Measurement of the production cross section ratio of X(3872) and ψ(2S) in the decays into J/ψ $\pi^+\pi^-$ in pp collisions at sqrt(s) = 7 TeV

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Introduction

- The *X(3872)* resonance was discovered in the decay channel $J/\psi\pi^+\pi$ by the Belle experiment in 2003, and subsequently confirmed by BaBar, CDF and D0.
- No charmonium state predicted with the observed mass.
- Mass consistent with the D^0D^{*0} threshold at 3871.81 ± 0.36 MeV and the proximity to this threshold gives plausibility to the assumption of a molecular state of two D mesons.
- Until now the nature of the *X(3872)* has not yet been fully understood. LHC data should provide important information to clarify this puzzle.

- We measured the inclusive cross section ratio w.r.t. the $\psi(2S)$ signal in the same decay channel $J/\psi\ \pi^+\pi^-$.
- **This is the first public result on the ratio at 7 TeV pp collisions on CMS/LHC experiment based on 2010 dataset.**
- Further studies on the nature of the X(3872) are in progress using larger data samples collected in 2011

Strategy

- Extract from the invariant mass spectrum of J/ψ $\pi^+\pi^-$ the number of $\psi(2S)$ and X(3872)
- $R = \frac{\sigma(pp\to X(3872)+anything)\times BR(X(3872)\to J/\psi\ \pi\pi)}{\sigma(pp\to \psi(2S)+anything)\times BR(\psi(2S)\to J/\psi\ \pi\pi)} = \frac{N_{X(3872)}}{N_{\psi(2S)}}/C$
- Correction factor $C = \frac{A_{J/\psi}(X)\cdot\varepsilon_{J/\psi}(X)\cdot A_{\pi\pi}(X)\cdot\varepsilon_{\pi\pi}(X)}{A_{J/\psi}(\psi')\cdot\varepsilon_{J/\psi}(\psi')\cdot A_{\pi\pi}(\psi')\cdot\varepsilon_{\pi\pi}(\psi')}$

- Where the terms are:
  - Acceptance of J/ψ ($A_{J/\psi}$)
    Fraction of all the generated J/ψ which have 2μ in the acceptance region.
  - Efficiency of J/ψ ($\varepsilon_{J/\psi}$)
    Fraction of J/ψ with 2μ inside the acceptance which has been triggered and reconstructed.
  - Acceptance × Efficiency for pions ($A_{\pi\pi}\cdot\varepsilon_{\pi\pi}$)
    Fraction of the X(3872) and $\psi(2S)$, with a triggered and reconstructed J/ψ, passing the whole selection.

- Where Acceptance and Efficiency factors are obtained from Monte Carlo and cross checked with data as much as possible .

Event selection

- J/ψ Selection:
- The J/ψ selection borrows heavily from the techniques used to measure the J/ψ production cross section. J/ψ candidates are selected with two identified muon candidates of opposite charge.
- The two identified muons require matching with trigger decision. And they must lie in the following kinematic range:

  pt > 3.3 GeV for | η |< 1.3;

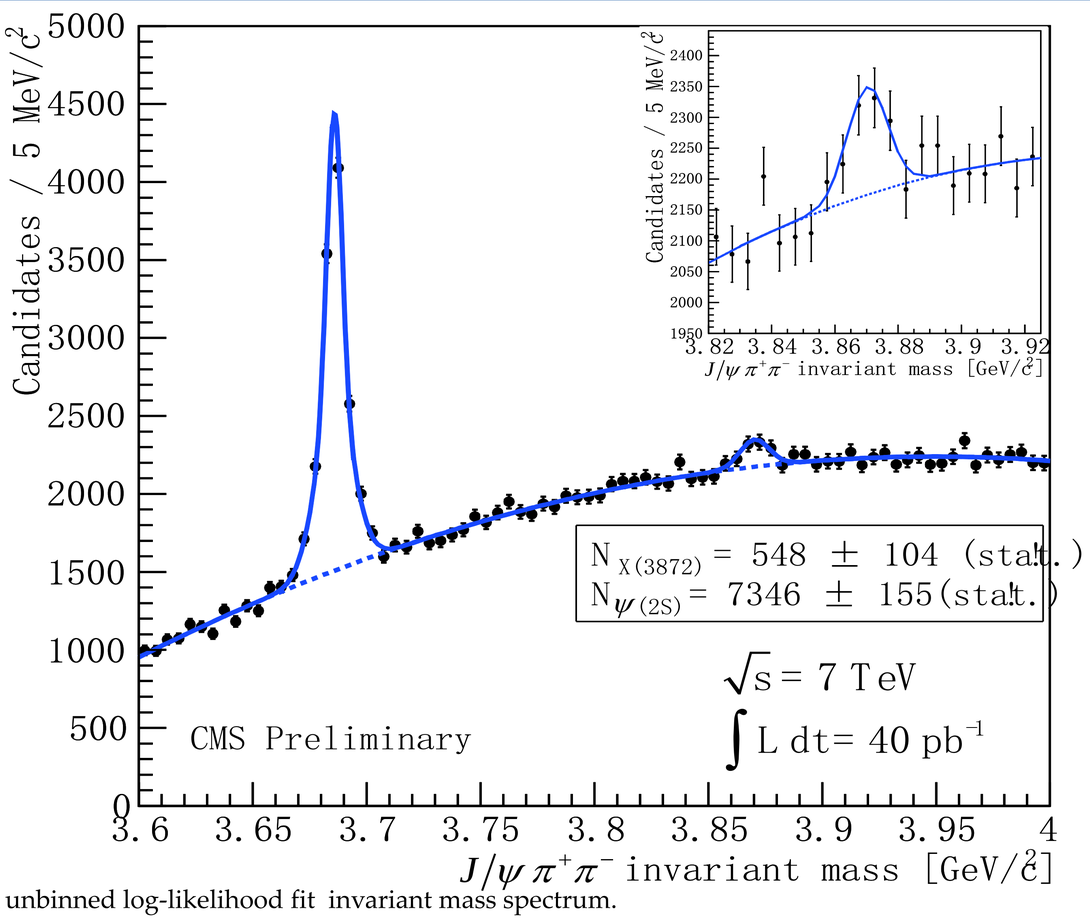
  p > 2.9 GeV for 1.3<| η |< 2.2;

  pt > 0.8 GeV for |η|>2.2
- 1 million reconstructed J/ψ candidates remain after selection.
- Pions Selection:
- High track quality[1]:
- To reduce the background:

  $p_t(\pi\pi) > 1.5$ GeV $\Delta R(J/\psi, \pi) < 0.7$

- All 4-tracks vertex fit is performed, where the dimuon invariant mass is constrained to the J/ψ mass PDG value.
- Candidate Vertex fit Probability has to be larger than 0.01. And invariant mass of the $J/\psi\pi^+\pi^-$system less than 5 GeV.

Mass spectrum



- An unbinned log-likelihood fit invariant mass spectrum.
- $\psi(2S)$ double Gaussian. *X(3872)* single Gaussian
- Background is modeled with a second order Chebyshev polynomial.

Acceptance and efficiency

- Good acceptance is found in the region of pt(X) > 8 GeV and |y|(X) < 2.2 .
- The Correction factor(C) can be split in 3 terms: Ratio of J/ψ acceptance $R(A_{J/\psi})$, Ratio of J/ψ efficiency $R(\varepsilon_{J/\psi})$, ratio of acceptance × Efficiency for pions $R(A_{\pi\pi}\cdot\varepsilon_{\pi\pi})$.
- The ratio $R(A_{\pi\pi}\cdot\varepsilon_{\pi\pi})$ is evaluated in a data driven way. The other two ratios come from MC.
- Assuming that 30% of the candidates in both the X(3872) and the ψ(2S) samples are from non-prompt production processes.
- The final correction factor in this scenario is:

$$C_{\text{30\% non-prompt}} = 0.872 \pm 0.015$$

R = 0.087 ± 0.017 (stat)

Systematic uncertainty

- Signal and Background parameterization
  - Different functions are used to fit the mass spectrum, changes in the yield give differences up to **5.3%**
- Variations of the non-prompt fractions of *X(3872)* and $\psi(2S)$
  - combination with relative difference of non-prompt component up to 20% results in difference up to **6%**
- Uncertainty on the pion tracking efficiency **4.0%**
- Lack of knowledge of the *X(3872)* production mechanism
  - Study on the effect of changes in the *X(3872)* pt shape **3.5%**
- Uncertainty due to limited statistics of MC samples
  - Estimated **1.5%**

Full systematic Error 10%

Results

- We have established a clear signal for the *X(3872)* in the $J/\psi\ \pi^+\pi^-$ decay channel based on the 2010 CMS data (40 pb^{-1}).
- A measurement of the ratio of $\sigma \times BR$ between *X(3872)* and $\psi(2S)$ in the decay channel $J/\psi\ \pi^+\pi^-$ (with J/ψ decay to $\mu^+\mu^-$) has been performed.

$$R = \frac{\sigma(pp\to X(3872)+anything)\ \times\ BR(X(3872)\to J/\psi\ \pi\pi)}{\sigma(pp\to \psi(2S)+anything)\times BR(\psi(2S)\to J/\psi\ \pi\pi)}$$

R = 0.087 ± 0.017 (stat) ± 0.009 (syst)

- A determination of the absolute cross-section for *X(3872)* production, and a comparison with theoretical calculations will be provided in the near future.

References

[1] CMS Collaboration "Measurement of the production cross section ratio of *X(3872)* and ψ(2S) in the decays into $J/\psi\ \pi^+\pi^-$ in pp collisions at sqrt(s) = 7 TeV", CMS PAS BPH-10-018