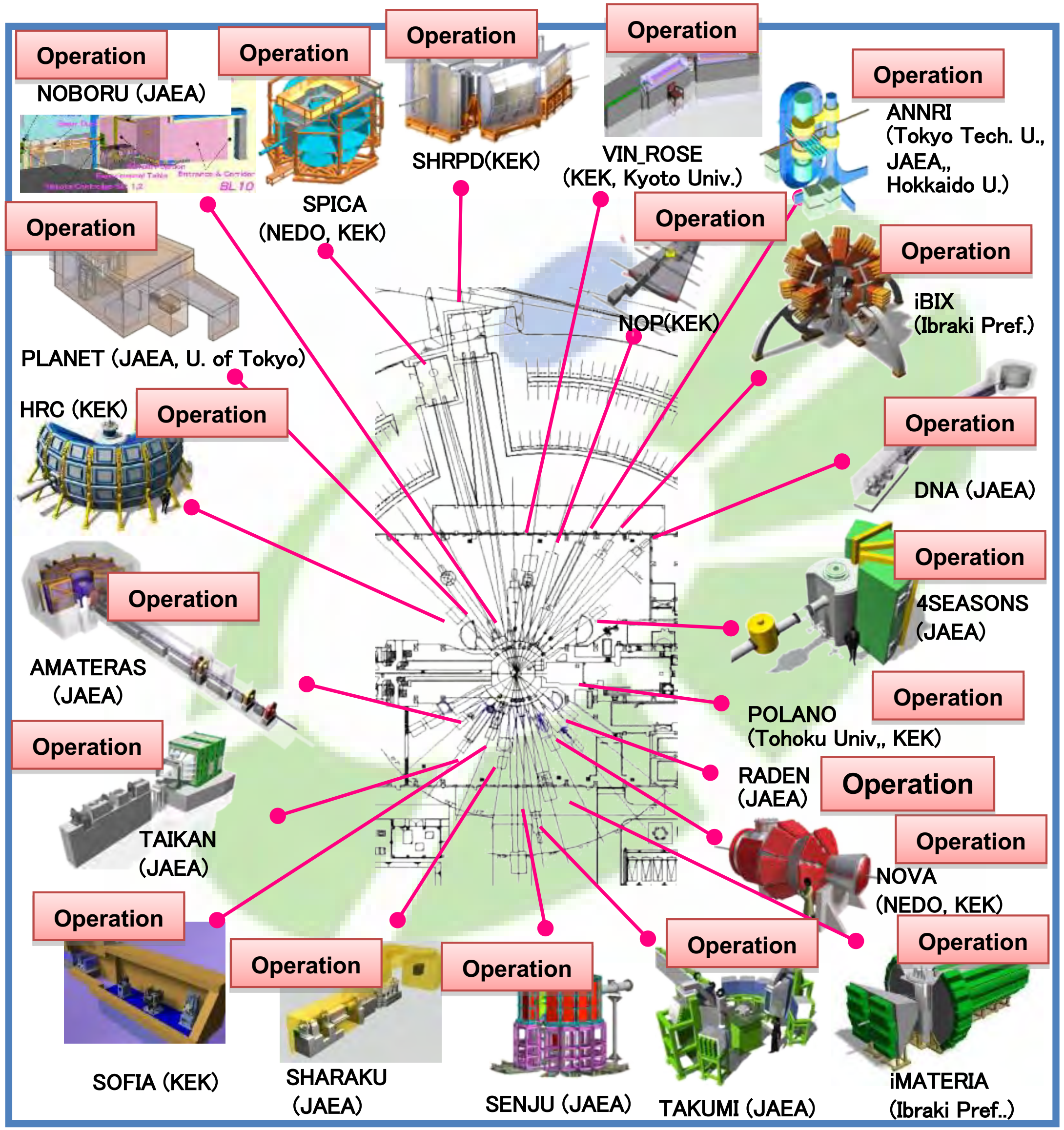
The Present and Future of MLF

IMSS KEK / J-PARC Center
Toshiya Otomo

パルス中性子・ミュオン発生40周年記念シンポジウム 2020/12/23

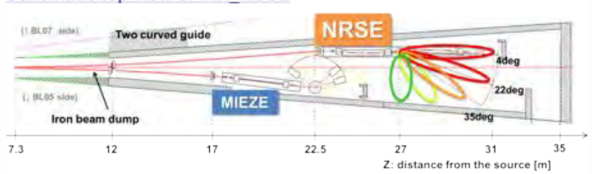
Neutron Instruments in MLF



- 23 Neutron Beam Ports
- Operation: 21 (April, 2018)
  Commissioning:0

VIN-ROSE (NSE): opened to users @2017B

Schematic top view of VIN_ROSE

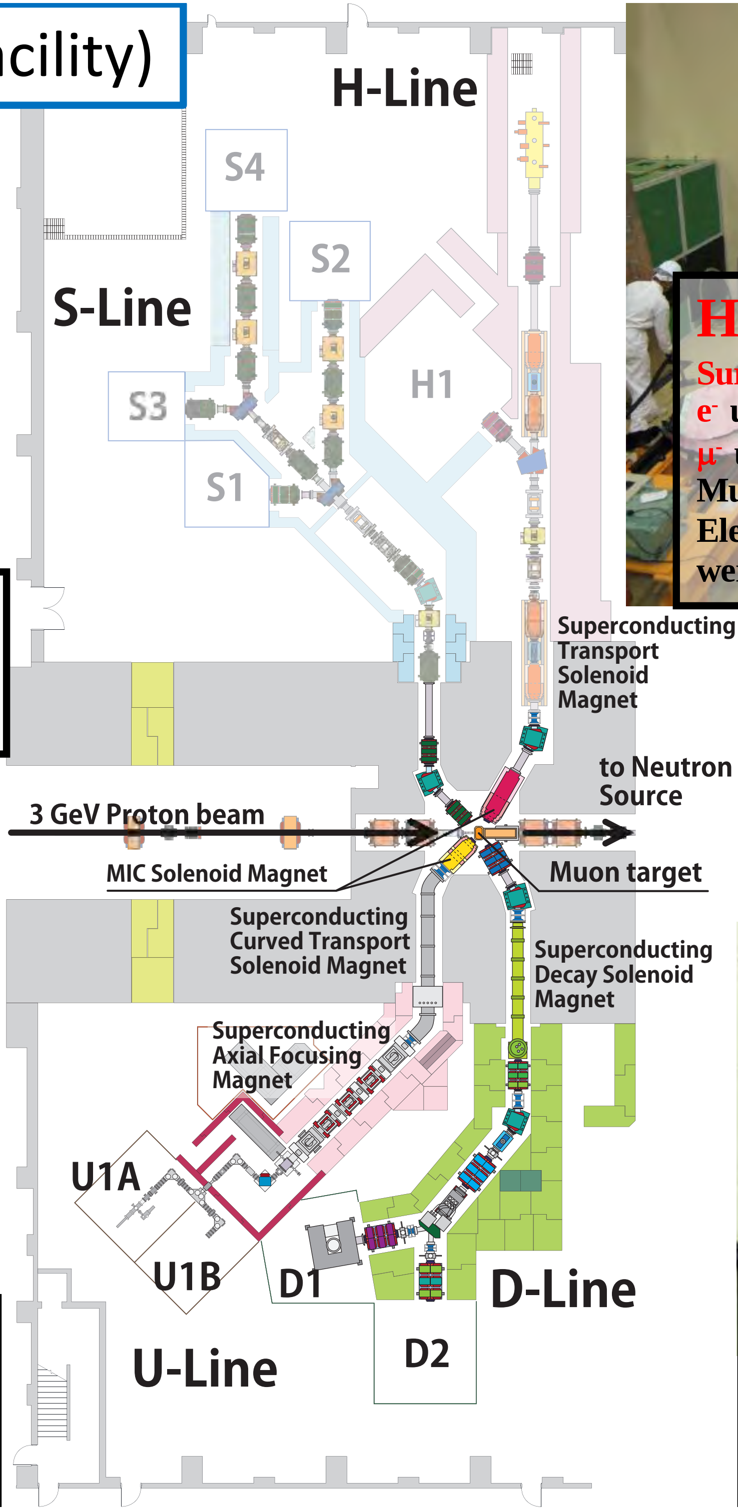


POLANO
(Polarization Analysis Spect.)

Opened to users @2019A

Status of MUSE (muon facility)

S-Line under commissioning.
Surface μ^+(30 MeV/c) S1 area is ready to extract μ^+ beam. (Open to users)



H-Line under construction.
Surface μ^+ For Mu-HF, g-2/EDM
e^- up to 120 MeV/c For DeeMe
μ^- up to 120 MeV/c For μCF
Muon Microscopy
Electromagnetic coils in H-Line tunnel were installed.

MUSE Facility @MLF

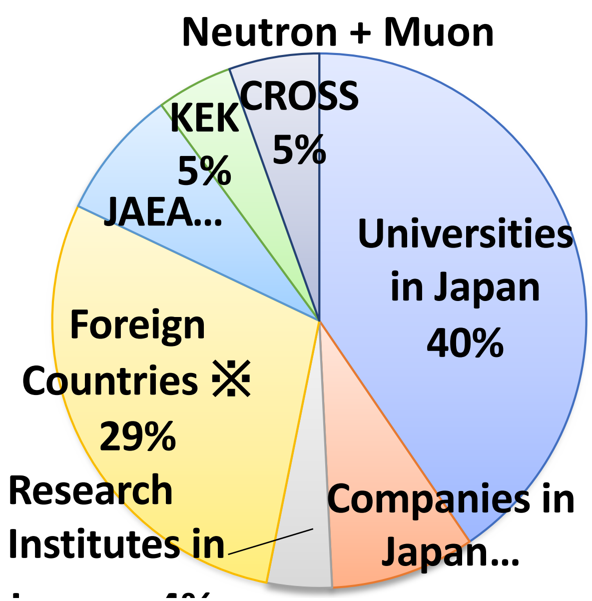
U-Line
Ultra Slow μ^+ (0.05-60keV)
First Ultra Slow muon beam is under commissioning.

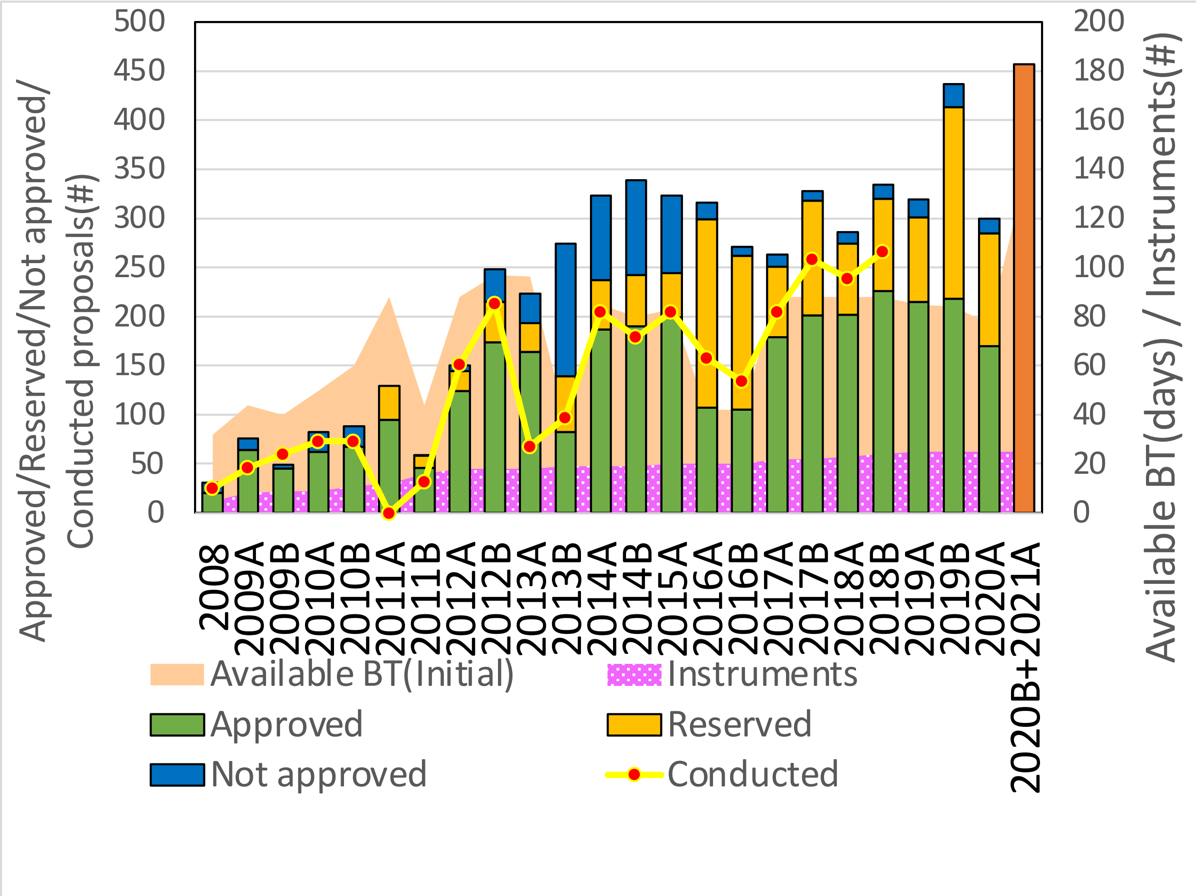
D-Line in operation
Surface μ^+(30 MeV/c)
Decay μ^+/μ^-(5-120 MeV/c)
Trouble in power supply of septum coil was happened. (Open to Users)

General Proposals to MLF at 2020B+2021A

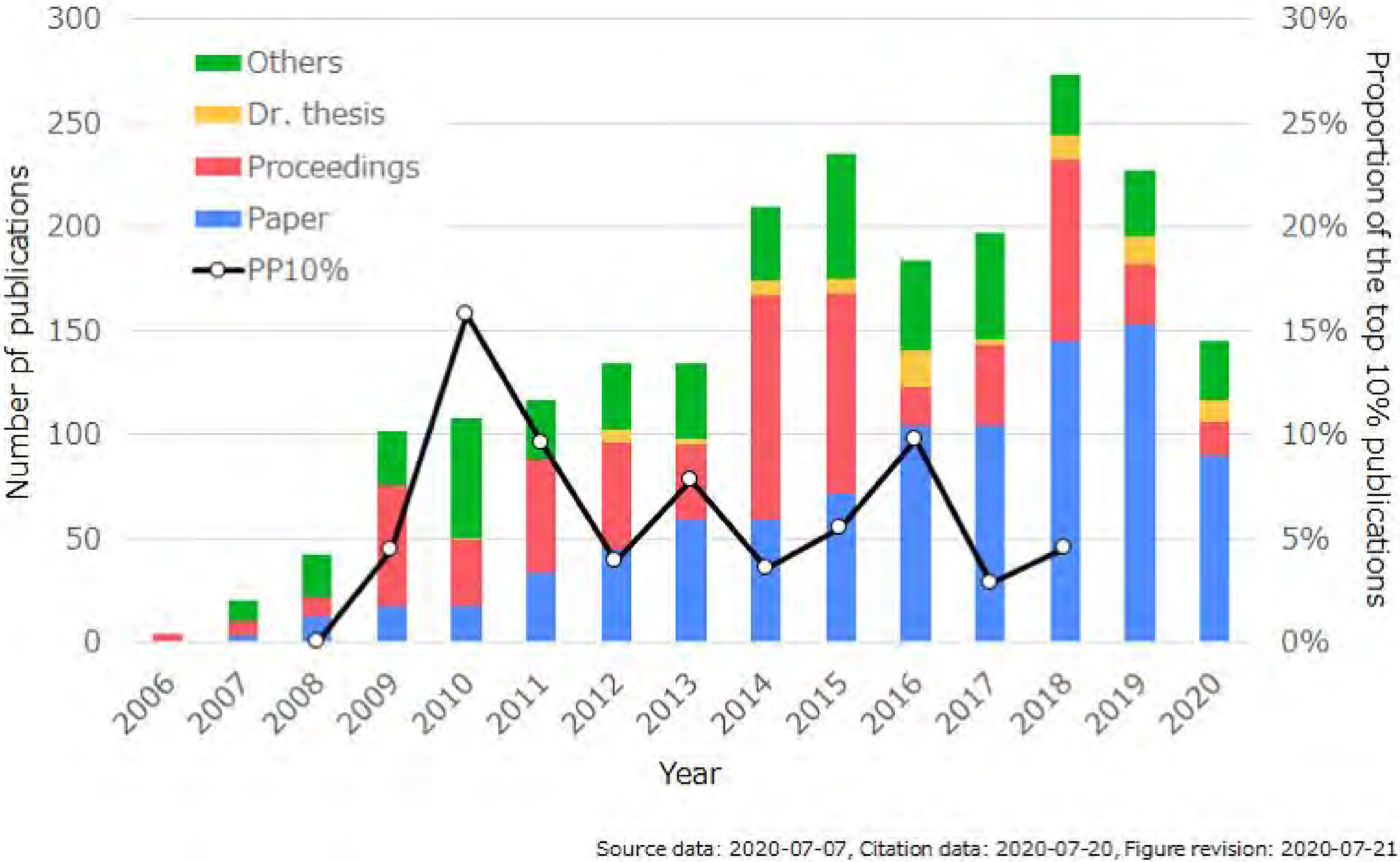
- # of proposal ~650 /y
- # of users ~1100/ y
- Competion rate ~1.6
- Operation days ~170 days

Applicants' Affiliations

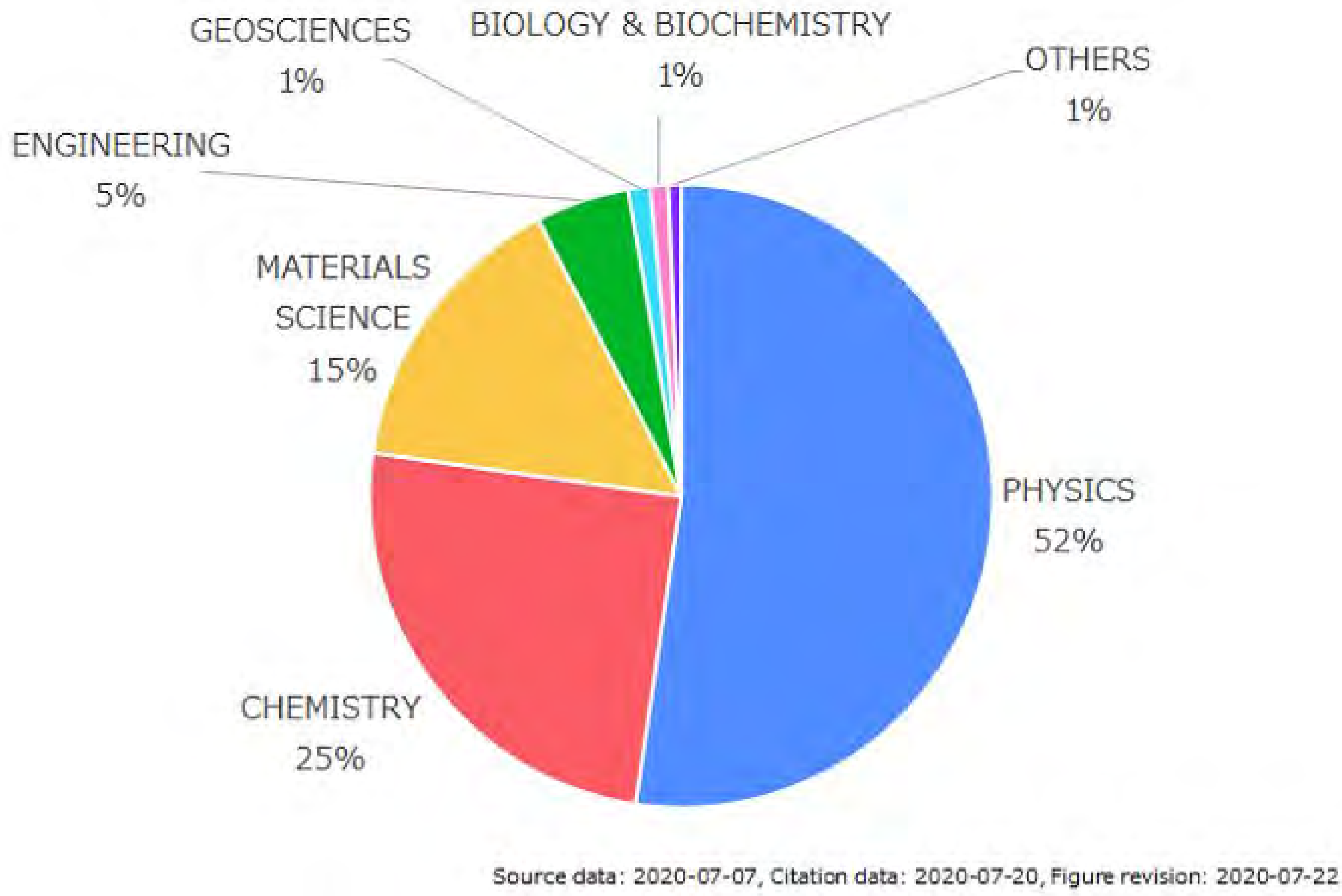




Number of publications of MLF



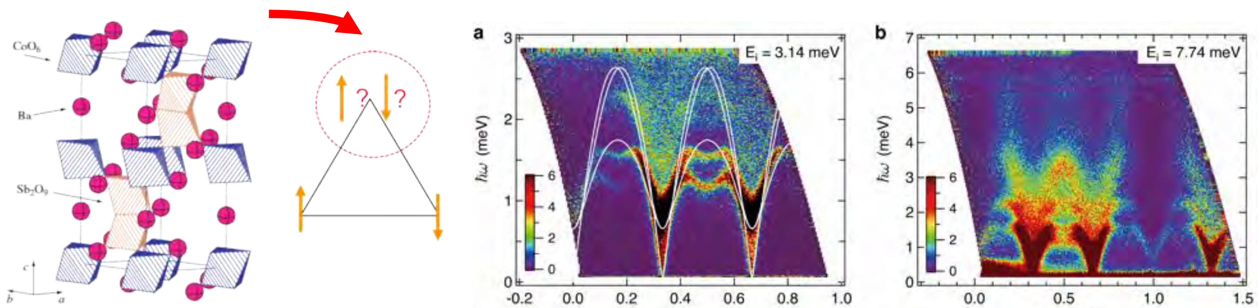
Research areas of publications (2006-2020 total)



MLF outcomes

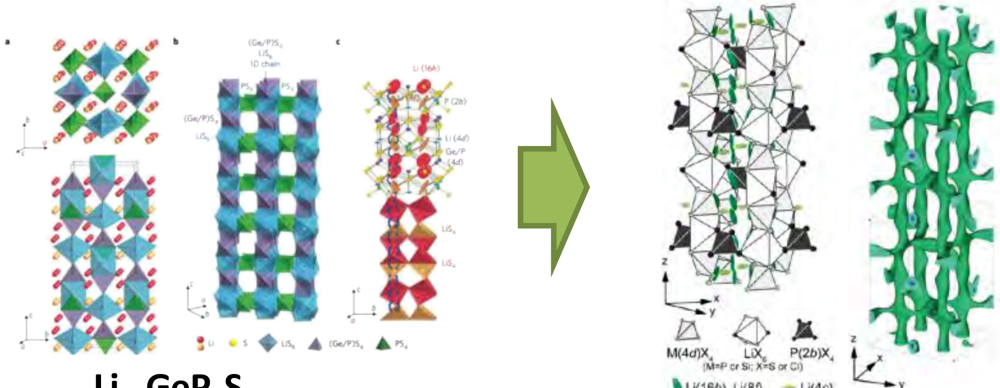
- Covering a wide range of fields from basic science to industrial applications

Highly frustrated *S*=1/2 quantum spin system (Tanaka, TIT)



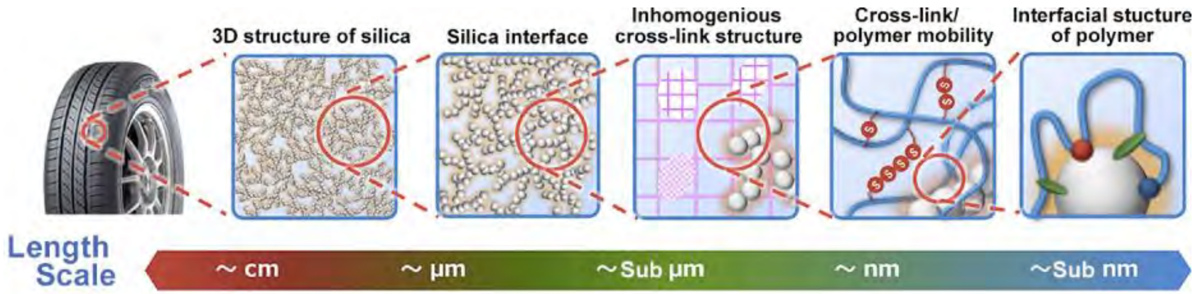
$Ba_3CoSb_2O_9$

Development of all-solid ceramic buttery（Kanno, TIT）



$Li_{10}GeP_2S_{12}$ $Li_{9.54}Si_{1.74}P_{1.44}S_{11.7}Cl_{0.3}$

Design of high-performance tire （Sumitomo Rubber Inds.）

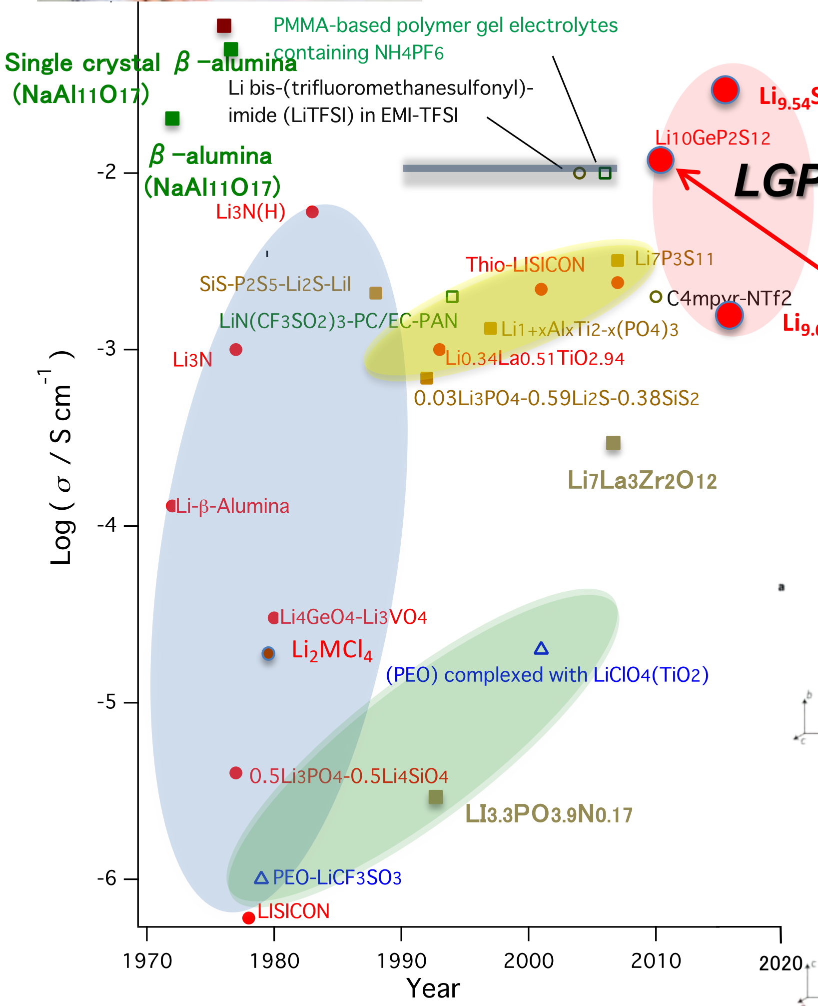


Prof. Kanno, TIT

Development of All Solid State Ceramic Battery

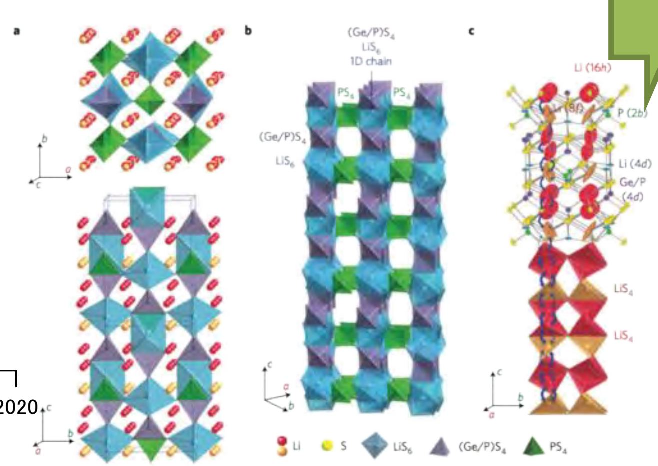
TIT、IMSS KEK、TOYOTA、Ibaraki Univ., Ibaraki Pref.

Analysis of diffusion path of Li atom with neutron diffraction stimulated the developments of novel material which Paves the way for the practical application of all-solid-state batteries



Discovered in 2011

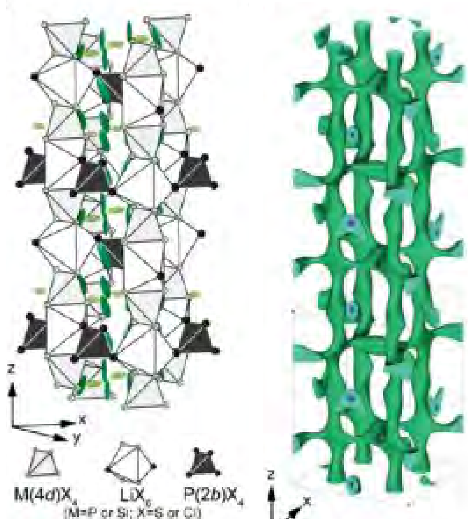
1D diffusion path



$Li_{10}GeP_2S_{12}$
Nature Materials (2011)
1679 citation (2020 Jul)

Discovered in 2016

3D diffusion path



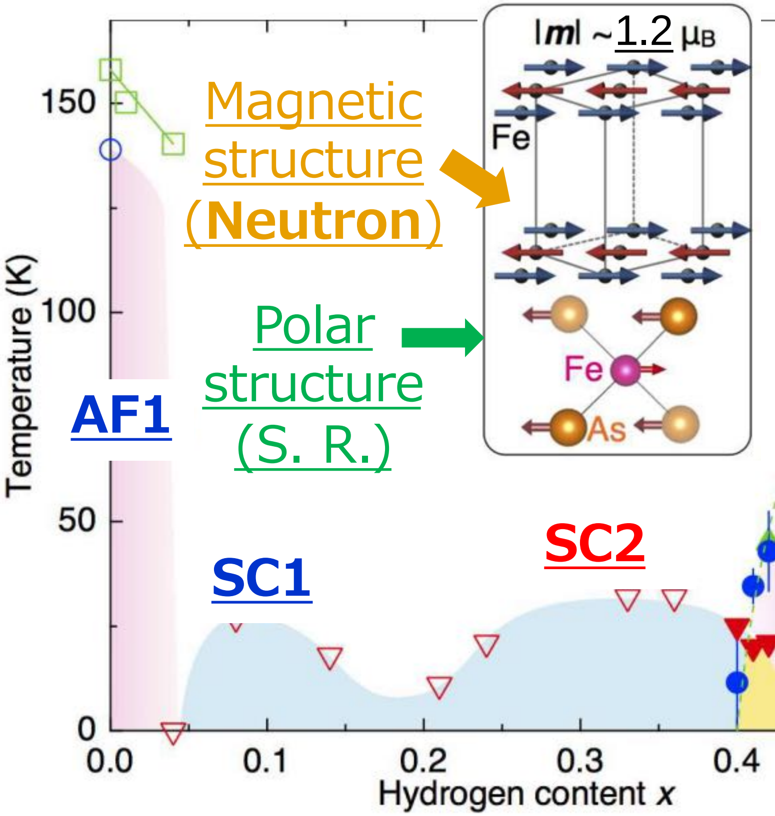
$Li_{9.54}Si_{1.74}P_{1.44}S_{11.7}Cl_{0.3}$
Nature Energy (2016)
776 citation (2020 Jul)

Fe-based SC (Magnetism) & Semiconductor (Hydrogen)

Collaborative use of quantum beam

Nat. Phys. 10, 300 (2014)
M. Hiraishi, J. Yamaura, H. Hiraka, et. al.

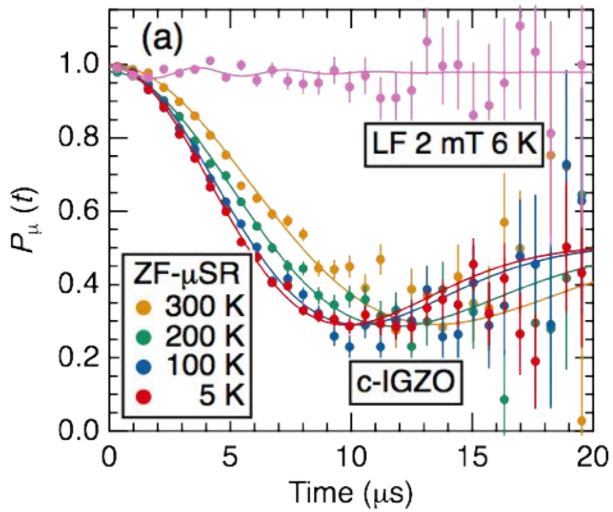
M. Hiraishi



Discovery of magnetically ordered phase (AF2) in over doped region.
→ We proposed the origin of the high-T_c.

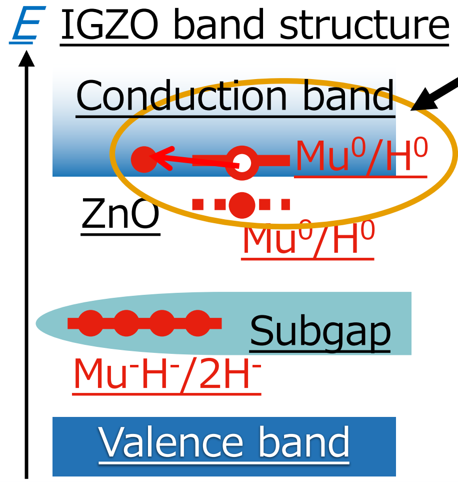
Electronic structure of H in IGZO

Appl. Phys. Lett. **115**, 122104 (2019)
K.M. Kojima, M. Hiraishi, R. Kadono, et. al.



K.M. Kojima

Newly developed e^+ detector **KALLIOPE**



Muons are hydrogen simulator!

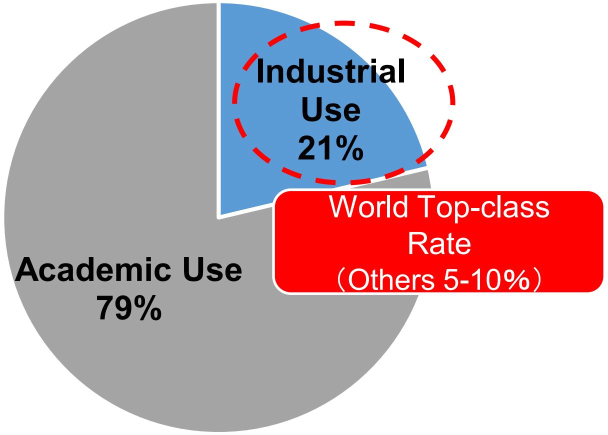
Dilute H in IGZO is an **electron donor.**

KEK & Tokyo-TECH collaboration (MEXT Element Strategy)

Trend of Approved Proposals in Ibaraki BLs

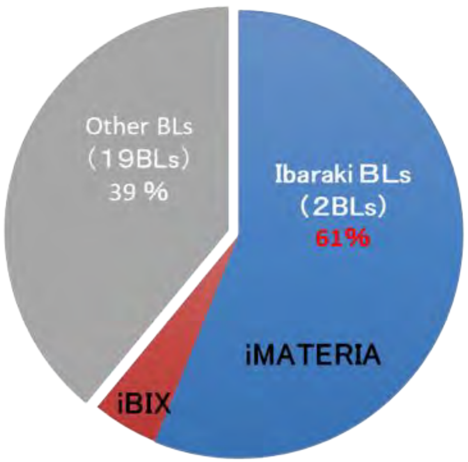
Ibaraki Pref.

① Percentage of approved industrial proposals in J-PARC MLF



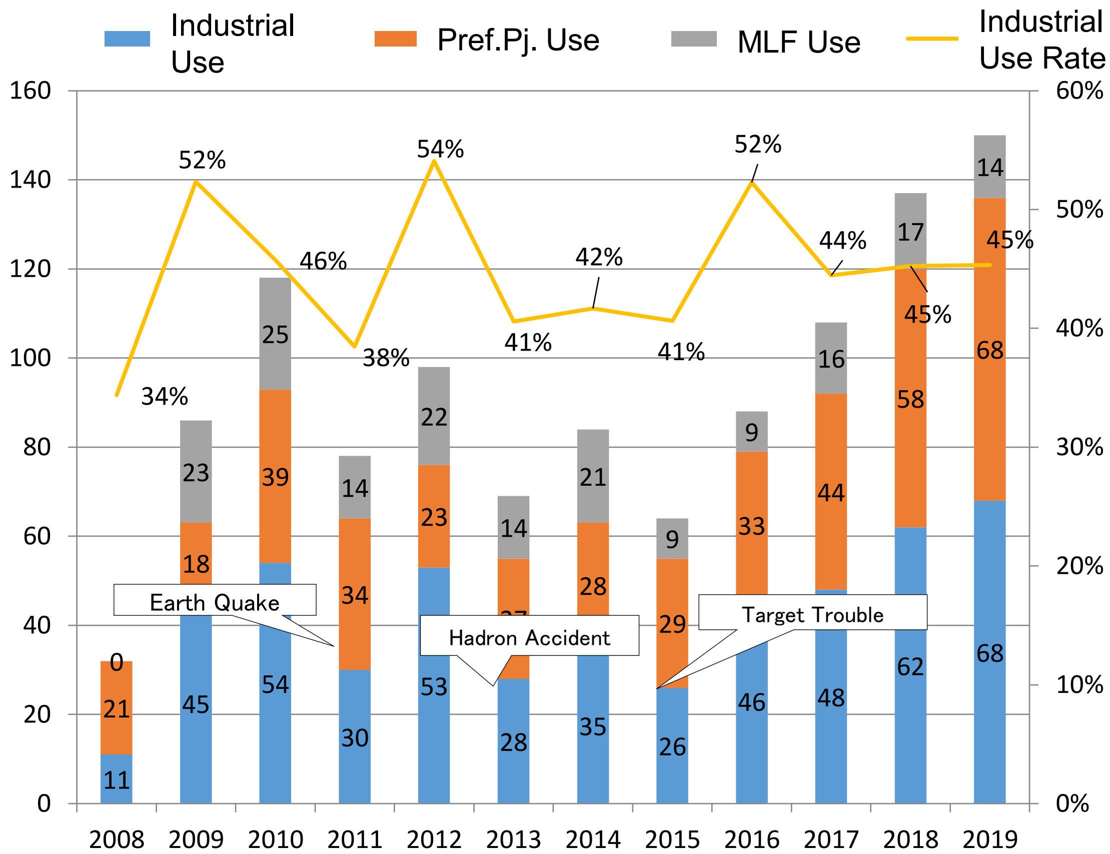
Applications from Industries are <u>21%</u>

② Percentage of Ibaraki BL's proposals to total approved Industrial proposals of J-PARC MLF



【 FY2008-19：835 proposals 】

③ Trend of approved proposals (FY2008-2019）



○	Industrial Use	506
○	Prefectural Pj. Use (R&D)	422
○	J-PARC MLF General Use	184
	合　計	1,112 proposals

Operando measurement

Harjo (MLF)

Neutron diffraction monitoring of ductile cast iron under cyclic tension–compression

- Ductile cast irons are important structural materials
- The relationship between internal stresses and work hardening and the role of graphite remains questionable

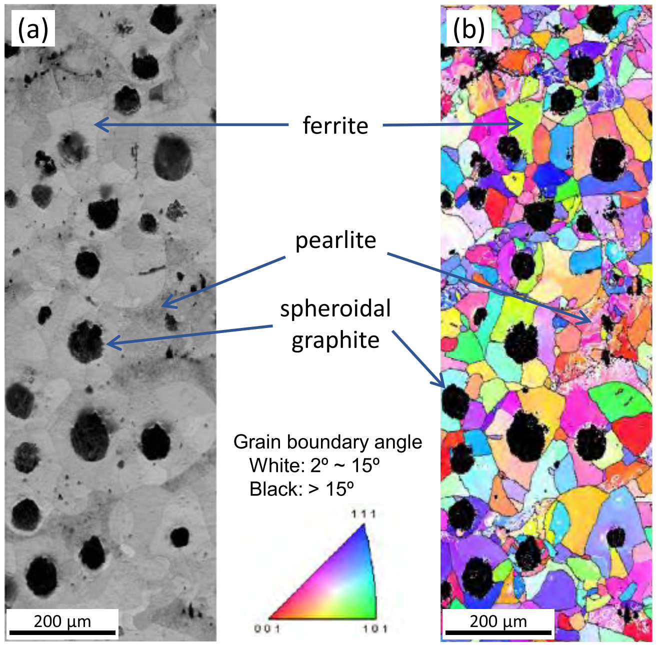
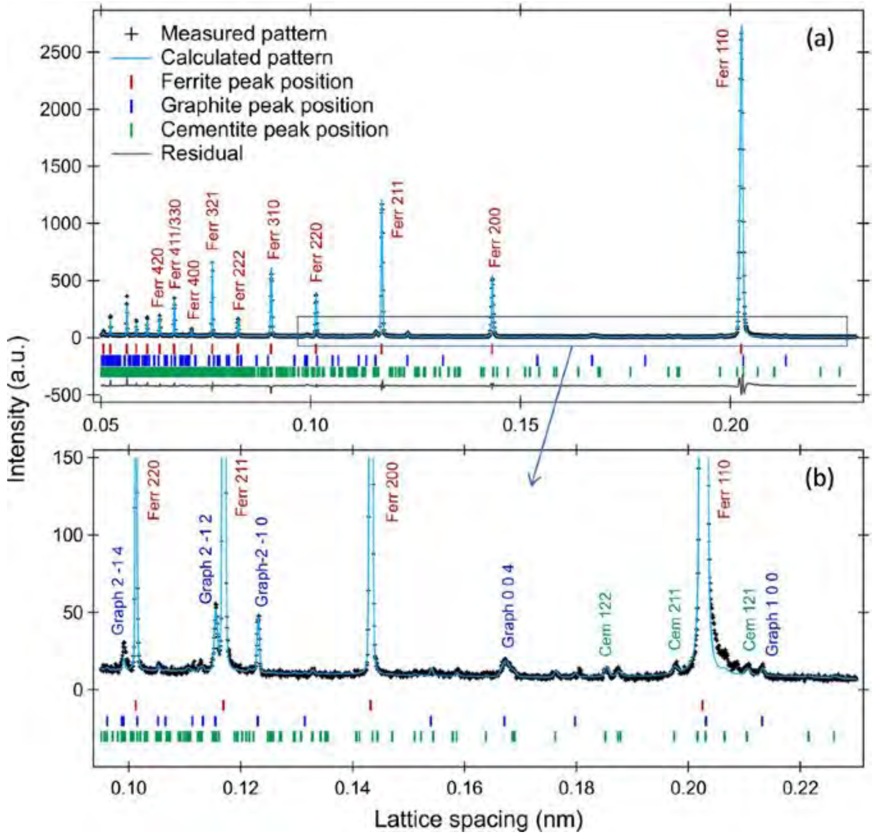


Fig. 1. (a) Image quality map and (b) inverse pole figure map of B20 steel before deformation.

S. Harjo, et al., Acta Materialia 196 (2020) 584–594

- Cyclic loading testing was conducted continuously, and the neutron diffraction data were collected continuously using an event data recording mode (sliced at 300s)



Operando measurement

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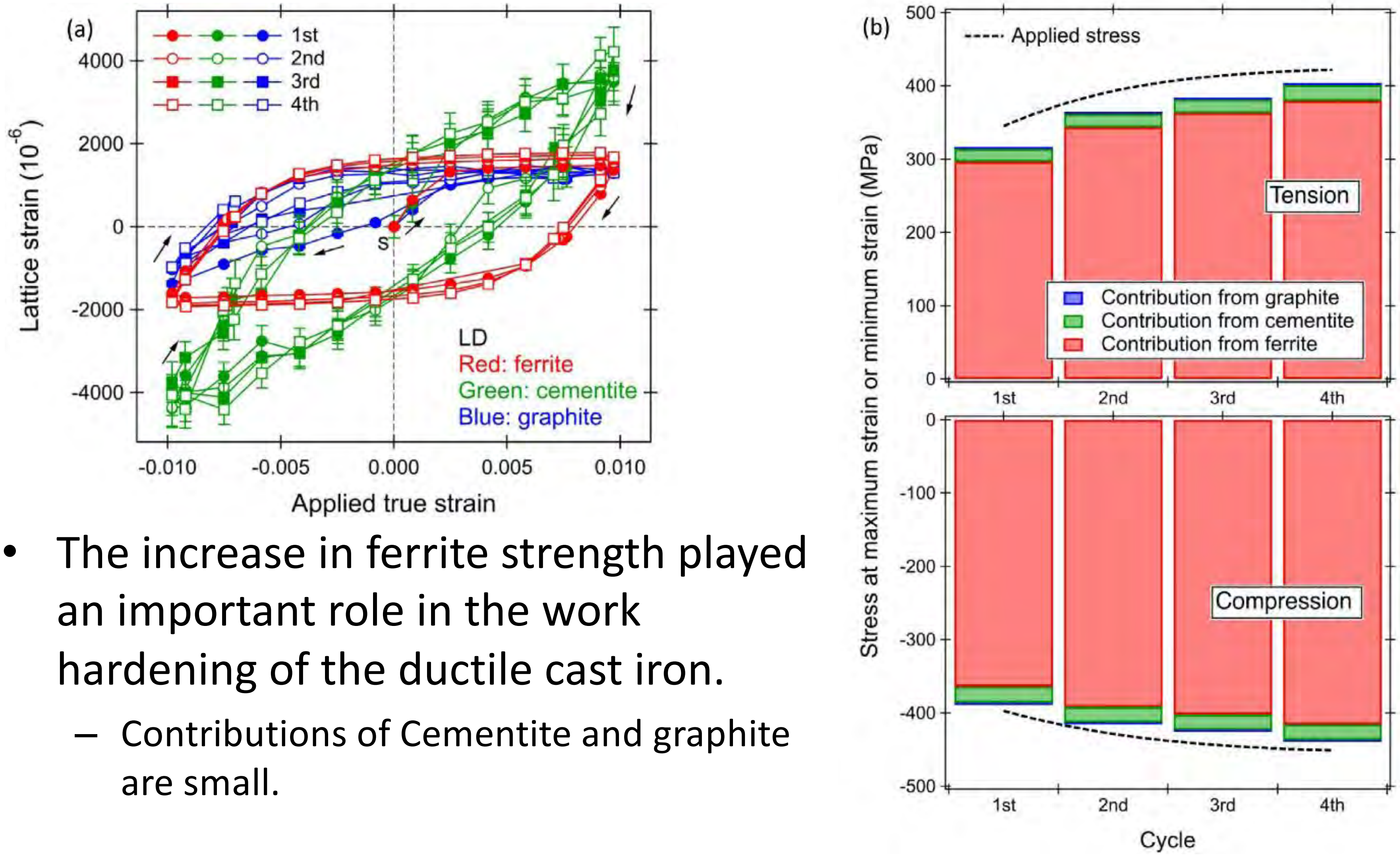


- The increase in ferrite strength played an important role in the work hardening of the ductile cast iron.
  - Contributions of Cementite and graphite are small.

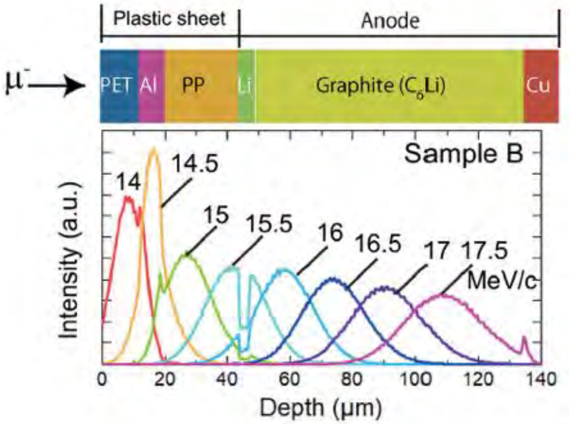
Umegaki (TCR)

TOYOTA CENTRAL RESEARCH AND DEVELOPMENT LABORATORIES, INCORPORATED

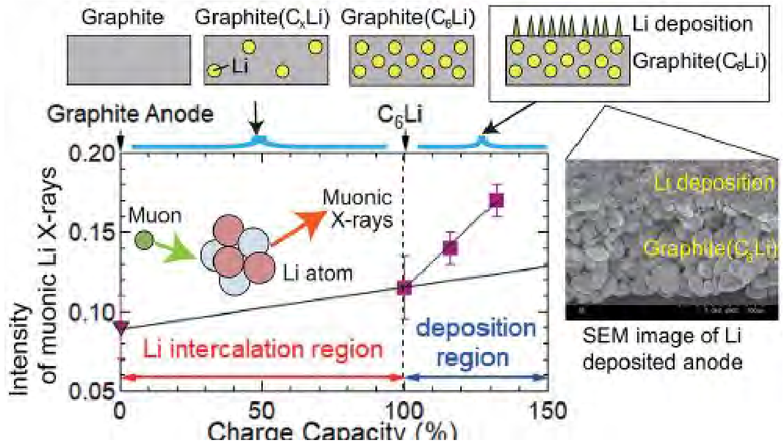
Nondestructive detection of Li deposition by muonic X-rays

I. Umegaki et al., Anal. Chem. (2020) 92,12,8194-8200.

Pictures of (up) Li metal deposition on the graphite, and (down) sample in a measurement chamber.



Distribution of muons with different momentum in a laminated graphite anode.

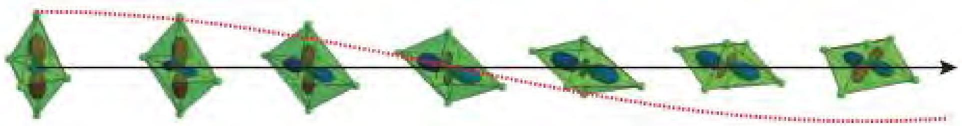


The relationship between the intensity of muonic Li X-rays and charge capacity, which corresponds to amount of Li, in the Li intercalation and the deposition regions.

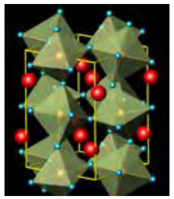
We succeeded to detect nondestructively Li metal deposition on the graphite anode by measuring muonic X-rays through a laminated package. We also demonstrated that, taking advantage of depth resolution of muons, a location of the deposition can be detected.

Cross Correlations in Material Science

A new elementary excitation? - finding orbiton by polarized neutron



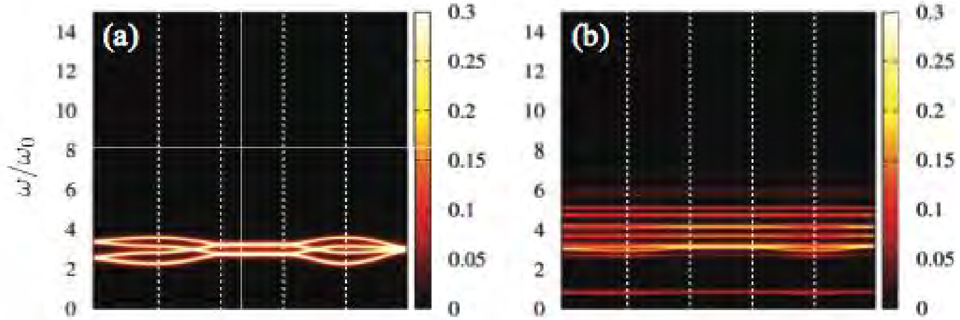
model calculation on YVO_3



calculated orbital excitation

(a) bare orbital excitation in YVO_3

(b) separated orbital excitation levels with correlating orbitals and phonons

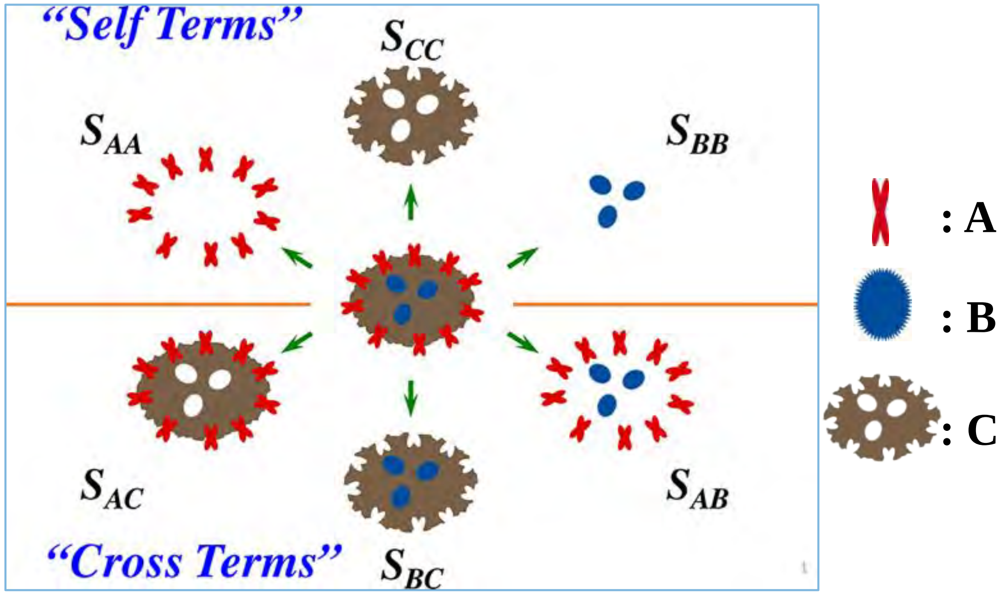


J. Nasu and S. Ishihara, PRB 88 (13) 205110

Polarized Neutron can directory observe spin dynamics (orbital-lattice coupling)

Resolve correlations in multi-component softmatter systems

“Multi Components” is a key to realize new phenomena & functions of softmatter.



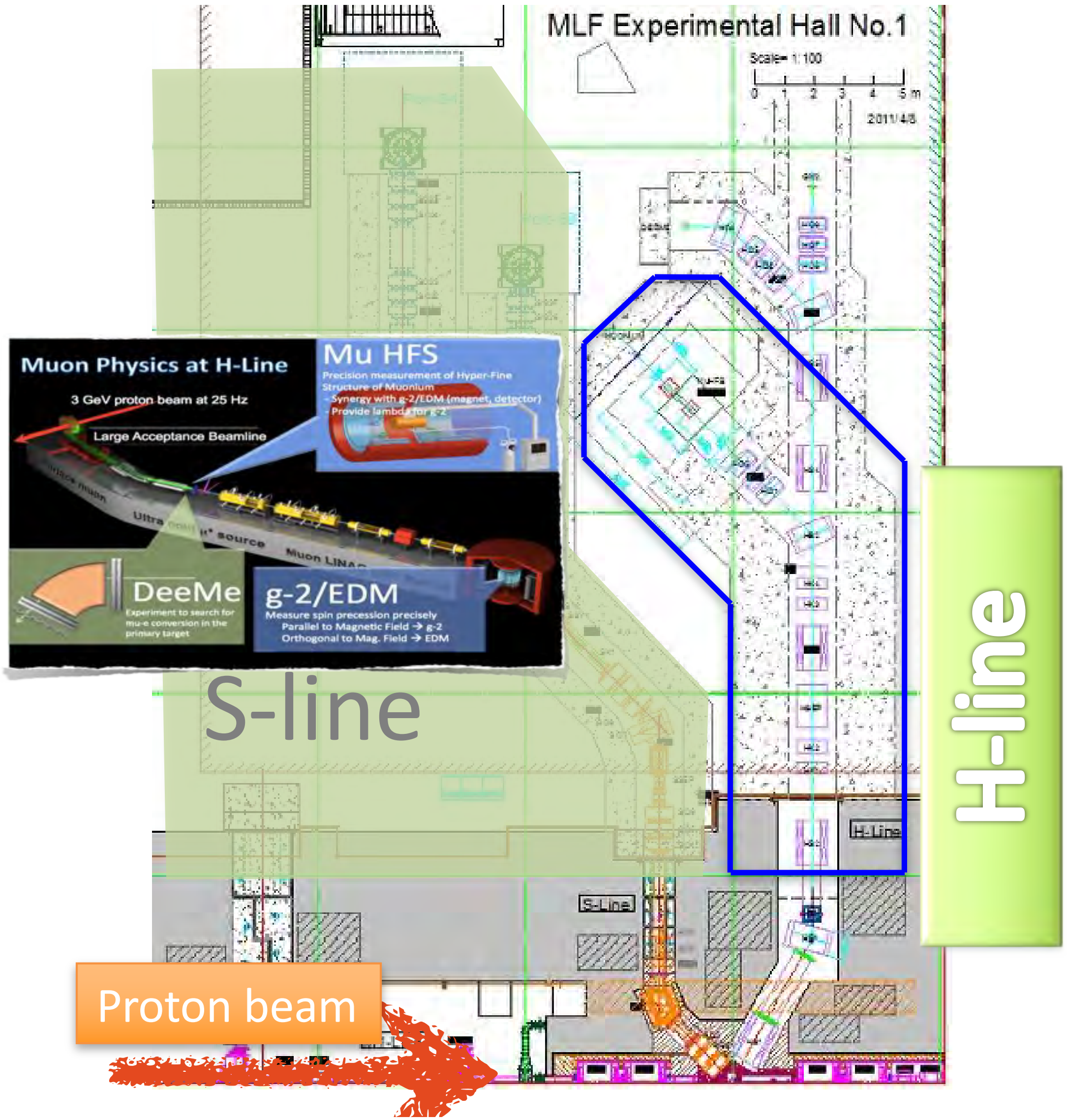
In ternary system, 6 contributions (3 self terms + 3 cross terms) must be considered.

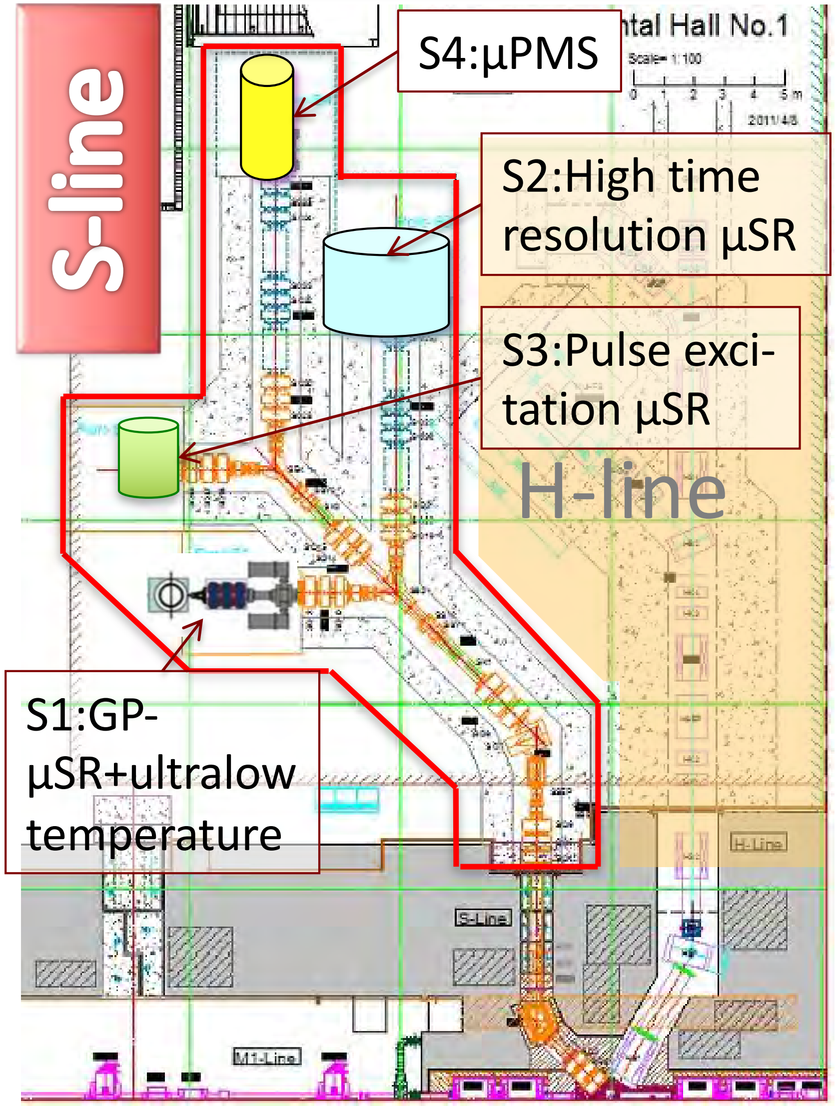
Contrast Variation can be typically realized by H (1.76barn)/D (5.59barn) replacement in Soft Materials.

Construction of H-line and S-line

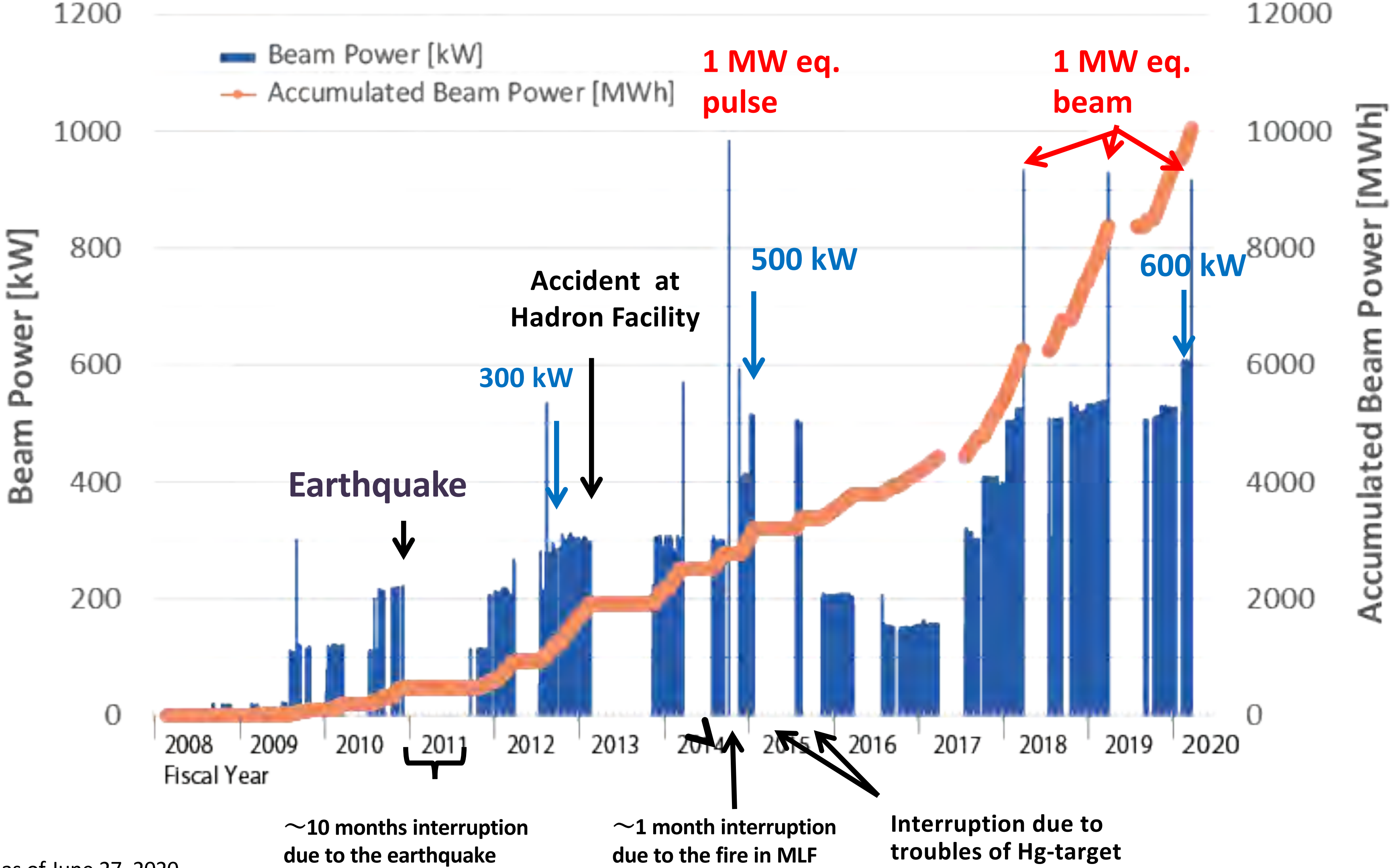
H-line infrastructure ¥0.6B

S-line cost ¥1.4B





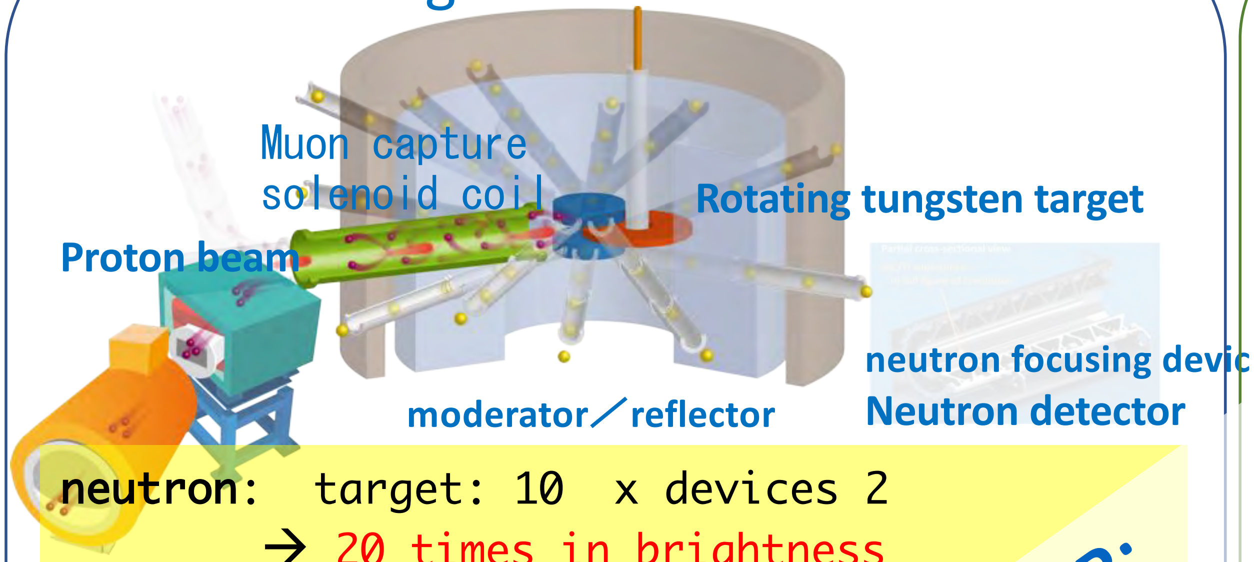
Beam Power History at MLF



as of June 27, 2020

New Neutron and Muon Target (TS2)

A unified target for neutron and muon



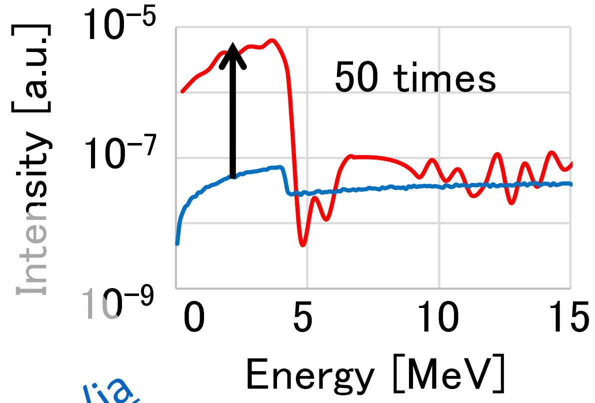
neutron: target: 10 x devices 2
→ 20 times in brightness

Muon :target : 10 x capture solenoid 5~10
→ 50 ～ 100 times in intensity

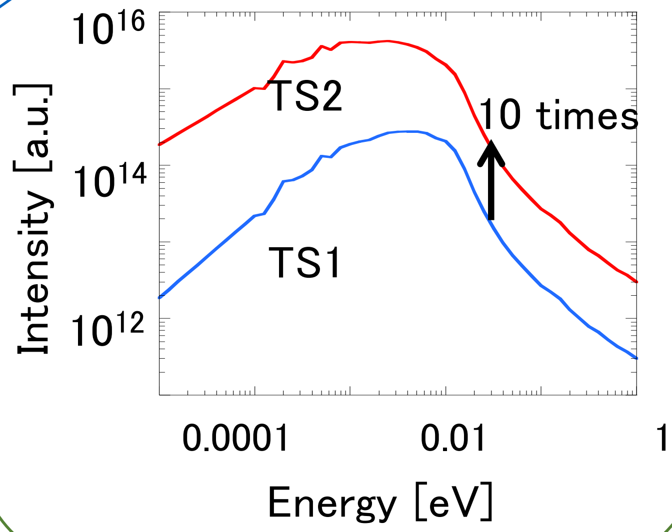
CDR: http://j-parc.jp/researcher/MatLife/ja/publication/files/TS2CDR.pdf

Calculation of Intensity

Muon



Neutron



Accelerator Upgrade

Power 1 MW → 1.5 MW (TS1:1MW, TS2: 0.5MW)

Repetition 25 Hz → 25 HZ (TS1:17Hz, **TS2: 8Hz**) **Long wavelength**

		1 MW	1.5 MW
Peak current	[mA]	50	62.5
Pulse width	[ms]	500	600
Repetition	[Hz]	25	25
Average current	[mA]	333.3	500
Max energy in lineac	[MeV]	400	400
Max energy in RCS	[GeV]	3	3

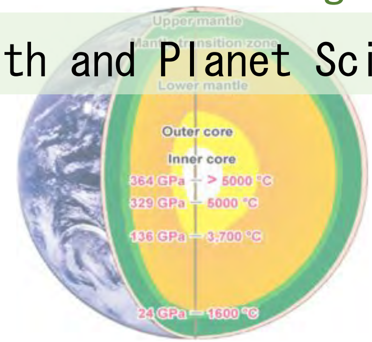
Peak Science (1)

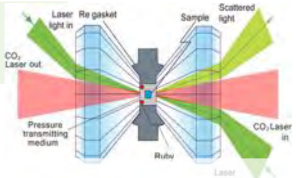
Neutron high brightness, muon high intensity→ micro beam (complementary use)

Extreme Condition
(High pressure, High external field)

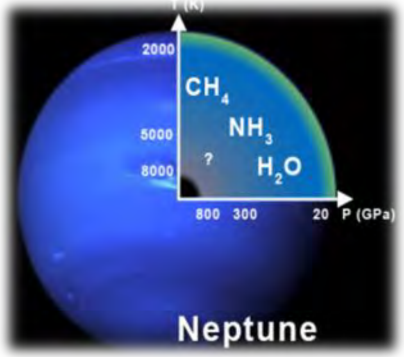
High Brilliance ：small sample

Earth and Planet Sci.

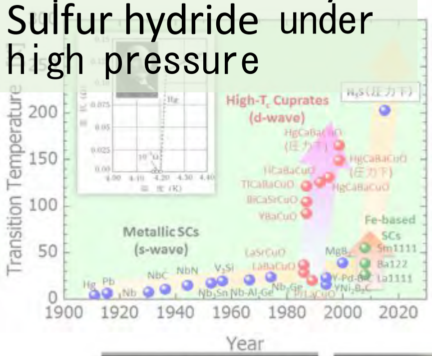




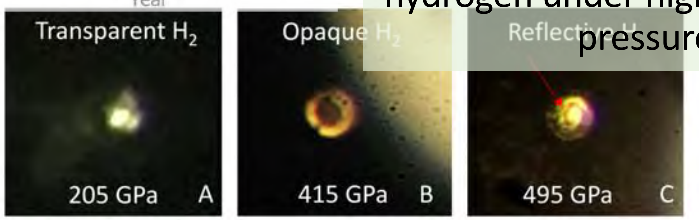
DAC



Super conductivity in Sulfur hydride under high pressure



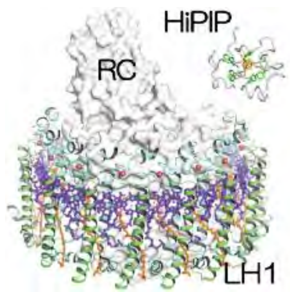
Metallization of hydrogen under high pressure



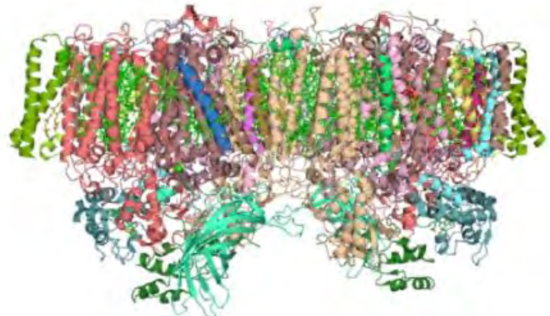
Bio Science

High brightness → Small sample

Photosynthesis protein

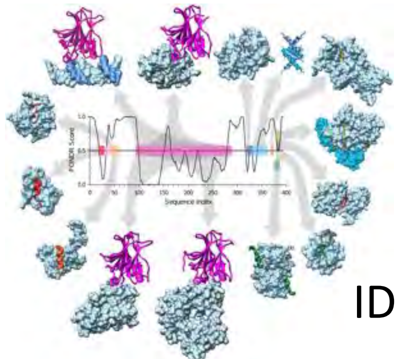


Proton transfer protein



long wavelength → slow dynamics of protein

Spin echo $t = \frac{\hbar}{m}\frac{\gamma_L H l}{\bar{v}^3} \sim H l \lambda^3$



IDP

Human derived protein for drug discovery

Fluctuations of structure

→ Cancer suppression mechanism

New approach for drug development

Top Science（2）

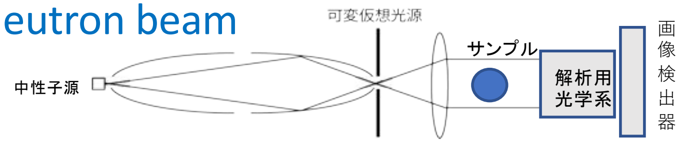
Neutron high brightness, muon high intensity

（complementary use）

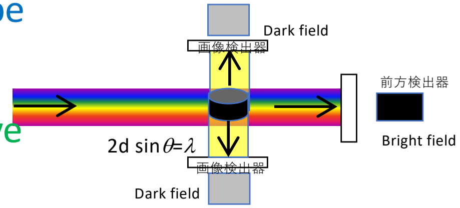
Real Space（nonuniform system） → Industrial applications

Imaging

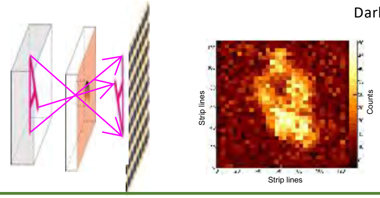
Parallel neutron beam



Diffraction microscope



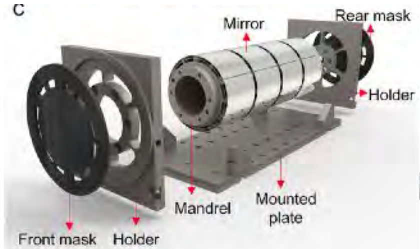
3D imaging by negative muon



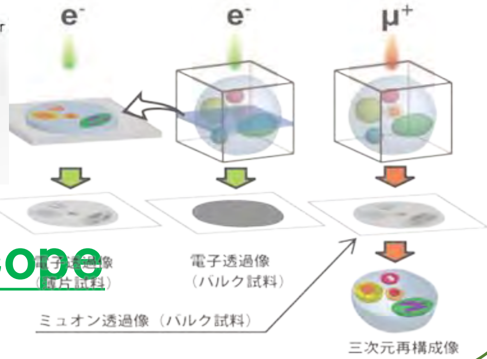
Resolution: several mm

Neutron microscope

NIM, A 940 (2019) 380–386



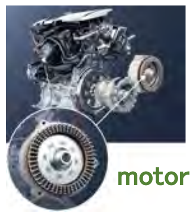
Muon microscope



Industrial Applications

Li batter y

PCU



motor

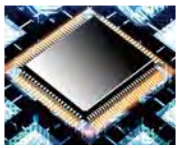
Visualization of system and module
(structure, stress, magnetic field)

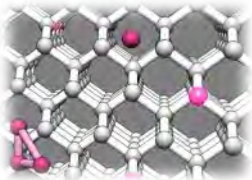
http://www.tyota.co.jp

Active site

micro μSR
muonic X ray analys

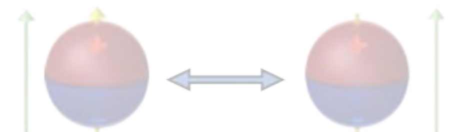
Neutron holography



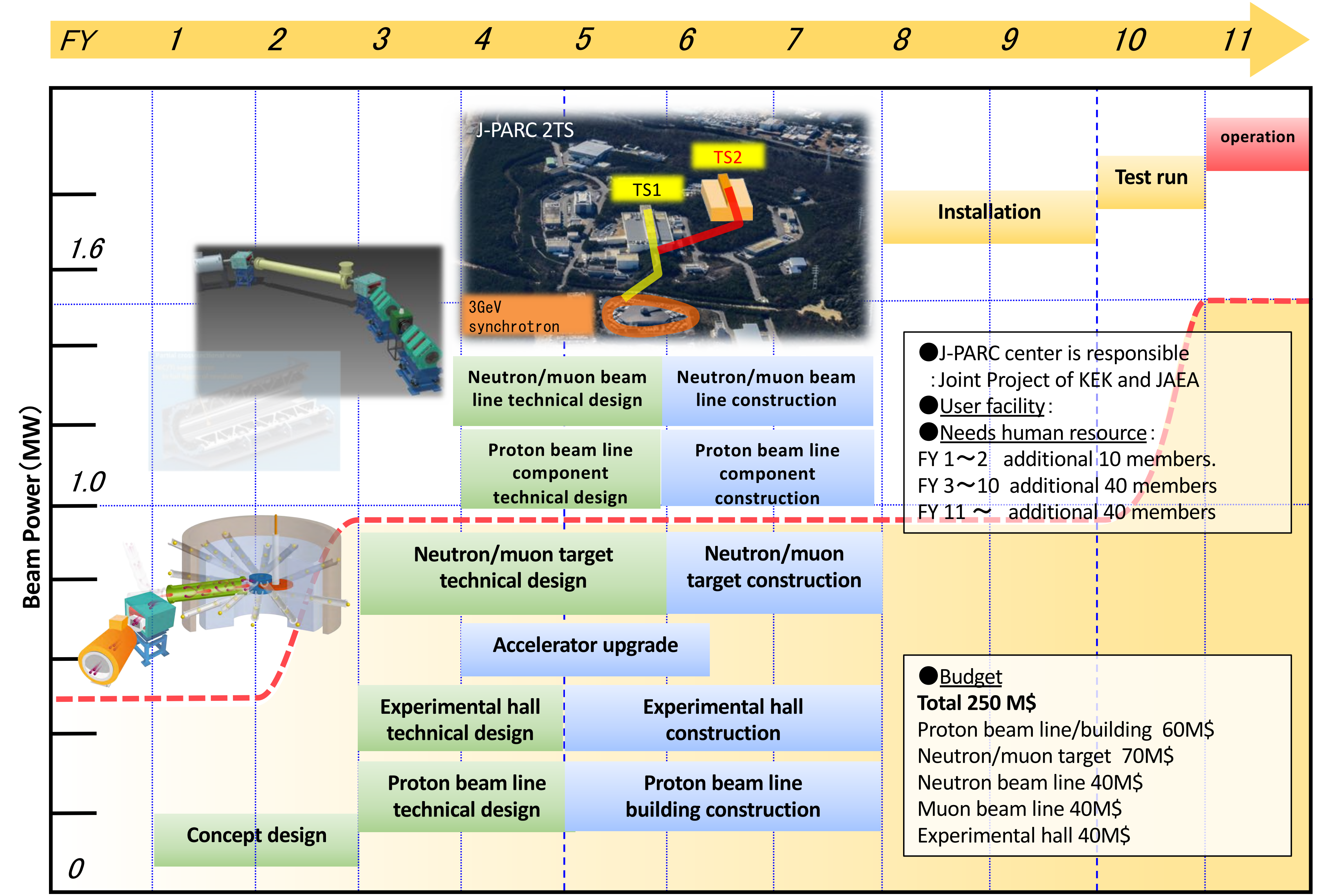


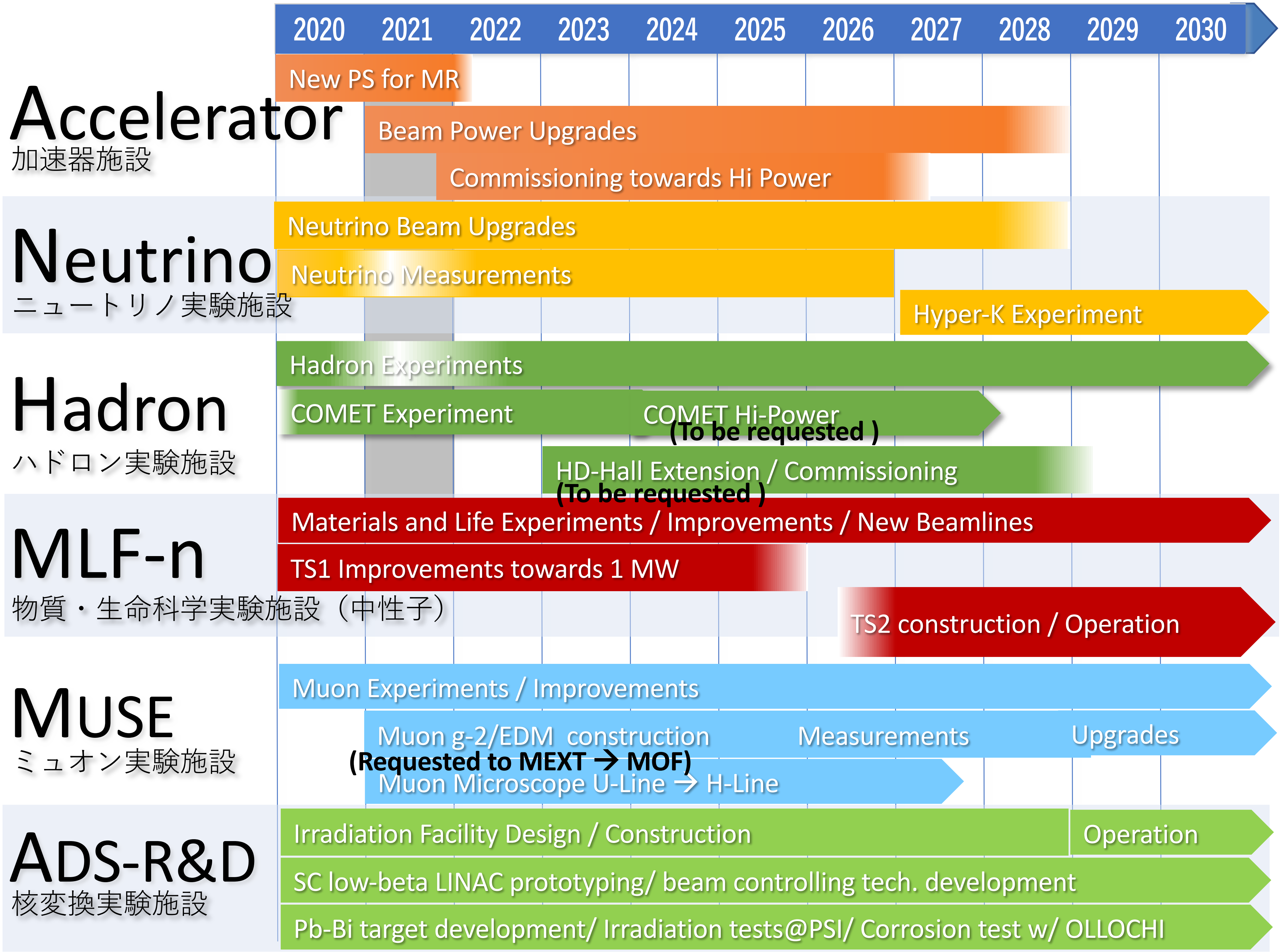
Active site below fraction of 1%

Fundamental Physics
Meitron EDM
Muon EDM



MLF TS2 Construction Schedule




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
(To be requested)
HD-Hall Extension / Commissioning
(To be requested)
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
(Requested to MEXT → MOF)
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

Issue： Strengthen functions and roles as a large-scale facility

- Huge operating expenses
- User support for 10,000 users*days per year
  - ~100 users/day
- Establishment of a sustainable operation system
- Development of a wide range of applications and promotion of advanced applications
- Comprehensive use of Quantum beam
- Internationalization