Charmonium dynamics in the UrQMD transport model

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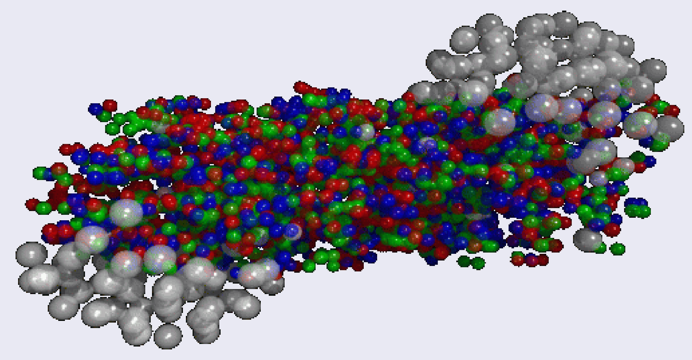
Motivation

- Charmonium dynamics in heavy ion collisions can provide multiple insights to extreme matter.
- In hot and dense space-time regions a QGP is produced in heavy ion collisions.
- T. Matsui and H. Satz [1] predicted charmonium suppression in a QGP due to Debye screening, therefore charmonium suppression can be a hint for the formation of a QGP.
- In the last two decades it was brought to light that the issue is more complex and charmonium recombination has to be taken into account also.
- We use the hadronic transport model UrQMD (Ultrarelativistic Quantum Molecular Dynamics) to model charmonium dynamics in heavy ion collisions.
- UrQMD can be used at multiple collision energies and system properties, therefore we have the opportunity to test different models of charmonium dynamics on universal validity.



Charmonium implementation to UrQMD

- Charm yields, fractions of charmonium states and momenta are fitted to experimental data and are implemented to UrQMD.
- Space-time points are determined in concordance to a Glauber model in UrQMD.
- Elastic cross sections from effective Lagrangian calculations are used [2].
- Inelastic cross sections from a two-body transition model fitted to data from Pb+Pb collisions at SPS energies [3].

$$\sigma_{1+2\to3+4}(s) = 2^4 \frac{E_1E_2E_3E_4}{s}|M_i|^2 \left(\frac{m_3+m_4}{\sqrt{s}}\right)^6 \frac{p_f}{p_i}$$

- Charmonium recombination included as well via the principle of detailed balance.

$$\sigma_{3+4\to3+4}(s) = \sigma_{1+2\to3+4}(s)\frac{(2S_1+1)(2S_2+1)p_f^2}{(2S_3+1)(2S_4+1)p_i^2}$$

- Enhanced cross sections for excited particles and reduced cross sections for strange particles.
- We implemented a prehadronic phase to account for prehadronic interactions of charmonia at high energy densities.

Purely hadronic model

- The purely hadronic model is used to reproduce the schematic UrQMD calculation of C.Spieles et al. [4] and to show thereby that the full UrQMD implementation works, see Fig.1.
- Due to the higher meson abundance at RHIC energies the charmonia produced from recombination exceed the initial charmonium rate by far as seen in Fig.2, therefore a purely hadronic model cannot explain the observed suppression.

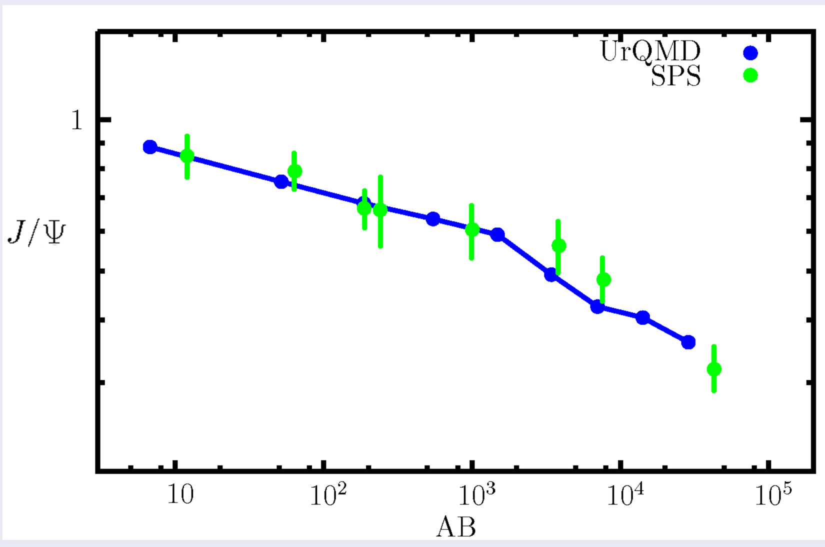


Figure 1: J/Ψ suppression at SPS energies in purely hadronic phase. SPS data from [5].

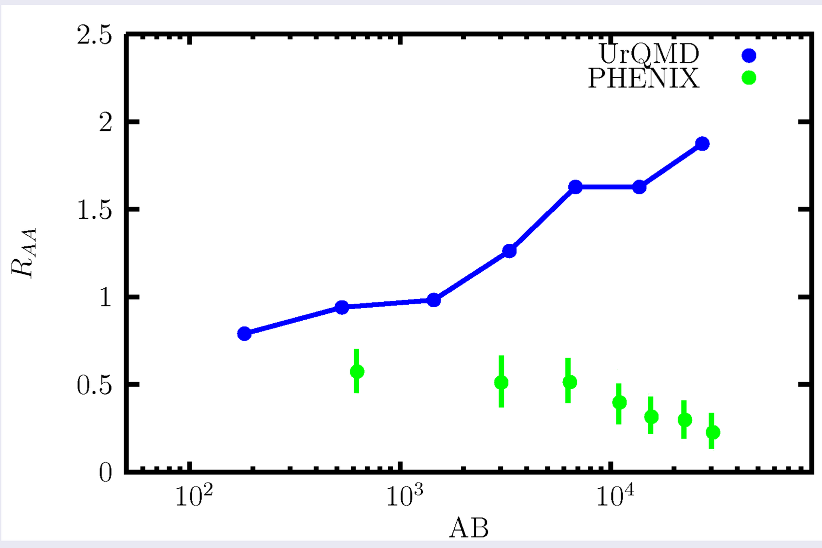


Figure 2: J/Ψ "suppression" at RHIC energies in purely hadronic phase. RHIC data from [6]. Rapidity cut: $|y| < 0.35$.

Implementation of prehadronic interactions

- Use of a prehadronic phase is supposed to take into account effects at high temperatures and densities.
- Transition temperature of prehadronic phase to hadronic phase is taken from S.Borsanyi at al. [7, 8].
- Particle formation times are neglected in this phase and there is assumed to be no D-Meson recombination.
- Cross sections in the prehadronic phase are fitted to data at SPS energies, see Fig.3
- Using the same cross sections for all collision energies we can see that the model works at RHIC energies also, see Fig.4.

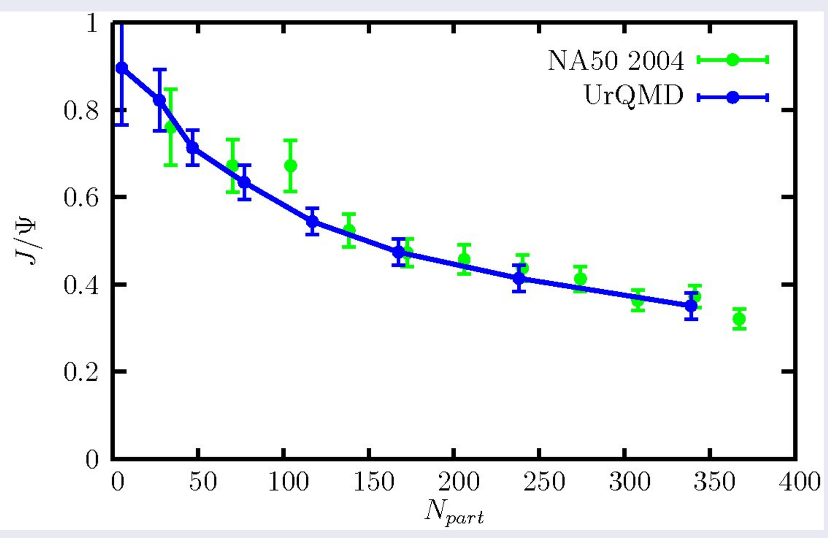


Figure 3: J/Ψ suppression at SPS energies using prehadronic and hadronic phase. SPS data from [9].

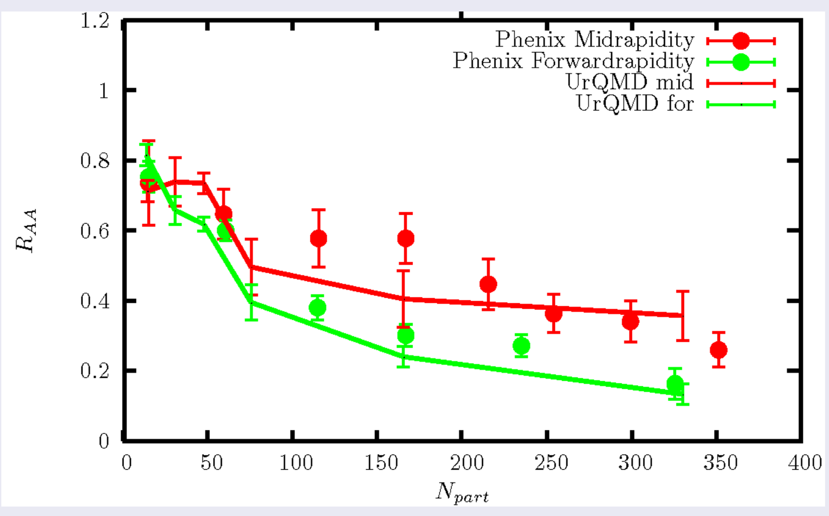


Figure 4: J/Ψ suppression at RHIC energies using prehadronic and hadronic phase. Same parameters as at SPS. RHIC data from [6]. Rapidity cuts: $|y| < 0.35$ and $1.2 \le |y| \le 2.2$.

UrQMD at LHC energies

- Also at LHC energies the same model as at SPS and RHIC energies is used.
- Due to the implemented energy cut and phase-space reasons the relative D-Meson recombination in Pb+Pb does not exceed the recombination at RHIC energies and UrQMD shows a charmonium suppression as seen in ATLAS measurements, see Fig.5.
- Besides our calculation for heavy ion collisions we have a look at medium effects in pp collisions. To be able to do that we evaluate variable multiplicity bins, see Fig.6.
- Due to the J/Ψ suppression in pp collisions one has to be careful in using charmonia abundances in pp collisions as reference value for the nuclear modification factor R_{AA} in heavy ion collisions.

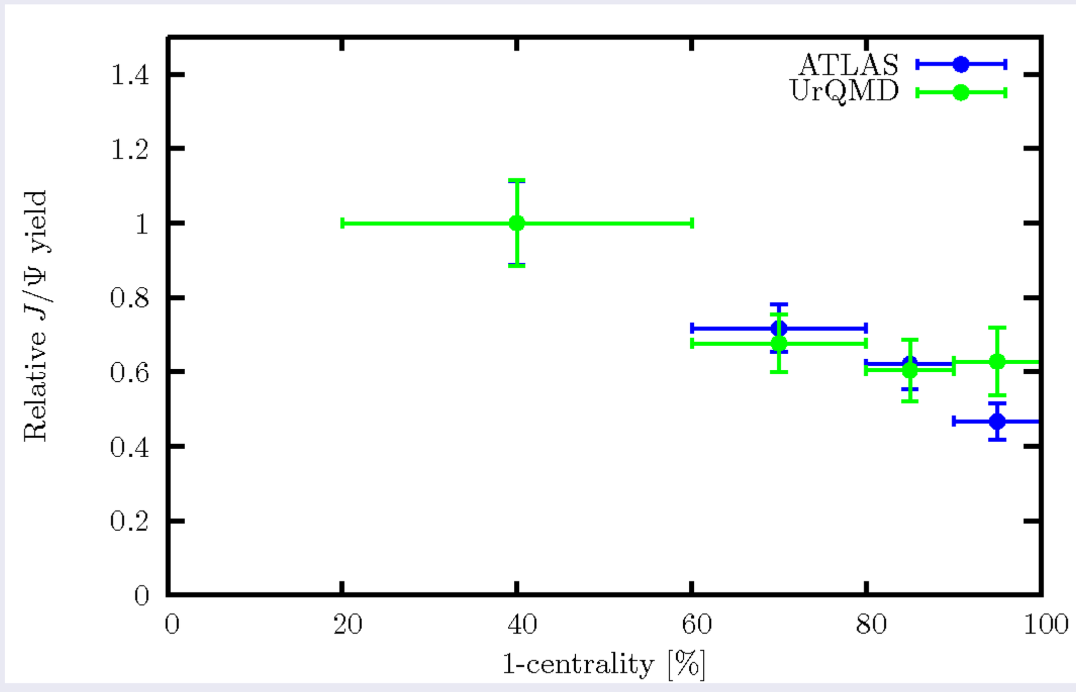


Figure 5: J/Ψ suppression in Pb+Pb collisions at $\sqrt{s} = 2.76$ *TeV* using prehadronic and hadronic phase. Same parameters as at SPS. ATLAS data points from [10].

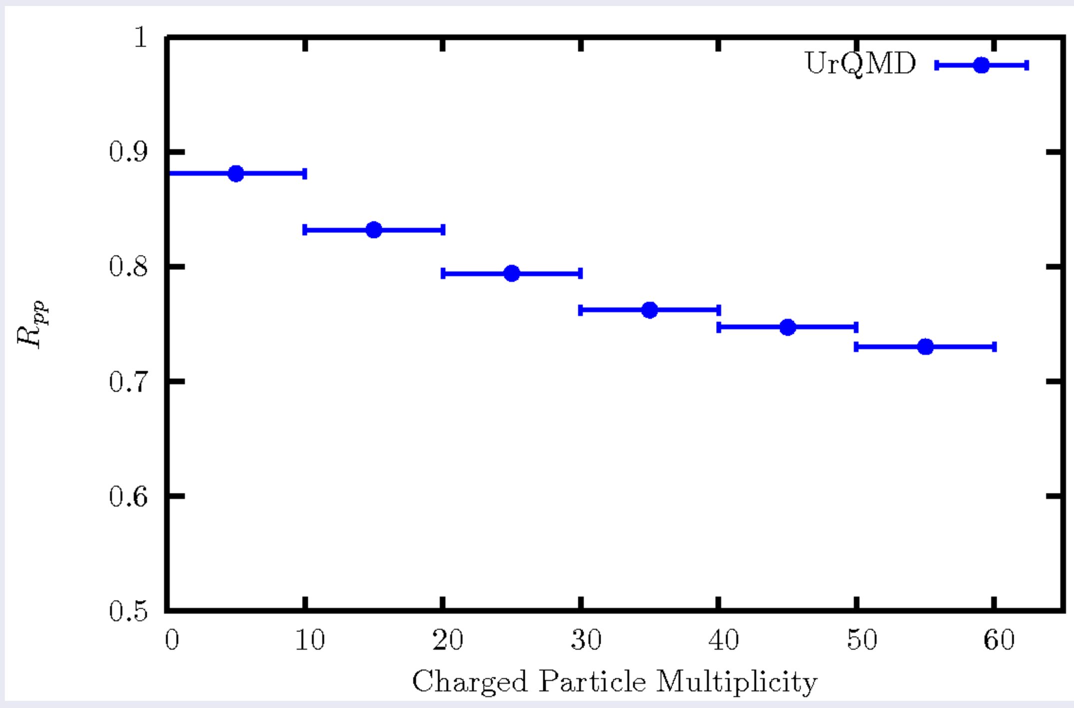


Figure 6: J/Ψ suppression in pp collisions at $\sqrt{s} = 7$ *TeV* using prehadronic and hadronic phase. Same parameters as at SPS. To measure the J/Ψ suppression dependent on the medium we have a look at various multiplicity bins. Rapidity cut: $|y| < 1$

Main results

- Using UrQMD we can describe charmonium suppression at SPS, RHIC and LHC energies using the same variables.
- A purely hadronic model cannot reproduce the measured data at RHIC and LHC energies.
- We predict a J/Ψ suppression in pp collisions at $\sqrt{s} = 7$ *TeV*.

Outlook

- We want to compare the UrQMD results to other transport models like HSD in detail.
- An analysis of observables like v_2 and p_T will be performed.
- The prehadronic phase has to be improved using partonic interactions and hydro simulations.

References

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FIAS Frankfurt Institute for Advanced Studies

HIC for FAIR Helmholtz International Center

H-QM Helmholtz Research School Quark Matter Studies

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