



Search for pentaquark states from hadronic Z decays in Aleph

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ALEPH Collaboration

Outline

Particle id

Search for NK resonances

Search for $\Xi\pi$ resonances

Search for charmed pentaquarks

Data sample

The data used for this analysis consist of the hadronic Z decays recorded by ALEPH during the period 1991 to 1995 in a LEP centre-of-mass energy range within 3 GeV from the Z resonance.

Events are selected with least six charged tracks in the TPC carrying at least 10% of the centre-of-mass energy and the thrust axis is required to have an angle to the beam axis exceeding 25° . A total of 3.5 million hadronic Z decays are retained, corresponding to 86% of the total hadronic cross-section.

A sample of simulated data, twice the size of the real data, is used for reference (**red histograms**). The simulation is based on JETSET, with parameters tuned to agree with ALEPH measurements. It simulates only octet and decuplet baryons.

Particle ID

The variable used to identify a particle of type i is the pull:

$$R_i = \frac{dE/dx(\text{measured}) - dE/dx(\text{expected for } i)}{\sigma(\text{expected for } i)}$$

which uses pulse heights on pads and wires in the TPC.

$$\pi^\pm: |R_\pi| < 2.5.$$

$$K^\pm: |R_K| < 2 \text{ always. } R_\pi < -1.5 \text{ for } p > 1.5 \text{ GeV/c, or } |R_\pi| > 2 \text{ and } |R_e| > 2.5 \text{ for } p < 0.8 \text{ GeV/c.}$$

$$p^\pm: |R_p| < 2 \text{ always. } R_\pi < -3 \text{ for } p > 2 \text{ GeV/c, or } R_\pi > 2.5 \text{ and } |R_e| > 2 \text{ for } p < 1.2 \text{ GeV/c.}$$

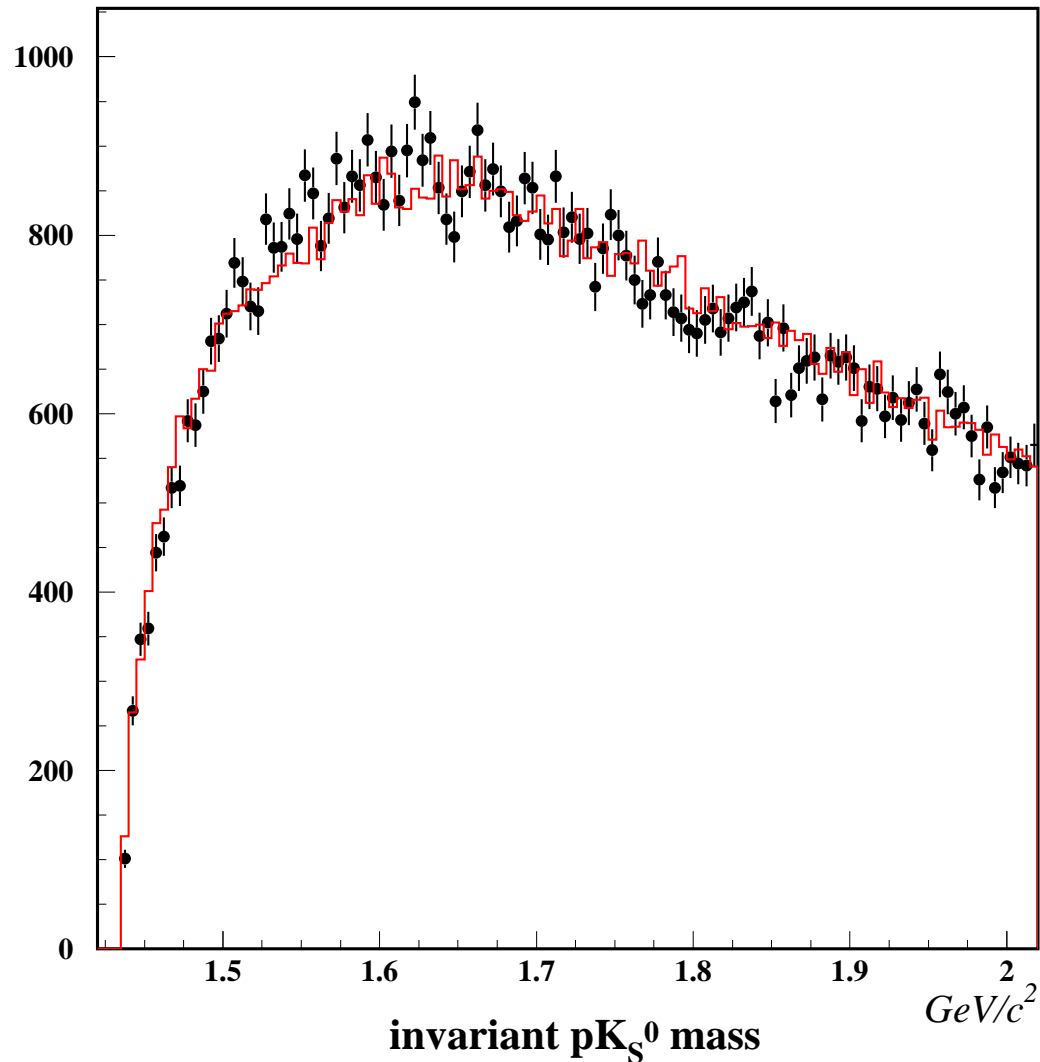
This selects 1.3 million proton candidates with a purity of 52% in the high momentum range and 96% in the low momentum range.

More Particle ID

- K_S^0 : are selected from a kinematic fit to two opposite charged pions emerging from a secondary vertex. This selects 1.2 million K_S^0 candidates with 93% purity.
- Ξ^- : are selected from a geometric fit to a Λ and a π^- emerging from a secondary vertex. 3350 candidates are selected with 76% purity.
- D-mesons:** are selected from $K\pi(\pi)$ combinations emerging from a secondary vertex separated by more than two σ from the primary vertex. About 25000 candidates are selected with about 80% purity for D^0 and about 50% purity for D^\pm .

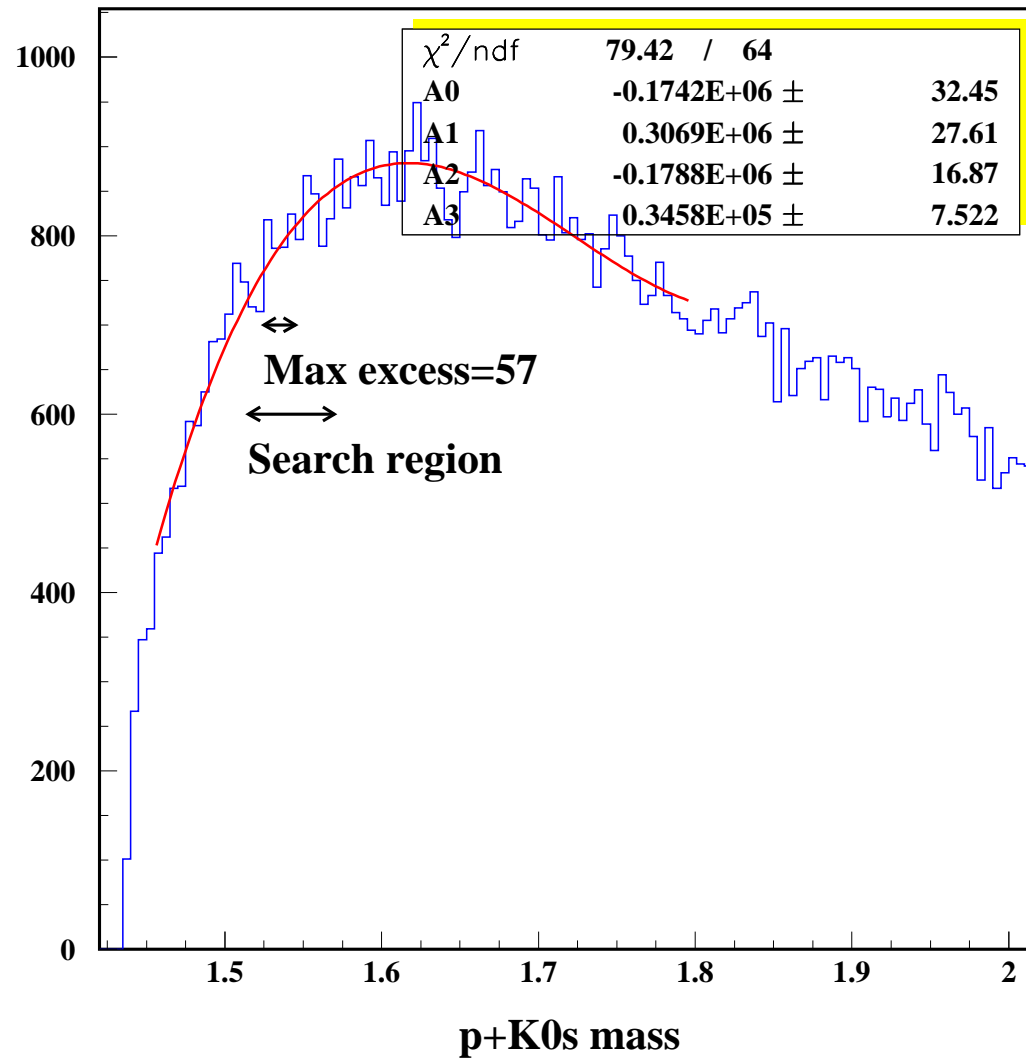
Search for exotic NK resonances

pK_S^0 combinations in the ALEPH LEP1 sample



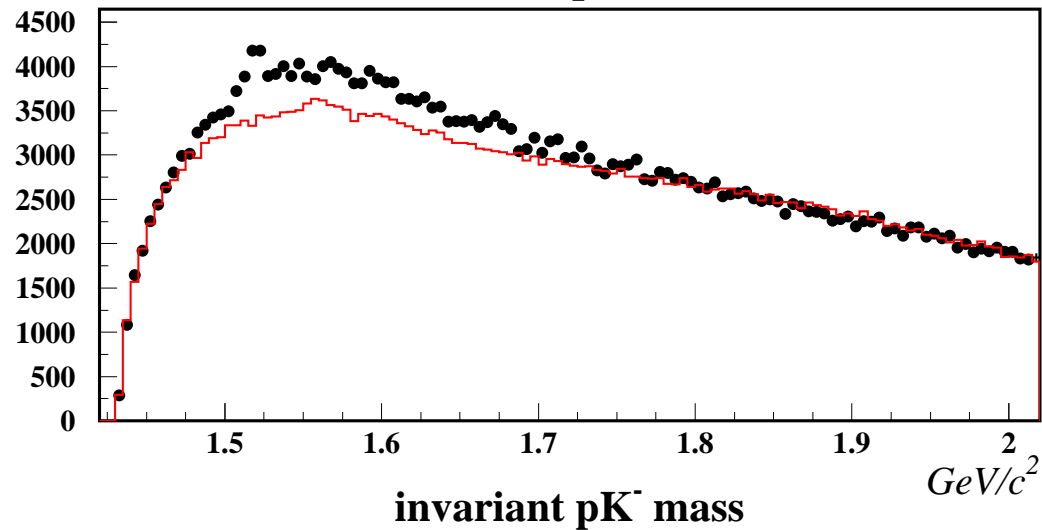
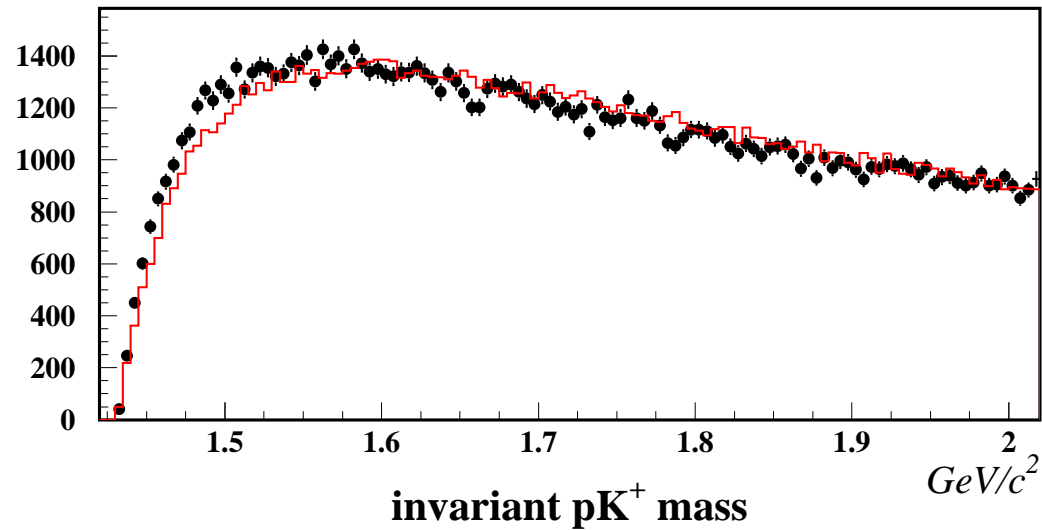
Search for exotic NK resonances

Excess over smooth fit in 20 MeV window



Non-exotic NK resonances

pK^\pm combinations in the ALEPH LEPI sample.

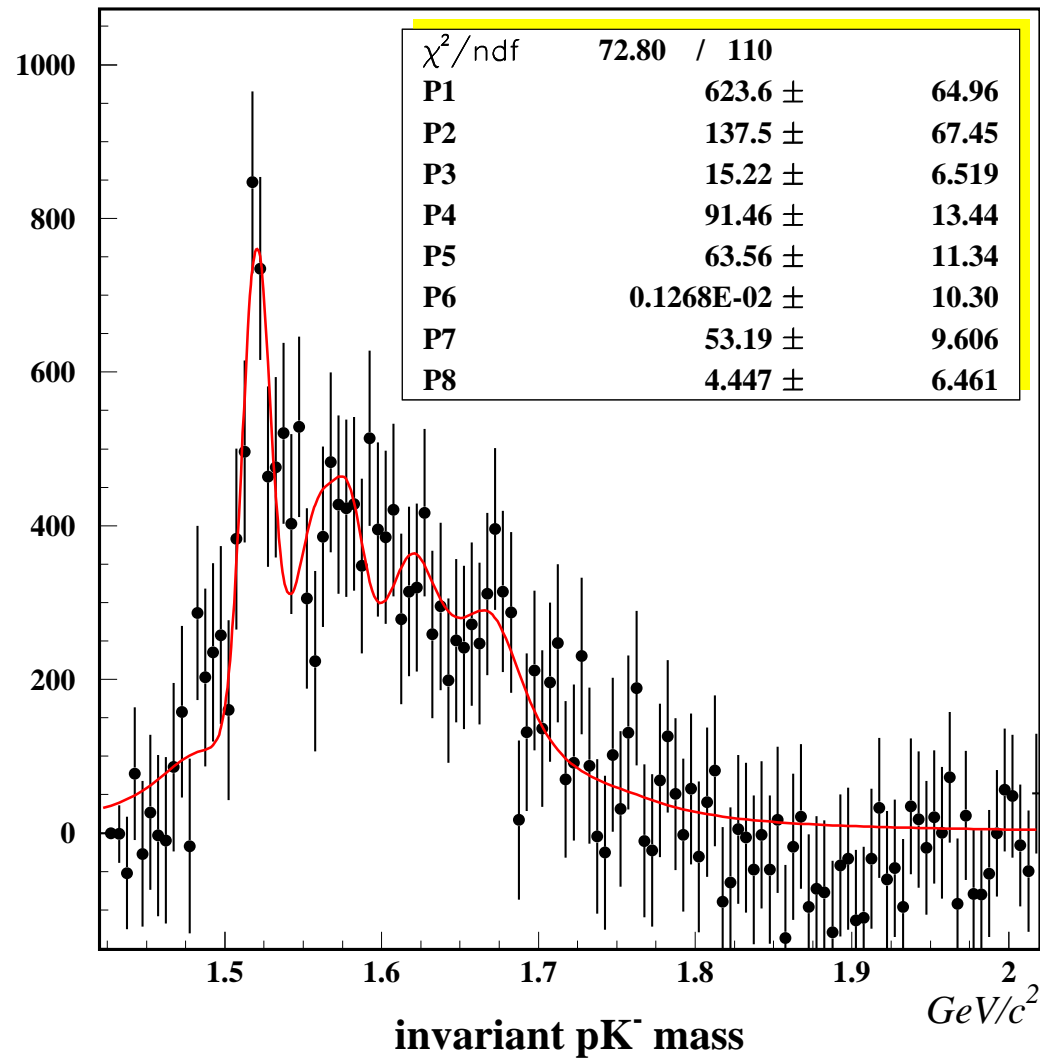


Correction to the MC

- No resonance structures are observed in the doubly charged pK combinations. However, a smooth deviation from the simulated mass spectrum is seen at the few percent level. This is caused by imperfect simulation of dE/dx for spacially close track pairs.
- The ratio of data to simulation in the doubly charged combinations is used to correct the simulation of neutral pK combinations.

Non-exotic NK resonances

Fit excess pK^- data to eight resonances.



Measurement of the $\Lambda(1520)$ rate

- A simultaneous fit to the strengths of eight more or less established resonances over a background taken from the simulated mass spectrum results in a $\Lambda(1520)$ excess of 2814 ± 293 combinations. A systematic error of 400 counts is assigned to this number.
- Taking the average acceptance of 0.10 into account, as well as the branching ratio of 22.5% for $\Lambda(1520) \rightarrow pK^-$, the average multiplicity becomes:

$$N_{\Lambda(1520)} = 0.029 \pm 0.03 \pm 0.04$$

This result is identical with the measurement from DELPHI and is one standard deviation above the measurement from OPAL.

Limit on Θ^+ production in Z decays

- An upper limit on the number of $\Theta^+ \rightarrow pK_S^0$ decays is obtained from the maximum number of combinations in a sliding window of width $20 \text{ MeV}/c^2$ in excess of a smooth 3'rd degree polynomial fit to the data.
- The maximum excess is found in the interval 1525–1545 MeV/c^2 to be 57 combinations over a background of 2840. The systematic error is estimated to be 50 combinations by varying the resolution and the background function. The 95% upper confidence limit on an excess is set to $57 + 1.64 * \sqrt{2840 + 57} + 50 = 195$ combinations.

Limit on Θ^+ production in Z decays

- Using the average acceptance of 0.063 and a branching ratio for of 1/4, the 95% confidence limit on the multiplicity of Θ^+ (*plus* its antiparticle) in hadronic Z decays then becomes:

$$N_{\Theta^+} < 0.0029$$

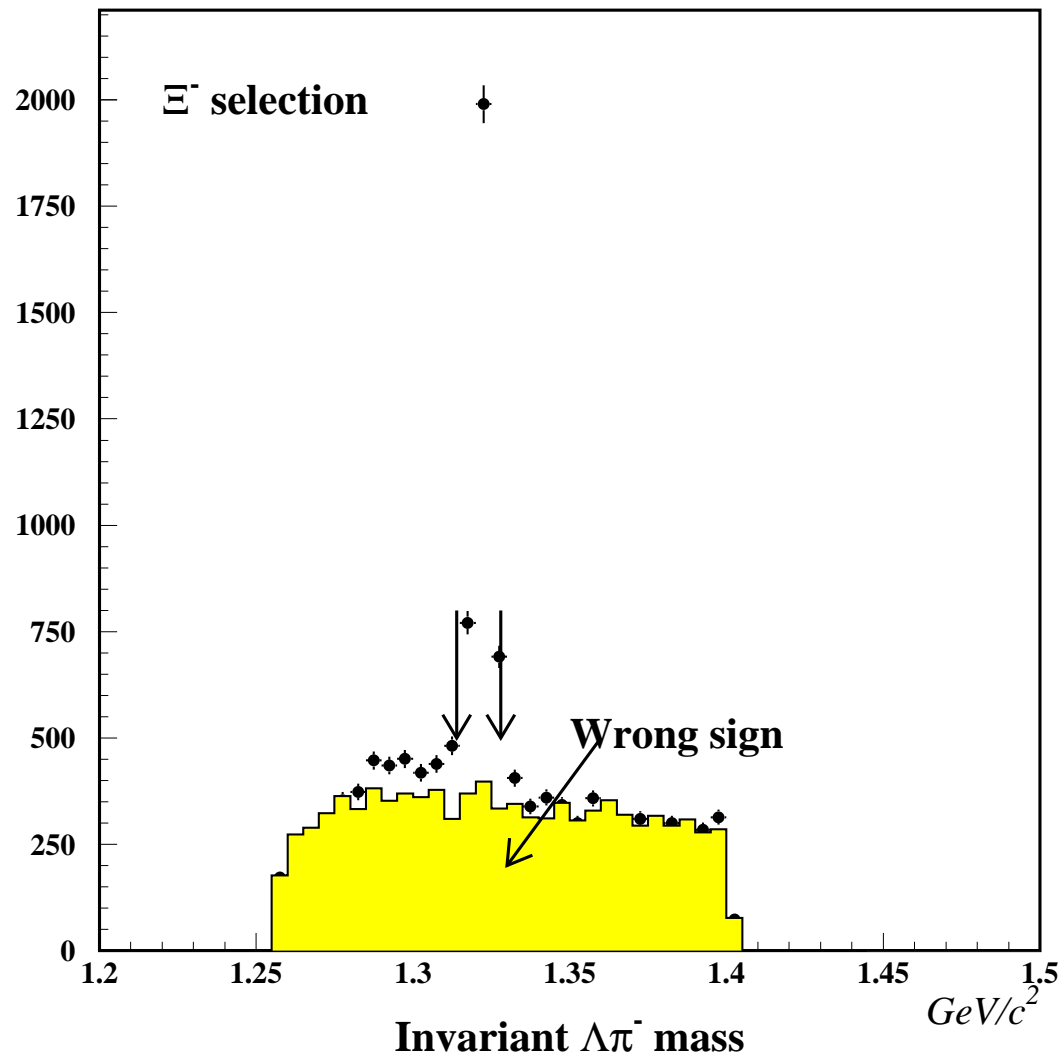
- For the ratio of Θ^+ to $\Lambda(1520)$ production in Z decays, we get the 95% confidence upper limit:

$$N_{\Theta^+} / N_{\Lambda(1520)} < 0.10$$

using the 1σ lower limit of the present measurement in the denominator. This limit is about a factor of 20 lower than the ratio in γd reactions measured by HERMES.

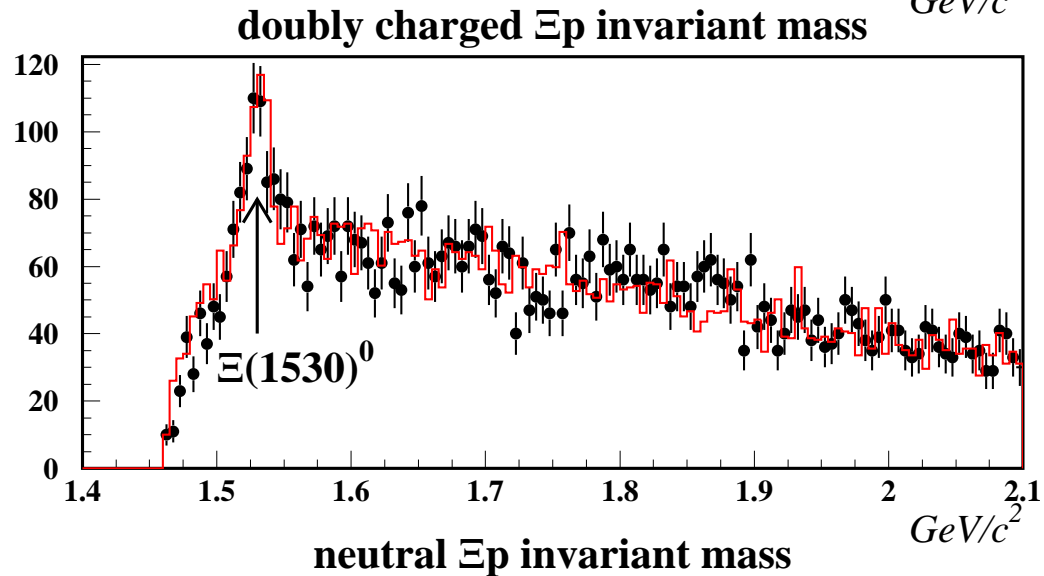
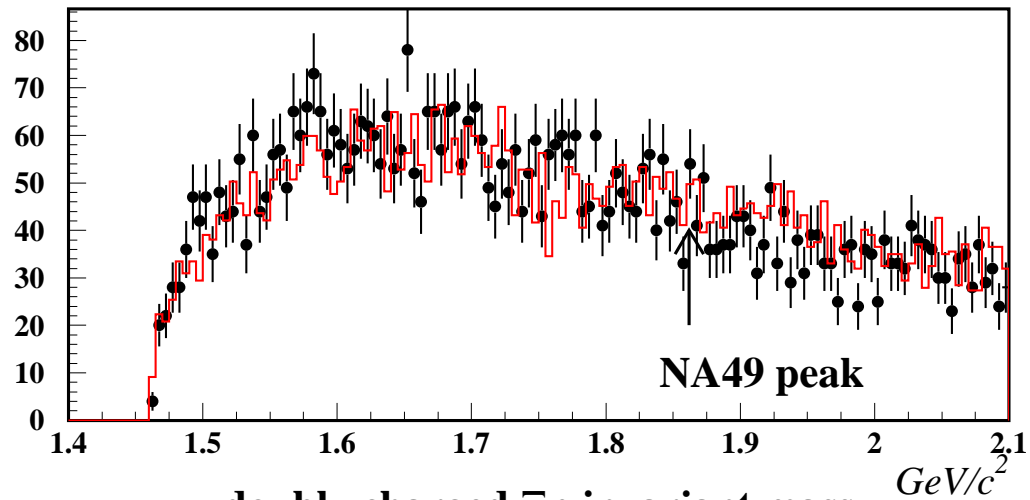
Selection of Ξ candidates

$\Xi \rightarrow \Lambda\pi$ candidates.



Search for $\Xi\pi$ resonances

$\Xi\pi$ combinations in the ALEPH LEPI sample.



Limit on Ξ^{--} production in Z decays

- The mass spectrum of the doubly charged combinations is well fitted by a linear background in the range 1620 MeV/c² to 2100 MeV/c². In the signal region between 1835 MeV/c² to 1885 MeV/c², the observed excess is -2 combinations over a background of 436. The acceptance is 0.021. Including a systematic uncertainty of 8%, we get a 95% upper limit on the Ξ^{--} multiplicity of

$$N_{\Xi(1862)^{--}} < 4 \cdot 10^{-4}$$

Comparing with the $\Xi(1530)^0$ signal

- The $\Xi(1530)^0$ multiplicity is found to be:

$$N_{\Xi(1530)^0} + N_{\bar{\Xi}(1530)^0} = (70 \pm 6 \pm 6) 10^{-4},$$

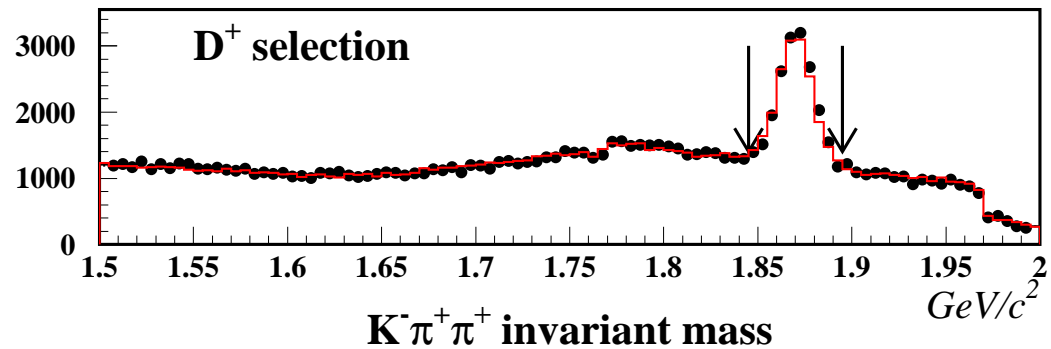
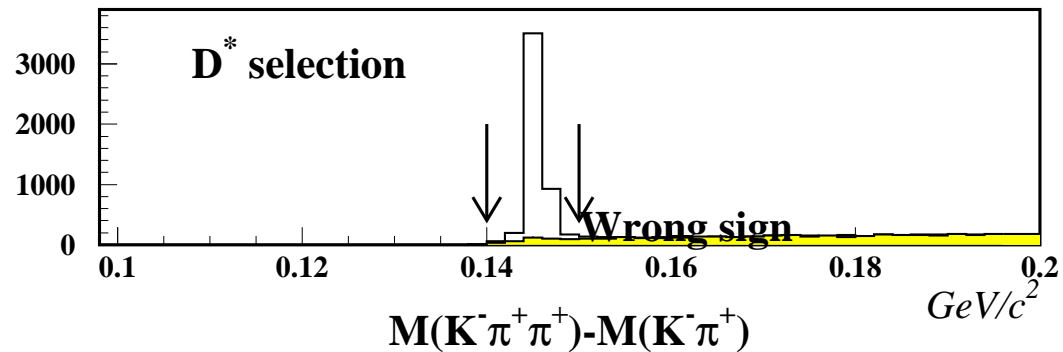
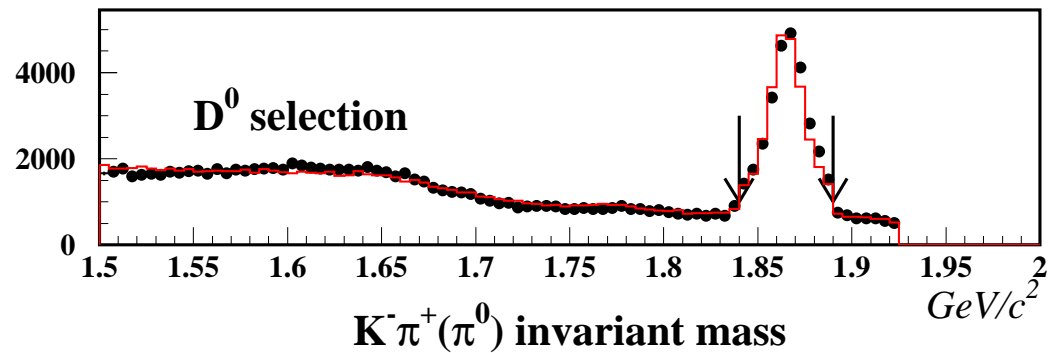
in good agreement with (but inferior to) the published ALEPH result of $(72 \pm 4 \pm 6) 10^{-4}$ and the OPAL result $(68 \pm 5 \pm 4) 10^{-4}$.

- Using the 1σ lower limit on the rate of $\Xi(1530)^0$ from the present measurement in the denominator, a 95% upper limit is obtained on the ratio:

$$N_{\Xi(1862)^-} / N_{\Xi(1530)^0} < 0.07$$

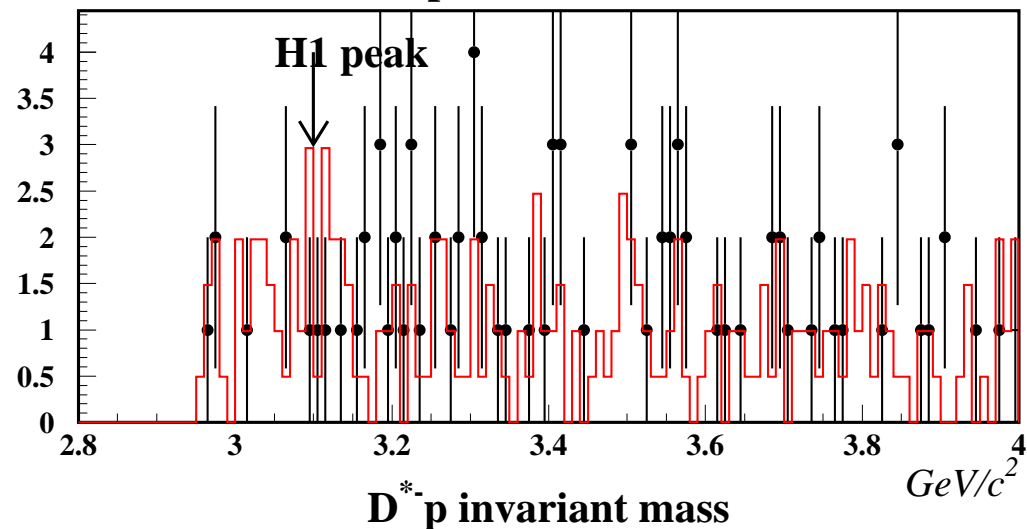
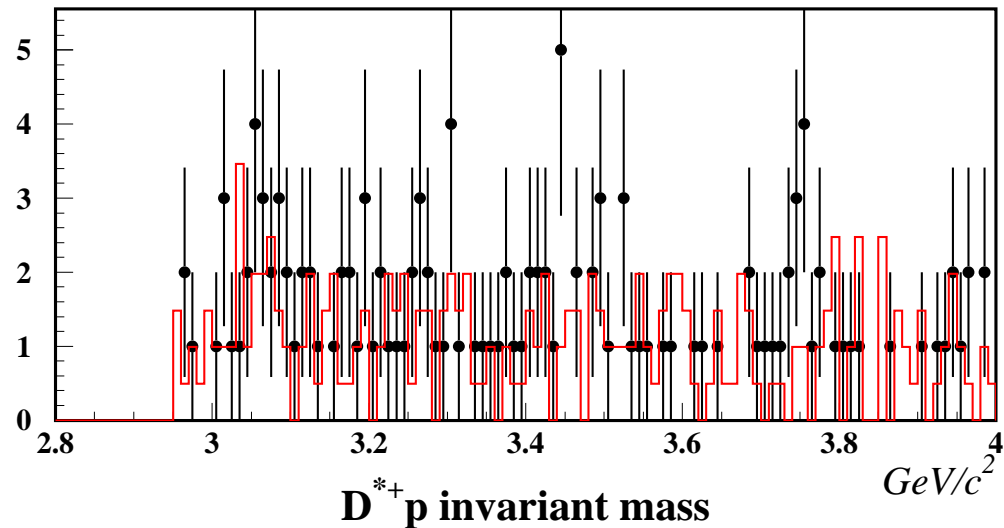
Selection of D-mesons

$K\pi(\pi)$ combinations with detached vertex.



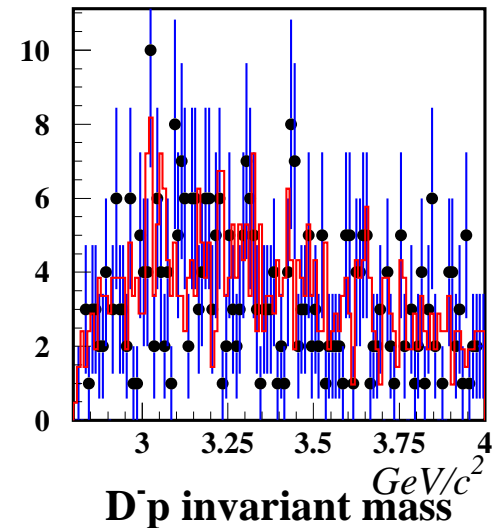
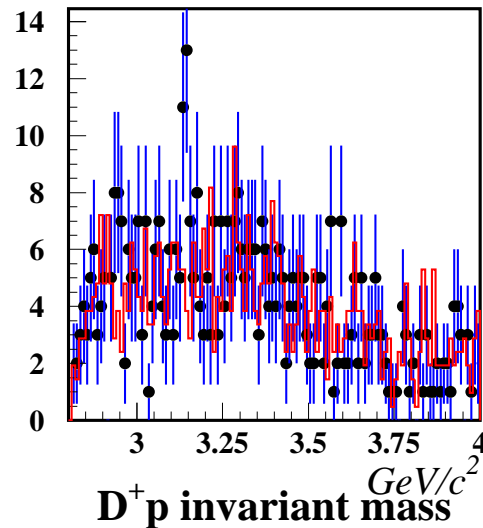
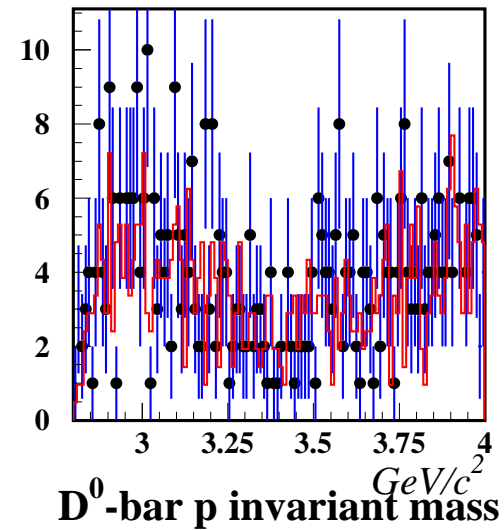
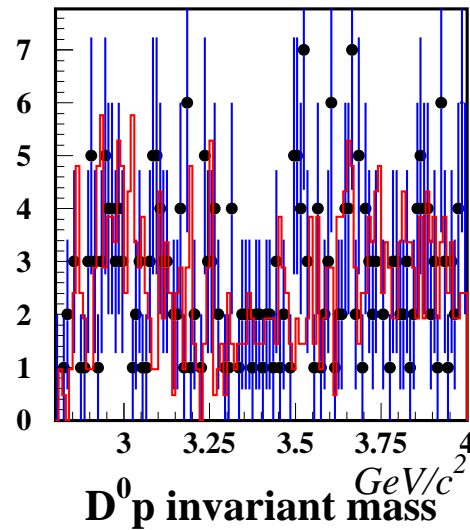
Search for pD^* resonances in ALEPH

pD^* combinations in the ALEPH LEPI sample



Search for pD resonances in the ALEPH

pD combinations in the ALEPH LEPI sample



Signals for a $p\bar{D}$ resonance at 3100 MeV

- A mass resolution of $3 \text{ MeV}/c^2$ is obtained by calculating the mass as
$$M(Dp) = M_{\text{meas}}(Dp) - M_{\text{meas}}(D) + M_{\text{PDG}}(D).$$
- In the $D^{*-}p$ channel, 2 combinations are observed with an invariant mass between $3090 \text{ MeV}/c^2$ and $3110 \text{ MeV}/c^2$, with 3.5 combinations expected from MC.
- In the D^-p channel, 13 combinations are observed with 8.5 expected.
- A possible charged partner is searched for in the \bar{D}^0p channel using a wider window of 40 MeV. Here, 21 combinations are observed with 14 expected.

Limit on a charmed pentaquark at 3100 MeV

- In conclusion, the 95% upper confidence limits on the number of Θ_c decays per Z are:

$$N_{\Theta_c(3100)^0} \cdot BR(\Theta_c^0 \rightarrow D^{*-} p) < 6 \cdot 10^{-4}$$

$$N_{\Theta_c(3100)^0} \cdot BR(\Theta_c^0 \rightarrow D^- p) < 25 \cdot 10^{-4}$$

$$N_{\Theta_c(3100)^+} \cdot BR(\Theta_c^+ \rightarrow \bar{D}^0 p) < 15 \cdot 10^{-4}$$

Conclusions I

- No evidence for exotic narrow baryon resonances have been found in the $e^+e^- \rightarrow Z \rightarrow q\bar{q}$ reactions collected by ALEPH during the LEP I running period.
- Upper limits at the 95% confidence level have been set on the multiplicity such resonances (including their antiparticles):

$$N_{\Theta(1535)^+} < 0.0031$$

$$N_{\Xi(1862)^{-}} < 5 \cdot 10^{-4}$$

$$N_{\Theta_c(3100)^0} \cdot BR(\Theta_c^0 \rightarrow D^{*-} p) < 6 \cdot 10^{-4}$$

$$N_{\Theta_c(3100)^0} \cdot BR(\Theta_c^0 \rightarrow D^- p) < 25 \cdot 10^{-4}$$

$$N_{\Theta_c(3100)^+} \cdot BR(\Theta_c^+ \rightarrow \bar{D}^0 p) < 15 \cdot 10^{-4}$$

Conclusions II

- Comparing with related non-exotic baryon states, 95% confidence level upper limits are set on the following ratios:

$$\frac{N_{\Theta^+}}{N_{\Lambda(1520)}} < 0.10$$

$$\frac{N_{\Xi(1862)^{--}}}{N_{\Xi(1530)^0}} < 0.07$$