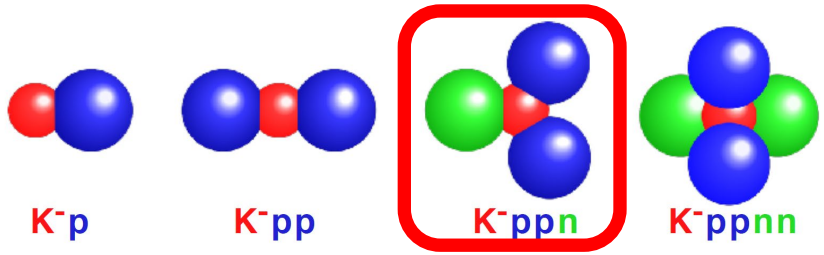
Status report on E80/P92

# Systematic Investigation of the Light Kaonic Nuclei

*– from the $\bar{K}N$ to $\bar{K}NNNN$ systems –*




**F. Sakuma, RIKEN**

on behalf of

the J-PARC E80/P92 collaboration

37th J-PARC PAC meeting, Jan 24-26, 2024

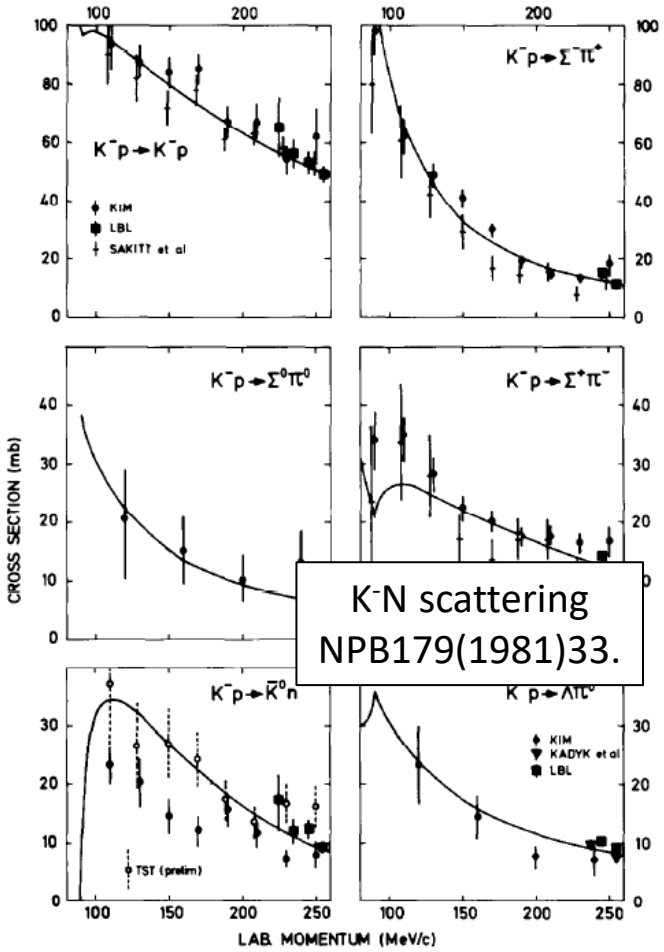
# Physics Goal

Reveal the meson properties inside nuclei via **the $\bar{K}N$ interaction**

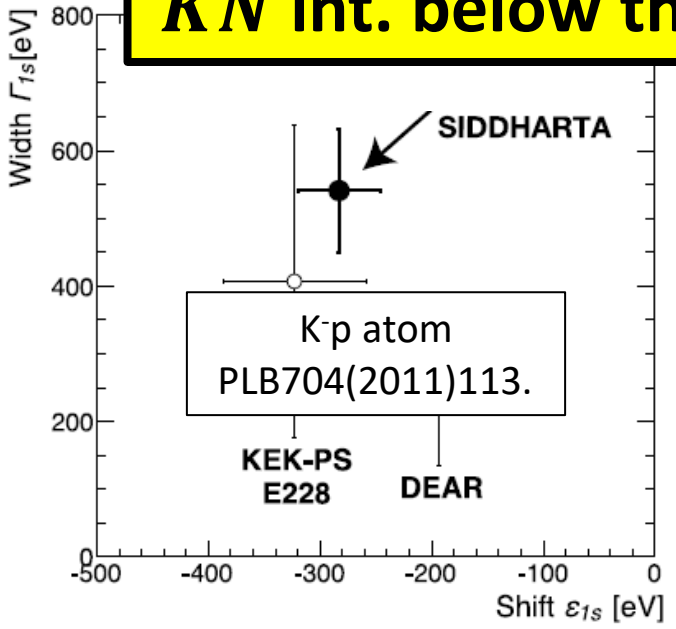
A powerful probe to understand low energy QCD

Strongly attractive in I=0 from extensive measurements

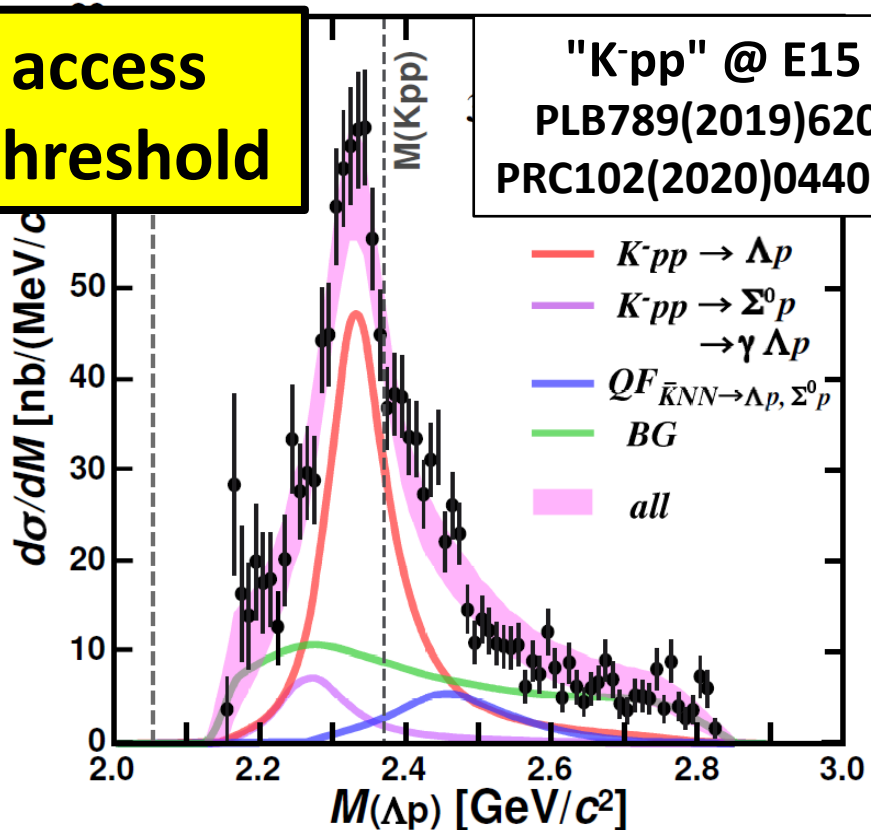
**Kaonic nuclei can access $\bar{K}N$ int. below the threshold**




K⁻N scattering
NPB179(1981)33.




K⁻p atom
PLB704(2011)113.



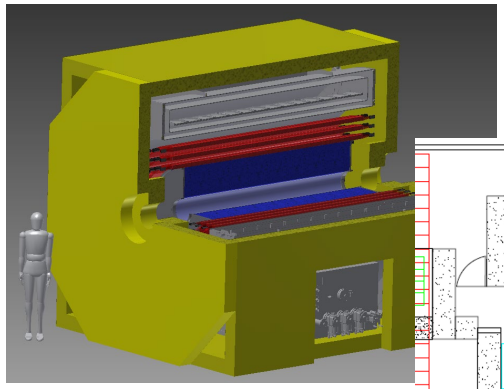

**"K⁻pp" @ E15**
**PLB789(2019)620.**
**PRC102(2020)044002.**

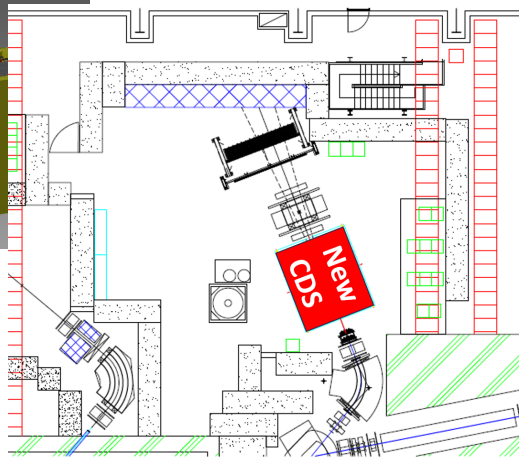
# Strategy

***- for systematic study from the $\bar{K}N$ to $\bar{K}NNNN$ systems -***

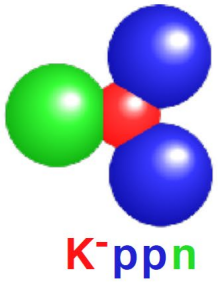
| | Reaction | Decays | Key | Experiment |
|---|---|---|---|---|
| $\bar{K}N$ | d($K^-$,n) | $\pi^{\pm 0}\Sigma^{\mp 0}$ | n/$\gamma$ identification | Future |
| $\bar{K}NN$ | $^3$He($K^-$,N) | $\Lambda$p/$\Lambda$n | polarimeter | P89 |
| $\bar{K}NNN$ | $^4$He($K^-$,N) | $\Lambda$d/$\Lambda$pn | large acceptance | E80 (P92) ← **A first step** |
| $\bar{K}NNNN$ | $^6$Li($K^-$,d) | $\Lambda$t/$\Lambda$dn/$\Lambda$pnn | many body decay | Future |
| *$\bar{K}\bar{K}NN$* | *$\bar{p}$ + $^3$He* | *$\Lambda\Lambda$* | *$\bar{p}$ beam yield* | *Future (LoI)* |

- To realize the systematic measurements, we need
  - ☐ **a large acceptance spectrometer** ← **new CDS**
    - detect/identify all particles to specify the reaction
  - ☐ **high-intensity kaon beam** ← **improved K1.8BR**
    - more $K^-$ yield than the existing beamline






*We take a **step-by-step** approach*




# $\bar{K}NNN$ @ E80

*via $^4$He(1 GeV/c $K^-$, n) reaction*

① **Establish the existence of $\bar{K}NNN$**

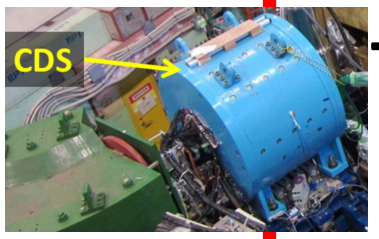
- "K-ppn"→Λd 2-body decay

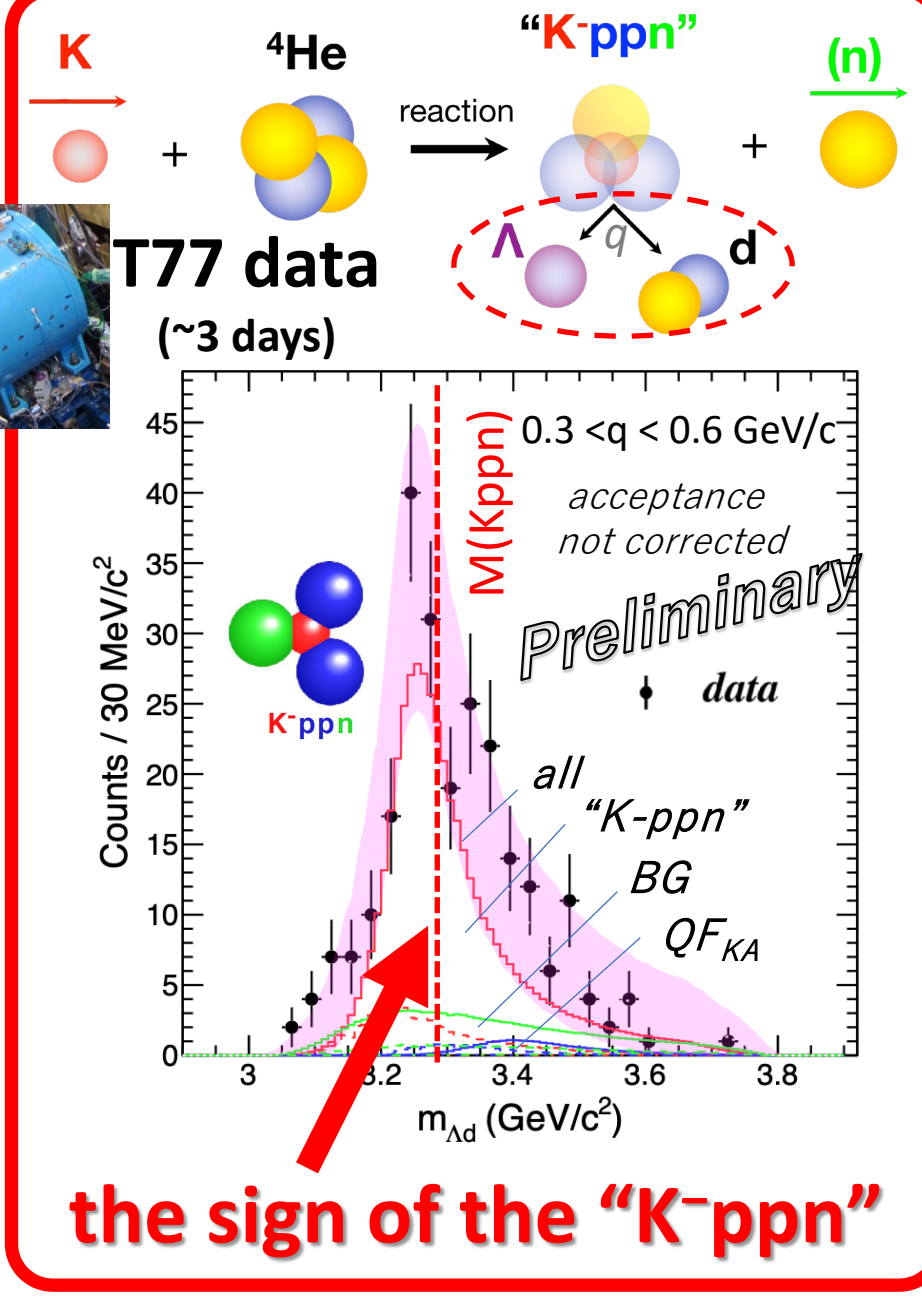
② **Study the multi-particle decay mode of $\bar{K}NNN$ toward understanding its internal structure**

- "K-ppn"→Λpn 3-body decay

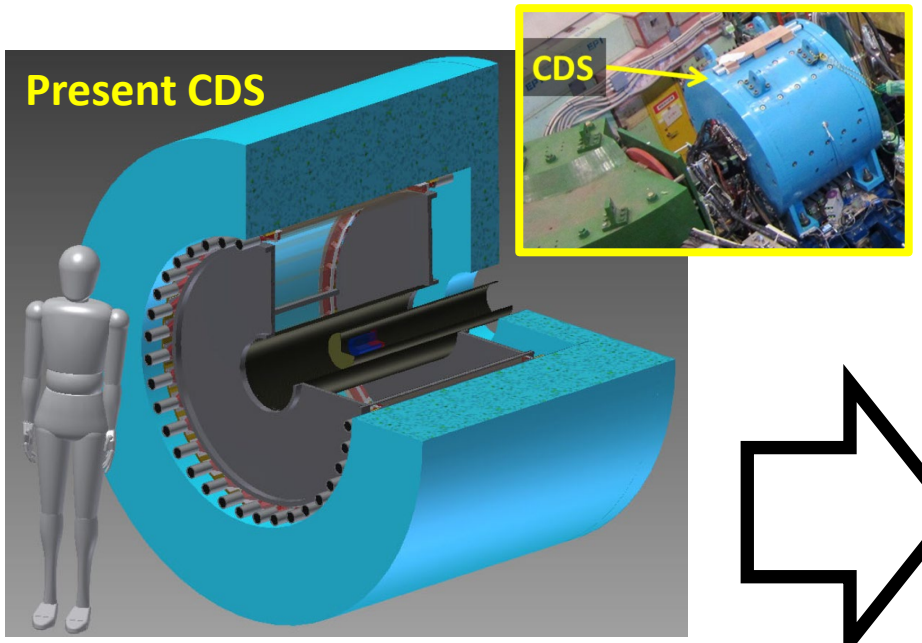
- **Feasibility study of spin-spin correlation measurement for P89**
  - *e.g.*, installing a prototype module of a polarimeter

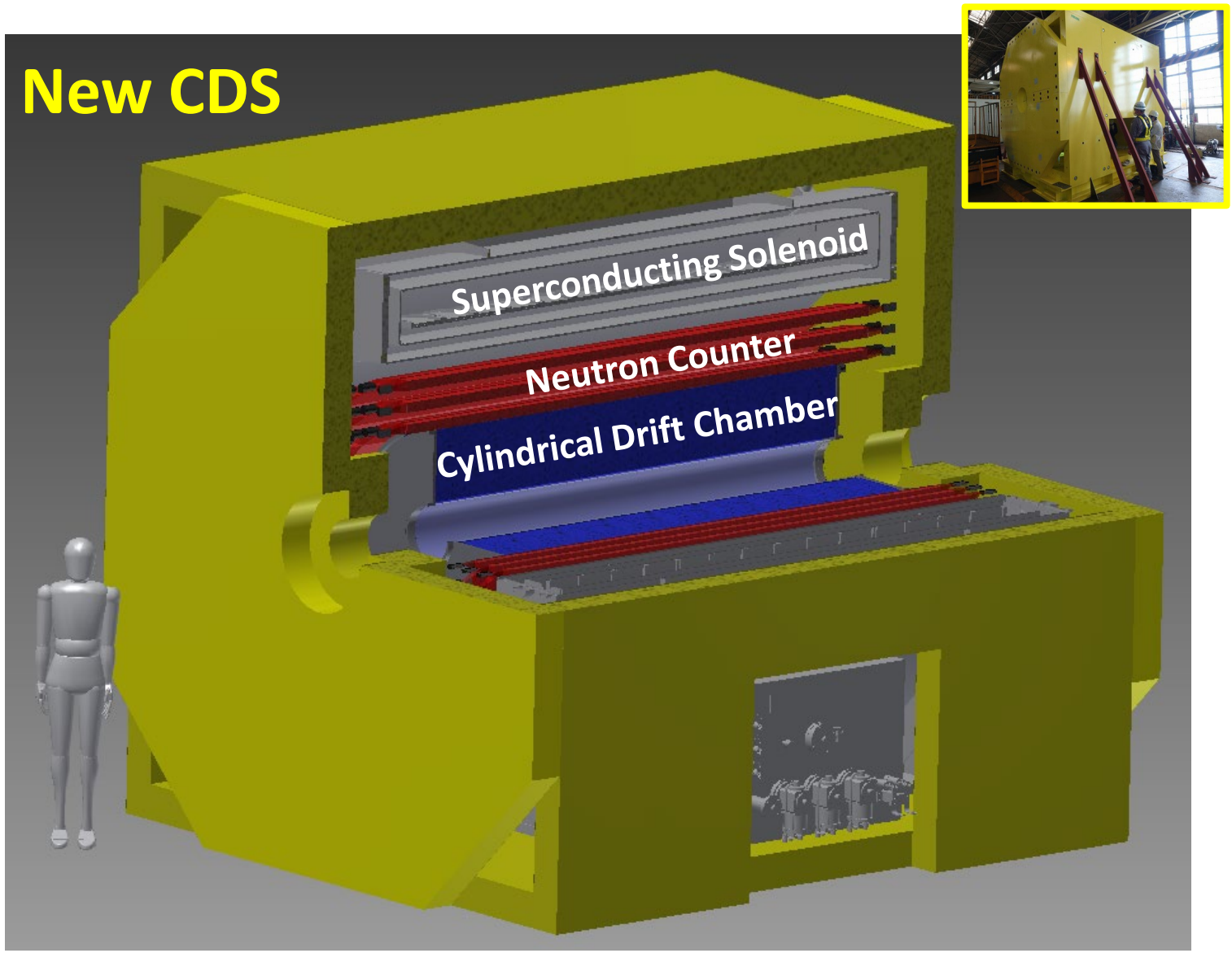
| Beam intensity | 90kW |
|---|---|
| Beam time | 1+1+3 weeks |



# New CDS




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

# Superconducting Solenoid Magnet

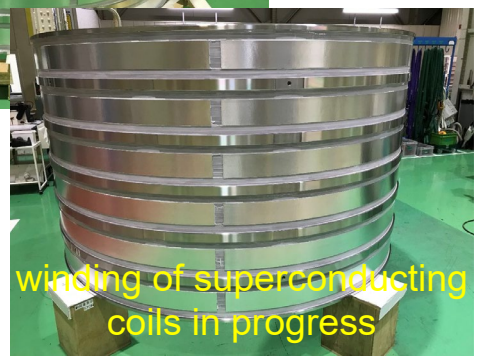
- Same design as “the detector solenoid magnet” for COMET-I

**being constructed in cooperation with the J-PARC Cryogenics Section**

- 3.3m x 3.3m x 4.1m, ~125t in total
- Max. field of 1.0T @ center
  - 189A – 10V
- NbTi/Cu SC wire, 98km in total
- **Conduction-cooling with GM*3**
- Semi-active quench-back system
- **Will be completed in FY2024**

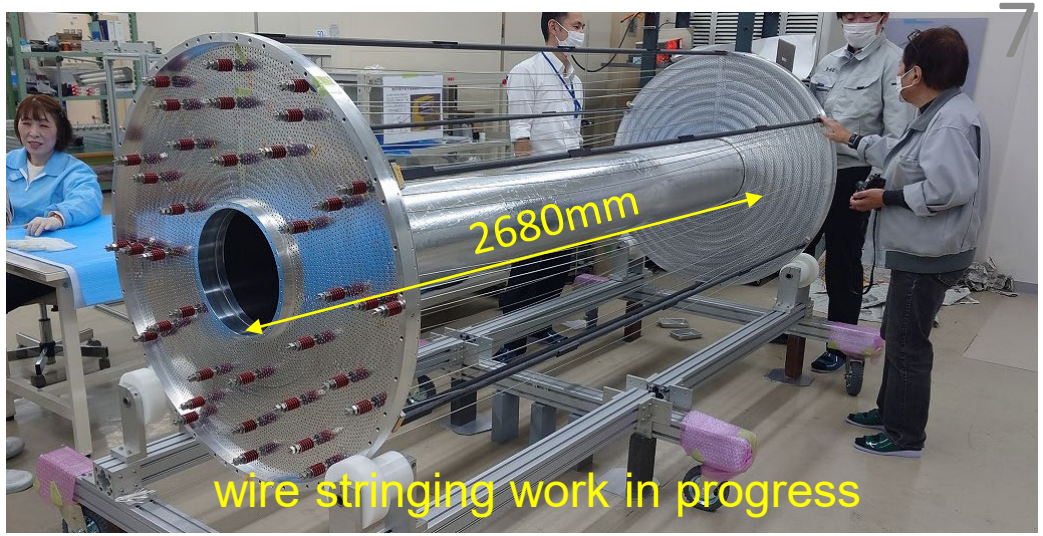
SHI FA-50
(air cooling)


SHI RDE-418D4

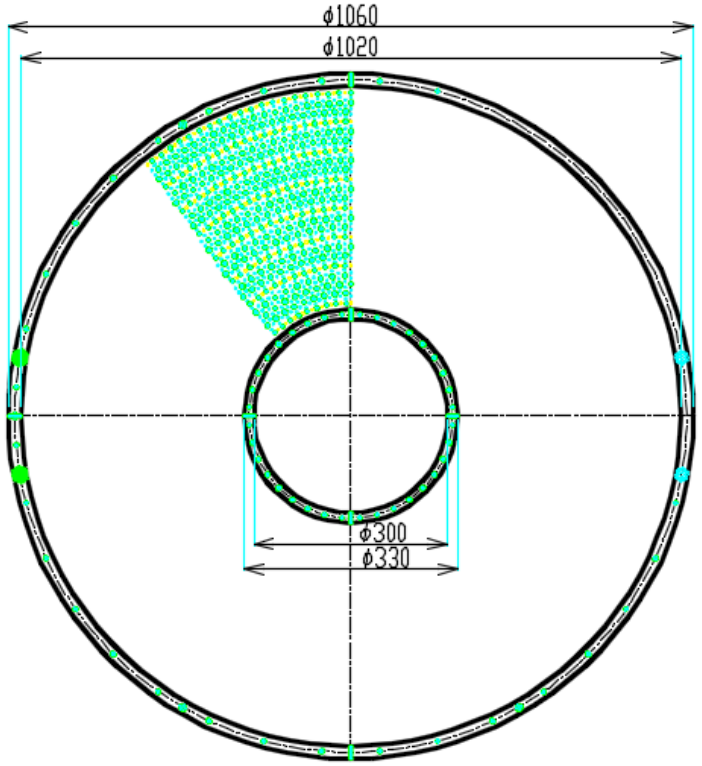


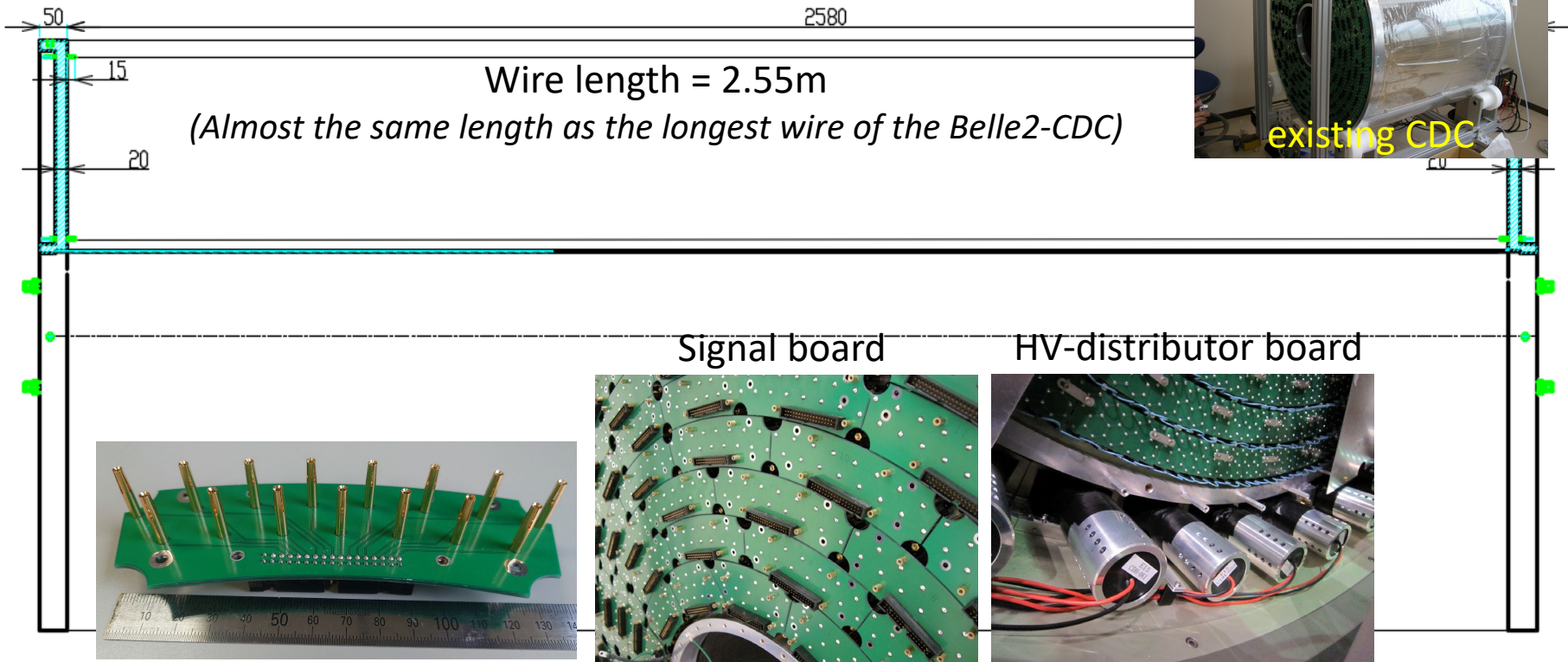

# Cylindrical Drift Chamber

- The same design of the present end-cap
  - Reuse the existing Signal/HV-distributor boards and readout systems
  - New CDC is 3 times the length of the existing CDC




**Will be completed in the first half of FY2024**





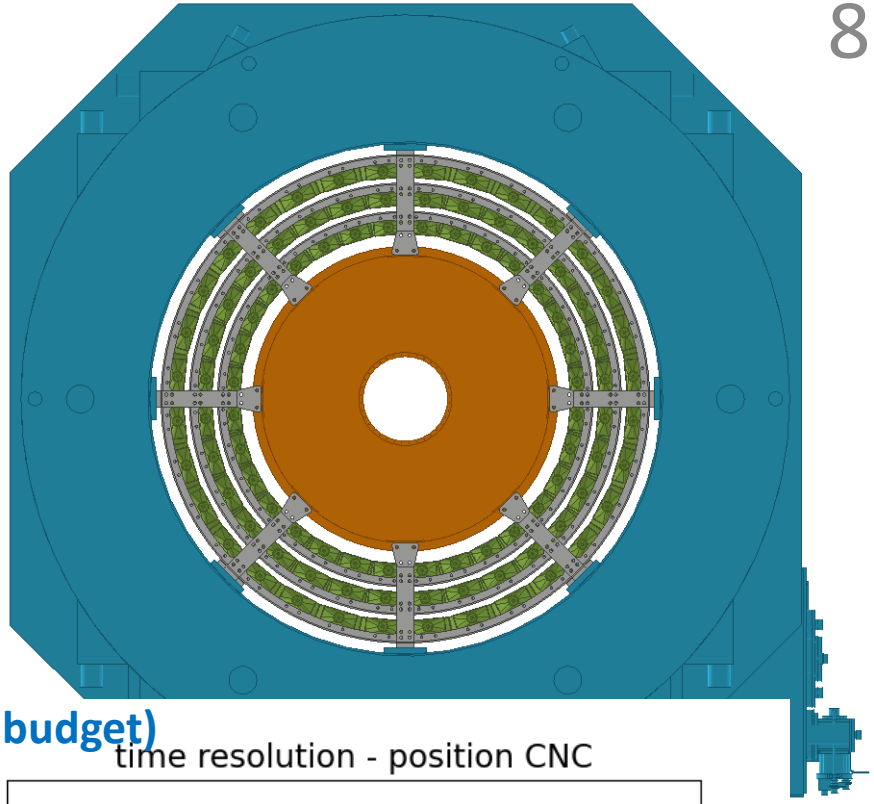


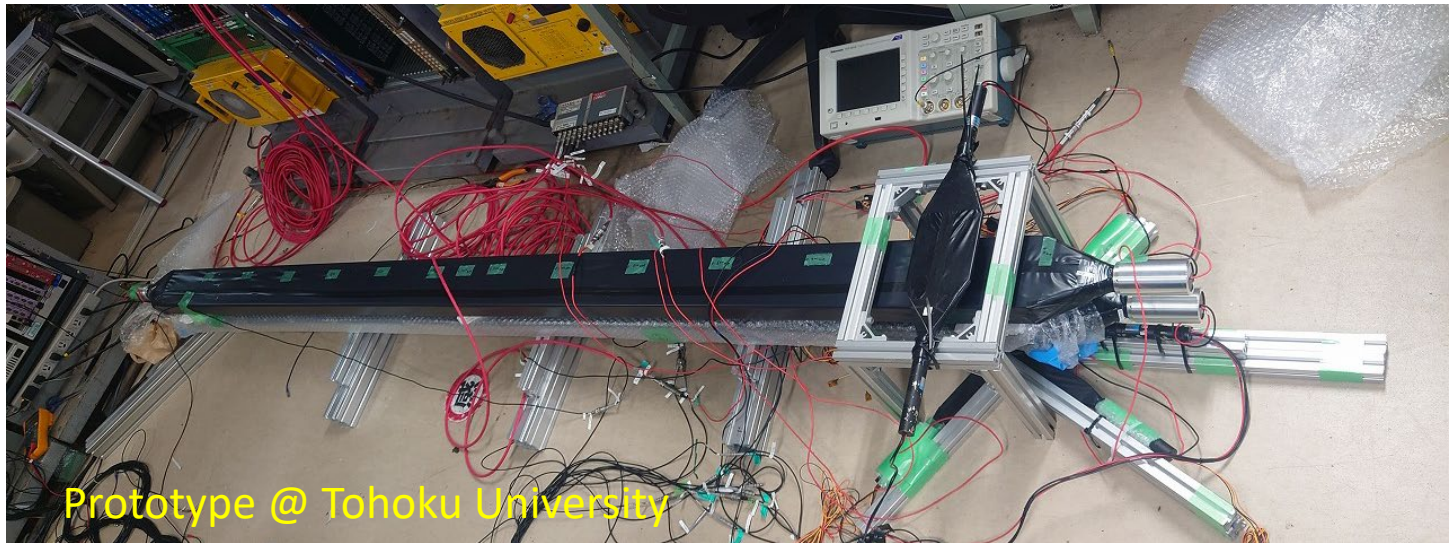
Signal board

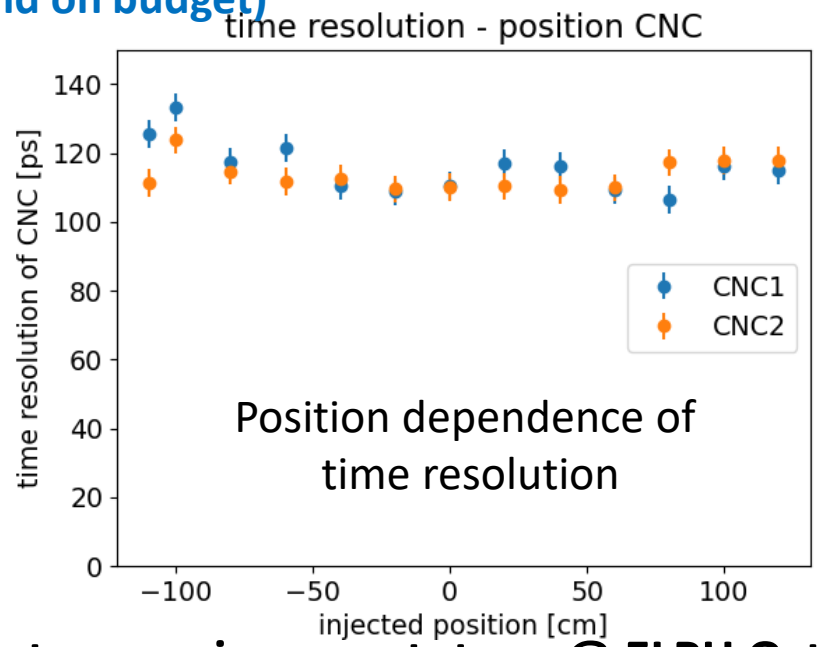
HV-distributor board

# Neutron Counter

- scintillator array: 3 layers, 32 segments
- ELJEN EJ-200: (T)50mm, (W)~130mm, (L)~3,000mm
- 1.5-inch FM-PMT [H8409(R7761)]
- Neutron detection efficiency of ~15%
- **Design will be finalized soon**
- **Will be fabricated in FY2024** **(# of first productions will depend on budget)**






**Test exp. using a prototype @ ELPH Oct.2023**

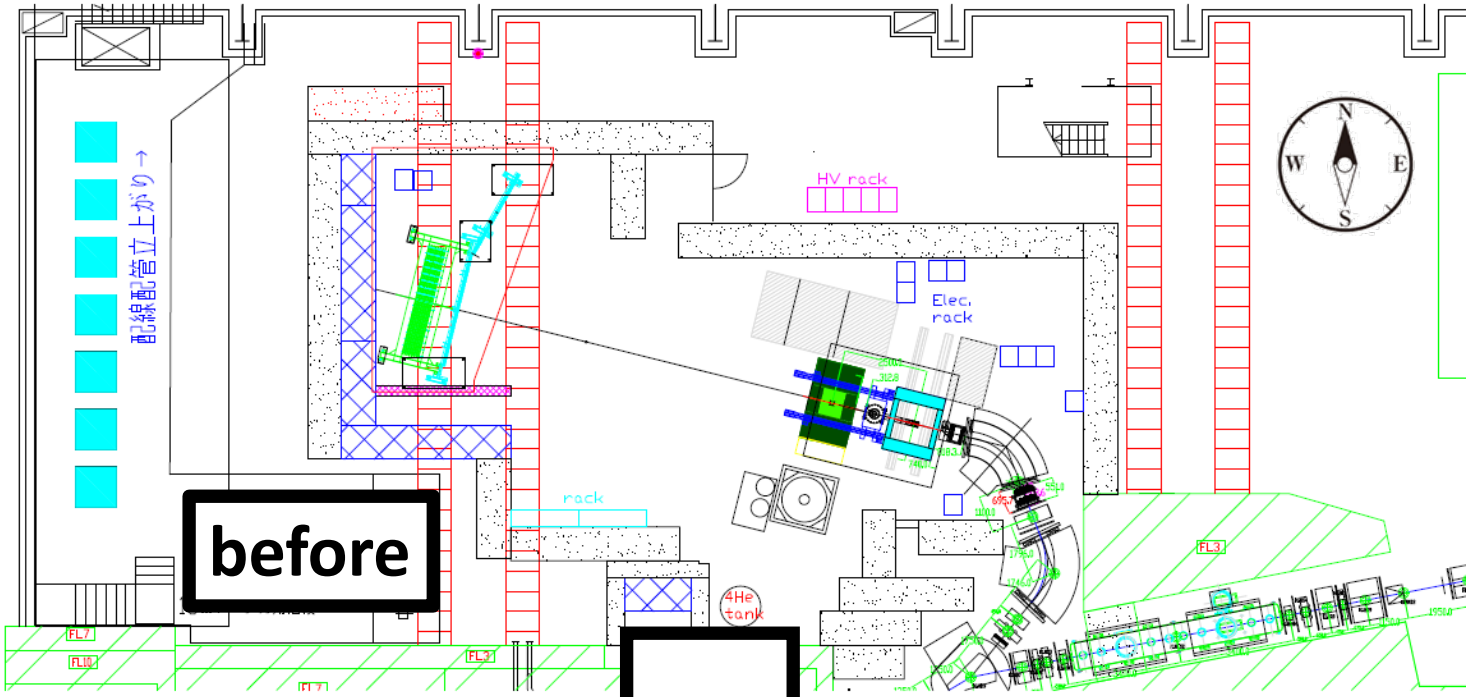
# K1.8BR Upgrade

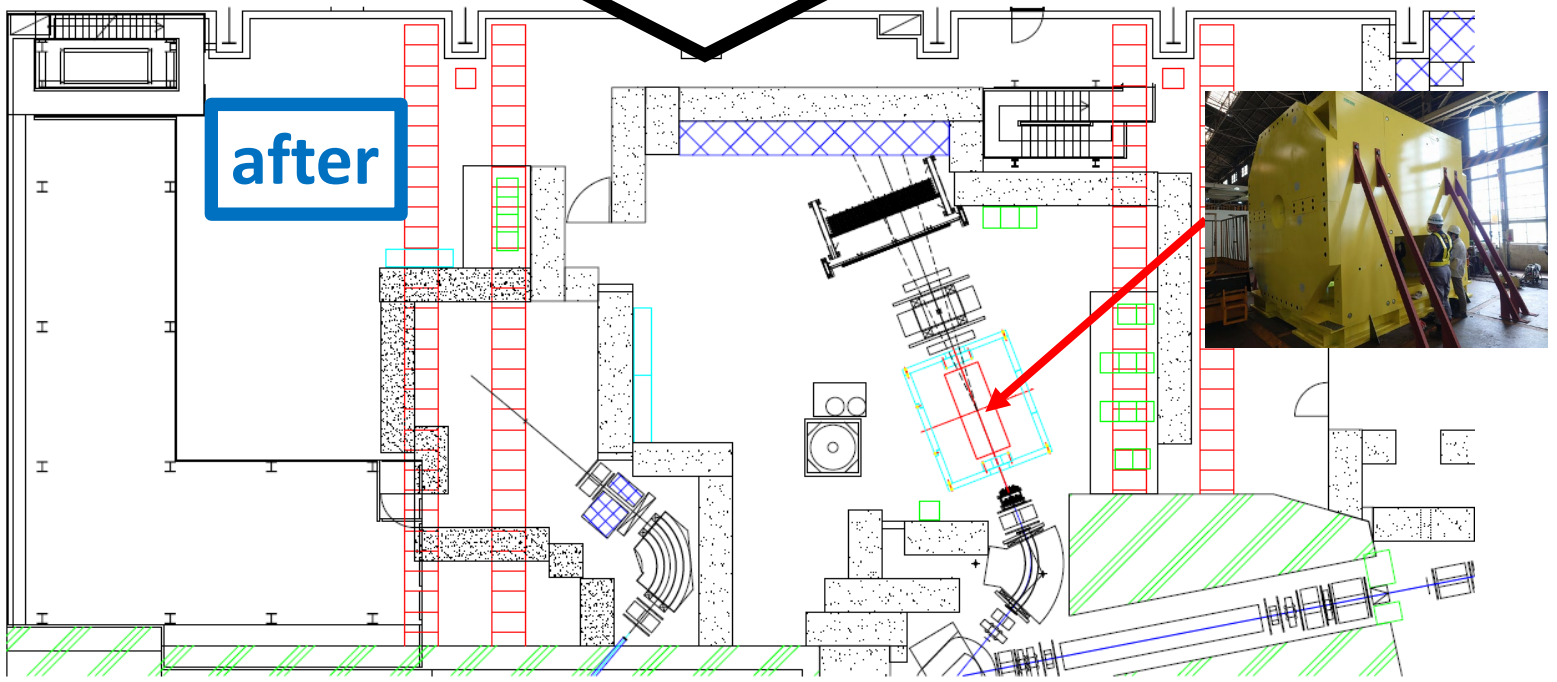
- **We have proposed a new configuration of the beam line**
  - ➢ K- yield is expected to increase by **~ 1.4 times @ 1.0 GeV/c** with π/K ~ 2

***Will contribute to electricity savings***

Shorten the beamline (~2.5m) by removing the final D5 magnet

| Relative beam-line length (m) | D5 | D4 |
|---|---|---|
| Present CDS | 0 | -3.7 |
| New CDS | +1.2 | **-2.5** |

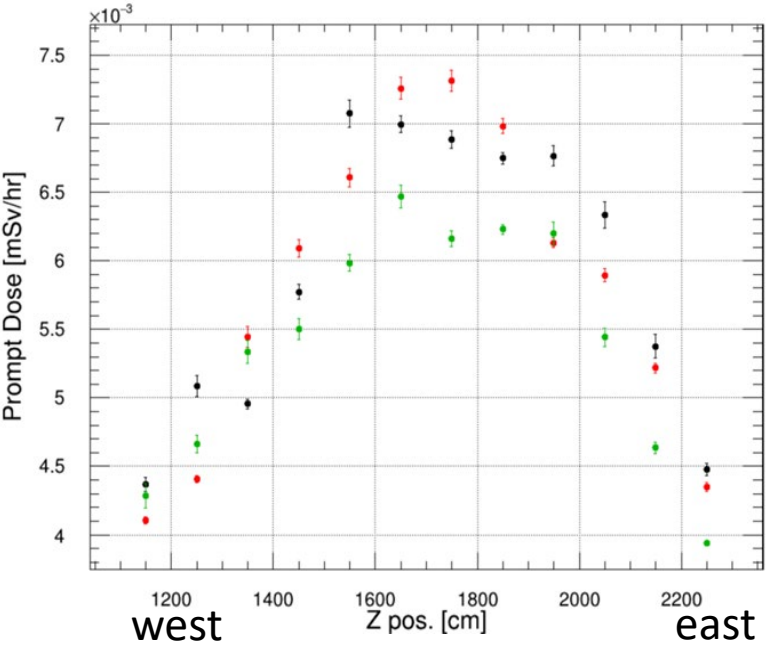


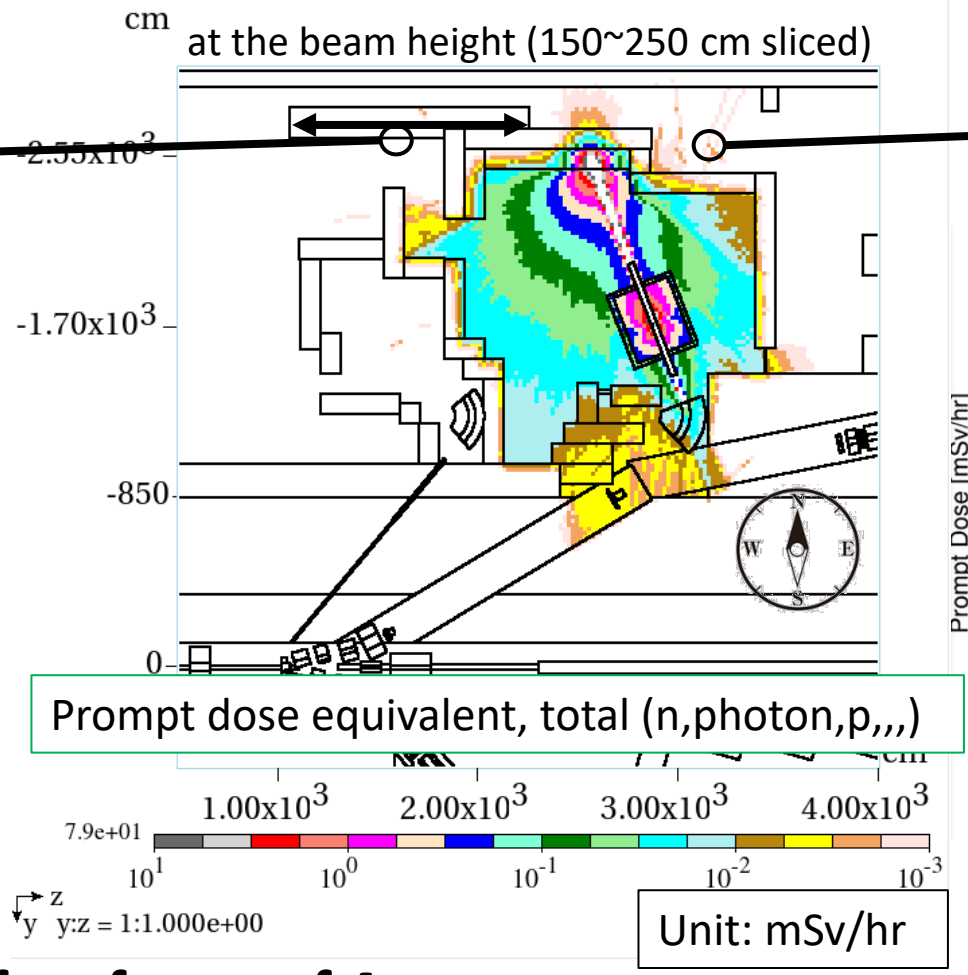



# Shielding Calculation using MARS

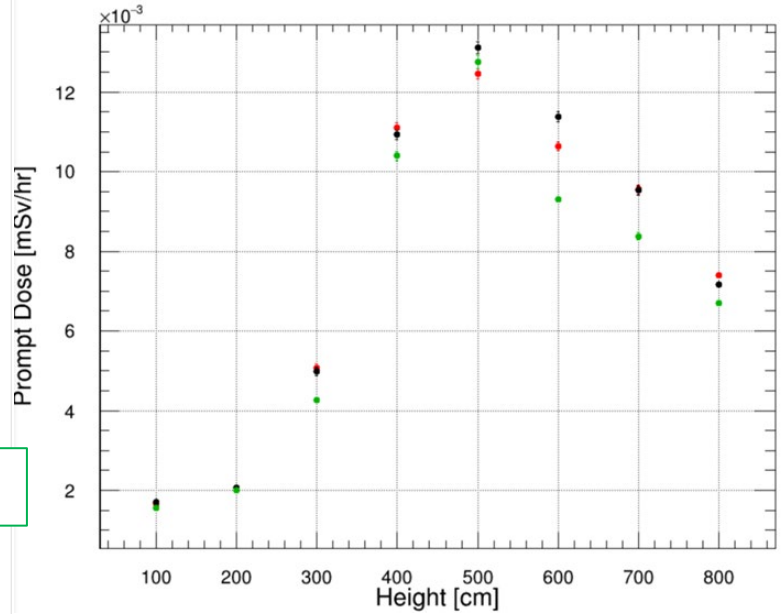
- ✓ 1.0 GeV/c pion
- ✓ intensity: $1.8 \times 10^{10}$/h → 30M/6s → 5 M/sec.

Catwalk position, east-west dependence




Stair position, up-down dependence



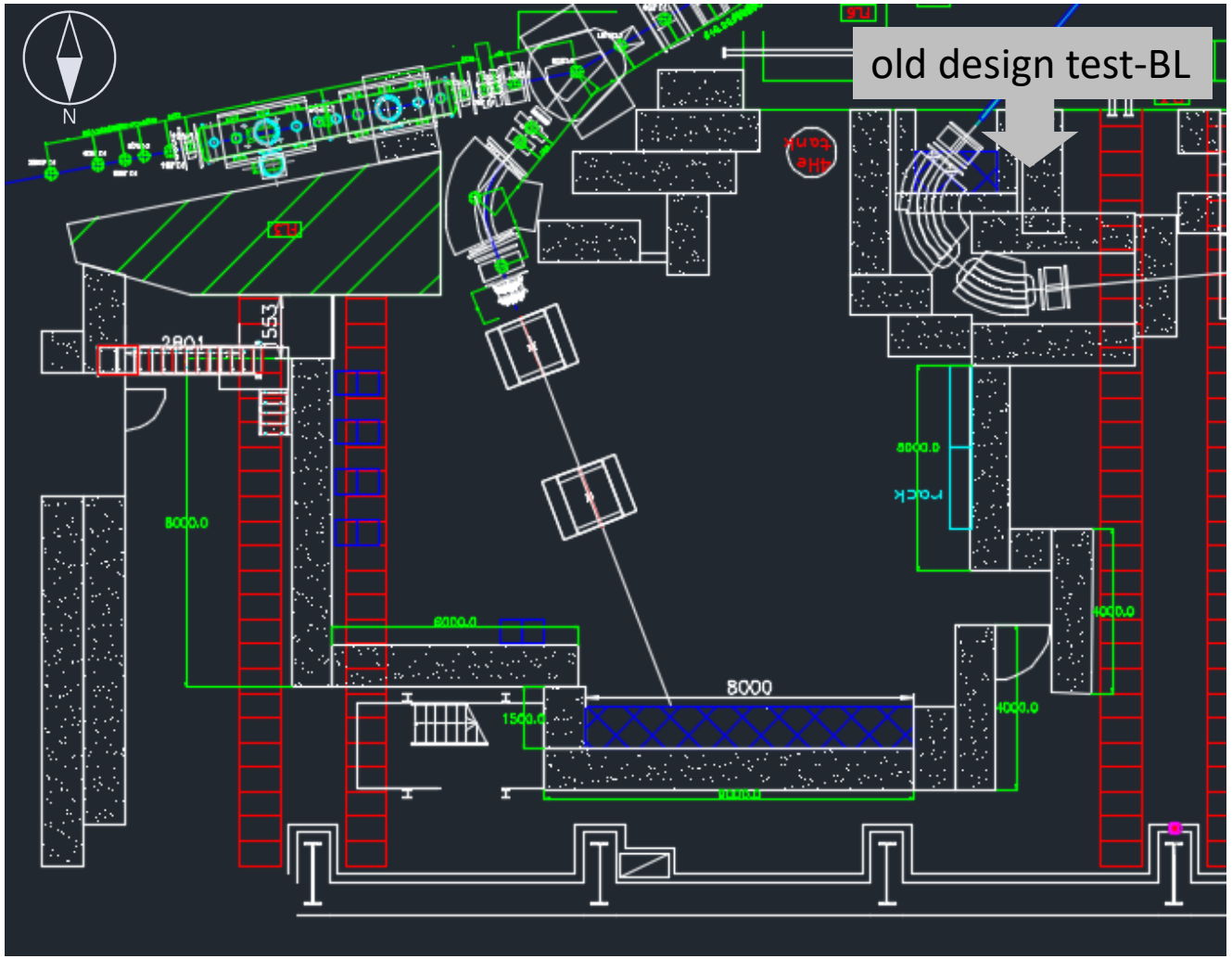

- Calculated optics
- Calculated optics (δy' x 3)
- pencil beam from D4

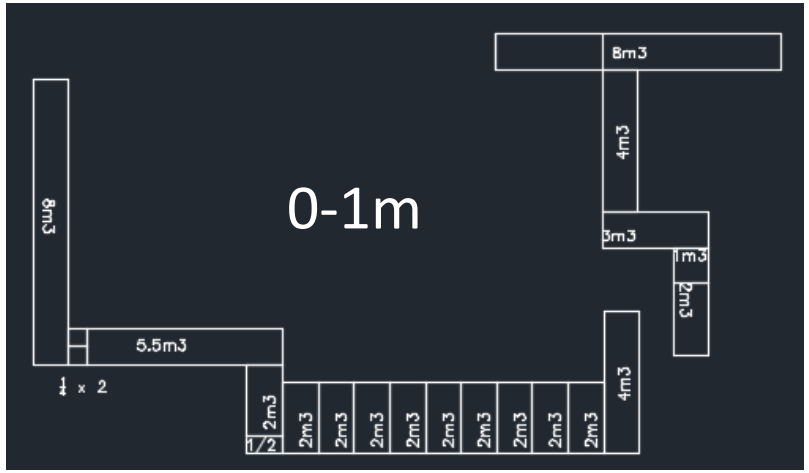
**The results include safety factor of 4**

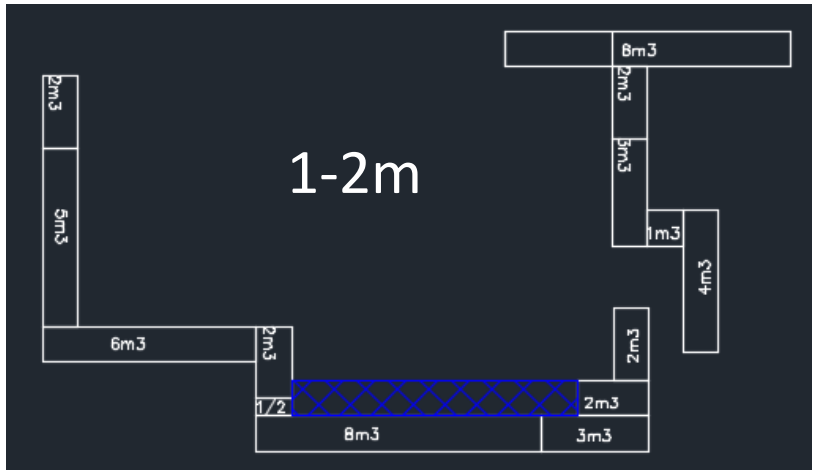
→ **Radiation level is below the limit of 25 μSv/h outside of the area**

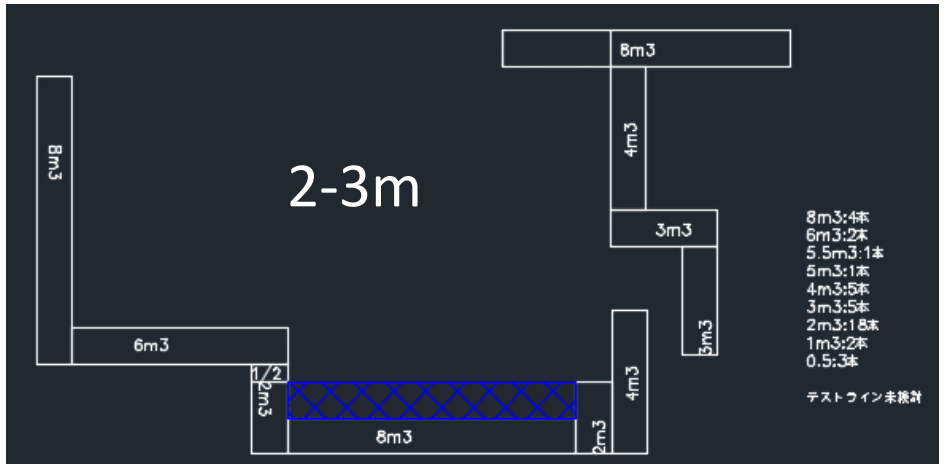
# Shield Reconfiguration

(thanks to HD-G Hirose-san)



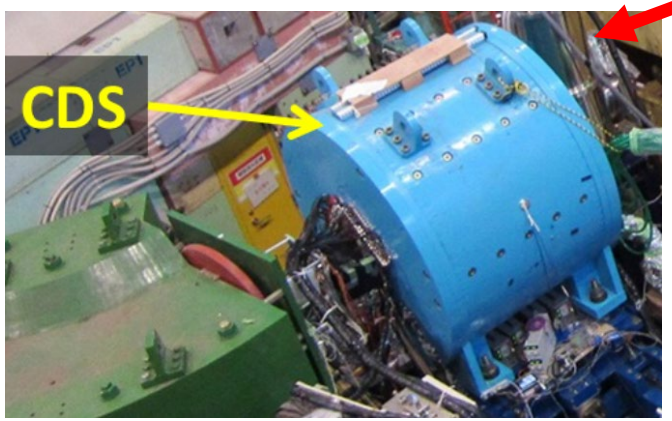



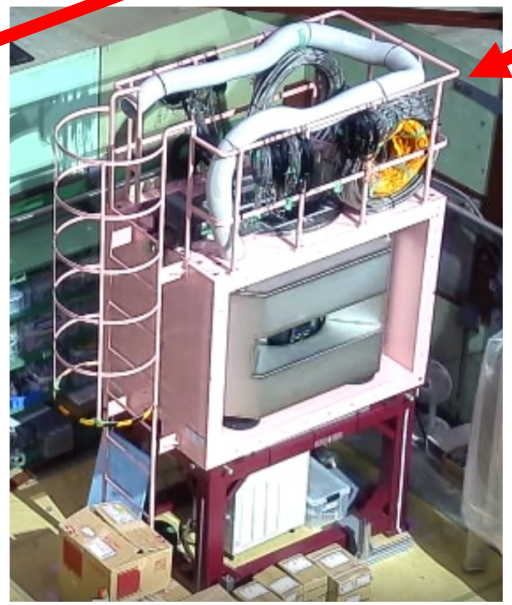

**possible to reconfigure shields with existing ones**

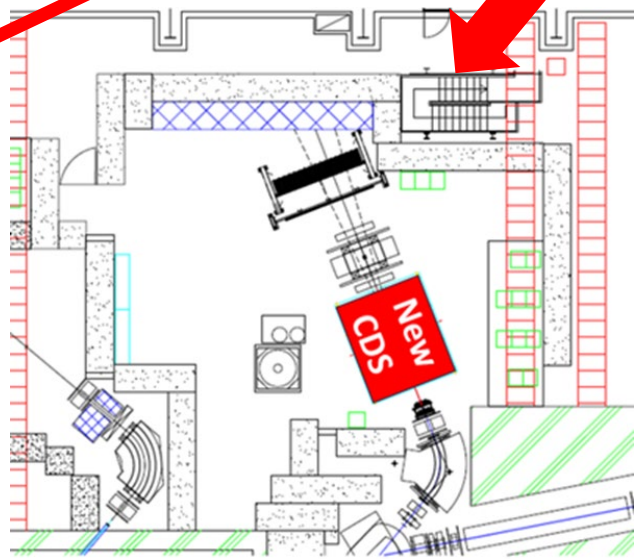
# Schedule

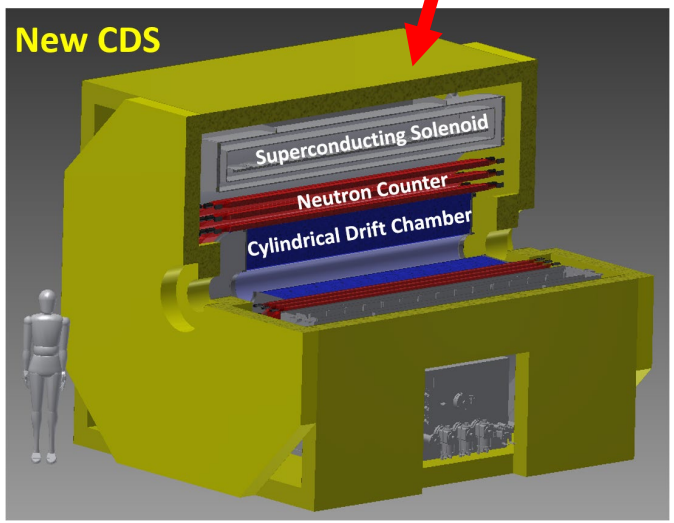
now

| | FY2022 | | | | FY2023 | | | | FY2024 | | | | FY2025 | | | | FY2026 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| SC Solenoid | Design | | Purchase (SC Wire) | | Construction | | | | | | | | | | Instration | Integration | | | Commissioning | Physics Run |
| NC | Design | | | | | | | | Purchase (Scinti.) | | Assembly | | Test & Commissioning | | | | | | | |
| CDC | Design | | | | Construction | | | | | | Test & Commissioning | | | | | | | | | |
| K1.8BR Beam Line | E73(CDS) | | | | | | | | E72(HypTPC) | | | | Upgrade | | | | E80 | | | |





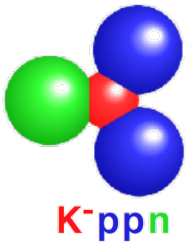



# Summary

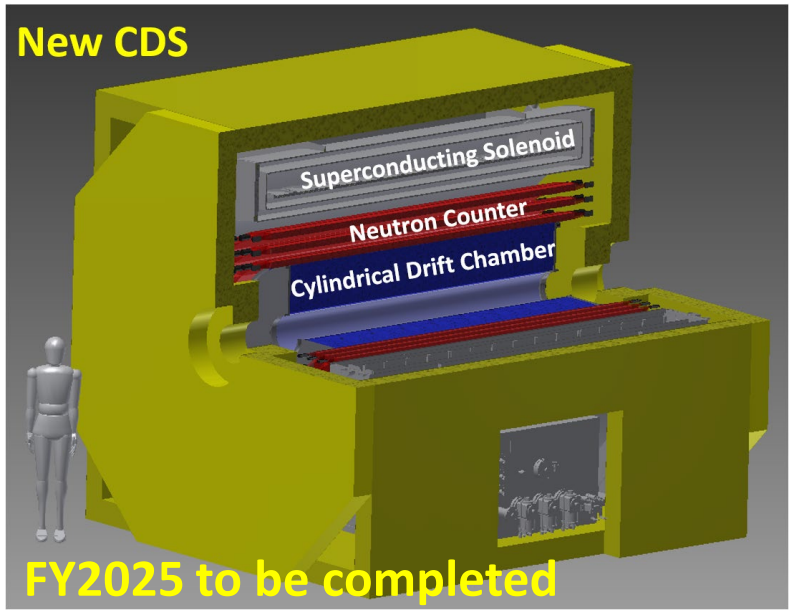
**E80** investigates the **"K⁻ppn"** bound state, toward the systematic study of the kaonic nuclei

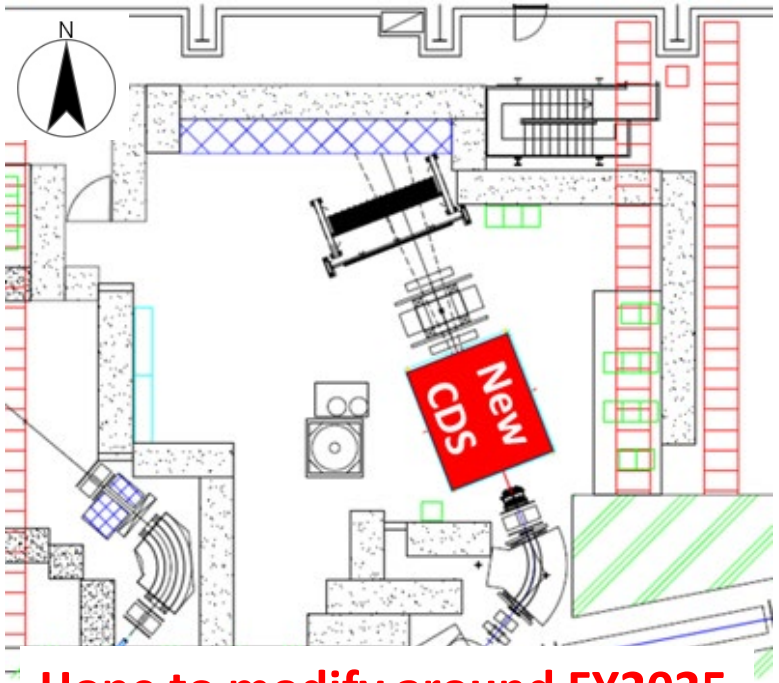
- **Constructing a large solenoid spectrometer**
- **Modify the K1.8BR to improve kaon yield**

| | |
|---|---|
| **Beam intensity** | **90kW** |
| **Beam time** | **1+1+3 weeks** |




- We request the PAC to endorse **"the K1.8BR beamline upgrade"**
  - ➢ because modifying the BL requires a time-consuming radiation application
- We will submit the revised TDR in May 2024 for requesting stage-2 approval of E80



# J-PARC E80 Collaboration

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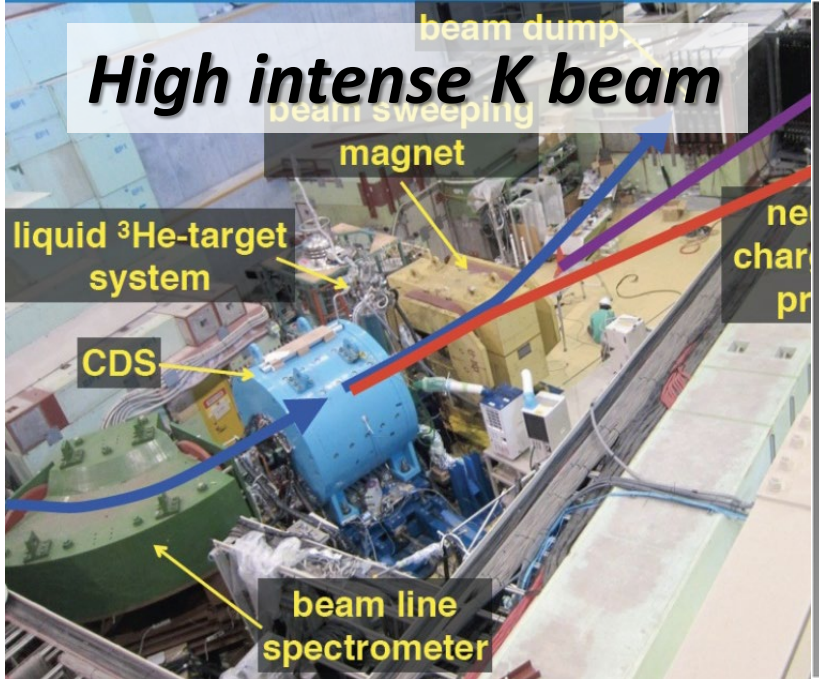
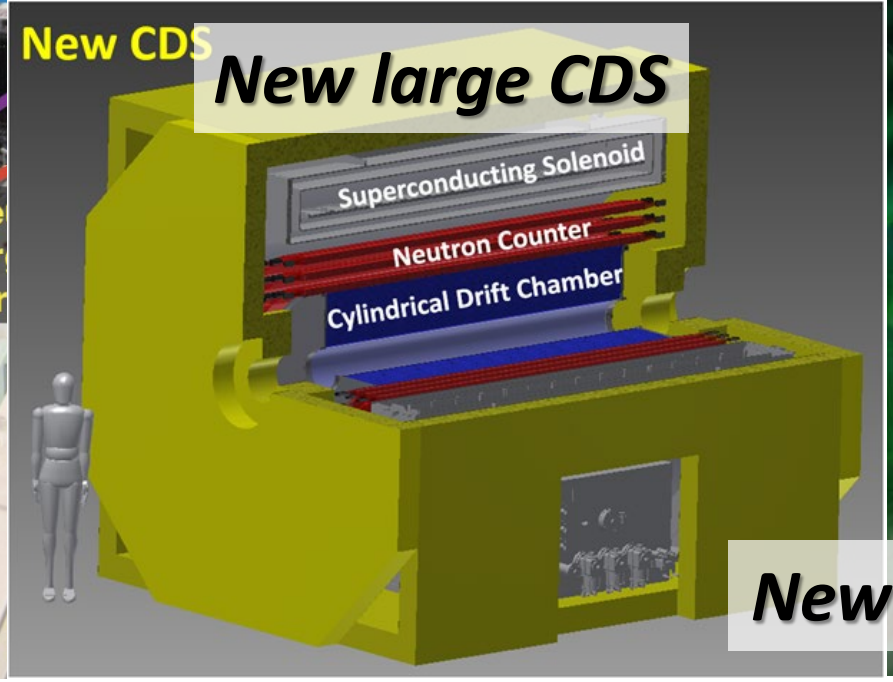
We're looking for new collaborators!

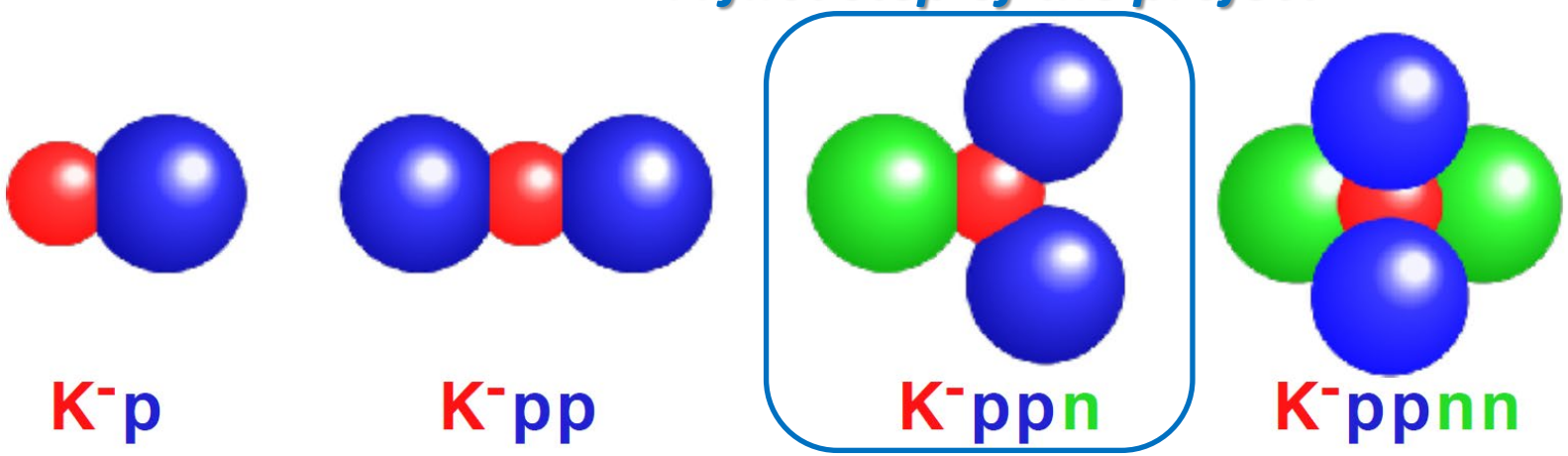




# Thank you for your attention!

*A first step of the project*




*via in-flight $^4$He($K^-$,N)*