Beijing

Charmed hadron signals of partonic medium

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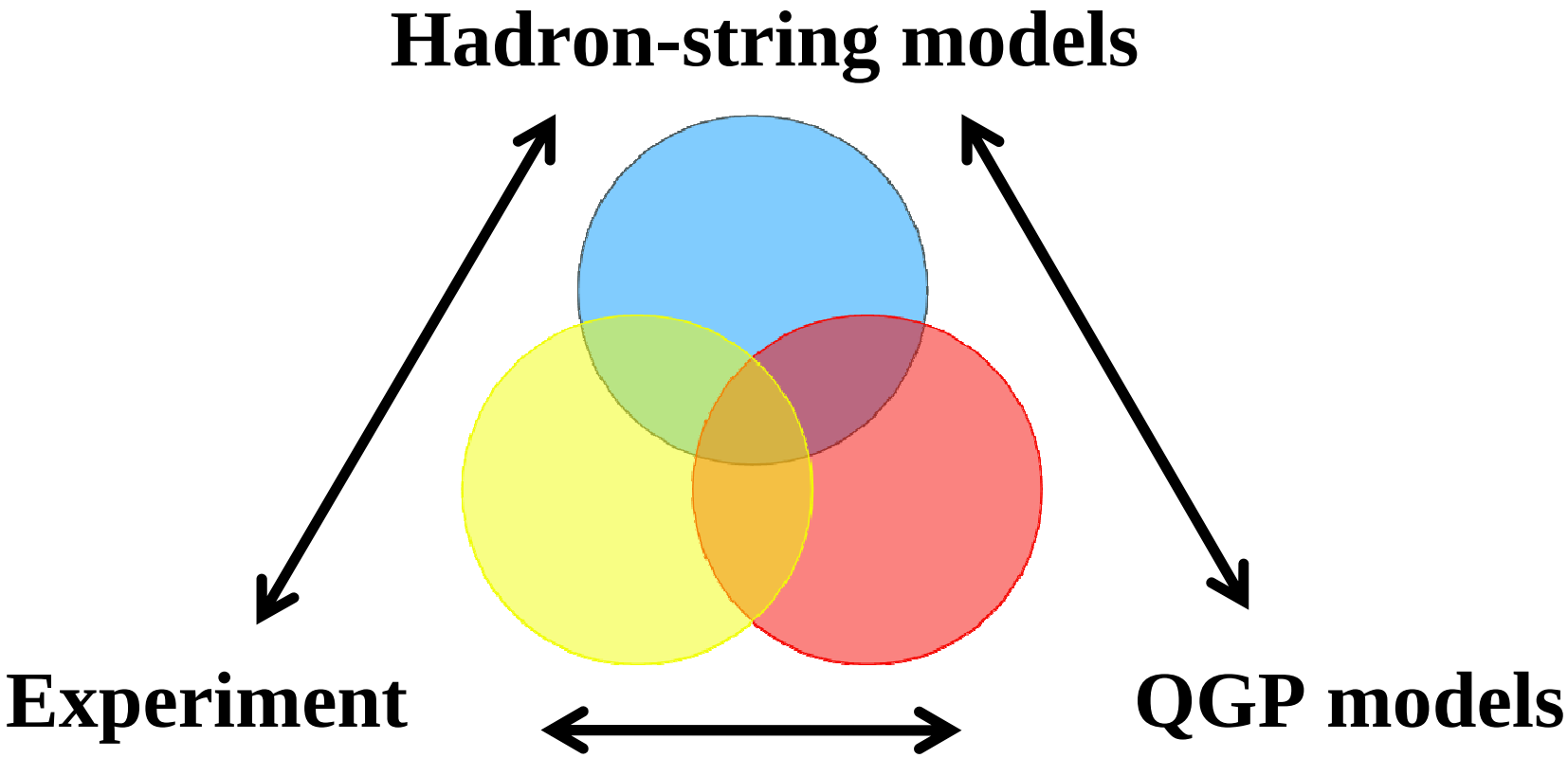
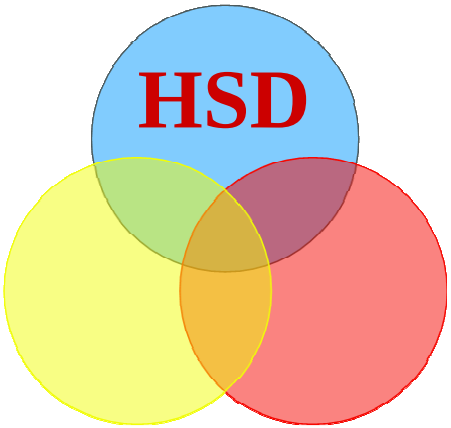
Our goal – properties of partonic matter



Observables



- Hadron abundances
- J/Ψ anomalous suppression at SPS
- J/Ψ anomalous suppression at RHIC
- J/Ψ rapidity distribution at RHIC
- Elliptic flow of D-mesons
- Elliptic flow of J/Ψ
- Quenching of charm at RHIC

Basic concepts of Hadron-String Dynamics

- for each particle species i (i = N, R, Y, π, ρ, K, …) the phase-space density f_i follows the transport equations

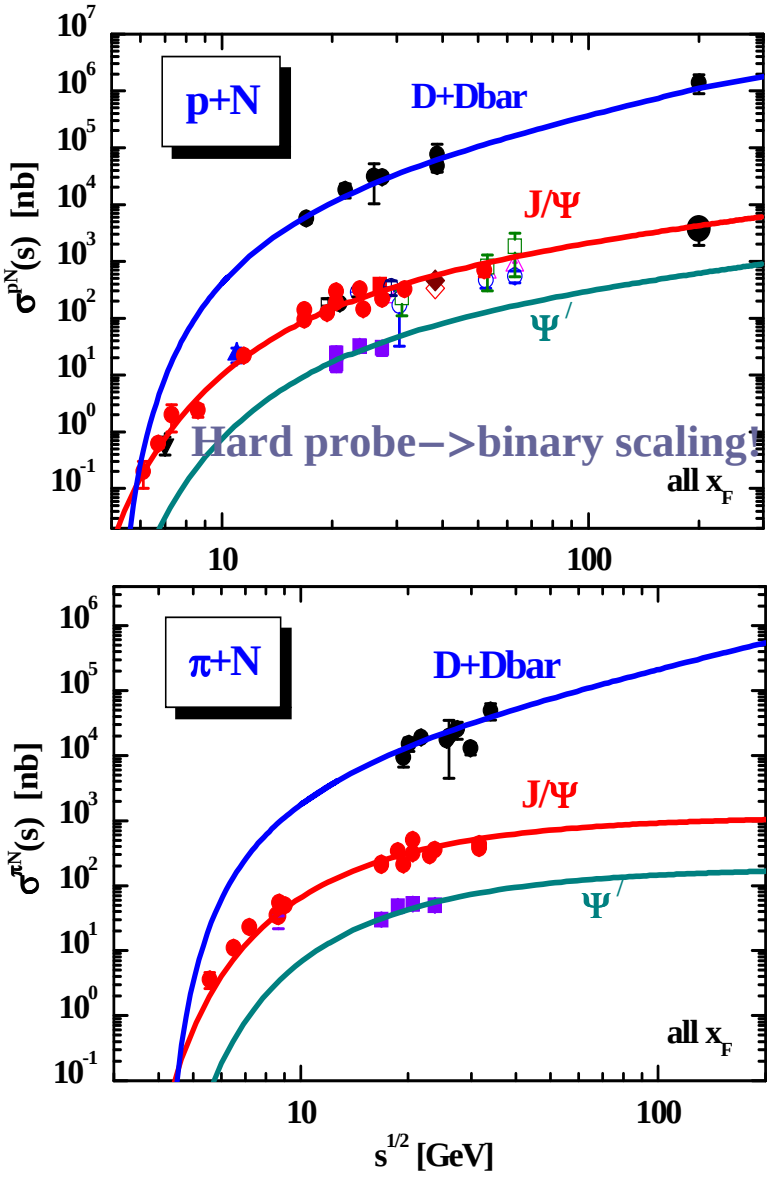
$$\left(\frac{\partial}{\partial t}+\left(\nabla_{\vec{p}}H\right)\nabla_{\vec{r}}-\left(\nabla_{\vec{r}}H\right)\nabla_{\vec{p}}\right)f_i(\vec{r},\vec{p},t)=I_{coll}(f_1,f_2,\ldots,f_M)$$

with the collision terms I_{coll} describing:

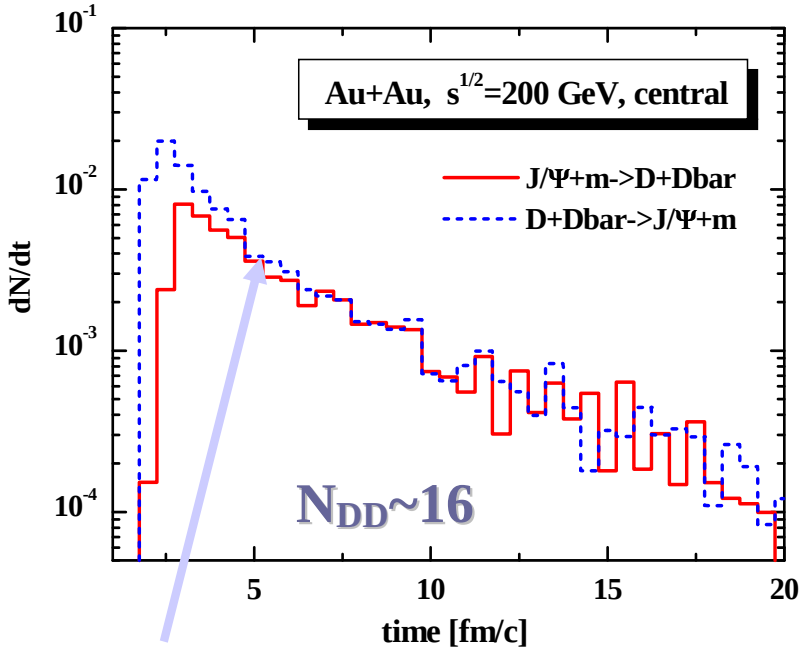
- elastic and inelastic hadronic reactions BB <–> B´B´, BB <–> B´B´m, mB <–> m´B´, mB <–> B´
- formation and decay of baryonic and mesonic resonances
- string formation and decay (for inclusive production: BB–>X, mB–>X, X =many particles)

- Implementation of detailed balance on the level of 1<–>2 and 2<–>2 reactions (+ 2<–>n multi-meson fusion reactions)
- Off-shell dynamics for short living states
- No explicit quark and gluon degrees-of-freedom, partons only in the strings

Charmonium production in HSD



- primary (Baryon+Baryon)
- secondary (meson+Baryon)
- recreation (D+$\bar{D}$ <–> J/Ψ+meson)

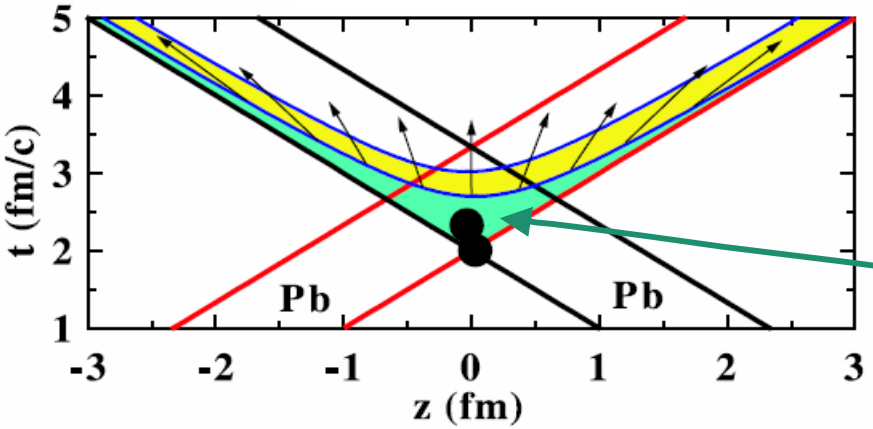


at **RHIC,** recreation of J/Ψ by D-Dbar annihilation is **strong!**

Charmonium interactions with the medium in HSD

Default comover absorption scenario:

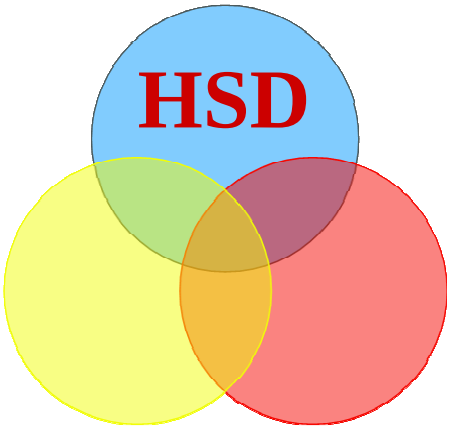
- **Interactions with nucleons (normal nuclear absorption, as in pA)**
- **Absorption on formed mesons (comovers), J/Ψ+m–>D+D**
- **Recombination by D+Dbar annihilation, D+D–>J/Ψ+m**



Modified comover, i.e. prehadron interaction scenario:

- ***additionally*, absorption and elastic scattering by prehadrons=mesons and baryons under formation time of τ~0.8 fm/c in their rest frame)**

Observables



- Hadron abundances
- J/Ψ anomalous suppression at SPS
- J/Ψ anomalous suppression at RHIC
- J/Ψ rapidity distribution at RHIC
- Elliptic flow of D-mesons
- Elliptic flow of J/Ψ
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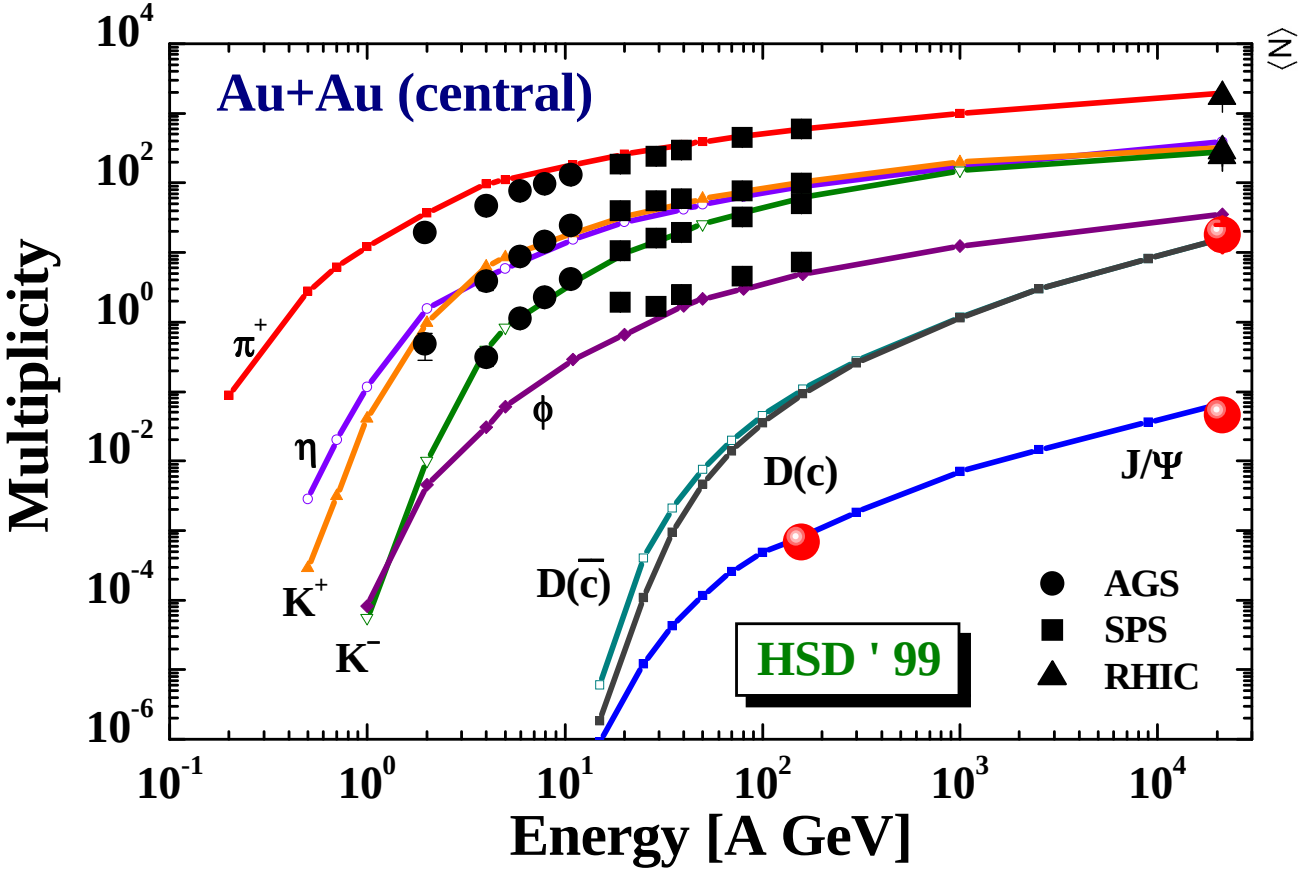
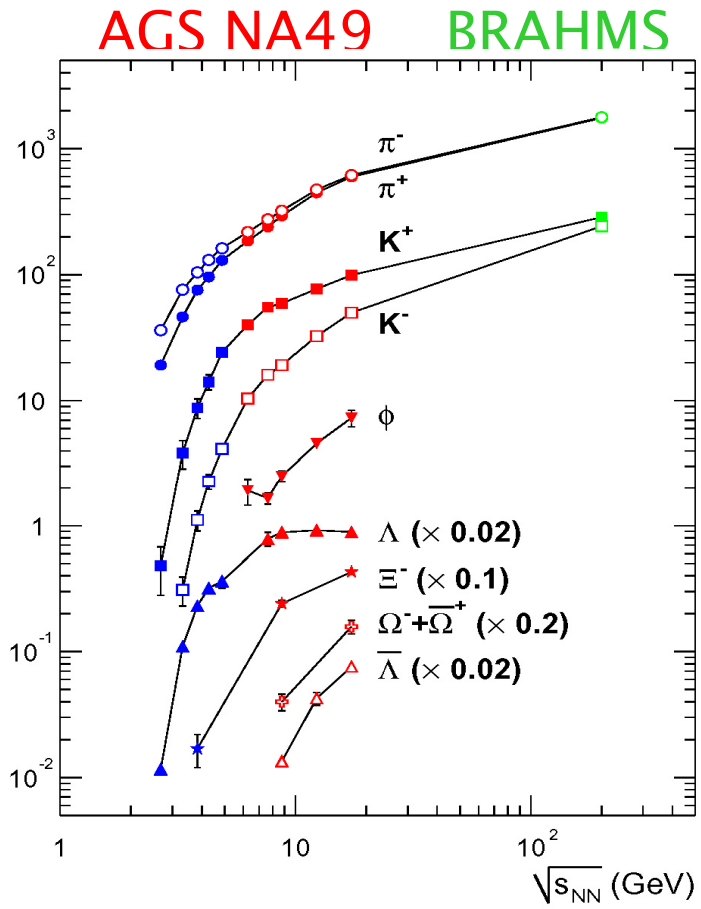
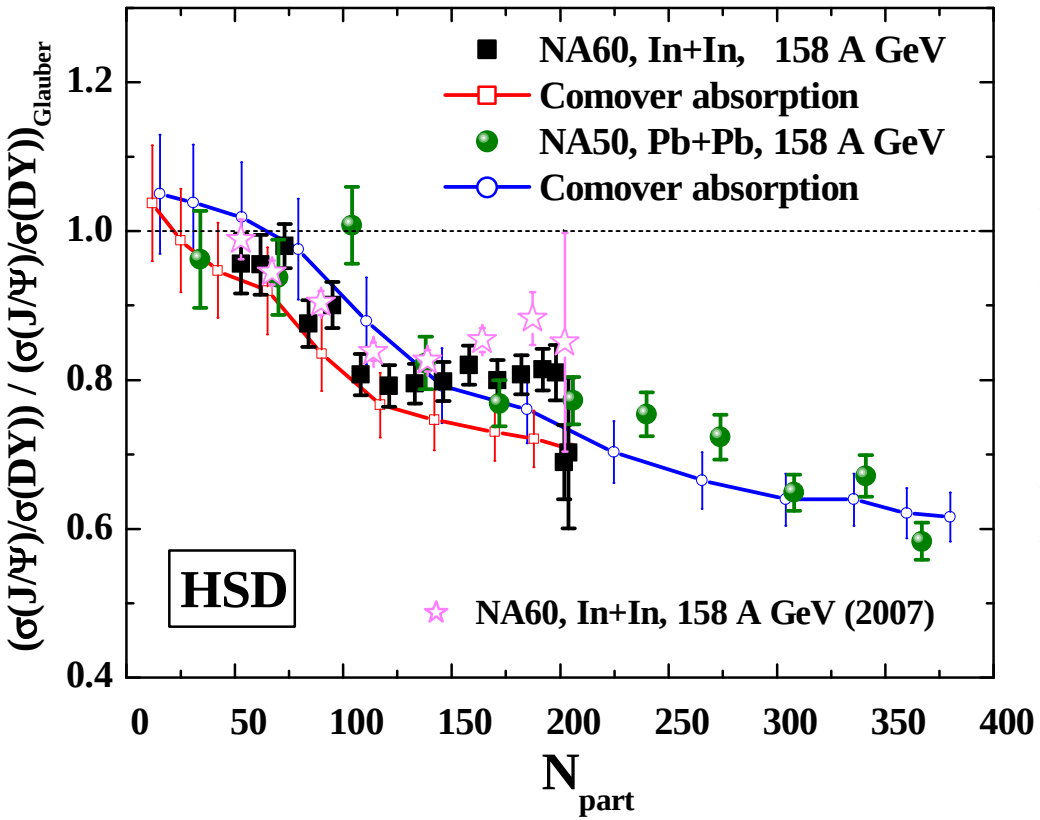
Hadron abundances

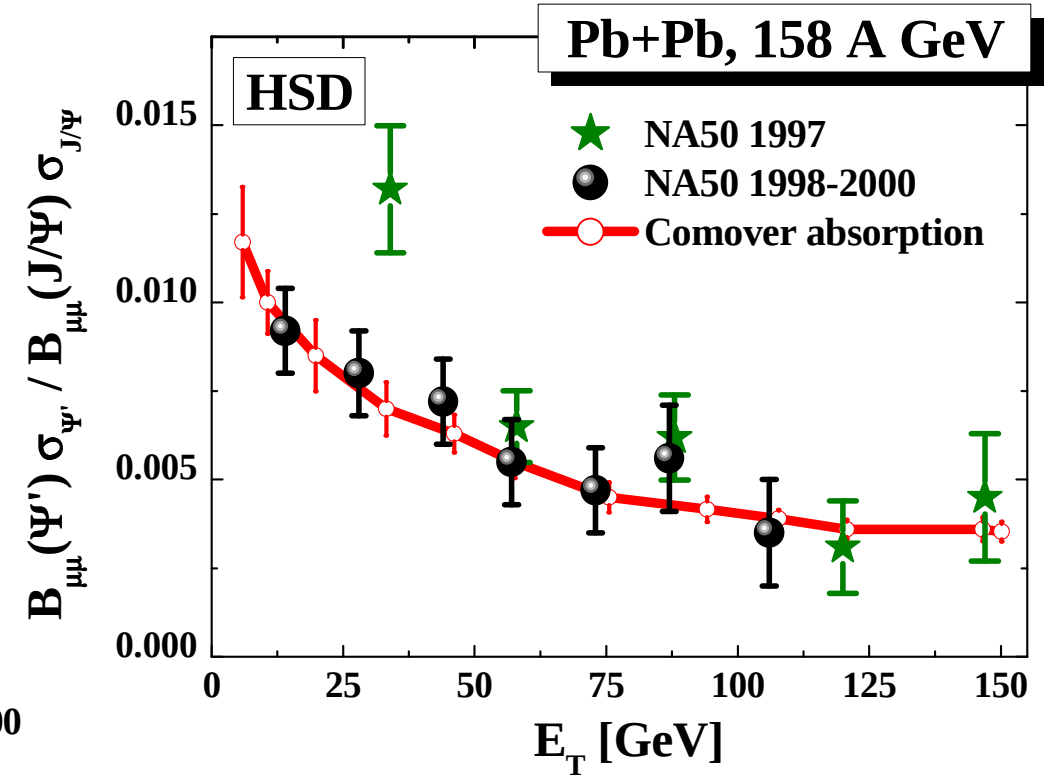
- very good description of particle production in pp, pA reactions with HSD
- unique description of nuclear dynamics from low (~100 MeV) to ultrarelativistic (~20 TeV) energies





J/Ψ anomalous suppression at SPS



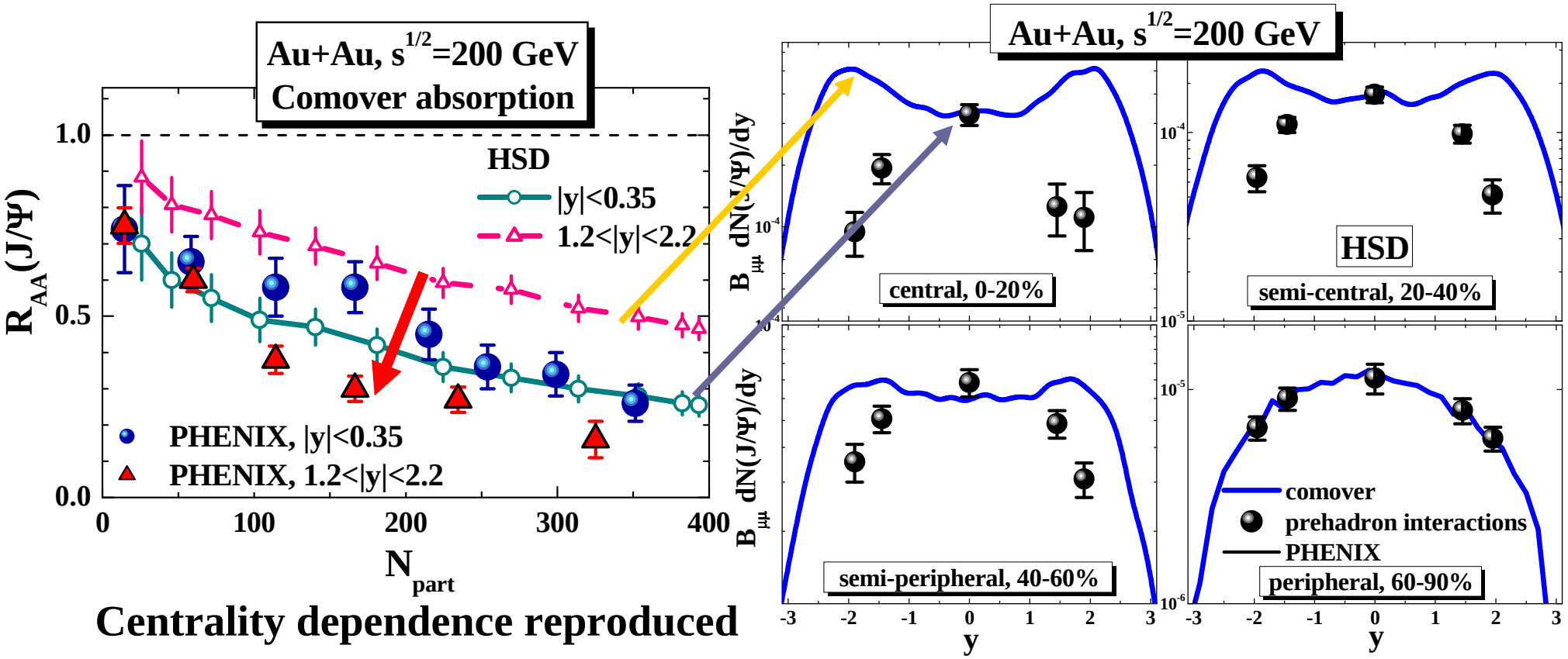


Both J/Ψ and Ψ' suppression in Pb+Pb and In+In @ 160 A GeV are consistent with the comover absorption scenario.

[OL et al., NPA 786 (2007) 183]

J/Ψ anomalous suppression at RHIC

comover scenario



Centrality dependence reproduced

But:

the suppression at mid-y is stronger than at forward y, unlike data!

[OL et al., PRC 76 (2007) 041901; NPA 807 (2008) 79]

Prehadron interaction scenario

1. **early interactions of charmonium (ccbar) and D-mesons with unformed (under formation time $t = \gamma \tau_F$, τ_F ~0.8 fm/c) baryons and mesons = prehadrons**
2. **comover absorption with recombination by D-Dbar annihilation**

- **Dissociation cross sections of charmonium by pre-hadrons:**
  $\sigma^{dis}_{cc\ pre\text{-}Baryon} = 5.8$ mb,
  $\sigma^{dis}_{cc\ pre\text{-}meson} = 2/3\ \sigma^{dis}_{cc\ pre\text{-}Baryon}$

Fitted to PHENIX data

- **Elastic cross sections with prehadrons:**
  Charmonium - prehadrons:
  $\sigma^{el}_{cc\ pre\text{-}Baryon} = 1.9$ mb,
  $\sigma^{el}_{cc\ pre\text{-}meson} = 2/3\ \sigma^{el}_{cc\ pre\text{-}Baryon}$
  D-meson - prehadrons:
  $\sigma^{el}_{D\ pre\text{-}Baryon} = 3.9$ mb,
  $\sigma^{el}_{D\ pre\text{-}meson} = 2/3\ \sigma^{el}_{cc\ pre\text{-}Baryon}$

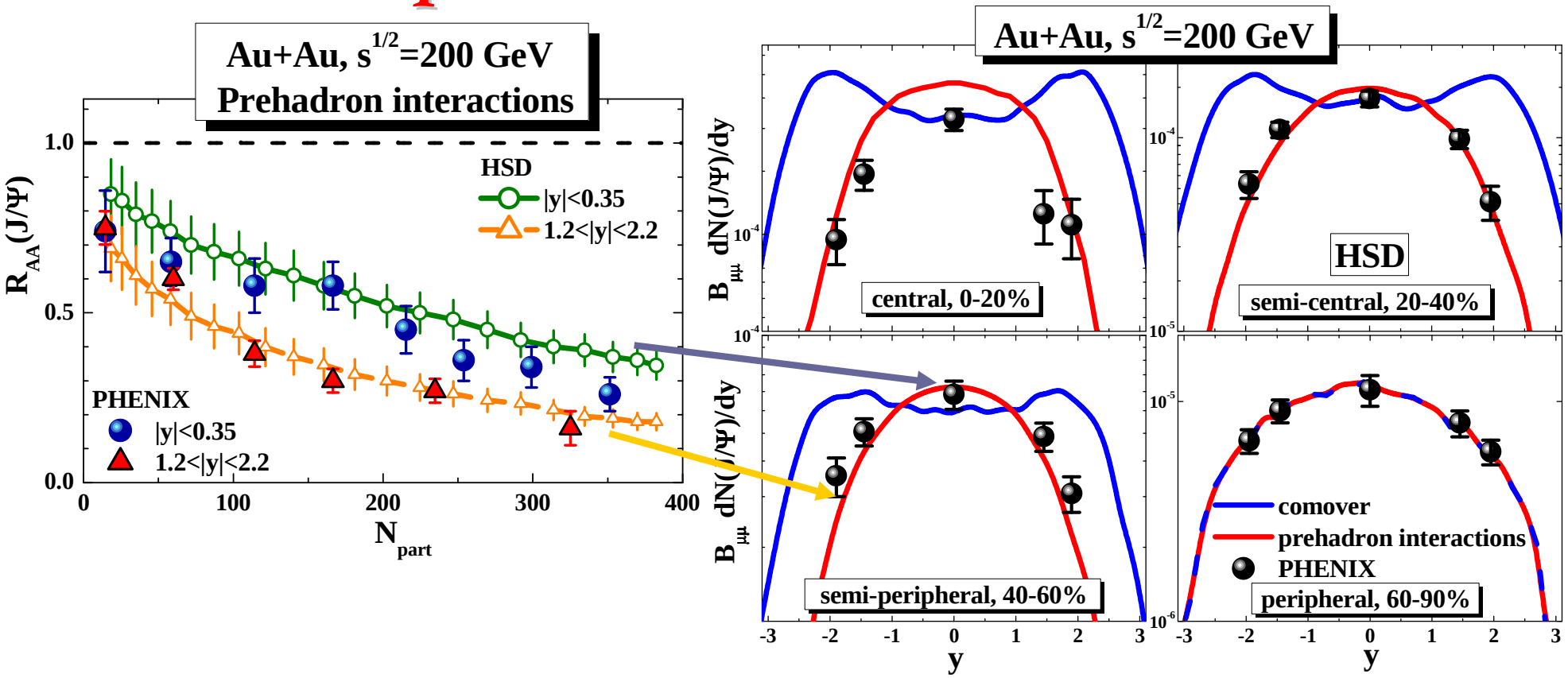
[For details see: OL et al., arXiv:0808.1504 Int J Mod Phys (2008)]

ⓘ **Pre-hadronic interaction scenario only ‚simulates' the interactions in the QGP without(!) explicit partonic interactions and phase transition**

=> NOT (yet!) a consistent description ! **=> PHSD**

J/Ψ anomalous suppression at RHIC

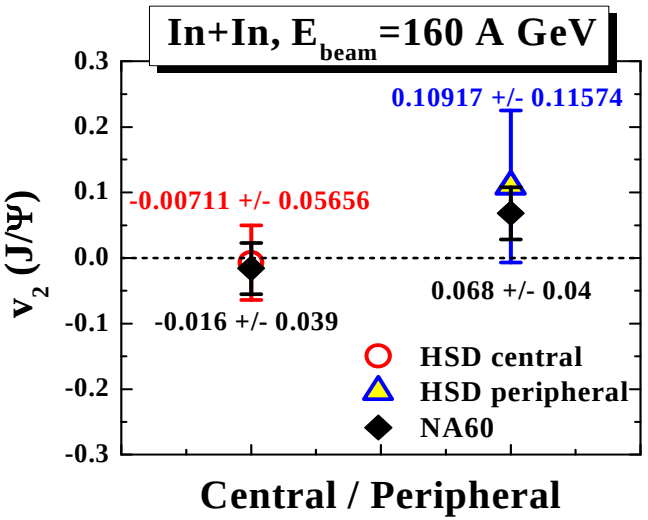
prehadronic interactions



In the prehadronic interaction scenario, the J/Ψ rapidity distribution has the right shape, reproduces the PHENIX data! => describes R_{AA} at mid- and forward-rapidity simultaneously.

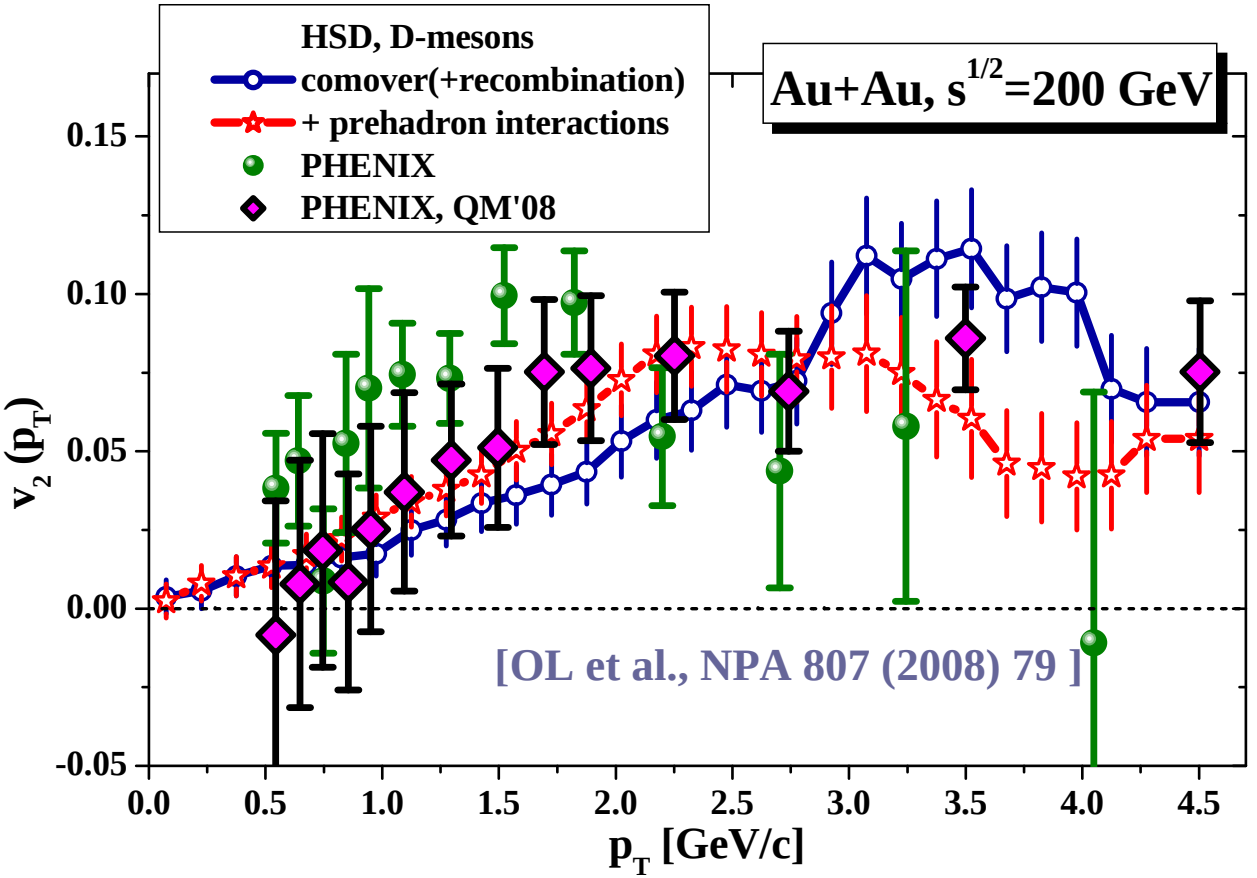
[OL et al., NPA 807 (2008) 79]

Elliptic flow of D-mesons



at SPS: v_2 is hadronic;

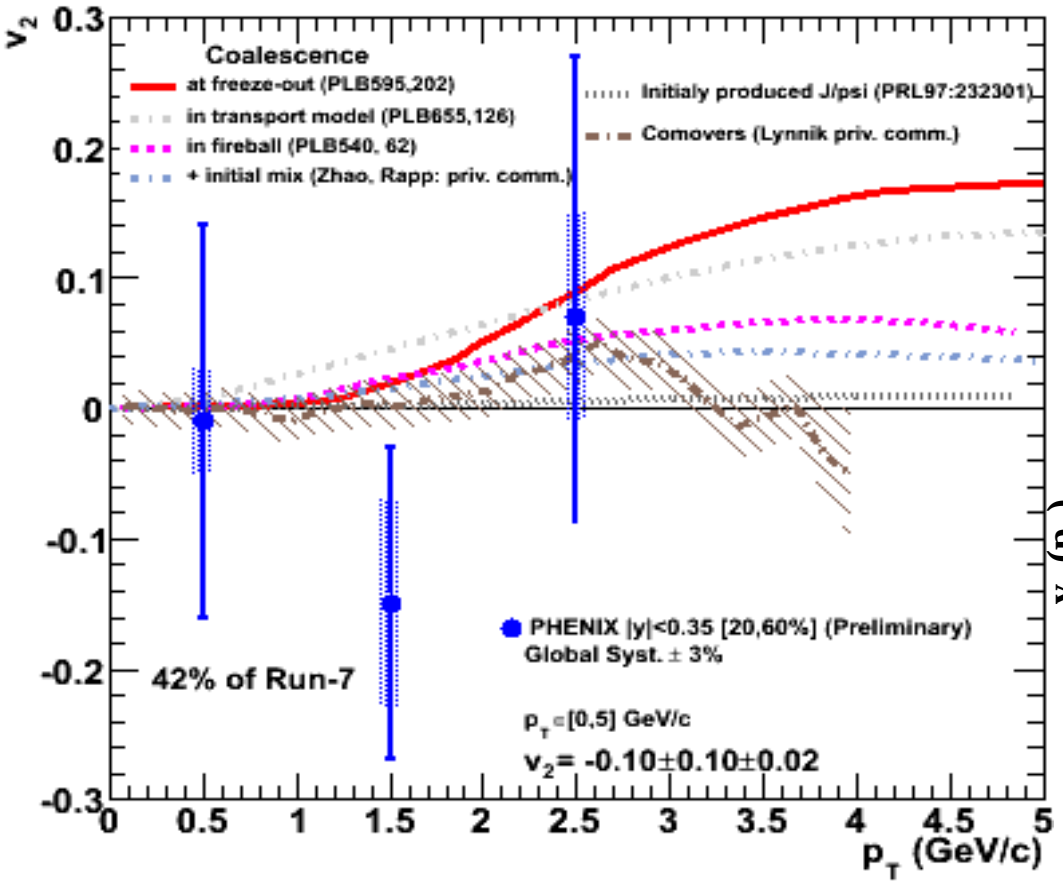
at RHIC:



- Default hadron comover scenario underestimates the data;
- Pre-hadron interactions lead to an increase of the elliptic flow v_2 of D mesons;
- The pre-hadronic scenario is ~consistent with the preliminary PHENIX data

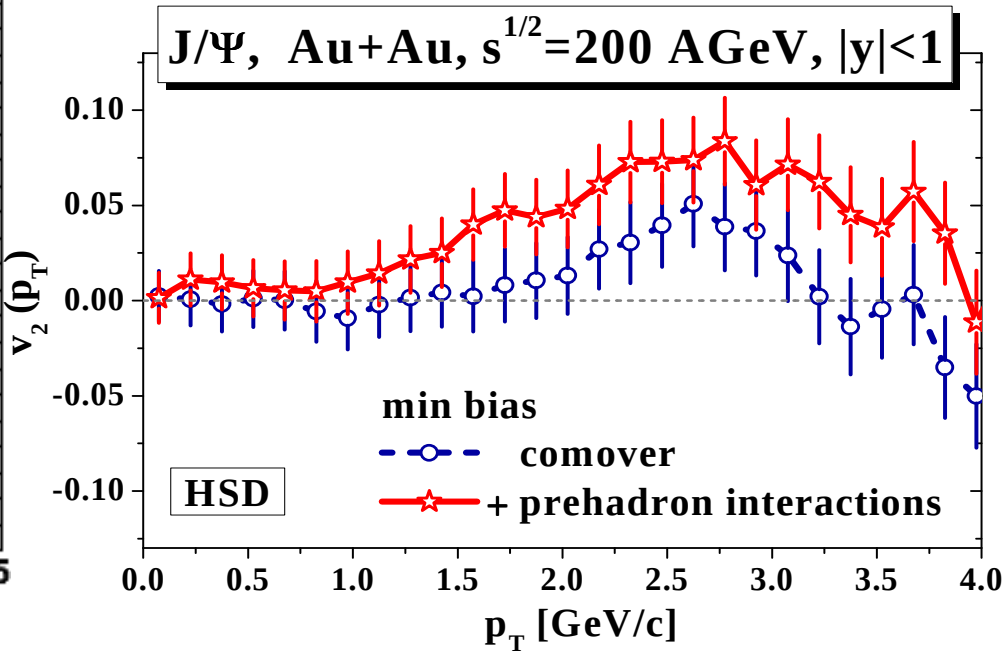
=> strong initial flow of non-hadronic nature!

Elliptic flow of J/Ψ



[R.Granier de Cassagnac J Phys G 35 (2008) 104023, C.Silvestre J Phys G 35 (2008) 104136]

More data needed!

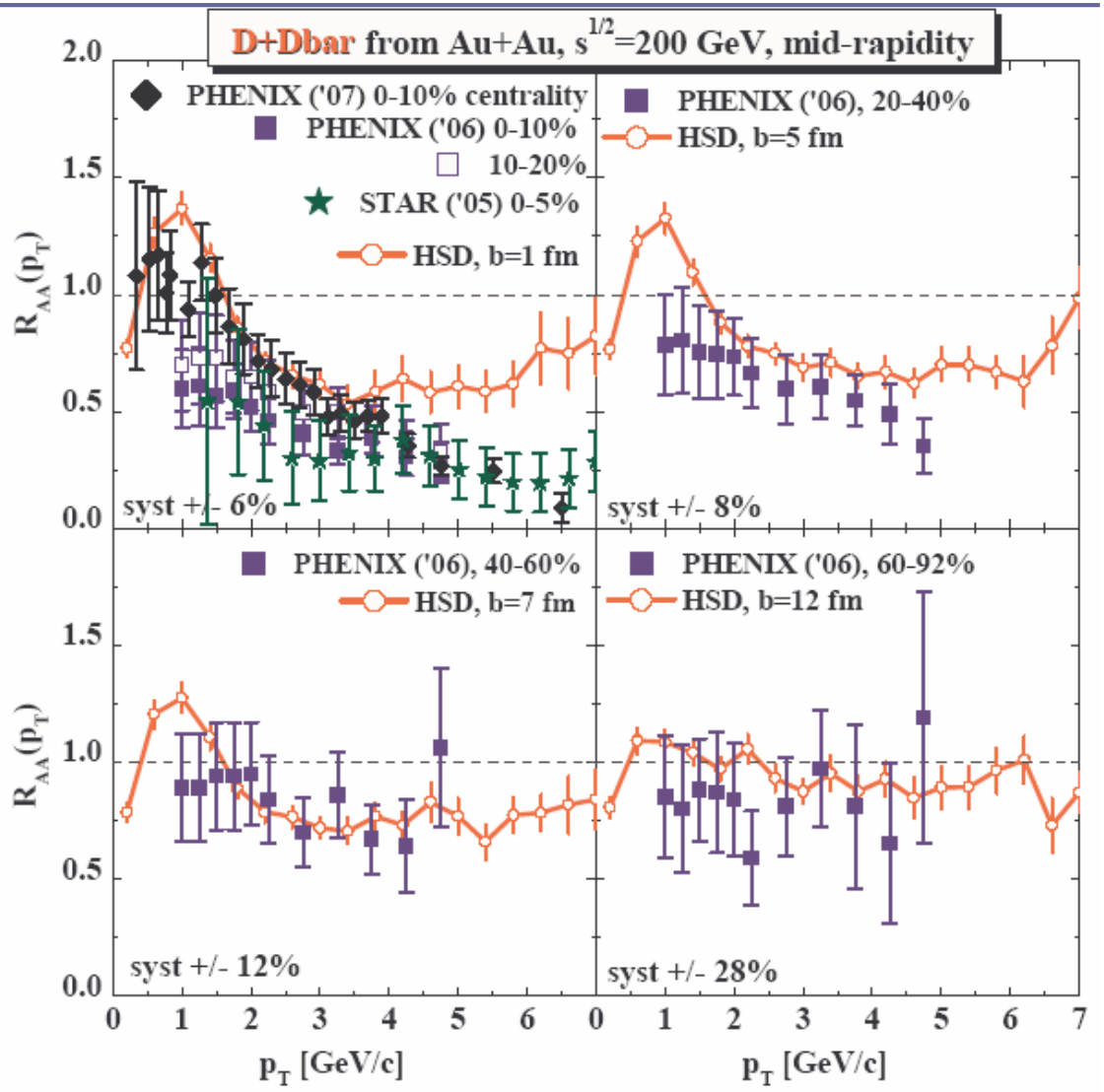


[OL et al., arXiv:0808.1504 Int J Mod Phys (2008)]

Quenching of D mesons at RHIC

Evidence of additional high p_T suppression in the most central collisions.

Suppression of D mesons in peripheral collisions is consistent with a purely hadronic scenario.



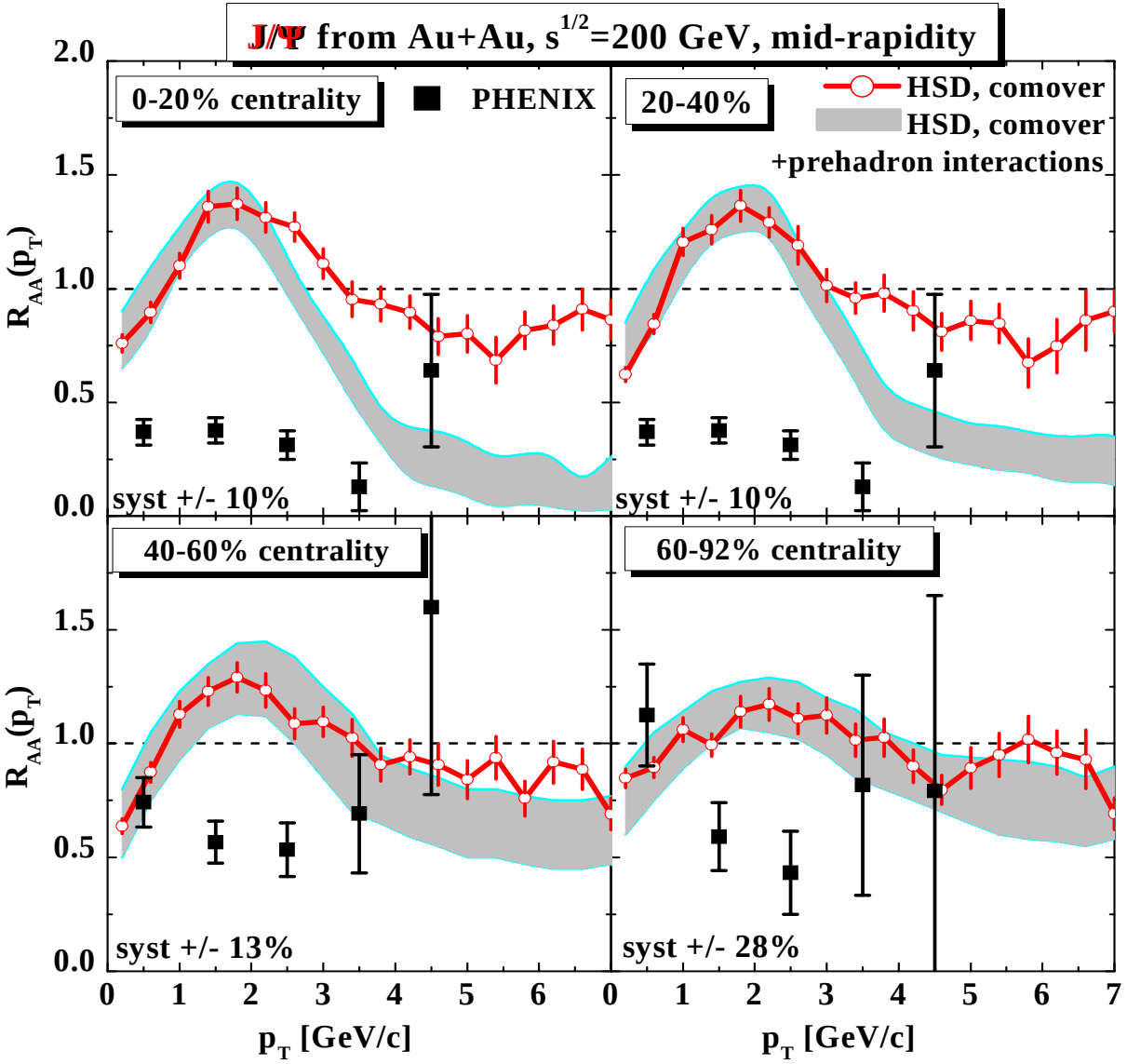
[OL et al., arXiv:0808.1504 Int J Mod Phys (2008)]

Quenching of J/Ψ at RHIC

Strong suppression at low p_T observed experimentally cannot be explained:

- **by hadronic absorption of initially produced J/Ψs**
- **or by D+D recombination, since J/Ψs would follow R_{AA} pattern similar to D mesons.**

Possible indication of J/Ψ formation by parton coalescence!



[OL et al., arXiv:0808.1504 Int J Mod Phys. E (2008)]

Conclusions

- **In search for partonic phase signatures, an understanding of hadron (string) matter effects is necessary, and HSD is the tool to model it**
- **Charm absorption at SPS is consistent with the hadronic comover picture**
- **But hadron comover absorption fails to describe the rapidity distribution of J/Ψ mesons from Au+Au at $s^{1/2}$=200 GeV**
- **In the prehadronic interaction scenario, the data at $s^{1/2}$=200 GeV for Au+Au at mid and forward rapidities are simultaneously reproduced**
- **However, RHIC data on high p_T suppression and v_2 of D mesons are not reproduced in the (pre-)hadron-string picture**

=> evidence for a plasma pressure ?!

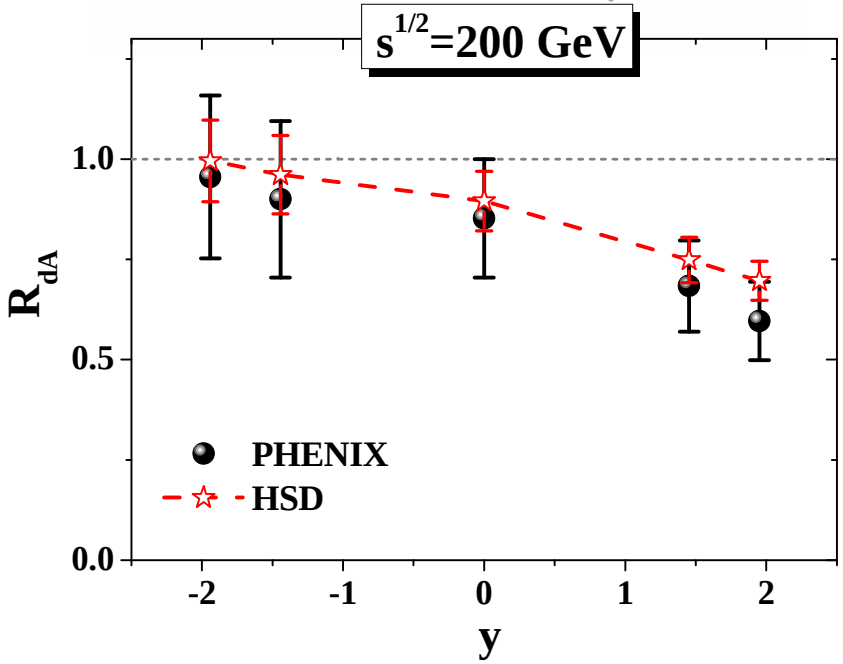
E. Bratkovskaya, W. Cassing, H. Stöcker

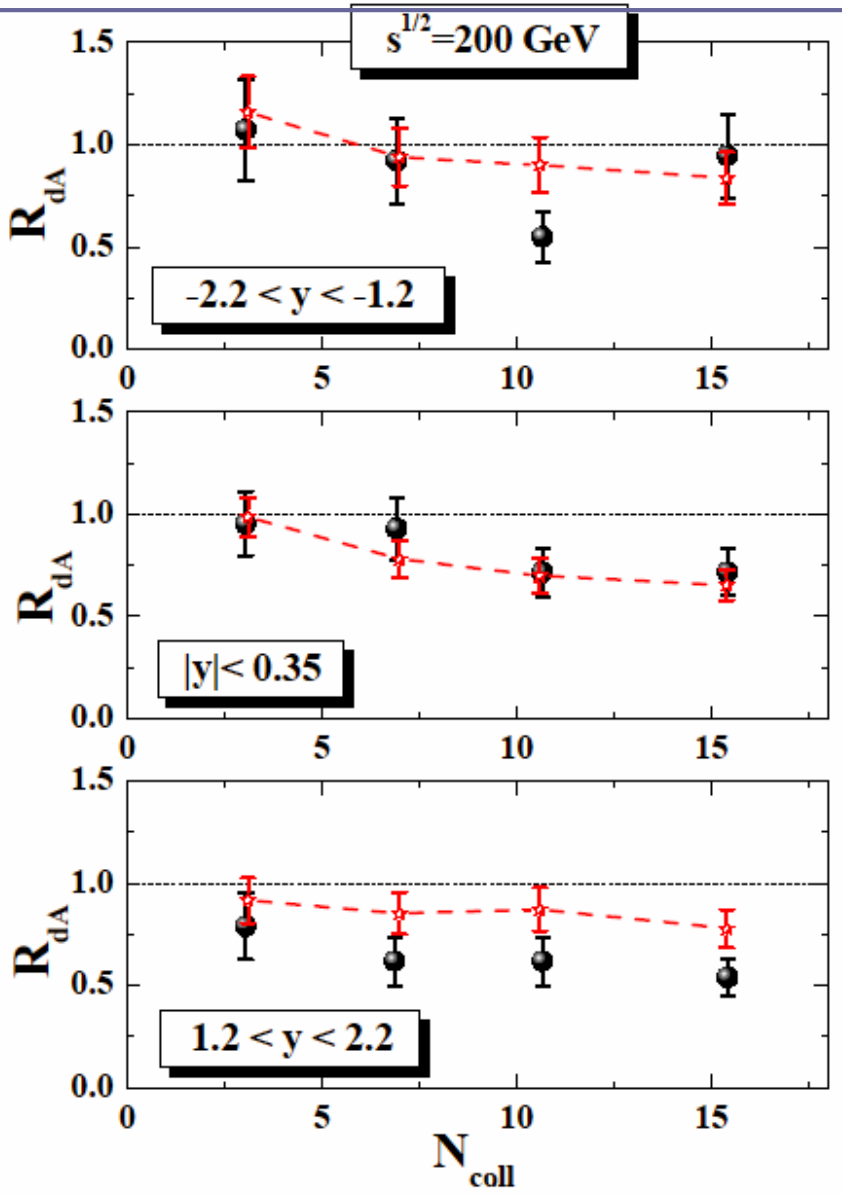
Thank you!

Review for Int. J. Modern Phys. E (September, 2008)
arXiv:0808.1504

Supression in pA at RHIC

$$R_{dA} \equiv \frac{dN^{dAu}_{J/\Psi}/dy}{\langle N_{coll}\rangle \cdot dN^{pp}_{J/\Psi}/dy},$$



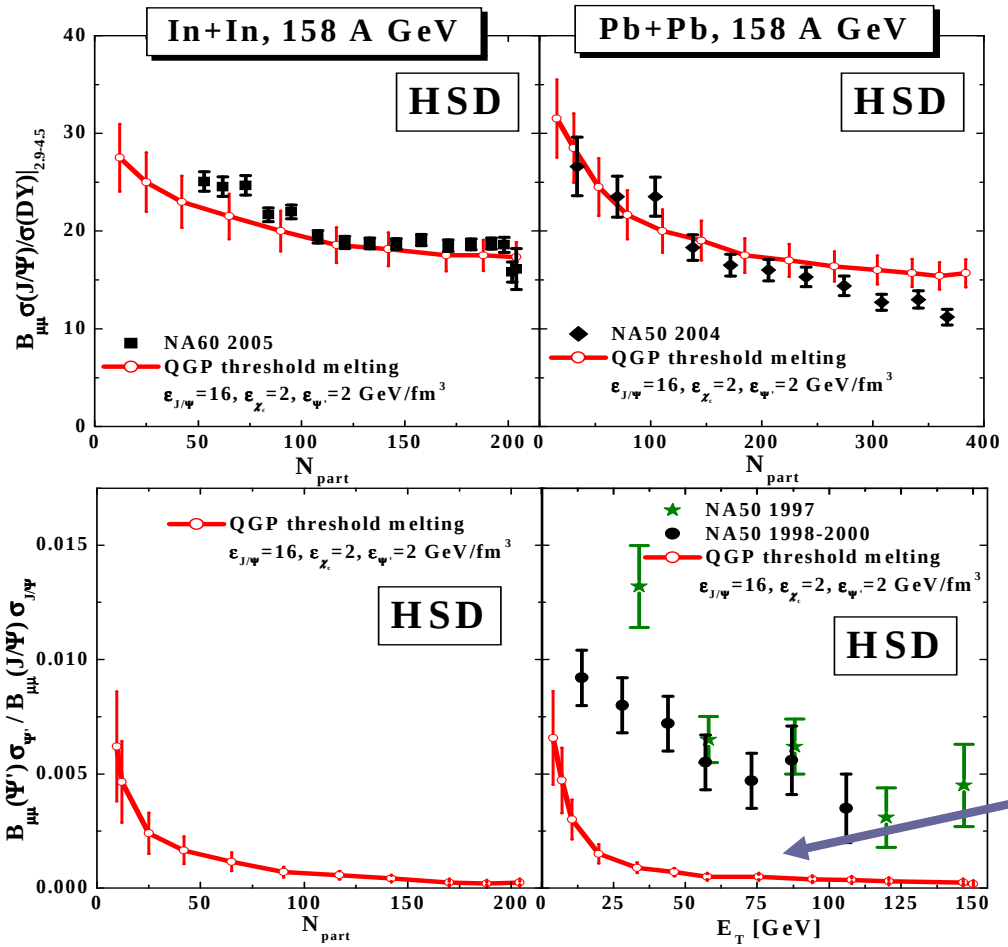


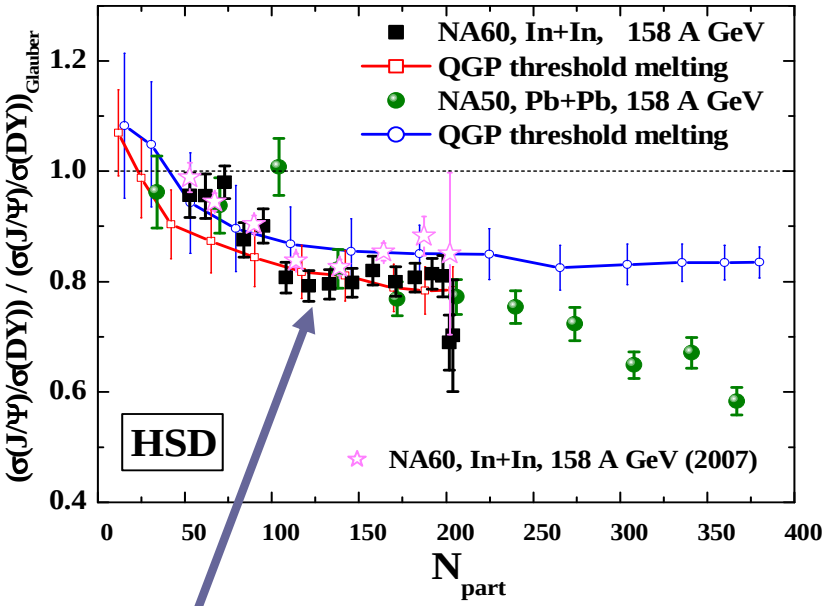
- Charmonium is absorbed on baryons
- Effect of shadowing at forward y

[OL et al., NPA (2008) 807, 79]

J/Ψ and Ψ′ from threshold melting scenario at SPS

Dissociation energy densities: ε(J/Ψ)=16 GeV/fm^3, ε(χ_c) =2 GeV/fm^3, ε(Ψ') =2 GeV/fm^3

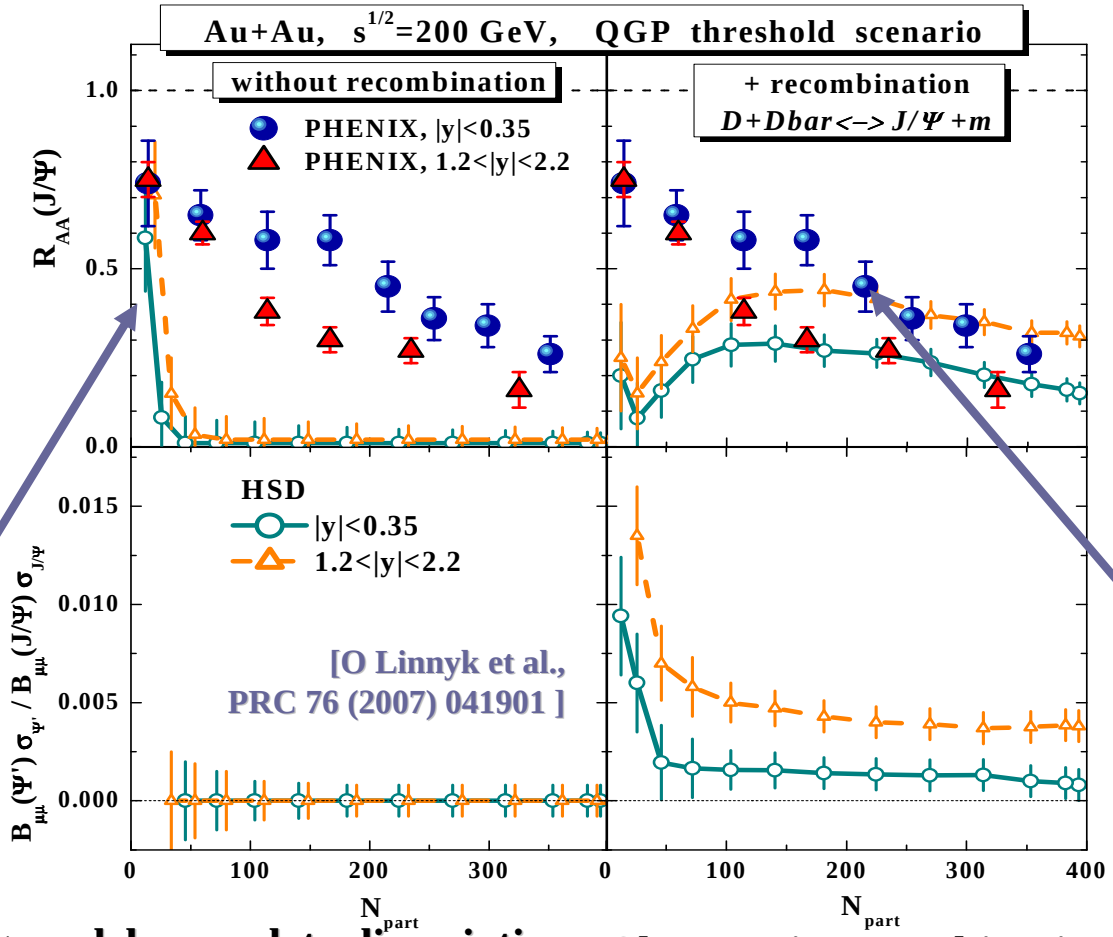




- **J/Ψ suppression is qualitatively described, but QGP threshold melting scenario shows a too strong Ψ' absorption, which contradicts the NA50 data!**

[OL et al., NPA 786 (2007) 183]

J/Ψ and Ψ′ from threshold melting scenario at RHIC



Threshold melting model: complete dissociation of initial J/Ψ and Ψ′ due to the huge local energy densities !

Charmonia recombination by D-Dbar annihilation is important, however, it can not generate enough charmonia, especially for peripheral collisions!

QGP threshold melting scenario is ruled out by PHENIX data!

Summary Threshold scenario vs Comover absorption

I. QGP ‚threshold melting'

versus experimental data

	SPS	RHIC
J/Ψ survival :	±	–
Ψ'/ J/Ψ ratio :	–	?

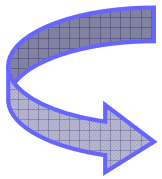
II. Comover absorption

(+ recombination by D-Dbar annihilation)

versus experimental data

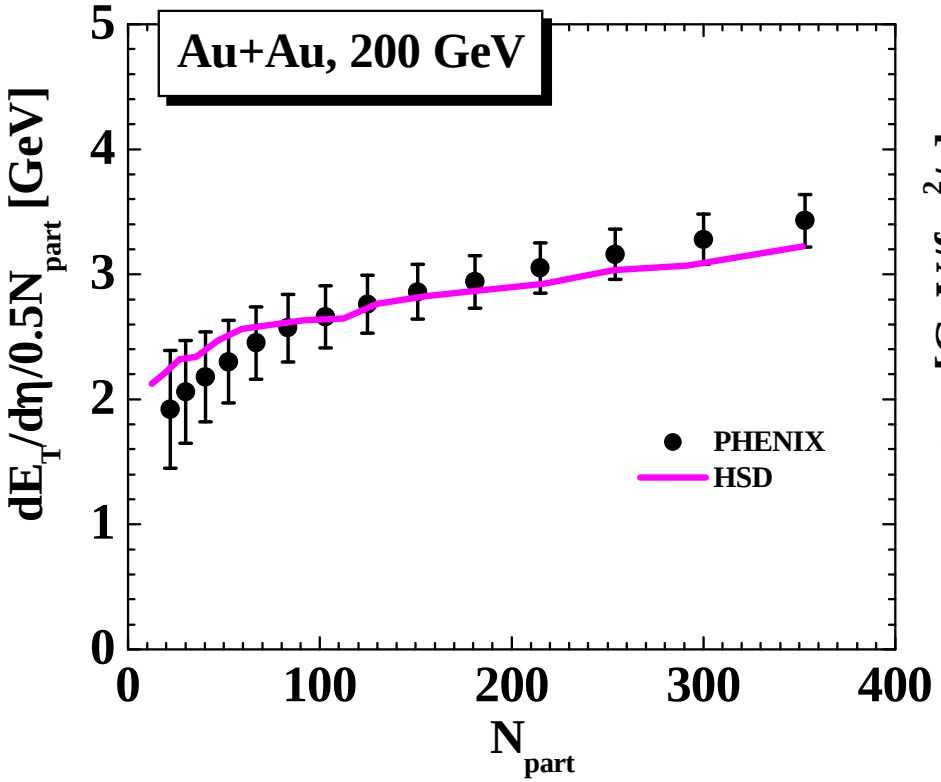
	SPS	RHIC
J/Ψ survival :	+	–
Ψ'/ J/Ψ ratio :	+	?

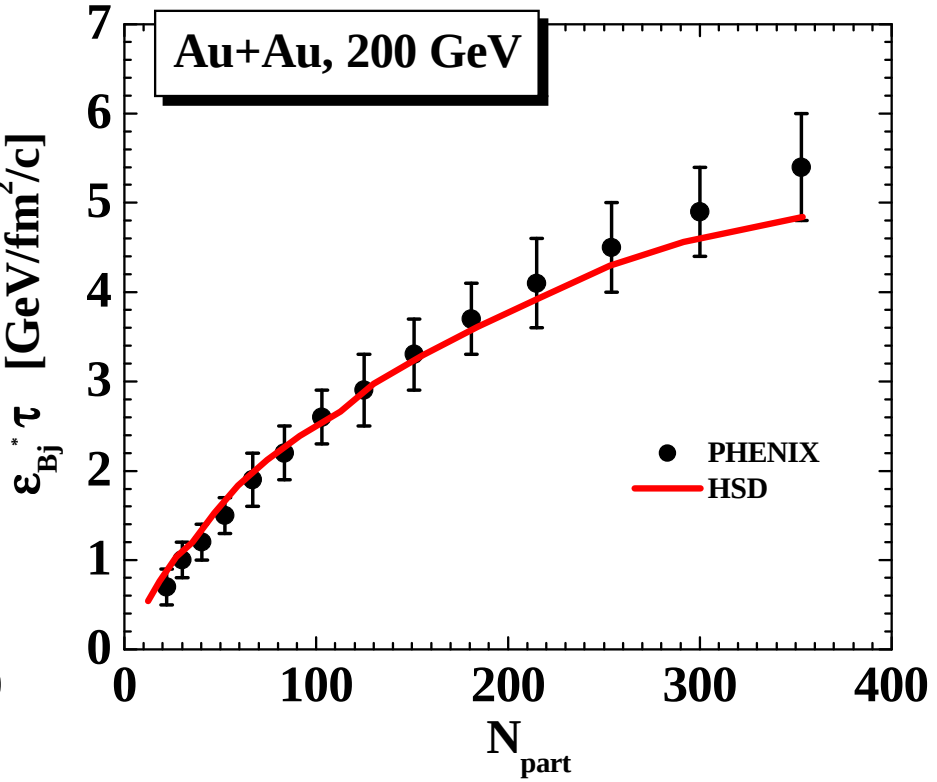
Comover absorption and threshold melting scenarios are ruled out by experimental data



evidence for non-hadronic interaction ?!

Bjorken energy density





$$\varepsilon_{Bj} = \frac{1}{A_\perp \tau}\frac{dE_T}{dy}$$

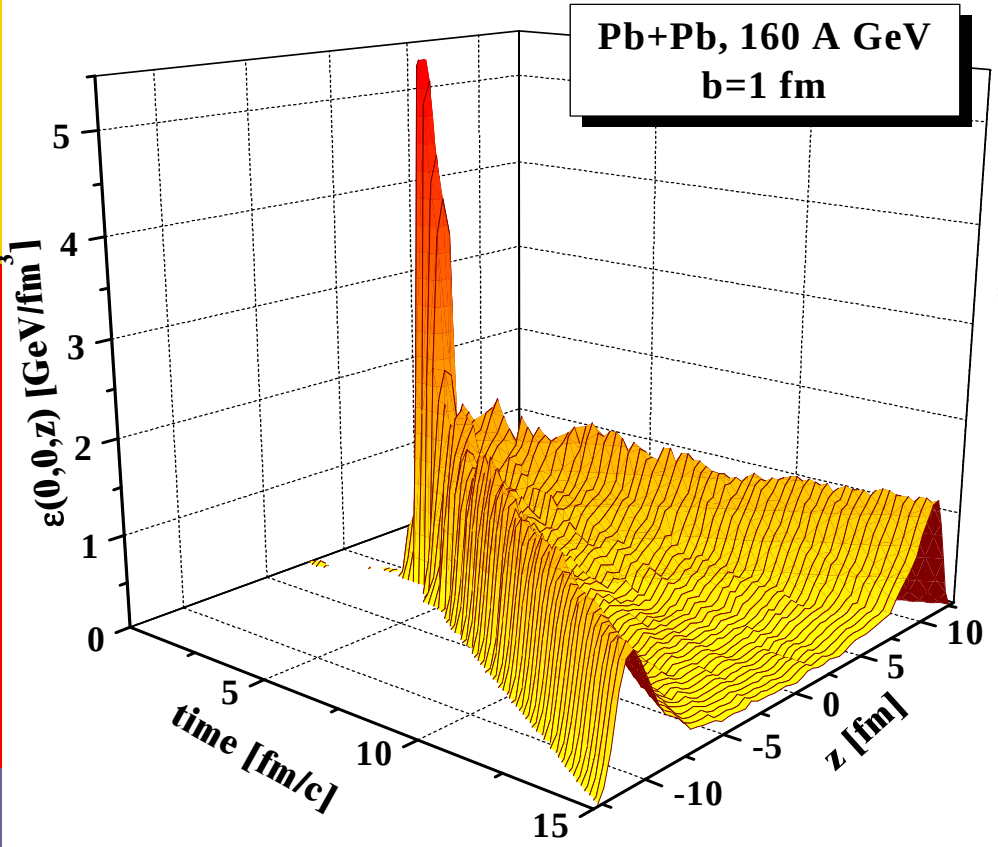
‚Local' energy density ε during transient time t_r~0.13 fm/c:

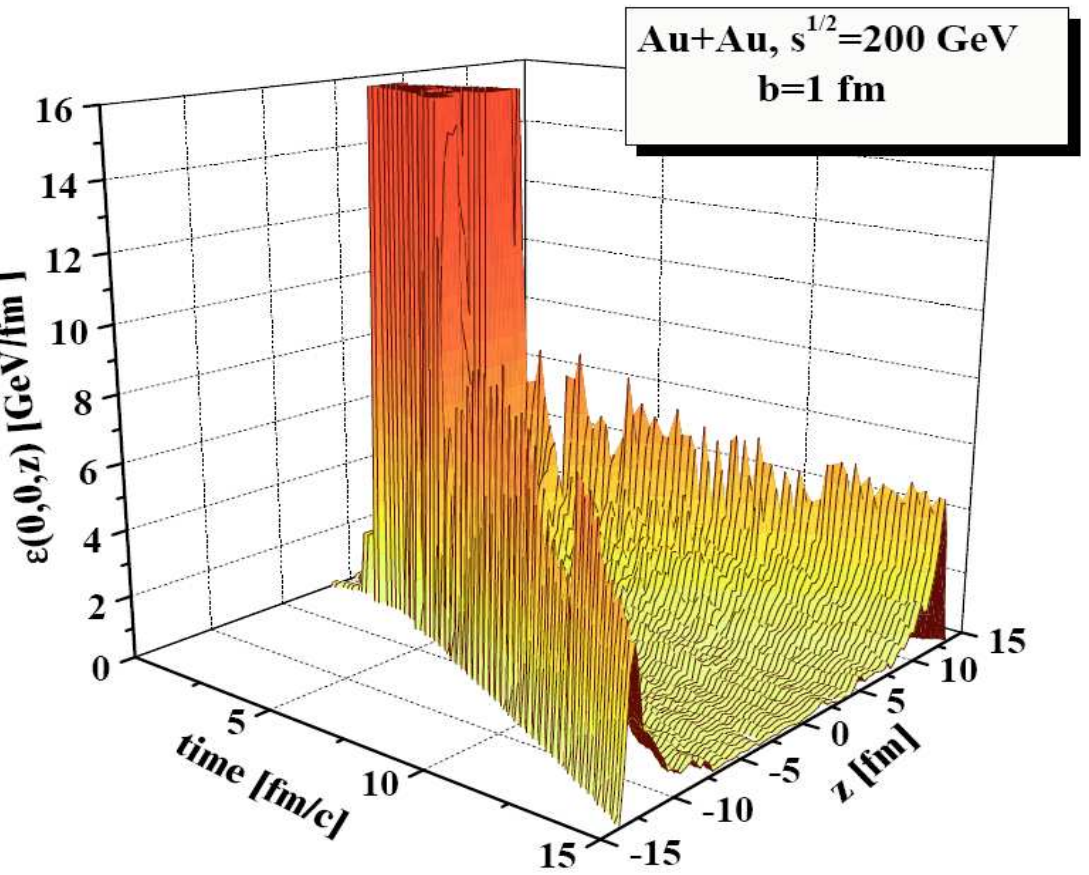
ε ~ 5[GeV/fm^2/c] / [0.13 fm/c]

~ 30 GeV/fm^3

[OL et al., NPA (2008) 807, 79]

Local energy density from HSD



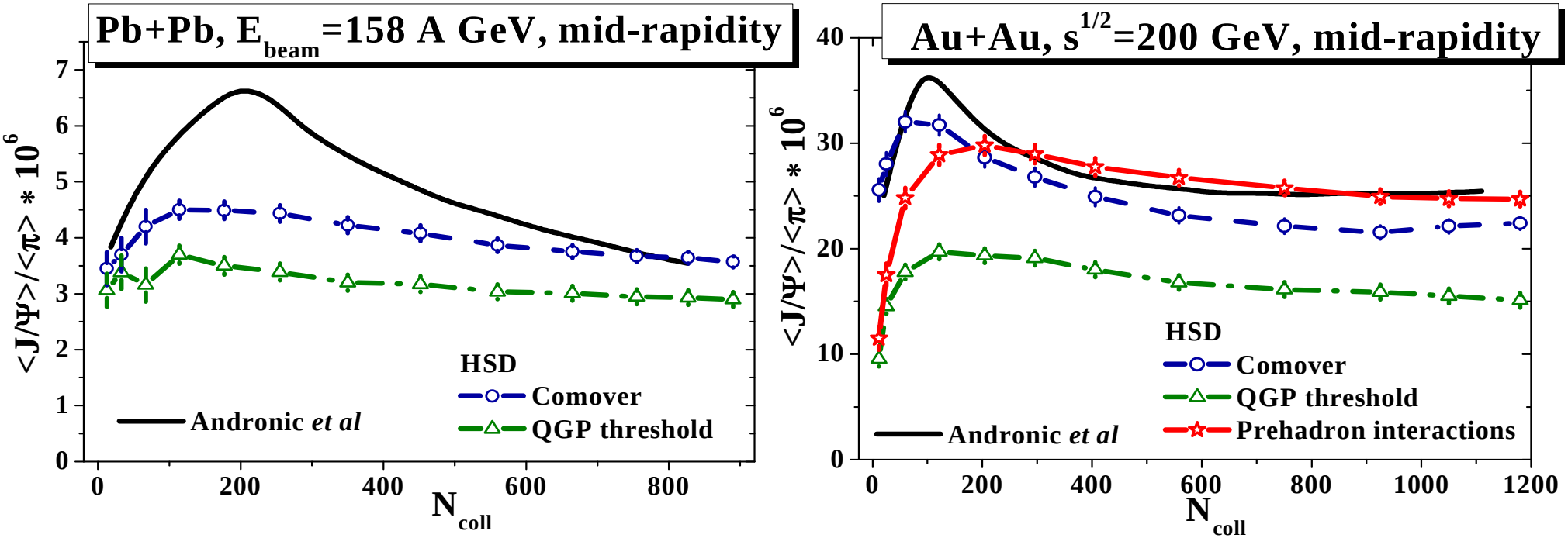


At RHIC, energy-densities above the critical value (~2 GeV/fm^3) exist in an extended space-time area

[OL et al., NPA 786 (2007) 183]

[OL et al., NPA (2008) 807, 79]

Comparison to statistical hadronization



[OL et al., NPA (2008) 807, 79]