Investigation of the $D^*p$ Resonance in the 3 GeV Region with HERA II Data at H1

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- Motivation
- Selection
- $D^*p$ Mass Distribution
Electron-Proton-Collisions at HERA

kinematics:

\[ \boldsymbol{P}_q = x \boldsymbol{P}_p \]

\[ Q^2 = -q^2 \]

\[ y = \frac{q \cdot \boldsymbol{P}_p}{k \cdot \boldsymbol{P}_p} \]
Motivation

- analysis of HERA I data (75 pb⁻¹): peak in $D^*p$ spectrum at 3.1 GeV
- based on reconstructed ~4000 $D^*$ mesons
- minimum quark content: $uudd\bar{c}$
Motivation

- standard selection: DIS, protons identified by dE/dx
- cross checks with different selections:
  - DIS, high proton momentum (no dE/dx cuts)
  - photoproduction ($Q^2 \approx 0$)
Motivation

• excess in $D^*p$ mass not confirmed by other experiments
  – ZEUS: $\sim63\,000$ D* ($\sim13\,500$ in DIS)
  – BaBar: $>750\,000$ D* in B decays
  – CDF: $540\,000$ D* in $p\bar{p}$ collisions
  – ALEPH: $\sim5\,000$ D* in Z decays
  – FOCUS: $\sim35\,000$ D* in $\gamma$ collisions with fixed target
  ➔ possible differences: kinematics / cuts / prod. mechanism / ...?
  ➔ HERA II data offer the chance to study an independent data sample with the same detector
  ➔ look at HERA II data with (nearly) same cuts
Selection

- full HERA II data, 348 pb$^{-1}$
  - HERA II analysis:
    - $0.05 < y_e < 0.7$
    - $2 < Q^2 < 100$ GeV$^2$
    - $E'_e > 10$ GeV
    - $\theta_e < 3.09$
    - radius cut: $r > 12$ cm (center shifted)
  - HERA I publication:
    - $0.05 < y_e < 0.7$
    - $1 < Q^2 < 100$ GeV$^2$
    - $E'_e > 8$ GeV
    - (no cut)
    - radius cut: $r > 8.7$ cm

- $-1.5 < \eta(D^*) < 1.0$, $p_t(D^*) > 1.5$ GeV, $z(D^*) > 0.2$, $p_t(K) > 0.5$ GeV, $p_t(\pi) > 0.25$ GeV, $p_t(\pi_s)$, $p_t(p) > 0.12$ GeV
- use „high proton momentum“ (p(p)$>$2 GeV) selection, no dE/dx cuts
D* Signal

- D* selection in „golden channel“
  \[ D^*_{\pm} \rightarrow D^0 \pi_{\pm} \rightarrow K^\pm \pi^\pm \pi^\pm \]

- 15576 ± 194 D*s in HERA II data

- less than increase in luminosity compared to HERA I data due to different phase space

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Investigation of the D*p Resonance
Cross Check: Higher Mass D Mesons

- Look for \(D_1(2420)^0\) and \(D_2^*(2460)^0\) \(\rightarrow D^*\pi\)
- Same \(D^*\) selection, use \(\pi\) mass for additional track
- \(\Delta M\) technique: 
  \[ M(D^*\pi) = m(K\pi\pi_s\pi) - m(K\pi\pi_s) + M_{D^*} \]
- Clear excess at expected positions
- Masses & widths of Breit-Wigners fixed to PDG values
  \(\rightarrow\) sensitivity to this kind of decays
• structure at 3.1 GeV in HERA I data also for this selection
• $D^*$ MC (normalised to number of $D^*$) + wrong charge D (from data) gives reasonable description away from 3.1 GeV
• ratio $N(D^*p)/N(D^*) = 0.8 \pm 0.2 \%$
HERA II $D^*p$ Mass Spectrum

- no peak structure around 3.1 GeV
- $D^*$ MC (normalised to number of $D^*$) + wrong charge $D$ (from data) gives reasonable description
Comparison HERA I and HERA II

- excess corresponding to the HERA I rate should be visible in the HERA II data
  - expected excess not there

y axes scaled roughly to luminosity
Limit

• limit determined with HERA II data only

• background function:
  \[ p_0 \ast (x - M_{D^*} - M_p)^{p_1} \ast e^{p_2 \ast (x - M_{D^*} - M_p)} \]

• signal: assumed 12 MeV mass resolution (from HERA I publication, compatible with 0 MeV natural width)

→ 95% confidence level limit on N(D*p) at 3.1 GeV: 16.3 events

→ HERA II limit on ratio \( \frac{N(D^*p)}{N(D^*)} \): 0.1 %
  HERA I data: 0.8 ± 0.2 %
Backward Analysis

- study D* mass in **signal region** (3.085 to 3.115) and **side bands** (2.990-3.070 and 3.130-3.210 GeV, scaled by 3/16) of \( D^*p \) distribution
- excess at nominal value in HERA I data in **signal sample** compared to **side bands**
  - **signal sample** is charm enriched
no excess in HERA II data in signal sample compared to side bands
Conclusions

- excess at 3.1 GeV in the D*p mass distribution in HERA I data also in the phase space of the HERA II analysis
- no excess in HERA II data for high proton momentum
- 95% CL limits from HERA II data:
  - \( N(D^*p, 3.1 \text{ GeV}) < 16.3 \text{ events} \)
  - \( \frac{N(D^*p)}{N(D^*)} < 0.1 \% \)
Sum of HERAI and HERAII

- sum of HERAI and HERAII shows no signal