SELEX: Recent Progress in the Analysis of Charm-Strange and Double-Charm Baryons

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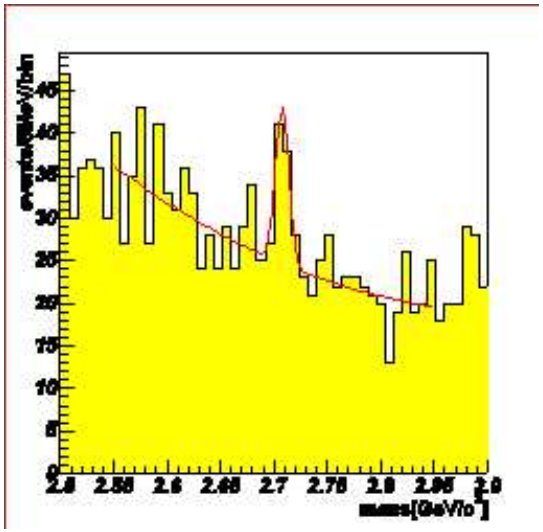
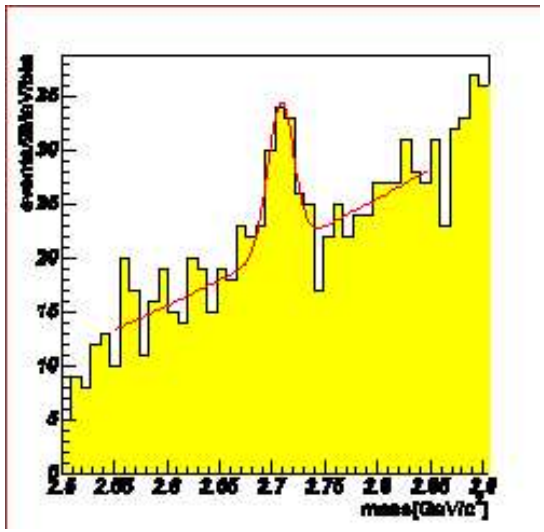
Outline

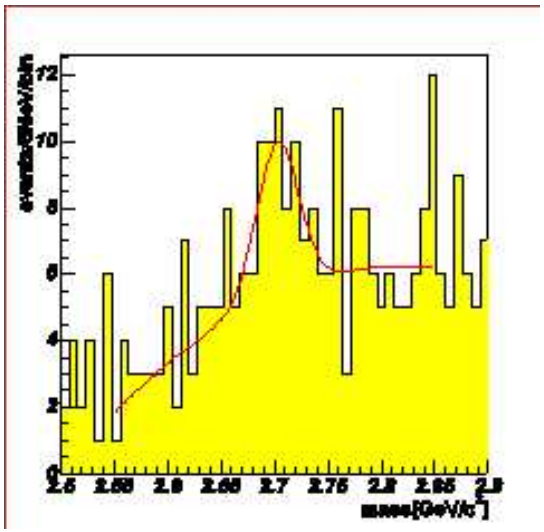
Ω_c^0 in Three Decay Modes



$\Omega_c^0 \to \Omega^- \pi^+$
Signal: 35 ± 12



$\Omega_c^0 \to \Omega^- \pi^+ \pi^+ \pi^-$
Signal: 44 ± 14



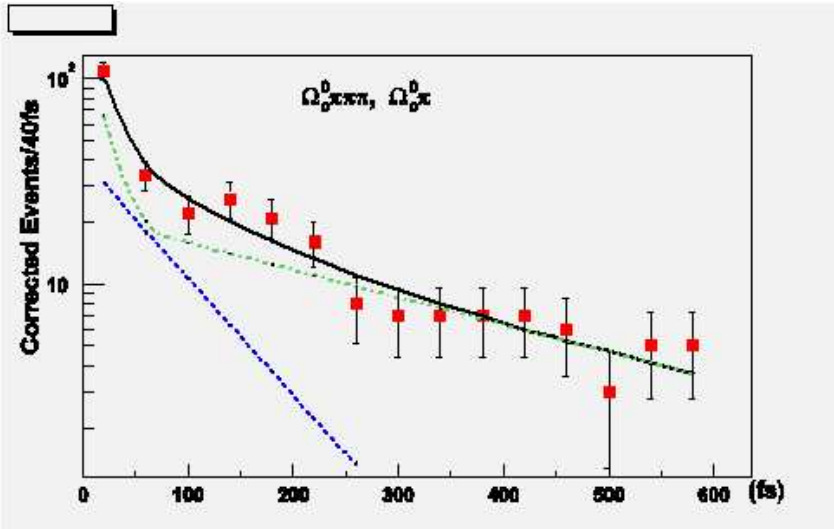
$\Omega_c^0 \to \Xi^- K^- \pi^+ \pi^+$
Signal: 28 ± 12

Total sample 107 ± 22 events (nearly half in $\Omega 3\pi$)
Working on systematics of Mass Measurement

Ω_c^0 Lifetime

- Calculate Reduced Proper Time: $ct = L - N\sigma/\gamma$
  Here: $N = 6$
- Proper Time Resolution: ~ 20 fs
- Maximize Likelihood for three exponentials (2 background)
  $N_s(1-\alpha)f(t)\tau^-1e^{-t/\tau}+\alpha N_B(\beta\tau_1^-1e^{-t/\tau_1}+(1-\beta)\tau_2^-1e^{-t/\tau_2})$
- Fit parameters are τ, α, β, τ_1, τ_2
- Use $\Omega_c^0 \to \Omega^-\pi^+$, $\Omega_c^0 \to \Omega^-\pi^+\pi^+\pi^-$
- First separate for each mode, then combined

Ω_c^0 Lifetime



$\Omega_c^0 \to \Omega^- \pi^+$: 67.5 ± 18.0 fs
$\Omega_c^0 \to \Omega^- \pi^+ \pi^+ \pi^-$: 72.3 ± 20.0 fs

combined (SELEX Prelim.):
$\tau(\Omega_c^0) = 69 \pm 14 \pm 9$ fs
PDG: 69 ± 12 fs
(175 evts from 3 exper)

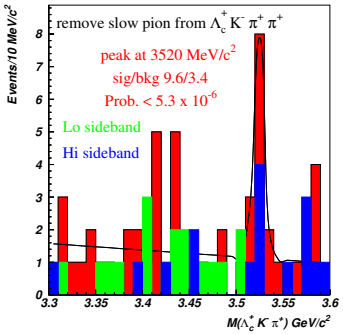
$$\frac{\tau(\Xi_c^0)}{\tau(\Omega_c^0)} = 1.5 \pm 0.3$$

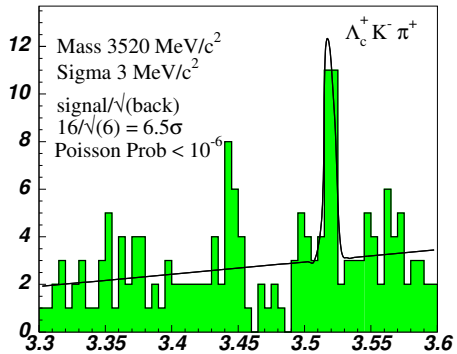
Theory: ~ 1

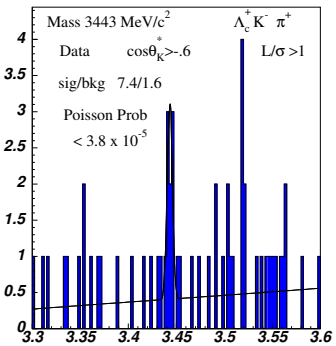
$$\frac{\tau(\Xi_c^+)}{\tau(\Lambda_c^+)} = 2.15 \pm 0.13$$

Theory: 1.2 – 1.7

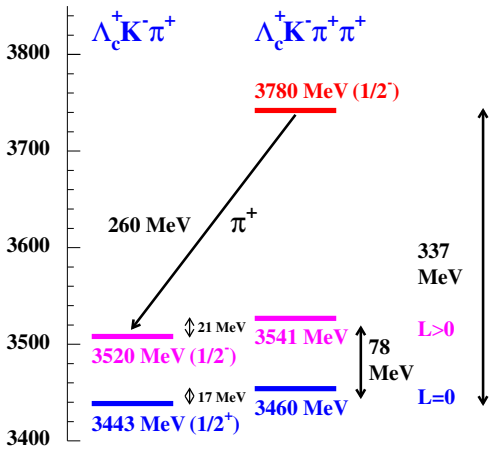
SELEX Double Charmed Baryon States – 2003

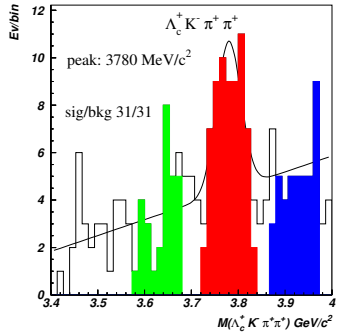


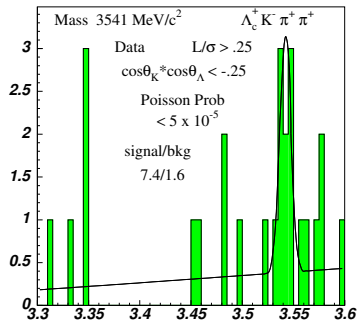


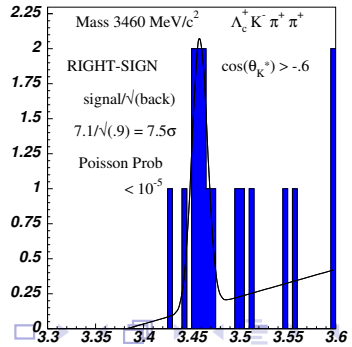


An exited state and a pair of isodoublets?









Features and Problems in Original Analysis...

- All Signals have very low statistics
- There is nearly no background ($\to$ difficult to determine)
- Entries in histograms only from baryon (Σ^-, proton) beams
- Other experiments do not see the states
  (but: nobody else has baryon beams...)
- Lifetime is short (< 33 fs)

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. . . and Possible Solutions

- Look for other decay modes to confirm DCB hypothesis
- Develop new method for background determination
- Include single-charm in vertex fit of double-charm vertex
- Redo full analysis chain to increase statistics

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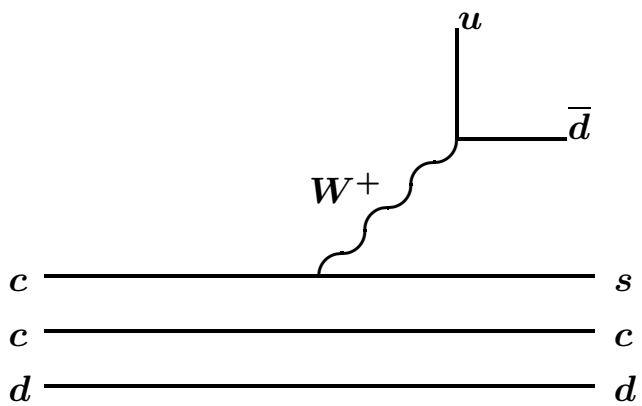
Other Decay Modes of Double Charm Baryons

Cabibbo allowed decay of Ξ_{cc}^+:



In Final State:

- Baryon
- Quarks $csdu\bar{d}$
  plus pairs from sea
- Cascaded decay chain

Easily accessible in SELEX:

$\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$
$\Xi_{cc}^+ \to p D^+ K^-$
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$\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$
$\Xi_{cc}^{++} \to p D^+ K^- \pi^+$ (?)
$\Xi_{cc}^{++} \to \Xi_c^+ \pi^+,$
$\Xi_{cc}^{++} \to \Xi_c^+ \pi^+ \pi^+ \pi^-$

$\Omega_{cc}^+ \to \Xi_c^+ K^- \pi^+,$
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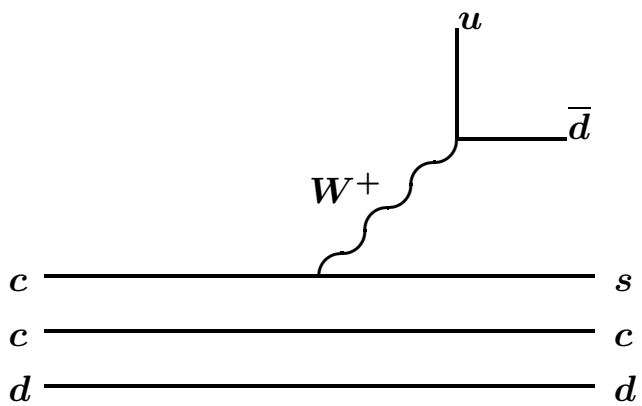

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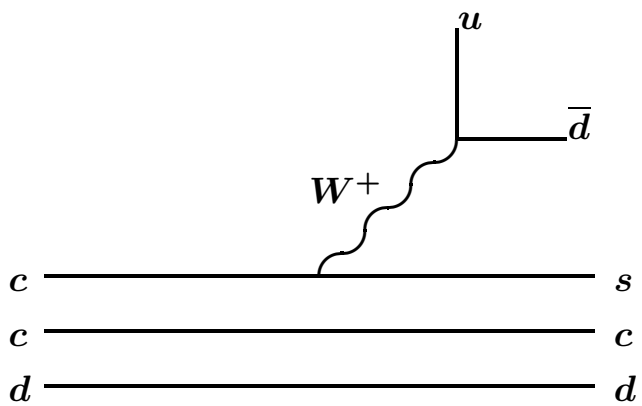

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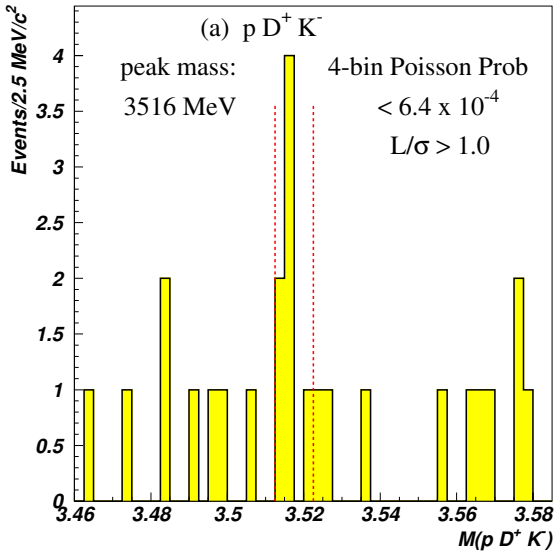
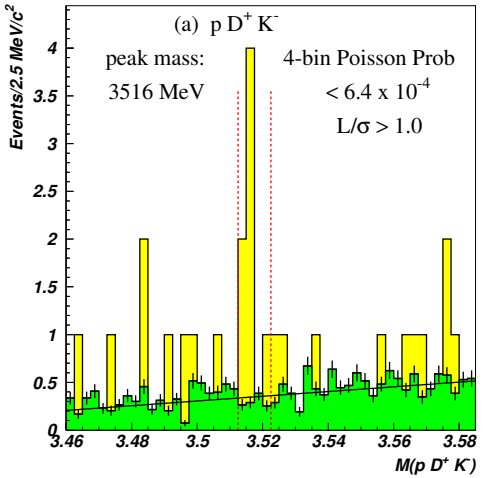
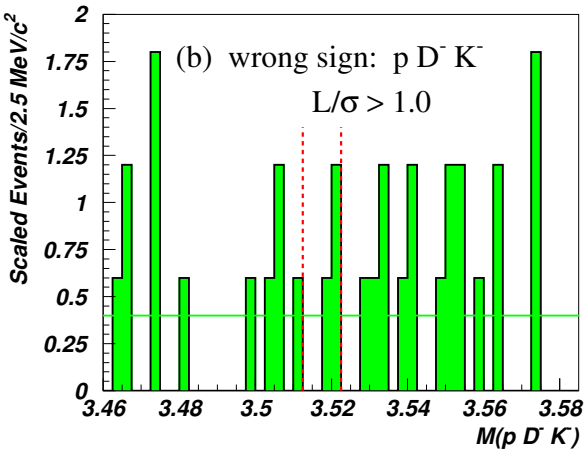
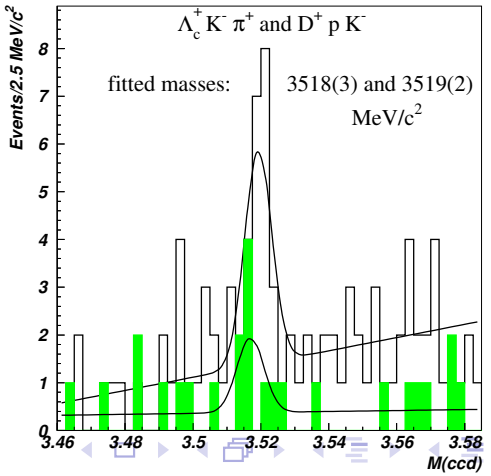
$\Xi_{cc}^+ \to pD^+K^-$ (PLB628 (2005) 18)

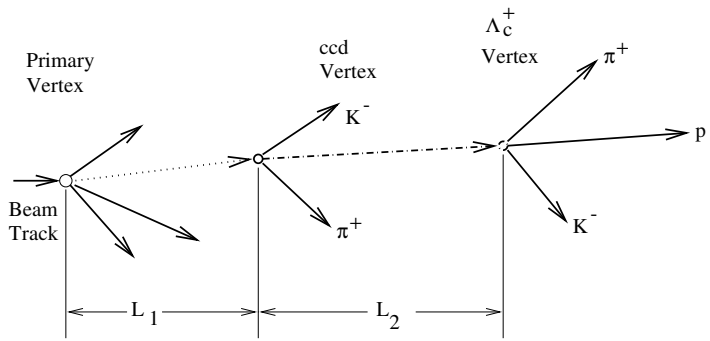








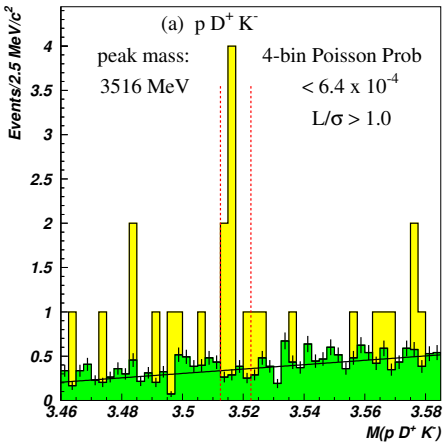
Background Determination: Event Mixing



Ξ_{cc}^+ Decay Schematic

- First decay vertex close to primary vertex: assume all bkgd is combinatoric
- Make combinatoric bkgd by taking first decay vertex from one event, second from other
- Use each single-charm event 25 times to increase statistics

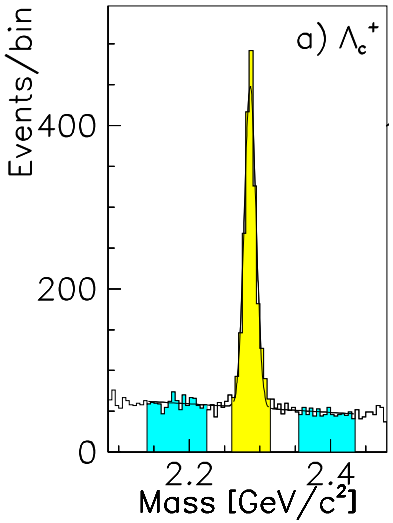
Resulting combinatoric bkgd is absolutely normalized $\Rightarrow$ Bkgd shape known

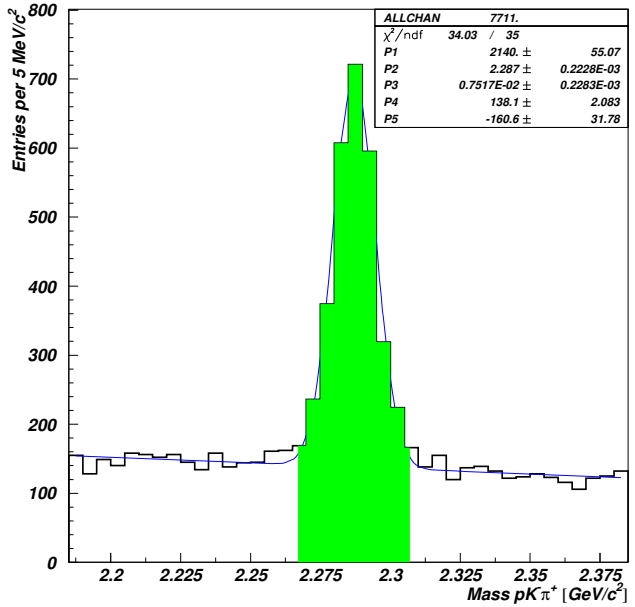


PLB628 (2005) 18

$\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$ – New Analysis

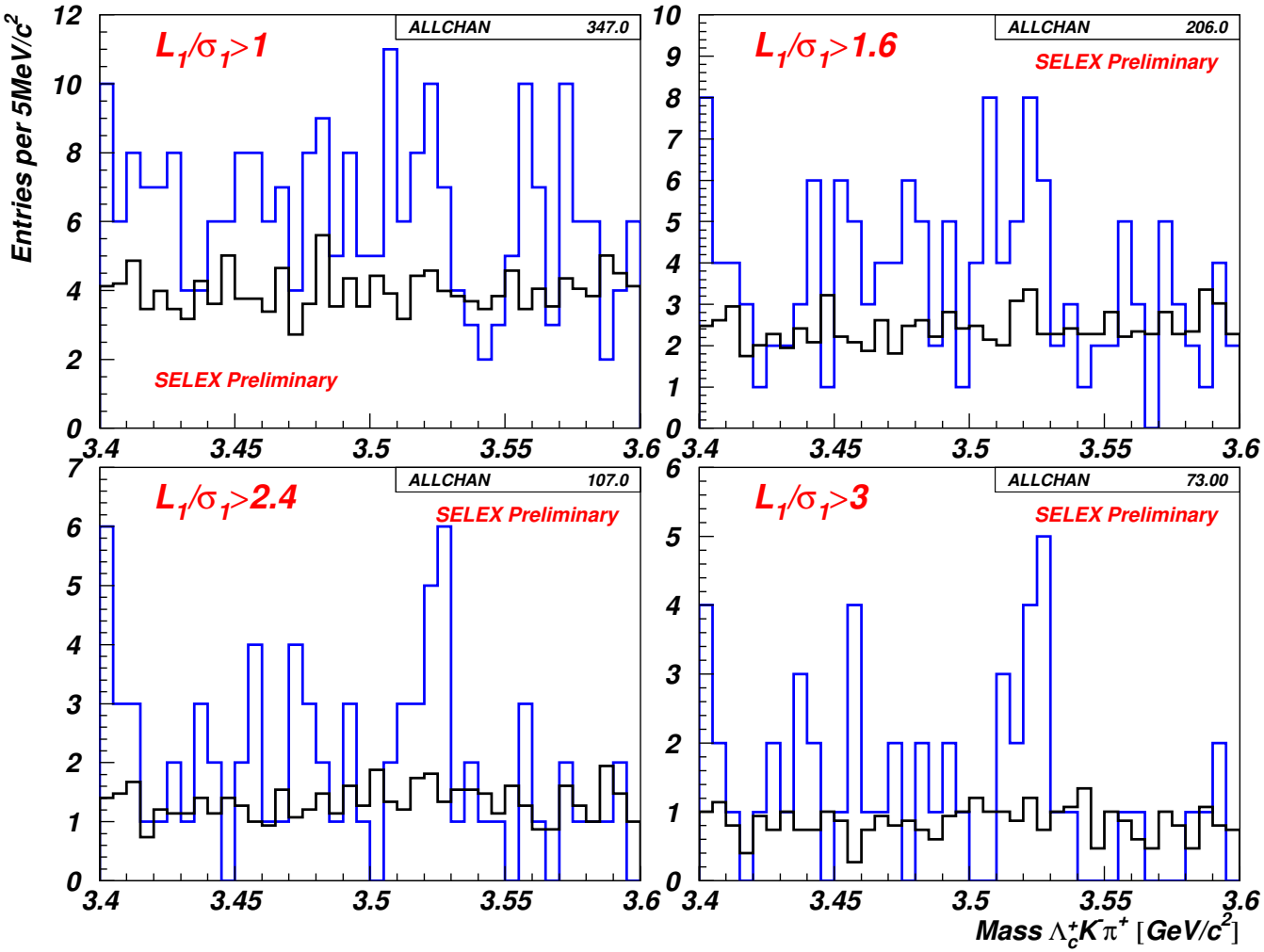
Re-analysis of full data set $\Rightarrow$ More Λ_c cands (1630 $\to$ 2450)





- Refit Ξ_{cc}^+ vertex using $\vec{p}_{\Lambda_c^+}$ together with $K^- \pi^+$ tracks
  $\Rightarrow$ Better *L*1 resolution
- Use event mixing for background

$\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$, $\Lambda_c^+ \to p K^- \pi^+$ – New Analysis

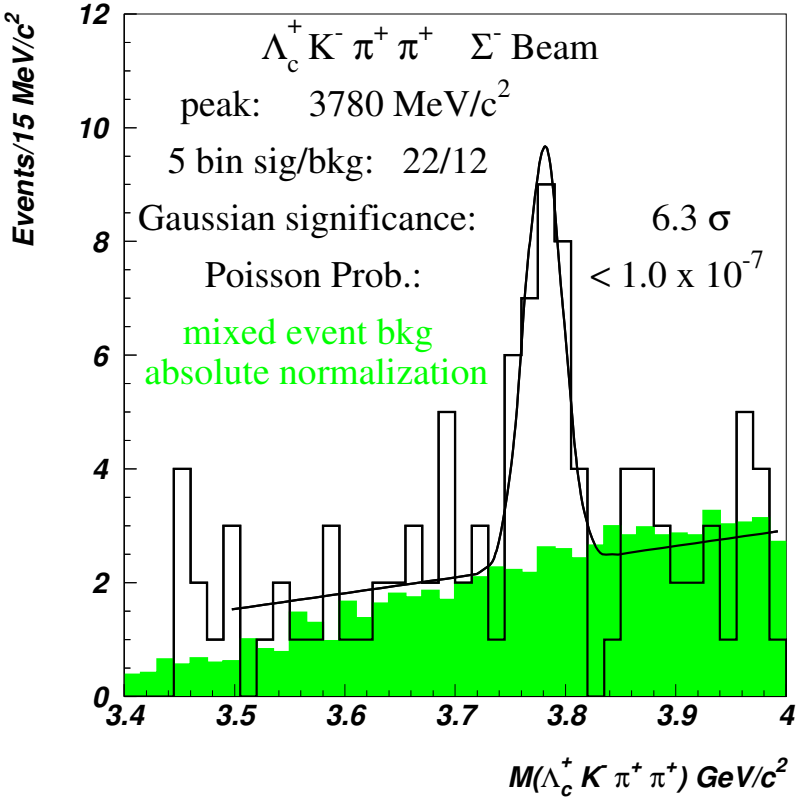


Features of new Analysis

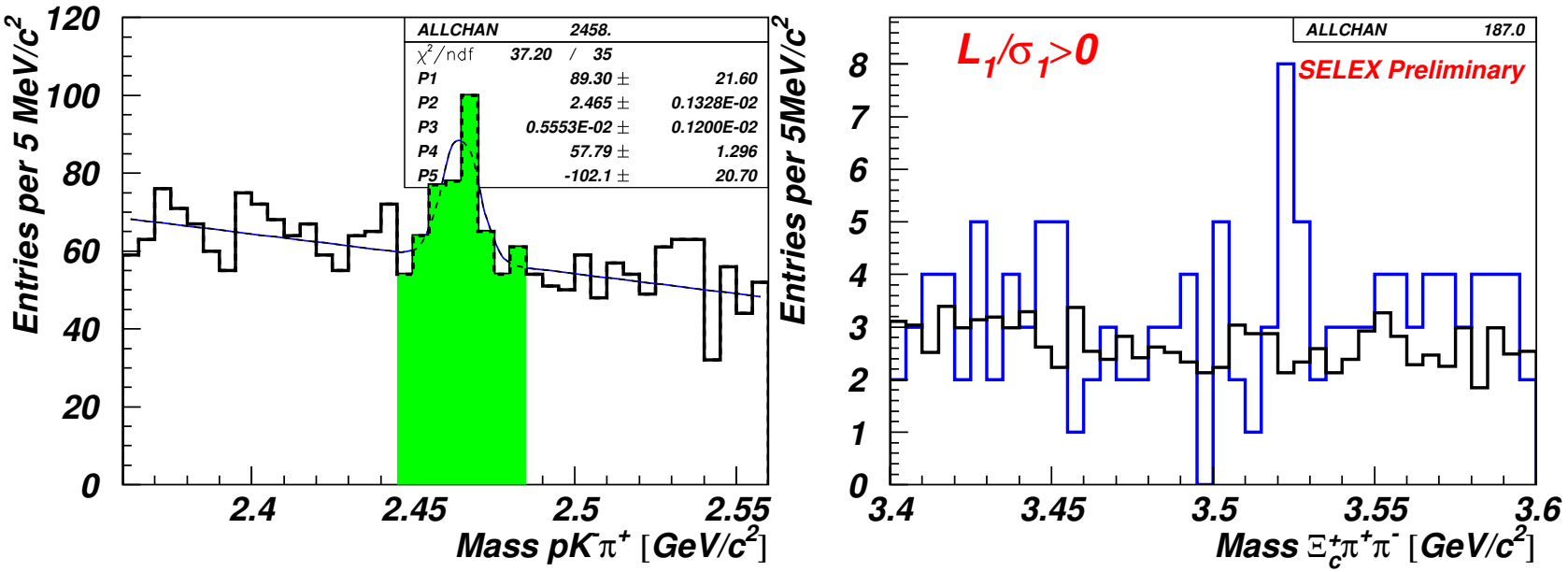
- Re-Analysis and Relaxing Cuts on Single Charm:
  - some more background, but shape is well understood from combinatoric analysis
  - more signal
- Improved sec. vertex resolution:
  - Cleaner Signals, access to other modes
  - Possibility (but challenging) to measure lifetime (is around 1 σ)

$\Xi_{cc}(3780)^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$

- Re-Analyzed Data
- Restrict to Σ^-–Beam
- Peak wider than Resolution
- Half decay to $\Xi_{cc}^+(3520)$
- Still working on Details

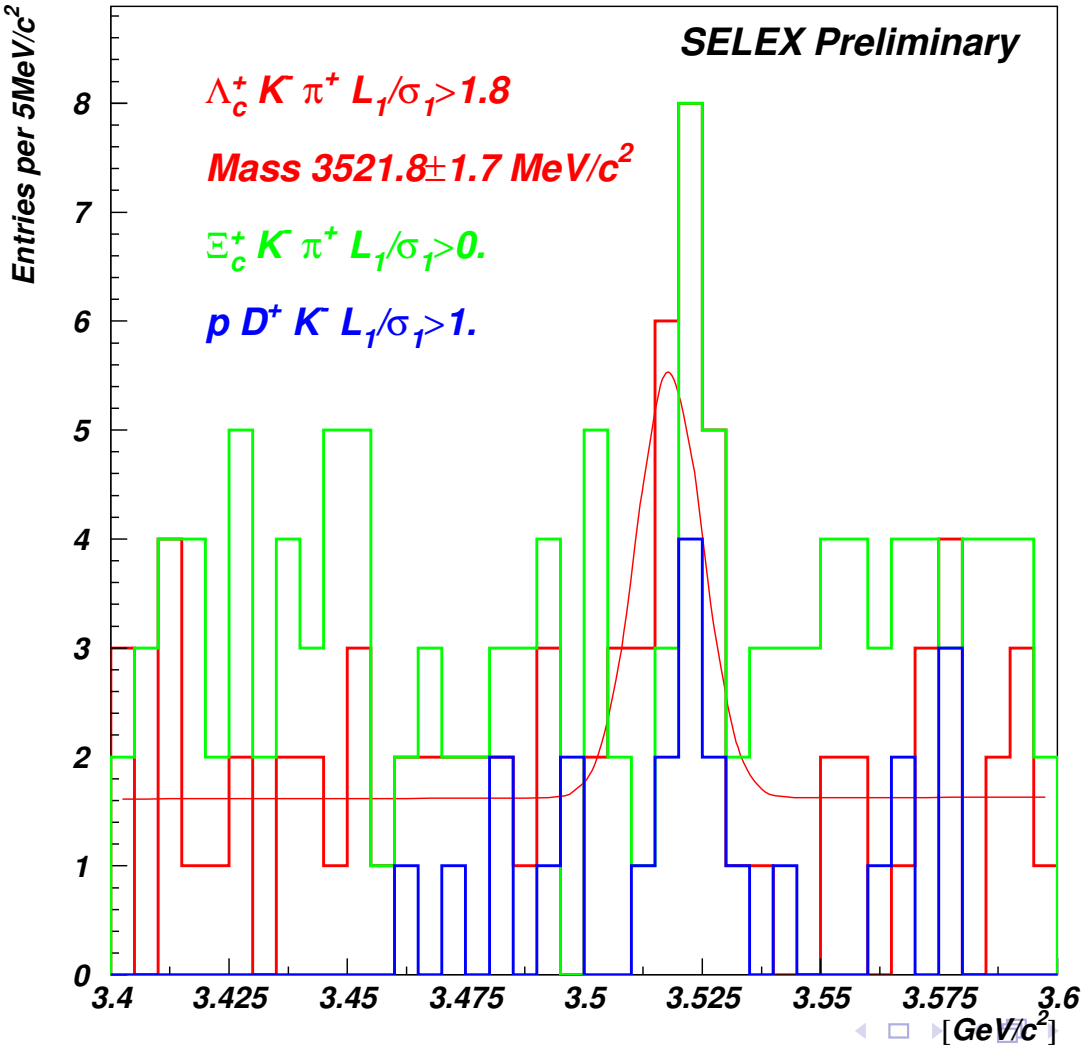


$\Xi_{cc}^+ \to \Xi_c^+ \pi^+ \pi^-$ – First Observation

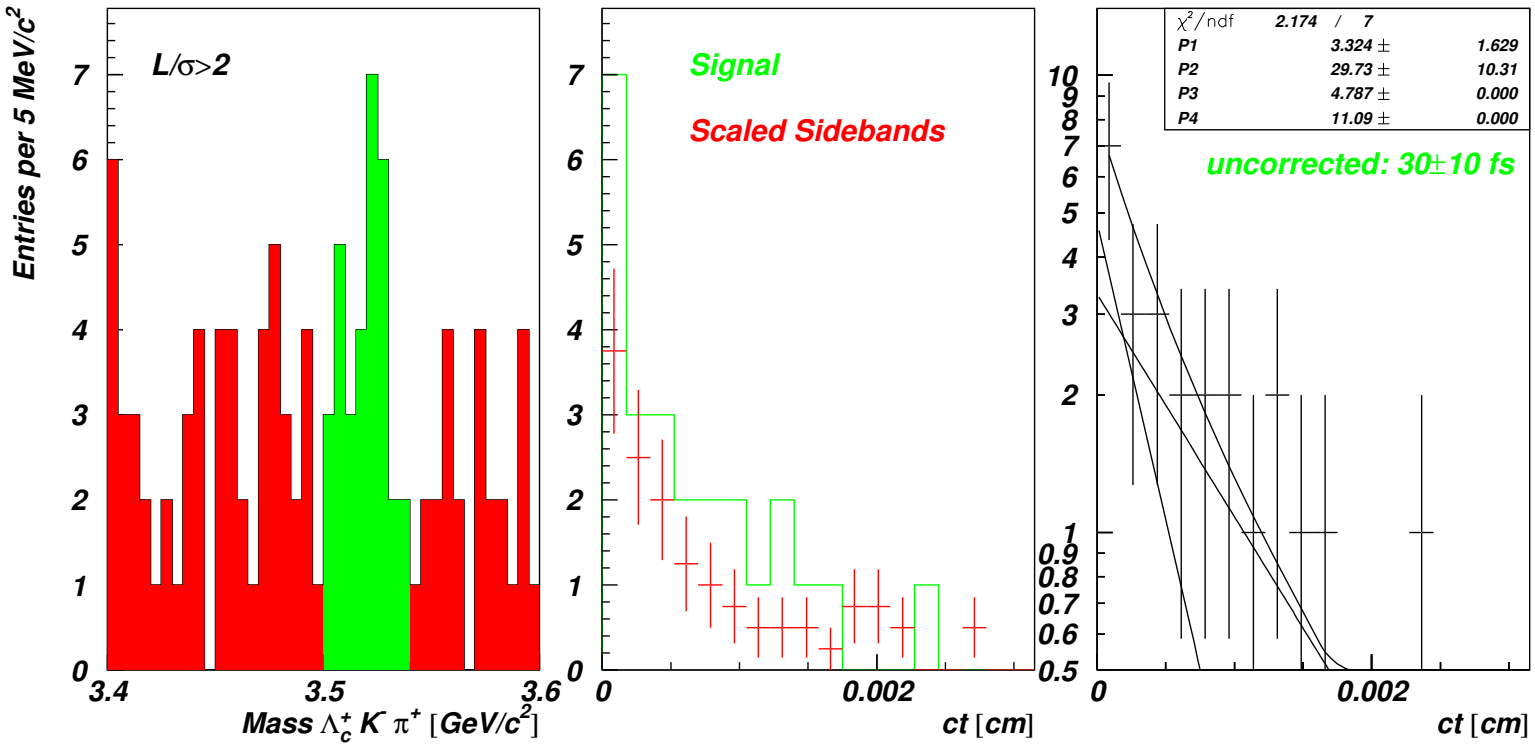


FIRST OBSERVATION: $\Xi_{cc}^+ \to \Xi_c^+ \pi^+ \pi^-$, $\Xi_c^+ \to pK^- \pi^+$

Comparing the Mass of the Three Decay Modes



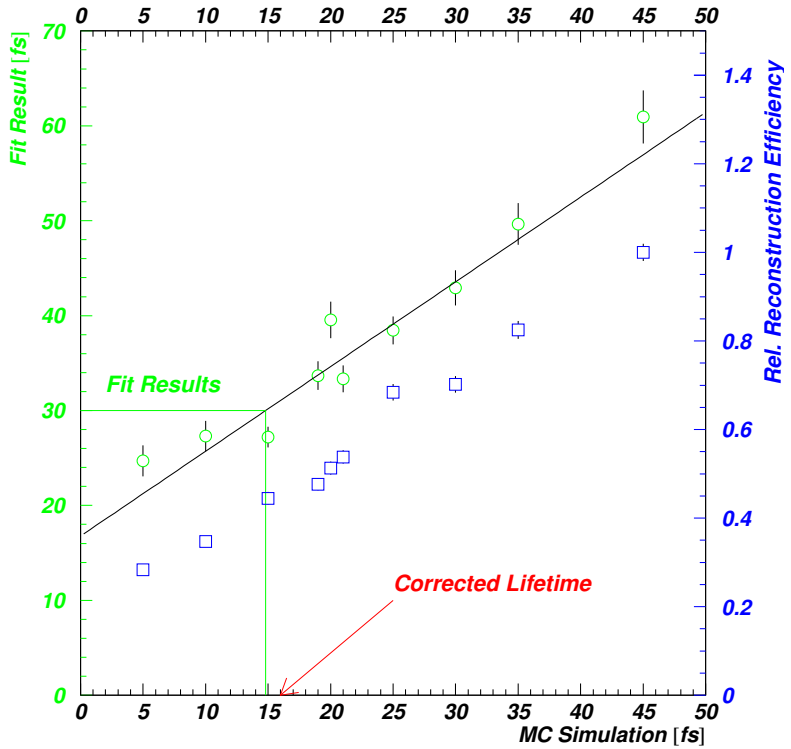
Lifetime of Ξ_{cc}^+



SELEX Preliminary Results

Lifetime of Ξ_{cc}^+

- Cuts loose events at small *ct*
- Use MC to correct for this effect
- Uncorrected Lifetime: $(30 \pm 10\,\text{fs})$
- Corrected Lifetime: $(15^{+10}_{-??} \pm ??)\,\text{fs}$



Conclusions

- SELEX is still the only experiment observing Double Charm Baryons
- Published results on
  - $\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$ (PRL86 (2002) 5243)
  - $\Xi_{cc}^+ \to p D^+ K^-$ (PLB628 (2005) 18)
- SELEX is re-analyzing the data, with improved efficiency
- Presented $\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$
- $\Xi_{cc}(3780)^{++}$ is still there
- First Observation of $\Xi_{cc}^+ \to \Xi_c^+ \pi^- \pi^+$
- Determination of the Ξ_{cc}^+ Lifetime

Future Work

- Finishing re-analysis of $\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$
- Finishing analysis of $\Xi_{cc}^+ \to \Xi_c^+ \pi^- \pi^+$
- Finishing lifetime analysis
- Finishing $\Xi_{cc}(3780)^{++}$
- Working on re-analysis of $\Xi_{cc}^+ \to pD^+ K^-$
- Search for Ω_{cc}^+
- Look for Ξ_{cc}^{++} in all corresponding decay modes around $3500\,\mathrm{MeV}/c^2$

STAY TUNED!