Short reports on Nuclear Physics LRP from Japan

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CENTER FOR NUCLEAR STUDY

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Japanese version of LRP

- Japanese LRP (2013 and 2021)
  - Community driven
  - Mainly for the community use and not for the funding

Low-Energy
- Nuclear matter, unstable nuclear, fundamental

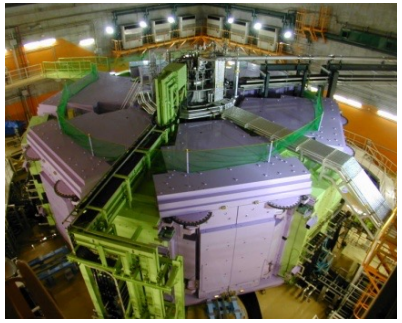
Middle-Energy
- Hadrons, strangness/hyper-nucleus

High-Energy
- High-energy heavy-ion, Nucleon structure

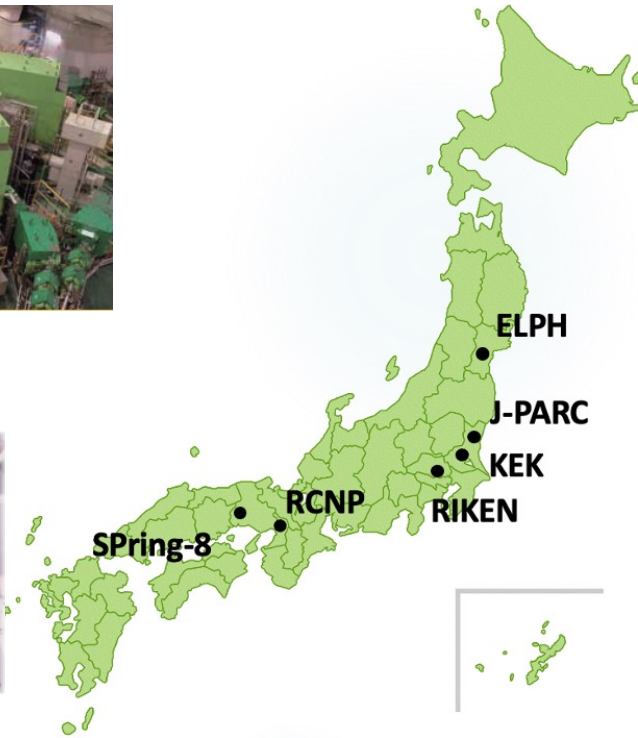
Japanese and Overseas Facilities

- **Low Energy Nuclear Physics**
  - **RIBF** and RCNP
  - ~200 researchers
- **Strangness and Hadron Physics**
  - **J-PARC**, Spring-8, and ELPH
  - ~100 researchers
- **High Energy QCD Physics**
  - **LHC**, RHIC, FAIR, **EIC**
  - RIKEN BNL Center (RBRC)
  - ~50 researchers

RIBF



RCNP

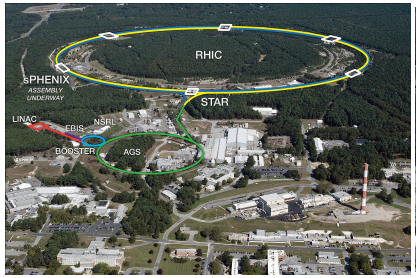


J-PARC

ELPH

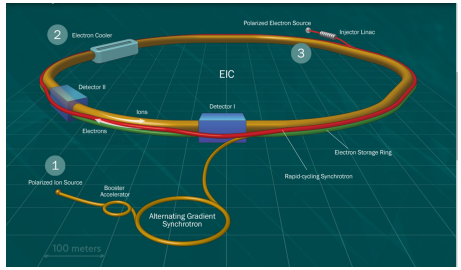
LHC

RHIC

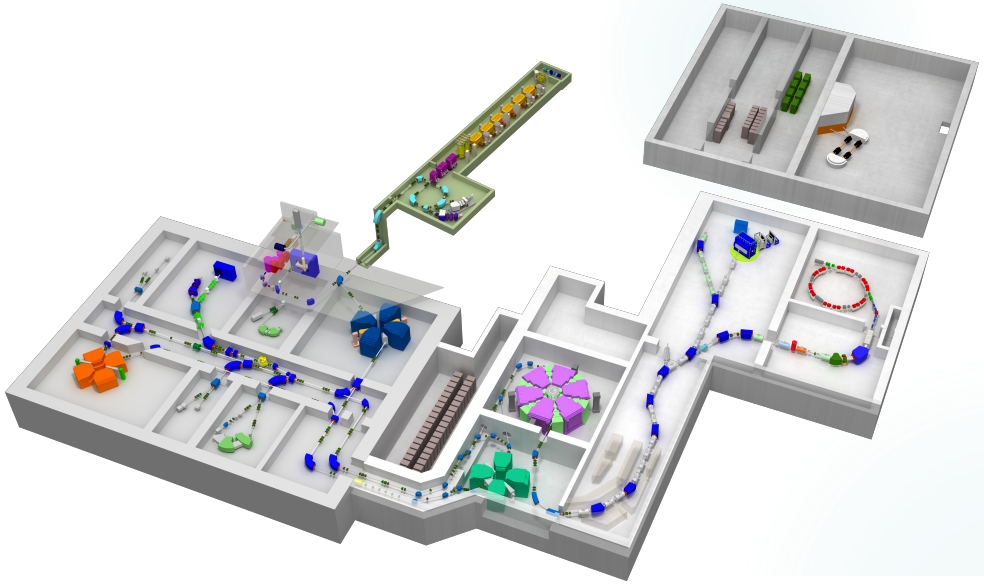


FAIR

EIC

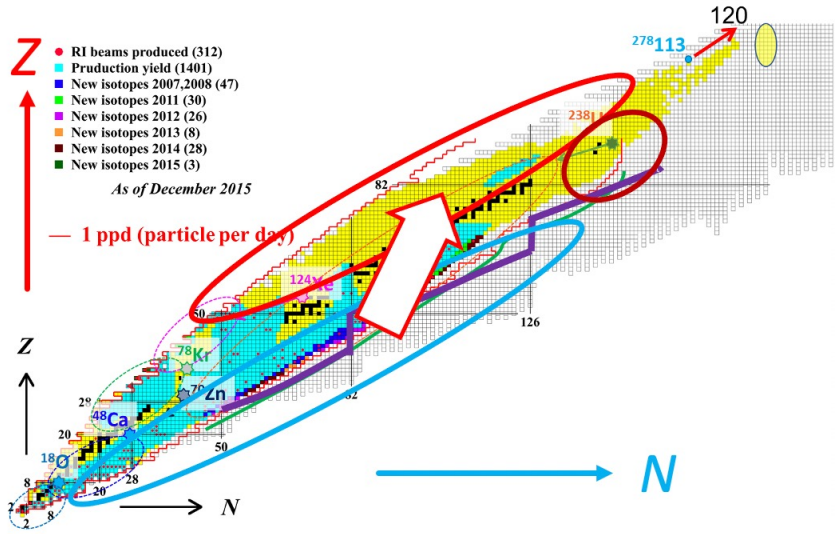


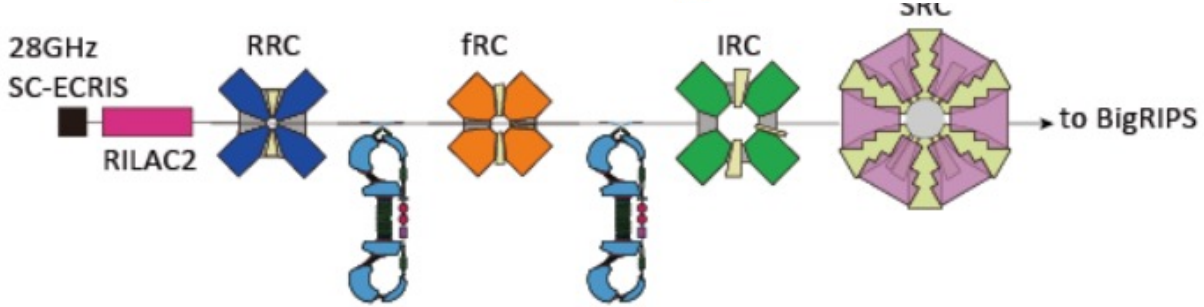
RIBF upgrade



- **RIBF upgrade**
  - **Intensity upgrade of heavy-ion LINAC (ongoing)**
    - **Super-heavy element (119)**
    - **ORNL-RIKEN Collaboration**
  - **New Charge Stripper Rings**
    - **150M$ (not funded)**
    - **submitted to MEXT roadmap 2023**

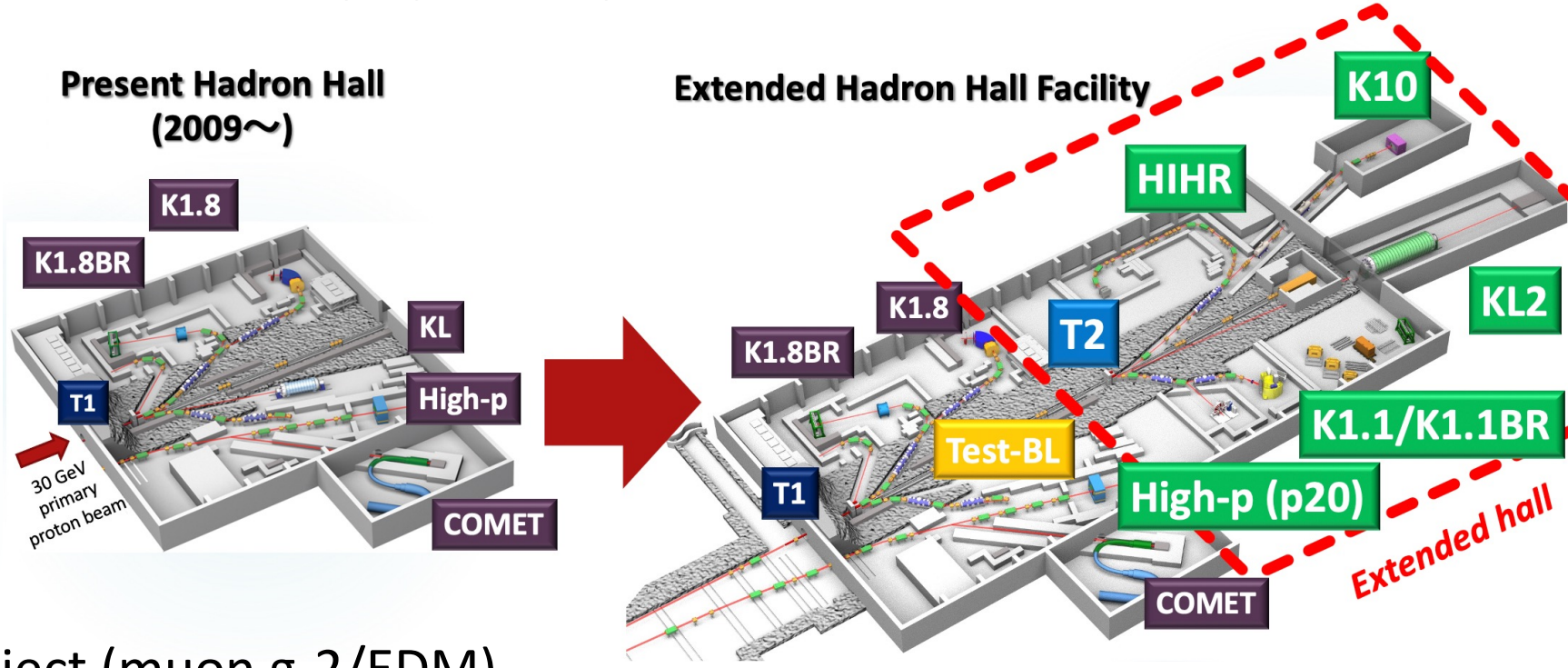
Charge Stripper Rings (CSR) : beam recycling to improve transmission efficiency (U^{35+}->U^{64+}) by x10-20





J-PARC Hadron facility extension

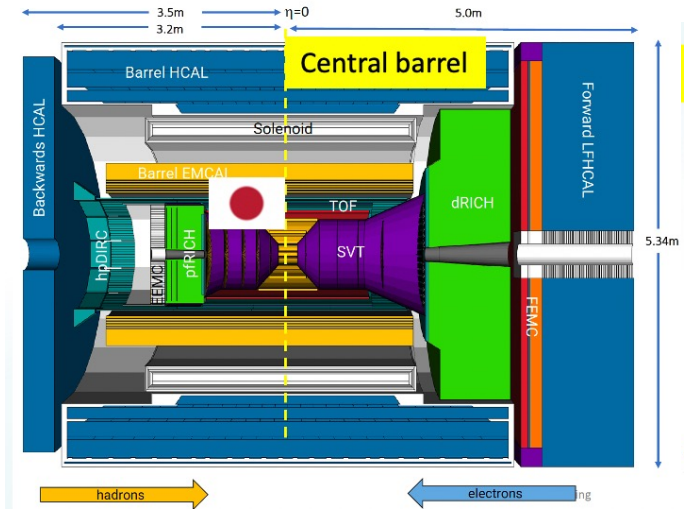
- **J-PARC Hadron facility extension**
  - **Enrich the strangness and hadron physics capabilites**
  - **100M$ (not funded)**
  - **Selected MEXT roadmap 2020**
  - Selected as **the top-priority project** in KEK's mid-term plan (FY2022-26)
    - Last top-priority project (muon g-2/EDM) has not been yet budgeted.

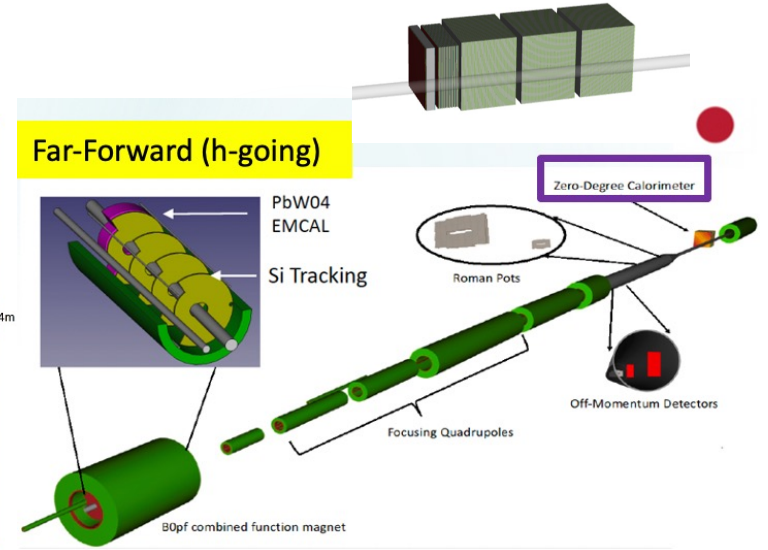


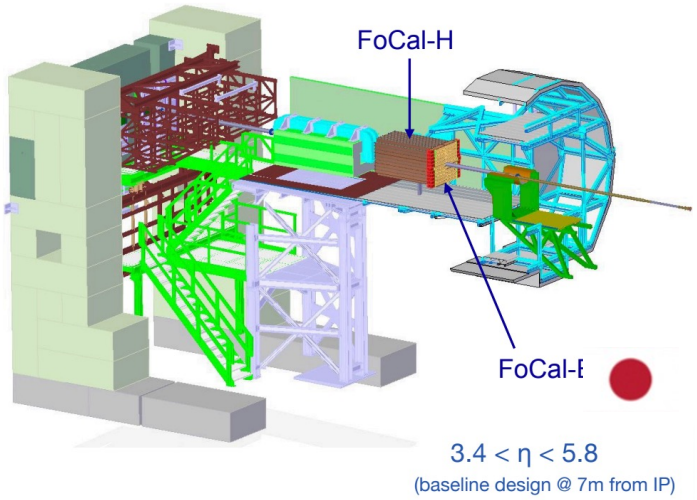
Plans for high-energy QCD physics

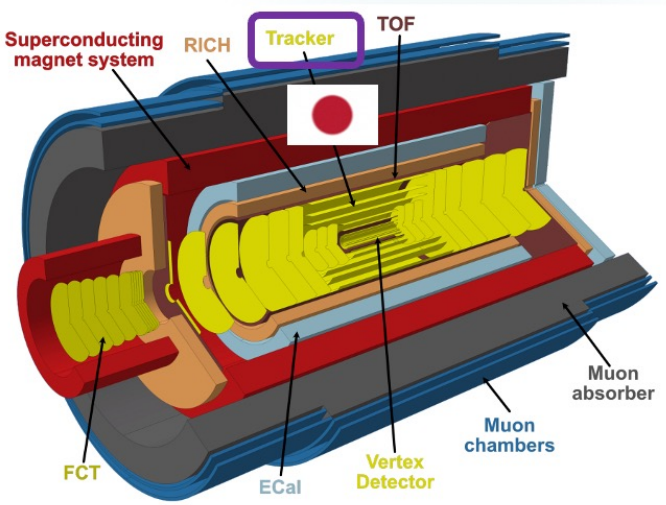
- **Focuses on ePIC and ALICE(3)**
- **Planned in-kind contributions**
  - **ePIC: 30M$ (not funded)**
    - **AC-LGAD for barrel TOF**
    - **ZDC (ECal ~ ALICE FoCAL)**
    - **Streaming DAQ**
  - **ALICE(3): 30M$ (not funded)**
    - **FoCAL**
    - **Outer MAPS Tracker**

Two proposals submitted to MEXT Roadmap 2023





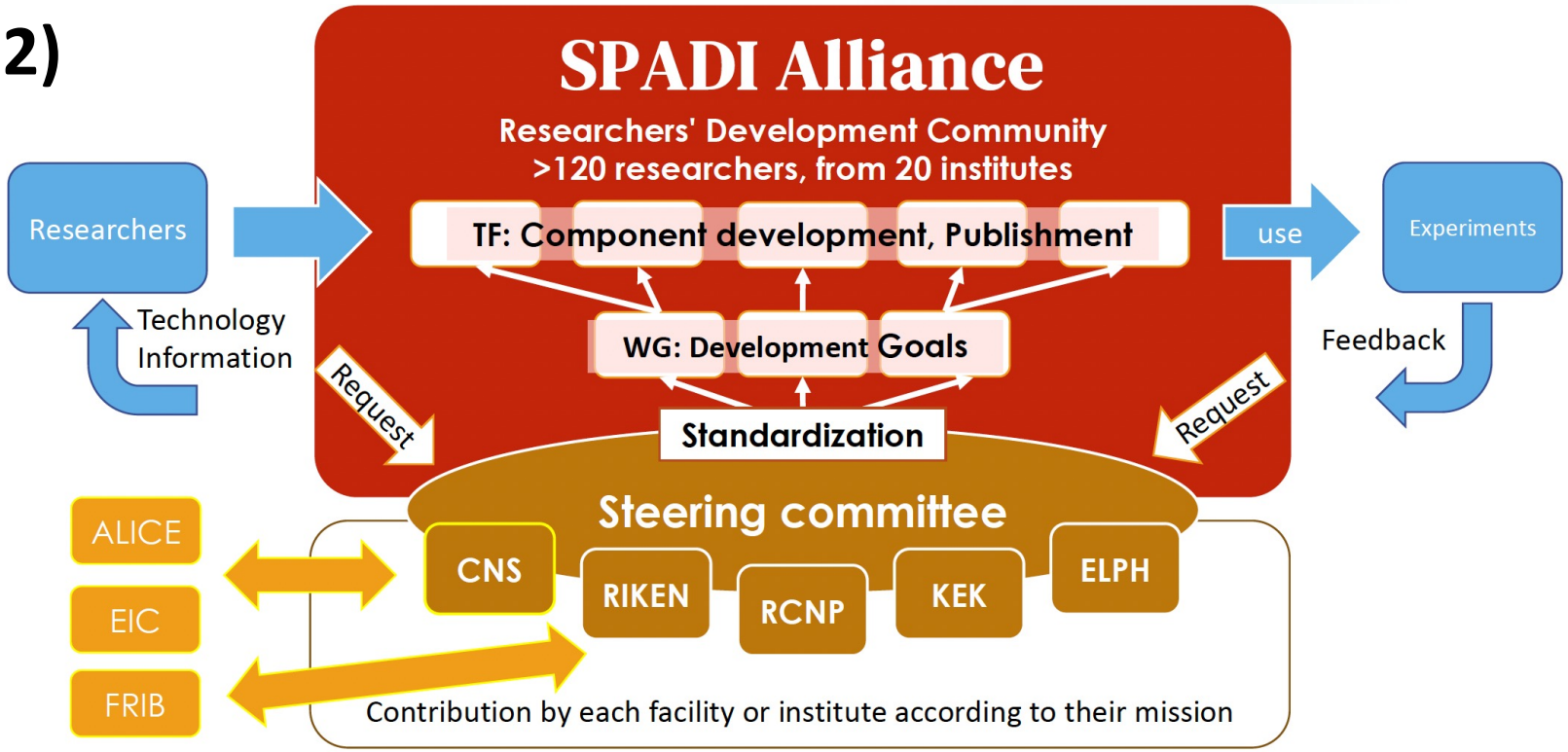




EIC: SPADI-Alliance

SPADI Alliance
Signal processing and data acquisition infrastructure alliance

- Streaming DAQ and computing are common needs in NP community
  - Future standard DAQ system at RIBF, RCNP, J-PARC, …
  - Synegies with EIC, Jlab, and HEP experiments (heterogeneous computing)
- SPADI-Alliance (since 2022) in NP community
  - >120 researchers
  - 20 institutes
  - different experiments from different facilities



EIC: SPADI-Alliance

SPADI Alliance

Signal processing and data acquisition infrastructure alliance

- 7 working groups
  - ASICs & Front-End, Timing synchronization/distribution systems, Framework,
  - Online data processing (heterogeneous technologies, AI/ML technologies)
  - Computing infrastructure, UI, Packaging

Taku Gunji

WG1
Frontend Electronics

Streaming type
Charge ASD board
Voltage ASD board
WF Digitizer board
Control Firmware dev.

WG2
Clock synch. / Data Transfer

General Clock Synch.
High throughput
Intra-board transfer

WG3
Acquisition software framework (NestDAQ + …)

Streaming type
FairMQ-based Scalable DAQ
Sampling, Time frame build, Event build, Monitoring…
Format

WG4
Event processing

Acceleration using GPU/FPGA
Zero suppression
Calibration, Clustering, Tracking, PID,

WG5
User Interface

Control, Monitor, Configure,

Trial with
SlowDash

WG6
Computing infrastr.

High throughput
Large volume
Flow and Archive
Power consumption
Interconnect
Networking
…

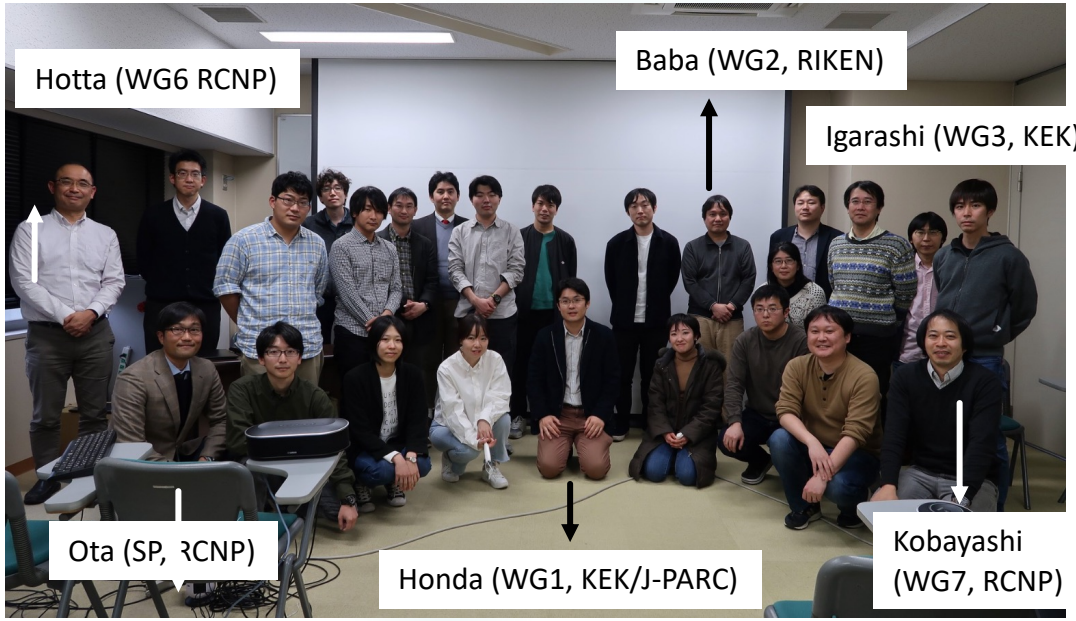
WG7
Packaging

Standalone system
Popularization
Standardization
Market research
User feedback

Analysis

Trial with
Artemis

SPADI-A meeeting (3/16-3/18/2023)



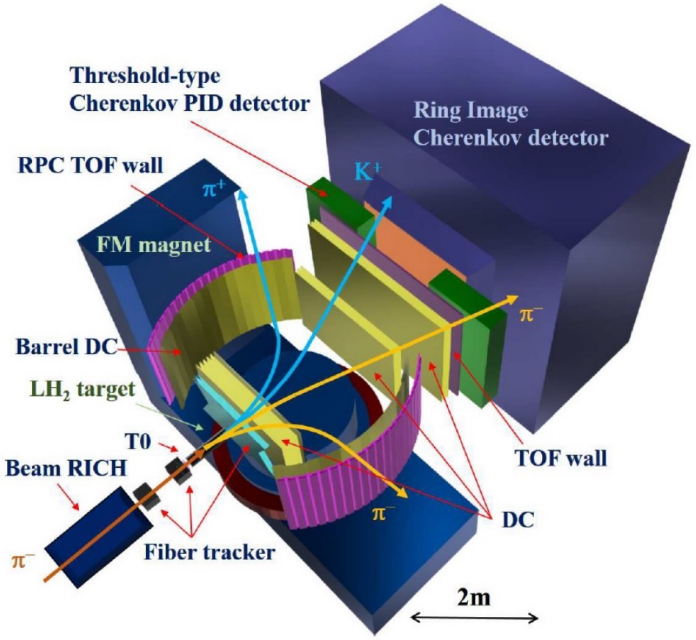
EIC: SPADI-Alliance

SPADI Alliance

Signal processing and data acquisition infrastructure alliance

- Start collaborating with US
  - DAQ Workshop at APS/JPS joing meeting at Hawaii (2023.11.26-12.2)
  - SRO workshop XI (11.28, 12.2-12.3) (SRO workshop XII or XIII will be in Japan – under discussion)
- We will start making concrete plans on the collaboration with ePIC DAQ/SRO.
  - Online processing, timing distribution system, ASICs
  - J-PARC E50 as a testbed for the streaming readout of ePIC

13:00	**Welcome to SRO-XI workshop!**	*Alexandre Camsonne, Douglas Hasell, Jan Bernauer, Marco Battaglieri, Taku Gunji*	13:00 - 13:10
	SPADI Alliance for Standardization of SRO DAQ in Japan	*Shinsuke Ota*	13:10 - 13:40
	SRO FEE development Japan	*Ryotaro Honda*	13:40 - 14:10
14:00	SRO timing distribution system in Japan	*Hidetada Baba*	14:10 - 14:40
	A DAQ software framework for SRO	*Youichi Igarashi*	14:40 - 15:10
15:00	Coffe break		



EIC: Nuclear Physics Consortium

- Nuclear Physics Consortium (NPC) was formed in 2009 to purseu the hadron physics at Belle(2) and joined the experiment.
  - 21 people from 10 institutes (RCNP, J-PARC, COMPASS, HERMES, theory)
    - Contact person: Takashi Nakano (RCNP)
  - Leading efforts in the Belle2 collaboration
    - exotic hadrons, fragmentation functions

- Future perspectives:
  - NPC will join the EIC activities and ePIC collaboration (under discussion).

EIC: University of Tokyo

- Preparation of the new "Quark Nuclear Science Institute" is underway in the Graduate School of Science, University of Tokyo.
  - Center for Nuclear Study and the Physics Department are working together to realize it.
  - New research contract between the Univ. of Tokyo and RIKEN will be made next year.
  - QNSI will cover a wide range of nuclear physics :
    - High-Energy QCD(EIC) + Hadron + RI-beam.
    - High-Energy QCD (EIC) division will be lead by Taku Gunji (Experiment) and Kenji Fukushima (Theory).

Summary – Japanese LRP

- Japanese LRP of nuclear physics
  - RIBF upgrade for low-energy nuclear physics (150M$)
  - J-PARC hadron facility upgrade for strangness and hadron physics (100M$)
    - Top-priority in KEK's mid-term plans (2022-2026)
  - ePIC and ALICE(3) for high-energy QCD physics (30M$ for ePIC and 30M$ for ALICE)
- Any of them are not yet granted.

Summary – EIC & ePIC related

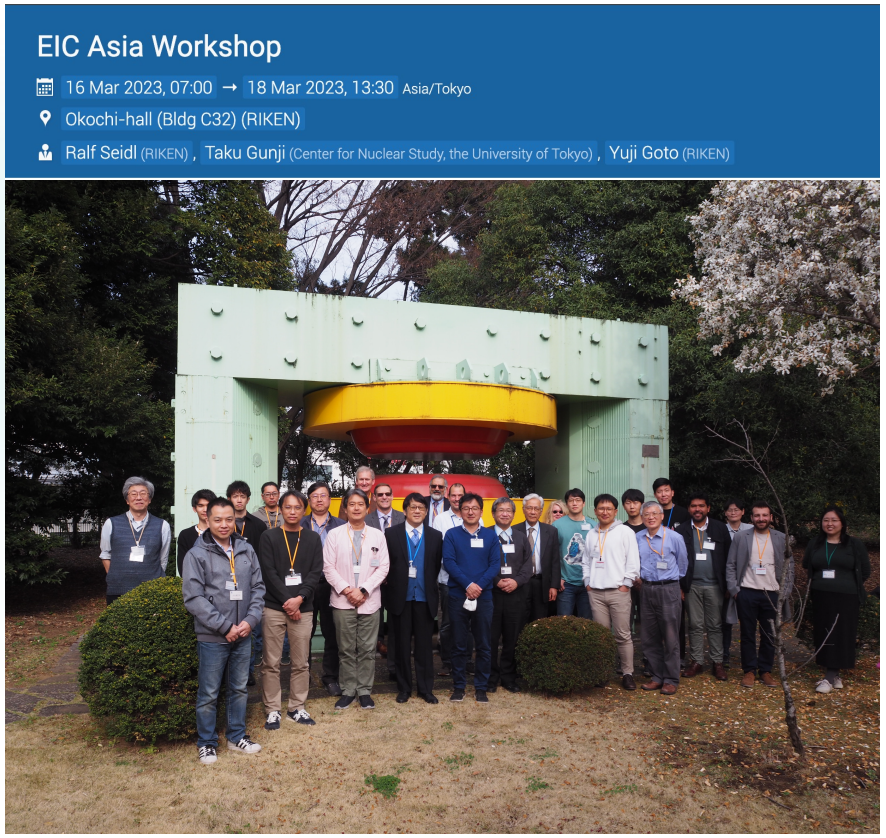
- For EIC, “complementality” with RIBF and J-PARC will be important.
  - EIC technologies will be important to drive RIBF and J-PARC projects.
    - SPADI-A collaboration for streaming readout in NP community. Collaboraiton with EIC (US) will start.
    - Other technologies (MAPS, 4D L-GAD sensors, …)
- Enlarge the EIC-Japan team including more instutites and experiments (ex, Belle2)
  - New ”Quark Nuclear Science Institute” under preparation in the University of Tokyo (CNS + physics department)
    - New reserarch contract between U-Tokyo + RIKEN
    - Support of EIC project is the highest priority.
  - NPC, ELPH (Tohoku university), Kyoto University …
  - Theories (pQCD, lattice QCD, Fugaku super-computer project) …

EIC-Asia workshop

- **Regular EIC-Asia workshop and monthly meeting to strengthen the collaboration**

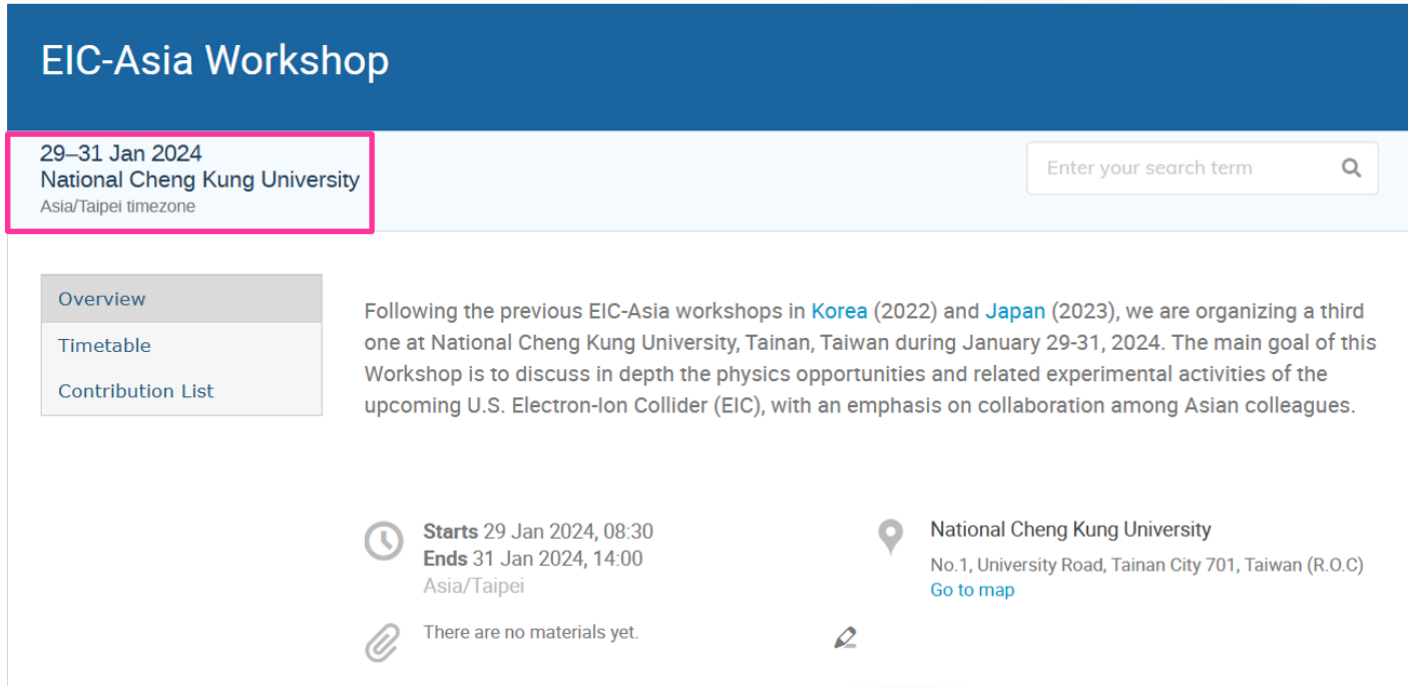
First EIC-Asia workshop at RIKEN in Japan (03/16-03/18, 2023), 70 participants

https://indico2.riken.jp/event/4389/



2nd EIC-Asia workshop at National Cheng Kung University in Taiwan (01/29-01/30, 2024),

https://indico.phys.sinica.edu.tw/event/88/

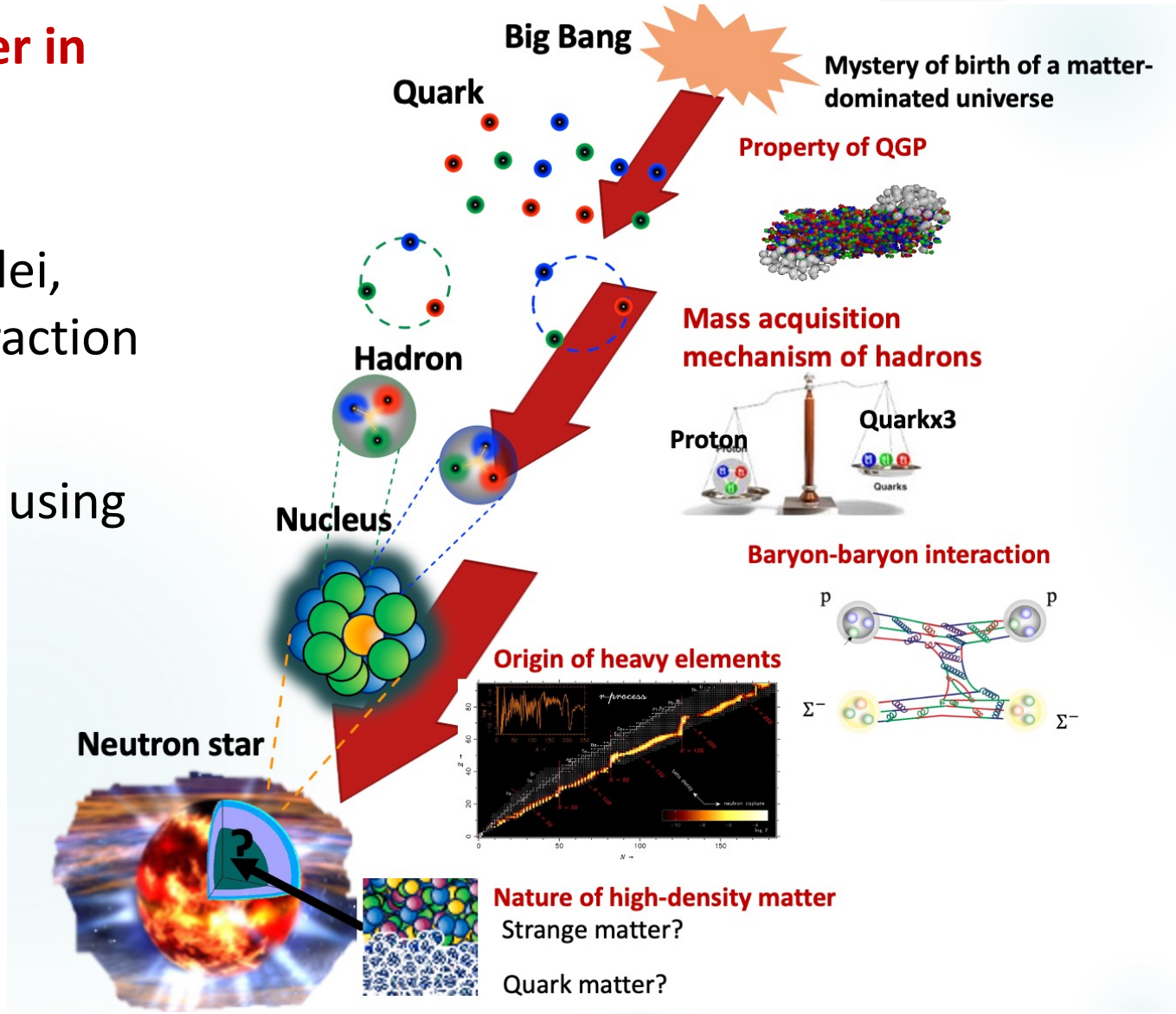


3rd EIC-Asia workshop in China at summer/autumn is underr discussion

Backup slides

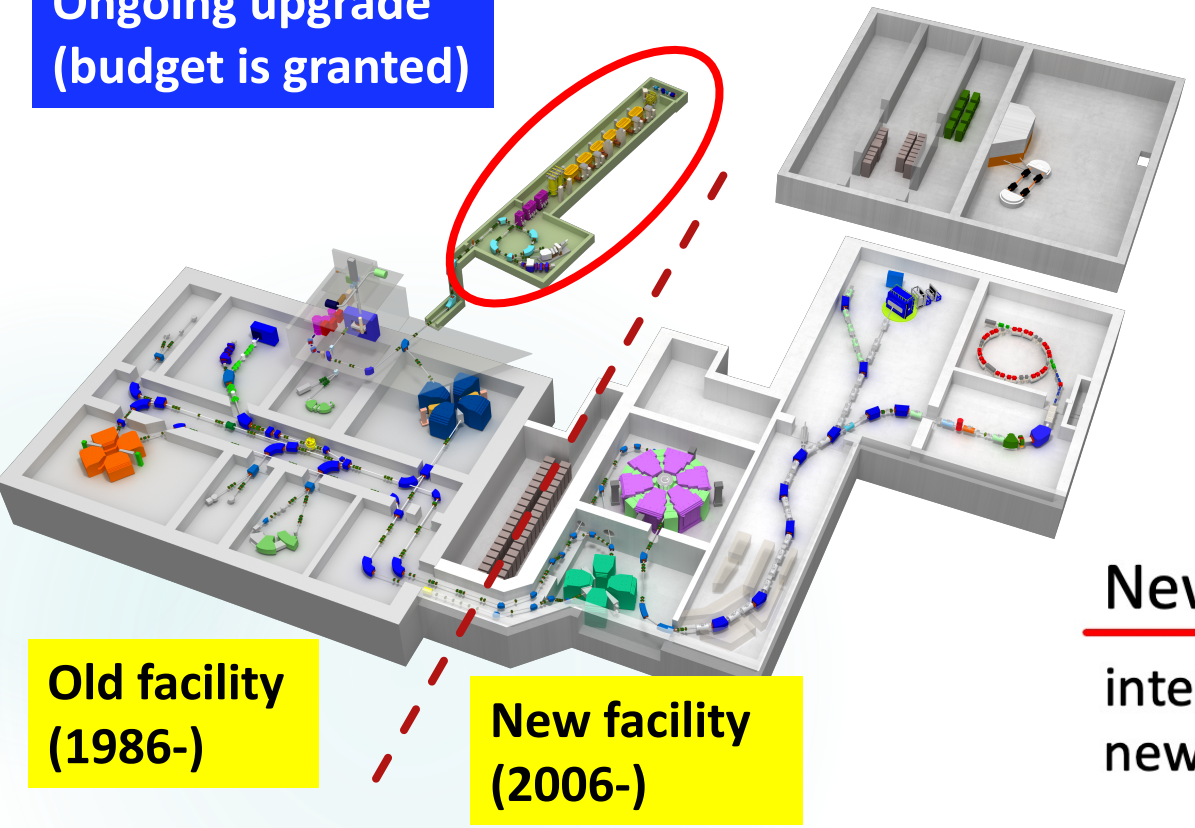
Vision of nuclear physics

- **How did quarks build up diverse matter in the universe during its evolution?**
- Aiming for a unified understanding of formation from quarks to hadrons, nuclei, neutron stars based on the strong interaction between quarks or hadrons.
- Systematic research on nuclear physics using various beams
  - Precise nuclear physics
  - Exotic (unstable) nuclear physics
  - Hadron, hypernuclear physics
  - High energy QCD physics



Low-Energy: RIBF Upgrade

Ongoing upgrade (budget is granted)



Old facility (1986-)

New facility (2006-)

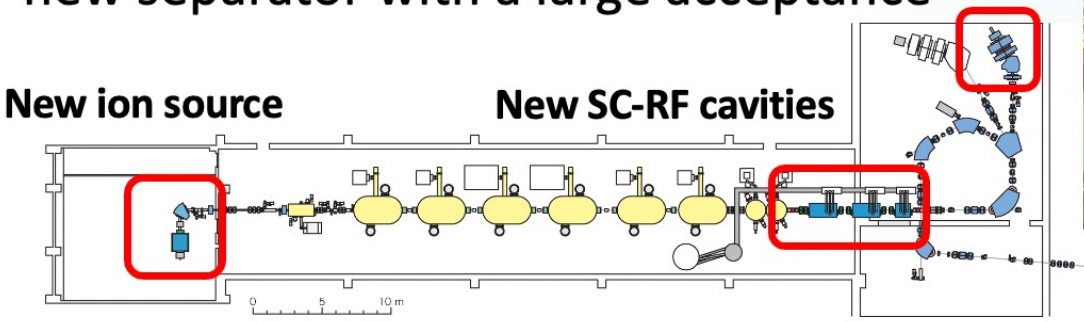
RIBF is one of the front runner facilities for low-energy nuclear physics in the world

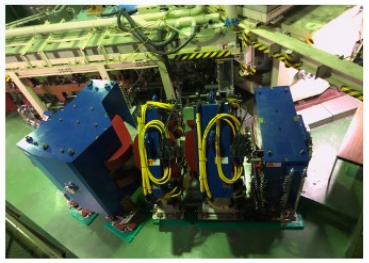
Search for super-heavy element

Search for Element 119 SRILAC+GARIS3
ORNL-RIKEN Collaboration

New setup towards the element 119 and beyond

intensity and energy upgrade of the heavy-ion LINAC
new separator with a large acceptance



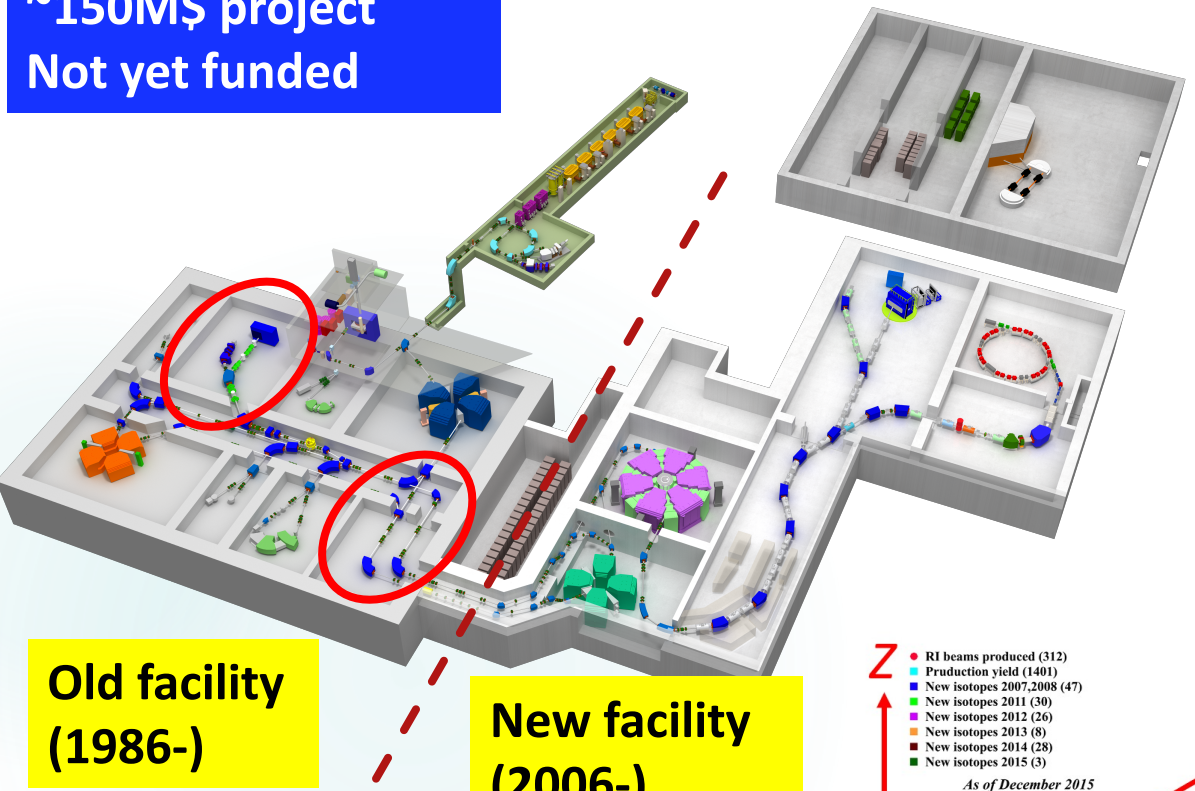


New separator

Element 113 “Nihonium”

Low-Energy: RIBF Upgrade

~150M$ project
Not yet funded



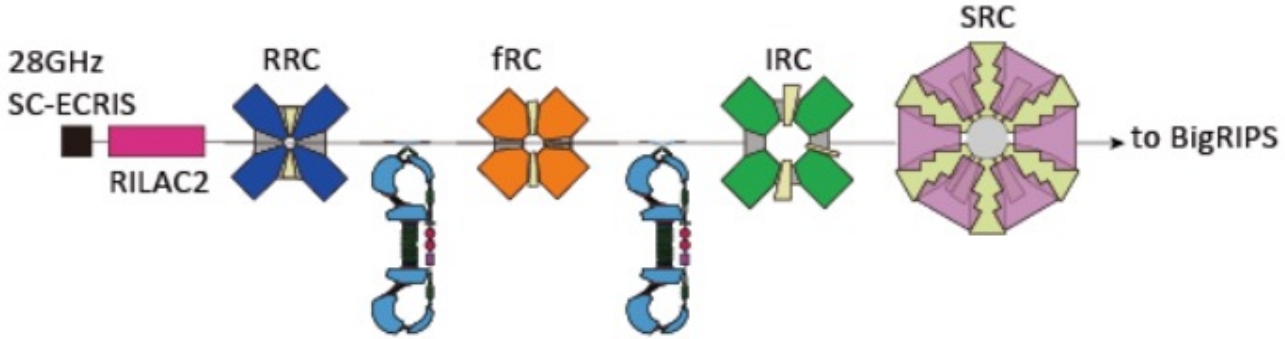
Old facility (1986-)

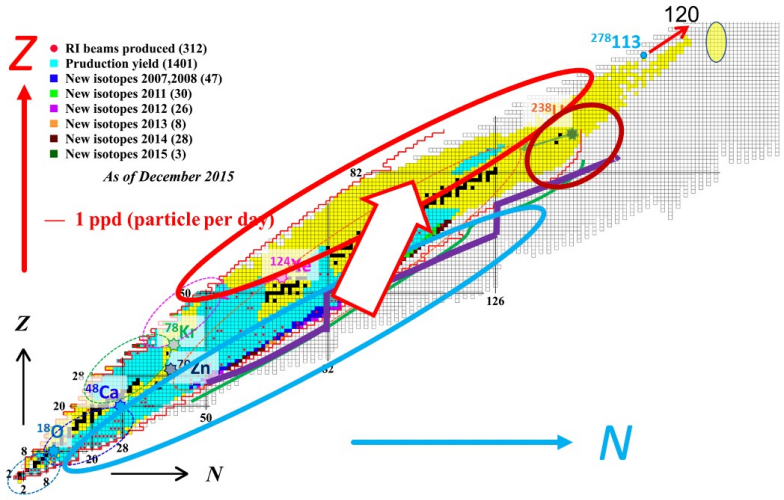
New facility (2006-)

Submitted to MEXT Roadmap 2023

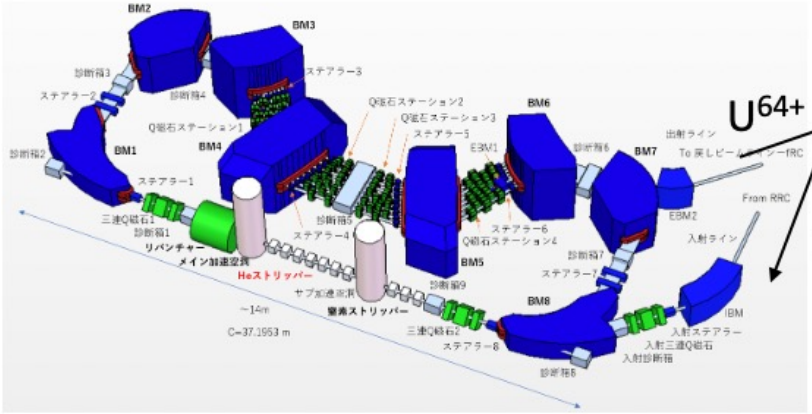
Exotic nuclei (fission and fusion reaction, alpha-cluster, shape co-existence, high-Z)

Charge Stripper Rings (CSR) for the intensity upgrade (x20)





CSR1



RIBF Upgrade timeline

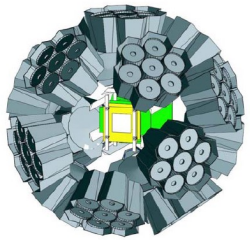
8-year project : 1st phase 5 years up to 500pnA
2nd phase 3 years up to 2000pnA

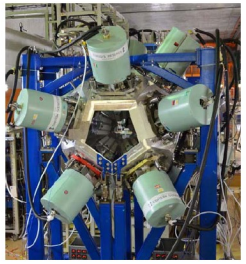
total budget needed 150M$

	Phase 1					Phase 2			
Year	1	2	3	4	5	6	7	8	9
Total Cost	22.4 BYen								
Accelerator System									
Injection system upgrade for IRC	design	construction	installation						
CSR1	design	design	construction	construction	installation				
ECR-IS upgrade	design	construction	construction	construction	installation				
SRC-RF upgrade	design	construction	construction	construction	installation				
fRC-RF upgrade		design	construction	construction	installation				
Infrasstructure upgrade	design	construction	installation						
CSR2			design	design	design	construction	construction	installation	
BigRIPS and ZeroDegree									
BigRIPS first stage for high power beam			design	design	design	construction	construction	installation	
BigRIPS first stage for high purity beam	design	design	construction	construction	installation				
Spectrometer upgrade			design	design	design	construction	construction	installation	
Achievement Goal									
Beam intensity						500 pnA			2000 pnA

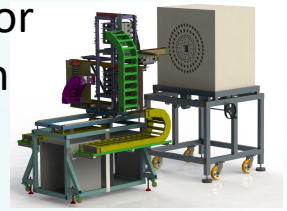
International collaboration at RIBF

EURICA (2011-2016):
EUroball-RIKEN Cluster Array

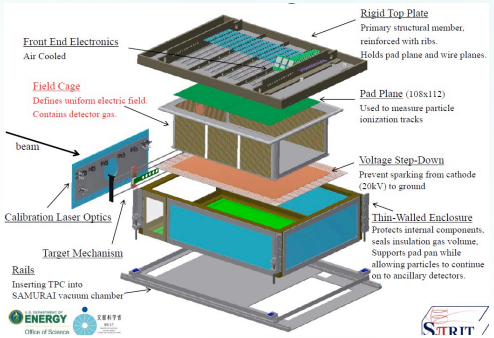




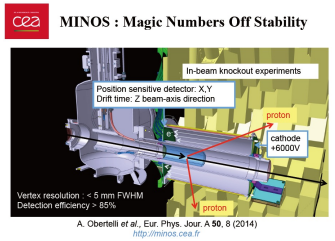
BRIKEN(2017-2021):
He-3 detector array for beta-delayed neutron



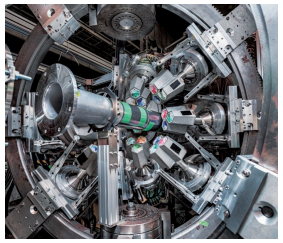
SpiRIT TPC (2015-):
heavy-ion collision program for EOS



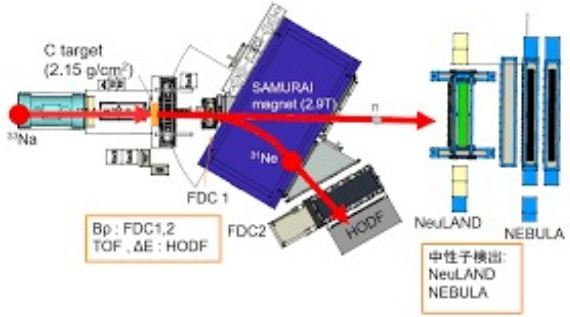
SEASTAR (2014-2017):
thick liq. H_2 +TPC+NaI
for in-beam gamma spectroscopy



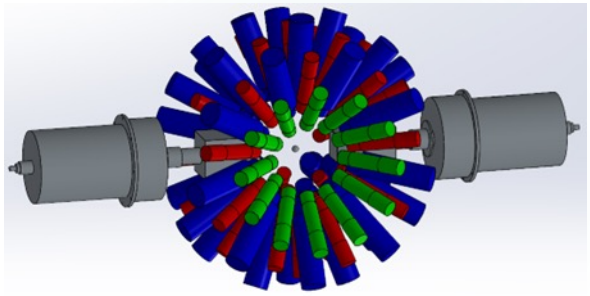
HiCARI (2019-2020):
Tracking Ge detectors for in-beam gamma spectroscopy



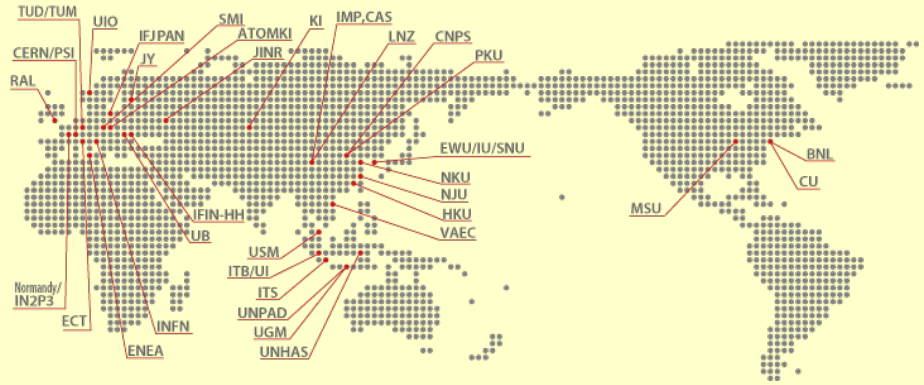
SAMURAI (2012-):
neutron detectors + CsI+…
for neutron correlation



IDATEN (2021-):
84 $LaBr_3$ (Ce) + 2 Cover Ge detectors to measure lifetime of excited states



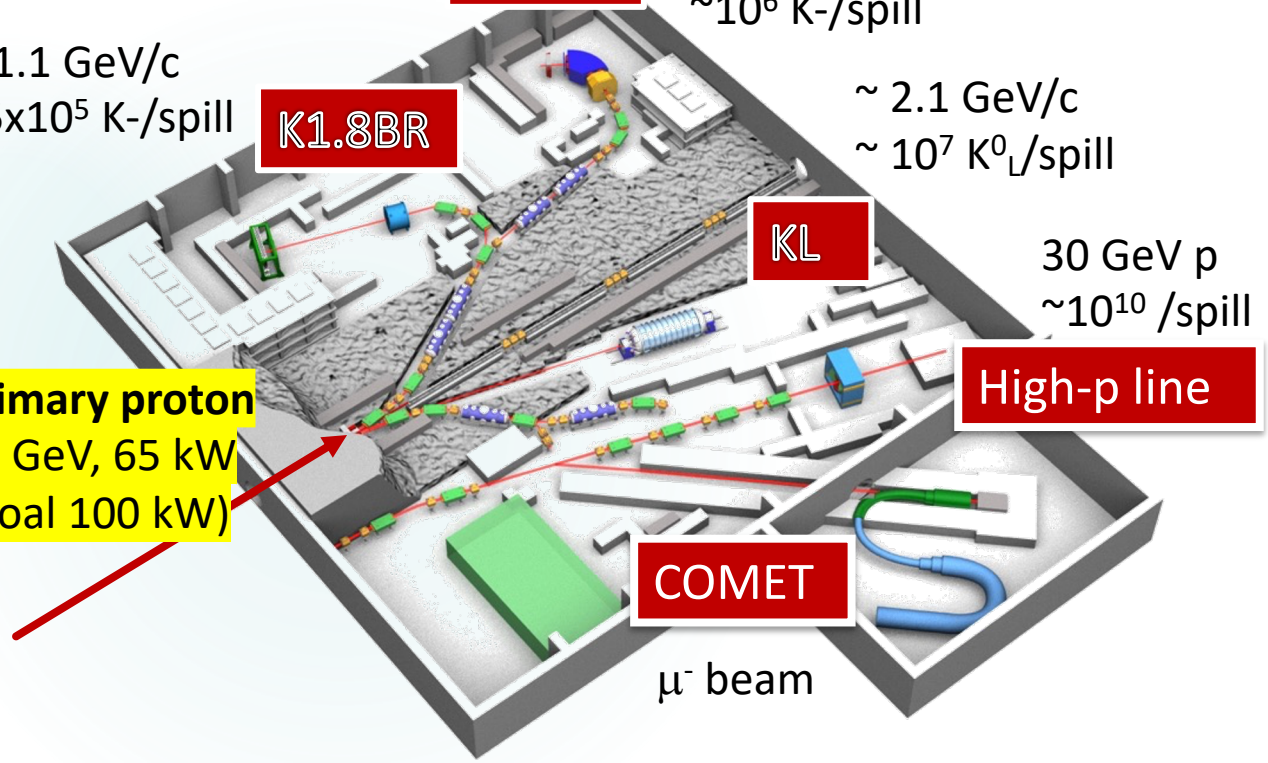
MoUs with
48 institutions and universities in 20 countries



Middle-Energy: Status of J-PARC

Intensity frontier accelerator providing intense and variety of secondary beams

J-PARC Hadron Hall



μ→e conversion measurement

Search for charged lepton flavor violation

100 times improvement over present upper limits

Rare decay of neutral kaon

Search for CP violation beyond the standard model

The world's highest sensitivity exceeding the standard model

Mass modification of vector mesons in nuclei

Mass acquisition mechanism of hadrons

Vector meson in nuclei : 10 times more precision

Systematic study of Kaonic nuclei

Study of exotic hadron bound system including K^-

Mass number dependence of kaonic nuclei

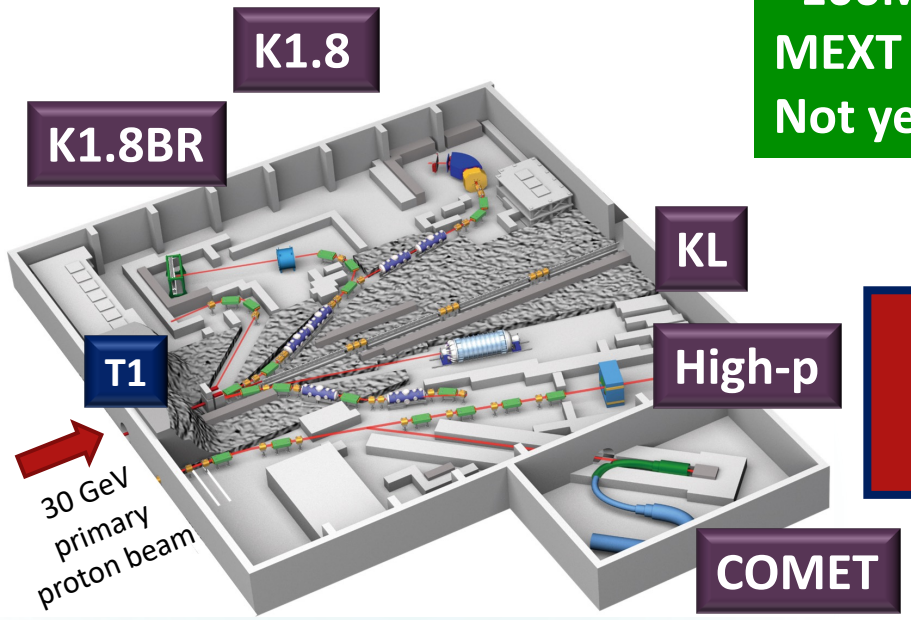
Spectroscopy of S=-1, -2 hypernuclei

Elucidation of the appearance mechanism of Ξ, Λ hyperons in dense matter

Excellent mass resolution of 2 MeV for X hypernuclei

J-PARC Hadron Facility Extension

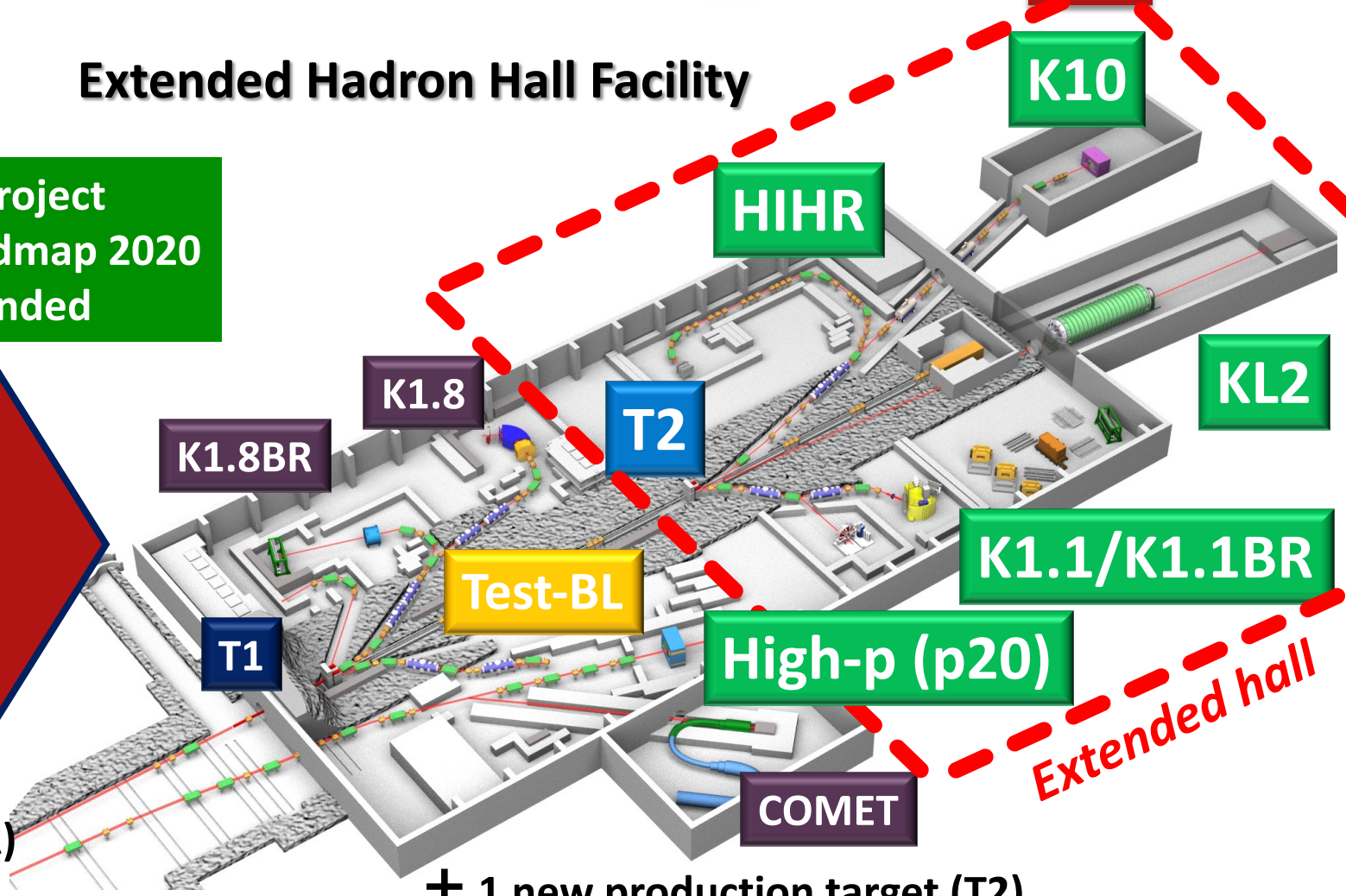
Present Hadron Hall (2009～)



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)

~100M$ project
MEXT roadmap 2020
Not yet funded

Extended Hadron Hall Facility



+ 1 new production target (T2)
+ 4 new beamlines (HIHR, K1.1/K1.1BR, KL2, K10)
+ 2 updated beamlines (High-p (π20), Test-BL)

Expanded Physics at J-PARC

Extract density dependent ΛN interaction

HIHR **Ultra-high-resolution Λ hypernuclear spectroscopy**
- intense dispersion matched π beam

K1.1 **Systematic ΛN scattering measurement**
- intense polarized Λ beam

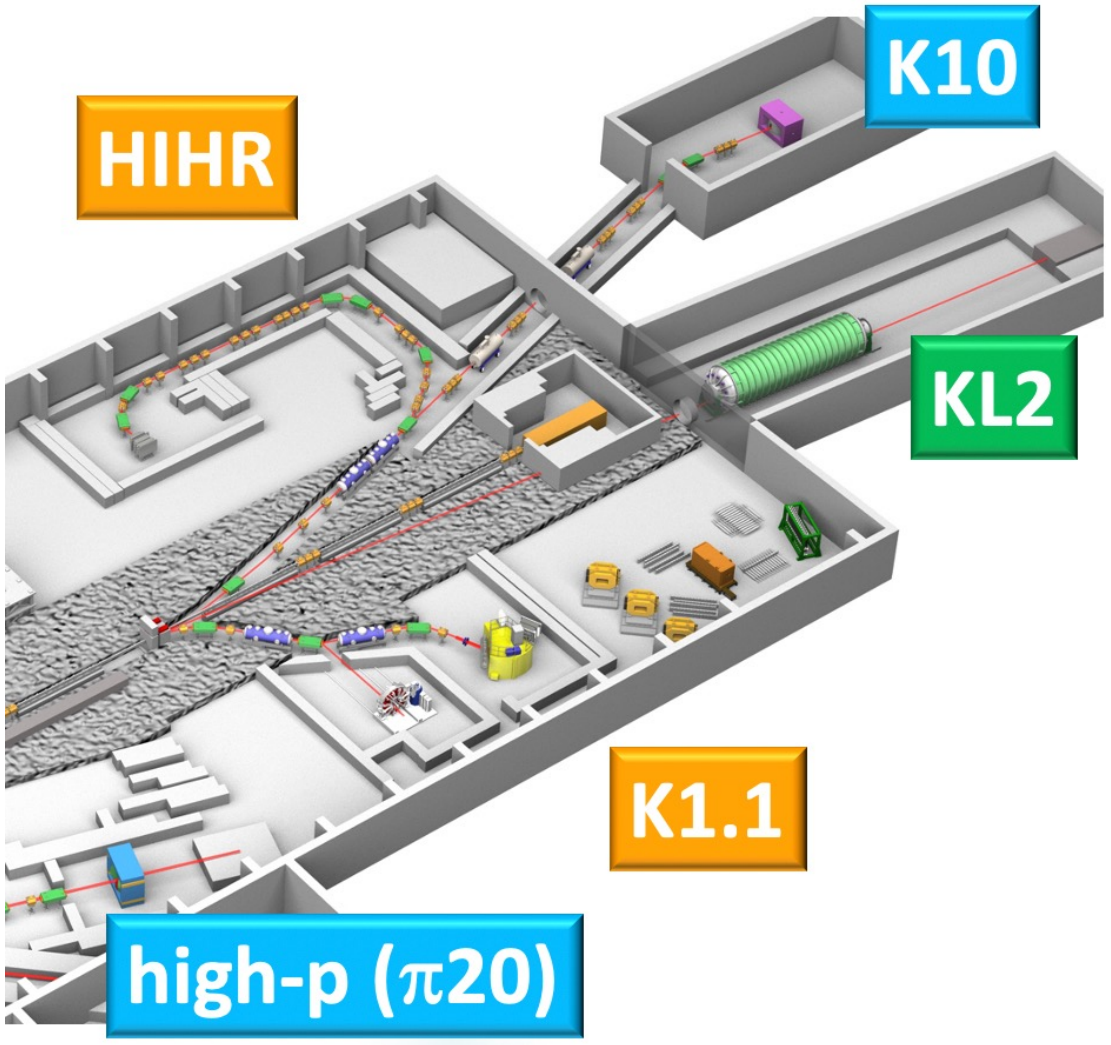
Investigate diquarks in baryons

high-p (π20) **High-resolution charm baryon spectroscopy**
- intense high-momentum π beam

K10 **High-resolution multi-strange baryon spectroscopy**
- intense high-momentum separated K beam

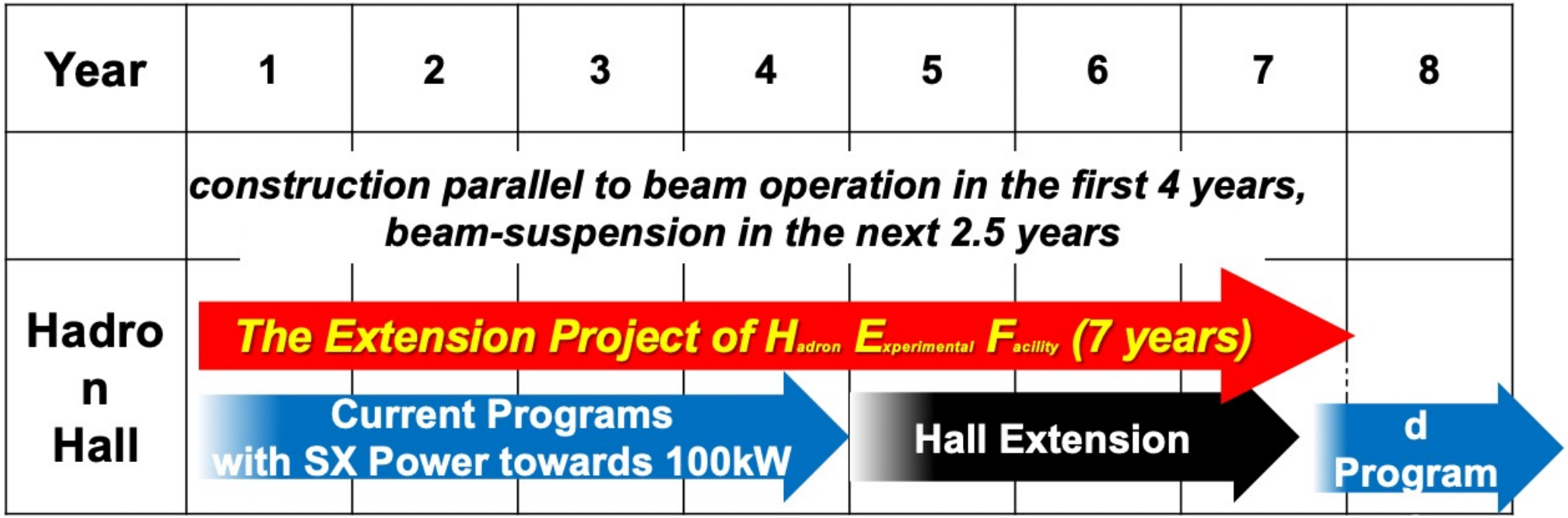
Search for new physics beyond the SM

KL2 **Most sensitive $K_L^0 \to \pi^0 \nu\bar{\nu}$ measurement**
- intense neutral K beam



Timeline of J-PARC Hadron Facility upgrade

total budget needed ~100M

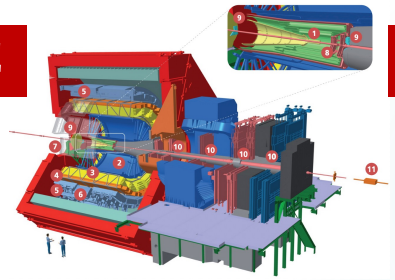


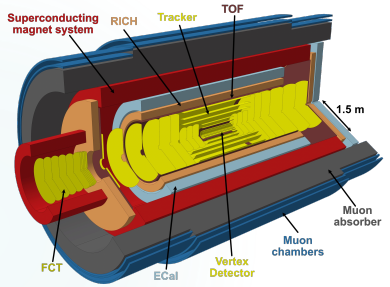
The project was selected as **the top-priority project** to be budgeted in the KEK's mid-term plan (FY2022-26) at KEK-PIP2022 (Project Implementation Plan)

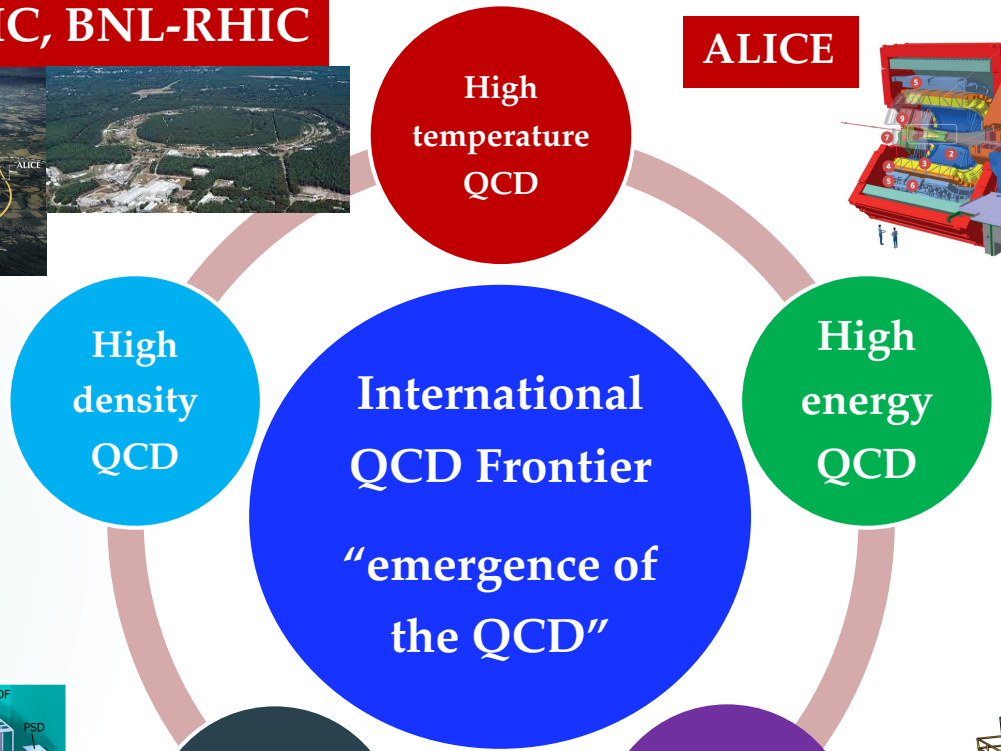
https://www.kek.jp/en/roadmap-en/

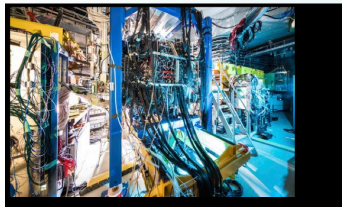
International QCD Frontier Initiative

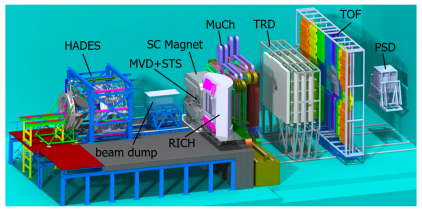
- **“Frontier of international high-energy quantum science: QCD research at overseas facilities”** proposed to Science Council of Japan (2022)

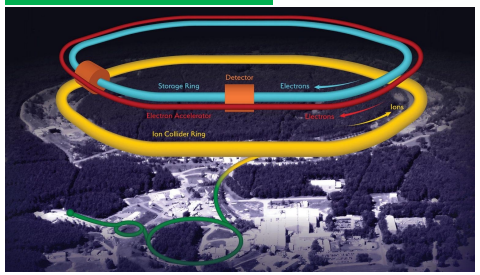


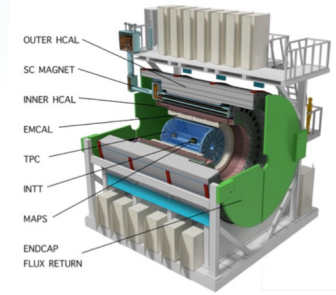


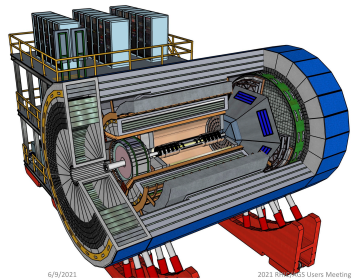










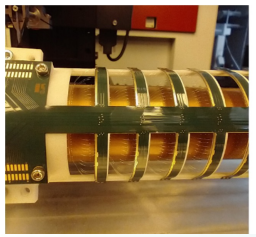


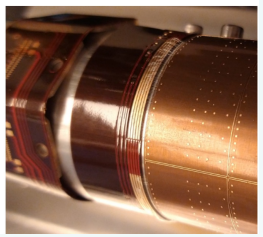
Brookhaven National Laboratory

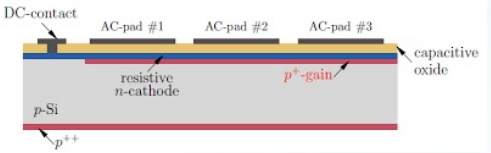
International QCD Frontier Initiative

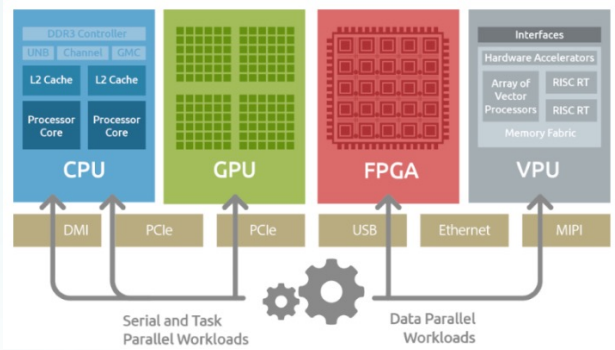
- Leading long-term international joint experimental research at overseas facilities
- Unify and strengthen Japanese teams from different projects and establish the collaboration according to project timelines/needs
- Human resource development for the next generation

- state-of-the-art common technology development
  - 4D (MAPS) Si pixel development
  - Heterogeneous computing









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