Measurement of the production cross section ratio of X(3872) and $\psi(2S)$ in the decays into $J/\psi\pi\pi$ in pp collision

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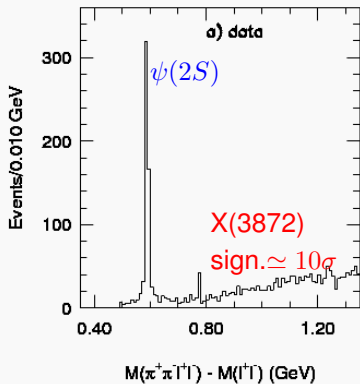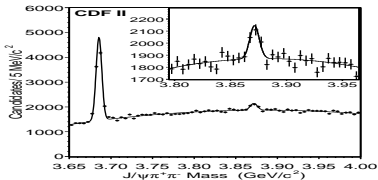
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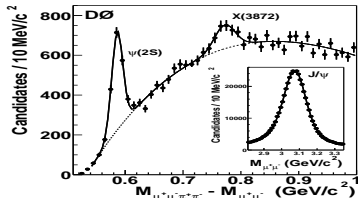
Outline

Early observations of the X(3872)

BELLE,PRL(2003)

Confirmation: CDFII(2004)

Confirmation: D0(2004)

X(3872) : many open questions

- No charmonium state predicted with the observed mass

- Mass consistent with the exact location of the $D^0 \bar{D}^{*0}$ threshold at $3871.81 \pm 0.36\ MeV$ and the proximity to this threshold gives plausibility to the assumption of a molecular state of two D mesons

Further study on the nature of $X(3872)$ is needed!

Primary Physics Goals of the CMS measurement

- Establish a clear signal of the $X(3872)$ using all data taken by CMS during the first year of collisions at LHC($\sim 40pb^{-1}$)

- Measurement of the inclusive cross section ratio w.r.t. the $\psi(2S)$ signal in the same decay channel $J/\psi\pi\pi$ with J/ψ going to two muons.

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

- A public document is available at
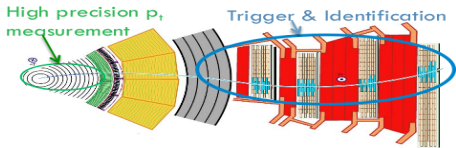 http://cdsweb.cern.ch/record/1345725/files/BPH-10-018-pas.pdf

Outline

Muon Reconstruction

- Combining information from center track and muon system
- $\sim 1\%$ momentum resolution for low p_T
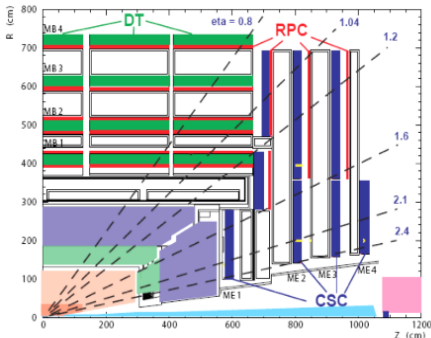
Muon acceptance region:

- $p_T > 3.3 GeV$ for $|\eta| < 1.3$
- $p > 2.9 GeV$ for $1.3 < |\eta| < 2.2$
- $p_T > 0.8 GeV$ for $|\eta| > 2.2$

J/ψ Reconstruction

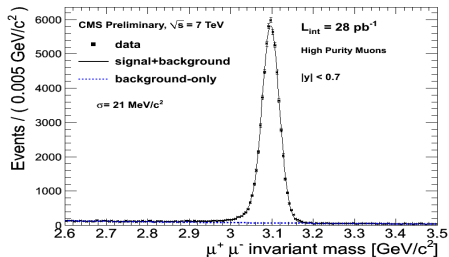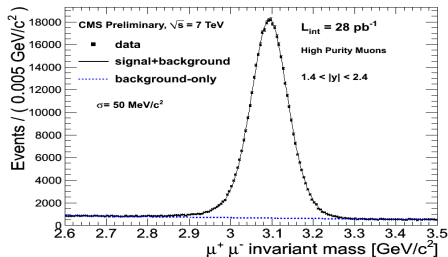- Adopt and apply techniques for J/ψ production cross section measurement. J/ψ are reconstructed requiring two opposite charge good quality muons.
- Double muon trigger path fired.
- Impose J/ψ mass window taking into account the detector resolution in the different rapidity regions

Barrel Region

CMS Preliminary, $\sqrt{s}$ = 7 TeV
- data
— signal+background
...... background-only
σ = 21 MeV/c^2

L_{int} = 28 pb^{-1}
High Purity Muons
|y| < 0.7

Endcap Region

CMS Preliminary, $\sqrt{s}$ = 7 TeV
- data
— signal+background
...... background-only
σ = 50 MeV/c^2

L_{int} = 28 pb^{-1}
High Purity Muons
1.4 < |y| < 2.4

Candidates selection

Pion pairs

Two opposite charge tracks of good quality, within a ΔR cone of 0.7 around J/ψ direction.

Vertex fit

- A four-track vertex fit is performed, where the invariant mass of $\mu^+\mu^-$ system is constrained to the PDG J/ψ mass.
- All candidates with vertex fit probability $> 1\%$ and in a mass range between 3.6 and 4.0 GeV

Kinematic region
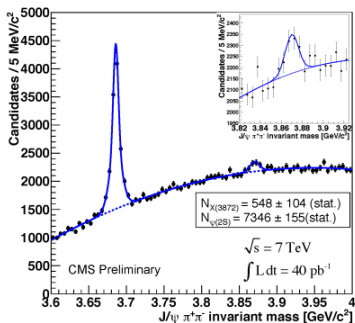
For X(3872) candidates: $P_T(X) > 8$ and $|y(X)| < 2.2$.

Outline

$J/\psi\pi\pi$ Mass Spectrum: X(3872) Signal at CMS

Consistent with PDG values

CMS measurement:
$m_{X(3872)} = 3870.2 \pm 1.9 MeV$
$m_{\psi(2S)} = 3685.9 \pm 0.1 MeV$

PDG value:
$m_{X(3872)} = 3871.56 \pm 1.9 MeV$
$m_{\psi(2S)} = 3686.09 \pm 0.04 MeV$

Cross Section Ratio Measurement

Recap

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

$$= \frac{N_{X(3872)}}{N_{\psi(2S)}}/C$$

Factorization of C

$$C = \frac{A_{J/\psi}(X) \cdot \epsilon_{J/\psi}(X) \cdot A_{\pi\pi}(X) \cdot \epsilon_{\pi\pi}(X)}{A_{J/\psi}(\psi(2S)) \cdot \epsilon_{J/\psi}(\psi(2S)) \cdot A_{\pi\pi}(\psi(2S)) \cdot \epsilon_{\pi\pi}(\psi(2S))}$$

- C components are separately determined from X(3872) and $\psi(2S)$ MC simulation for both prompt and non-prompt components

Data Yield and Corrected Ratio

- From the fit to the invariant mass distribution:

$$N_{X(3872)} = 578 \pm 104(stat.)$$
$$N_{\psi(2S)} = 7346 \pm 155(stat.)$$

- Assuming the contribution from non-prompt process to be 30%, the correction factor is found to be:

$$C = 0.872 \pm 0.015$$

- The cross section ratio is measured to be:

$$R = 0.087 \pm 0.017(stat.)$$

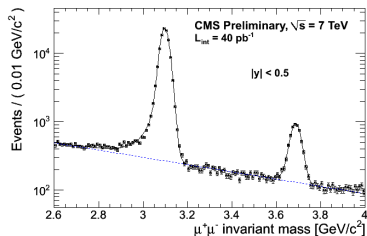# Outline

Systematic Uncertainties

- Background parametrization and signal extraction 5.3%
- Variation of the non-prompt fraction for X(3872) and $\psi(2S)$ in a range $30\% \pm 20\%$ 6.0%
- Lack of knowledge of X(3872) production mechanism 3.5%
  - Study on the effect of changes in the X(3872) p_T shape
- Uncertainty due to limited statistics in MC samples 1.8%
- Uncertainty on the pion tracking efficiency 4.0%
  - Data-driven cross check comparing the decay channels $\psi(2S) \to J/\psi\pi\pi$ and $\psi(2S) \to \mu\mu$

Total systematic uncertainty: 10%

Data Driven Evaluation $A_{\pi\pi}(\psi(2S)) \cdot \epsilon_{\pi\pi}(\psi(2S))$

- Check the value for $A_{\pi\pi}(\psi(2S)) \cdot \epsilon_{\pi\pi}\psi(2S)$ comparing the decay channels $\psi(2S) \to J/\psi\pi\pi$ and $\psi(2S) \to \mu\mu$ in our fiducial region.

- Determine the number of
  - $\psi(2S) \to \mu\mu$
  - $\psi(2S) \to J/\psi\pi\pi$
- Correcting the ratio for
  - branching ratios (PDG)
  - acceptances and efficiencies of J/ψ and $\psi(2S)$ decaying into two muons

CMS Preliminary, √s = 7 TeV
L_{int} = 40 pb⁻¹

|y| < 0.5

Outline

Summary and Outlook

Final results

- CMS has established a clear signal for the X(3872) resonance using data collected during the first year of collisions at the LHC
- The measurement of the ratio of cross sections

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

yields:

$$R = 0.087 \pm 0.017(stat.) \pm 0.009(syst.)$$

Outlook

- More detailed studies of the X(3872) with increased statistics (2011 data) are going to be performed at CMS.
- A measurement of the $\psi(2S)$ cross section will soon become available.

Thanks for your attention!