf=2+1 flavors





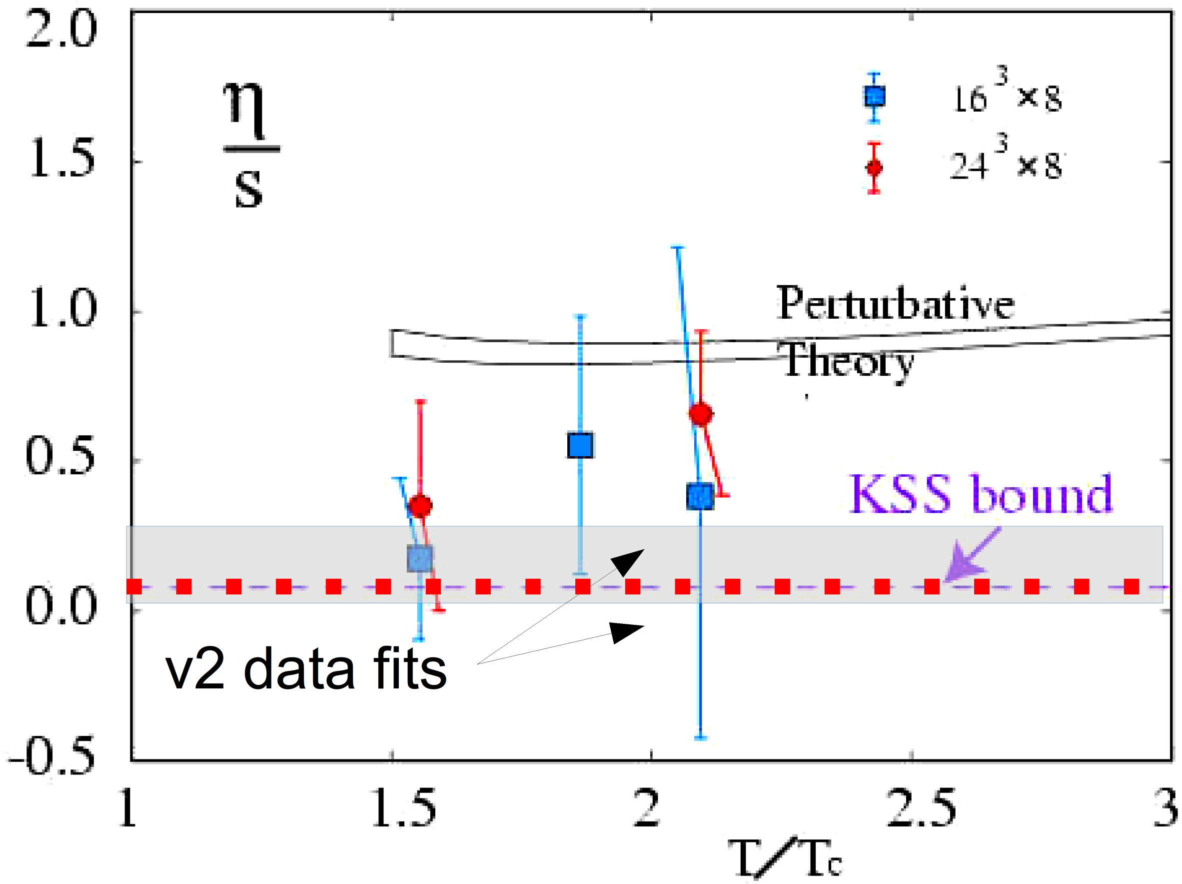
In the QCD transition temperature range 150 < T< 200 MeV the sQGP is

(1) *NOT* a Hadron Resonance Gas (HRG)
(2) *NOT* a perturbative Q+G plasma of quasi free quarks and gluons
(3) *NOT* a conformal AdS Black Hole
(4) Could be a semi-QGP + Mag monopole Plasma (sQGMP)

Shear Viscosity Transport coefficient of a QGP: Lattice QCD *vs* pQCD *vs* AdS/CFT

vs RHIC v2 data constraints

Lattice QCD: A.Nakamura,S.Sakai, 2004



Danielewicz, MG, (1985) *

Perturbative QCD

$$\boxed{\frac{T\,\lambda_{pQCD}}{5} \approx \frac{(0.3)^2}{\alpha^2 \log 1/\alpha} \sim 1}$$ *

$$\boxed{\left(\frac{\eta}{\sigma}\right)_{adS/CFT} = \frac{1}{4\pi}}$$

N=4 SUSY

$g^2N_c \rightarrow \infty$

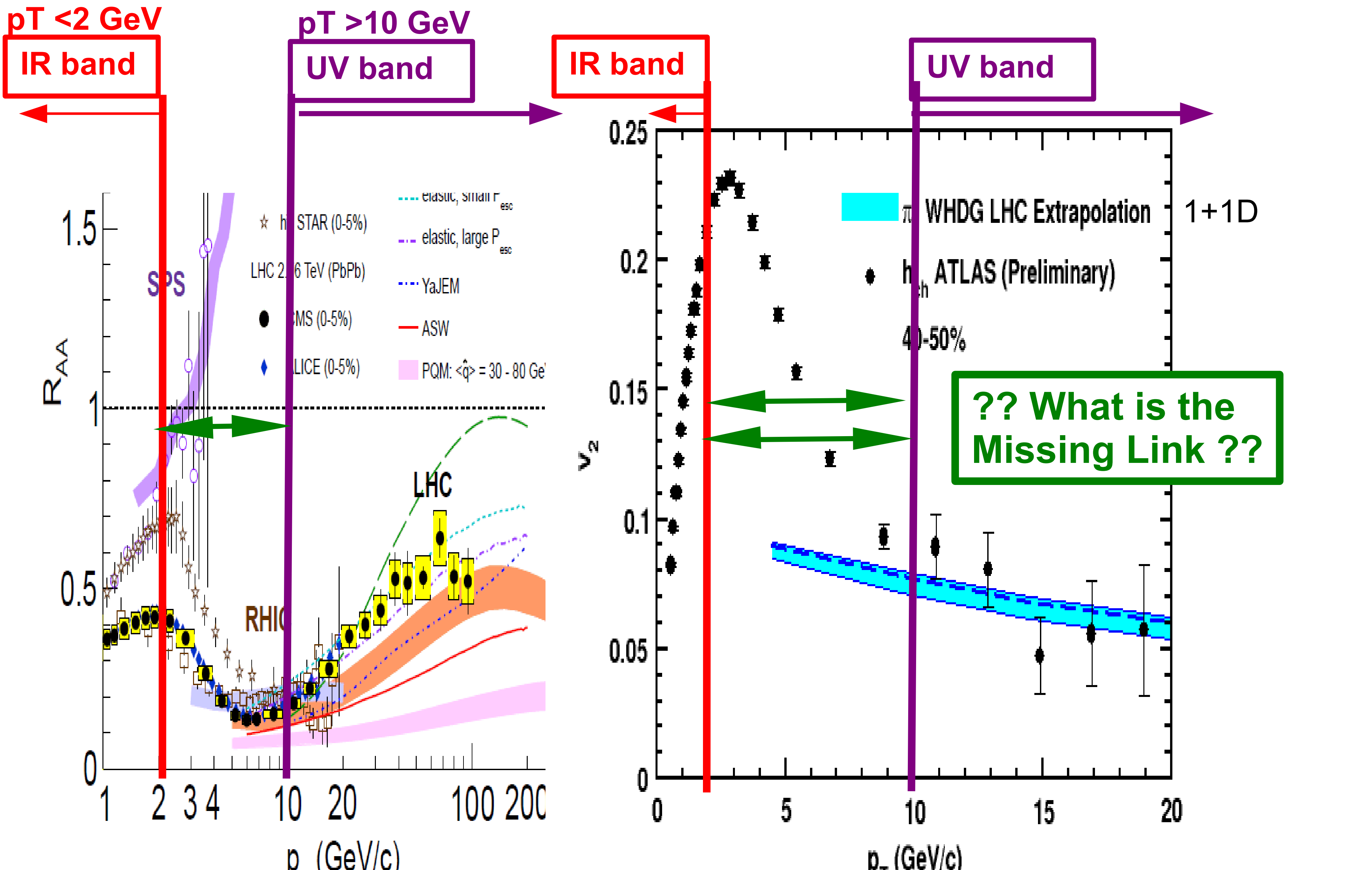
N=4 SUSY: Policastro, Son, Starinets (2001)

Kovtun,Son,Starinets (2004)

$$\boxed{\frac{T\lambda_{min}}{5} \approx \frac{\hbar = 1}{15}}$$ *

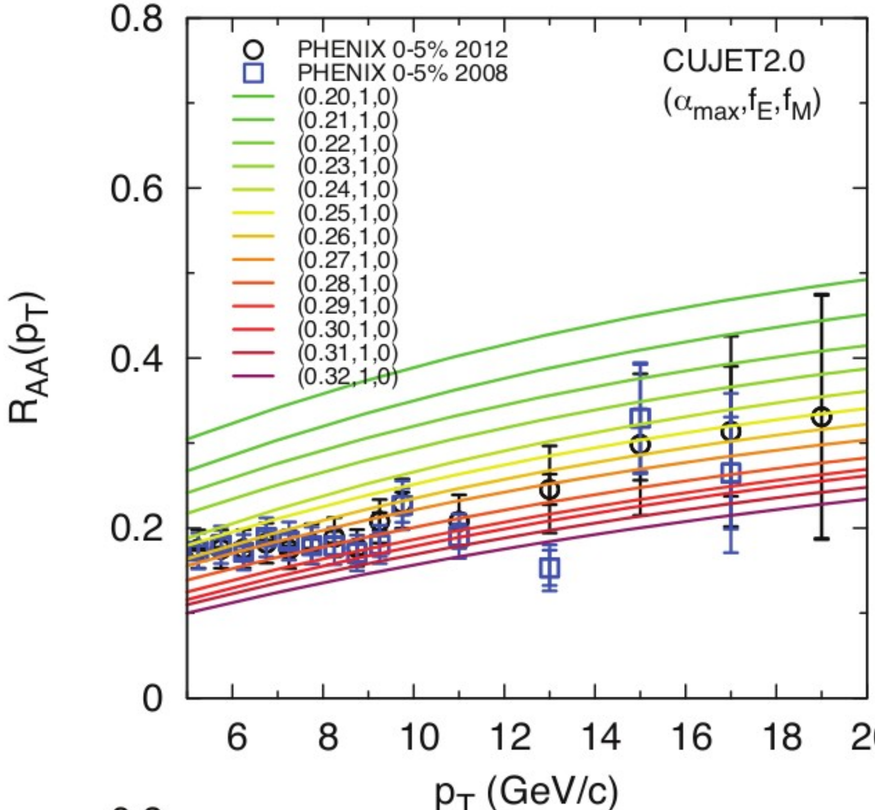
Minimum uncertainty estimate

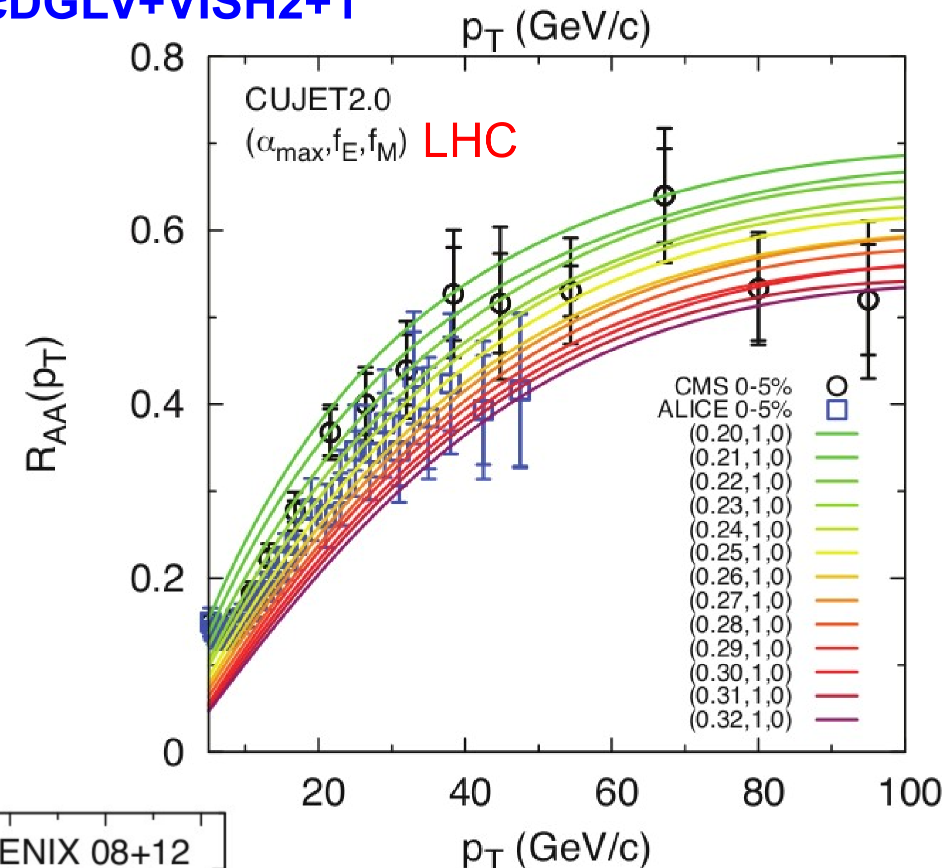
Bulk IR vs Jet Quenching UV Physics in A+A from SPS to LHC

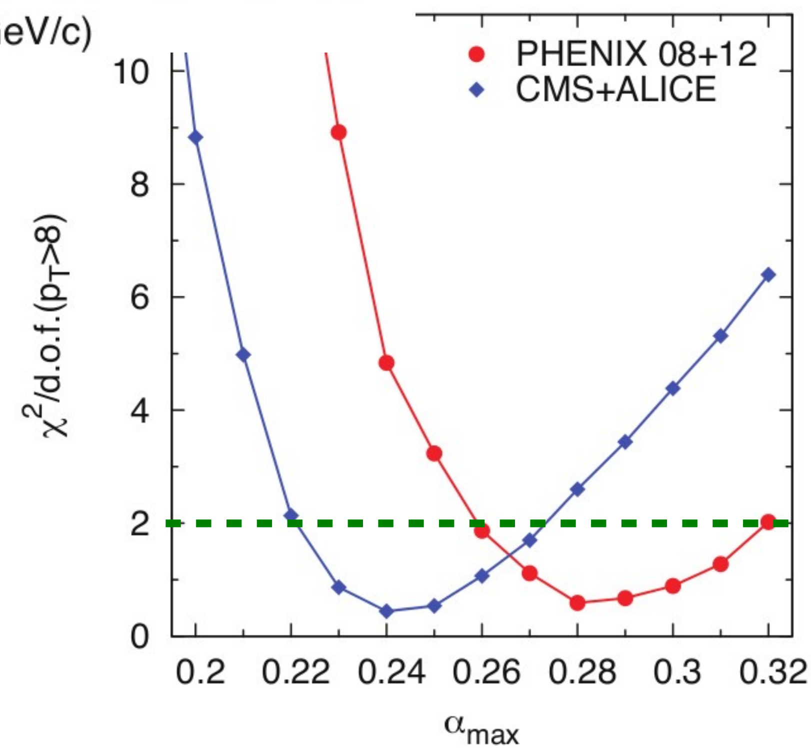


How ro relate the physics in the bulk "IR" decoupled from jets in the "UV"

Jiechen Xu, A. Buzzatti, MG: **CUJET2.0 = rcDGLV+VISH2+1**







LHC RHIC

$$\alpha_{max} = 0.24 - 0.28$$

Consistent with RAA at both RHIC and LHC at ~1.5 sigma

For HTL plasma with fE=1, fM=0

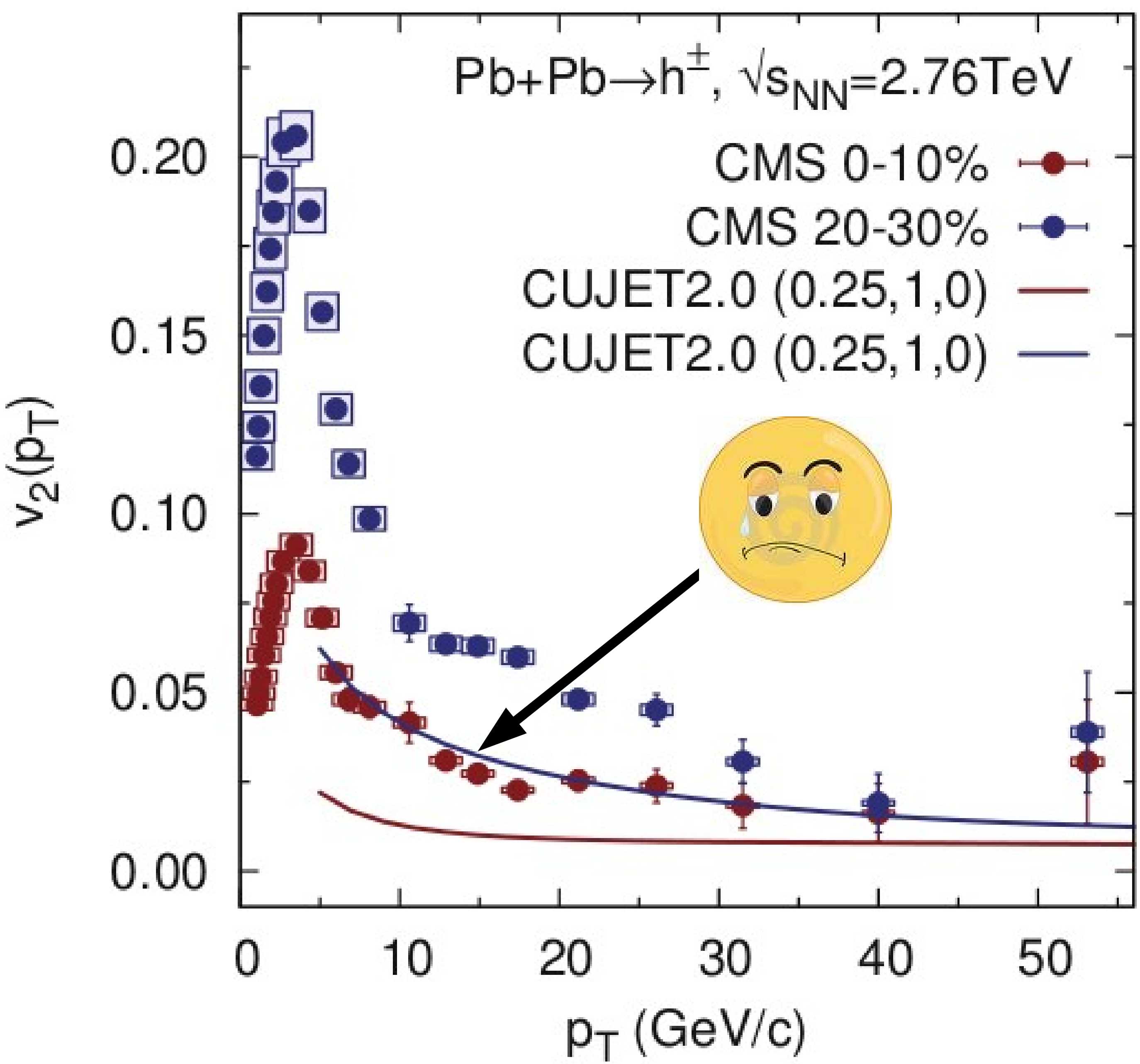
Jiechen Xu, A.Buzzatti, MG, JHEP 1408 (2014) 063

The v2 Albatross
2

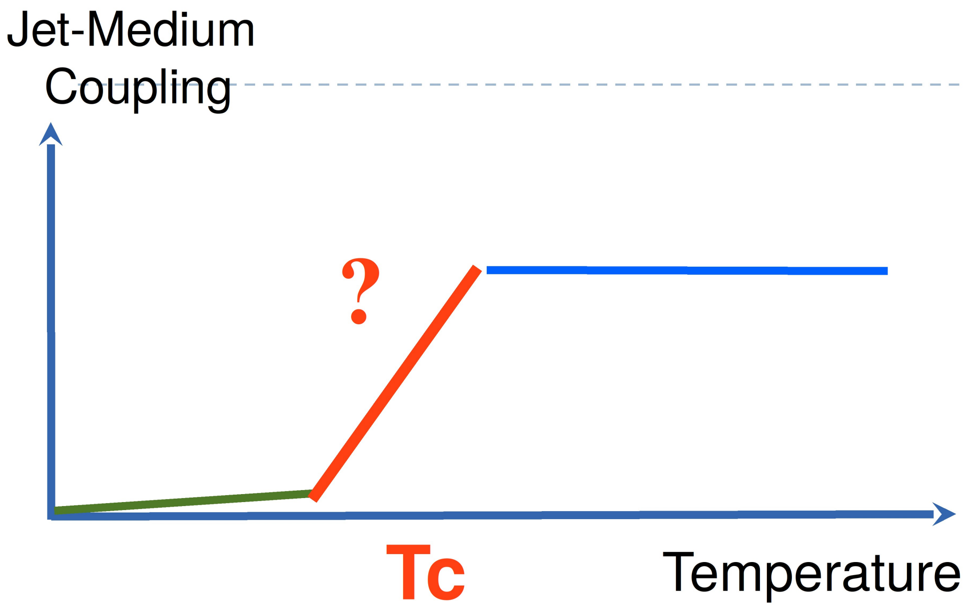
CUJET2.0
Under predicted
Jet v2 at LHC

With alpha_max
Constrained by
RAA(RHIC+LHC)

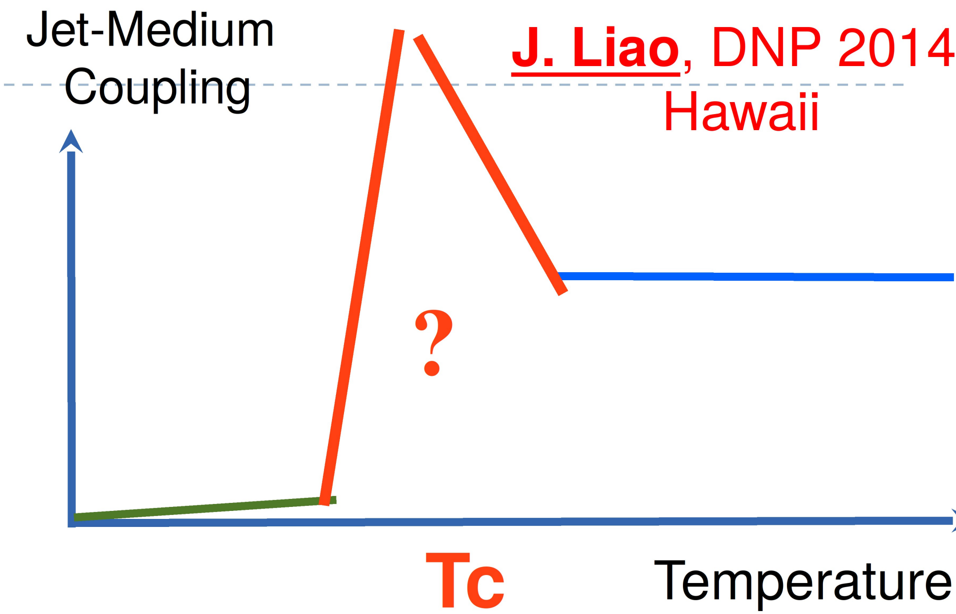
The CUJET2.0 v2 Albatross



How Does the Jet-Medium Coupling Interpolate between T< Tc Transparency to T>Tc Opaqueness



"Waterfall" scenario



J. Liao, DNP 2014, Hawaii

"Volcano" scenario

- How to reconcile jet transparency for T<<Tc be reconciled with color confinement below Tc and perfect fluidity near Tc?

The Theoretical Challenge:

At ***long wavelength*** pT<2 GeV QGP seems like almost infinitely coupled fluid

But at ***small wavelengths*** pT>10 GeV probes QGP appear perturbative

(This is not common, e.g. in superfluids and superconductors)

Can we reconcile these apparently contradictory properties of QGP

In some unified picture??

We need a “missing link” ingredient like Cooper pairs in superconductors

that interpolate phtzics between near conformal perturbative QCD short wavelength

And far from conformal nonperturbative confinement physics near Tc ~ 200 MeV

Part 2: Our proposed sQGMP solution to puzzles

sQPMP = *semi*-chomo-Electric(Q+G)+ *semi*-chromo-Magnetic Monopoles M

semi color Elect quasiparticles Q+G are suppressed by Polyloop and Polyloop^2 (aka Pisarski et el) or suppressed by Quark susceptibility (aka Petreczky et al)

semi color Magnetic quasiparticle M that are emergent d.o.f in vicinity of Tc (aka Liao and Shuryak)

Semi also in sense that the competing three Q+G+M Deg. of Freedom That evolve into a perturbative Q+G HTL DOF for T > 3 Tc

A <u>key missing ingredient</u> in both pQCD and AdS/CFT are Hadron Resonances!!

Something must confine color electric q and g degrees of freedom below Tc

The most natural candidate from analogy with condensed matter physics

is the magnetic dual of superconductivity (Nambu, Mandelstam, T'Hooft ~ 1974)

IF QCD has *emergent chromo-magnetic monopole* degrees of freedom near Tc

And *IF* they condense below Tc (like Cooper pairs do in superconductors)

Then they can provide the missing sQGMP link physics between

the T >> Tc asymptotic pQCG wQGP world

and

the T<< Tc confined color neutral HRG world

CUJET3 tests quantitatively if critical scattering on elec amd mag monopoles
Can explain perfect fluidity as well as jet quenching near Tc

Slide from Jinfeng Liao on

Dual Superconductivity

- Dual superconductivity is a promising mechanism for quark confinement. [Y.Nambu (1974). G.'t Hooft, (1975). S.Mandelstam, (1976) A.M. Polyakov (1975)]

superconductor	**dual superconductor**
➢ Condensation of electric charges (Cooper pairs)	➢ Condensation of magnetic monopoles
➢ Meissner effect: Abrikosov string (magnetic flux tube) connecting monopole and anti-monopole	➢ Dual Meissner effect: formation of a hadron string (chromo-electric flux tube) connecting quark and antiquark
➢ Linear potential between monopoles	➢ Linear potential between quarks

Akihiro, Shibata, Trento 2013

ArXiv:1409.1599 : **a 277 page review !**
Also arXiv:1412.8009 [hep-lat]

Status of QCD Magnetic Monopoles
Remains highly uncertain
despite 40 years of theoretical effort!!

A-EP-209
t 2014-23

Quark confinement: dual superconductor picture based on a non-Abelian Stokes theorem and reformulations of Yang-Mills theory

Kei-Ichi Kondo[a], Seikou Kato[b], Akihiro Shibata[c], Toru Shinohara[d]

Abstract

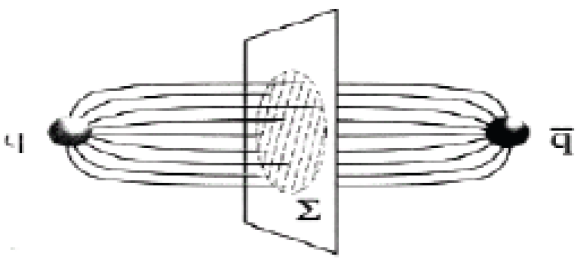
The purpose of this paper is to review the recent progress in understanding quark confinement. The emphasis of this review is placed on how to obtain a manifestly gauge-independent picture for quark confinement supporting the dual superconductivity in the Yang-Mills theory, which should be compared with the Abelian projection proposed by 't Hooft. The basic tools are reformulations of the Yang-Mills theory based on change of variables extending the decomposition of the $SU(N)$ Yang-Mills field due to Cho, Duan-Ge and Faddeev-Niemi, together with the combined use of extended versions of the Diakonov-Petrov version of the non-Abelian Stokes theorem for the $SU(N)$ Wilson loop operator.

For the fundamental quark for $SU(3)$, the maximal stability group is $U(2)$, which is different from the maximal torus group $U(1) \times U(1)$ suggested from the Abelian projection. Therefore, the chromomagnetic monopole inherent in the Wilson loop operator responsible for confinement of quarks in the fundamental representation is the non-Abelian magnetic monopole, which is distinct from the Abelian magnetic monopole for the $SU(2)$ case. Therefore, we claim that the mechanism for quark confinement for $SU(N)$ ($N \geq 3$) is the non-Abelian dual superconductivity caused by condensation of non-Abelian magnetic monopoles. We give some theoretical considerations and numerical results supporting this picture. Finally, we discuss some issues to be investigated in future studies.

The Liao-Shuryak sQGMP Scenario

T<< Lambda_QCD | T ~ Lambda_QCD | T>> Lambda_QCD

Vacuum: confined | **Tc** | sQGP | ***wQGP: screening*** | **T**



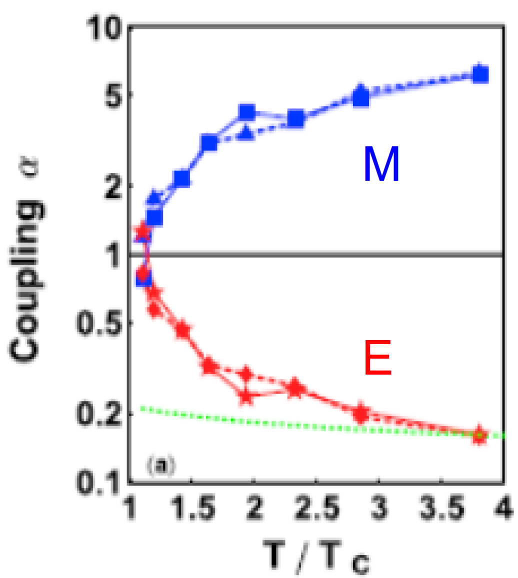
Electric Flux Tube:
Magnetic Condensate

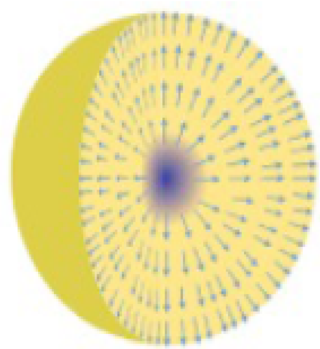
Emergent plasma with E & M charges:
chromo-magnetic monopoles are the "missing DoF"

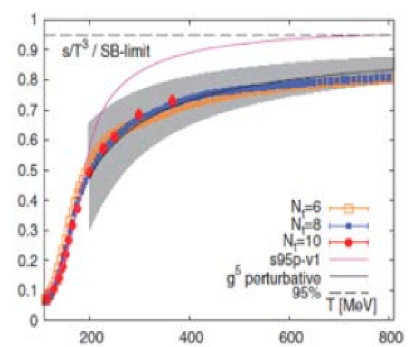
$$\alpha_E * \alpha_M = 1.$$

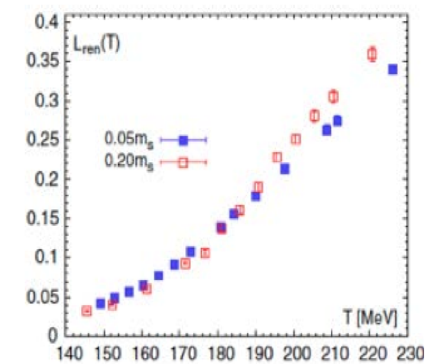
Plasma of E-charges
E-screening: g T
M-screening: g^2 T

$$L(\mathbf{x}) = \frac{1}{N_c} \mathrm{tr}\mathcal{P}\exp\left[ig\int_0^{1/T} A_4(\tau,\mathbf{x})d\tau\right]$$









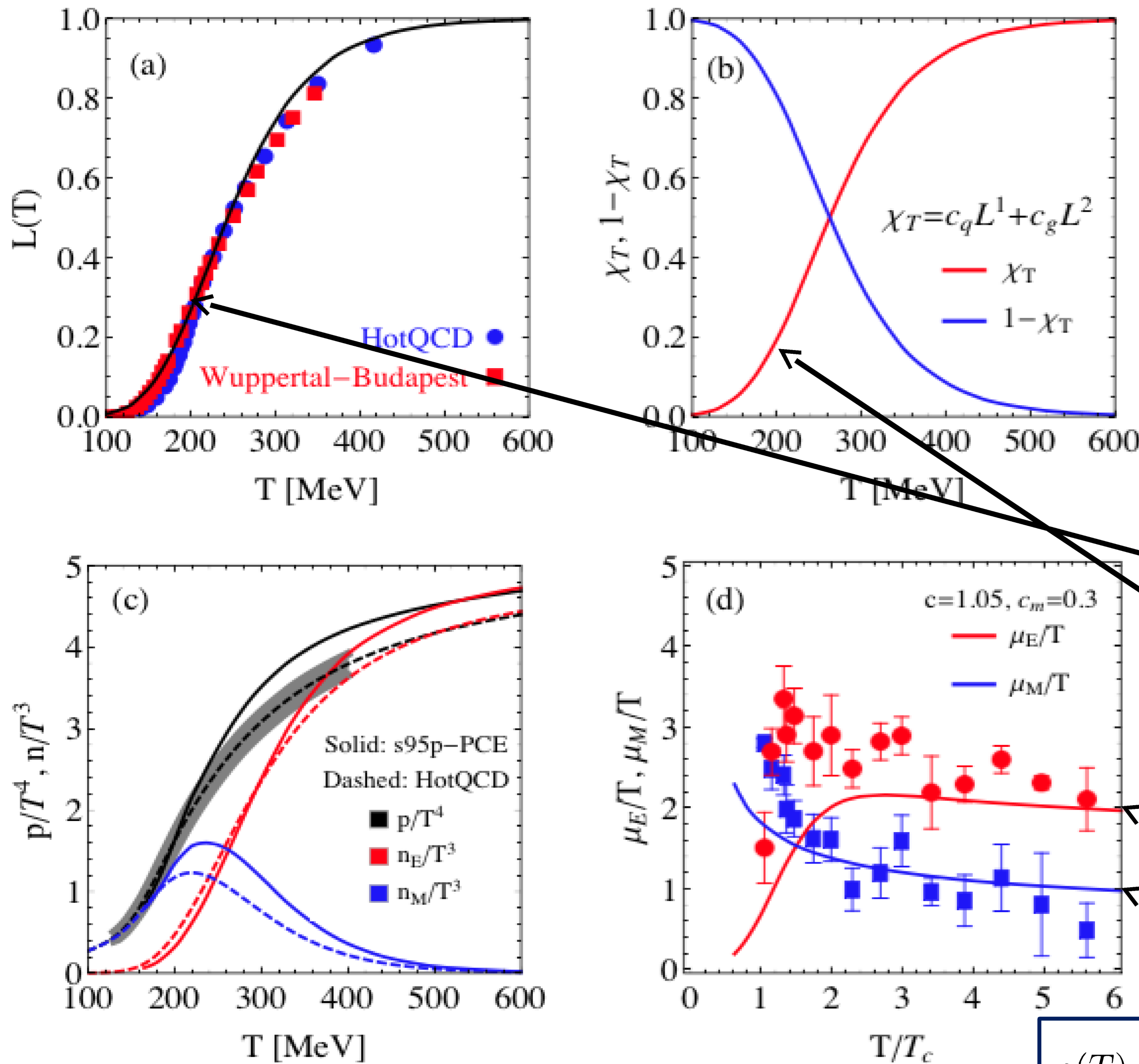
A region around Tc with liberated degrees of freedom
but only partially liberated color-electric objects—missing D.o.F.:
semi-QGP + emergent magnetic component

Jingeng Liao and Ed Shuryak

Phys.Rev.C75:054907,2007; Phys.Rev.Lett.101:162302,2008;
Phys.Rev.C77:064905,2008; Phys.Rev.D82:094007,2010;
Phys.Rev.Lett.109:152001,2012.

❖ Slide from Jinfeng Liao, APS DNP Hawaii 2014

Lattice QCD: Polyakov Loop, EOS, Screening Masses



$$L(\mathbf{x}) = \frac{1}{N_c} \mathrm{tr} \mathcal{P} \exp\left[ig \int_0^{1/T} A_4(\tau, \mathbf{x}) d\tau\right]$$

FIG. 1: (Color online) (a) The Polyakov loop $L(T)$ parameterization of Eq.(8) compared with lattice data from the HotQCD [54] and Wuppertal-Budapest Collaboration [55]; (b) The relative ratios of electric (red, $\chi(T)$) and magnetic (blue, $1-\chi(T)$) quasi-particles in the QCD matter. (c) The EOS from HotQCD (gray band: lattice data, dashed black: parametrization, both in [56]) as well as the number density of E (red) and M (blue) components at various temperatures. (d) The temperature dependence of the screening mass μ_E/T (red, electric) and μ_M/T (blue, electric) in CUJET3.0 compared with lattice calculation [57].

$$L(T) = \left[\tfrac{1}{2} + \tfrac{1}{2} Tanh[0.00769(T - 72.6)]\right]^{10}$$

$$\chi_T = c_q\, L + c_g\, L^2$$

$$\mu_E^2 \sim \alpha_E n_E / T$$

$$f_E = \mu_E/\mu = \sqrt{\chi_T}$$

$$f_M = \mu_M/\mu = c_m g$$

$$g(T) = \sqrt{4\pi\alpha_s(\mu^2(T))} = \mu(T)/(T\sqrt{N_c/3 + N_f/6})$$

Peshier, hep-ph/0601119

J.Xu, , J. Liao, MG, arXiv:1411.3673

- The CUJET3.0 implementations of electric and magnetic components are constrained by available lattice data. No new free parameters introduced sQGP Kinetic theory => inverse connection between eta/s and the jet transport qhat(T,E) field

Jiechen Xu, Jinfeng Liao, MG arXiv:1411.3673 [hep-ph]

We now turn to the shear viscosity. As in [4–6], an estimate of shear viscosity per entropy density η/s can be derived from kinetic theory in the weak coupling limit:

$$\eta/s = \frac{1}{s}\frac{4}{15}\sum_a \rho_a \langle p\rangle_a \lambda_a^{tr}$$
$$= \frac{4T}{5s}\sum_a \rho_a \left(\sum_b \rho_b \int_0^{\langle \mathcal{S}_{ab}\rangle/2} dq^2 \frac{4q^2}{\langle \mathcal{S}_{ab}\rangle}\frac{d\sigma_{ab}}{dq^2}\right)^{-1}$$
$$= \frac{18T^3}{5s}\sum_a \rho_a/\hat{q}_a(T, E = 3T) \ . \qquad (9)$$

In sQGMP , a=1,2,3
(1) L suppresed quarks Q
(2) L^2 suppressed glue G
(3) emergent mag monopoles M

Extracting jet transport coefficient from jet quenching at RHIC and LHC

: arXiv:1312.5003 Phys.Rev. C90 (2014) 1, 014909

Karen M. Burke,[1] Alessandro Buzzatti,[2,3] Ningbo Chang,[4,5] Charles Gale,[6] Miklos Gyulassy,[3] Ulrich Heinz,[7] Sangyong Jeon,[6] Abhijit Majumder,[1] Berndt Müller,[8] Guang-You Qin,[5,1] Björn Schenke,[8] Chun Shen,[7] Xin-Nian Wang,[5,2] Jiechen Xu,[3] Clint Young,[6] and Hanzhong Zhang[5]

(The JET Collaboration) Posted 11/17/13

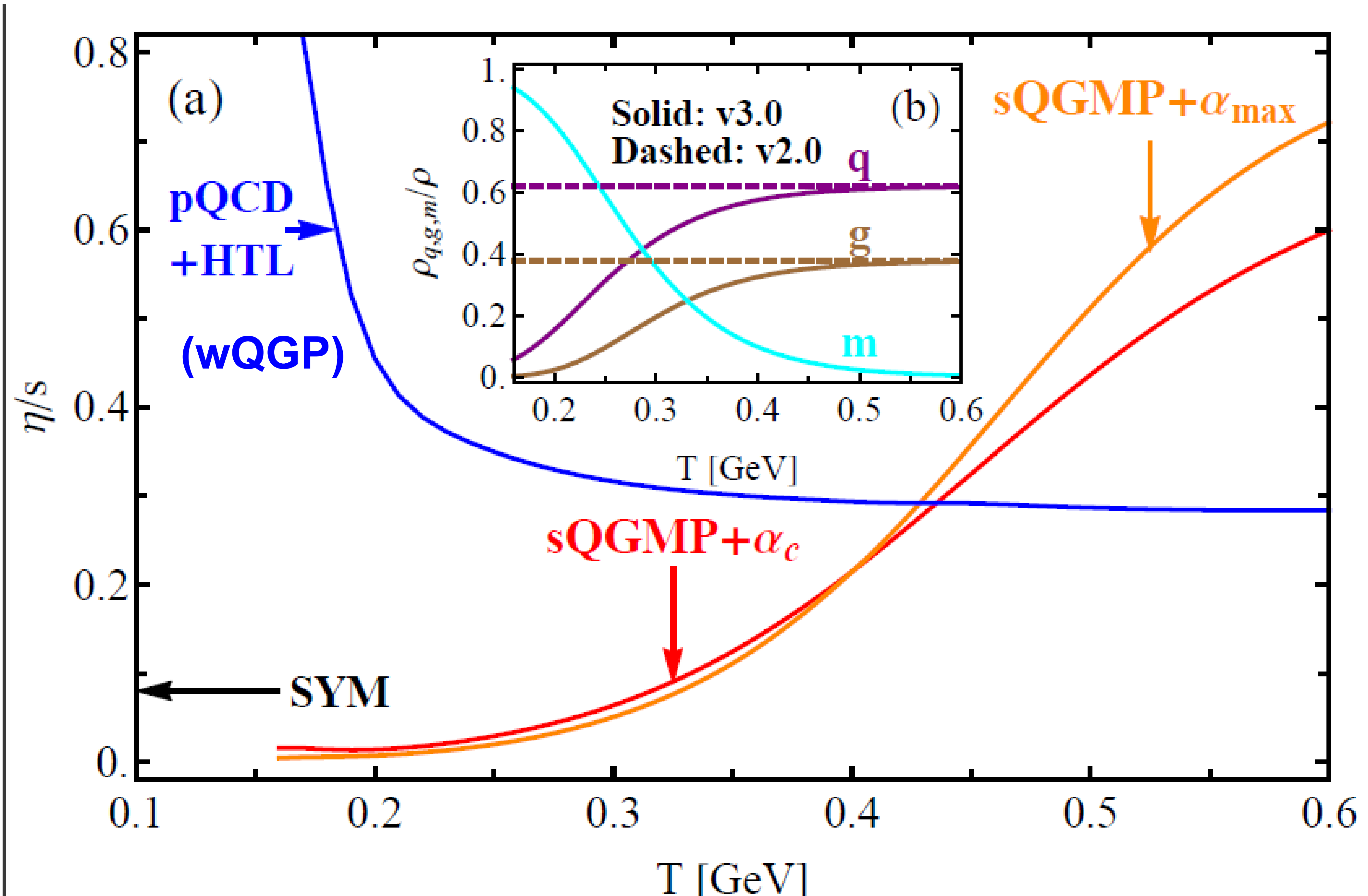
CUJET2.0 sQDP+DGLV+VISH2 $\alpha_s(Q^2) = \min[\alpha_{max}, 2\pi/9\log(Q^2/\Lambda^2)]$

$$x\frac{dN_{Q\to Q+g}}{dx}(\mathbf{r},\phi) = \int d\tau\rho(\mathbf{r}+\hat{\mathbf{n}}(\phi)\tau,\tau)\int\frac{d^2\mathbf{q}_T}{\pi}\frac{d^2\sigma}{d^2\mathbf{q}_T}\int\frac{d^2\mathbf{k}_T}{\pi}\alpha_s(k_T^2/(x(1-x))$$
$$\times\frac{12(\mathbf{k}_T+\mathbf{q}_T)}{(\mathbf{k}_T+\mathbf{q}_T)^2+\chi(\tau)}\cdot\left(\frac{(\mathbf{k}_T+\mathbf{q}_T)}{(\mathbf{k}_T+\mathbf{q}_T)^2+\chi(\tau)}-\frac{\mathbf{k}_T}{\mathbf{k}_T^2+\chi(\tau)}\right)\left(1-\cos\left[\frac{(\mathbf{k}_T+\mathbf{q}_T)^2+\chi(\tau)}{2x_+E}\tau\right]\right),$$

where the effective running differential cross section is

$$\frac{d^2\sigma}{d^2\mathbf{q}_T} = \frac{\alpha_s^2(\mathbf{q}_T^2)}{(\mathbf{q}_T^2+f_E^2\mu^2(\tau))(\mathbf{q}_T^2+f_M^2\mu^2(\tau))}, \qquad (3)$$

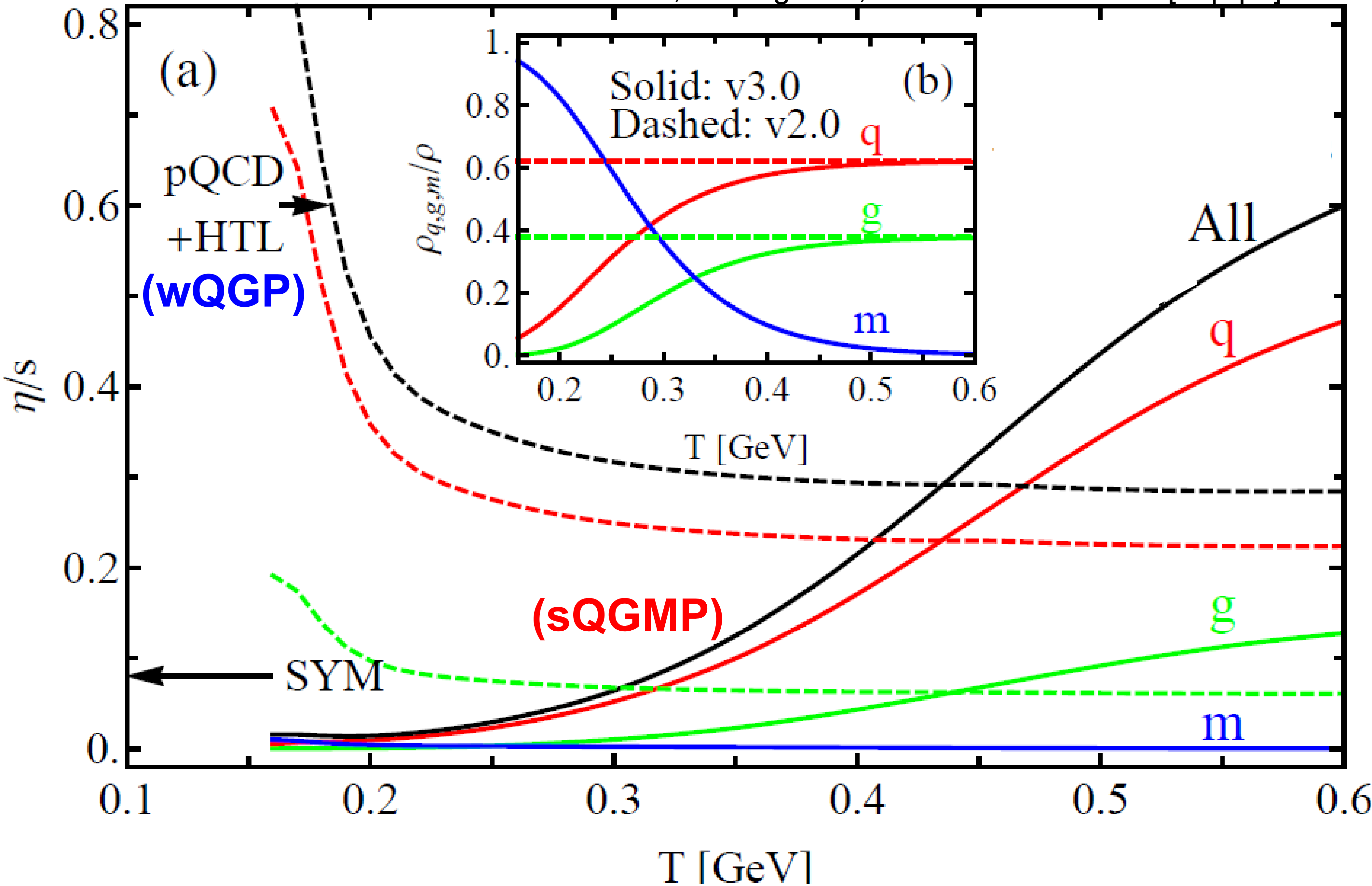
that runs with both q_T and the local temperature through $\mu^2(\tau) = 4\pi\alpha_s(4T^2)T^2$, the local HTL color electric Debye screening mass squared in a pure gluonic plasma with local temperature $T(\tau)\propto\rho^{1/3}(\mathbf{r},\tau)$ along the jet path $\mathbf{r}(\tau)$ through the plasma.



(a)
pQCD
+HTL
(wQGP)
SYM
sQGMP+α_c
sQGMP+α_{max}
η/s
T [GeV]
(b)
Solid: v3.0
Dashed: v2.0
q
g
m
$\rho_{q,g,m}/\rho$
T [GeV]

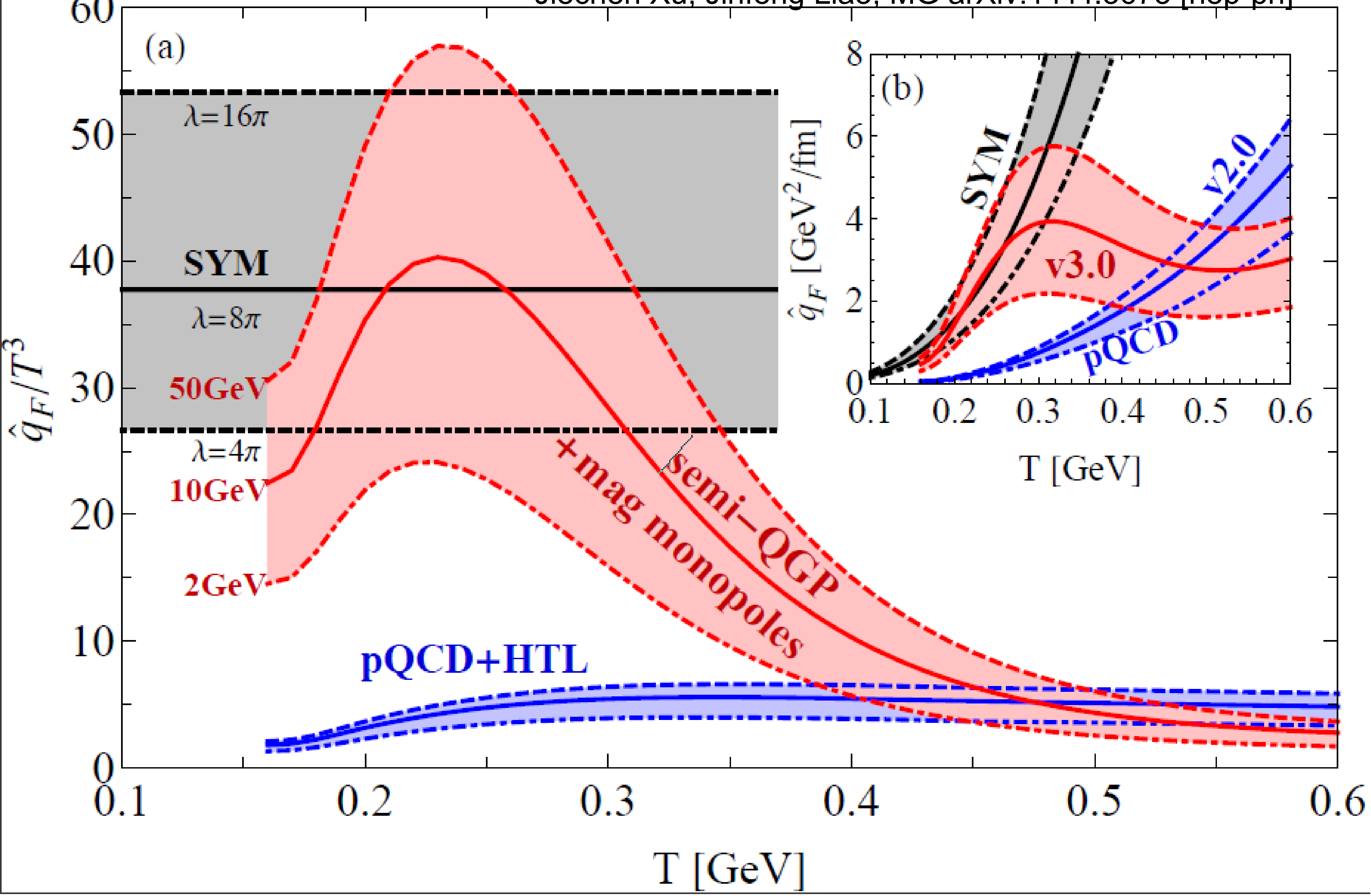
CUJET 2.0 vs 3.0 result fig 1: eta/s > 0.3 wQGP vs eta/s < 0.1 sQGMP for T< 300 MeV

Jiechen Xu, Jinfeng Liao, MG arXiv:1411.3673 [hep-ph]



sQGMP interpolates between conformal pQCD and AdS limits Non-Conformally in T~ (1-2)Tc

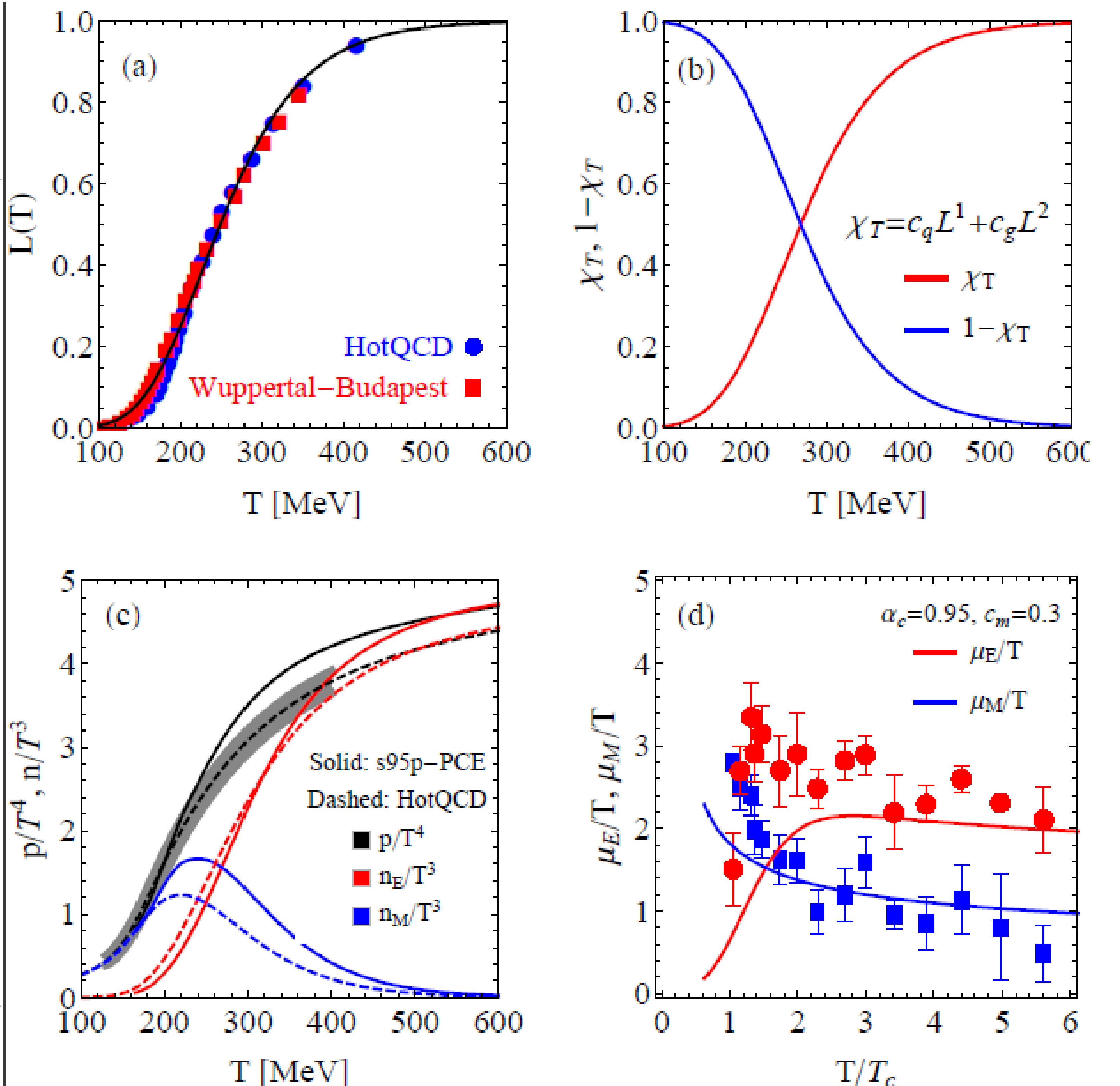
Jiechen Xu, Jinfeng Liao, MG arXiv:1411.3673 [hep-ph]



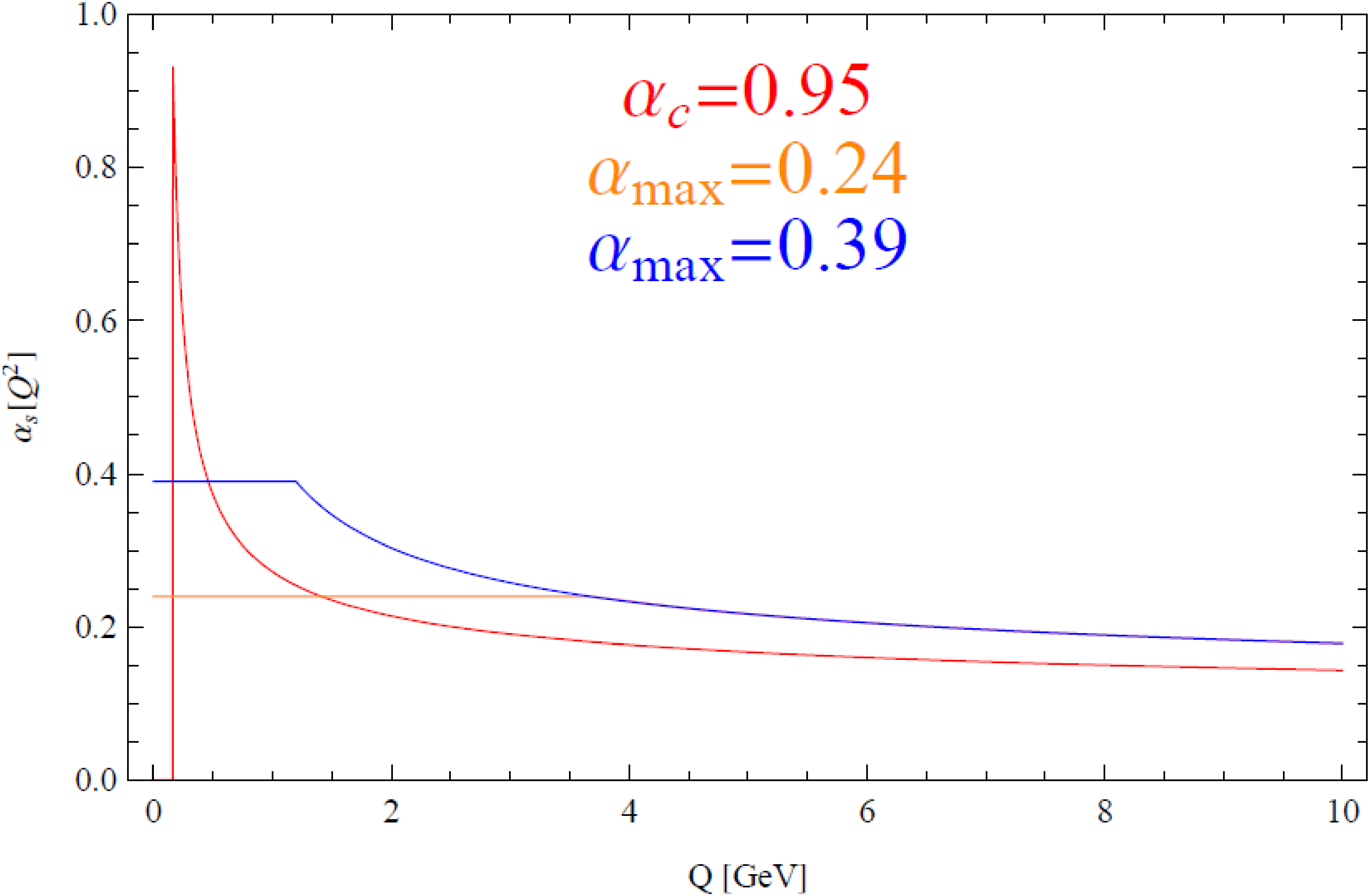
Lattice QCD
Input data to

CUJET3.0
XLG, **1411.3673v2**
Result Fig.3

Only parameter
Ro be fixed by
RAA(pt=10) LHC
Is
alpha_max



The running coupling model choices in CUJET3



CUJET3.0 = CUJET2.0 + semi-QGP + Mag. Monopoles

We now include both color-electric and color-magnetic scattering centers.

Original DGLV has only quark/gluon scattering centers

$$\frac{dE}{dx} \propto \dots \int_{q^2} \frac{n_e\, \alpha_s^2(q^2)\, f_E^2}{q^2(q^2+f_E^2\mu^2)} \dots$$

$$\frac{dE}{dx} \propto \dots \int_{q^2} \left[n_e \frac{\boxed{(\alpha_s(q^2)\alpha_s(q^2))}\, f_E^2}{q^2(q^2+f_E^2\mu^2)} + n_m \frac{\boxed{(\alpha_s^e(q^2)\alpha^m(q^2))}\, f_M^2}{q^2(q^2+f_M^2\mu^2)} \right] \dots$$

$$\frac{dE}{dx} \propto \dots \int_{q^2} \frac{n_T}{(q^2+f_E^2\mu^2)(q^2+f_M^2\mu^2)} \times \kappa(q^2,T)$$

=1, by Dirac Quantization

$$\kappa(q^2,T) \equiv \boxed{\alpha_s^2(q^2)}\, \chi_T \left(f_E^2 + \frac{f_E^2 f_M^2 \mu^2}{q^2}\right) + (1-\chi_T)\left(f_M^2 + \frac{f_E^2 f_M^2 \mu^2}{q^2}\right)$$

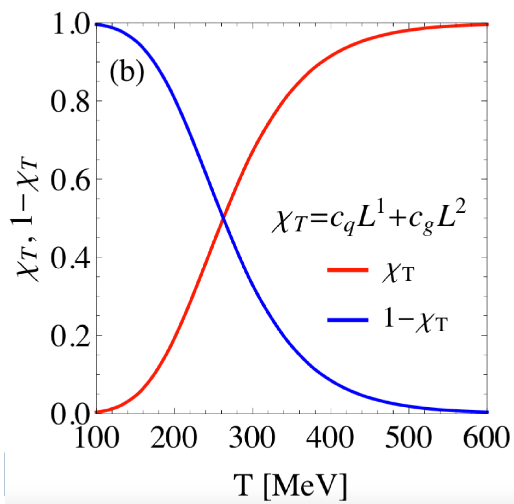
$$\chi_T = c_q L + c_g L^2$$

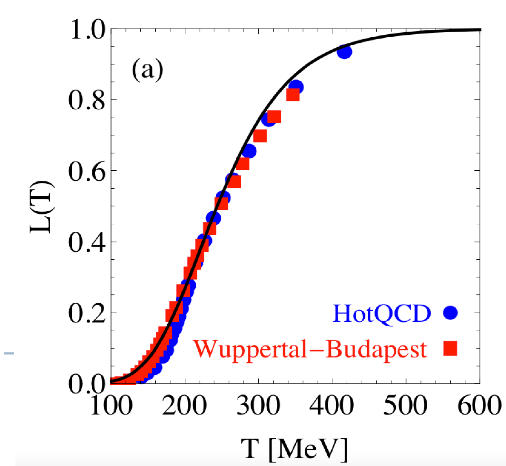
Polyakov Loop suppressed color electric component

$$f_E = \sqrt{\chi_T}$$

$$f_M = C_m g_T$$

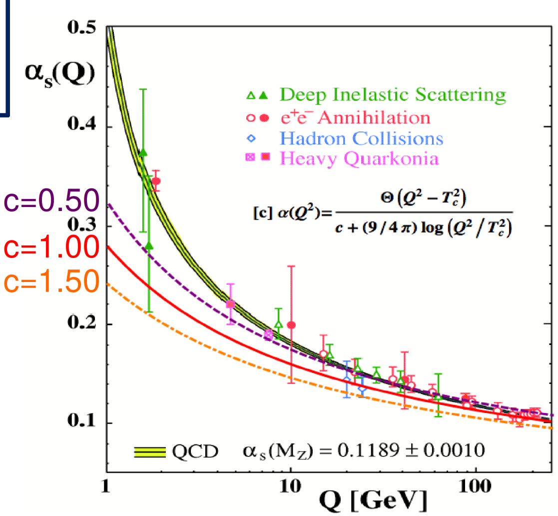
$$L(\mathbf{x}) = \frac{1}{N_c} \mathrm{tr}\mathcal{P} \exp\left[ig \int_0^{1/T} A_4(\tau,\mathbf{x})d\tau\right]$$





Bazavov et al., PRD 80 (2009)

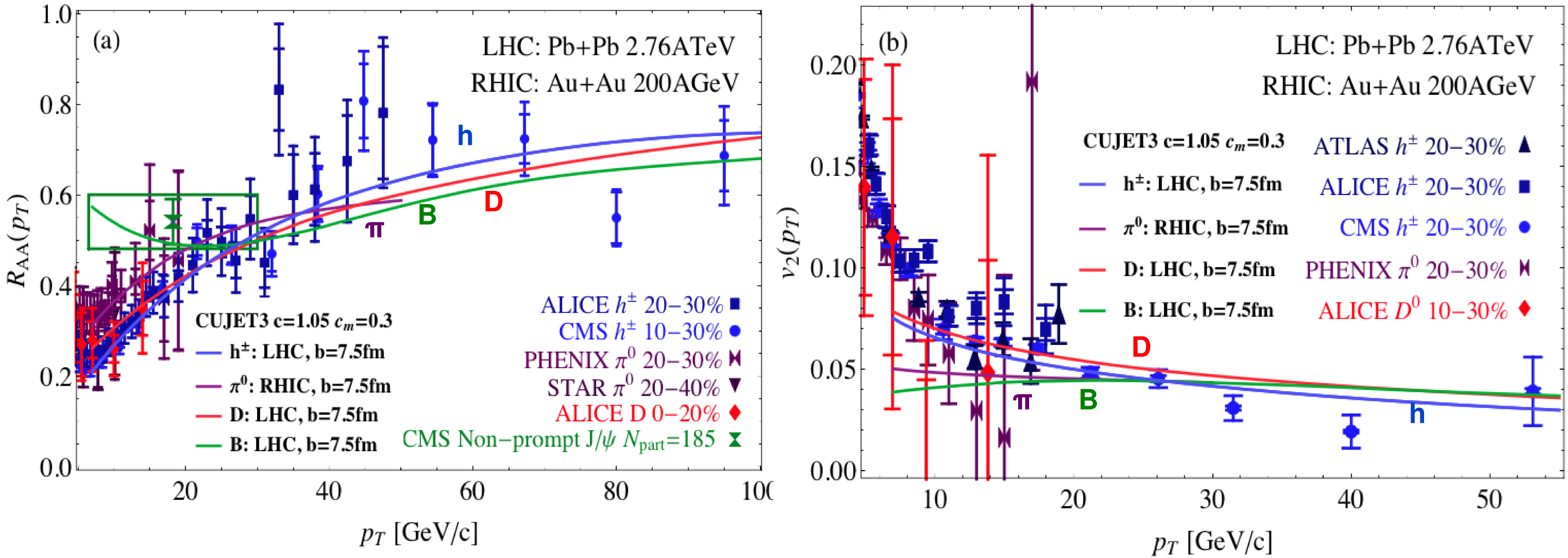
Borsanyi et al., JHEP 09 (2010)



$$\alpha_s^2(q^2) \approx [1/[c + (9/2\pi)Log(q/\Lambda)]]^2$$

c = 1/alf_max is THE free param

CUJET3.0 with sQGMP simultaneously describes (RHIC+LHC) * (R_{AA}+v_2) * (light + heavy)



JX, J. Liao, M. Gyulassy, arXiv:1411.3673

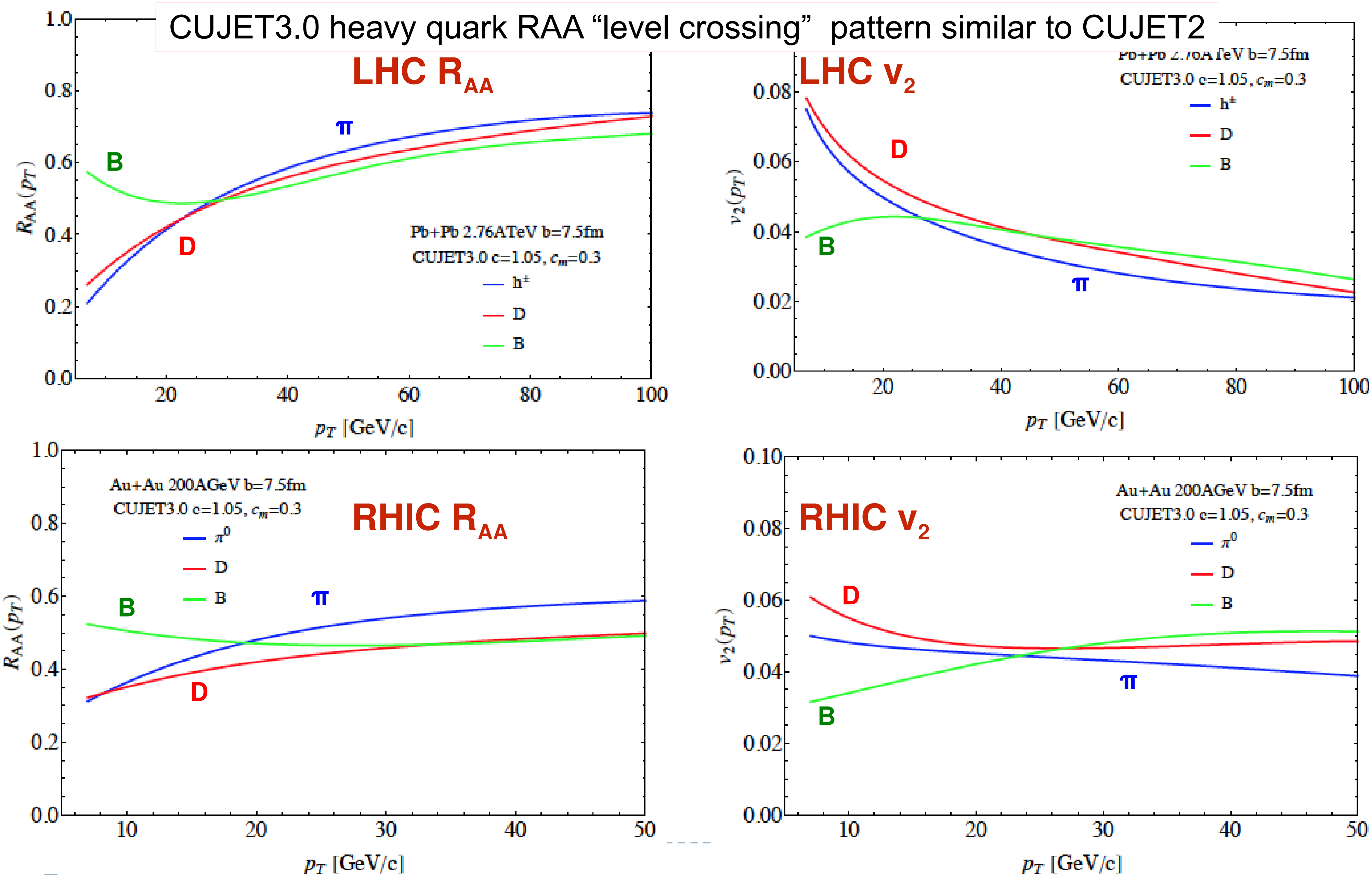
The combined set of observables

(RHIC+LHC) * (R_{AA}+V_2) * (pion+D+B)

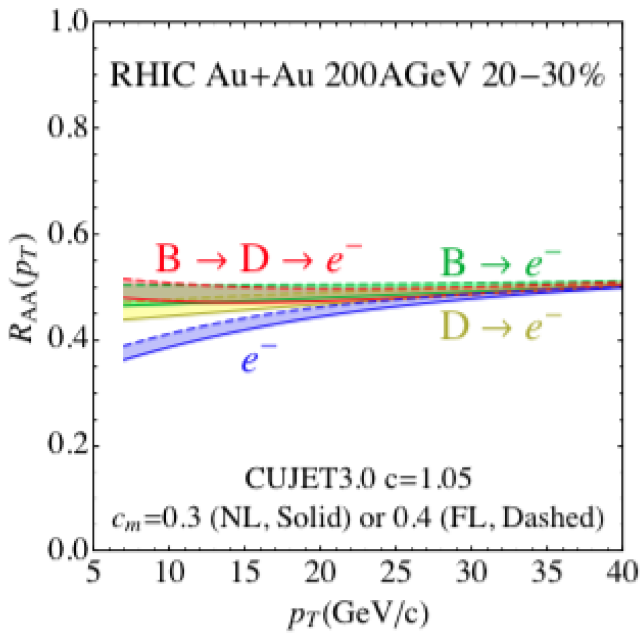
are consistently accounted for (within present experimental errors) in the CUJET3.0 sQGMP framework using lattice QCD constrained near-Tc enhanced jet-medium coupling and a VISH2+1 evolved semi-QGMP decomposition that reduces to HTL wQGP at high T>3Tc

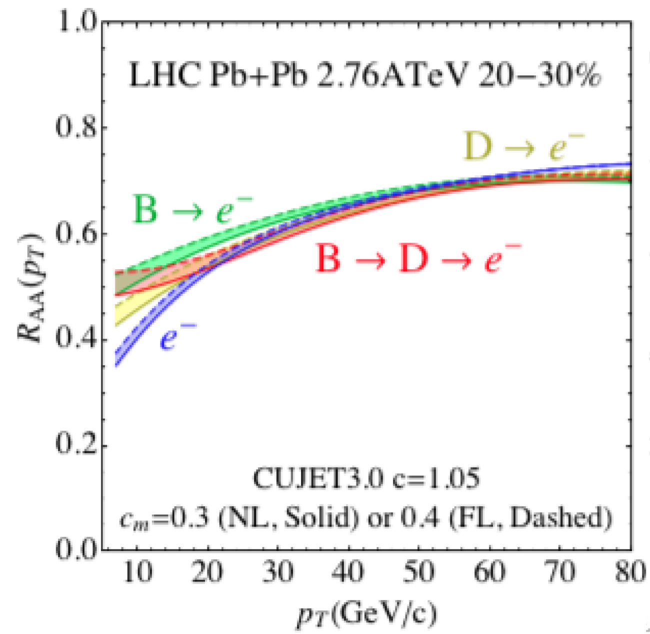
Open charm and beauty at high p_T R_{AA} and v_2 at RHIC and LHC (20-30% centrality) from CUJET3.0

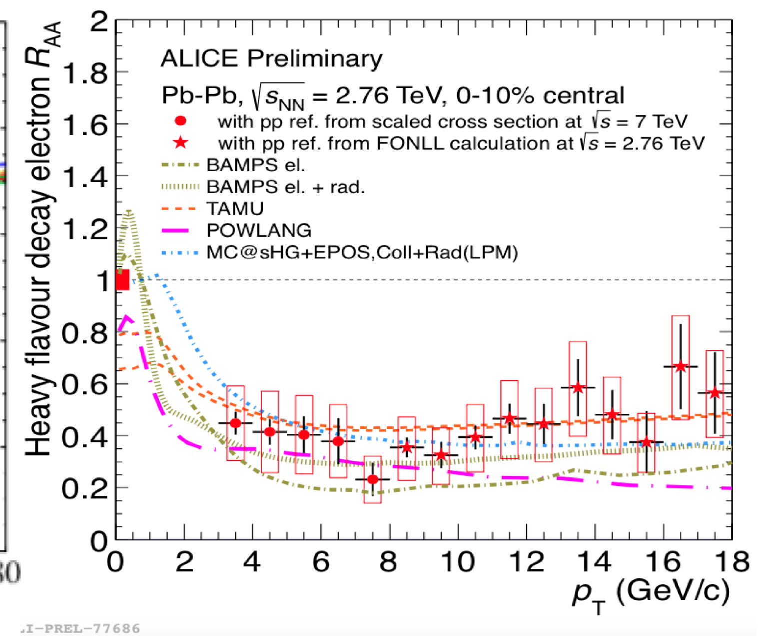
CUJET3.0 heavy quark RAA “level crossing” pattern similar to CUJET2

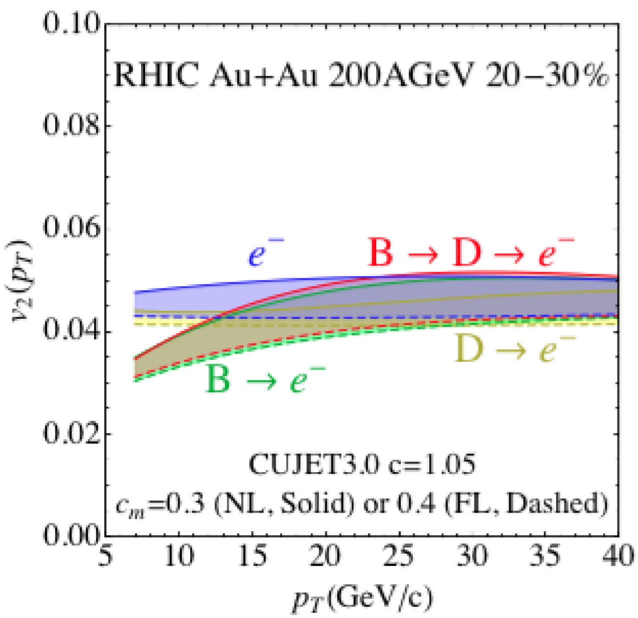


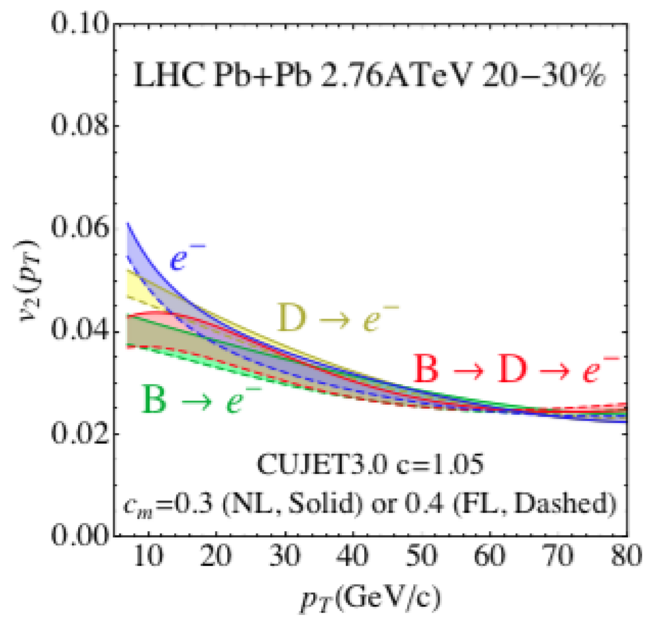
CUJET3.0: HF Decay Electron RAA & v2

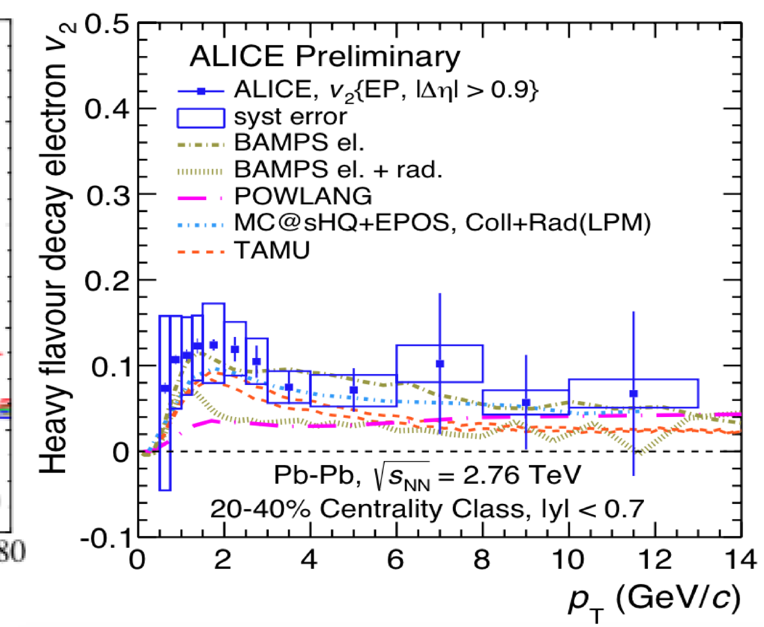












❖ To be compared with data

Summary :

(1) The combined 12 sets of observables,

(RHIC + LHC) * (RAA + V2) * (pion + D + B),

are consistently accounted in the CUJET3.0 sQGMP framework using a lattice QCD constrained Q, G and M decomposition of bulk constrained VISH2+1 hydrodynamic evolved fluids.

(2) Most remarkably, for the first time, the CUJET3.0 sQGMP framework may solve the apparent paradoxical inconsistency between previous perturbative QCD based high E>10 jet transport field, qhat(E,T), and the small kinetic theory eta/s (~ sum n_a/qhat_a(3T , T)) needed to account for bulk "Perfect Fluidity".

In sQGMP this is explained by 1/alf_s enhancement of color electric interactions with emergent nonabelian color magnetic monopoles near Tc together with nonperturbative suppression of color electric components

Overtime section:

work currently in progress:

Slow quark liberation with Polyakov Loop L(T) leads to super-ideal eta/s<1/4pi fluidity near Tc.

Can Fast quark liberation suggested by quark susceptibility lattice data restore unitarity bound ?

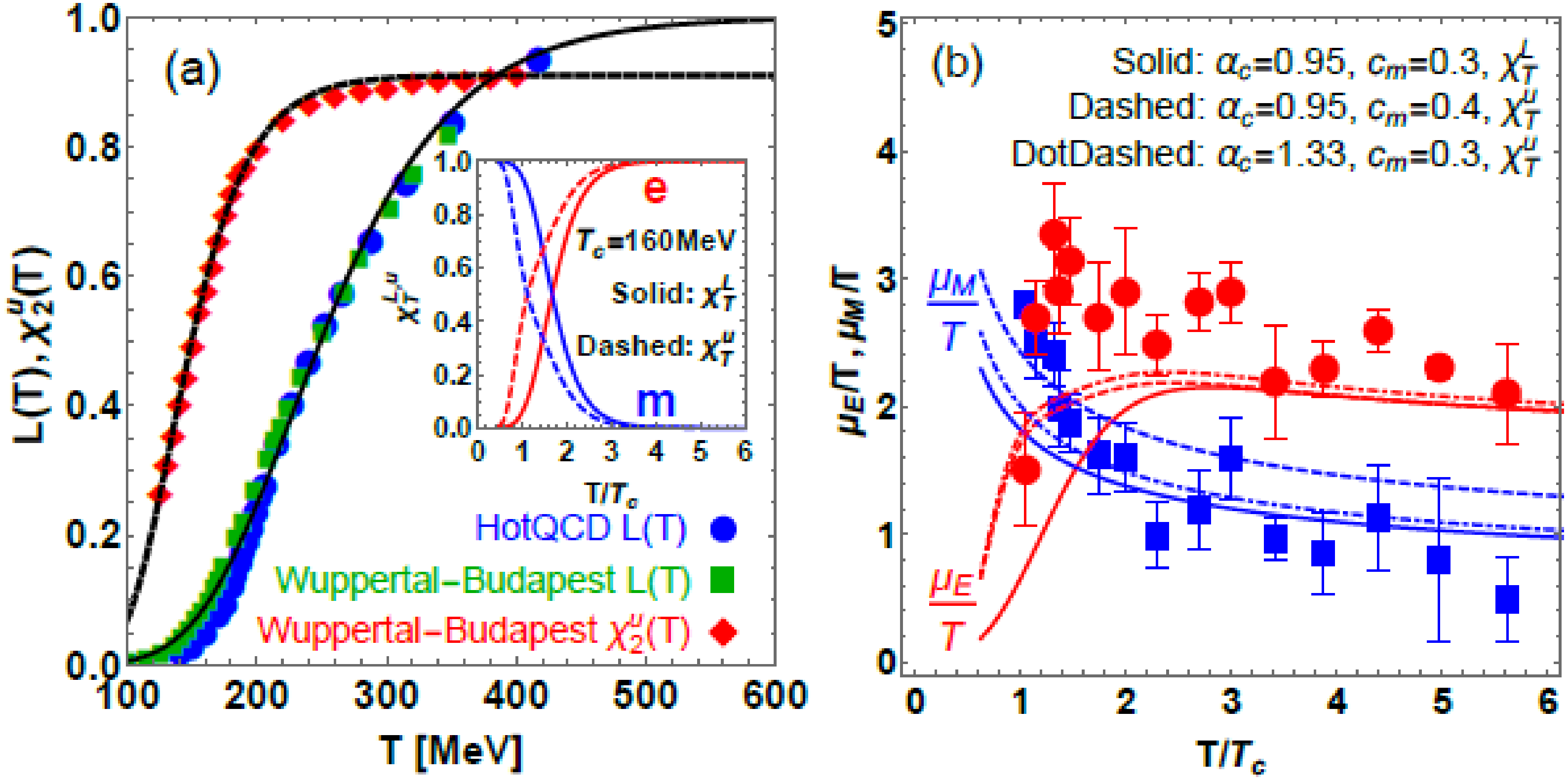
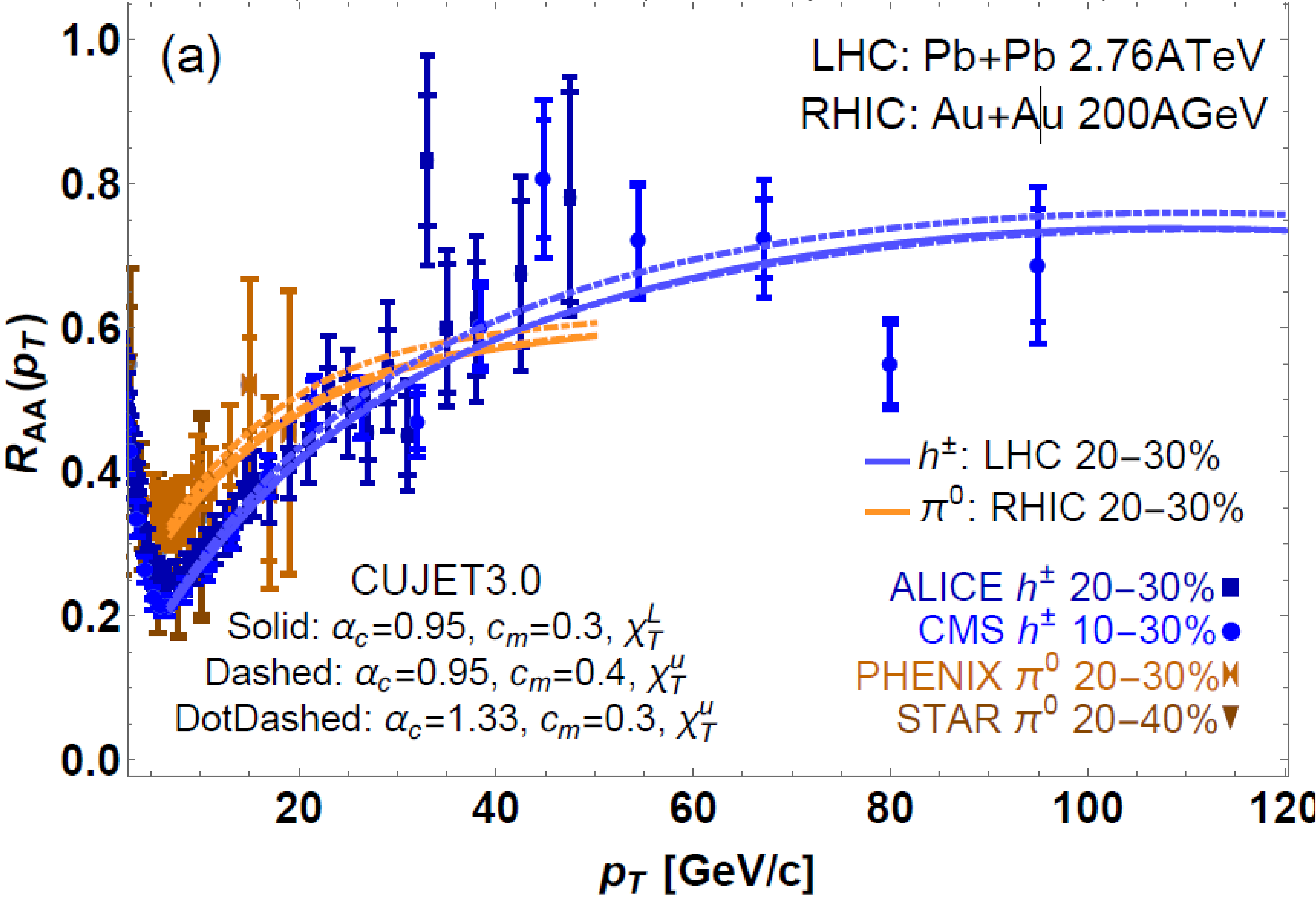


Figure 1. (Color online) (a) Renormalized Polyakov loop $L(T)$ (blue circle: [49], green square: [50]) and diagonal susceptibility of light quark number density $\chi_2^u(T)$ (red diamond: [52]) computed from lattice QCD, fitted with the parametrization of Eq. (2.17) and (3.4). The inset shows the the density fraction of color electric DOFs (red, $\chi_T = \rho_E/\rho$) and color magnetic DOFs (blue, $1-\chi_T = \rho_M/\rho$) within the liberation scheme χ_T^L (solid) and χ_T^u (dashed), in the temperature range $T \sim 0.6 - 6.0\, T_c$, where $T_c = 160$ MeV. Notice that in χ_T^L, $\rho_E \approx \rho_M$ at $T \sim 1.7\, T_c$; in χ_T^u, $\rho_E \approx \rho_M$ at $T \sim 1.1\, T_c$; and these temperatures are where $r_d(T) \equiv d\chi_T/dT$ shall peak in $\chi_T^{L,u}$. (b) The dimensionless electric (red) and magnetic (blue) screening mass $\mu_{E,M}/T$ in the CUJET3.0 model

Xu, Liao, MG 2015 in prep

Quark susceptibility “Fast Liberation” cannot yet be distinguised from “slow” Polyakov suppress



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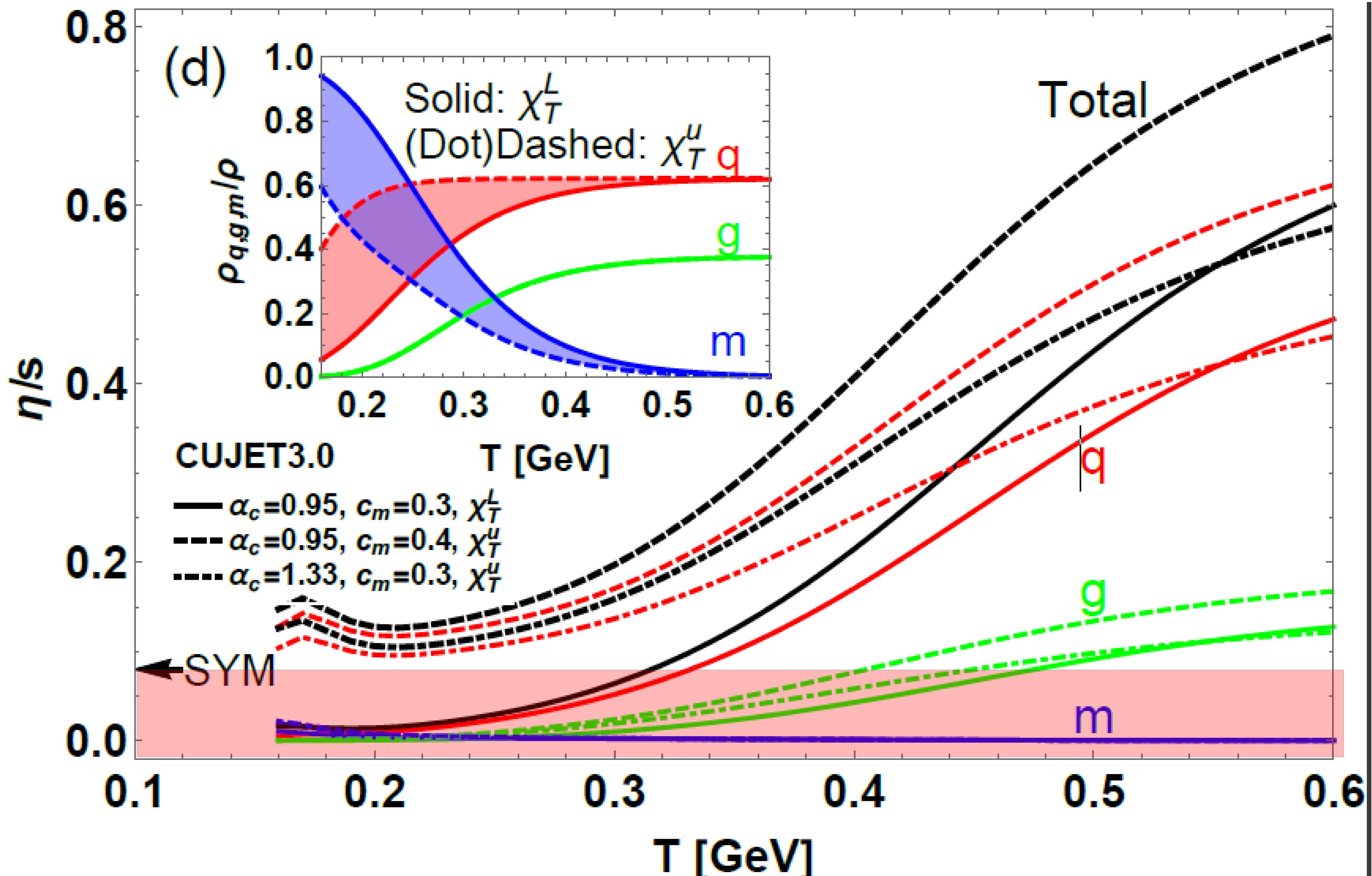
Fast Liberation of Quarks restores viscosity unitarity eta/s (T ~ Tc) > 1/4pi
And thus preferred over Slow Liberation (PolyLoop) scenario



Xu, Liao, MG 2015 in prep