The devlopment of the new Cylindrical Detector System for the systematic investigation of light kaonic nuclei

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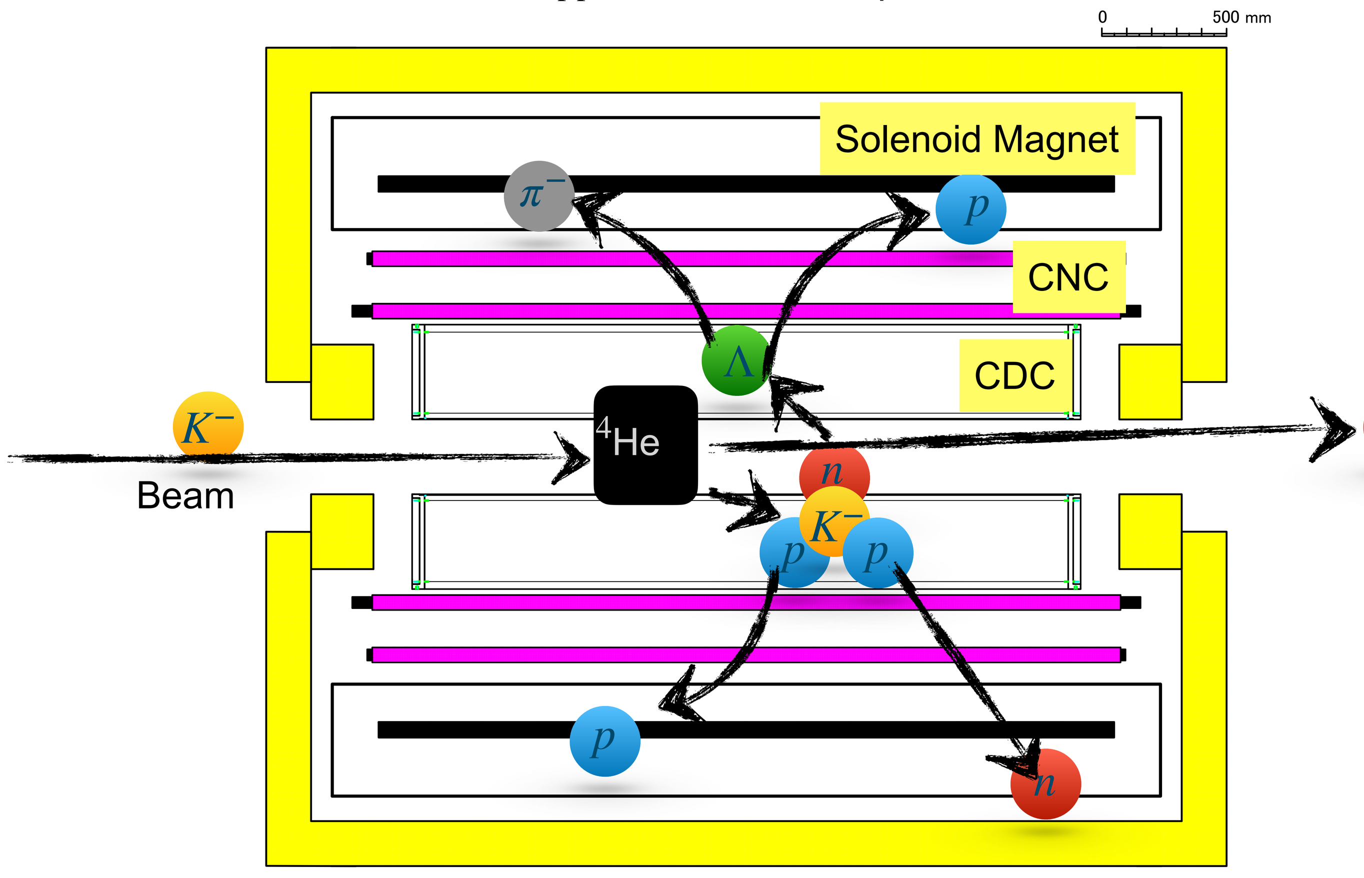
Abstract Following the observation of the simplest kaonic nucleus "K^-pp" in the J-PARC E15 experiment, the J-PARC E80 experiment is planned for the systematic study of kaonic nuclei. As a first step, we will search for X = "K^-ppn" by the in-flight $K^-(^4\mathrm{He}, X)\,n$ reaction, focusing on the non-mesonic decays to Λd and Λpn. These decay particles from the kaonic nucleus are detected by the Cylindrical Detector System (CDS) which we are developing for this purpose. With an enlarged acceptance and neutron detection capability, we plan to measure the kaonic nucleus which has more decay particles than the case of E15. In this poster, I will introduce J-PARC E80 experiment and show the current status of the new CDS development, especially about the Cylindrical Drift Chamber (CDC) and the gases for the CDC.

1. J-PARC E80 : The first step in systematic study of kaonic nuclei

The J-PARC E15 experiment confirmed the existence of the simplest kaonic nuclei K^-pp. The obtained binding energy was approximately 50 MeV. Kaonic nuclei have several interesting aspects;

- Kaonic nuclei, bound states between $\bar{K}$'s and N's, are formed by the strongly attractive $\bar{K}N$ interaction
  —> The best probe to understand $\bar{K}N$ interaction in the subthreshold region.
- Deeper binding energy than normal nuclei
  —> Could this suggest high dense matter?
- The system includes a real boson.
  —> Potential to gain new insight into the composition of matter

"$\bar{K}NNN$" should exist, but predicted binding energies and widths are widely spread depending on $\bar{K}N$ interaction models.
Therefore, we will search for "K^-ppn" with the new spectrometer at first in the following way;

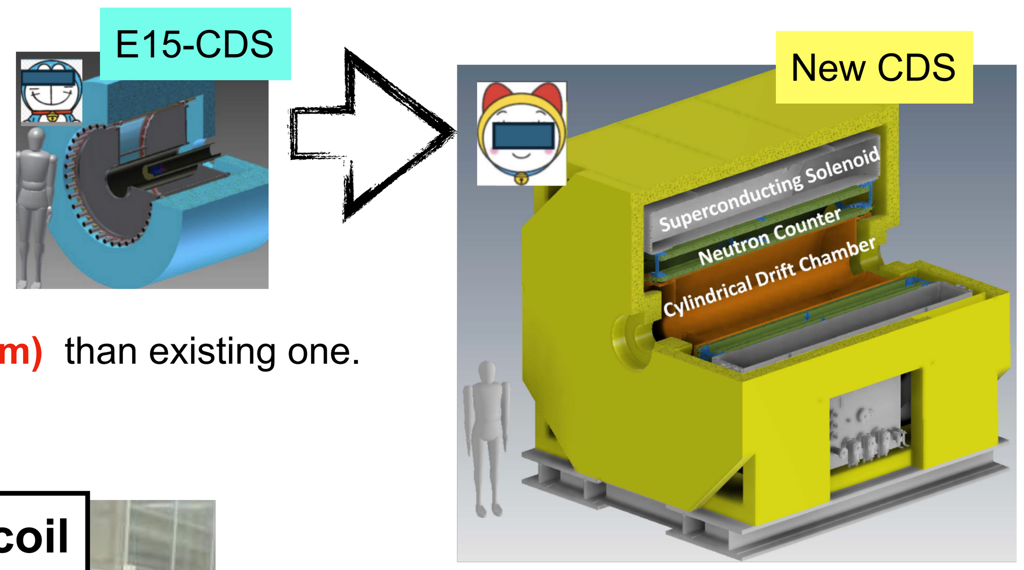


We will measure all the decay particles from "K^-ppn".

Then, the invariant mass of "K^-ppn" will be reconstructed.
If it exists, we can obtain information about its binding energy and decay width.

The new CDS

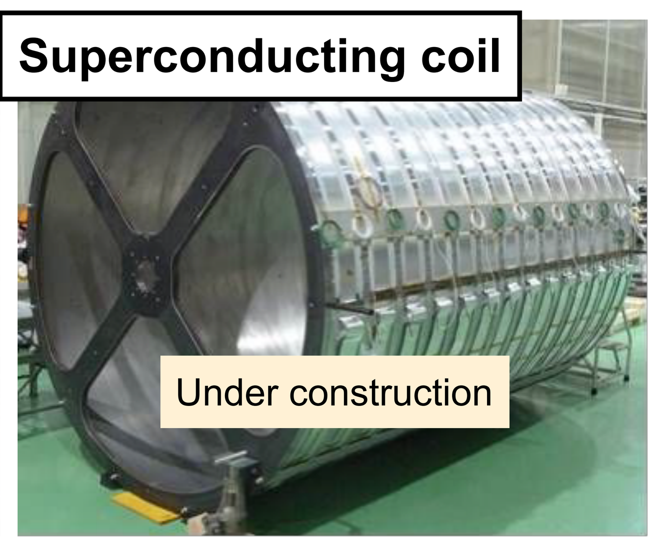
The new CDS has two advantages compared to the E15-CDS.
It has **1.6 times larger solid angle (59% —> 93%)**
and **4 times higher neutron detection efficiency (3cm —> 12cm)** than existing one.



Developing status

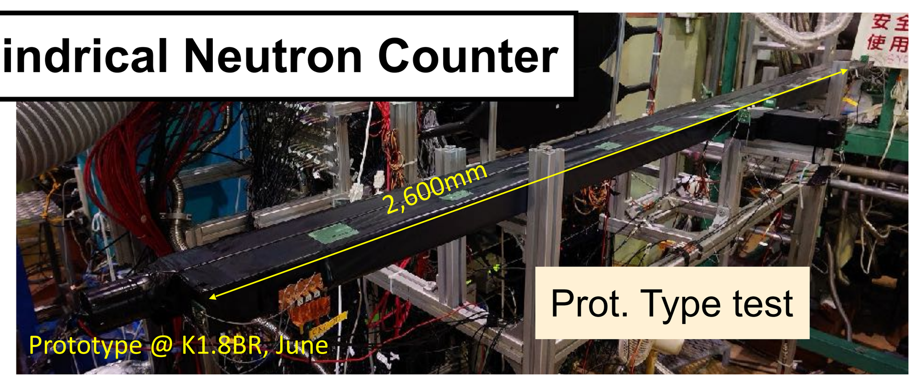
Solenoid York

Superconducting coil



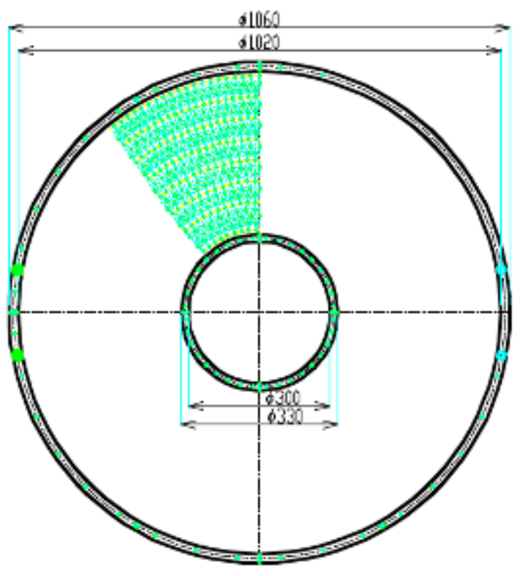
- 3.3m x 3.3m x 3.9m, ~108t in total
- Max. Field of 1.0T @ center
  - 189A - 10V
- NbTi/Cu SC wire, 98km in total
- Will be completed in FY2024

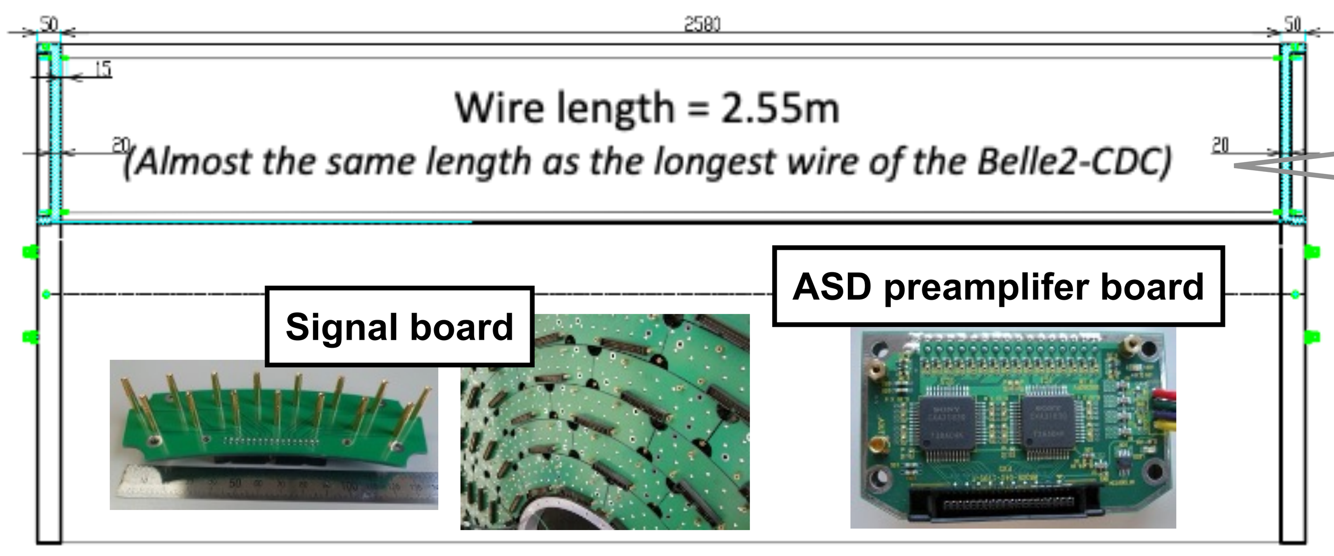
Cylindrical Neutron Counter



- Scintillator array: 2 layers, 12 cm thickness
- Fine Mesh PMT & MPPC array
- Neutron detection efficiency of 12~36%
- Intrinsic time resolution of ~80ps
- Will be fabricated in FY2024

2. Development status of CDC : Currently, we are mainly developing the CDC at J-PARC.



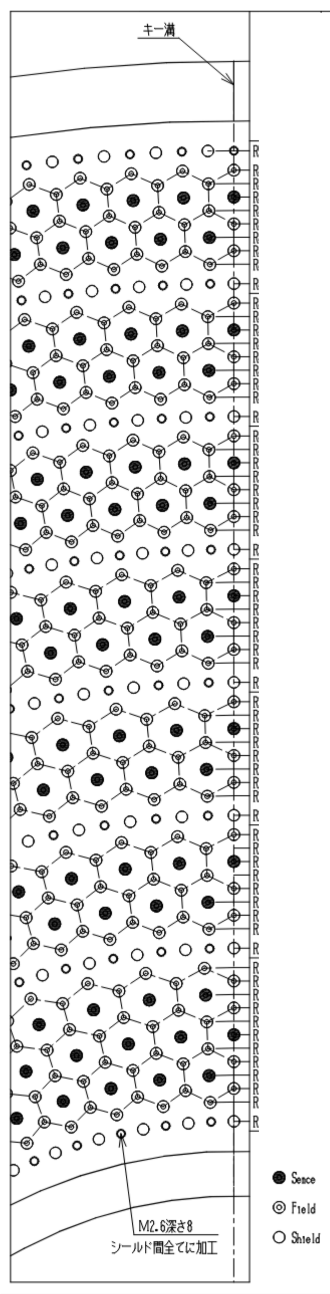


- The CDC consists of two aluminum end plates and a CFRP cylinder as the inner wall.
- 8,244 wires
  (The wire tension was applied
  so that the wire sag was less than 200 um.);

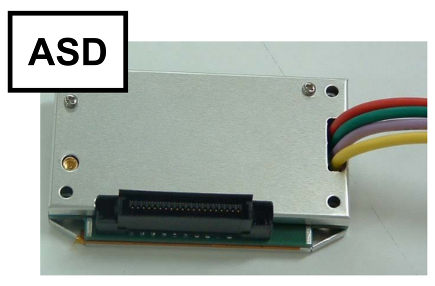
Wire type	Wire diameter	Wire material	Number of wires	Wire tension
Sense	ϕ30 μm	Au-W	1,816	70 g
Filed	ϕ80 μm	Be-Cu	5,376	240 g
Guard	ϕ80 μm	Be-Cu	1,052	240 g
In total			8,244	1.67 tons

- 15 layers of hexagonal cells with a typical drift length of 9 mm

Super-layer	layer	Wire direction	Radius (mm)	Cell width (degree)	Cell width (mm)	Stereo angle (degree)	Signal channels per layer
A1	1	X	190.5	5.00	16.7	0	72
	2	X'	204.0		17.8	0	
	3	X	217.5		19.0	0	
U1	4	U	248.5	4.00	17.3	-2.27	90
	5	U'	262.0		18.3	-2.39	
V1	6	V	293.0	3.60	18.4	2.42	100
	7	V'	306.5		19.3	2.53	
A2	8	X	337.5	3.00	17.7	0	120
	9	X'	351.0		18.4	0	
U2	10	U	382.0	2.40	16.0	-2.82	150
	11	U'	395.5		16.6	-2.92	
V2	12	V	426.5	2.25	16.7	2.96	160
	13	V'	440.0		17.3	3.05	
A3	14	X	471.0	2.00	16.4	0	180
	15	X'	484.5		16.9	0	



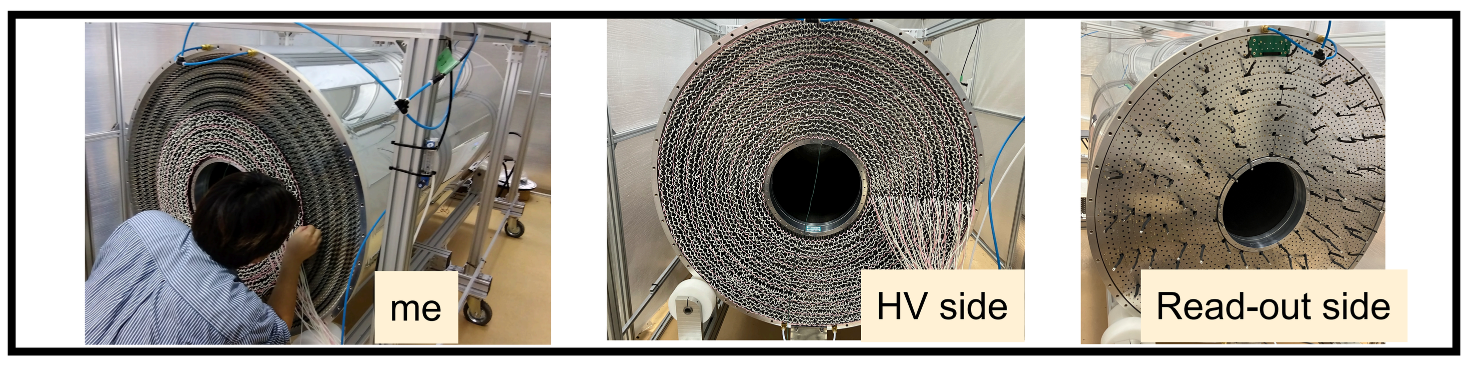
ASD



Readout system

- Preamplifiers with ASDs
  (SONY CXA3653Q or ASAGI)
- HUL (multi-hit TDCs) or AMANEQ (Streaming DAQ)

Transfered to J-PARC



- A total of 6,428 field wires were connected using daisy chains.
- Signal readout side is being assembled.

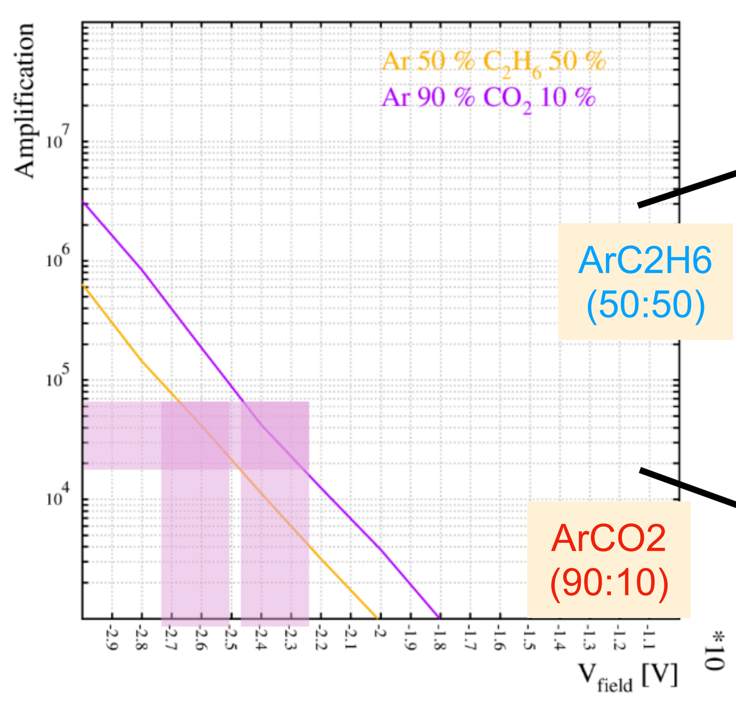
What gases will we use?

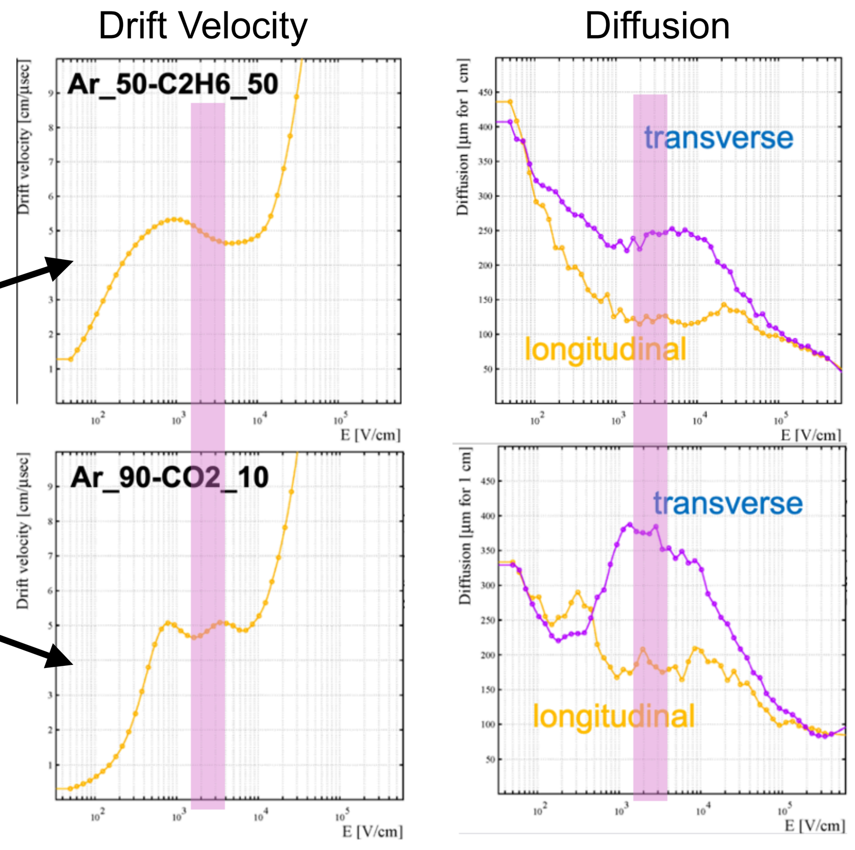
We used Ar-C_2H_6 (50-50) mixture for the E15-CDC. However, we want to use non flammable and low-cost gases because the CDC has 3 times the volume of the E15-CDC.

3. Gas study with the existing CDC : Comparison between Ar-CO_2 and Ar-C_2H_6(50-50)

We have investigated whether Ar-CO_2(90-10) could perform as well as Ar-C_2H_6 (50-50) .

Simulation by Garfield





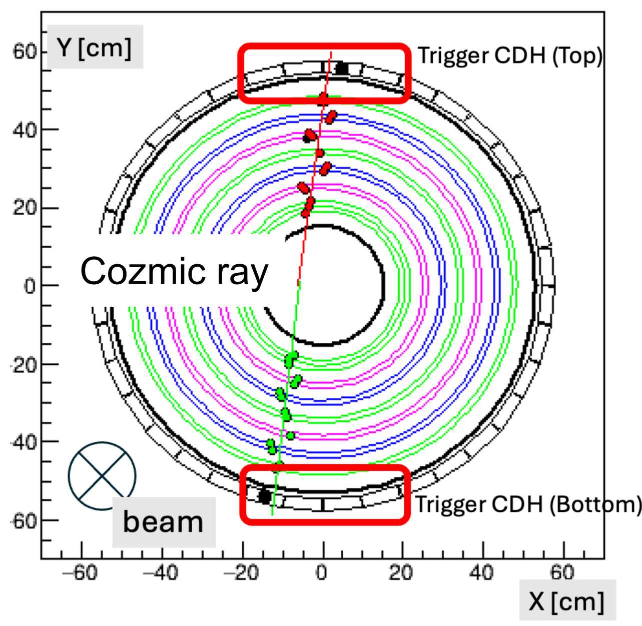
HV applied to field wire;
ArC2H6(50:50) : ~2700 V
ArCO2(90:10) : ~2400 V

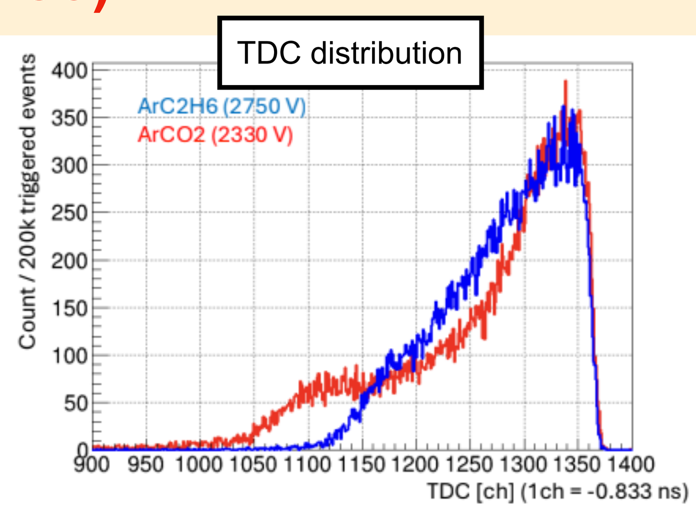
- Drift Velocity : Almost the same value & large plateau area
- Diffusion : Longitudinal diffusion affects to resolution.
  Comparable value (~ 50 um)

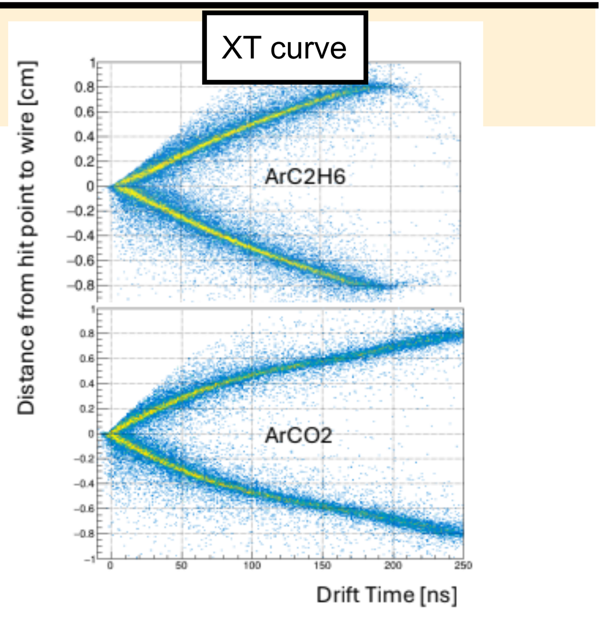
Ar-CO_2 is a good candidate.

Cozmic Ray Test

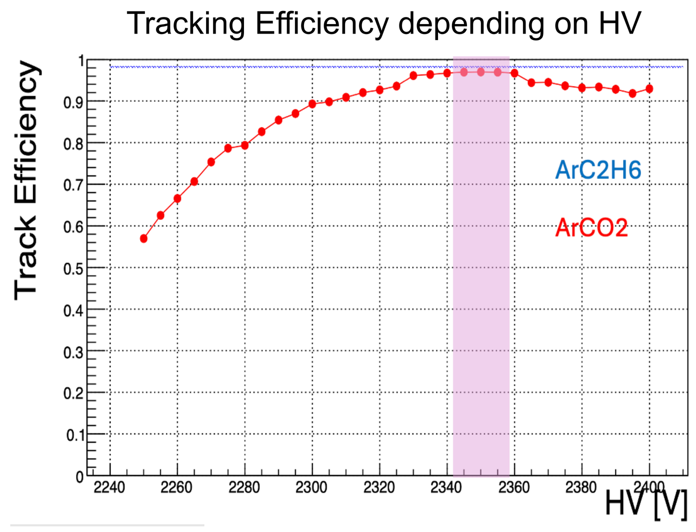
- The study used the E15-CDC
- No magnetic field
- Ar-C_2H_6 (50-50) : -2750 V
- Ar-CO_2 (90-10) : -2250 ~ -2400 V
- Preamplifiers with ASDs
  (SONY CXA3653Q, τ =16ns)
- HUL (multi-hit TDCs)



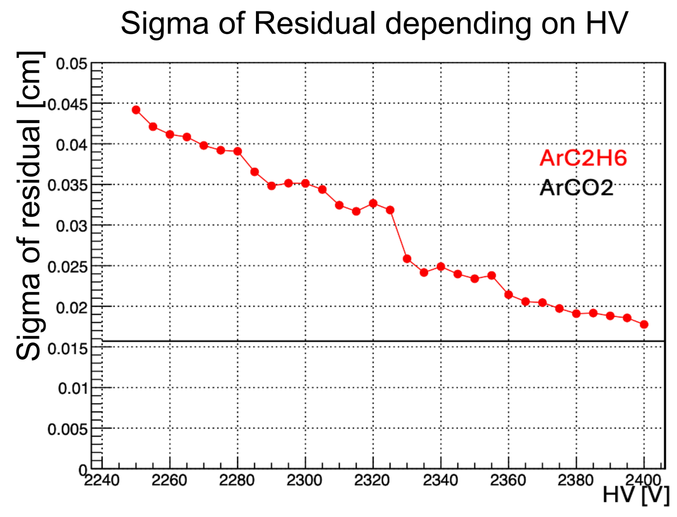




Tracking Efficiency depending on HV



Sigma of Residual depending on HV



Approximately 2350 V corresponds to the expected Efficiency (~ 97 %).
The residual(related to resolution) approaches an adequate level at 2400 V.

The performance with Ar-CO_2 (90-10) is satisfactory.

The first data taking is expected in FY2026.
J-PARC E80 will open a new era in the study of kaonic nuclei!