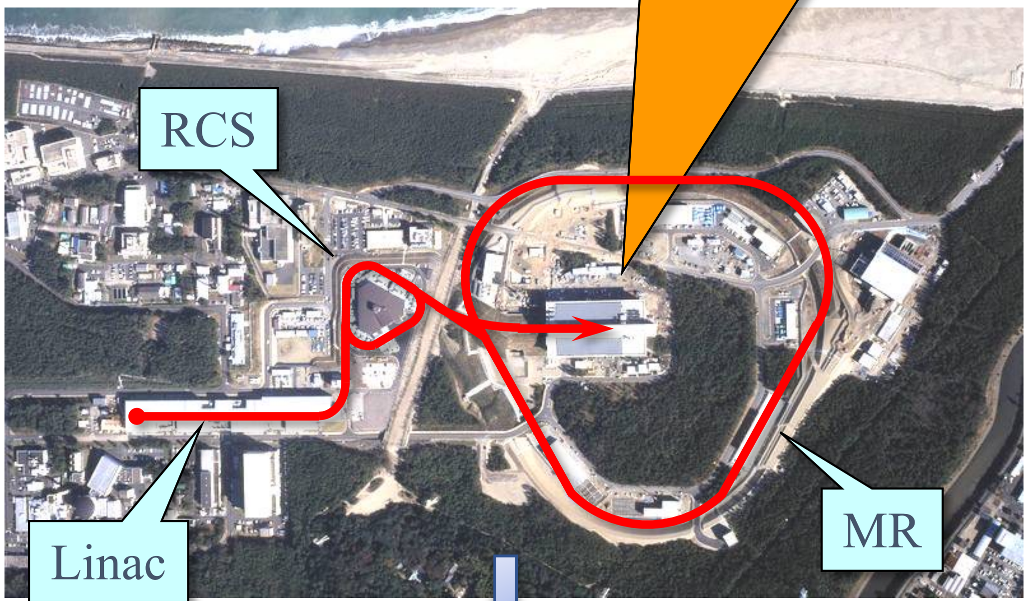
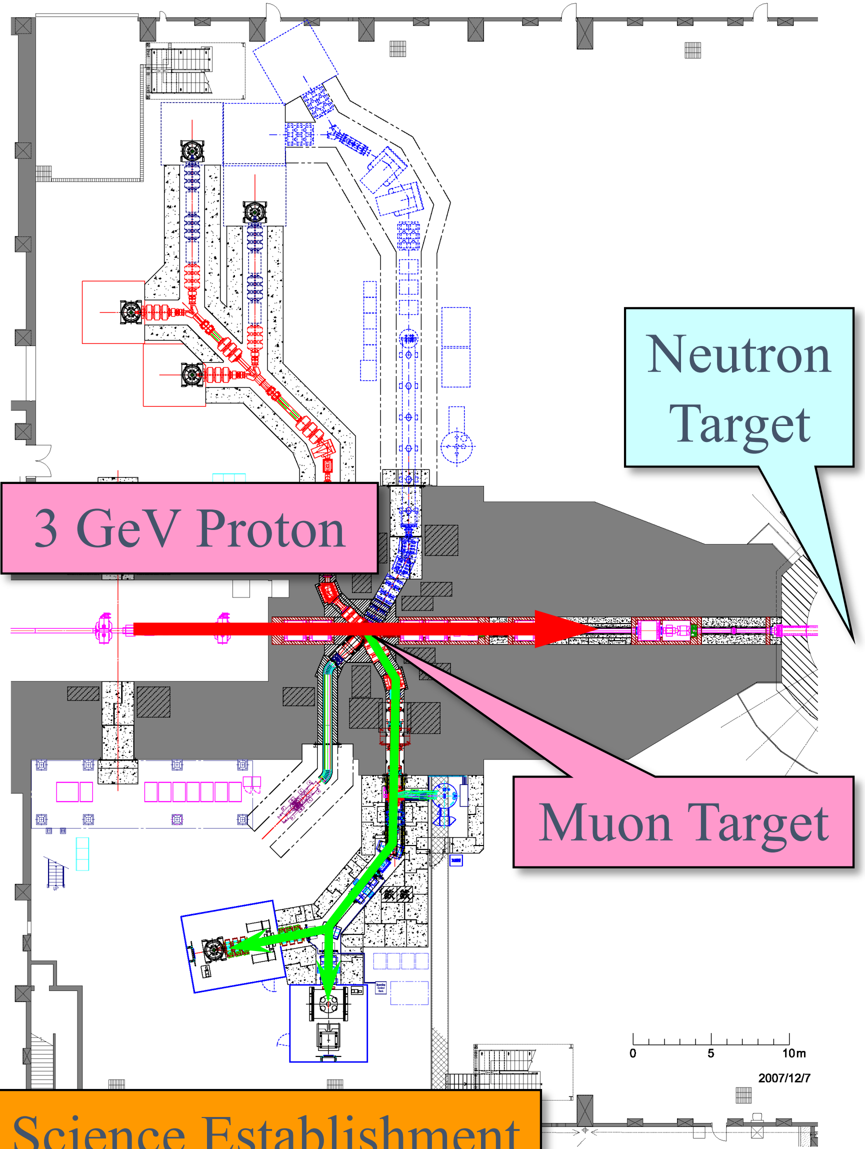
Surface muon beamline and Sample environments at J-PARC MLF

Akihiro Koda

J-PARC/KEK

J-PARC - MLF


Pacific ocean
Materials and Life Science Experimental Facility (MLF)
RCS
Linac
MR
To Kamioka


Neutron Target
3 GeV Proton
Muon Target
0 5 10m
2007/12/7
Muon Science Establishment (MUSE) @ MLF

Materials and Life Science Division

total number of staff is ~173

Neutron Instrumentation S.
R & D on neutron detectors and devices

Leader : Tatsuya Nakamura
7 staffs (JAEA)
3 staffs (KEK)
1 CA staff (Ibaraki U.)

Neutron Science S.
Neutron Instrumentation and Promoting Science

JAEA total 31 members
27 Staffs
PD 4 members
KEK total 18 members
13 staffs
PD 1
Engineer 4

Leader : Yukinobu Kawakita
Sub-Leader : Mitsutaka Nakamura
Sub-Leader : Tetsuya Yokoo

Materials and Life Science Division
Div. Head : Toshiya Otomo
Deputy D Head : Kazuya Aizawa
Deputy D Head : Hiroshi Takada
Deputy D Head : : Koichiro Shimomura

Neutron Source S.
Leader : Katsuhiro Haga
Sub-Leader : Kenji Sakai
27 staffs (JAEA)

Operation, maintenance and management of spallation neutron source and R & D of their related technology

Neutron R&D Division (CROSS)
Div. Head : Jun-ichi SUZUKI
Deputy D Head : Kenichi FUNAKOSHI
Deputy D Head : Masato MATSUURA
35 staffs

support for the use of the public beamlines & experimental preparation rooms of CROSS

Technology Development S.
Leader : Takayuki Oku
16 staffs (JAEA)

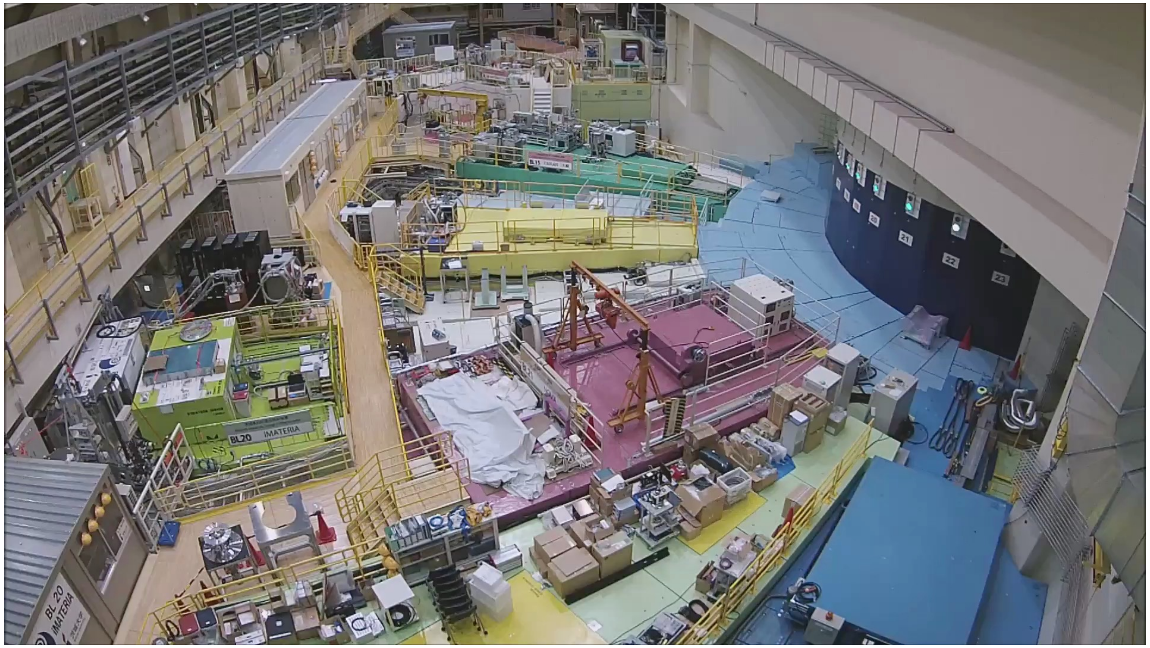
Introduction and grade-up of common equipment and SEs
Grade-up and application of ^{3}He spin filter

Muon S.
Leader : Naritoshi Kawamura
Sub-Leader : Akihiro Koda
31 Staffs (KEK)

R & D of muon target, beamlines and spectrometers

User support and cutting-edge studies by using muon

MLF experimental hall NO. 1

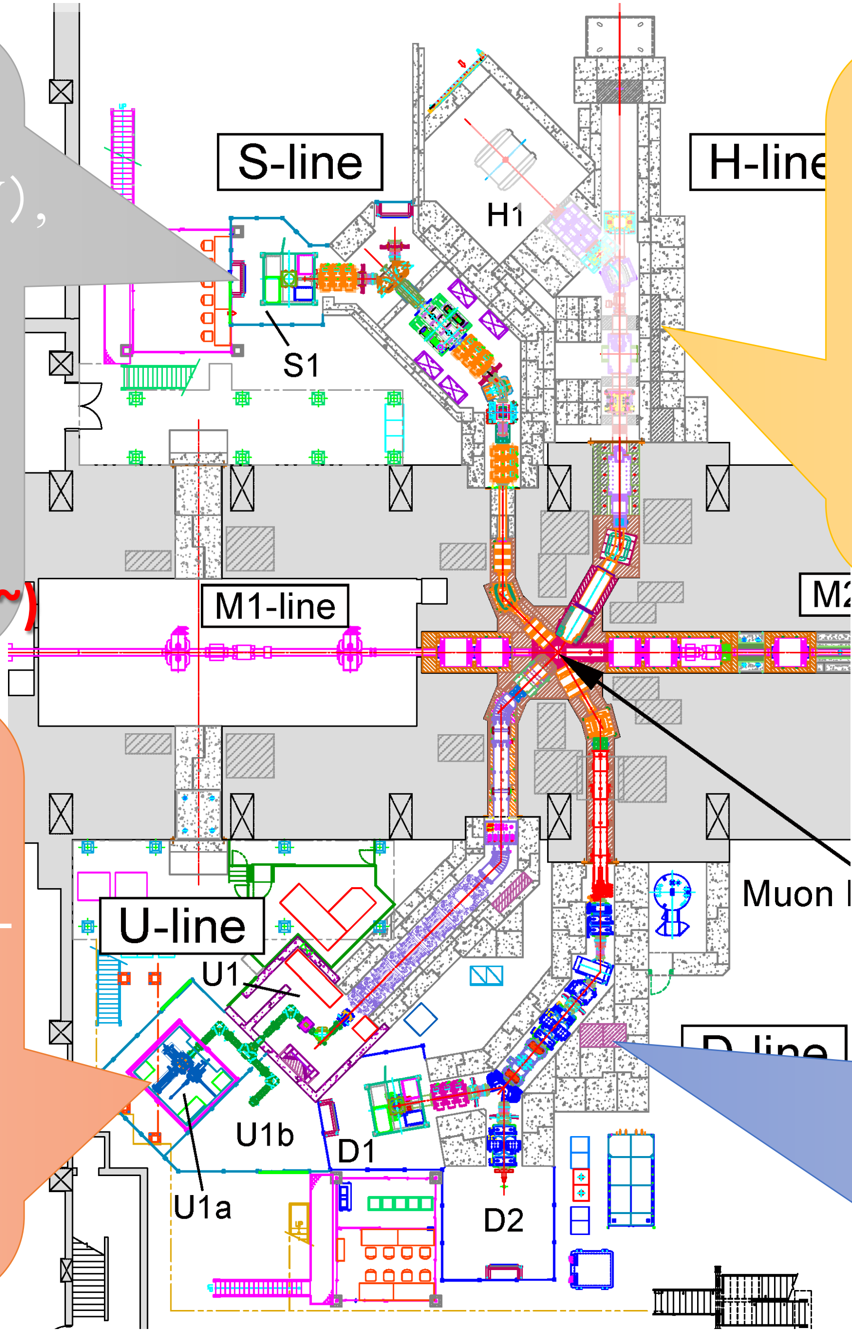


MLF experimental hall No. 2

MUSE: current status

S-line μ⁺

Slow beam (4 MeV), dedicated to bulk μSR ultralow temperature/high magnetic field/ pulsed excitations.
(S1:2014~/S2:2021~)



H-line μ±

Slow (4 MeV)~fast (50 MeV) beam, for particle physics, atomic physics ("precision frontier")
(H1:2021~)

U-line μ⁺

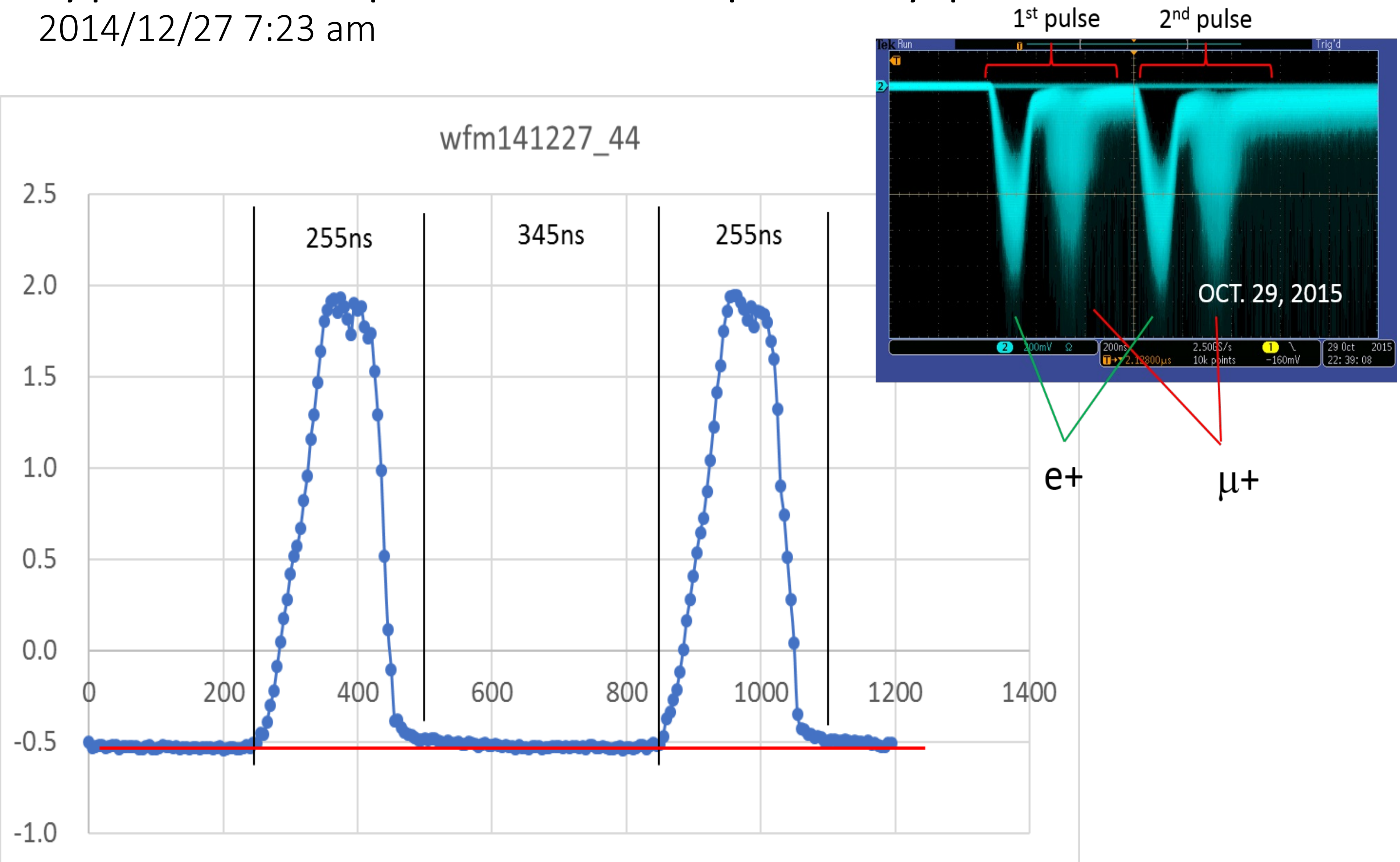
Ultra slow beam (0.1~30 keV), near-surface, sub-micron scale condensed matter physics, chemistry, etc.
(2014~/2016~)

D-line μ±

Slow (4 MeV) ~fast (50 MeV), general-purpose beamline with 2 exp. areas.
(2009~)

typical time-profile of the primary proton beam

2014/12/27 7:23 am

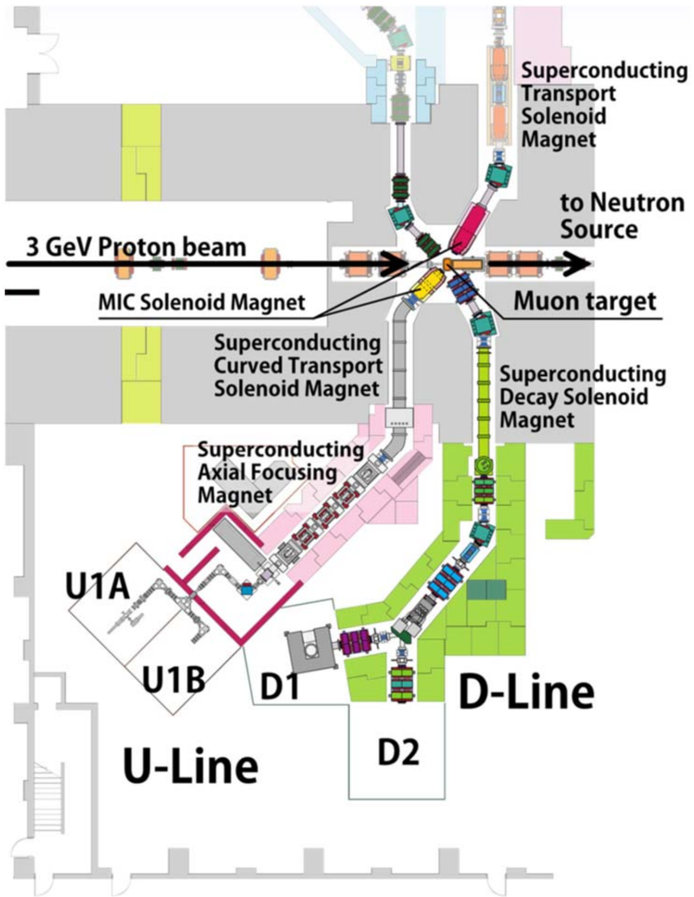


D-Line

The first and versatile muon beamline at J-PARC MLF

D-line

The secondary beamline for transporting decay and surface muons to D1 and D2 areas



Instrument specifications (as of 2022)

- **Beam line**
  - D-line was constructed at 2008.
  - Magnetic kicker system (2013)
  - Warm bore long solenoid magnet (2015)
  - High power magnet for beam transport (Ongoing)
- **Beam**
  - Surface and decay muons are available.
  - Positive and negative muons are available.
  - Variable momentum beam from 3 to 120 MeV/c
  - Single pulse beam
- **Experimental areas**
  - D1: μSR (Spectrometer)
  - D2: General purpose (Open geometry)

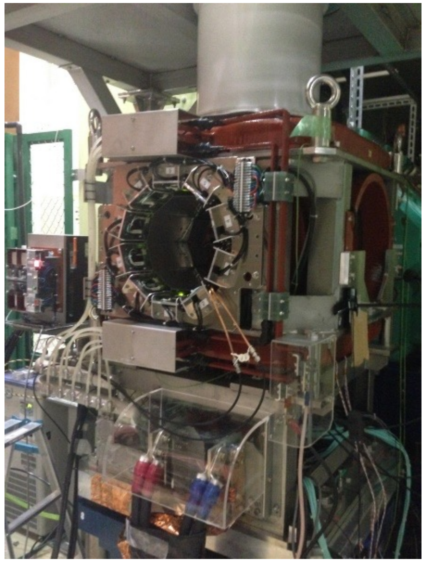
D1 Instrument (Muon Spectrometer for Mater. Life Sci. Expt.)

Muon spin rotation/relaxation (μSR) spectrometer for the research on electronic property of materials and/or electronic state of hydrogen introduced to the material.

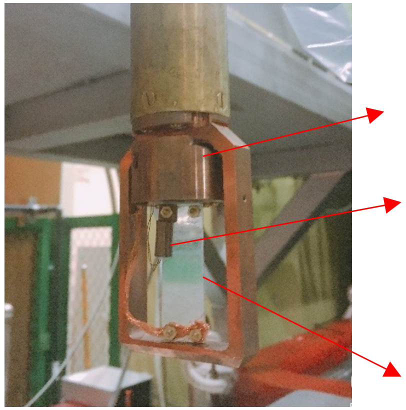
Instrument specifications (as of 2022)

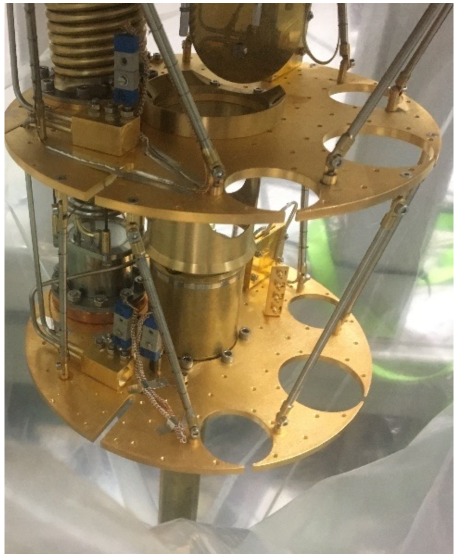
- μSR spectrometer with an energy-variable μ^+/μ^- muon beam
- Typical μ^+ flux: 1k /pulse/cm^2 @27 MeV/c (Single pulse, ϕ15mm collimator, 700kW)
- Typical μ^- flux : 100 /pulse/cm^2 @35 MeV/c (Single pulse, ϕ40mm collimator, 700kW)
- A wide variety of sample environments including low temperature (down to 80 mK).

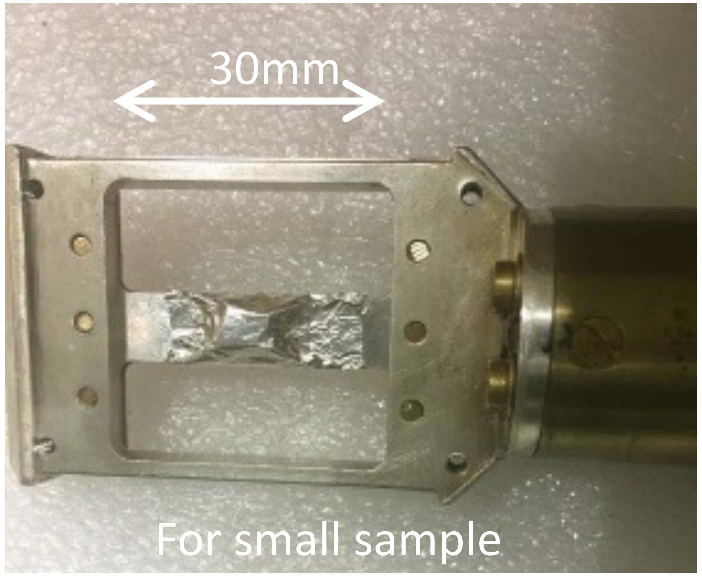
Top-loading type “dry” dilution refrigerator at D1 (Higemoto)

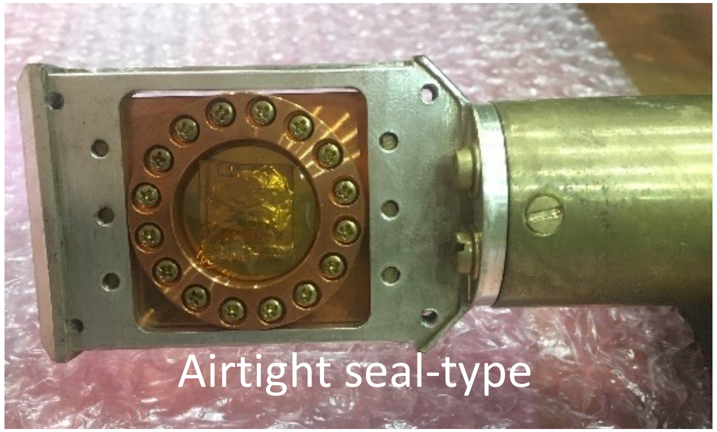


Sample Holders



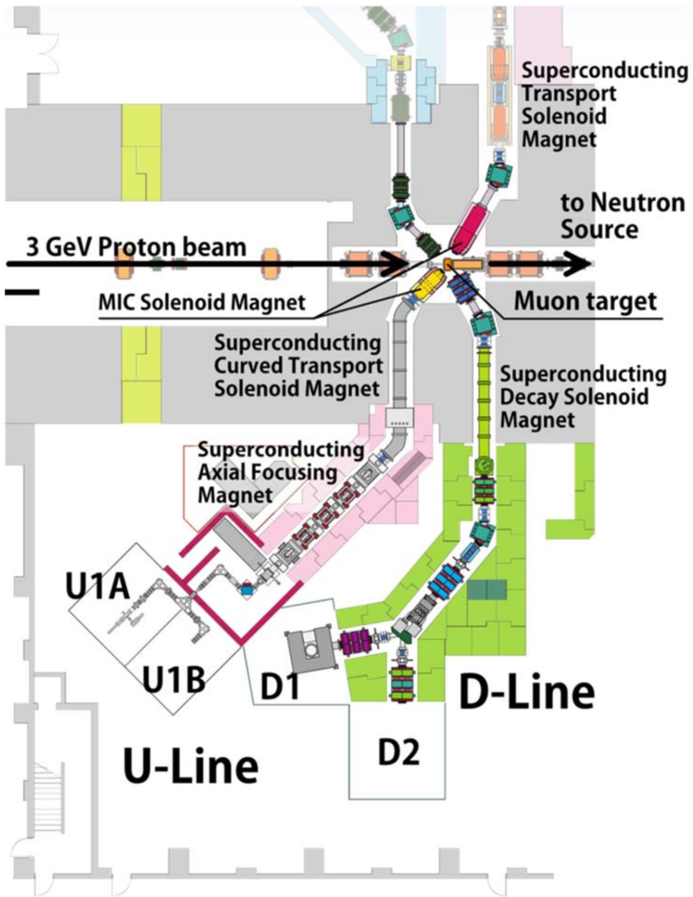






D-line

The secondary beamline for transporting decay and surface muons to D1 and D2 areas



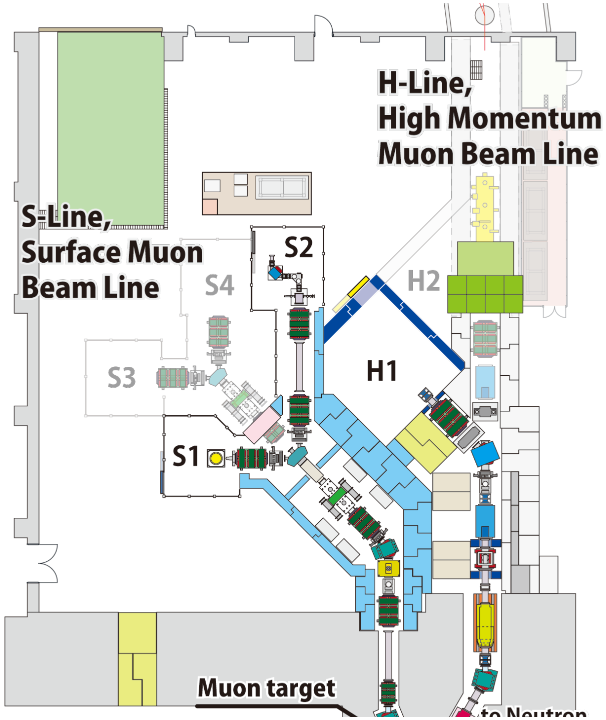
Instrument specifications (as of 2022)

- **Beam line**
  - D-line was constructed at 2008.
  - Magnetic kicker system (2013)
  - Warm bore long solenoid magnet (2015)
  - High power magnet for beam transport (Ongoing)
- **Beam**
  - Surface and decay muons are available.
  - Positive and negative muons are available.
  - Variable momentum beam from 3 to 120 MeV/c
  - Single pulse beam
- **Experimental areas**
  - D1: μSR (Spectrometer)
  - D2: General purpose (Open geometry)

S-Line

S-line

The secondary beamline for transporting surface muons to S1 through S4 area



Instrument specifications (as of 2022)

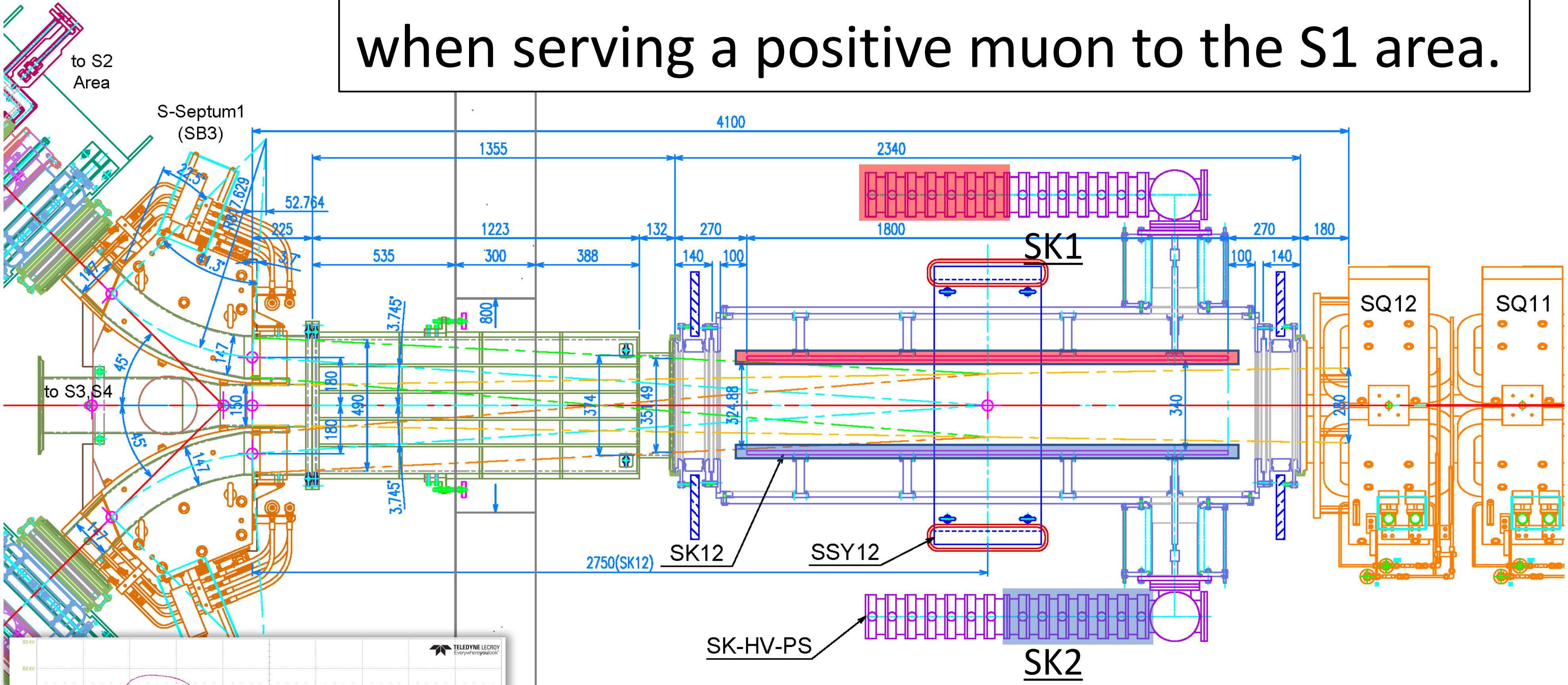
- Typical beam spot size at S1: ø20-25 mm
- Data taking rate: 90 Mevents/hour (single pulsed beam)
- Double pulsed beam either to S1 or S2 is available by using the switchyard magnet.
- Single pulsed beam is available to both S1 and S2 simultaneously, by using the kicker device.

The kicker device is the key component for stable and simultaneous operation both at S1 and S2 areas.

<u>S1</u>: Three staff members and two temporary staff members support the execution of the inter-university research programs. The beamline equipment such as magnets and power supplies are maintained by one technical staff member.
<u>S2</u>: Twelve members of the research group led by Prof. Uetake of Okayama Univ. are participating in the commissioning of the beamline as instrument group members.

S-Line Electric Kicker System No.1

when serving a positive muon to the S1 area.

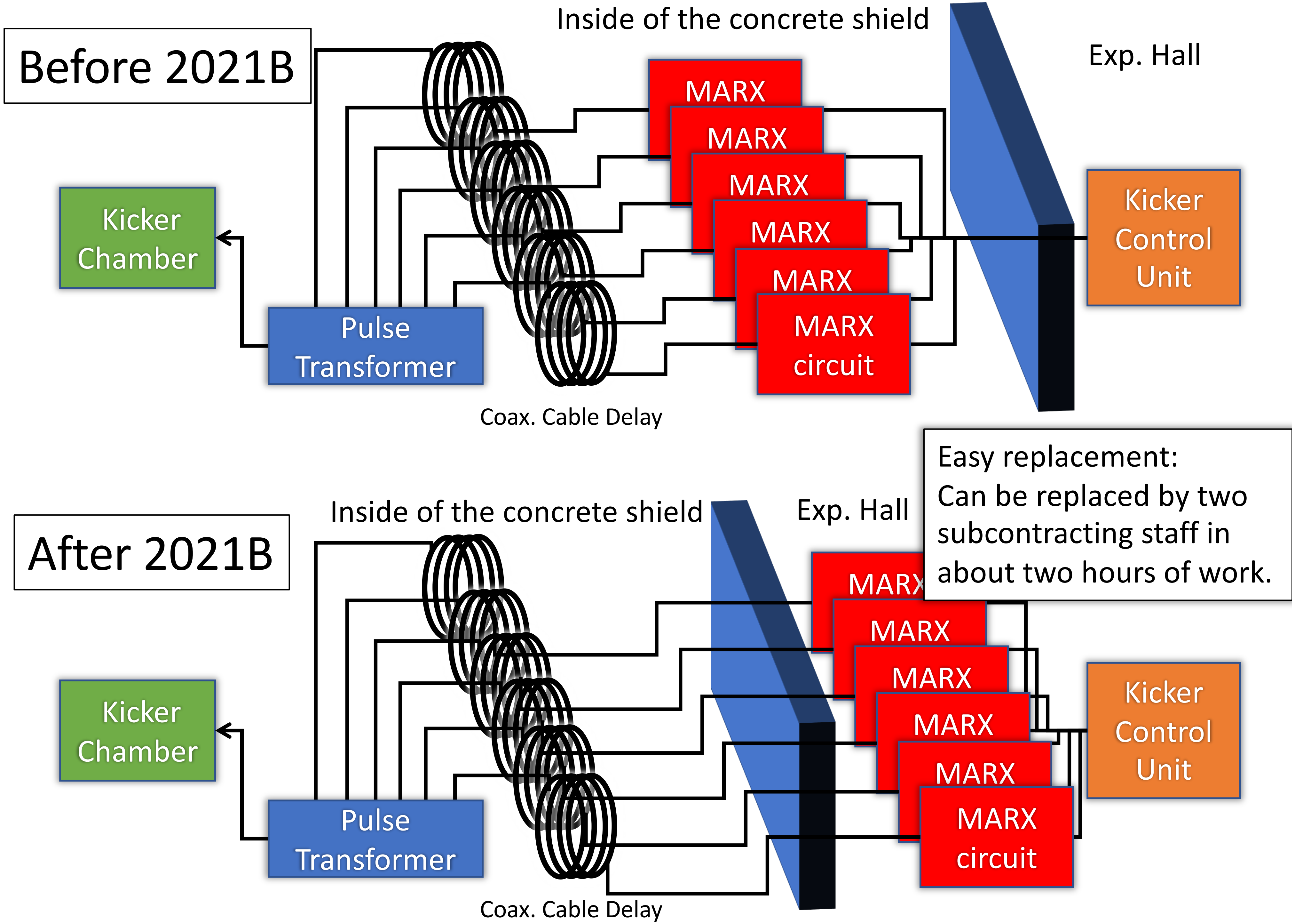


SK12:

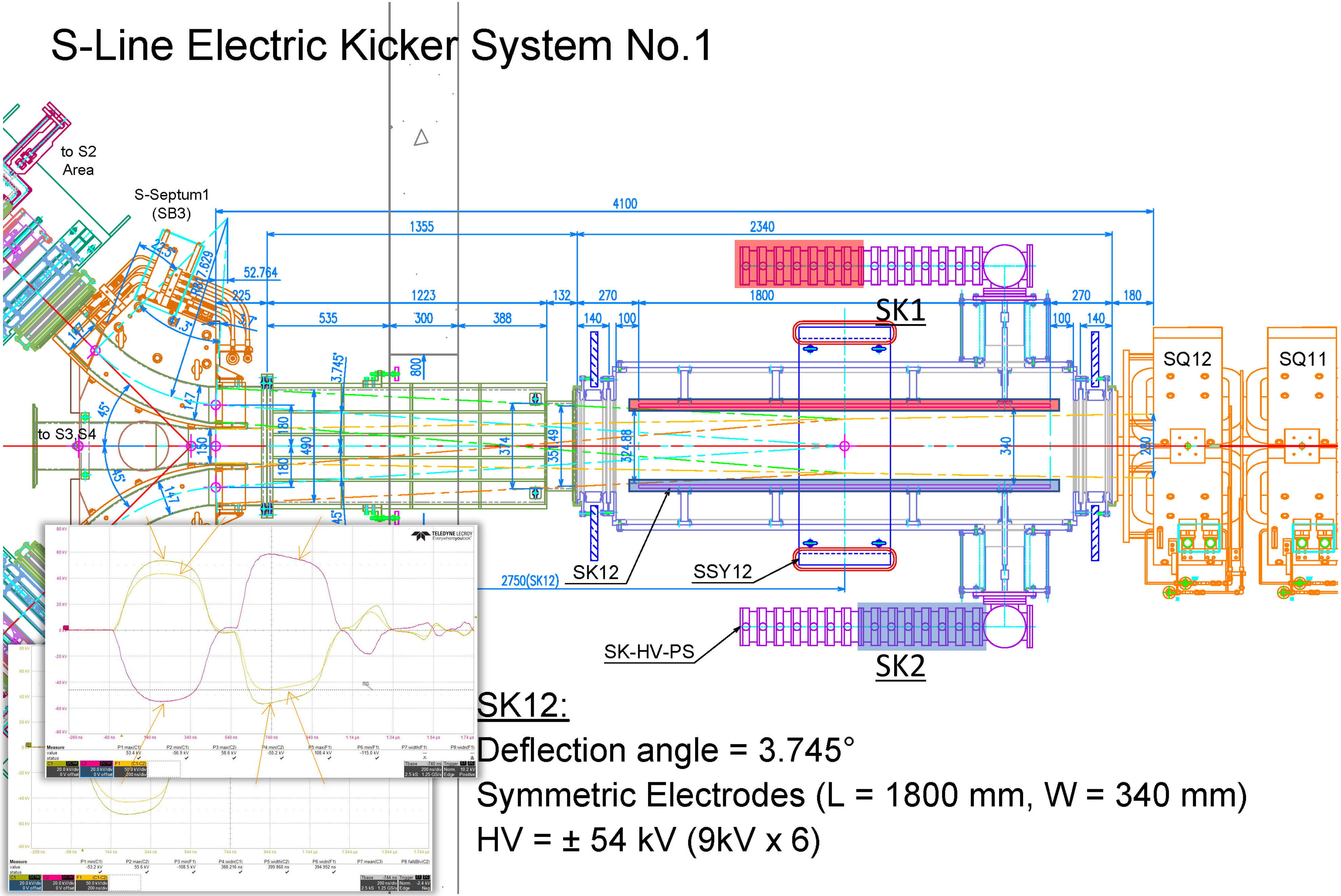
Deflection angle = 3.745°

Symmetric Electrodes (L = 1800 mm, W = 340 mm)

HV = ± 54 kV (9kV x 6)


Before 2021B
Inside of the concrete shield
Exp. Hall
Kicker Chamber
Pulse Transformer
MARX
MARX
MARX
MARX
MARX
MARX circuit
Kicker Control Unit
Coax. Cable Delay
After 2021B
Inside of the concrete shield
Exp. Hall
Easy replacement:
Can be replaced by two subcontracting staff in about two hours of work.
Kicker Chamber
Pulse Transformer
MARX
MARX
MARX
MARX
MARX
MARX circuit
Kicker Control Unit
Coax. Cable Delay

S-Line Electric Kicker System No.1



SK12:

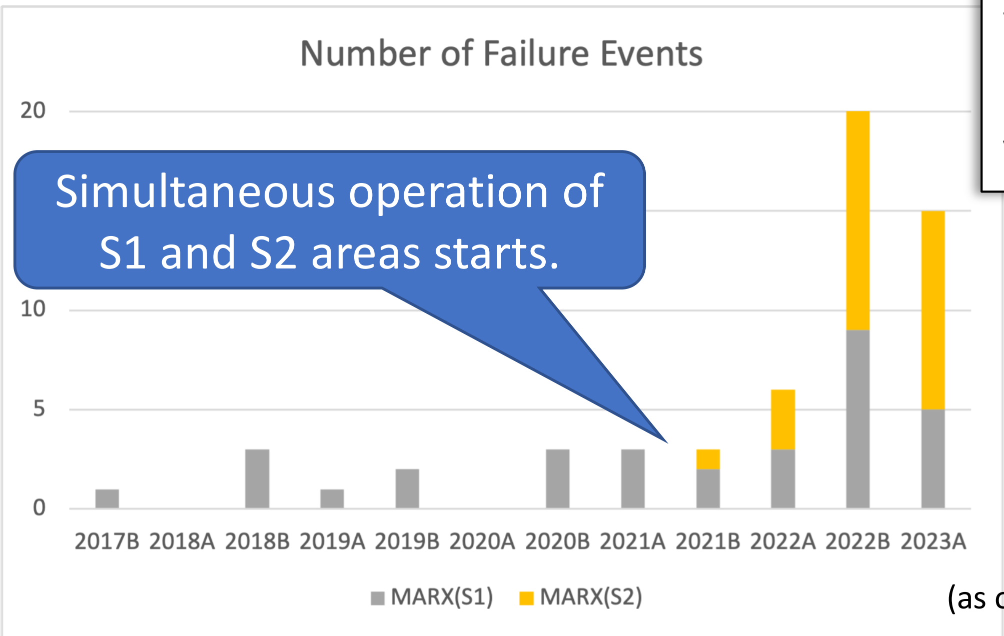
Deflection angle = 3.745°

Symmetric Electrodes (L = 1800 mm, W = 340 mm)

HV = ± 54 kV (9kV x 6)

S-line Kicker trouble (T. Yuasa and A. Koda)

- Most kicker power supply failures are currently caused by MARX board breaking.
- At the repairing work in Oct. 2022, a study was conducted on how to perform preventive diagnosis of the MARX board.
- The leakage current when 650 VDC was applied was measured, and while most boards had a leakage current of around 20 uA, one board was found to have a leakage current of 140 uA and was replaced.
- By establishing a preventive diagnosis method, we expected to be able to perform preventive replacement work on maintenance days and achieve stable operation during beamtime…(sigh)
- HOWEVER, the results, as shown below, indicate that preventive diagnosis is far from being effective.



(as of Jun. 2023)

We are considering to replace the MARX boards with new SiC FETs.

Heliox ACV: ^{3}He cryostat (Nakamura)

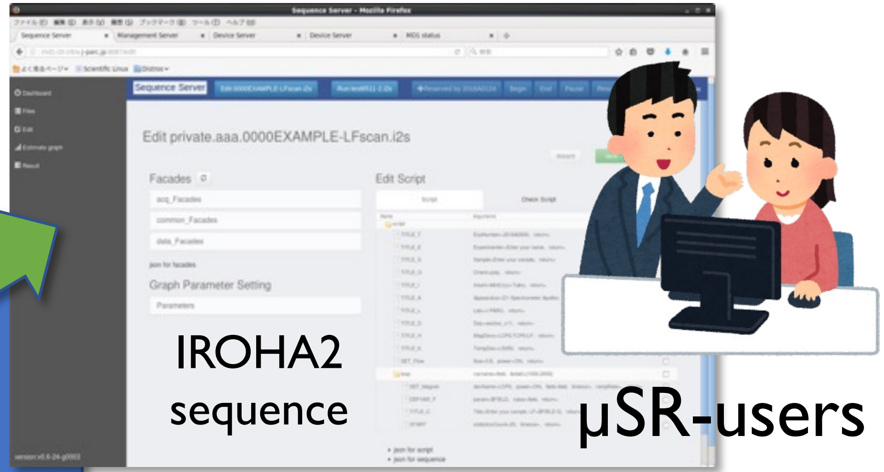
- Dry-type 3He cryostat using a pulse tube refrigerator.
- It takes about 2 days to cool down from RT.
- The sample changing is performed at RT by opening the vacuum cans.
- Silver sample holders are used which are common with DR at D1.
- 3 proposals using Heliox ACV are approved in the 2023A term, which is 18% of the entire proposals at S1.

D1/S1 Instrument (μSR)

Inter-operability between D1 and S1

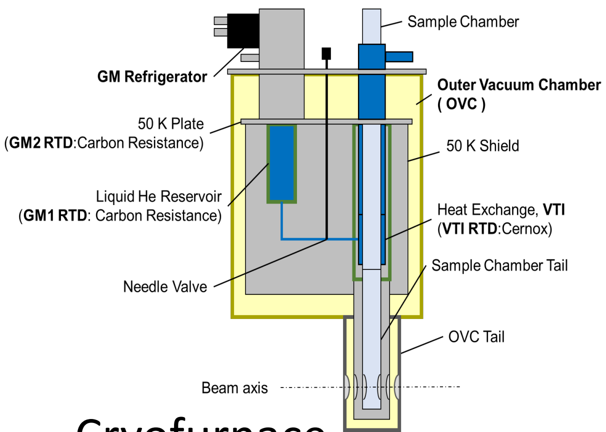
	D1	S1	duality
Microstat (T>4K)	OK!	OK!	Yes
Vertical cryostat (T>3K)	OK!	OK!	No
Closed Cycle Fridge (T>1.5K); w/ HT option (T<800K)	NA	OK	
^{3}He cryostat (T>0.3K)	NA	OK	
Dilution Fridge (T>0.08K)	OK	NA	
Infrared Furnace (T<1000K)	OK!	OK!	No
Micro Transverse-field Coils (μTC; TF<40mT)	OK	OK	Yes

Common Look & Feel to the users



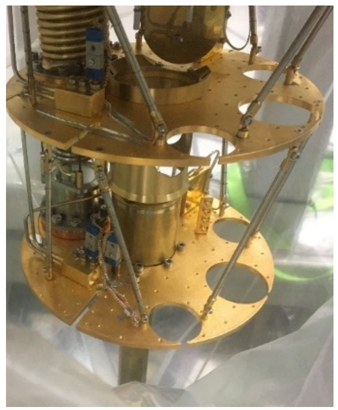
Device server

Temp. controller



Cryofurnace

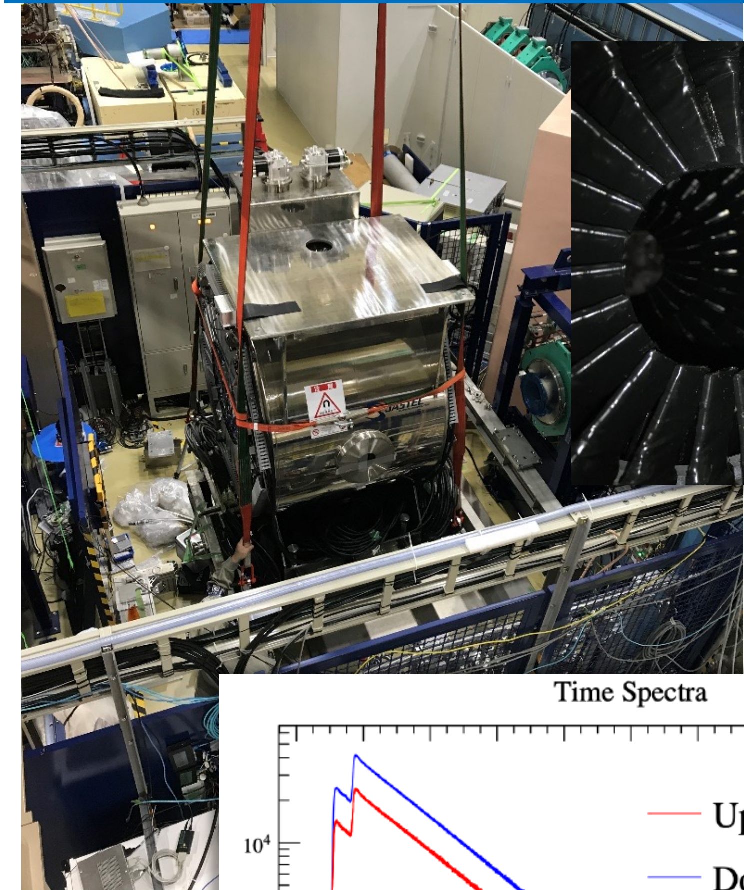
Microstat

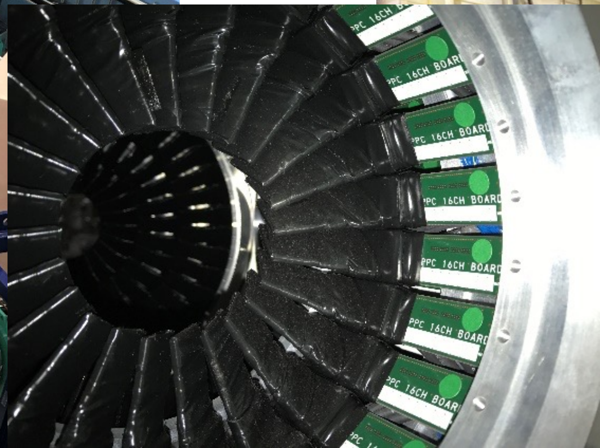


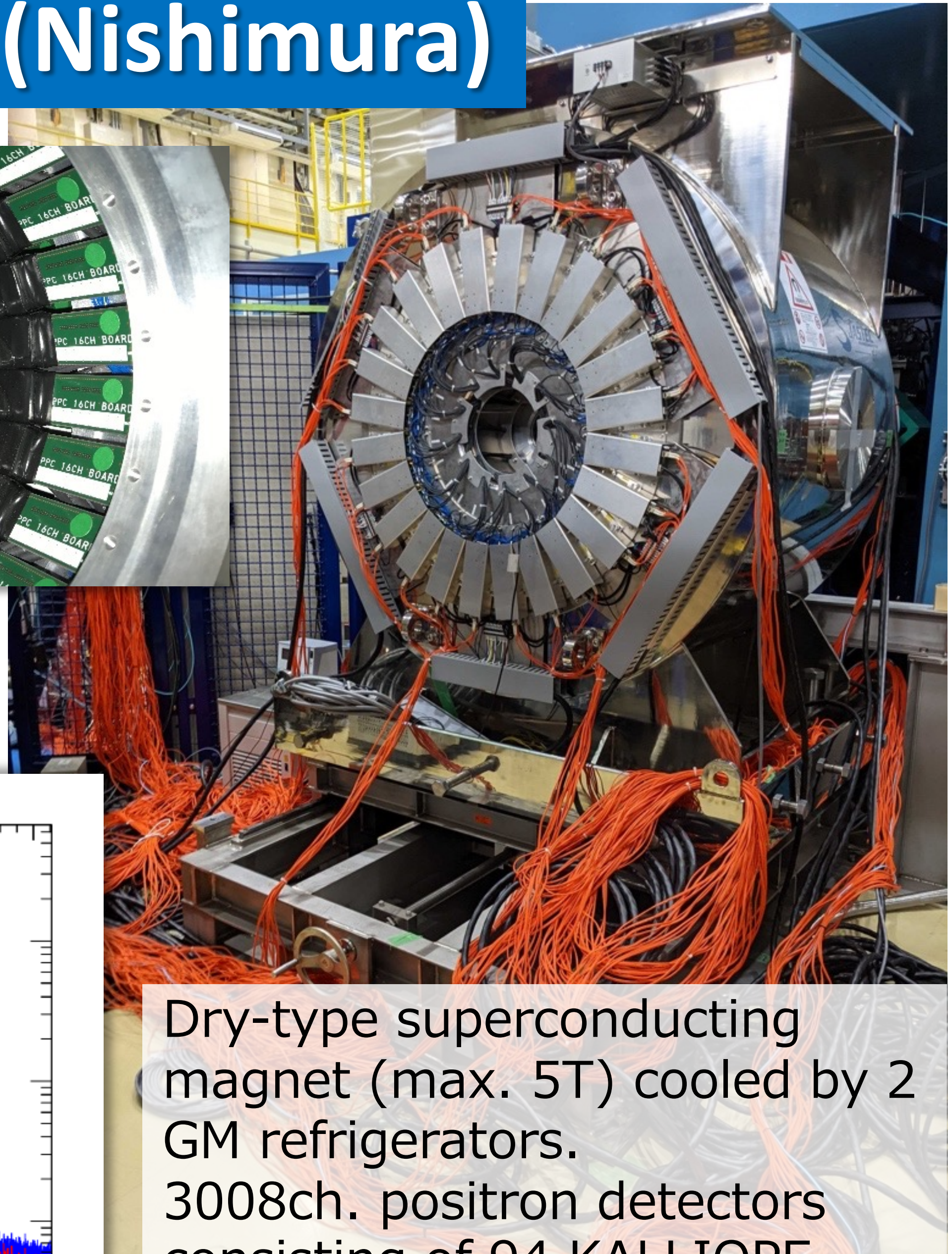
Dilution Fridge

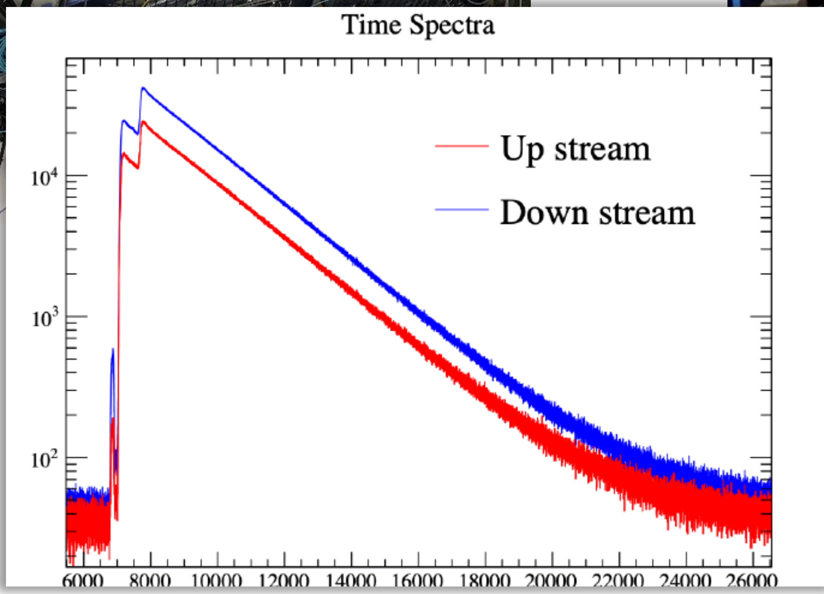
High Field Spectrometer: CYCLOPS

5T μSR spectrometer (Nishimura)



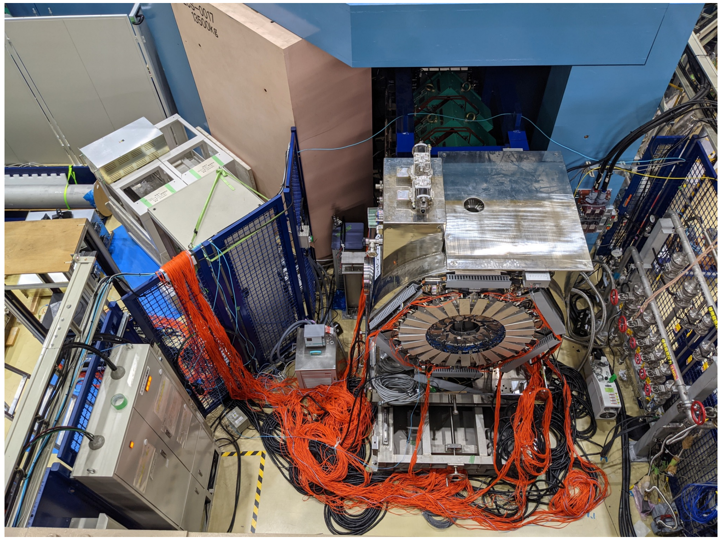


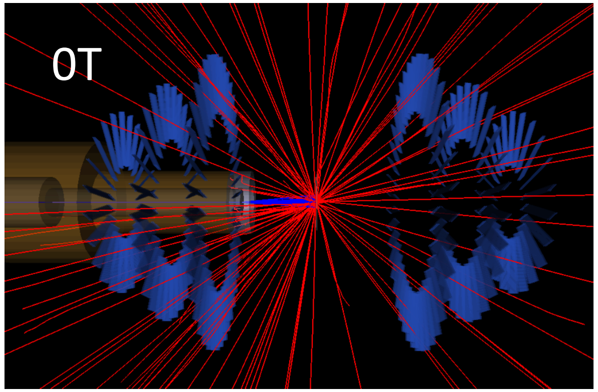


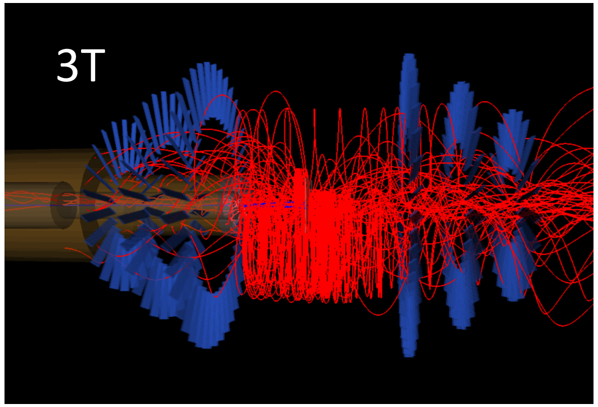


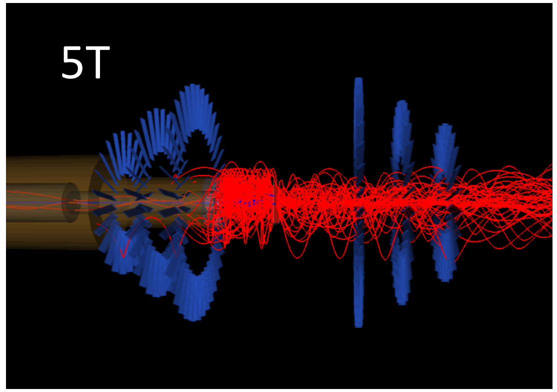
Dry-type superconducting magnet (max. 5T) cooled by 2 GM refrigerators.
3008ch. positron detectors consisting of 94 KALLIOPE modules.

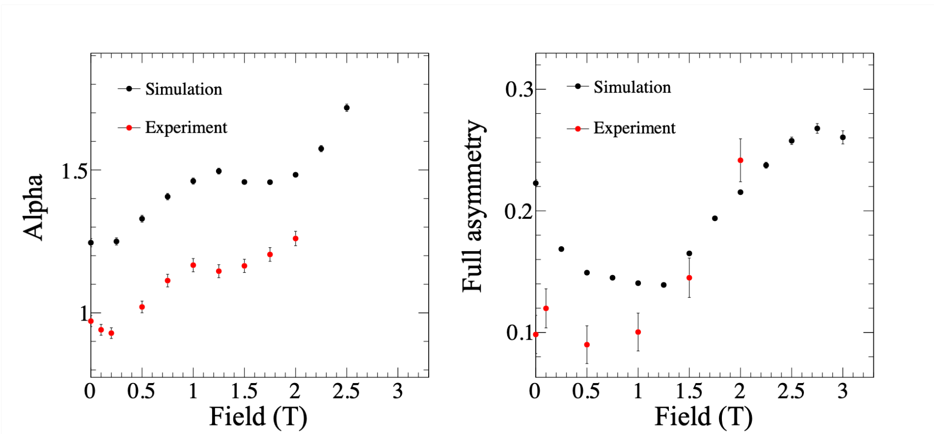
CYCLOPS (5T superconducting μSR spectrometer): The commissioning work has begun upon comparing the behavior of the detector under magnetic fields with simulations.











There was a problem when applying fields above 2T due to the cooling problem of the superconducting coil, so the repairing work was carried out at the factory of the manufacturer.

Development of new technique: transient μSR

Nuclear Instruments and Methods in Physics Research A 1056 (2023) 168669

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

Full Length Article

Development of transient μSR method for high-flux pulsed muons

Shoichiro Nishimura [a,b,*], Hirotaka Okabe [a,c], Masatoshi Hiraishi [d], Masanori Miyazaki [e], Jumpei G. Nakamura [a,b], Akihiro Koda [a,b,f], Ryosuke Kadono [a,b]

[a] Muon Science Laboratory, Institute of Materials Structure Science, High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki 305-0801, Japan
[b] Materials and Life Science Division, J-PARC Center, Tokai, Naka, Ibaraki 319-1106, Japan
[c] Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan
[d] Graduate School of Science and Engineering, Ibaraki University, Mito, Ibaraki, 310-8512, Japan
[e] Muroran Institute of Technology, Muroran, Hokkaido 050-8585, Japan
[f] Department of Materials Structure Science, The Graduate University for Advanced Studies (Sokendai), Tsukuba, Ibaraki 305-0801, Japan

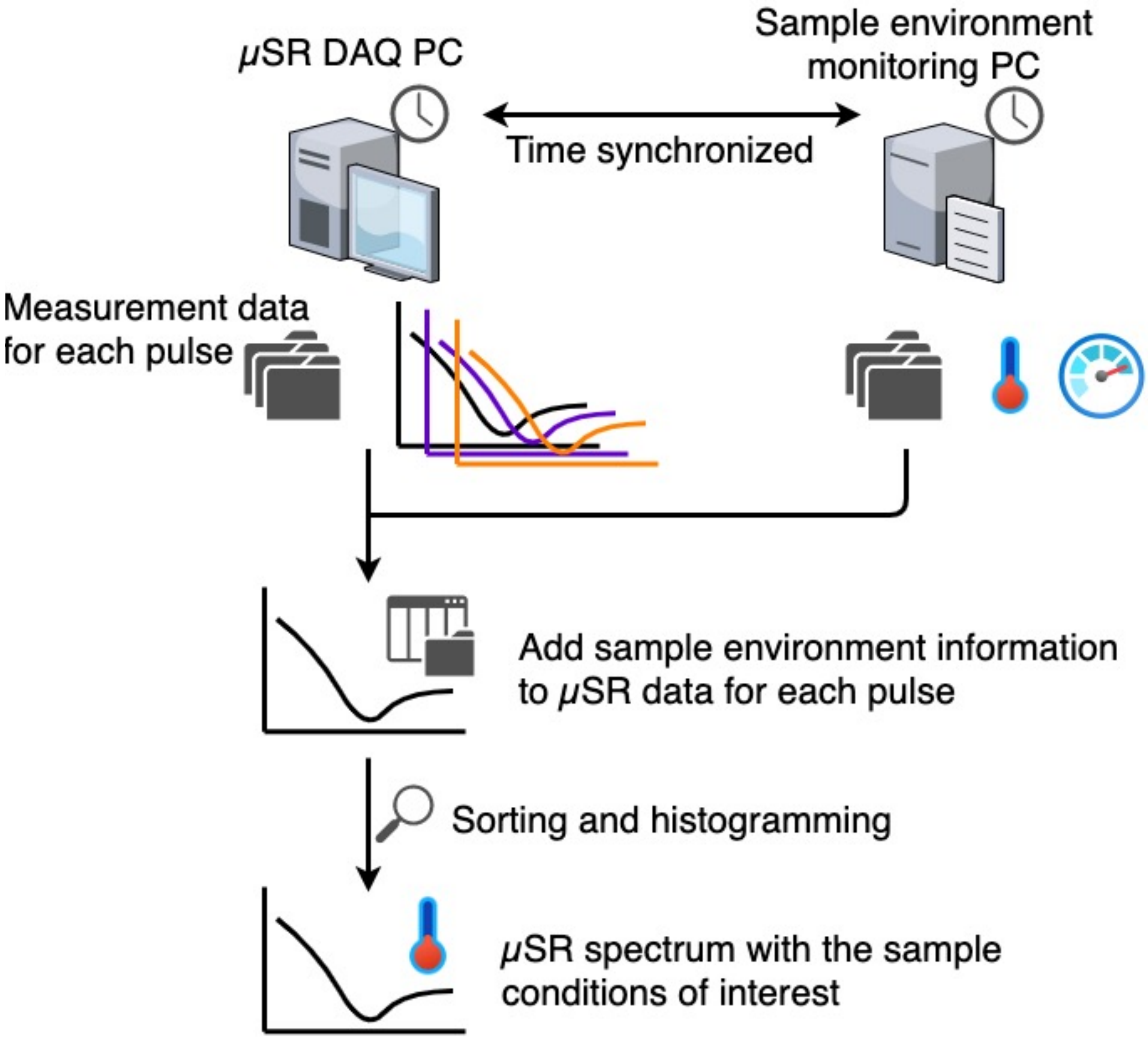
ARTICLE INFO

Keywords:
Muon spin rotation
Relaxation
And resonance
x beam
omena

ABSTRACT

In order to expand the applicability of muon spin rotation, relaxation, and resonance (μSR) experiments with pulsed muons and to make effective use of the high-flux beam, we have developed a new experimental method "transient μSR". In this method, μSR data for each muon pulse are tagged with external parameters such as temperature and magnetic field in real time, allowing the sample environment to be changed without interrupting data collection. As a result, continuous μSR measurements under sample conditions that vary on a time scale longer than the beam pulse interval (40 ms) are realized, and efficient beam utilization is achieved by eliminating the lag time associated with moving between discrete measurement points. The transient μSR method was applied to the study of the magnetic properties of cupric oxide (CuO) and the observation of level-crossing resonance relaxation in copper, and the method was successfully established by confirming that the results reproduce those in the previous reports.

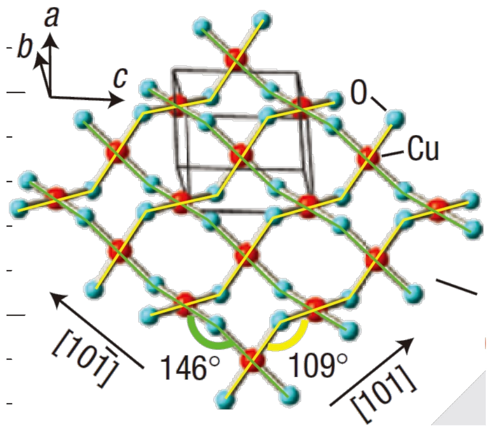
https://doi.org/10.1016/j.nima.2023.168669

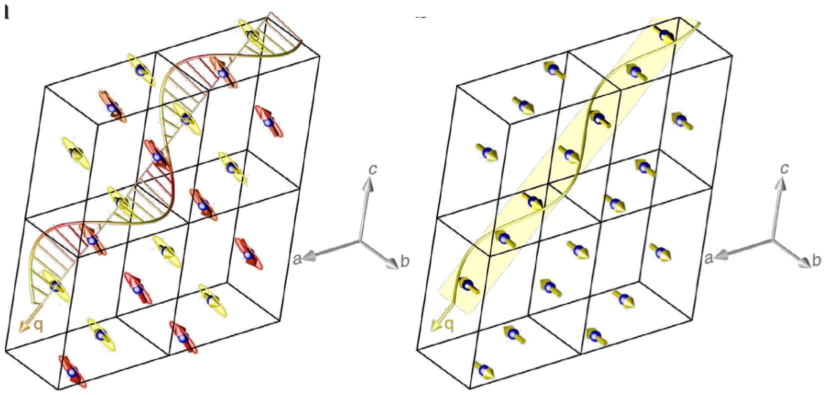


μSR DAQ PC
Sample environment monitoring PC
Time synchronized
Measurement data for each pulse
Add sample environment information to μSR data for each pulse
Sorting and histogramming
μSR spectrum with the sample conditions of interest

キャプション

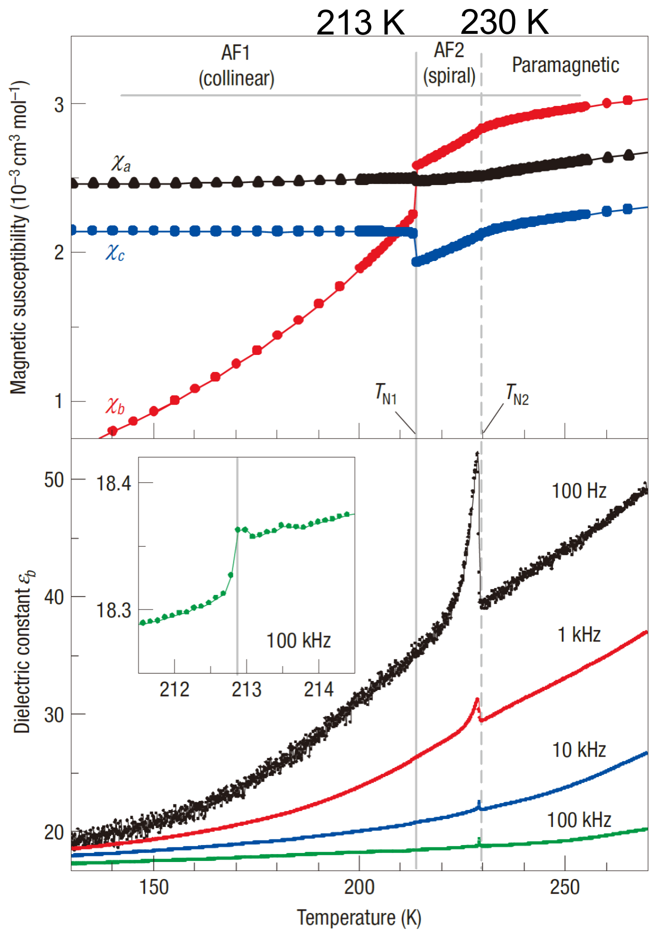
CuO



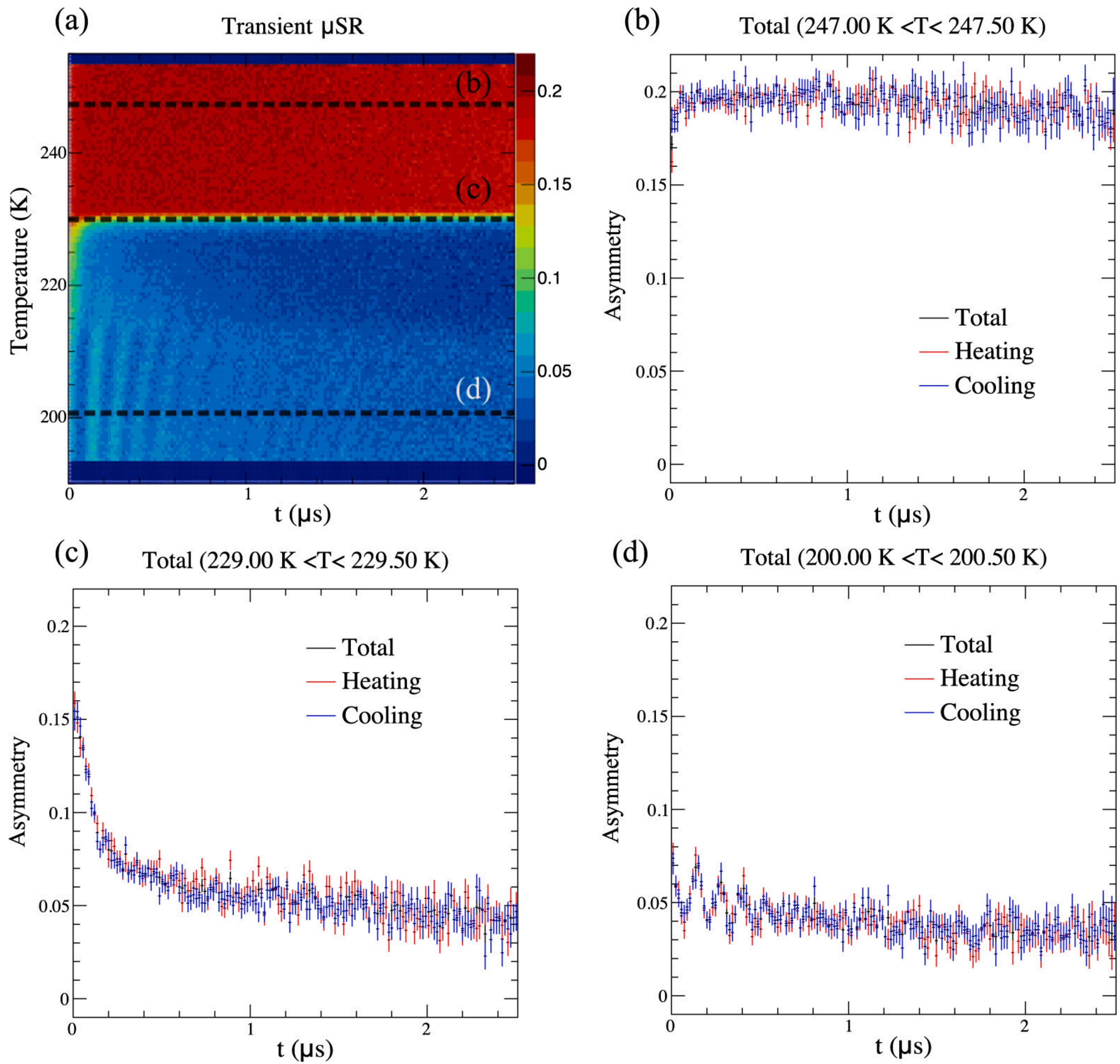


Commensurate Incommensurate

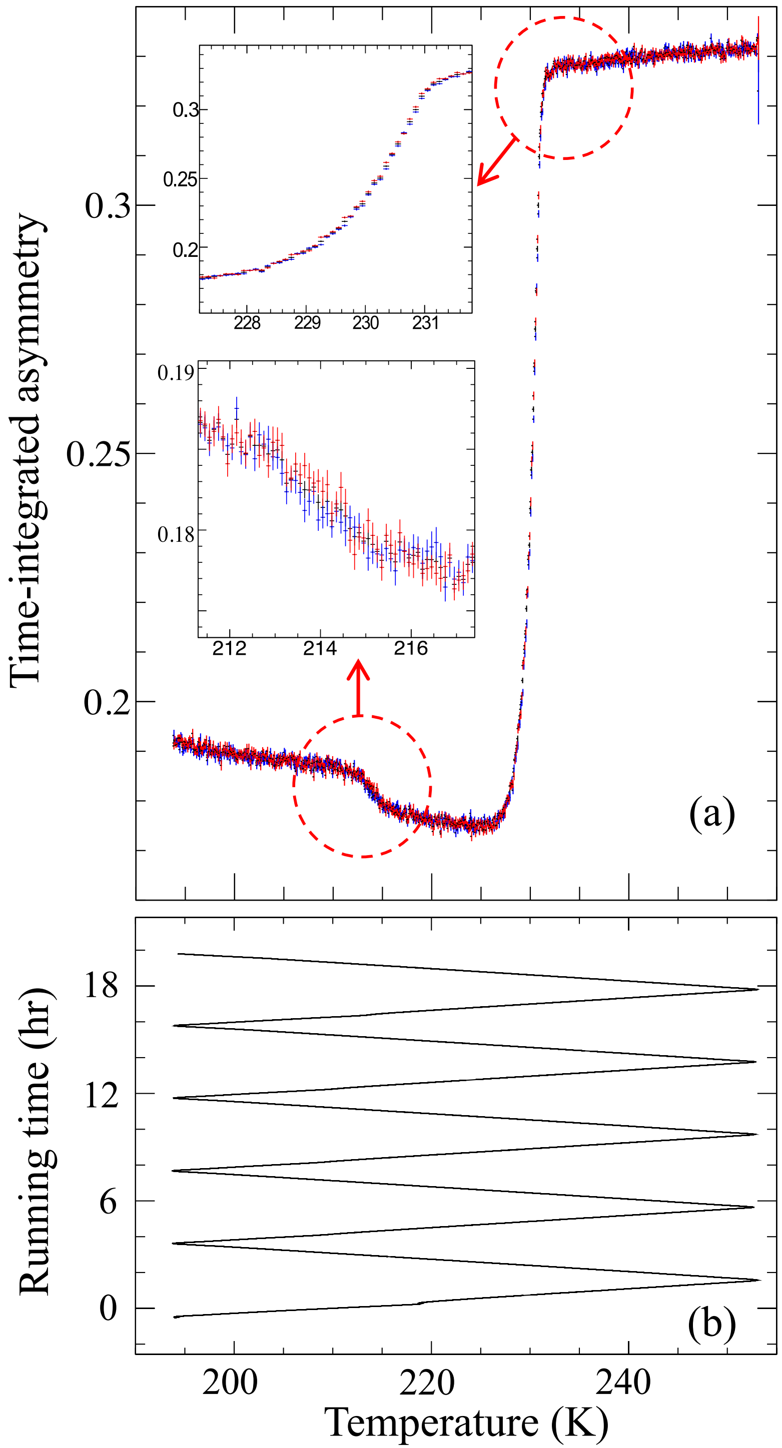
Z. Wang, Nature Communications 7, 10295 (2016).



T. Kimura, Nature Materials 7, 291-4.(2008).

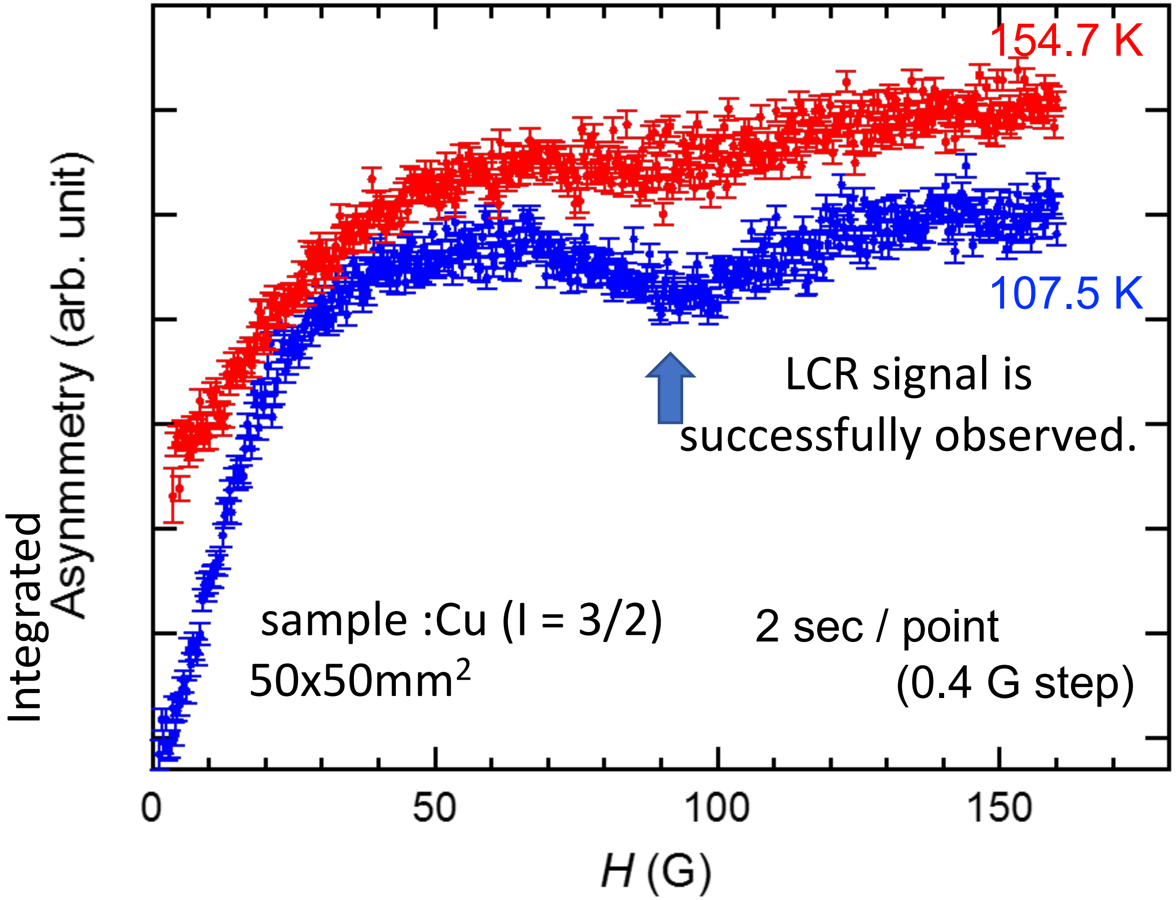


Nishimura et al.



Nishimura et al.

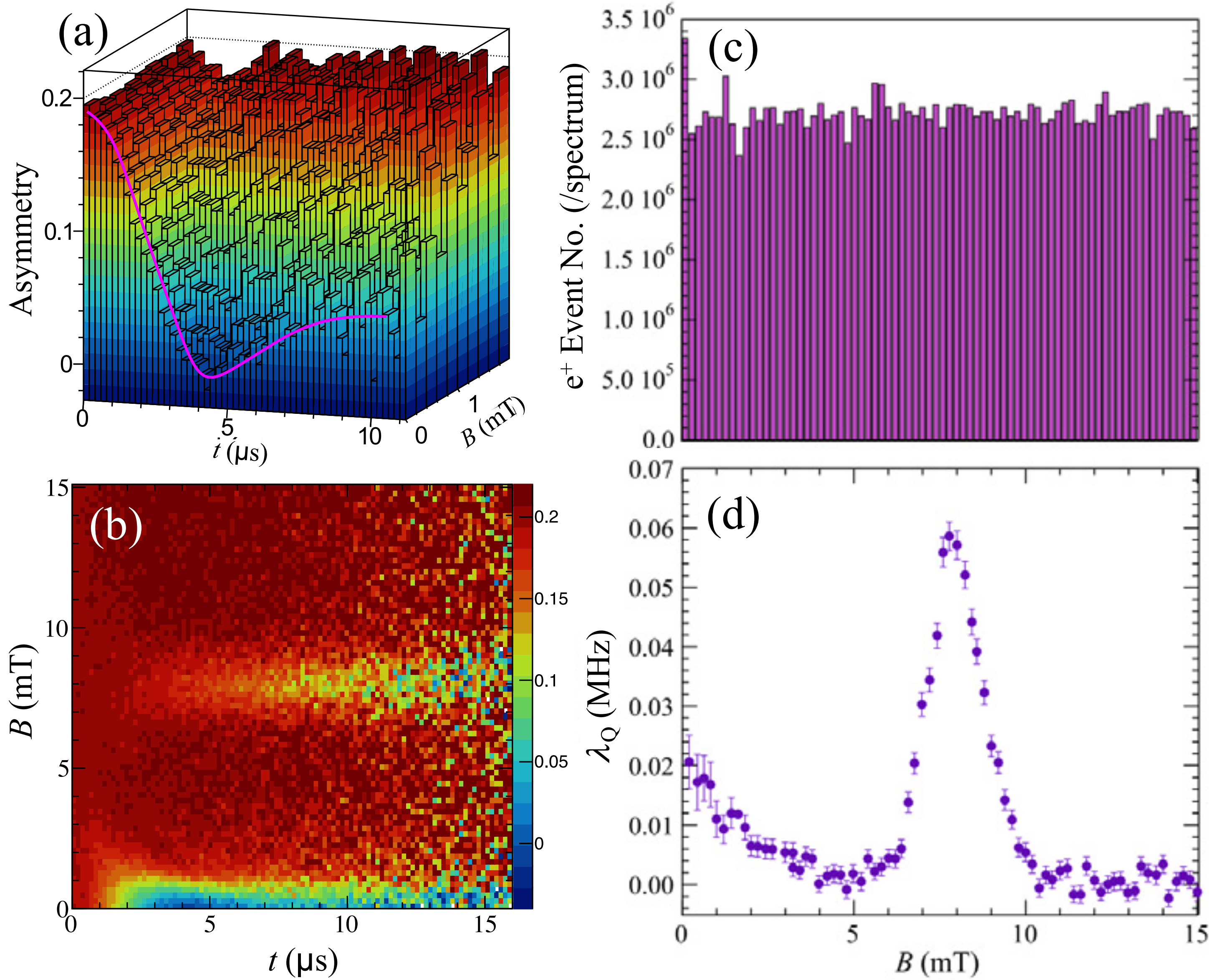
Cu-LCR test measurement at 1MW test operation



Muon decay events were accumulated for **2 Sec.** at each point.

400 points were measured with increasing or decreasing field, roughly taking 14 min.

Cu-LCR at T=50K



Nishimura et al.

Summary

- At both D-line and S-line in J-PARC MLF, surface muon beam is available.
- In particular, positive and negative muon experiments, or surface and decay muon experiments are sharing the beamtime at D-line, because D-line can provide versatile muon beam.
- Besides, S-line is mainly designed to serve positive surface muon beam. At this stage, S1 and S2 areas are operating. In future, it is planned to construct further two experimental areas, S3 and S4, sharing the single pulsed beam.
- However, the key beamline equipment, the electric kicker, fails frequently.
- The sample environments are commonly shared with the multiple experimental areas. In order to operate smoothly, duality is necessary. This is also important from the viewpoints of both development and improvement.
- New techniques such like the high-field spectrometer and the transient μSR have been intensively developed.

fin.