SPring-8/LEPS2 experiment to search for the K⁻pp bound state

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Introduction

TOHOKU UNIVERSITY

ELPH

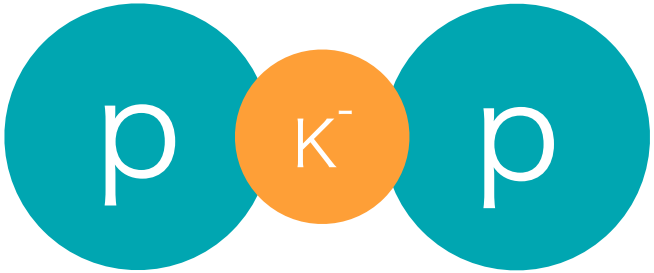
Physics Motivation

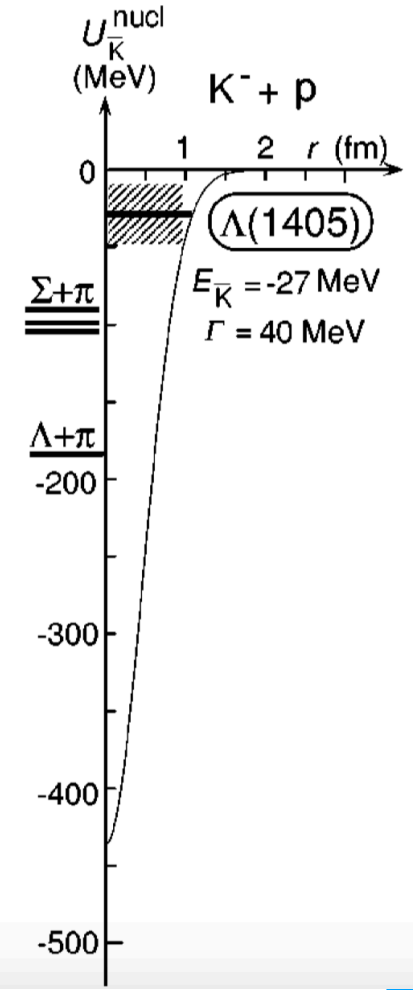
$\bar{K}N$ interaction

It is known that $\bar{K}N$ interaction is attractive from Kaonic-hydrogen X-ray data and $\bar{K}N$ scattering data.

Y. Akaishi and T. Yamazaki calculated $\bar{K}N$ potential.

- $\bar{K}N$ interaction is strongly attractive.
- **Kaonic nucleus** can exist.
- The simplest kaonic nucleus
  … **K⁻pp bound state**





Y. Akaishi and T. Yamazaki, Phys. Rev. C 65, 044005 (2002)

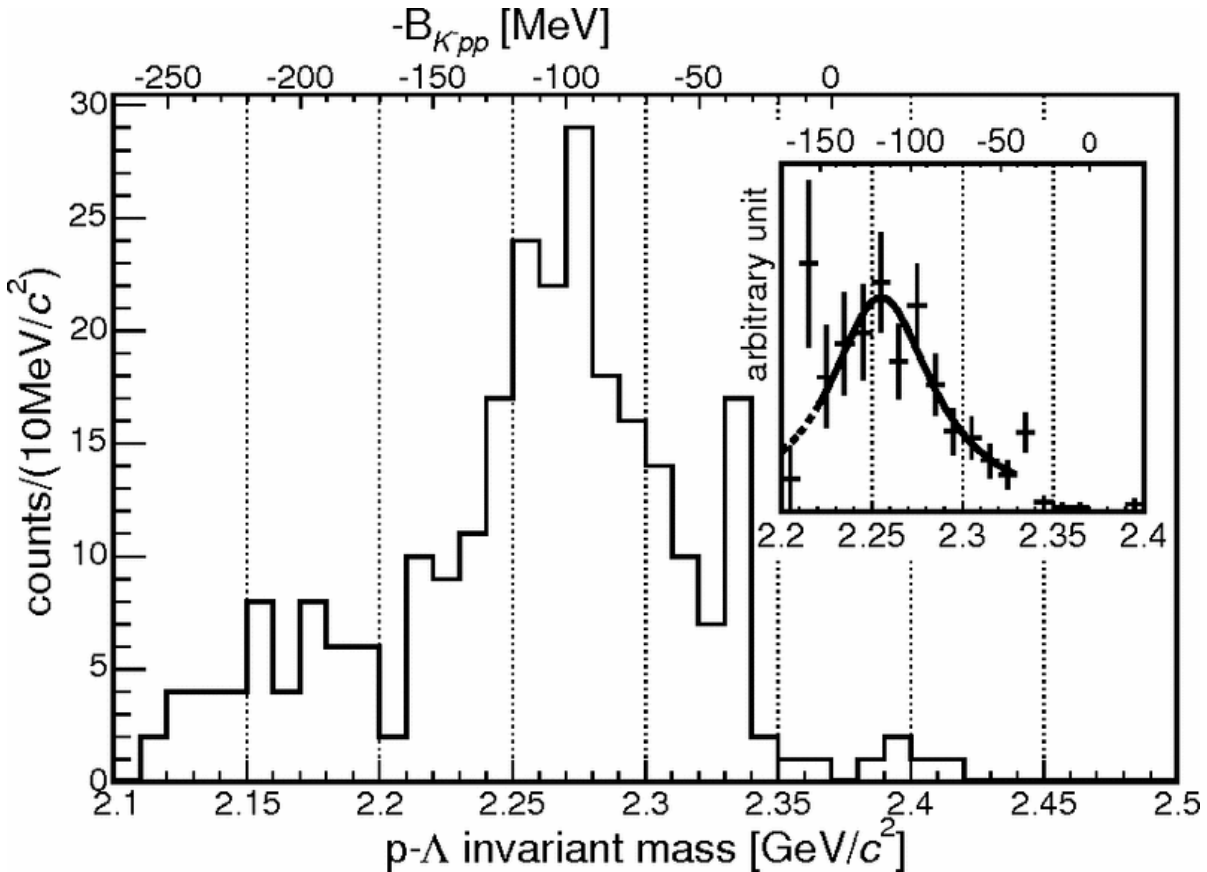
Physics Motivation

Search for K⁻pp bound state

FINUDA at DAΦNE

stopped K⁻ reaction (target : $^{6}Li, ^{7}Li, ^{12}C$ ...)

invariant mass spectrum (Λp)



B.E. : $115^{+6}_{-5}(stat)^{+3}_{-4}(syst)$ MeV

Γ : $67^{+14}_{-11}(stat)^{+2}_{-3}(syst)$ MeV

Physics Motivation

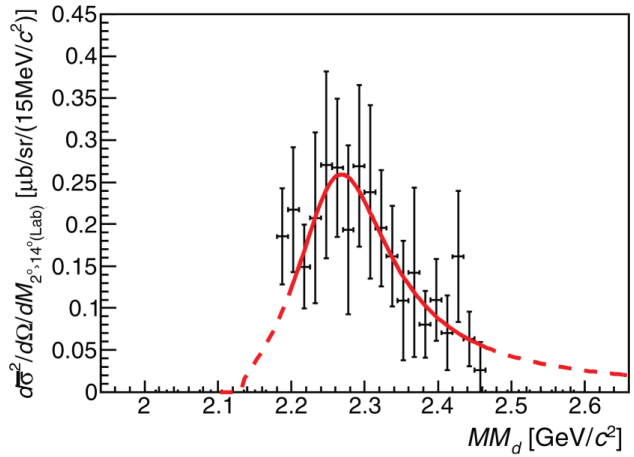
Search for K⁻pp bound state

J-PARC E27

- $\pi^+ d \to K^+ X$
- missing mass spectrum + identification of final state ($\Sigma^0 p$)

B.E. : $95^{+18}_{-17}(stat)^{+20}_{-21}(syst)$ MeV

Γ : $162^{+87}_{-45}(stat)^{+66}_{-78}(syst)$ MeV



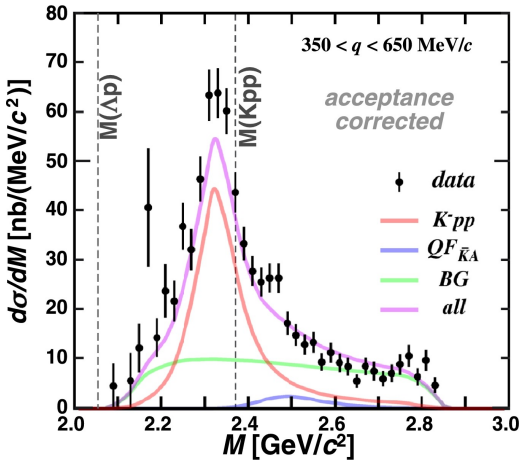
Y. ichikawa *et al.*, Prog. Theor. Exp. Phys (2015) 021D01

J-PARC E15

- $K^- {}^3\mathrm{He} \to nX$
- missing mass spectrum + invariant mass spectrum (Λp)

B.E. : $47^{+3}_{-3}(stat)^{+3}_{-6}(syst)$ MeV

Γ : $115^{+7}_{-7}(stat)^{+10}_{-20}(syst)$ MeV

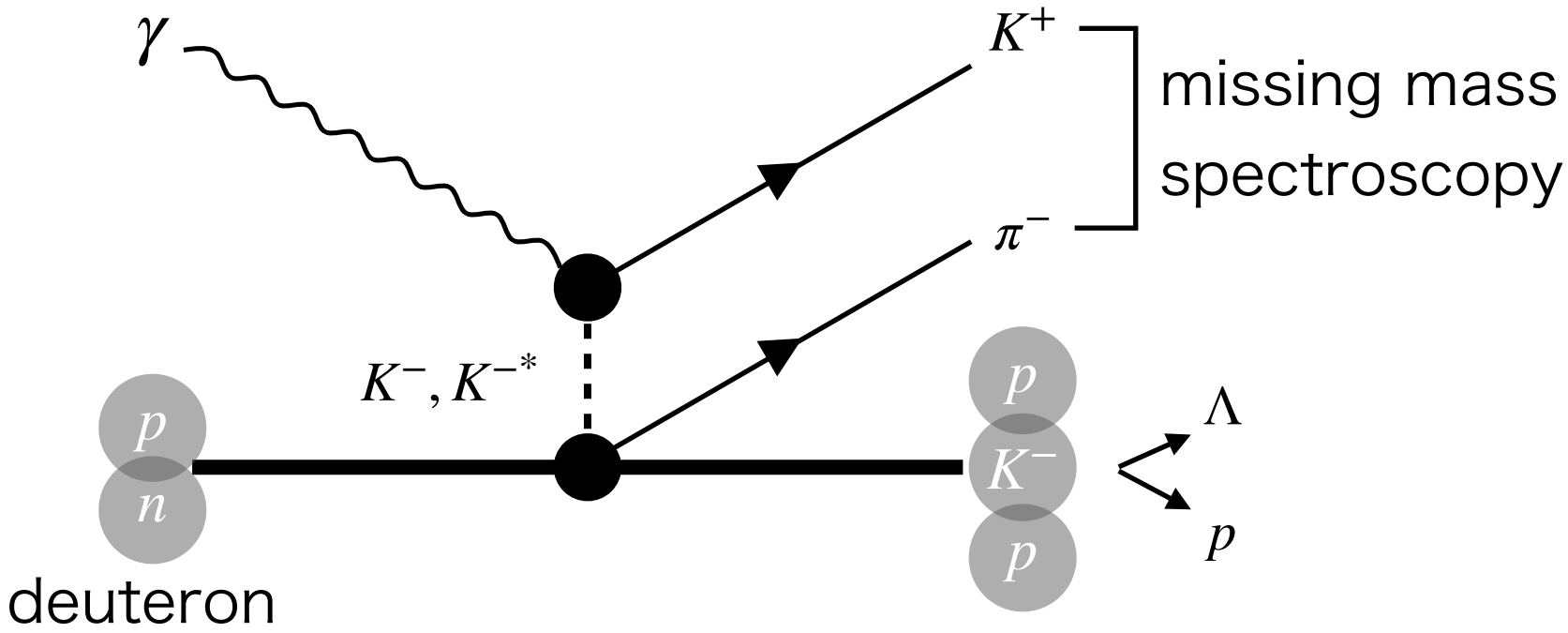


S. Ajimura *et al.*, Phys. Lett. B 789, 620-625(2019)

Physics Motivation

Search for K⁻pp bound state via photo production

LEPS at SPring-8



E_γ = 1.5 - 2.4 GeV, intensity ~ 10^6 cps, acceptance region < 20°

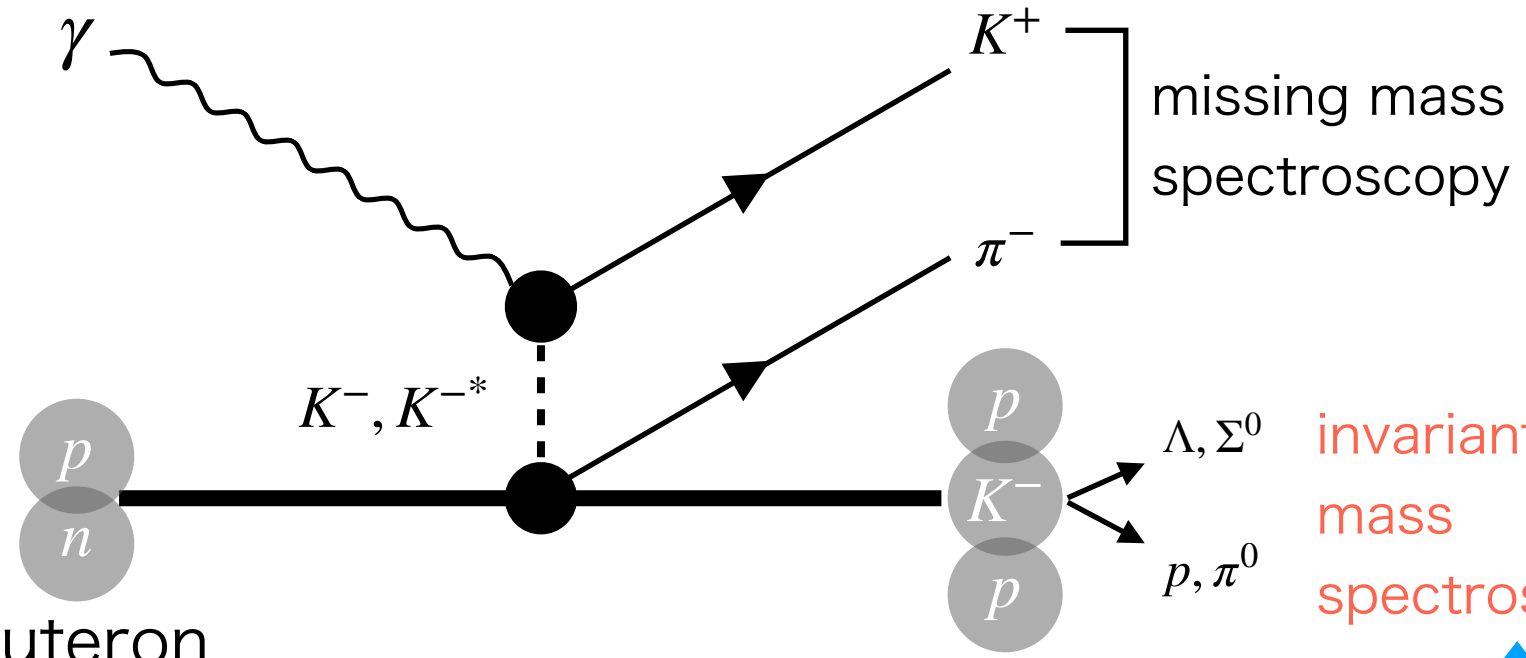
upper limits of differential cross section for Γ = 20, 60, 100 MeV

··· (0.17 - 0.55) μb, (0.55 - 1.7) μb, (1.1 - 2.9) μb

Physics Motivation

Search for K⁻pp bound state via photo production

LEPS2 at SPring-8



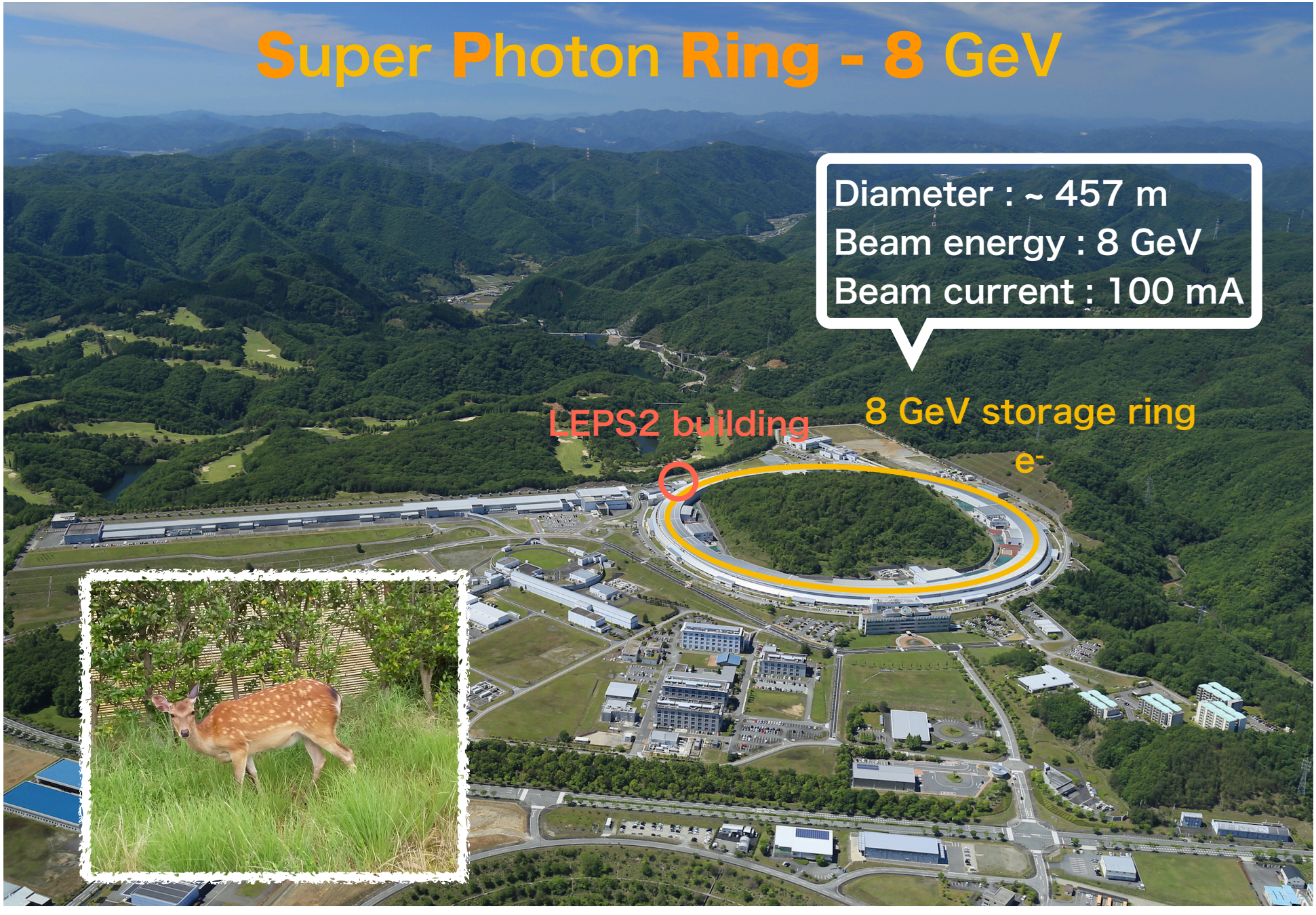
we can reduce main background : $\gamma p \to K^+\Lambda(1520)$, $\gamma p/n \to K^+\pi^-\pi^0\Lambda/\Sigma$

E_γ = 1.5 - 2.9 GeV, intensity ~ 5×10⁶ cps

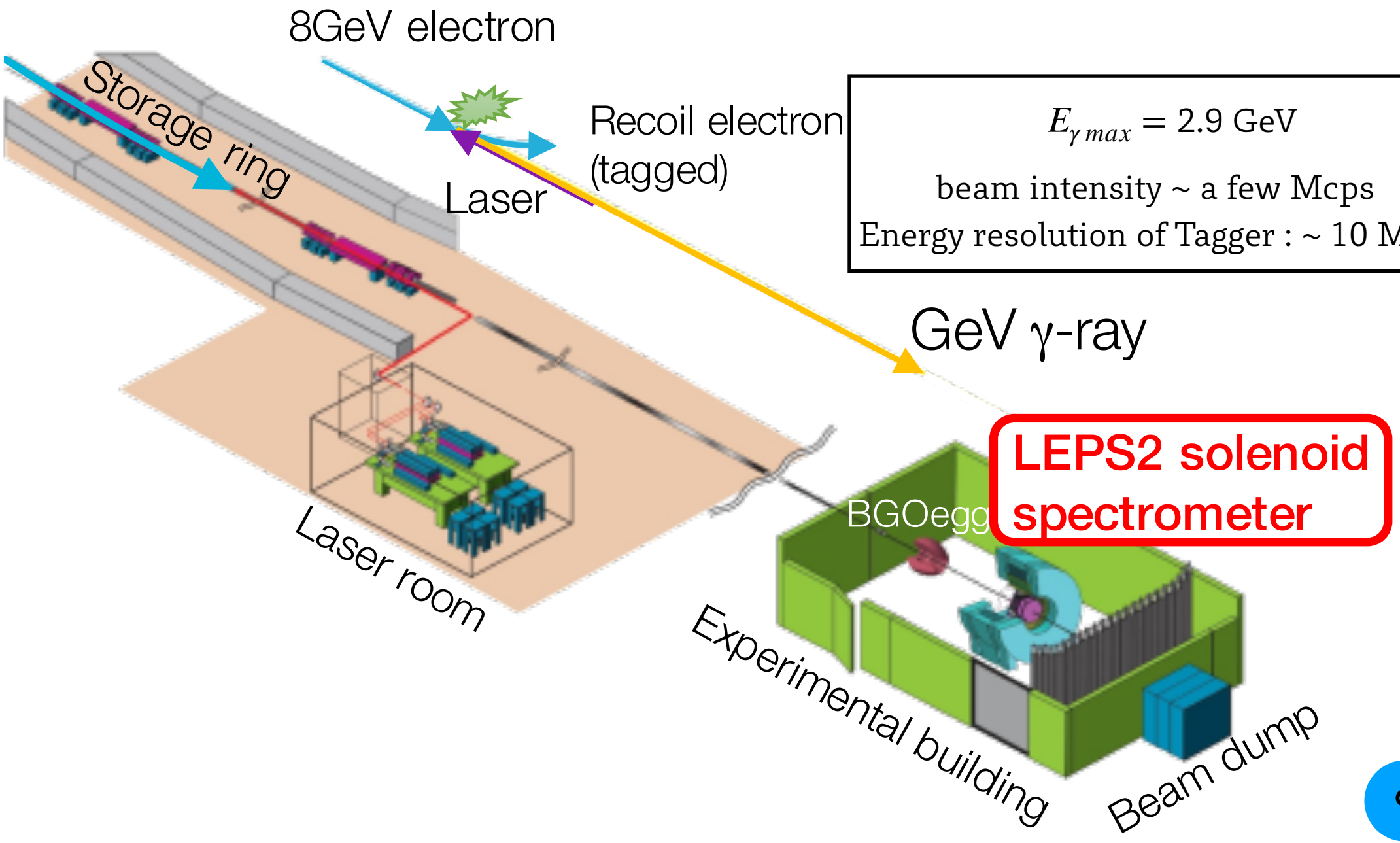
acceptance region (charged particle) : 7 - 110°

acceptance region (**gamma ray**) : 40 - 110°

SPring-8


Super Photon Ring - 8 GeV
Diameter : ~ 457 m
Beam energy : 8 GeV
Beam current : 100 mA
LEPS2 building
8 GeV storage ring
e-

LEPS2 beamline

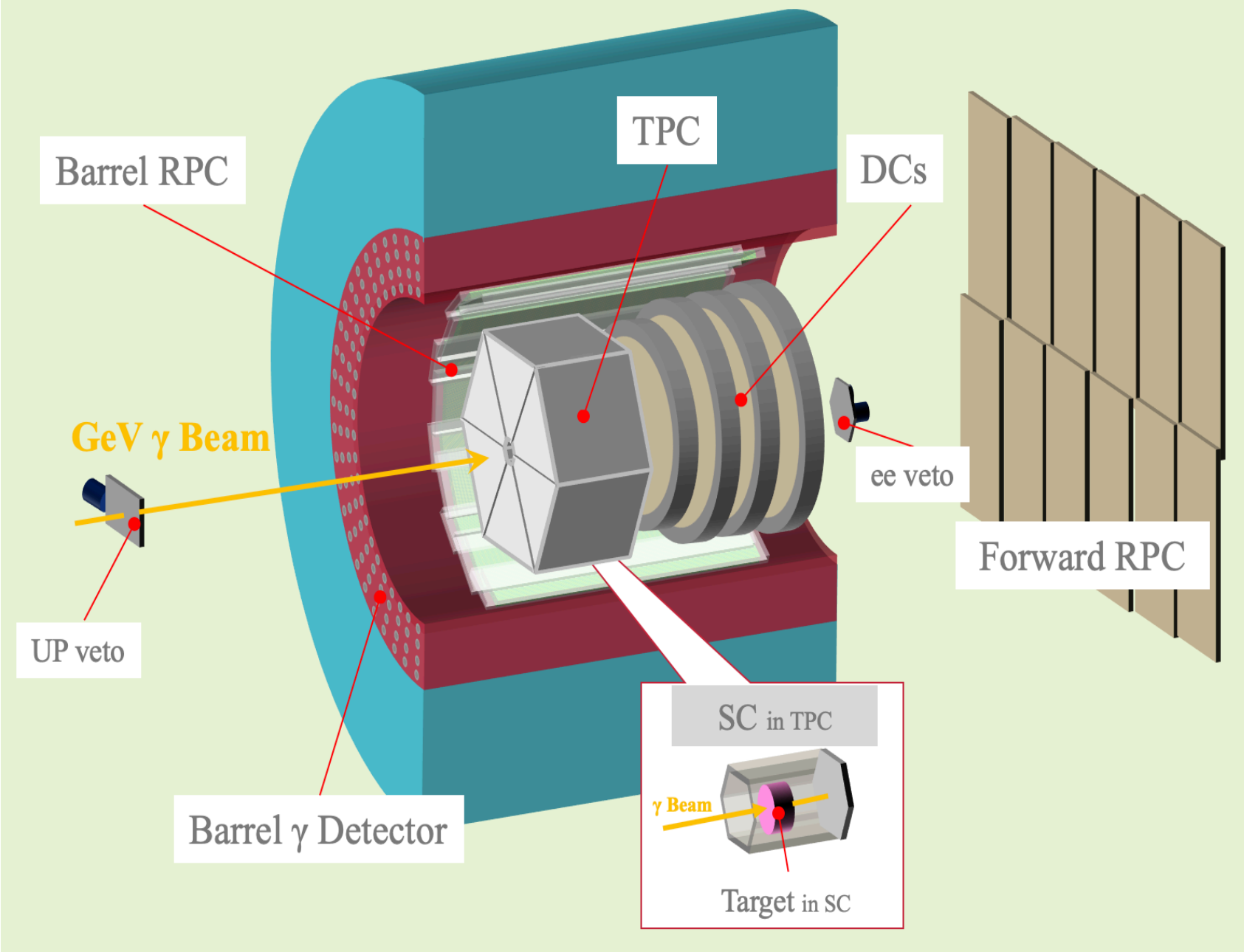


$E_{\gamma\,max} = 2.9$ GeV

beam intensity ~ a few Mcps

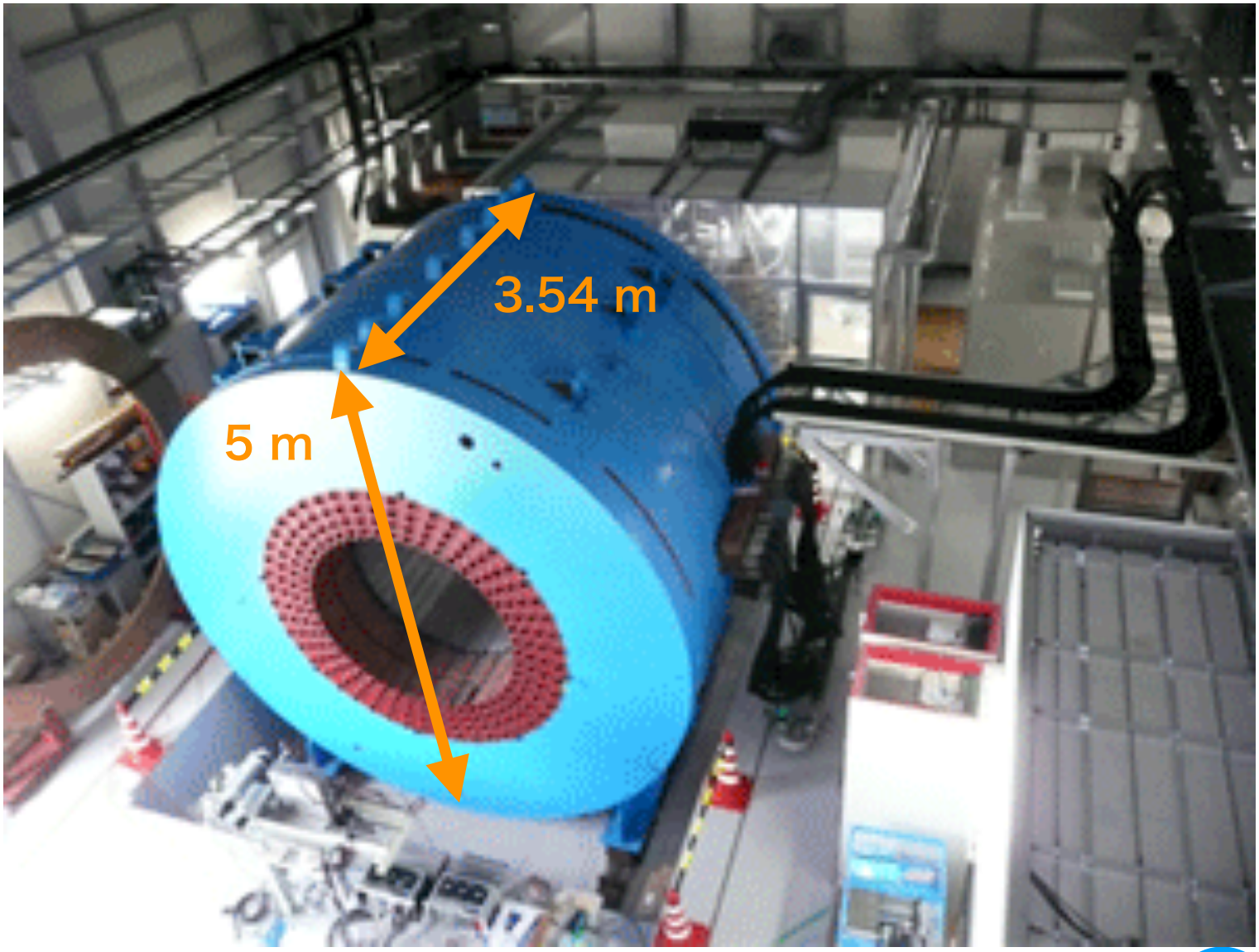
Energy resolution of Tagger : ~ 10 MeV

LEPS2 solenoid



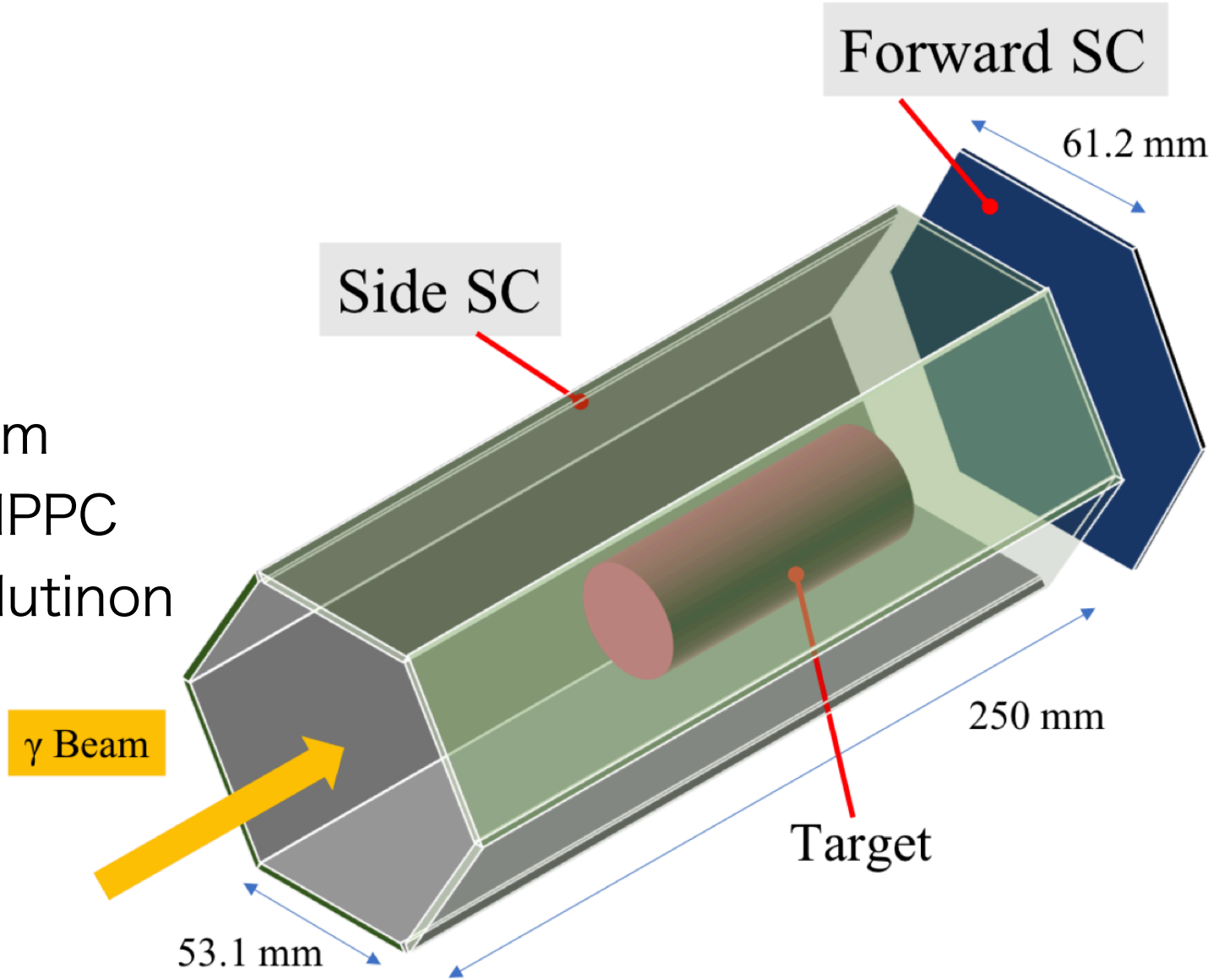
Solenoid magnet

- E949 at BNL
- weight : ~ 400 t
- B = 1 T

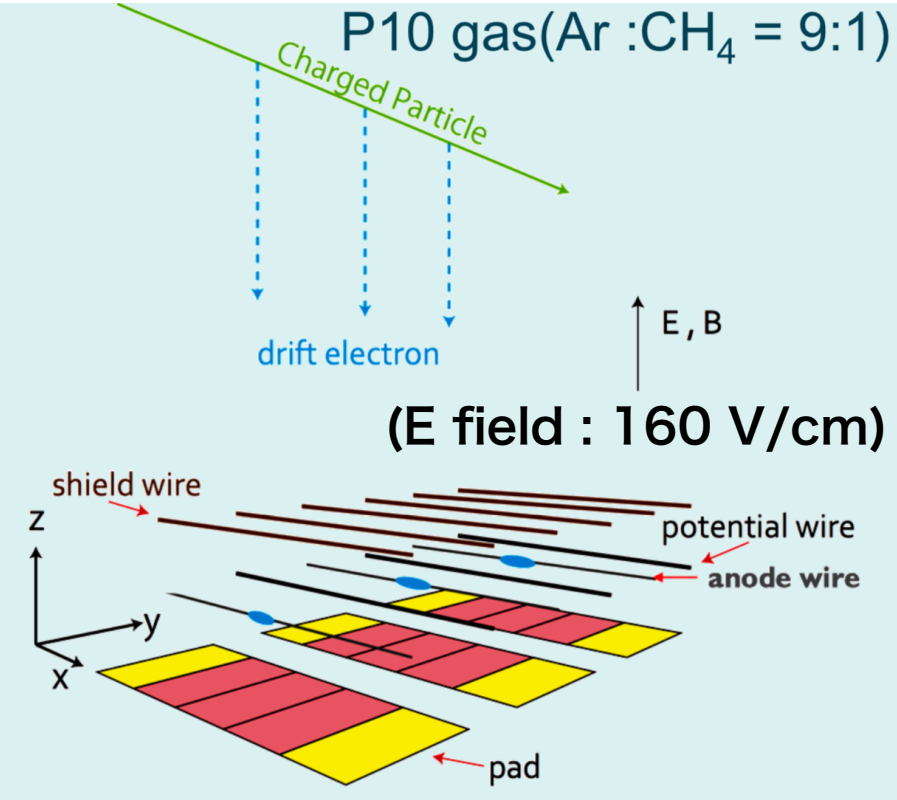


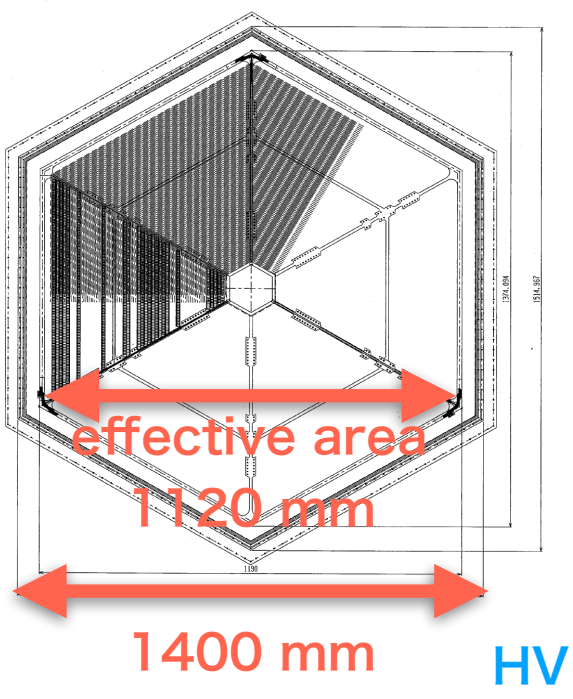
Start Counter (SC)

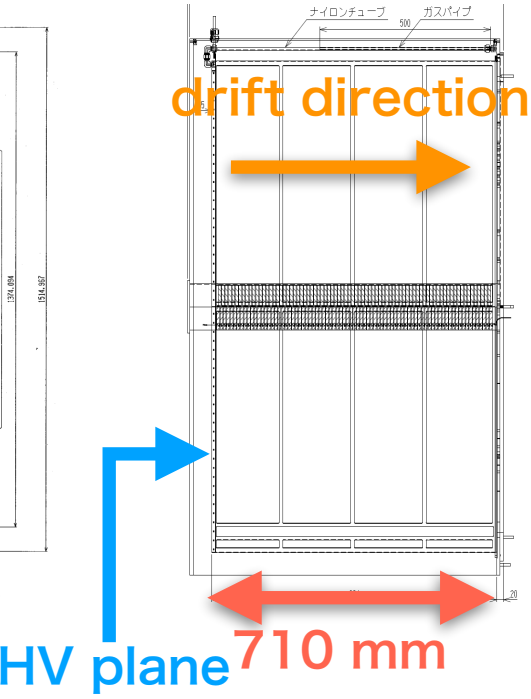
- Plastic Scintillator
  - Thickness : 4 mm
- Photo detector : MPPC
- typical timing resolutinon
  - … 300 ps



Time Projection Chamber (TPC)



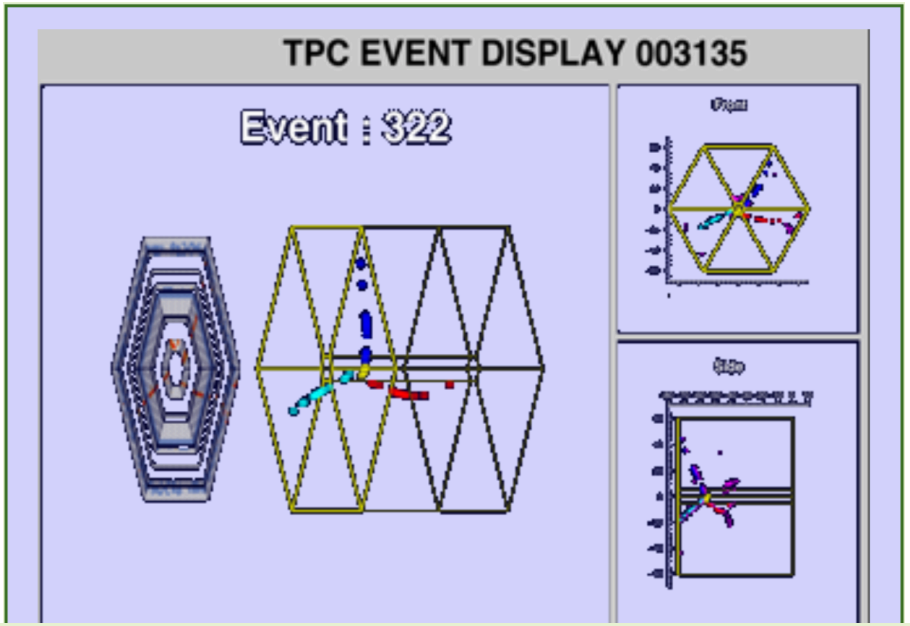


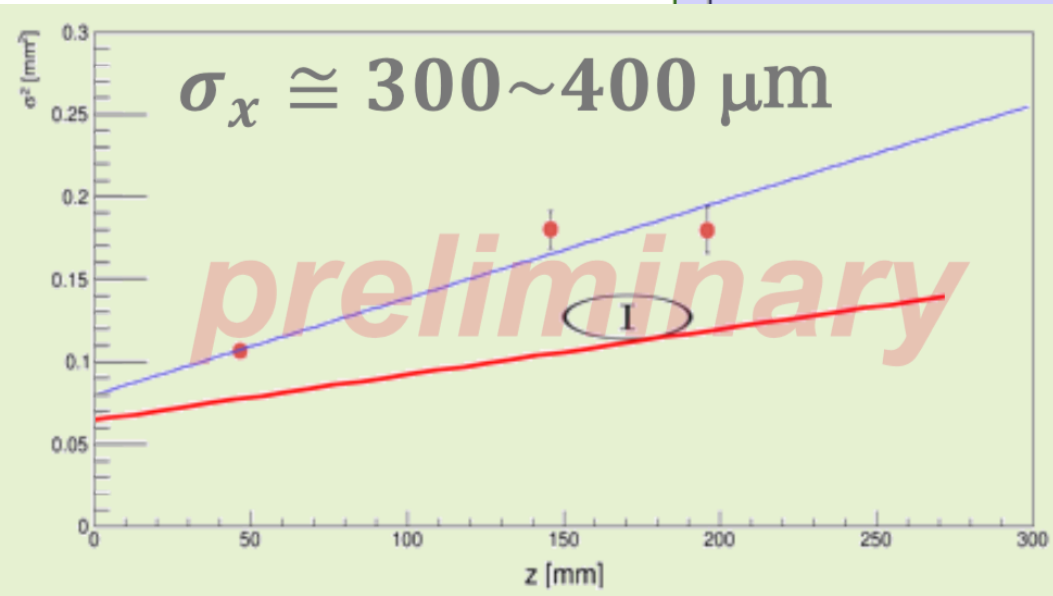


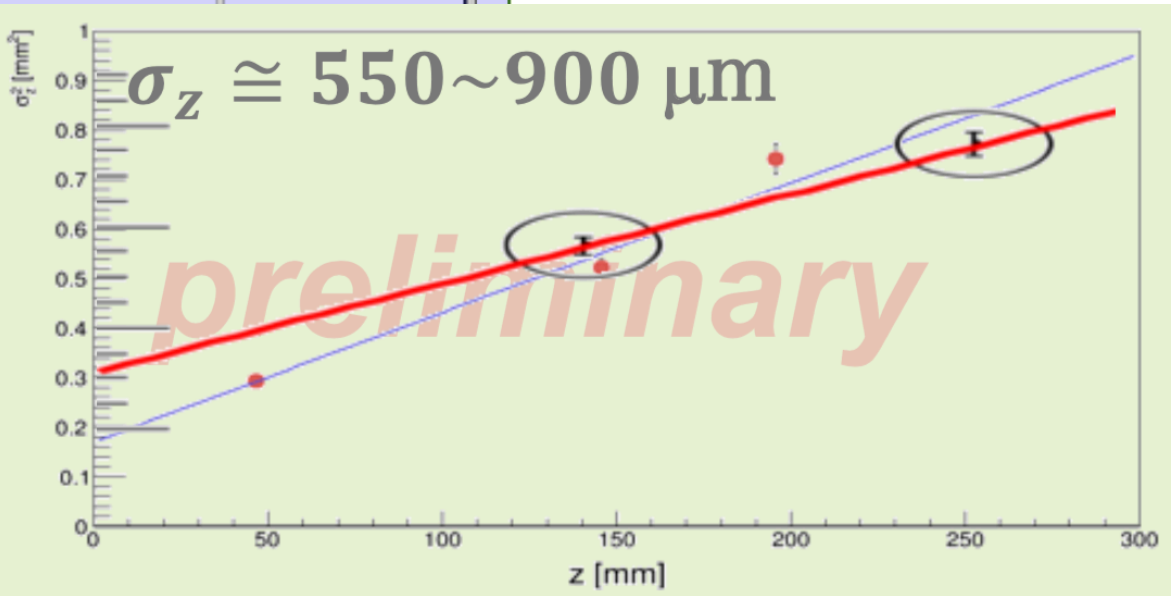
- x position
  … the center of charge in pads
- y position
  … the center of layer
- z position
  … the drift time of electron

- Pad size
  - x : 4.6 mm, y : 10 mm
- Pad layer : 24 layers
- Pad number : 10830 pads

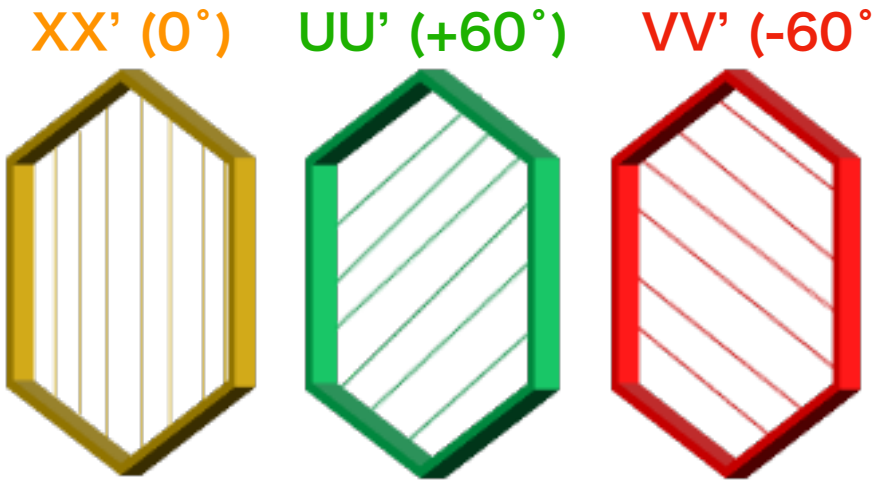
Position resolution of TPC



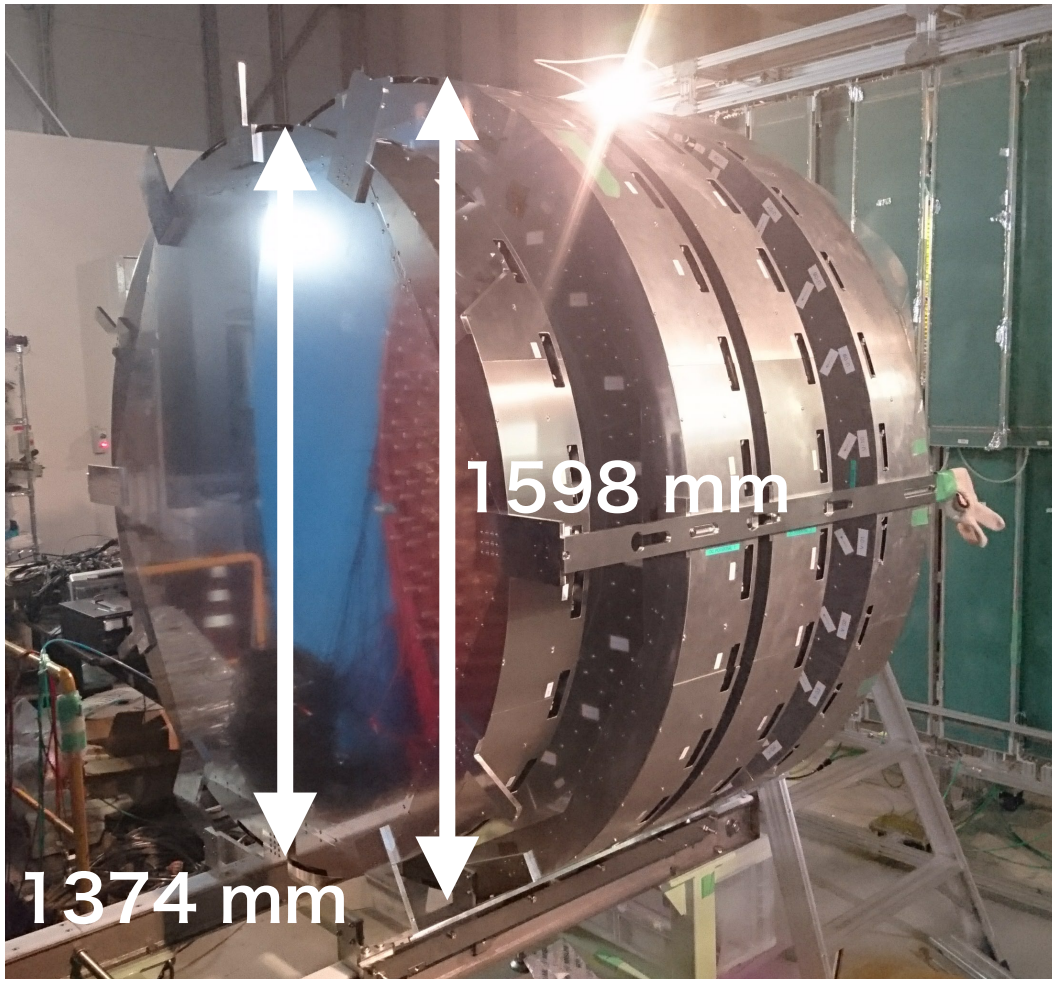




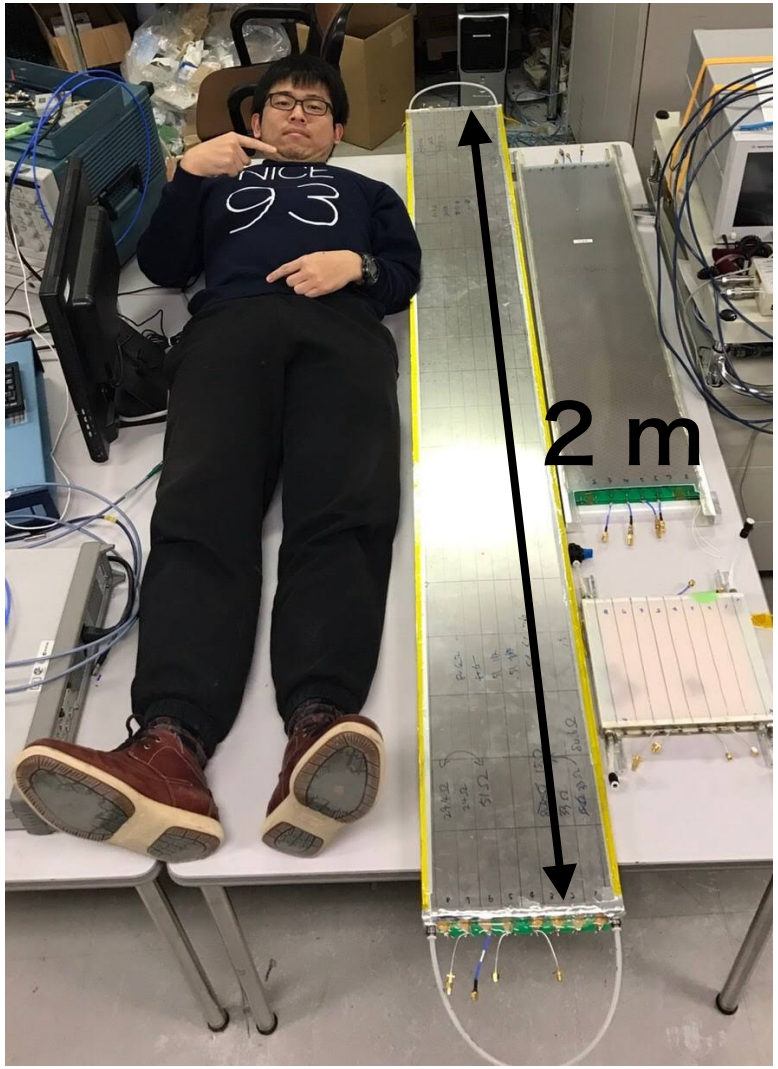
Drift Chamber (DC)

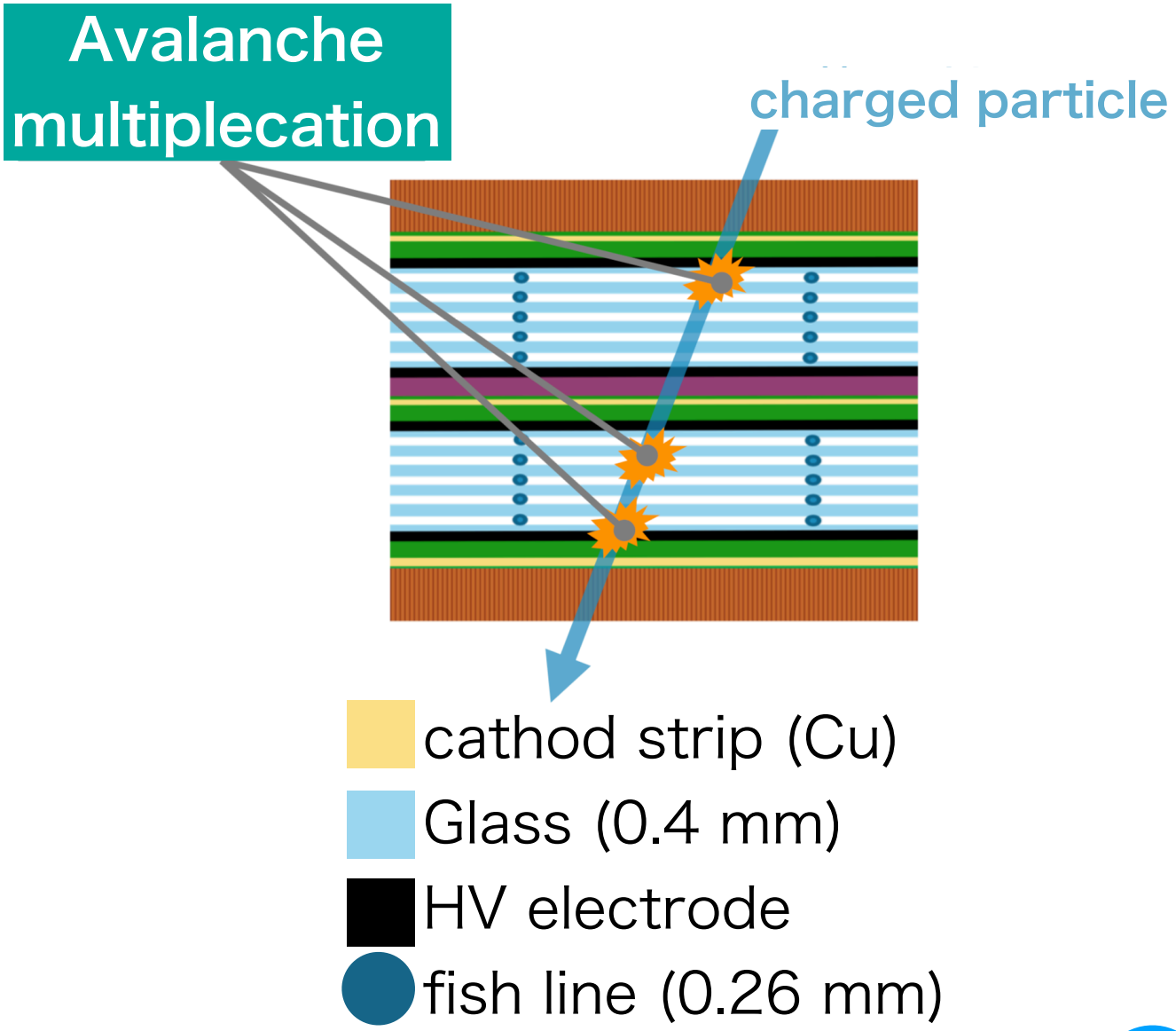


- 80 ch/layer × 6 layer = 480 ch
- Position resolution < 150 um

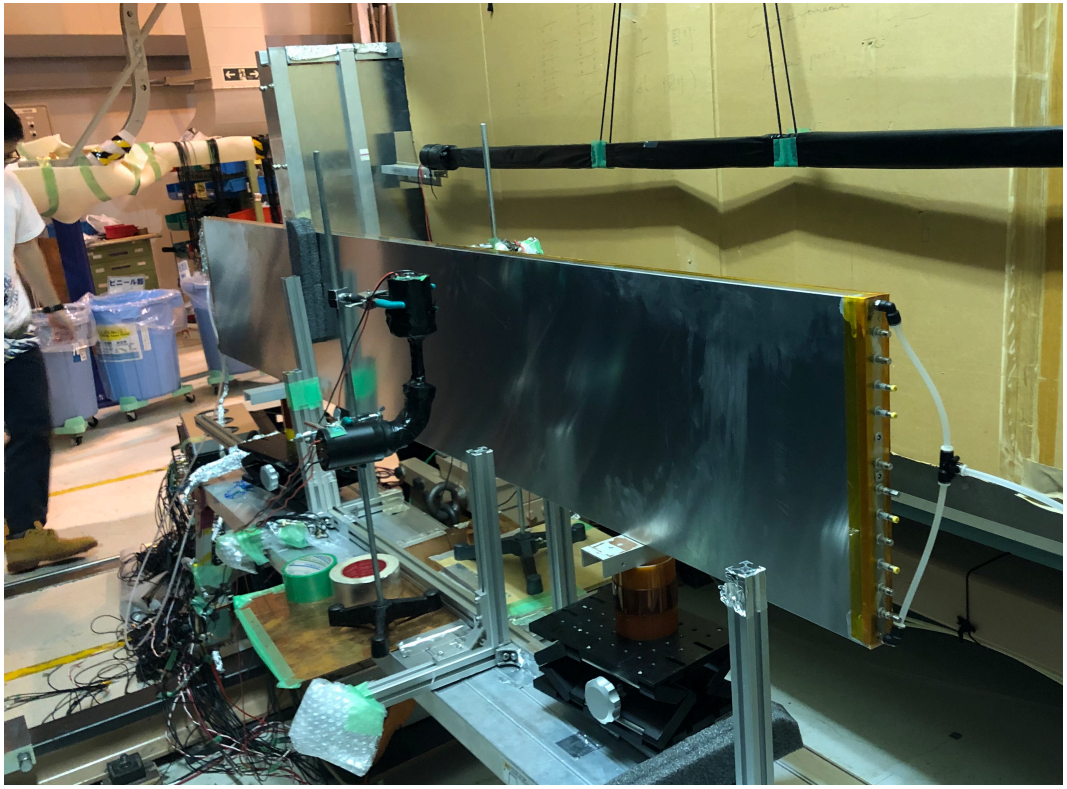


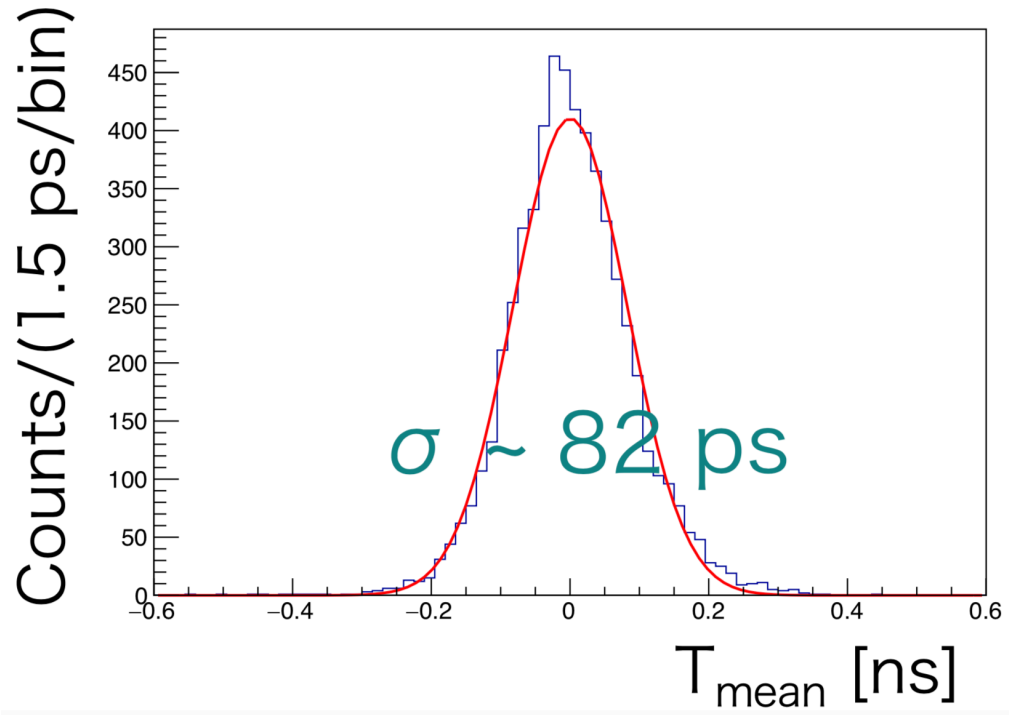
Resistive Plate Chamber (RPC)





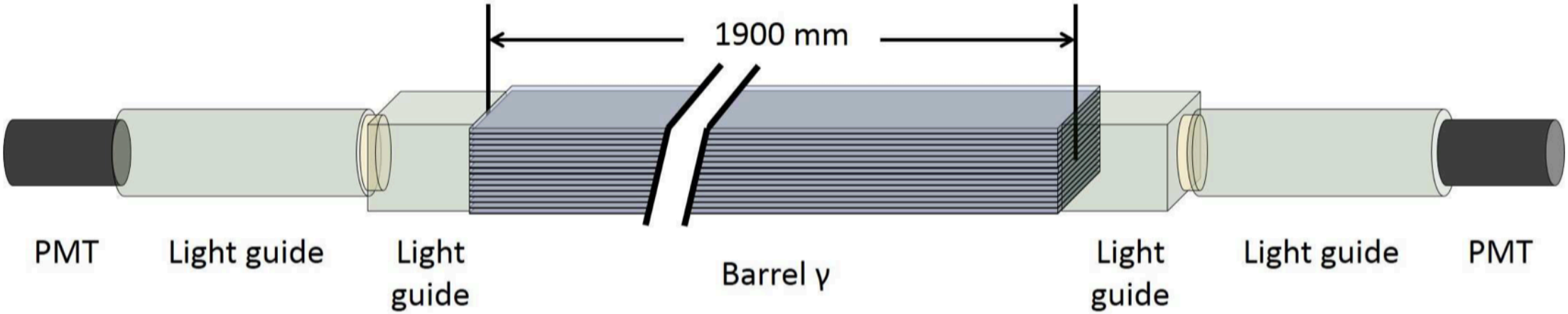
Time resolution of RPC





Typical time resolution : 70 ps

Barrel Gamma detector



- Lead (1 mm)
- Plastic scintilatter (5 mm)
- 48 modules/layer × 4 layers
  - … length of 4 layers : $14.3\,X_0$
- 2 layers are installed now.

Aerogel Cherenkov counter

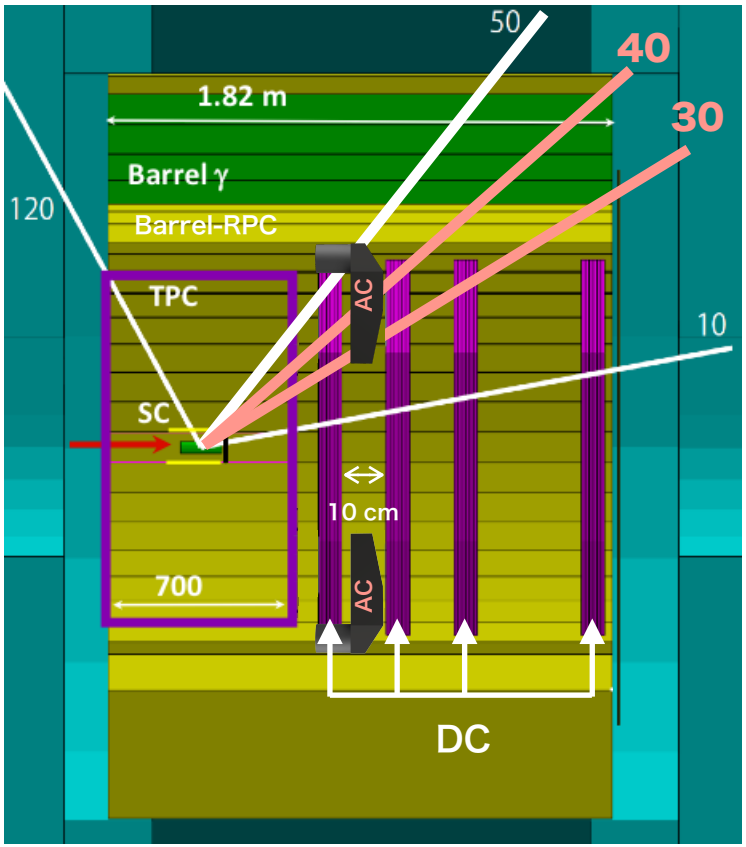
Perpose : separate π/K in the momentum region 1 - 2 GeV/c

- This region cannot separate cleary using RPC-TOF system.

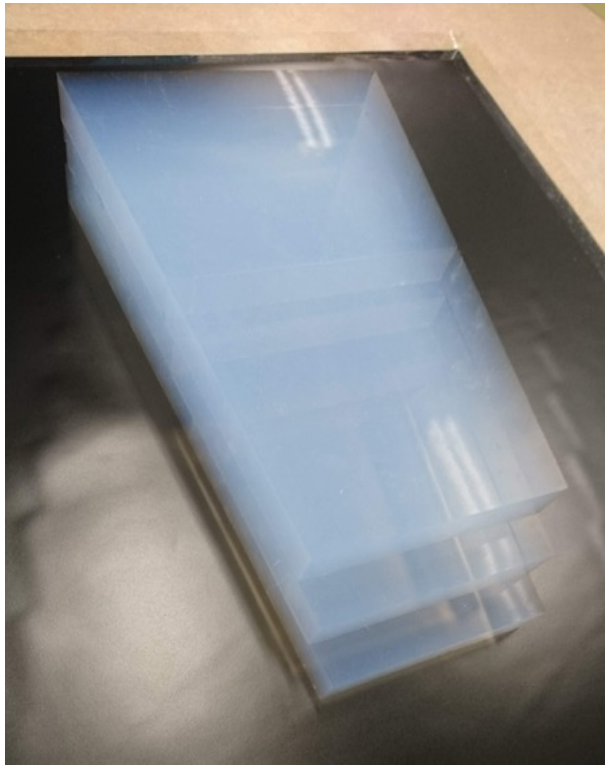
Requrement

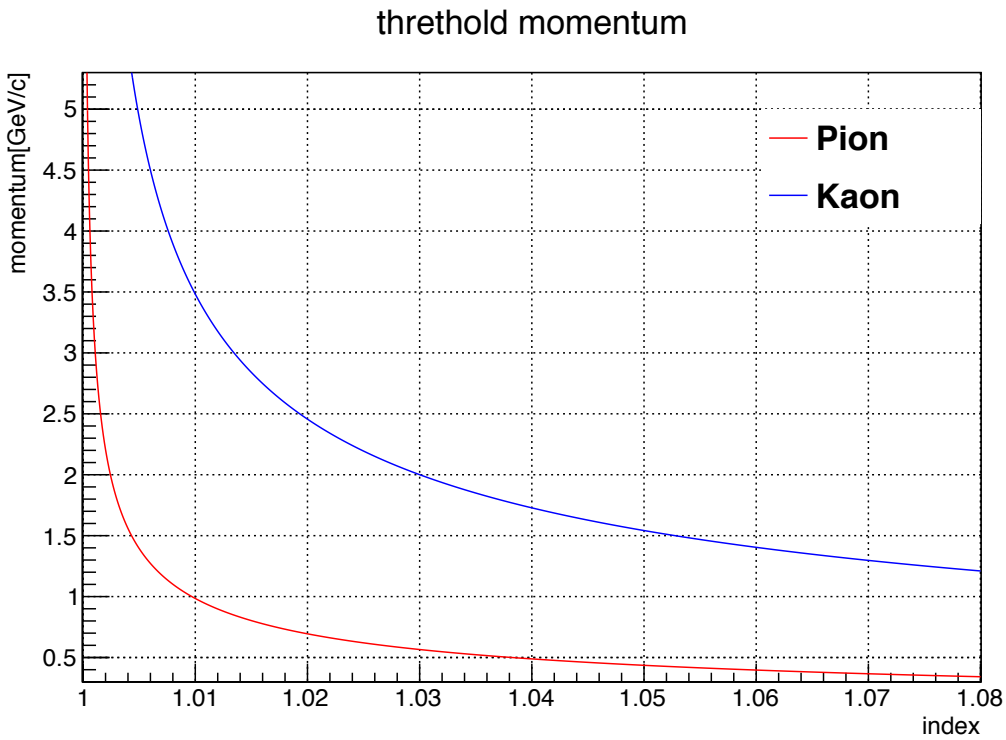
- π detection efficiency > 95%
- acceptance region : 30° - 40°
- install in the small gap (10 cm)
- work in the magnetic field
- minimize the material budget

➡ We use aerogel and fine-mesh PMTs.



Aerogel





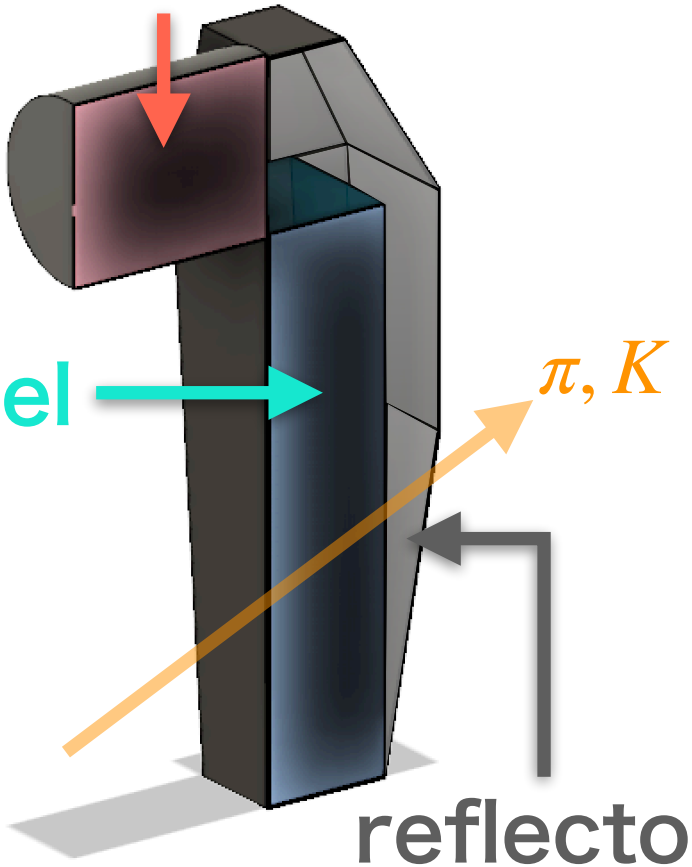
Threshold velocity and momentum

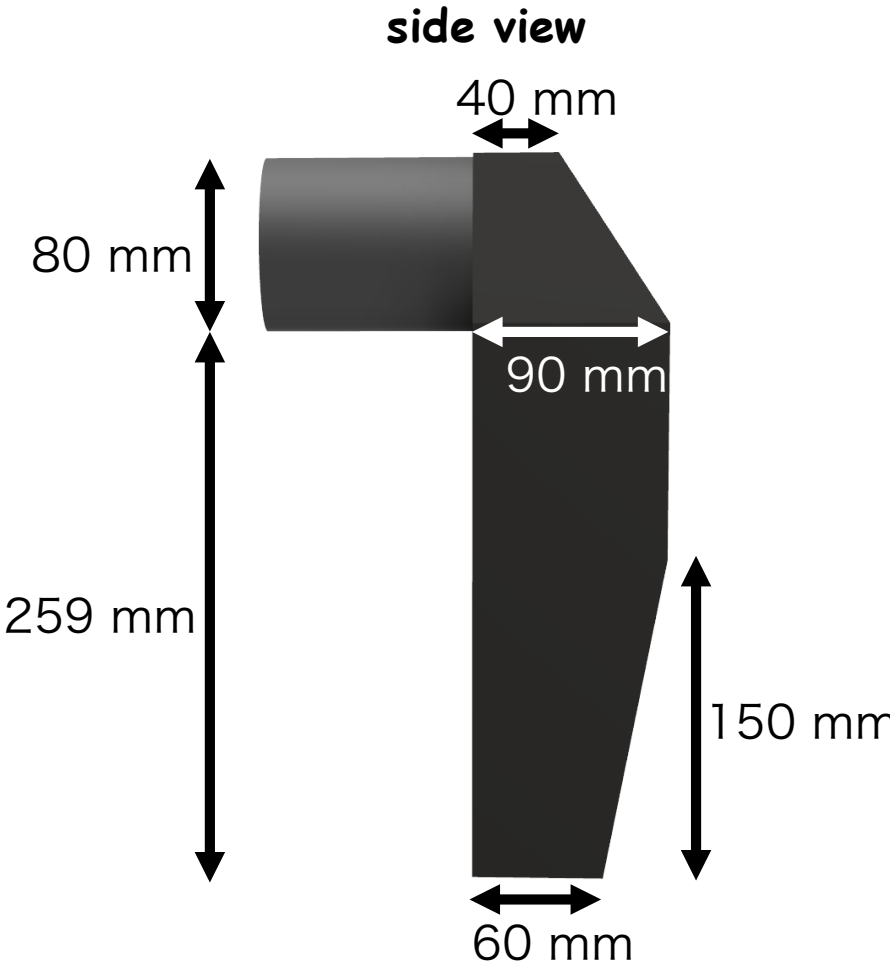
$$\beta_{th} = \frac{1}{n} \ , \ p_{th} = \frac{m}{\sqrt{n^2 - 1}}$$

n (refractive index) = 1.03

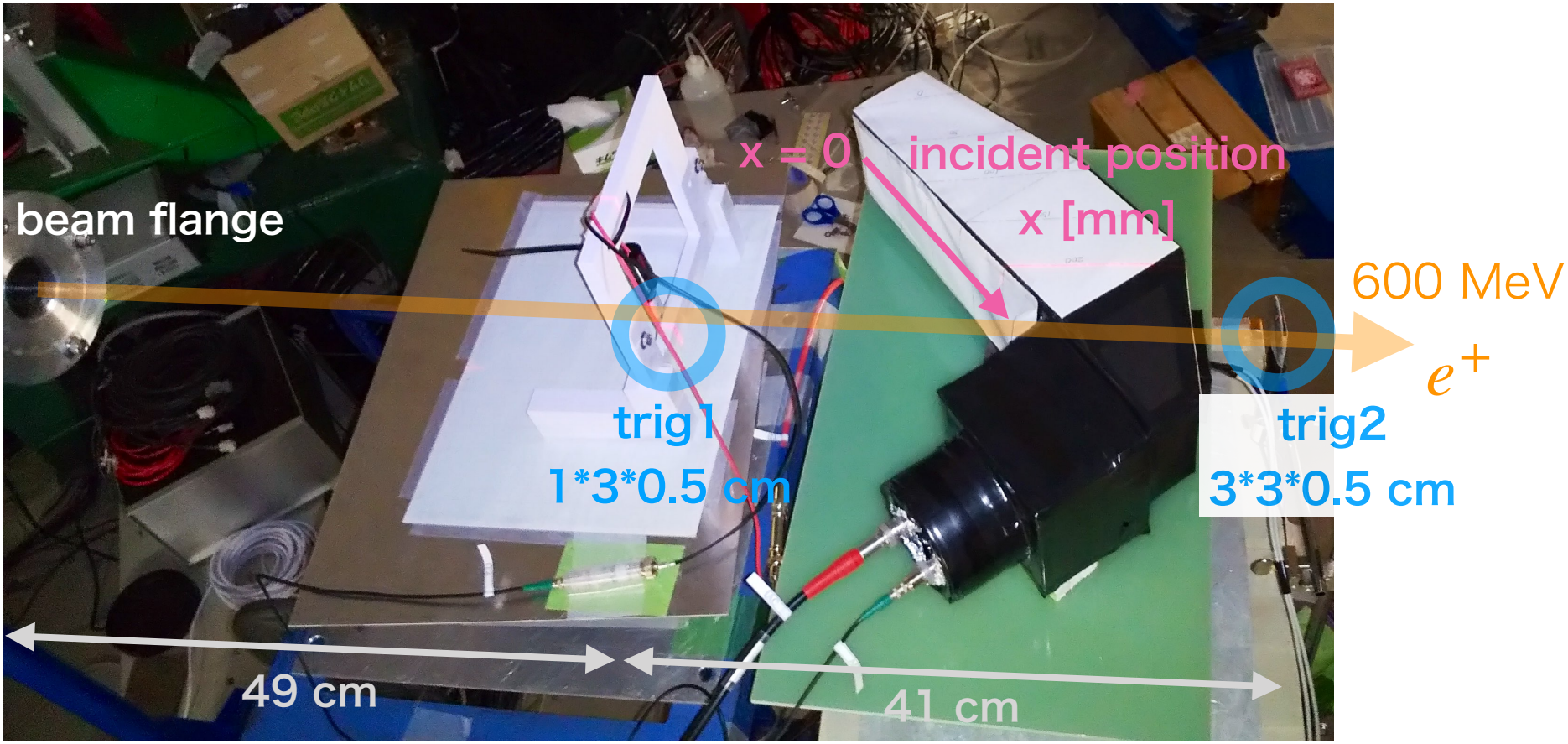
Shape of AC

3 inch Fine mesh PMT
(HAMAMATSU R5543)





positron beam test @ELPH

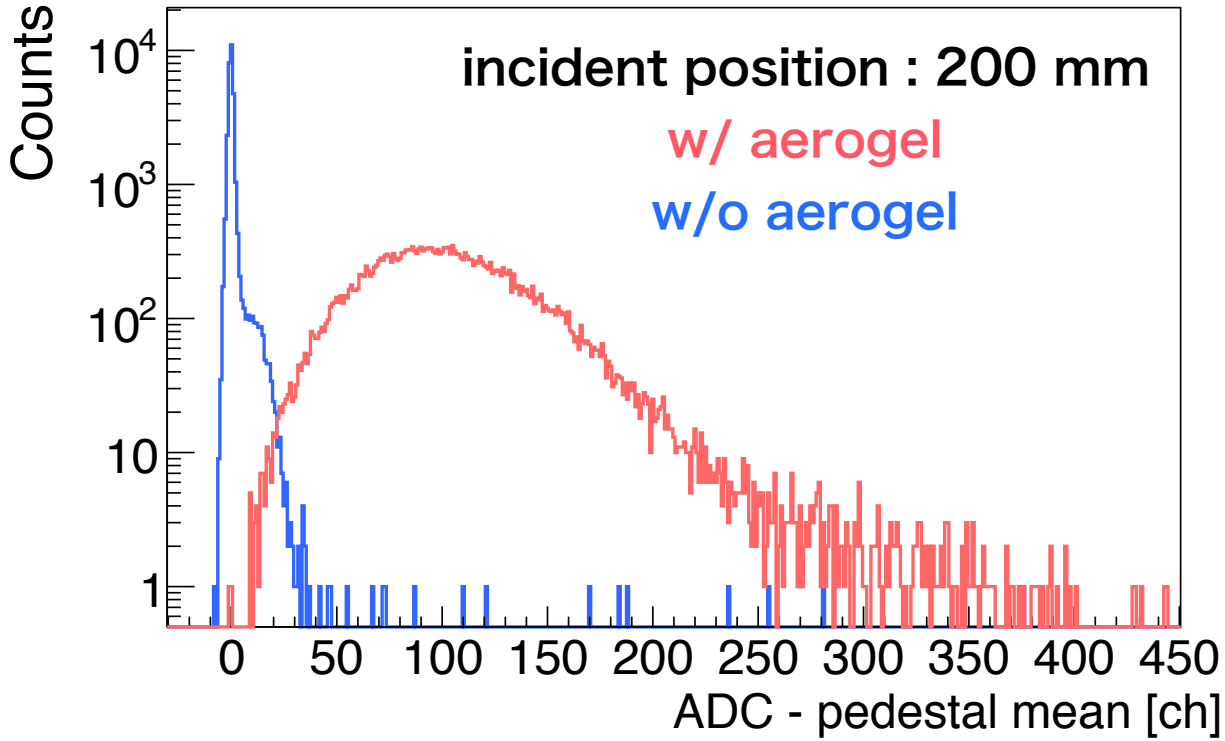


- trigger : trig1 & trig2
- trigger rate : ~ 80 Hz
- incident position [mm]
  - w/ aerogel : 0,50,100,150,200
  - w/o aerogel : 0,100,200

π detection efficiency

Charge distribution (w/ aerogel or w/o aerogel)

…estimate π detection efficiency or K misidentification probability



π detection efficiency > 95%

K misidentification probability < 10%

Status and Schedule

main detectors	status
SC	installed
TPC	under repair
DC	installed
RPC	Mass production was finished.
AC	will be installed in Jan
Barrel gamma	installed

Commissioning is performed until the end of this FY.

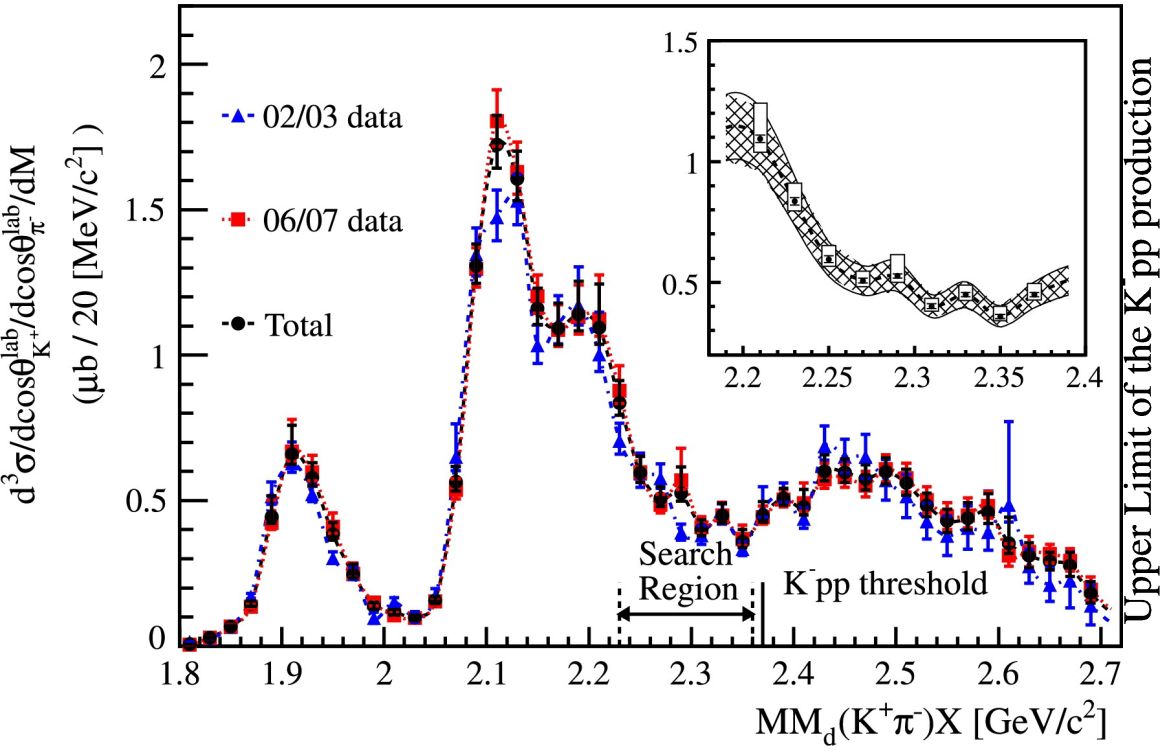
Physics data will be taken from next FY !

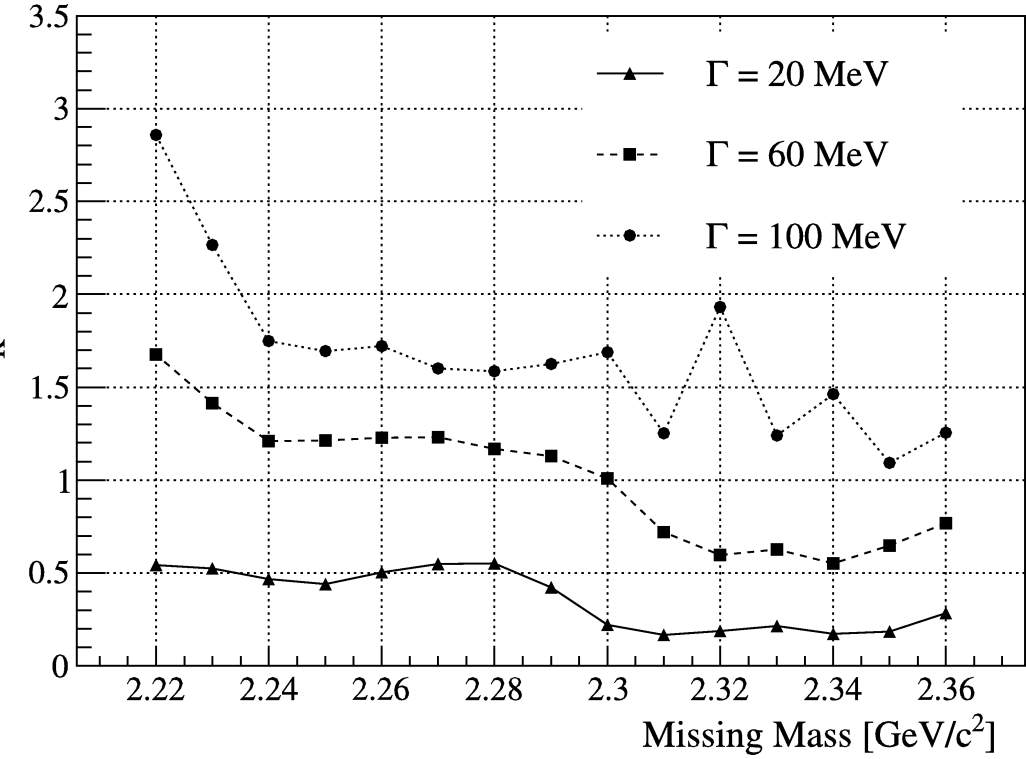
Summary

- $\bar{K}N$ intraction is strongly attractive.
  - Kaonic nuclei can exist. The simplest one is K$^-$pp bound state.
- A signal of the K$^-$pp bound state has been observed at J-PARC.
  - However, the property of the bound state has not been determined yet. A new experiment with different production channel, such as photo production, is important.
  - LEPS2 experiment : We will search for K$^-$pp bound state via photo production.
- Almost all detectors are already installed in the solenoid magnet. Commisioning is ongoing now.
- Physics data will be taken from next FY.

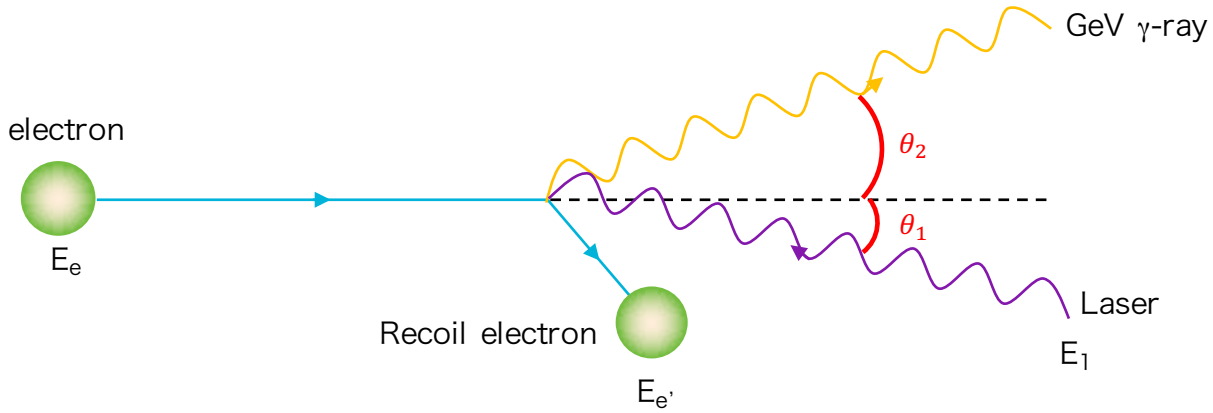
appendix

results of LEPS





γ ray generated by backward Compton scattering



$$E_\gamma = E_1 \frac{1-\beta\cos\theta_1}{(1-\beta\cos\theta_2)+\frac{E_1}{E_e}(1-\cos(\theta_2-\theta_1))}$$

$E_{\gamma\,max}$ ~ 2.9 GeV (laser wave length : 266 nm)

$E_{\gamma\,max}$ ~ 2.4 GeV (laser wave length : 355 nm)