Azimuthal J/Ψ-Hadron Correlations in Proton-Proton Collisions @ √s=7TeV

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Azimuthal J/Ψ-Hadron Correlations in pp @ √s=7 TeV

Outline

1) Physics Motivation
2) J/Ψ with ALICE at Mid-Rapidity
3) Analysis Method
4) First Results
5) Conclusion and Prospects

1) Physics Motivation

J/Ψ-production in hadronic collisions known since 1974

Difficult to describe in pp ($p\bar{p}$) collisions:

→ multiscale problem involving bound state physics

3 intrinsic scales:

a) charm quark mass

b) typical momentum of c-quarks in $c\bar{c}$ rest frame

c) binding energy

extrinsic scale m_T: perturbative $c\bar{c}$-production

J/Ψ-production in pp ($p\bar{p}$):

→ test for **factorization** of hard $c\bar{c}$-production and binding

References: discovery of J/Ψ in p beam on Be: E598 Collaboration, Phys.Rev.Lett, vol 33, p. 1404-1406, 1974
recent review (experimental and theoretical): arXiv:1010.5827v3 [hep-ph]

1) Physics Motivation

- Several theoretical approaches to charmonium in pp ($p\bar{p}$)
  - → Color Singlet Model (CSM) at higher order (NLO and NNLO*)
  - → Non-Relativistic QCD: combining Color Singlet & Color Octet contributions (NLO)
  - → Color Evaporation Model (CEM)
- Interpretation of cross section and polarization at pp ($p\bar{p}$)-colliders challenging for theory
- Understanding of J/Ψ-production in pp ($p\bar{p}$) contributing to clearer picture of J/Ψ-production in heavy-ion collisions

Recent theory references (no claim of completeness)

CSM: J.P. Lansberg, EPJC 61,693,2009, Talk at ICHEP 2012;

NRQCD: M. Butenschön and B. Kniehl 2012: PRL 108:172002, Talk at ICHEP 2012 by M. Butenschön;
Chao et al. 2012: PRL 108:242004; Gong et al. 2012: http://arxiv.org/pdf/1205.6682v1.pdf ;

CEM: R. Vogt: talk at 4th Berkeley school 2012;

Ansatz with unintegrated PDFs and reggeized gluons: Saleev et al.: Phys.Rev. D85 (2012) 074013

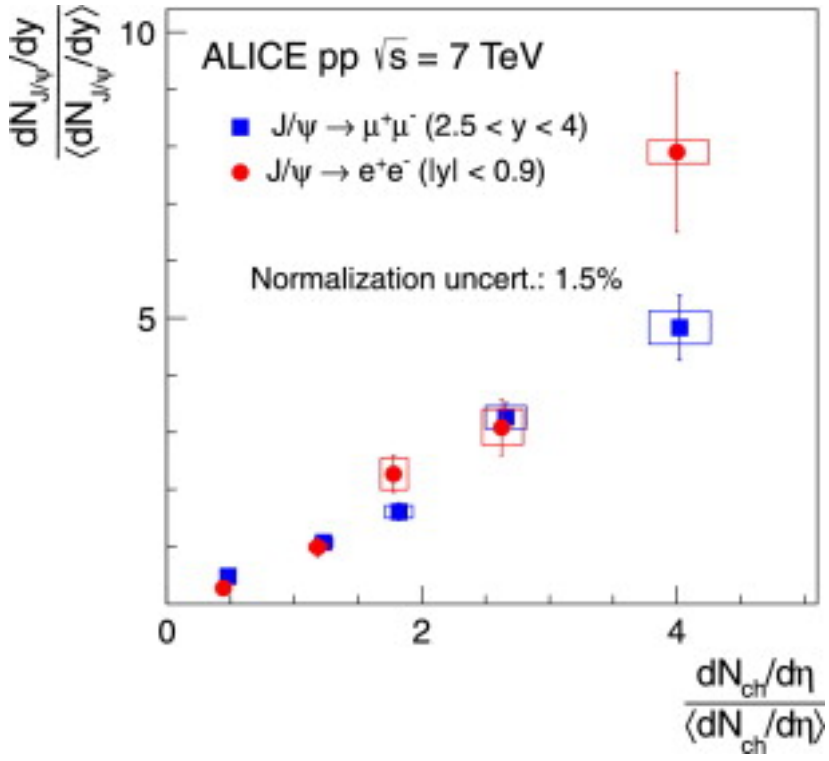
1) Physics Motivation

- Additional aspect:
  relation of J/Ψ-production in pp

  with global event characteristics

  → Multiplicity dependence

  measured by ALICE Collaboration



- Several possible explanations

  - Multi-Parton Interactions (MPI)

  - dependence of hard production processes on impact parameter and on gluon density fluctuations

  → Need for additional observables to understand J/Ψ-production in pp

References: ALICE measurement: Physics Letters B, Vol.7, No.3, p. 165 – 175, 2012,
MPI: S. Porteboeuf, R. Granier de Cassagnac, http://arxiv.org/abs/1012.0719v1,
geometry and gluon density fluctuations: M. Strikman, PHYSICAL REVIEW D 84, 011501(R) (2011)

1) Physics Motivation

Correlations between J/Ψ and charged hadrons:

→ **J/Ψ-hadron**: hadronic „activity“ associated with J/Ψ at azimuthal angles of 0 or π?

→ **J/Ψ - leading-p_T:** J/Ψ @ 7 TeV (un)correlated with high-p_T particle production?

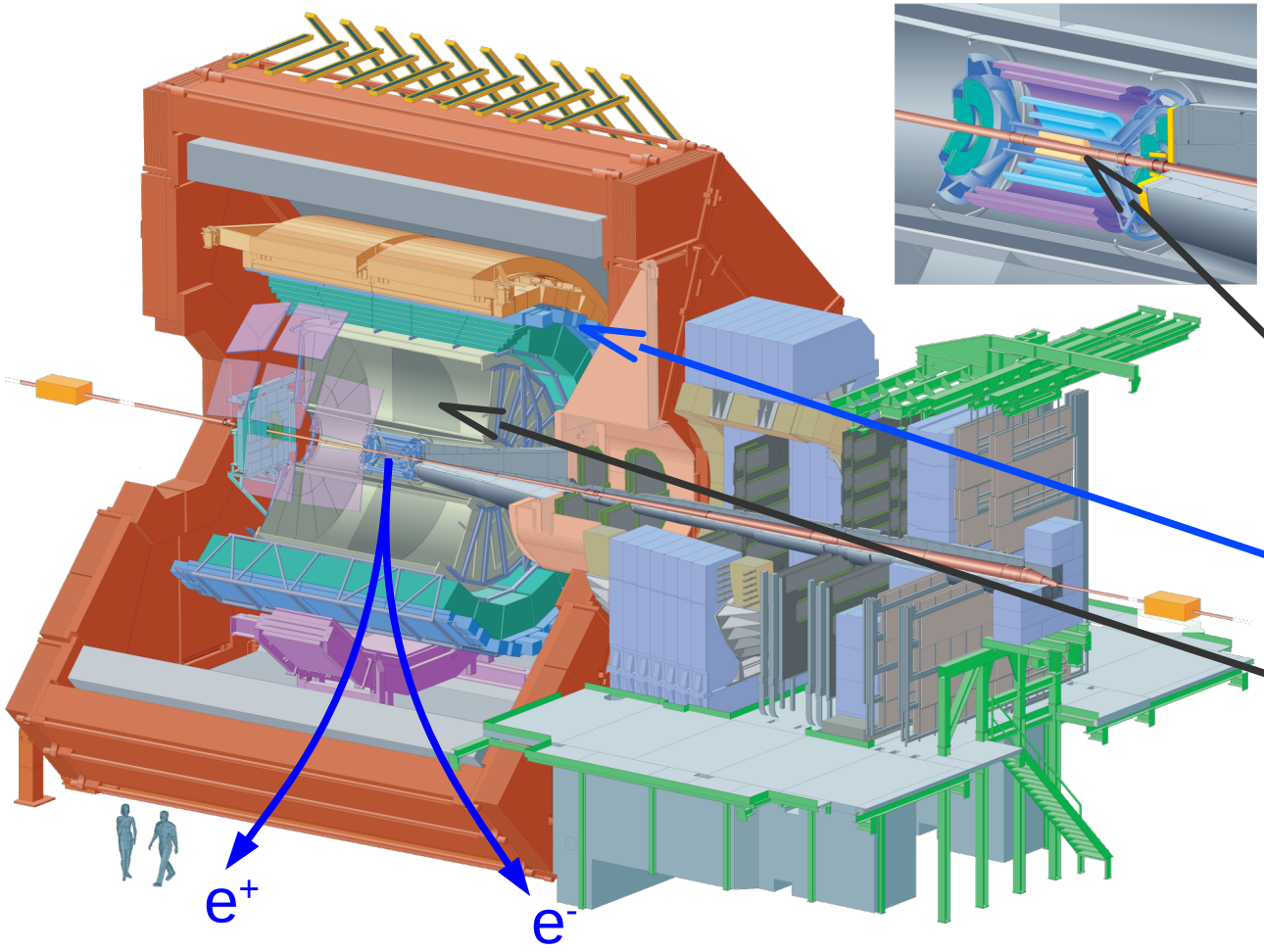
Complementary observables to cross section, polarization and multiplicity dependence

In the past, J/Ψ-hadron correlations used for b-feed-down determination in pp ($p\bar{p}$)*;

At the LHC and the TEVATRON 2^{ndary} vertexing used (silicon detectors)

*Reference: STAR: arXiv:1012.0233v1; UA1: Phys. Lett. B Volume 200 no. 3 ('87)

2) J/Ψ with ALICE at Mid-Rapidity



Acceptance:
$0 < \varphi < 2\pi$
$|\eta^e| < 0.9$
$p_T > 0$ GeV/c

Detectors used for tracking and/or for PID in this analysis:

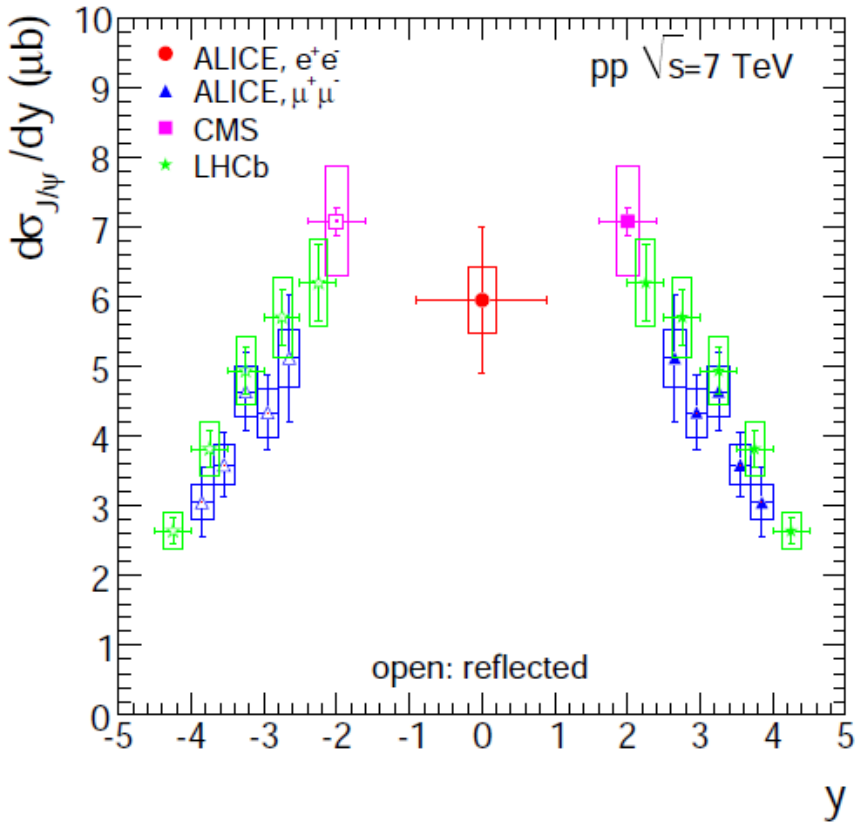
Inner Tracking System

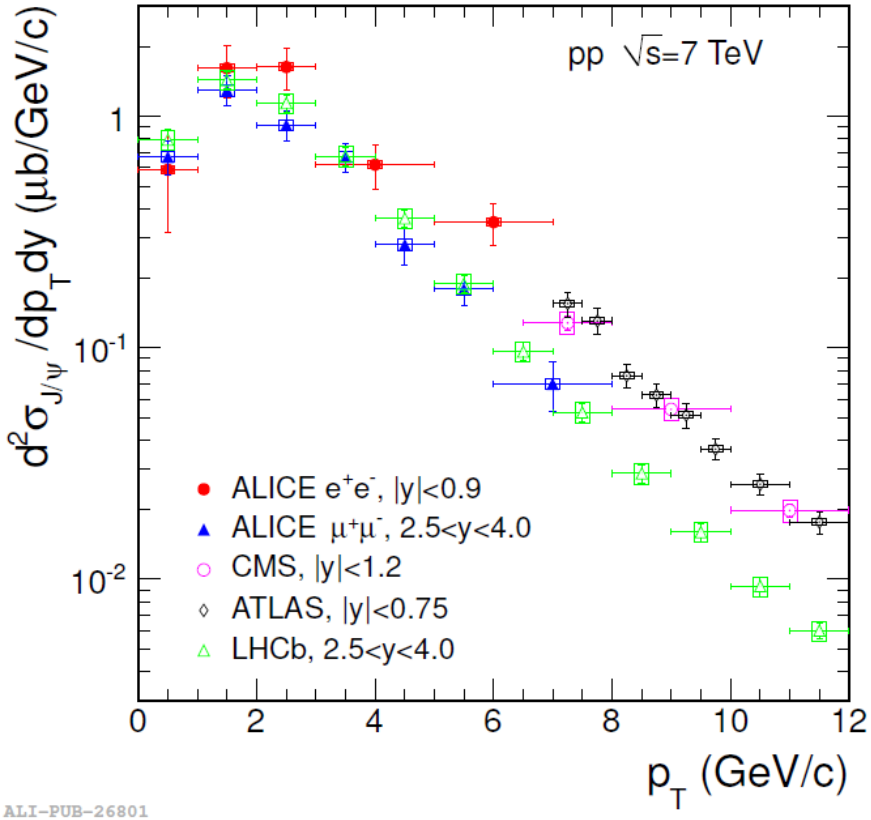
Time Of Flight detector (TOF)

Time Projection Chamber(TPC)

J/Ψ at mid-rapidity with ALICE via dielectron channel

2) J/Ψ with ALICE at Mid-Rapidity



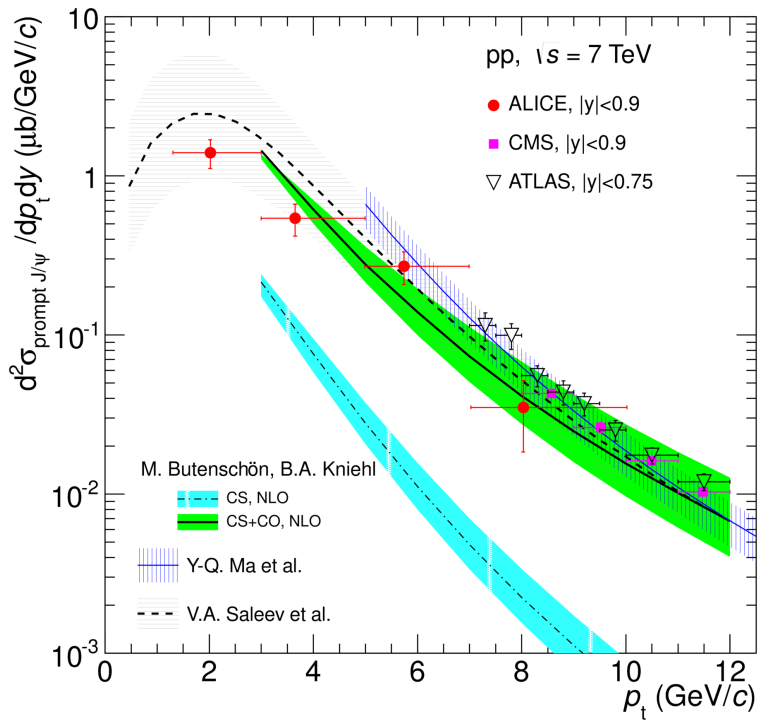


Bulk of inclusive J/Ψ at mid-rapidity (down to p_T = 0 GeV/*c*)

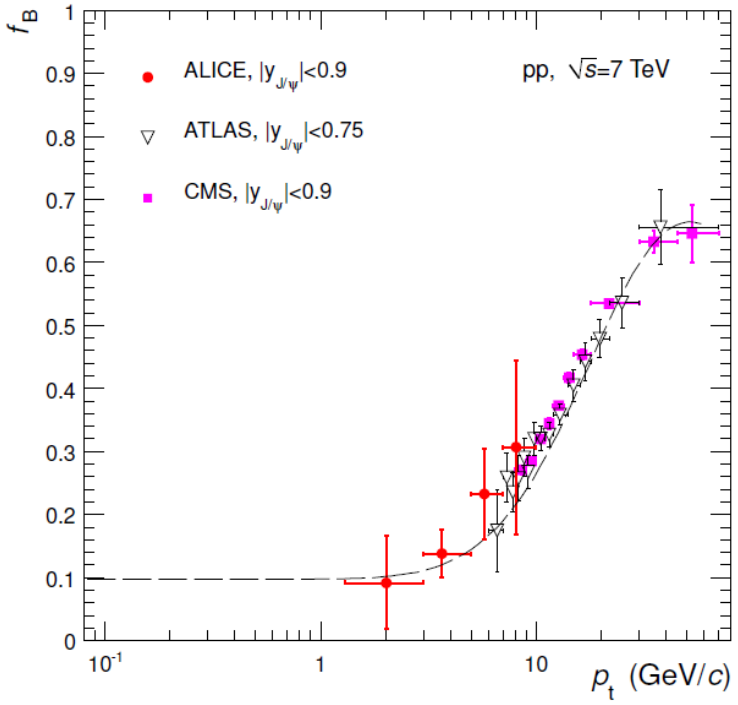
→ most important benchmark for J/Ψ in heavy-ion collisions

References ALICE measurement at 7 TeV: inclusive J/Ψ: *Phys.Lett. B704 (2011) 442-455,arxiv.org/abs/1105.0380 ;*

2) J/Ψ with ALICE at Mid-Rapidity



ALI-PUB-16286



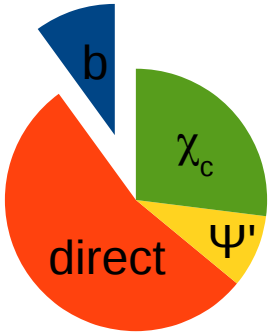
ALI-PUB-16282

Dashed line: phenomenological parametrization relying on:
F. Bossu, Z. Conesa del Valle, A. de Falco et al., arXiv:1103.2394 (2011) (for inclusive J/Ψ) and M. Cacciari, S. Frixione, M.L. Mangano, P. Nason, and G.Ridolfi, J. High Energy Phys.07, 033(2004)(for J/Ψ from B)

Able to disentangle feed-down from b-hadrons in pp

N.B.: J/Ψ in hadronic collisions:

- feed-down from b-hadrons: „non-prompt“
- feed-down from χ_c's and Ψ' contributes to „prompt“ J/Ψ

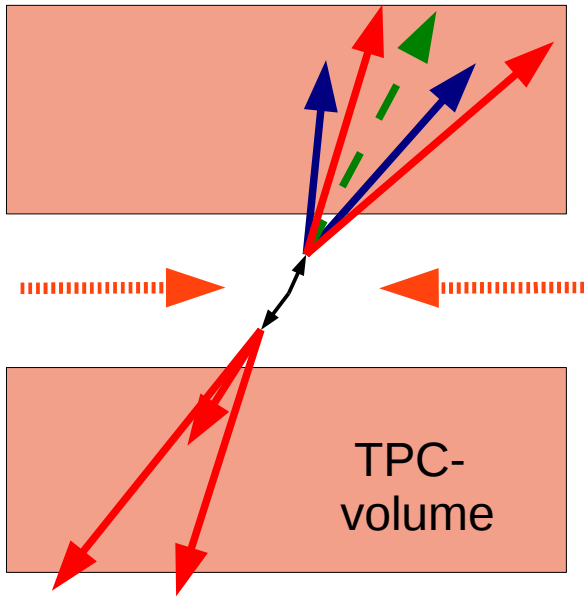


Reference: non-prompt and prompt J/Ψ measured by ALICE: *arxiv.org/abs/1205.5880*

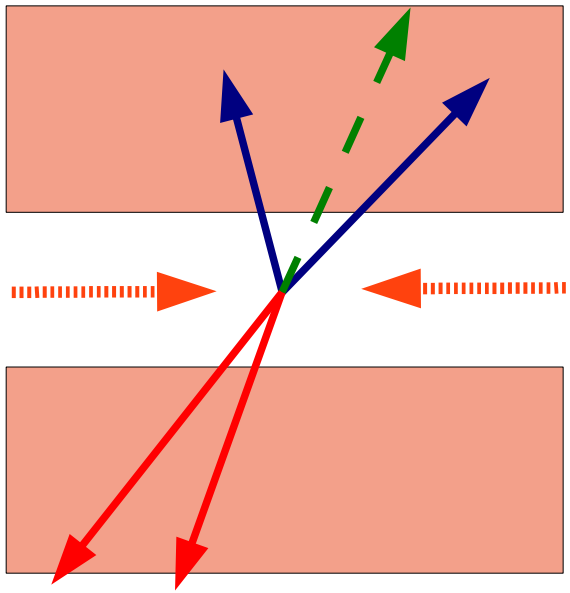
2) J/Ψ with ALICE at Mid-Rapidity

J/Ψ-production signatures in ALICE

$gg \rightarrow b\bar{b} \rightarrow$ J/Ψ + X



$gg \rightarrow$ J/Ψ + g
(LO in Color Singlet Model)



protons from LHC-beam

detected e^+/e^-

J/Ψ decaying in e^+-e^--pair

detected hadron. tracks

b-hadron, flight distance just illustration

→ better understanding of J/Ψ-production using event topology

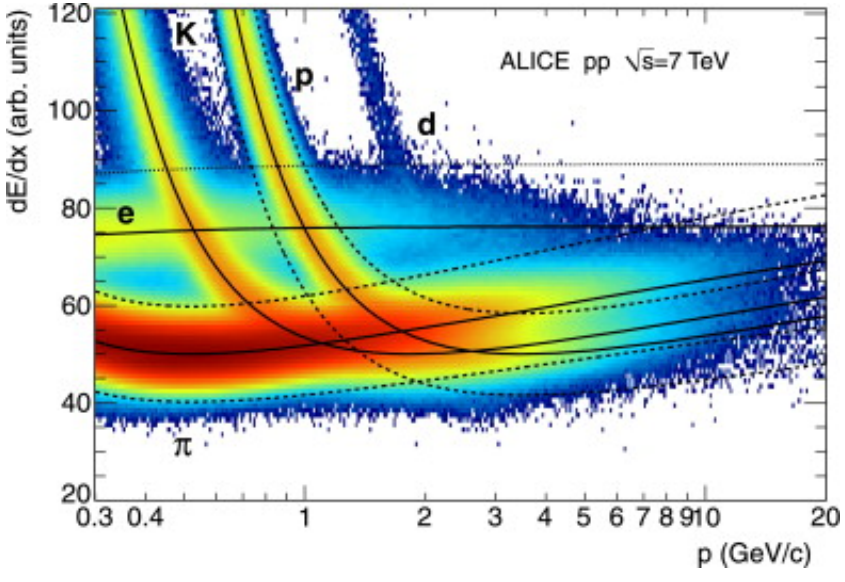
3) Analysis Method: Specifics

- For first analysis: Minimum-Bias events from 2010 @7TeV
  $3.5*10^8$ pp-events after quality selection, sample as for cross-section measurement
- Differences wrt. published cross section measurement:

  - Restrict $|\eta_{e+e-}|$ and $|\eta_{h\pm}|$ to the same range $|\eta| < 0.9$ instead of $|y|<0.9$

  - only relative efficiency for J/Ψ needed:

    → optimize statistics by using TOF in d*E*/d*x*-crossing of TPC-(anti)proton and -(positron)electron band



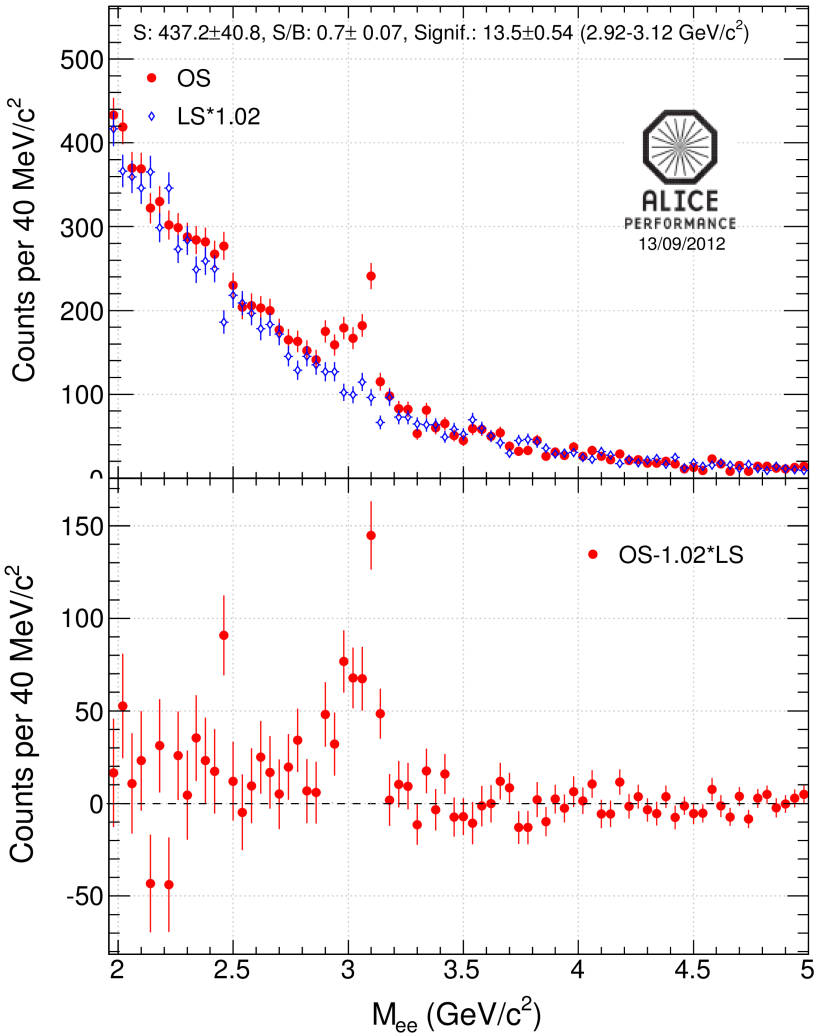
TPC-PID after quality cuts
Phys.Lett. B704 (2011) 442-455

3) Analysis Method: J/Ψ-Extraction

→ increased signal efficiency with comparable significance

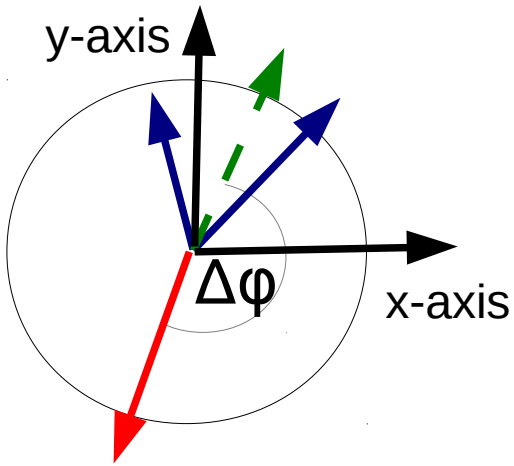
compared to cross section measurement in same sample although $|\eta_{e+e-}| < 0.9$ instead of $|y_{e+e-}| < 0.9$

→ background description under study



inclusive J/Ψ-cross section measurement: *Phys.Lett. B704 (2011) 442-455,http://arxiv.org/abs/1105.0380:*
352 ±32 (stat.)±28 (syst.) signal counts with significance: 13.9

3) Analysis Method: Corrections



- Corrections applied on Δφ-correlations:

  1) MC driven tracking efficiency correction

     for associated tracks as a function of p_T :

     entry weighting of with inverse MC-tracking efficiency

  2) φ-dependent efficiency/acceptance effects

     same event Δφ-distributions corrected by division of mixed event Δφ-distributions sorted in classes of dielectron invariant mass

- No additional dielectron-efficiency correction so far

  → not of primary importance, since all correlation results normalized by number of dielectron pairs or J/Ψs, no strong dependence of efficiency on J/Ψ-p_T in exploited p_T-interval

3) Analysis Method: Background Treatment

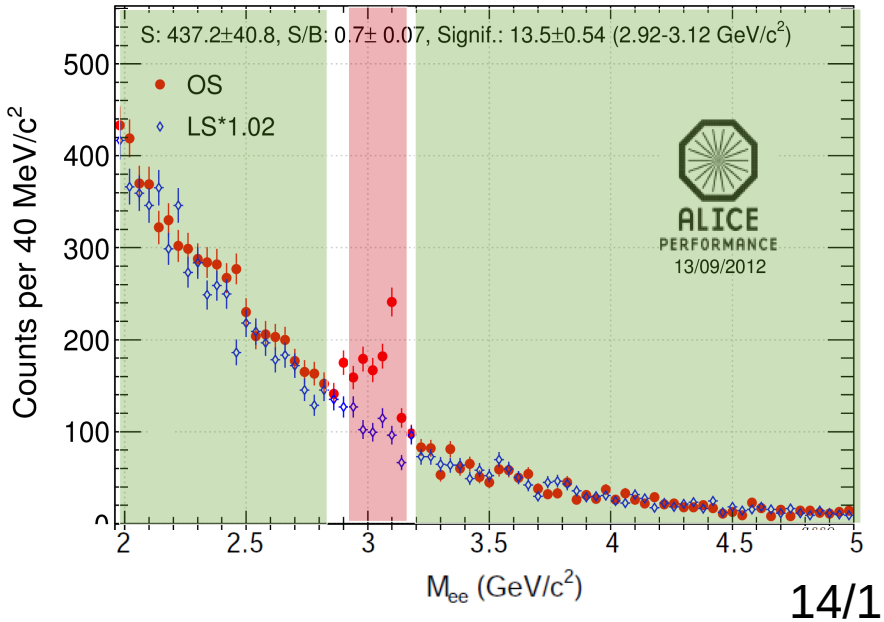
- Not background free and significant correlation of background
- Various background sources
  ($e^{\pm}$ from photon conversions, open charm/bottom, Drell-Yan, non $e^{\pm}$-contamination)
- Precise event generator description difficult

  → data driven subtraction using information from invariant mass regions next to the J/Ψ-peak

$$\frac{dN_{ass.,e^+e^-}}{d(\Delta\phi)} = \frac{dN_{ass.,J/\psi}}{d(\Delta\phi)} + \frac{dN_{ass.,bkg}}{d(\Delta\phi)}$$

$$= N_{J/\psi} \cdot \boxed{\frac{1}{N_{J/\psi}} \frac{dN_{ass.,J/\psi}}{d(\Delta\phi)}}$$

From correlation of dielectron pairs in J/Ψ-mass region
From correlation in sidebands of J/Ψ-peak
Rectangle: physical quantity to be extracted
Solid lines „directly“ available after corrections
Broken lines: bkg. subtraction or interpolation involved

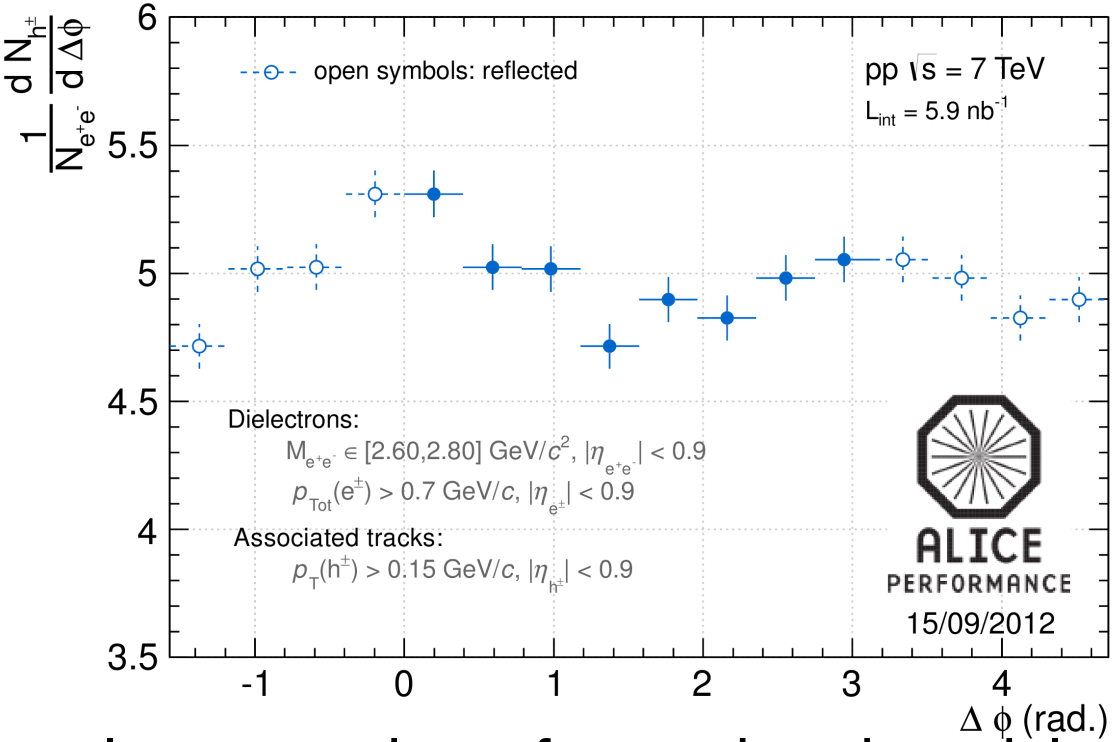


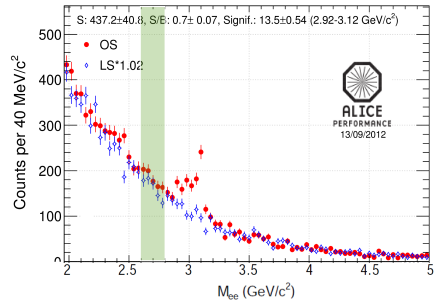
4) First Results: smaller invariant Mass than J/Ψ

- Tracking efficiency corrected and mixed event divided correlation in $m_{e+e-} \epsilon$ [2.6,2.8] GeV/c^2

$$\frac{1}{N_{e^+e^-}} \frac{dN_{asso.,e^+e^-}}{d(\Delta\phi)}$$

→ part of background estimate for final extraction of J/Ψ-correlation





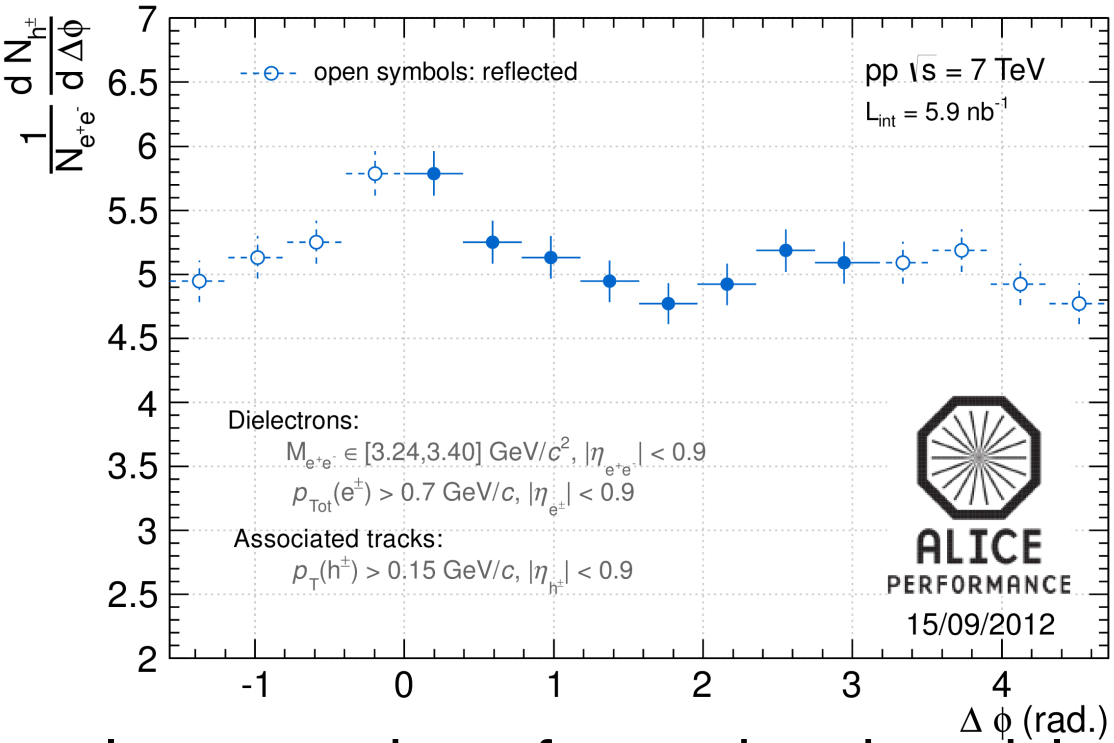
→ large number of associated particles

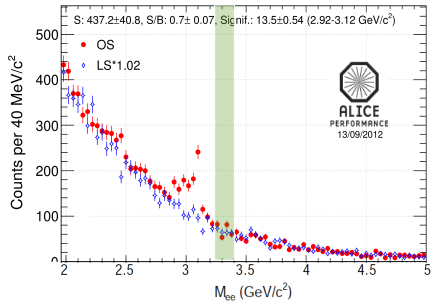
4) First Results: larger invariant Mass than J/Ψ

- Tracking efficiency corrected and mixed event divided correlation in $m_{e+e-} \in [3.24,3.4]$ GeV/c^2

$$\frac{1}{N_{e^+e^-}} \frac{dN_{asso.,e^+e^-}}{d(\Delta\phi)}$$

→ part of background estimate for final extraction of J/Ψ-correlation





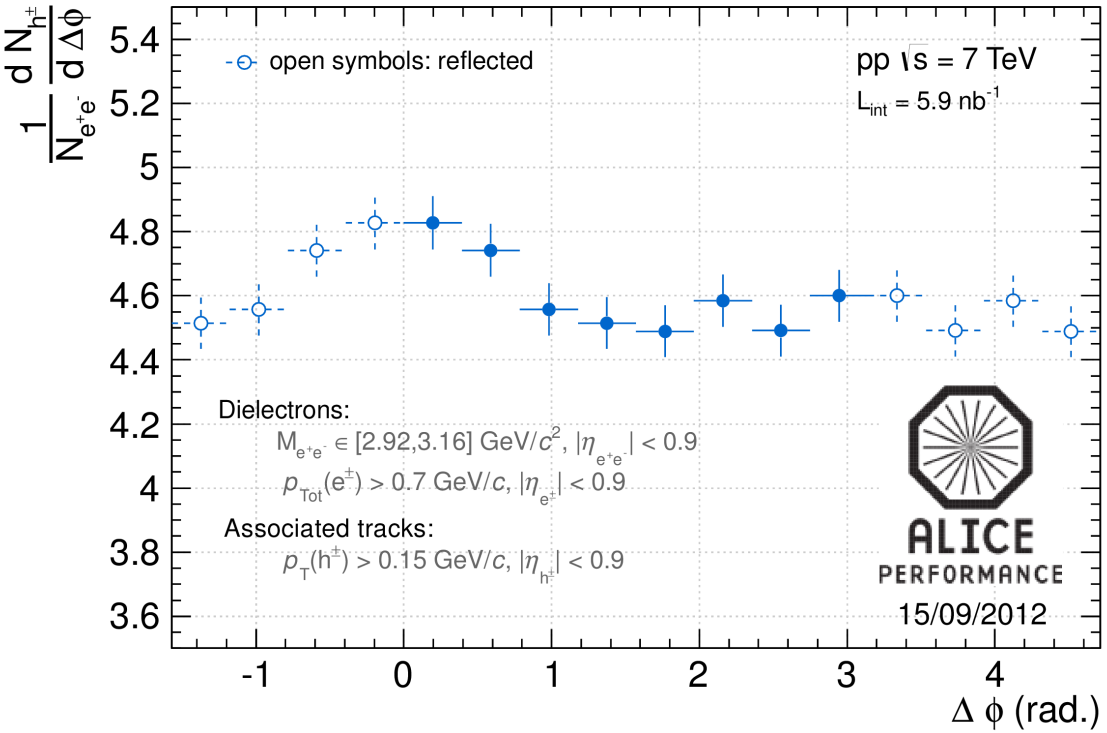
→ large number of associated particles

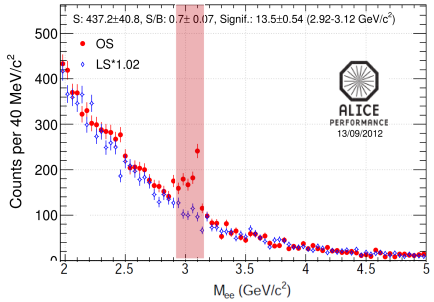
4) First Results: J/Ψ-Signal Region

- Tracking efficiency corrected and mixed event divided raw correlation in $m_{e+e-} \in [2.92,3.16]$ GeV/c^2

$$\frac{1}{N_{e^+e^-}} \frac{dN_{asso.,e^+e^-}}{d(\Delta\phi)}$$

→ invariant mass interval for final extraction of J/Ψ-correlation





→ large number of associated particles

5) Conclusion

- Theoretical understanding in pp collisions challenging

  → at high p_T, but even more at low p_T

- J/Ψ-hadron correlations providing additional information

- ALICE: opportunity to investigate J/Ψ-events at midrapidity in detail including correlations

- Analysis started for Minimum Bias sample @ 7 TeV
- Main measurement difficulties:

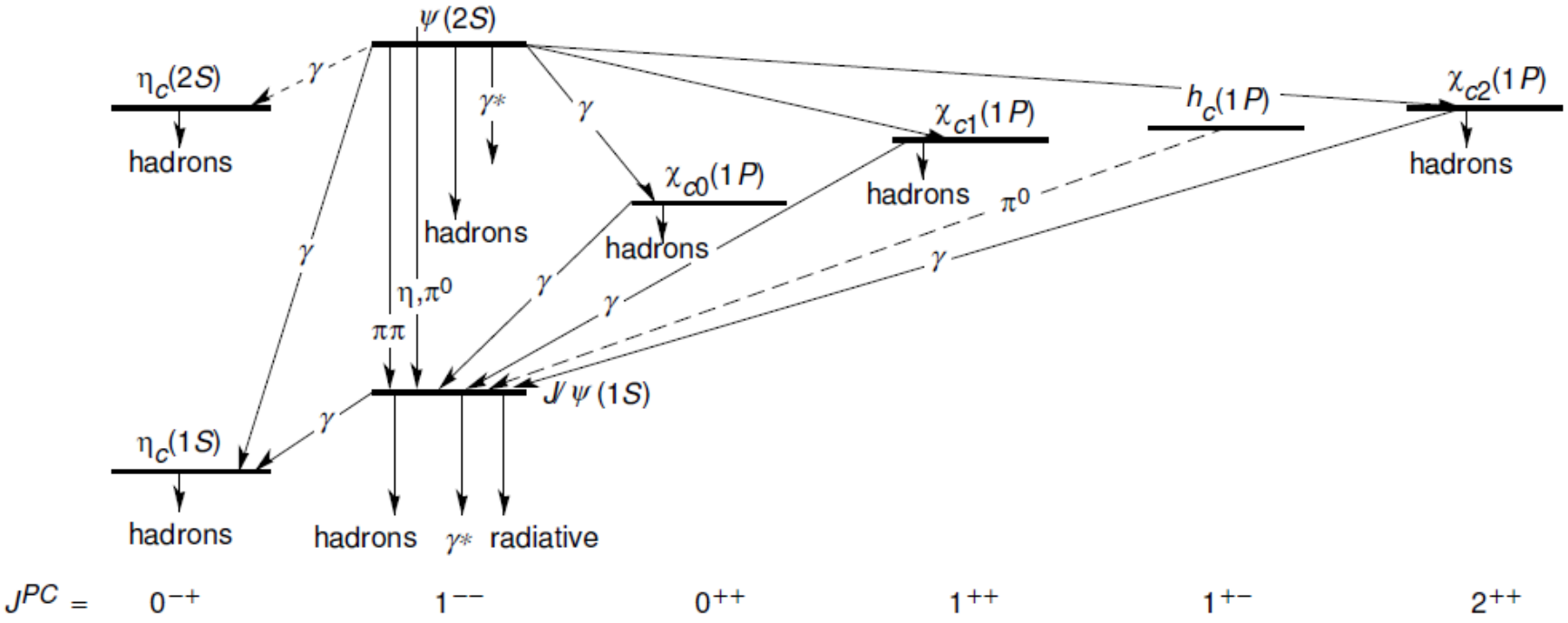
  → limited statistics

  → correlated background

5) Prospects

- Background-subtracted inclusive-J/Ψ - hadron correlation
- Analysis on first calorimeter triggered J/Ψs at higher p_T from 2011
- Analysis will profit in future from increased J/Ψ-statistics in pp-collisions using calorimeter and Transition Radiation detector triggers
  - → for different p_T-intervals, for J/Ψ and $h^{\pm}$
  - → prompt J/Ψ-hadron correlations
  - → multiplicity dependence of correlation

Back-Up: Charmonium Spectrum



Meson	$n^{2S+1}L_J$	J^{PC}	Mass (GeV)	$\Gamma_{\mu\mu}$ (keV)
η_c	$1\ ^1S_0$	0^{-+}	2.980	N/A
J/ψ	$1\ ^3S_1$	1^{--}	3.097	5.40
$\chi_{c0},\ \chi_{c1},\ \chi_{c2}$	$1\ ^3P_{0,1,2}$	$0^{++},1^{++},2^{++}$	3.415,3.511,3.556	N/A
h_c	$1\ ^1P_0$	1^{+-}	3.523	N/A
$\eta_c(2S)$	$2\ ^1S_0$	0^{-+}	3.594	N/A
ψ'	$2\ ^3S_1$	1^{--}	3.686	2.12

Reference: S. Eidelman et al. [Particle Data Group Collaboration], Phys. Lett. B 592 (2004) 1.

Back-Up: Feed-Down Contributions to J/Ψ

CDF measurement at TEVATRON (√s=1.8 TeV):

χ_c and Ψ' feed-down contributions to J/Ψ

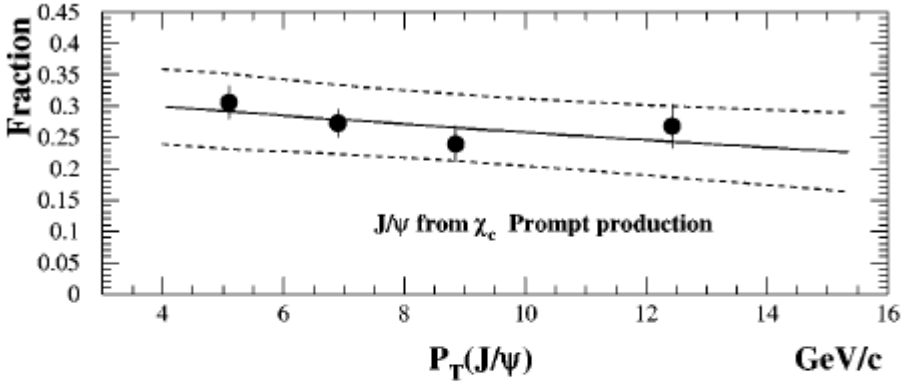


FIG. 2. The fraction of J/ψ mesons from χ_c decays as a function of $P_T^{J/\psi}$ with the contribution from b's removed. The error bars correspond to the statistical uncertainty. The solid line is the parametrization of the fraction. The dashed lines show the upper and lower bounds corresponding to the statistical and systematic uncertainties combined.

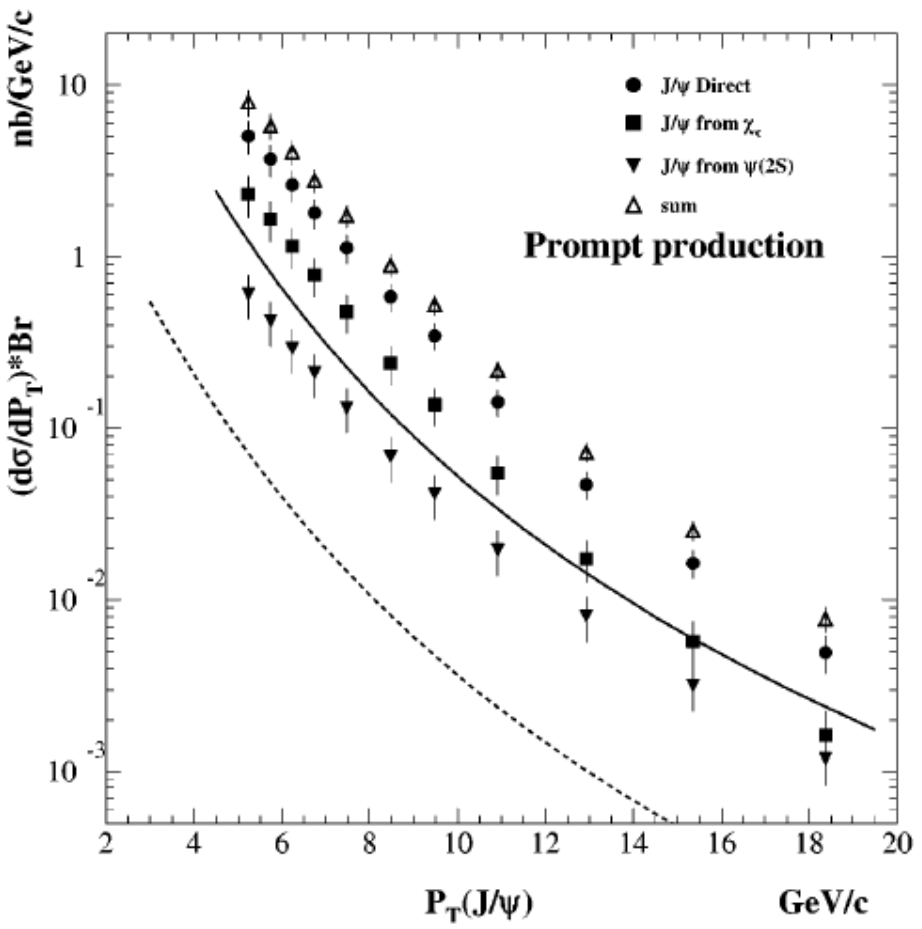


FIG. 3. The differential cross sections of prompt $J/\psi \to \mu^+\mu^-$ as a function of $P_T^{J/\psi}$. The dashed curve is the color singlet calculation for J/ψ production. The solid curve is the calculation of $\chi_c \to J/\psi\gamma$ production and includes both color singlet and color octet contributions. The error bars correspond to the statistical and systematic uncertainties combined and include the uncertainties common to all data points.

PHYSICAL REVIEW LETTERS VOLUME 79, NUMBER 4 p. 578 (1997)

Back-Up: applied Selection Criteria

- event cuts
  require vertex
  minVtxContributors 1
  z-vertex-positon: -10 - + 10 cm

- track cuts
  TPConly tracks
  p_T>150 MeV/c^2
  #Cluster>70 (from max. 159)
  χ^2/n.d.f. < 4
  |η|<0.9
  |DCAxy|< 2.4 cm
  |DCAz| < 3.2 cm
  no kink daughters

- leg cuts
  |nsigTPCelectron|<3
  |nsigTPCkaon|>3&&|nsigTPCpion|>3
  |nsigTPCproton|>3 || (|nsigTPCproton|<3&&|nsigTOFelectron|<3)
  |DCAz| < 3.0 cm
  |DCAxy| < 1.0 cm

  |η|<0.9
  no kink daughters
  χ^2/n.d.f. < 4
  p > 0.7GeV/*c*
  TPC, ITS refit
  #Cluster>70 (from max. 159)
  X^2/n.d.f. < 4
  SPDany

- pair cuts
  |η|<0.9
  pair prefilter: reject pairs with M_{pair} <50 MeV/c^2 and preselected conversions