Heavy Ion Collisions

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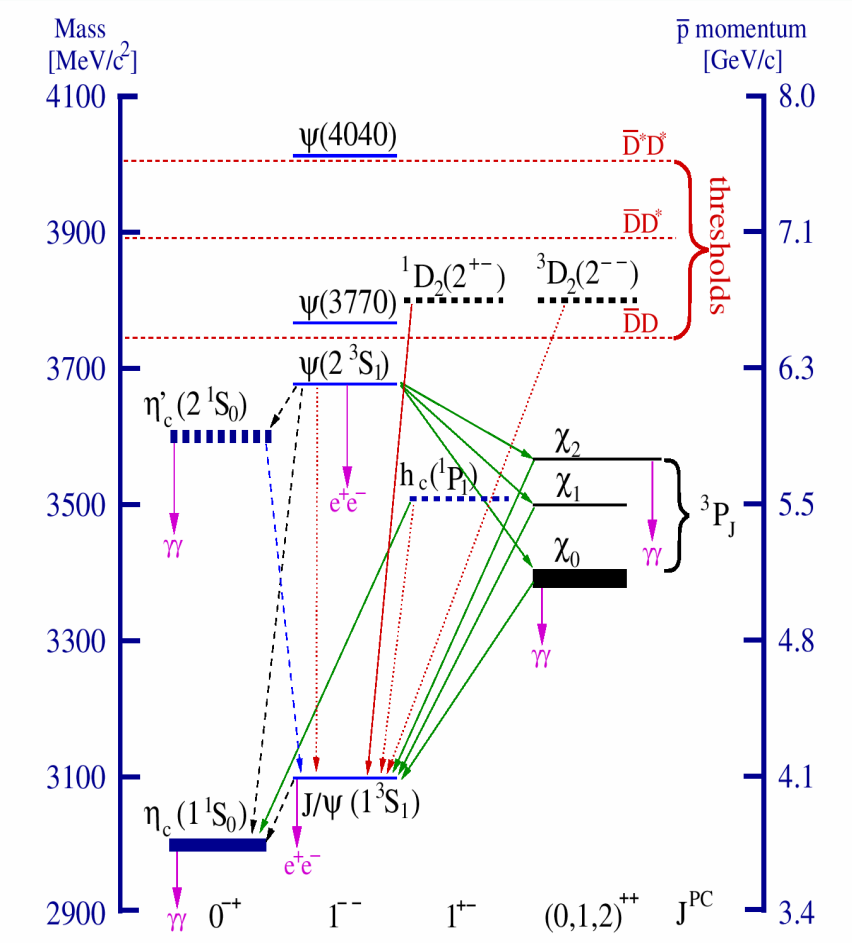
Quarkonia:

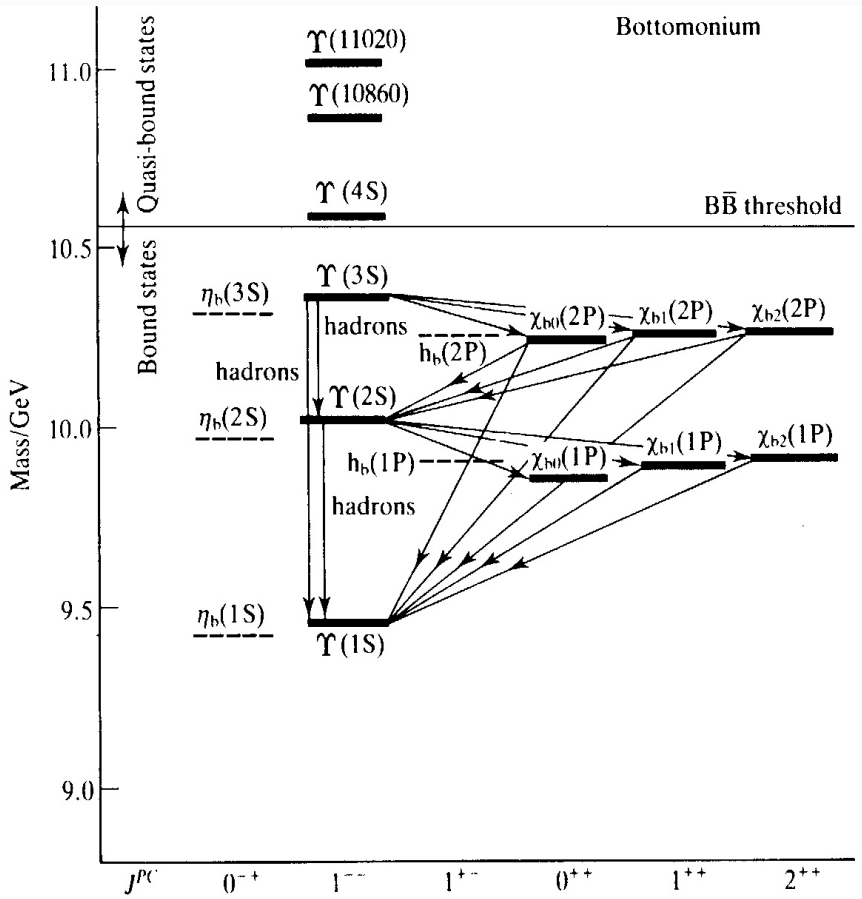
Quarkonia

Quarkonia are heavy quark antiquark bound states, i.e. ccbar and bbar.

Stable with respect to strong decay into open charm or bottom.

$M_{c\bar{c}} < 2M_D$ and $M_{b\bar{b}} < 2M_B$





Production of charmonia

Table 1 Masses, binding energies, and radii of the lowest $c\bar{c}$ and $b\bar{b}$ bound states [3]; the listed radii are $1/2\sqrt{\langle r_i^2 \rangle}$, given by Eq. (3)

State	J/ψ	χ_c	ψ'	Υ	χ_b	Υ'	χ_b'	Υ''
Mass (GeV)	3.10	3.53	3.68	9.46	9.99	10.02	10.36	10.36
ΔE (GeV)	0.64	0.20	0.05	1.10	0.67	0.54	0.31	0.20
Radius (fm)	0.25	0.36	0.45	0.14	0.22	0.28	0.34	0.39

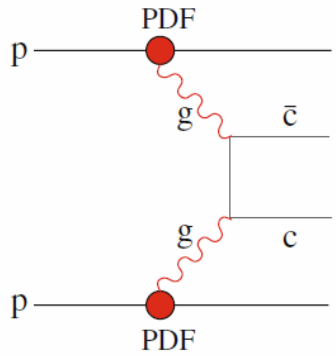


Fig. 10 Lowest order Feynman diagram for $c\bar{c}$ production through gluon fusion

- ccbar production
- color octet to color single (color neutralization)
- physical bound state (J/Ψ)

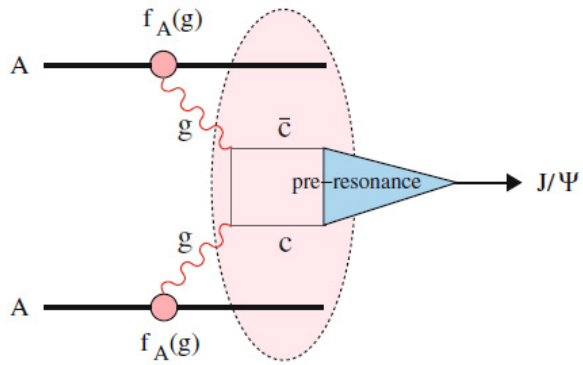


Fig. 12 J/ψ production in a nuclear medium

- Posible modifications of PDF due to other nucleons
- ccbar pair can suffer absorption while traversing nuclear matter

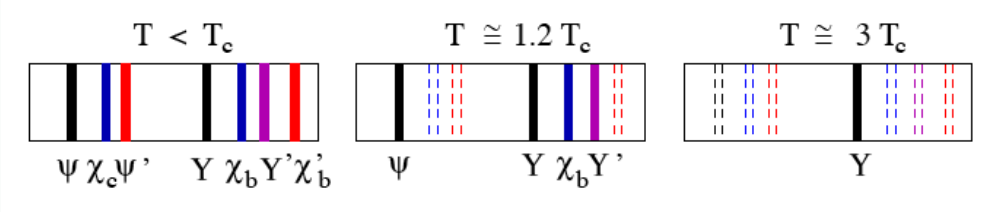
Quarkonia in Heavy-Ion Collisions

Quarkonia (J/Ψ, Υ):

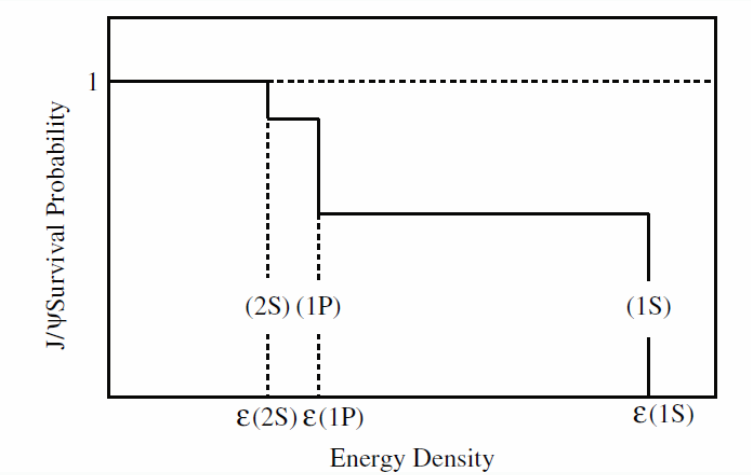
26 years ago: Matsui & Satz (Phys. Lett. B178(1986) 416)

color screening in deconfined matter $\rightarrow$ J/ψ suppression = "smoking gun"

- Sequencial dissociation versus T in QGP (Matsui/Satz)

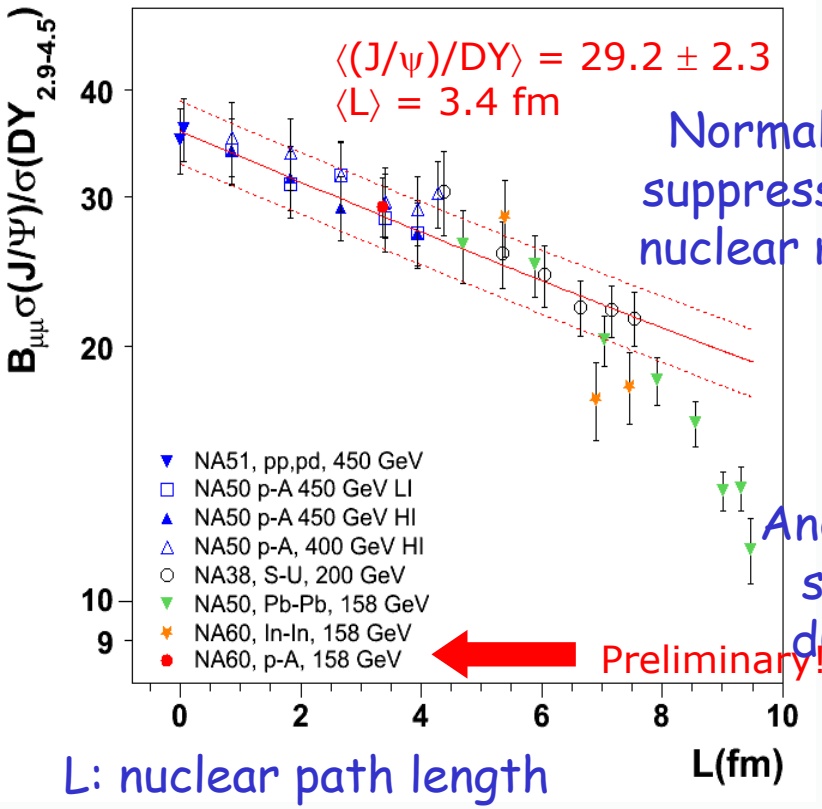


Can be used as thermometer of the medium



Disappearance of J/Ψ comming from Ψ', χ_C and directly produced J/Ψ

J/Ψ at SPS energies

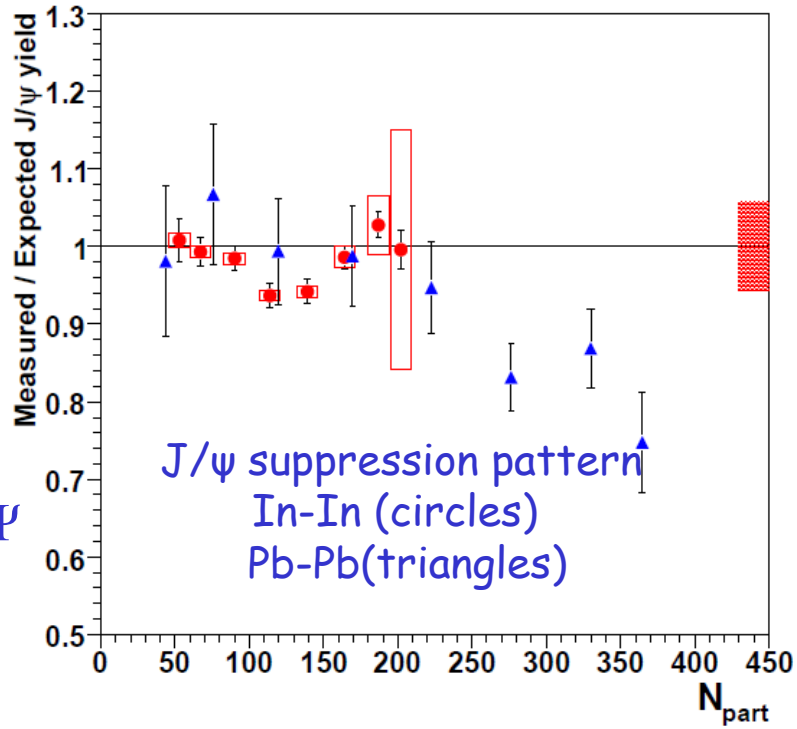


Normal J/Ψ suppression on nuclear matter

Anomalous J/Ψ suppression due to QGP?

L: nuclear path length

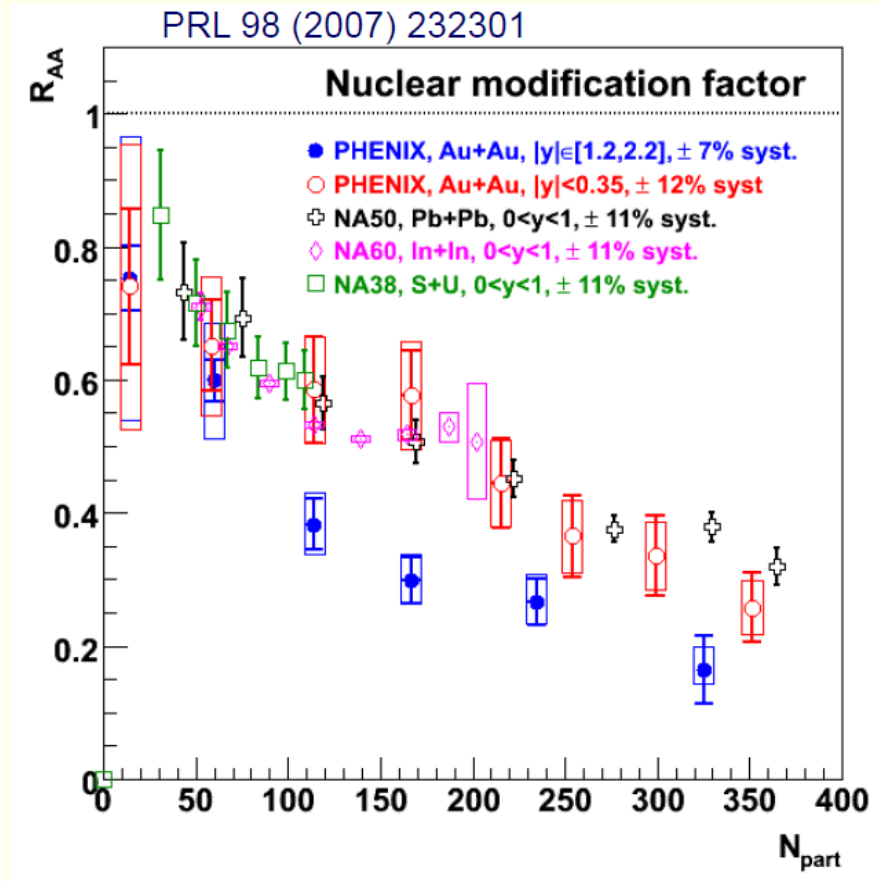
Arnaldi, Nucl.Phys.A830,345c (2009)



with $\sigma^{J/\Psi}_{abs}$ = 7.6 ± 0.7 ± 0.6 mb

For very central Pb-Pb collisions
(N_{part} > 200) an anomalous J/ψ suppression,
of the order of 20-30%, is still visible.

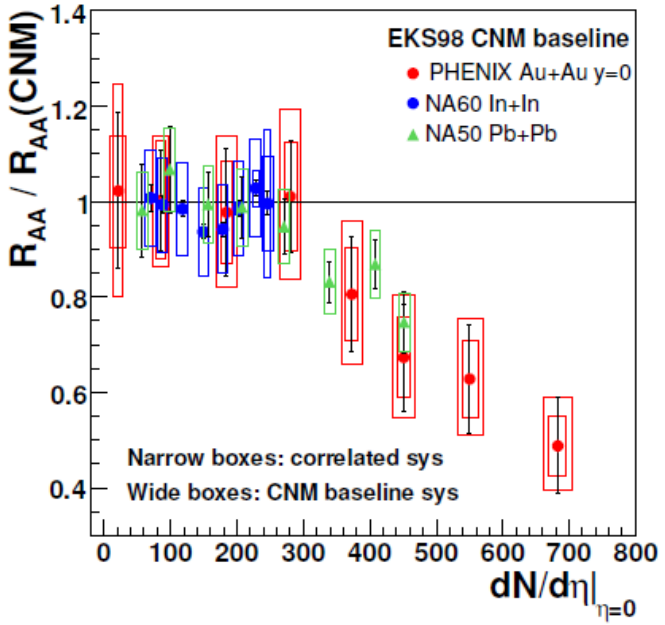
J/Ψ at RHIC & SPS energies



more suppression at forward rapidity!

opposite to trend from co-mover or CNM absorption

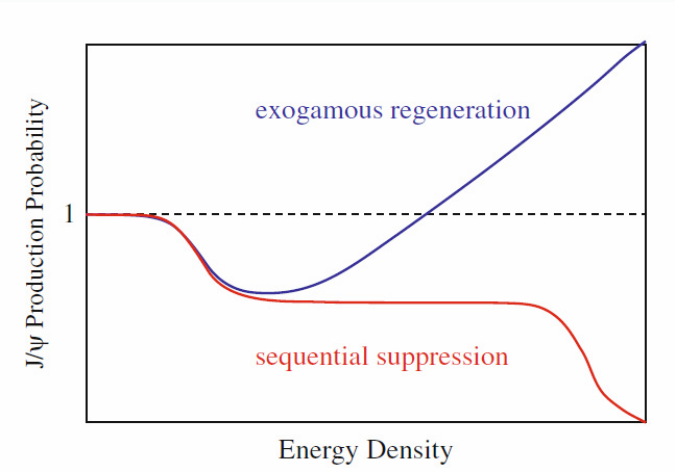
At mid-rapidity suppression at RHIC very similar to SPS

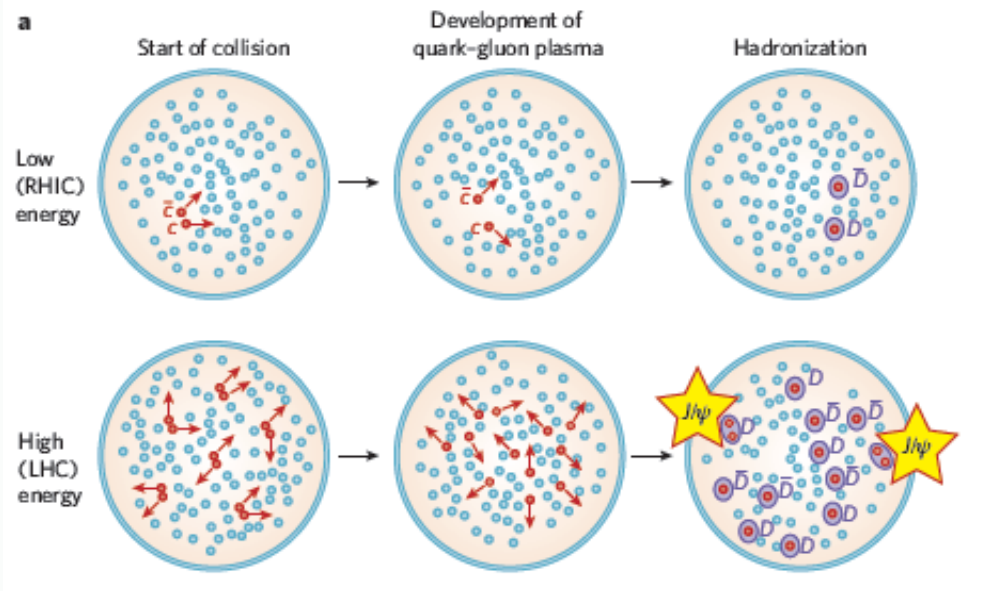


Eur.Phys.J.C71:1534,2011

FIG. 89: Comparison of the anomalous suppression at the SPS and RHIC as a function of $dN_{\rm ch}/d\eta$ at $\eta = 0$

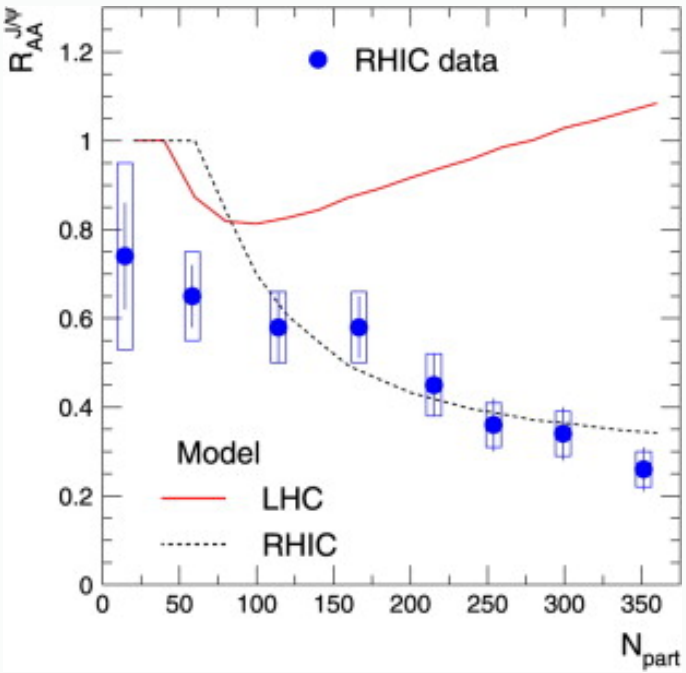
Suppression versus regeneration



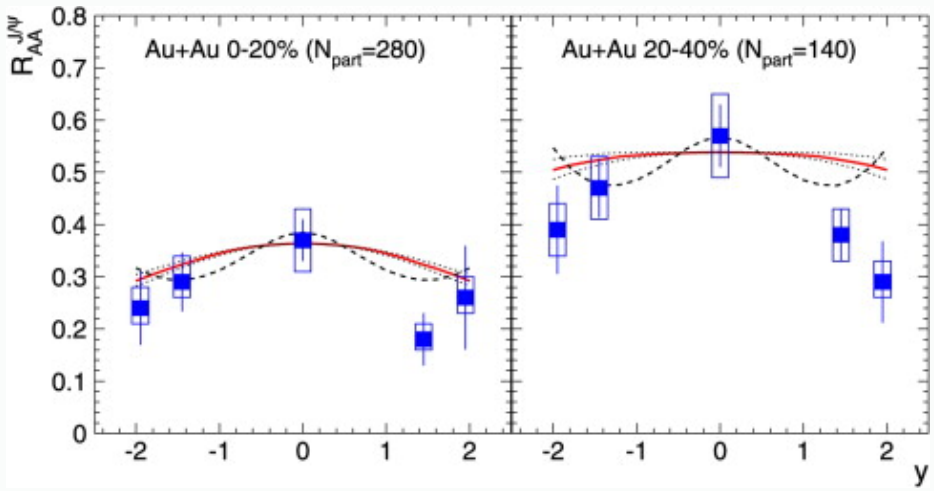


P.Braun-Munzinger & J. Stachel,
Nature 448 (2007) 302

Statistical Hadronization Model



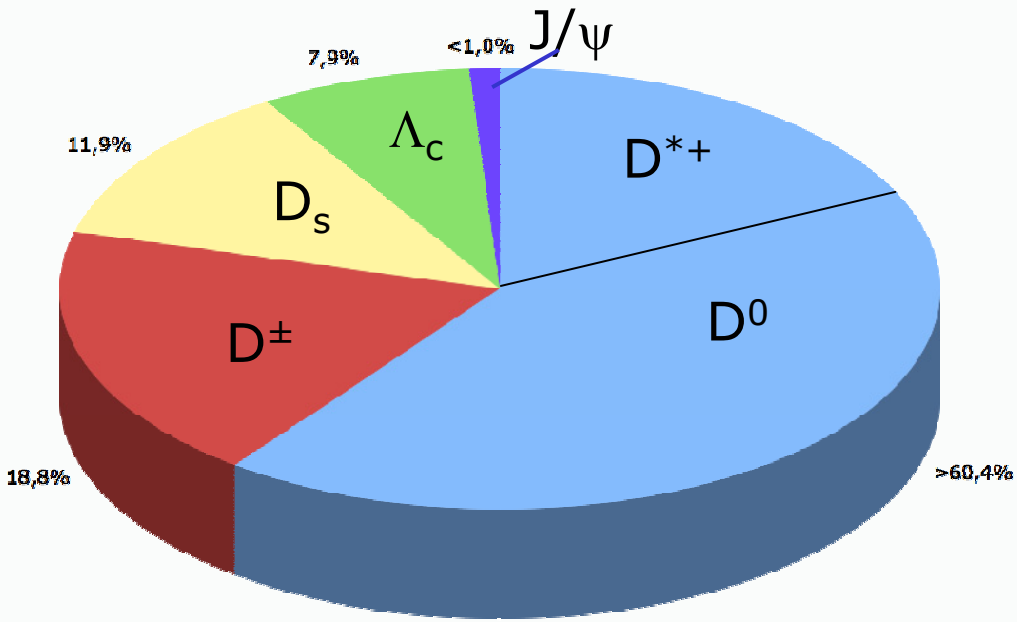
PLB 652 (2007) 259



Clear signal for generation of charmonia due to statistical hadronization at the phase boundary

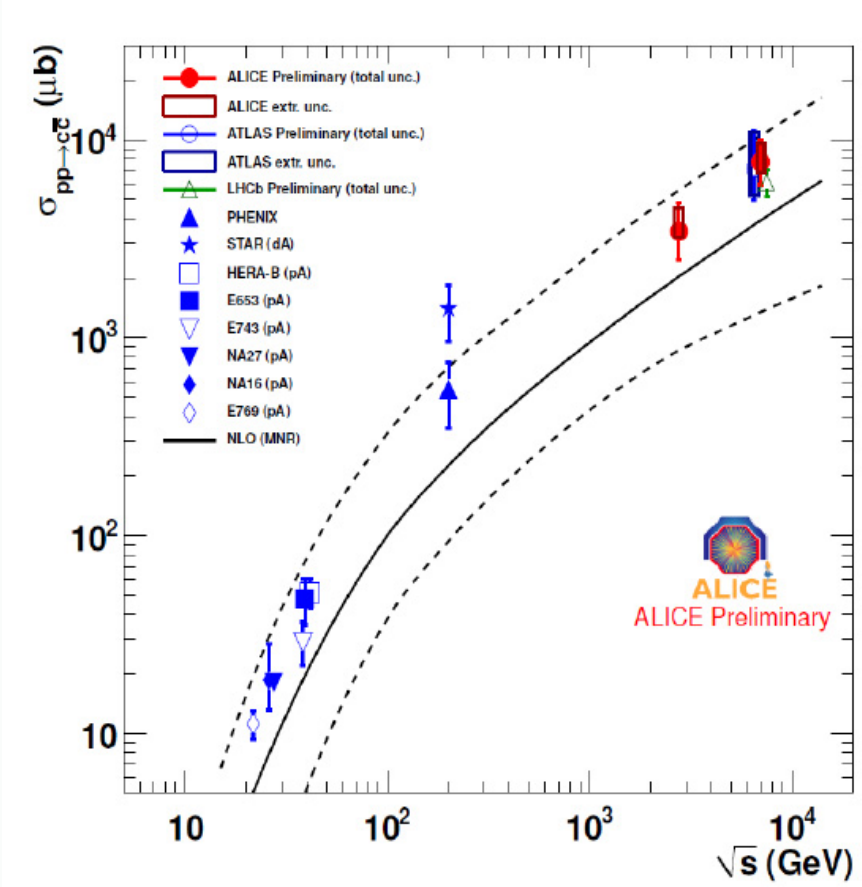
Where does all the charm go ?

Total ccbar cross section in pp collisions needs to be known



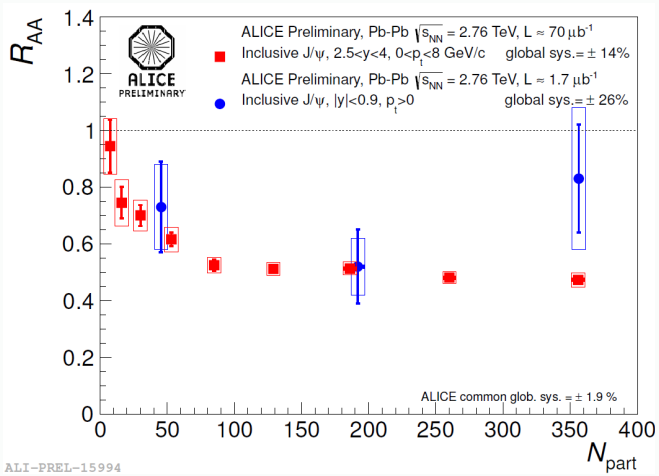
Total charm cross section: **open-charmed** hadrons,
e.g. **D^0**, **D^***, Λ_c, … or **c,b → e(μ) + X**
Quarkonia, e.g. **J/ψ** carries **≈1%** of **total charm**

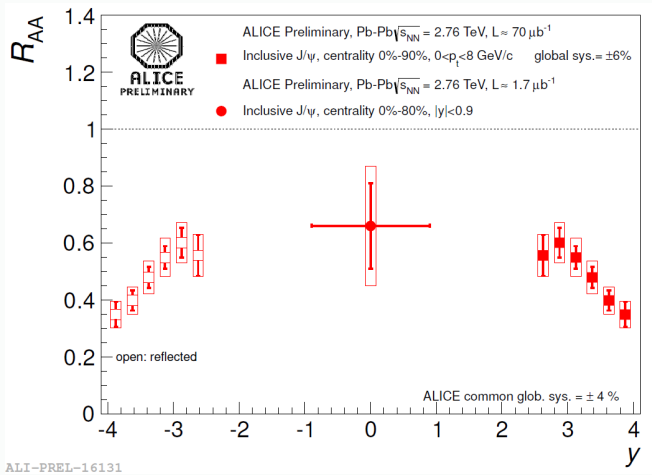
Total ccbar cross section in pp collisions

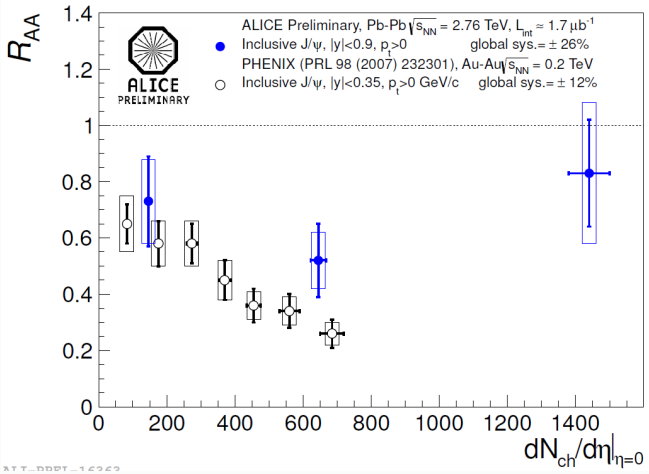


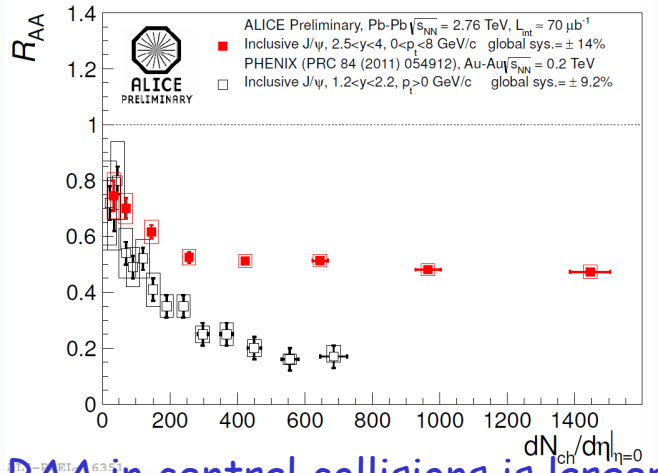
- Good agreement ALICE-ATLAS-LHCb
- Data factor 2 ± 0.5 above central value of FONLL but well within uncertainty
- Beam energy dependence follows well FONLL

J/Ψ at LHC: ALICE





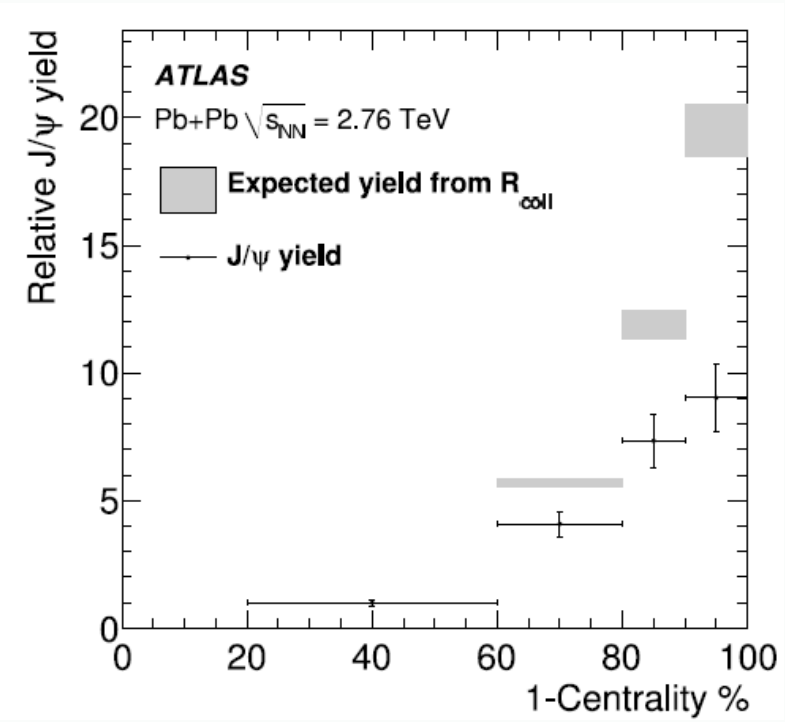


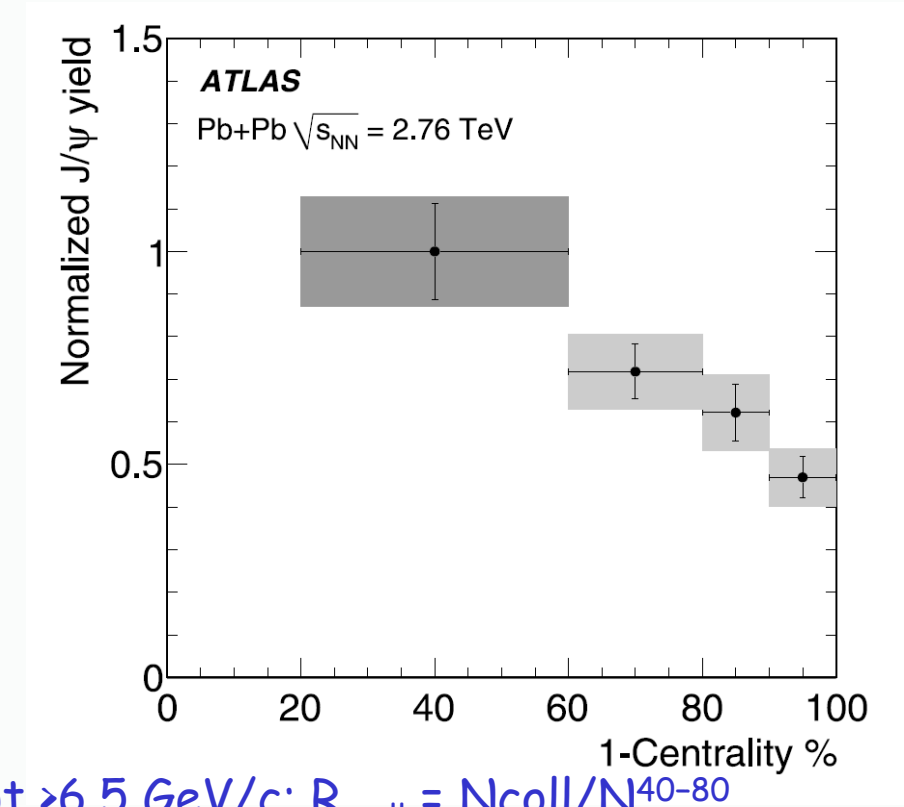


J/psi RAA in central collisions is larger at LHC in 2.5<y<4 than at RHIC in 1.2<|y|<2.2
And shadowing at LHC estimated to be large.

J/ψ at LHC: ATLAS

arXiv:1012.5419



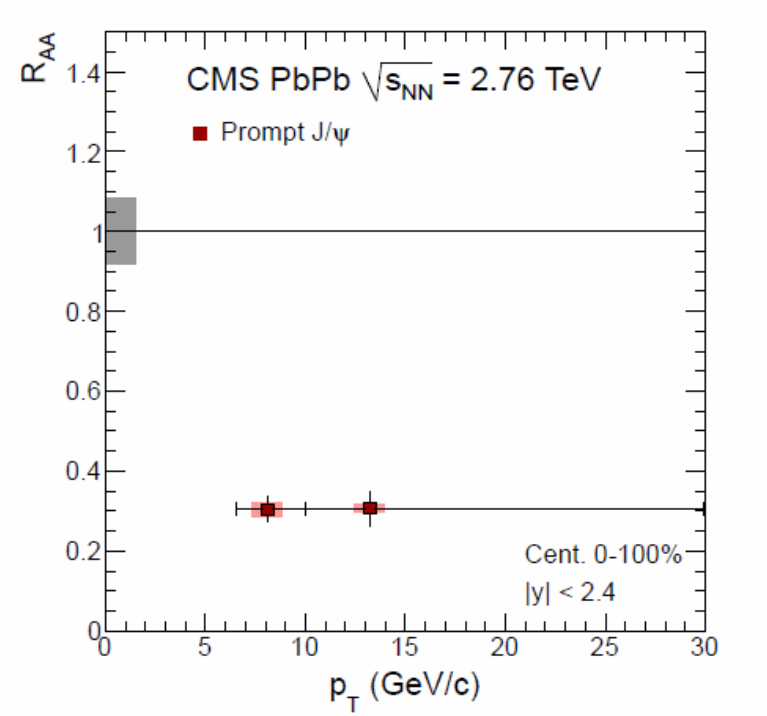


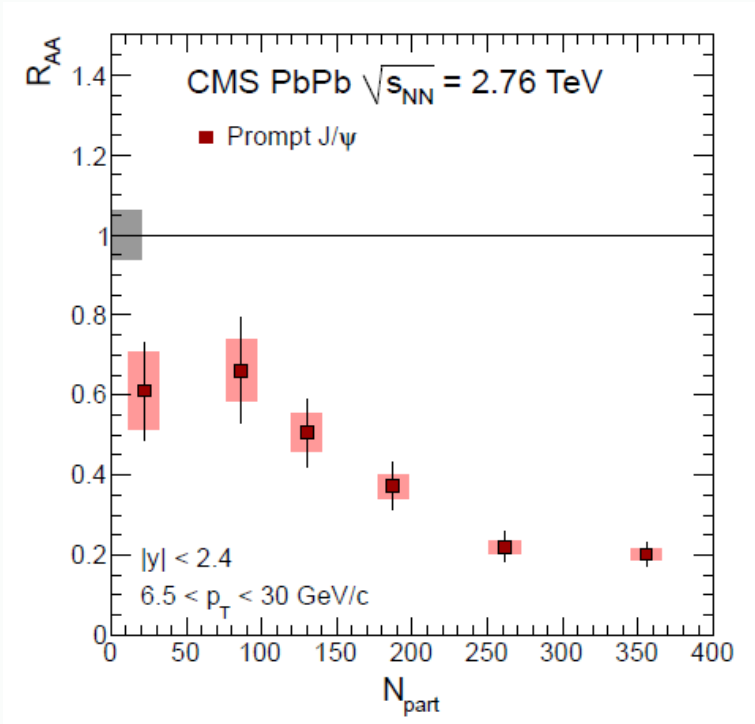
80% of J/ψ's (510 in all) have pt >6.5 GeV/c; $R_{coll} = Ncoll/N^{40-80}$

A centrality dependent suppression is observed in the normalized J/ψ yield

J/ψ at LHC: CMS

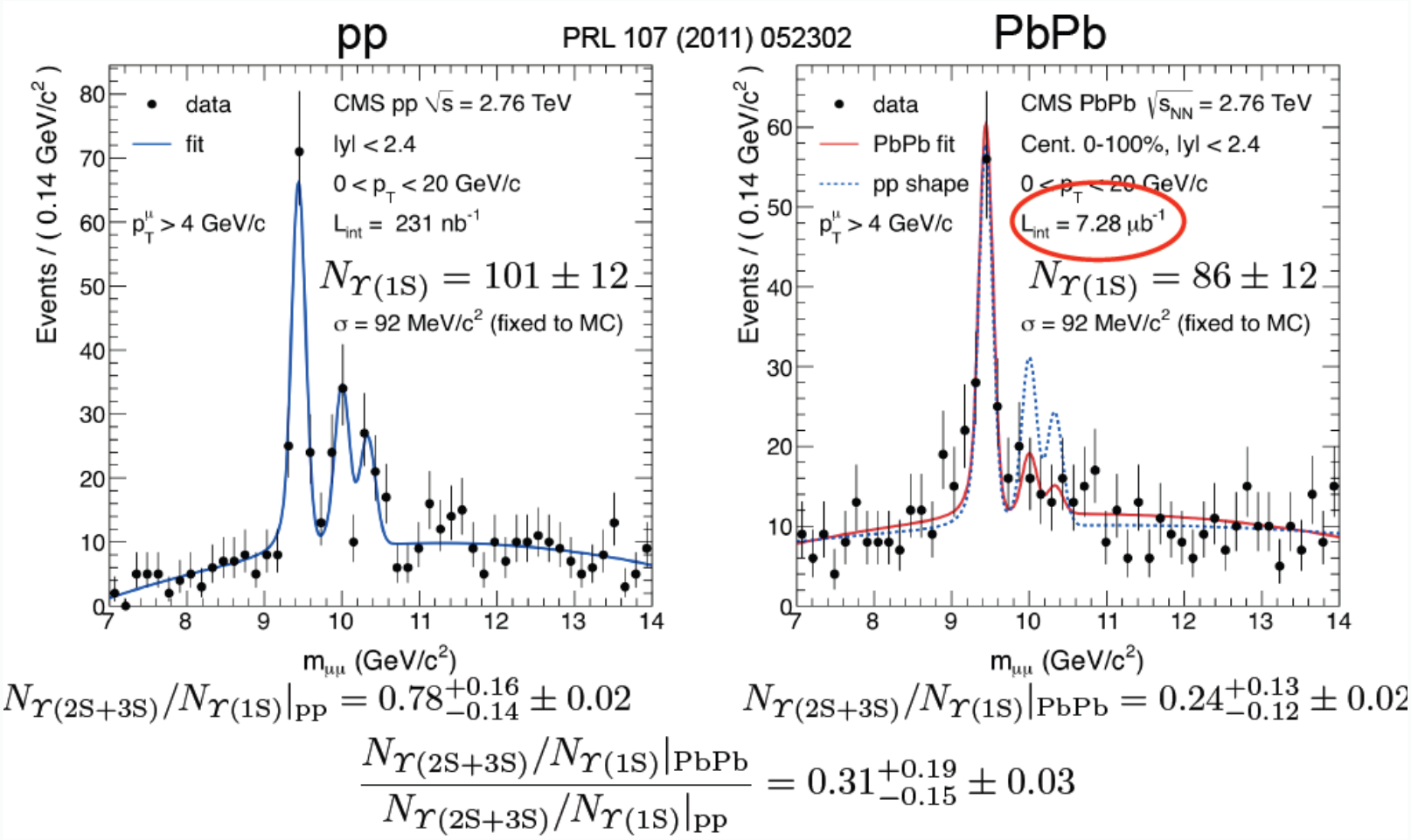
arXiv:1201.5069





Prompt J/ψ are found to be suppressed,
with a strong centrality dependence

Bottonium



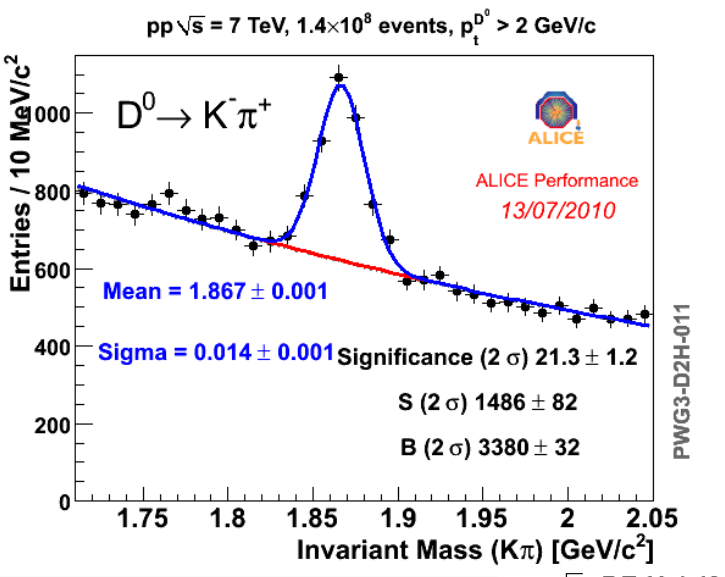
$$N_{\Upsilon(2S+3S)}/N_{\Upsilon(1S)}|_{pp} = 0.78^{+0.16}_{-0.14} \pm 0.02$$

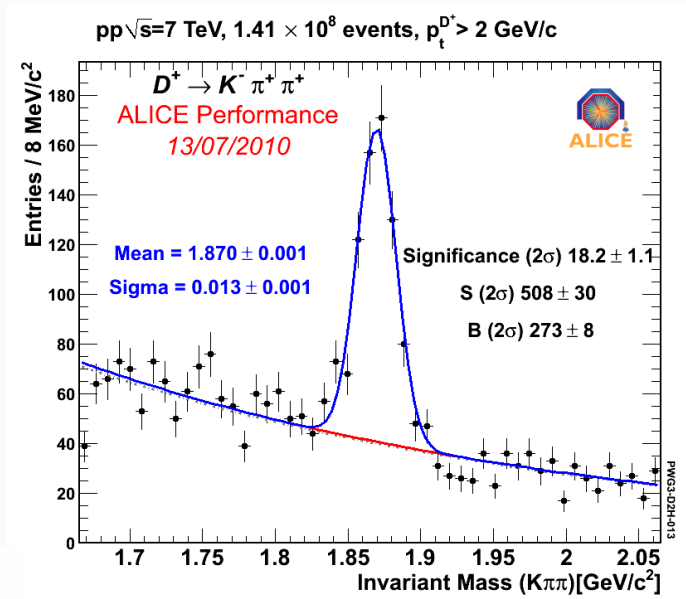
$$N_{\Upsilon(2S+3S)}/N_{\Upsilon(1S)}|_{PbPb} = 0.24^{+0.13}_{-0.12} \pm 0.02$$

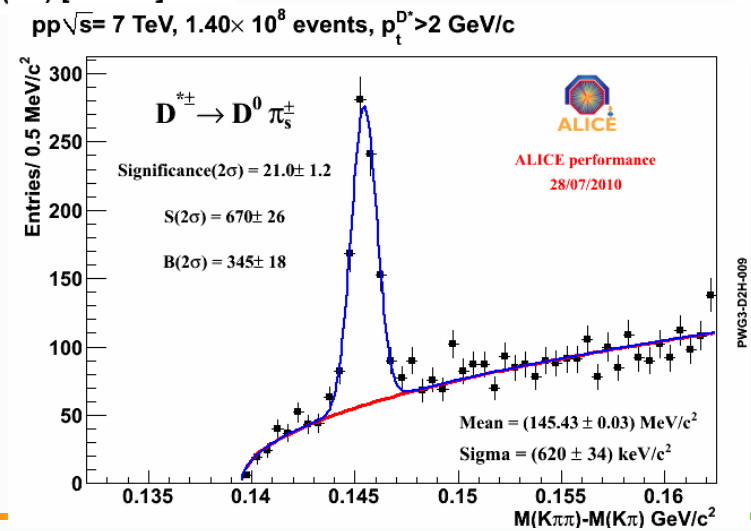
$$\frac{N_{\Upsilon(2S+3S)}/N_{\Upsilon(1S)}|_{PbPb}}{N_{\Upsilon(2S+3S)}/N_{\Upsilon(1S)}|_{pp}} = 0.31^{+0.19}_{-0.15} \pm 0.03$$

backup

Open – charm from ALICE

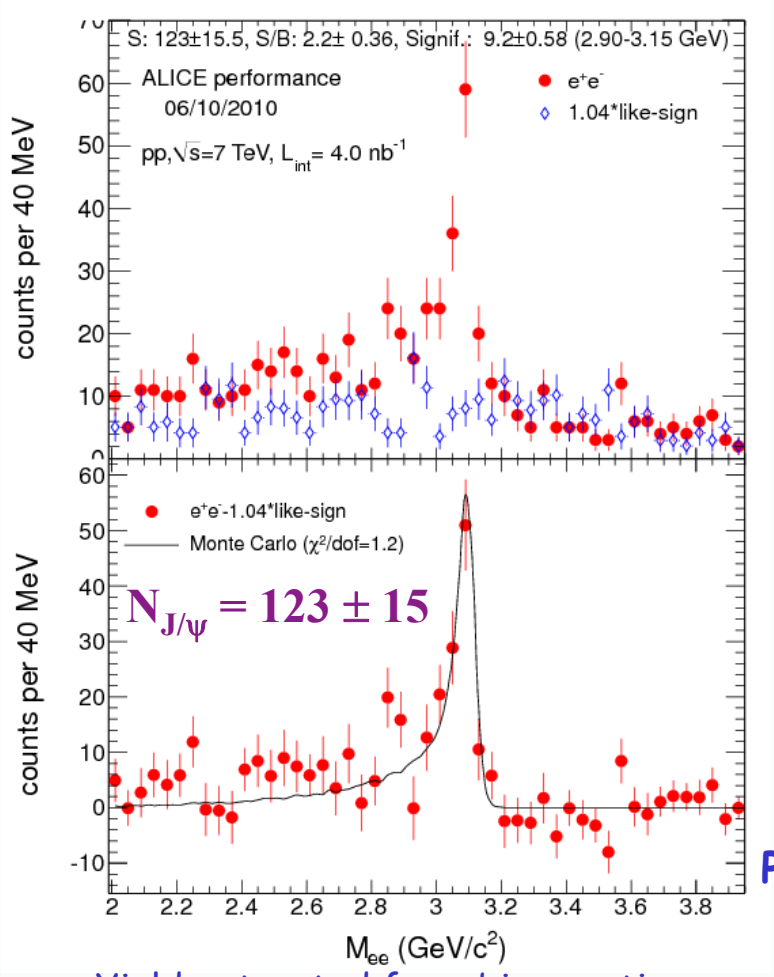




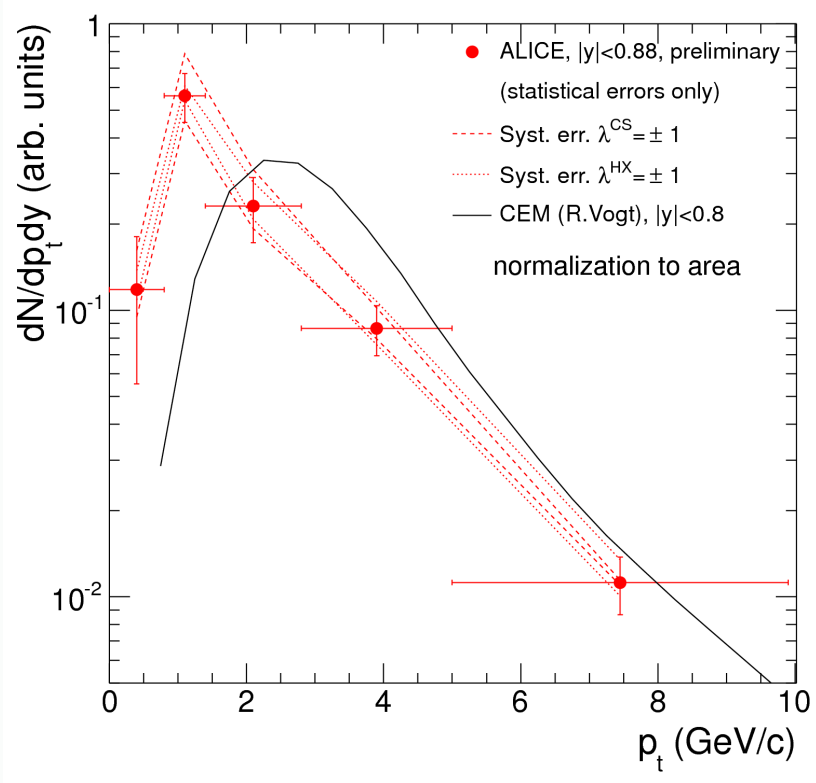


Study open charm production in as many channels as possible

$J/\psi \rightarrow e^+e^-$



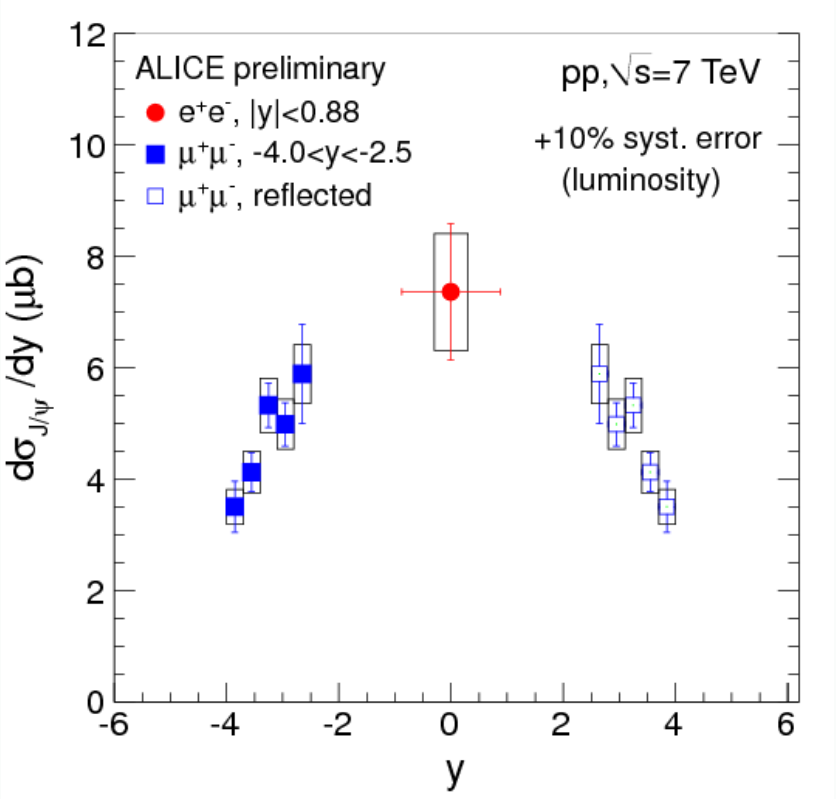
Yield extracted from bin counting (above like-sign background) in $M_{e^+e^-}$=2.9-3.15 GeV/c^2



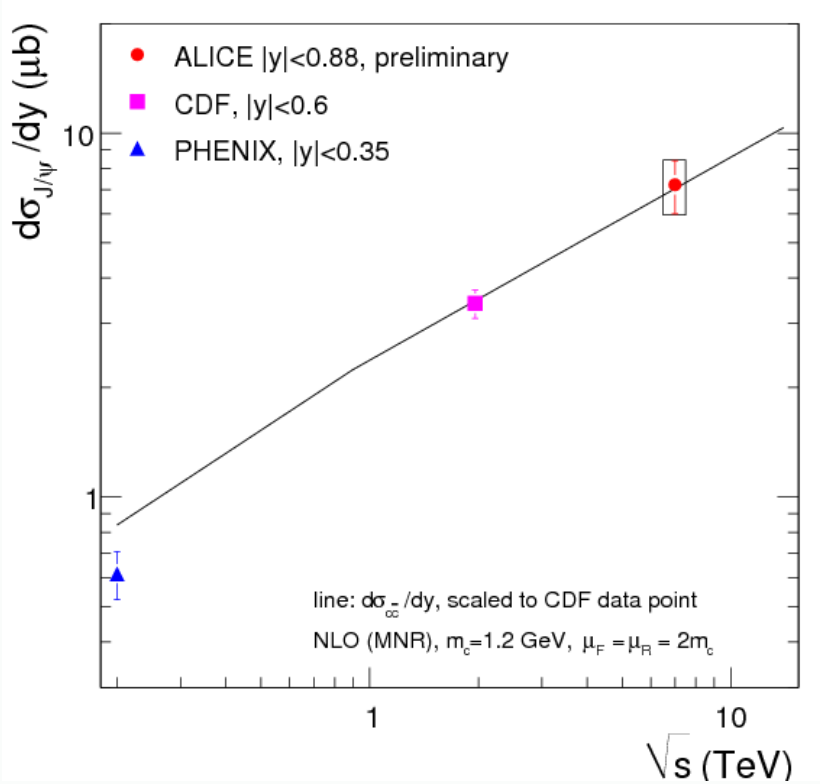
Preliminary p_T differential distribution (from a larger data sample), compared to CEM calculation

Measured spectrum is softer than the calculated one

J/ψ production cross section



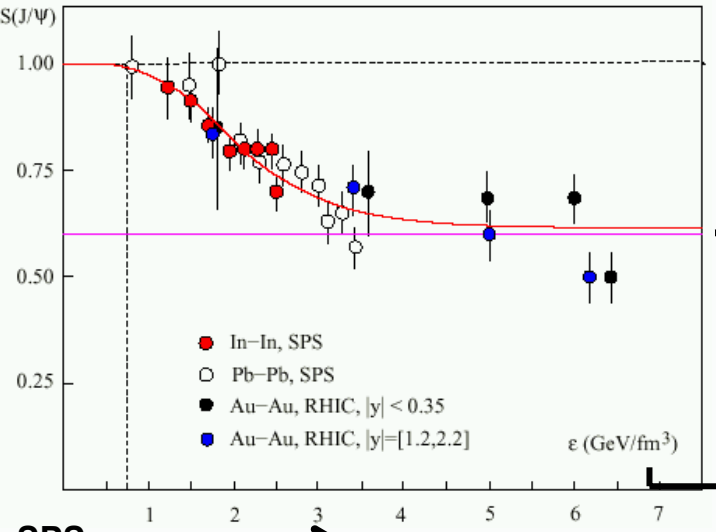
J/ψ production cross section measured in the two rapidity ranges covered by the ALICE experiment



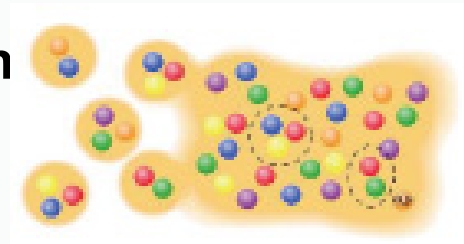
The cross section obtained at mid-rapidity is compared to PHENIX and CDF results
The curve is the MNR NLO calculation for the $c\bar{c}$ production cross section, scaled to match the CDF point

Quarkonia at LHC: ψ (cc̄) & ϒ (bb̄)

- J/ψ suppression & regeneration?
- χ_c, ψ' suppression (J/ψ T_D ~ 1.5-2 T_c)?



enhanced regeneration



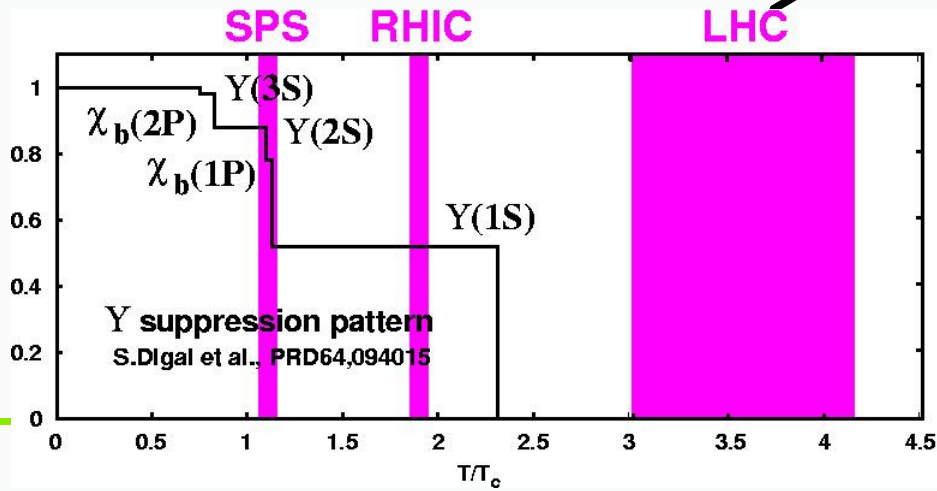
enhanced suppression

T_{LHC} >> J/ψ T_D

30

SPS
RHIC
LHC

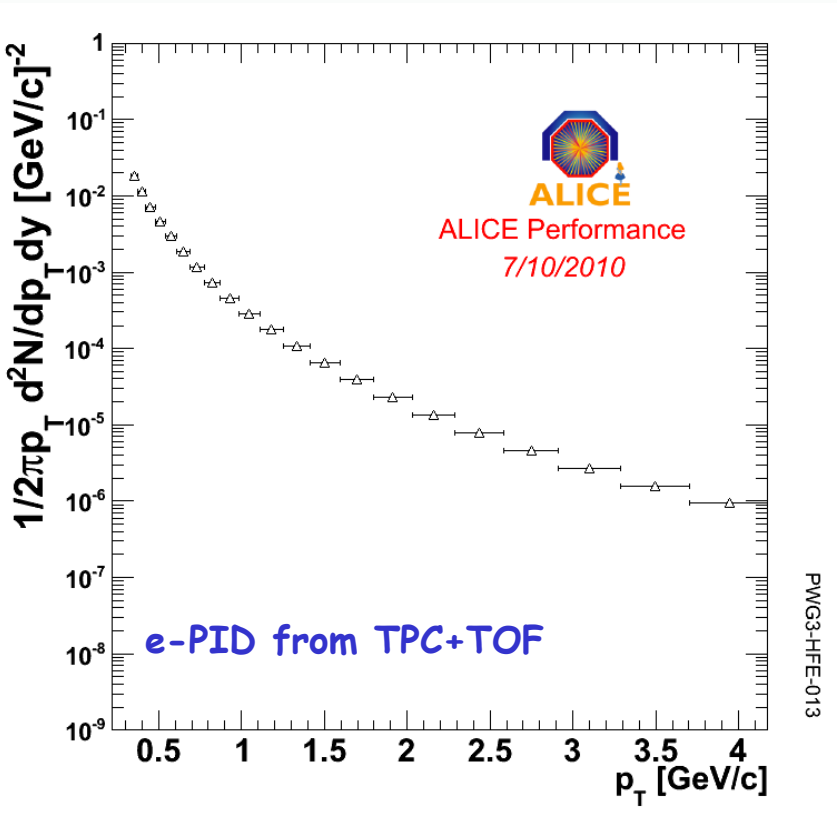
- ϒ melts only at LHC
- ϒ' T_D ~ J/ψ T_D
- Small ϒ regeneration
  →ϒ' can unravel J/ψ suppression VS regeneration

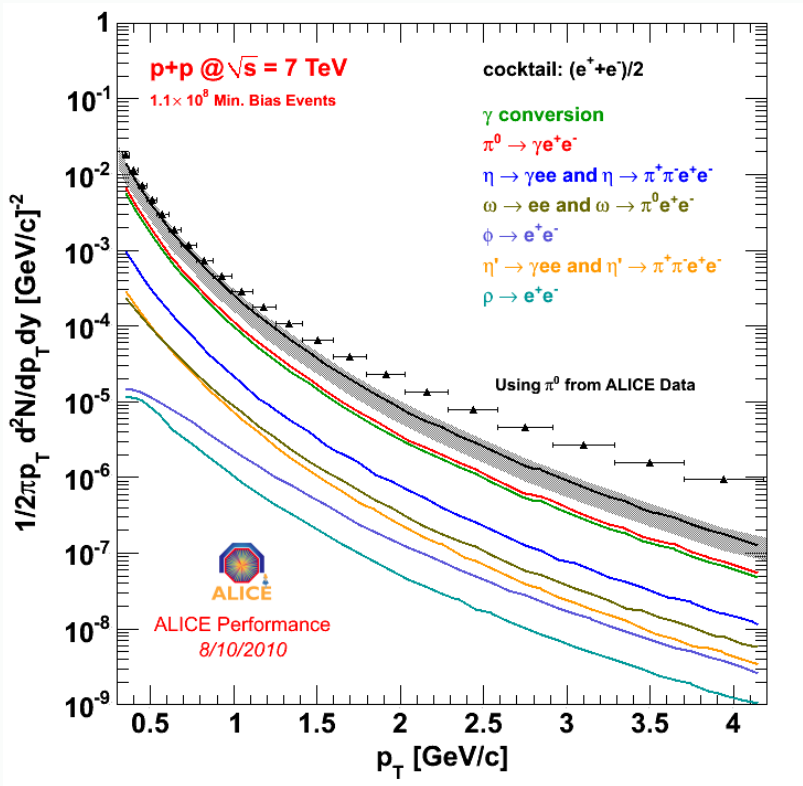


Charm measurement:

- Test of NLO pQCD
- Needed for quarkonia studies
- Reference data for PbPb

Single electron spectrum and cocktail

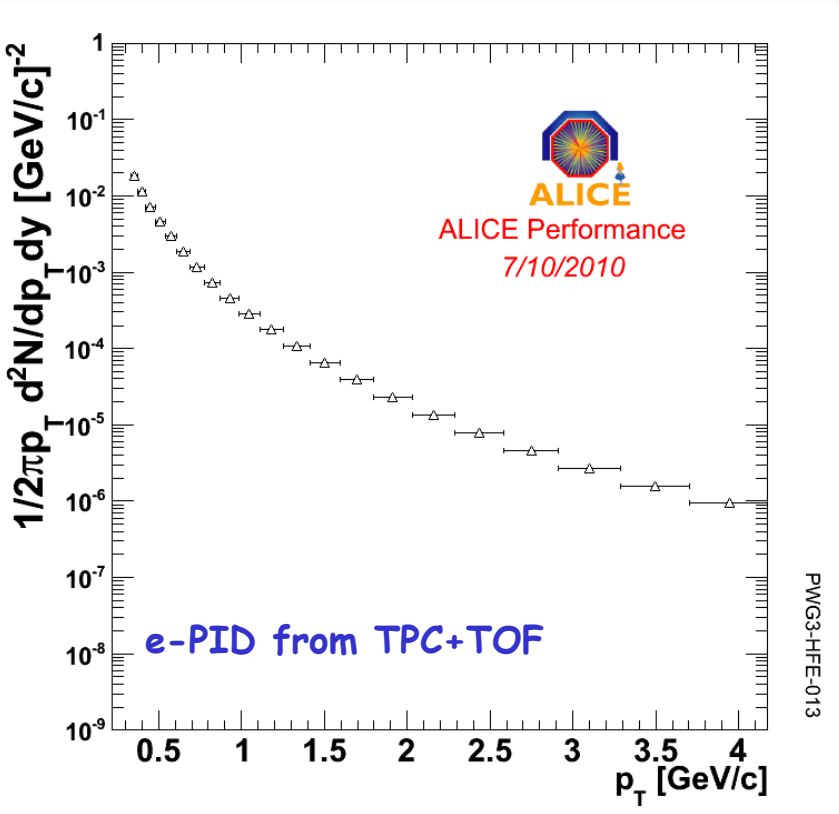


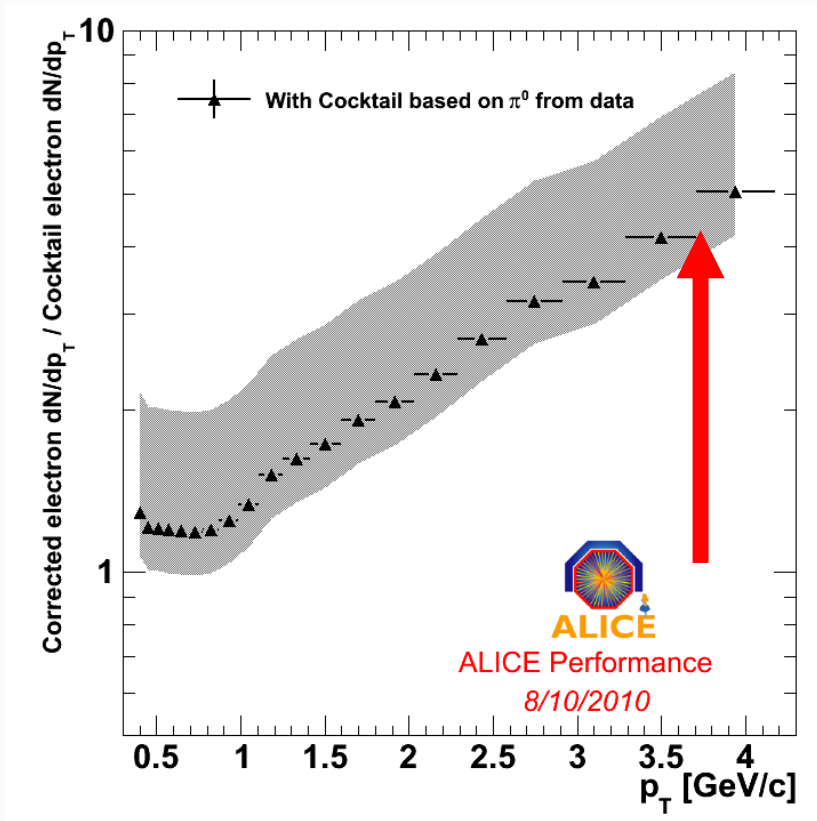


- Subtraction of residual hadronic contamination
- Corrections for acceptance and efficiency
- Correction for pT detector resolution (electron bremsstrahlung)

Excess from charm and beauty semileptonic decays, +(small contribution from J/ψ,and direct γ)

Single electron spectrum and cocktail





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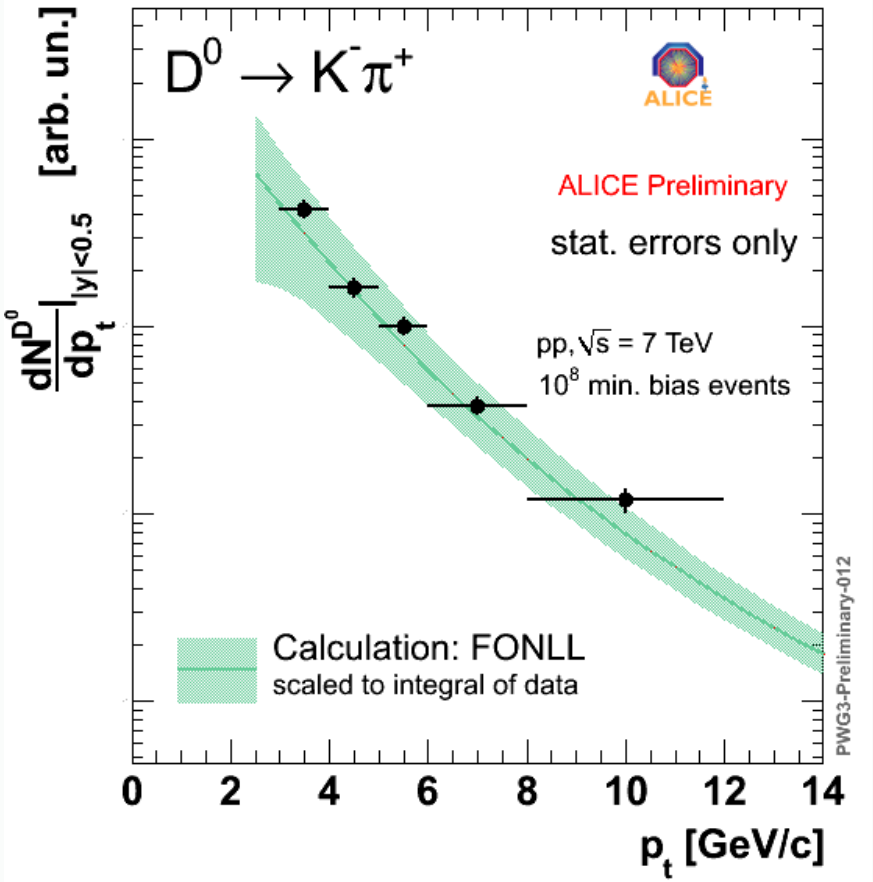
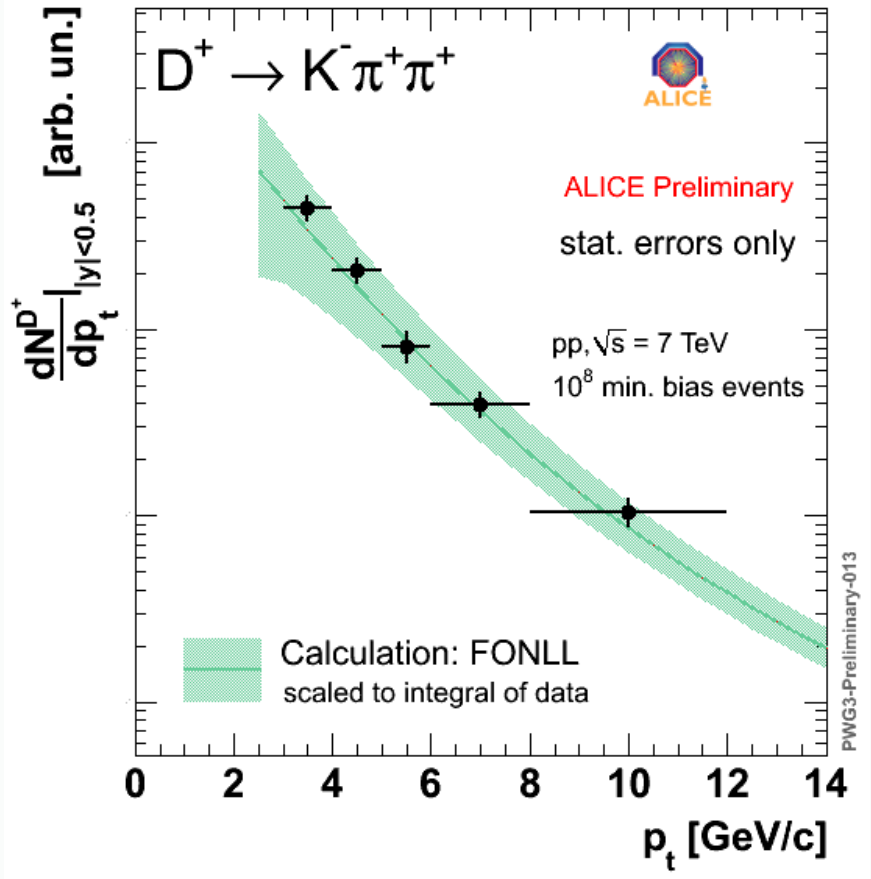
D^0 and D^+ transverse momentum





Shape compares well with pQCD (FONLL)

Ongoing: extension at low p_t and absolute normalization