R&D for Neutron Physics

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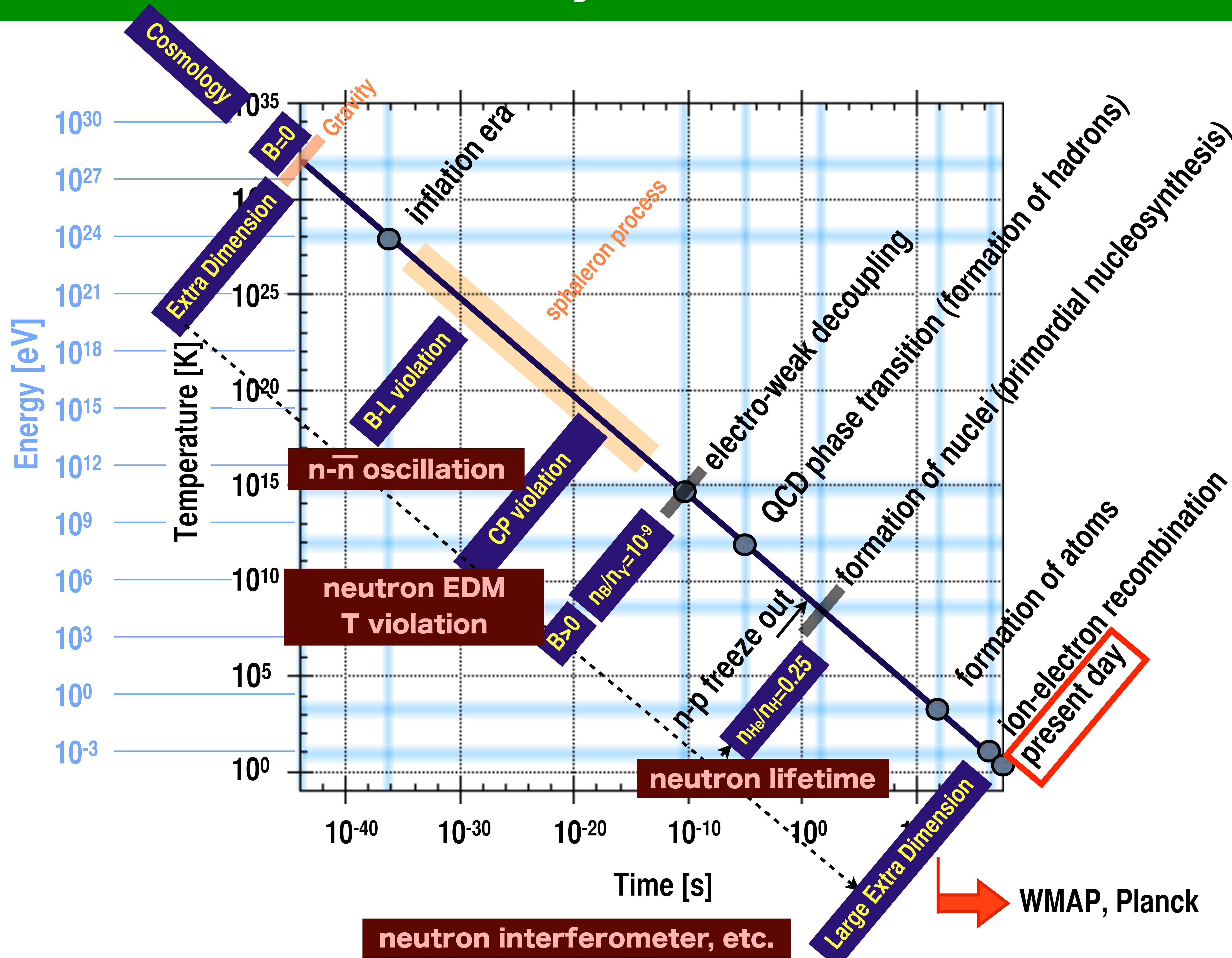
Introduction

Fundamental Physics with Neutrons



T-violation search using compound nuclear resonance

Candidates of Sample targets

^{139}La (E$_n$ = 0.73eV)

^{131}Xe (E$_n$ = 3.2 eV)

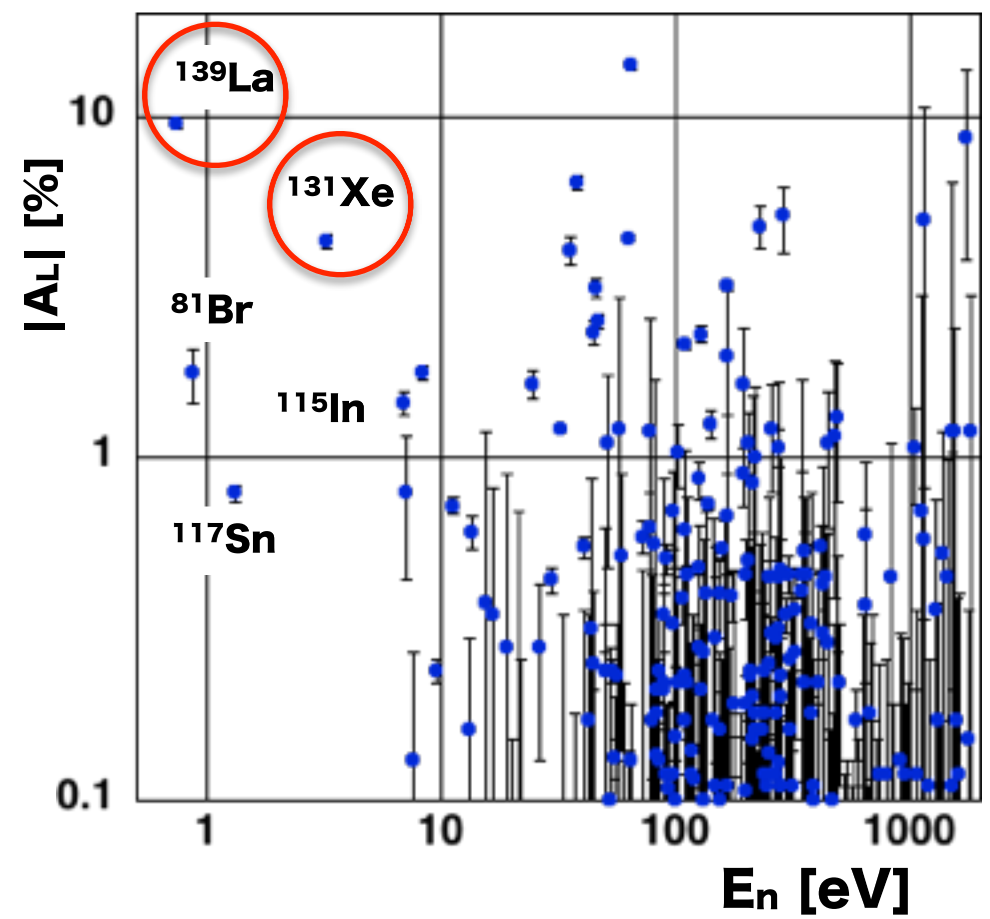
^{81}Br, ^{115}In, ^{117}Sn

Measurements

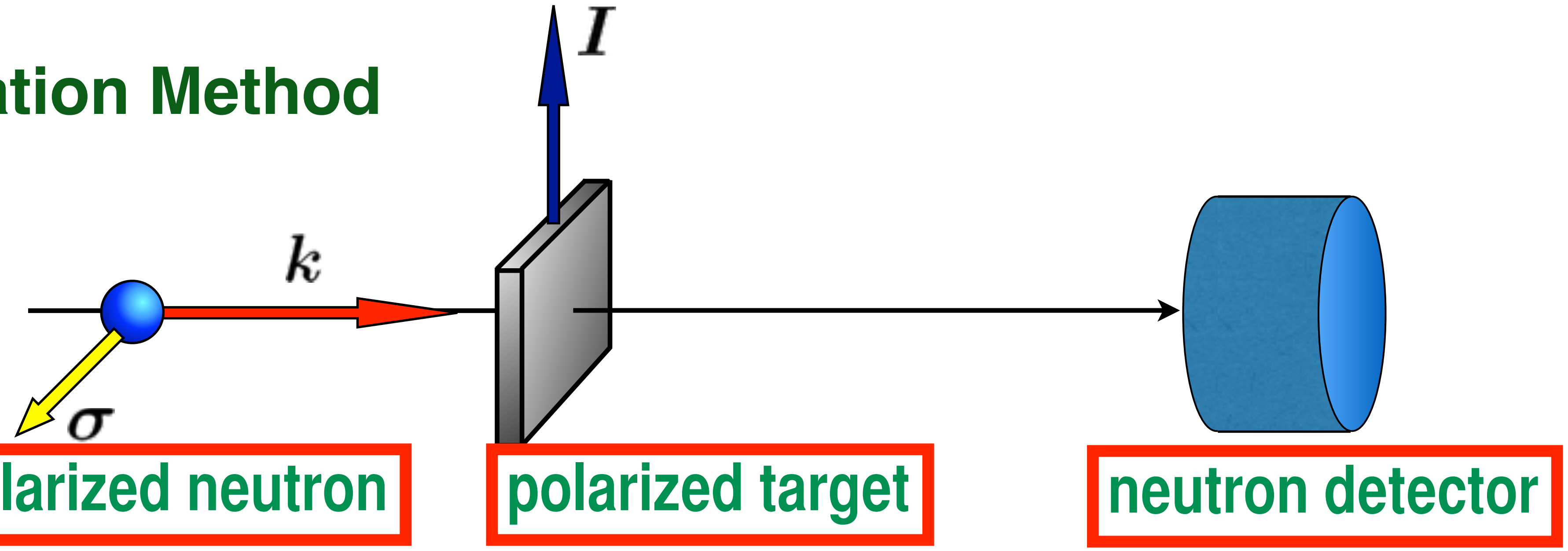
neutron attenuation

(n,γ) measurements

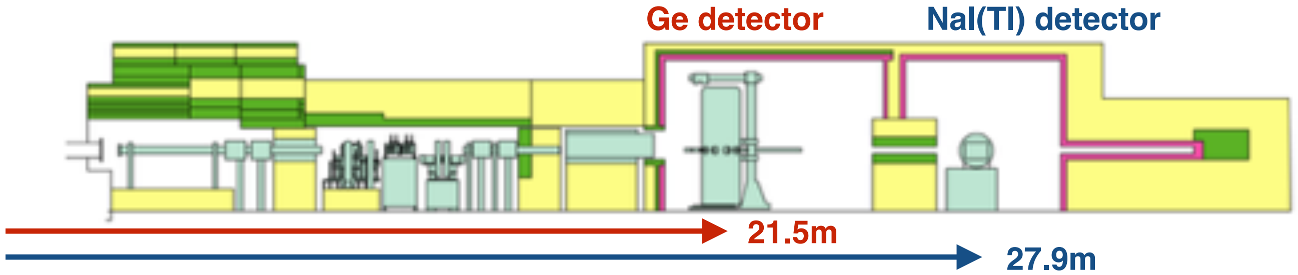
P-violating Asymmetry



Attenuation Method



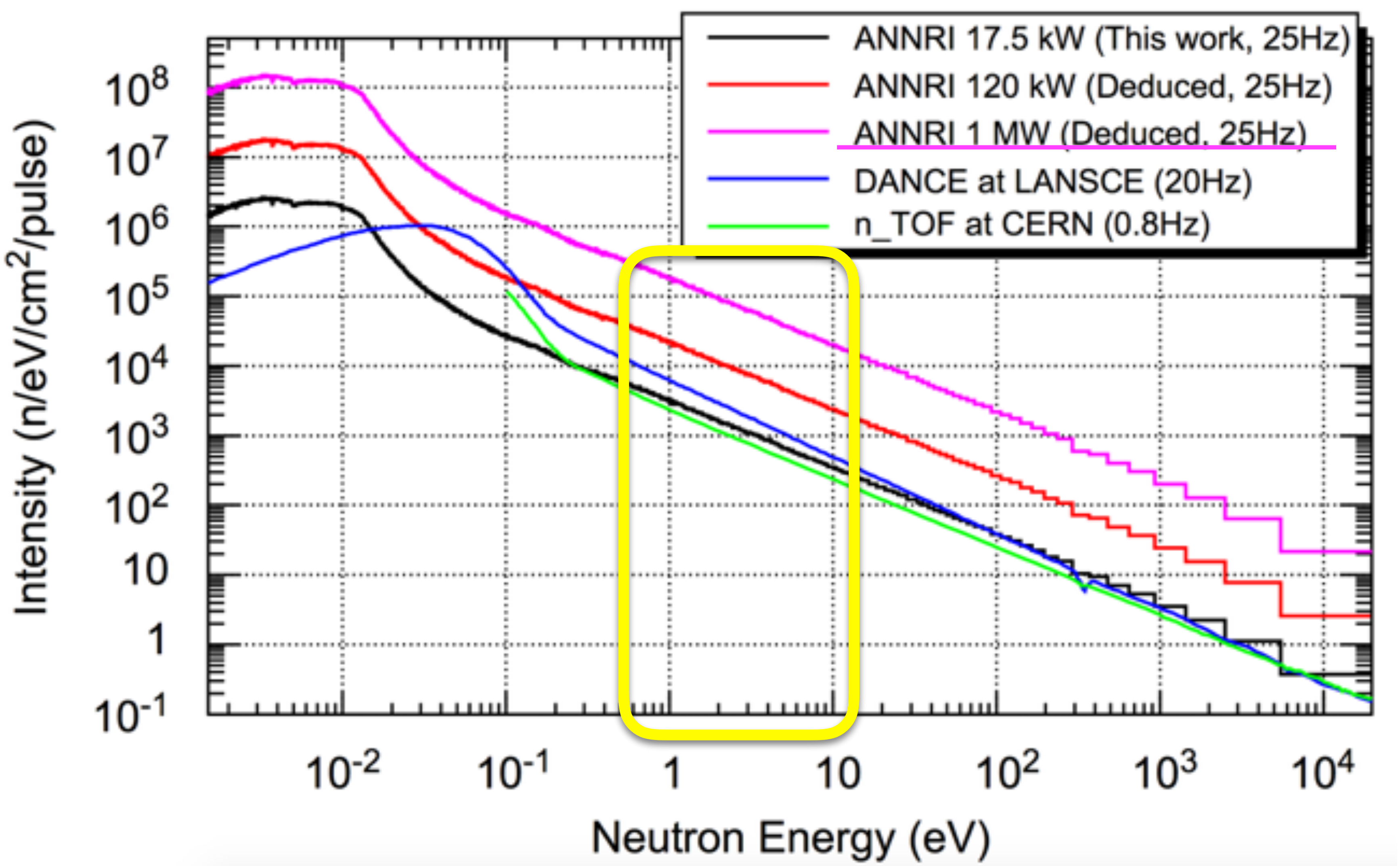
Requirements for Neutron Detector



For La case,　(at L= 21.5 m)
0.7- 0.8 eV neutrons are coming 120 usec
→　**160 Mcps / cm²**

For Xe case,
3.0 -3.5 eV neutrons are coming in 67usec
→　**420Mcps /cm²**

Neutron Flux at J-PARC BL04 (ANNRI)



ref)　Kino et.al., NIM A626 (2011) 58

High count rate detector

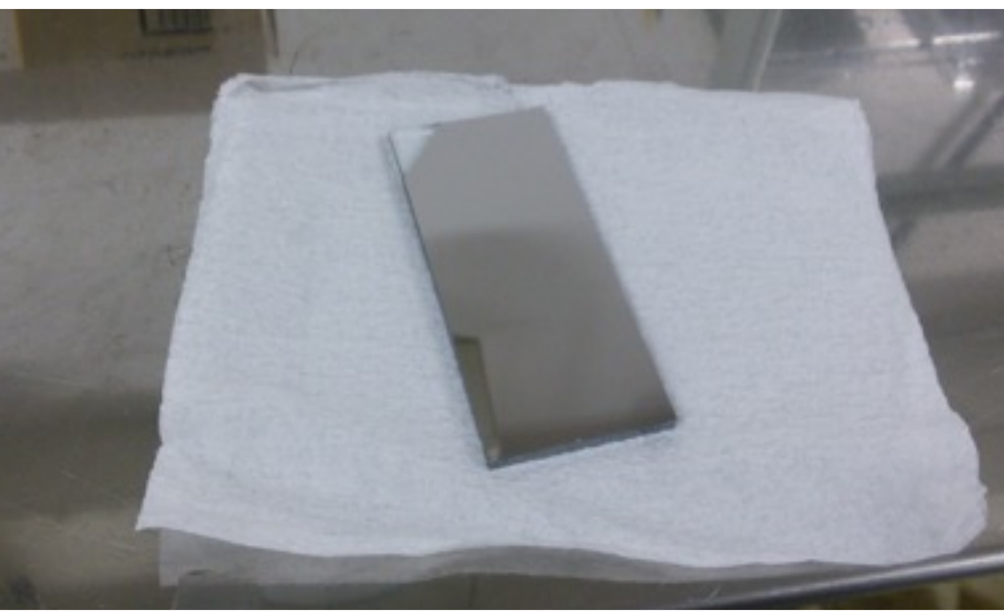
- fast DAQ system
- fast decay time scintillator
- n/γ separation, simple algorithm → install to DAQ system

Candidate of scintillator

		Light output % Anthracene	Wavelength (nm)	Decay time(ns)	neutron converter	neutron absorption at 0.75eV , 1cm thickness	neutron absorption at 3eV, 1cm thickness
NE213 BC501A, EJ301	Liguid	78	425	3.2	-		
BC523A	Liquid	65	425	3.7	Boron 4.41 %	82%	**57%**
GS20 (Li Glass)	Solid	20 - 30	395	16, 49 & 78	Lithium 6.6 %	93%	74%
LBO:Cu ($Li_2B_4O_7$)	Solid	0.5	360	< 1	Li 8% B 26%	99%	93%

Neutron Mirror Development

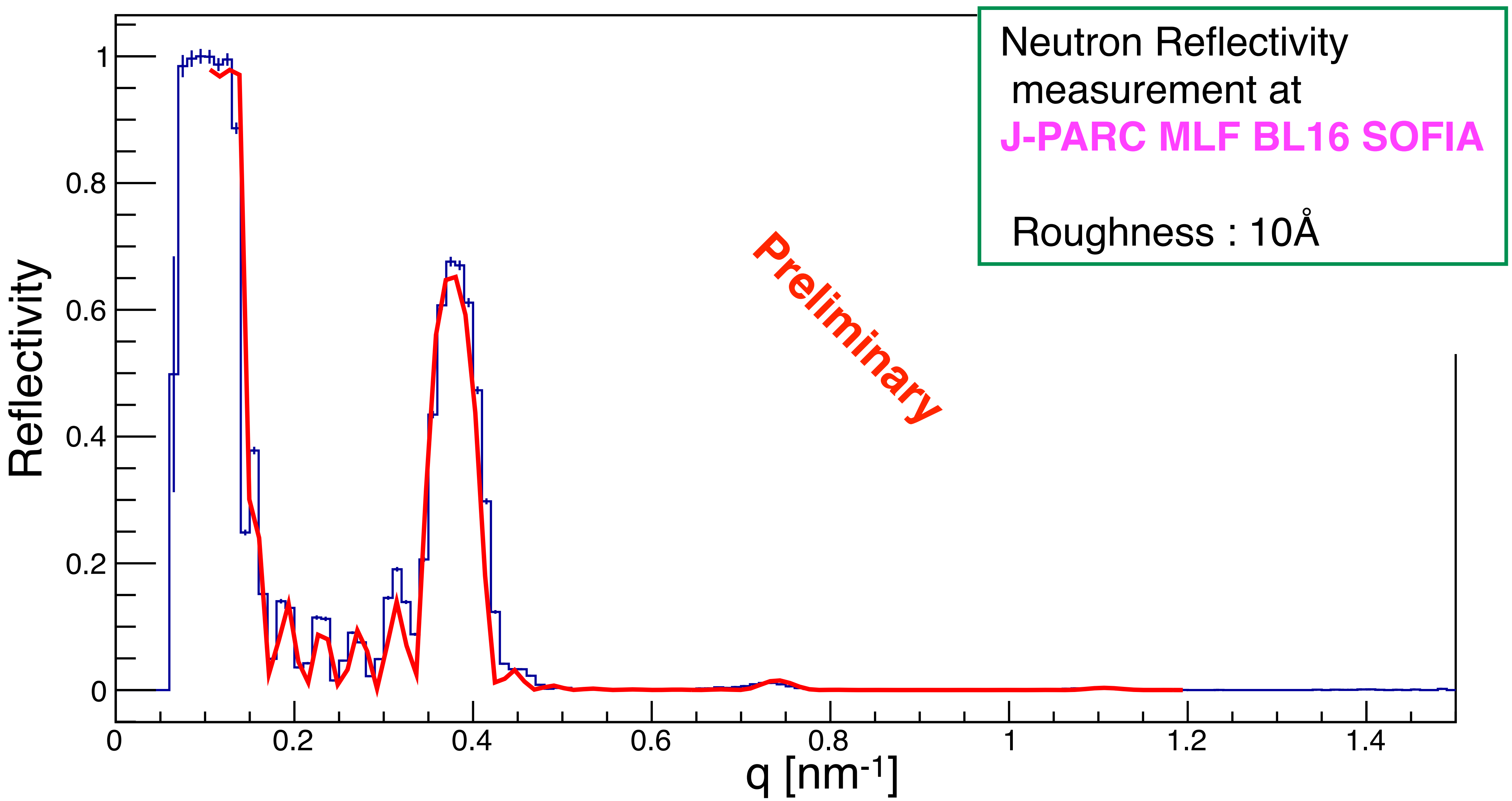
DC magnetron sputtering system with Ux Lab.



First example of multilayer neutron mirror by DC Sputter.
m = 2, 14 layer

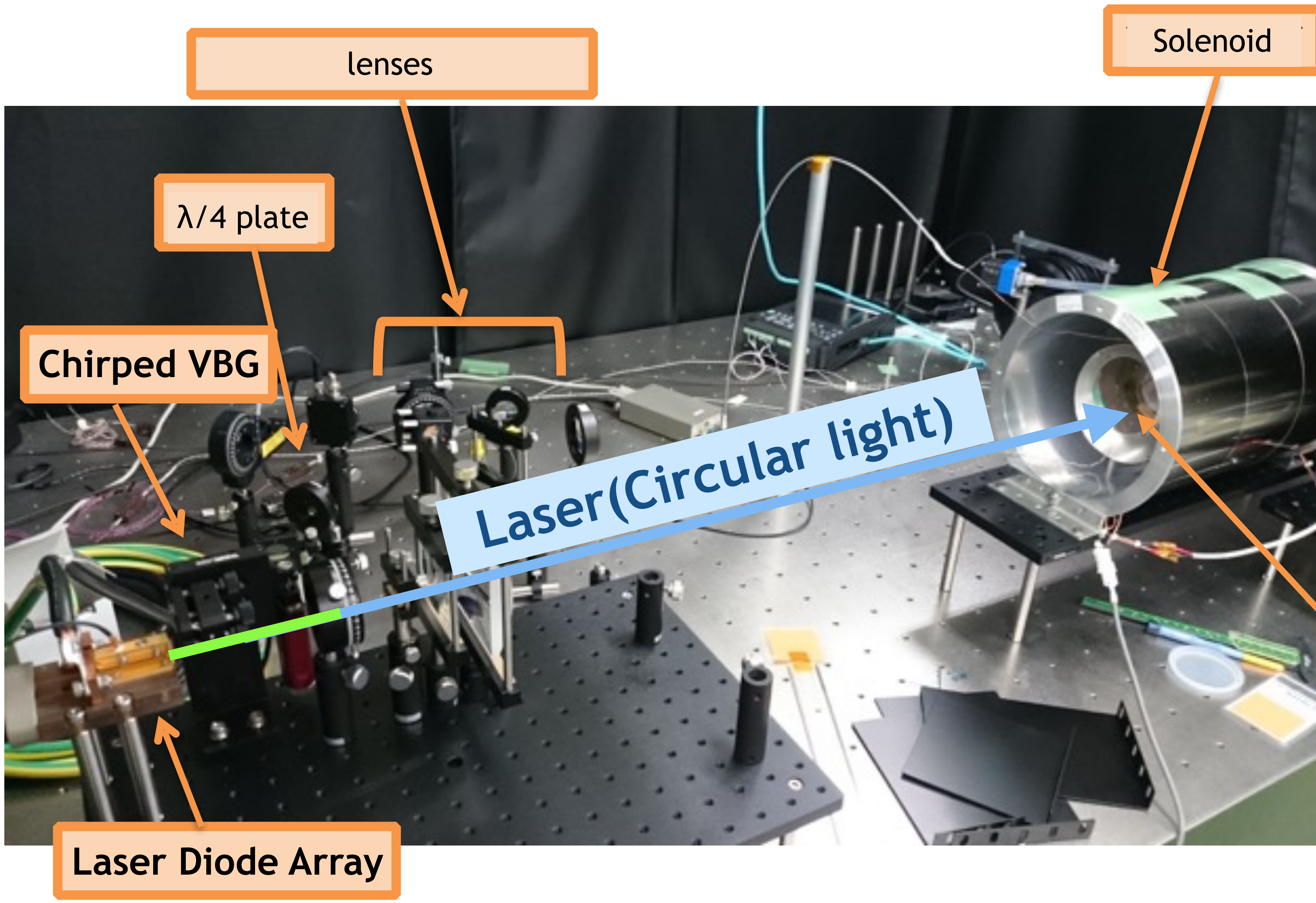
DC magnetron sputtering system with Ux Lab.

Nichrome -Ti multilayer: 7 nm thickness, 14 layers

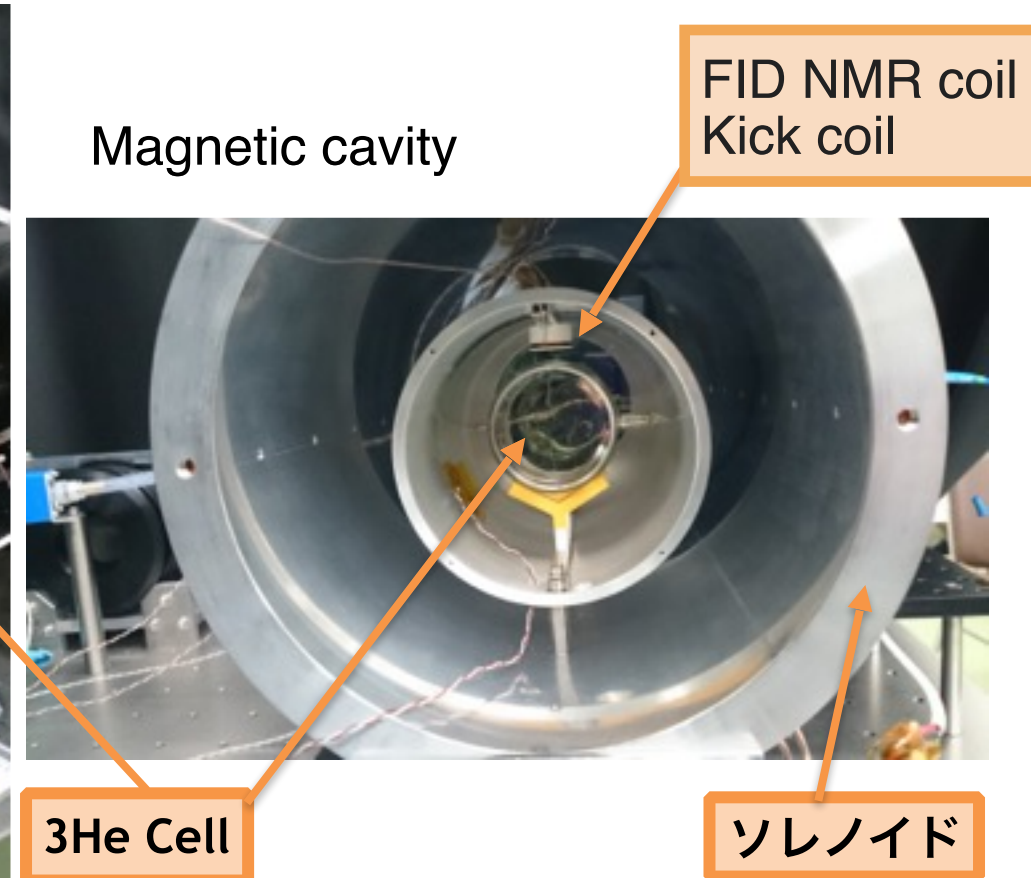


Polarized Neutron beam - SEOP

Spin Exchange Optical Pumping



Free Induction Decay



^{3}He Polarization : (61.4 ±0.2) % (at J-PARC MLF BL05)

estimate → Neutron Polarization : 19 % (E_n=0.75 eV)

Device development

We need neutron devices for our experiments

Mainly for nnbar oscillation search

・neutron mirror (multilayer material mirror)

: m=6~10 (~ 10,000 layer)

Mainly for T-Violation search

・Neutron Polarizer (or Analyzer)

: epithermal neutron beam (〜eV)

・High counting rate neutron detector : ~ GHz/detector

We also need neutron beam for developing these devices.

→ We decide to construct new compact neutron source

In Nagoya University Campus.

Compact Neutron Source

Nagoya University Accelerator-driven Neutron Source

NUANS

Nagoya University Science-Engineering Quantum Beam

Intra-university Collaboration

Science : Φ-Lab. + N-Lab. + F-Lab.

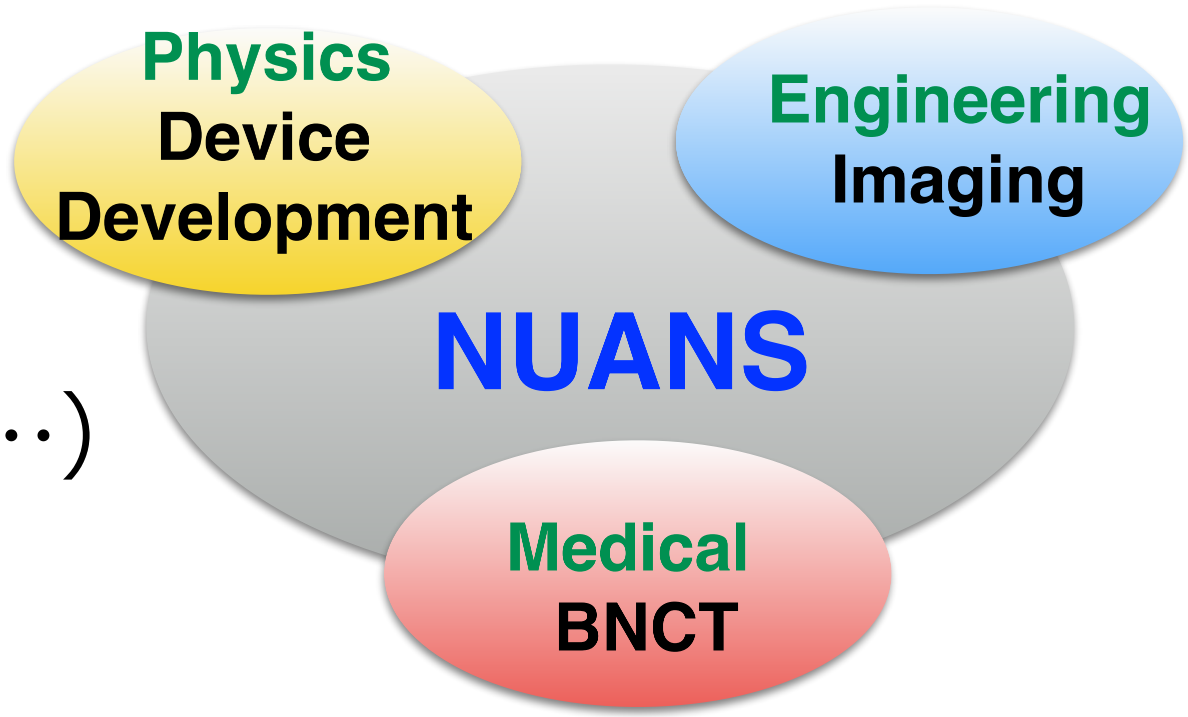
Engineering: Uritani-Lab. + Iguchi-Lab.

NUANS

Two beamlines are designing at NUANS

1st beamline (42kW)

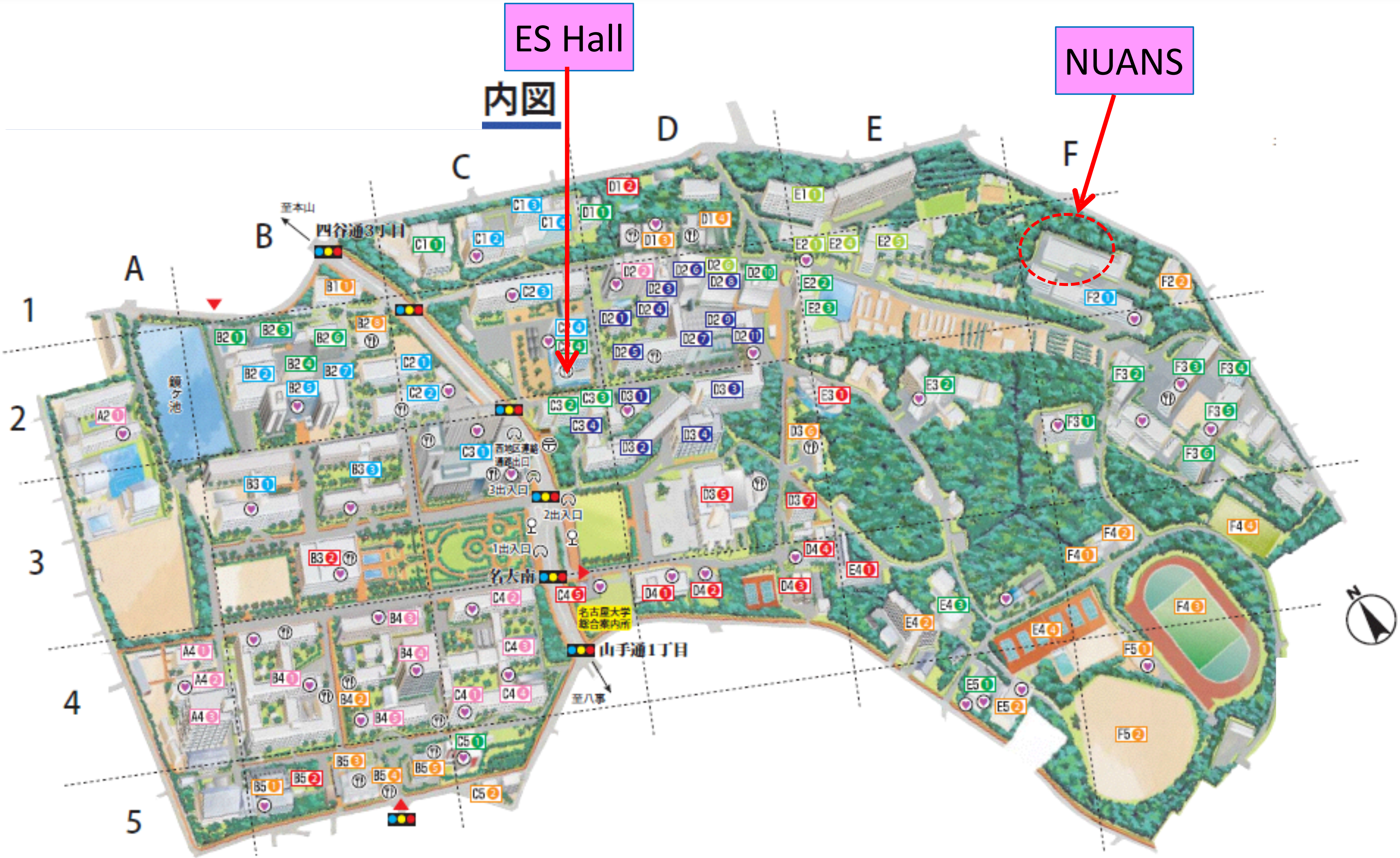
- Device and system development for BNCT (Li-Target、moderator, etc…)



2nd beamline (4kW)

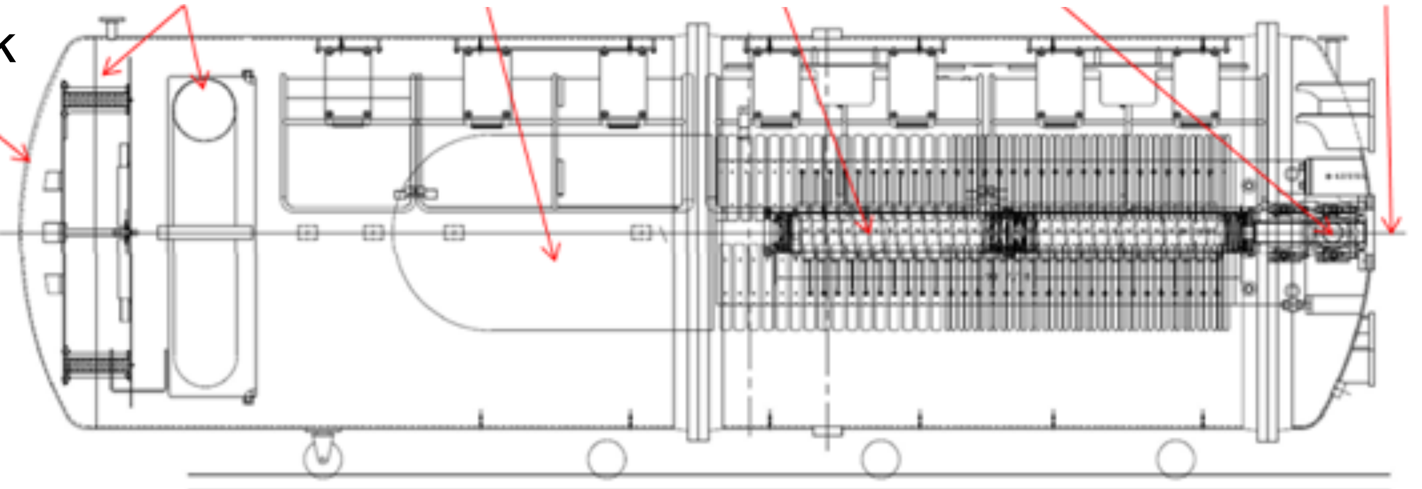
- Neutron Imaging
- Neutron Detector Development
- Neutron optics Development (mirror, lens, etc…)
- Education

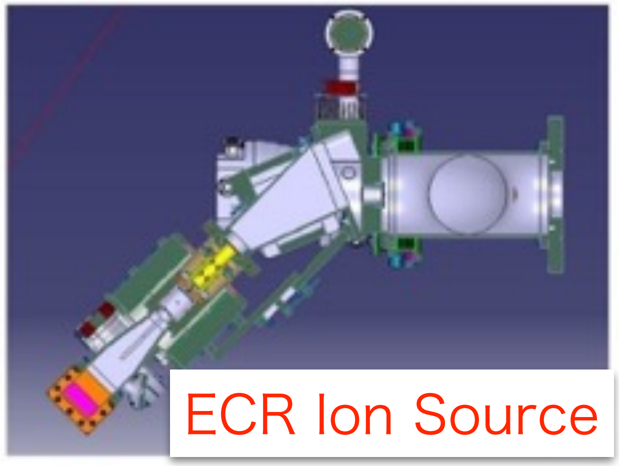
Location of NUANS

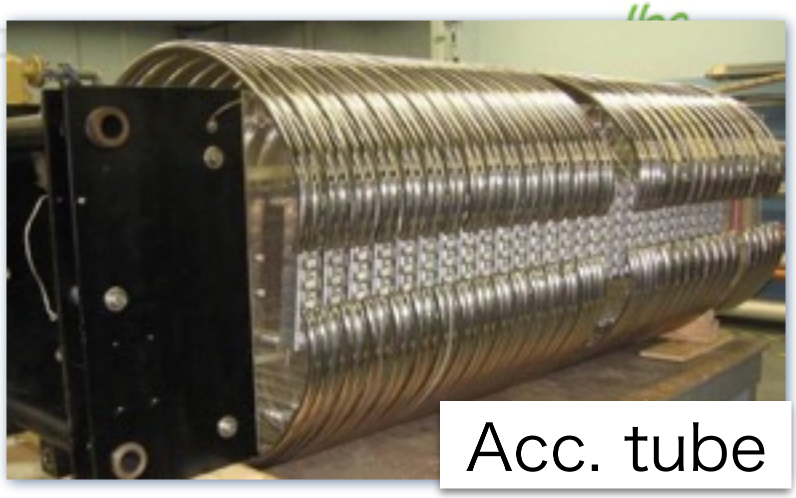


Electrostatic proton accelerator

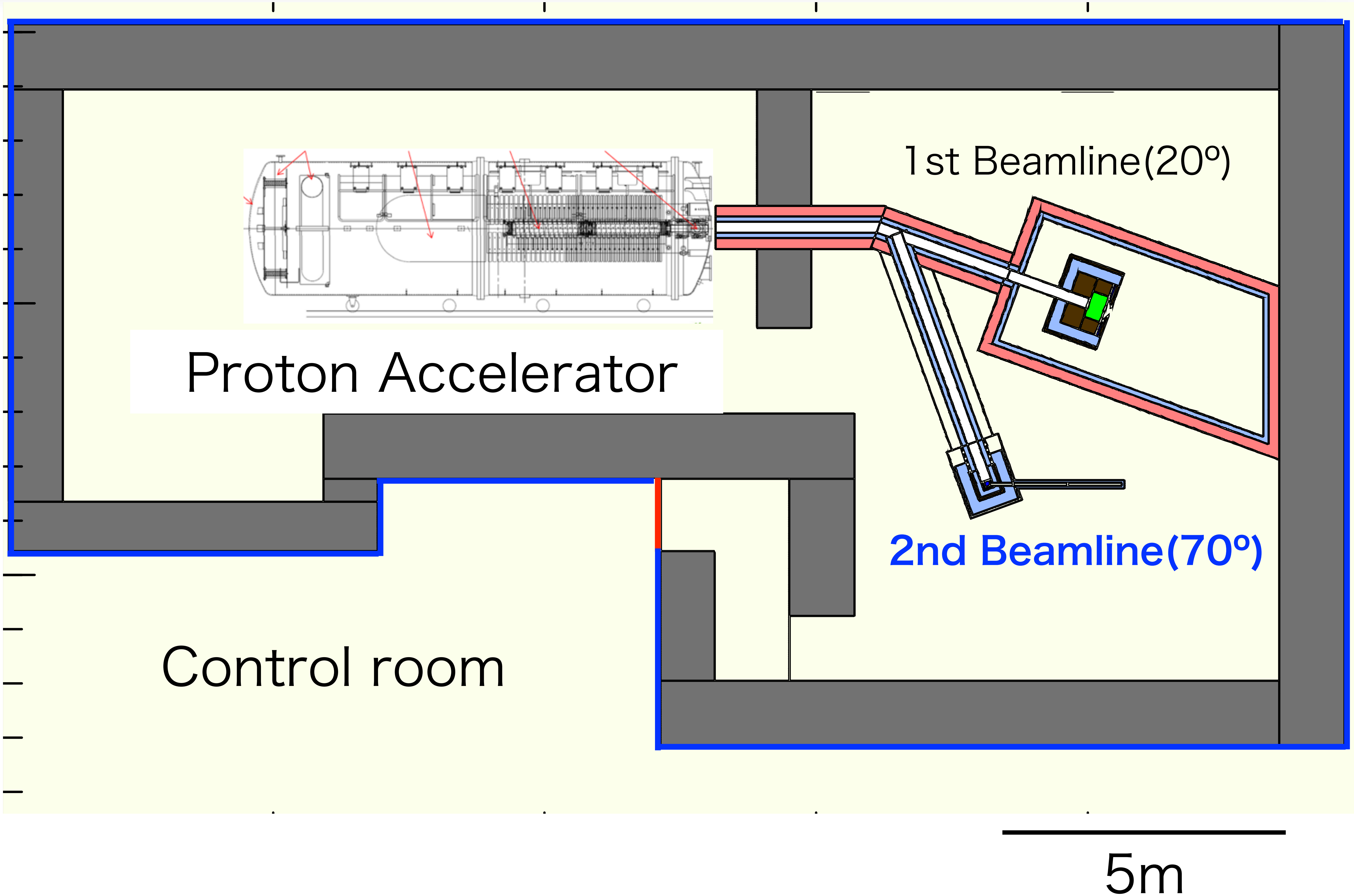
Dynamitron Accelerator (**DC beam**) by IBA Indust.
Proton Energy: 1.9MeV-**2.8MeV**
Proton beam current: Maximum **15mA**, 1.5mA(2nd BL)
Size : 7.5m x 2.8m 6.5ton



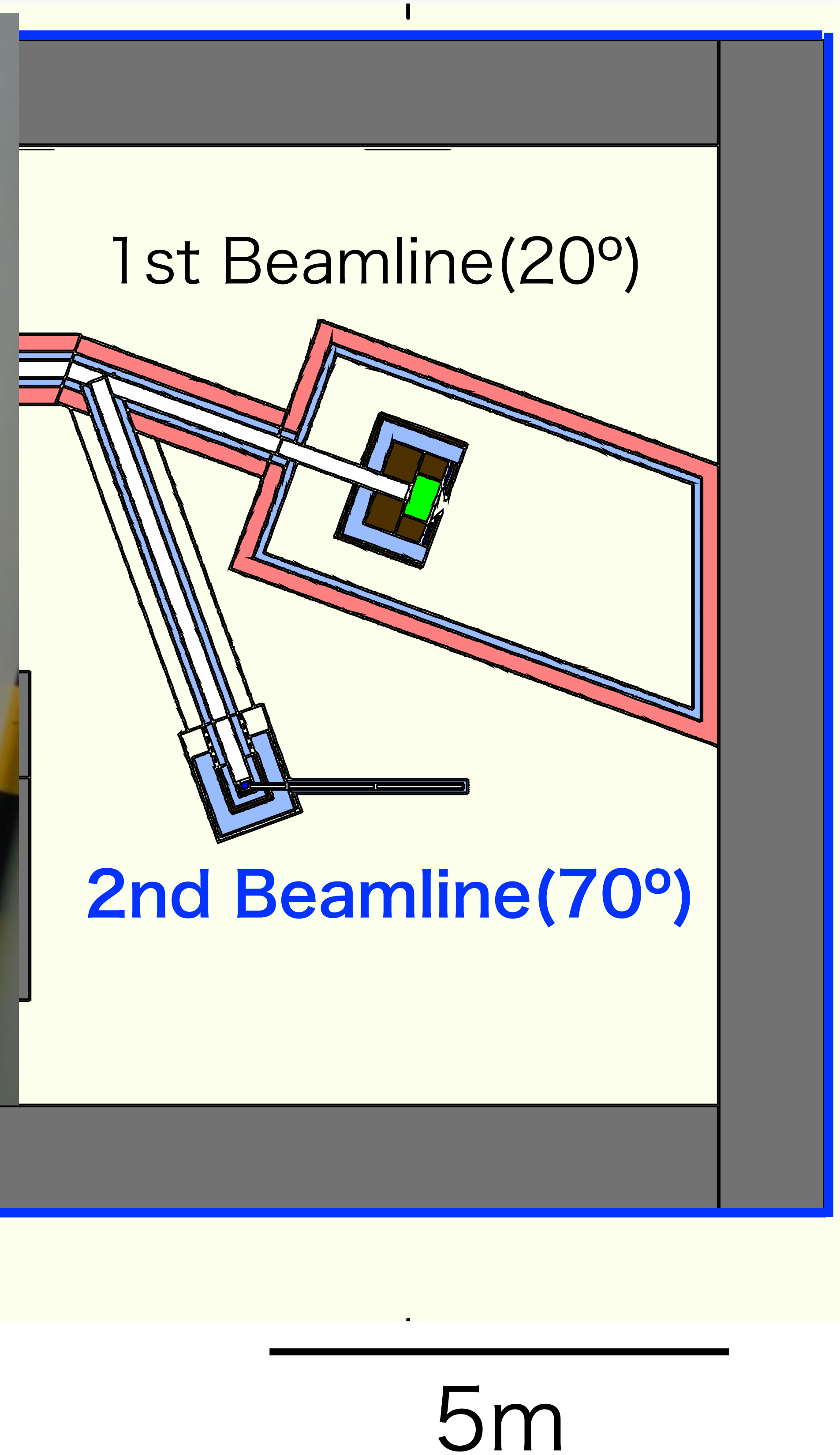

ECR Ion Source


Acc. tube

NUANS is constructing now !



NUANS is constructing now !



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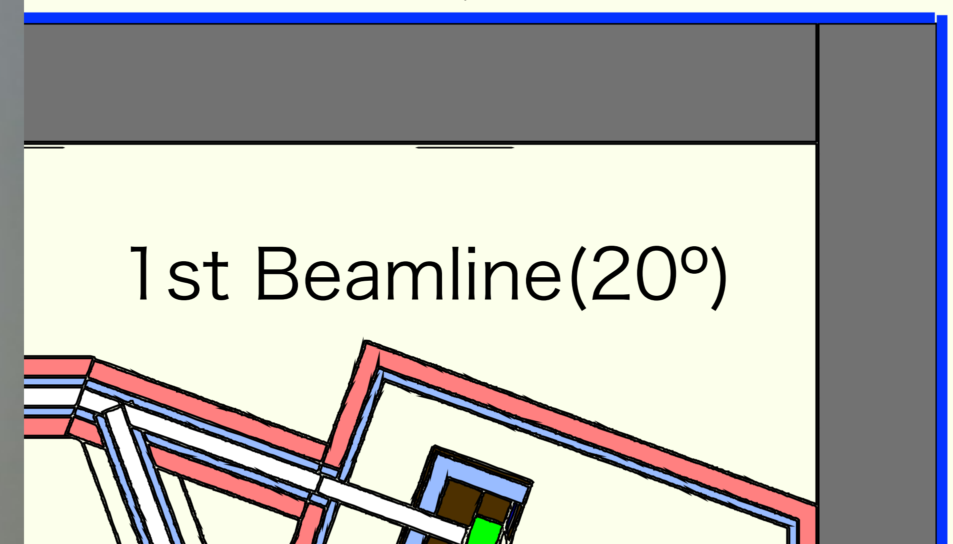
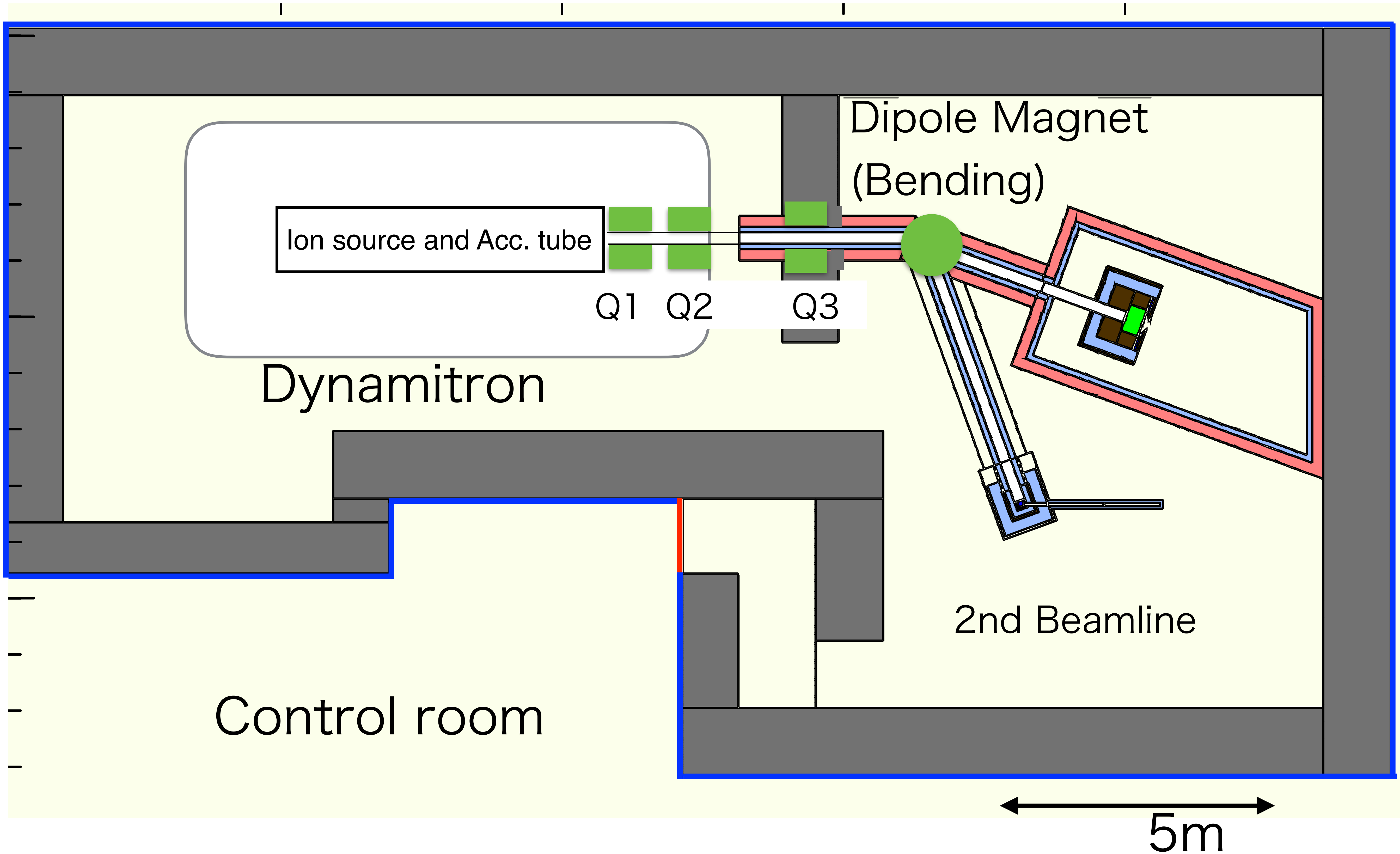


2nd beamline

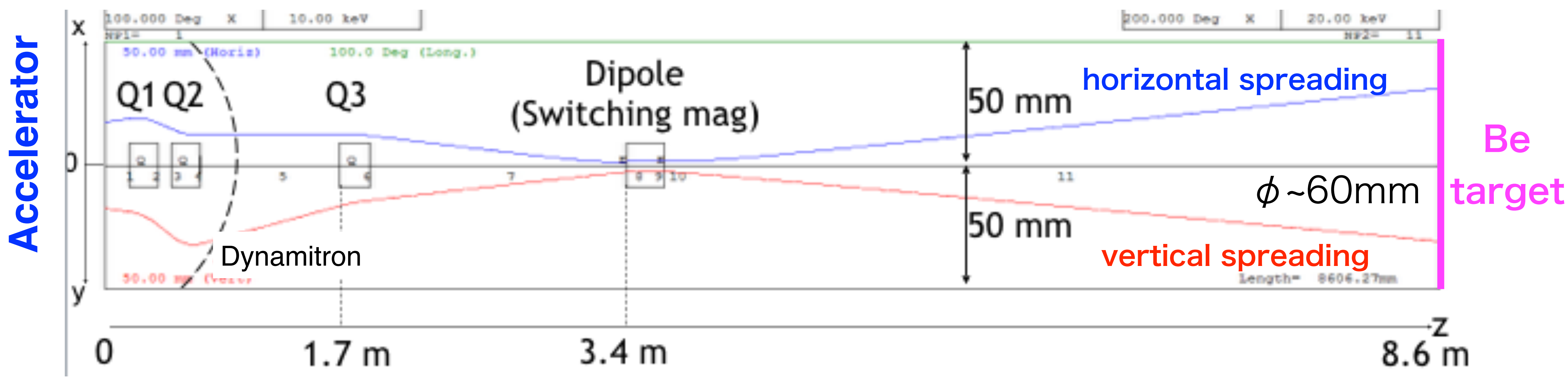
- multi-purpose beamline : easy handle, low cost
  Neutron Imaging
  Neutron detector and devices development
- Proton beam current **1.5mA** 〜 4kW
- **Be** target ϕ100mm → target simulation
- **Polyethylene** moderator(**thermal neutron**)
- radiation level : < 0.1 μSv/h (desired value)
  shield weight : < 2 ton : request by floor capacity
- thermal neutron flux 10^6 n/cm^2/s @50cm
  Neutron Flight path : Short (50cm) or Long (2m)

Proton beamline



Proton beam simulation

We want to set the proton beam size around ϕ80 mm at target position.



Sim. Code : TRACE3D

→Available to control the beam size: ϕ60mm~ϕ100mm

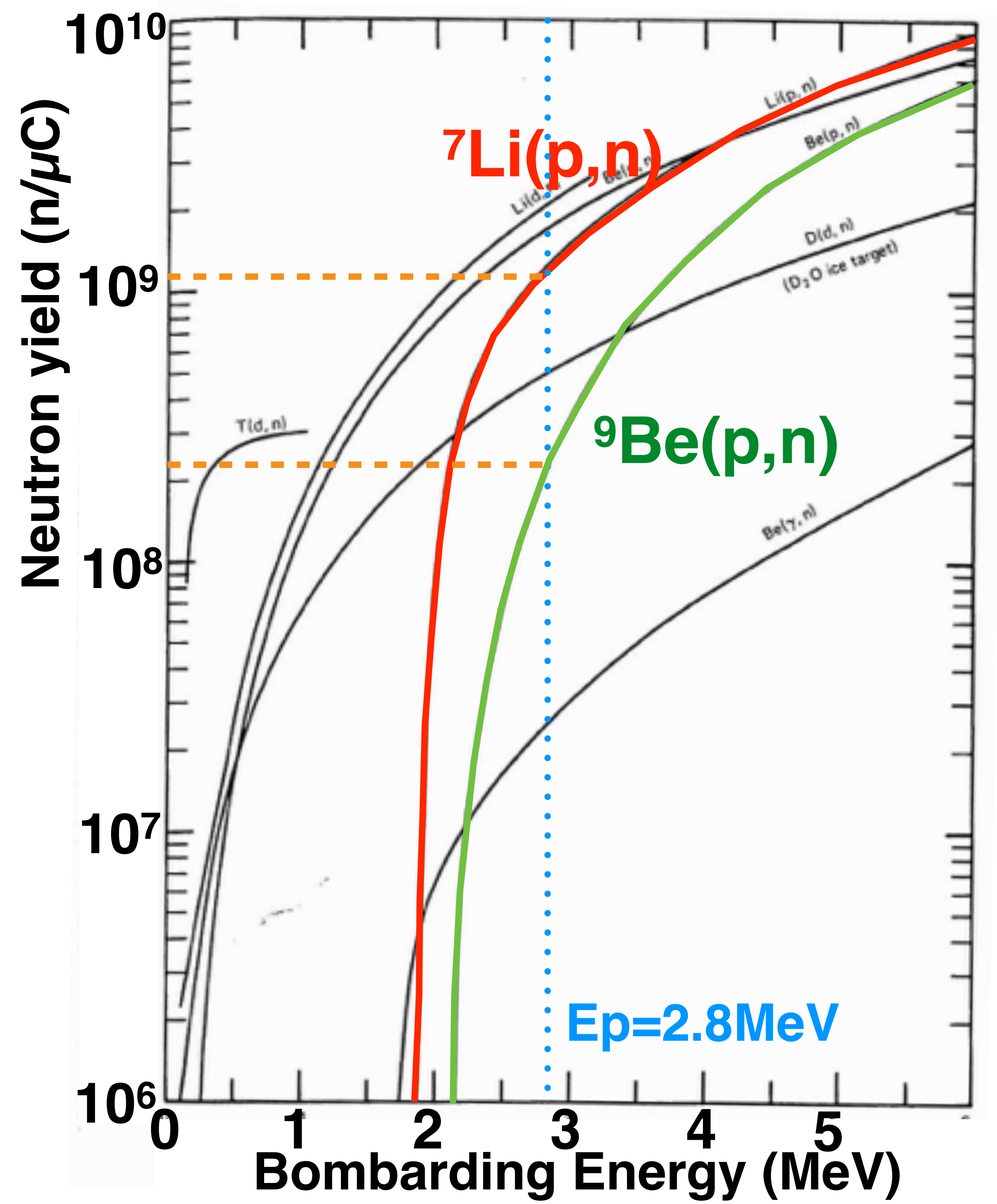
Neutron target

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

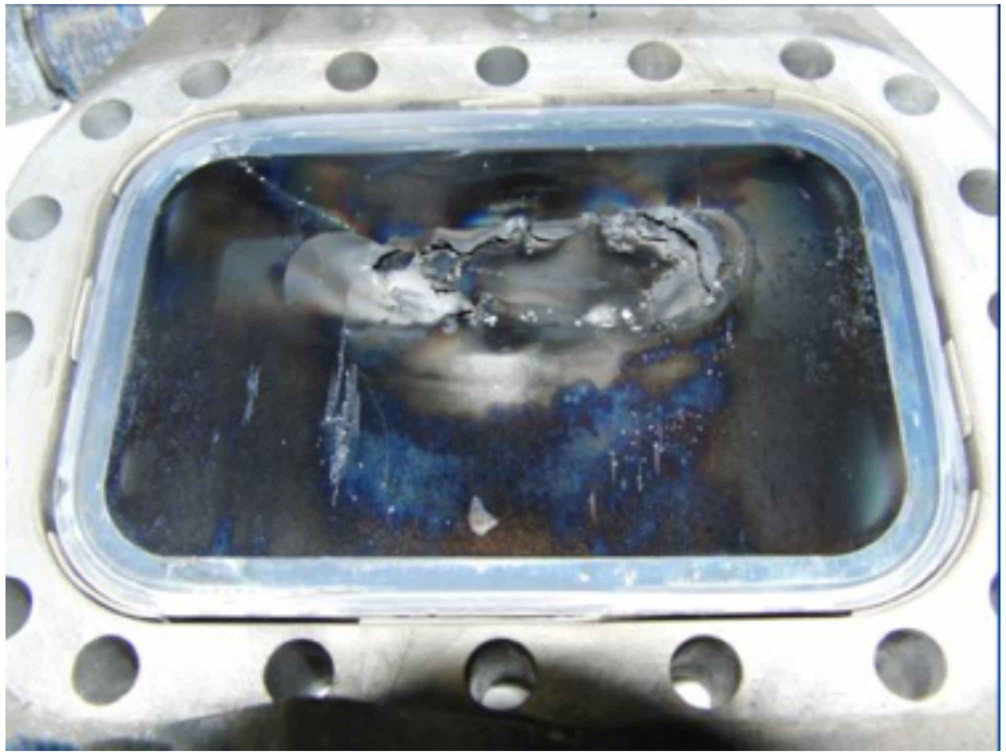
2nd BL : ^{9}Be target
- Chemically stable
- Succeeded to use at RANS, KUANS



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

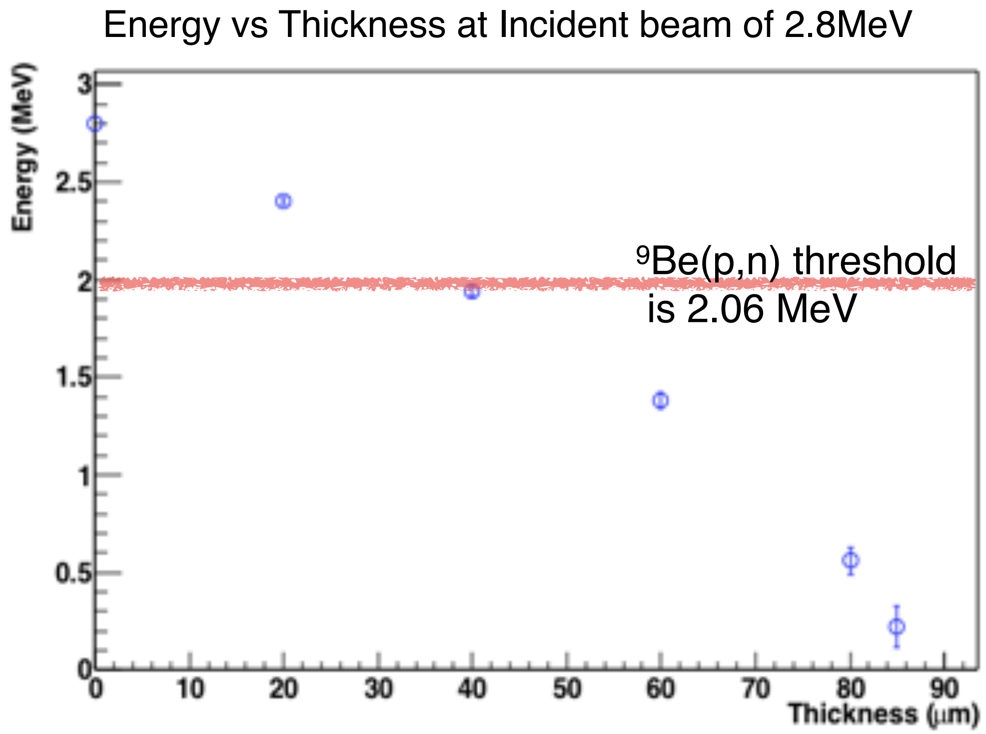
Hydrogen blistering

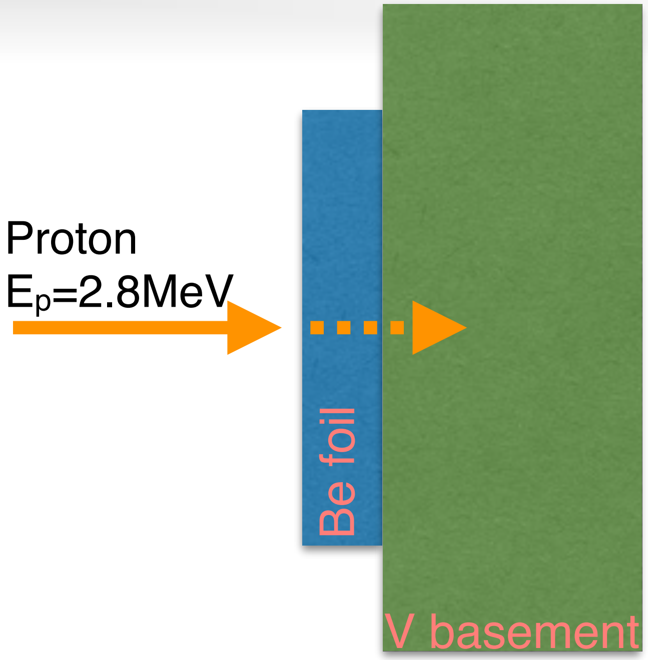
Be Target was broken by hydrogen blistering.
Be target is also difficult to use for low energy neutron source.

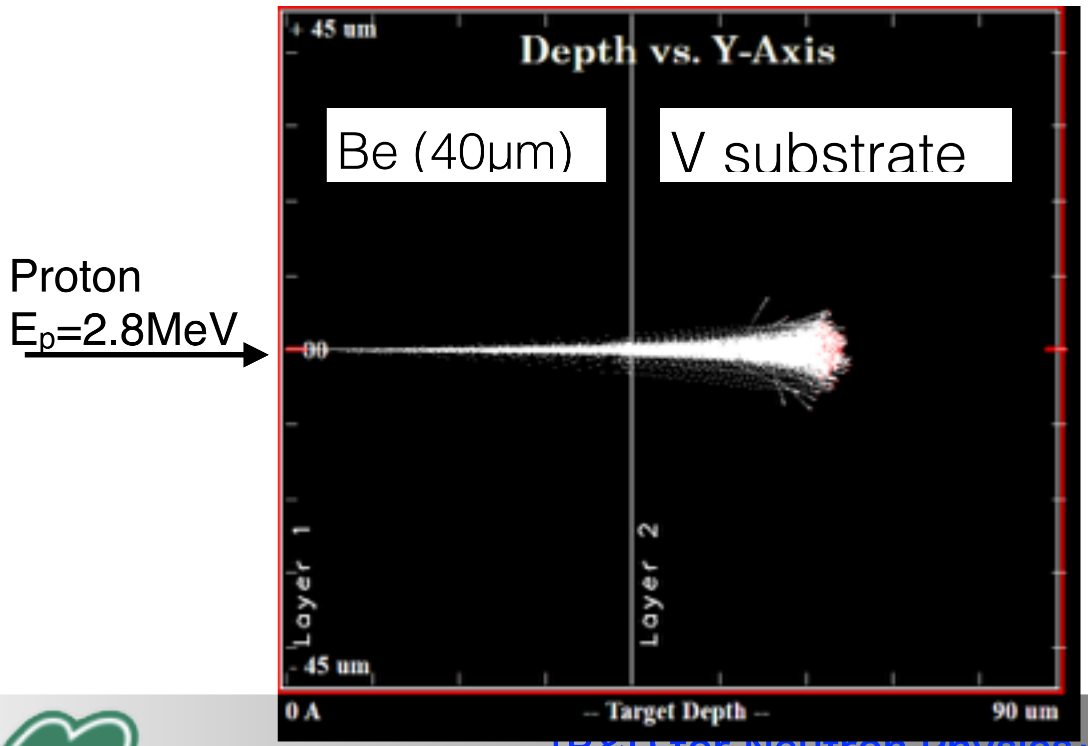


Indiana University

Neutron Target :
Proton Injection simulation







Neutron Shielding

Polyethylene

Slowdown the neutron velocity by elastic scattering with the hydrogen. Neutron absorption is decrease with velocity.

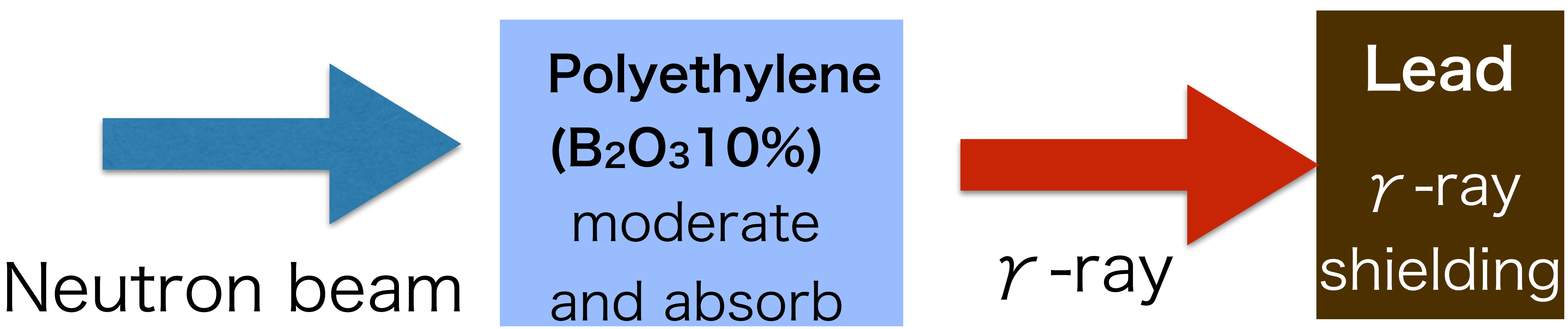
Boron (B_2O_3)

absorb thermal neutron and emitt gamma-ray

$^{10}B(n,\alpha)^{7*}Li \quad ^{7*}Li \rightarrow {}^{7}Li + \gamma$

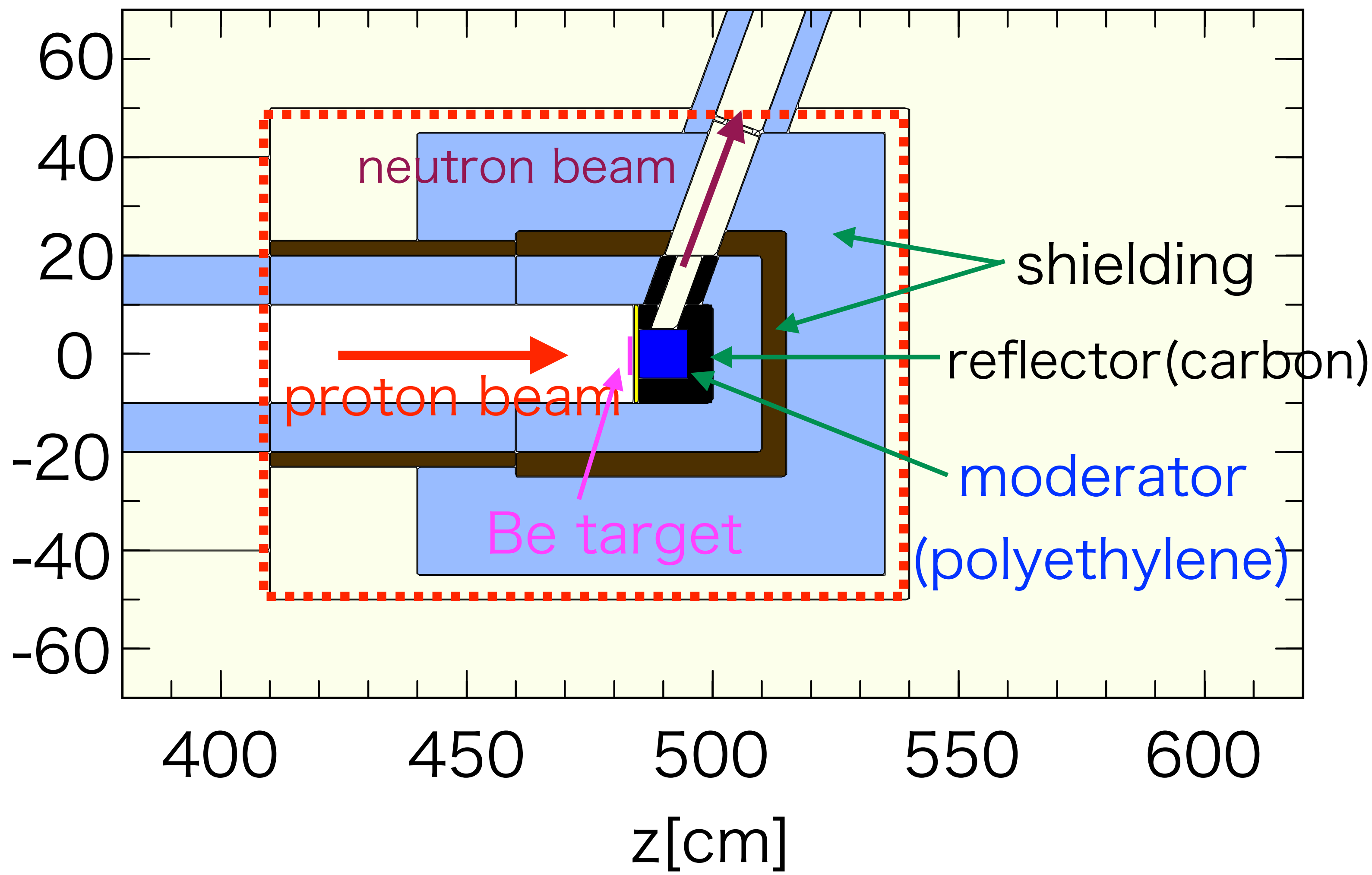
Lead

Shielding the gamma-ray and transparence neutron



Optimize the target shielding by PHITS

around the 2nd target shielding



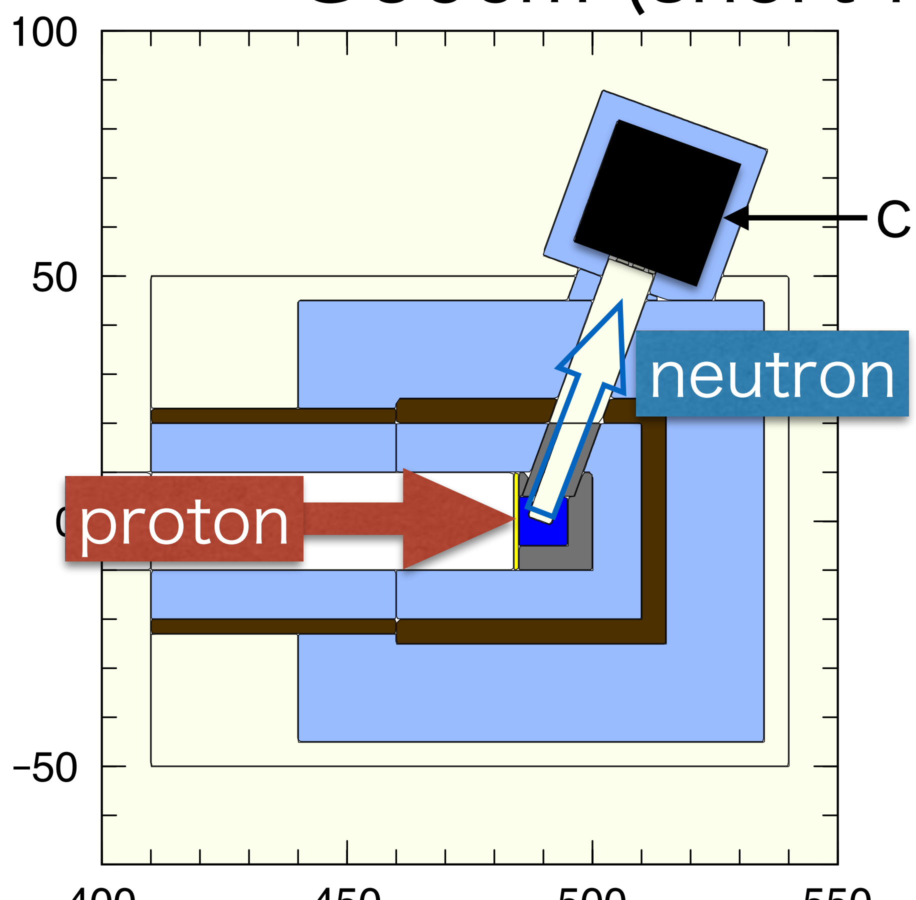
- Shielding : BPE(Polyethylene with B_2O_3), Lead
- weight (inside the red line): about 1.7ton
- radiation level at border door: about 0.05μsv/h

Neutron beam flux

We can select two neutron path.

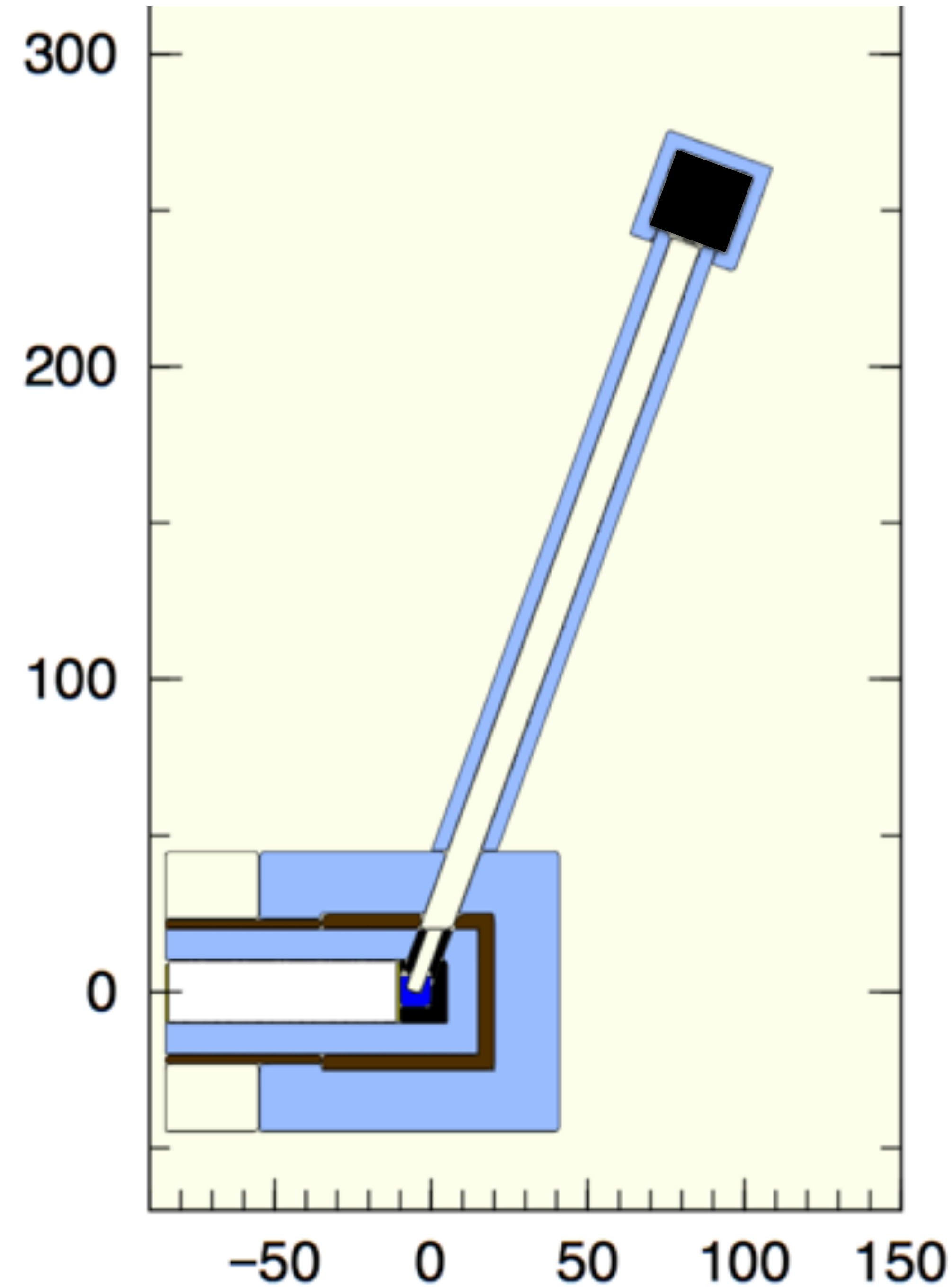
$O(10^6)$ /cm^2/s

@50cm (short flight path)

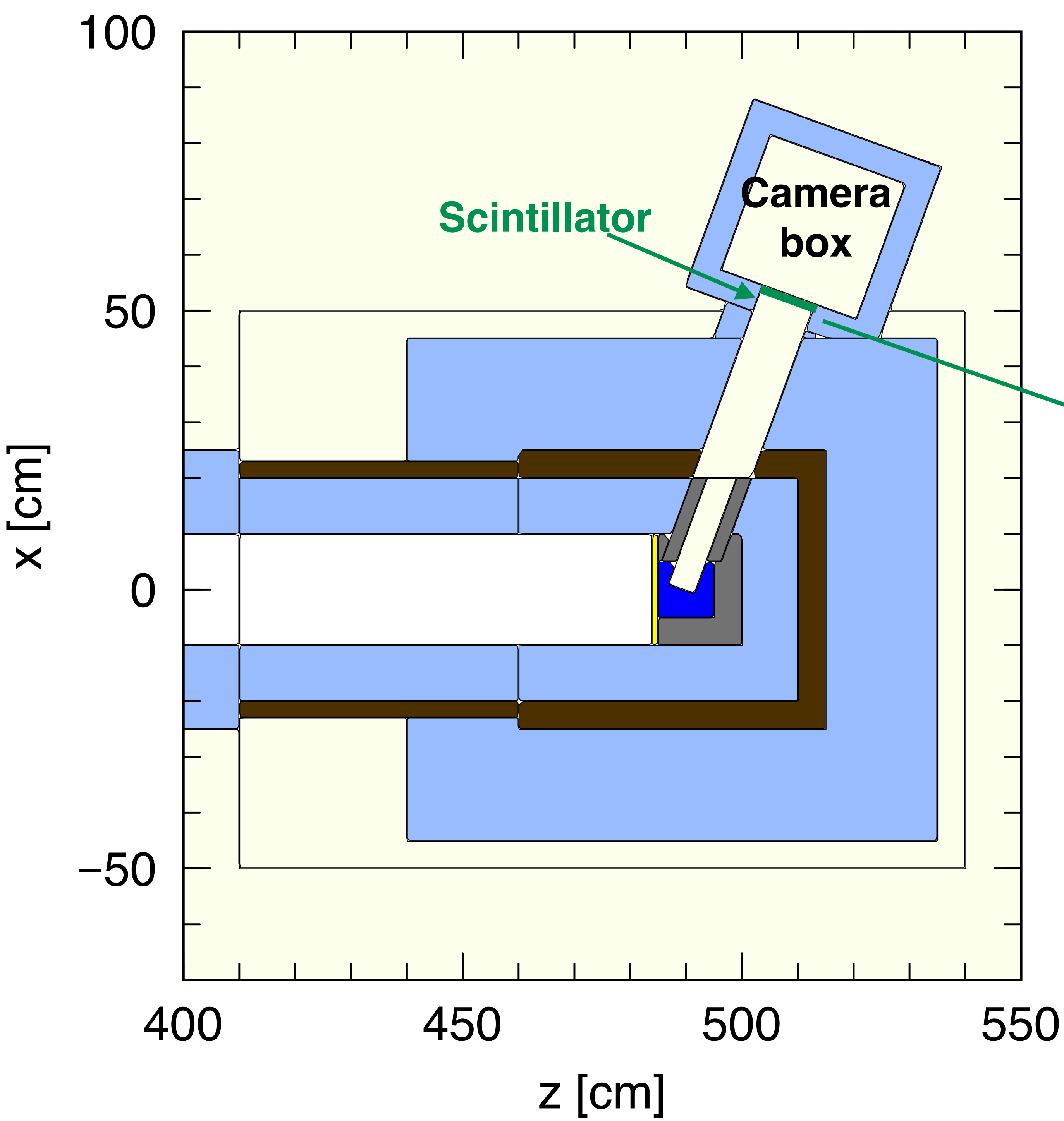


$O(10^4)$ /cm^2/s[1]

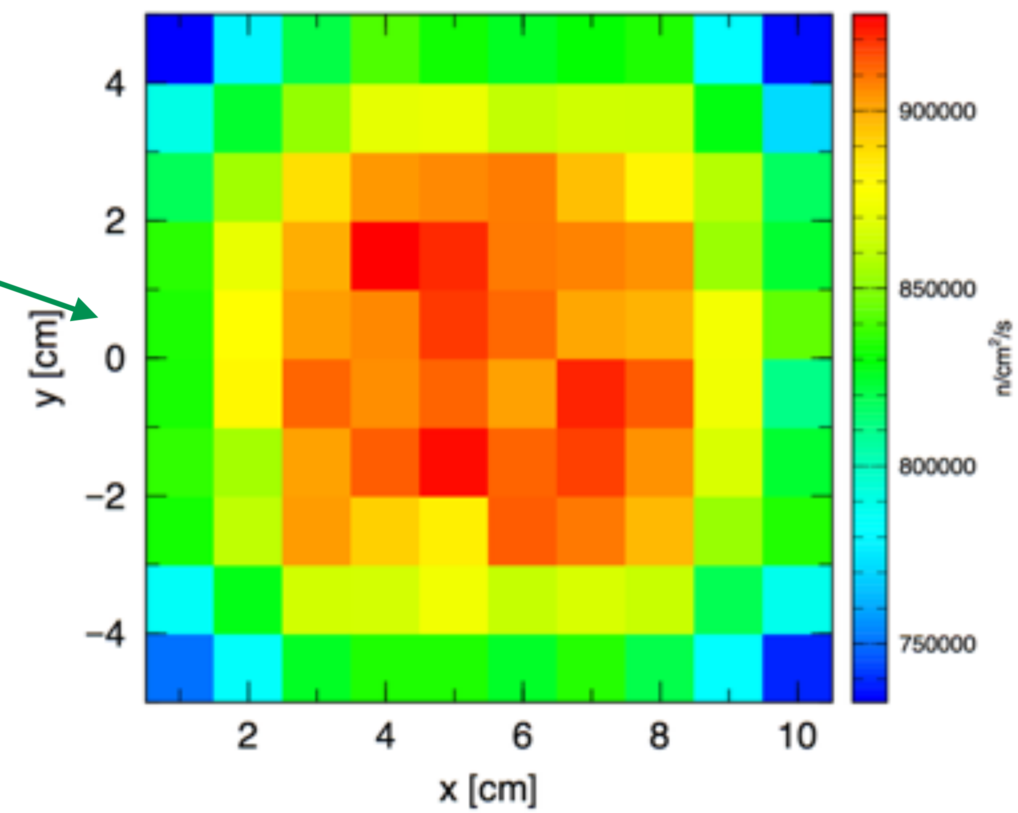
@250cm(long flight path



Imaging port of 2nd BL (Short)



Neutron flux distribution on the scintillator surface



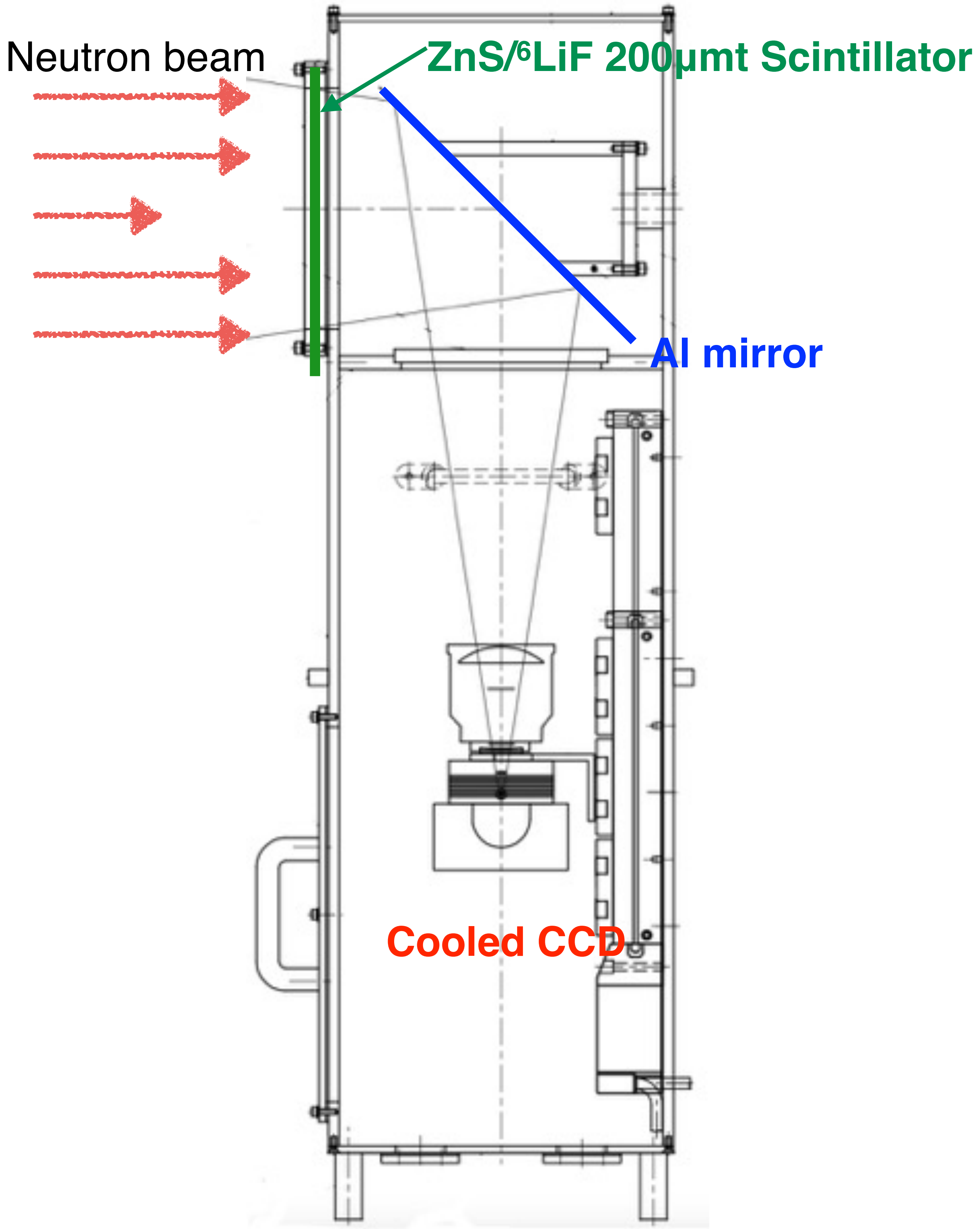
Scintillator size : 10cm x 10cm

Beam flux : Max =9.5 x 10^5 n/cm^2/s,

Min.=7.3x 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)

Summary

We are developing Neutron devices

- Multilayer Neutron Mirror by using DC sputter system.
  NiCr-Ti m=2, 14 layers mirror
- ^{3}He Spin filter for polarized neutron beam
- High counting rate (1GHz) Neutron detector

- NUANS for neutron device development.
  NUANS with electrostatic accelerator
  E_p=2.8MeV I_p=15mA (42kW)
  Designing and constructing beamlines
  - Li and Be target (Be for physics experiment)
  - Proton beamline simulation
  - Shielding < 0.1 μv/h, weight < 2 ton
  - Neutron flux estimation :
    10^4n/cm^2/s at 2m from moderator

Thank you for your attention