Properties of the X(3872) State

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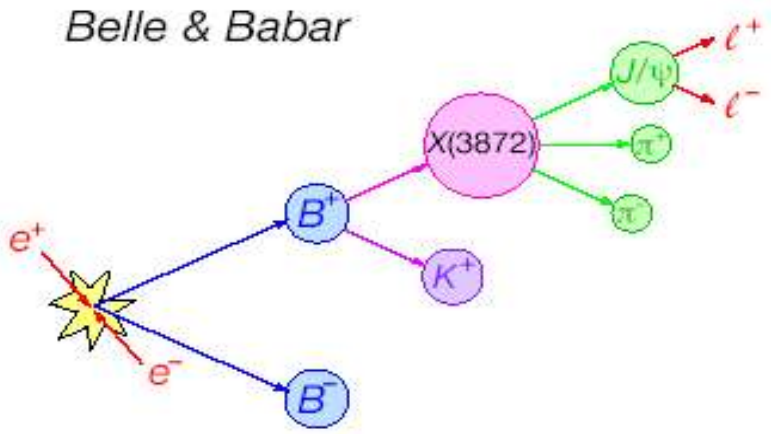
Representing the DØ Collaboration

Overview

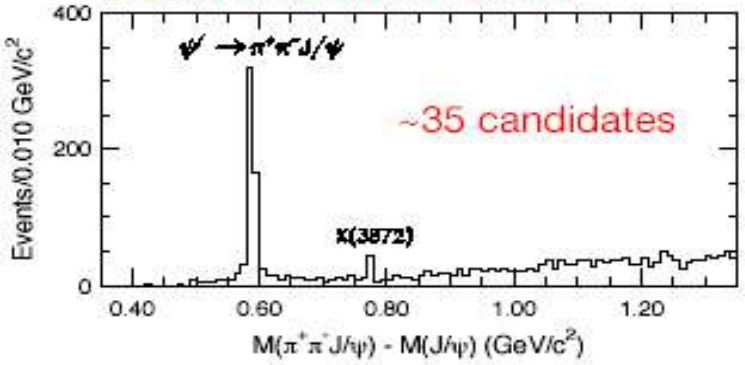
- First observed by Belle. Confirmed by CDF, DØ, BaBar.
- The quark makeup of X(3872) unknown
- Theories include:
  - Another charmonium state
  - D D* molecular state
- Since the X(3872) lies close in mass to the $\psi(2S)$ charmonium state, and has a common decay mode ($X \rightarrow J/\psi \pi^+ \pi^-$), we compare production and decay properties of these two states through this decay mode

Belle & Babar



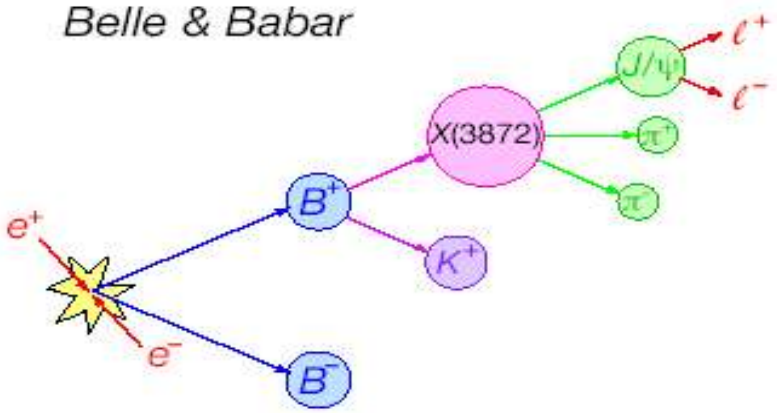
Belle, PRL 91 (2003) 262001

Mass 3872.0 ± 0.6 ± 0.5 MeV

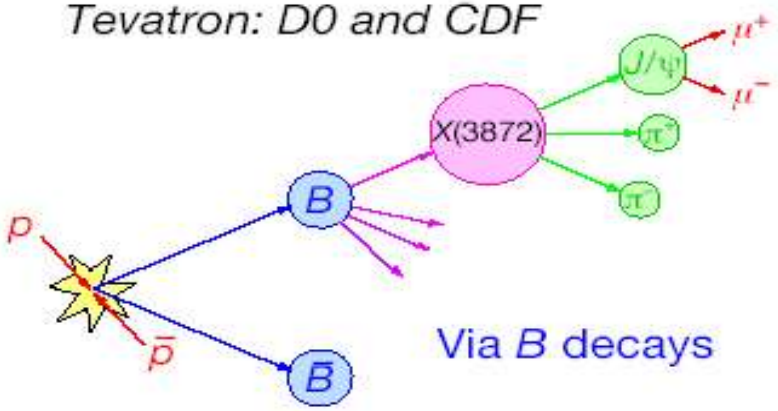


BaBar: hep-ex/0406022

Belle & Babar

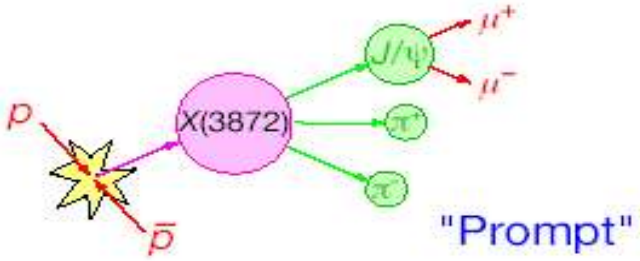


Tevatron: D0 and CDF



Via *B* decays

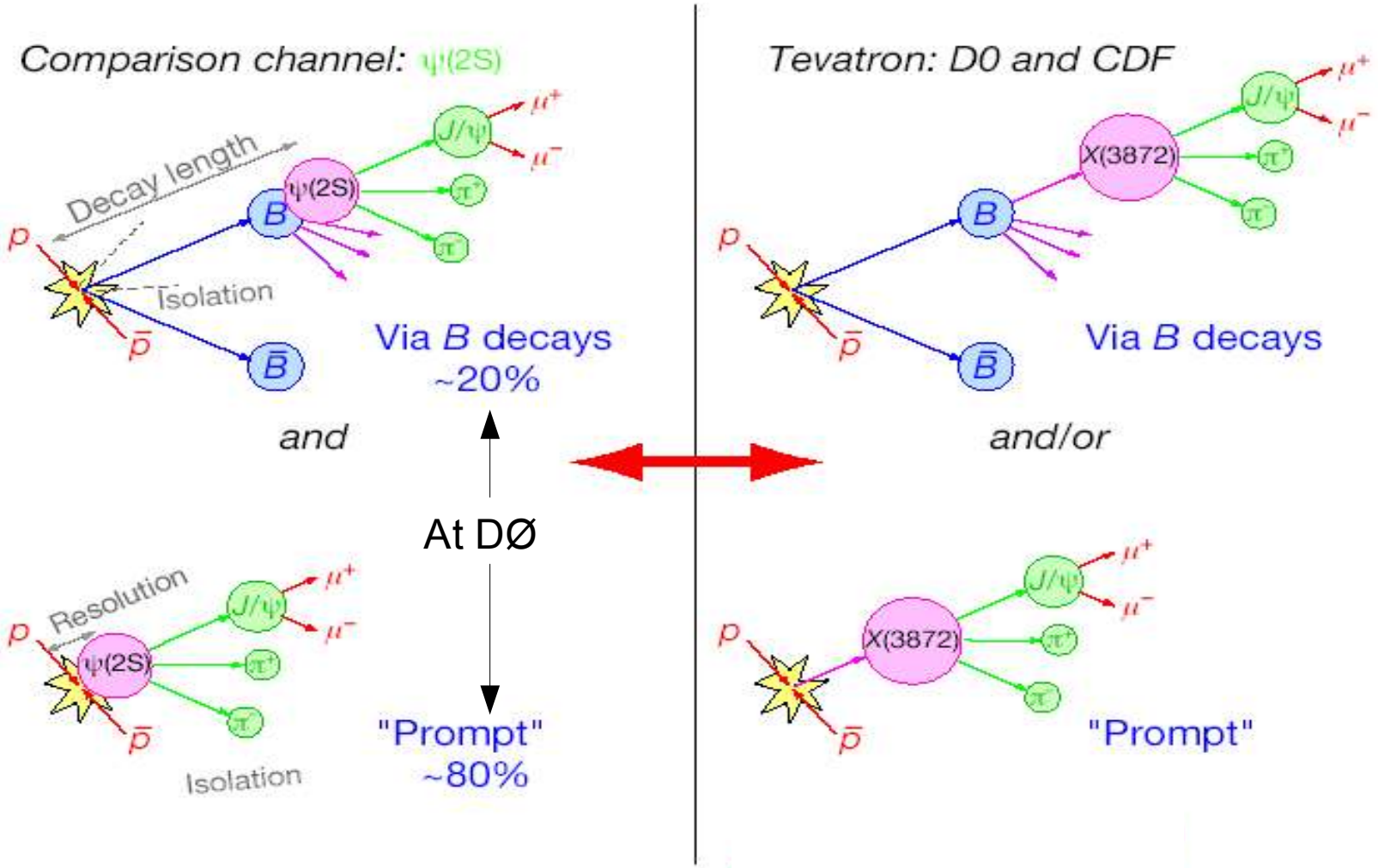
and/or



"Prompt"

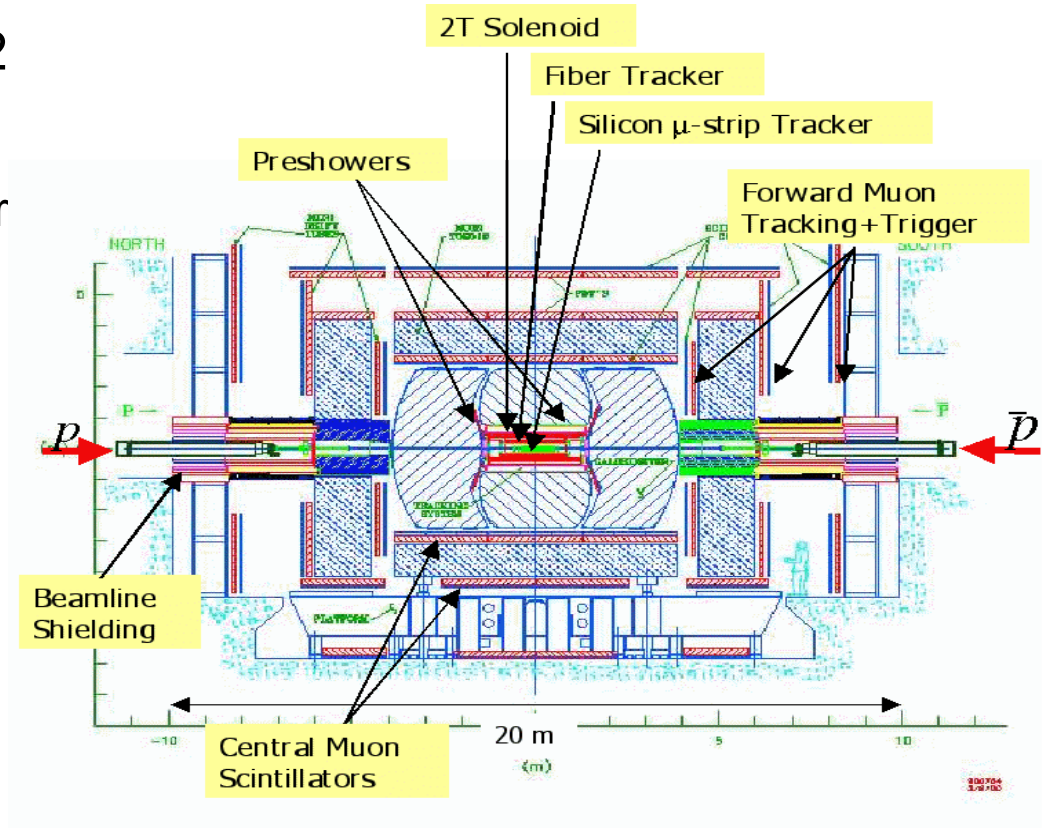
Probing different production mechanisms in hadronic collisions

D0: hep-ex/0405044 (sub.)
CDF: hep-ex/0312021 (acc.)


Comparison channel: ψ'(2S)
Decay length
Isolation
Via B decays
~20%
and
Resolution
Isolation
"Prompt"
~80%
At DØ
Tevatron: D0 and CDF
Via B decays
and/or
"Prompt"

Data and Analysis

- Used ~225 pb^{-1} data collected by the DØ detector between April 2002 and January 2004.
  - selected events that passed any dimuon trigger
- Reconstruct a J/ψ from 2 well identified muons
  - Add 2 tracks, assuming each track is a charged pion.
  - Look for signal in ΔM, $M(\mu^+\mu^-\pi^+\pi^-) - M(\mu^+\mu^-)$ to improve resolution.
  - large backgrounds



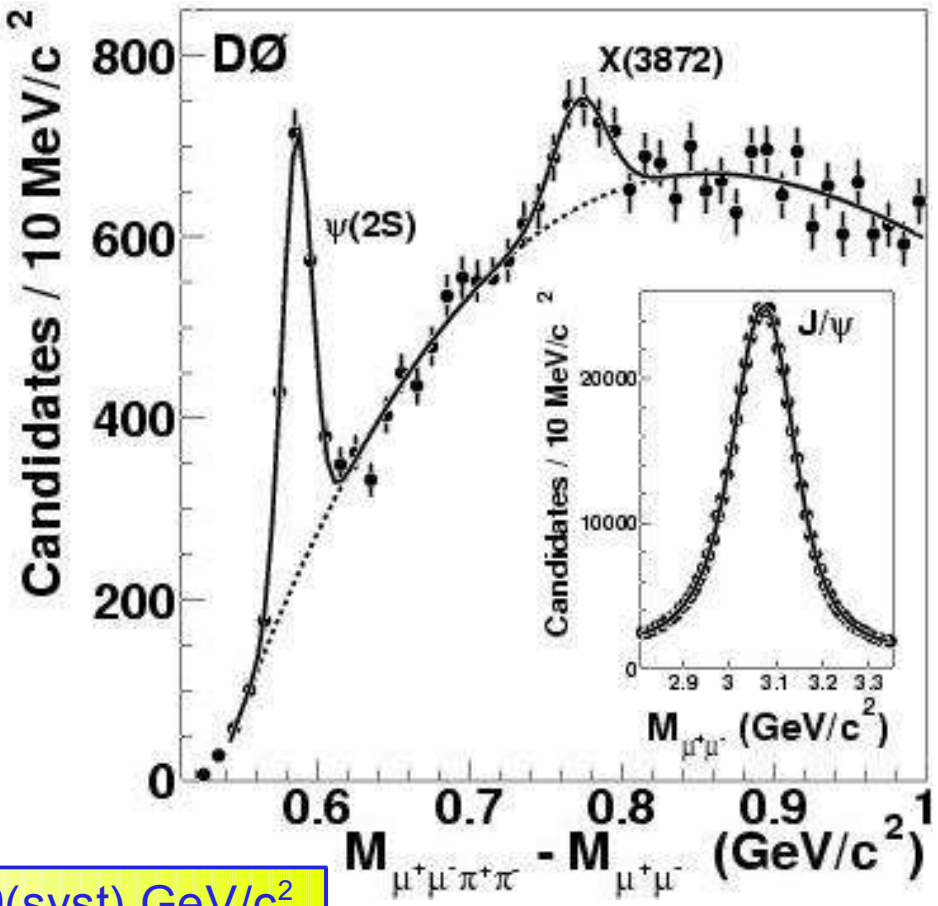
Cuts

- Cuts designed to reduce background while keeping a reasonable signal of $\psi(2S)$
  - At least two of the $\mu^+ \mu^- \pi^+ \pi^-$ tracks must have at least one silicon hit.
  - Require a good vertex.
    - $(\mu^+ \mu^- \pi^+ \pi^-)$ Vertex $\chi^2 < 16$ for 5 degrees of freedom
  - There must be less than 100 tracks in the event.
  - Dimuon invariant mass must be between 2.8 and 3.4 GeV/c^2
  - P_T (J/ψ) > 5 GeV/c
  - P_T (π) > 0.7 GeV/c
  - Spatial seperation cut to keep pions near the X candidate
    - ΔR, the spatial separation (sqrt($\Delta\eta^2 + \Delta\varphi^2$)) of each pion with respect to the $J/\psi\ \pi\ \pi$ system must be < 0.4
  - M ($\pi\pi$) > 0.52 GeV/c^2

X(3872) at DØ

- After applying all cuts, we arrive at the following:
  - mass spectrum in $\Delta M = M_{\mu\mu\pi\pi} - M_{\mu\mu}$ to improve resolution
    - effectively $M_X - M_{J/\psi}$
  - Systematic from uncertainty in momentum scale.

522 ± 100 events



$\Delta M = 0.7749 \pm 0.0031(\text{stat}) \pm 0.0030(\text{syst})$ GeV/c^2

Comparison to $\psi(2S)$

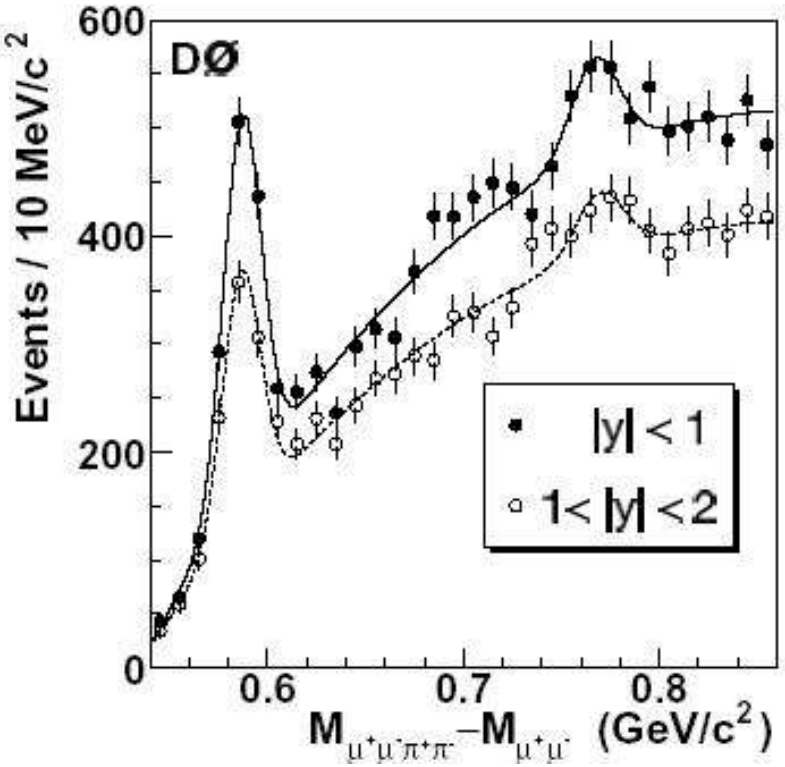
- Compared production and decay ratios of X(3872) and $\psi(2S)$ in production and decay variables
- For each variable, split into two subsamples, a and b and form ratio:
  - $\frac{N_a}{(N_a + N_b)}$
- Production Variables:
  - P_T ($J/\psi\ \pi\ \pi$)
    - a: <15 GeV
    - b: >15 GeV
  - Rapidity (|y|)
    - a: <1
    - b: >1
  - x-y decay length (dl)
    - a: <100 microns
    - b: > 100 microns
    - gives an idea of prompt vs from B-decay

Comparison to ψ(2S)

- Decay variables:
  - Isolation
    - a: =1
    - b: <1
      - » Isolation is defined as the ratio of the X(3872) momentum to the sum of the X(3872) momentum and the momentum of all other particles in a cone of 0.5
  - $\cos(\theta_{\pi})$
    - a: <0.4
    - b: >0.4
      - » Cos(θ) is found by boosting the X(3872) and one of the pions (or muons) into the dipion (or dimuon) rest frame and measuring the angle between these two particles
      - » Helicity of dipion (or dimuon) system can be inferred from this angle
  - $\cos(\theta_{\mu})$
    - a: <0.4
    - b: >0.4

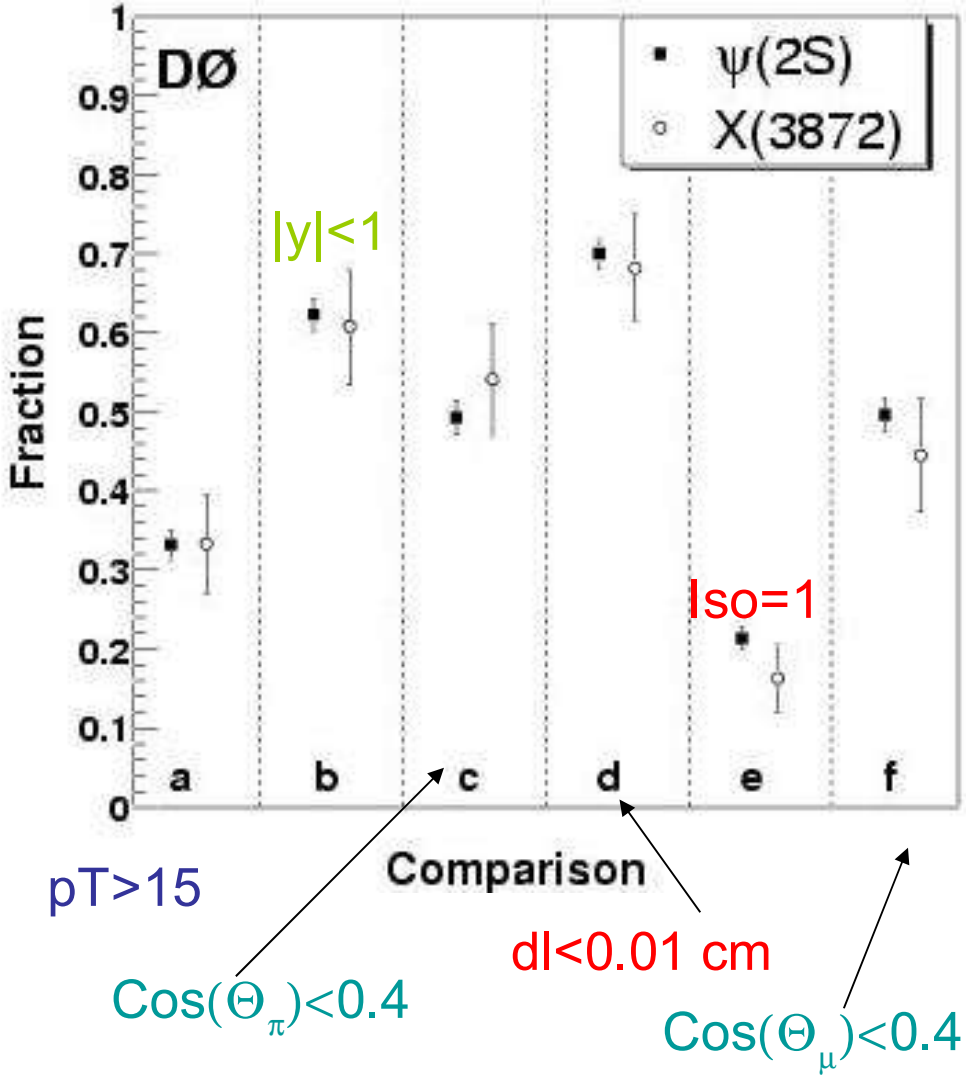
Comparison to ψ(2S)

- After splitting data into 2 subsamples, fit the mass spectrum to obtain the number of ψ(2S) and X(3872) in each region
- Example: rapidity →



Comparison

- Observe no significant differences between ψ(2S) and X
- This comparison will be more useful once we have models of the production and decay of, e.g., meson molecules that predict the observables used in the comparison.
  - such as Braaten, hep-ph/0408230



Conclusions and plans

- DØ confirms the existence of X(3872) and measures the mass difference
  - $\Delta M = M_{X(3872)} - M_{J/\psi} = 0.7749 \pm 0.0031\ (stat) \pm 0.0030\ (syst)$ GeV
- Further, in the production and decay properties examined, the X(3872) is consistent with $\psi(2S)$ charmonium state.
- Future
  - Measure prompt fraction. [e.g. using decay length, isolation]
  - Search for radiative decays
  - Search for charge conjugate of the X in $X^+ \rightarrow J/\psi\, \pi^+ \pi^0$
    - reconstruction of neutrals is difficult, but progress has been made
  - $m(\pi^+ \pi^-)$ spectrum

Backup slides

Systematic Error

- Linear scaling of mass difference between Ψ(2S) and J/Ψ for DØ and the same quantity as accepted by PDG.