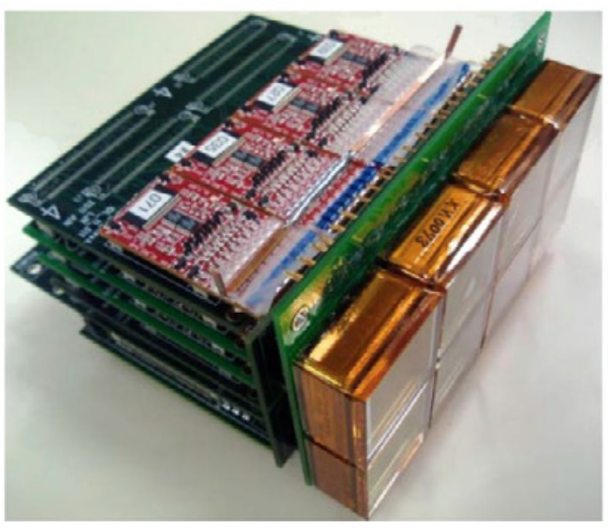
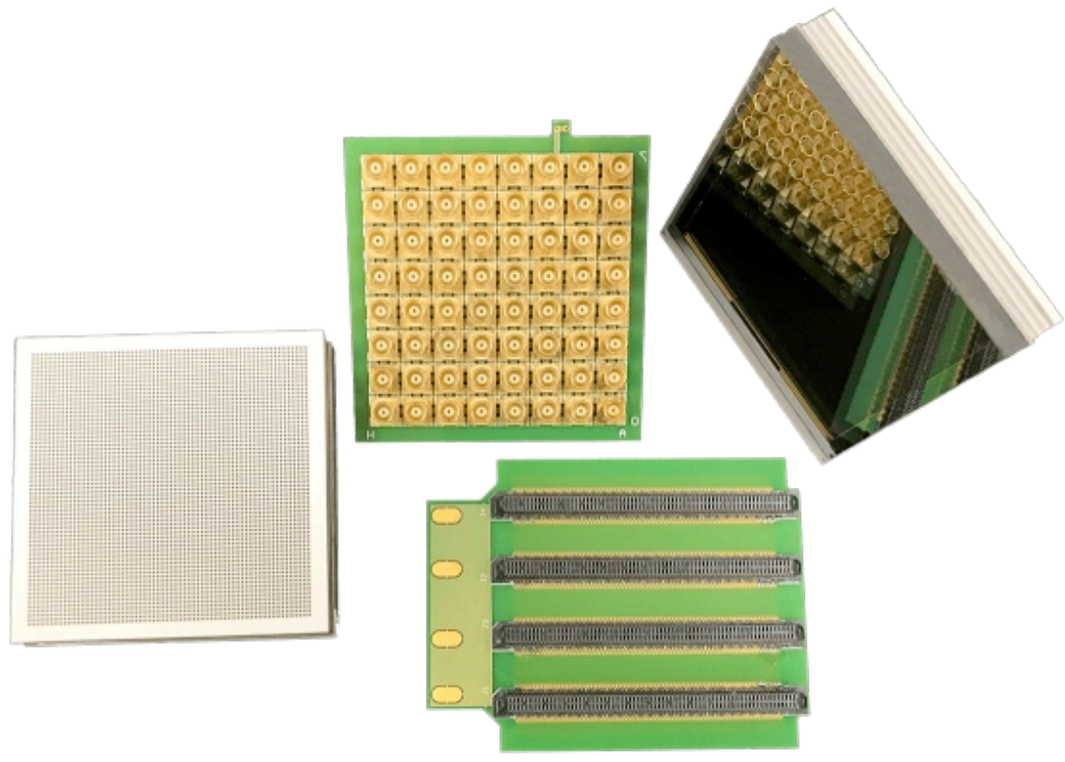
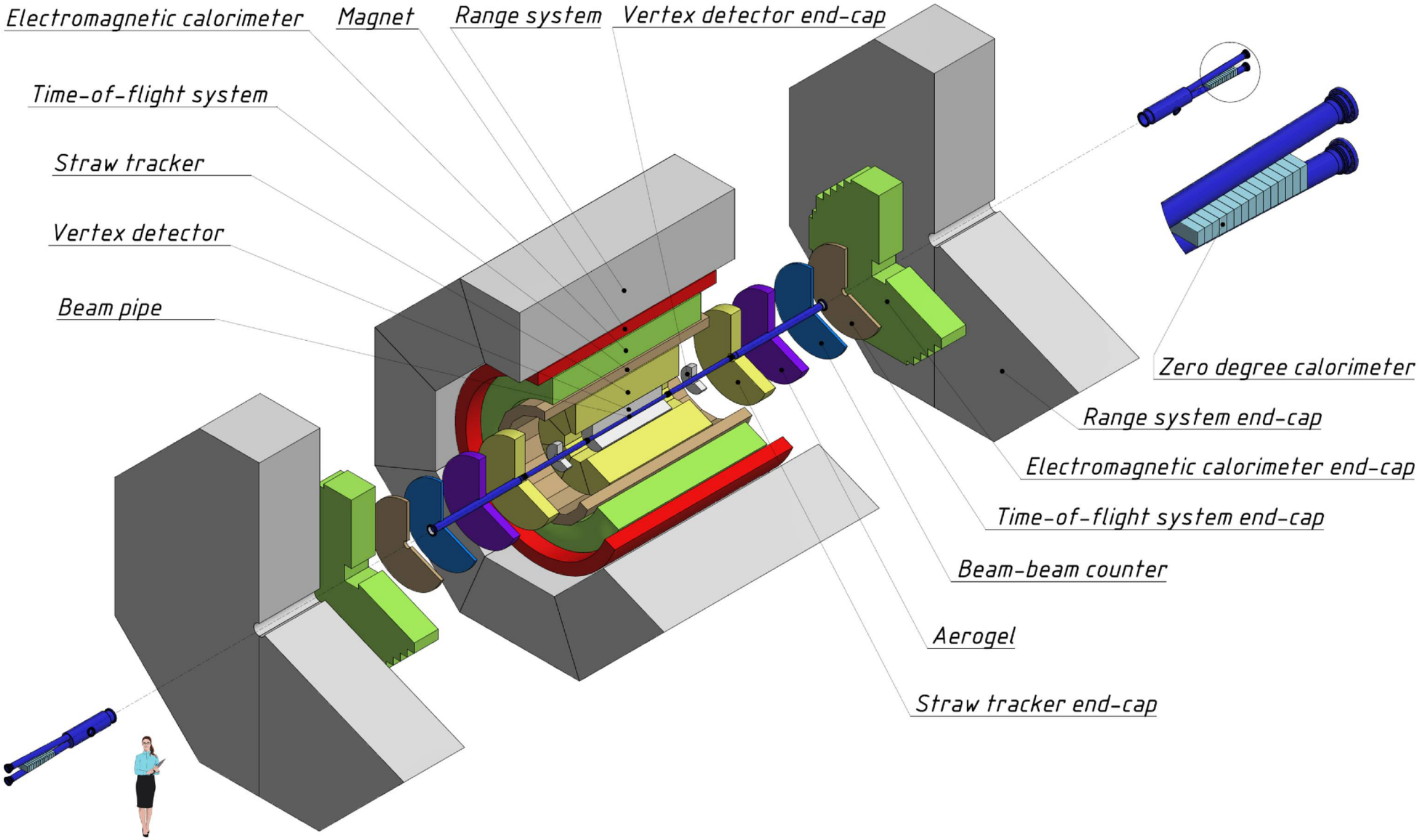
Multi-anode MCP-PMT for ARICH detector of SPD

A.Korzenev, A.Kulikov

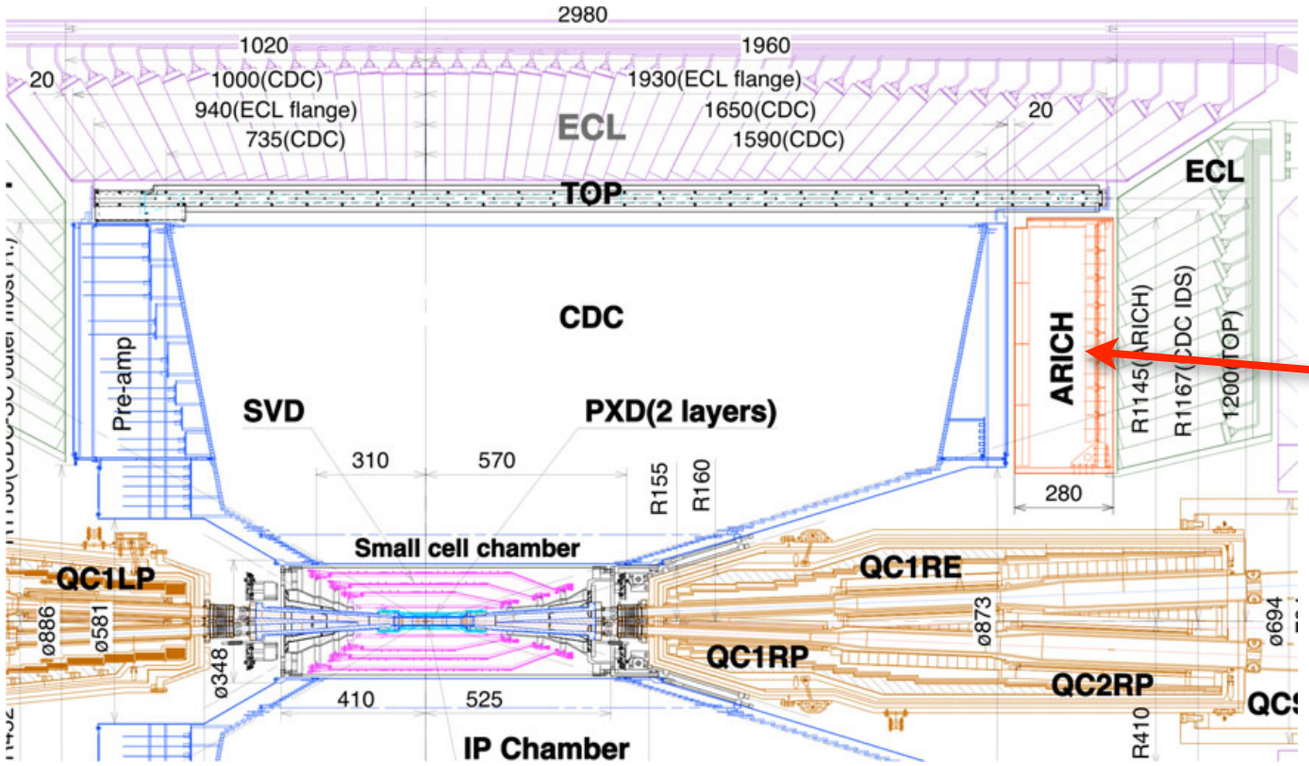


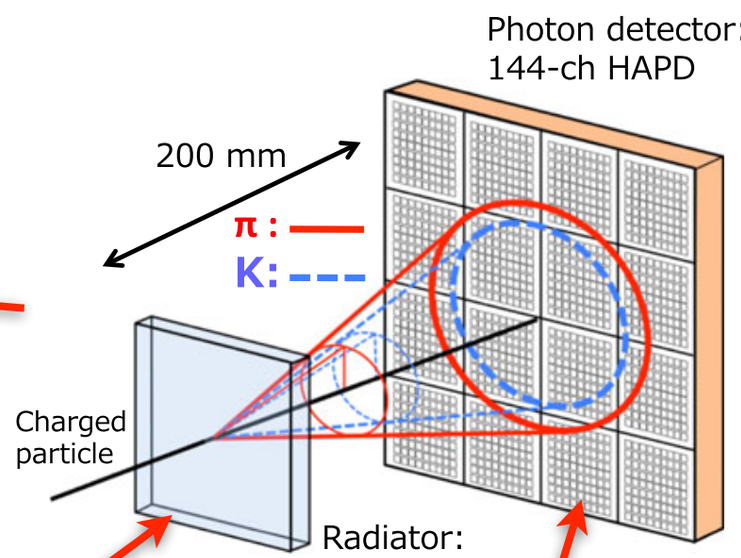


SPD setup (TDR, Jan 2023)



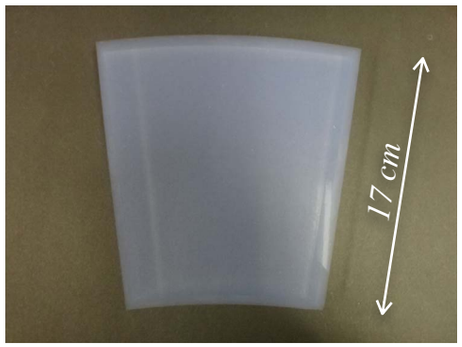
ARICH (in endcap) of the Belle II experiment

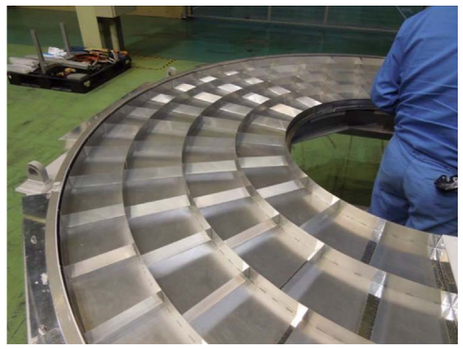


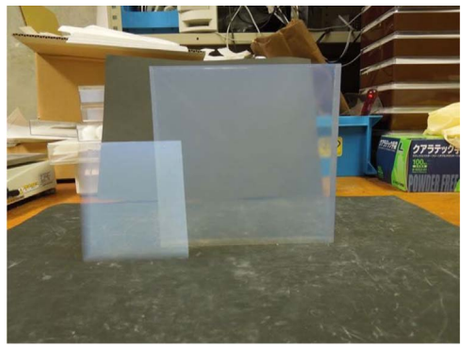


Dual-Aerogel radiator

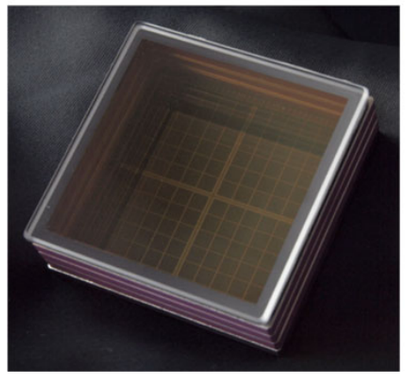
- Focusing effect using n_1=1.045 and n_2=1.055
- Mass production in 2014
- Ref: *NIMA 876 (2017) 129*

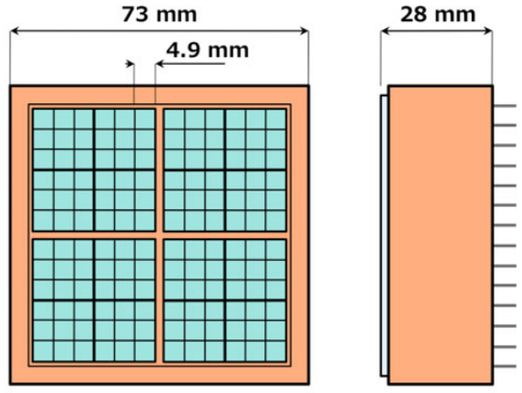




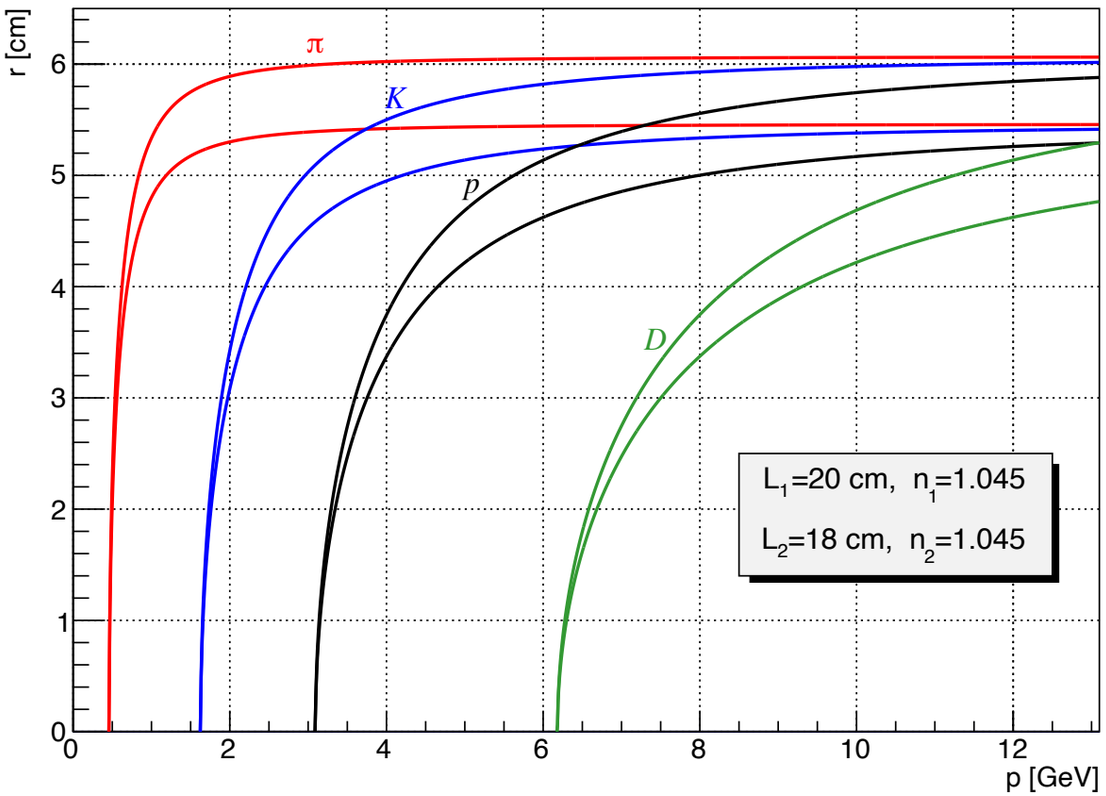


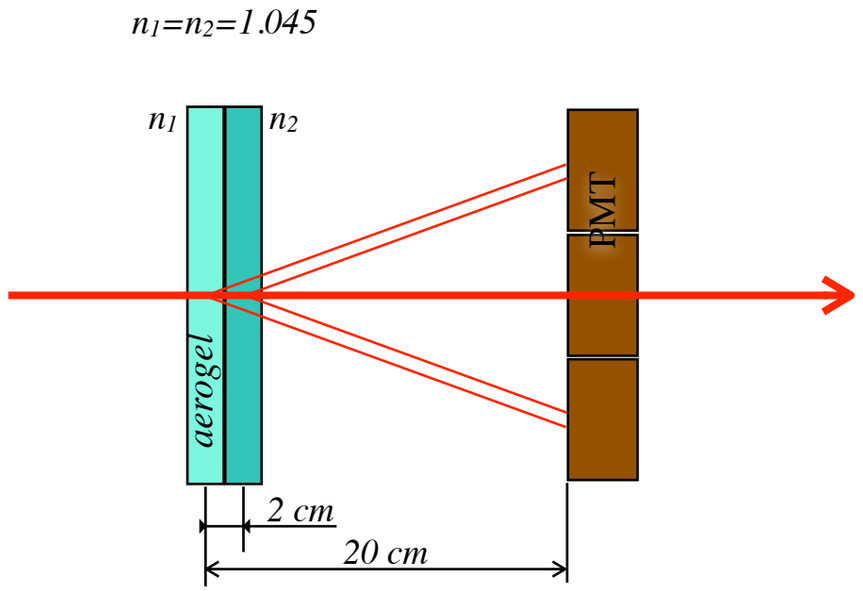
HAPD (Hybrid Avalanche Photo Detector)

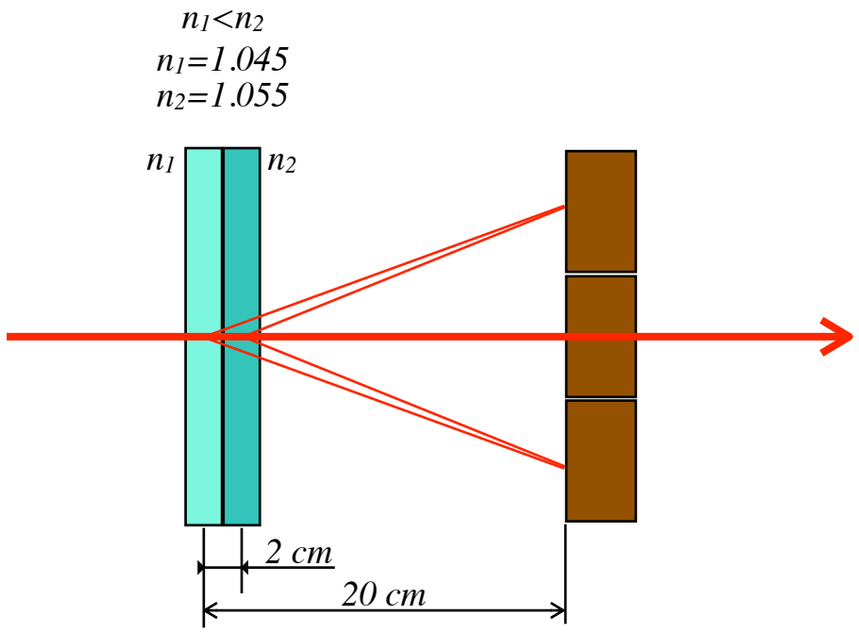


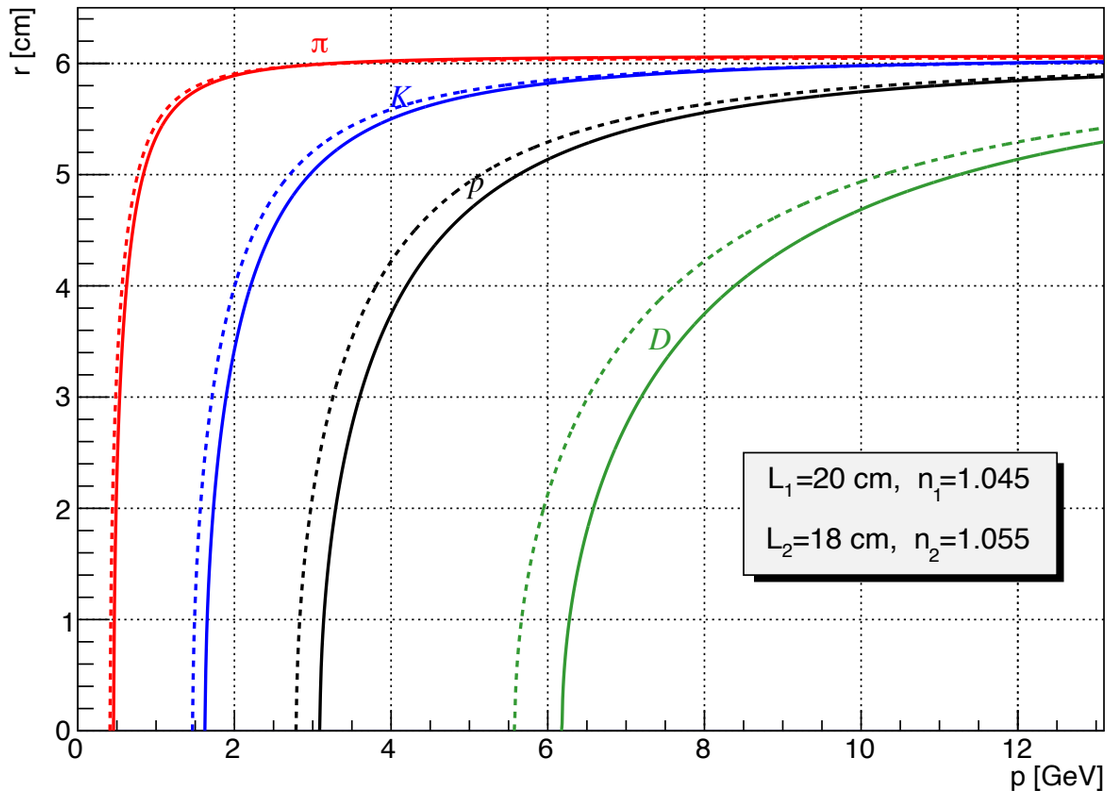


- $R_\pi - R_K$ = 5 mm for p = 4 GeV → pixel size is 5 mm
- Ref: *PTEP 2016 (2016) 3, 033H01 [1603.02503]*

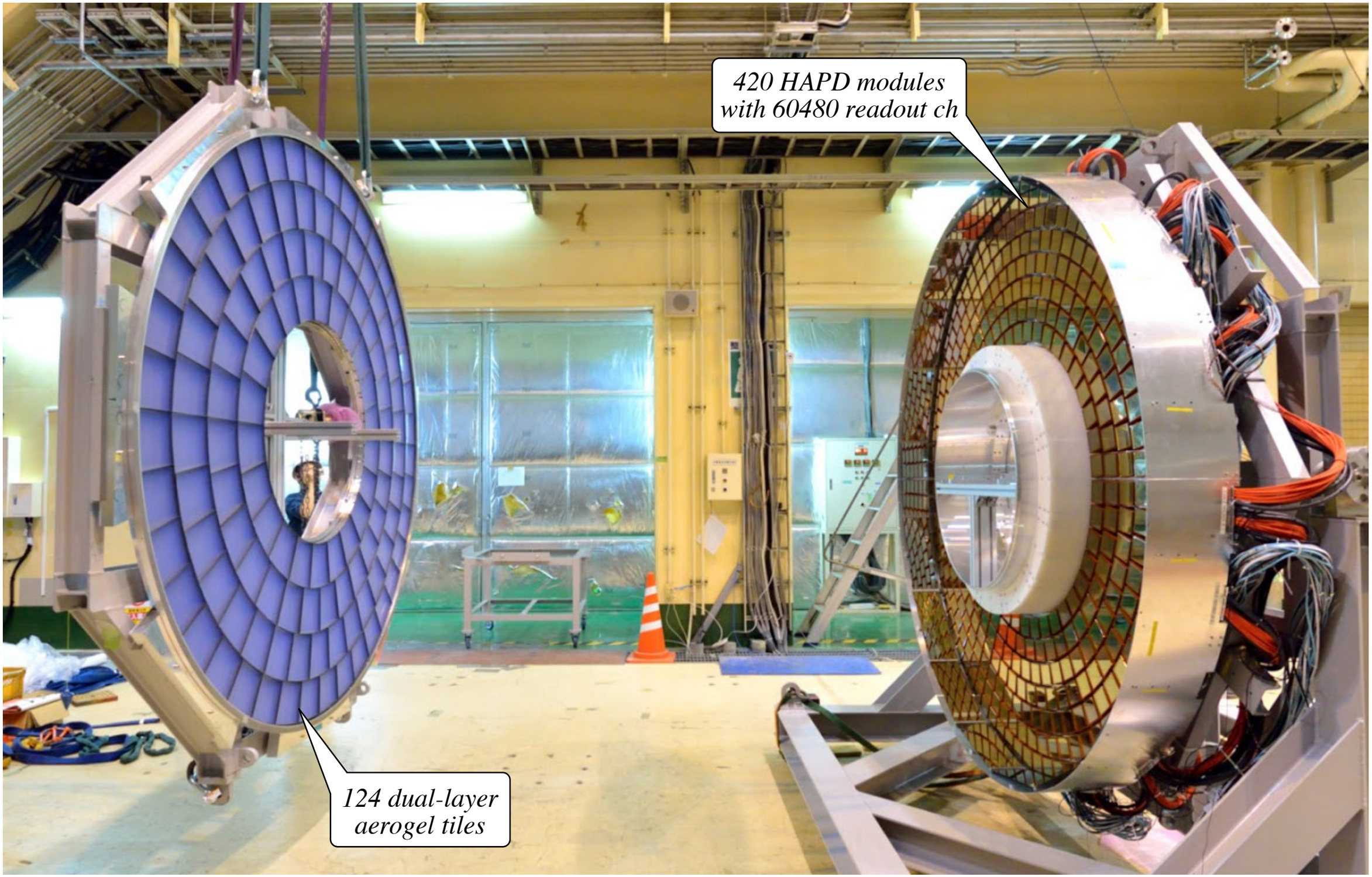

r [cm]
p [GeV]
π
K
p
D
L1=20 cm, n1=1.045
L2=18 cm, n2=1.045


n1=n2=1.045
n1
n2
aerogel
PMT
2 cm
20 cm


n1<n2
n1=1.045
n2=1.055
n1
n2
2 cm
20 cm


r [cm]
p [GeV]
π
K
p
D
L1=20 cm, n1=1.045
L2=18 cm, n2=1.055

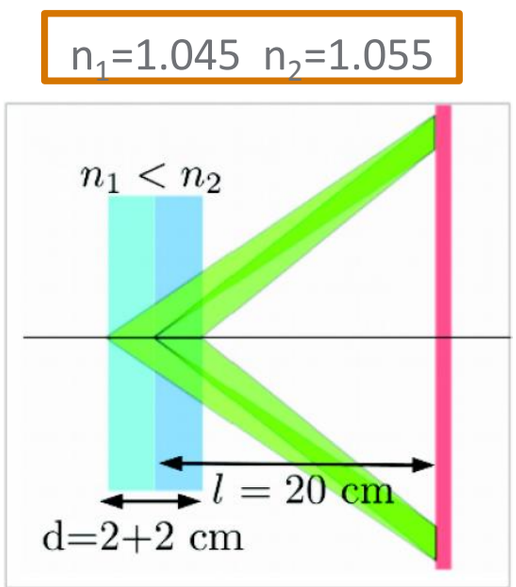
ARICH (in endcap) of the Belle II experiment

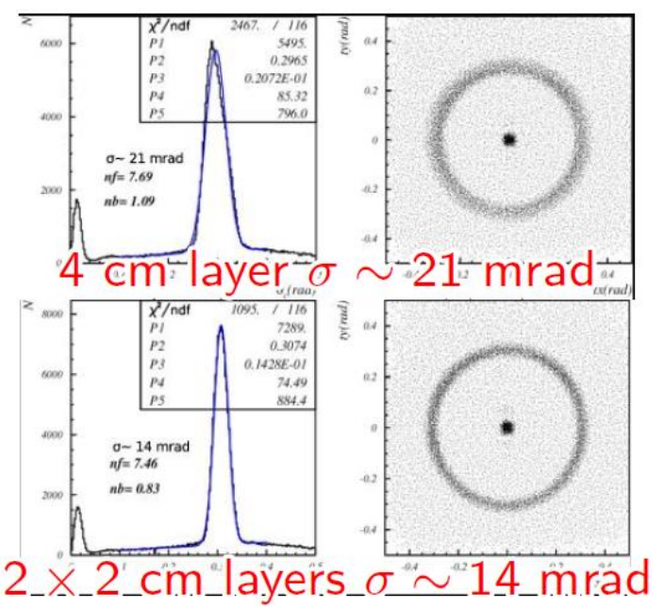


Installed in Oct 2017

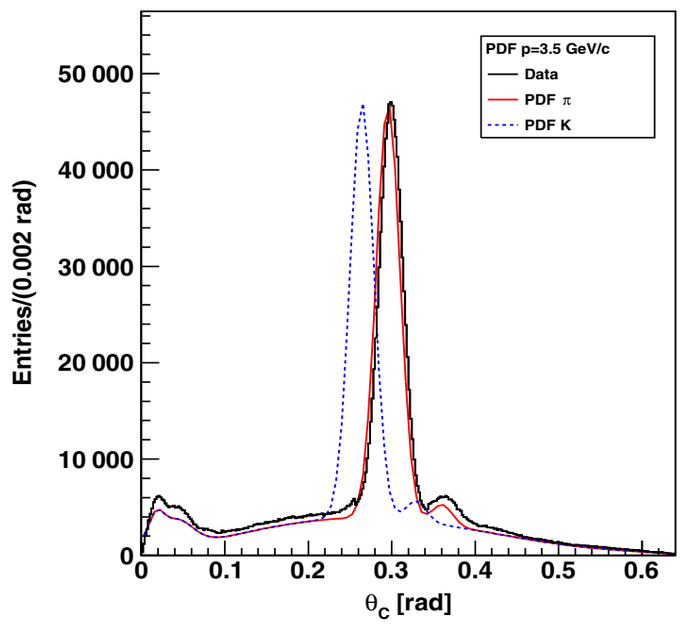
ARICH (in endcap) of the Belle II experiment

Focusing principle

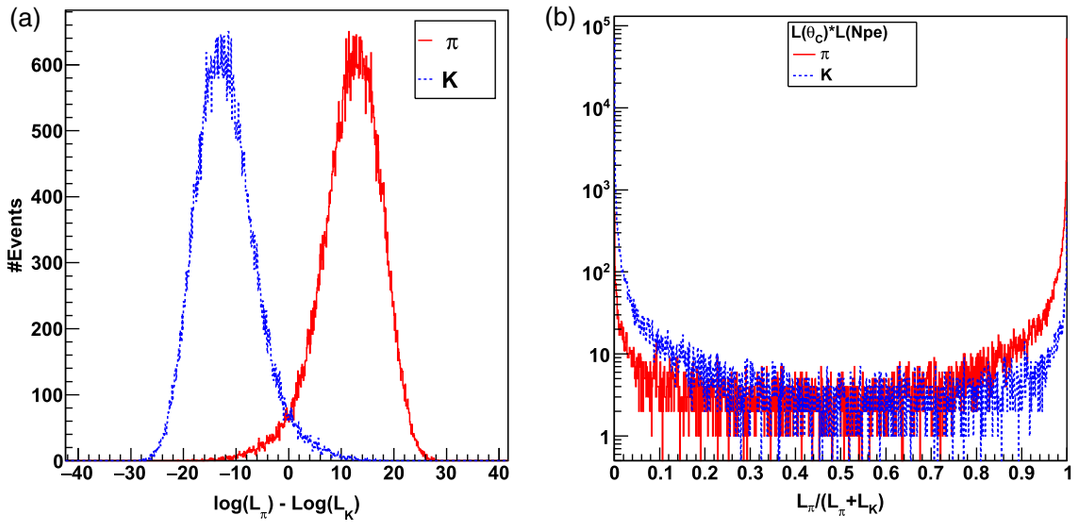




Cherenkov angle for π and K



π and K likelihoods



The difference between the likelihoods — Likelihood ratio distribution

Fig. 15. (a) Distribution of the likelihood difference between the pion (solid line) and kaon (dashed line) at 3.5 GeV/c. (b) Likelihood ratio distribution for pions and kaons at 3.5 GeV/c.

Efficiency of π and K identification

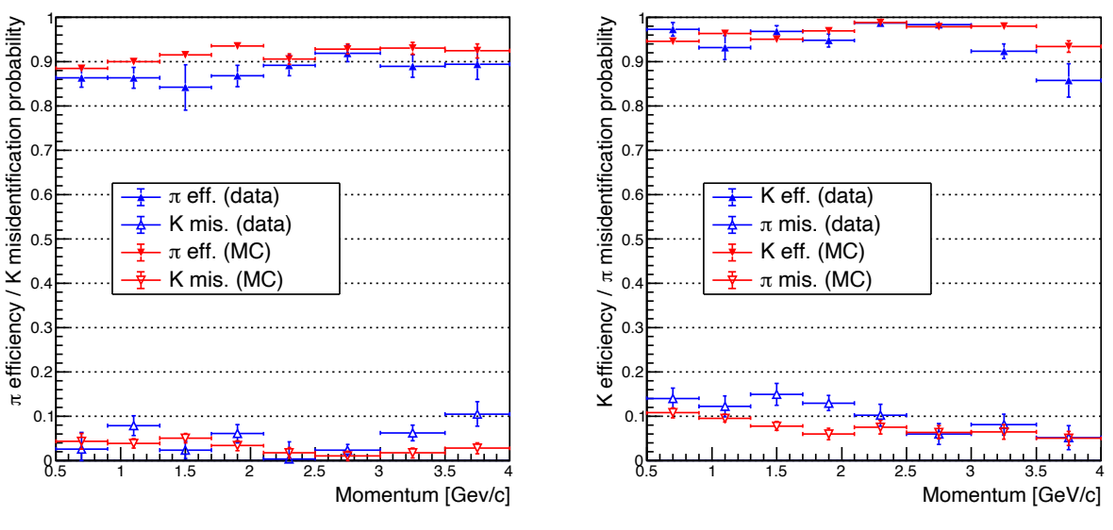
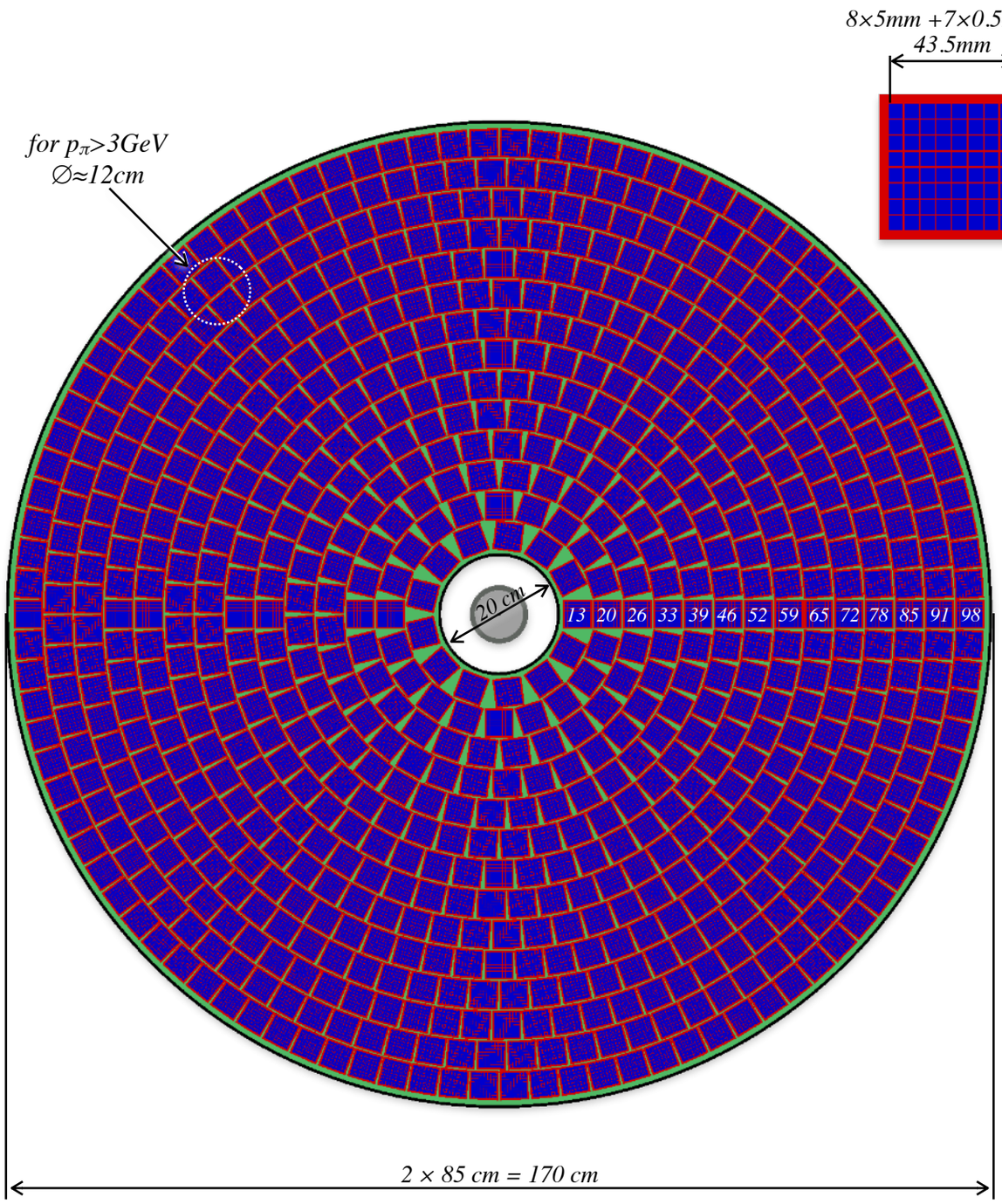
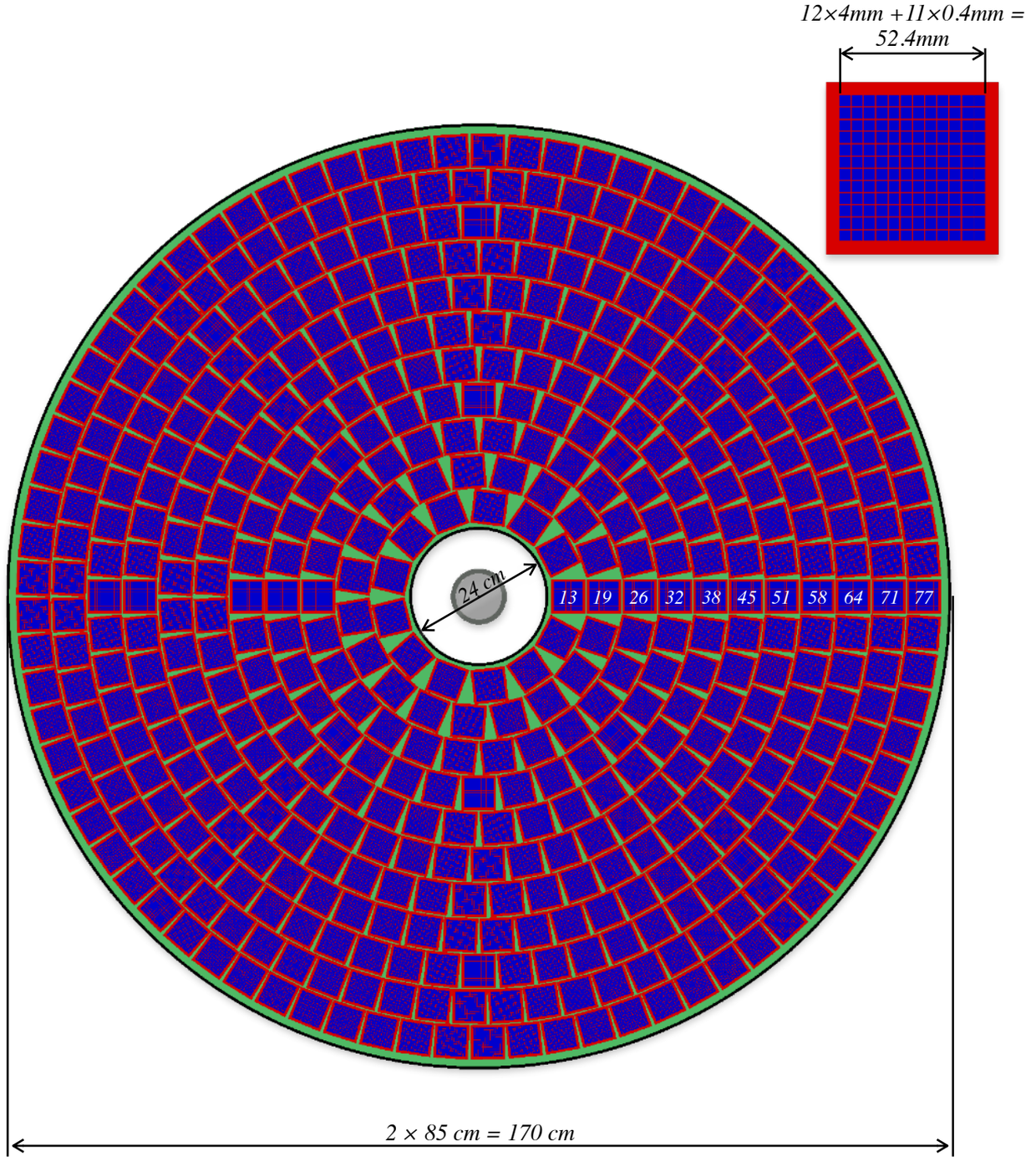


Figure 14: Efficiency and misidentification probability as a function of the momentum: π efficiency and K misidentification probability (left), and K efficiency and π misidentification probability (right).

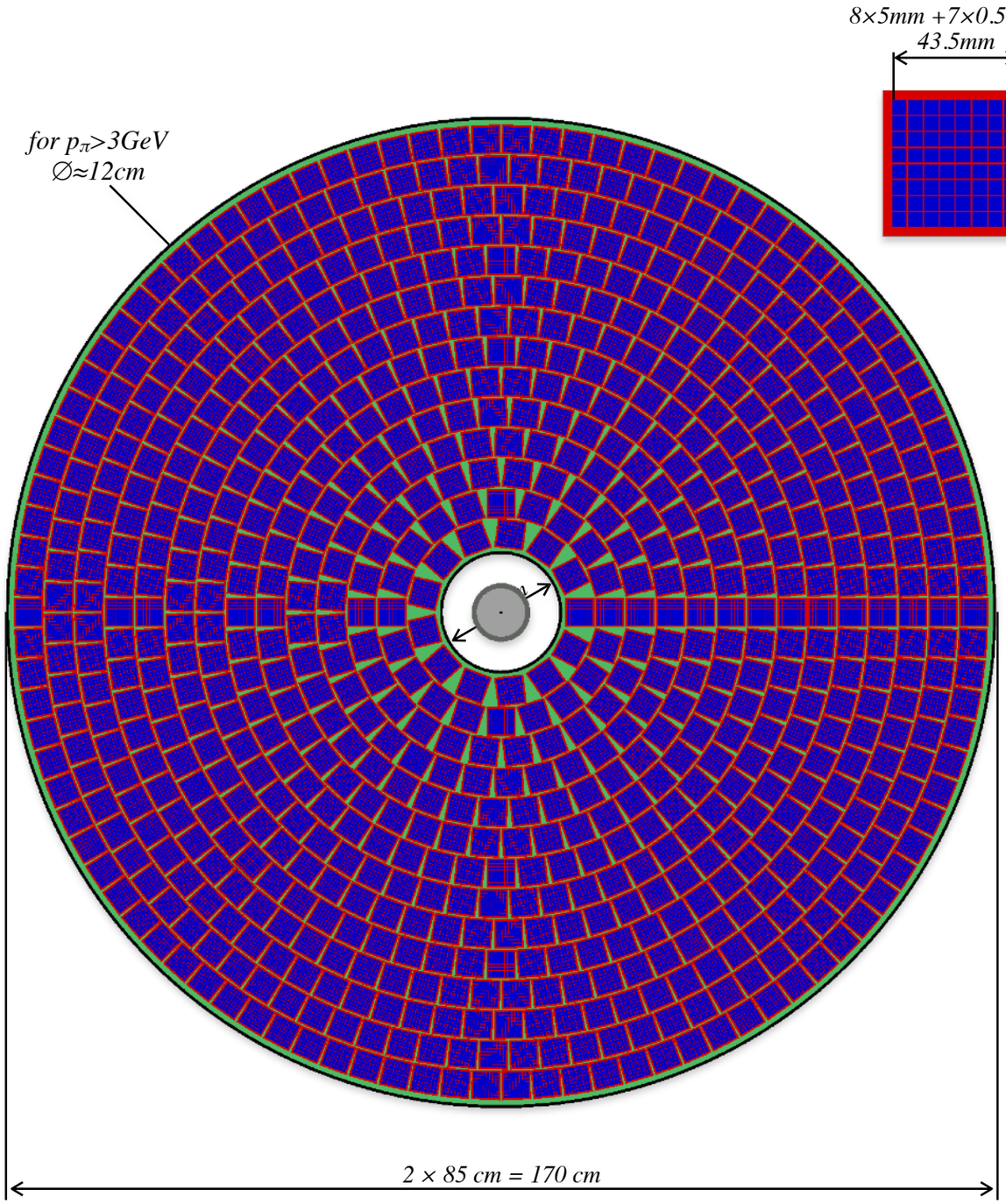
Multi-Anode MCP-PMT: $8 \times 8 = 64$ pads, $S_{pad} = 5 \times 5$ mm^2
S_{ARICH}=2.2 m^2, $N_{PMT} = 777$, filling=56%, $N_{ch} = 777 \times 64 \approx 50$k

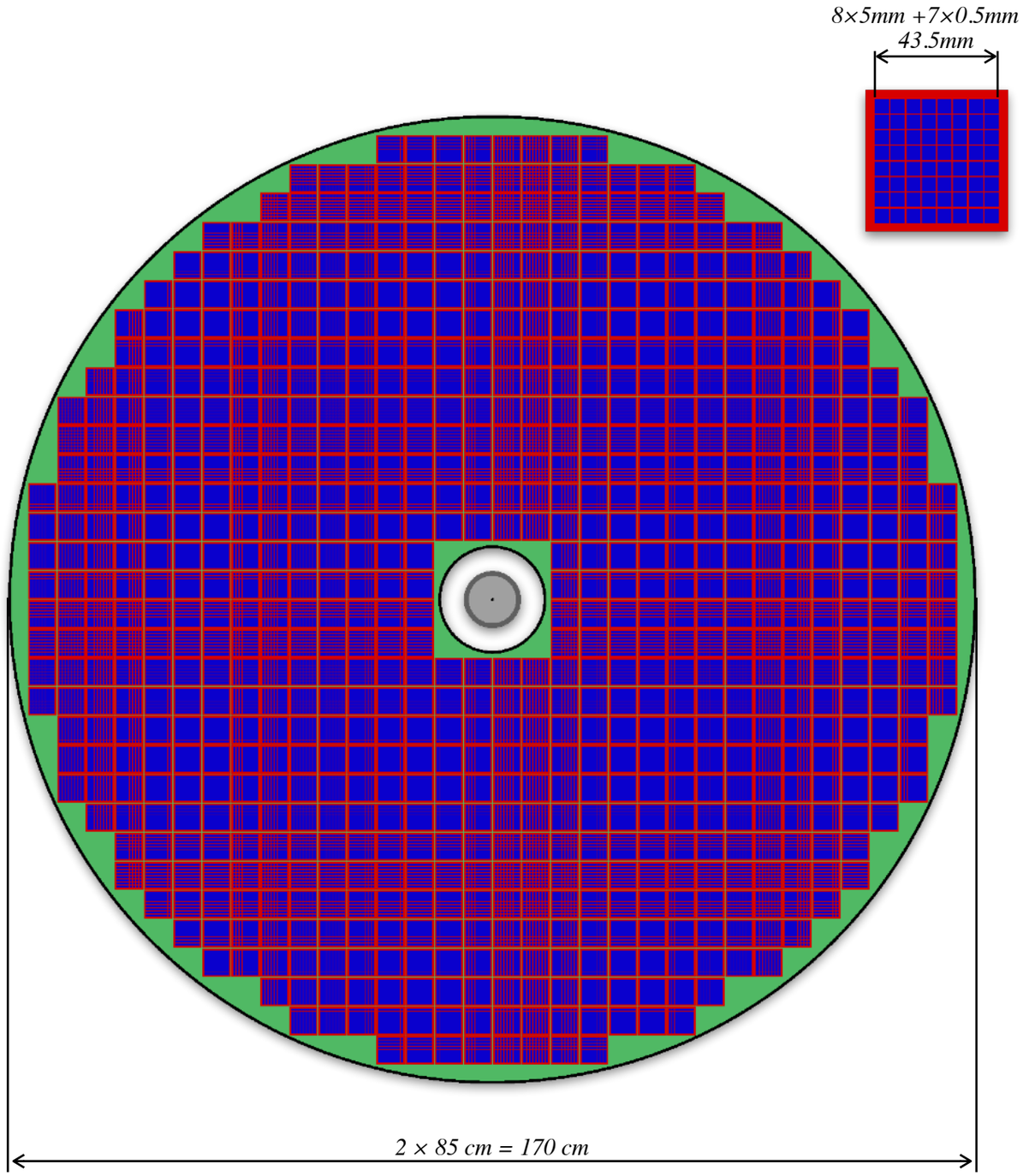


Multi-Anode MCP-PMT: $12 \times 12 = 144$ pads, $S_{pad} = 4 \times 4$ mm^2,
S_{ARICH}=2.2 m^2, $N_{PMT} = 494$, filling=51%, $N_{ch} = 494 \times 144 \approx 71$k

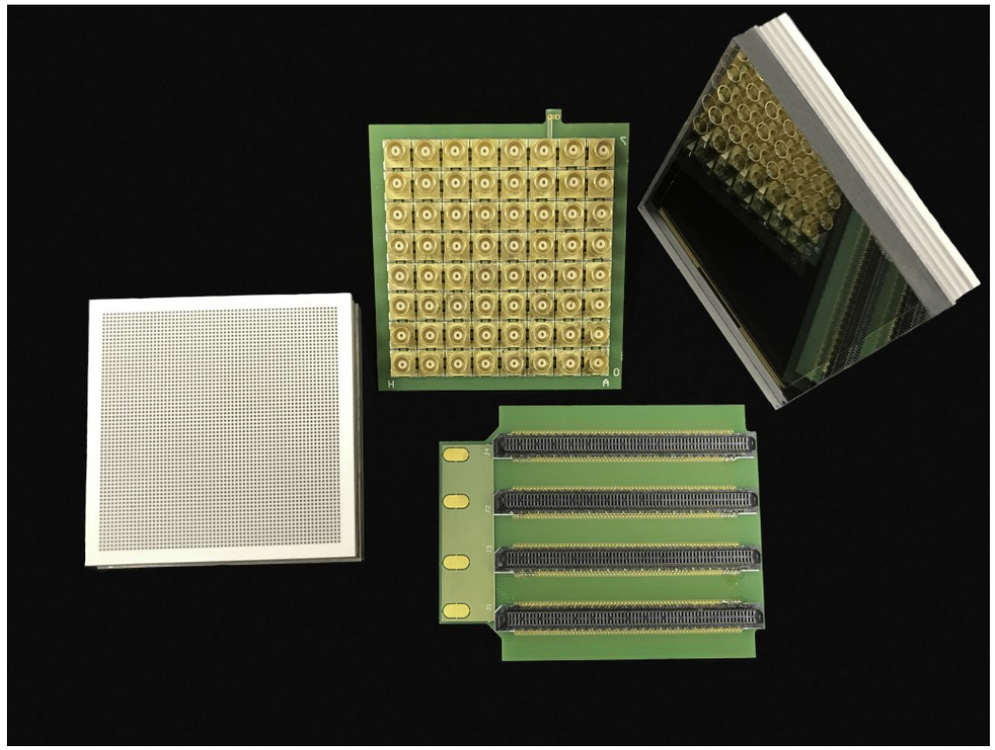


Different PMT layouts





MAPMT253



PRODUCT OVERVIEW

General Characteristics	
Window	Fused Silica (Optional Fibre Optic)
Active Area	53 x 53 mm
Electron Multiplier	Dual MCP
Anode Format	64 x 64 (Reconfigurable)
Anode Pitch	0.828 mm
Photocathode	Solar Blind, Bi-Alkali, S20, S25

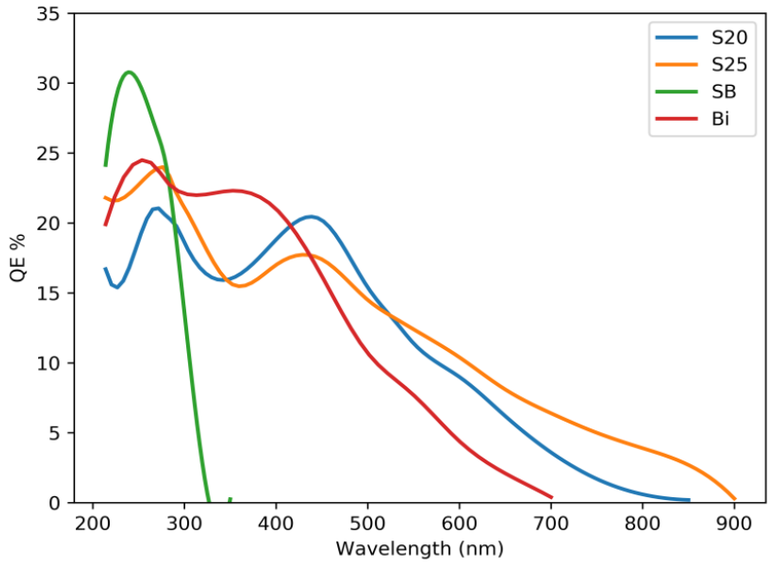
APPLICATIONS

- Ring Imaging Cherenkov (RICH)
- Detection of Internally Reflected Cherenkov (DIRC)
- Sampling Calorimeter Readout
- Wavelength Shifting Fibre Readout
- Scintillating/Cherenkov Fibre Readout
- Beam Monitor
- High Content Screening
- Time Resolved Spectroscopy
- LIDAR
- Standoff Chemical/Biological Detection
- Microplate Readout

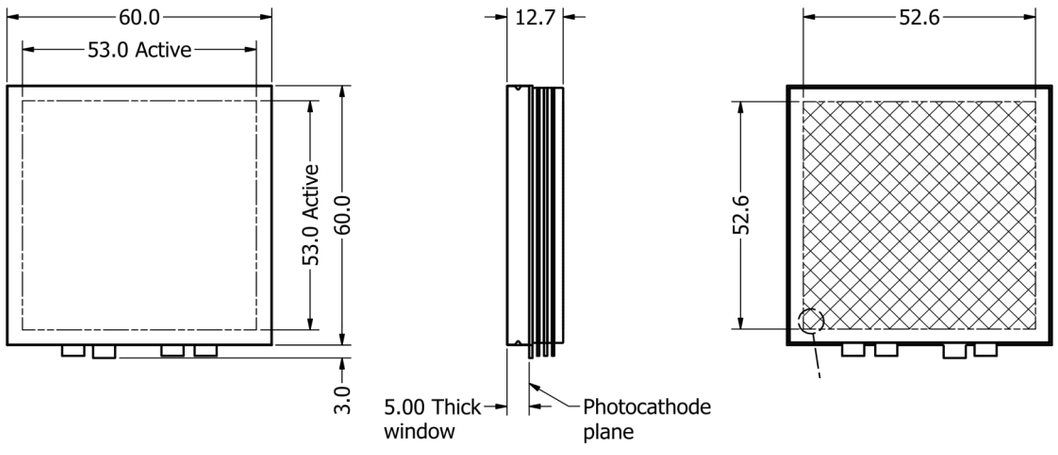
MAPMT253

SPECIFICATIONS

Single Photon Response	Typical
Dark Counts per Anode	< 2 cps
Pulse Risetime (10% to 90%)	<175 ps
Pulse Width	<430 ps FWHM
Transit Time Spread	<40 ps RMS
Pulse Height Distribution	100% FWHM
Linear Total Count Rate	Up to 10 MHz
Maximum Ratings	
Overall Voltage	< 3500 V
Operating Temperature	-50 to +50°C
Storage Temperature	-50 to +50°C

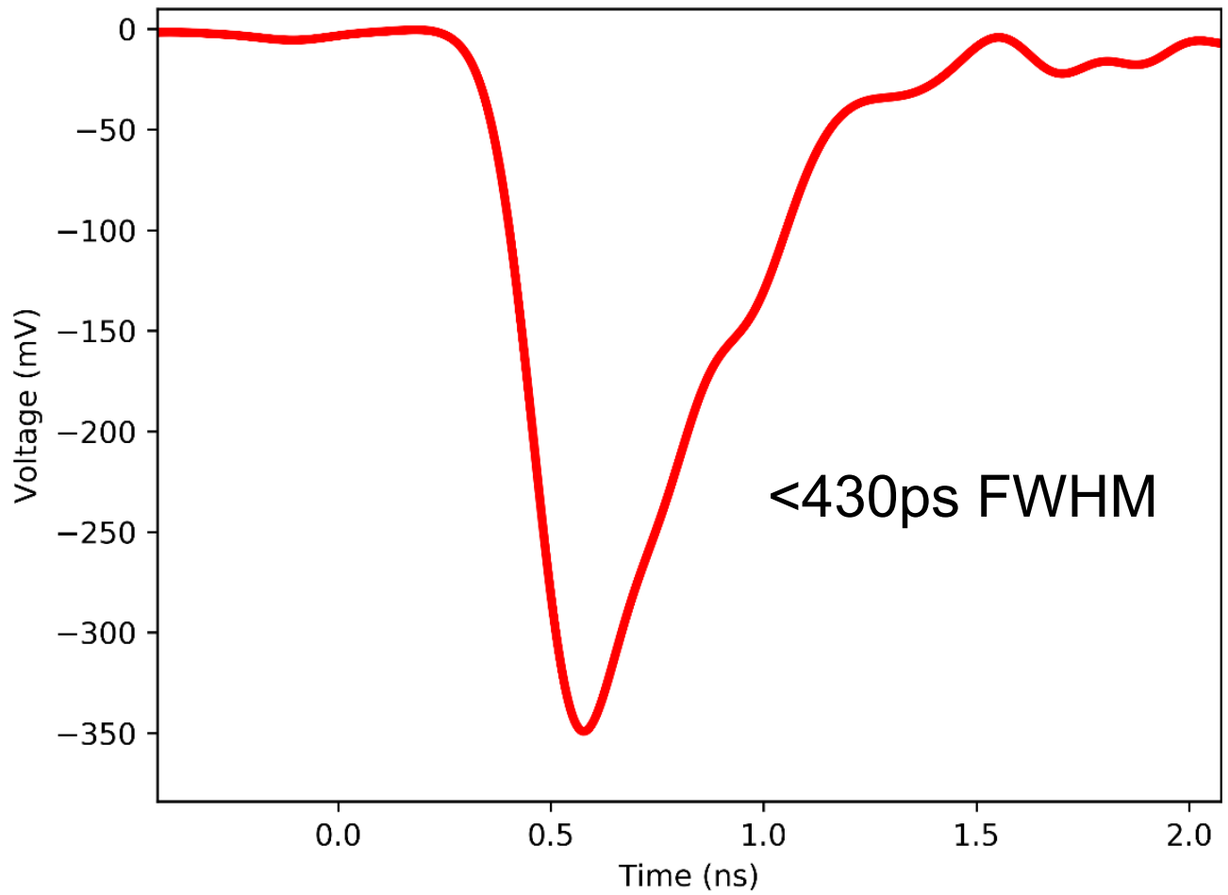


Available photocathodes on fused silica window. Optional fibre optic window will reduce sensitivity and no response below 300 nm.



Anode Format	Pitch X (mm)	Pitch Y (mm)	Total Anodes
32 x 32	0.88	0.88	1024
16 x 16	1.76	1.76	256
32 x 8	0.88	0.88	256
8 x 8	3.52	3.52	64

Single anode signal



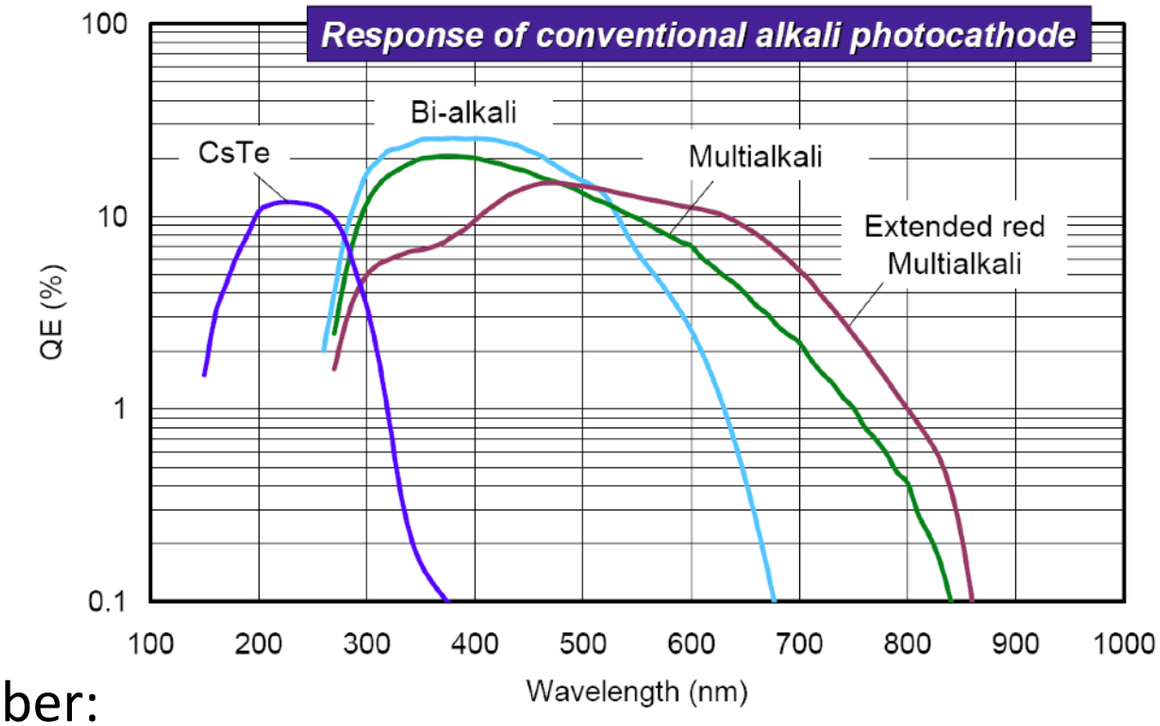
Average of 50 single photon pulses measured on 5 GHz, 20 GS/s scope, using a Photek LPG-405 pulsed laser.

backup slides

What signal can we have in SPD with the PMT as a photon detector?

The most suitable type of the photocathodes for detection of the Cherenkov light is Bi-alkali (Sb-K-Cs, Rb-Sb-Cs), with sensitivity extending from ~260 to 650 nm and maximum QE≈20% between 300 and 500 nm.

$$N = 2\pi\alpha l\,(1/\lambda_1 - 1/\lambda_2)\,\sin^2\theta$$



Parameters used in calculation of the p.e. number:

- aerogel thickness 20 mm, n=1.045 + 20 mm, n=1.055
- effective area of the MCP 60%
- sensitive area of the detector 60%
- quantum efficiency 20% at 300-500 nm
  10% at 270-300 and 500-550 nm

The number of photoelectrons calculated without account of the light losses →

	π	K	p
1 GeV/c	44	---	---
2	52	21	---
3	54	41	1
4	54	46	26
5	54	49	36

Transmission length at λ=400 nm (from BELLE-II):

47 mm at n= 1.0451

36 mm at n= 1.0547

Then, in our case (20mm n=1.045 + 20mm n=1.055) transmission will be (roughly) ≈60%

and the number of photoelectrons, i.e. points on the Cherenkov ring →

	π	K	p
1 GeV/c	26	---	---
2	31	13	---
3	32	25	---
4	32	28	16
5	32	29	22

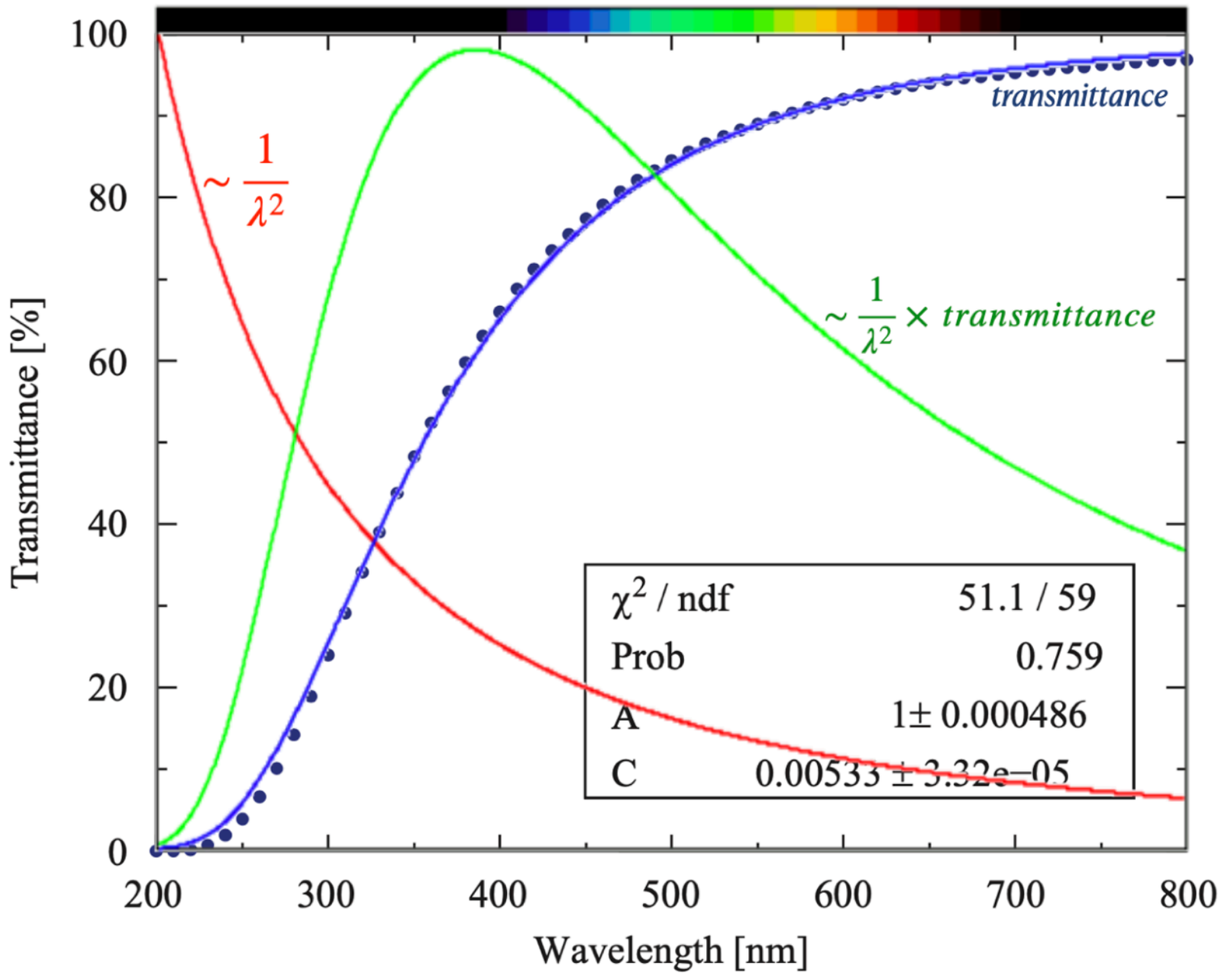
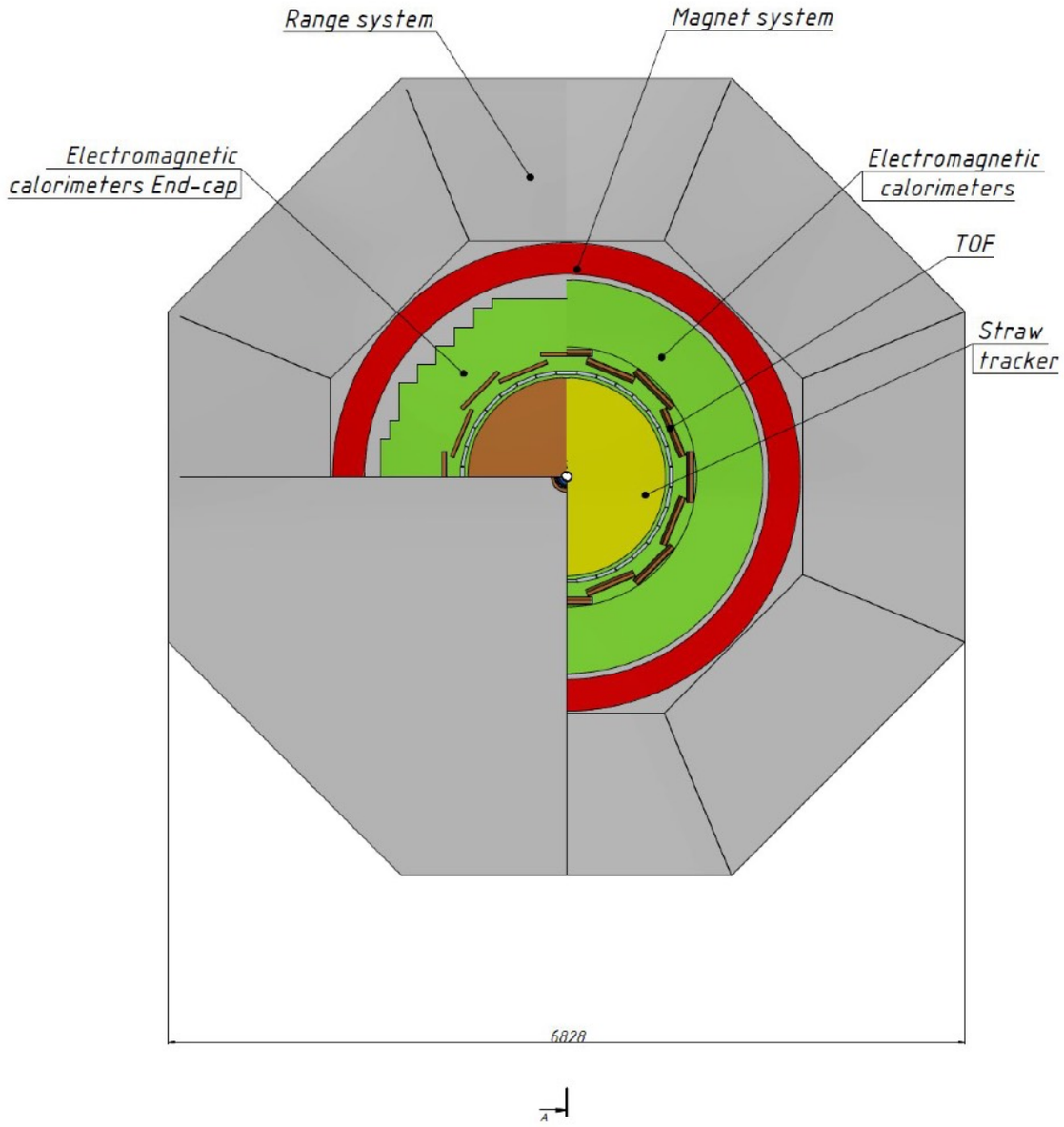
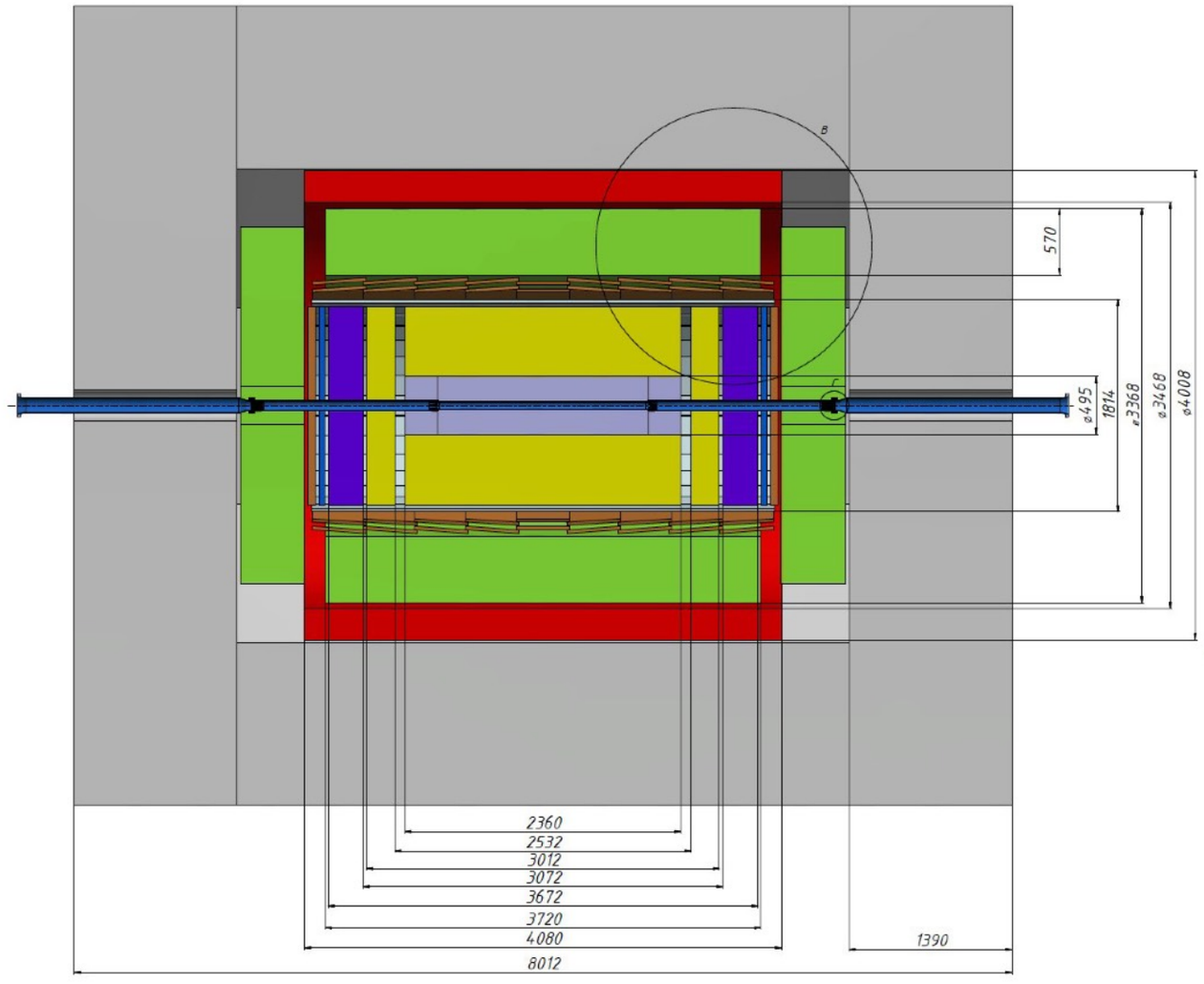


Fig. 6. Aerogel transmittance curve for aerogel ID=PDR21-2a, $n=1.044$, and $t=20.8$ mm. Circles show the transmittance measured every 10 nm by the spectrophotometer and the solid line shows the fit. The parameters obtained from the fitting with $T=A\exp(-Ct/\lambda^4)$ are $A=1$ and $C=0.00533\pm 0.00003\ \mu m^4/cm$. The upper limit of the parameter A was set to 1 in the fitting procedure. The corresponding transmission length was calculated to be 50 mm at $\lambda=400$ nm.

SPD setup (Mar 2023)





SPD setup (Mar 2023)