Elastic Scattering:
The undersides of quarkonia propagation and collectivity in the QGP

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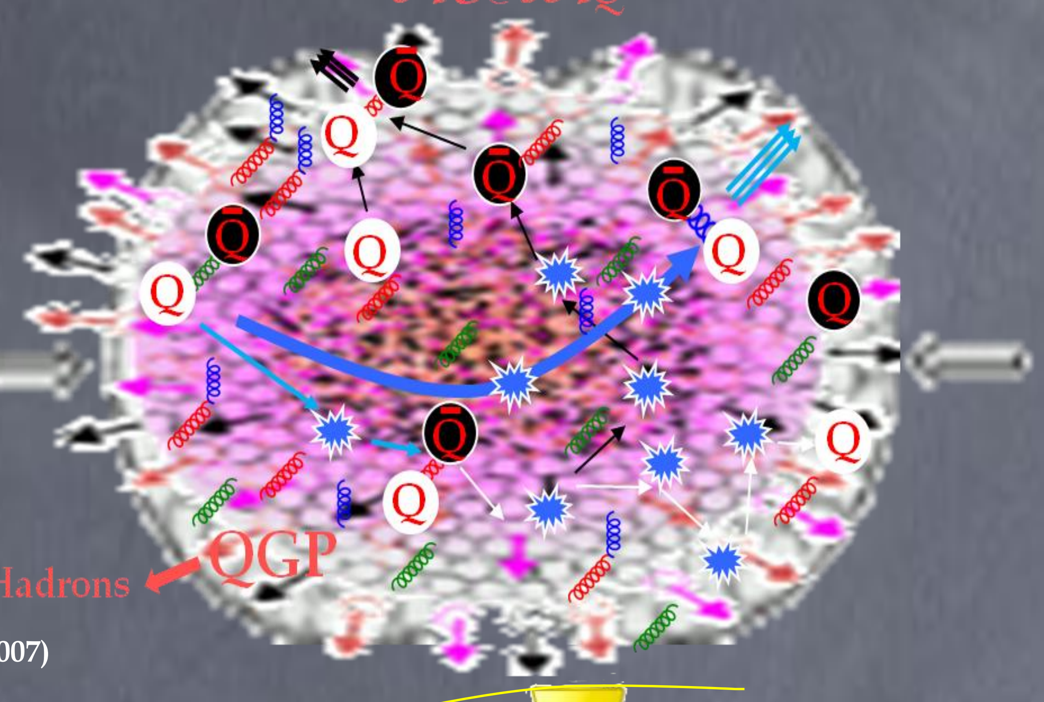
0. Toward a Complete Description of J/ψ in QGP & Hadronic Medium

Medium Description

- Hydrodynamical description of QGP
  (U. Heinz & P. Kolb)
- Glauber model for the initial state
  (Nucl.Phys., B21:135157, 1970)

Cold Nuclear Matter Effects

- 1st J/ψ suppression:
  Nuclear absorption, Cronin effect, ...
  R.G. De Cassagnac parameterization (J.Phys.G, G34:S955958,2007)



$Q\bar{Q}$ Stochastic Evolution

- Quarkonia as Brownian particles (*Friction & Stochastic Forces*)
- In MC@sHQ: ... Sampling the distributions of Langevin forces

Hot QGP Matter Effects

- Instantaneous melting/thermal excitation ($T > T_{diss}$)
- Q-$\bar{Q}$ → Quarkonia fusion-recombination ($T < T_{diss}$)
- Hard gluon dissociation à la **Bhanot-Peskin** ($T < T_{diss}$)

Dual Model

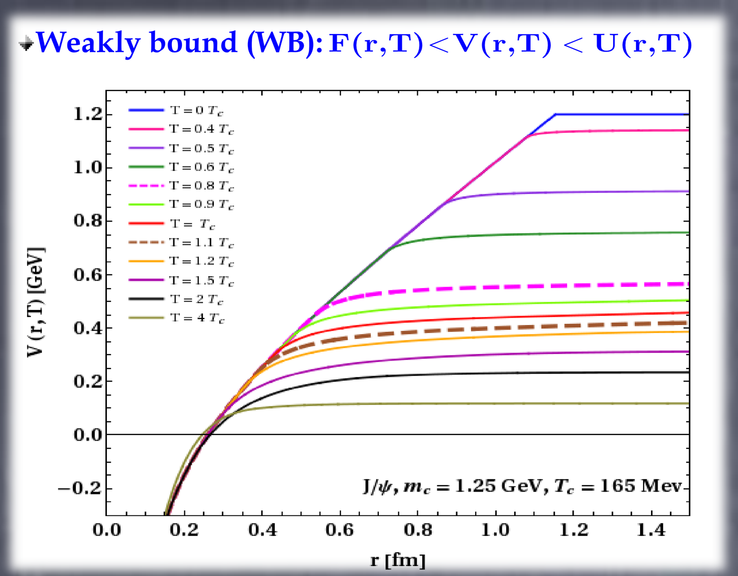
- Elastic scattering & stochastic propagation
- ...

I. $Q\bar{Q}$ in a Static Medium at finite Temperature

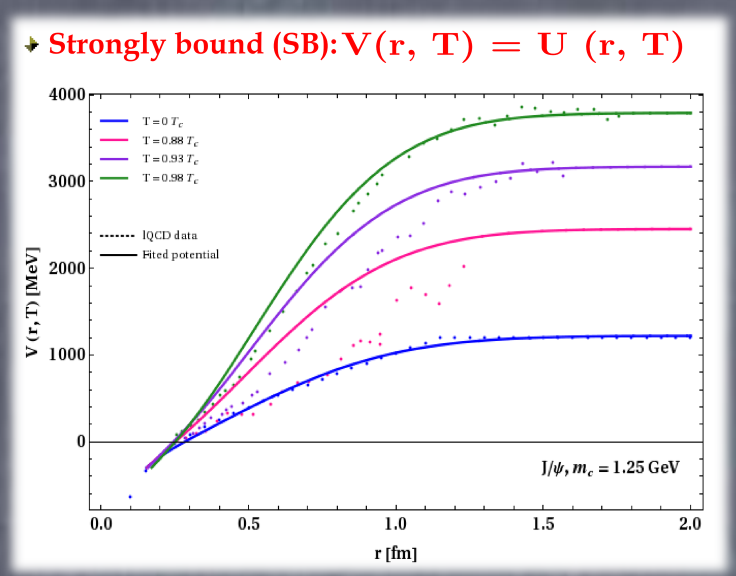
- Our parameterization of $Q\bar{Q}$ Potential (finite T): $\mathbf{U(r,T) = F(r,T) - T\left(\frac{\partial F(r,T)}{\partial T}\right)}$

A. Mocsy and P. Petreczky (arXiv:0705.2559v2[hep-ph], 2007- arXiv:0706.2183v2[hep-ph],2007)

Weakly bound (WB): $F(r,T) < V(r,T) < U(r,T)$

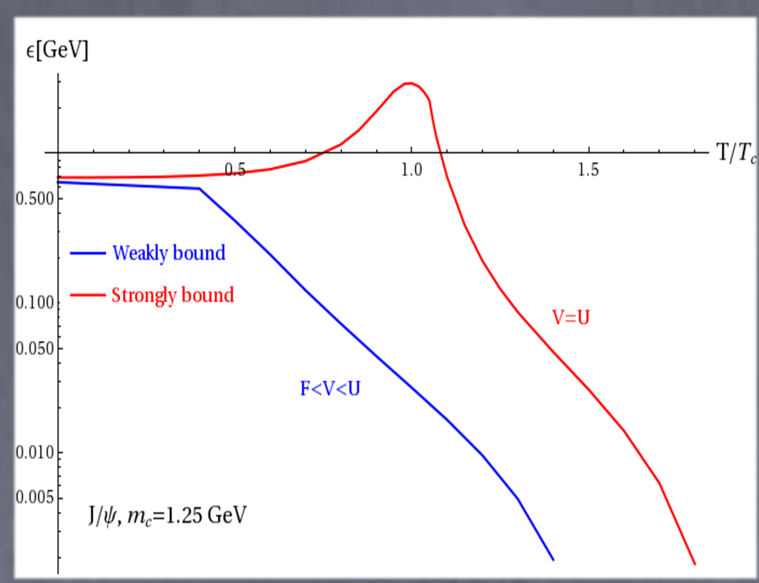


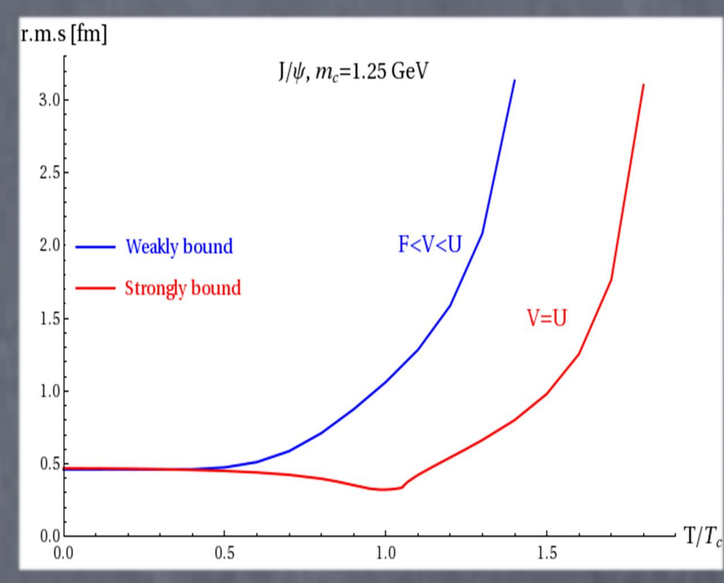
Strongly bound (SB): $V(r,T) = U(r,T)$



- V (r, T) for J/ψ and ϒ for different T (T > Tc)
- SB more binding in the medium than in the vacuum
- The survival of J/ψ and ϒ is related to the medium conditions

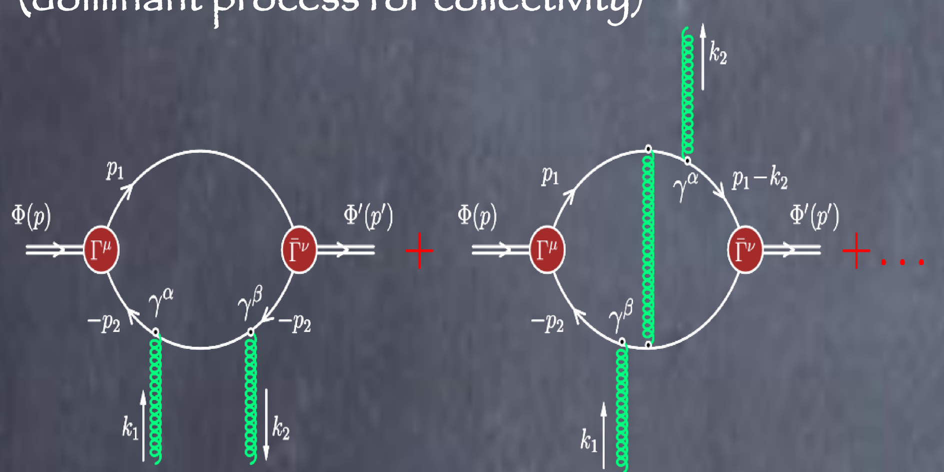
- J/ψ binding energy (ε) & mean square radius (r.m.s)





II. $Q\bar{Q}$-Partons/Hadrons Elastic Scattering Processes

- Elastic process: Compton diffusion
  (dominant process for collectivity)

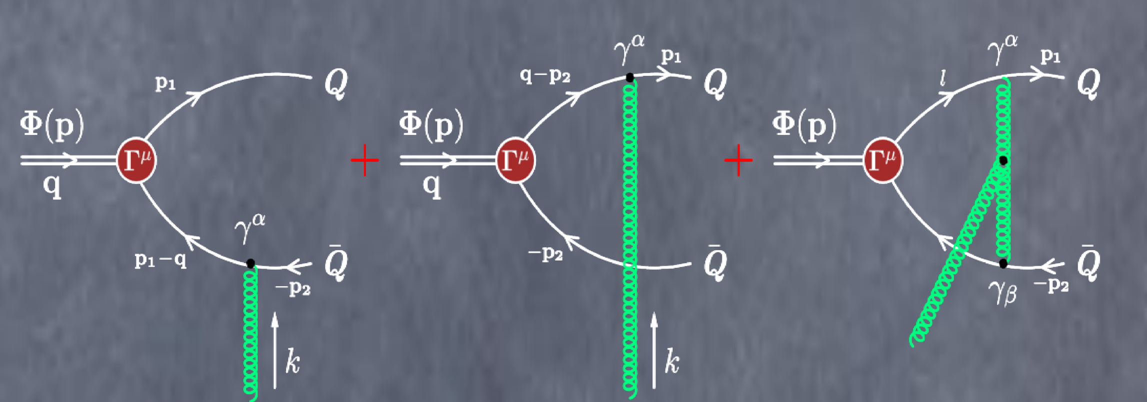


- σ_{elas} calculation: How ?

a) Low energy: Bhanot-Peskin formalism (OPE)
(Nucl. Phys., B156:391, 1979)

b) High & intermediate energy: Bethe-Salpeter (BS) formalism, (Phys,Rev 87,2, 1952)

- Inelastic process: Gluo-dissociation
  (dominant process for suppression)

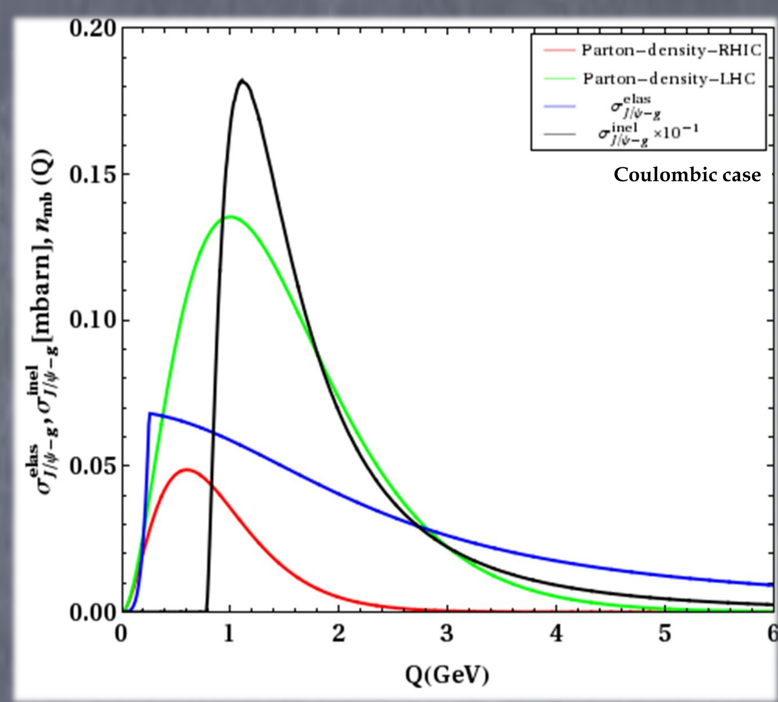


- σ_{inel} calculation: How ?

a) Effective models (quark & meson exchange models)

b) pQCD calculations (OPE, QCD sum rules, BS formalism)
(Nucl. Phys., B156:391, 1979 , Y. Oh, S. Kim, S. Houng Lee, (2002))

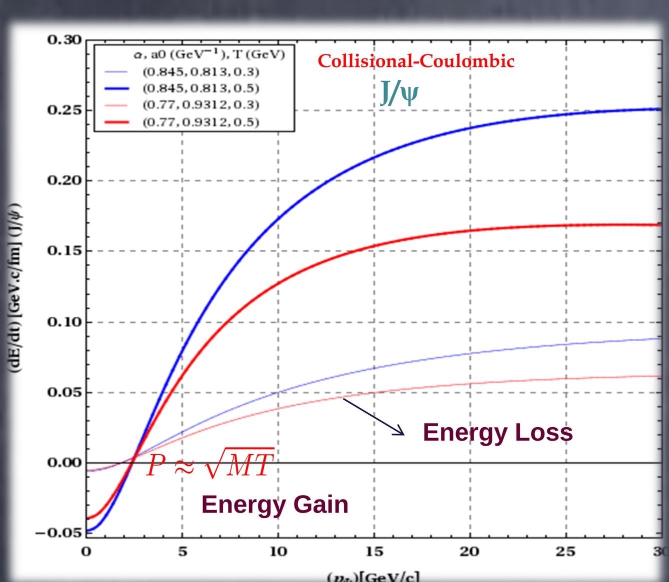
- J/ψ-g, gluo-dissociation *vs* Compton diffusion (σ_{elas} interest)



- Inelastic cross section has a threshold
- $\sigma_{elas} < \sigma_{inel}$ but the overlapping between these cross sections with the parton density distribution moderate this comparison and compensate the small value of σ_{elas}

III. Fokker-Planck Coefficients Calculations

- Collisional Energy Losses (given by Bjorken)



$$\frac{dE}{d\tau} = \sum_i \int d^3q\, n_i(\vec{q})\, \frac{\sqrt{(p.q)^2 - M^2m^2}}{Ee} \int dt\, \frac{d\sigma_{elas}}{dt}\, (E' - E)$$

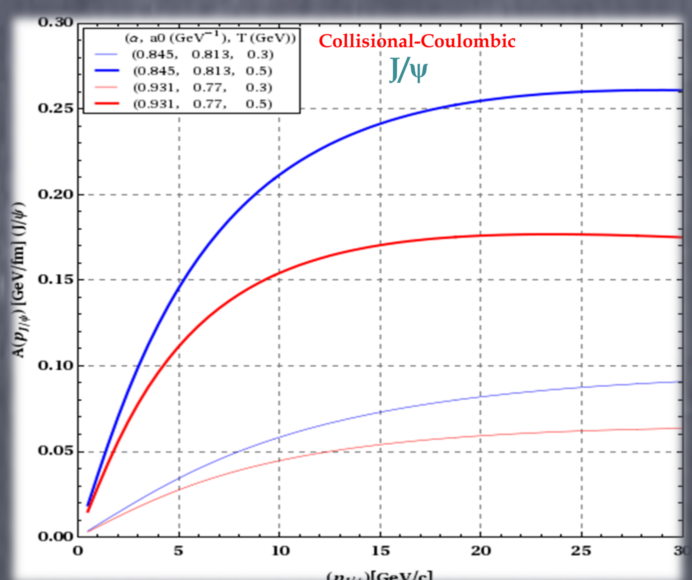
$$A_i = \frac{M}{E} \sum_i \int d^3q\, n_i(\vec{q})\, \frac{\sqrt{(p.q)^2 - M^2m^2}}{Ee} \int dt\, \frac{d\sigma_{elas}}{dt}\, \frac{\left\langle (\vec{P}-\vec{P}').\, \vec{P}\right\rangle}{\|\vec{P}\|}$$

- **For (*HQ, J/ψ, ϒ*):** $\frac{dE}{dt},\ A_i \nearrow$ with $T \nearrow$

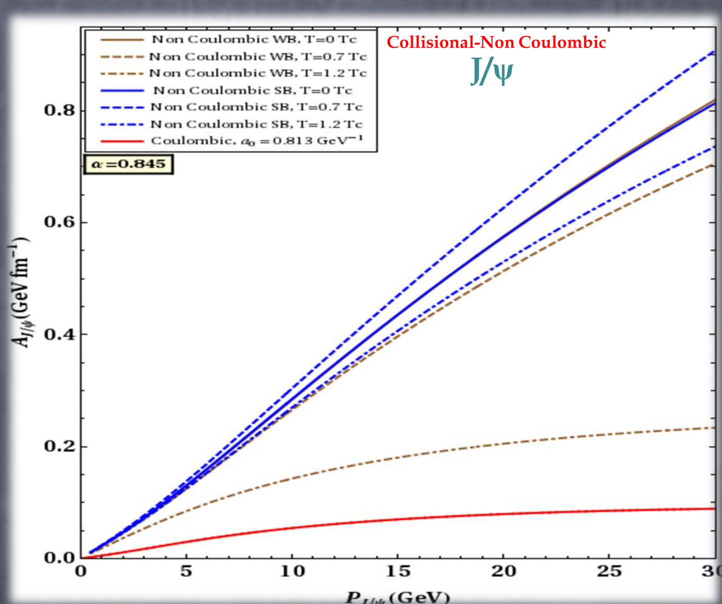
- $B(E) = \int_E^{+\infty} dE'\, A_i(E') \times \frac{E'}{P'}\, e^{-(E'-E)/T},$

$B_\perp = B_\parallel = B$, **B ↔ A Einstein relation**

- Drag & Diffusion Coefficient



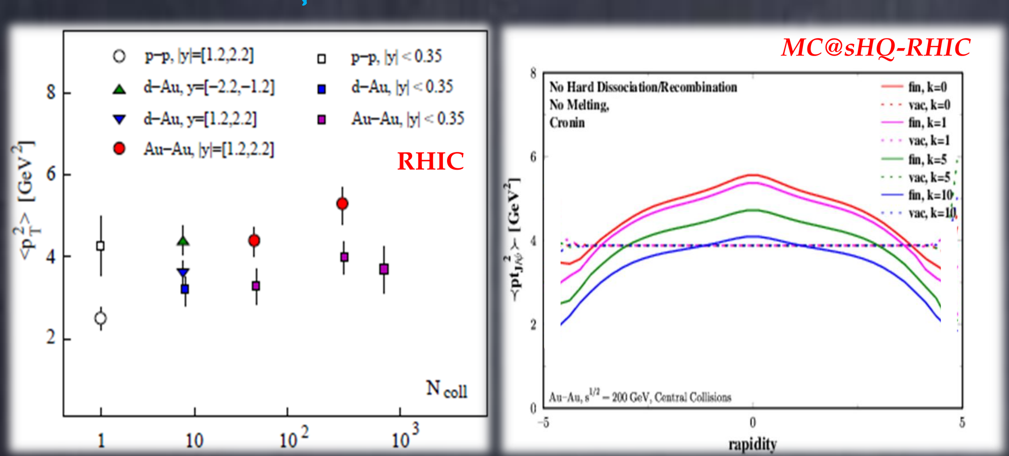
- Wave function influence on dE/dt, Ai, B



- Weakly & strongly bound > coulombic case
- Behaviour related to $V_\infty(T)$ and $\epsilon(T)$

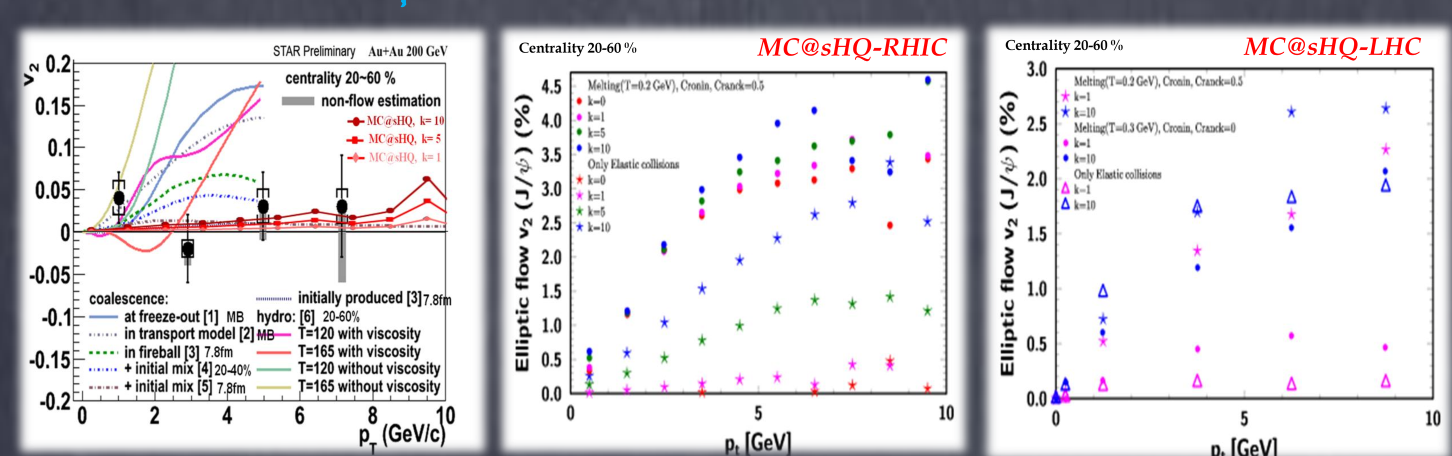
IV. J/ψ Stochastic Transport Observables & Collective Behaviour

- J/ψ Mean <p_t^2>- RHIC



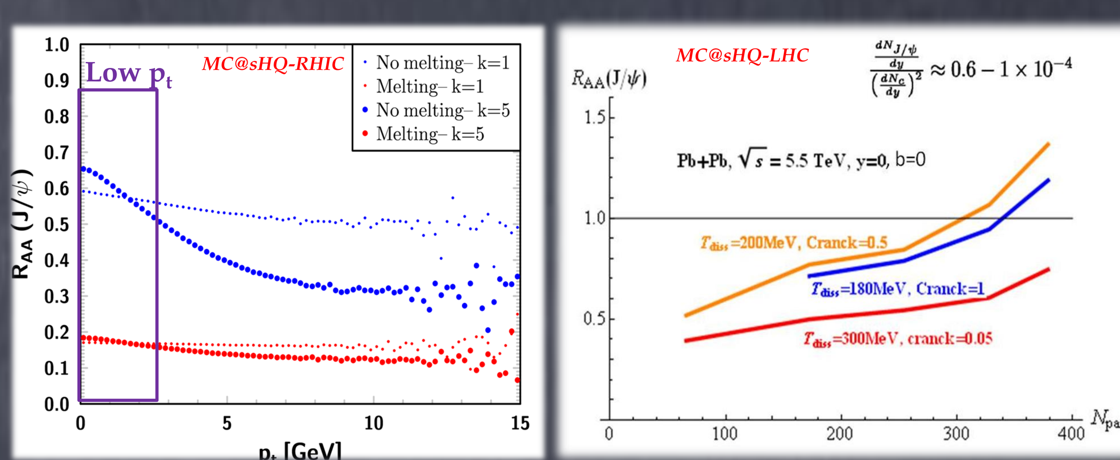
- J/ψ interaction with the medium reduces J/ψ mean p_t
- Saturation of J/ψ p_t broadening in SPS & RHIC central collisions (J/ψ cooling) is reproduced with our model for the study of elastic collisions

- Elliptic flow v_2(J/ψ)- RHIC/LHC



- Non zero elliptic flow
- Increase of elastic processes (σ_{elas}) → v_2 (J/ψ) increases
- Reproduce qualitatively v_2 (J/ψ) preliminary STAR data by considering elastic scattering processes

- R_{AA}(J/ψ) Nuclear modification factor



- Part of R_{AA} is due to elastic scattering processes
- Some ingredients neglected in our model at high p_t
- Fusion of c-quarks at LHC: 15-25 more probable than at RHIC, but strong increase of the prompt J/ψ as well

V. Conclusions

- Develop a theoretical & phenomenological model to study quarkonia propagation and collectivity
- Highlight the role of elastic scattering processes. These processes were never considered in the literature
- Elastic processes (forgotten in previous work), should be considered equally with other phenomena studied in the characterization of quarkonia in the QGP, especially in a quantitative analysis

H. Berrehrah, P.B. Gossiaux, J. Aichelin. J. Phys.: Conf. Ser. 270 012036. – H. Berrehrah, P.B. Gossiaux, J. Aichelin. "Perturbative calculation of quarkonium-gluon, hadron elastic cross sections in vacuum and in medium". In preparation.
P.B. Gossiaux, H. Berrehrah, J. Aichelin."Perturbative calculation of QED bound states elastic cross section". In preparation . – H. Berrehrah, P.B. Gossiaux, J. Aichelin. "Quarkonia collectivity: study of collisional energy loss, elliptic flow and other collective phenomena". In preparation