Double $J/\psi$ Production at LHCb

On behalf of the LHCb Collaboration

Andrew Cook

University of Bristol, UK.

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Motivation I

- $J/\psi$ is quarkonia; a heavy quark-antiquark meson.
- Quarkonia production is an ideal testing ground for QCD.
- Described by NRQCD:
  - Perturbative short distance process.
  - Non-perturbative long distance process.
  - Colour octet (CO) and colour singlet (CS) models.
- Models of production cannot describe both the kinematics and polarisation.
- More data from LHC on quarkonia production required
Motivation II

- Double production possible probe to double parton scattering (DPS): two hard collisions per pp event.
- In double J/ψ production DPS theorised to be of the same order as SPS [1].

The LHCb Experiment

- LHCb is particularly suited for the study of quarkonium:
  - Excellent separation of primary and secondary vertices.
  - Excellent $\mu$ reconstruction.
  - Large production cross-sections.
  - Low $p_T$ triggers.
  - Rapidity complementary to ATLAS and CMS: $2 < y < 4.5$.

LHCb-CONF-2010-013
Using 2010 data (38 pb$^{-1}$) LHCb published [2]
- First observation of 2x$J/\psi$ at hadron colliders.
- Total cross section $\sigma^{J/\psi J/\psi} = 5.1 \pm 1.0 \pm 1.1$ nb.

Kinematic properties are being studied with larger dataset.
→ the subject of this talk.

This study: aprox 1/3 of total 2011 luminosity (306 pb$^{-1}$).
- Extend to full 2011 and 2012 dataset with reprocessed data sample soon available.

Reconstruct $J/\psi \rightarrow \mu^+\mu^-$ with selection:

- Muon tracks well reconstructed and identified.
- Muon tracks $p_t^\mu > 650$ MeV/c.
- Opposite sign muons from well reconstructed $J/\psi$ vertex.

Selection of double $J/\psi$:

- Dimuon pairs originating from well reconstructed common vertex compatible with primary vertex.
- Remove non-prompt $J/\psi$ from B decays.
- Fit in 2 Dimensional space.
- Double Crystal Ball for signal, exp for background.
- Parameters fixed from simulation.
- Raw yield $1227 \pm 61$. 

Projection of 2D fit of $J/\psi_1$ invariant mass  

Projection of 2D fit of $J/\psi_2$ invariant mass
Efficiency and Corrected Yield

- Efficiency for double $J/\psi$ events given by:
  - Geometric acceptance: estimated from Monte Carlo.
  - Reconstruction and selection: estimated from MC.
  - Muon identification: estimated from data.
  - Trigger: estimated from data.
- Use efficiency to calculate a corrected yield with SWeight method [3], which uses 2D fit PDFs to statistically separate signal from background.
- Corrected yield $6036 \pm 363$.

Cross-Section and Uncertainty

\[ \sigma_{J/\psi J/\psi} = \frac{1}{L \times B_{\mu^+ \mu^-}^2} \times N_{corr}^{J/\psi J/\psi} \]

- \( L \) integrated luminosity.
- \( B_{\mu^+ \mu^-}^2 \) branching ratio of \( J/\psi \) to \( \mu^+ \mu^- \) (5.93 ± 0.06%).
- \( N_{corr}^{J/\psi J/\psi} \) efficiency corrected number of events.
- Unofficial cross-section with preliminary errors: \( 5.6 \pm 0.3(stat) \pm 1.2(syst) \) nb.
- cf. 2010 result \( 5.1 \pm 1.0(stat) \pm 1.1(syst) \) nb.
- Theory prediction: LO CS SPS - 4.1 nb, DPS - 2.0 nb. [4]

Theory (red): LO CS with pythia parton showering [3].
- Single parton scattering (SPS) only.
- Includes feed-down from higher states.

Theoretical models suggest may require significant contributions from:
- Double Parton Scattering (DPS).
- Colour Octet (CO).
- Higher order corrections to CS.

Conclusions

- Quarkonia production ideal testing ground of QCD.
- 2010 data allowed first observation of $2\times J/\psi$ at hadron colliders.
- $\frac{1}{3}$ of 2011 data enables us to commence study of kinematics.
- Analysis of full 2011 and 2012 dataset to follow soon.
Delta y and DPS

- Difficult to disentangle SPS and DPS modes on basis of azimuthal or transverse momentum correlations.
- As difference only becomes visible at sufficiently high Pt where production rates are very small.
- Rapidity difference between $J/\psi$ "looks more promising".

Tetraquarks

- Tetraquark - meson composed of four quarks
- May be possible to see evidence of tensor tetraquark on the lower end of the double Jpsi mass spectrum.

A.V Berezhnoy et al, Production of J/psi meson pairs and 4c-tetraquark at LHC, Phys.Rev. D 84 (2011) 094023