Search for Pentaquarks in Proton-Nucleus collisions at $\sqrt{s}$=41.6 GeV

Tomi Živko
for the HERA-B Collaboration

24. August 2004
19th European Few-Body Conference

- Introduction
- The HERA-B experiment
- Search for $\Theta^+ \to pK^0_S$
- Search for $\Xi^{--} \to \Xi^- \pi^-$
- Summary

preliminary results: J.Phys.G30:S1363-S1366,2004 (hep-ex/0403020)
final results: submitted to PRL (hep-ex/0408048)

Introduction

- more than 10 experiments claim evidence for $\Theta^+ \rightarrow nK^+$ or $\Theta^+ \rightarrow pK^0_S$ around 1540 MeV/c^2
- observed width of peak (≈ 20 MeV/c^2) can be explained by experimental resolution
- pK^0_S peaks are regarded as Θ^+ on grounds "no narrow $\Sigma^{\star +}$ is known at 1.5 GeV/c^2" (however, until recently the same was true for a narrow Θ^+)
- typical significance of presented peaks is of order of 5 σ
- nK^+ experiments give larger value of Θ^+ mass
- models predict existence of I=3/2 doubly strange pentaquark family
- NA49 observed evidence for such a family in decay channel $\Xi\pi$ at 1862 MeV/c^2
- H1 observed Θ^0_C in the channel $D^{\star -}p$ at 3100 MeV/c^2
- the number of high statistics experiments reporting negative search results is growing

The existence of pentaquarks is not proven beyond reasonable doubt.

Introduction

Several experiments presented $\Lambda(1520) \to pK^-$ peaks.
It could be deduced that the ratio $\frac{\Theta^+}{\Lambda(1520)} \approx 20\%$ or larger.

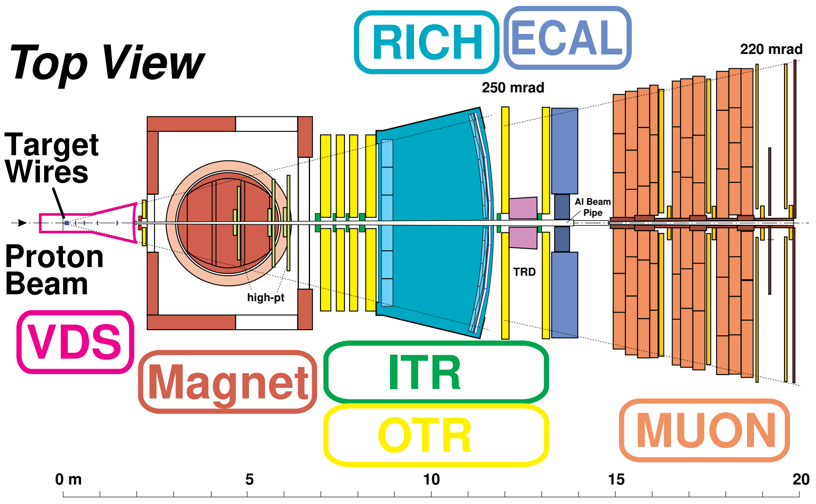
Reconstruction of $\Lambda(1520)$ is doubly interesting:

- it proves identification and reconstruction capabilities of a detector
- ratio $\Theta^+/\Lambda(1520)$ is predicted by theoretical models

Scope of this analysis is to:

- measure x-section (or upper limits) for $\Theta^+ \to pK^0_S$ and $\Xi^{--} \to \Xi^- \pi^-$
- measure ratios $\frac{\Theta^+}{\Lambda(1520)}, \frac{\Theta^+}{\Lambda}, \frac{\Xi^{--}}{\Xi^0(1530)}, \frac{\Xi^{--}}{\Xi^-}$

Experiment HERA-B



- HERA-B (p-A, $\sqrt{s} = 41.6$ GeV/c^2) is a fixed target experiment operating in the halo of the HERA proton beam
- wire target (C, Ti, W)
- tracking: VDS, main tracker
- magnet: $\int Bdz = 2.13$ Tm
- excellent particle ID:
  - RICH - charged particles
  - ECAL - e
  - MUON - μ

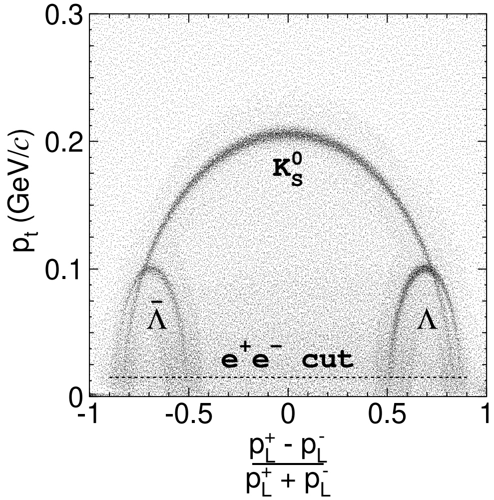
HERA-B has acceptance in the mid-rapidity region. Consequently, all results correspond to the mid-rapidity region.

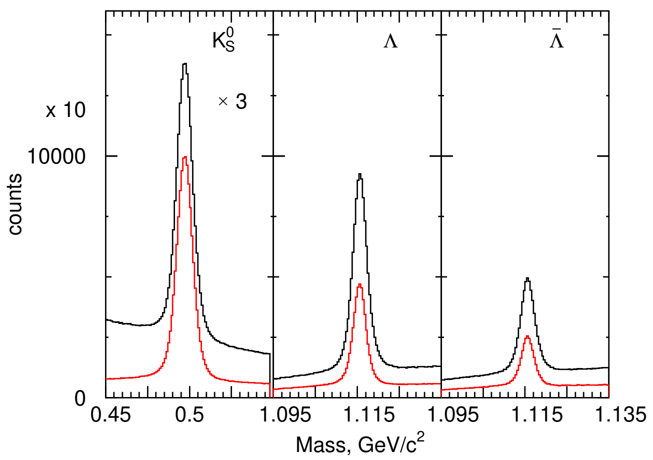
The data sample used in this analysis contains about 200 M of minimum bias events taken on 3 targets: C, Ti, W.

Advantages of HERA-B for this analysis are: large statistics, good mass resolution and good identification.

Good operation of the tracking system is illustrated by the reconstruction of $K^0_S, \Lambda, \bar{\Lambda}$.
No particle identification necessary for reconstruction of V^0.

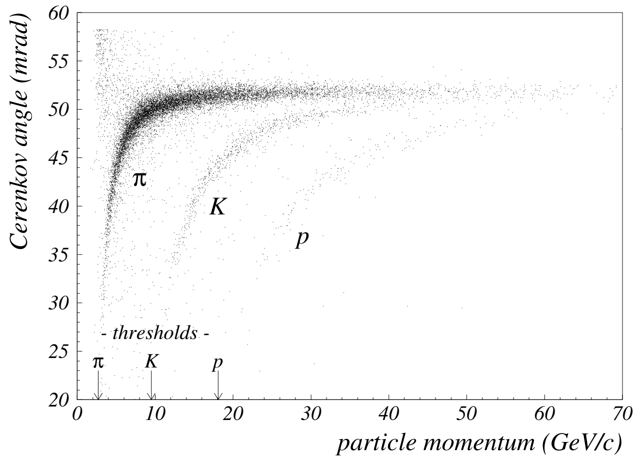
Signal	C target	all targets	σ [MeV/c^2]
K^0_S	2.2M	4.9M	4.9
Λ [$\bar{\Lambda}$]	440k[210k]	1.1M[520k]	1.6
Λ(1520) [$\bar{\Lambda}$(1520)]	1.9k[1.1k]	5.1k[2.3k]	2.3
Ξ^- [$\bar{\Xi}^+$]	4.7k [3.4k]	11.8k [8.2k]	2.6
$\Xi(1530)^0$ [$\bar{\Xi}(1530)^0$]	610 [380]	1.4k [940]	2.9

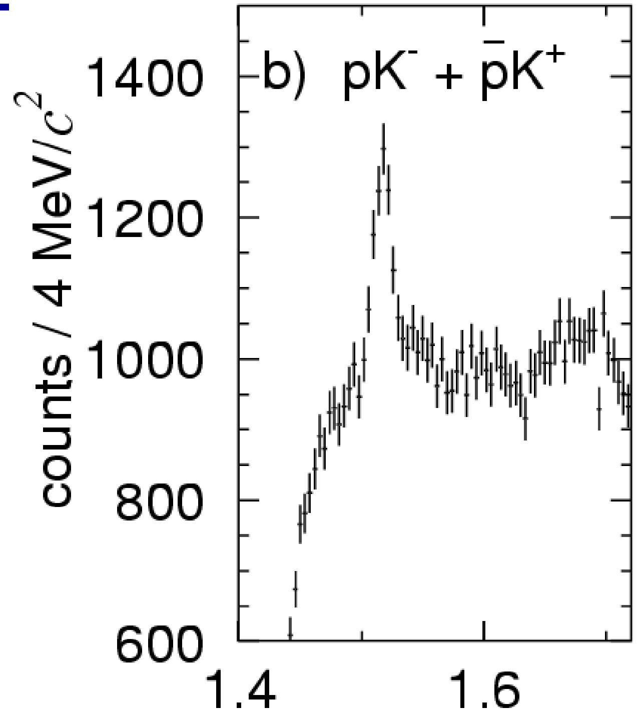




(a) V^0 signals

Experiment HERA-B





(b) RICH performance (left), Λ(1520) with C target (right)

Strong test for capabilities of RICH is the reconstruction of $\Lambda(1520) \rightarrow pK^-$. In this channel both charged particles (p, K^-) have to be identified. The number of identified Λ(1520) depends on the cut on RICH likelihood. The presented distribution is obtained using data from the C target and likelihood cuts $lr(K) > 0.95$ and $lr(p) > 0.95$. Probability for a π to fulfill this cut ($lr(p) > 0.95$) and to be misidentified as proton is 1%.

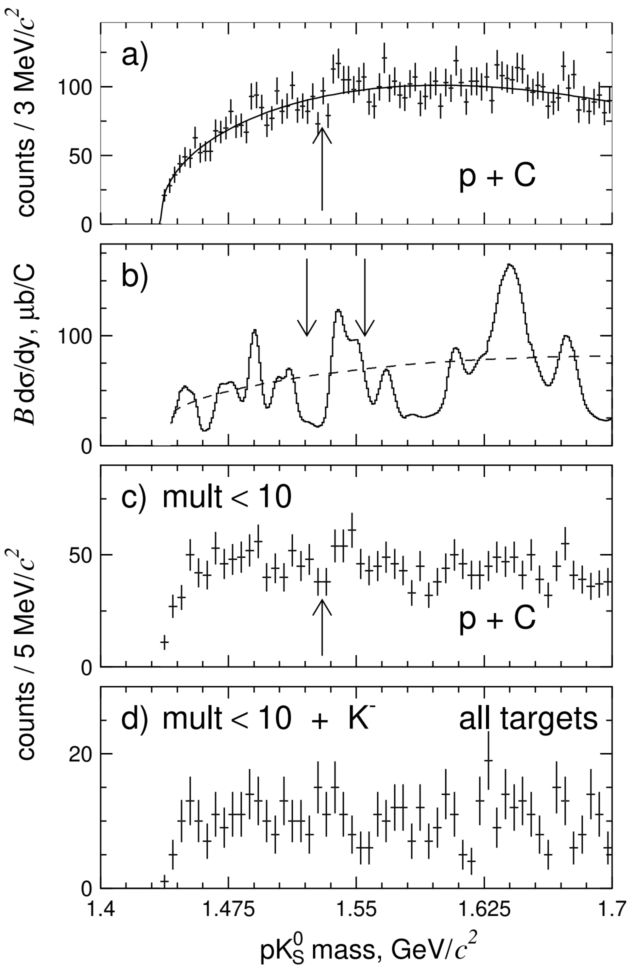
Values of mass and natural width of $\Lambda(1520)$ are consistent with table values.

Search for $\Theta^+ \rightarrow pK_S^0$

- Λ and $\bar{\Lambda}$ candidates were removed using mass cut
- a clean K_S^0 sample remained
- proton candidates had to have $lr(p) > 0.95$
- mass resolution at mass of 1540 MeV/c^2 was found to be 3.9 MeV/c^2
- analysis was done separately for each target material
- background was determined by event mixing
- no Θ^+signal was observed, and we determined upper limits @ 95% C.L.

In order to reduce the combinatorial background, we also tried with strangeness tagging (pK_S^0 + particle with quark s (Λ, K^-) in an event).
Also, various cuts on multiplicity of tracks were applied, and the value of the RICH likelihood cut for the proton was varied.

Search for $\Theta^+ \to pK^0_S$



Plots correspond to data from C target.

Assuming $\sigma_A \propto A^{0.7}$,
$Br \times d\sigma/dy|_{y=0} < 3.7\,\mu b/\mathrm{nucleon}$ @ 95% C.L. (using carbon target).
The upper limit using all targets is similar.

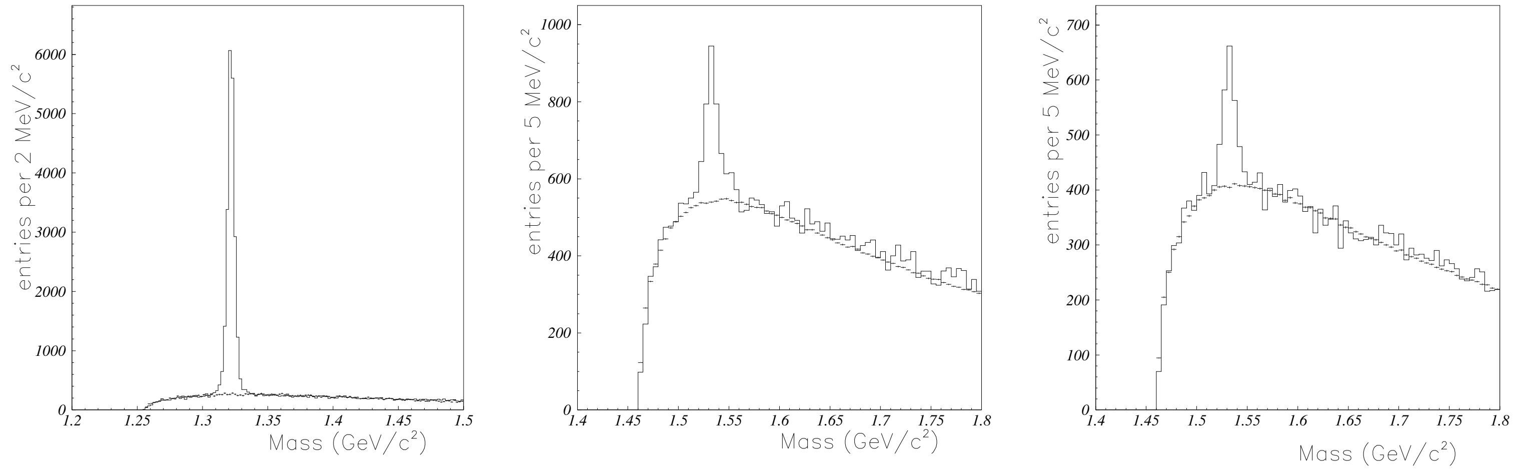
Assuming $Br(\theta^+ \to pK^0_S)$=1/4

- $\frac{\Theta^+}{\Lambda(1520)} < 2.7\%$ @ 95% C.L. (this result is two orders of magnitude below the HERMES result, and one order of magnitude below predictions of statistical hadronization models)
- $\frac{\Theta^+}{\Lambda} < 0.92\%$ @ 95% C.L.

Search for $\Xi^{--} \to \Xi^- \pi^-$

Our ability to reconstruct possible signal for $\Xi^{--} \to \Xi^- \pi^-$ can be verified by reconstruction of $\Xi(1530)^0 \to \Xi^- \pi^+$.

- Ξ^- candidates were selected in a 10 MeV/c^2 window around the table mass
- RICH and ECAL information do not forbid the π mass hypothesis
- the shape of the background was obtained by event mixing

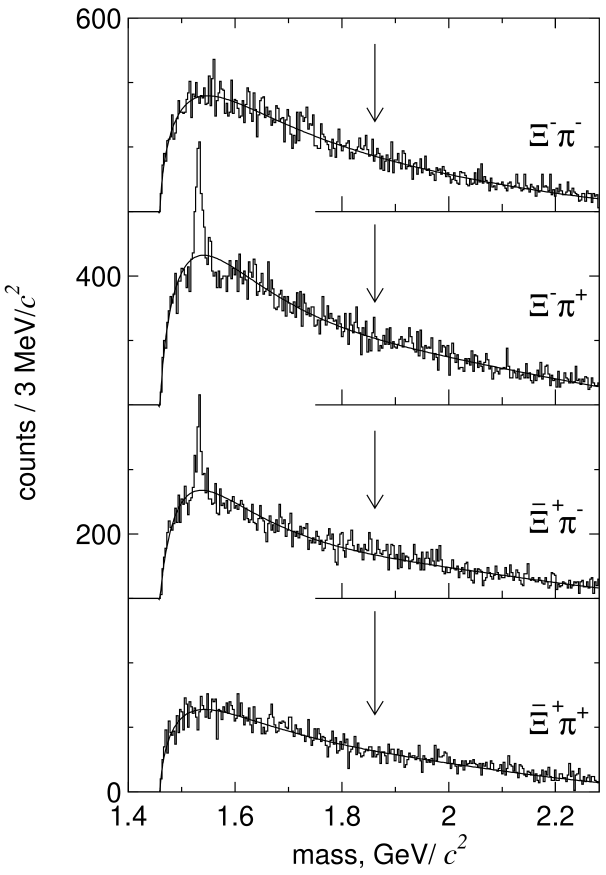


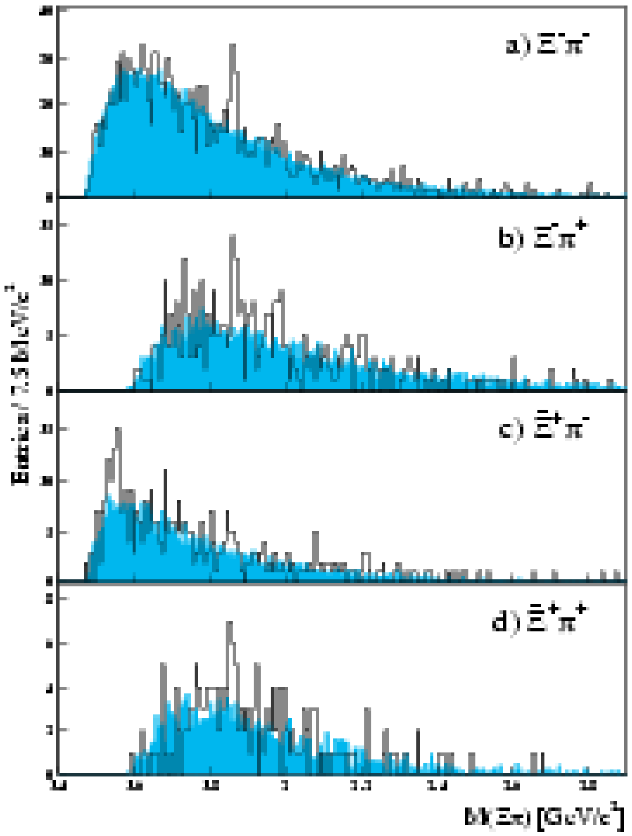
(c) all targets: Ξ^- and $\bar{\Xi}^+$ (left), $\Xi(1530)^0$ (middle) and $\bar{\Xi}(1530)^0$ (right)

Values of mass (Ξ^- and $\Xi^{0\star}$) and natural width ($\Xi^{0\star}$) are consistent with table values.

Search for $\Xi^{--} \rightarrow \Xi^- \pi^-$

Comparison between HERA-B (carbon target, left) and NA49 (right)



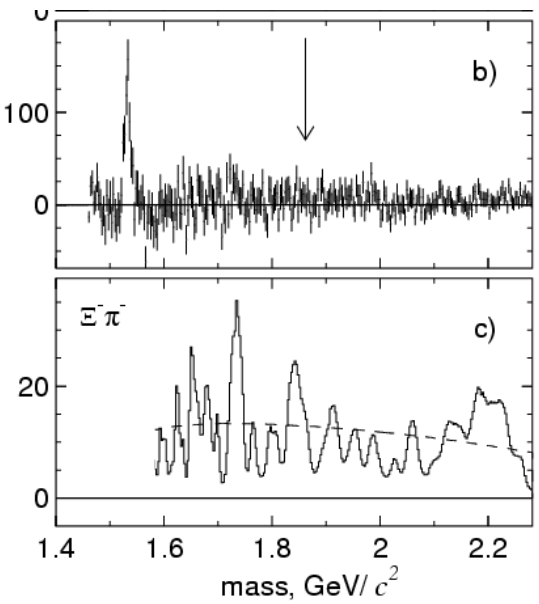


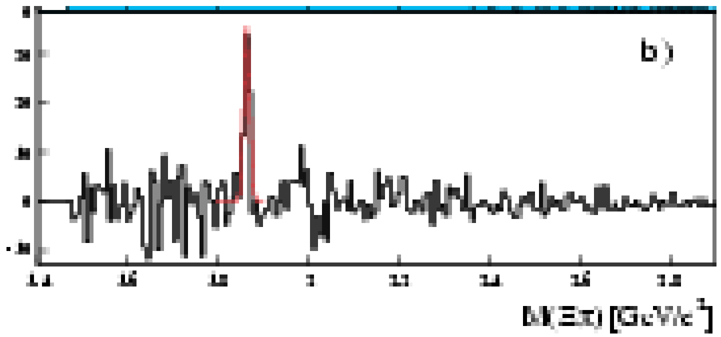
(d) $\Xi\pi$ mass

We selected $\Xi^-\pi^-$and $\bar{\Xi}^+\pi^+$candidates analogously to $\Xi^-\pi^+$and $\bar{\Xi}^+\pi^-$candidates. Mass resolution at 1862 MeV/c^2 is 6.6 MeV/c^2.

Search for $\Xi^{--} \rightarrow \Xi^-\pi^-$

Comparison between HERA-B (carbon target, left) and NA49 (right)





Assuming $\sigma_A \propto A^{0.7}$, we obtained (C target)

Br$\times$dσ/dy$|_{y=0}$ of Ξ^{--}(1862) $<$ $2.5\mu b$/nucleon.

The corresponding upper limits in the channels $\Xi^-\pi^+$, $\bar{\Xi}^+\pi^+$ and $\bar{\Xi}^+\pi^-$ are 2.3, 0.85 and 3.1 μb/nucleon.

The upper limits using all targets are similar.

Also,

- $\frac{\Xi^{--}}{\Xi^-} < 3/Br\%$ @ 95% C.L.
- $\frac{\Xi^{--}}{\Xi^0(1530)} < 4/Br\%$ @ 95% C.L. (in contradiction with NA49)

Summary

- we searched for pentaquarks in channels pK_S^0 and $\Xi\pi$
- HERA-B has good acceptance in the mid-rapidity region, and has reconstructed a large number of strange particles which were produced in pA interactions
- advantages of HERA-B for this analysis are: large statistics, good mass resolution and good identification
- we did not find any evidence for $\Theta^+ \rightarrow pK_S^0$ and $\Xi^{--} \rightarrow \Xi^- \pi^-$

We give upper limits @ 95% C.L. on

- $Br \times d\sigma/dy|_{y=0}$ of $\Theta^+(1530) < 3.7\ \mu b/\mathrm{nucleon.}$

In the mass region 1521-1555 MeV/c^2 this upper limit ranges from 3 to 22 $\mu b/\mathrm{nucleon}$. The upper limits using all targets are similar.

- $\frac{\Theta^+}{\Lambda(1520)} < 2.7\%$
  this result is two orders of magnitude below the HERMES result, and one order of magnitude below predictions of statistical hadronization models
- $\frac{\Theta^+}{\Lambda} < 0.92\%$

Summary

We did not find evidence for $\Xi(1862) \rightarrow \Xi\pi$.
We give upper limits (carbon data) @ 95% C.L. on

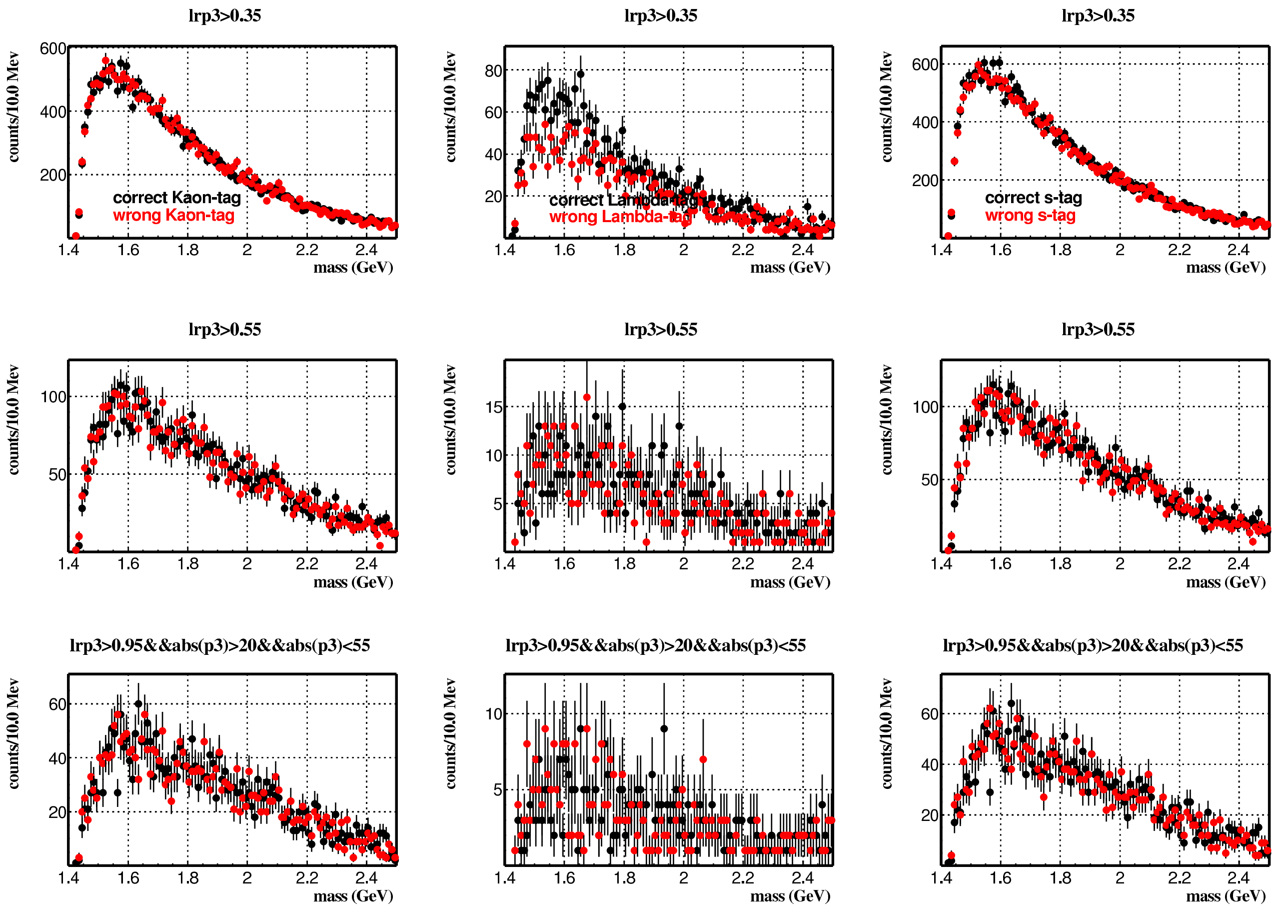
$$Br \times d\sigma/dy|_{y=0} \text{ of } \Xi^{--}(1862) \; < \; 2.5 \; \mu b/\text{nucleon}.$$

The corresponding upper limits in the channels $\Xi^-\pi^+$, $\bar{\Xi}^+\pi^+$ and $\bar{\Xi}^+\pi^-$ are 2.3, 0.85 and 3.1 μb/nucleon. The upper limits using all targets are similar.

- $\frac{\Xi^{--}}{\Xi^-} < 3/Br\%$
- $\frac{\Xi^{--}}{\Xi^0(1530)} < 4/Br\%$ not compatibile with NA49

If existent, strange pentaquarks (Θ^+, Ξ^{--}) seem also to exhibit exotic production mechanisms.

BACKUP - Search for $\Theta^+ \rightarrow pK^0_S$



Θ^+should be accompanied by a particle with s quark

black: correct tagging, red: wrong tagging

(e) all targets, strangeness tagging of pK^0_S, variation of RICH likelihood