RICH Counters for b-Experiments

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- Motivation
- RICH counters for e^+e^- B-factories and their upgrades
- RICH counters for B physics at hadron machines

Why do we need a excellent hadron ID at all?

One of the main driving forces of the R+D of RICH counters was in the last decade 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 $B \to \pi\pi$ from πK, $B \to K\pi\pi$ from $KK\pi$ etc.

New tasks, with larger data sets becoming available:

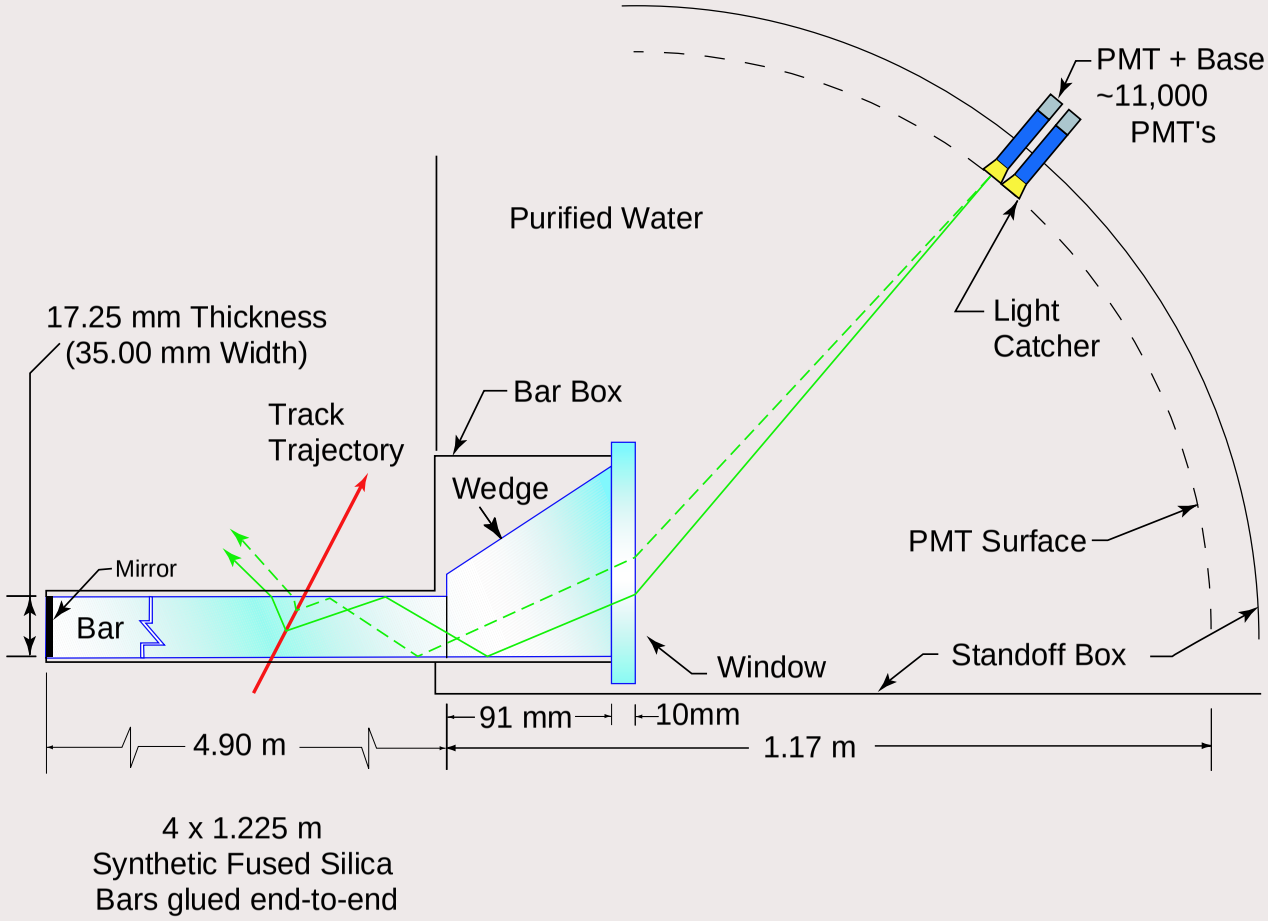
- π/K separation for $b \to d\gamma$ / $b \to s\gamma$
- Separation of low momentum (< 1 GeV/c) e and μ from π for $B \to \ell^+\ell^- X_s$ and $B \to \ell^+\ell^- X_d$ decays

Cherenkov counters in B experiments

- BaBar: DIRC
- Belle: ACC - aerogel (threshold) Cherenkov counter
- Cleo III: proximity focusing RICH with a gas based photon detector (TEA-methane in a MWPC with pad readout)

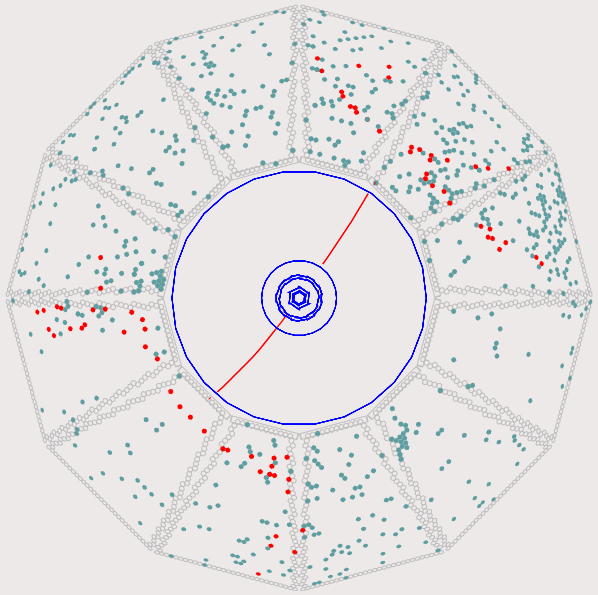
DIRC - detector of internally reflected Cherenkov light

Principle of DIRC at BaBar

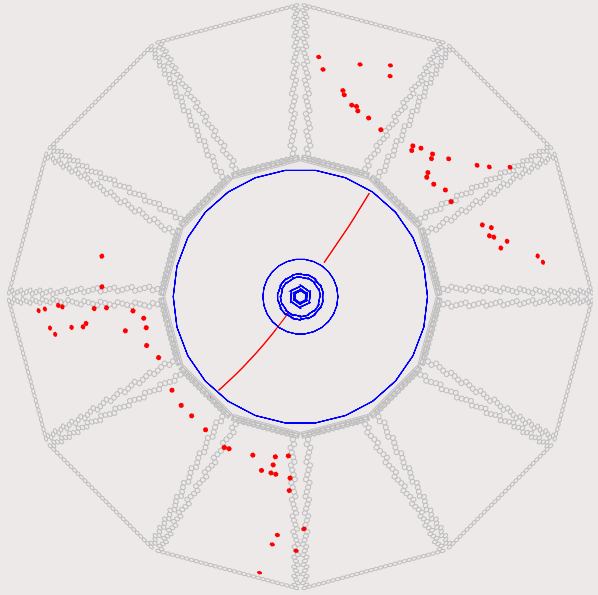


DIRC time filtering

DIRC event, no time cut (± 300 ns)



DIRC event, with time cut (± 4 ns)

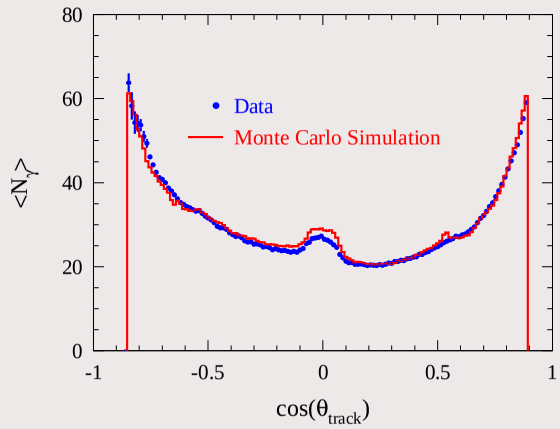


Use time constraint to :

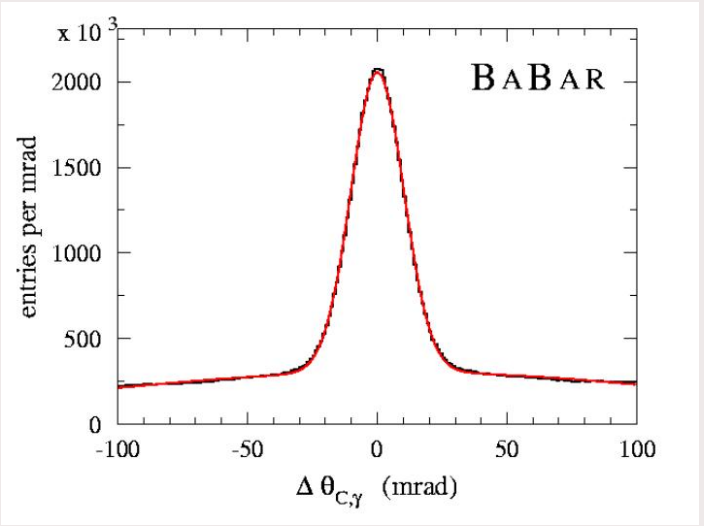
- eliminate background from conversions in the water tank
- assign photons to proper tracks
- eliminate most of the ambiguities in the photon-track reconstruction

DIRC performance

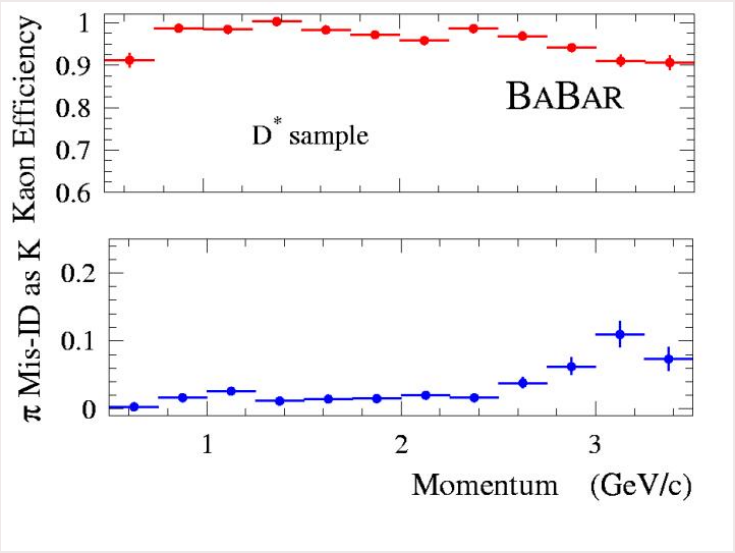
Number of detected photons



Single photon resolution

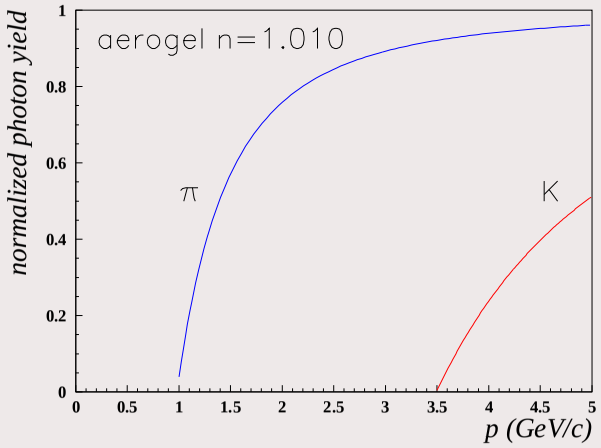


Check performance with tagged $D^0 \to K^-\pi^+$ decays (from $D^{*+} \to D^0\pi^+$)

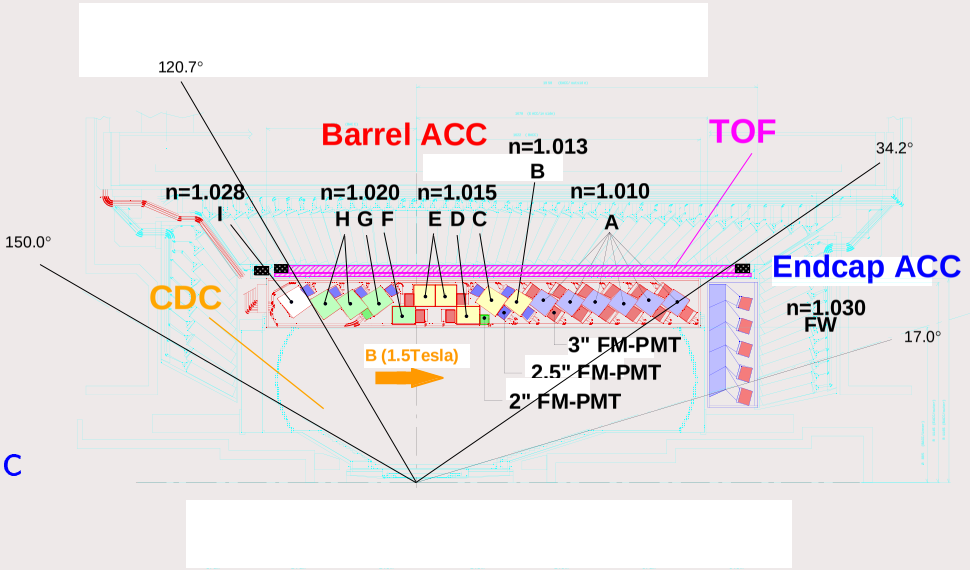


Belle, present: aerogel threshold Č. (ACC)

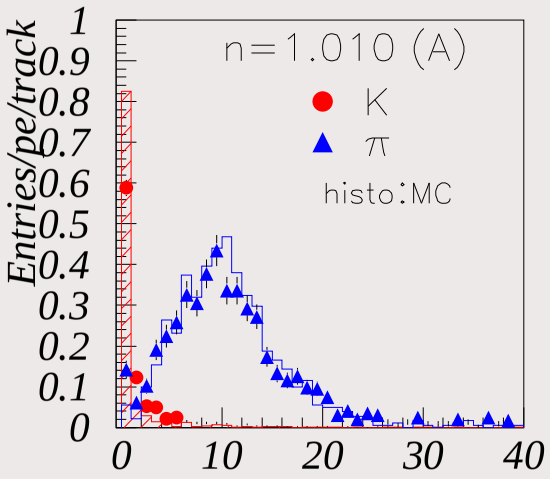
expected average yield vs p



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



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



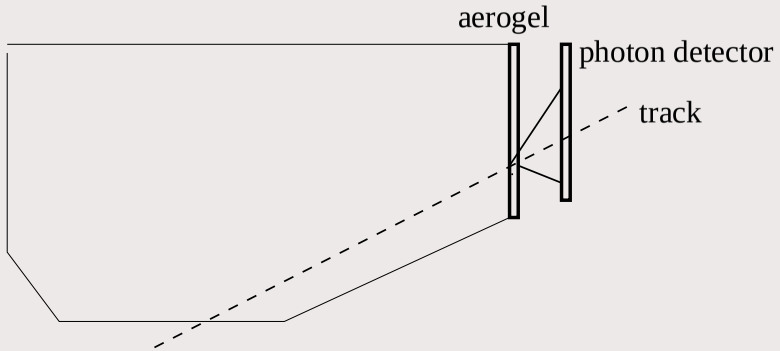
Barrel: covers both tagging and $B \to \pi\pi, K\pi$
Forward (endcap): tagging only

PID upgrades

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

PID upgrade options considered at Belle:

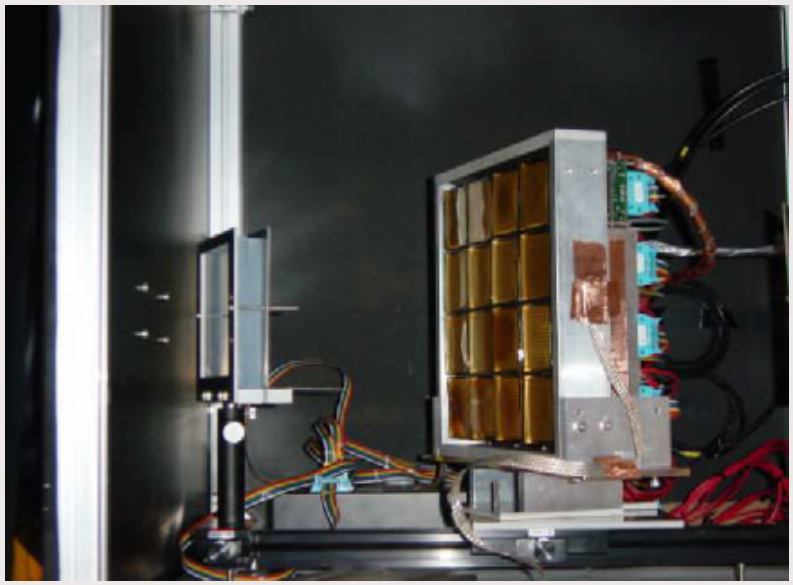
- Time-of-propagation (TOP) counter in the barrel region ('inverted DIRC': use time of arrival to determine θ_c)
- Proximity focusing RICH in the forward direction (endcap)



Challenge: photon detectors for both have to work in a high magnetic field (1.5 T). TOP needs a single photon time resolution of < 100 ps.

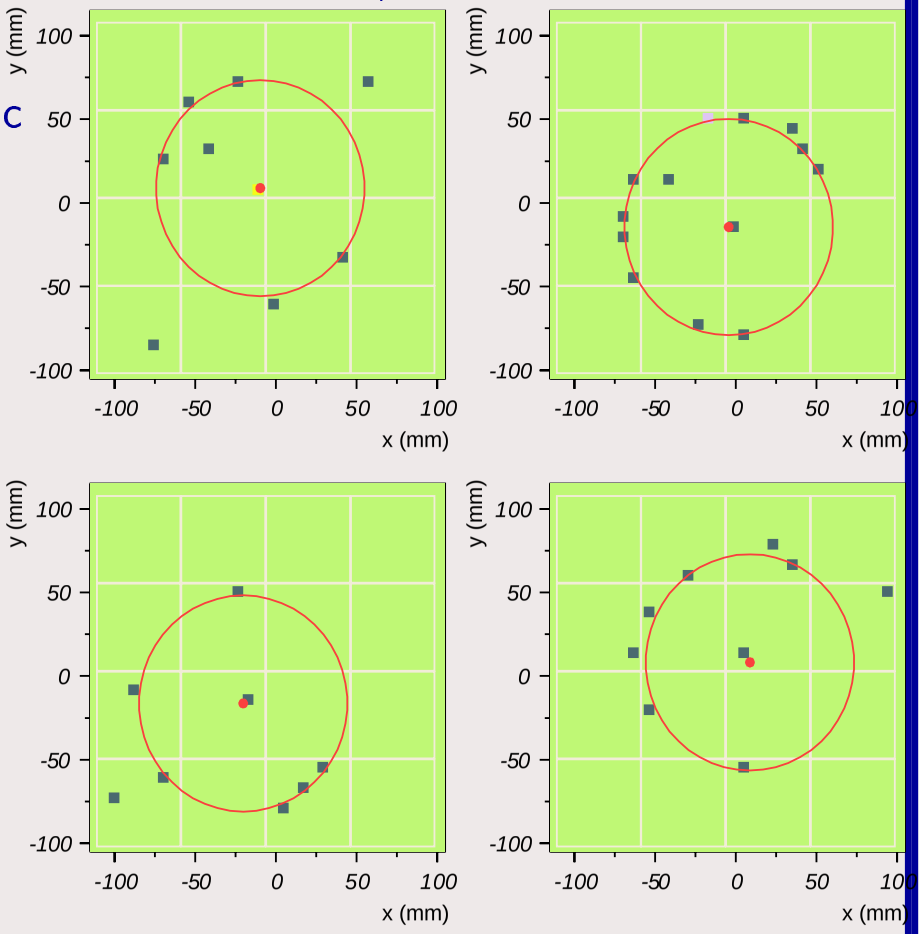
Belle endcap PID upgrade

Endcap: replace ACC with a proximity focusing RICH and aerogel as radiator
$\rightarrow$ get a 4σ π/K separation up to 4 GeV/c



prototype in the beam test

events, beam test data

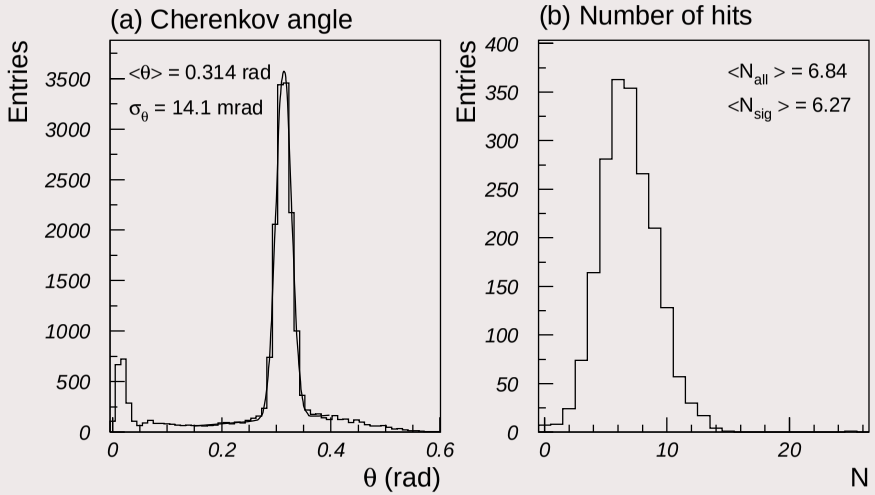


- aerogel: hydrophobic Matsushita $n \approx 1.05$
- photon detector: Hamamatsu H8500 flat panel PMTs with 8x8 pads (6mm x 6mm)

Proximity focusing RICH - performance

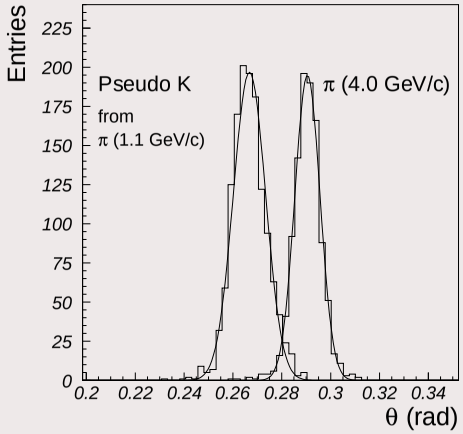
Single photon resolution:
typically 13-14 mrad
Average number of photons:
around 6

(both for 2 cm thick aerogel)



Čerenkov angle distribution per track
at 4 GeV/c:

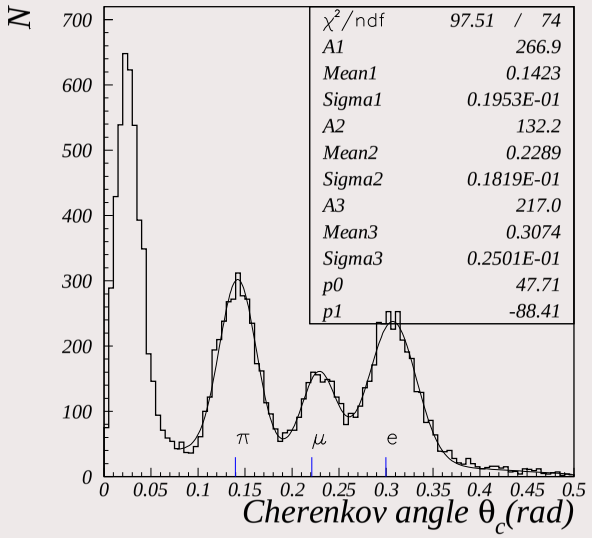
π vs 'K' ($= \pi$ at 1.1 GeV/c)



Proximity focusing RICH - status

Another benefit: $e/\mu/\pi$ separation at low momenta
(essential for $B \to K\ell^+\ell^-$)

single photon Čerenkov angle distribution from beam tests at 0.8 GeV/c $\rightarrow$

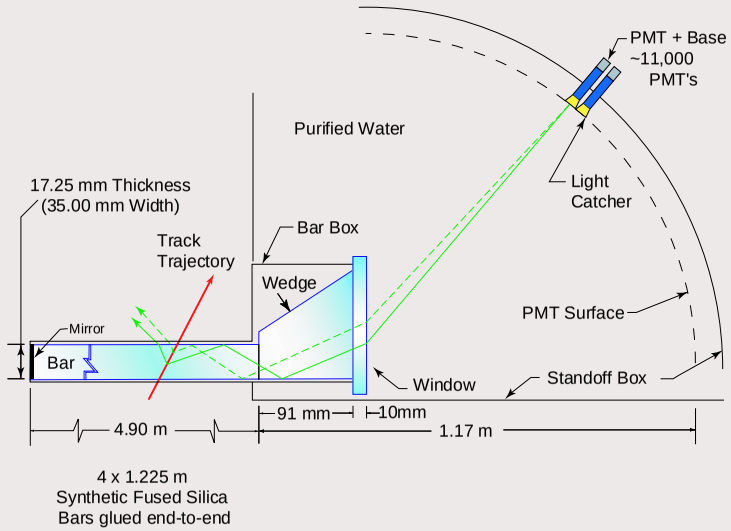


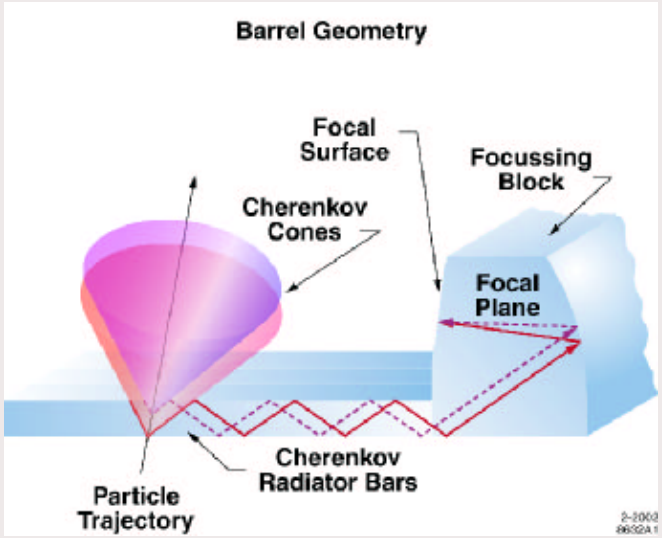
Counter status

- Proof of pinciple: OK
- Photon detector: R+D (together with Hamamatsu) for a multianode device to work at 1.5 T (HPD or microchannel plate PMT)
- Aerogel: hydrofobic material OK, R+D to increase tile size, stable mass production

BaBar DIRC upgrade

DIRC with a smaller expansion volume and multianode PMTs





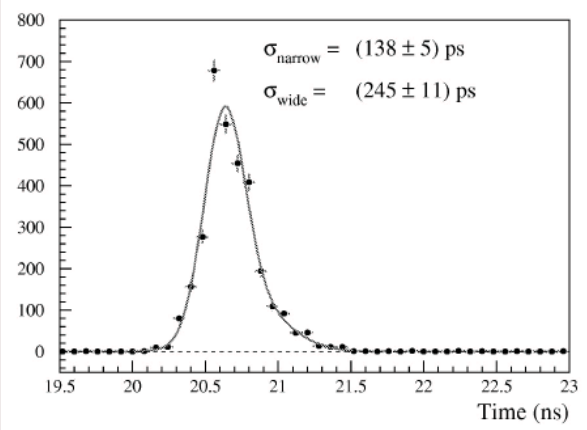
- reduce expansion volume (stand-off box) from ≈ 1 m of water to ≈ 0.1 m of quartz $\rightarrow$ less background
- use focusing optic instead of pin-hole $\rightarrow$ reduce bar size uncertainty
- use PMTs with an improved time resolution $\rightarrow$ reduce chromatic uncertainty

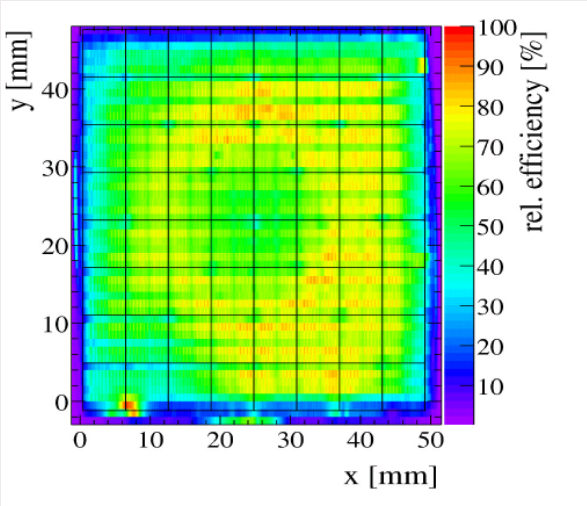
$\rightarrow$ Need a position sensitive photon detector (multianode device) with a single photon time resolution of 50-100 ps.

BaBar DIRC upgrade, photon detector R+D

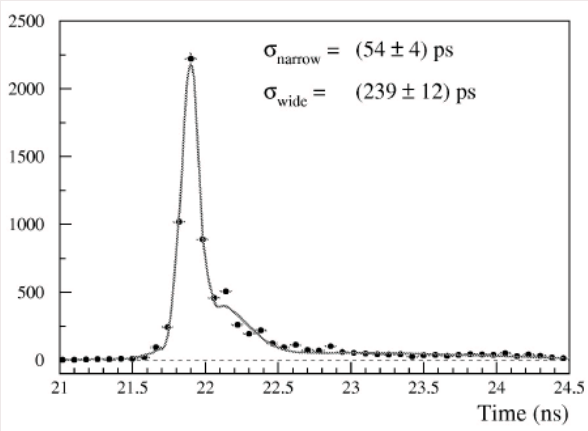
Use single photons from a pico-second laser to study two candidates with 8x8 pads.

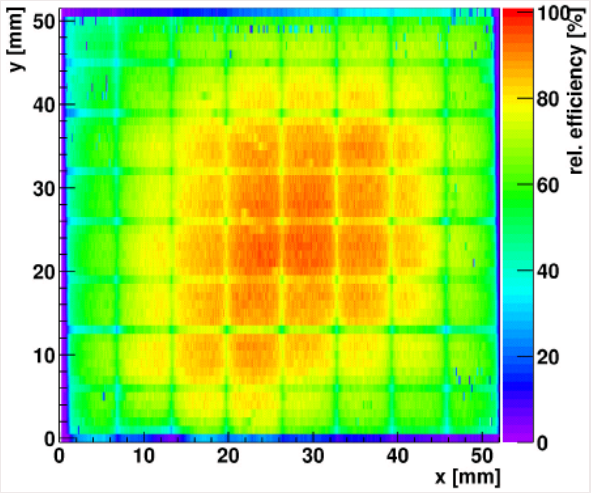
Hamamatsu H8500 flat panel PMT





Burle 85011 micro channel plate (MCP) PMT





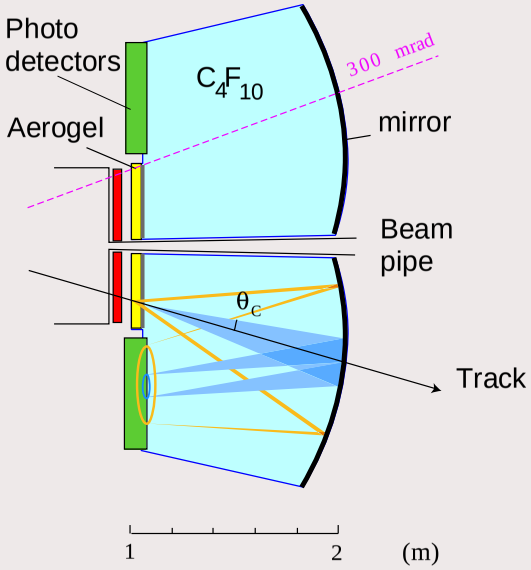
RICHes for B factories at hadron machines

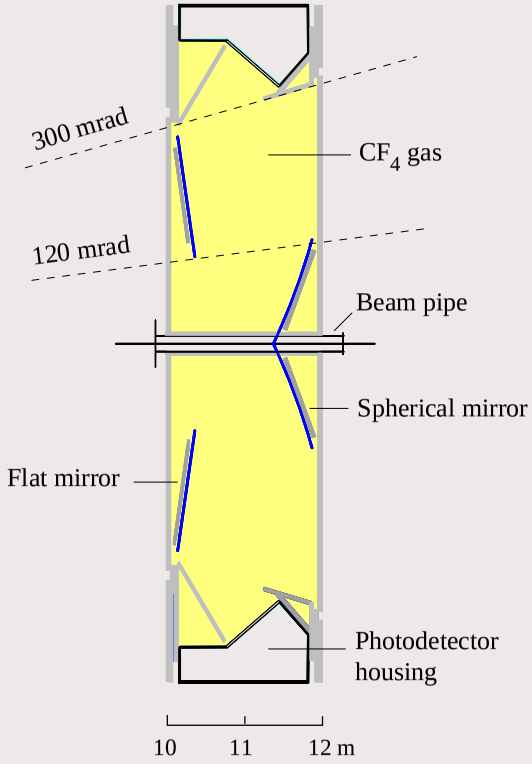
Need: π/K separation $1 < p < 150$ GeV/c for LHCb (similar for BTeV)

How many radiators? The kinematic region covered by a single radiator RICH, $p_{min} \rightarrow p_{max}$, 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: $\frac{p_{max}}{p_{min}} \approx 4 - 7$

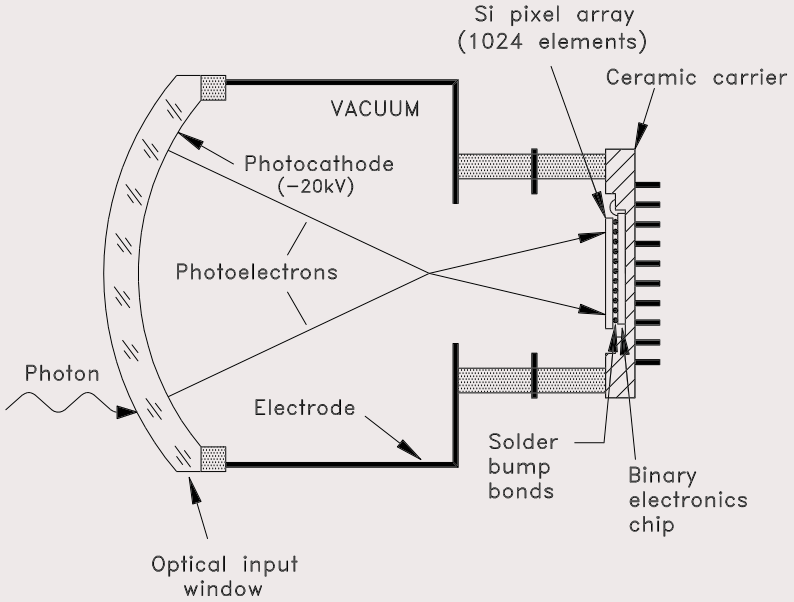
$\rightarrow$ 3 radiators for LHCb

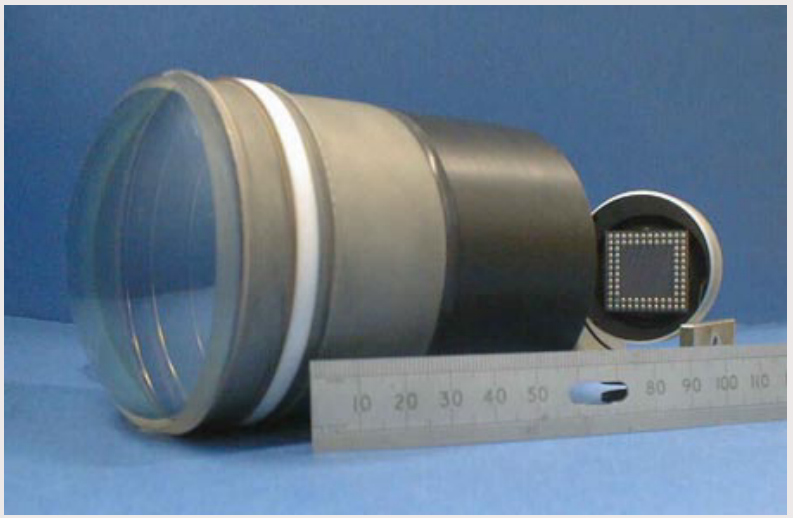




Photon detectors LHCb, BTeV

HPD with integrated pixel read-out (DEP)





The electronics is integrated in the tube → not easy!

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

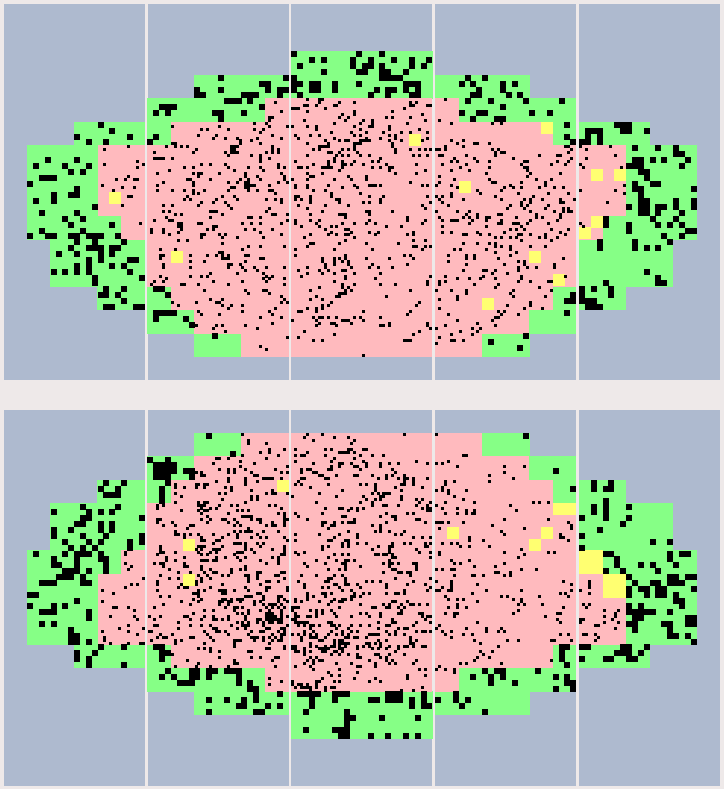
Tested in the beam, including the light collection system: OK.

Proof of principle for the RICHes at hadron machines

HERA-B RICH: the first LHC environment-like RICH in the pre-LHC era.

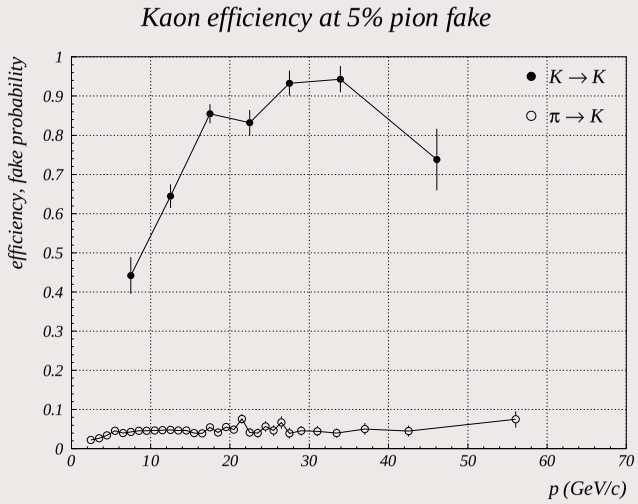
Photon detector: multianode PMTs (R5900-M16) with a light collection system.

HERA-B: a typical event



Typical rates: 1MHz in the hottest areas, 10% occupancy, significant ring overlap.

Still: hadron ID works!



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

Summary

- Cherenkov counters have contributed significantly to the incredible B physics harvest of the last two years
- R+D is going on to make them fit for the next generation of e^+e^- 'super' B factories, with already some promissing results
- RICH counters will surely play a decisive role in the next generation of precision B physics experiments at hadron machines