Aerogel RICH for Belle-II experiment

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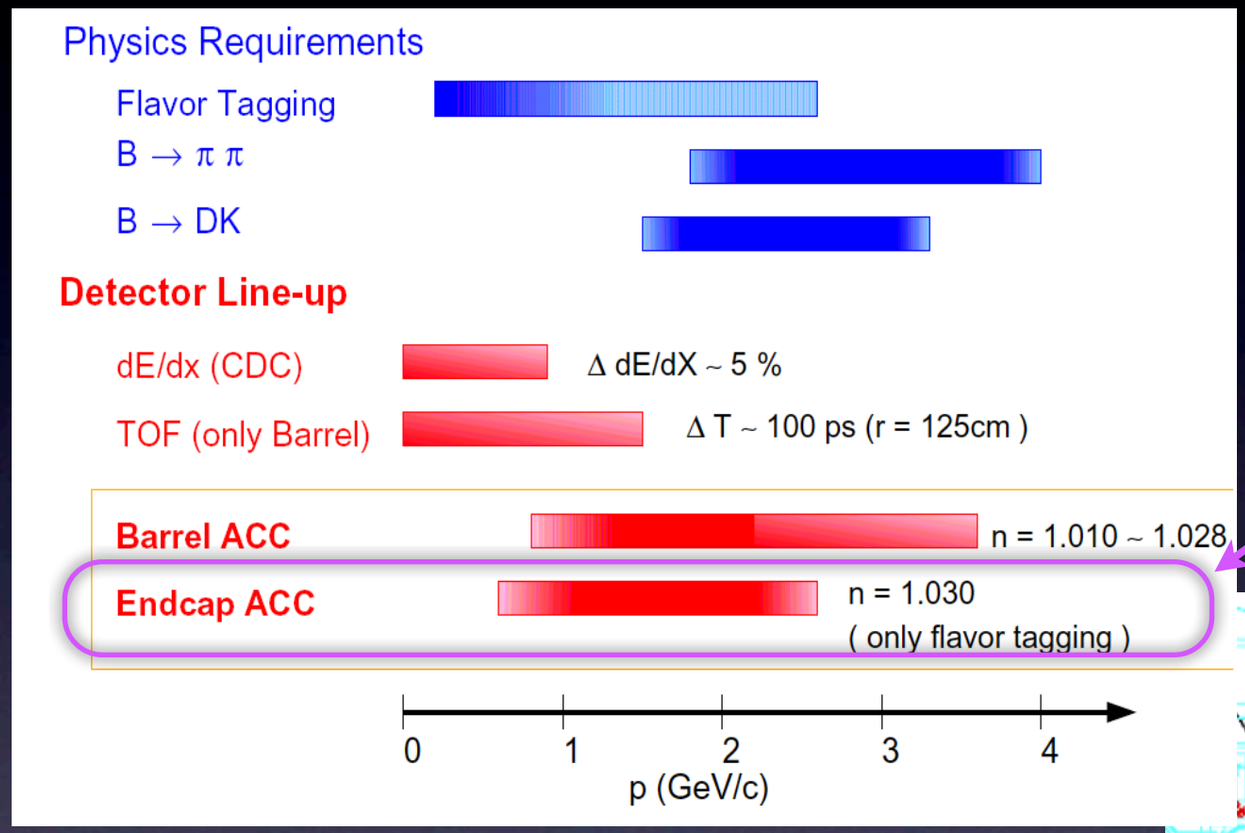
「新ハドロン」キックオフ研究会　於名古屋大学

Introduction

- Present Belle PID performance



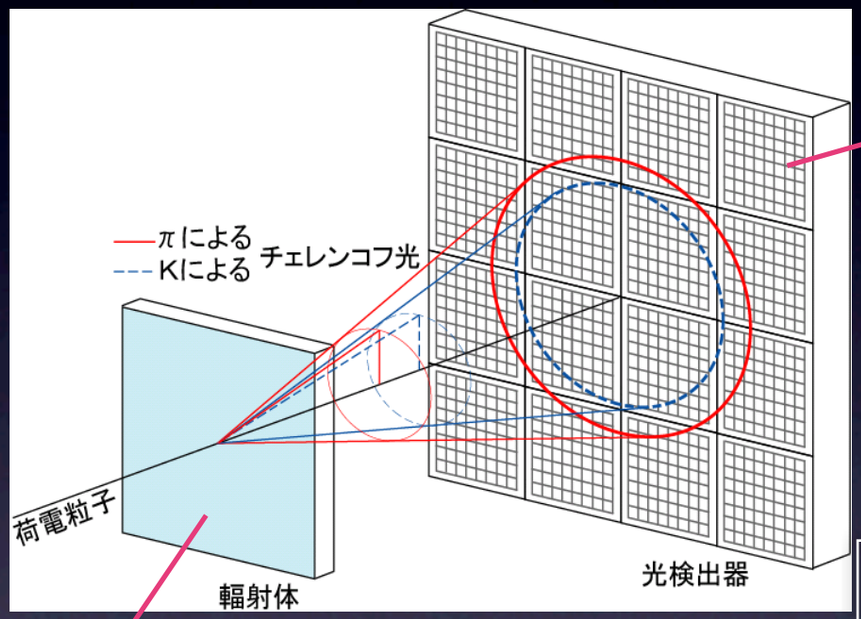
Threshold-type aerogel Cherenkov counter (ACC) equipped as PID device, in particular for pion and K separation

We do not have PID at high momentum (P>2.5GeV/c) for a forward endcap

Further performance upgrade
Our target: pion/K 4σ separation at 4 GeV/c

Aerogel RICH

proximity focusing ring imaging
based on silica aerogel (ARICH)



position-sensitive photon detector
+
readout electronics

silica aerogel

experience at ACC

Requirements

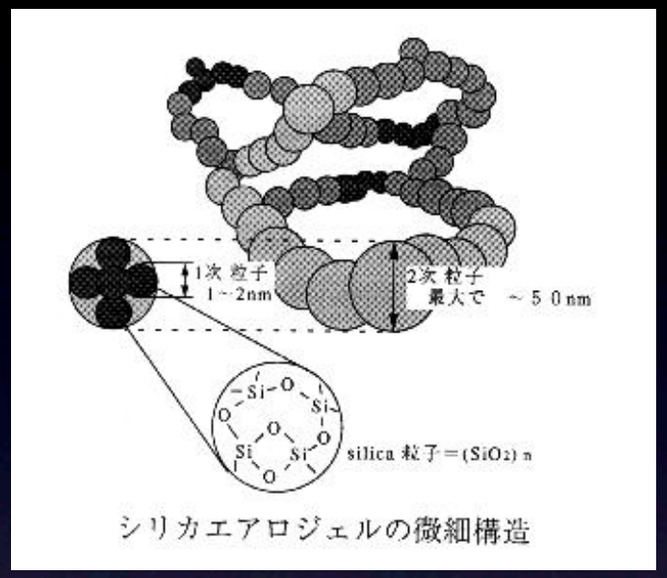
highly transparent aerogel radiator

single-photon detectable photon detector operated in B-field
(~5mmx5mm pixel)

readout electronics to manage~100K

compact layout

Silica Aerogel ?



シリカエアロジェルの微細構造

3D network of SiO2 molecules
porous structure
low density
low thermal conductivity
hydrophobic

1980's
hydrophilic

2009
hydrophobic

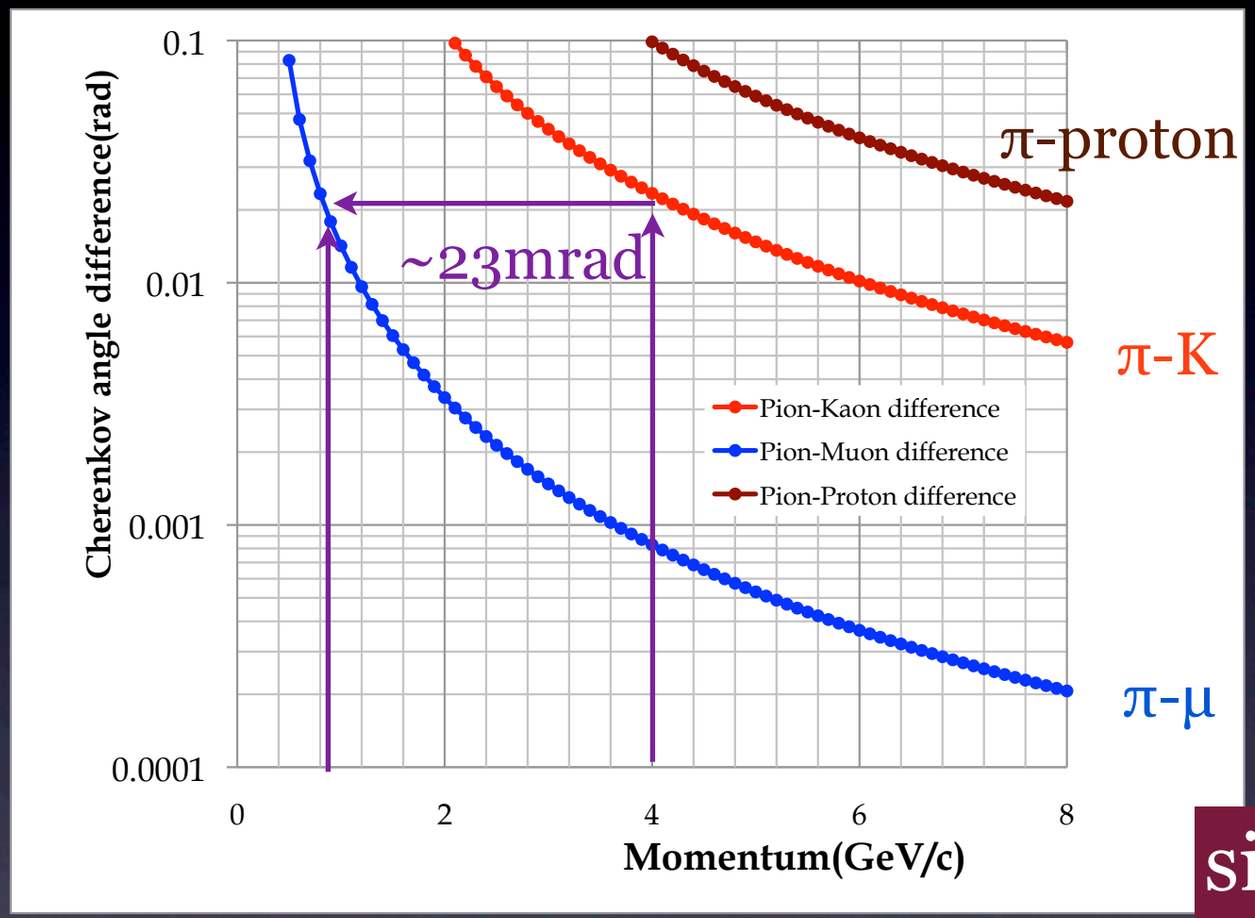
material	index	density	remarks
silica aerogel	1.007~1.07 (重いものも可能に)	0.028~0.28	
air	1.00028	0.001293	25deg, 1atm
water	1.3428	0.9984	20deg
glass	1.48~2.0	2.4~2.6	

index manageable

Cherenkov radiator
High energy experiment
Dust capture
JAXA/NASA
Nuclear fusion

PID separation

n=1.050 radiator



n=1.050 aerogel
θ(π)-θ(K)=23mrad
at 4GeV/c

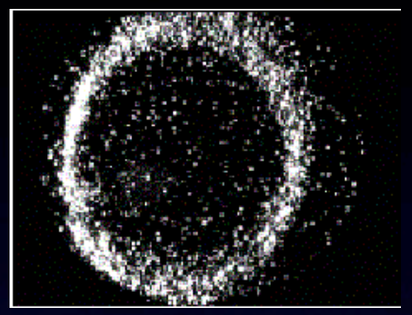
~ |θ(μ)-θ(π)| at 0.8GeV/c

single photon resolution σ~14mrad
Npe~6

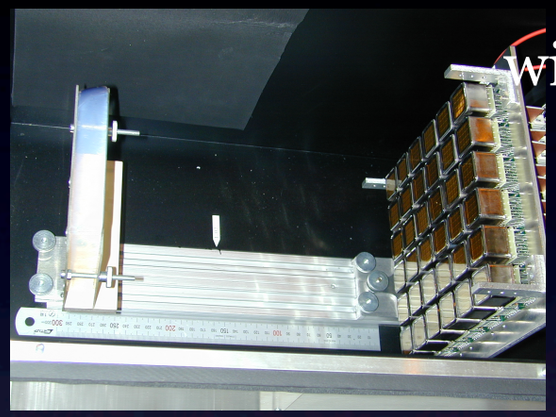
→ 4 σ separation

Principle of Operation

2000年 clear ring observed by IIT(Iijima san)



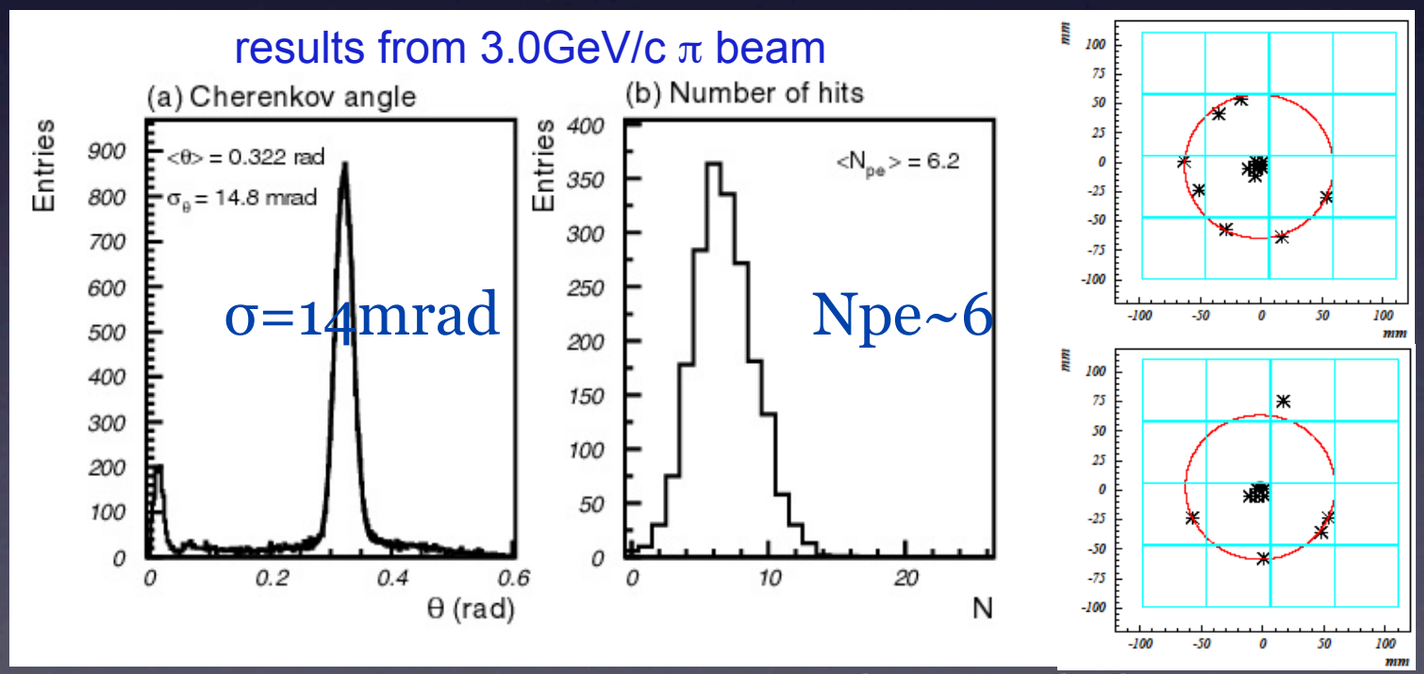
n=1.030



2001年multi-anode PMT readout with Ljubljana group

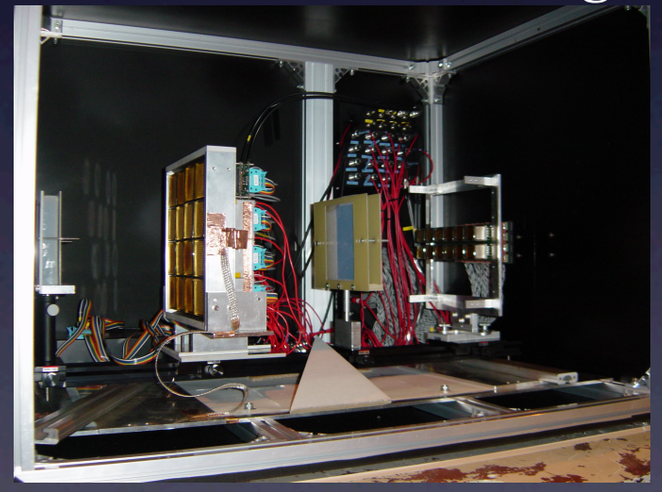
n=1.050

2002年multi-anode flat-panel PMT with analog readout



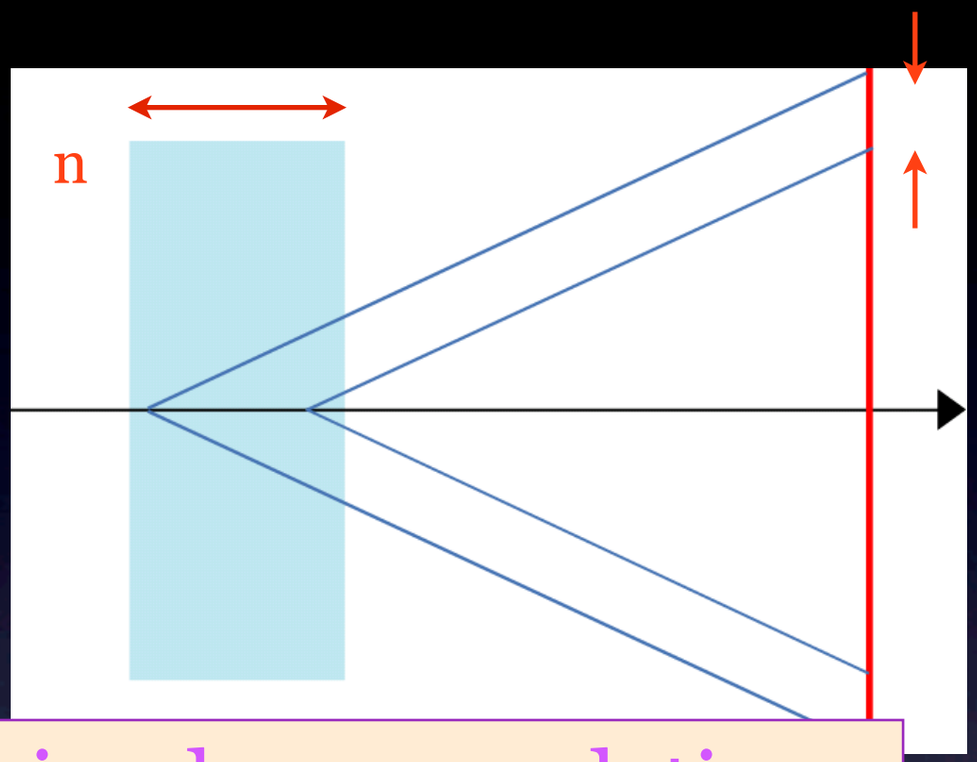
σ=14mrad

Npe~6



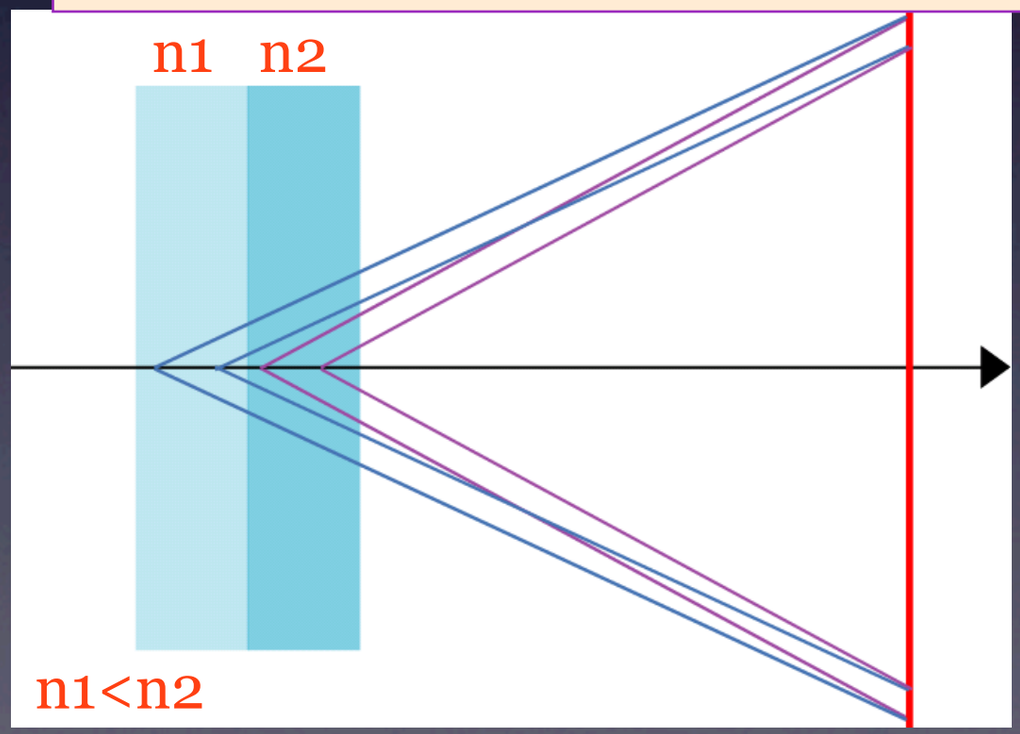
4σ separation achieved, but more photoelectrons!
photon detection devices only work in no B-field

Focusing Scheme



simple accumulation of radiator layers does not help improving resolution !

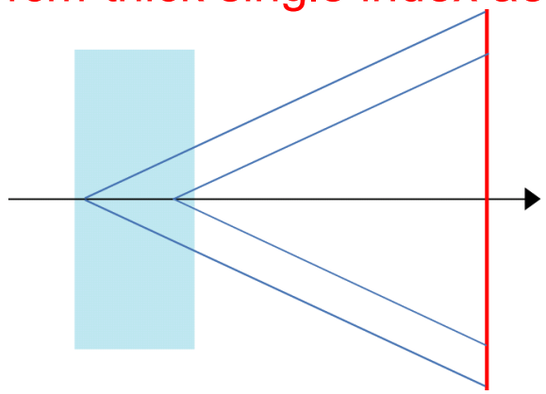
employ two layers having different indices so that Cherenkov image from each radiator can overlap

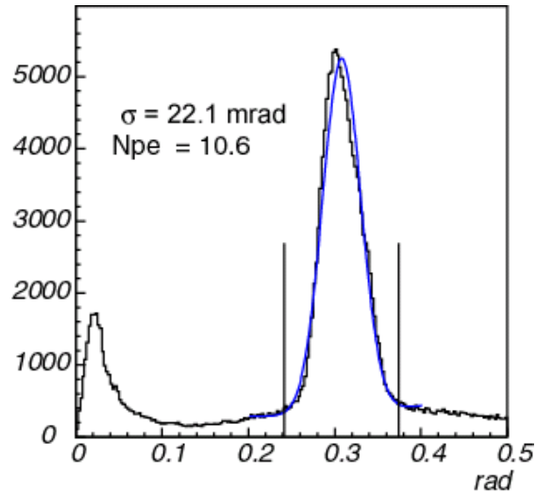


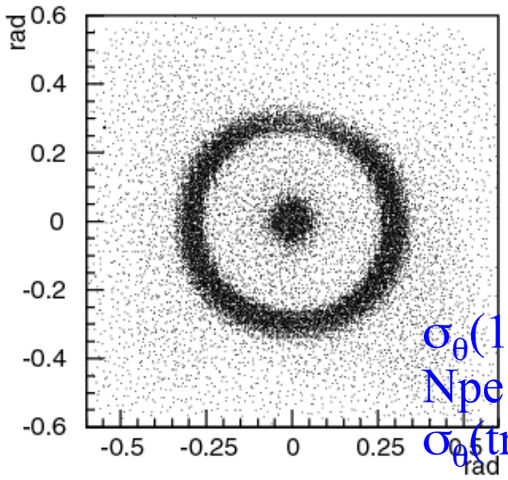
Possible only for aerogel radiator since index can be managed

Experimental Verification

4cm-thick single index aerogel

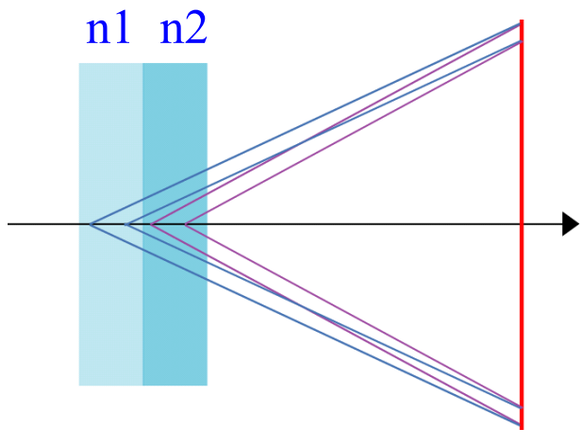


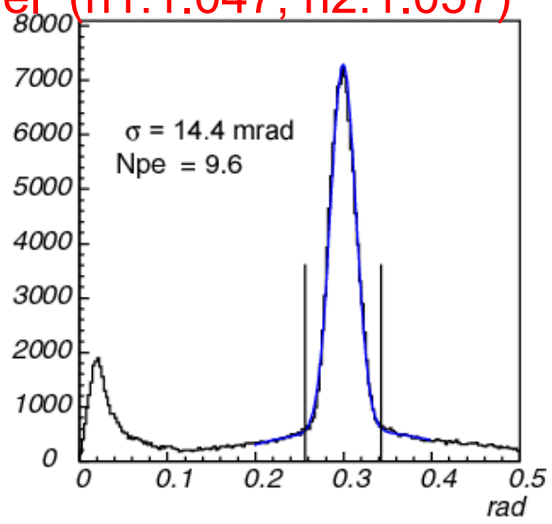


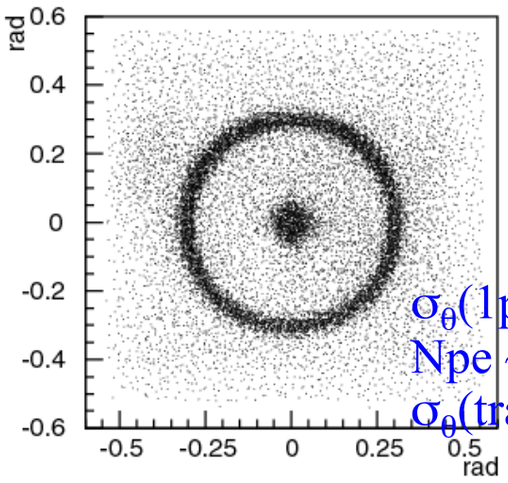


σ_θ(1p.e.) = 22 mrad
Npe ~ 10.6
σ_θ(track) = 6.9 mrad

Focusing by 2cm+2cm aerogel (n1:1.047, n2:1.057)





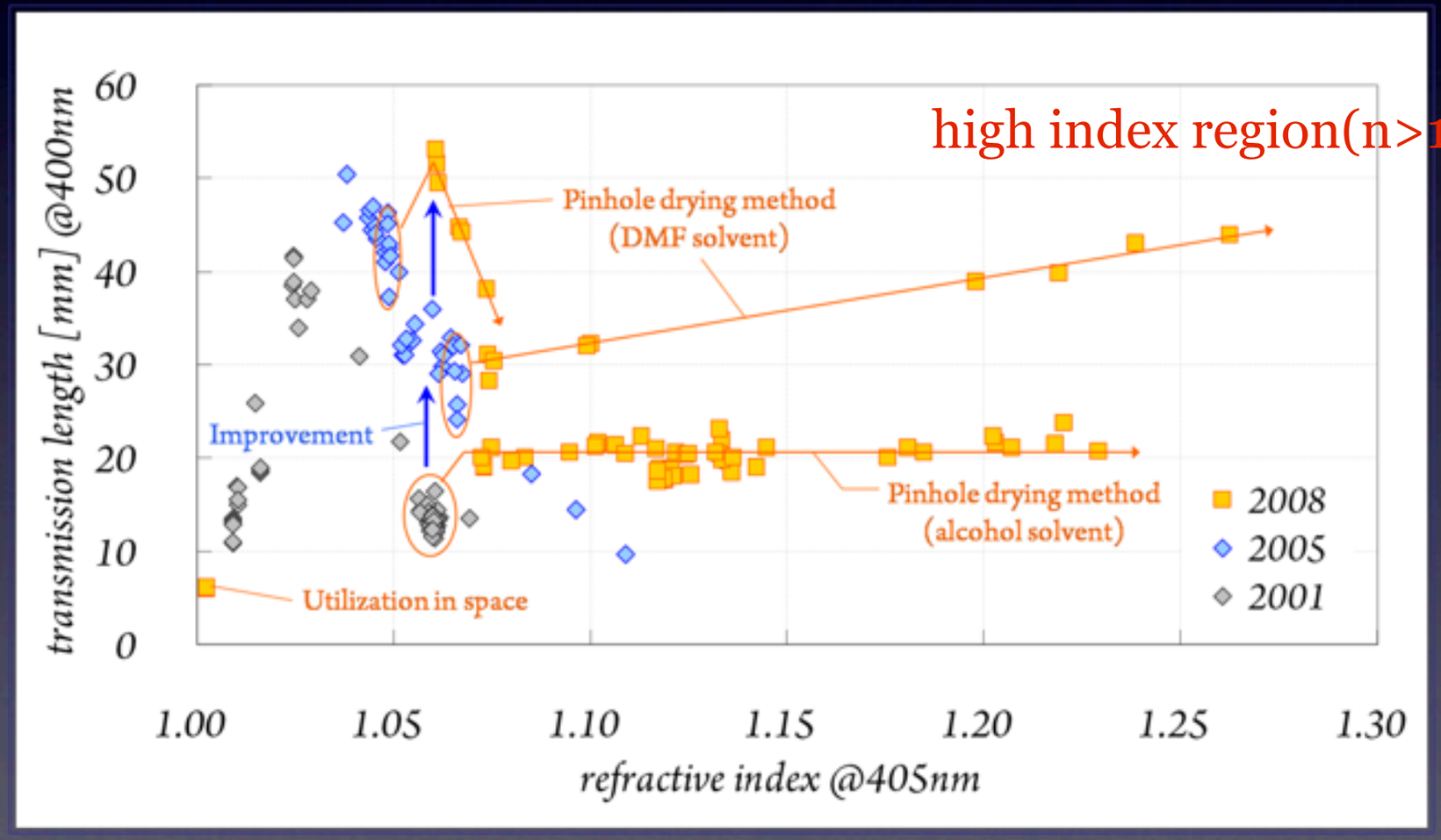


σ_θ(1p.e.) = 14.4 mrad
Npe ~ 9.6
σ_θ(track) = 4.8 mrad

working fine !

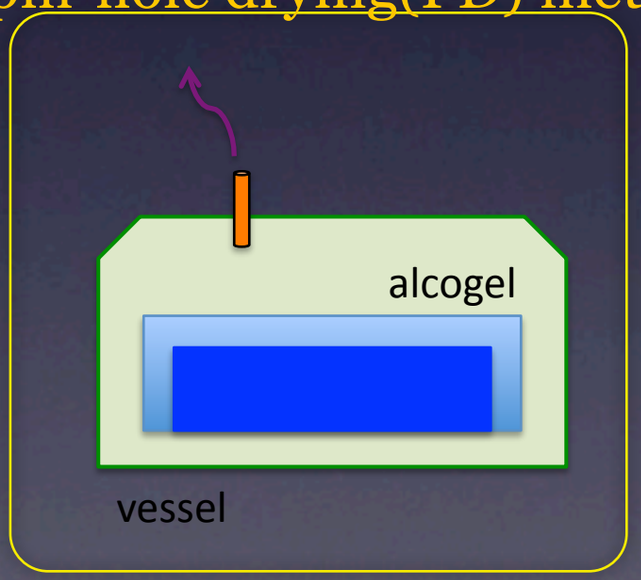
Aerogel Improvement

- optical quality
  - Recently transparency of aerogel around 1.055~1.060 at 400nm tripled compare to at 2001



high index region(n>1.060) much improved

pin-hole drying(PD) method

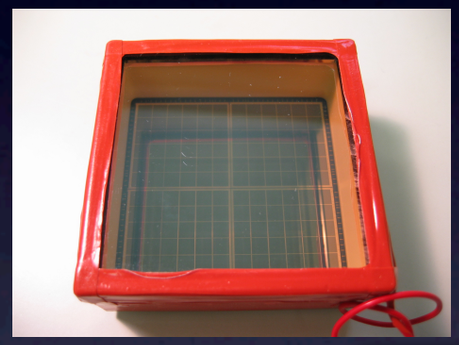


by M.Tabata (JAXA)

Photon Detector

- Requirements
  - single photon sensitivity
  - ~5mmx5mm pixel resolution
  - operational under 1.5 Tesla
  - large sensitive area

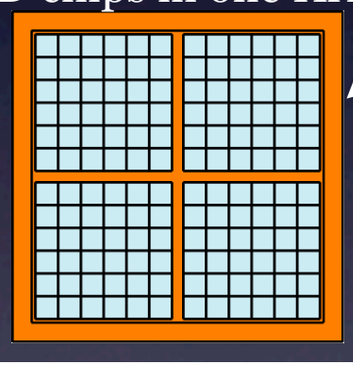
→ Multi-Anode Hybrid Avalanche Photo-Detector(HAPD)

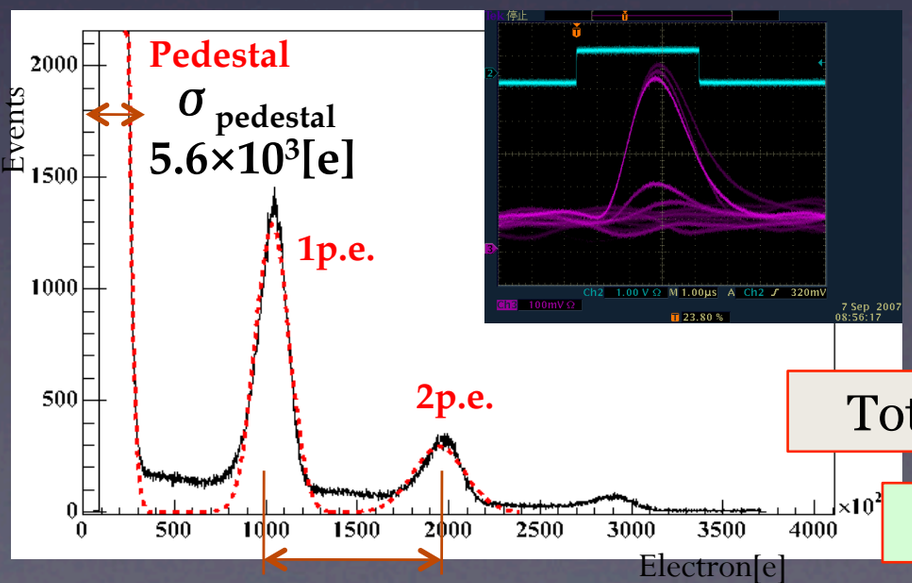


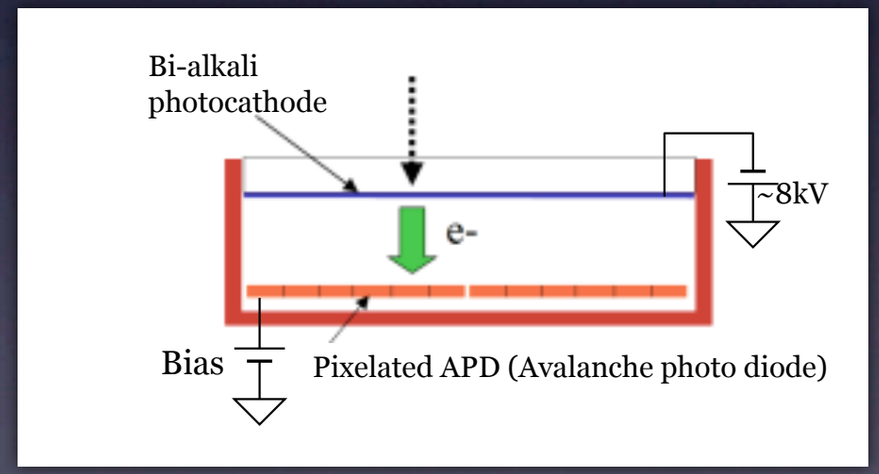
developed with Hamamatsu Photonics

package size	72mmx72mm
# of pixels	144(36x4AD chips)
pixel size	5mmx5mm
sensitive area ratio	67%

4 AD chips in one HAPD





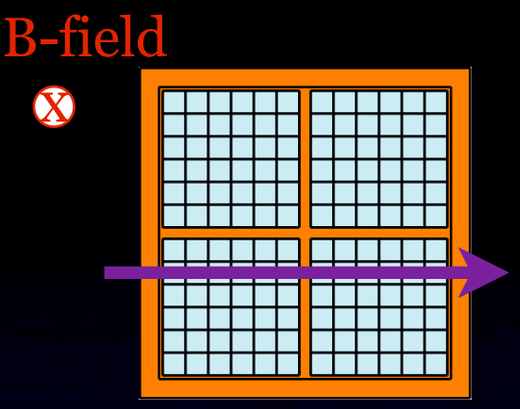


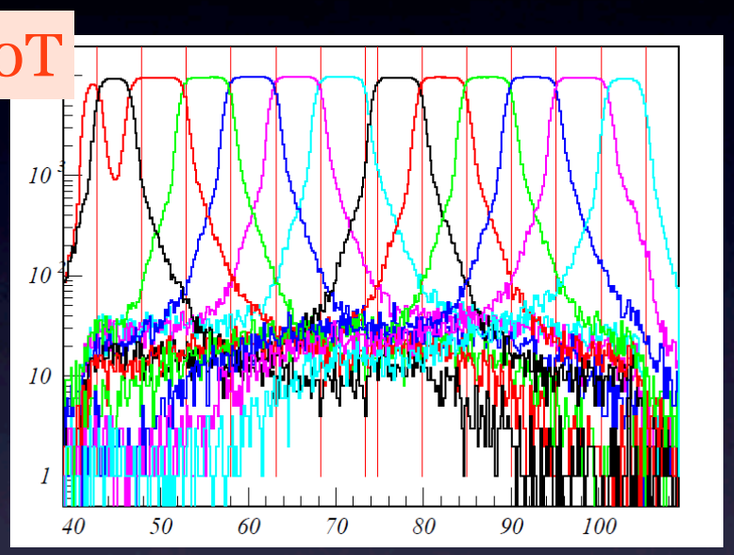
Total gain 9.1×10⁴

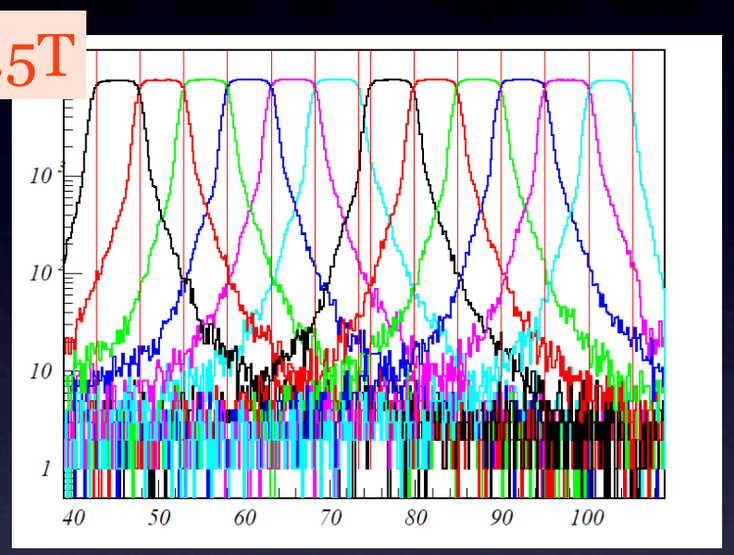
S/N 16.4

HAPD R&D

- Test under B-field
  - response scan using light source





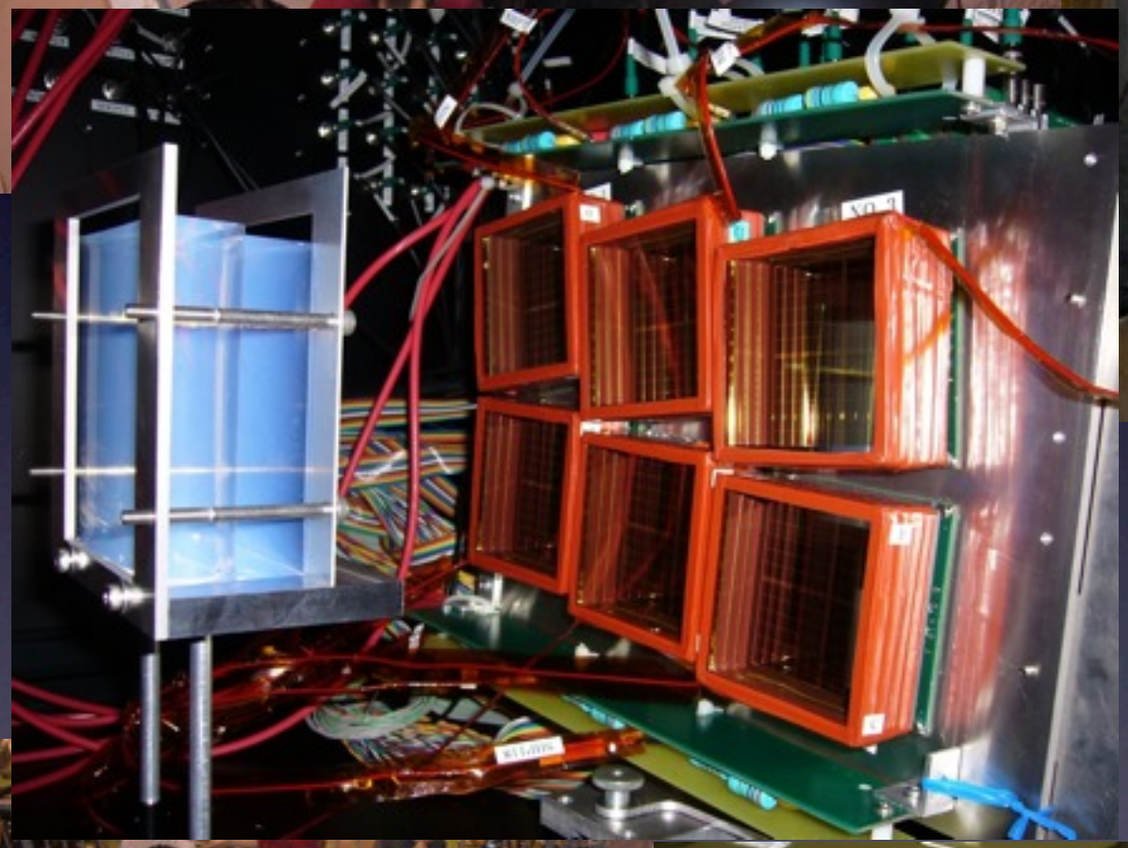


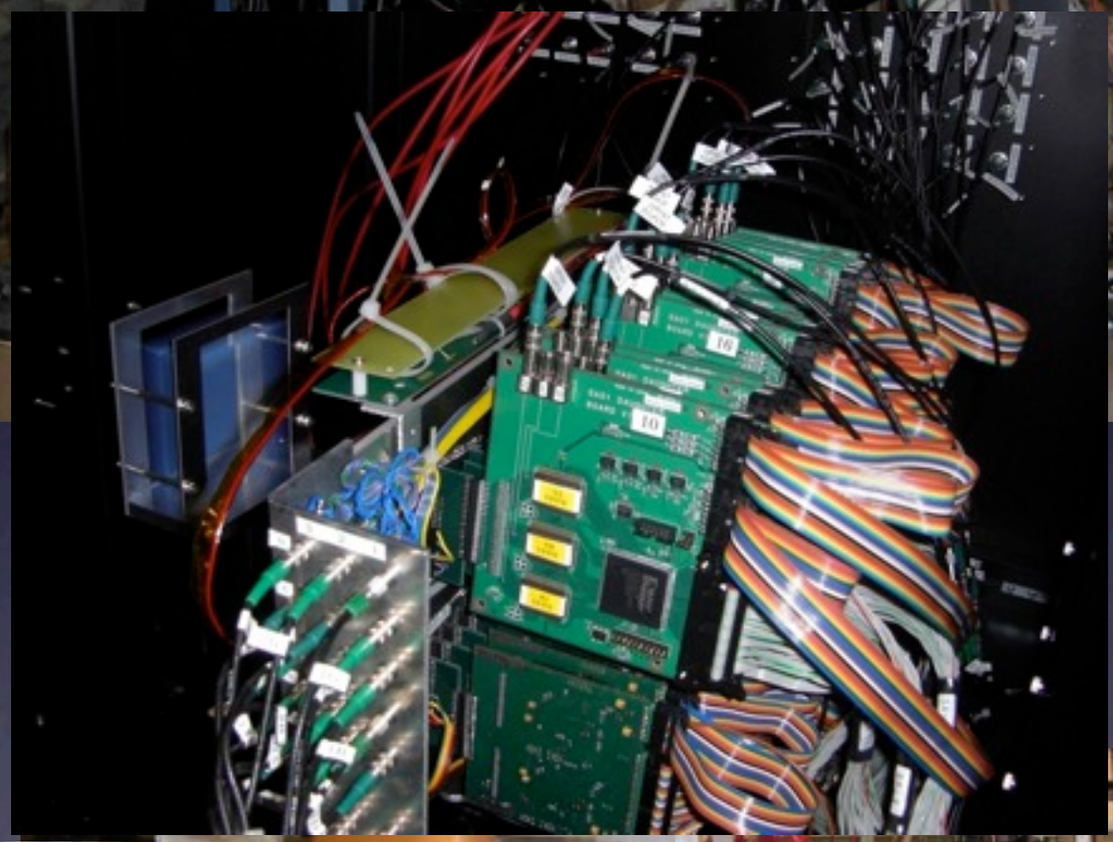
tested by Shiizuka san et al.(Nagoya)

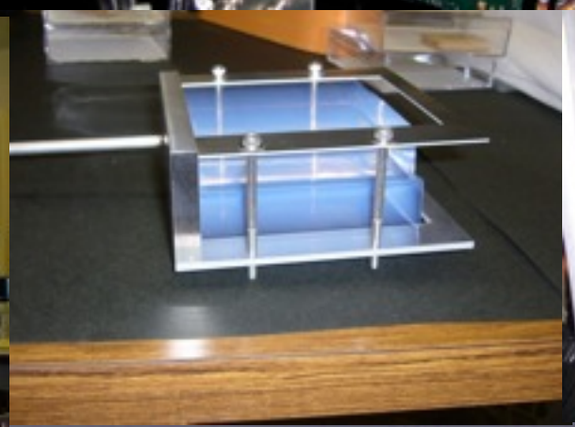
- QE improvement at HPK
  - 20% --> ~30% around 400nm
- Radiation test
  - neutron irradiation

Recent Beam Test

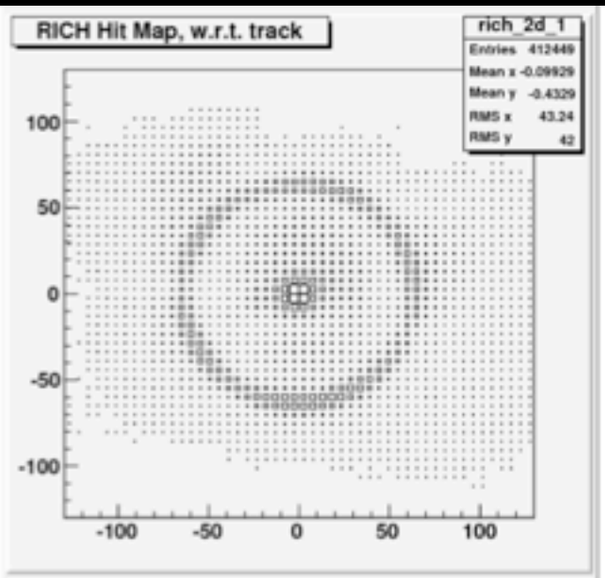
- Beam test performed this November at Fuji test beam line (2GeV/c electrons)
  - new aerogel radiator + new HAPD + new electronics

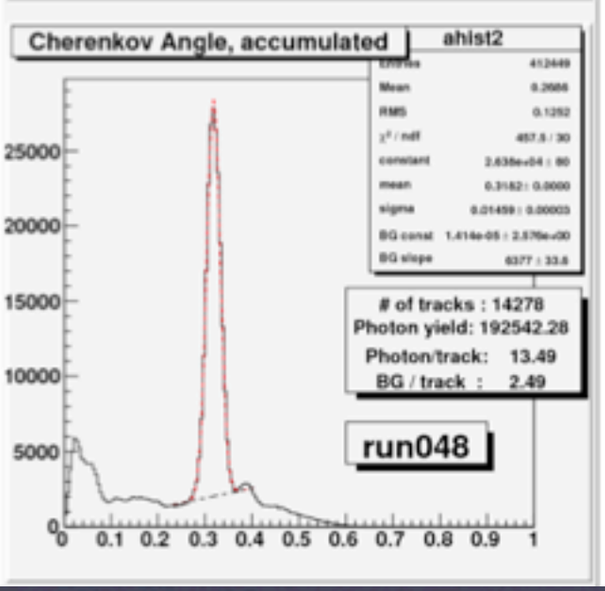






Preliminary Results





RICH Performance

- Focusing 2cm x 2gels

n=1.0536 trans. length 47.8mm (PDR20-3a)
n=1.0646 trans. length 55.4mm (PDR11-4a)

- Best configuration in this test

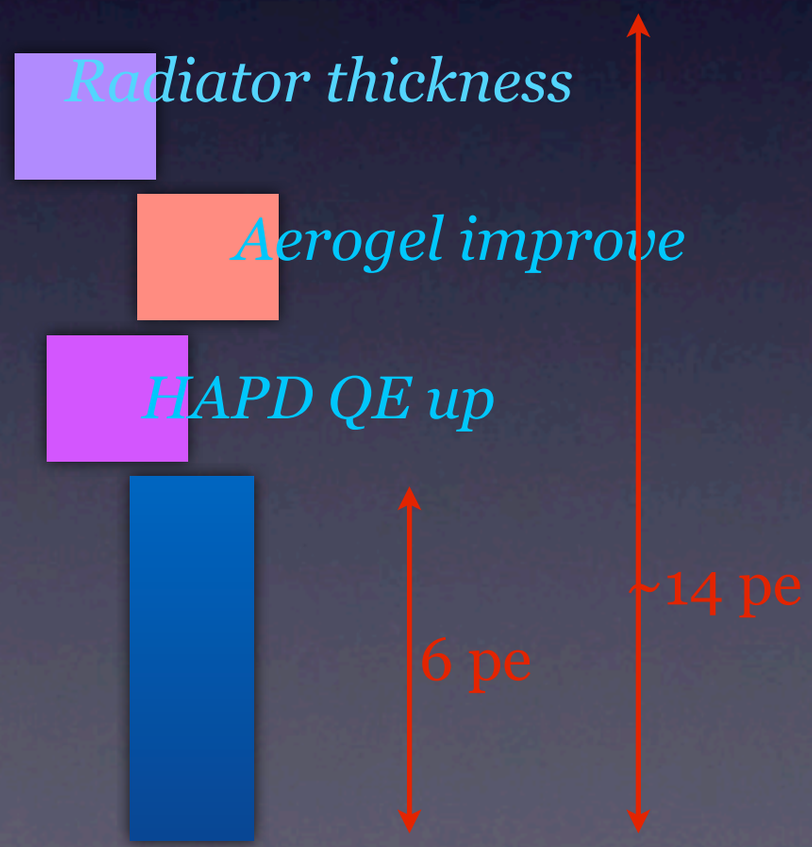
#photons/track = **13.5**
Resolution/photon =14.6 mrad
Resolution/track = **4.0mrad**
(5.8σ K/π @ 4GeV/c)

cf.) Best in 2008 June beam test
1cm x 3
n=1.0462 trans. length 46.9mm(J07-A2)
n=1.0501 trans. length 41.4mm(J07-B2)
n=1.0560 trans. length 35.4m m(J07-C2)
#photons/track = 5.7
Resolution/photon =13.2 mrad
Resolution/track= 5.6 mrad

9

analyzed by Hara san(Nagoya)

Notable improvement !



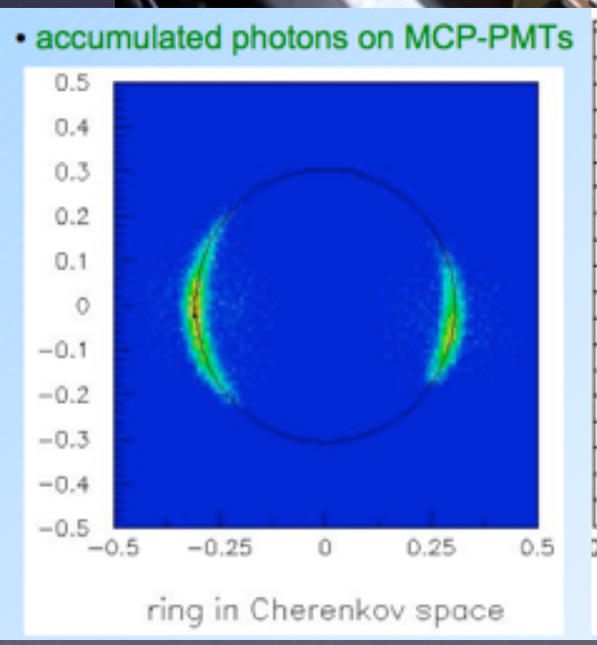
More detailed design toward real detector construction !

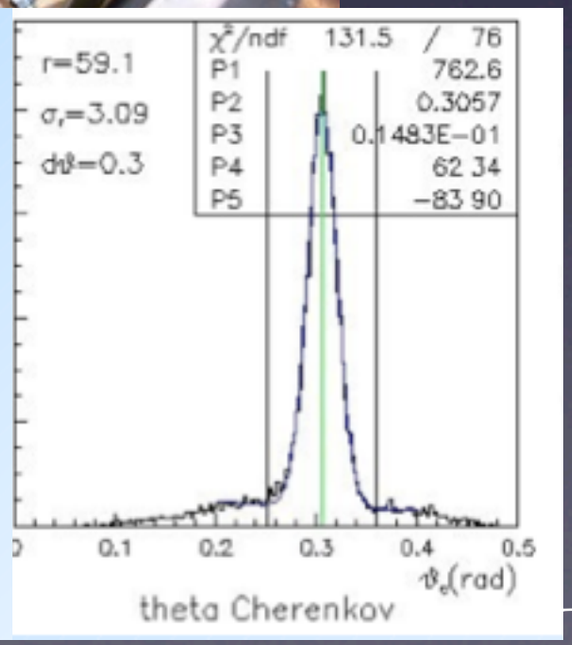
done by Ljubljana group

Other Photon Detectors

MCP-PMT

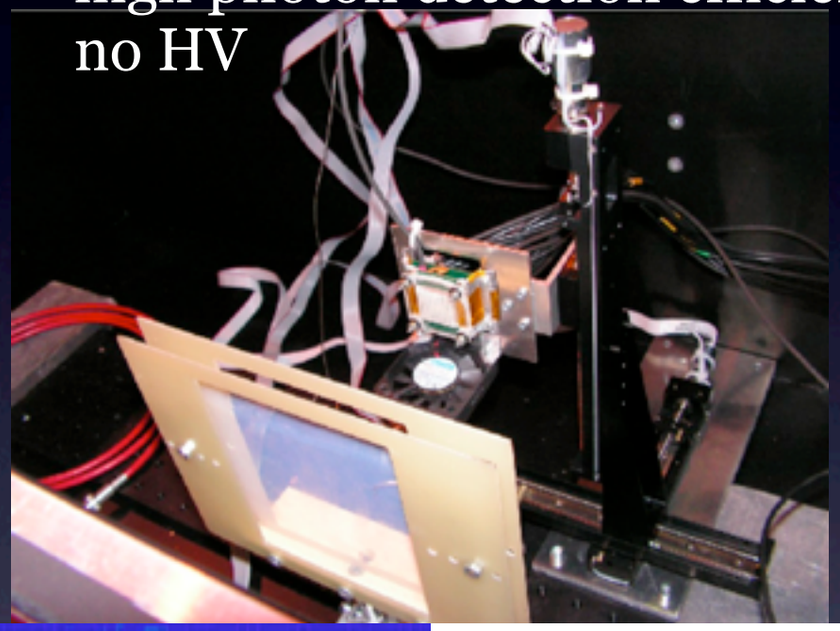
Photonis Planacon
work inside B-field with 10 micron-pore
8x8 channels

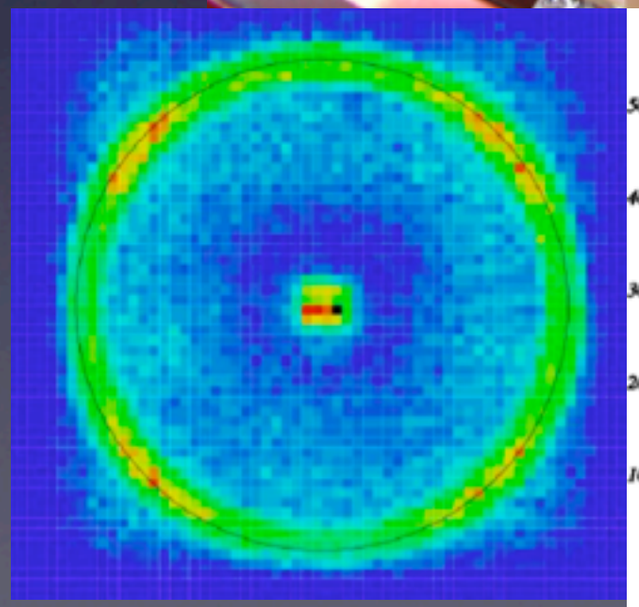


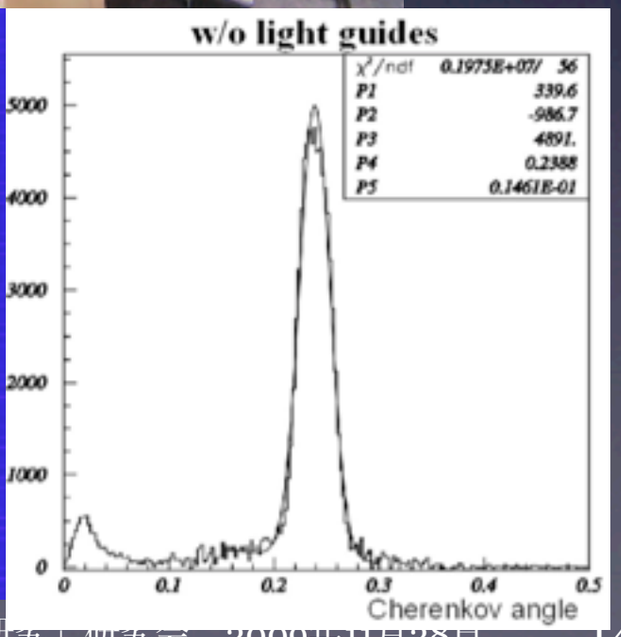


MPPC

Hamamatsu MPPC
high photon detection efficiency
no HV







Other Applications

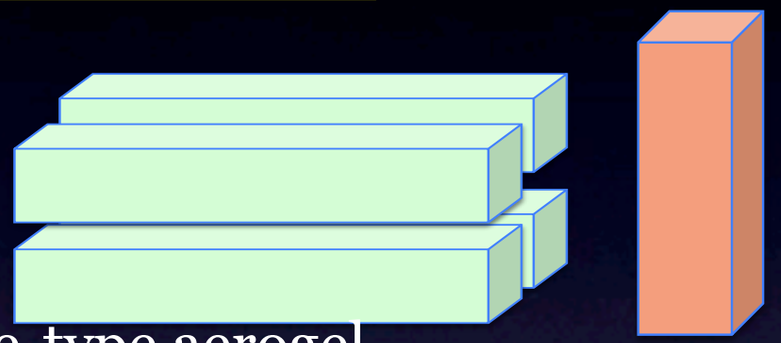
barrel part

MPPC array or MPGD+PC?

low material PID

fibre counter

MPPC array or multi-anode PMT

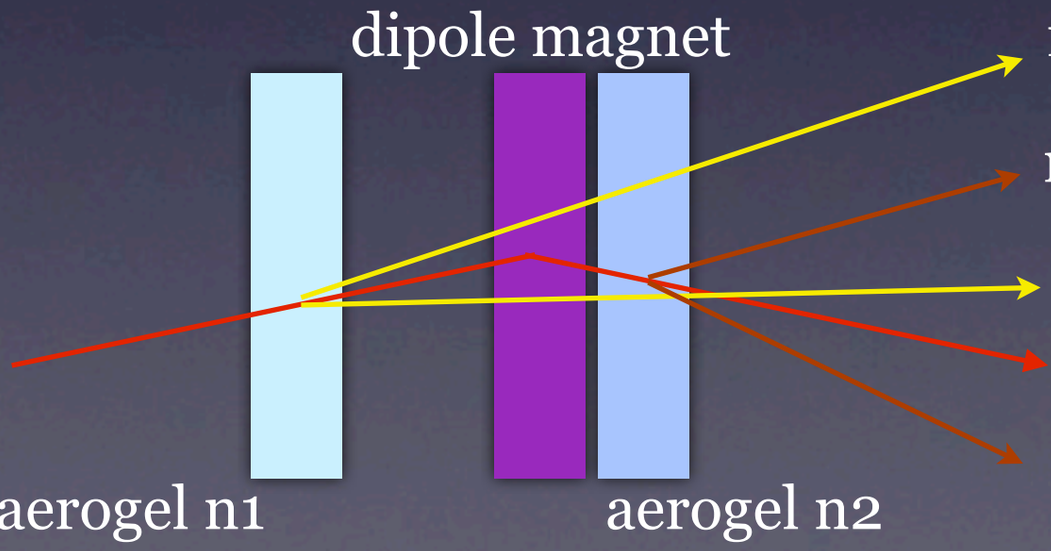


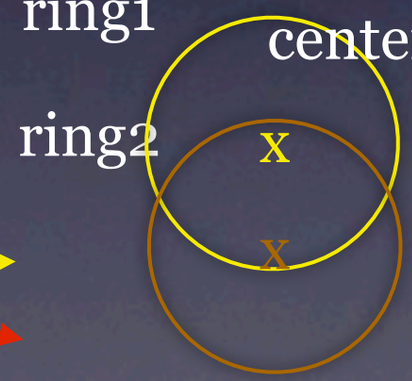
fibre-type aerogel with high index

tracking

triggering device

magnetic spectrometer





distance between centers of ring1 & ring2 → momentum

PID & momentum triggering device

maybe more...

Summary

- Proximity focusing RICH with a silica aerogel radiator has been developed for the Belle-II experiment
- Performance using a prototype has been evaluated at beam test and our target was found to be achieved
- More application?