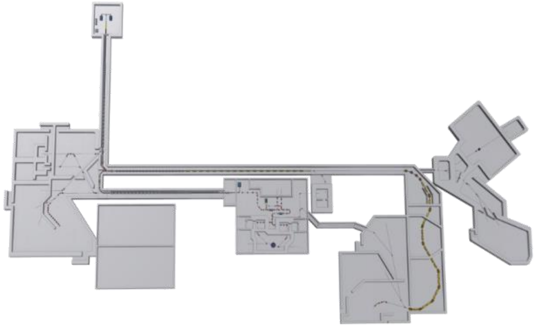
RAON 중성자 연구시설 구축 현황 및 계획

2016.10.26

김 재 천

RI Experimental System Team
Systems Installation Division, RISP
Institute for Basic Science



Overview of NSF

Development of Components

Radiation Safety Analysis

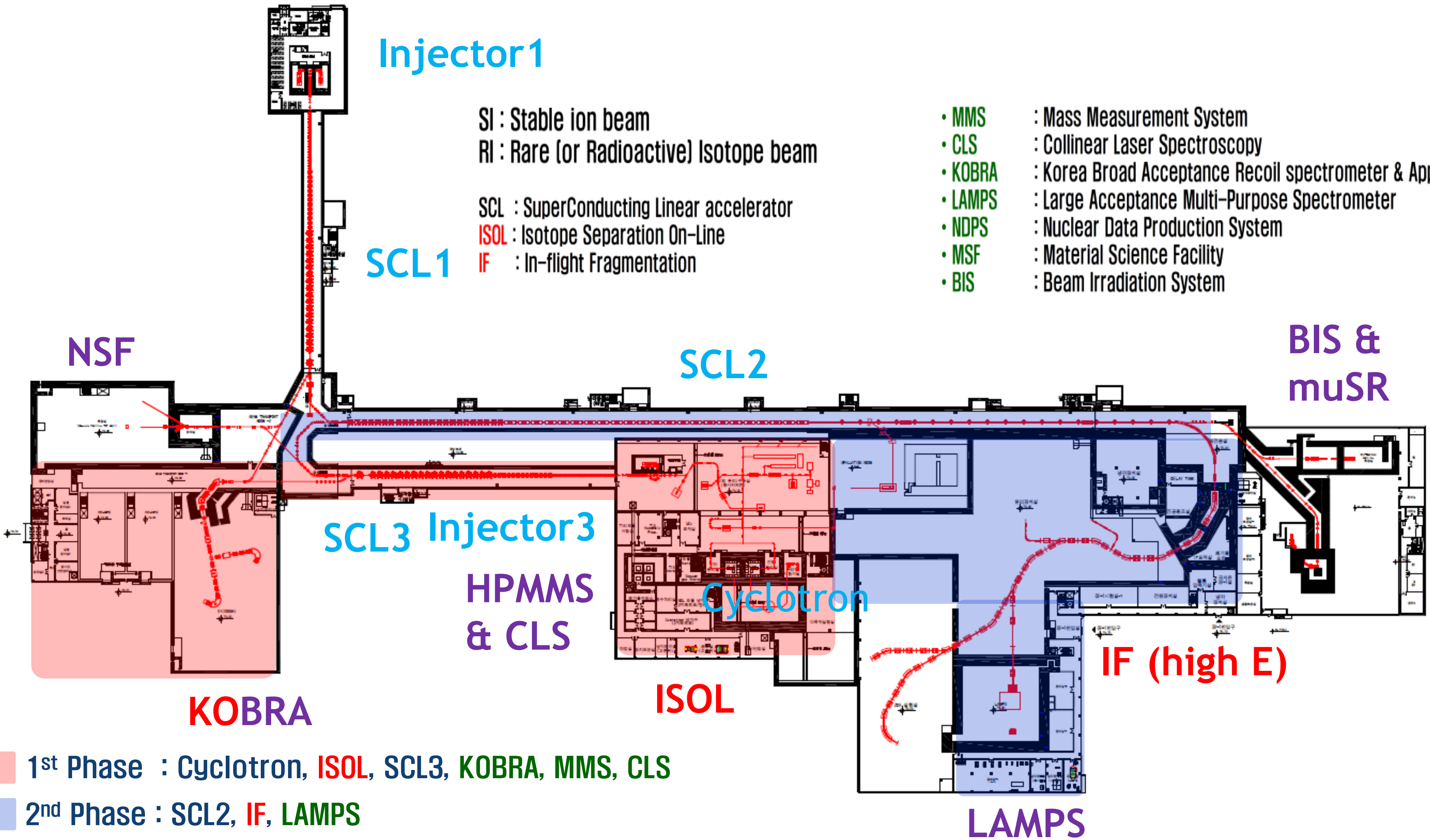
Layout of RAON

RAON

SI : Stable ion beam
RI : Rare (or Radioactive) Isotope beam

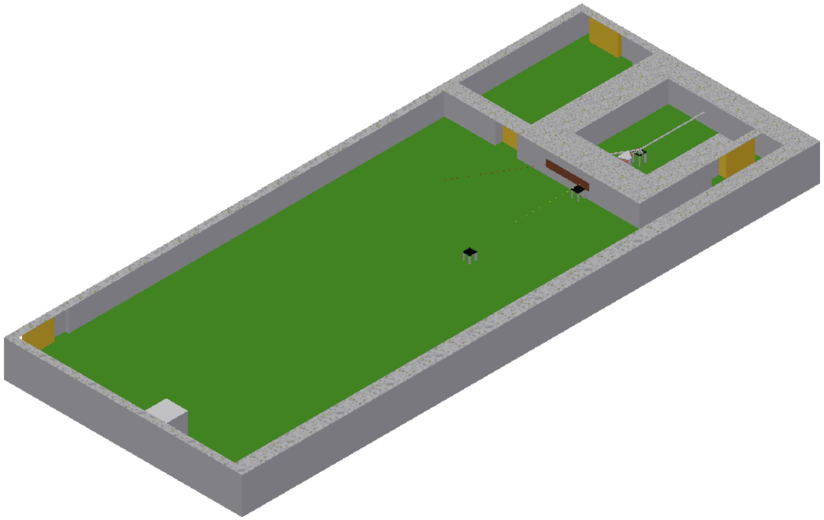
SCL : SuperConducting Linear accelerator
ISOL : Isotope Separation On-Line
IF : In-flight Fragmentation

- MMS : Mass Measurement System
- CLS : Collinear Laser Spectroscopy
- KOBRA : Korea Broad Acceptance Recoil spectrometer & Apparatus
- LAMPS : Large Acceptance Multi-Purpose Spectrometer
- NDPS : Nuclear Data Production System
- MSF : Material Science Facility
- BIS : Beam Irradiation System



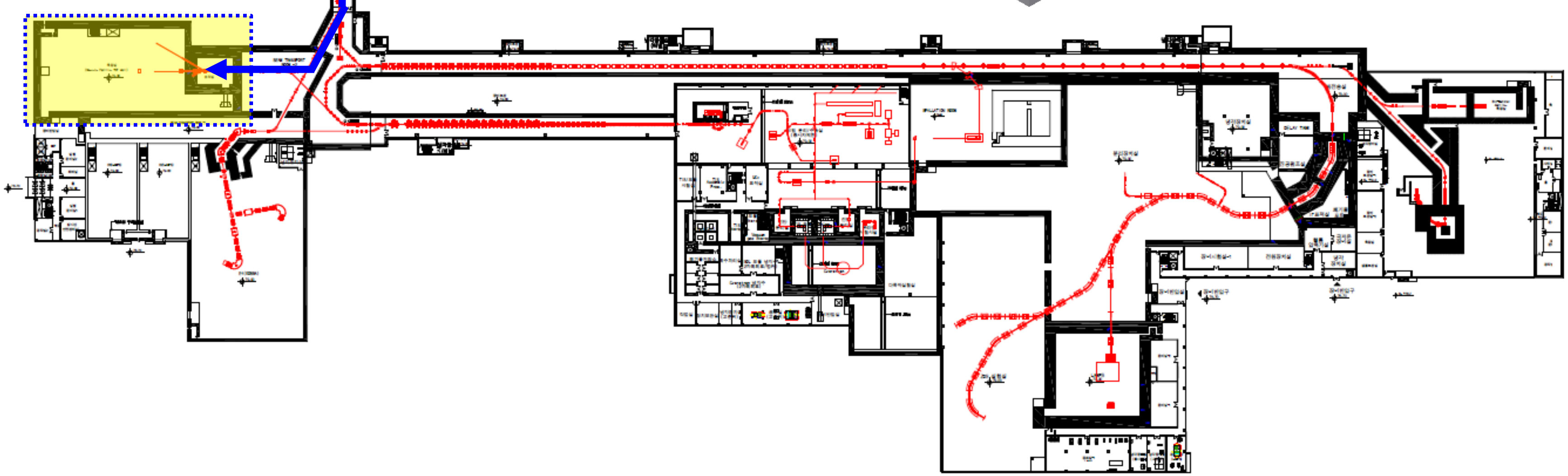
1st Phase : Cyclotron, ISOL, SCL3, KOBRA, MMS, CLS
2nd Phase : SCL2, IF, LAMPS
3rd Phase : SCL1, NDPS, MSF, BIS

NSF@RAON



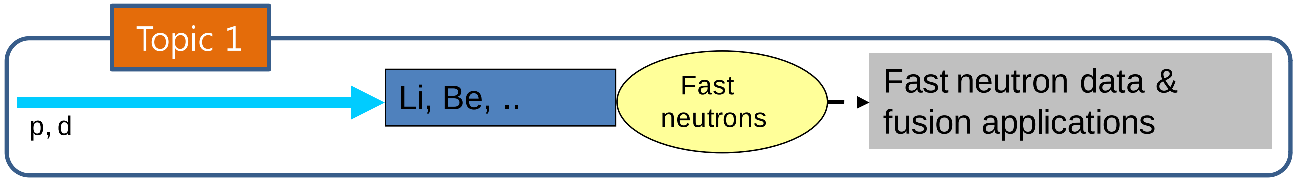
Neutron Science Facility

Primary beams
- ≤ 53 MeV deuteron
- ≤ 88 MeV protons



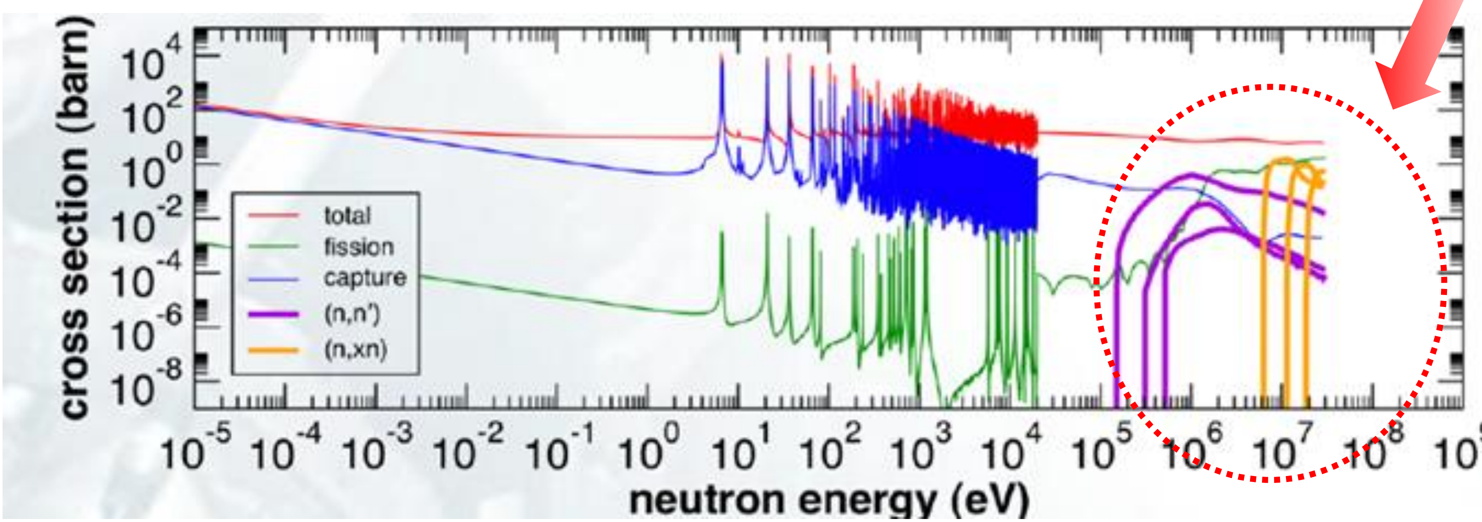
Research Topics

Short



- Fission cross-section (n,f)
- Inelastic scattering cross-section (n,n')
- Neutron multiplicity (n,xn)
- Capture cross-section (n,γ)

1-100 MeV



System Requirement & First Goal

System Requirement

Primary beams (1mA, 81.25 MHz)

- ≤ 53 MeV pulsed deuteron beam
- ≤ 88 MeV pulsed proton beam
- Repetition rate: 1 kHz ~ 1 MHz
- Beam current: ~12.3 μA (1 MHz)
- Beam width: 1-2 ns → challenging !!

Pulsed fast neutron beams

- C(d,n): white neutrons with < 53 MeV
- Li(p,n): mono-energetic neutrons with < 88 MeV

Fission Cross-section Measurement (in more than 10 MeV) with ~ few % uncertainty

For fission, 2-3 % below 14 MeV and over 10 % at higher energies

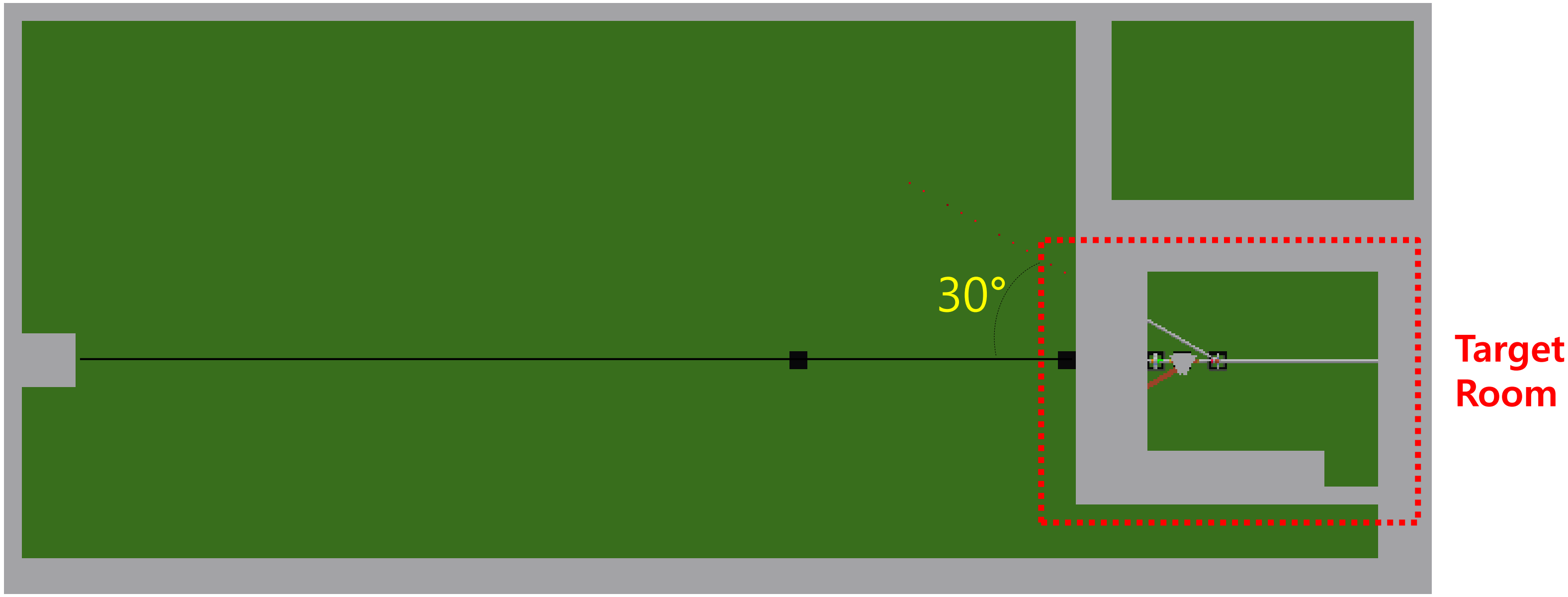
4. Safety	Evaluation of radiation risk Radiation monitoring system
3. Nuclear Data Measurement System	Employment of IC Use of ^{238}U sample
2. Beam Line	0° beam line Collimator
1. Target	C target, white (~70 % of Be)

Neutron Science Facility

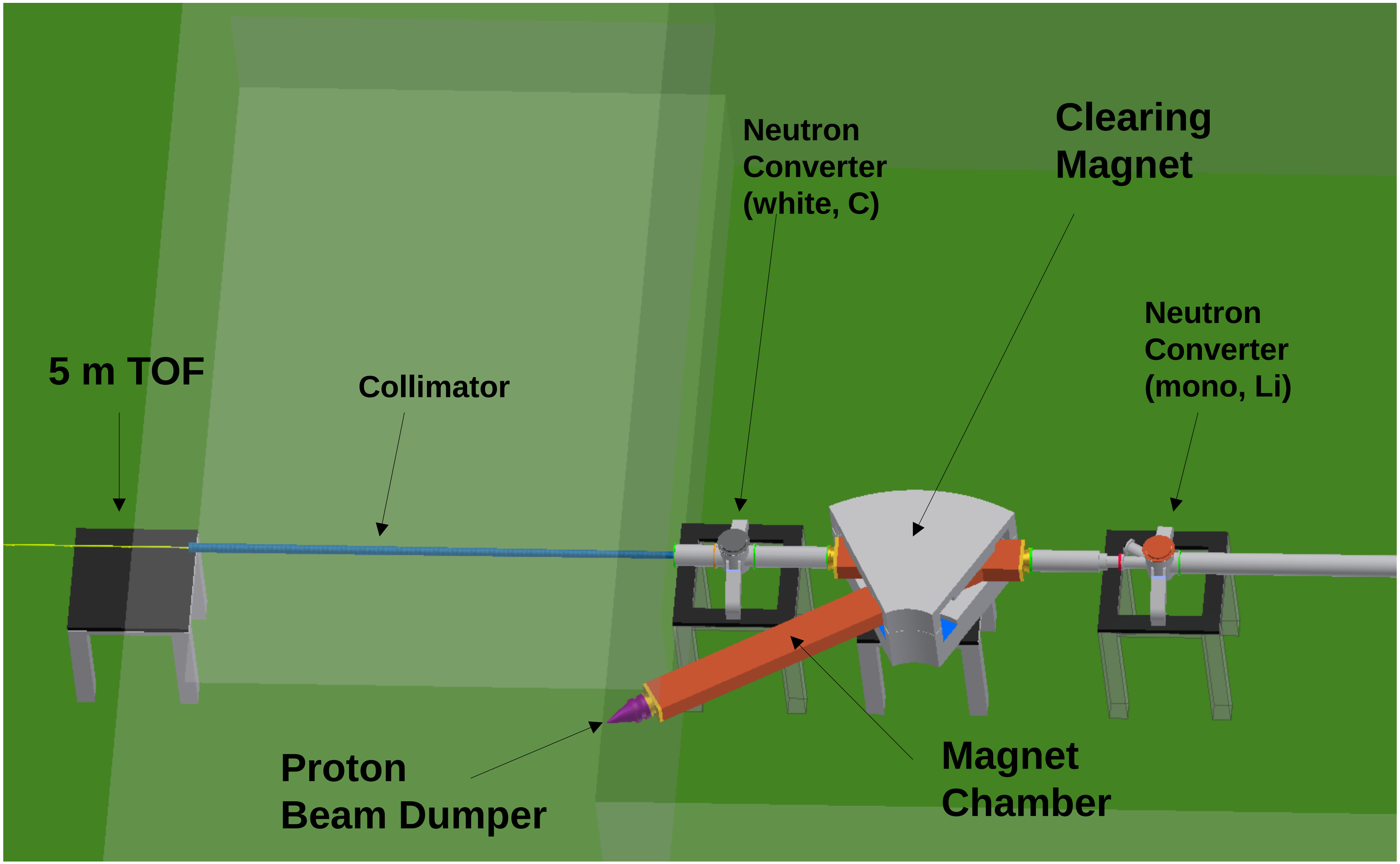
Primary beams
- ≤ 53 MeV deuteron
- ≤ 88 MeV protons

RAON driver linac (SCL1)

NSF 3D Modeling



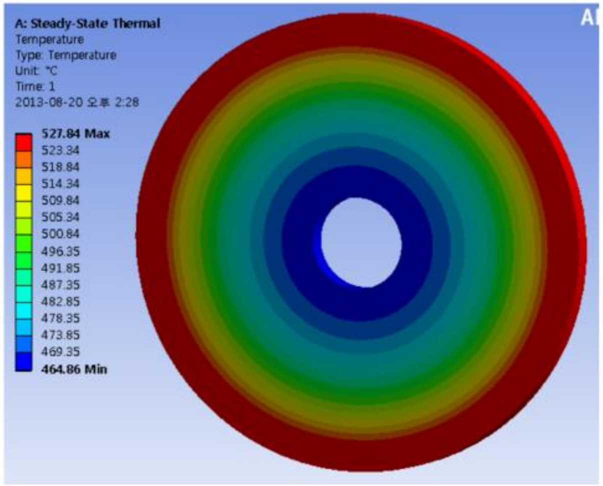
Detailed Design of Main Components

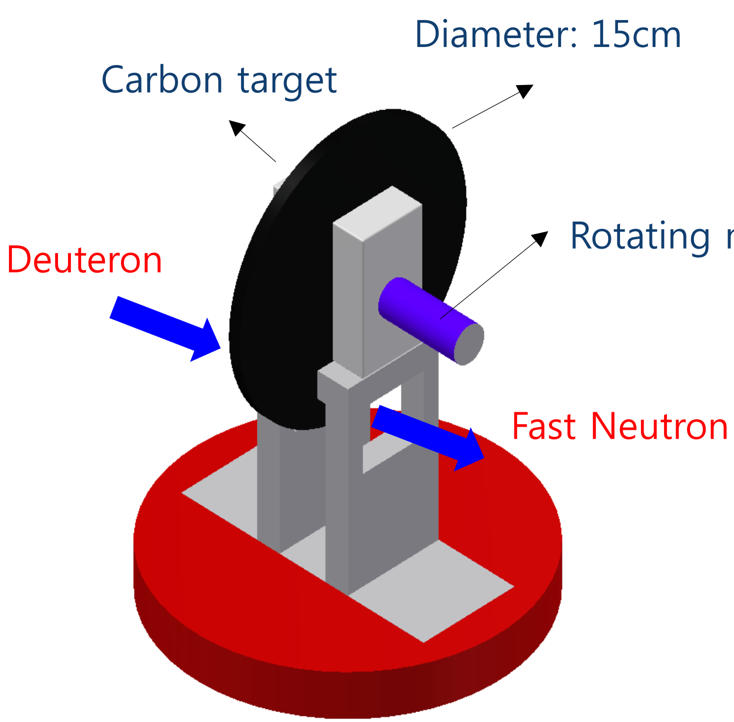


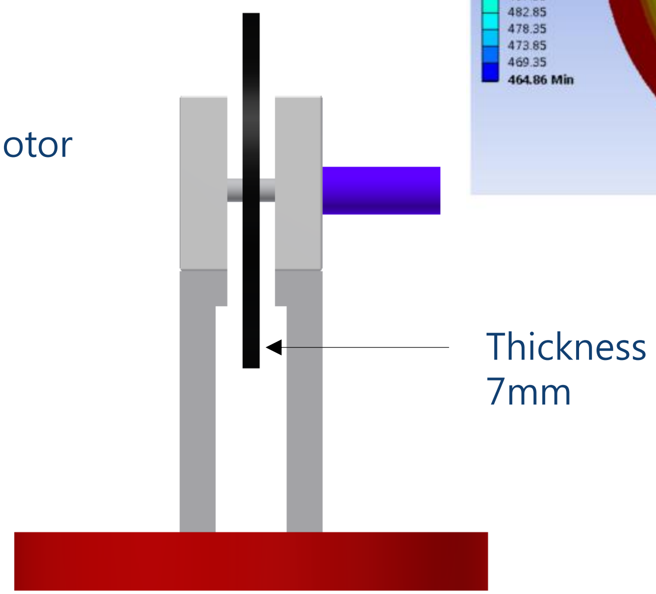
Neutron Converter (White, C)

- **White Neutron**
  - McDeC (considering striping of neutron)
  - ~2.0×10^{12} n/sr/μA : 53MeV d + C
  - Yield of C target: ~70% of Be target
  - Melting point: 3500 ℃→ Much higher !!

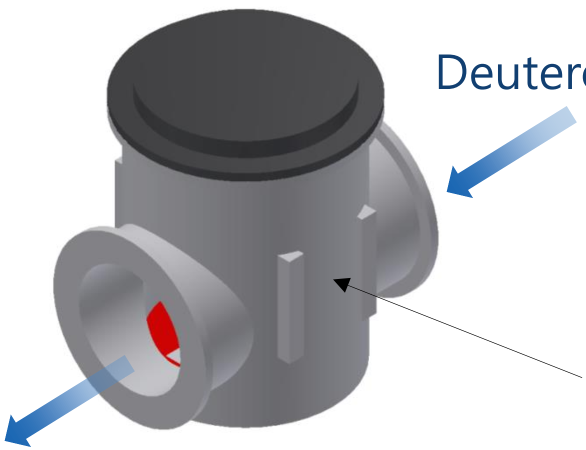
1 MHz, 12.3 μA
Density : 2.253 g/cm^3
Emissivity : 0.8
Thickness : 7 mm
Max. Temp. : 528 ℃

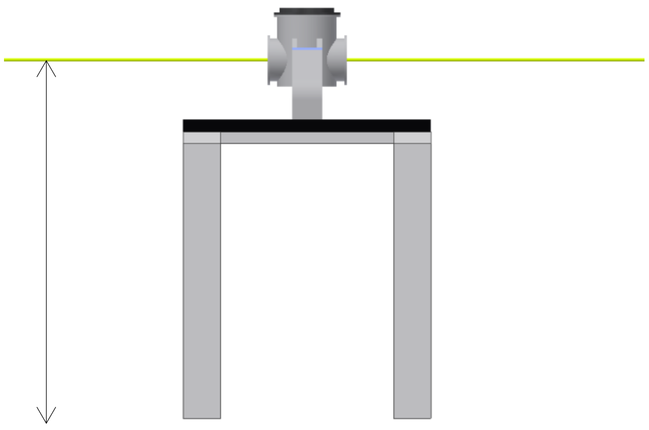


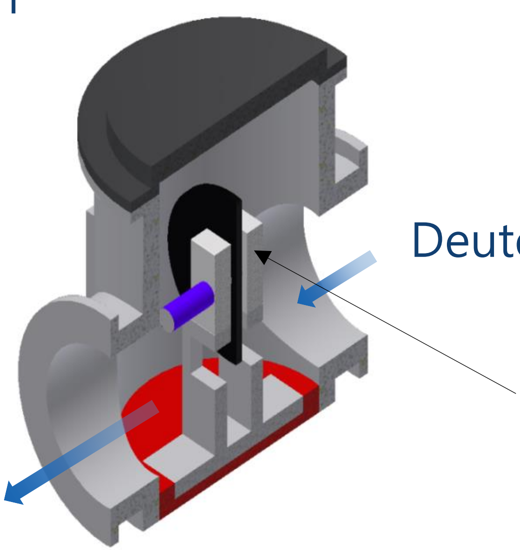


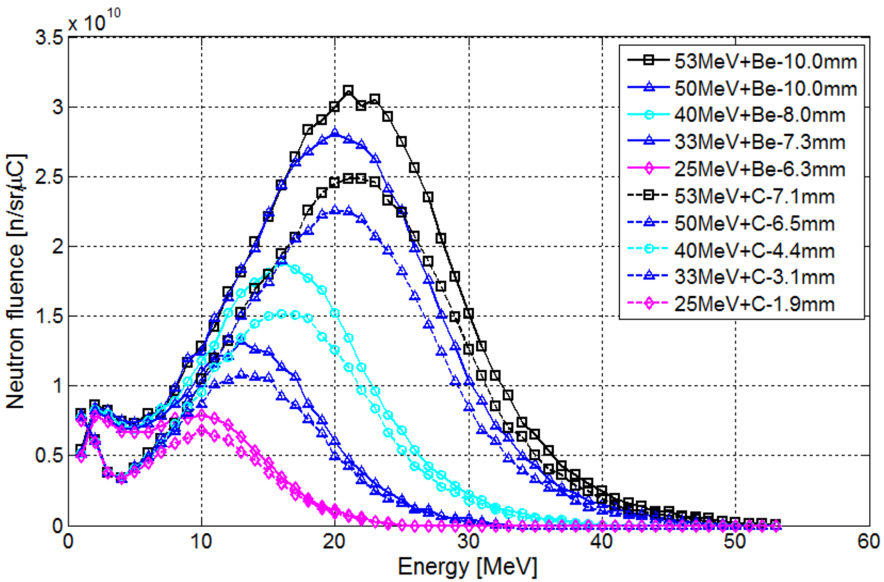


Target + Chamber + Table







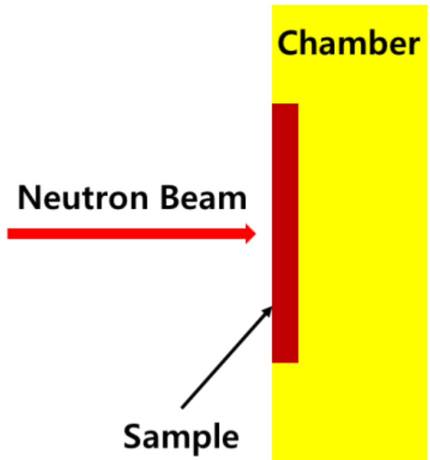


Fission Cross-Section Measurement

	IC	PPAC	Micromegas
Thickness of target	**Thin**	Thin	Thick
Thickness of detector	**Thick**	Thin	Thin
Fission identification	**Signal amplitude**	Timing coincidence	Signal amplitude
Particle positioning	**X**	O	X
Solid angle	**Restricted**	Restricted	Restricted
Data processing	**Easy**	Hard	Easy
Number of DAQ channel	**Little**	Many	Little
Application	• **Fission cross section** • **Neutron flux**	• Fission cross section • Neutron flux • Neutron flux geometry • Angular distribution	• Fission cross section • Neutron flux
Additional device required	• **Equipment for handling unsealed radioactive sources**	• Equipment for handling unsealed radioactive sources • Gas regulation system	• Equipment for handling unsealed radioactive sources • Gas regulation system

Fission Cross-Section Measurement

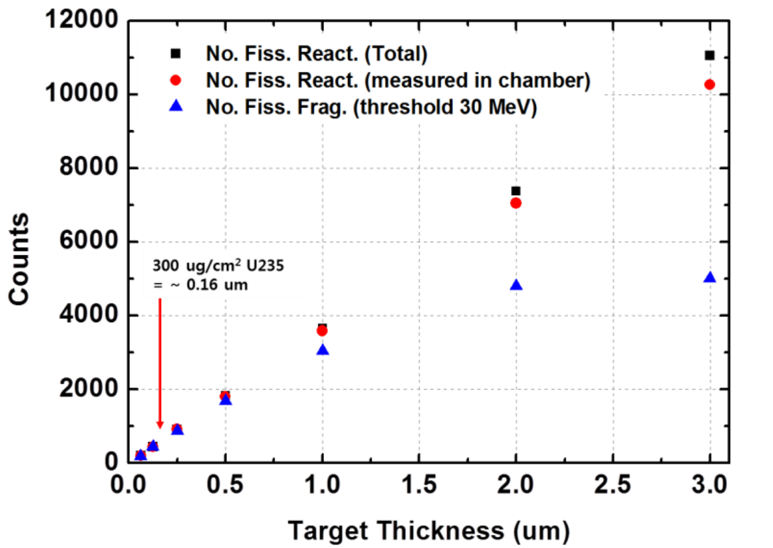
RAON



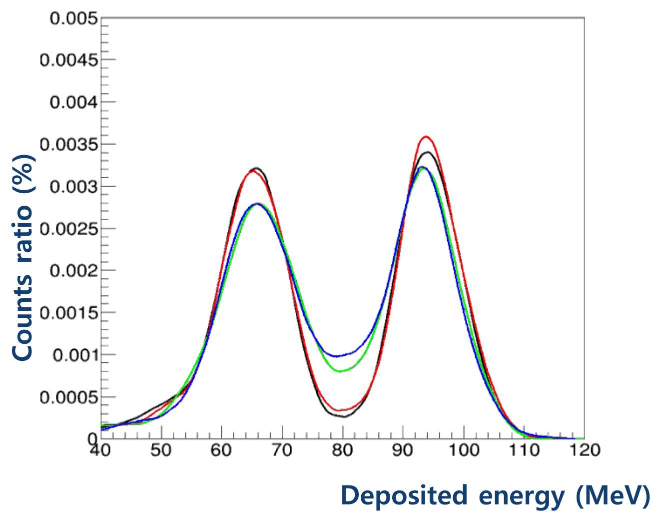
Chamber dimension	10 cm x 10 cm x gap
Gap	variable → 1.5 cm
Gas composition	Ar (90%) + CF_4 (10%)
Gas pressure	variable → 1 bar
Sample	U235
Sample dimension	1 cm x 1 cm x thick.
Sample thickness	variable → 1.6 μm
Source	variable

<Simulation Geometry & Condition>

Optimized detector condition



Counts depending on the sample thickness



Ion chamber spectrum depending on the neutron energy

Black : 1 MeV
Red : 5 MeV
Green : 10 MeV
Blue : 15 MeV

기초과학연구원 Institute for Basic Science
RISP Rare Isotope Science Project

Beam Monitoring System (MICROMEGAS)

Table 1. Neutron flux monitor in experimental areas of primary facilities

Facility	CERN n_TOF	SPIRAL2 NFS
Detector	MicroMegas SiMON (Silicon Monitor)	MicroMegas Proton Recoil Telescope

MicroMegas is considered as neutron beam monitor in NSF.

- **Advantage**
  robustness
  high resistance to radiations
  non-sensitivity to gamma background
  low budget

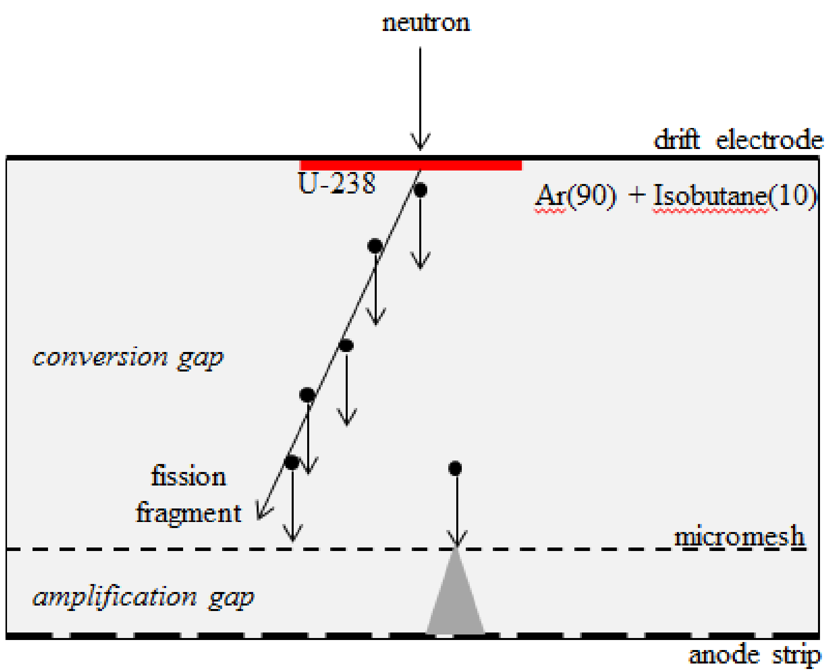
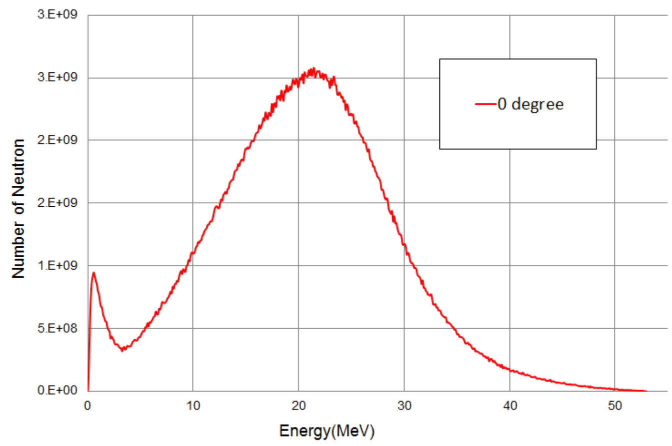


Fig. 1. MicroMegas detector principal

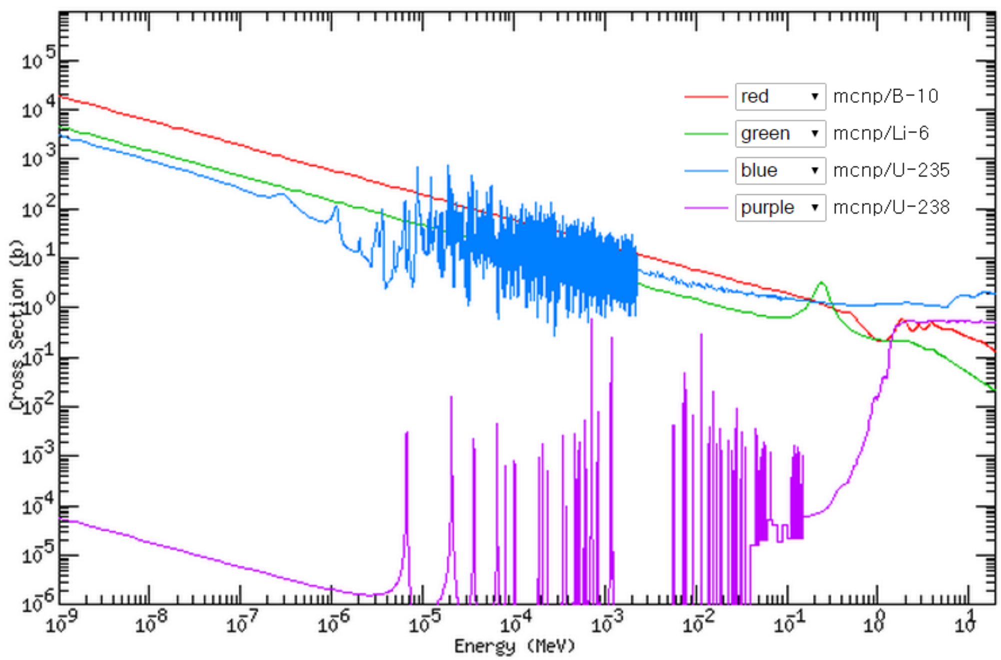
Converter Materials for MICROMEGAS



Neutron beam energy interval: thermal - 53 MeV

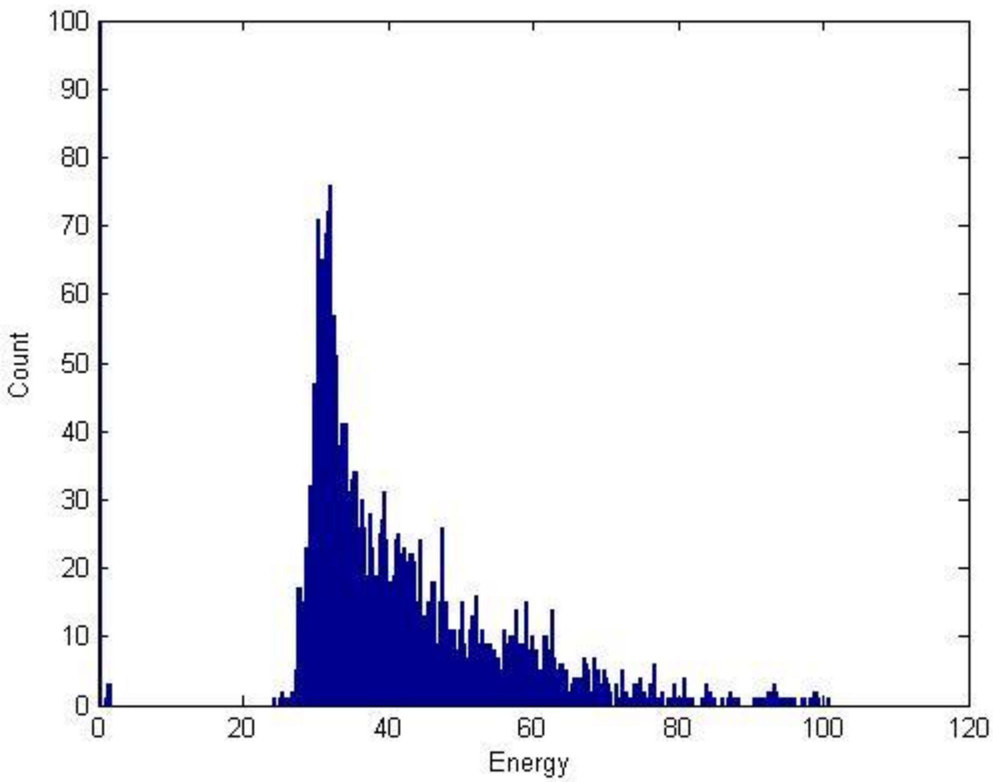
Converter	Available energy interval
^{6}Li(n,α)t	thermal - 1 MeV
^{10}B(n,α)7Li	thermal - 1 MeV
^{235}U(n,f)	thermal - 53 MeV
^{238}U(n,f)	thermal - 53 MeV

Available energy interval according to converter type



Cross-section for converter materials

MICROMEGAS Simulation by Using GEANT4



Reference Design Parameters:

Detector Size : 20cm X 20cm X 3mm

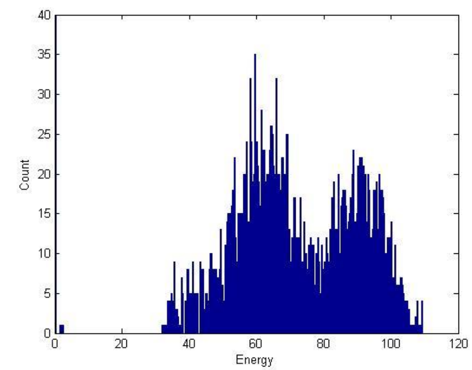
Converter Type : ^{238}U

Converter Size : 2cm X 2cm X 0.5um

Gas Type : Ar(90) + Isobutane(10)

Gas Pressure : 1bar

Neutron Energy : up to 20 MeV

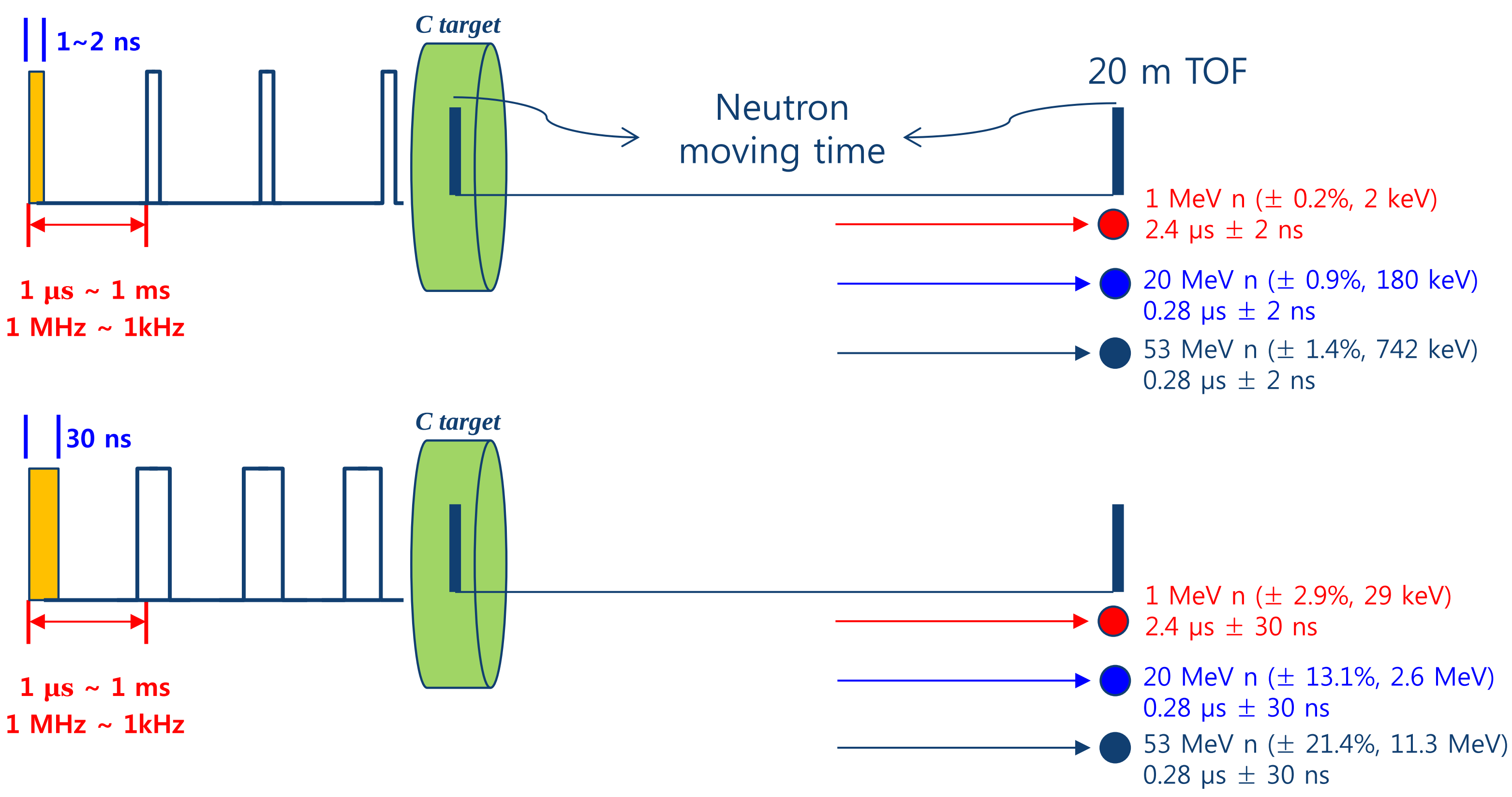


Detector Thickness : 20mm

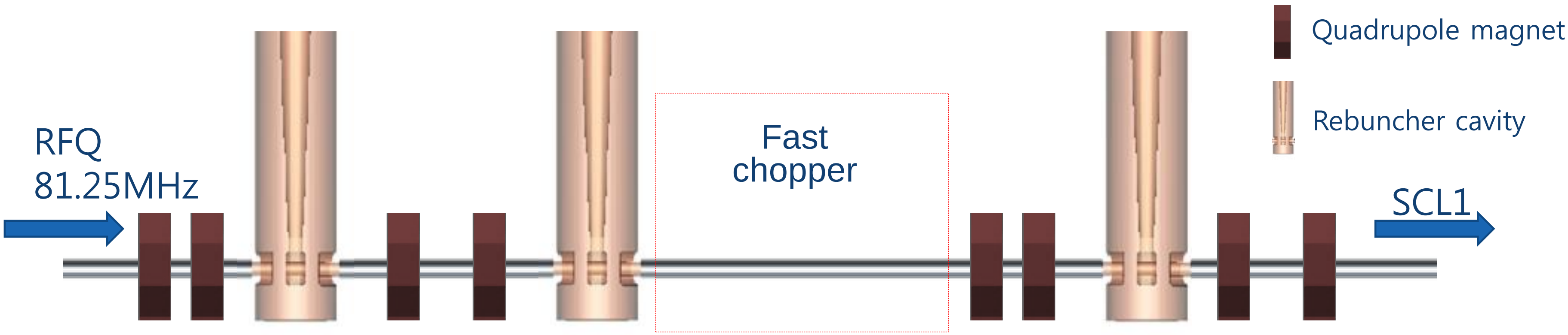
In case of 3mm thickness, we don't know energy of two fission fragments.
However, available to measure neutron flux of NSF.

Pulse Width of Primary Beam

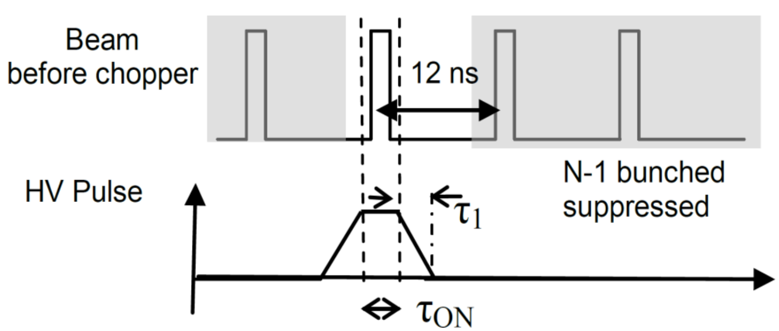
- **Goal of pulse width: 1-2 ns**
- **Repetition rate: 1 kHz ~ 1 MHz (~12 μA)**
- **Assume: pulse width is only factor for uncirtainty of time-of-flight.**

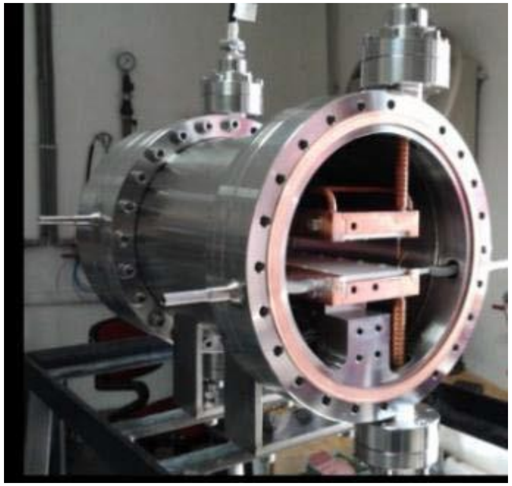


Fast Chopper in MEBT Layout



Fast chopper
: deutron 1mA (peak)

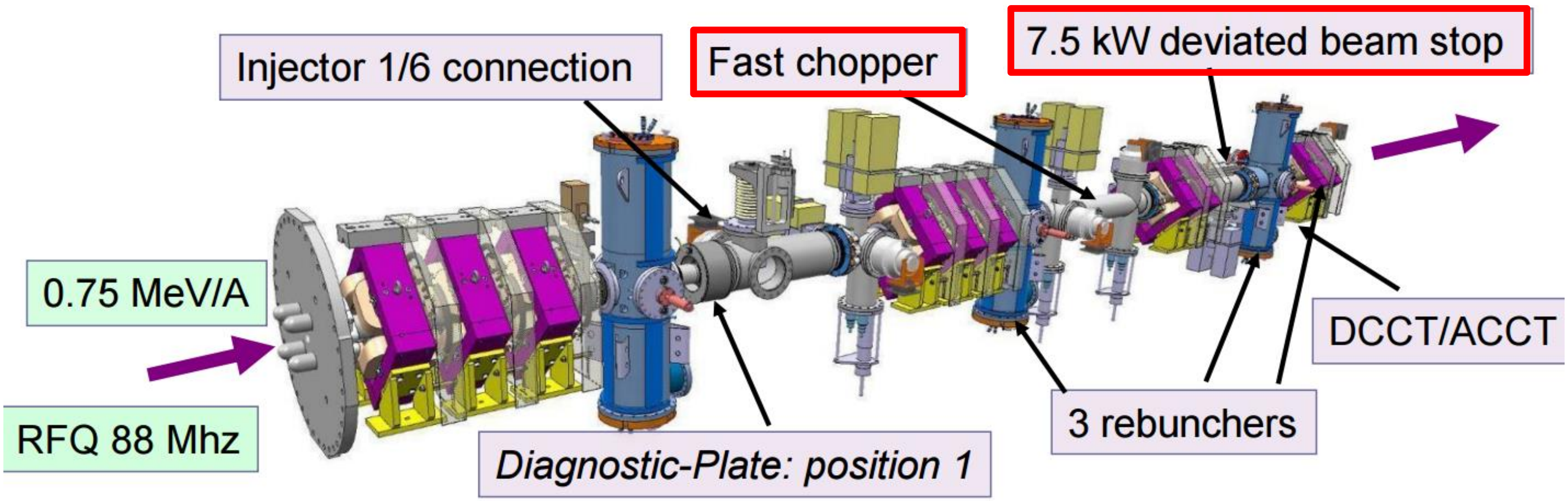




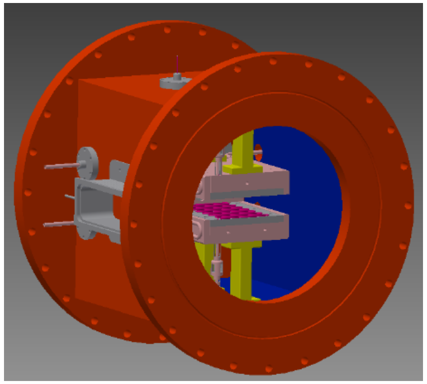
Single Bunch Selector in MEBT, SPIRAL2/Ganil

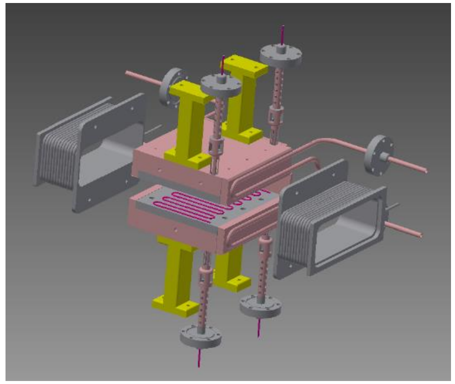
2012, Patrick Bertrand, SPIRAL2 accelerator Construction progress

The MEBT Challenge…

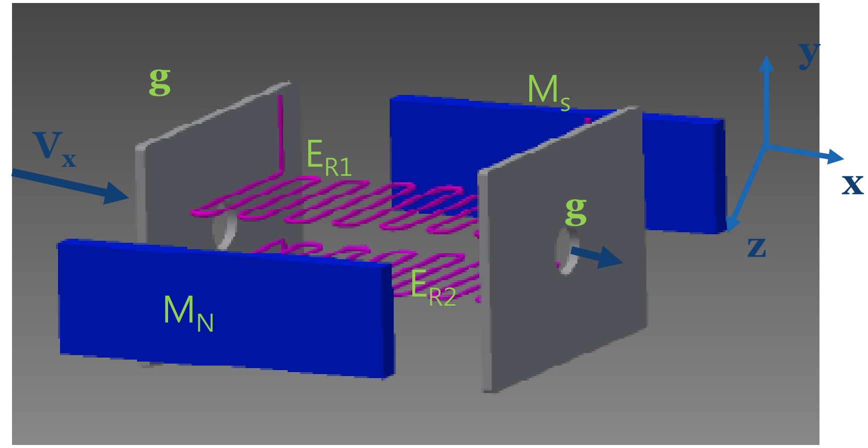


Modeling of RAON Single Bunch Selector

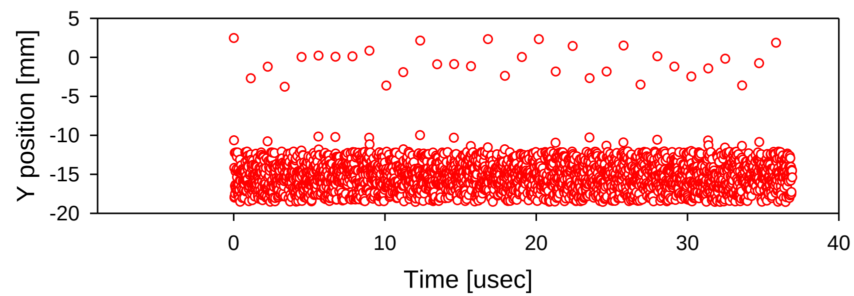




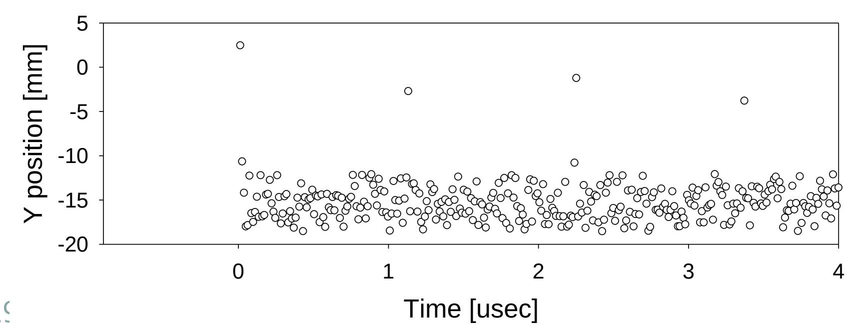
Length : 35 cm , OD : 47 cm, ID : 26cm



Electric : Diameter : 2 mm, meander interval : 10 mm, meander length : 130 mm, Width : 80 mm, interval : 30 mm
Magnetic : Width :50 mm, Length : 137 mm, Thickness : 10 mm, interval : 290 mm

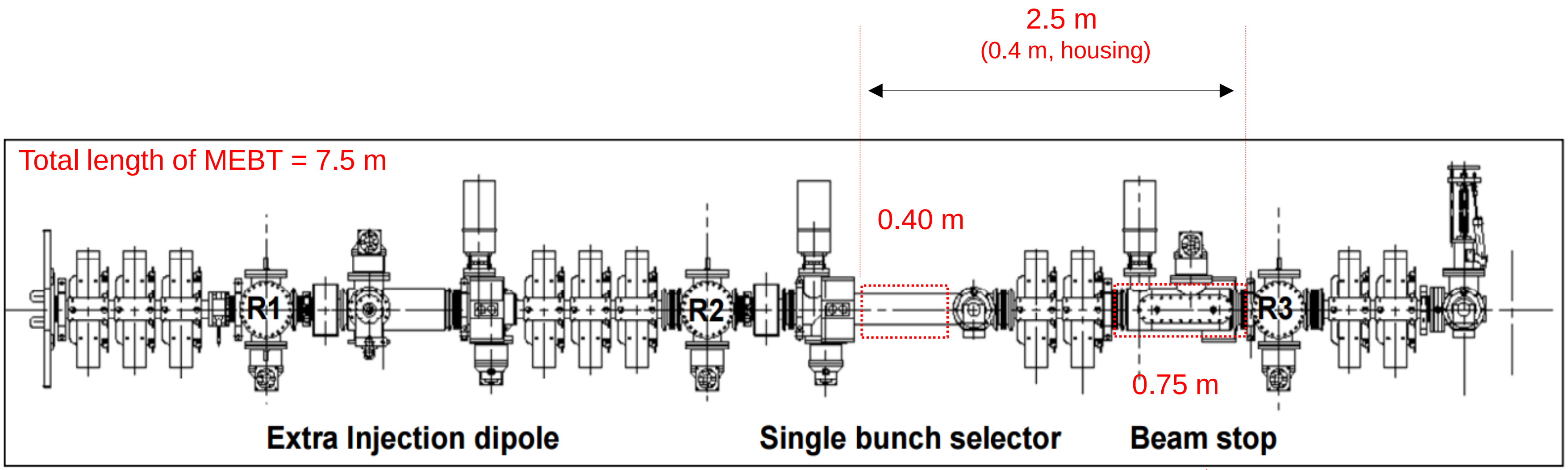


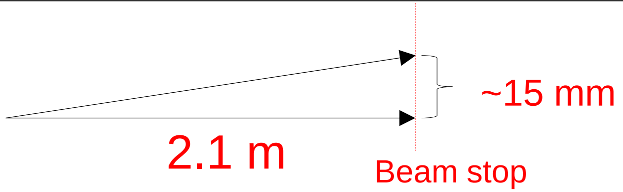
- Emittance : 0.3 π mm mrad, d energy : 1 MeV
- Radius : 2 mm , angle : 0.027°
- Observation point from SBS : 2.1 m (deflection = 15 mm)
- RF field : 1550V, magnetic field: 45 gauss



Parameters

- Single Bunch Selector: 0.4 m
- Beam Stopper: 0.75 m
- Total Length: 2.5 m

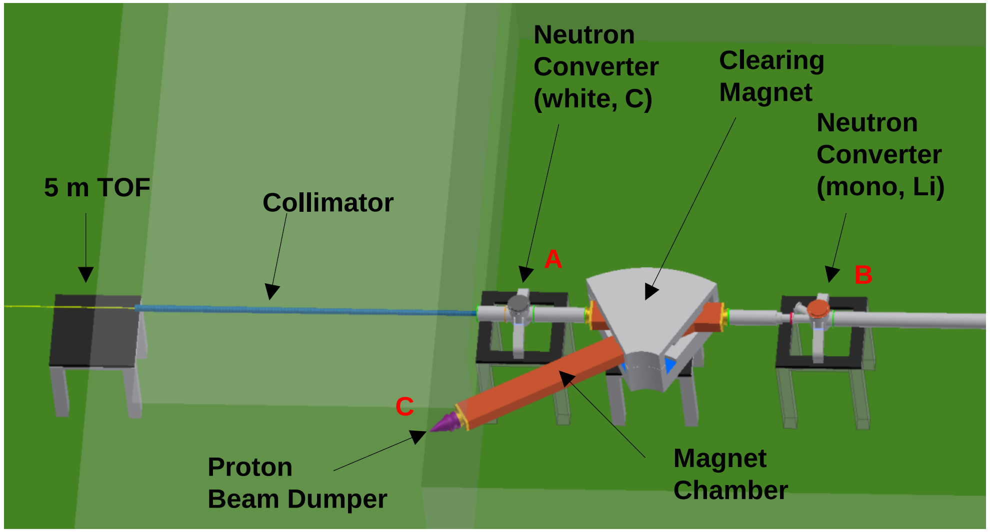


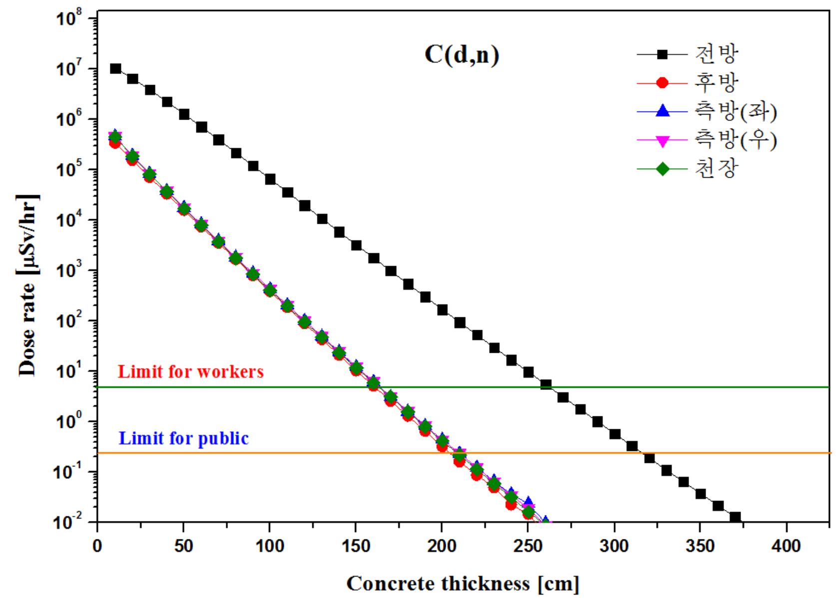


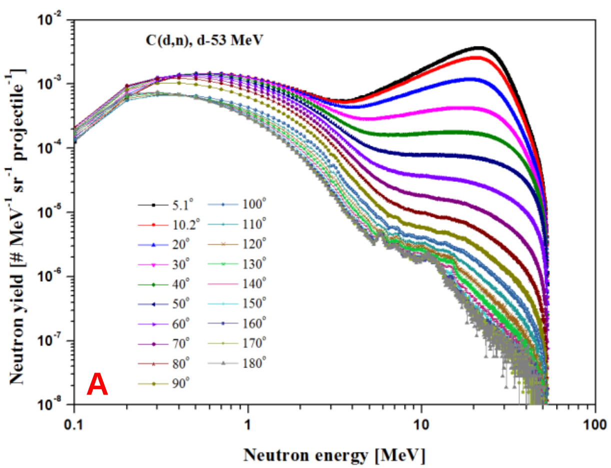
Beam deflection angle

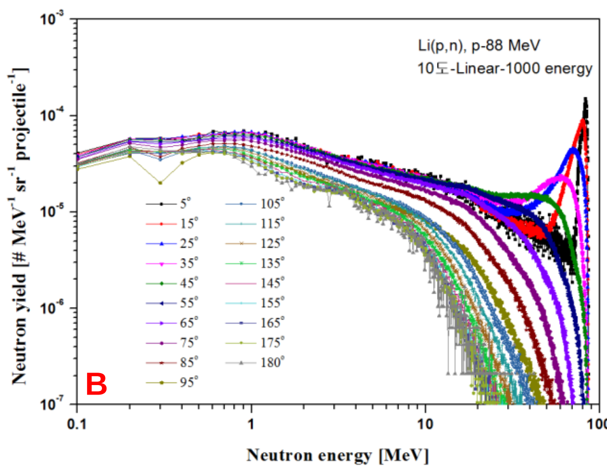
Radiation Safety : Source

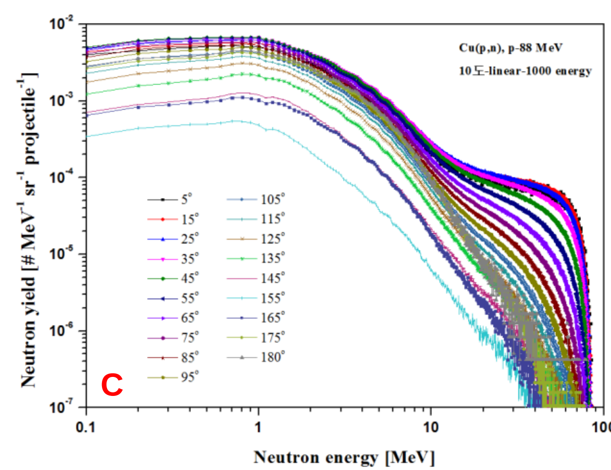
- White: 53 MeV deuteron, ~12.3 μA, C Target (0.7 cm)
- Mono: 88 MeV proton, ~12.3 μA, Li Target (0.5 cm)



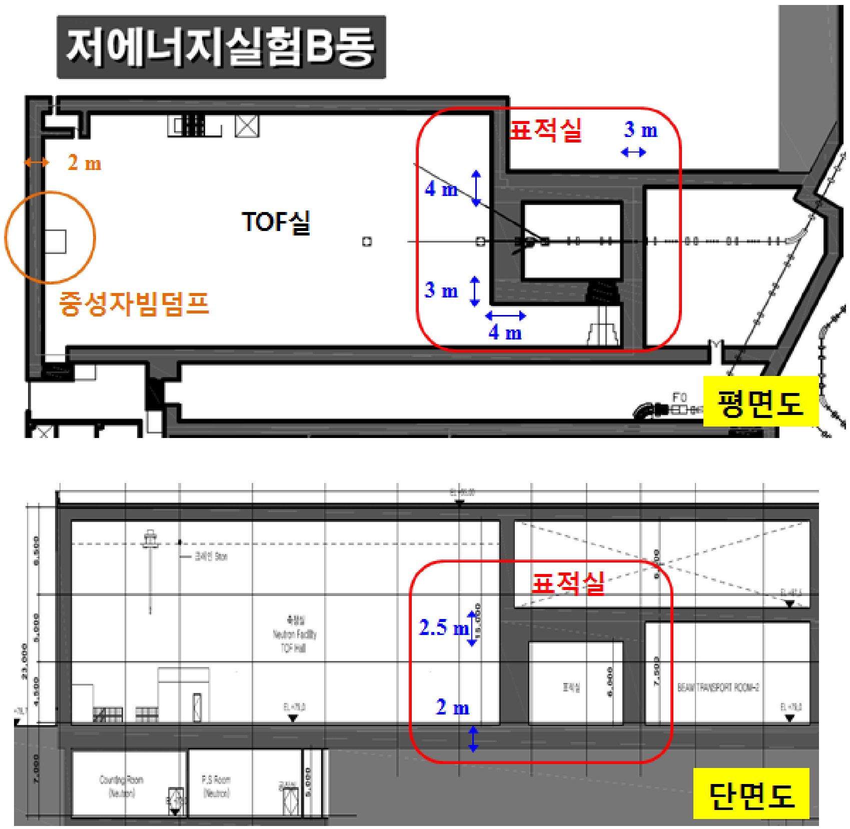




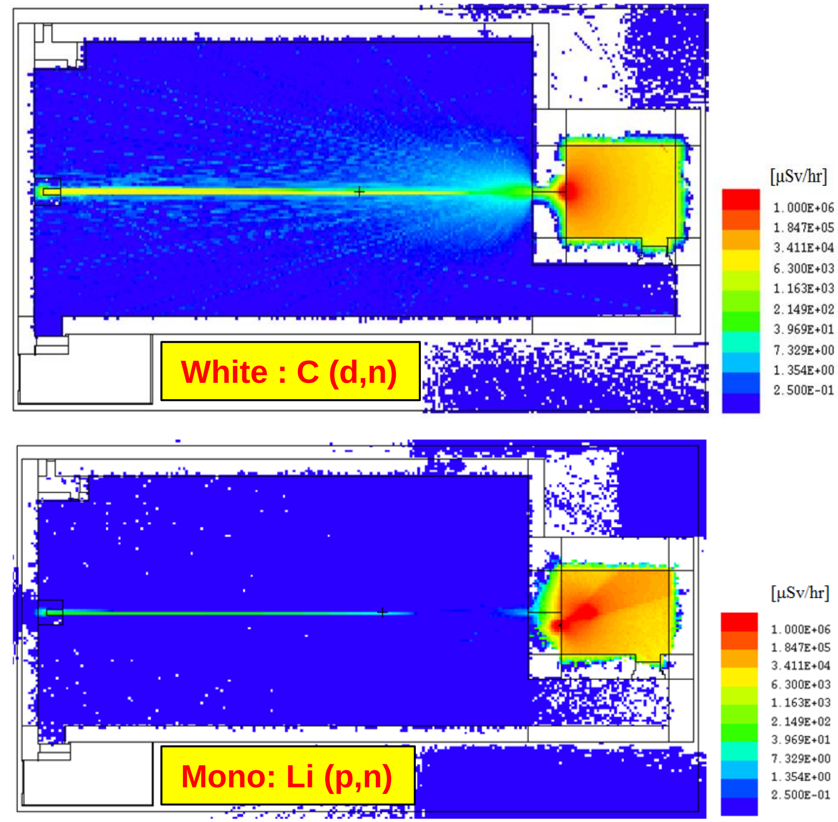




Radiation Safety : Building Design



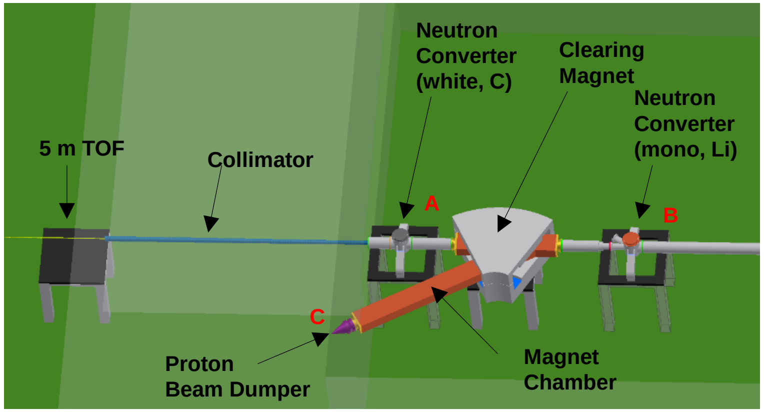
Building design of NSF

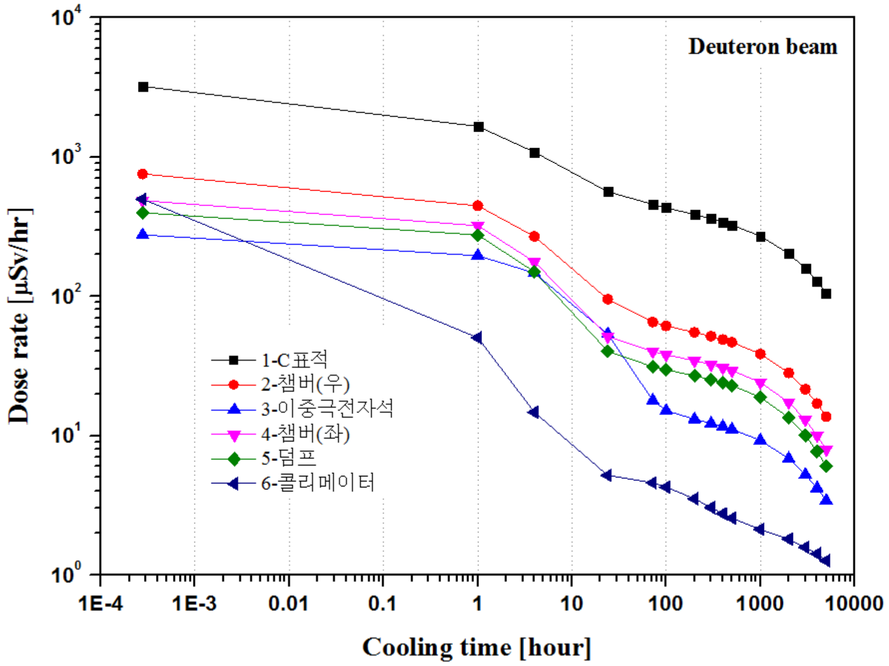


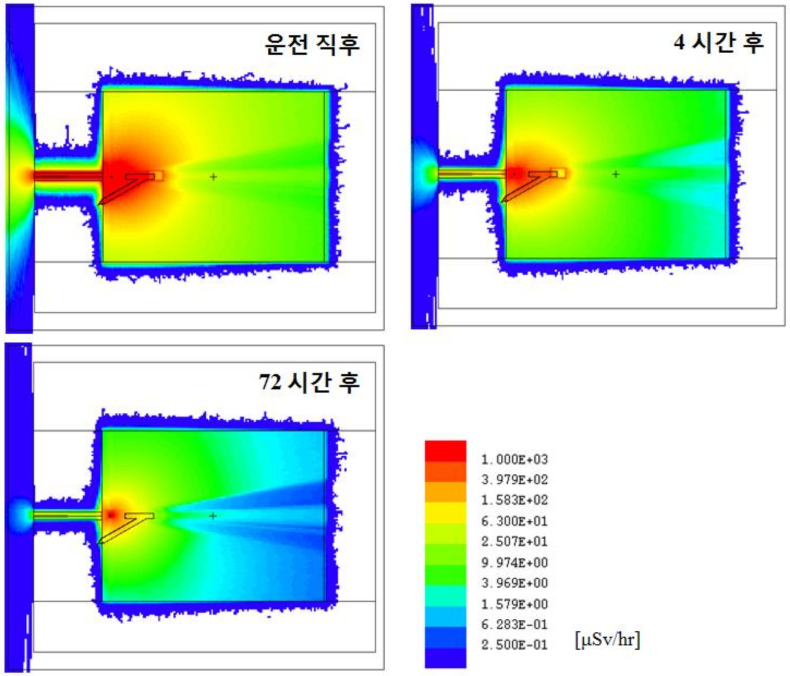
Dose map due to prompt neutrons

Radiation Safety : Device Activation

- Maximum operation time: 1000 hr
- After operaton and considerable cooling time, activities of the most devices are still strong !!
- It is better for target disc to be dislocated in lead shield after operation.
- Neet to prepare remote handling system for maintenance and replacement !!







Summary

- **To measure fission cross-section in 1-100 MeV energy region, neutron science facility (NSF) will be built as a part of RAON.**
  - Primary beams from linac (SCL1): 1 mA, 81.25 MHz
  - ≤ 53 MeV deuteron and ≤ 88 MeV protons
  - Repetition rate: 1 kHz ~ 1 MHz (~12 μA), Beam width: 1~2 ns
  - C target : < ~53 MeV white by (d, n)
  - Li target : < ~88 MeV mono-energetic by (p, n)
  - Construction of fast neutron TOF
  - Development of fission cross-section measurement system

- **Some issues**
  - The developing schedule has been delayed for 3 years. (man-power, time)
  - The fulse width of 1-2 ns will be a big challenge.
  - The building design for radiation safety should be carefully considered.

Thank You