Dilepton production in heavy ion collision

Su Houng Lee

Will talk about heavy quark sector

Thanks to Dr. Kenji Morita(YITP), Dr. Taesoo Song(Texas A&M)
Sungtae Cho (Yonsei) and present group members

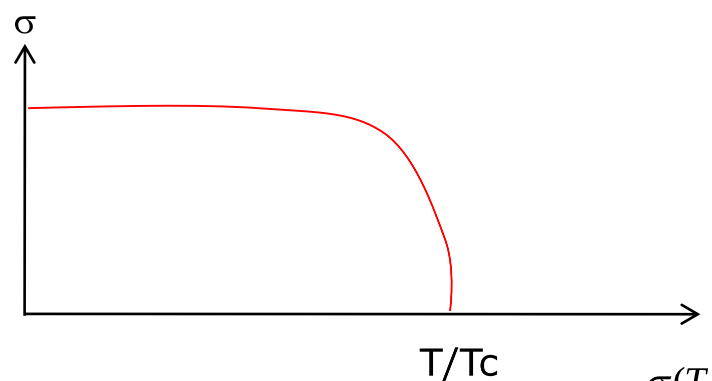
YONSEI UNIVERSITY

Early work on J/ψ at finite T *(Hashimoto, Miyamura, Hirose, Kanki)*

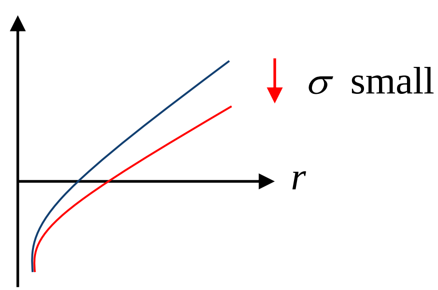
VOLUME 57, NUMBER 17 PHYSICAL REVIEW LETTERS 27 OCTOBER 1986

Mass Shift of Charmonium near Deconfining Temperature and Possible Detection in Lepton-Pair Production

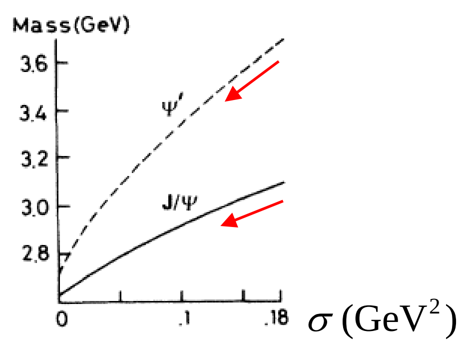
String Tension:
QCD order parameter

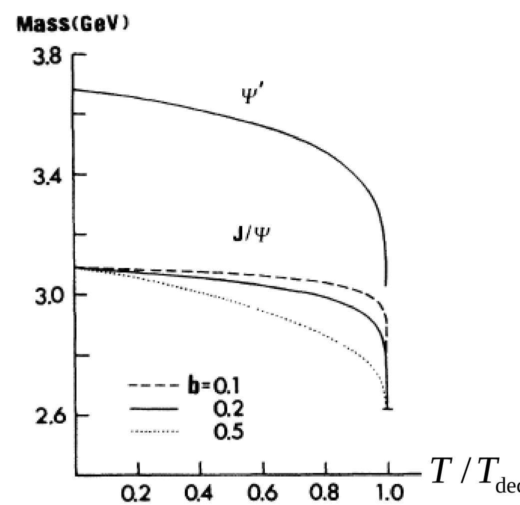


$$\sigma(T) = \sigma(0) \times \left[\left(T_{\text{dec}} - T\right)/T_{\text{dec}}\right]^{\text{b}}$$



$$V(r) = -\frac{4}{3}\frac{\alpha_s(r)}{r} + \sigma \times r$$





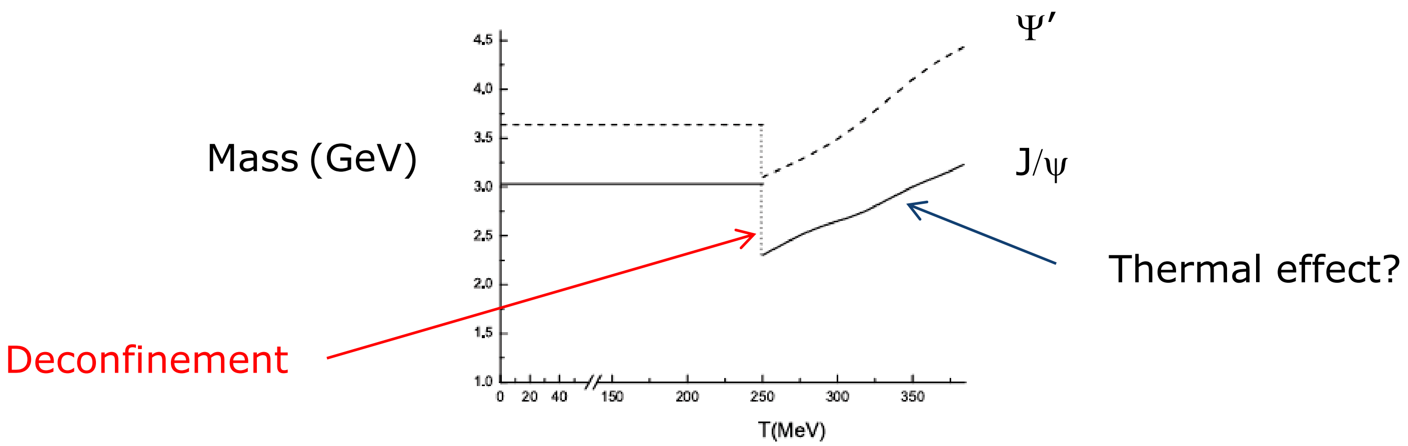
J/ψ suppression in RHIC

- Matsui and Satz: J/ψ will dissolve at Tc due to color screening

Recent works on J/ψ in QGP

- Lattice MEM : Asakawa, Hatsuda, Karsch, Petreczky , Bielefield, Nonaka….
  J/ψ will survive Tc and dissolve at 2 Tc .. Still not settled at QM2011
- Potential models (Wong …) : .
- Refined Potential models with lattice (Mocsy, Petreczky…)
  : J/ψ will dissolve slightly above Tc
- Perturbative approaches: Blaizot et al… Imaginary potential
- pNRQCD: N. Brambial et al.
- Lattice after zero mode subtraction (WHOT-QCD)
  : J/ψ wave function hardly changes at 2.3 Tc
- AdS/QCD (Kim, Lee, Fukushima, Stephanov…. ..)
- NRQCD: UK group+ S.Y. Kim
- QCD sum rule (Morita, Lee) , QCD sum rule+ MEM (Gluber, Oka, Morita)

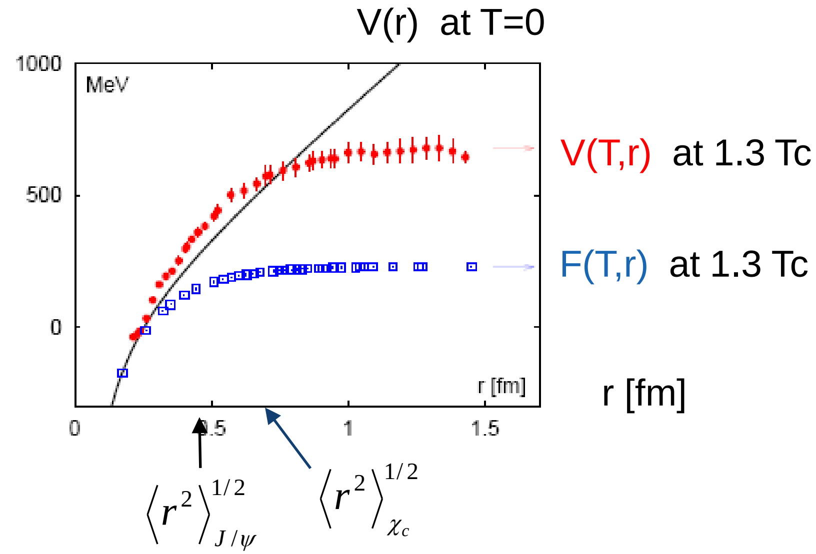
AdS/QCD (Y.Kim, J.P.Lee, SHLee 07)



J/ψ from potential models

- Lattice result on singlet potential F(T,r) =V(T,r) -TS(T,r)

Kaczmarek , Zantow hep-lat/0510094



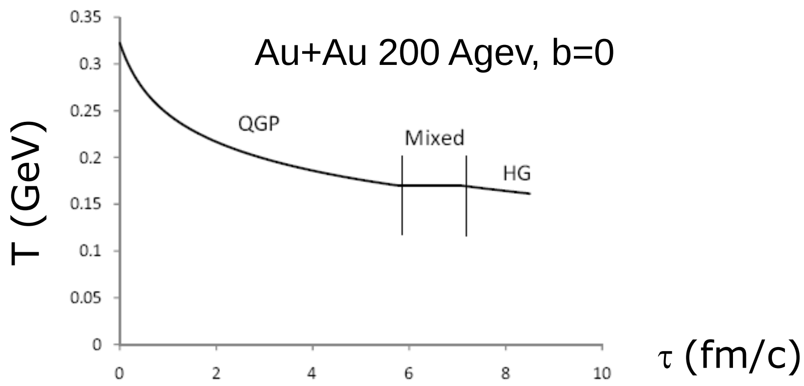
- Quarkonium dissociation temperature for different potentials

state	J/ψ	χ_c	ψ'	Υ	χ_b	Υ'	χ_b'	Υ''	
$E_s^i[GeV]$	0.64	0.20	0.005	1.10	0.67	0.54	0.31	0.20	
T_d/T_c	1.1	0.74	0.1-0.2	2.31	1.13	1.1	0.83	0.75	Using F(T,r)
T_d/T_c	~ 1.42	~ 1.05	unbound	~ 3.3	~ 1.22	~ 1.18	-	-	Wong 04
T_d/T_c	1.78-1.92	1.14-1.15	1.11-1.12	$\gtrsim 4.4$	1.60-1.65	1.4-1.5	~ 1.2	~ 1.2	Using V(T,r)

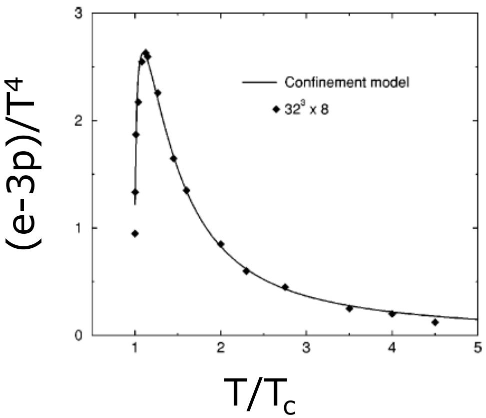
Another model independent approach ?

Few things to note about Tc region

- Tc region is important in HIC

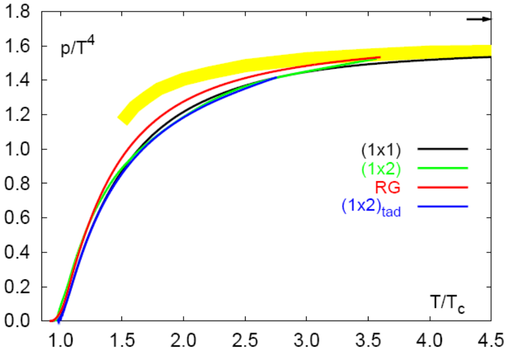


- Large non-perturbative change at Tc



- Resumed perturbation fails

Karsch hep-lat/0106019



A non perturbative method for quarkonium near Tc

K.Morita, SHL: PRL 100, 022301 (08)

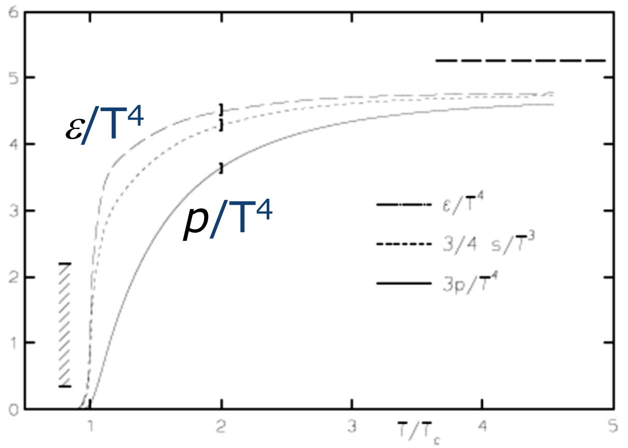
K.Morita, SHL: PRC 77, 064904 (08)

SHL, K. Morita: PRD 79, 011501 (09)

Y.Song, SHL, K.Morita: PRC 79, 014907 (09)

Gluon field configurations near Tc

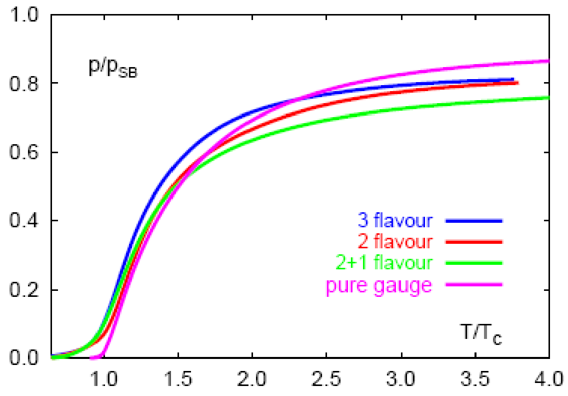
Lattice data on (e ,p) near Tc



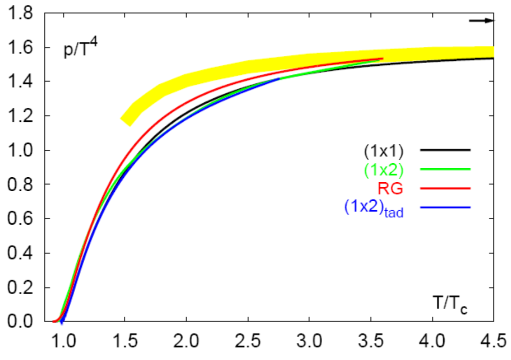
Lattice result for purge gauge (Boyd et al 96)

Sudden increase in ε

Slow increase in p

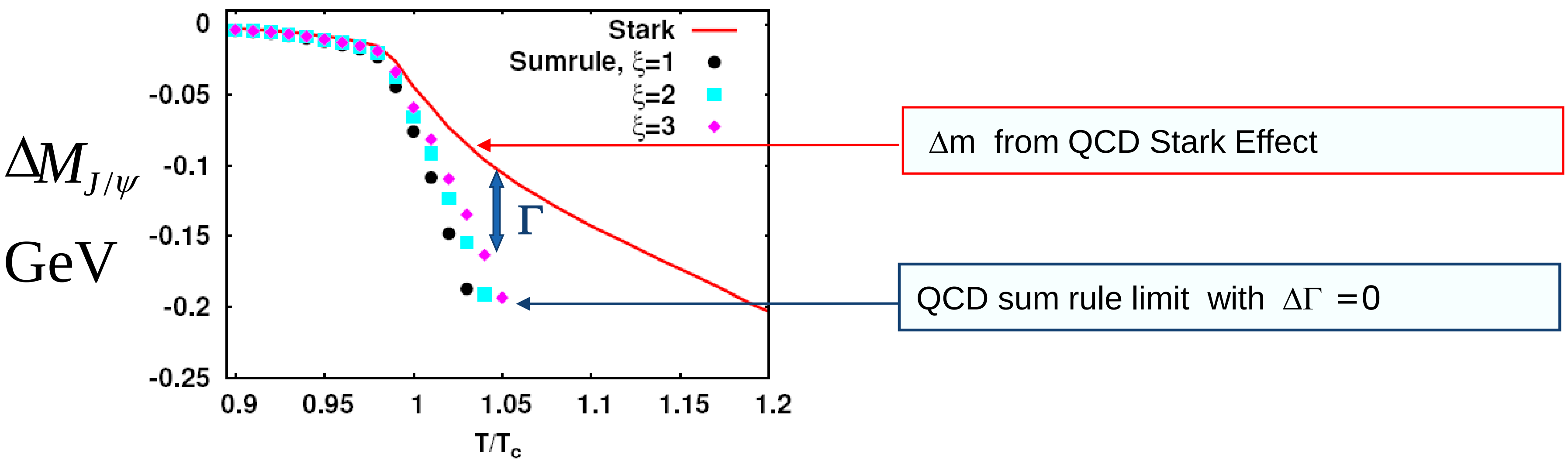


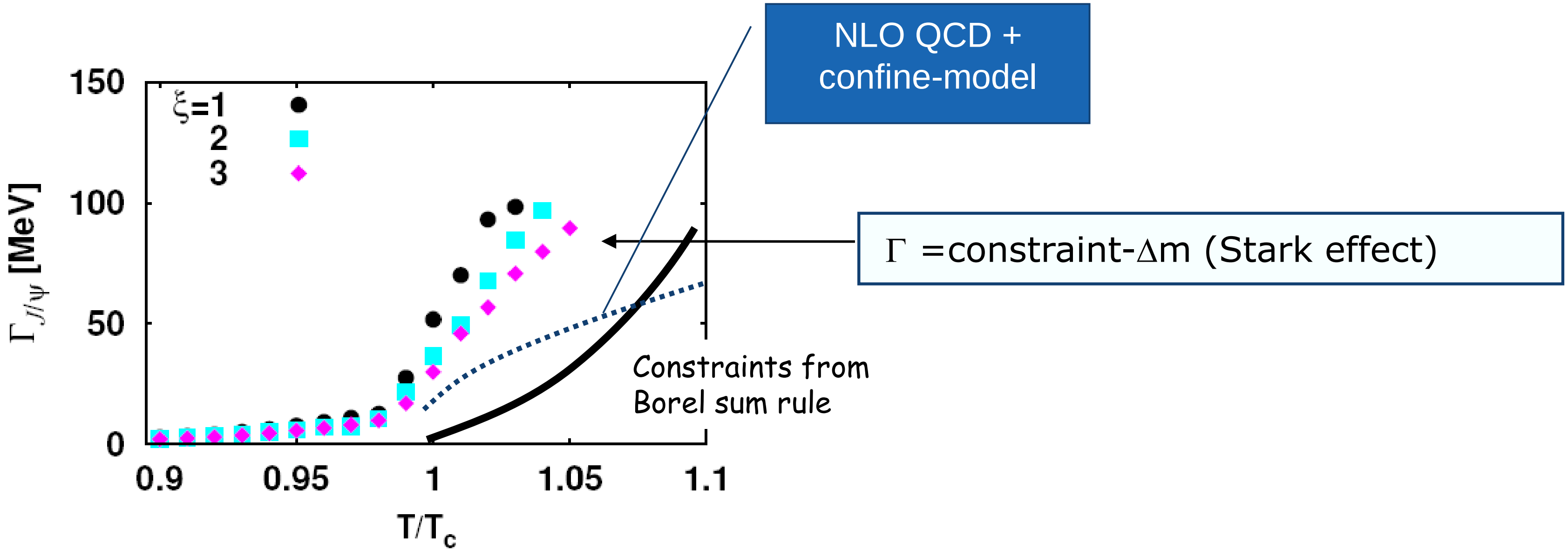
Rescaled pressure (Karsch 01)



Karsch hep-lat/0106019

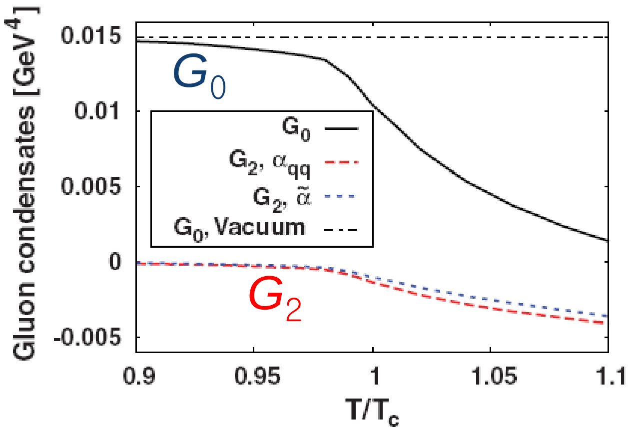
Mass and width of J/ψ near Tc (Morita, Lee 08, M, L & Song 09)

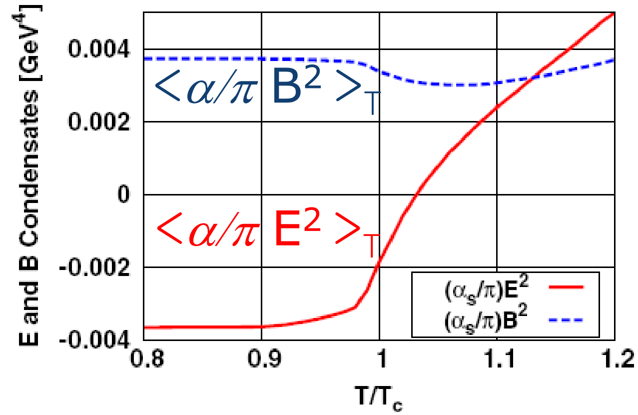




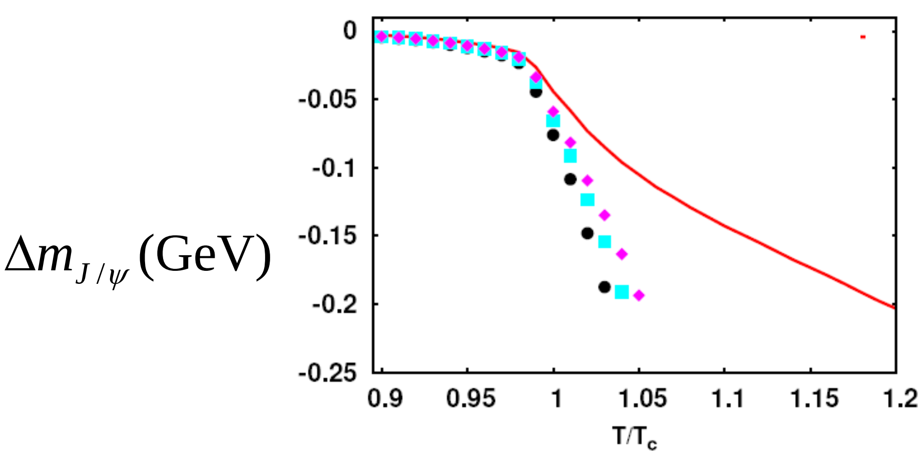
Summary of analysis

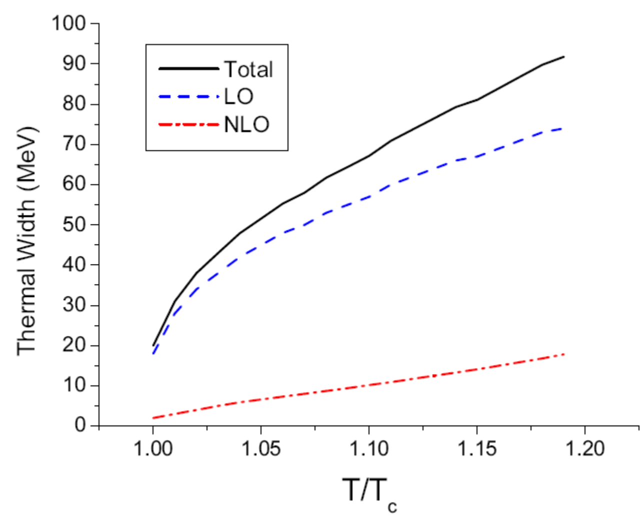
- Due to the sudden change of condensate near Tc





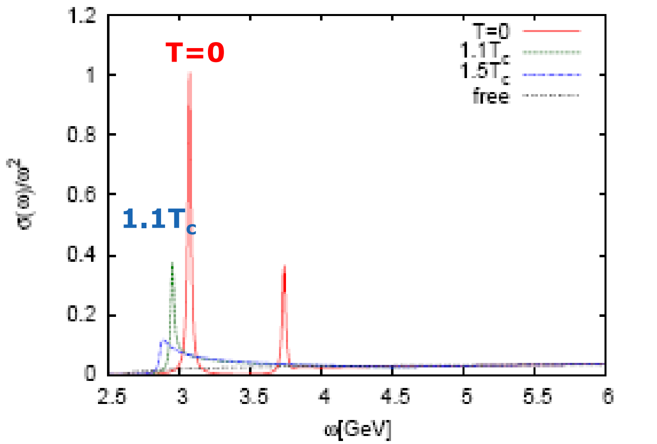
- Abrupt changes for mass and width near Tc





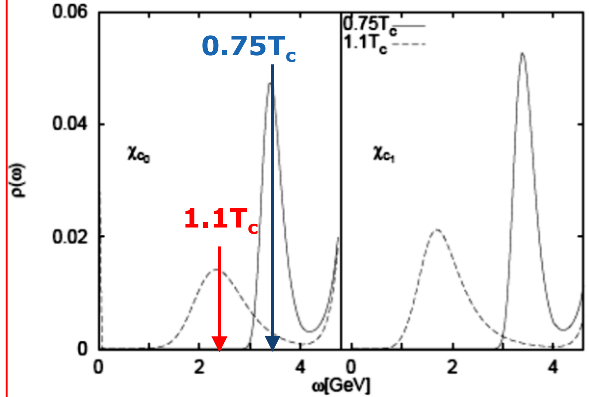
Comparison to other approach

Mocsy, Petreczky



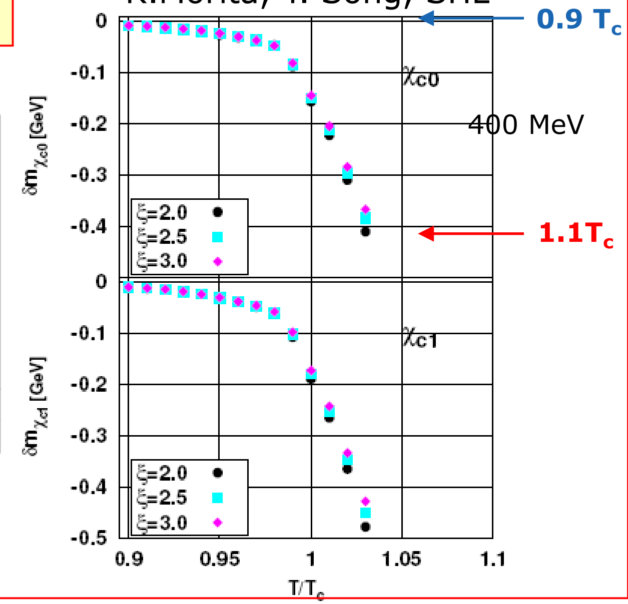
χ_c state from lattice

Karsch et al.



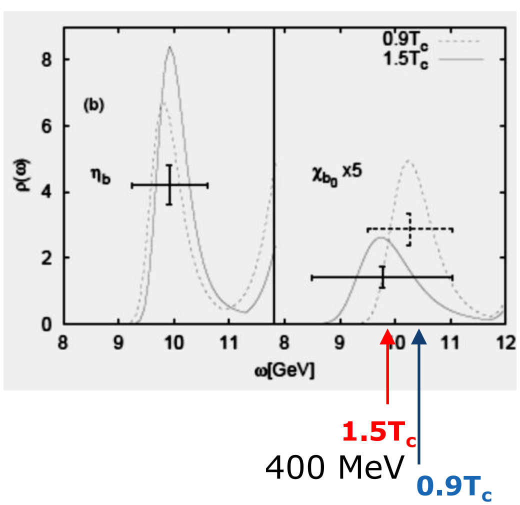
1 GeV

K.Morita, Y. Song, SHL

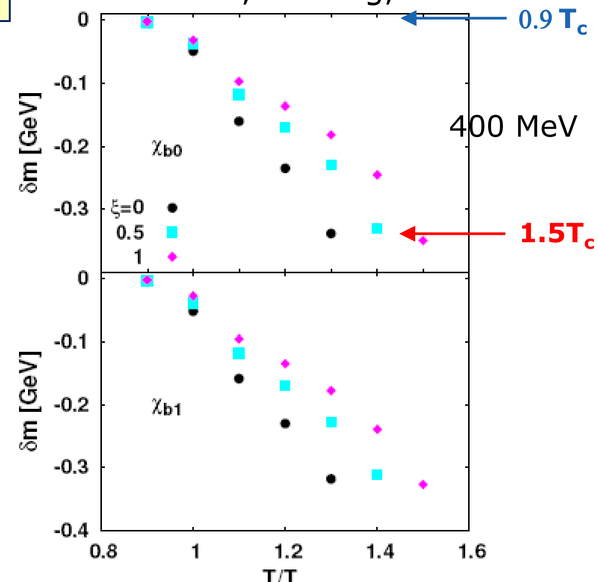


χ_b state from lattice

Karsch et al.

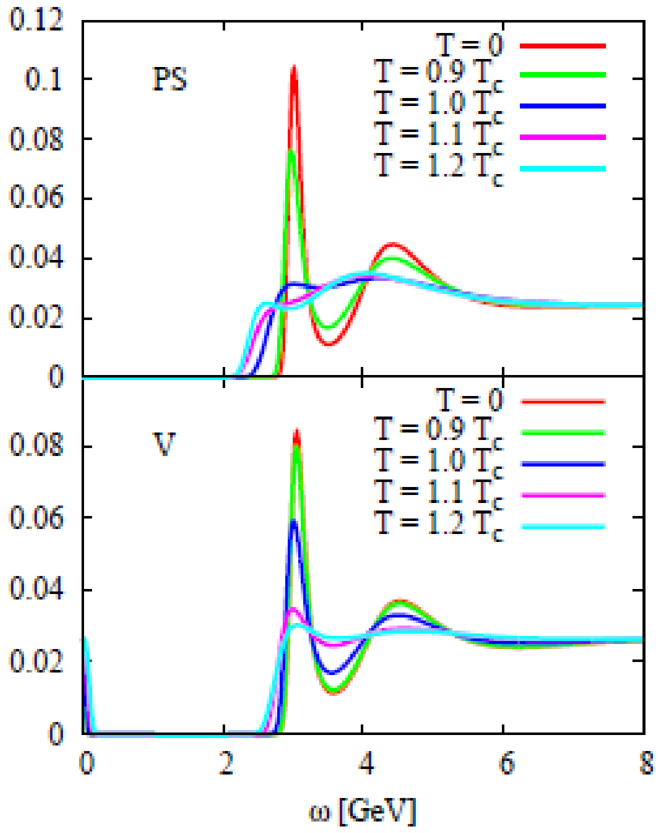


K.Morita, Y. Song, SHL



Gubler, Morita, Oka (2011)

- QCD OPE + MEM



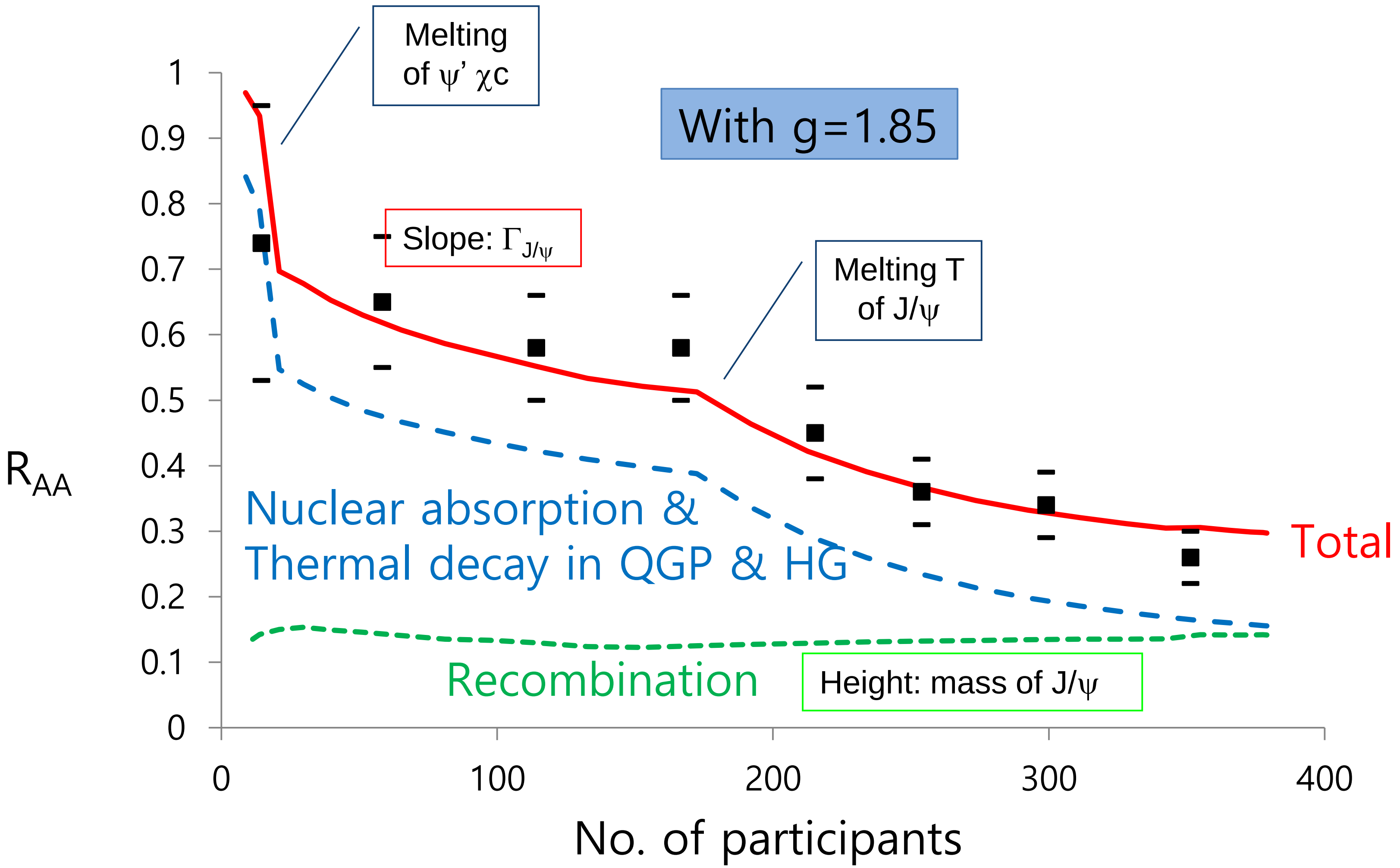
R_{AA} and v_2 of Charmonium

T. Song, W. Park, SHL :   Phys. Rev. C **81, 034914 (2010)**

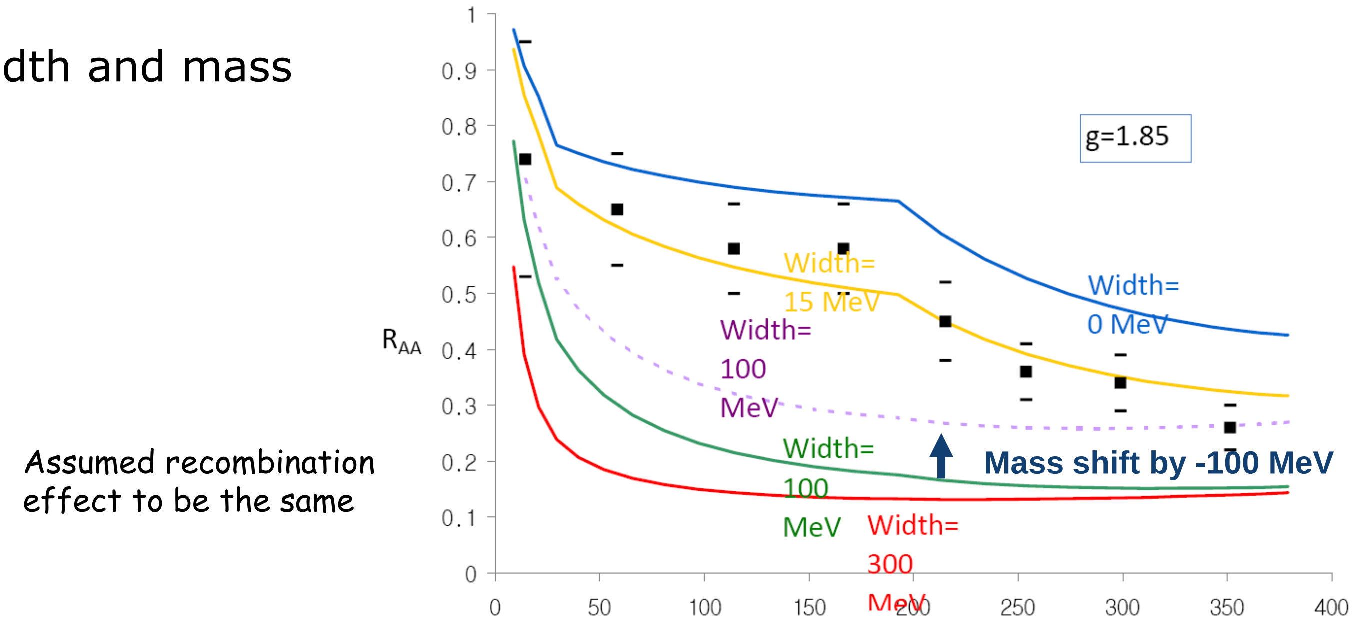
T. Song, C. M. Ko, SHL, Jun Xu : Phys. Rev. C **83, 014914 (2011)**

T. Song, C. M. Ko, K. Han, SHL: in preparation

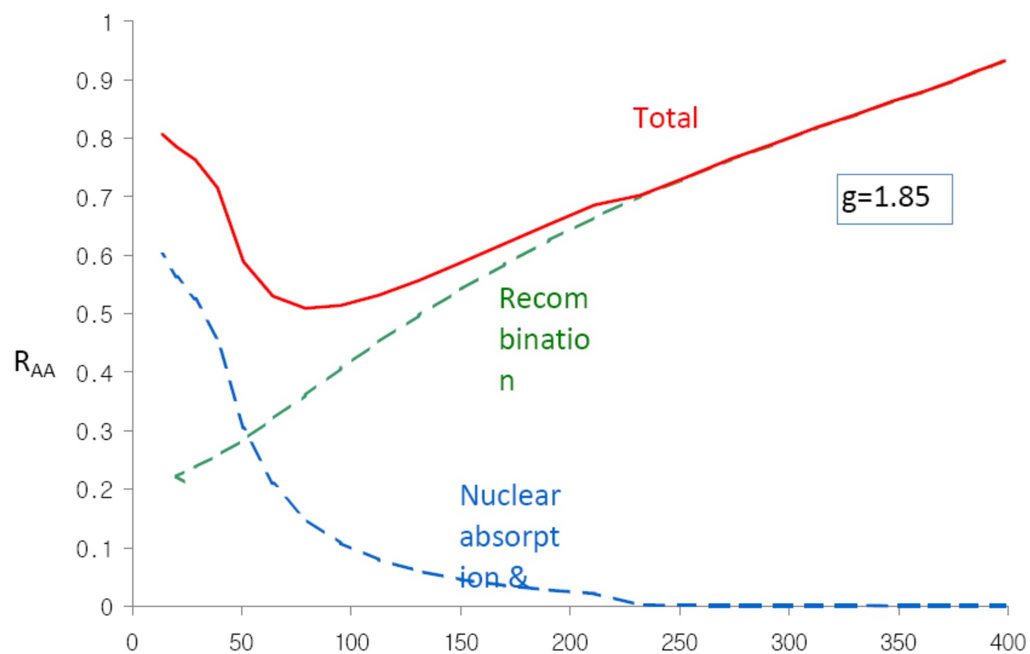
RAA from RHIC ($\sqrt{s}$=200 GeV y=0 , 2-comp model (Rapp) Song, Park, Lee 10)



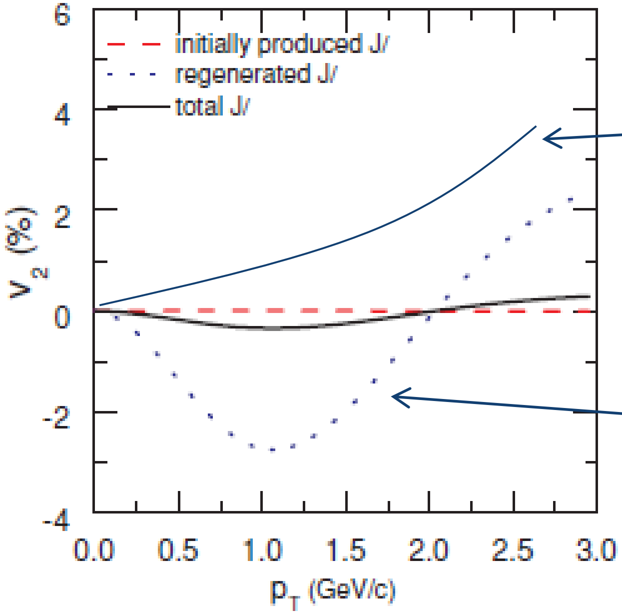
- Effects of width and mass



- At LHC



V2 T. Song et al.



Hydro + $c\underline{c}$ conservation

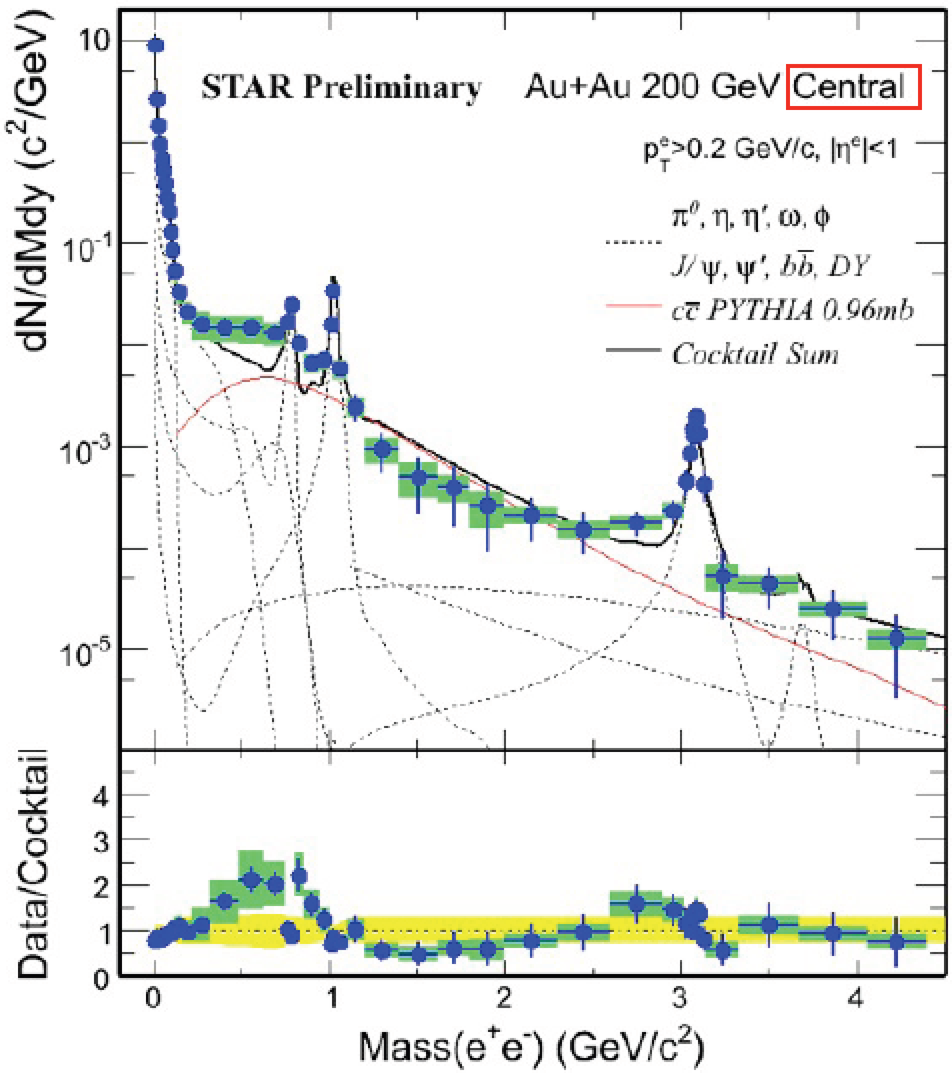
Thermal + flow

From QM 2011

No analysis yet !!

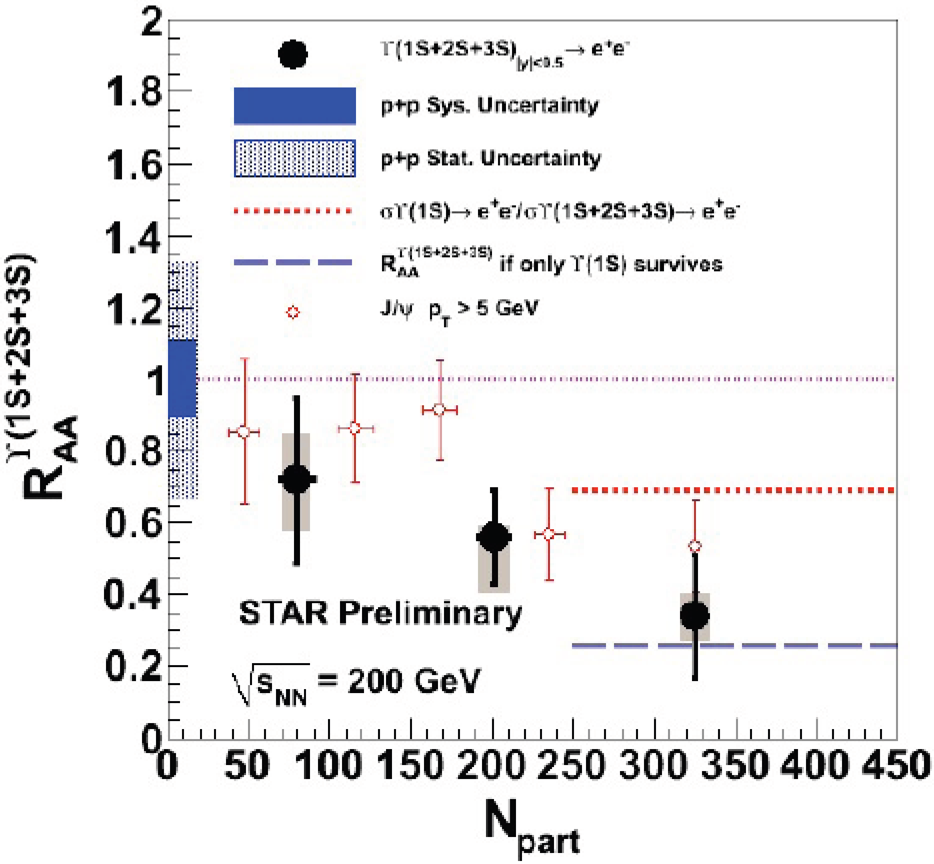
Di-electron spectrum in Au+Au

Jie Zhao, Thu/26 15:40



- Enhancement in low mass region at central 0-10%
  - ρ contribution not included in the cocktail
  - In-medium modification of ρ ?
- Charm contribution from PYTHIA × N_{bin} (0.96 *mb*) overestimate the data at intermediate mass region → modification of charm ? thermal radiation ?

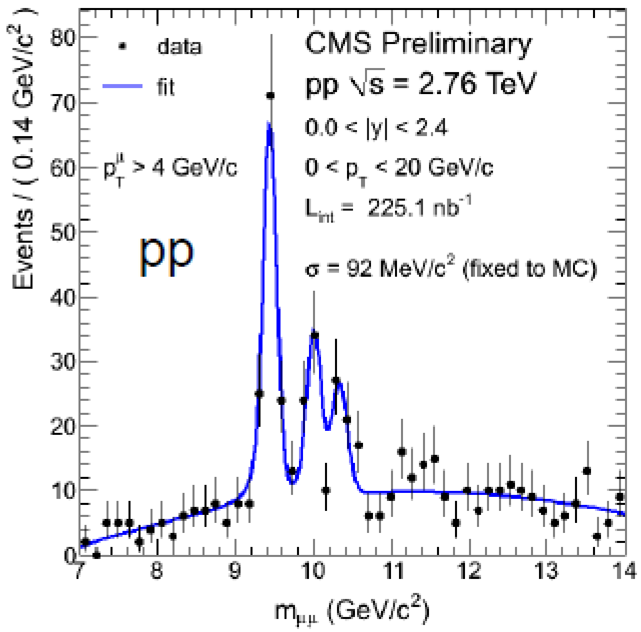
ϒ R_{AA}

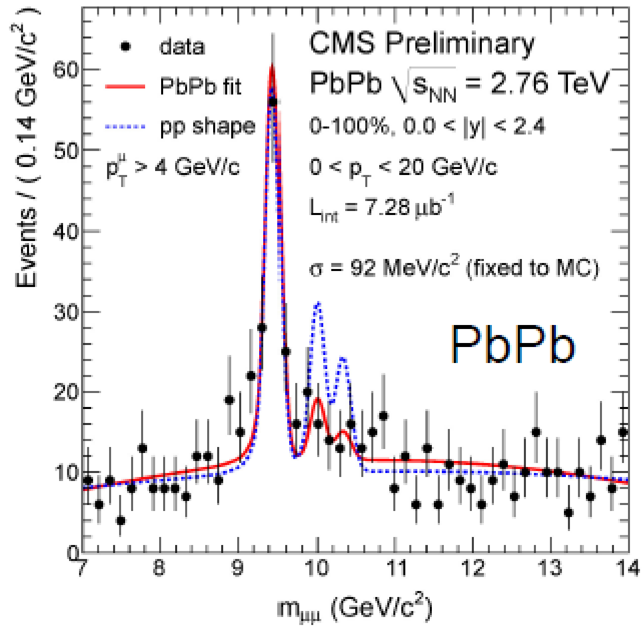


Rosi Reed, poster board 48, Thu/26

- ϒ(1S+2S+3S) suppression at central collisions
  - Similar suppression with high p_T *J/ψ*
- First measurement of ϒ suppression
- Statistical uncertainty will be improved by more than a factor of 2
  - × 3 in p+p 2009
  - × 2 in Au+Au 2011

Suppression of excited Υ states





$$\Upsilon(2S+3S)/\Upsilon(1S)\Big|_{pp} = 0.78^{+0.16}_{-0.14} \pm 0.02 \qquad \Upsilon(2S+3S)/\Upsilon(1S)\Big|_{PbPb} = 0.24^{+0.13}_{-0.12} \pm 0.02$$

$$\frac{\Upsilon(2S+3S)/\Upsilon(1S)\Big|_{PbPb}}{\Upsilon(2S+3S)/\Upsilon(1S)\Big|_{pp}} = 0.31^{+0.19}_{-0.15} \pm 0.03$$

- Excited states Υ(2S,3S) relative to Υ(1S) are suppressed
- Probability to obtain measured value, or lower, if the real double ratio is unity, has been calculated to be less than 1%

Z. Hu (TODAY), C. Silvestre (Fri)

Cornell Potential

TABLE II. $c\bar{c}$ bound states in naive model, and their properties. Parameters used are $m_c = 1.84$ GeV, $a = 2.34$ GeV^{-1}, and $\kappa = 0.52$.

State	Mass (GeV)	Γ_{ee} (keV) [b]	$\langle \frac{v^2}{c^2} \rangle$	$\langle r^2 \rangle^{1/2}$ (fm)	Candidate
1S	3.095 [a]	4.8	0.20	0.47	$\psi(3095)$
1P	3.522 [a]		0.20	0.74	$\chi_{0,1,2}(3522 \pm 5)$
2S	3.684 [a]	2.1	0.24	0.96	$\psi'(3684)$
1D	3.81		0.23	1.0	$\psi'(3772)$ [c]
3S	4.11	1.5	0.30	1.3	$\psi(4028)$
2D	4.19		0.29	1.35	$\psi(4160)$ [d]
4S	4.46	1.1	0.35	1.7	$\psi(4414)$
5S	4.79	0.8	0.40	2.0	

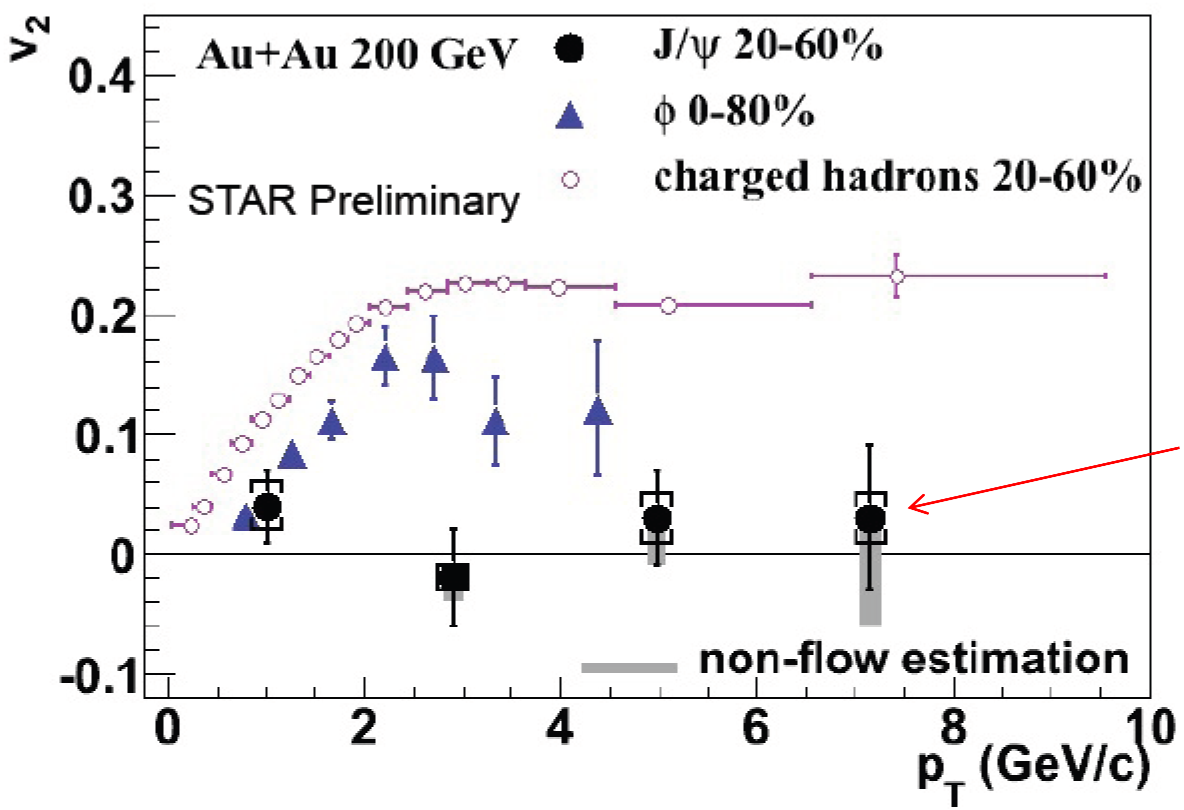
TABLE IV. Naive-model $b\bar{b}$ bound states and their properties. Parameters used are $m_b = 5.17$ GeV, $a = 2.34$ GeV^{-1}, and $\kappa = 0.52$.

State	Eigenvalue (MeV)	Mass (GeV)	Γ_{ee} [b] (keV)	$\langle \frac{v^2}{c^2} \rangle$	$\langle r^2 \rangle^{1/2}$ (fm)
1S	0	9.46 [a]	1.25	0.096	0.20
1P	498	9.96		0.065	0.39
2S	591	10.05	0.45	0.076	0.48
1D	747	10.20		0.067	0.53
2P	852	10.31		0.076	0.64
3S	936	10.40	0.31	0.085	0.72
2D	1040	10.50		0.080	0.75
3P	1135	10.60			
4S	1213	10.67	0.25	0.097	0.92
3D	1292	10.75			
5S	1455	10.92			
6S	1675	11.14			

[a] Input.

J/Ψ v_2

charged hadrons, STAR, **PRL93**, 252301 (2004)
φ, STAR, **PRL99**, 112301 (2007)



Hao Qiu, poster board 60, Thu/26

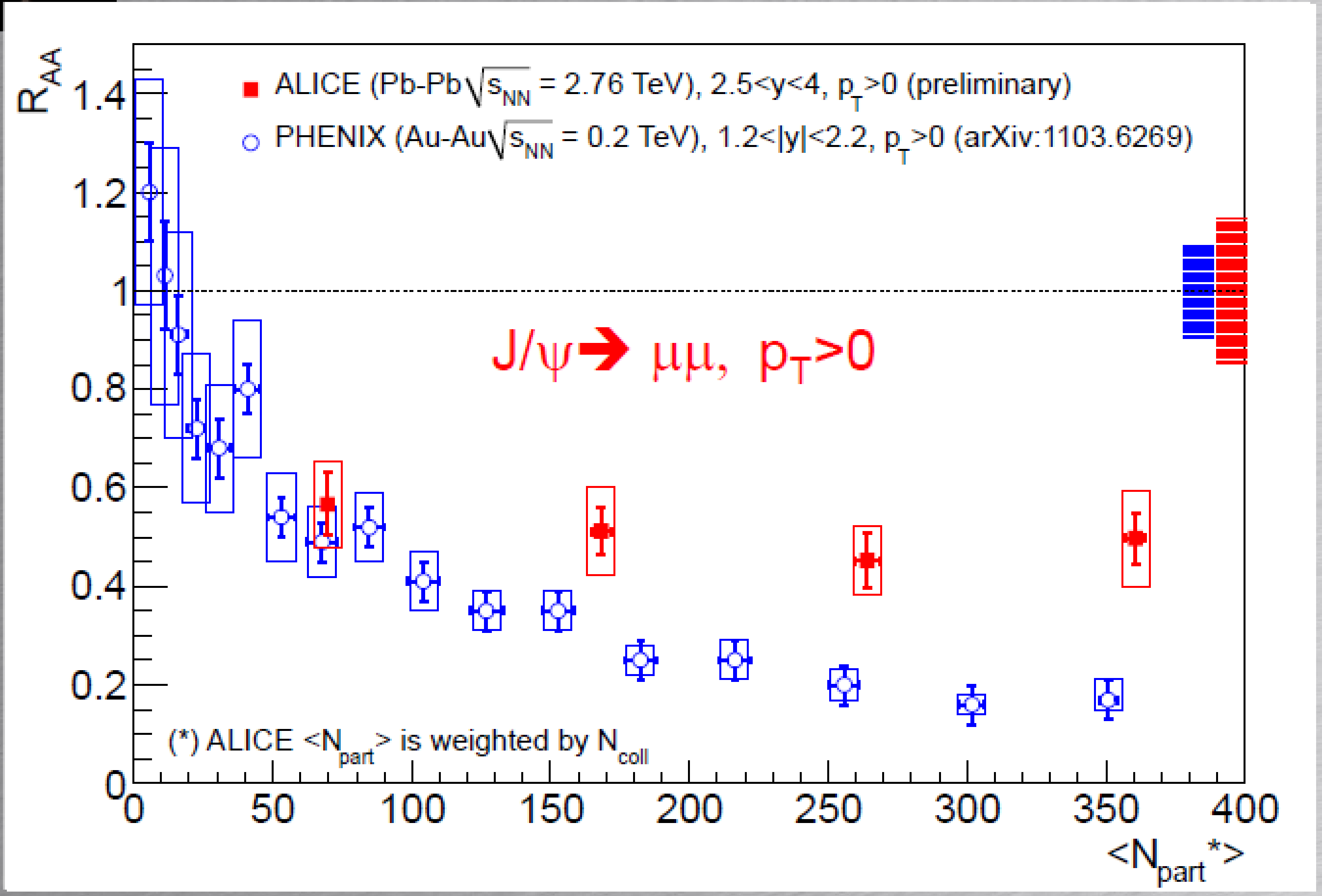
Zebo Tang, Tue/24 15:40

No regeneration
→ too much suppression?
→ mass shift

- J/ψ v_2 ~ 0 up to p_T ~ 8 GeV/c in mid-central 20-60%

➡ Disfavors coalescence from thermalized charm quarks

J/ψ R_{AA} 0.2 / 2.76 TeV



J/y R_{AA} larger at LHC (2.5<y<4) than at RHIC (1.2<|y|<2.2);
Similar as RHIC (|y|<0.35), except for the most central bin;
$dN_{ch}/d\eta(N_{part})^{LHC} \sim 2.1 \times dN_{ch}/d\eta(N_{part})^{RHIC}$ (A. Toia talk).

Summary

1. Deconfinement→ Potential → Quarkonium masses
2. Abrupt changes for quarkonium masses
3. Looking forward to Raa, v2 charmonium bottomonium ratio and finer mass resultion from RHIC and LHC
4. production inside a nuclear at FAIR and

심광숙 선생님, 더욱 건강하시고 계속 뵙기를 바랍니다.

References

1. Finite temperature lattice: Karsch: arXiv:0711.0661, 0711.0656, 0710.0354, Kaczmarek et al. PRD 70, 074505
2. Sum rule method at finite T: https://wiki.bnl.gov/qpg/index.php/Sum_rule_approach
3. J/psi formal: Hashimoto et al. PRL 57,2123 (1986), Matsui and Satz, PLB 178, 416 (1986), Asakawa, Hatsuda PRL 92, 012001 (2004), Morita, Lee, PRL 100,022301, Mocsy, Petreczky, PRL, 99, 211602 (2007)
4. J/Psi Phenomenology: Gazszicki, Gorenstein, PRL 83, 4009 (1999) , PBM , J. Stachel, PLB490, 196 (2000), Andronic et al. arXiv::nucl-th/0611023, Grandchamp and Rapp, NPA 709, 415 (2002), Yan, Zhuang, Xu, PRL,97,232301 (2006), Song, Park, Lee arXiv: 1002.1884
5. J/psi in medium, Brodsky et al. PRL 64,1011 (1990) , Lee, nucl-th/0310080,