Status Overview of J-PARC MLF

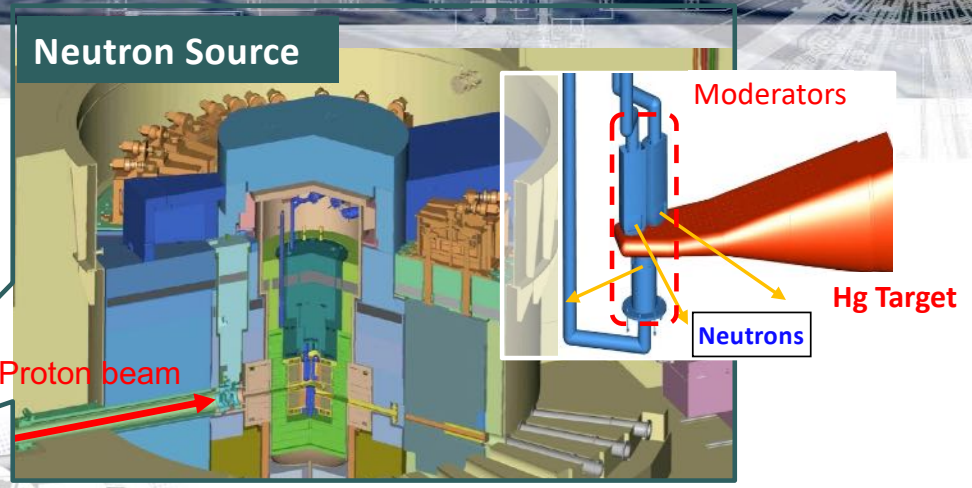
Toshiya Otomo

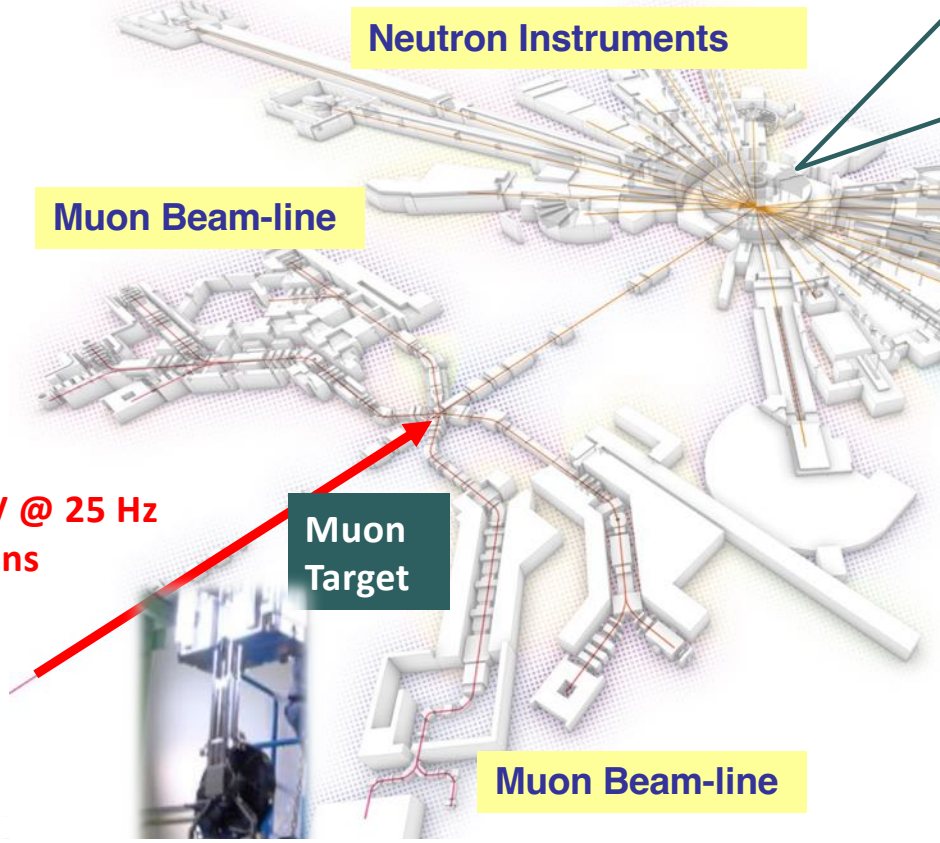
Materials & Life Science Division, J-PARC center, Tokai, Japan
Insititute of Materials Structure Science, KEK, Japan

CURRENT STATUS

Materials and Life Science Experimental Facility (MLF)

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



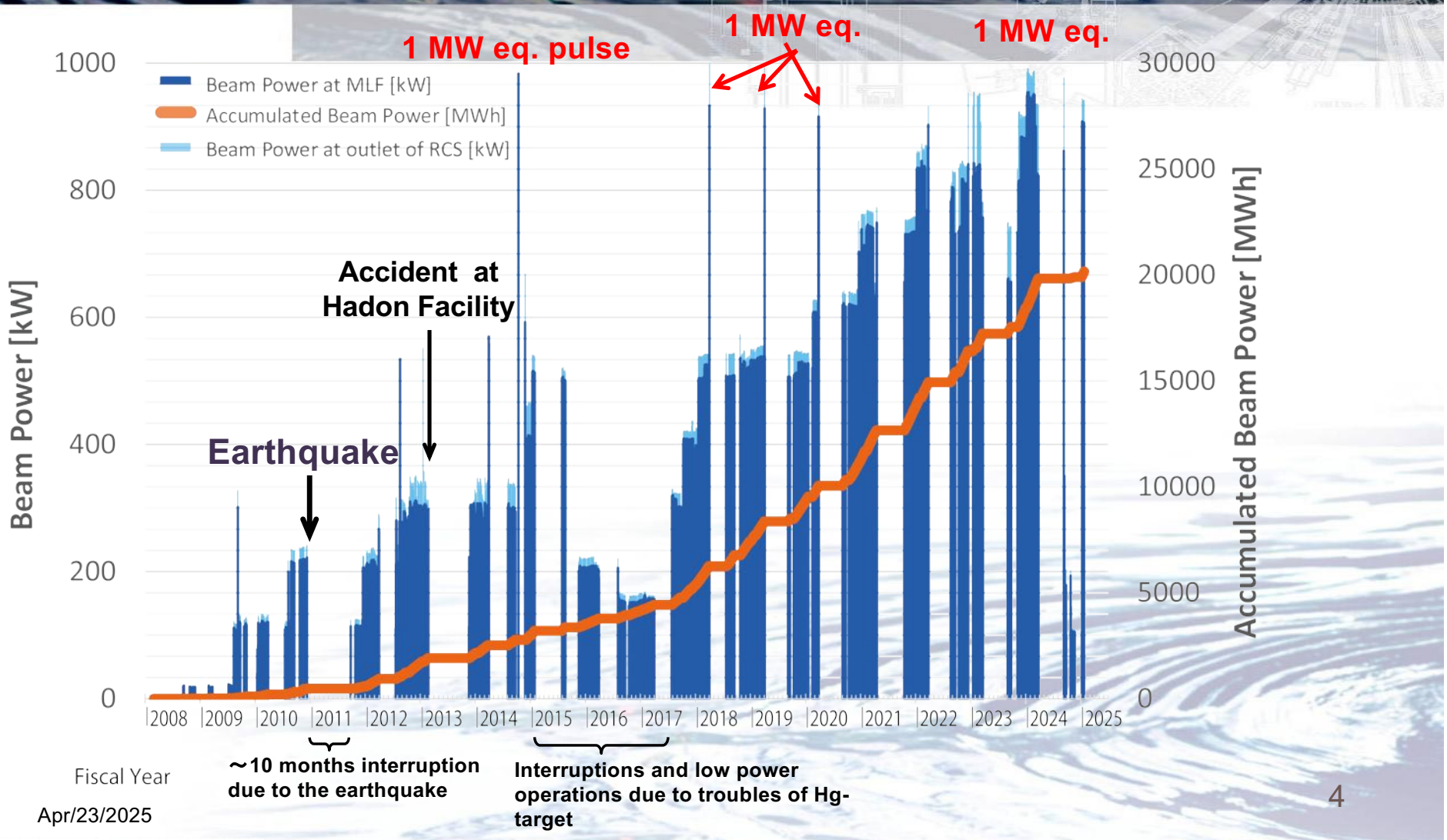


21 neutron and 4 muon beam lines (8 areas) are in operation, carrying out studies of

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

etc.

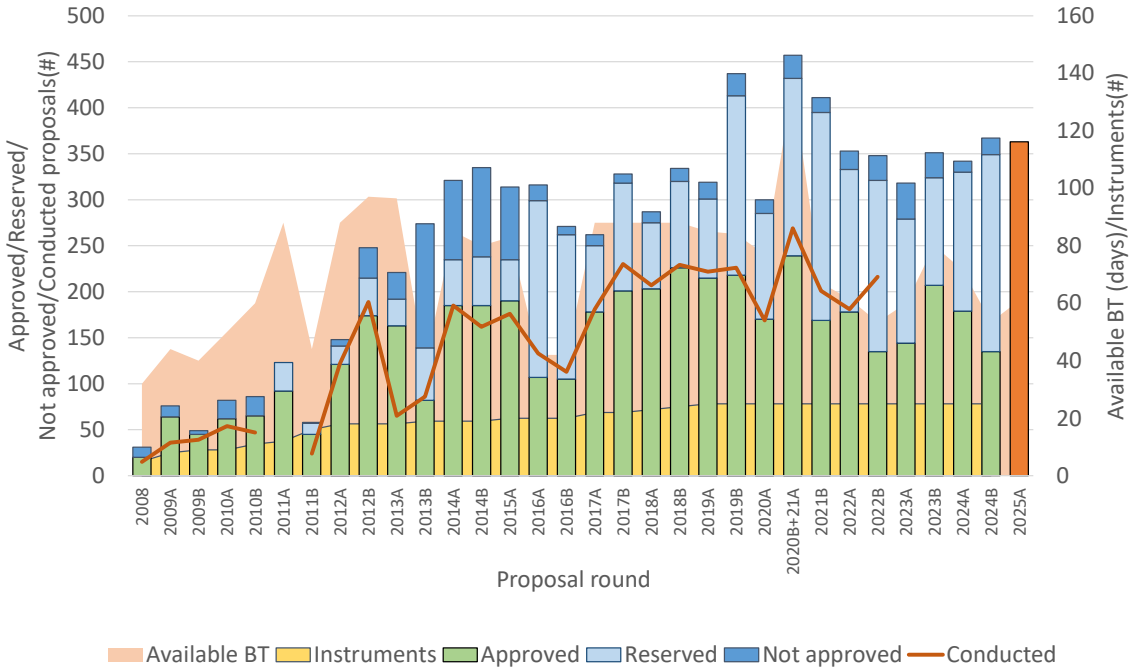
Beam Power History at MLF



Proposal & Publication(Neutron & Muon)

Number of proposals

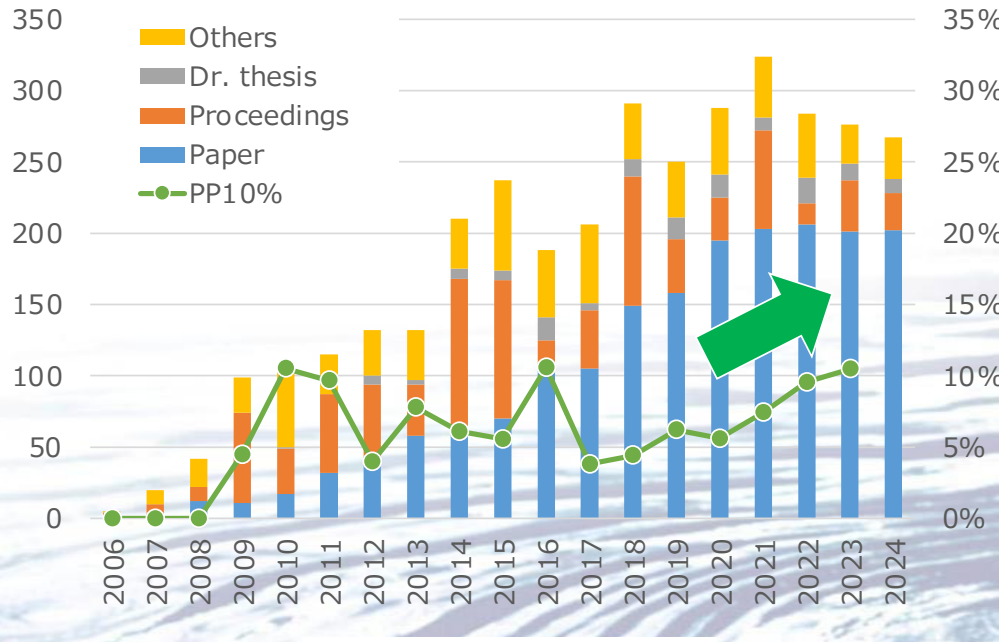
~ 700 /year



~ 350 / round x 2 round / year
Ave. competition rate ~ 2

Number of publications

~ 250 /year



Publication year

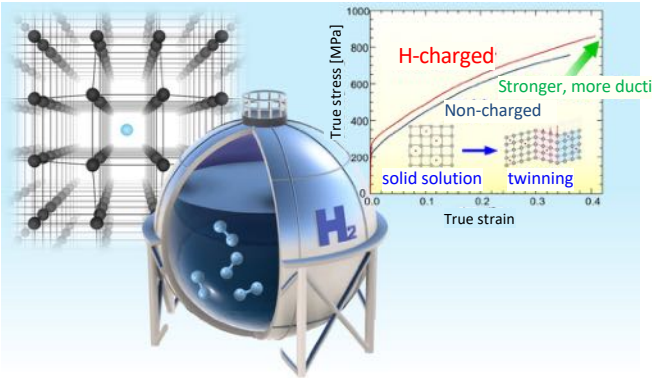
Figure revision @ 2025-01-17

Recent Outcomes from Neutron BLs @MLF

Hydrogen Strengthens Stainless Steel

Neutrons Reveal How Stainless Steel Becomes Stronger and More Ductile — Toward a Safer Hydrogen Future

Conventional metals usually become brittle in hydrogen, but certain stainless steels show the opposite—becoming stronger and more ductile. Neutron analysis revealed that hydrogen slightly distorts the atomic structure, leading to solid-solution strengthening and the formation of deformation twins that enhance both strength and elongation.



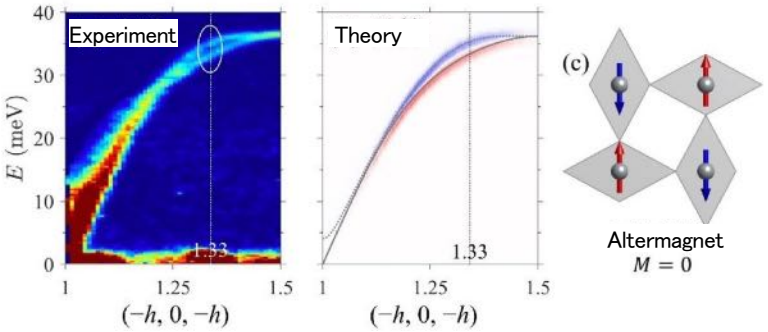
■ **These findings provide new insights into designing steels that resist hydrogen embrittlement while maintaining excellent mechanical performance.**

Acta Materialia Press released on Apr 1, 2025

Verification of a New Magnetic Concept

First Observation of Magnon Spectrum Splitting in an Altermagnet

Chiral magnon splitting was observed in MnTe for the first time, demonstrating that this material is an altermagnet, a new magnetic concept. The presence of chiral magnons that carry spin currents in altermagnets was also revealed.



Observed magnon splitting indicating altermagnetism

■ **Open the way to next-generation magnetic memory devices that are faster and more efficient than conventional ferromagnets.**

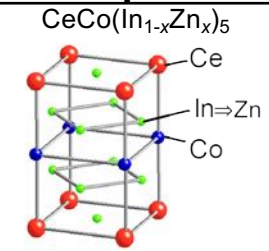
Phys. Rev. Let., Editor's Choice Press released on Dec 9, 2024

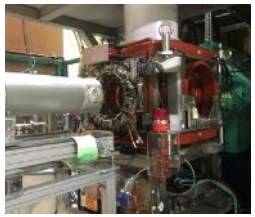
10.1103/PhysRevLett.133.156702

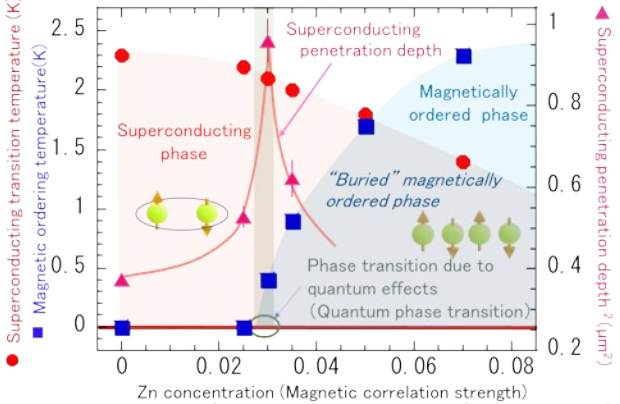
Muon Facility Muse @ MLF

Quantum fluctuation induced novel ordered state –Observation of quantum magnetism coupled with superconductivity

By substituting a part of elements in superconductor, we obtained evidence that magnetic order and superconductivity are strongly coupled. This achievement significantly contributes to elucidating the mechanism behind the emergence of superconductivity and holds promise for future development.

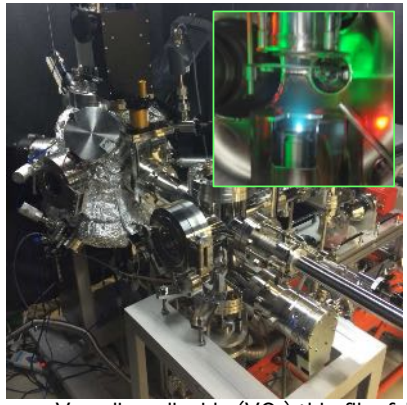


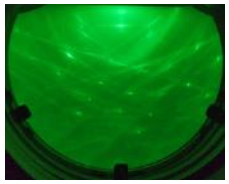




W. Higemoto, M. Yokoyama, T. U. Ito, T. Suzuki, S. Raymond , and Y. Yanase, PNAS 2022 Vol. 119 No. 49 e2209549119

Unique method for observing the dynamics of hydrogen in nanoscale regions





Vanadium dioxide (VO_2) thin film fabricated by a pulsed laser deposition method.

The innovation is in the use of **muons as a microscopic simulator of dilute hydrogen** to investigate the dynamics of trace hydrogen in nanoscale regions such as thin films, which is very difficult to do using conventional methods.

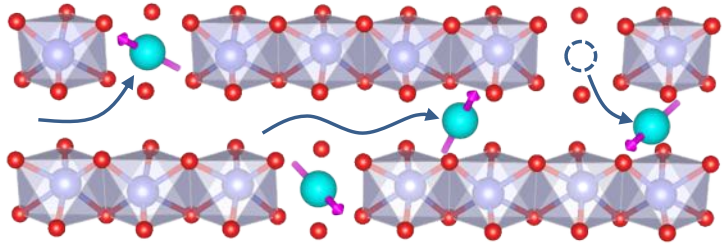


Image of nanoscale hydrogen diffusion in vanadium dioxide (VO_2), a promising next-generation electronic device for artificial neural networks.

H. Okabe, M. Hiraishi, A. Koda, Y. Matsushita, T. Ohsawa, N. Ohashi, R. Kadono, Physical Review Materials 8, 024602 (2024) **Editors' suggestion**.

MLF has largely met its intended performance goals.

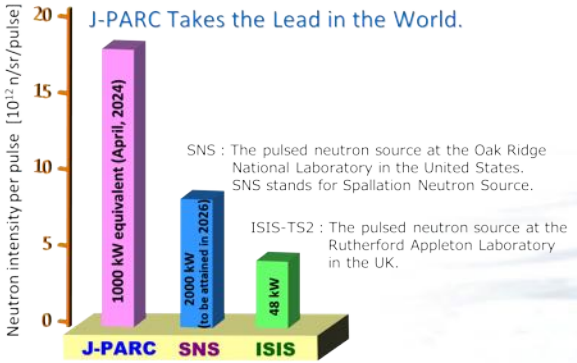
WHAT'S NEXT

MLF roadmap

~2030 ~2040?

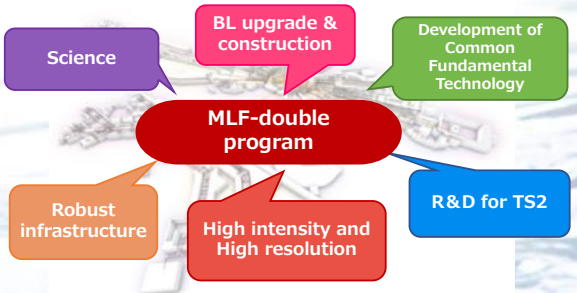
Review current performance "MLF2030"

Highest flux/pulse achieved on TS1



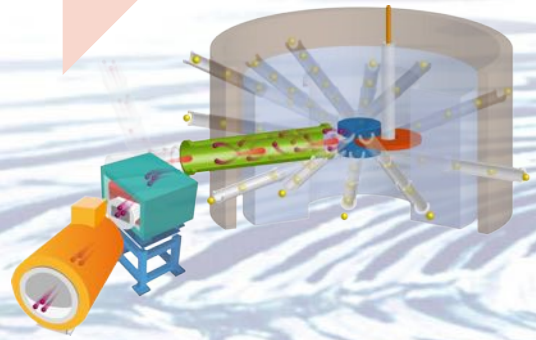
Upgrade planning of TS1 "MLF double"

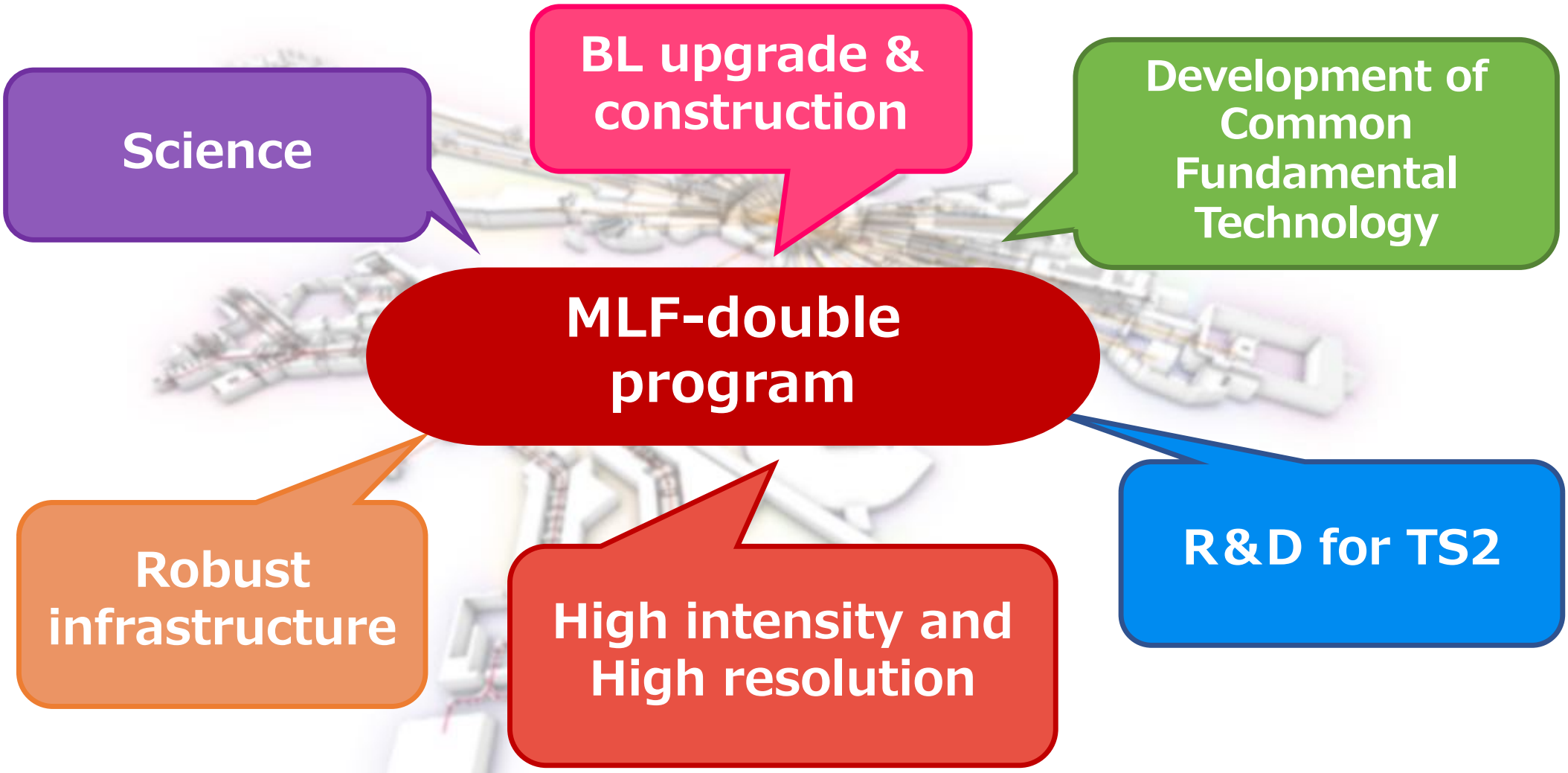
Double the effectiveness of TS1: realize max use of TS1



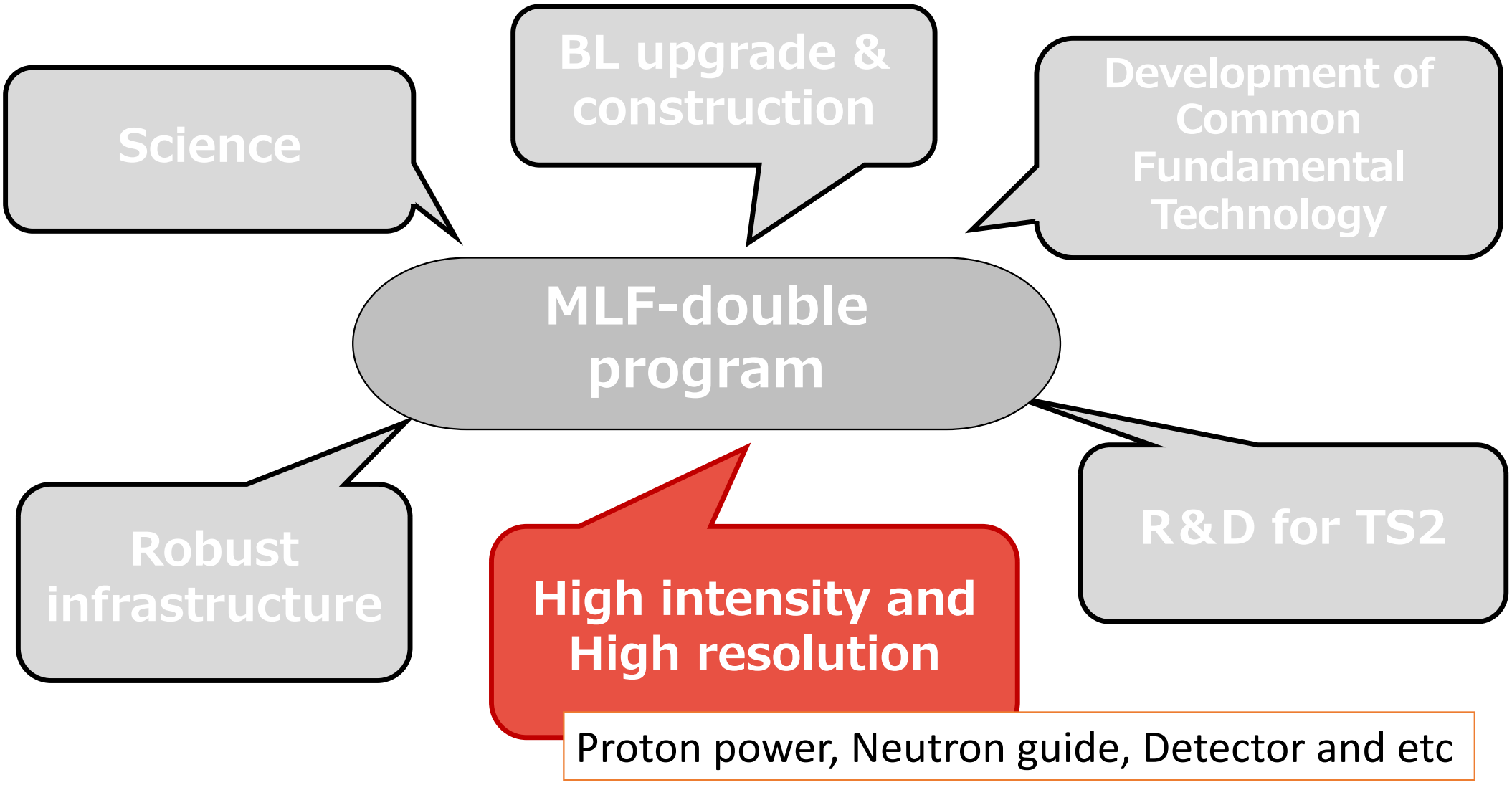
Construction of TS2 and operation

TS2 > TS1* 20-100





Aiming to double the effectiveness of TS1: realize max use of TS1


Science
BL upgrade & construction
Development of Common Fundamental Technology
MLF-double program
Robust infrastructure
High intensity and High resolution
R&D for TS2
Proton power, Neutron guide, Detector and etc

Increase of Neutron Production: Proton Power

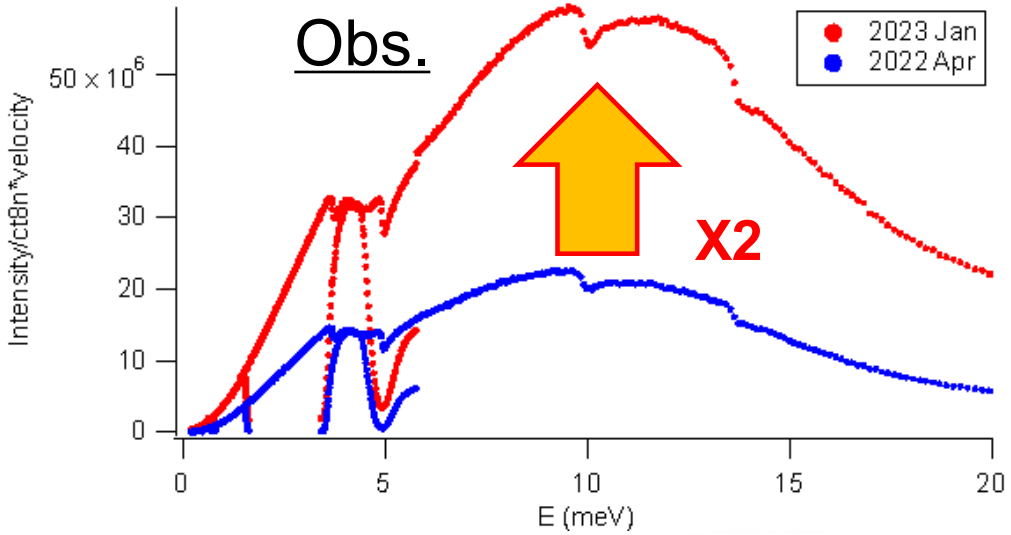
1. Stable 2-year operation at **1 MW**
   - We plan to start 2-year operation from Nov. 2025 at 700~800 kW because of the target trouble.

2. **1.16 MW/pulse** is acceptable 2028~
   - To keep 1 MW operation under 1.16 extraction to MR
   - **Neutron/pulse X1.1: feasible**

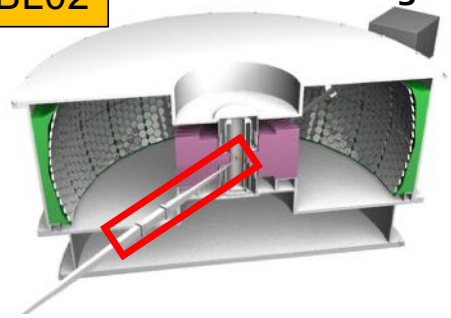
3. **1.74 MW/pulse** will be acceptable by vessel structure modification
   - 1 MW heat load assuming 0.5 MW will be delivered to TS2
   - **Neutron/pulse X1.74: challenging**

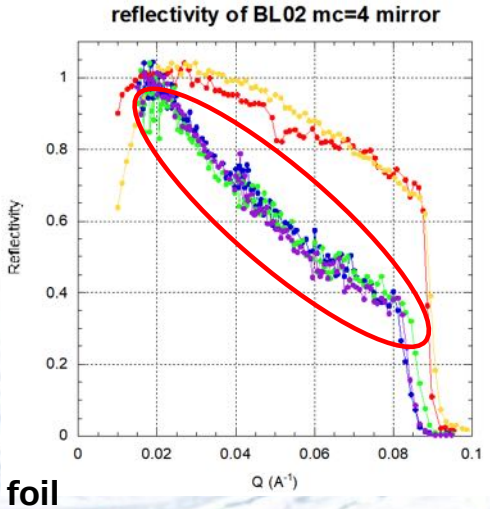
High Intensity: Neutron guide upgrade

Neutron flux is doubled by replacing the low-reflectivity focusing mirror!



BL02 **Back scattering**





	2022June	2023Jan
Area	n/cm^2/s@1MW	n/cm^2/s@1MW
R<5mm	1.38E+09	2.80E+09
R<10mm	1.30E+09	2.63E+09
R<20mm	1.02E+09	2.07E+09
R<30mm	7.12E+08	1.44E+09
30x30mm	6.03E+08	1.22E+09

Gold-foil attached on imaging plate

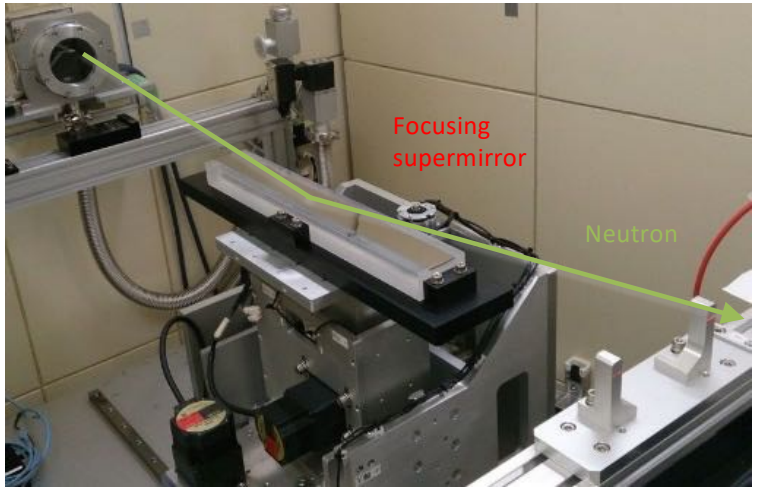
- **Estimation of neutron flux at the sample position by Gold foil irradiation (absolute val) + imaging plate (2D)**
- **Upgrade of BL14 is under-way: Guides will be replaced in FY2026**

Focusing supermirror (unpolarized)

Develop an elliptic focusing supermirror for Grazing-Incidence SANS measurements

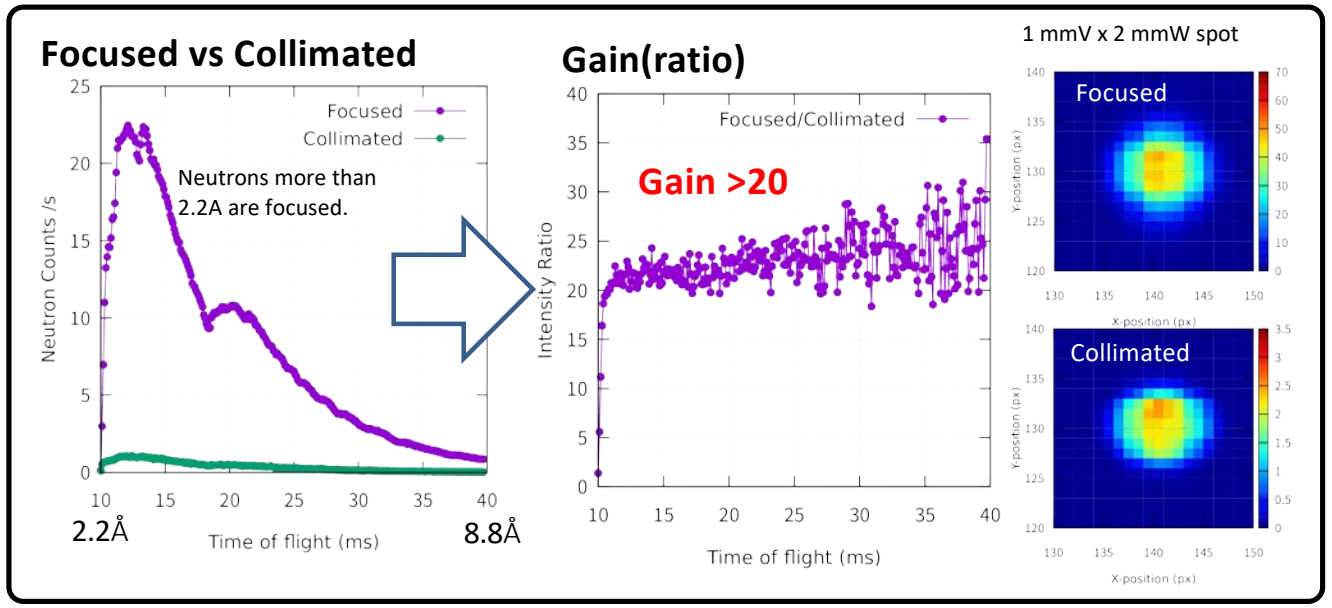
GI-SANS measurement is a powerful tool for studying the structure of surfaces and buried interfaces. However, a high-intensity, well-collimated, low-divergence neutron beam is needed. **A multi-channel, one-dimensional elliptical focusing supermirror is being developed** to realize GI-SANS at BL17 of MLF.

Neutron focusing test at BL17



Focusing supermirror on a quartz substrate fabricated by elastic emission machining method.

Neutron focusing test at BL17 (FY2022)



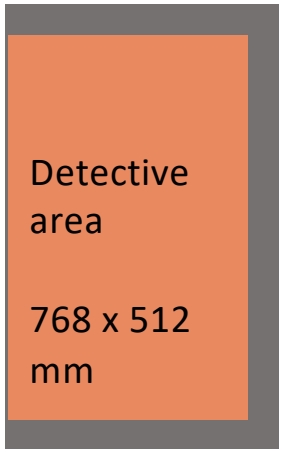
Neutron intensity gain ~20 has been achieved in FY2022.

High Intensity: detector improvements

- Based on MLF's unique scintillator/wavelength-shifting fiber method

256
x 256 mm

Original



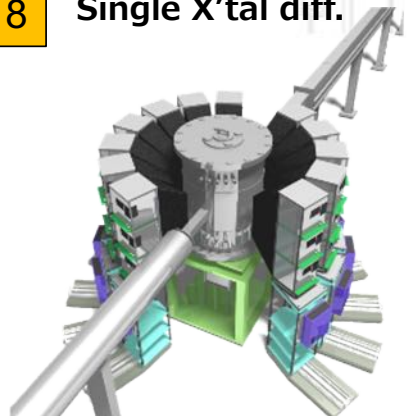
New

X 1.8

Effective detection area x **1.4**

Detection efficiency x **1.3**

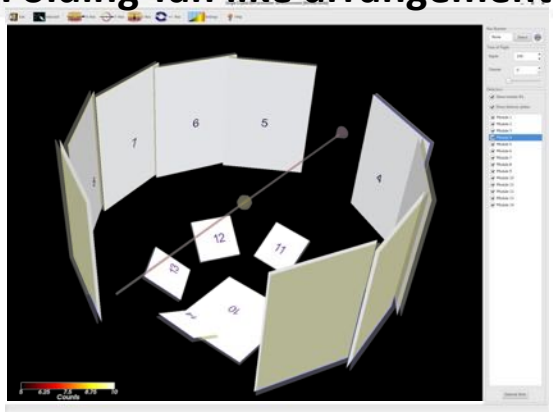
BL18 **Single X'tal diff.**



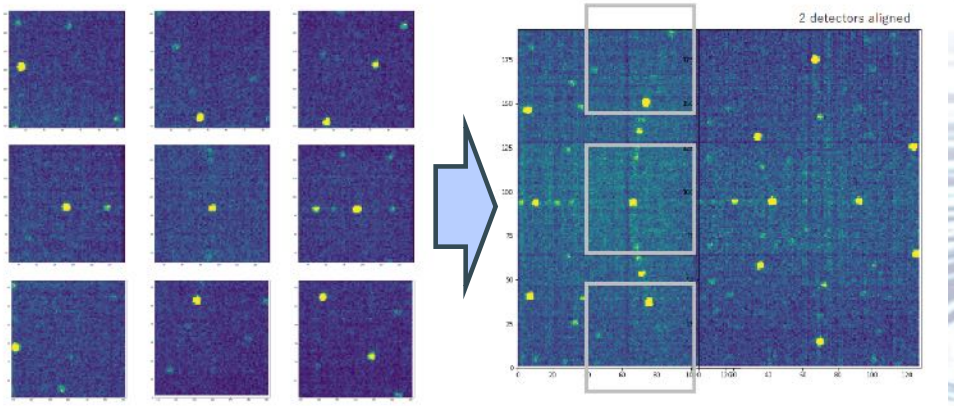
Original Detectors

208 x 208 mm

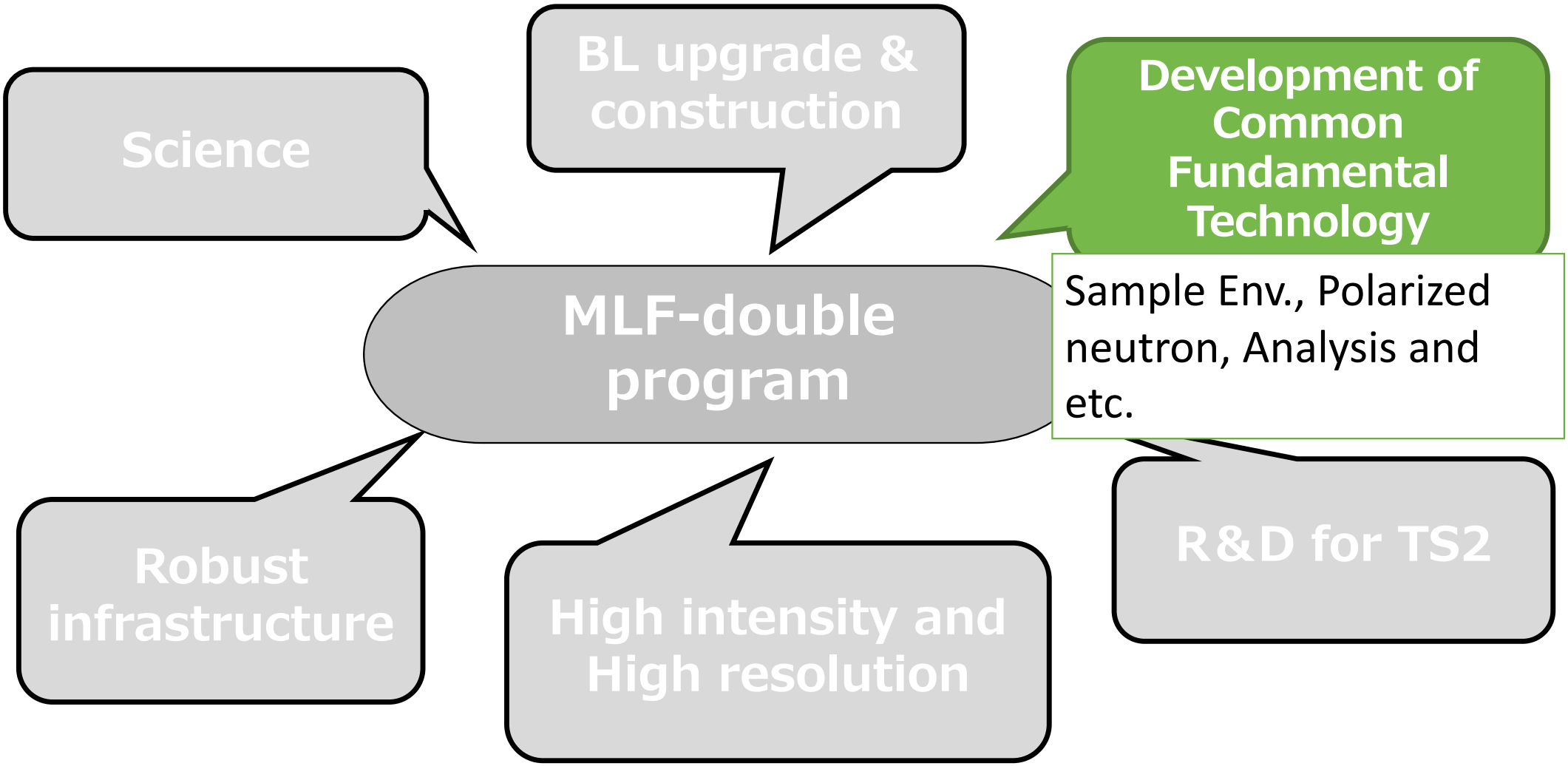
Folding-fan like arrangement



New Large Detectors (2x3)

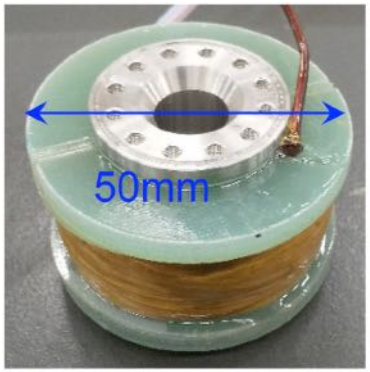


720 x 1232 mm

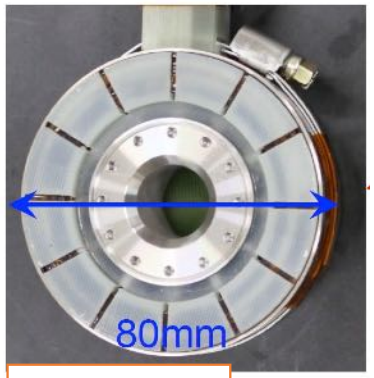

Science
BL upgrade & construction
Development of Common Fundamental Technology
MLF-double program
Sample Env., Polarized neutron, Analysis and etc.
Robust infrastructure
High intensity and High resolution
R&D for TS2

Developments with Universities : examples

Sample environments



40 T
Tohoku Univ.

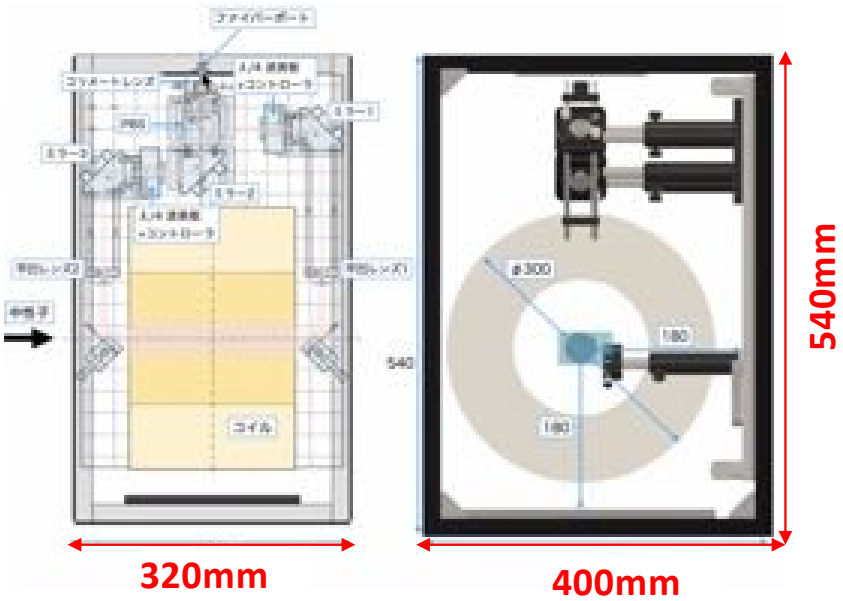


Long pulse
15 T (-> 20 T)
ISSP U. Tokyo

working on

- Extreme condition
- Operando measurements

A compact on-beam SEOP



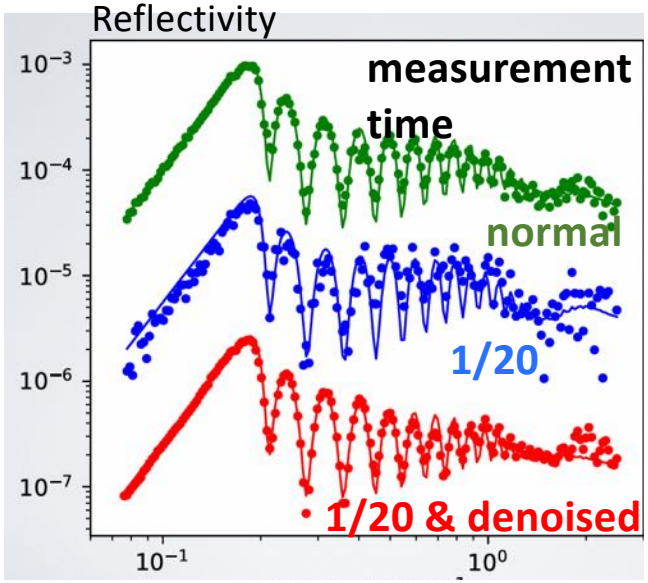
Ibaraki Univ., Nagoya Univ., Tohoku Univ.

working on

- Increase BL for polarization
- Large solid angle analyser
- High energy neutron polarization

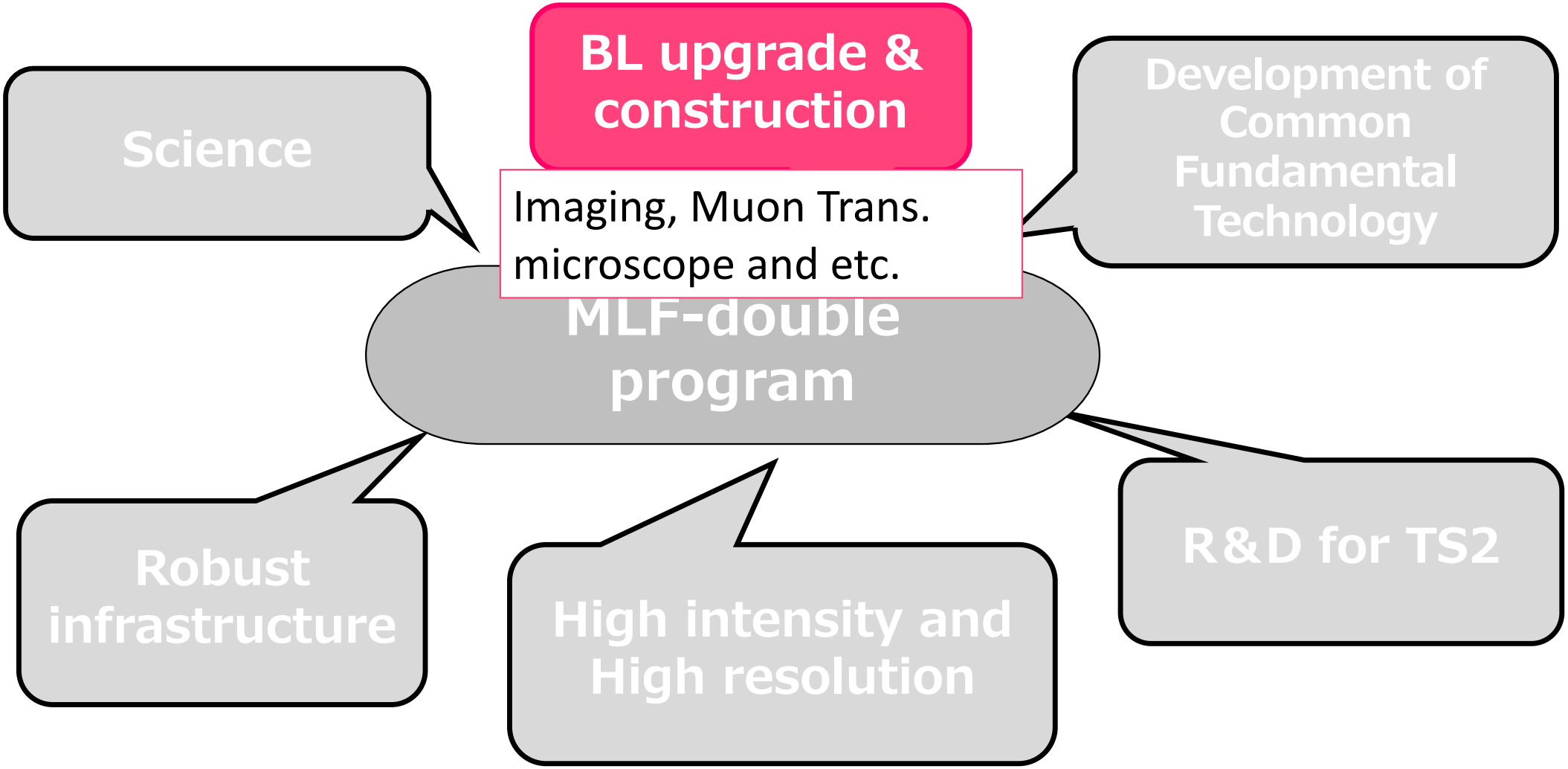
Denoising with Artificial Neural Network

X10?



working on

- Reflectometry (BL16, 17)
- MD with ML Interatomic Potential
- Collaboration with **Hitotsubashi Univ.** on data science started


BL upgrade & construction
Science
Development of Common Fundamental Technology
Imaging, Muon Trans. microscope and etc.
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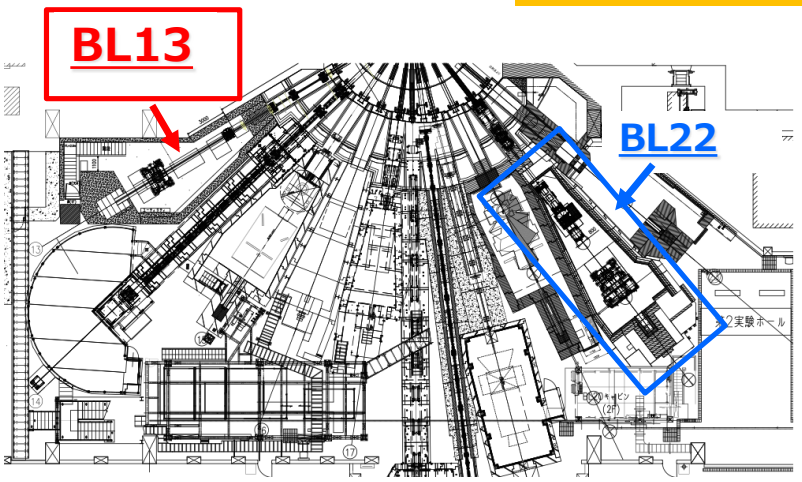
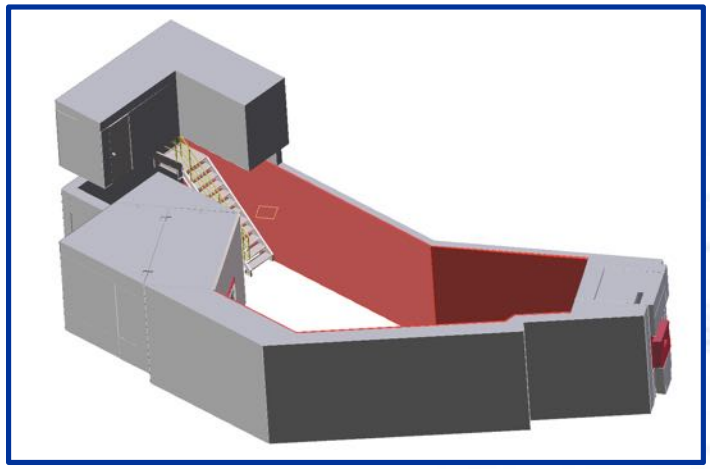
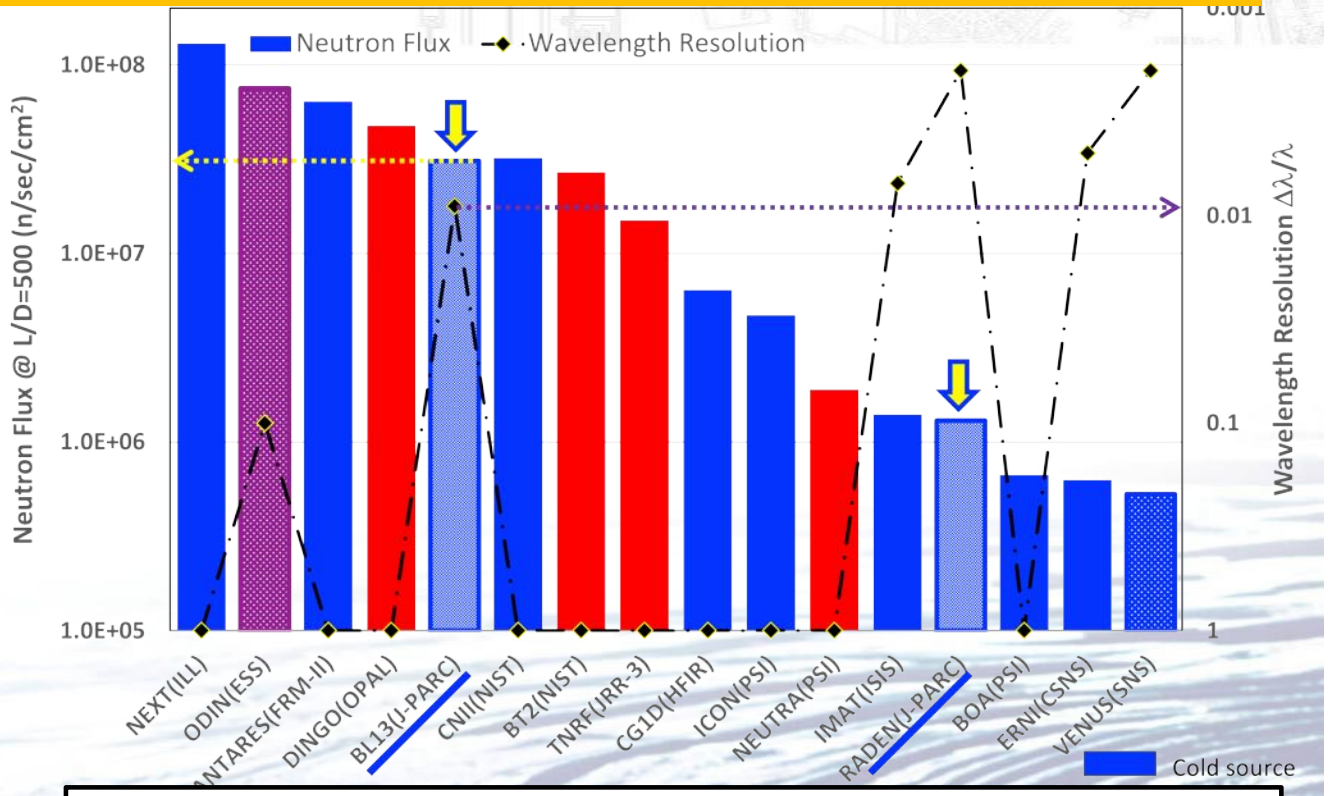
New BL: "Imaging BL" @ BL13

10 times higher flux than BL22 with coupled moderator





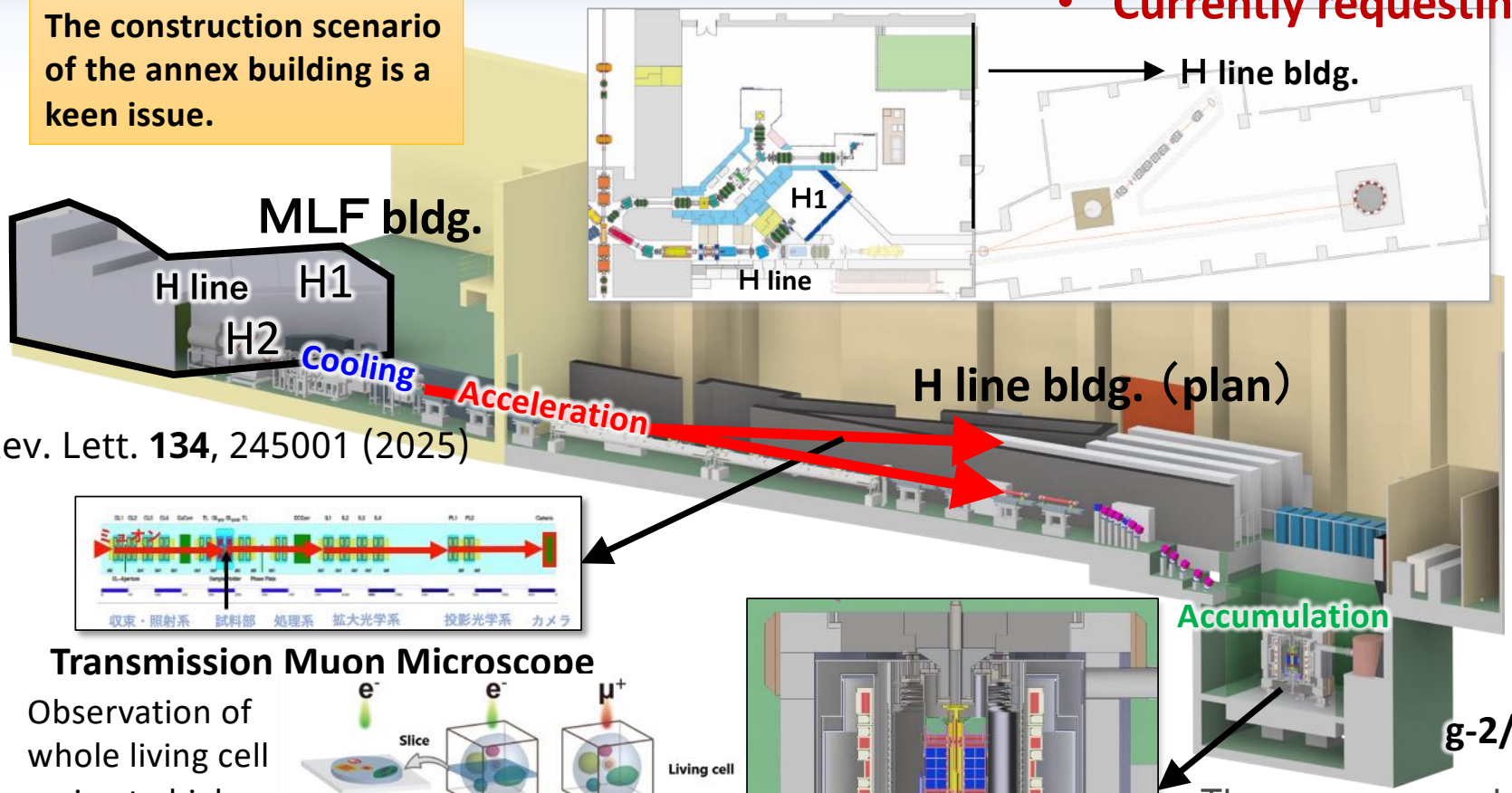


- **Currently requesting a budget**
- R&D for neutron microscope (μm) -> TS2
- User program from 2029 (plan) incl. Industrial use

New BL of Muon

- **Currently requesting a budget**

The construction scenario of the annex building is a keen issue.

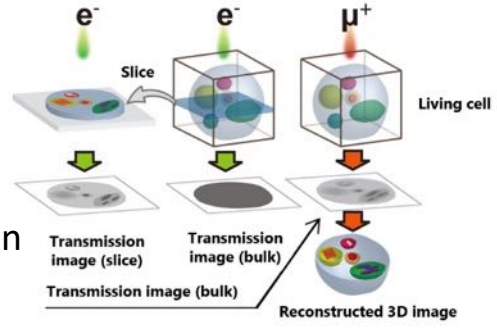


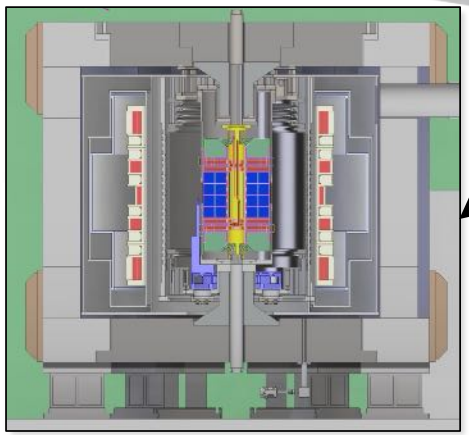
Phys. Rev. Lett. **134**, 245001 (2025)

Transmission Muon Microscope

Observation of whole living cell owing to high transmittance capability of muon

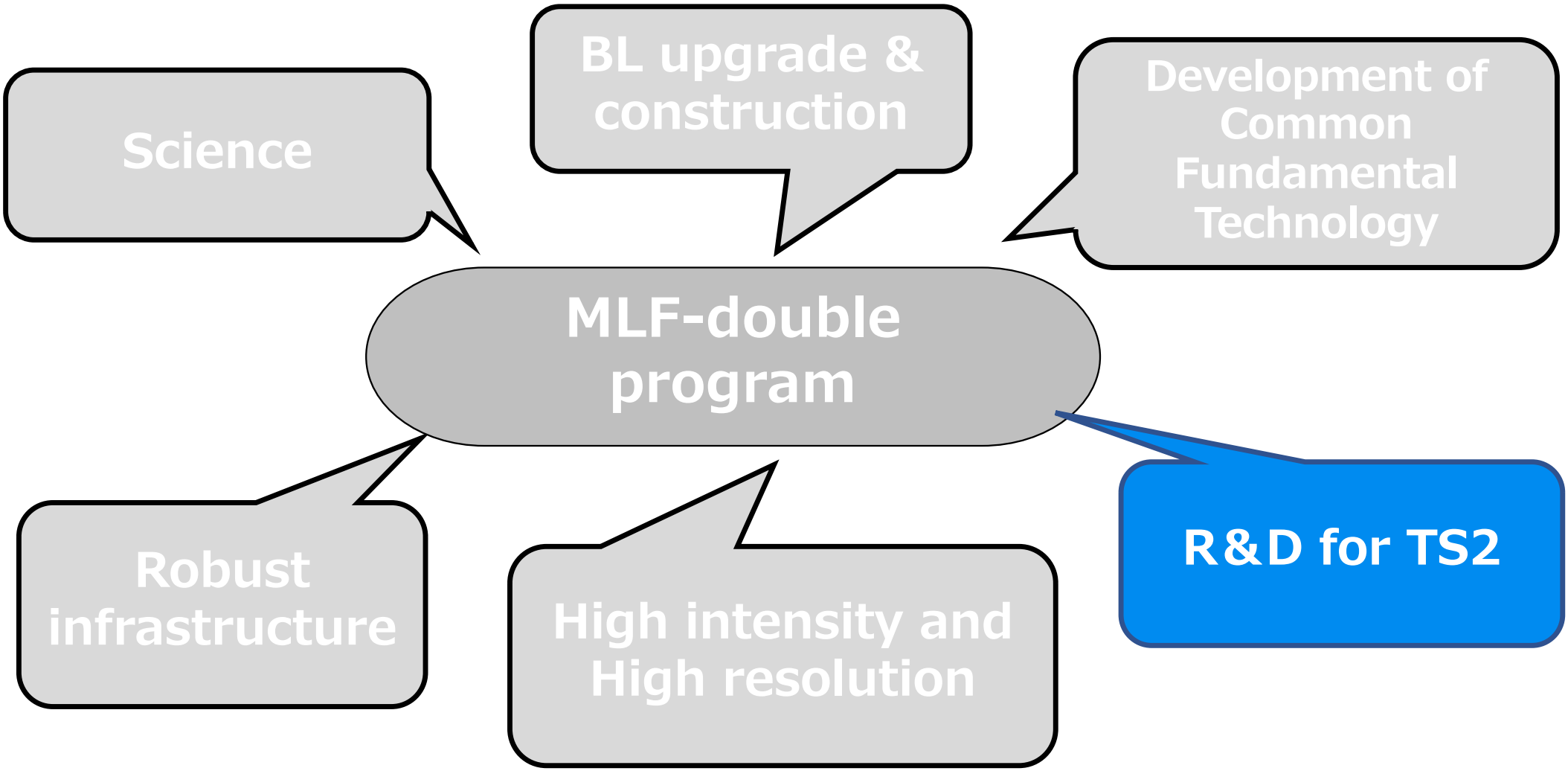
-> TS2





g-2/EDM exp.

The muon anomalous magnetic moment (g−2) and the electric dipole moment (EDM)
Search for “Beyond Standard Model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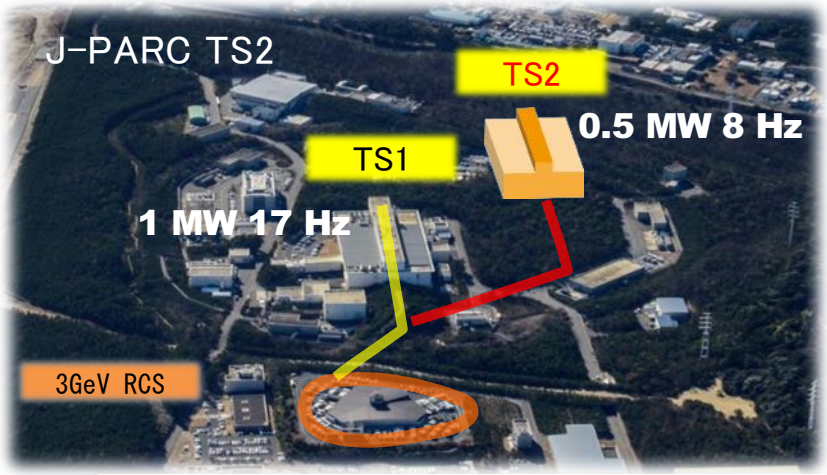
Upgrades of acc. driven N&M sources

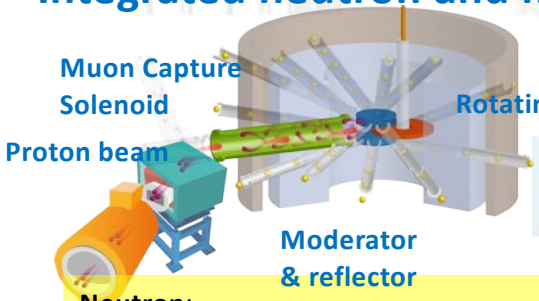
- ISIS
  - Endeavour Programme (5 upgrades + 4 new instruments) in **2023-2033**
  - Endeavour+
  - ISIS-II construction in **2032-2040**
- SNS
  - Ramp up to 2.8 MW and User Program on STS will start in **2034**
- CSNS
  - Phase II (Ramp up to 0.5 MW + construct +9 BLs + muon facility) will be completed in **2029**
- ESS
  - Beam on target in **2026**, User program will be started in **2028**
- PSI
  - SINQ++
  - HIPA upgrade will be completed in **2027** (10^{10} surface muon/sec)

Target Station - 2

World's first new target station (TS2) integrating neutrons and muons



Integrated neutron and muon target



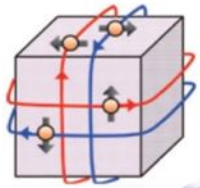
Neutron:
10 (target) x 2 (device) → 20 times gain of brightness

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

Science using the high-brilliance neutron/high-intensity muon at TS2

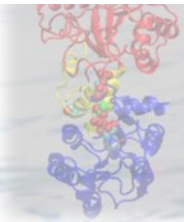
Due update

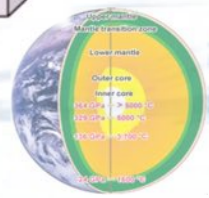
Polarized electron spin currents at the surface of a topological insulator



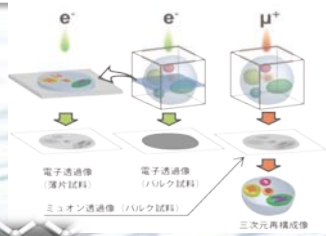
Neutron EDM
Muon EDM

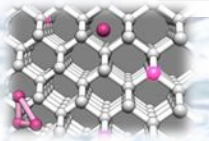
Dynamics of soft matter and proteins



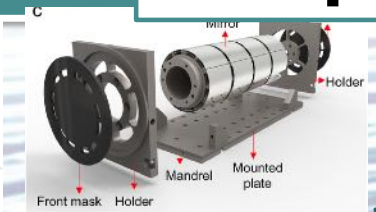


Structural analysis of the Earth's mantle

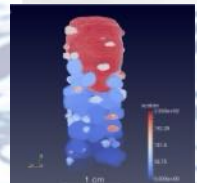




Cell Imaging



μm Imaging



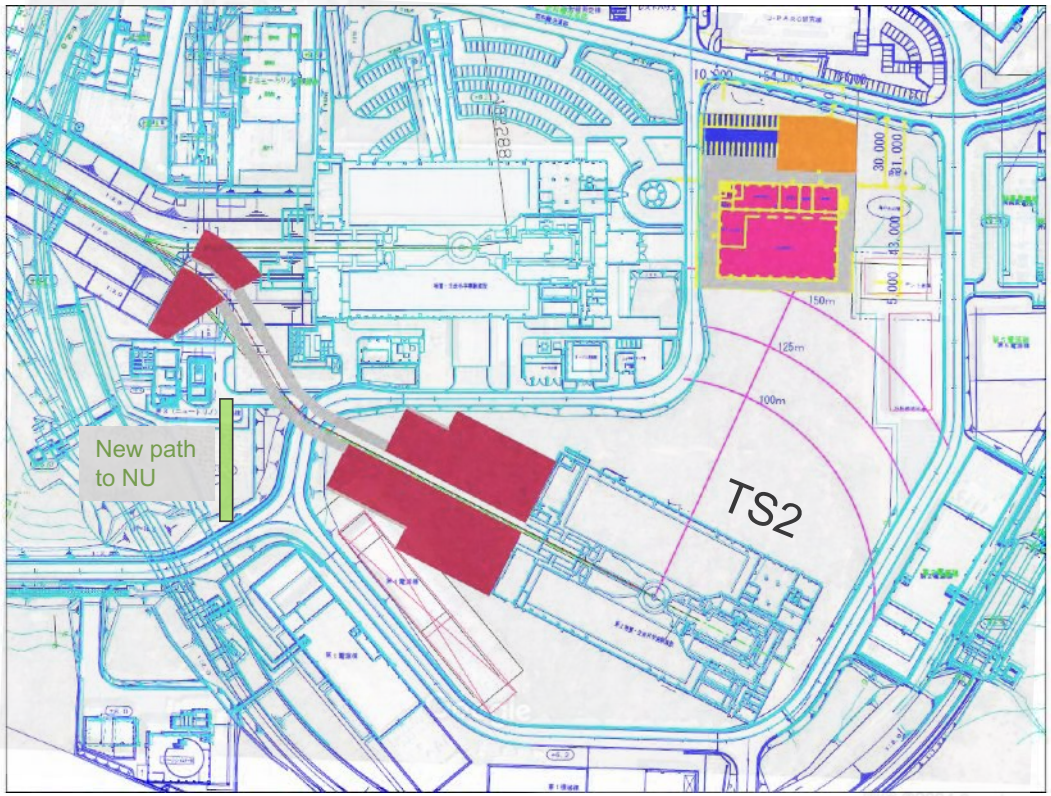
Structure around dopant (active site)

Neutron diffraction imaging

TS2 R&D

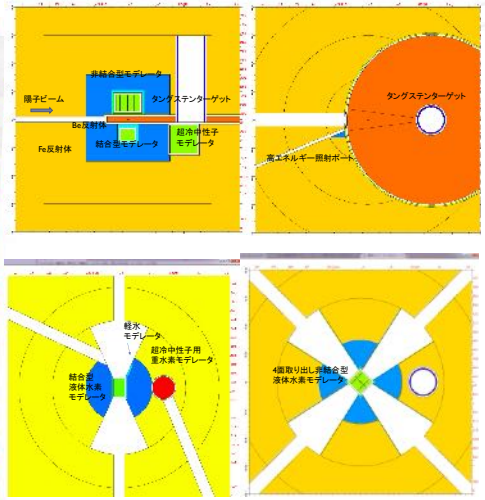
TMRA

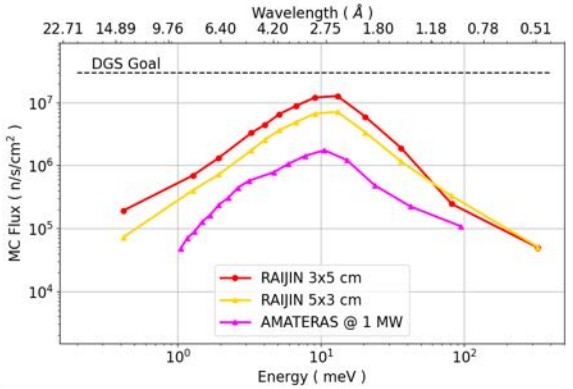
MC simulation of neutron spectrometer

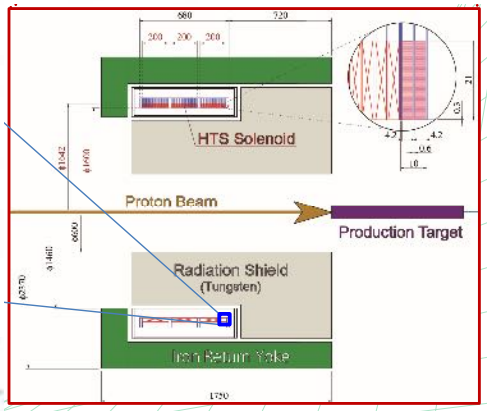


Composite on Google map

Layout of TS2



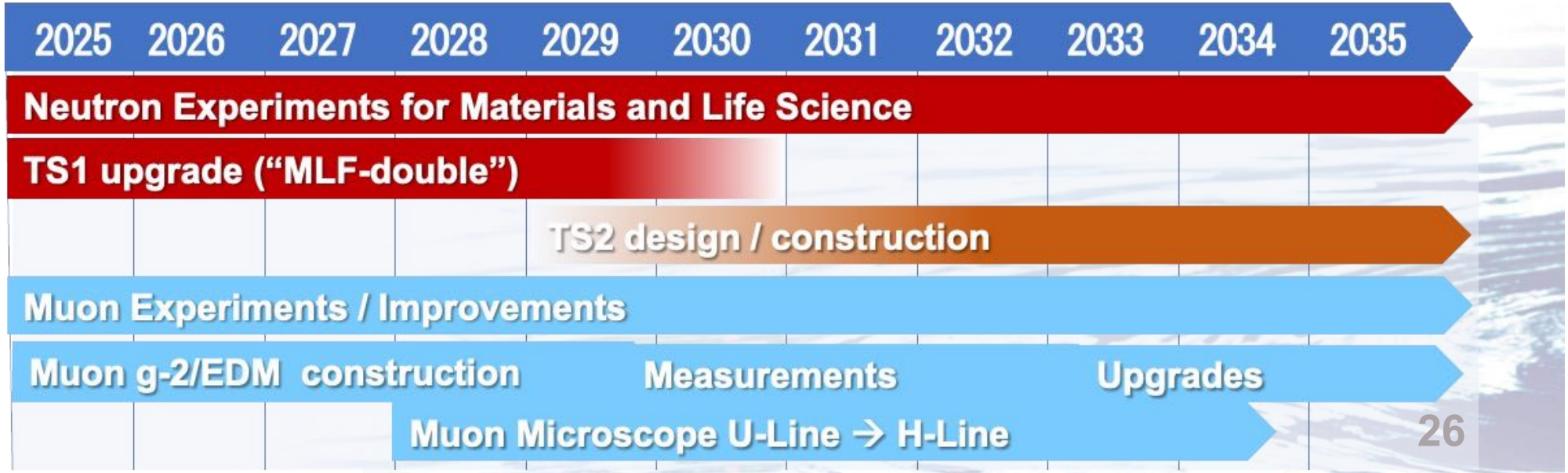




SC Solenoid coil for pion capture

Summary

- MLF roadmap has been preparing
  - The scientific landscape should be drawn with communities
    - “scientific impacts”
  - Budget, human resources and priority are under-discussion



THANK YOU FOR YOUR ATTENSION!