

# Solenoid (Doraemon) Spectrometer at J-PARC K1.8BR

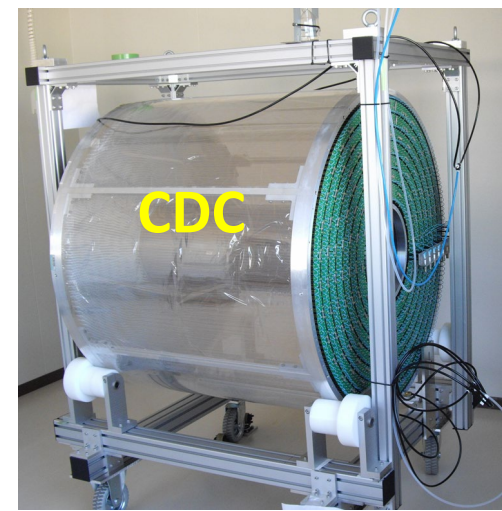
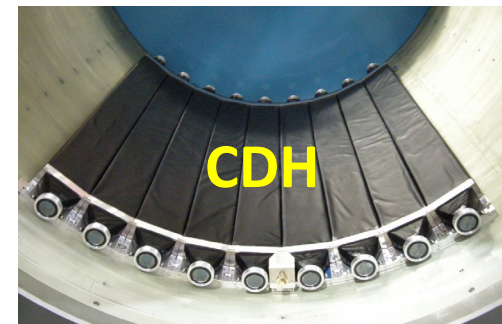
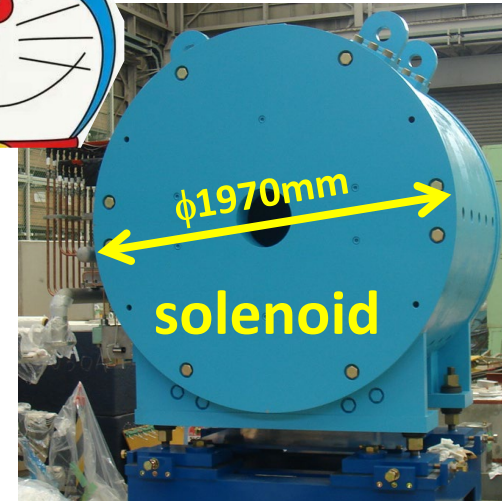
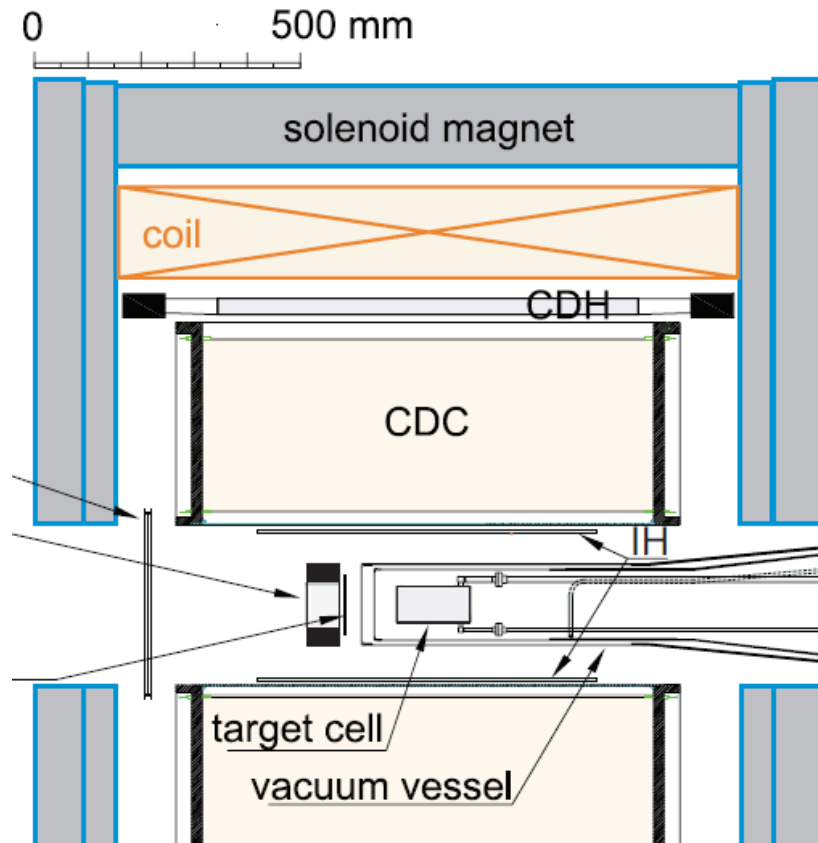
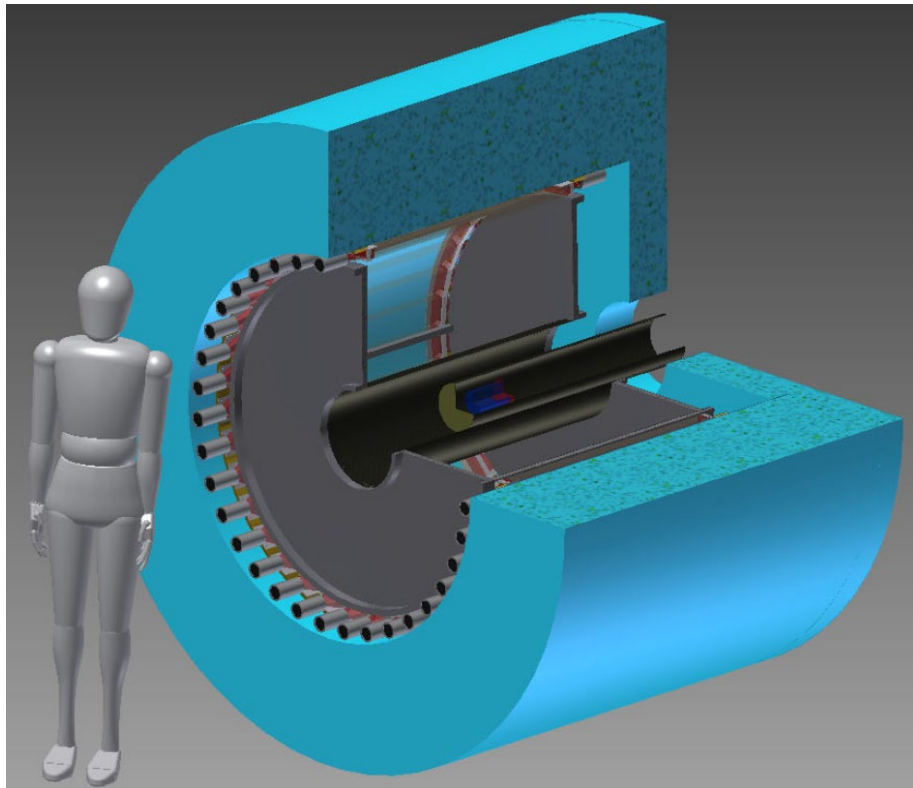
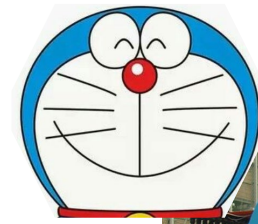


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# The Doraemon spectrometer (CDS)



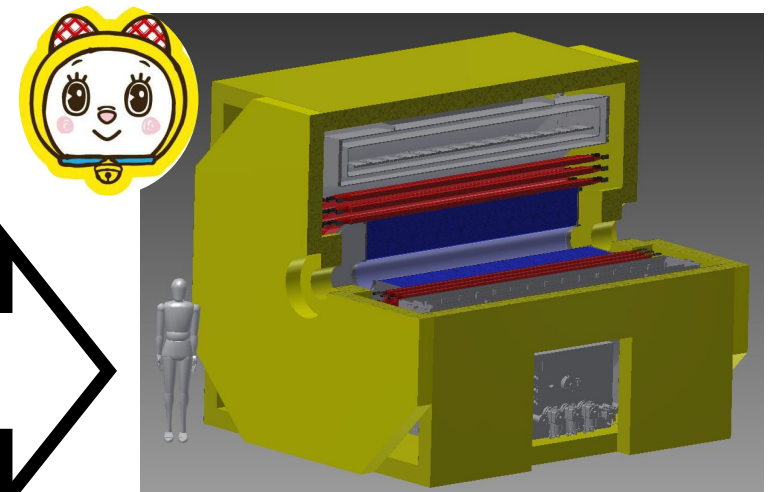
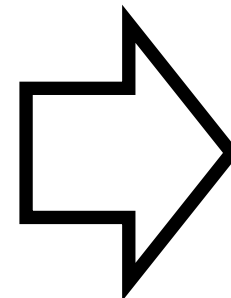
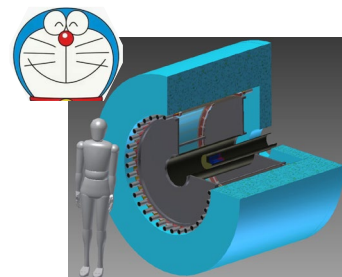
- CDC (15 layers, 1816ch) + CDH (36 seg) + 0.7T
  - solid angle: 60% of  $4\pi$
  - $\delta p_t/p_t = 6.0\%p_t \oplus 0.8\%/\beta$

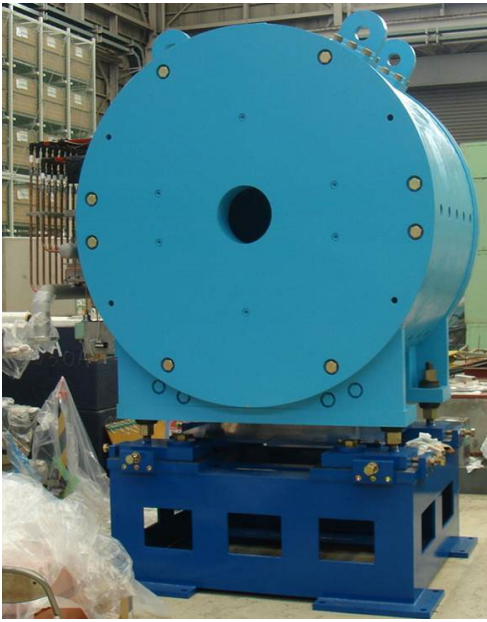
# History of the Doraemon Spectrometer

- 2006~ : Design/Construction started
  - with budget of Grant-in-Aid for Scientific Research on Priority Areas 2007-09, “Multi-quark Systems with Strangeness”, PI:Prof.Nagae(Kyoto.U)
- 2010 : Completion and commissioning with beam @ K1.8BR
- 2013-15: E15 exp. (kaonic nuclei)
- 2016-18: E31 exp. ( $\Lambda(1405)$ )
- 2019 : E57-1<sup>st</sup> exp. (kaonic hydrogen)
- 2020-24: E73 exp. (hyper-triton)
- 2024 : will be uninstalled

特定領域研究

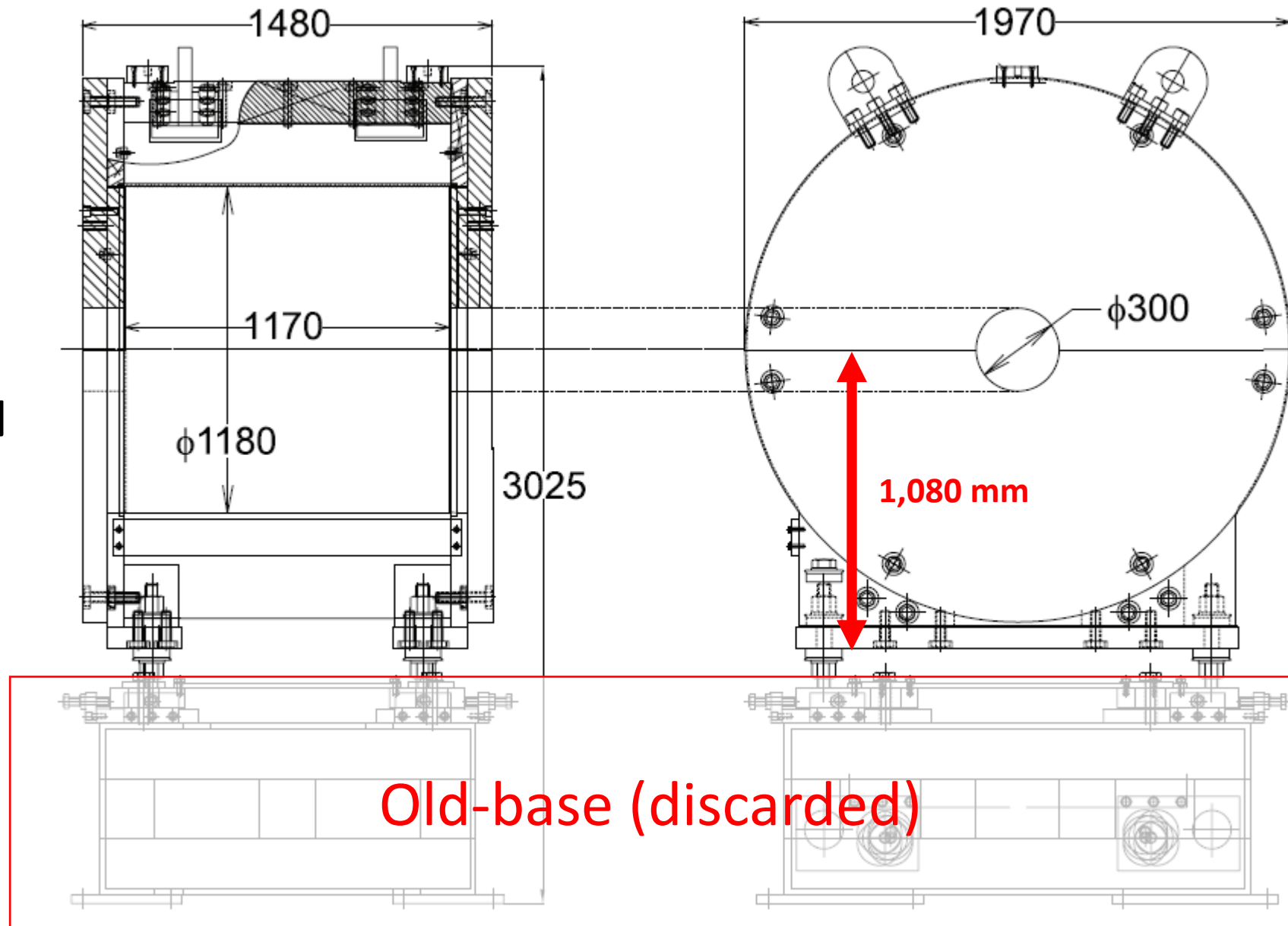
strangeness nuclear physics





# Doraemon Magnet

- Manufactured by TOKIN
  - ~50 million yen in total
    - ~40M(solenoid)+~10M(base)
- Bore diameter: 1.18 m
- Length: 1.17 m
- Overall weight: 21 tons
- Operated at 0.7 T
  - almost max. field



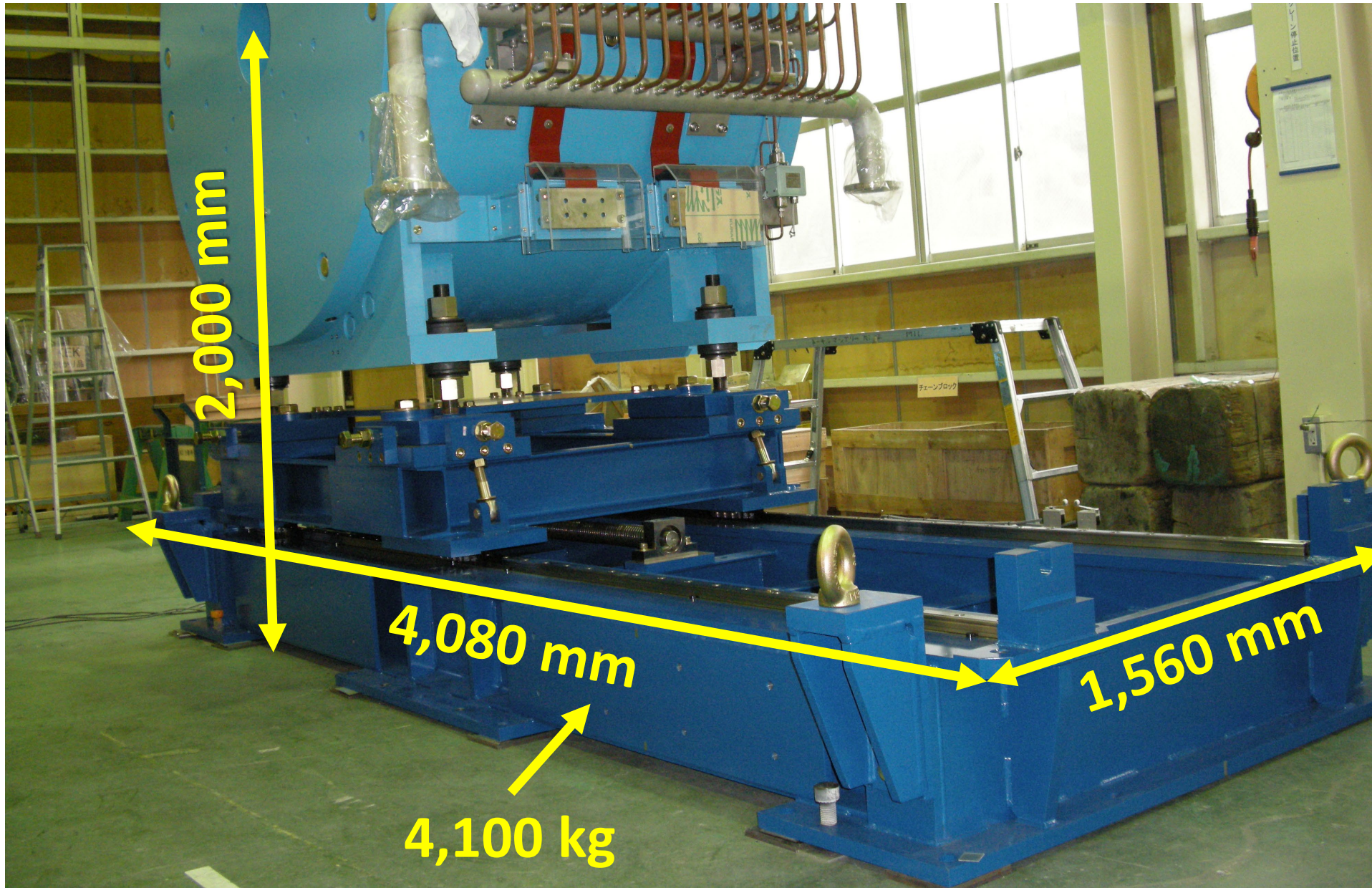


# Decomposition of the Magnet





# Base-mount with electric sliding mechanism



3Φ AC200V  
speed=2m/10min.  
(Manual sliding is also OK)



endcap holders





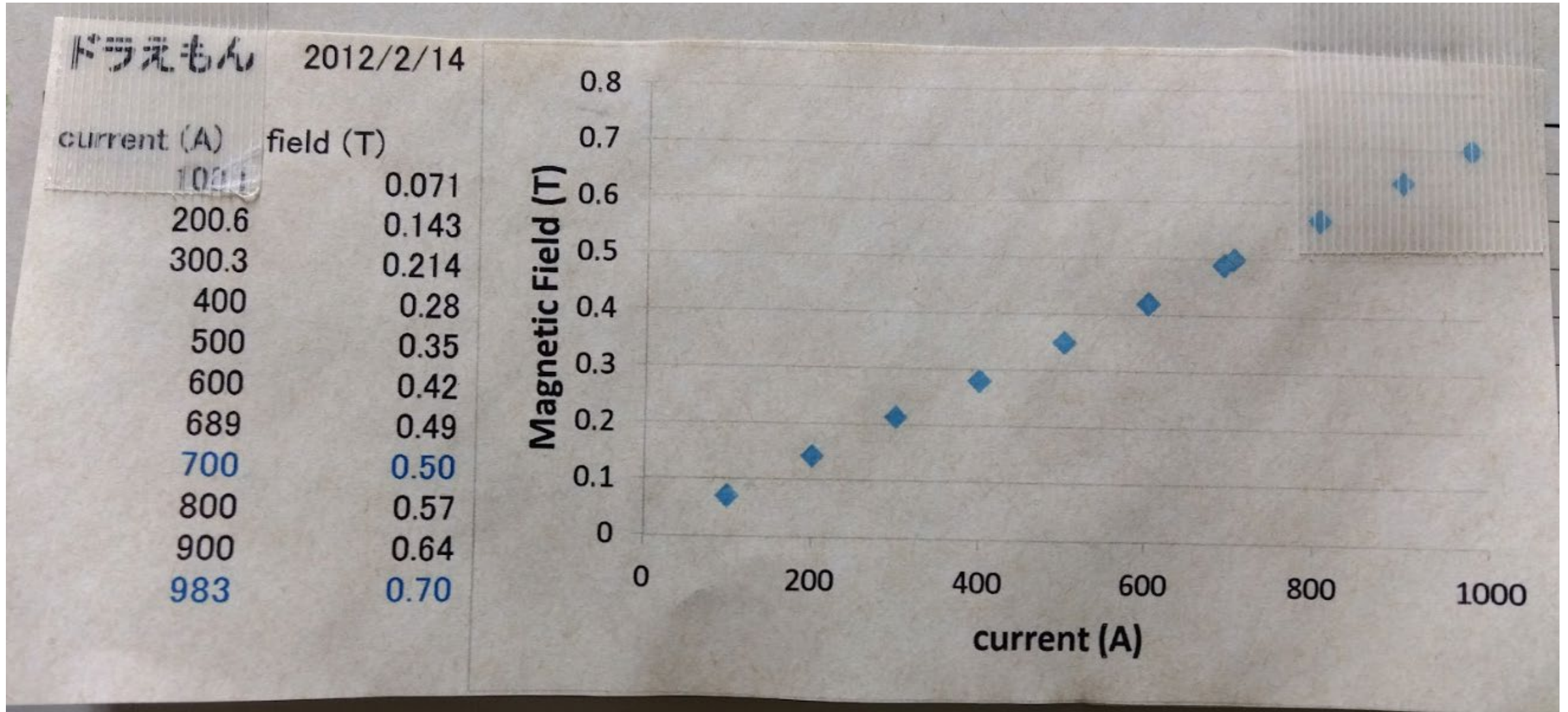
# Specification, Power Supply

1. Magnetic pole diameter	$\phi$ 300 mm (inlet/outlet) $\phi$ 1180 mm (electromagnet internal bobbin)
2. Magnetic pole length	1170 mm
3. Magnetic field strength	0.7 T
4. current	1050 A
5. voltage	350 V/unit
6. Power	367.5 kW/unit
7. DC resistance	0.293 $\Omega$ /unit
8. Wire used	16 x 16 x $\phi$ 10
9. Number of turns	680 turns/unit
10. Cooling method	Direct water cooling
11. Number of cooling channels	34 water channels/unit
12. Cooling water flow rate	280 L/min/unit
13. Cooling water pressure loss	0.6 MPa
14. Water temperature rise	Approx. +18° C
15. Range of motion	Front-back, left-right, up-down $\pm$ 20 mm
16. Weight	Approx. 22.9 ton



電源名称	電磁石用直流電源 (BPS500)
定格出力	2500A, 200V (1次側100% 2次側並列)
	2500A, 100V (1次側 50% 2次側並列)
	1250A, 400V (1次側100% 2次側直列)
	1250A, 200V (1次側 50% 2次側直列)
所要電源	AC420V (462V~399V) 3 $\phi$ , 50Hz, 603KVA
冷却水	入口圧力 0.7MPa
	冷却水必要量 25 $\ell$ /min以上
型式	IPN-2025004
製造番号	13919
製造年月	平成14年1月
重量	2590kg

# Central Magnetic Field

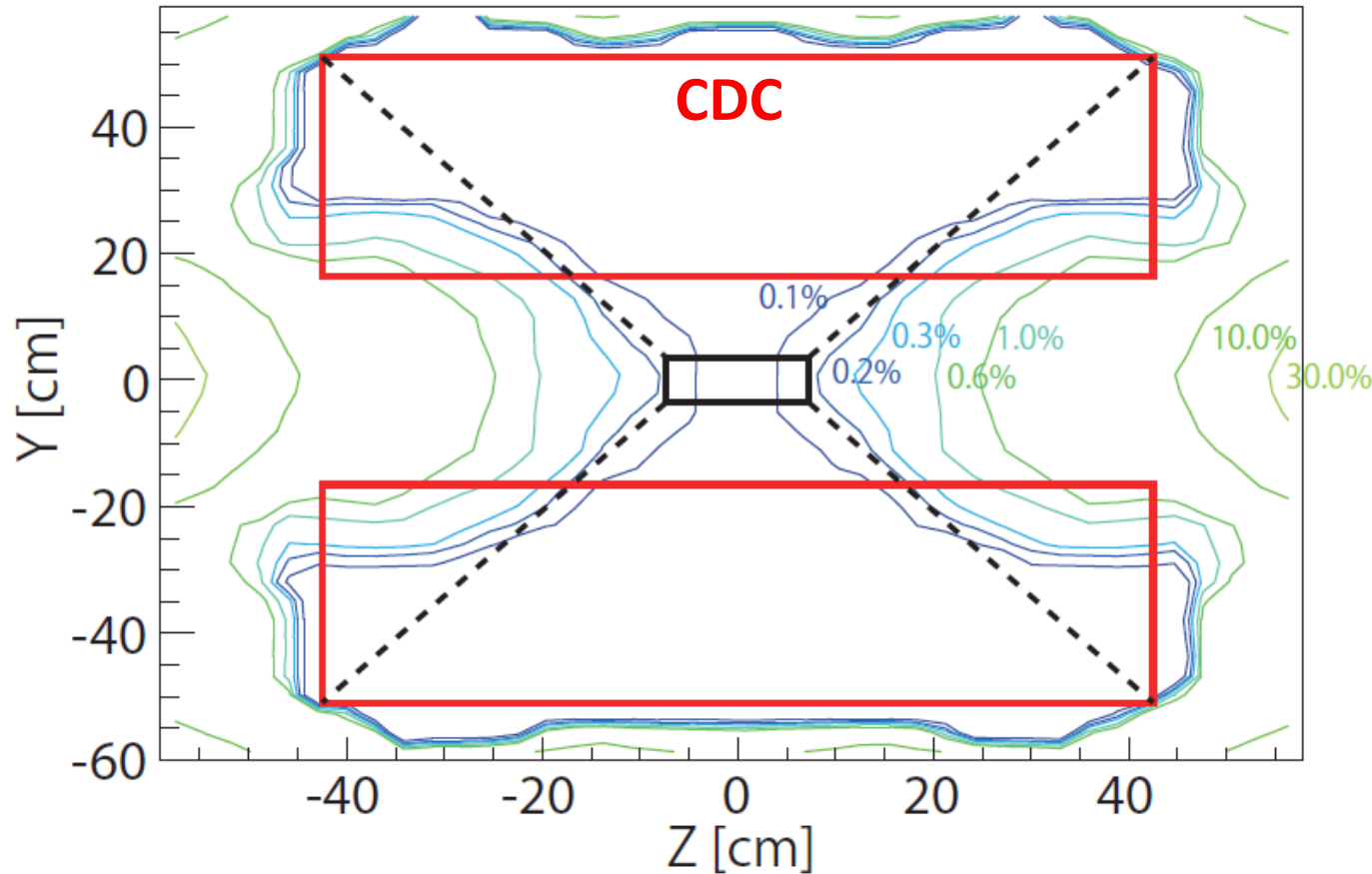


**Magnet has been operated at 983A (150V) corresponding to 0.7T**

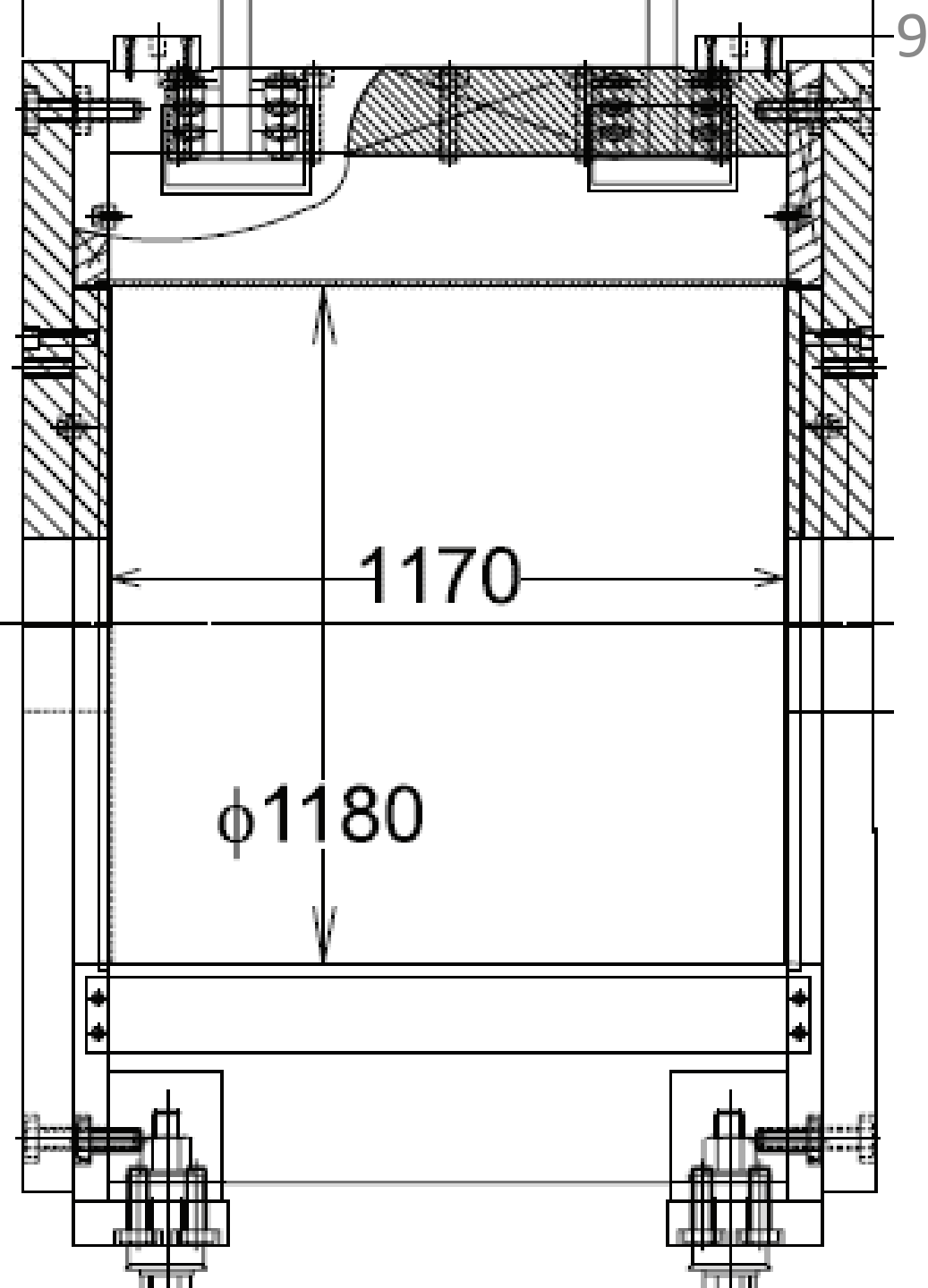


# Magnetic Field Uniformity

calculated by TOSCA



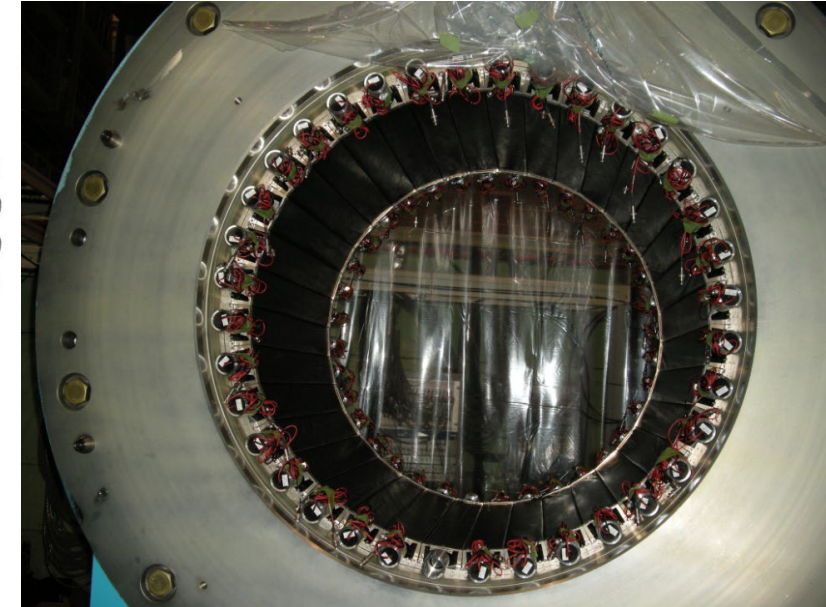
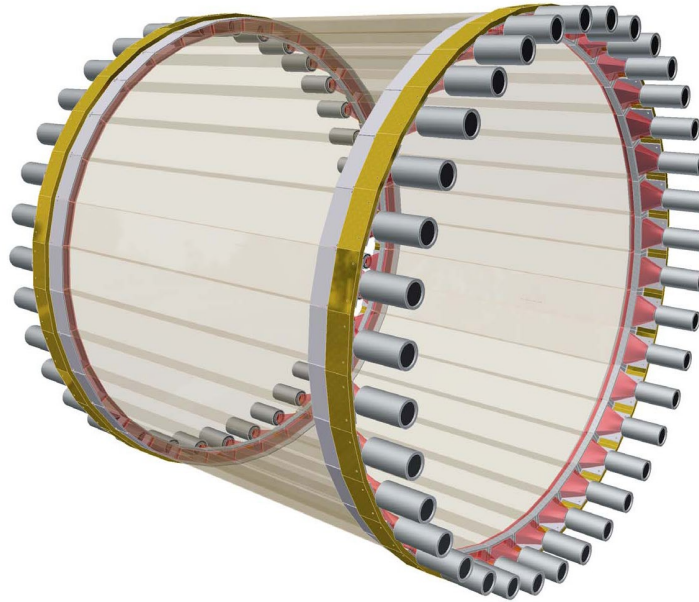
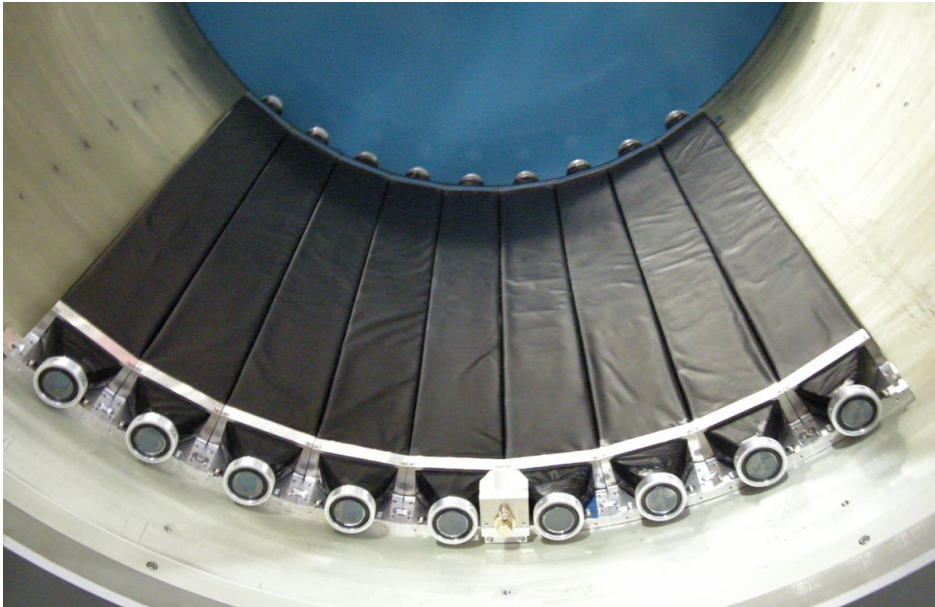
Very good uniformity → NO Runge-Kutta



# Cylindrical Detector Hodoscope (CDH)

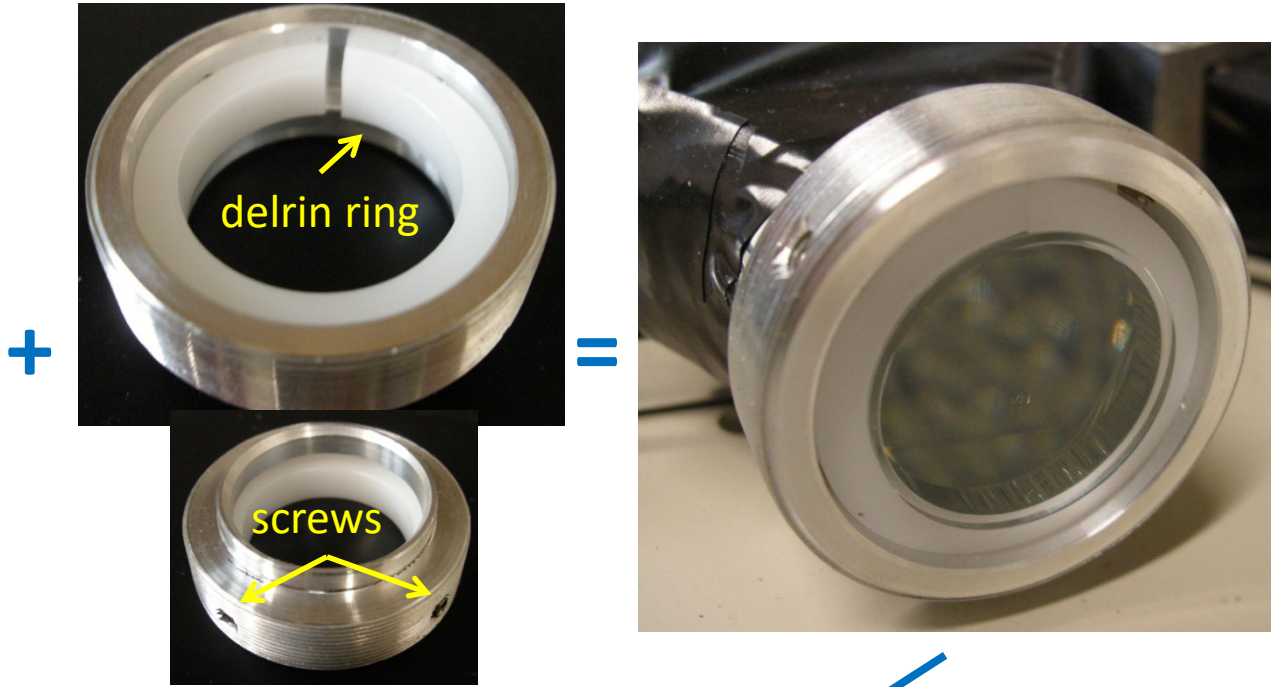
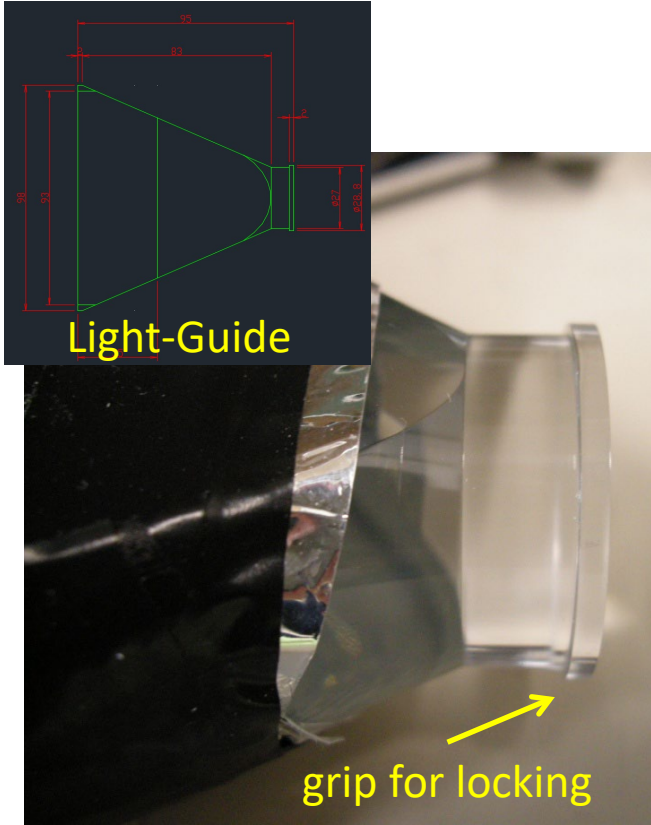
- Manufactured by G-tech
  - ~5 million yen in total
- Plastic Scintillator: 99x30x790 mm<sup>3</sup> (Eljen EJ-200)
  - 36 modules
  - Mounted on the inner wall of the solenoid
- PMT: Hamamatsu H8409 (fine mesh) x 72
  - ~ 15 million yen
- $\sigma_{\text{int}} \sim 71 \pm 3 \text{ ps}$

**PMT will be reused for  
a new large CDS at J-PARC**





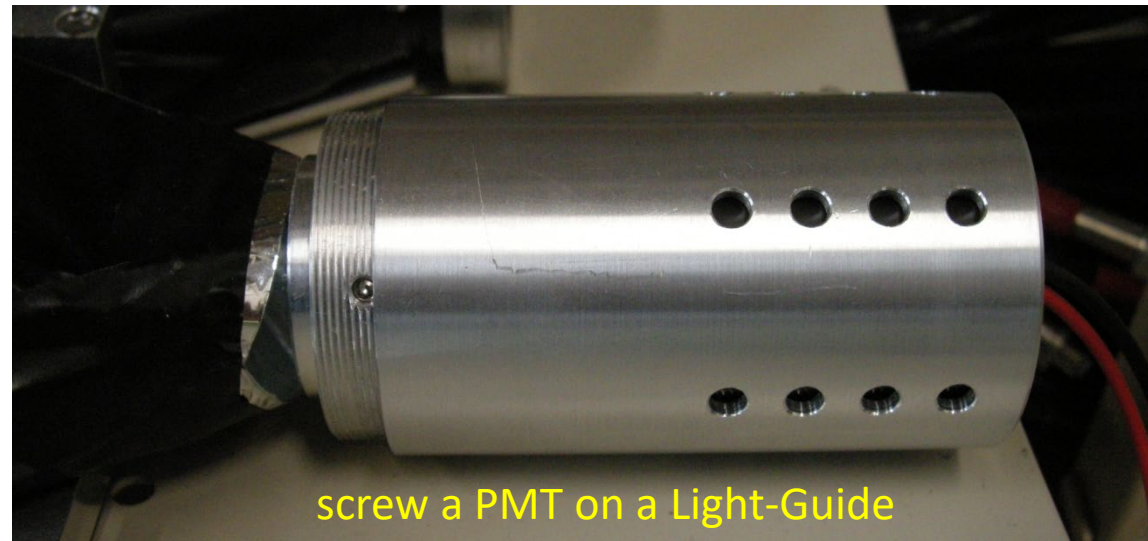
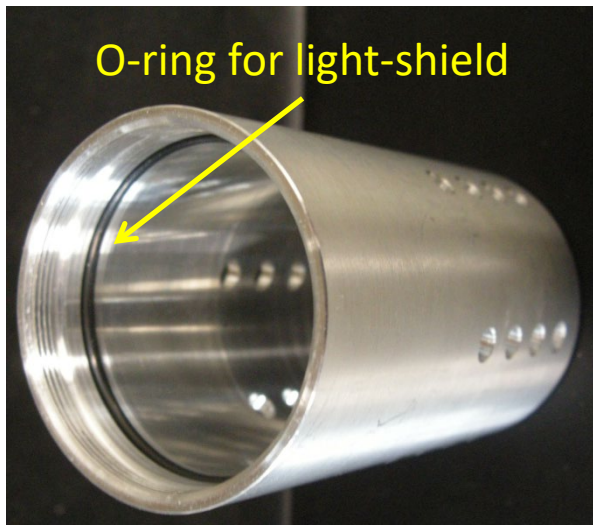
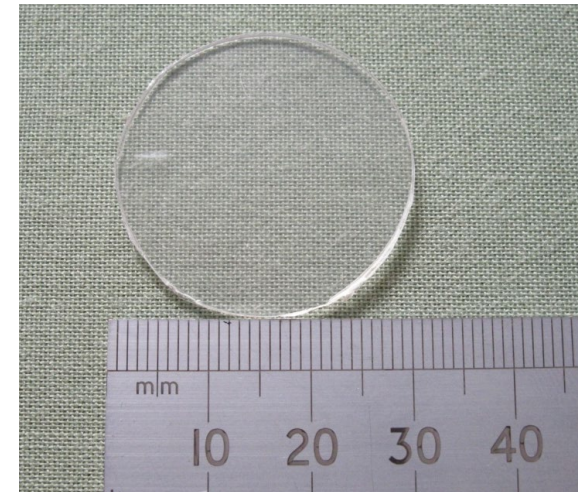
# CDH Design



*silicone cookie for PMT-Light-Guide connection*

ELJEN EJ-560

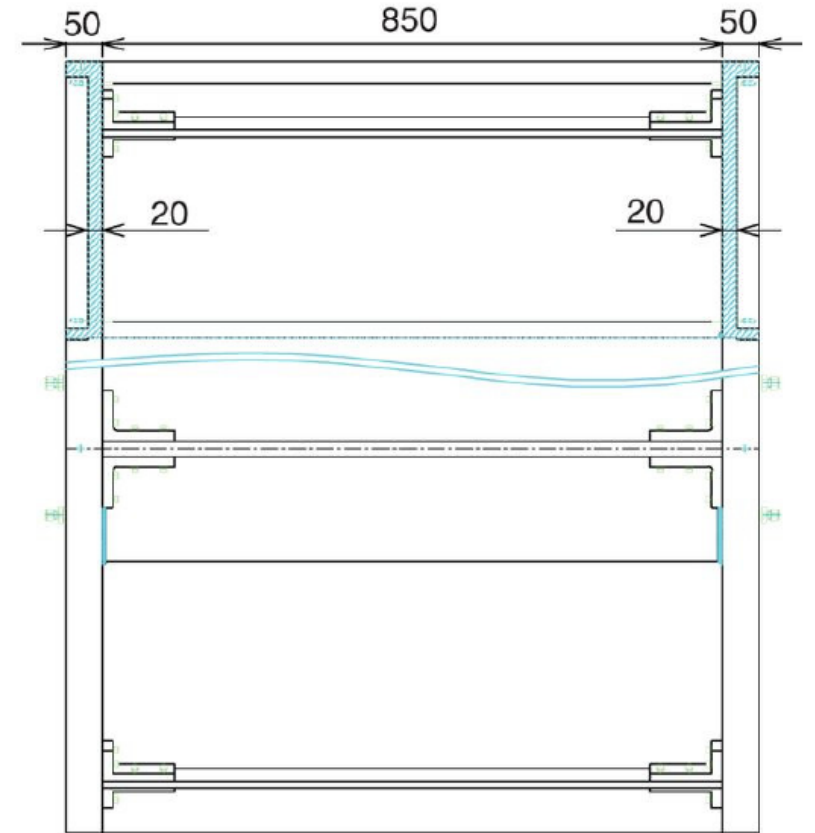
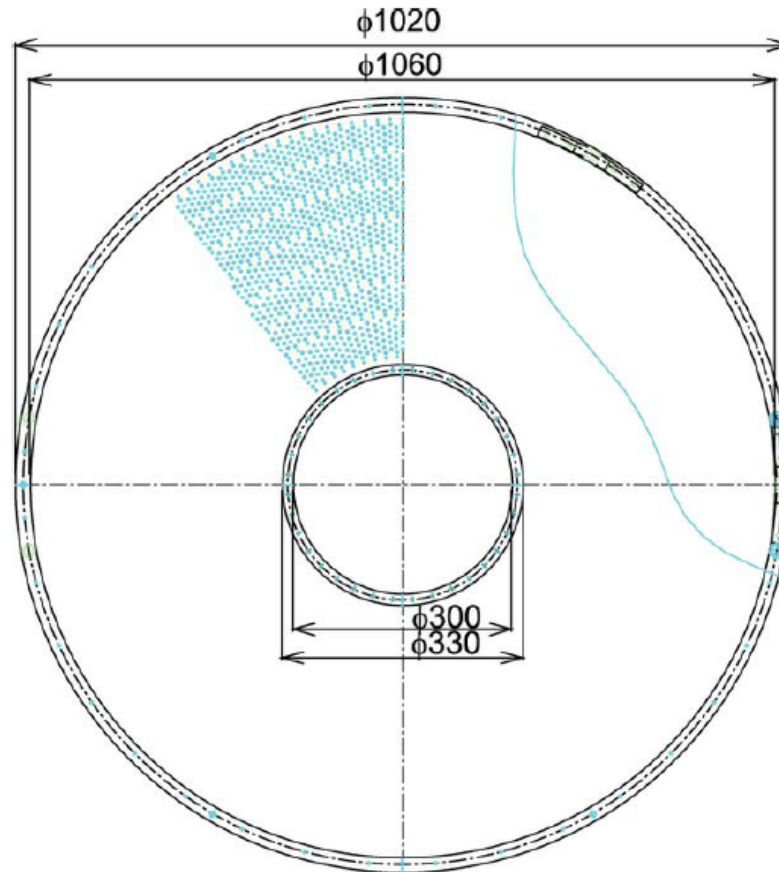
[ $\phi$ 30mm, 1mm thickness]



# Cylindrical Drift Chamber (CDC)



- Manufactured by REPIC
  - ~30 million yen
- 15 layers
  - AUVAUVA super layers
- Solid angle:  $49^\circ < \theta < 131^\circ$  (66% of  $4\pi$ )
  - Tracking volume: r190.5 - r484.5 mm (~300 mm)
  - Wire length: 833.8 mm





# Structure of CDC

- Material : Aluminum, CFRP
- Weight : ~ 100 kg
- Number of wires : 8136
  - Readout : 1816ch
- Total wire tension : ~ 600kg

## *sense wires:*

Au-plated W,  $\phi 30\mu\text{m}$

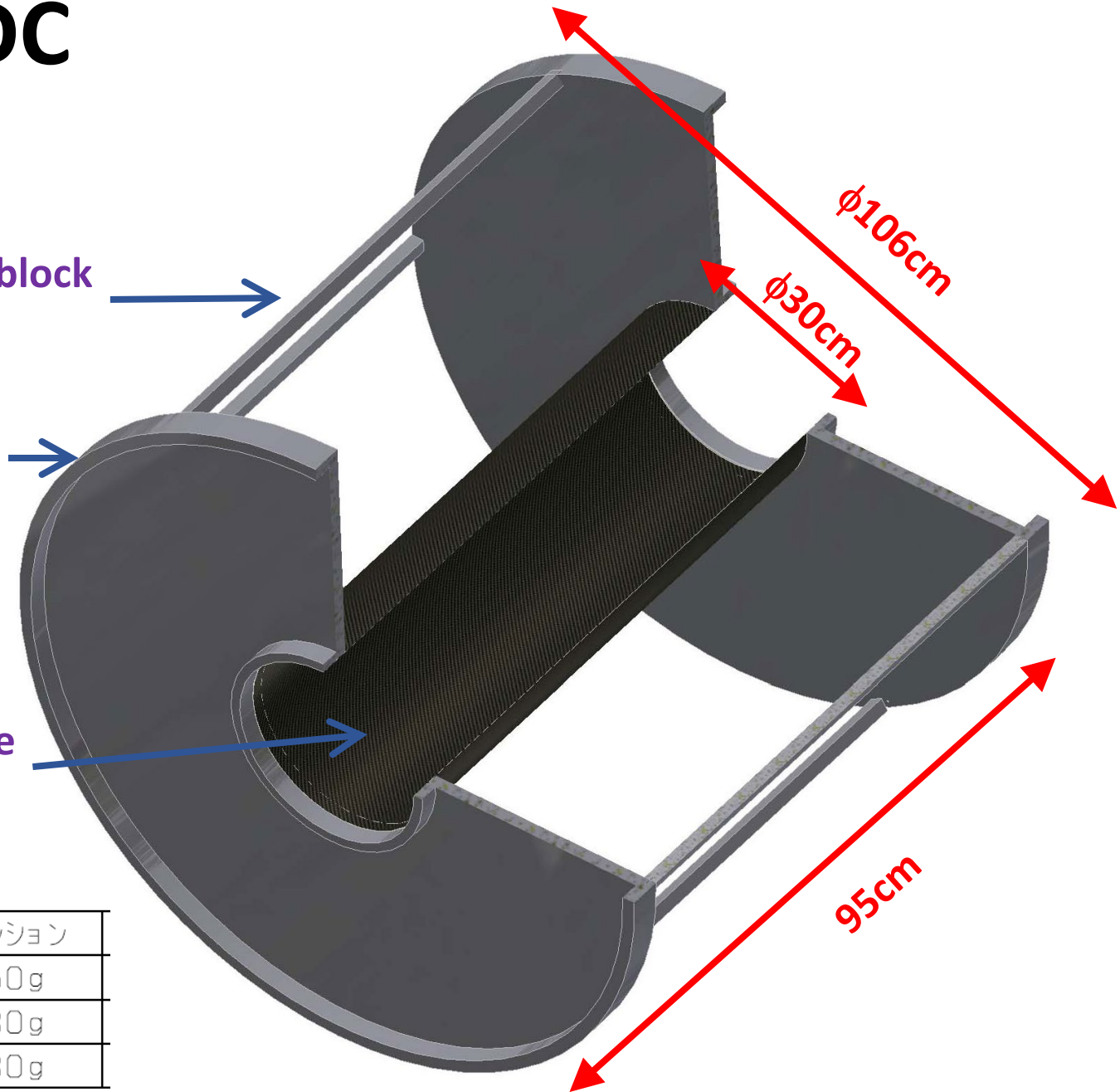
## *field & guard wires:*

Au-plated Al,  $\phi 100\mu\text{m}$

aluminum block  
(x6)

aluminum  
end-plate

CFRP tube  
(t1mm)



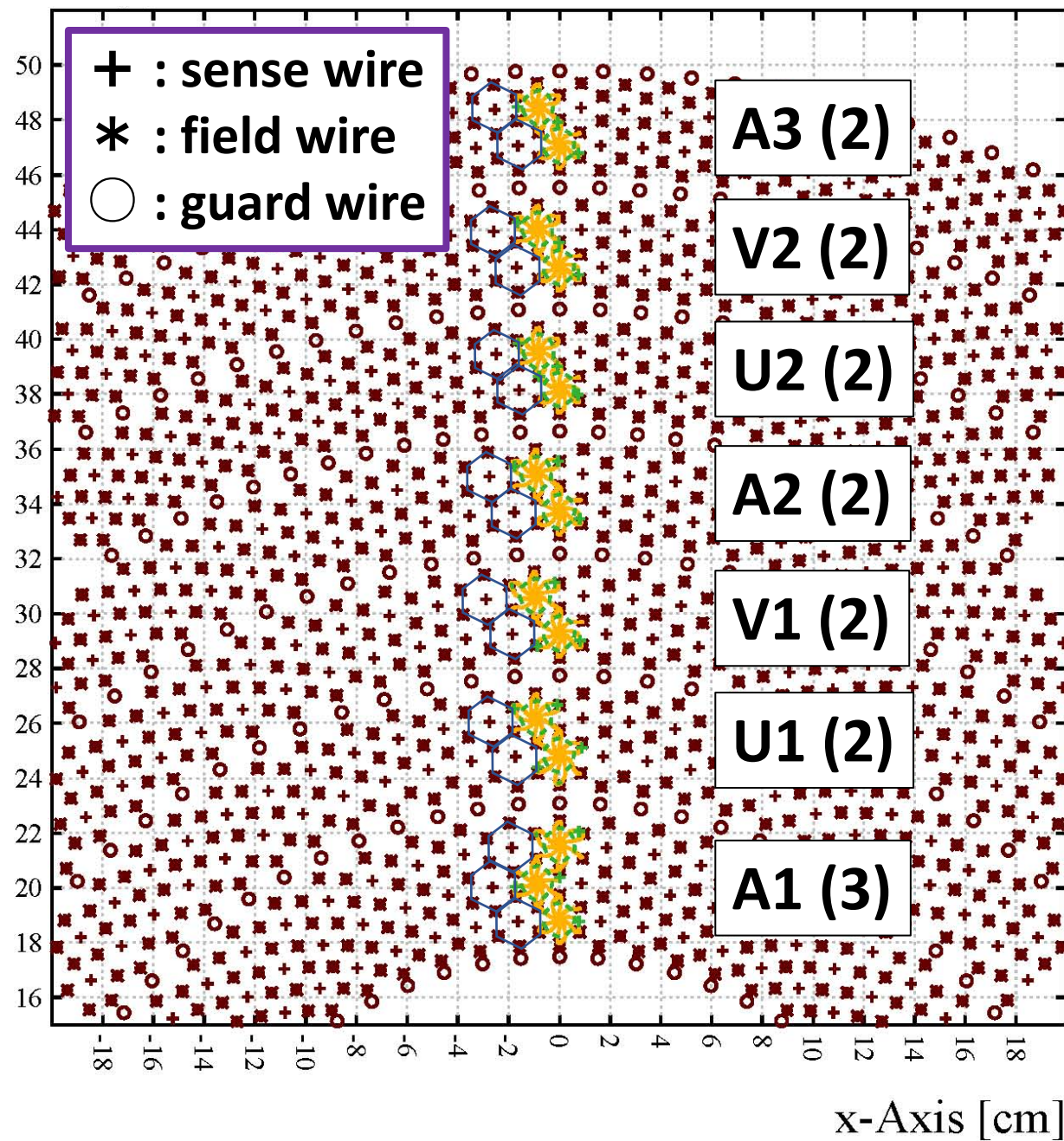
ワイヤー要目表

ワイヤー種類	ワイヤー径	ワイヤー材質	本数	テンション
センスワイヤ	$\phi 30\mu$	Au-W	1816	50g
ポテンシャル	$\phi 100\mu$	Au-Al	5376	80g
グラウンド	$\phi 100\mu$	Au-Al	1052	80g

# Cell Configuration [cm]

Table 2.3: Wire configuration of the CDC.

Super-layer	layer	Wire direction	Radius [mm]	Cell width [degree]	Cell width [mm]	Stereo angle [degree]	readouts per layer
A1	1	$X$	190.5	5.00	16.7	0	72
	2	$X'$	204	5.00	17.8	0	72
	3	$X$	217.5	5.00	19	0	72
U1	4	$U$	248.5	4.00	17.3	-3.55	90
	5	$U'$	262	4.00	18.3	-3.74	90
V1	6	$V$	293	3.60	18.4	3.77	100
	7	$V'$	306.5	3.60	19.3	3.94	100
A2	8	$X$	337.5	3.00	17.7	0	120
	9	$X'$	351	3.00	18.4	0	120
U2	10	$U$	382	2.40	16	-3.28	150
	11	$U'$	395.5	2.40	16.4	-3.39	150
V2	12	$V$	426.5	2.25	16.7	3.43	160
	13	$V'$	440	2.25	17.3	3.54	160
A3	14	$V$	471	2.00	16.4	0	180
	15	$V'$	484.5	2.00	16.9	0	180



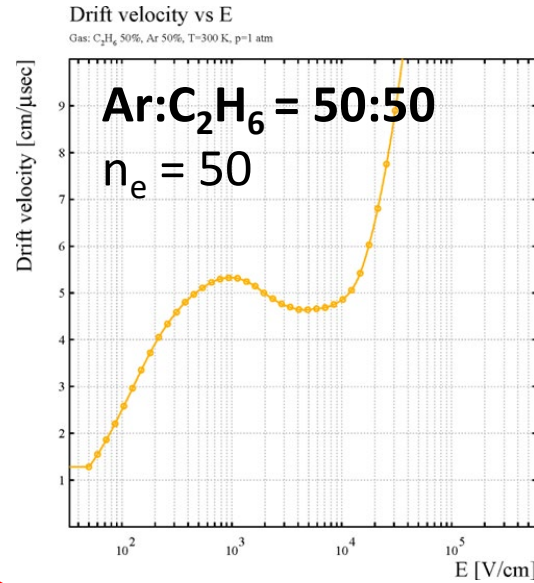
	Name	IOSet	V0Set	IMon	VMon
02.000	Layer1	10.00 uA	2750.00 V	6.54 uA	2750.00 V
02.001	Layer2	10.00 uA	2850.00 V	6.64 uA	2849.50 V
02.002	Layer3	10.00 uA	2850.00 V	5.24 uA	2850.25 V
02.003	Layer4	10.00 uA	2800.00 V	3.90 uA	2799.50 V
02.004	Layer5	10.00 uA	2800.00 V	4.32 uA	2799.50 V
02.005	Layer6	10.00 uA	2800.00 V	3.60 uA	2799.75 V
02.006	Layer7	10.00 uA	2800.00 V	3.30 uA	2799.75 V
02.007	Guard	10.00 uA	646.00 V	0.02 uA	645.75 V
02.008	Inner	10.00 uA	1535.00 V	0.00 uA	1534.50 V
02.009	Outer	10.00 uA	1830.00 V	0.00 uA	1829.75 V

@ Ar:C<sub>2</sub>H<sub>6</sub>  
= 50:50

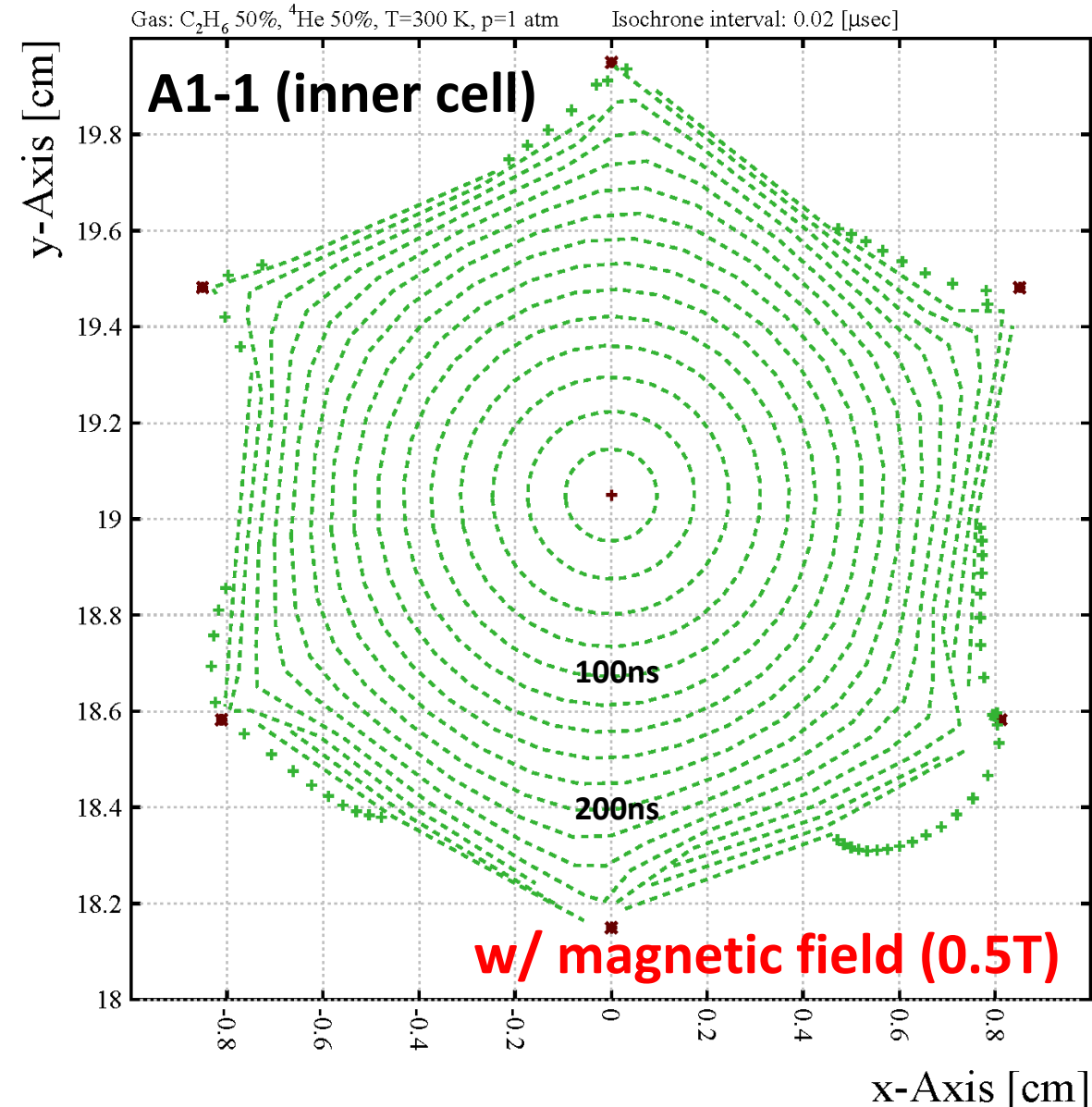
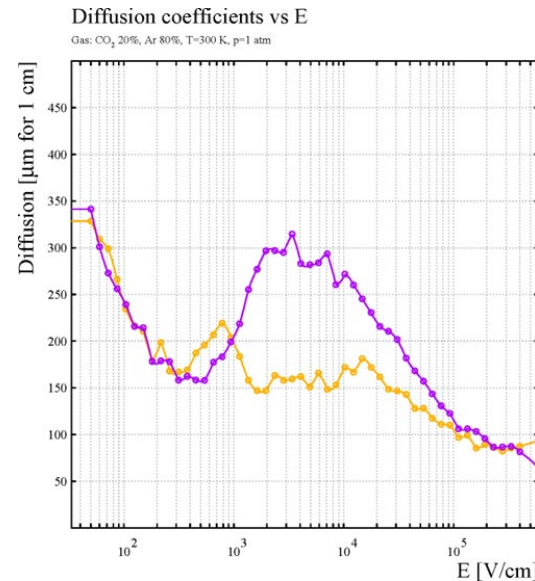
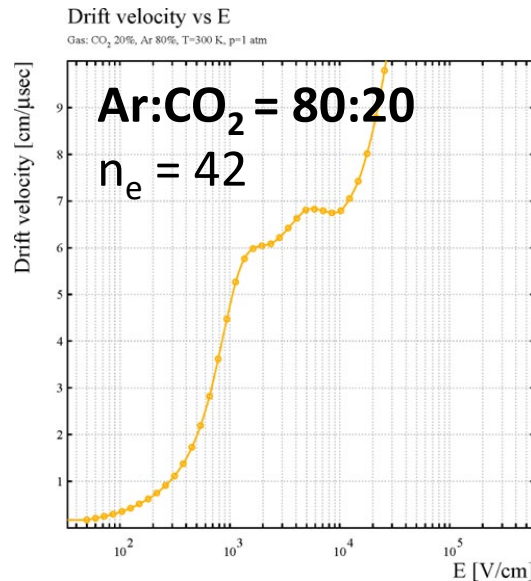
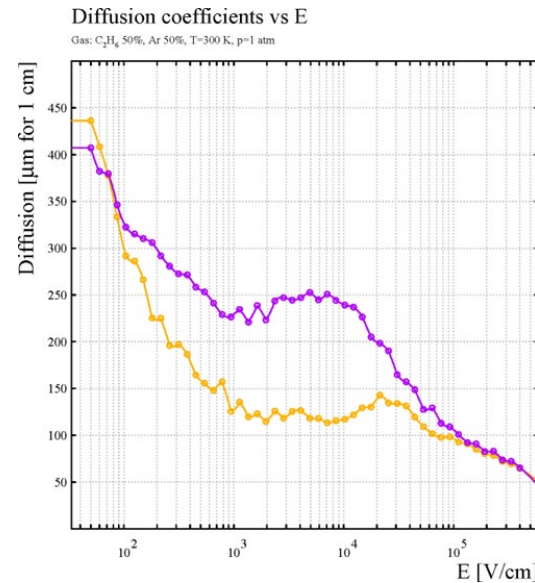


# Gas & Drift-Time-Isochrones *Calculated using garfield-9*

## velocity vs. E



## diffusion

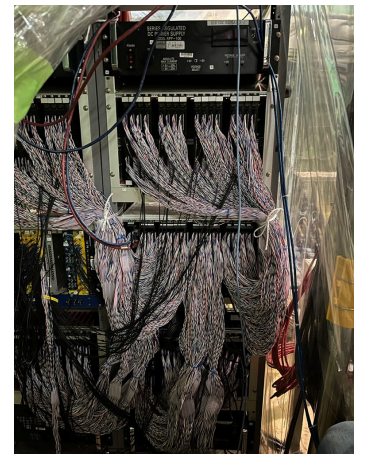
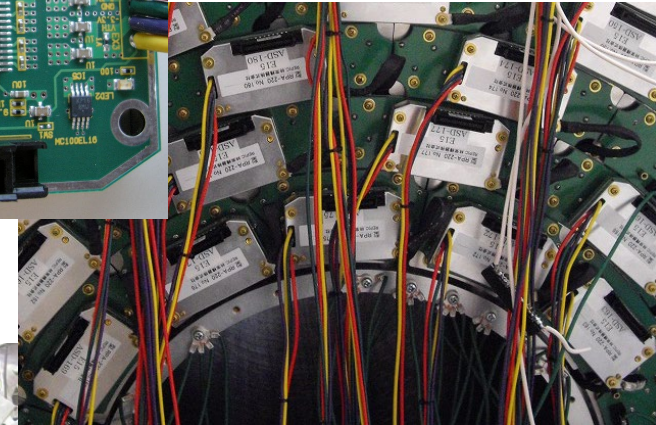
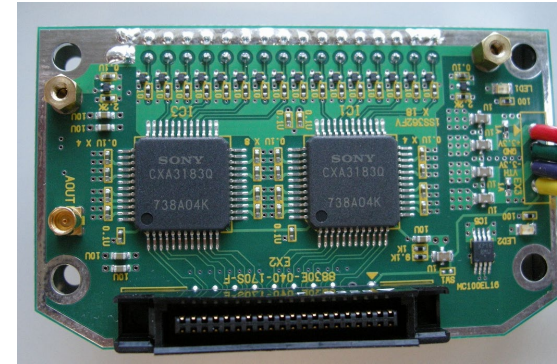
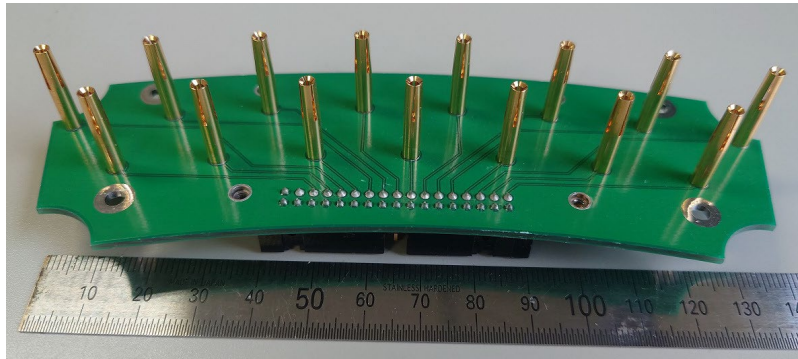




# CDC Readout

will be reused for a new large CDC at J-PARC

- Signal/HV-distributor boards used
- ASDs (SONY-CXA3183Q,  $\tau = 16$  ns) and HUL multi-hit TDCs
  - 16ch / preamp-card
  - 118 cards in total
  - preamp (LVDS)  $\rightarrow$  repeater (LVDS $\rightarrow$ ECL)  $\rightarrow$  HUL (ECL)

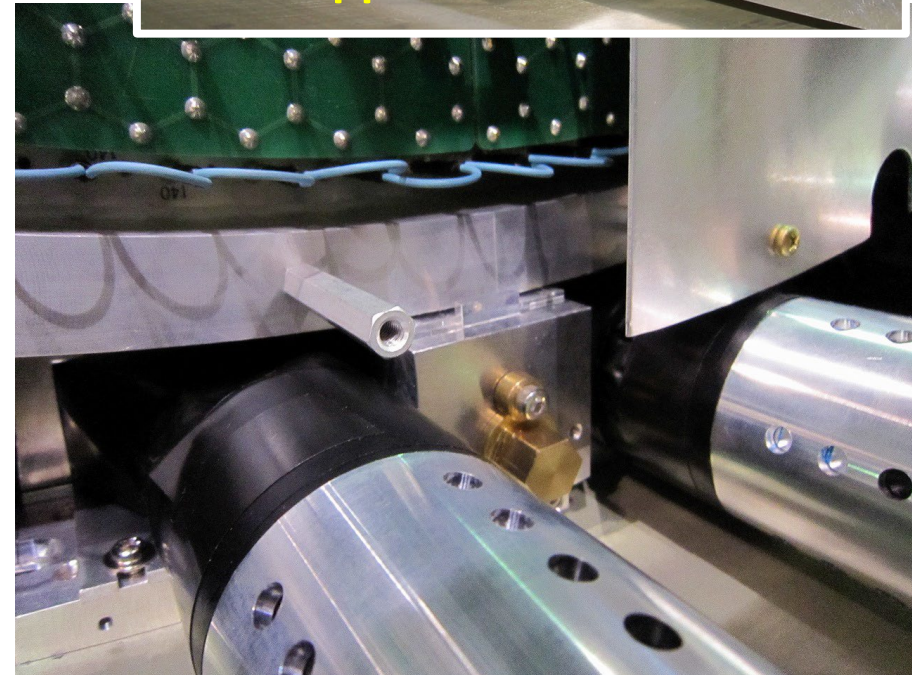
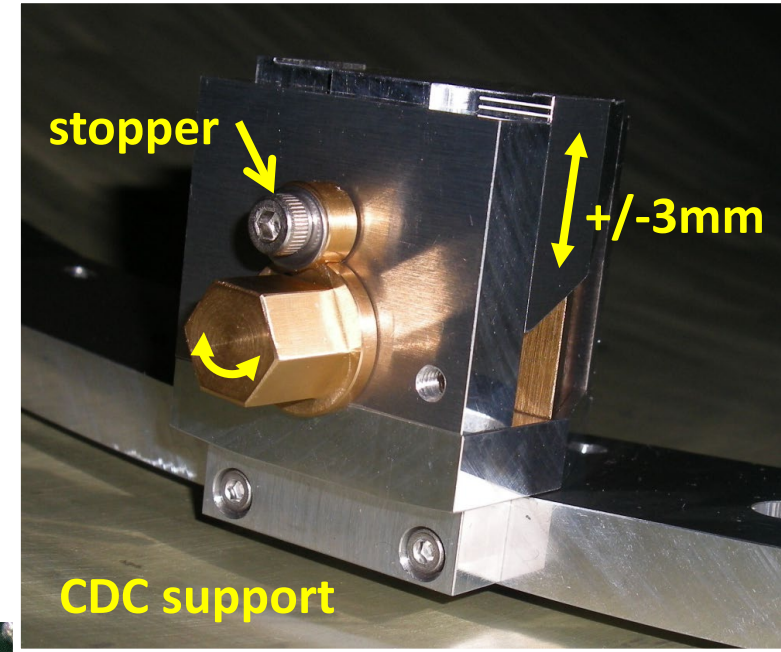
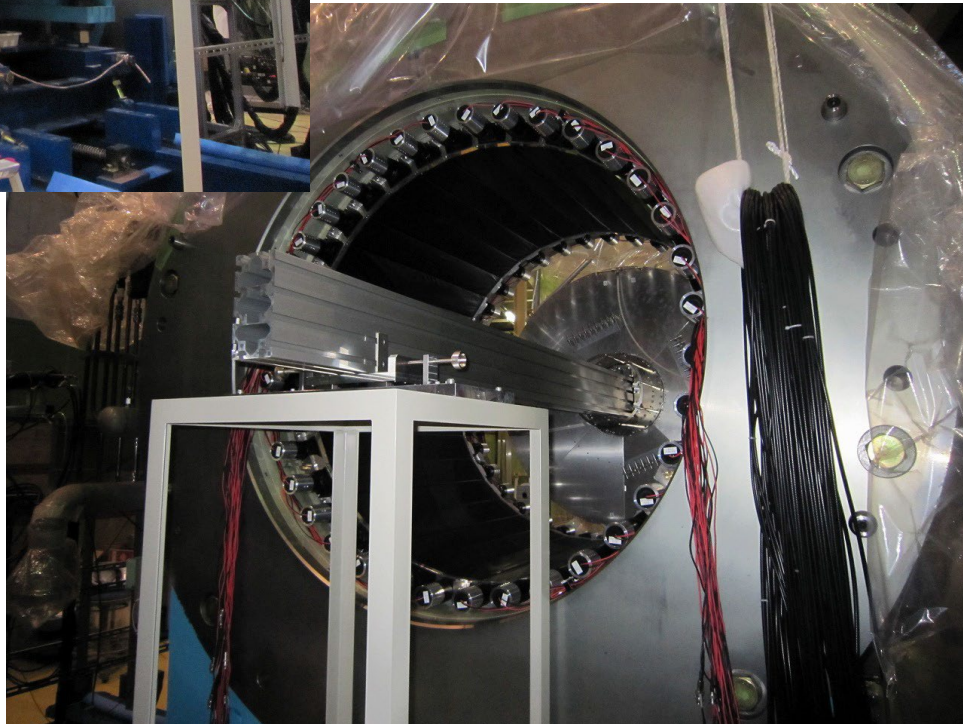


Signal board

HV-distributor board



# CDC Installation



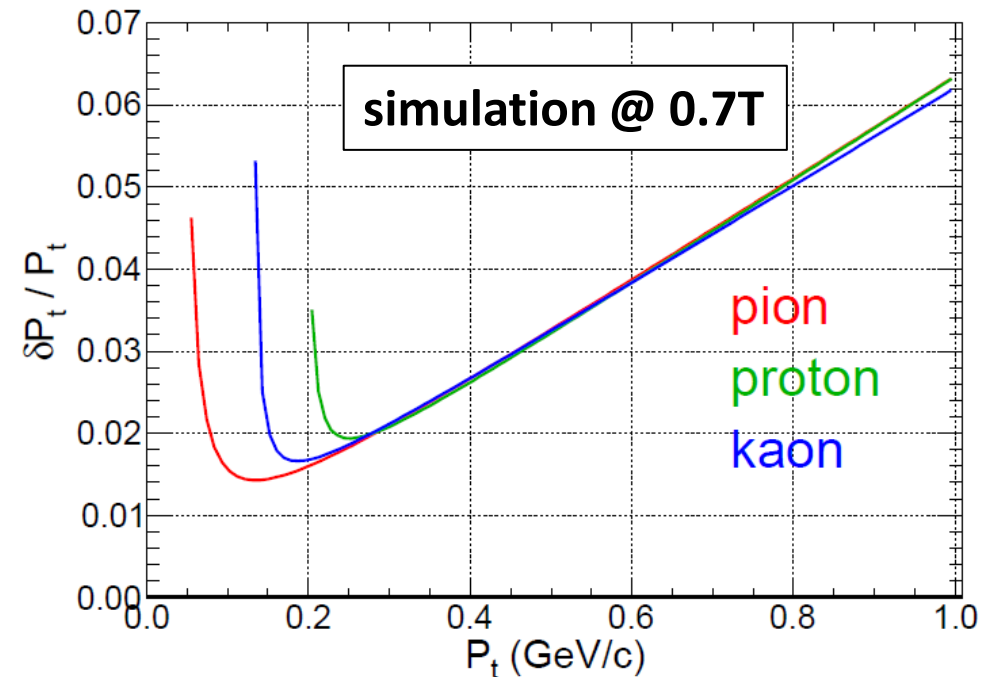
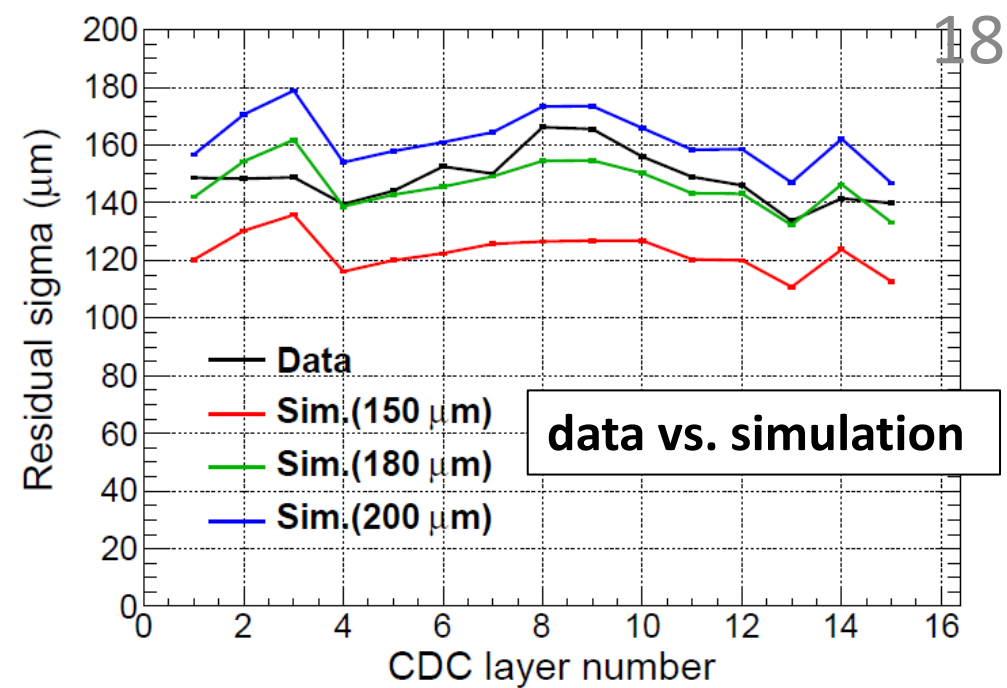
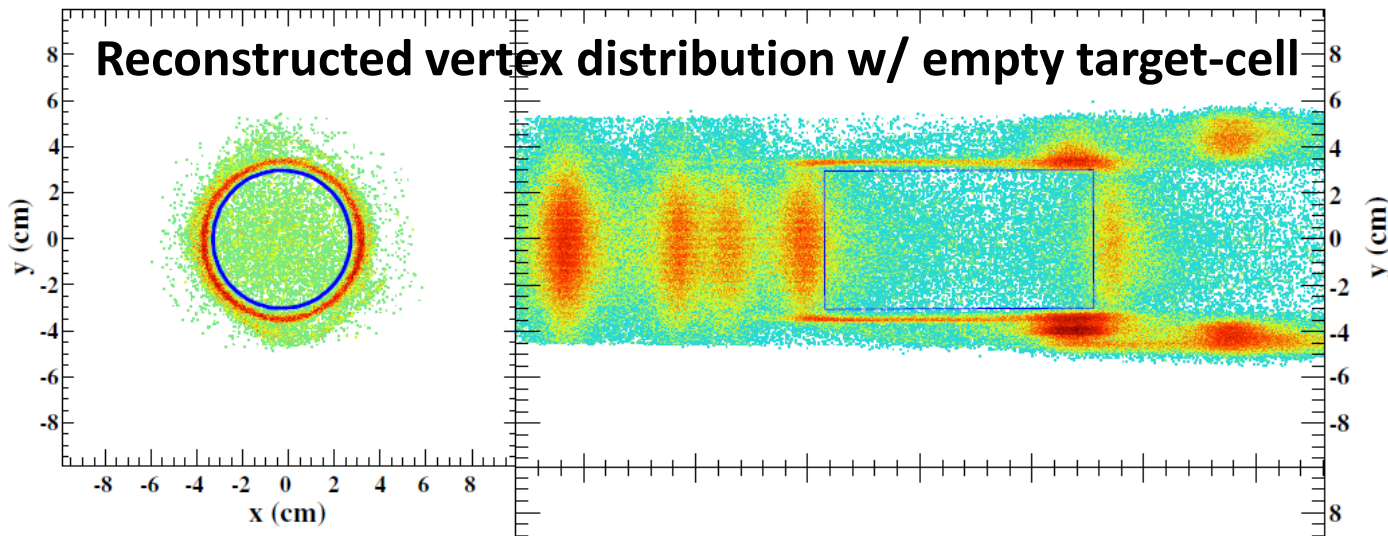


# CDC Performance

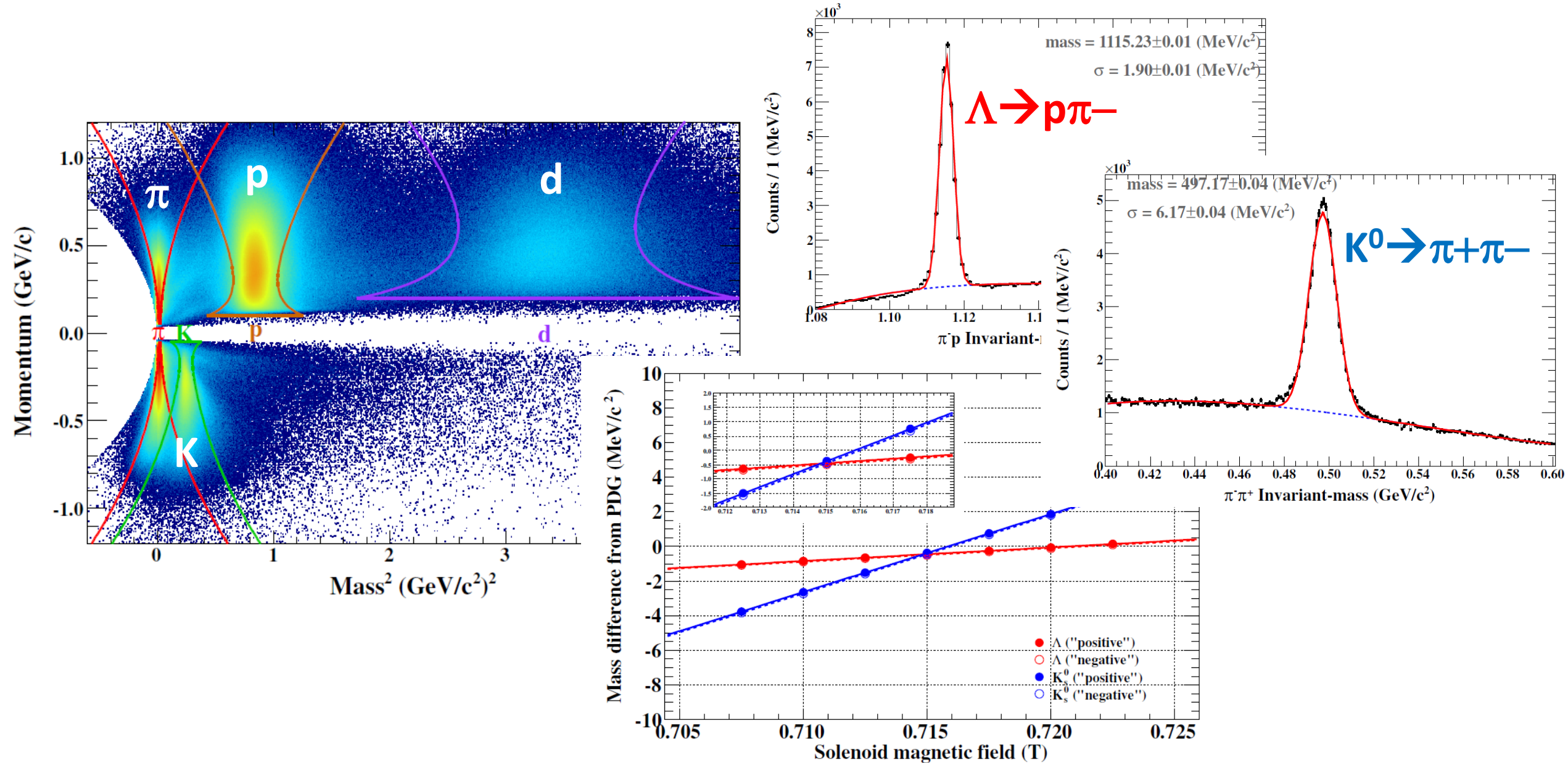
- CDC position resolution:  $\sim 180 \mu\text{m}$
- $p_t$  resolution at 0.7T:

$$\delta p_t / p_t = 6.0\% p_t \oplus 0.8\% / \beta$$

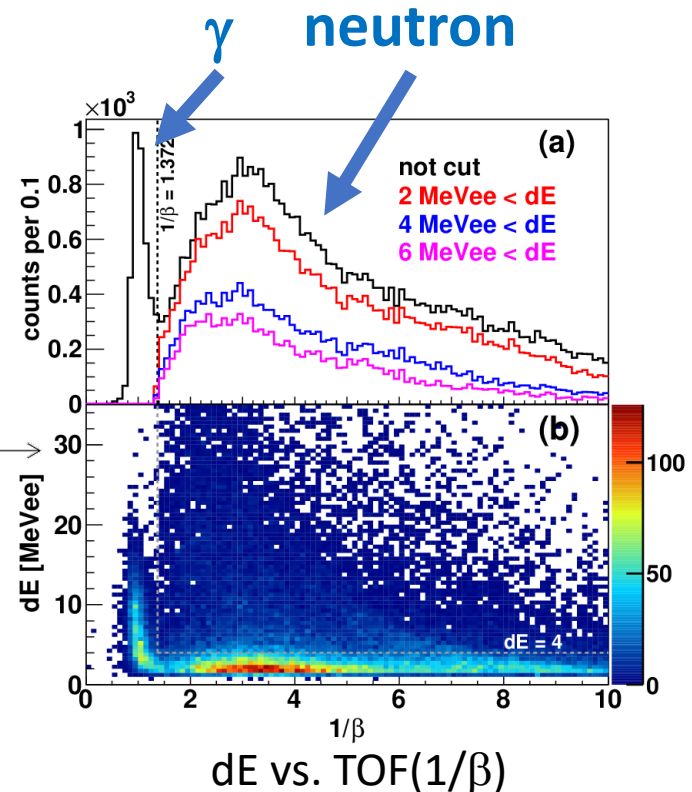
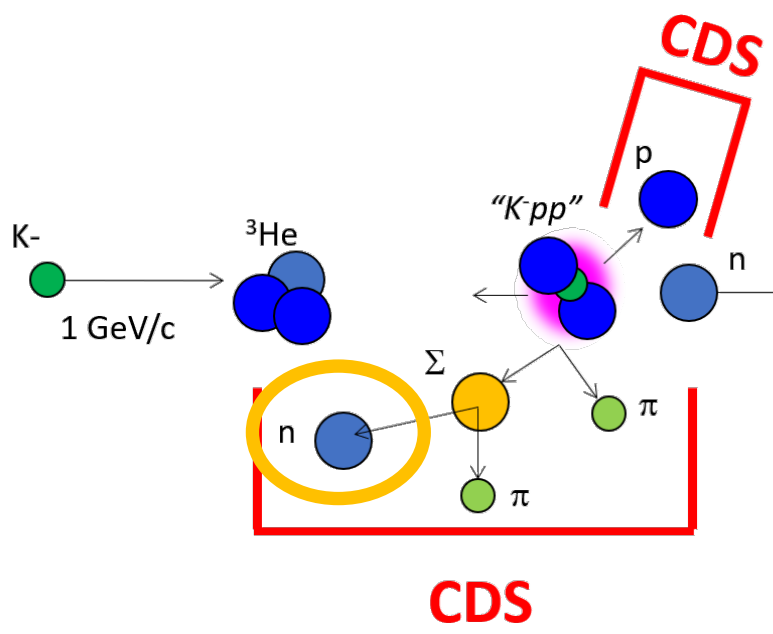
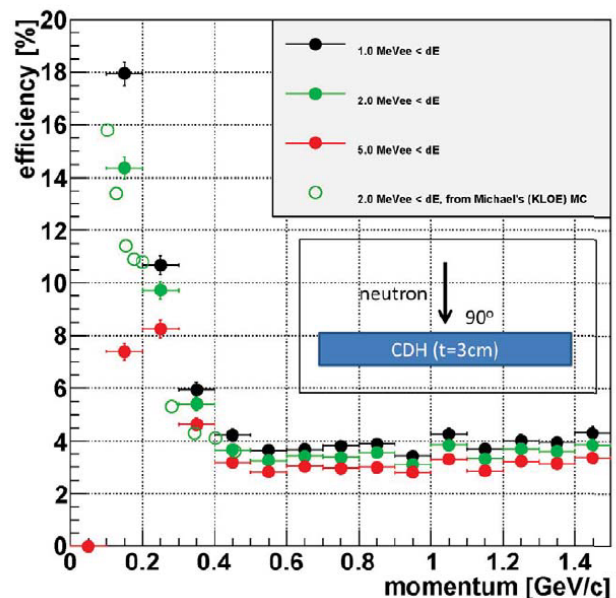
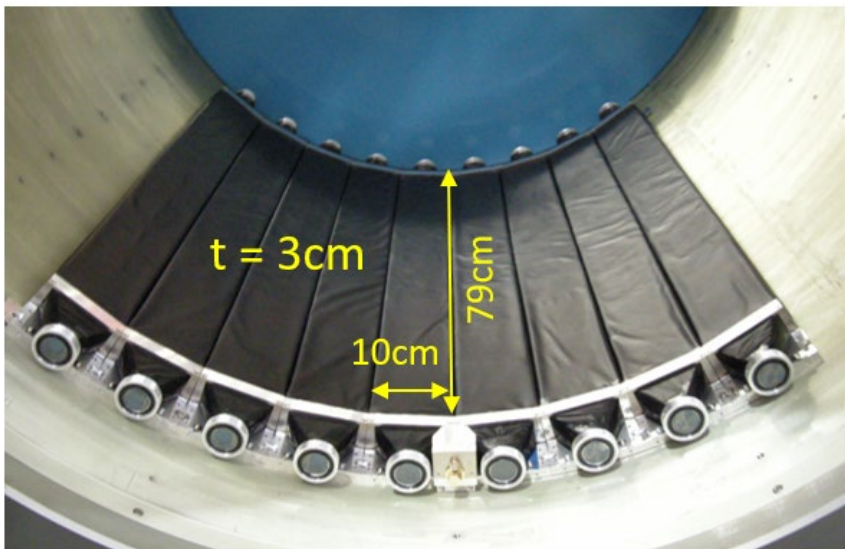
- Vertex resolution:
  - xy:  $\sim 1.5 \text{ mm}$
  - z:  $\sim 6.5 \text{ mm}$



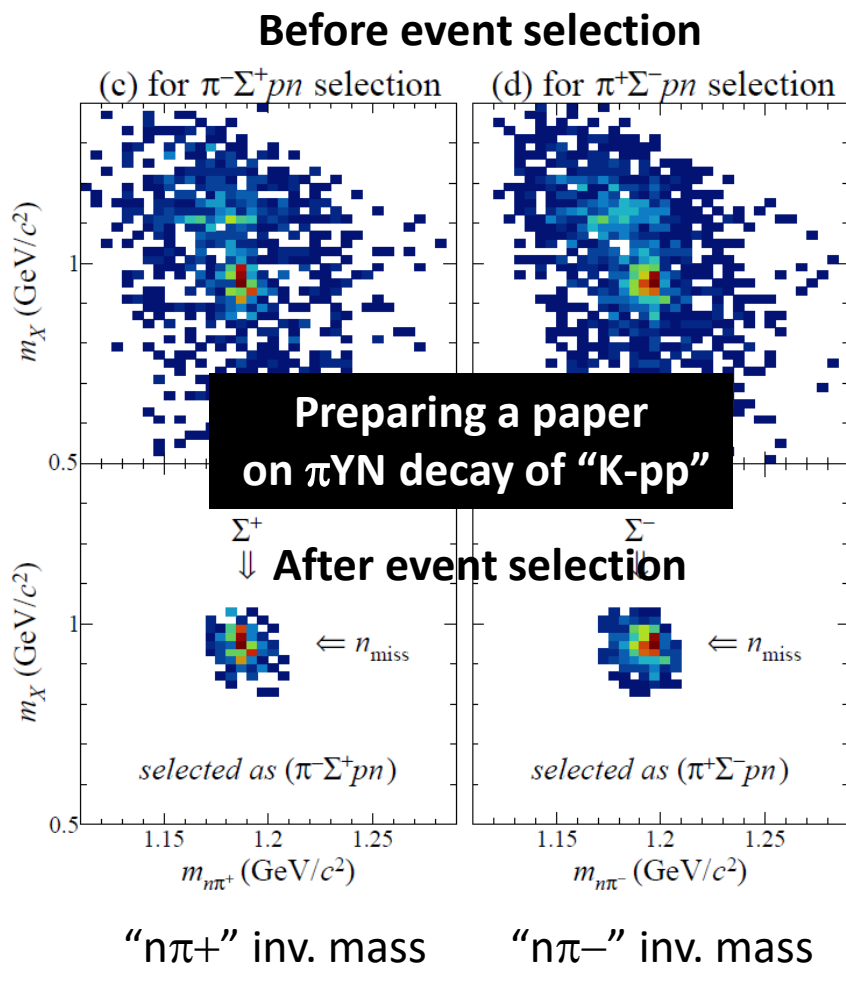
# CDS Performance



# Neutron Detection



## Successful recognition of $\pi\Sigma pn$



"(K,  $\pi\pi n$ )n" missing mass

"n $\pi^+$ " inv. mass

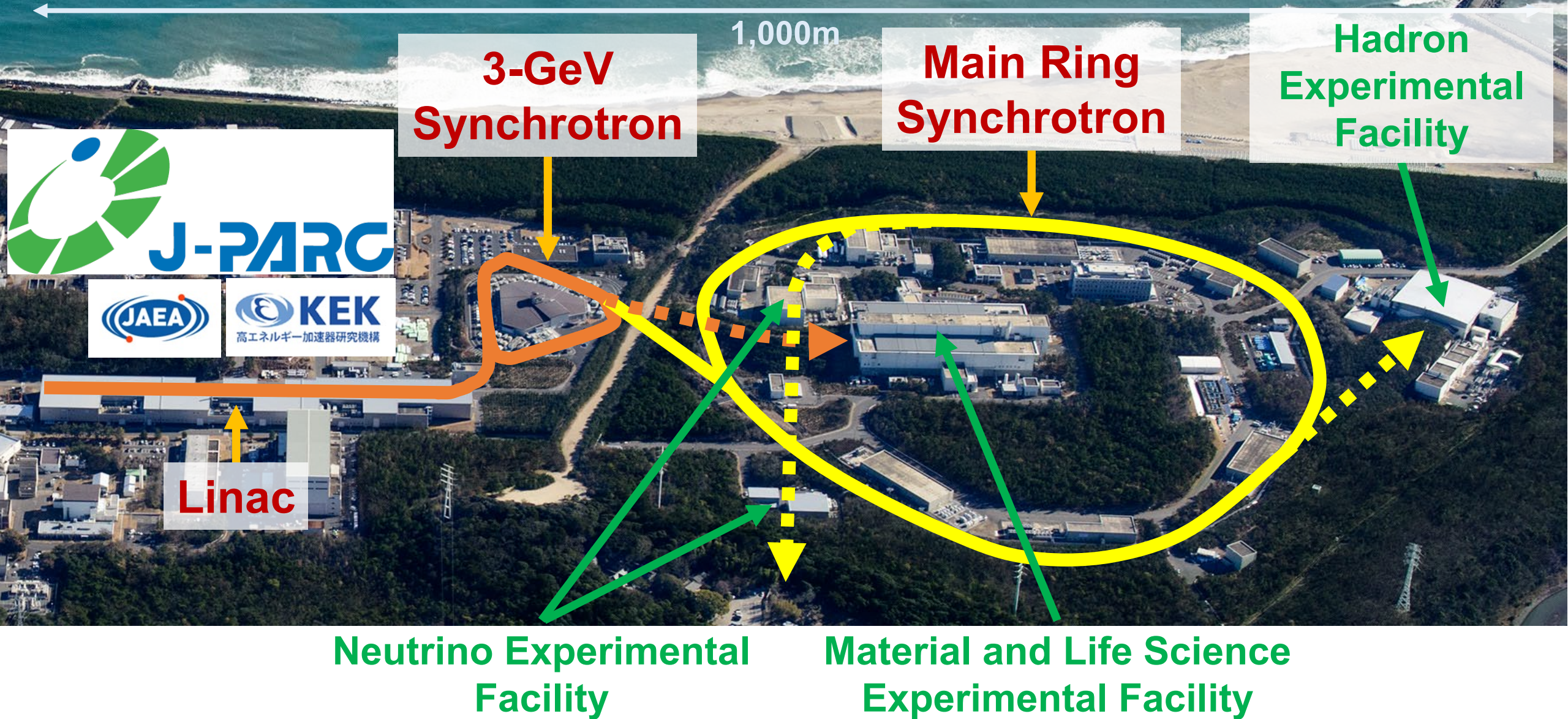
"n $\pi^-$ " inv. mass



# Experiments @ J-PARC K1.8BR

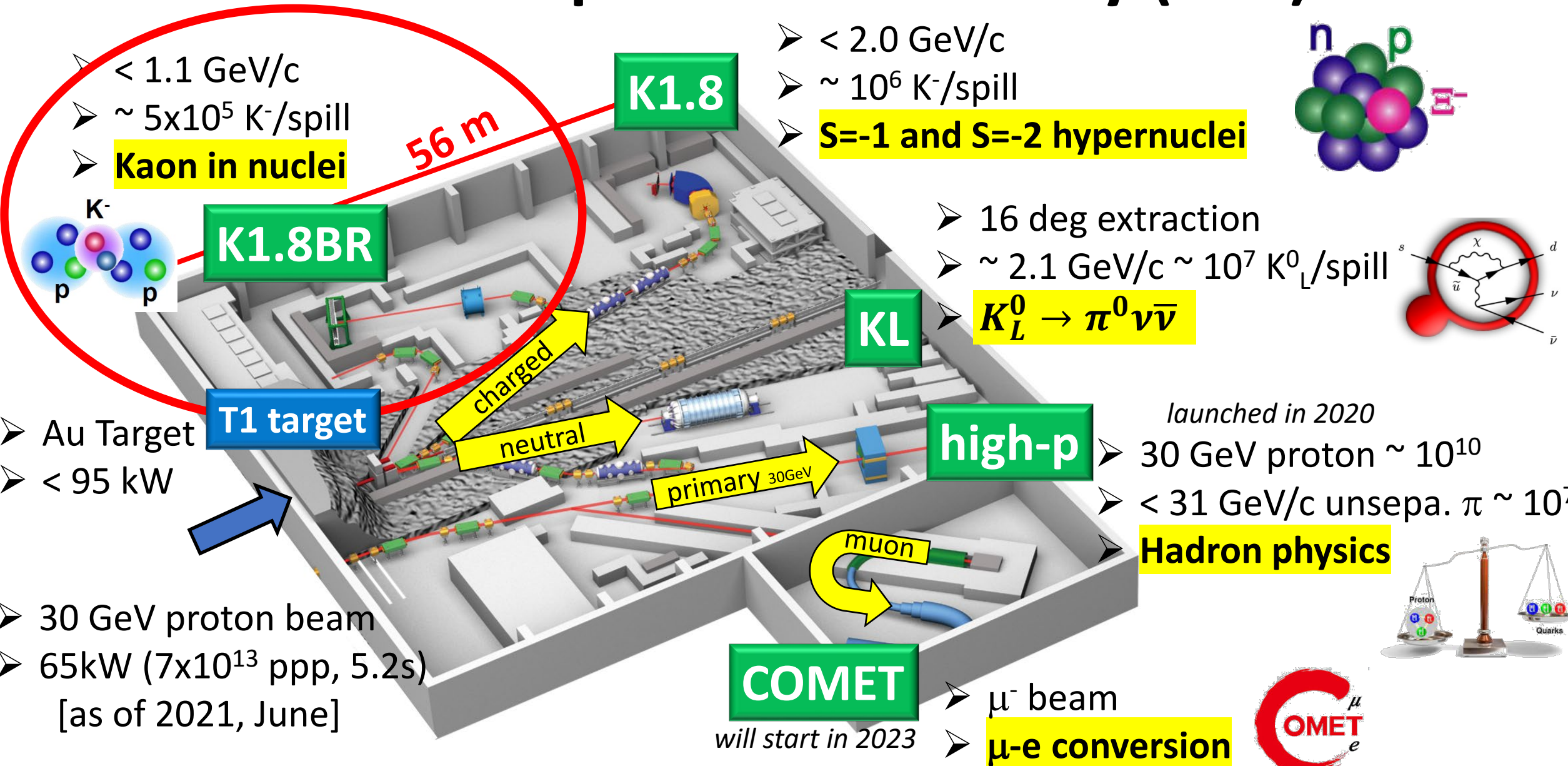
# J-PARC

## Japan Proton Accelerator Research Complex





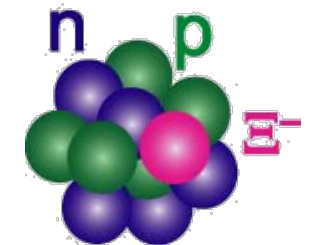
# Hadron Experimental Facility (HEF)



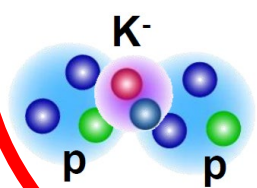
- < 1.1 GeV/c
- ~ 5x10<sup>5</sup> K<sup>-</sup>/spill
- **Kaon in nuclei**

**K1.8**

- < 2.0 GeV/c
- ~ 10<sup>6</sup> K<sup>-</sup>/spill
- **S=-1 and S=-2 hypernuclei**

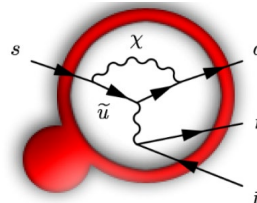


**K1.8BR**



**KL**

- 16 deg extraction
- ~ 2.1 GeV/c ~ 10<sup>7</sup> K<sub>L</sub><sup>0</sup>/spill
- **K<sub>L</sub><sup>0</sup> → π<sup>0</sup>νν̄**



**T1 target**

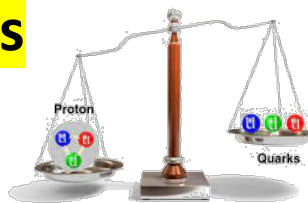
- Au Target
- < 95 kW

charged  
neutral

primary 30GeV

**high-p**

- launched in 2020
- 30 GeV proton ~ 10<sup>10</sup>
- < 31 GeV/c unsepa. π ~ 10<sup>7</sup>
- **Hadron physics**



muon

**COMET**

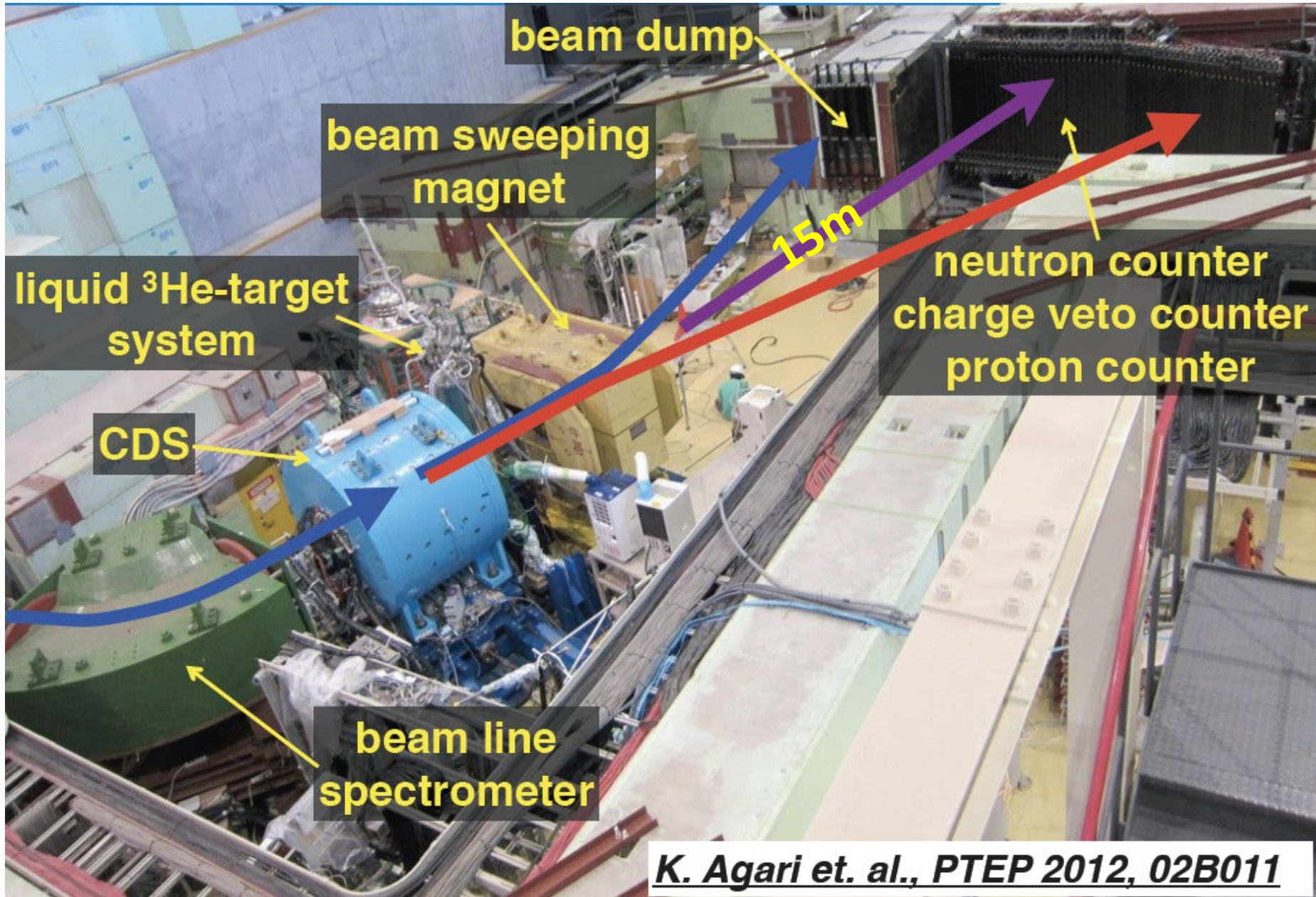
- 30 GeV proton beam
- 65kW (7x10<sup>13</sup> ppp, 5.2s)
- [as of 2021, June]

- μ<sup>-</sup> beam
- **μ-e conversion**





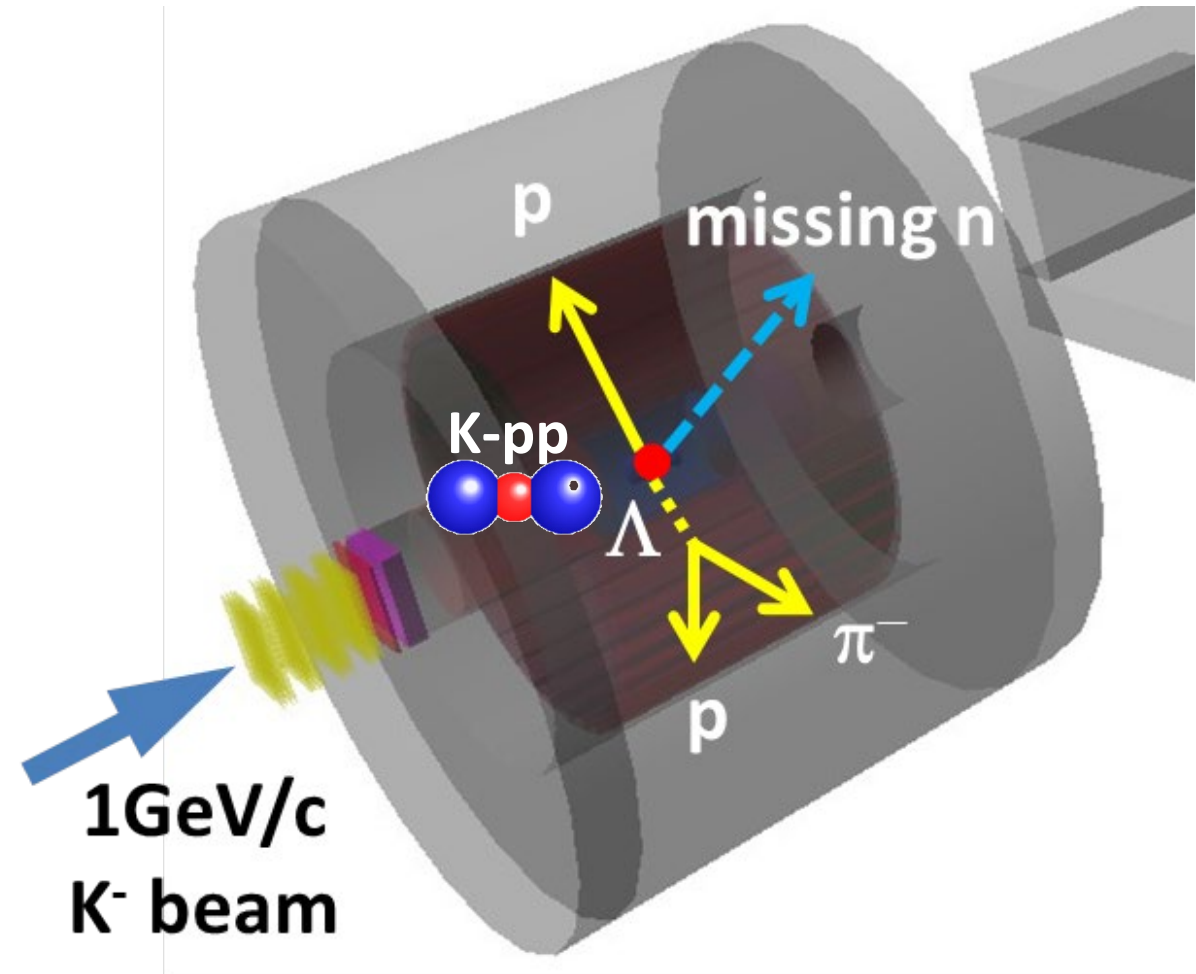
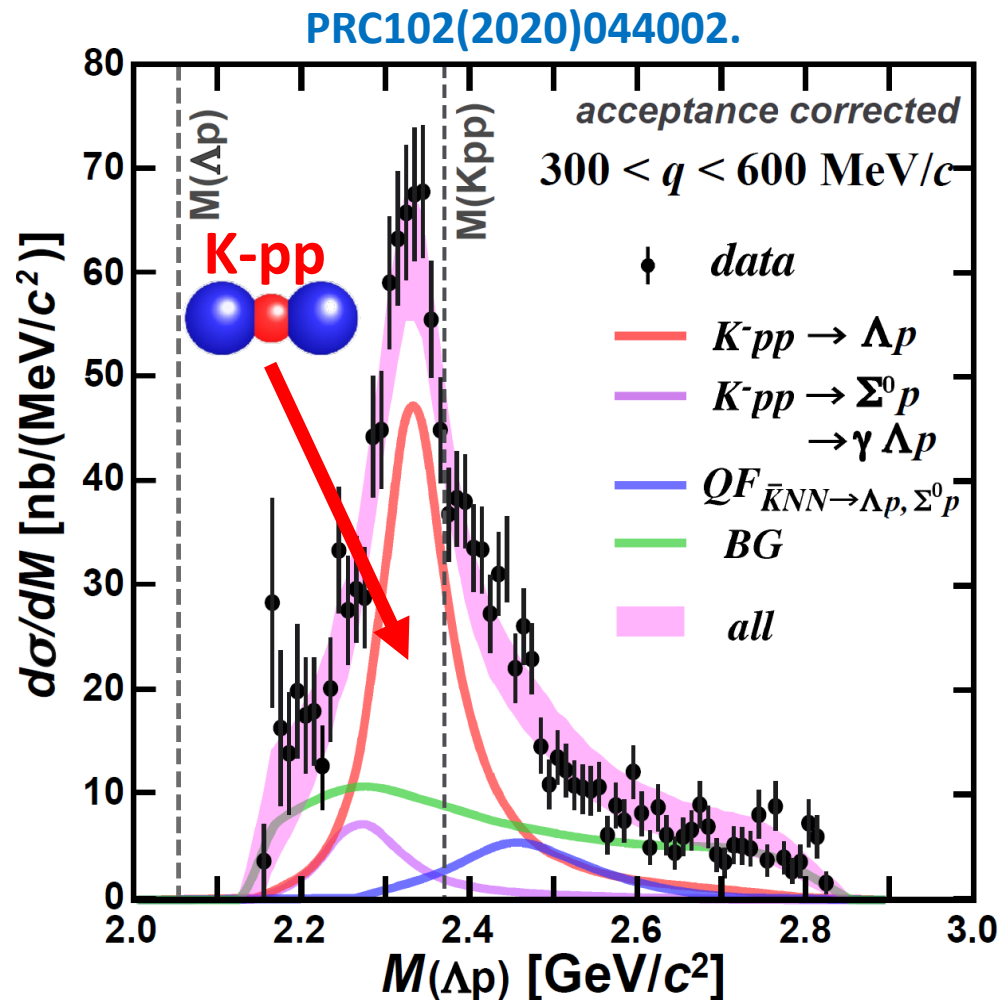
# Experimental Setup @ K1.8BR





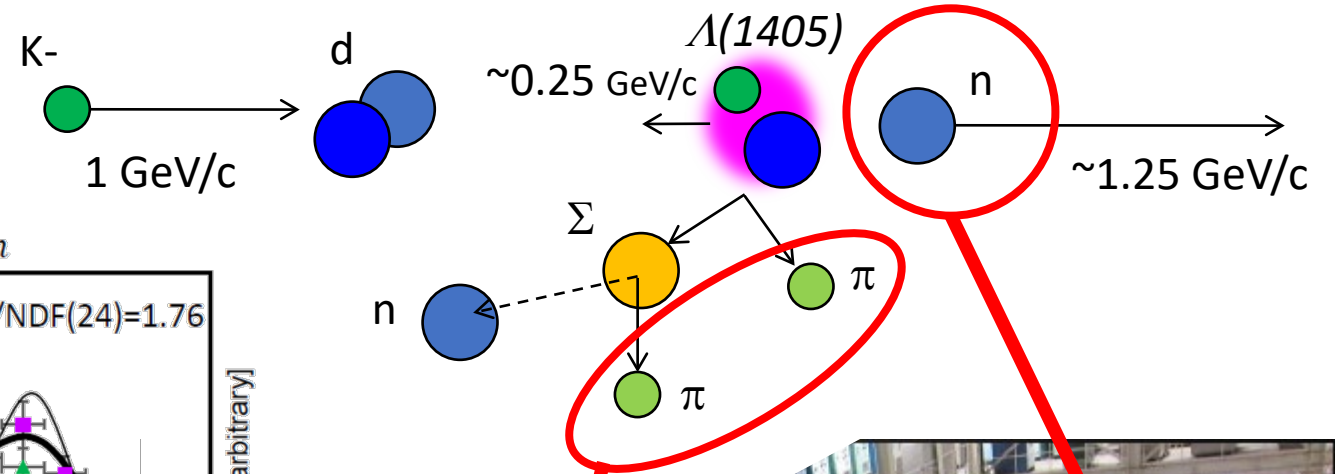
# J-PARC E15 Experiment

- Search for the “K-pp” bound state
  - “K-pp” was observed via its  $\Lambda p$  decay

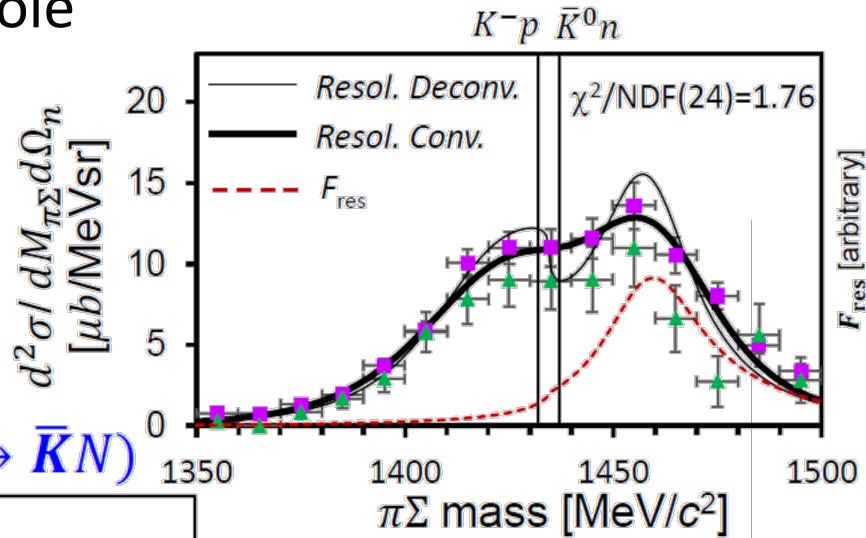


# J-PARC E31 Experiment

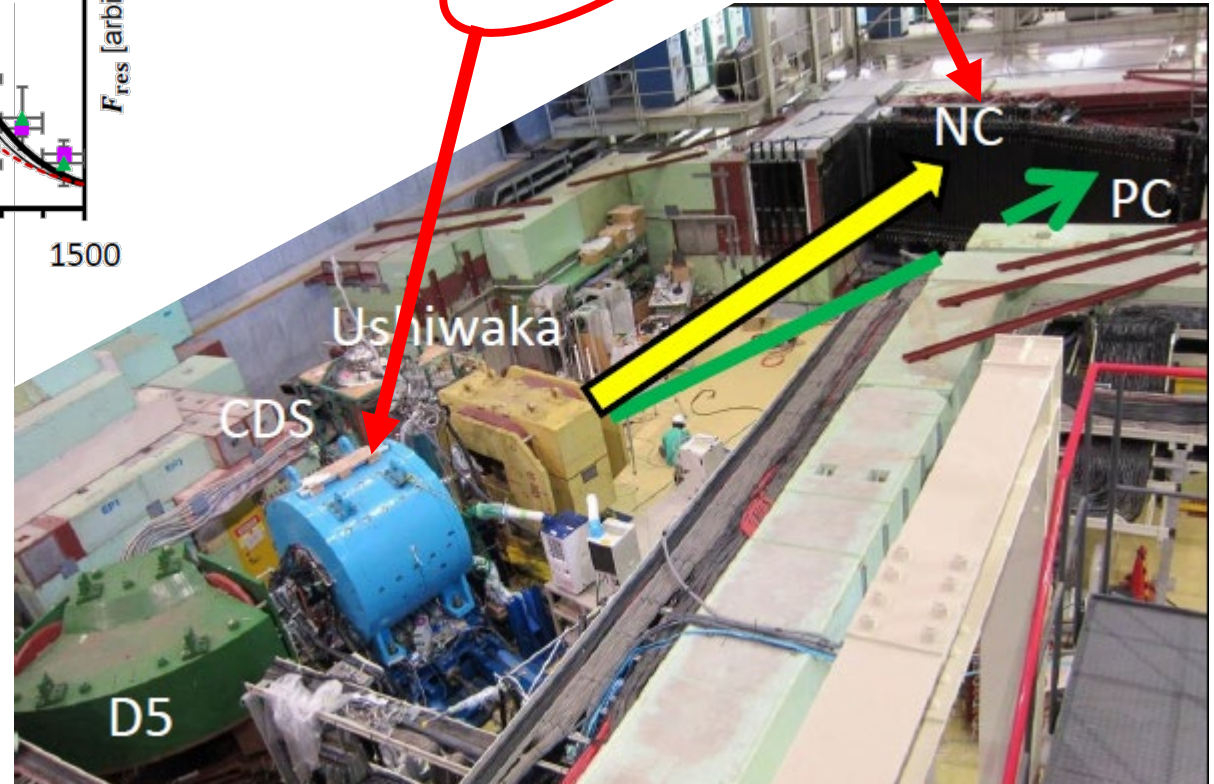
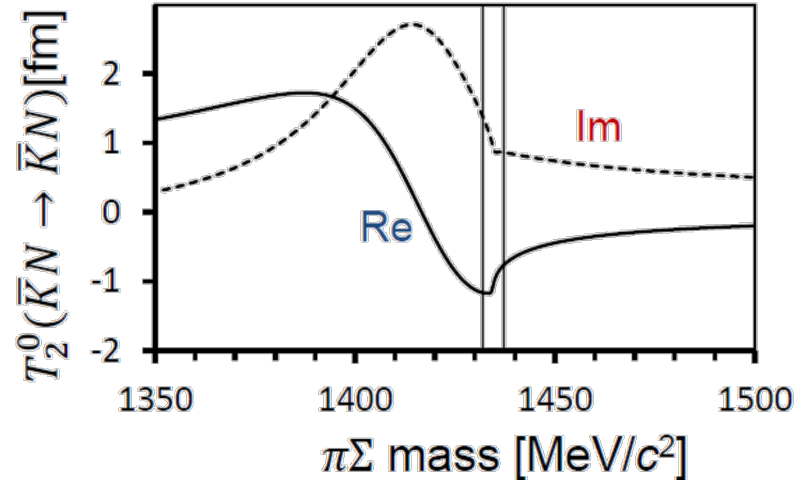
- Investigation of  $\Lambda(1405)$  line shape
  - Extracted  $K^{\text{bar}}N$  scattering amplitude and  $\Lambda(1405)$  pole



PLB837(2023)137637.



$$T_2^{I'}=0(\bar{K}N \rightarrow \bar{K}N)$$

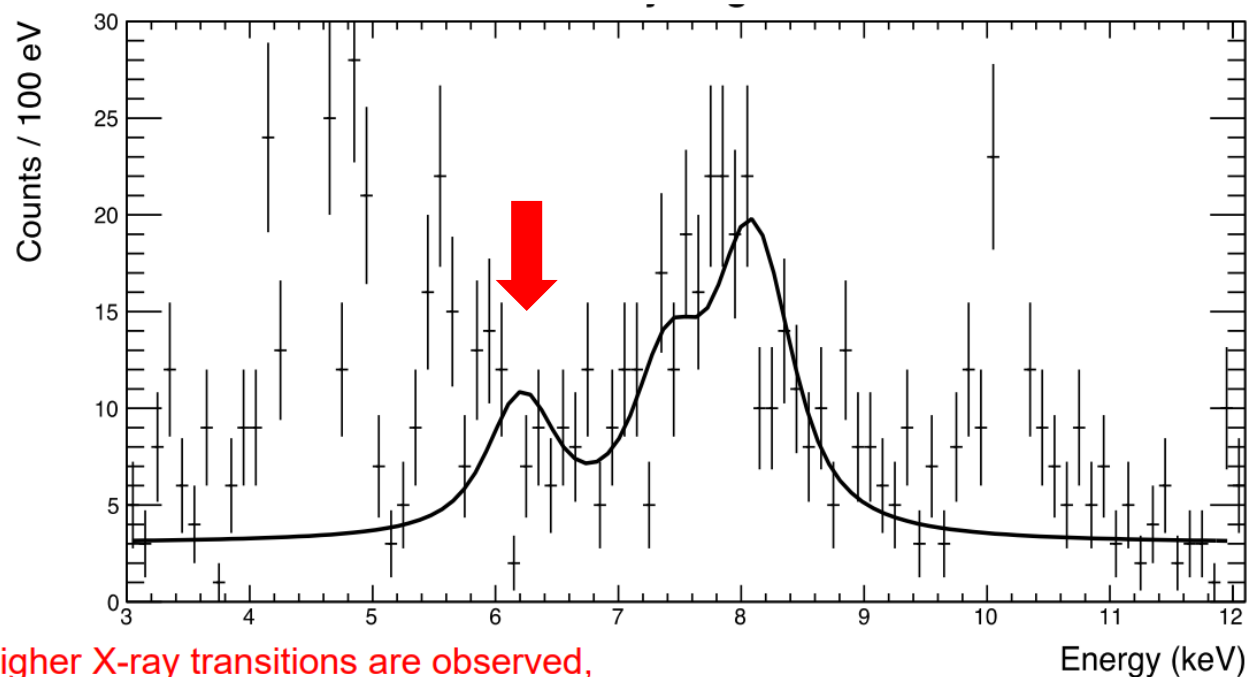




# J-PARC E57 Experiment

- Measurement of kaonic deuterium
  - will be continued as E57-2nd

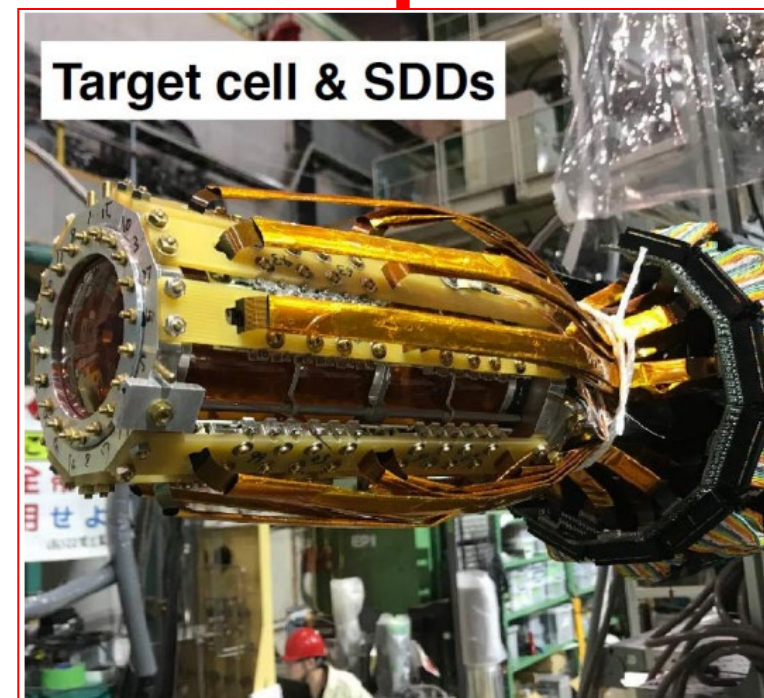
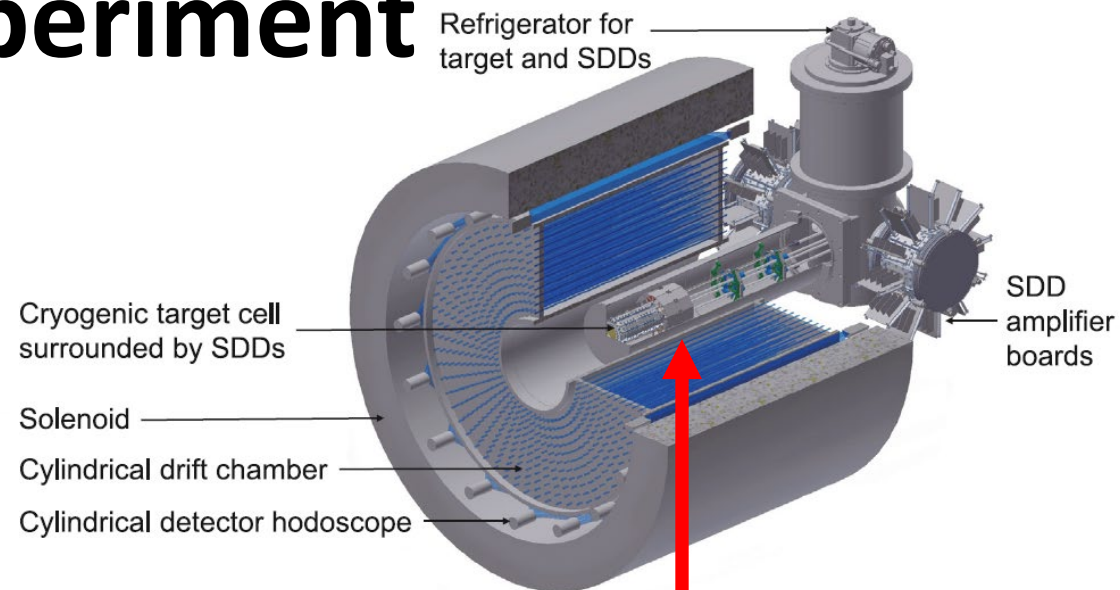
Kaonic Hydrogen spectrum with 90-hour data taking



Higher X-ray transitions are observed,  
 $K\alpha$  events less than expected

28th J-PARC PAC meeting July 17, 2019

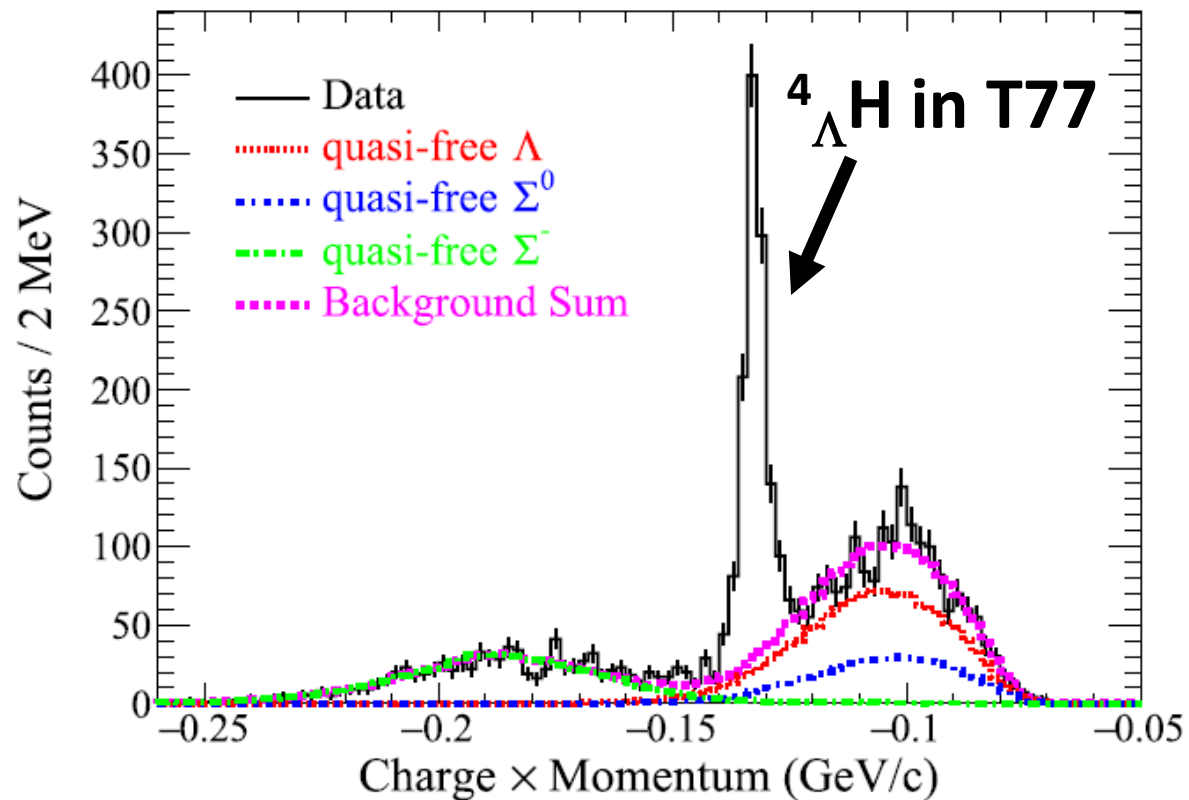
T. Hashimoto



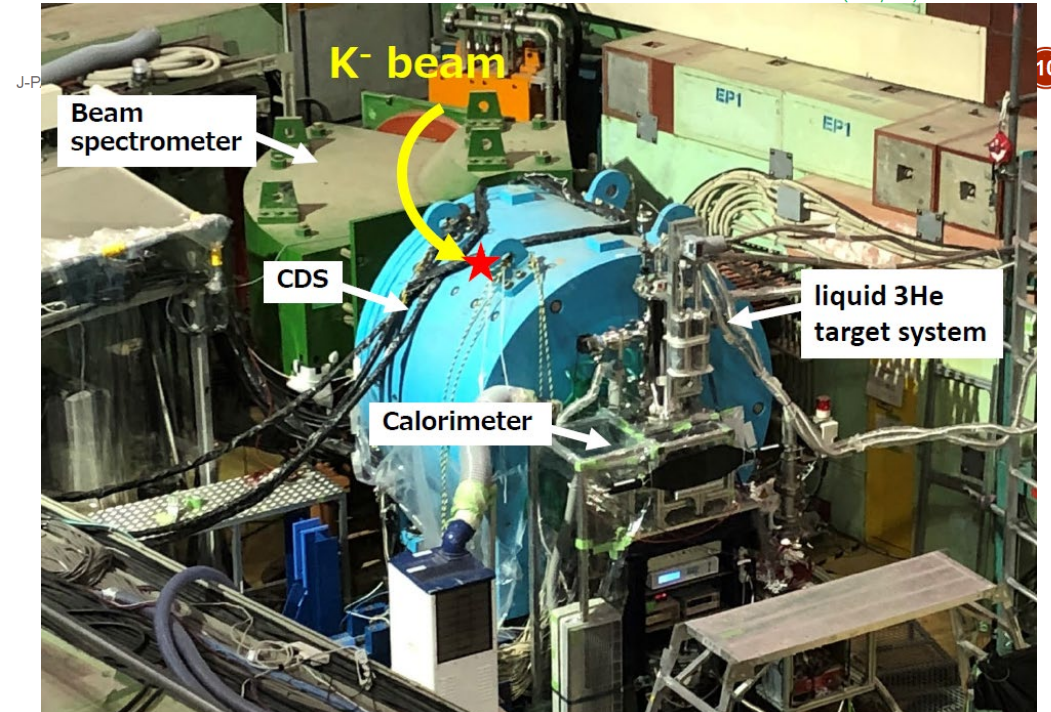
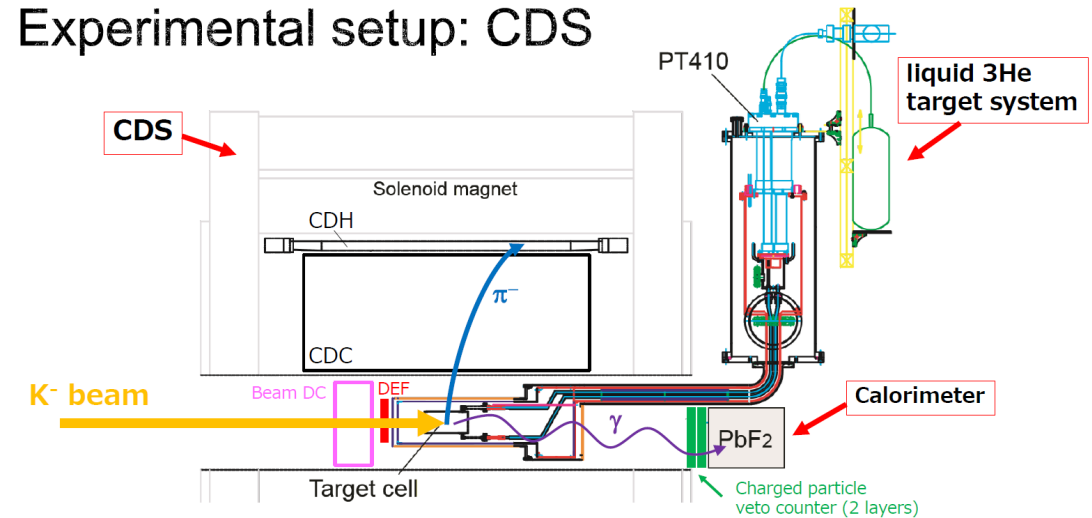
# J-PARC E73 Experiment

- Measurement of hyper-triton ( ${}^3_{\Lambda}\text{H}$ ) life-time via ( $\text{K}^{-}, \pi^0$ ) reaction
  - will be completed in Apr. & May., 2024

PLB845(2023)138128.

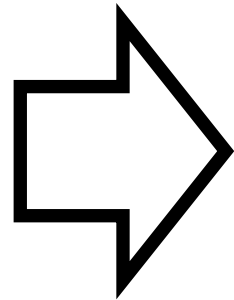
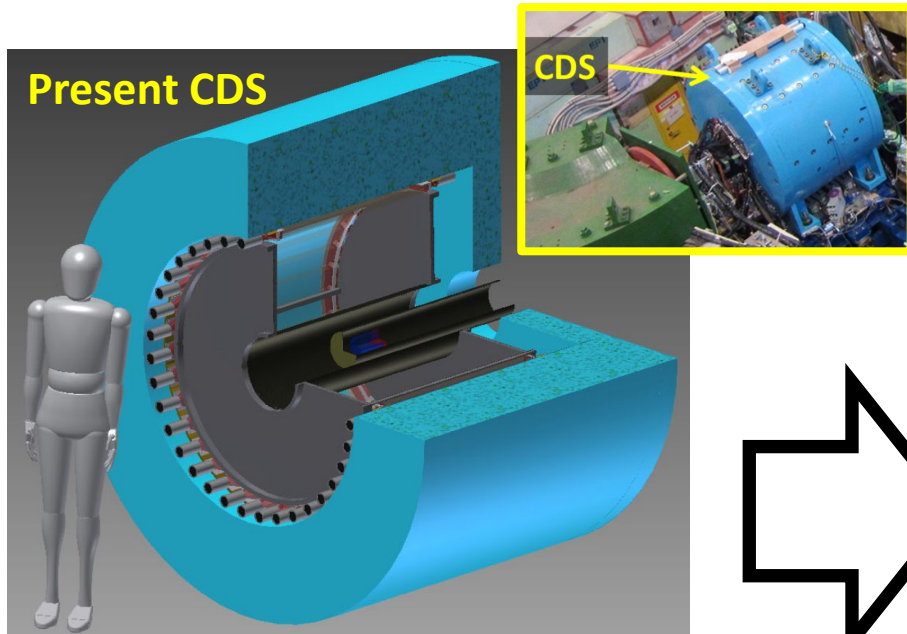


Experimental setup: CDS

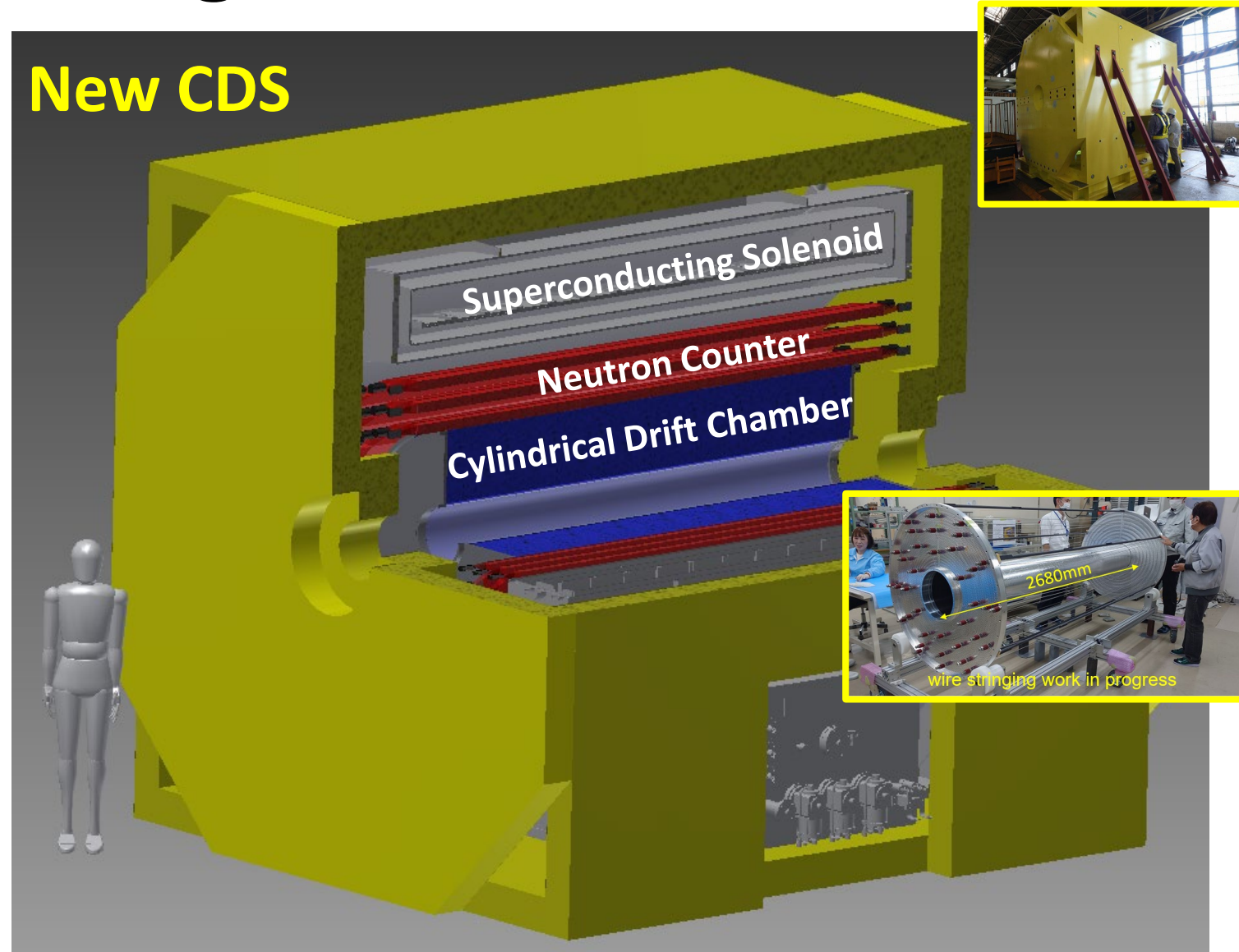




# New Large CDS for Systematic Investigation of Kaonic Nuclei



- ✓ Solid angle: **x1.6** (59% → 93%)
- ✓ Neutron eff.: **x8** (3% → 15%x1.6)



# J-PARC E80 Collaboration

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 M. Tsuruta<sup>f</sup>, E. Widmann<sup>d</sup>, T. Yamaga<sup>b</sup>, C. Yoshida<sup>f</sup>, and J. Zmeskal<sup>d</sup>

(J-PARC E80 Collaboration)

We're looking for  
 new collaborators!

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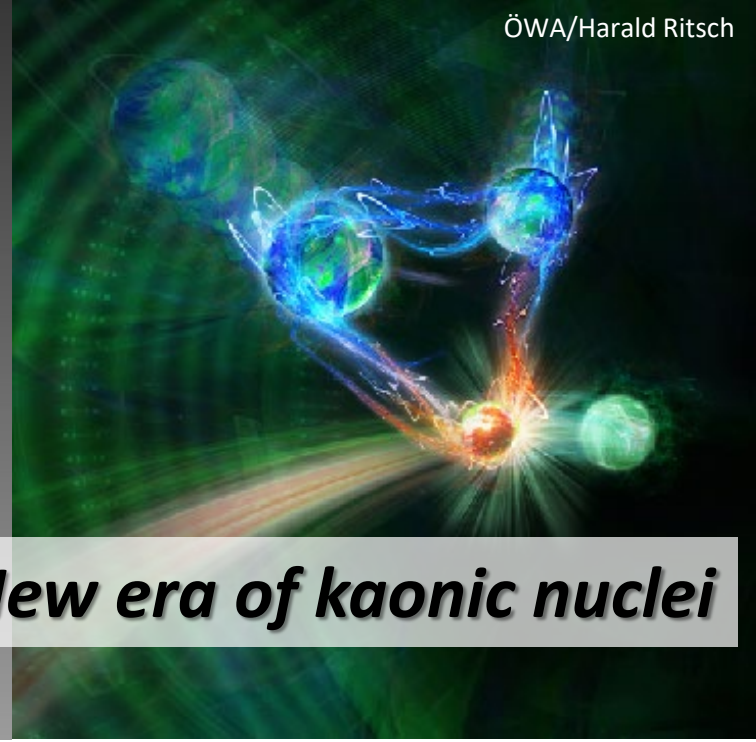
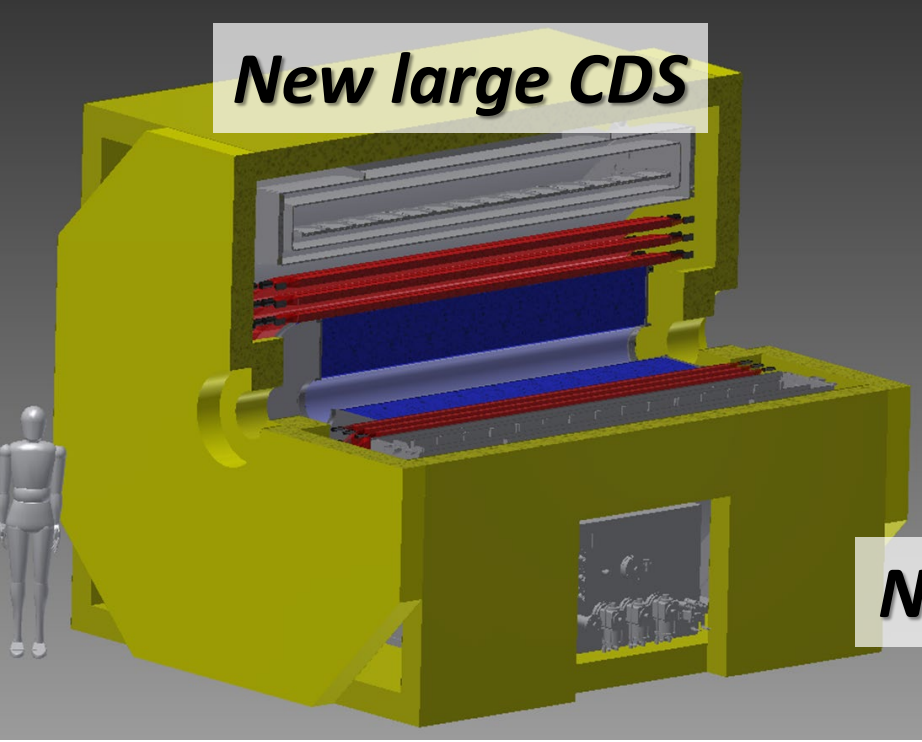
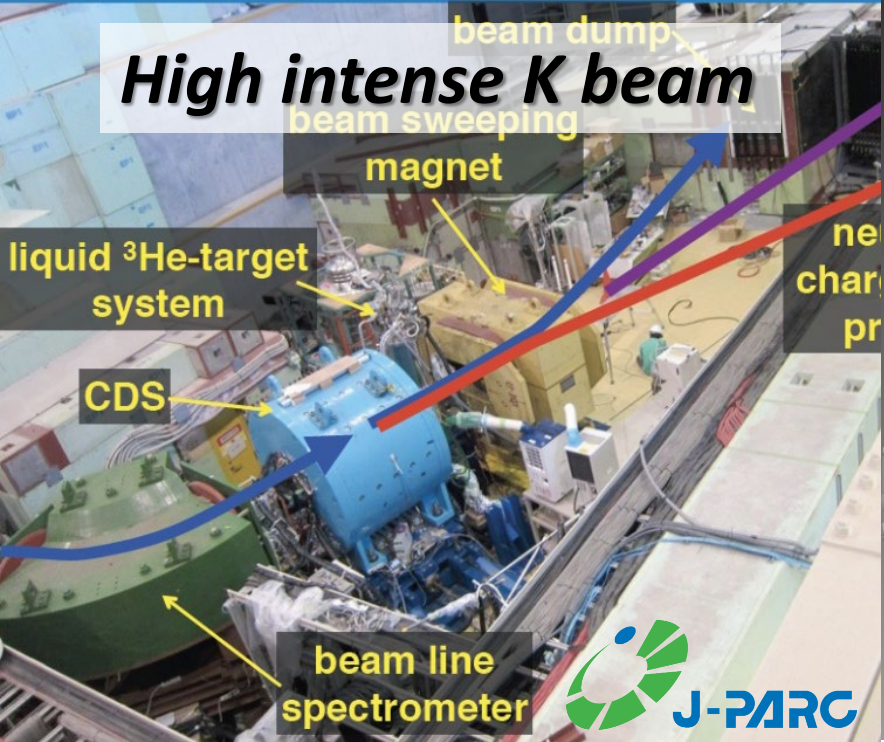
(i) Department of Physics, Kyoto University, Kyoto, 606-8502, Japan



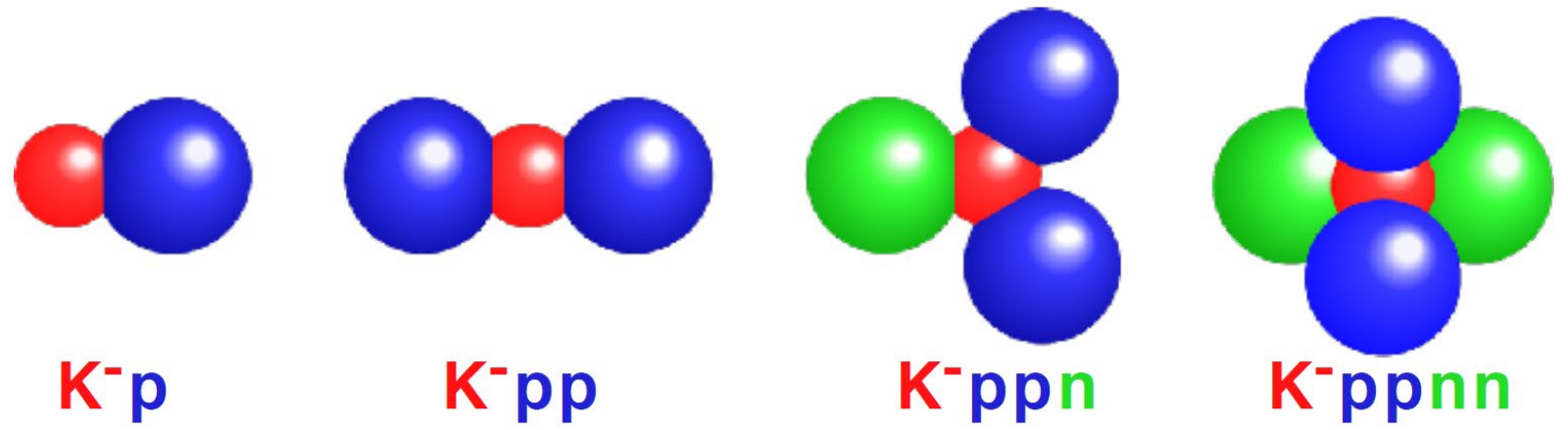
Tokyo Tech







**Thank you for your attention!**



**KEK/J-PARCには置き場が無い、  
このことで廃棄の危機。**

**是非ともRIBFでの有効な活用を  
お願いいたします！**