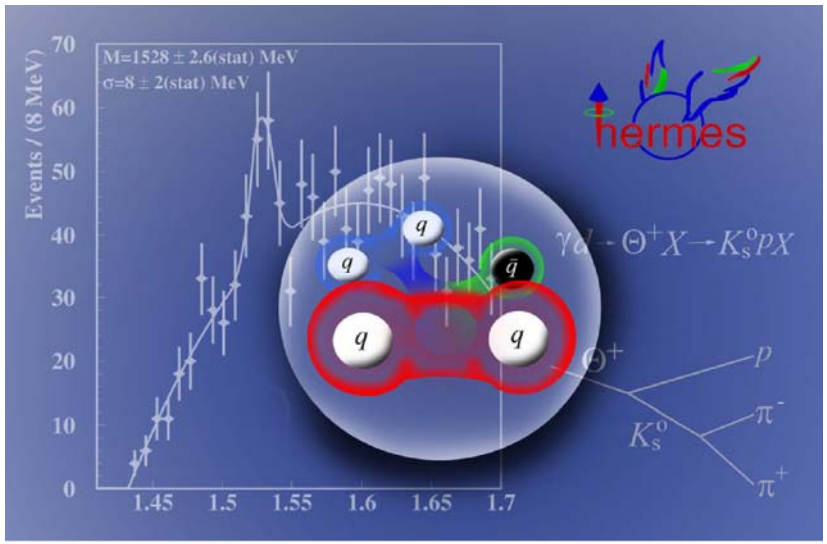
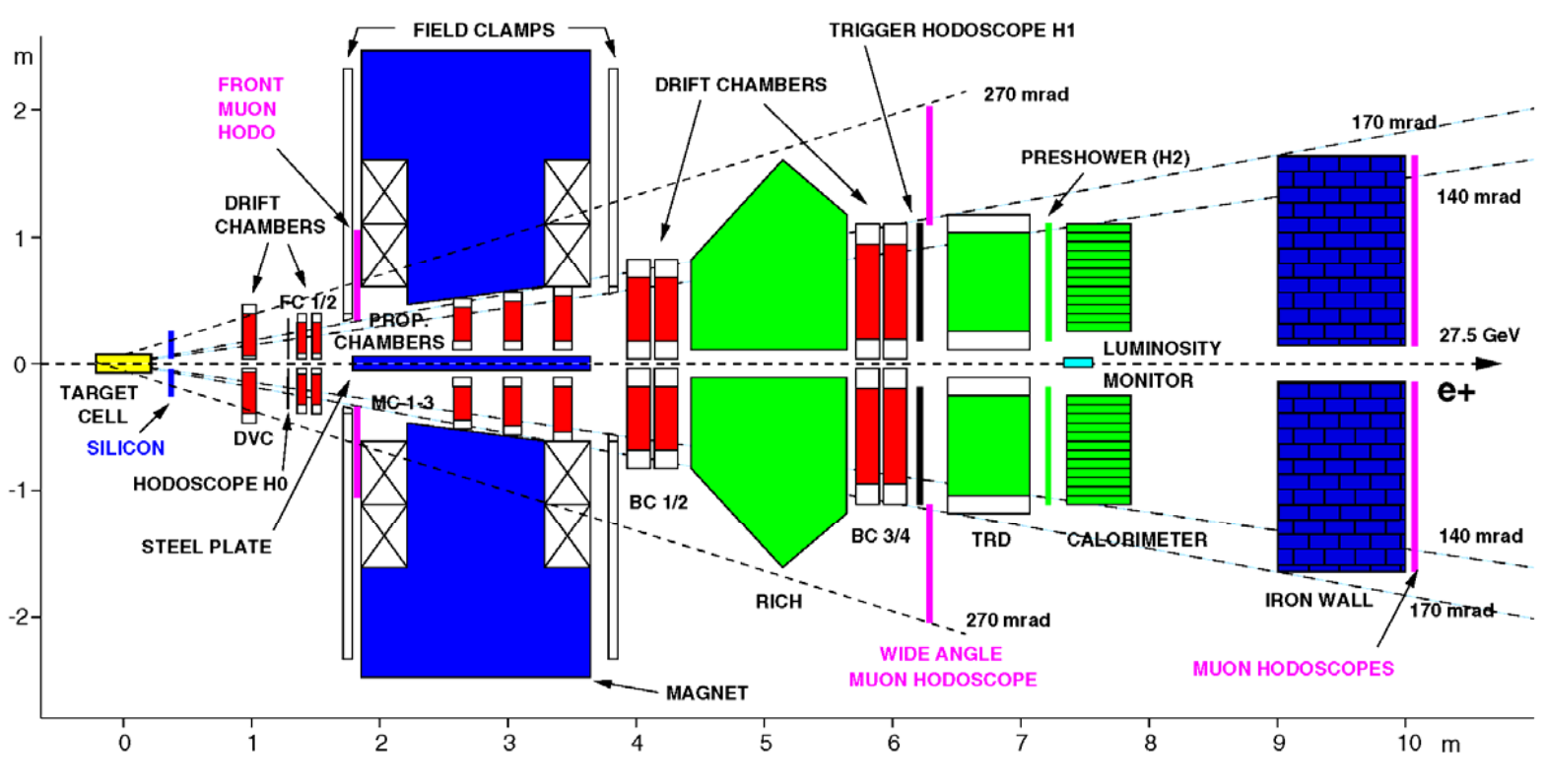
Search for exotic Baryons at HERMES

Wolfgang Lorenzon (University of Michigan)

on behalf of the HERMES Collaboration



The HERMES Spectrometer



Beam: 27.6 GeV e^+/e^- from HERA accelerator

Track reconstruction: $\Delta p/p < 2\%$, $\Delta\theta < 0.6$ mrad

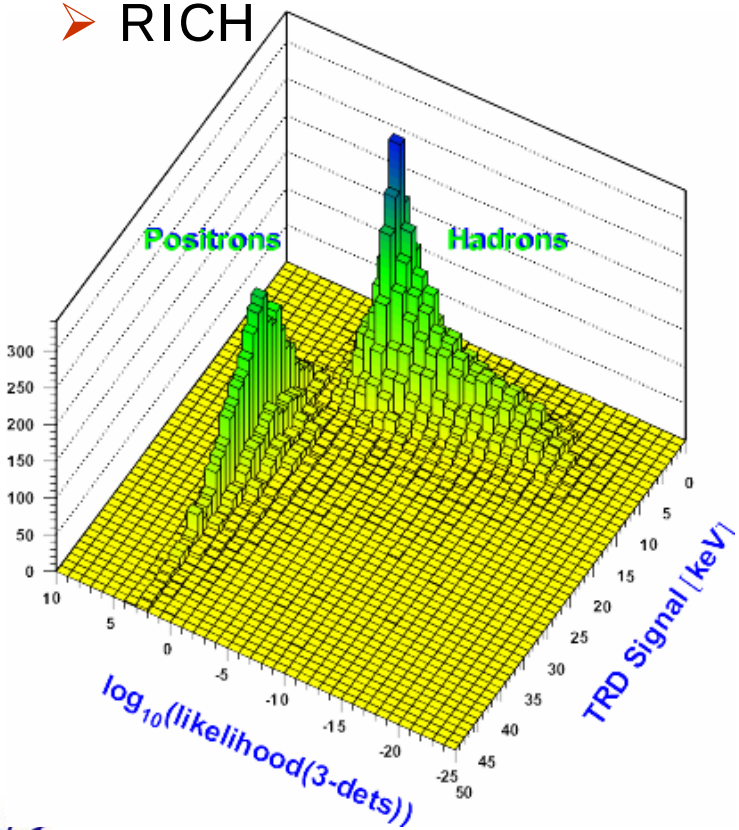
Particle ID: TRD, Preshower, Calorimeter (hadron/lepton sep.)
dual radiator RICH (π, K, p separation)

Particle Identification

hadron/lepton separation

Combination of:

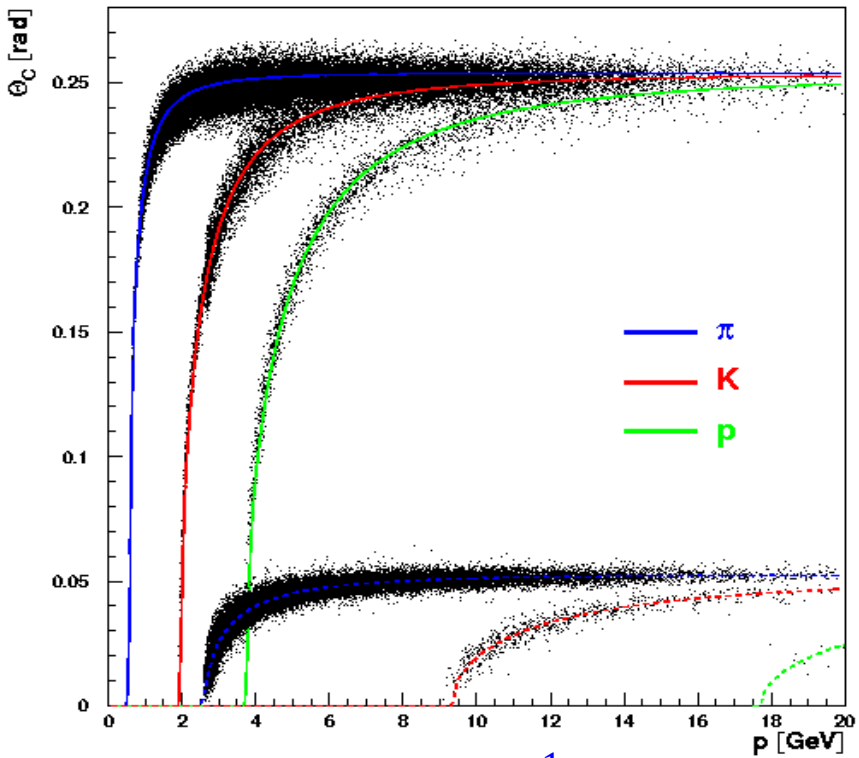
- TRD
- calorimeter
- preshower
- RICH



hadron identification

Dual radiator RICH

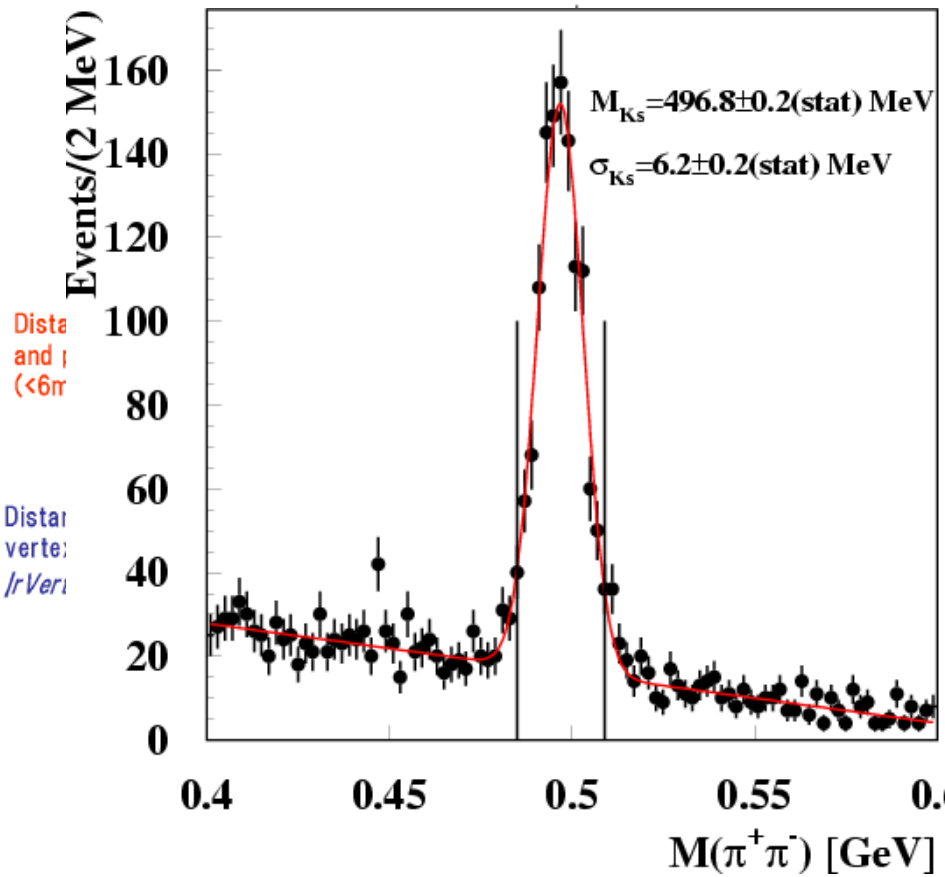
- aerogel: n=1.03
- C_4F_{10} gas: n=1.0014

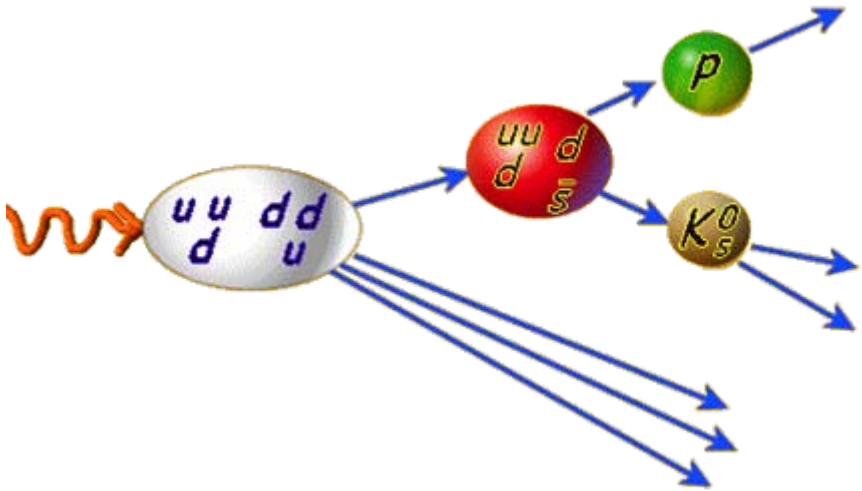


$$\cos\Theta = \frac{1}{n}$$

Event Reconstruction

$$e^+ + D \rightarrow \Theta^+ + X \rightarrow p K^0_S + X$$



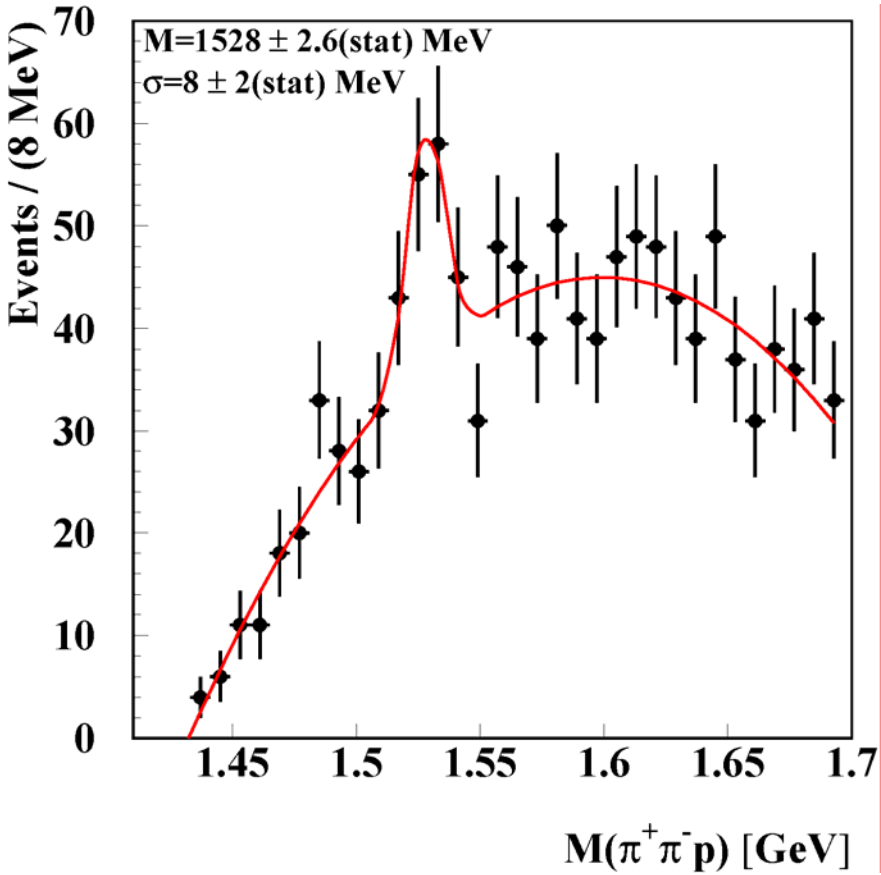


τ: 1–15 GeV *p*: 4–9 GeV

on of each decay particle,

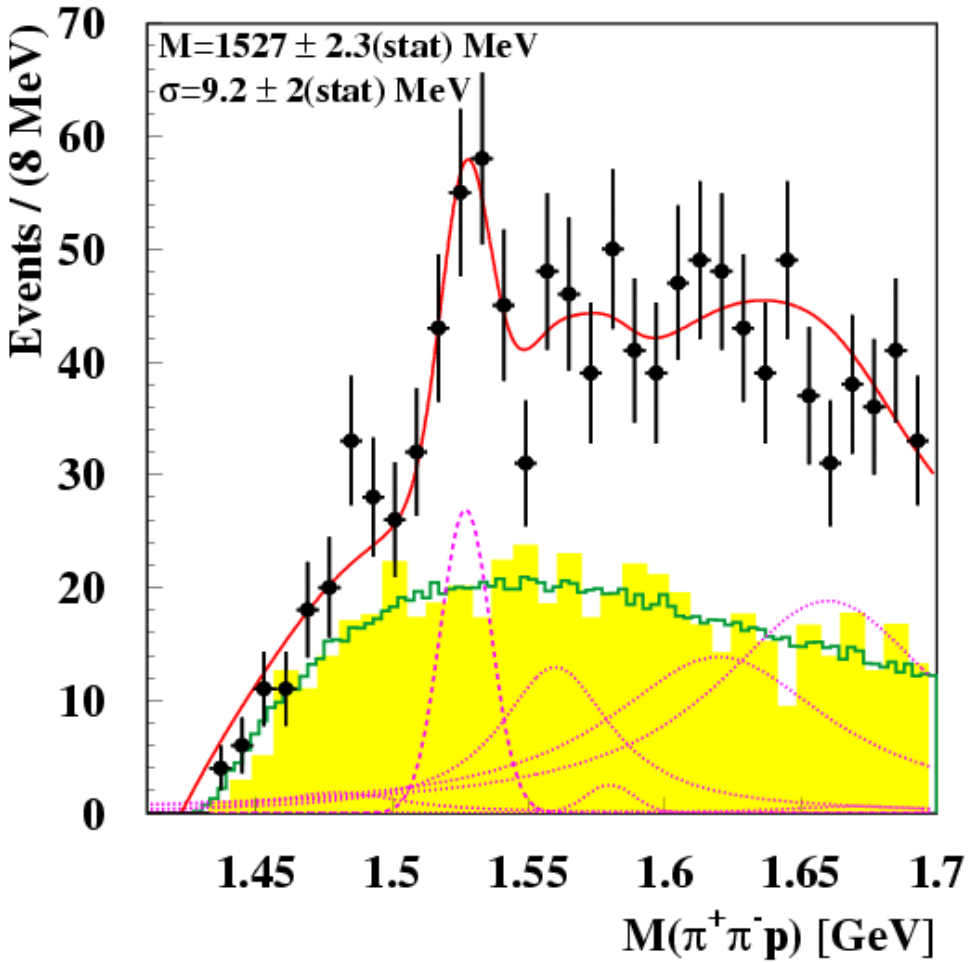
- Suppress contamination from $\Lambda(1116) \rightarrow p\pi^-$

Invariant Mass Distribution of $p\pi^+\pi^-$



- events selected in a $\pm 2\sigma$ window about K_S peak
- Peak is observed at $1528 \pm 2.6(stat) \pm 2.1(syst)$ MeV in pK_S invariant mass distribution
- Width, $\sigma = 8$ MeV, is observably larger than experimental resolution
- No known positively charged strange baryon in this mass region
- Statistical significance is $3\text{–}5\ \sigma$
- Three models of background were studied

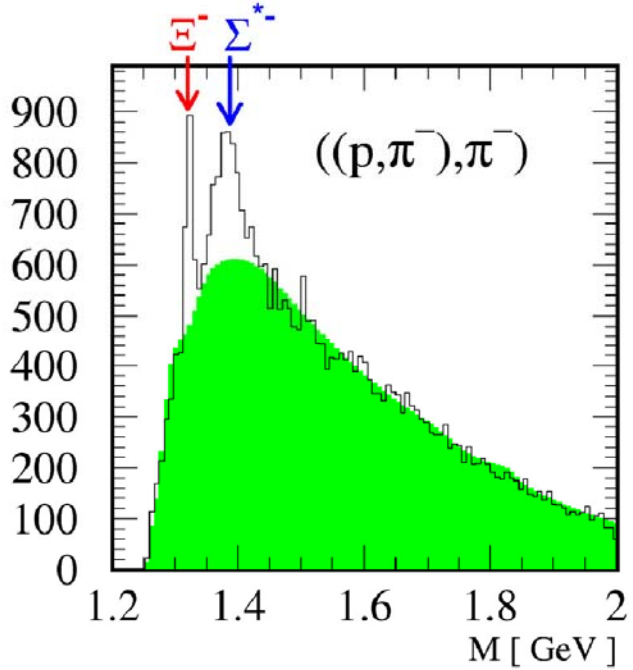
PYTHIA6 and mixed-event backgrounds

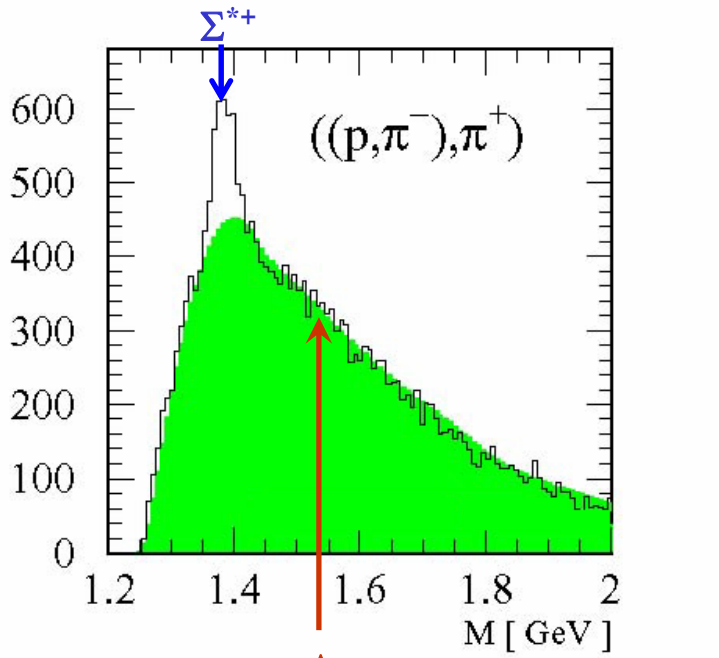


- Filled histogram: PYTHIA6 MC (lumi normalized): No resonance structure from reflections of known mesonic or baryonic resonances
- Green histogram: mixed event background normalized to PYTHIA6: reproduces the shape of PYTHIA6 simulation
- Excited Σ^* hyperons not included in PYTHIA6 lie below 1500 MeV and above 1550 MeV
- Mass= 1527 ± 2.3 MeV
- σ= 9.2 ± 2 MeV
- Significance 4.3σ

Θ^+ or Σ^{*+} ?

- Is our peak a previously missing Σ^* or a pentaquark state?
- If peak is $\Sigma^{*+} \Rightarrow$ also see a peak in M($\Lambda\pi^+$)

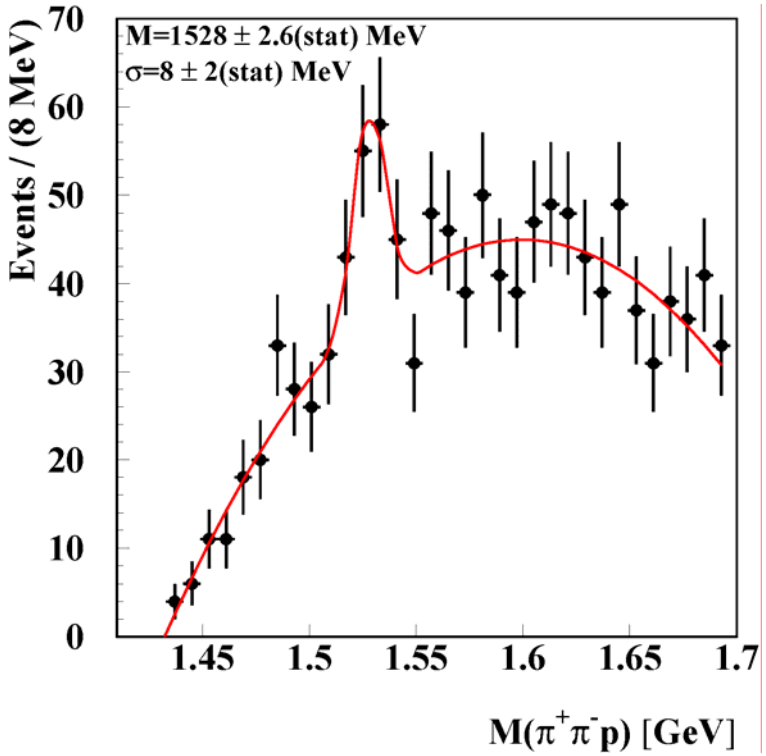


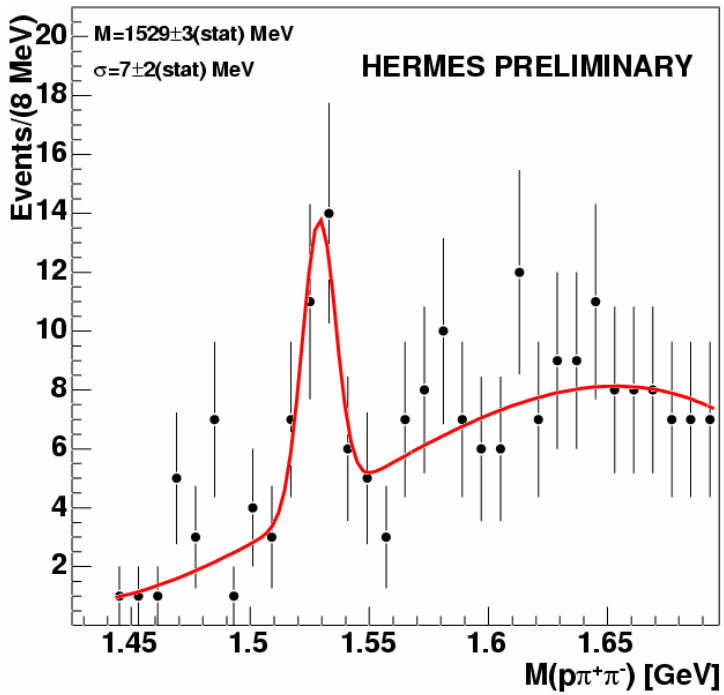


No peak in $\Lambda\pi^+$ spectrum near 1530 MeV

→ *but no Σ^*s (1480, 1560, 1580, 1620) too!!!!*
should we say all bumps in pK_s spectrum are pentaquarks?

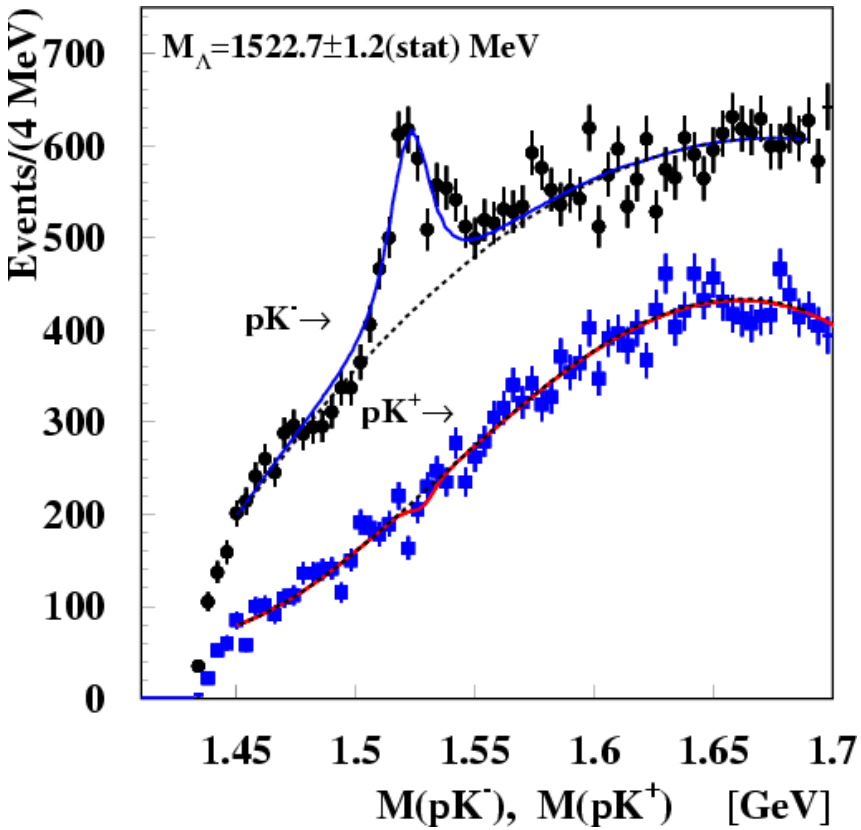
Further background suppression - additional π





- signal/background: 1:3
- signal/background: 2:1
  same kinematic cuts

What is the Isospin of the Θ^+?



In the decay channels:

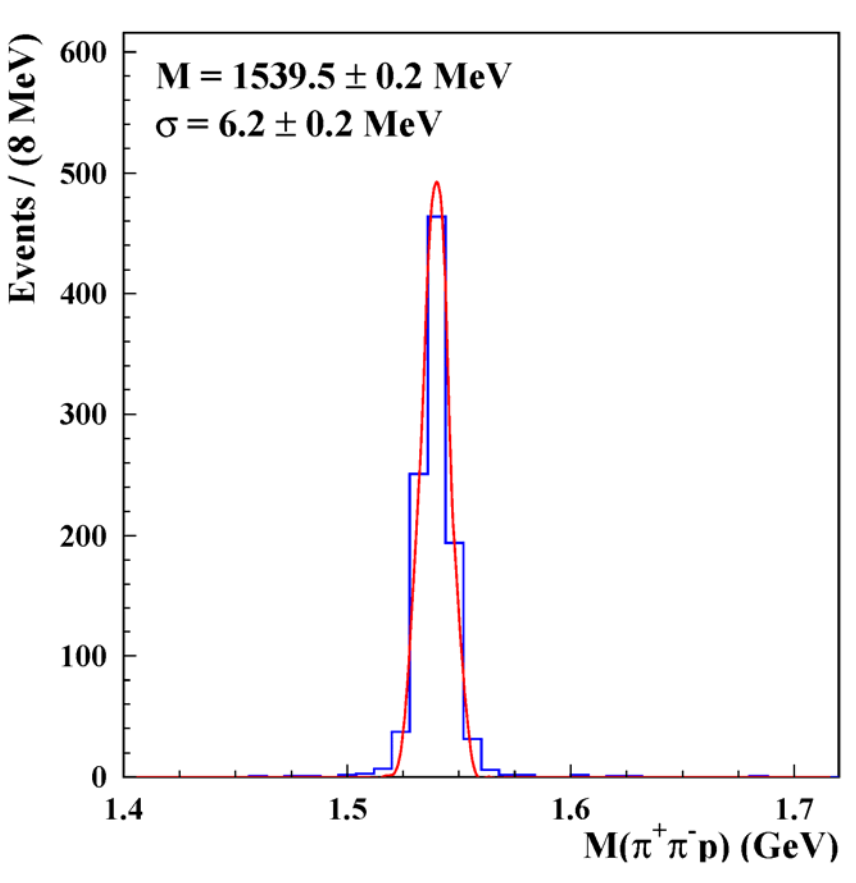
- $\mathbf{pK^-}$: clear $\Lambda(1520)$ peak at 1522.7 MeV
- $\mathbf{pK^+}$: no peak, zero counts at 91% C.L.

Not isotensor

→ probably **iso-singlet**

Width of Peak

- Θ^+ Monte Carlo with complete detector simulation
- generated peak:
  M=1540 MeV, σ=2 MeV
- reconstructed peak:
  M=1539.5 MeV, σ=6.2 MeV
  $\Delta_{detect.}$(FWHM) = 10–14.6 MeV
- $FWHM_{meas.}$ = 19–24 MeV



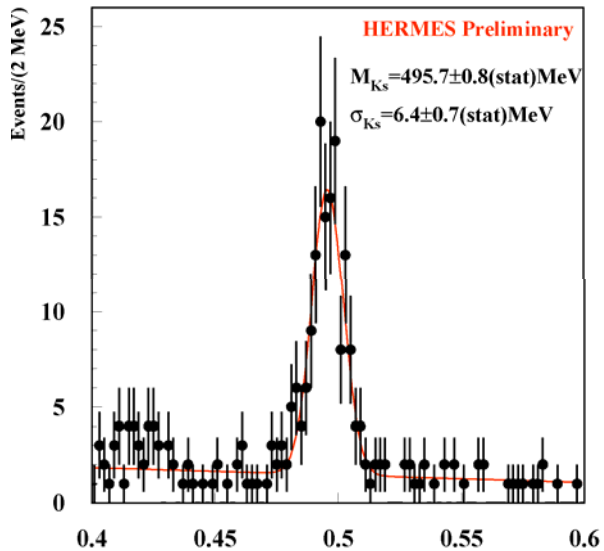
Intrinsic width: **Γ = 17 ± 9 ± 3 MeV**

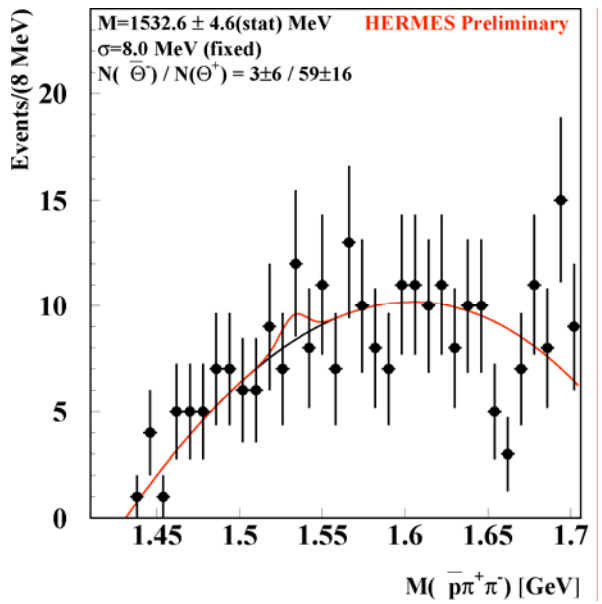
Invariant Mass Distribution of $\bar{p}\pi^+\pi^-$

- Goal: compare cross section ratio of Θ^- to Θ^+ production with ratio of $\bar{\Lambda}(1520)$ to $\Lambda(1520)$ production (~1:5) or $\bar{\Xi}^0(1530)$ to $\Xi^0(1530)$ production (1:4)

  → shed light on production mechanism

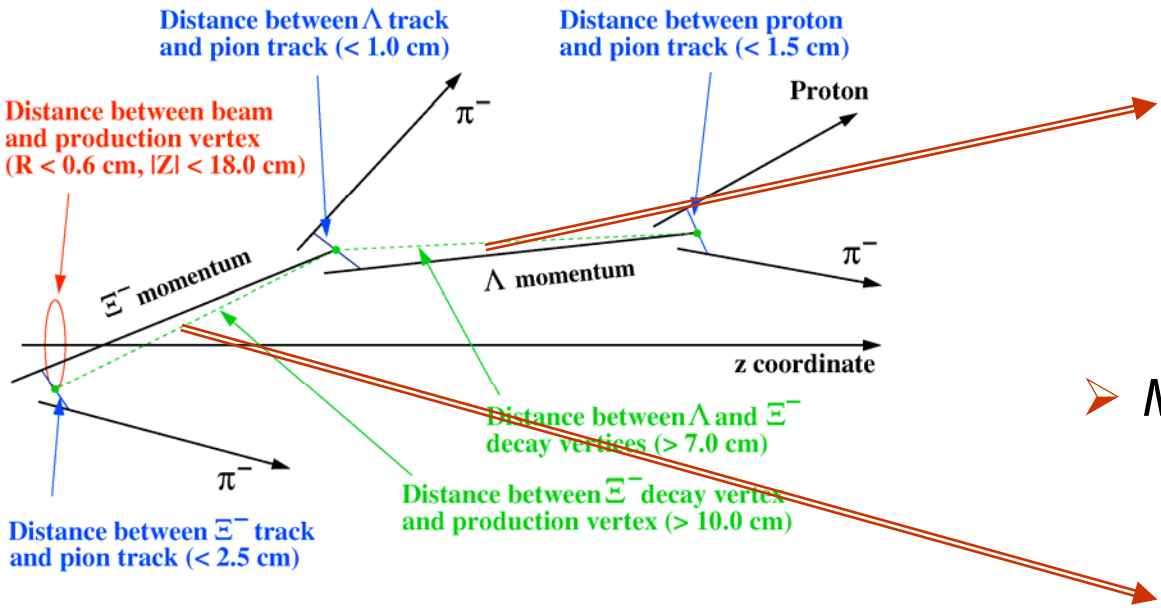
- same event selection and kinematic constraints as for $p\pi^+\pi^-$
- Gaussian plus 3rd order polynomial, width of Gaussian fixed
- no peak is observed
  - hint that in HERMES kinematics target-remnant plays an important role different to ZEUS, which has basically the same number of Θ^+ and Θ^-.



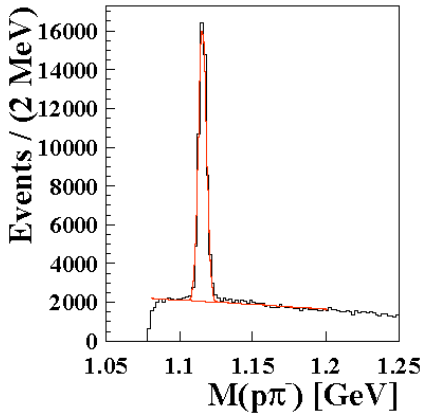


Search for reported $\Xi^{--}(1862)$ Exotic

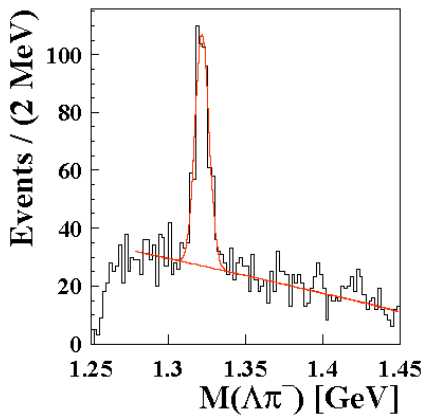
- Channel: $\Xi^{--} \rightarrow \Xi^{-}\pi^{-} \rightarrow \Lambda\pi^{-}\pi^{-}$
- Topology:



- $M(p\pi^{-})$ with Λ



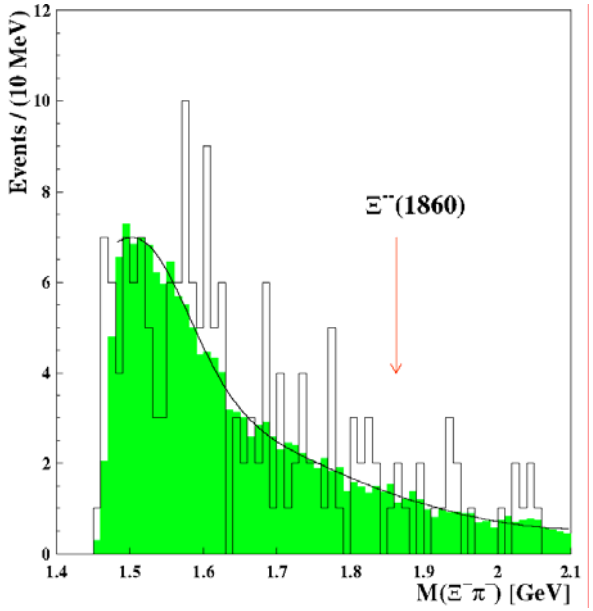
- $M(p\pi^{-}\pi^{-})$ with Ξ^{-}



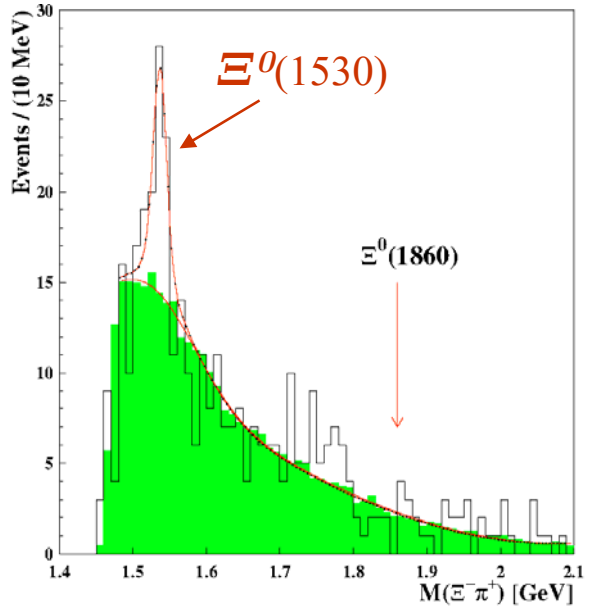
- Selected Λ events ($\pm 3\sigma$ window)
- Selected Ξ^{-} events ($\pm 3\sigma$ window)

$\Xi^{--}(1862)$ search (II)

- $M(p\pi^-\pi^-\pi^-)$ spectrum



- $M(p\pi^+\pi^-\pi^-)$ spectrum



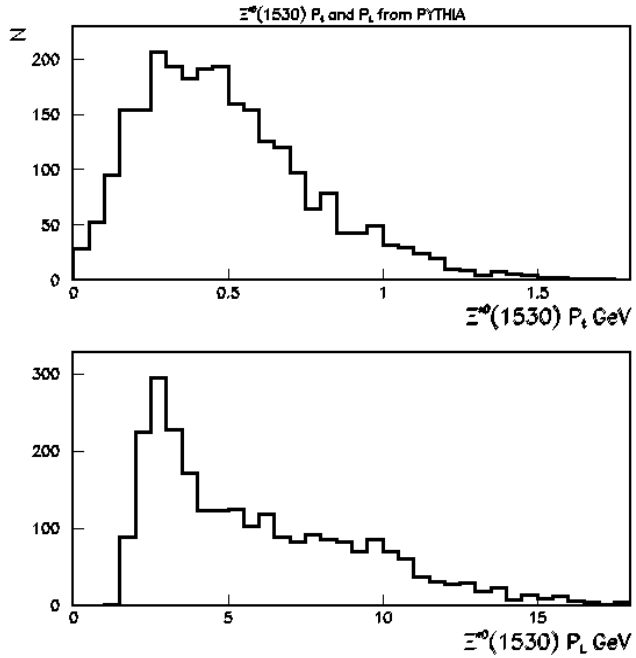
- mixed-event background
- No Ξ peaks around 1860 MeV
- $\Xi^0(1530)$ seen, as expected

- upper limit $\sigma(\Xi^{--})$: 1.0–2.1 nb
- upper limit $\sigma(\Xi^0)$: 1.2–2.5 nb
- $\sigma(\Xi^0(1530))$ = 8.8–24 nb

Production Cross Sections

- Integrated luminosity: 290 pb^{-1}
- all measurements done in quasi-real photoproduction ($Q^2 << 1 GeV^2$)
- Acceptances from Monte Carlo:
  - $\Lambda(1520)$: 1.5%
  - Θ^+: 0.05%
  - $\Xi^0(1530)$: 0.036-0.1%
  - $\Xi^0(1860)$: 0.065%
  - $\Xi^{--}(1860)$: 0.031%

PYTHIA6 p_t and p_z spectra



OR: p_t and p_z spectra from Λ_{exp}

$\sigma(\Theta^+) = 100\text{-}220$ nb ± 25%(stat)
(add. x2 from prod. kinematics)

$\sigma(\Lambda(1520)) = 62 \pm 11$ nb
$\sigma(\Xi^0(1530)) = 8.8\text{–}24$ nb

Production process at HERMES ?

- can additional pion come from these exclusive processes?

$$\gamma p \to \overline{K}^0 K^0 p \to \overline{K}^0 \Theta^+$$

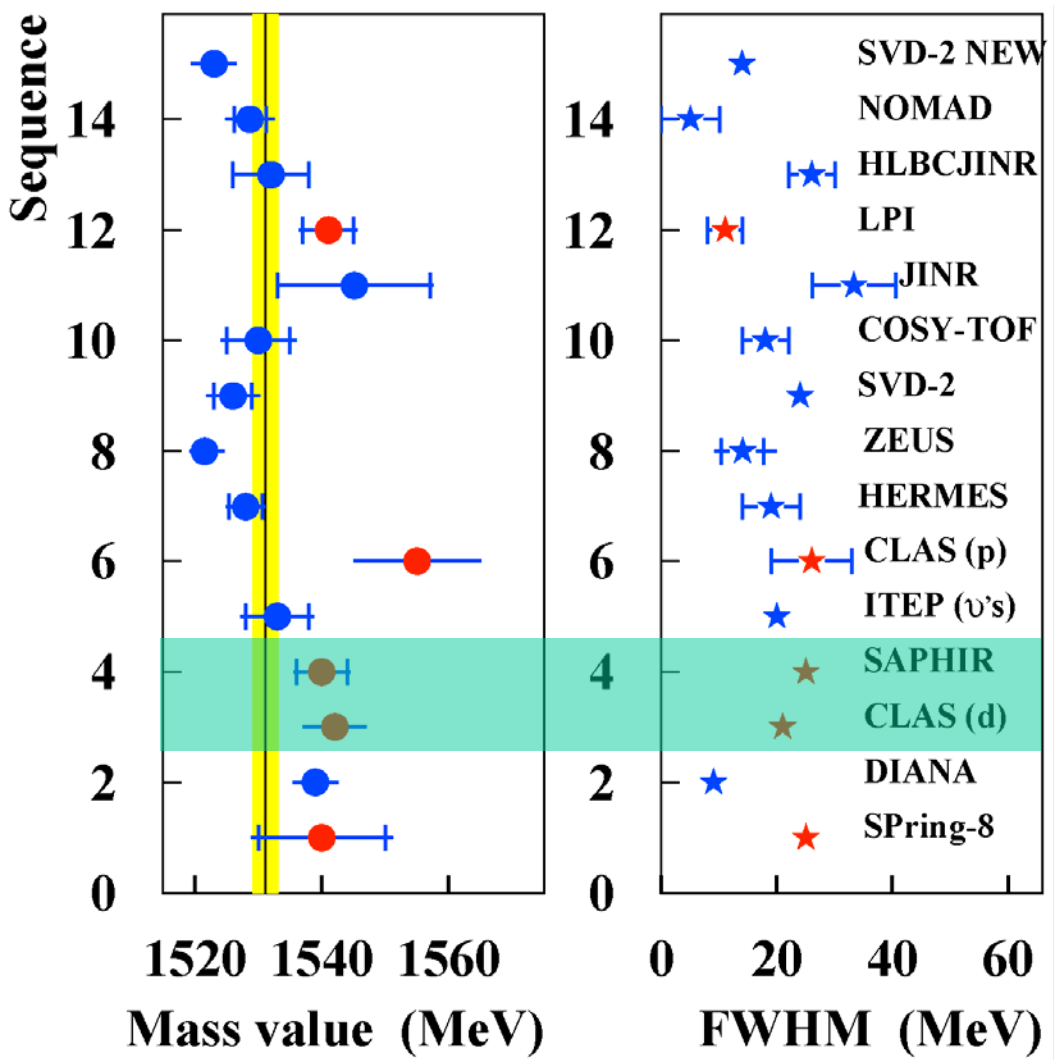
$$\pi^+ \pi^- \qquad K_S^0 p \to \pi^+ \pi^- p$$

$$\gamma\ n \to K^- K^0 p \to K^- \Theta^+$$

$$K_S^0 p \to \pi^+ \pi^- p$$

- associated K^- or K_S from exclusive processes goes backward
  - — even decay pions from K_S are inaccessible
  - — PID threshold requires p(Θ^+) > 7 GeV/c
- tagged pions events cannot come from these exclusive processes

Comparison with World Data



Decay channel:

nK^+ pK_s^0

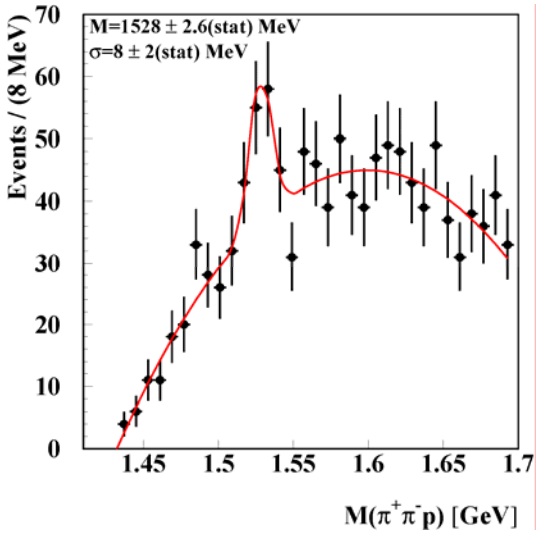
World Average:

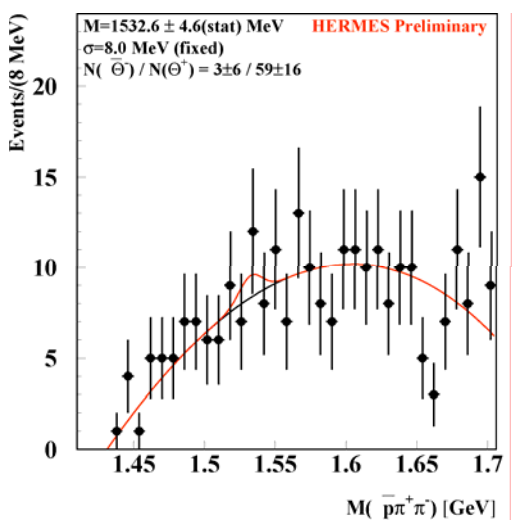
1531.1±2.1 MeV

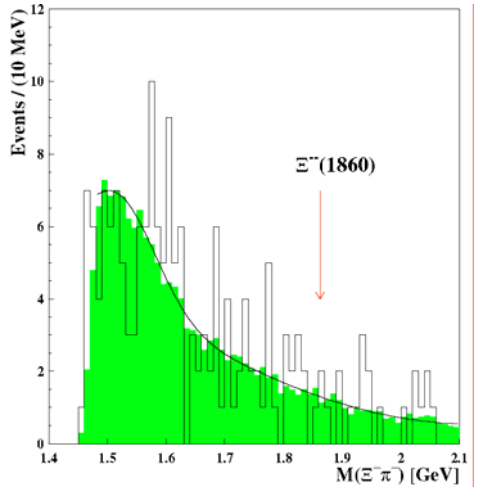
Observation of peak in two decay channels in same experiment

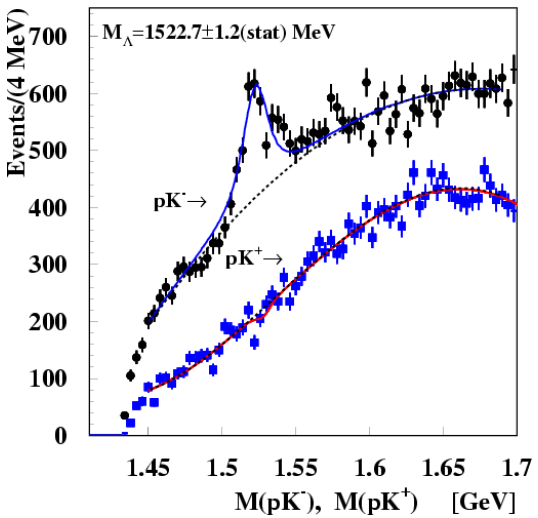
→ would be convincing!

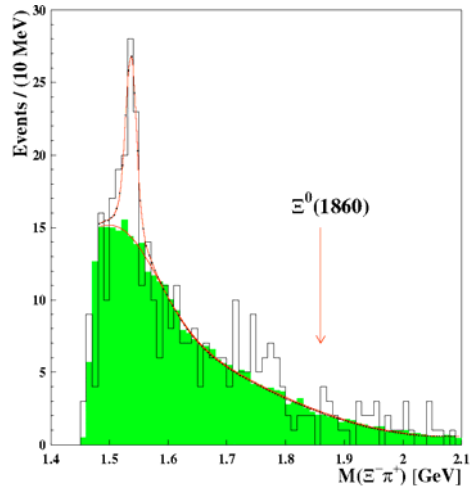
Summary – HERMES results on 5q exotics











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Conclusions and Outlook

- From reconstruction of pK_s invariant mass in

$$eD \rightarrow \Theta^+ + X \rightarrow pK_s^0 + X$$

- Mass: $M = 1528.2 \pm 2.6(stat) \pm 2.1(syst)$ MeV

  Intrinsic Width: $\Gamma_{\Theta^+} = 17 \pm 9 \pm 3$ MeV

  Significance: ~ 4 σ

- Θ^+ is probably an iso-singlet

- additional π improves signal/background,

  → eliminates K_S contamination from various processes

- No evidence observed for Ξ^{--} or Ξ^0 near 1860 MeV

- Anticipate x5 higher statistics by summer 2007