J/Ψ suppression in PbPb collisions

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ALICE publication to be discussed

- Centrality, rapidity and transverse momentum dependence of J/Ψ suppression in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76\text{TeV}$

arXiv:1311.0214 [nucl-ex]

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Summary

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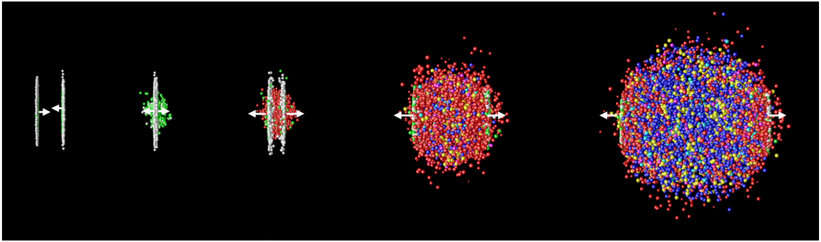
How to study matter, how to study QGP

- Study matter: E.g. via Rutherford Experiment

How to study QGP medium?
Auto generated probes:

- Heavy quarks only form in (initial) hard processes
- They experience entire evolution of the system
  $\rightarrow$ Use heavy quarks as probe



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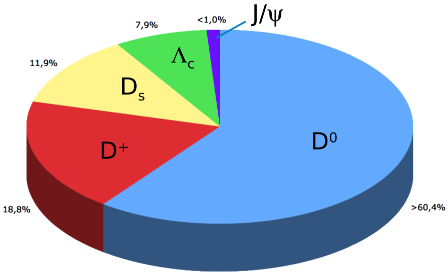
Charm quarks in QGP

Heavy quarks (e.g. charm quarks) are unique probes:

- charm quarks only produced in early stage (no thermal production)
- number of charm quarks conserved throughout collision
- No annihilation of charm quarks (very small cross section)

After hadronisation: Only 1% charmonium ($c\bar{c}$)



Dissertation Y. Wang

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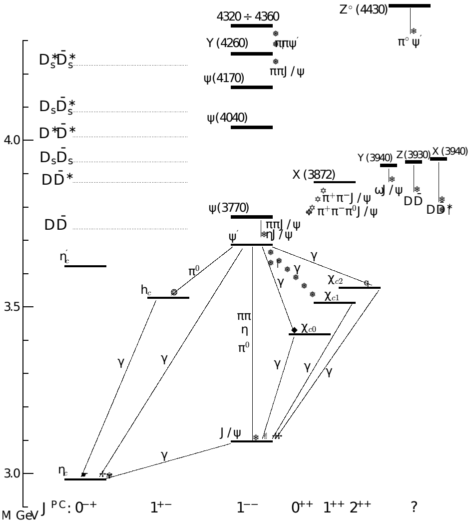
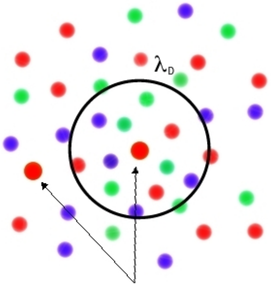
Charmonium resonances



M.B. Voloshin, arXiv:0711.4556 [hep-ph]

J/Ψ suppression and melting

Deconfined interior of QGP: colour screening prevents $c\bar{c}$ binding



$$q\bar{q} \text{ pair in vacuum: } V(r) = -\frac{\alpha}{r} + kr \quad (1)$$

$$\text{in QGP: } V(r) = -\frac{\alpha}{r} e^{(-r/\lambda_D)} \quad (2)$$

- Debye length $\lambda_D = \lambda_D(T)$
- if e.g. $r_{J/\Psi} > \lambda_D \rightarrow$ no J/Ψ production ("melting")
- $r_{J/\Psi} < r_{\Psi(2s)}$: infer temperature

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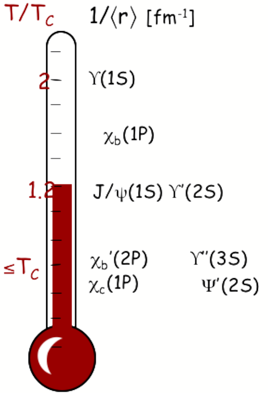

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J/Ψ properties and decay modes

From PDG particle physics booklet:

110 Meson Summary Table

$J/\psi(1S)$ $\quad I^G(J^{PC}) = 0^-(1^{--})$

Mass $m = 3096.916 \pm 0.011$ MeV
Full width $\Gamma = 92.9 \pm 2.8$ keV (S = 1.1)
$\Gamma_{ee} = 5.55 \pm 0.14 \pm 0.02$ keV

$J/\psi(1S)$ DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
hadrons		(87.7 ± 0.5) %		–
virtual $\gamma \to$ hadrons		(13.50 ± 0.30) %		–
$g g g$		(64.1 ± 1.0) %		–
$\gamma g g$		(8.8 ± 1.1) %		–
$e^+ e^-$		(5.94 ± 0.06) %		1548
$e^+ e^- \gamma$	[kkkk]	$(8.8 \pm 1.4) \times 10^{-3}$		1548
$\mu^+ \mu^-$		(5.93 ± 0.06) %		1545

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Data taking

Both decay modes are measured with ALICE:

- $\mu^+\mu^-$ using forward muon arm
- e^+e^- in central barrel using ITS and TPC
- For event characterization (N_{part}) and triggering: ZDC and VZERO

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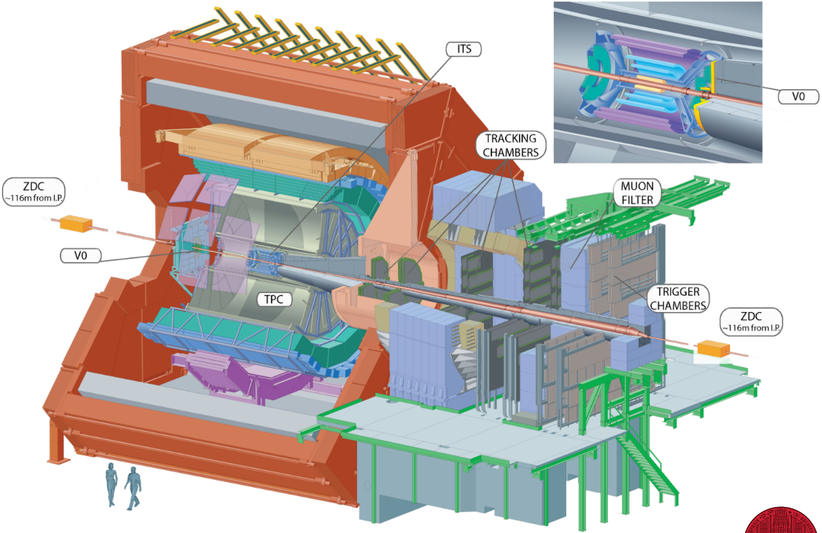
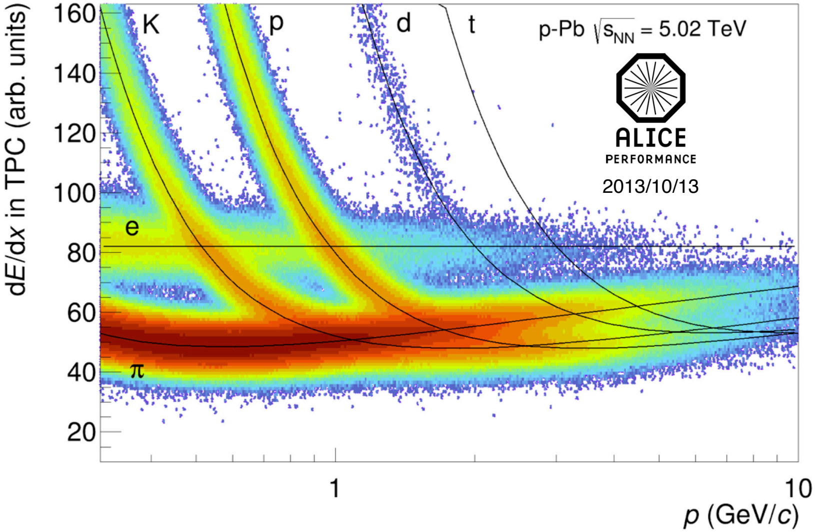

ITS
V0
TRACKING
CHAMBERS
ZDC
~116m from I.P.
MUON
FILTER
V0
TPC
TRIGGER
CHAMBERS
ZDC
~116m from I.P.

Data analysis

- J/Ψ candidates: Opposite-sign electron or muon tracks
- typical background: e^+e^--pairs from photon conversion in detector material
- → demand hit in one of two innermost ITS layers
- e^- identification: TPC e^- hypothesis of (-2.0;+3.0)σ resp. (-1.5;+3.0)σ for 2010 resp. 2011 data
- J/Ψ yield: number of events in range $2.92 < m_{e^+e^-} < 3.16\text{GeV}/c^2$

TPC particle identification



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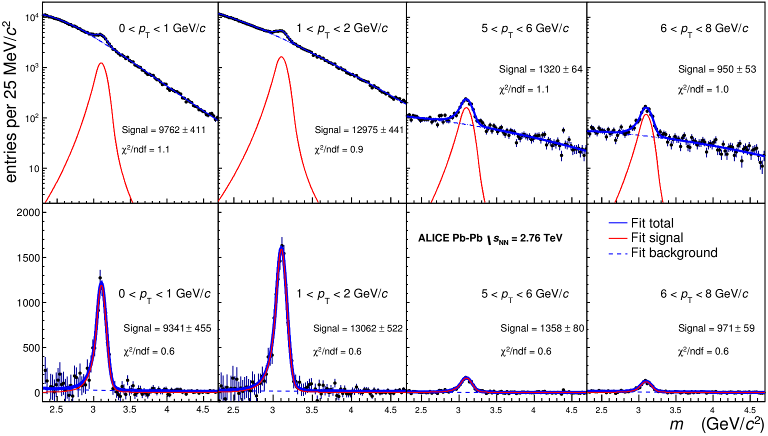
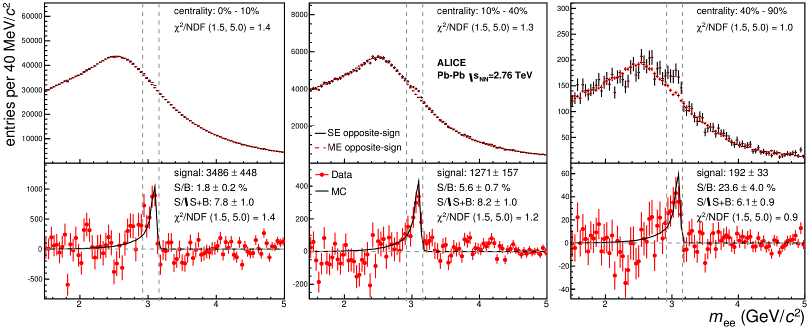
Background analysis $\mu^+\mu^-$



- Background: Variable Width Gaussian
- Signal: "extended Crystal Ball" function (Gaussian core with power-law low-end tail)

Background analysis e^+e^-



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J/Ψ yield and R_{AA}

J/Ψ yield:

$$Y^i_{J/\Psi} = \frac{N^i_{J/\Psi}}{\mathrm{BR}_{J/\Psi\to l^+l^-} N^i_{\mathrm{events}} A \times \epsilon^i} \quad (3)$$

$$A < 1, \epsilon < 1 \quad (4)$$

Nuclear modification factor:

$$R_{\mathrm{AA}} = \frac{Y^{\mathrm{Pb\text{-}Pb}}_{J/\Psi}}{\langle T_{\mathrm{AA}}\rangle \times \sigma^{\mathrm{pp}}_{J/\Psi}} \quad (5)$$

with nuclear overlap function $\langle T_{\mathrm{AA}}\rangle$

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Systematic uncertainties - overview

- tracking efficiency (up to 11%)
- trigger efficiency (2%)
- signal extraction procedure (1-3% in μ channel)
- input MC parameterization (3-5%)
- nuclear overlap function $\langle T_{\mathrm{AA}} \rangle$ (3-8%)
- J/Ψ pp cross-section $\sigma_{J/\Psi}^{\mathrm{pp}}$ (9-12%)
- matching efficiency (1%)
- centrality limits (0-5%)

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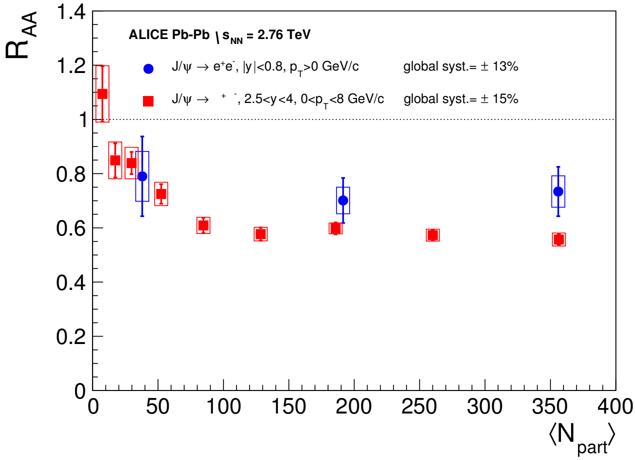
Results: J/Ψ suppression as function of $\langle N_{\rm part} \rangle$



- Mid-rapidity centrality integrated $R_{\rm AA}^{0-90\%} = 0.72 \pm 0.06(\rm stat.) \pm 0.10(\rm syst.)$
- Forward-rapidity $R_{\rm AA}^{0-90\%} = 0.58 \pm 0.01(\rm stat.) \pm 0.09(\rm syst.)$

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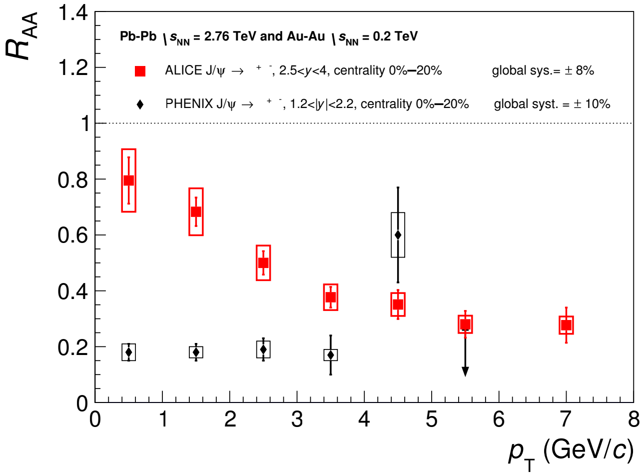
Results: (Re)combination



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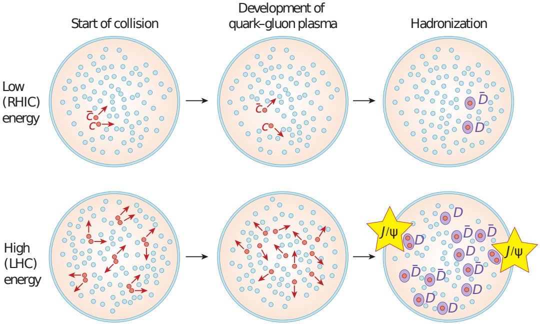
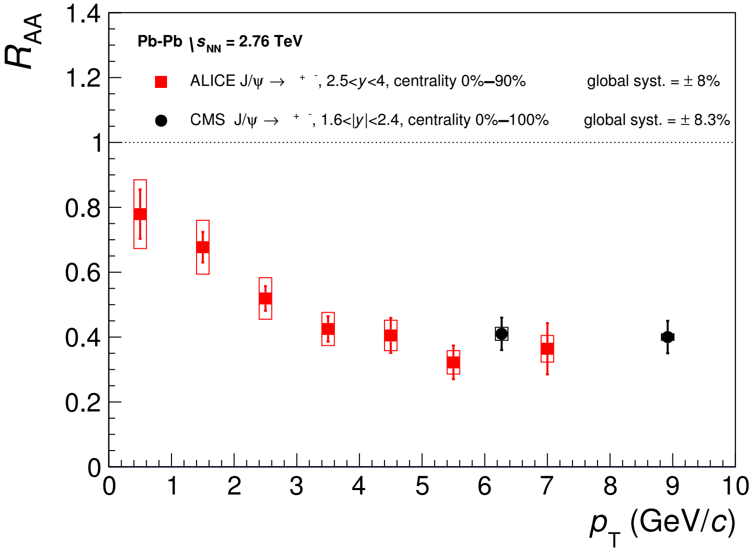
Recombination at higher energies

- less suppression at LHC PbPb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76\mathrm{TeV}$ compared to RHIC (PHENIX) AuAu collisions at $\sqrt{s_{\mathrm{NN}}} = 0.2\mathrm{TeV}$
- LHC energy higher → higher charm quark density → recombination of individual c and $\bar{c}$ → J/Ψ can happen



P. Braun-Munzinger and J. Stachel, Nature 448 (2007) 302.

Results: J/Ψ suppression as function of p_T



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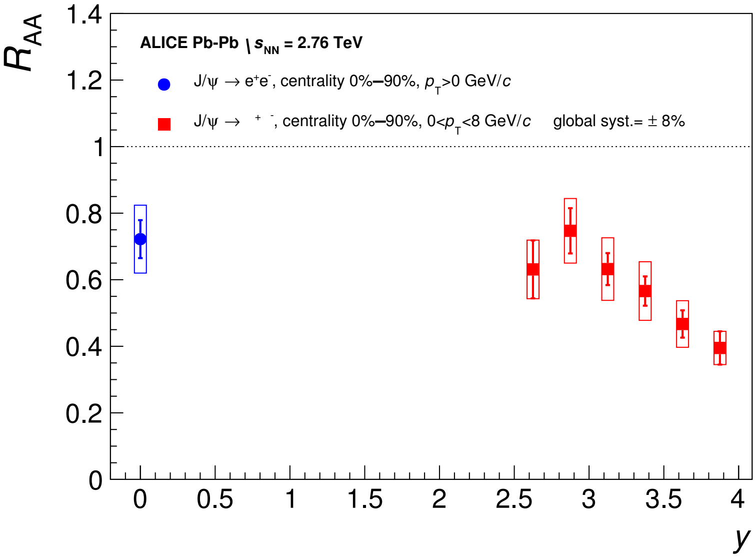
Results: J/Ψ suppression as function of rapidity



Conclusions

- Clear suppression of J/Ψ
- No significant dependence of R_{AA} on centrality for $\langle N_{part} \rangle > 70$
- High p_{T} J/Ψ more suppressed than low p_{T}
- R_{AA}: p_{T} dependence in contrast to PHENIX result
  $\rightarrow$ suggest recombination of charm quarks at LHC $\sqrt{s_{\mathrm{NN}}}$

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