J/ψ measurements in proton-proton collisions with the ALICE experiment at the LHC

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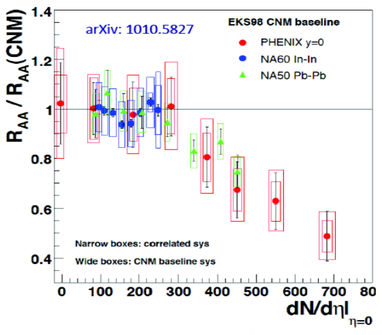
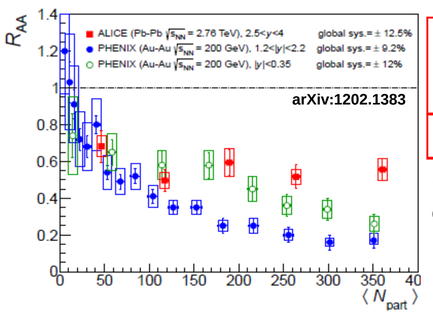
Physical Motivations

- Proton-proton collisions:
  - ✓ understand the J/ψ production mechanism by providing constraints for QCD calculations
    - ✓ the main theoretical approaches to explain quarkonium production in pp are Color Evaporation Model (CEM) and Color Singlet (CS) plus Color Octet (CO) NRQCD calculations at NLO
  - ✓ reference for A-A collisions
- p-A collisions:
  - ✓ important to understand Cold-Nuclear-Matter (CNM) effects (nuclear shadowing/anti-shadowing, gluon saturation, Cronin effect…)
- A-A collisions:
  - ✓ the J/ψ suppression via Color Debye Screening (T. Matsui and H. Satz, Phys. Lett. B178, 416) in heavy ion collisions is one of the proposed signals for the study of the hot and dense deconfined quark-gluon medium created





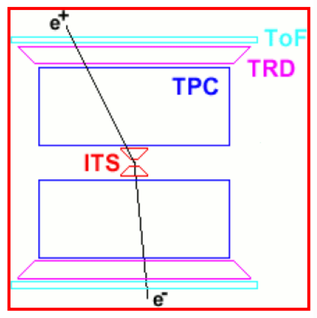
In most central A-A collisions	SPS 20 GeV	RHIC 200 Gev	LHC 2.76 TeV
N_{ccbar}/event	~0.2	~10	~60

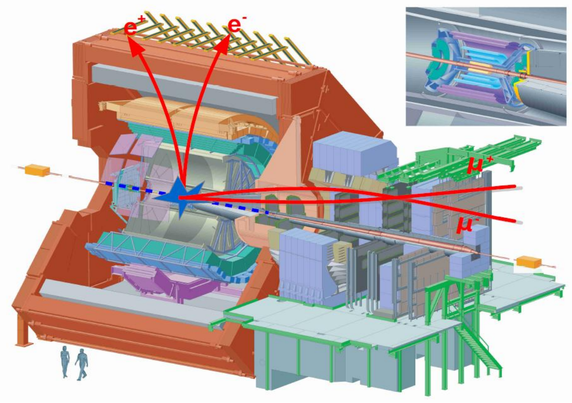
✓ Larger number of charm quarks created in Pb-Pb collisions at LHC

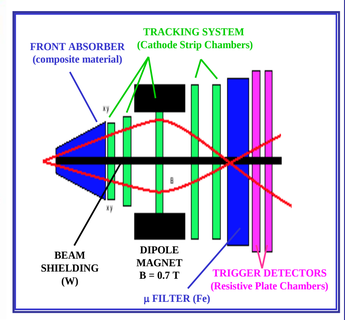
→ Regeneration vs suppression ?

✓ J/ψ suppressions observed at SPS and RHIC are surprisingly similar
✓ larger suppression at forward w.r.t. central rapidity observed at RHIC
✓ first results from ALICE (QM 2011) have shown a smaller suppression with respect to RHIC, compatible with J/ψ (re)generation (ALICE coll., arXiv:1202.1383) → deeper understanding now thanks to the high-lumi 2011 Pb run (see talks by: R. Arnaldi, I. Arsene, E. Scomparin)

J/ψ measurement in ALICE







J/ψ → e^+e^- at central rapidity ($|y| < 0.9$)

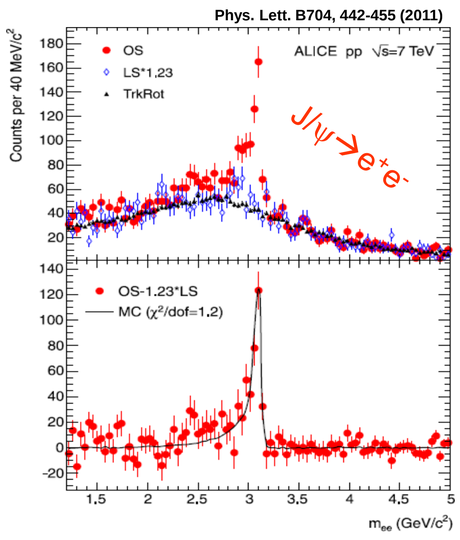
- good track quality: tracking with ITS+TPC (+TRD)
- electron identification by:
  - ✓ energy loss in TPC
  - ✓ time-of-flight from TOF (to reject proton and kaon at low momentum) and transition radiation signal from TRD (both are not used in the present analysis)
  - ✓ EMCAL: triggering and PID at high pt
- Good resolution on secondery vertex for displaced J/ψ (coming from B-hadron decays) thanks to the ITS

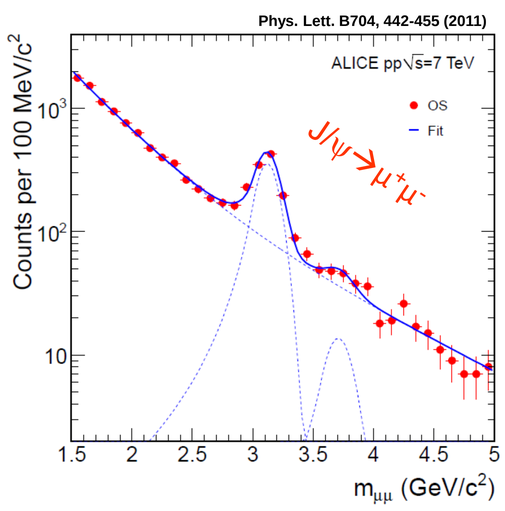
J/ψ → $\mu^+\mu^-$ at forward rapidity ($2.5 < y < 4$)

- Absorbers (to filter out hadrons):
  - ✓ Front absorber (carbon 2m, concrete 1.5m, steel 0.5m): designed to limit scattering and energy loss in muon path
  - ✓ Muon Filter(Fe): suppresses the hadron rate on trigger chambers
  - ✓ Beam shield (Pb and W, along pipe): protects detectors
- Tracking: 5 stations of Cathode Pad Chambers
- Trigger chambers: 2 stations of Resistive Plate Chambers

Inclusive J/ψ production cross section

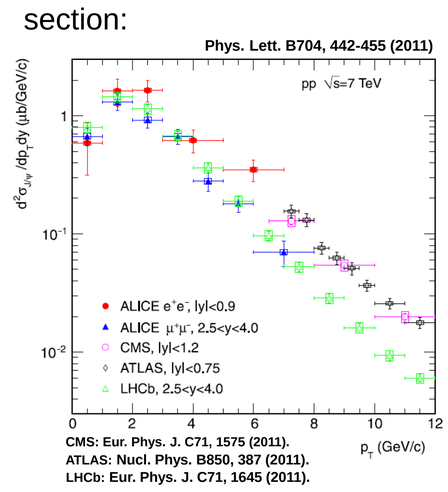
- Invariant mass distributions in proton-proton at √s = 7 TeV:

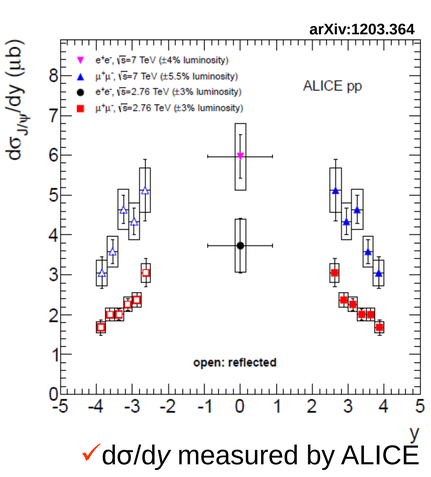




- 350 M minimum bias proton-proton events, L_{int}=5.6 nb^{-1}
- Signal extraction:
  - ✓ Like-sign ($N^{++}+N^{--}$) scaled to match with unlike-sign between 3.2-5 GeV/c^2
  - ✓ Bin counting in 2.92-3.16 GeV/c^2
- Triggered data, L_{int}=15.6 nb^{-1}
- Signal extracion:
  - ✓ function used for the fit: sum of two Cristal Ball for J/ψ and ψ(2S) plus two exponential terms for the background

- Transverse momentum and rapidity dependence of J/ψ cross section:





✓ dσ/dy measured by ALICE at mid and forward rapidity: comparison of results at √s=2.76TeV and √s=7TeV

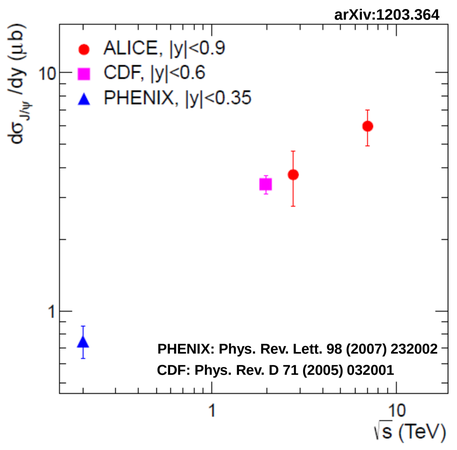
✓ vertical bars show statistical errors while boxes represent systematic uncertaintes

✓ dσ/dydp_T: comparison with CMS, LHCb and ATLAS results

✓ p_T distribution at mid-rapidity is harder than at forward rapidity

✓ At mid-rapidity CMS and ALICE cover complementary p_T ranges

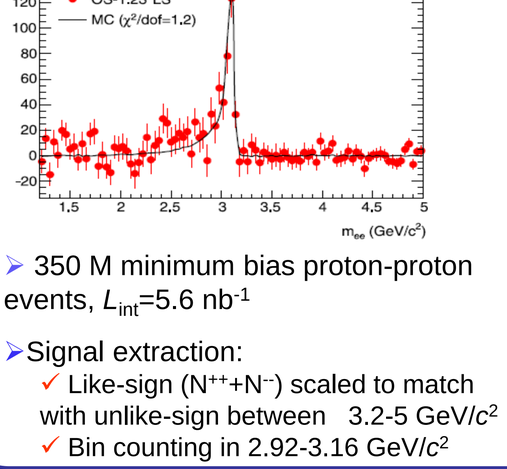
- √s dependence of J/ψ cross section:



✓ Kinematic coverage of the ALICE experiment is unique at LHC (down to p_T = 0 at central rapidity) → This allows a comparison with similar results from lower energy collider experiments

Polarization, multiplicity dependence and non-prompt J/ψ production in proton-proton at √s = 7 TeV

- J/ψ polarization ($2.5 < y < 4$)

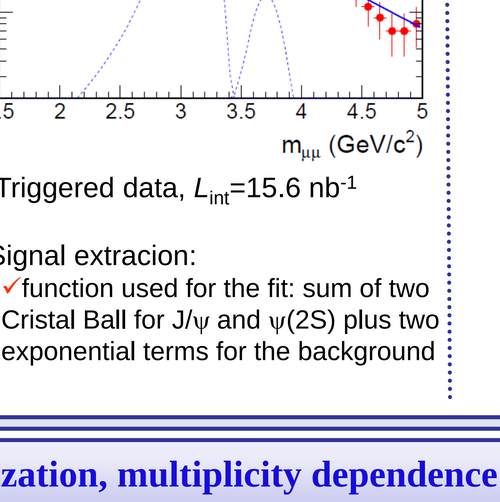


✓ Observables: angular distribution of decay muons
- ✓ Azimuthal angle φ → $W(\varphi) \propto 1+\frac{2\lambda_\varphi}{3+\lambda_\varphi}\cos 2\varphi$
- ✓ Polar angle θ → $W(\cos\theta) \propto \frac{1}{3+\lambda_\theta}(1+\lambda_\theta \cos^2\theta)$
- ✓ Reference frames considered: Helicity (HE) and Collins Soper (CS)

✓ Polarization very small: λ_θ and λ_φ close to zero (inclusive J/ψ considered)

✓ Crucial test for models → e.g. NLO CS model [1] predicts large longitudinal polarization in HE frame (λ_θ = -0.6 for p_T = 5 GeV/c)

- J/ψ production as a function of multiplicity

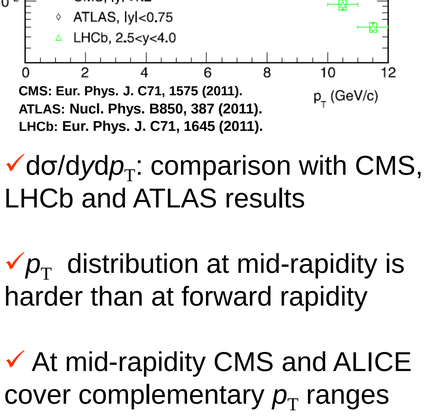


✓ Division into event classes
- ✓ up to ~ five times mean multiplicity (dN_{ch}/dη =30). Comparable to semi-peripheral Cu-Cu collisions with √s = 200 GeV (RHIC)

✓ Approx linear increase of J/ψ yield as a function of multiplicity

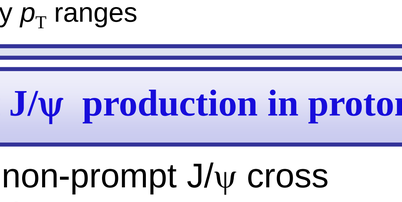
✓ Similar at mid- and forward rapidity (dN_{ch}/dη always at mid-rapidity)

- Prompt and non-prompt J/ψ cross section ($|y|$<0.9)



ATLAS: Nucl. Phys. B850, 387 (2011).
CMS: Eur. Phys. J. C71, 1575 (2011).

✓ p_T distribution of prompt J/ψ. Good agreement with NRQCD calculations that includes CS and CO contributions [2,3,4]



✓ y distribution of non-prompt J/ψ. Good agreement with FONLL [5] calculations

CMS: Nucl. Phys. B850, 387 (2011).
LHCb: Eur. Phys. J. C71, 1645 (2011).

✓ Total $b\bar{b}$ cross section using FONLL [5] for extrapolation to p_T=0

$$\sigma(pp \to b\bar{b} + X) = 244 \pm 64(stat)^{+90}_{-59}(syst)^{+7}_{-8}(extr)$$

Conclusions

- Inclusive spectra and cross section at √s = 7 TeV down to p_T = 0 → good agreement with NRQCD calculations
- Results at √s = 2.76 TeV → reference for heavy ion studies
- No significant polarization in the forward region (√s = 7 TeV)
  - ✓ first polarization measurement at LHC
- Results on prompt, non-prompt J/ψ and estimate of $b\bar{b}$ cross section ($|y| < 0.9$)
  - ✓ unique measurement at central rapidity at low p_T
- Linear increase of inclusive J/ψ yield ($|y|$<0.9 and 2.5<y<4) with dN_{ch}/d$\eta|_{y=0}$

References:

[1] Buthenshön and Kniehl, Phys. Rev. Lett. 108 172002 (2012).
[2] Butenschön and Kniehl, Phys. Rev. Lett. 106, 022003 (2011).
[3] Y.-Q. Ma, K. Wang, K.T. Chao, Phys. Rev. Lett. 106, 042002 (2011).
[4] Saleev, Nefedov and Shipilova, Phys. Rev. D 85, 074013 (2012).
[5] Cacciari, Frixione, Mangano, Nason and Ridolfi, JHEP 07, 033 (2004).