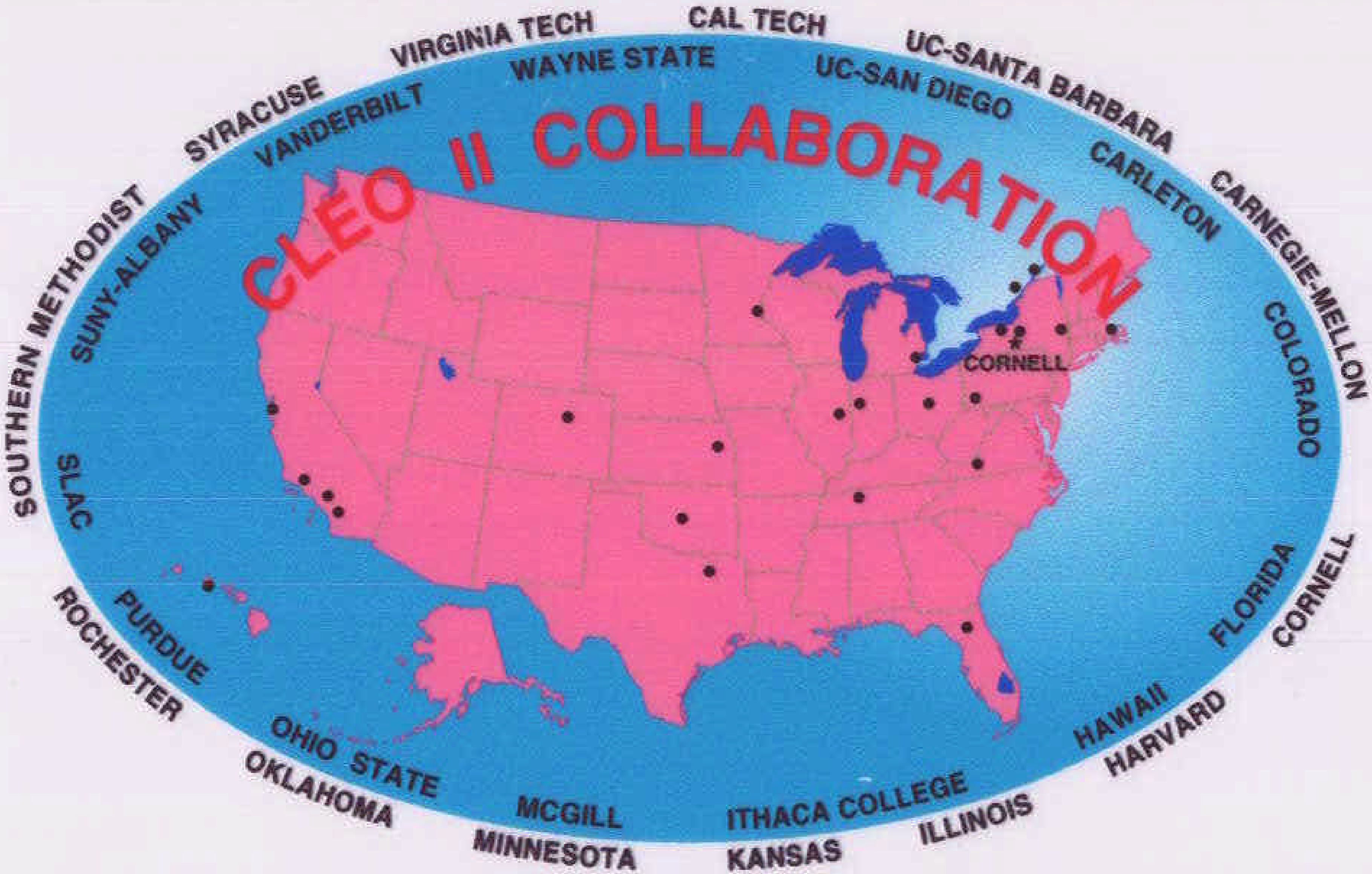

RECENT RESULTS FROM CLEO: Excited Charmed Baryons

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Outline of talk

- data set/detector
- Introduction to charmed-baryon spectroscopy
- Ξ_{c1} ($J^P = 1/2^-$) candidates
- New structure in $\Lambda_c \pi^+ \pi^-$
- speculation/conclusions

ALL RESULTS PRESENTED HERE ARE PRELIMINARY!

- See hep-ex//007049 and hep-ex__ for details
  $\Lambda_c \pi^+ \pi^-$ 007051 : Ξ_{c1}

Data Set

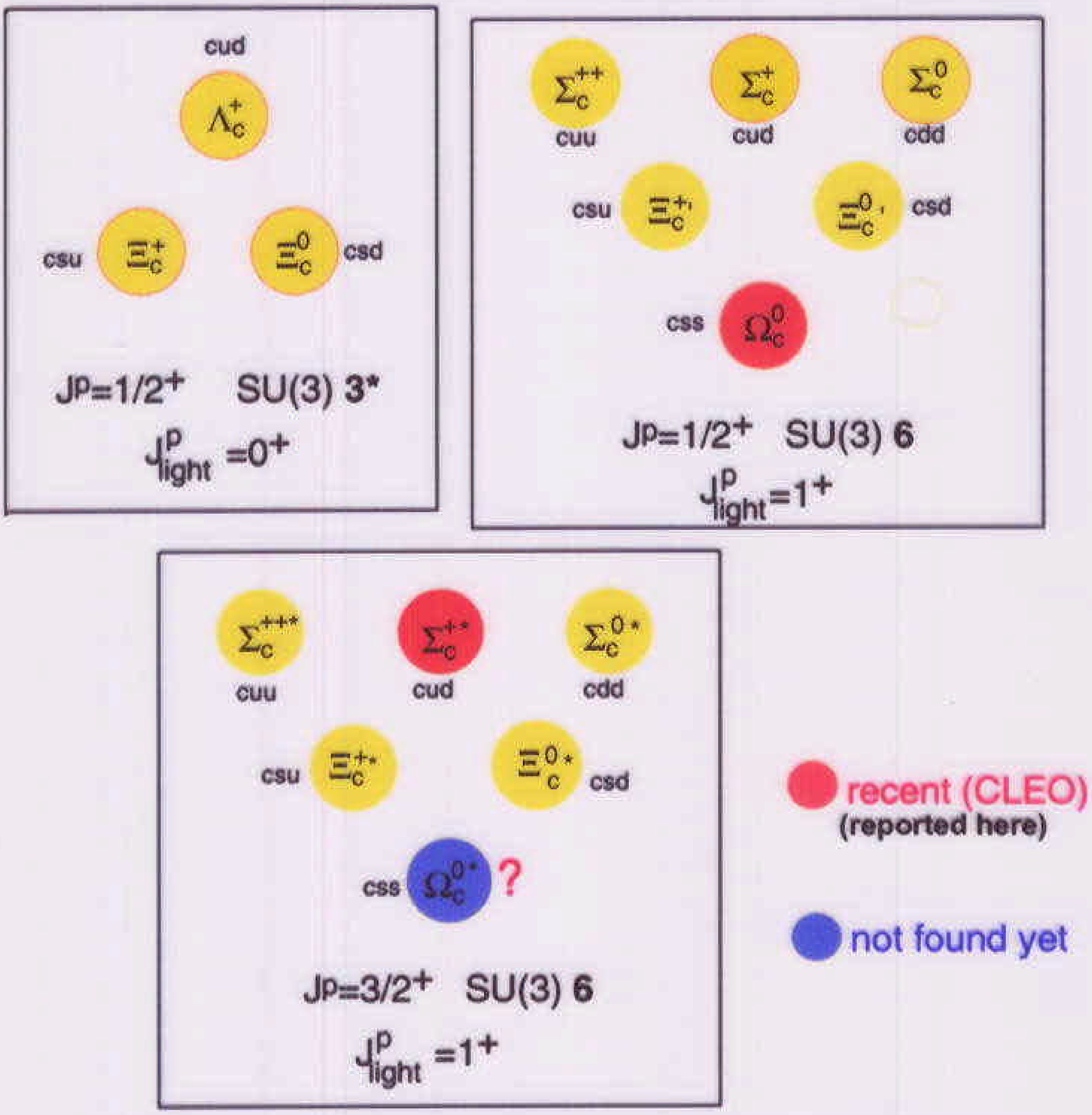
- $13.7\ fb^{-1}$ in data set, CLEOII + CLEOII.V
- $\sqrt{s} \sim 10.5$ GeV: Y(4S) and nearby continuum
- More than 3000 Ξ_c in sample (for Ξ_{c1} search)
- More than 58000 Λ_c in search for higher Λ_c/Σ_c excitations.

CLEO in a few words:

A by-now standard 4π detector with excellent p/E resolution for both charged particles and γ's.

- Tracking: $\sigma(p)/p = \sqrt{(.15p)^2+(0.5)^2}$ %
- γ energy resolution: ~2% at 1GeV, 4% at 100MeV provided by CsI(Tl) calorimeter .
- dE/dX in drift chamber+TOF : proton/pion/kaon identication.
- Special attention to reconstruction of secondary vertices (Λ), tertiary vertices (Ω, Ξ), π^0, soft γ
- CLEOII.V has a Si tracker and improved tracking. Not used for the baryon analyses, but important for others.

"Ground State" (s-wave) Charmed Baryons



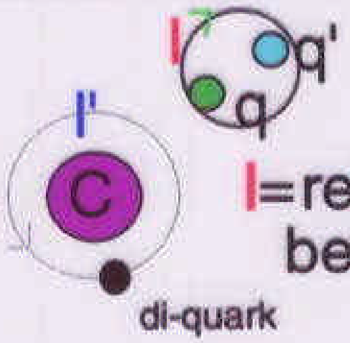
The singly-charmed Baryon Landscape: 15 states

ICHEP 2000:rde

"Excited States" (p-wave)

- Heavy Quark Effective Theory (HQET) is our guide to organizing states.

l'= ang. mom. between light and heavy



l=relative ang. mom. between light quarks

- {l=0, l'=1} config. expected lowest lying : light-quark spin (S=1 or S=0) combines with l'.

$$J^{P}_{light} = 1^-, \{2^-, 1^-, 0^-\}$$

add to c quark spin:

- For S=0 we get two **3***s, J^P= $1/2^-$ and $3/2^-$. These are "antisymmetric" Λ_C- like .
- For S=1 we get five **6**'s, $J^P = (1/2^- \oplus 3/2^-)$(twice) and $5/2^-$. These are "symmetric " Σ_C-like.

36 states!

More on classification:

- States may be impure (configuration mixing).

HQET models favor little mixing between S_{light} =0 and S_{light}=1 configurations of same J^P.

- {l'=0, l=1} gives more states (higher mass?):

2 **6**'s and 5 **3***'s	27 more!

- Ξ_C 's can occur in both **3***'s and **6**'s. (csu, csd), no symmetry constraints.

Recent references:

1. (CLEO): Phys. Rev. Lett. **83**, 3390 (1999) :Ξ^*_{c1}(J=3/2)

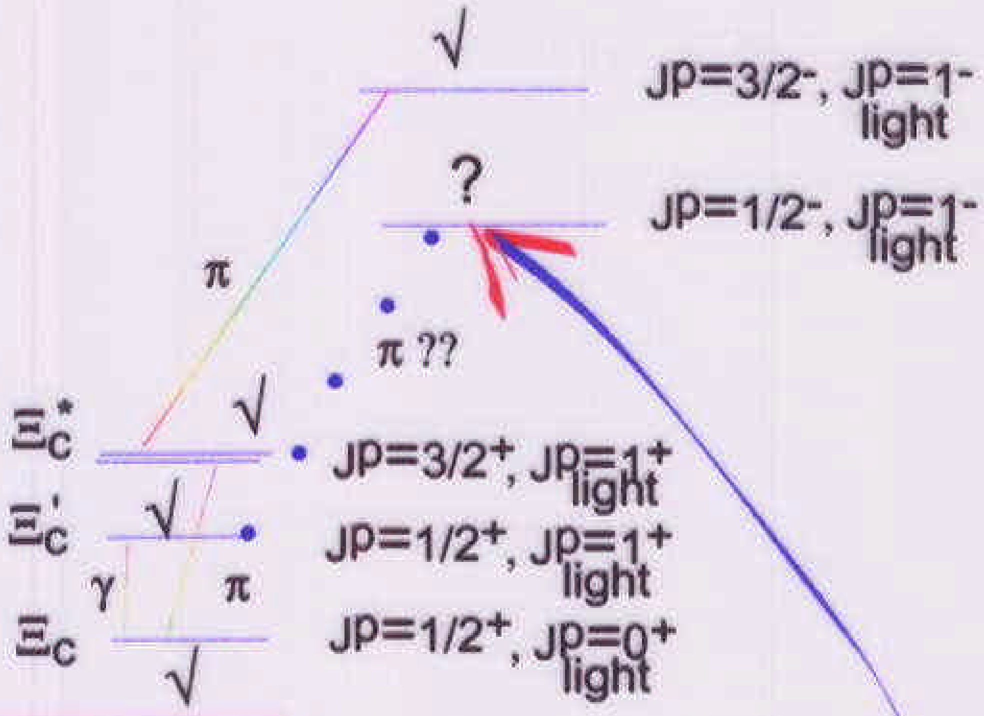
2.J.G. Körner, M. Krämer, and D. Pirjol, Prog. in Part. Nucl. Phys.**33** 787 (1994),

3.D. Pirjol and T-M Yan, hep-ph/9701291 v2 (1197),

4.G. Chiladze and A. Falk , hep-ph/9707507(1997)

5. J.L. Rosner hep-ph/9508252 (1995)

Ξ_c spectroscopy, shown for one isospin state



- First, make Ξ_c'

- Use good γ resolution: $E\gamma$ >100MeV, combine with Ξ_c .14 modes, for statistics.

- veto γ's belonging to π^0's

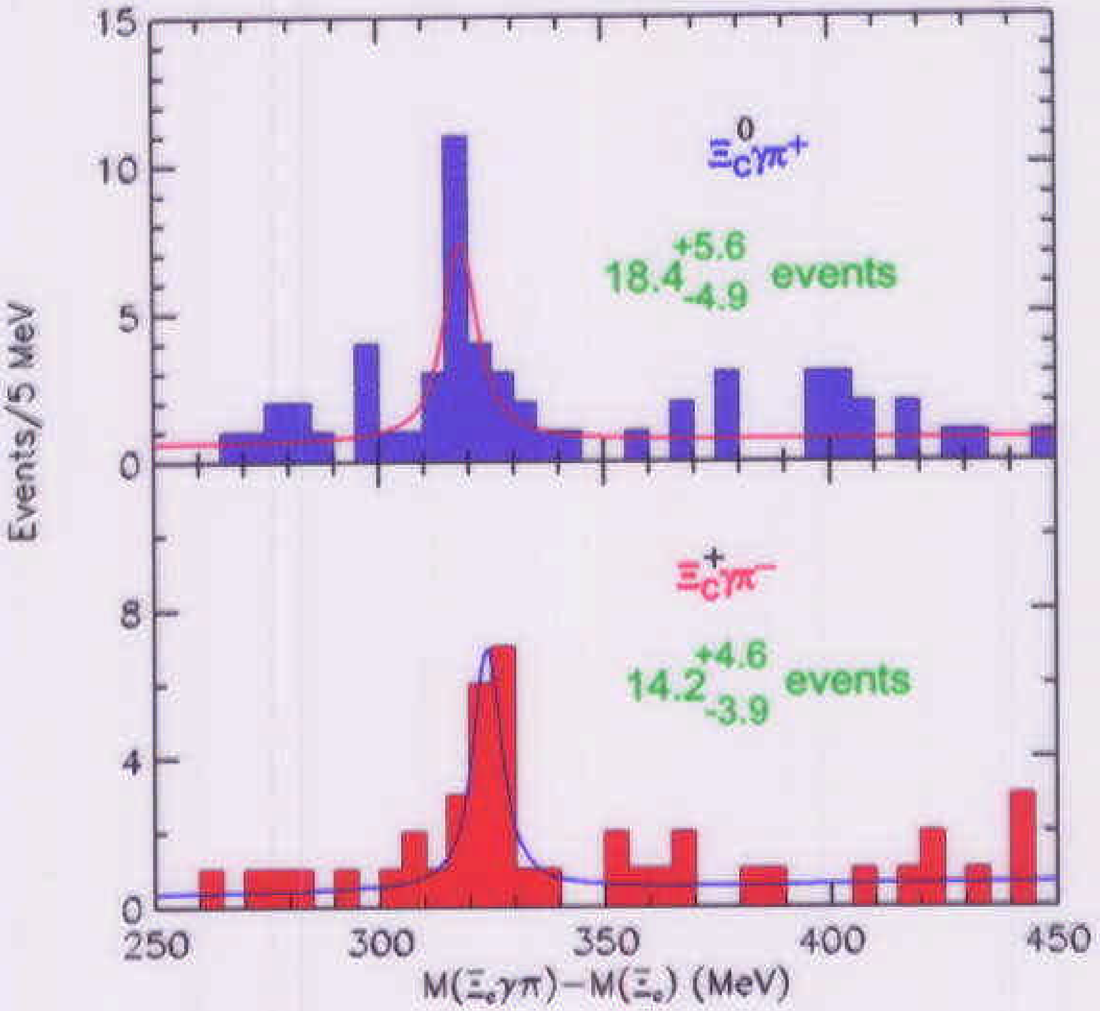
- expect hard x_p spectrum

$$\left(x_p = \sqrt{\frac{E^2_{beam} - M(\Xi_{c1})^2}{P_{beam}}} \right)$$

look for this!

Finding the $J^P = 1/2^- \ \Xi_{c1}$ states

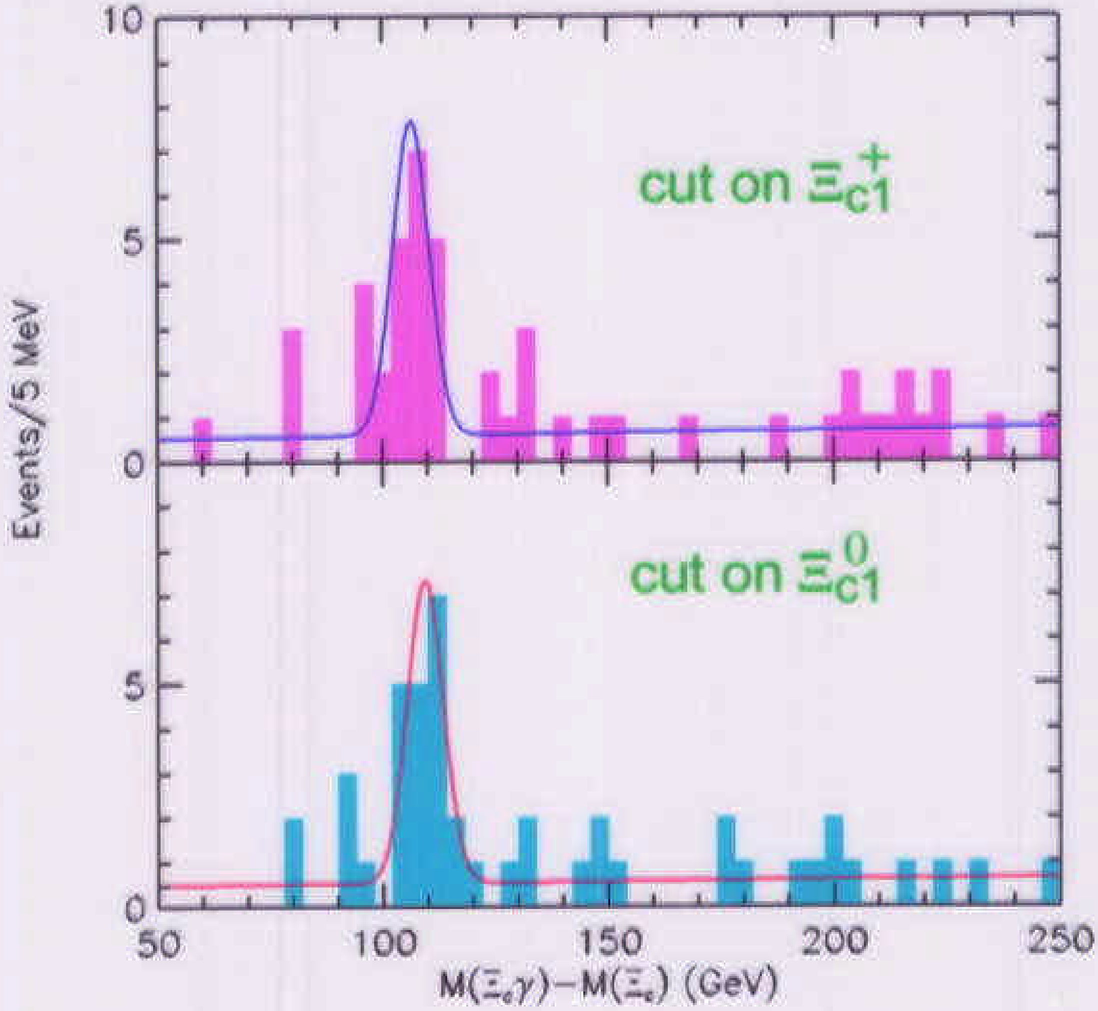
- select $\Xi_c \gamma$ combinations at Ξ_c' mass $\pm$ 8 MeV (2 σ)
- combine with right-sign π and plot.



Breit-Wigner convoluted with resolution + polynomial background

Ξ_{c1} (J=1/2), continued

- Check : cut on " Ξ_{c1}" mass (± 8 MeV): look for Ξ_c'



- Ξ_c' mass differences close to published values
- consistent with ALL decays proceeding via Ξ_c'

PRELIMINARY Numbers for Ξ_{c1} ($J^P=1/2^-$)

$M(\Xi_{c1}^{+}(J=1/2)) - M(\Xi_c^{0}) = 318.4 \pm 1.5 \pm 2.9$ MeV

$\Gamma < 16$ MeV @ 90% confidence (our preference is to quote a limit , for now)

$M(\Xi_{c1}^{0}(J=1/2)) - M(\Xi_c^{+}) = 323.9 \pm 1.4 \pm 3.0$ MeV

$\Gamma < 13$ MeV @ 90% confidence

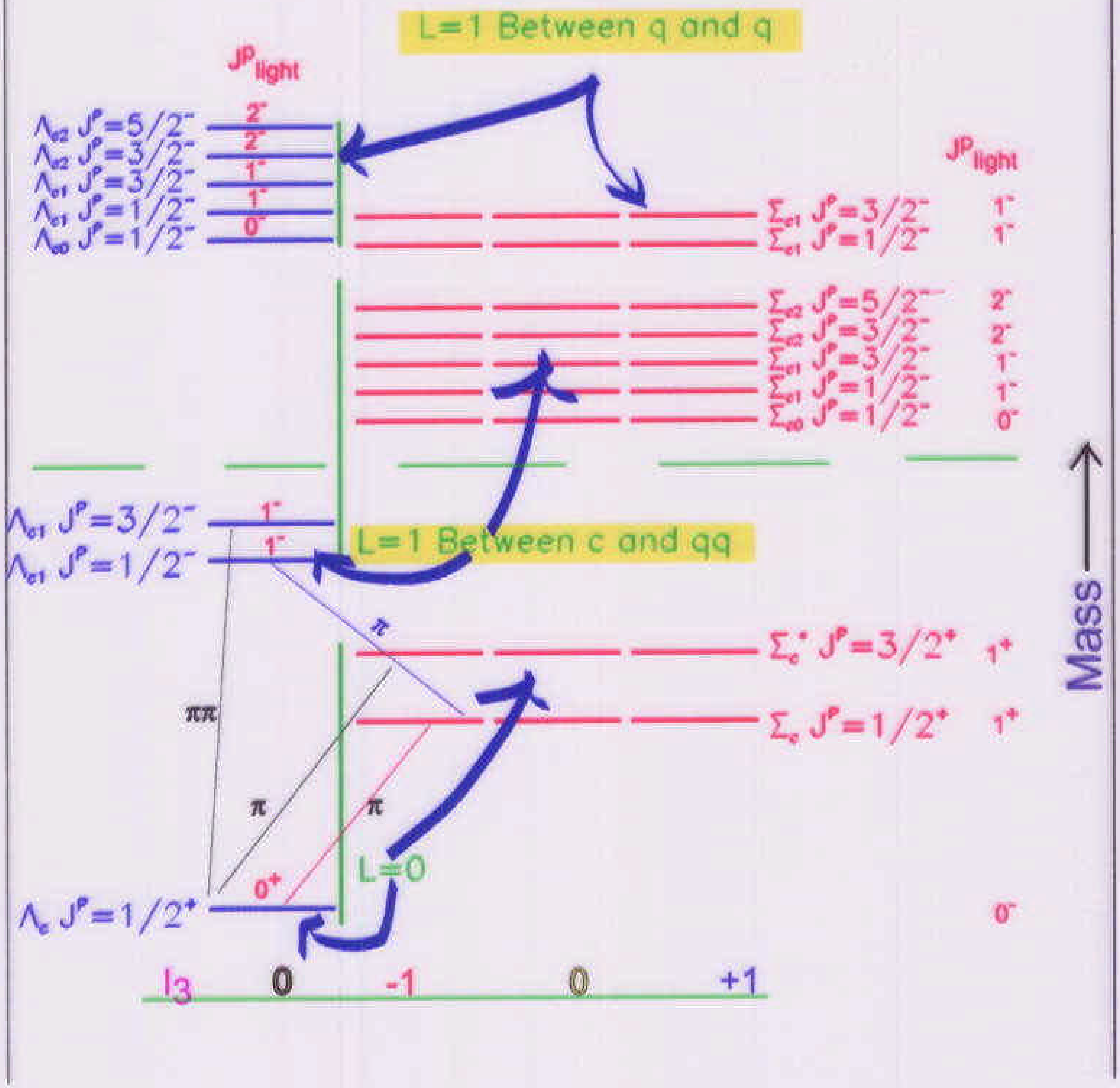
Relative to the Ξ_c', the mass differences are:

$M(\Xi_{c1}^{0}(J=1/2)) - M(\Xi_c^{+\prime}) = 216.1 \pm 1.4 \pm 1.0$ MeV

$M(\Xi_{c1}^{+}(J=1/2)) - M(\Xi_c^{0\prime}) = 211.4 \pm 1.5 \pm 1.0$ MeV

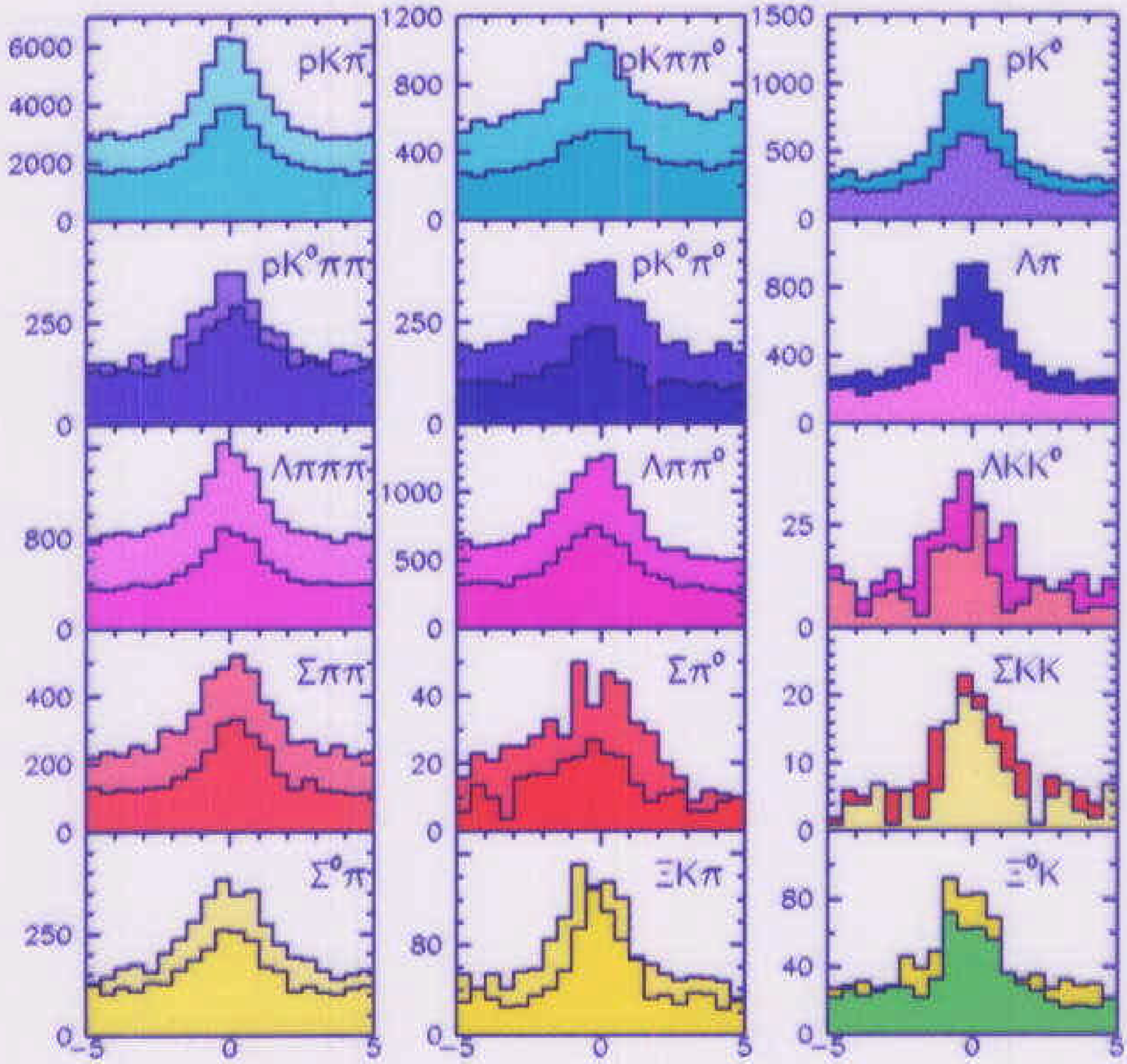
(reduced systematic error reduced: from Ξ_c' mass.)

Λ_c and Σ_c Spectroscopy



Λ_c^+ in 15 channels

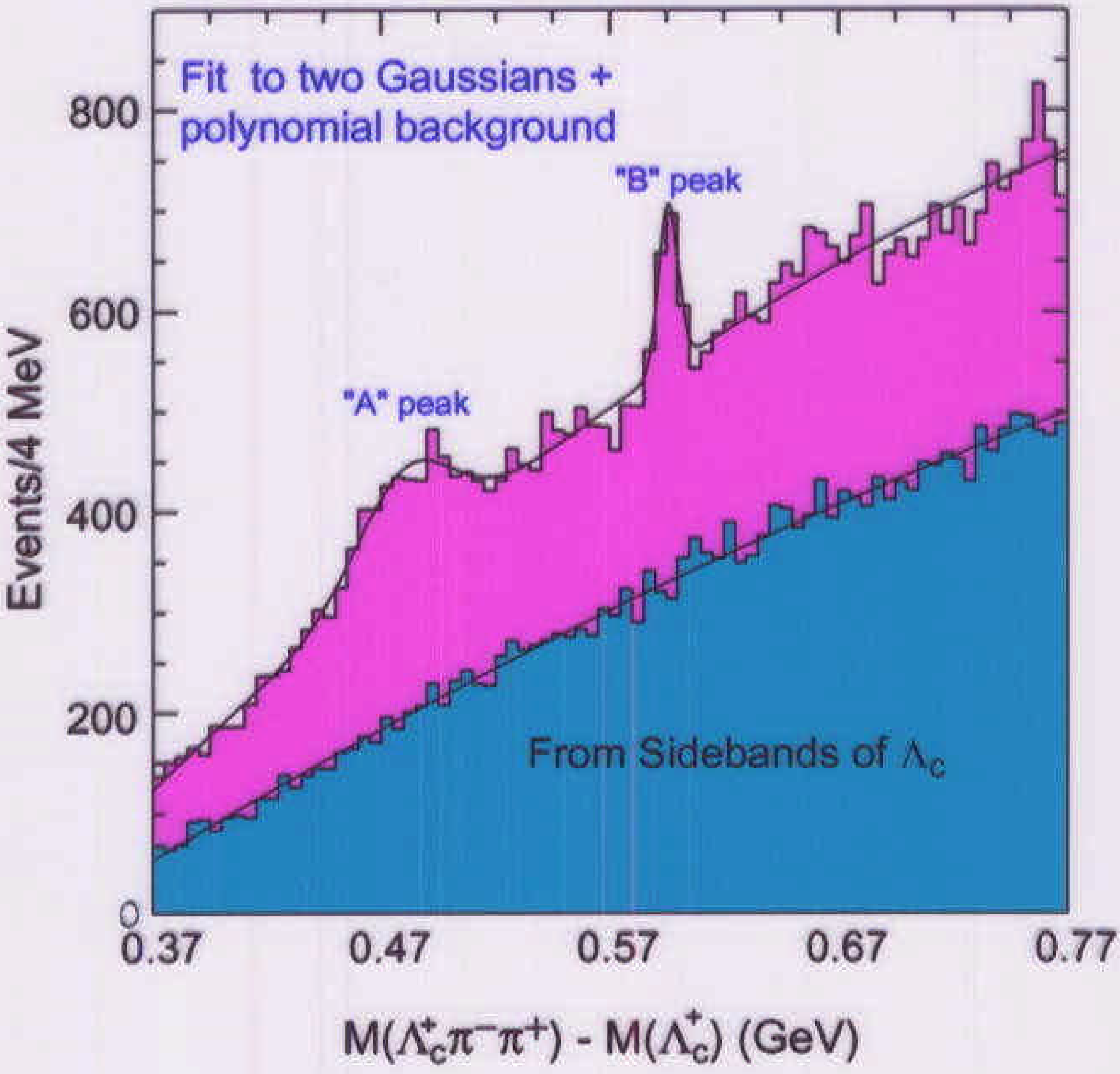
- 58000 in signal with $x_p>0.5$; S/N=1.2:1
- plotted in σ of deviation from channel mass



We need statistics!

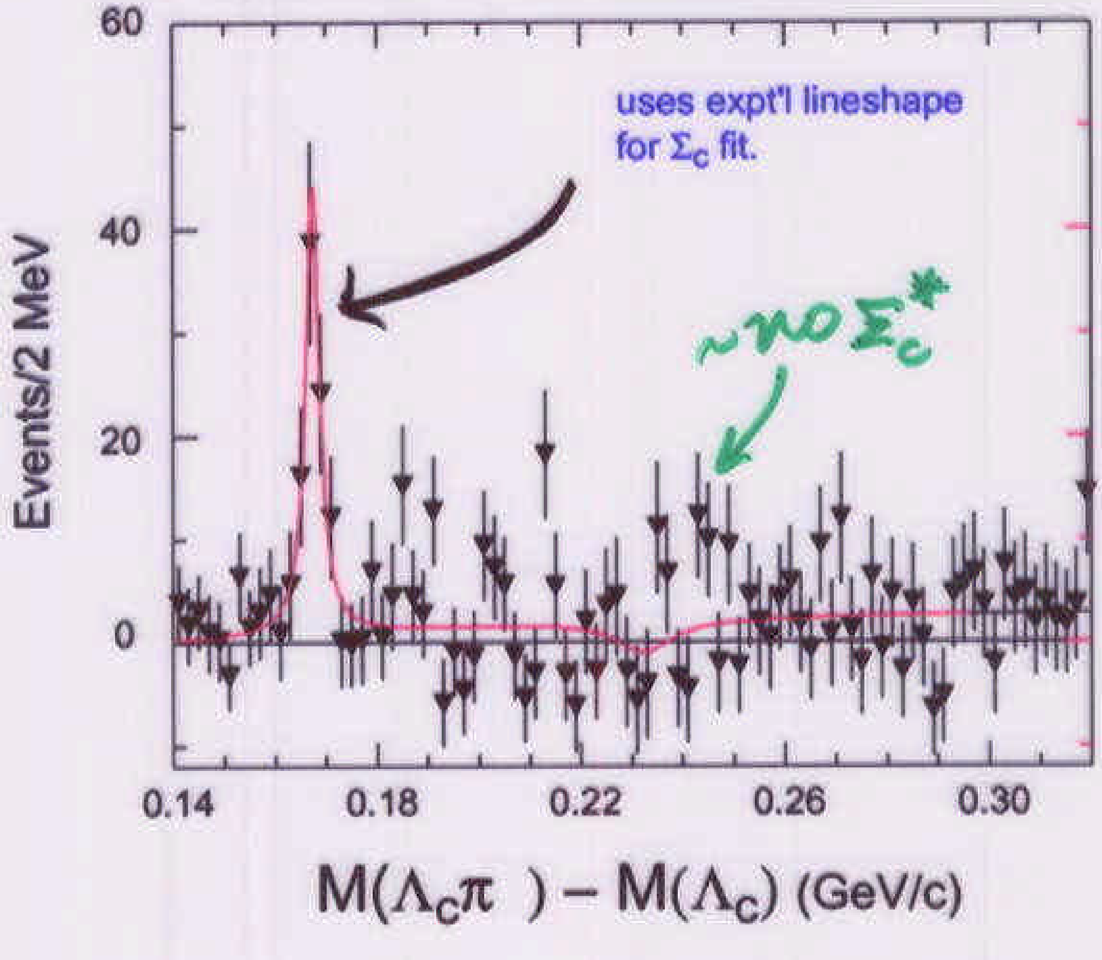
Two new "bumps in $\Lambda_c^+\pi^-\pi^+$ mass

- Above Λ_{c1} (2593, 2620) doublet



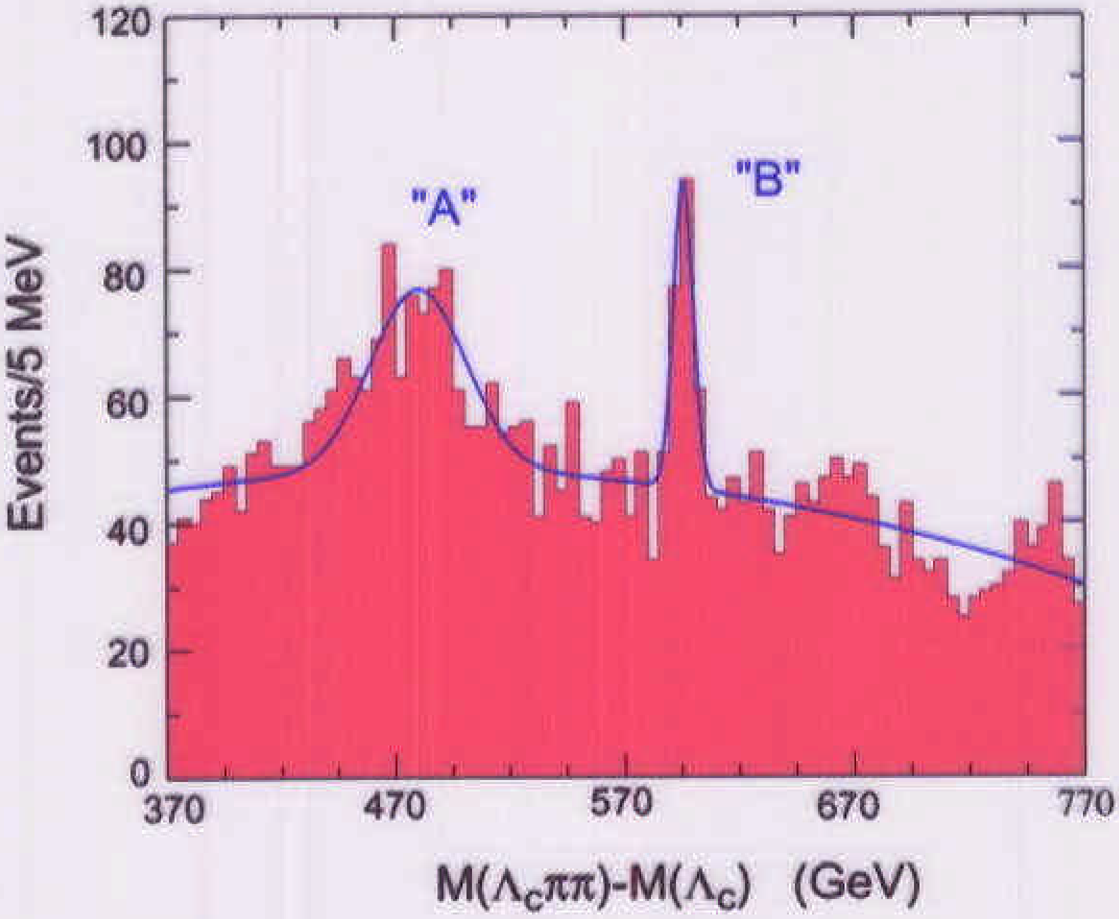
Look for resonant substructure in "B"

- cut on "B"(upper) peak: plot $M(\Lambda_c\pi\ ) - M(\Lambda_c)$
- do same for (normalized) sidebands
- subtract



Looking for Σ_c Baryons

- Cut ± 4 MeV about Σ_c in $M(\Lambda_c\pi\pi)-M(\Lambda_c)$



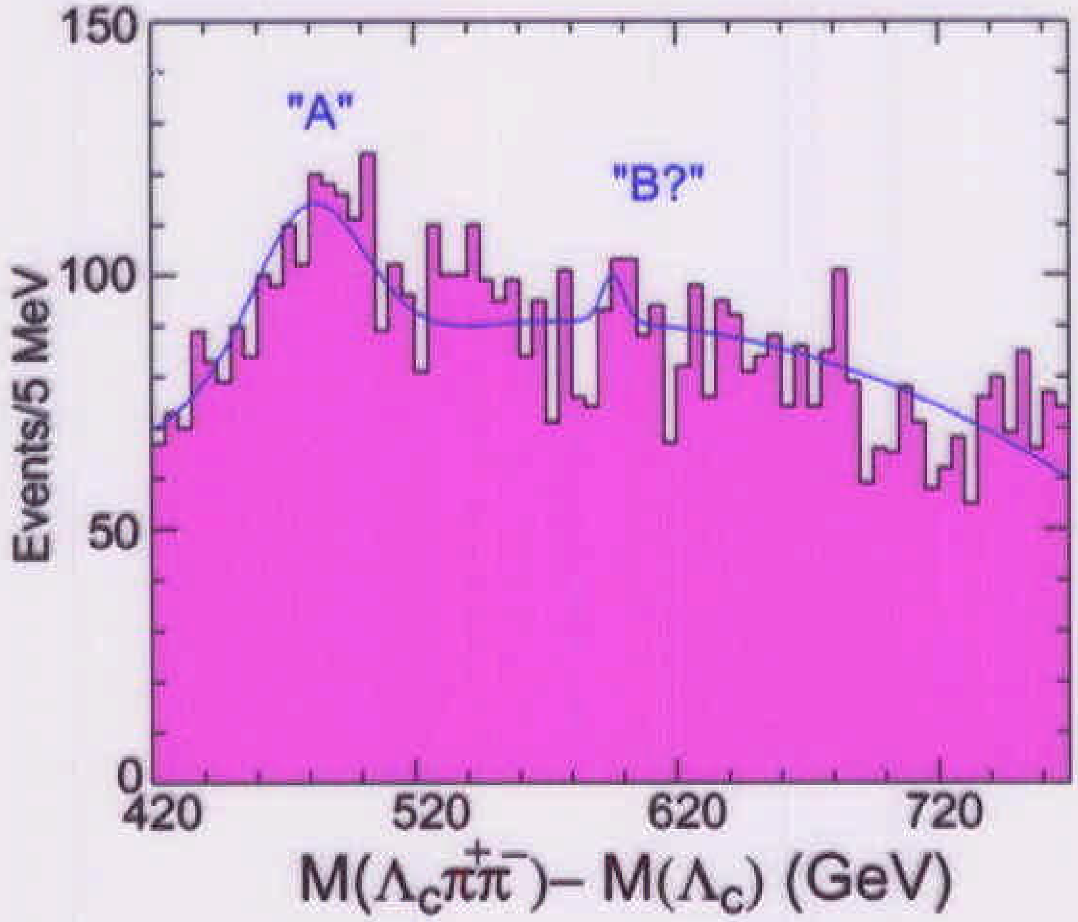
Conclude: both A and B decay to Σ_c

Looking for Σ_c^* Baryons

- Cut ± 10MeV about Σ_c^{0*} in $M(\Lambda_c^+\pi^\pm) - M(\Lambda_c^+)$

  A: Probably there

  B: Not much there.



PRELIMINARY Numbers for $\Lambda_c\pi^+\pi^-$ states

- Found at high x_p (x_p > 0.7), sensible production rate.

Broad state: "A"

$M(\Lambda_c^+ \pi^+\pi^-) - M(\Lambda_c^+) \cong 400$ MeV

It may NOT be a single state !

$\Gamma \cong 50$ MeV

Narrow state "B'

$M(\Lambda_c^+ \pi^+\pi^-) - M(\Lambda_c^+) = 596 \pm 1 \pm 2$MeV

$\Gamma < 8$ MeV @ 90% confidence

Speculative spectroscopy

- possible first examples of Σ_{cJ} states ("A") and states with angular momentum within light diquark ("B").

Preliminary

TABLE III. The substructure of resonances A and B

Method	A		B	
	Σ_c	Σ^*_c	Σ_c	Σ^*_c
1 - sideband subtracting			38± 7%	7± 10%
2 fitting sidebands	37 ± 9%	66 ± 14%	42± 6%	11 ± 13%
3 - cutting on resonances	36 ± 15%	51 ± 8%	34± 6%	4 ± 8%

Truth and Speculations

TABLE IV. Charmed Baryon Spectroscopy

Particle	J^P	J_l^P	M MeV	Width (MeV)	Expected Decays
First those with no angular momentum					
Λ_c	$\frac{1}{2}^+$	0^+	0	0	Decays Weakly
Σ_c	$\frac{1}{2}^+$	1^+	167	2.3	$\Lambda_c\pi$ (p-wave)
Σ^*_c	$\frac{3}{2}^+$	1^+	233	14	$\Lambda_c\pi$ (p-wave)
Next those with angular momentum between c and qq					
Λ_{c1}	$\frac{1}{2}^-$	1^-	308	5	$\Sigma_c\pi$ (s-wave)
Λ_{c1}	$\frac{3}{2}^-$	1^-	341	< 1.5	$\Lambda_c\pi\pi$ (non-resonant)
Σ_{c0}	$\frac{1}{2}^-$	0^-	470?	Wide (600?)	$\Lambda_c\pi$ (s-wave)
Σ_{c1}	$\frac{1}{2}^-$	1^-	470?	Fairly wide (100?)	$\Sigma_c\pi$ (s-wave)
Σ_{c1}	$\frac{3}{2}^-$	1^-	470?	Fairly wide (100?)	$\Sigma^*_c\pi$ (s-wave)
A?? Σ_{c2}	$\frac{3}{2}^-$	2^-	470?	Fairly narrow (10?)	$\Lambda_c\pi$ (d-wave)
Σ_{c2}	$\frac{5}{2}^-$	2^-	470?	Fairly narrow (10?)	$\Lambda_c\pi$ (d-wave)
Next those with angular momentum between the light quarks.					
Σ'_{c1}	$\frac{1}{2}^-$	1^-	600?	Wide	$\Sigma_c\pi$ (s-wave)
Σ'_{c1}	$\frac{3}{2}$	1^-	600?	Wide	$\Sigma^*_c\pi$ (s-wave)
B? Λ'_{c0}	$\frac{1}{2}$	0^-	600?	Narrow	$\Lambda_c\pi\pi$ (non-resonant)
Λ'_{c1}	$\frac{1}{2}$	1^-	600?	Wide	$\Sigma_c\pi$ (s-wave)
Λ'_{c1}	$\frac{3}{2}$	1^-	600?	Wide	$\Sigma^*_c\pi$ (s-wave)
Λ'_{c2}	$\frac{3}{2}$	2^-	600?	Fairly narrow (10?)	$\Sigma_c^{(*)}\pi$ (d-wave)
Λ'_{c2}	$\frac{5}{2}$	2^-	600?	Fairly narrow (10?)	$\Sigma_c^{(*)}\pi$ (d-wave)

L=2, radial excitations ignored

Summary

1) Ξ_{c1} $(J^P = \frac{1}{2}^-)$ appears to be found.

pattern very similar to $\Lambda_{c1}(2593)$, $\Lambda_{c1}(2625)$

2) New structures in $\Lambda_c \pi^+ \pi^-$

a) probable state with Σ_{c1} content

b) narrow state is possibly Λ'_{c0} with $L=1$ between light quarks.