HERA-B RICH: performance and physics impact

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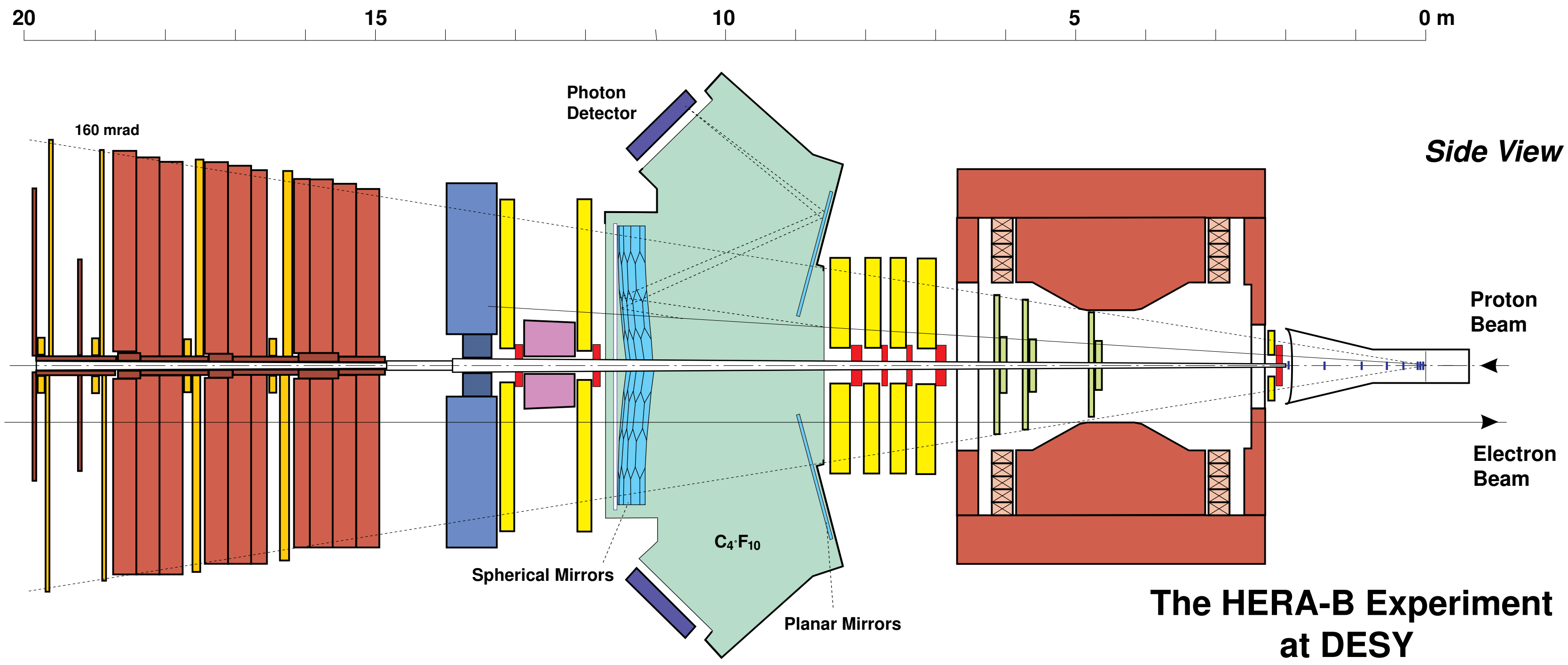
1. Introduction
2. RICH performance
3. RICH in physics analysis
4. Summary

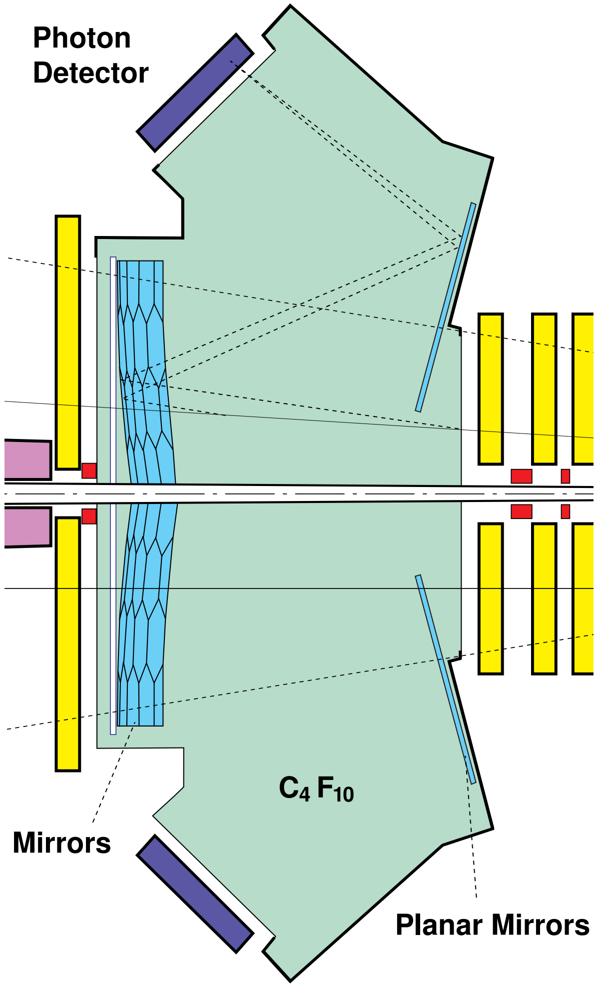
The HERA-B experiment

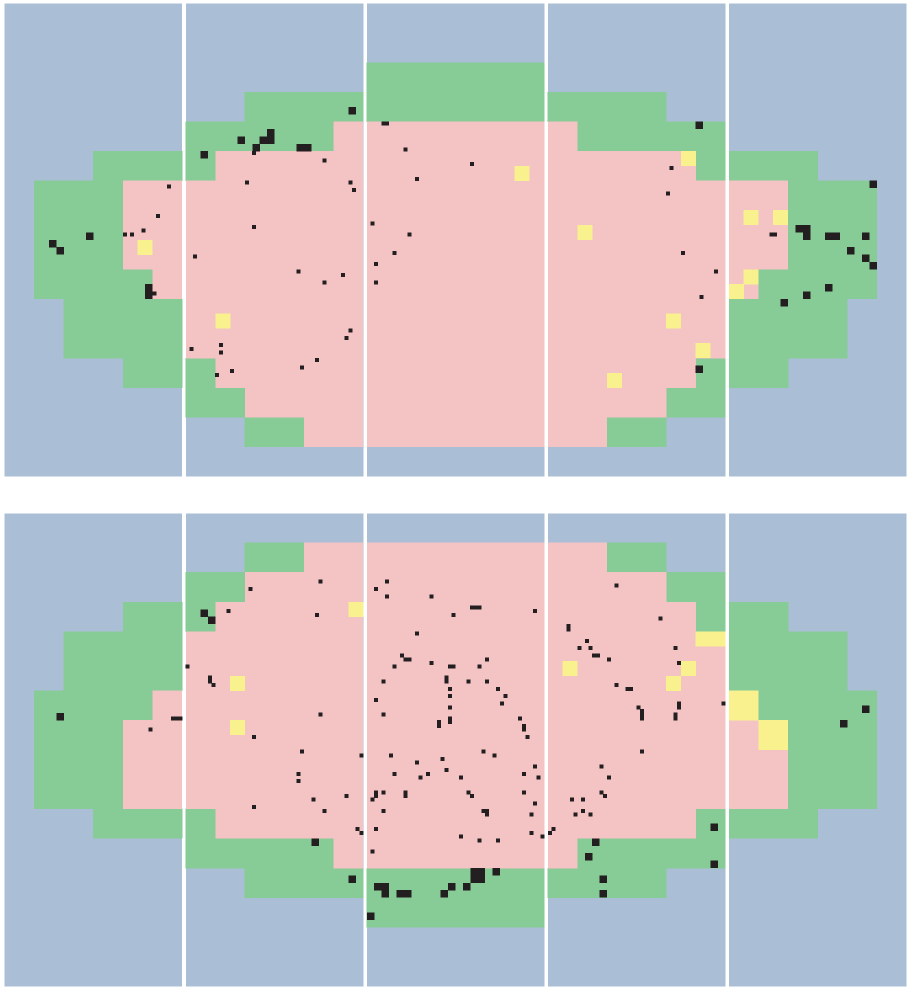
- Fixed target experiment at HERA proton beam (920 GeV/c)
  - High rate forward spectrometer (<40 MHz interaction rate)
  - Wire targets of different material in the beam halo
  - High resolution vertexing
  - Very good particle ID for e, μ, π, K and p
  - Hardware track trigger for lepton pairs ($J/\psi \rightarrow l^+l^-$)



The HERA-B RICH

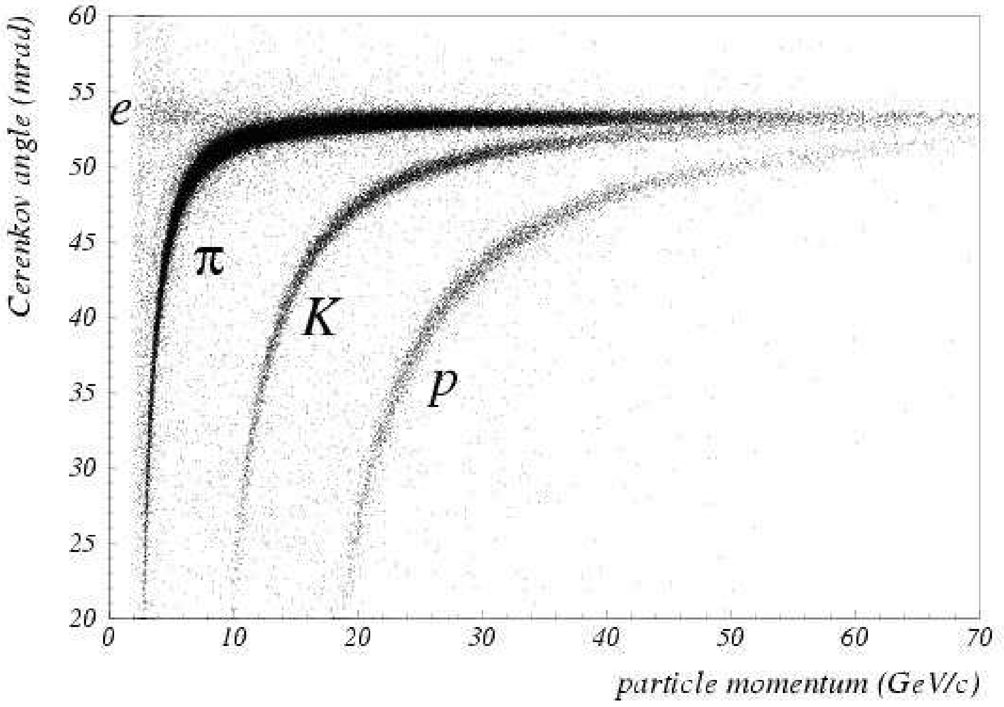
- $108 m^3$ of C_4F_{10} ($\gamma_t = 19.1$)
- Two spherical mirrors, tilted by 9^0, $f = 5.7m$
- Photon detector with Hamamatsu multi-anode PMT's





Parameters of the RICH

- Čerenkov angle for $\beta = 1$ particle: 52 mrad
- Number of photons per $\beta = 1$ particle: 32
- Figure of merit N_0: $42 cm^{-1}$
- Single photon angular resolution:
  - ▷ 16 channel PMT region: (0.7 $\oplus$ 3.5/p) mrad
  - ▷ 4 channel PMT region: (1.0 $\oplus$ 3.5/p) mrad
  - ▷ including track error: 1.2 mrad (mean) , 0.8 mrad (above 40GeV/c)



$\pi - K$ separation:
5 - 50 GeV/c

$\pi - p$ separation:
5 - 100 GeV/c

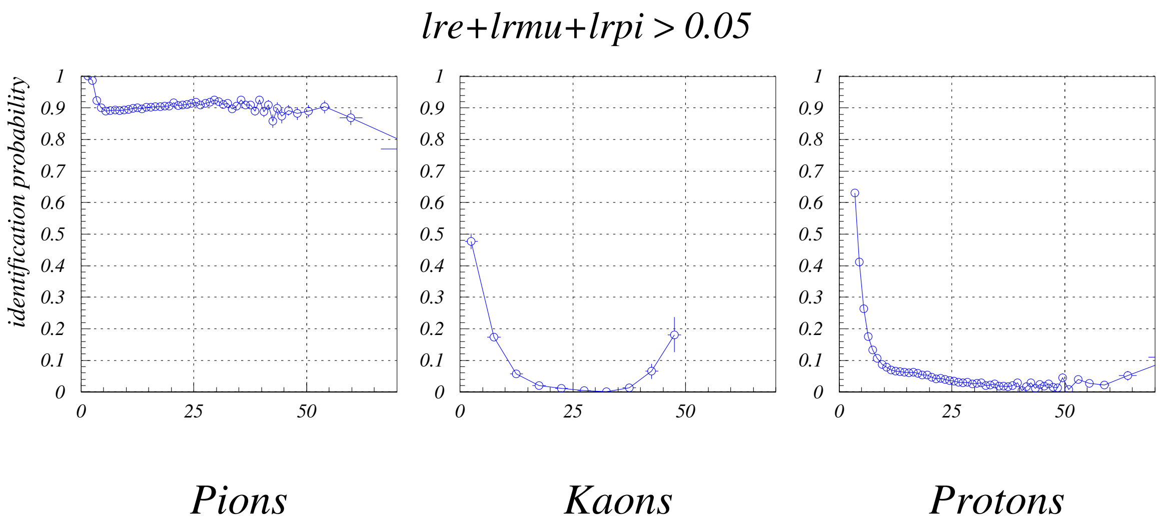
$K - p$ separation:
10 - 100 GeV/c

Identification efficiencies

- Extended maximum likelihood method used (reported on RICH2002, Pylos)
  $\longrightarrow$ normalized likelihood probabilities for e, μ, π, K, p
- Particle selection made by applying a cut on the appropriate likelihood
- Identification efficiencies measured on real data by using the decays:

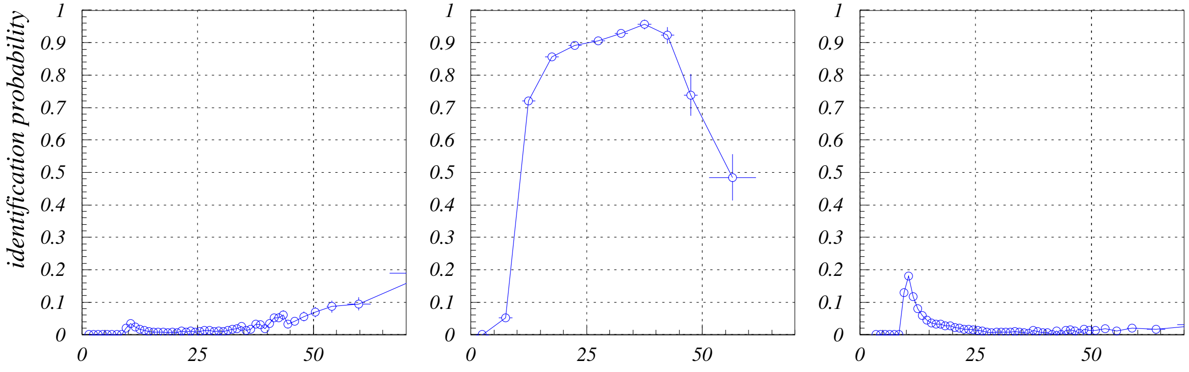
$$K_s^0 \longrightarrow \pi^+\pi^-$$
$$\phi \longrightarrow K^+K^-$$
$$\Lambda(\bar{\Lambda}) \longrightarrow p\pi^-(\bar{p}\pi^+)$$

Pion identification



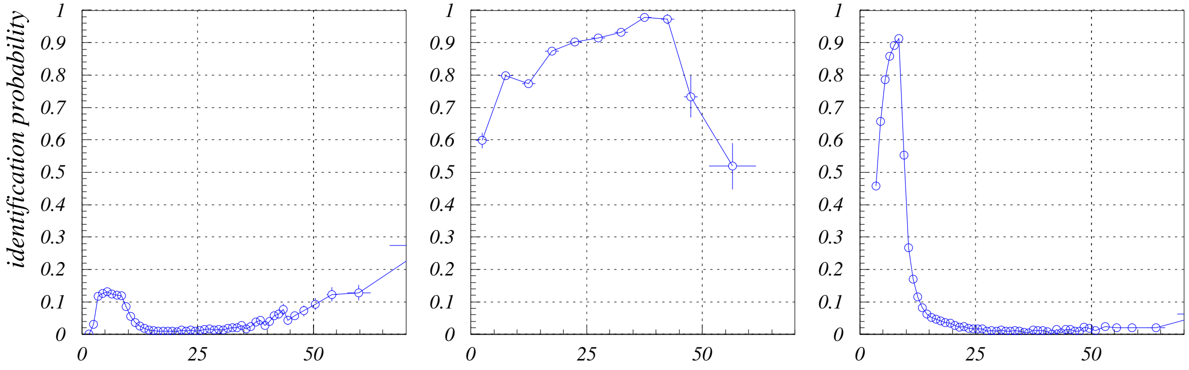
Kaon identification

lrk > 0.50



Pions *Kaons* *Protons*

lrk > 0.30

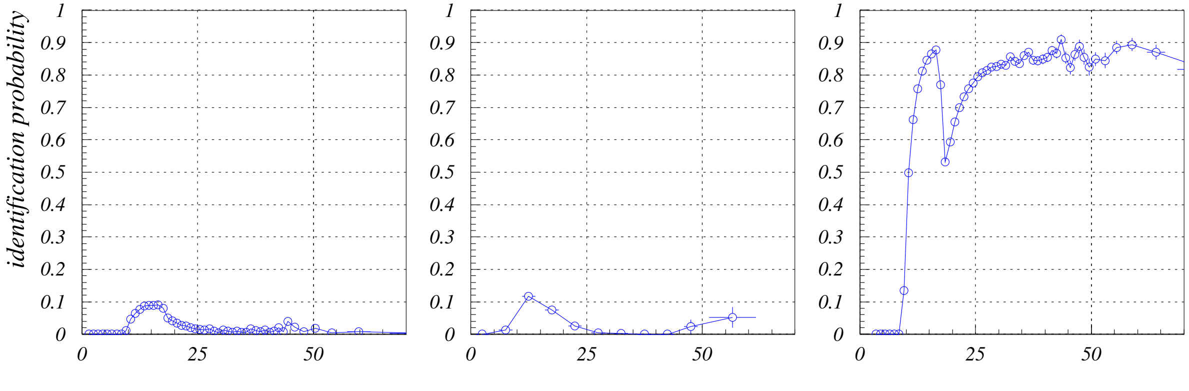


Pions *Kaons* *Protons*

Identification efficiencies

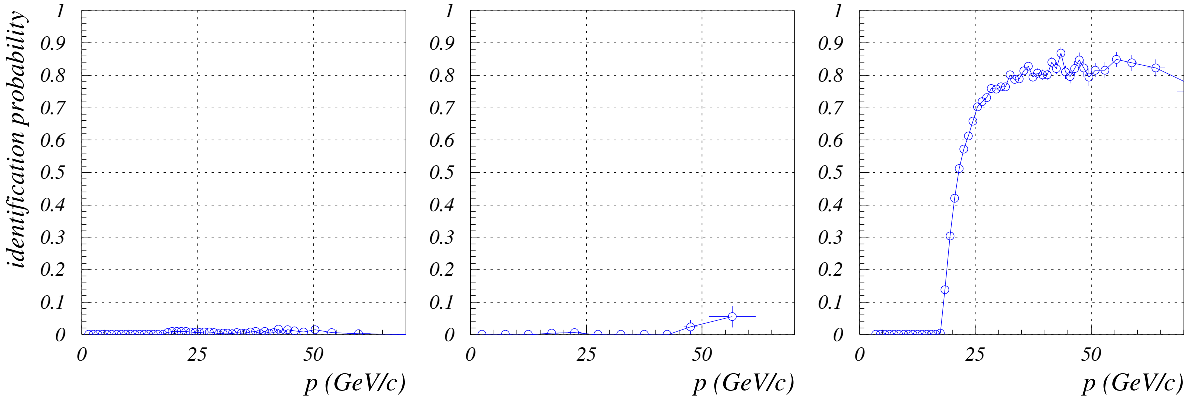
Proton identification

lrp > 0.45



Pions *Kaons* *Protons*

lrp > 0.90

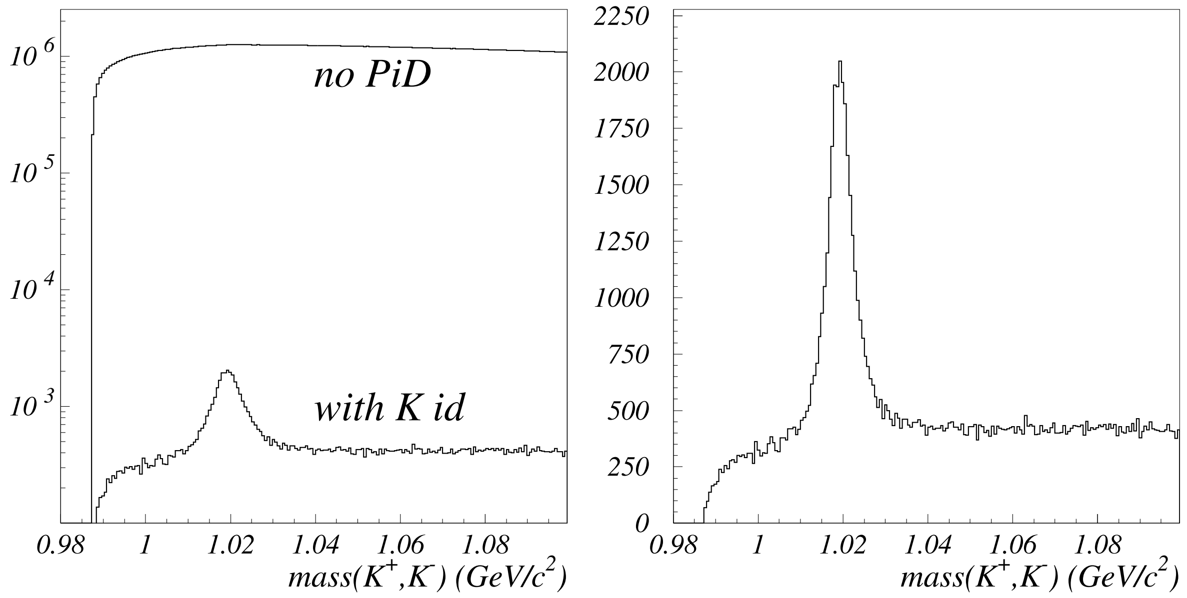


Pions *Kaons* *Protons*

RICH in Physics Analysis

- RICH is playing a crucial role in physics analysis, where decay products include kaons and/or protons.
- At hadron collisions:
  - large particle multiplicities (10 - 30 charged tracks)
  - mostly pions (70% - 80%)
    $\longrightarrow$ large combinatorial background
- Good particle identification:
  $\longrightarrow$ kills combinatorial background
  $\longrightarrow$ removes reflections

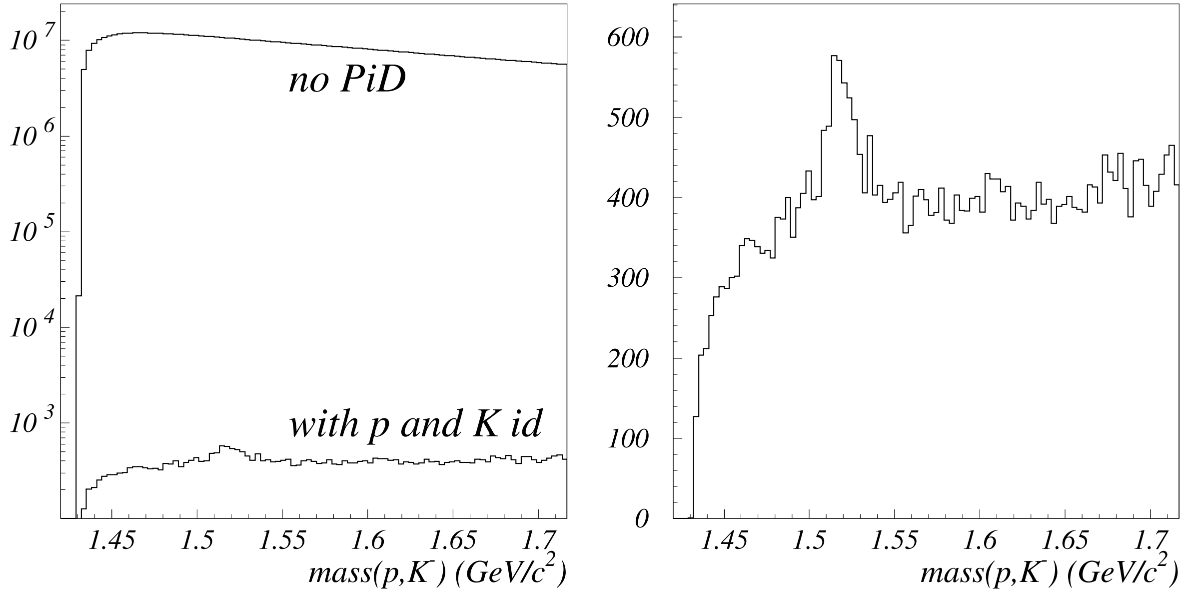
$$\phi(1020) \rightarrow K^+K^-$$



Another Two Examples

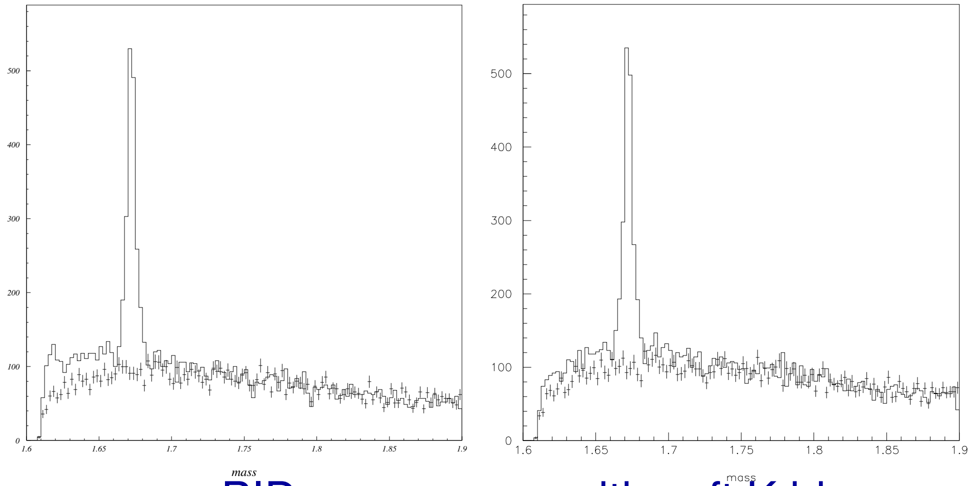
$\Lambda(1520) \to pK^-$

short lived
(decays inside target)



$\Omega^- \to \Lambda K^-$

long lived
(decays far away)



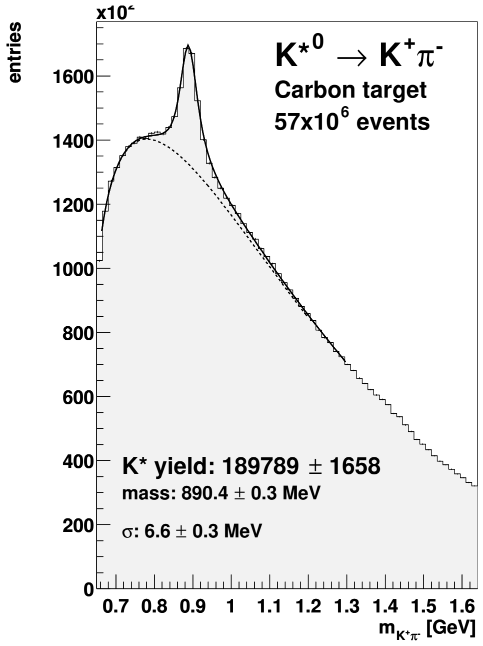
no PID   with soft K id

Physics at HERA-B

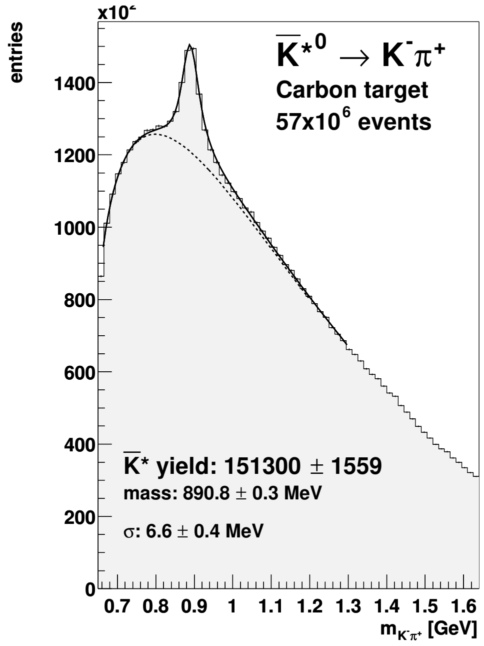
- Mainly devoted to studies of particle production in proton-nucleus collisions
- Two large data samples were collected during 2002/2003 run period
  - di-lepton trigger data: 150M events, 300k J/ψ
  - minimum bias data (interaction trigger): 210M events
- Three analysis will be briefly presented:
  - production of vector mesons ϕ and K^{*0}
  - production of open charm
  - search for Θ^+ and Ξ^{--} pentaquarks
- Minimum bias data used (C, Ti and W target)

$K^{*0}(892)$ *and* $\phi(1020)$ *production*

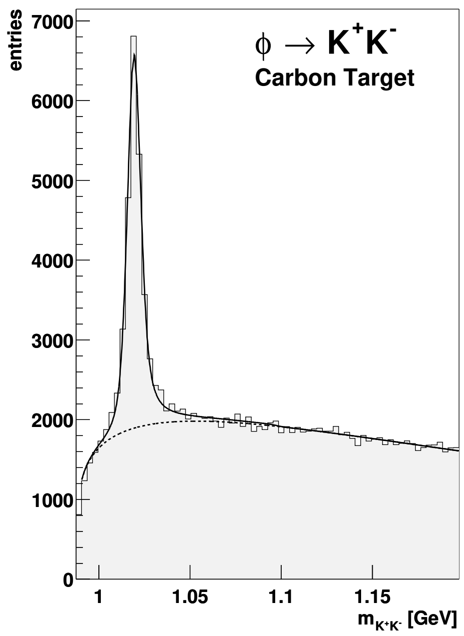
- Minimum bias data (150M events)
- Three target materials: C, Ti, W
- Data selection:
  - vertex reconstruction
  - kaon identification



$N_{K^{*0}} = 540k$



$N_{\bar{K}^{*0}} = 420k$



$N_{\phi} = 51k$

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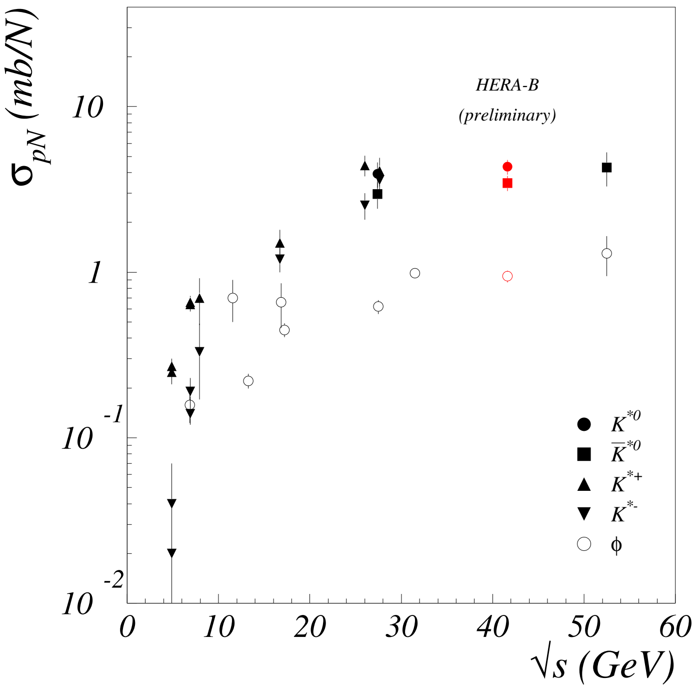
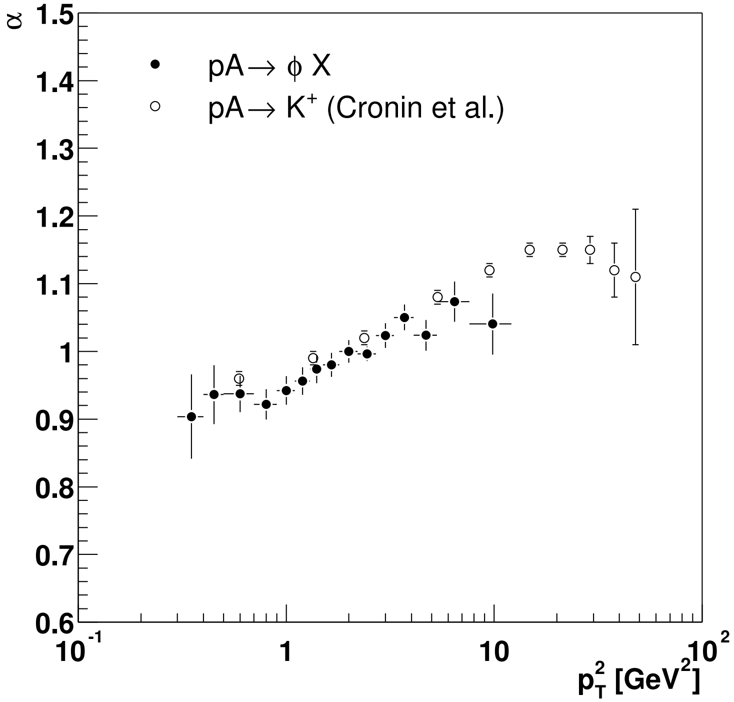
$K^{*0}(892)$ *and* $\phi(1020)$ *production*

Preliminary results for:

- total production cross sections σ_{pC}, σ_{pTi} and σ_{pW}
- single differential production cross sections $d\sigma/dy$ and $d\sigma/dp_T^2$
- A-dependence of cross sections: $\sigma_{pA} = \sigma_{pN} A^{\alpha}$
  - ▷ proton-nucleon cross section σ_{pN} and exponent α
- Cronin effect observed for the first time in the production of K^{*0} and ϕ (exponent α increases with p_T)

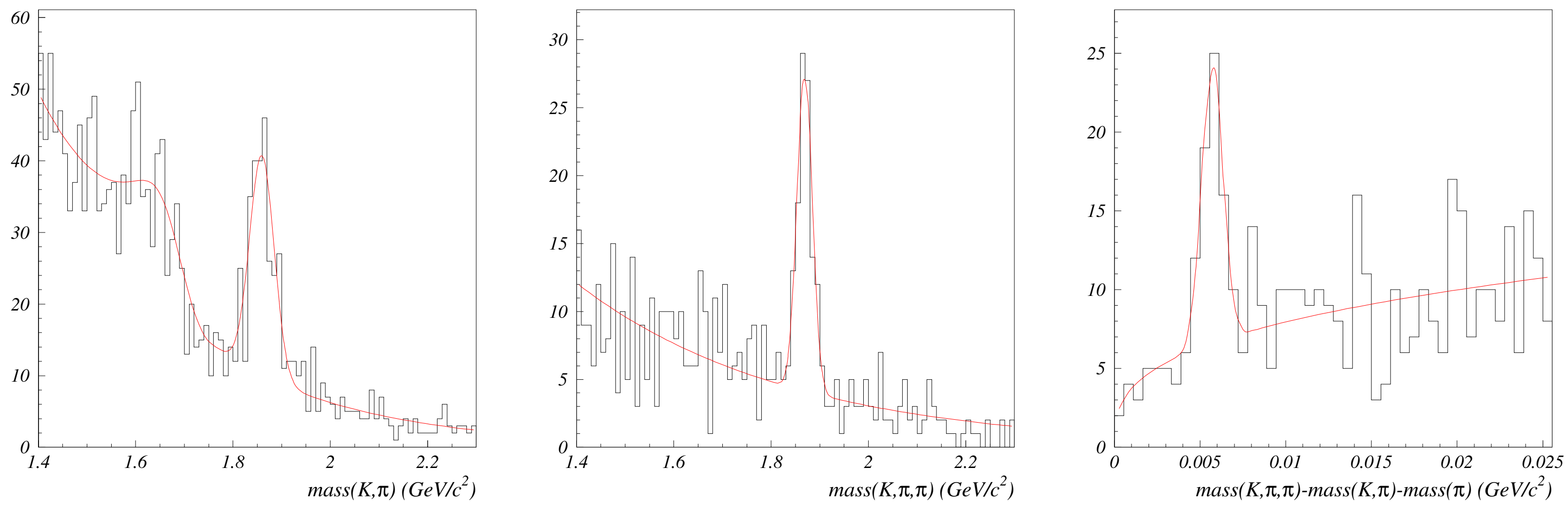




Open Charm

- Minimum bias data (200M events)
- Charm cross section 3 orders of magnitude smaller than inelastic
- Large boost ($\gamma = 22$): D mesons decay several mm from target
- Data selection:
  - vertex reconstruction (resolution $\sigma_{\Delta z} \approx 500\mu$m)
  - detached vertex requirement
  - kaon and pion identification

$D^0 \to K^-\pi^+$ $\quad$ $D^+ \to K^-\pi^+\pi^+$ $\quad$ $D^{*+} \to D^0\pi^+$

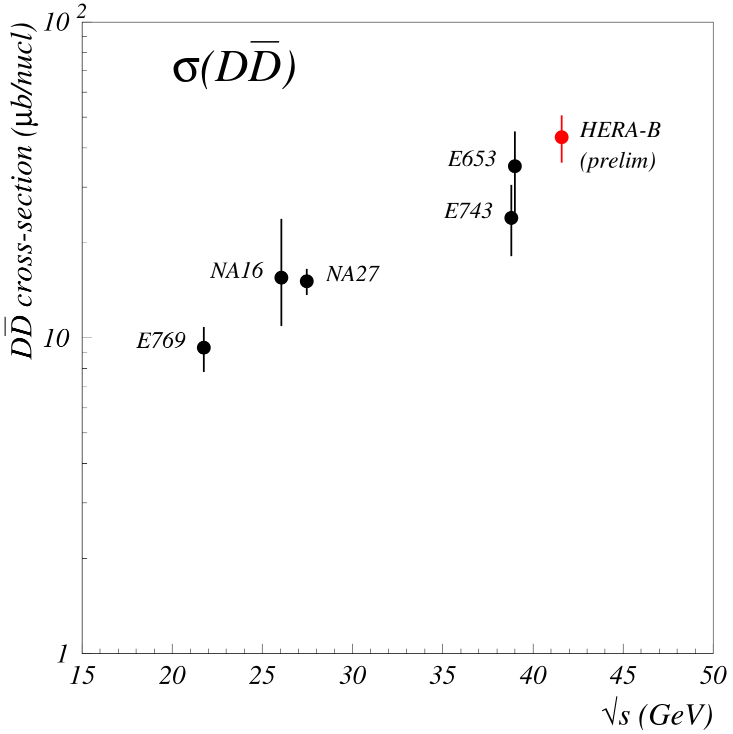


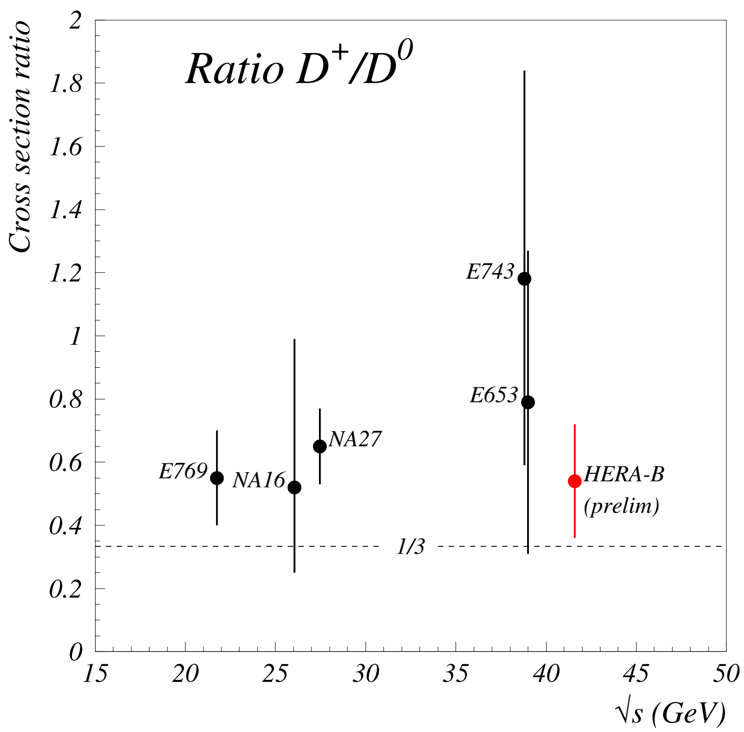
$N_{D^0} = 194 \pm 20$ $\quad$ $N_{D^+} = 92 \pm 11$ $\quad$ $N_{D^{*+}} = 49 \pm 10$

Open charm

Preliminary results for:

- total production cross sections σ_{pC}, σ_{pTi}, σ_{pW} and σ_{pN}
- D meson production ratios: D^+/D^0 and D^{*+}/D^0



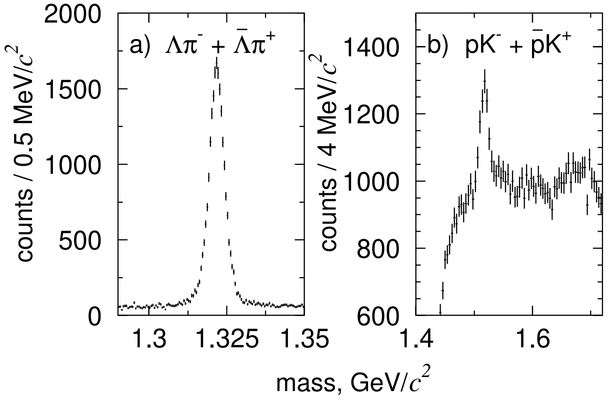


Search for pentaquarks

Motivation:

- Recently more than 10 experiments have reported the observation of narrow state in either nK^+ or pK^0_S decay channels at 1540 MeV/c^2.
- Another candidate resonance have been found in $\Xi^-\pi^-$ and $\Xi^-\pi^+$ decay channel at 1862 MeV/c^2.
- HERA-B collected large minimum bias data sample
- Statistics of the relevant reconstructed signals

signal	statistics	σ (MeV/c^2)
K^0_S	4.9M	4.9
Λ [c.c]	1.1M [520k]	1.6
$\Lambda(1520)$ [c.c]	3.5k [2.1k]	2.3
Ξ^- [c.c]	12k [8.2k]	2.6
$\Xi(1530)^0$ [c.c]	1.4k [940]	2.9



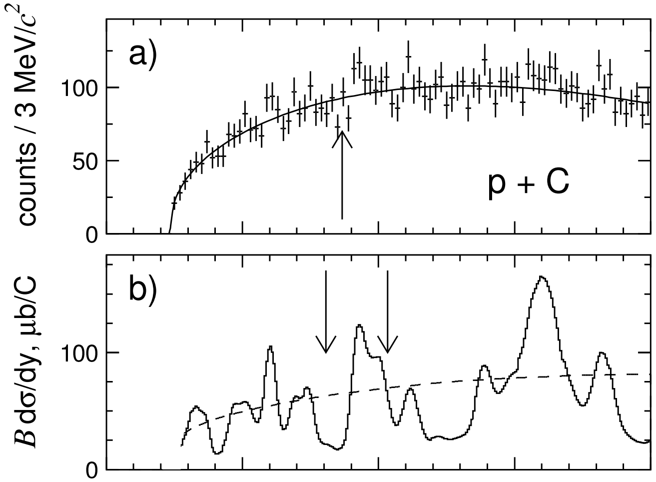
Search for pentaquarks

Particle ID:

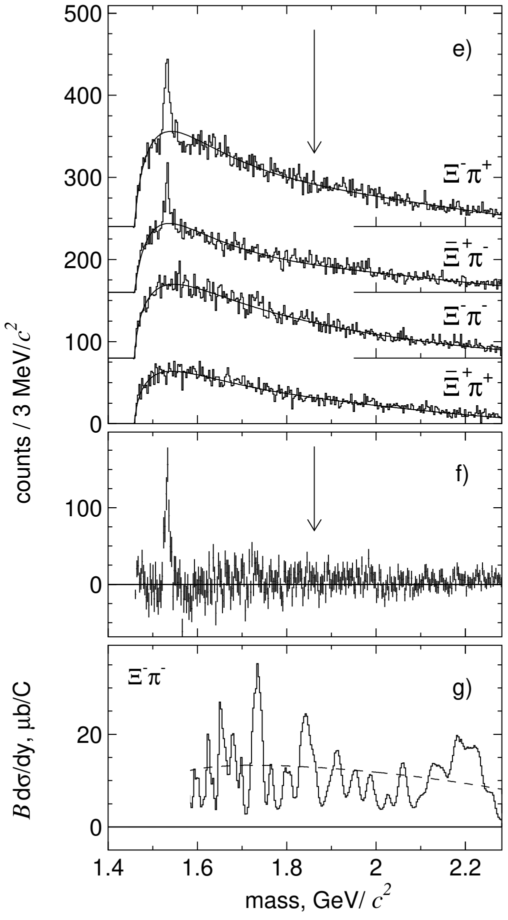
- $\Theta^+ \to pK_S^0$ strong cut on proton likelihood (>0.95)
  - ▷ mis-identification <1%
- $\Xi^{--} \to \Xi^-\pi^-$ week cut on pion likelihood (>0.05)
  - ▷ reduces background from K and p

Results:

- No evidence for PQ narrow signals found
  - ▷ Upper limits for production cross sections
  - ▷ UL for yield ratio to $\Lambda(1520)$ and $\Xi(1530)^0$
- Published in *Phys.Rev.Lett.93, 212003(2004)*



$\Theta^+ \to pK_S^0$



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

Summary

- Performance of the HERA-B RICH and its impact on physics analysis have been presented.
- With the RICH we can identify pions, kaons and protons essentially in the entire kinematic range of our experiment, with the efficiency as large as 90% and with the mis-identification probability at the 1% level.
- By kaon and proton identification the combinatorial background is in some cases reduced by more than 3 orders of magnitude.
- Three physics analysis were shown, which wouldn't be possible without high performance of the RICH particle identification system.
- The HERA-B experiment finished data taking in spring 2003. The spectrometer (and RICH) has been dismounted.