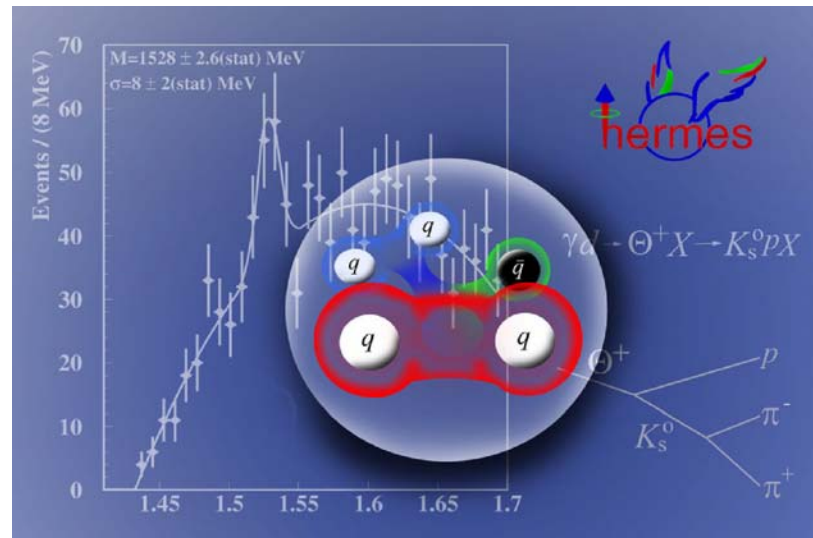


# Search for exotic Baryons at HERMES

Wolfgang Lorenzon (M UNIVERSITY OF MICHIGAN)

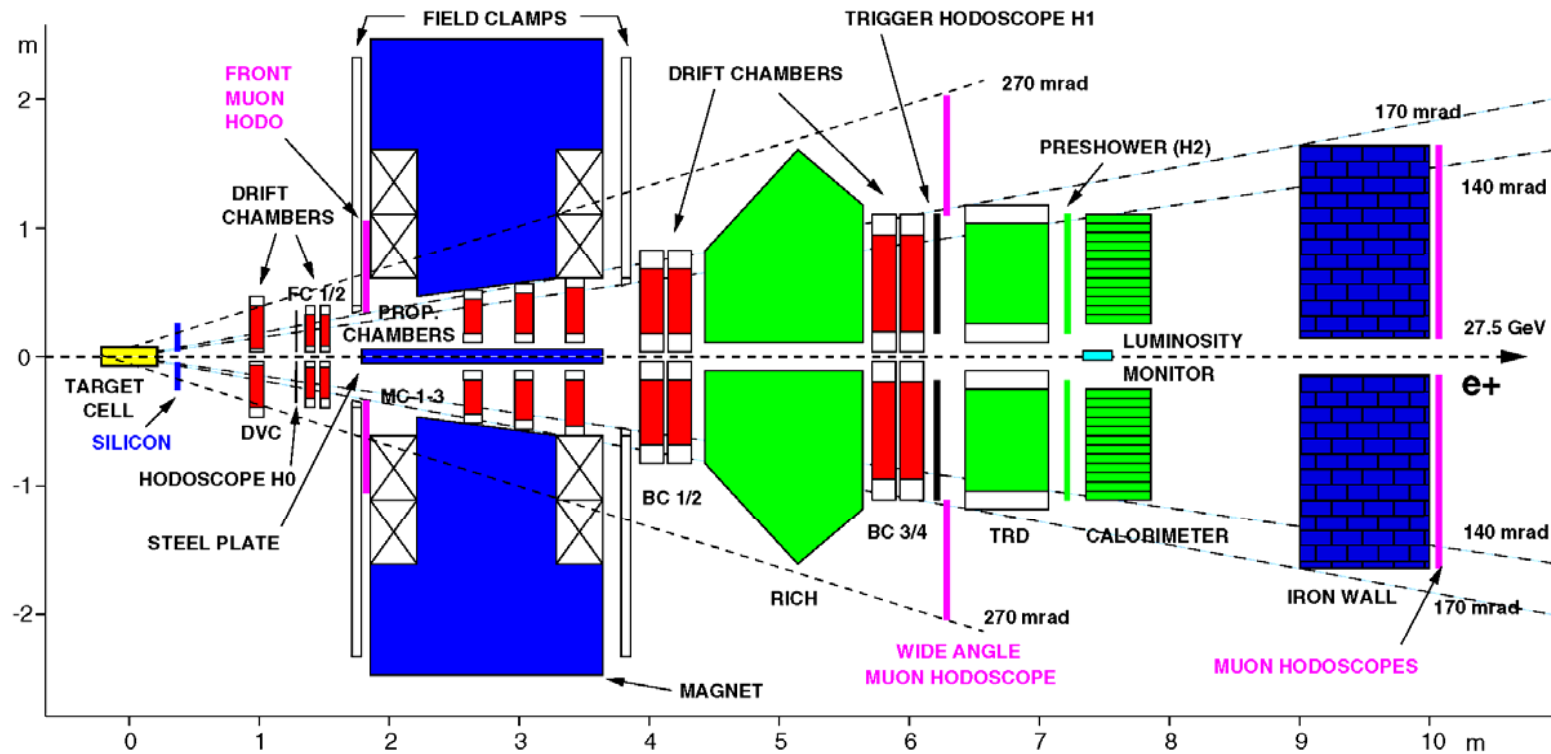
on behalf of the HERMES Collaboration



W. Lorenzon

Pentaquark05 – Oct 2005

# 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 ( $\pi$ ,  $K$ ,  $p$  separation)

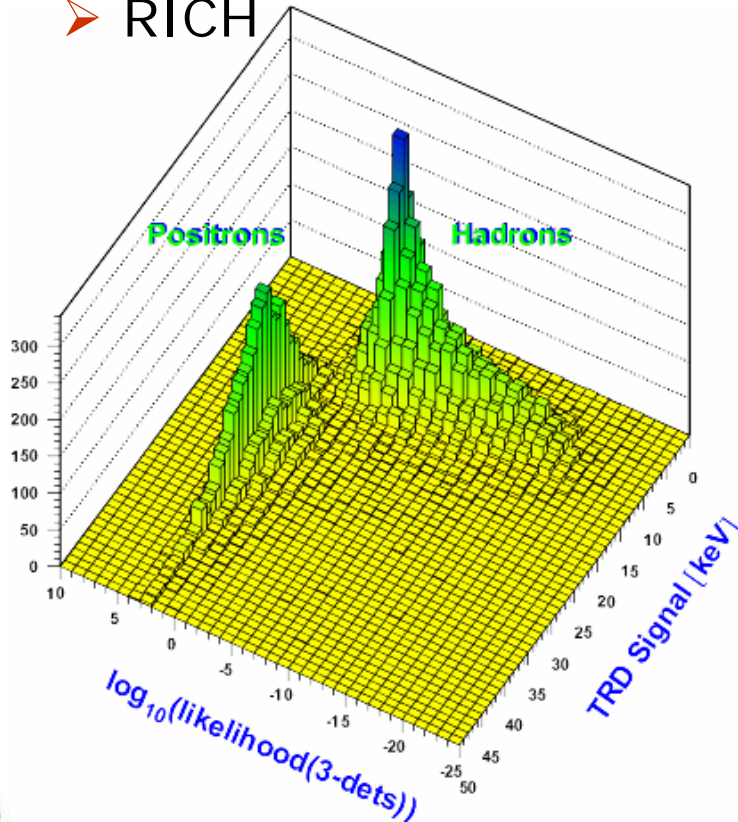


# Particle Identification

## hadron/lepton separation

Combination of:

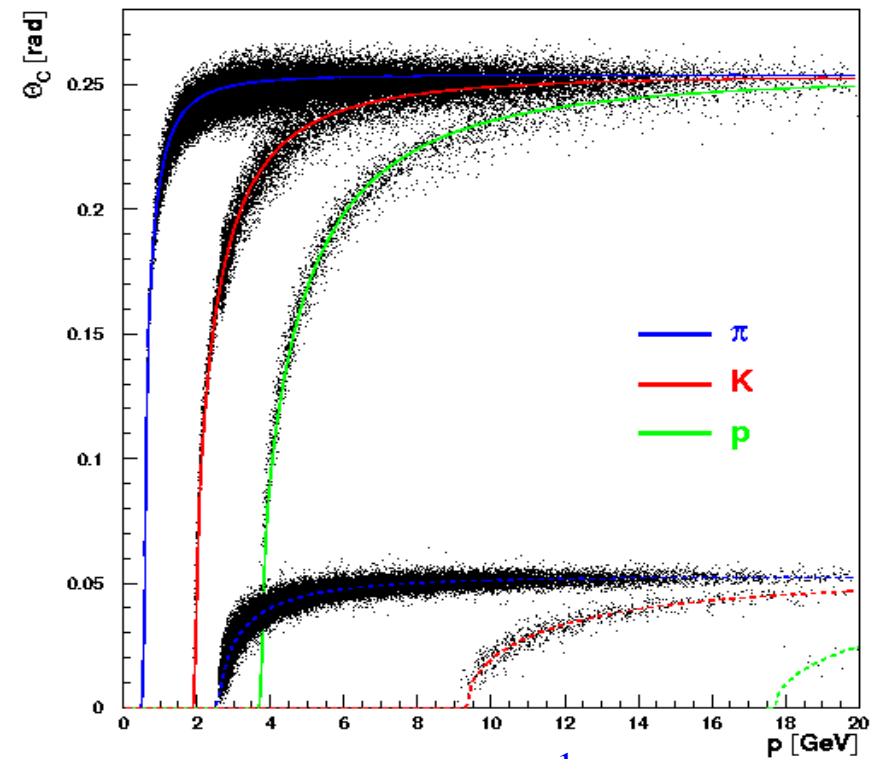
- TRD
- calorimeter
- preshower
- RICH



## hadron identification

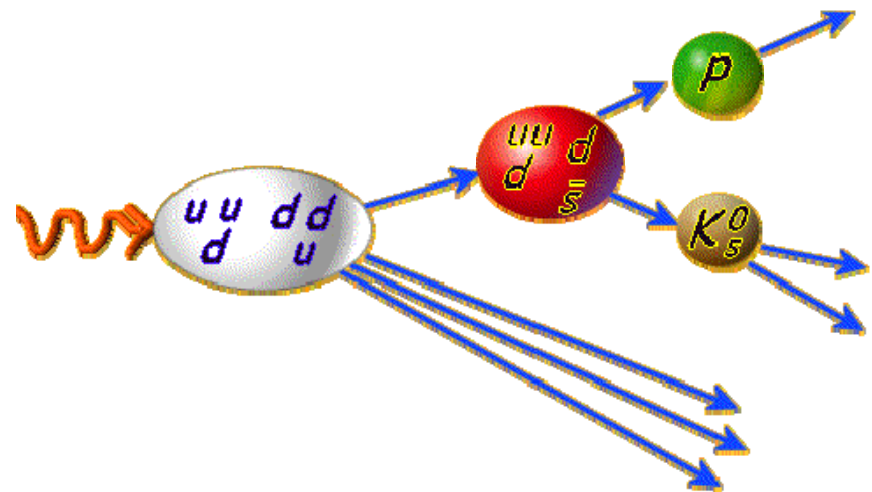
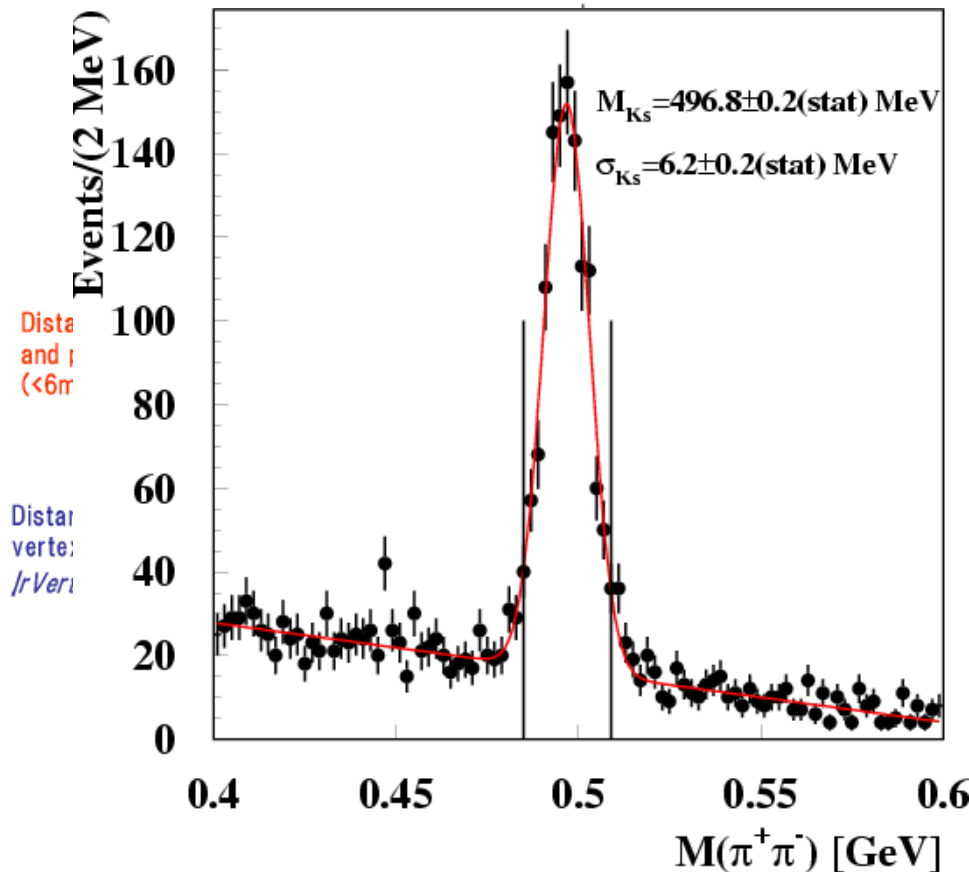
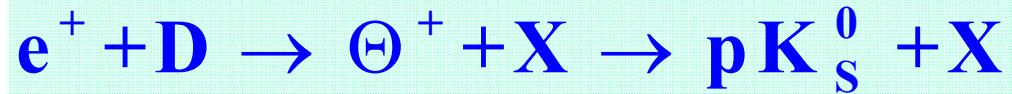
Dual radiator RICH

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



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

# Event Reconstruction

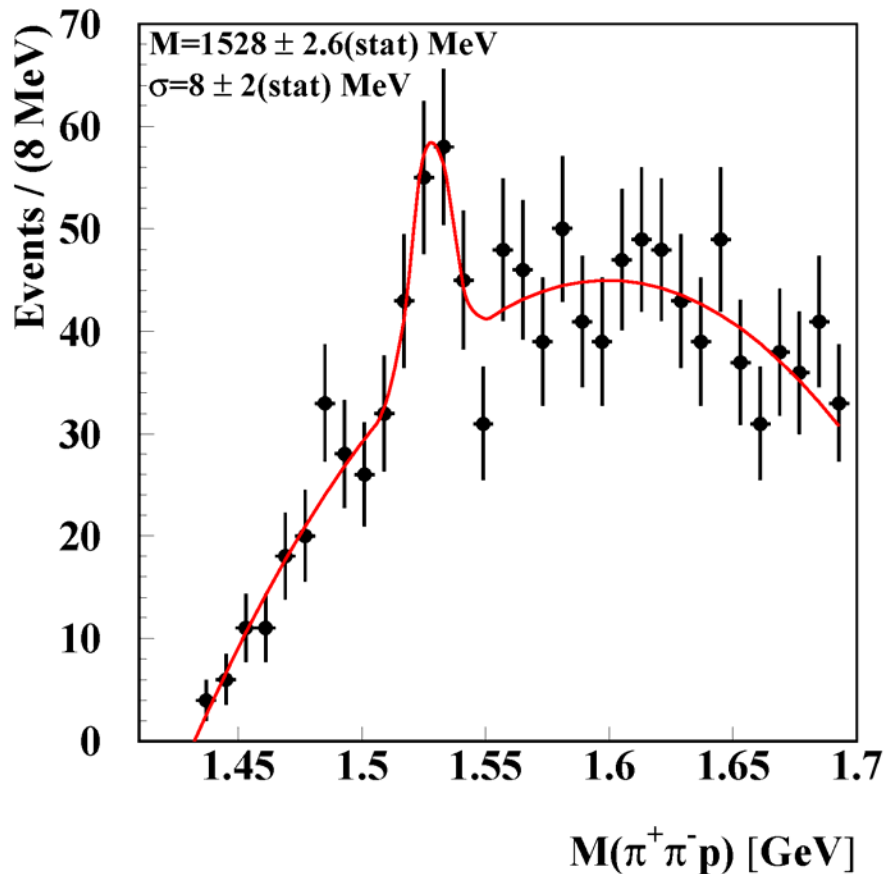


$\tau$ : 1–15 GeV  $\rho$ : 4–9 GeV

on of each decay particle,

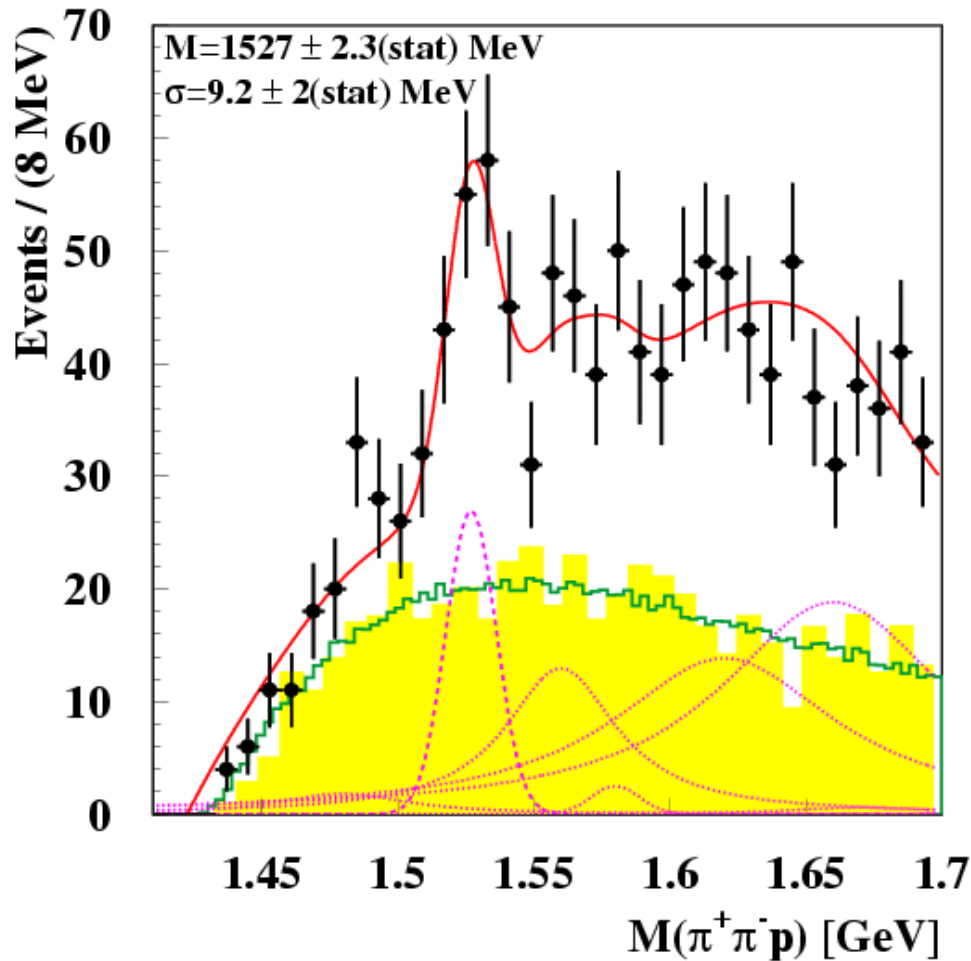
- Suppress contamination from  $\Lambda(1116) \rightarrow p\pi^-$

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



- events selected in a  $\pm 2\sigma$  window about  $K_S$  peak
- Peak is observed at  $1528 \pm 2.6(\text{stat}) \pm 2.1(\text{syst})$  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  $3-5 \sigma$
- Three models of background were studied

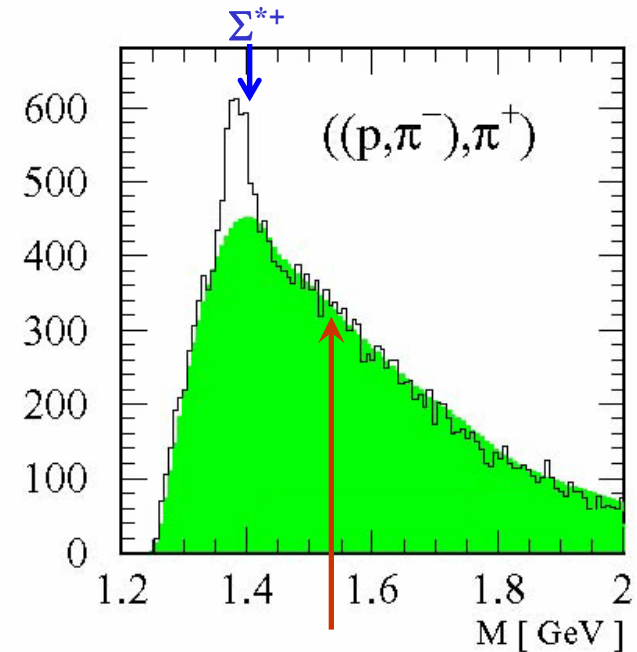
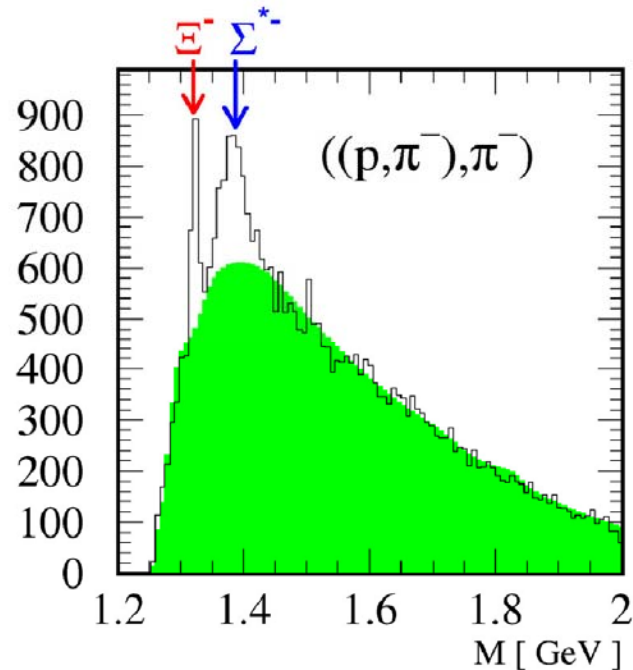
# PYTHIA6 and mixed-event backgrounds



- **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  $\Sigma^*$  hyperons not included in PYTHIA6 lie below 1500 MeV and above 1550 MeV
- **Mass =  $1527 \pm 2.3 \text{ MeV}$**
- **$\sigma = 9.2 \pm 2 \text{ MeV}$**
- **Significance  $4.3\sigma$**

# $\Theta^+$ or $\Sigma^{*+}$ ?

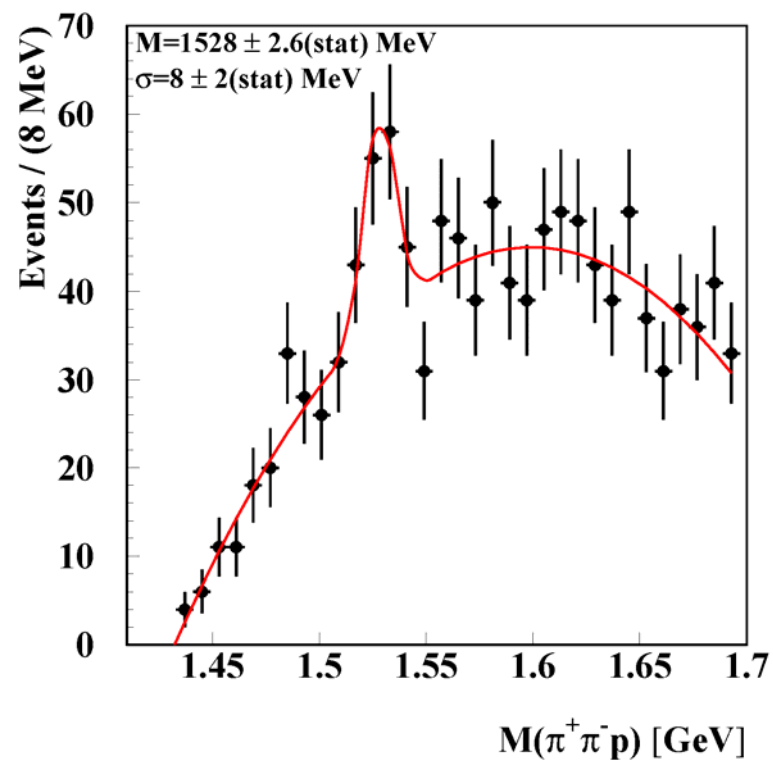
- Is our peak a previously missing  $\Sigma^*$  or a pentaquark state?
- If peak is  $\Sigma^{*+}$   $\Rightarrow$  also see a peak in  $M(\Lambda\pi^+)$



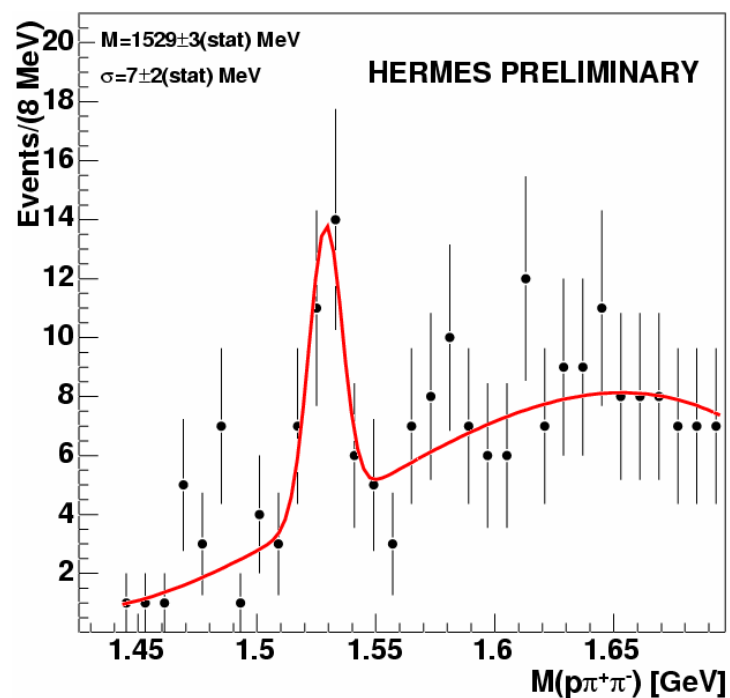
No peak in  $\Lambda\pi^+$  spectrum near 1530 MeV

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

## Further background suppression - additional $\pi$



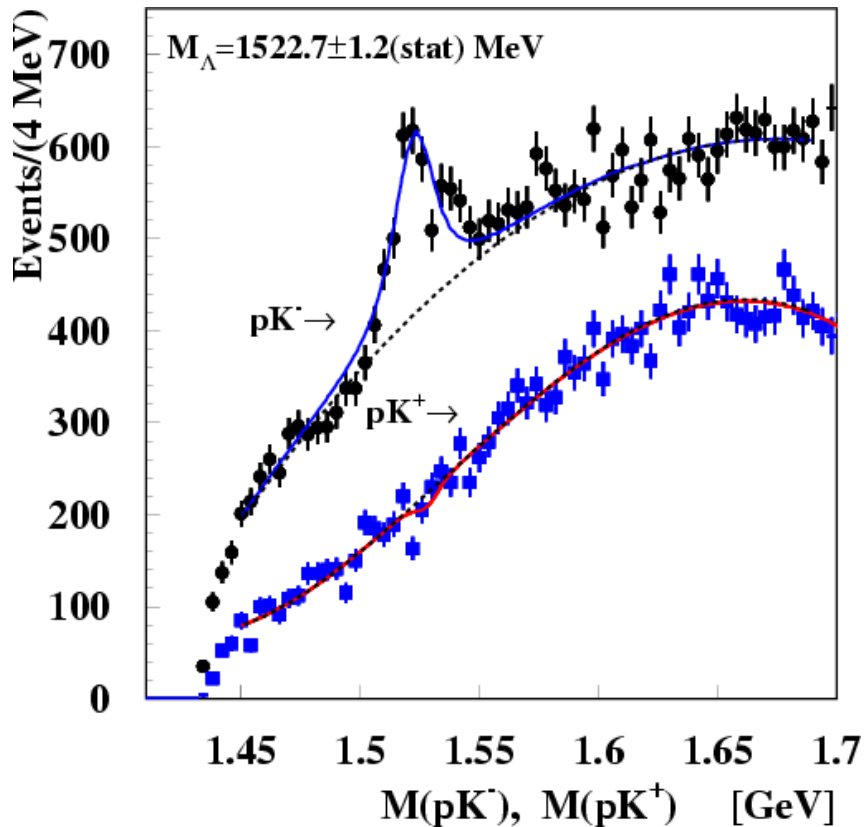
➤ signal/background: 1 : 3



➤ signal/background: 2 : 1  
same kinematic cuts



# What is the Isospin of the $\Theta^+$ ?



In the decay channels:

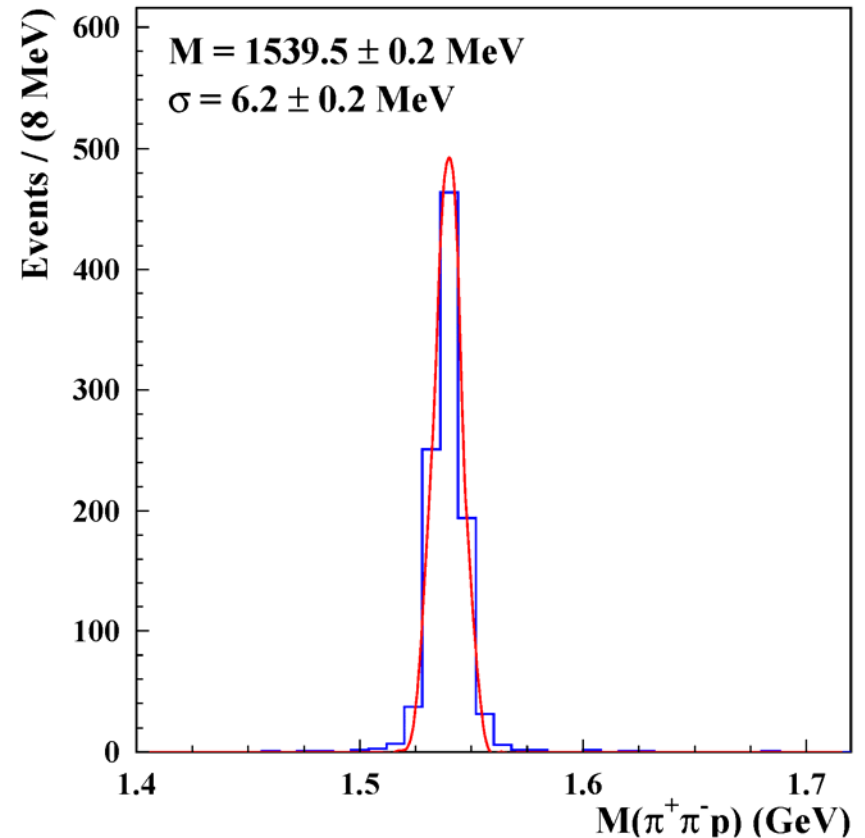
- $pK^-$ : clear  $\Lambda(1520)$  peak at 1522.7 MeV
- $pK^+$ : no peak, zero counts at 91% C.L.

Not isotensor

➔ probably **isosinglet**

# Width of Peak

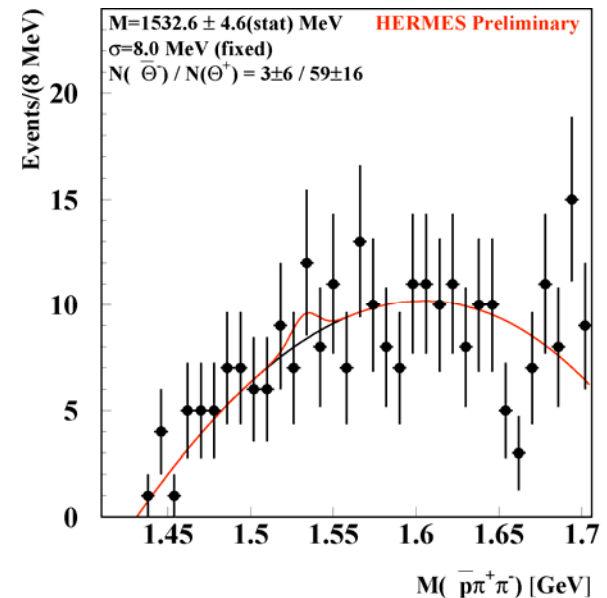
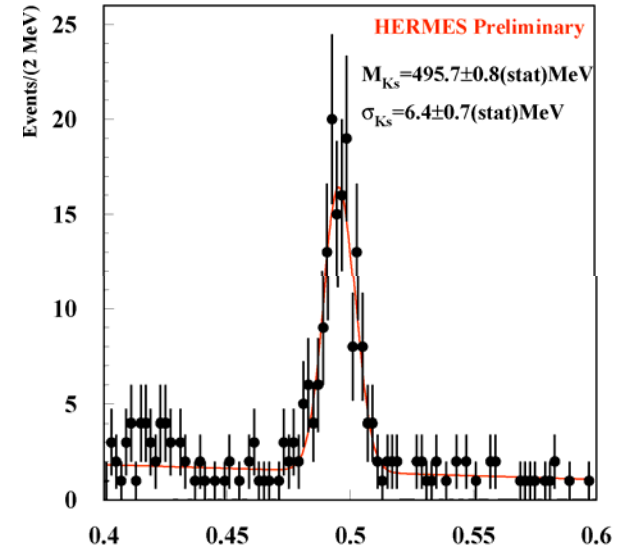
- $\Theta^+$  Monte Carlo with complete detector simulation
- generated peak:  
 $M = 1540 \text{ MeV}$ ,  $\sigma = 2 \text{ MeV}$
- reconstructed peak:  
 $M = 1539.5 \text{ MeV}$ ,  $\sigma = 6.2 \text{ MeV}$   
 $\Delta_{\text{detect.}} (\text{FWHM}) = 10\text{--}14.6 \text{ MeV}$
- $\text{FWHM}_{\text{meas.}}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



***Intrinsic width:  $\Gamma = 17 \pm 9 \pm 3 \text{ MeV}$***

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

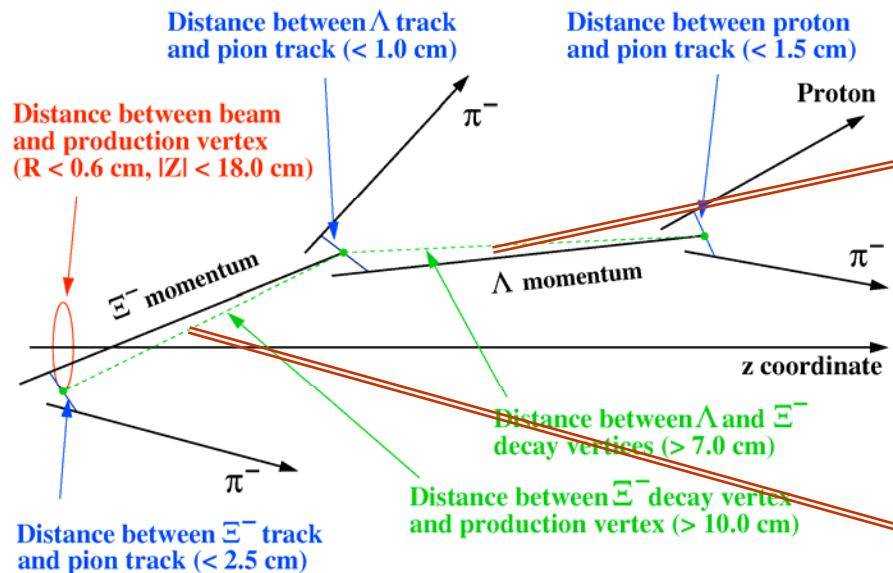
- **Goal:** compare cross section ratio of  $\Theta^-$  to  $\Theta^+$  production with ratio of  $\bar{\Lambda}(1520)$  to  $\Lambda(1520)$  production ( $\sim 1:5$ ) or  $\bar{\Xi}^0(1530)$  to  $\Xi^0(1530)$  production (1:4)  
→ shed light on production mechanism
- same event selection and kinematic constraints as for  $\rho\pi^+\pi^-$
- Gaussian plus 3<sup>rd</sup> 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  $\Theta^+$  and  $\Theta^-$ .



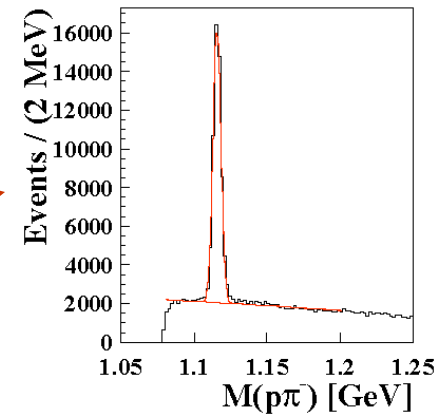
# Search for reported $\Xi^{--}$ (1862) Exotic

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

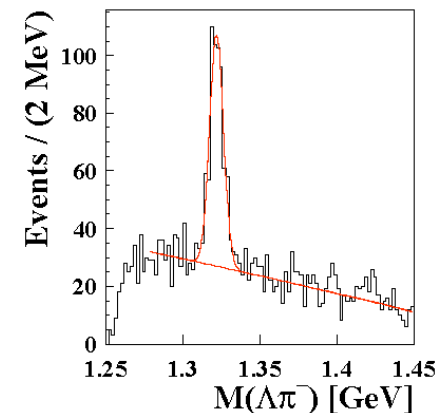
➤ Topology:



➤  $M(p\pi^-)$  with  $\Lambda$



➤  $M(p\pi^-\pi^-)$  with  $\Xi^-$

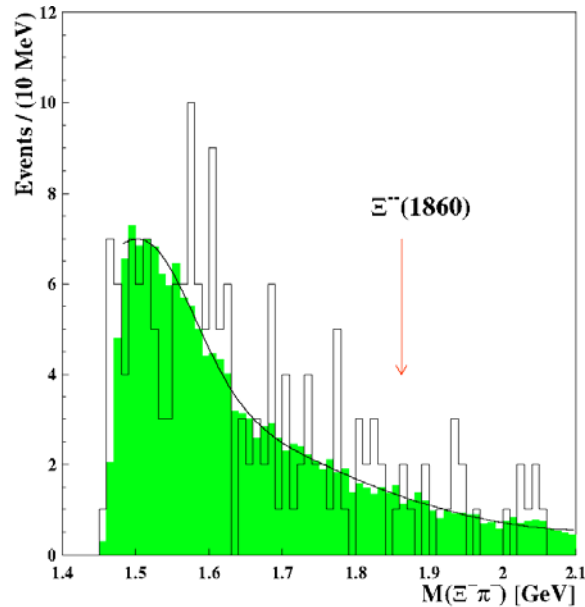


➤ Selected  $\Lambda$  events ( $2\sigma$  window)

➤ Selected  $\Xi^-$  events ( $2\sigma$  window)

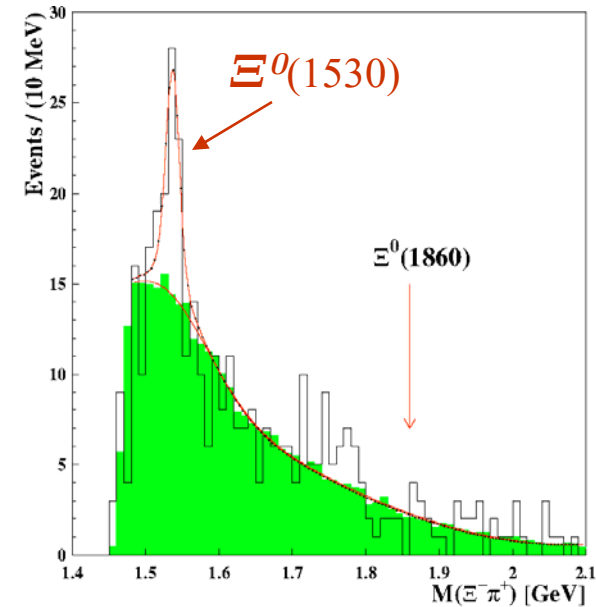
# $\Xi^{--}$ (1862) search (II)

➤  $M(p\pi^-\pi^-\pi^-)$  spectrum



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

➤  $M(p\pi^+\pi^-\pi^-)$  spectrum



- 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<sup>-1</sup>
- all measurements done in quasi-real photoproduction ( $Q^2 \ll 1 \text{ GeV}^2$ )
- Acceptances from Monte Carlo:

$\Lambda(1520)$ : 1.5%

$\Theta^+$ : 0.05%

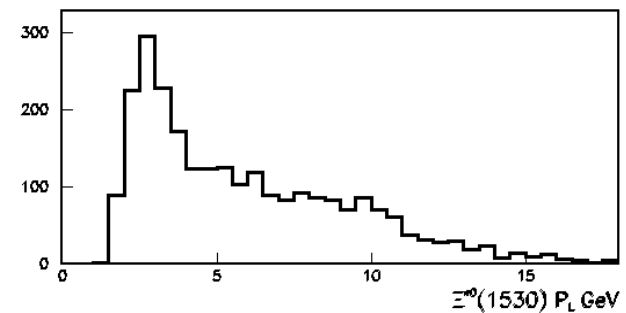
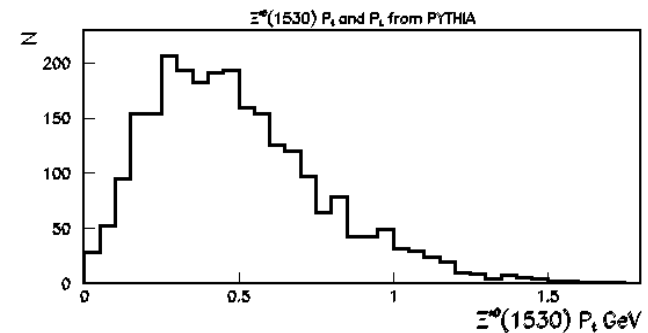
$\Xi^0(1530)$ : 0.036-0.1%

$\Xi^0(1860)$ : 0.065%

$\Xi^{*-}(1860)$ : 0.031%

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

PYTHIA6  $p_t$  and  $p_z$  spectra



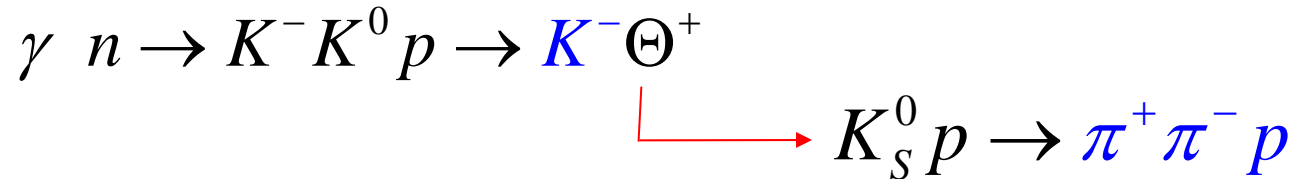
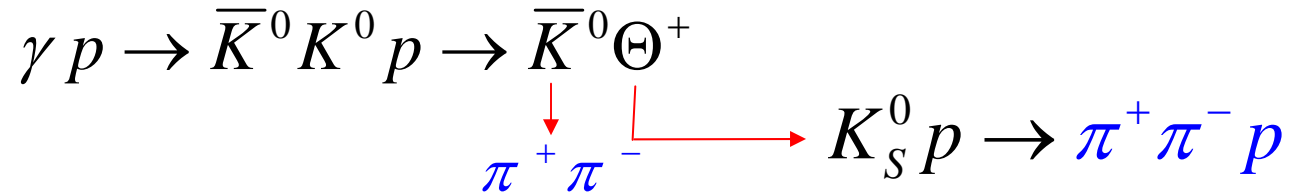
OR:  $p_t$  and  $p_z$  spectra from  $\Lambda_{\text{exp}}$

$\sigma(\Lambda(1520)) = 62 \pm 11 \text{ nb}$

$\sigma(\Xi^0(1530)) = 8.8\text{-}24 \text{ nb}$

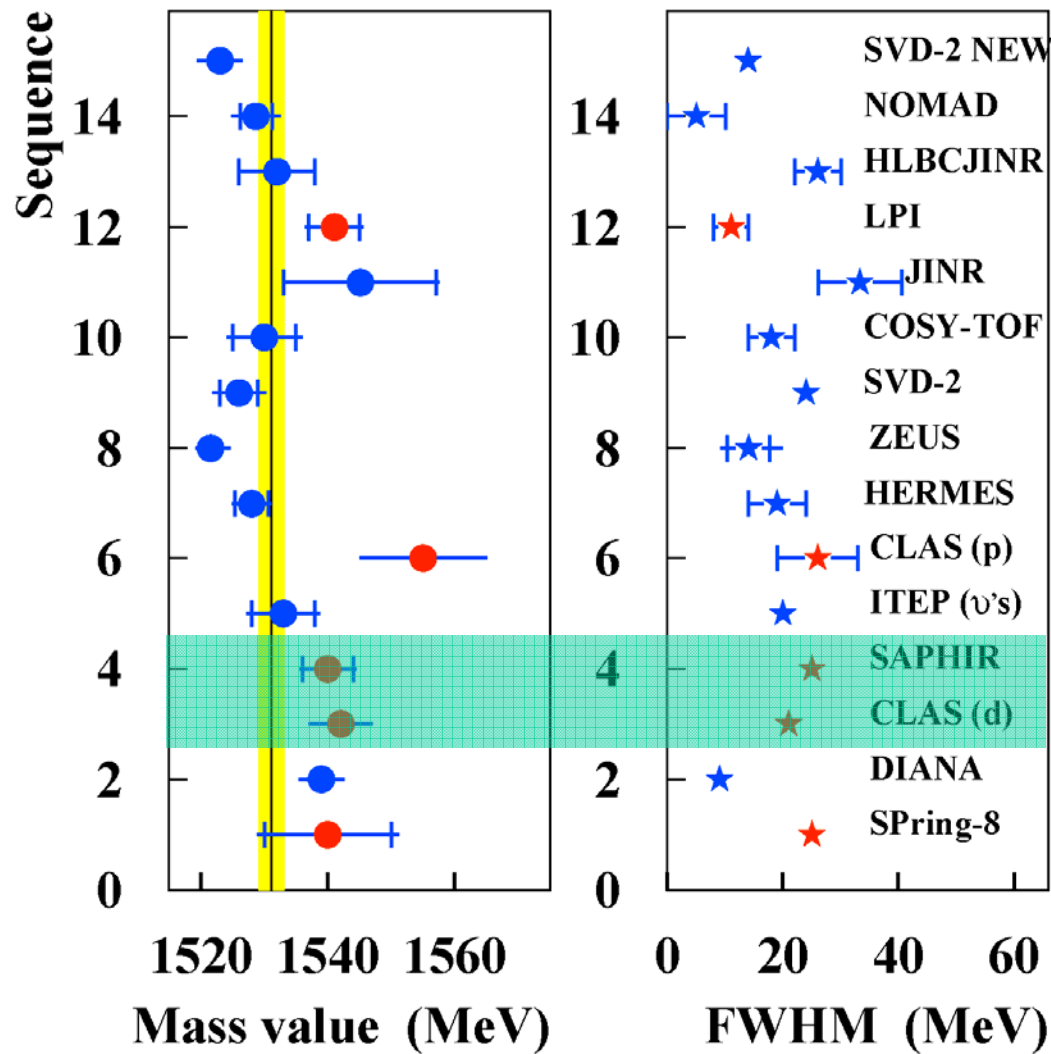
# Production process at HERMES ?

- can additional pion come from exclusive processes?



- associated  $K^-$  or  $K_S$  from exclusive processes goes backward
  - even decay pions from  $K_S$  are inaccessible
  - PID threshold requires  $p(\Theta^+) > 7 \text{ GeV}/c$
- tagged pions events cannot come from these exclusive processes
  - ⇒ production process has to be at least partially inclusive
    - inclusive processes increase with higher energy
    - exclusive processes decrease with higher energy

# Comparison with World Data



Decay channel:



World Average:

**1531.1 ± 2.1 MeV**

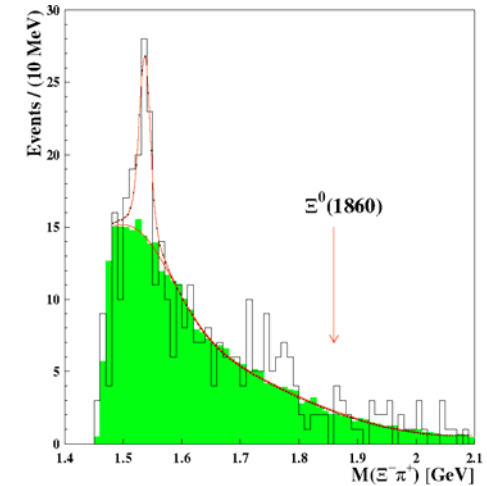
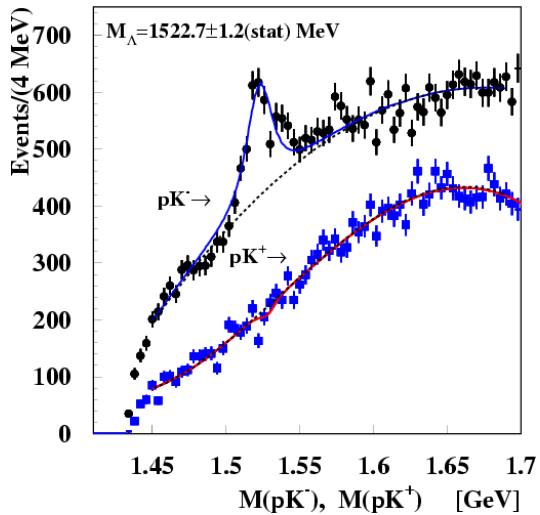
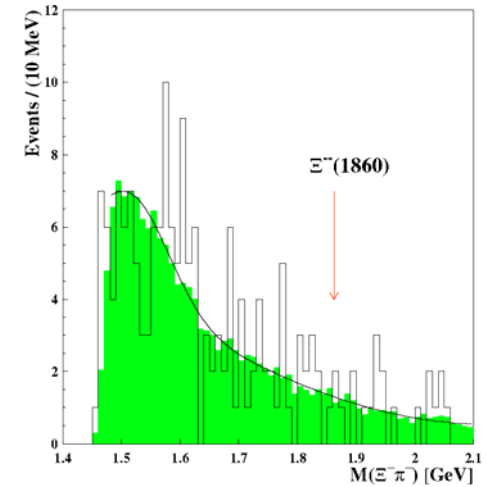
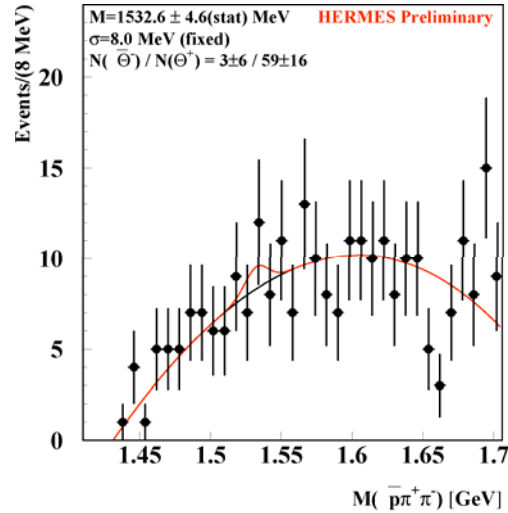
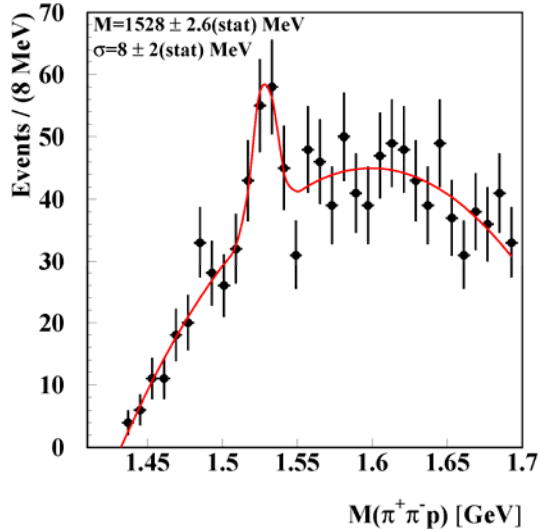
Observation of peak in two decay channels in same experiment

→ would be convincing!





# Summary – HERMES results on 5q exotics



PLB 585 (2004) 213

PRD 71 (2005) 032004



W. Lorenzon

Pentaquark05 – Oct 2005

# Conclusions and Outlook

- Direct reconstruction of  $pK_s$  invariant mass



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

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

Significance:  $\sim 4 \sigma$

- $\Theta^+$  is probably an **isosinglet**
- additional  $\pi$  improves signal/background,  
→ eliminates  $K_s$  contamination from various processes
- Production process is at least partially inclusive
- No evidence observed for  $\Xi^-$  or  $\Xi^0$  near 1860 MeV
- Anticipate x5 higher statistics by summer 2007