Status overview of Materials and Life science Facility (MLF)　J-PARC

Toshiya Otomo

Materials & Life Science Division, J-PARC center, Tokai, Japan

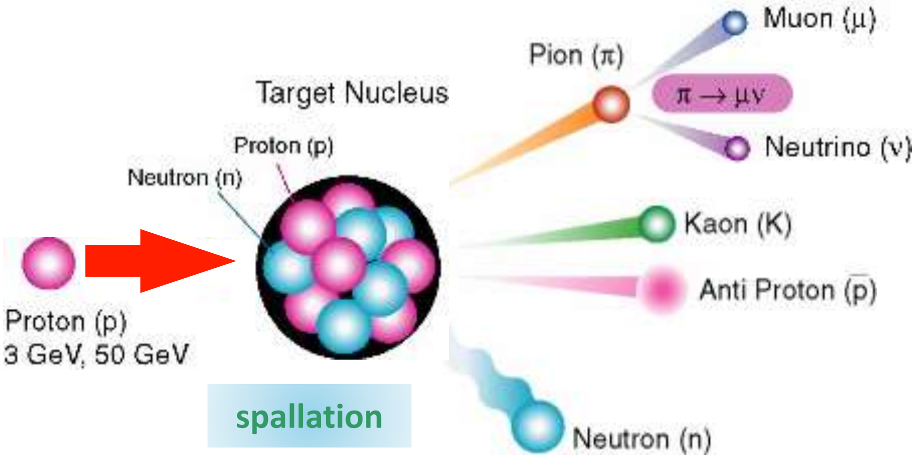
- Introduction of J-PARC
- Neutron target
- Outcomes
- Developments
- Future plan

Versatile Quantum Beams for Microscopic World

J-PARC

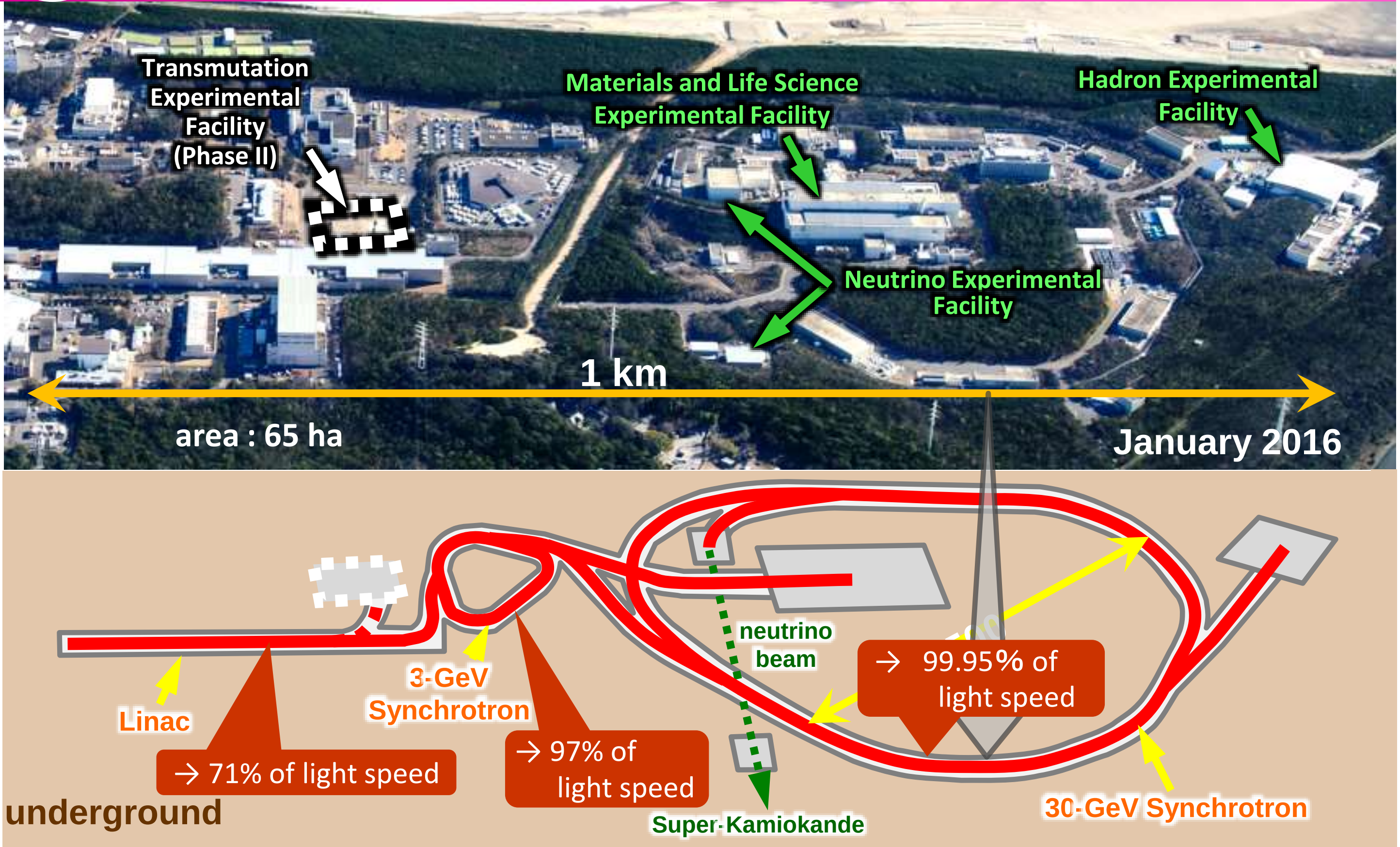
Japan Proton Accelerator Research Complex

Power-frontier accelerators and multi-purpose user facilities



Variety of secondary particles generated with high-energy and high-intensity protons

Japan Proton Accelerator Research Complex



3 proton accelerators and 3 experimental facilities

J-PARC Experimental Facilities

Wide range of research fields

- ☐ Materials & Life Science Experimental Facility
  - neutron and muon beams
  - materials science, life science, industrial applications
- ☐ Hadron Experimental Facility
  - K mesons, π mesons, muons ····
  - nuclear physics and particle physics
- ☐ Neutrino Experimental Facility
  - muon neutrino beams
  - neutrino oscillation search with Super-Kamiokande
- ☐ Transmutation Experimental Facility (Phase II)
  - R&D for accelerator-driven nuclear transmutation with neutrons

Versatile Quantum Beams for Microscopic World

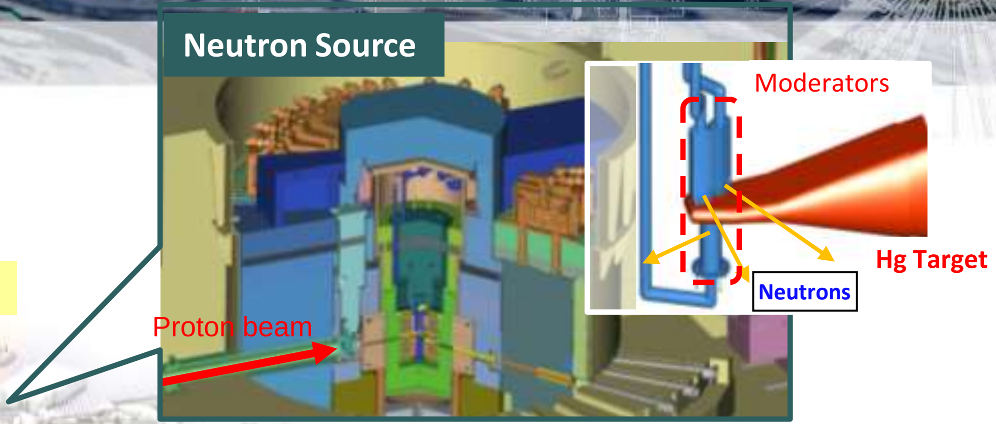
J-PARC

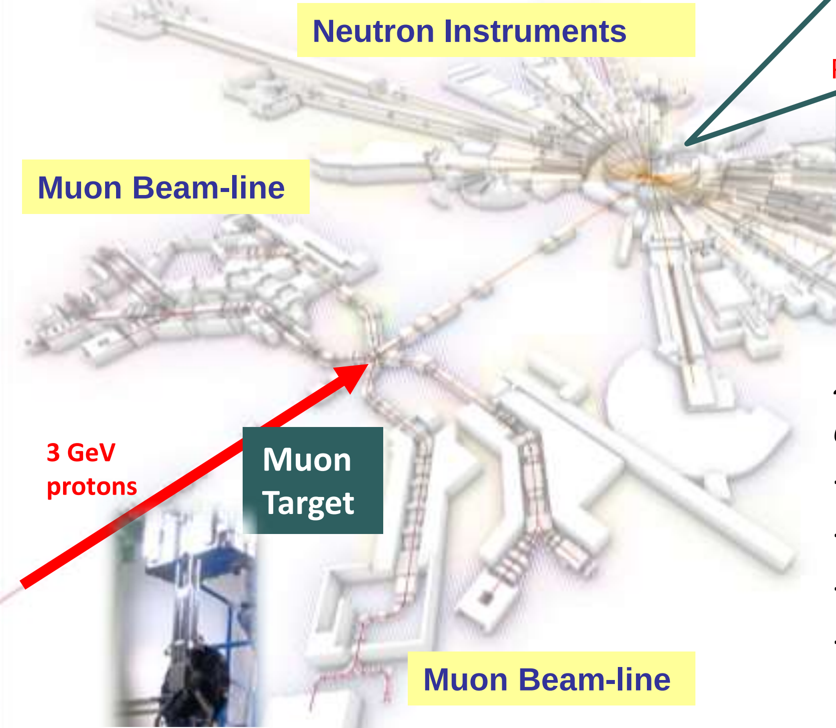
- Constructed jointly by High Energy Accelerator Research Organization (**KEK**) and Japan Atomic Energy Agency (**JAEA**)
  – construction from 2001 to 2007
  – beam commissioning from 2007 to 2009
  – construction cost: \152.4B
- Operated by J-PARC Center
  – J-PARC Center is joint organization of KEK and JAEA
  – operations for user programs from 2008
  – Currently **~160-day** operation / year for user programs
  – high beam availability (**90% – 95%**)
  – **~ 3,000-person·day** users / month *(before COVIT-19 pandemic)*

Materials and Life Science Experimental Facility

Materials and Life Science Experimental Facility (MLF)

- **Neutron** and **muon** beams
  - materials science, life science, industrial applications
- **most powerful** neutron and muon sources





21 neutron and 4 muon beam lines (8 areas) are in operation, carrying out studies of

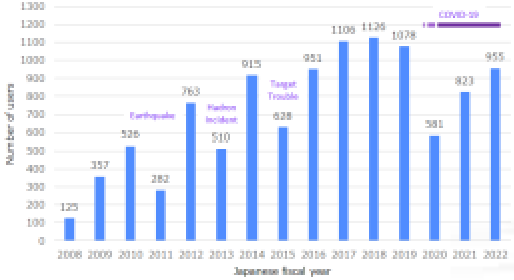
- *high-temperature superconductors*
- *protein, soft matter*
- *fuel cell, catalyst, new materials*
- *innovative products and drugs*

etc.

J-PARC by Numbers 2022

J-PARC, MLF

955 users



in 2022 JFY

418 proposals

PI's affiliation

73 % Japanese organization

27 % Foreign organization

*approved proposals

233 publications

Field

48 % Physics

26 % Chemistry

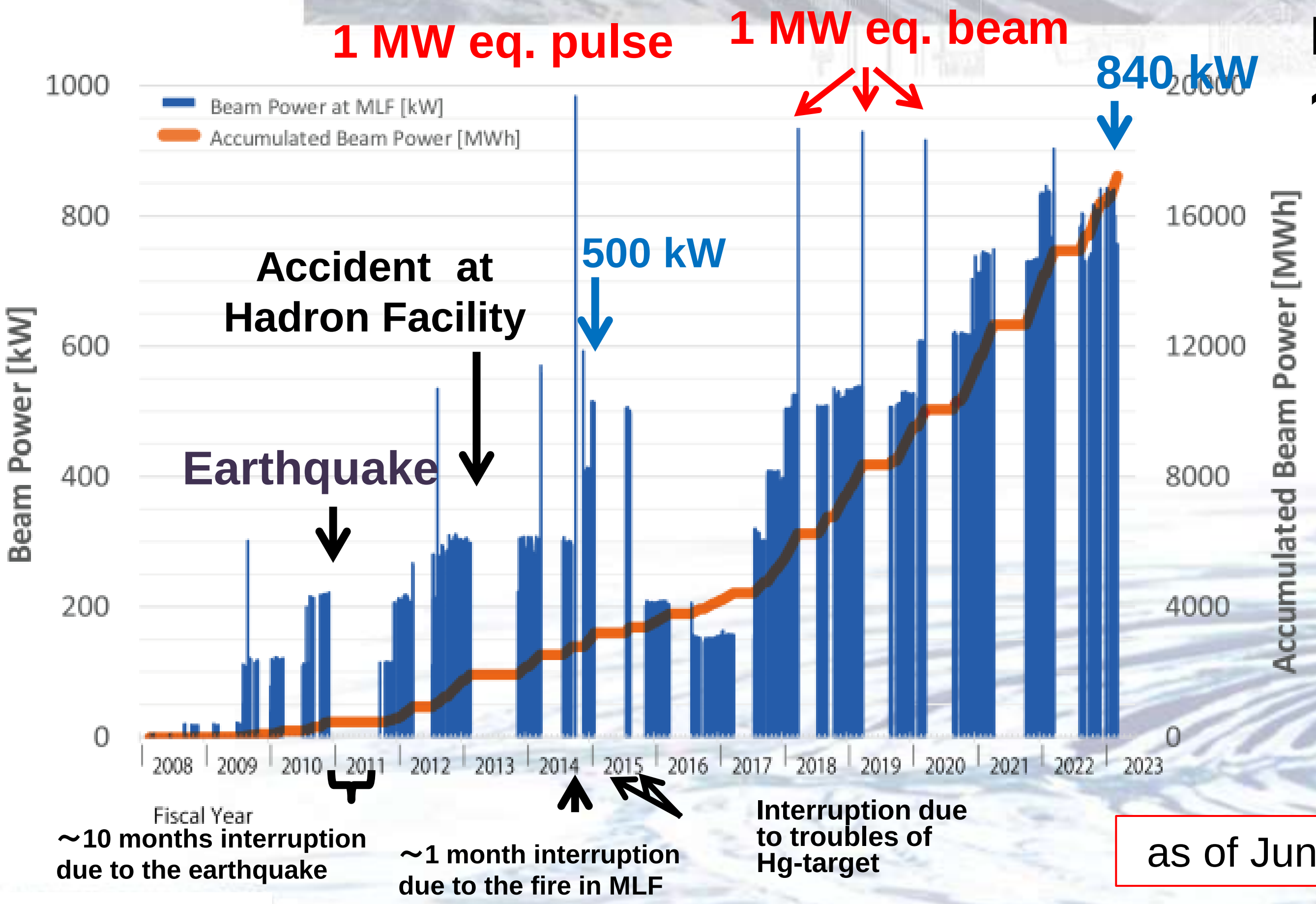
18 % Material Science

- Engineering 5%
- Biology & Biochemistry 1 %
- Geosciences 1%

2006-2022

NEUTRON TARGET

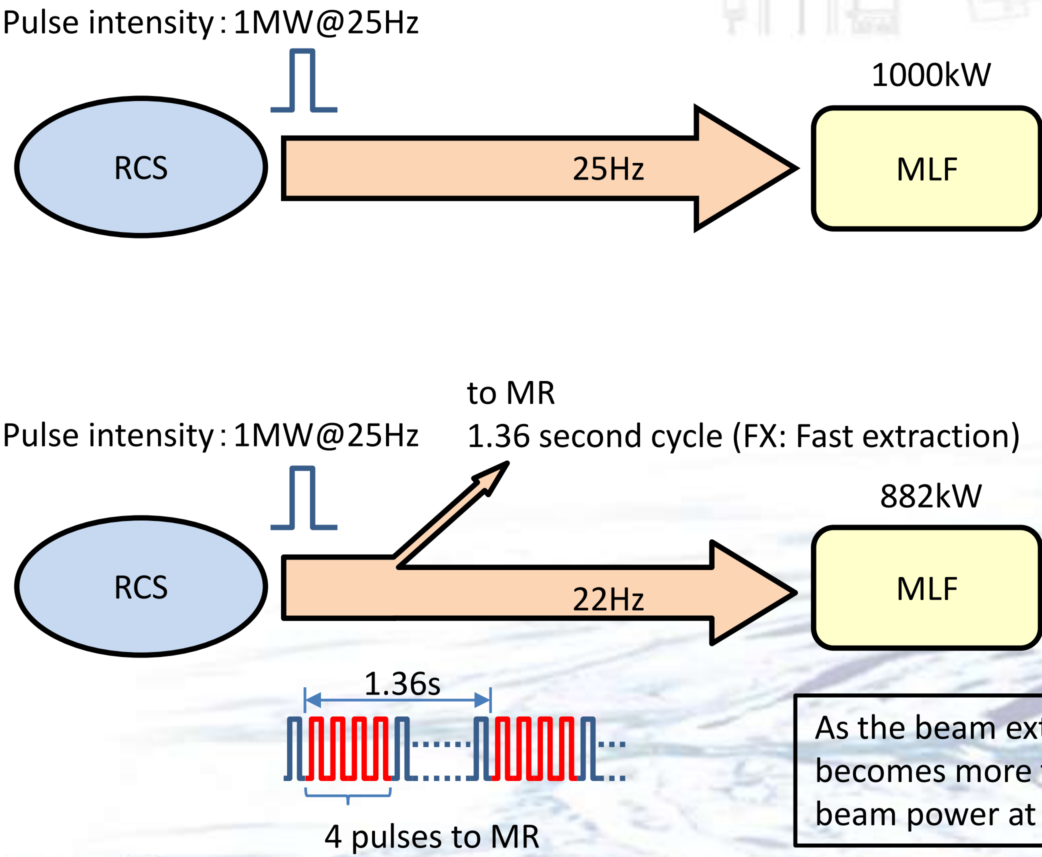
Beam Power History at MLF



RCS
~ 940 kW

as of June 22, 2023

Influence of Beam Extraction Cycle to MR on MLF Power



As the beam extraction to MR becomes more frequent, beam power at MLF decreases.

Influence of Beam Extraction Cycle to MR on MLF Power

SX: Slow extraction -> Operation mode for the hadron facility
FX: Fast extraction -> Operation mode for the neutrino facility

Pulse intensity@25Hz	Beam extraction cycle to MR [second]	Power at MLF [kW]
1 MW	SX 5.2	969
	FX 2.48 (~2021)	935
	FX 1.36 (2022~)	882
	FX 1.16 (2028~)	862

In the future

1.16 MW	FX 1.16	1000

Increase of pulse intensity is needed to achieve 1MW at MLF.

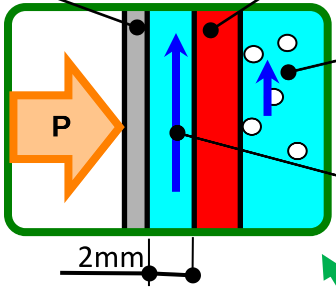
Pitting damage of the target vessel is increased.
Damage depth is proportional to the 4th power of pulse intensity.

- R&D for high power target is further important.
- Pulse intensity will be decided holding stable operation to the top priority.

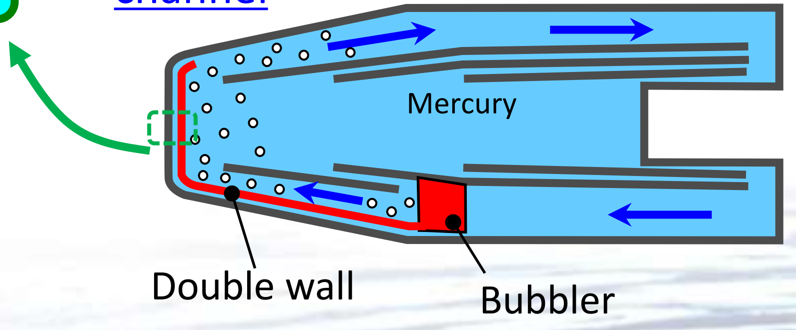
Mitigation of Pitting Damage

Outer wall (thickness:3 mm, Hg boundary)
Protected by Hg flow in the narrow channel

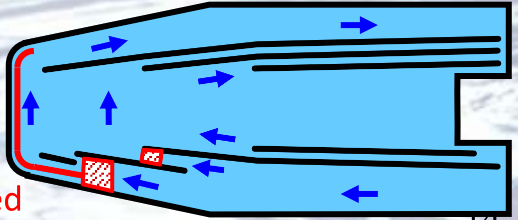
Inner wall (thickness: 5 mm)
Protected by microbubbles



Damage mitigation by gas microbubble injection



- Damages on the outer wall, the mercury boundary, was negligibly small
    - Cut-out specimens of outer and inner walls have been examined
- Based on the good reproducibility of the damage mitigation, one year operation with 1 MW pulse won't be a problem.



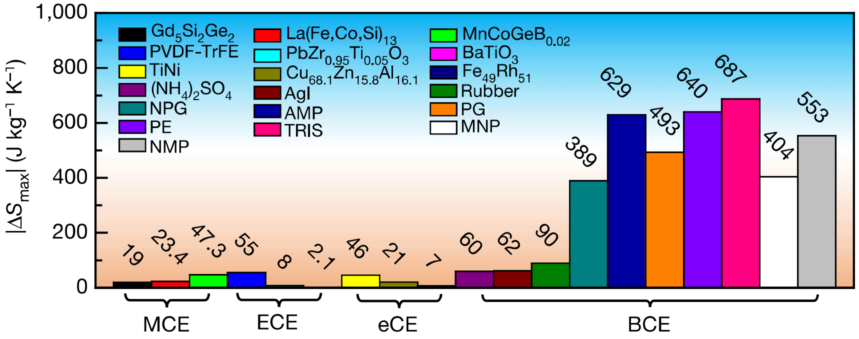
Bubbler was split and moved forward by around 200 mm.

RECENT OUTCOMES

New cooling technology using solid refrigerant

Li Bing, et al., Nature **567**, 506–510 (2019)

TOP <1%

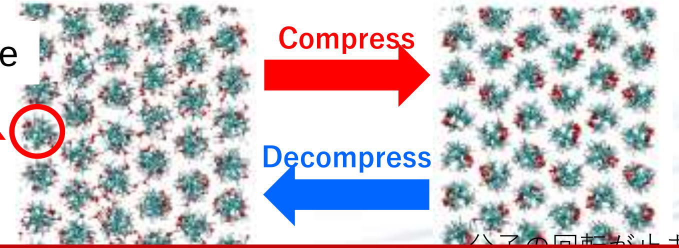


- Solid Refrigerants with Less Environmental Impact
- Atomic-Level Clarification of the Mechanism of the Massive "Pressure Calorific Effect" in "Soft Viscous Crystals," which Generate 10 Times More Heat than Conventional Solid Refrigerants

Free rotation
Small entropy
high temp. equiv.

No free rotation
High entropy
low temp. equiv.

NPG molecule



- Focusing on NPG (neopentylglycol), a soft viscous crystal that shows large pressure calorimetric effects
- The origin of the pressure calorimetric effect was analyzed at the atomic level using neutron beams at J-PARC and X-rays at SPring-8.
- From neutron quasi-elastic scattering observations of NPG, the origin of the huge pressure calorimetric effect was clarified to be the huge entropy change accompanying the rotation of the NPG molecule.

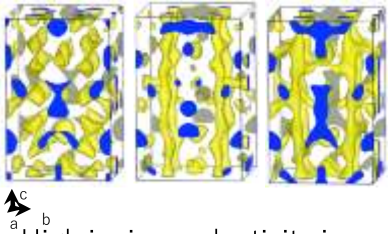
Elucidation of colossal barocaloric effects of plastic crystals
（Academic Achievements）
⇒ Contribution to next environmentally friendly cooling technology
（Social Achievements）

Developments of All-Solid-State Li Battery Material

Tokyo Institute of Technology, KEK IMSS, Univ. Tokyo, J-PARC center

$Li_{10}GeP_2S_{12}$

Nature Materials 2011



High ionic conductivity is observed when lithium ions diffuse in **three-dimensional** direction. However, **high temperature is required.**

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

Nature Energy 2016

Lithium Ions diffuse in three directions even **at room temperature**.

TIT, KEK IMSS, TOYOTA, Ibaraki Pref., Ibaraki Univ., J-PARC center

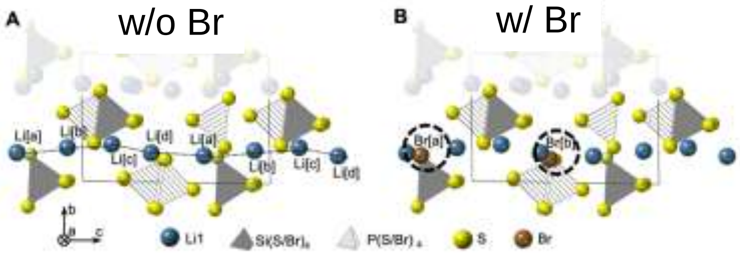
Number of citations 2000 or more (2 articles combined) , TOP < 0.02%

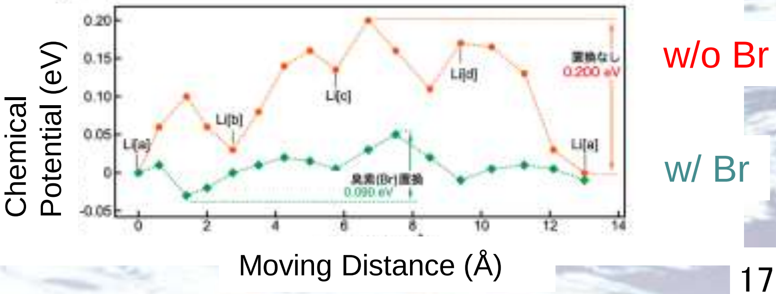
Analysis of the location of elements containing lithium by neutron diffraction leads to an understanding of the lithium ion diffusion mechanism, contributing to the development of all solid-state batteries

$Li_{9.54}[Si_{0.6}Ge_{0.4}]_{1.74}P_{1.44}S_{11.1}Br_{0.3}O_{0.6}$

Science 2023

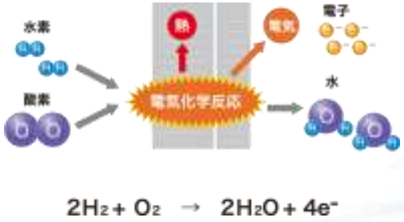
Thick-film cathode with 1.8 times the current capacity per electrode area is fabricated and combined with a lithium metal anode to create an all solid-state battery that exhibits **high-capacity and high-current** characteristics.

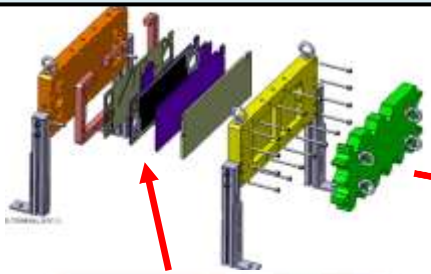


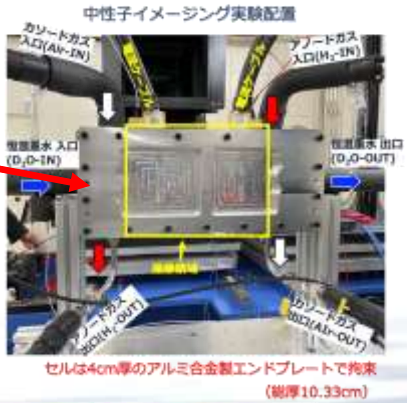


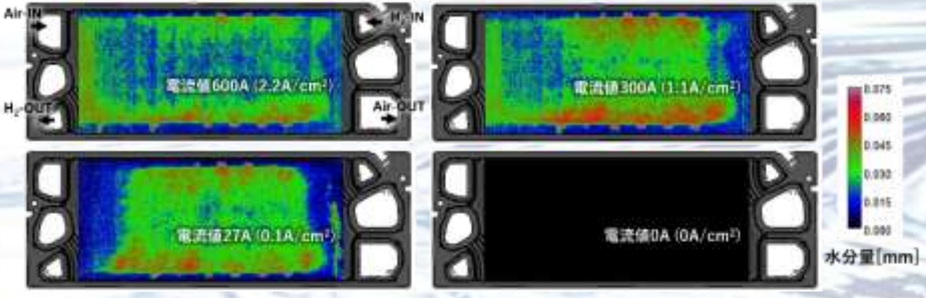
Fuel cell operand measurement

- Neutron irradiation of a fuel cell while it is actually operating (generating electricity) and real-time observation of the distribution of produced water inside
- Advanced fuel cell observation technology utilizing the high penetrating power of neutron beams is being developed in collaboration with industries.









Success in Visualizing Condensate of water in a Working MIRAI Cell by Neutron Imaging

NEDO, KEK, JAEA, J-PARC center, Nissan Arc, FC-Cubic

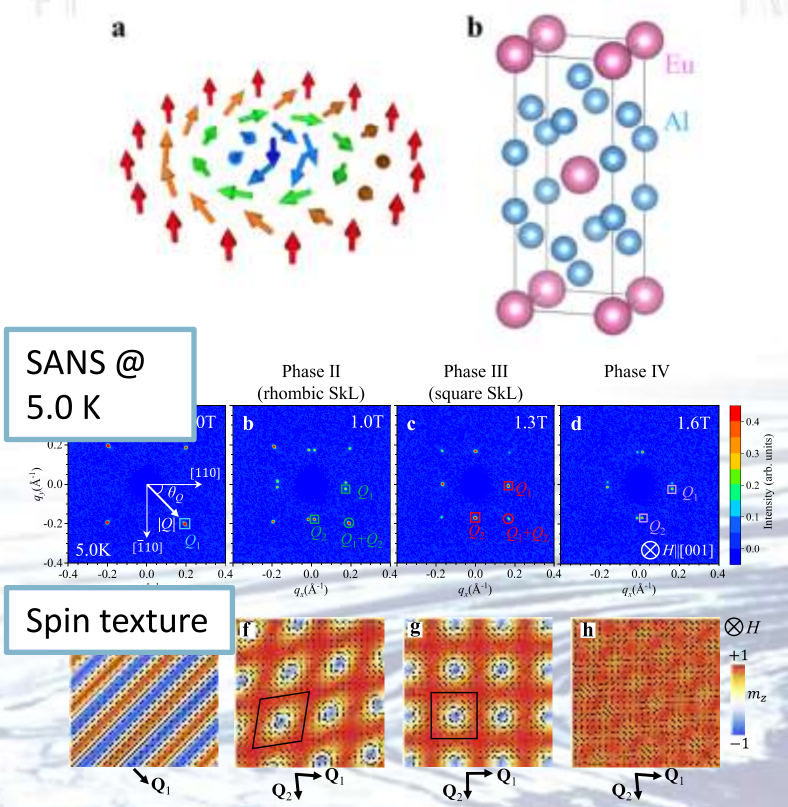
Discovery of a Binary Alloy Material Exhibiting Ultra-Dense Magnetic Vortices

Univ. Tokyo, RIKEN, Tohoku Univ., Toyama Univ., Osaka Univ., CROSS, JAEA, J-PARC center and etc.

Nature Comm (2022)

- Magnetic **skyrmion**, which are candidates for new information carriers.
  - originally discovered in noncentrosymmetric systems
  - Recently, centrosymmetric rare-earth compounds, such as Gd_2PdSi_3 and $GdRu_2Si_2$
- Magnetic **skyrmion** have been reported to form in a centrosymmetric **binary** compound **$EuAl_4$**,
- Elucidation of the mechanism of magnetic skyrmion formation in a simple centrosymmetric binary compound.

- Polarized small-angle neutron scattering under a 1T magnetic field and resonant elastic X-ray scattering
- Magnetic skyrmion with 3.5 nm diameter observed



It is expected to provide important guidelines for future material design and exploration as well as for the development of control methods.

Asteroid samples returned by the Hayabusa2 mission

Ryugu

Cover:
Science vol. 379, No. 6634

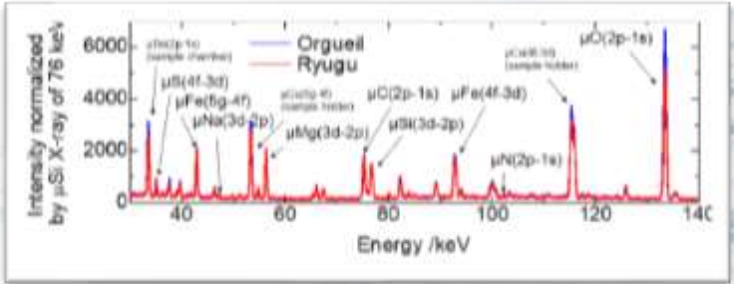
Muon measurement contributed to quantify C, Si, Mg and O concentrations as a part of the initial analysis that was performed soon after the sample recovery to the Earth. (collaboration with the initial analysis team (STONE) led by T. Nakamura.)

→ New standard of element composition of primordial solar system

Ex. The μC-Kα is 75 keV versus the fluorescence C-Kα is 0.3 keV (200 times larger !)

Muon-induced characteristic X-rays is an ideal method for studying the amount and the distribution of elements that are contained inside a sample.

Muon D-Line

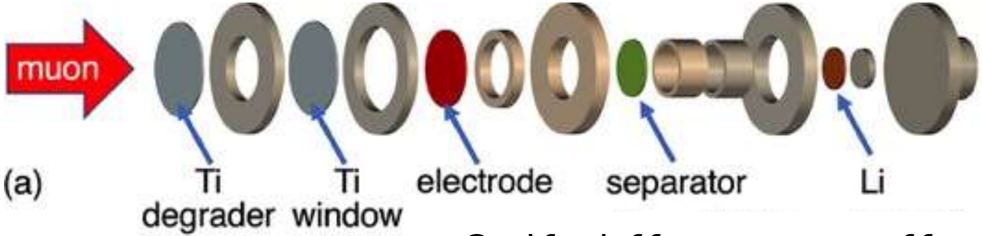


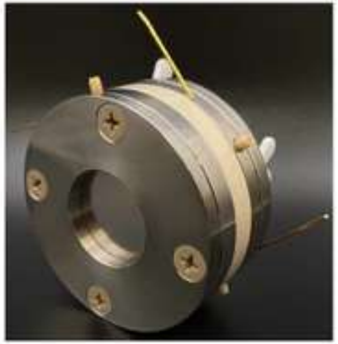
Sample

T. Nakamura *et al.,* DOI : 10.1126/science.abn8671

Operando μ^+SR on Li-ion battery

Research of Li ion diffusion in a Li-ion battery



(b)


Self-diffusion coefficient of Li ions in Li_xCoO_2 has been measured with operando μ^+SR **during a charge and discharge process** (0.2<x<0.9).

PRESS

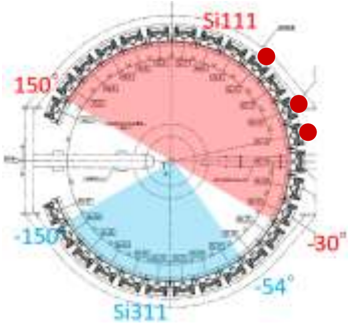
D. Igarashi
Ph.D student in Department of Applied Chemistry, Tokyo Univ. of Science

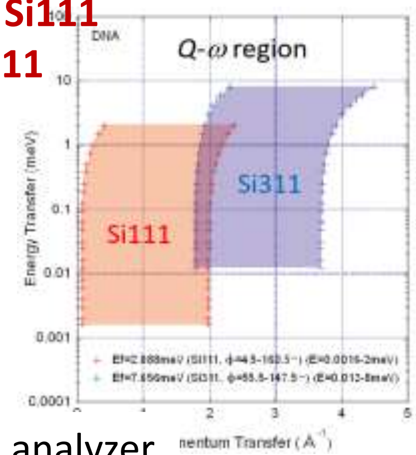
Operando Muon Spin Rotation and Relaxation Measurement on $LiCoO_2$ Half-Cell
K.Ohishi *et al.*, *ACS Appl. Energy Mater.* **5**, 12538 (2022).

DEVELOPMENTS

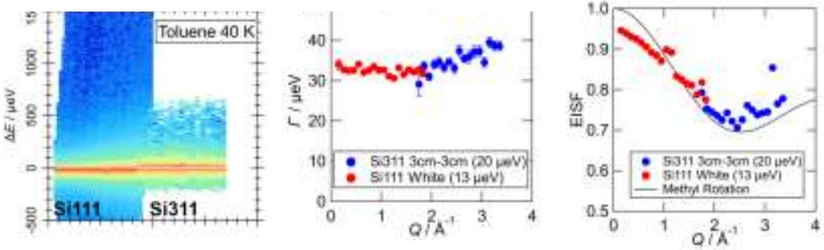
BL02 DNA
(Biomolecular Dynamics Spectrometer)

Analyzer mirror aging of Si111 & comissioning of Si311





Commissioning of Si311 analyzer



Replacement of damaged Si111 analyzer

The No10,12, and 13 banks (●)with damaged Si111 mirrors with Gd back coating were replaced to the refabricated Si111 mirrors with Gd_2O_3 back coating.

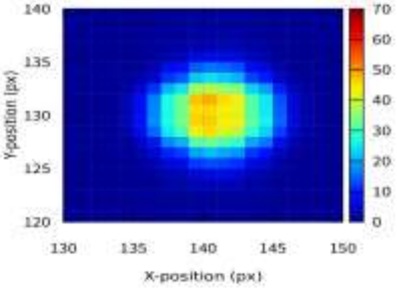
BL17 SHARAKU
(Polarized Neutron Reflectometer)

Focusing Mirror for GISANS

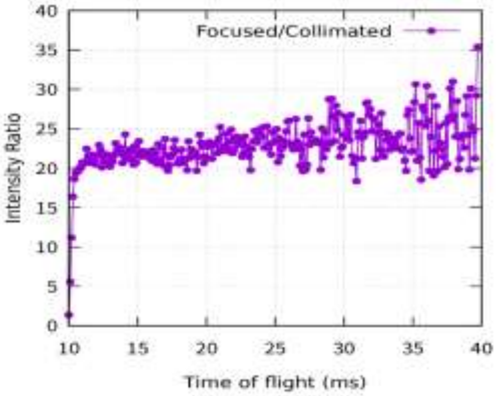
The gain of the new mirror is > 20 at a whole wavelength range, which is 4 times higher than the previous one. It would make GISANS feasible at BL17.

Photo of mirror

Beam profile



Gain factor

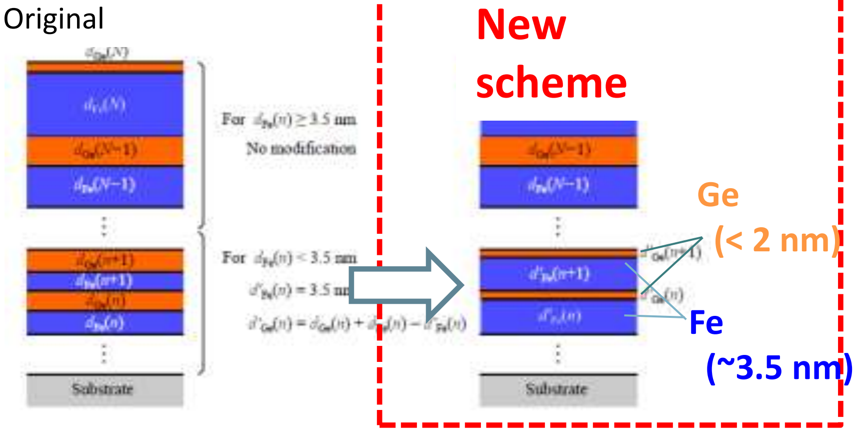


Polarized Neutron

Development of polarized super mirror

$m > 6$

New multilayer scheme



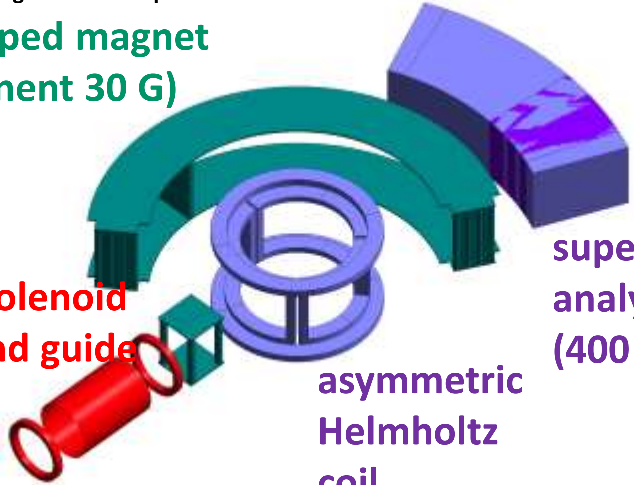
R. Maruyama et al., J. Appl. Phys. **130** 083904 (2021).

Magnetic system for polarization on BL23

All new design of magnetic systems completed test operations

<u>On BL test of Helmholtz coils and FS-magnet</u>

Magnetic system is another importance to realize polarization experiment. fun-shaped (FS) magnet and Helmholtz coils were newly redesigned and complete the test on the beamline.



J-PARC MLF Deuteration Laboratory

J-PARC MLF operates D-lab in cooperation with QST and CROSS.

Development/management of deuteration facility (MLF)

- Wet lab with fume hoods and clean bench
- High-pressure reactor
- Jar fermentor etc.

Characterization/analysis

- NMR (400 MHz)
- LC-MS/MS
- UV-Vis/FTIR spectroscopy
- QCM etc.

Development and expansion of facility

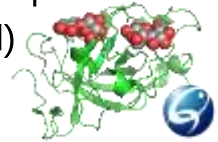
Development of preparation method

Development and expansion of facility

Development of preparation method

Biological deuteration (QST/MLF)

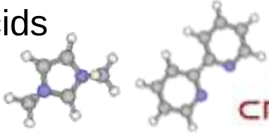
- Proteins and peptides
- DNA (Plasmid)
- E. coli cells



Chemical deuteration (CROSS)

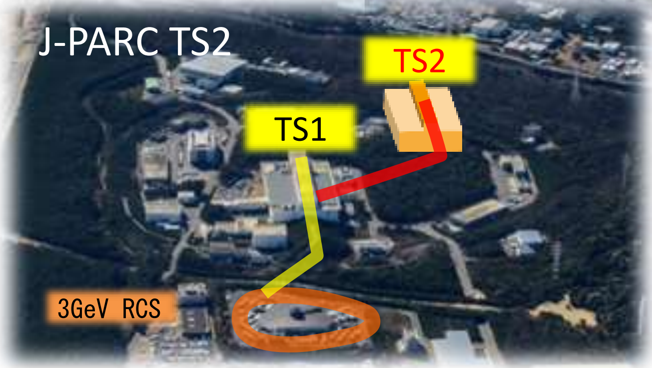
Direct H-D exchange using H_2/2-PrOH

- Carboxylic acids
- Ionic liquids
- Amides, etc.



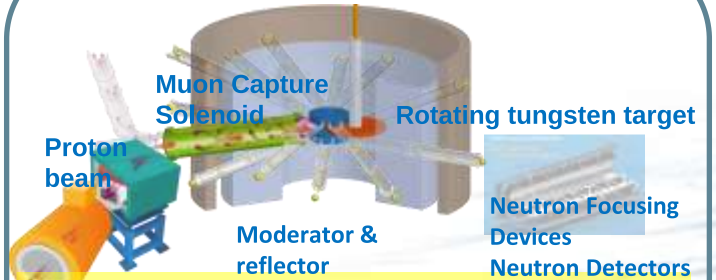
Target Station - 2

The Science Council of Japan has decided to formulate a new "Future Science Promotion Plan"



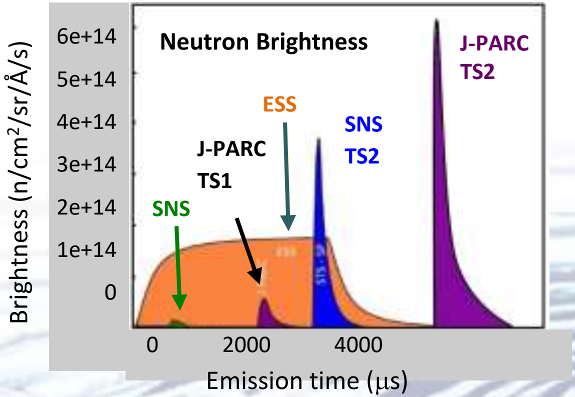
- Integration of neutron and muon sources (world's first)
- J-PARC proton accelerator intensity (1 MW) increased to 1.5 MW
- 1 MW (17 Hz) for TS1 and 0.5 MW (8 Hz) for TS2

Integrated neutron and muon target

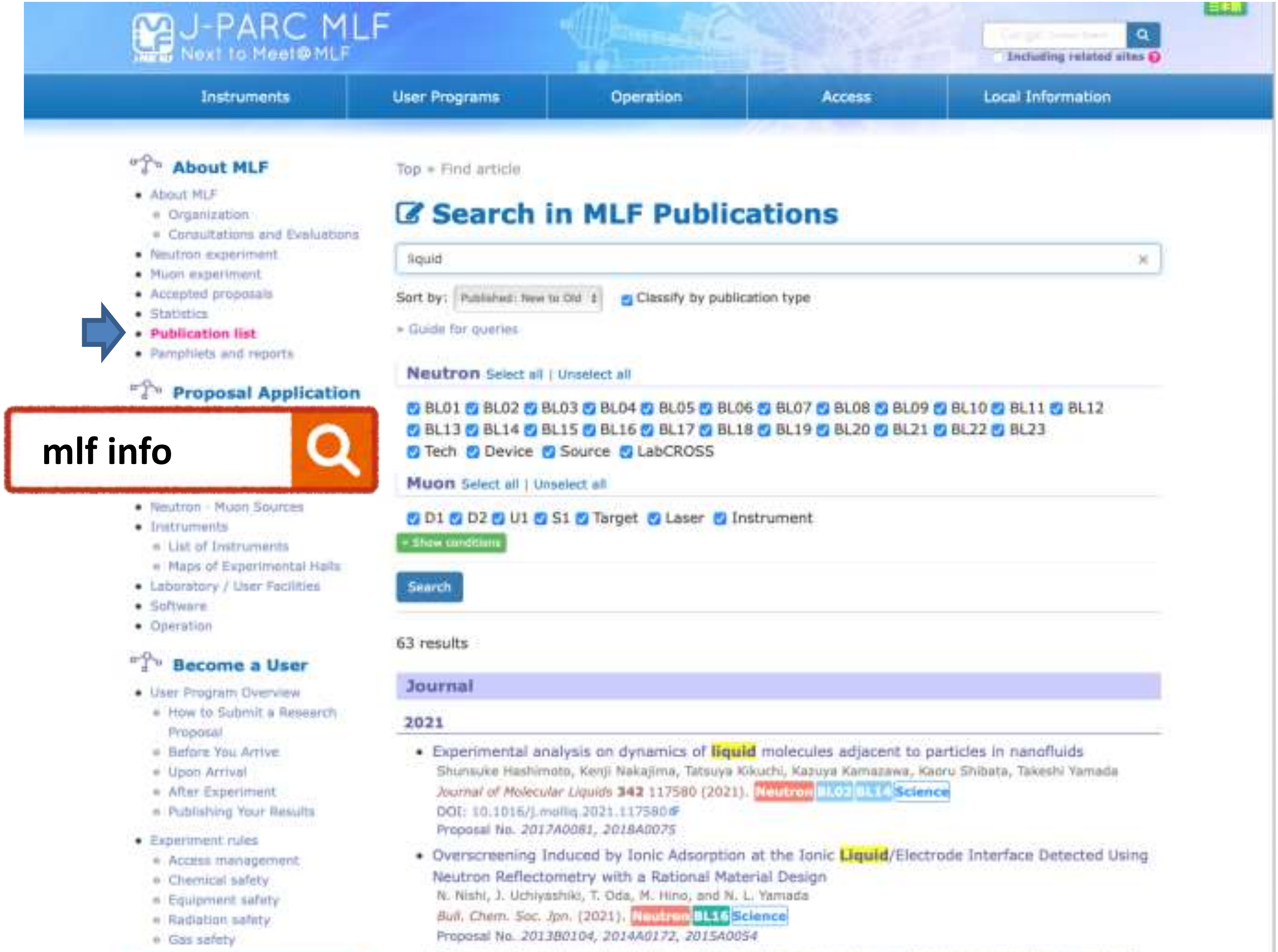


Neutron:
10 (target) x 2 (device) → 20 times gain of brightness

Muon: :
10 (target) x 5~10 (Muon capture solenoid) → 50 ~100 times gain of flux



Brightness of MLF TS2 will be the world's highest compared to the next plan of overseas facilities


J-PARC MLF
Next to Meet@MLF
Including related sites
Instruments
User Programs
Operation
Access
Local Information
About MLF
About MLF
Organization
Consultations and Evaluations
Neutron experiment
Muon experiment
Accepted proposals
Statistics
Publication list
Pamphlets and reports
Proposal Application
mlf info
Neutron · Muon Sources
Instruments
List of Instruments
Maps of Experimental Halls
Laboratory / User Facilities
Software
Operation
Become a User
User Program Overview
How to Submit a Research Proposal
Before You Arrive
Upon Arrival
After Experiment
Publishing Your Results
Experiment rules
Access management
Chemical safety
Equipment safety
Radiation safety
Gas safety
Top » Find article
Search in MLF Publications
liquid
Sort by: Published: New to Old
Classify by publication type
» Guide for queries
Neutron Select all | Unselect all
BL01 BL02 BL03 BL04 BL05 BL06 BL07 BL08 BL09 BL10 BL11 BL12
BL13 BL14 BL15 BL16 BL17 BL18 BL19 BL20 BL21 BL22 BL23
Tech Device Source LabCROSS
Muon Select all | Unselect all
D1 D2 U1 S1 Target Laser Instrument
+ Show conditions
Search
63 results
Journal
2021
Experimental analysis on dynamics of liquid molecules adjacent to particles in nanofluids
Shunsuke Hashimoto, Kenji Nakajima, Tatsuya Kikuchi, Kazuya Kamazawa, Kaoru Shibata, Takeshi Yamada
Journal of Molecular Liquids 342 117580 (2021). Neutron BL02 BL14 Science
DOI: 10.1016/j.molliq.2021.117580
Proposal No. 2017A0081, 2018A0075
Overscreening Induced by Ionic Adsorption at the Ionic Liquid/Electrode Interface Detected Using Neutron Reflectometry with a Rational Material Design
N. Nishi, J. Uchiyashiki, T. Oda, M. Hino, and N. L. Yamada
Bull. Chem. Soc. Jpn. (2021). Neutron BL16 Science
Proposal No. 2013B0104, 2014A0172, 2015A0054

Collaboration with JRR-3 " J-JOIN"

- **J-JOIN :（J-PARC, JRR-3, JAEA）-JOIN**
- It is a platform aiming to
  - connect support organizations related to neutrons and muons users
  - solve problems in academia and industry with neutrons and muons
  - gather human resources from different industries and fields from industry, academia and government to create new collaborations
  - collect and provide information on academic and industrial use in J-PARC and JRR-3
- **A portal site for neutron & muon users opened**
  - Centralization of information related to the use of neutrons and muons
  - One-stop consultation for neutron & muon use

coordinators of the consultation service

CROSS Science Coordinators　JRR-3 Userr Office　Ibaraki Pref. Coordinators

Summary

- Stable 840 kW operation achieved
  - Proton power per pulse : 940 kW
- User program and technical technical developments have been steadily progressed.
- Planning of the facility upgrade is on-going
- Collaboration with JRR-3 is becoming active

mlf info