Beam loss monitoring in NanoTerasu storage ring with active neutron dosimeter

Photo courtesy of PhoSIC

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Session 1

SATIF-16 @ INFN-LNF

Outline

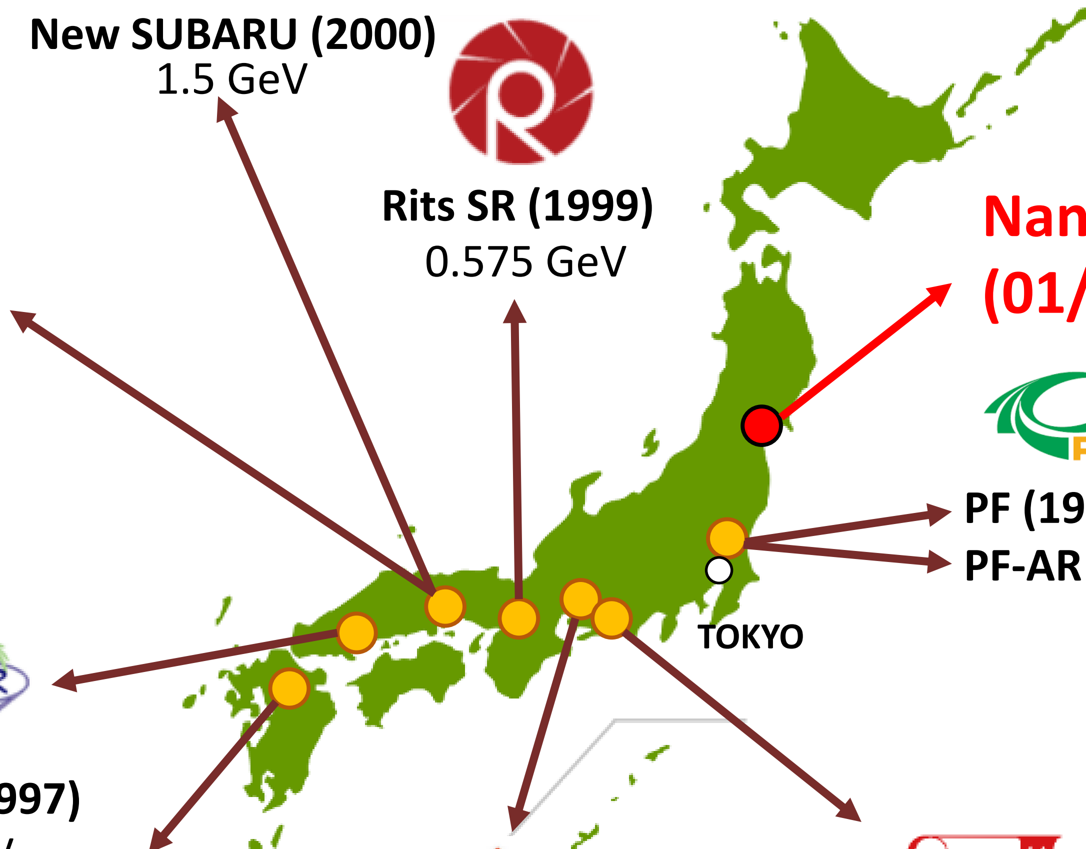
1. NanoTerasu
    a. Synchrotron Radiation Facilities in Japan
    b. Introduction
    c. Overview

2. Experiment
    a. Motivation
    b. Beam losses
    c. Detector
    d. Regular loss
    e. Irregular loss

3. Summary

1-a : Synchrotron Radiation Facilities in Japan

(Operation start)



SACLA (2012)
8 GeV

SPring-8 (1997)
8 GeV

New SUBARU (2000)
1.5 GeV

Rits SR (1999)
0.575 GeV

NanoTerasu
NanoTerasu
(01/04/2024~)
3.0 GeV

PF (1983) 2.5 GeV
PF-AR (1987) 6.5 GeV

HiSOR (1997)
0.7 GeV

SAGA-LS (2006)
1.4 GeV

AichiSR (2013)
1.2 GeV

UVSOR (1984)
0.75 GeV

1-b: Introduction

NanoTerasu

Origin of the facility's name

Nano	:	the scale of observation that will be conducted at the facility
Terasu	:	the Japanese word for shining a light on something
		the goddess of the sun in Japanese mythology "Amaterasu"

14/05/2023

The G7 Science and Technology Ministers' Meeting was held in the experimental hall of NanoTerasu.

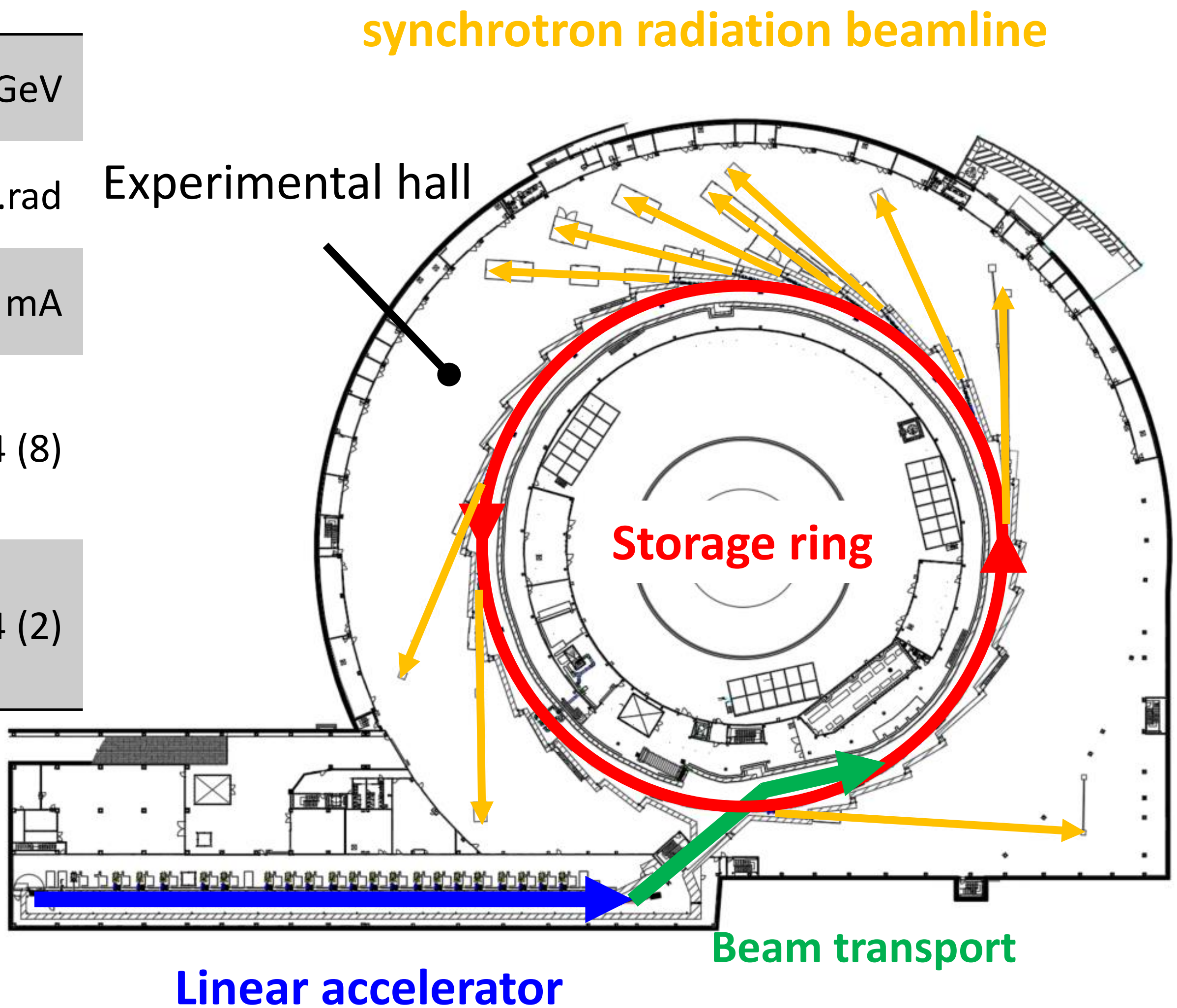
20/05/2024

NanoTerasu signs Memorandum of Understanding (MoU) with MAX IV

https://www8.cao.go.jp/cstp/english/others/2023/g7_2023_en.html

1-c: Overview of NanoTerasu

Parameters	
Beam energy	3 GeV
Normalized emittance	1.14 nm.rad
Beam current	400 mA
Max (Beginning). number of undulators	14 (8)
Max (Beginning). number of multi-pole wigglers	14 (2)

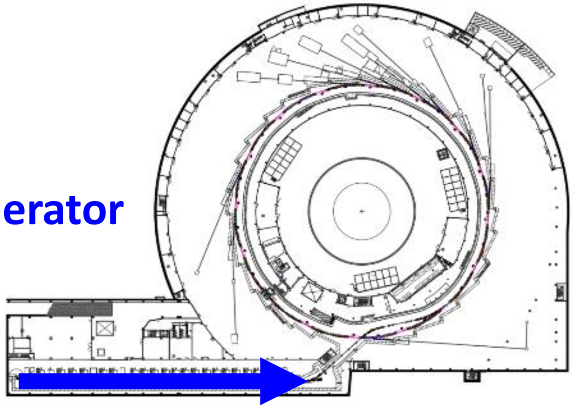


Maps Data: Google, ©2020 CNES / Airbus, Maxar Technologies, Planet.com

1-c: Linear accelerator

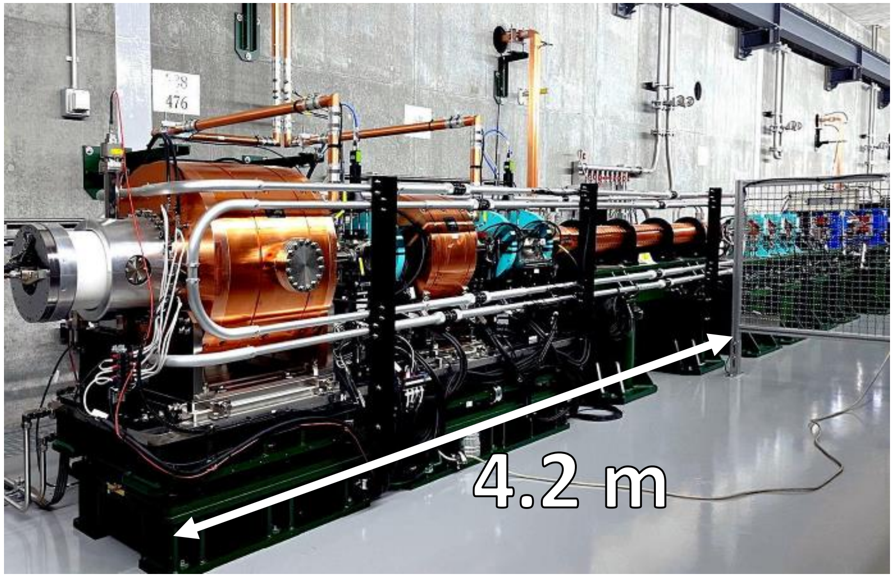
Compact and high performance

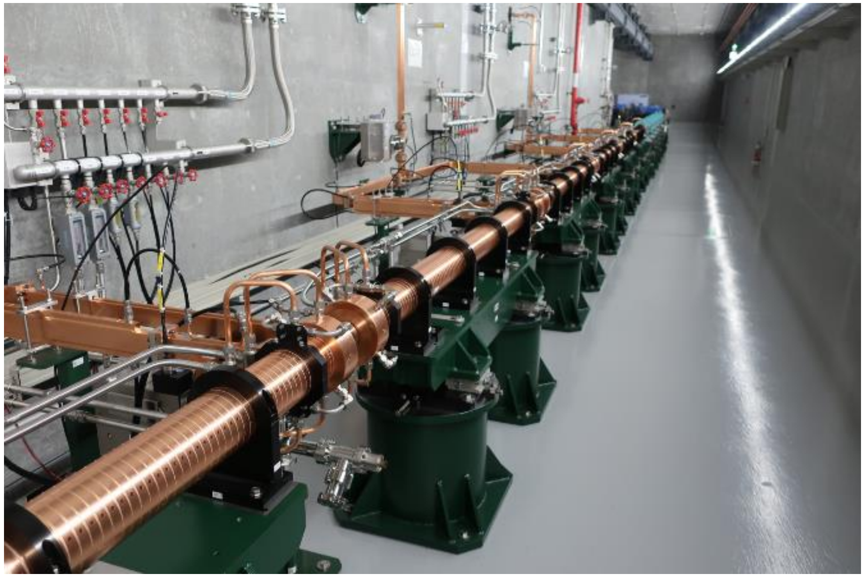
3GeV Linear accelerator	length
NanoTerasu	110 m
MAX IV (Sweden)	300 m



New compact electron gun system using a commercial grid thermal cathode

3 GeV C-band (5.7 GHz) accelerator (40 of 2m-long-cavities)

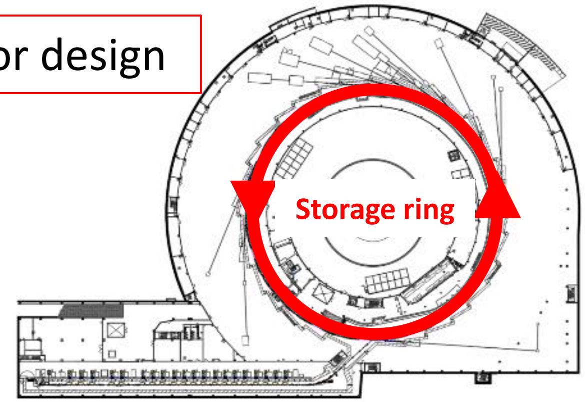


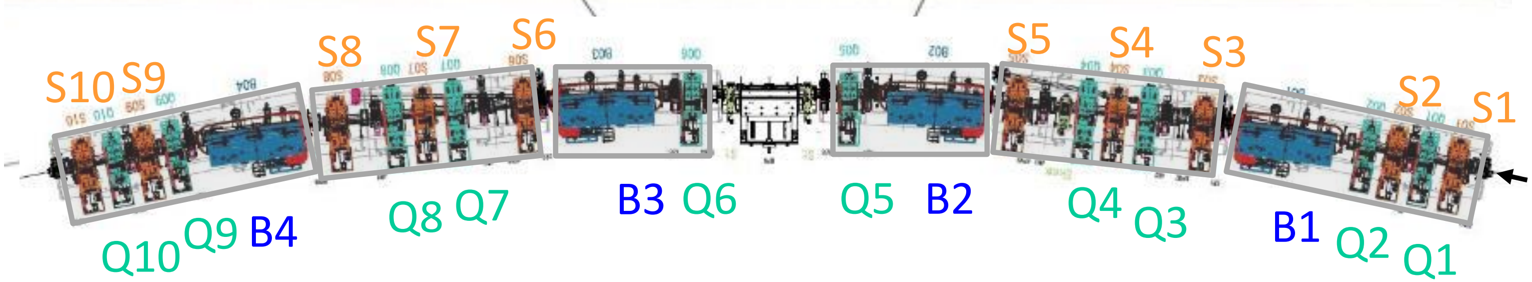


1-c: Storage Ring

MBA (Multi-bend achromat) lattice with the latest accelerator design

3GeV Storage Ring	circumference
NanoTerasu	349 m
TPS (Taiwan Photon Source)	518 m



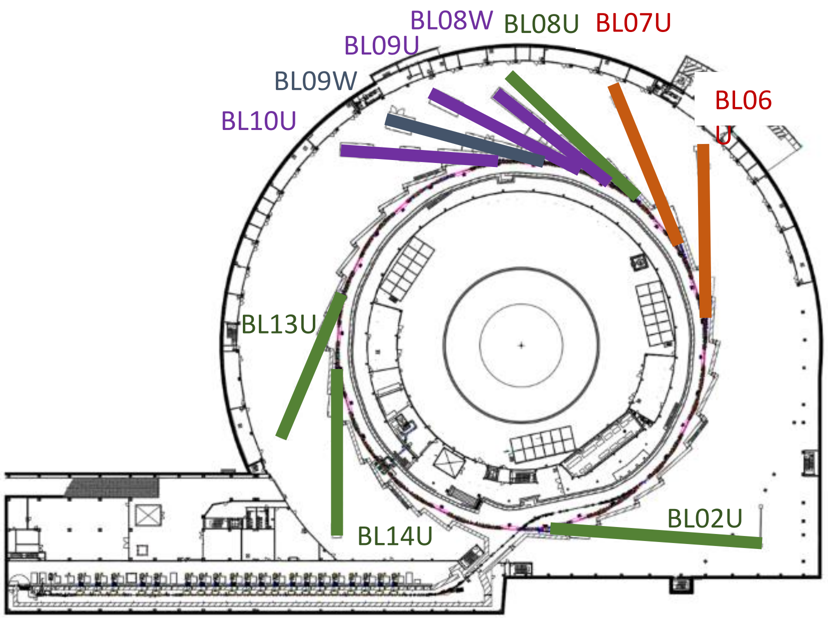


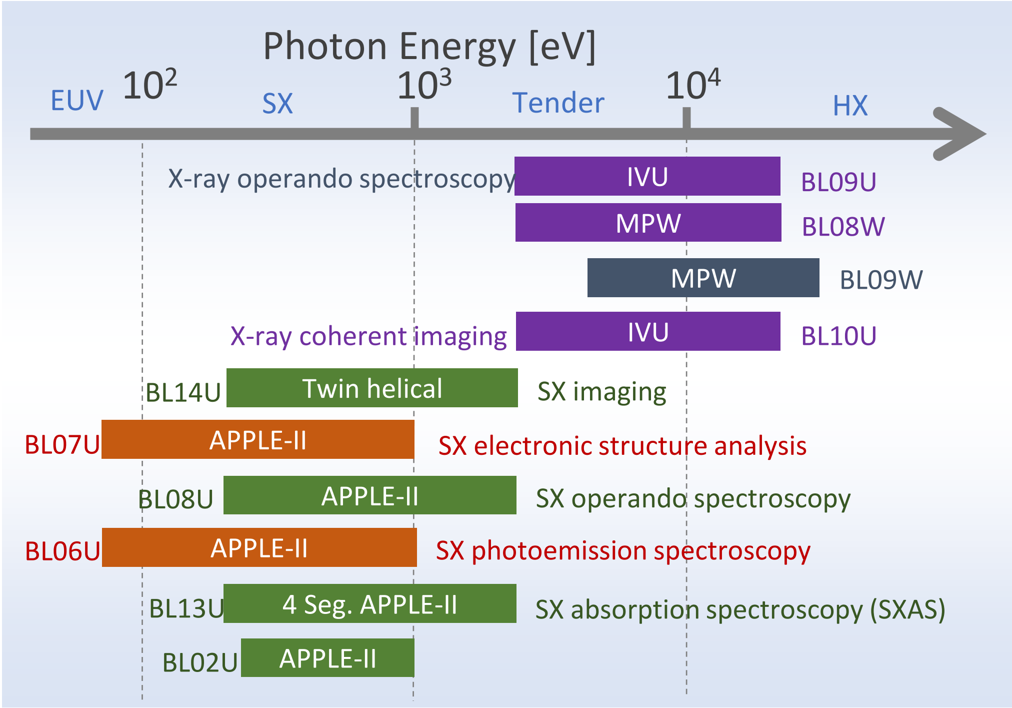
B : Bending magnet 4
Q: Quadrupole magnet 10
S: Sextupole magnet 10

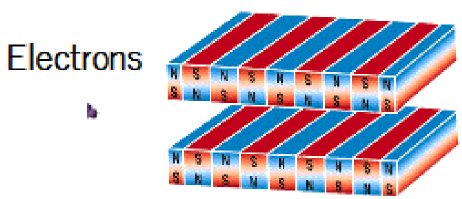
× 16 Cells

1-c: Beamlines

All the beamlines use insertion devices Undulator or Multipole Wiggler







Synchrotron radiation from undulator magnets

Undulator

APPLE-II
4 Seg. APPLE-II
Twin helical
IVU

2-a: Motivation

- Measurement of beam loss in the accelerator tunnel

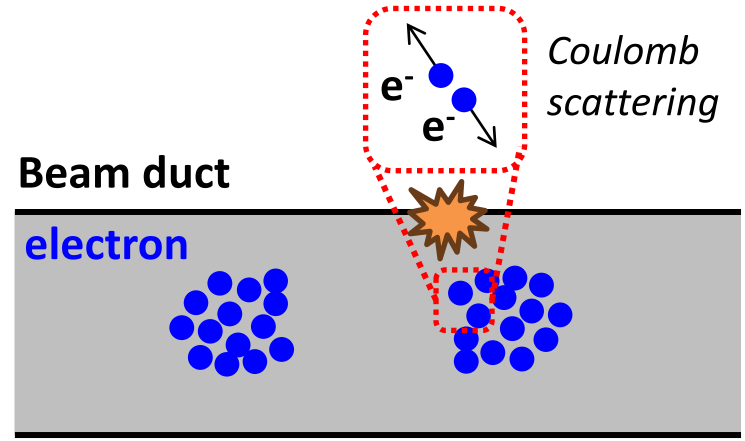
- Stable operation of accelerators

➡ Radiation measurements that can be compared with accelerator operating conditions

Comparative data
Beam current, Vacuum pressure, Undulator Gap, etc.

2-b: Beam losses

Regular losses:

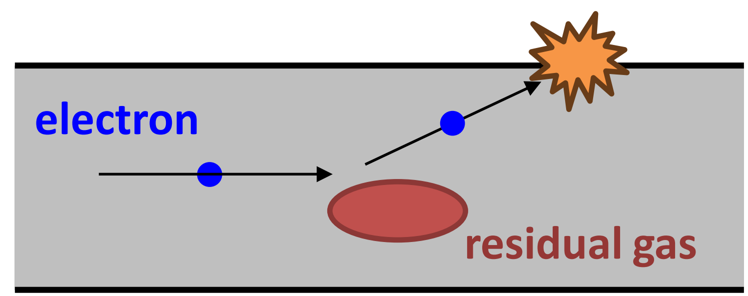


- Touschek Scattering

Dependence of beam current

- Residual Gas Scattering

Dependence of vacuum pressure



Irregular losses:

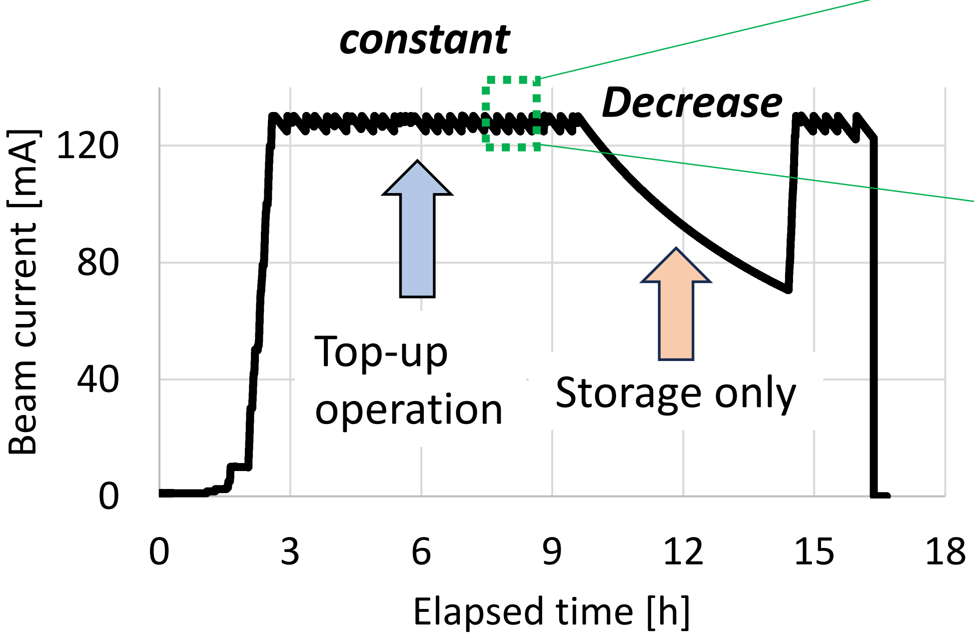
- Equipment abnormality, etc.

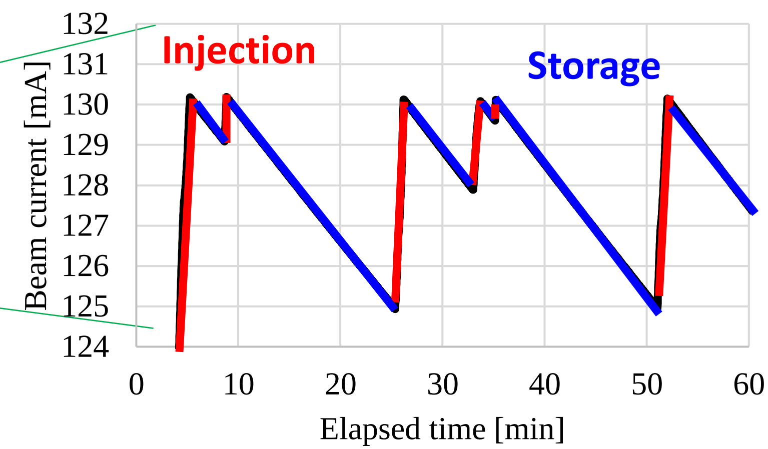
2-b: Beam losses

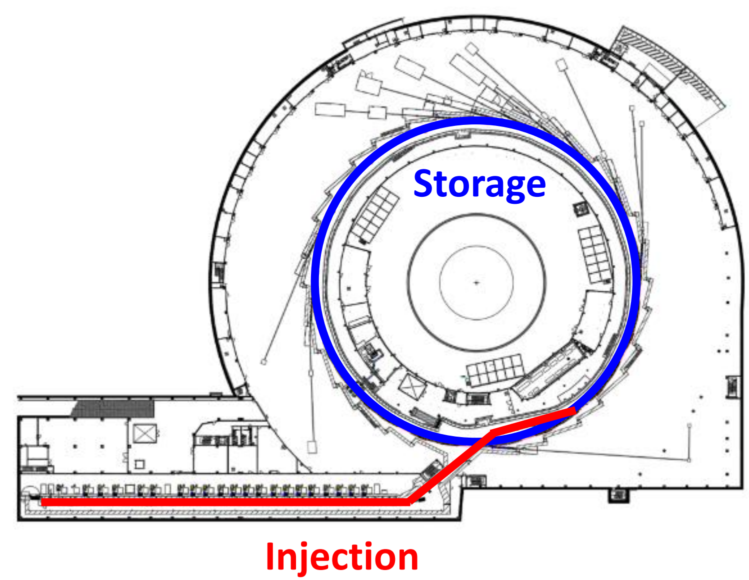
Storage Ring Operation

Electrons are frequently injected into the storage ring to keep the current

➡ *Top-up operation*







In the case of storage only, beam current decreases due to regular loss.

2-c: Detector

Personal Electronic Dosimeter DMC3000N（Neutron Module）

MIRION TECHNOLOGIES

Neutron Module

	Photon	Neutron
Detector	Silicon diode	Li-6, PE + Silicon diode
Energy range	15 keV ~ 7 MeV	0.025 eV ~ 15 MeV
Dose range	1 uSv ~ 10 Sv	1 uSv ~ 10 Sv
accuracy	<±10%	<±10%

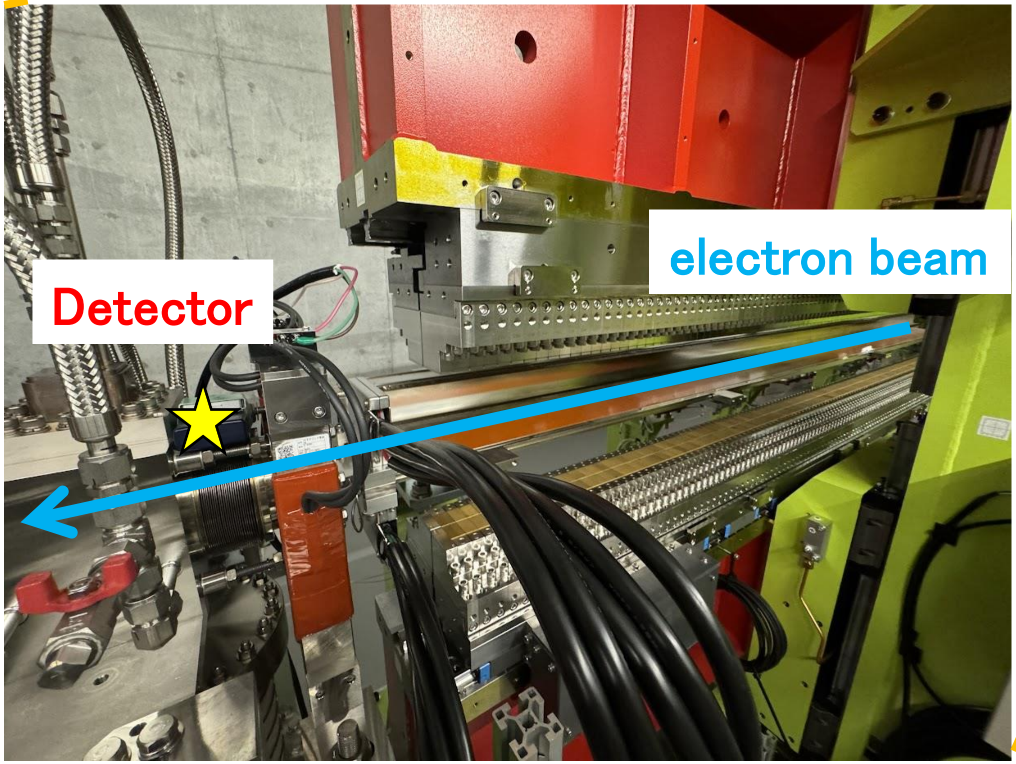
- Easy to set up
- Battery: standard AAA (3,000 h battery life in continuous mode)

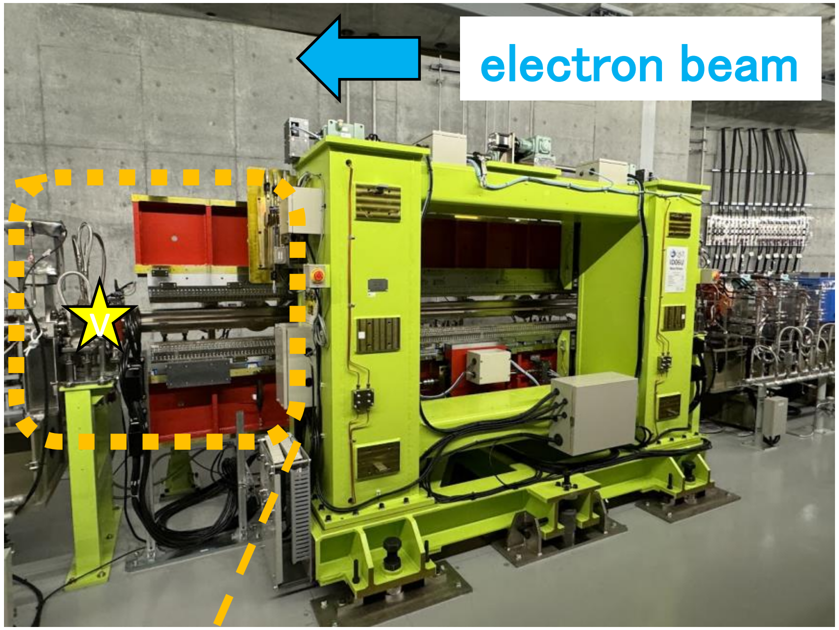
Size : 13cm × 6cm × 2cm
Weight : 140g

- **Time series data can be acquired (settable intervals 10 s, 60 s, 10 m, 1 h, 24 h)**

https://www.mirion.com/products/technologies/health-physics-radiation-safety-instruments/dosimetry-telemetry-systems/electronic-dosimeters/dmc-3000-solutions/neutron-module-hp10-for-the-dmc-3000-dosimeter

2-d: Location of the measurement point





Undulator

2-d: Measurement of regular losses

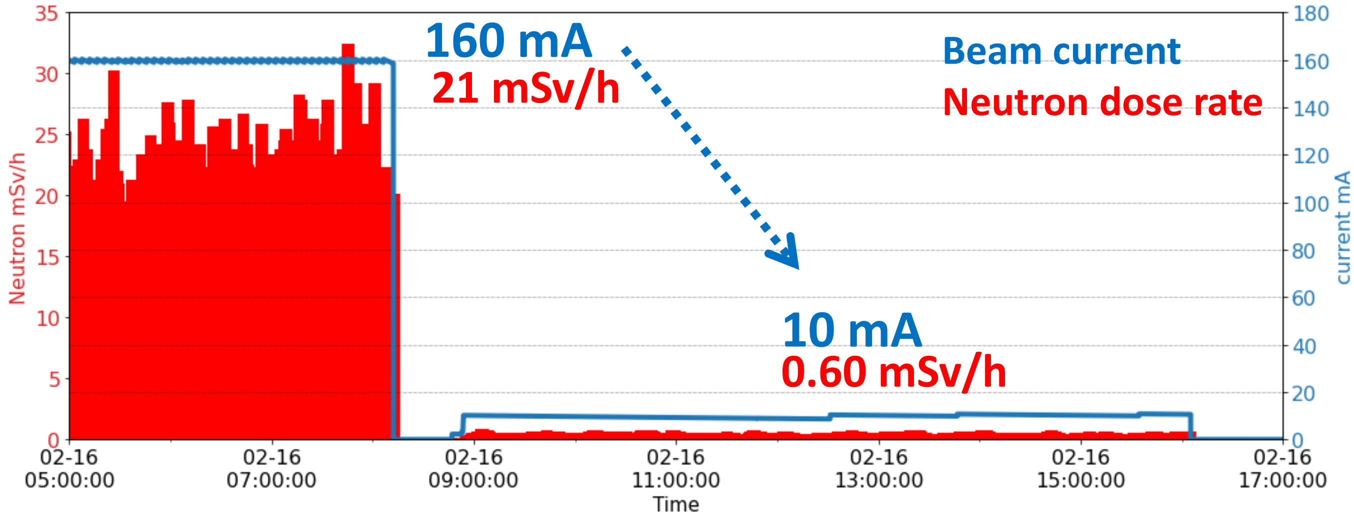
Dependent on beam current

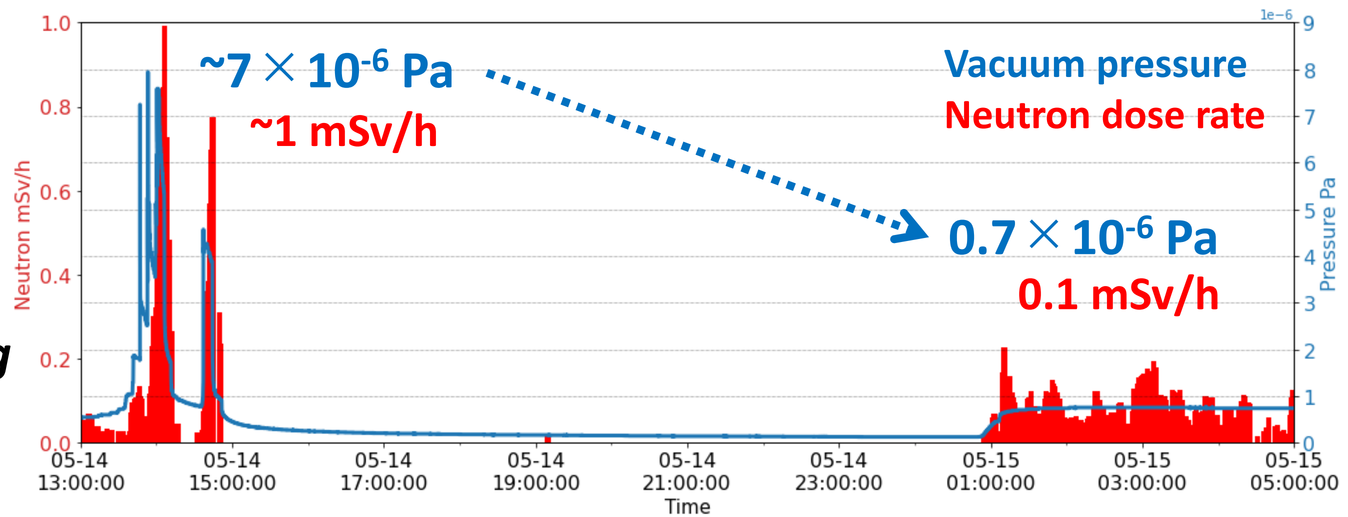
·Touschek Scattering

Dependent on vacuum pressure

·Residual Gas Scattering

Time series data comparison of dose and accelerator data

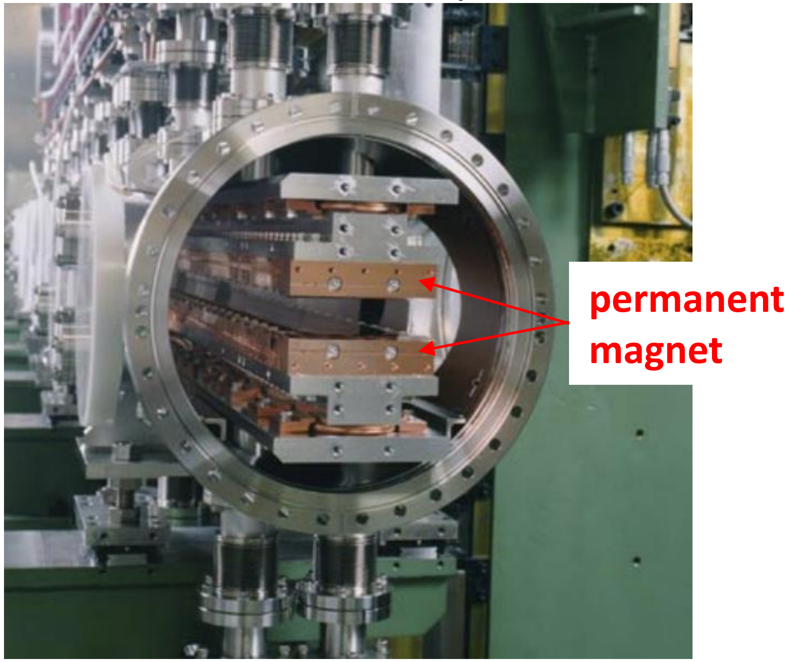




2-e: Irregular loss event

IVU:In-Vacuum Undulator

Reference
Cross-sectional photo

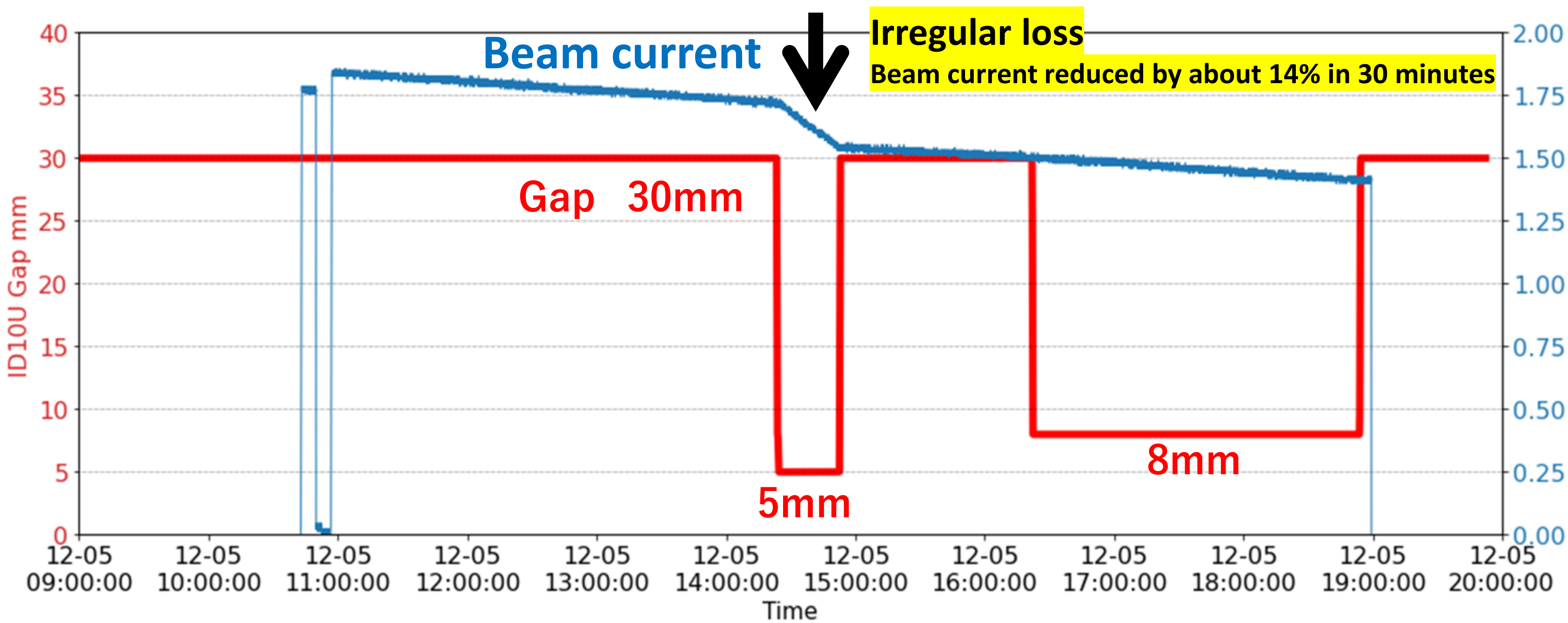


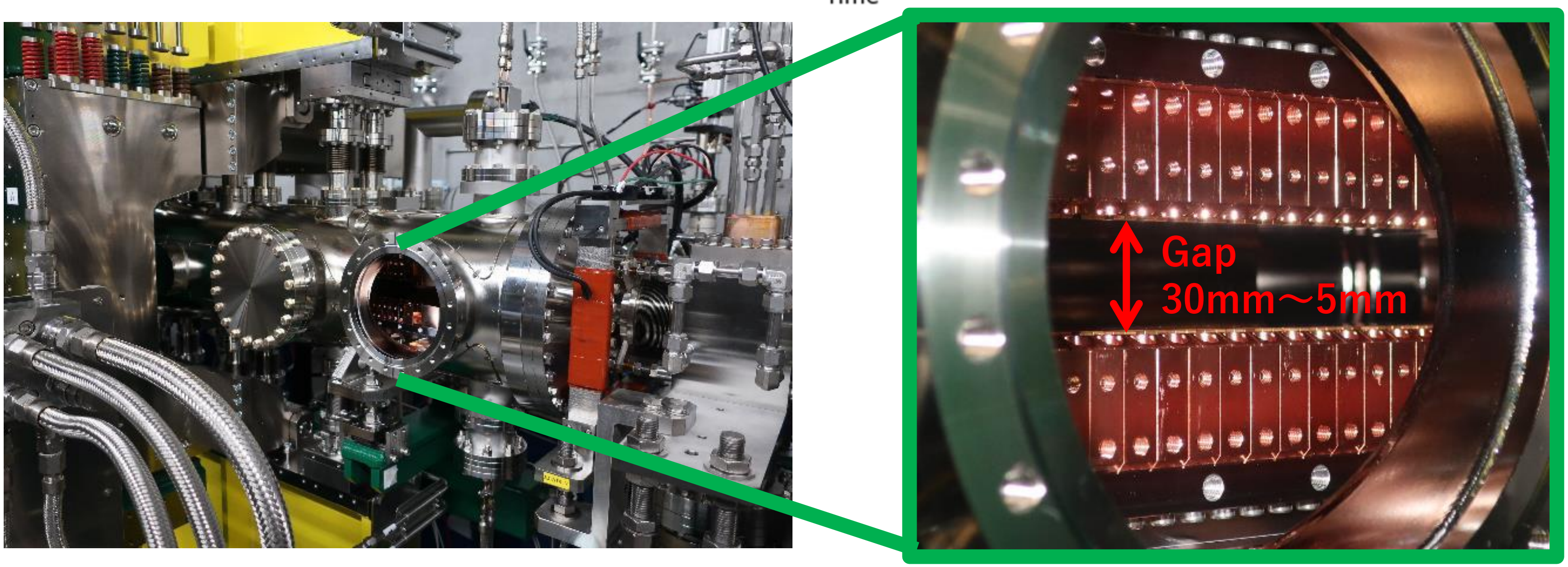
https://www2.kek.jp/imss/pf/pfnews/21_4/p14-18.pdf

In an IVU, the permanent magnet rows are inside a vacuum chamber, so the magnet gap is free from physical limitations and can be designed to be as small as possible.

One of the two installed IVUs had a problem during the first beam commissioning.

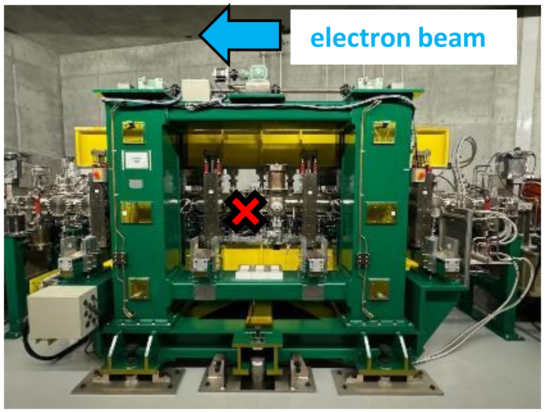
2-e: Accelerator Operation Status

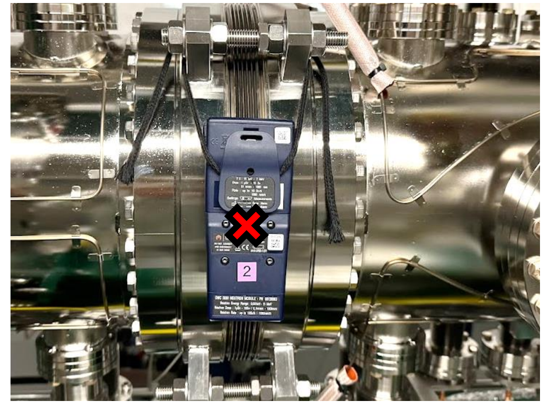




2-e: Measurement of irregular loss

IVU



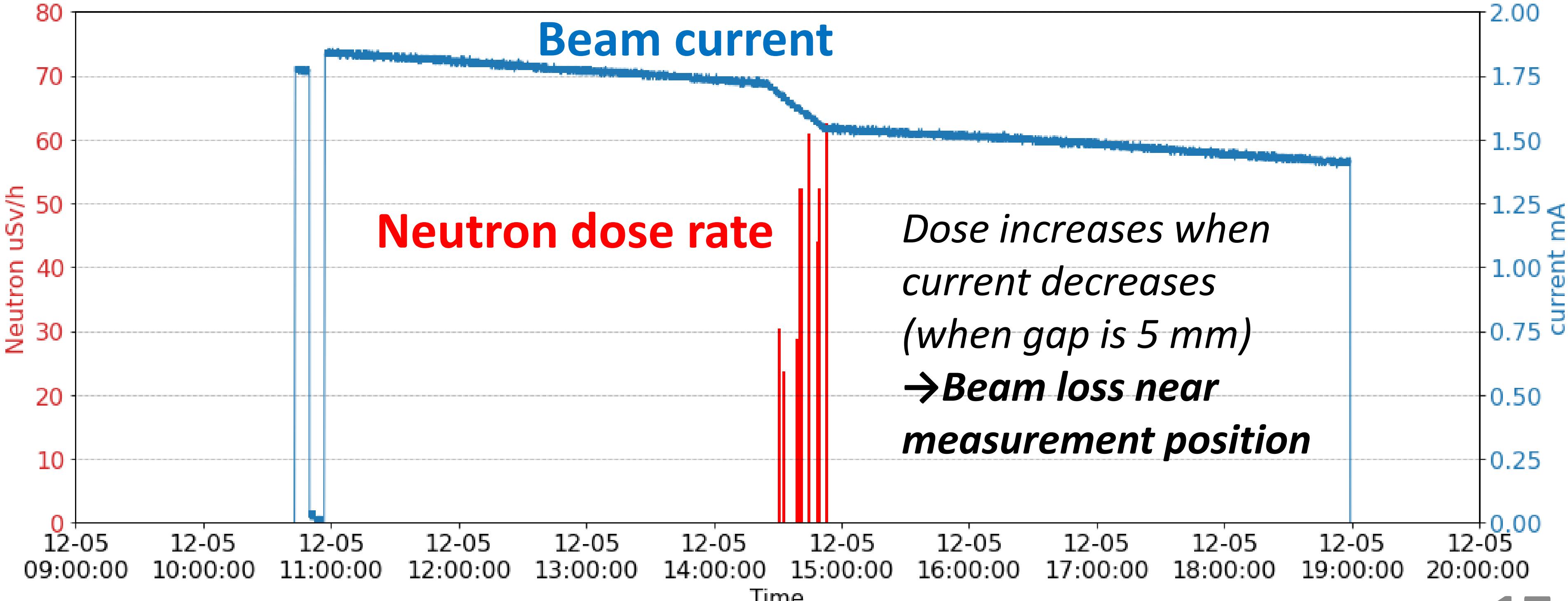


Detector on the surface of the chamber

Installation

Removal

Time series data

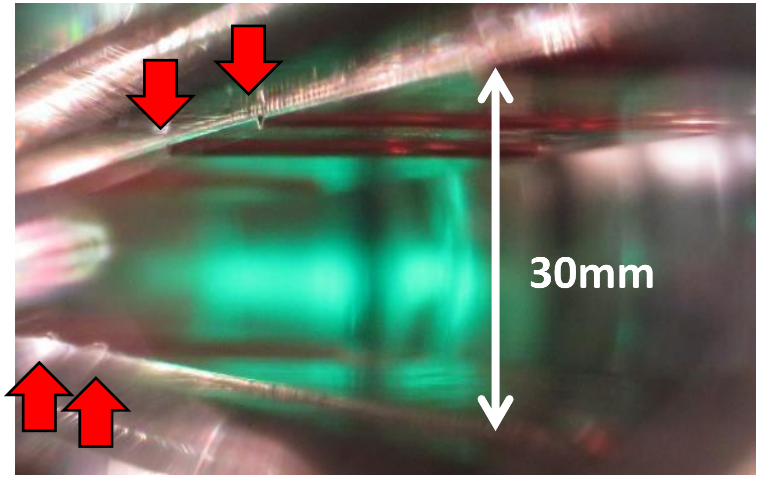


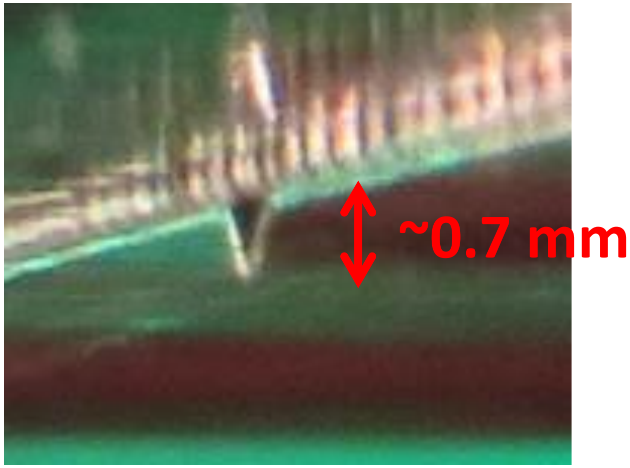
2-e: Identifying causes of beam loss

Visual check inside the IVU chamber

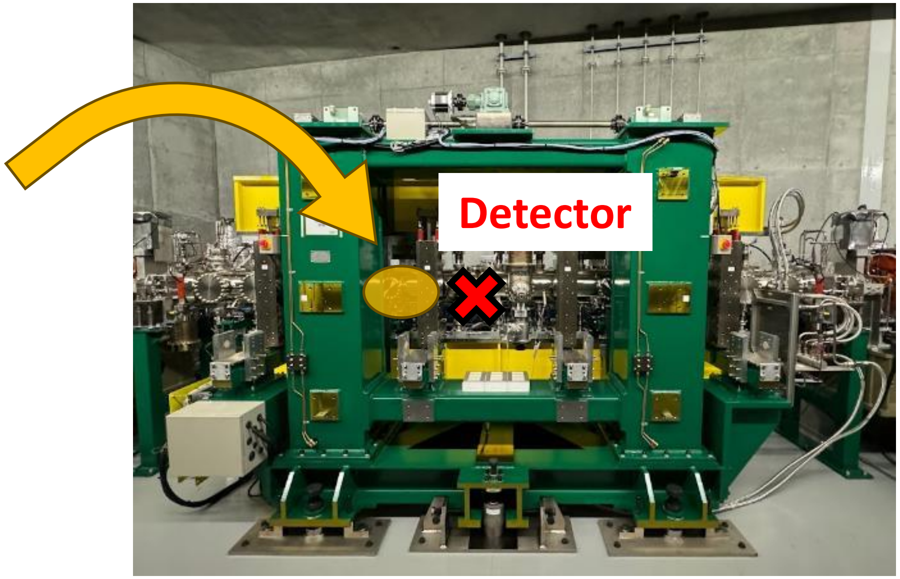
Cu/Ni sheet installed on the surface of the magnet rows was raised.

Beam size
x: 85 um
y: 10 um





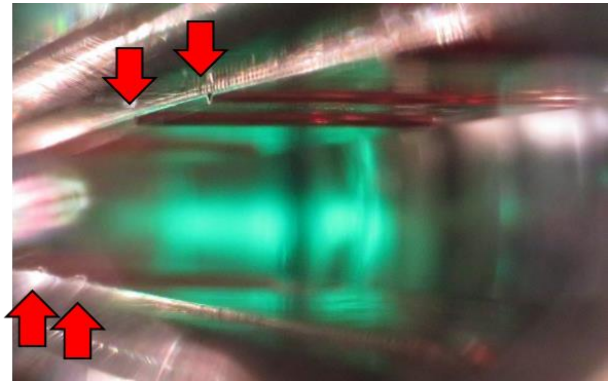
Location of abnormalities in Cu/Ni sheet



※Cu/Ni sheet has been replaced

4 : Summary

- Identification of beam loss with DMC3000N
- Identification of beam loss location



- Solution for irregular loss
- Resumption of user operation with 5 mm gap in IVU

Thanks for your attention!

Enlighten the Nano Universe to Drive a Sustainable World

Photo courtesy of PhoSIC