Evidence for exotic baryon decaying to K_s^0 – (anti)proton

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for the ZEUS Collaboration

YITP workshop
``Multi-quark hadrons; four, five and more?"
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Motivation

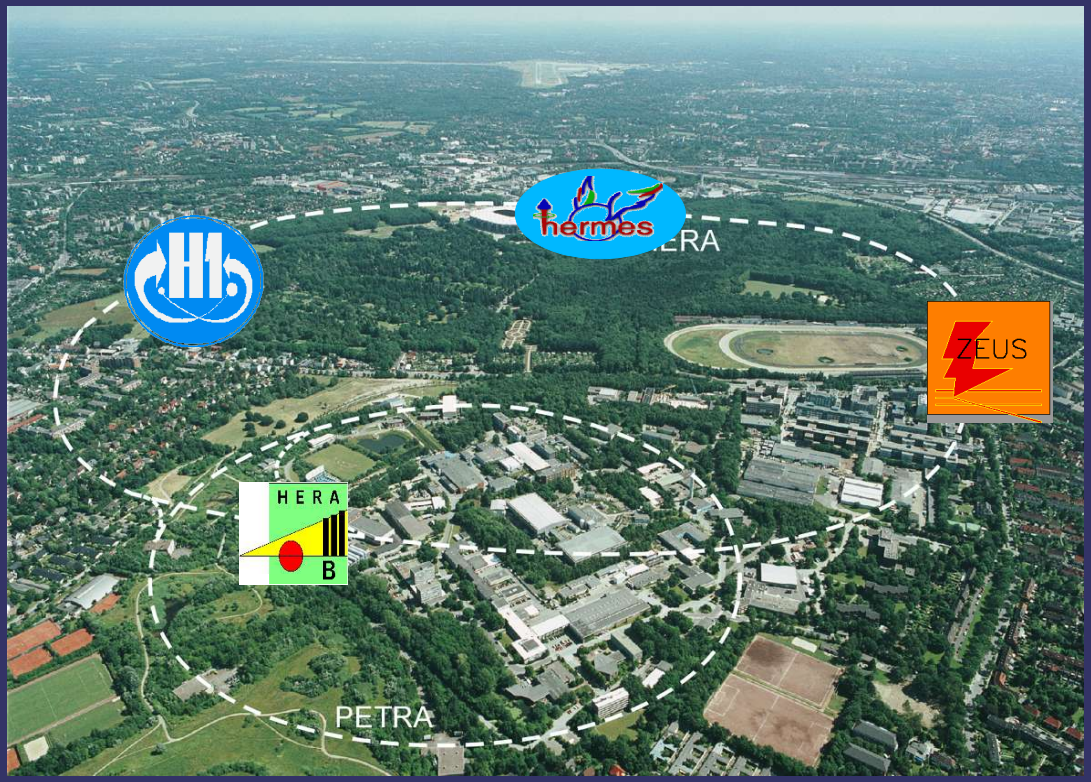
- Significant interest in baryon spectroscopy triggered by recent observations of possible pentaquark at **1530 MeV and width <15 MeV**, predicted by D.Diakonov, V.Petrov and M. Polyakov;

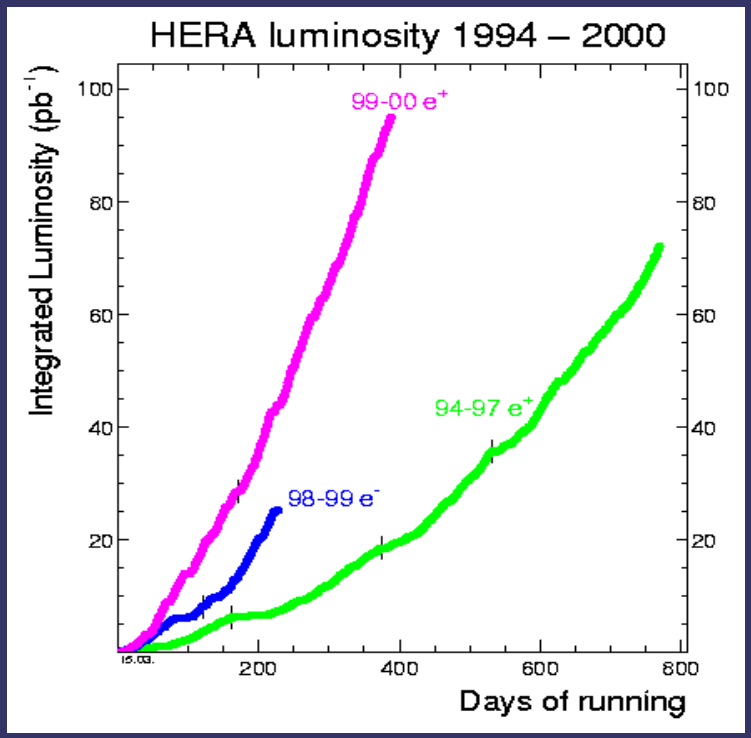
- Number of experiments observed a peak at similar mass (LEPS, DIANA, CLAS, SAPHIR, HERMES, SVD) – all are low-energy experiments;

- In this study, we attempt to find such a state by reconstructing K^0-(anti)proton invariant mass;

- Measurement is based on the central-tracking region, where the particle production is dominated by fragmentation. ZEUS is a colliding experiment
  → to reconstruct regions dominated by proton remnants is difficult

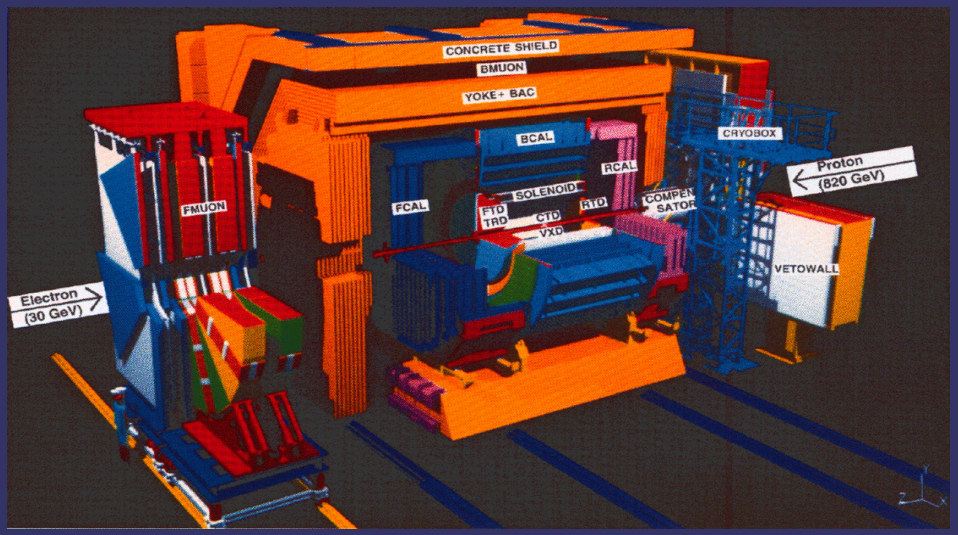
HERA experiments





Proton 820/920 GeV

Electron/positron 27.6 GeV



ZEUS detector

DIS kinematics

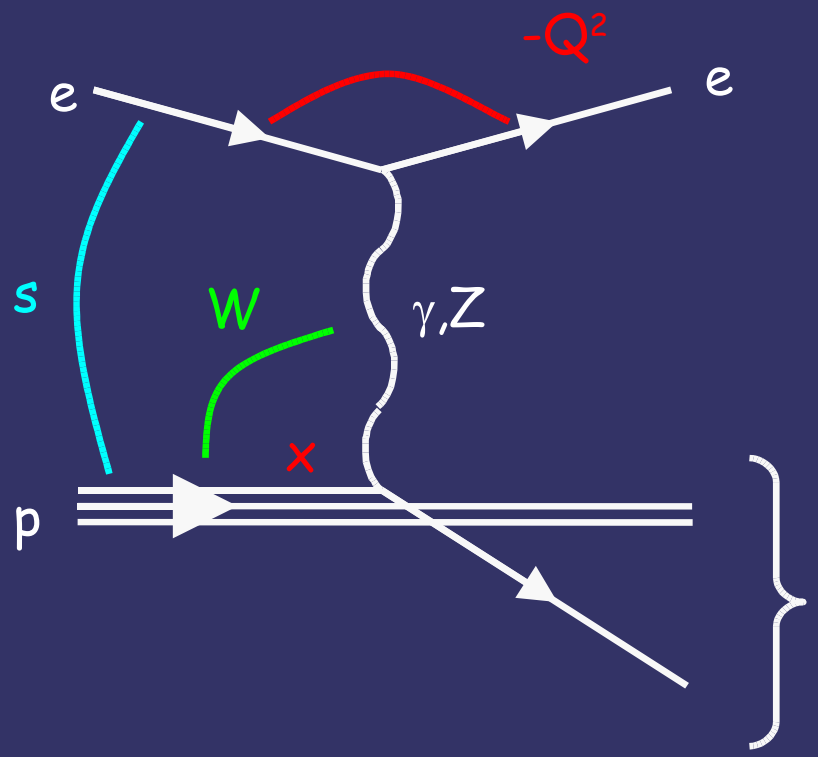
- ***s***: e-p c.m. energy

  $\sqrt{s}$ = 300 – 318 GeV

- $Q^2 = -q^2$: 4-momentum transfer squared

- ***x***: fraction of proton momentum carried by quark

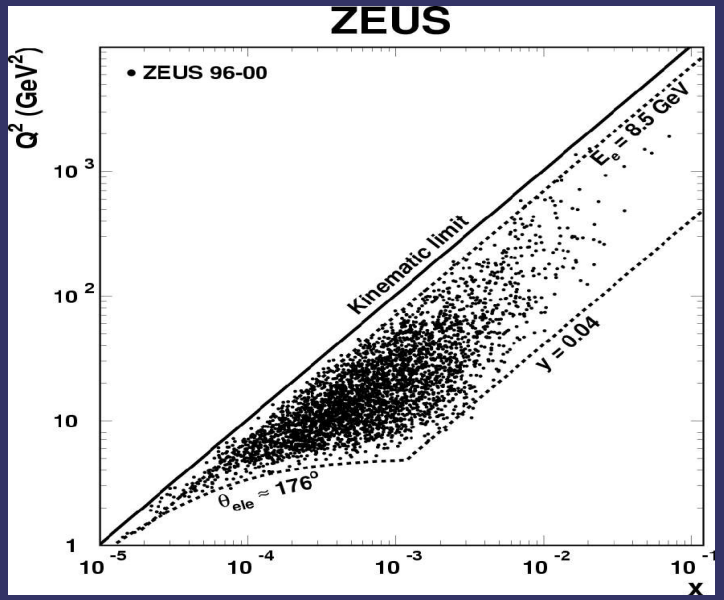
- ***W***: γ -p c.m. energy



Measurements are done in the central fragmentation region. Proton remnant usually escapes undetected

Event selection

- 121 pb^{-1} , 1996-2000,
- e^+p and e^-p collisions;
- CM energy of 300-318 GeV;
- $Q^2>1$ GeV^2 .



K^0_S selection

- CTD tracks, $p_T>150$ MeV, $-1.75 < \eta < 1.75$;
- K^0_S reconstructed from secondary-vertex tracks;
- Photon conversions removed: $M(e^+e^-) < 50$ MeV;
- Λ's removed $M(\pi p) < 1121$ MeV;
- $p_T(K^0)>300$ MeV; $|\eta(K^0)| < 1.5$;

Resolution for M (K^0_S -(anti)proton) masses ~ 4 ± 1 MeV (from Monte Carlo simulation)

K^0_S mass peak

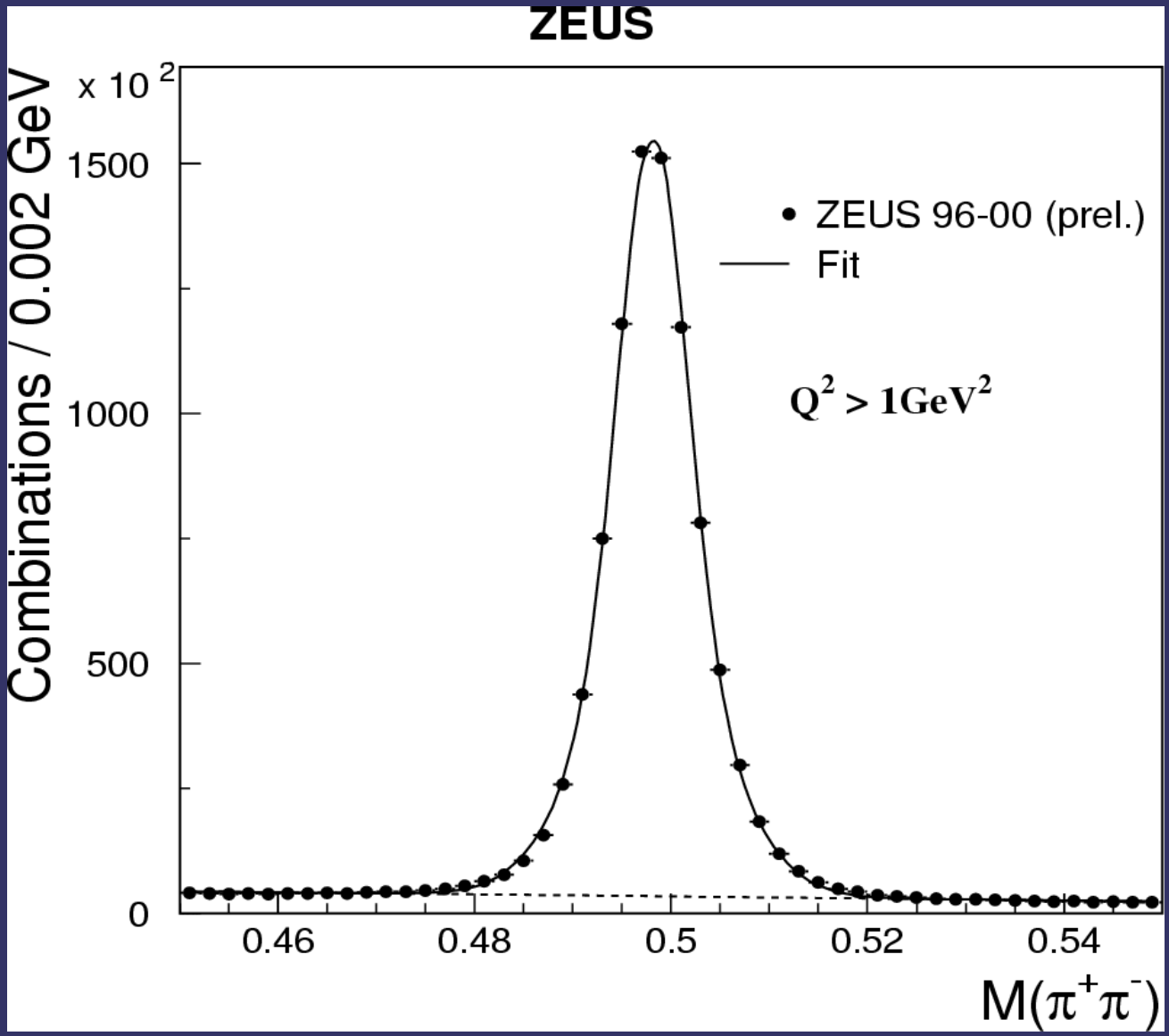
Double Gaussian + linear background for the fit

869690 ±1016 candidates

Background ~ 6 %

Peak at:
498.12 ± 0.01 (stat) MeV

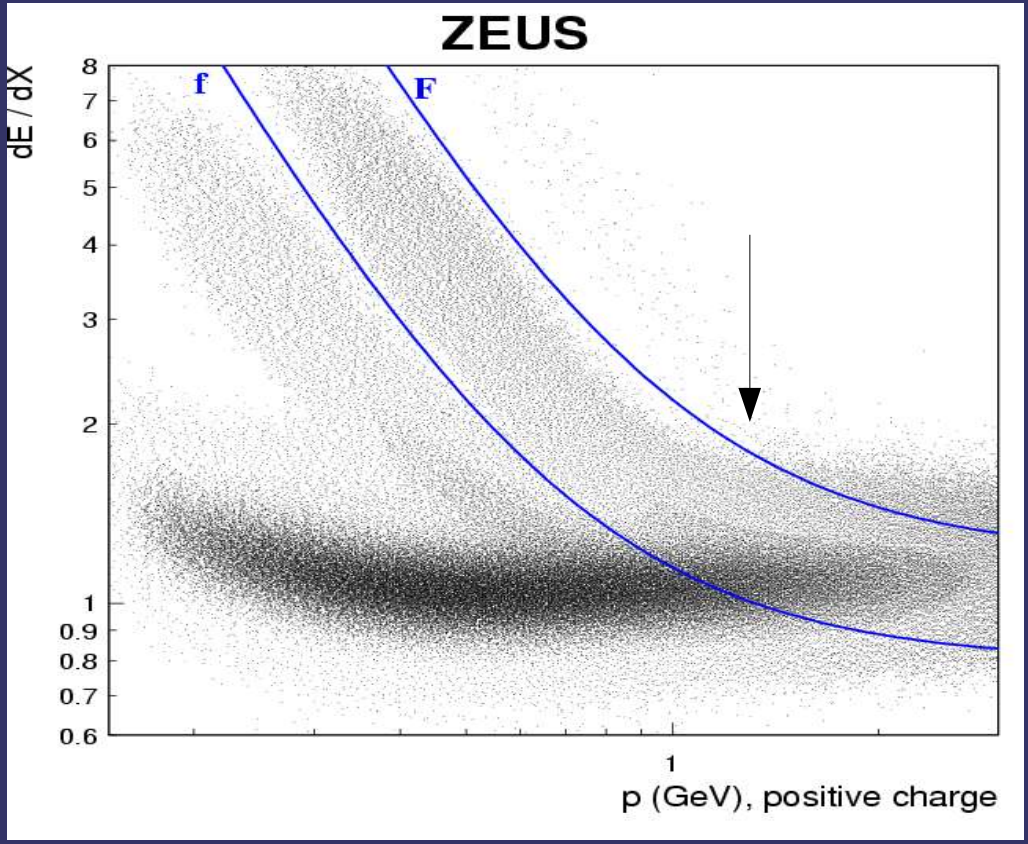
Shift by +0.8 MeV
from the PDG value



Proton and antiproton selection

Only primary tracks are taken with: f< dE/dX <F

- found from a visual examination of dE/dX;
- verified using a sample with reconstructed Λ;
- (anti)protons from ARIADNE have a similar band.

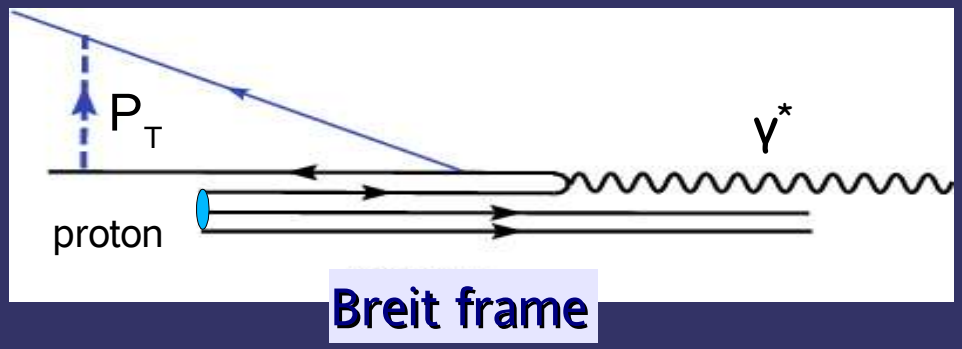


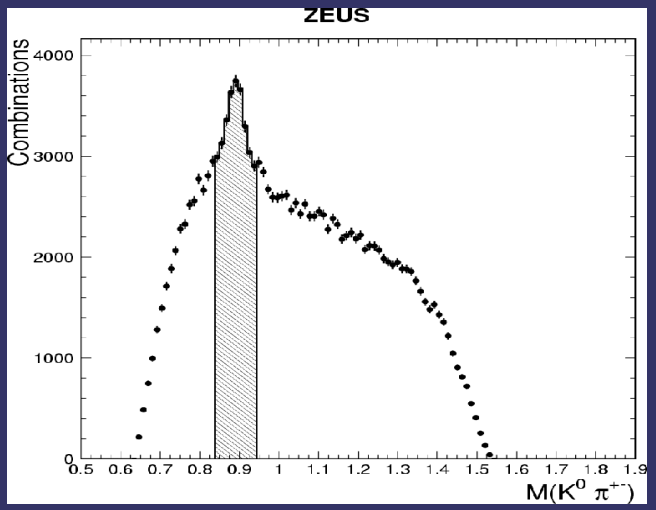
Proton and antiproton selection

Most protons are concentrated in the region p ~ 0.8-2 GeV:

☞ Large pion background

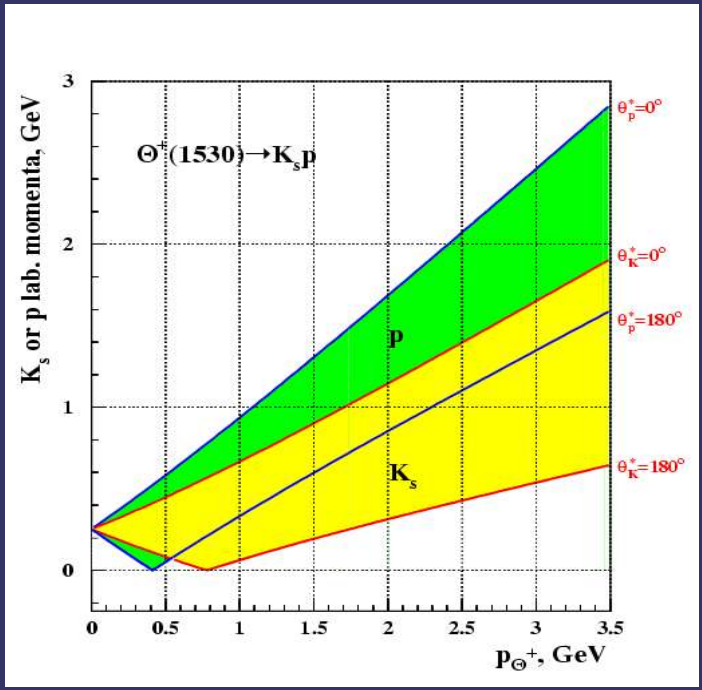
- Reject tracks with p>1.3 GeV inside the dE/dX band;
- Assign pion mass to proton candidate, reconstruct $K^0\pi$ mass, rejects pions from K^* : 800 <$M(K^0\pi)$ <980 MeV;
- E(proton)>$E(K^0)$;
- P_T>0.5 GeV in the Breit frame to look at gluon-rich DIS region (applied posteriori)

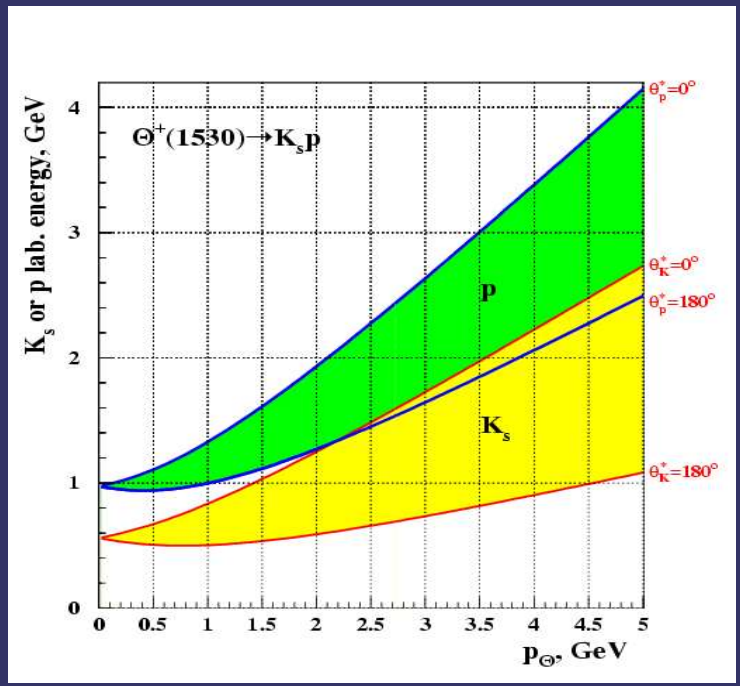




Why so complicated ?

Going to high dE/dX values one can get the best possible purity for protons, but in this case the momenta of protons are too low (typically, lower than average momentum of K^0!) ☞ no phase space left for pentaquark production





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hep-ph/0401122

How to reduce combinatorial background? (average charged multiplicity ~ 16 per event!)

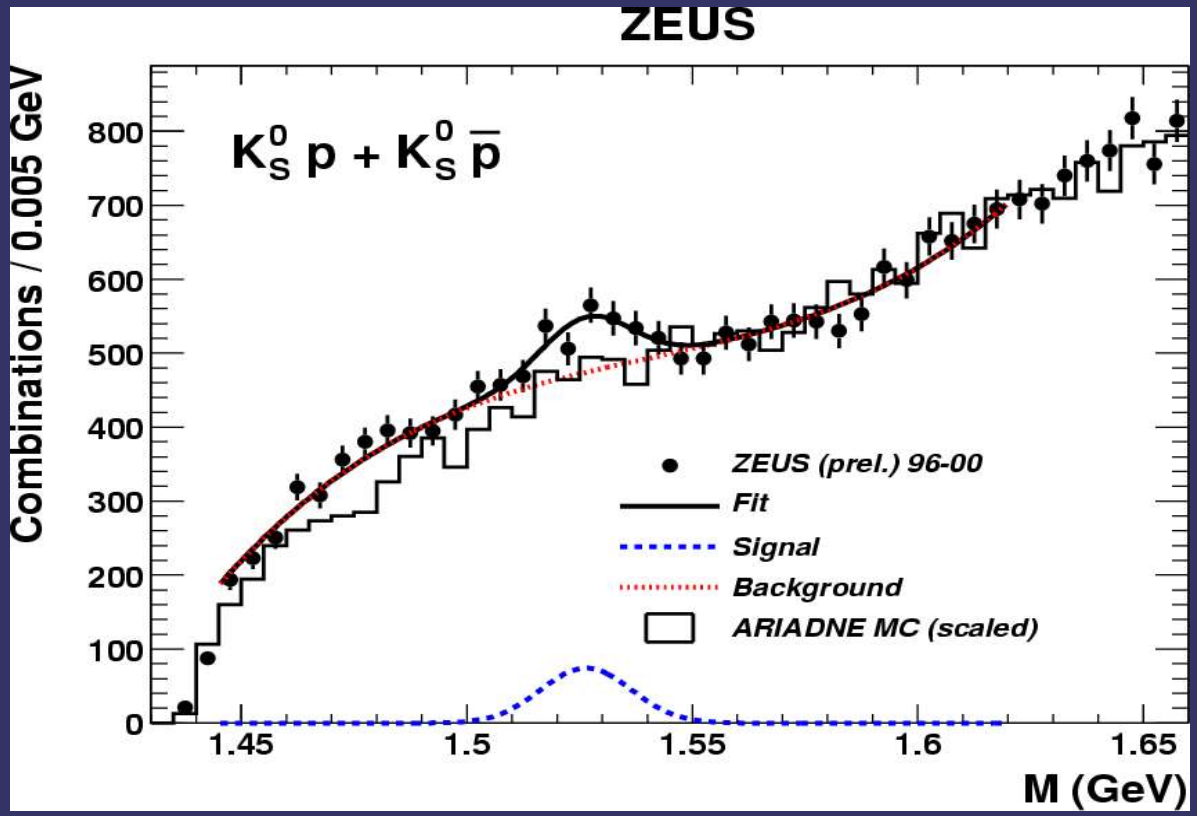
☞ use energy-difference cut, go to low W, restrict charged multiplicity, etc..

Possible reflections from known resonances

- Plenty of weakly decaying resonances cannot be reflected to narrow peaks;
- Narrow decays from charmed/bottom mesons cannot give reflections due to their large masses;
- MC contains reflections from known decays or possible misreconstruction.

ZEUS preliminary results

Fit: Gaussian + P3 (free parameters)



Combined sample: 372±75 candidates
peak=1527±2(stat.) MeV, W=10 ±2(stat.) MeV

ZEUS preliminary results

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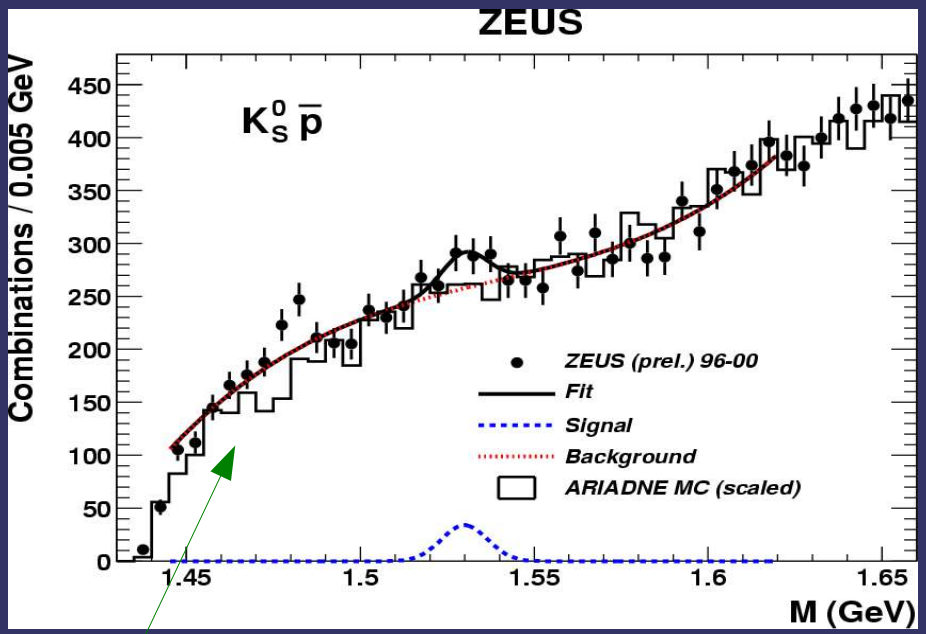
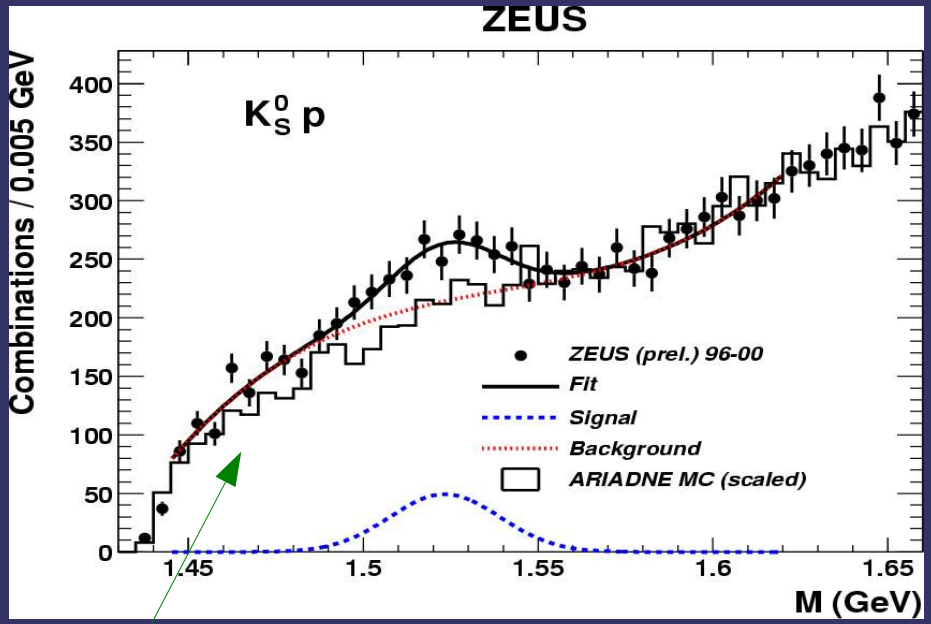




Σ(1480) bump?

K^0-antiprotons: 126±50 candidates
peak=1529±3(stat) MeV, W=7 ±3 MeV(stat)

Σ(1480) bump?

K^0-protons: 393±86 candidates
peak=1523±3(stat) MeV, W=16 ±3(stat) MeV

Note: if the width is fixed to ~ 10 MeV, the fit is still OK

Systematic study

- Several systematic checks were performed:
  - ✔ Momentum cut varied within 1.1-1.7 GeV;
  - ✔ Q^2 raised to 20 GeV^2;
  - ✔ K^* cut removed, replaced by soft dEdX cut (dE/dX>1.15);
  - ✔ P_T in Breit frame removed (decreases the signals by ~0.7 σ);
  - ✔ Fit done with Breit-Wigner (instead of Gaussian) + different order polynomials.

Peak position found to be robust

- Most convincing check: combine K^0 with tracks from region dE/dX<1.2 and p<0.9 GeV, where all particles except for (anti)protons can contribute to mass spectra:

  – NO 1527 MeV PEAK!

Comparisons with other experiments

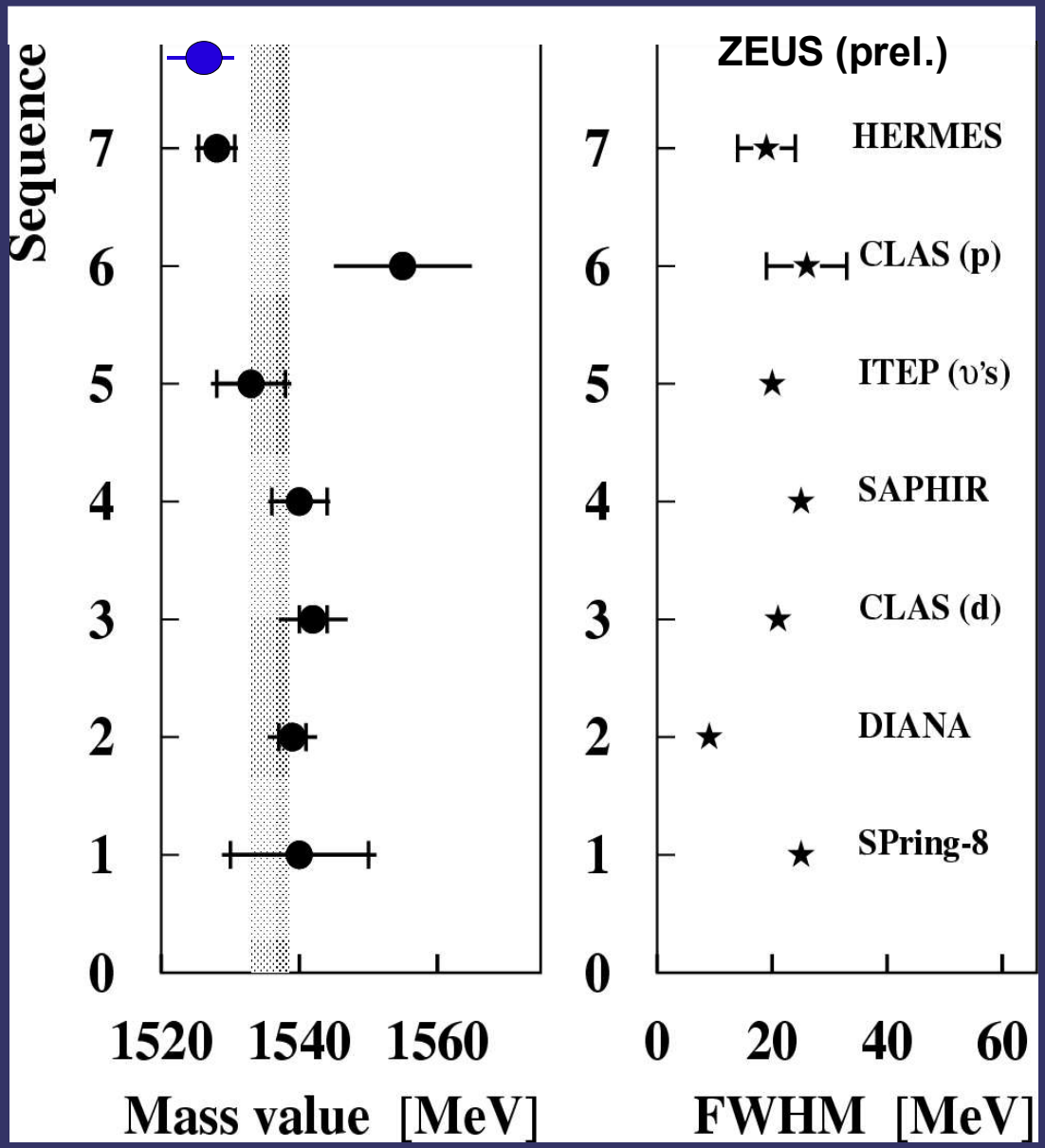
- Word average:

  1536.2 ± 2.6 MeV

  (compiled by HERMES, without prel. ZEUS result)

- HERA results prefer smaller pentaquark mass;

- Inclusion of prel. ZEUS result would shift the mass to a lower value



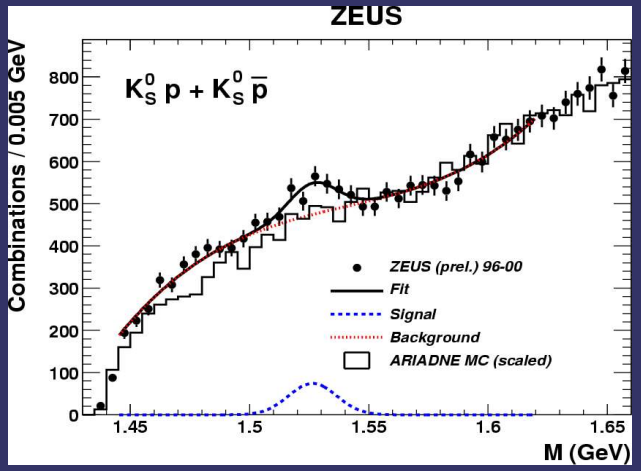
Modified from hep-ex/0312044 (HERMES Coll.)

Summary

- A signal at 1527±2(stat.) MeV, with a Gaussian width of 10±2 MeV:
  - ✔ ~ 5 σ statistical significance (from Gaussian fit);
  - ✔ exists for both K^0-protons and K^0-antiproton channels (antipentaquark);
  - ✔ consistent with the predicted pentaquark (1530 MeV, <15 MeV width);
    - But lower than the mass measured by CLAS and SAPHIR;
    - Consistent with HERMES;
  - ✔ Systematics (~ a few MeV) need to be estimated;
  - ✔ PRELIMINARY results! Final results are coming ...
- First measurement in HEP colliding experiment

  (in a region dominated by hadronisation!)

  ☞ Can this disfavor some pentaquark models?



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