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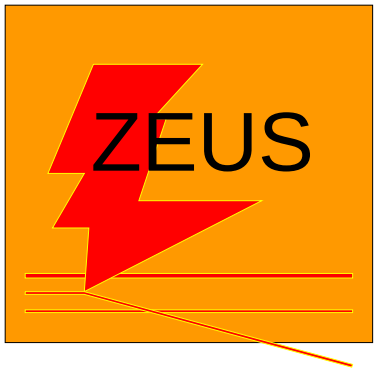


Search for Pentaquarks in DIS at HERA

Pentaquark Workshop

Trento

February 10, 2004

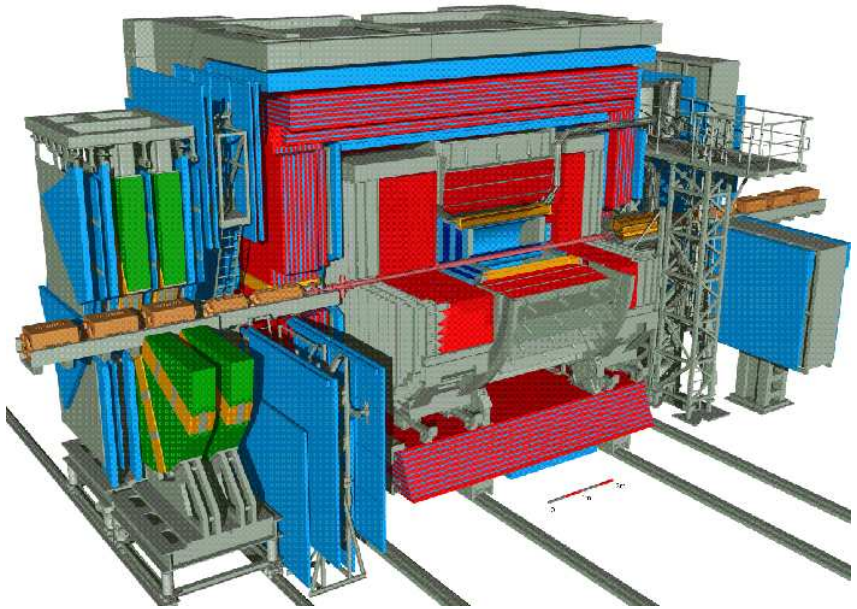
- **Introduction**
- **K^0_S and Proton Selection**
- **Preliminary Results**
- **Summary**

Introduction

- **Five-quark bound state $\Longrightarrow$ Pentaquark**
- **Most recent prediction: Diakonov, Petrov and Polyakov $\Longrightarrow$ Quark Soliton Model**
- **Several experiments claim observations of possible pentaquark $\Longrightarrow$ Mass: 1530 MeV, Width: $<$ 15 MeV**
  - **LEPS (SPring8):** $\gamma \mathbf{n}(\mathrm{C}^{12}) \rightarrow \mathrm{K}^{+}\mathrm{K}^{-}\mathbf{n}$
  - **DIANA (ITEP):** $\mathrm{K}^{+}\mathrm{Xe} \rightarrow \mathrm{K}^{0}_{\mathrm{S}}\mathbf{p}\mathrm{X}$
  - **CLAS (JLAB):** $\gamma \mathbf{d} \rightarrow \mathbf{p}\mathrm{K}^{+}\mathrm{K}^{-}\mathbf{n}$
  - **SAPHIR (ELSA):** $\gamma \mathbf{p} \rightarrow \mathrm{K}^{0}_{\mathrm{S}}\mathrm{K}^{+}\mathbf{n} \rightarrow \pi^{+}\pi^{-}\mathrm{K}^{+}\mathbf{n}$
  - **HERMES (HERA):** $\mathbf{eD} \rightarrow \mathrm{K}^{0}_{\mathrm{S}}\mathbf{pX}$
  - $\nu\bar{\nu}$ **collision bubble chamber experiments at CERN and FNAL**
  - **and more . . .**

Pentaquarks with ZEUS Detector

- Deep Inelastic Scattering (DIS): ep $\rightarrow$ e'X
- CM energy: 300-318 GeV
- Reconstruct K^0_S-(anti)proton invariant mass
- Central Tracking Detector (CTD) $\Rightarrow$ particle production dominated by fragmentation



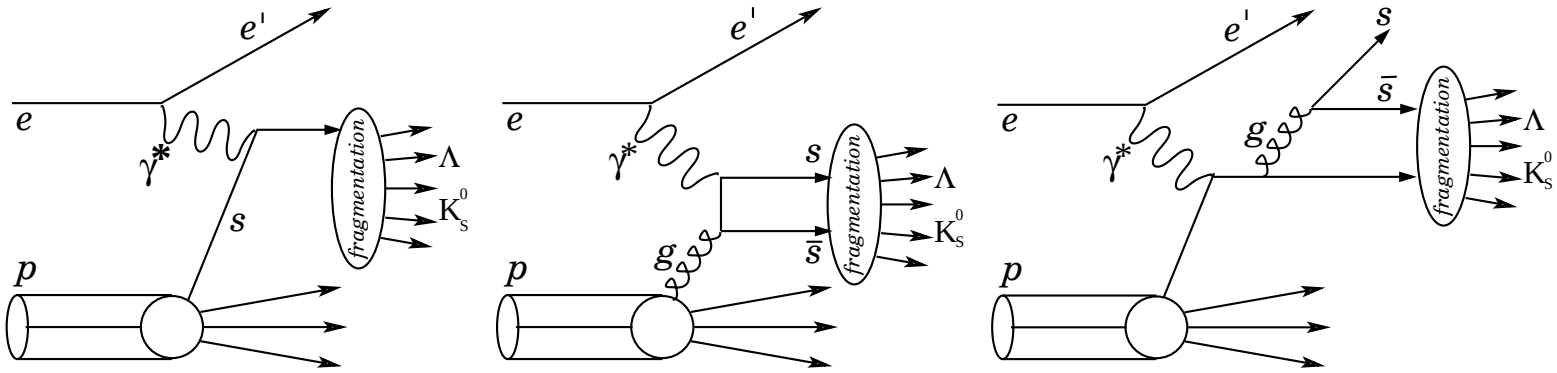
Strange Quark Production in DIS & Fragmentation to Hadrons

Kinematics of DIS:

$$q = e - e' \qquad Q^2 = -q^2 = sxy$$

$$x = \frac{Q^2}{2p\cdot q} \qquad y = \frac{p\cdot q}{p\cdot e}$$

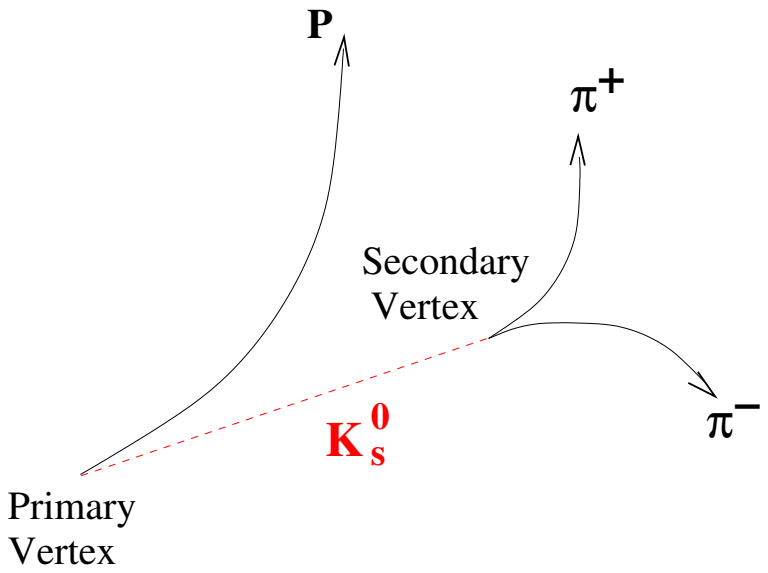
Possible Mechanisms of Strange Quark Production:

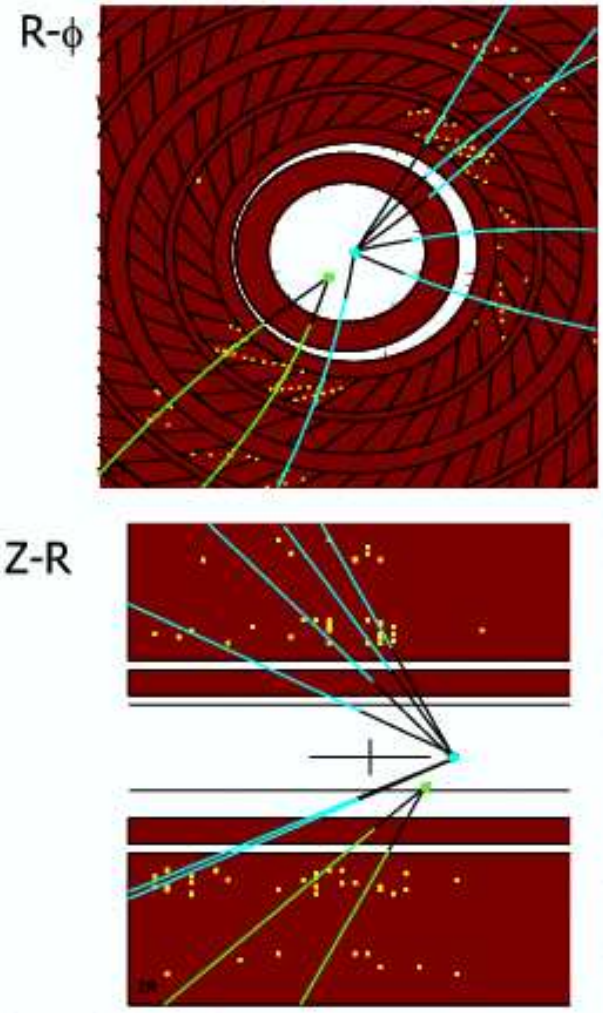


Flavour Excitation **Boson-Gluon Fusion** **Gluon-Splitting**

DIS Event Selection

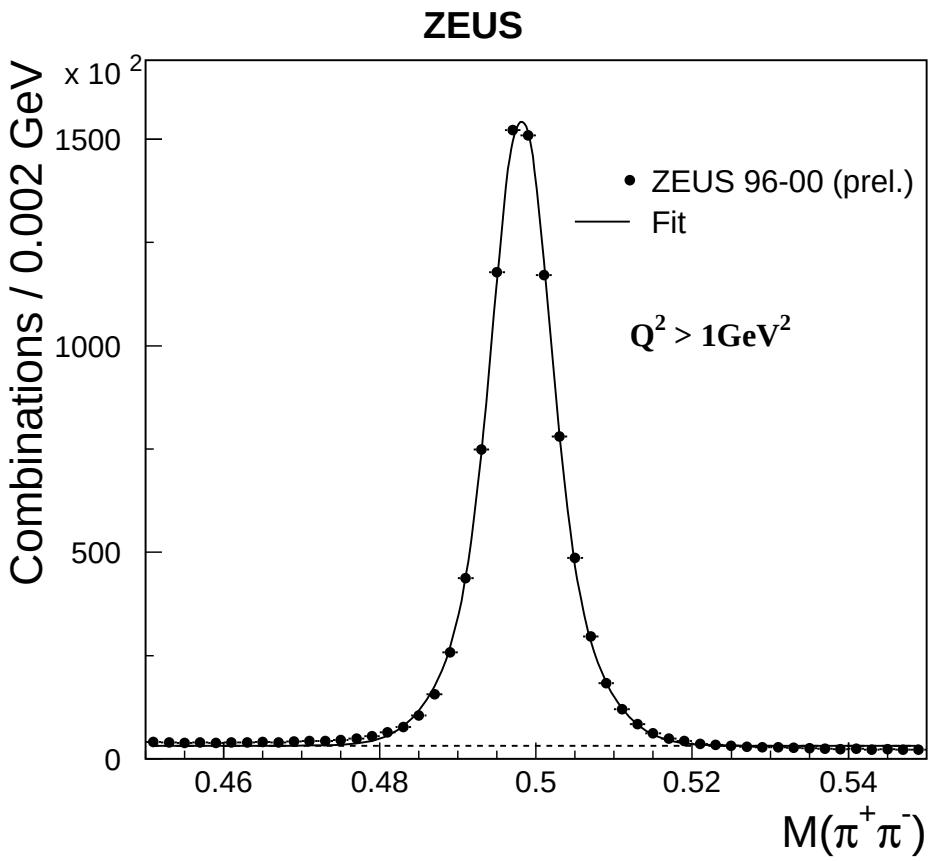
- 96-00 data sample $\Rightarrow \mathcal{L} = 121\ \mathrm{pb}^{-1}$
- e^+p, e^-p collisions, $Q^2 > 1$
- proton: require one primary vertex track
- K^0_S: require two secondary vertex tracks with opposite charges $\Rightarrow$ assume π mass for each track





K^0_S Selection

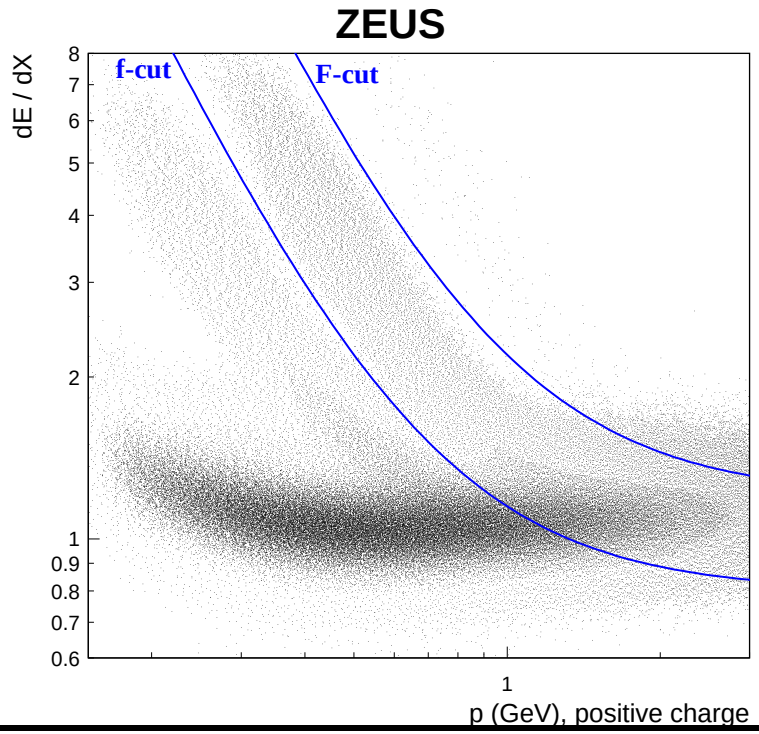
- **CTD Track Selection**
  - $p_T > 150$ MeV
  - $|\eta| \leq 1.75$
- **K^0_S Selection**
  - $p_T(K^0_S) > 300$ MeV
  - $|\eta(K^0_S)| \leq 1.5$
  - $483 \leq M(\pi^+\pi^-) \leq 513$ MeV
  - γ conversion removal
    $\Longrightarrow M(e^+e^-) \geq 50$ MeV
  - Λ removal
    $\Longrightarrow M(\pi p) \geq 1121$ MeV
- **Peak: 498.12±0.01 MeV**
- **Candidates: 870K±1K**
- **Background: ≈ 6%**

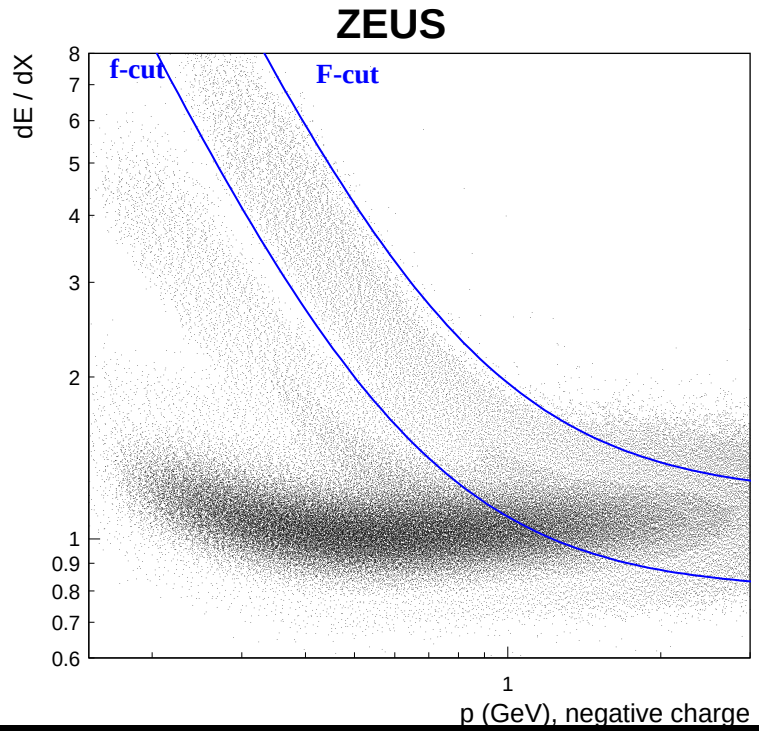


Fit: Double Gaussian + Linear Bg

(anti)proton Selection I

- Tracks from primary vertex only
  - $p_T > 150$ MeV, $|\eta| \leq 1.75$
- Require f < dE/dx < F (f & F motivated by Bethe-Bloch equation)
  - found from a visual examination of dE/dx
  - verified using a sample with reconstructed Λ
- anti(protons) from ARIADNE have similar bands





(anti)proton Selection II

- Protons concentrated in region p $\approx$ 0.8 - 2 GeV

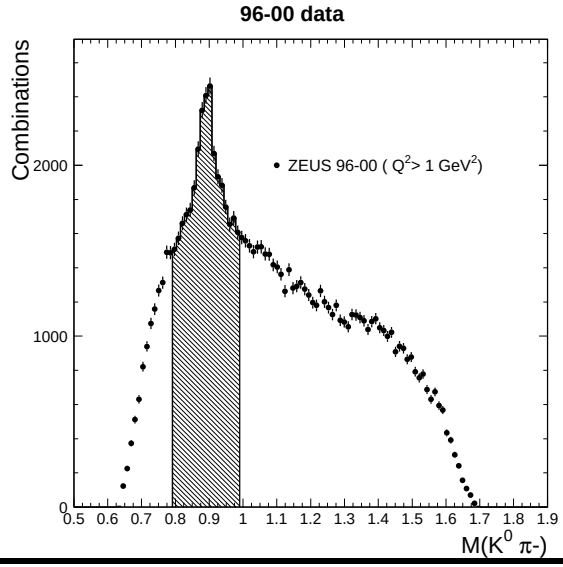
  $\Longrightarrow$ Large pion background

  - Choice 1: reject protons with p $>$ 0.7 GeV (+ dE/dx band)
    - gain proton purity (90%)
    - lose statistics (70-80%)
  - Choice 2: reject protons with p $>$ 1.2-1.6 GeV (+ dE/dx band)
    - gain statistics
    - lose purity (70-30%)
  - Compromise $\Longrightarrow$ reject tracks with p $>$ 1.3 GeV (+ dE/dx band)
    - 50% purity
    - need other means of pion removal $\cdots$

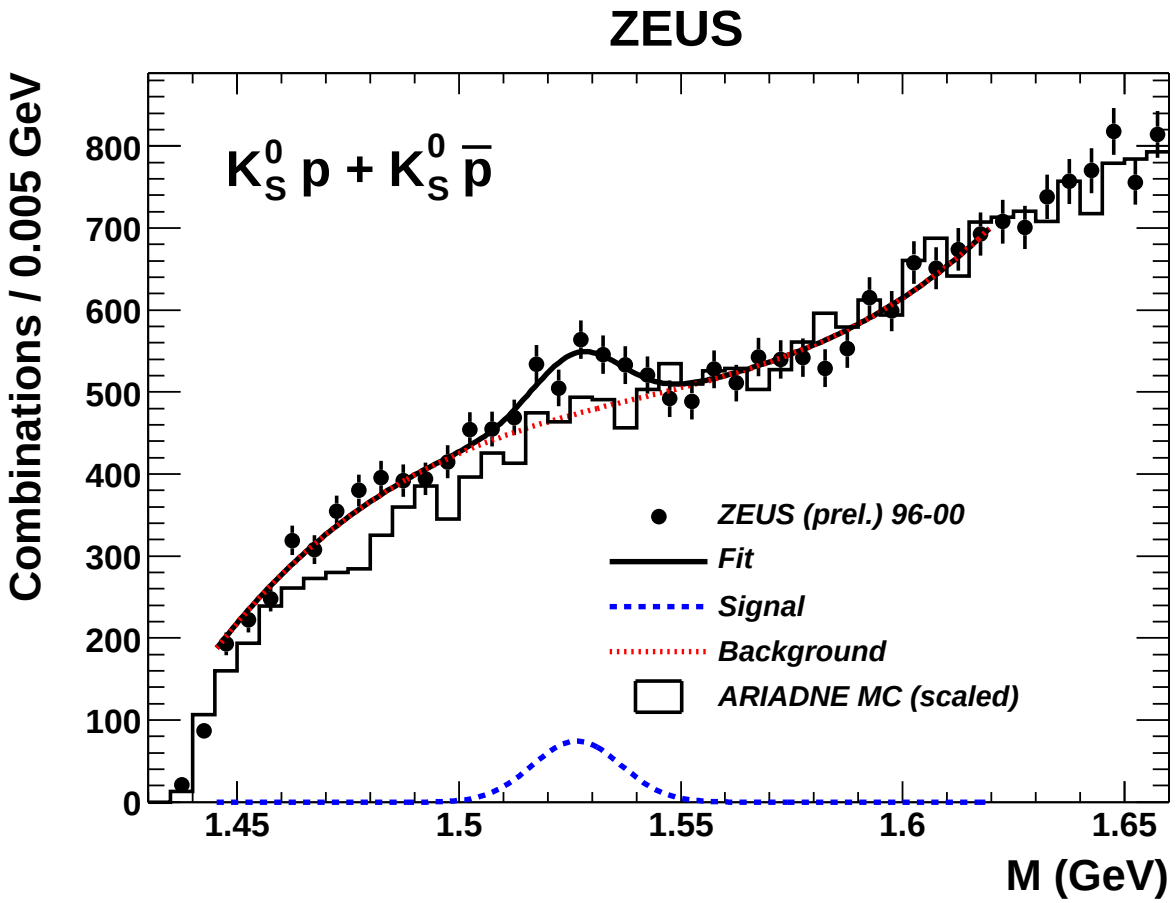
- Require E(proton) $>$ E(K^0_S)

Possible Reflections

- Possible reflection from $K^\star \to K^0_S\pi$ (if $\pi^\pm$ misidentified as (a)proton)
  - reconstruct $K^0_S\pi$ mass $\Rightarrow$ assign pion mass to proton candidate
  - removes pions from $K^\star$: $800 < M(K^0_S\pi) < 980$ MeV
- Weakly decaying resonances cannot be reflected as narrow peaks
- Narrow decays from charm/bottom mesons cannot give reflections $\Longrightarrow$ large mass
  - e.g. $D^\pm \to K^0K^\pm$ (if $K^\pm$ misidentified as (a)proton)
- MC contains reflections from known decays or possible misreconstruction

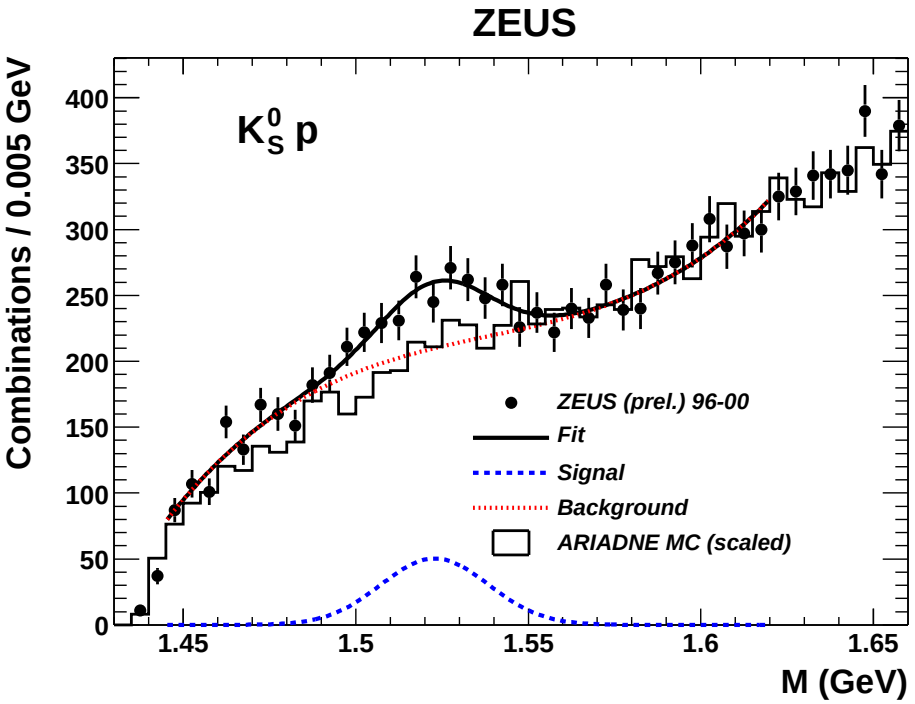


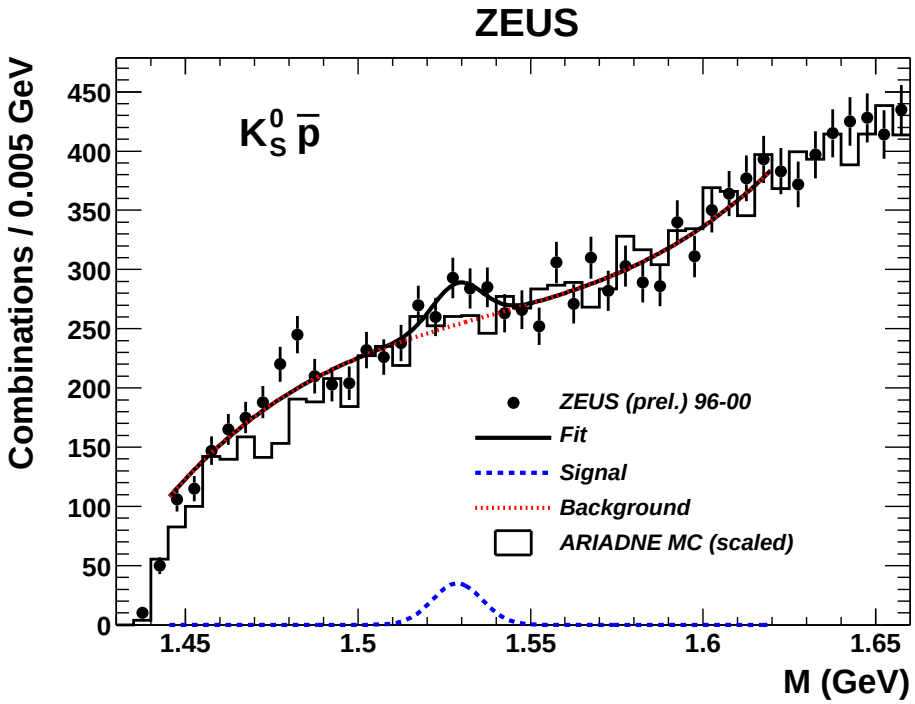
ZEUS Preliminary Results I



- Fit: Gaussian + P3 (free parameters)
  - $\Longrightarrow$ Combined Sample: 372 ± 75 candidates
  - $\Longrightarrow$ Peak: 1527 ± 2 (stat) MeV Width: 10 ± 2 (stat) MeV

ZEUS Preliminary Results II





- Fit: Gaussian + P3 (free parameters)
- K^0_S-proton: 393 ± 86 candidates
  $\Longrightarrow$ Peak: 1523 ± 3 (stat) MeV Width: 16 ± 3 (stat) MeV
- K^0_S-antiproton: 126 ± 50 candidates
  $\Longrightarrow$ Peak: 1529 ± 3 (stat) MeV Width: 7 ± 3 (stat) MeV

Systematic Study

- Several systematic checks performed:
  - Momentum cut varied within 1.1 - 1.7 GeV
  - Q^2 raised to 20 GeV^2
  - $K^\star$ cut removed
  - Fit done with Breit-Wigner + different order polynomials

  Peak position found to be robust

- Most convincing check:
  - combine K^0_S with tracks from pion dominated region
    $\Rightarrow$ dE/dx $<$ 1.2 and p $<$ 0.9 GeV
  - NO 1527 MeV PEAK!

Summary

- **Signal $\Longrightarrow$ M = 1527 $\pm$ 2(stat) MeV, Width = 10 $\pm$ 2 (stat) MeV**

  - $\approx$ 4-5 σ statistical significance (from Gaussian fit)
  - exists for K^0_S-proton/antiproton channels (antipentaquark!)
  - consistent with mass and width of predicted pentaquark
  - possible systematic shift for peak within $\approx$ 1 MeV
    $\Longrightarrow$ from K^0_S, Λ, $K^\star$ measurements

- **Full systematics need to be estimated $\Longrightarrow$ work in progress $\cdots$**

- **First measurement by HEP colliding experiment!**