July 7, 2021
International Workshop on the Extension Project for the J-PARC Hadron Experimental Facility (J-PARC HEF-ex WS)

Welcome

Takashi Kobayashi

J-PARC Management

rc.jp/c/about/organization.html

令和3年4月1日時点

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幅 淳二

JAEA担当理事：
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原科研所長：
大井川 宏之 → 遠藤 章

KEK東海キャンパス所長：
小関 忠 → 小林 隆
KEK東海キャンパス副所長：
瀬戸 秀紀


Takashi Kobayashi

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Fujio Naito
(Dep. Dir.)

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（安全統括担当）
宮本 幸博


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(Dep. Dir)

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（JAEA担当）
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中根 佳弘／別所 光太郎


Safety D.: Yoshihiro Nakane

放射線管理セクション
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安全推進セクション
春日井 好己／伊藤 崇

加速器ディビジョン
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Acc D.: Michikazu Kinsho

加速器第一セクション
小栗 英知
加速器第二セクション
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加速器第五セクション
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下村 浩一郎


MLF D: Toshiya Otomo

中性子源セクション
羽賀 勝洋／酒井 健二
中性子利用セクション
川北 至信／横尾 哲也、中村 充孝
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中村 龍也
ミュオンセクション
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素粒子原子核ディビジョン
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PN D.: Takeshi Komatsubara

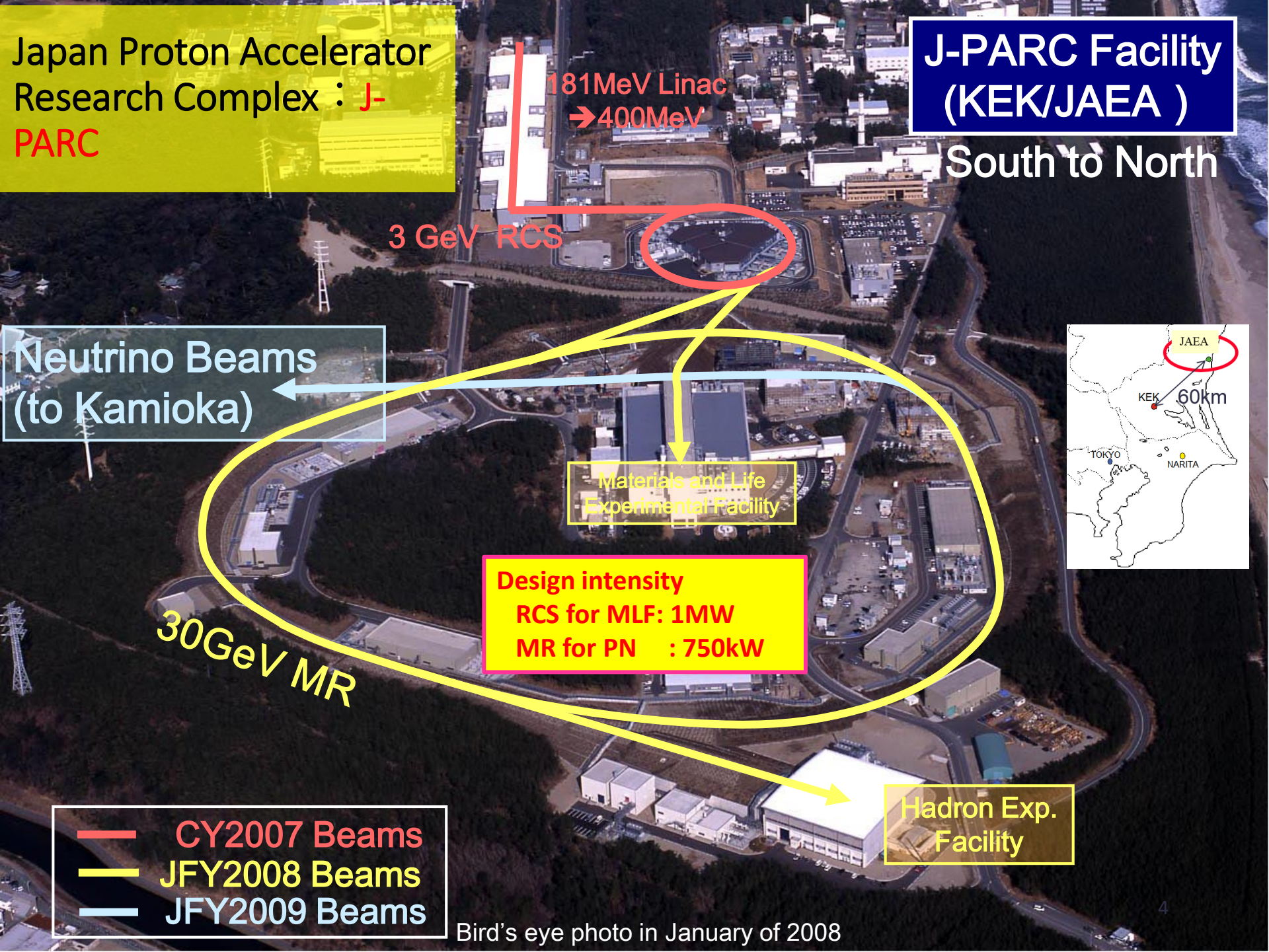
ニュートリノセクション
中平 武
ハドロンセクション
澤田 真也

Theory Center
Director
Shoji HASHIMOTO

Wako Nuclear Science Center @ RIKEN
Director
Michiharu WADA

- ATLAS
- Belle
- Neutrino
- Primary P
- Strangeness
- KOTO
- Hadron

- ILC
- CMB
- Muon/Neutron
- Cryogenic
- Electronics Sys
- Mechanics
- Computing
- Safety

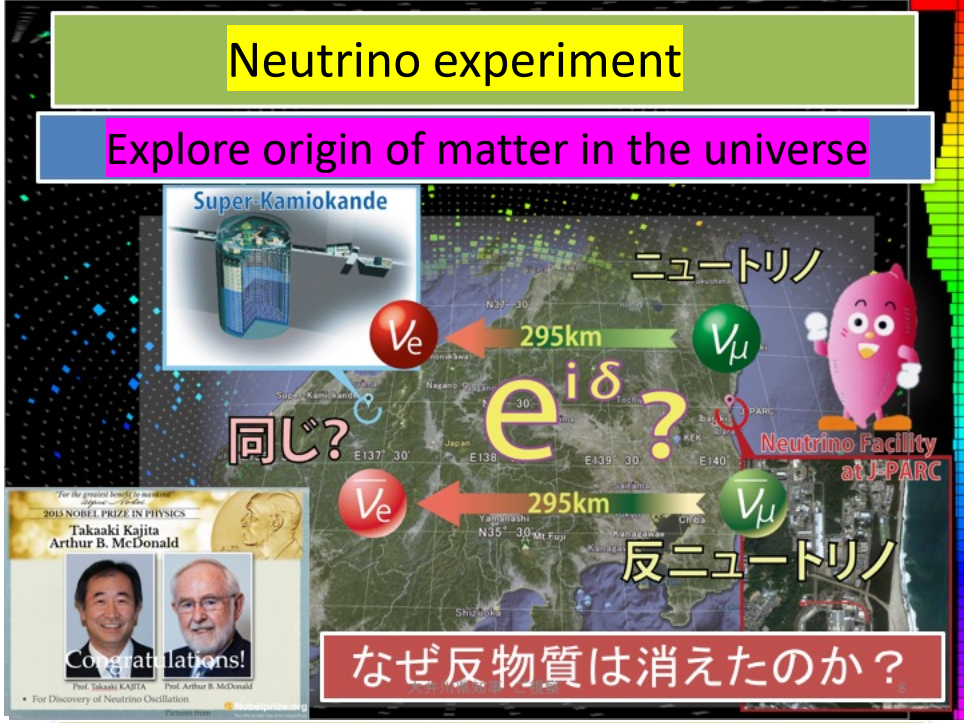

Japan Proton Accelerator Research Complex : J-PARC
J-PARC Facility (KEK/JAEA)
South to North
181MeV Linac
→400MeV
3 GeV RCS
Neutrino Beams (to Kamioka)
Materials and Life Experimental Facility
Design intensity
RCS for MLF: 1MW
MR for PN : 750kW
30GeV MR
Hadron Exp. Facility
JAEA
KEK
60km
TOKYO
NARITA
CY2007 Beams
JFY2008 Beams
JFY2009 Beams
Bird's eye photo in January of 2008

Science at MLF w/ n/mu

物質や Material and life sciences の起源を探る

Neutrino experiment

Explore origin of matter in the universe

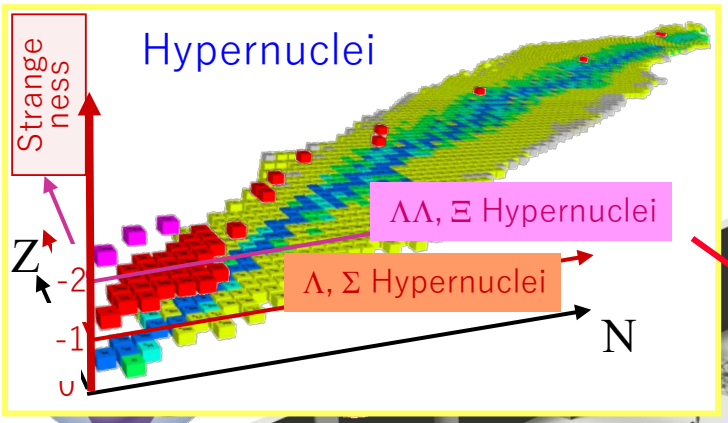


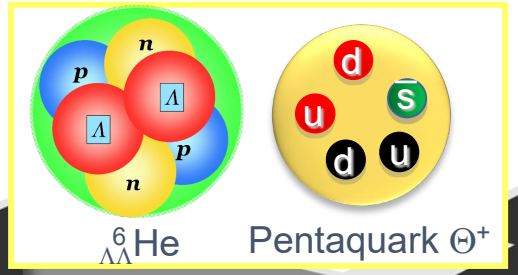
Hadron experiments

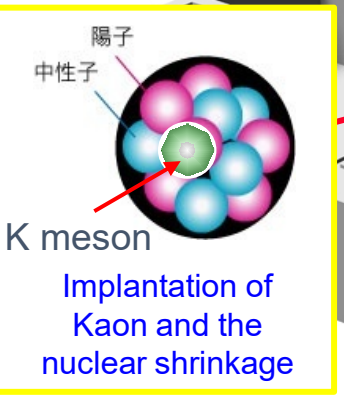
物質の形成過程における謎を探る！

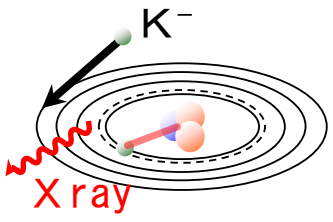
Development Accelerator Driven nuclear transmutation System: ADS

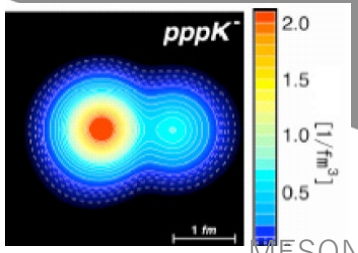
Current Physics Program at Hadron Hall

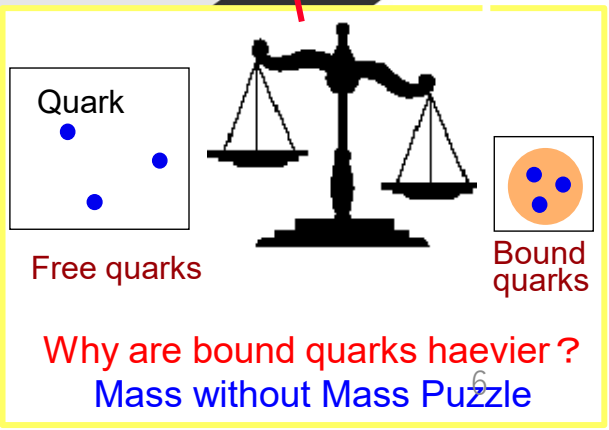




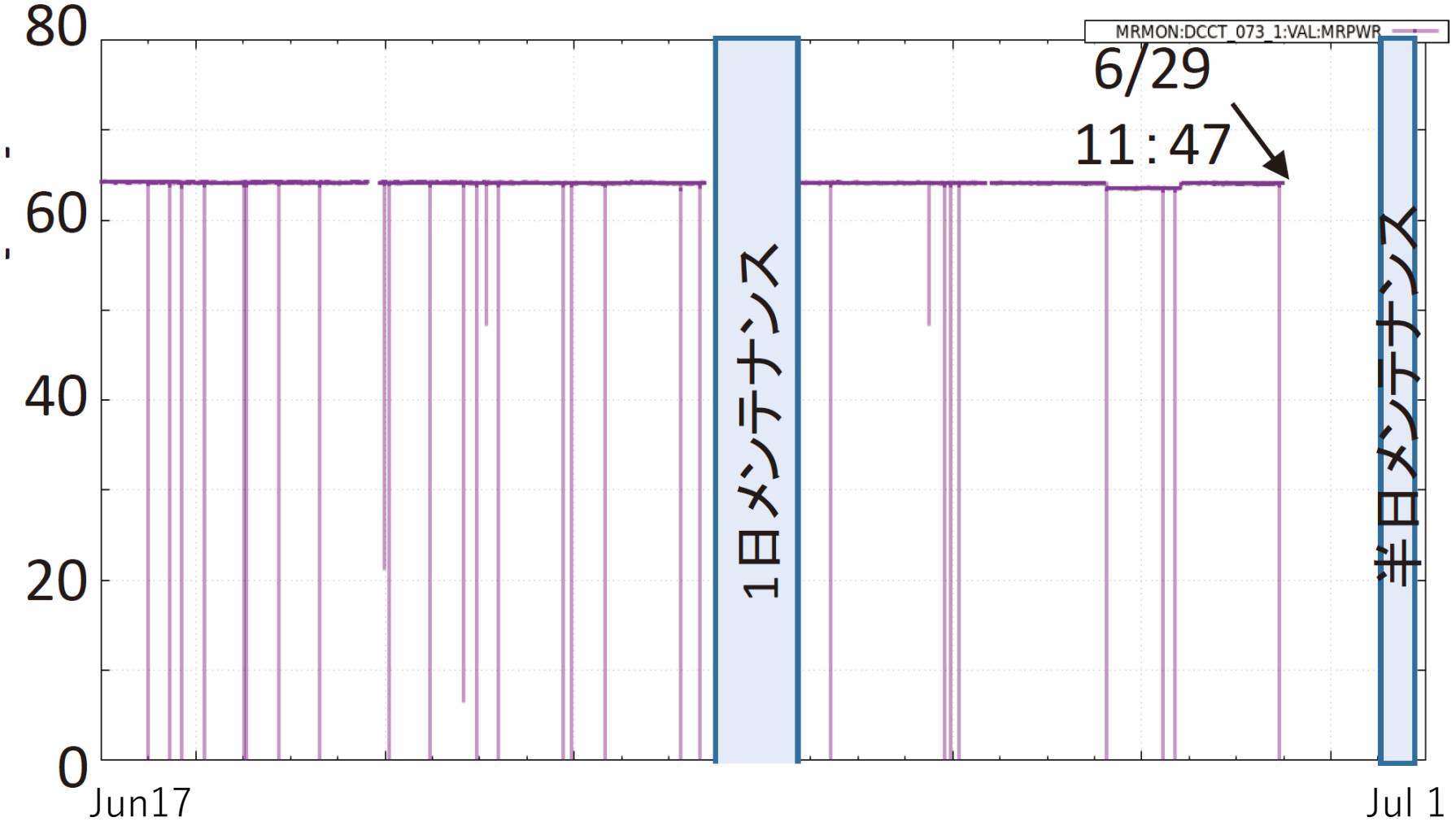








Very stable operation of SX at 64kW last months



Kinsho
A-TAC2021

Mid-term Plan of MR

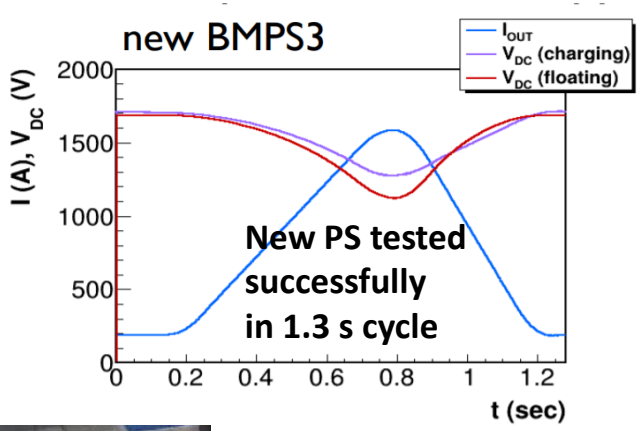
FX: The higher repetition rate scheme : Period 2.48s → 1.32 s for 750 kW
(= shorter repetition period) → 1.16 s for 1.3 MW
SX: Mitigation of the residual activity for the beam power upgrade

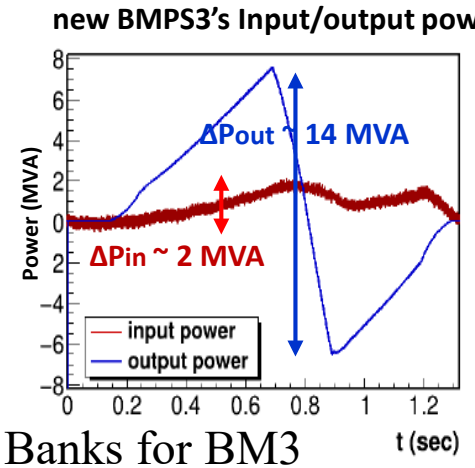
JFY	2020	2021	2022	2023	2024	2025	2026	2027	2028
Event		long shutdown							
FX power [kW]	515	-	>700	800	900	>1000	>1100	>1200	1300
SX power [kW]	55	60~70	>80	>80	>80	>80	~100	~100	~100
Cycle time for Fast Extraction	2.48s		1.32s	1.32s	1.32s	1.32s	<1.32s	<1.32s	1.16s
New Magnet PS	Mass Production Installation/Test →								
RF system upgrade			←	—	—	→			
2nd harmonic rf system	←	—	—	—	—	→			
Collimator system		Add.colli. (3.5kW)							
Injection system	Kicker PS improvement, Septa manufacture /test →								
FX system									
Beam Monitors (BPM circuits)	←	—	—	—	—	→			
SX Local sheild									
Diffuser/ Bent crystal/ VHF	←	—	—	—	—	→			

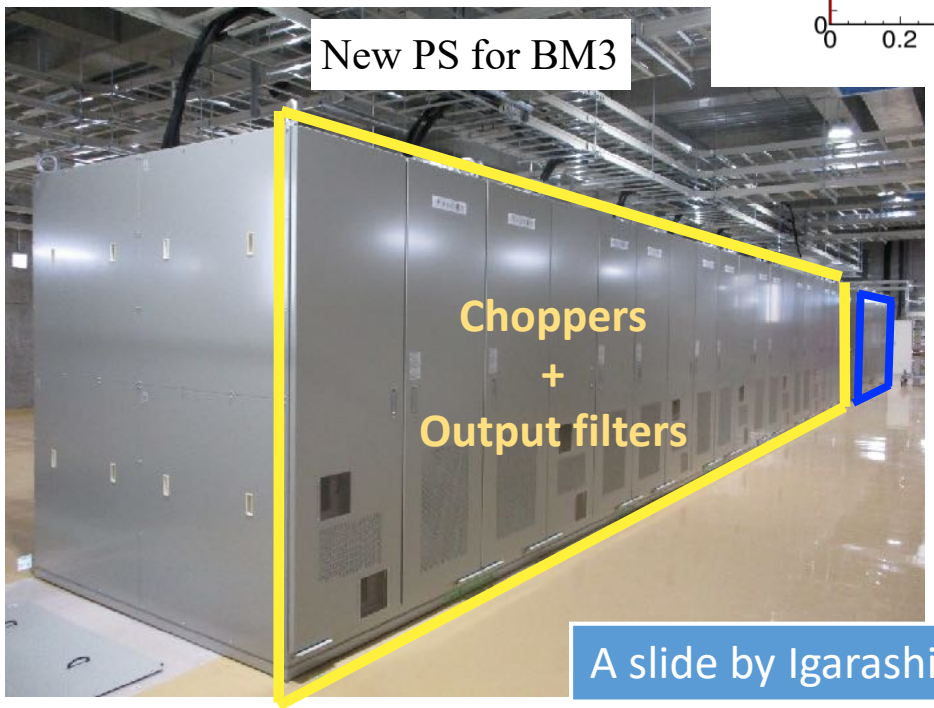
New Magnet Power Supplies with Capacitor banks

- Continuous operation with T=1.3 s for more than 50 hours without errors.
- The peak-to-peak variation of input power reduced from 14 MVA to 2 MVA.
- The current ripple decreased by 1/10 comparing to present PSs at low frequencies.

- **Installation of remaining power supplies in 2021.**
- **All processes are on schedule for beam test in Jun 2022.**







Capacitor Banks for BM3

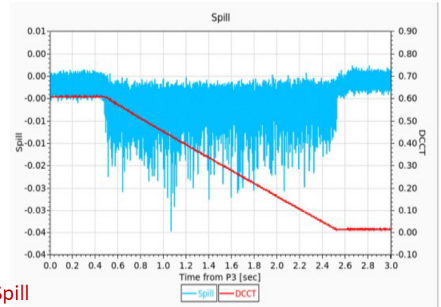
A slide by Igarashi et al.

Improvement of spill structure for SX experiments

Beam Spill Time Structure Improvements

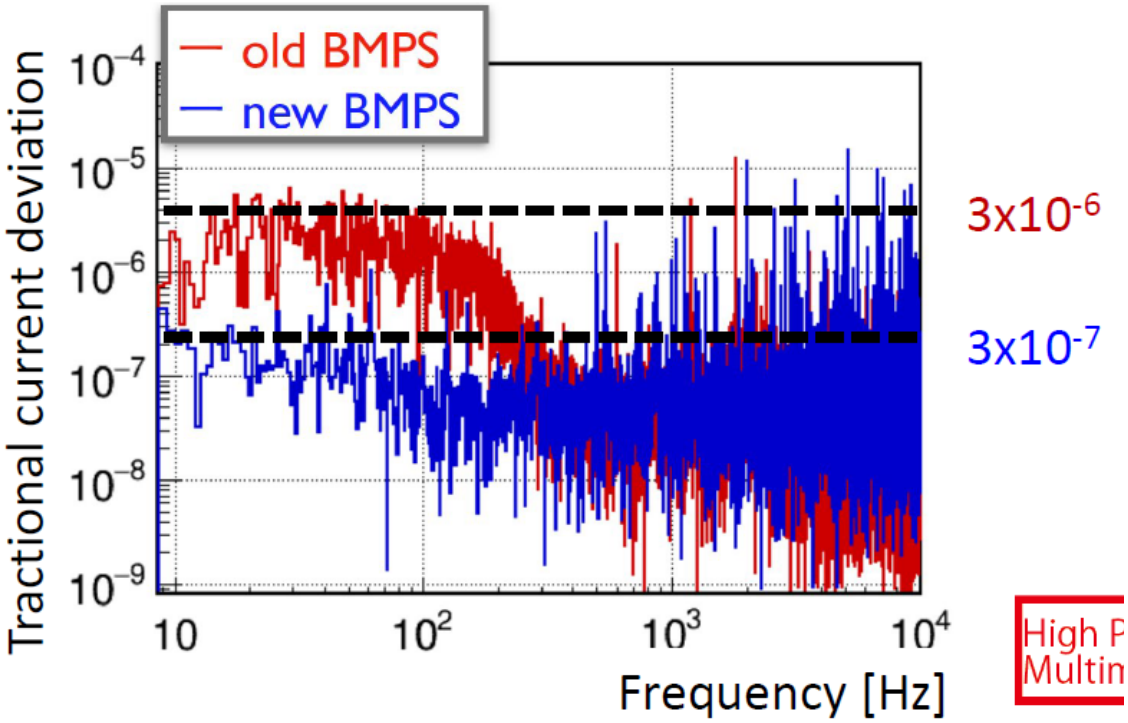
- Present power supply ripples of bends and quads are very large ⊿I/I 10^{-4} level.
  - Spill feedback by Fast response quads controlled by a DSP
  - Transverse RF field with noise width by two sets of strip line kickers
  - Coil short: (High frequency ripple is in bypath)
  - Spill duty factor has been improved from several % to 55% at present (ideally 100%).

- Plans to improve the spill time structure for a higher beam power
  - New power supply current ripples of bends and (partial) quads will be improved by 1 order.
  - Transverse RF field feedback (beam test is underway) *
  - Ripple canceller (beam test is underway) *
  - Multi-harmonic carrier frequencies for Transverse RF fields (collaboration with Nihon Univ.)
  - Machine Learning (US/Japan collaboration with BNL and FNAL)



55.7kW Beam Spill

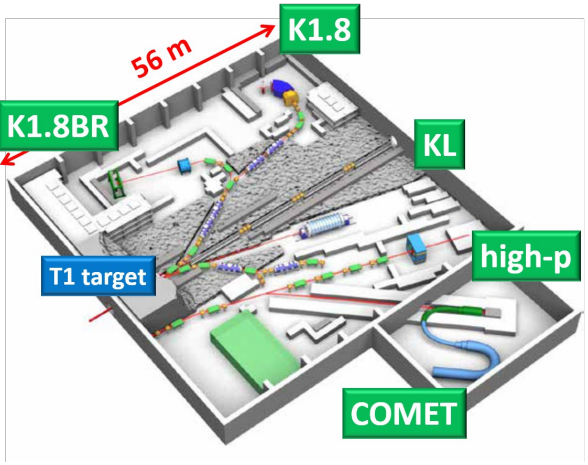
Kinsho
A-TAC2021



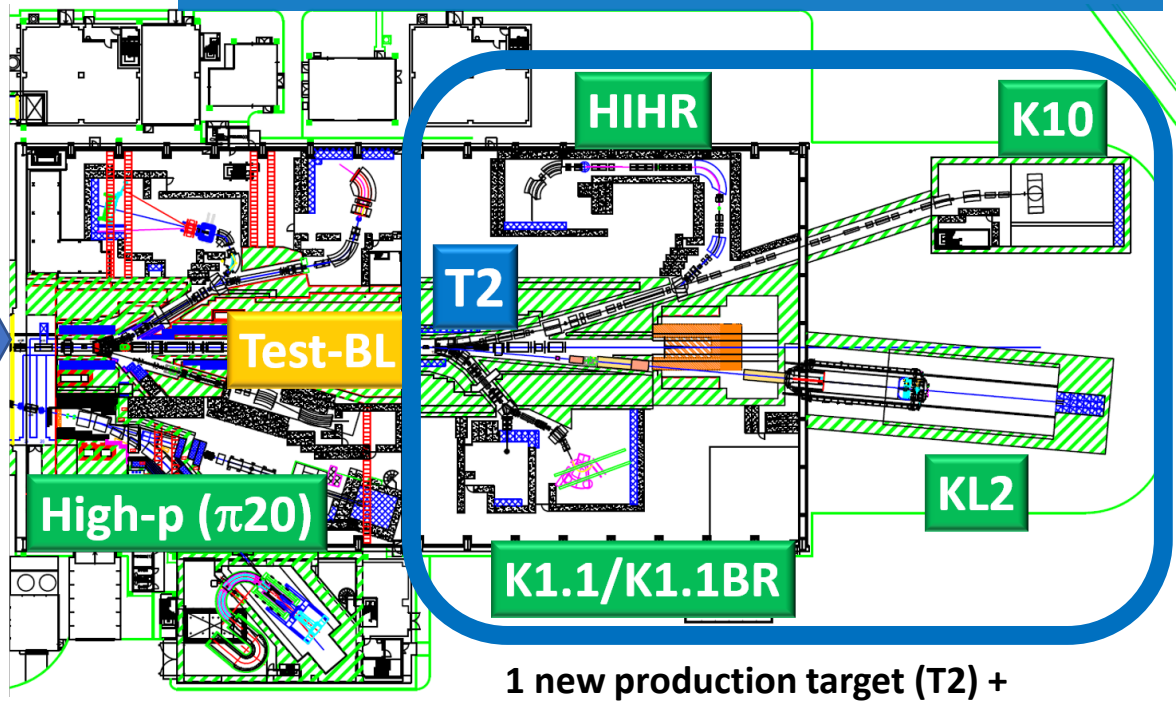
Hadron Experimental Facility Extension (HEF-ex) project

Open new physics that cannot be implemented at the existing facility

Present facility

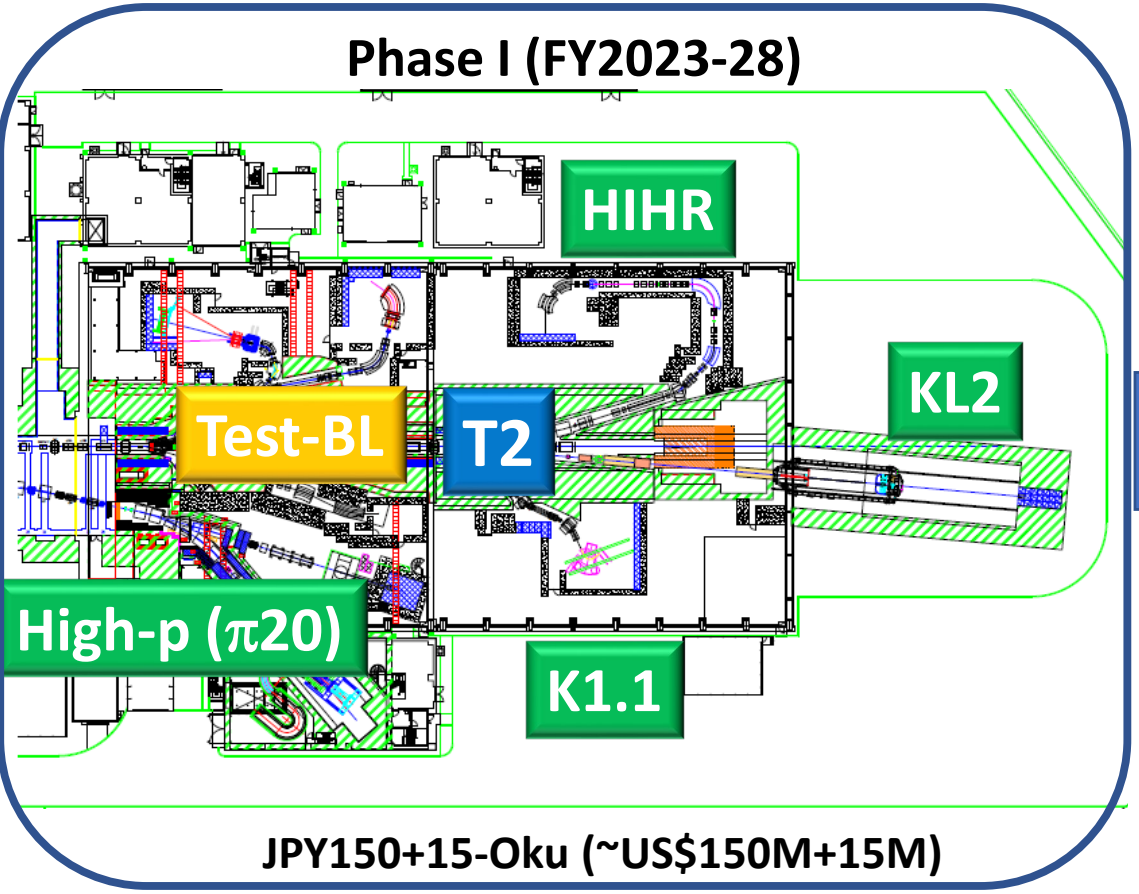


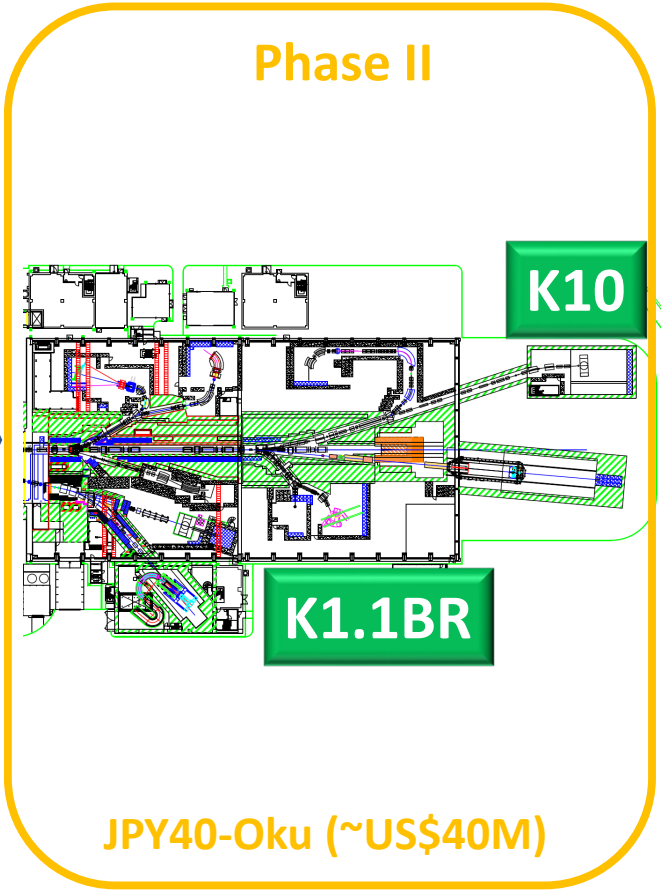
1 production target (T1) +
2 charged beamlines (K1.8/1.8BR, High-p)
1 neutral beamline (KL)
1 muon beamline (COMET)



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

A Staging Plan





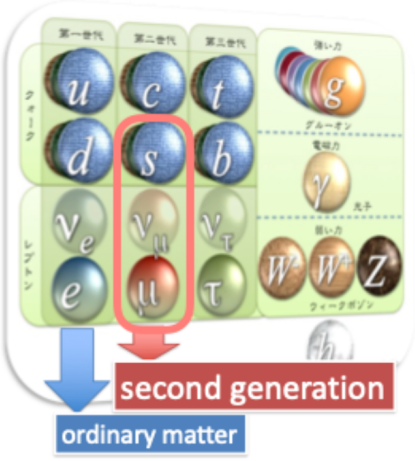
Toward realizing J-PARC upgrade

- J-PARC upgrade for Hyper-Kamiokande approved and funding started from JFY2019 supplementally budget
- J-PARC operation (9month) and upgrade project “Quest for the origin and evolution of universe and matters with high-intensity proton beams” was selected as one of the 15 large projects in MEXT Roadmap 2020
  - Hadron hall extension
  - Mu g-2/EDM
  - COMET phase-II
  - 9 cycle operation
- “KEK Roadmap” is updated after year-long discussion in JFY2020
  - J-PARC upgrade for Hyper-K remains to be a major priority
  - Reviewed by KEK SAC
- Discussion on new KEK-PIP started aiming to reviewed again by SAC and finalized within FY2021

KEK Roadmap update (JFY2022-27)

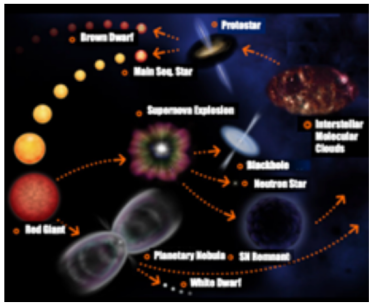
・J-PARC

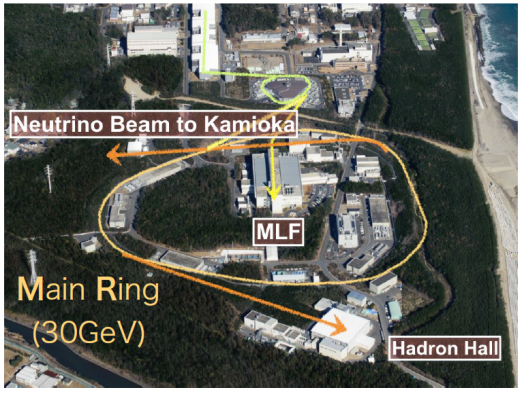
All experimental facilities including neutrino, hadron, and materials and life science experimental facilities will be pushed to meet their design beam intensities, while maintaining an appropriate balance between beamtime availability and facility upgrades. For upgrades, the beam enhancement for Hyper-K, the muon g-2/EDM experiment, the extension of the Hadron Experimental Facility, and phase II of the COMET experiment will be steadily carried out. In addition, the development and research plans of the second target station, which is a major future plan of the Materials and Life Science Facility, will be materialized.



- beam intensities
- beamtime

- facility upgrades :
  - beam enhancement for Hyper-K
  - muon g-2/EDM
  - extension of
    - Hadron Experimental Facility
  - phase II of COMET



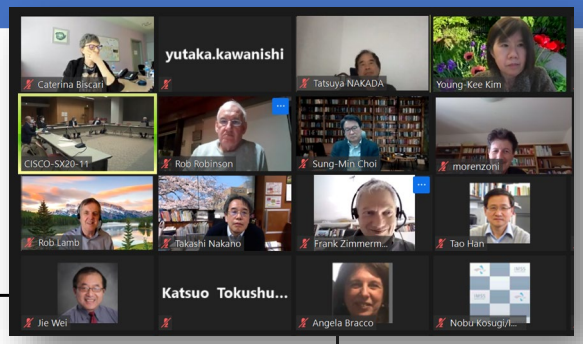


KEK50 年

KEK 2021

KEK Science Advisory Committee 2021

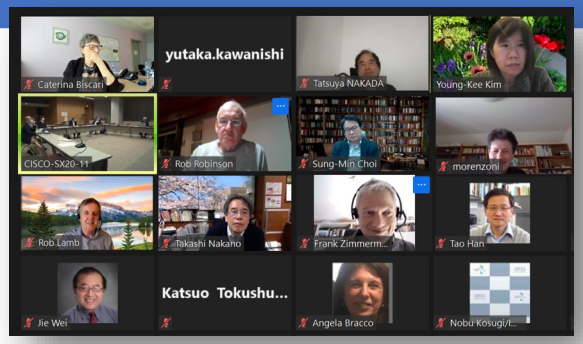
- KEK-SAC met on March 19, 20 and 30, virtually.



Field	Name	Affiliation
HEP	Young-Kee Kim	University of Chicago
	Jun Cao	Institute of High Energy Physics, Chinese Academy of Science
	Tatsuya Nakada	EPFL, Ecole polytechnique fédérale de Lausanne
Theory	Tao Han	University of Pittsburgh
Nuclear	Takashi Nakano	Osaka University
	Angela Bracco	INFN, Istituto Nazionale di Fisica Nucleare
Accelerator	Frank Zimmermann	CERN, European Organization for Nuclear Research
	Jie Wei	Michigan State University
PF (Synchrotron Radiation)	Caterina Biscari	ALBA Synchrotron
	Robert Norman Lamb	CLS, Canadian Light Source
Neutron	Robert Alan Robinson	University of Wollongong, Australia (retired, ex ANSTO)
	Sung-Min Choi	KAIST, Korea Advanced Institute of Science and Technology
Muon	Elvezio Morenzoni	PSI, Paul Scherrer Institute

KEK Science Advisory Committee 2021

- KEK-SAC met on March 19, 20 and 30, virtually.



Comments and Recommendations:

KEK's priorities should include providing sufficient beam time for Belle II and T2K experiments, KEK's continued involvement, together with Japanese university groups, in the ATLAS experiment and its upgrades, continued contribution to the necessary effort for hosting the ILC in Japan, and successful execution of its contribution to the HyperK project.

In addition, the SAC offers the following recommendations:

- Support the wide-range particle and nuclear physics programs at J-PARC and the upgrade of the J-PARC hadron hall.
- Prepare to develop KEK long term strategies without the ILC.
- Develop a strategy and policy for the longer term regarding future participation in projects elsewhere, including those in cosmology and astro/astroparticle physics.
- Foster common detector R&D efforts among the different projects not only within IPNS, but also in other research areas of KEK.
- Continue to strengthen the close interactions and mutual support between the Theory Center and experimental groups, and include some prospects for the Theory Center in the roadmap.

KEK Project Implementation plan (PIP)

- Prioritize projects requiring new funding (request)
- 1st KEK PIP (2016) https://www.kek.jp/ja/About/OrganizationOverview/Assessment/Roadmap/KEK-PIP.pdf
    1. J-PARC upgrade for Hyper-Kamiokande project
    2. High Luminosity LHC
    3. Muon g-2/EDM
    4. Hadron hall extension
- HK and HL-LHC funding started, g-2 funding request started
- Discussion to update the PIP for next 6 years from FY2022 started to conclude within JFY2021
    - Oct2021: PIP2022 outline
    - Nov2021: PIP2022 draft
    - Feb2022: SAC
    - Mar2022: conclude PIP2022
- Propose ~ 8 projects to SAC and ask to prioritize 4 projects among those out of
    - HD extension, SuperKEKB/Belle II upgrade, Additional contribution to HL-LHC, COMET phase-II, MLF TS2, Transmission Muon microscope, future light source, neutrino EDM, LiteBIRD, KAGRA upgrade, Slow positron facility, KISS II, Structural Biology Research Center, +??

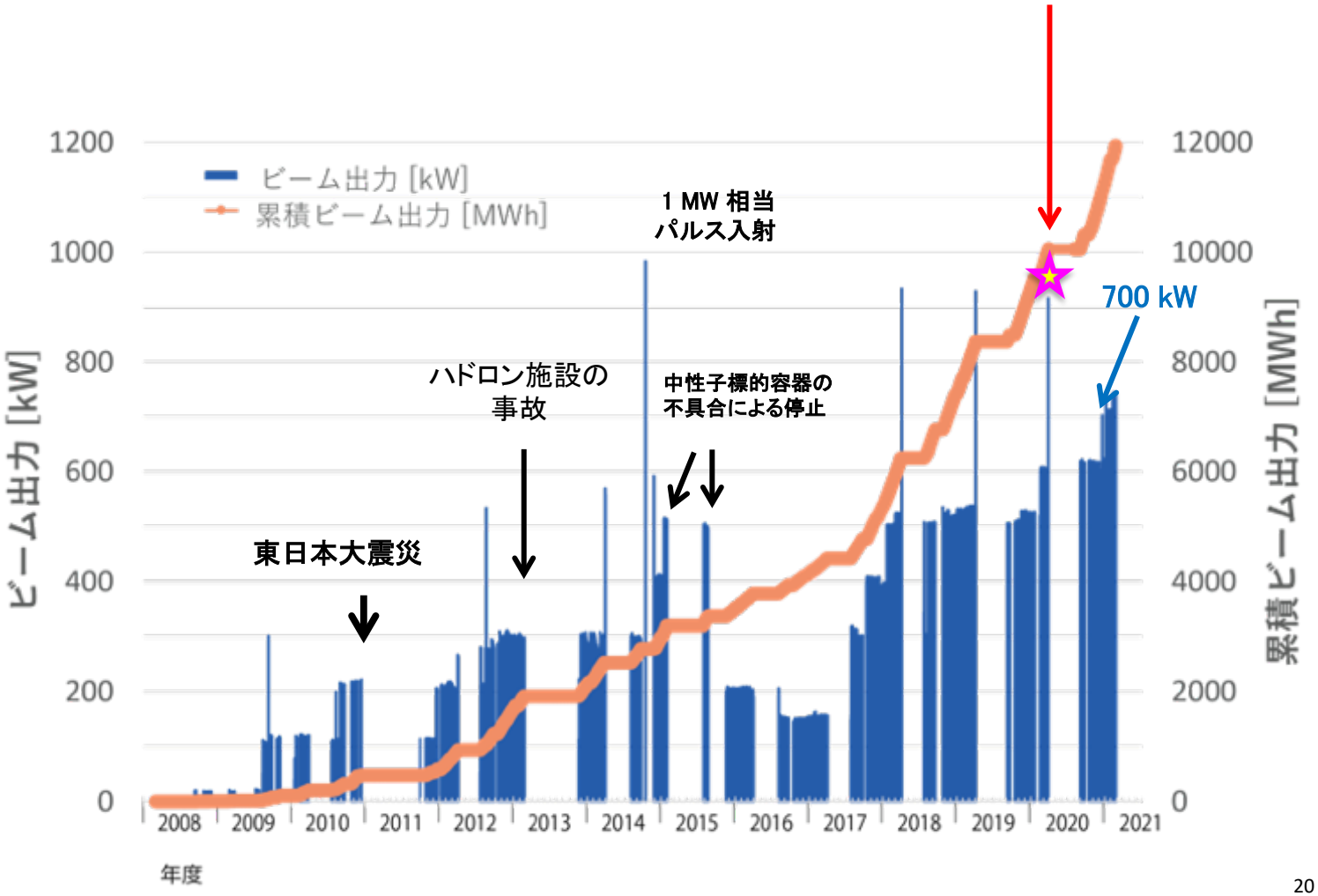
Selected as a high priority project in KEK-PIP is a MUST (necessary condition) to be funded

To realize HEF extension project

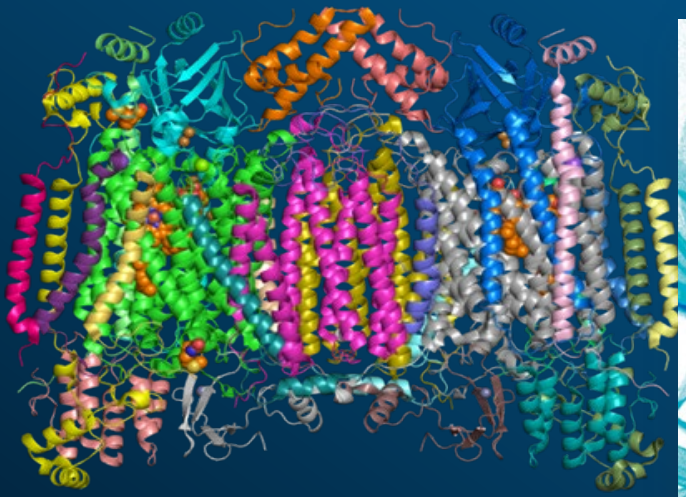
- Strong science
  - ➔Purpose of this workshop
- Strong interest/passion of “young” researchers
  - Who really want to/will do science at HEFex

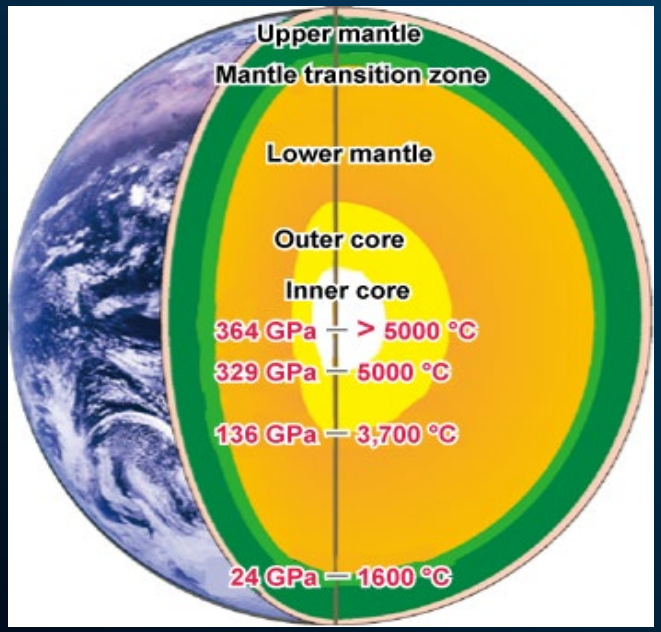
Spare

RCS beam history

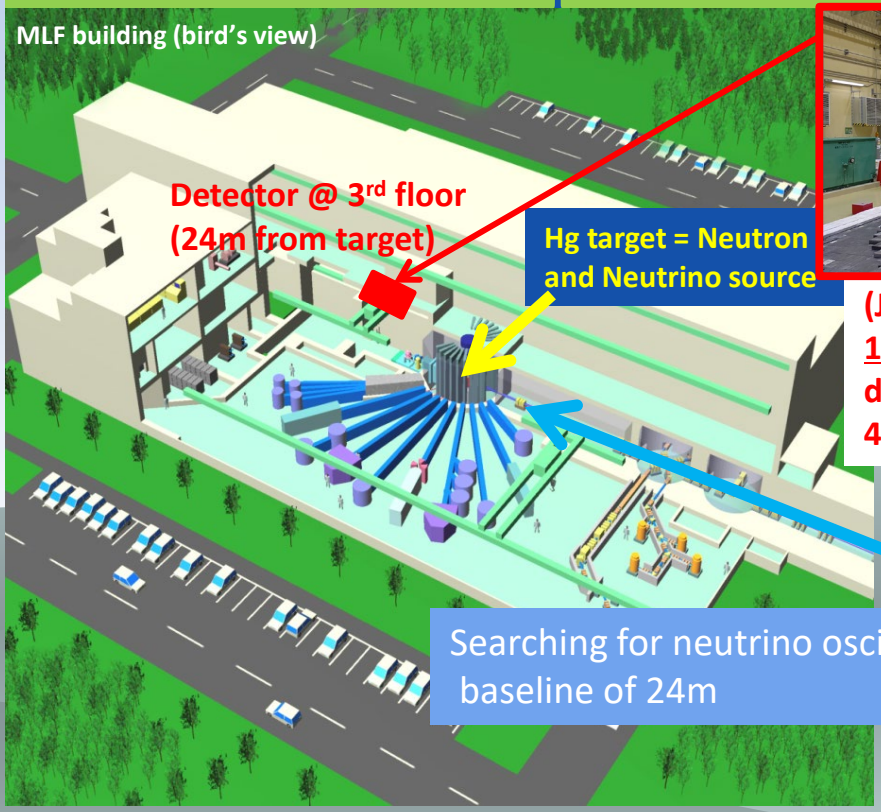


Science at MLF

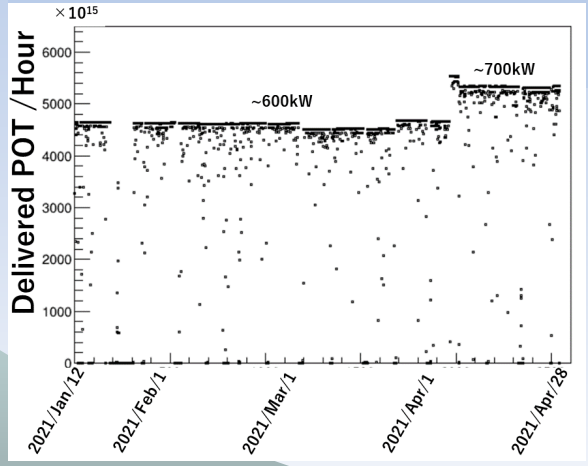




JSNS^2 experiment : Search for sterile neutrinos

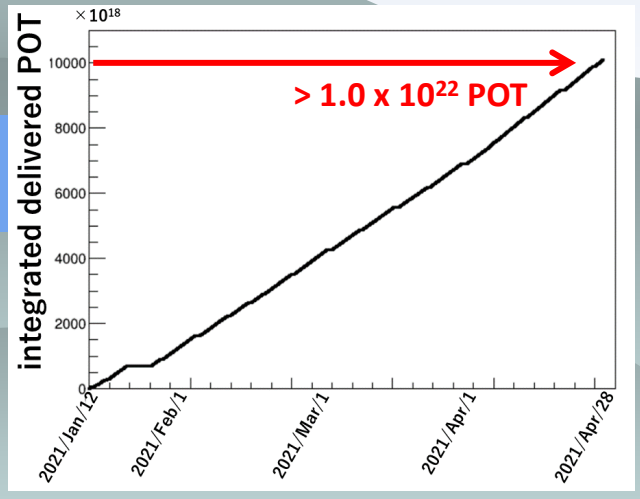


(JSNS^2)
17t GdLS fiducial (target) detector (4.6m dia. x 4.0m height, 120 10" PMTs)



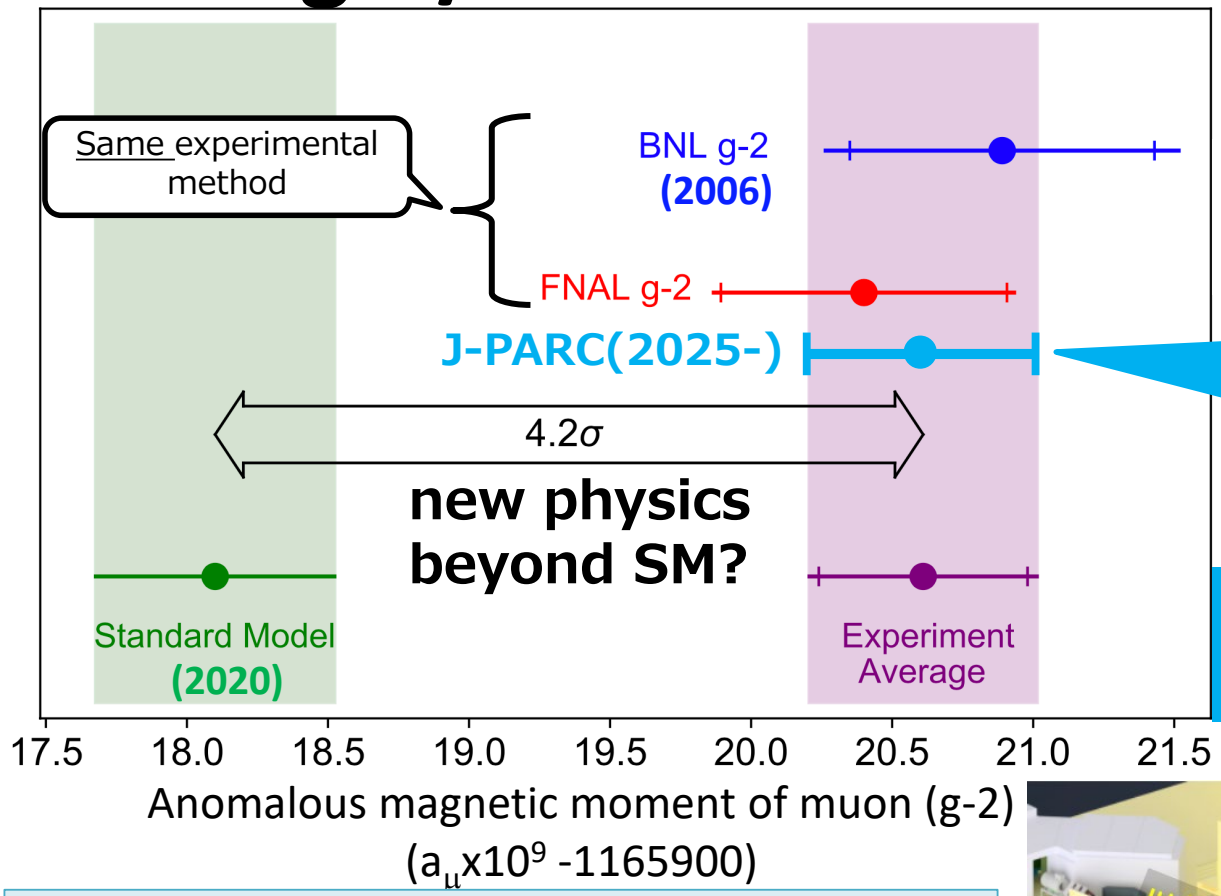
Searching for neutrino oscillation with baseline of 24m

3GeV pulsed proton beam



JSNS^2 :Started the first physics run on Jan 12, 2021

Muon g-2/EDM

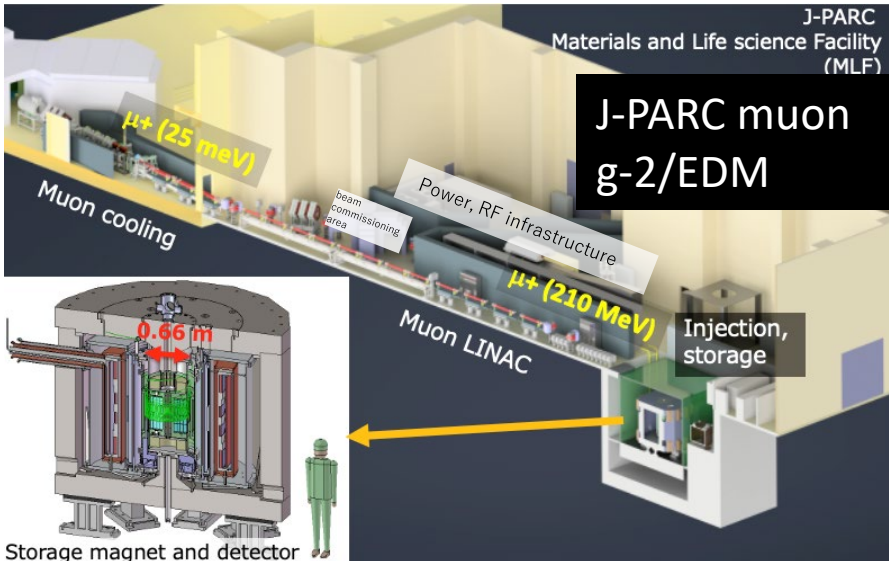


New result from FNAL
on April 7, 2021

(1) Confirmed previous BNL result
(2) Deviation from the SM became 4.2σ (was 3.7σ)

An independent evaluation with a novel experimental method at J-PARC

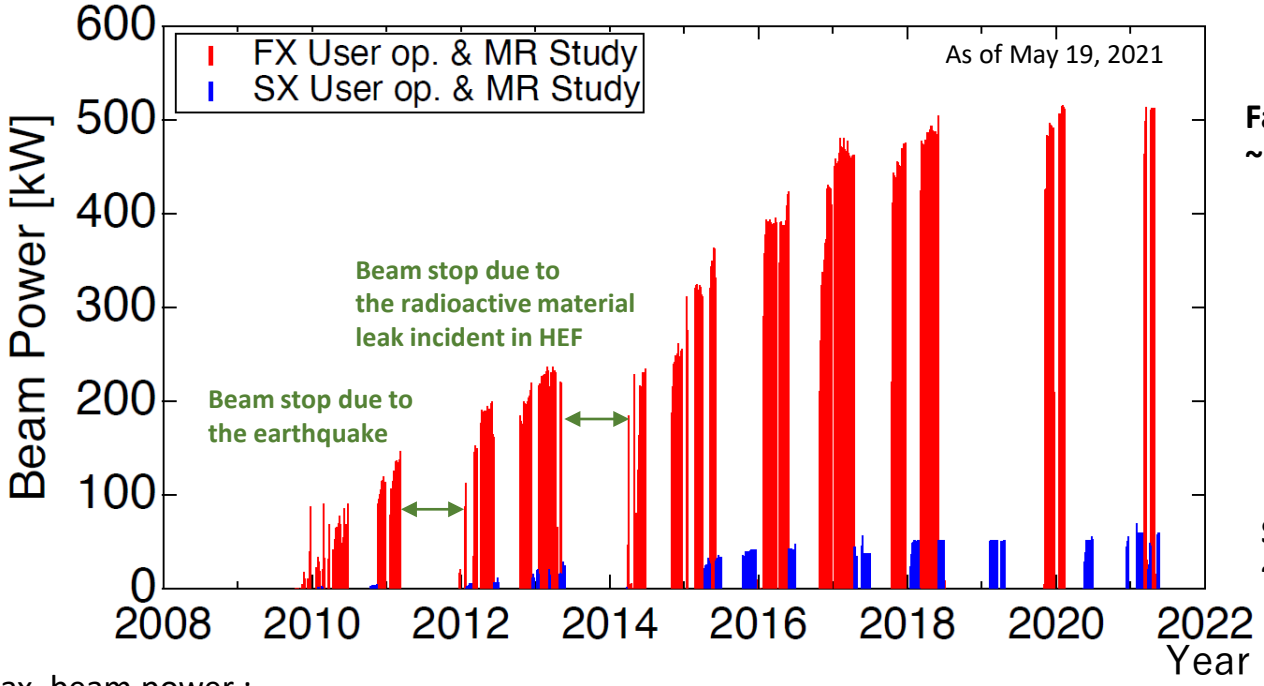
(1) Funding requested from KEK
(2) Aiming to start data taking from 2025.



Features of the J-PARC experiment

- **Low emittance beam** (1/1,000)
- Improvements
  - High injection efficiency (x10)
  - Compact storage ring (1/20)
    →Better field uniformity (x10)
  - High granularity tracking detector (x10)
- Simultaneous measurement of EDM (x70 better)

Beam power history of MR



Fast extraction
~ 515 kW in 2.48 s cycle

Slow extraction
~ 60 kW in 5.20 s cycle

Max. beam power :
Fast extraction ~ 515 kW (2.66 x10^{14} ppp), the world highest ppp in synchrotrons.
Slow extraction ~ 60 kW (6.5 x10^{13} ppp) in 5.20 s cycle for users with the extraction efficiency of 99.5 %.

Future (on-going) Main ring upgrade

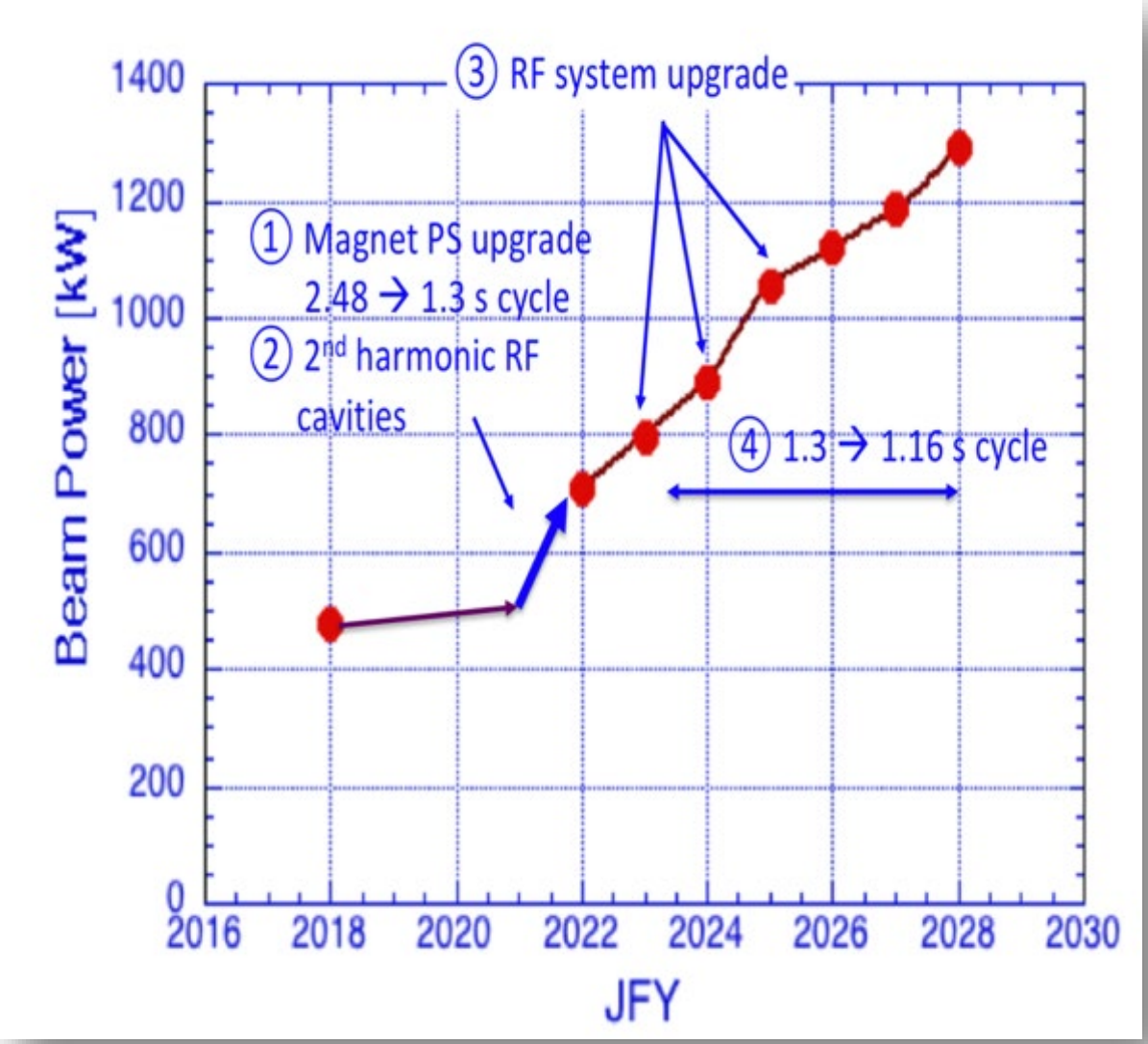
More Rapid Cycle:

2.48 s → 1.32 s → 1.16 s

- Main Power Supply to be renewed
- High gradient RF Cavity
- Improve Collimator
- Rapid cycle pulse magnet for injection/extraction

More Protons / Pulse：

- Improve RF Power
- More RF Systems
- Stabilize the beam with feedback



MR-SX Plans Summary Table

8 bunched, flat top 2.61sec. (TP: tera protons)

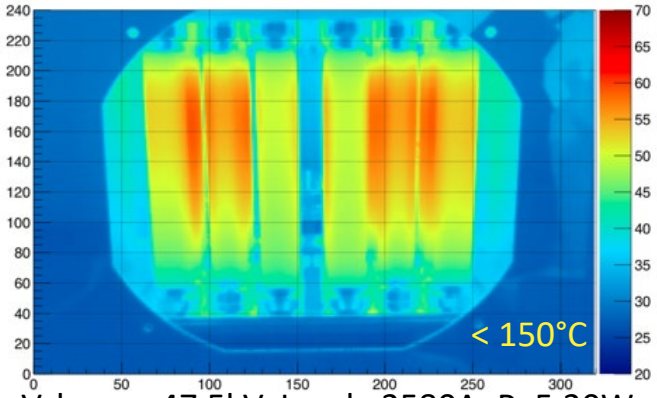
	Power	cycle	Acc.	proton	proton	year	New Approach
	kW	sec.	sec.	TP/pulse	TP/bunch	JFY	
(1)	55.7	5.2	1.4	60.3	7.54	2020	2 step debunch
(2)	60	5.2	1.4	65.0	8.12	2021	2 step debunch+other
(3)	80	4.2	0.65	70.0	8.74	2022-	High repetition
(4)	95	4.2	0.65	83.1	10.4	2026-	VHF cavity, diffuser/crystal

Kincho
A-TAC2021

Upgrades for RF, Injection and Extraction Devices

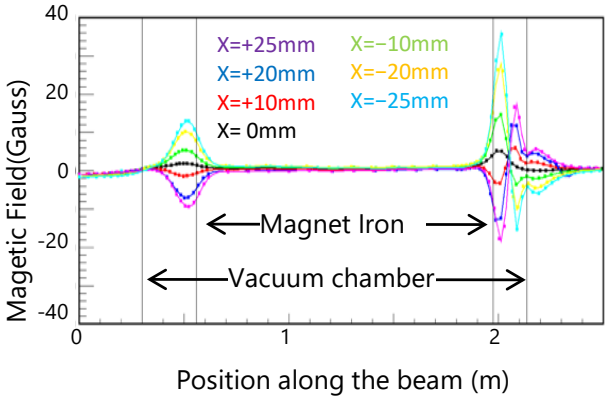
The 2nd harmonic RF cavities were installed in 2020.

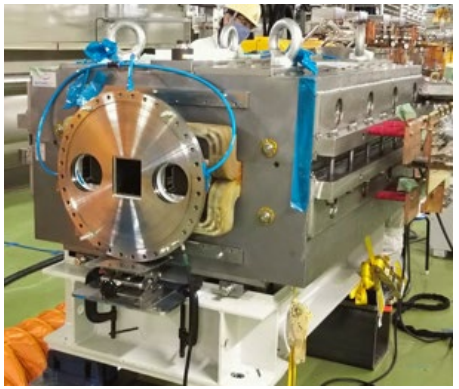
RF Anode power supplies will be upgraded by 2025 as they were done for RCS.



Vcharge=47.5kV, Ipeak=2580A, P=5.20W

Matching resisters were developed for the faster cycling of the injection kickers.

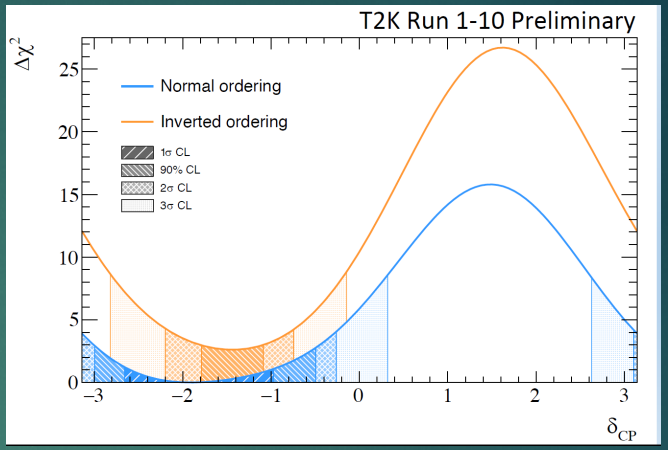


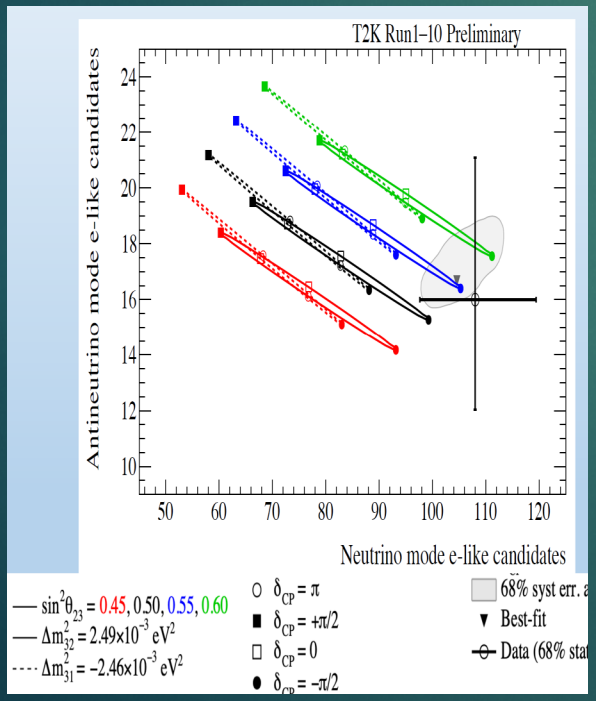


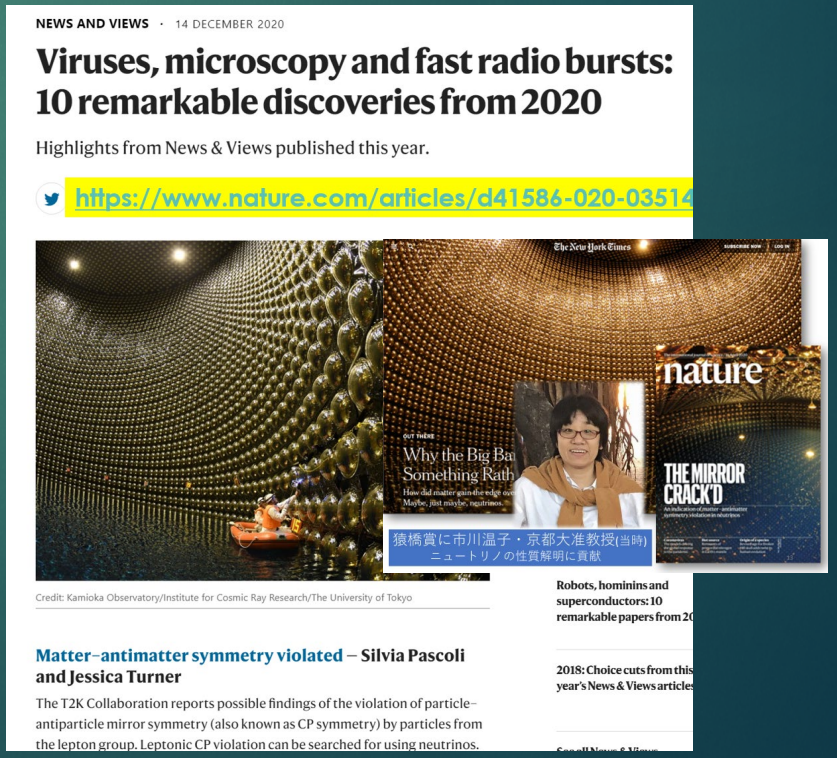
New extraction septum magnets were tested for magnetic fields and vibrations with the faster cycling.

A slide by Igarashi et al.

T2K experiment (2009~)

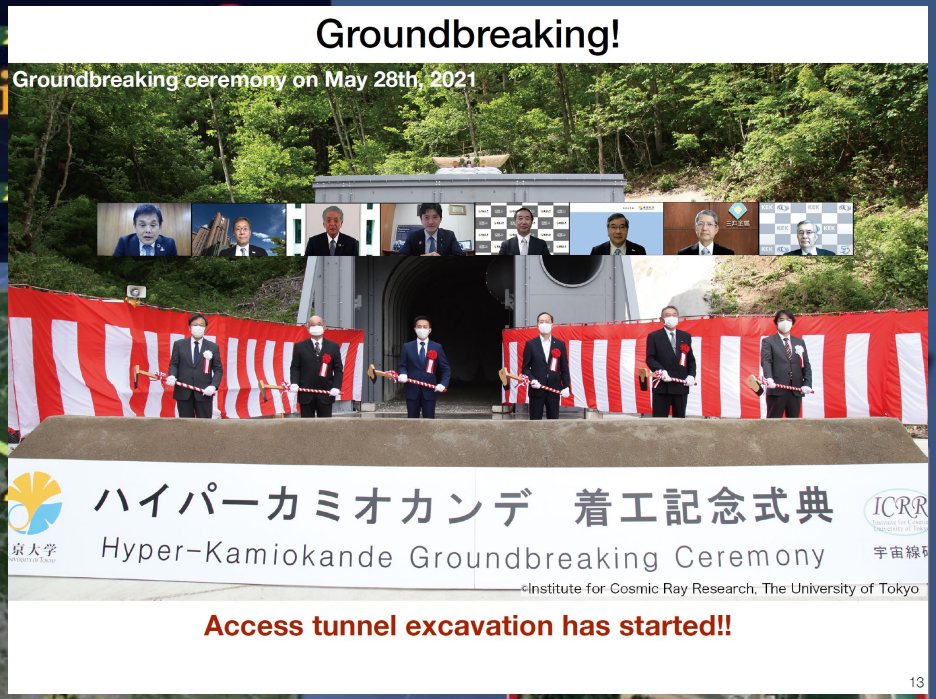


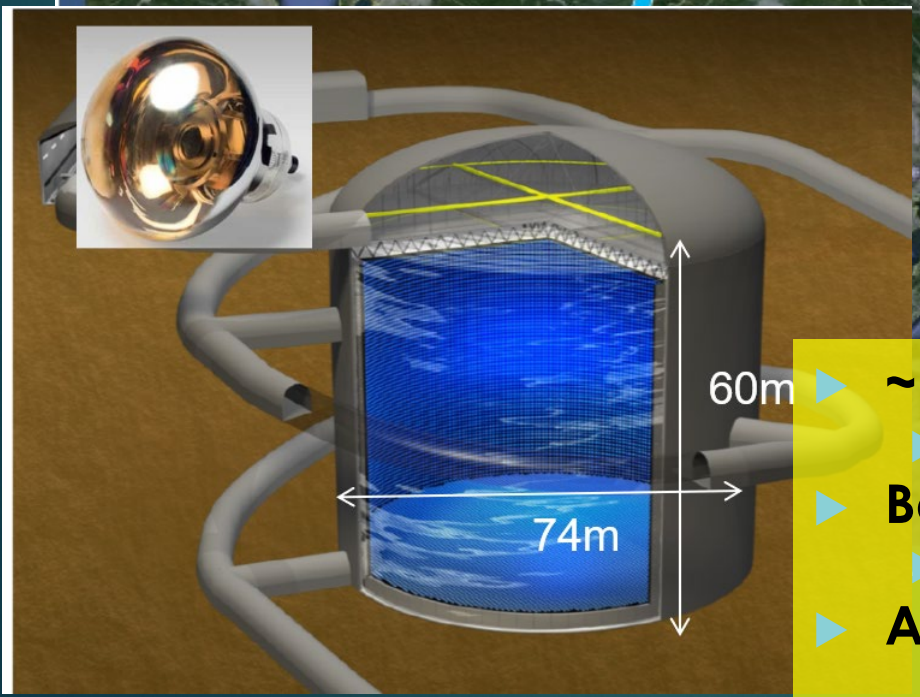




Hyper-Kamiokande project started!

Start operation in 2027

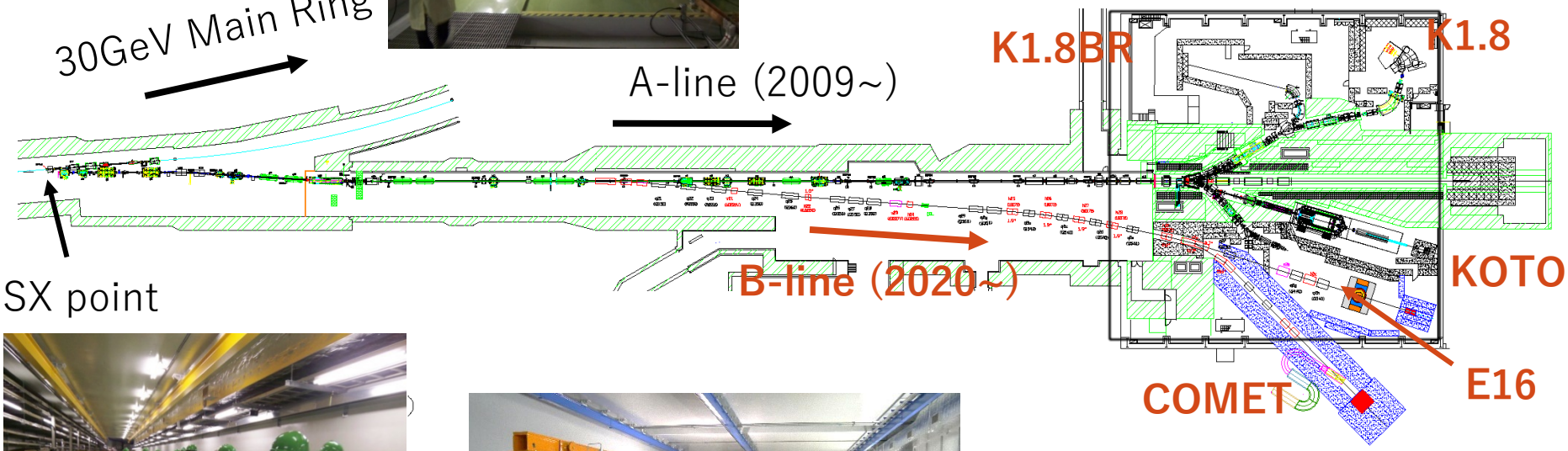


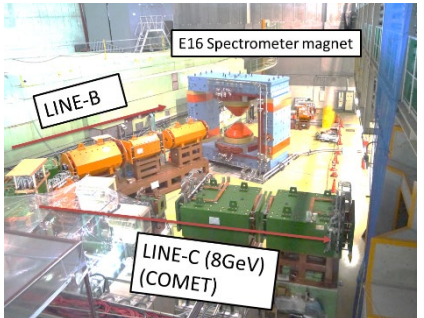


- ~ 10 times larger detector
  - Fiducial mass: SK22.5kton→HK 190kton
- Beam power
  - 0.5MW → 1.3MW
- Aim to discover CPV and n decay etc

Hadron beam line and experimental facility

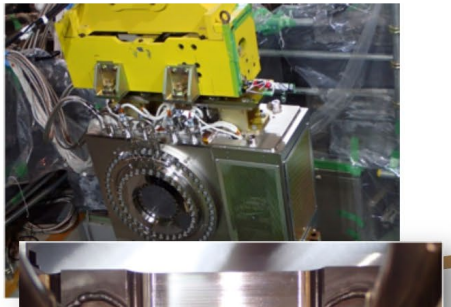
Hadron experimental facility (HEF)

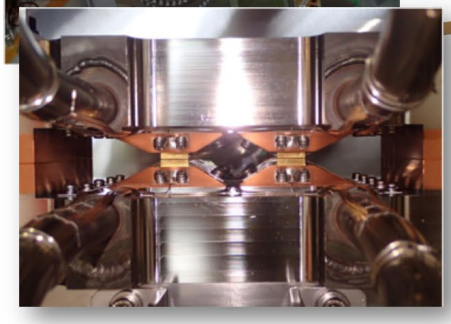


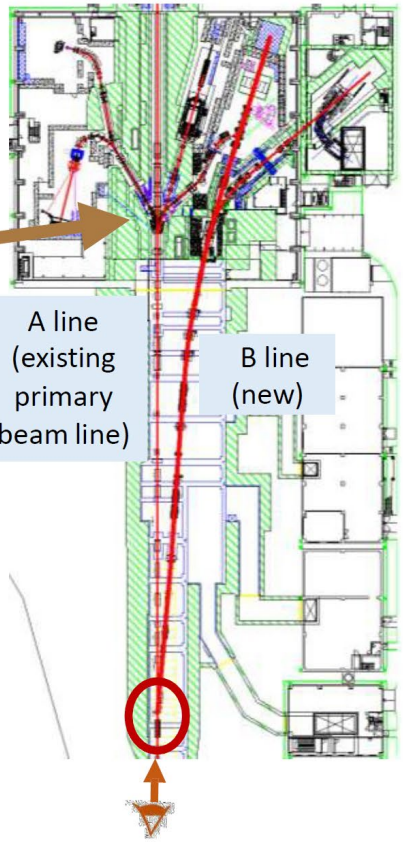


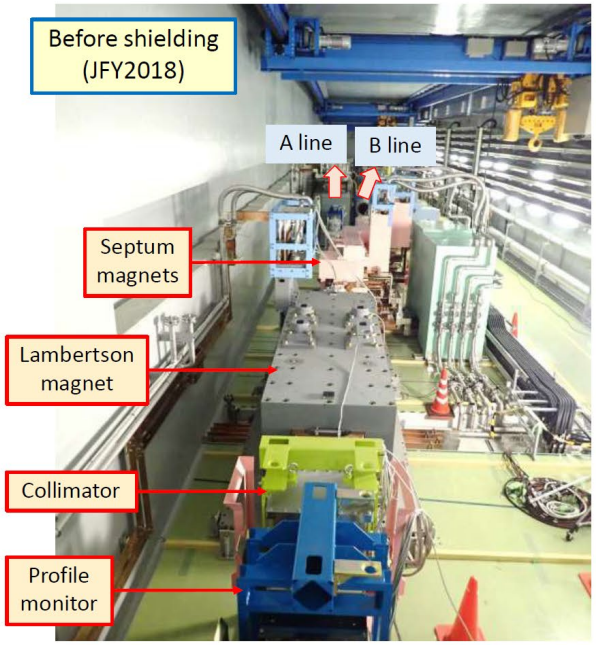
achievements - Hadron

New target (capable of 95kW w/ 5.2sec cycle) and B line (30GeV primary protons) are in operation.









achievements - Hadron

E07 at K1.8 beam line

PHYSICAL REVIEW LETTERS **126,** 062501 (2021)

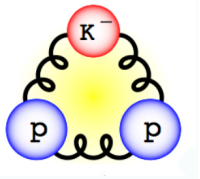
Editors' Suggestion | Featured in Physics

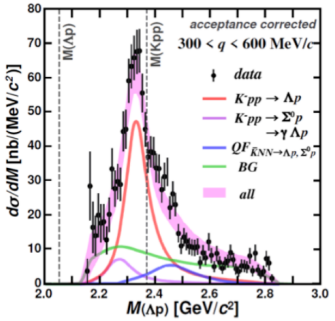
Observation of Coulomb-Assisted Nuclear Bound State of Ξ^-–^{14}N System

E15 at K1.8BR beam line

PHYSICAL REVIEW C **102**, 044002 (2020)

Observation of a $\overline{K}NN$ bound state in the ^{3}He$(K^-, \Lambda p)n$ reaction



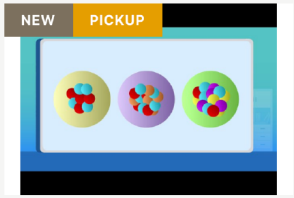


E05 at K1.8 beam line

PTEP

Prog. Theor. Exp. Phys. **2020**, 123D01 (34 pages)
DOI: 10.1093/ptep/ptaa139

An event excess observed in the deeply bound region of the ^{12}C(K^-,p) missing-mass spectrum



New Findings Hint Towards Existence of Kaonic Nuclei and Hyper-nuclei

2021-3-3

featured in

JPS Hot Topics

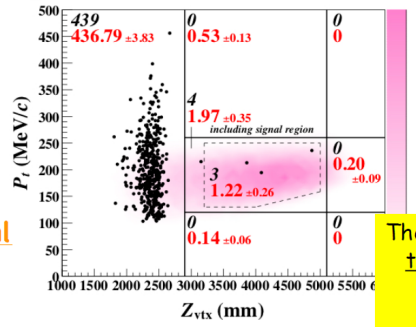
with
infographics and videos

https://jpsht.jps.jp/article/248.html

KOTO

arXiv:2012.07571 *to be published in Phys.Rev.Lett.*
Editors' Suggestion

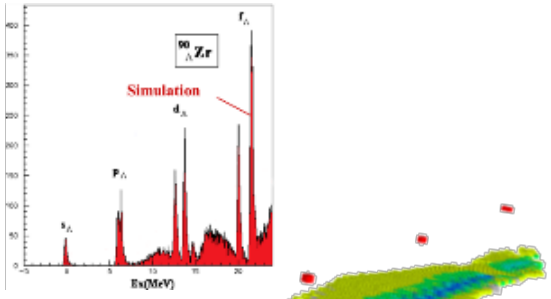
Study of the $K_L \to \pi^0 \nu \overline{\nu}$ decay at the J-PARC KOTO experiment

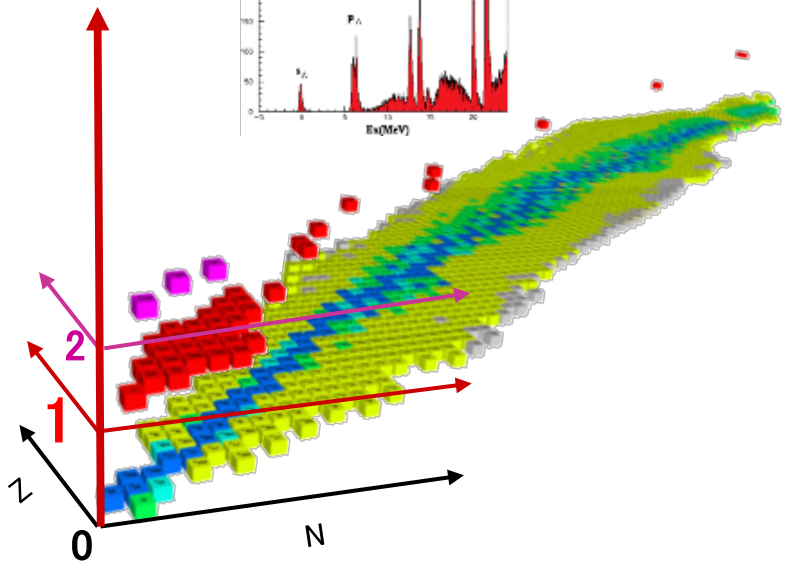


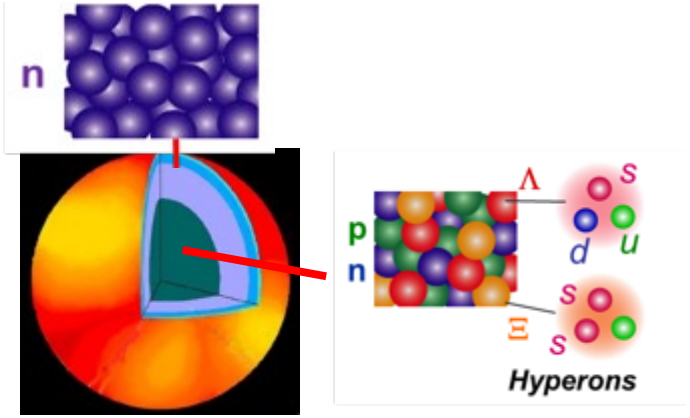
The analysis of 2016-18 data:
three candidate events
at 7.2 x 10^{-10}
w/ 1.22±0.26 bgd expectation

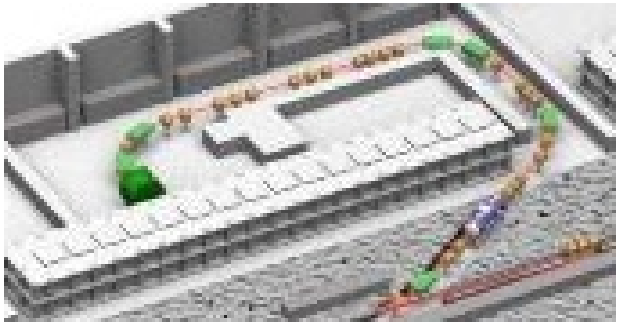
Hadron Nuclear Experiments to solve Hyperon Puzzle

Sπ K at HIHR & Λp scattering Exp. at K1.1



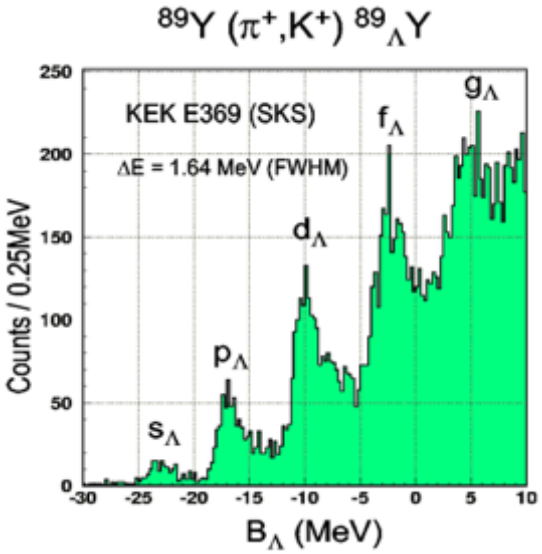






Ultra high resolution spectroscopy of Λ hypernuclei at HIHR

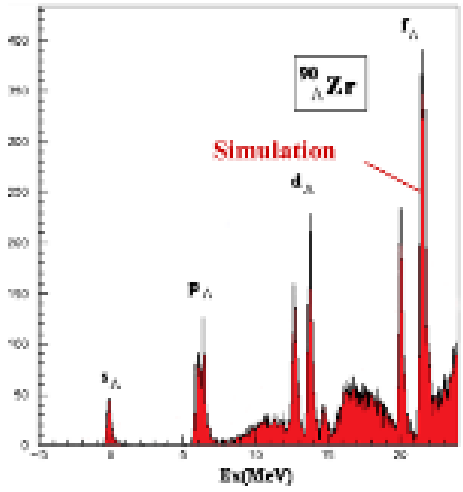
SKS@KEK-PS



ΔM_{FWHM}~1.64 MeV

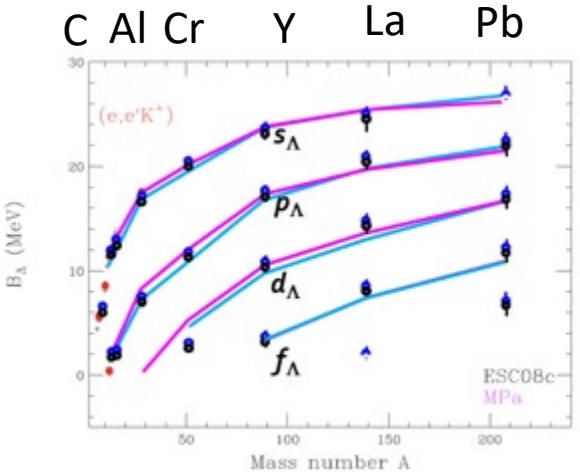
~60 days with 3M/spill π^+ beam

HIHR@J-PARC



ΔM_{FWHM}~0.1MeV

~30 days with 0.2G/spill π^+ beam



Precise determination of Λ single-particle energies in wide mass region

Detection of the effect of density-dependent Λ interaction, 3BRF

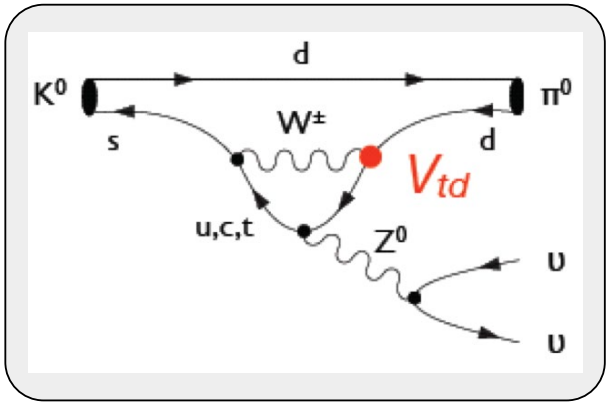
+ Λ p scattering data (ΛN int. in free space)

Understanding of **hadron interactions** and **high-density hadronic matters**

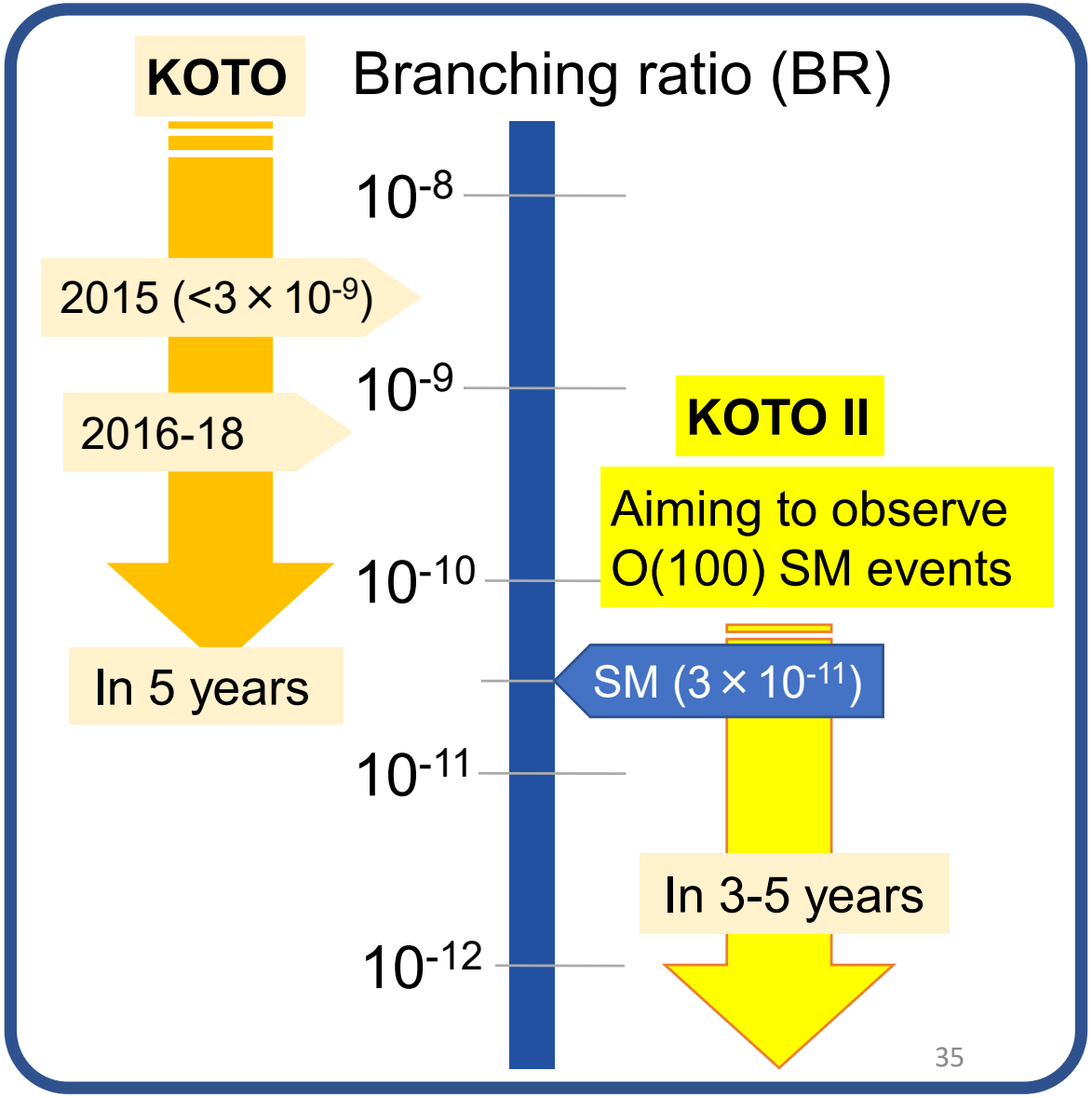
KOTO II in the extended hadron hall

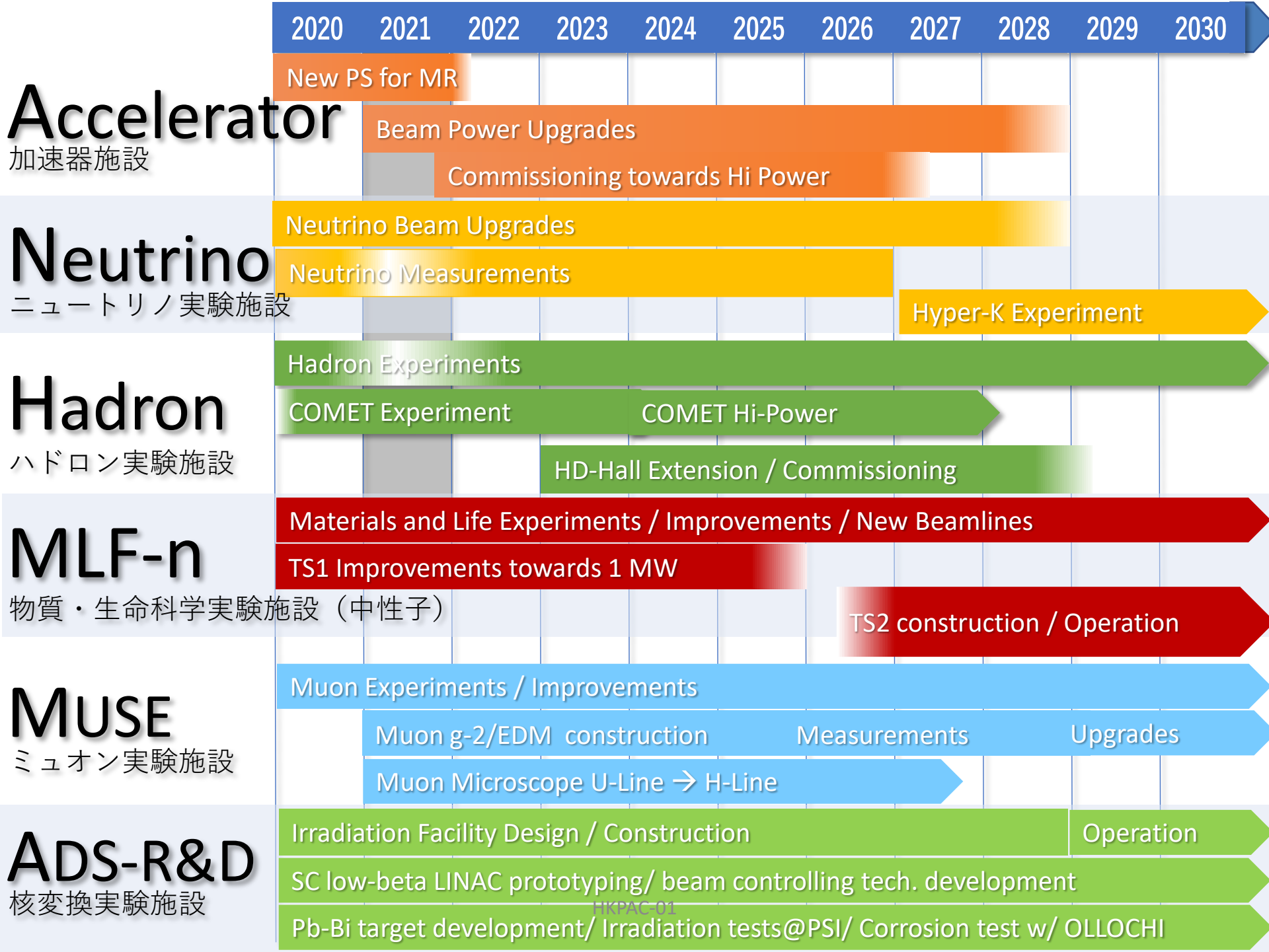
$K_L \rightarrow \pi^0 \nu\nu$ study at J-PARC

- CP violating process
- FCNC via loop diagrams



- BR in Standard Model (SM) $=3 \times 10^{-11}$
- ~2% theoretical uncertainty
- **Good probe for new physics search**




2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Accelerator
加速器施設
New PS for MR
Beam Power Upgrades
Commissioning towards Hi Power
Neutrino
ニュートリノ実験施設
Neutrino Beam Upgrades
Neutrino Measurements
Hyper-K Experiment
Hadron
ハドロン実験施設
Hadron Experiments
COMET Experiment
COMET Hi-Power
HD-Hall Extension / Commissioning
MLF-n
物質・生命科学実験施設（中性子）
Materials and Life Experiments / Improvements / New Beamlines
TS1 Improvements towards 1 MW
TS2 construction / Operation
MUSE
ミュオン実験施設
Muon Experiments / Improvements
Muon g-2/EDM construction
Measurements
Upgrades
Muon Microscope U-Line → H-Line
ADS-R&D
核変換実験施設
Irradiation Facility Design / Construction
Operation
SC low-beta LINAC prototyping/ beam controlling tech. development
Pb-Bi target development/ Irradiation tests@PSI/ Corrosion test w/ OLLOCHI

achievements - Hadron

E07 at K1.8 beam line

data taken in 2016,17

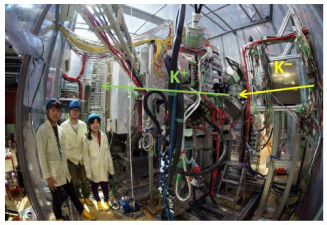
PHYSICAL REVIEW LETTERS **126,** 062501 (2021)

Editors' Suggestion | Featured in Physics

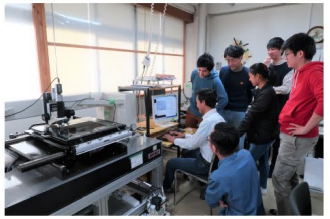
Observation of Coulomb-Assisted Nuclear Bound State of Ξ^-–^{14}N System

$\Xi^- + {}^{14}N \rightarrow {}^{15}_{\Xi}C \rightarrow {}^{10}_{\Lambda}Be + {}^{5}_{\Lambda}He$

$B_\Xi = 1.27 \pm 0.21$ MeV



- K- beam to diamond target
- " hybrid " : emulsion and counters



- " AI " : scanning system

PTEP

Prog. Theor. Exp. Phys. **2019**, 021D02 (11 pages)
DOI: 10.1093/ptep/pty149

Letter

Observation of a Be double-Lambda hypernucleus in the J-PARC E07 experiment

The 26th Outstanding Paper Award of the Physical Society of Japan

Physics https://physics.aps.org/articles/v14/s15 SYNOPSIS

Doubly Strange Nucleus Observed

Particle physicists have detected a short-lived nucleus containing two strange quarks, whose properties could provide new insights into the behavior of other nuclear particles.

By Michael Schirber

Prof. Kazuma NAKAZAWA received The 66th Nishina Memorial Prize (subatomic physics)