Observation of Doubly charmed baryons (Selex-E781)

M. Iori

University of Rome "La Sapienza" and INFN

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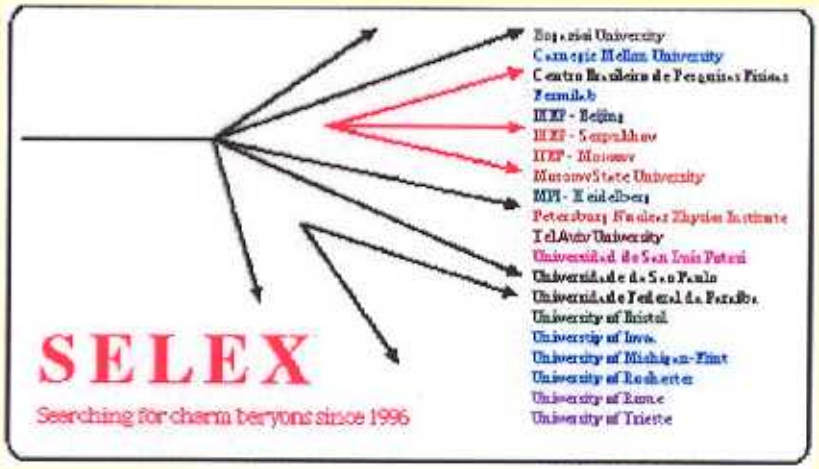

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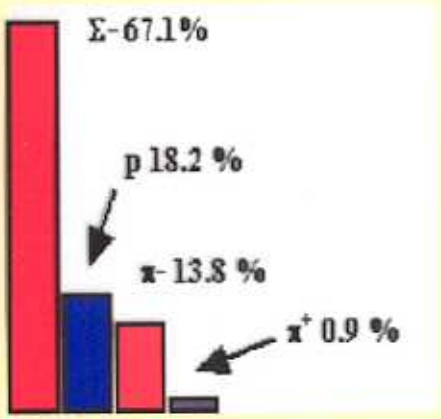
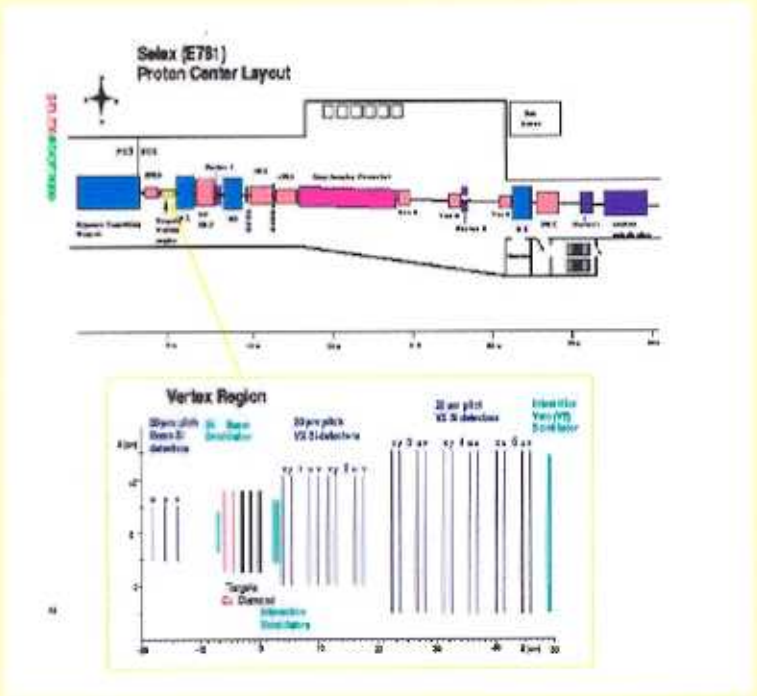
The SELEX spectrometer

- **Segmented target (2Cu and 3 C)**
- **High precision vertex detector σ_{prim}=270μm , σ_{sec}=550μm**
- **Particle identification: 2σ, K/π separation up to 165 GeV/c**
- **Typical Lorenz Boost ~100**
- **15 billion interactions taken with 600 GeV/c Σ^-/π^- beam and 550 GeV/c p**



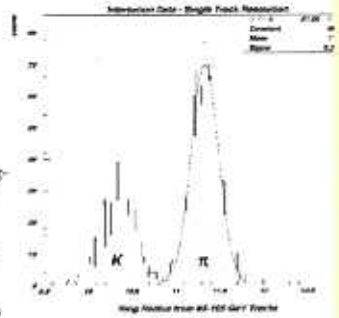


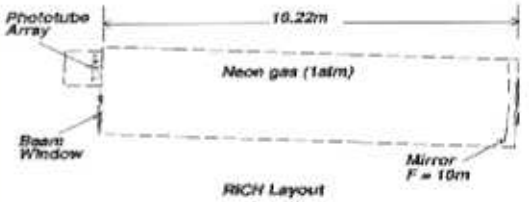
RICH Detector

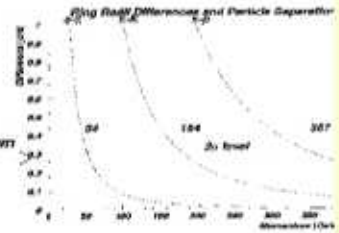
The SELEX Phototube RICH Detector

(First results published in FERMILAB-Conf-97/210-E)

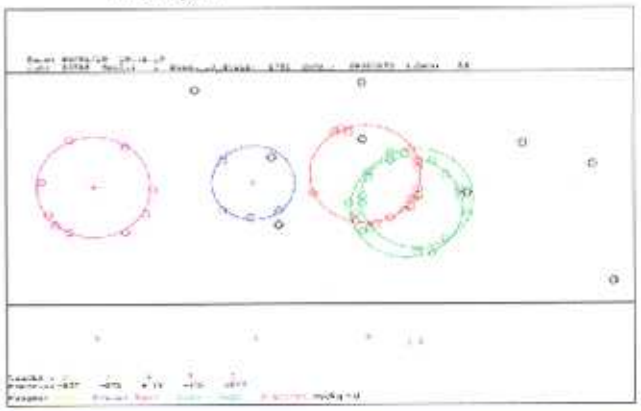
- **Radiator** - 10m long with Neon gas at atmospheric pressure
- **Mirror** - spherical with focal length F=890cm built up of 16 hexagonally shaped spherical mirrors, covering a total area of 2.4m × 1.2m.The mirror reflectivity is > 85 % at 160 nm.
- **Photocathode** - matrix of 80x32 phototubes (15mm diameter)
- **Performance** - in a 600 GeV/c π^- beam the number of photons detected per ring is 14, giving a figure of merit N_0 of 104 cm^{-1}. The ring radius resolution obtained is 1.2 %, which provides 2σ π-K separation up to 180 GeV/c and π-p separation up to 360 GeV/c.



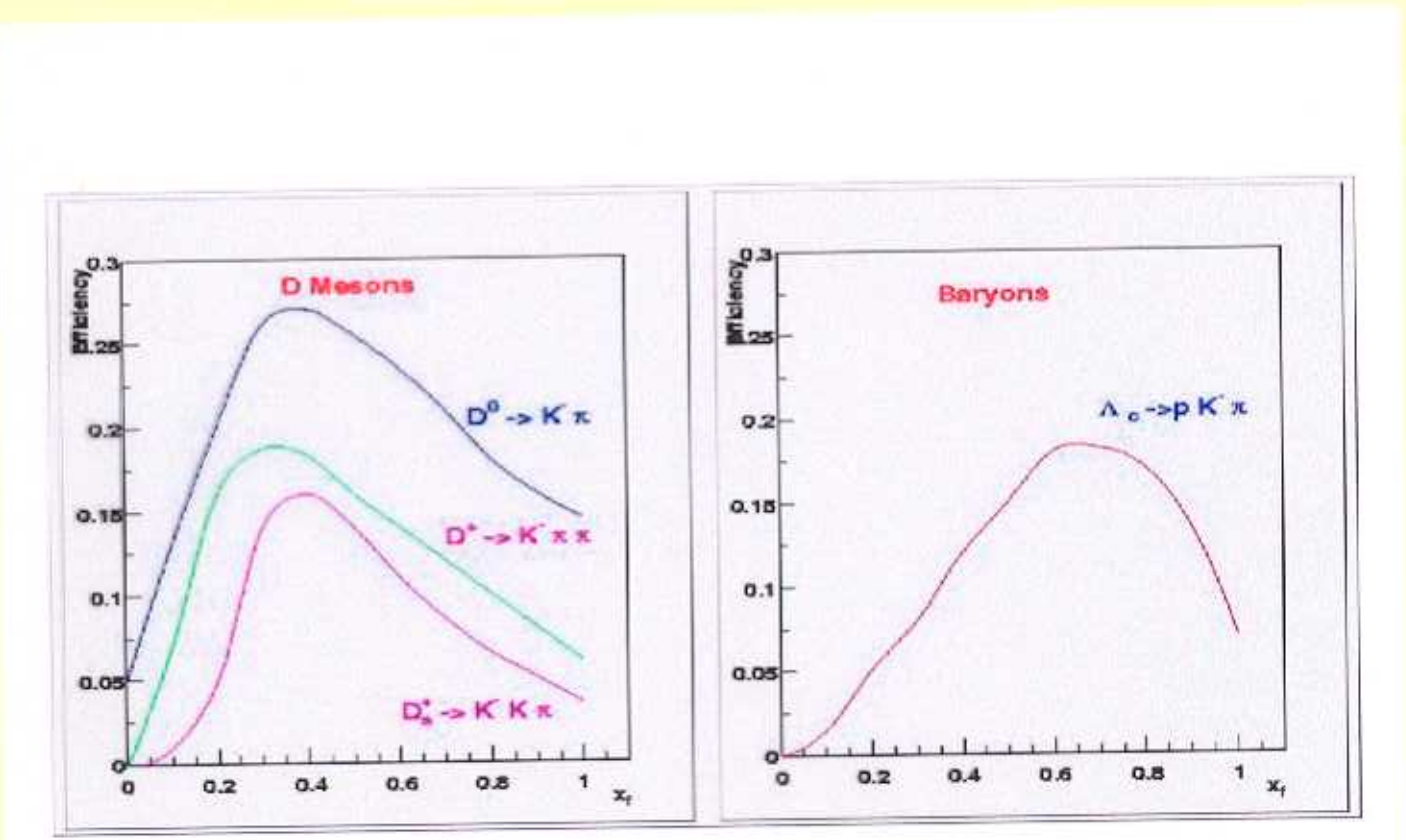




RICH Layout



- The spectrometer acceptance remains high at large x_F. The efficiencies for charge coniugate modes differ by less than 2%



Production and decay of doubly charmed baryons

PRODUCTION

- The valence quarks are relevant for the x_F production as measured in D mesons and Λ_c production
- In particular the Σ^- beam can be relevant to produce charmed baryons
- Some guesses for doubly charmed baryons production cross-section via charm excitation in proton (Gunter,Salev hep-ph/0104173) predicts

  $\sigma_{cc}/\sigma_{charm}=10^{-3}\text{-}10^{-4}$ at Tevatron, 10^{-5} at fixed target

Production and decay of doubly charmed baryons cont'd

MASS

- Many model predictions give 3.5-3.8 GeV range based on

  Lattice QCD (R. Lewis et al.), relativistic quark model (D. Ebert et al.)

  potential model (Likhoded et al.) ⇒ next slide

DECAY

- Lifetime prediction order of 100 fs (as function of the baryon wave function, $|\psi(0)|^2$, probability two quarks are at the same place)

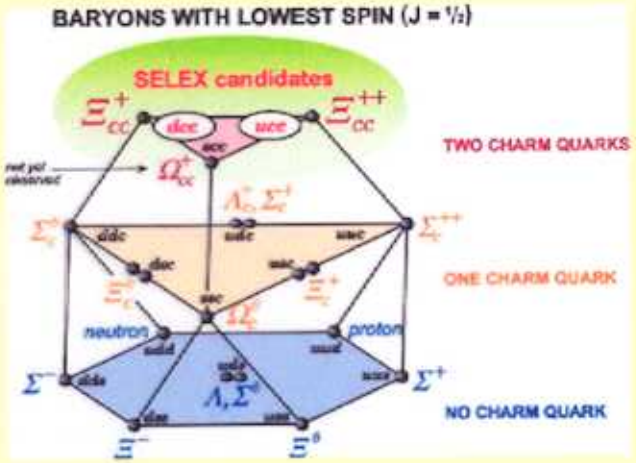
Estimates masses of Baryons C=2

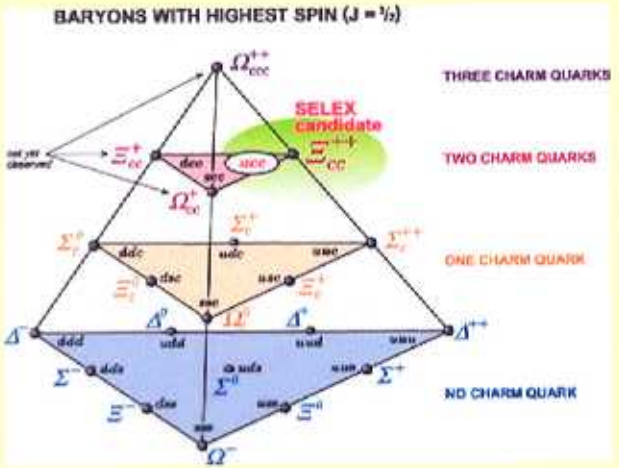
	J=3/2	J=1/2
Ω_{ccc}(ccc)	4925±90 MeV/c^2	
Ω_{cc}(ccs)	3840±60 ,3730	3594
Ξ_{cc}(ccu,d)	3695±60, 3727	3562 ±47, 3635, 3620, 3478
	3625 ±20, 3610	

References:

- N. Mathur,R Lewis, R M. Woloshyn hep-ph/0203253 (Lattice NRQCD)
- V. Kiselev, A.K. Likhoded hep-ph/0206140 (potential model)
- J. FD. Biorken Conf-85/69
- D. Erbert, R. Faistov,O. Galkin,A. Martynenko hep-ph/0201217 (relativistic quark model)

SOME NOMENCLTURE





- $\Xi^{++}_{cc}(J=1/2) = ccu$
  $\rightarrow \Lambda^{+}_{c} K^{-} \pi^{+} \pi^{+}$
- $\Xi^{+}_{cc}(J=1/2) = ccd$
  $\rightarrow \Lambda^{+}_{c} K^{-} \pi^{+}$

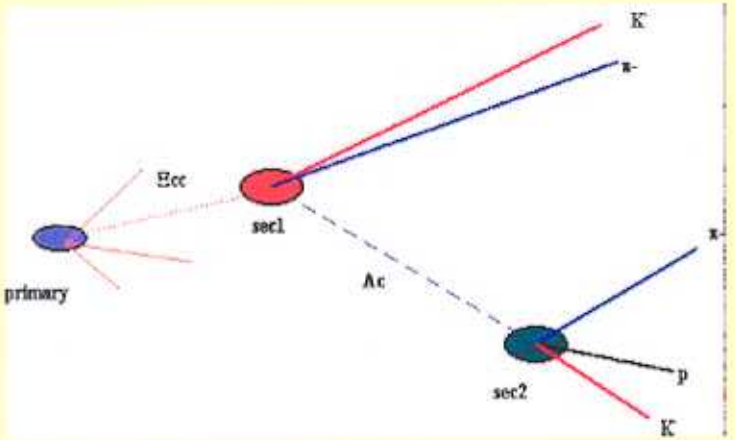
$\Xi^{++}_{cc}(J=3/2) = ccu^{*}$
$\rightarrow \Lambda^{+}_{c} K^{-} \pi^{+} \pi^{+}$

Search strategy

- cc(u,d) → c quark, s quark and a Baryon
- Selex's strength is charged tracks

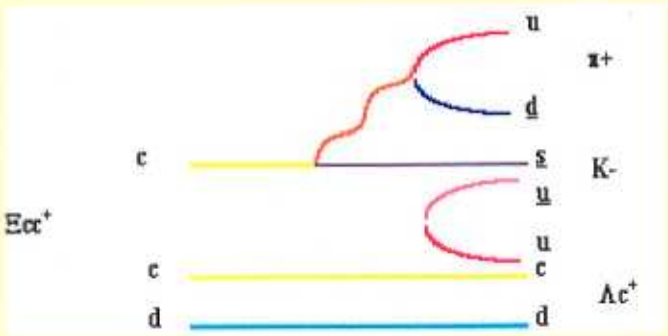
$\Xi^{+}_{cc} \rightarrow \Lambda^{+}_{c} K^{-} \pi^{+}$

$\Xi^{++}_{cc} \rightarrow \Lambda^{+}_{c} K^{-} \pi^{+} \pi^{+}$ from 1630 Λ^{+}_{c}



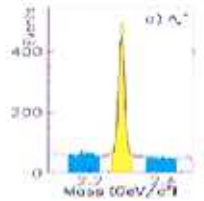
CUTS:

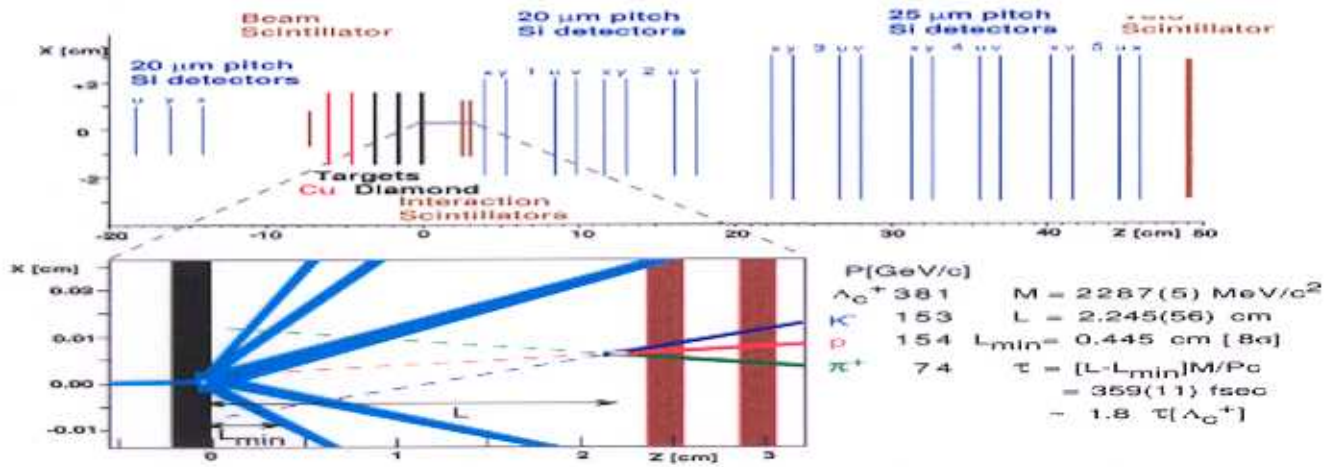
- Primary vertex contains beam track ~4μm
- Secondary vertex outside the material
- Secondary vertex separation significance $L/\sigma > 8$
- 2 largest missing distance significance $> 2\sigma$
- Λ^{+}_{c} points to primary
- RICH identified p and K in Λ^{+}_{c}



Λ^+_c event

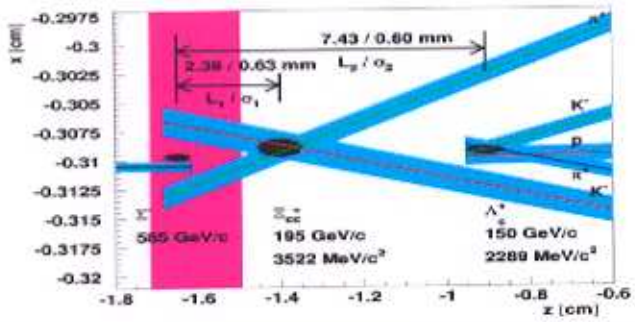
1630 Λ_c^+↘





New secondary vertex

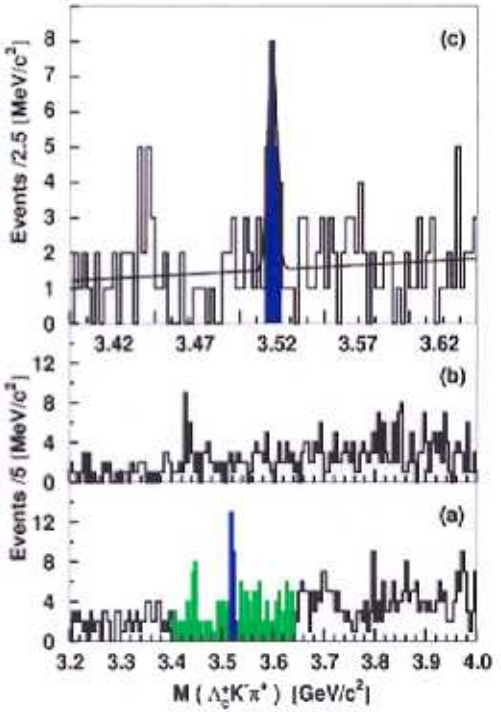
- New secondary vertex significance
  $L/\sigma > 1$
- Point back ccd^+ to primary
  $\chi^2 < 4$
- No RICH PID on K,π $< 15\%$
  in the RICH



Ξ_{cc}^{+} search $K^{-}\pi^{+}\Lambda_c^{+}$ mass plot

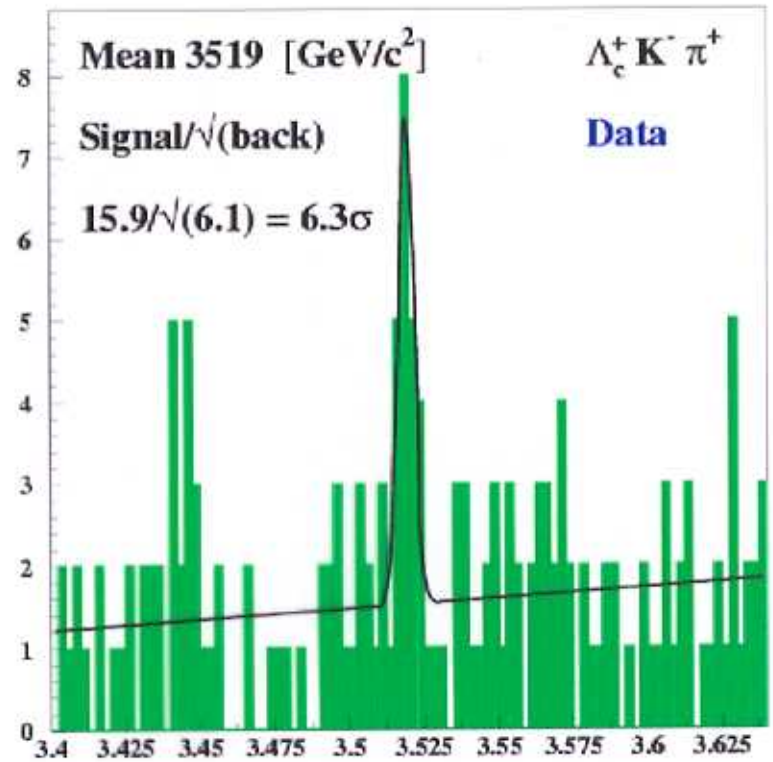
- Use a baryon to find a baryon: require a Λ_c^{+} daughter

- ❑ Look for extra vertex between primary and Λ_c^{+}
- ❑ If it's double ,ccq decay makes a K^{-}
- Wrong-sign channel (b) has no significant structure (note the feature around 3.45 shows in wrong too!)
- ❑ Right-sign (a) channel has a peak at 3519 MeV/c^2 ⇒



Is this a Ξ_{cc}^{+} signal?

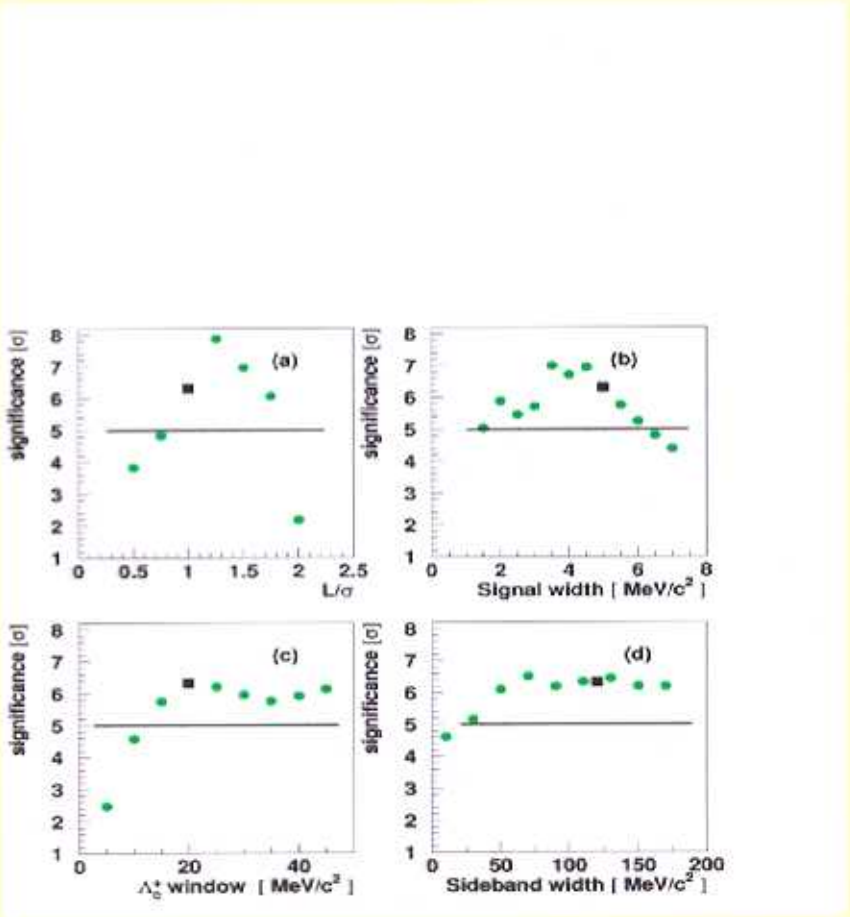
- Single-bin significance 6.3 σ
- Single-bin Poisson probability 10^{-6}
- Fluctuation probability anywhere $<1.1\ 10^{-4}$
- Width 3±1 MeV/c^2, consistent with simulation



Stability of signal significance vs cuts

- ccd^+ vertex significance L/σ
- ccd^+ signal width
- Λ^+_c mass window
- ccd^+ mass width sideband

- The black points are the values used in this analysis



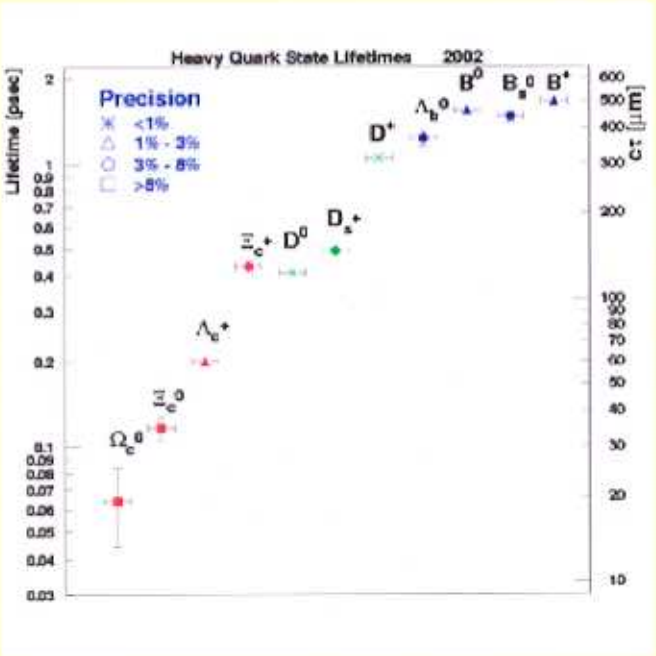
What's about Ξ_{cc}^{+} lifetime

- No other mechanism than spectator mechanism
- $c + d \rightarrow s + u$

  than the lifetime should be of order of Ξ_c^{0}(cds) (100 fs)
- Guberina et al. predict:

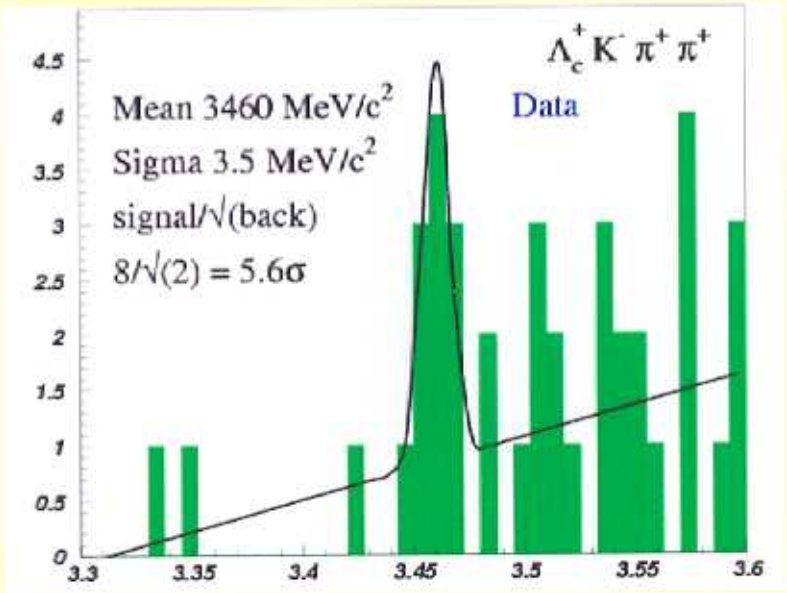
  $\tau(\Xi_{cc}^{+}) \sim \tau(\Omega_{cc}^{+}) << \tau(\Xi_{cc}^{++})$
- From the data

  the upper limit 90% C.L. is 33 fs



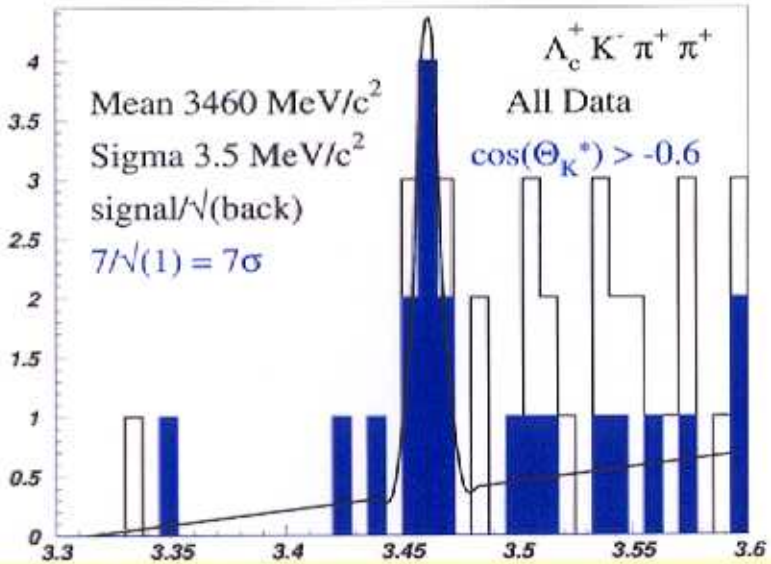
There is a narrow ccu++partner to the ccd+ candidate?

- The ccd(3520) should have an iso-doublet partner.
- Look in the ccu mass plot with finer bin size (5 MeV/c^2)
- Narrow 4.8 σ significant excess at 3460 MeV/c^2
- Width is 6.0 MeV/c^2
- Simulated acceptance ratio [ccu++(3460)]/[ccd+(3520)]=0.5



Is the 3460 bump a Ξ_{cc}^{++} ?

- Cut soft pion fakes at backward angles (D's)
- right-sign $\cos\theta^*_K$>-.6
  peak at 3460 MeV/c^2 (BLUE)
  Optimized on $S_{MC}/Bcktot^{1/2}$
- Poisson probability $<10^{-5}$
  anywhere in the plot



Level diagram for doubly charmed baryon

$\Xi_{cc}^{++}(3783)$ ccu (J=3/2) $\Xi_{cc}^{+}(????)$ ccd (J=3/2)

$\searrow \pi^+$

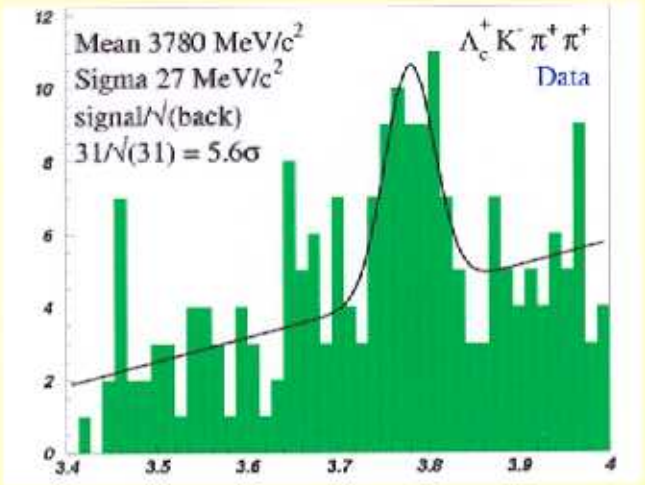
✓ $\Xi_{cc}^{+}(3519)$ ccd (J=1/2)$\Rightarrow \Lambda_c^+ K^- \pi^+$

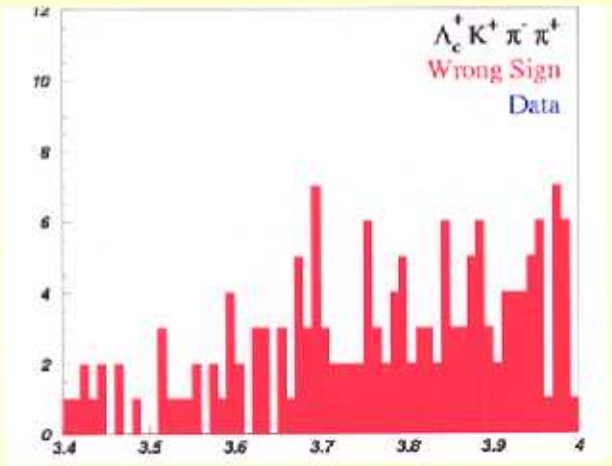
✓ $\Xi_{cc}^{++}(3460)$ ccu (J=1/2)$\Rightarrow \Lambda_c^+ K^- \pi^+ \pi^-$

Preliminary results Ξ^{++}ccu search

- Broad structure at 3.78 GeV/c^2
- No significant structures in wrong sign mass combination (RED)

⇒Right sign ccu^{++} candidate is NOT a random combination of primary vertex tracks

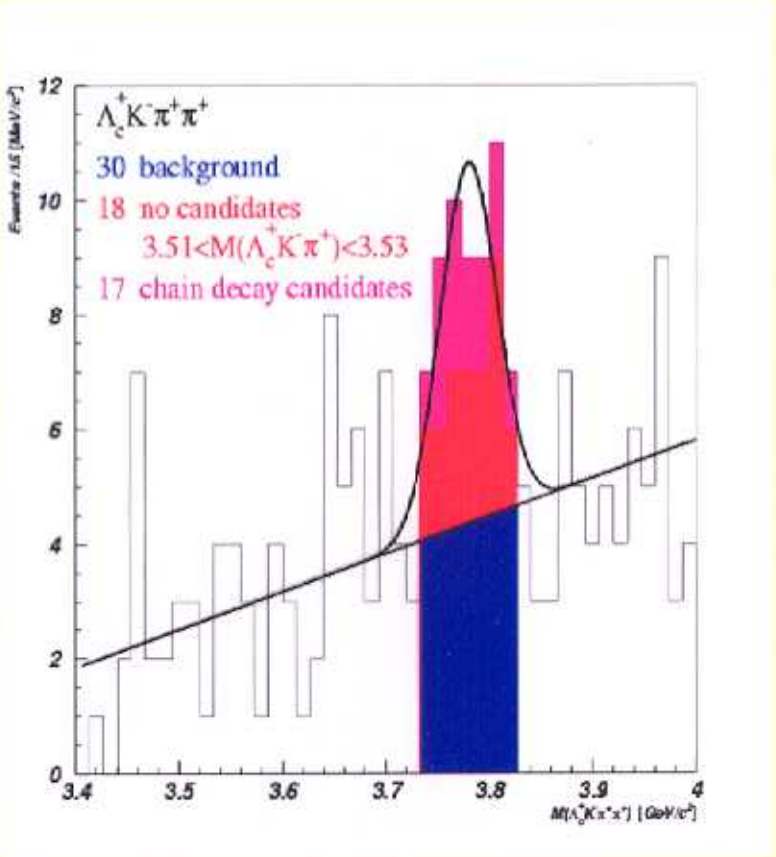




Are the ccu^{*++} and ccd^{+} related?

- The blue region is the background on the ccu* plot
- Half of the the decays are candidates for $ccu^{*++} \rightarrow ccd^{+}\,\pi^{+}$
- The other half have no such candidates →Two decay modes?
- Background structure is complicated:

the structure at 3660 MeV/c^2 is from combinatorial bck, simulation reproduces this effect



What about production?

	Σ^-	π^-	p	π^+	diamond	copper
Luminosity fraction	0.67	0.13	0.18	0.01	0.68	0.32
$\Xi_{cc}^+(3519)$ signal	18	0	4	0	18	4
$\Xi_{cc}^+(3519)$ sideband	110	7	21	2	93	47
$\Xi_{cc}^{++}(3780)$ signal	43	12	1	0		
$\Xi_{cc}^{++}(3780)$ sideband	30	10	3	0		

- Dominantly produced by baryon beam
- $\langle x_F \rangle = 0.35$ (200 GeV/c^2)
- Belle observes $\sigma(e^+ e^- \rightarrow \Psi ccX)/\sigma(e^+ e^- \rightarrow \Psi X) = 0.60$ (hep-ecx-0205104)

Summary

- SELEX reports 3 candidates for doubly charmed baryons

statistically strong with $\cos\vartheta^*_{K^-}$ cut →

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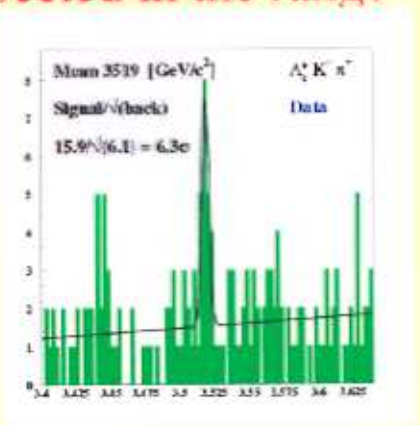
OK

expected in the range



statistically marginal but chain decays to $\Xi_c^+(3519)$, wide, strong decay ↓