J-PARC MLF

Materials and Life Science Experimental Facility

Instruments at J-PARC MLF

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Neutron Instruments

Inelastic Neutron Scattering	
・BL01 4 SEASONS	4D-Space Access Neutron Spectrometer
・BL02 DNA	Biomolecular Dynamics Spectrometer
・BL06 VIN ROSE	Village of Neutron Resonance Spin Echo Spectrometers (*)
・BL12 HRC	High Resolution Chopper Spectrometer
・BL14 AMATERAS	Cold-neutron disk-chopper spectrometer
・BL23 POLANO	Polarization Analysis Neutron Spectrometer (*)
Neutron Diffraction	
・BL03 iBIX	IBARAKI Biological Crystal Diffractometer
・BL08 SuperHRPD	Super High Resolution Powder Diffractometer
・BL09 SPICA	Special Environment Powder Diffractometer
・BL11 PLANET	High-Pressure Neutron Diffractometer
・BL18 SENJU	Extreme Environment Single Crystal Neutron Diffractometer
・BL19 TAKUMI	Engineering Materials Diffractometer
・BL20 iMATERIA	IBARAKI Materials Design Diffractometer
・BL21 NOVA	High Intensity Total Diffractometer
SANS and Neutron Reflectometry	
・BL15 TAIKAN	Small and Wide Angle Neutron Scattering Instrument
・BL16 SOFIA	Soft Interface Analyzer
・BL17 SHARAKU	Polarized Neutron Reflectometer
Neutron Imaging	
・BL22 RADEN	Energy Resolved Neutron Imaging System
Prompt Gamma-ray Analysis	
・BL04 ANNRI	Accurate Neutron-Nucleus Reaction Measurement Instrument
Fundamental Physics, R&D	
・BL05 NOP	Neutron Optics and Fundamental Physics
・BL10 NOBORU	Neutron Beam-line for Observation and Research Use

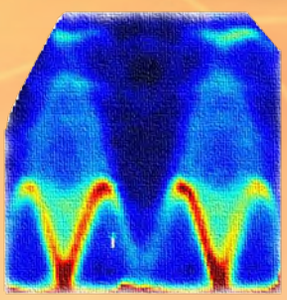
(*) under construction

Muon Instruments

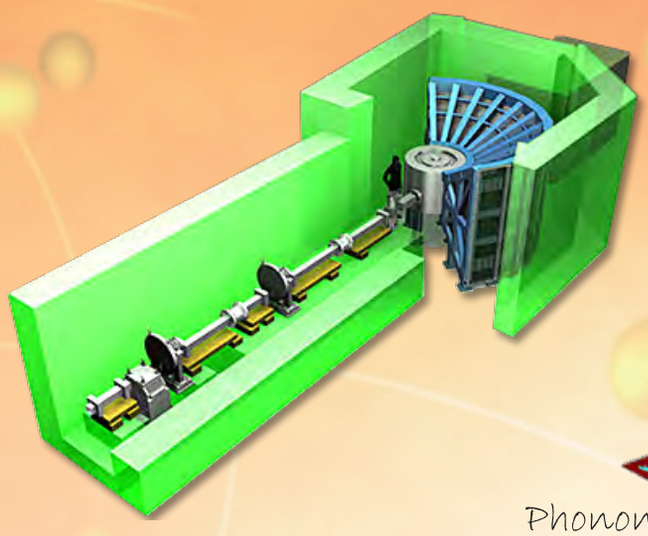
・ D1 Muon D1	Muon experimental area for Materials and Life science specimen
・ D2 Muon D2	Muon Spectrometer for Basic Science Experiments

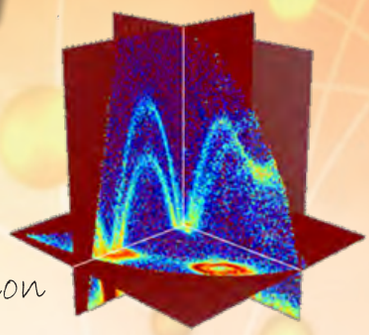
BL 01

4D-Space Access Neutron Spectrometer
4SEASONS



Quantum spin





Phonon

4SEASONS is a high-intensity Fermi-chopper spectrometer to efficiently collect weak inelastic signals from novel spin and lattice dynamics in condensed matters. The instrument is intended to provide high counting rate up to 300 meV neutron energy with moderate resolution ($\Delta E/E_i > 5\%$ at $E = 0$).
To achieve this goal, the spectrometer is equipped with advanced instrumental design such as an elliptic-shaped converging neutron guide and a wide area position sensitive detector consisting of long-length (2.5 m) ^{3}He tubes arranged cylindrically inside the vacuum scattering chamber. Furthermore, the spectrometer is ready for multi-incident-energy measurements by the repetition rate multiplication method, which promises much higher measurement efficiency compared with conventional chopper spectrometers.

APPLICATIONS

Study of magnetic excitations, phonons, and atomic vibrations in condensed matters including

- Superconductors and related materials
- Quantum magnets, frustrated magnets, and itinerant magnets
- Ferroelectrics and multiferroics
- Glasses and other non-crystalline materials

SPECIFICATION

Moderator	Coupled hydrogen moderator
Source-sample distance	18 m
Sample-detector distance	2.5 m
Chopper-sample distance	1.7 m
Incident neutron energy	$5 < E_i < 300$ meV
Detection angle	Horizontal : -35° - 91° Vertical : -25° - 27°
Resolution	$\Delta E/E_i > 5\%$ (@ $E = 0$ meV)
Neutron intensity at sample position	~3×10^5 n /s /cm^2 (@ $E_i = 50$ meV, $\Delta E/E_i = 5\%$) (@ 1 MW, calculated value)
Beam size at sample position	maximum 45 mm × 45 mm, optimum 20 mm × 20 mm, adjustable by motorized slits

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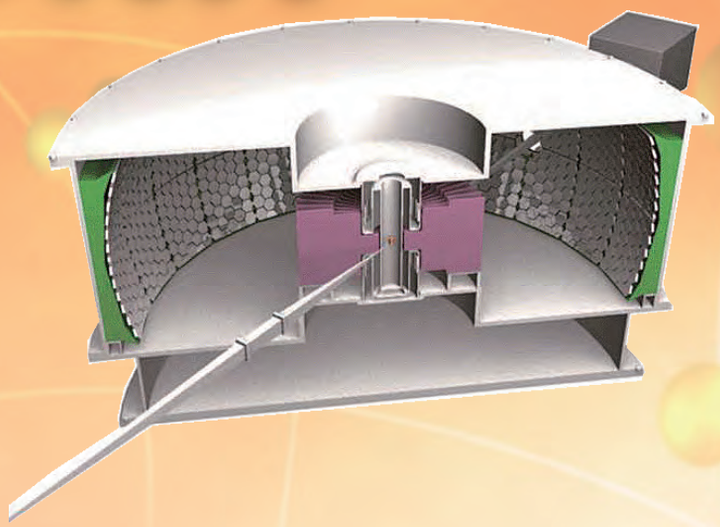
BL 02

Biomolecular Dynamics Spectrometer

DNA



DNA is a near backscattering TOF spectrometer using Si perfect crystal as analyzer. DNA spectrometer has a wide dynamic range from pico to nano second, which covers a wide field of basic sciences and industrial applications including soft matter, bio-molecular, chemical molecular, battery, catalyst, and magnetism.

SPECIFICATION

Moderator	Coupled hydrogen moderator
Analyzer Crystal and Reflection index (Analyzed Energy Ef)	Si (111) : 2.02 meV, Si (311) : 7.4 meV
Bragg angle of analyzers	~ 87.5 deg
Scan angle	Horizontal : -30° ~ +150° : Si (111), -90° ~ -78° : Si (311), (-150° ~ -42° : Si (311) in plan) Vertical : -14° ~ +21°
Energy Resolution [meV]	2.4 μeV (@ elastic) : Si(111) 1cm x 1cm slit 3.5 μeV (@ elastic) : Si(111) 3cm x 3cm slit 12 μeV (@ elastic) : Si(311) 3cm x 3cm slit
Momentum range	$0.08 < Q < 1.98$ [A^{-1}] : Si (111) $1.04 < Q < 3.79$ [A^{-1}] : Si (311) (in plan)
Scan energy range	$-500 < E < +1500$ (μeV) : with changing phase of pulse shaping chopper, $-30 < E < 100$ (μeV) : with fixed phase of pulse shaping chopper at Ef
Beam size at sample position	3 cm (vertical) x 2 cm (horizontal)
Sample size and/or volume	[liquid, soft matter] 14 mm φ x ~ 30 mm (height) thickness depends on transmittance [hard matter] 1 cm^3
Ancillary equipment and sample environment	(Default) Toploading type Cryo-Fanace with Closed cycle refrigerator (5 - 600 K), (Available SE equipments) ^{3}He cryostat (300 mK-), Dilution cryostat (100 mK-)

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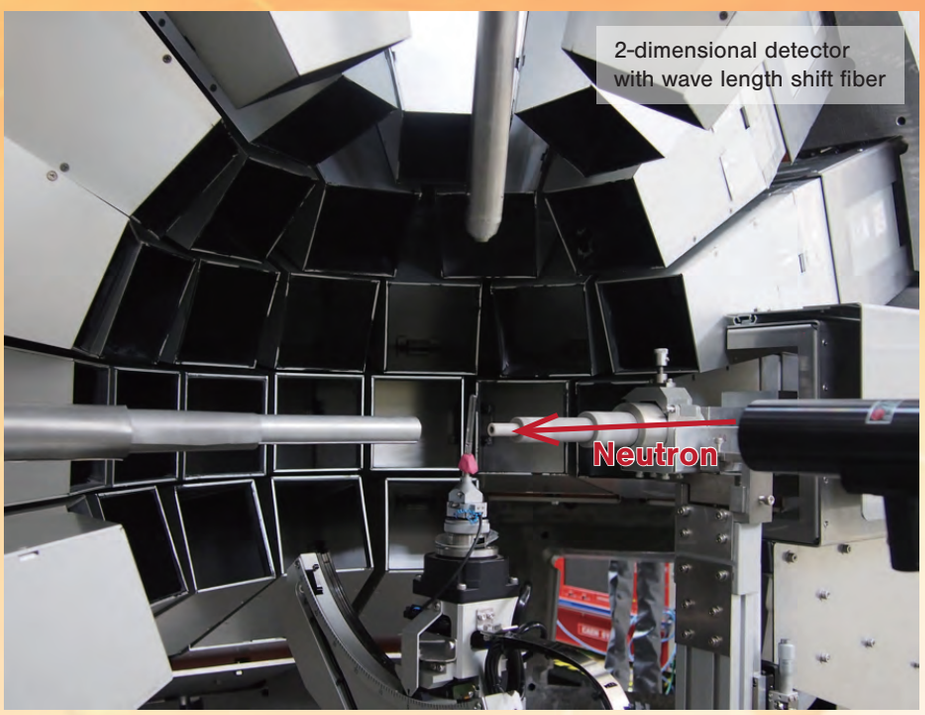
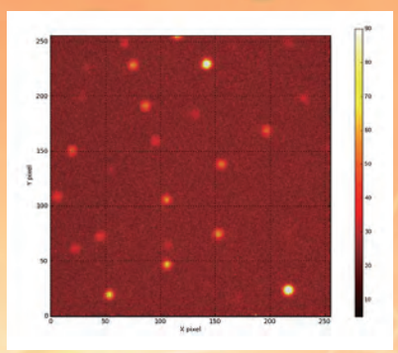
BL 03

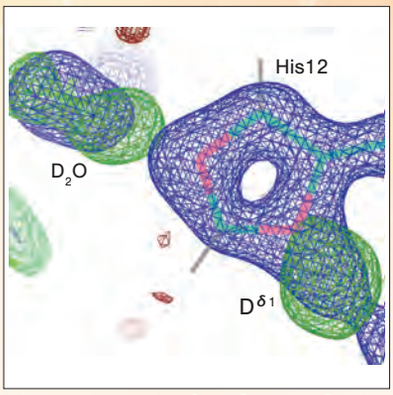
IBARAKI biological crystal diffractometer iBIX



Hydrogen atoms and water molecules around proteins play a very important role in the stability of the three-dimensional structure and in many physiological functions of them. The IBARAKI biological crystal diffractometer called iBIX which is a high-performance time-of-flight single-crystal neutron diffractometer was constructed at the BL03 of MLF/J-PARC, for mainly elucidating of the hydrogen, protonation and hydration structures of biological macromolecules and organic compound in various life processes.



Diffraction pattern of standard protein sample (RNase A) measured by iBIX.



Neutron scattering length map of active site histidine residues of standard protein sample. Water molecule(D_2O) and Hydrogen atom(D) can be obserbed.

APPLICATIONS

- Elucidation of the hydrogen and hydration structures of biological macromolecules.
- Structure analysis including hydrogen atoms for organic compounds.
- Analysis of fiber diffraction from polymer samples.

SPECIFICATION FOR USERS

	Actual results @ 500kW	plan@1MW
Max. cell volume	133.4 X 133.4 X 133.4 Å^3	135 X 135 X 135 Å^3
Sample size	0.5 ~ 6 mm^3	1 mm^3
Measurement time	less than 10 days	less than 1 week
Resolution	around 2.0 Å	around 2.0 Å

SPECIFICATION

Moderator	Coupled moderator
Wavelength of incident neutron	0.7 ~ 4.0 Å (1st frame) 4.0 ~ 8.0 Å (2nd frame)
Neutron intensity (@1MW)	0.7 × 10^6 n/s/mm^2
L_1	40 m
L_2	500 mm
Solid angle of detectors	19.5% for 4 π
Detector covered region	+ 15.5 ~ + 168.5 deg.
Detector size	133 × 133 mm
Detectors pixel size	0.52 × 0.52 mm
No. of detectors	30

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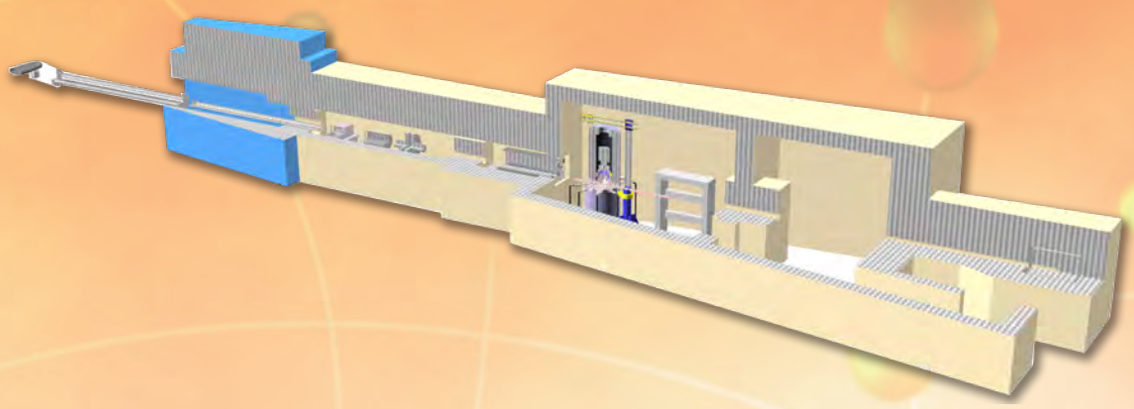
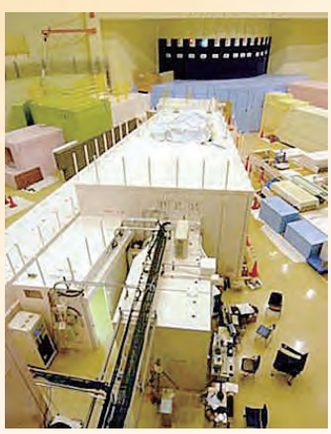
BL 04

Accurate Neutron-Nucleus Reaction Measurement Instrument

ANNRI



ANNRI is used for studies of nuclear science
(nuclear data measurement for nuclear technology and astrophysics, quantitative analyses etc.)



USAGE

- Nuclear Data Measurement
  - Minor Actinides
    ^{244}Cm, ^{246}Cm etc.
  - Long Lived Fission Products
    ^{129}I, ^{99}Tc, ^{93}Zr etc.
- Elemental Analysis
  cosmochemistry,
  radioactive material

SPECIFICATION

Moderator	Coupled hydrogen moderator
Incident neutron energy	En > 0.0015 eV
Spectrometer	Ge Spectrometer (Flight length : 21.5 m) NaI Spectrometer (Flight length : 28 m)
Neutron intensity (@ sample position @ 1MW)	@ 21.5 m sample position 4.3×10^{7} n/cm^2/s 1.5 meV < En < 25 meV 9.3×10^{5} n/cm^2/s 0.9 eV < En < 1.1 eV 1.0×10^{6} n/cm^2/s 0.9 keV < En < 1.1 keV
Maximum sample size	Width 2 cm, Height 3 cm.
Beam sizes	Using the most downstream collimator, neutron beams with diameters of 22, 15, 7, and 6 mm are provided to suit samples of different sizes.

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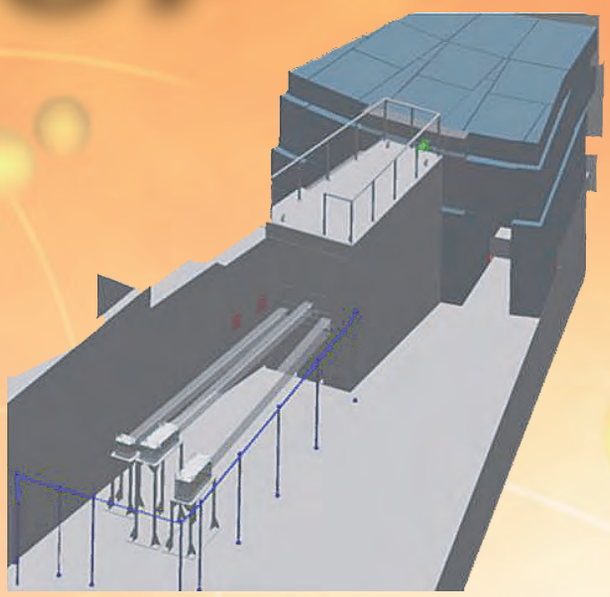
BL 05

Neutron Optics and Fundamental Physics

NOP



The NOP beamline provides three unique neutron beams, a low-divergence beam, an unpolarized beam, and a polarized beam, by splitting one beamline with supermirror benders.

SPECIFICATION

Moderator	Coupled hydrogen moderator
Neutron wavelength	2 Å ～ 9 Å
Beam profile (16 m position, height × width)	Low-divergence beam branch : 80 mm × 20 mm Unpolarized beam branch : 55 mm × 45 mm Polarized beam branch : 80 mm × 50 mm
Neutron intensity (16 m position, @ 1 MW)	Low-divergence beam branch : 5.4×10^{4} n/s/cm^2 Unpolarized beam branch : 9.4×10^{7} n/s/cm^2 Polarized beam branch : 3.9×10^{7} n/s/cm^2
Beam divergence (16 m position)	Low-divergence beam branch : 5.4×10^{-2} μstr Unpolarized beam branch : 1.0×10^{2} μstr Polarized beam branch : 1.9×10^{2} μstr
Average neutron polarization	Polarized beam branch : 96%
Auxiliary equipment	B_4C slits at the 7.5 m and 12 m positions on the low-divergence beam branch. B_4C slits at the 12 m position on the unpolarized and polarized beam branches. A Doppler shifter for UNC production.
Other	Proper radiation shielding is required for experimental setups that emit gamma rays or scatter neutrons, as the walls and ceiling of the NOP beamline are not shielded.

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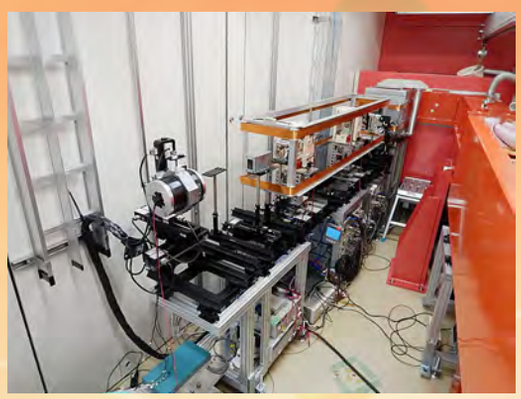
BL 06

Village of Nrutron Resonance Spin Echo Spectrometers

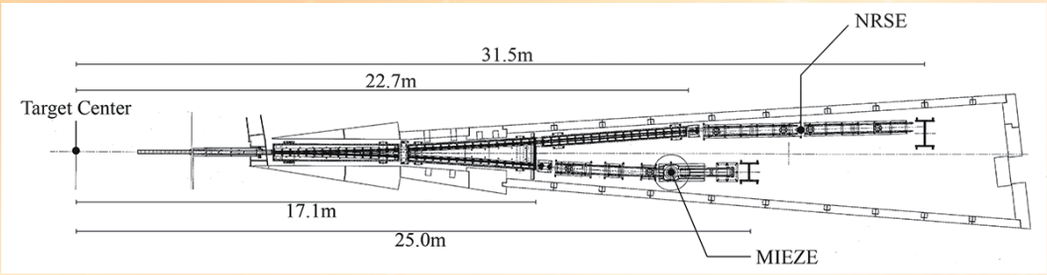
VIN ROSE

Users' program will start from 2017JFY for MIEZE and 2018JFY for NRSE.

Picture of BL06 in July 2015.



Picture of MIEZE spectrometer in April 2015.



Schematic top view of BL06 VIN ROSE

The neutron spin echo (NSE) technique is an essential spectroscopic method, which has achieved the highest neutron energy resolution at the present moment. NSE with a pulsed neutron source makes it possible to scan a wide spatiotemporal space very efficiently. Kyoto University and KEK are jointly installing two types of NSE spectrometers at BL06, that is, a neutron resonance spin echo (NRSE) instrument and a modulated intensity by zero effort (MIEZE) instrument. Both NRSE and MIEZE make use of neutron resonance spin flippers, which made it possible to design and install compact and multiple spectrometers machines in a narrow space. We named the beam line "VIN ROSE" (**VI**llage of **N**eutron **R**es**O**nance **S**pin **E**cho spectrometers), which will spawn a new field of spectroscopic methods.

Planning instrumental specifications of VIN ROSE:

Spectrometer	Wavelength	Q range [Å^{-1}]	Fourier Time
MIEZE	$3 < \lambda < 13$ [Å]	$0.2 < Q < 3.5$	1 [ps] < t < 2 [ns]
NRSE	$5 < \lambda < 20$ [Å]	$0.02 < Q < 0.65$	0.1 [ns] < t < 0.1 [μs]

APPLICATIONS

- Slow dynamics of soft condensed matters (polymers, proteins, colloids, microemulsions, etc.)
- Spin glass dynamics in magnetic field

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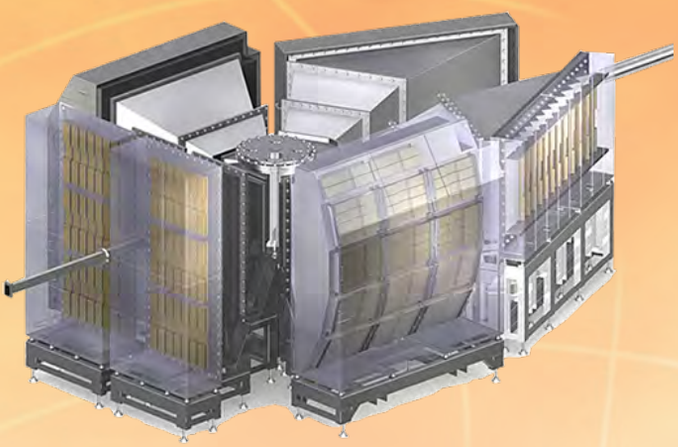
BL 08

Super High Resolution Powder Diffractometer

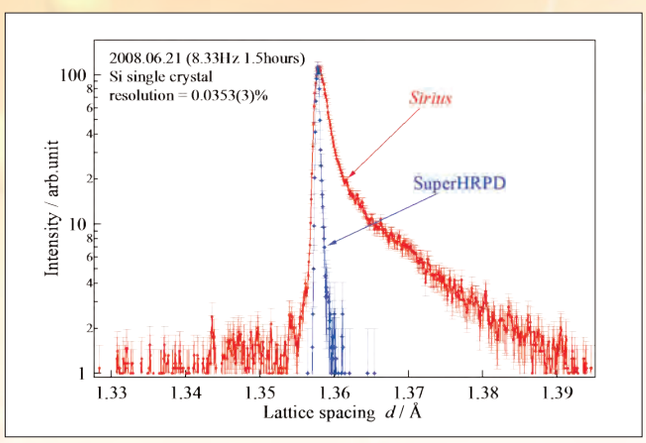
SuperHRPD



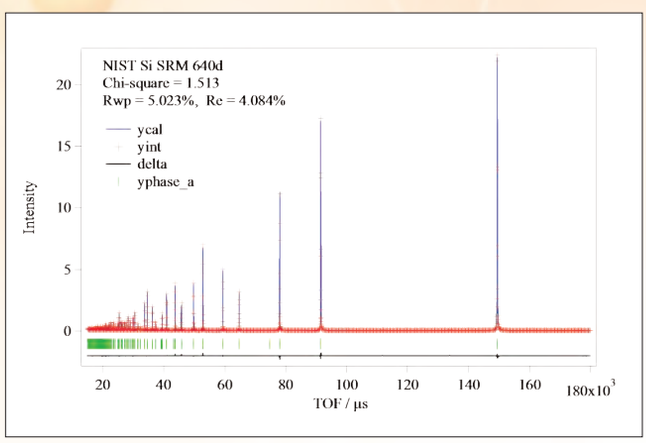
SuperHRPD is located at about 100 m from a thin side of a decoupled poisoned moderator, which has been developed to produce a high-resolution & good S/N neutron pulses to achieve the ~0.035% resolution in $\Delta d/d$.

Typical measurement time using standard sample can:

Sample	Measurement time
Si	1~3 hours
CeO_2	
Al_2O_3	
Li-spinel (ex.$LiMn_2O_4$)	
amino acid	~ 24 hours
to refine the magnetic structure	~ 24 hours



Comparison of the resolution using the Si single crystal.



The Rietveld analysis result for NIST Si powder.

APPLICATIONS

- Structure science of new materials with hybrid structures and nanostructure.
- Structural physics with strongly correlated system, multi-interaction systems such as multiferroic systems, devil's flower etc...
- Structure science in pharmaceutical compounds and super molecules.

SPECIFICATION

***d*-range**	0.3-4.0 Å : High-angle bank ($150° < 2\theta < 175°$) 0.4-7.5 Å : Middle-angle bank ($60° < 2\theta < 120°$) 0.7-45 Å : Low-angle bank ($10° < 2\theta < 40°$)
Resolution $\Delta d/d$	Optimal resolution ~ 0.03% (at 2θ ~ 172°) 0.1 ~ 0.15% (High-angle bank) 0.4 ~ 0.7% (Middle-angle bank) 0.7 ~ 3.0% (Low-angle bank)
Sample size	~ 3 cc
Other information	Standard V-Ni sample can : ϕ 6 mm x 55 mm (h)

SAMPLE ENVIRONMENT

- Top-loading cryostat (8 - 300 K)
- Bottom-loading cryostat (4 - 300 K)
- Vanadium furnace (20 - 950 ℃)
- Auto sample changer (10 samples)

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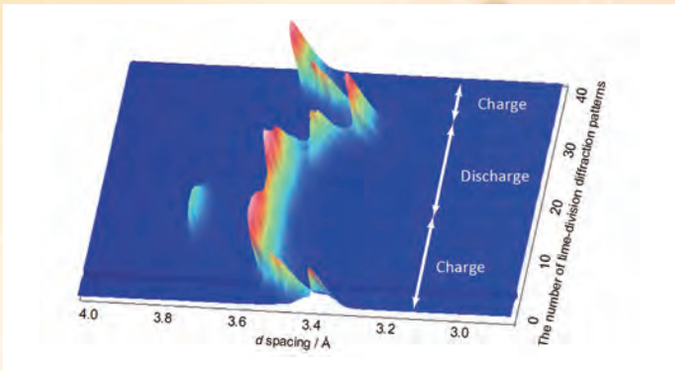
J-PARC MLF

BL 09

Special Environment Neutron Powder Diffractometer SPICA

SPICA, a special environment powder neutron diffractometer is the first instrument dedicated for the study of next-generation batteries in J-PARC. This instrument designed for *in situ* and *operando* measurements to determine the structural changes of battery materials at the atomic level.



APPLICATIONS

- Structure science of functional materials in wide *d* range.
- *In situ* and *operando* measurements with special environments.
- battery study in practical use.

SAMPLE ENVIRONMENT

- Auto Sample Changer (40 samples)
- Auto Sample Changer for in operando measurements (10 samples)
- Attachments for in operando measurements
- Top-loading type Cryostat (10 - 300 K in commissioning)
- Top-loading type Hot Stage (Cryo-furnace) (20 - 800 K in commissioning)
- Vanadium furnace (RT - 1273 K in commissioning)
- Detectors for imaging measurements

SPECIFICATION

Moderator	Poisoned decoupled Hydrogen
Primary flight path	L1, 52 m
Secondary flight path	L2, 2 m
Elliptical guide tubes	m = 3 – 6
Beam-size at sample pos.	40 (H) mm x 20 (w) mm
Incident neutron wavelength	0.2 < λ < 2.9 Å (25 Hz) 0.2 < λ < 8.7 Å (8.33 Hz)
Detectors Arrangement	Back Scattering Bank (150°≤ 2θ ≤ 175°) Multipurpose Bank (13° ≤ 2θ ≤ 140°) Small Angle Bank (1.6°≤ 2θ ≤ 30°)
Sample size	~ 1 g
Powder Sample	Standard V-Ni sample can (φ 6 mm x 55 mm (h))

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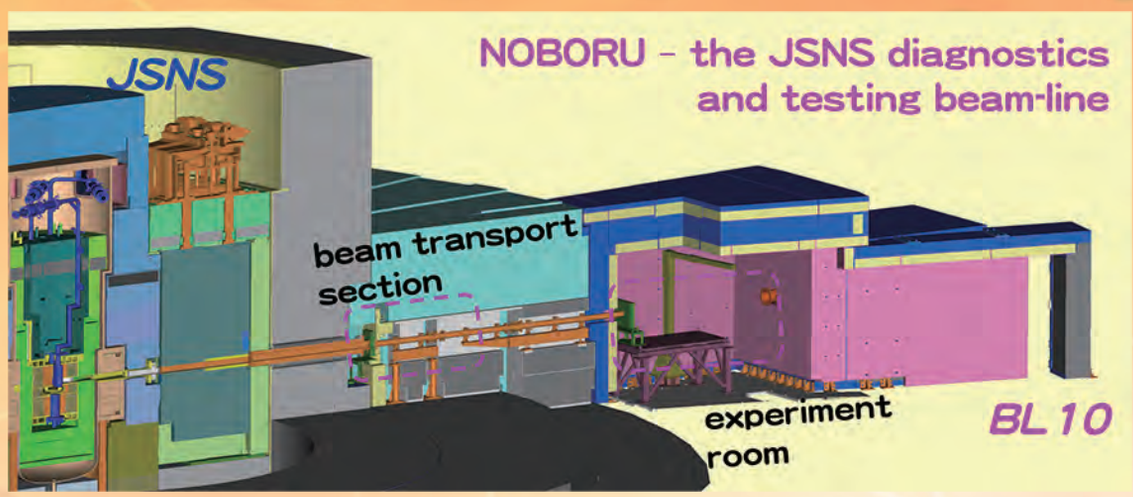
J-PARC MLF

BL 10

NeutrOn Beamline for Observation & Research Use

NOBORU



NOBORU was constructed at BL10 of the MLF at J-PARC in 2007. The primary mission of NOBORU is facility diagnostics to study neutronic performance of JSNS. NOBORU also provides a suitable neutron environment for testing various detectors & devices, new ideas for experimental techniques and irradiation of high-energy (~MeV) neutrons.

USAGE

- Neutron irradiation
- Multiple-wavelength neutron holography
- Developments for detector system, SEOP system, pulsed neutron imaging, etc.

SPECIFICATION

Wavelength	< 10 Å
Resolution ($\Delta\lambda/\lambda$)	0.33%
Neutron intensity (@ 14 m @ 1 MW)	4.8×10^7 n/s/cm^2 (< 0.4 eV) 1.2×10^7 n/s/cm^2 (> 1 MeV) 1.2×10^6 n/s/cm^2 (> 10MeV)
Beam size	Maximum 10 × 10 cm^2
Other information	Collimation ratio (L/D = 140, 190, 600, 1875) and insertion filters (Pb, Bi, acryl, borosilicate glass) are selectable. Small beam divergence due to neutron guideless beamline design. Experimental space of 2.5 m (W) × 3.5 m (L) × 3.0 m (H) to introduce various experimental equipment. Strong radiation shield that can endure large samples (scattered) up to a 10 cm steel cube.

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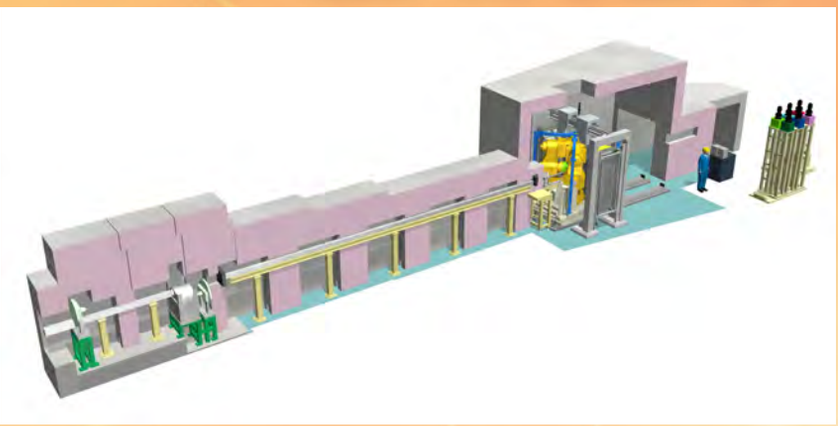
J-PARC MLF

BL 11

High-Pressure Neutron Diffractometer
PLANET



The cutaway view of PLANET beamline.

The 6-axis multi-anvil press "ATSUHIME".

PLANET is a powder diffractometer which specializes in high-pressure experiments. The beamline is equipped with two 90-degree detector banks for diffraction and a neutron imaging camera for radiography. Incident and receiving collimators enable us to obtain scattering only from the sample without contamination from surrounding materials, such as a heater and a sample container. Contamination-free diffraction patterns allow the precise determination structures of crystals, amorphous solids and liquids – *in situ* under high-pressure and high-temperature conditions. Several high-pressure devices, such as the 6-axis multi-anvil press "ATSUHIME", a Paris-Edinburgh press and the "MITO system" are available for use on PLANET depending on the pressure and temperature conditions of interest. With these devices the current range in pressure and temperature conditions available on PLANET covers 0-20 GPa and 30-2000 K.

APPLICATIONS

Geophysics

Hydrogen position and content in hydrous minerals, including in crystalline and amorphous materials.

The effect of hydrogen on physical properties of minerals and the Earth.

Planetary Science

The inner structure of icy planets at low-T and high-P conditions.

Material Science

Synthesis and *in-situ* observation of new hydrides, unquenchable to ambient conditon.

Physics

The mechanism of a liquid-liquid phase transition.

Typical exposure time at accelerator power of 400 kW to refine the crystal structure of a mineral (*).

Device	Pressure Condition		
	2 GPa	10 GPa	20 GPa
ATSUHIME	4 h	8 h	24 h
P-E press	3 h	5 h	6 h
MITO system	0.5 h	--	--

*These values vary with the chemical composition and the crystal structure of sample, and are increased by the factor of about 4 for liquid and amorphous solids. The relevant time is required for measurements of empty cell and vanadium, which are used to correct intensity from the sample.

SPECIFICATION

Source-to-sample distance	25 m
Sample-to-detector distance	1.5 – 1.85 m
Angular coverage	90° ± 11.3° (horizontal) 0° ± 34.6° (vertical)
Wavelength	0.3–6.0 Å
***d*-range**	0.2–4.2 Å (single frame) 0.2–8.4 Å (double frame)
***Q*-range**	1.5–30 $Å^{-1}$ (single frame) 0.8–30 $Å^{-1}$ (double frame)
Resolution	$\Delta d/d$ = 0.6%
Neutron flux at sample position in ϕ 10 mm	5.3 × 10^7 neutrons cm^{-2} s^{-1} (@ 1MW)
Pressure and temperature range	0–16 GPa, RT–2000 K (ATSUHIME) 0–20 GPa, RT (P-E press) 0–20 GPa, 30–673 K (MITO system)
Typical initial sample volume	50 mm^3 for 0-10 GPa

SAMPLE ENVIRONMENT

- Six-axis multi-anvil press (ATSUHIME)
- Paris-Edinburgh press (VX4)
- Temperature control high-pressure system (MITO system)

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J-PARC MLF

BL 12

High Resolution Chopper Spectrometer
HRC

Observation of elementary excitations such as magnons and phonons in materials under relatively high resolutions with relatively high energy neutrons.

APPLICATIONS

- Dynamics on atoms, molecules and spins in condensed matter.

SPECIFICATION

Moderator	Decoupled hydrogen moderator
Neutron energy	5 meV < E_i < 2000 meV
Scattering angle	Horizontal : - 31° ~ 62° Vertical : ± 20°
Neutron intensity (@ sample position @ 1MW)	1 x 10^5 n/s/cm^2 ($\Delta E/E_i$ = 2.5%)
Energy resolution	$\Delta E/E_i \geq$ 2.5% (@ E = 0 meV)
Maximum sample size	5 cm x 5 cm
Ancillary equipment and sample environment	Bottom-loading cryostat (4 - 300 K) Bottom-loading cryostat (T_{min} = 0.6 K)

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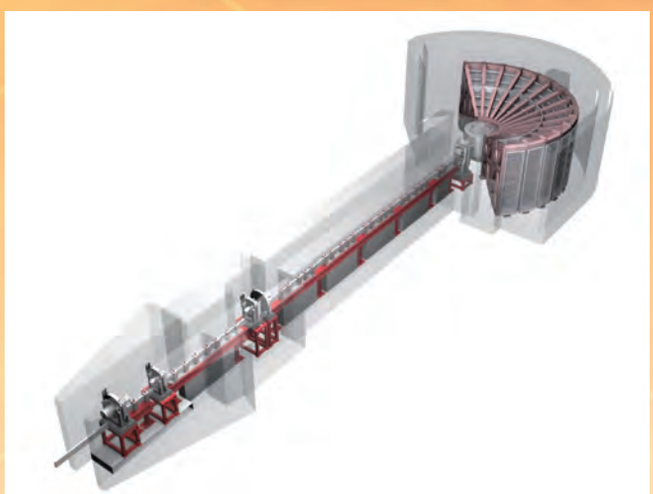
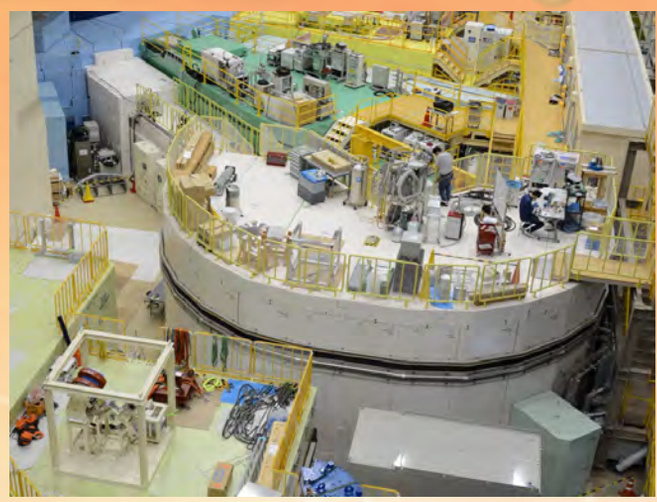
J-PARC MLF

BL 14

A cold-neutron disk-chopper spectrometer

AMATERAS





AMATERAS is a disk-chopper type spectrometer. The spectrometer is designed to carry out inelastic and quasielastic neutron scattering experiments on single-crystals, powder, liquid and amorphous samples in the range from cold to sub-thermal neutron energy. The most characteristic feature of AMATERAS is that the spectrometer employs the pulse shaping technique. The pulse shaping chopper cuts out a sharp and symmetric peak from the source pulse from a coupled moderator at MLF, which has a large intensity but broad and asymmetric pulse shape. AMATERAS also has capability to carry out multi-E_i measurements, which enhances measuring efficiency. By utilizing these techniques, AMATERAS realizes high intensity and fine and flexible energy resolution measurements.

APPLICATIONS

- Diffusion of atoms, ions and molecules in liquids, polymers, biomaterials etc.
- Local and collective excitations and fluctuations of lattice and spins in crystalline materials.

SAMPLE ENVIRONMENT

- Bottom-loading closed cycle refrigerator (5 - 300 K)
- Top-loading closed cycle refrigerator (7 - 300 K)
- High-temperature stick (T < 500 K)
- Other BL-common equipment is also available*1

(*1 On AMATERAS, some of equipment cannot be used at their full-spec. Please contact BL14 staff members for more details.)

SPECIFICATION

Moderator	Coupled
Flight path lengths	Moderator - Sample : 30 m Sample - Detectors : 4 m Moderator - Monochromating Chopper : 28.4 m
Incident energy range	1 meV < E_i < 80 meV
Detection angle	Horizontal : +3.4° - +116° (It will be extended upto -40° - +135° in future) Vertical : -16° - +23°
Energy Resolution ($\Delta E/E_i$)	E_i < 3 meV : $\Delta E/E_i$ > 1% E_i < 20 meV : $\Delta E/E_i$ > 2~3% E_i < 80 meV : $\Delta E/E_i$ > 4~5%
Typical sample size	10 mm (width) × 20 mm (hight)

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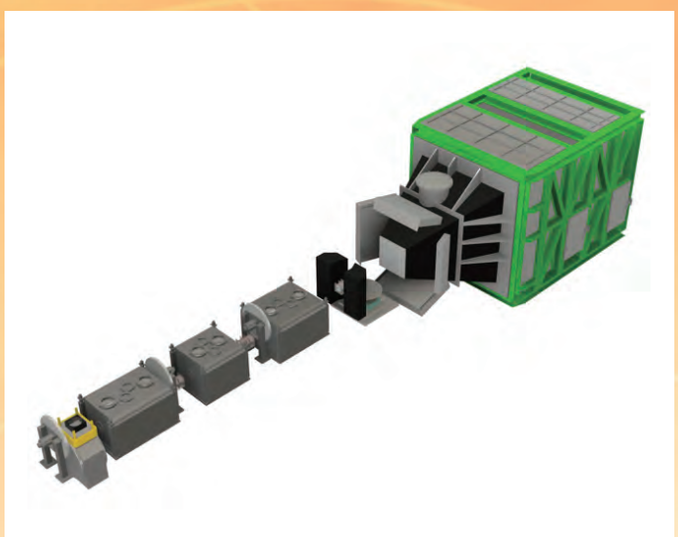
J-PARC MLF

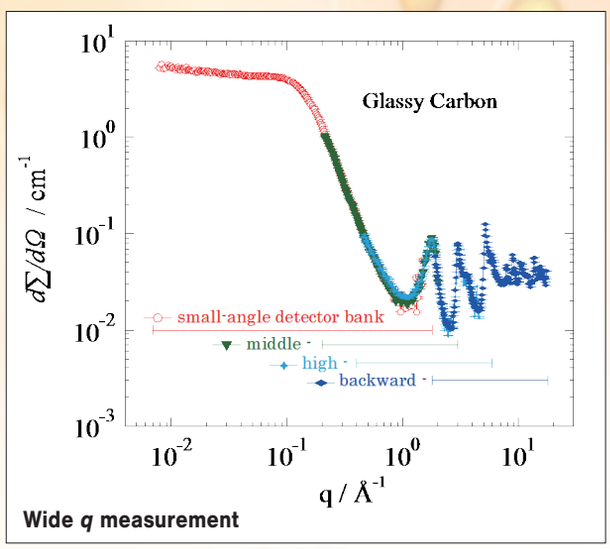
BL 15

Small and Wide Angle Neutron Scattering Instrument

TAIKAN



TAIKAN is a powerful instrument for the analysis of hierarchical-structure ranging from sub-nanometer to micrometer in various materials such as polymers, biomolecules, metals, magnets, and superconductors. TAIKAN covers wide q range by using neutrons in the wide wavelength range and small-, middle-, high-angle, and backward detector banks. Polarizing and focusing neutron devices, and a high-resolution detector will be used to extend q_{min} to 5×10^{-4} Å^{-1}.



Wide q measurement

SPECIFICATION

Wavelength λ	0.7 – 7.8 Å (first frame)
Source-sample distance	14.35 m
Sample-detector distance	0.6 m (backward) – 5.65 m (small-angle)
q-range	0.005 – 17 Å^{-1} (unpolarized neutron) 0.005 – 2.5 Å^{-1} (polarized neutron)
Neutron polarization	> 95% (λ > 3 Å)
Sample size	10 mm × 10 mm (typical)

SAMPLE ENVIRONMENT

- Sample changer (10 samples, T = 2 – 125 ℃)
- Bottom-loading cryostat (T = 3.5 – 300 K)
- Rheometer (Shear rate = 5×10^{-6} – 10^{4} s^{-1})
- Tensile load cell (Tensile force = 100 N – 1 kN, T = RT – 300 ℃)
- 0.2 Tesla slolenoid magnet (Horizontal field, RT)
- 1 Tesla magnet (Vertical/Horizontal field, RT)
- 4 Tesla solenoid cryomagnet (Horizontal field, T_{min} < 2 K)
- 7 Tesla cryomagnet (Vertical field, T_{min} < 2 K)
- 10 Tesla magnet (Vertical field, RT)

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J-PARC MLF

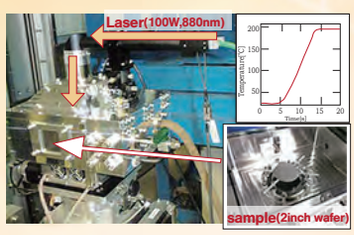
BL 16

Soft Interface Analyzer SOFIA

The SOFIA reflectometer is a horizontal type reflectometer for investigating various kinds of interfaces, mainly for softmatters, on the nanometer to sub-micrometre length scale in the depth direction. Owing to characteristics of neutrons, it is possible to distinguish an interesting part labeled with deuterium and/or observe an interface between solid and liquid through a substrate. In addition, high flux neutron beam of J-PARC enable us to follow structural changes after temperature-jump or liquid-contact with the time-slice of the seconds to tens of minutes in a wide q_z-region utilizing special apparatus for the time-slicing measurement.

View of the SOFIA reflectmeter from the downstream side.

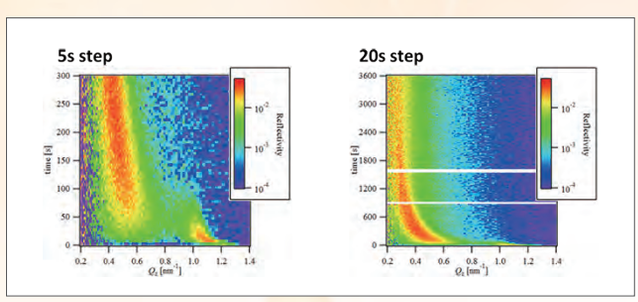
Sample cells for time-slicing measurements at solid/ liquid interfaces (liquid can one-by-one be injected just before the measurement).



Laser heating system for changing temperature with very short time (10 seconds from room temperature to 200 °C).

Interface	Max q_z	Measurement time (size)
Air / h-polymer / Si	2 nm^{-1}	1 hour (76 mmØ)
Air / d-polymer / Si	4 nm^{-1}	30 minutes (76 mmØ)
Air / D_2O	2 nm^{-1}	15 minutes (40 mmØ)
Air / NRW	1 nm^{-1}	3 hour (40 mmØ)
Si / h-polymer / D_2O	2 nm^{-1}	1 hour (76 mmØ)
Si / thick d-polymer / H_2O	2 nm^{-1}	1 hour (76 mmØ)

Typical maximum q_z and measurement time to cover the full-q_z region under various conditions at 500 kW of beam power (NRW: Null Reflection Water):



Time dependence of reflectivity profiles (same data was analyzed with different time-slices)

APPLICATIONS

- Multi-layered organic films such as an organic light emittance device
- Solid/liquid interfaces such as an electrodeof lithium ion batteries
- Free interface on a liquid such as a monomolecularfilm of detergents on soap water

SPECIFICATION

Wavelength	0.2 – 0.88 nm (single frame), 0.2 – 1.76 nm (double frame)
Incident angle	< 6 degrees
Background	> 3×10^{-7} (depending on sample)
Sample size	< 50 mm (width) × 100 mm (traveling direction)
Mode	Simultaneous measurement of specular reflection, off-specular reflection, and background, Time-slicing measurement with arbitrary time-binning (tens of seconds under a suitable condition)

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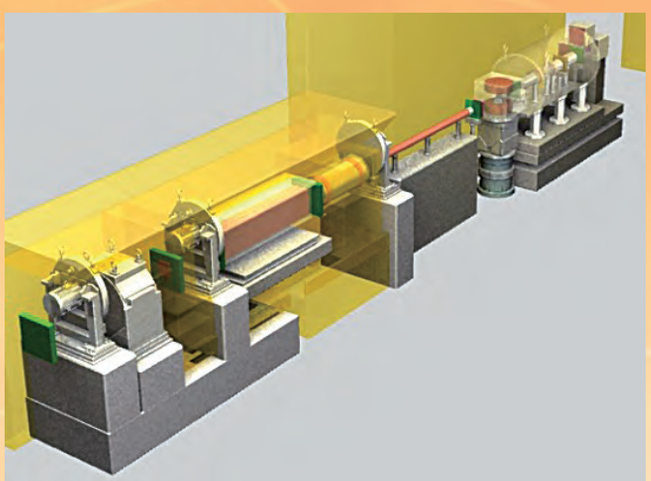
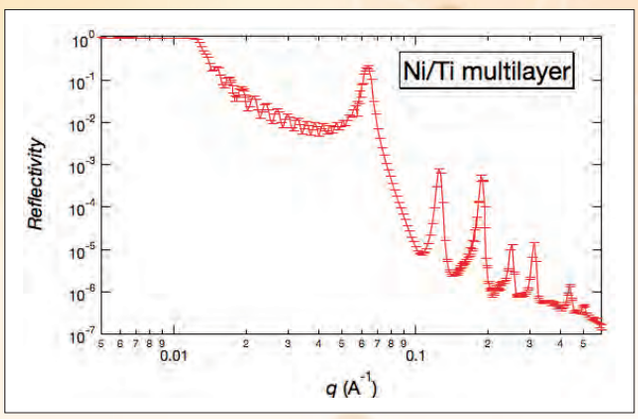
J-PARC MLF

BL 17

Polarized Neutron Reflectometer SHARAKU



SHARAKU is a polarized neutron reflectometer with vertical sample geometry and can cover wide q range by using neutrons in the wide wavelength range with changing the angle range of reflection covered by a detector. SHARAKU is used to analyze surface and interface structures in various nanomaterials such as magnetic films, polymer films, battery cells, electrodes, and superconductors. A 3K cryostat, a few magnets, and humidity conditioning cells etc. are available for such researches.



SPECIFICATION

Wavelength λ	0.24 ～ 0.88 nm （polarized neutron） 0.11 ～ 0.88 nm （unpolarized neutron）
Source-sample distance	15.5 m
Sample-detector distance	2.5 m
Reflection angle	0 ～ 18°
***q*-range**	0.06 ～ 8.19 nm^{-1} （polarized neutron） 0.05 ～ 17.8 nm^{-1} （unpolarized neutron）
Beam size	0.03 ～ 5 mm （horizontal） 5 ～ 50 mm （vertical）

SAMPLE ENVIRONMENT

- Bottom-loading cryostat （T = 3 ～ 300 K）
- 0.2 Tesla slolenoid magnet （Horizontal field, RT）
- 1 Tesla magnet （Vertical field, RT）
- 4 Tesra cryomagnet （Horizontal field, T = 1.6 K ～ R.T.）
- 7 Tesla cryomagnet （Vertical field, T_{min} < 2 K）
- Humidity conditioning cell （RH = 0 ～ 90%, RT）

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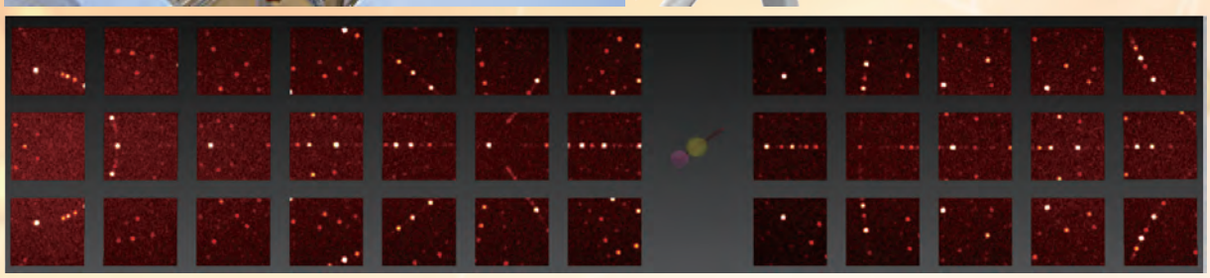
J-PARC MLF

BL 18

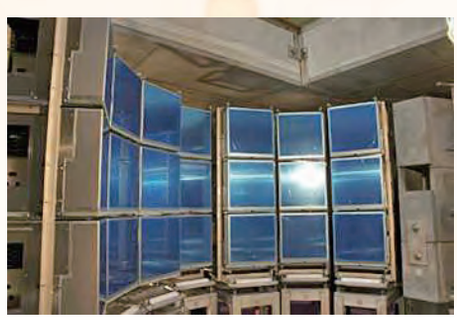
Extreme Environment Single Crystal Neutron Diffractometer
SENJU



SENJU, a TOF-Laue single crystal neutron diffractometer at the BL18 of MLF/J-PARC, was designed for precise crystal and magnetic structure analyses under multiple extreme environments such as low-temperature, high-pressure and high-magnetic field, and also with the capability of measuring small samples, less than 1.0 mm^3 in volume.

APPLICATIONS

- Precise structure analysis including light atoms.
- Magnetic structure analysis.
- Structure responses under extreme environments.



SPECIFICATION

Moderator	Decoupled poisoned	**Detector angle**	- 13 deg ~ - 167 deg +58 deg ~ +167 deg
Incident neutron wavelength	0.4 ~ 4.4 Å (1st frame) 4.6 ~ 8.8 Å (2nd frame) 9.0 ~ 13.2 Å (3rd frame)	**Typical sample size**	> 0.5 x 0.5 x 0.5 mm
Neutron intensity	1.3 x 10^6 n/s/mm^2	**Sample environment**	GM cryostat : > 3.6 K Magnetic field : < 7 T Nb furnace : < 1600 T

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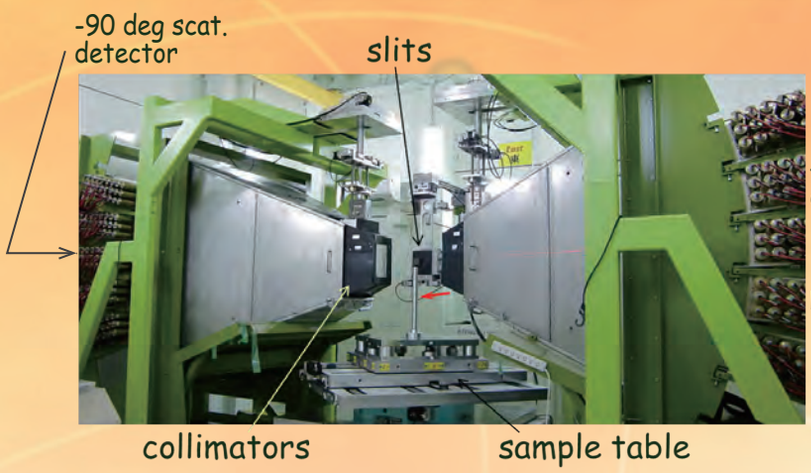
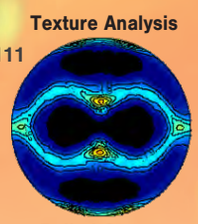
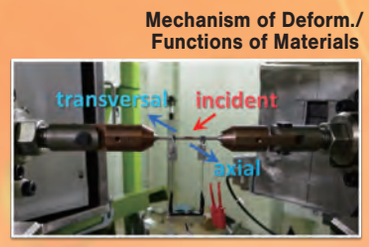
J-PARC MLF

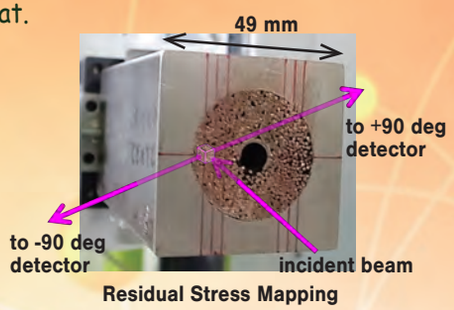
BL 19

Engineering Materials Diffractometer
TAKUMI









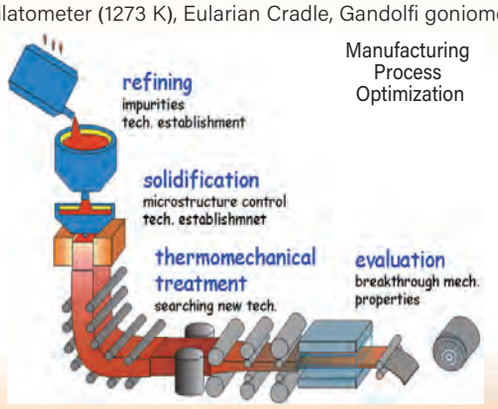
TAKUMI is a TOF neutron diffractometer dedicated for engineering sciences. Careful analysis of the Bragg peaks in a neutron diffraction pattern can reveal important structural details of a sample material such as internal stresses, phase conditions, dislocations, texture etc. Such information is often crucial in engineering applications and the ability to carry out either *ex-situ* or *in-situ* measurements makes neutron diffraction particularly useful in this respect.

APPLICATIONS

- Internal strain mapping in engineering components
- Microstructural evolutions during deformations and/or thermal processes of structural or functional materials
- Microstructural evolutions during manufacturing (thermo-mechanical) processes of structural or functional materials
- Crystallographic investigations of small regions in engineering materials
- Texture analyses of engineering materials

SAMPLE ENVIRONMENT

BL19 Standard loading machine (50 kN), Furnace system for high temp loading (1273 K), 100 K cooling system for loading experiment (80 K – 473 K), Cryogenic loading machine (50 kN, 6 K – 220 K), Fatigue machine (60 kN, < 30 Hz), High temperature loading machine for small specimen (25 kN, 1273 K), Dilatometer (1273 K), Eularian Cradle, Gandolfi goniometer



SPECIFICATION

Wavelength bandwidth	0.38 nm (single frame) 0.75 nm (double frame)
Detectors	A pair of 90 deg scattering detector bank (per bank has horizontal coverage : ± 15 deg, vertical coverage : ~ 36 deg) A 2D detector bank with 155 deg scattering angle
***d*-range**	Standard (single frame) : Δd ~ 0.25 nm (d_{min} and d_{max} are tunable) Wide (double frame) : Δd ~ 0.50 nm (d_{max} is about 0.50 nm)
S/N ratio	~ 10^{-3}
Sample size	Loading : D ≤ 6 mm rod or T 2 mm × W 6 mm plate Strain mapping : less than 250 x 250 x 2000 mm^3 Powder samples for reference, etc
Instrumental mode (combination of resolution and *d*-range)	Low resolution $\Delta d/d$: ~ 0.4%, flux ~ 4.8 × 10 $cm^{-2}s^{-1}$ Medium resolution $\Delta d/d$: ~ 0.3%, most cases High resolution $\Delta d/d$: ~ 0.2%, flux ~ 2.1 × 10 $cm^{-2}s^{-1}$ Standard d-range Δd ~ 0.25 nm Wide d-range Δd ~ 0.50 nm
Radial collimators	1 mm, 2 mm, 5 mm (a pair of each)
Data acquisiton	▪ Event recording (data reduction with the functions of time-slicing, TOF-binning width, and detector range can be done during or after the experiment.) ▪ Online data monitoring (per several seconds) ▪ Data reduction based on the physical conditions (load, strain, temperature, etc.) is under development

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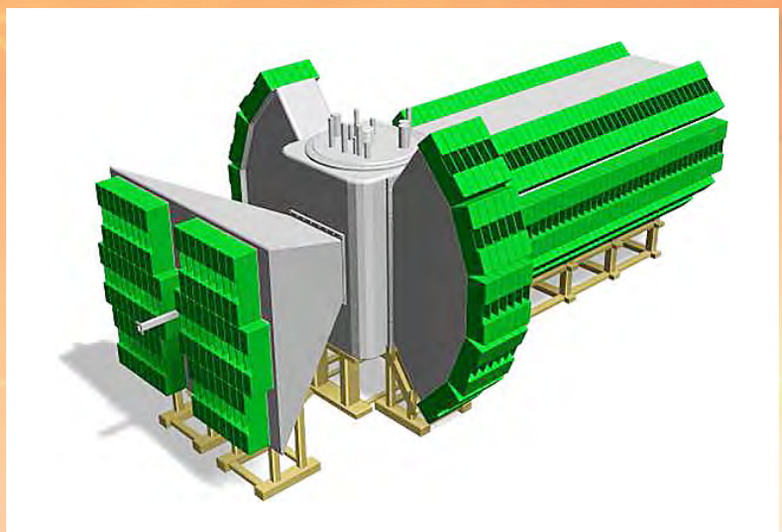
J-PARC MLF

BL 20

IBARAKI Materials Design Diffractometer
iMATERIA



High-efficiency, general-purpose neutron diffractometer for the analysis of crystal structure of powder samples over a wide *d*-range (*Q*-range).

SPECIFICATION

Moderator	Poisoned decoupled hydrogen moderator
Incident neutron wavelength	0.2 ～ 10 Å
Range of *d*-spacing	0.181 ～ 2.6 Å (SF mode), 5.09 Å (DF mode) (backward detector bank) 0.255 ～ 3.6 Å (SF mode), 7.2 Å (DF mode) (90-degree detector bank) 0.25 ～ 20 Å (SF mode), 40 Å (DF mode) (low-angle detector bank) 12.5 ～ 450 Å (SF mode), 900 Å (DF mode) (small-angle detector bank)
Resolution (Δ *d*/*d*)	0.16% (@ backward detector bank) 0.5% (@ 90 degree detector bank)
Estimated measurement time (@ **500 kW, 25 Hz operation**)	7 minutes (DF mode) for Si 9 minutes (DF mode) for $LiCoO_2$

Sample size and environment

Sample size

Approximately 1.4 cc
(ϕ 6 mm x 50 mm high. Samples with a height of 20 mm are exposed to the neutron beam.
Measurement will take longer for samples with a smaller volume.)

Auxiliary equipments

Sample changer (room temperature at atmospheric and low pressures)
High temperature furnace (900 °C)
High temperature gas controlled furnace (1000 °C)
Closed cycle refrigerator (~10 K - RT, RT- 400 °C)
Sample changer for Small angle measurement
Refrigerator with sample changer (10 K - RT, RT - 800 K, 10 samples) is under commission.

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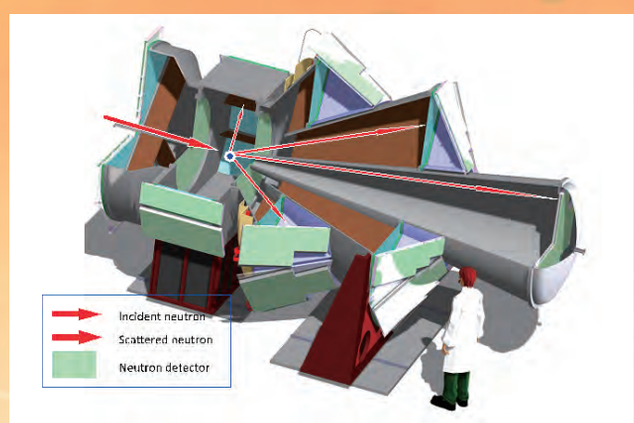
J-PARC MLF

BL 21

High Intensity Total Diffractometer NOVA



NOVA is a total scattering instrument to investigate (magnetic) structural changes or pair correlations affecting hydrogen-induced physical properties, hydrogen storage materials or amorphous compounds. NOVA covers a wide momentum transfer range, $0.03 \leqq Q \leqq 100$ Å^{-1} ($Q = 2\pi/d$, where d is a lattice constant) in one measurement and consequently pair correlation functions in high atomic distance resolution are obtained. Based on the high neutron flux of J-PARC, real-time observation of time-transient phenomena is also feasible.

APPLICATIONS

- Materials structure analysis during hydrogen absorption and desorption process under a H_2/D_2 gas atmosphere
- Structure analysis of isotopic substituted glasses and liquids
- Crystal and magnetic structure analysis including diffuse scattering components

SPECIFICATION

Wavelength	0.12 – 8.3 Å
***Q*-resolution**	$\Delta Q/Q > 0.35\%$
***Q*-range**	$0.03 \leqq Q \leqq 100$ Å^{-1}
Beam size at sample	min : 5 mm x 5 mm max : 20 mm x 20 mm
Standard sample cell	6 mm ϕ x 20 mm (approx. 0.6 cm^3)

SAMPLE ENVIRONMENT

- Auto sample changer (RT, 10 or 40 samples per load)
- Top-Loading cryo-furnace
  Low-temp. stick : 5 - 300 K
  High-temp stick : 5 - 700 K
  Hydrogen-gas atmosphere stick : 50 - 473 K, ~10 MPa H_2/D_2
- Auto sample changer with closed cycle refrigerator (20 - 750 K, 18 samples per load)
- Vanadium furnace (300 - 1273 K)
- Fermi chopper for Inelastic scattering measurement (Reso.: 5 - 20%)

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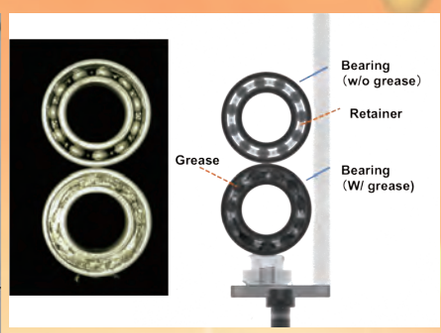
J-PARC MLF

BL 22

Energy-resolved neutron imaging system

RADEN



RADEN is the first energy-resolved neutron imaging instrument using pulsed neutrons in the world. According to the pulsed neutrons nature, it becomes possible to visualize spatial distribution of various quantities concerning crystallographic structure, elemental concentration, temperature, and magnetic field, together with the normal neutron radiography and tomography.

APPLICATIONS

- **Neutron radiography and tomography**
- **Energy-resolved neutron imaging**
  - Bragg edge imaging
  - Resonance absorption imaging
  - Polarized neutron imaging

SPECIFICATION

Moderator	Decoupled hydrogen moderator
Sample position	18 m and 23 m
Wavelength range	< 6.8 Å (L = 23m) < 8.8 Å (L = 18m)
Resolution($\Delta\lambda/\lambda$)	> 0.20% (L = 23m) > 0.26% (L = 18m)
Neutron intensity (@ 19 m, 1 MW)	2.6 x 10^7 n/sec/cm² (< 0.5 eV)
Beam sizes	Maximum 300 mm x 300 mm
Spatial resolution	> 100 μm

AVAILABLE EQUIPMENT

2D Detectors	***Imaging type*** Scintillator + CCD camera (Δ > 100 μm, FOV < 300 mm x 300 mm) Neutron image intensifier + CMOS camera High speed camera (Δ > 100 μm, FOV < 9 inch - φ) ***Counting type*** μNID (Δ = 0.12 mm, FOV = 100 mm x 100 mm, Δ t > 10 nsec) GEM (Δ = 0.8 mm, FOV = 100 mm x 100 mm, Δ t > 10 nsec) Pixel detector (Δ = 3mm, FOV = 50mm x 50 mm, Δ t > 10 nsec)
Filters	Bi, Pb, Cd, BK-7, Acrylic resin
Collimators	L/D = 180~7500
Sample stages	Large (L = 23 m, Maximum load 1.0 ton) Medium (L = 18 m, Maximum load 600 kg) Small (Maximum load 10 kg, attached with Large/Medium stage)
Sample chamber	600 x 600 x 900 H mm, 10 ~ 40 ºC, 20 ~ 80% RH, rotation stage
Optical equipment	Polarization analysis apparatus Gamma-ray detectors Diffraction detectors

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http://j-parc.jp/researcher/MatLife/en/instrumentation/ns.html

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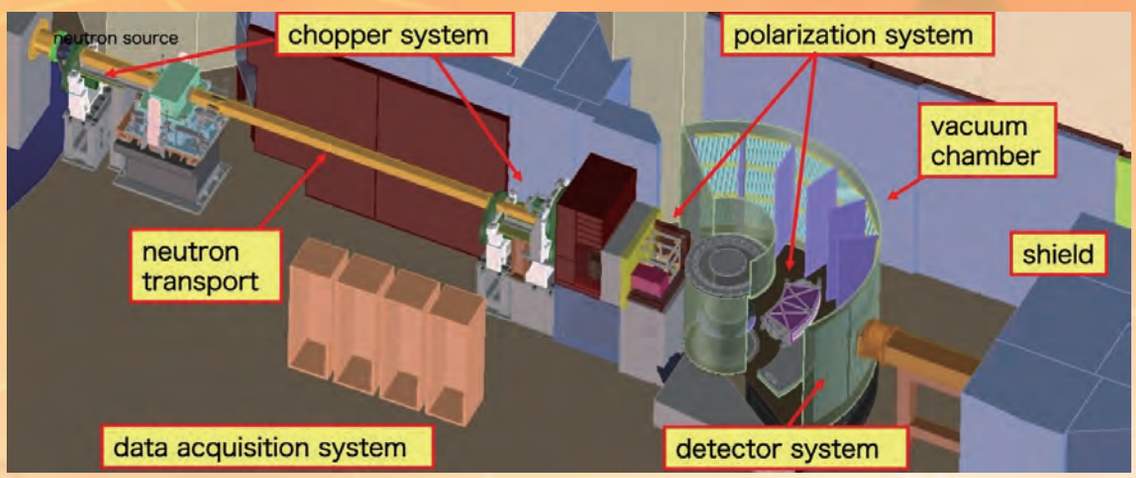
BL 23

Polarization Analysis Neutron Spectrometer

POLANO



Although the polarized neutron technique has been developed and used for many years, the application of the time-of-flight (TOF) method has only been realized in recent years. In the light of recent discoveries in material science, many of the observed complex phenomena are largely due to the entangled physical degrees of freedom of spins, charges, orbitals, and even lattice vibration. In neutron scattering experiments, a unique, effective, and direct way to observe these properties separately is via the polarization analysis. The POLANO enables polarization analysis of inelastic scattering experiments to investigate the dynamical properties of the above mentioned multiple degrees of freedom.

APPLICATIONS

- Dynamical properties of spin/lattice/orbital
- Magnetic structure

SPECIFICATION

Moderator	H_2 decoupled	**Sample size**	20 × 20 mm
L1, L2, L3	17.5 m, 2.0 m, 1.85 m	**Detector angle (holizontal)**	-20˚ ~ 120˚
Maximum incident energy E_i	Unpolarized : 1 eV Polarized : 100 meV	**Detector angle (vertical)**	-8˚ ~ 8˚
Energy resolution $\Delta E/E_i$	3 ~ 5% at elastic position		
Momentum resolution $\Delta Q/k_i$	1 ~ 2%		

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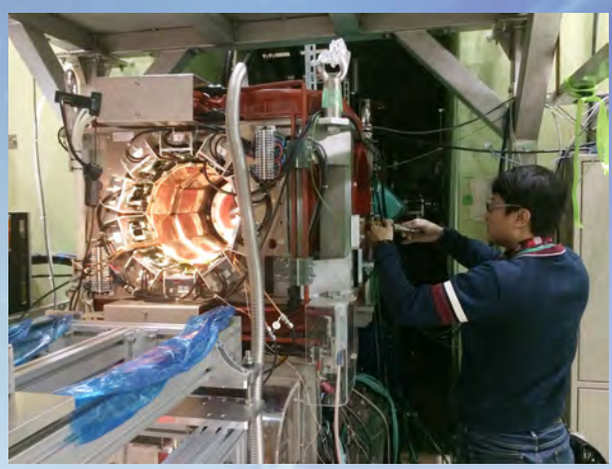
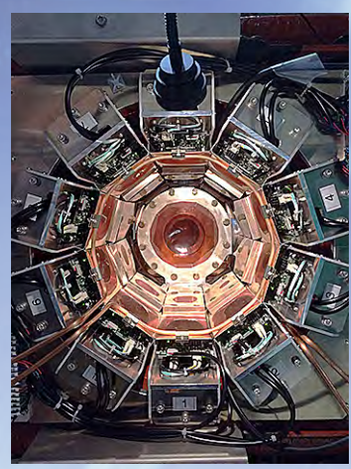
Muon D1 Muon experimental area for Materials and Life Science Specimen



A user is installing a mini-cryostat into the position.



Detectors of the general-purpose spectrometer, with a vacuum chamber for mini-cryostat installed.

General purpose spectrometer is placed, which may accommodate a dilution refrigerator, a few types of helium cryostat or a high temperature furnace, with an additional installation of sample environment such as pulse-synchronised flash-lamp photo excitations. This muon beam line is also characterised by the capability of high momentum muon beam delivery. This enables a usage of a clamp cell to apply high static pressure to the sample (under commissioning).

SPECIFICATION

Beam characteristics

Surface muon or positive / negative muon beam up to 120 MeV / c
Double pulse, single pulse with a width of 80 ns

Beam intensity (@ 300 kW proton beam)

3.0×10^6 μ^+ / s
180 M/hour event-rate (double pulse) for 20 × 20mm sample
5 × 5 mm sample may be measured background free for a reduced rate

Detectors and sample environment

Positron detectors	640 ch telescopic pairs	**Mini-Cryostat (conduction-type)**	4 - 500 K
Longitudinal magnetic field	0.4 T	**Dilution Refrigerator (top-loading)**	50 mK
Transverse magnetic field	12 mT	**Infrared furnace**	1100 K
Zero magnetic field	< 0.4 μT	**Vertical cryostat (exchange gas-type)**	1.8 - 500 K
		Pulse-synchronized flash-lamp	100 W

Contact
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Muon D2 Muon Spectrometer for Basic Science Experiments

From basic science to muon catalyzed nuclear fusion using positive and negative muons

Elementary particle physics, muonic atoms, muon catalyzed fusion, non-destructive investigation of archaeological specimens.
The D2 area is designed to allow users to install any dedicated experimental setup to explore various muon science with use of negative or positive muons.

SPECIFICATION

Beam characteristics

Surface muon or positive/negative muon beam up to 120 MeV/c
Double pulse, single pulse with a width of 80 ns

Beam intensity (@ 300 kW proton beam)

Surface muon :
3.0×10^6 μ^+ / s
180 M/hour event-rate (double pulse)
for 20 × 20 mm sample

Decay muon :
6×10^6 $\mu^\pm$ / s @ 50MeV / c
2×10^6 $\mu^\pm$ / s @ 30MeV / c

Detectors and sample environment

3 Ge detectors for midium energy range : 10 keV~300 keV, resolution 600 eV @ 122 keV FWHM

3 Ge detectors for high energy range : 100 keV~10 MeV, resolution 1.9 keV @ 1.33 MeV FWHM

2 Ge detectors for lower energy range : 2 keV~100 keV, resolution 100 eV @ 14 keV FWHM

High purity (> 99.9%) Al chamber (600 mm diameter, 380 mm height) for elemental analysis

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For more information about J-PARC・MLF and the Neutron Beamline User Program at the MLF, please visit our website.

J-PARC ---------- http://j-parc.jp/index.html

MLF ---------- http://j-parc.jp/MatLife/ja/index.html

User's Office --- http://j-parc.jp/uo/index.html

CROSS---------- http://www.cross-tokai.jp/ja/