Interim Report of my Master Thesis
修論中間報告

木村佑斗 (Yuto Kimura), M2

RARiS三神峯 雑誌会

2024/11/7

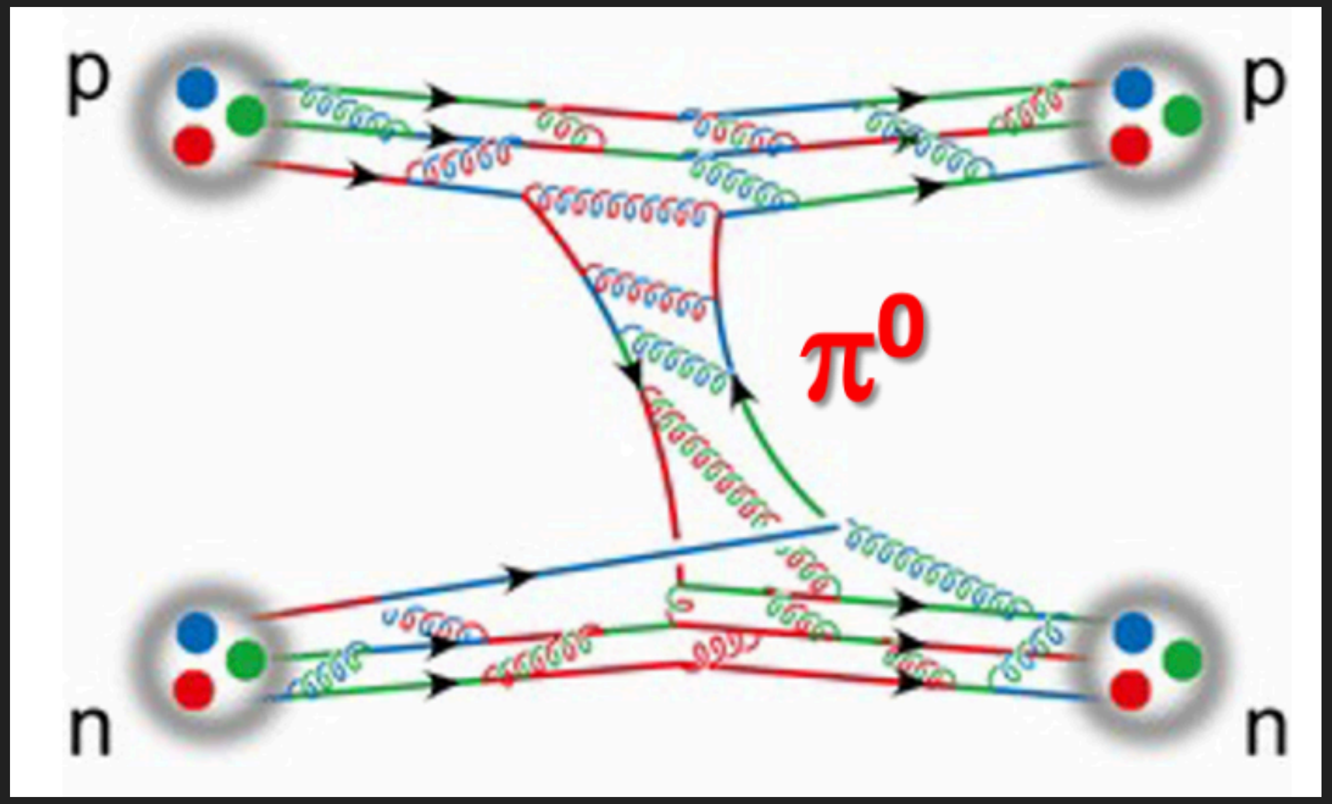
Outline

1. Anti-Kaonic Nuclei
2. “J-PARC E15 experiment”
3. “J-PARC E80 experiment” → My Theme of D
   - Search for anti-kaonic nuclei “$K^{-}ppn$”
4. Cylindrical Drift Chamber (CDC)
5. Gas Study for CDC

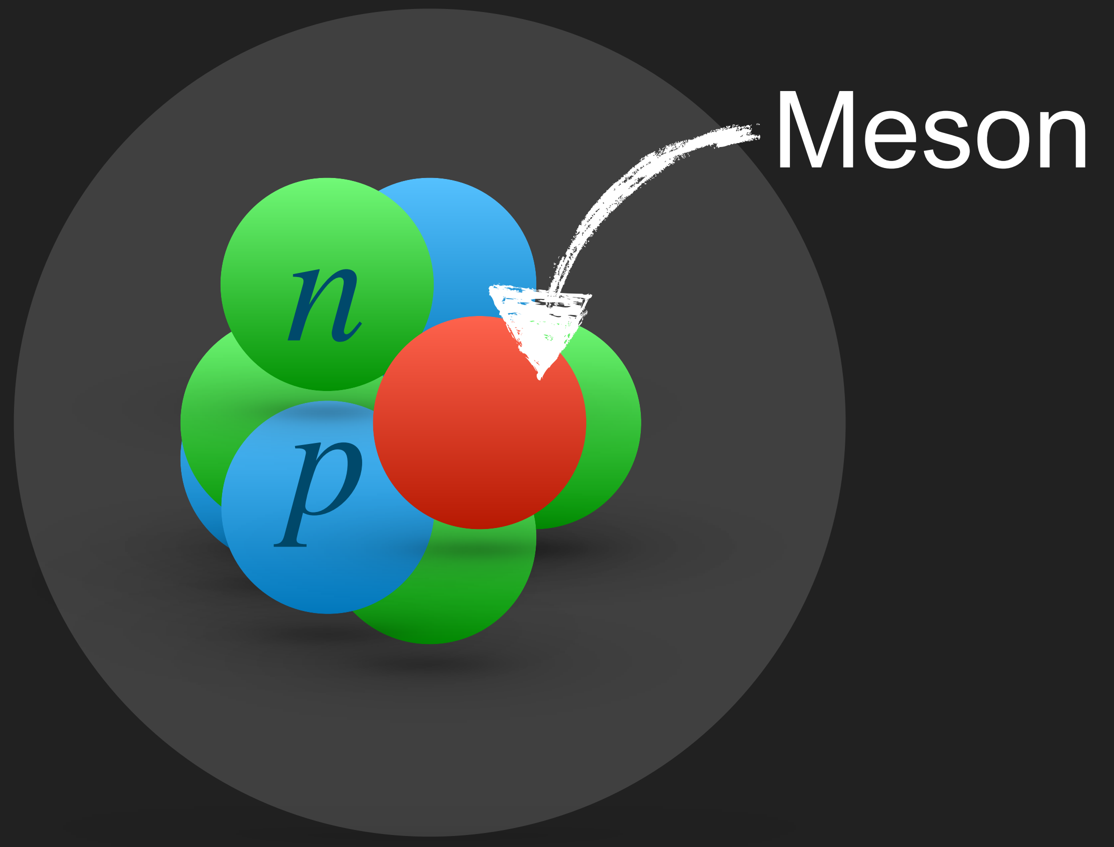
   } → My Theme of M
   - To decide on the gas to be used for the CDC
   - To operate the CDC
   - To acquire the first data, and confirm that the performance satisfies our expectations
6. Summary

Meson in nuclei

Meson: quark-antiquark ($\bar{q}q$) pair



- **In nuclei**, mesons are **virtual** particles and form nuclear potential (Yukawa theorem).

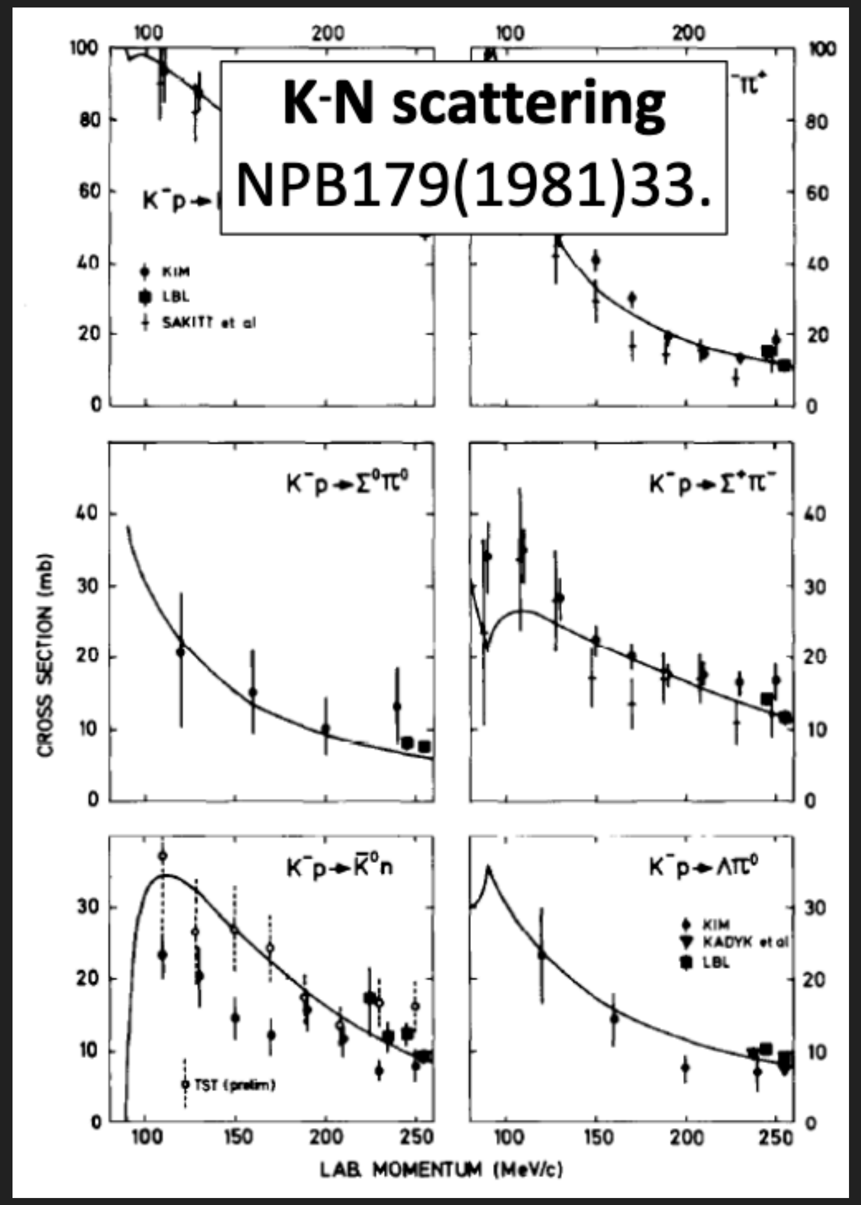


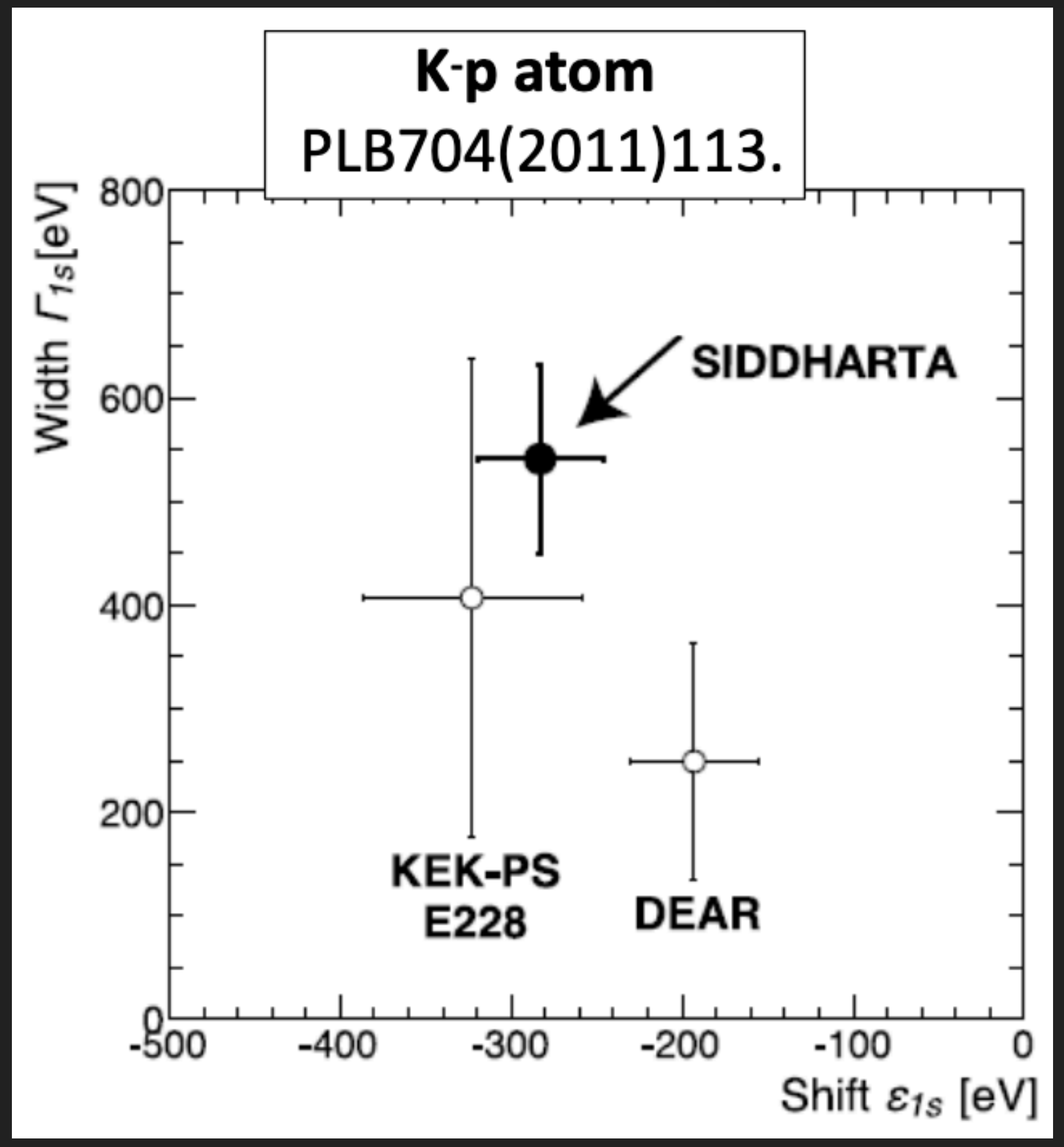
- **In vacuum**, mesons are **real** particles having own intrinsic masses (cf. meson beam).

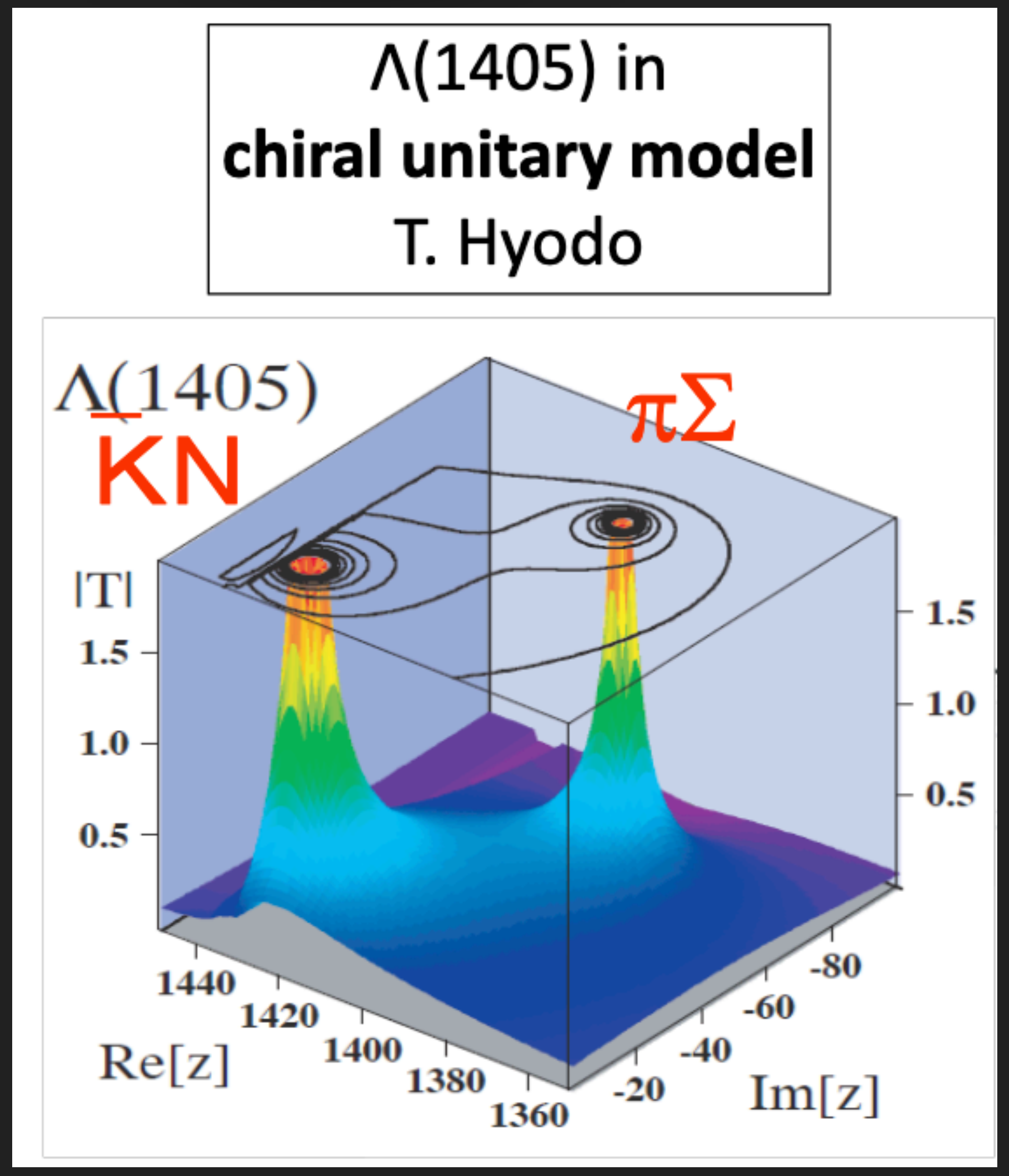
Can meson be a constituent particle forming nuclei?

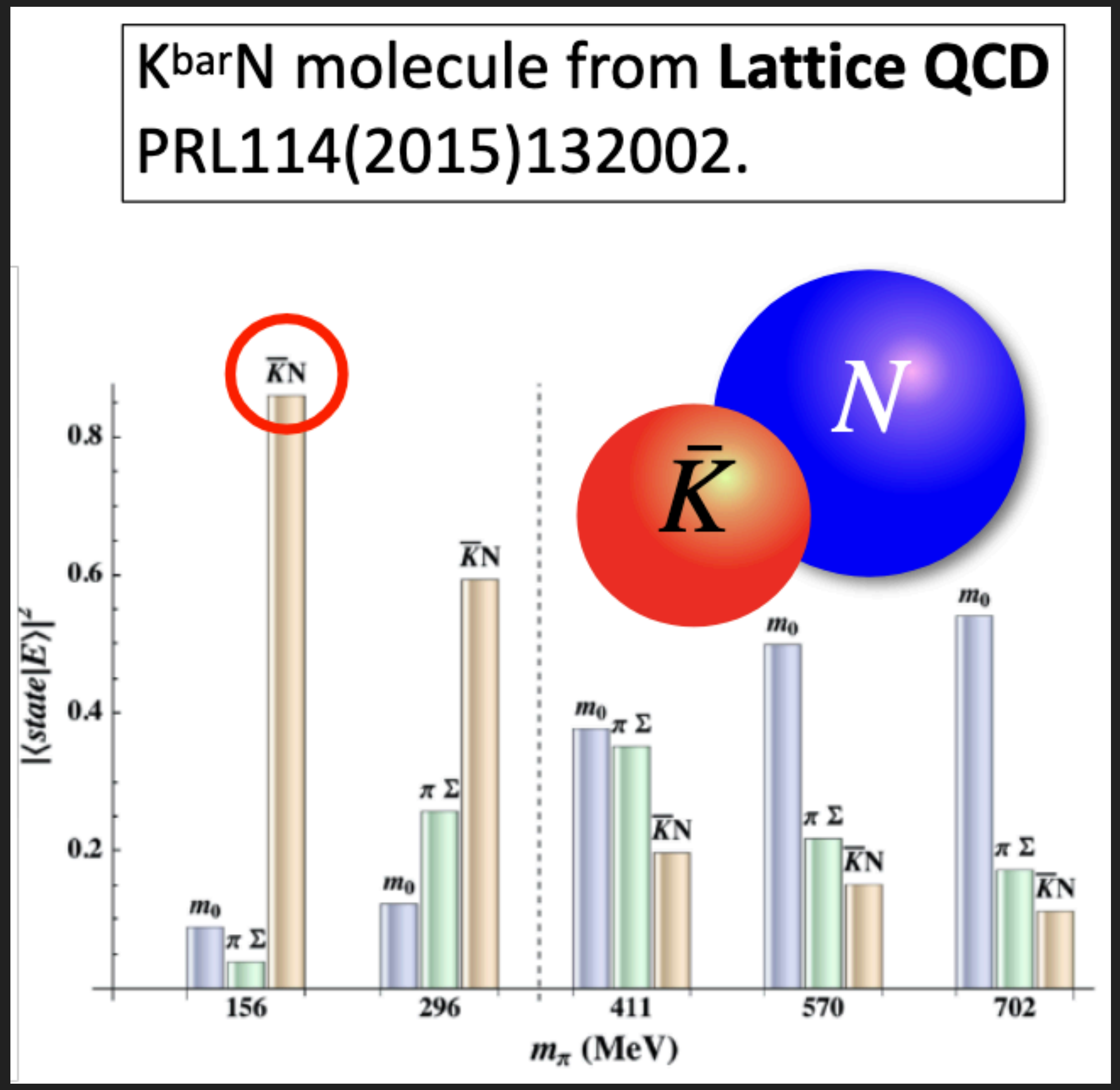
If yes, how do meson and core nucleus change?

$\bar{K}N$ interaction

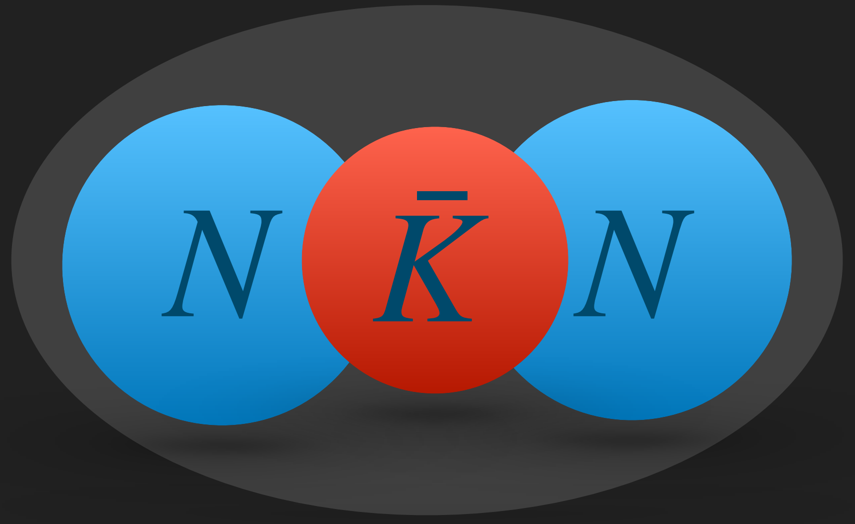






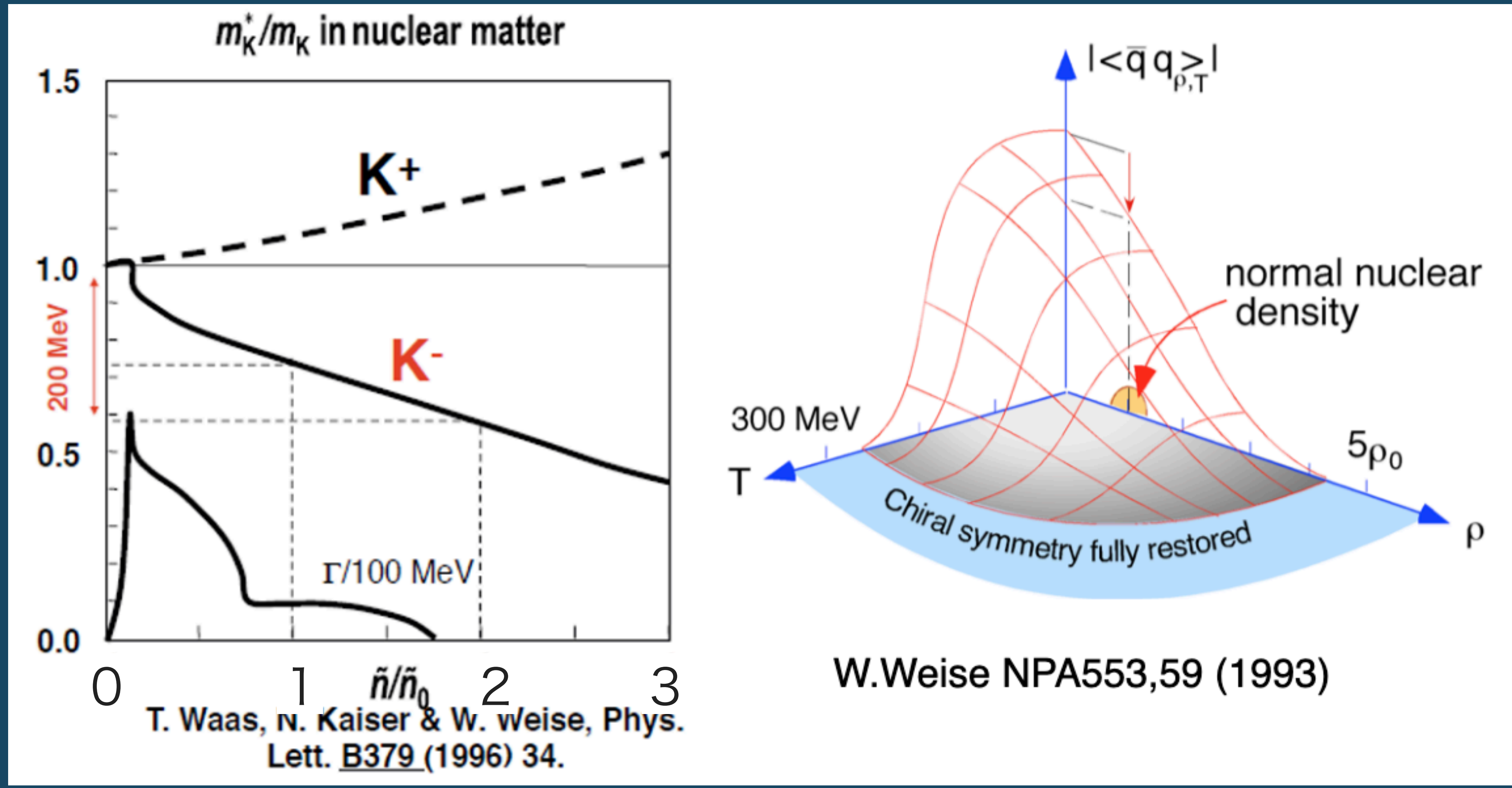


- Strong attraction in $I = 0$ from scattering and X-ray experiments.
- $\Lambda(1405) = \bar{K}N$ molecule picture is now widely accepted.



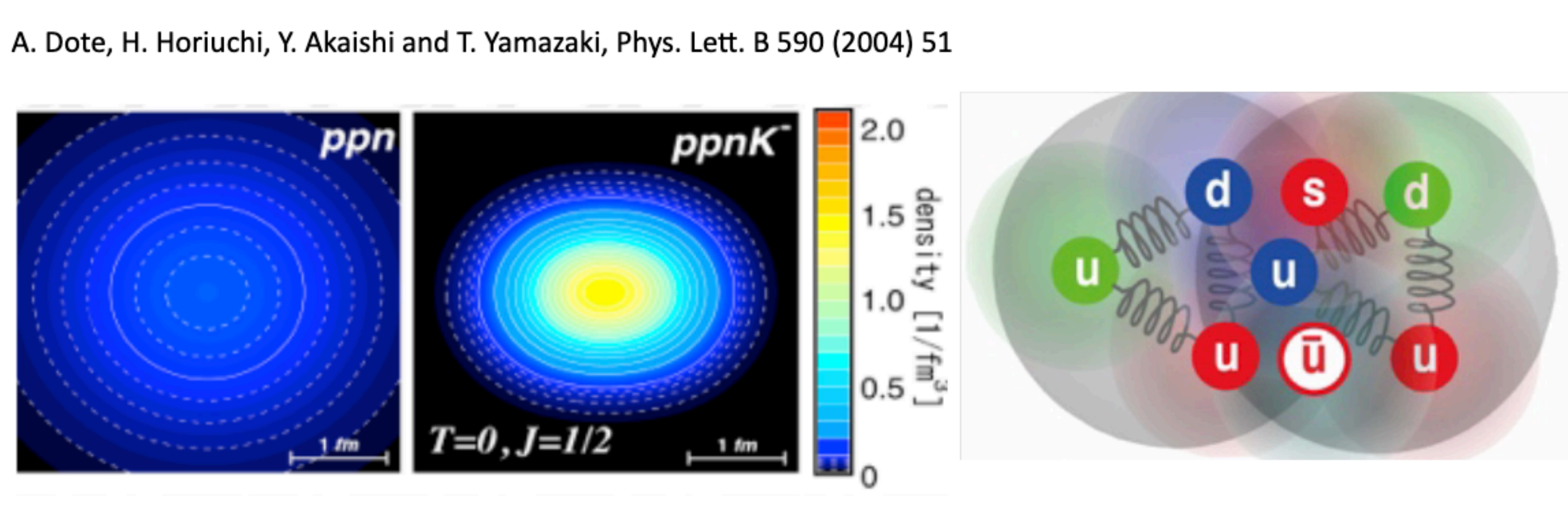
Why not anti-kaonic nucleus with additional nucleons?

Anti-Kaonic Nuclei

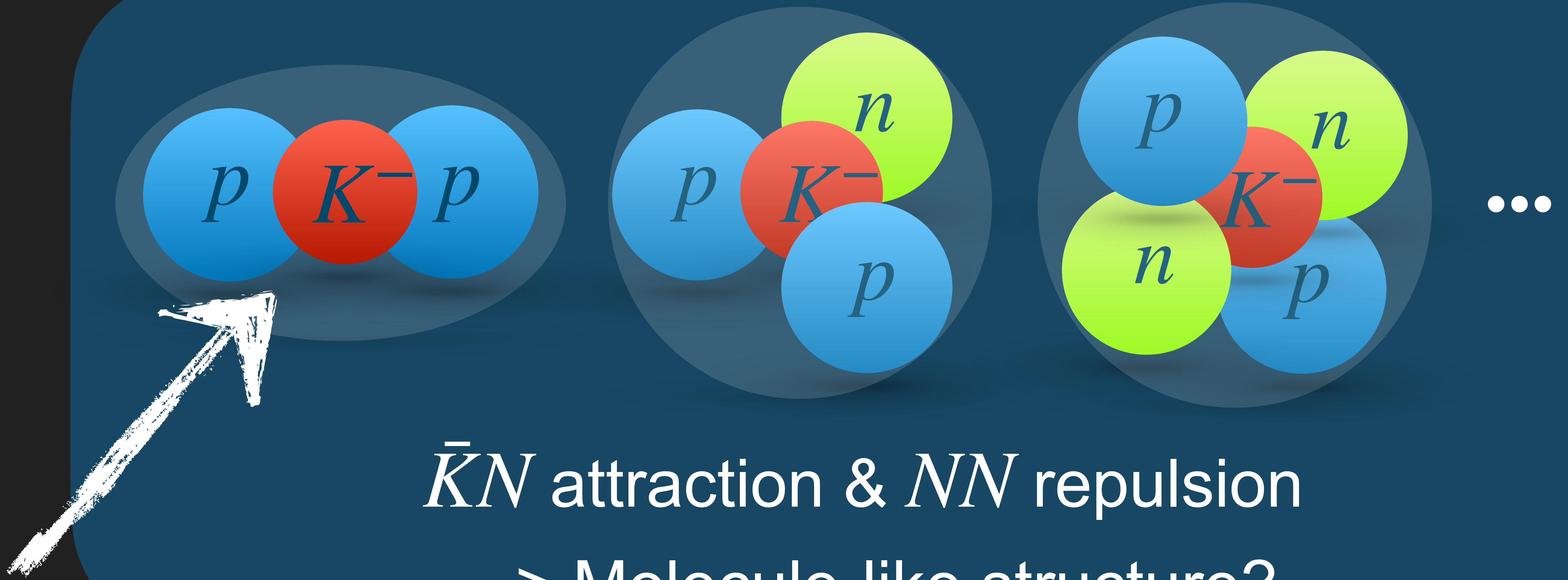


Kaon mass changes?

New materials composed of real bosons
—> Unknown properties emerge?



Compact system?
—> Nucleon overlaps? Dense matter?

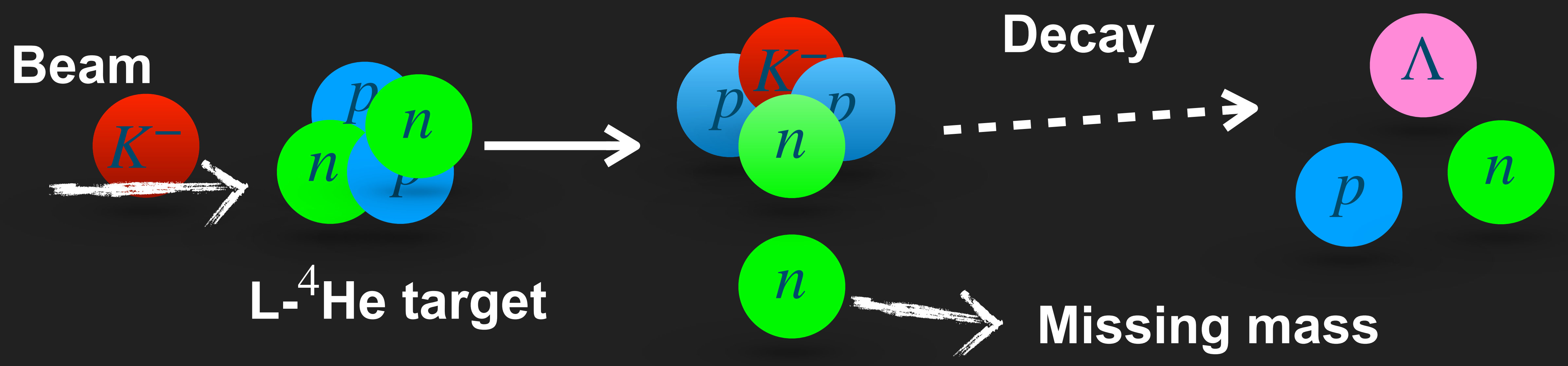


Confirmed by J-PARC E15 exp.

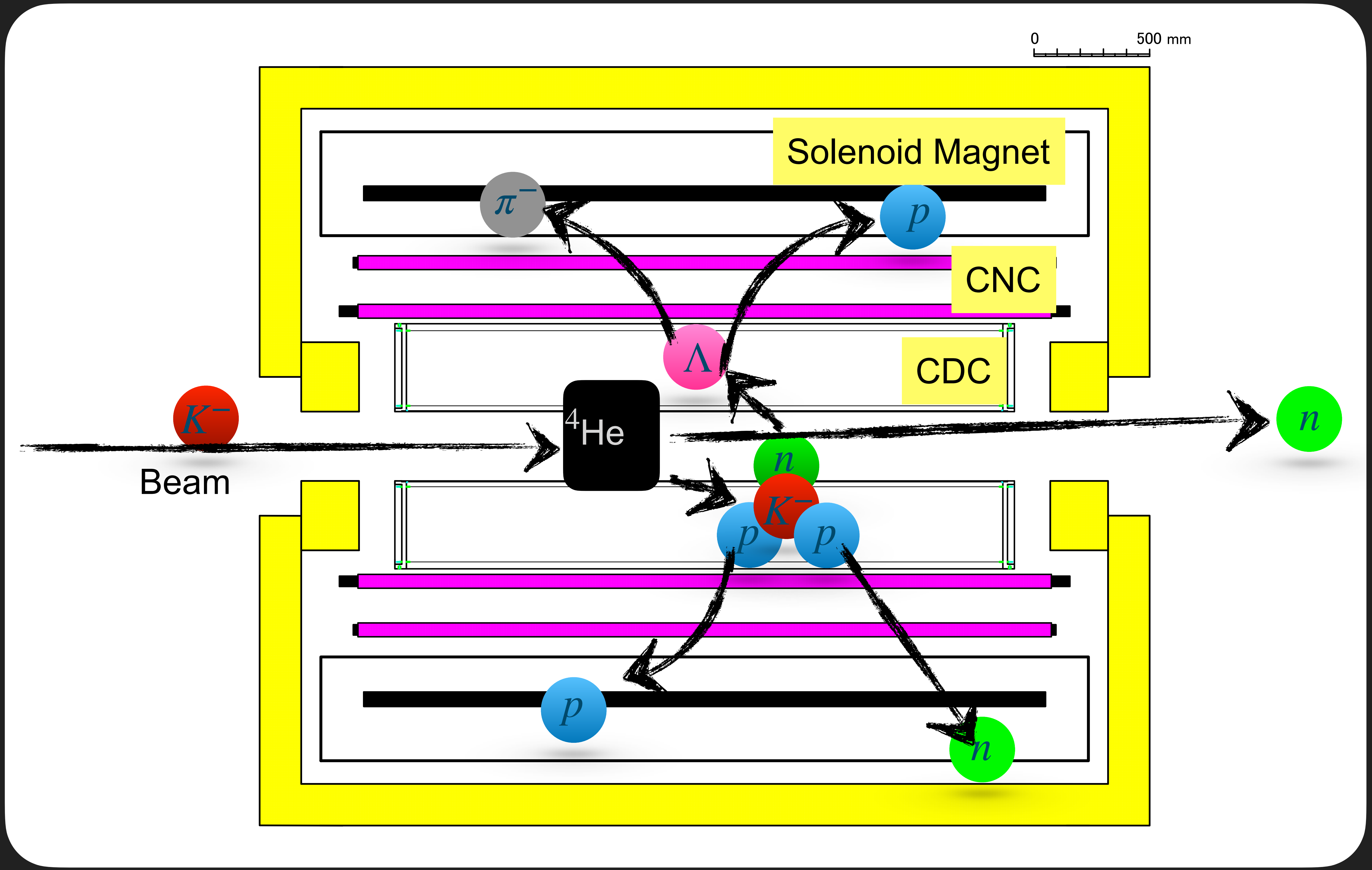
$\bar{K}N$ attraction & NN repulsion
—> Molecule-like structure?

Anti-kaonic nucleus could be a new & unique probe for low-energy QCD.
—> We plan to do the systematic research on anti-kaonic nucleus.

J-PARC E80 exp.



- "$\bar{K}NNN$" should exist.
- Predicted binding energies and widths are widely spread depending on $\bar{K}N$ interaction models.
- We will measure all the decay particles from "K^-ppn".
- If it exists, we can obtain information about its binding energy and decay width.



Detecting more decay particles including a neutron than E15 is needed.

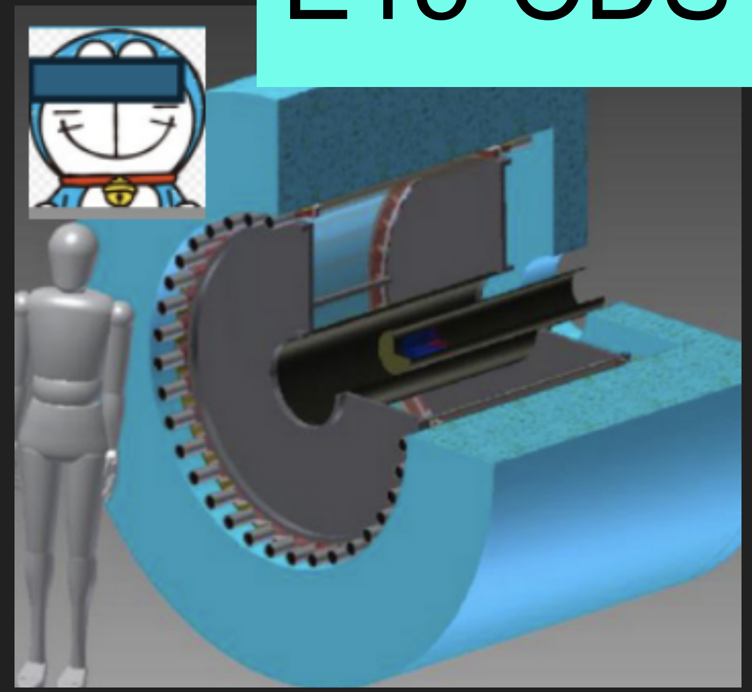
The new detector system for E80 is being developed now.

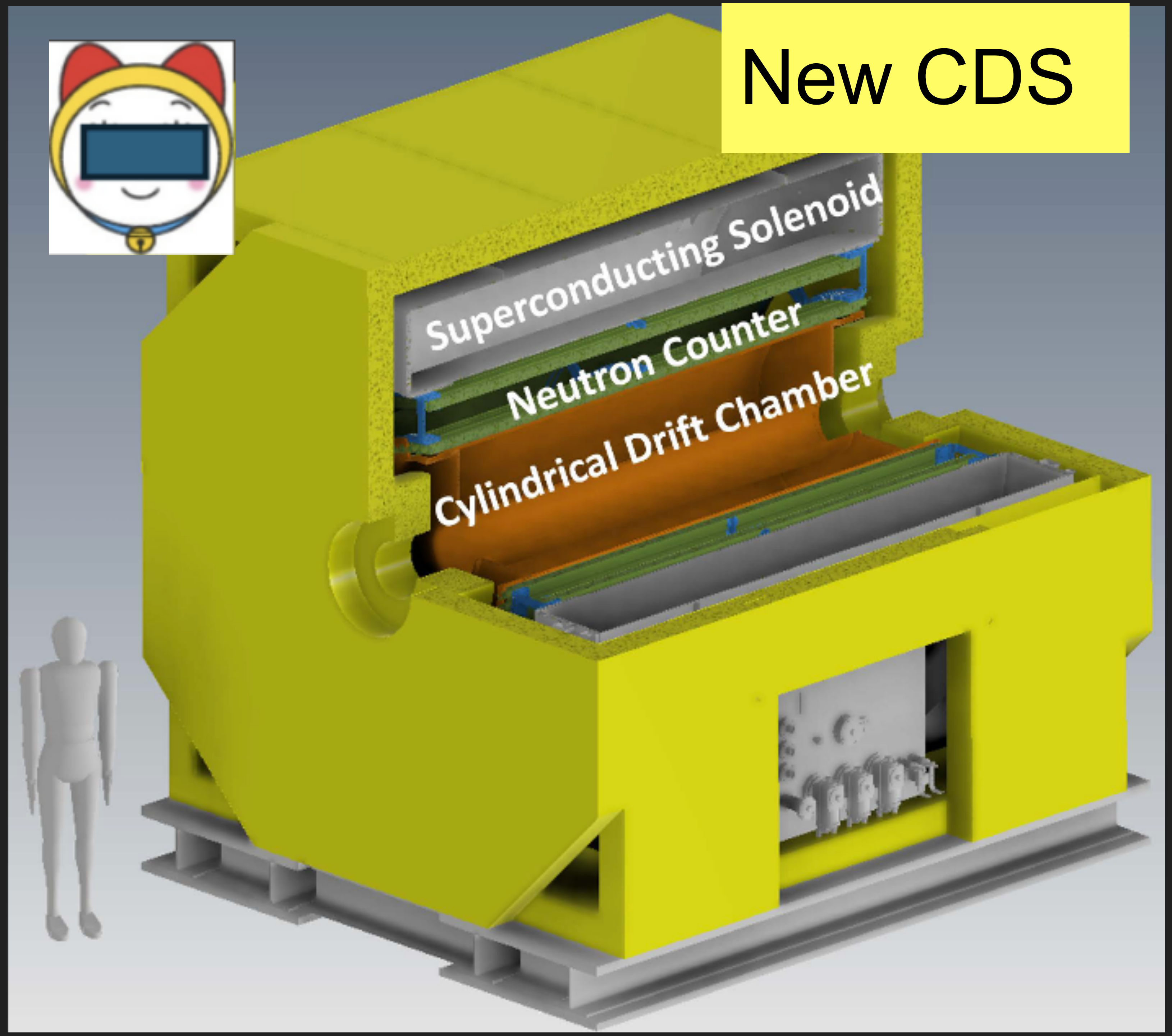
New Cylindrical Detector System (CDS)

Under construction

Two advantages of the new CDS compared to the E15-CDS

- 1.6 times larger solid angle (59% —> 93%)
- 4 times higher neutron detection efficiency (3cm —> 12cm)

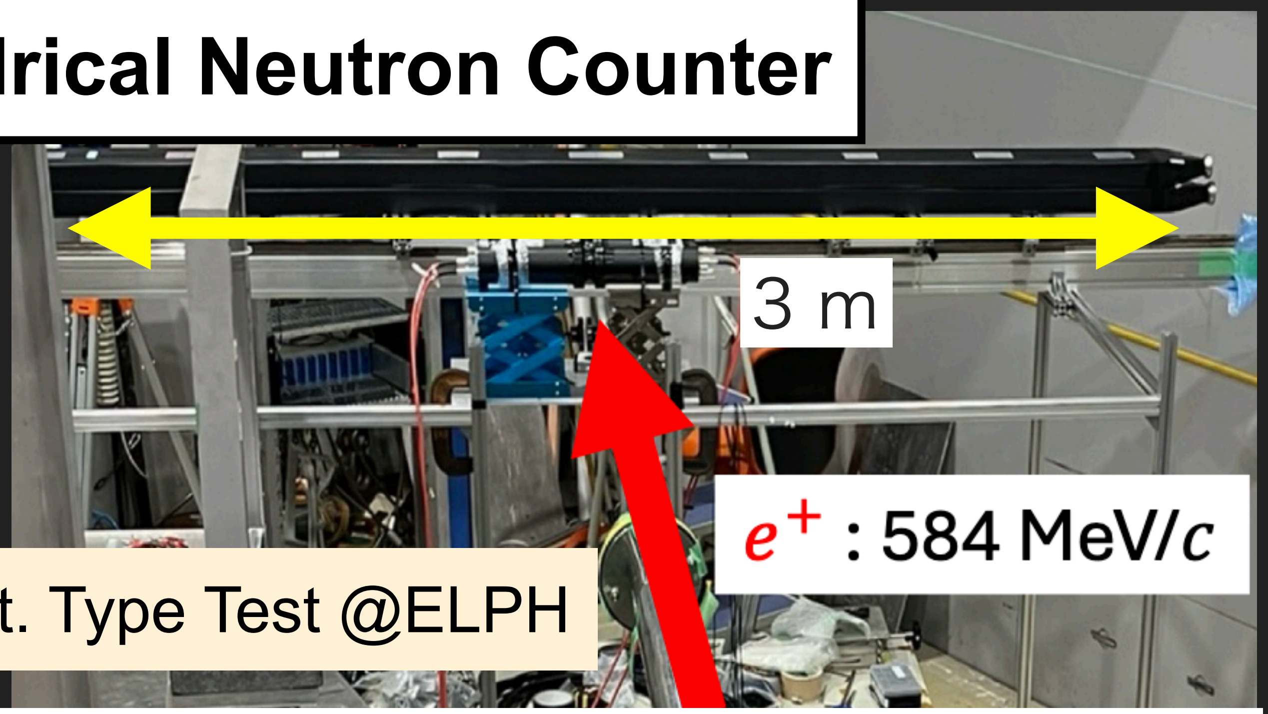




Solenoid York

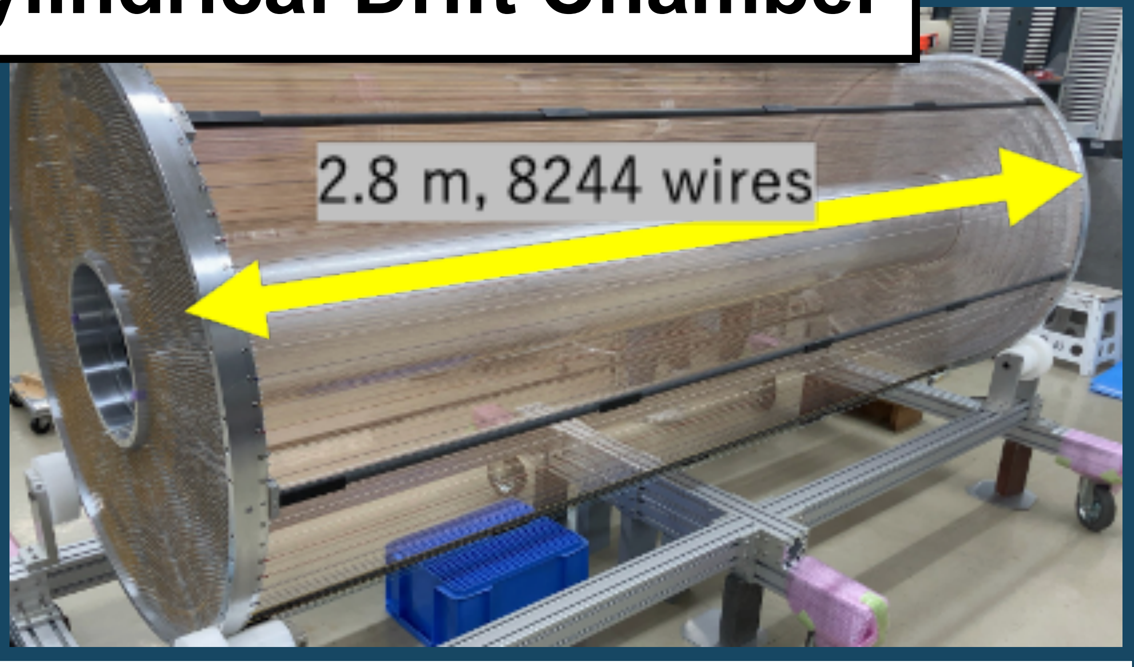
Superconducting coil

Cylindrical Neutron Counter



2023/12/11, SNP school (J-PARC)
2024/3/8, ELPH symposium (online, poster)
2024/3/19, JPS meeting (online)

Cylindrical Drift Chamber

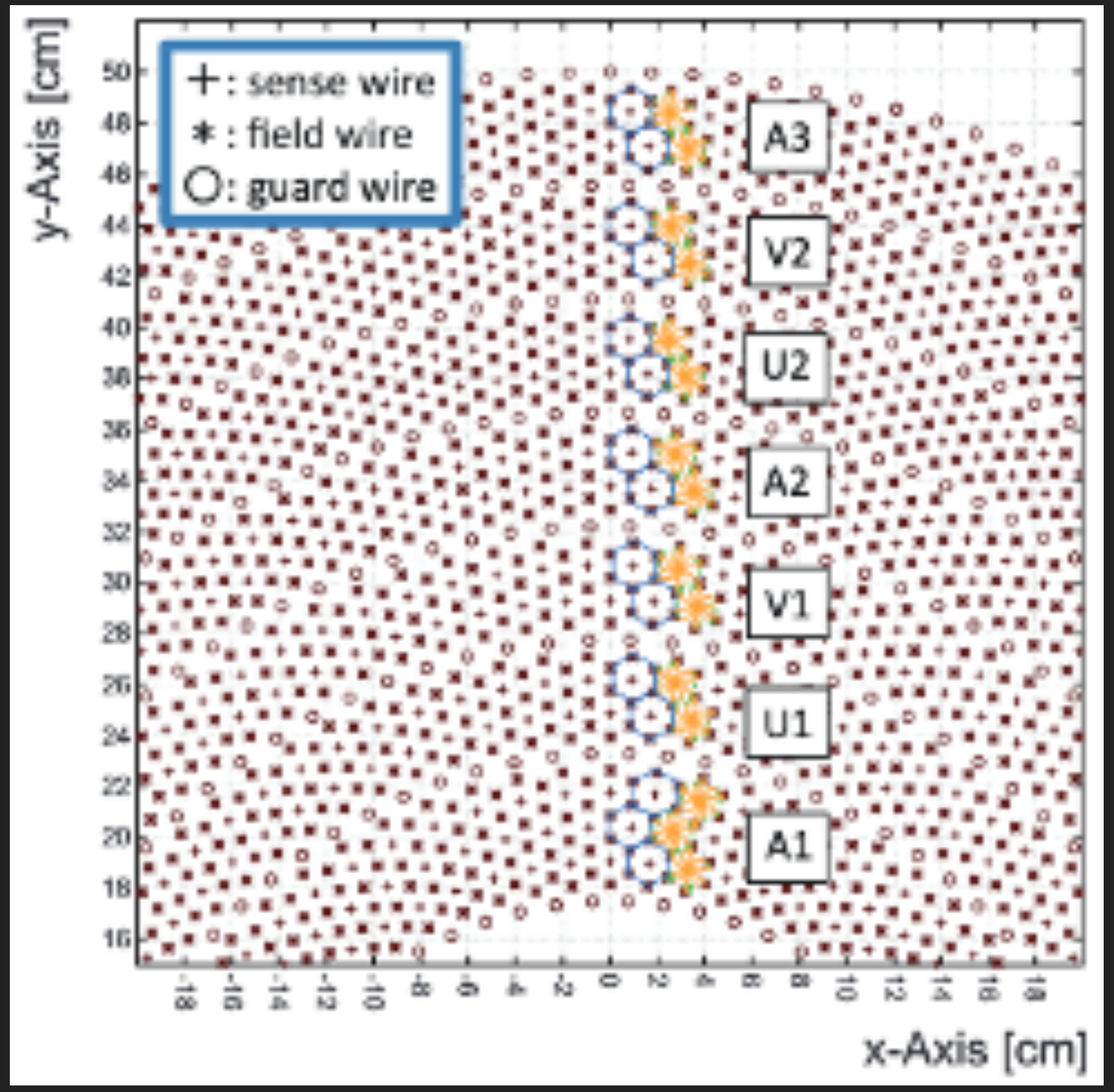


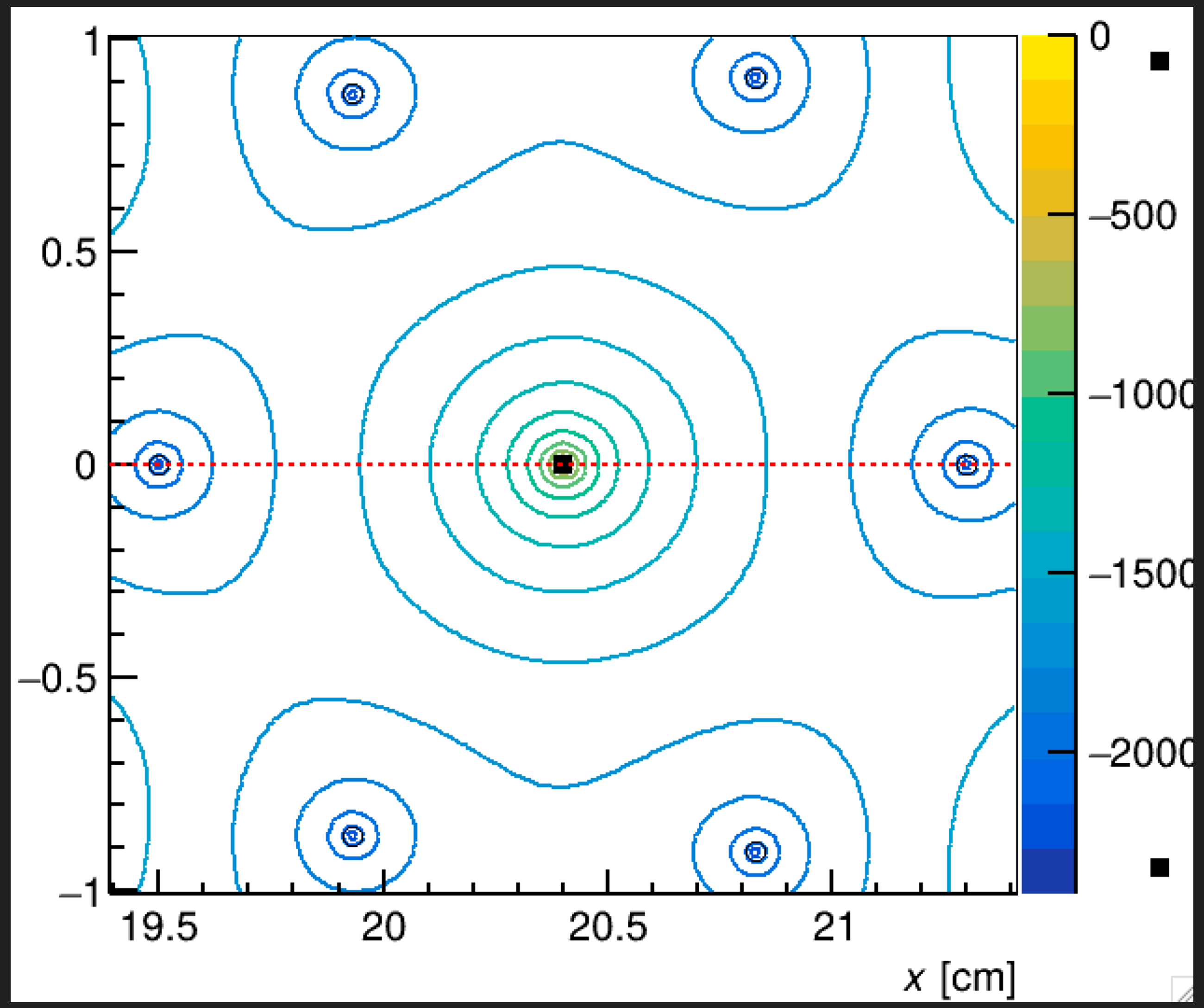
2024/9/19, JPS meeting (Hokkaido univ.)
2024/10/15, J-PARC symposium (poster)

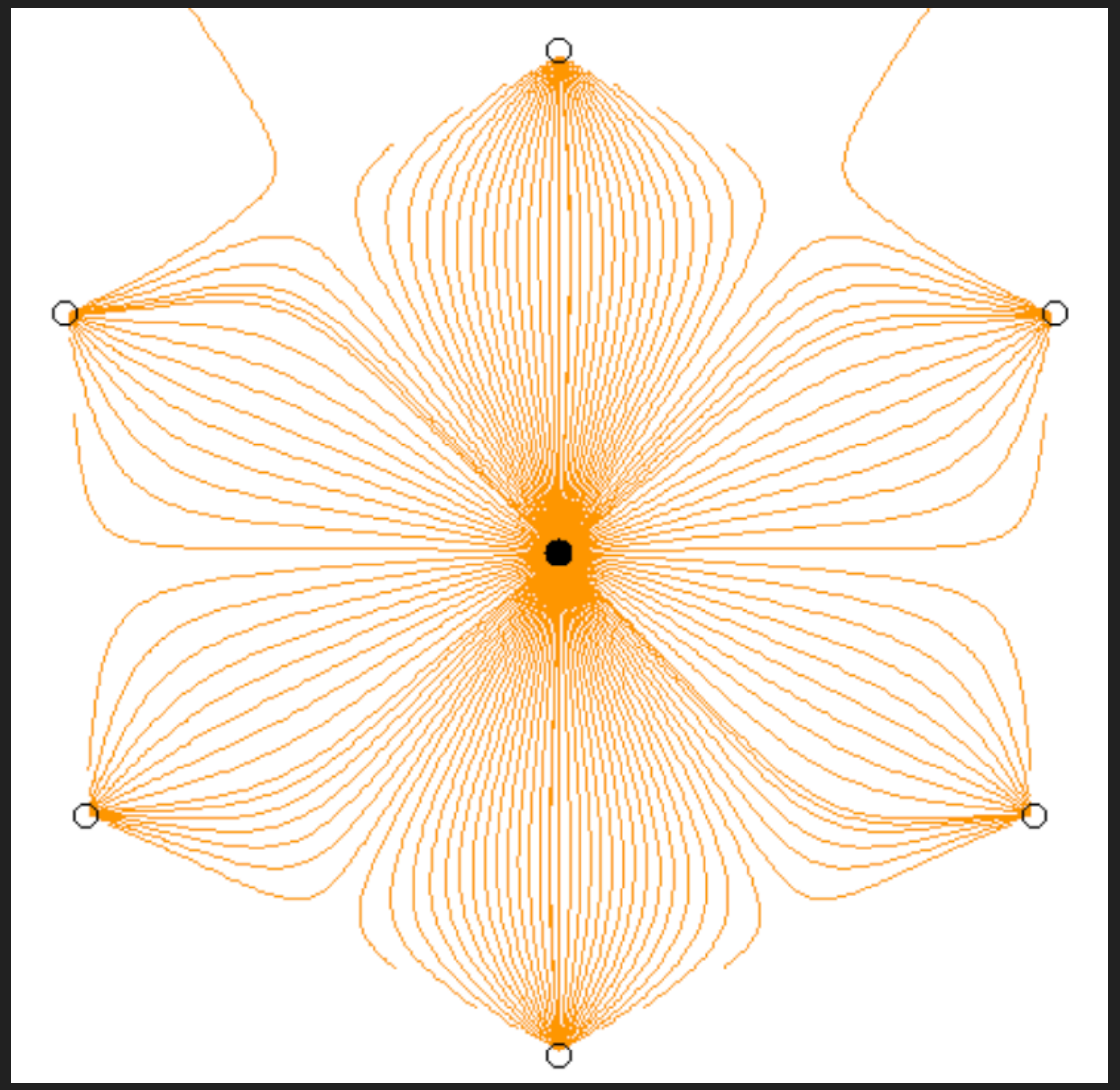
CDC立ち上げ

- *Designed by F. Sakuma (RIKEN)*

Exp.	cell	wire	Num of channel	area (Beam軸垂直)	area (Beam軸方向)
J-PARC E15	六角形 15層	Au-W(Au-Al) ø30 um(100 um)	1,816 (6,428)	ø(1060 - 300) mm	850 mm
J-PARC E80	六角形 15層	Au-W((Be-Cu) ø30 um(80 um)	1,816 (6,428)	ø(1060 - 300) mm	2580 mm







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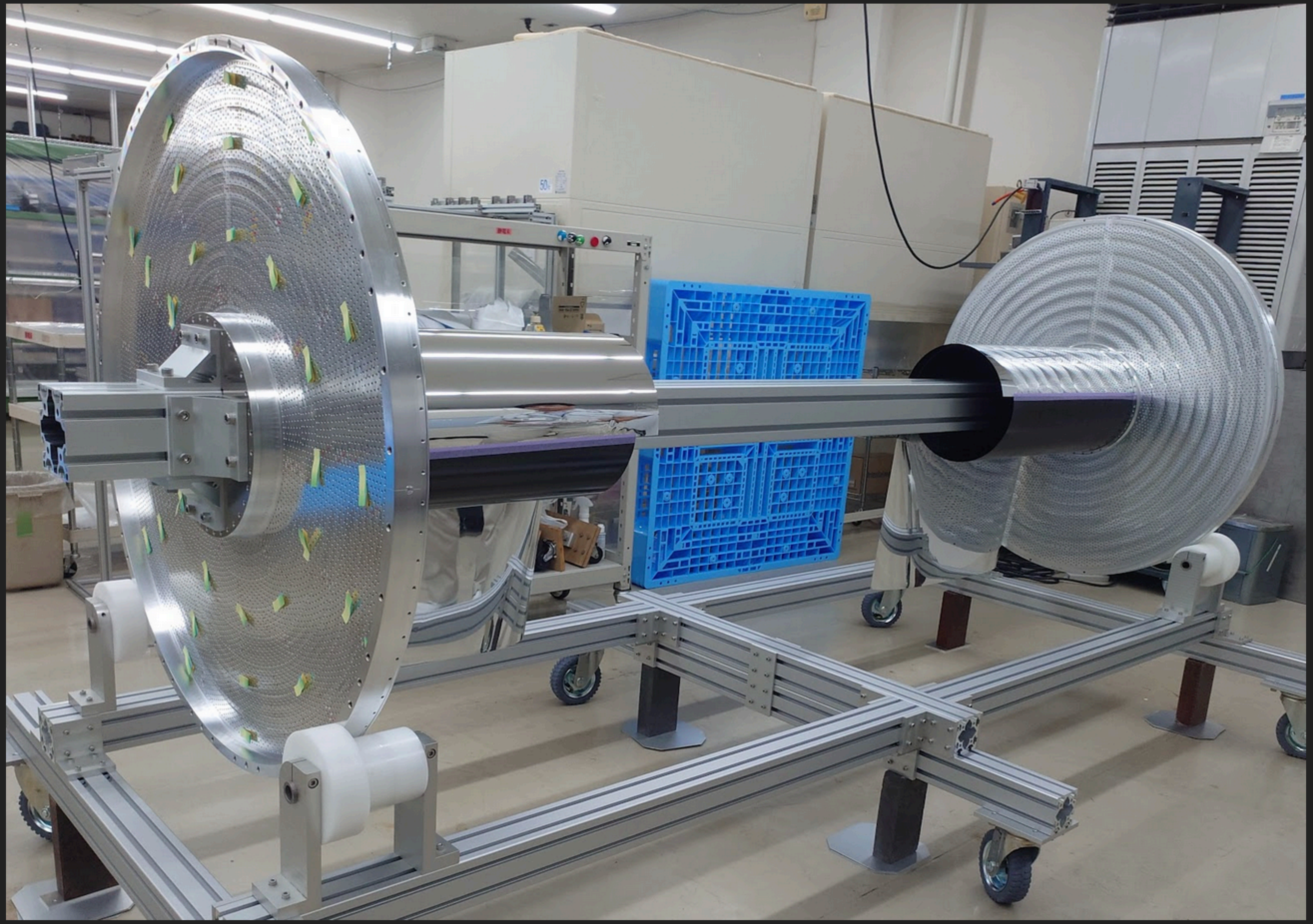
- *Wire stringing work by workers of Hayashi Repic corp. (Dec. 2023 ~ Jun. 2024)*



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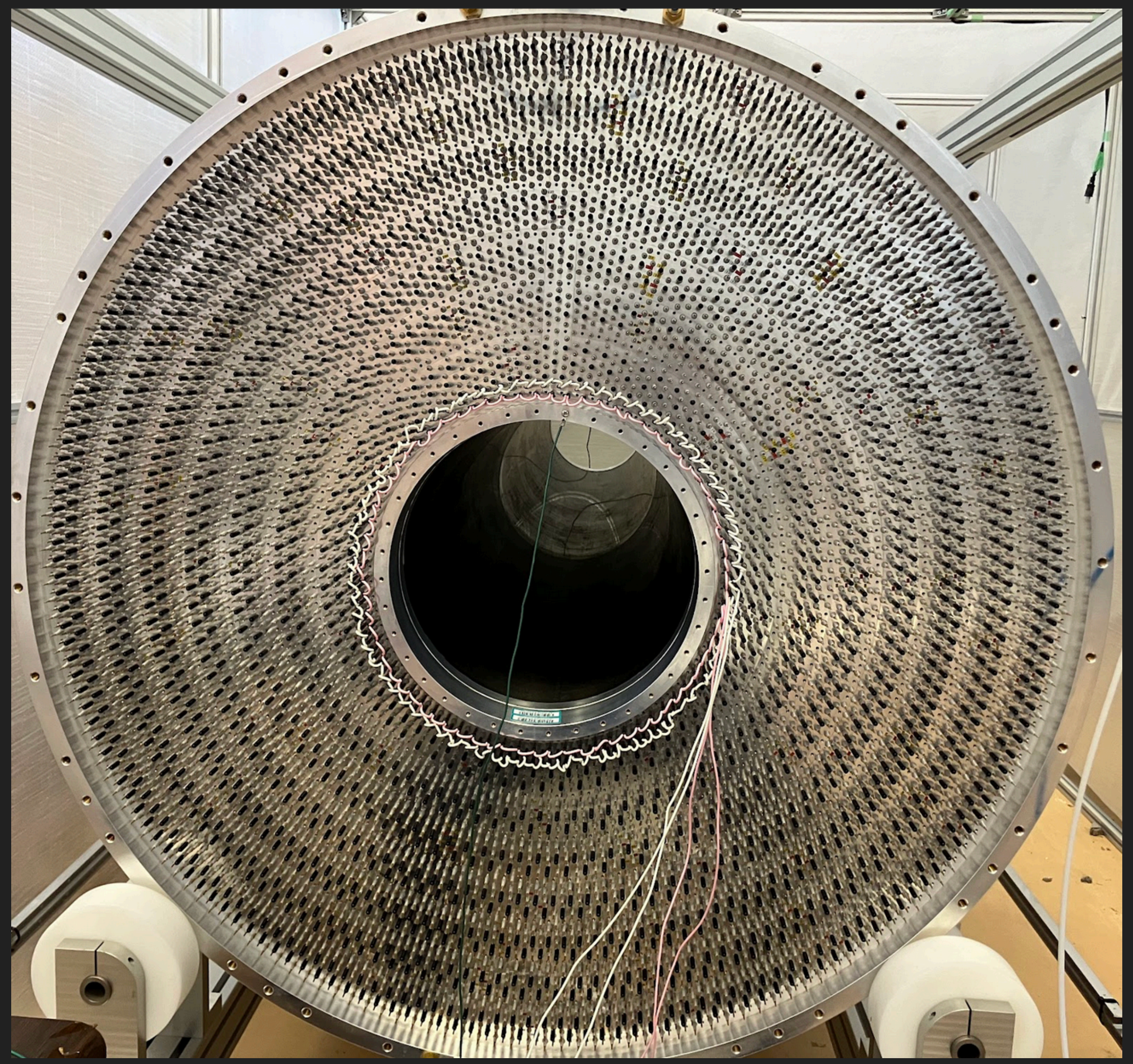
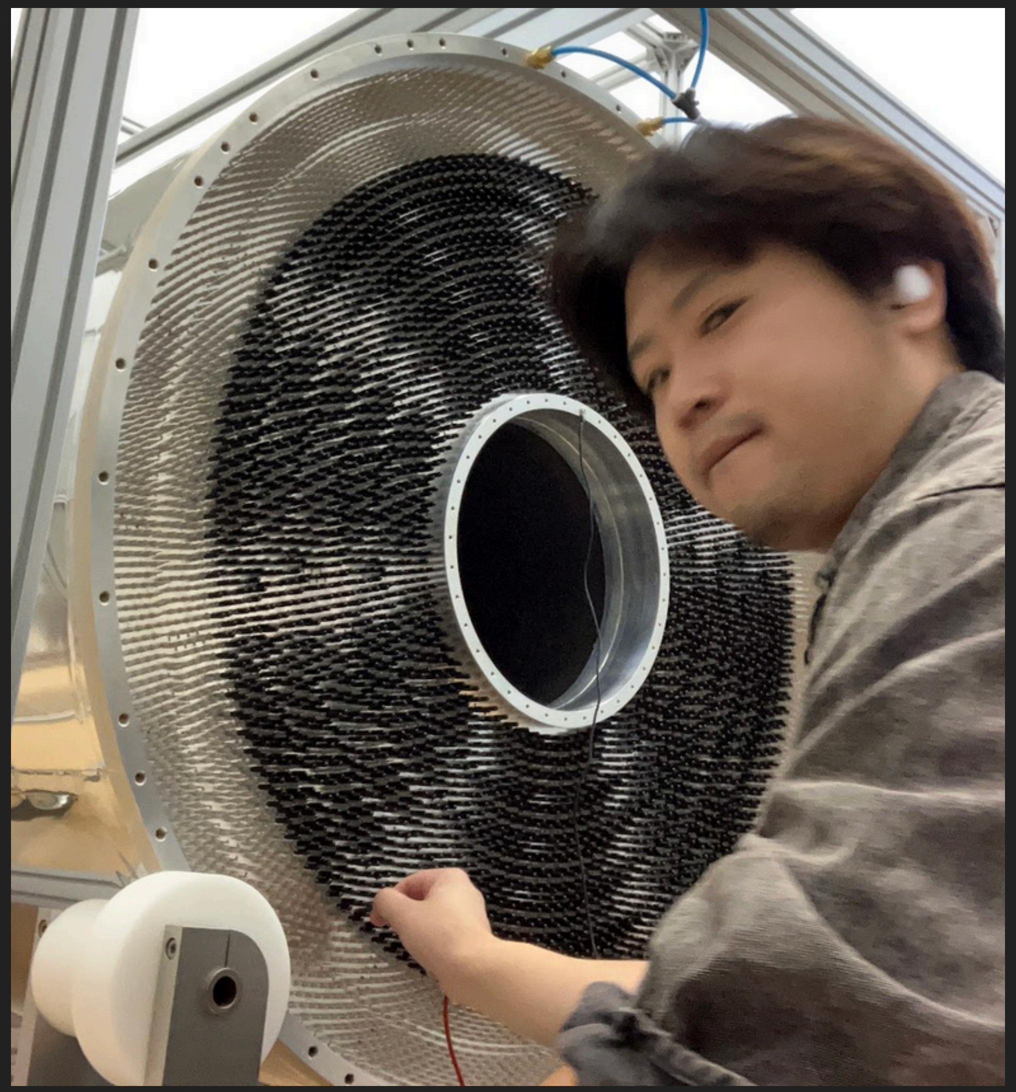
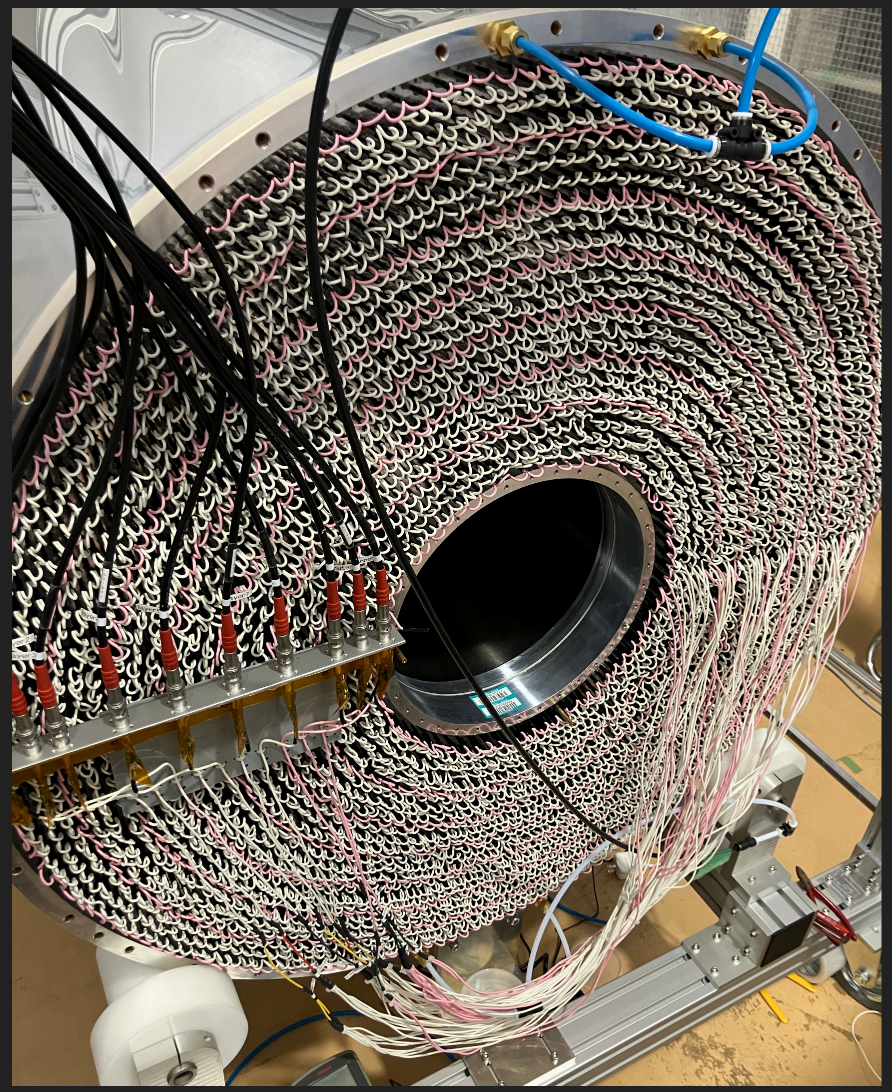
HV side



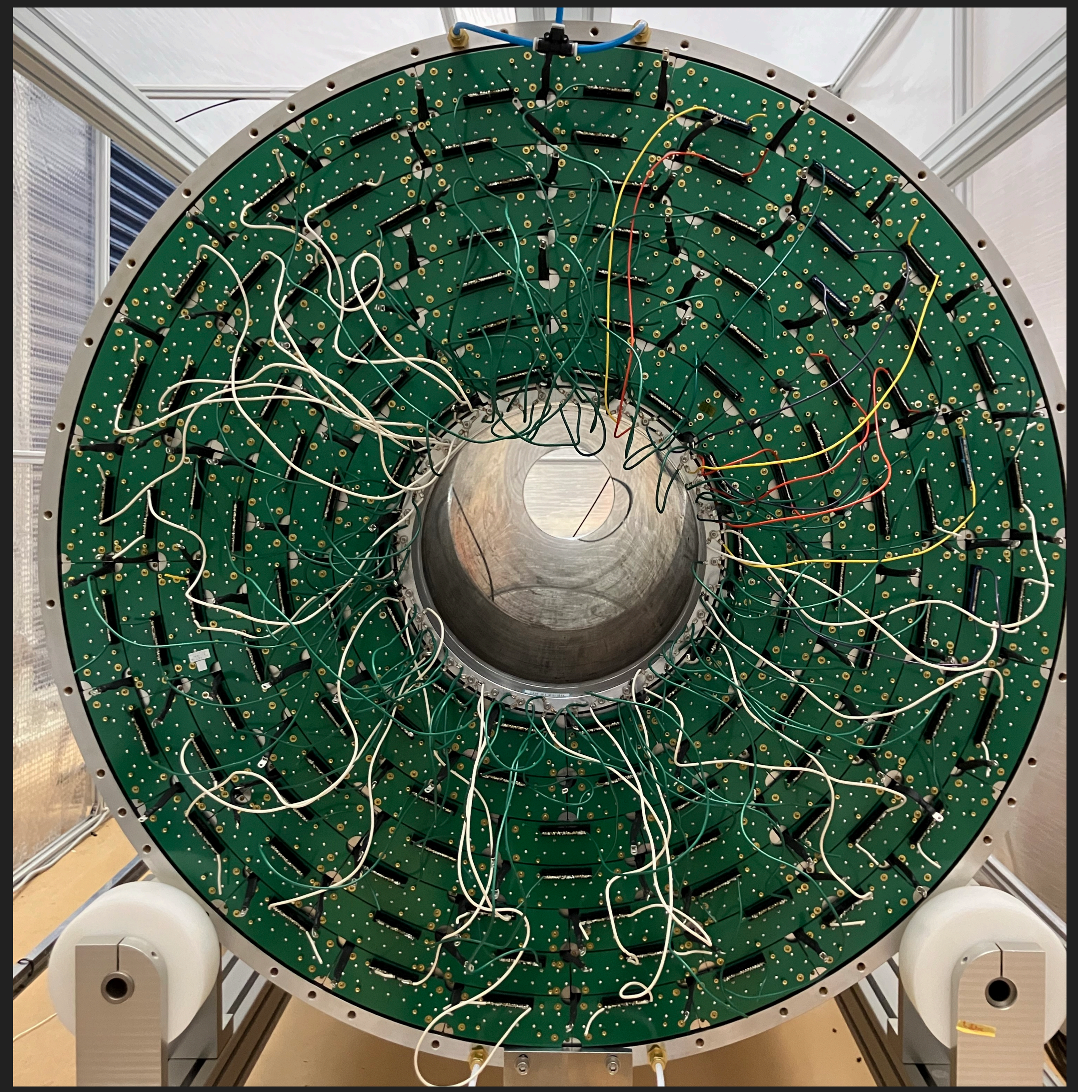
Read-out side



HV side’



Read-out side’



We thought that finally it’s time to apply HV! But, it didn’t work well…

We spent a week to find two broken wires.

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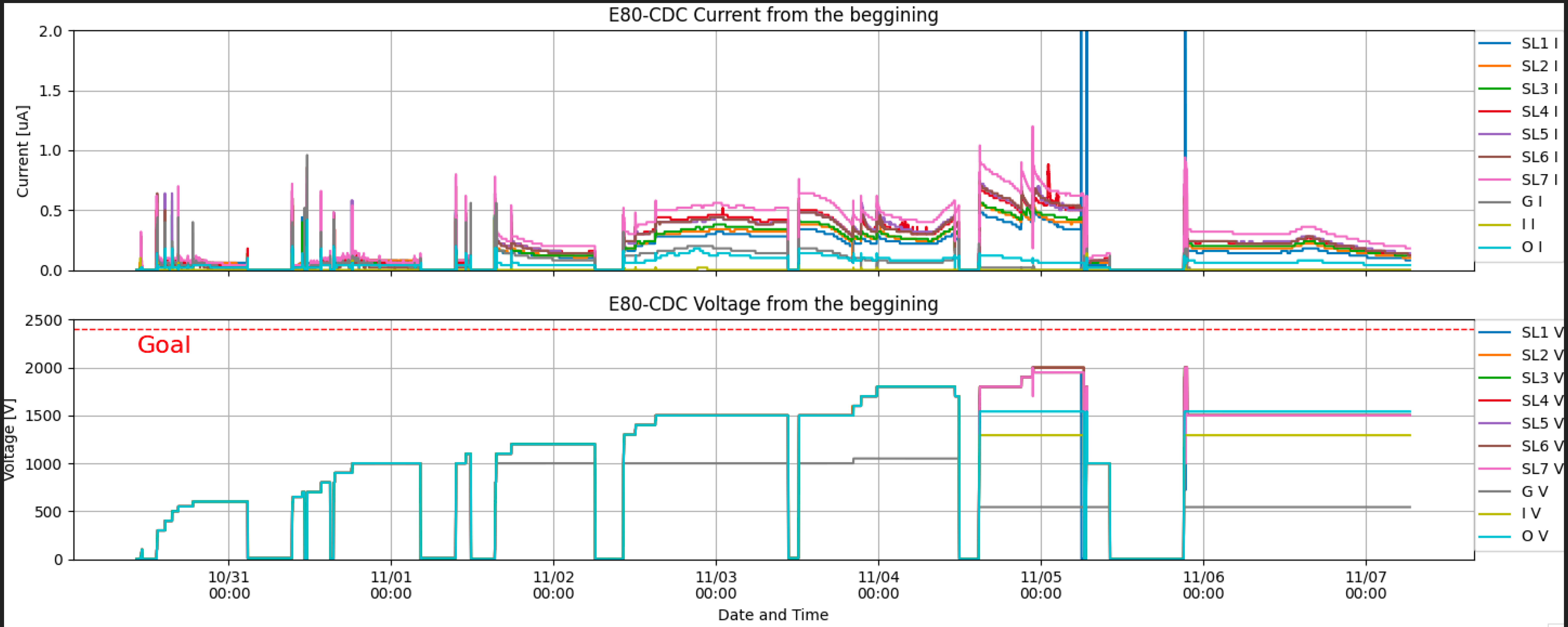

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- *Wire aging by Y. Kimura (me) (Oct. 2024 ~)*

Things to do for my master thesis (~ Dec 26, 2024)

- *Check the analog signals*
- *Reduction of noises*
- *Cosmic ray test*

ガスについて

Exp.	cell	wire	Num of channel	area (Beam軸垂直)	area (Beam軸方向)	Gas mixture
J-PARC E15	六角形 15層	Au-W(Au-Al) ø30 um(100 um)	1,816 (6,428)	ø(1060 - 300) mm	850 mm	Ar(50%) C2H6(50%)
J-PARC E80	六角形 15層	Au-W((Be-Cu) ø30 um(80 um)	1,816 (6,428)	ø(1060 - 300) mm	2580 mm	?

- We want to decide the gas mixture.
- 3 times the volume of the E15-CDC
- Non-flammable and low-cost gases are expected.

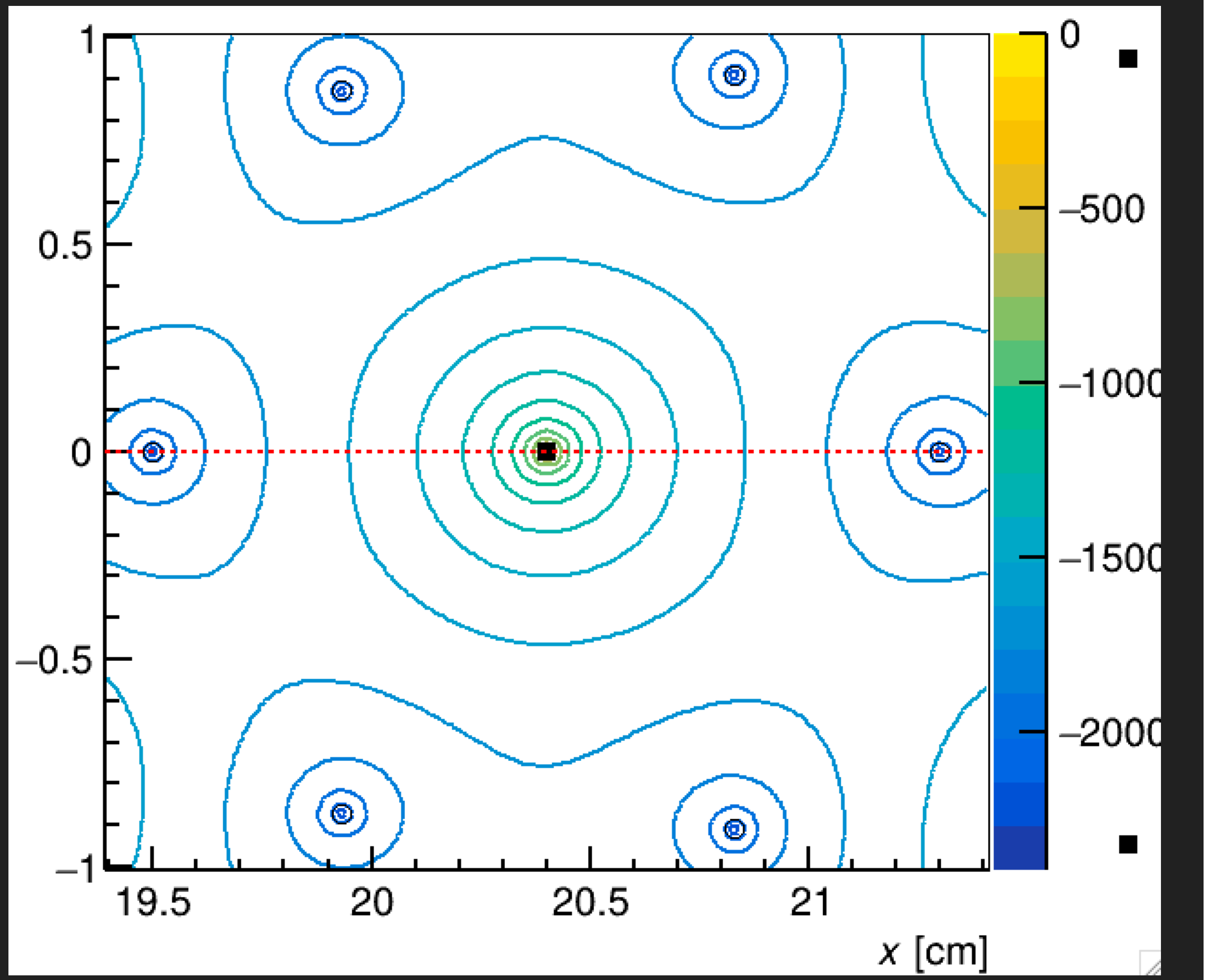
→ Ar-CO_2 is a good candidate.

I studied the characteristics of Ar-CO_2 using simulation tool, Garfield++ and cosmic ray.

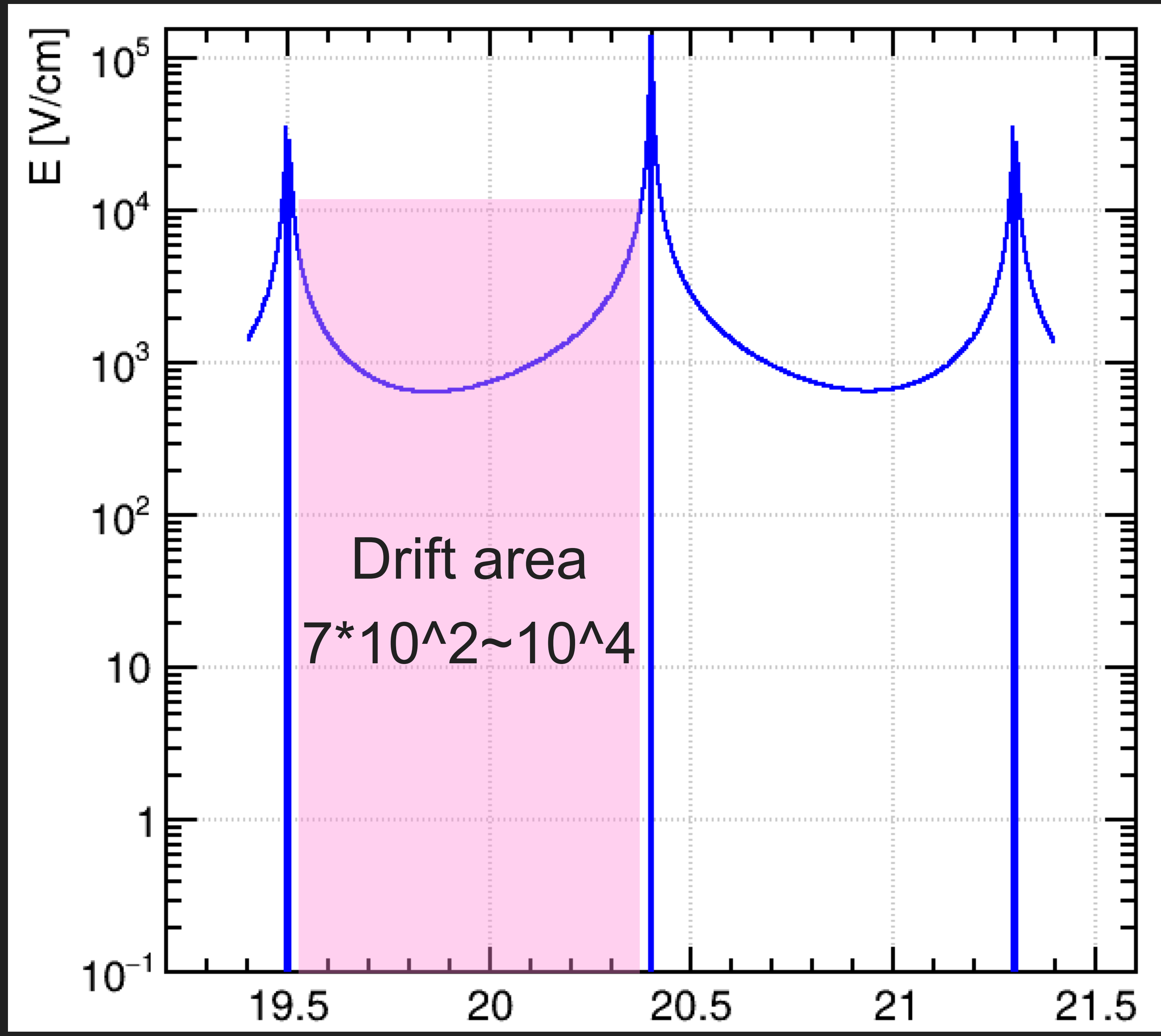
ガスについて: Simulation

Electric Field and Avalanche

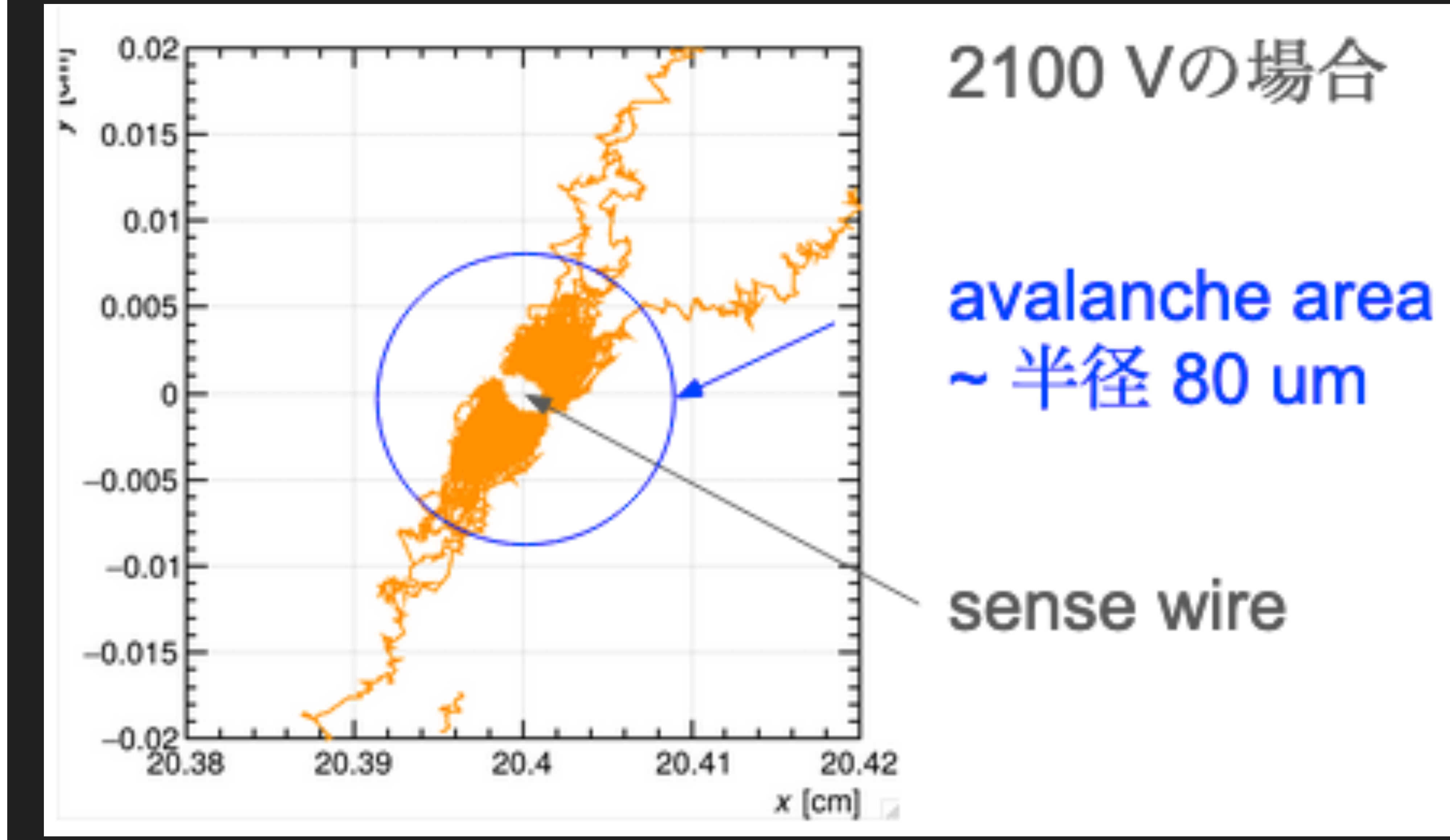
1 cell



Electric Field



Avalanche



ガスについて: Simulation

Comparison of various Ar-CO_2 mix ratios

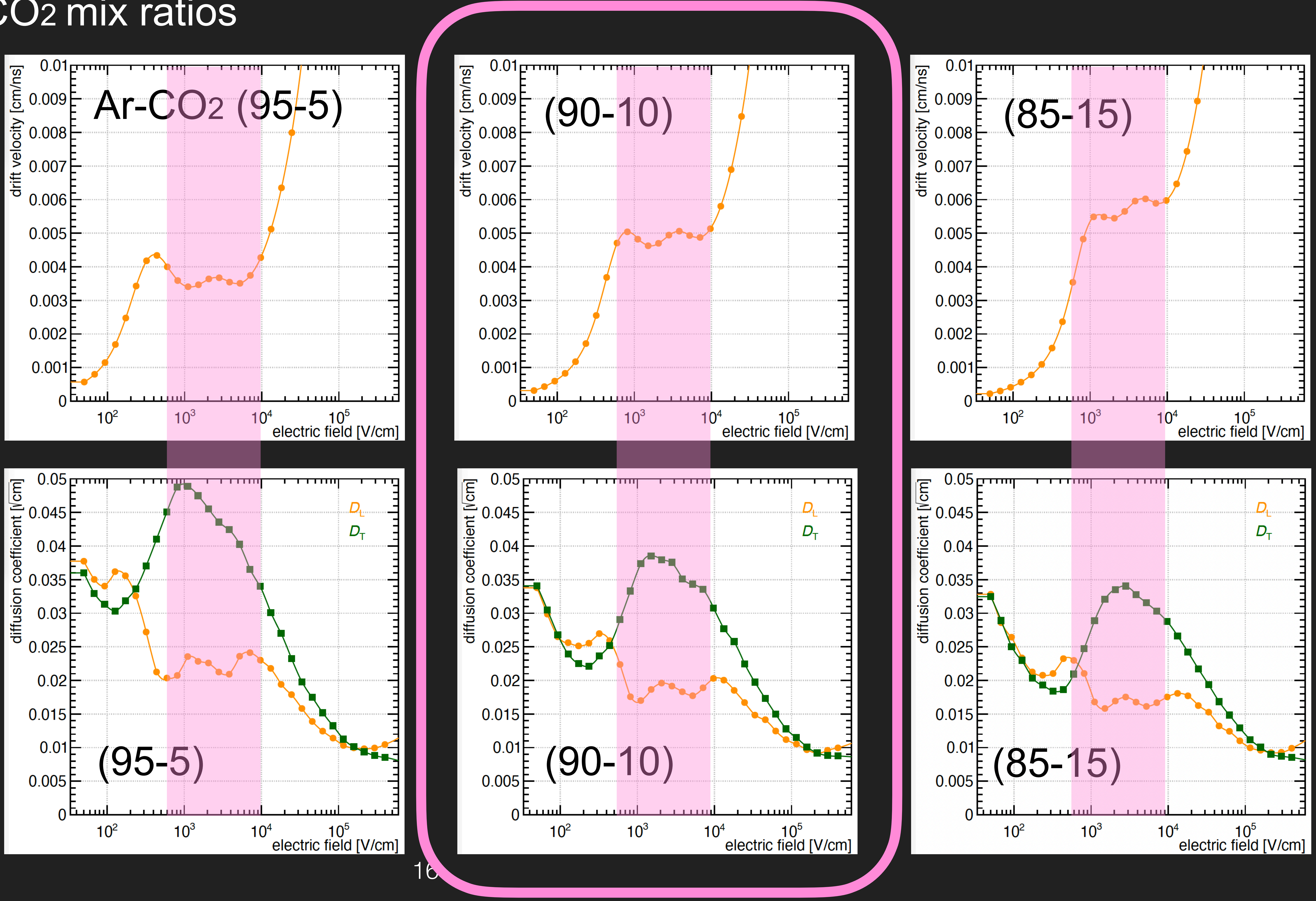
Better ?

Drift Velocity

Drift areaでフラットになっててほしい。

Diffusion

Drift areaでLongitudinal(進行方向)が小さいと良い。

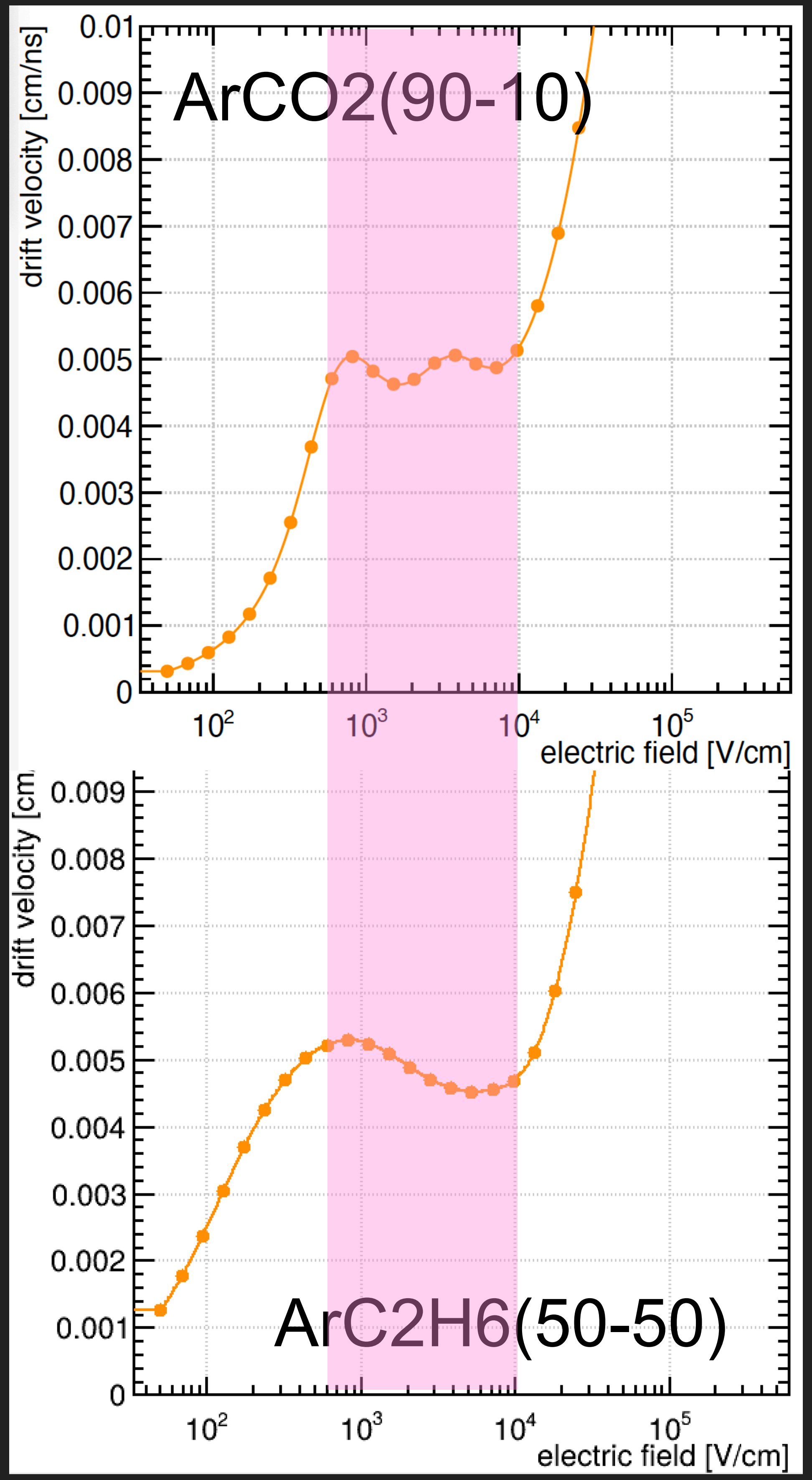


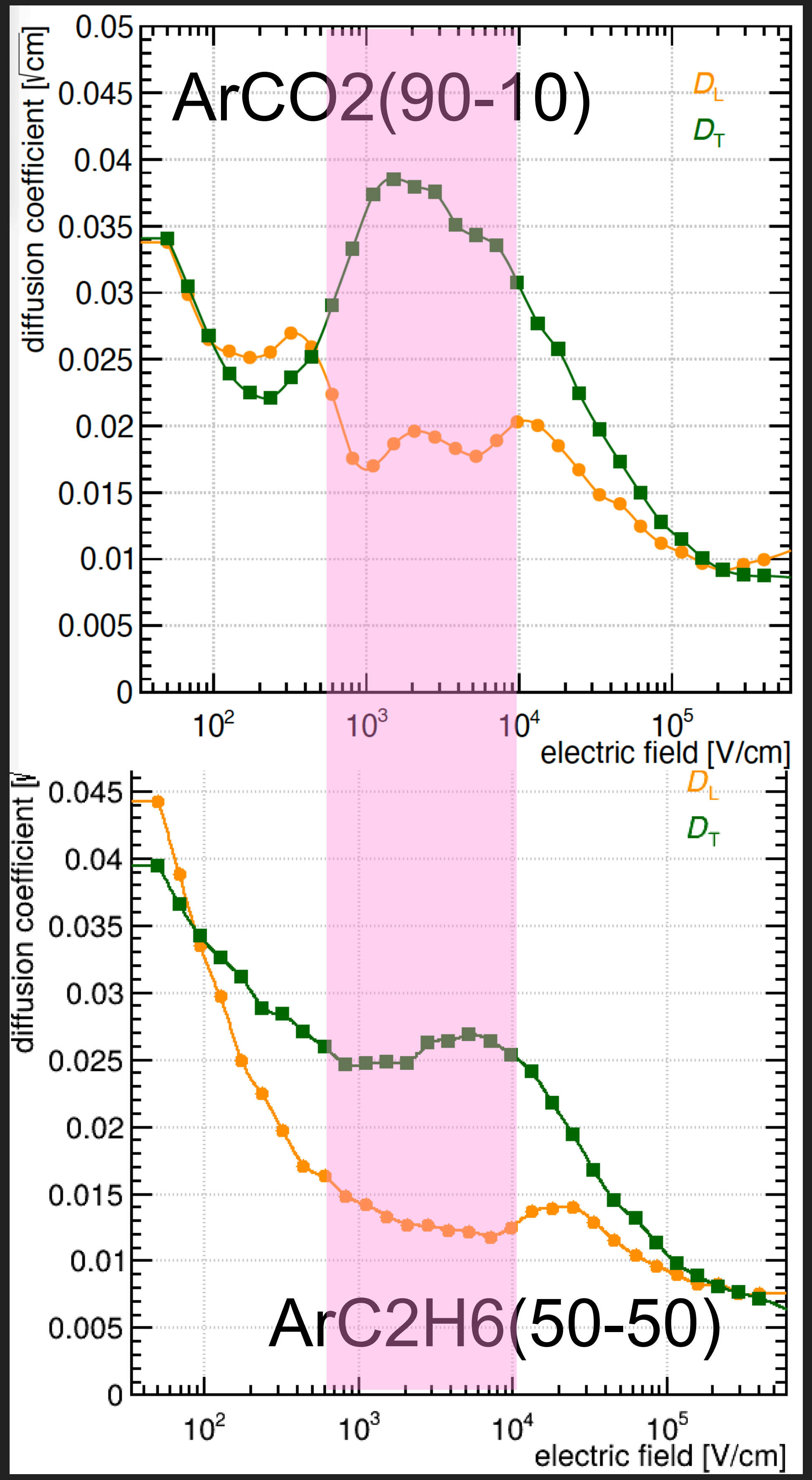
ガスについて: Simulation

Comparison between Ar-CO2 (90-10) and Ar-C2H4 (50-50)

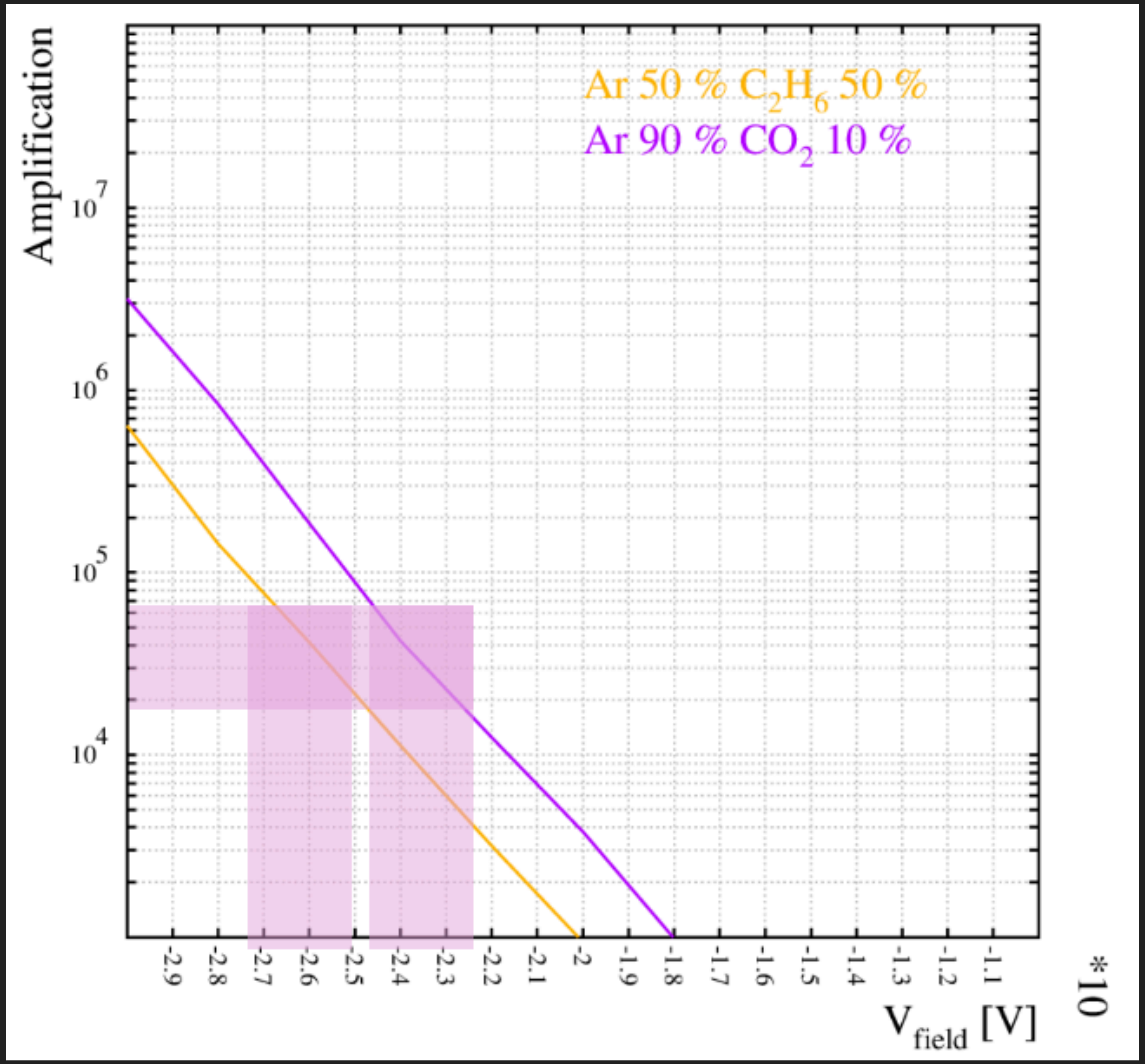
Drift Velocity

Diffusion





Amplification



The Ar-CO_2 (90-10) mixture should provide sufficient performance.

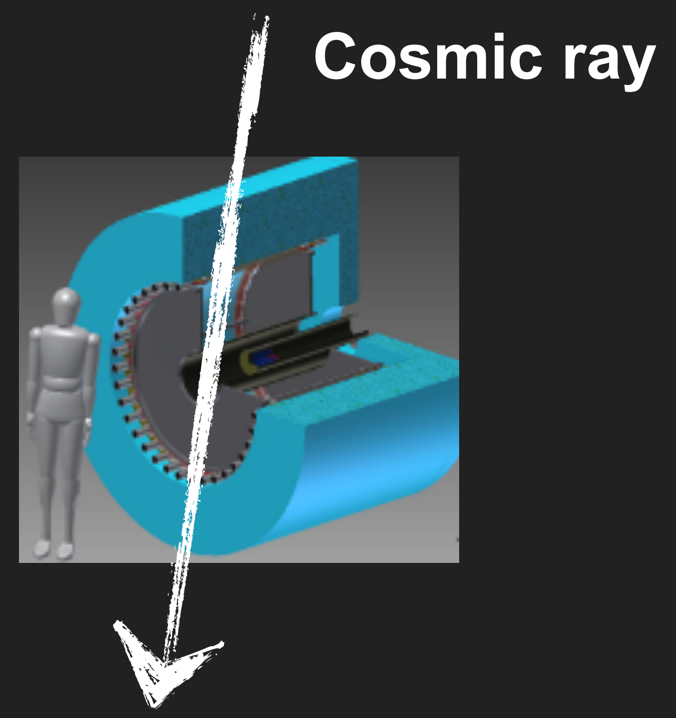
ガスについて: 宇宙線テスト

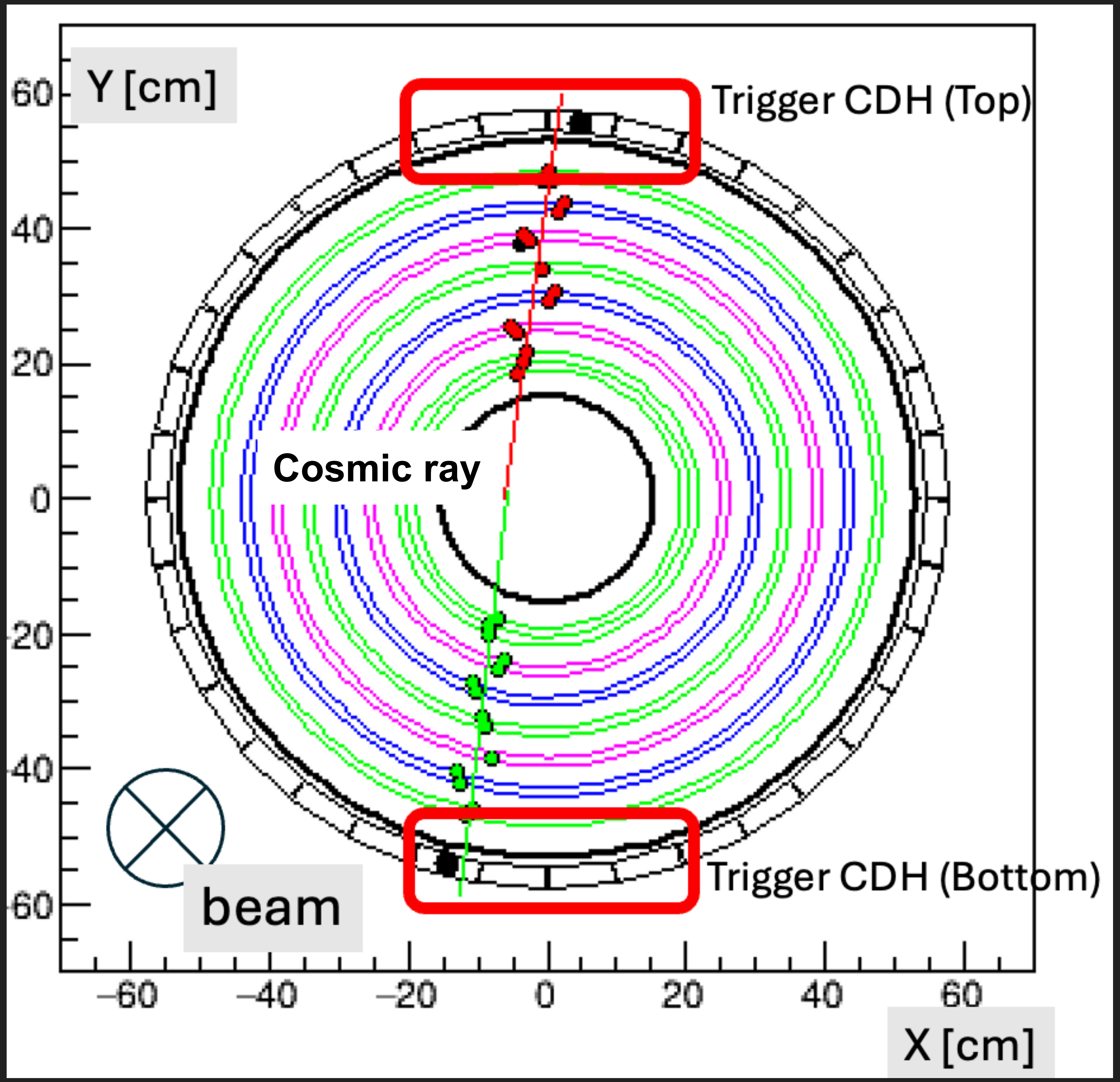
Comparison between Ar-CO_2 (90-10) and Ar-C_2H_4 (50-50)

Focused on Tracking Efficiency and Residual (position resolution)

Experiment

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

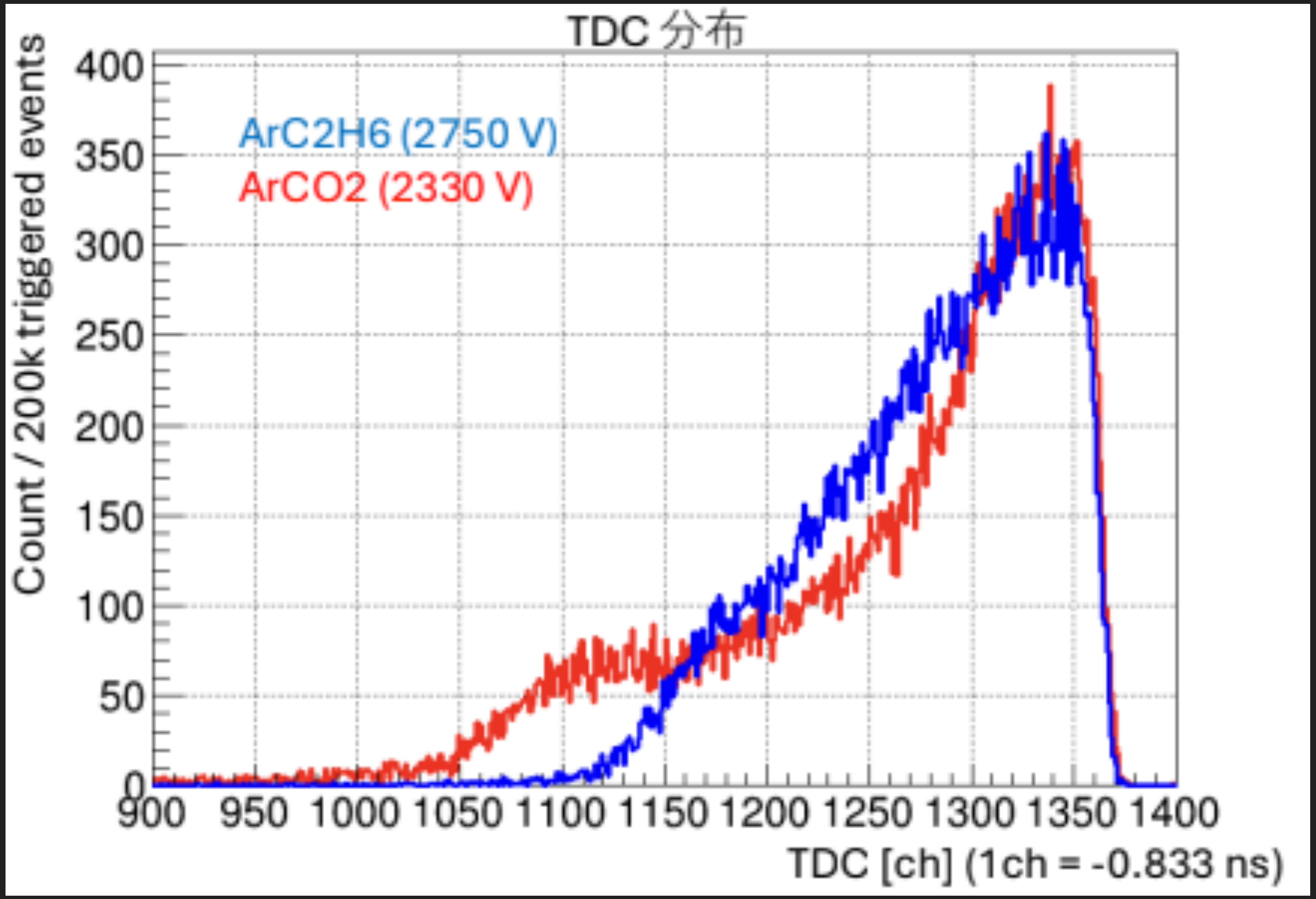


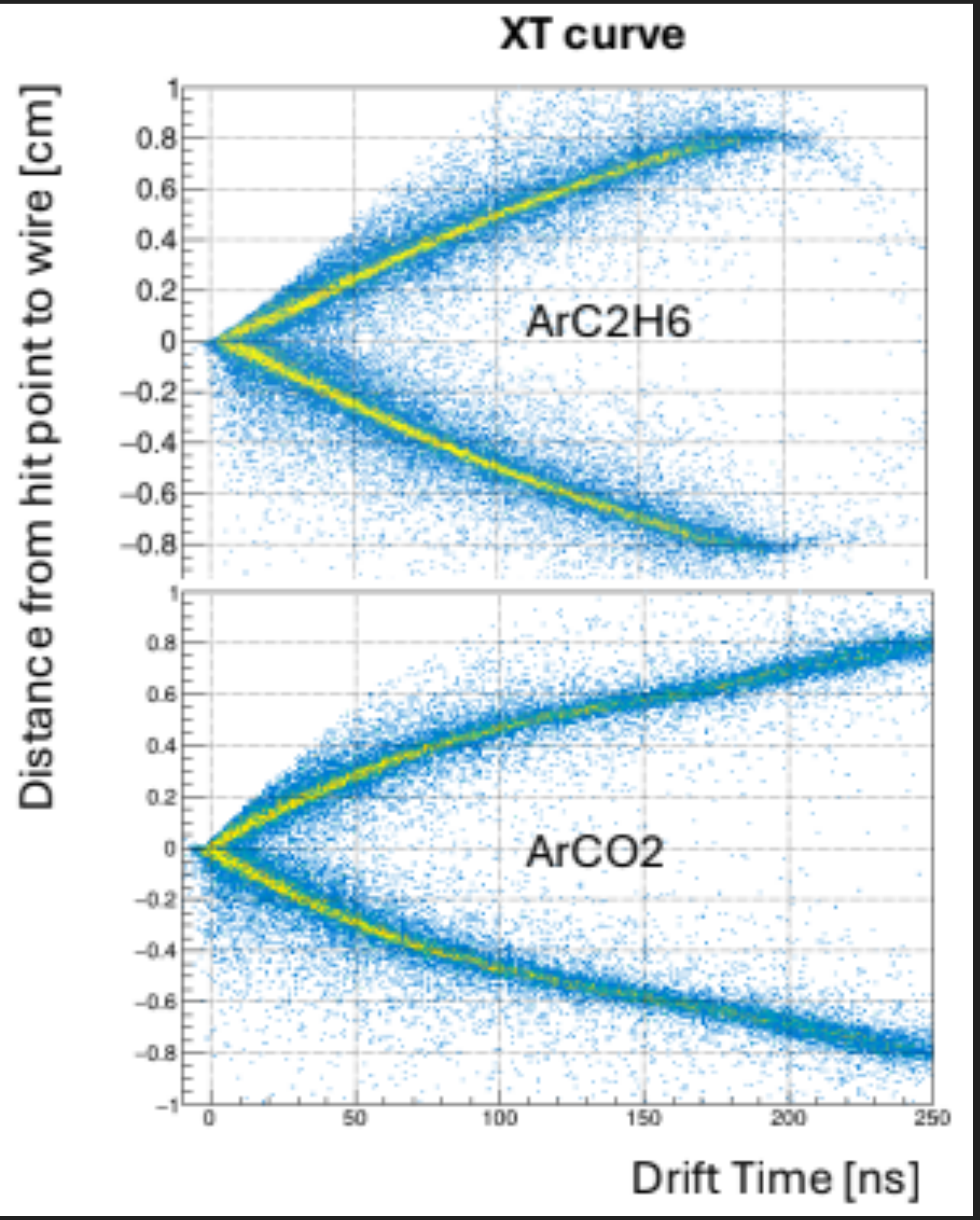


ガスについて: 宇宙線テスト

Comparison between Ar-CO_2 (90-10) and Ar-C_2H_4 (50-50)

Shapes of the TDC and XT curve





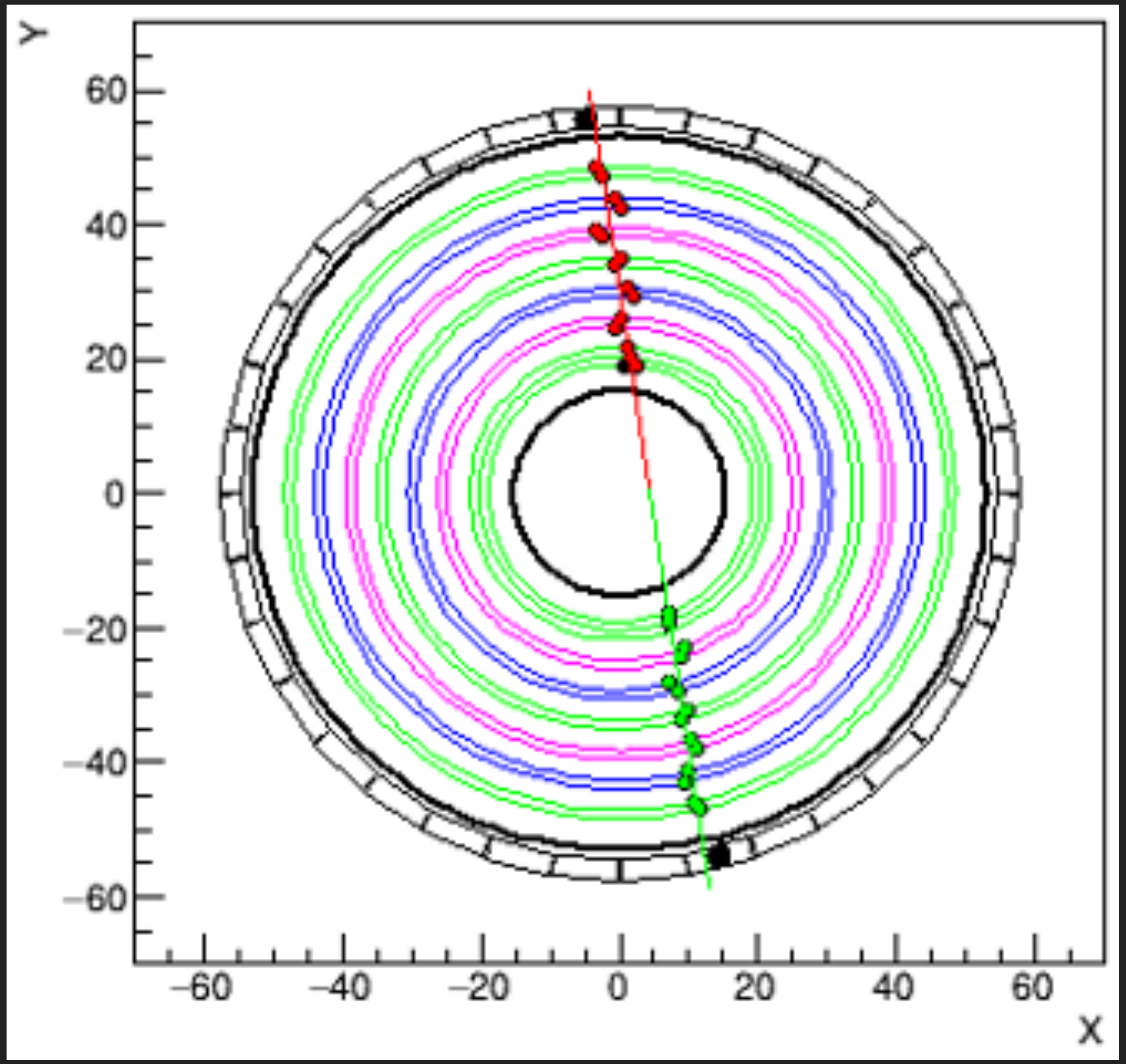
The differences between the types of gases were clearly visible.

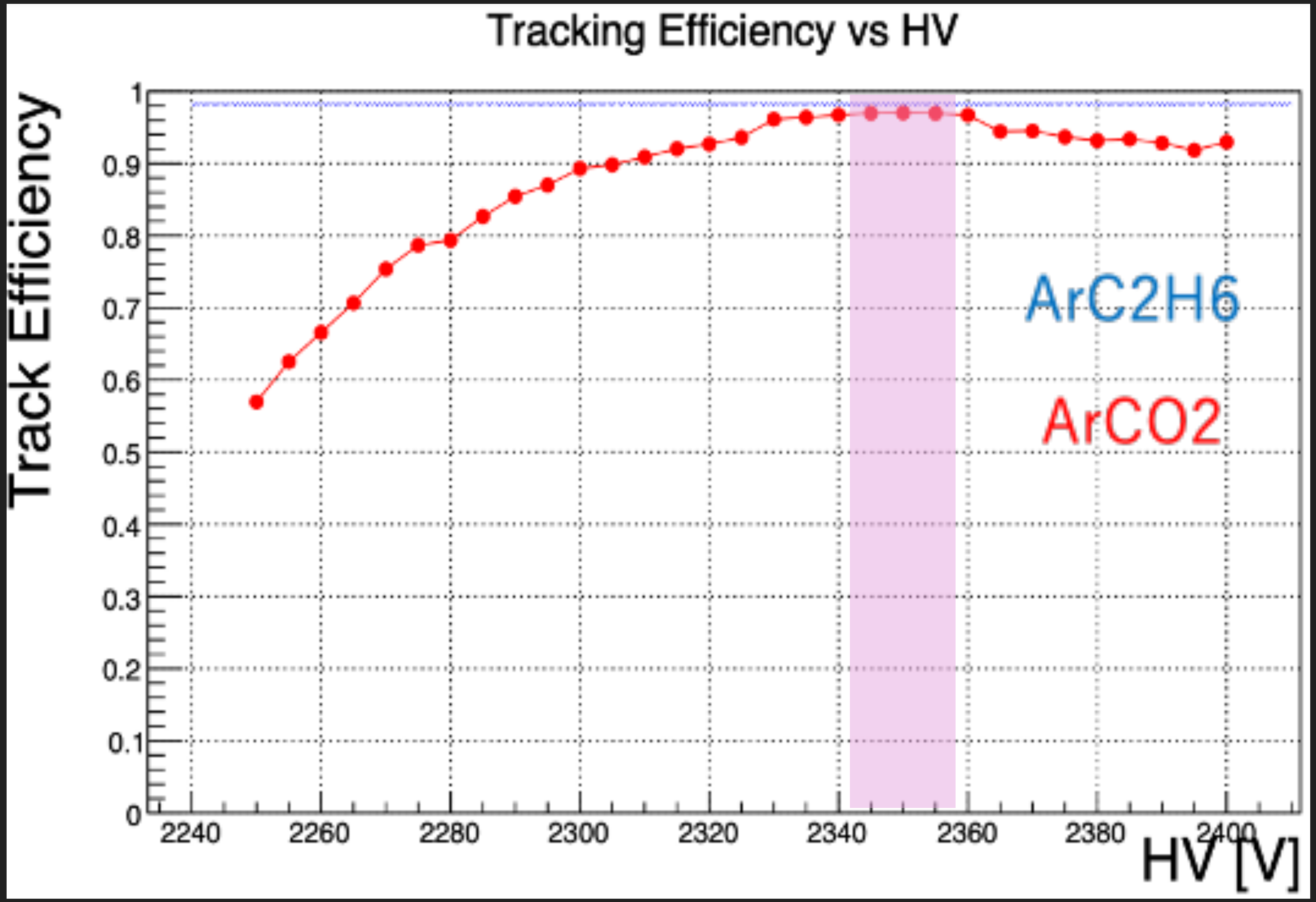
ガスについて: 宇宙線テスト

Comparison between Ar-CO_2 (90-10) and Ar-C_2H_4 (50-50)

HV scan of tracking efficiency

$$Eff_{track} := \frac{2\ Track\ Events}{CDH\ 2Hit\ Events}$$





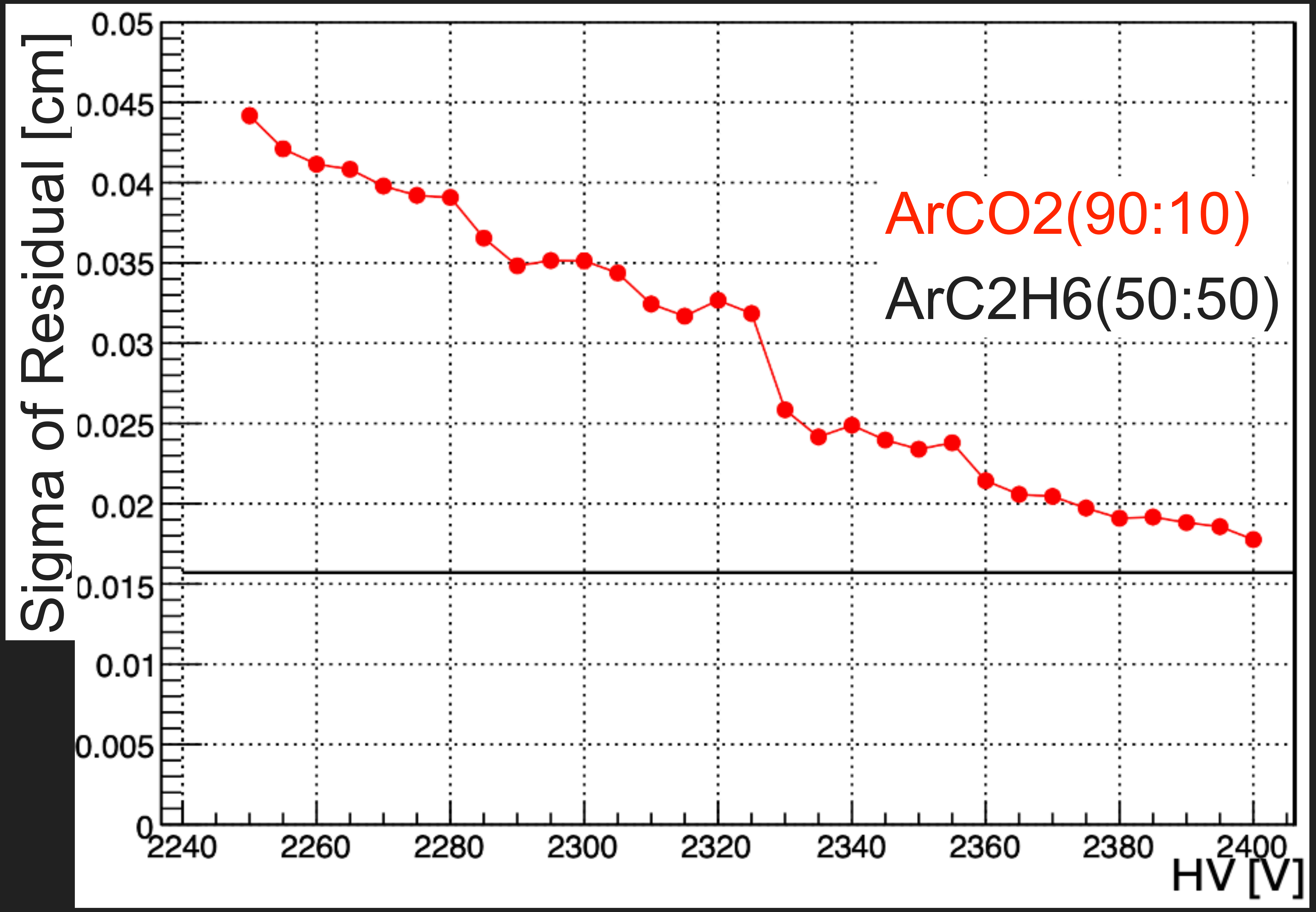
Approximately <u>2350 V</u> corresponds to the expected Efficiency (~ 97 %).

ガスについて: 宇宙線テスト

Comparison between Ar-CO_2 (90-10) and Ar-C_2H_4 (50-50)

HV scan of the Residual

$$Residual := Hit\ distance\ - Track\ distance\ (from\ wire)$$



The residual (related to resolution) approaches an adequate level at <u>2400 V</u>.

Things to do for my master thesis

- *To acquire the data of HV scan with Ar-C_2H_6 (50-50)*
- *To check the analog signal using “test chamber”*

Summary

- I study about the Cylindrical Drift Chamber which will be used for the anti-kaonic nuclei "$K^- ppn$" search, J-PARC E80 exp.

- About the new CDC,
  - I've finished assembling for applying HV and read out the signal.
  - I'll conduct the aging, checking the analog signal, noise reduction and first cosmic ray test.

- About gases for the CDC,
  - I've finished the simulation to choose the ratio of Ar-CO_2 and cosmic ray test filling Ar-CO_2 (90-10).
  - I'll improve the precision of the way of X —> T conversion.
  - I'll check the analog signal using "test chamber" filling Ar-CO_2 (90-10).
  - I'll acquire the HV scan data using E15-CDC(old CDC) filling Ar-C_2H_6 (50-50) to compare to Ar-CO_2 (90-10) in more detail.

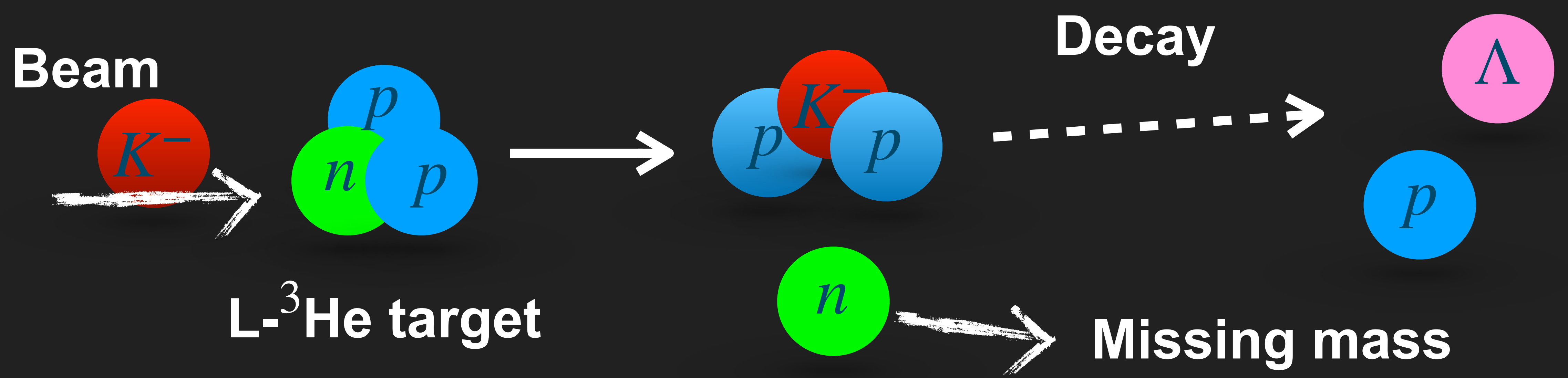
Thank you, that's all.

Back-up

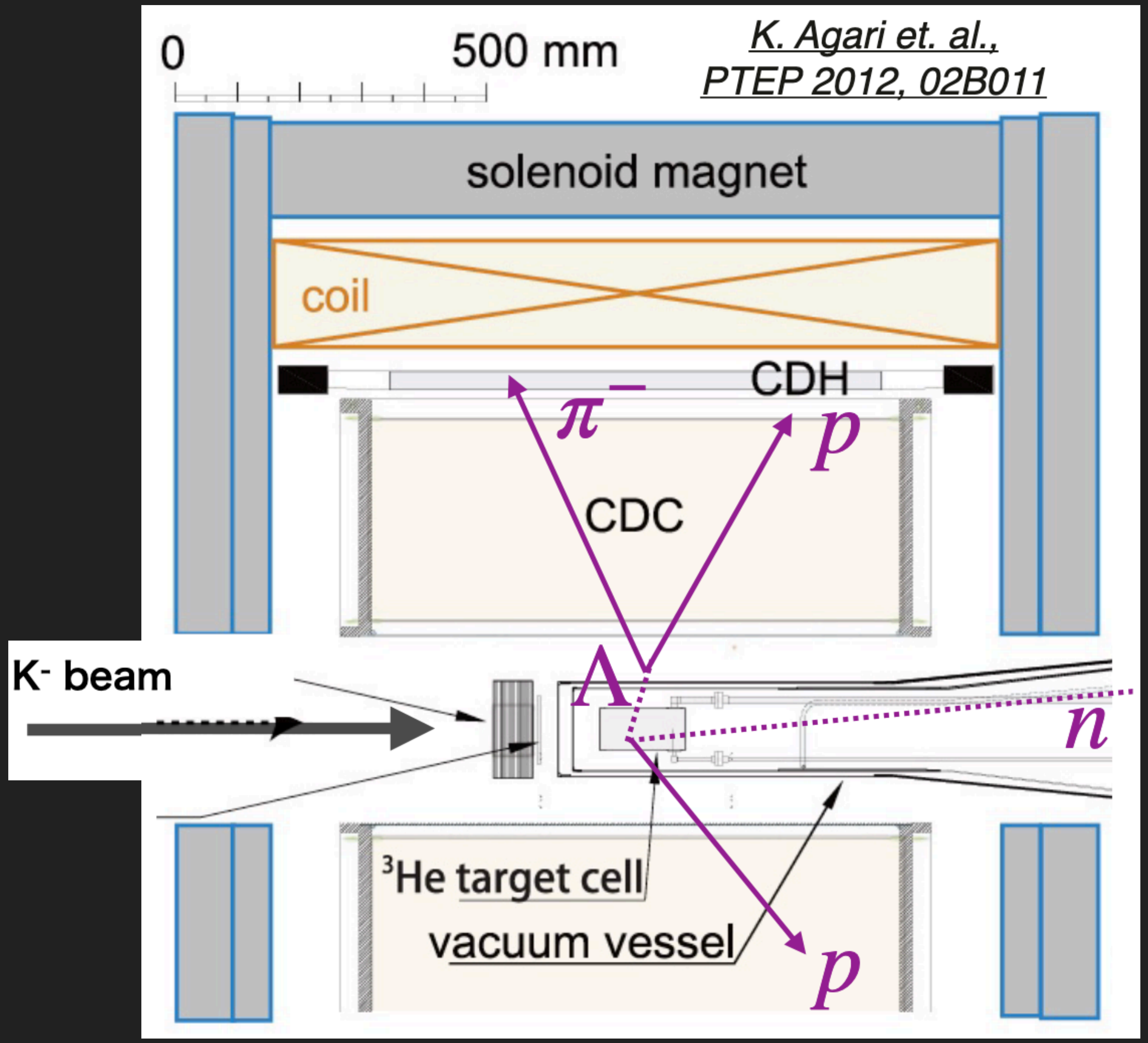
Table 12: Cell configuration of the CDC.

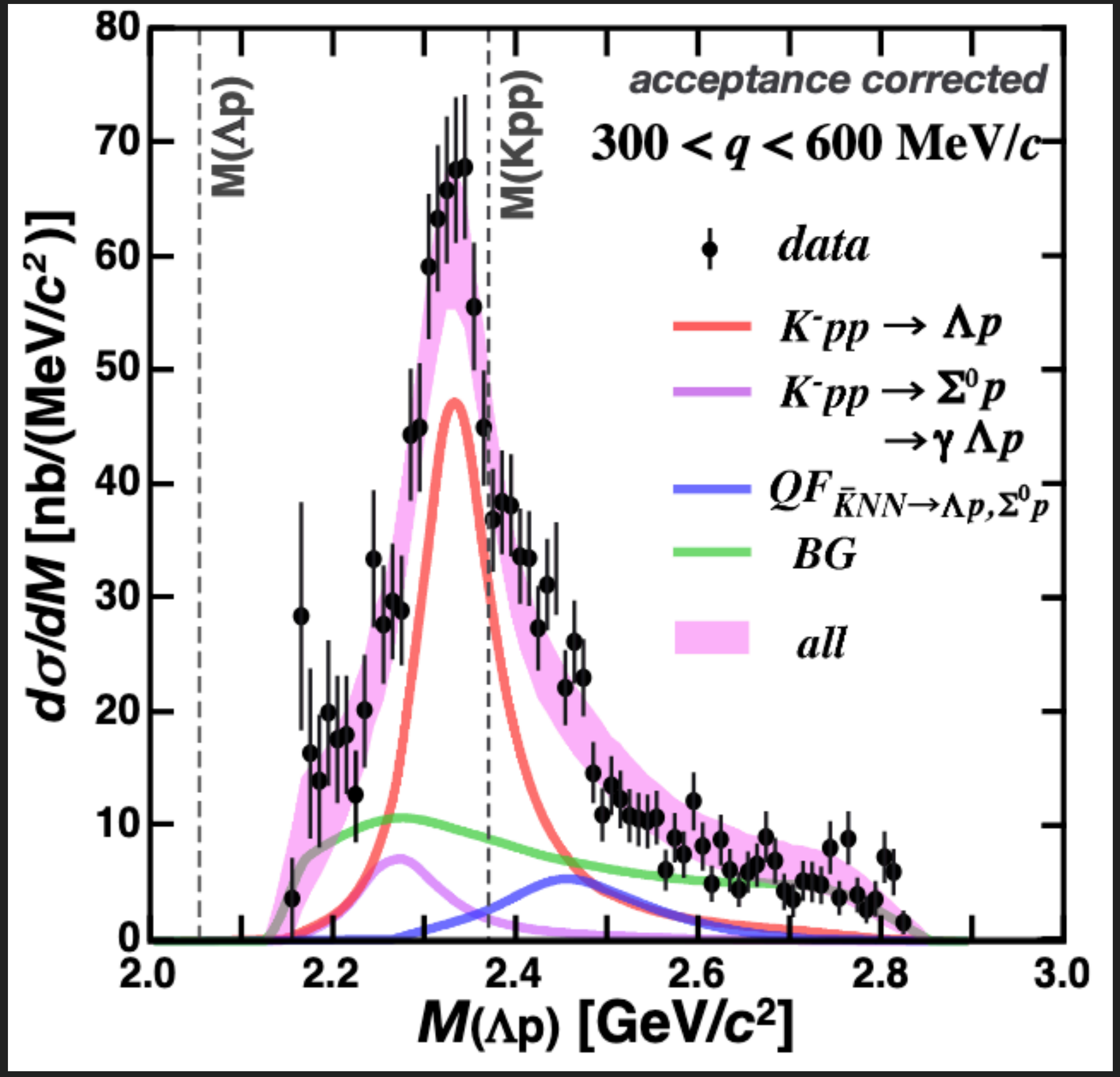
Super-layer	layer	Wire direction	Radius (mm)	Cell width (degree)	Cell width (mm)	Stereo angle (degree)	Signal channels per layer
A1	1	X	190.5	5.00	16.7	0	72
	2	X'	204.0		17.8	0	
	3	X	217.5		19.0	0	
U1	4	U	248.5	4.00	17.3	-2.27	90
	5	U'	262.0		18.3	-2.39	
V1	6	V	293.0	3.60	18.4	2.42	100
	7	V'	306.5		19.3	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	

J-PARC E15 exp.



- “K^-pp” search
- Prior study on J-PARC E80 exp.
- First exclusive experiment and analysis for “K^-pp” in the world





(*1) Binding Energy ~ 50 MeV

Decay Width ~ 100 MeV

—> Deep Bound Sate

Larger Width than $\Lambda(1405)$

—> (*2) Further Analysis by T. Yamaga

(Mesonic decay channel

—> Inside of “K^-pp”)

—> Further Experiment, J-PARC P89

(Isospin partner, Spin structure)

*1) T.Yamaga, *et al.*, Phys Rev C 102, 044002 (2020)
*2) T.Yamaga, *et al.*, Phys Rev C110, 014002 (2024)

Avalanche

2400 V