RICH Counters with Vacuum Based Photon Detectors

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RICH 2002, Pylos

- Motivation: physics case
- Present: BaBar, HERA-B, Hermes, Selex
- Next generation: BTeV, LHCb
- Upgrades of existing spectrometers: BaBar, Belle

Why do we need a RICH at all?

One of the main driving forces of the RICH R+D in the last decade was the need to have excellent hadron identification for precision B physics measurements:

CP violation in the B system: tag B meson decays with kaon charge.

Few body hadronic decays: separate $\pi\pi$ from πK, $K\pi\pi$ from $KK\pi$ etc.

After considerable efforts went into developing an efficient gas based photon detector for high interaction rates, all experiments which aimed at CP violation measurement, chose vacuum based devices.

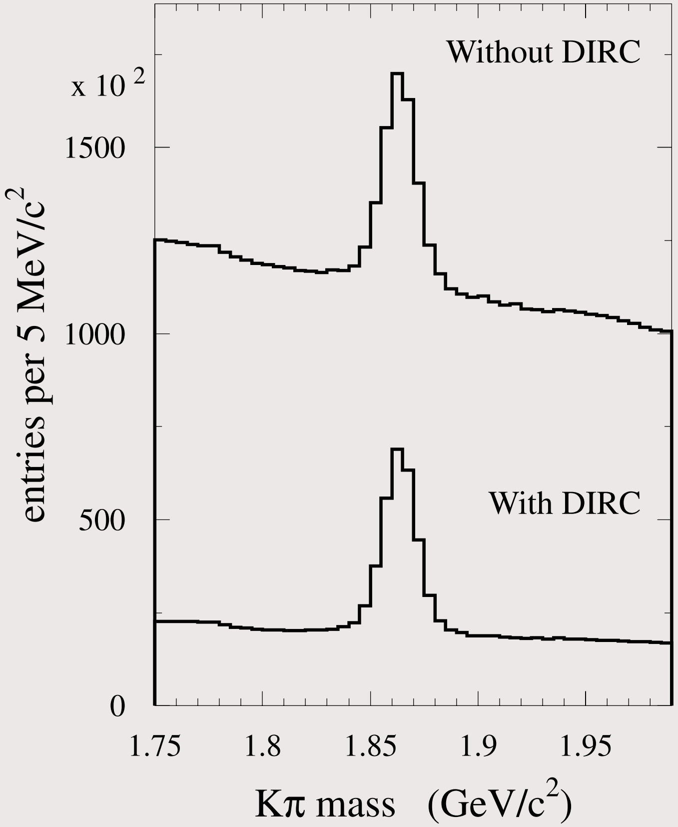
- BaBar: single channel photomultiplers in DIRC
- Belle: fine mesh single channel PMTs in a threshold aerogel Čerenkov
- HERA-B: multianode PMTs in a 'normal' gas radiator RICH

All three Čerenkov counters perform extremely well.

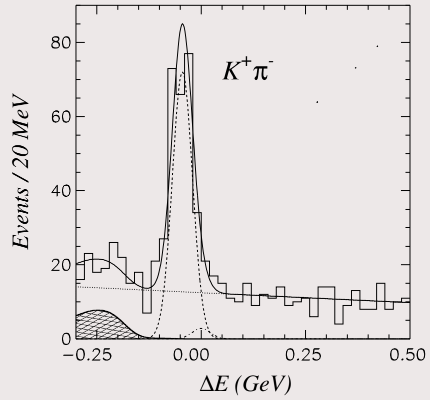
At Belle and BaBar they have contributed considerably to the success of the CP violation measurements.

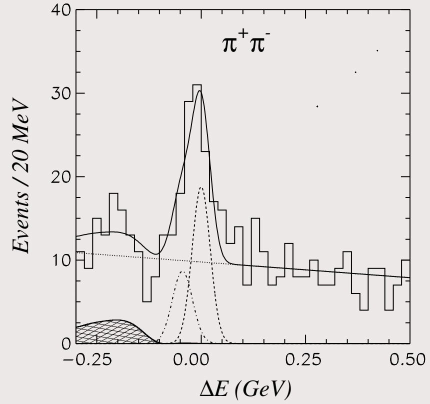
Performance relevant to B physics studies

BaBar: Example of performance in the D^0 selection



Belle: $B \to K^+\pi^-$ and $B \to \pi^+\pi^-$

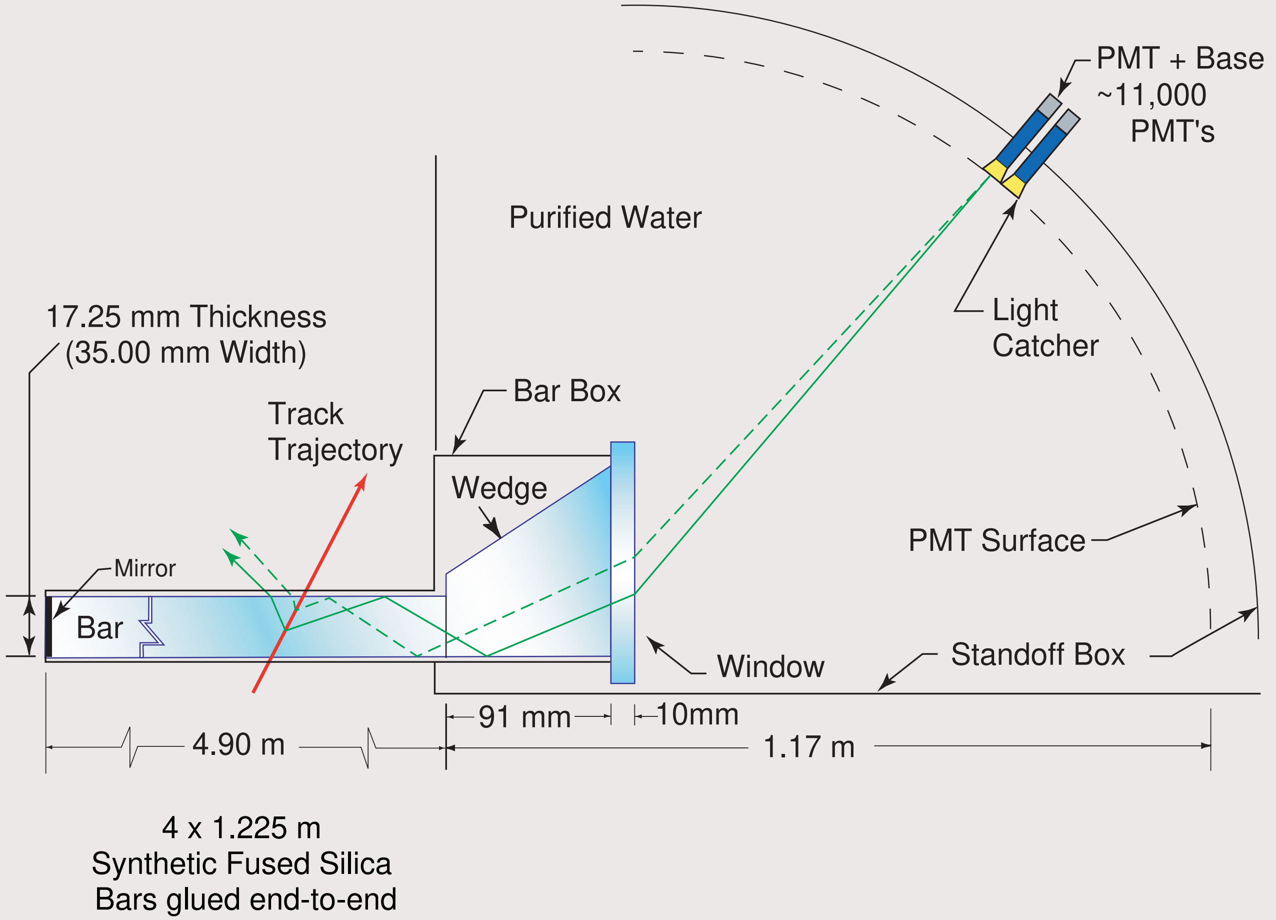




Aerogel Čerenkov counter contributed to the signal clean up $\to$ first measurement of CP asymmetry in $B \to \pi^+\pi^-$.

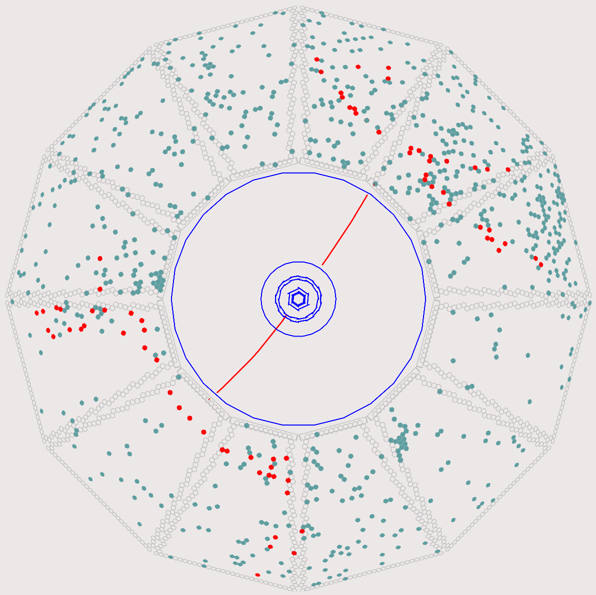
DIRC - detector of internally reflected Cherenkov light

Principle of DIRC

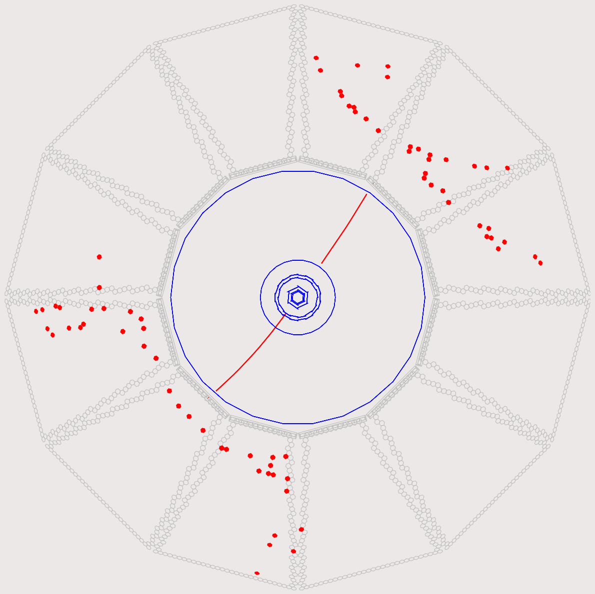


DIRC time filtering

DIRC event, no time cut (± 300 ns)



DIRC event, with time cut (± 4 ns)

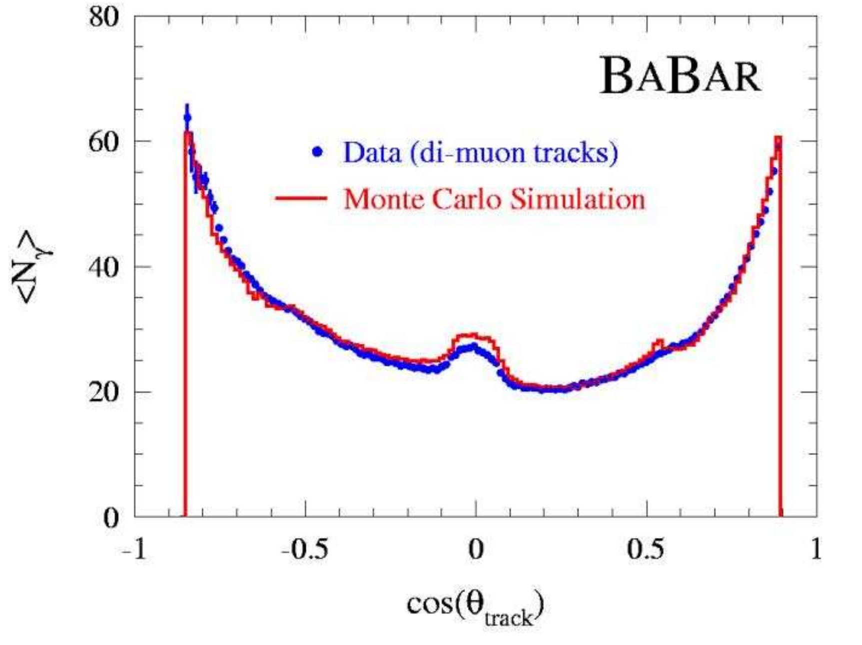


Use time constraint to :

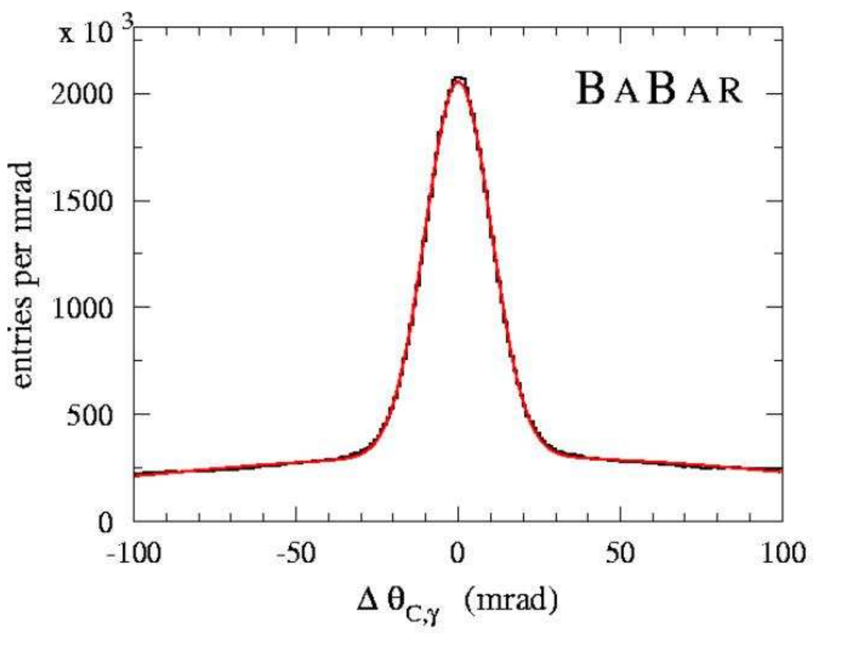
- eliminate background from conversions in the water tank
- assign photons to proper tracks
- eliminate most of the ambiguities in the photon-track reconstruction

DIRC performance

Number of detected photons

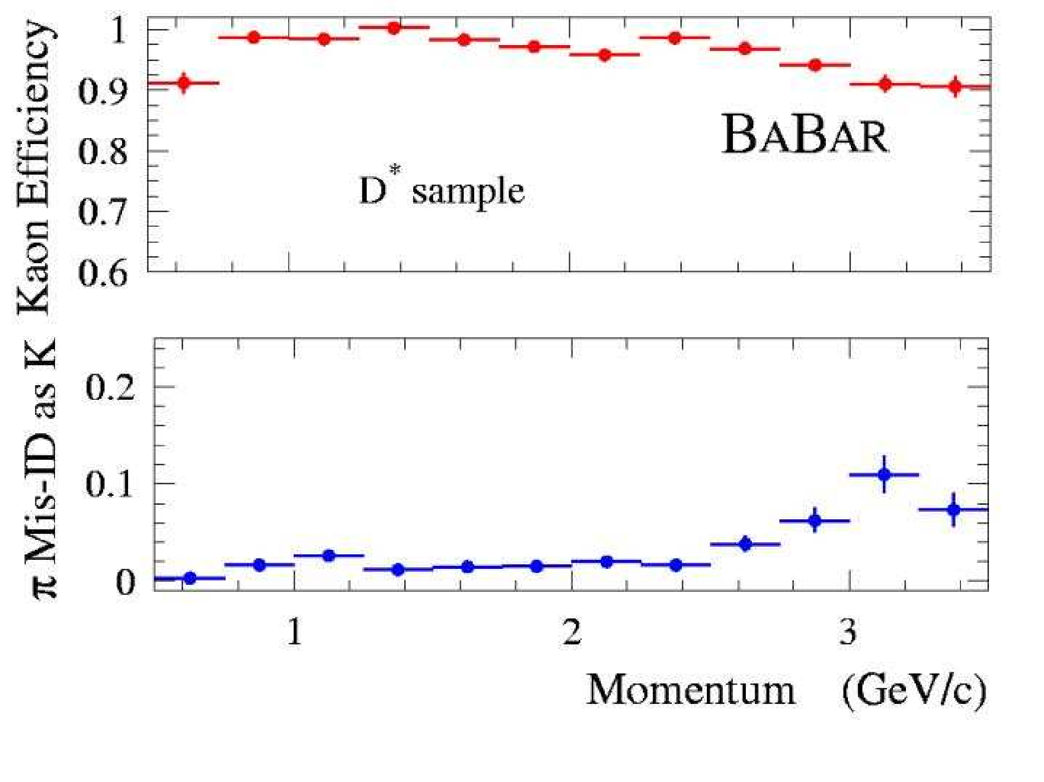


Single photon resolution



DIRC performance

Check performance with tagged $D^0 \to K^-\pi^+$ decays (from $D^{*+} \to D^0\pi^+$)



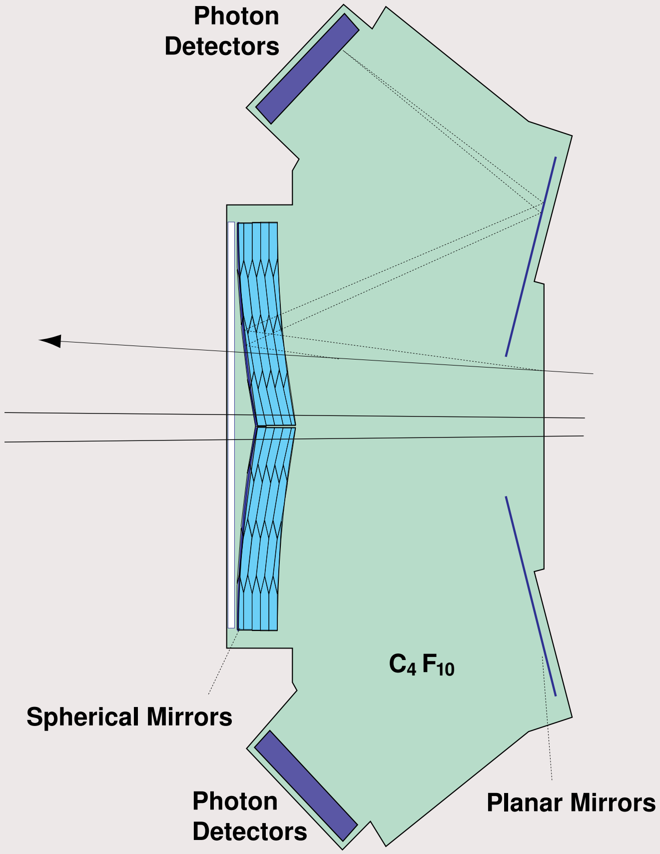
→ talk by J. Schwiening, this session

HERA-B RICH

The first LHC environment-like RICH in the pre-LHC era.

Radiator: C_4F_{10} with a nominal pion threshold at 2.7 GeV/c

Photon detector: multianode PMTs with lenses as a light collection system



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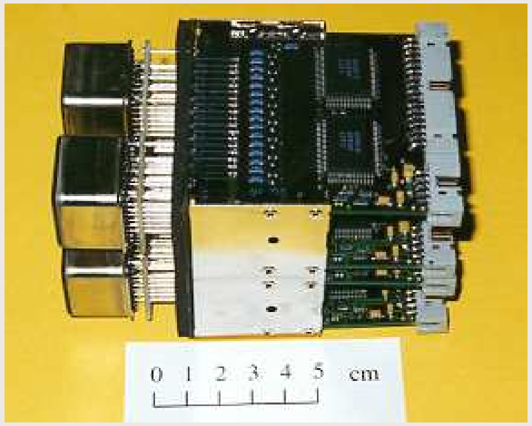
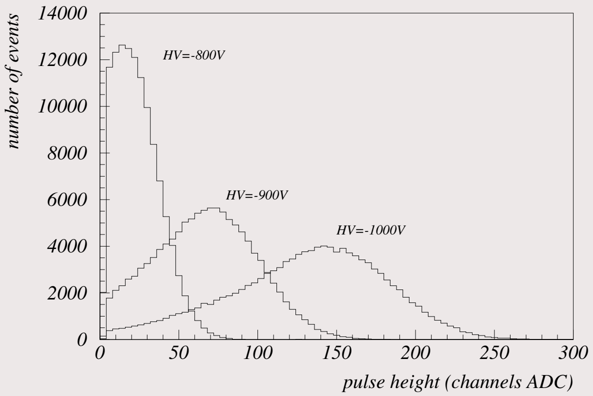
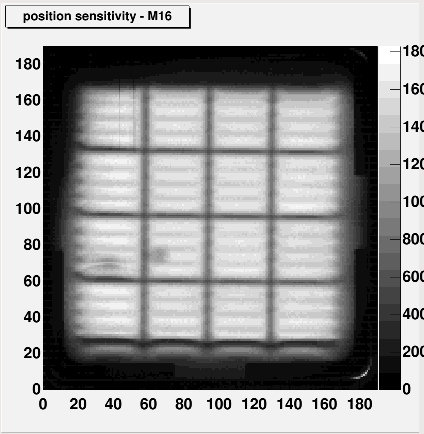
Multianode PMTs in HERA-B



Fully equipped photomultiplier basic module housing Hamamatsu R5900 photomultiplier tubes type M16.

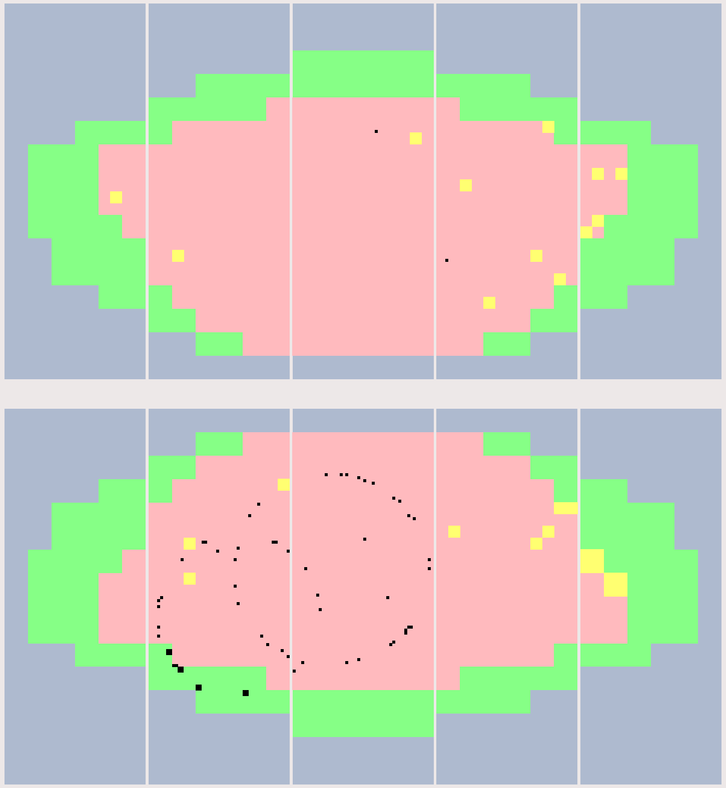


Pulse height distributions due to single photoelectrons.



Sensitivity of a M16 PMT surface when scanned by a light beam spot of about 30 μm diameter.

Multianode PMTs in HERA-B



HERA-B low multiplicity event: clear rings, no noise

RICH parameters:

- Number of hits = 32 per saturated ring ($N_0 = 42$ cm^{-1})
- Resolution = 0.7 mrad (M16), 1.0 mrad (M4)

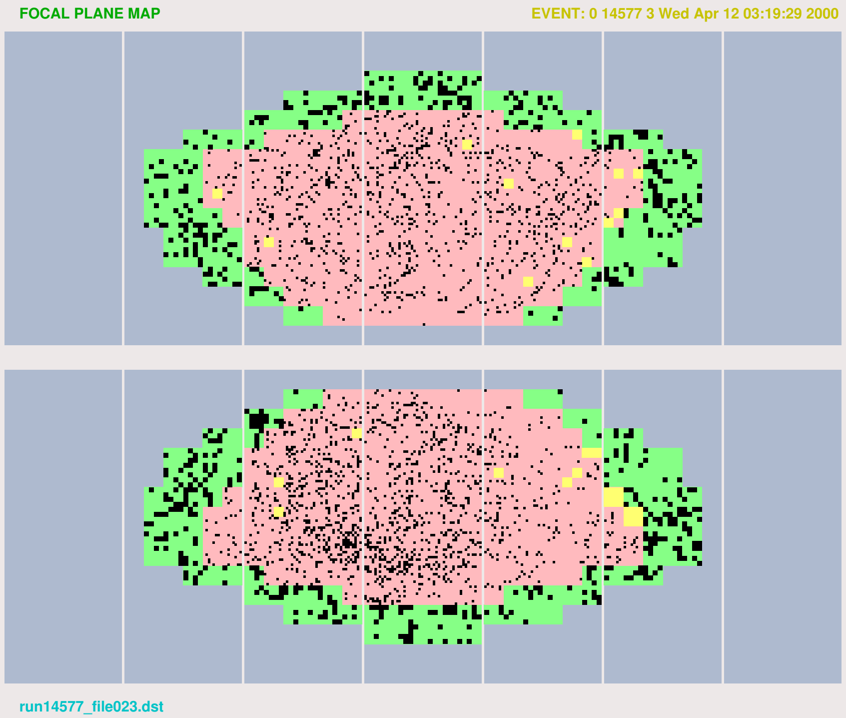
→ in very good agreement with expectations

- Typical rates: 1MHz in the hottest areas
- In operation since summer 1998
- No degradation of performance has been observed

→ talk by S. Korpar, this session

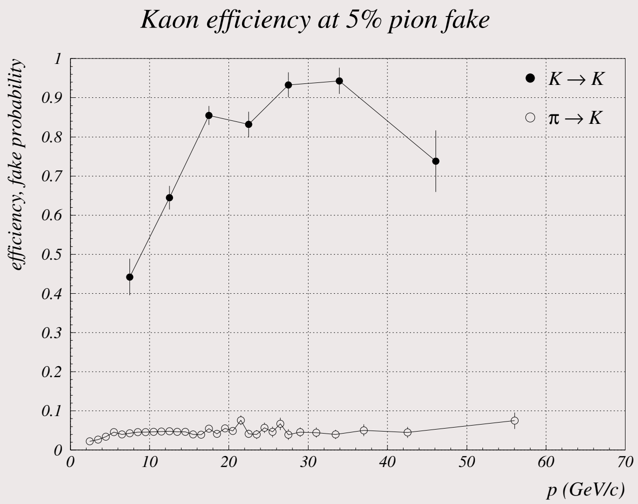
HERA-B: RICH PID at high track densities

- Challenge: occupancy exceeds 10% in hottest regions, significant ring overlap



HERA-B: Typical event

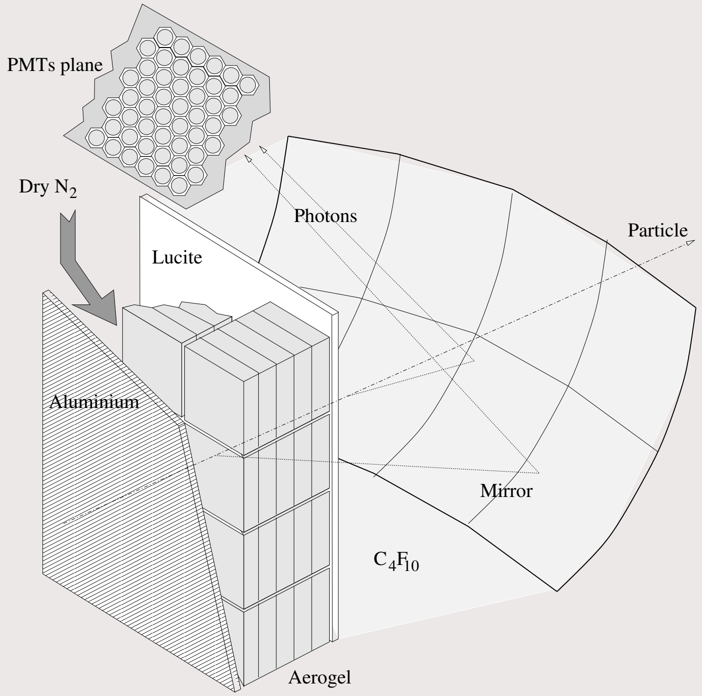
Still: hadron ID works!



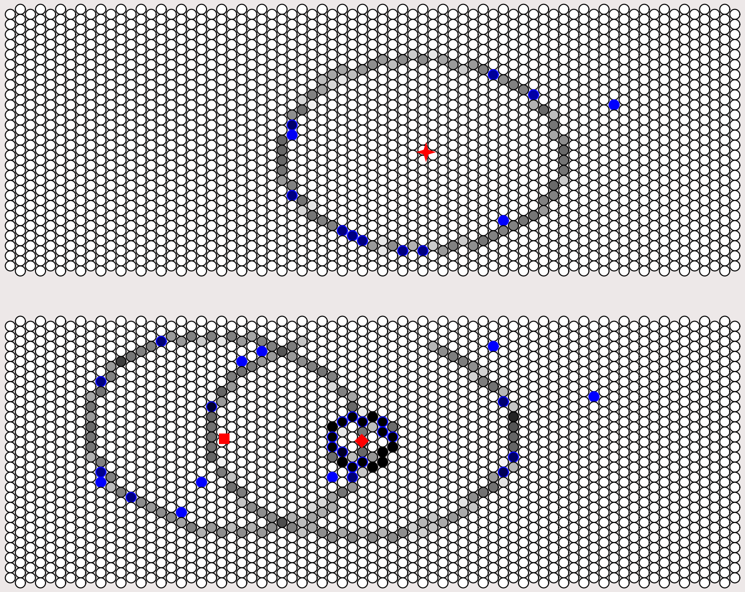
Kaon identification efficiency (at 5% π fake probability).

$\rightarrow$ talk by M. Starič on Sunday

Two radiator RICH (aerogel+C_4F_{10}) and single channel PMTs (Phillips XP1911) with light cones



event on both detector halves

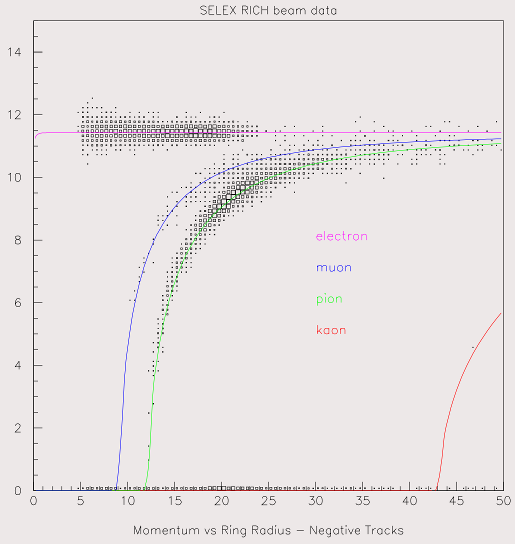


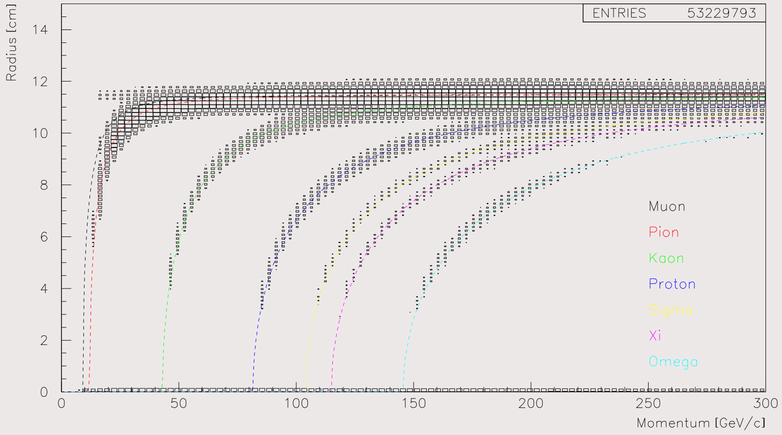
Efficiency, example at 5 GeV/c: $\epsilon(K \to K) = 0.97$, $\epsilon(\pi \to K) = 0.003$, $\epsilon(p \to K) = 0.026$

Important experience for the next RICH generation: a system with two radiators, one of which is aerogel.

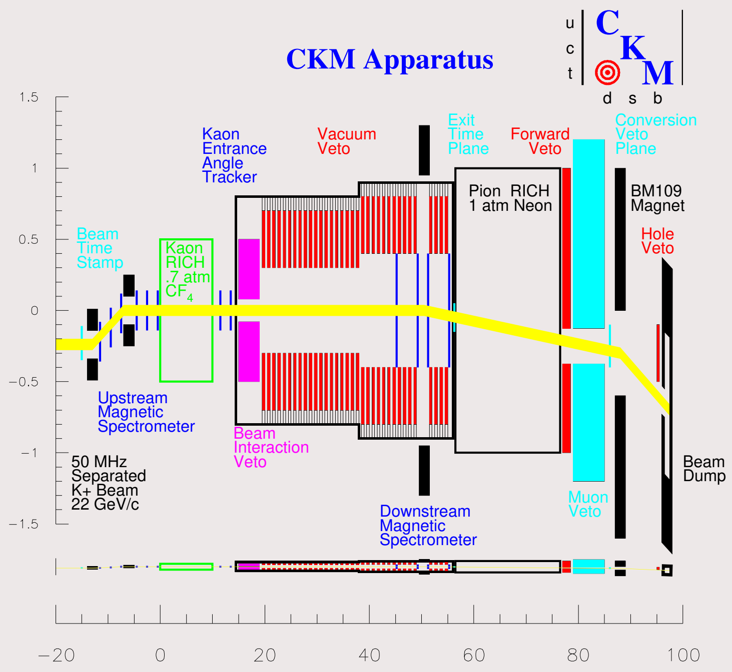
$\to$ next talk by H. Jackson in this session

SELEX RICH: 10 m of neon and single anode PMTs





Experience from SELEX will be used in the next experiment - CKM - with two RICHes to identify the K and π from the $K \rightarrow \pi\nu\nu$ decay



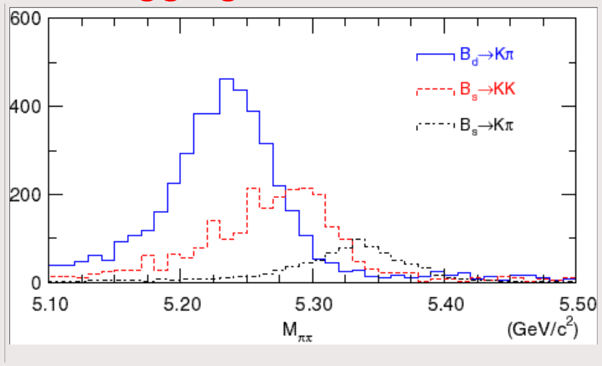
→ talks by J. Engelfried, this session and on Sunday

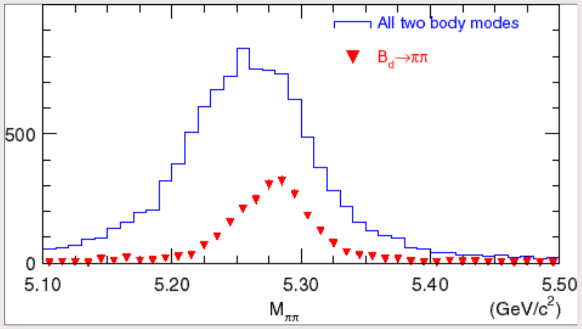
Next generation

Next generation of dedicated B physics experiments relies again on the vacuum based tubes:

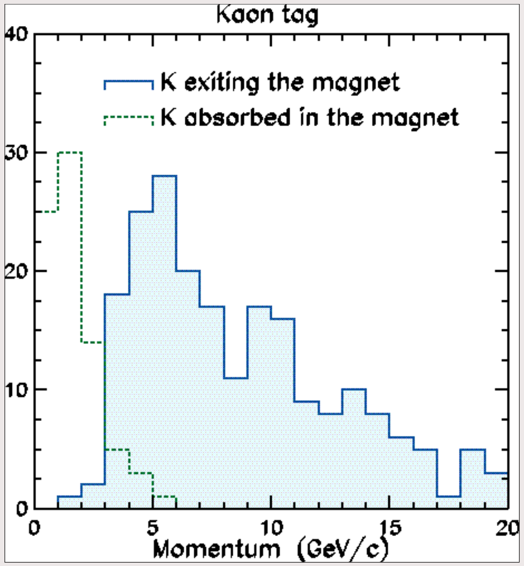
- B-TeV: hybrid photodetector (HPD) and single channel PMTs
- LHCb: hybrid photodetector (HPD) or multianode PMTs

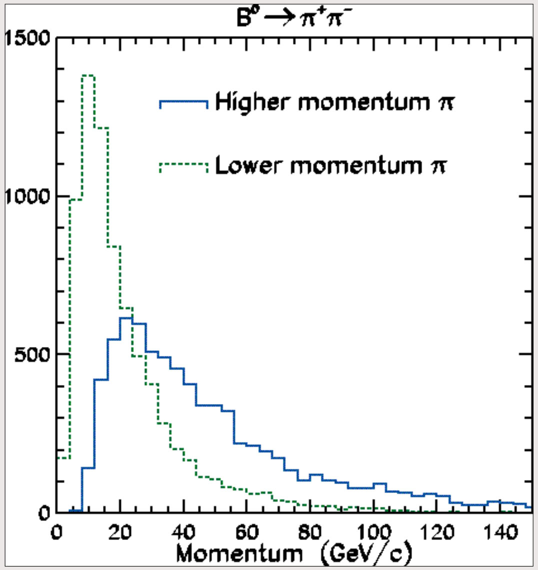
Needed: for kaon tagging, and for $B \to \pi^+\pi^-$



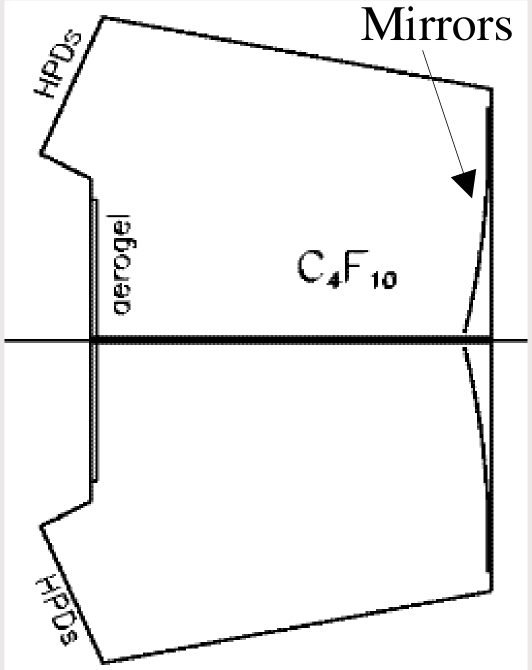


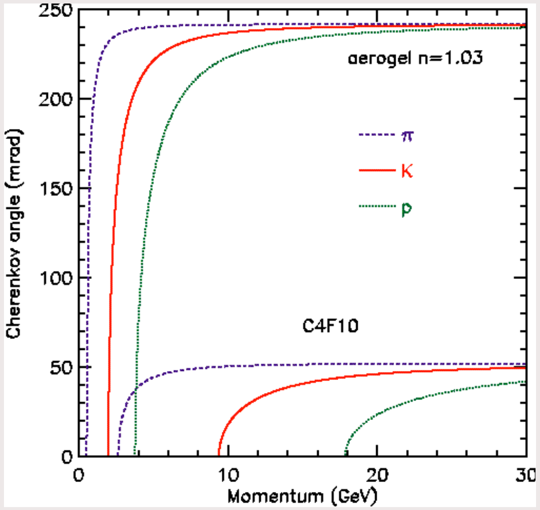
Momentum spectra of tagging K's and pions from $B \to \pi^+\pi^-$





Cover π/K separation, $3 < p < 70$ GeV/c
Radiator: C_4F_{10}
Detector: hybrid photon detectors (HPD)





With two radiators the separation of K and p improves substantially.
Presently considered: instead of aerogel use a liquid radiator (C_5F_{12}), with single channel PMTs at the side walls

→ talk by S. Blusk, this session
→ talk by R. Mountain, Saturday

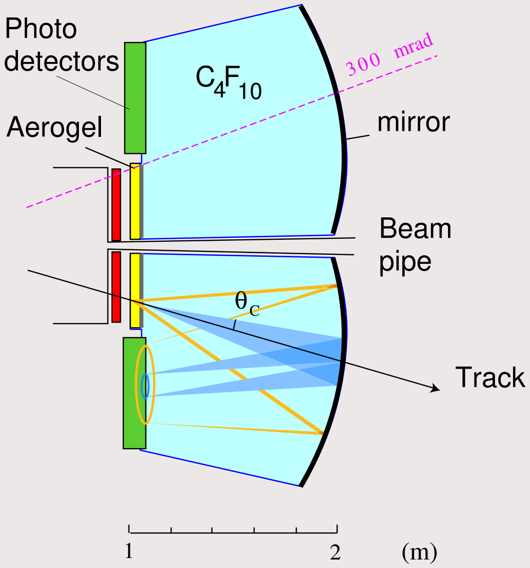
RICHes for LHCb

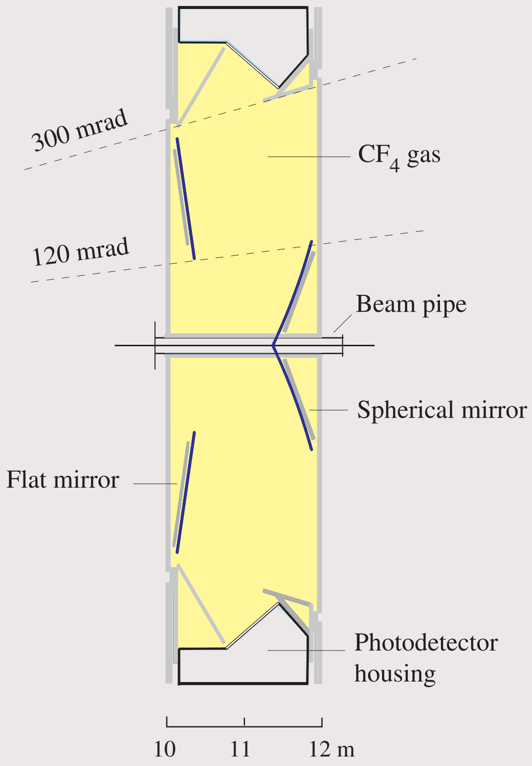
Need: π/K separation $1 < p < 150$ GeV/c

How many radiators? The kinematic region covered by a single radiator RICH, $p_{min} \to p_{max}$, depends on the threshold momentum for the lighter of the two particles we want to separate, and the resolution in Čerenkov angle (ultimately given by the dispersion)

A general property: $\frac{p_{max}}{p_{min}} \approx 4 - 7$ (see review in RICH98)

→ 3 radiators for LHCb





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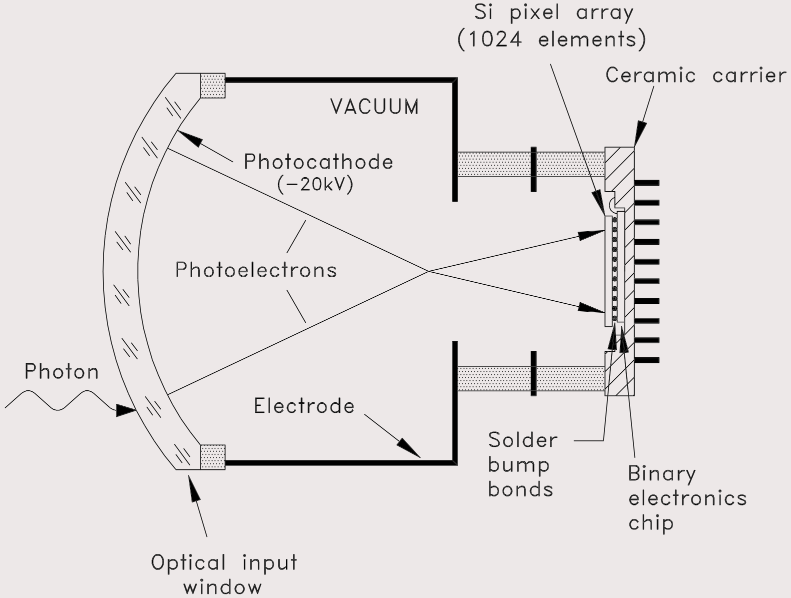
HPD with pixel read-out (DEP)



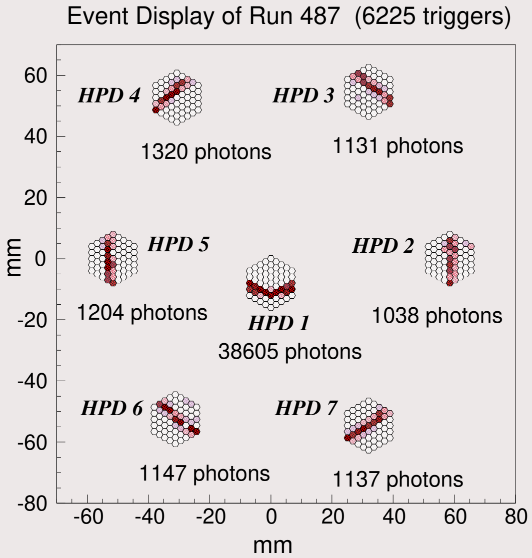
Tube ready, beam tested with 61 channel read out.
1024 channel pixel sensor with electronics in preparation.

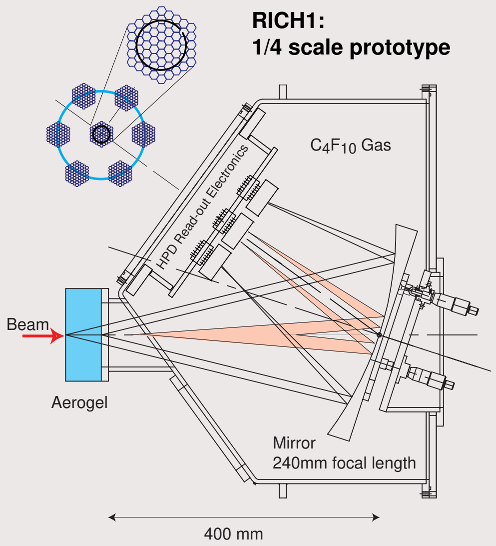
Alternative for LHCb: 64 channel multianode PMT (Hamamatsu).

Tested in the beam, including the light collection system.

→ talks by S. Easo and F. Muheim, this session

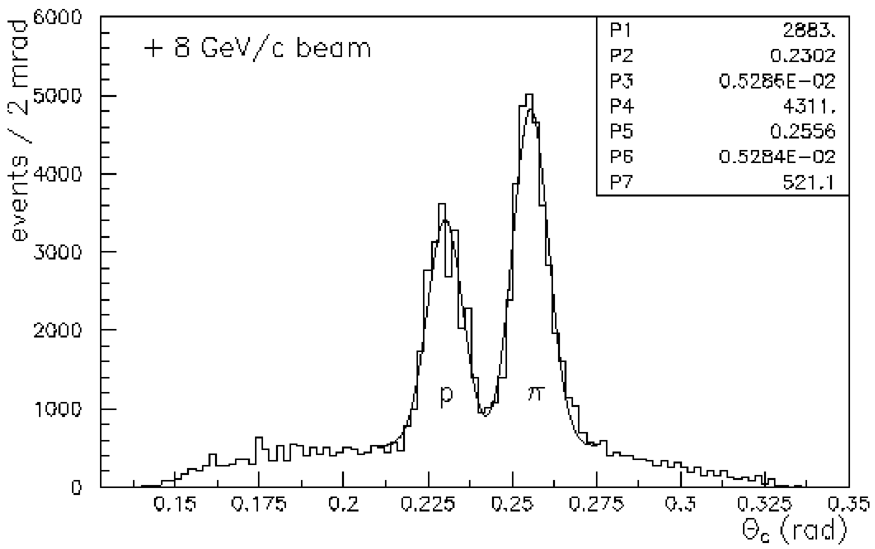
HPD beam tests





< – DEP with 61 pixels,
gas and aerogel radiators

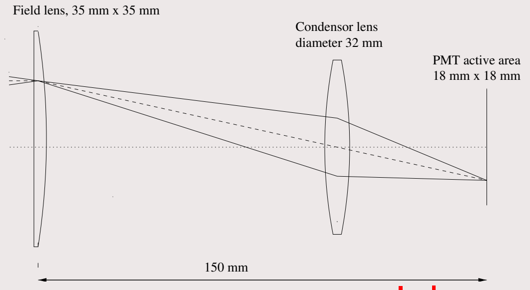
CERN pad version with 2048 pixels, 4 tubes
aerogel radiator



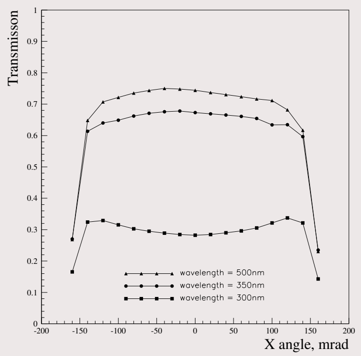
Optical systems for light collection and demagnification

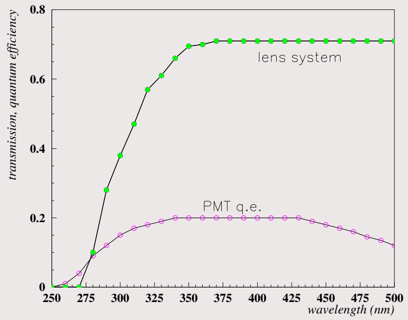
→ reduce dead area, adapt pad size

HERA-B: two UVT plexi-glass lens system



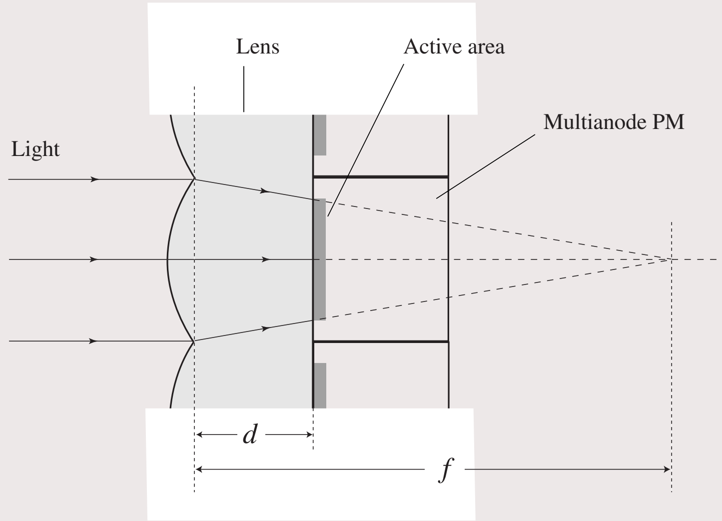
→ angular acceptance, material transmission





Flat acceptance for incident angles below 140 mrad

LHCb: quartz lens + multianode PMT



has to cover larger angles of incidence.

Belle, BaBar PID upgrade

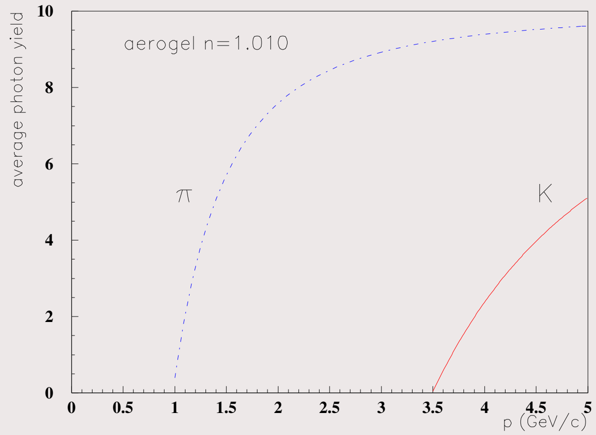
For the next round of B physics experiments at upgraded e^+e^- machines ('Super B factories') considerable upgrades of PID devices are envisaged to cope with higher rates and with an improved separation capabilities for rare decay channels:

- Belle upgrade: proximity focusing aerogel with flat panel PMTs, time-of-propagation counter with multianode PMTs
- BaBar upgrade: DIRC with smaller expansion volume and multianode PMTs

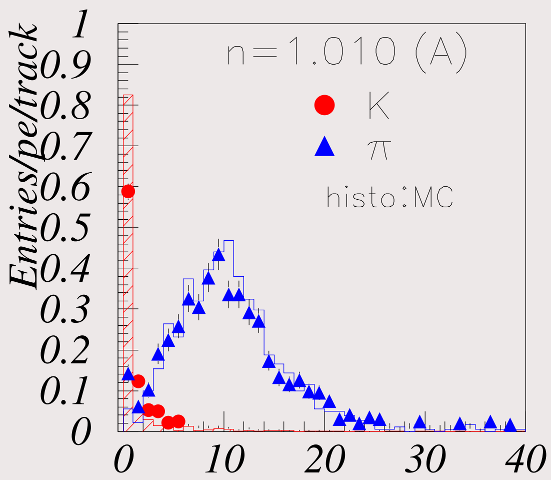
BaBar DIRC upgrade: replace single channel PMTs with a multichannel device (Hamamatsu flat panel 64 channel PMTs, proximity focusing DEP HPD, 64 channel multianode PMT) $\rightarrow$ talk this afternoon

Belle: aerogel threshold Č.

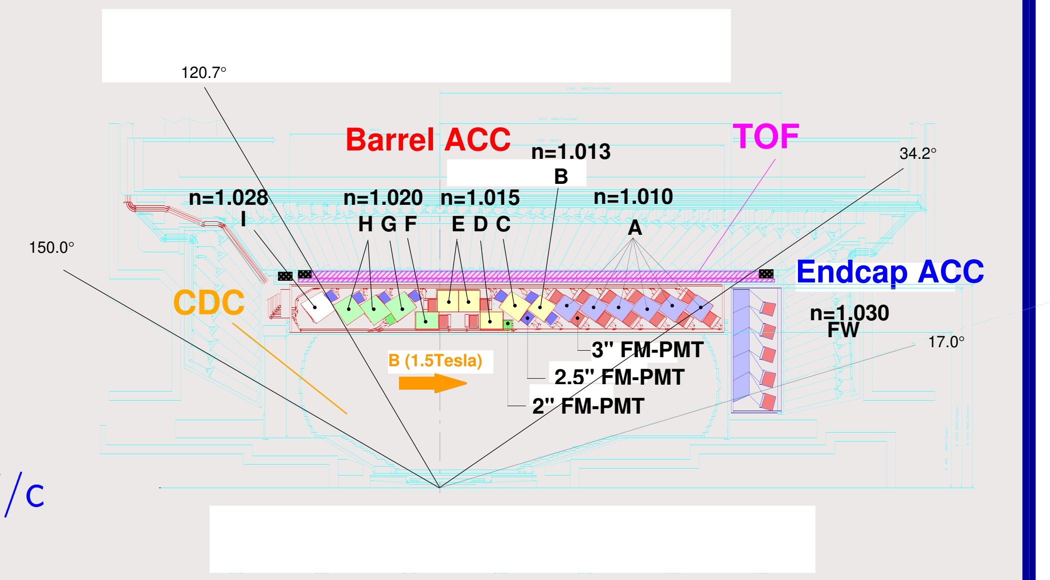
expected average yield vs p



measured for 2 GeV/c< p <3.5 GeV/c



separation of K (below) vs. π (above thr.): properly choosing n for a given kinematic region



→ T. Sumiyoshi's review talk on Thursday

Barrel: covers both tagging and $B \to \pi\pi, K\pi$
Forward: tagging only

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Belle: PID upgrades

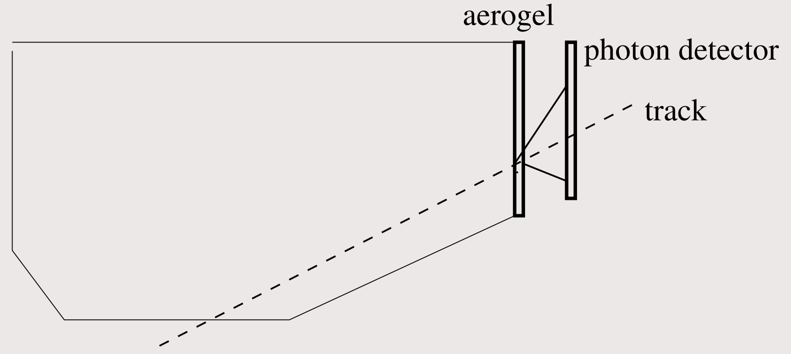
Upgrade options considered:

- Proximity focusing RICH in the forward direction $\rightarrow$ talk by T. Iijima, Saturday
- Time-of-propagation counter in the barrel region ('inverted DIRC': use time of arrival to determine θ_c) $\rightarrow$ talk by T. Ohshima, Thursday

Challenge: photon detectors for both have to work in a high magnetic field (1.5 T).

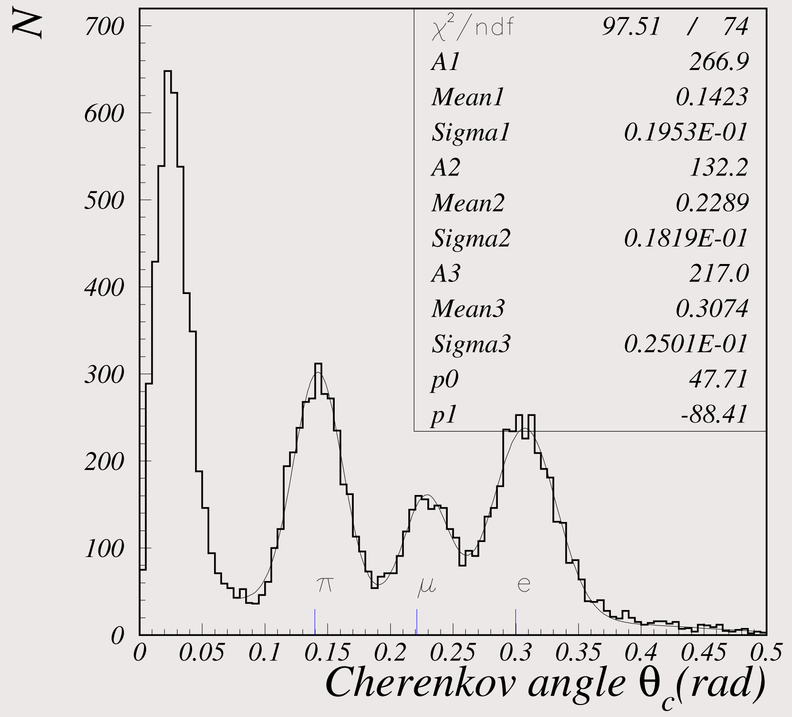
Proximity focusing RICH in the forward direction

In the present aerogel Čerenkov of Belle $B \to \pi\pi$ decays are not covered in the end-cap.
Idea: replace ACC with proximity focusing RICH and aerogel as radiator



Proximity focusing RICH - principle

Another benefit: $e/\mu/\pi$ separation at low momenta (for $B \to Kll$)



beam test result at 0.8 GeV/c
$\to$ talk, Iijima

Summary

- Vacuum based photon detectors have contributed significantly to the incredible B physics harvest
- HERA-B has shown that a vacuum photodetector based RICH can operate in the very rough environment of a hadron machine.
- Multianode PMTs have become a well established single photon counter with excellent performance.
- New photon detectors are entering the field - HPDs, flat panel PMTs, ...

- Vacuum photon detector based RICH counters will play a decisive role in the next generation of precision B physics experiments (LHCb, BTeV)
- and at the next generation of e^+e^- 'super' B factories