Λ_c Production and Decay

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Introduction

The Λ_c is more than just a c quark in a baryon!

Naively, one might expect:

- $\Gamma_{tot}(\Lambda_c) = \Gamma_{tot}(D^0)$
  But: W exchange differs, Pauli interference, ...
- Exp's would have nailed down one absolute Λ_c branching ratio
  But: $\mathcal{B}(\Lambda_c \to pK\pi)$ still needed
- Independent fragmentation of quarks in $e^+e^- \to c\bar{c}$
  But: contrary evidence in this talk!

CLEO is working on all of these issues (and more!)

Today, I will present CLEO results on:

- Measurement of the Λ_c Lifetime
- $\mathcal{B}(\Lambda_c \to pK\pi)$ using $\Lambda_c - D^{(*)}$ Correlations
- Correlated Production of the Λ_c Baryon

Data Set

Data Sets used:

9.0 fb^{-1} with Silicon Detector, for Λ_c decay lifetime

4.7 fb^{-1} pre-Silicon data, for $\mathcal{B}(\Lambda_c \to pK\pi)$

All of the above data used for Λ_c production correlations.

All of the analyses presented use only charged tracks.

CLEO II Detector:

- 3 Layers double-sided silicon OR 6-layer straw-tube chamber
- 61 layers of wire-chamber tracking plus 4 cathode layers
- 49-sample dE/dx and Time-of-Flight system for particle ID
- CsI(Tl) calorimeter for electron ID

Λ_c Lifetime

CLEO recently published precise D meson lifetimes:

G. Bonvicini et al.; PRL 82, 4586 (1999)

D^0: $408.5 \pm 4.1^{+3.5}_{-3.4}$ fs

D^+: $1033.6 \pm 22.1^{+9.9}_{-12.7}$ fs

D_s: $486.3 \pm 15.0^{+4.9}_{-5.1}$ fs

The technique used here is very similar.

Analysis:

- Use Λ_c momenta > 2.6 GeV/c
- Mean Λ_c momentum: 3.3 GeV/c ($\gamma\beta c\tau \simeq 75\mu$m)
- Vertex resolution along flight direction: $\sim 80\mu$m
- Run-by-run beam spot centroid used
- Beam spot xyz size: $350\mu\text{m} \times 7\mu\text{m} \times 10^4\mu\text{m}$
- Use only y-components of decay length and momentum to extract decay time: $(m/p_y)l_y$

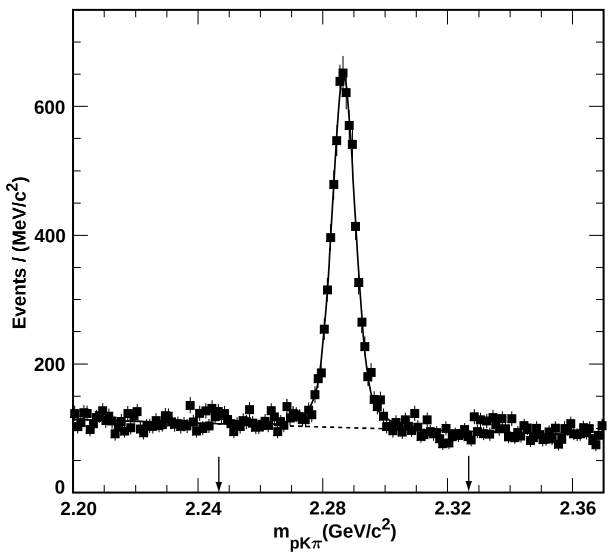
  y beam size $<<$ vertex resolution

Veto $D^+ \to K^-\pi^+\pi^+$ background!

could easily bias fit (D^+ lifetime very large!)

Λ_c Lifetime

$\Lambda_c \to pK\pi$ Mass Peak



Data: 5513 ± 120 events

Unbinned Likelihood Fit:

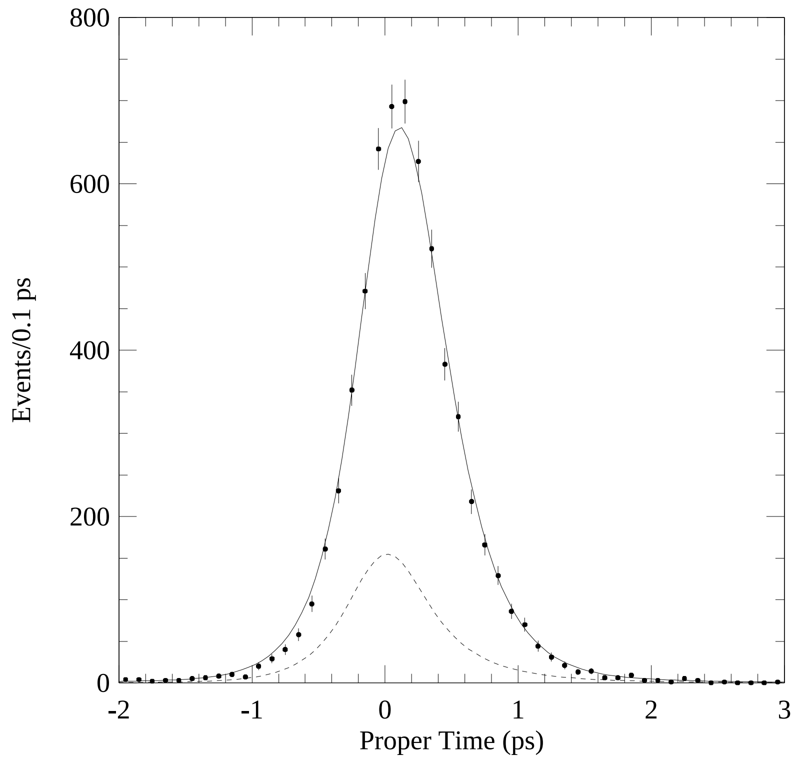
- Use ± 40 MeV mass window
- Background vs. signal probability based on mass

Seven fit parameters:

- 1: Λ_c lifetime
- 2: Global scale factor for per-candidate resolution
- 3: Fraction of signal with wide resolution function
  (width of wide resol'n Gaussian fixed at 8 ps)
- 4,5: Fraction and lifetime of mis-reconstructed events
- 6,7: Background lifetime, and fraction of prompt background

Λ_c Lifetime

Λ_c Lifetime Fit



Result: $\tau(\Lambda_c) = 177.6 \pm 5.9 \pm 4.0$ fs

Largest systematics are:

- 2.2 fs from possible bias in fit to zero-lifetime sample of $\gamma\gamma \to 4\pi$
- 2.7 fs from statistical accuracy of a MC fit tests
- 1.8 fs from dependence on Λ_c mass
- 9 systematics considered.

PDG2000 World Ave: 206 ± 12 fs

Best previous measurement: $215 \pm 16 \pm 8$ fs (E687; 1993; 1340 events)

FOCUS'99 (prelim.): 204.5 ± 3.4 fs (stat. error only)

SELEX'98 (very prelim.): 177 ± 10 fs (stat. error only)

$\mathcal{B}(\Lambda_c \to pK\pi)$

Hard to measure an absolute Λ_c branching ratio

Some previous measurements use B decays, assuming:

- $\mathcal{B}(B \to \Lambda_c \bar{N} X) = 100\%$

  If true; $B \to \bar{p}X$ is unbiased source of $B \to \Lambda_c \bar{p} W^-$

But assumptions are not true!

- $B \to \Xi_c \bar{\Lambda}_c$, $\bar{\Lambda}_c \to \bar{p}X$
- $B \to D N \bar{N} X$

B decay method underestimates $\mathcal{B}(\Lambda_c \to pK\pi)$!

PDG treats by adding 30% systematic:

$$\mathcal{B}(\Lambda_c \to pK\pi) = (4.14 \pm 0.91 \pm 1.24)\%$$

Other measurements use: $\Gamma(\Lambda_c \to \Lambda \ell \nu)/\Gamma(\Lambda_c \to pK\pi)$

- Assume $\Gamma(\Lambda_c \to X_s \ell \nu) \simeq \Gamma(D^0 \to X_s \ell \nu)$

  and $\Gamma(\Lambda_c \to \Lambda \ell \nu) \simeq \Gamma(\Lambda_c \to X_s \ell \nu)$

These approximations have sizable errors, taken as 30% by PDG:

$$\mathcal{B}(\Lambda_c \to pK\pi) = (7.7 \pm 1.5 \pm 2.3)\%$$

We will use $c\bar{c}$ charm-tagging here.

CLNS 00/1664, CLEO 00-3 (hep-ex/0004001) submitted to PRD

$\mathcal{B}(\Lambda_c \to pK\pi)$

Technique:

Usually have (corrections will be made)

- Λ_c and an $\bar{N}$ in one hemisphere,
- $\bar{c}$ hadronizing in other hemisphere.

(NOTE: We'll use a | to separate final state into hemispheres)

Example: $e^+e^- \to (c|\bar{c}) \to (\Lambda_c\bar{p}|\bar{D})$

Measure BR as:

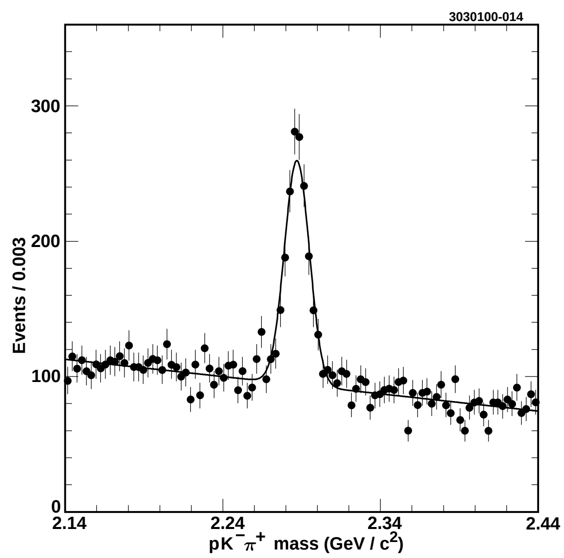
$\mathcal{B}(\Lambda_c \to pK\pi) = (\bar{p}\Lambda_c(\to pK\pi)|\bar{D})/(\bar{p}|\bar{D})$

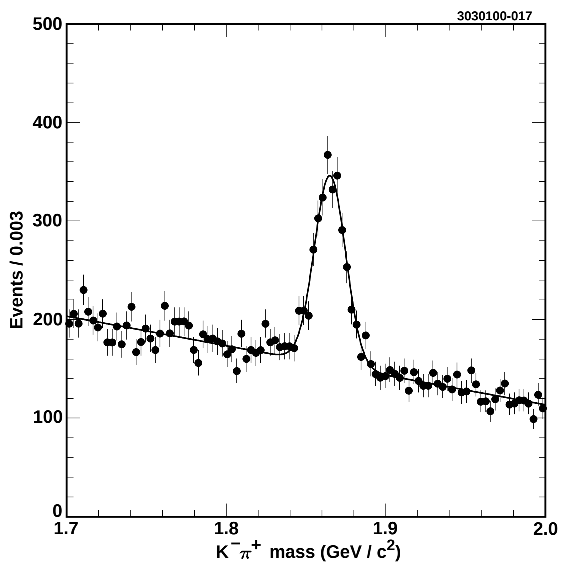
Three types of $\bar{c}$ tags used:

- One of: $\bar{D}^0 \to K^+\pi^-$, $D^- \to K^+\pi^-\pi^-$, or $D_s^- \to \phi\pi^-$
- Soft π^- from $D^{*-} \to \bar{D}\pi^-_{soft}$

  Use angular correlation with jet thrust
- e^- from $\bar{D} \to Xe^-\nu_e$

Plots using D^0 tagging





$\mathcal{B}(\Lambda_c \to pK\pi)$

Correct numerator for:

- Events with no $\bar{D}$ tag: $(\bar{p}\Lambda_c|N\bar{\Lambda}_c)$
- Fake protons

Correct denominator for:

- Events with baryons in opposite hemispheres $(\bar{p}D|\bar{D}N)$
- Fake protons

Results:

- $(4.9 \pm 0.5)\%$ from $\bar{D}$ tags
- $(5.2 \pm 1.3)\%$ from π_{soft} tag
- $(5.6 \pm 2.5)\%$ from e^- tag

Combining all three tag methods:

$\mathcal{B}(\Lambda_c \to pK\pi) = (5.0 \pm 0.5 \pm 1.2)\%$

Systematics dominated by:

- Tag proton ID and spectrum (15%)
- Event selection and MC modeling $(12 - 5\%)$
- 13 different errors evaluated

Λ_c Production Correlations

Many analyses are simpler if c and $\bar{c}$ fragment independently

- Preceding $\mathcal{B}(\Lambda_c \to pK\pi)$ analysis
- CLEO analysis of $\Lambda_c \to \Lambda X$

Analysis:

- Measure (Λ_c^+ | Λ_c^-) vs. (Λ_c^+ | $\bar{D}^{(0,-)}$)
- Normalize to number of $\Lambda_c^-, \bar{D}^0, D^-$

Denote norm'd ratio as: $(\Lambda_c^+ \mid \mathrm{TAG})/\mathrm{TAG}$

where $\mathrm{TAG} = \Lambda_c^-, \bar{D}^0, \mathrm{or} D^-$

If fragmentation is independent:

- Expect $(\Lambda_c^+ \mid \Lambda_c^-)$ / Λ_c^- $= (\Lambda_c^+ \mid \bar{D})/\bar{D}$

We will compare the ratio of these ratios to 1.

Can also look at Λ as an indicator of Λ_c:

- Higher statistics, but perhaps additional systematics...

Another way of phrasing independent fragmentation:

- baryon # conservation occurs in Λ_c hemisphere

Some correlation should not be too surprising.

Λ_c Production Correlations

Results:

Correlations are indicated by a deviation from 1

NOTE: MC has NO correlations

	Data	Data	Monte Carlo	Monte Carlo
	$pK\pi$	$p\bar{K}^0_S$	$pK\pi$	$p\bar{K}^0_S$
$\frac{(\Lambda_c^+\|\Lambda_c^-)/\Lambda_c^-}{(\Lambda_c^+\|\bar{D}^0)/\bar{D}^0}$	3.11 ± 0.91	3.40 ± 1.10	0.85 ± 0.85	1.40 ± 0.99
$\frac{(\Lambda_c^+\|\Lambda_c^-)/\Lambda_c^-}{(\Lambda_c^+\|D^-)/D^-}$	2.71 ± 0.87	2.93 ± 1.08	0.62 ± 0.63	1.61 ± 1.22
$\frac{(\Lambda\|\Lambda_c^-)/\Lambda}{(\Lambda\|\bar{D}^0)/\bar{D}^0}$	3.58 ± 0.23	2.97 ± 0.34	1.55 ± 0.18	1.08 ± 0.27
$\frac{(\Lambda\|\Lambda_c^-)/\Lambda}{(\Lambda\|D^-)/D^-}$	3.17 ± 0.24	2.63 ± 0.32	1.26 ± 0.15	0.88 ± 0.22

Clear and consistent evidence for production correlations!

Perhaps not earth-shaking, BUT:

Monte Carlos generally assume independence!!!

Should be easy to confirm and quantify with large new datasets from CLEOIII, BaBar, and Belle...

Conclusion

CLEO has a long history of charm baryon physics:

- Discovered more states than all others combined!
  (see spectroscopy session for more new ones...)
- Many investigations of decay modes,
  production in B decays, etc.

Today, several new contributions to Λ_c physics:

New, precise (and lower) Λ_c lifetime
New method and result for $\mathcal{B}(\Lambda_c \to pK\pi)$
Evidence for correlations in charm fragmentation