Search for ‘exotic’ baryons at HERMES

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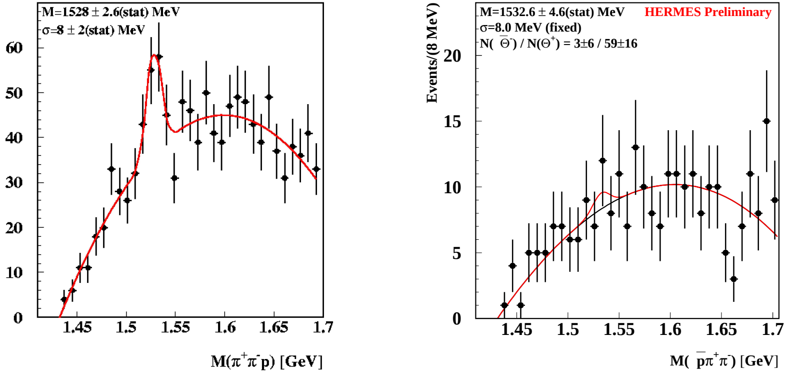
Overview

- Motivation
  - $\Theta(1540)$ at HERMES
  - Photo-production of $\Lambda(1520)$ and $\Theta(1540)$
  - Hadron photo-production
- The HERMES Spectrometer
- Event selection and reconstruction
- $\Lambda(1520)$ spectra and cross section
- Conclusions

Motivation

Exotics at HERMES

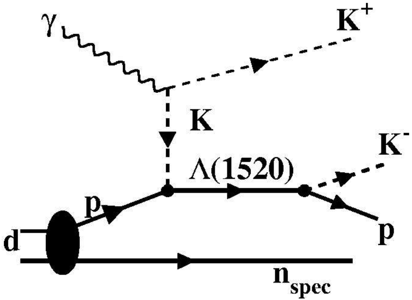
- $\Theta(1540)$ observed (59 ± 16 events)
  $M = 1528 \pm 2.6(\text{stat}) \pm 2.1(\text{syst})$ MeV
- $\bar{\Theta}(1540)$ not observed (3 ± 6 events)

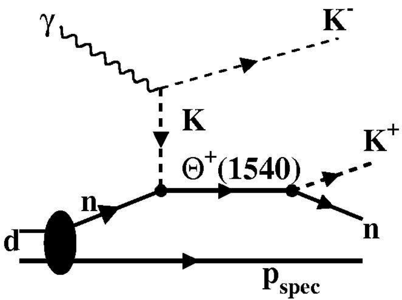


Motivation

Photo-production of $\Lambda(1520)$ and $\Theta(1540)$

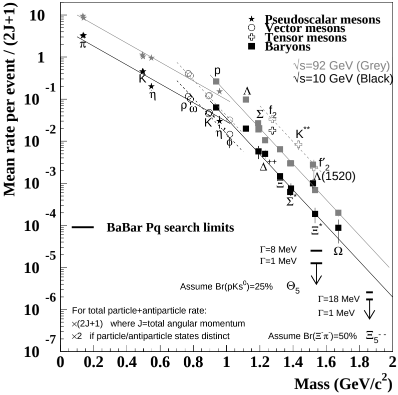
- In some models: production mechanism similar
- Assumption: anti-particle/particle ratio similar
- Determine cross section ratios $\bar{\Lambda}/\Lambda$, Θ/Λ, $\bar{\Theta}/\bar{\Lambda}$





Motivation

Hadron production



BaBar: search for Θ^+ and Ξ^{--}

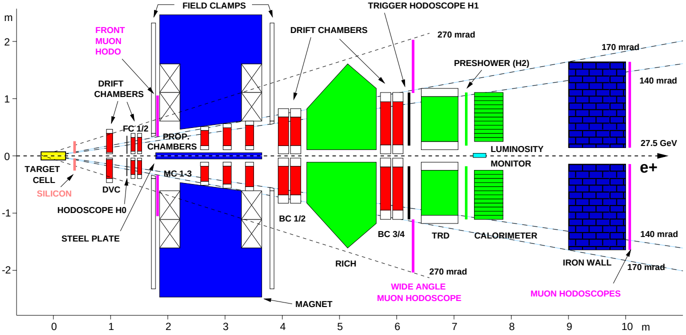
Mesons and baryons

- BaBar: $ee \rightarrow (q\bar{q})^n \rightarrow X$
- Different slope for mesons and baryons!

Exotics at HERMES

- HERMES: photo-production
- Do exotics have a different slope?
- Where is our σ_Θ?

The HERMES Spectrometer



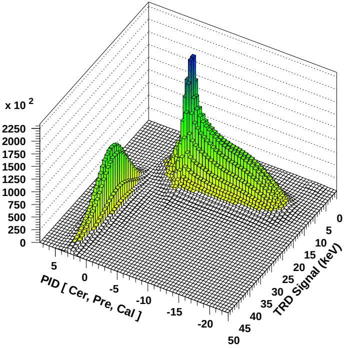
- 27.6 GeV $e^{\pm}$ HERA beam on $\overrightarrow{H}$, $\overrightarrow{He}$, $\overrightarrow{D}$ or H_2, D_2, He,...
- Resolution: $\frac{\Delta p}{p}$ = 1.4 – 2.5%, $\Delta\vartheta \lesssim 0.6$ mrad
- TRD, Calorimeter and Preshower: hadron/lepton separation
- RICH: hadron identification (p, π, K)

The HERMES Spectrometer

Hadron/lepton separation:

combination of

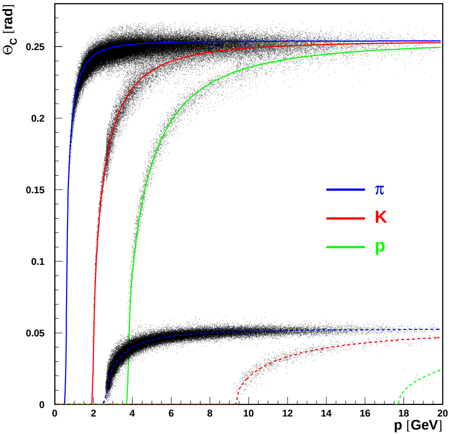
- TRD
- Calorimeter
- Preshower
- RICH



Hadron identification:

dual radiator RICH

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

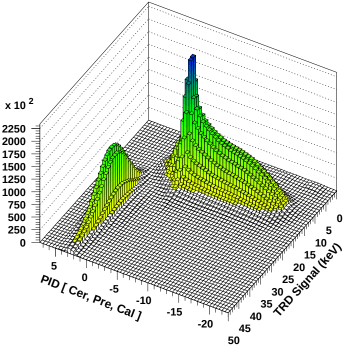


The HERMES Spectrometer

Hadron/lepton separation:

combination of

- TRD
- Calorimeter
- Preshower
- RICH



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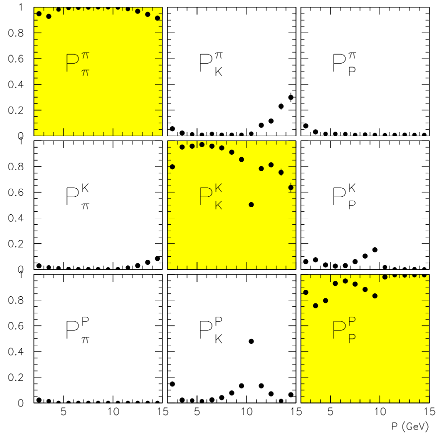


Event selection and reconstruction

209.2 pb^{-1} of deuterium data

- $e^+D \to \Lambda(1520)X \to pK^-X$
- $e^+D \to \bar{\Lambda}(1520)X \to \bar{p}K^+X$

Event topology (checked in Monte Carlo)

- p and K tracks closer than 0.6 cm
- $\Lambda(1520)$ decayed inside target
  - $R < 0.4\,\mathrm{cm}$
  - $|z| < 18\,\mathrm{cm}$
- $\Lambda(1520)$ decay length $< 5\,\mathrm{cm}$ (motivated by resolution)

Invariant mass spectra

Acceptance correction (MC)

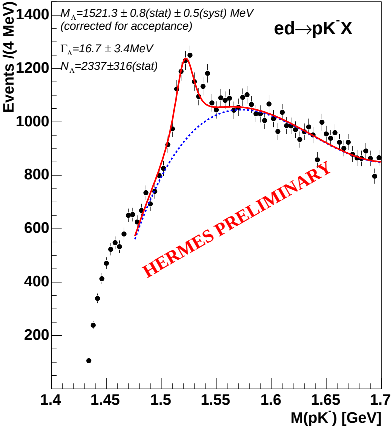
- Acceptance varies in $\Lambda(1520)$ mass region
- Shape of peak changes to skewed Breit-Wigner
- Mass from simple Breit-Wigner 1.5 ± 0.5 MeV too high

Unbinned maximum likelihood fi t

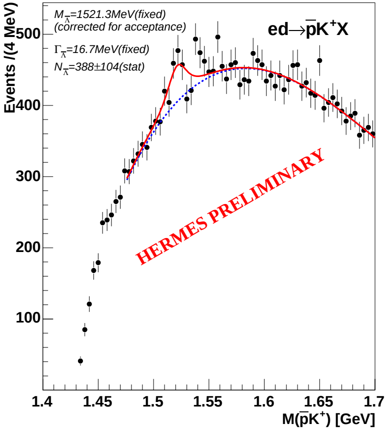
- Breit-Wigner resonance shape
- Convolved with Gaussian detector resolution (4 MeV)
- Polynomial background (third order)
- Procedure:
  - Determine the M and Γ from $\Lambda(1520) \rightarrow pK^-$ spectrum
  - Fix M and Γ for $\bar{\Lambda}(1520) \rightarrow \bar{p}K^+$ spectrum

Invariant mass spectra

$\Lambda(1520) \rightarrow pK^-$



$\bar{\Lambda}(1520) \rightarrow \bar{p}K^+$



- $M = 1521.3 \pm 0.8(\text{stat}) \pm 0.5(\text{syst})\,\text{MeV}$
- $\Gamma = 16.7 \pm 3.4\,\text{MeV}$

- $M_{PDG} = 1519.5 \pm 1.0\,\text{MeV}$
- $\Gamma_{PDG} = 15.6 \pm 1.0\,\text{MeV}$

Partial cross sections and ratio

Method of calculation (total cross section)

$$\sigma_{\gamma^* D \to \Lambda(1520) X} = \frac{N^{eD \to \Lambda(1520) X}_{observed}}{\Phi \cdot Br \cdot \mathcal{L} \cdot \epsilon} \qquad (1)$$

- photon flux $\Phi = 0.02\,\mathrm{GeV}^{-3}$
- branching ratio $Br = 22.5\%$
- integrated luminosity $\mathcal{L} = 209.2\,\mathrm{pb}^{-1}$
- efficiency and acceptance ϵ... (full momentum range)

Effi ciency and acceptance ϵ

- Determine ϵ using Monte Carlo simulation
- PYTHIA Monte Carlo: no $\Lambda(1520)$ state available...
- Model for decay momentum distribution of $\Lambda(1520)$ necessary

Partial cross sections and ratio

Effi ciency and acceptance ϵ

- Previous results (Θ, Ξ^{--}): assumed Ξ^{0*} momenta
- Now: looked at several hyperons (Λ, Σ, Ξ, Σ^*, Ξ^*)
- ϵ depends strongly on decay momentum distribution
  - 0.03 – 3% for full momentum range, depending on model
- In HERMES acceptance ($P_z > 6$ GeV): momenta very similar
  - 3 – 4% inside acceptance
- Differences from behavior outside HERMES acceptance

Polarization $\Lambda(1520)$

- $\Lambda(1520)$ has spin $J = \frac{3}{2} \rightarrow$ momentum distributions change
- Presented results assume isotropic decay ($J = 0$)
- Effect of $J \neq 0$ not in systematic uncertainty

Partial cross sections and ratio

$P_z > 6\,\mathrm{GeV}$

- Motivated by HERMES acceptance for $\Lambda(1520)$

Photo-production cross sections

- $\sigma_{\gamma^* D \to \Lambda(1520) X} = 65.3 \pm 8.8(\mathrm{stat}) \pm 6.9(\mathrm{syst})\,\mathrm{nb}$
- $\sigma_{\gamma^* D \to \bar{\Lambda}(1520) X} = 9.8 \pm 2.6(\mathrm{stat}) \pm 0.9(\mathrm{syst})\,\mathrm{nb}$

Cross section ratio $\bar{\Lambda}(1520)$ over $\Lambda(1520)$

- $R_{\bar{\Lambda}/\Lambda} = 0.15 \pm 0.05(\mathrm{stat}) \pm 0.02(\mathrm{syst})$

Extrapolation to $\bar{\Theta}(1540)$

Assumptions

- Production mechanism $\Lambda(1520)$ and $\Theta(1540)$ similar
- Cross section ratio $\Lambda(1520)$ and $\Theta(1540)$ equal

Expected number of $\bar{\Theta}(1540)$

- 59 ± 16 $\Theta(1540)$ observed
- 10 ± 4 $\bar{\Theta}(1540)$ are expected when $R_{\bar{\Theta}/\Theta} = R_{\bar{\Lambda}/\Lambda}$
- 3 ± 6 $\bar{\Theta}(1540)$ were observed

Conclusions

Summary

- Partial cross sections of the $\Lambda(1520)$ ($P_z > 6\,\mathrm{GeV}$) presented:
  - $\sigma_{\gamma^* D \to \Lambda(1520) X} = 65.3 \pm 8.8(\mathrm{stat}) \pm 6.9(\mathrm{syst})\,\mathrm{nb}$
  - $\sigma_{\gamma^* D \to \bar{\Lambda}(1520) X} = 9.8 \pm 2.6(\mathrm{stat}) \pm 0.9(\mathrm{syst})\,\mathrm{nb}$
- Ratio of $\bar{\Lambda}(1520)$ over $\Lambda(1520)$ production
  - $R_{\bar{\Lambda}/\Lambda} = 0.15 \pm 0.05(\mathrm{stat}) \pm 0.02(\mathrm{syst})$
- Assuming similar $\Theta(1540)$ and $\Lambda(1520)$ production mechanisms, the expected number $\bar{\Theta}(1540)$ is 10 ± 4, and 3 ± 6 were observed.

Plans

- Data taking on hydrogen and deuterium is continuing
- Analysis of hydrogen data ongoing