ARICH detector (within BELLE 2 experiment)

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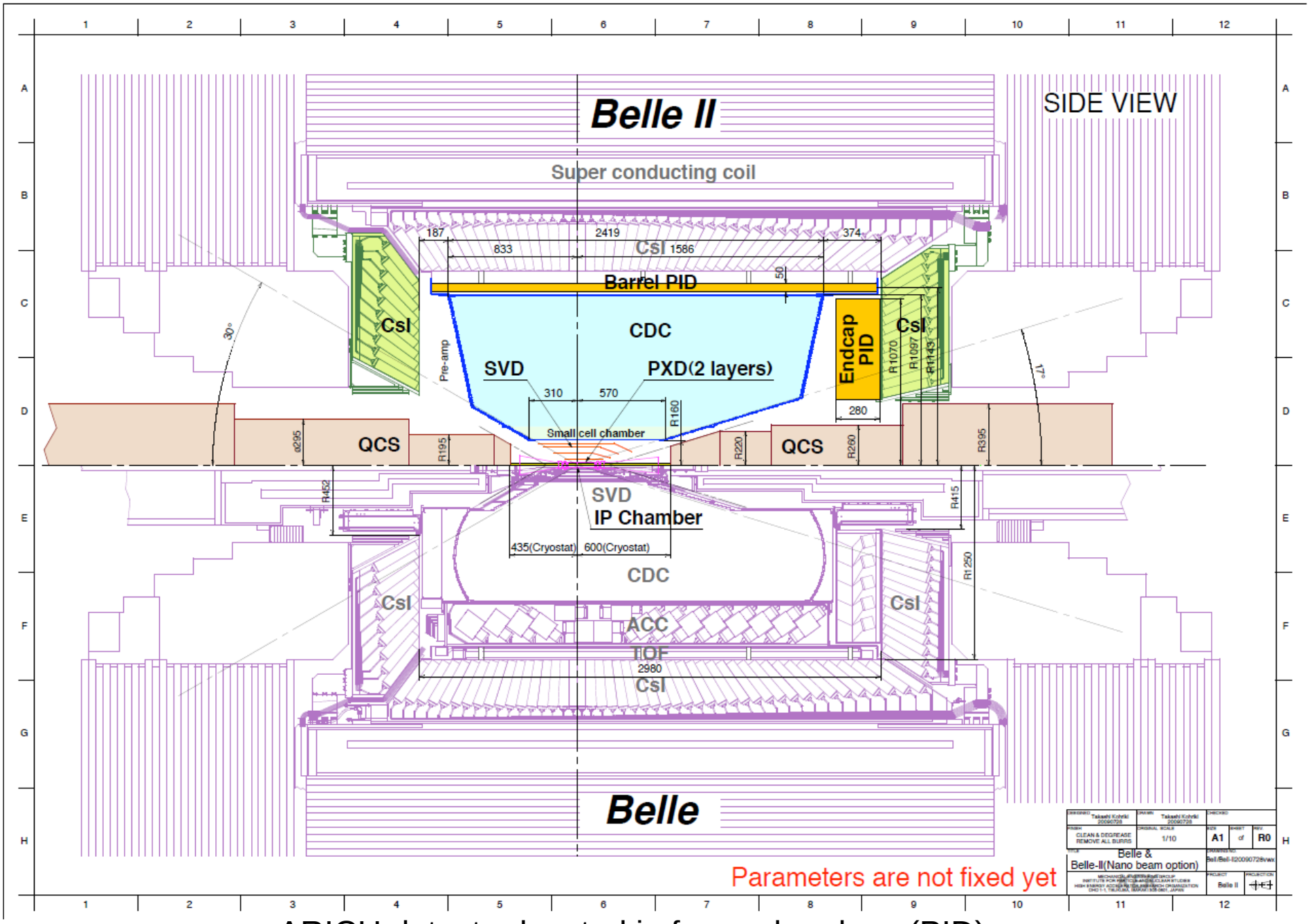
BELLE2 detector



ARICH detector located in forward endcap (PID)

Target performance : K/pi separation at > 4σ C.L. @ 0.5 < p < 4 GeV/c.

ARICH

Detailed description of the detector :

https://confluence.desy.de/pages/viewpage.action?spaceKey=BI&title=ARICH+NutShell

Need to have DDESY Belle2 account

→ Proximity-Focusing **R**ing **I**maging **Ch**erenkov counter using Aerogel

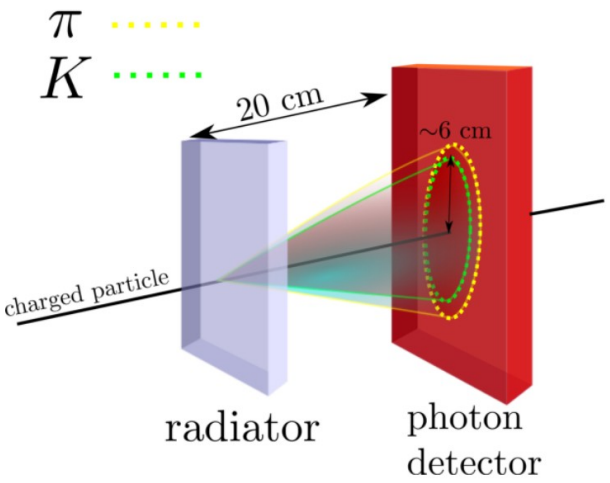
→ Particle mass is identified according to emission angle in aerogel radiator

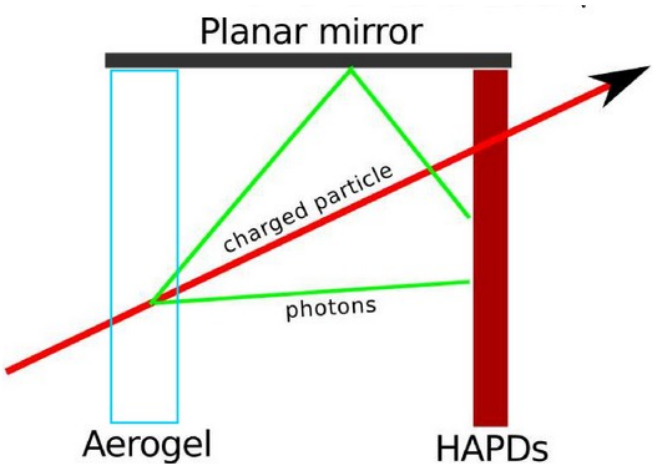
Particle momentum

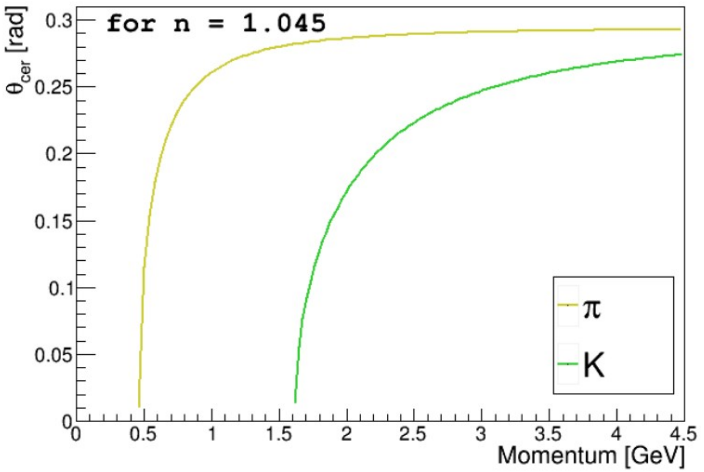
Particle mass ← $m = \frac{p}{c}\sqrt{n^2\cos^2\theta_c - 1}$

Particle Cherenkov angle

Aerogel refractive index momentum



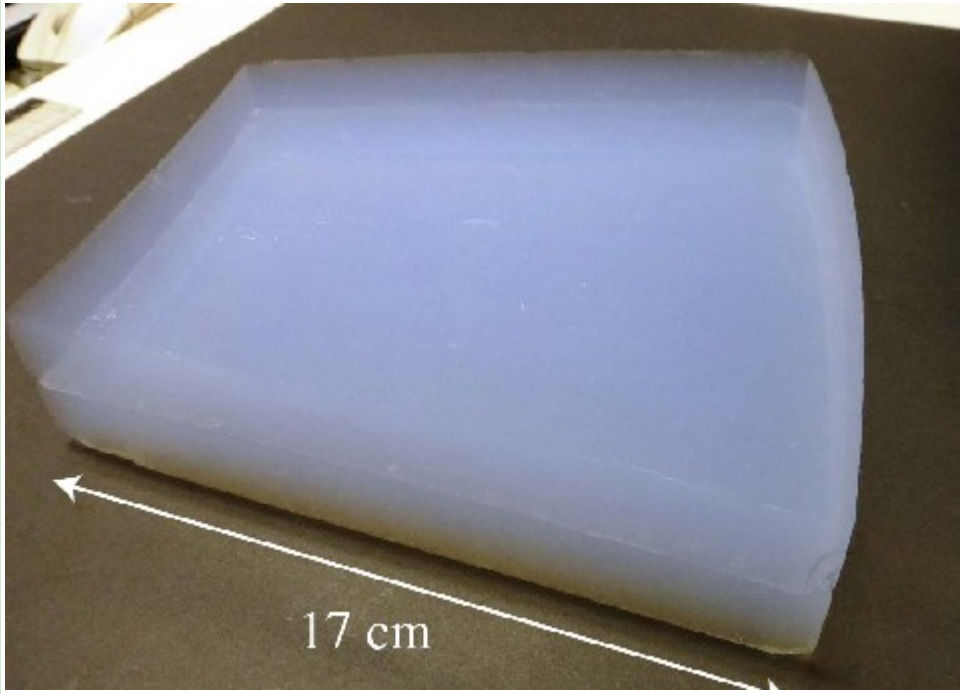




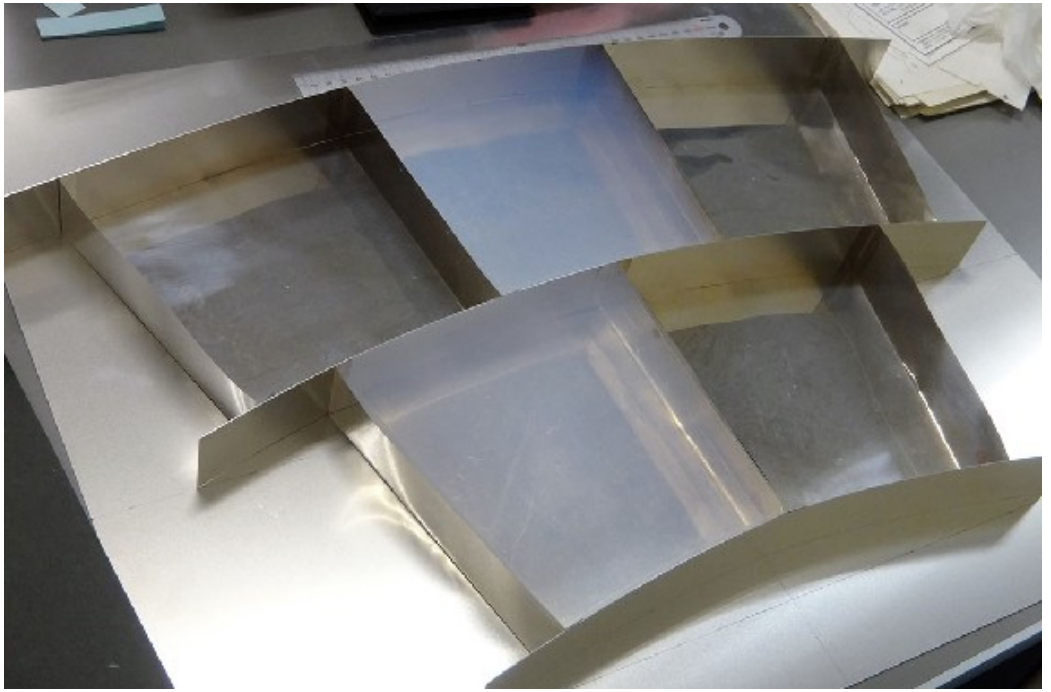
Silica Aerogel radiator

- As a radiator a silica aerogel is used. Aerogel is an amorphous, highly porous solid of fused silica (silicon dioxide – SiO_2). Refractive index can be adjusted.
- The size of the porous is smaller than 0.1 um - this explain the bluish color due to Rayleigh scattering.
- For ARICH use two different Refractive indexes $n_1 = 1.045$ and $n_2 = 1.055$ for focusing purpose.
- Thickness of one layer is 20 mm (40 mm) in total.
- Light transmission length is 45 mm for first layer and 35 mm for second one.

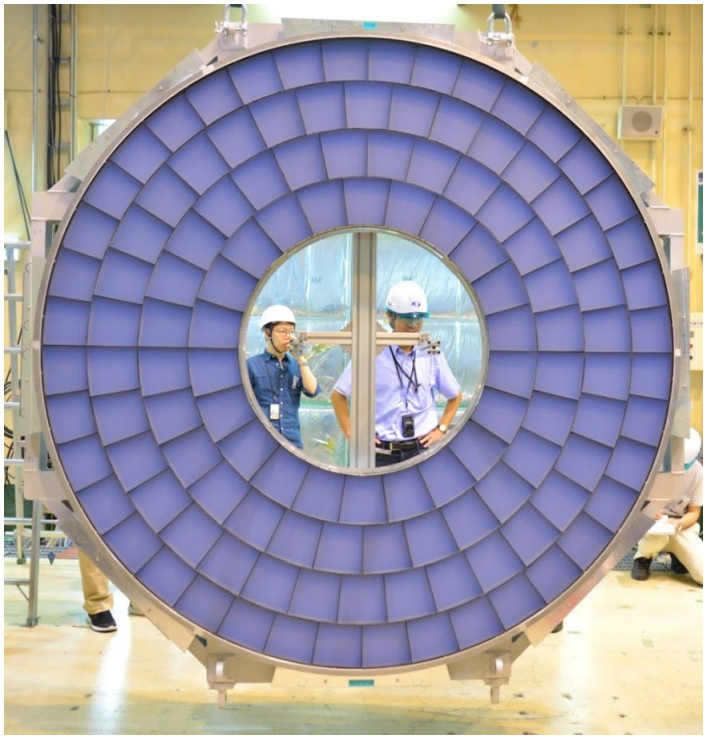
Two layers of wedge-shaped aerogel single tiles of size 17 x 17 x 4 cm^3

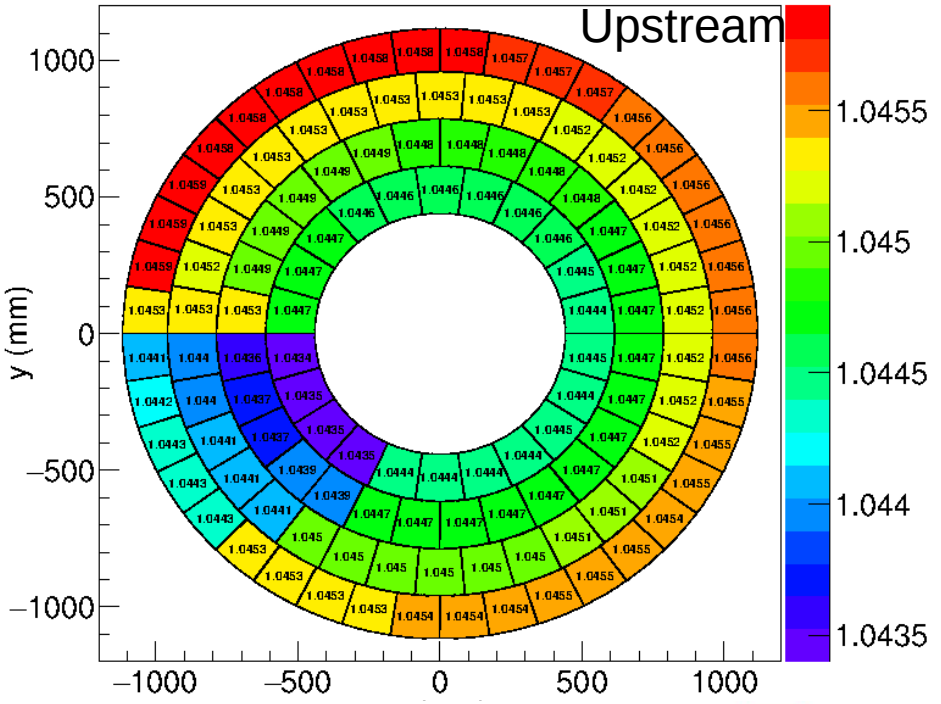


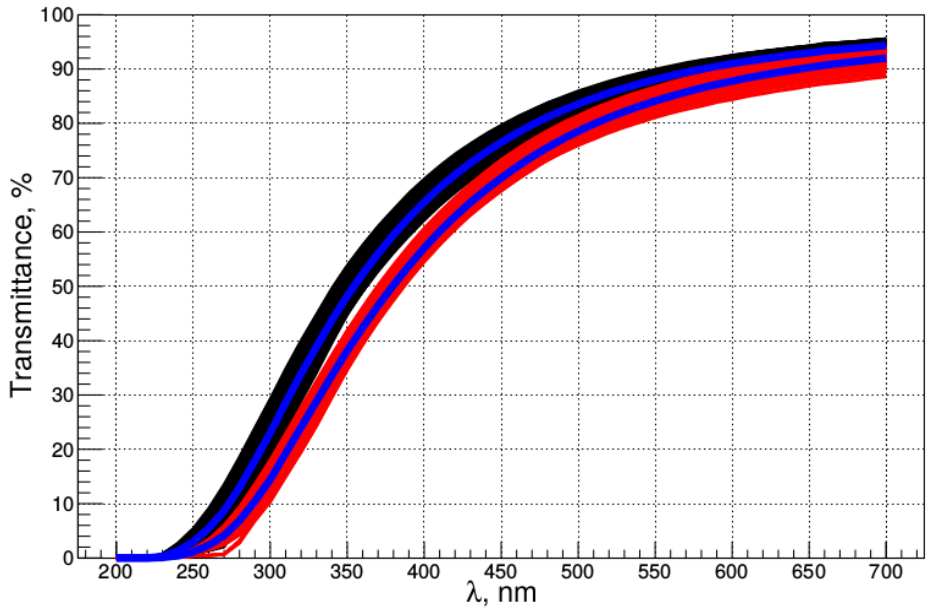
Aluminum support frame mockup for aerogel radiator

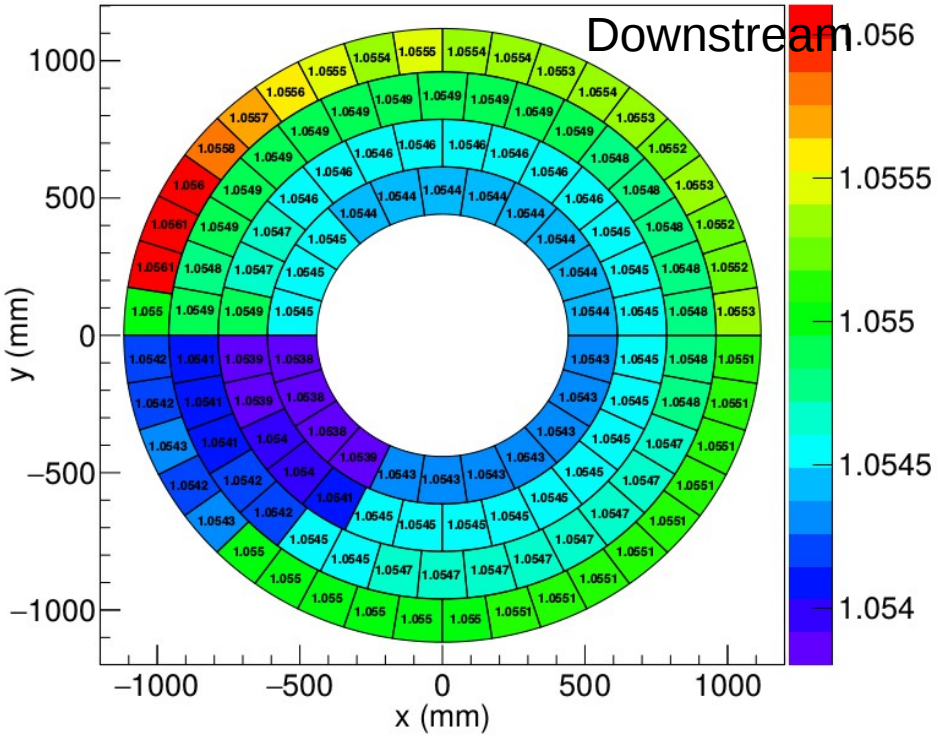


Silica Aerogel radiator





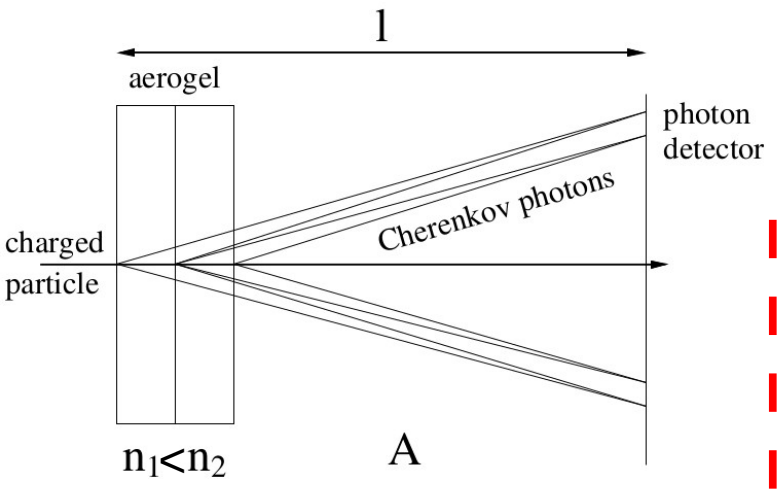




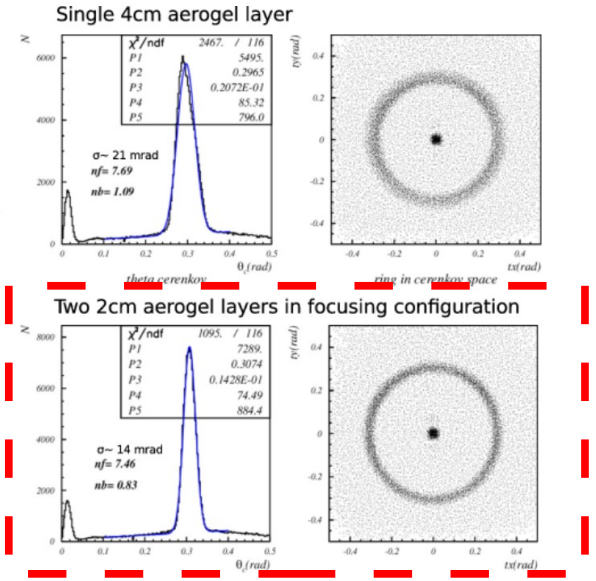
Double layer configuration of ARICH

One of the contribution to the width of Cherenkov ring is thickness of the radiator. Use of thinner layer with different n can mitigate this effect. There are two possible double layer configuration.

Focusing configuration $n_1 < n_2$



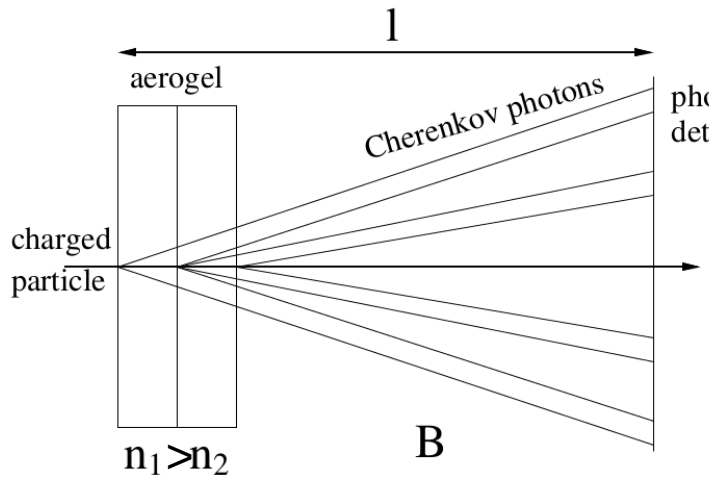
Focusing configuration
(two layers) vs single layer



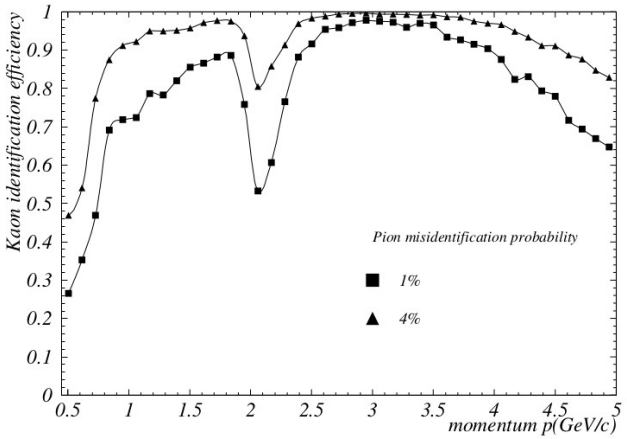
Configuration 1

- Detection of the single ring.
- The Cherenkov ring is sharp with respect to single layer.
- Optimal configuration.

De- focusing configuration $n_1 > n_2$



Kaon detection efficiency
for fixed pion mis-id.



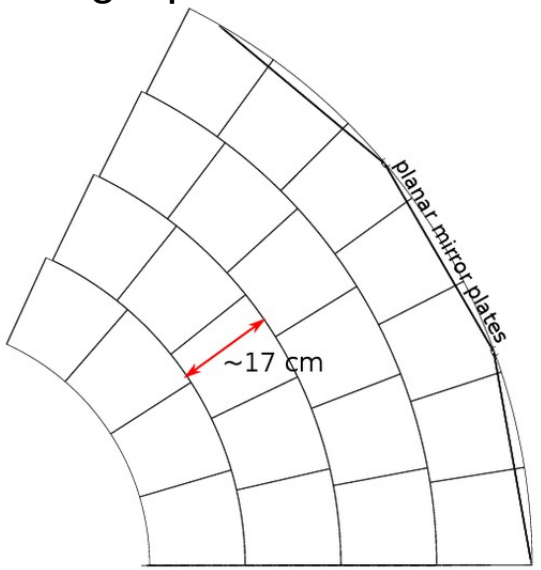
Configuration 2

- Detection of the inner and outer rings for one particle.
- Drop of the efficiency (p ~ 2 MeV/c). Due to overlap of kaon (inner) and pion (outer) rings

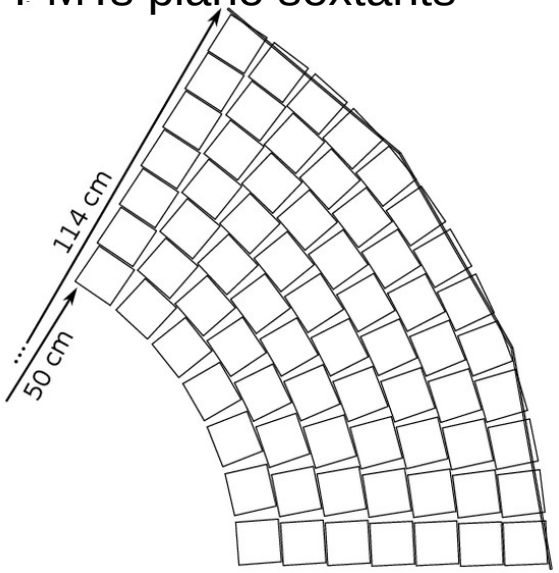
Overall ARICH detector

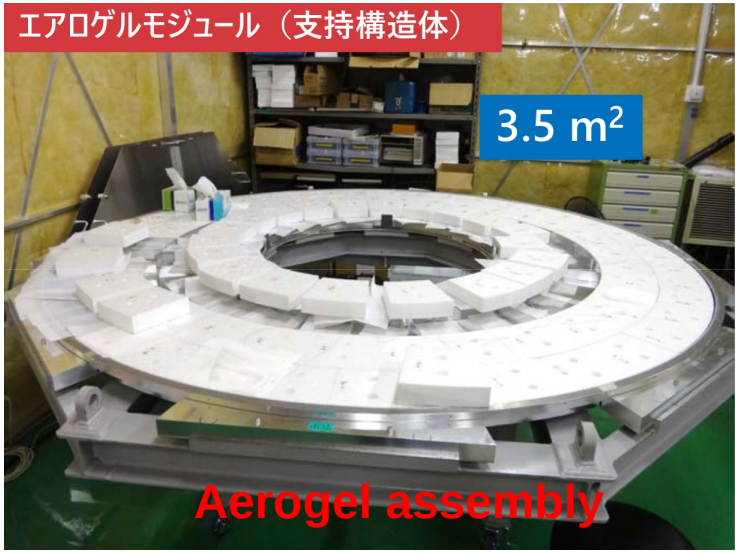
- Placed 2 m from I.P.
- r_{in} = 56 cm, r_{out} = 114 cm
- 3.5 m^2 coverage surface
- 6 sectors
- 2 x 124 = 248 aerogel tiles
- 420 HAPD modules with
- 60480 redout channels
- 18 planar mirror plates

Aerogel plane sextants

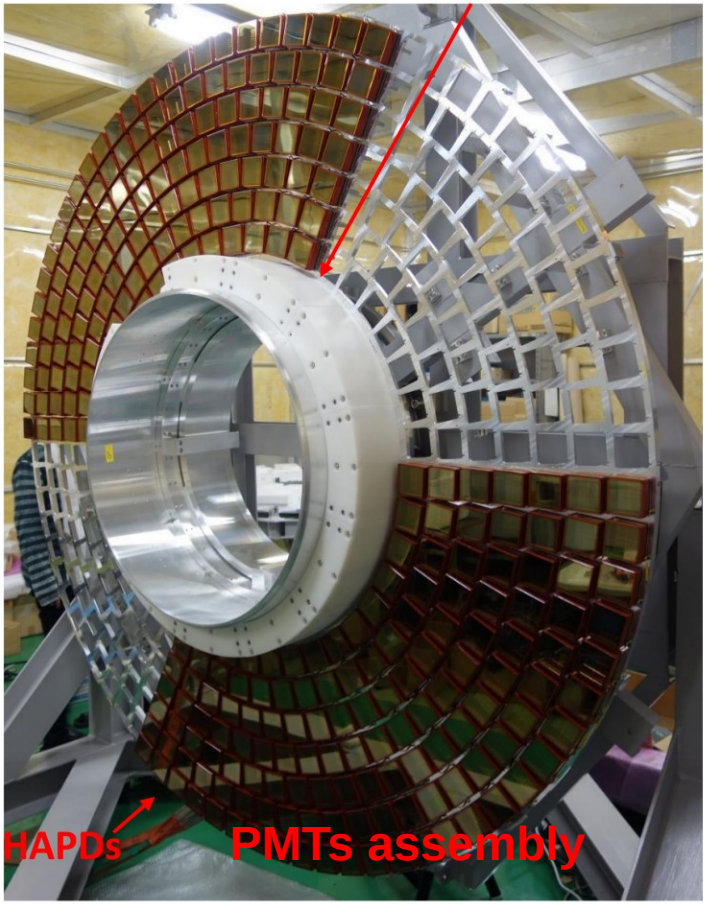


PMTs plane sextants



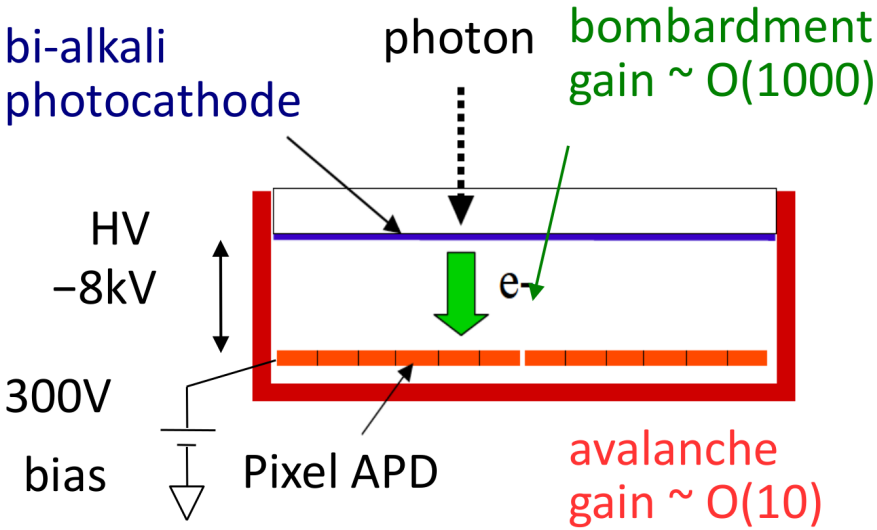


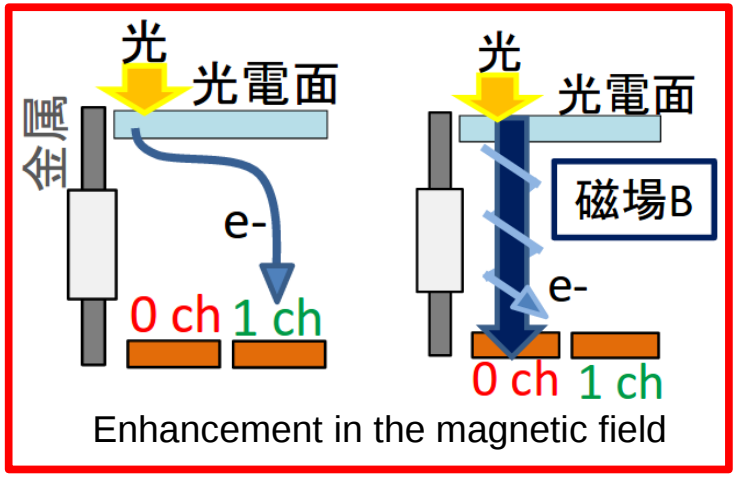
Polyethylene shields

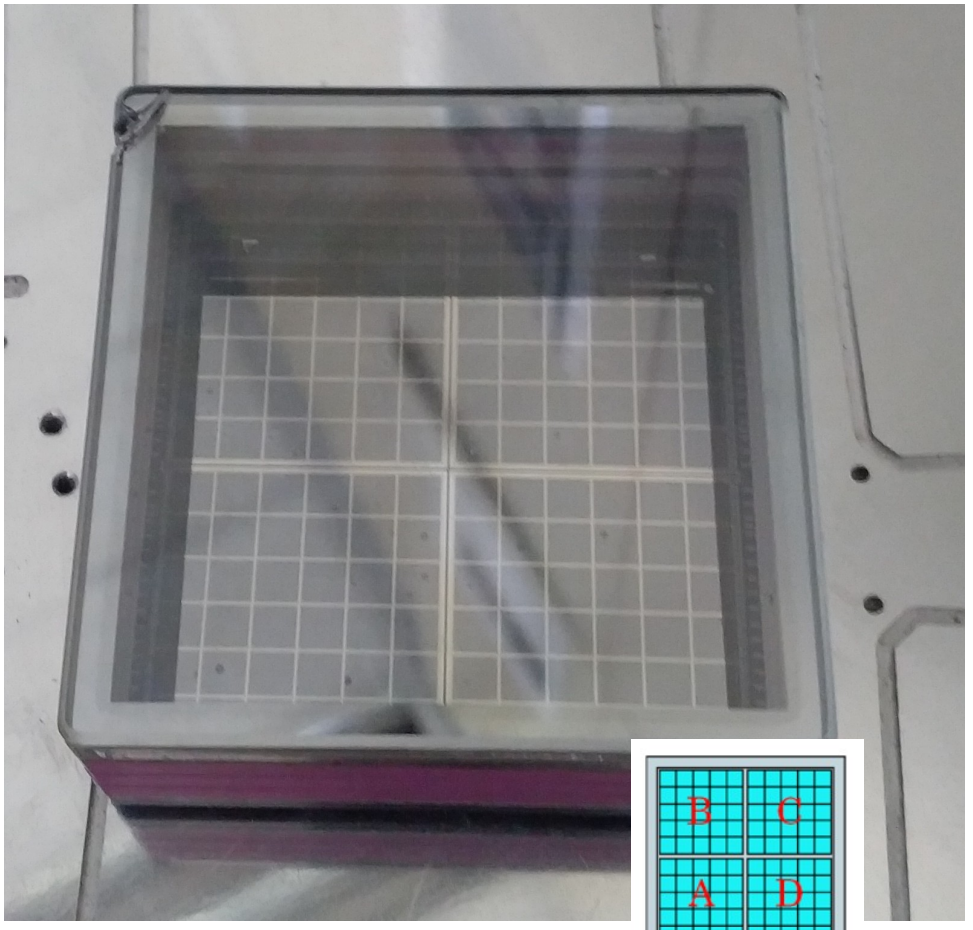


PMT

- Hybrid Avalanche Photo Detector (HAPD). Co-developed with Hamamatsu.
- 144 pixelated APDs : 5 x 5 mm^2 position resolution. Effective area : 63 mm×63 mm in 73 mm x 73 mm.
- Signal gain > $4x10^4$ by Hybrid amplification process.
- Gamma / neutron tolerance for 10 years operation of Belle II.
- Operation in 1.5 T magnetic field.
- This detector have very poor time resolution (~ 100 ns) but this is not important for ring reconstruction.



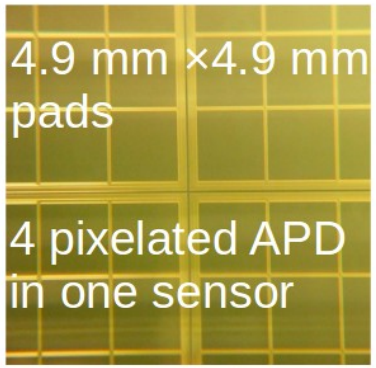


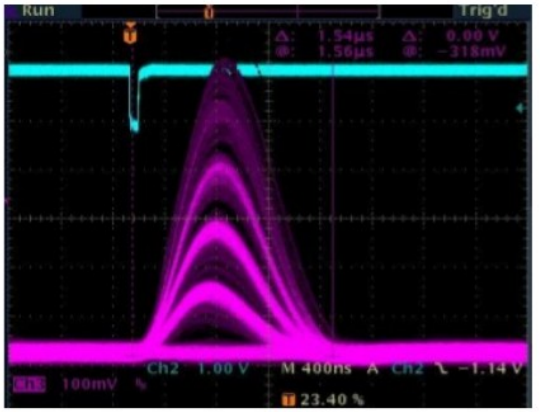


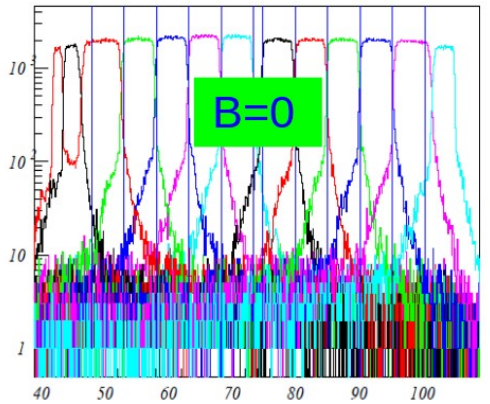
PMT (2)

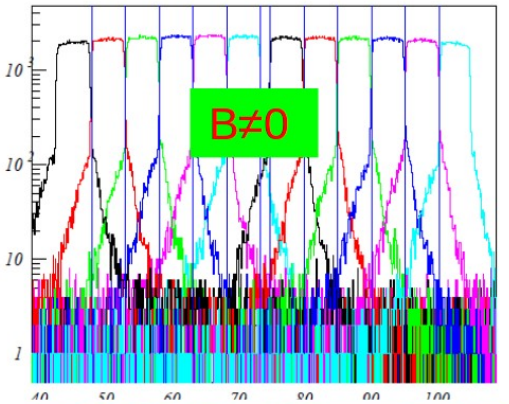
Separate
1 – 2 – 3 p.e.

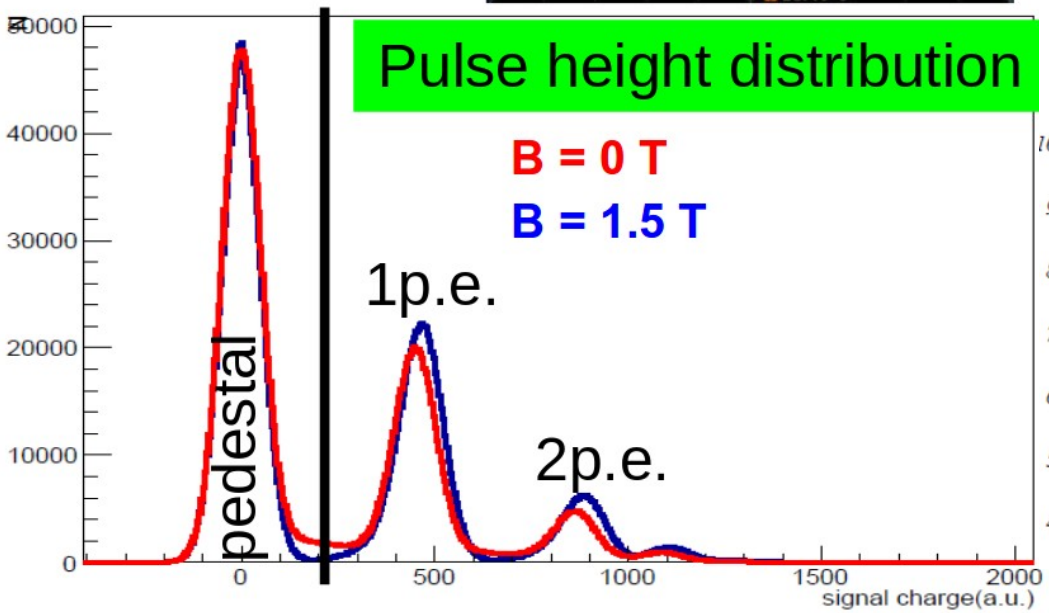
Operation in 1.5 T magnetic field.

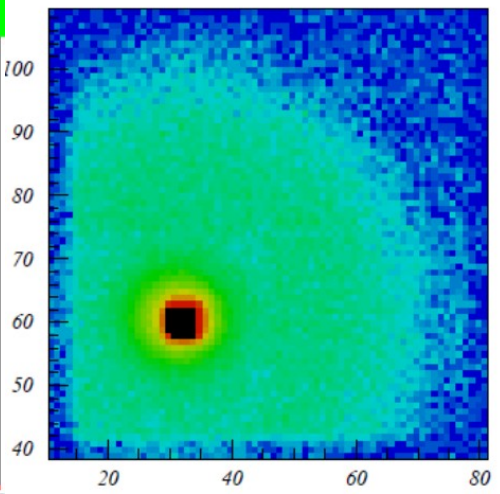


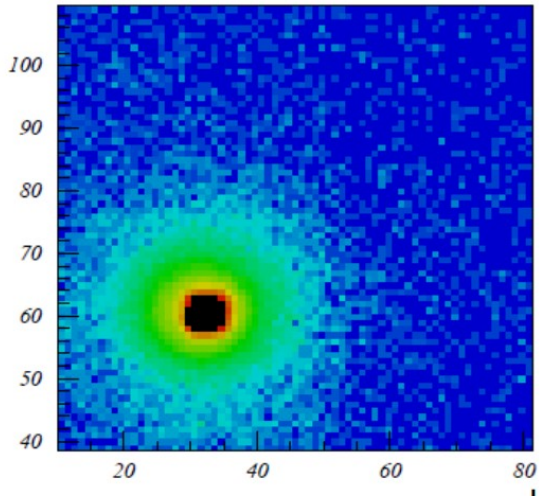








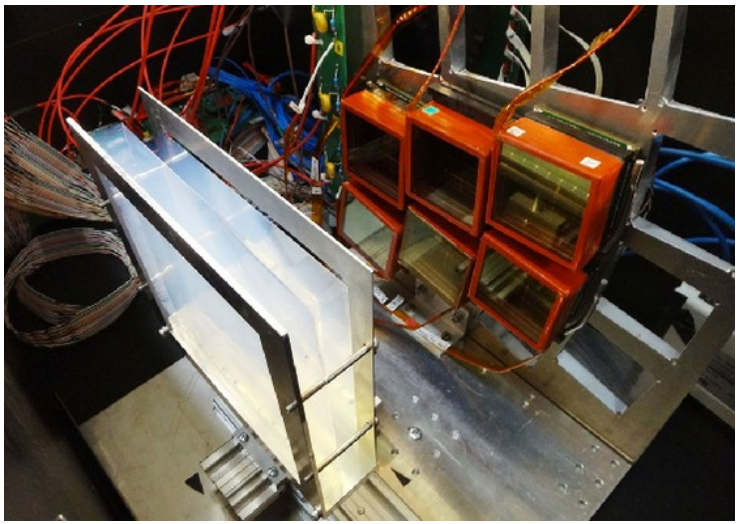


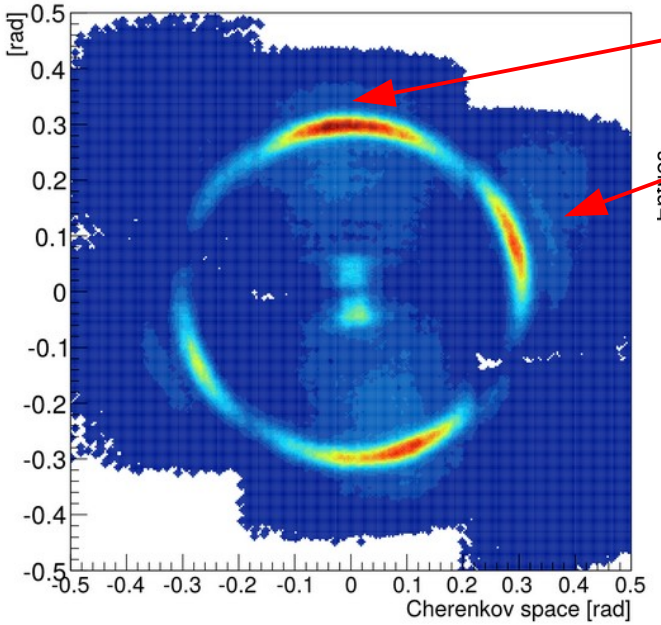


Beam tests.

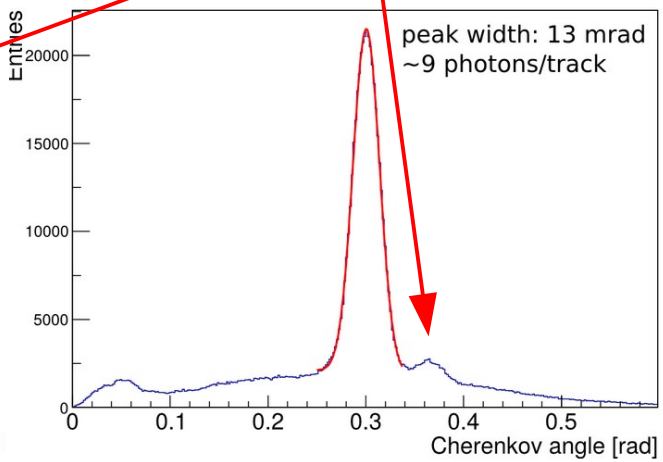
- Performance of the designed ARICH has been tested on beam tests.
- Small prototype with focusing configuration and 6 HAPD modules arranged as in a part of actual detector layout
- KEK in 2009 (3 GeV electron beam).
- CERN in 2011 (120 GeV hadron beam).
- DESY in 2013 (4-5 GeV/c electron).
- Single photon angle resolution is measured to be 13 mrad.
- On average 9 photons per track are detected.

Beam test at DESY in 2013 (4-5 GeV/c electron).





Deflected photon from APD



RICH reconstruction. PID.

- “Simple” ring fit and Cherenkov angle reconstruction provide PID information but less precise then logarithm likelihood analysis.
- PID with ARICH detector based on logarithm likelihood analysis.

$$lnL = -N + \sum_{\text{hit } i} n_i + ln\left(1 - e^{-n_i}\right)$$

Expected number of detected photons

Number of detected photons

Probabilities for a HAPD pad to be hit.

Hit probability

$$n_i = n_s^i + n_b^i$$

Signal

Background

Detection efficiency

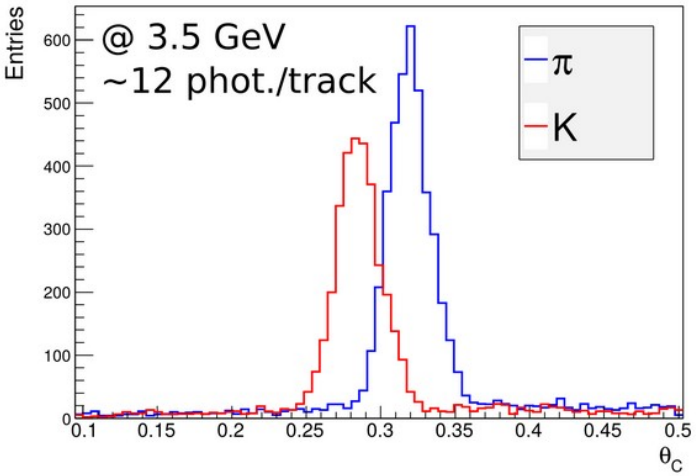
$$n_{s,r}^i = \varepsilon_i n_{t,r} \int_{\Omega_i} S_r(\theta_r, \phi_r) d\theta_r d\phi_r$$

Radiator

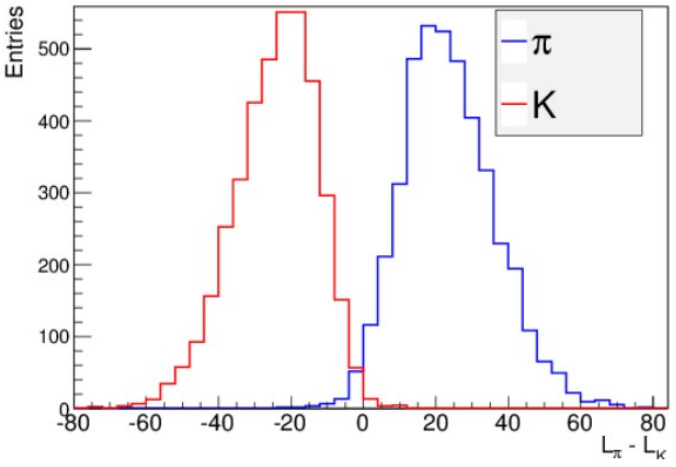
Total number of photons emitted in the radiator of type r

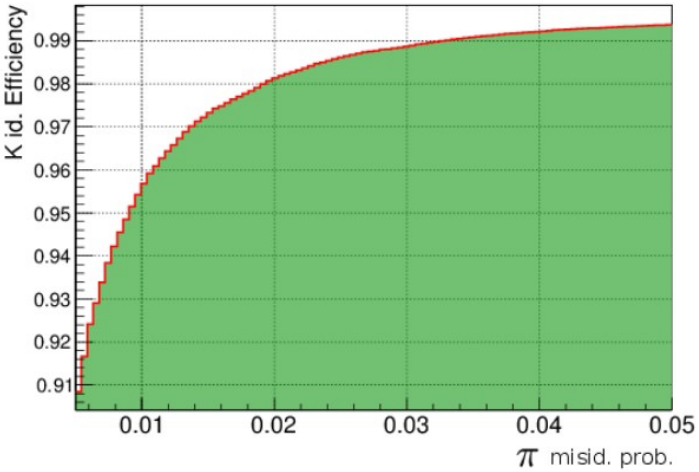
Is the probability for a Cherenkov photon being emitted by particle.

PID with Cherenkov angle reconstruction



PID with likelihood analysis

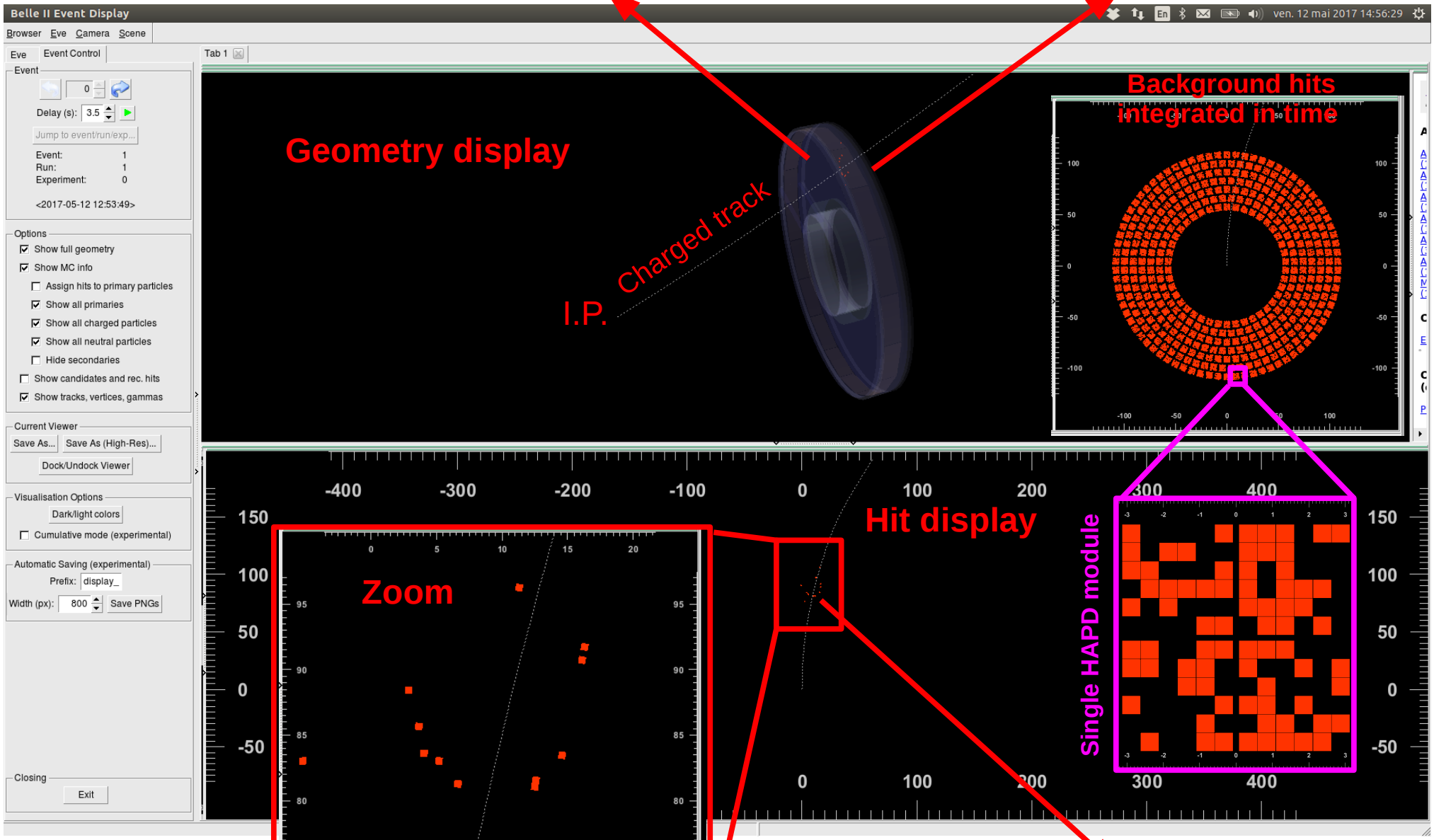




BASF2 – ARICH - Event Display

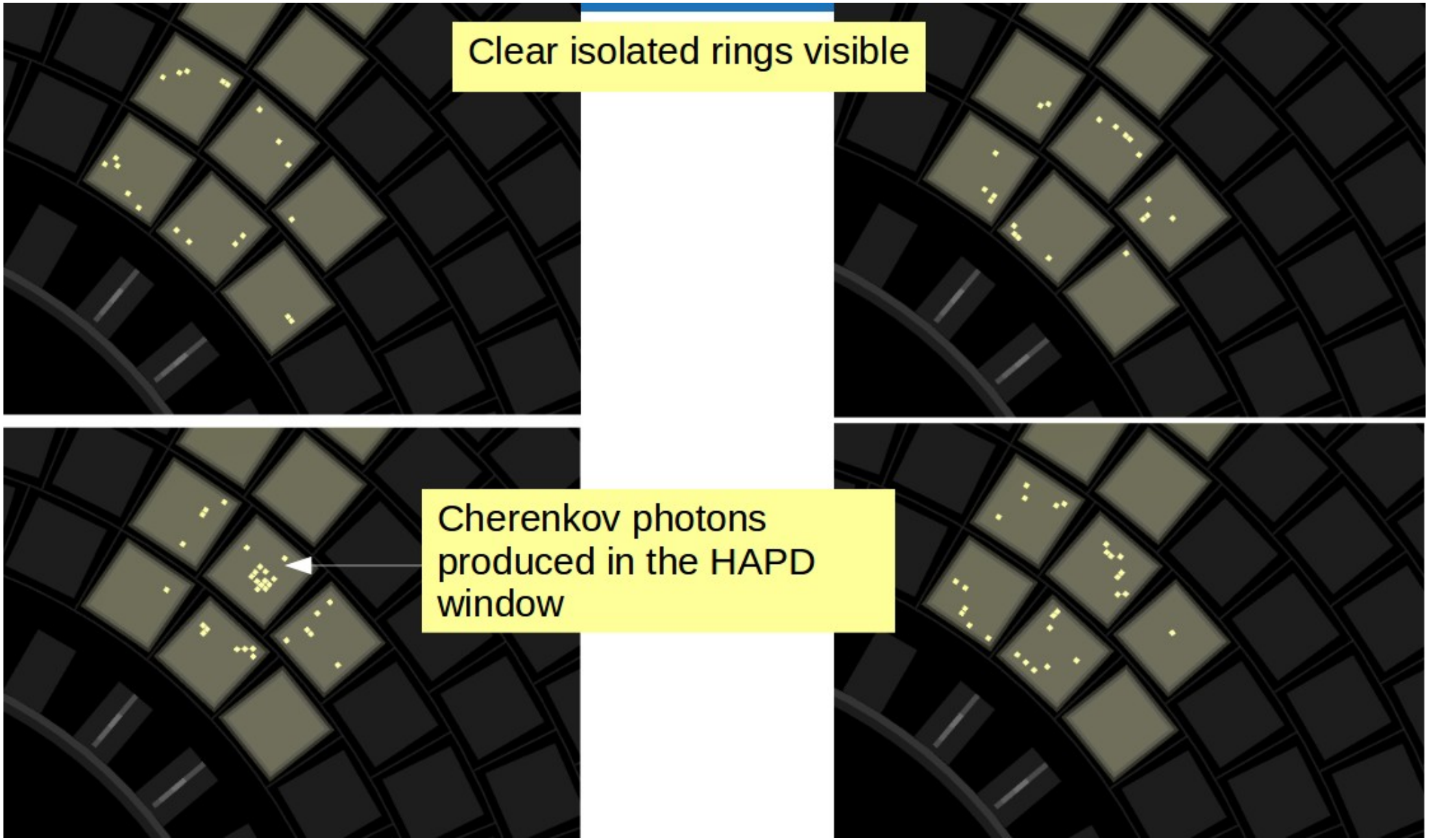
Aerogel radiator.

HAPD (photon detector plane).



Cherenkov ring on HAPD plane.

Cosmic muon test.



Conclusions

- LAL have joined BELLE2 experiment.
- ARICH activity have recently started within BELLE2 experiment.
  - ARICH have been installed in the beginning of September installed.
  - Cable installation from ARICH to electronics – hut is almost finished.
  - Simulation improvements and alignment algorithms need to be developed.