Particle Identification with HERA-B RICH

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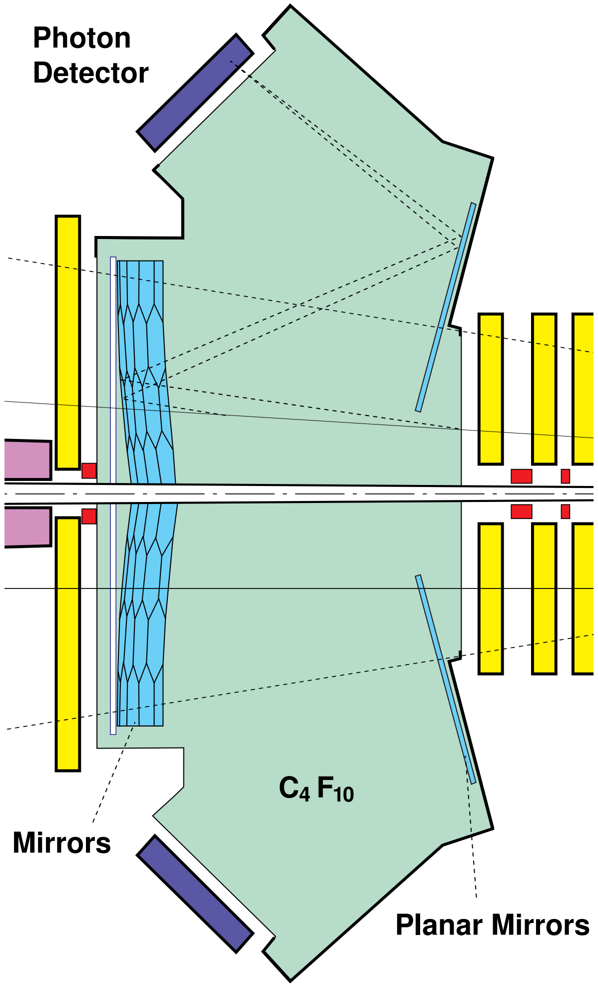
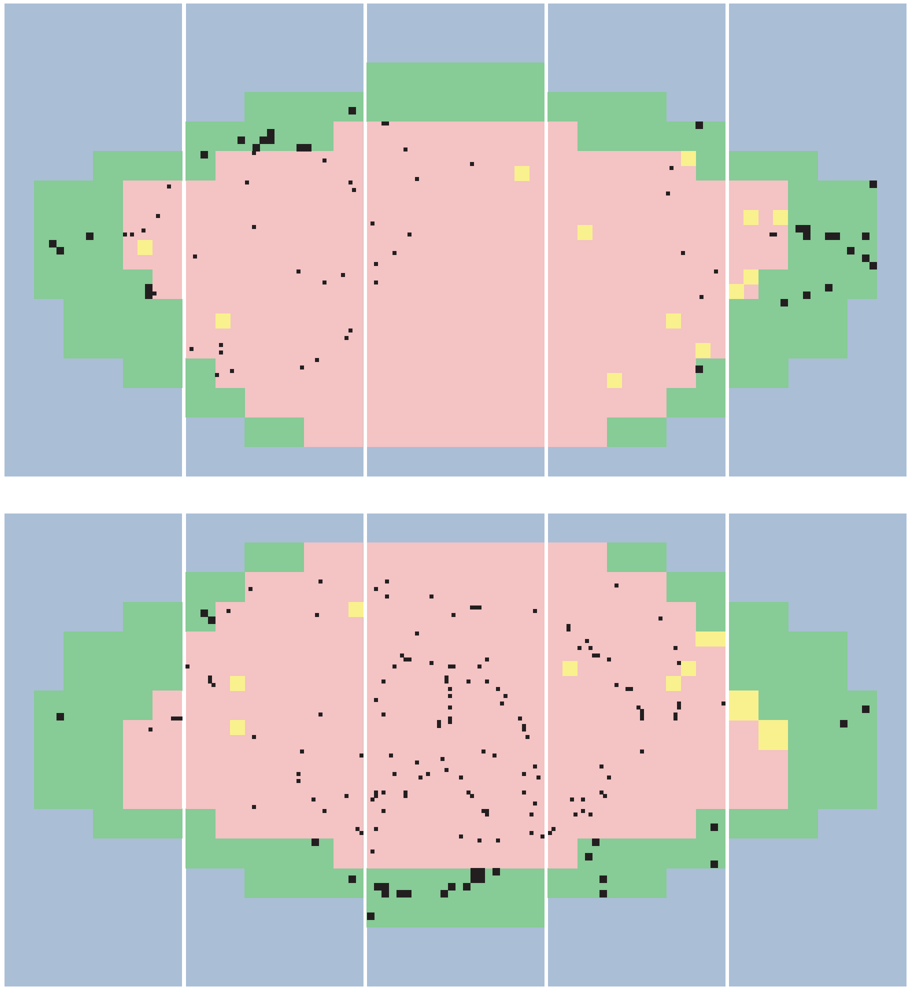
1. Brief description of HERA-B RICH
2. Particle identification method
3. Results (run 2000 data)
4. Conclusions

The HERA-B RICH

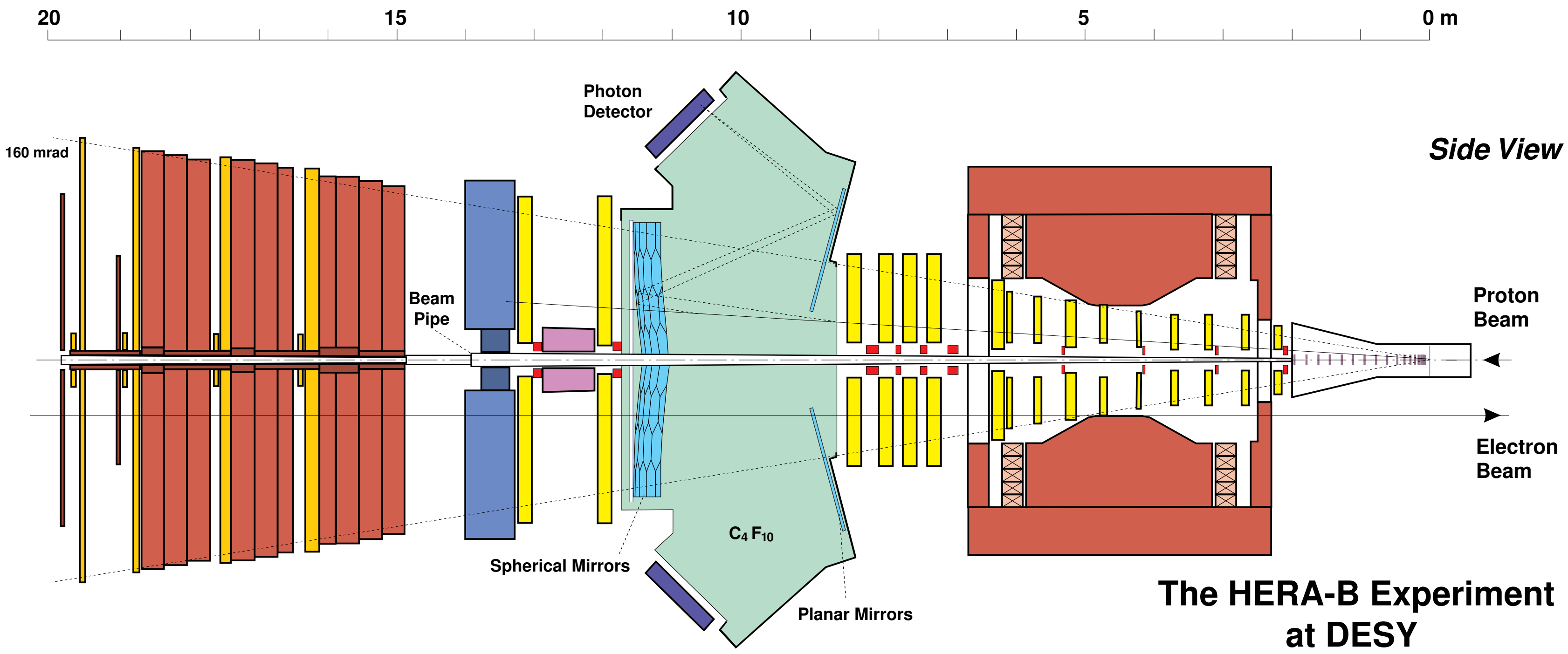
- $108m^3$ of C_4F_{10} ($\gamma_t = 19.1$)
- Two spherical mirrors, tilted by 9^0, $f = 5.7m$
- Photon detector with Hamamatsu multi-anode PMT's





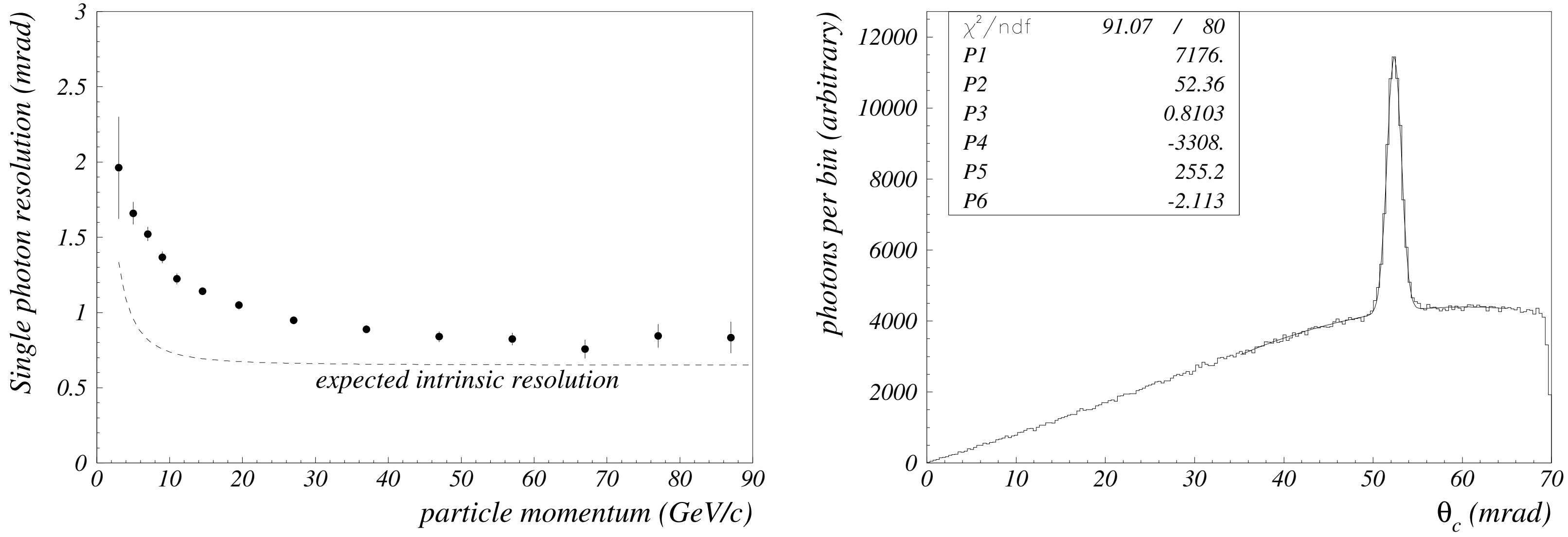
The HERA-B experiment

- Fixed target experiment at HERA proton beam
  - → Target(s) in the beam halo
  - → 10 to 20 MHz interaction rate
  - → High track multiplicities



Parameters of the RICH

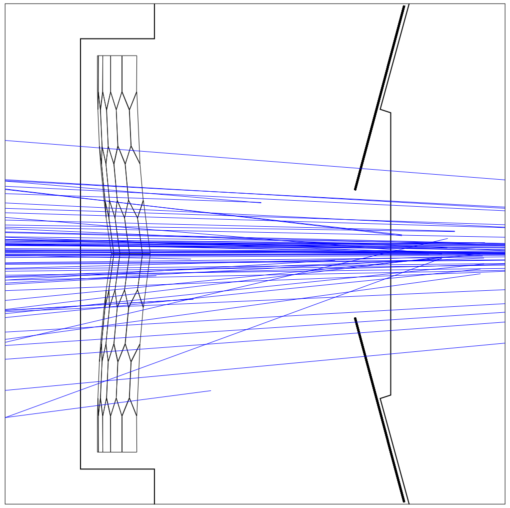
- Čerenkov angle for $\beta = 1$ particle: 52 mrad
- Number of photons per $\beta = 1$ particle: 32
- Figure of merit N_0: $42cm^{-1}$
- Single photon angular resolution:
  - $\rightarrow$ 16 channel PMT region: (0.7 $\oplus$ 3.5/p) mrad
  - $\rightarrow$ 4 channel PMT region: (1.0 $\oplus$ 3.5/p) mrad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

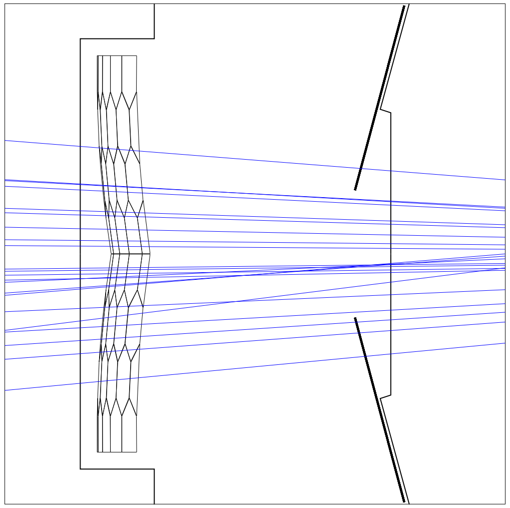


Experimental environment

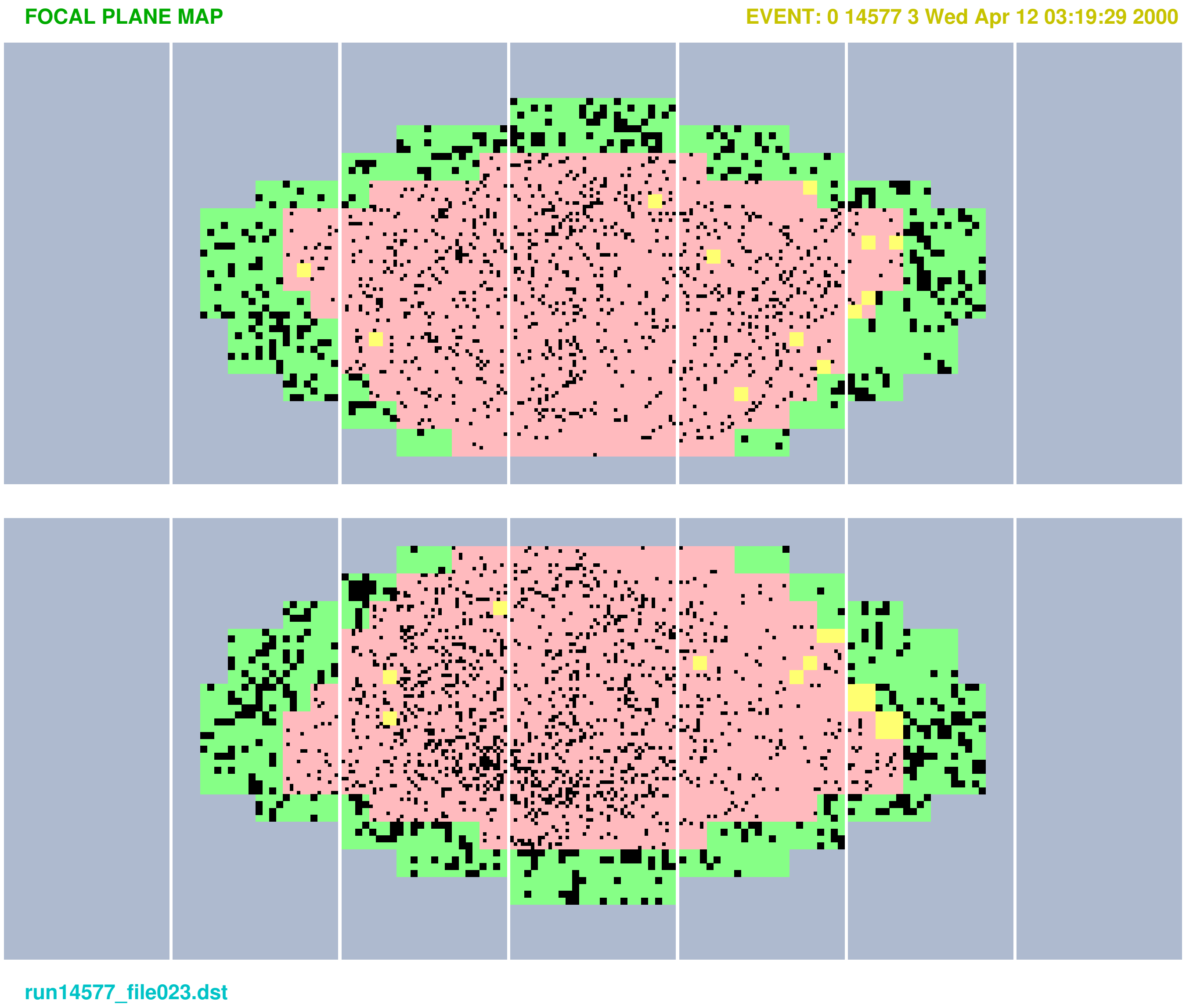
- Events every 96 ns
- Several interactions per event
  - $\rightarrow$ on average 200 charged particles enter the RICH
  - $\rightarrow$ on average 80 rings on the photon detector
  - $\rightarrow$ channel occupancies up to 20%
- Only 20 completely reconstructed tracks per event (on average), 15 above Čerenkov threshold
  - $\rightarrow$ for those tracks PID is required
  - $\rightarrow$ 80% of background rings

$\Longrightarrow$ Extended likelihood method is used for PID





A typical event



Particle identification: the method

- 6 possible hypotheses for a track:

  electron, muon, pion, kaon, proton, ghost

- Measurement: Čerenkov angle θ_i of photon-track pairs
- Extended likelihood probability for k-th hypothesis:

$$\log \mathcal{L}_k = \sum_{i=1}^{N_{ph}} \log(pG(\theta_i) + (1-p)B(\theta_i)) + \log P(N^{exp}, N_{ph})$$

$G(\theta_i) = \frac{1}{\sqrt{2\pi}\sigma_i} e^{\frac{(\theta_i - \Theta_k)^2}{2\sigma_i^2}}$	Gaussian shape of signal (Θ^k, σ_i)
$B(\theta_i) = a\theta_i$	normalized linear background
$p = \frac{N_S}{N^{exp}}$	signal fraction
N_S	expected number of signal photons
$N^{exp} = N_S + N_{Bgr}$	expected number of signal + background photons
N_{ph}	number of photons within $\theta_i < 70 mrad$
$P(\mu, n) = \frac{\mu^n}{n!} e^{-\mu}$	Poisson distribution

- N_{Bgr} estimated by counting photons outside $\pm 3\sigma$ of expected peak positions

Particle identification: the method

- Normalized likelihood probability:

$$l_k = \frac{\mathcal{L}_k}{\sum_{i=1}^{6} \mathcal{L}_i}, \qquad k = e, \mu, \pi, K, p, ghost$$

$\Longrightarrow$ Likelihood probabilities have range of values between 0 and 1.

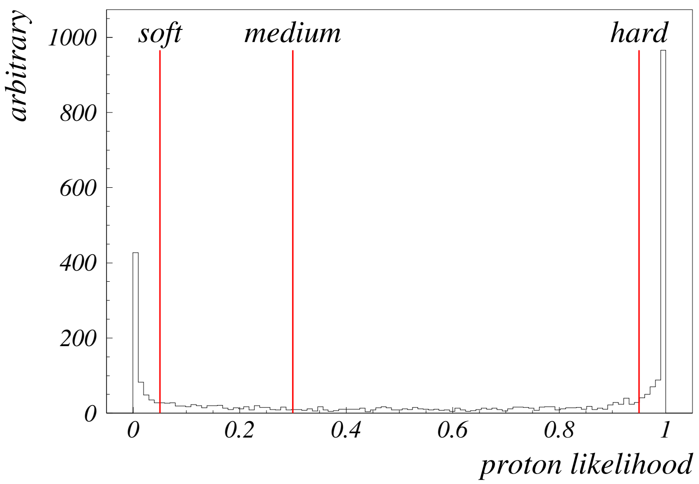
- Particle selection made by applying a cut on the appropriate likelihood

Particle identification: selection criteria

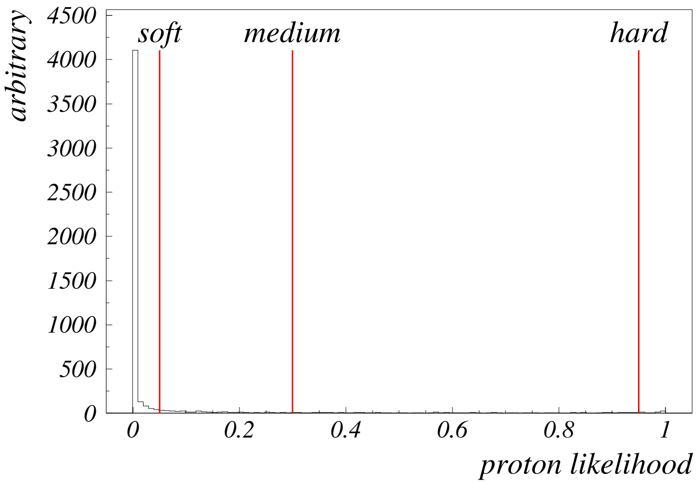
- Soft, medium and hard selection cuts defined
  - pion selection: cut on sum of e, μ, π likelihood probabilities
  - kaon selection: cut on K likelihood probability
  - proton selection: cut on p likelihood probability

selection	soft	medium	hard
pion	0.05	0.50	0.95
kaon	0.05	0.30	0.95
proton	0.05	0.30	0.95

Protons

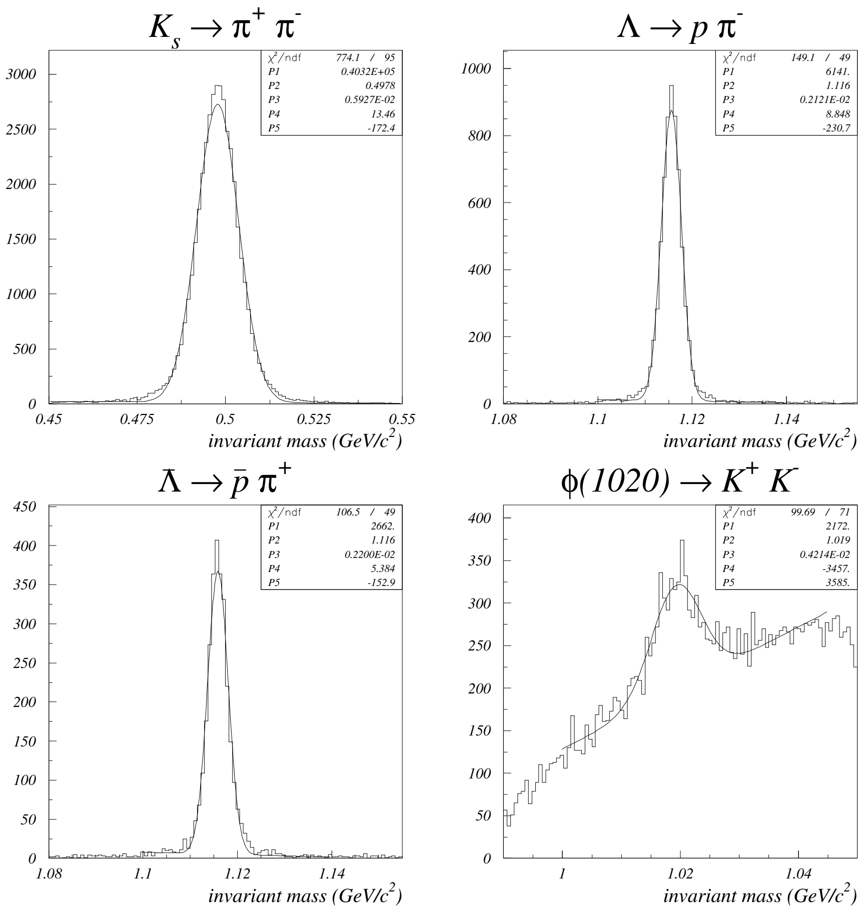


Pions



Particle identification: particle sources

- pions: $K_s \to \pi^+\pi^-$, $\Lambda \to p\pi^-$, $\bar{\Lambda} \to \bar{p}\pi^+$
- kaons: $\phi(1020) \to K^+K^-$
- protons: $\Lambda \to p\pi^-$, $\bar{\Lambda} \to \bar{p}\pi^+$



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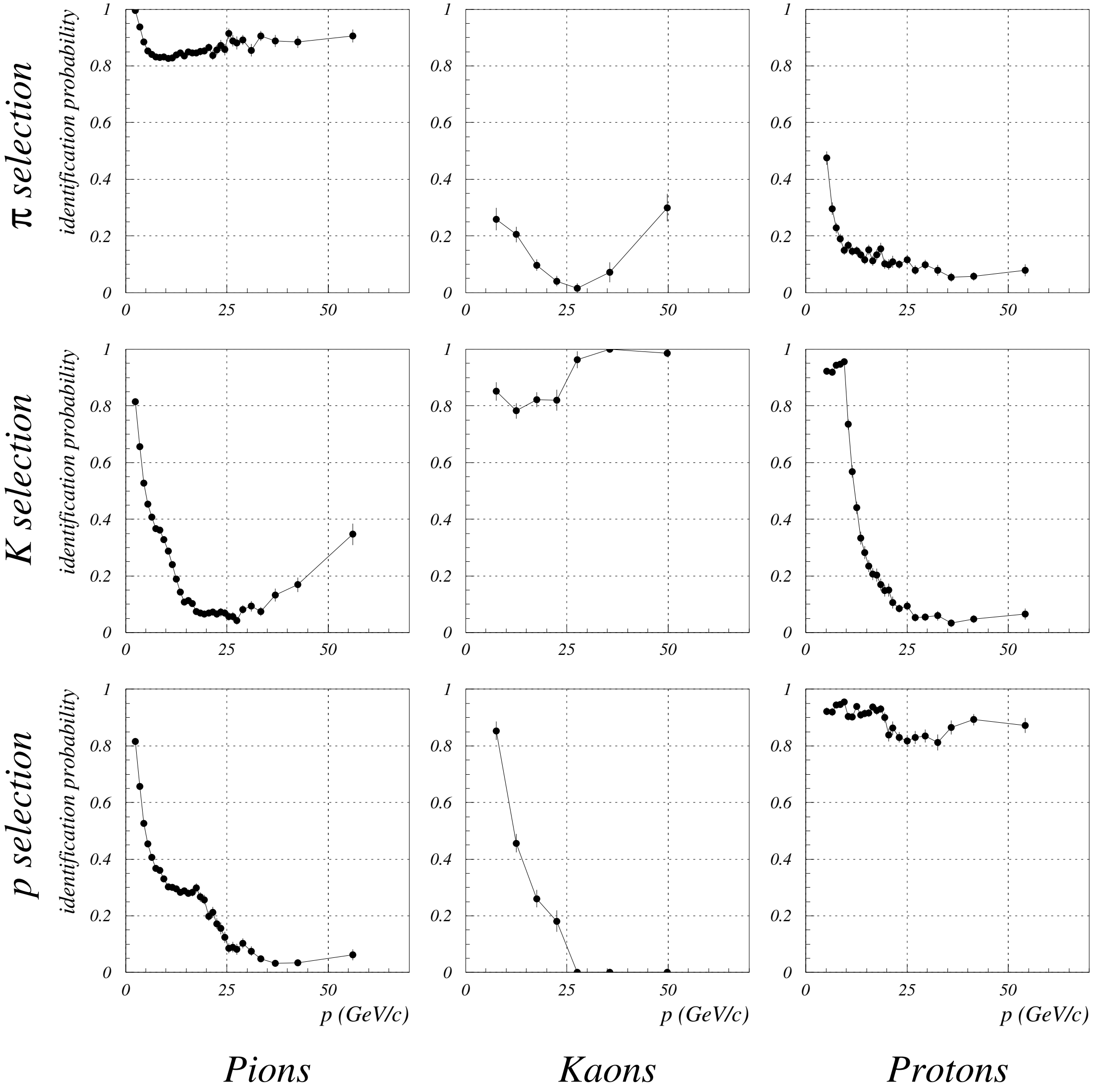
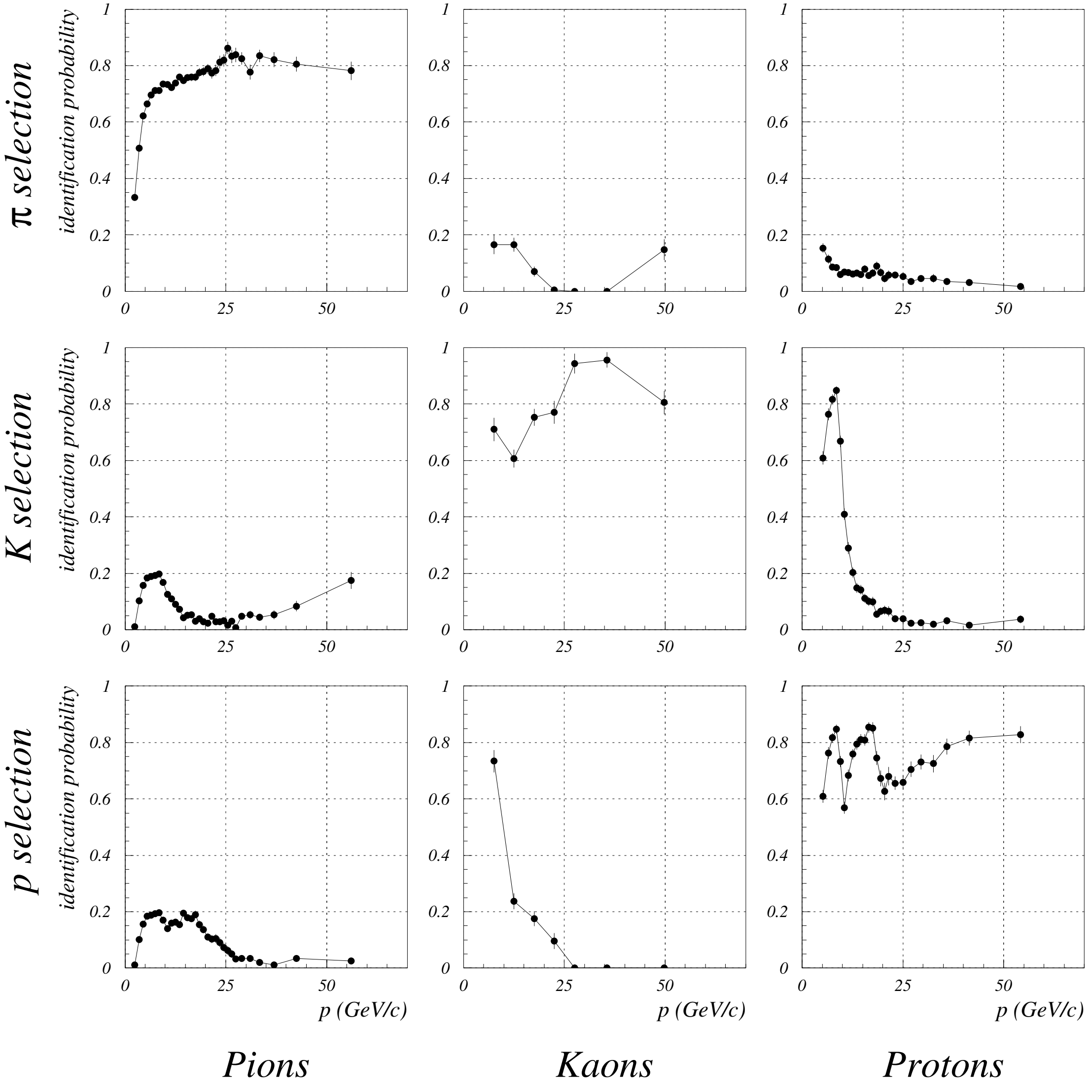
Particle identification: results

Efficiency Matrix: soft selection



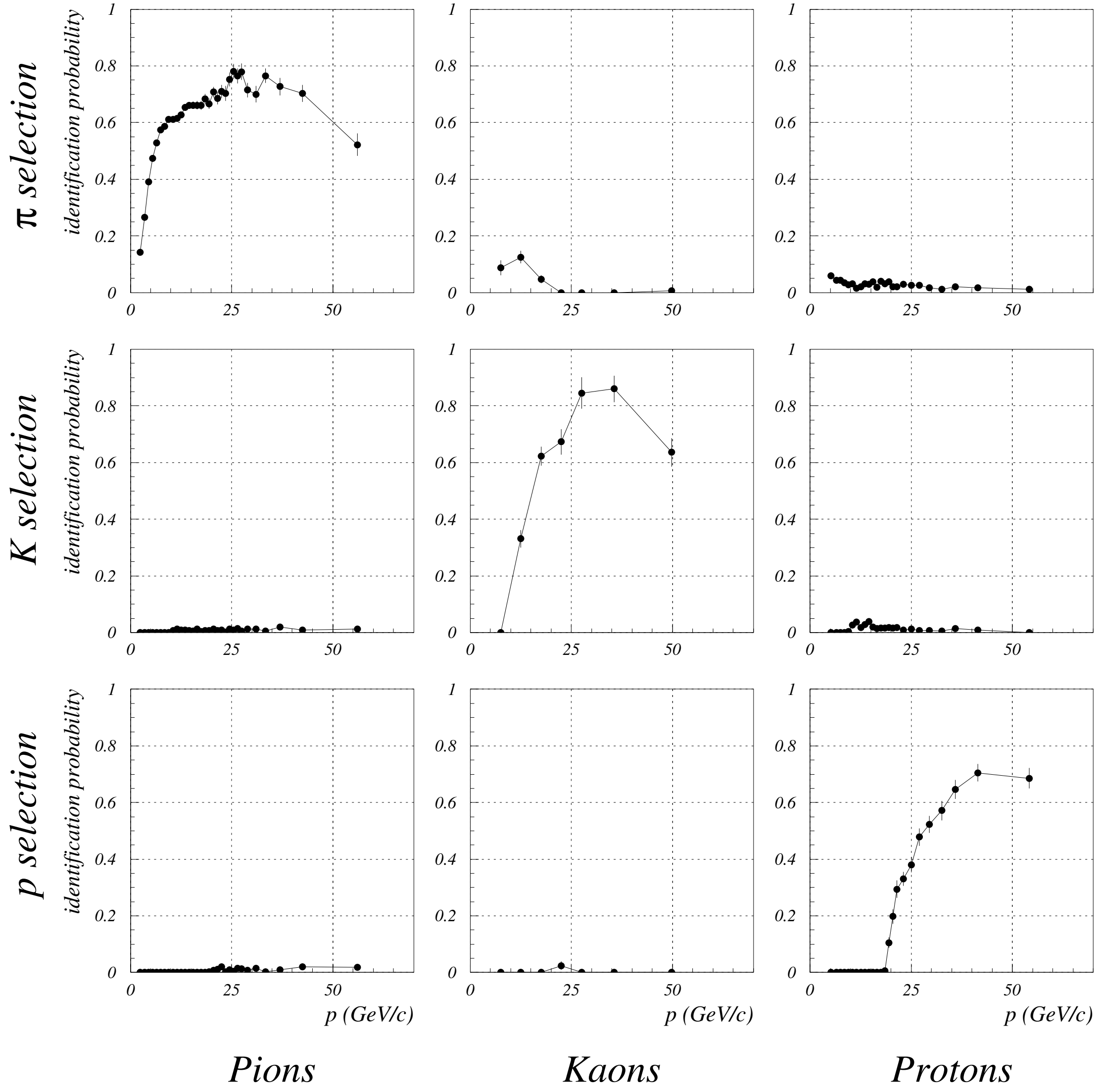
Particle identification: results

Efficiency Matrix: *medium selection*



Particle identification: results

Efficiency Matrix: *hard selection*

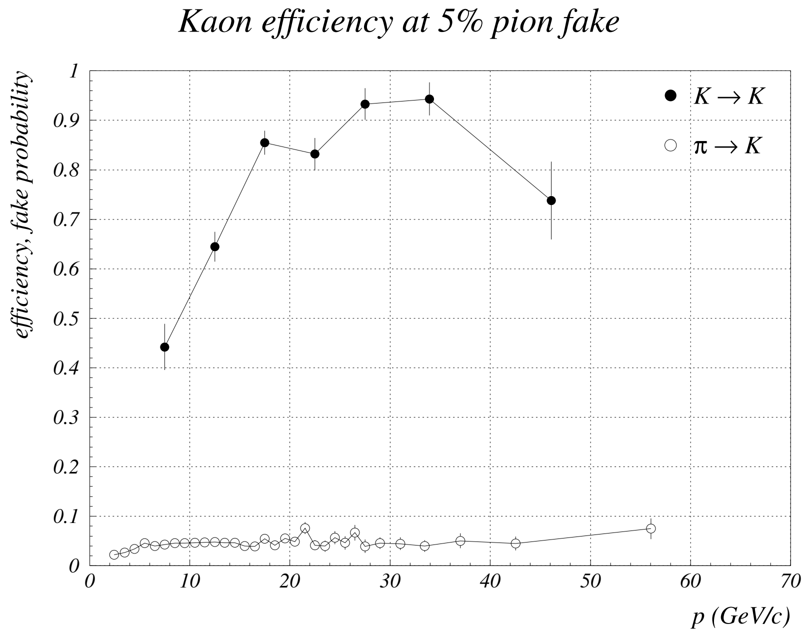


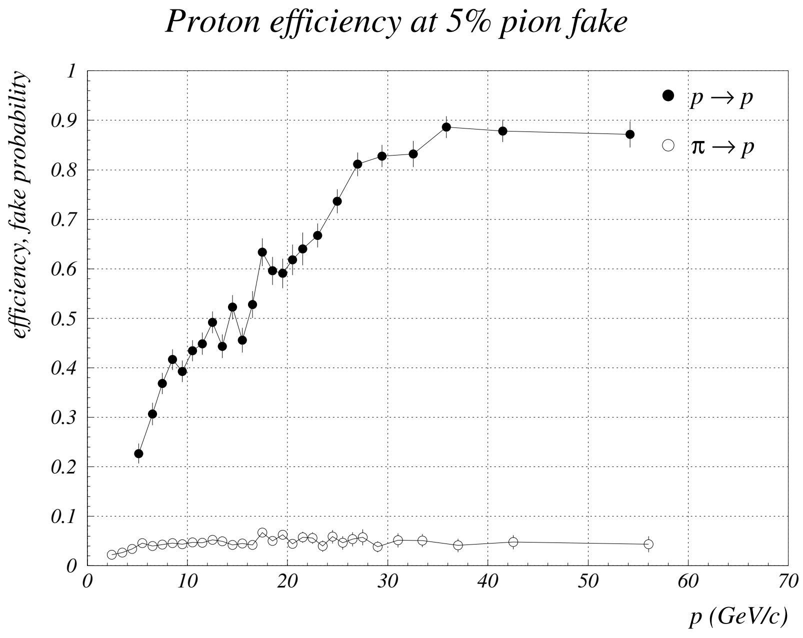
Particle identification: results

- Momentum dependent cut: keep pion fake probability at a given level
- Cut applied on log-likelihood difference:

$$\log \mathcal{L}_k - \log \mathcal{L}_\pi > C_{K\pi}(p) \qquad \log \mathcal{L}_p - \log \mathcal{L}_\pi > C_{p\pi}(p)$$

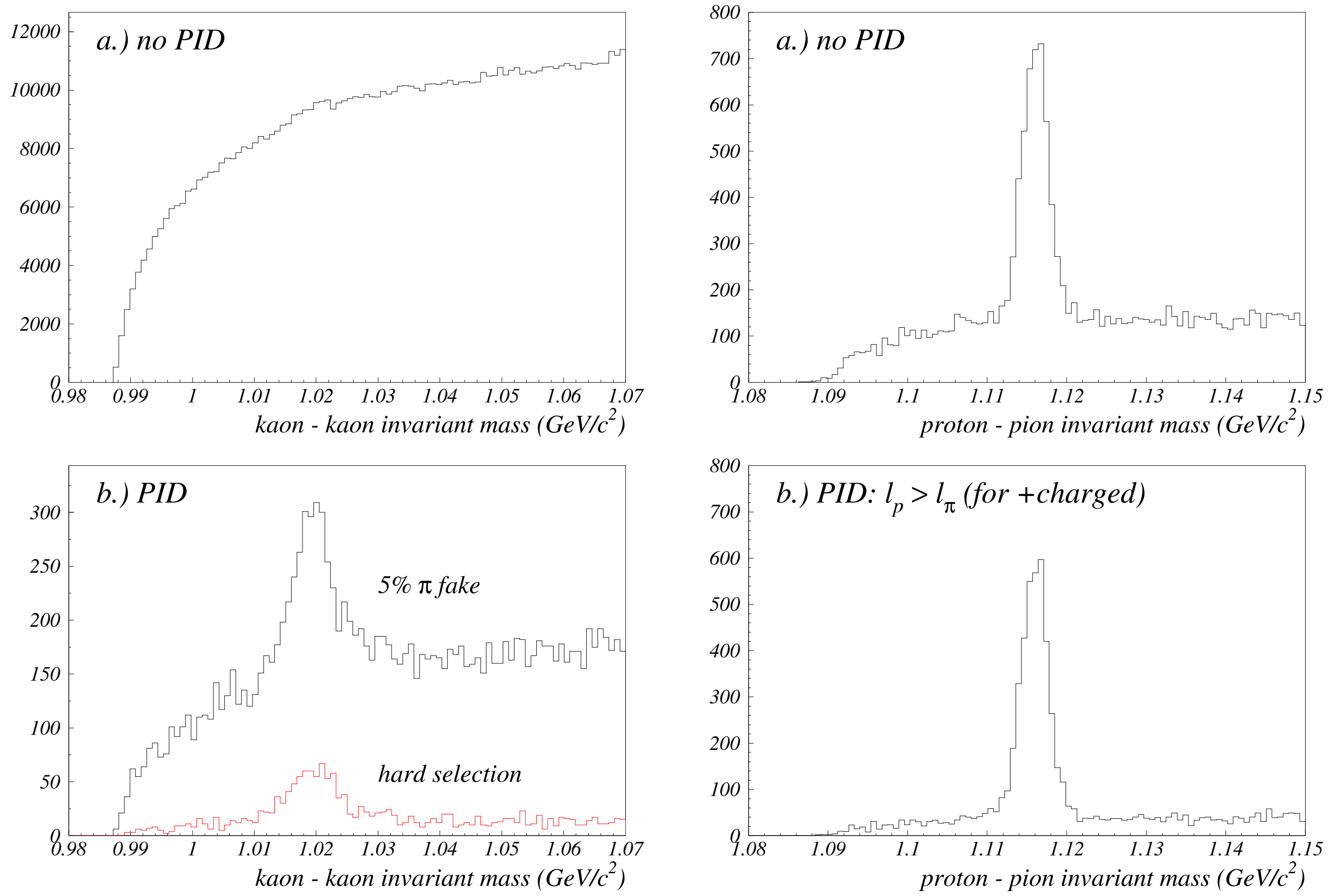
Efficiency at 5% pion fake





Particle identification: results

$\phi(1020) \rightarrow K^+K^-$ $\Lambda \rightarrow p\pi^-$



a.) before particle selection b.) after particle selection

Conclusions

- Particle identification capabilities of HERA-B RICH have been presented.
- For the particle identification an extended likelihood method is used.
- It has been shown, using the data of run period 2000, that the RICH is capable of efficient particle identification at high track densities and high interaction rates of the HERA-B experiment.