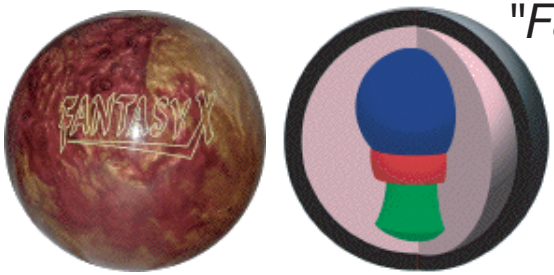
Properties of the X(3872) State

X(3872): What is it??

- Higher *L* charmonium state?
- $D^0 - \bar{D}^{*0}$ "molecule"?
- $c\bar{c}g$ hybrid?
- Google search:



"*Fantasy X Particle*"
Bowling Ball

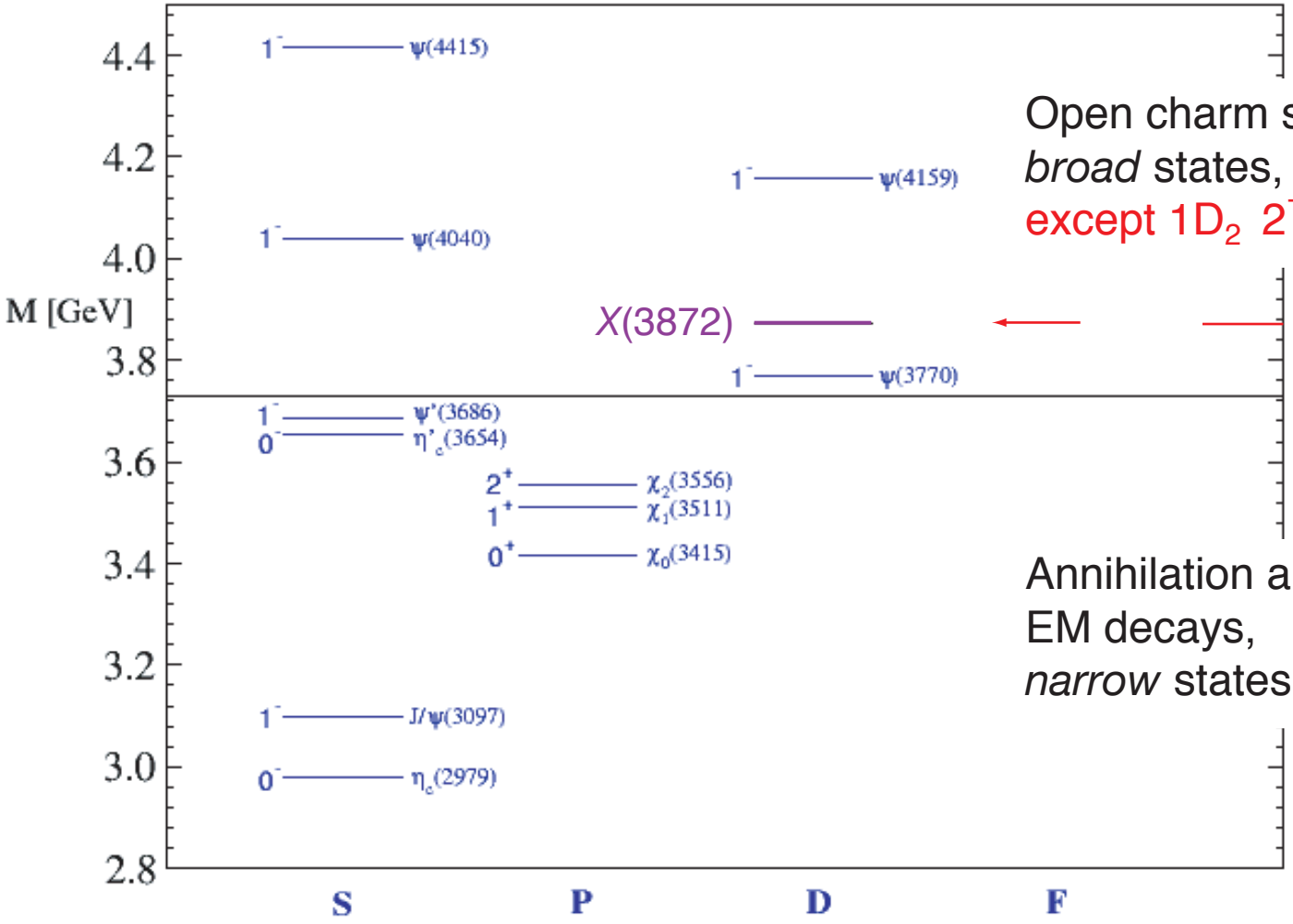
Rick Van Kooten
Indiana University
Representing the
DØ Collaboration

Session 10:
Hadron Spectroscopy
& Exotics
ICHEP04, Beijing, China
17 Aug. 2004

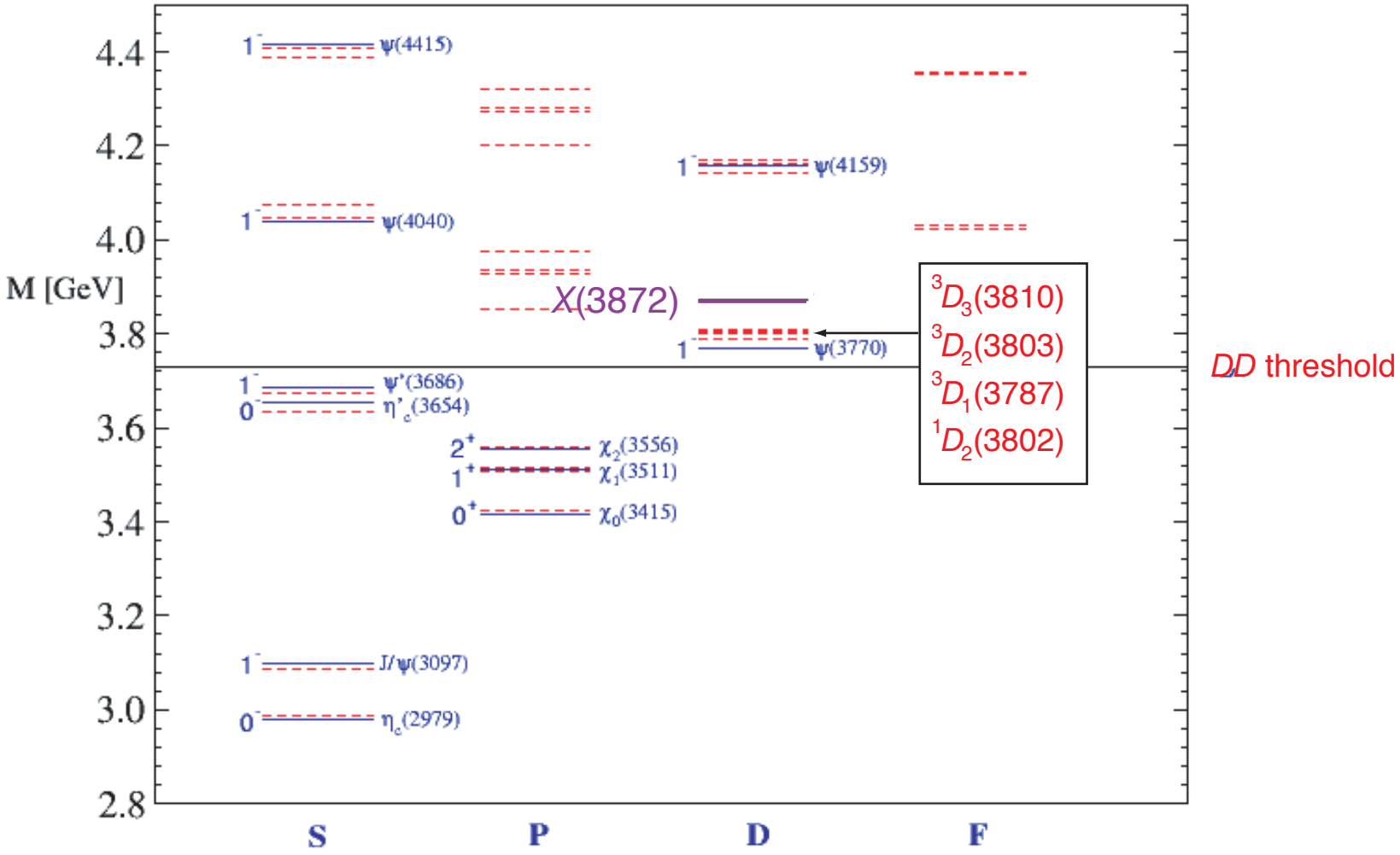
- exotic "mesonic molecule", D-D^* ? Unexpectedly narrow.

  $M(D^0 + D^{*0}) = 3871.5 \pm 0.5$ MeV (accidental??)

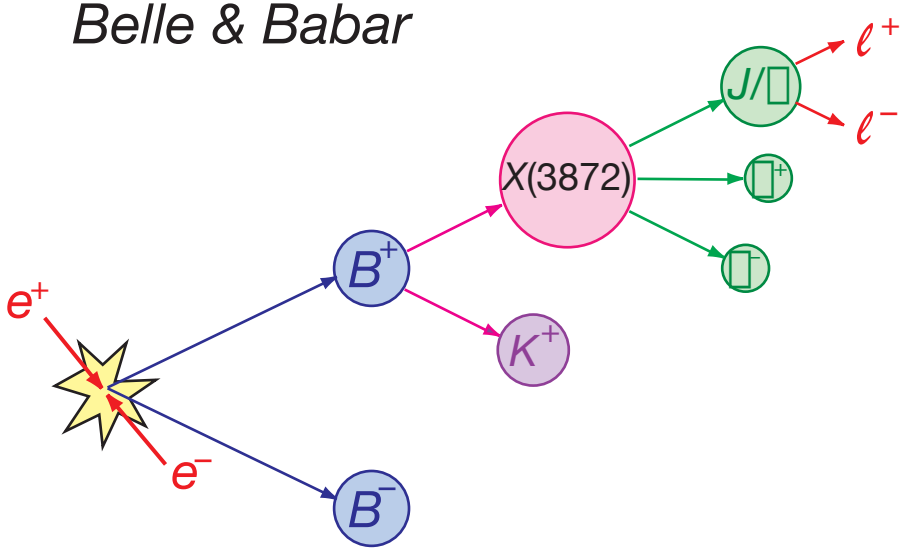
  $M(D^- + D^{*+}) = 3879.5 \pm 0.7$ MeV



- Coulomb + scalar confining potential model predictions (Barnes et al, red)
- If *X*(3872) is charmonium, *L*-excited multiplet is split much more than expected assuming scalar confinement (and roughly consistent with lattice gauge models)

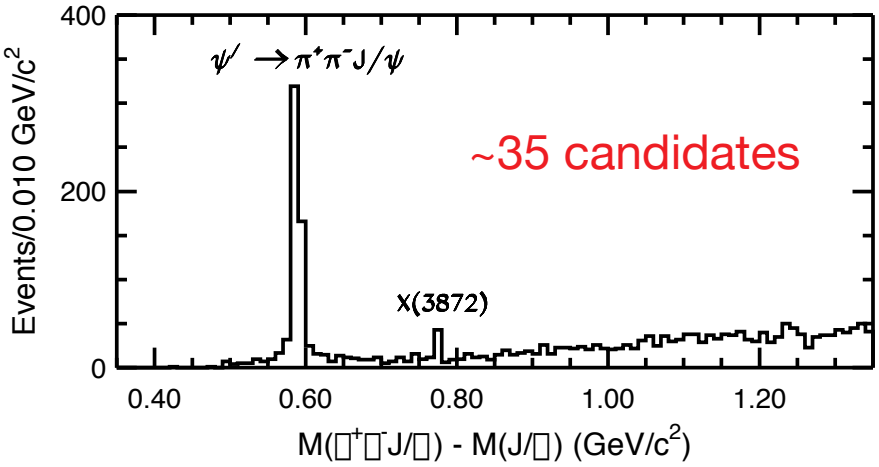


Belle & Babar



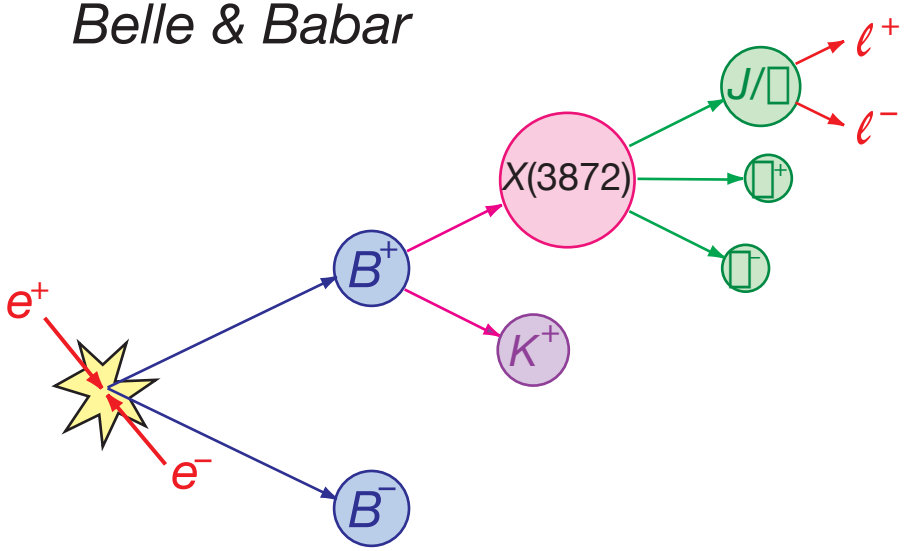
Belle, PRL 91 (2003) 262001

Mass 3872.0 ± 0.6 ± 0.5 MeV

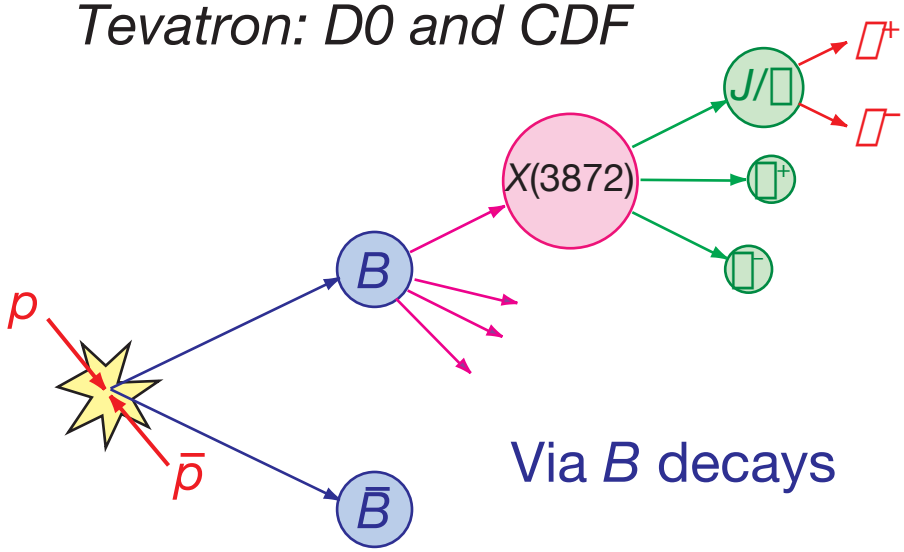


BaBar: hep-ex/0406022

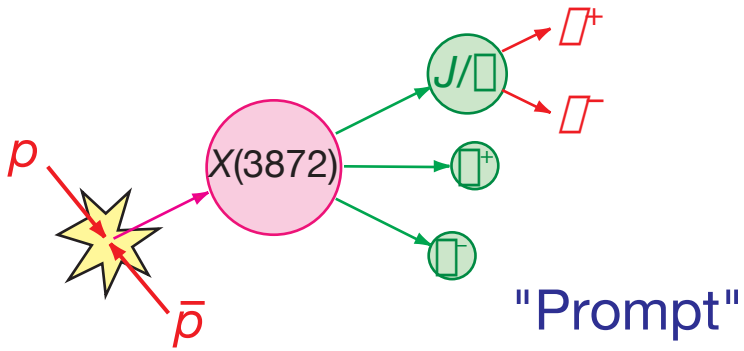
Belle & Babar



Tevatron: D0 and CDF



and/or

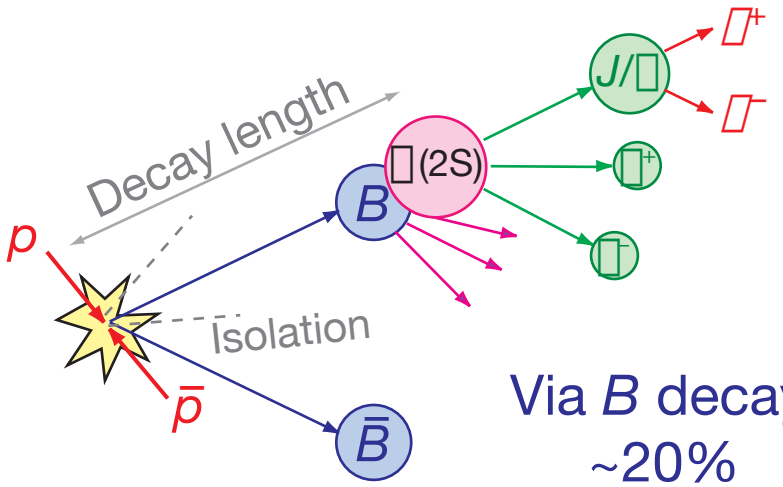


Probing different production mechanisms in hadronic collisions

D0: hep-ex/0405044 (sub.)

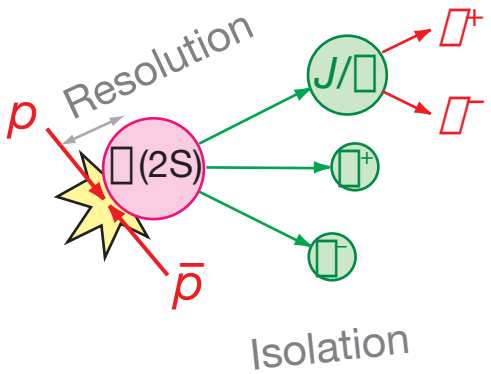
CDF: hep-ex/0312021 (acc.)

Comparison channel: □(2S)



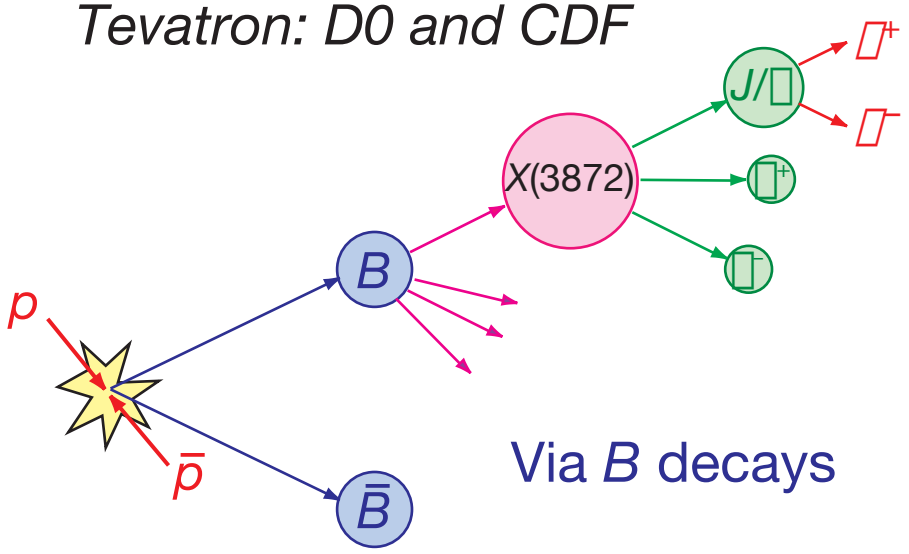
Via *B* decays
~20%

and



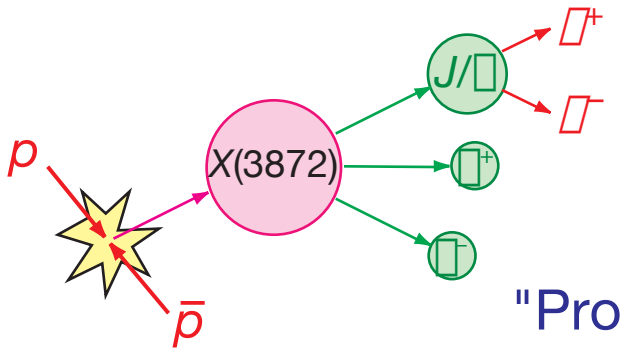
"Prompt"
~80%

Tevatron: D0 and CDF



Via *B* decays

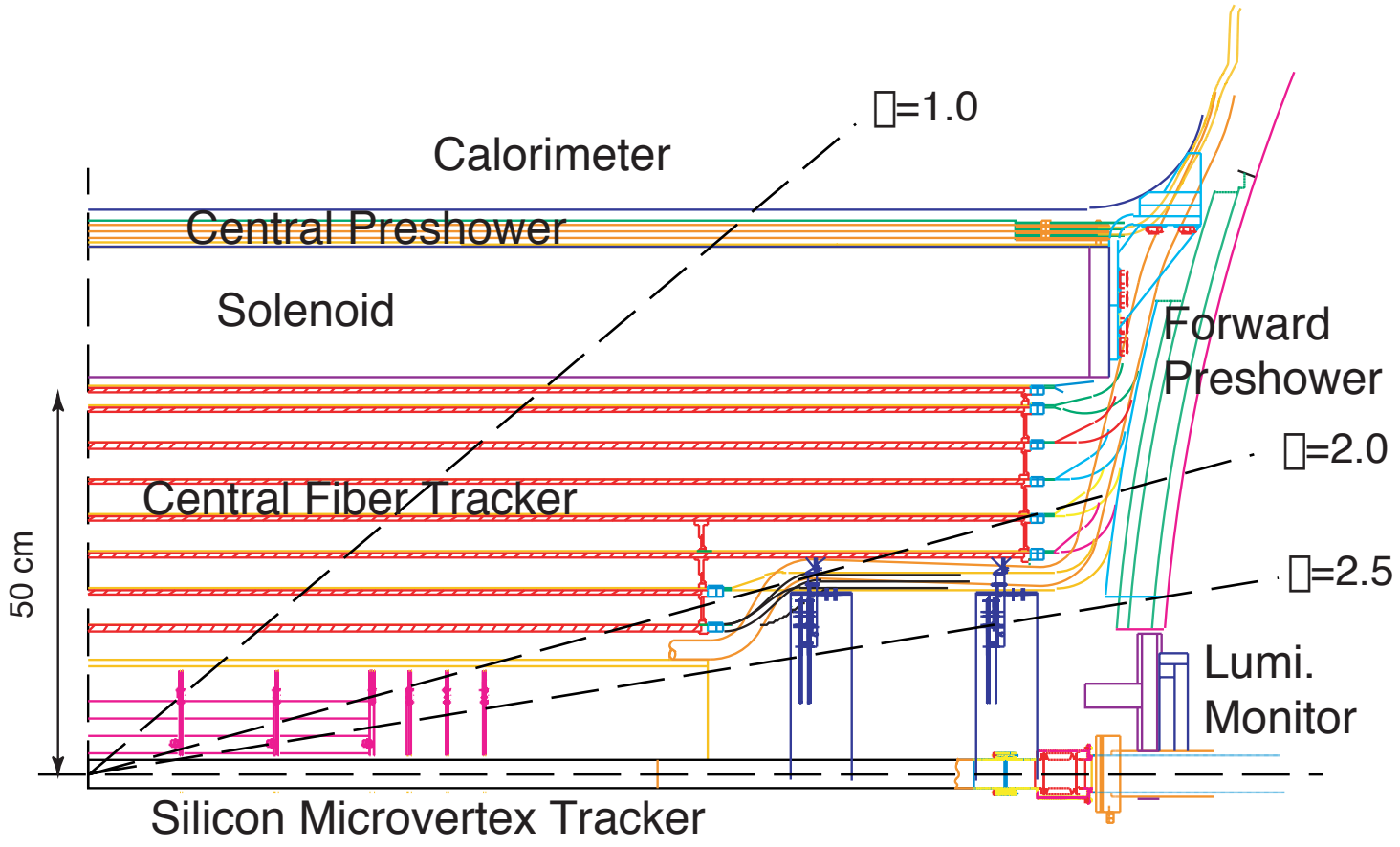
and/or



"Prompt"

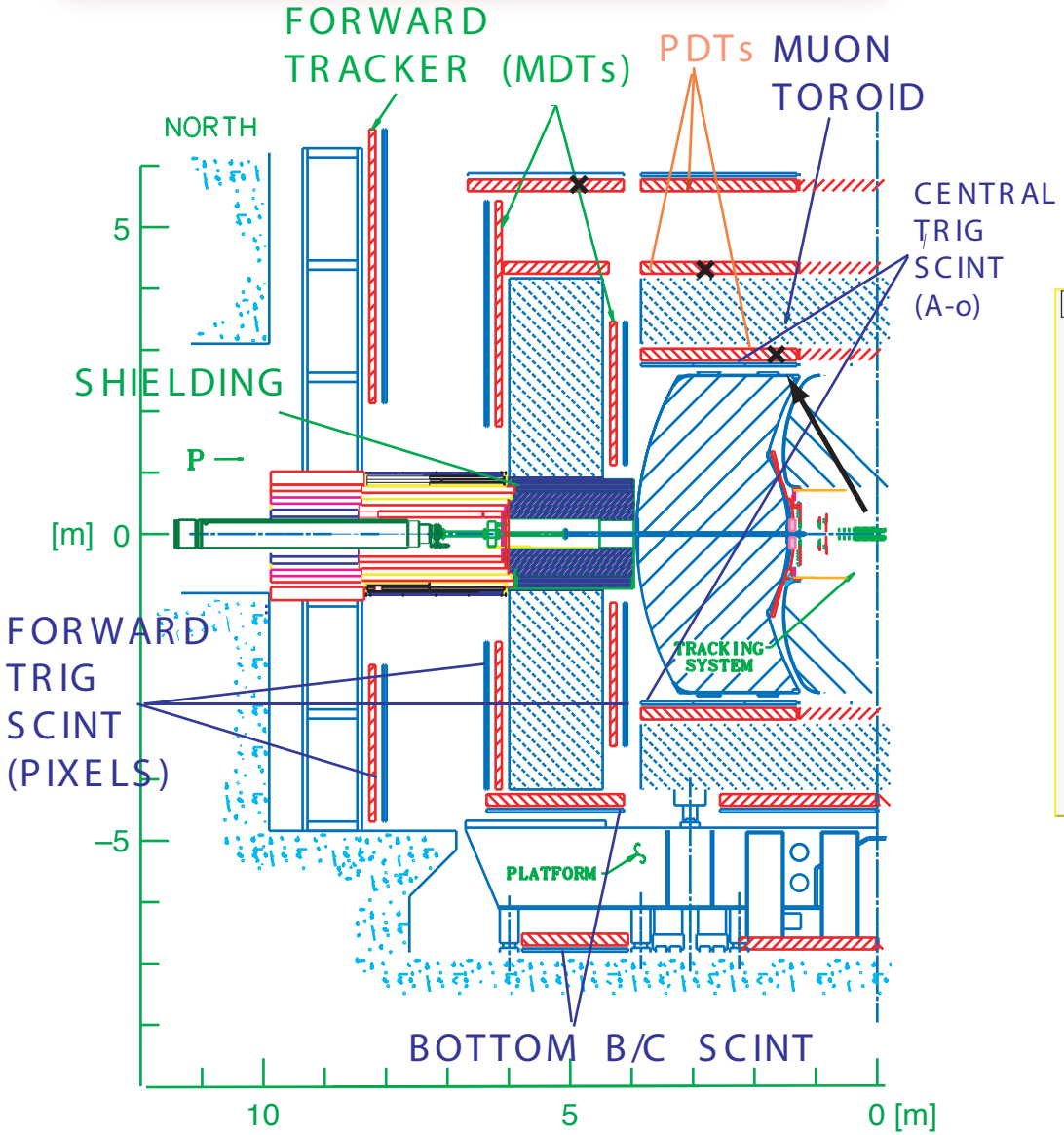
D0: hep-ex/0405044 (sub.)
CDF: hep-ex/0312021 (acc.)

D0 Detector: Tracking Systems



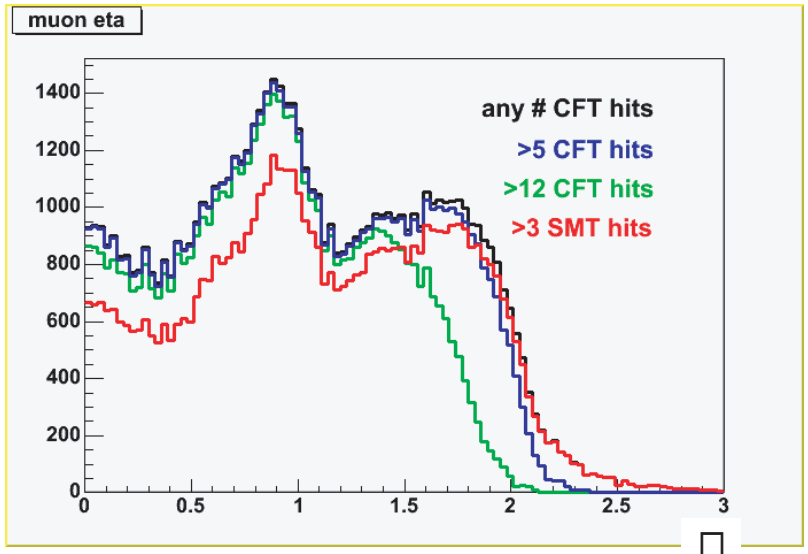
- Excellent coverage of both microvertex and fiber tracker out to forward regions

D0 Detector: Muon System



- Excellent muon coverage (matched by tracking system)

□ of track matched to □ in J/□ events



□

- Dimuon triggers
- Data collected between April 2002 – Jan. 2004, ~230 pb^{-1}

- "Local" momentum measurement in toroidal field

Analysis:

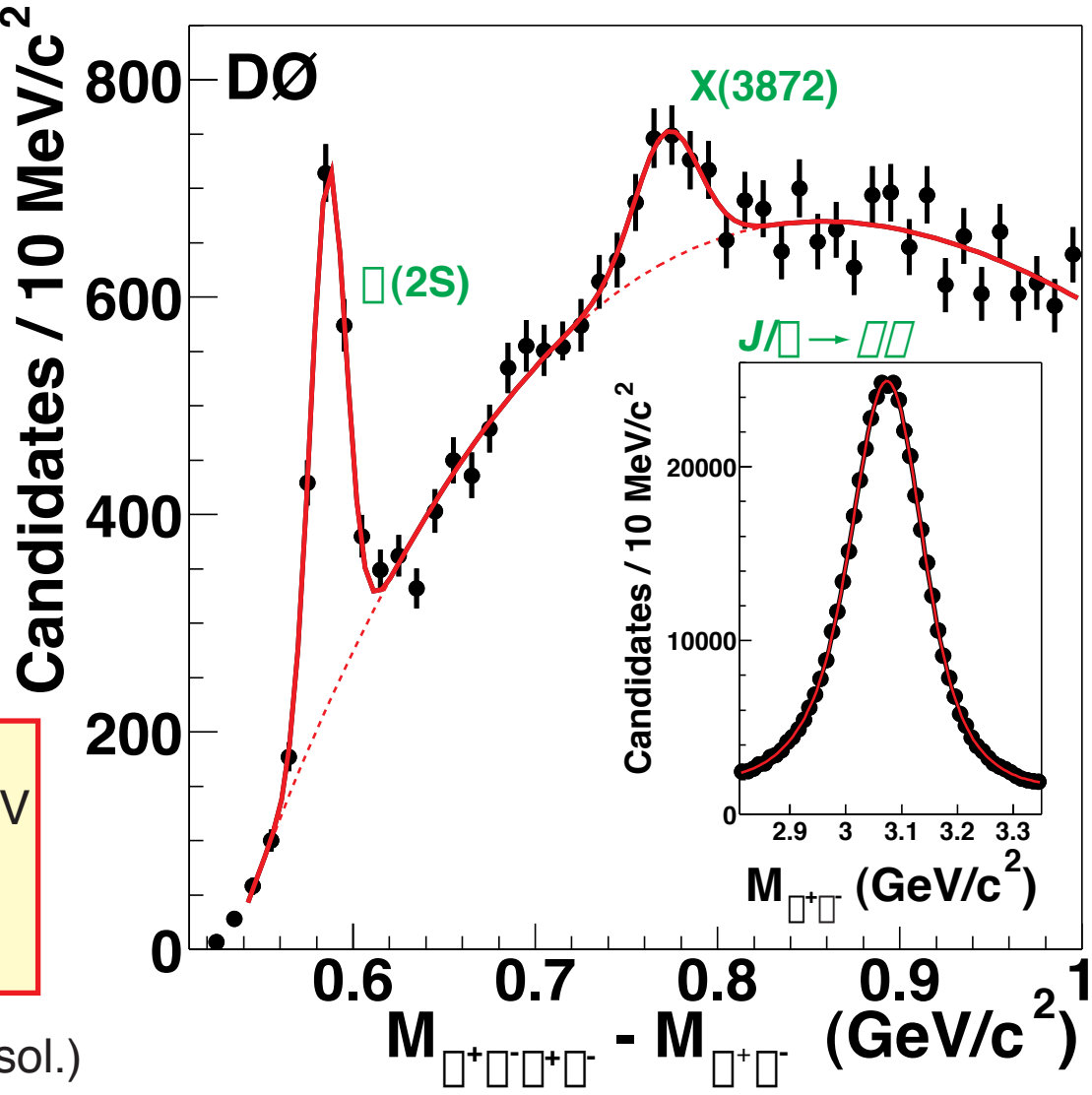
- Reconstruct $J/\psi \to \mu^+\mu^-$, two opposite-sign well identified muons, good vertex
- Add tracks
- $p_T(J/\psi) > 5$ GeV
- $p_T(\pi) > 0.7$ GeV
- $\Delta R > 0.4$ ($\Delta R^2 = \Delta\eta^2 + \Delta\phi^2$) (between both π's and J/ψ)
- $M(\pi\pi) > 0.52$ GeV
- Good $\mu^+\mu^-\pi^+\pi^-$ vertex

- Mass difference (to J/ψ) has better resolution:

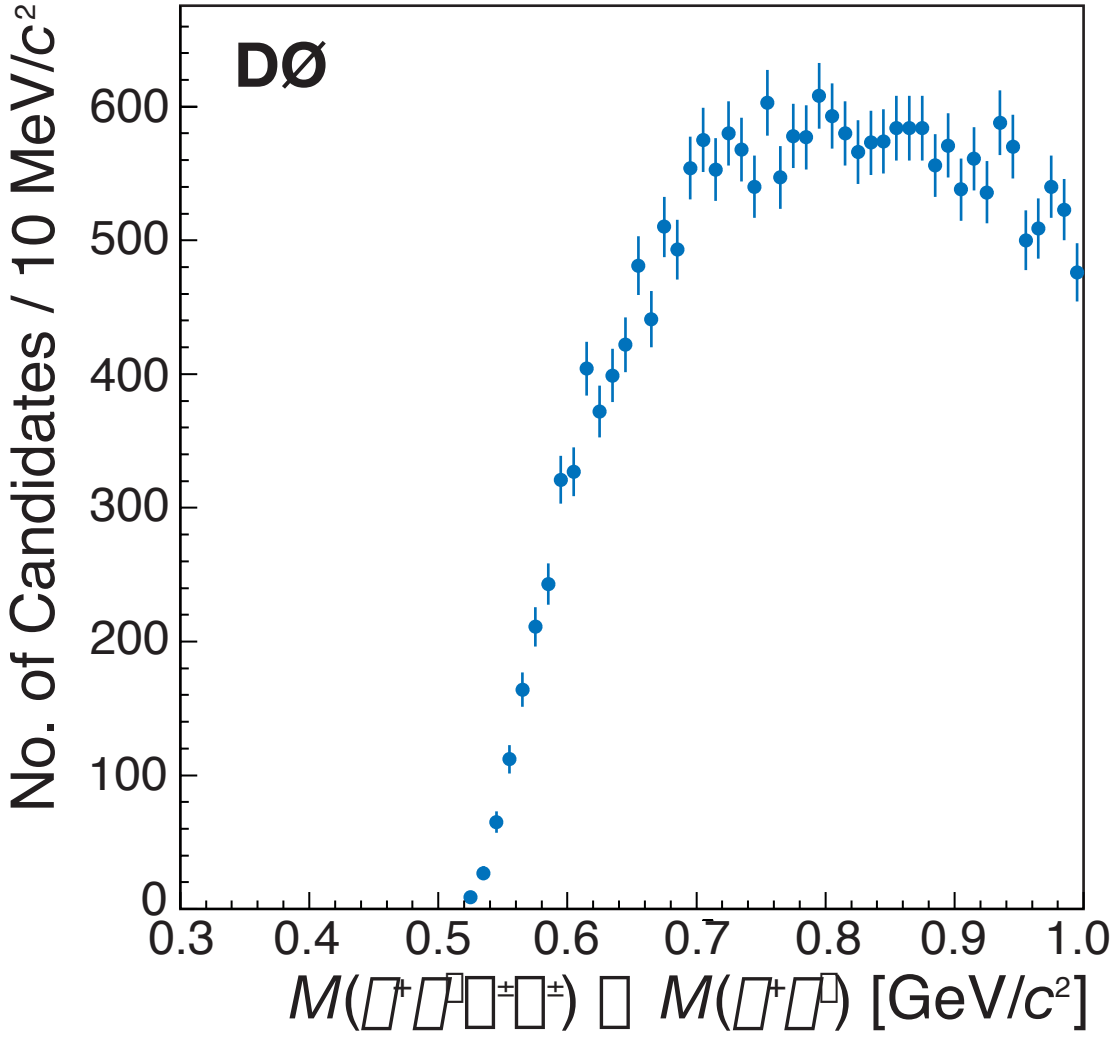
$\Delta M = 0.7749 \pm 0.0031$ (stat) ± 0.0030 (syst) GeV

522 ± 100 $X(3872)$ candidates in ~230 pb^{-1} of data

Fitted width 17 ± 3 MeV (det. resol.)



- No peak if same-sign pions are added to the *J*/□
- Checked that peak not due to any kinematic reflections



- Signal established, examine properties

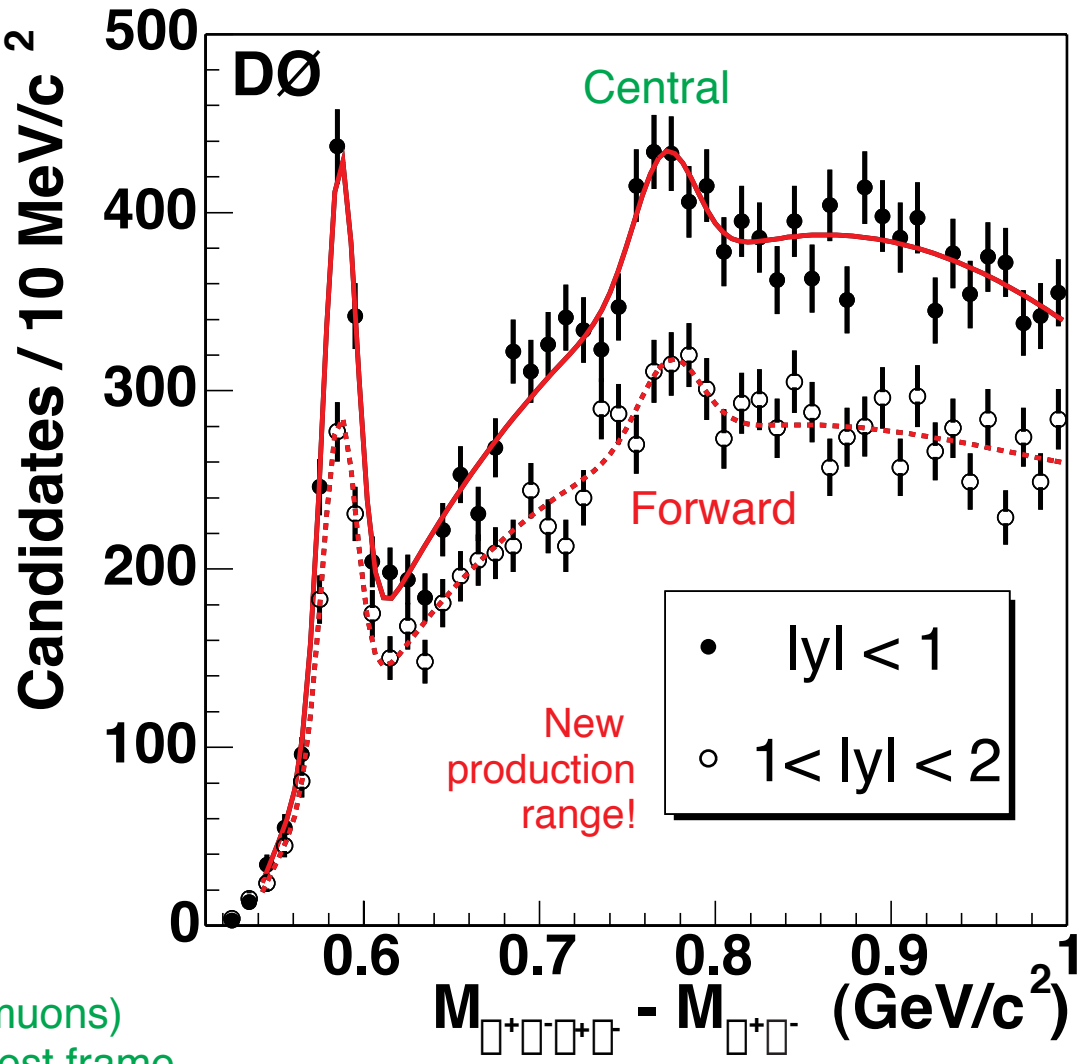
Split data

- Compare production and decay properties to that of □(2S)
- Find fraction of total sample first for *X* state and then for □(2S) with
  - $p_T > 15$ GeV
  - $|y| < 1$ (i.e, central)
  - decay length in *x-y* plane, $L_{xy} < 0.01$ cm

  (direct production, small decay length; decay length if via *B* decay)
  - "isolated" (decay products only in $\Delta R < 0.5$ cone)

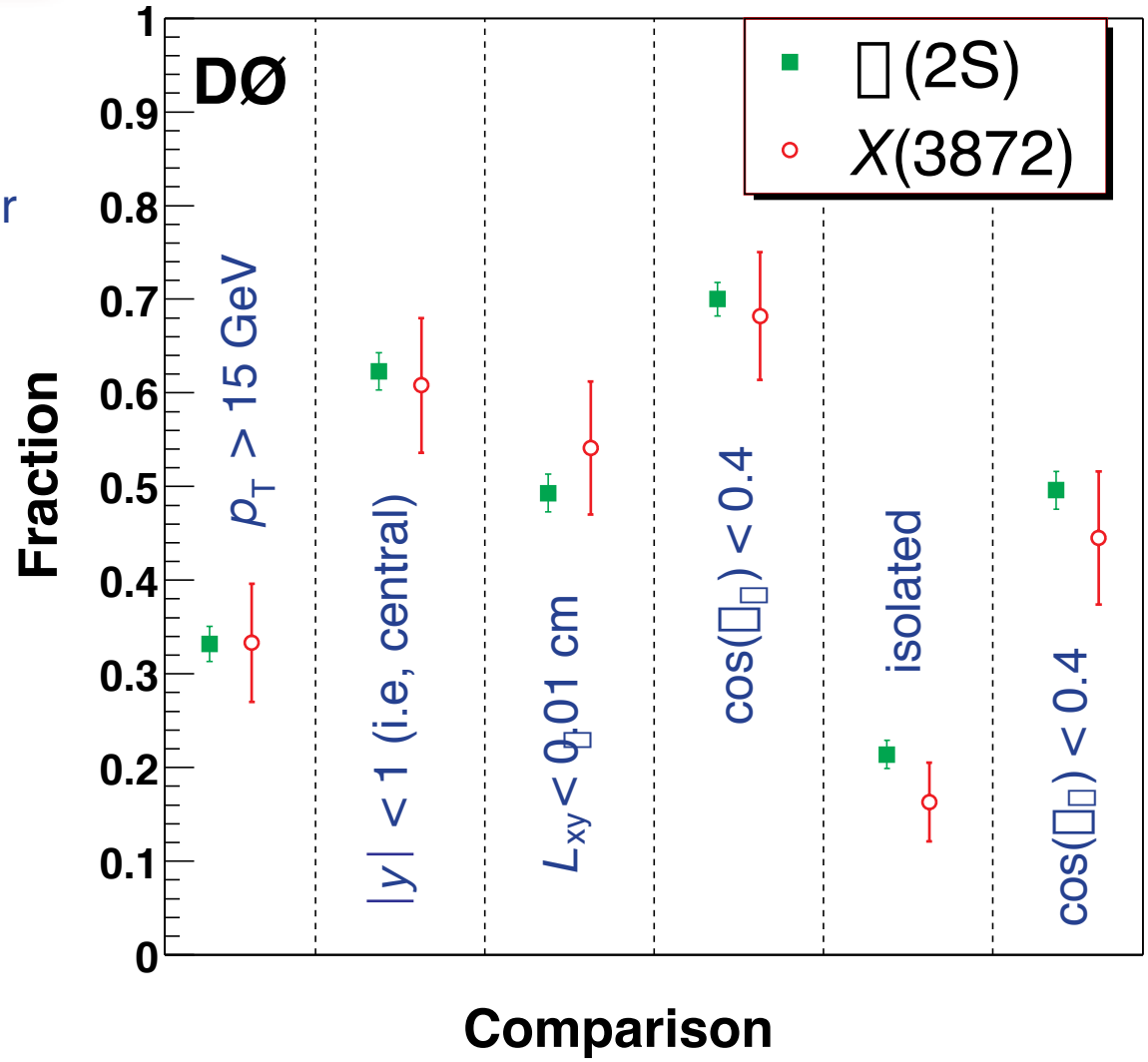
  (directly produced charmonia more isolated than through *B* decay)
  - $|\cos(\theta_{\square})| < 0.4$
  - $|\cos(\theta_{\square})| < 0.4$

(for both, boost one of the pions (muons) and *X*(3872) into dipion (dimuon) rest frame, angle between pion (muon)) and *X*(3872))



Comparison results

- To within errors, fraction in each case is consistent with behavior of □(2S)
- Need models for more quantitative comparison



Summary

- $X(3872)$ signal established (522 ± 100 candidates) including in the forward region, mass difference to J/ψ measured
- We can study (hadronic) production and decay properties of state (more candidates, but more backg.)
- Selected properties of $X(3872)$ and $\psi(2S)$ are similar to within errors

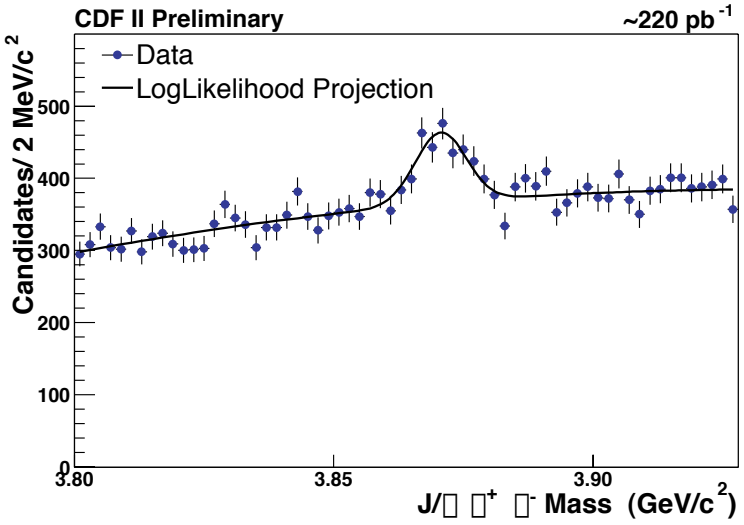
Need theoretical input and model predictions!
(particularly p_T production spectrum)

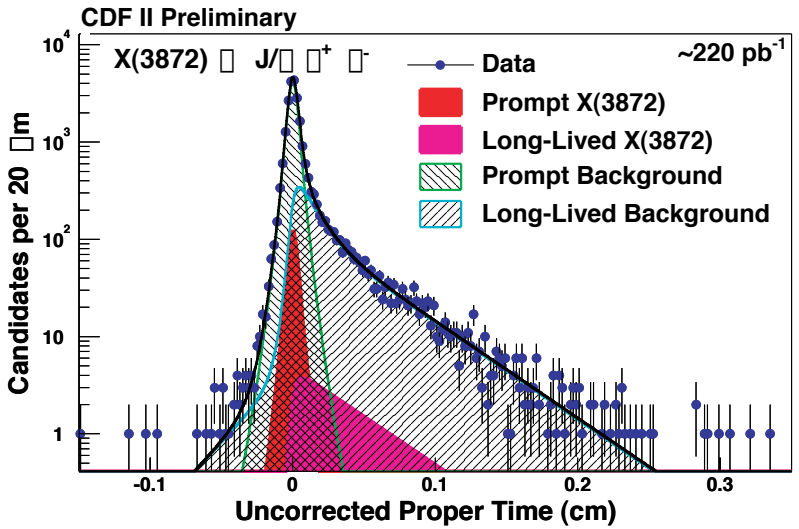
- Future
  - extract quantitative promptly produced fraction (decay length, isolation)
  - search for charged analog: $X^+ \to J/\psi\,\pi^+\pi^0$
  - search for radiative decays

Reconstruction of neutrals tough, but progress has been made

CDF Result

Backup





- More quantitative extraction of prompt fraction
- Simultaneous fit to mass and uncorrected proper time
- (2S): fraction from *B* hadron decays: 28.3 ± 1.0 (stat) ± 0.7 (syst)%
- *X*(3872): fraction from *B* hadron decays: 16.1 ± 4.9 (stat) ± 2.0 (syst)%
- Sample specific, depending on kinematic regime (e.g., $p_T(J/\psi) > 4$ GeV)