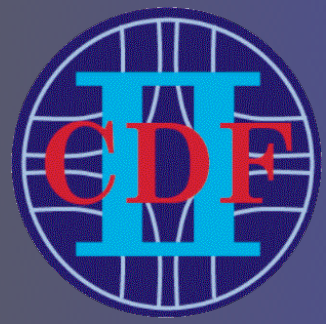
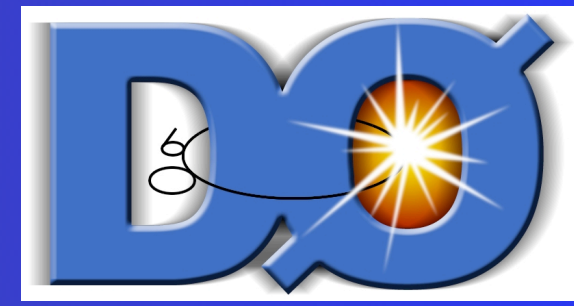




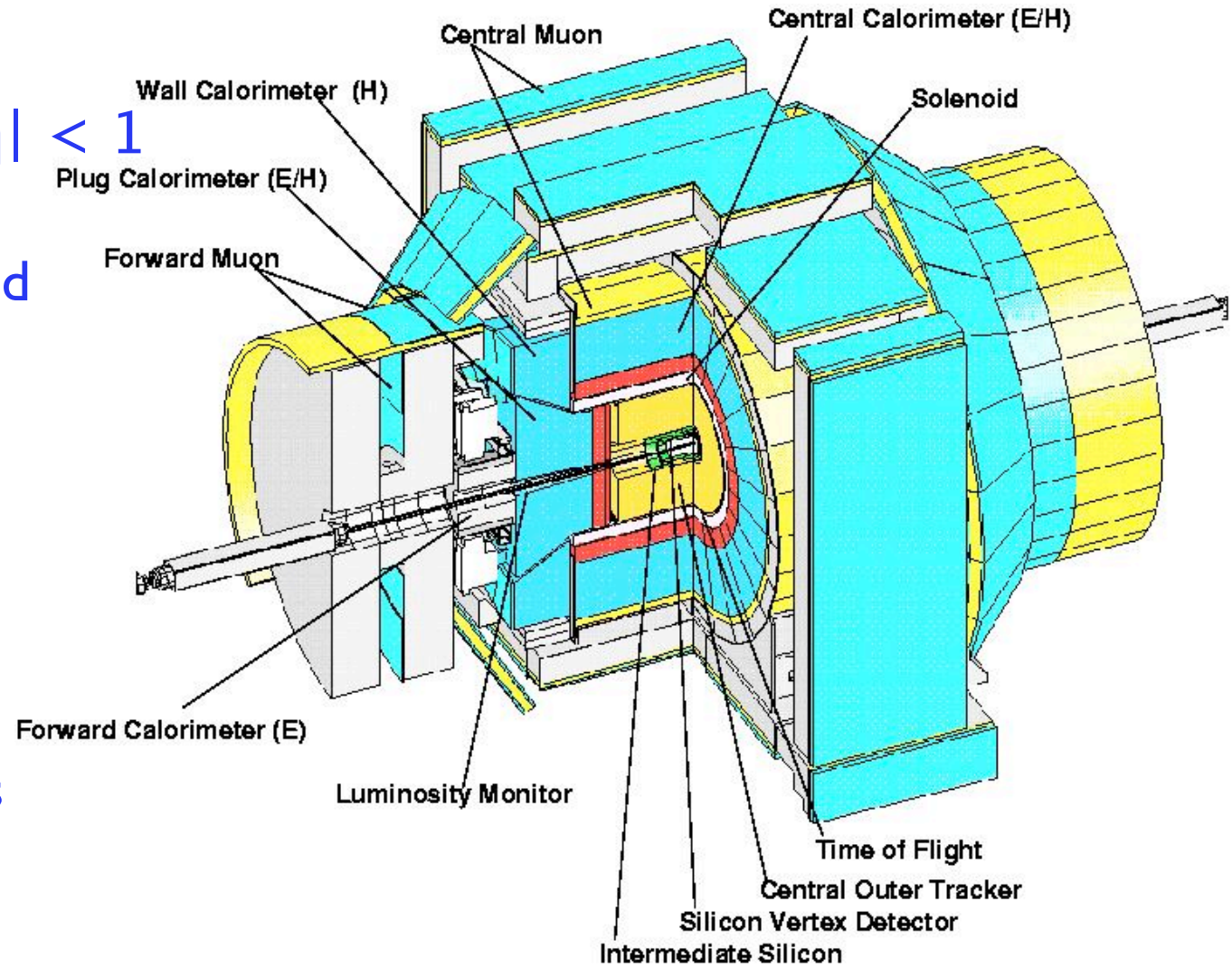
X(3872) and Pentaquark Searches at the Tevatron

R.J. Tesarek
Fermilab

CDF Experiment

Detector

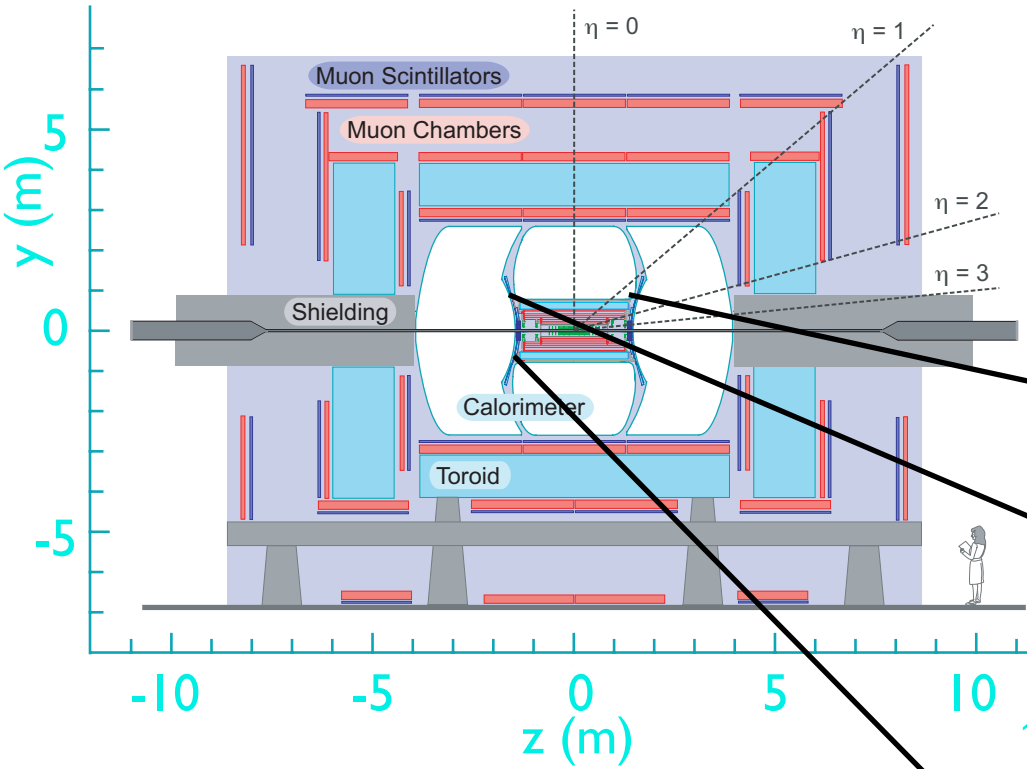
- Tracking/muon $|\eta| < 1$
- Silicon $|\eta| < 2$
- 1.4 T magnetic field



Trigger

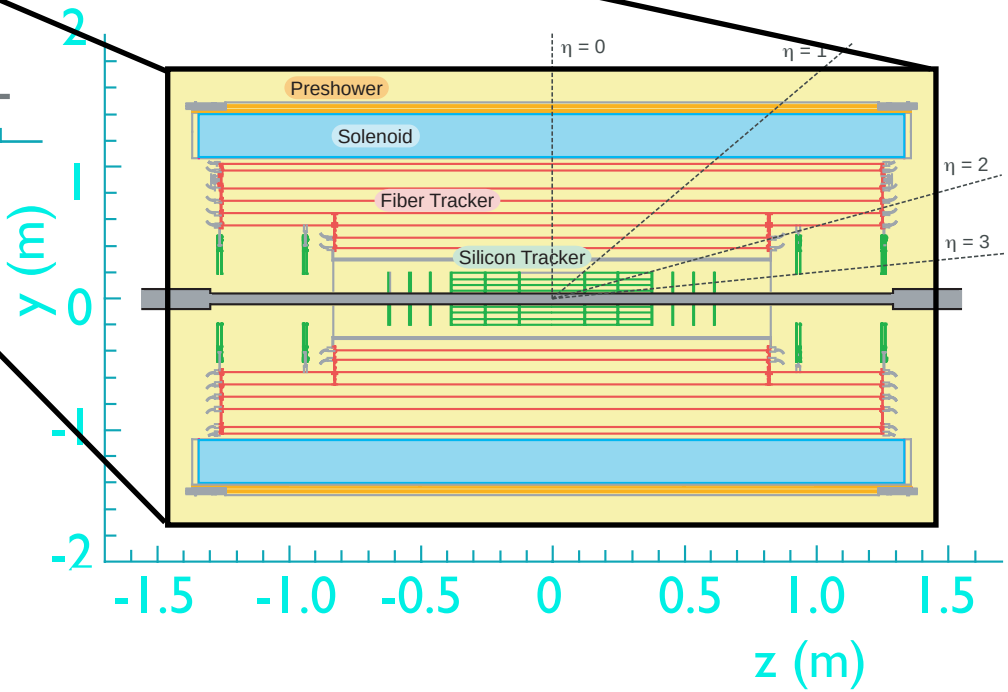
- Tracks
- Leptons
- Displaced vertices
- Impact parameter

D0 Experiment



Detector

- Muon/tracking coverage $|\eta| < 2$
- Silicon coverage $|\eta| < 3$
- 2 T magnetic field



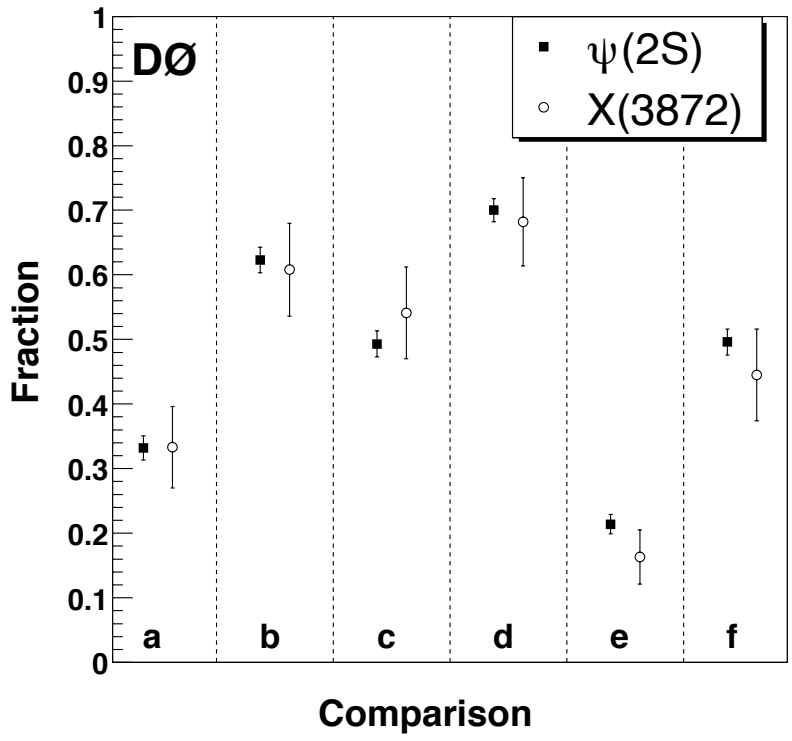
Trigger

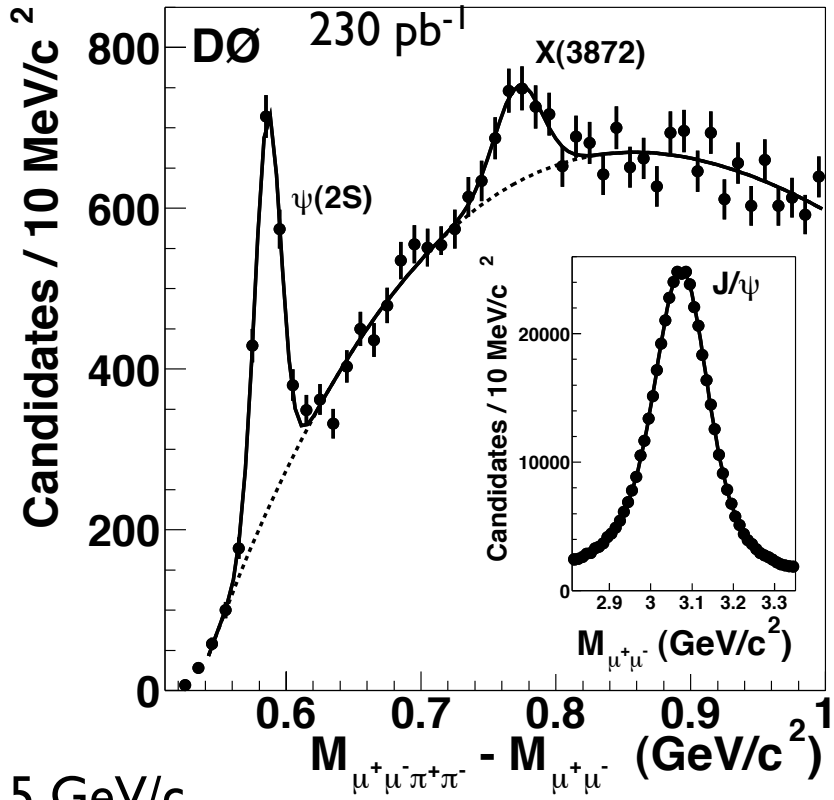
- Tracks
- Leptons

X(3872)

X(3872) at the Tevatron

- ~520 X(3872) candidates observed
- Comparison of X(3872) properties with ψ(2S).
- Properties X similar to ψ(2S)



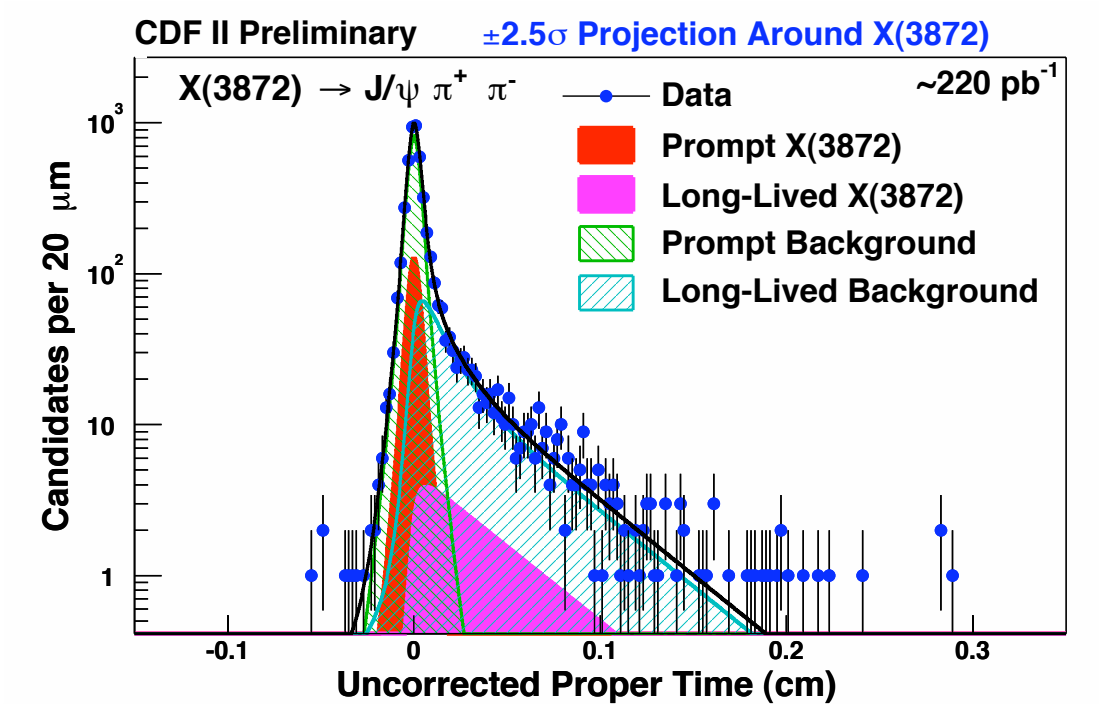


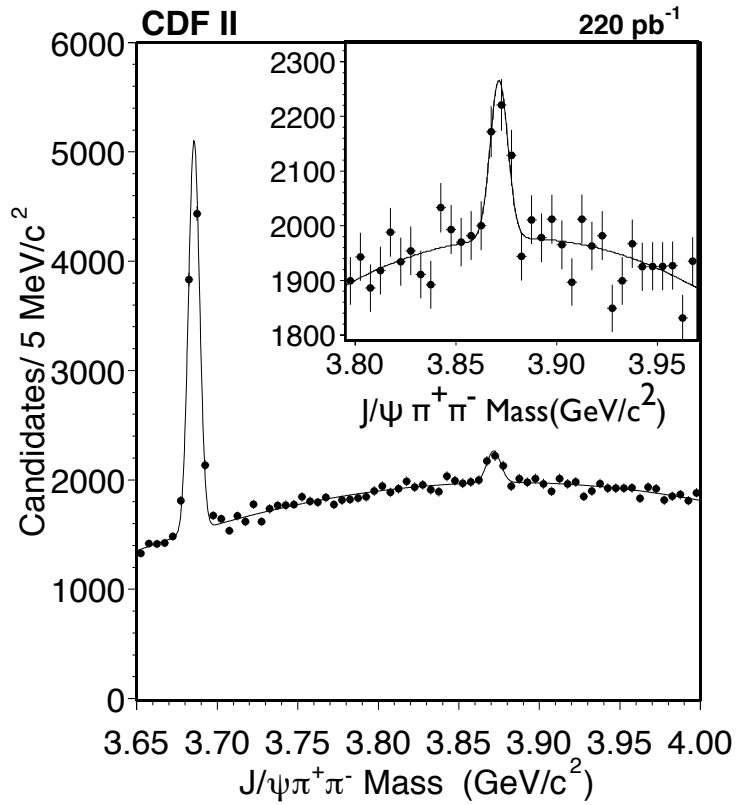
a: pT > 15 GeV/c
b: $|y(J/\psi\pi\pi)| < 1$
c: $\cos(\theta_\pi) < 0.4$
d: decay length < 0.01 cm
e: $J/\psi\pi\pi$ isolation = 1
f: $\cos(\theta_\mu)$

PRL 93 (2004) 162002.

X(3872) at the Tevatron

- ~730 X(3872) candidates observed
- "Lifetime" properties similar to ψ(2S)
- signal enhanced for $M_{\pi\pi}$ > 500 MeV/c^2





PRL 93 (2004) 072001.

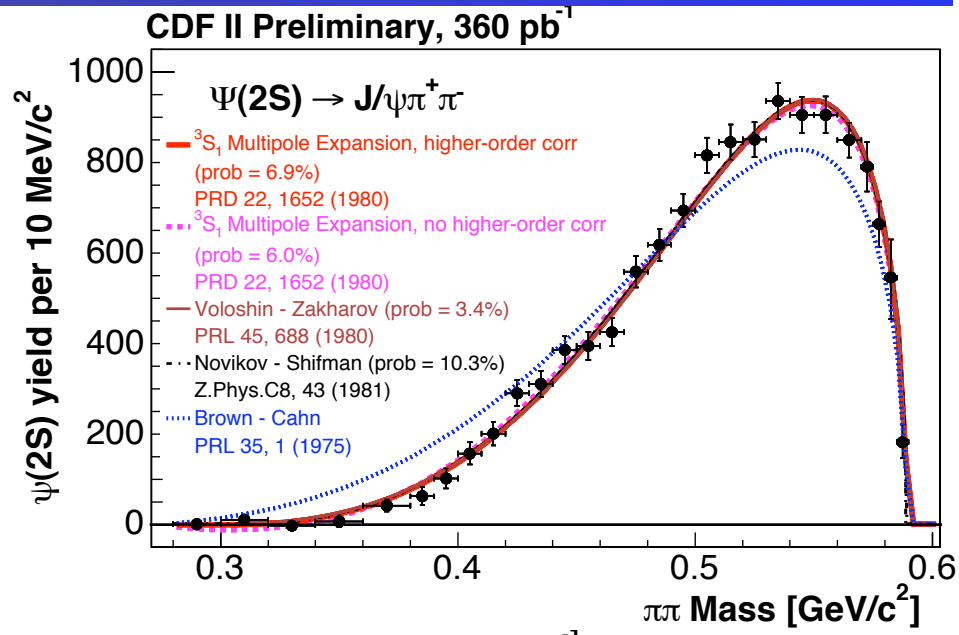
Particles from B decays

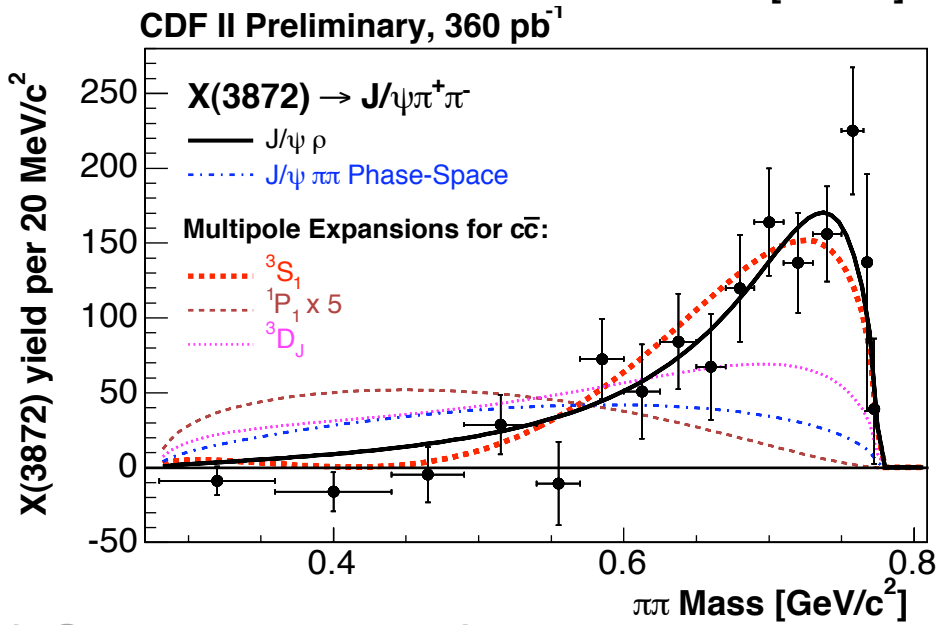
ψ(2s)	$28.3 \pm 1.0(stat.) \pm 0.7(syst.)\%$
X(3872)	$16.1 \pm 4.9(stat.) \pm 2.0(syst.)\%$

X(3872) Dipion mass

Fit for yield as a function of dipion mass

- $M_{\pi\pi}$ for $\psi(2S)$ agrees with expectation.
- $M_{\pi\pi}$ for X(3872) inconsistent with $^1P_1$ and ^3D_J charmonium.
- consistent with $J/\psi\rho^0$ and $^3S_1$ charmonium.





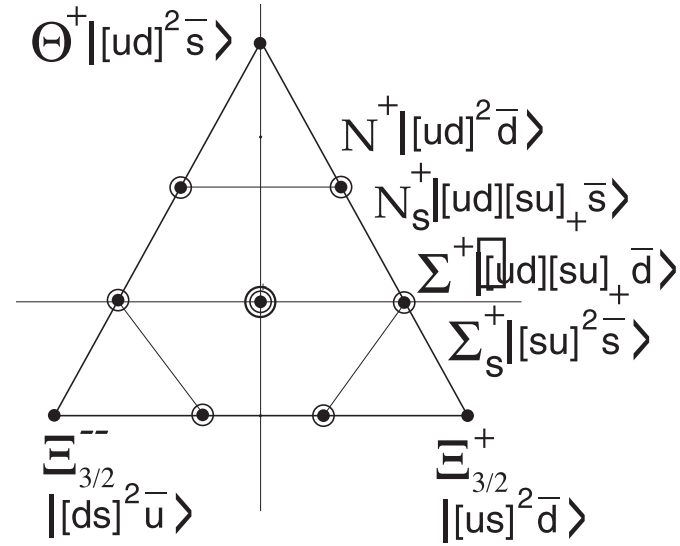
Pentaquark Searches

Pentaquark Searches at CDF

"meson + baryon" bound state:

$[ud]^2\,s$: $3_f \otimes 3_f \otimes 3_f = 8_f \oplus 10_f$

Jaffe, Wilczek hep-ph/0307341



Search in 2-body decay modes

Notation	Quark content	Decay channel	Reference Channel(s)	sightings
Θ^+	$\bar{s}uudd$	pK_S^0	$\Lambda(1520) \to pK^-,\ K^{*+} \to K_S^0\pi^+$	5 (nK^+)/6(pK^0)
Φ^{--}	$\bar{u}ddss$	$\Xi^-\pi^-$		1($\Xi\pi$)
Φ^0	$\bar{d}udss$	$\Xi^-\pi^+$	$\Xi^0(1530) \to \Xi^-\pi^+$	1($\Xi\pi$)
Θ_c^0	$\bar{c}dudu$	$D^{*-}p$	$D^{**} \to D^{*+}\pi^-$	1($D^{*-}\pi^+$)
Θ_c^0	$\bar{c}dudu$	D^-p	$D^{**} \to D^+\pi^-$	
Θ_c^+	$\bar{c}uudu$	$\bar{D^0}p$	$D^{**} \to D^0\pi^+$	

"Observations" with significance in excess of 5 σ

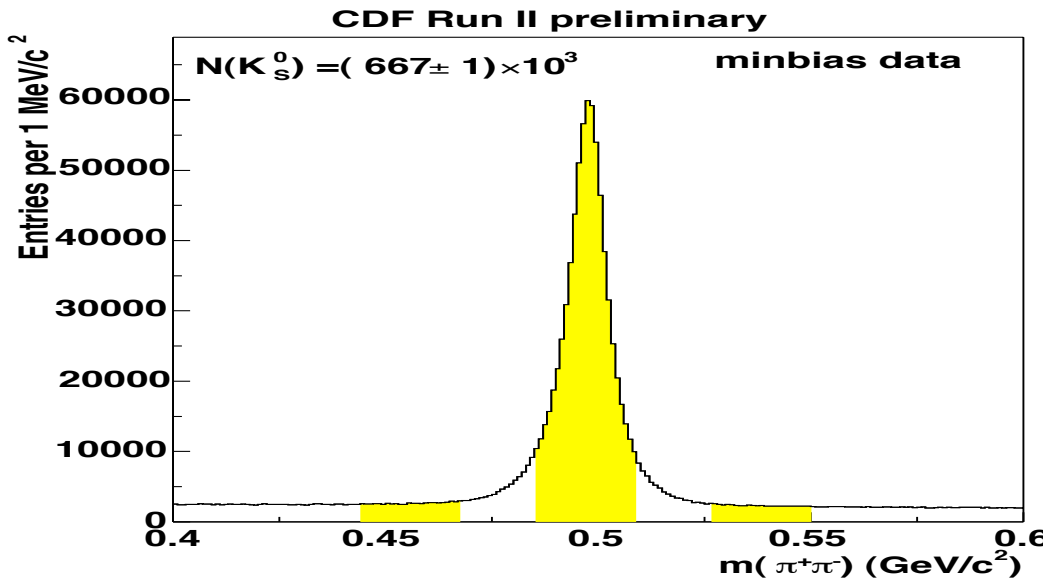
Pentaquark search strategy

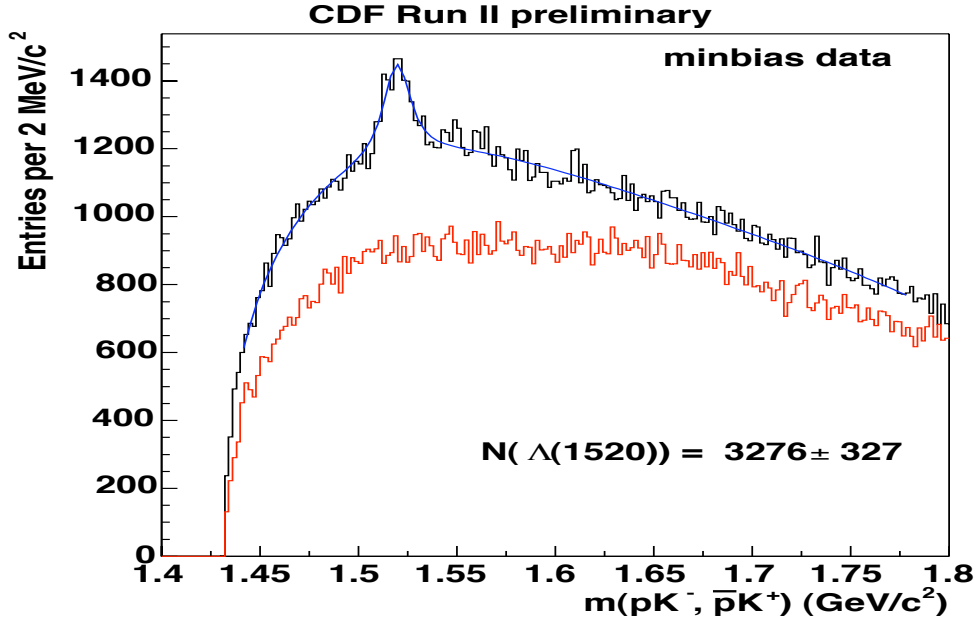
Reconstruct resonance with similar topology (normalization)

Use PID to identify proton

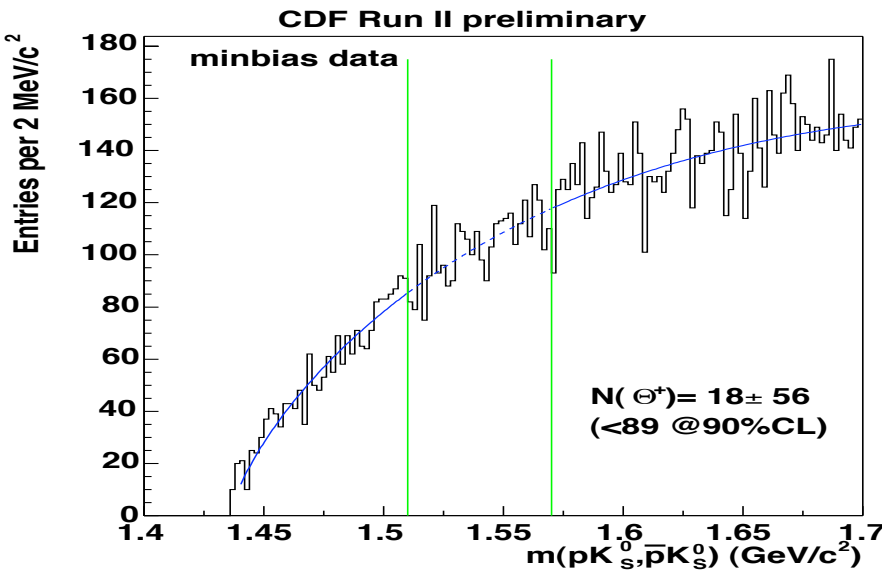
Triggers

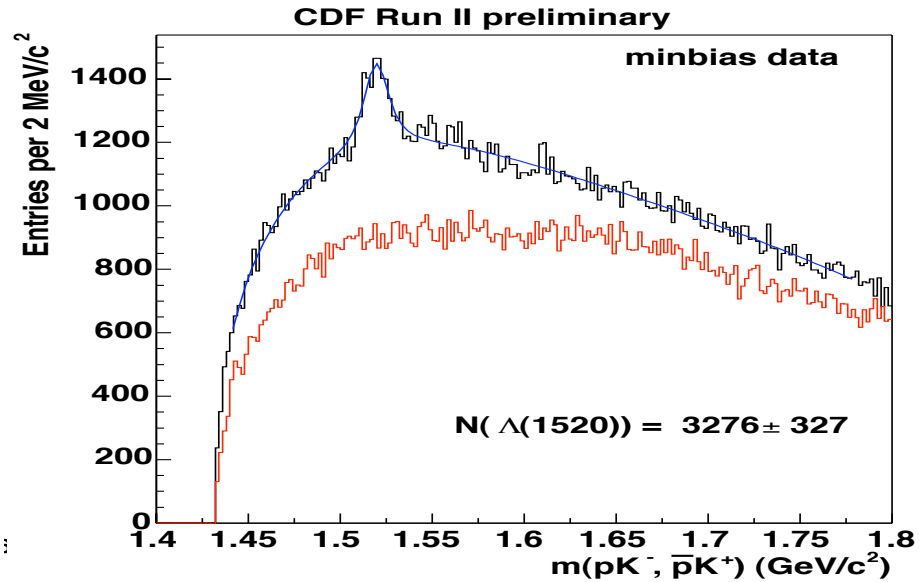
- Zero/Minimum bias (bunch crossing, inelastic collision)
- Jet 20 (E_T > 20 GeV)
- 2 track (displaced vertex) for charm





$\Theta^+ \rightarrow pK_s^0$



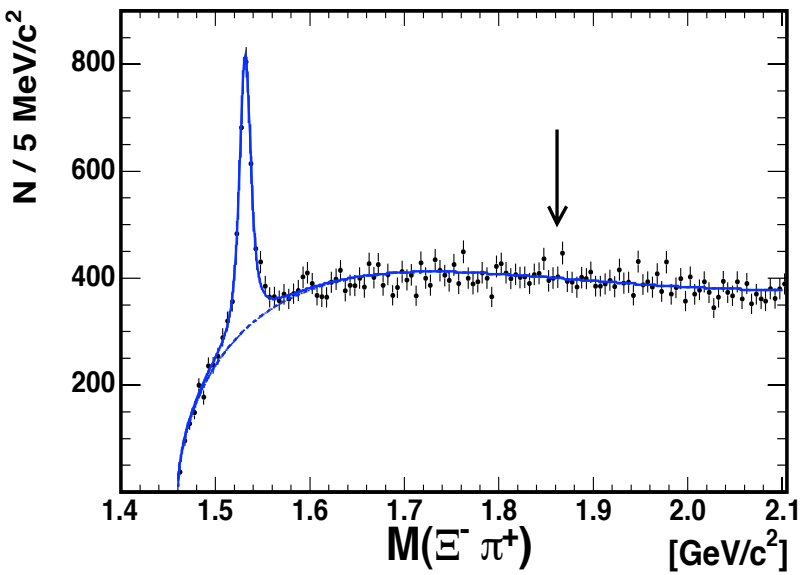


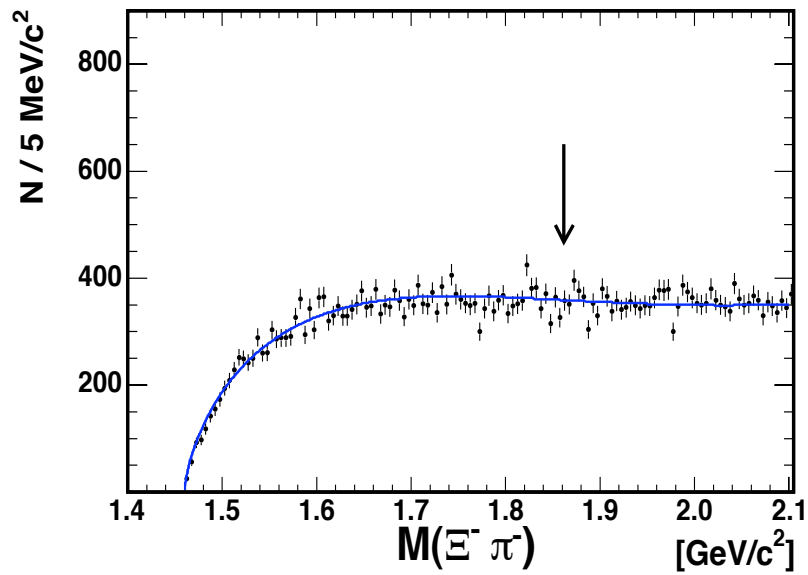
Resonance	Minbias data
$\phi \rightarrow K^+K^-$	$19,721 \pm 273$
$\Lambda \rightarrow pK^-$	$3,276 \pm 327$
$K^{*+} \rightarrow K^0_S\pi^+$	$15,695 \pm 775$
$\Theta^+ \rightarrow pK^0_S$	18 ± 56
90% CL limit on Θ^+	< 89

work on relative yield $\Theta^+/\Lambda(152)$ is in progress. The relative yield (assuming $B(\Theta^+ \rightarrow pK^0_S) = 0.25$) is in the the ballpark of 5%.

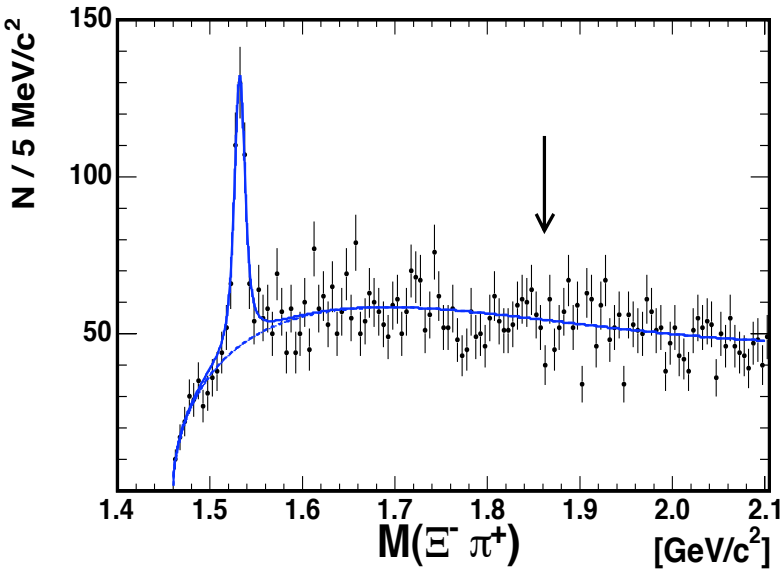
Φ^0, Φ^{++} Search

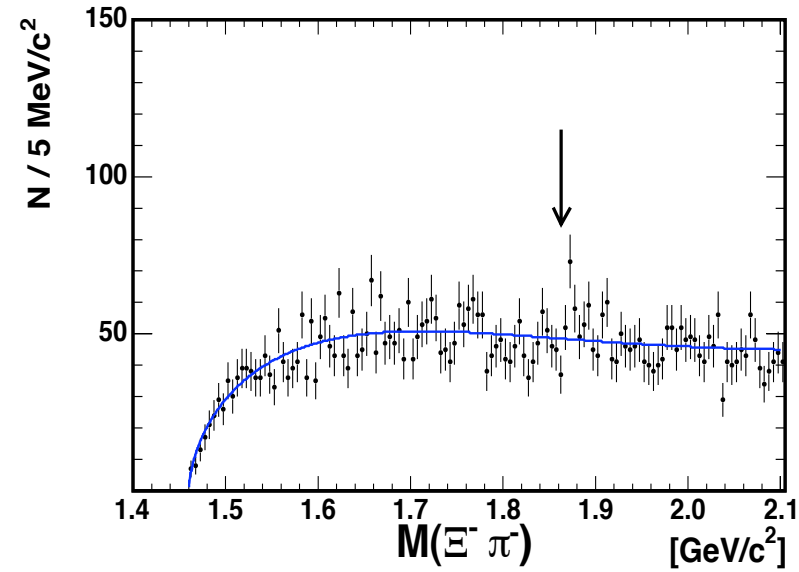
- SVT data





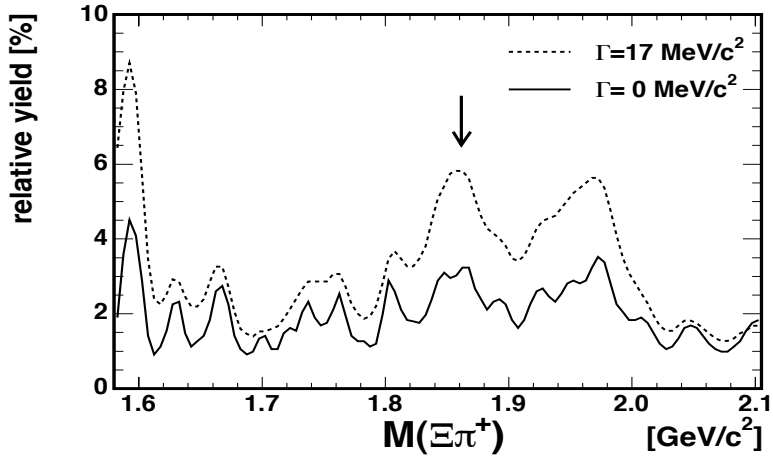
- Jet20 data

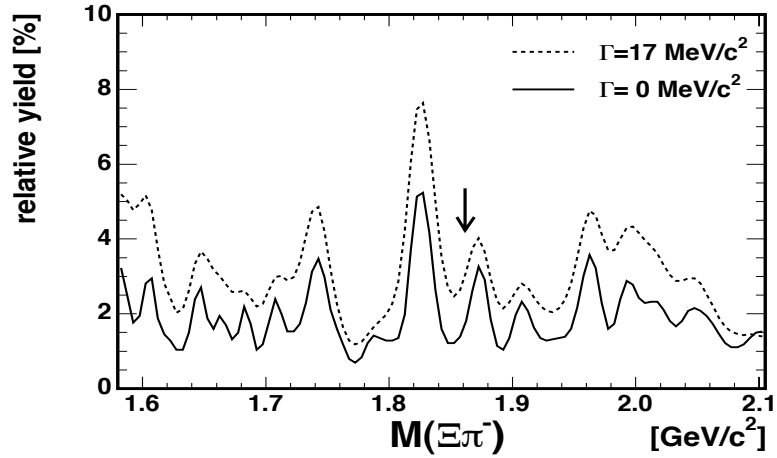




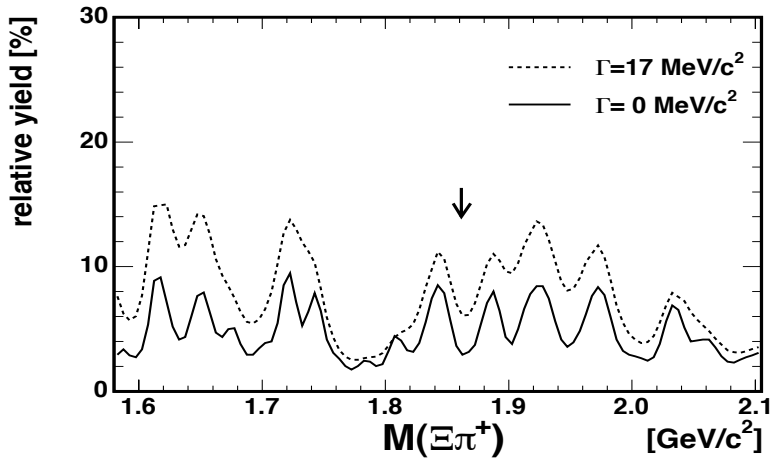
Φ^0, Φ^{++} Search

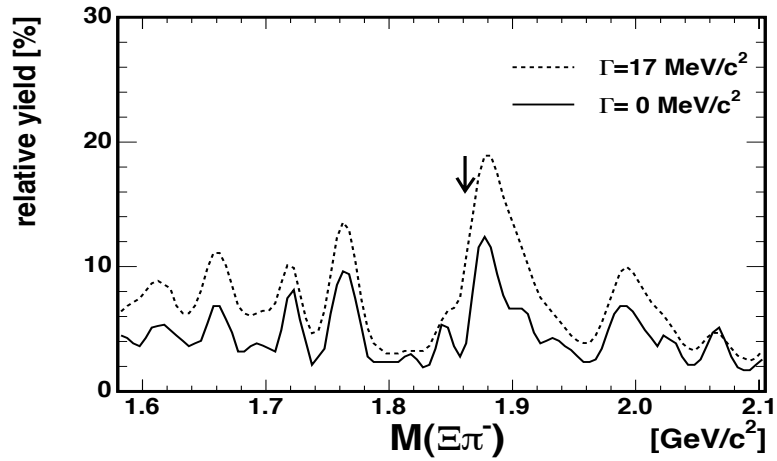
- SVT data:





- Jet20 data:





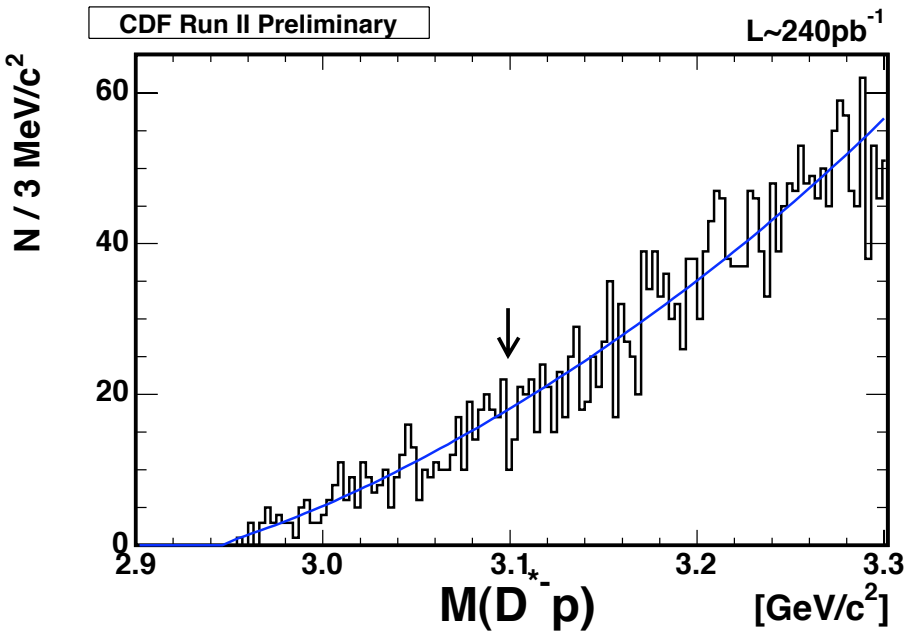
Φ^{--}, Φ^0 at CDF

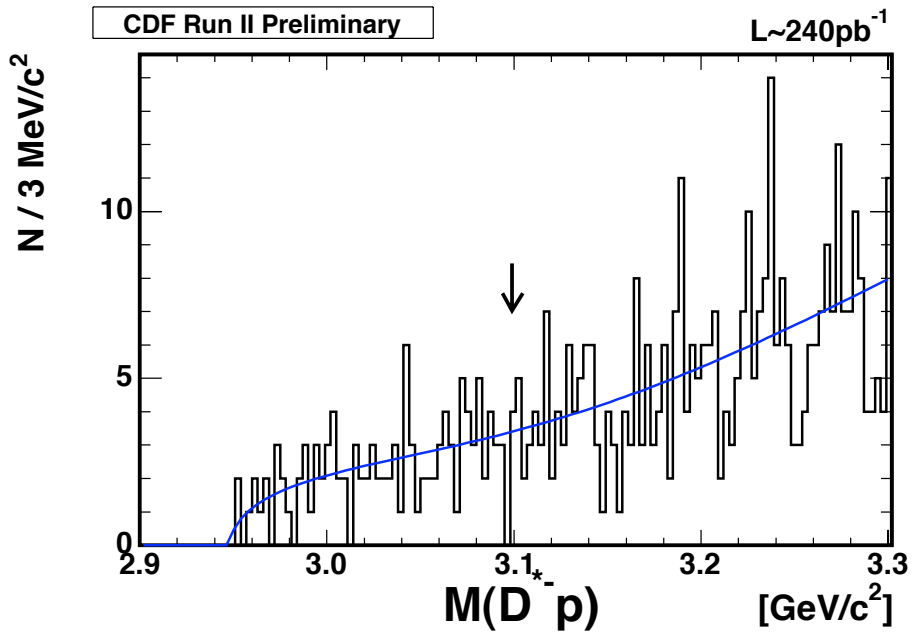
90% CL upper limits

	SVT trigger($\Gamma = 17$ MeV/ c^2)	Jet20 trigger($\Gamma = 17$ MeV/ c^2)
N(Ξ)	35722 ± 326	4870 ± 122
N($\Xi(1530)$)	1923 ± 80	313 ± 28
$\frac{\sigma_{\Phi--}(p_T>2\ \text{GeV/c})\cdot\mathcal{B}(\Phi^{--}\to\Xi\pi^-)}{\sigma_{\Xi(1530)}(p_T>2\ \text{GeV/c})}$[%]	< 1.7 (3.1)	< 3.2 (10.1)
$\frac{\sigma_{\Phi^0}(p_T>2\ \text{GeV/c})\cdot\mathcal{B}(\Phi^0\to\Xi\pi^+)}{\sigma_{\Xi(1530)}(p_T>2\ \text{GeV/c})}$[%]	< 3.2 (5.8)	< 3.0 (9.2)

Event yields of Ξ^-, $\Xi(1530)$ and upper limits on relative cross sections of $\Phi^{--,0}$ pentaquarks at the mass reported by NA49 and $\Xi(1530)$ at 90% Confidence Levels. The numbers in parentheses represent limits on relative cross section assuming natural width $\Gamma = 17$ MeV/ c^2 for the pentaquarks.

Charmed Pentaquark ($D^{*-}p$)

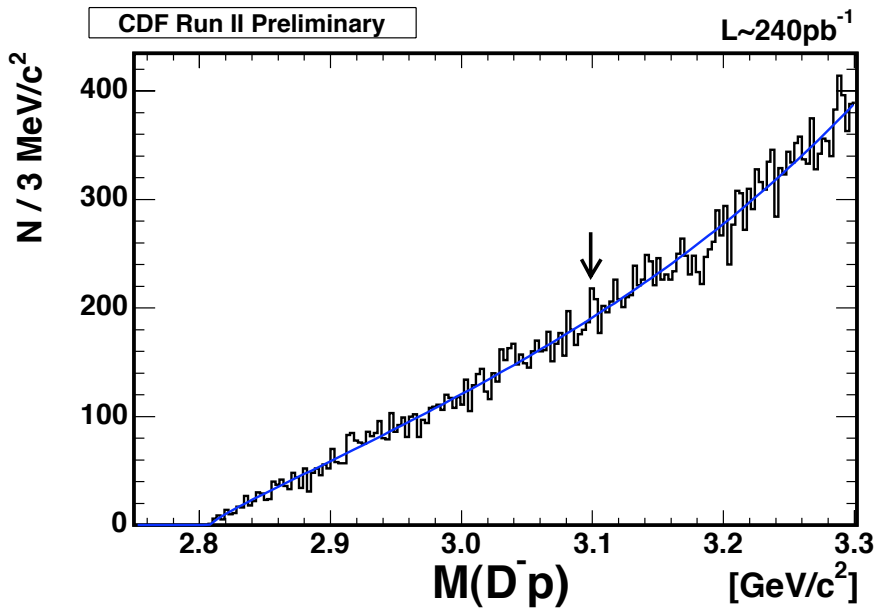




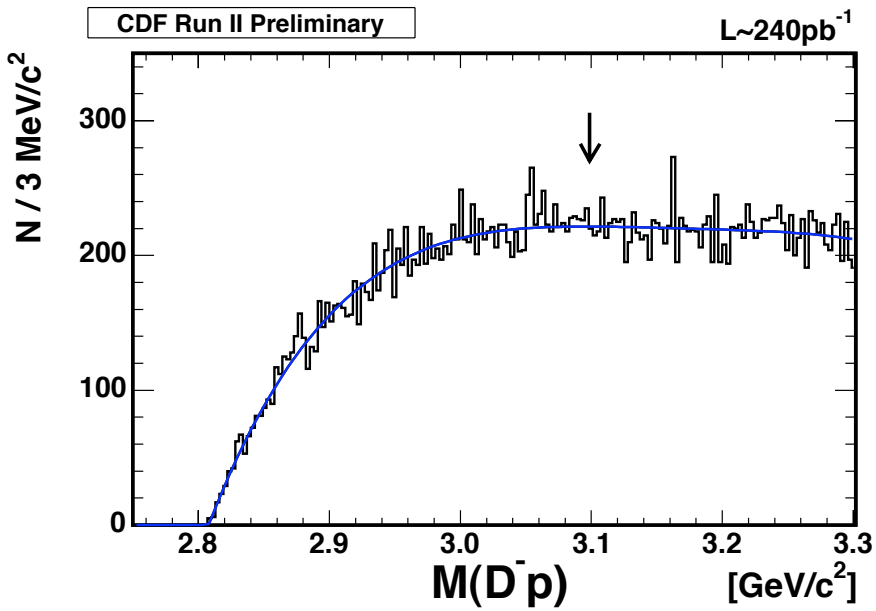
- prompt production
- $\Gamma = 0$ MeV/ c^2: 21@90%CL
- $\Gamma = 12$ MeV/ c^2: 32@90%CL

- secondary production
- $\Gamma = 0$ MeV/ c^2: 8@90%CL
- $\Gamma = 12$ MeV/ c^2: 15@90%CL

Charmed Pentaquark (D^-p)

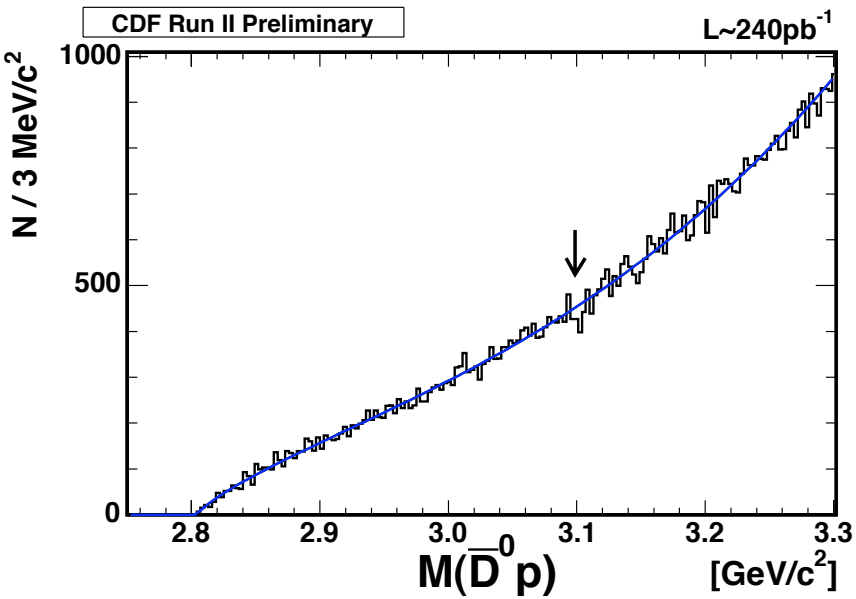


- prompt production
- $\Gamma = 0$ MeV/ c^2: 80 @90%CL
- $\Gamma = 12$ MeV/ c^2: 84 @90%CL

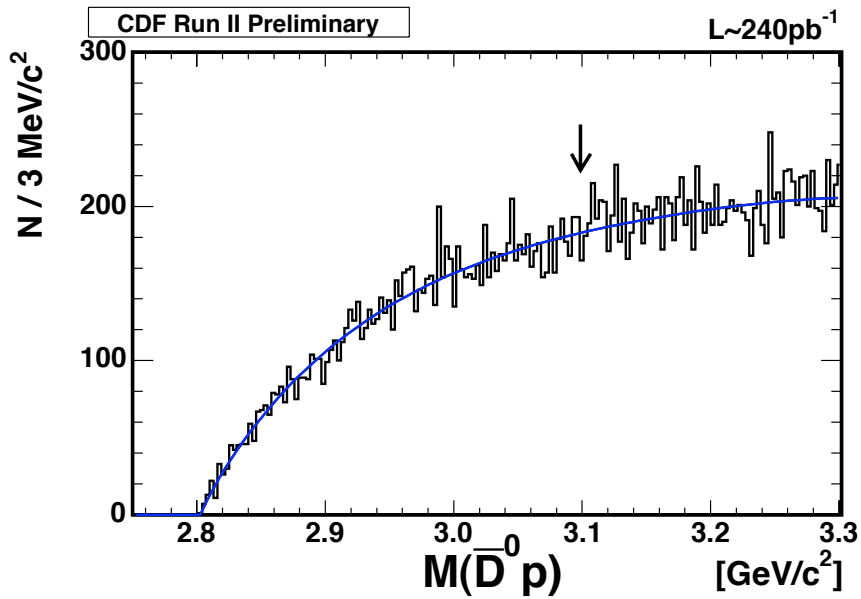


- secondary production
- $\Gamma = 0$ MeV/ c^2: 61 @90%CL
- $\Gamma = 12$ MeV/ c^2:
  - 118 @90%CL

Charmed Pentaquarks



- prompt production
- Γ = 0 MeV/ c^2: 87 @90%CL
- Γ = 12 MeV/ c^2: 122 @90%CL



- secondary production
- Γ = 0 MeV/ c^2: 107 @90%CL
- Γ = 12 MeV/ c^2: 214 @90%CL

Limits on Θc Yield

- search window $3,099 \pm 18\ \mathrm{MeV}/c^2$
- take worst point from the limit vs mass inside the window

Reference channel		Search channel	
$D_2^{*0} \to D^+ \pi^-$	6247 ± 1711	$\Theta_c^0 \to D^{*-} p$	< 21 @ 90% CL
$D_2^{*0} \to D^+ \pi^-$	34509 ± 1092	$\Theta_c^0 \to D^- p$	< 89 @ 90% CL
$D_2^{*+} \to D^0 \pi^+$	13628 ± 813	$\Theta_c^+ \to \bar{D}^0 p$	< 87 @ 90% CL
		$\Theta_c^+ \to D^0 p$	< 97 @ 90% CL

- conversion of event yields into $\sigma \times B$ limits is on the way.

Summary

X(3872)

- CDF/D0 confirm observation.
- Production properties similar to $\psi(2S)$.
- ~16% of X(3872) from B hadron decays (28% for $\psi(2S)$).
- Fits to dipion mass distribution consistent with $J/\psi\rho^0$ and $^3S_1$ charmonium.

Pentaquark Searches

- Several pentaquark states searched for

$$\Theta^+,\ \Phi^{--},\ \Phi^0,\ \Theta_c{}^0,\ \Theta_c{}^0$$

- No observations to date at CDF!
- Yield ratio upper limits set
- Calculations of σ x BR upper limits underway

Backup Slides

Particle ID at CDF

- combine ToF and dE/dx information for a given track into common χ_i^2 :

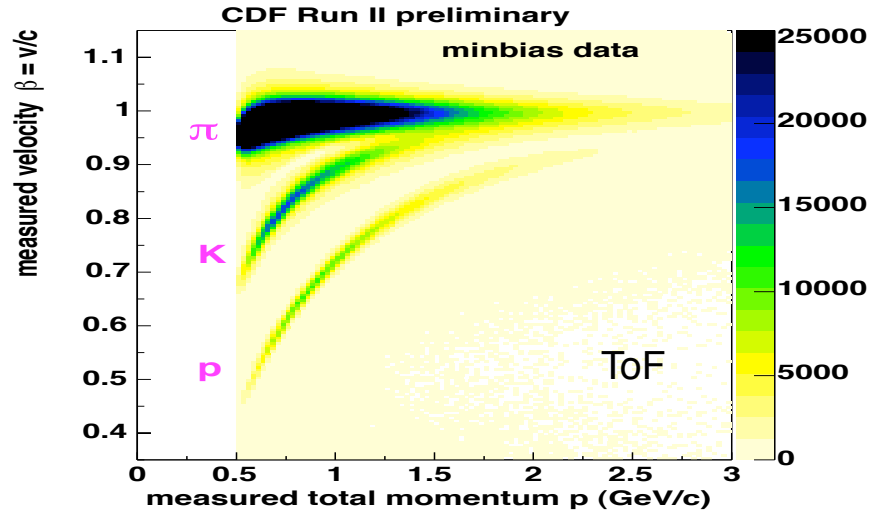
$$\chi_i^2 = \chi_i^2(\mathrm{ToF}) + \chi_i^2(\mathrm{dE/dx})(\mathrm{COT}),$$

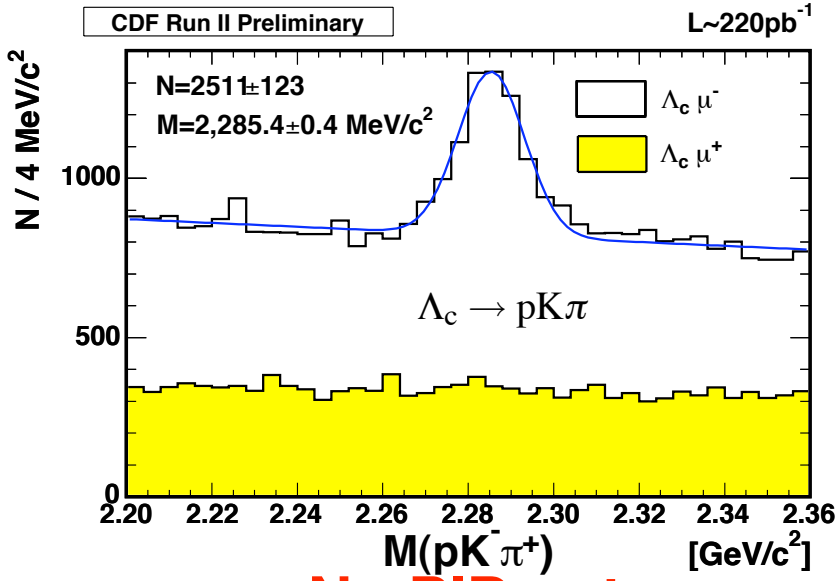
where $i = p, K, \pi, e, \mu$

- form normalized likelihood ratio:

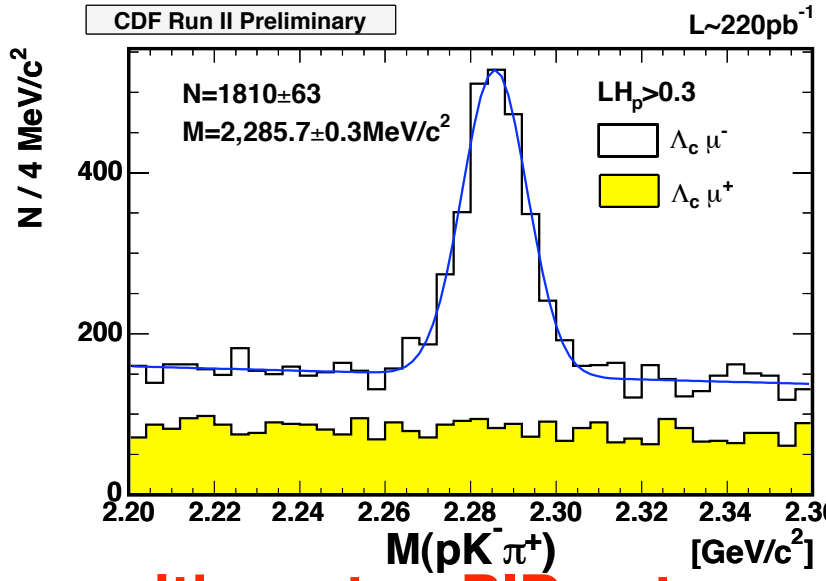
$$LH_i = \frac{lh(i)}{lh(p) + lh(K) + lh(e) + lh(\mu) + lh(\pi)}$$

where $lh(i) = \exp(-\chi_i^2/2)$,





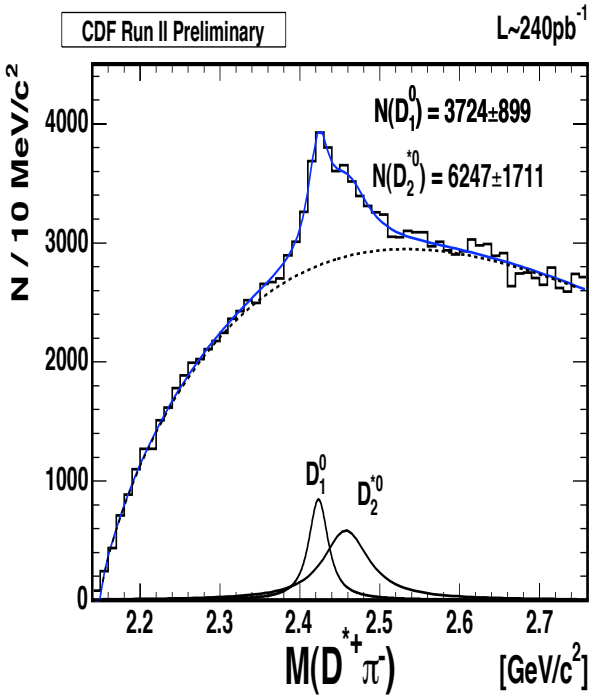
No PID cut



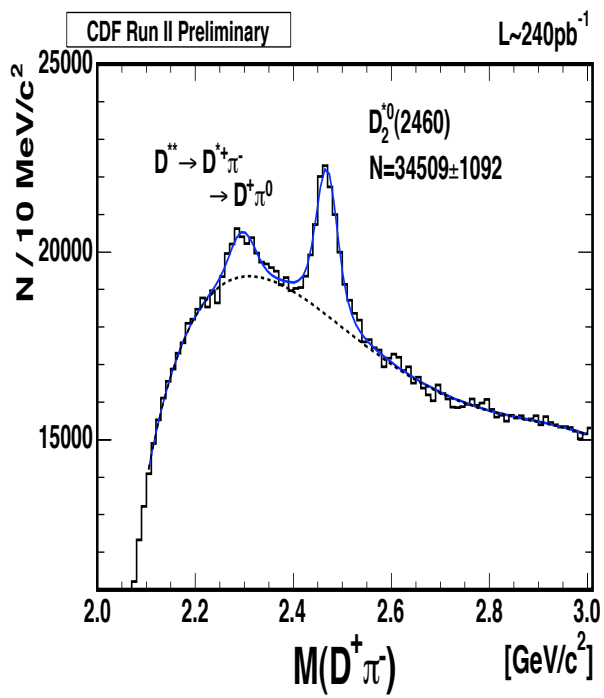
with proton PID cut

Charm Pentaquark Reference Modes

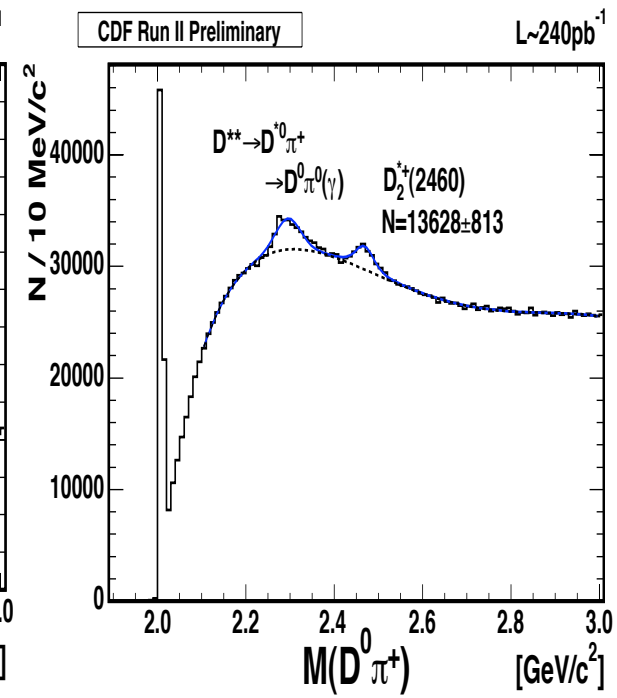
Reference channels



$$D^{**} \rightarrow D^{*+}\pi^- \hookrightarrow D^0\pi^+ \hookrightarrow K^-\pi^+$$



$$D^{**} \rightarrow D^{+}\pi^- \hookrightarrow K^-\pi^+\pi^+$$



$$D^{**} \rightarrow D^{0}\pi^+ \hookrightarrow K^-\pi^+$$