Accelerator-driven Compact Neutron Sources in Japan

Present Status and Future Plan

Katsuya Hirota

Nagoya University, JAPAN

Introduction

Compact neutron Source

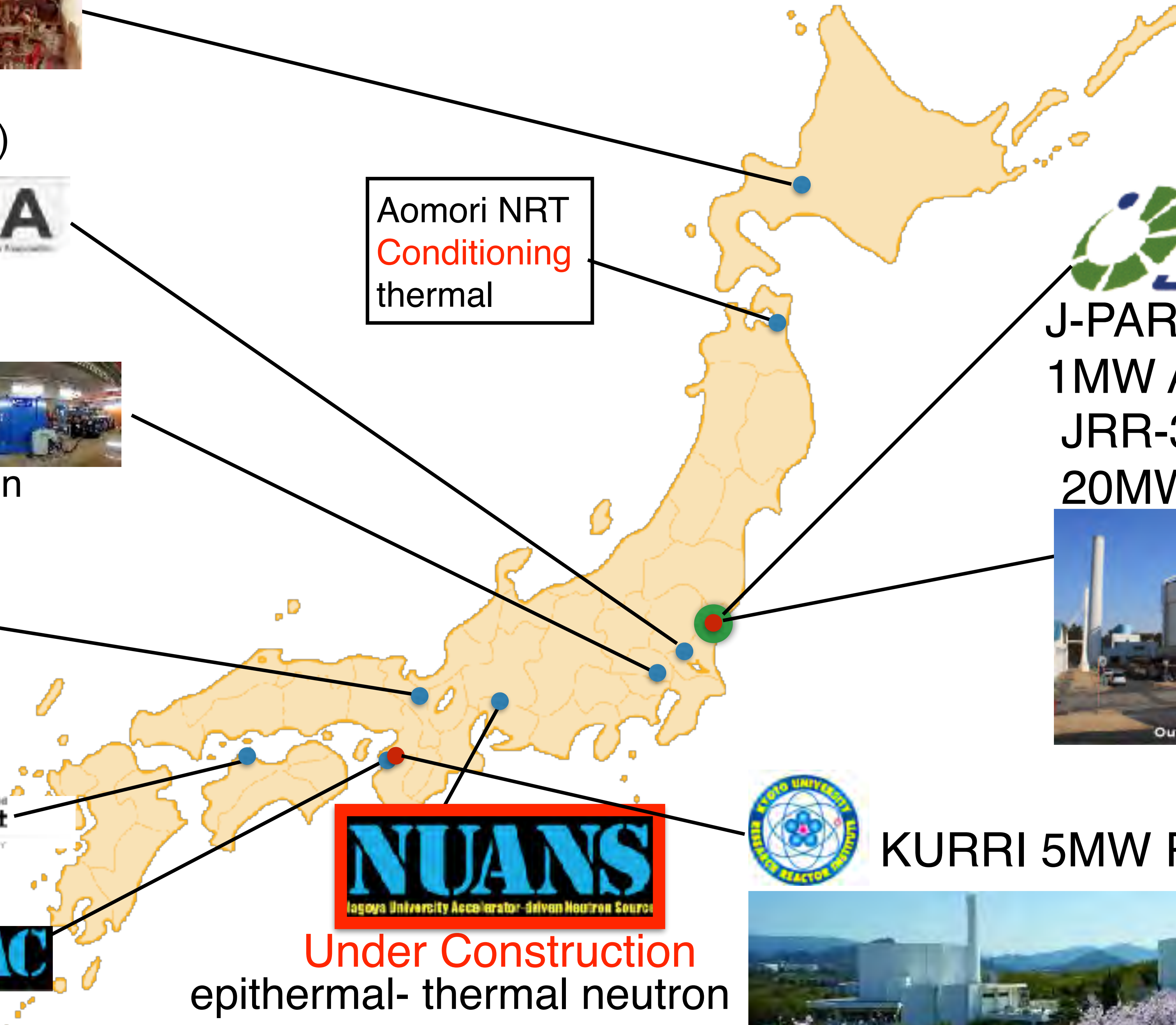
Neutron beam is a good probe to investigate materials.
The **large neutron facilities** are useful for a **high statistic measurement.**

However, they have limited opportunities to use because of the limited beamline compared with the users.
It is hard to get much beam time.It is not so convenient.

Now, we construct the Compact Accelerator-driven Neutron Sources (CANS) to use for preliminary measurement or neutron device development.

Neutron sources in Japan

for Research use



HUNS
Hokkaido University Neutron Source

cold-fast neutron
10^4n/sec/cm^2(cold)

AIST ISMA

Under Construction
cold neutron

RANS
RIKEN Accelerator-driven Neutron Source

thermal-fast neutron
10^5n/sec/cm^2

KUANS
Kyoto University Accelerator-driven Neutron Source
thermal neutron
10^4n/sec/cm^2

SHIEI 住重試験検査株式会社
INTEGRATED INSPECT ENGINEERING COMPANY
NRT : Thermal

KURRI-LINAC
Kyoto University Research Reactor Institute – Linear Accelerator
Epithermal neutron

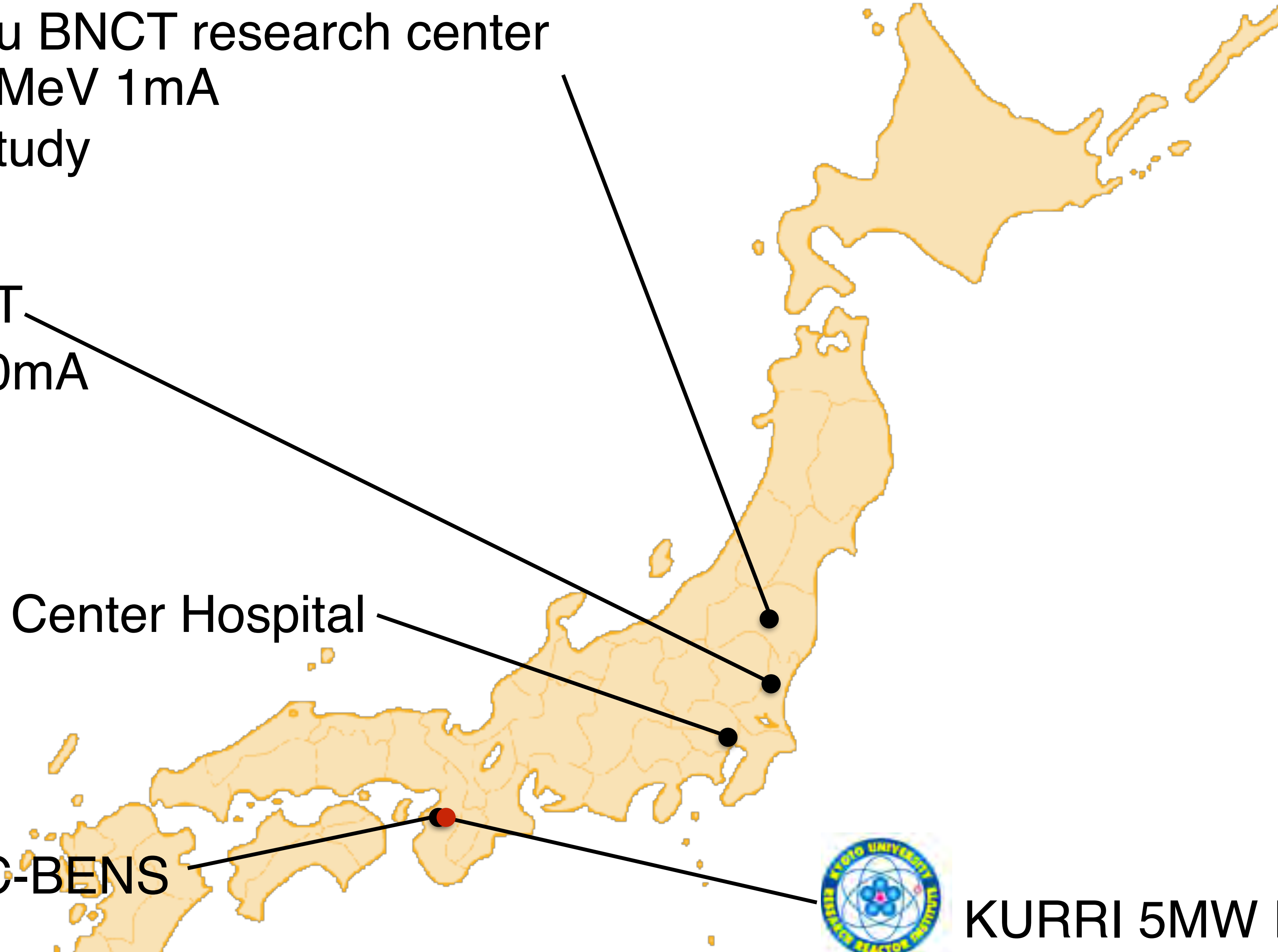
Aomori NRT
Conditioning
thermal

J-PARC
J-PARC MLF
1MW Accelerator
JRR-3
20MW Reactor

NUANS
Nagoya University Accelerator-driven Neutron Source
Under Construction
epithermal- thermal neutron

KURRI 5MW Reactor

Neutron sources in Japan
for BNCT use



Southern Tohoku BNCT research center
Cyclotron 30MeV 1mA
Clinical trial study

Conditioning
IQBRC- iBNCT
Linac 8MeV 10mA

Conditioning
National Cancer Center Hospital
Linac 2.5MeV

KURRI C-BENS
Cyclotron 30MeV 1mA
Clinical trial study

KURRI 5MW Reactor

Current Status of Compact Neutron Source

HUNS → **Prof. Furusaka**

Hokkaido University Neutron Source

(TBD) New Neutron Source!

Accelerator-based compact Neutron Source in AIST

RANS

RIKEN Accelerator-driven Neutron Source

KUANS

Kyoto University Accelerator-driven Neutron Source

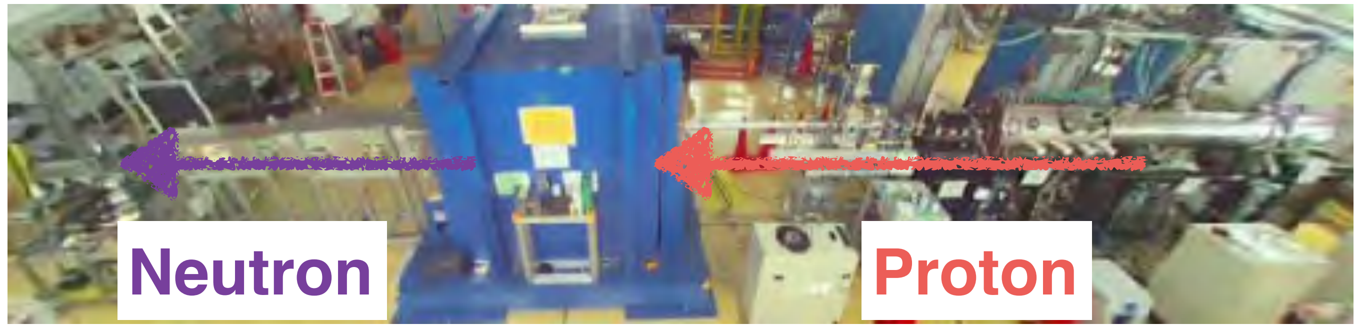
NUANS → **Detail**

Nagoya University Accelerator-driven Neutron Source

RANS : RIKEN Accelerator-driven compact Neutron Source

Responsible person: Y. Otake yotake@riken.jp
http://rans.riken.jp/en/

15m



Detector Area

Neutron Flight Path.
Neutron Detector
^{3}He, Scintillator, CCD, II, Ge
Shield

Measurement:
Thermal, fast neutron imaging
Diffraction, Small Angle Scattering

Be Target
Thermal Moderator
Shield

Proton Acc.

Commercially sold Acc.
Proton Energy : 7MeV
Proton Current < 100μA ave.
< 10 mA peak
Pulse width : 10-180 μs
Reputation : 20 - 180 Hz

RANS: Change the set up for each measurement

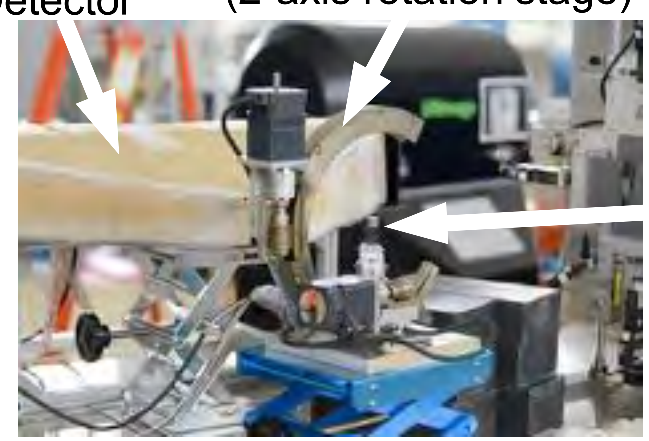
Example of Diffraction

High Statistics

(typical parameter)
proton beam pulse width 63μs
Current 55μA
Rap. rate 100Hz

He3 Detector

Eulerian cradle (2-axis rotation stage)

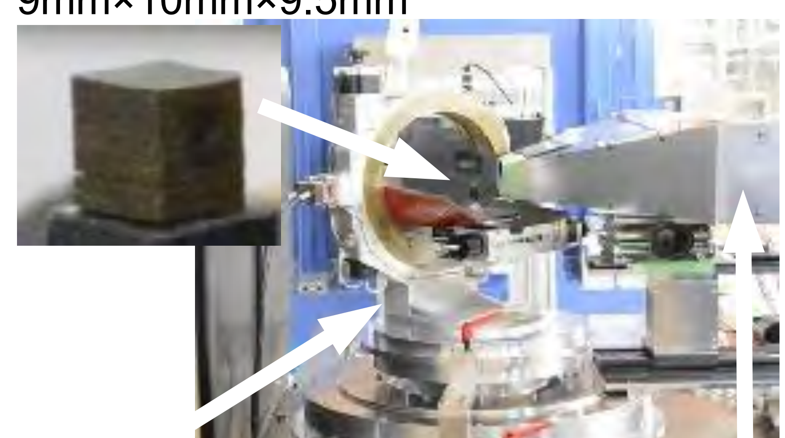


Sample material (IF Steal plates)

High Resolution

(typical parameter)
proton beam pulse width 30μs
Current 34μA
Rap. rate 100Hz

Sample material
9mm×10mm×9.5mm



Eulerian cradle (2-axis rotation stage)

He-3 detector

KUANS Kyoto University

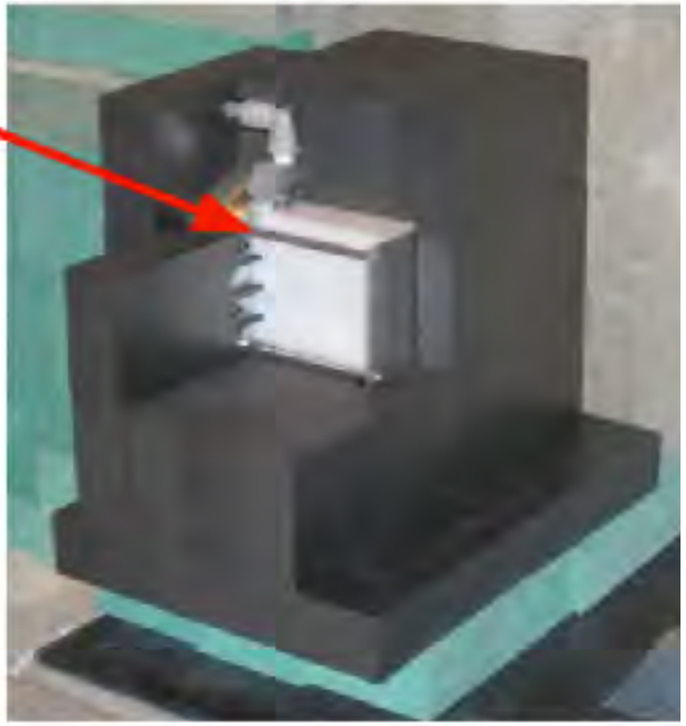
- 3.5MeV proton beam (Accsys Technology Inc.)
- Proton current: 20mA(peak), 30μA(ave.), maximum 100μA(ave.)
- Repetition: 100Hz

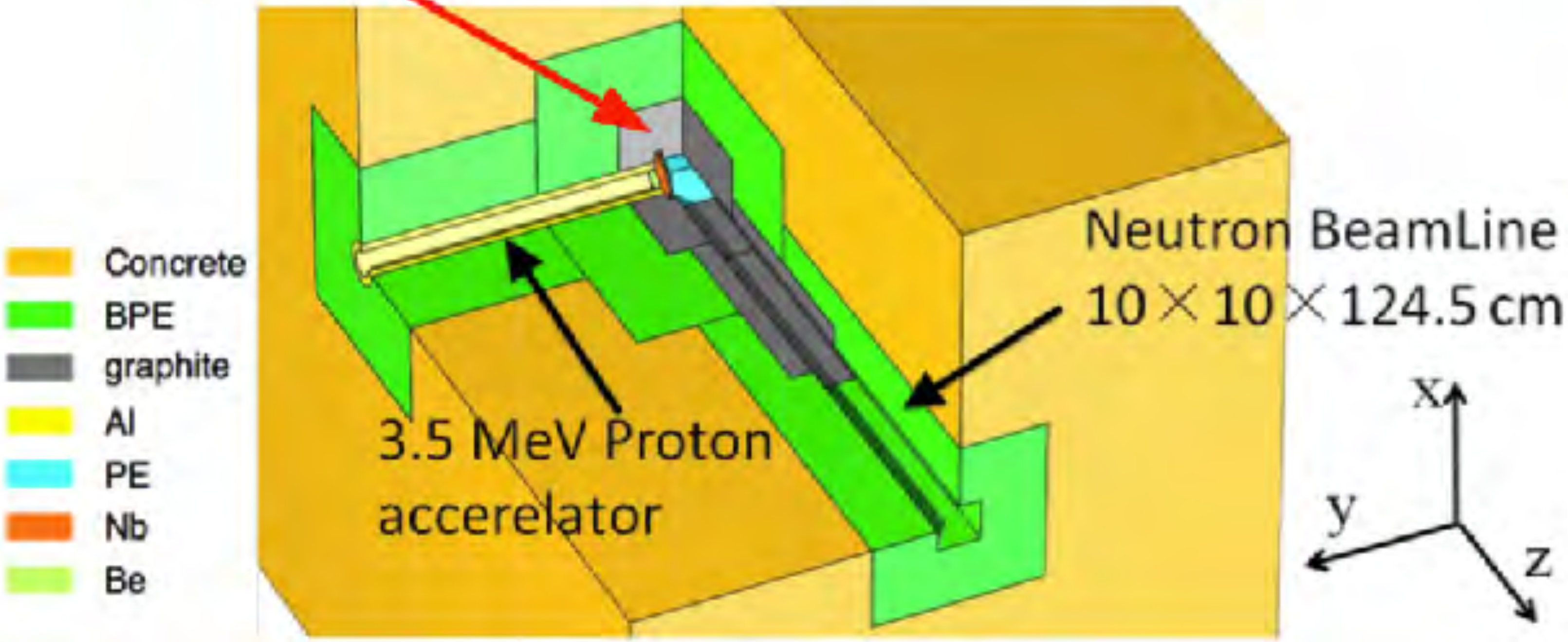
One of the smallest CANS

It is useful for students education, because the accelerator and the neutron target is very close!

KUANS target

- Thin Be target, brazed on Nb plate. (RIKEN produced)
- Polyethylene moderator (10cm x 10cm x 10cm) at ambient temperature.
- The moderator is surrounded by carbon reflector.





NUANS

Nagoya University Accelerator-driven Neutron Source

First Neutron beam is planning this Spring.

NUANS Nagoya University

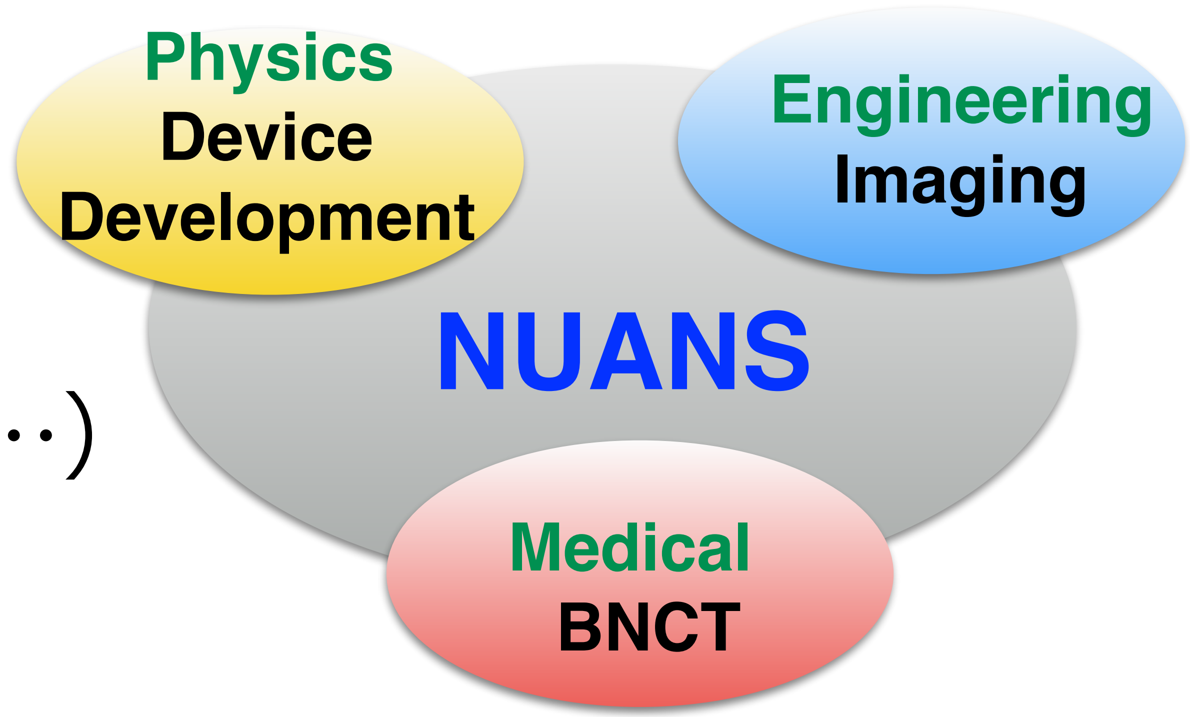
Two beamlines are designing at NUANS

1st beamline (42kW)

- Device and system development for BNCT (Li-Target、moderator, etc…)

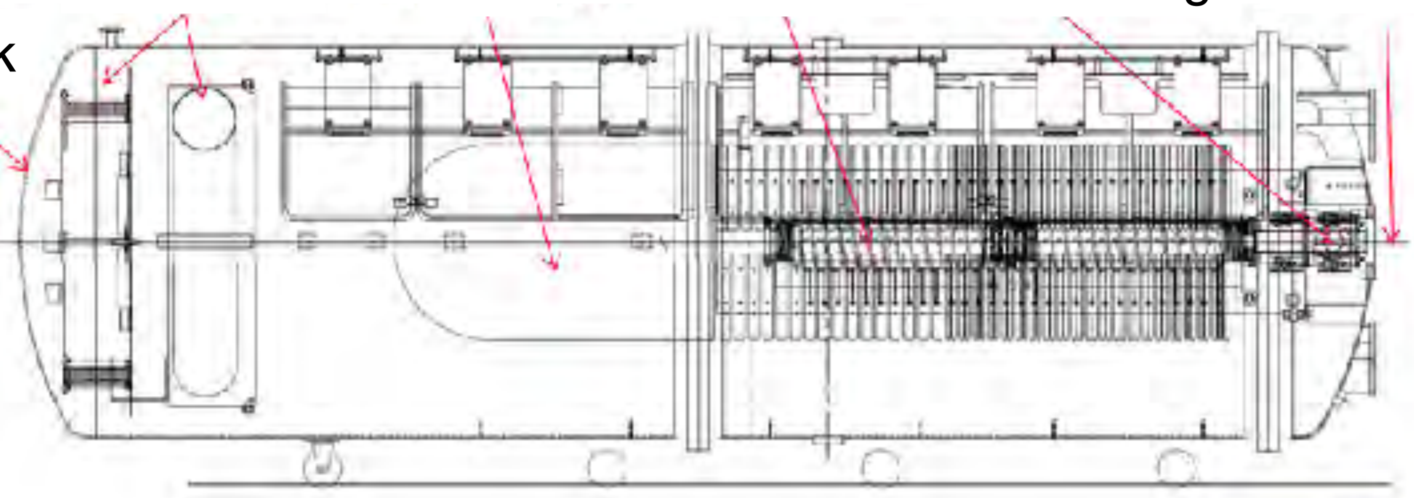
2nd beamline (4kW)

- Neutron Imaging
- Neutron Detector Development
- Neutron optics Development (mirror, lens, etc…)
- Education

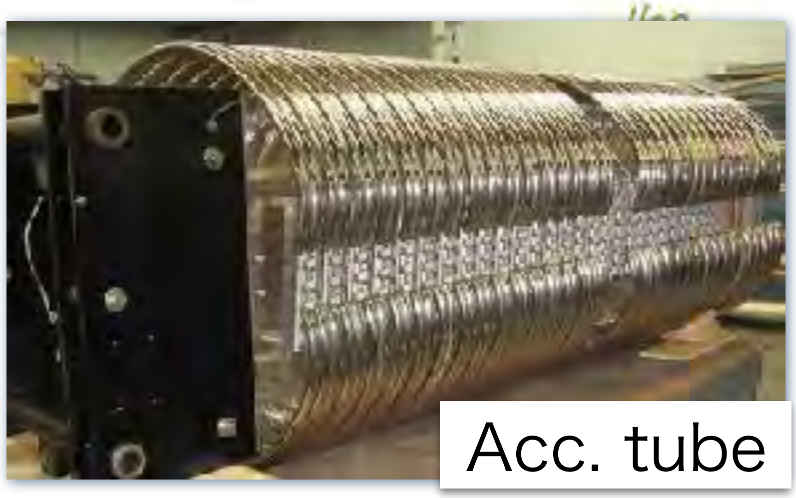


Electrostatic proton accelerator

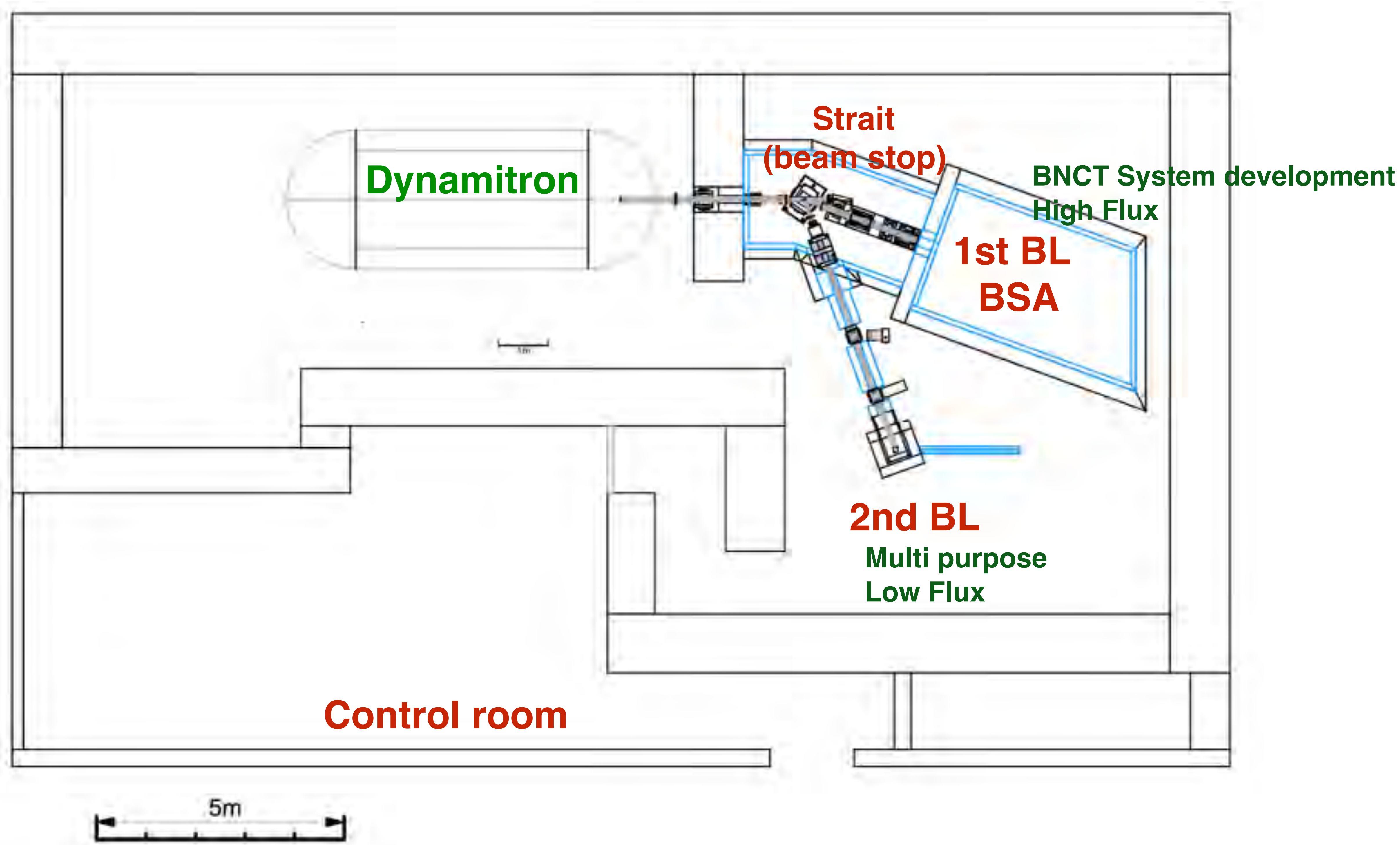
Dynamitron Accelerator (**DC beam**) by IBA Indust.
Proton Energy: 1.9MeV-**2.8MeV**
Proton beam current: Maximum **15mA**, 1.5mA(2nd BL)
Size : 7.5m x 2.8m 6.5ton

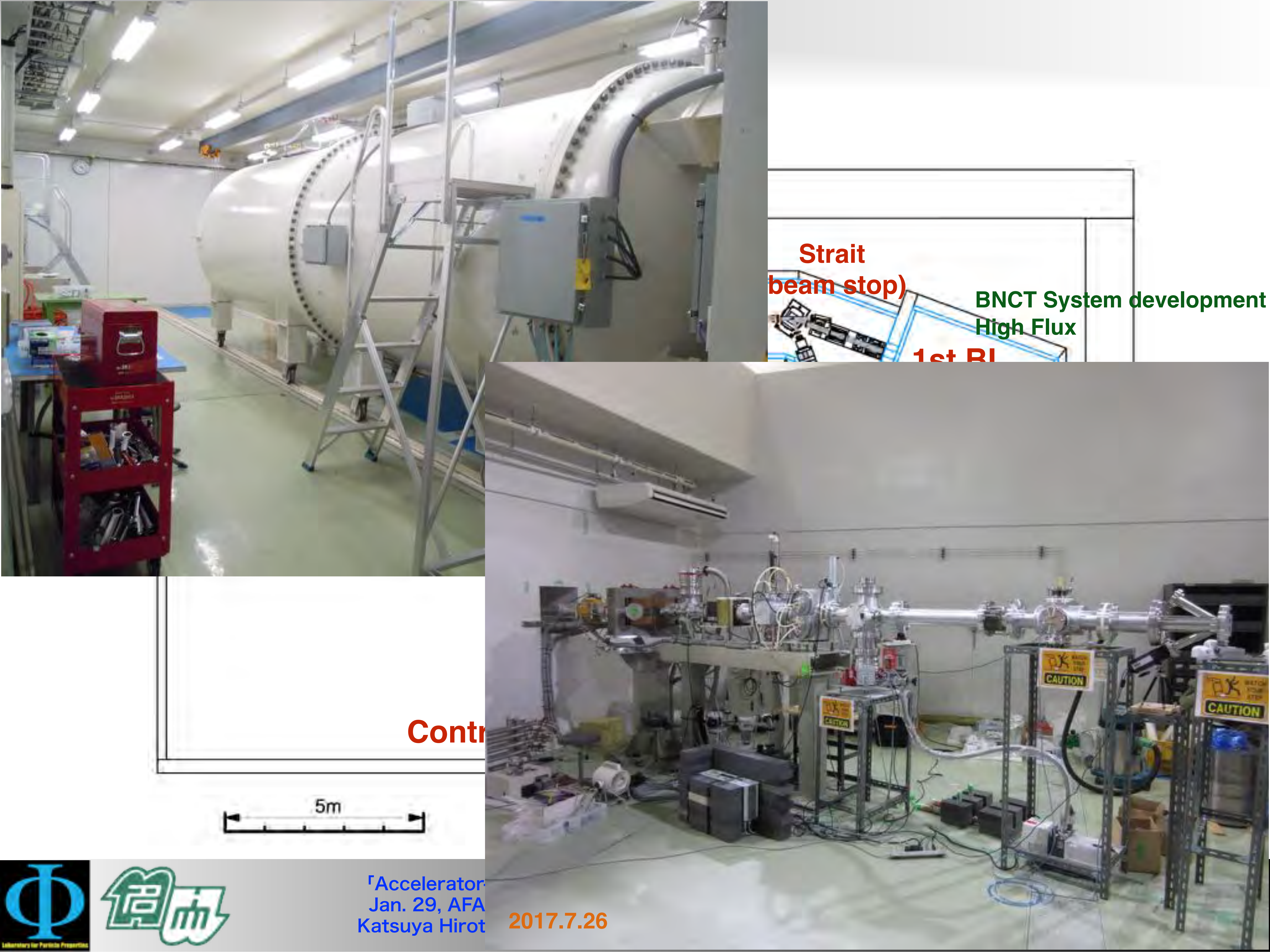



ECR Ion Source


Acc. tube

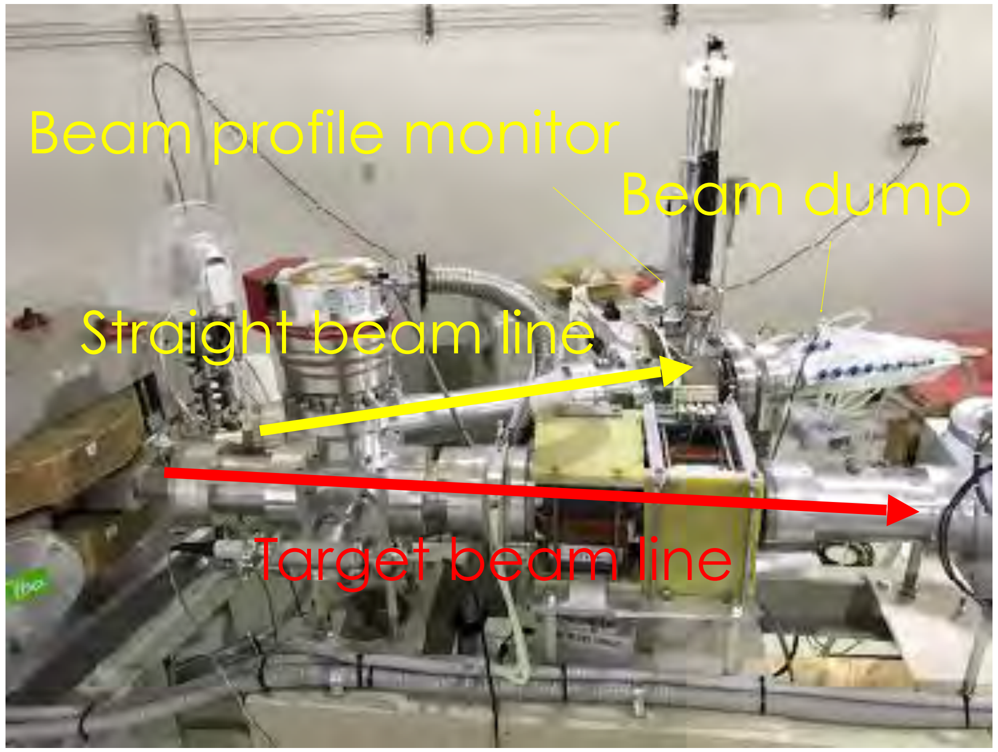
NUANS layout

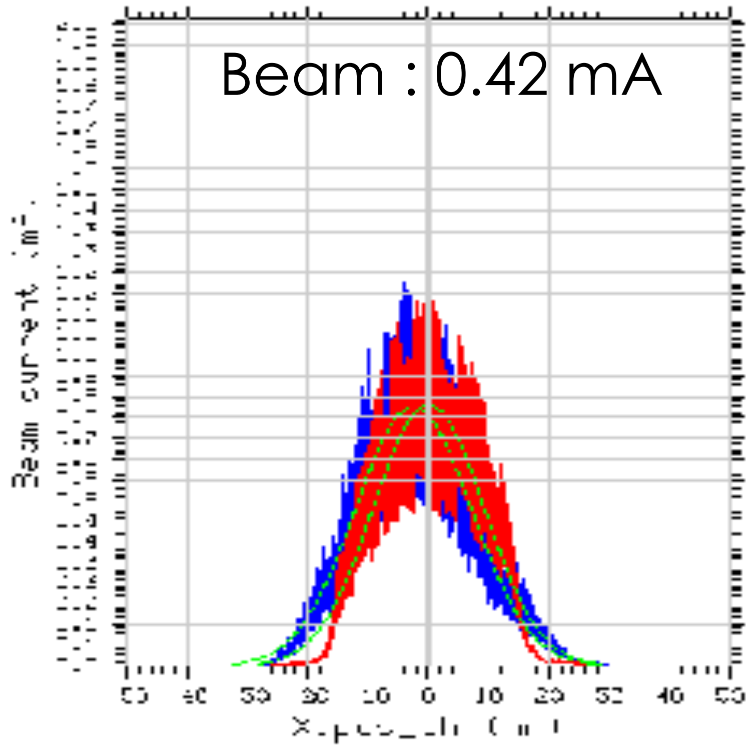




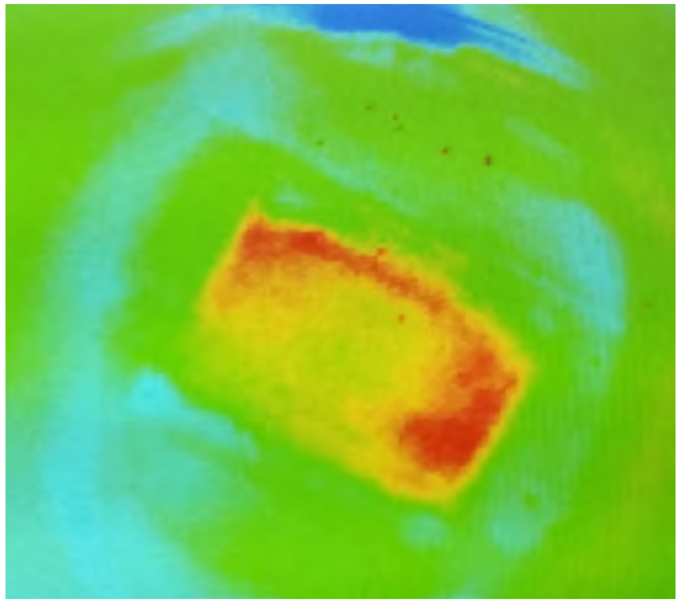
Strait
beam stop)
BNCT System development
High Flux
Contr
5m
CAUTION
CAUTION
2017.7.26

Beam Profile

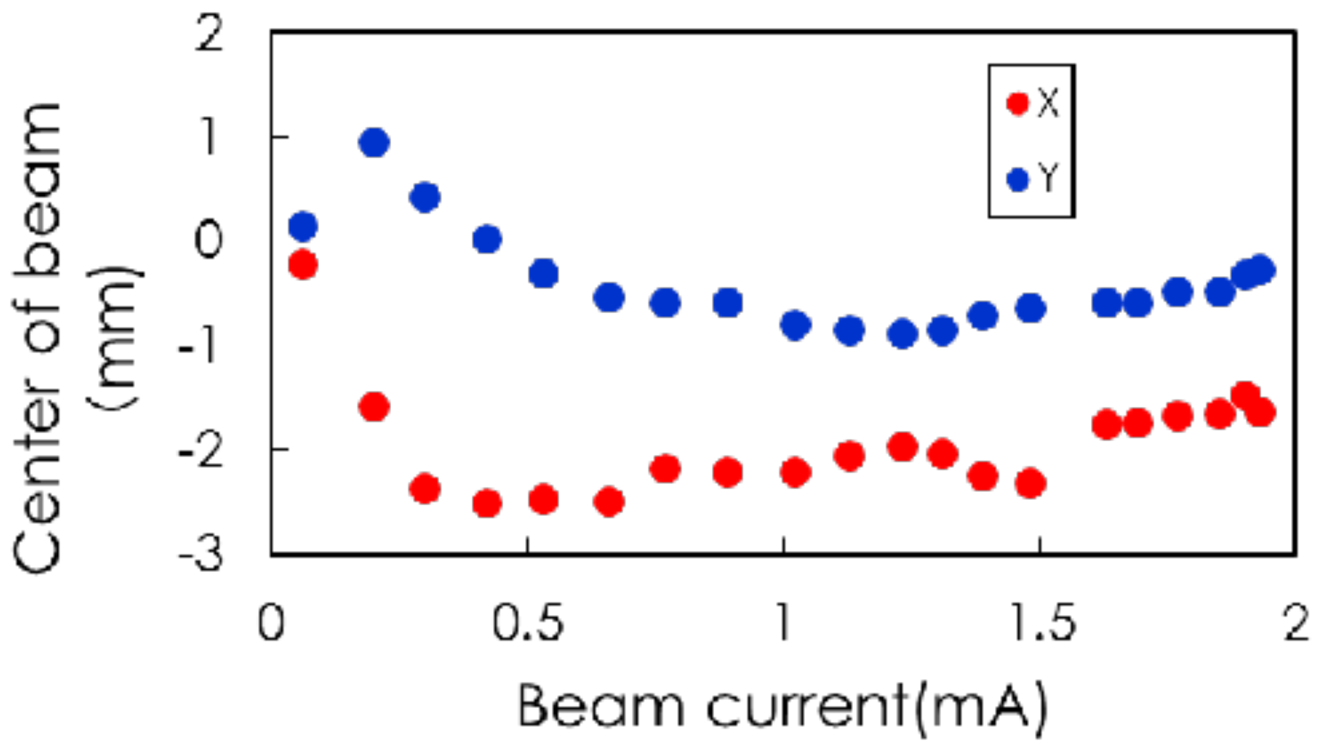


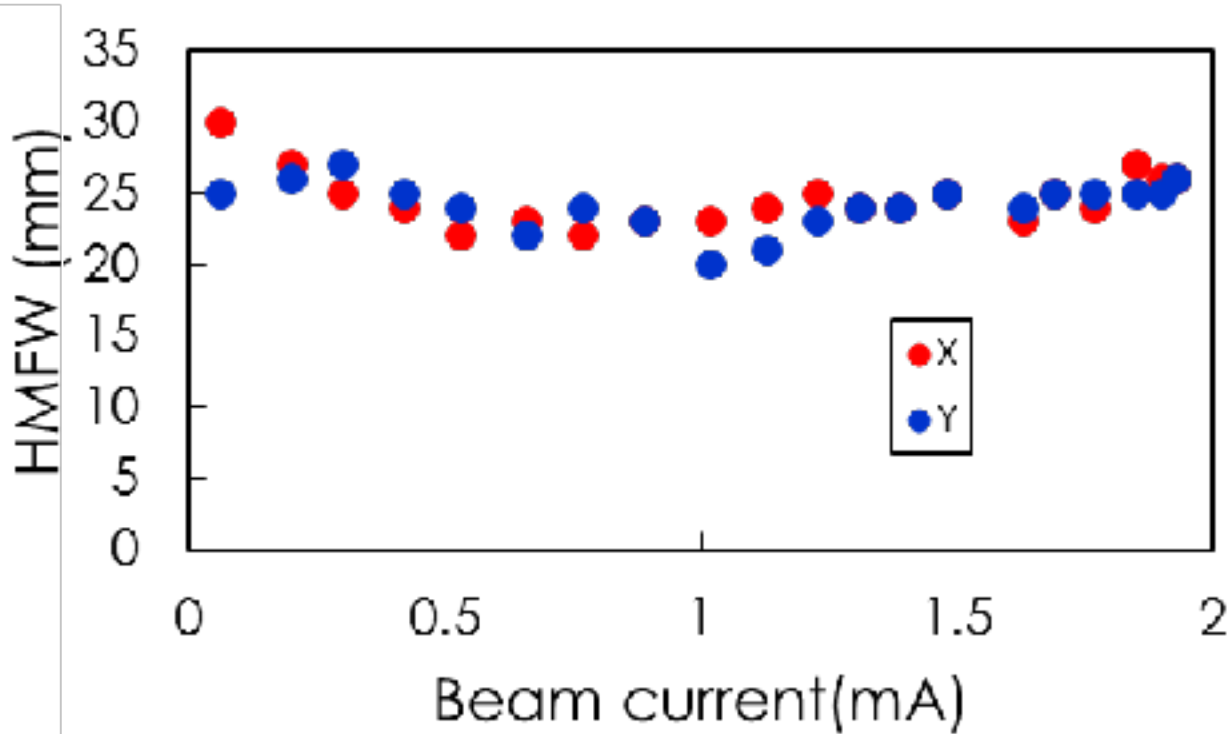


Beam profile monitor



Beam profile measured
By IR camera on the target





Results of Beam profile monitor

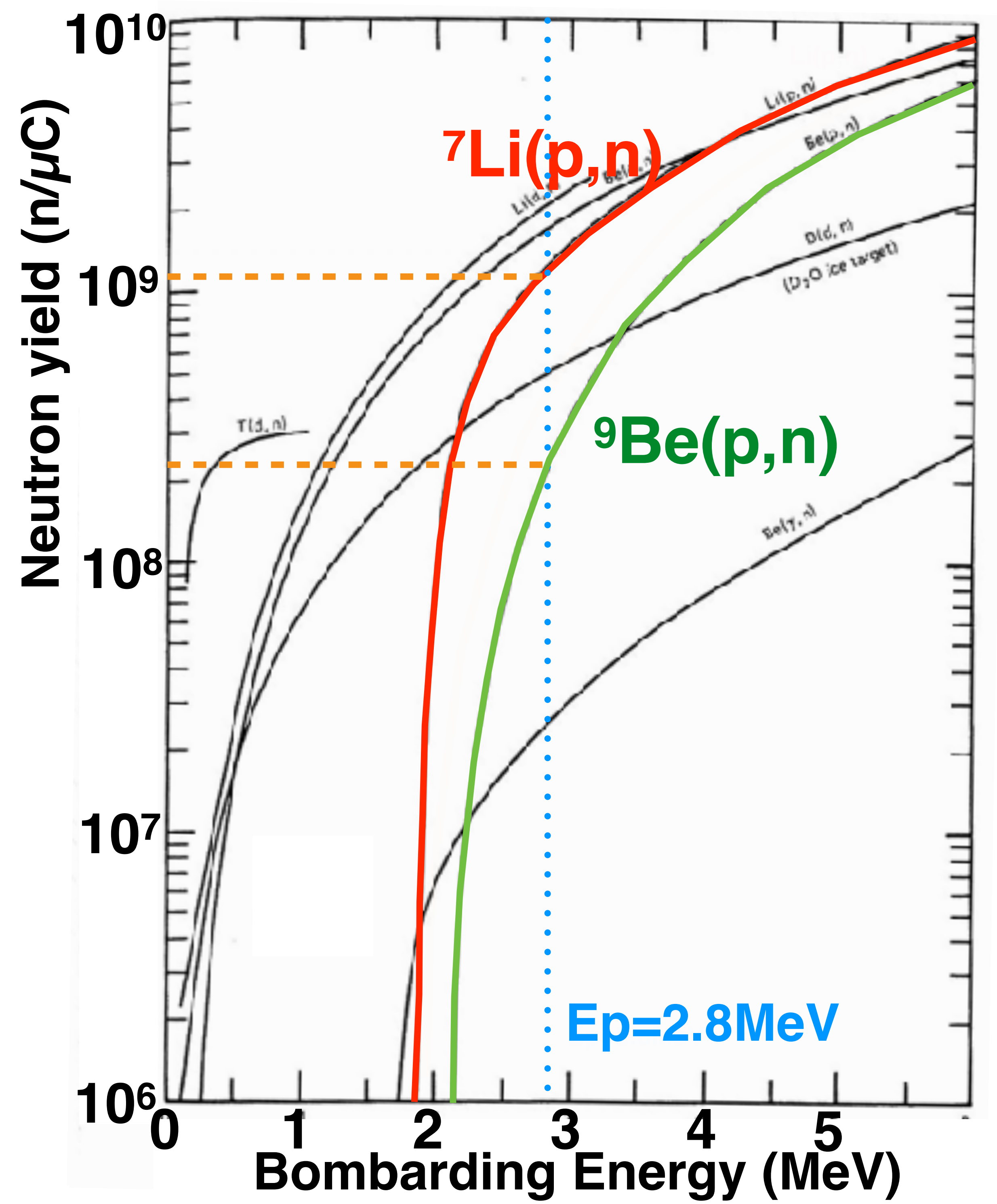
Neutron target

Li Neutron yield ～10^{13}n/sec for 15mA

Be Neutron yield ～10^{12}n/sec for 15mA

1st BL : ^{7}Li target
- high neutron intensity
- Chemically unstable

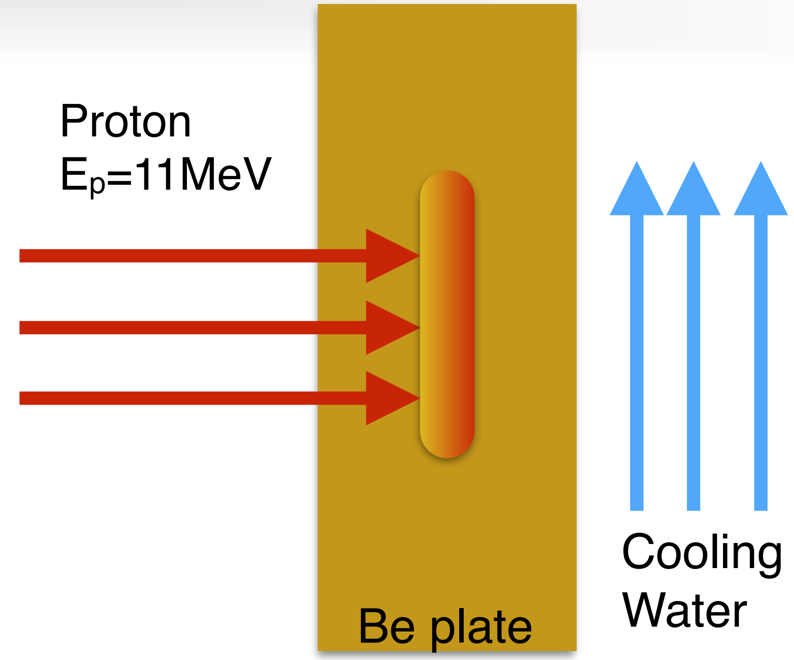
2nd BL : ^{9}Be target
- Chemically stable
- Succeeded to use at RANS, KUANS



Ref) M.R.Hawkesworth, Atomic Energy Review 15 2(1977) P169

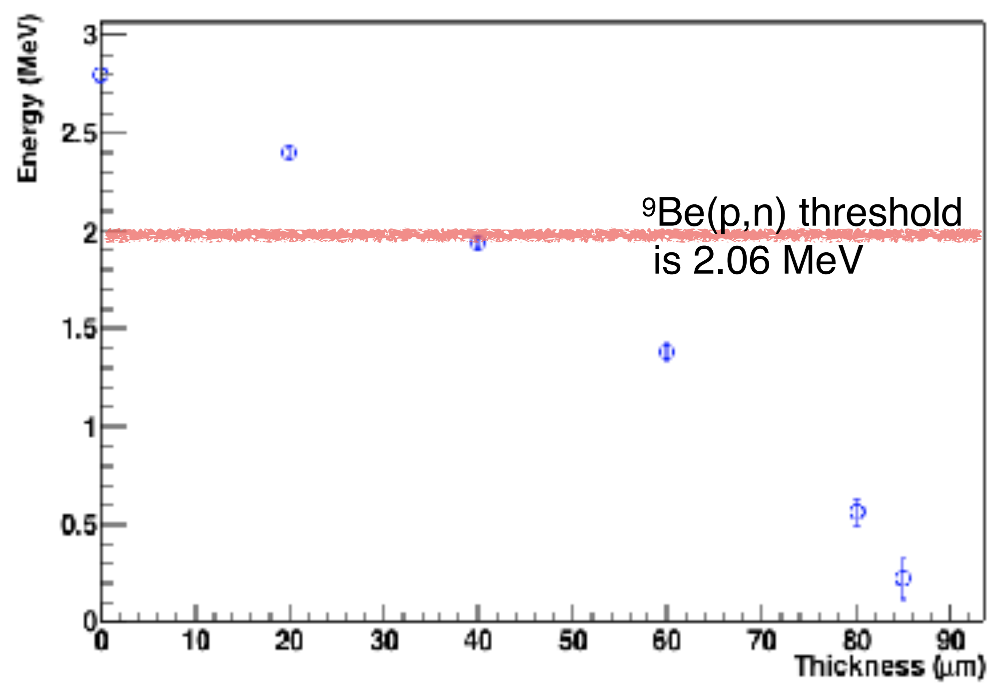
Hydrogen blistering

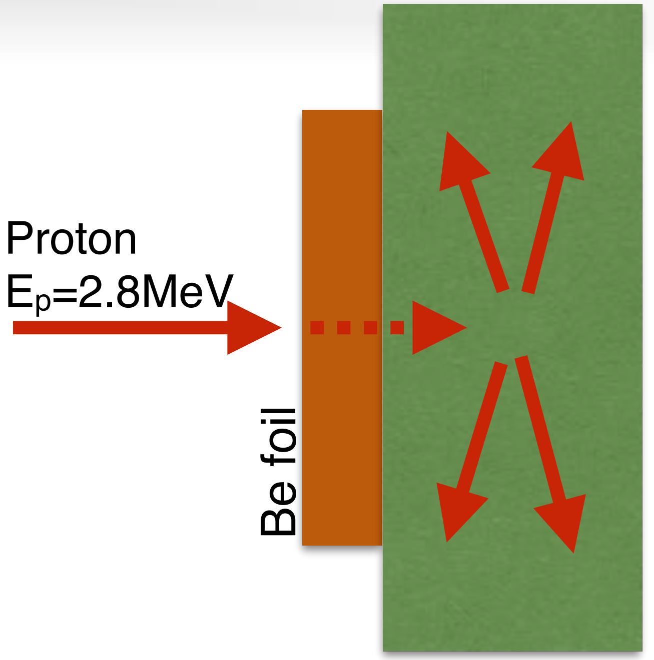
Be Target was broken by hydrogen blistering.
Be target is also difficult to use
for low energy neutron source.



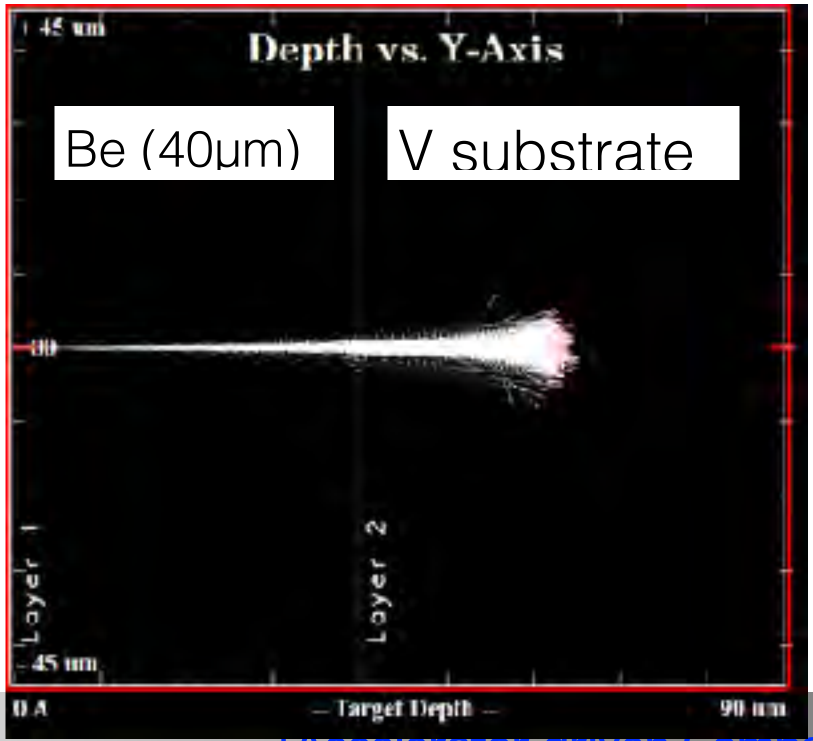
Indiana University

Neutron Target :
Proton Injection simulation



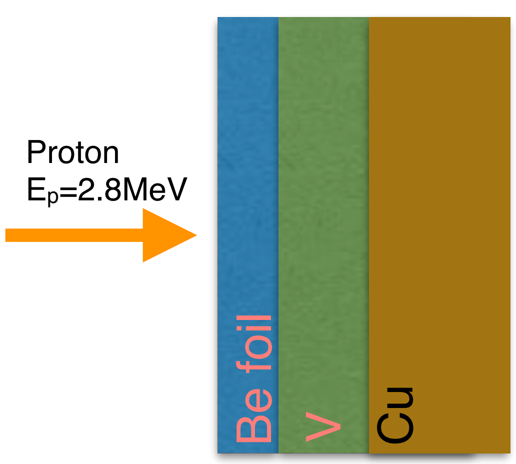


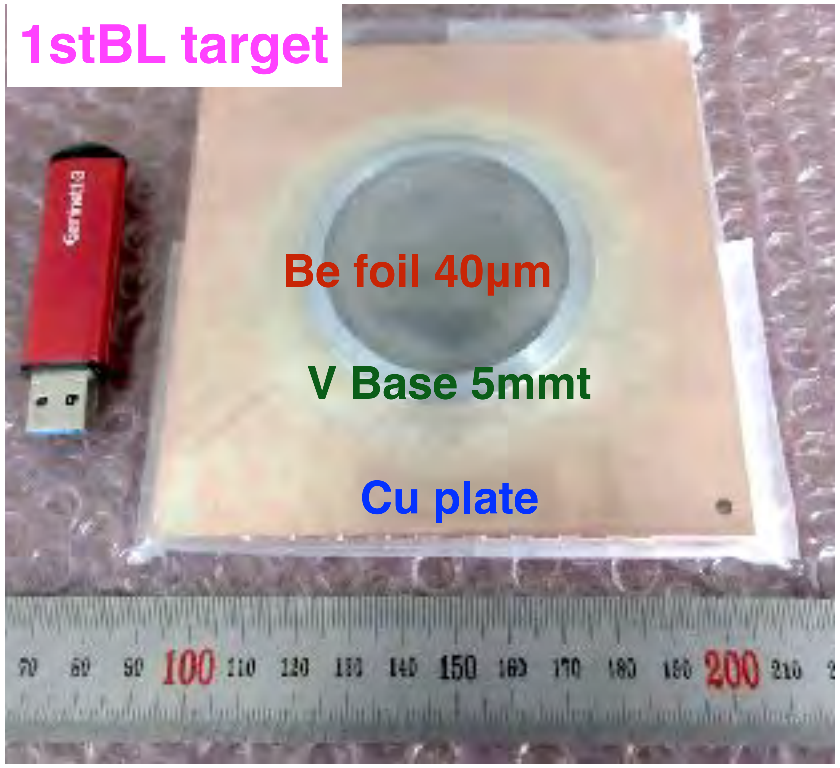
Proton
E_p=2.8MeV

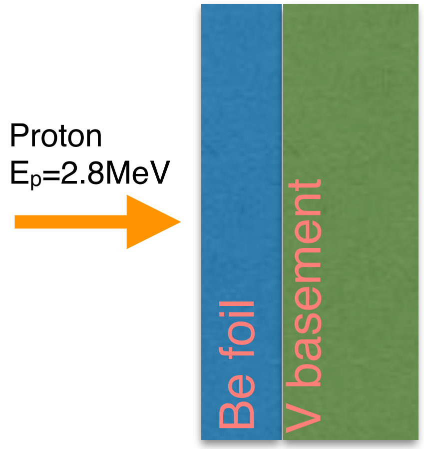


^{9}Be Neutron Emission Target

	1st BL Target(High Flux)	2nd BL target
• ^{9}Be thickness :	40 μm	40 μm
• ^{9}Be size :	ϕ50	ϕ100
• V-basement :	2mmt	5mmt
	Cu (water cooling cavity)	N/A
• Be-V bonding:	Diffusion bonding	Silver brazing



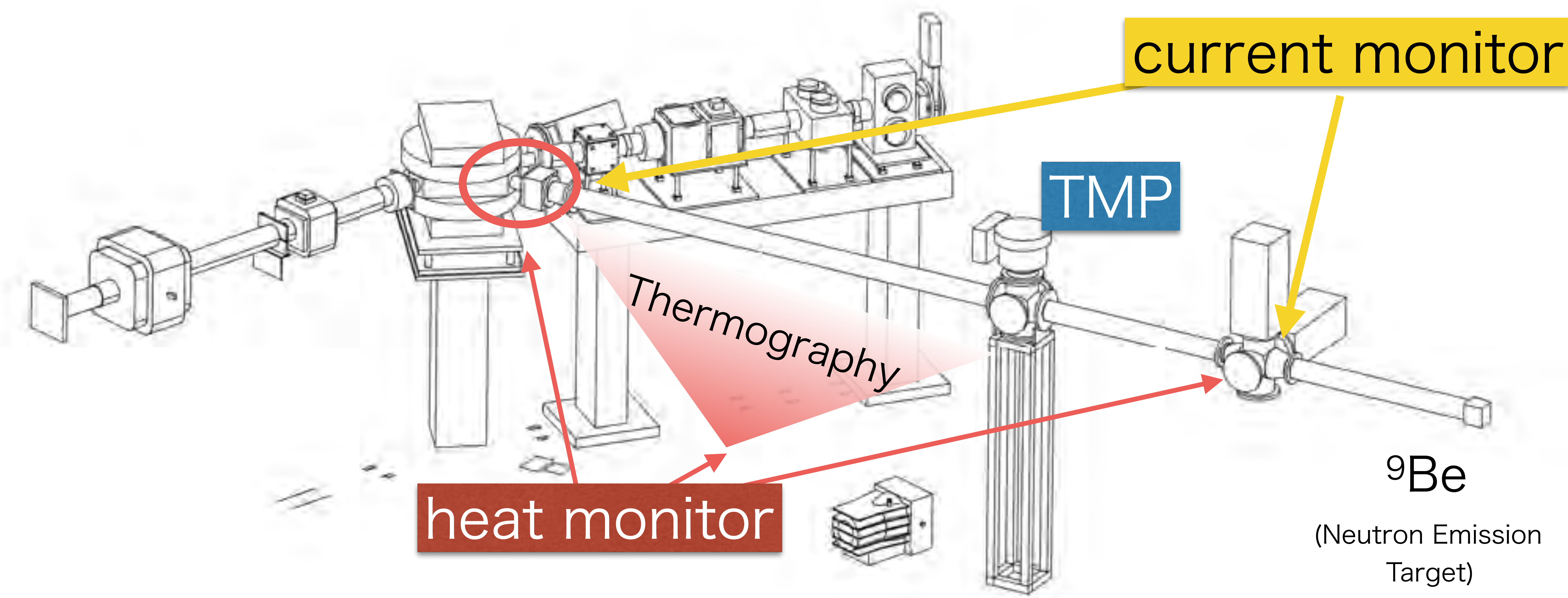




Beam monitor for 2nd Beamline

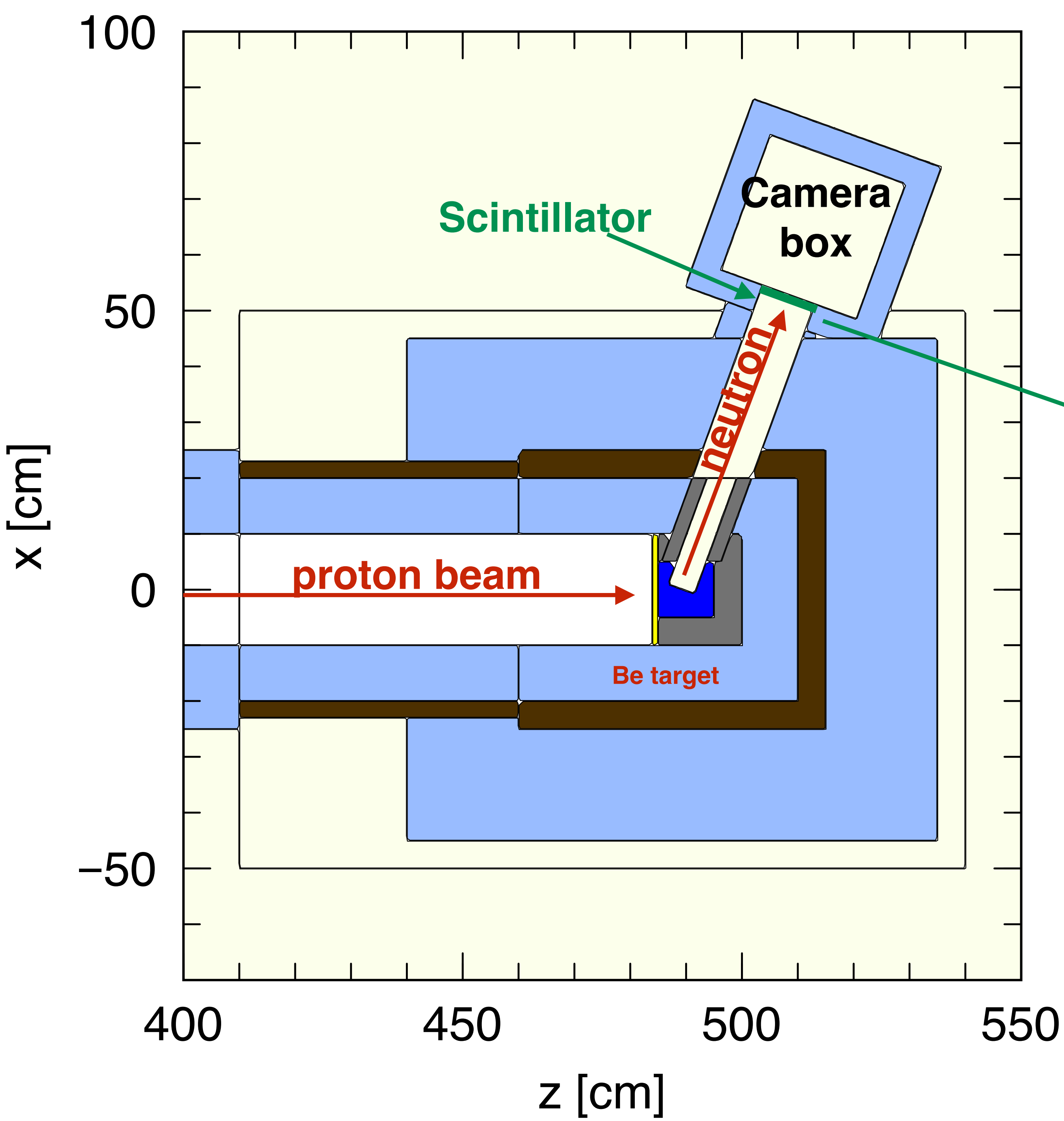
inexpensive as possible・・・

・Consider not to irradiate the duct with a beam, since the proton current is too high

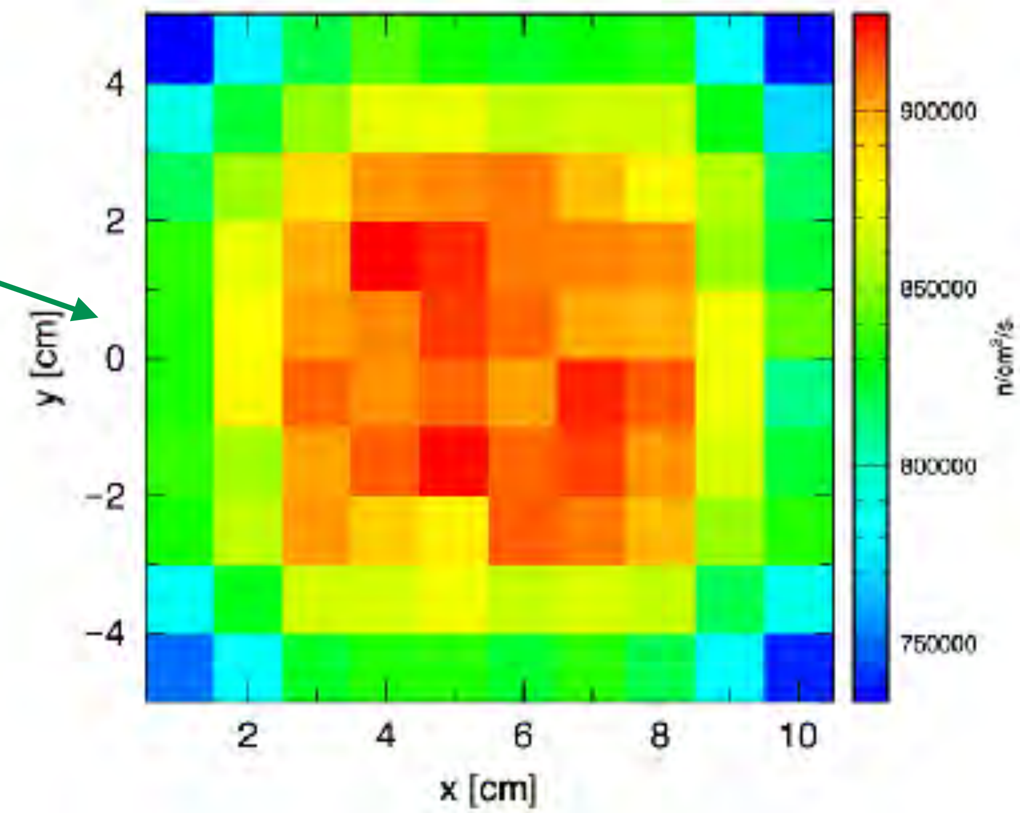


	Sensor	position
vacuum	Vacuum gage	1) TMP、2) Target
proton current	Cu Collimator	Bending Magnet, Upstream of Target
heat	thermocouple and thermography	especially exit of Bending Magnet

Imaging port of 2nd BL (Short)

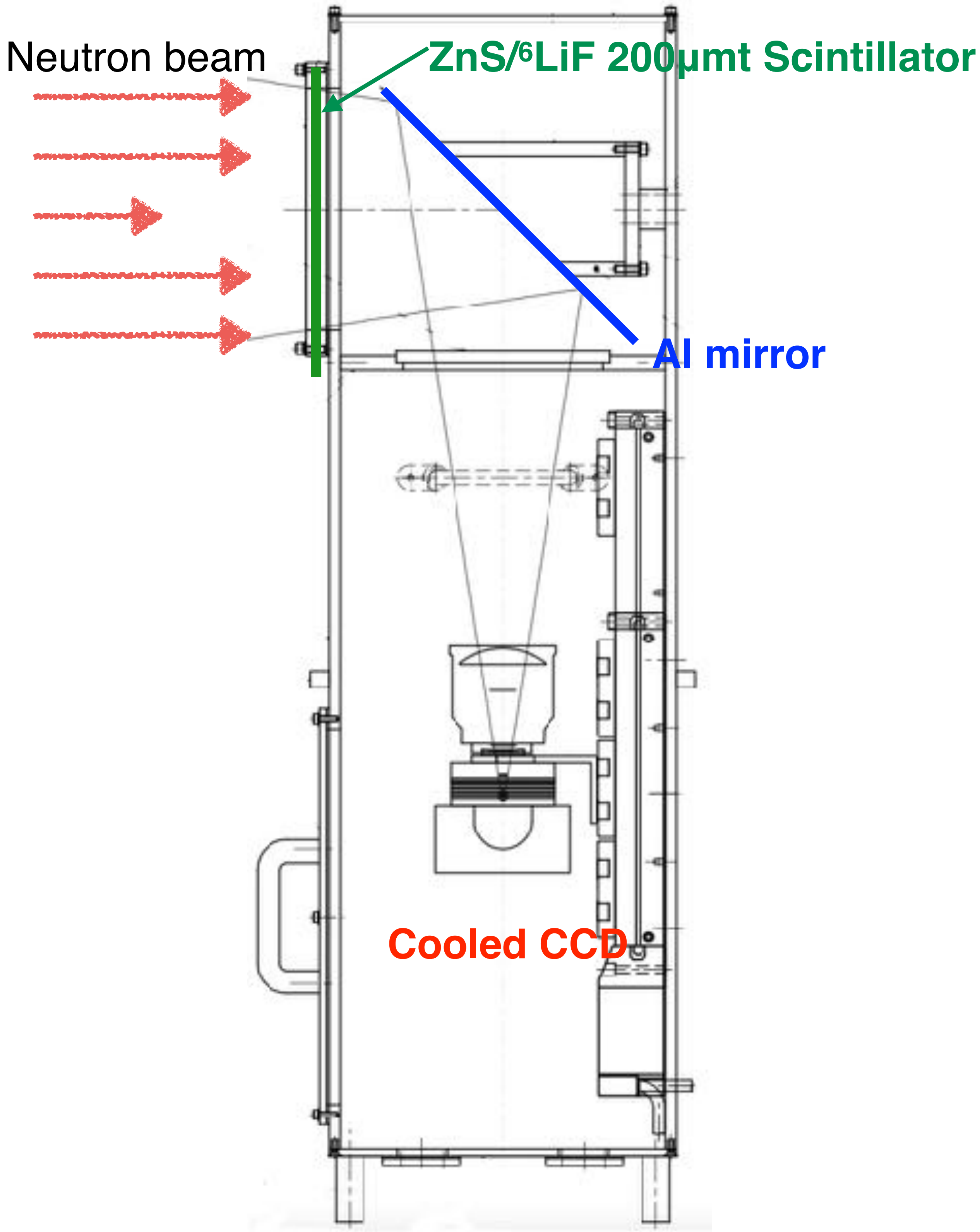


Montecarlo Simulation(PHITS)
Neutron flux distribution
on the scintillator surface



Scintillator size : 10cm x 10cm
Beam flux : Max =**9.5×10^5 n/cm^2/s**,
Min.=7.3×10^5 n/cm^2/s
25% peak to peak

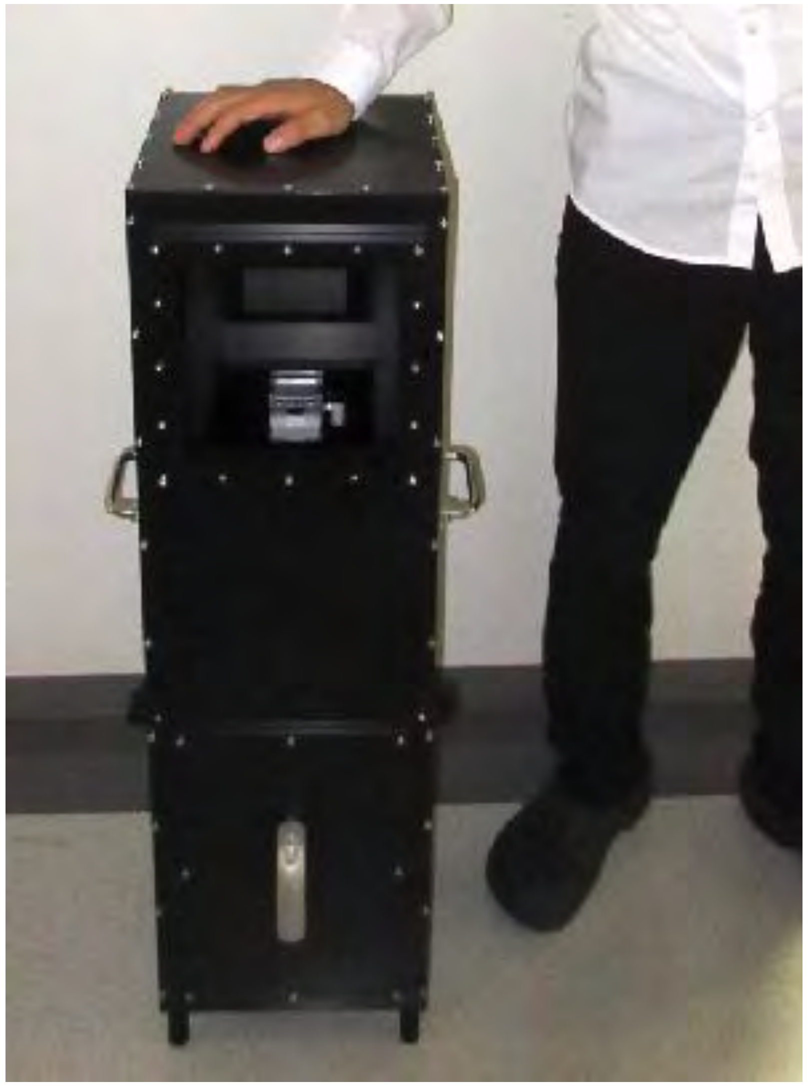
Imaging Camera box for Engineering application



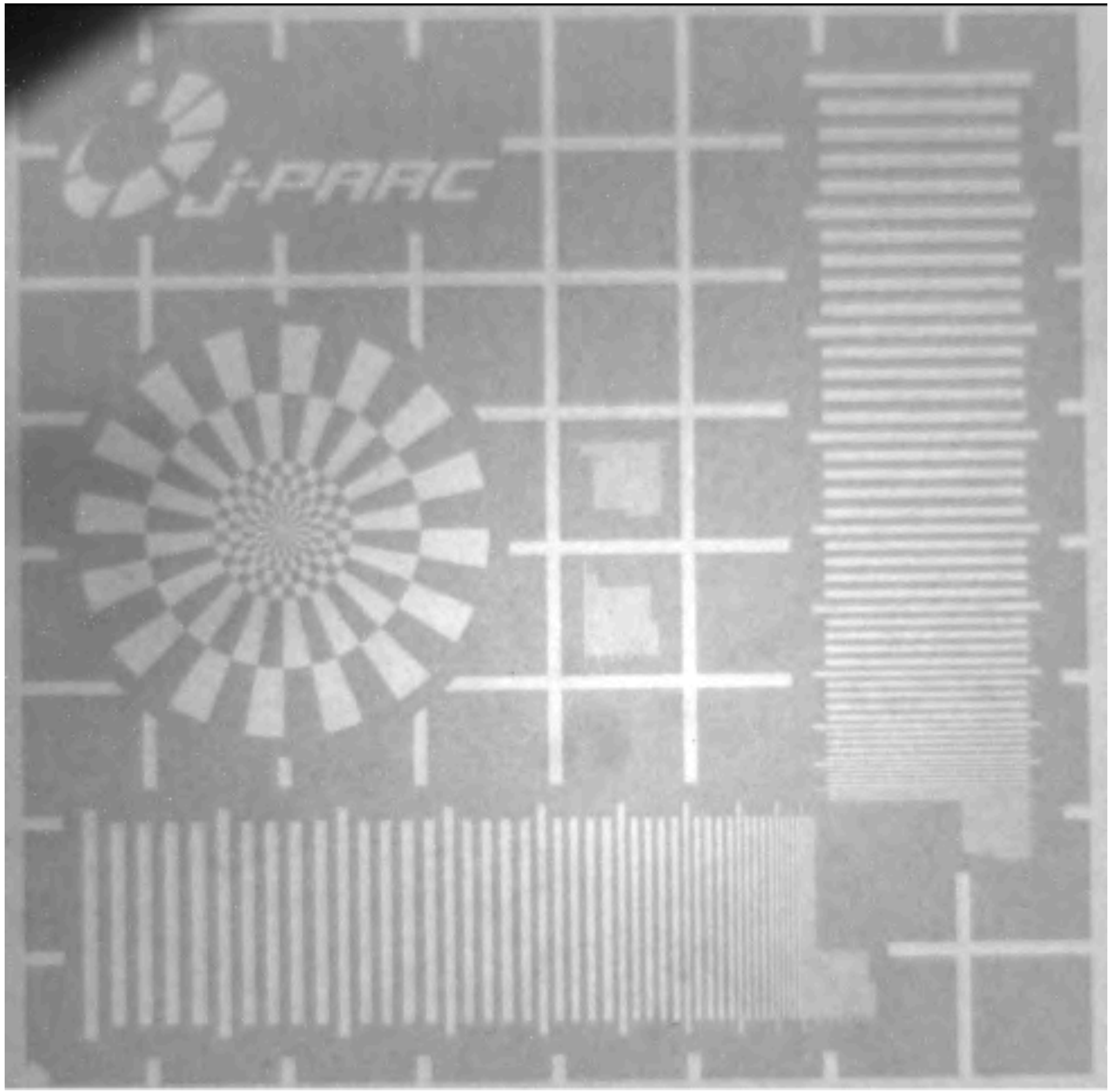
CCD and Scintillator system

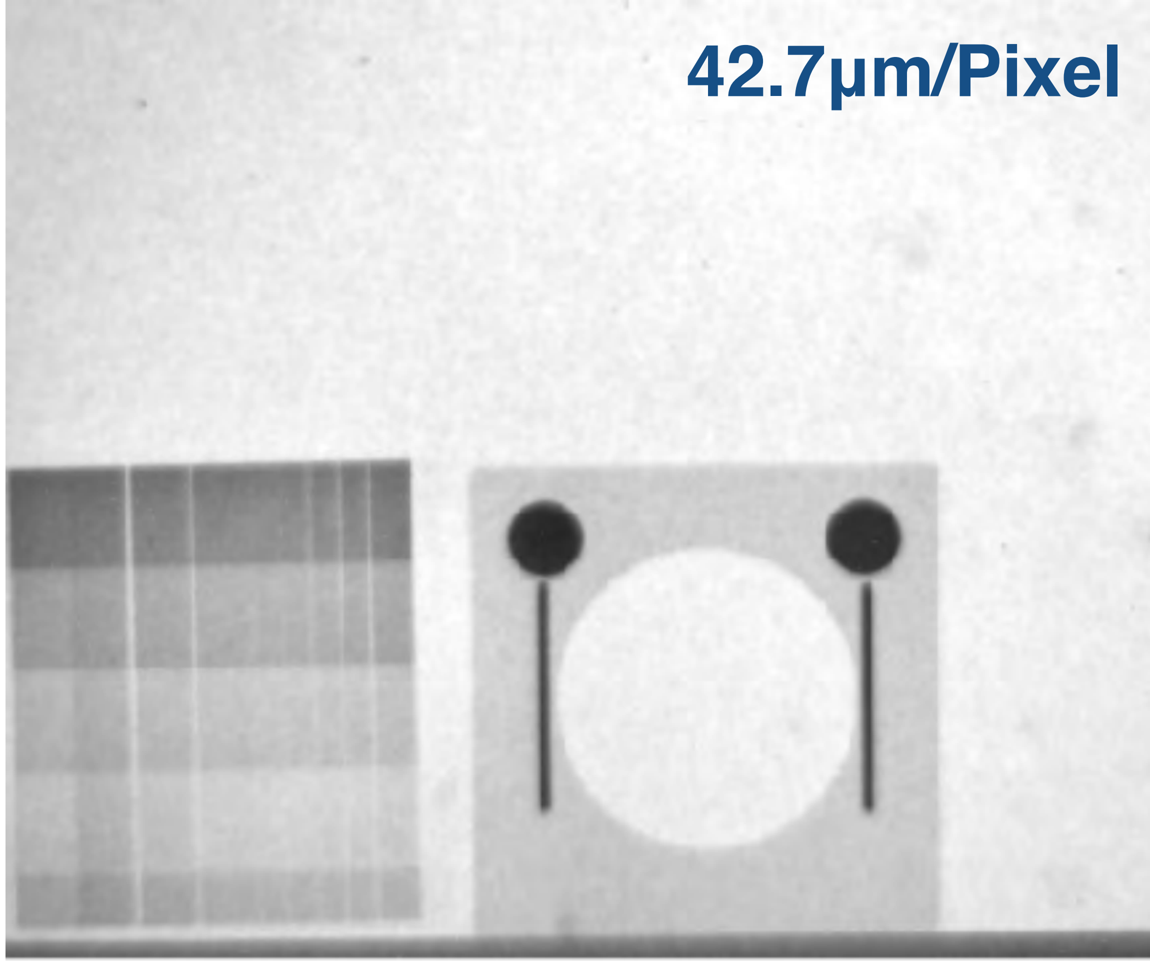
Spatial resolution: ～200 μm

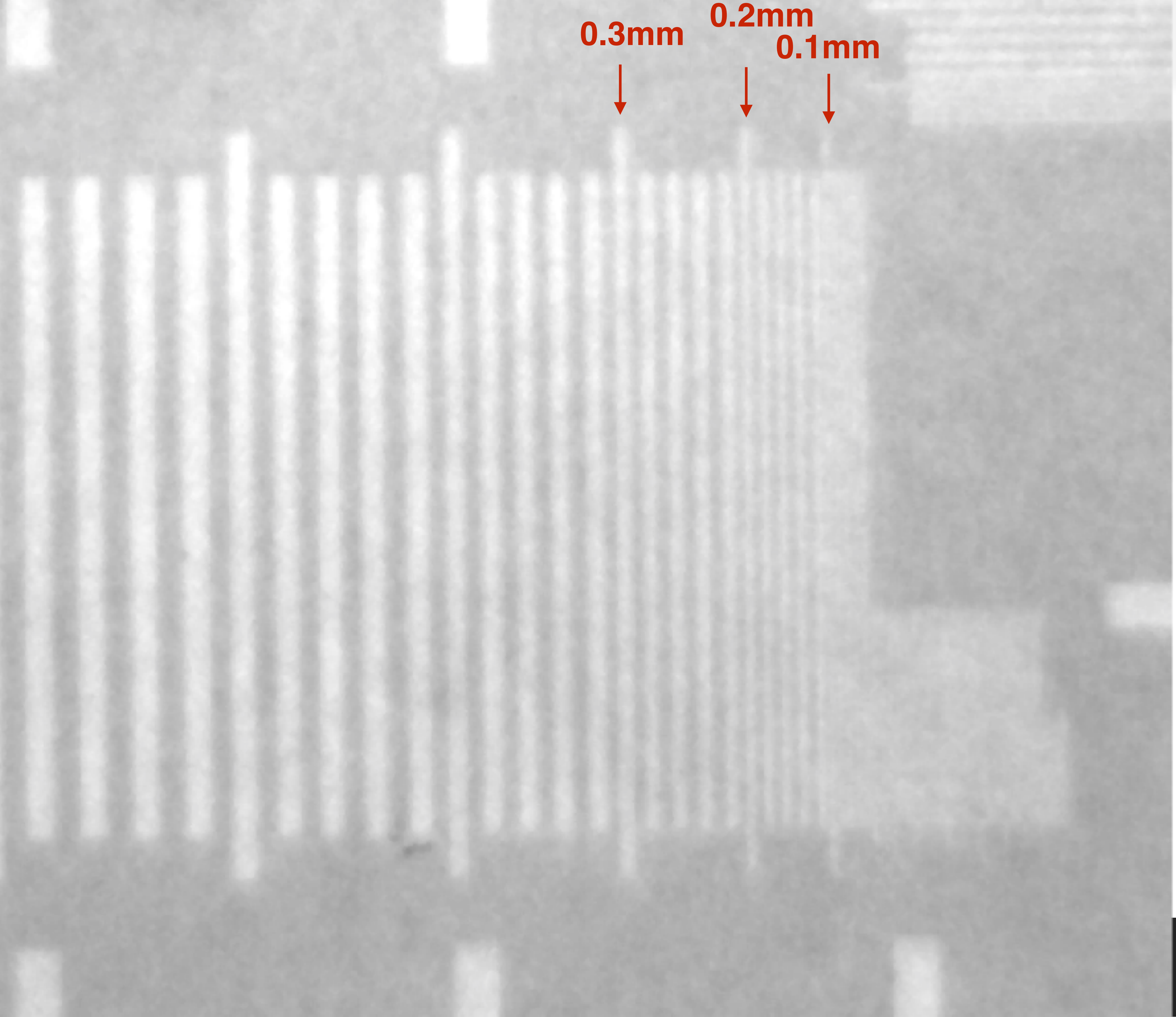
Irradiation time : ~ min.
Movie is available : (DC beam)



Neutron Camera Check at KUR






0.3mm
0.2mm
0.1mm

Future Plan

Development and Construction of **compact neutron sources(CANS)** have realized that neutron sources are “familiar and easy to use”.

CANSs are convenient. However, CANSs are **not versatile** and there are many **restrictions**. CANS do not replace the large facilities.

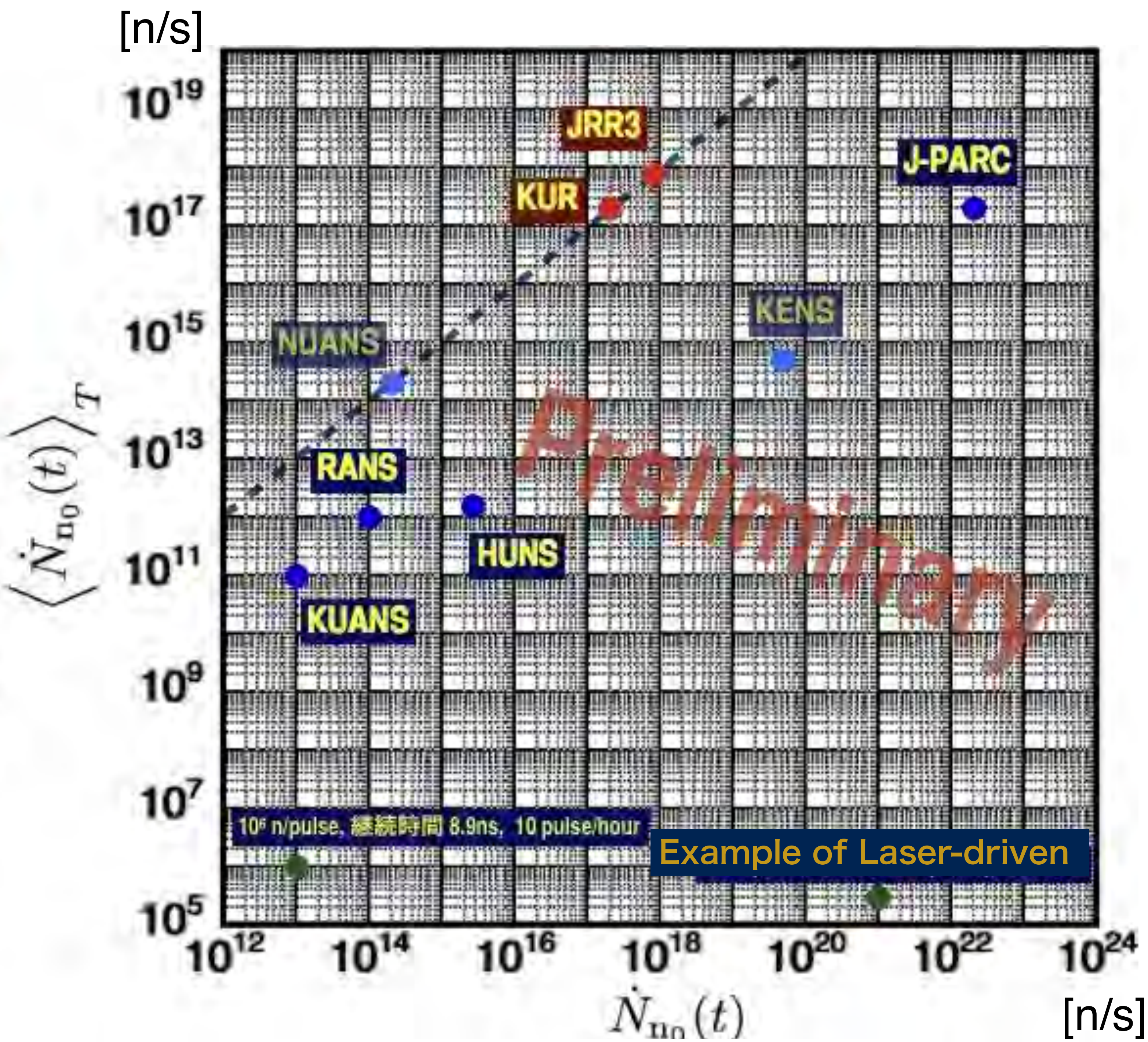
Now, we need “**reasonable neutron statistics**”, “**Low cost**” and “**High usage frequency**” facilities.

Middle Scale New Neutron Source

Average and Instantaneous neutron emission

Time Average Neutron Emission

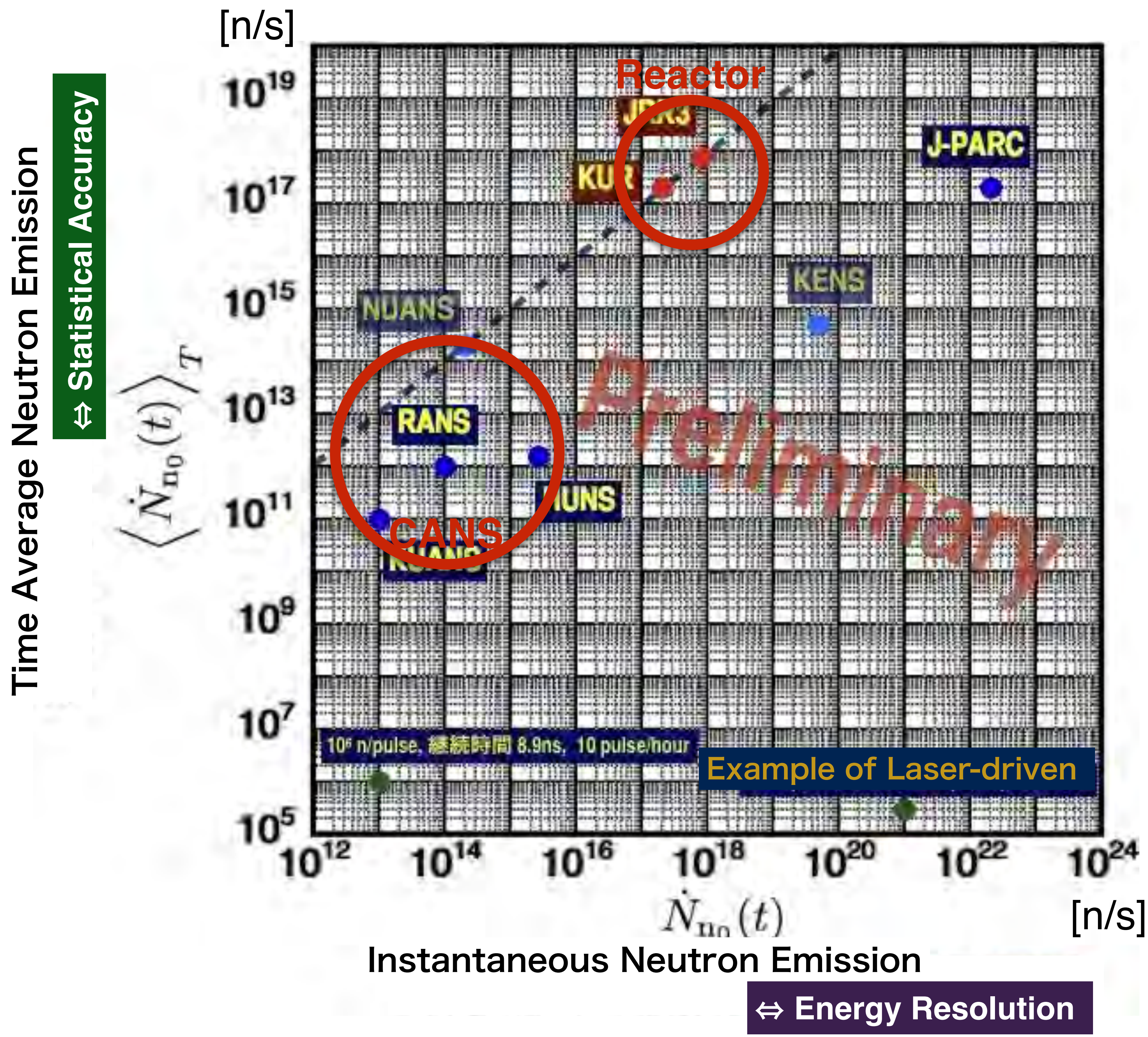
⇔ Statistical Accuracy



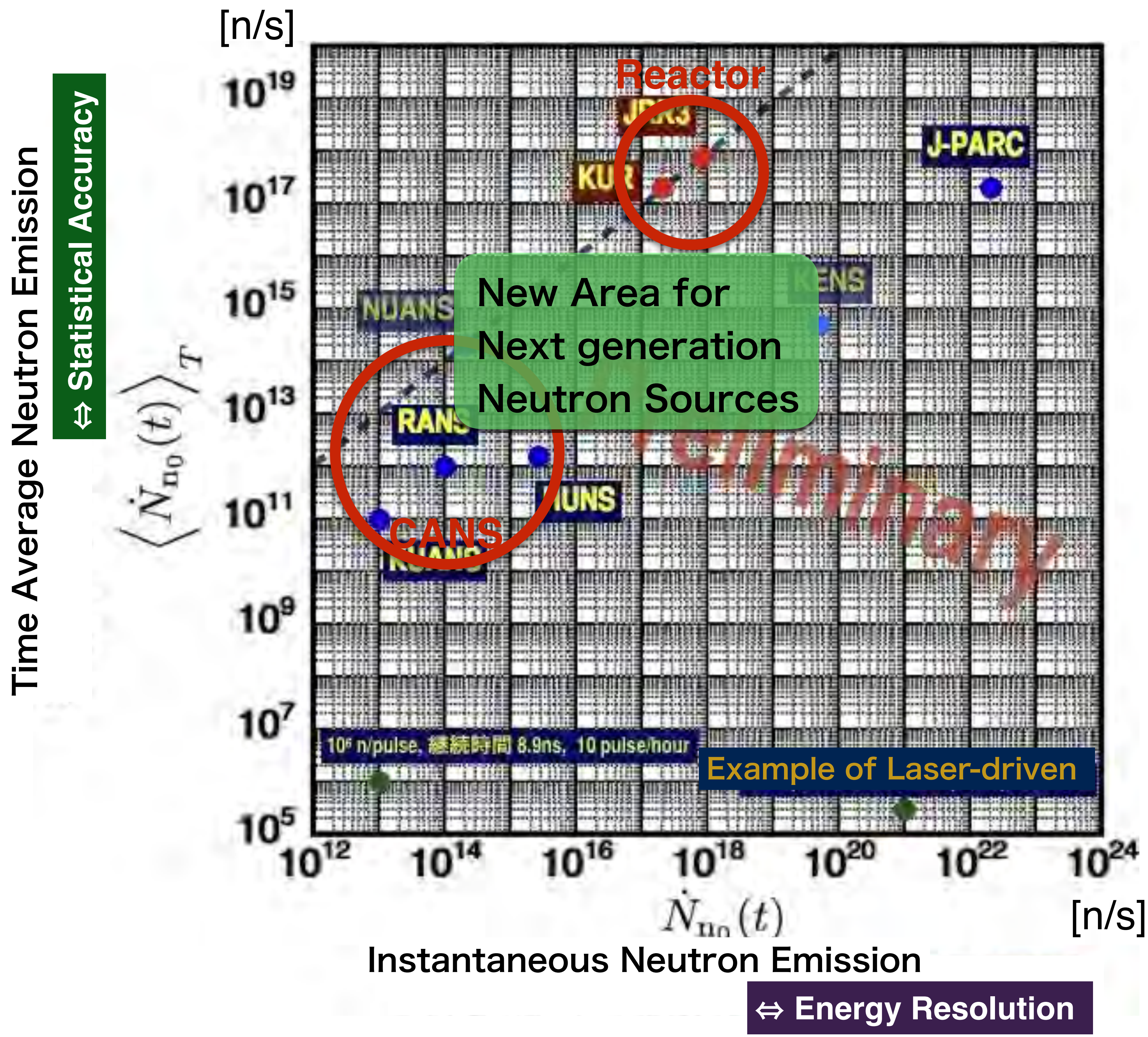
Instantaneous Neutron Emission

⇔ Energy Resolution

Average and Instantaneous neutron emission



Average and Instantaneous neutron emission



Summary

Accelerator-driven compact neutron sources are very attractive tools for neutron science and we are constructing.
More than ten neutron facilities are active or under constructing in Japan.

In Future plan,
To improve the neutron environment,
we start planning the middle scale size neutron facility.

Thank you for your attention