The NA49 Ξ_5 pentaquark search/update

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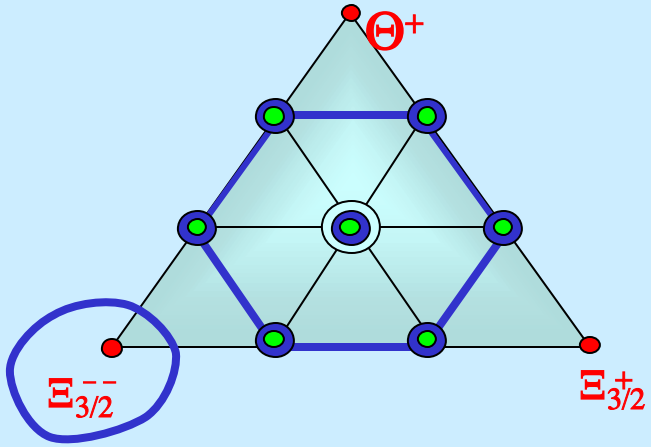

Outline

- NA49 published experimental results, with:
  - additional systematics/checks/rechecks with original analysis
  - additional channels with original analysis
- Ξ_5 world status
  - still alone…
- Current efforts/reanalysis/new results
  - Ξ_5 still there…
- Plans (besides waiting to be confirmed…)

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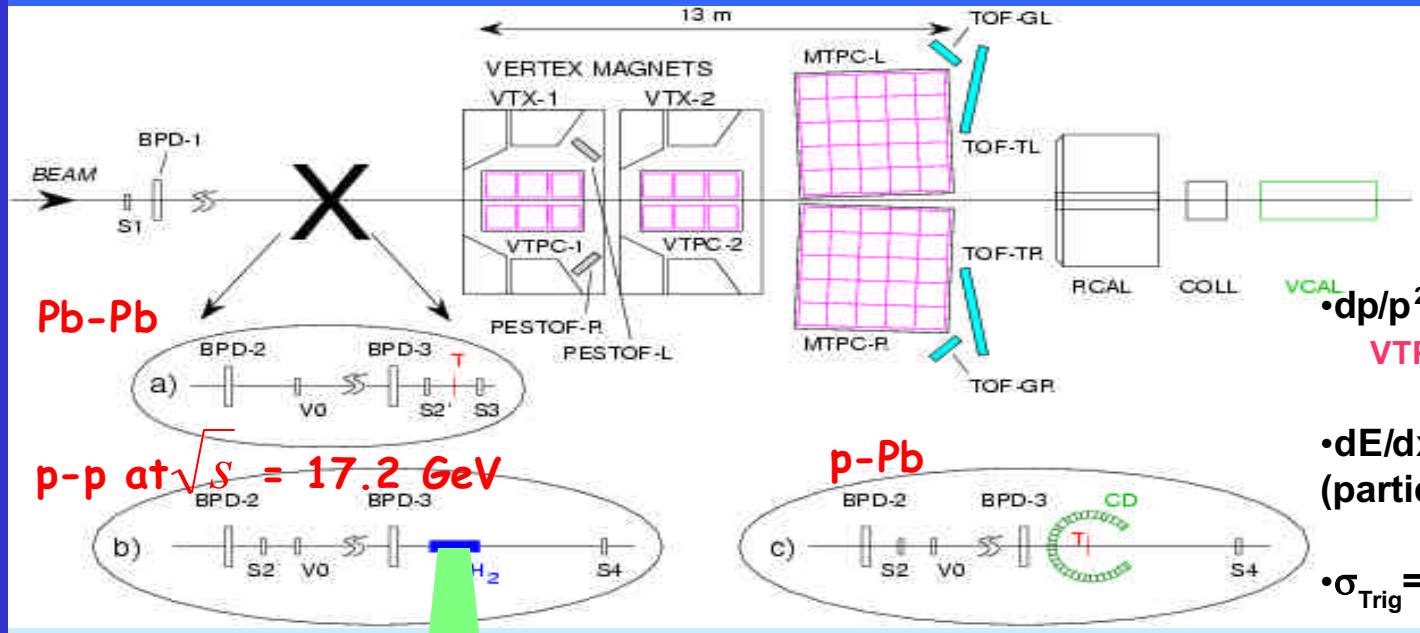
NA49 Experiment at CERN



- dp/p^2 = 7 x (0.3) 10^{-4} (GeV/c)$^{-1}$
  VTPC-1 (VTPC-2+MTPC)
- dE/dx resolution: 3-6 % (particle identification)
- σ_{Trig} = 28.1 mb

Reconstructed main vertex has to be within target:

- Fit converged
- $x^2+y^2 < 1$ cm^2
- -590.5 cm < z < -572.5 cm

	Before vertex cut	After Vertex Cut
1999	1.2 M	0.66 M
2000	2.7 M	1.5 M
2002	2.9 M	1.6 M
Total	**6.8 M**	**3.76 M**

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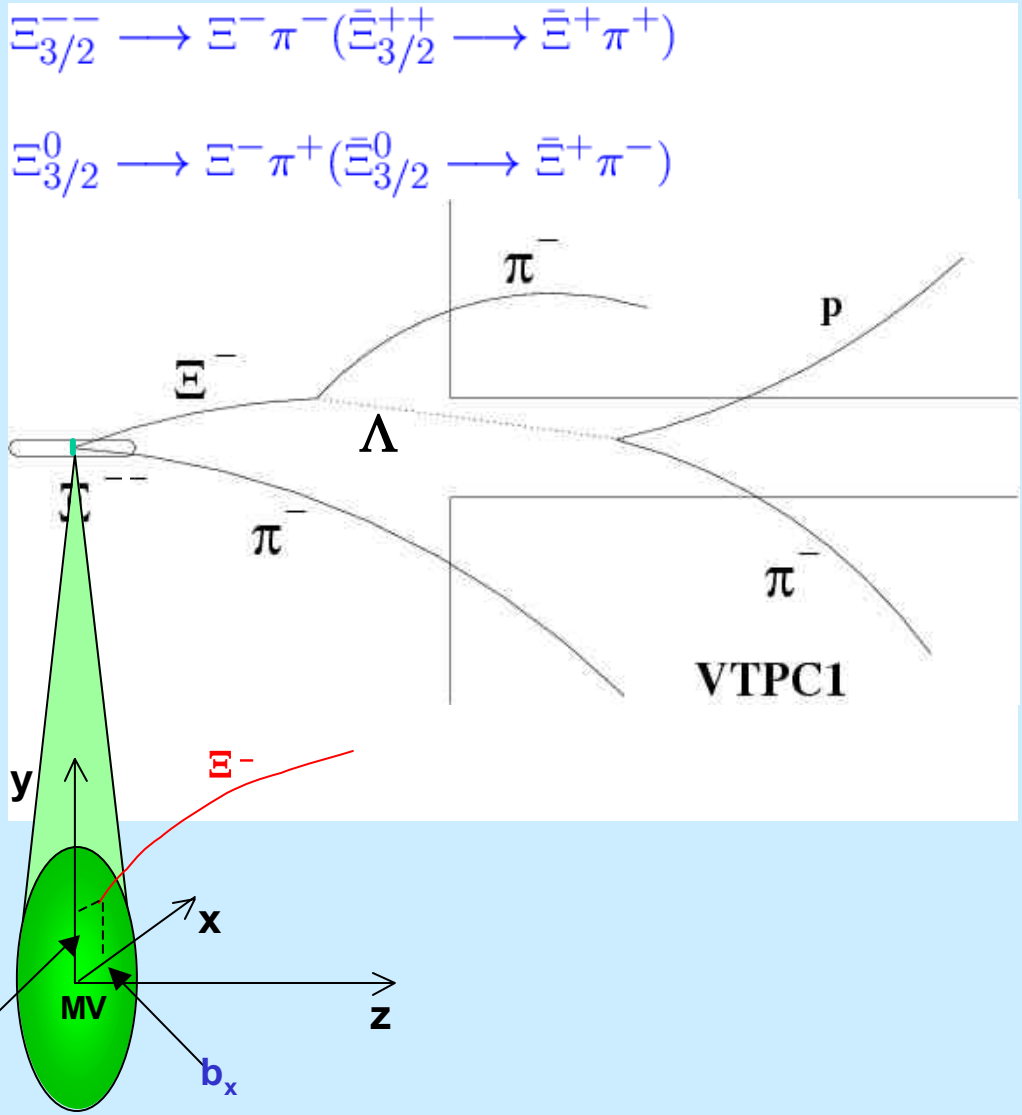
Ξ_5 search: Ξ^- selection



- Distance to Bethe- Bloch curve of all daughter tracks:
  $|d_{bb}| < 3\,\sigma$
- $|M(p\pi^-) - M(\Lambda)| < 0.015$ GeV
- $Z_{\Xi} - Z_{main\_vtx} > 12$ cm
- Ξ^- position at main vertex (b_x, b_y):
  $|b_x| < 2$ cm
  $|b_y| < 1$ cm
- π (from Ξ^- decay) position at main ver
  $|b_y| > 0.5$ cm

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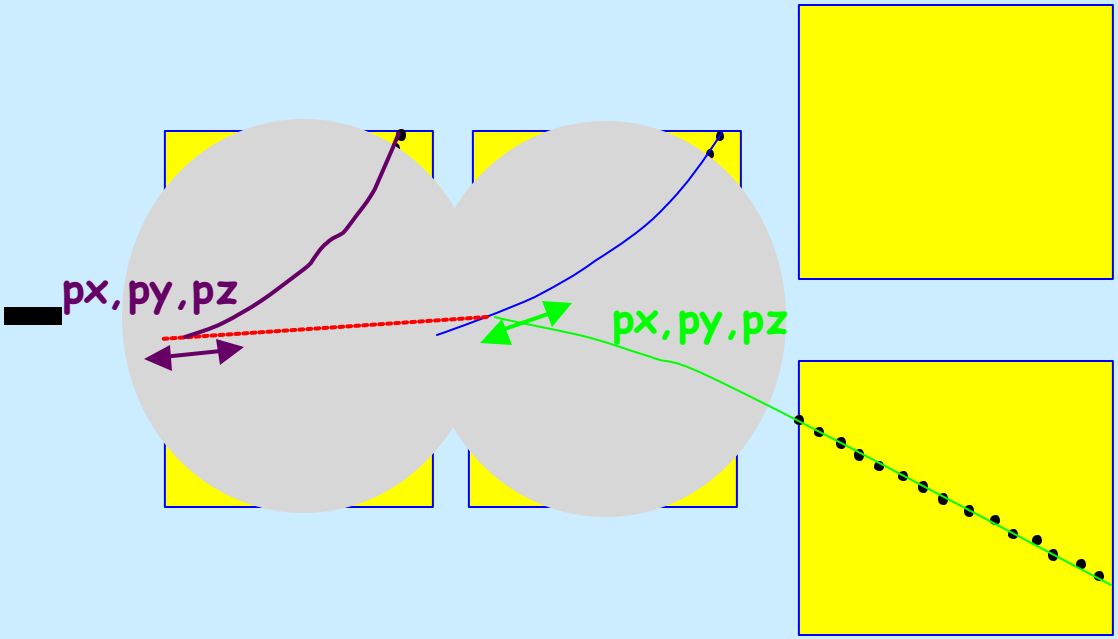
V0/Ξ finder/fitter



V0 finding

- Longest track in mag field is unchanged
- Shorter track in mag field varied (momentum) to be along above track and to minimize χ^2

Ξ finding

- Extrapolate Λ
- use 4 parameter fit (momentum of π from Ξ and z along Λ path)

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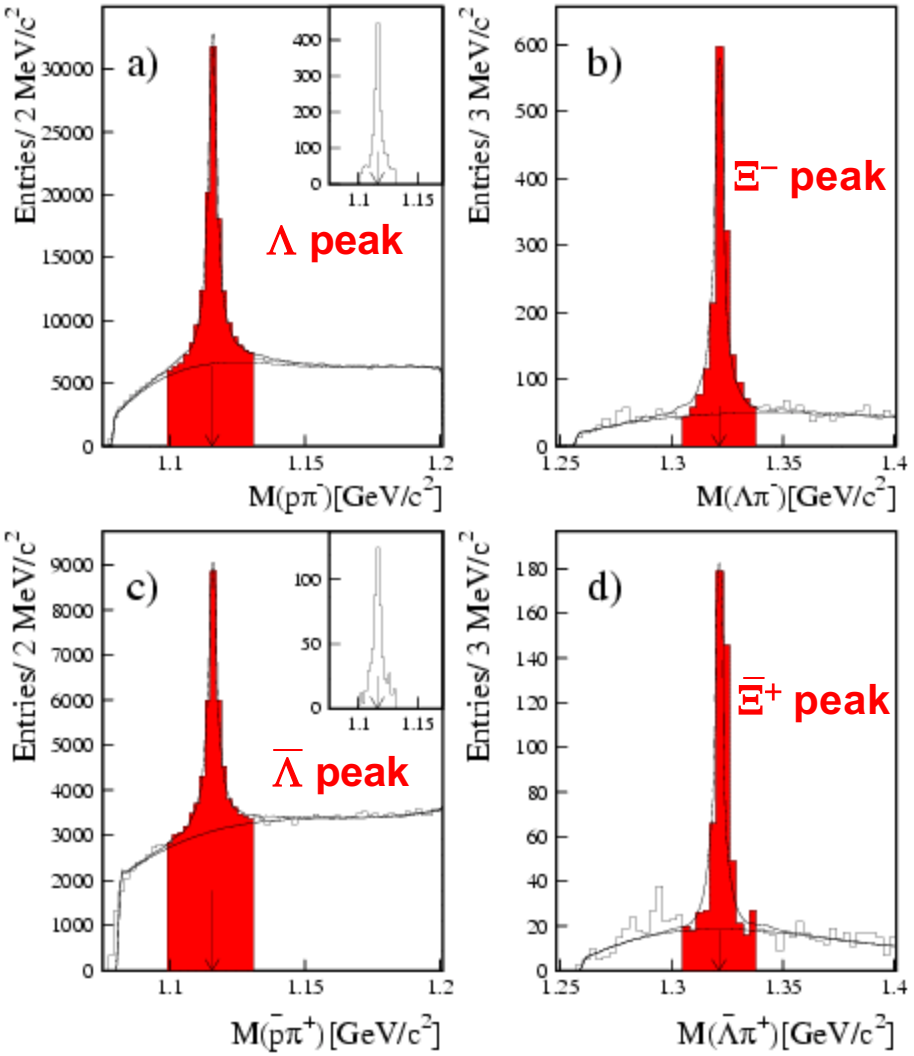
V0 and Ξ Invariant Mass Spectra



1640 events

$|M(\Lambda\pi)-M(\Xi)| < 0.015$ GeV

551 events

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Primary pion selection

Impose additional selection on primary pion (as it is not purified by Ξ and Λ cuts)

$$(\Xi^- \pi,\ \bar{\Xi}^+ \pi)$$

- $|d_{bb}^{\pi}| < 1.5\ \sigma$, d_{bb} .... **distance to Bethe-Bloch curve**
- **position at main vertex (b_x, b_y):**
  $|b_x| < 1.0$ cm
  $|b_y| < 0.5$ cm
- **# of points > 10**

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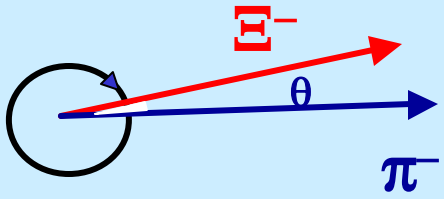
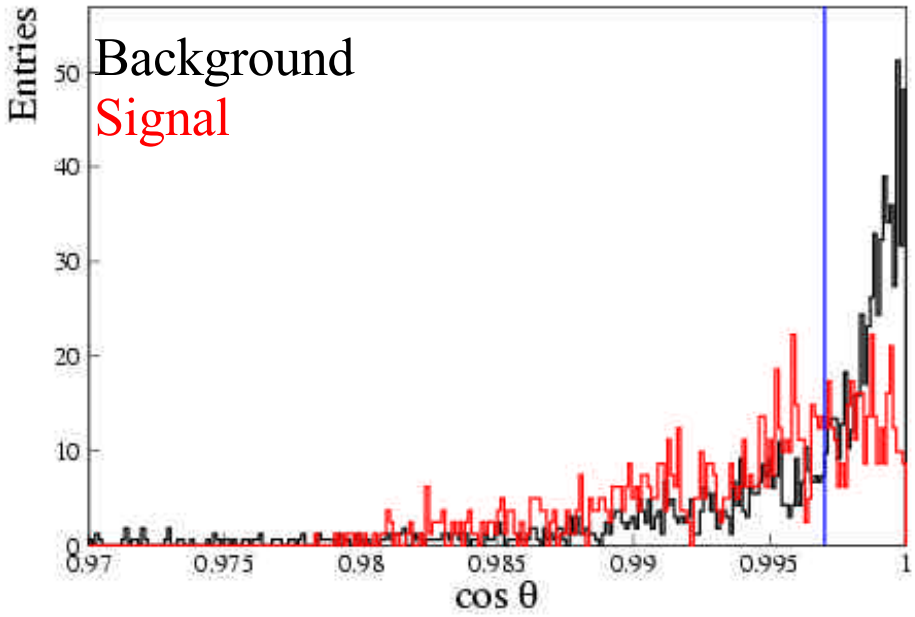
Additional cuts on primary pion (some not obvious)

$\cos(\theta) < 0.997 \quad (\theta > 4.5)$

θ: angle between Ξ i π





	Ξ^-	$\bar{\Xi}^+$
π^-	-1.5 σ < dbb < 1.5σ	-1.5 σ < dbb < 1.5 σ
π^+	-0.5 σ < dbb < 1.5σ p > 3 GeV/c	-1.5 σ < dbb < 1.5 σ p > 3 GeV/c

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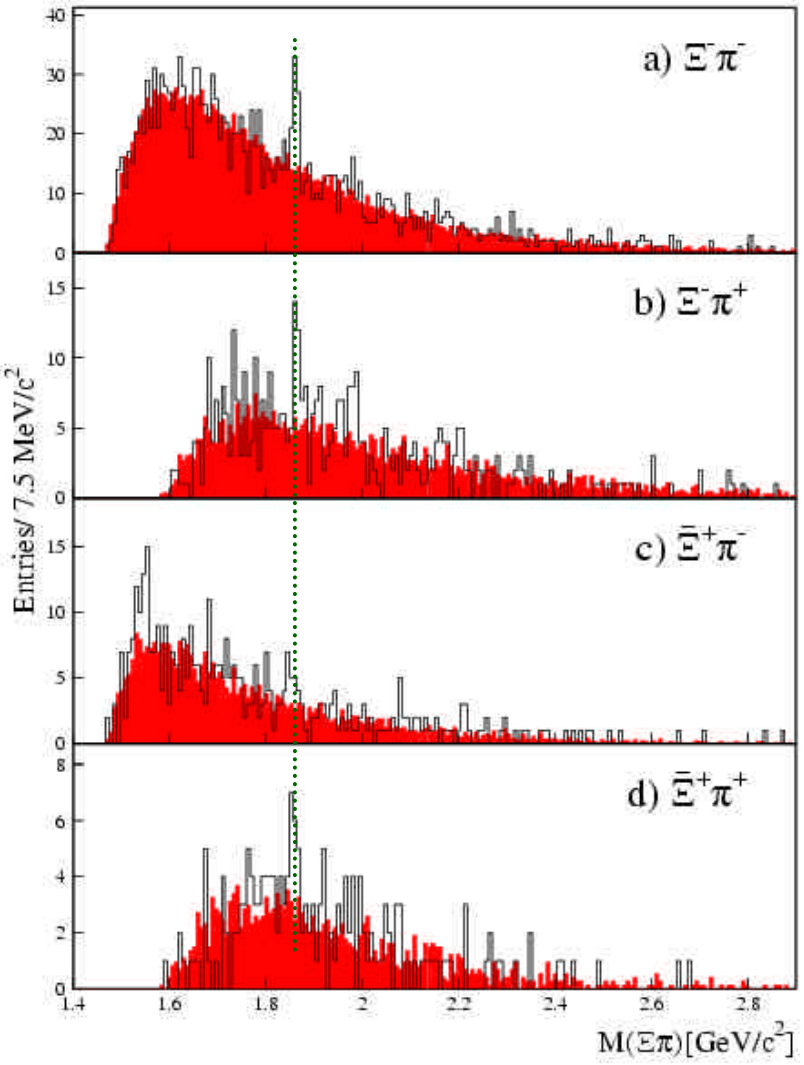
Final Ξπ Invariant Mass



Baryon spectra:
peak at 1.86 GeV

Antibaryon spectra:
enhancement at the same ma

C. Alt et al., Phys. Rev. Lett. 92

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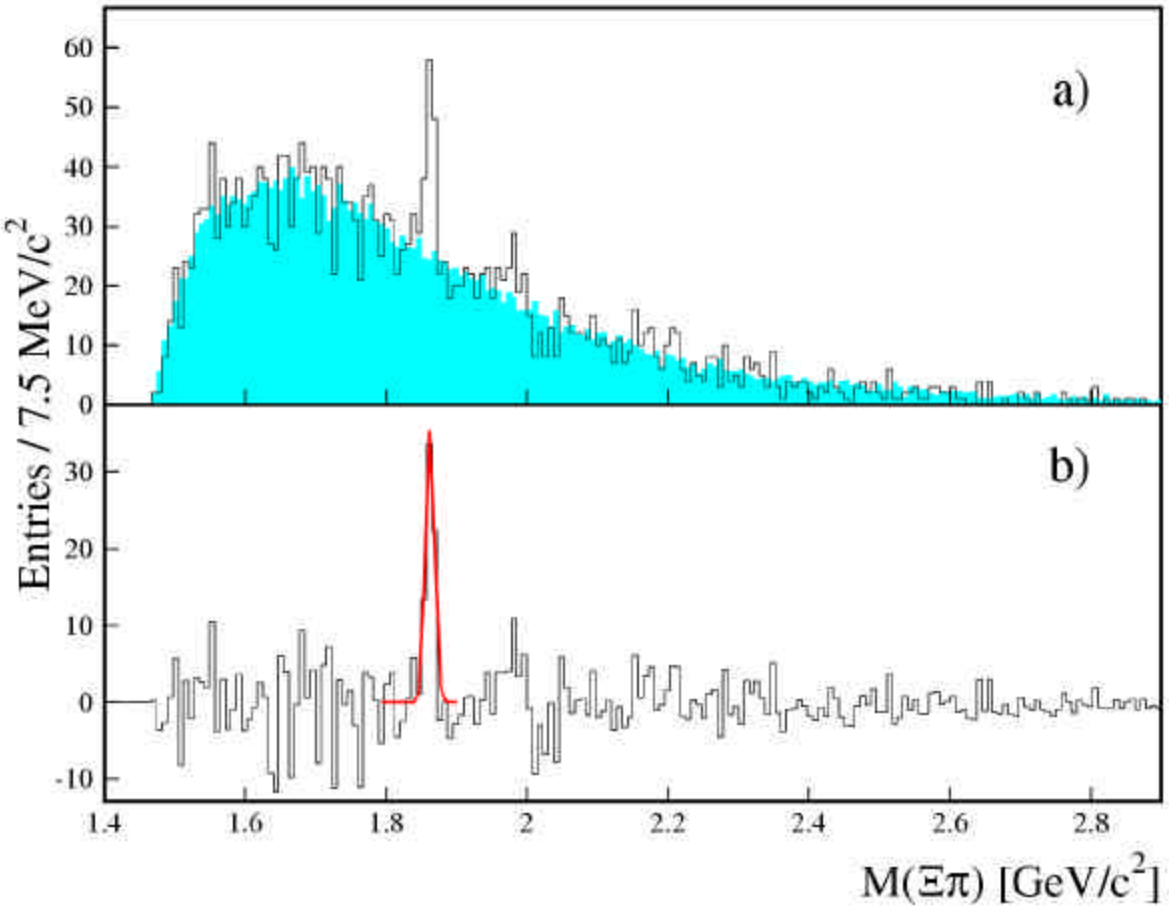
Summed spectra



M = 1.862 ± 0.002 GeV/c^2 Γ= 18 MeV/c^2

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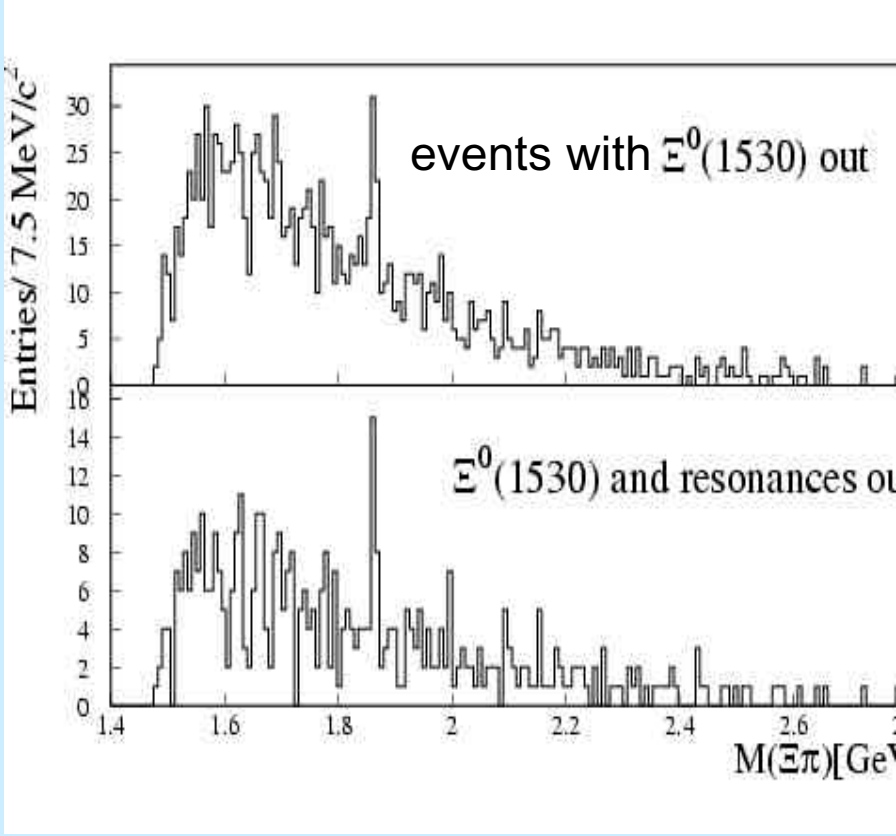
Systematics study I

Remove resonances:

	π^-	K^-	$\bar{p}$
π^+	497.6 ±10 769.0 ±60	892.0 ±30	1115.7 ±10
K^+	892.0 ±30	1019.0 ±10	1520.0 ±15
p	1115.7 ±10	1520.0 ±15	



By changing:

- mass cuts around Ξ and Λ
- dE/dx cut
- number of points cut
- b_x, b_y cuts
- e.t.c.

Peak remains robust

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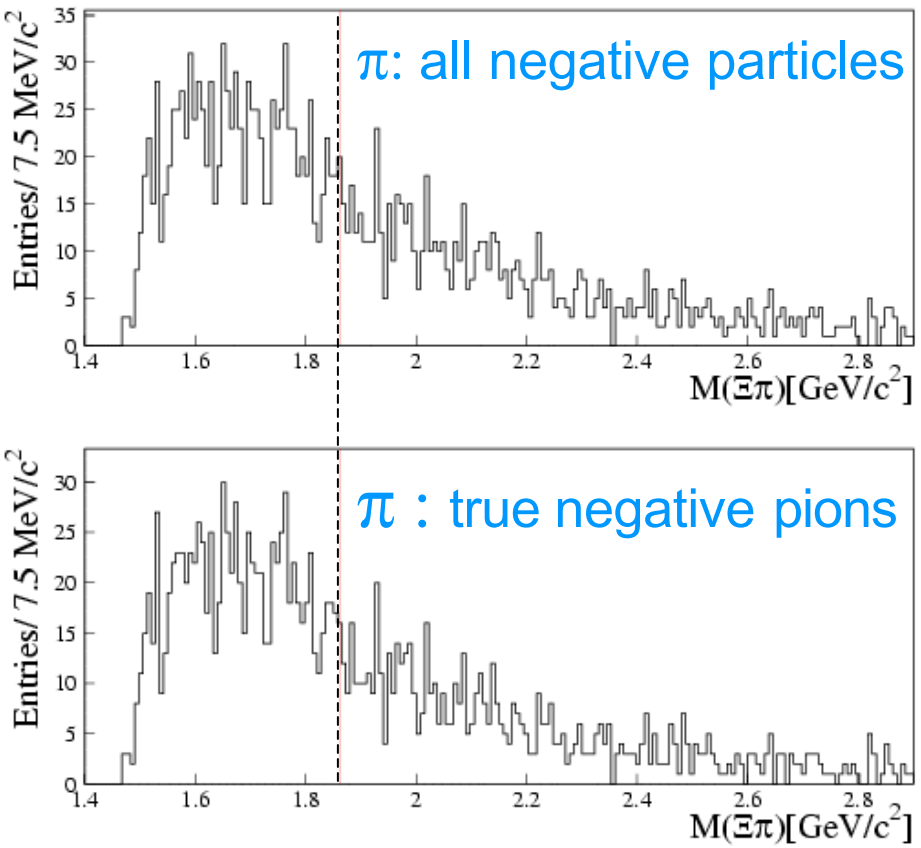
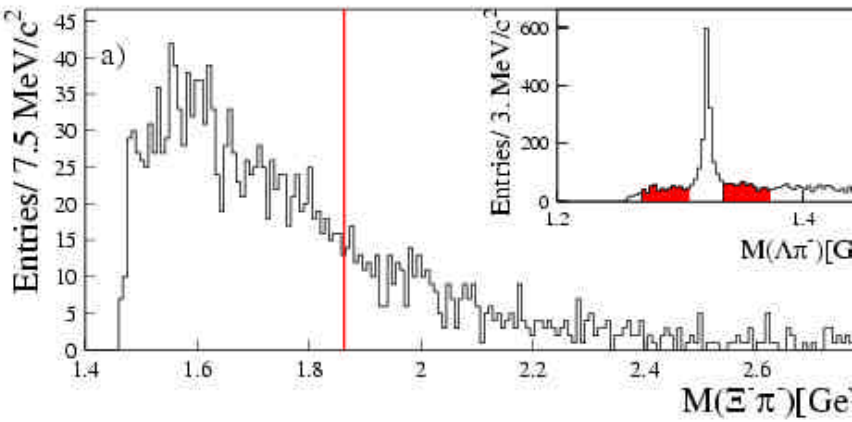
Systematics study II

$\Xi^-\pi$ (VENUS + GEANT + REC.)



DATA (Ξ shoulders)



No structure at 1.86 GeV

No structure at 1.86 G

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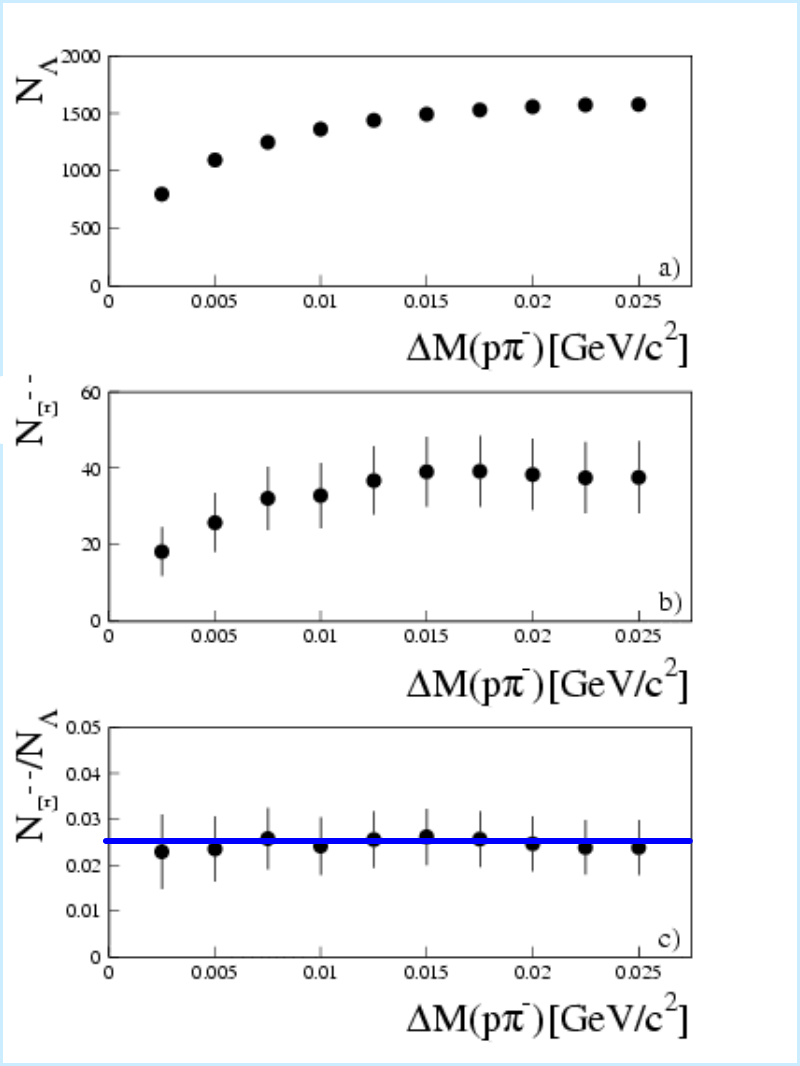
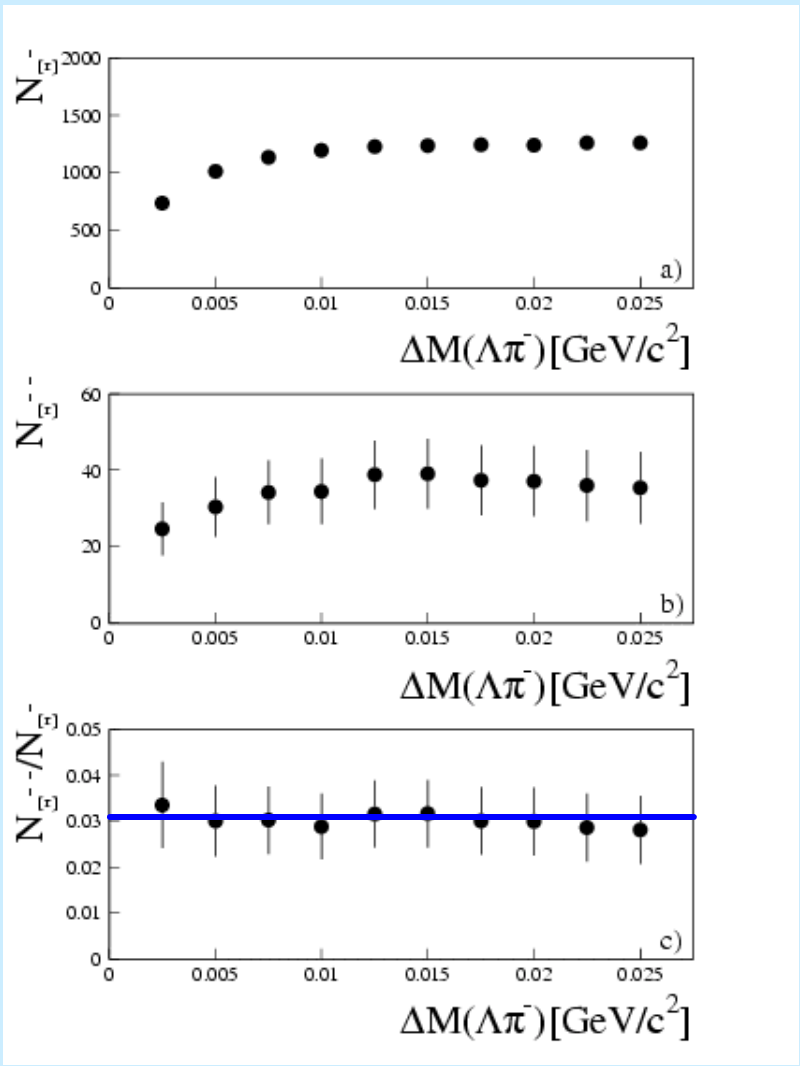
Systematic study III – mass cut

Λ Ξ^-





Very healthy behavior - if something is faking the Ξ^{--}, it is not background of the Λ and Ξ^- spectra

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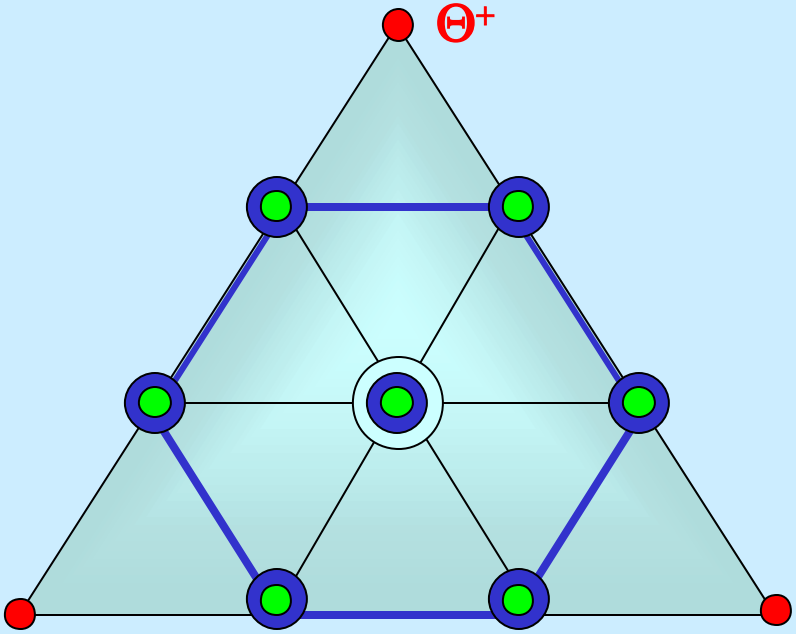
Additional analysis:Check existence of 8_f



Jaffe/Wilczek diquark picture

In SU(3)

$\overline{10} \not\rightarrow 10 \oplus 8$

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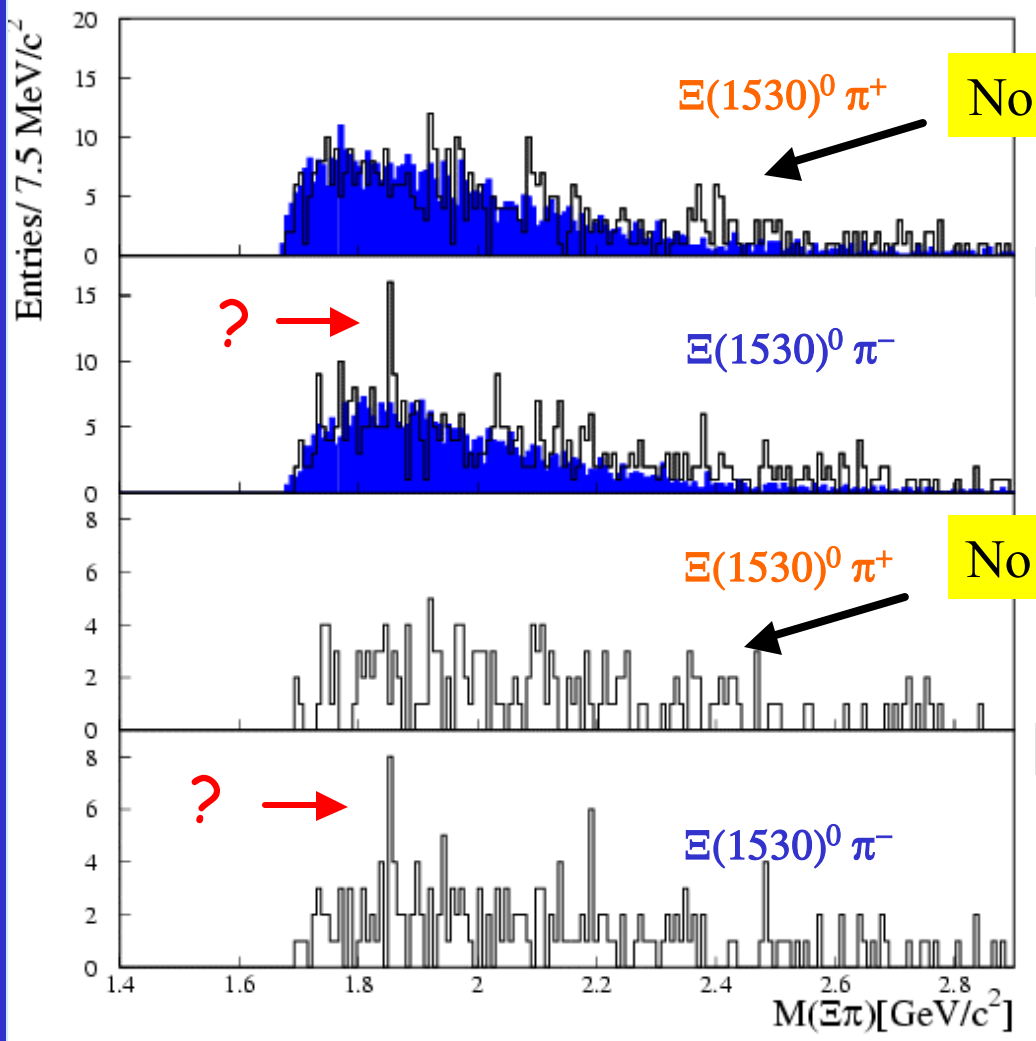
Additional analysis: $\Xi(1530)^0\,\pi$



No evidence for $\Xi^+_{3/2}$ to $\Xi(1530)^0\,\pi^+$ deca

No additional cuts

No evidence for $\Xi^+_{3/2}$ to $\Xi(1530)^0\,\pi^+$ deca

additional cuts to purify π^+:

- $-0.5\,\sigma < d^{\pi}_{bb} < 1.5\,\sigma$
- $p_\pi > 3$ *GeV/c*

Preliminary!

To be honest, our statistics probably too small to be able to tell one way or the other in the best of cases

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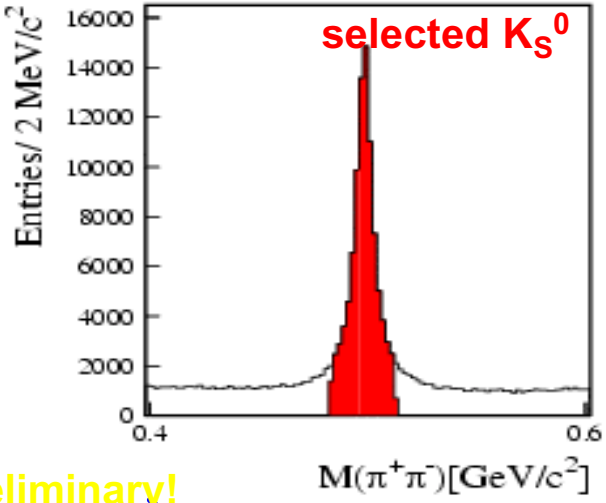
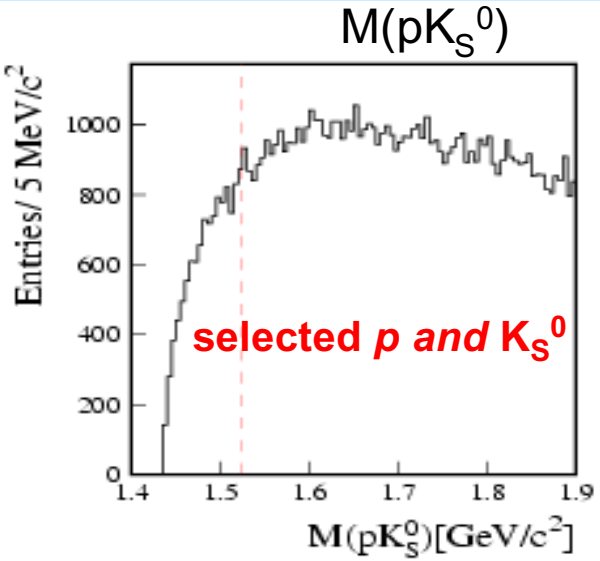
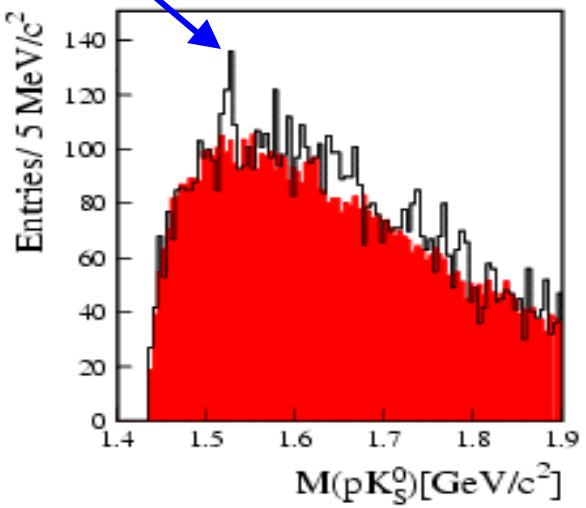
Additional analysis: M(pK_S^0)





Preliminary!



M(pK_S^0)

Additional proton selection

- $0.5\,\sigma < d_{bb} < -3\,\sigma$
- $|b_x| < 1$ cm, $|b_y| < 0.5$ cm
- 5 GeV/c < p_p < 30 GeV
- 0.2 GeV/c < p_T < 0.9 GeV/c

$M_{\Theta+} = 1.526 \pm 0.002$ GeV/c^2, $\Gamma < 15$ MeV/c^2

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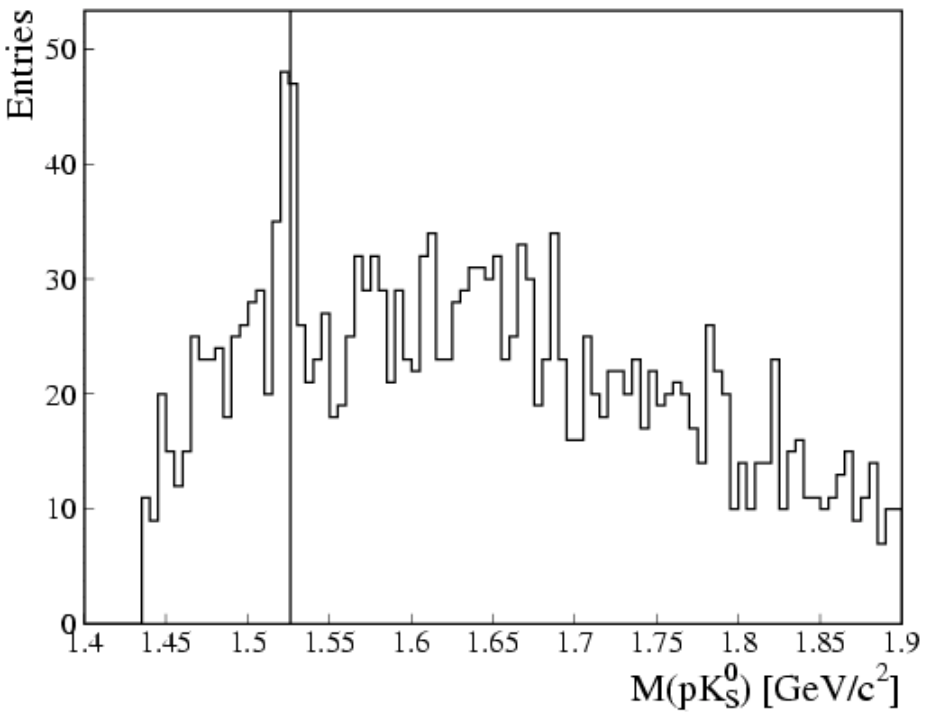
Additional analysis: $M(pK_S^0)$ II



Additional proton selection

- $0.5\,\sigma < d_{bb} < -3\,\sigma$
- $|b_x| < 1$ cm, $|b_y| < 0.5$ cm
- 5 GeV/c < p_p < 30 GeV
- 0.2 GeV/c < p_T < 0.9 GeV/c

+

80 < # of points (primary proton) < 1

????

Preliminary!

Note the "PRELIMINARY" label: We ourselves are NOT sure we see the θ^+

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Pentaquark status

Experiment	Θ_s^+	Ξ_5	Θ_c^+	Reaction	Energy
CDF				$p\bar{p} \rightarrow (\Theta,\Xi)X$	$\sqrt{s}$ = 1.9 TeV
E690				$pp \rightarrow (\Theta,\Xi)X$	$\sqrt{s}$ = 39 GeV
BaBar				$e^+e^- \rightarrow (\Theta,\Xi)X$	$\sqrt{s}$ =10.6 GeV
ZEUS				$e\,p \rightarrow (\Theta,\Xi)X$	$\sqrt{s}$ =310 GeV
ALEPH				$e^-e^+ \rightarrow (\Theta,\Xi)X$	$\sqrt{s}$ =91.2 GeV
WA89				$\Sigma^- A \rightarrow \Xi X$	E_Σ =340 GeV
HERA-B				$pA \rightarrow (\Theta,\Xi)X$	E_p=920 GeV
FOCUS				$eBeO \rightarrow (\Theta,\Xi)X$	E_e=300 GeV
HERMES				$ed \rightarrow (\Theta,\Xi)X$	E_e=27.6GeV
NA-49				$pp \rightarrow (\Theta,\Xi)X$	$\sqrt{s}$ =17.6 GeV

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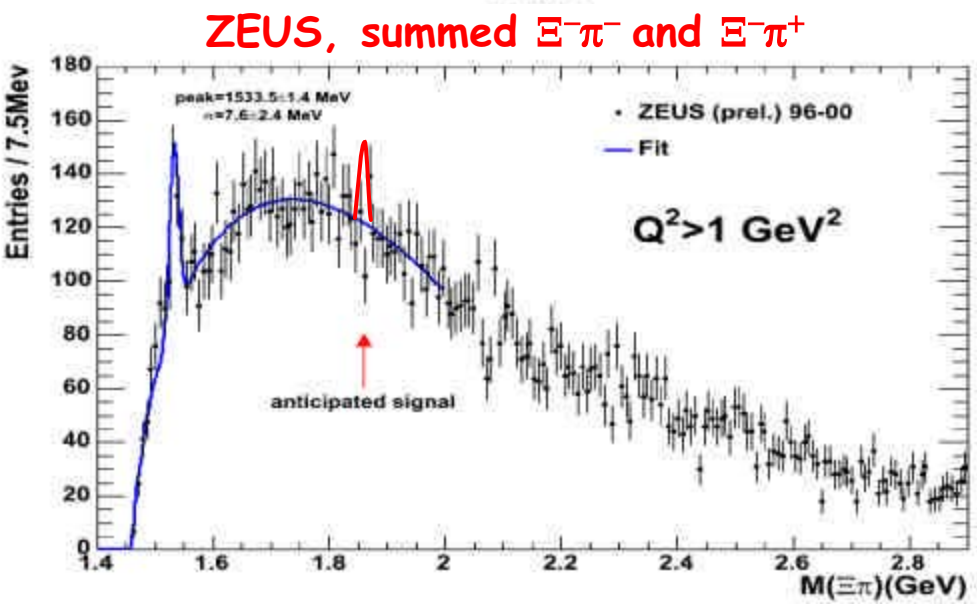
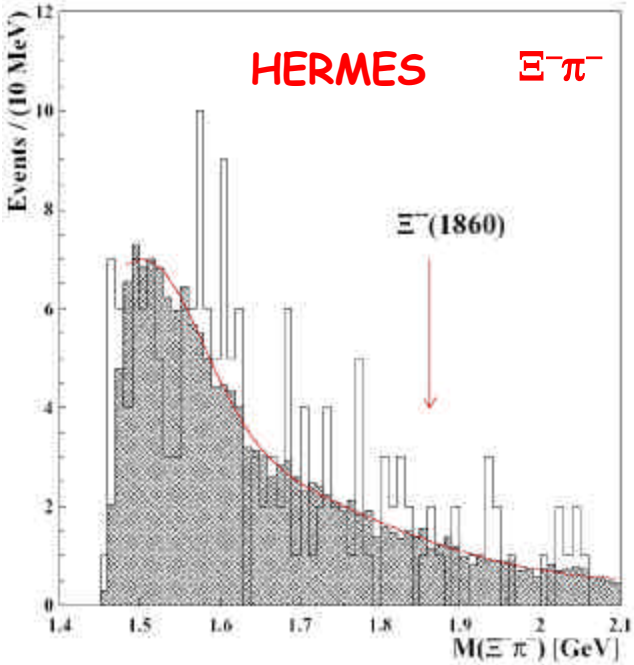
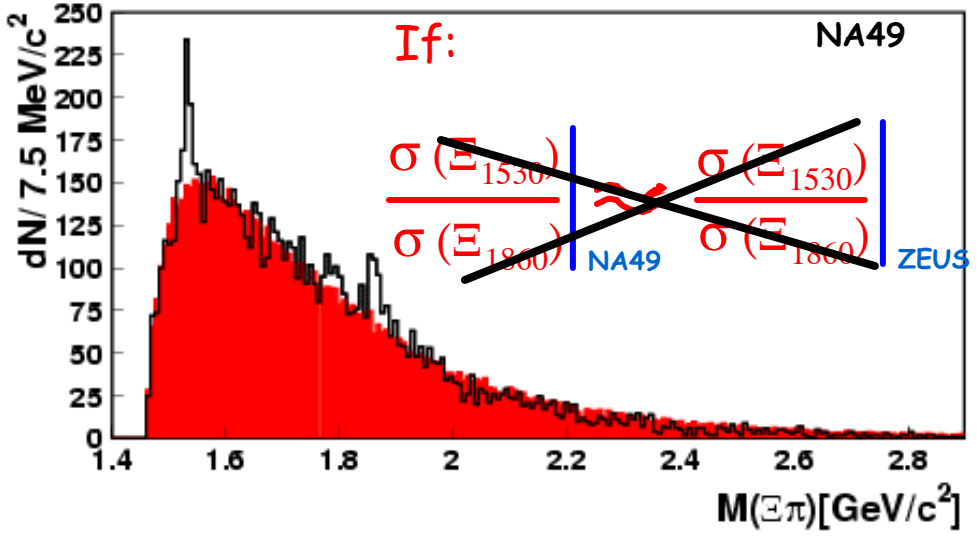
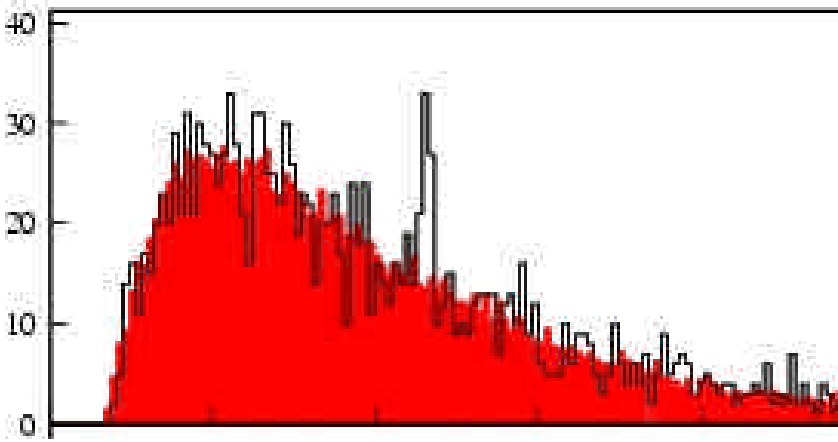
ZEUS and HERMES vs. NA49









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Trento 2005

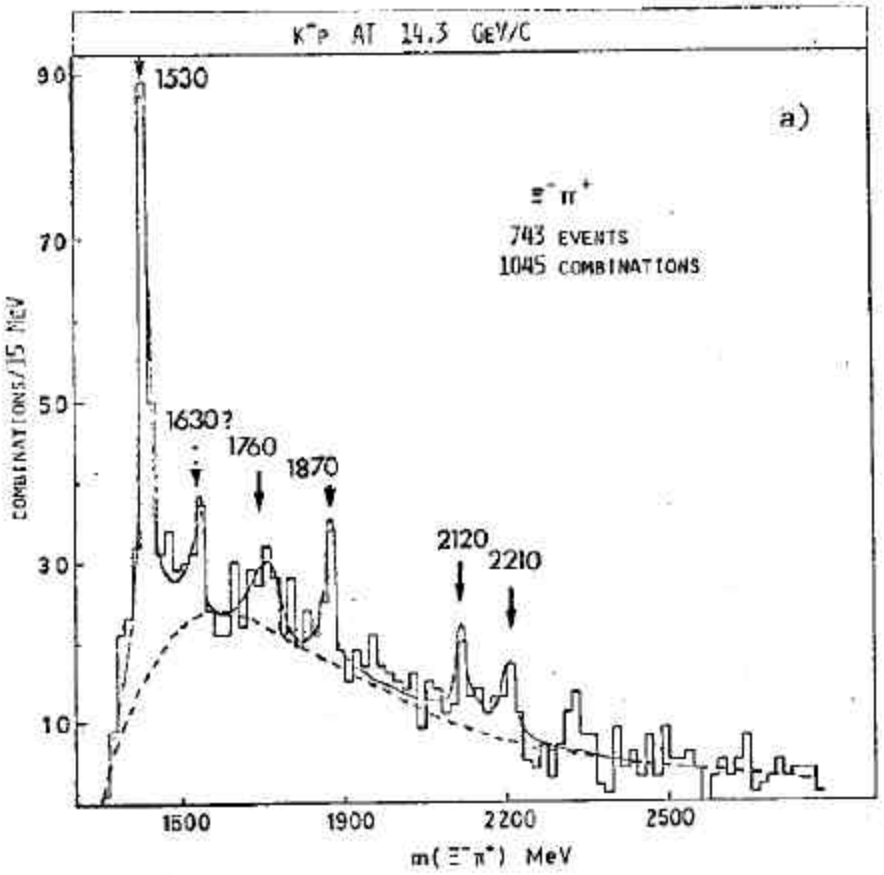
Ξ old and new data (so far our only hope...)

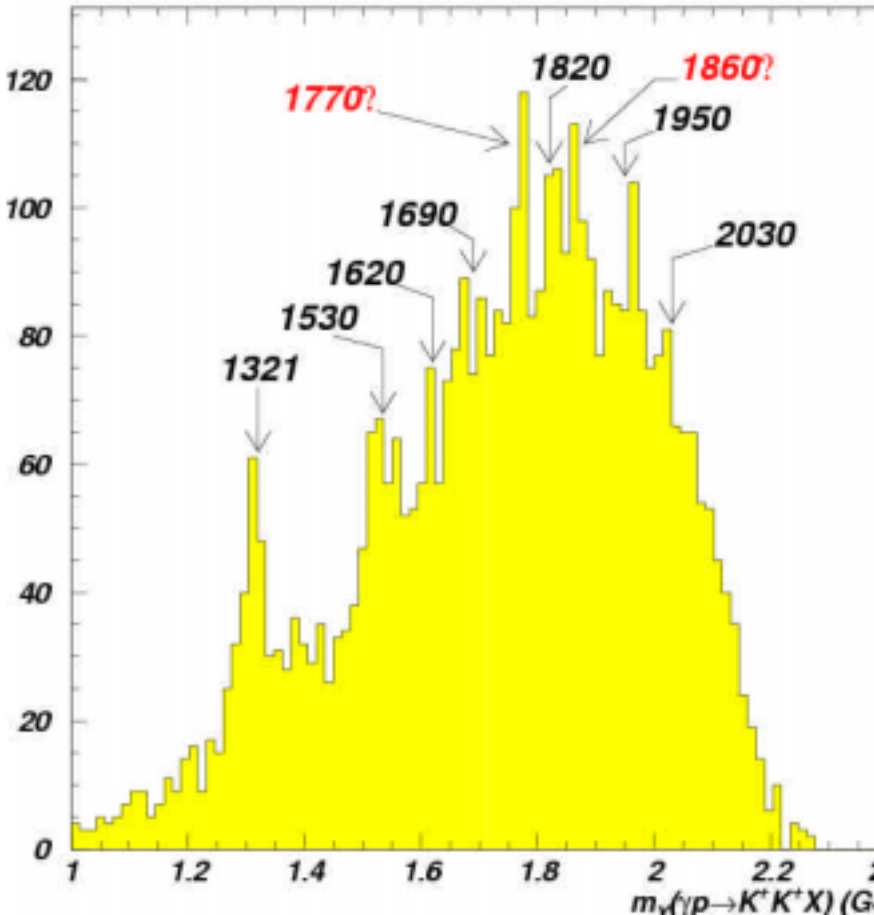
J.M. Gago et al.,
"Ξ* Production in K⁻p Interactions at 14.3 GeV/c"
Ecole-Polytechnique-Saclay-RHEL Collaboration,
(CERN/EP/PHYS 76-50)

J.W.Price,J.Ducote,J.Goetz,B.M.K.Nefkens,
"Photoproduction of the double-strange Ξ hyperon
For the CLASS Collaboration,
(arXiv:nucl-ex/0402006)

Ξ^{0*}

Ξ^{-*}





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Trento 2005

Announced for some time now “to do list”

or, what have we been up to since publication of our results at end of 2003 ?

Create consistent (and debugged!) reconstruction code for all data ▪There were relatively significant code changes for different years/data sets	✓
Code a new and independent V0/Ξ finder, analysis program to have a completely separate analysis to compare results (very important, and major effort)	✓
Improved main vertex determination ▪Exclude V0 and Ξ tracks from fit ▪Use higher quality tracks	✓
Further improvement of experimental resolution ▪Residual corrections	~
Use new procedure, with 30% more data, to redo analysis	×

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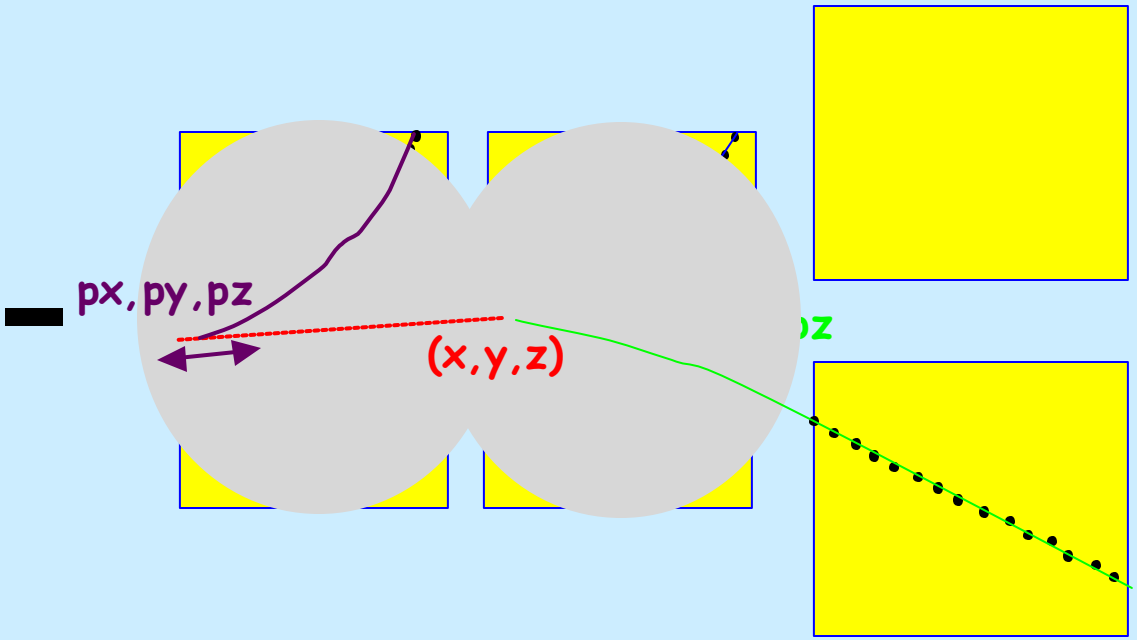
V0/Ξ finder/fitter



Use a 13 parameter Levenberg-Marquart minimization:

- Momentum of proton from Λ
- Momentum of pion from Λ
- x,y,z position of lambda vertex
- z position along extrapolated Λ
- Momentum of pion from Ξ

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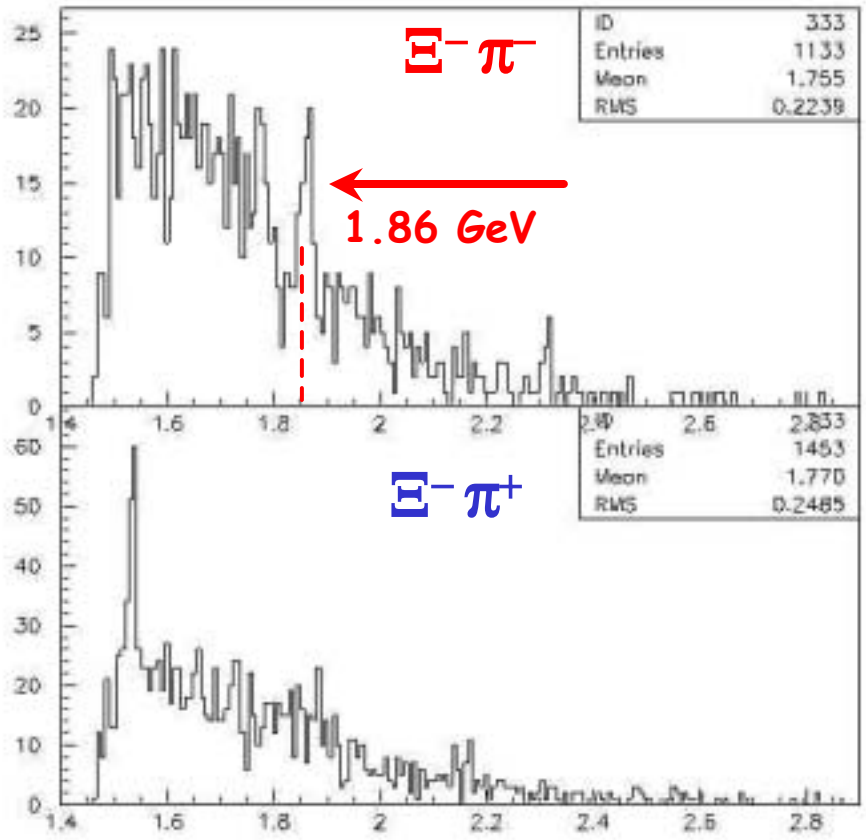
New V0/Ξ finder/fitter - hot off the



- No "exotic" cuts (no cos(θ))
- Used χ^2 to select very high quality tracks and Ξ^-s
- improved main vertex
- Also, the new and consistent reconstruction code used

- Ξ^{--} clearly seen at 1.86 GeV!
- There is a hint of a peak at 1.78 GeV (spin 1/2 , 3/2 states ????)
- Like before, with cos(θ) cut the 1.86 peak much clearer, and with asymmetric $d\pi_{bb}$ and momentum cut there is a bump at 1.86 GeV in the $\Xi^-\pi^+$ spectrum

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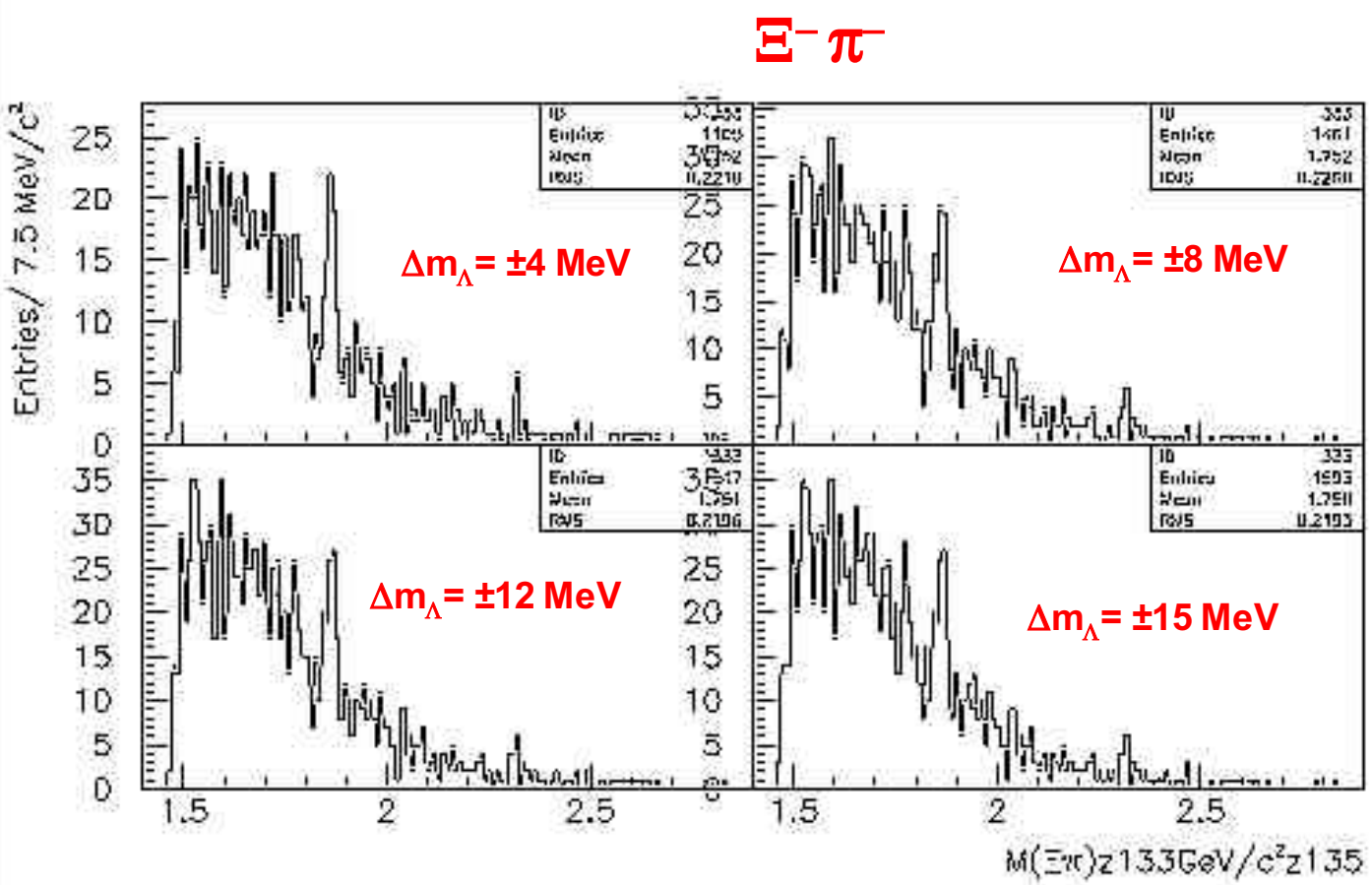
New V0/Ξ finder – Λ mass cut



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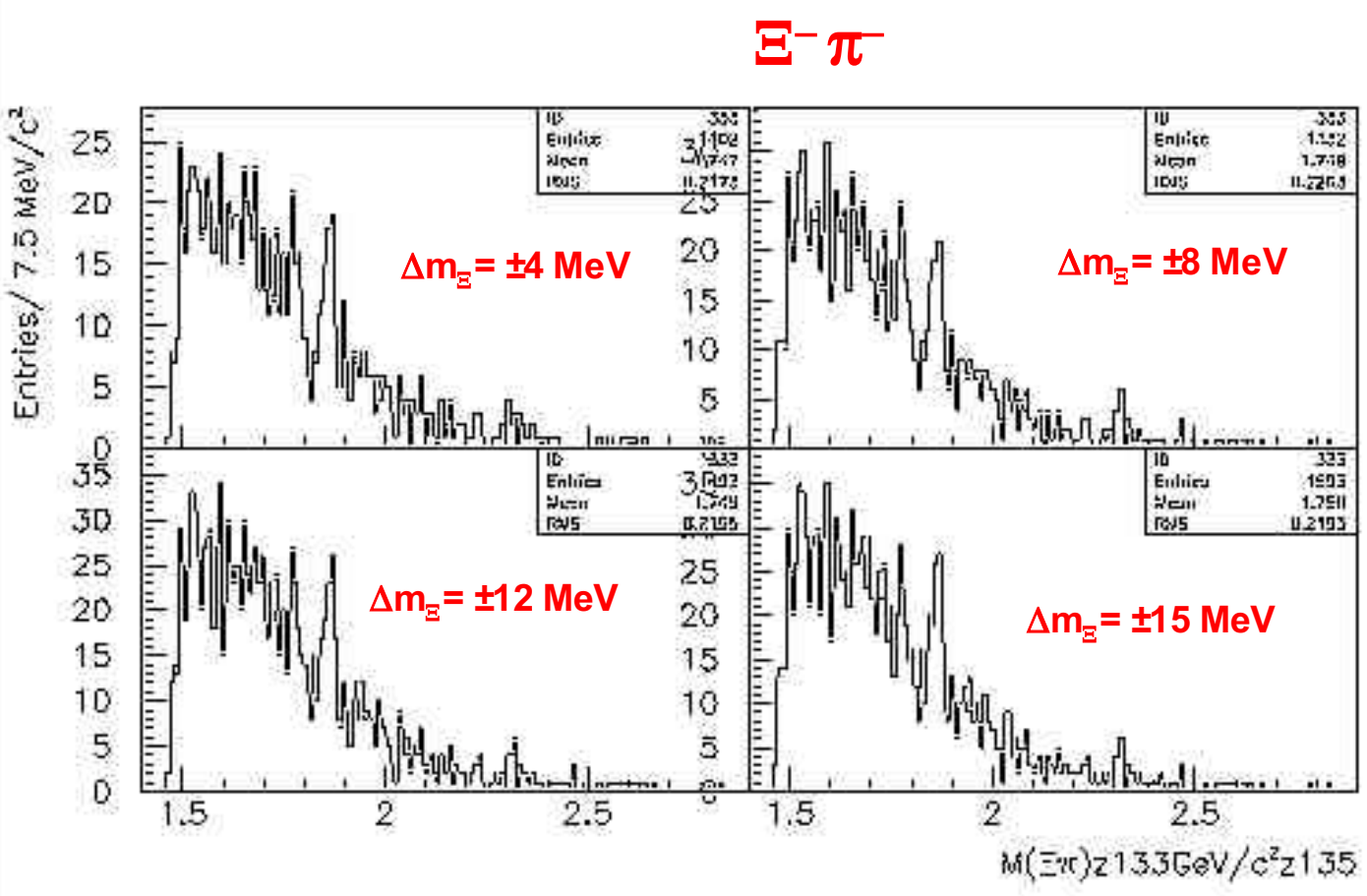
New V0/Ξ finder – Ξ mass cut



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Conclusion/to do list

- More detailed systematic study confirms our previous Ξ_5^{--} conclusion
- An independent analysis/finder/fitter again confirms our previous Ξ_5^{--} conclusion
- Do new analysis with additional 30 % data, new procedure, new V0/Ξ finder, higher quality tracks to:
  - Verify old results
  - Look for known resonances (this started as an ordinary, and still unpublished hyperon paper…)
  - Look for other possible decay channels of the Ξ_5
    $\Xi_5 \rightarrow \Xi(1530)\,\pi$ (difficult…)
    $\Xi_5 \rightarrow \Lambda K$
    $\Xi_5 \rightarrow \Lambda K_s^0$
  - Look for other pentaquark states, do a detailed analysis of our Θ^+ signal, including simulation
- Hope someone else sees the Ξ_5^{--}!

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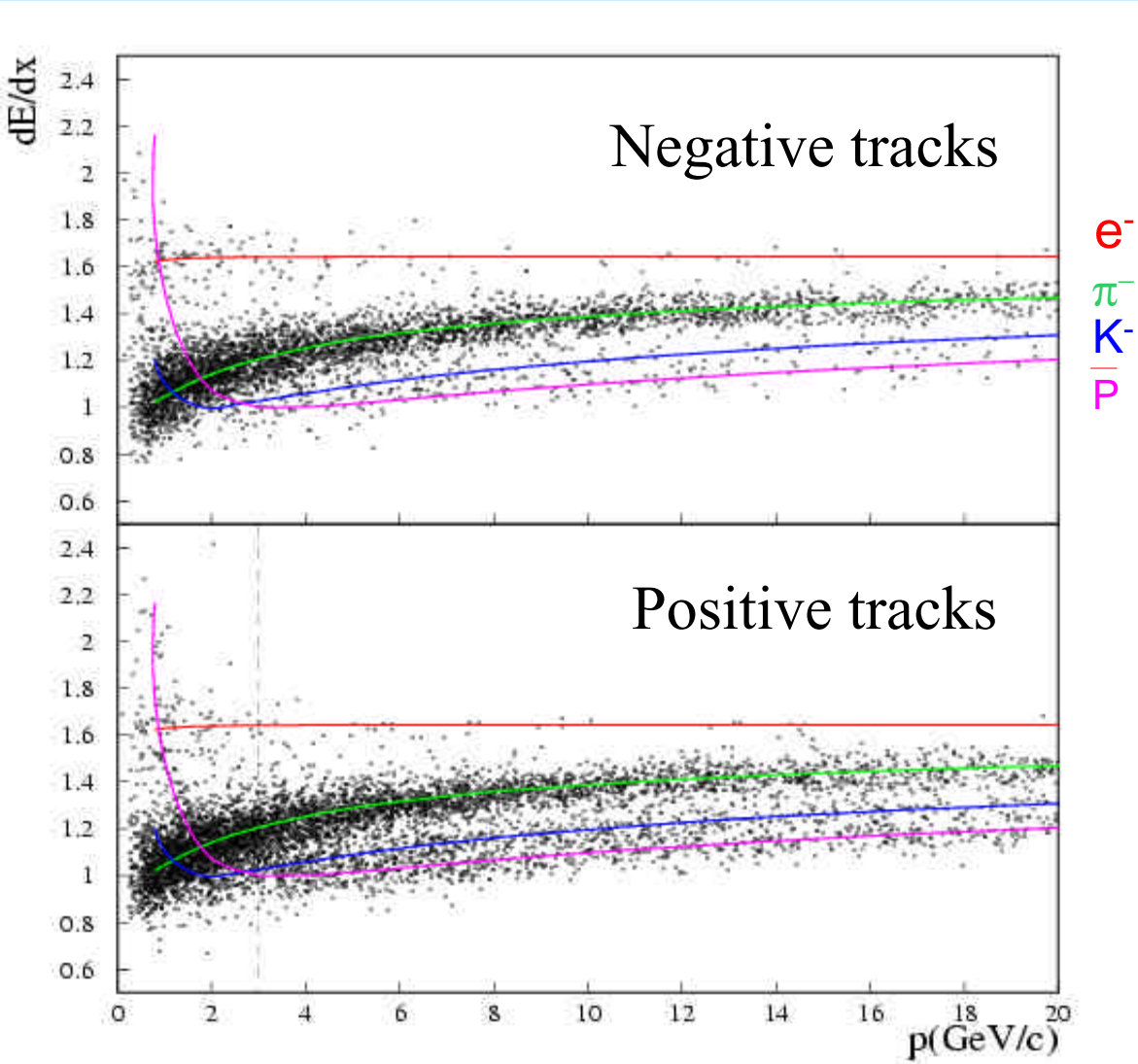

$(\Xi^- \pi^-)$ events

$(\Xi^- \pi^+)$ events