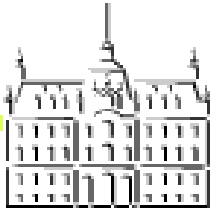
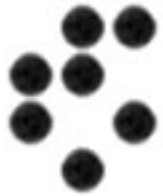




Univerza v Ljubljani

Proximity focusing RICH with TOF capabilities for the Belle upgrade

Peter Križan

University of Ljubljana and J. Stefan Institute

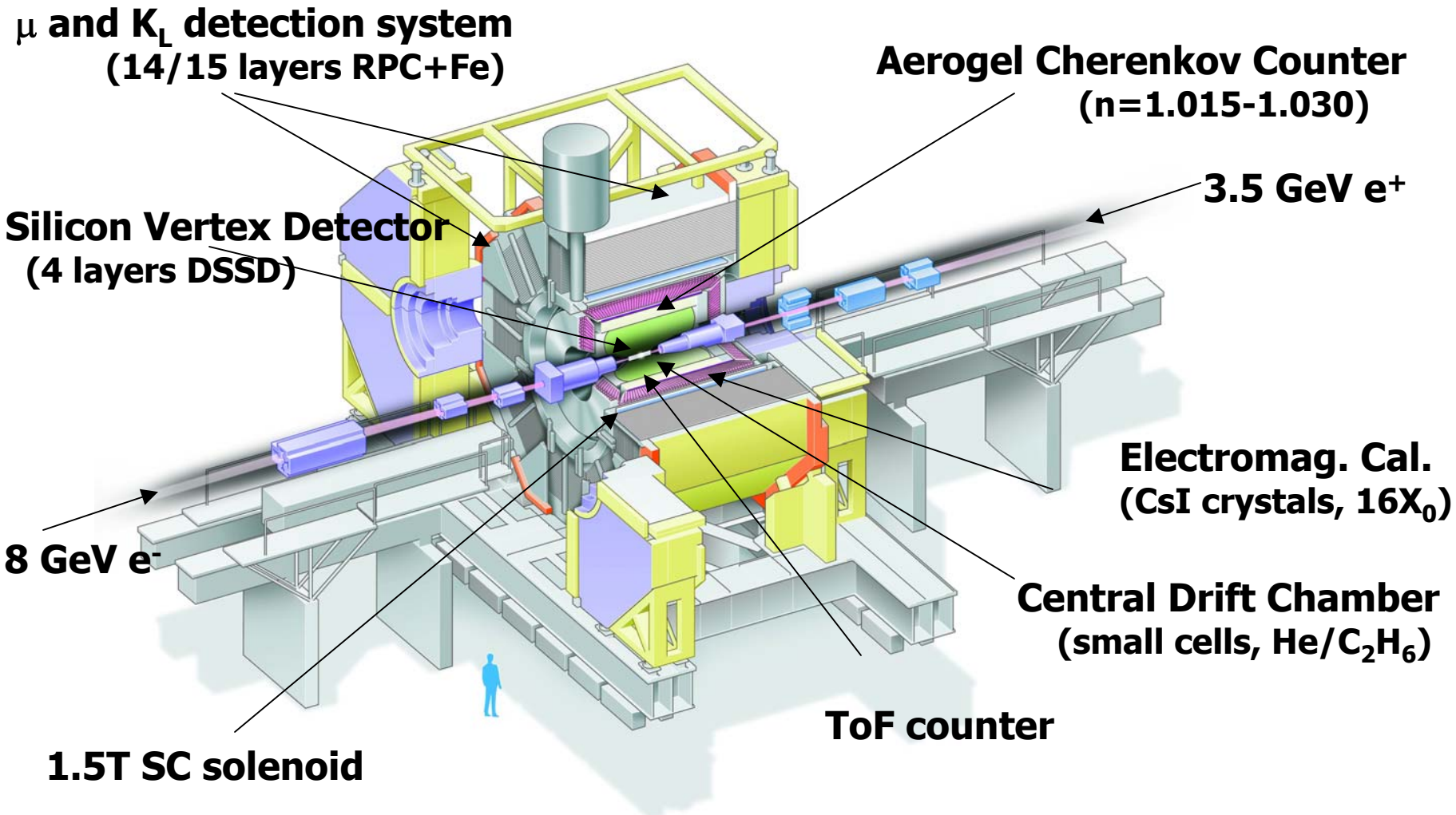
For the Belle Aerogel RICH R&D group

European Physical Society
HEP 2007

EPS HEP 2007, July 19-23 2007,
Manchester, UK

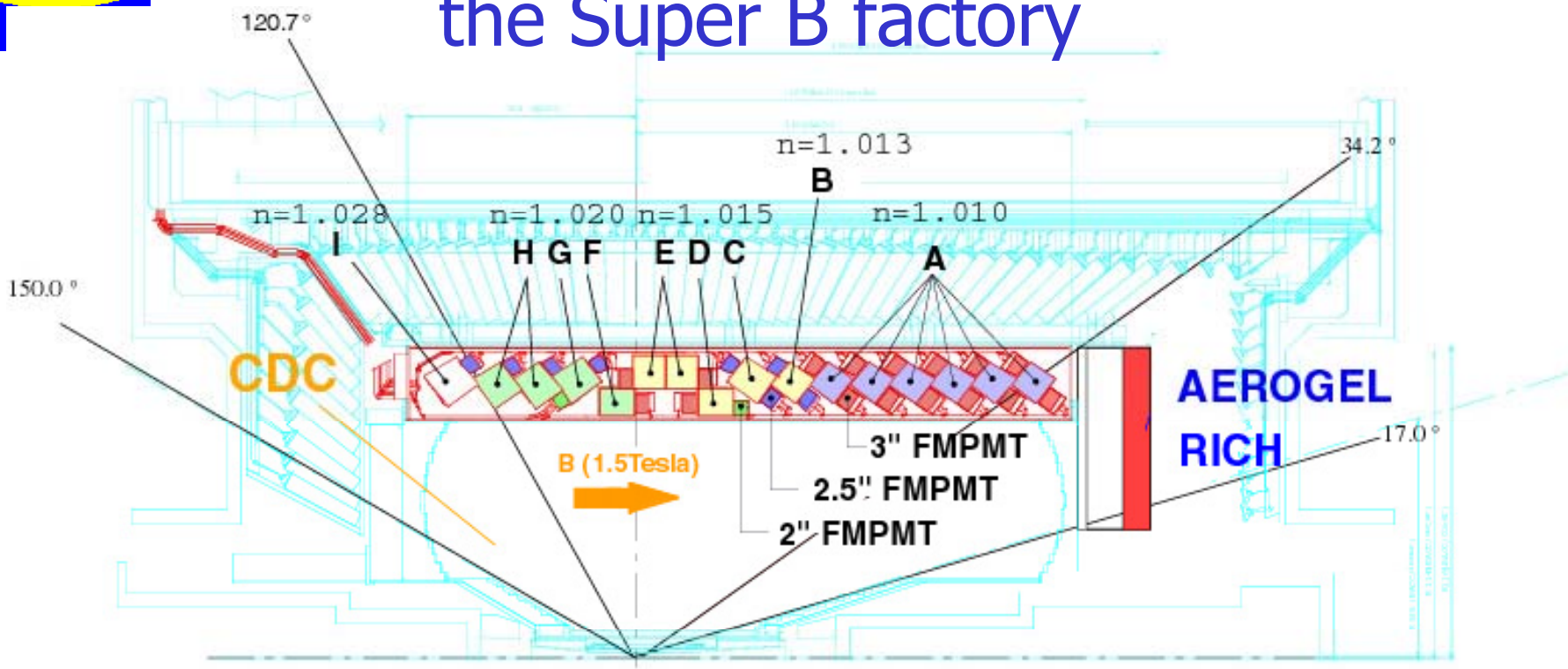
Belle @ KEK-B in Tsukuba

Belle spectrometer at KEK-B



Accumulated data sample ~700 M BB-pairs

PID upgrade in the endcap for the Super B factory



improve K/π separation in the forward (high p) region for few-body decays of B mesons

good K/π separation for b → dγ , b → sγ

improve purity in fully reconstructed B decays

low momentum (<1GeV/c) e/μ/π separation (B → Kll)

keep high the efficiency for tagging kaons

BELLE Aerogel RICH group

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Contents

Introduction, motivation and requirements

Radiator with multiple refractive indices

Time-of-flight measurement with a RICH

Beam tests

Photon detector R+D

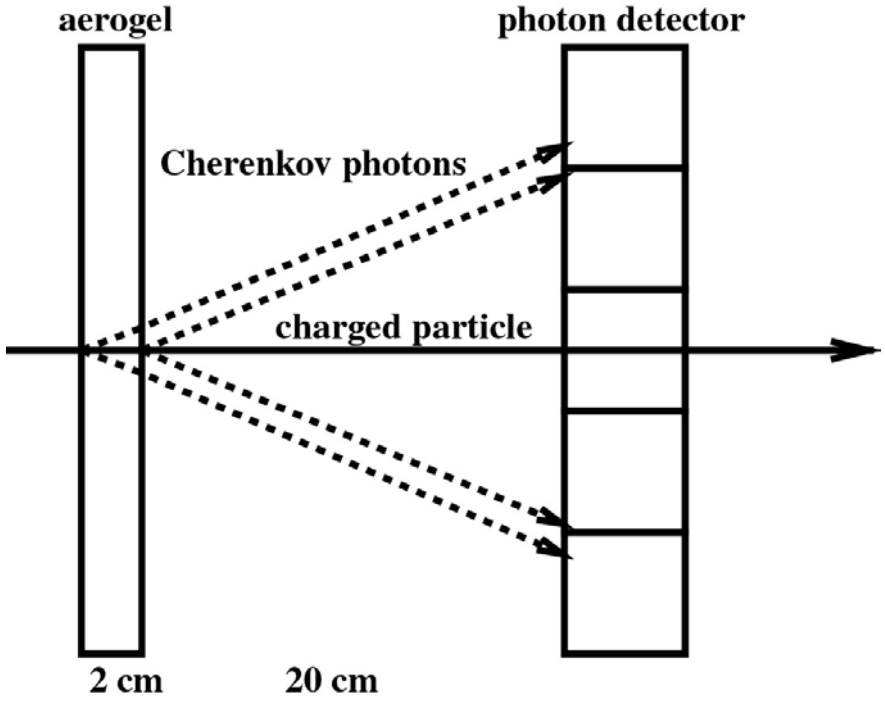
Summary

Proximity focusing RICH in the forward region

Requirements and constraints:

- ~ 5 σ K/π separation @ 1-4 GeV/c
- operation in magnetic field 1.5T
- limited available space ~250 mm

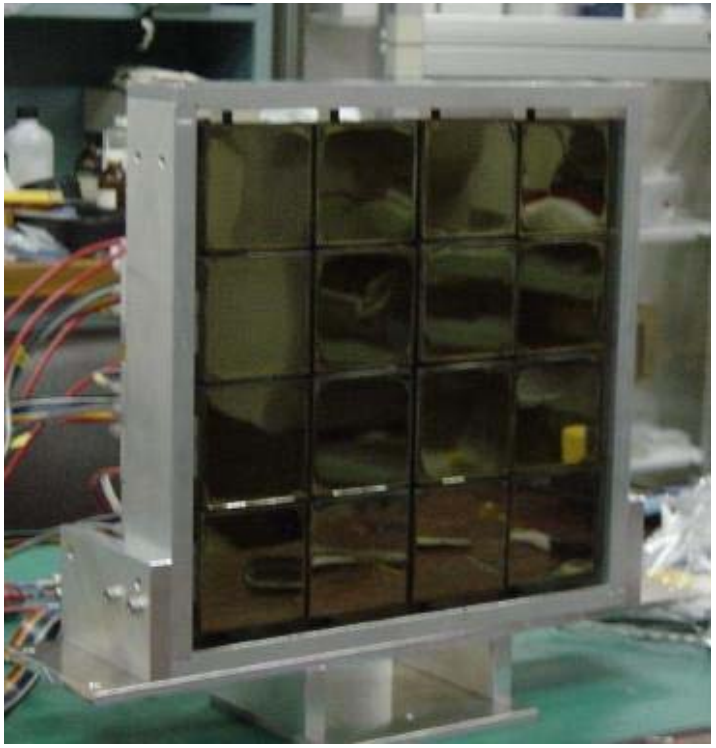
Proximity focusing aerogel RICH



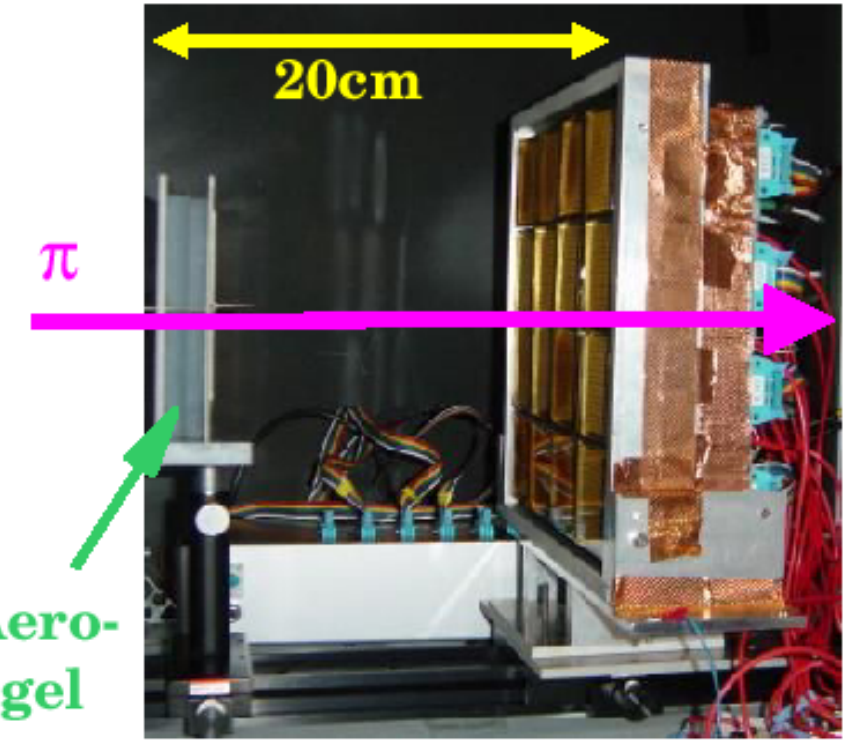
- n = 1.05
- $\theta_c(\pi)$ ~ 308 mrad @ 4 GeV/c
- $\theta_c(\pi) - \theta_c(K)$ ~ 23 mrad
- pion threshold 0.44 GeV/c,
- kaon threshold 1.54 GeV/c

- time-of-flight difference (2m):
  t(K) - t(π) = 180 ps @ 2 GeV/c
  45 ps @ 4 GeV/c

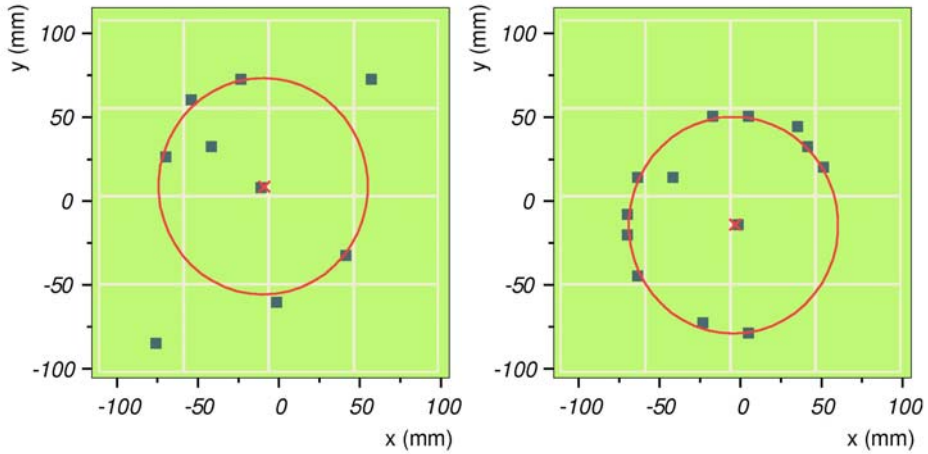
Beam tests



Photon detector: array of 16 H8500 PMTs



Clear rings, little background



Beam tests: Cherenkov angle resolution and number of photons

Beam test results with 2cm thick aerogel tiles:
excellent, >4σ K/π separation

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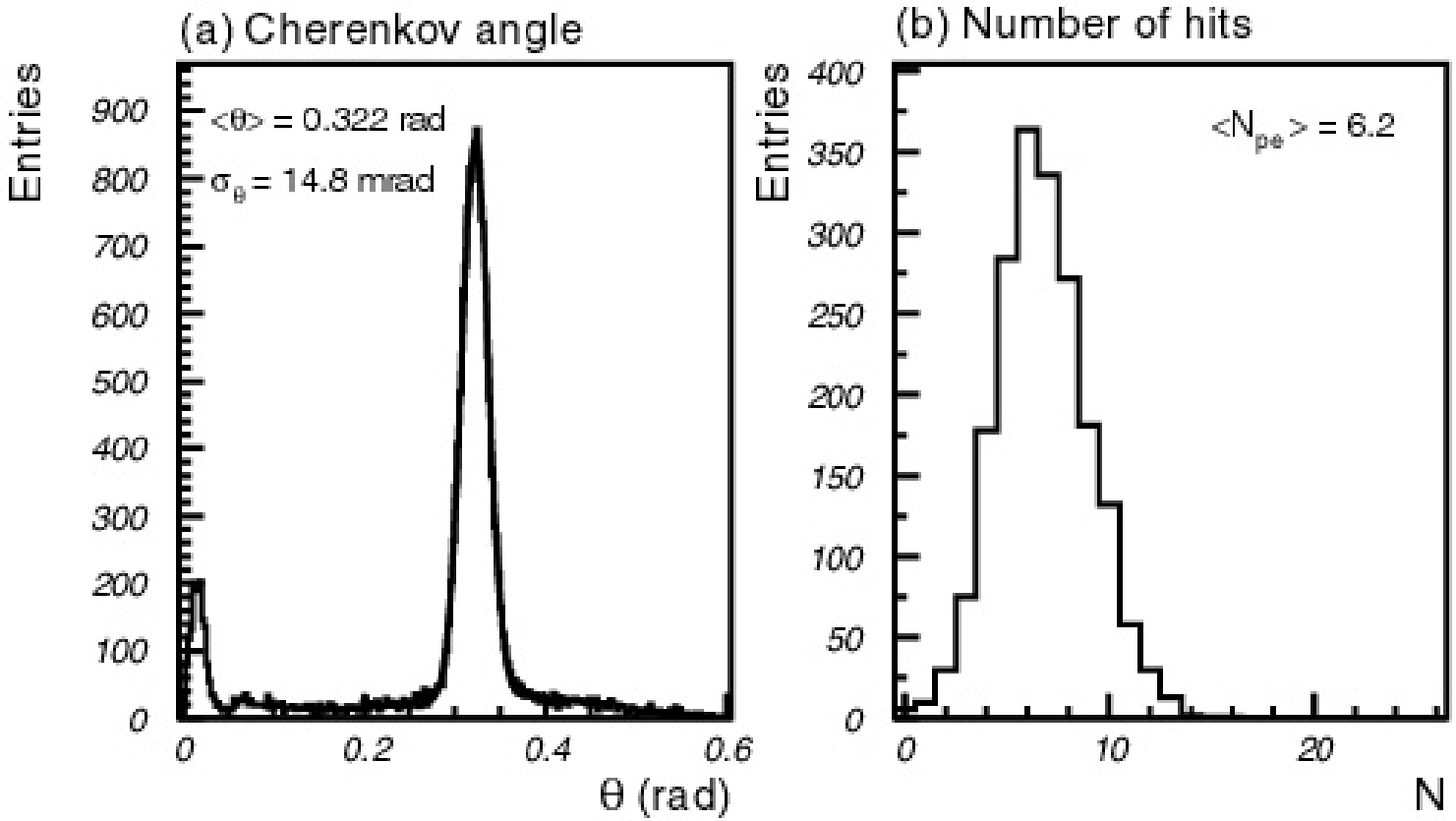
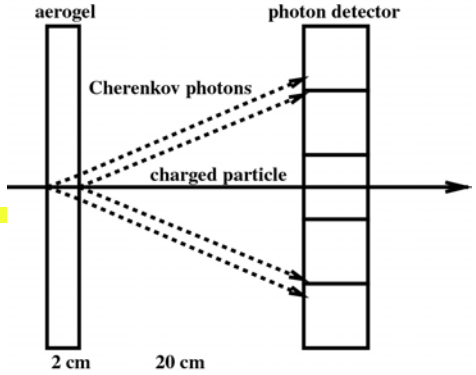


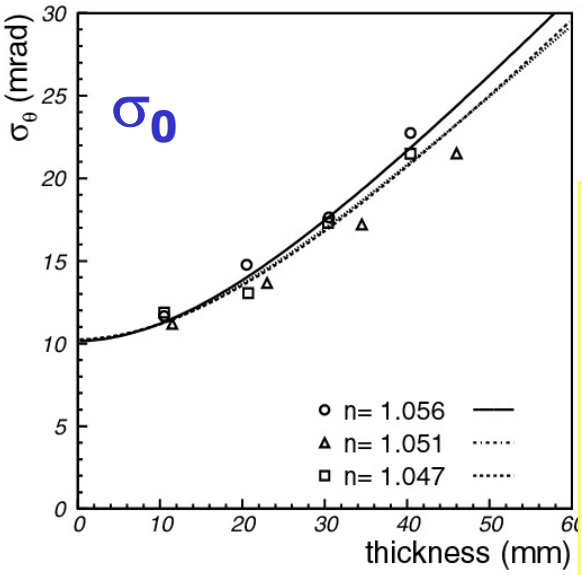
but: Number of photons has to be increased. →

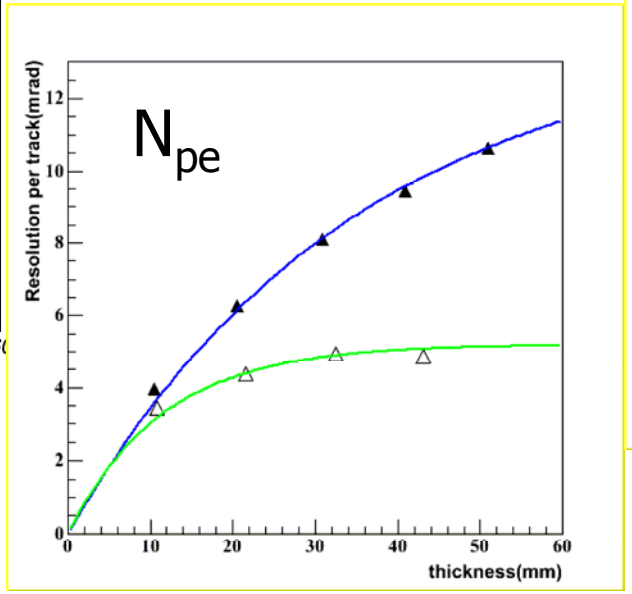
How to increase the number of photons?

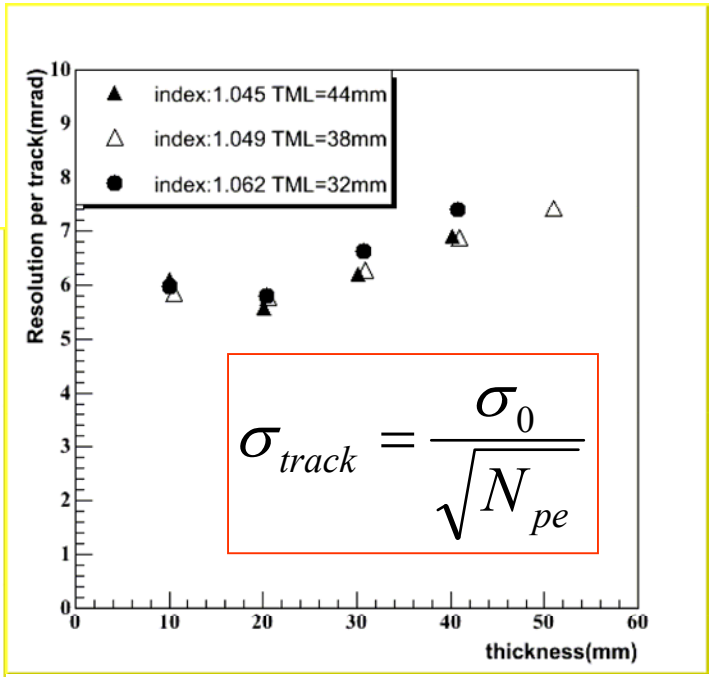


What is the optimal radiator thickness?

Use beam test data on σ_0 and N_{pe}







Minimize the error per track: → Optimum is close to 2 cm

Radiator with multiple refractive indices

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

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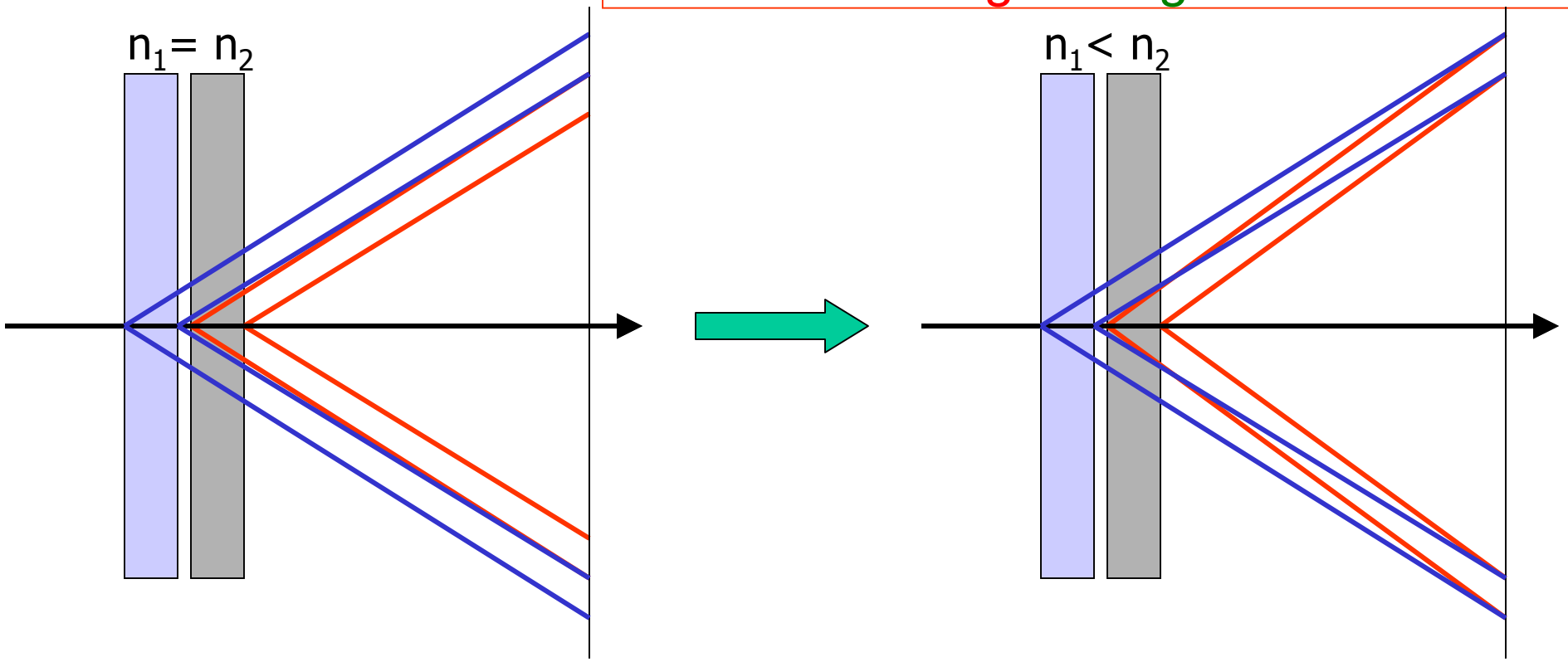
→ stack two tiles with different refractive indices: "focusing" configuration

normal



→ focusing radiator

Focusing configuration

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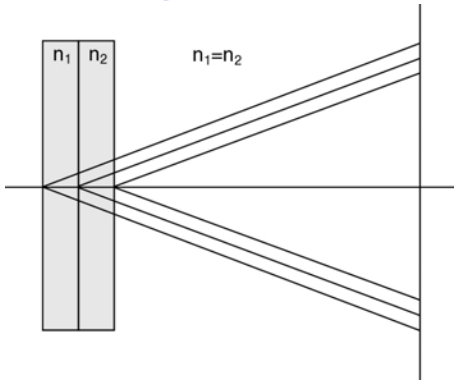
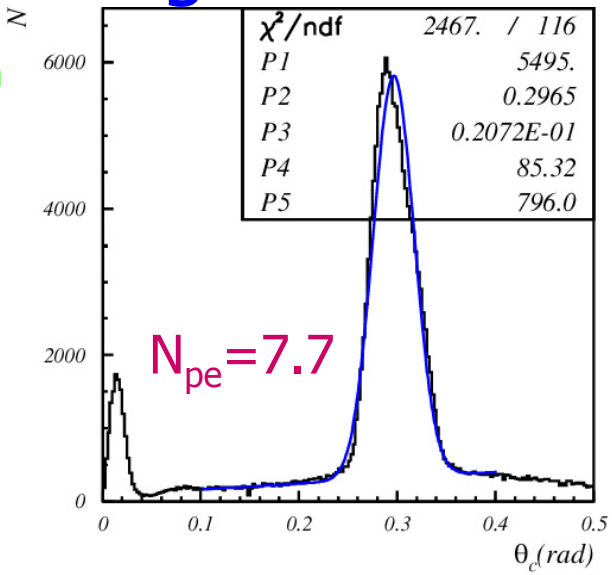
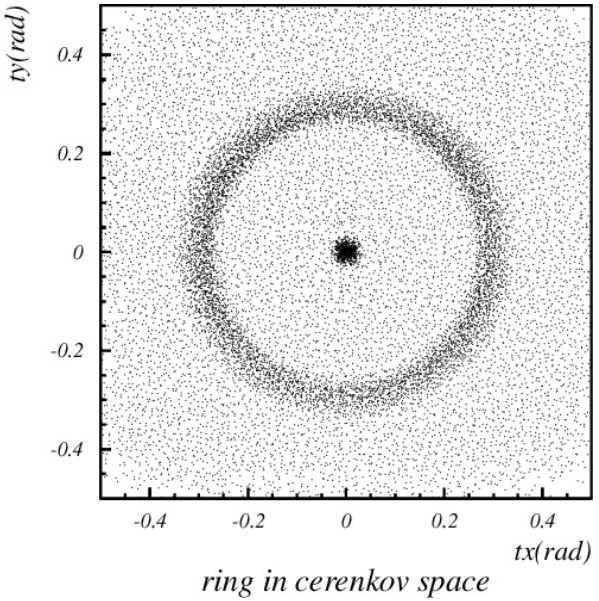
4cm single index

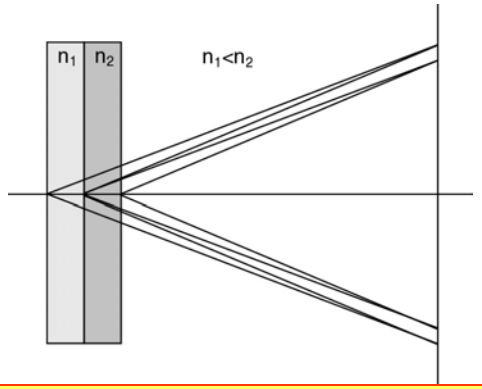


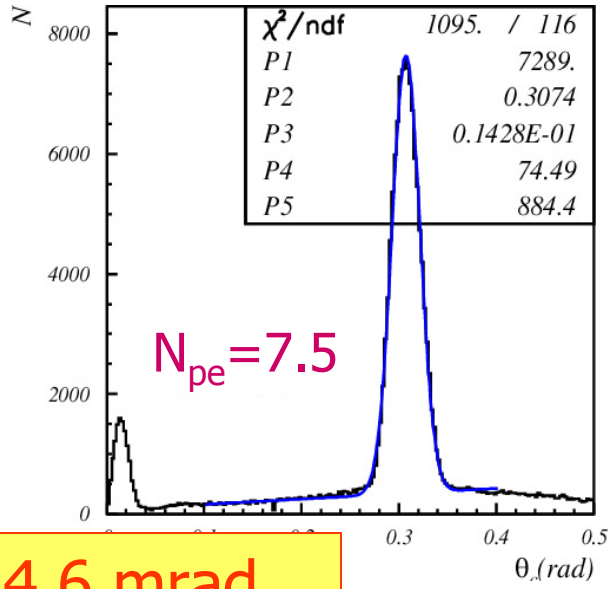


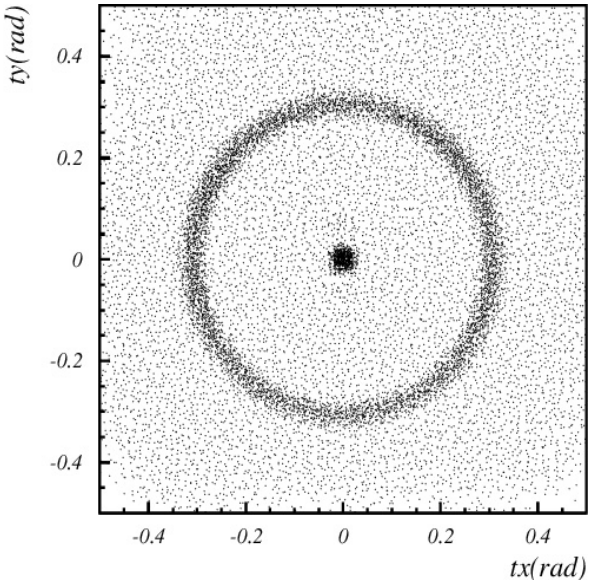


σ_0= 21 mrad, σ_{track}= 6.4 mrad

2+2cm, two indices



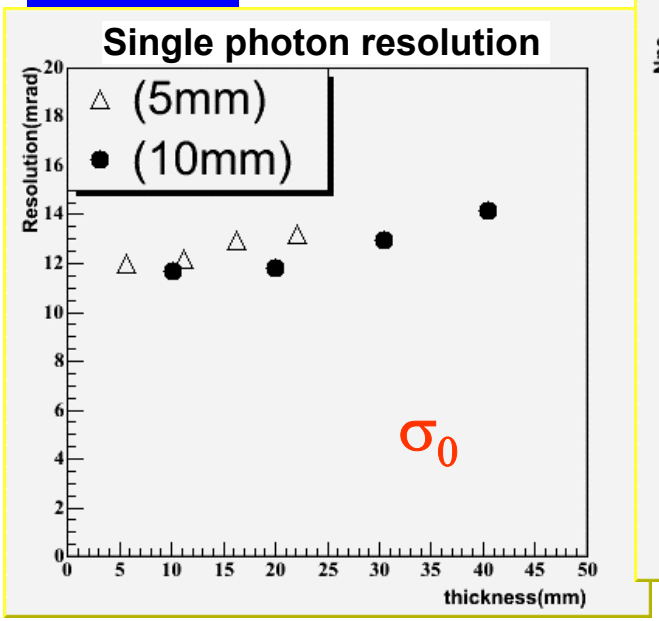


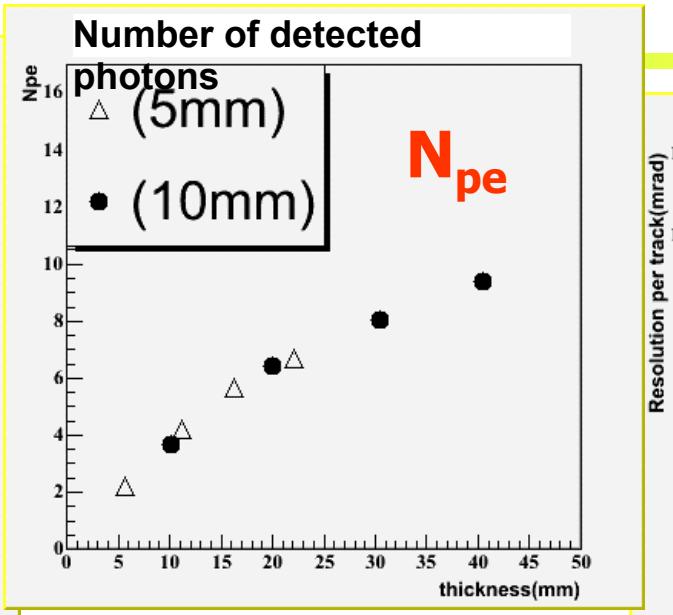


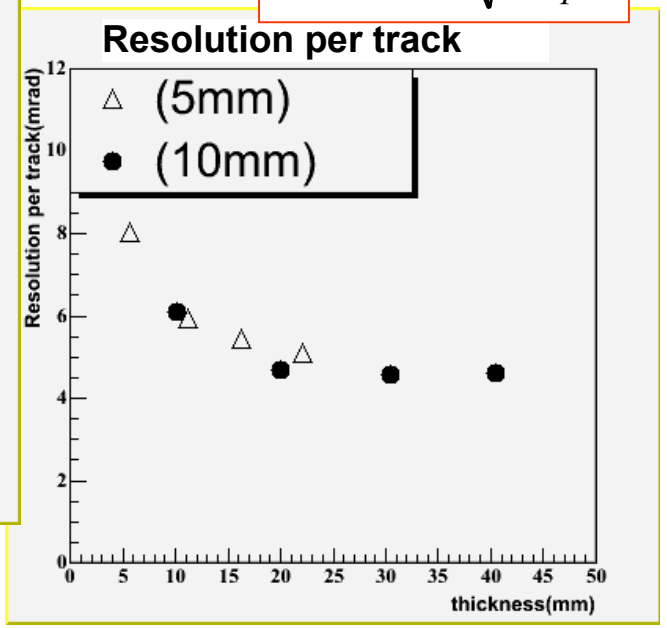
σ_0= 14 mrad, σ_{track}= 4.6 mrad

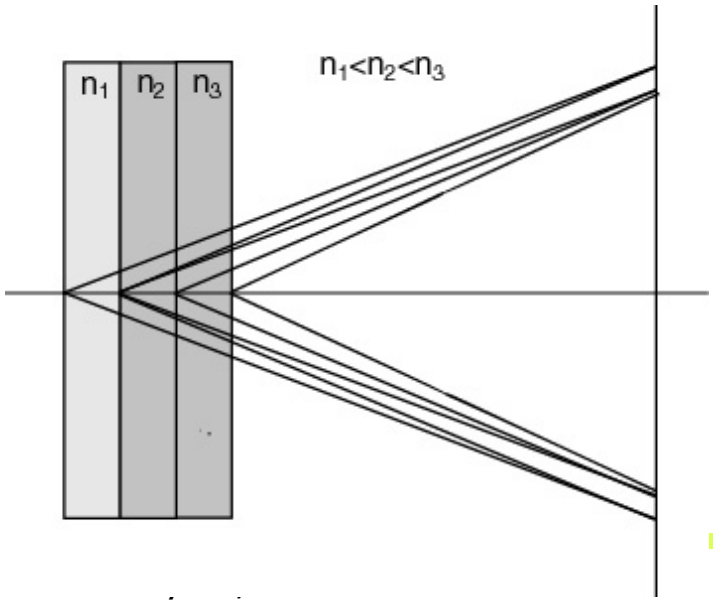
Multilayer extensions

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







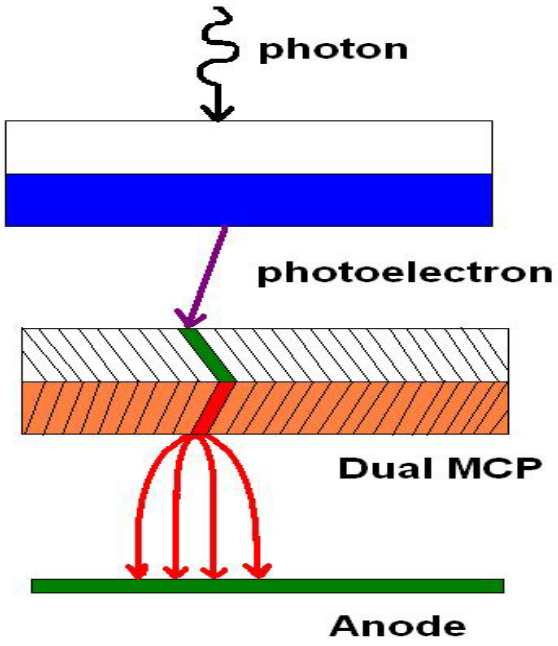


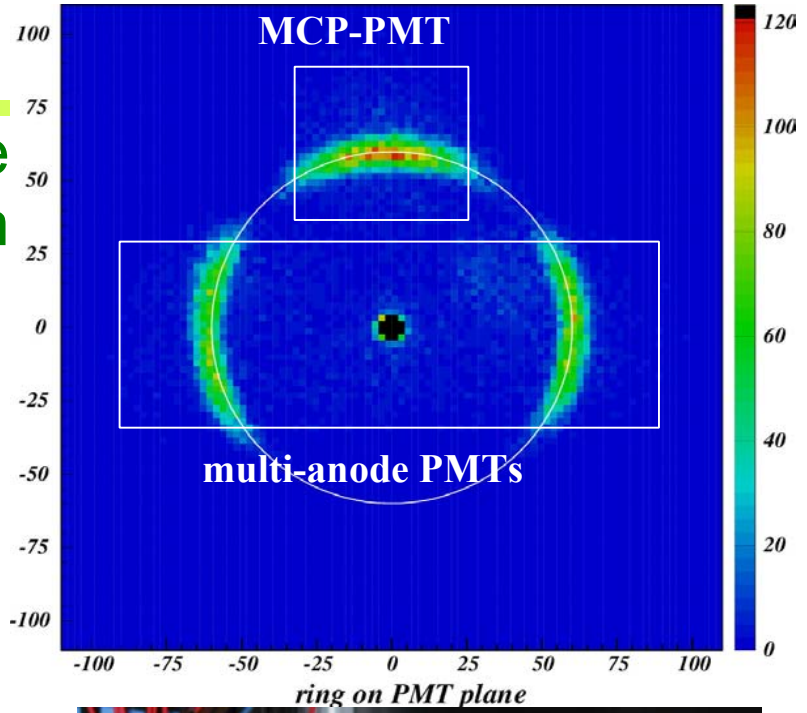
- Multiple layer radiators combined from 5mm and 10mm tiles
- Cherenkov angle resolution per track: ~4.3 mrad

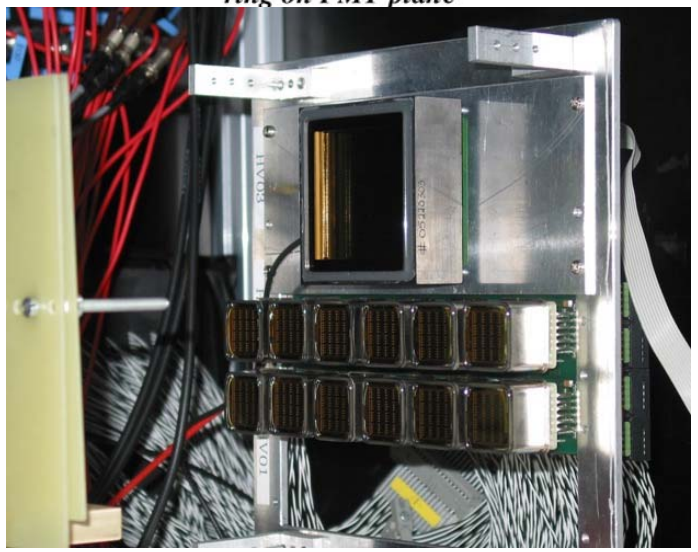
→ π/K separation at 4 GeV: better than **5**σ

Photon detector candidate for 1.5 T: MCP-PMT

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







→good performance in beam and bench tests

→ very fast (σ=50ps, single photons)

→ R+D: ageing

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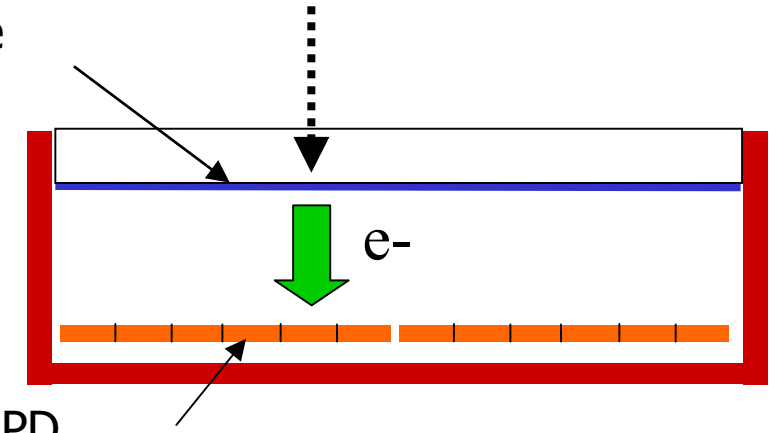
Photon detector candidate: H(A)PD

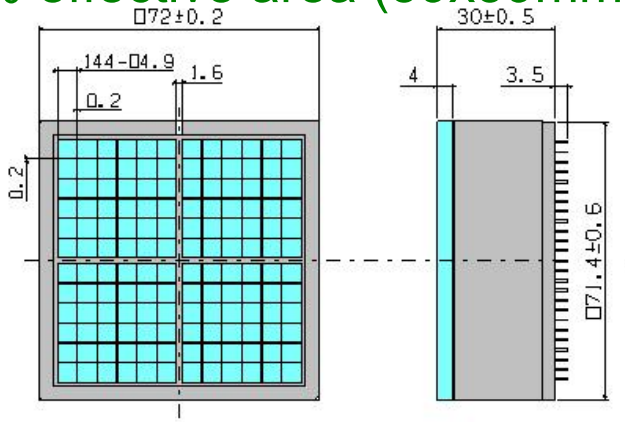
Multialkali photocathode

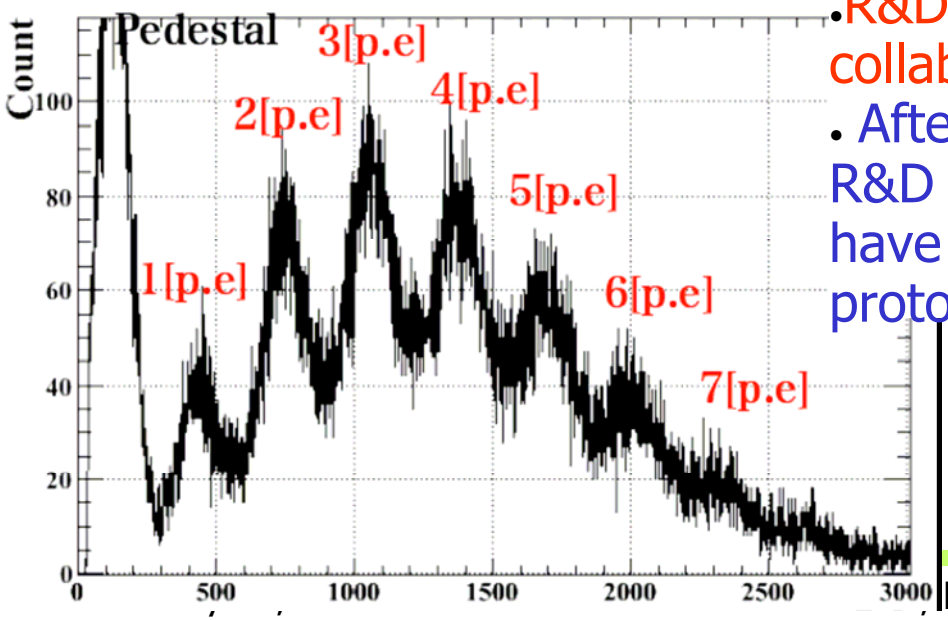


-10kV
15~25mm

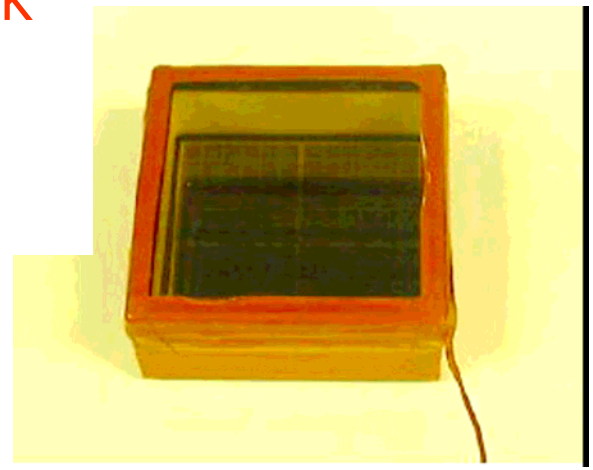
Pixel PD or APD

- 12 x 12 channels
- 65% effective area (59x59mm^2)





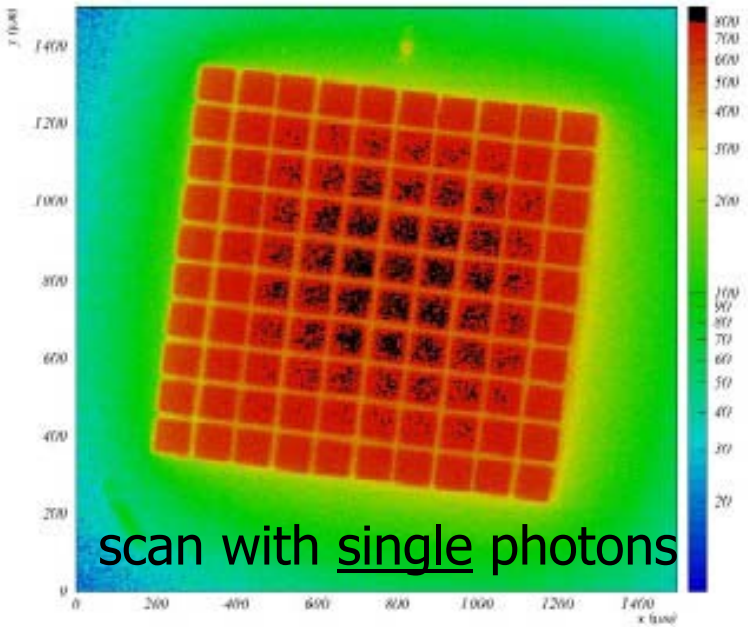
- R&D project in collaboration with HPK
- After a considerable R&D effort we finally have two full size prototypes to study

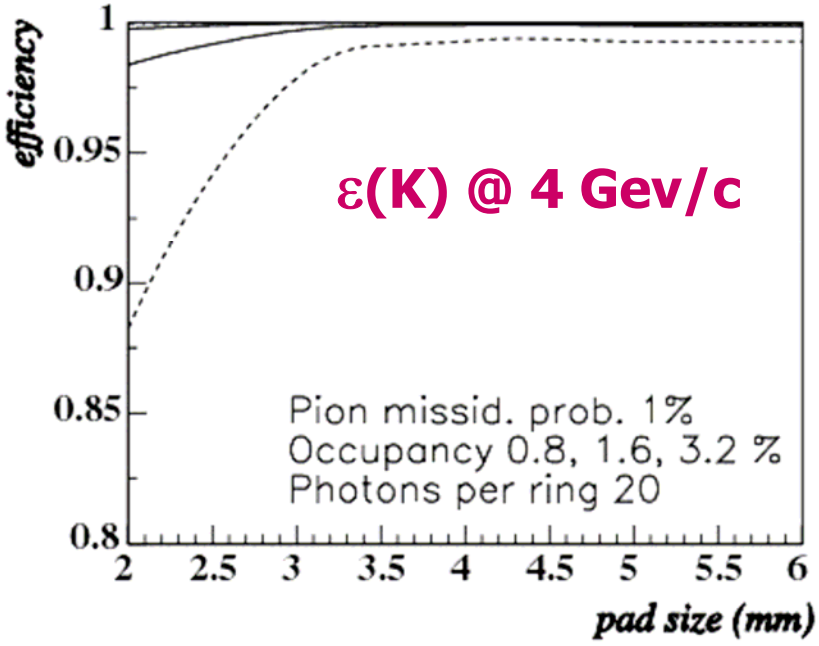


Photon detector candidate: SiPM

- immune to magnetic field
- high single photon detection efficiency up to 70%
- good timing properties (~300ps FWHM)
- no high voltage
- low material budget
- high noise rate ~ 1MHz/mm^2
- radiation damage - increase of dark noise

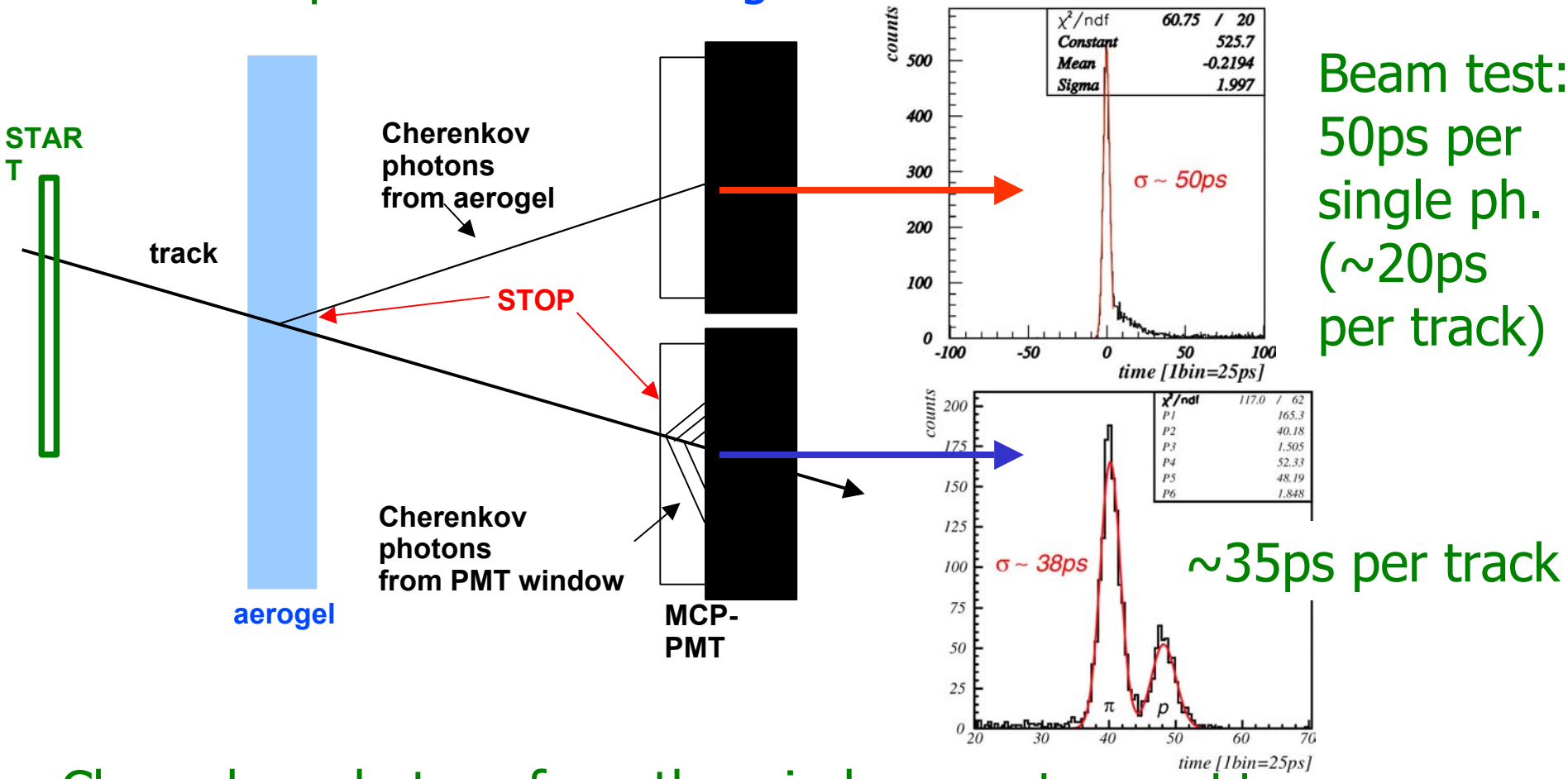
→ Increase signal to noise ratio by using narrow time (<10ns) window and light guides.





Additional feature: time-of-flight measurement

Make use of fast photon detectors: measure time-of-flight with Cherenkov photons from aerogel radiator and PMT window



Beam test: 50ps per single ph. (~20ps per track)

~35ps per track

Cherenkov photons from the window can be used to positively identifiy particles below the threshold in aerogel

Summary

- A proximity focusing RICH with ~ 20 cm radiator to photon detector distance and ~ 6x6mm^2 pads is being developed for the upgrade of the Belle forward PID.
- Single refractive index radiator has an optimal radiator thickness of ~ 2 cm; increasing the thickness results in degradation of Cherenkov angle resolution per track.
- Way out: use of multi layer radiator with varying refractive index
- Expected performance of the focusing configuration: excellent π/K separation up to 4 GeV/c
- More studies are needed to decide which photon detector to use for the Belle PID upgrade

- Such a counter can also be used for TOF measurement
  → extend PID capabilities into low momentum region