Univerza v Ljubljani

Recent progress in particle identification methods

Peter Križan

University of Ljubljana and J. Stefan Institute

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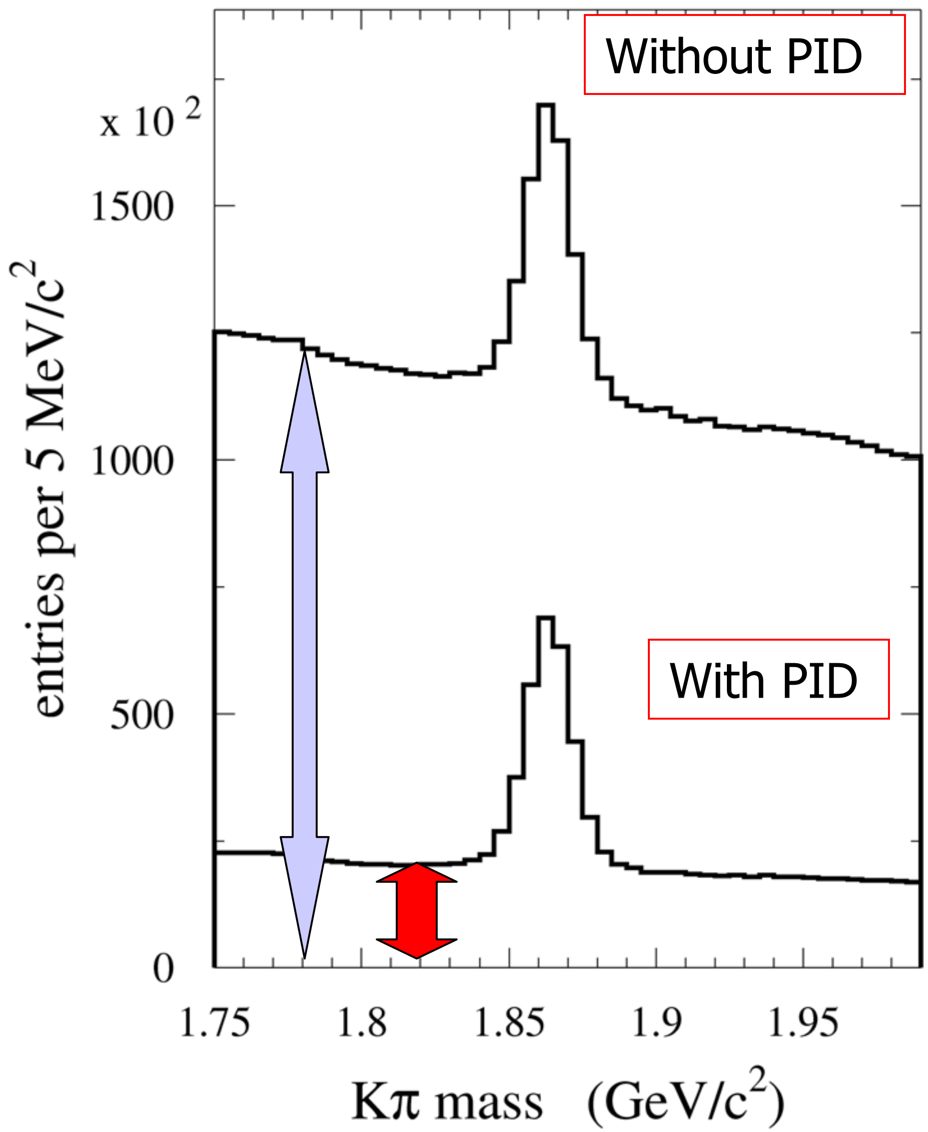
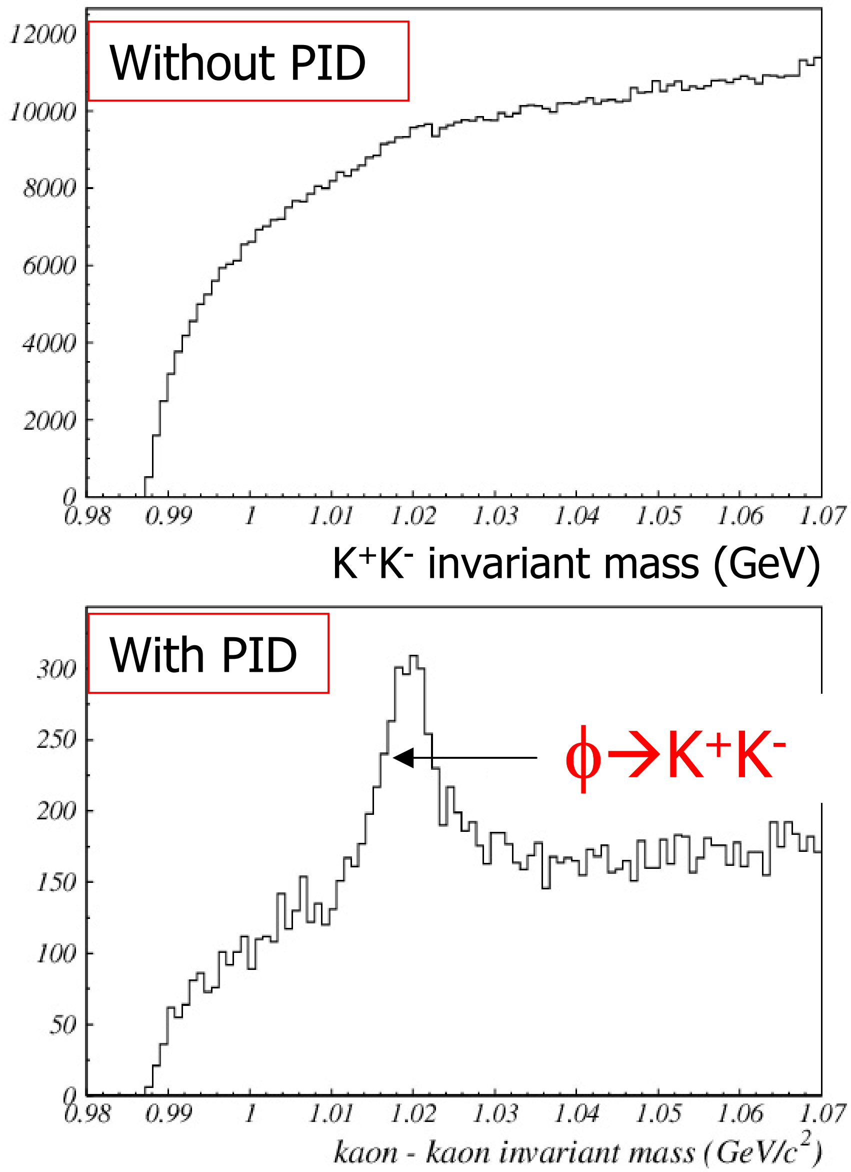
Introduction: why particle ID?



Example 1: B factory

Particle identification reduces the fraction of wrong Kπ combinations (combinatorial background) by ~6x

Introduction: why particle ID?

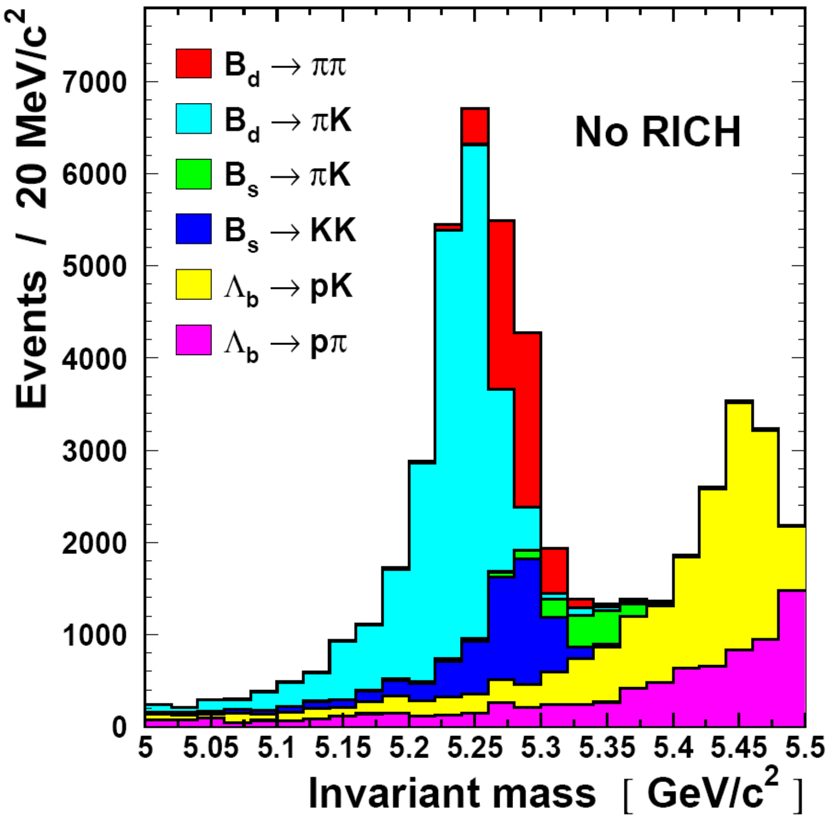


Example 2: HERA-B

K^+K^- invariant mass.

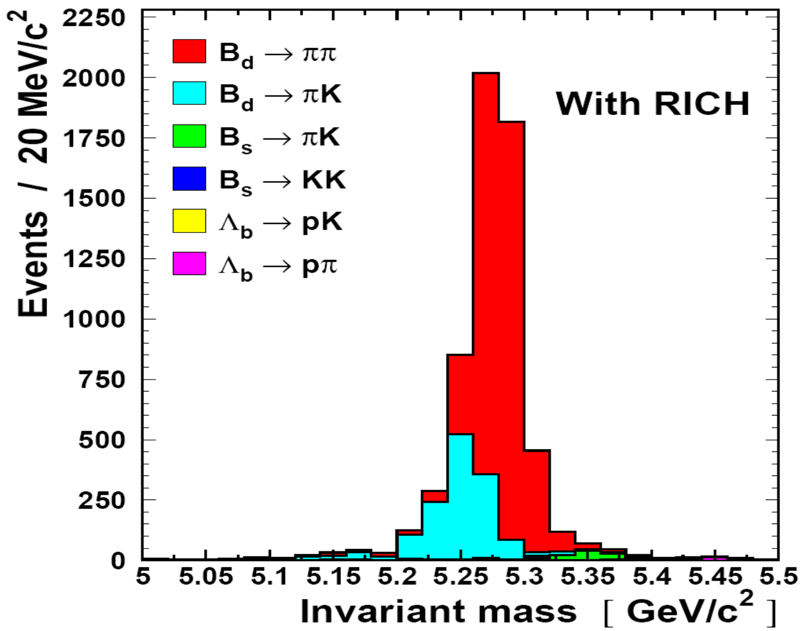
The inclusive $\phi \rightarrow K^+K^-$ decay only becomes visible after particle identification is taken into account.

Introduction: why particle ID?



Example: LHCb

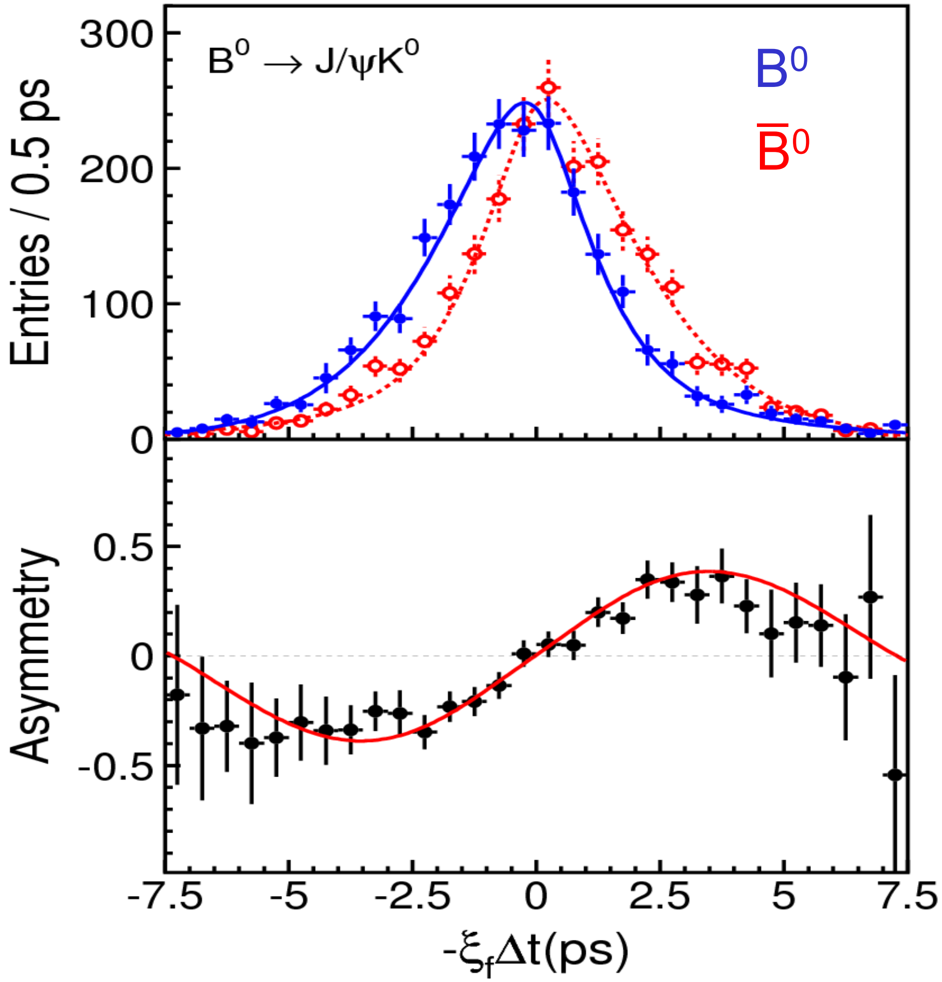
(MC prediction)



Need to distinguish $B_d \to \pi\pi$ from other similar topology 2-body decays and to distinguish B from anti-B using K tag.

Introduction: why particle ID?

Particle identification at B factories (Belle and BaBar): was essential for the observation of CP violation in the B meson system.

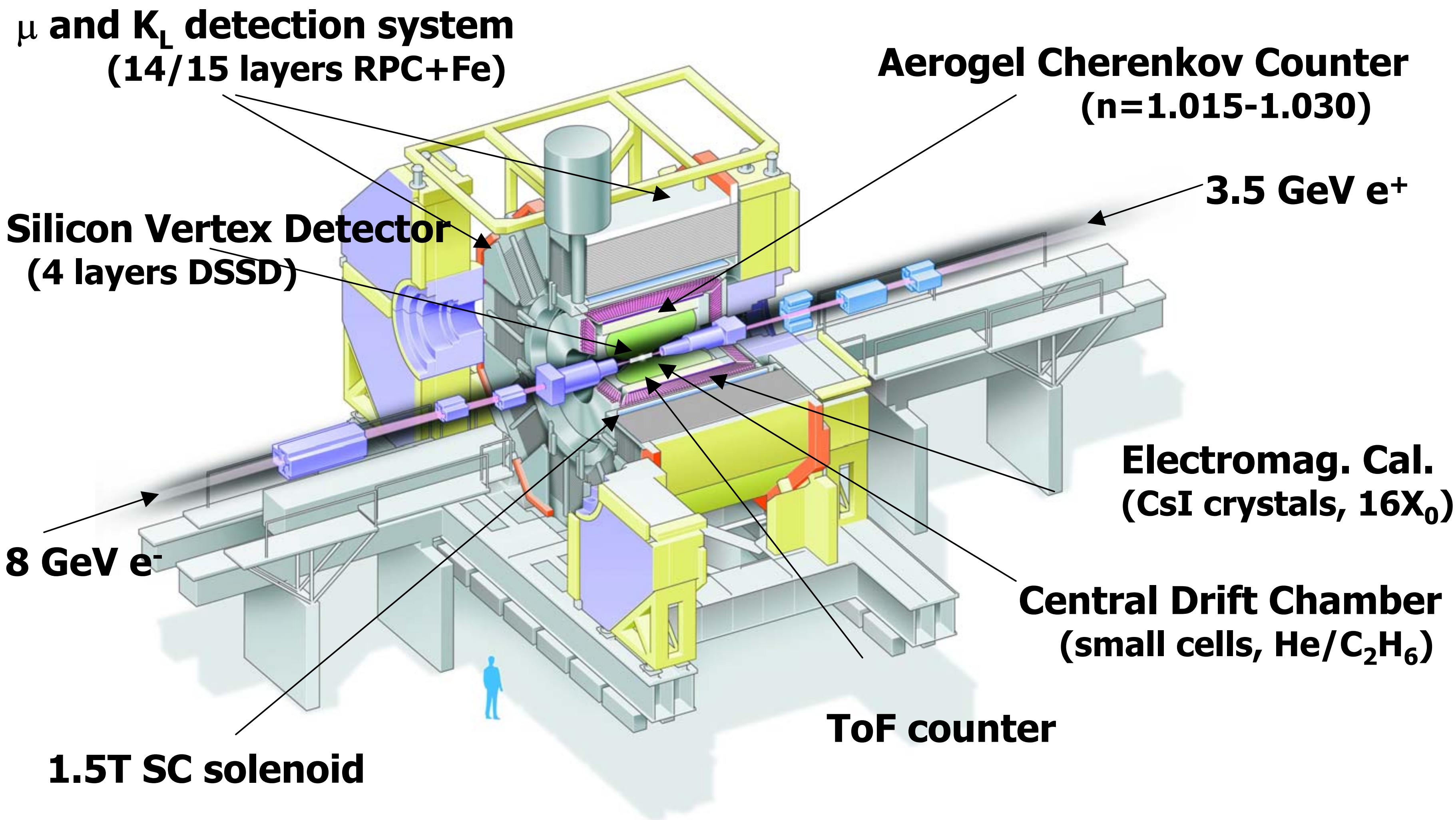


B^0 and its anti-particle decay differently to the same final state $J/\psi\ K^0$

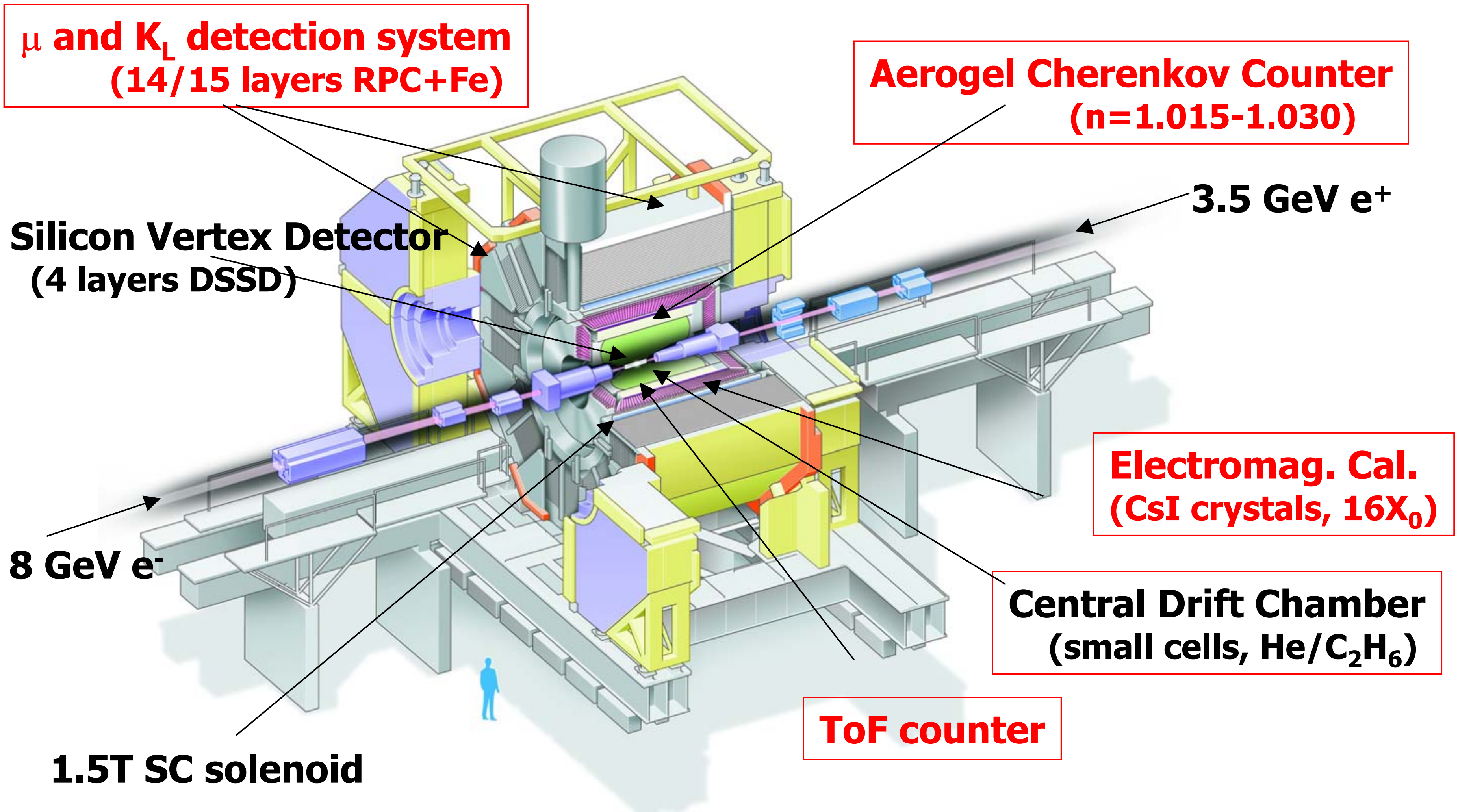
Flavour of the B: from decay products of the other B: charge of the kaon, electron, muon

→particle ID is compulsory

Example: Belle



Particle identification systems in Belle



Identification of charged particles

Particles are identified by their mass or by the way they interact.

Determination of mass: from the relation between momentum and velocity, $p=\gamma mv$. Momentum known (radius of curvature in magnetic field)

→Measure velocity:

- time of flight
- ionisation losses dE/dx
- Cherenkov angle
- transition radiation

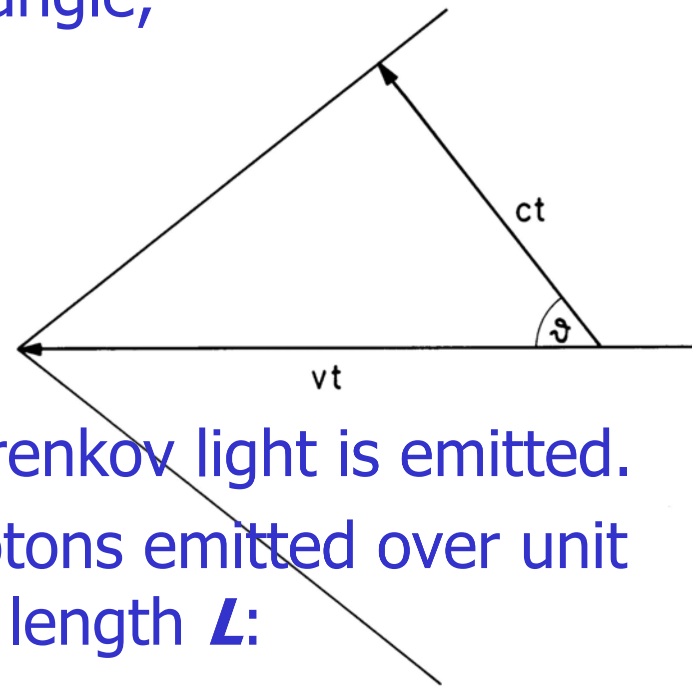
Mainly used for the identification of hadrons.

Identification through interaction: electrons and muons (→ separate sessions at this conference)

Cherenkov radiation

A charged track with velocity $v=\beta c$ exceeding the speed of light c/n in a medium with refractive index n emits polarized light at a characteristic (Čerenkov) angle,

$\cos\theta = c/nv = 1/\beta n$



Two cases:

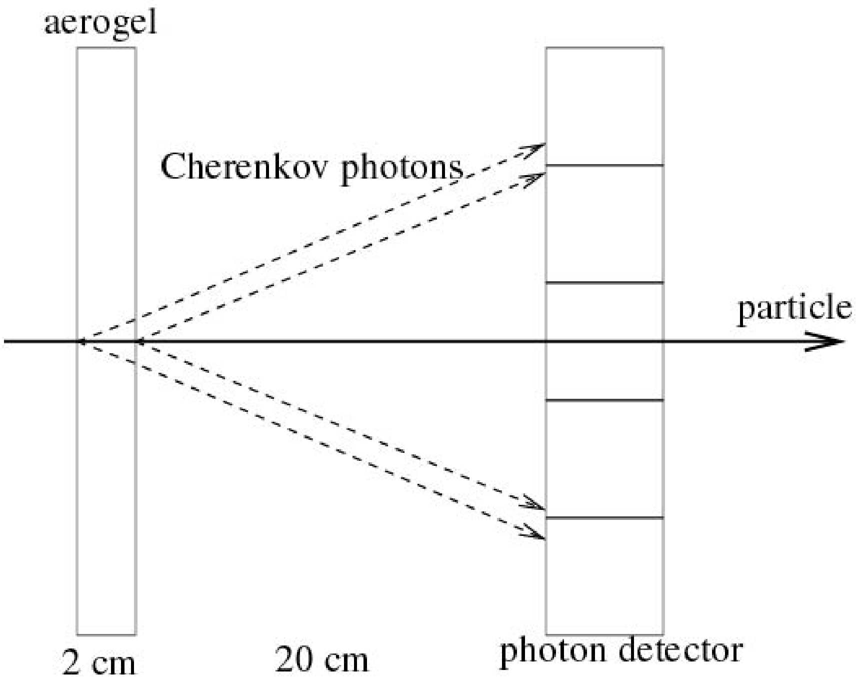
→ $\beta < \beta_t = 1/n$: below threshold no Cherenkov light is emitted.

→ $\beta > \beta_t$: the number of Cherenkov photons emitted over unit photon energy $E=h\nu$ in a radiator of length ***L***:

$$\frac{dN}{dE} = \frac{\alpha}{\hbar c} L \sin^2\theta = 370(cm)^{-1}(eV)^{-1} L \sin^2\theta$$

→Few detected photons

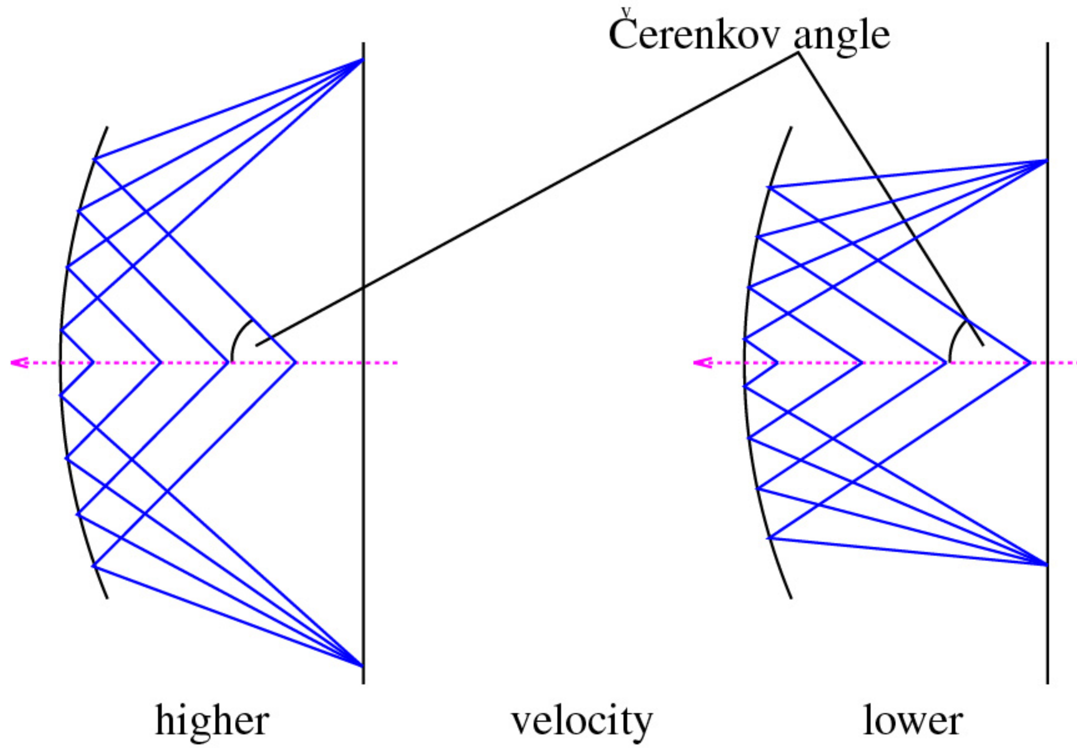
Measuring Cherenkov angle



Idea: transform the direction into a coordinate → ring on the detection plane

→ Ring Imaging CHerenkov

Proximity focusing RICH



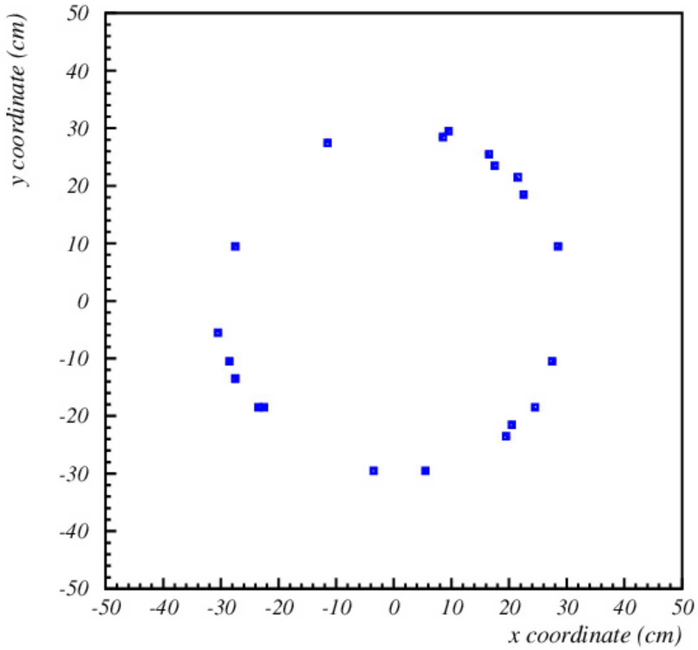
RICH with a focusing mirror

Photon detection in RICH counters

RICH counter: measure photon impact point on the photon detector surface

→ detection of single photons with

- sufficient spatial resolution
- high efficiency and good signal-to-noise ratio
- over a large area (square meters)



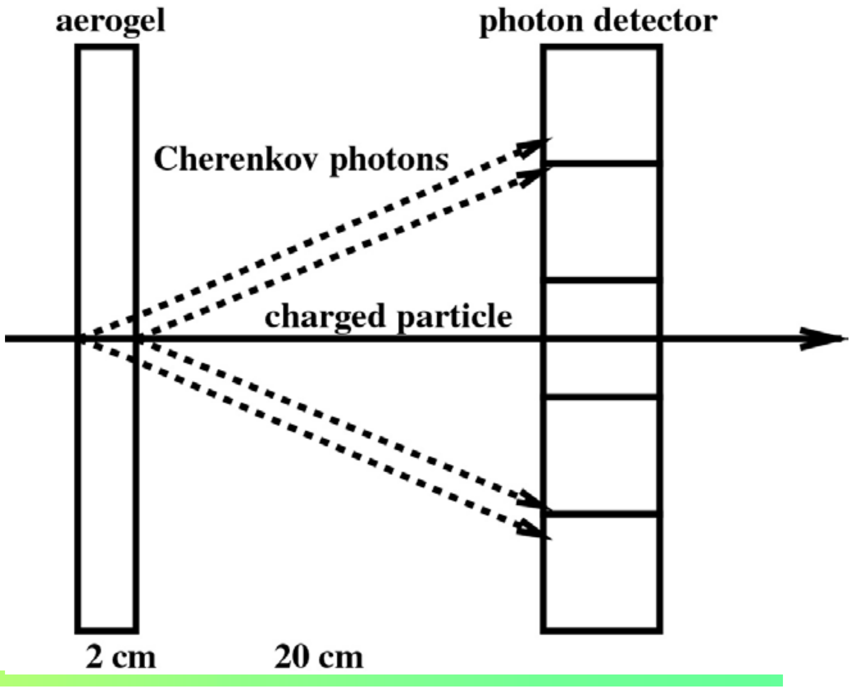
Special requirements:

- Operation in magnetic field
- High rate capability
- Very high spatial resolution
- Excellent timing (time-of-arrival information)

Resolution of a RICH counter

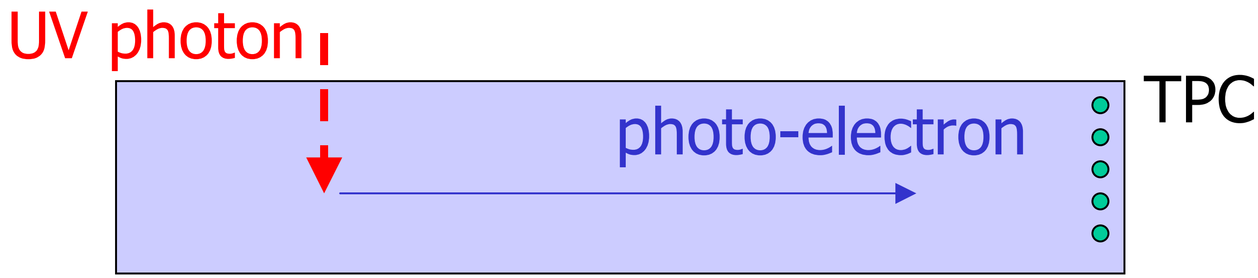
Determined by:

- Photon impact point resolution (~photon detector granularity)
- Emission point uncertainty (not in a focusing RICH)
- Dispersion: $n=n(\lambda)$ in $1/\beta = n \cos\theta$
- Errors of the optical system
- Uncertainty in track parameters

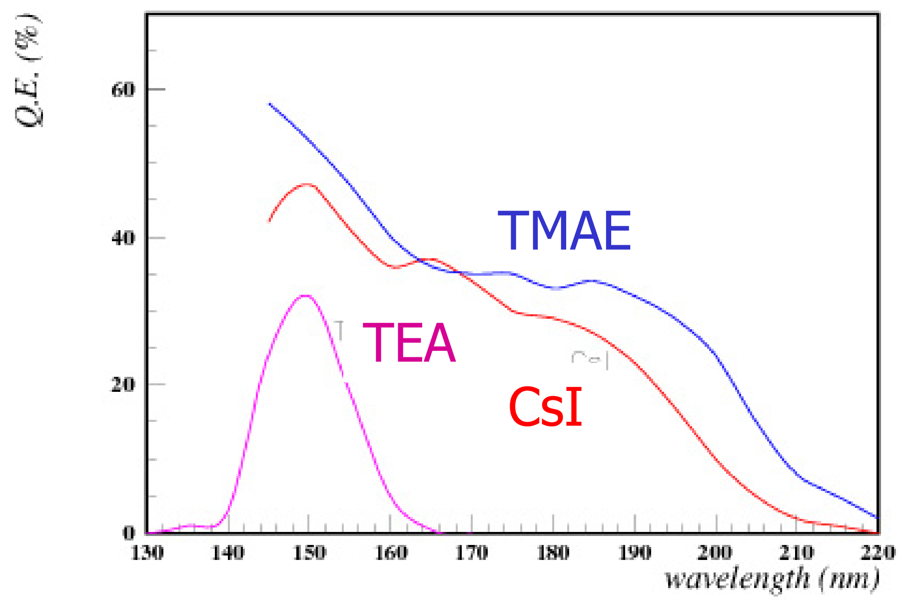


First generation of RICH counters

DELPHI, SLD, OMEGA RICH counters: all employed wire chamber based photon detectors (UV photon → photo-electron → detection of a single electron in a TPC)

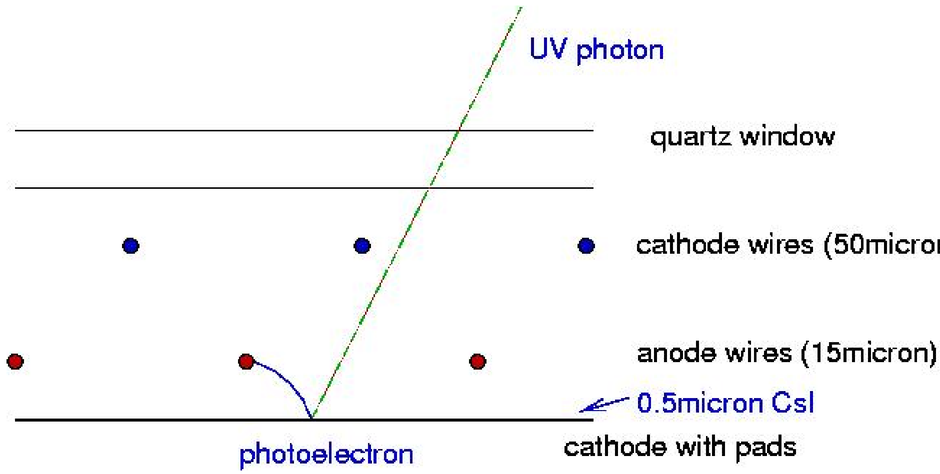


Photosensitive component: TMAE added to the gas mixture



Fast RICH counters with wire chambers

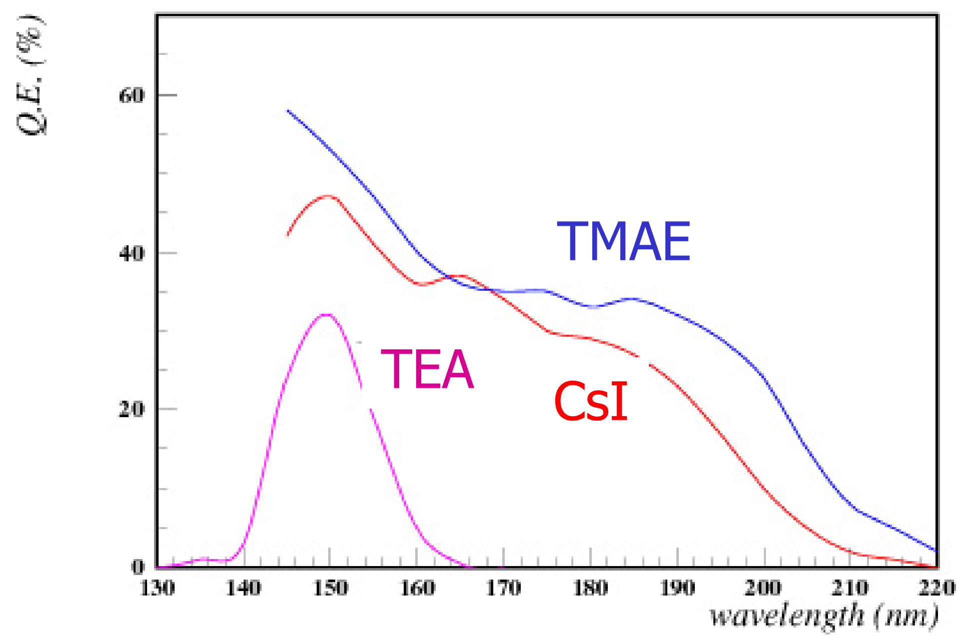
Multiwire chamber with pad read-out: → short drift distances, fast detector



Photosensitive component:

•in the gas mixture (TEA): CLEOIII RICH

•or a layer on one of the cathodes (CsI on the printed circuit pad cathode) →

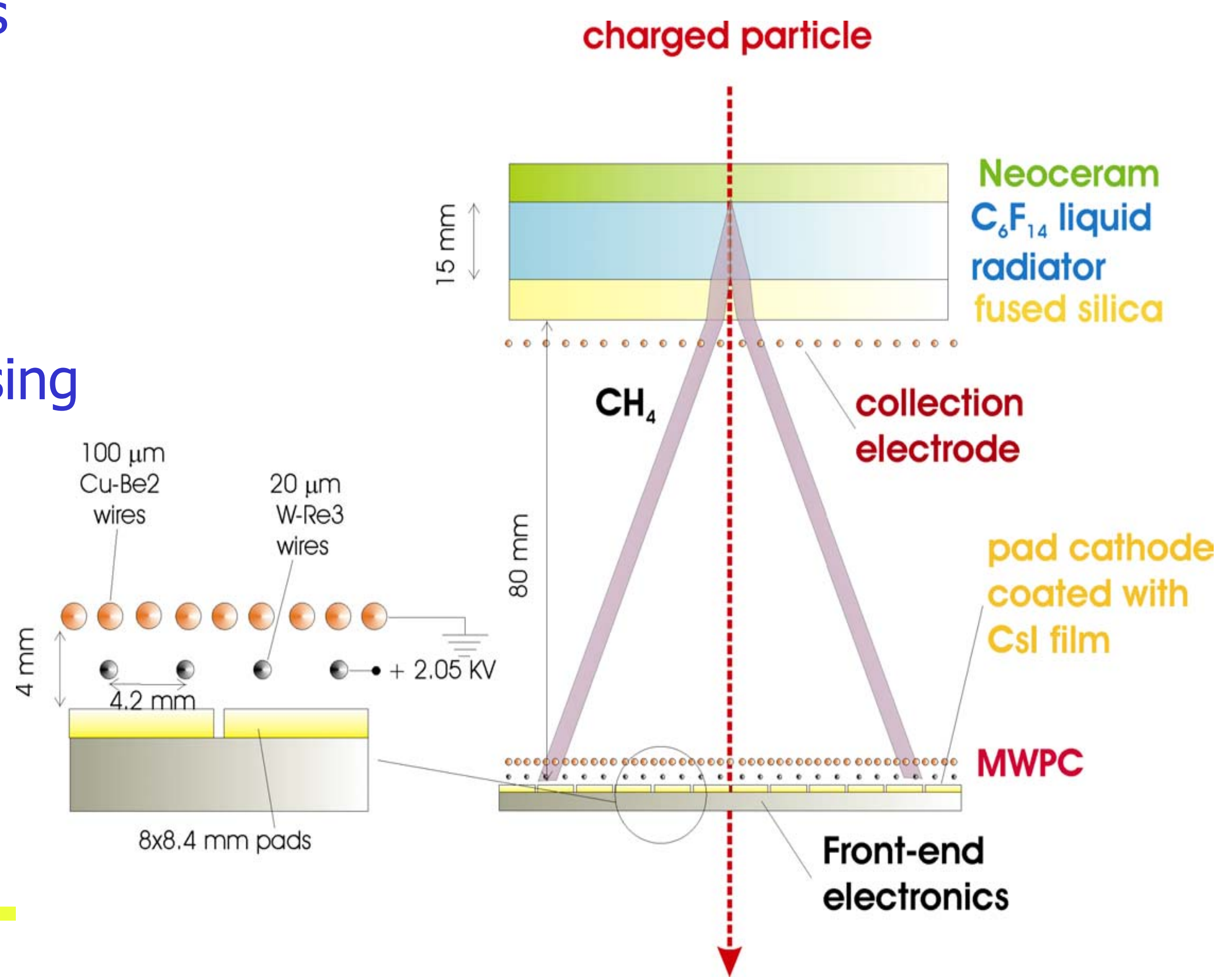


CsI based RICH counters: HADES, COMPASS, ALICE

HADES and COMPASS RICH: have been running stably for several years

ALICE:

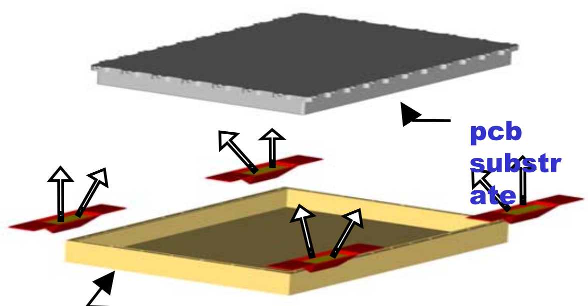
- liquid radiator
- proximity focusing

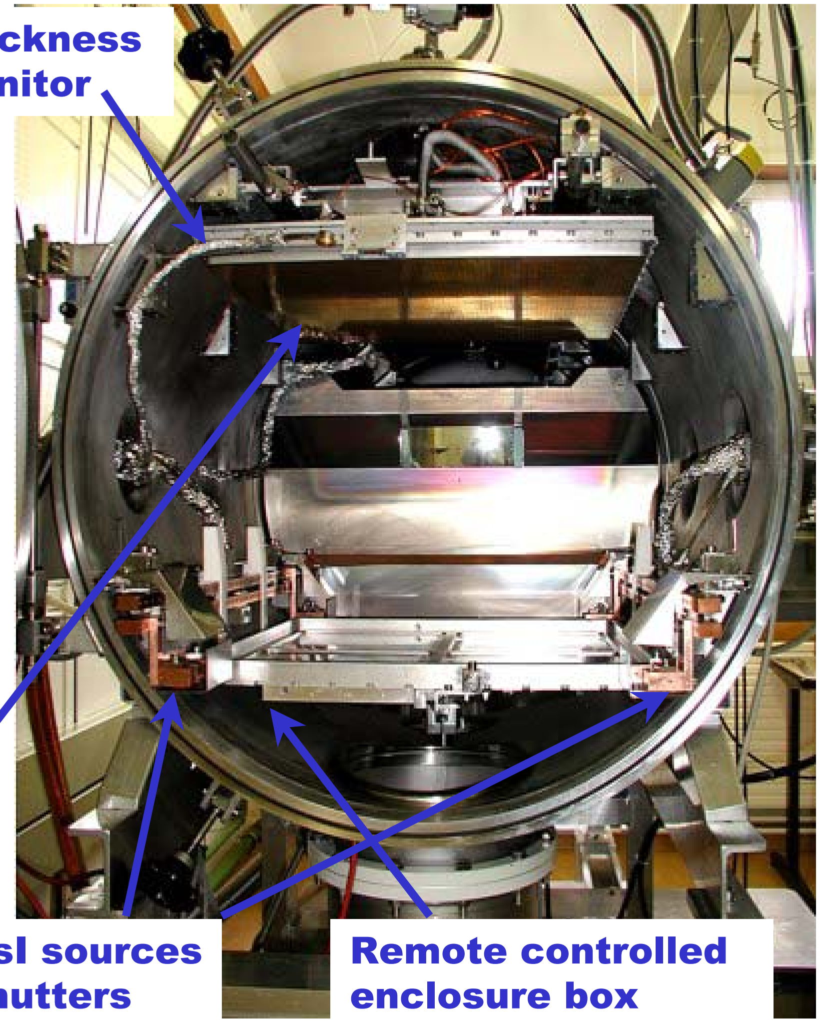


CERN CsI deposition plant

Photocathode produced with a well defined, several step procedure, including heat conditioning after CsI deposition

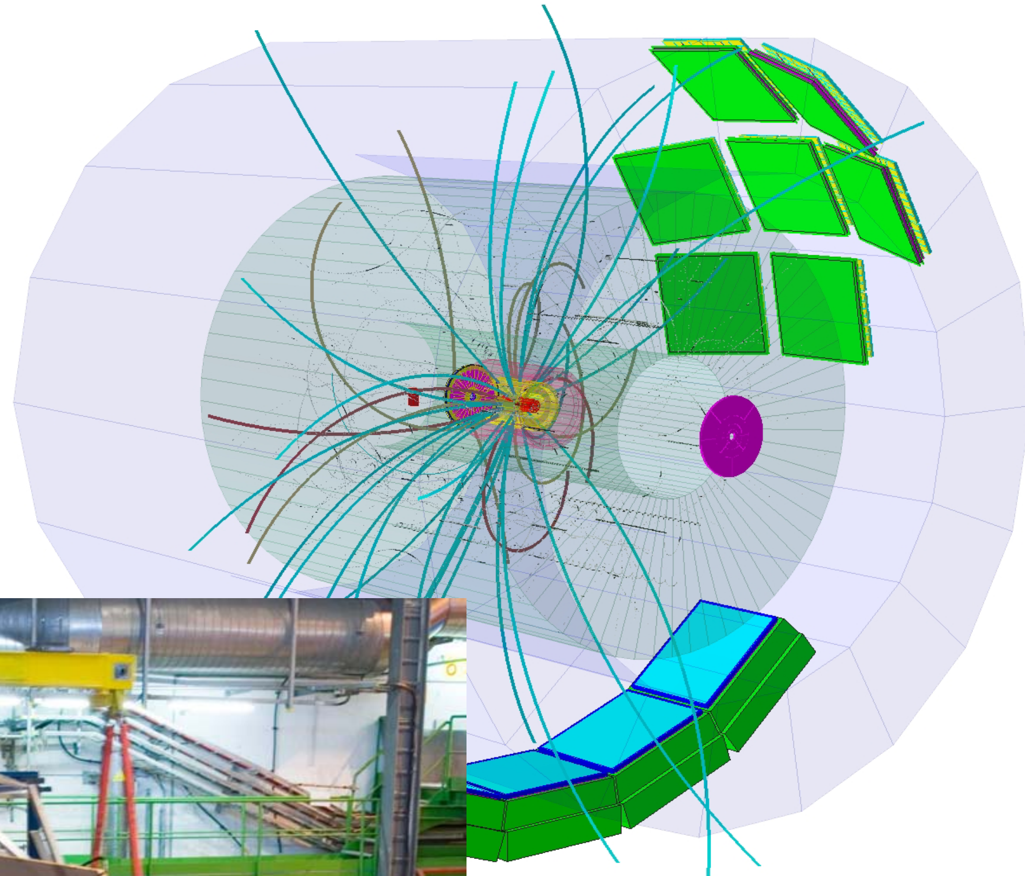
In situ quality control





ALICE RICH

The largest scale (11 m^2) application of CsI photo-cathodes in HEP!



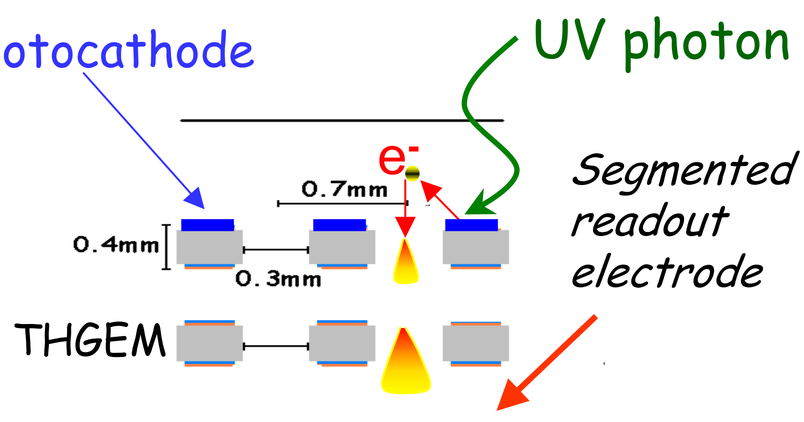
→ Talk by E. Scaparone

Wire chamber based photon detectors: recent developments

Instead of MWPC:

•Use multiple GEM with semitransparent or reflective photocathode → PHENIX RICH

•Use chambers with multiple thick GEM (THGEM) with transm. or refl. photocathode → talk by A. Breskin

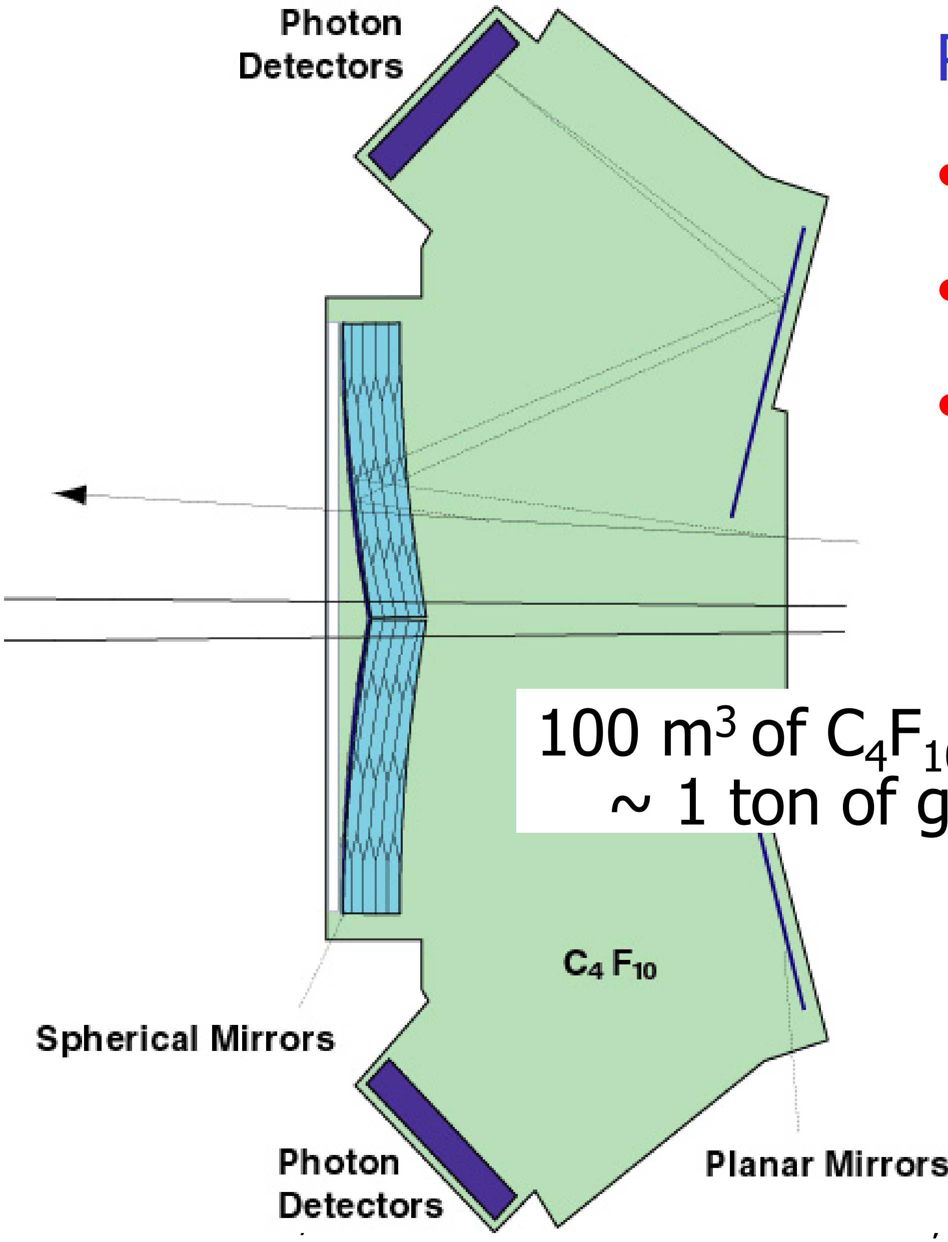


Ion damage of the photocathode: ions can be blocked → talk by A. Lyashenko

Cherenkov counters with vacuum based photodetectors

Some applications: operation at high rates over extended running periods (years) → wire chamber based photon detectors were found to be unsuitable (problems in high rate operation, ageing, only UV photons, difficult handling in 4π spectrometers)

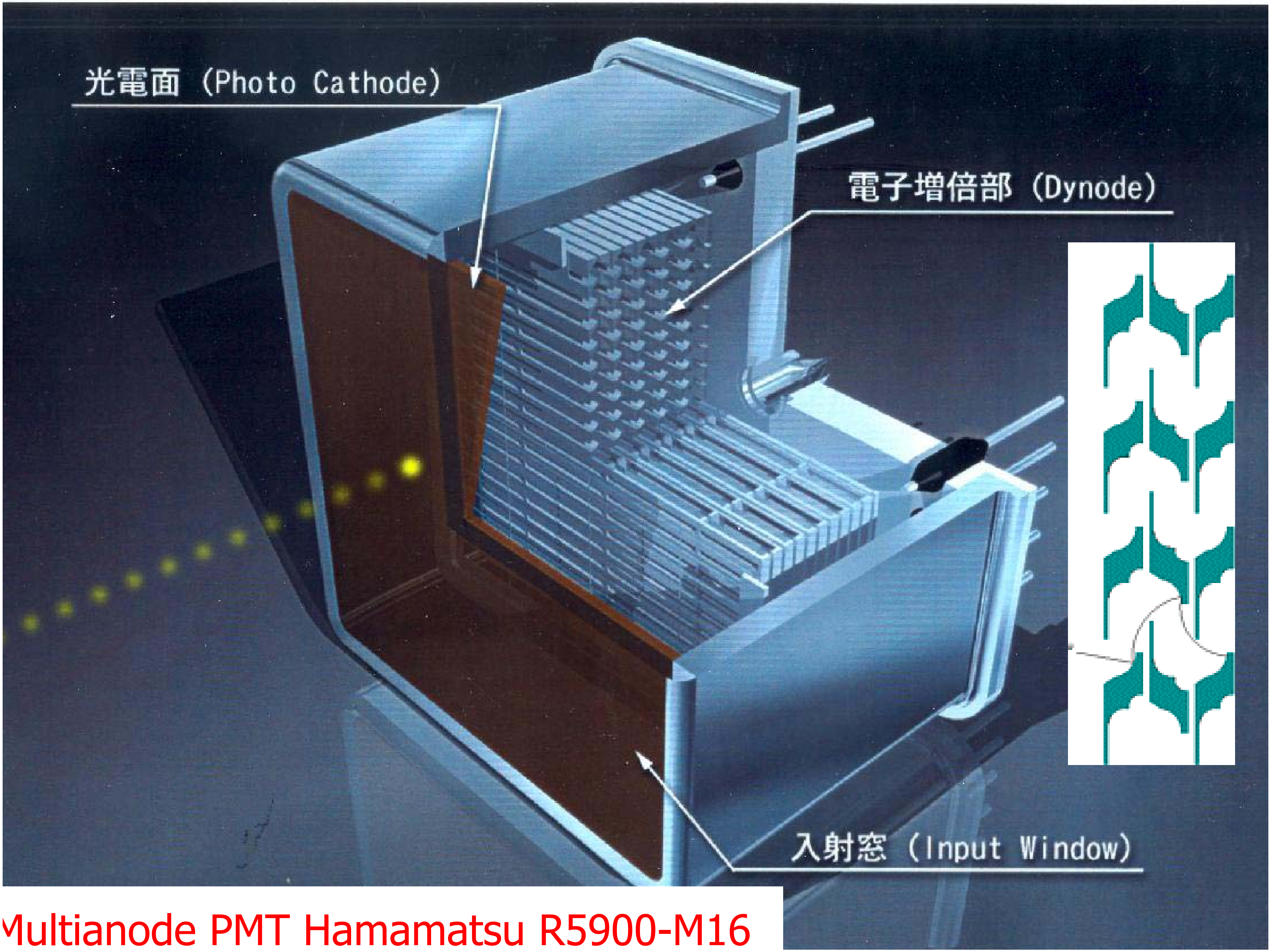
HERA-B RICH



100 m^3 of C_4F_{10}
~ 1 ton of gas

Photon detector requirements:

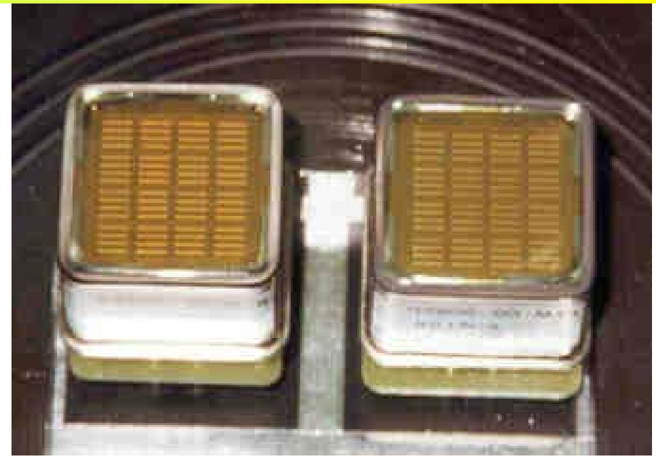
- High QE over ~3m^2
- Rates ~1MHz
- Long term stability

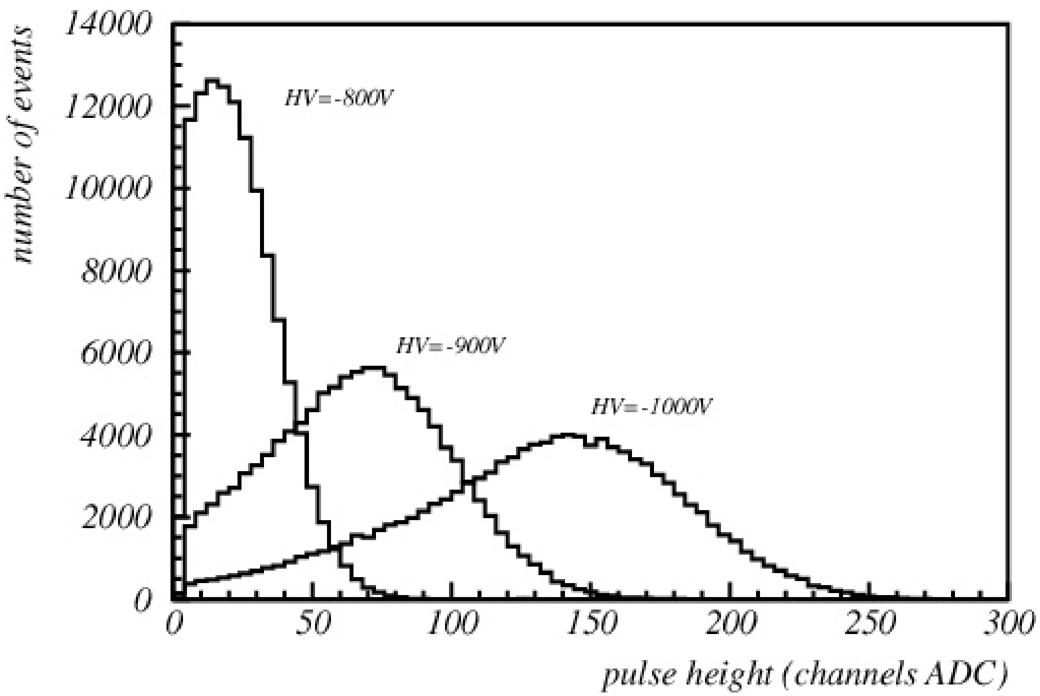


Multianode PMT Hamamatsu R5900-M16

Multianode PMTs

R5900-M16 (4x4 channels)
R5900-M4 (2x2 channels)





single photon pulse height

Key features:

- Excellent single photon pulse height spectrum
- Low noise (few Hz/ch)
- Low cross-talk (<1%)

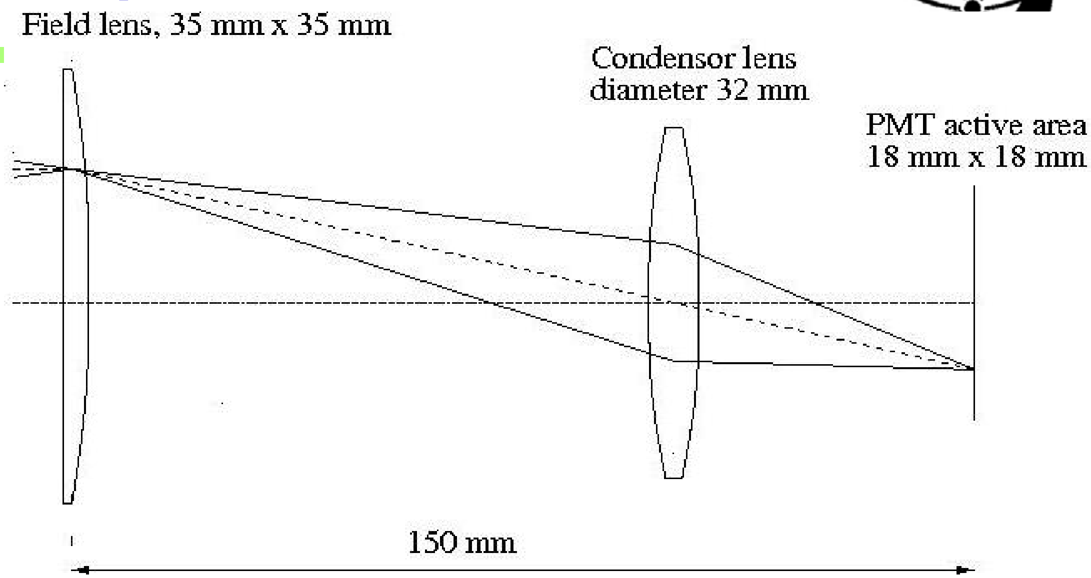
→ NIM A394 (1997) 27

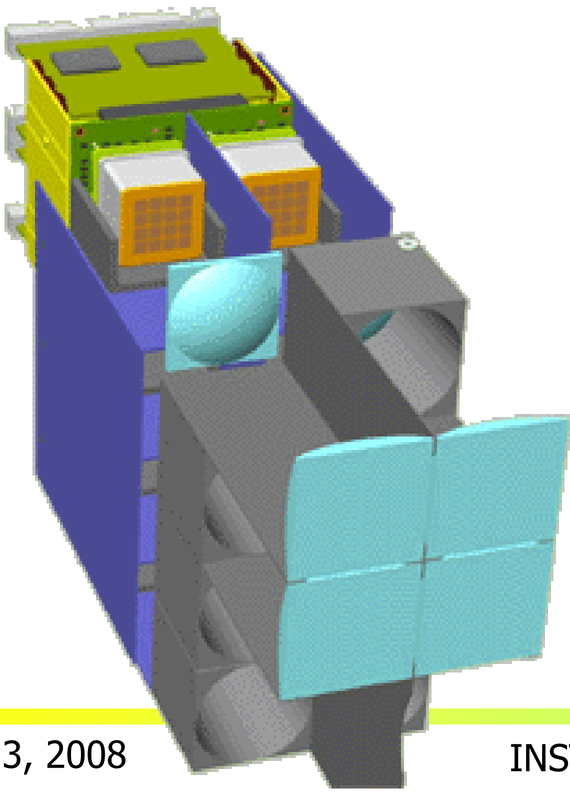
HERA-B RICH photon detector

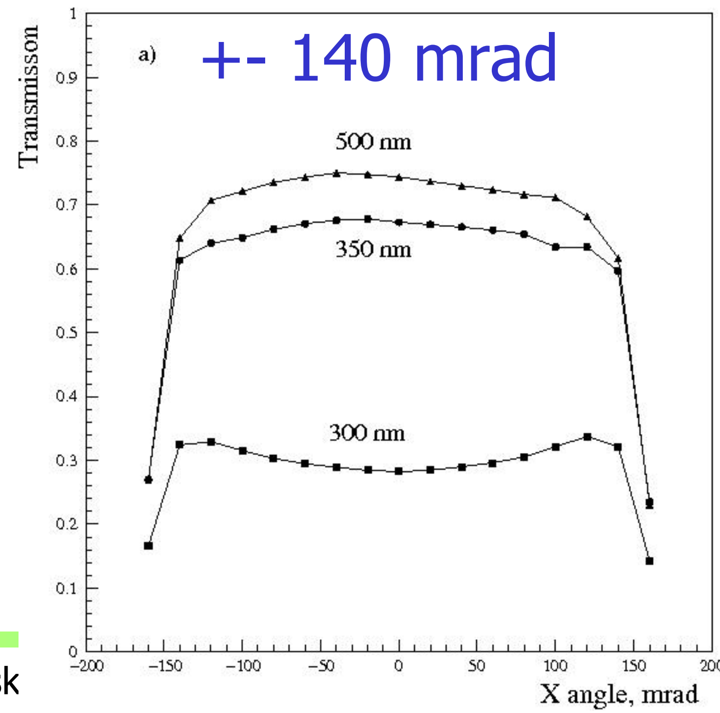
Light collection system (imaging!) to:

-Eliminate dead areas

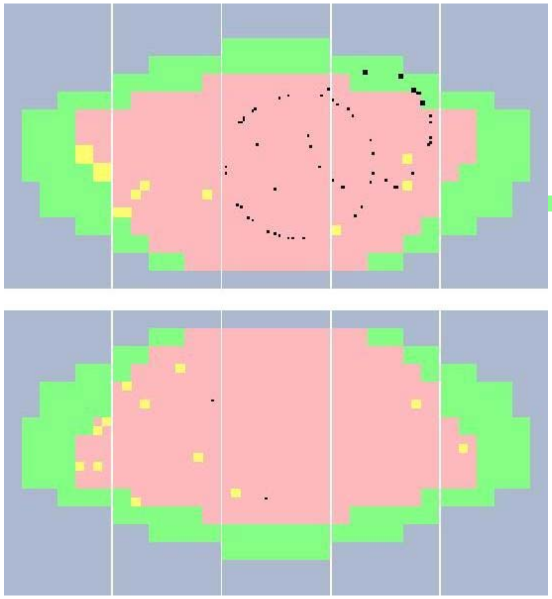
-Adapt the pad size





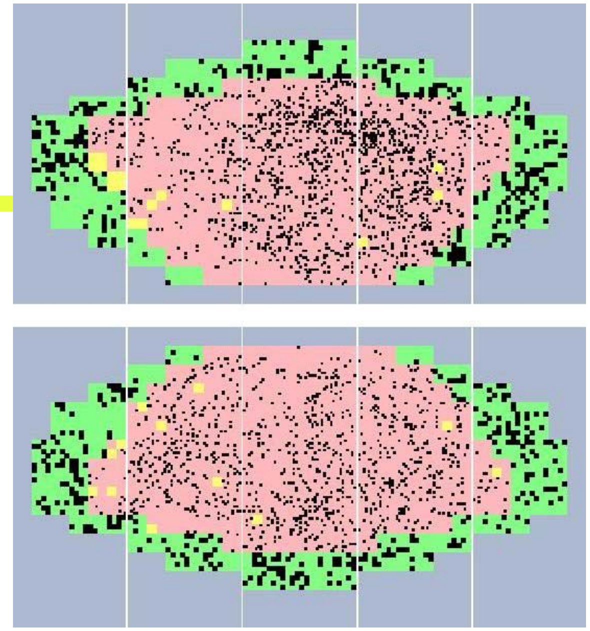


HERA-B RICH

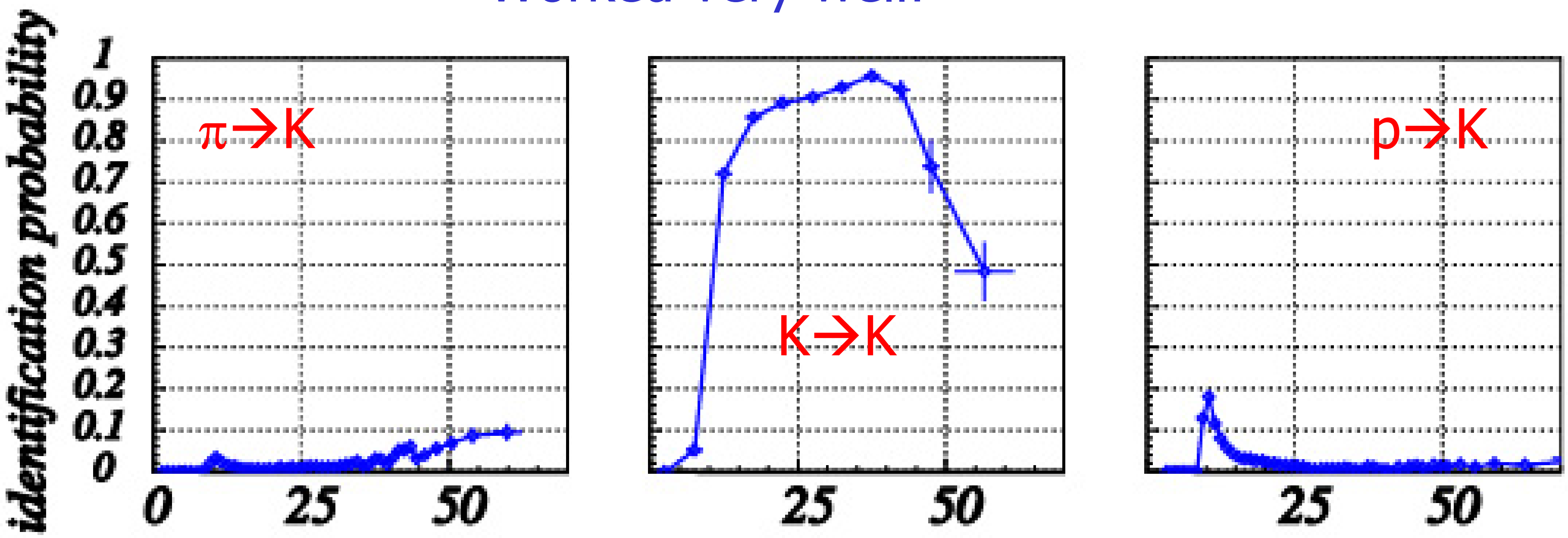


← Little noise, ~30 photons per ring

Typical event →

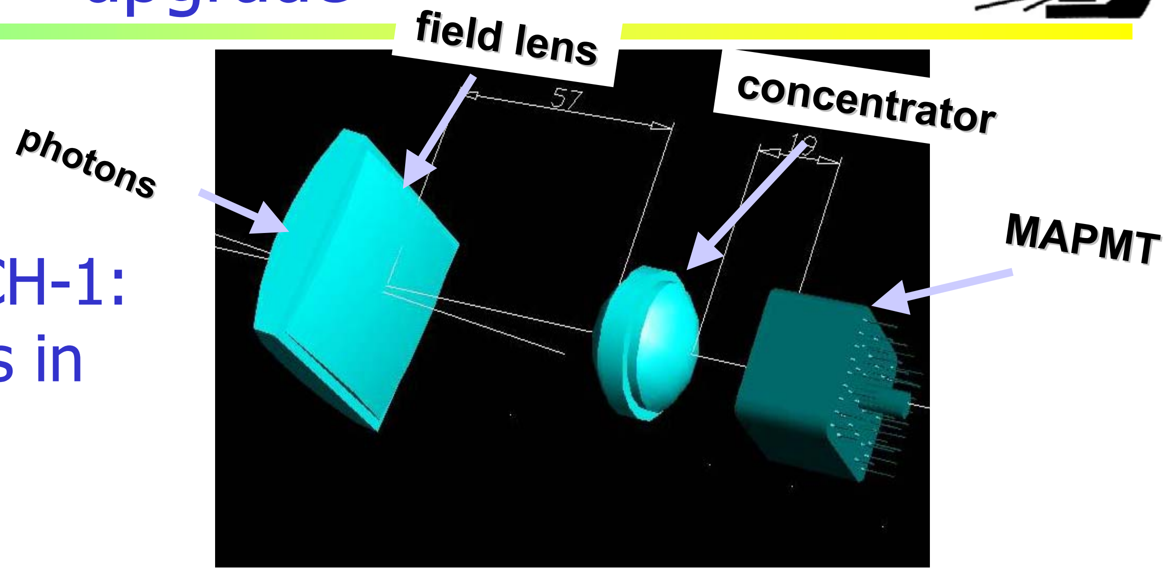


Worked very well!



Kaon efficiency and pion, proton fake probability

Photon detector for the COMPASS RICH-1 upgrade



Upgraded COMPASS RICH-1:
the same concept as in HERA-B RICH

New features:

- UV extended PMTs & lenses (down to 200 nm)
- surface ratio = (telescope entrance surface) / (photocathode surface) = 7
- fast electronics with <120 ps time resolution

Photon detector for the COMPASS RICH-1 upgrade

Preliminary results:

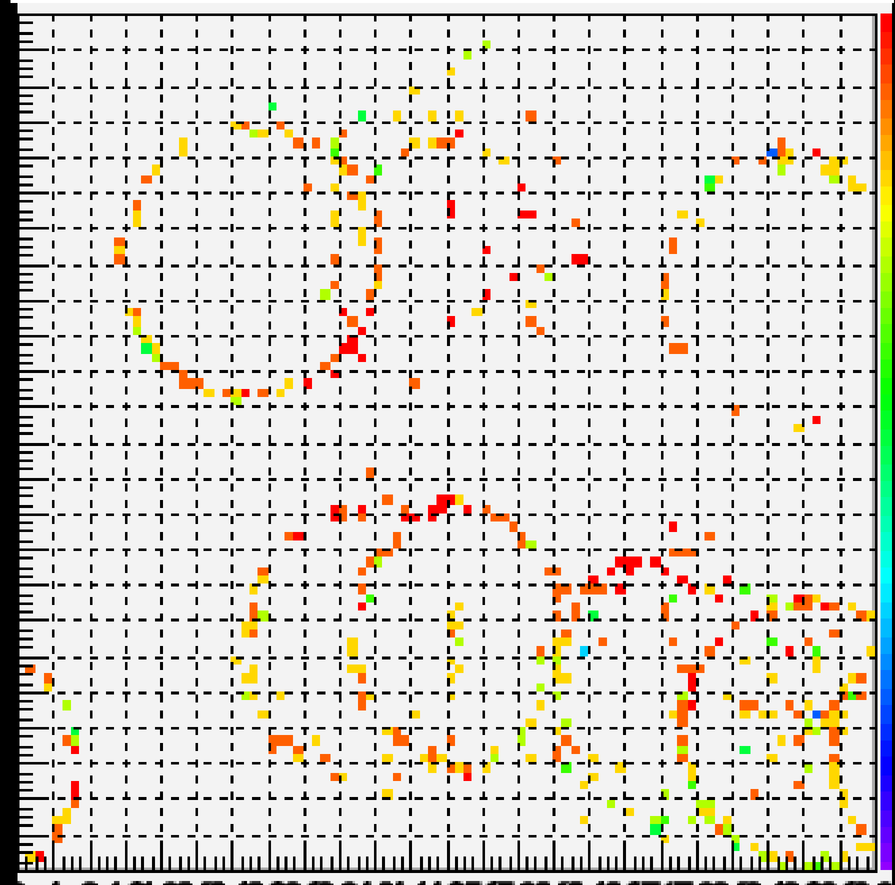
~ 60 detected photons per ring at saturation (β = 1) → N_0 ~66 cm^{-1}

σ_θ ~ 0.3 mrad → 2 σ π-K separation at ~ 60 GeV/c

K-ID efficiency ($K^\pm$ from Φ decay) > 90%

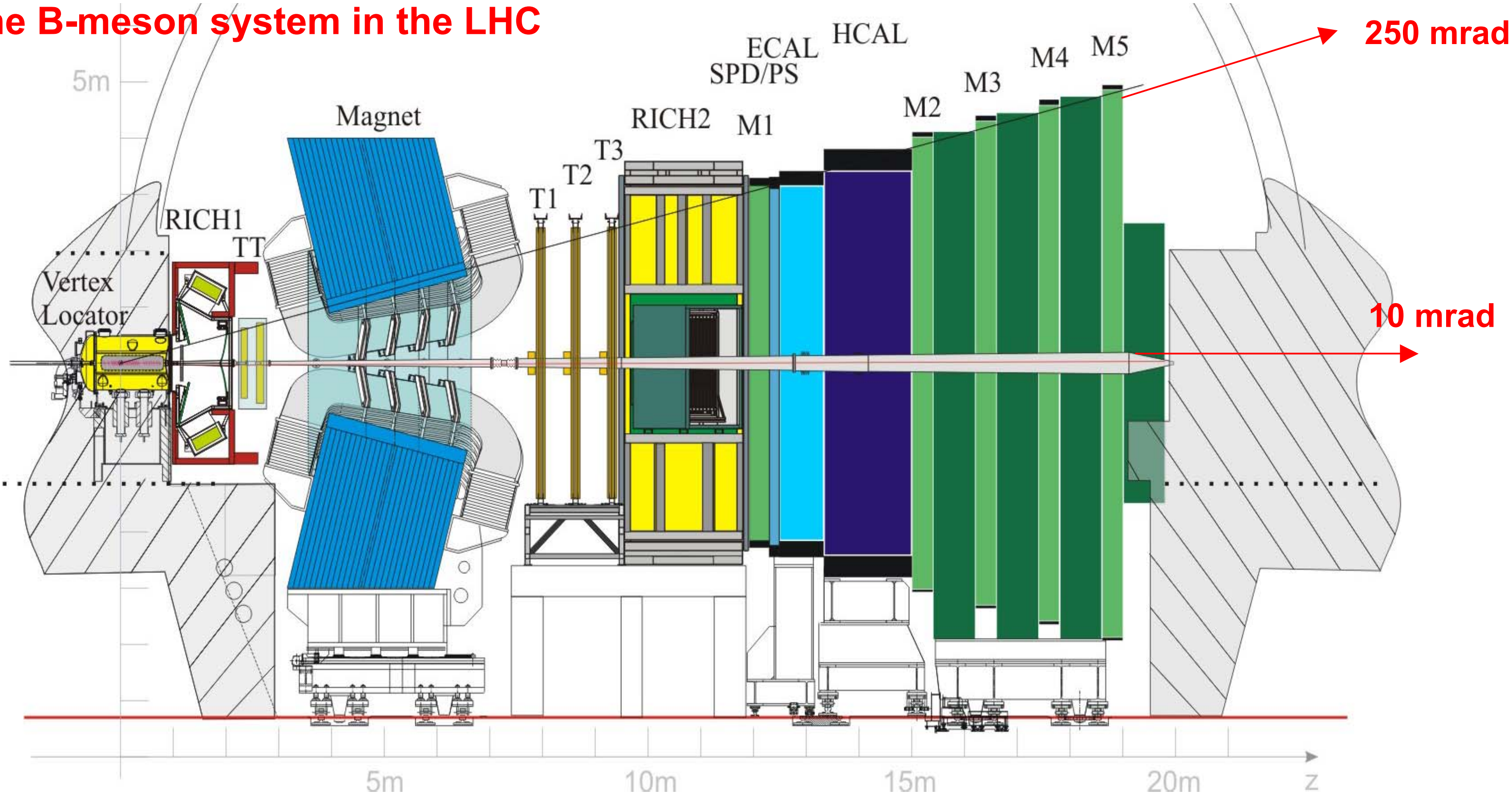
π → K misidentification ($\pi^\pm$ from K_s decay) ~ 1 %

IMAGE FROM THE ON-LINE EVENT DISPLAY



The LHCb detector

Single arm spectrometer for precise CP Violation measurements and rare decays in the B-meson system in the LHC



Vertex reconstruction:
VELO

Trigger:
Muon Chambers
Calorimeters
Tracker

PID:
RICHes
Calorimeters
Muon Chambers

Kinematics:
Magnet
Tracker
Calorimeters

LHCb RICHes

Need:

•Particle identification for momentum range ~2-100 GeV/c

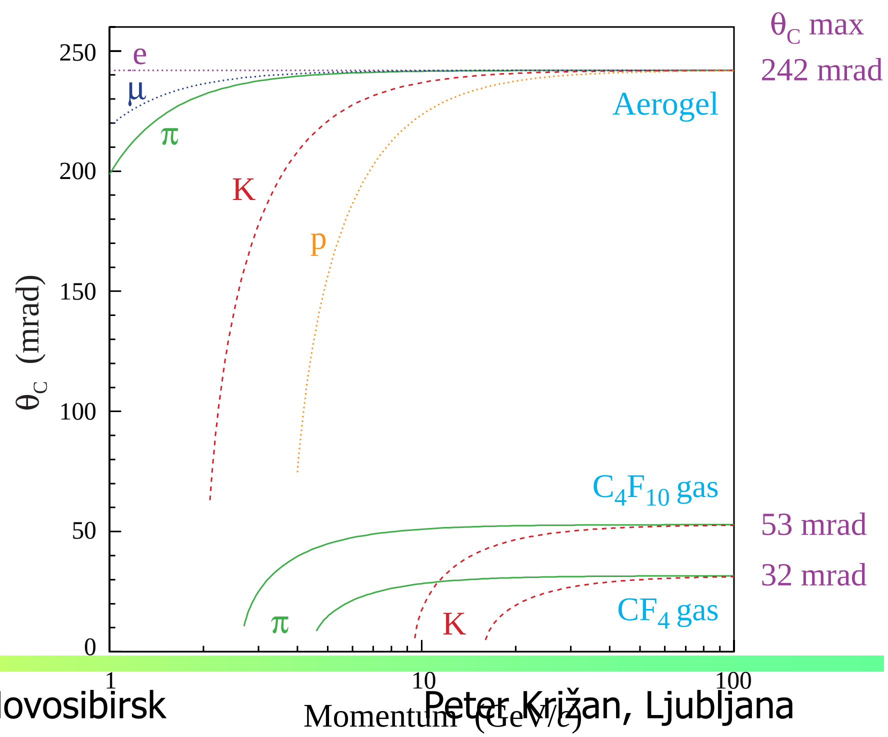
•Granularity $2.5x2.5mm^2$

•Large area ($2.8m^2$) with high active area fraction

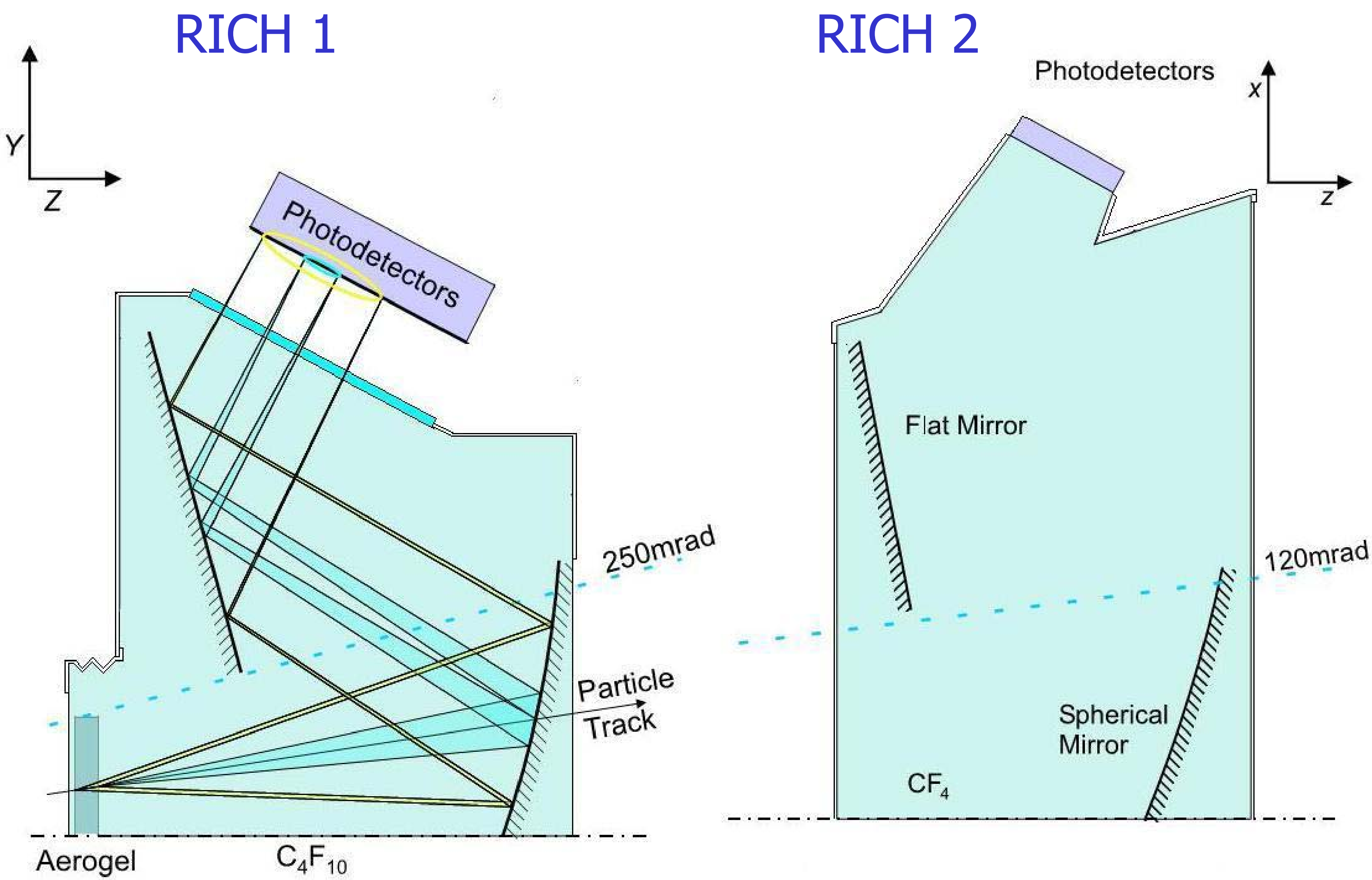
•Fast compared to the 25ns bunch crossing time

•Have to operate in a small magnetic field

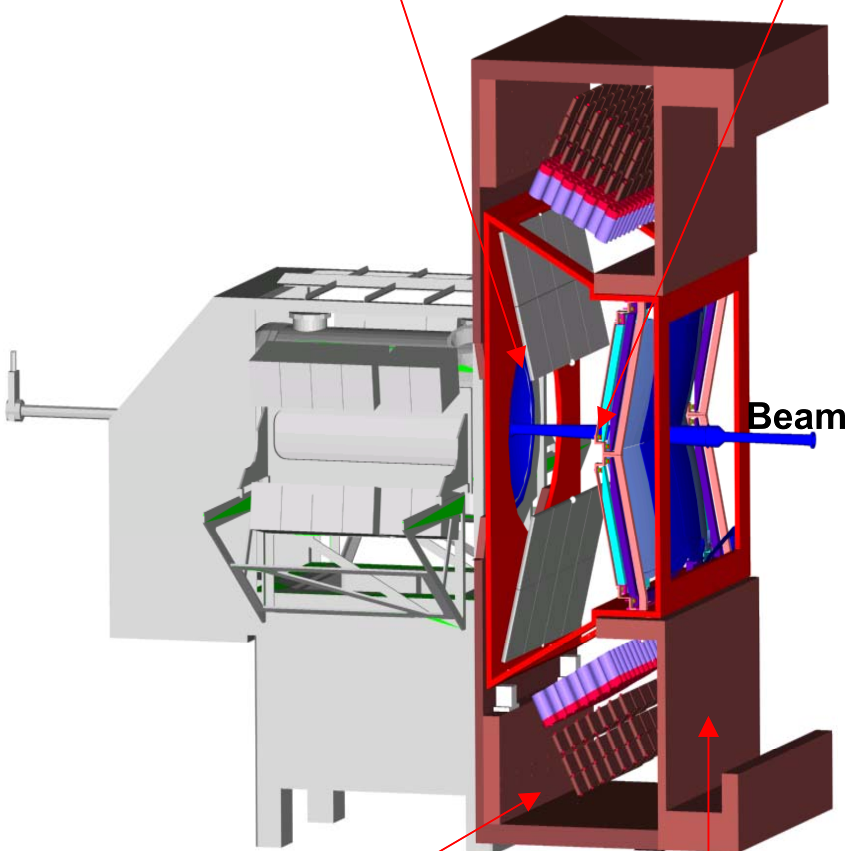
→3 radiators
(aerogel, CF_4, C_4F_{10})



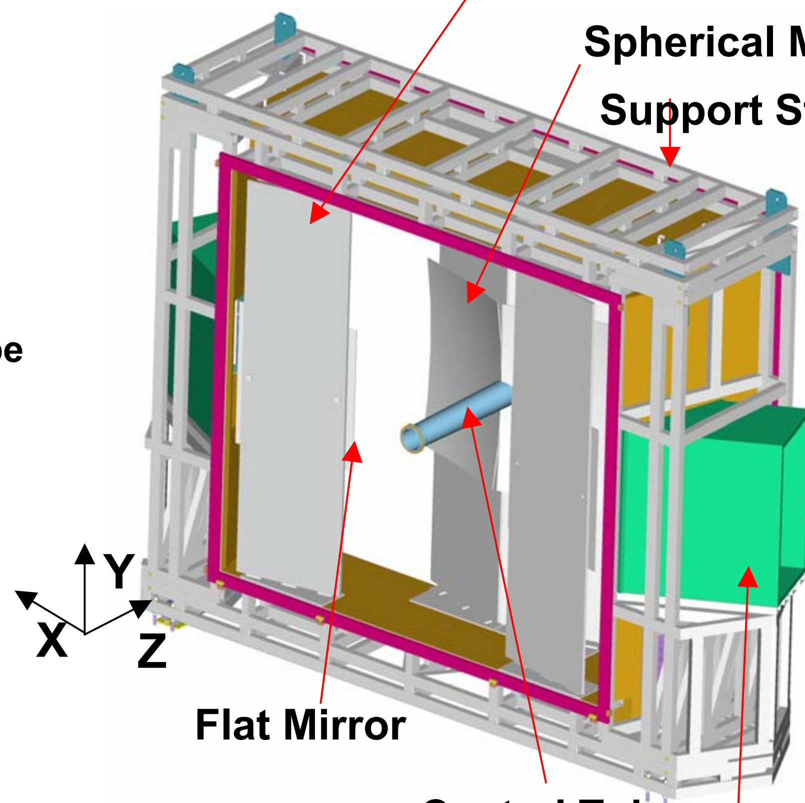
LHCb RICHes


RICH 1
RICH 2
Y
Z
Photodetectors
250mrad
Particle
Track
Aerogel
C_4F_{10}
Photodetectors
x
z
Flat Mirror
120mrad
Spherical
Mirror
CF_4

LHCb RICHes



Flat mirrors
Spherical mirrors
Beam pipe
Photon detectors
Magnetic shielding
(16 tonnes of iron)



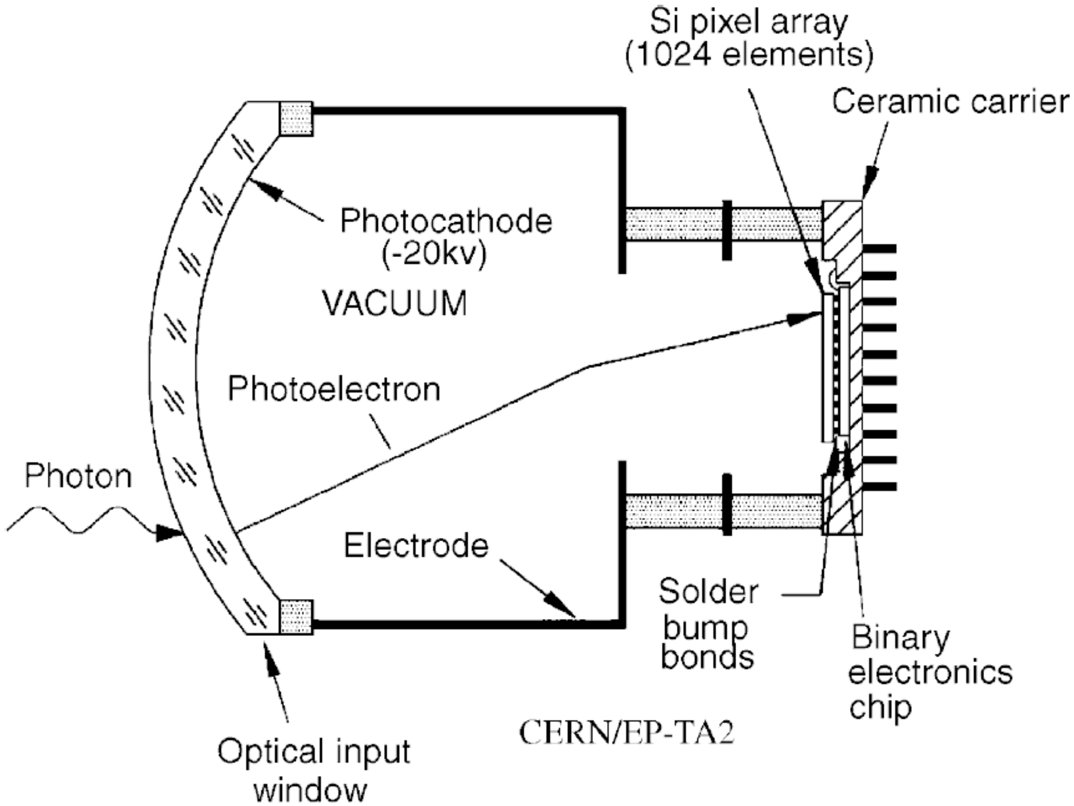
Mirror Support Panel
Spherical Mirror
Support Structure
Y
X
Z
Flat Mirror
Central Tube
Photon funnel+Shielding

LHCb RICHes

R+D: study two types of hybrid photon detectors and MAPMT with a lens

Final choice: hybrid PMT (R+D with DEP) with 5x demagnification (electrostatic focusing).

Hybrid PMT: accelerate photoelectrons in electric field (~10kV), detect it in a pixelated silicon detector.



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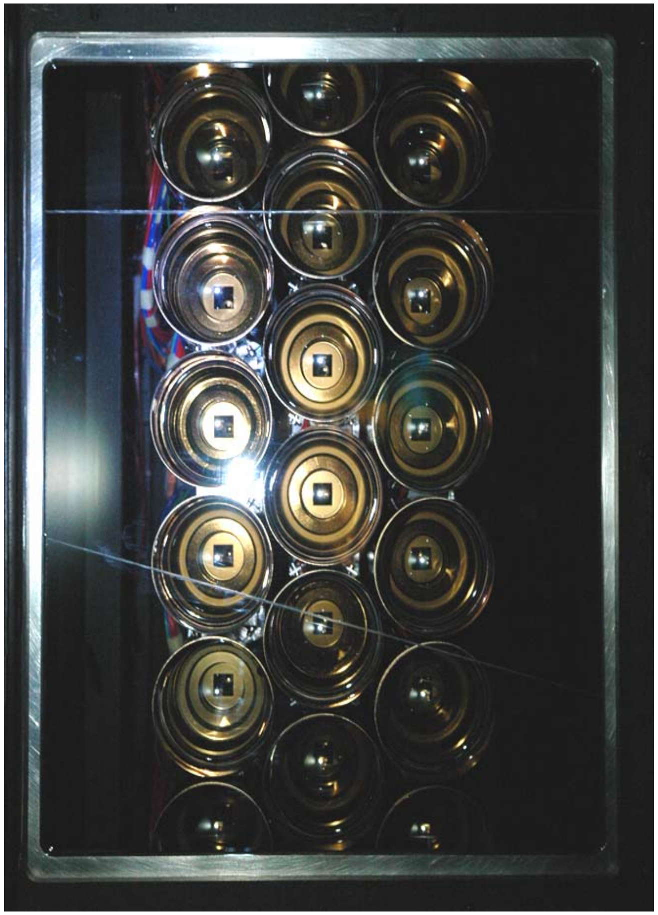
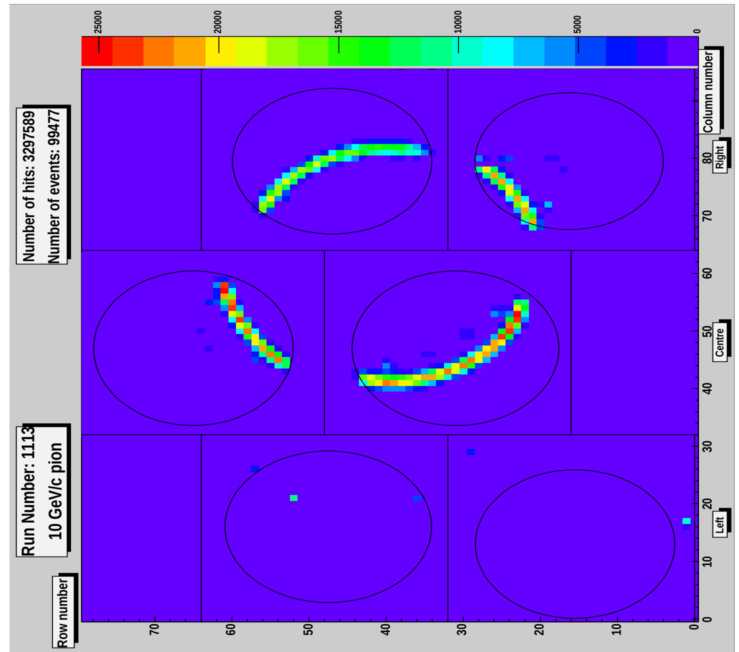
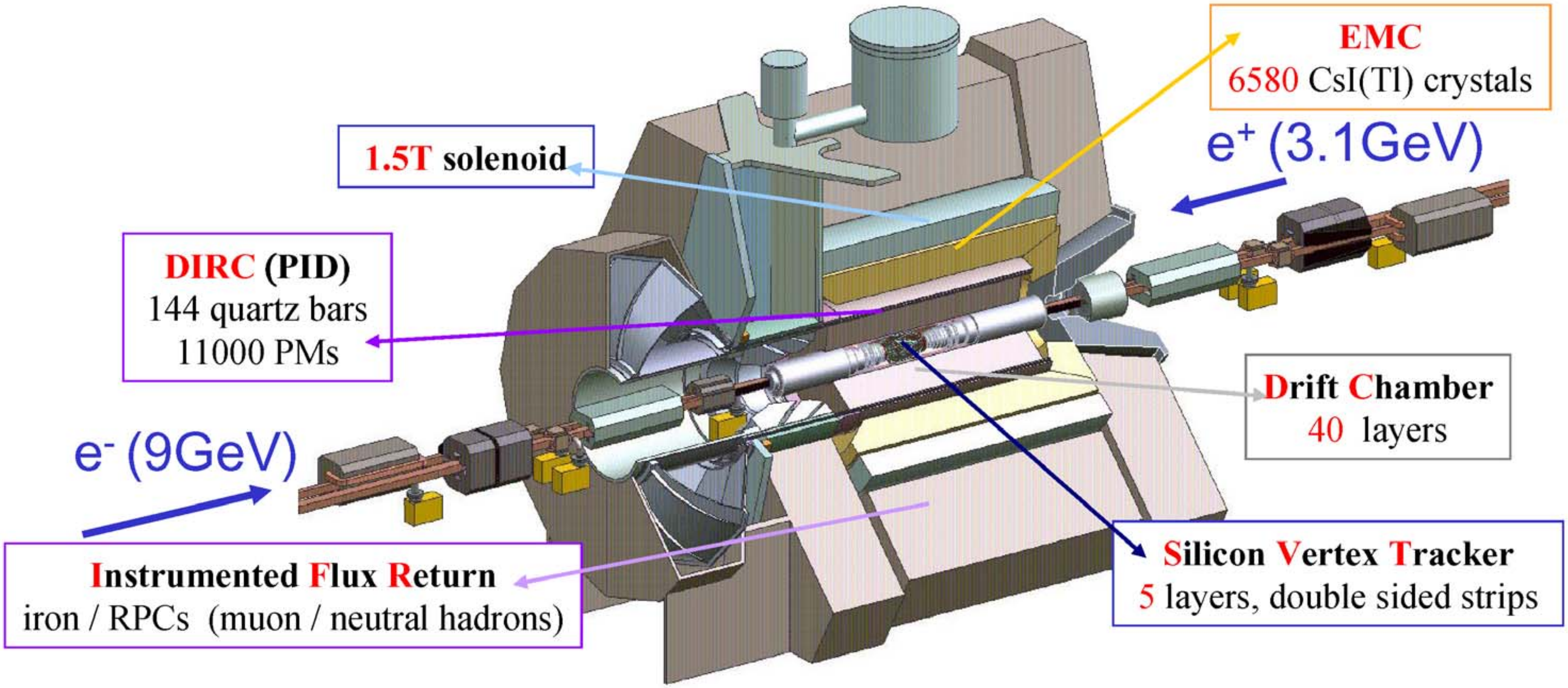
LHCb RICH System test





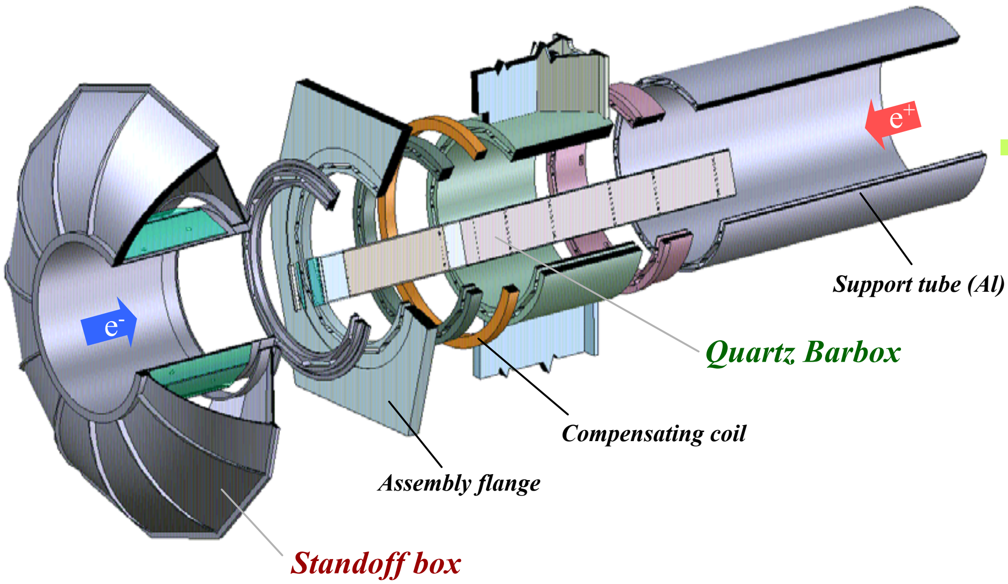
→ Talk by T. Belunato

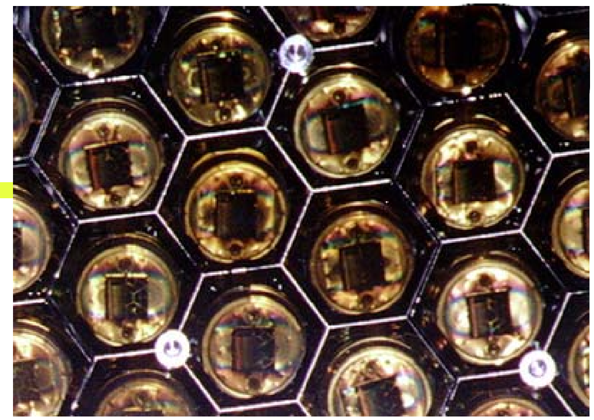
BaBar spectrometer at PEP-II

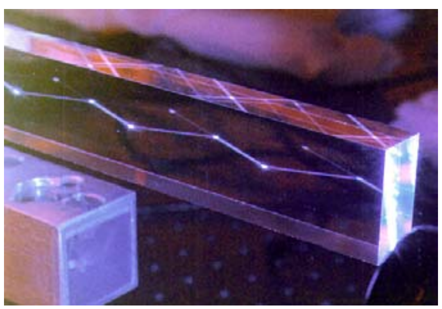


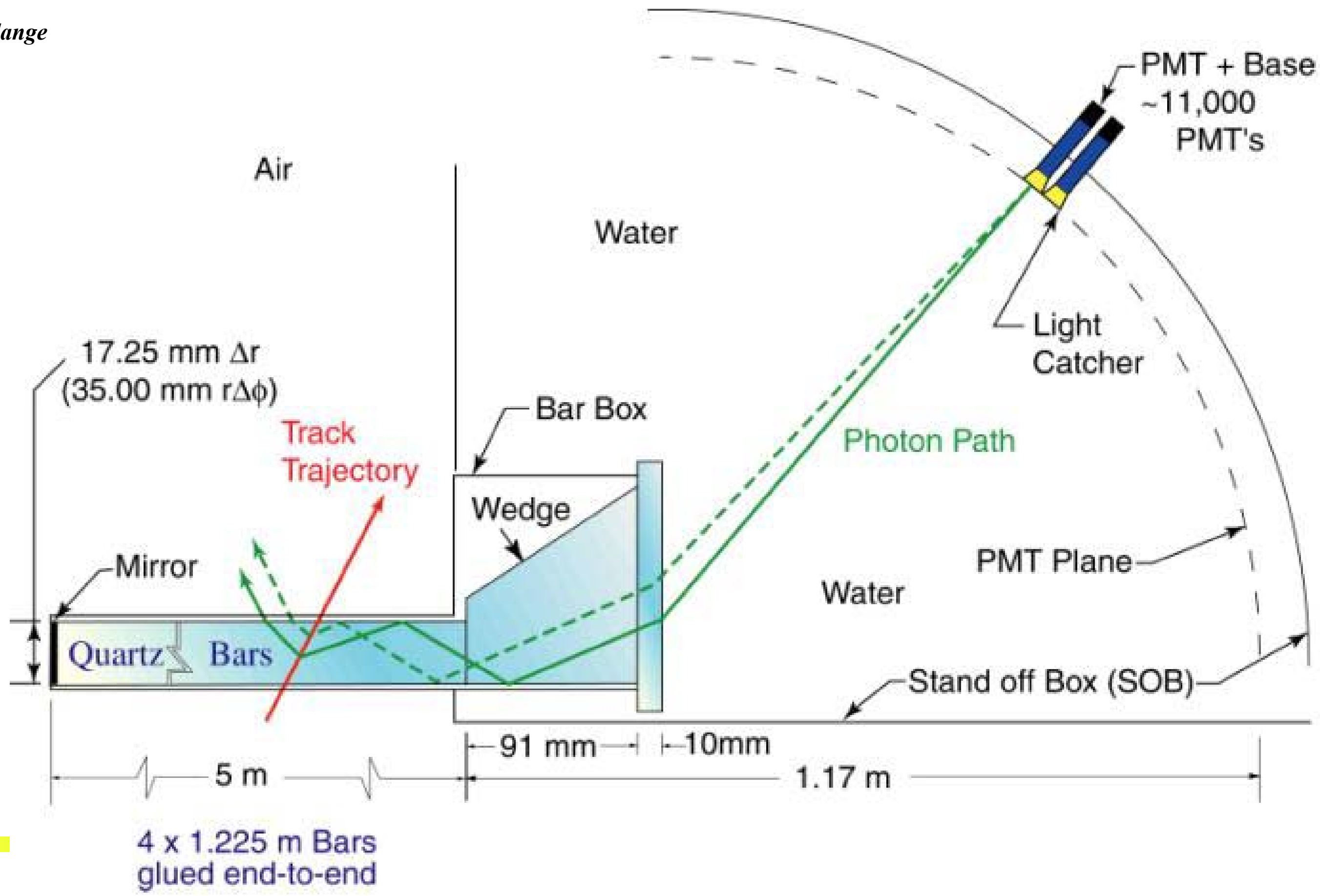
DIRC - detector of internally reflected Cherenkov light

DIRC



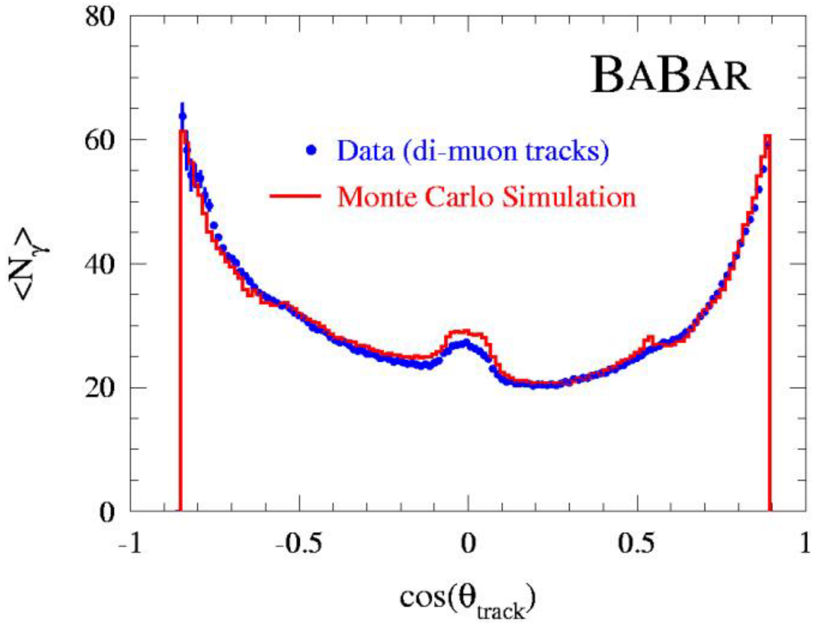






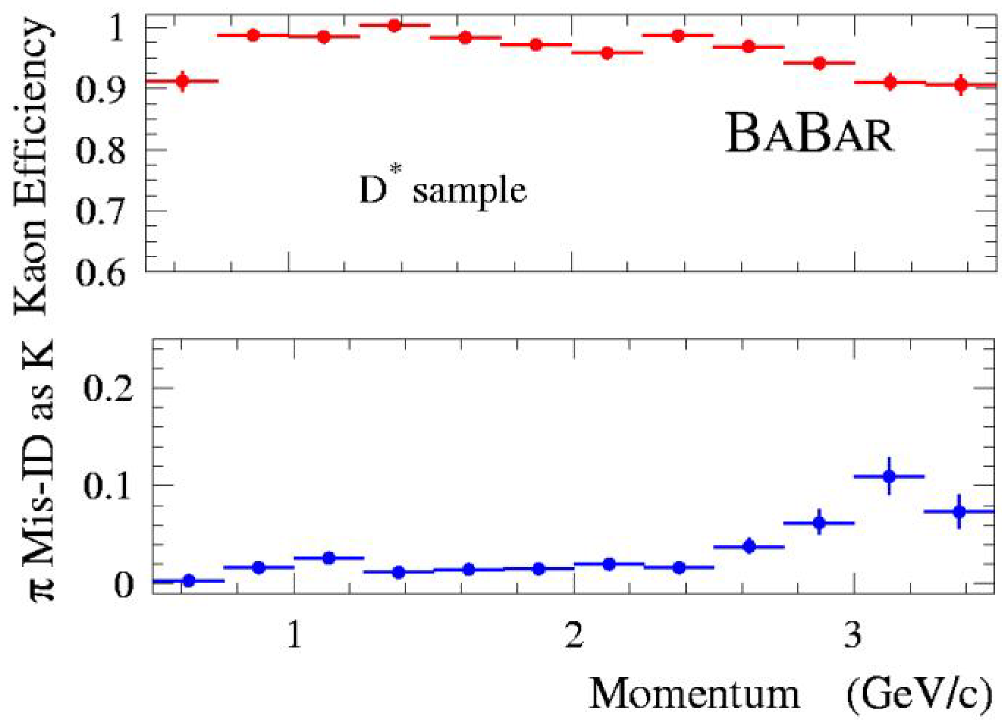
March 3, 2008

DIRC performance



← Lots of photons!

Excellent π/K separation



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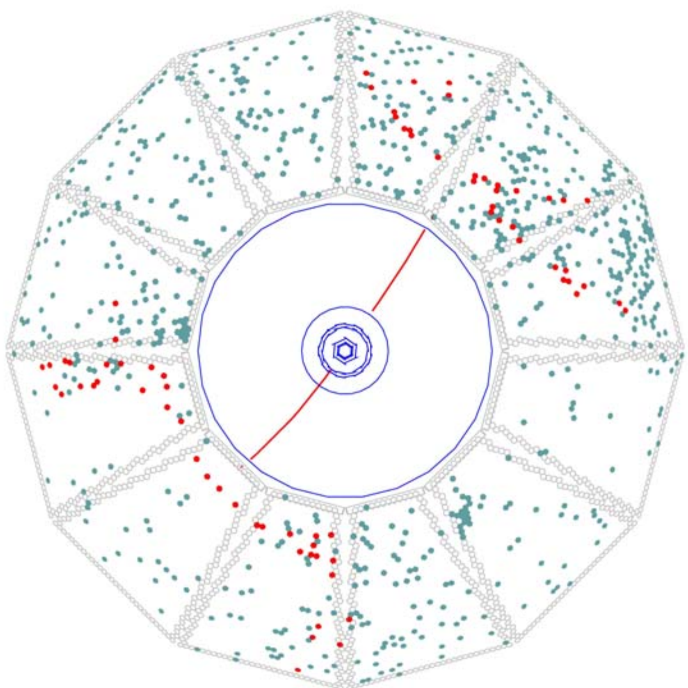
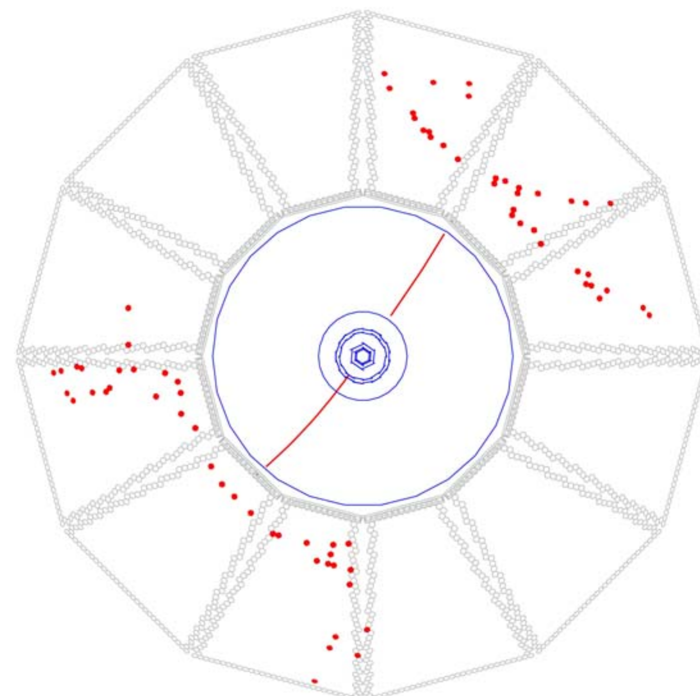
DIRC

BaBar DIRC: a Bhabha event $e^+ e^- \rightarrow e^+ e^-$



No time cut on the hits

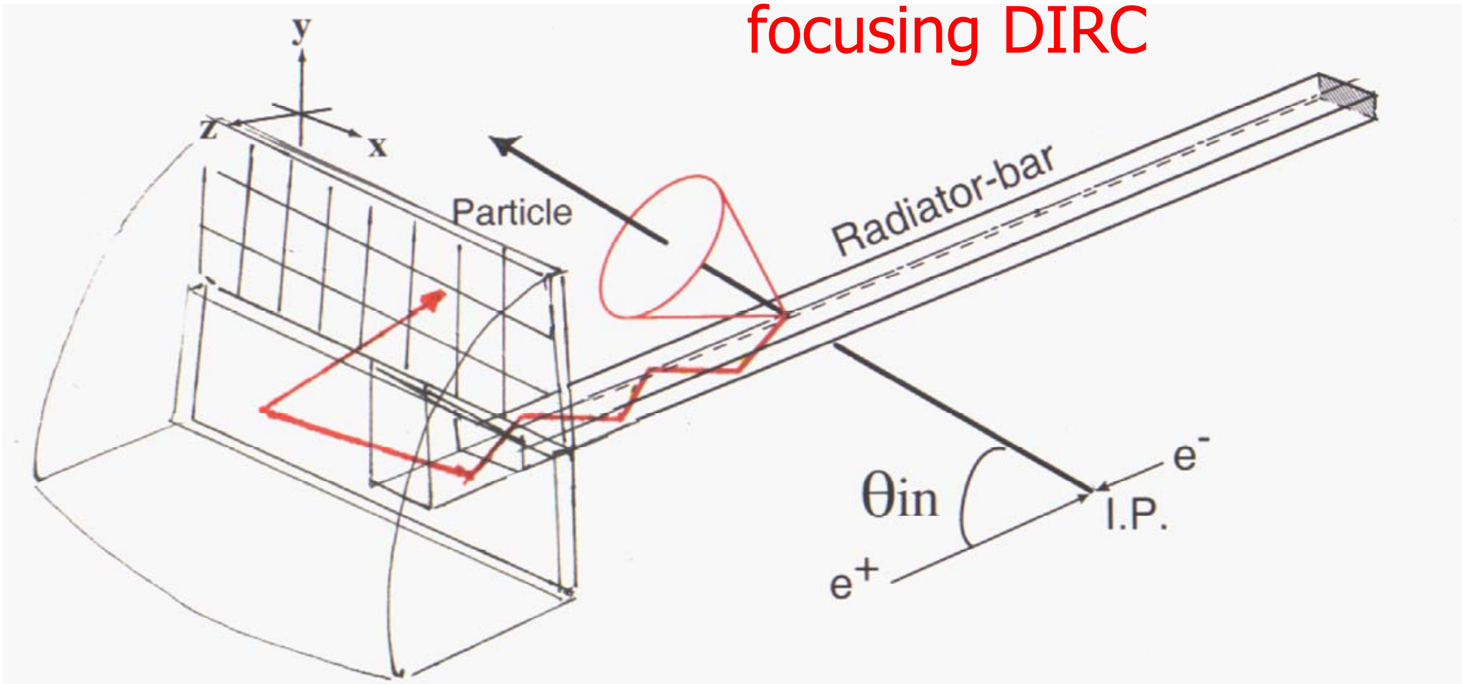


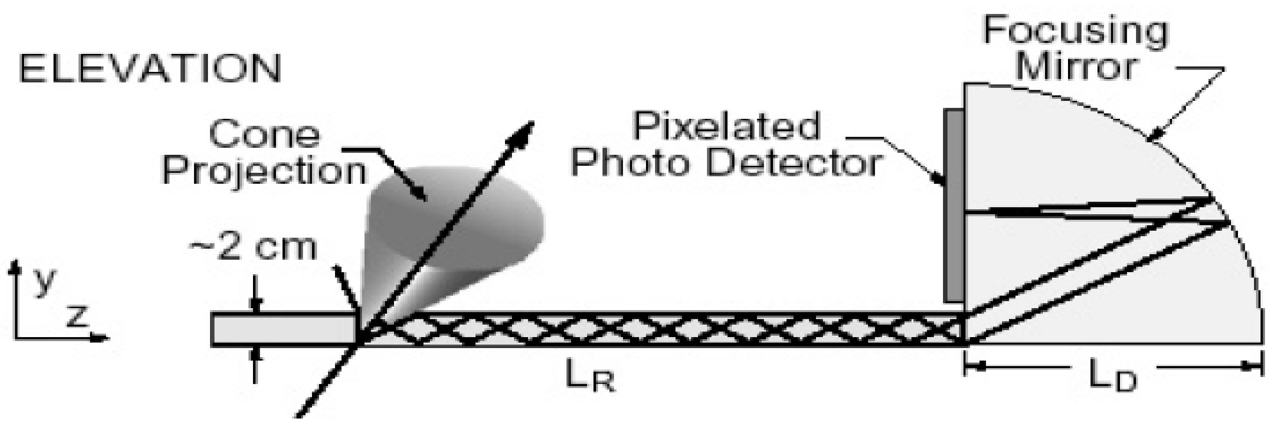
With a +-4ns time cut

Timing information is essential for background reduction

Focusing DIRC

Upgrade: step further, remove the stand-off box → focusing DIRC





Focusing DIRC

Super-B factory: 100x higher luminosity => DIRC needs to be smaller and faster

Focusing and smaller pixels can reduce the expansion volume by a factor of 7-10 !

Timing resolution improvement: σ ~1.7ns (BaBar DIRC)
→ $\sigma \leq$150-200ps (~10x better) allows a measurement of the photon group velocity $c_g(\lambda)$ to correct the chromatic error of θ_c.

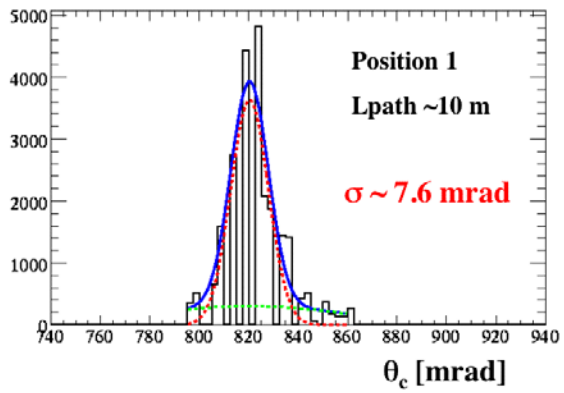
Photon detector requirements:

- Pad size <5mm
- Time resolution ~50-100ps

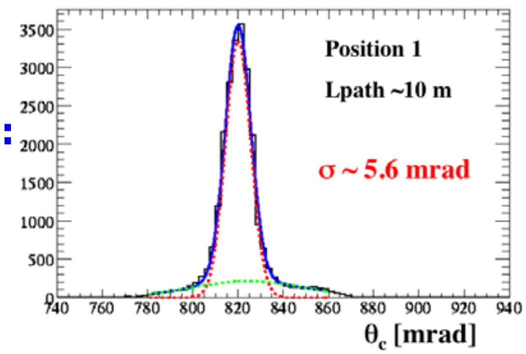
Focusing DIRC- the chromatic correction

Beam test results with BURLE/Photonis MCP PMT

Correction off:

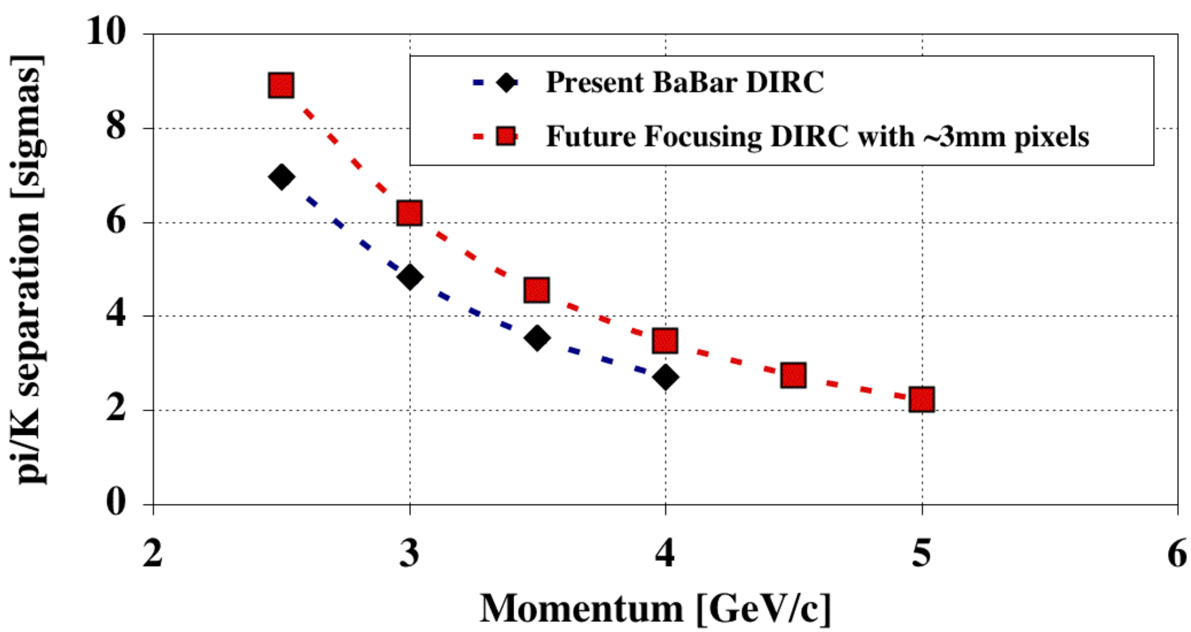


Correction on:



θ_C resolution and chromatic correction for 3mm pixels:

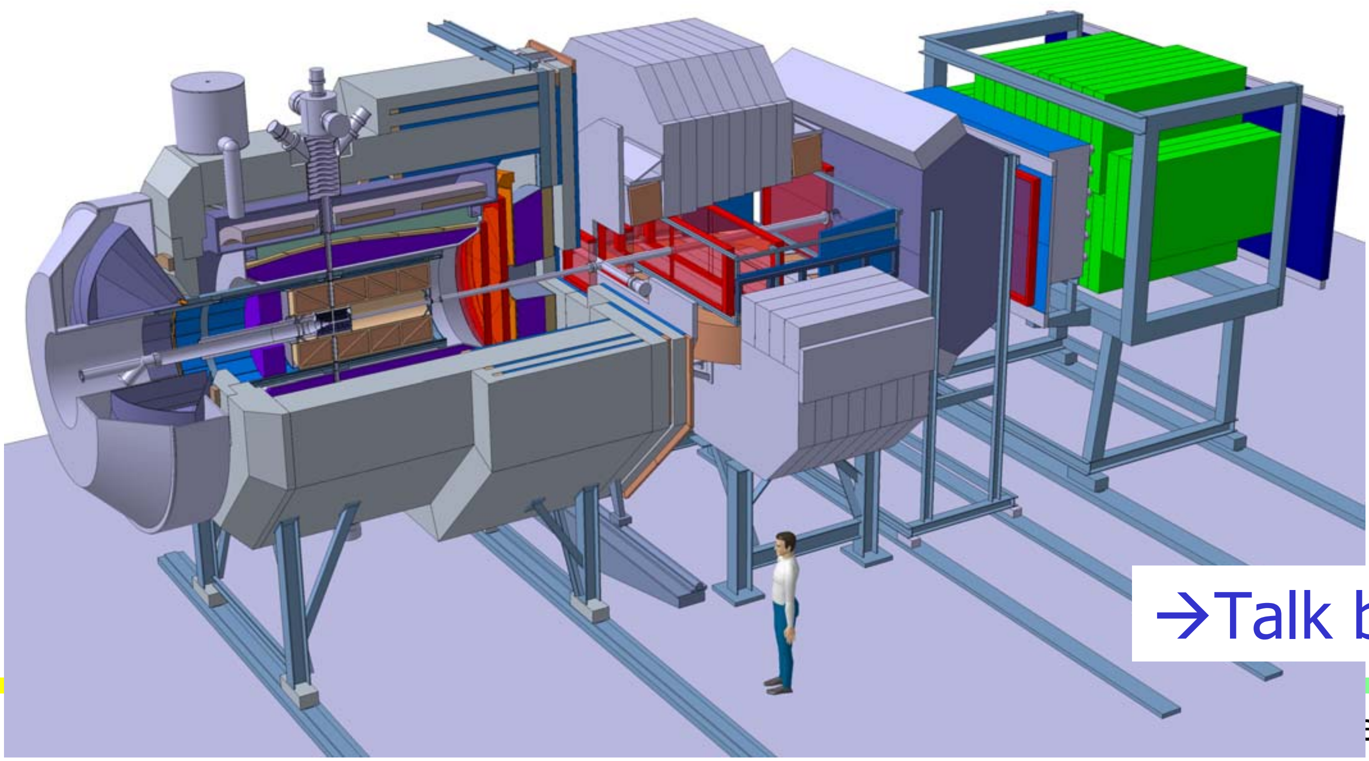
Expected PID performance:



DIRC counters for PANDA (FAIR, GSI)

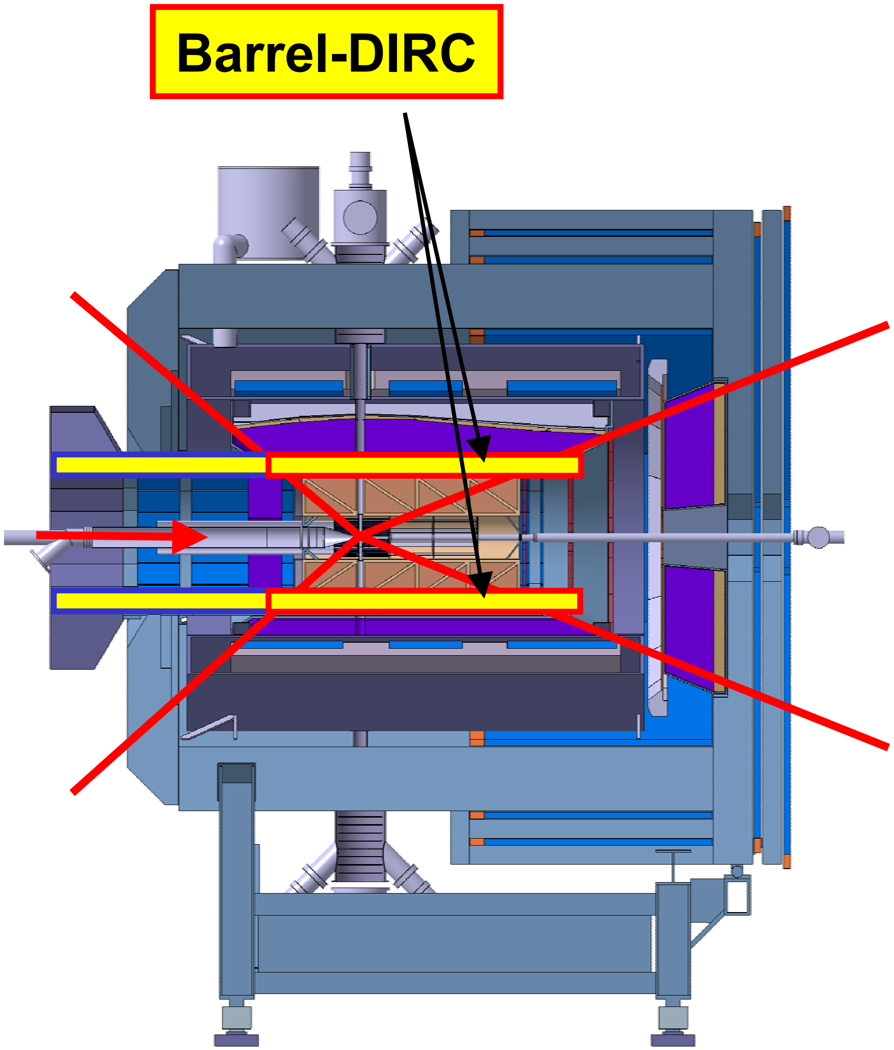
Two DIRC like counters are considered for the PANDA experiment:

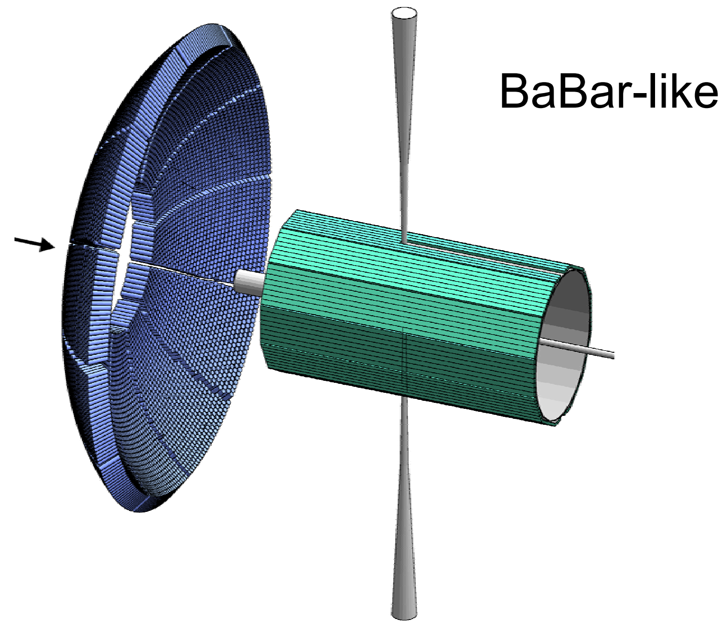
- one very similar to the current DIRC in BaBar,
- the other of focusing type



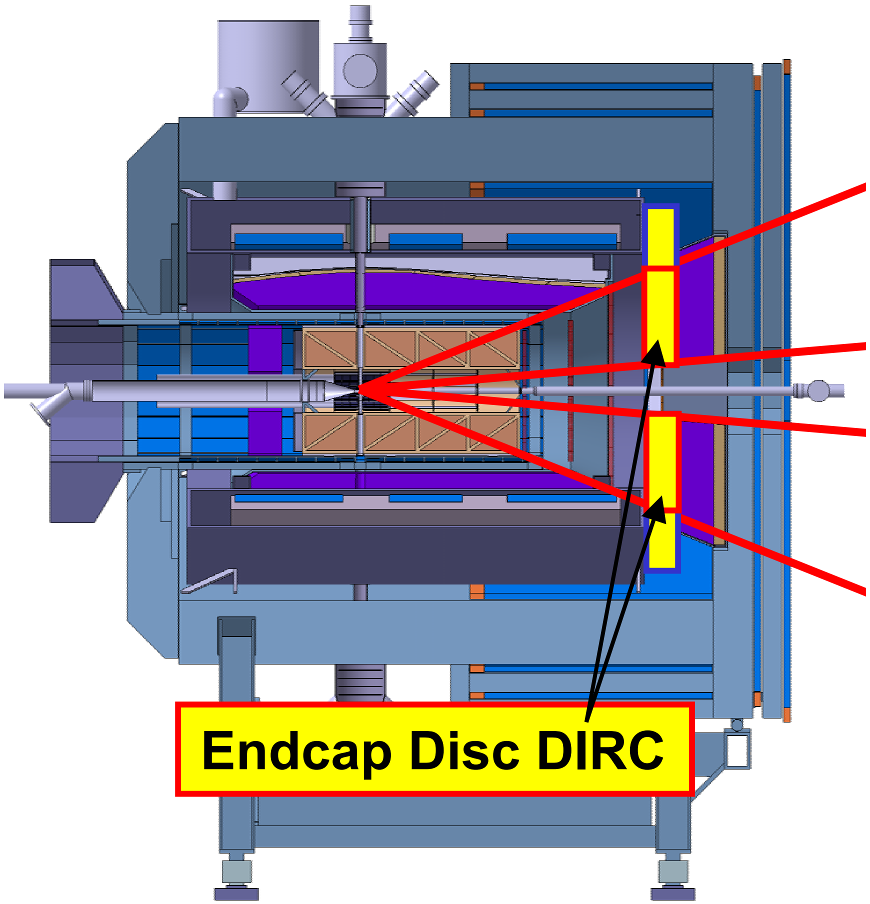
→Talk by G. Schepers

PANDA barrel DIRC



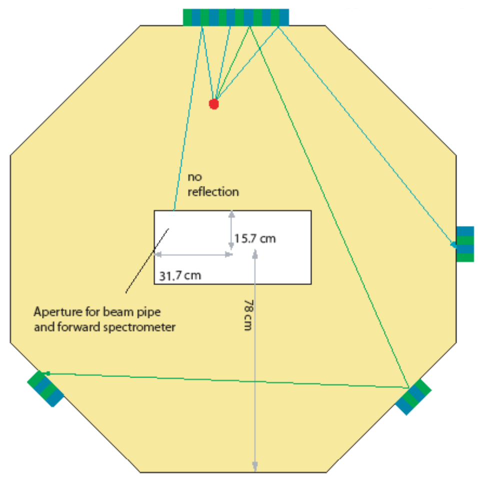


PANDA endcap DIRC



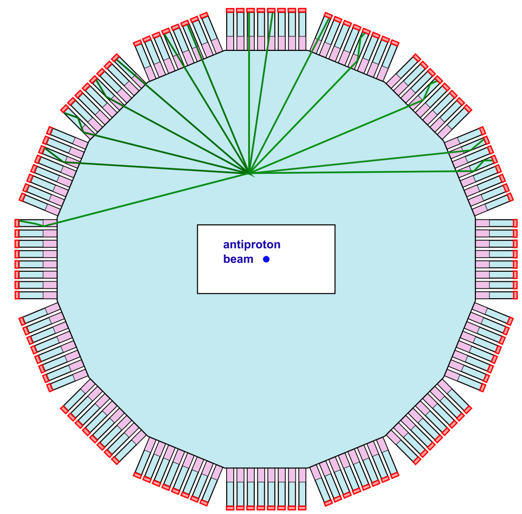
Two different readout designs:

Time-of-Propagation



(1+1)D design

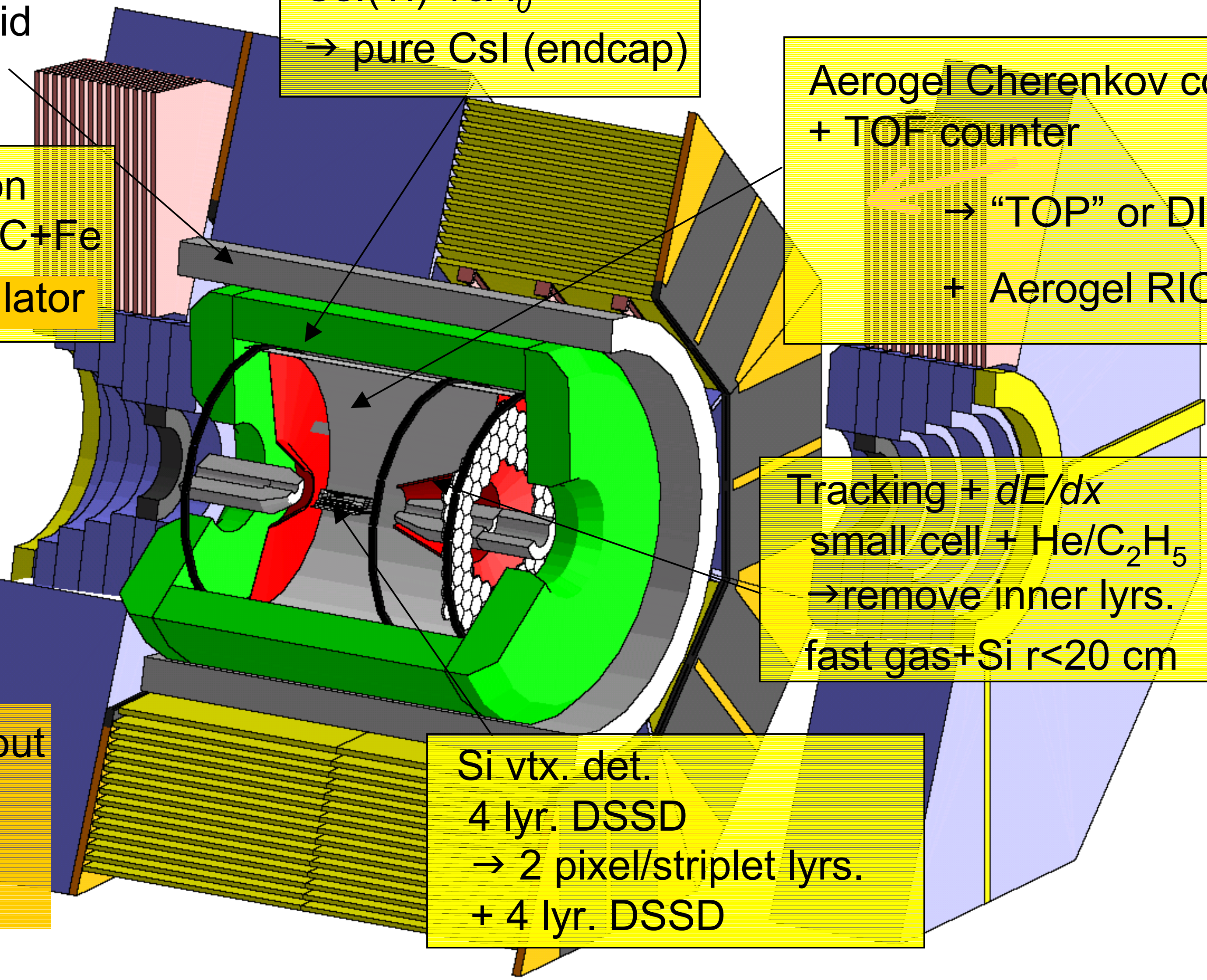
Focussing light guide



2D + t design

→Talk by G. Schepers

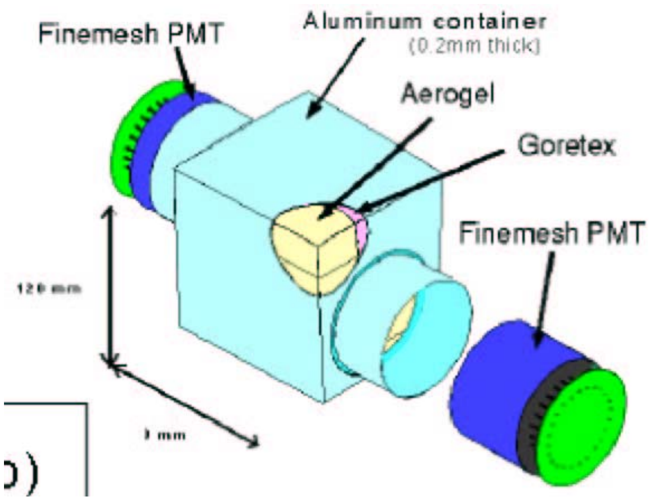
Belle upgrade for Super-B

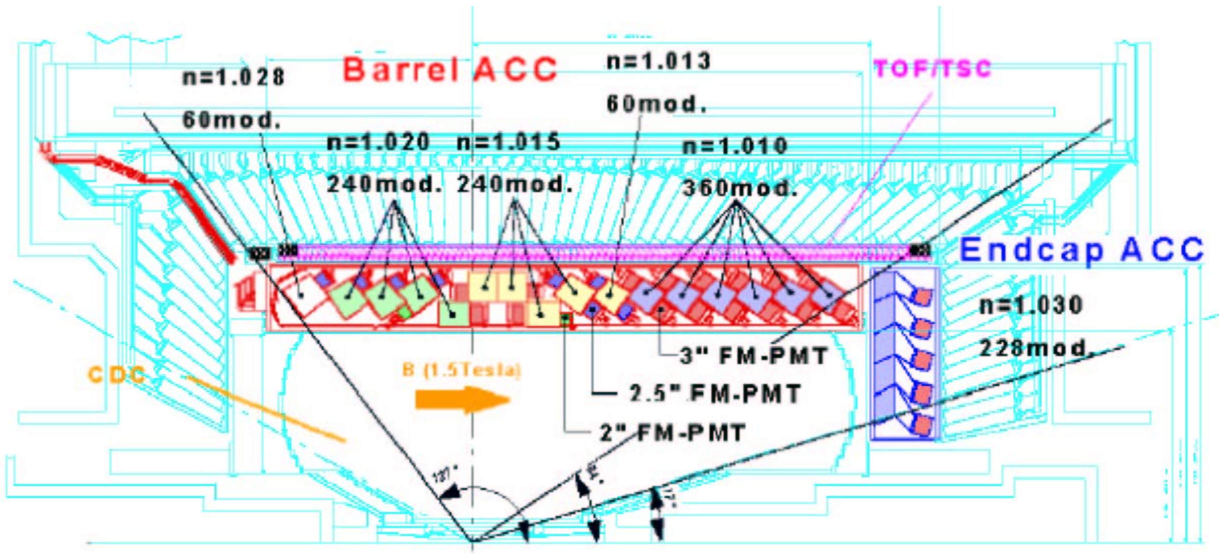


Present Belle: threshold Cherenkov counter ACC (aerogel Cherenkov counter)

K (below threshold) vs. π (above) by properly choosing n for a given kinematic region (more energetic particles fly in the 'forward region')

Detector unit: a block of aerogel and two fine-mesh PMTs

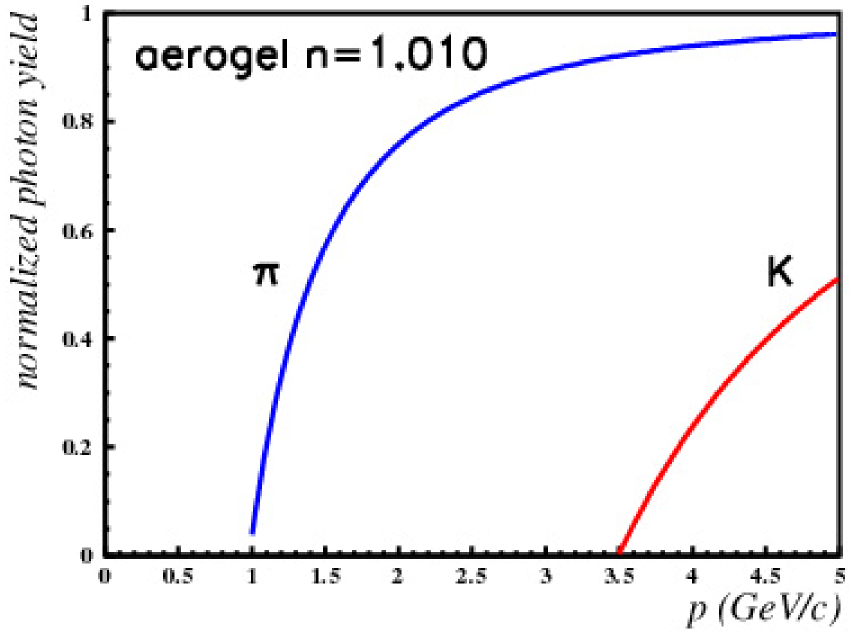




Fine-mesh PMT: works in high B fields

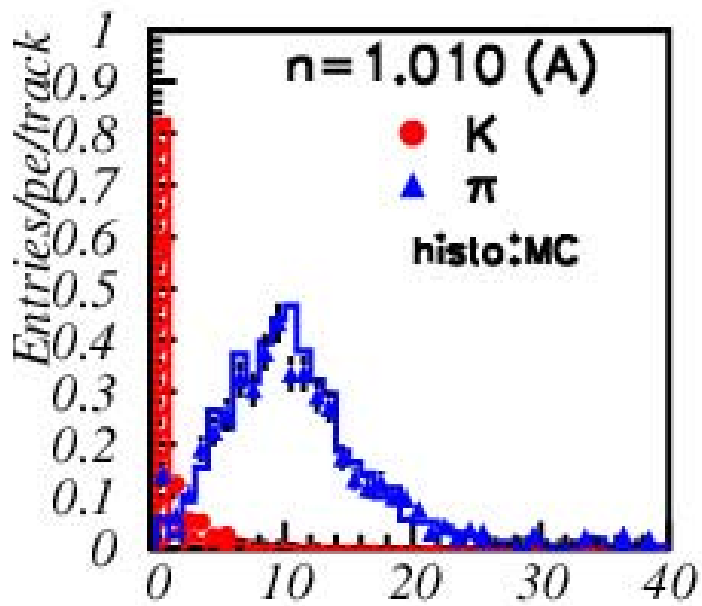
Belle ACC : threshold Cherenkov counter

expected yield vs p

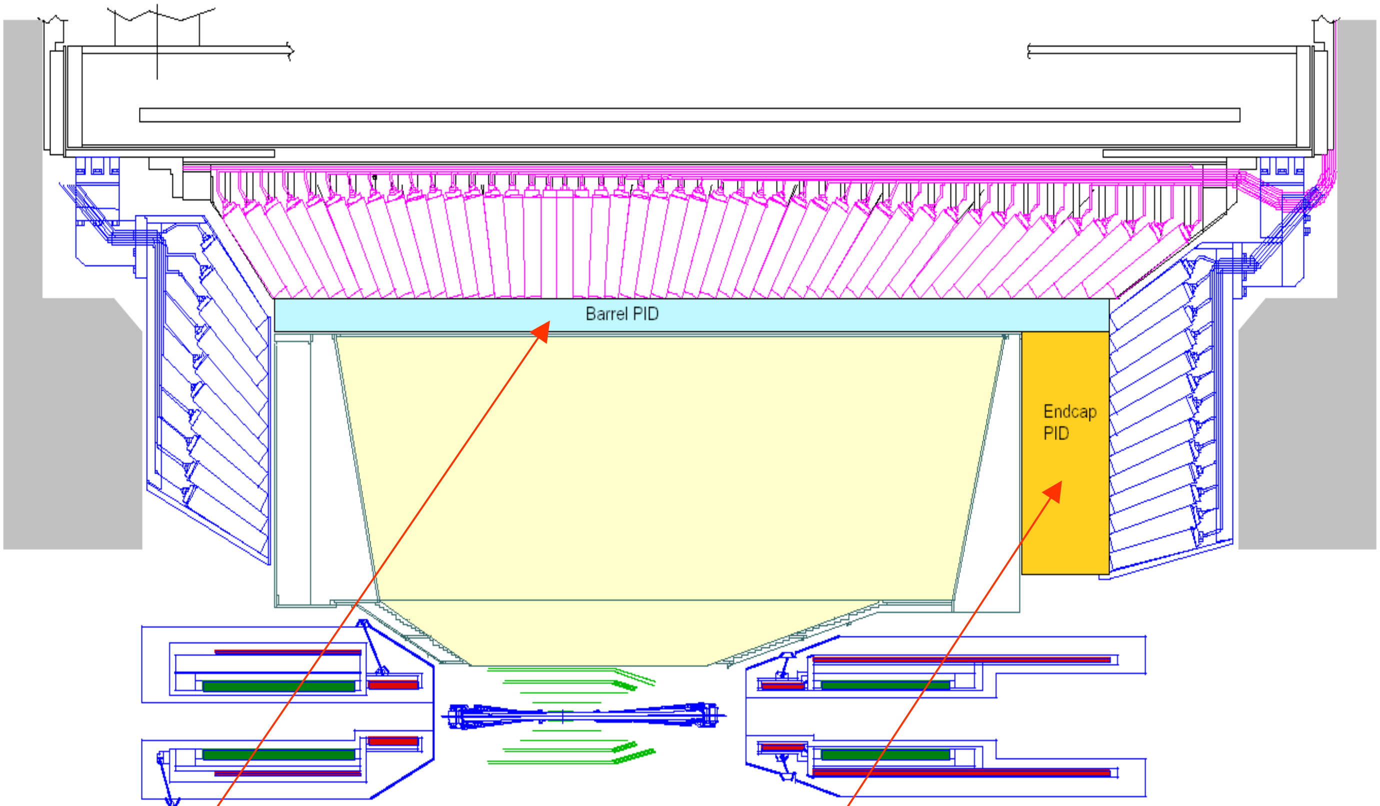


NIM A453 (2000) 321

yield for 2GeV<p<3.5GeV: expected and measured number of hits



Belle upgrade – side view



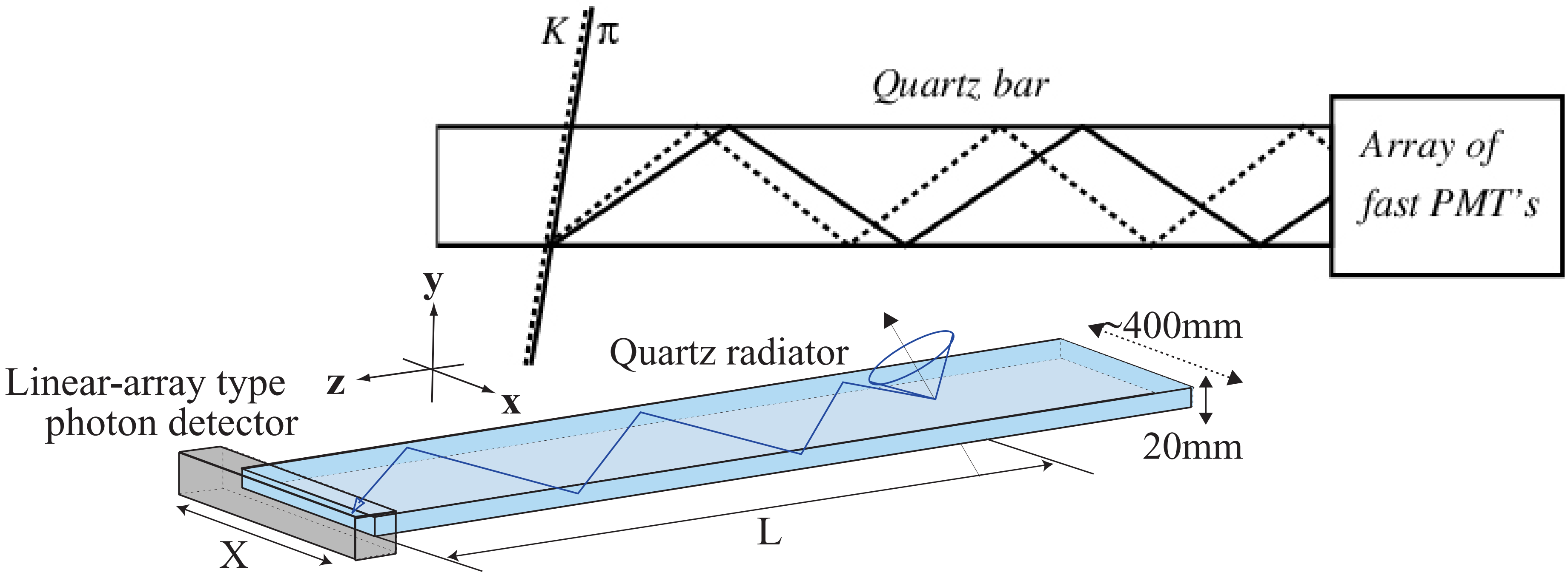
Two new particle ID devices, both RICHes:

Barrel: TOP or focusing DIRC

Endcap: proximity focusing RICH

→Talk by T. Iijima

Time-Of-Propagation (TOP) counter

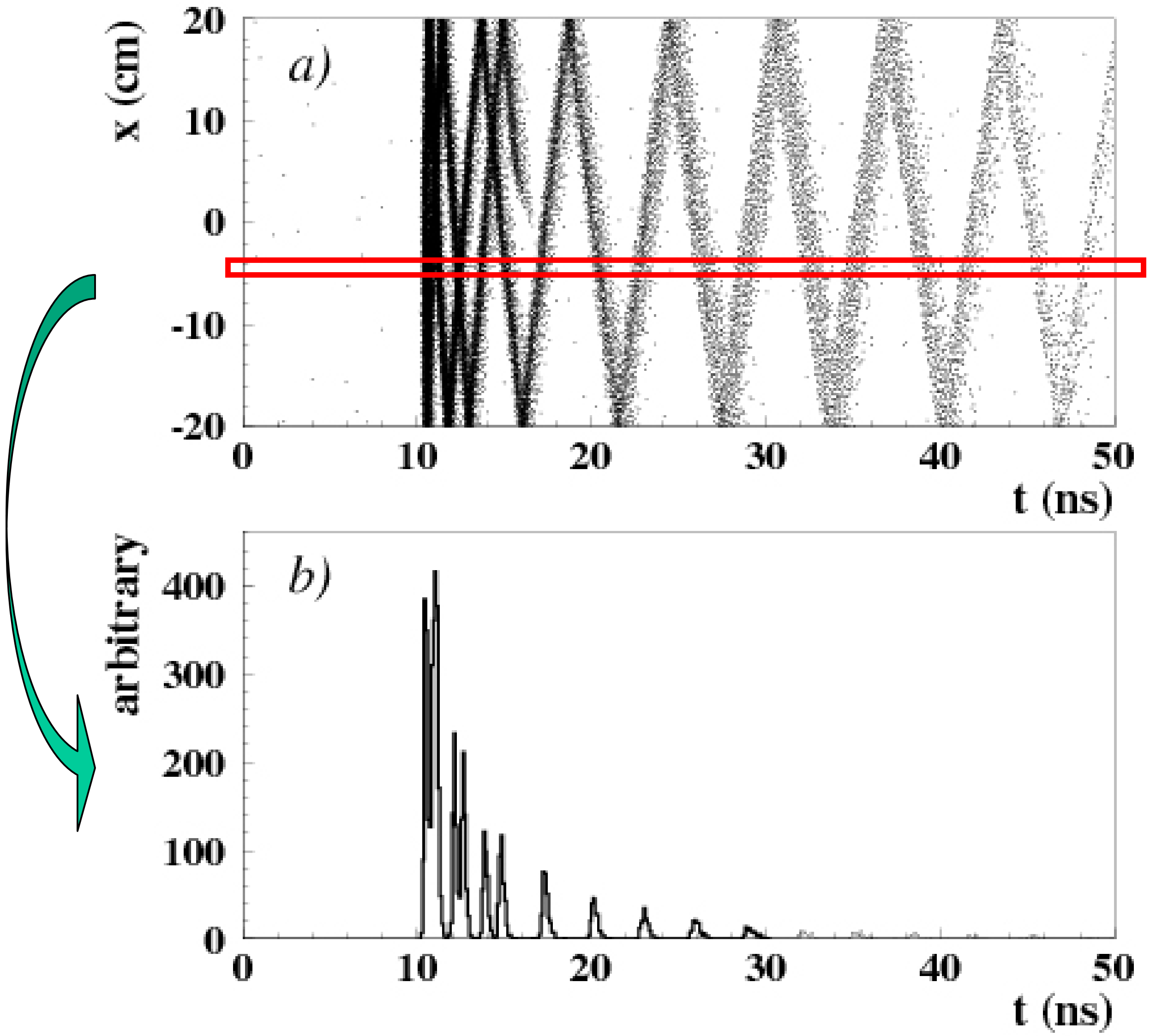


Similar to DIRC, but instead of two coordinates measure:

- One (or two coordinates) with a few mm precision
- Time-of-arrival

→ Excellent time resolution < ~40ps
required for single photons in 1.5T B field

TOP image



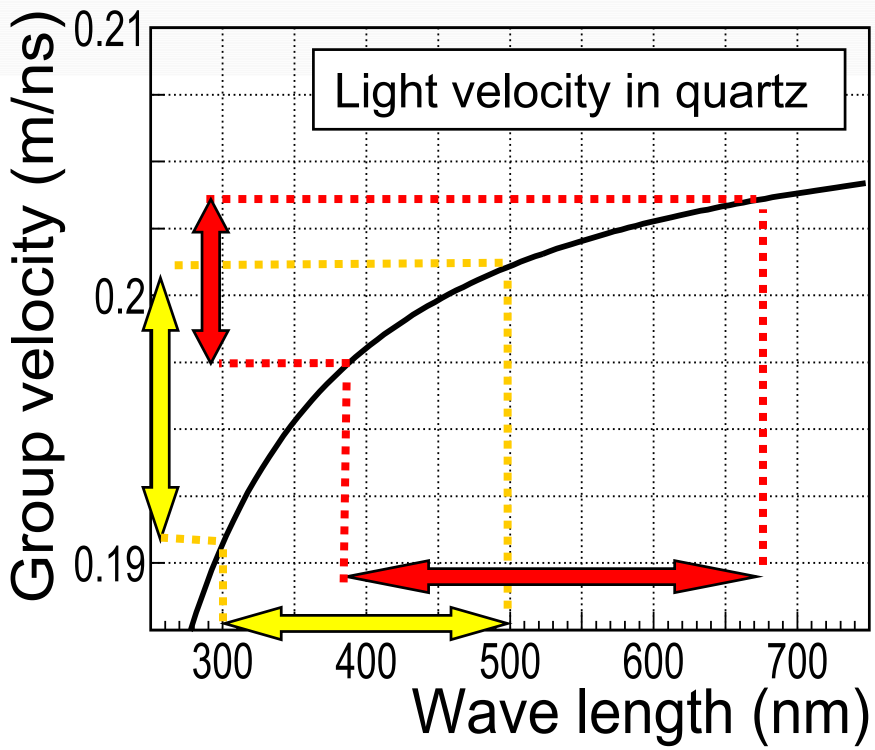
Pattern in the coordinate-time space ('ring') of a pion hitting a quartz bar with ~80 MAPMT channels

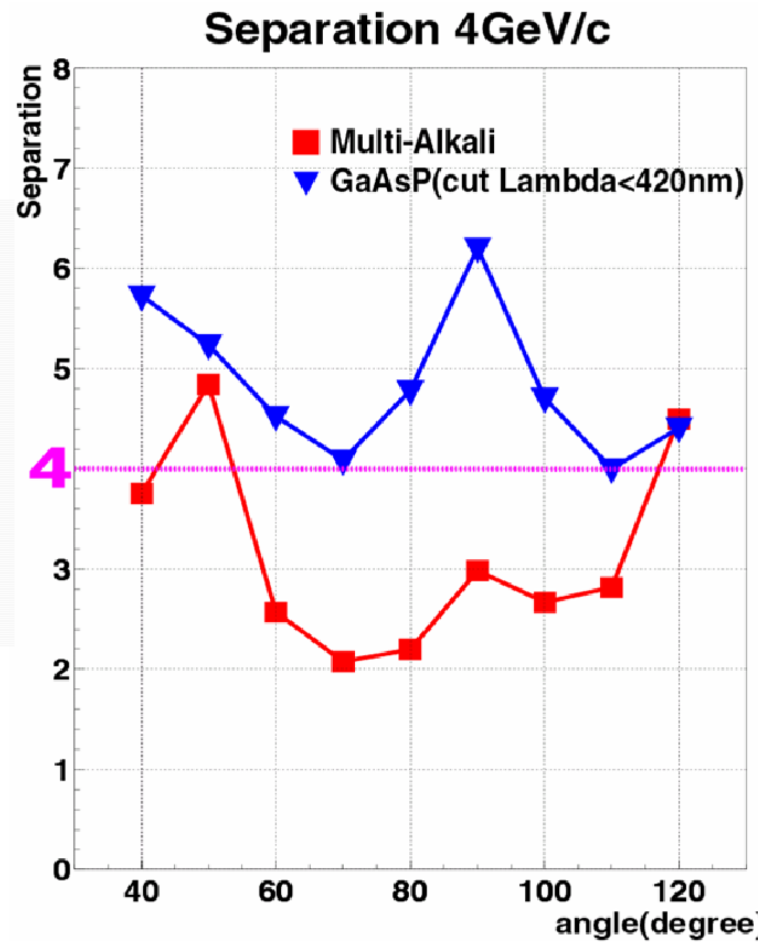
Time distribution of signals recorded by one of the PMT channels: different for π and K

TOP counter MC

Expected performance with:

bi-alkali photocathode: <4σ π/K separation at 4GeV/c (← chromatic dispersion)



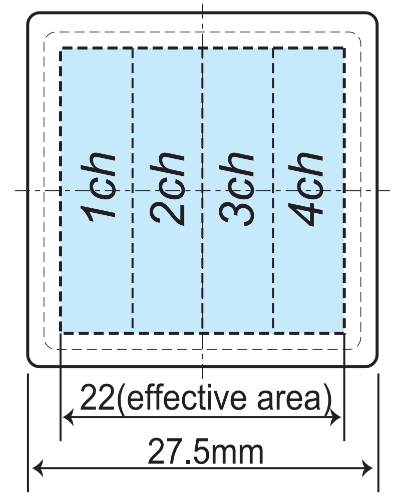


with GaAsP photocathode: >4σ π/K separation at 4GeV/c

GaAsP MCP-PMT with pads

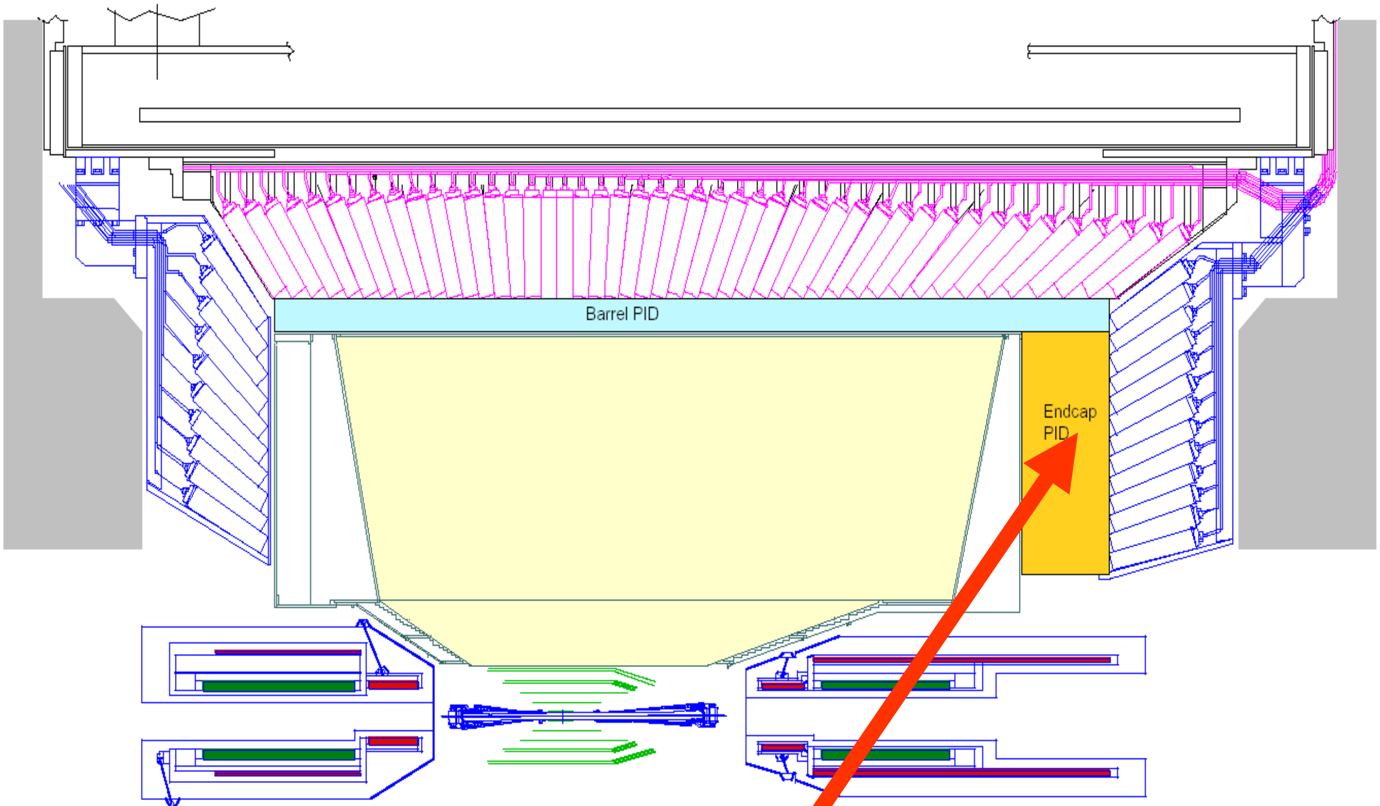
- Square-shape MCP-PMT with GaAsP photo-cathode
- First prototype
  - 2 MCP layers
    - $\phi 10 \mu m$ holes
  - 4ch anodes
  - Slightly larger structure
    - Less active area

Target structure



- Enough gain to detect single photo-electron
- Good time resolution (TTS=42ps) for single p.e.
- Good uniformity
- Next: increase active area frac., study ageing

Belle upgrade – side view

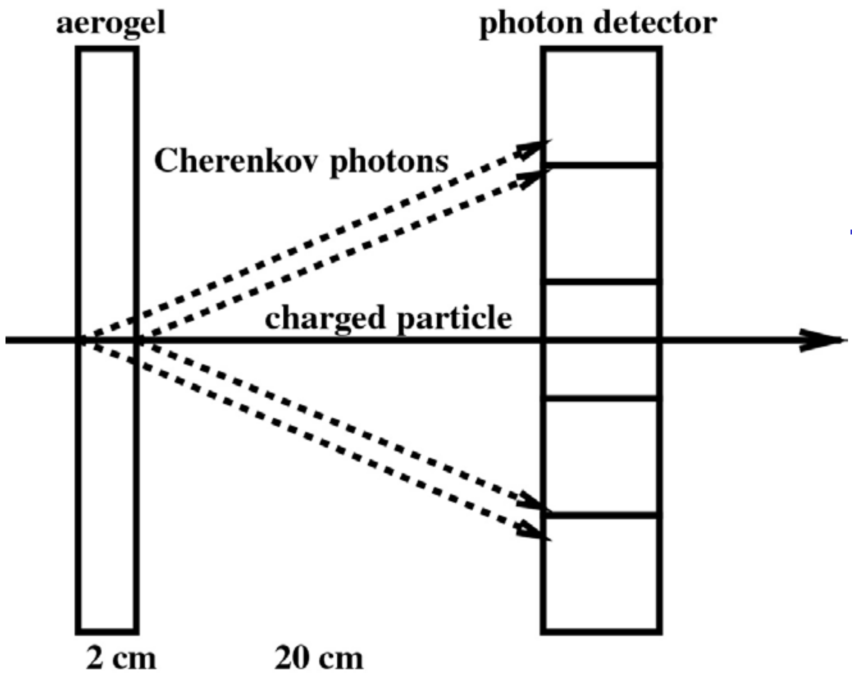


Two new particle ID devices, both RICHes:

Barrel: TOP or focusing DIRC

Endcap: proximity focusing RICH

Endcap: Proximity focusing RICH



K/π separation at 4 GeV/c:
$\theta_c(\pi)$ ~ 308 mrad (n = 1.05)
$\theta_c(\pi) - \theta_c(K)$ ~ 23 mrad

For single photons: $\delta\theta_c$(meas.)=σ_0 ~ 14 mrad,
typical value for a 20mm thick radiator and 6mm PMT pad size

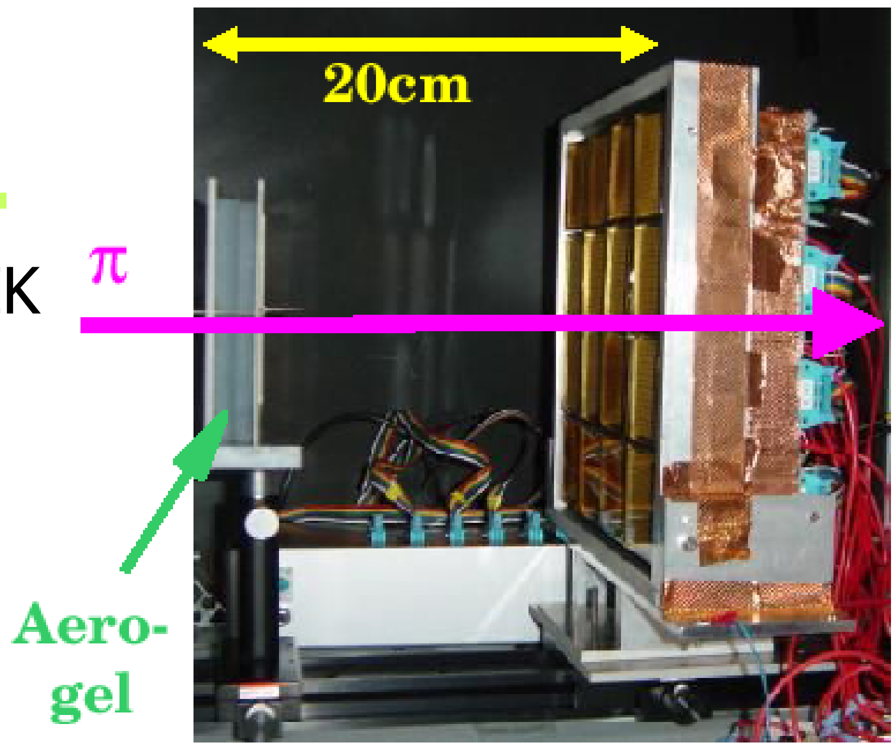
Per track: $$\sigma_{track} = \frac{\sigma_0}{\sqrt{N_{pe}}}$$

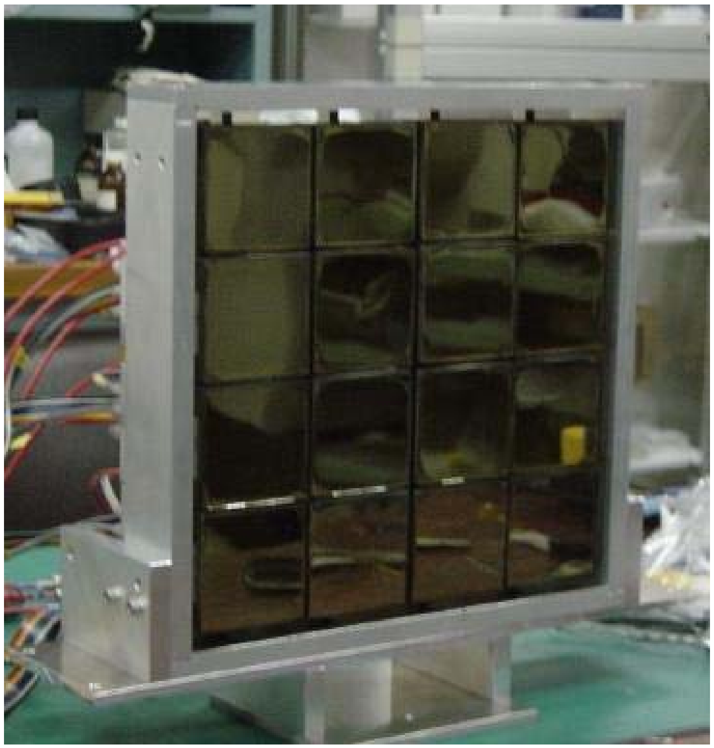
Separation: $[\theta_c(\pi) - \theta_c(K)]/\sigma_{track}$

→ 5σ separation with N_{pe}~10

Beam tests

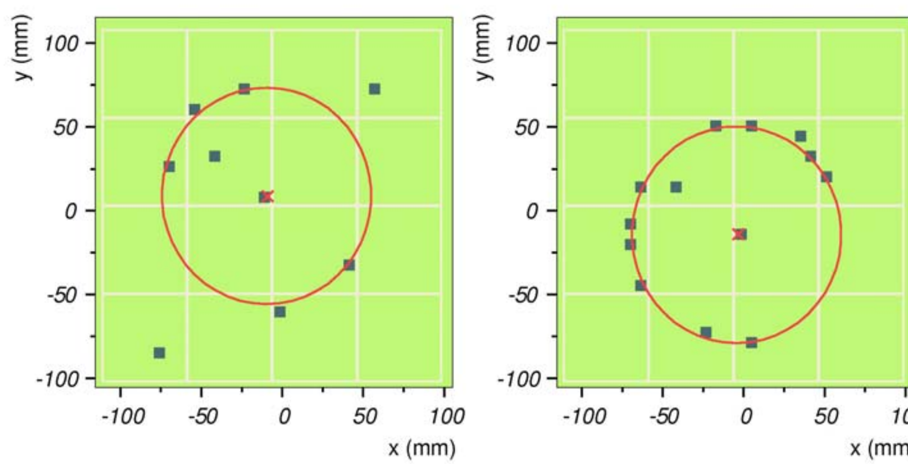
pion beam (π2) at KEK





Photon detector: array of 16 H8500 PMTs

Clear rings, little background

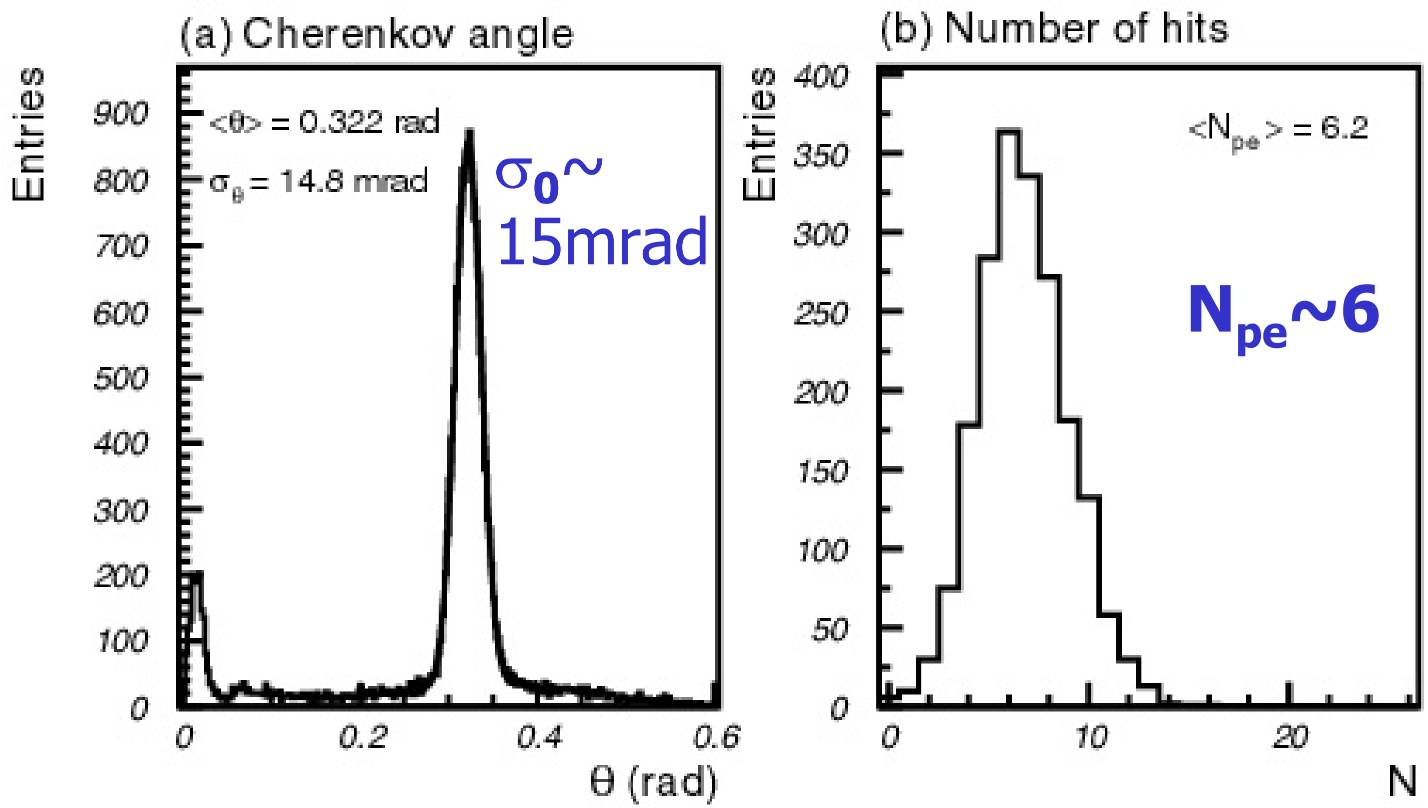


Beam test: Cherenkov angle resolution and number of photons

NIM A521(2004)367; NIM A553(2005)58

Beam test results with 2cm thick aerogel tiles:

>4σ K/π separation



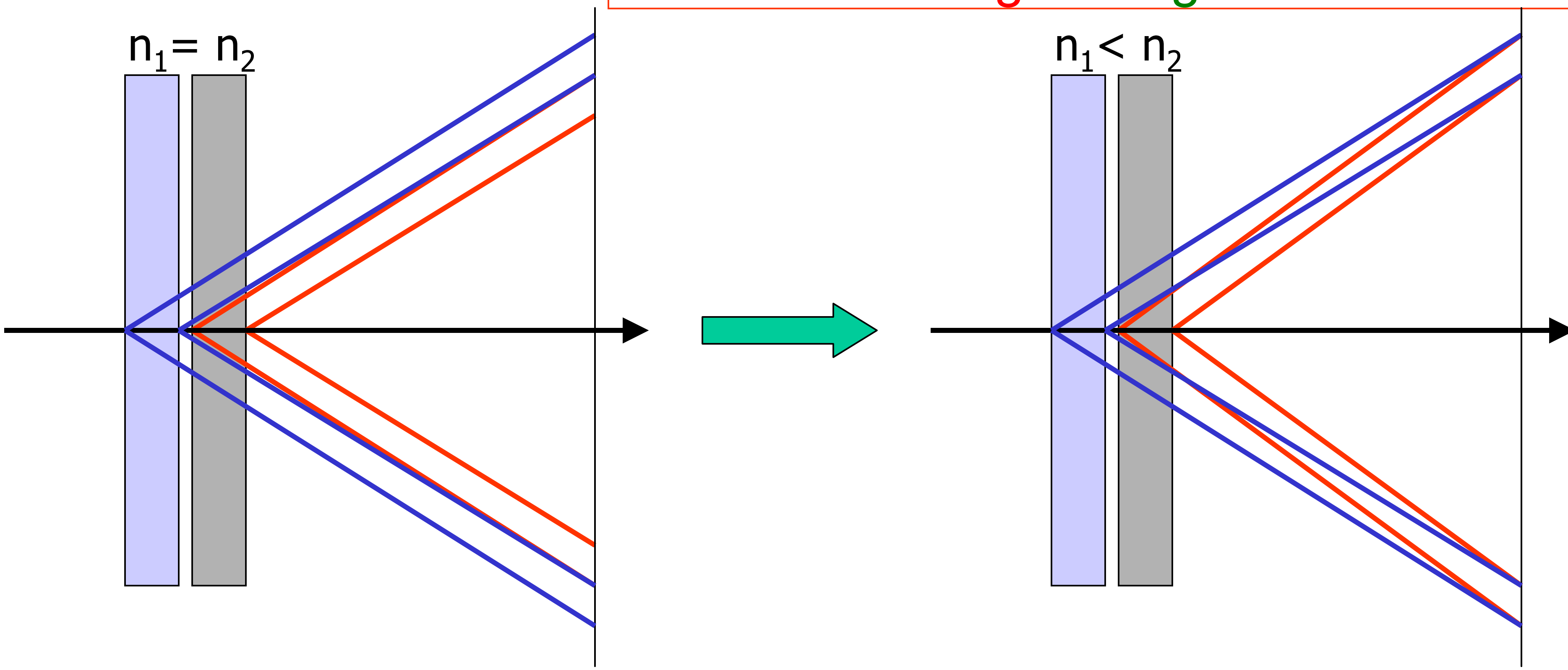
→ Number of photons has to be increased.

Radiator with multiple refractive indices

How to increase the number of photons without degrading the resolution?

→ stack two tiles with different refractive indices: "focusing" configuration

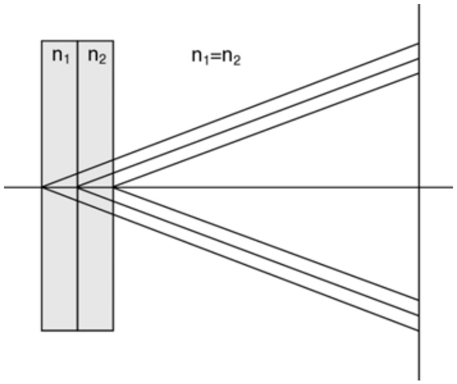
normal

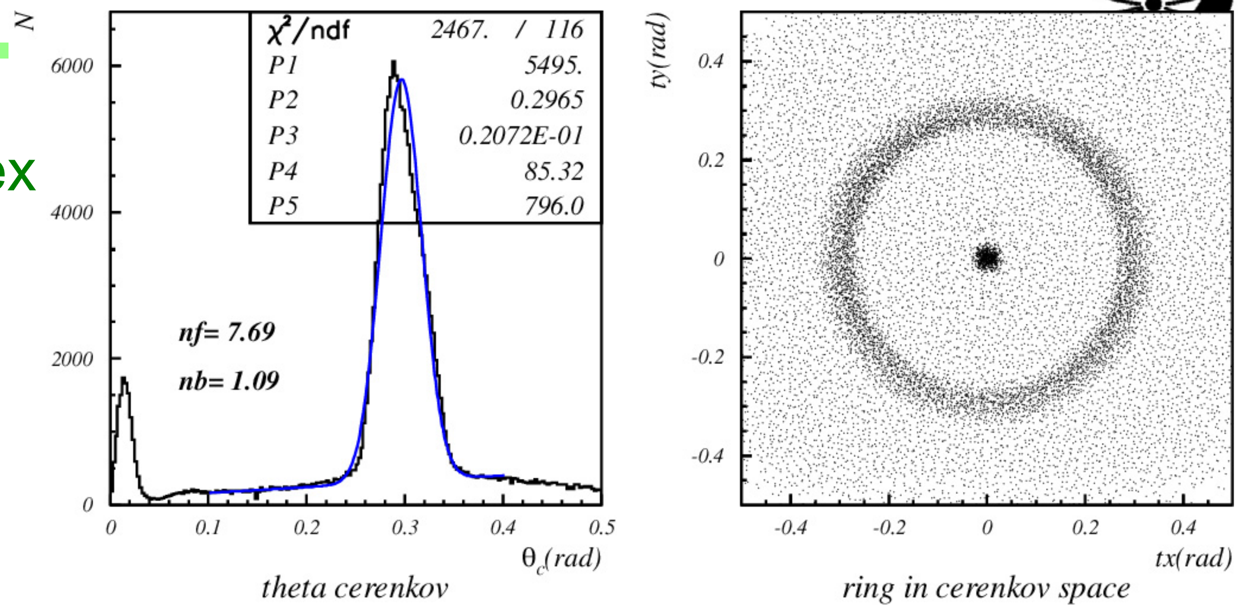


→ focusing radiator

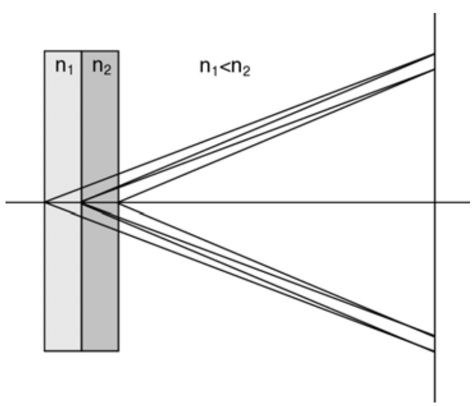
Focusing configuration – data

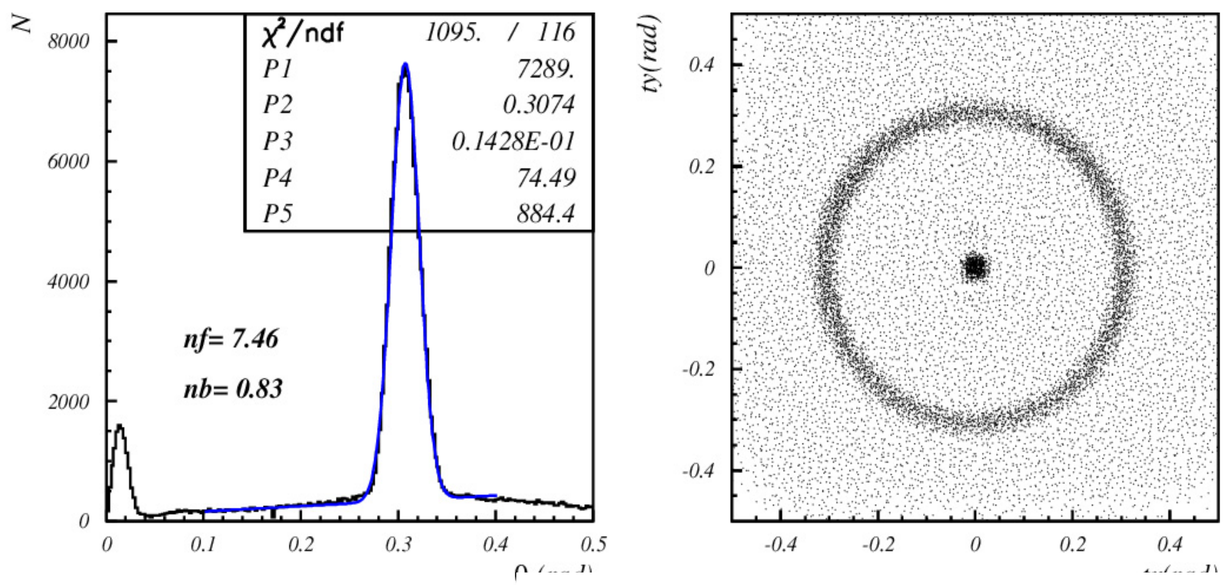
4cm aerogel single index





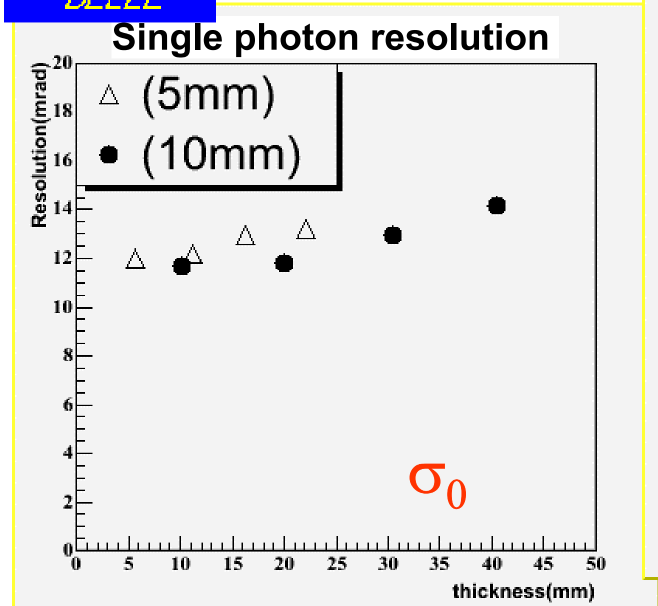
2+2cm aerogel

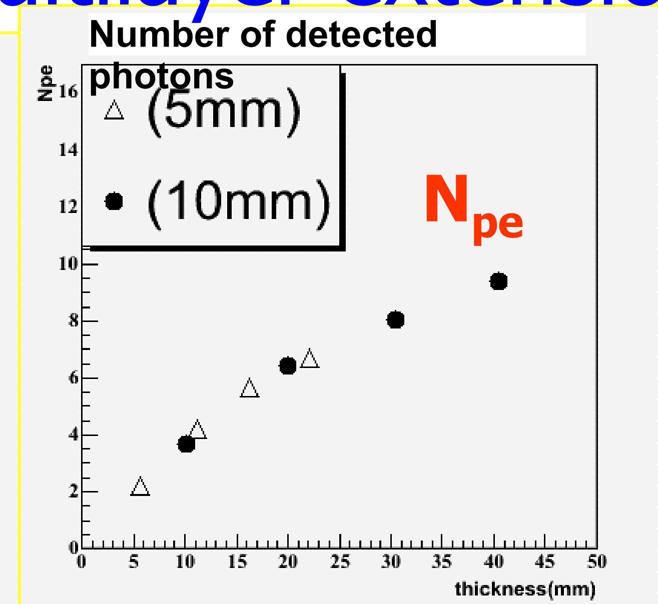


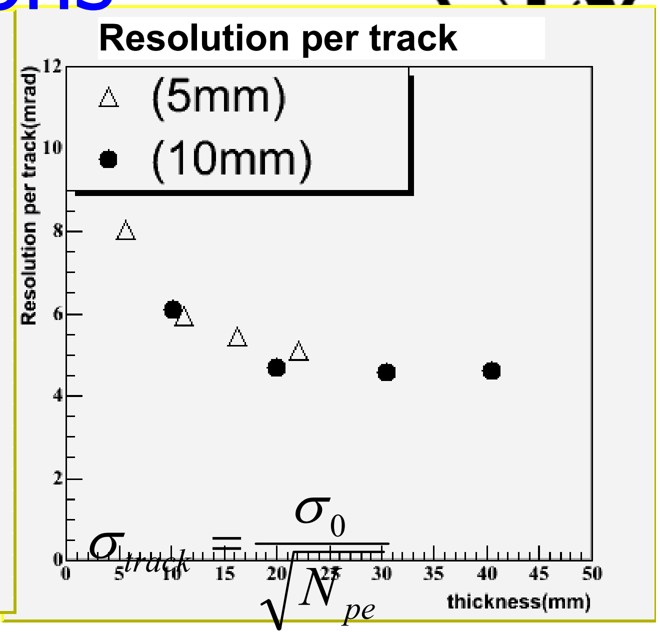


→NIM A548 (2005) 383

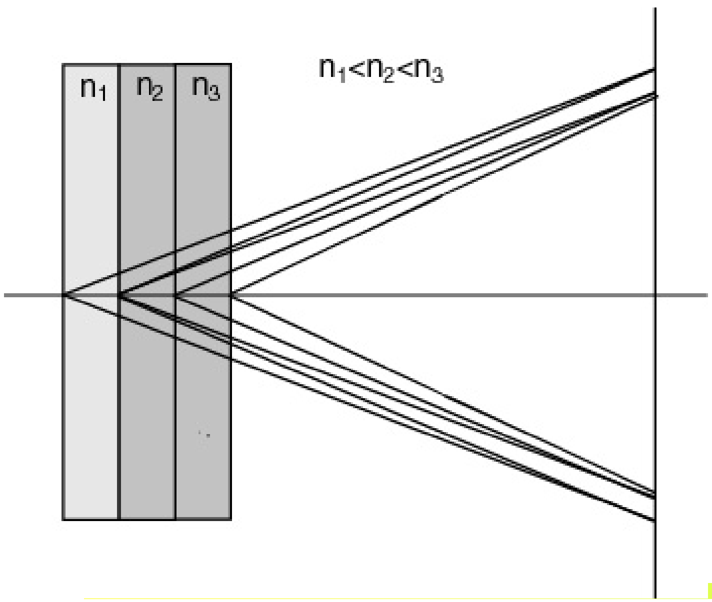
Multilayer extensions







$$\sigma_{track} = \frac{\sigma_0}{\sqrt{N_{pe}}}$$



Cherenkov angle resolution per track: around 4.3 mrad

→ π/K separation at 4 GeV: >5σ

Several optimisation studies:

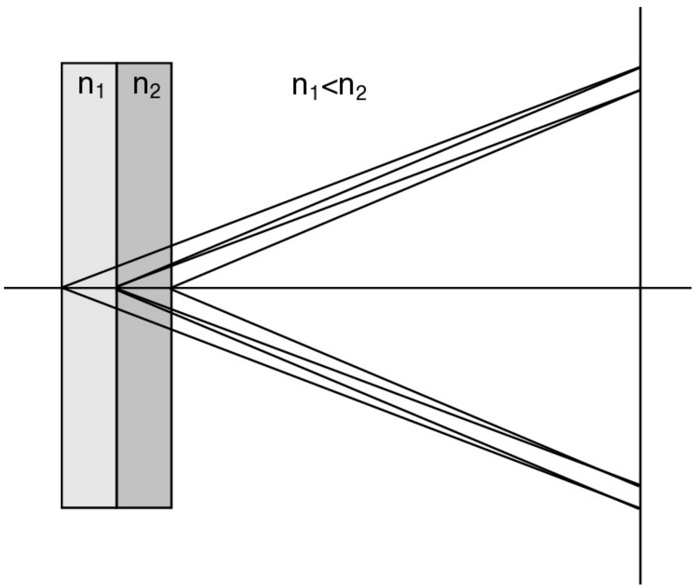
Križan et al NIMA 565 (2006) 457

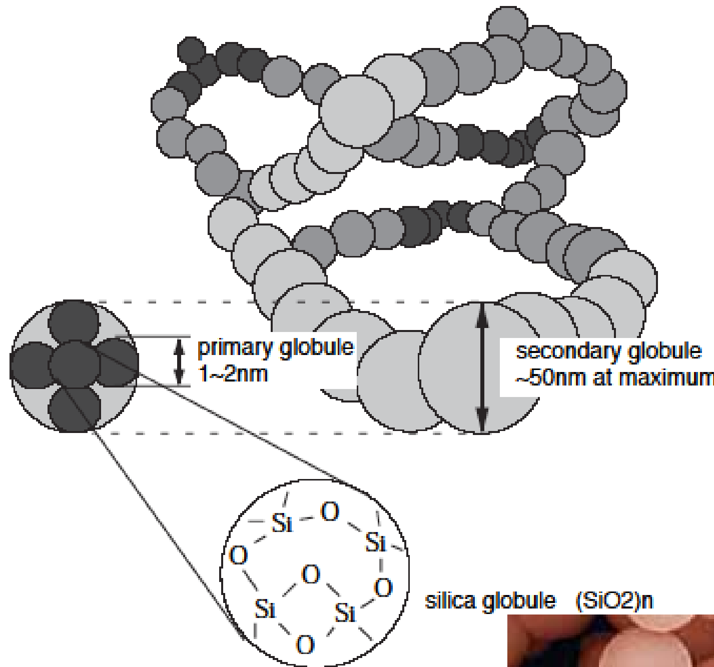
Barnyakov et al NIMA 553 (2005) 70

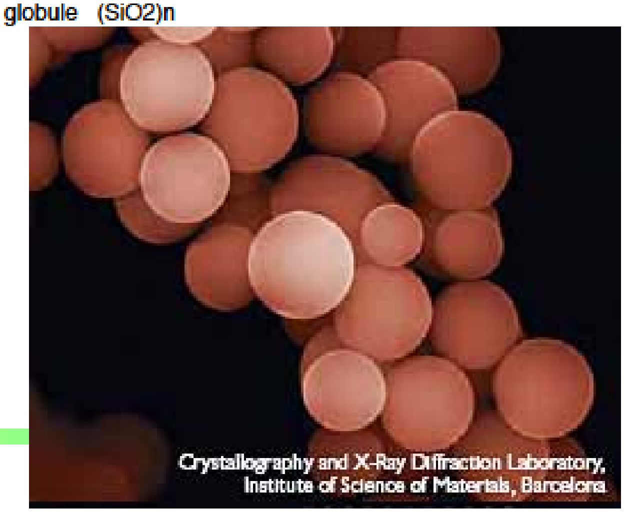
→Poster by S. Kononov

Radiator with multiple refractive indices

Such a configuration is only possible with aerogel (a form of Si_xO_y) – material with a tunable refractive index between 1.01 and 1.13.





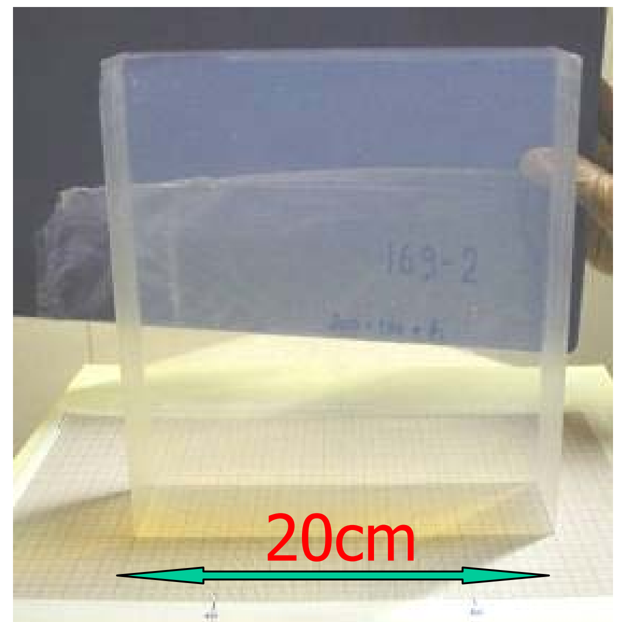


Aerogel production

Two production centers: Boreskov Institute of Catalysis, Novisibirsk, and KEK+Matsushita

Considerable improvement in aerogel production methods:

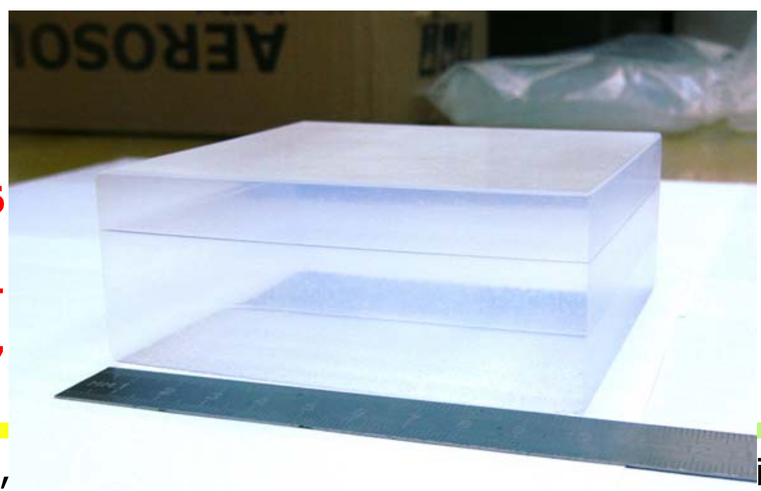
- Better transmission (>4cm for hydrophobic and ~8cm for hydrophylic)
- Larger tiles (LHCb: 20cmx20cmx5cm)
- Tiles with multiple refractive index



$n1=1.046$

$n2=1.041$

$n3=1.037$

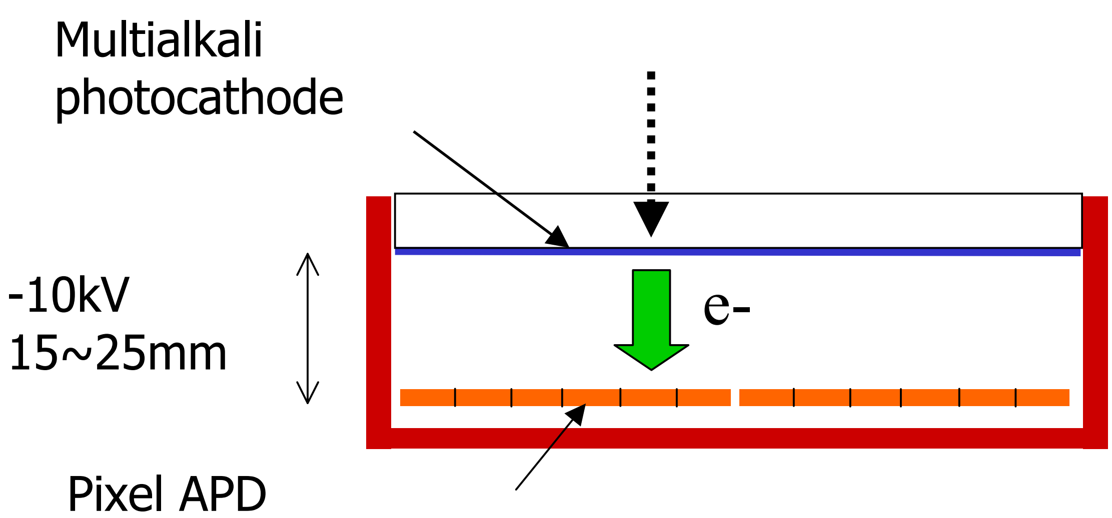


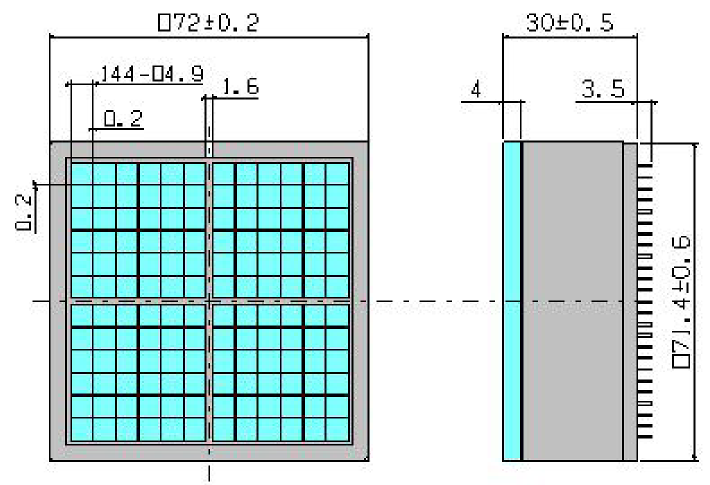
Photon detectors for the aerogel RICH requirements and candidates

Need: Operation in a high magnetic field (1.5 T)

Pad size ~5-6mm

One of the candidates: large active area HAPD of the proximity focusing type





HAPD R&D project in collaboration with HPK.

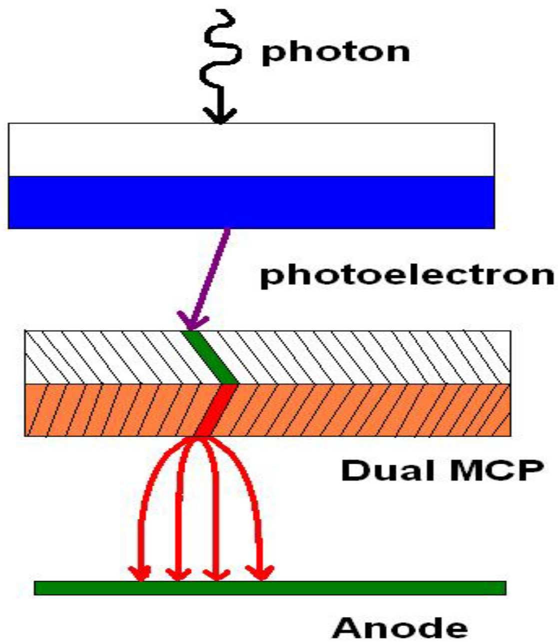
Long development time, now working test samples.

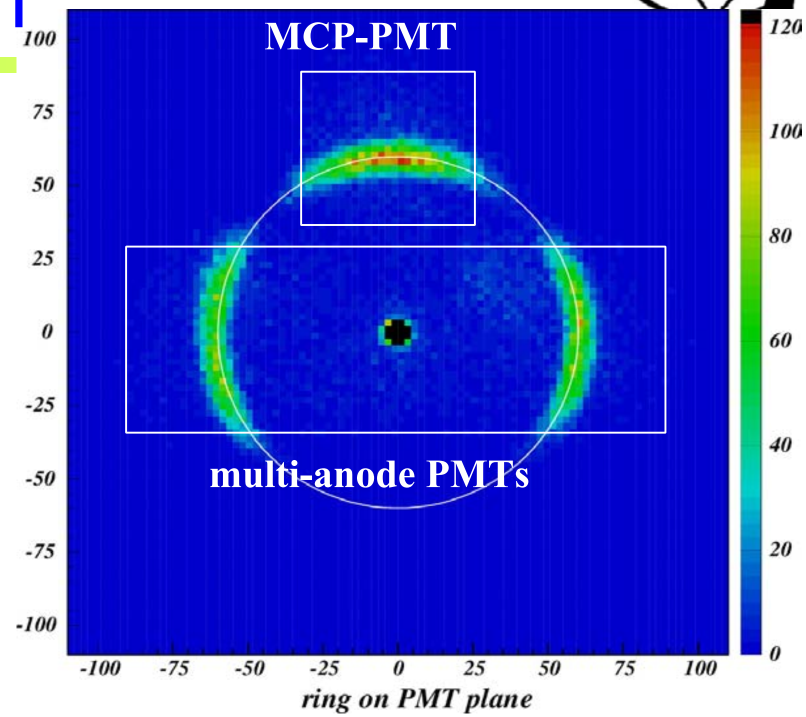
→ To be tested in the beam in three weeks

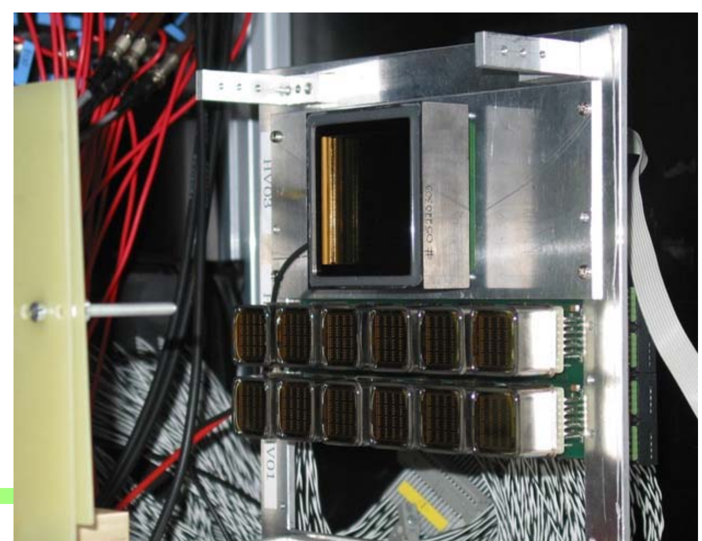
→Talk by T. Iijima

Photon detector candidate: BURLE/Photonis MCP-PMT

BURLE 85011 microchannel plate (MCP) PMT: multi-anode PMT with two MCP steps







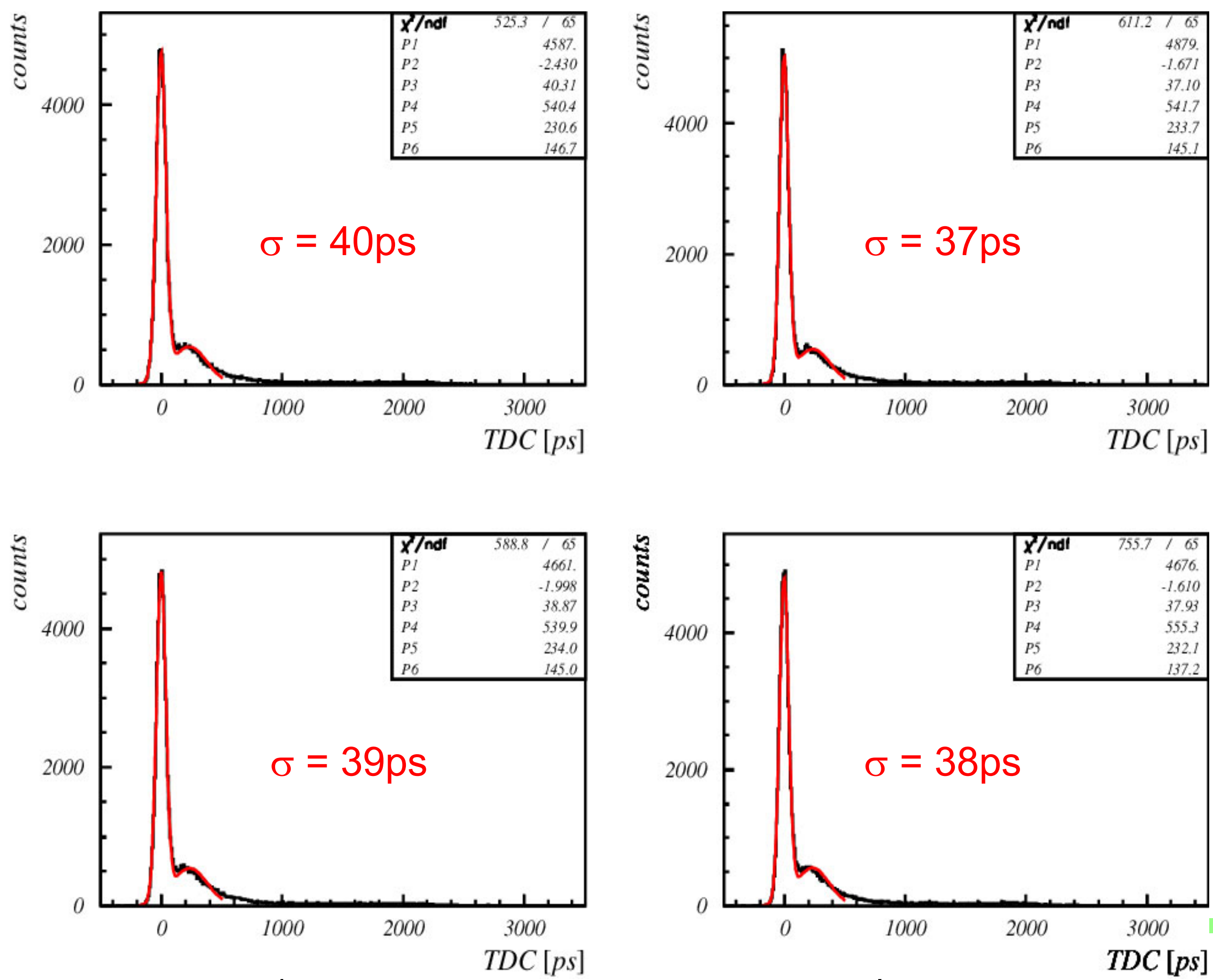
→good performance in beam and bench tests, NIMA567 (2006) 124

→ very fast

→ R+D: ageing

Photon detector candidate: BURLE/Photonis MCP-PMT

BURLE 85011 microchannel plate (MCP) PMT: time resolution after time walk correction



Tails can be significantly reduced by:

- decreased photocathode-MCP distance and
- increased voltage difference

SiPM as photon detector?

Can we use SiPM (Geiger mode APD) as the photon detector in a RICH counter?

+immune to magnetic field

+high photon detection efficiency, single photon sensitivity

+easy to handle (thin, can be mounted on a PCB)

+potentially cheap (not yet...) silicon technology

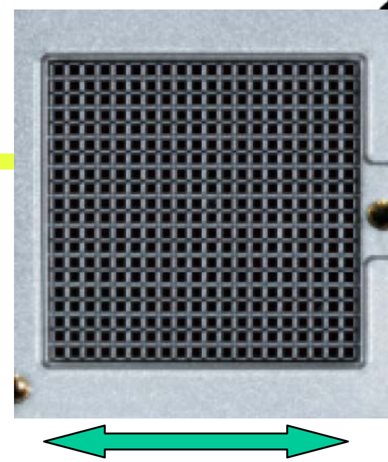
+no high voltage

-very high dark count rate (100kHz – 1MHz) with <u>single photon pulse height</u>

-radiation hardness

→Talks by D. Renker and Yu. Musienko

SiPMs as photon detectors?

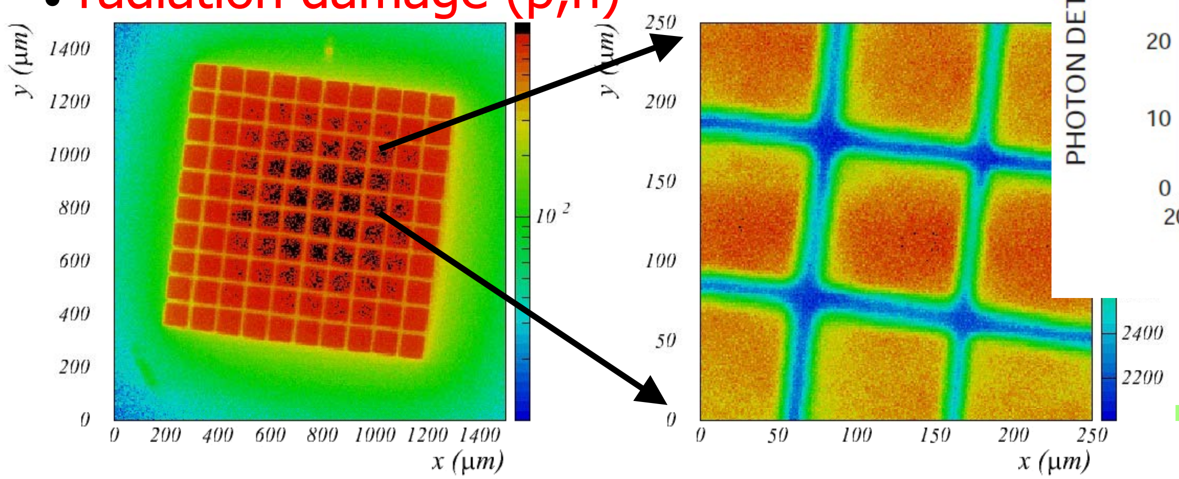


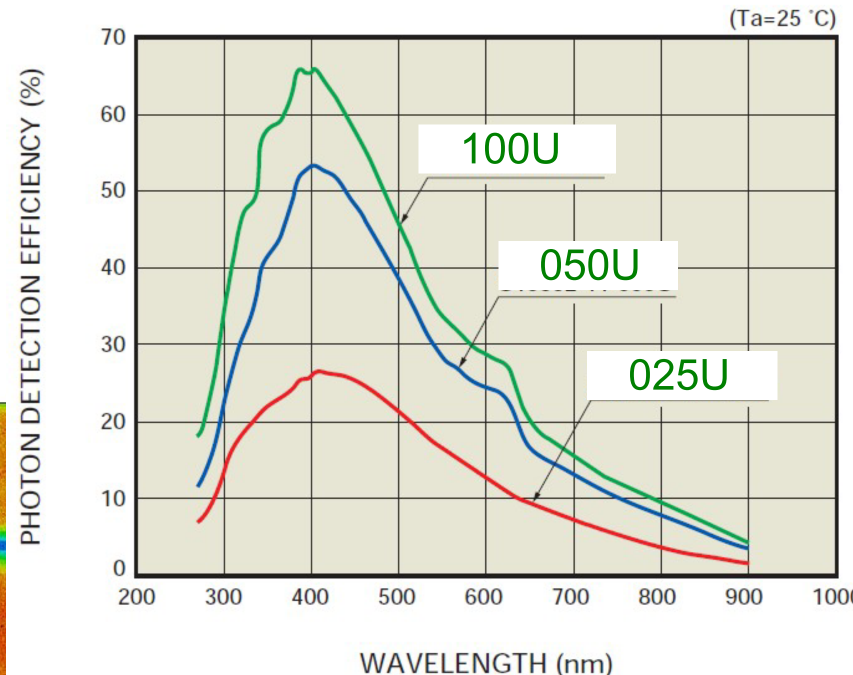
1 mm

SiPM is an array of APDs operating in Geiger mode. Characteristics:

- low operation voltage ~ 10-100 V
- gain ~ 10^6
- peak PDE up to 65%(@400nm)

  PDE = QE x ε_{geiger} x ε_{geo}
- ε_{geo} – dead space between the cells
- time resolution ~ 100 ps
- works in high magnetic field
- dark counts ~ few 100 kHz/mm^2
- radiation damage (p,n)





Hamamatsu MPPC: S10362-11

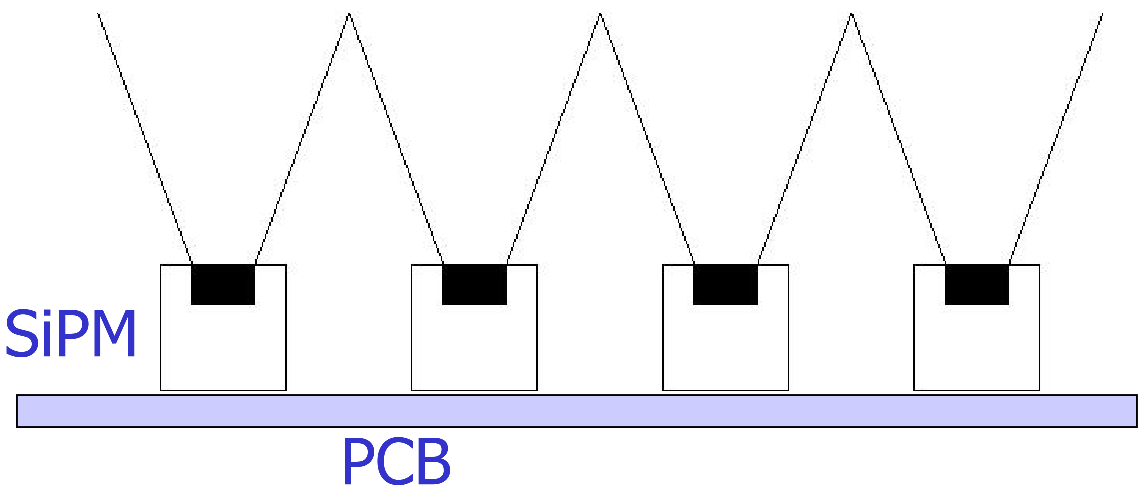
Can such a detector work?

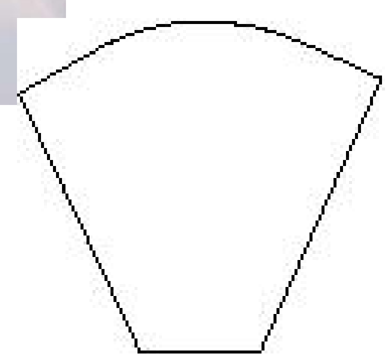
Improve the signal to noise ratio:

•Reduce the noise by a narrow (<10ns) time window

•Increase the number of signal hits per single sensor by using light collectors and by adjusting the pad size to the ring thickness

E.g. light collector with reflective walls





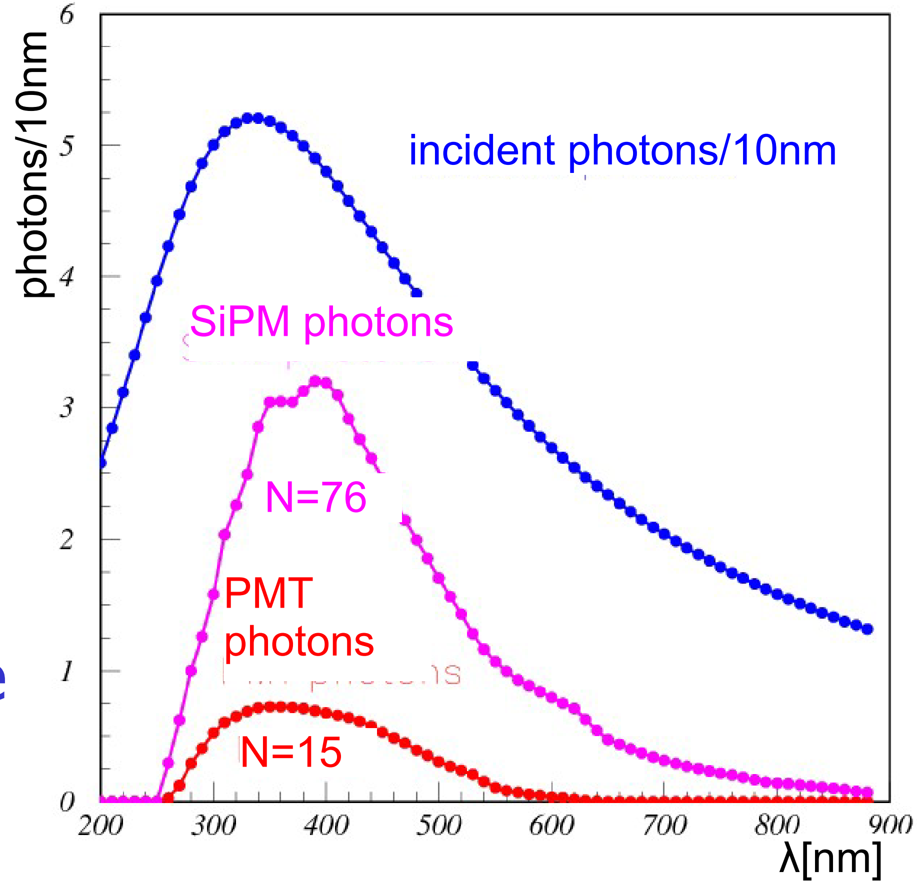
or combine a lens and mirror walls

Expected number of photons for aerogel RICH

with multianode PMTs or SiPMs(100U), and
aerogel radiator: thickness 2.5 cm, n = 1.045
and transmission length (@400nm) 4 cm.

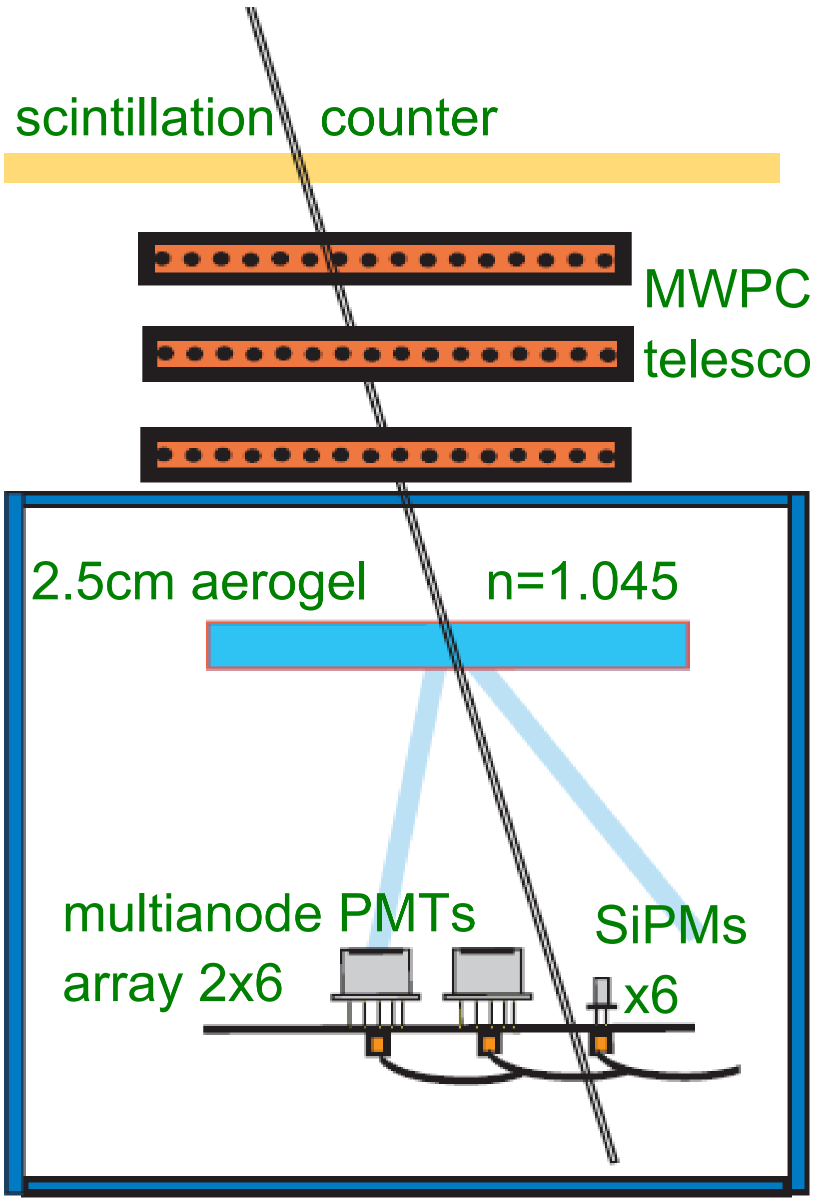
N_{SiPM}/N_{PMT}~5

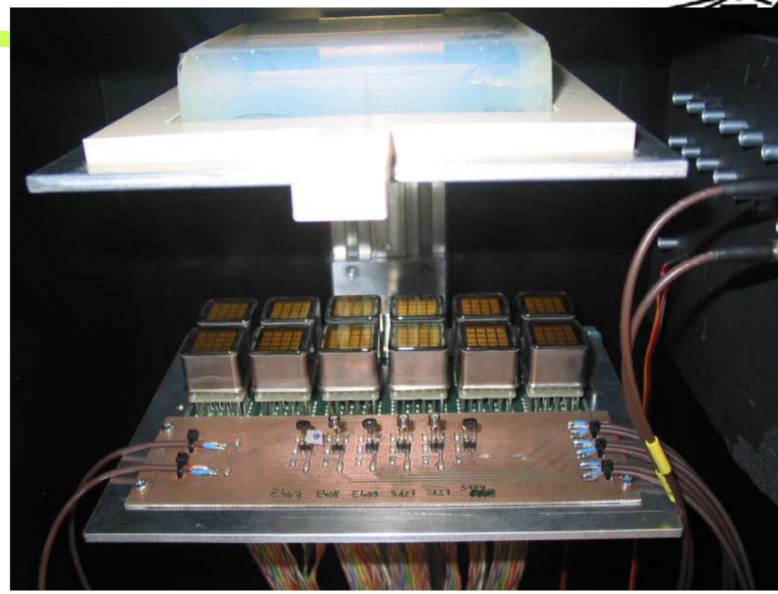
Assuming 100% detector active area



Never before tested in a RICH where we have to detect single photons. ← Dark counts have single photon pulse heights (rate 0.1-1 MHz)

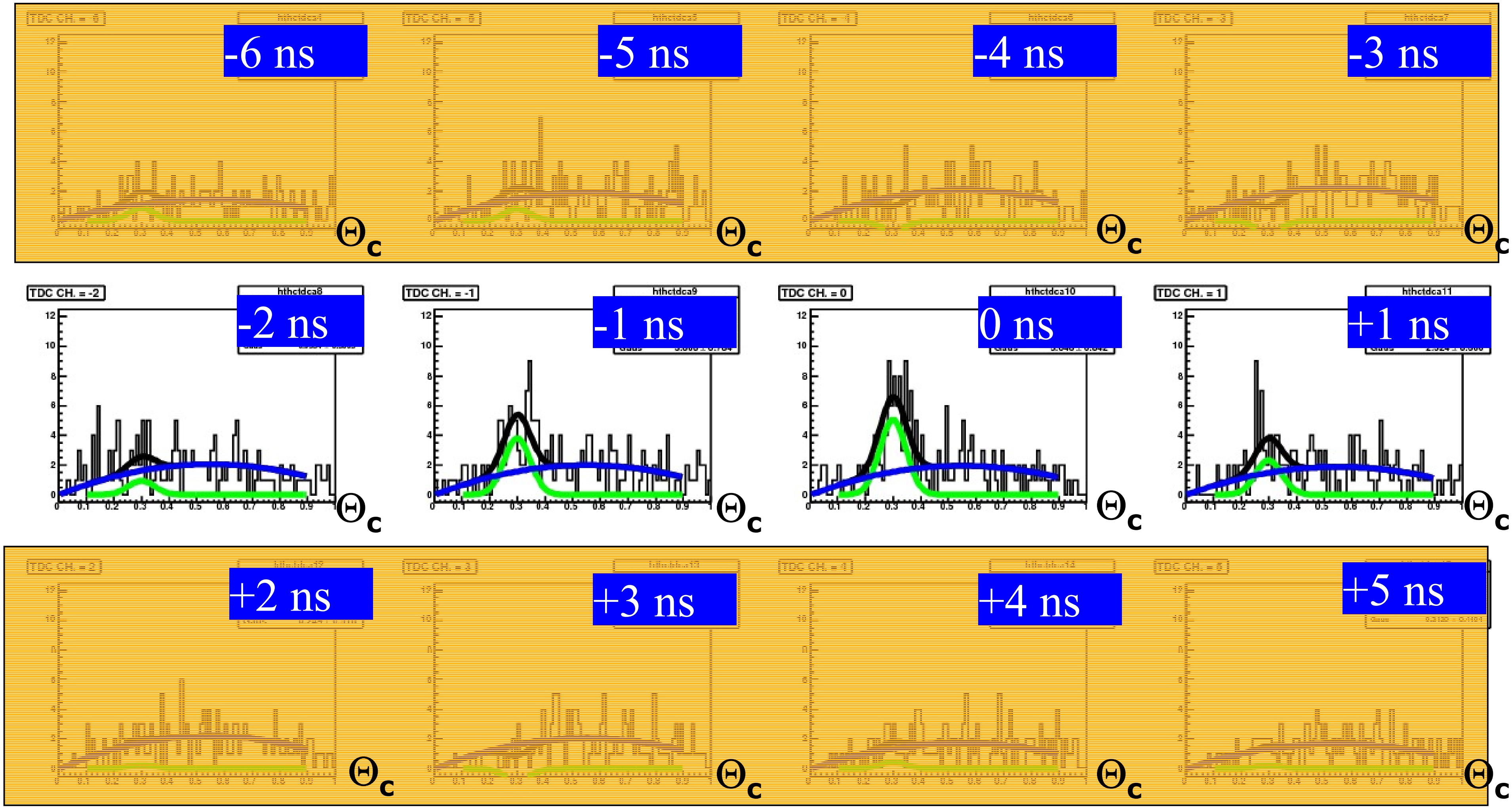
Cosmic test setup





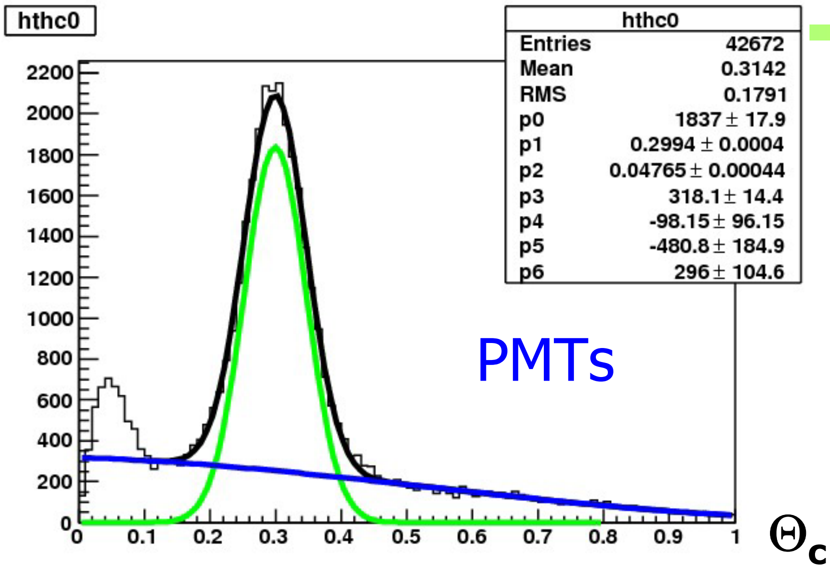
- 6 Hamamatsu SiPMs used:
  - 2x 100U; background ~400kHz
  - 2x 050U; background ~200kHz
  - 2x 025U; background ~100kHz
- signals amplified (ORTEC FTA820),
- discriminated (EG&G CF8000) and
- read by multihit TDC (CAEN V673A) with 1 ns / channel

SiPM: Cherenkov angle distributions for 1ns time windows

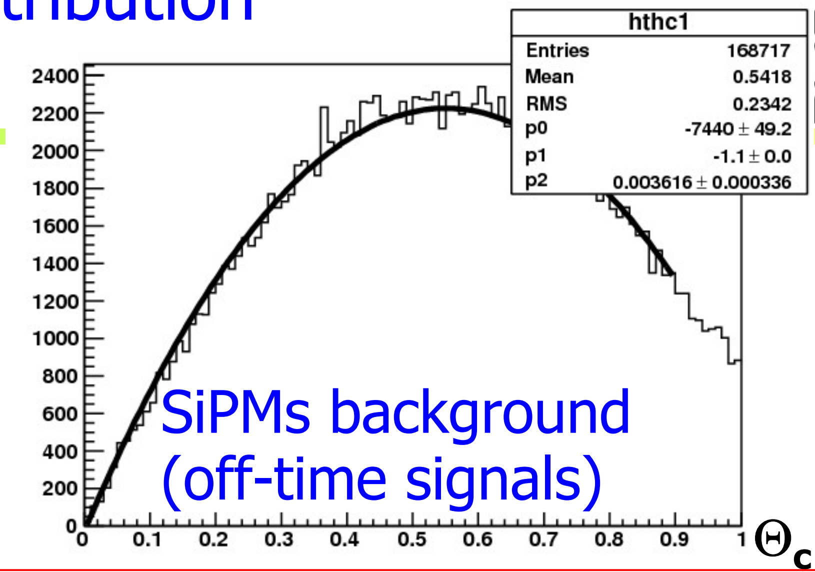


Cherenkov photons appear in the expected time windows →
First Cherenkov photons observed with SiPMs!

SiPM Cherenkov angle distribution



+

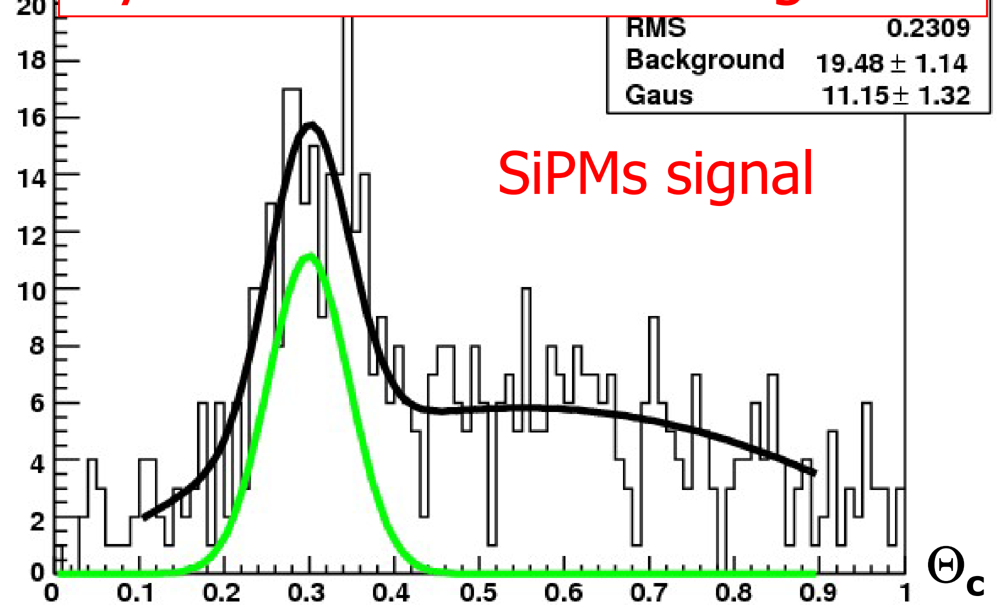


Fit function is a combination of

- a background (quadratic) and
- a signal (Gaussian).

Only scale parameters are free – others fixed.

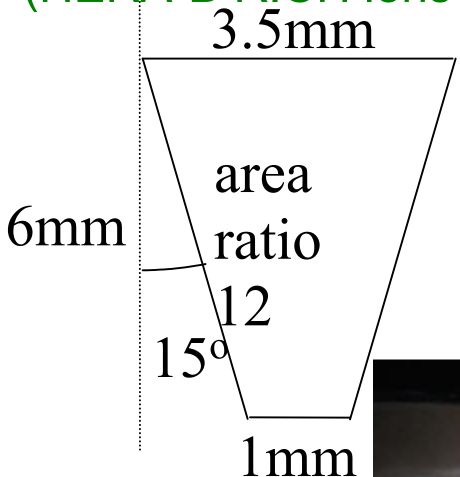
N.B. Signal/noise will improve by x3 with better tracking!

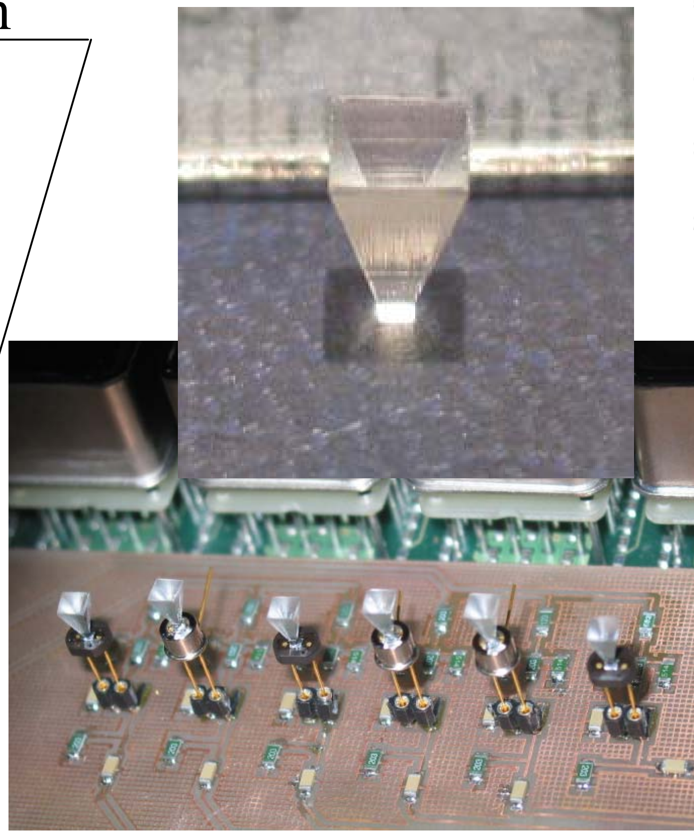


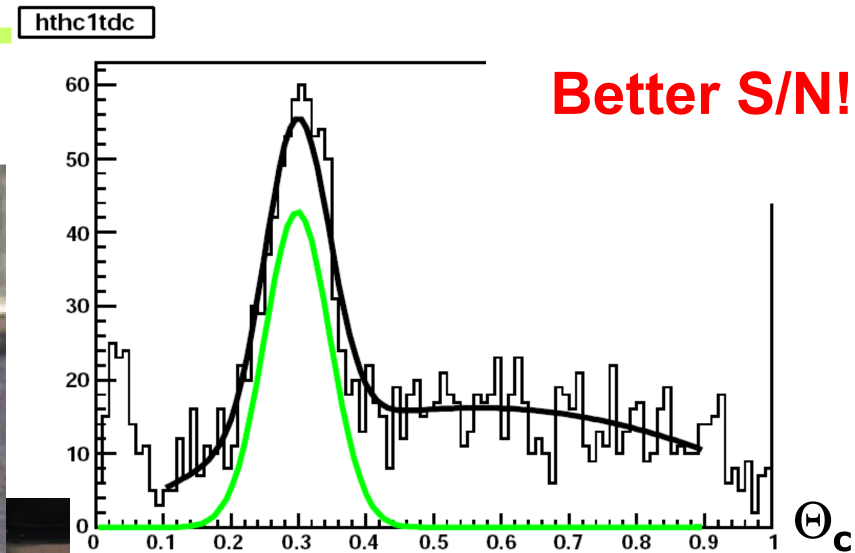
→ SiPMs give 4 x more photons than PMTs per photon detector area – in agreement with expectations

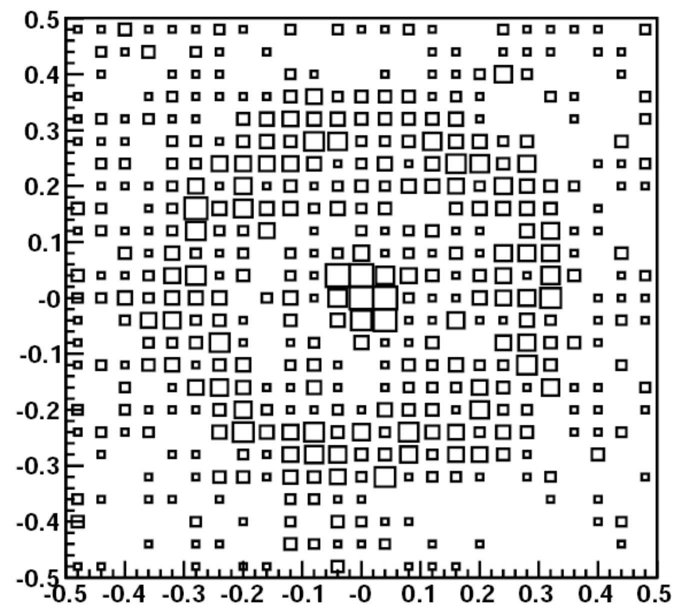
Cherenkov photons with light collectors

Machined from a plastic plate (HERA-B RICH lens material).





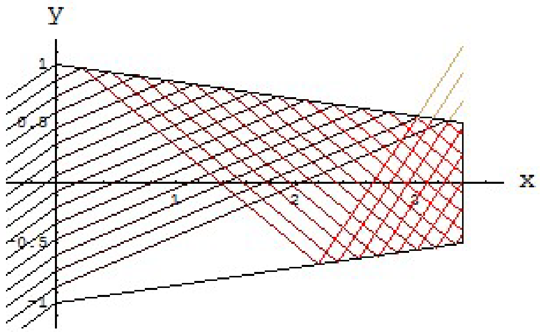


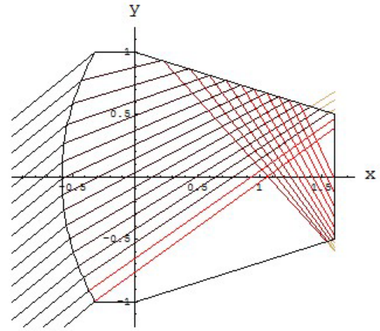


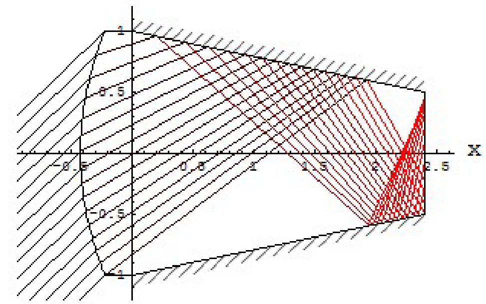
- in agreement with the expectations
- Further improvements possible by
  - reducing the epoxy protective layer
  - using better light collector

Accumulated rings in Cherenkov space

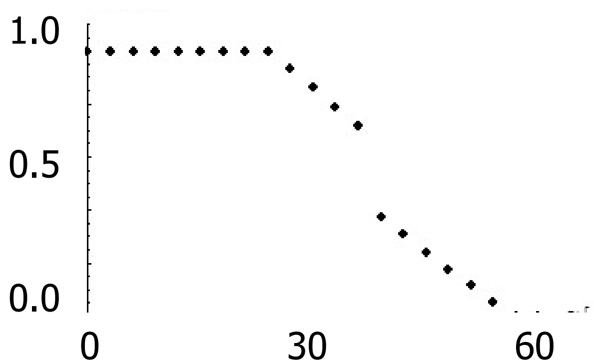
Planar entry window | **Spherical entry window** | **Spherical entry window, reflective sides**

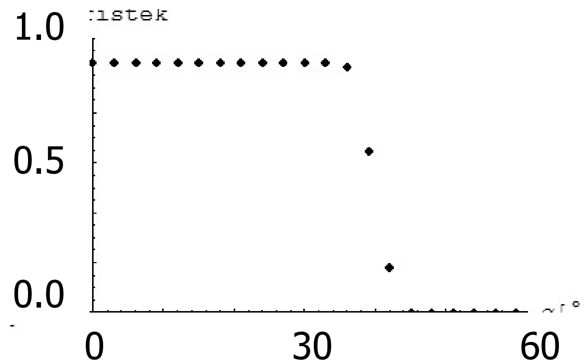


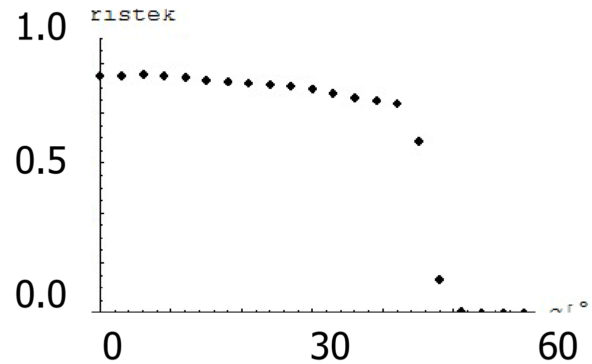




Efficieny vs. angle of incidence α



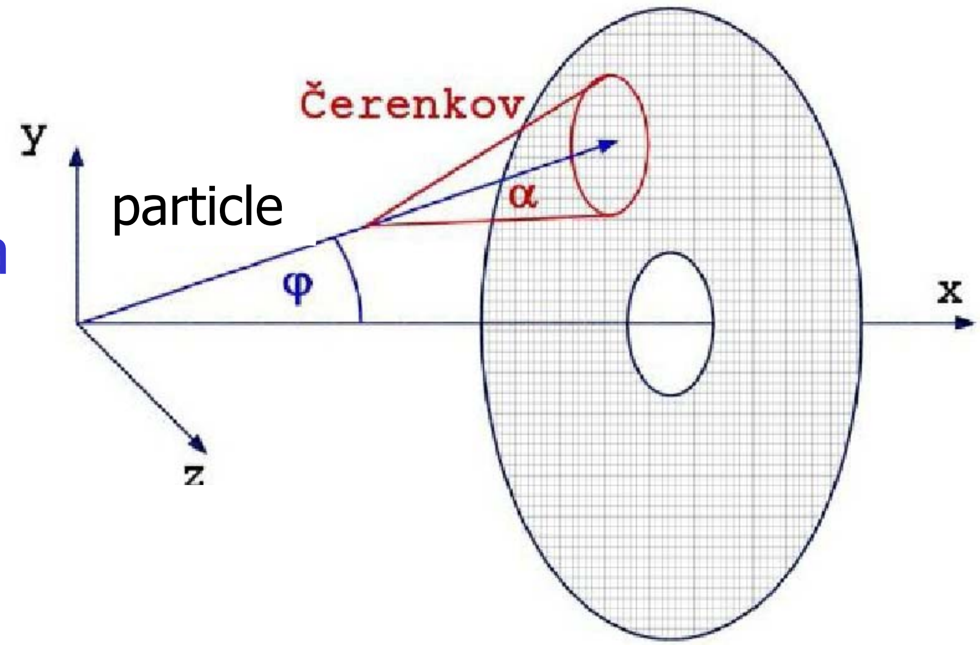


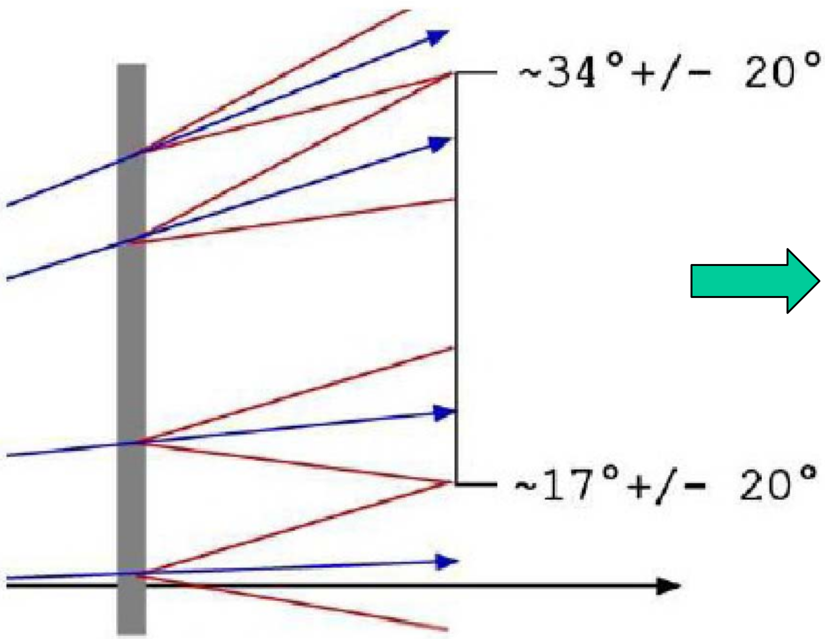


Light guide	d/a	R/a	α_{min} , α_{max}	I(-60°, 60°)
Planar entry	**3.4**	**-**	**–24°, 24°**	**64%**
Sph. entry	**1.6**	**2.0**	**–35°, 35°**	**66%**
Reflective sides	**2.4**	**2.6**	**–44°, 44°**	**69%**

Light collection: required angular range

For our application only a limited angular range of incident has to be covered at a given position on the detector



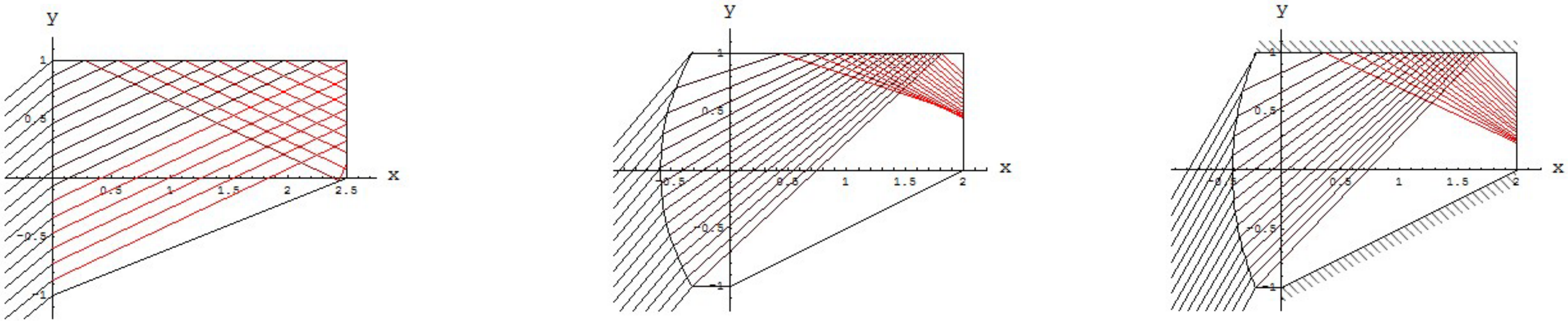


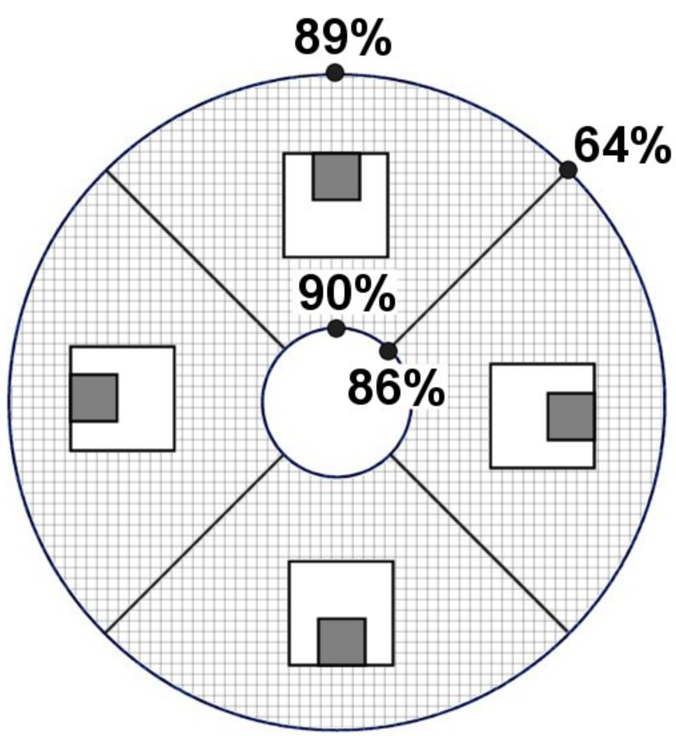
~ -3°... 54°

→ Take this asymmetry into account when designing the light collection system.

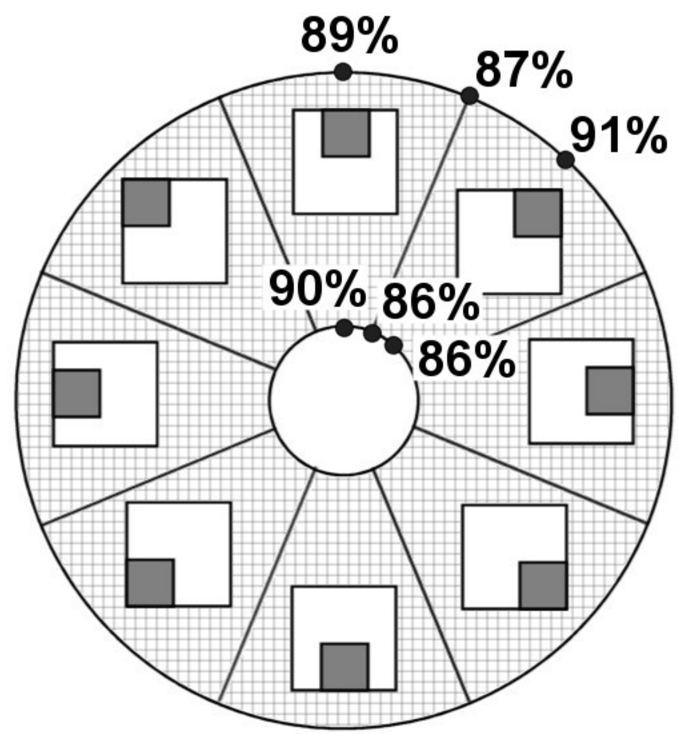
Peter Križan, Ljubljana

Slanted light collectors



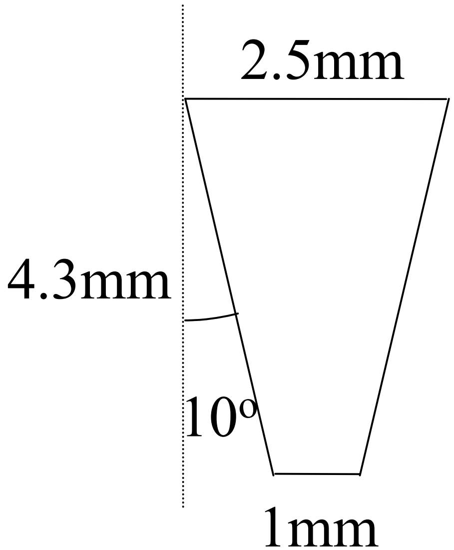


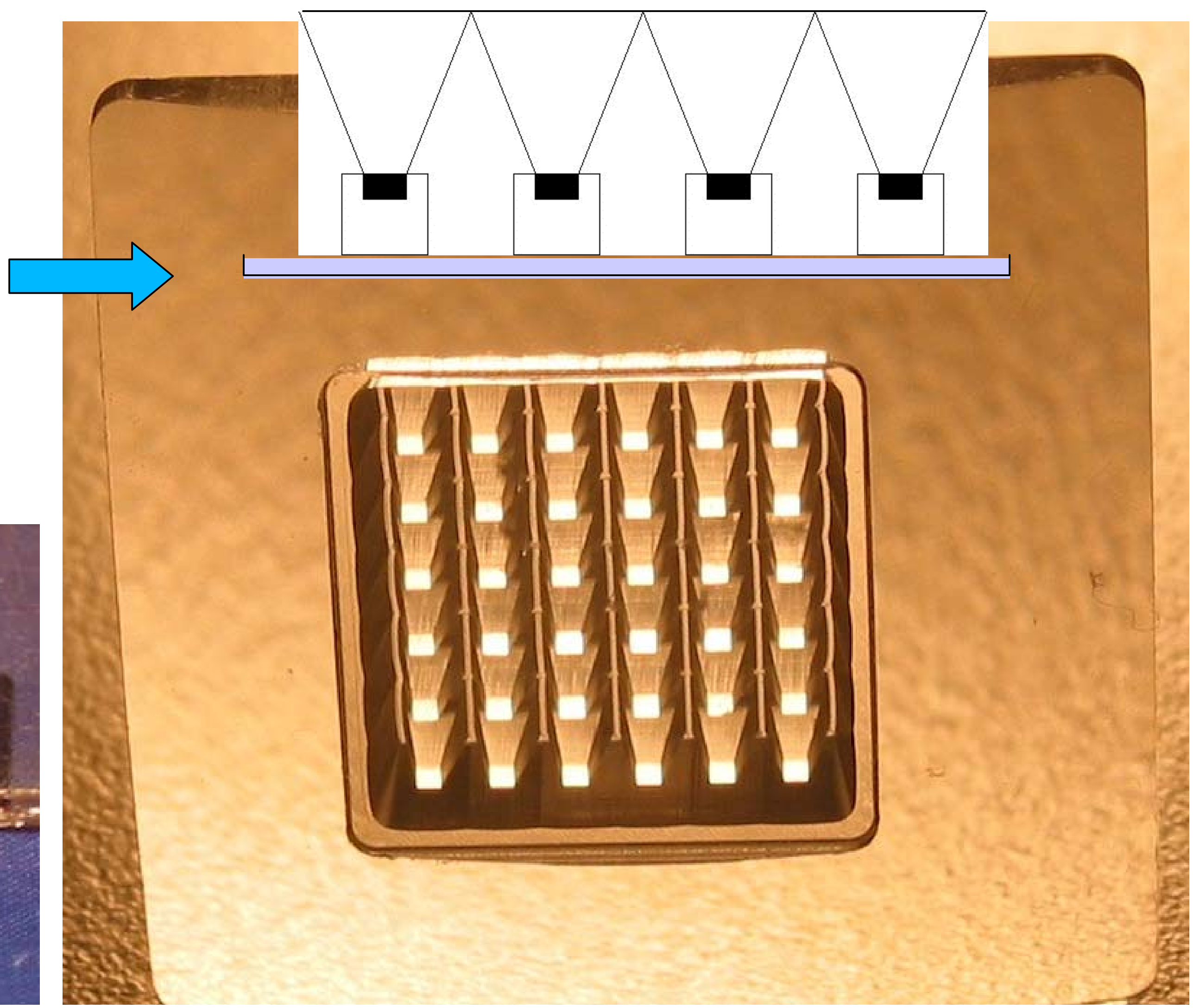
Design with a single light guide type

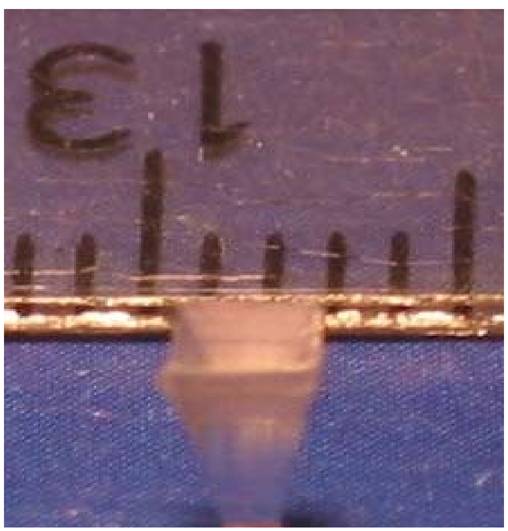


Design with a two light guide types

Detector module design





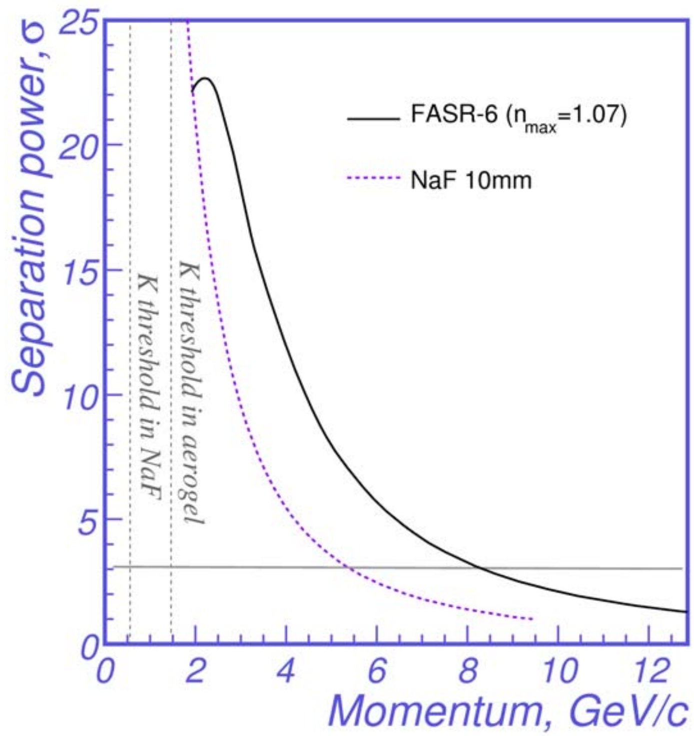


A multi-channel module is being prepared for a beam test in June

Proximity focusing RICH with NaF as radiator

Radiator revisited: NaF

π/K separation



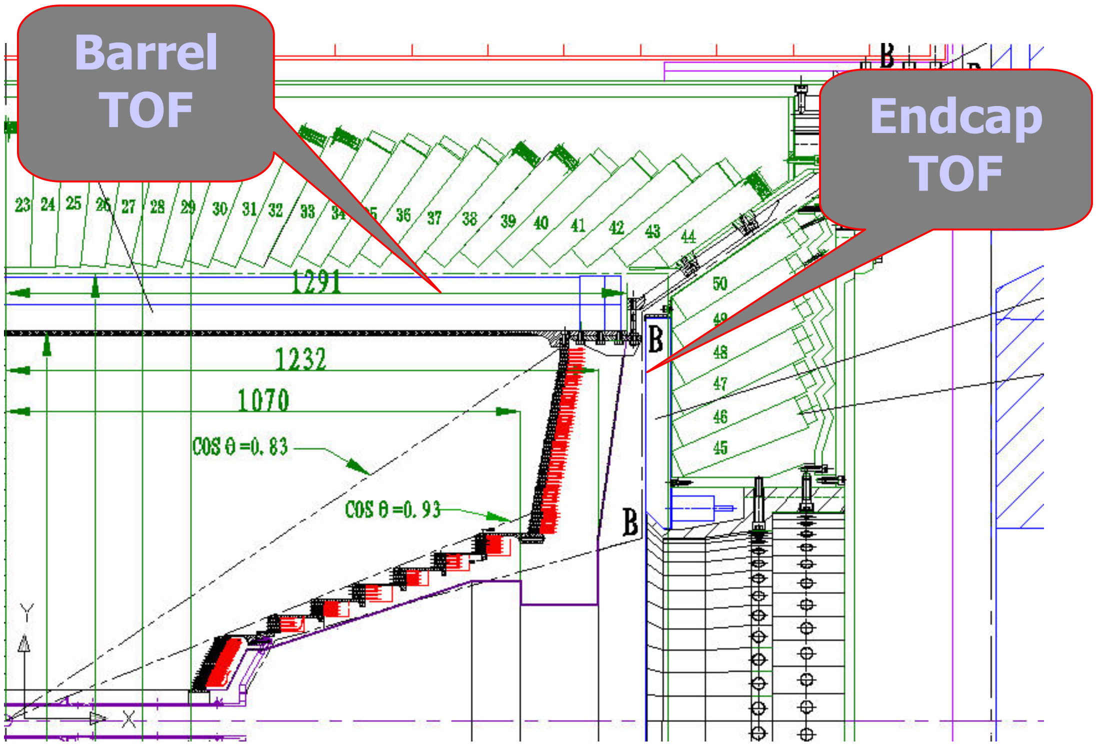
Instead of aerogel use 1cm of NaF, assume biakali PMTs as photon detector:

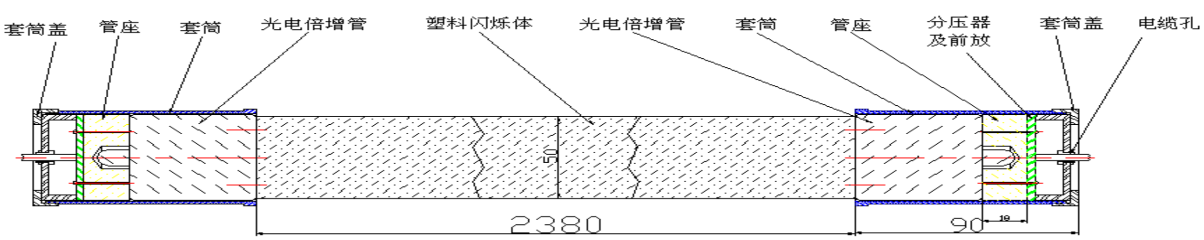
- Higher refractive index → lower Cherenkov threshold
- More photons
- Worse single photon resolution
- Partly compensated, resolution per track somewhat worse than with aerogel
- But: more material in front of ECAL

→S. Kononov et al. VCI2007 NIM A581 (2007) 410

BESIII: Time-Of-Flight counters

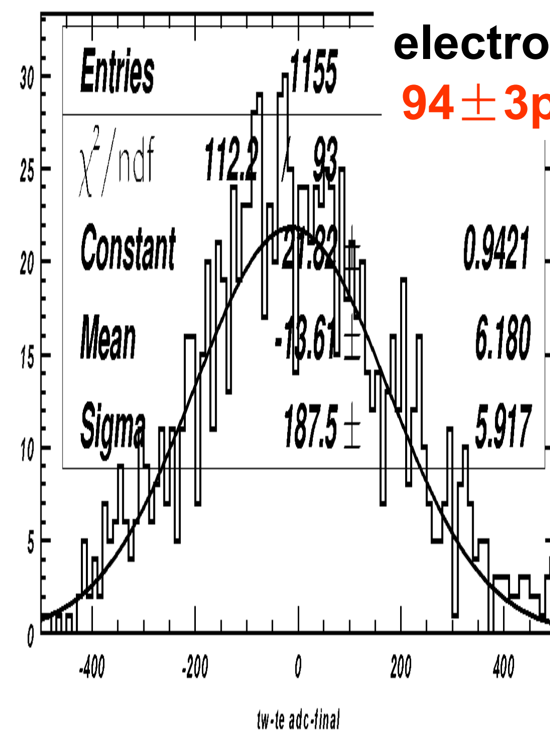
Barrel TOF: two scintillator rings to improve time resolution





TOF module: high quality plastic scintillator: 2.4 m long, 5cm thick, two PMTs with preamplifiers

Beam test results: two TOF modules



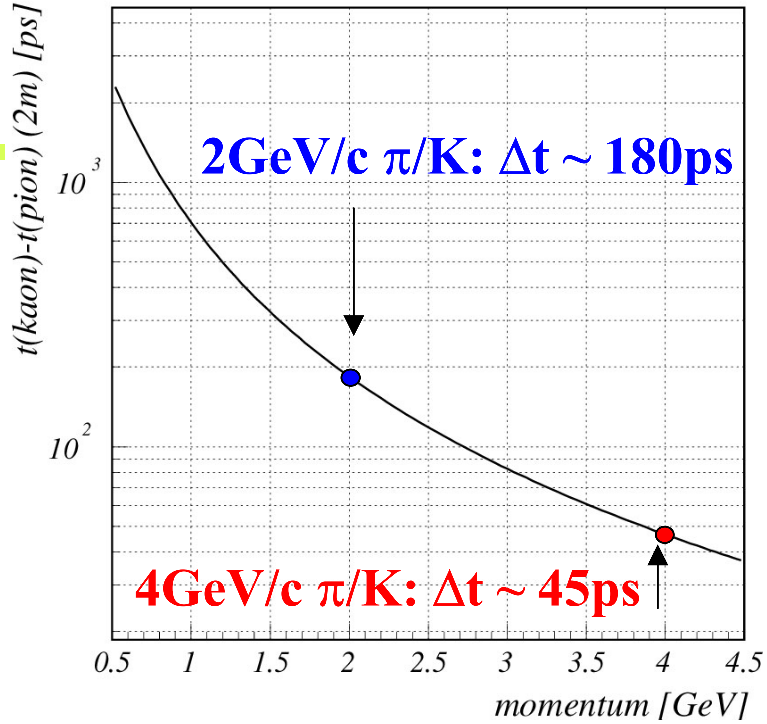
electrons
94±3ps

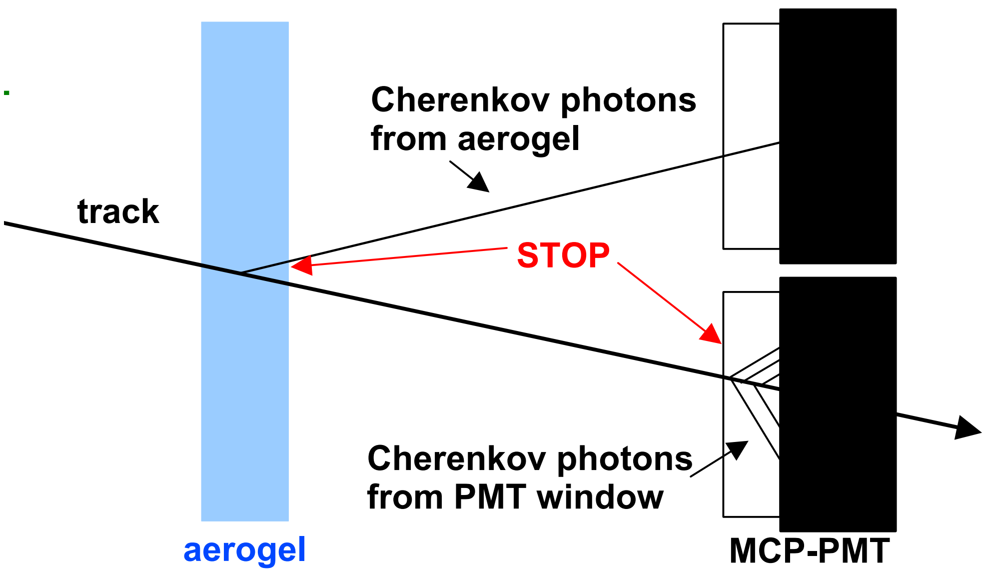
→ talk by B. Yu

TOF capability of a RICH

With a fast photon detector (MCP PMT), a proximity focusing RICH counter can be used also as a time-of-flight counter.

Time difference between π and K →





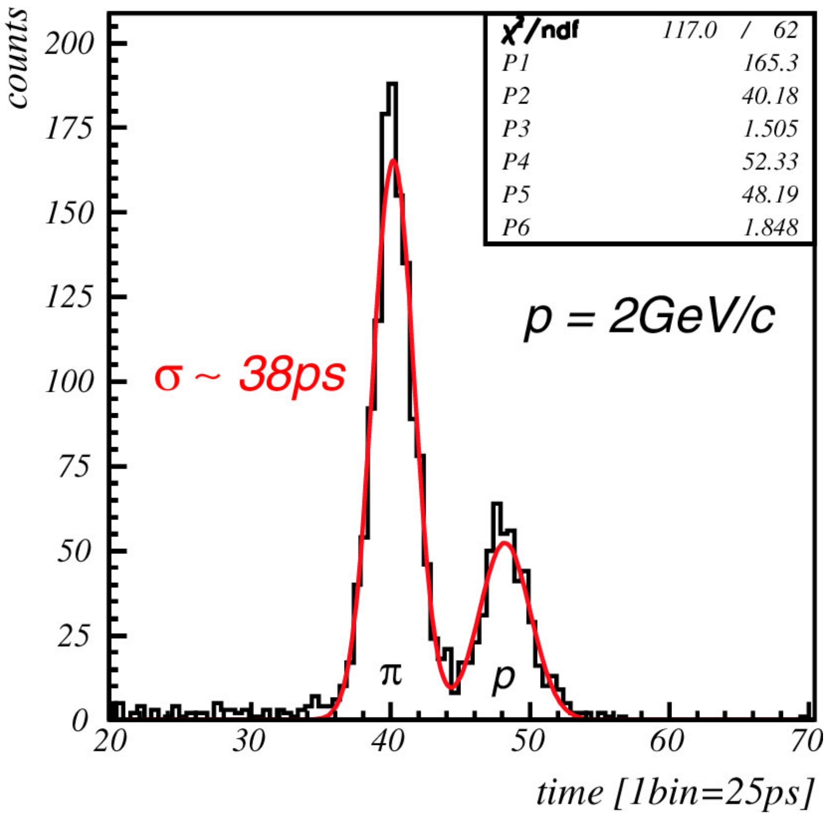
Cherenkov photons from two sources can be used:

- photons emitted in the aerogel radiator
- photons emitted in the PMT window

TOF capability: window photons

Expected number of detected Cherenkov photons emitted in the PMT window (2mm) is ~15

→ Expected resolution ~35 ps



TOF test with pions and protons at 2 GeV/c.

Distance between start counter and MCP-PMT is 65cm

→ In the real detector ~2m

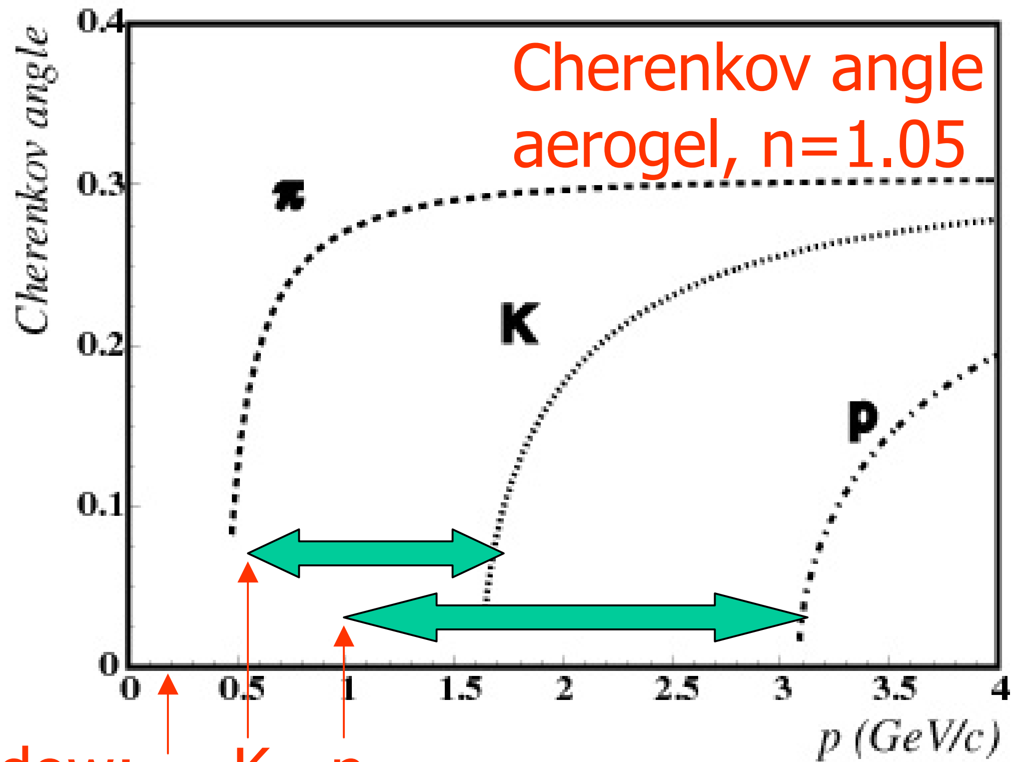
→ 3x better separation

NIM A572 (2007) 432

Time-of-flight with photons from the PMT window

Benefits: Čerenkov threshold in glass (or quartz) is much lower than in aerogel.

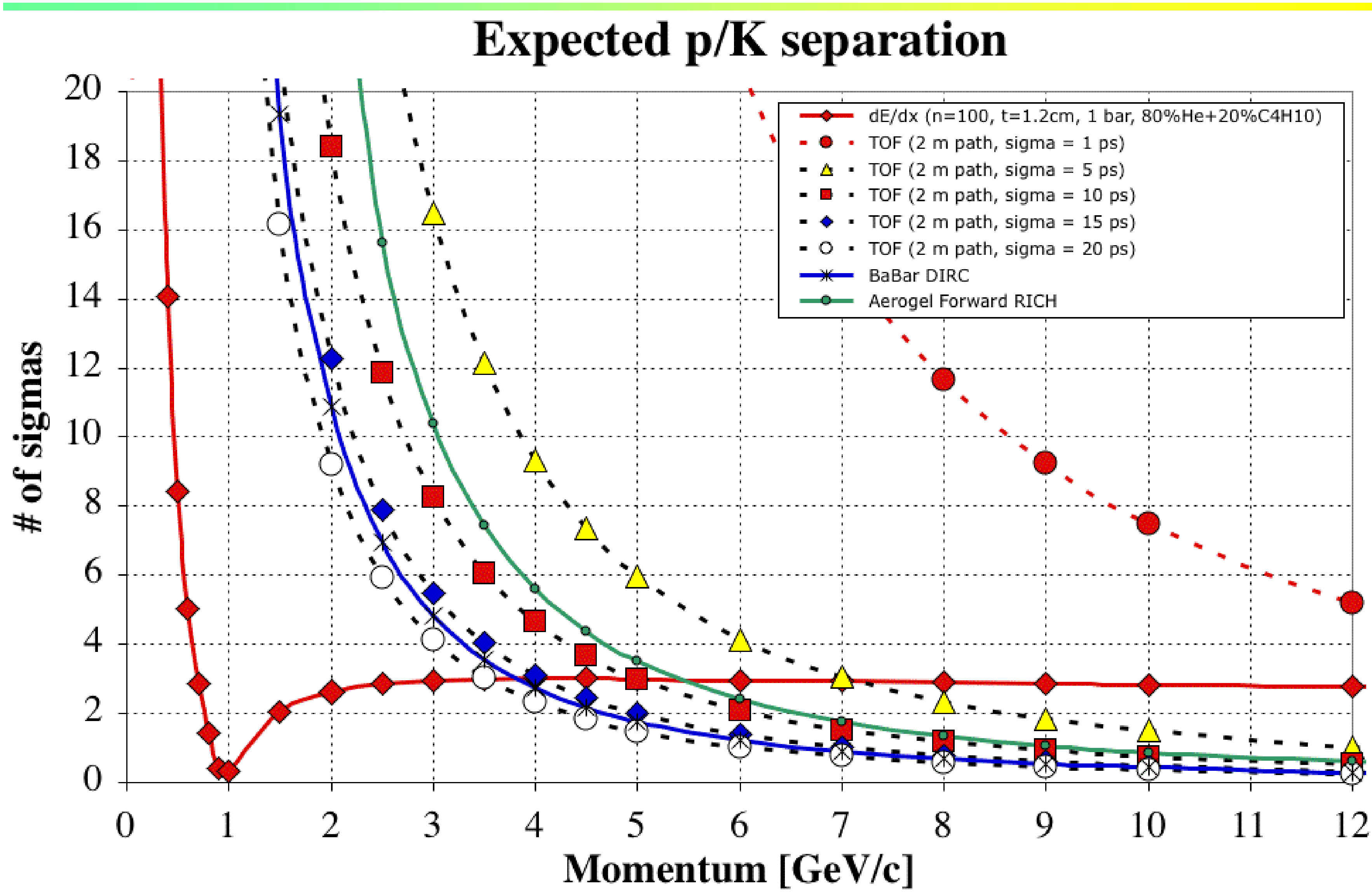
Aerogel: kaons (protons) have no signal below 1.6 GeV (3.1 GeV): identification in the veto mode.



Threshold in the window: π K p

Window: threshold for kaons (protons) is at ~0.5 GeV (~0.9 GeV): → positive identification possible.

Time-of-flight: stand-alone, revisited

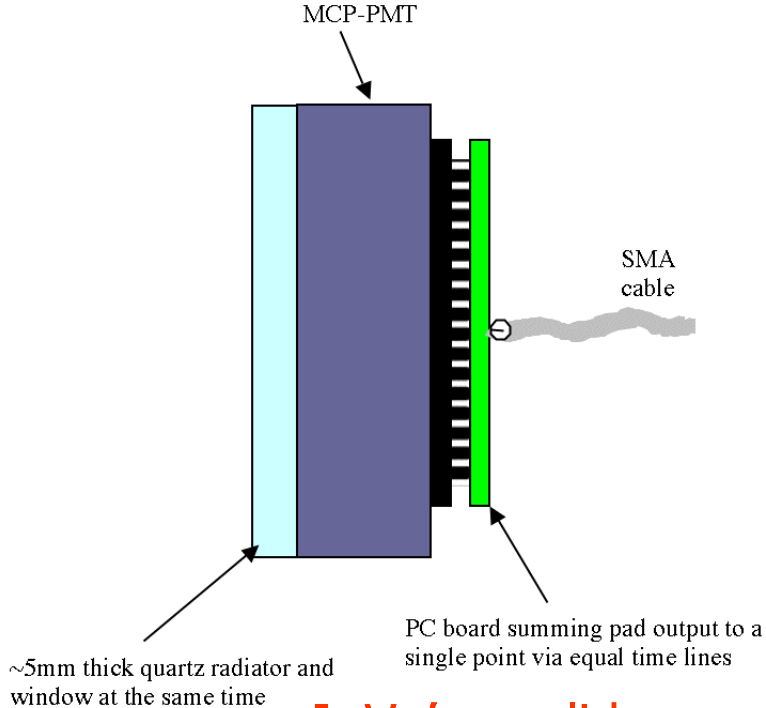


J. Va'vra, slides shown at RICH07

Time-of-flight: stand-alone, revisited

New ingredients:

- Faster photon detectors
- Use of Cherenkov light instead of scintillation photons
- Faster electronics



J. Va'vra, slides shown at RICH07

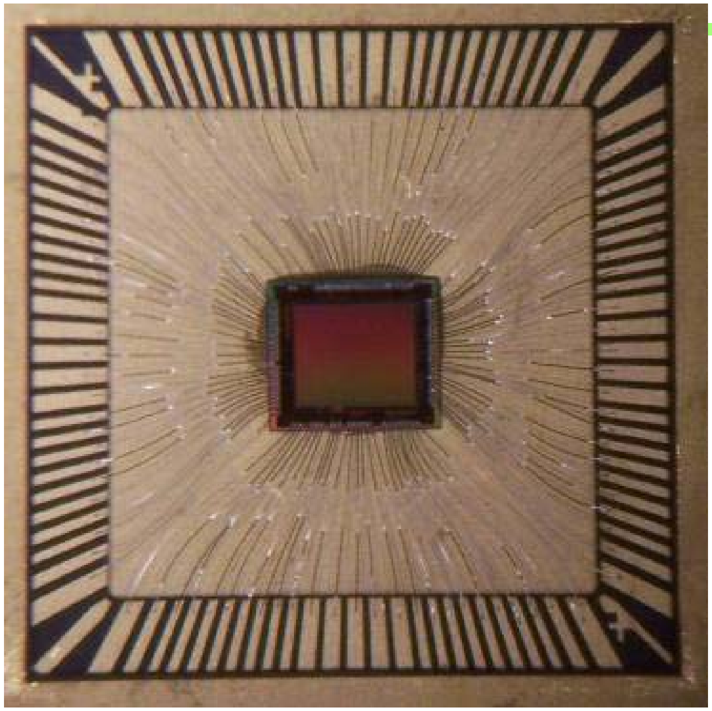
Recent results:

→resolution ~5ps measured

- K. Inami NIMA 560 (2006) 303
- J. Va'vra (RICH07)

Open issues: read-out, start time

Read out: Buffered LABRADOR (BLAB1) ASIC



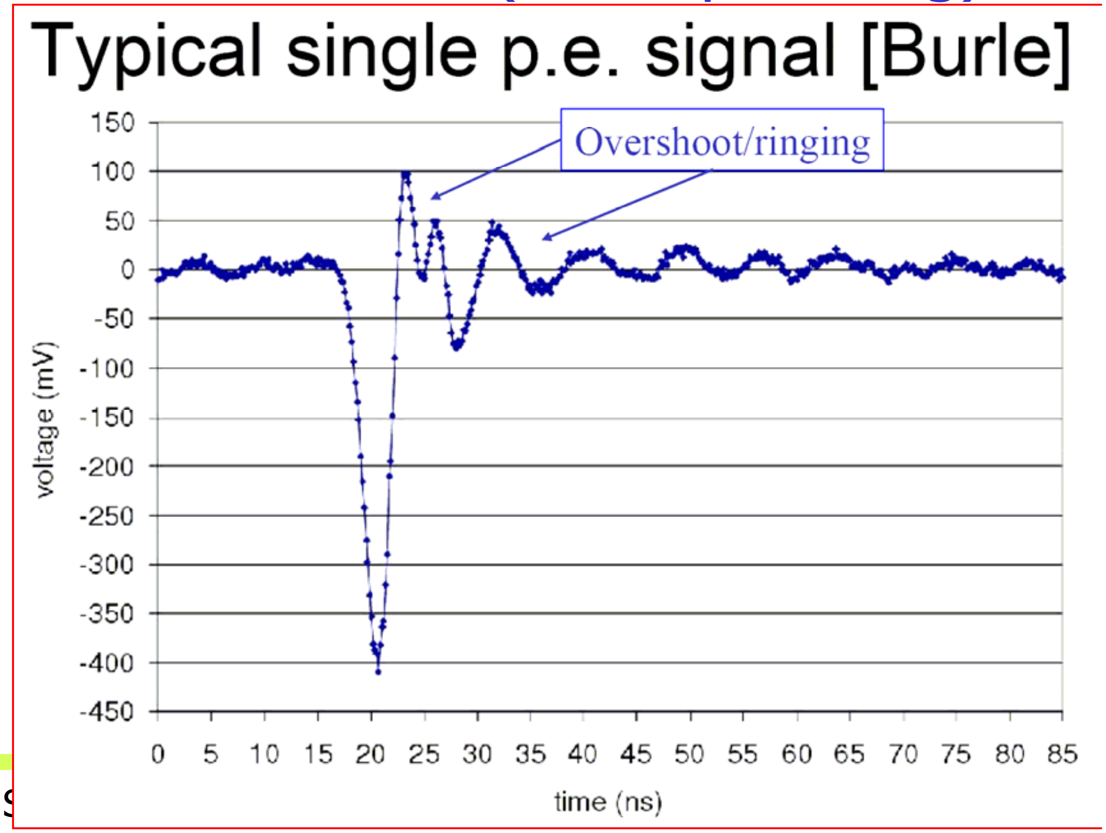
Gary Varner, Larry Ruckman (Hawaii)

Variant of the LABRADOR 3

Successfully flew on ANITA in Dec 06/Jan 07 (<= 50ps timing)

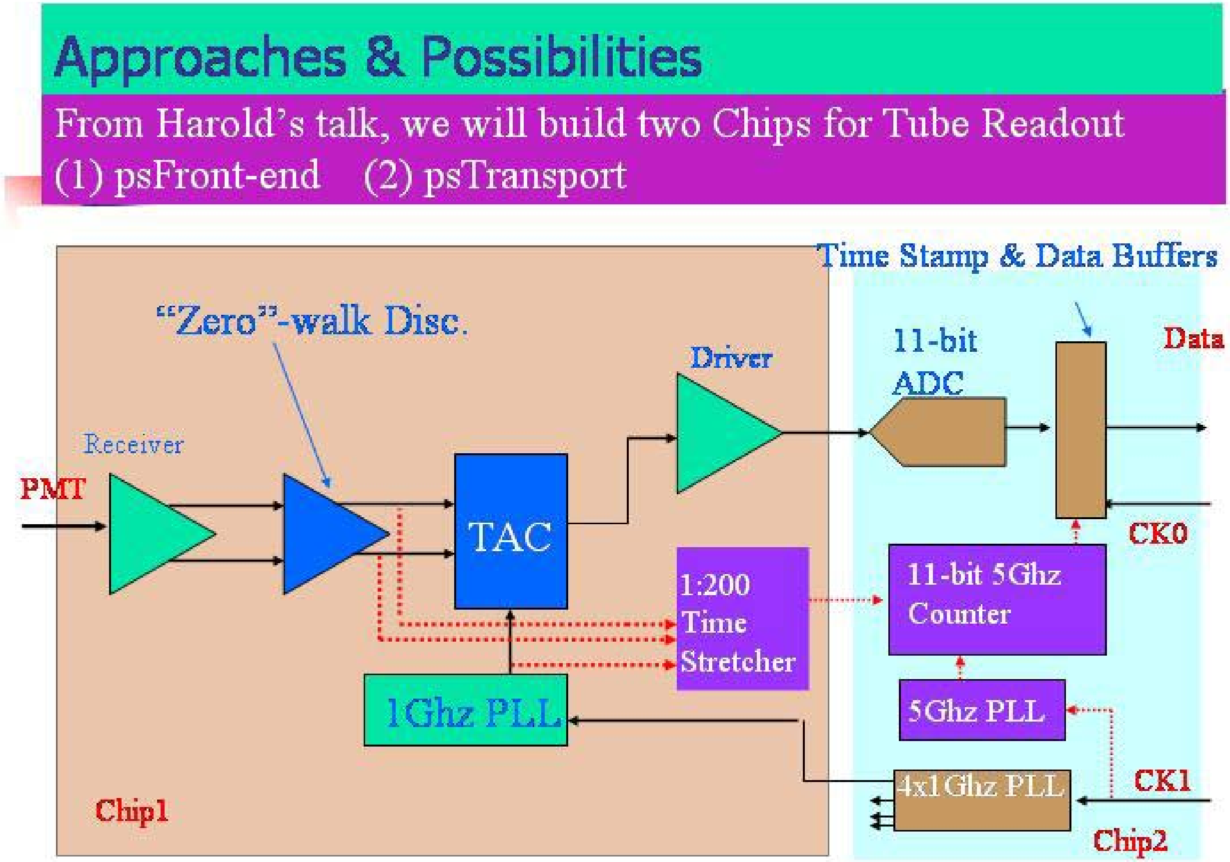
3mm x 2.8mm, TSMC 0.25um

- 64k samples deep
- Multi-MSa/s to Multi-GSa/s



Effort to develop ps TOF counter

H. Frisch & H. Sanders, Univ. of Chicago, K. Byrum, G. Drake, Argonne lab



- ASIC-based technology for a new CFD & TDC

Summary

Particle identification is an essential part of several experiments, and has contributed substantially to our present understanding of elementary particles and their interactions.

RICH counters have evolved to a standard and reliable tool in experimental particle physics.

They will play an essential role in the next generation of B physics experiments at the LHC and SuperB factories, as well as at hadron structure experiments.

New concepts (focusing radiator, combination with time of flight) and new photon detectors are being developed.

With new fast photon detectors there is a revived interest in the time-of-flight measurements, also in combination with a RICH counter.