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CERN PPE Seminar
1 April 1996

Recent Charm Results From CLEO

- CLEO - II detector at CESR (Cornell U.)
- Data: $e^+e^- \to \Upsilon(4S)$ [10.6 GeV] about $\frac{2}{3}$
  and off-resonance about $\frac{1}{3}$

3.5 million (3.5 fb^{-1}) $e^+e^- \to B\bar{B}$ events processed!
More than 4 million (4 fb^{-1}) $e^+e^- \to c\bar{c}$ events!

- CLEO has excellent charm physics program!

Charm results to discuss:

- Model independent measurement of $B(D_s^- \to \phi\pi^-)$
- Inclusive D^0 semi-electronic branching ratio
- Precise meas. of $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$
- Observation of two new excited Ξ_c states
- Study of flavor-tagged Λ_c in B decays
- Measurement of color-suppressed mode $\Lambda_c^+ \to p\phi$

Monday PPE Seminar, CERN April 1, 1996

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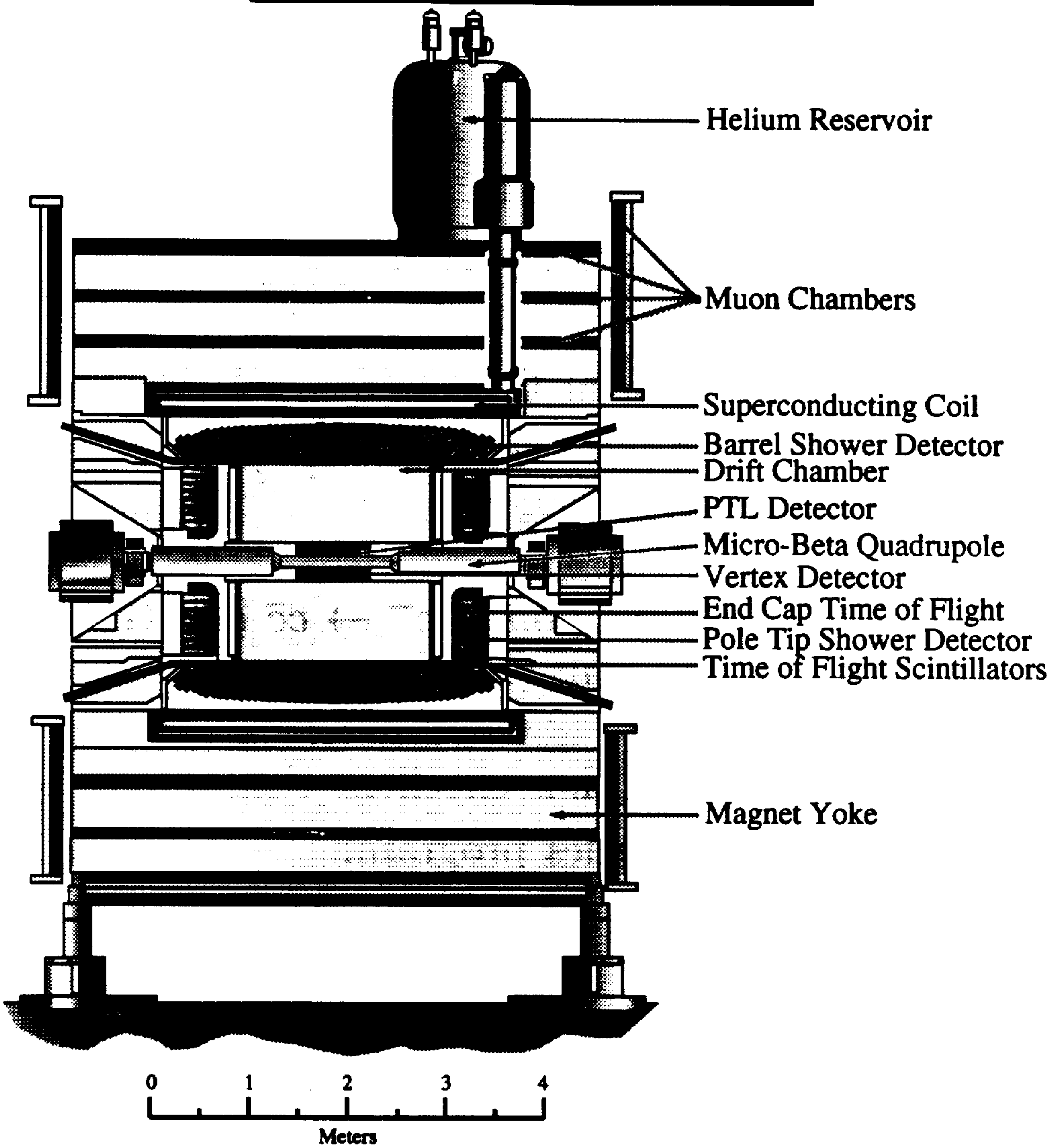
CLEO II Detector



- Tracking: 67 layers
- PID: combine ionization energy loss measurement (dE/dx) in DR with scintillation TOF
- EM showers: 7800 thallium-doped CsI crystals
- 1.5 T superconducting solenoidal magnet

Absolute $B(D_s^- \to \phi\pi^-)$

- Branching fraction measurements for D_s^- decay modes are made relative to $\phi\pi^-$

No absolute scale, only model dependent estimates

- First absolute measurement: BES

$B(D_s^- \to \phi\pi^-) = 3.9^{+5.1+1.8}_{-1.9-1.1}\%$ 2 double tag D_s events

- New CLEO measurement: model independent, high statistics!

Technique:

$B(D^0 \to K^-\pi^+)$ is well-measured absolutely

Measure $B(D_s^- \to \phi\pi^-)/B(D^0 \to K^-\pi^+)$ to get

$$B(D_s^- \to \phi\pi^-)$$

$\Rightarrow$ Partially reconstruct $\bar{B}^0 \to D^{*+}D_s^{*-}$

Analysis used 2.5 fb^{-1} (2.7 M $B\bar{B}$)

Method to Extract $B(D_s^- \to \phi\pi^-)$

Method to extract $B(D_s^- \to \phi\pi^-)$:

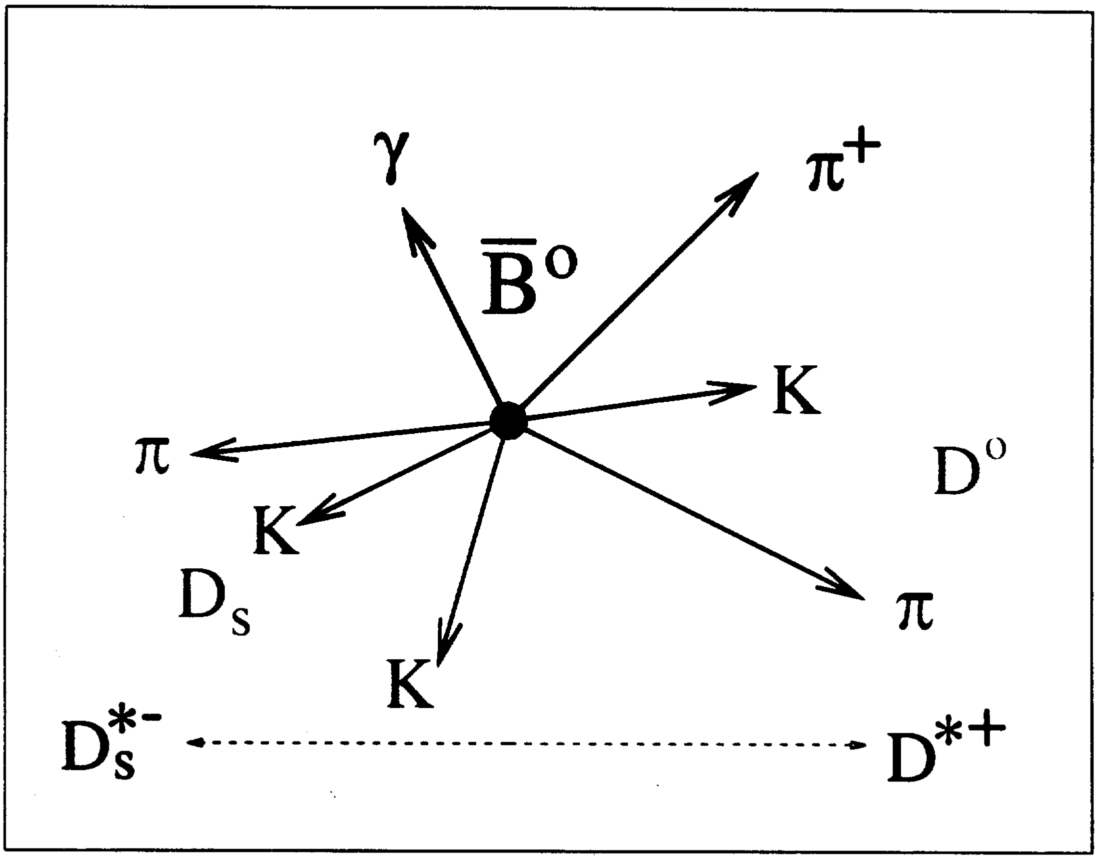
- Reconstruct $\bar{B}^0 \to D^{*+} D_s^{*-}$ two ways:

  1) fully reconstruct D_s^{*-}, combine soft pion from

  $$D^{*+} \to D^0 \pi^+ \qquad (N_{D_s^*})$$

  2) fully reconstruct D^{*+}, combine soft photon from

  $$D_s^{*-} \to D_s^- \gamma \qquad (N_{D^*})$$



- Measure efficiency corrected B meson yields from both methods and constrain them equal

Method to Extract Branching Fraction Ratio

- For one reconstruction mode:

$$\frac{B(D_s^- \to \phi\pi^-)}{B(D^0 \to K^-\pi^+)} = \frac{N_{D_s^*}}{\varepsilon(D_s \to \phi\pi)} \frac{\varepsilon(D^0 \to K\pi)}{N_{D^*}}$$

- Add in other decay modes to improve statistics:

$$\frac{B(D_s^- \to \phi\pi^-)}{B(D^0 \to K^-\pi^+)} = \frac{N_{D_s^*}}{\Sigma_{i=1}^{N_{D_s}^{FS}} R_i(\varepsilon \cdot B)_i} \frac{\Sigma_{j=1}^{N_{D^0}^{FS}} R_j(\varepsilon \cdot B)_j}{N_{D^*}}$$

Lots of systematics cancel!

Tag event by fully reconstructing D_s^{*-}

- Reconstruct three D_s^- decay modes

$D_s^- \to \phi\pi^-$ $\quad$ $D_s^- \to K^0 K^-$ $\quad$ $D_s^- \to K^{*0} K^-$

- Combine D_s^- w/ soft photon $\Rightarrow$ D_s^{*-}

- Using measured $\vec{p}_{D_s^{*-}}$ and constraint $E_B = E_{beam}$

$\Rightarrow$ can calculate $|\vec{p}_{D^*}|$ and one angle

$$E_B = E_{D^*} + E_{D_s^*} = E_{beam}$$

$$\vec{p}_B = \vec{p}_{D^*} + \vec{p}_{D_s^*}$$

where $\vec{p}_{D^*} = \sqrt{(E_B - E_{D_s^*})^2 - m_{D^*}^2}$

- D^{*+} direction constrained to lie on:

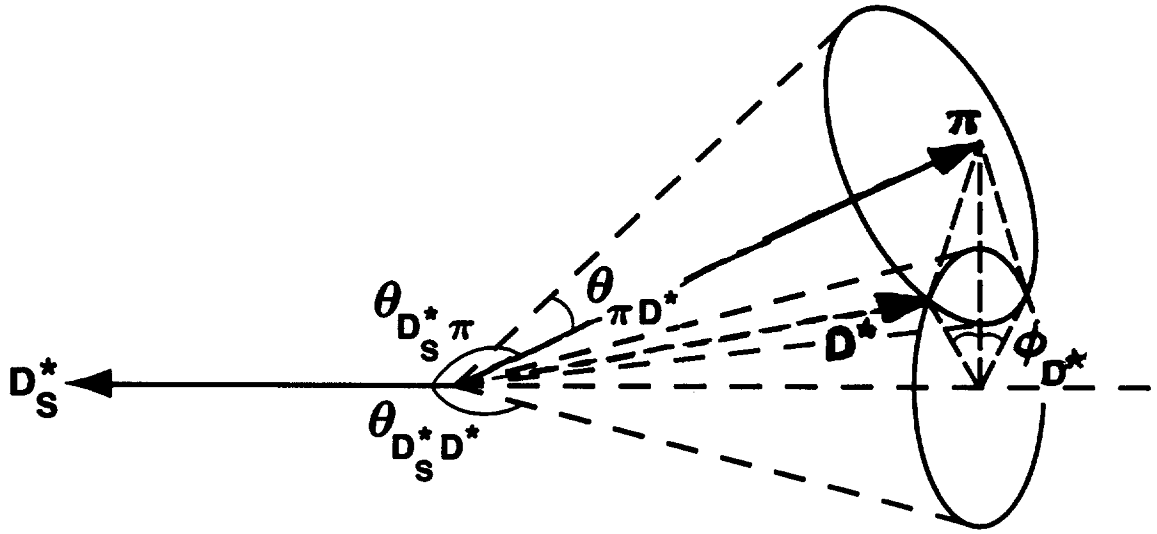
1) cone of $\Theta_{D_s^* D^*}$ w/R to D_s^{*-} direction

$$\cos\Theta_{D_s^* D^*} = (p_{D_s^*}^2 + p_{D^*}^2 + p_B^2)/2p_{D_s^*} + p_{D^*}$$

2) cone of $\Theta_{\pi D^*}$ w/R to soft pion direction

D^{*+} direction one of two intersections of these 2 cones

$$|\cos\phi_{D^*}| = \frac{\cos\Theta_{\pi D^*} - \cos\Theta_{D_s^* D^*}\cos\Theta_{D_s^*\pi}}{\sin\Theta_{D_s^* D^*}\sin\Theta_{D_s^*\pi}} < 1$$



Tag event by fully reconstructing D^{*+}

- Reconstruct three D^0 decay modes

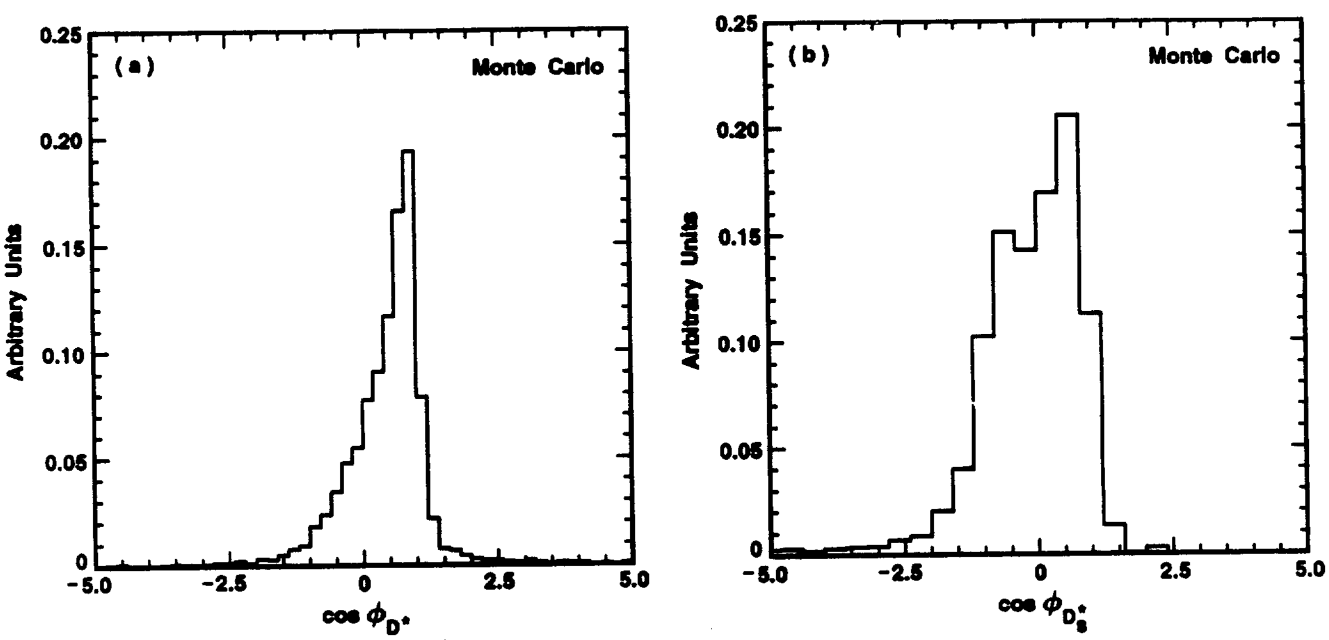
$D^0 \to K^-\pi^+$ $\quad$ $D^0 \to K^-\pi^+\pi^0$ $\quad$ $D^0 \to \bar{K}^0\pi^+\pi^-$

- Combine D^0 w/ soft pion $\Rightarrow$ D^{*+}

- Obtain $\cos\phi_{D_s^*}$ in same fashion as $\cos\phi_{D^*}$

Use $\cos\phi$ distribution) extract signals

- Expectations from MC:



(a) Signal MC $\cos\phi$ for fully reconstructed D_s^{*-}

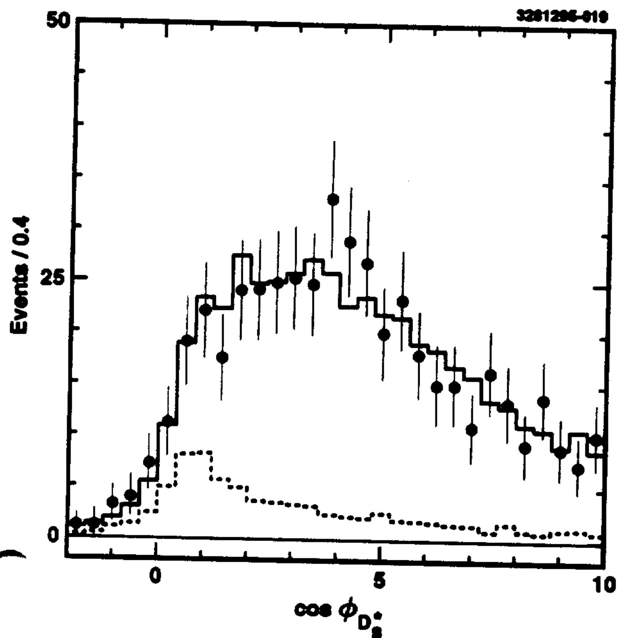
(b) Signal MC $\cos\phi$ for fully reconstructed D^{*+}

Backgrounds

D_s^{*-} full reconstruction

- Two background sources:
  1) fake D_s^{*-} w/ true or random pions
  2) random pions w/ true D_s^{*-}
- Obtain $\cos\phi_{D^*}$ for both bkgs from MC
- Use data to normalize fake D_s^{*-} contribution

Sideband distribution of $\cos\phi_{D^*}$



$$60 < \Delta M_{D_s^*} < 90 MeV/c^2$$
$$170 < \Delta M_{D_s^*} < 220 MeV/c^2$$
where $\Delta M_{D_s^*} = m_{D_s^*} - m_{D_s}$

Data: points with errors

BKG: solid hist is total of MC bkgs

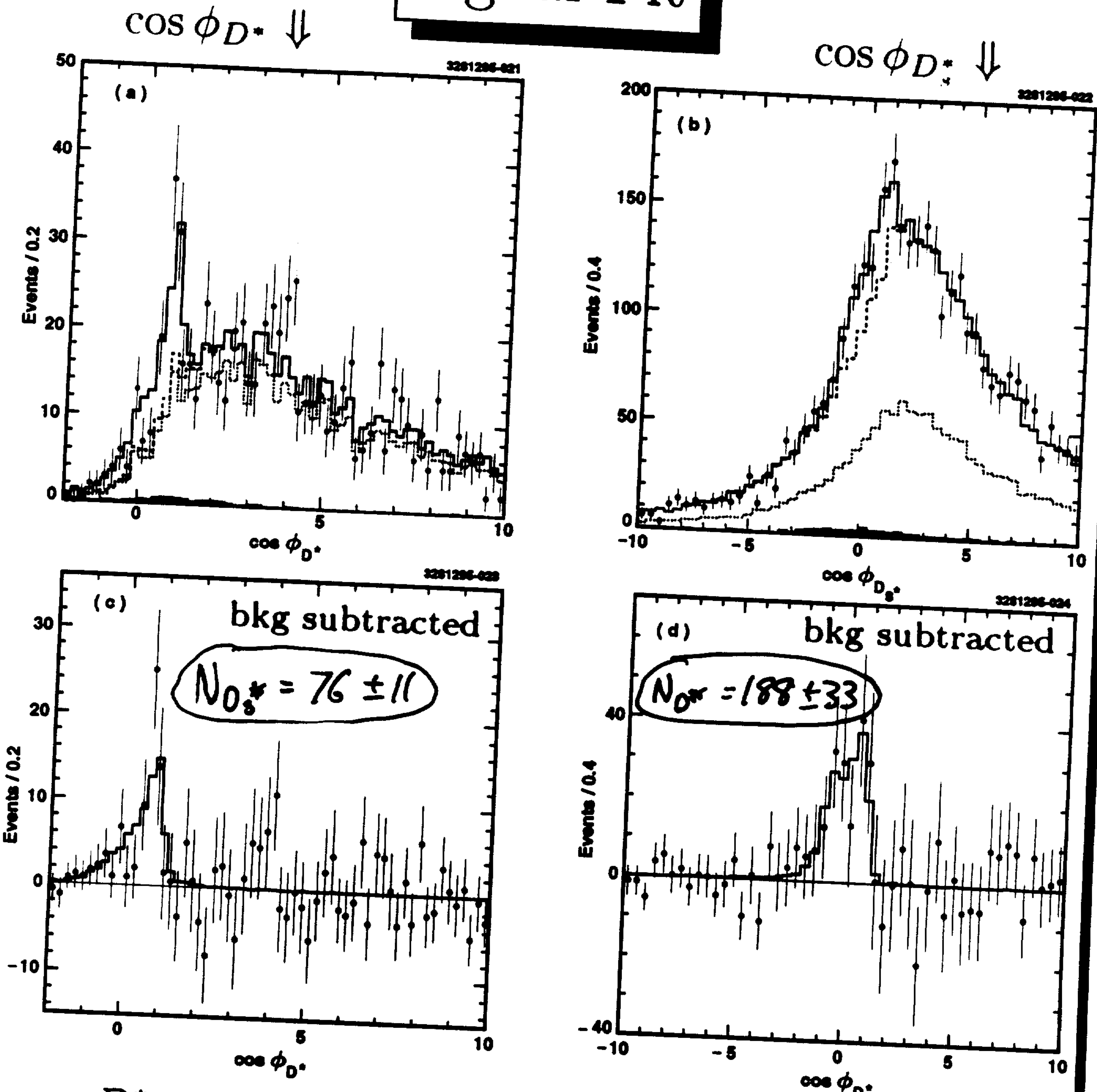
dashed hist is fake D_s^{*-} w/ true pion

D^{*+} full reconstruction - similar

Feed-down

- Many sources but only $1-2\%$ of total bkg

Signal Fit



D_s^{*-} ⇑ *Full Reconstruction* ⇑ D^{*+}

Data: Data points with fit solid histogram

BKG: Dashed line sum of all backgrounds

⇒ Dotted: fake D_s^{*-} or D^{*+} bkg

⇒ Hatched: feed-down bkg

$D_s^- \to \phi\pi^-$ Results

- Values of $R(\varepsilon \cdot B)$

Decay Mode	$R(\varepsilon \cdot B)(\%)$
for D_s^{*-} full reconstruction	
$D_s^- \to \phi\pi^-$	2.34 ± 0.06
$D_s^- \to K^0K^-$	1.85 ± 0.30
$D_s^- \to K^{*0}K^-$	2.50 ± 0.27
for D^{*+} full reconstruction	
$D^0 \to K^-\pi^+$	7.42 ± 0.13
$D^0 \to K^-\pi^+\pi^0$	6.13 ± 0.35
$D^0 \to \bar{K}^0\pi^+\pi^-$	1.61 ± 0.14

- Major systematic errors:

  8% random γ shape

  4% fake D^*, D_s^* normalization

  2% feed down normalization

  6% uncertainty $R_i(\varepsilon \cdot B)$ for D_s^-

  3% uncertainty $R_j(\varepsilon \cdot B)$ for D^0

- Obtain:

$$\frac{B(D_s^- \to \phi\pi^-)}{B(D^0 \to K^-\pi^+)} = 0.92 \pm 0.20 \pm 0.11$$

$D_s^- \to \phi\pi^-$ Results

- Using CLEO measurement:

$$B(D^0 \to K^-\pi^+) = 3.91 \pm 0.19\%$$

gives

$$B(D_s^- \to \phi\pi^-) = (3.59 \pm 0.77 \pm 0.48)\%$$

- Using the fully reconstructed D^{*+} we get:

$$B(\bar{B}^0 \to D^{*+}D_s^{*-}) = 1.85 \pm 0.30 \pm 0.49\%$$

- Agrees with our full $D^{*+}D_s^{*-}$ reconstruction result:

$$2.11 \pm 0.52 \pm 0.37\%$$

Inclusive D^0 Semi-Electronic Branching Fraction

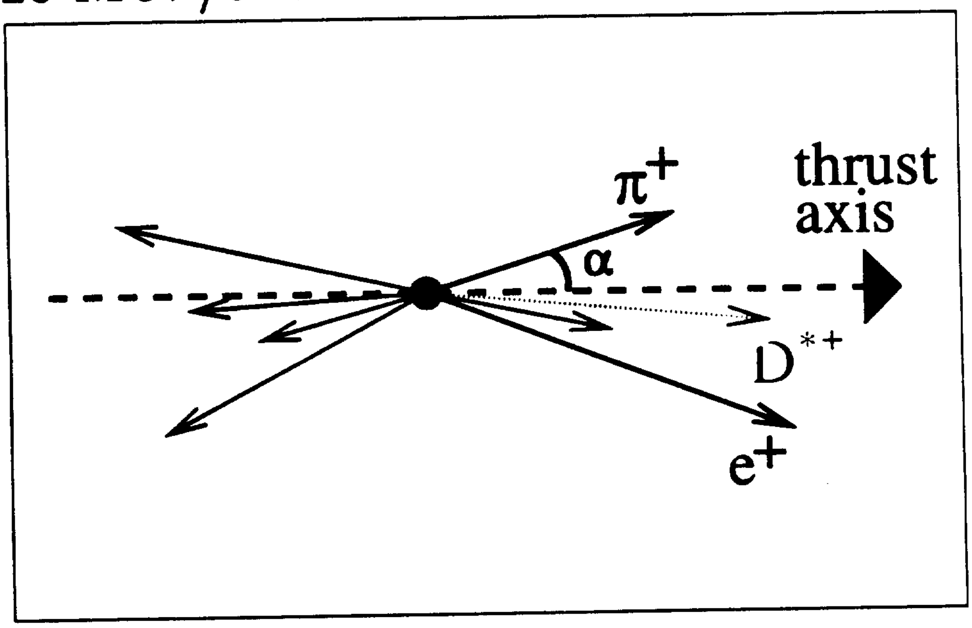
- $D^0 \to Xe^+\nu$ interesting and useful measurement:
  - Compare it to the sum of exclusive modes

    Anything missing?
  - Check e^+ spectrum against JETSET-based MC

    Last measured by DELCO, MC accurate?

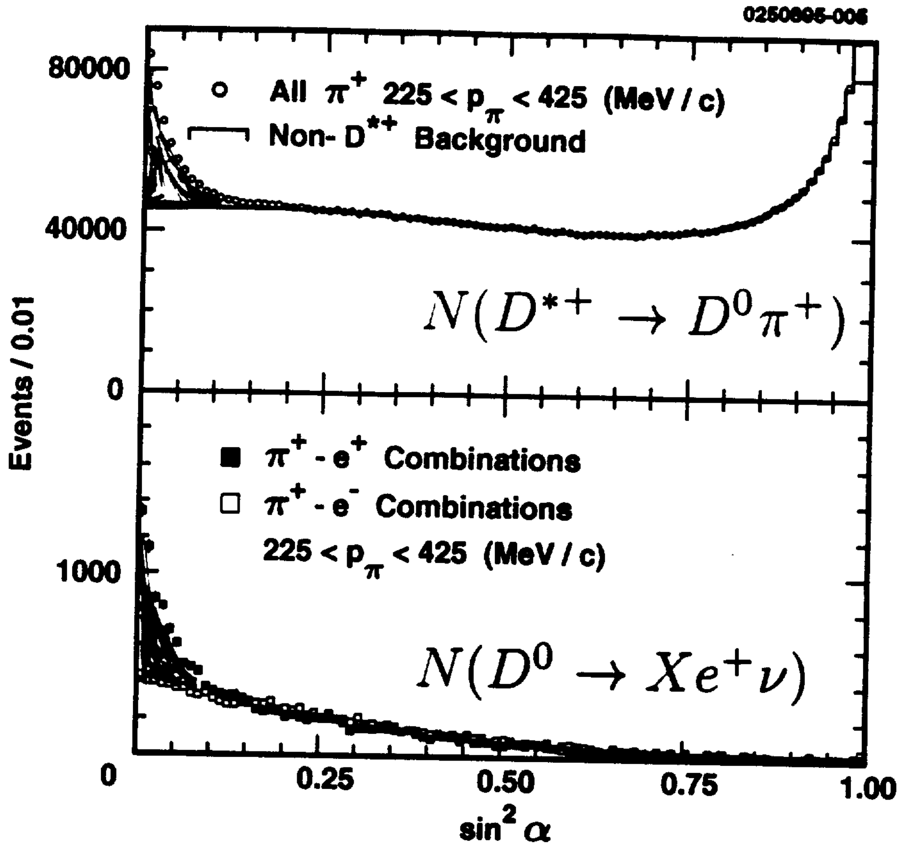
- For measurement, utilize decay $D^{*+} \to D^0\pi^+$:

  1) for $e^+e^- \to c\bar{c}$, event thrust axis approximates D^{*+} direction
  2) limited phase space for $D^{*+} \to D^0\pi^+$ produces small angle α between thrust axis and π^+
  3) no D^{*+} from B decays if pion momentum $> 225\ MeV/c$ for $e^+e^- \to c\bar{c}$



- Now look for electron w/i cone around π^+ direction

Measurement of $D^0 \to Xe^+\nu$



- Next, look for an electron
- Signal: same sign correlation between:
  - low momentum pion near thrust axis
  - close-lying electron

- Need to correct for background contributions
  - 1) hadron misidentified as an electron
  - 2) electron from $D^0 \to X\pi^0 \to Xe^+e^-\gamma$

Measurement of $D^0 \to Xe^+\nu$

- Once corrected yields are measured, get:

$$B(D^0 \to Xe^+\nu) = \frac{N(D^{*+} \to D^0\pi^+)}{N(D^0 \to Xe^+\nu) \cdot \epsilon(D^0 \to Xe^+\nu)}$$

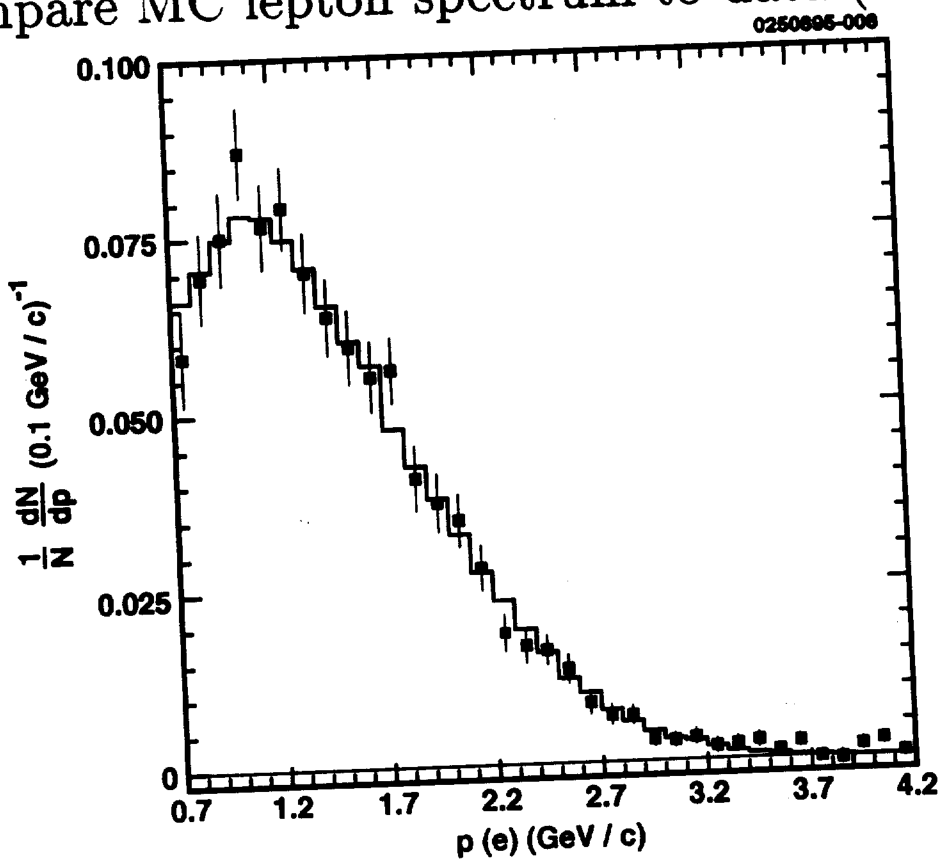
$$= \frac{4609 \pm 121}{165{,}658 \pm 1149 \pm 2485 \cdot \epsilon(D^0 \to Xe^+\nu)}$$

$\epsilon(D^0 \to Xe^+\nu)$ *is electron detection efficiency*

[Measurement actually done in 8 pion momentum bins]

Electron Efficiency

- Used cocktail of exclusive modes JETSET-based MC to determine e^+ efficiency for inclusive decay
- Compare MC lepton spectrum to data (lab frame)



MC provides good simulation of data

Result of $D^0 \to Xe^+\nu$ Measurement

- $\epsilon(D^0 \to Xe^+\nu)$ ranges between 38 – 51%

- Measure inclusive branching fraction:

$$B(D^0 \to Xe^+\nu) = (6.64 \pm 0.18 \pm 0.29)\%$$

- Compare to most recent sum of exclusive modes:

$$5.73 \pm 0.25\%$$ [a]

Still a 14% discrepancy

- Using only CLEO measurements for exclusive modes and world average if no CLEO data:

$4.7 \pm 7.5\%$ *discrepancy*

[a] Burchat and Richman, UCSB HEP-95-08, to appear in Review of Modern Physics

Precise Measurement of $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$

- Many analyses need precise measurements of common charm decay modes $\Rightarrow$ **Reduce systematic error**
- $D^0 \to K^-\pi^+\pi^0$ useful normalization for channels with π^0 in final state

Ratio $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$

Experiment	Year	Measurement
ARGUS	1992	$3.04 \pm 0.16 \pm 0.34$
NA14	1991	$4.0 \pm 0.9 \pm 1.0$
CLEO 1.5	1991	$2.8 \pm 0.14 \pm 0.52$
Mark III	1988	$3.17 \pm 0.42 \pm 0.43$
E516	1984	4.2 ± 1.4
Mark II	1981	2.85 ± 1.13
PDG Ave.		3.07 ± 0.29
PDG Fit		3.51 ± 0.28

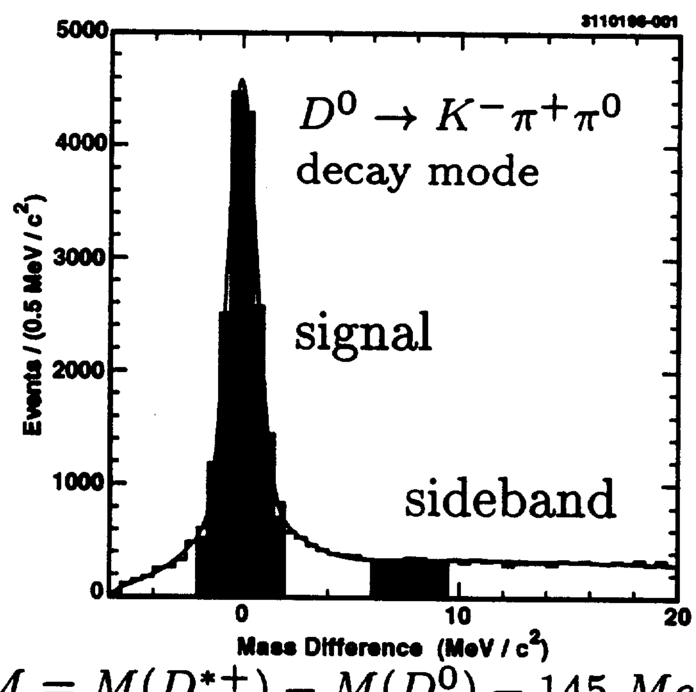
Current world average appears too low

- PDG average and fit in poor agreement
- In $B \to$ charmed final states, branching ratios higher for D^0 reconstructed through $K^-\pi^+\pi^0$ than $K^-\pi^+$

D^0 Decay Reconstruction

- Reconstruct $D^0 \to K^-\pi^+$ and $D^0 \to K^-\pi^+\pi^0$
  CLEO has excellent π^0 reconstruction efficiency
- D^0 must come via $D^{*+} \to D^0\pi^+$
  - Pion $(225 - 425\ MeV/c)$ from D^{*+} has same charge as pion from D^0
  - Reduces combinatoric background
- D^{*+} produced with hard fragmentation function
  - Require $x_{D^{*+}} > 0.6$ where $x_p = \frac{p_{D^{*+}}}{\sqrt{E^2_{beam} - m^2_{D^{*+}}}}$

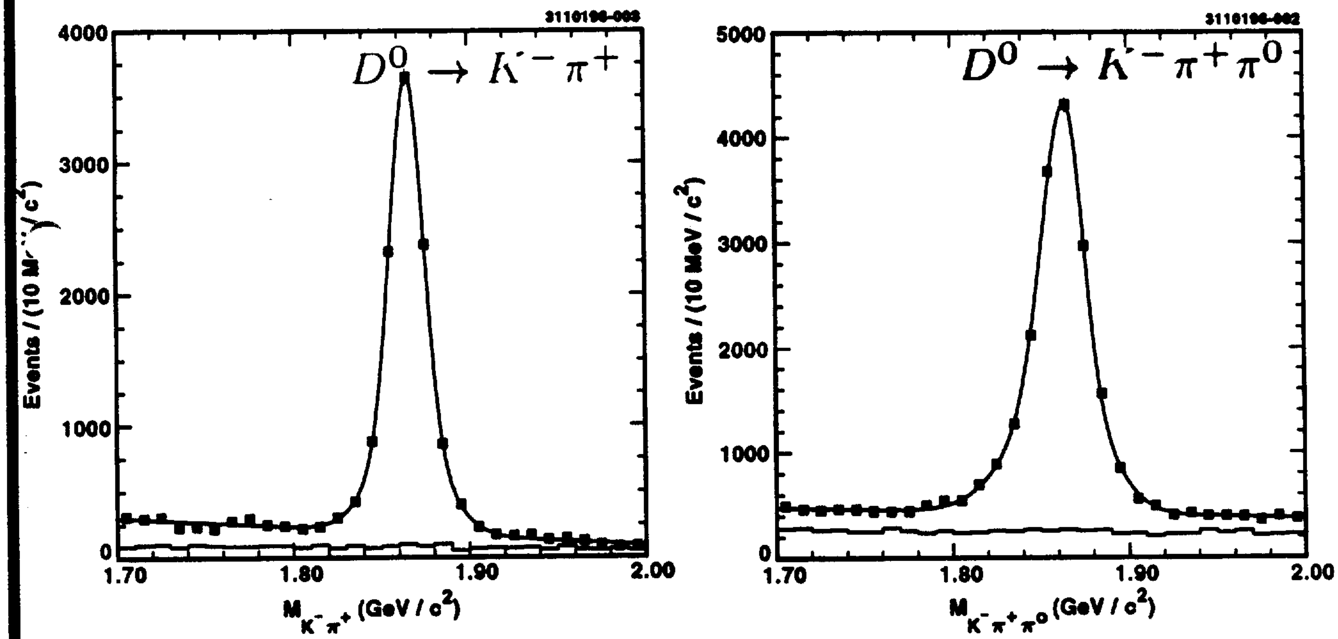
D^{*+} Mass Difference



$$\Delta M = M(D^{*+}) - M(D^0) - 145\ MeV/c^2$$

- Use sideband to estimate fake decays

D^0 Invariant Mass Spectra



Fit: 2 bifurcated Gaussians

Bkg: Straight line with sideband subtraction

Yield: $9808 \pm 127\ K^-\pi^+$ $\quad$ $\mathbf{15,013 \pm 204}\ K^-\pi^+\pi^0$

Geant based MC determined efficiency

20.4% $\quad$ 8.2%

Ratio $\frac{K^-\pi^+\pi^0}{K^-\pi^+} \Rightarrow R = 3.81 \pm 0.07$

Summary of $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$

- Main systematic errors:
  - π^0 finding efficiency — 5.5%
  - variation of $D^0 \to K^-\pi^+\pi^0$ efficiency due to resonant substructure — 3.4%

Summary

- Most precise to date - high stats!

$$R = \frac{B(K^-\pi^+\pi^0)}{B(K^-\pi^+)} = 3.81 \pm 0.07 \pm 0.26$$

[3.07 ± 0.29 PDG Ave
3.51 ± 0.28 PDG Fit]

- Combine with CLEO's recent measurement:

$$B(D^0 \to K^-\pi^+) = 0.0391 \pm 0.0008 \pm 0.0017$$

gives:

$$B(D^0 \to K^-\pi^+\pi^0) = 0.149 \pm 0.004 \pm 0.012$$

Current PDG fit: 0.135 ± 0.011

CLEO is working to reduce systematic error

Observation of Two New Excited Ξ_c States

- Well established: ground state isodoublet

$$\Xi_c^+ \text{ and } \Xi_c^0 \qquad (J^P = \tfrac{1}{2})$$

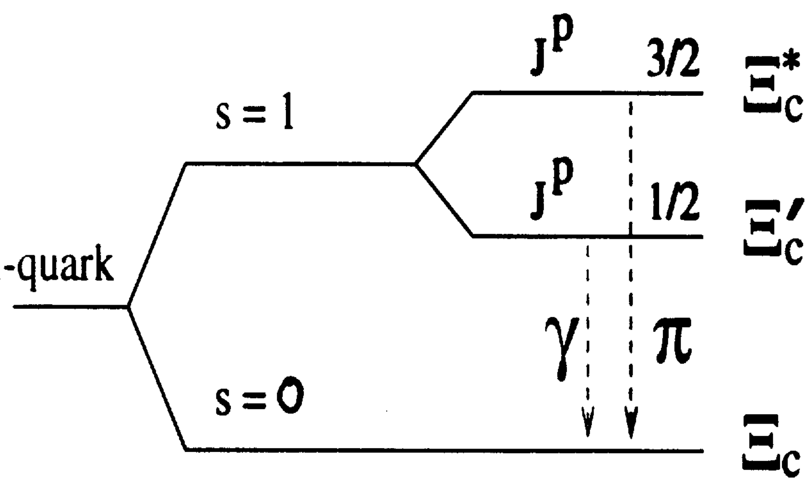
Two lighter quarks antisymmetric under interchange of flavor ⇒ Spin 0 configuration

- Next higher states:

$$\Xi_c' \ (J^P = \tfrac{1}{2}) \text{ and } \Xi_c^* \ (J^P = \tfrac{3}{2})$$

Two lighter quarks symmetric ⇒ Spin 1 configuration

<u>Theory predicts:</u>



Mass $\Xi_c^* > \Xi_c \pi$
Mass $\Xi_c' < \Xi_c \pi$

- CLEO observes: *Narrow state decaying into* $\Xi_c^+ \pi^-$
  Narrow state decaying into $\Xi_c^0 \pi^+$

Believe we are seeing $J^P = \frac{3}{2}$ spin excitation of Ξ_c^0 and its isospin partner

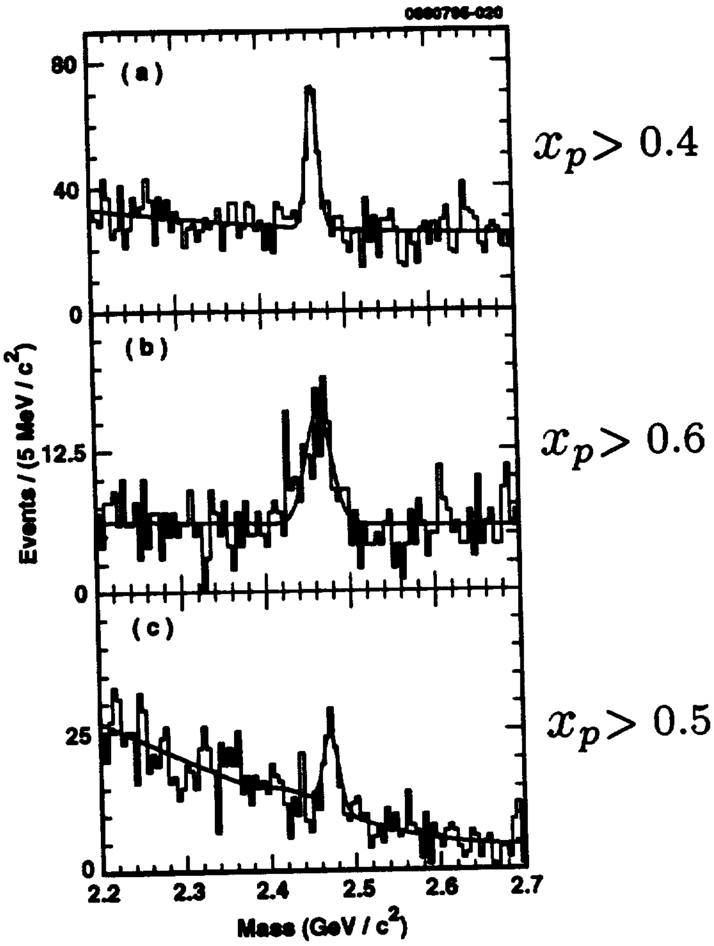
Reconstruction of $\Xi_c^{*0} \to \Xi_c^+ \pi^-$

- Reconstruct Ξ_c^+:

a) $\Xi^- \pi^+ \pi^+$
  └→ $\Lambda \pi^-$
    └→ $p \pi^-$

b) $\Xi^0 \pi^+ \pi^0$
  └→ $\Lambda \pi^0$
    └→ $p \pi^-$

c) $\Sigma^+ K^{*0}$
  └→ $K^- \pi^+$
  └→ $p \pi^0$



Require w/i 2.5σ of Ξ_c^+ mass

Decay Mode	Yield
$\Xi^- \pi^+ \pi^+$	160 ± 18
$\Xi^0 \pi^+ \pi^0$	76 ± 12
$\Sigma^+ K^{*0}$	59 ± 12

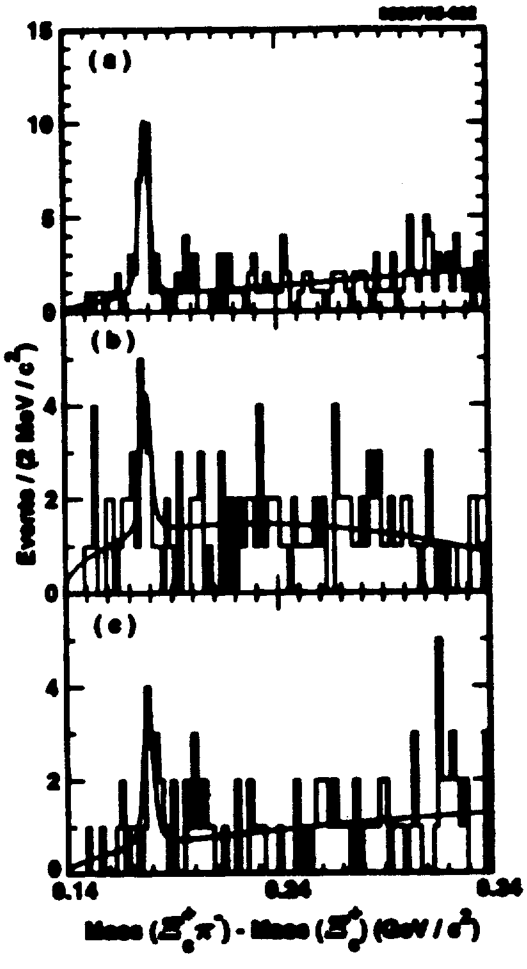
Now relax cut on x_p for Ξ_c^+ ...

Reconstruction of $\Xi_c^{*0} \to \Xi_c^+ \pi^-$

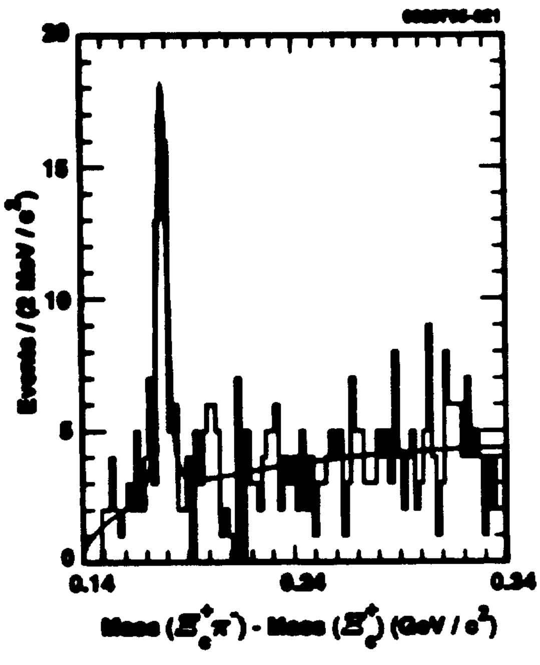
- **Reconstruct Ξ_c^{*0}:**

  Combine each Ξ_c^+ candidate with each remaining π^-

  Place mode dependent x_p cut on $\Xi_c^+ \pi^-$ combination



modes summed



Clear peak around $178 MeV/c^2$

Fit: **Chebyshev polynomial with threshold suppression**

Breit-Wigner with Gaussian resolution ($\sigma = 1.6 MeV/c^2$)

Yield: 54.6 ± 12.1 [a) 31.8 ± 6.6, b) 10.5 ± 4.6, c) 10.9 ± 4.3]

Reconstruction of $\Xi_c^{*+} \to \Xi_c^0 \pi^+$

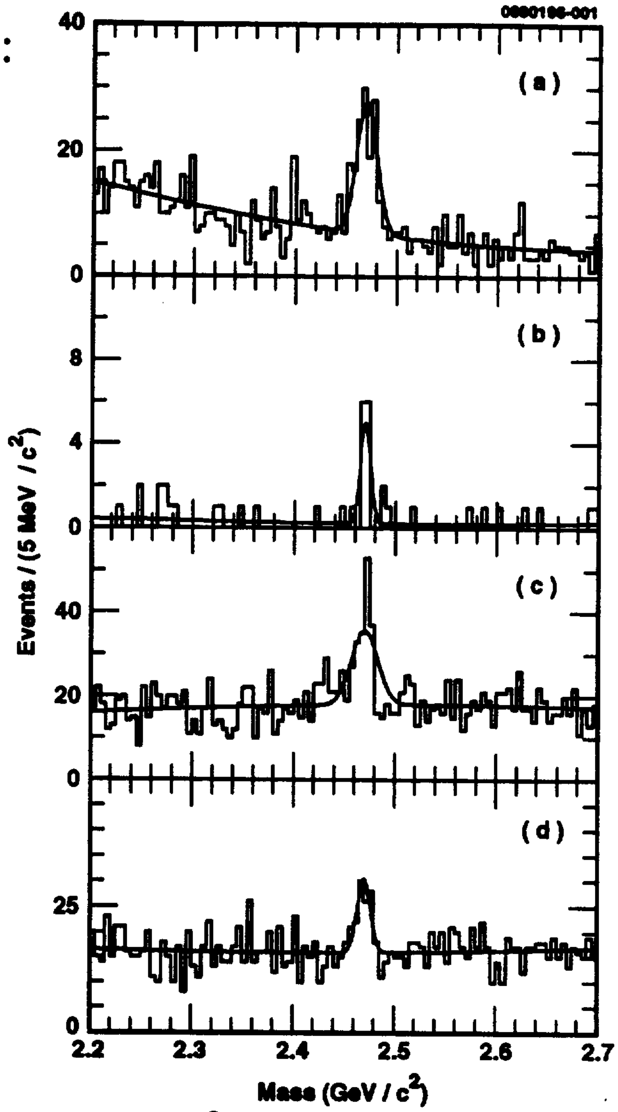
- Reconstruct Ξ_c^0:

a) $\Xi^- \pi^+$
  $\hookrightarrow \Lambda \pi^-$
    $\hookrightarrow p\pi^-$

b) $\Omega^- K^+$
  $\hookrightarrow \Lambda K^-$
    $\hookrightarrow p\pi^-$

c) $\Xi^- \pi^+ \pi^0$
  $\hookrightarrow \Lambda \pi^-$
    $\hookrightarrow p\pi^-$

d) $\Xi^0 \pi^+ \pi^-$
  $\hookrightarrow \Lambda \pi^0$
    $\hookrightarrow p\pi^-$



Require w/i 2.5σ of Ξ_c^0 mass and $x_p > 0.5$

Decay Mode	Yield
$\Xi^- \pi^+$	106 ± 13
$\Omega^- K^+$	14 ± 4
$\Xi^- \pi^+ \pi^0$	118 ± 18
$\Xi^0 \pi^+ \pi^-$	48 ± 12

Now relax cut on x_p for Ξ_c^+ ...

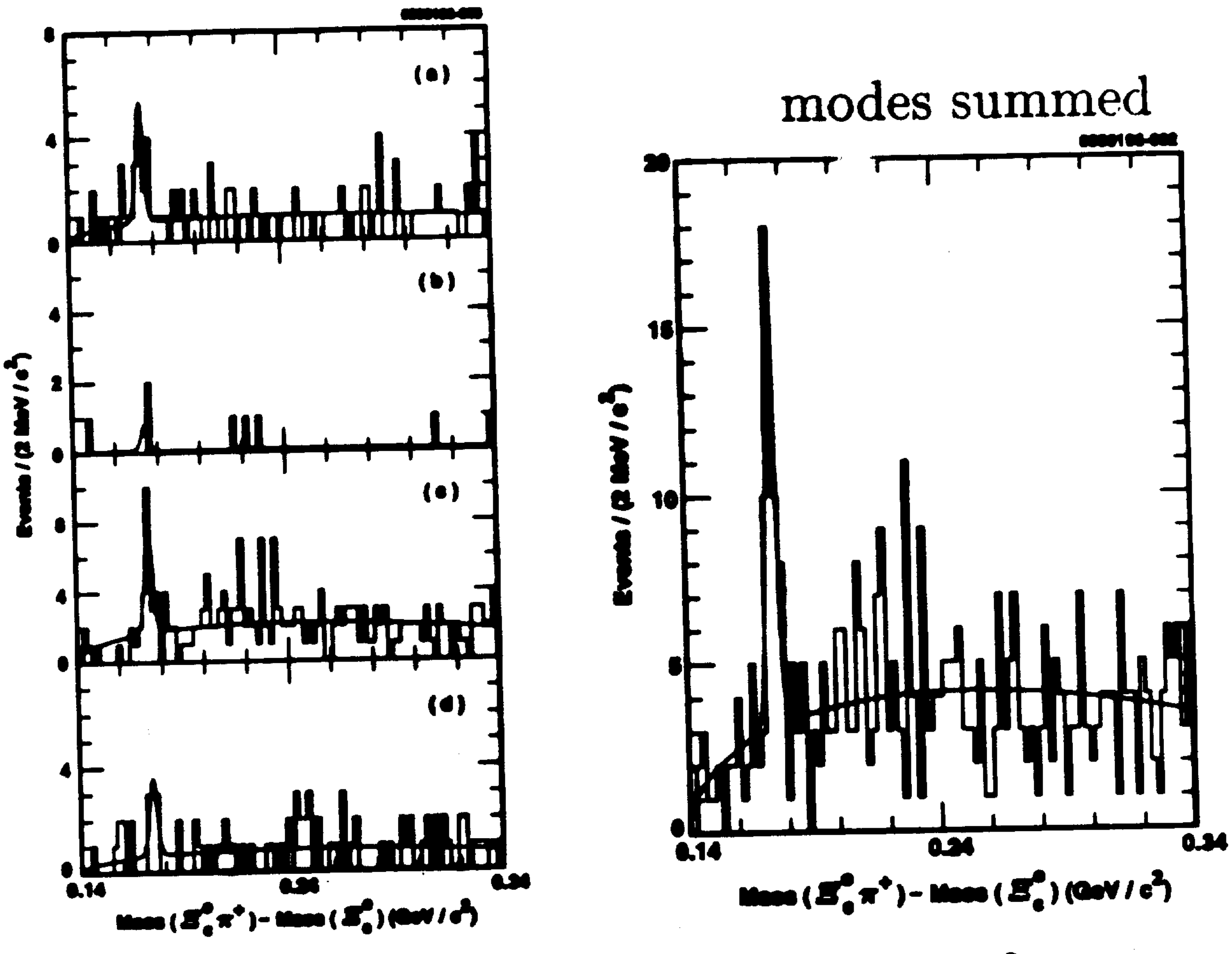
Reconstruction of $\Xi_c^{*+} \to \Xi_c^0 \pi^+$

- Reconstruct Ξ_c^{*+}:

  Combine each Ξ_c^0 candidate with each remaining π^+

  Place $x_p > 0.5$ cut on $\Xi_c^0 \pi^+$ combination

modes summed



Clear peak around 174MeV/c²

Fit: **Chebyshev polynomial with threshold suppression**

Breit-Wigner with Gaussian resolution ($\sigma = 1.6 MeV/c^2$)

Yield: $34.2^{+8.9}_{-7.9}$ a) 12.0 ± 4.0 b) 1.8 ± 1.4 c) 14.7 ± 4.8 d) 6.9 ± 3.1

Summary of Excited Ξ_c Results

a) M($\Xi_c^+ \pi^-$) - M(Ξ_c^+) $= 178.2 \pm 0.5 \pm 1.0 MeV/c^2$

$\Gamma < 5.5 MeV/c^2$ (90% CL)

$\Rightarrow J = \frac{3}{2}$ spin excitation Ξ_c^{*0}

b) M($\Xi_c^0 \pi^+$) - M(Ξ_c^0) $= 174.3 \pm 0.5 \pm 1.0 MeV/c^2$

$\Gamma < 3.1 MeV/c^2$ (90% CL)

$\Rightarrow$ isospin partner Ξ_c^{*+}

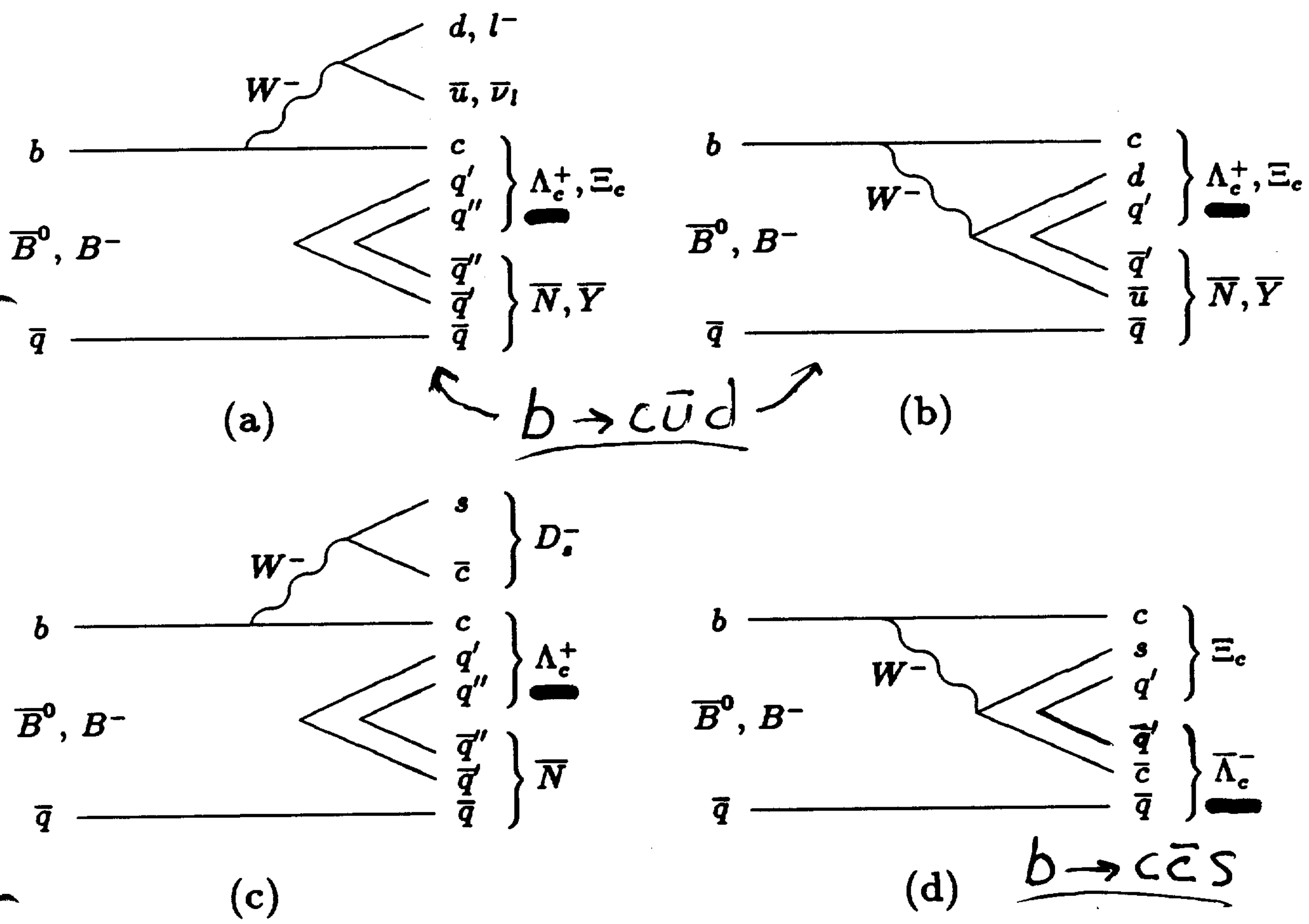
c) M(Ξ_c^{*0}) - M(Ξ_c^{*+}) $= -1.3 \pm 2.6 MeV/c^2$

- Identification as Ξ_c^* only by mass difference
- States are narrow, as expected

  Just at threshold $\Rightarrow$ little phase space
- Mass difference between two states small

Flavor Tagged Λ_c Production in B Decays

- B produces baryons in its weak decays



Mechanisms to produce Λ_c from $\bar{B} \to \Lambda_c X$

- Expect a) and b) dominant sources of Λ_c^+
- Expect c) to be negligible $\Rightarrow$ limited phase space
- Expect d) source of $\bar{\Lambda}_c^-$ - *suggested may be significant by Dunietz et. al, Phys. Rev. Lett. 73:1075*

What is ratio of $\bar{\Lambda}_c^-$ to Λ_c^+?

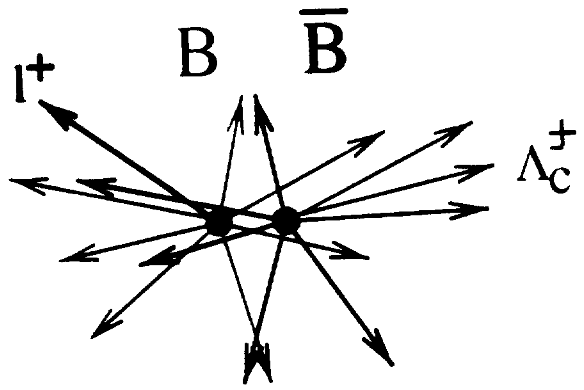
Flavor Tagged Λ_c Production

- Previous experiments [ARGUS and CLEO] studied
  Λ_c from $B\bar{B}$ decays
  Did not show if Λ_c came from B or $\bar{B}$

This analysis tags the flavor of the B

Method: high p lepton / baryon sign correlation

- Tag one side of $B\bar{B}$ with $B \to Xl^+\nu_l$
- Tag other side with $\bar{B} \to \bar{\Lambda}_c^- X$ or $\bar{B} \to \Lambda_c^+ X$



$$R_{\Lambda_c} = \frac{N_{\bar{\Lambda}_c^- l^+}}{N_{\Lambda_c^+ l^+}} = \frac{B(\bar{B}\to\bar{\Lambda}_c^- X)B(Xl\nu)}{B(\bar{B}\to\Lambda_c^+ X)B(Xl\nu)}$$

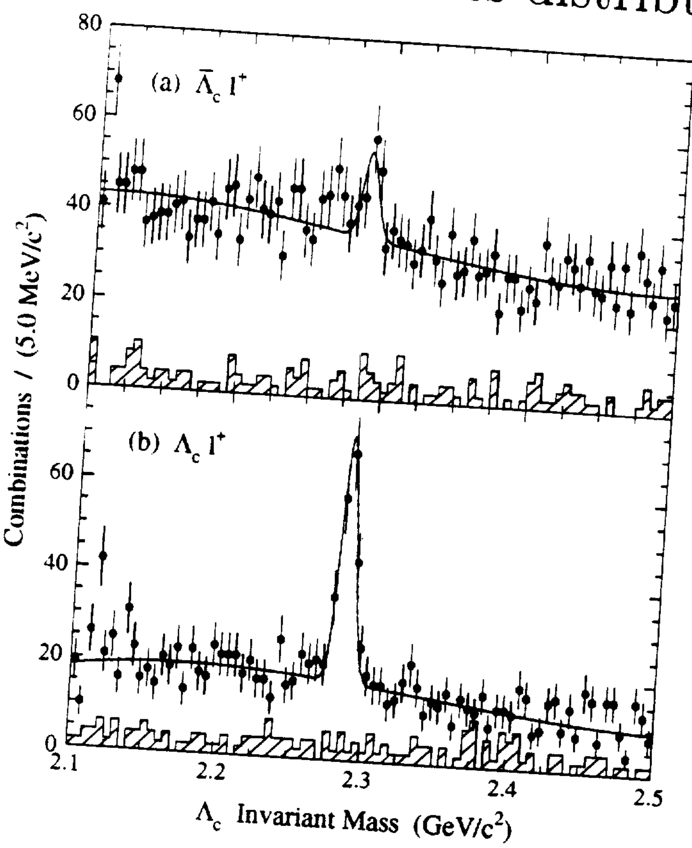
$\Rightarrow R_{\Lambda_c}$ direct measure of fraction of charmed baryons produced in $b \to c\bar{c}s$ relative to $b \to c\bar{u}d$
w/ small correction for $B\bar{B}$ mixing

- Reconstruct Λ_c: $pK^-\pi^+$ $\quad p\bar{K}_s^0$ $\quad \Lambda\pi^+$ $\quad \Sigma^0\pi^+$
  $2.2M B\bar{B}$ *pairs* $\Rightarrow 3154 \pm 160 \Lambda_c$ *candidates*

- Next pair Λ_c with lepton candidate

Flavor Tagged Λ_c Production

- Λ_c invariant mass distributions



Resonance data
$50 \pm 15\ \bar{\Lambda}_c^- l^+$

Scaled continuum
$7 \pm 7\ \bar{\Lambda}_c^- l^+$

Resonance data
$143 \pm 15\ \Lambda_c^+ l^+$

Scaled continuum
$2 \pm 6\ \bar{\Lambda}_c^- l^+$

- After subtracting continuum, hadrons faking leptons, and cascade leptons:

  $38 \pm 16\ \bar{\Lambda}_c^- l^+$ $\qquad$ $139 \pm 16\ \Lambda_c^+ l^+$

- Need to correct for $B\bar{B}$ mixing! 15%

$$R_{\Lambda_c} = 0.20 \pm 0.12 \pm 0.04 = \frac{b \to c\bar{c}s}{b \to c\bar{u}d}$$

Internal spectator $b \to c\bar{c}s$ not dominant source of charmed baryons in B meson decay

$\Rightarrow$ *consistant with 0*

Measurement of $\Lambda_c^+ \to p\phi$

- Color suppression works for B decays
- Doesn't work well for charm decays:

$$B(D_s^+ \to \bar{K}^{*0} K^+)/B(D_s^+ \to \phi\pi^+)$$

Color matching: $= \frac{1}{9}$

Experiment (PDG): ~ 1

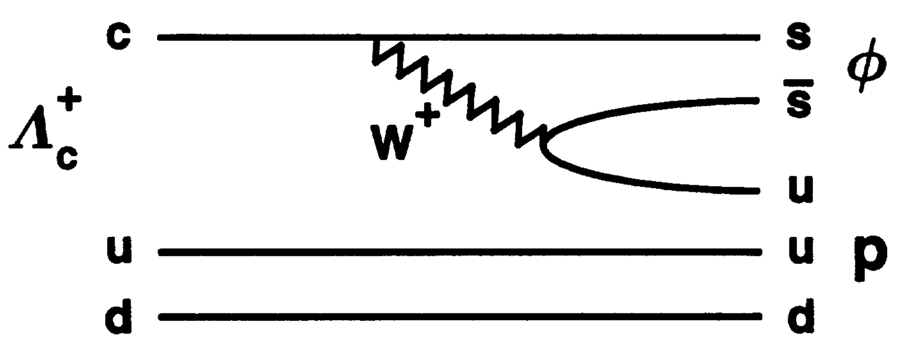
Same for charm baryons? Study ratio:

$$B(\Lambda_c^+ \to p\phi)/B(\Lambda_c^+ \to pK^-K^+)$$

- Test color suppression for charm baryons

Cabibbo suppressed $\Lambda_c^+ \to p\phi$ *decay 'color suppressed'*

Only internal factorizable diagram $\Rightarrow$ good test



Previous measurements:

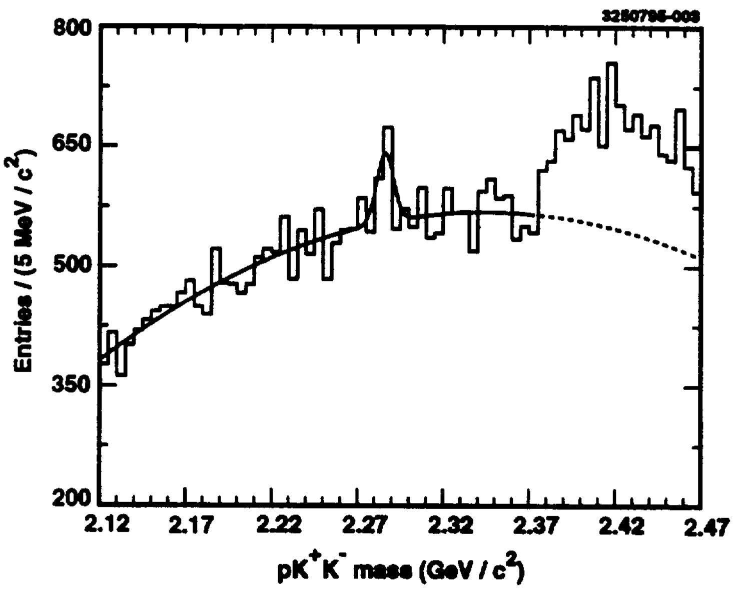
- $\Lambda_c^+ \to p\phi$ seen by ACCMOR (2.8 ± 1.9 events)
- E687: upper limit when measured Cabibbo suppressed $\Lambda_c^+ \to pK^-K^+$

Reconstruction of $\Lambda_c^+ \to p\phi$

- Reconstruct $\Lambda_c^+ \to pK^-K^+$

  Use 3.46 fb^{-1}

  Require $x_p = \frac{p_{\Lambda_c}}{\sqrt{E_{beam}^2 - m_{\Lambda_c^2}}} > 0.5$



Fit: Gaussian with $\sigma = 4.9 MeV$

Bkg: 2^{nd} order Chebyshev polynomial

Above 2.37 GeV/c^2 excluded, from $\Lambda_c^+ \to pK^-\pi^+$

214 ± 50 events   Mean $2285.5 \pm 1.2\ MeV/c^2$

Now look for K^-K^+ from ϕ

Reconstruction of $\Lambda_c^+ \to p\phi$

- Look for $\phi \to K^- K^+$ substructure

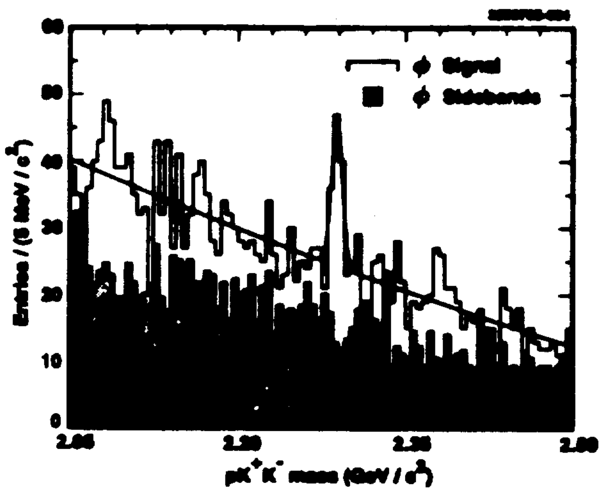
Divide into signal: $1.012 < m_{KK} < 1.027 GeV/c^2$

sidebands: $0.990 < m_{KK} < 1.005 GeV/c^2$

$1.035 < m_{KK} < 1.050 GeV/c^2$

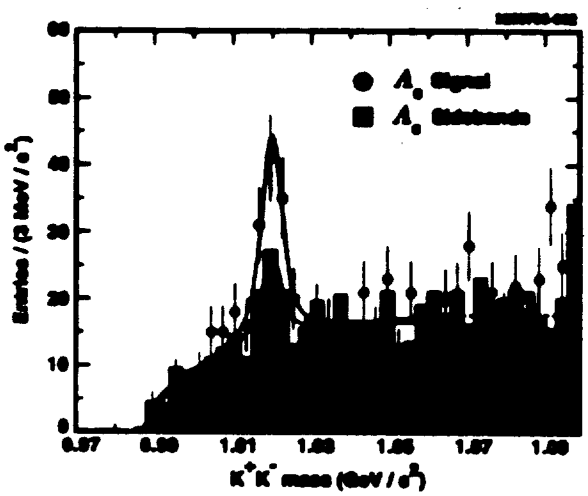
<u>Two methods</u>

a) fit invariant mass of $pK^- K^+$ combinations



yield 54 ± 13 events

b) fit $K^- K^+$ mass peak for $pK^- K^+$ combinations



yield 56 ± 22 events

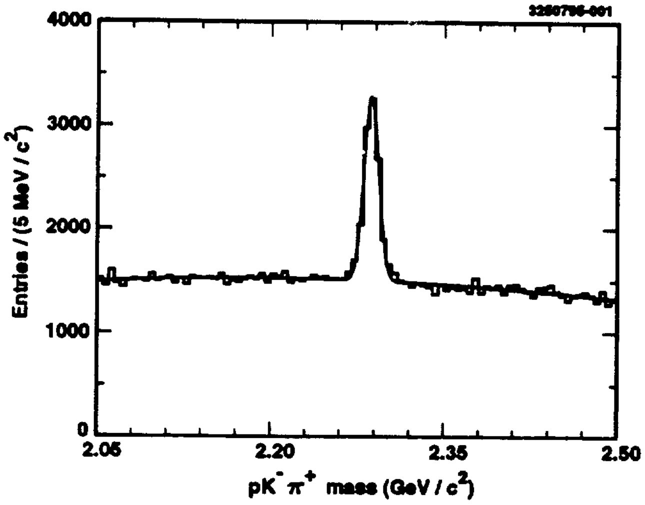
Agrees!

estimate $< 1\%$ *fake rate from* $D_s^+ \to \phi\pi^+$

Normalization to $\Lambda_c^+ \to pK^-\pi^+$

- Use same analysis and cuts as $\Lambda_c^+ \to pK^-K^+$

  Only loosen PID cuts for π^+



Yield: 5683 ± 138

Mean: $2286.8 \pm 0.2, \Gamma = 6.4 \pm 0.2\ MeV/c^2$

- Calculate relative branching ratios

Decay Mode	$p\phi$	pK^-K^+	$pK^-\pi^+$
Raw Yield	54 ± 13	214 ± 50	5683 ± 138
Efficiency	$.178 \pm .004$	$.216 \pm .005$	$.224 \pm .005$
$B(\phi \to K^-K^+)$	$.491 \pm .005$		
Corr. Yield	618 ± 138	991 ± 233	25371 ± 837
$B/B(pK^-\pi^+)$	$.024 \pm .006$	$.039 \pm .009$	1
$B/B(pK^-K+)$	$.62 \pm .20$	1	

All errors systematic only!

Results of $\Lambda_c^+ \to p\phi$ Study

- Have measured the Cabibbo-suppressed decays
  $\Lambda_c^+ \to p\phi$ and $\Lambda_c^+ \to pK^-K^+$

- Compare our results to other experiments and
  phenomenological predictions:

Ratio	$B(p\phi)/B(pKK)$	$B(pKK)/B(pK\pi)$	$B(p\phi)/B(pK\pi)$
CLEO II	$.62\pm.20\pm.12$	$.039\pm.009\pm.007$	$.024\pm.006\pm.003$
NA32			$.04\pm.03$
E687	$< .58@90\%CL$	$.096\pm.029\pm.010$	
Theoretical prediction (no color suppression)			0.01 - 0.05

Expect $B(p\phi)/B(pK\pi)$ down factor of 15
if color suppressed

- CLEO II measurement:

⇒ $B(p\phi)/B(pKK)$ consistent with E687 U.L.

⇒ $B(pKK)/B(pK\pi)$ differs from E687 by 1.7 σ

⇒ Phenom. predictions agree w/i factor of 2 - 3

Supports non-validity of color suppression
for charmed baryons

Summary of Recent CLEO Charm Results

1) Observation of 2 new excited Ξ_c states

$\Rightarrow$ Seeing $J = 3/2$ spin excitation of Ξ_c

Ξ_c^{*0}: $M(\Xi_c^+\pi^-) - M(\Xi_c^+) = 178.2 \pm 0.5 \pm 1.0$ MeV/c^2

Ξ_c^{*+}: $M(\Xi_c^0\pi^+) - M(\Xi_c^0) = 174.3 \pm 0.5 \pm 1.0$ MeV/c^2

$M(\Xi_c^{*0}) - M(\Xi_c^{*+}) = -1.3 \pm 2.6$ MeV/c^2

2) Measurement of 'color suppressed' $\Lambda_c \to p\phi$

(a) $\mathcal{B} = \dfrac{\mathcal{B}(\Lambda_c^+ \to p\phi)}{\mathcal{B}(\Lambda_c^+ \to pKK)} = 0.62 \pm 0.20 \pm 0.12$

(b) charm <u>hadrons</u> do not obey color suppression

3) Flavor tagged Λ_c production

$R_{\Lambda_c} = 0.20 \pm 0.12 \pm 0.04 \to \dfrac{b \to c\bar{c}s}{b \to c\bar{u}d}$

internal spectator $b \to c\bar{c}s$ <u>not</u> dominant source of charmed baryons in B decay

4) <u>Lots</u> of new branching fractions...

$\mathcal{B}(D_s^- \to \phi\pi^-) = 3.59 \pm 0.77 \pm 0.48\%$

$\mathcal{B}(D^0 \to Xe^+\nu) = 6.64 \pm 0.18 \pm 0.29\%$

$\dfrac{\mathcal{B}(D^0 \to K^-\pi^+\pi^0)}{\mathcal{B}(D^0 \to K^-\pi^+)} = 3.81 \pm 0.07 \pm 0.26$

Preprints found on http://w4.lns.cornell.edu/