



# J-PARC Hadron Experimental Facility Overview

October 20, 2025

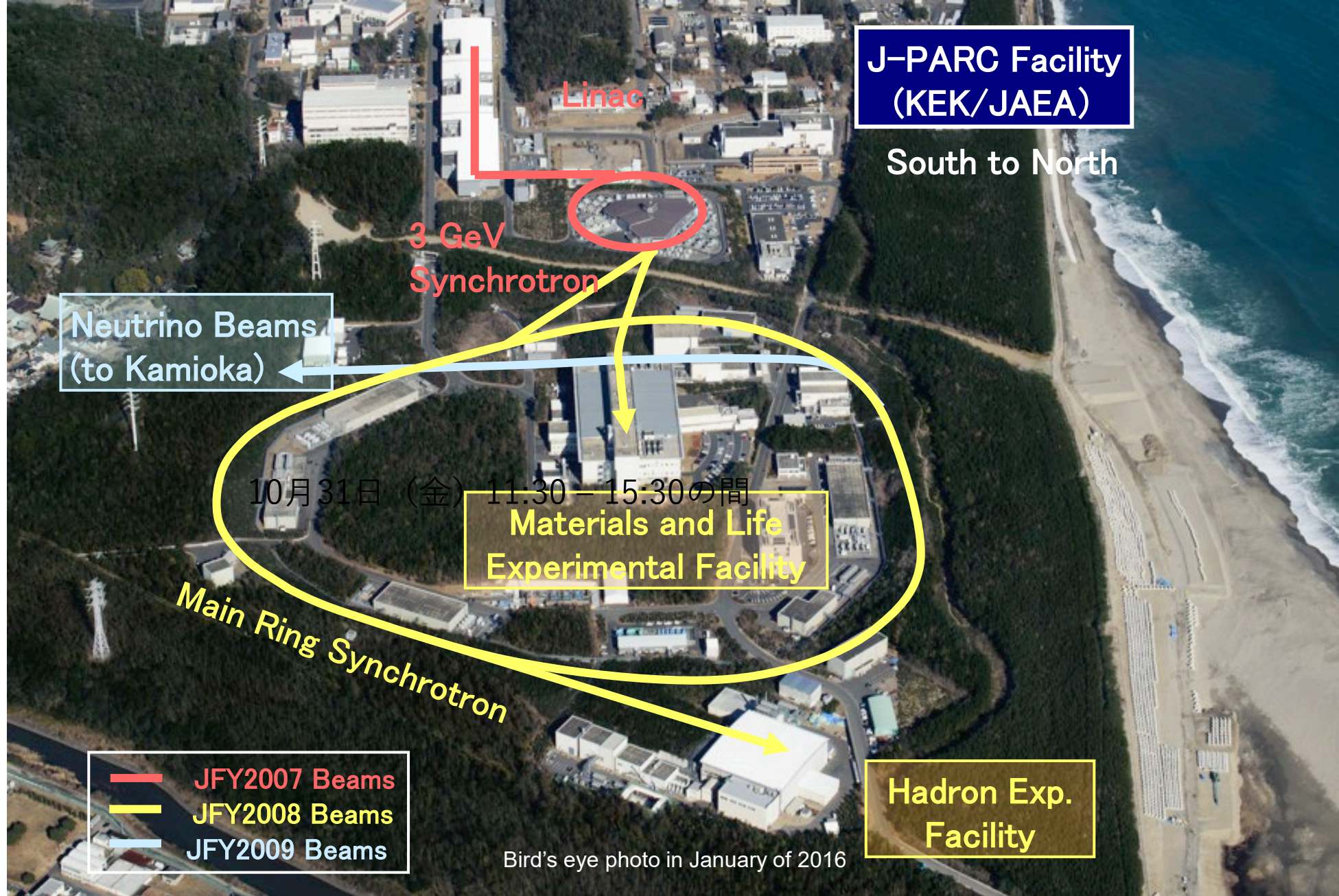
High Energy Accelerator Research Organization (KEK)

J-PARC Center

SAWADA, Shinya

# Contents

- J-PARC and Hadron Experimental Facility
- Research
- Key components/technologies
- Future
- Summary

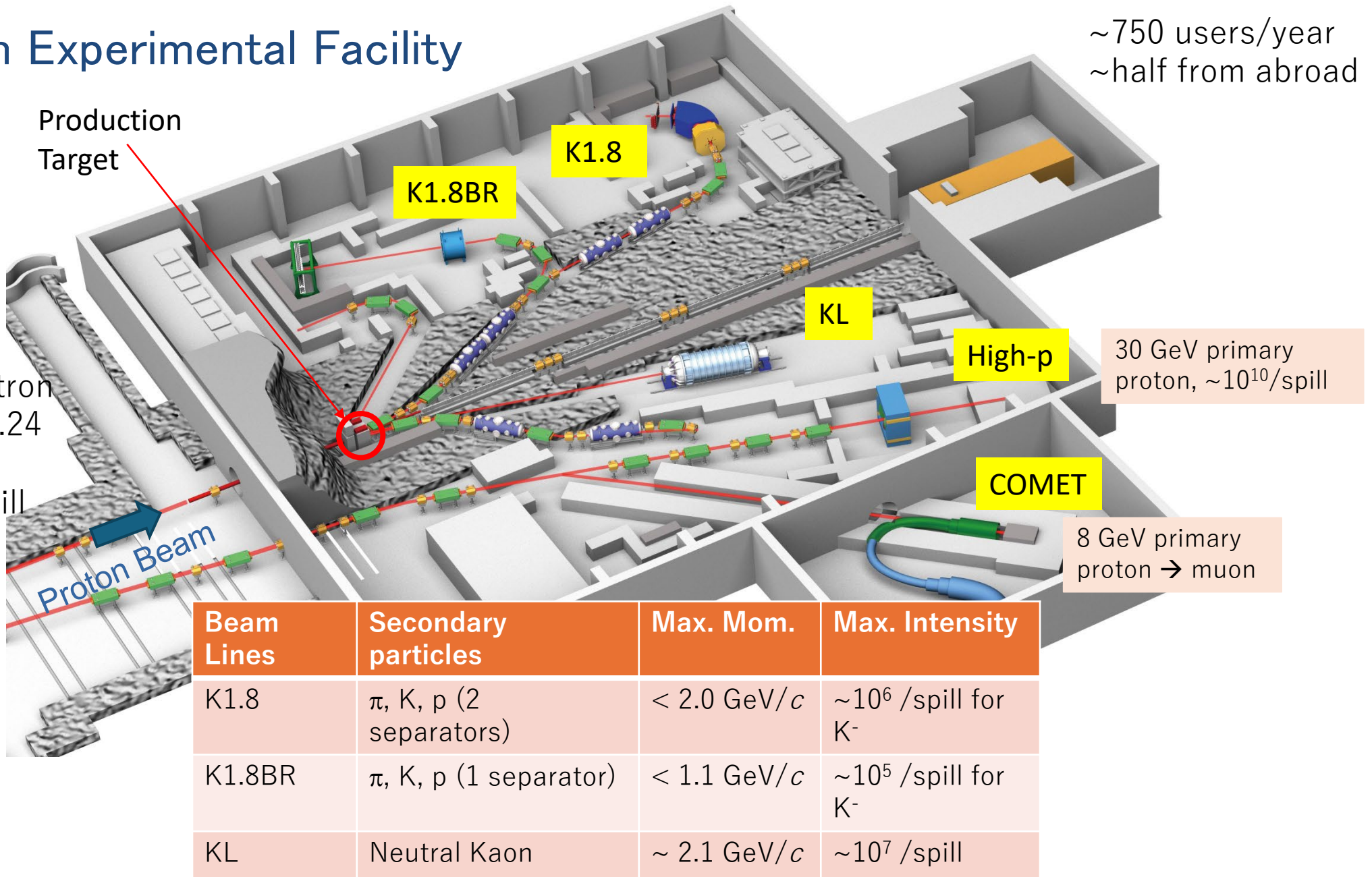




# Hadron Experimental Facility

~750 users/year  
~half from abroad

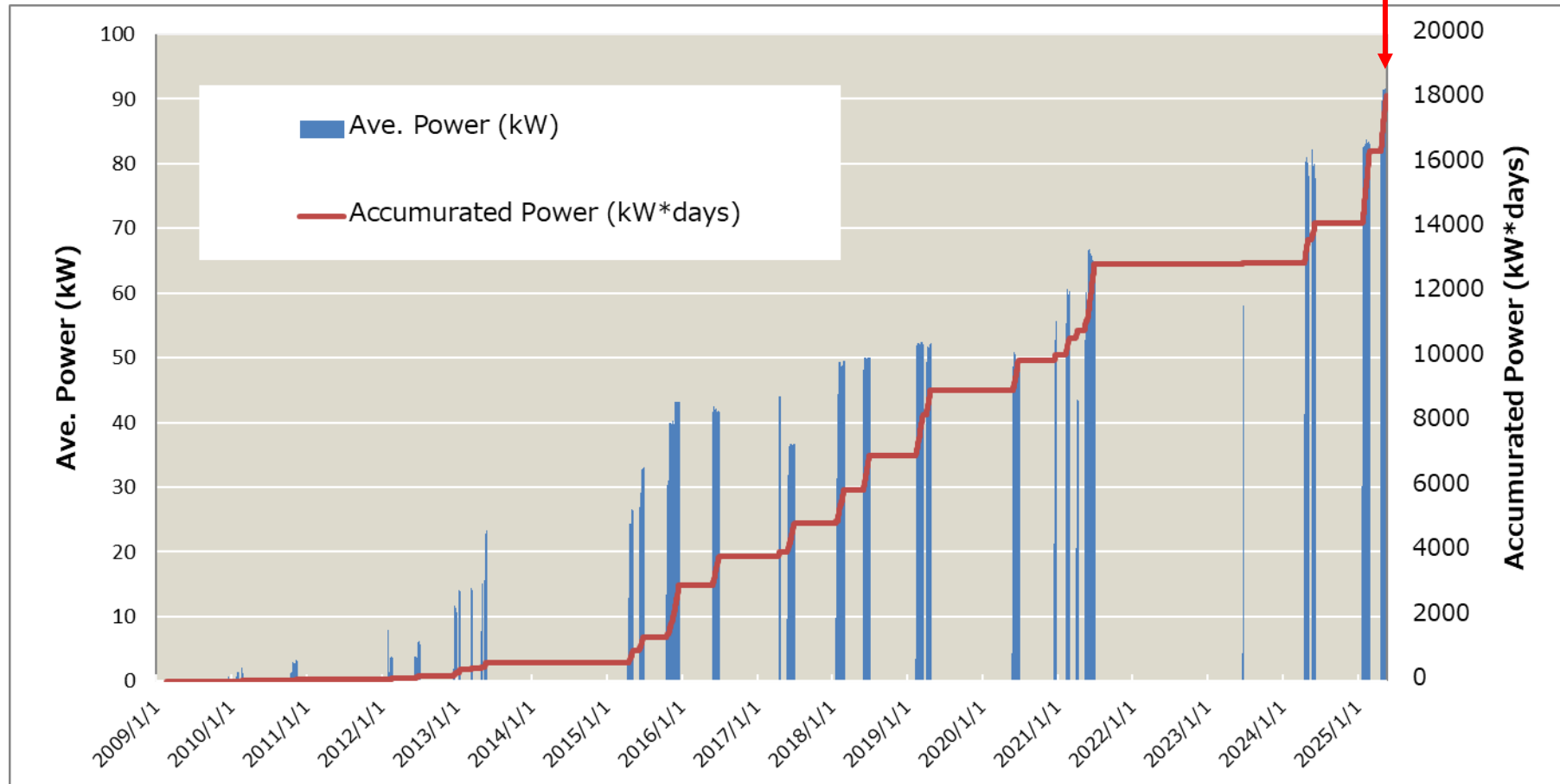
- 30 GeV protons
- Slowly extracted from MR synchrotron
- 2 s beam out of 4.24 s cycle
- ~80 T protons/spill



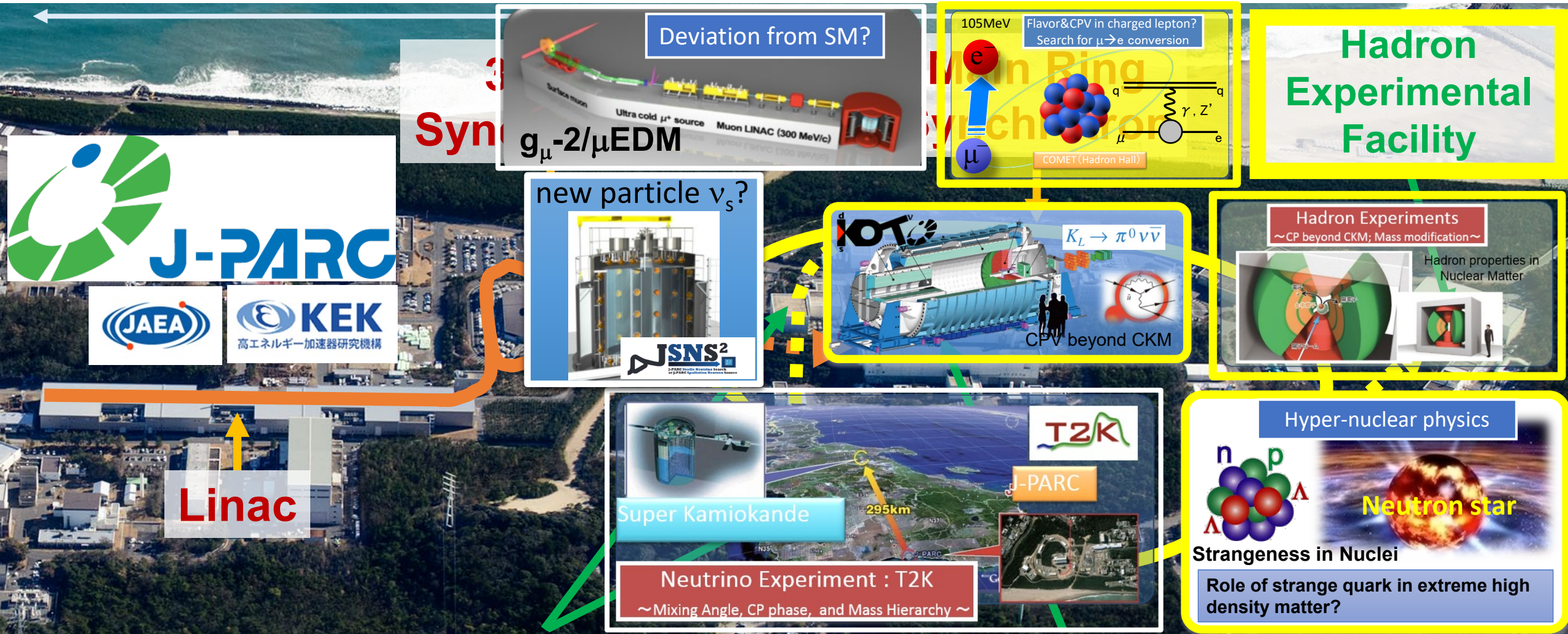


# SX Beam Power History

max beam power: *92 kW*



# Particle and Nuclear Physics @ J-PARC





# Origin & Evolution of Matter

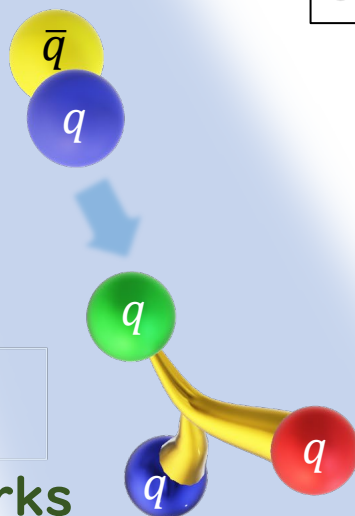
## Matter-Antimatter Symmetry

matter dominated universe

## Flavor Physics

CP violation  
weak interaction  
→ new physics

Kaon rare decays  
 $\mu \rightarrow e$  conversion



## Hadron Physics

quark interactions  
hadron mass-generation mechanism  
Hadron spectroscopy  
Meson in nuclei

## Strangeness Nuclear Physics

hadron interactions  
hadronic many-body systems  
Hyperon-Nucleon scattering  
Hypernuclear spectroscopy



Hadron Experimental Facility @BRIDGE

## Origin of Matter Creation

formation of hadrons from quarks

## Matter in Extreme Conditions

dense matter in neutron stars

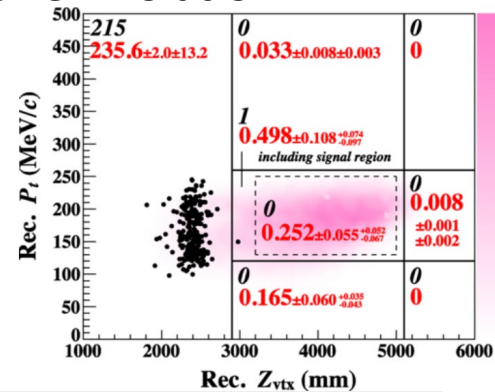


# Achievements in Research at the Hadron Experimental Facility

## Flavor Physics

$K_L^0 \rightarrow \pi^0 \nu \bar{\nu}$  search @ KOTO

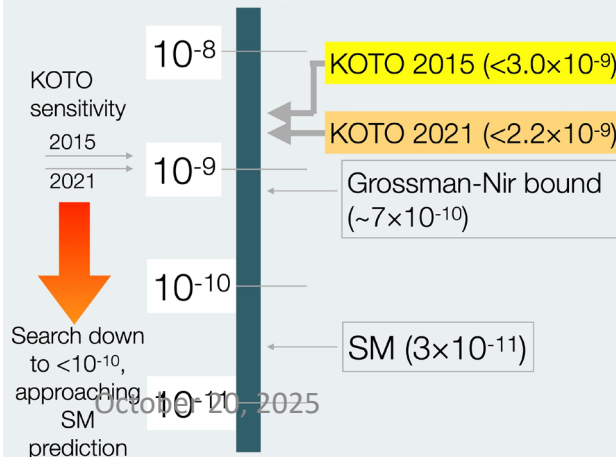
→ Approaching the SM sensitivity  
for CP violation



KOTO 2021

Single Event  
Sensitivity =  
 $9 \times 10^{-10}$

Branching ratio (BR)

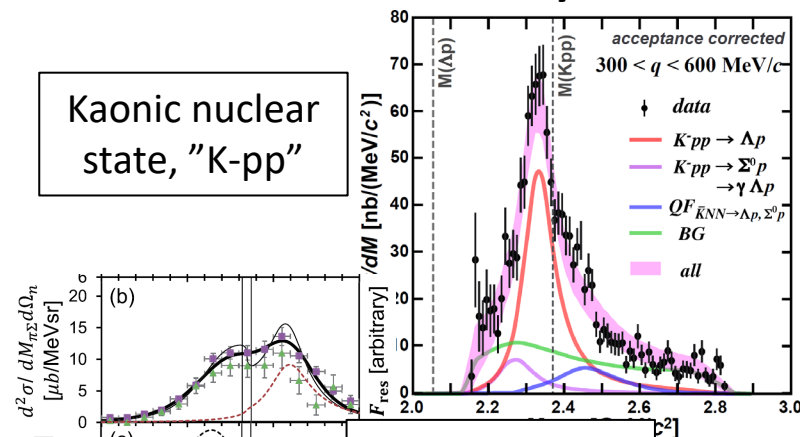


## Hadron Physics

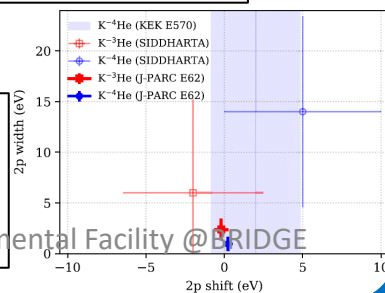
Observation of an exotic hadron bound system including  $K^-$  meson

→ Established a new direction to understand meson-baryon int.

Kaonic nuclear state, "K-pp"



Ultra-precise  
measurement  
of kaonic atoms

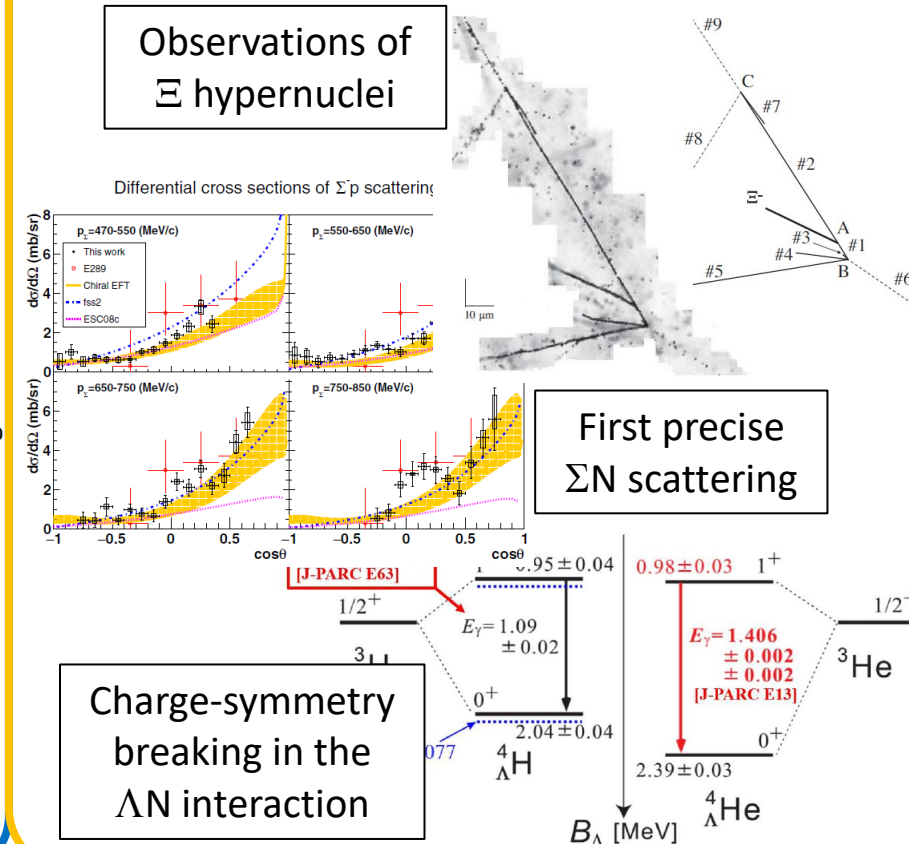


## Strangeness Nuclear Physics

A lot of progress in hypernuclear research

→ Clarified attractive  $S=-2$   $\Xi N$  interaction and deepened  $S=-1$   $\Lambda N, \Sigma N$  interactions

Observations of  $\Xi$  hypernuclei



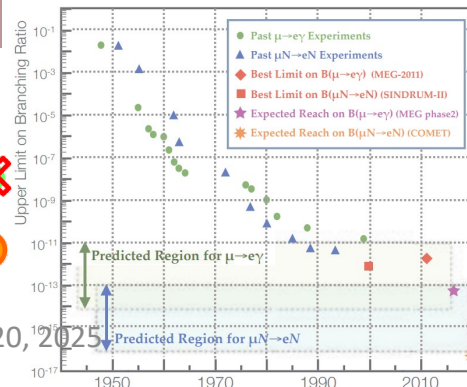
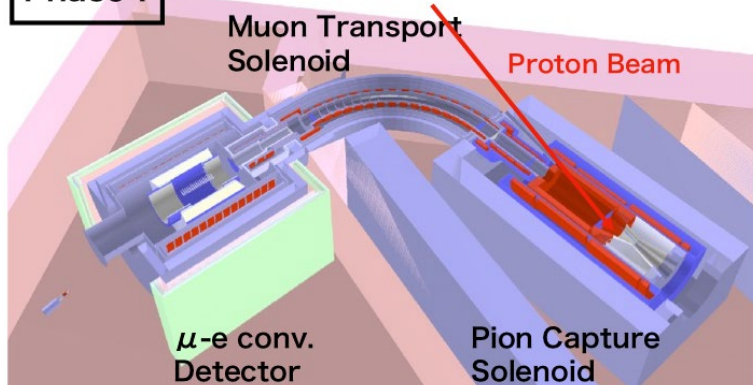
# Ongoing Research Programs at the Hadron Experimental Facility

## Flavor Physics

Search for  $\mu \rightarrow e$  conversion @ COMET (2023~)

→ Search for charged lepton flavor violation

Phase-I

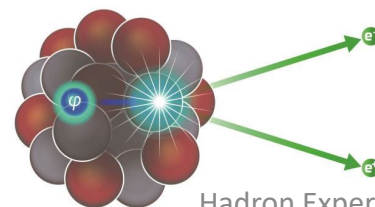
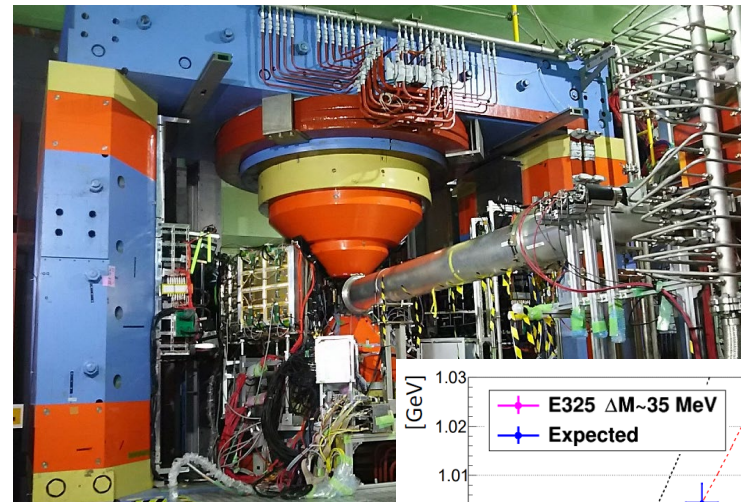


October 20, 2025

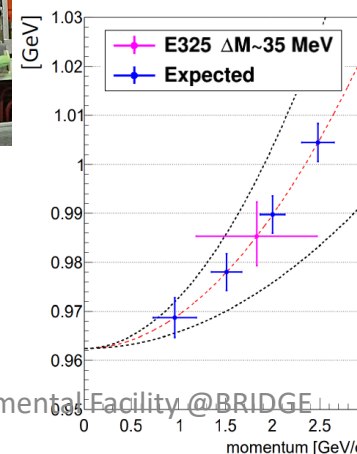
## Hadron Physics

Measurement of spectral modification of  $\phi$  meson in nuclei (2020~)

→ Investigate mass-generation mechanism of hadrons



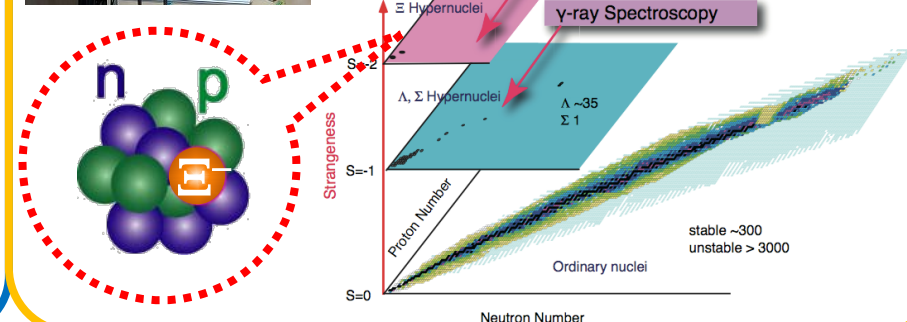
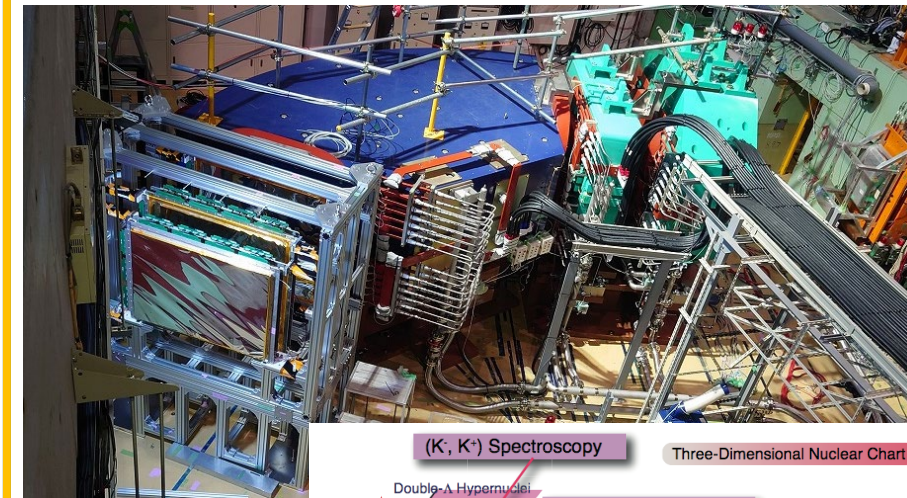
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## Strangeness Nuclear Physics

High-resolution spectroscopic study of  $S=-2$   $\Xi$ -hypernuclei (2023~)

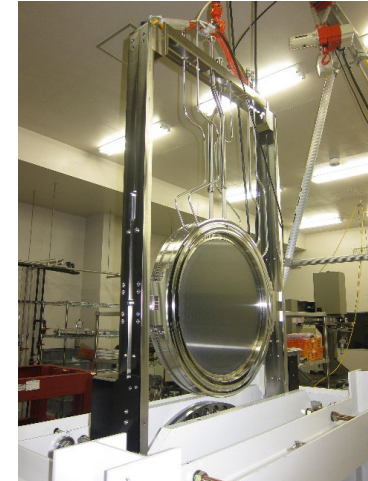
→ Provide accurate and systematic information on  $\Xi N$ ,  $\Lambda\Lambda$  interactions





# Key components and technologies

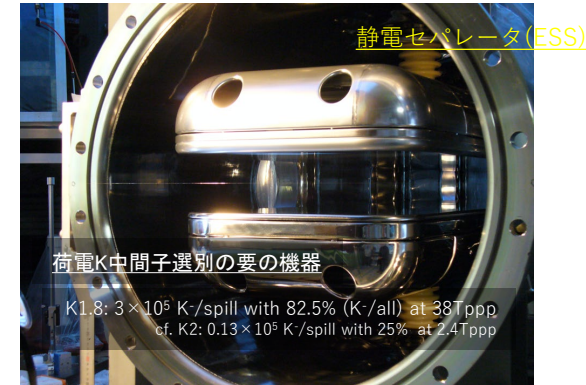
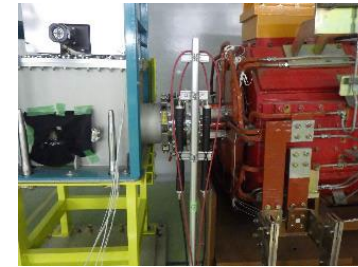
- Radiation-resistant (normal conducting) magnets
  - cables cured with BT resin or mineral insulation cables
  - many second-hand magnets with epoxy → scheduled upgrade necessary
- Air tightness of the primary beamline
  - not to release radioactive materials to the hall
- Vacuum system
  - metal sealing, quick maintenance
  - pillow seal, beam slit, beam collimator, ...





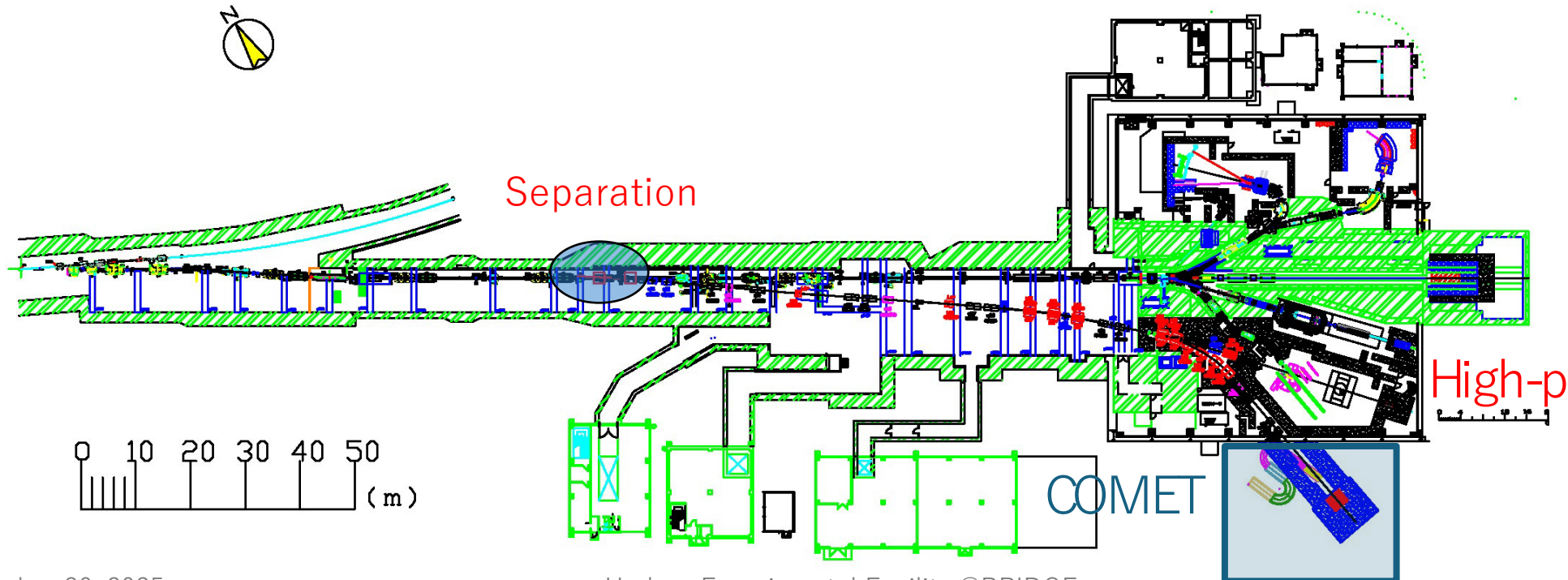
# Key components and technologies

- Production target → Hiroaki WATANABE's talk today
  - Currently 115 kW target used → should be upgraded
  - Also Fumimasa MUTO's poster
- Beam monitors
  - Residual gas ionization monitors
  - Beam loss monitors
- Power supply
  - Many old power supplies to be replaced
- Control system
- Beam dump
- Electrostatic separators



## (Near) Future: 2ndary beams at High-Momentum Beamline

- The high-momentum beamline is used only for primary 30-GeV proton experiments.
- Needs for high-momentum secondary beams



(Near) Future: 2ndary beams at High-Momentum Beamline

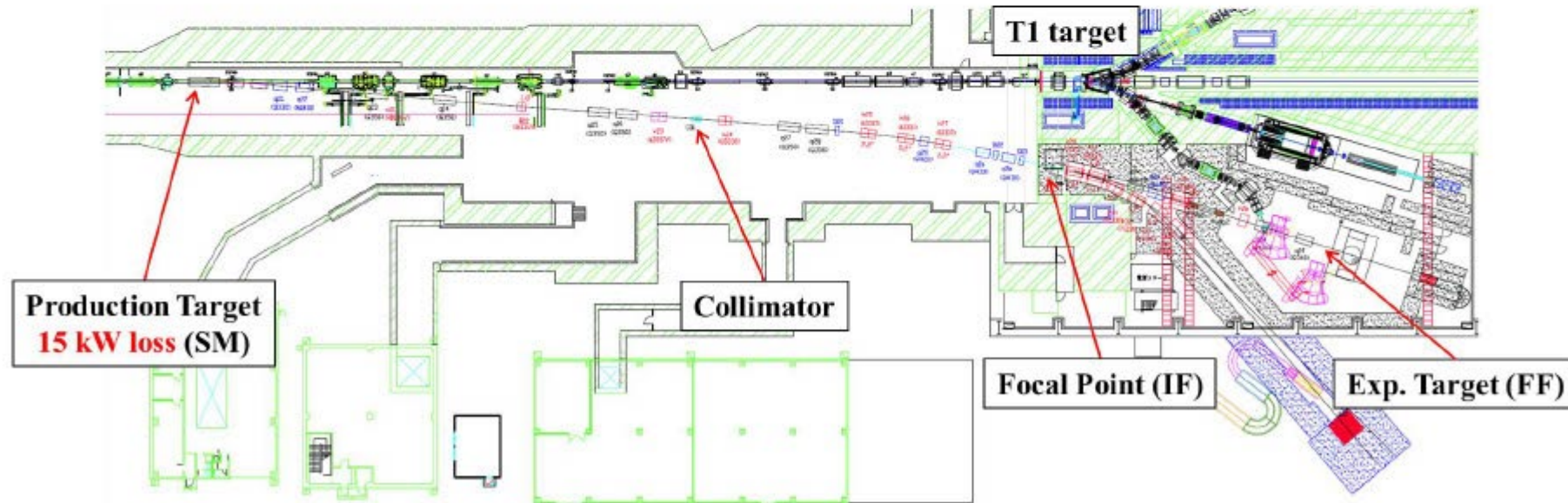
2

## High-p beam line for 2<sup>ndary</sup> beam: $\pi 20$

\* High-p: 2<sup>ndary</sup> beams can be provided from the primary proton beam.

- High intensity:  $>10^7$  /spill for  $\pi^\pm$ ,  $p$  ( $>10^5$  /spill for  $K^-$ ,  $\bar{p}$ ) up to 20 GeV/c
- High momentum-resolution beam:  $\Delta p/p = 0.1\%(\sigma)$

⇒ Construction staging toward realizing E50: Phase 1, 2, 3





# (Near) Future: 2ndary beams at High-Momentum Beamline

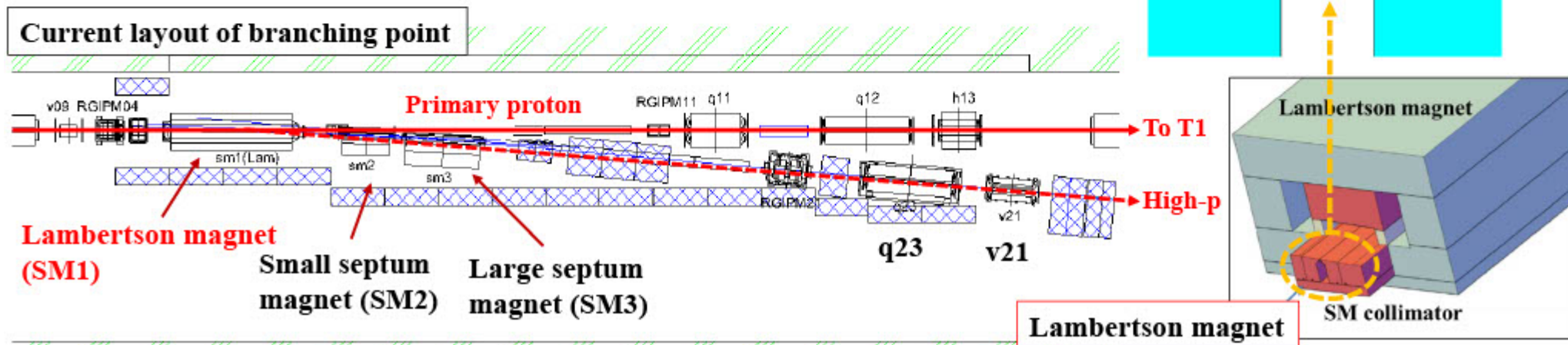
3

## $\pi 20$ Phase 1

- **Secondary particles from branching point (Lambertson magnet)**
  - **No modification** of beam line components and radiation shields
  - **Polarity change device** for negative beam  $\Rightarrow$  **Budget secured**
- $\Rightarrow$  **Evaluation of secondary beam properties: T106/P93 experiment**

### \* Experiments in Phase 1

- $\phi N$  interaction study via  $\pi^- p \rightarrow \phi n$  reaction (E95)
- Pilot runs:  $\Lambda^*/\Sigma^*$  spectroscopy,  $\eta' N$ , ...



(Near) Future: 2ndary beams at High-Momentum Beamline

22

## Staging plan toward constructing $\pi 20$

### Phase 1: Minimum modification

- 2<sup>ndary</sup> beam from A-B branching point (Lambertson magnet)  
⇒  $\sim 10^5$  /spill  $\pi$  @ 2–20 GeV/c
- Key equipment: Polarity change device

Also muon beam possibility →  
Hitoshi TAKAHASHI's talk today

### Phase 2: High-intensity & high-momentum (for $\Xi$ spectroscopy)

- Upgrade of A-B branching point (Several kW loss)  
⇒  $> \text{Several } 10^6$  /spill  $\pi$  @ 2–20 GeV/c &  $\sim 10^5$  /spill  $K^-/\bar{p}$  @ 5–10 GeV/c
- Key equipment: Thin prod. target, beam swinger magnets

### Phase 3: Full $\pi 20$ (for Charmed baryon and $\Omega$ spectroscopy)

- Full specification for 2<sup>ndary</sup> beam production ( $\sim 15$  kW loss)  
⇒  $> 6.0 \times 10^7$  /spill  $\pi$  @ 2–20 GeV/c &  $\text{Several } 10^5$  /spill  $K^-/\bar{p}$  @ 5–10 GeV/c
- Key equipment: Gas tight prod. target, radiation shields



# Hadron Experimental Facility eXtension (HEF-ex) Project

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# Hadron Experimental Facility eXtension (HEF-ex) Project

Present HEF  
(2009~)

expand research programs  
at the Hadron Experimental Facility  
to further explore  
**Origin & Evolution of Matter**

Extended HEF

K10

HIHR

KL2

K1.1/K1.1BR

High-p ( $\pi 20$ )

Extended hall

COMET

Test-BL

T2

K1.8

K1.8BR

T1

High-p

COMET

KL

K1.8

K1.8BR

T1

30 GeV  
primary  
proton beam

1 production target (T1)

1 secondary-charged beamline (K1.8/K1.8BR)

1 neutral beamline (KL)

1 primary beamline (High-p)

1 muon beamline (COMET)

+ 1 new production target (T2)

+ 4 new beamlines (HIHR, K1.1/K1.1BR, KL2, K10)

+ 2 updated beamlines (High-p ( $\pi 20$ ), Test-BL)

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## Determine density dependent $\Lambda N$ interaction

HIHR

### Ultra-high-resolution $\Lambda$ hypernuclei spectroscopy

- intense dispersion matched  $\pi$  beam

K1.1

### Systematic $\Lambda N$ scattering measurement

- intense polarized  $\Lambda$  beam

## Investigate diquarks in baryons

high-p  
( $\pi 20$ )

### High-resolution charm baryon spectroscopy

- intense high-momentum  $\pi$  beam

K10

### High-resolution multi-strange baryon spectroscopy

- intense high-momentum separated K beam

## Search for new physics beyond the SM

KL2

### Most sensitive $K_L^0 \rightarrow \pi^0 \nu \bar{\nu}$ measurement

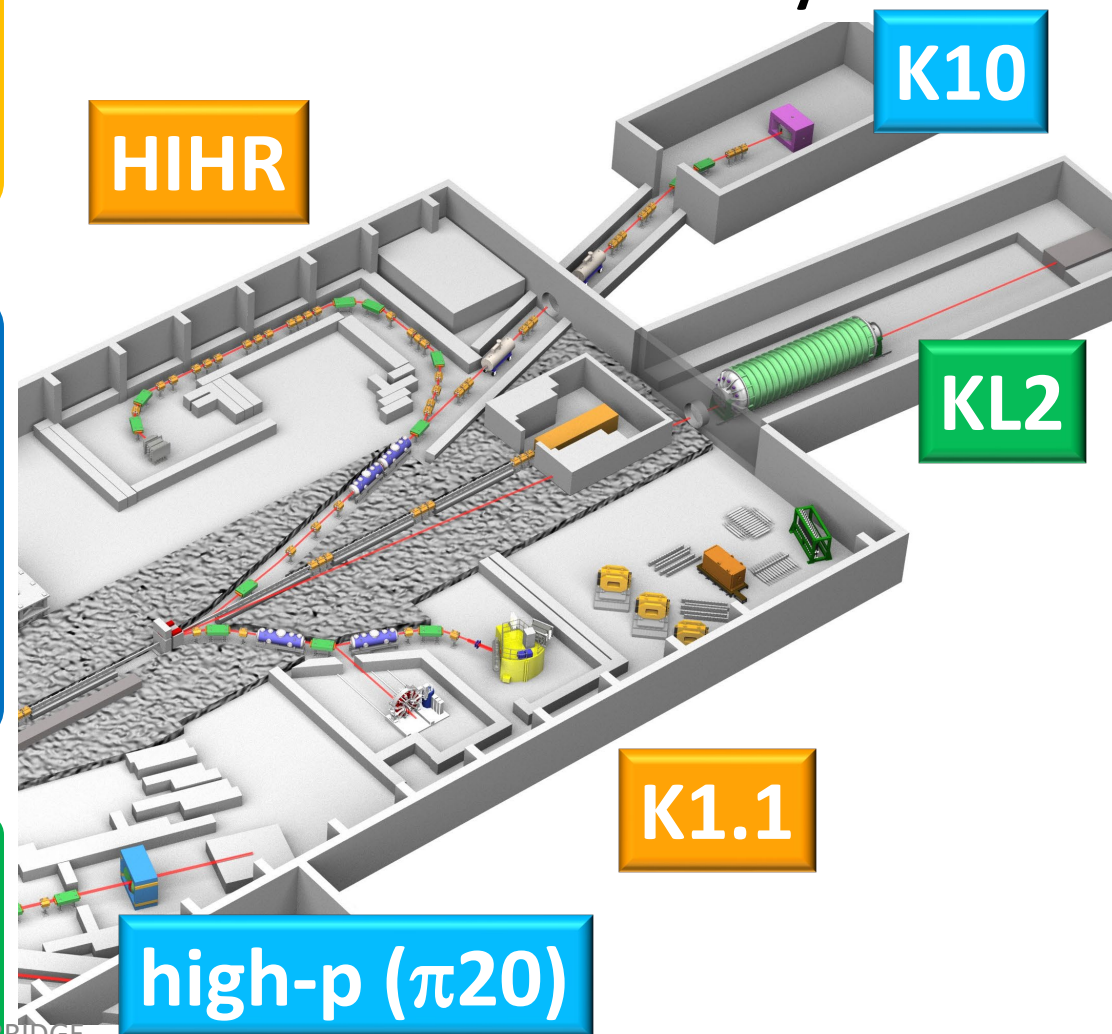
- intense neutral K beam

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# Expanded Research Programs

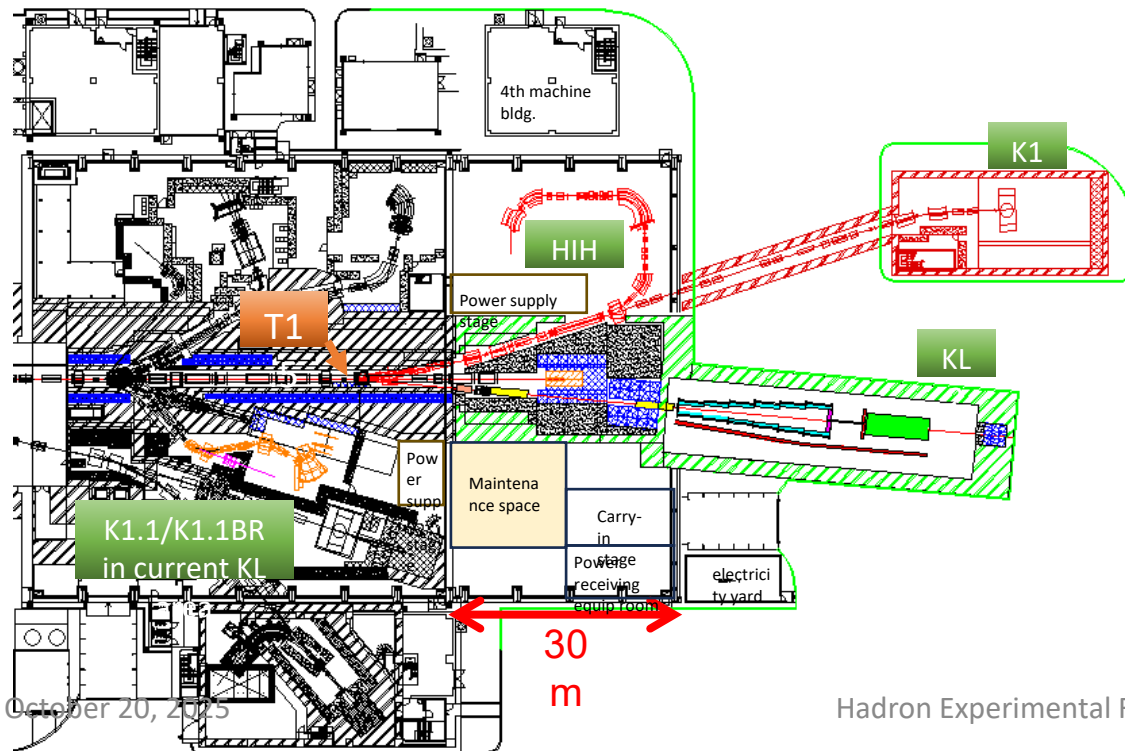
at the Extended Facility



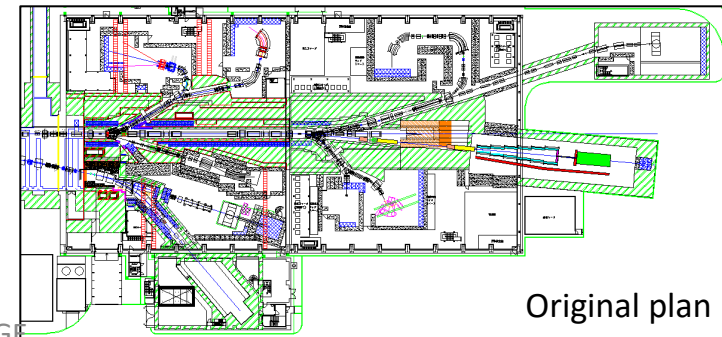
# Staging approach for extension

- In KEK-PIP2022 (Project Implementation Plan), HEF-ex project got 1<sup>st</sup> priority for the budget request.
- However, construction cost was significantly increased after COVID-19: 150 → 200 Oku-yen.
- Cost reduction/optimization and staging plans with smaller steps are under discussion for early realization of the project.

## Reduced plan (under discussion)



- 2nd target is installed in current hall. (referred to as “T1.5” to distinguish from T2 in the original plan)
- K1.1/K1.1BR are built in current KL area.



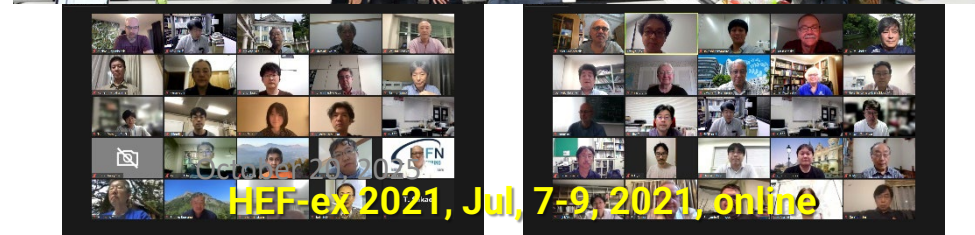
Original plan





# Project Refined with Communities

<https://www.rcnp.osaka-u.ac.jp/~jparchua/en/hefextension.html>





# Summary

- J-PARC Hadron Experimental Facility has secondary beamlines and primary beamlines
- Used for nuclear and particle physics experiments
- Intensity of the 30-GeV primary proton beam has been successfully improved to 92 kW with the slow extraction
- There are key components/technologies with high radiation environment
- Future upgrades are also planned/considered