Pentaquark search at HERA-B

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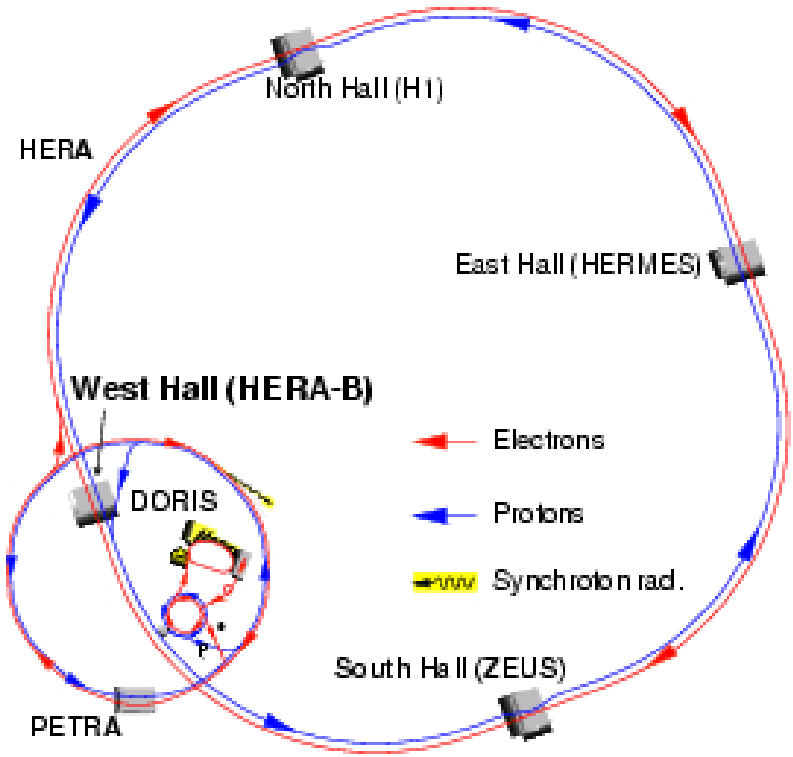
- Detector
- Data sample
- Classical states
- Pentaquark: p-K^0 and Ξ-π channels
- Conclusion

Experiment location

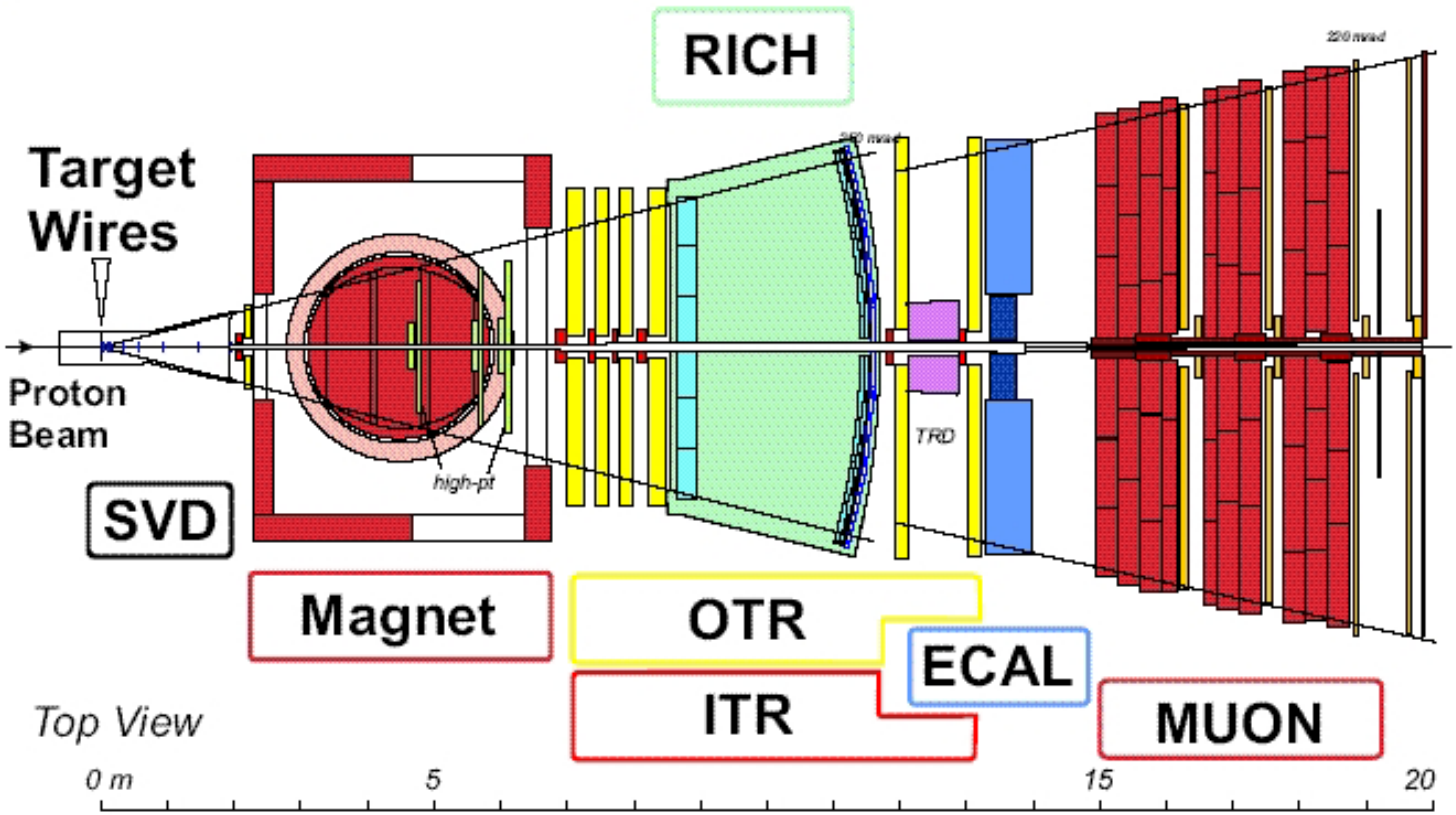
HERA-B is a fixed target experiment at the HERA storage ring at DESY.

It detects the charged particles generated in the interactions of the 920 GeV proton beam halo with different target wires (^{12}C, ^{184}W, ^{48}Ti)



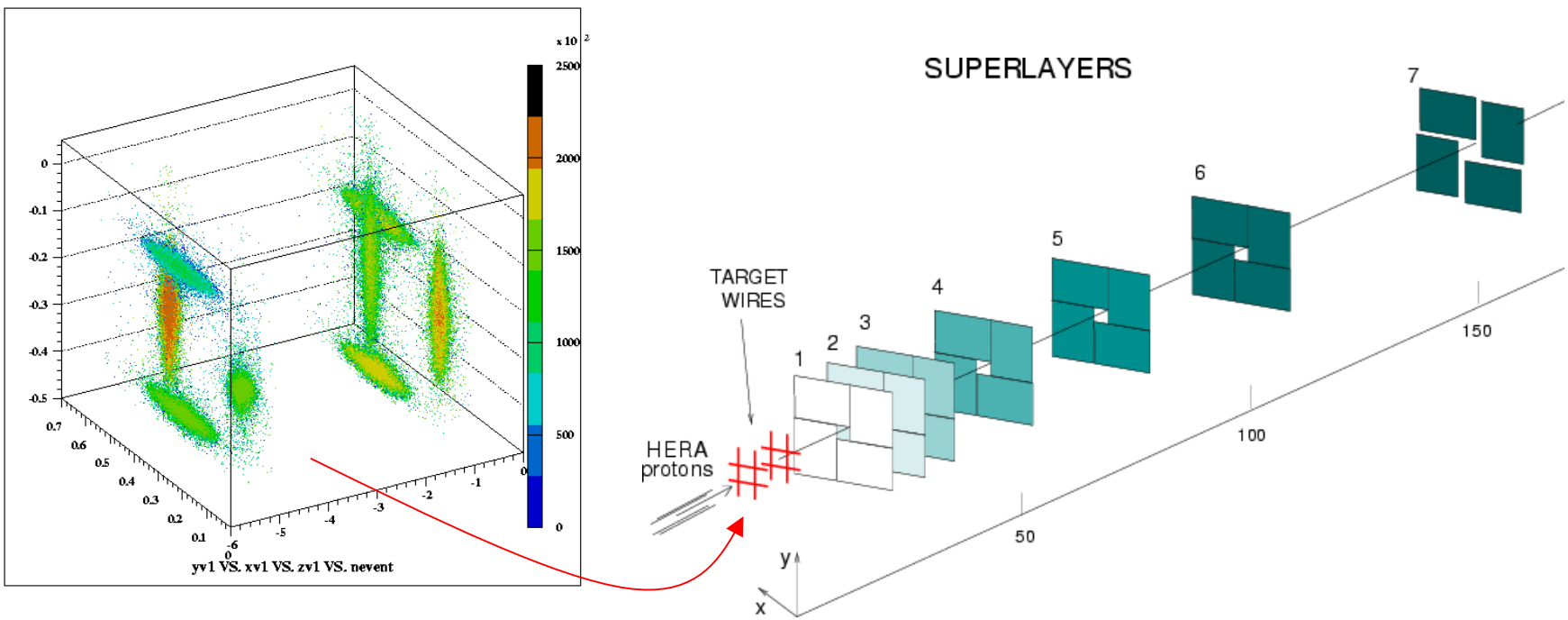
HERA-B detector

- pA interaction at E_{cms} ~ 41.6 Gev and IR ~ 5 MHz
- Large acceptance at mid-rapidity (y: 15-160 mrad, x: 15-220 mrad)



Silicon Vertex Detector

- 7 superalyers of silicon microstrips
- High primary vertex resolution ($\sigma_x \sim \sigma_y \sim 50\ \mu m$, $\sigma_z \sim 450\ \mu m$)

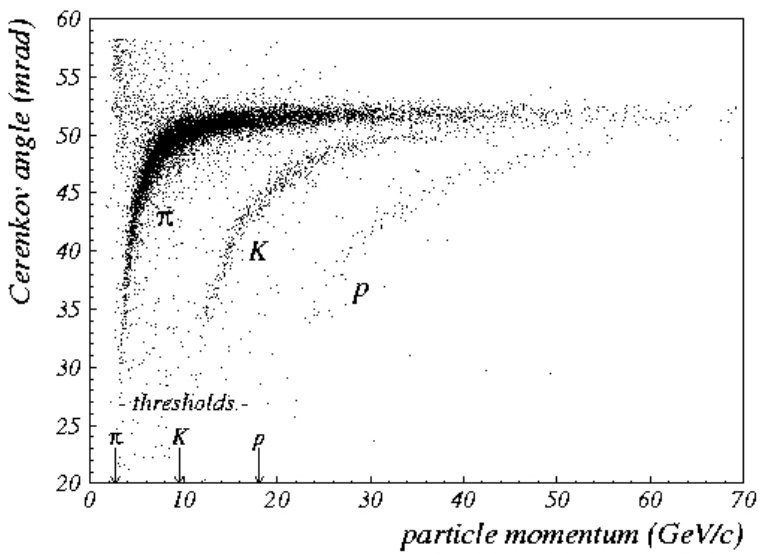


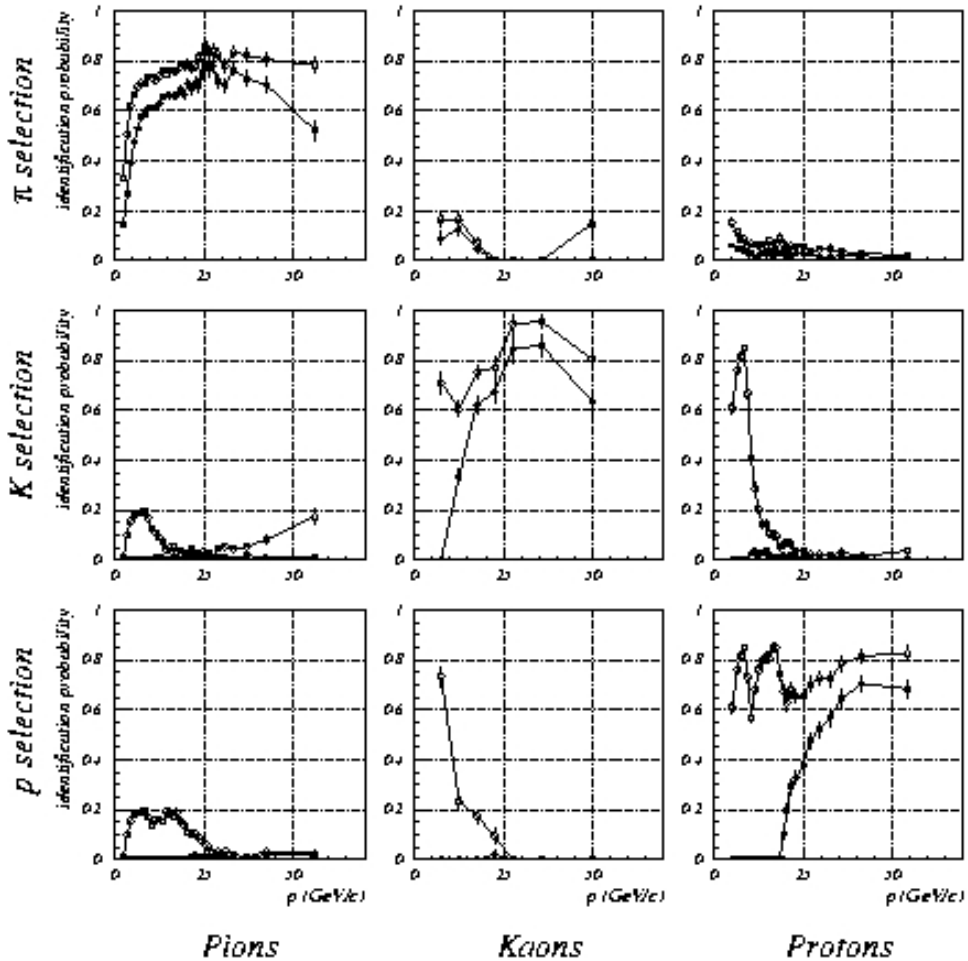
Ring Imaging CHerenkov detector

good kaon ID for 10< p <60 GeV

good proton ID for 20< p <60 GeV

(Arino et al., hep-ex/0303012)





Data Sample

Data taken in November 2002 – February 2003

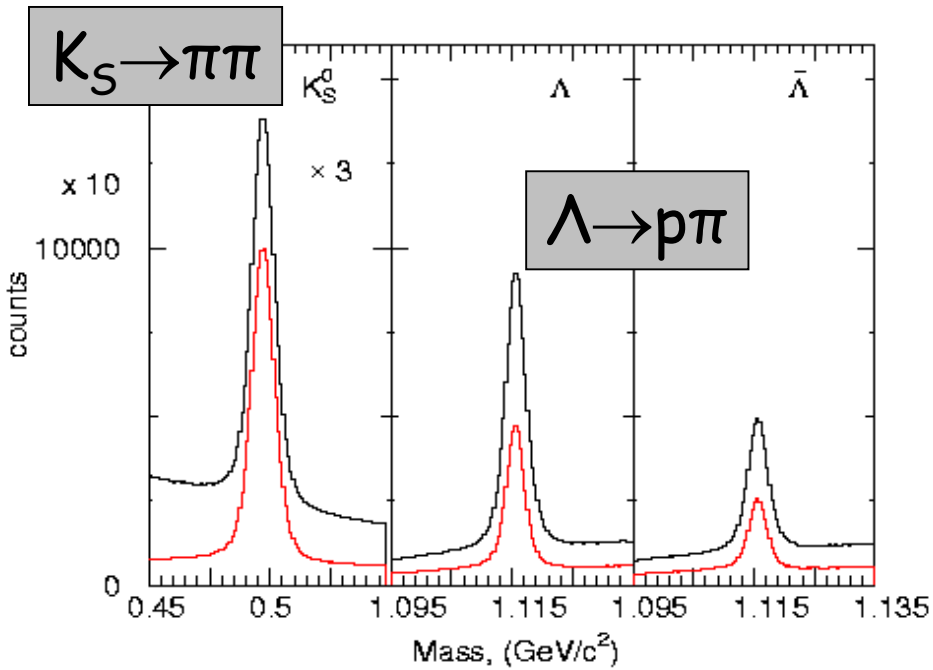
210×10^6 "minimum bias" events (^{12}C, ^{184}W and ^{48}Ti)

• Interaction trigger: events with a minimum number of hits in the RICH or in the ECAL were written to tape at the speed of ~ 1 kHz.

In addition (for possible further improvement):

150×10^6 events (^{12}C, ^{184}W) using J/Ψ trigger: events with at least 2 muon or electron candidates were written to tape at the speed of ~ 100 Hz (~300.000 J/Ψ)

Reconstruction of K^0, Λ



cuts applied:

- impact to primary vertex < 500 μm
- dist. closest approach < 300 μm
- $p_t c\tau$ > 0.02 (Gev/c)×cm

Backgound rejection: 95%

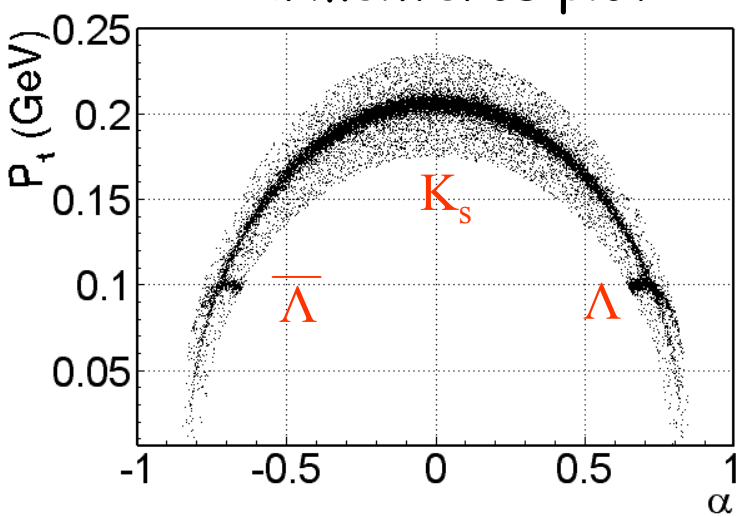
Signal efficiency: 90%

stat.: ~3.400.000 K_s, σ ~ 4,9 MeV

stat.: ~940.000 (~450.000) Λ, σ ~ 1,8 MeV

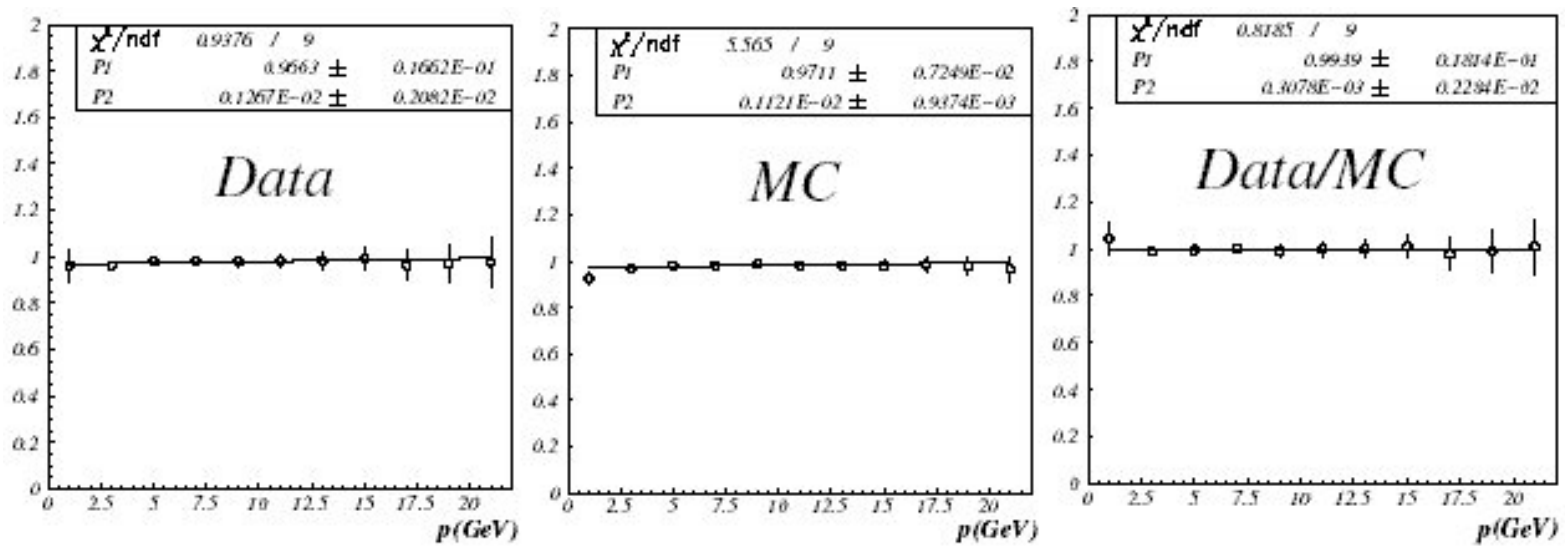
-> good starting point for PQ

Armenteros plot



Tracking efficency

Using the large sample of $K^0 \rightarrow \pi\pi$ decays, it is possible to estimate the tracking efficiency.



For tracks hitting all superlayers, the average efficiency in the full kinematical range is (96.7 ± 0.9)% and it is almost constant.

Reconstruction of $\varphi \rightarrow K\,K$

good kaon identification

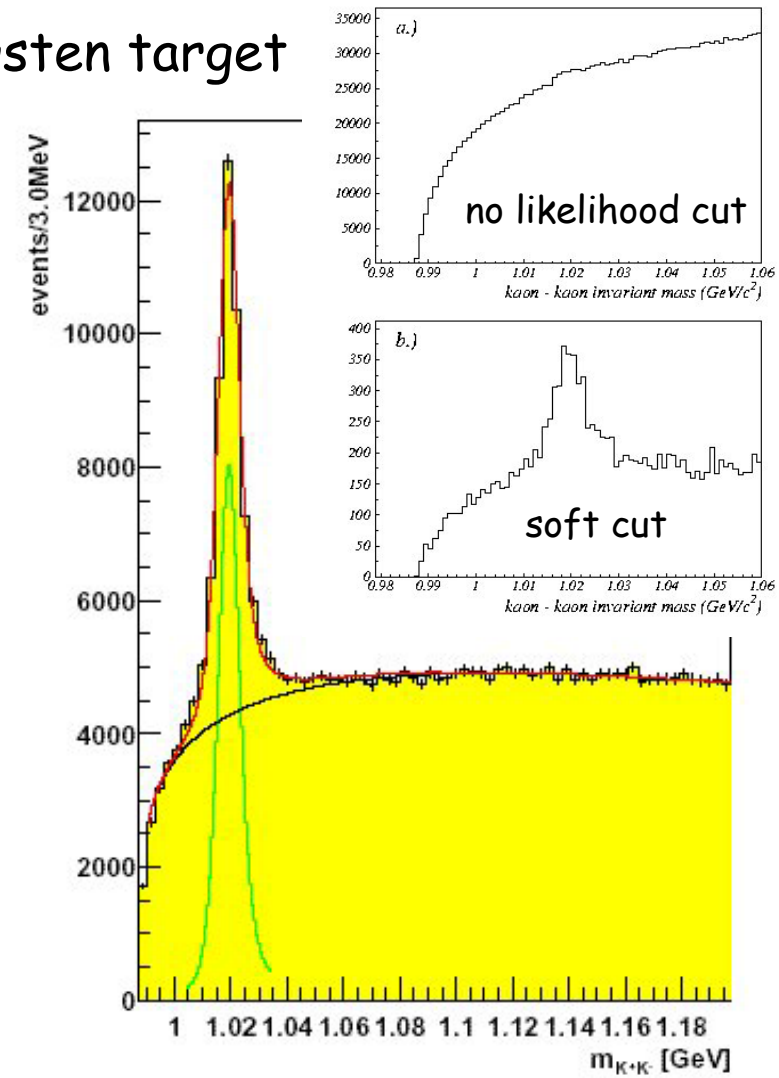
cuts applied:

- soft cut on K likelihood
- vertex prob. > 10^{-6}
- p_k > 10 GeV

stat.: ~ 50.000 φ (~130 M events)
σ: ~ 2,6 MeV

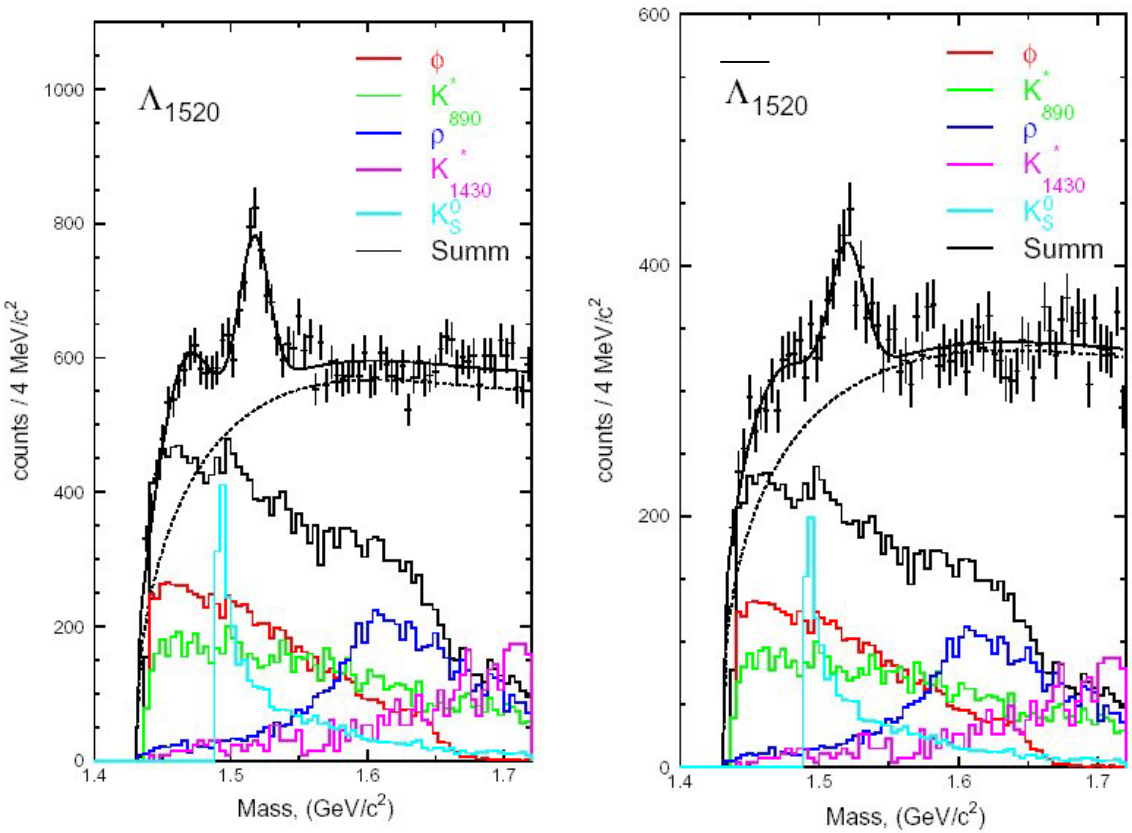
Interensting to make comparison with other experiments

Tungsten target



Reconstruction of $\Lambda(1520) \rightarrow p\ K$

Carbon target



cuts applied:

p likelihood > 0.95

K likelihood > 0.95

A strong signal visible at 1520 Gev for both particle and antiparticle.

Simulation of kinematic reflections of two-body decays are also shown.

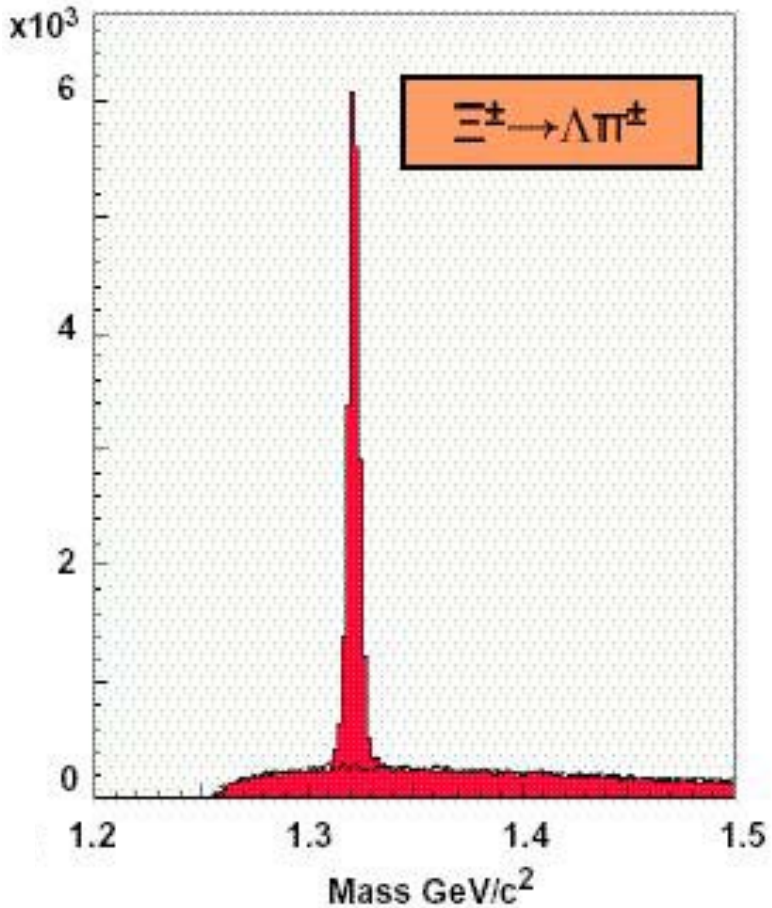
good proton identification

$\overline{\Lambda}$: ~ 2000, σ ~ 8 MeV

Λ: ~ 1000, σ ~ 8 MeV

Reconstruction of $\Xi \rightarrow \Lambda\pi$

All targets



For this analysis a subsample of ~ 160 M events has been used.

- Λ selection has been shown.
- Ξ^- candidate point to the primary.
- Λ and π have large impact to primary

The peak is at the correct position

statistics: ~11.300 Ξ^-, ~7.700 $\bar{\Xi}^+$,
resolution: ~ 2,6 MeV

PQ and HERA-B data

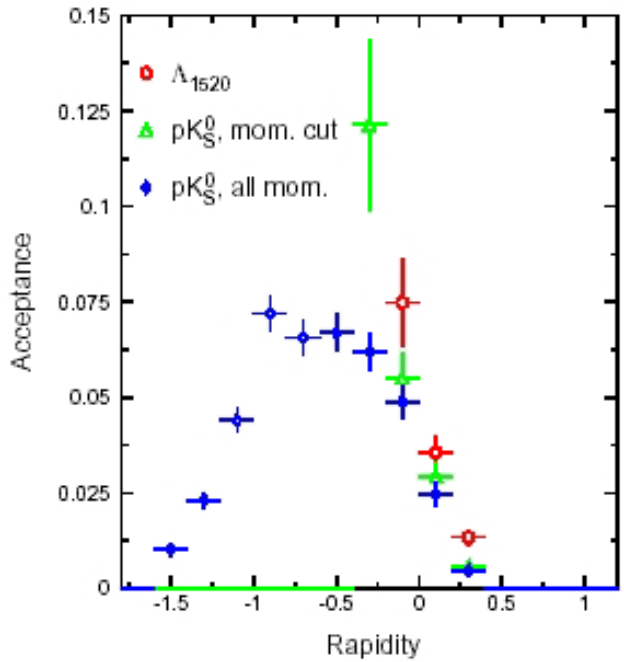
Use the full minimum bias data sample (~210M events) to:

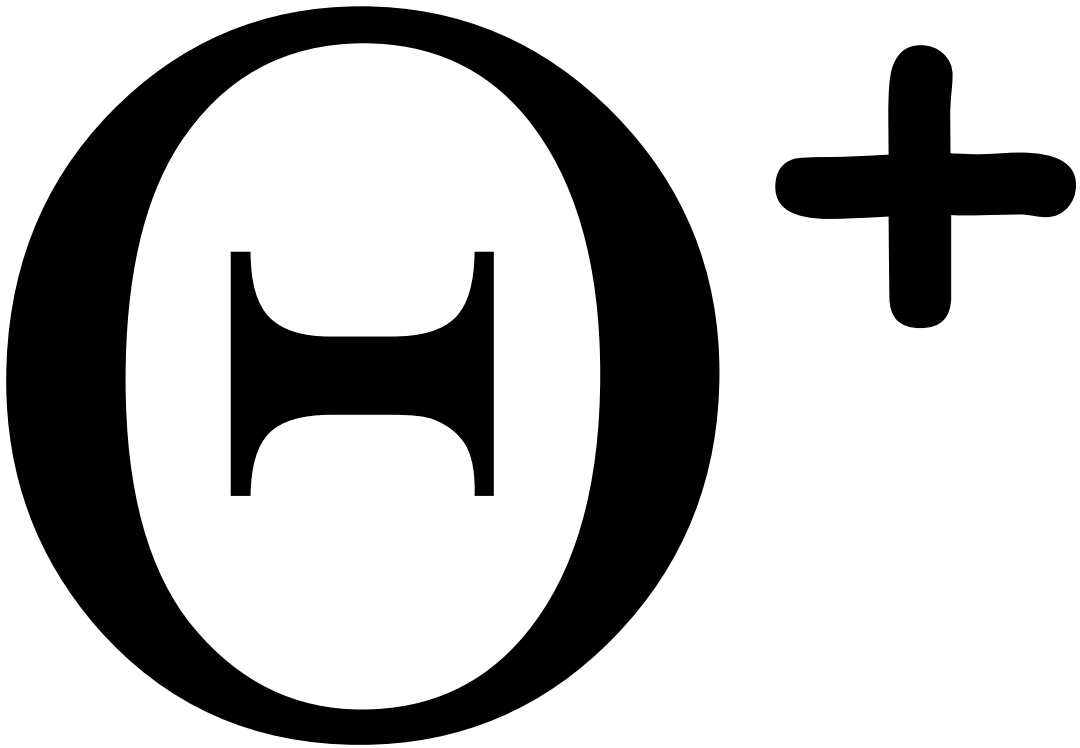
- confirm the reported pentaquark signals
- possibly determine physical quantities (width, spin, parity, charge) of pentaquarks for different final states (p-K^0, Ξ-π)

Acceptance for p-K^0 and p-K is similar at mid-rapidity (the average in the full acceptance range is ~ 4%) .

Similar arguments for Ξ-π.

-> we can provide upper limits on particle yield ratios and compare them to theoretical predictions.





p-K^0: Monte Carlo

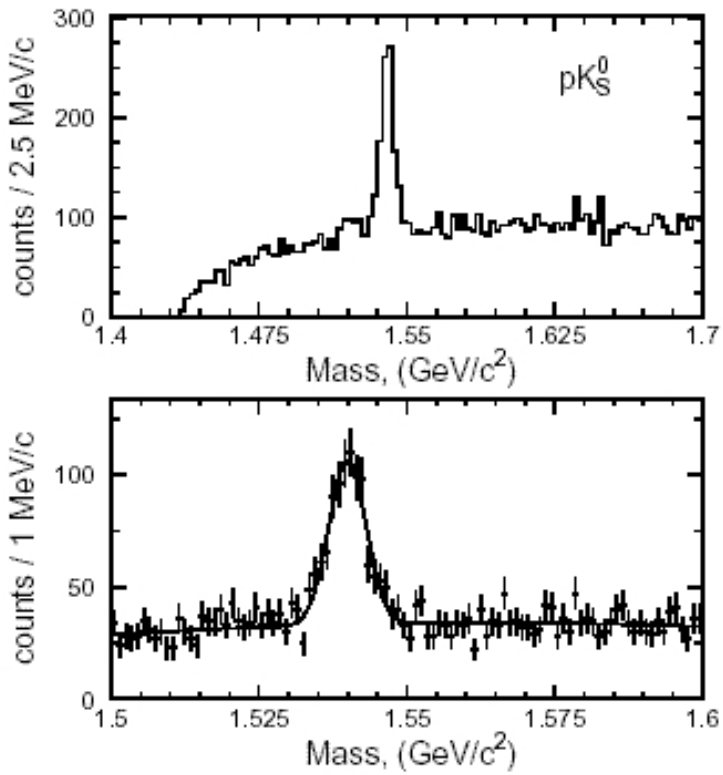
Kinematic distributions: flat x_f (n=0) and B=2.1

$$\frac{d^2\sigma}{dp_t^2 dx_F} = C(1-|x_F|)^n \cdot exp(-Bp_t^2)$$

The remaining momentum is assigned to a virtual pion which is fed into FRITIOF 7.02 to simulate further interactions inside the nucleus

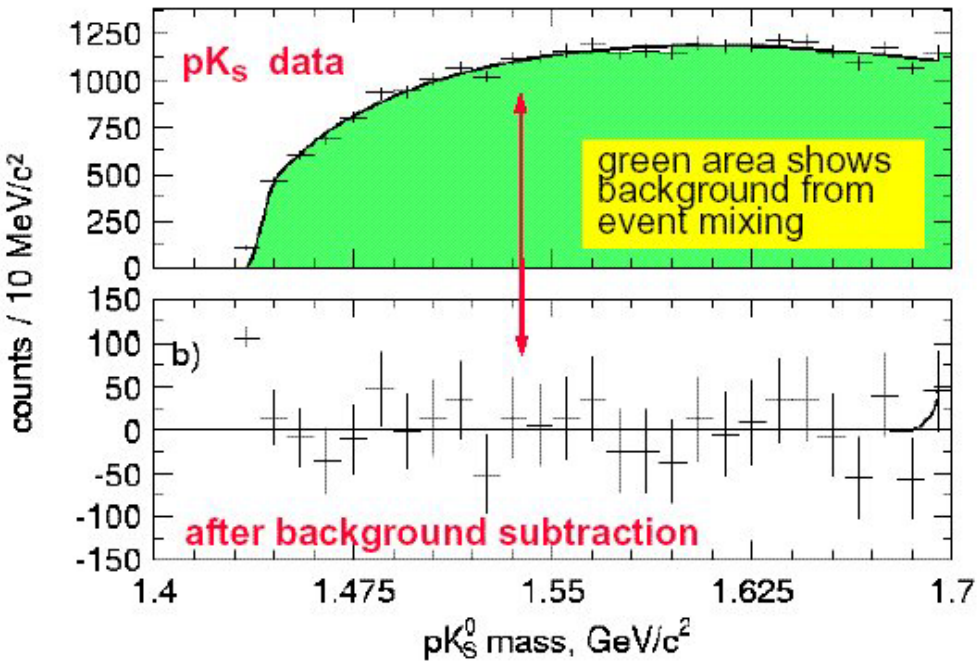
width at generation ~ 50 keV

exp. mass resolution = 3.2 $\pm$ 0.2 MeV/c



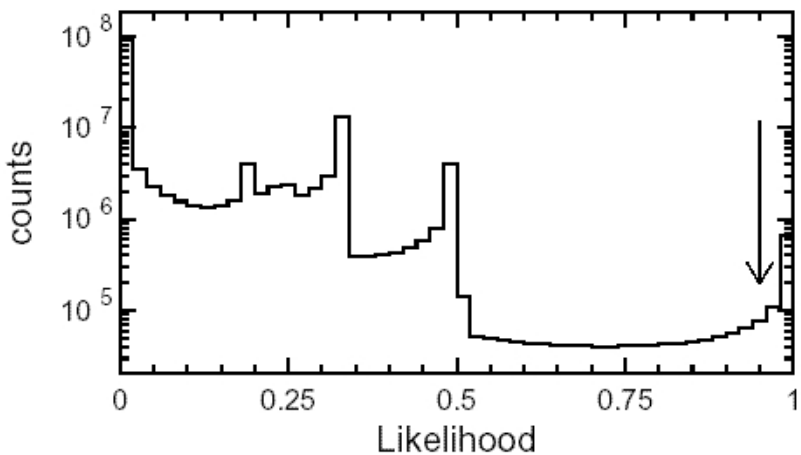
p-K^0: invariant mass

Carbon target



Preliminary!

- K^0 selection has been shown before
- likelihood (p) > 0.95



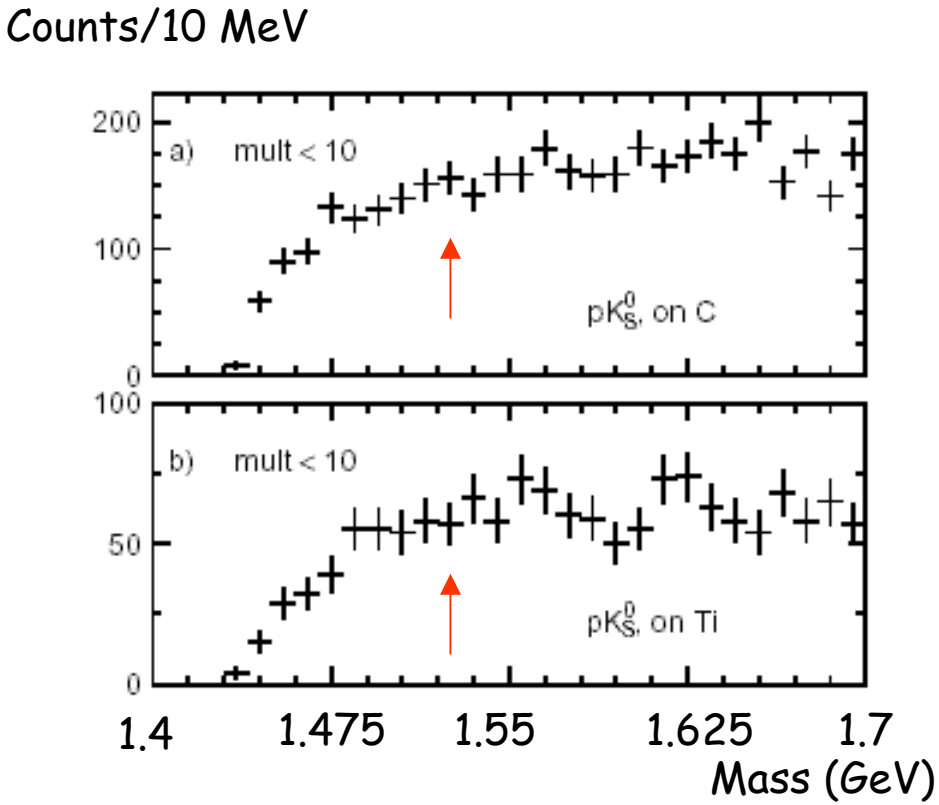
No evidence of resonances in the mass region around 1.530 GeV.

Alternative strategies

Since no evidence of structures in the invariant mass spectrum of p-K^0 is seen, we tried several different alternative cuts:

- track multiplicity in the event

p-K^0: multiplicity cut



Preliminary!

The track multiplicity in the event depends on the target on which the proton hits.

Invariant mass spectra are shown for the 2 targets (C, Ti).

Multeplicity < 10.

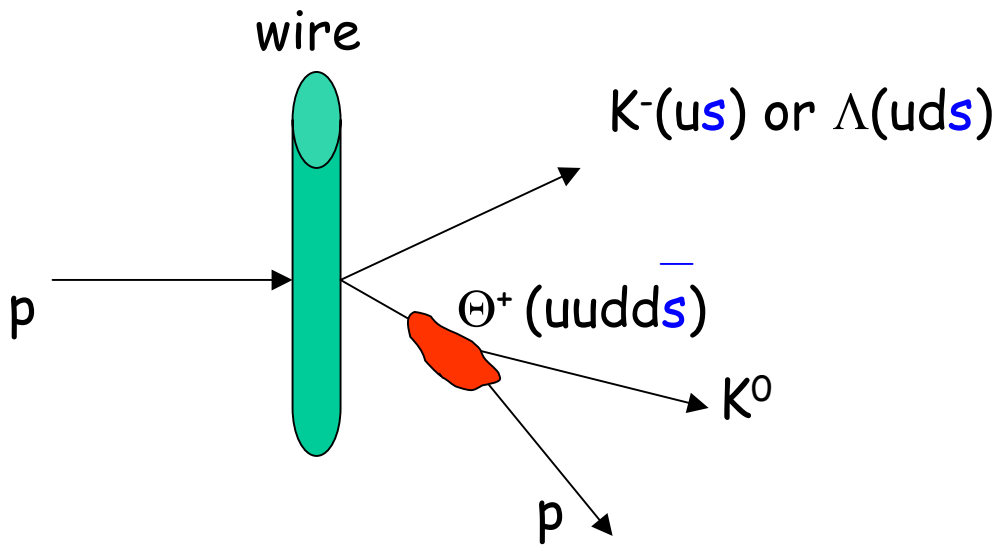
No statistically significant signal is observed.

Strangeness tagging

The high track capability of the HERA-B detector allows to look for other particles created simultaneously with the Θ^+ candidate.

If Θ^+ contains an $\bar{s}$ quark -> the s quark should hadronize with high probability into $K^-(us)$ or $\Lambda(uds)$

Only a small fraction of the selected canditates have a Λ tag (~10%)



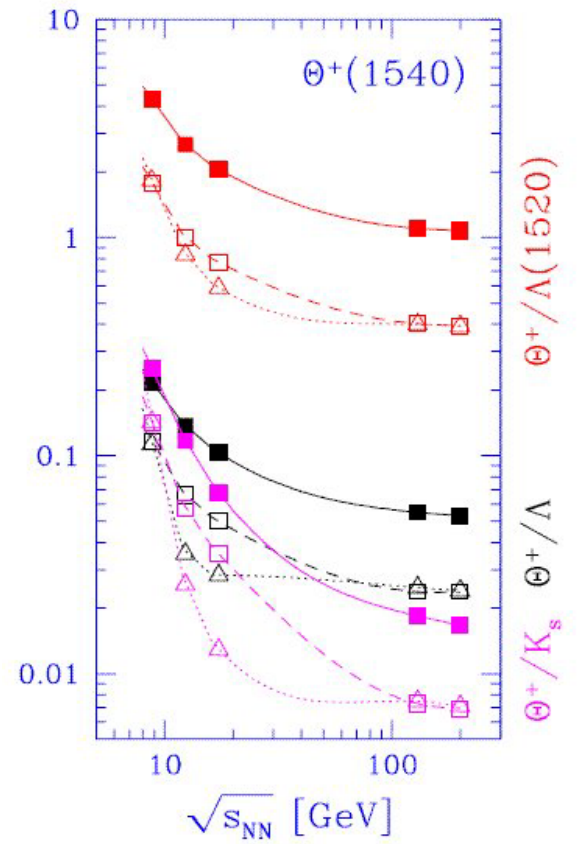
Results: Θ^+

- At mid-rapidity the sensitivity in BR * $d\sigma/dx_f$ is better than 5 μb/nucleon. An upper limit for the cross section will be provided.

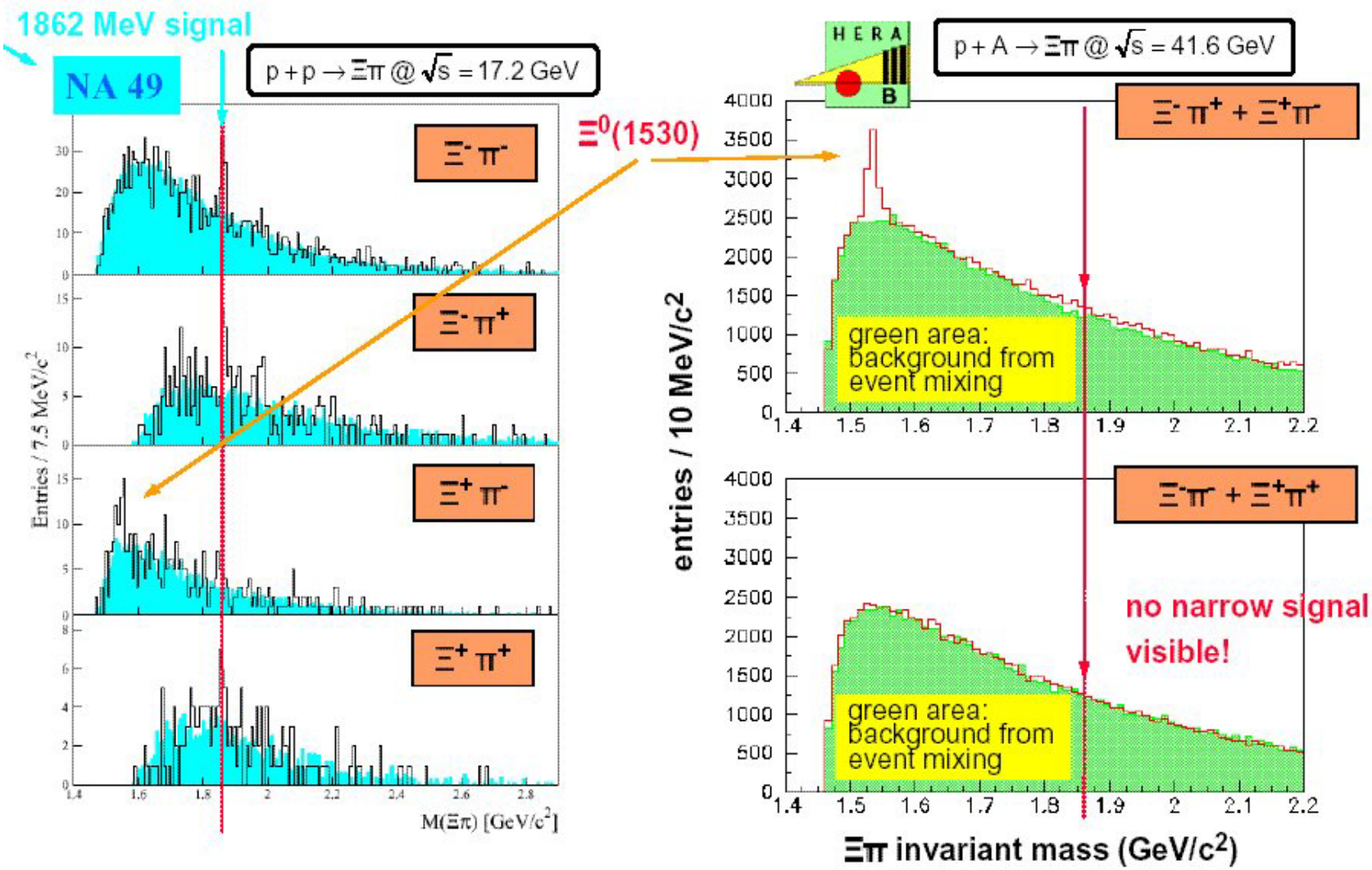
- At mid-rapidity the acceptance for Θ^+ (1530) is very similar to Λ (1520), a preliminary upper limit for the particle yield ratio is:

Θ^+ (1530)/Λ (1520) < 0.002 at 95% C.L.

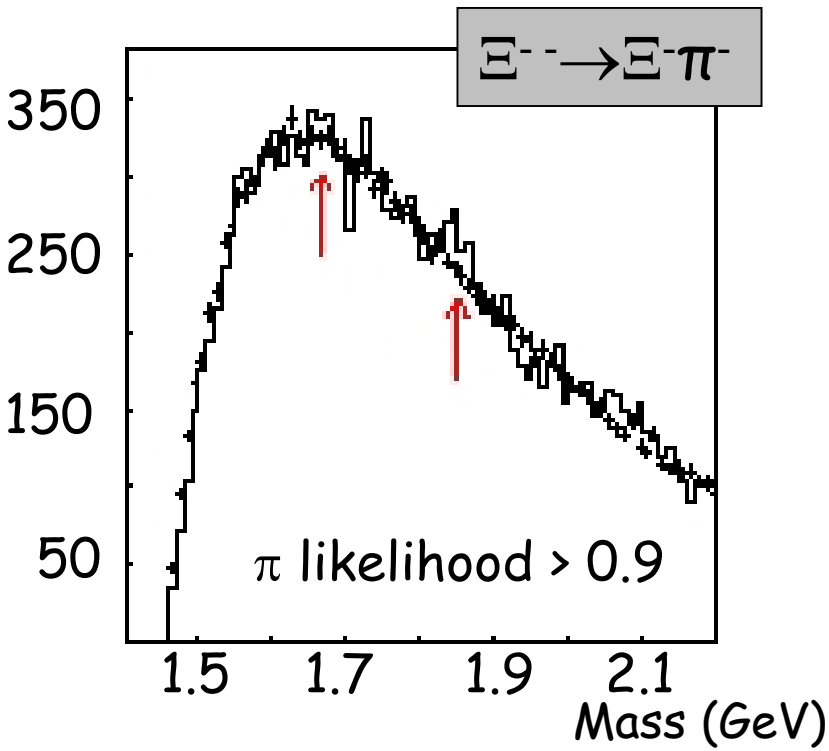
- This value differs significantly from the existing theoretical prediction based on statistical hadronization (Letessier et al., hep-ph/0310188)

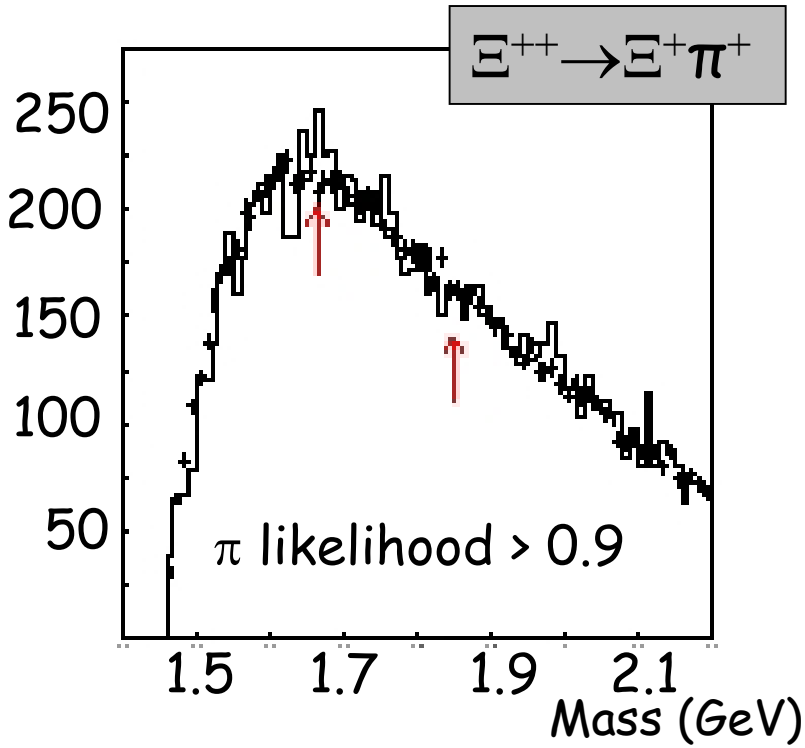


Ξ-π: invariant mass



Ξ-π: cut on pion likelihood





The shape of the background is well reproduced with event mixing.
A small excess of events (119 $\pm$ 59) at 1.85 GeV, visible in $\Xi^{-}\pi^{-}$, doesn't occur in $\Xi^{+}\pi^{+}$ -> spurious effect.

Results: Ξ^{--}

- At mid-rapidty the sensitivity in $BR*d\sigma/dx_f$ is in the order of 10 μb/nucleon. An upper limit for the cross section will be provided.

- Preliminary values for the particle yield ratio are:

$\Xi^{--}(1862)/\Xi^{0}(1530) < 0.04$ at 95% C.L.

$\Xi^{++}(1862)/\Xi^{0}(1530) < 0.055$ at 95% C.L.

- This sensitivity is good enough to test existing theoretical predictions (Letessier et al., hep-ph/0310188).

Conclusion 1

A large sample of strange baryons and mesons has been collected with the HERA-B detector in pA interactions at 41.6 GeV CMS energy on different target wires (^{12}C, ^{184}W, ^{48}Ti):

K^0	: 3.400.000	σ ~ 4.9 MeV
Λ	: 940.000/450.000	σ ~ 1.8 MeV
φ	: 50.000	σ ~ 2.6 MeV
$\Lambda(1520)$:	2.000/1.000	σ ~ 8.0 MeV
$\Xi^-(1321)$:	11.300/7.700	σ ~ 2.6 MeV

Conclusion 2

- $\Xi^0(1530) \rightarrow \Xi^- \pi^+$: strong signal
- $\Lambda(1520) \rightarrow pK^-$: strong signal

- $\Theta^+ \rightarrow pK^0$: no signal visible
- $\Xi^{--}(1862) \rightarrow \Xi^- \pi^-$: no signal exceeding 2σ (and only Ξ^{--}, not Ξ^{++})

- Preliminary upper limits on the relative yield at mid-rapidity:
  - $\Theta^+(1530)/\Lambda(1520) < 0.002$ at 95% C.L.
  - $\Xi^{--}(1862)/\Xi^0(1530) < 0.04$ at 95% C.L.

- upper limits on cross sections will be provided