Workshop on Radiation Effects in Superconducting Magnets and Materials 2014 (RESMM'14) at Wroclaw POLAND , from May 12 to May 15

Radiation Transport Calculation for the In-Flight Fragment Separator of RISP

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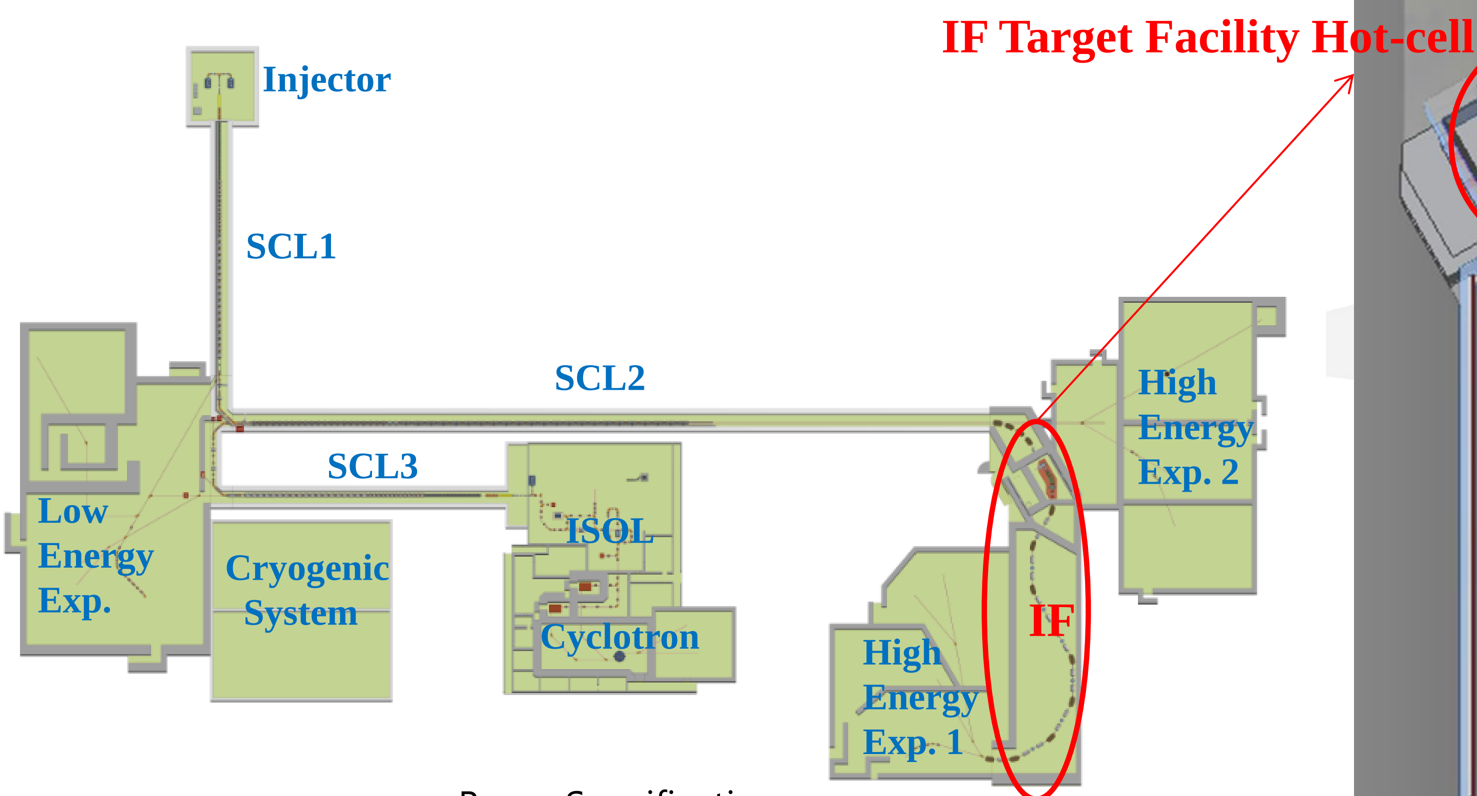
Institute for Basic Science(IBS)
Mijung Kim

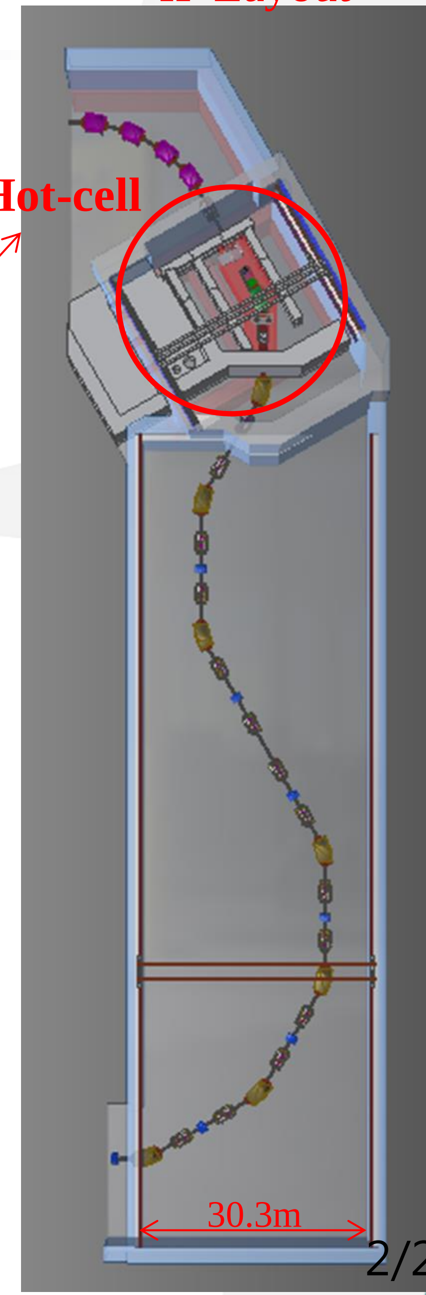
기초과학연구원 Institute for Basic Science

RISP

Raon Accelerator Layout



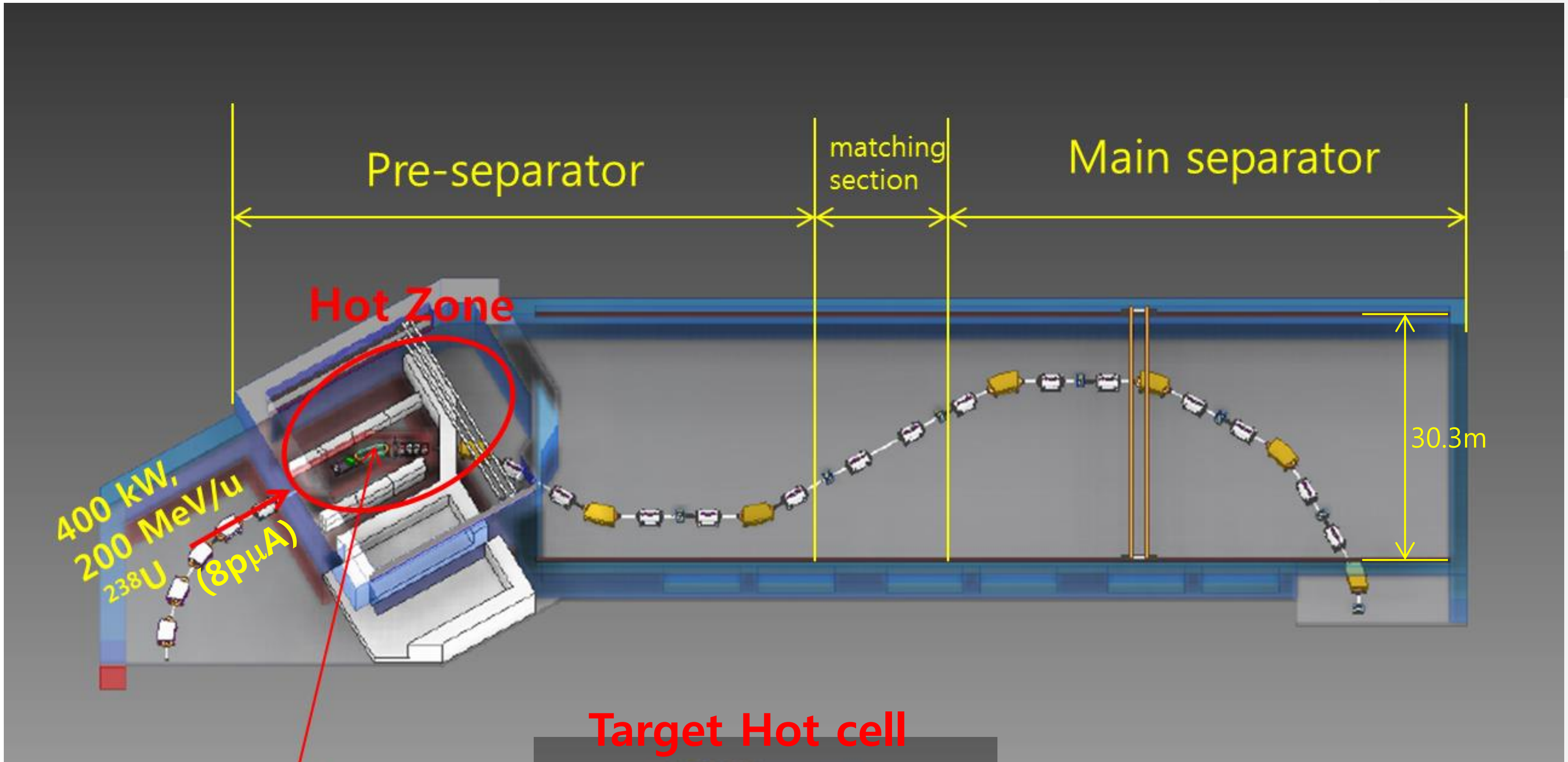
IF Layout

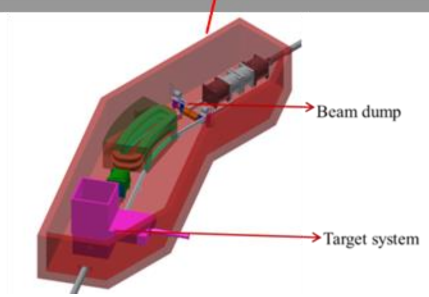


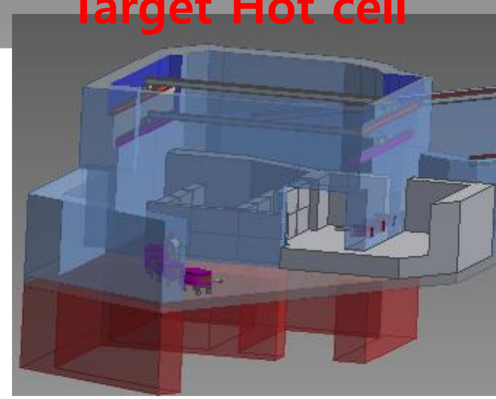
Beam Specification

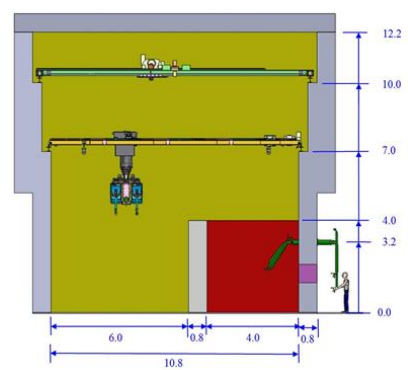
Accelerator	Driver Linac			Cyclotron
particle	proton	Xe^{+54}	U^{+79}	proton
Beam energy(MeV/u)	600	251	200	70MeV
Beam current(pμA)	660	11	8.3	1mA
Power on target(kW)	400	400	400	70 kW

IF Separator Layout

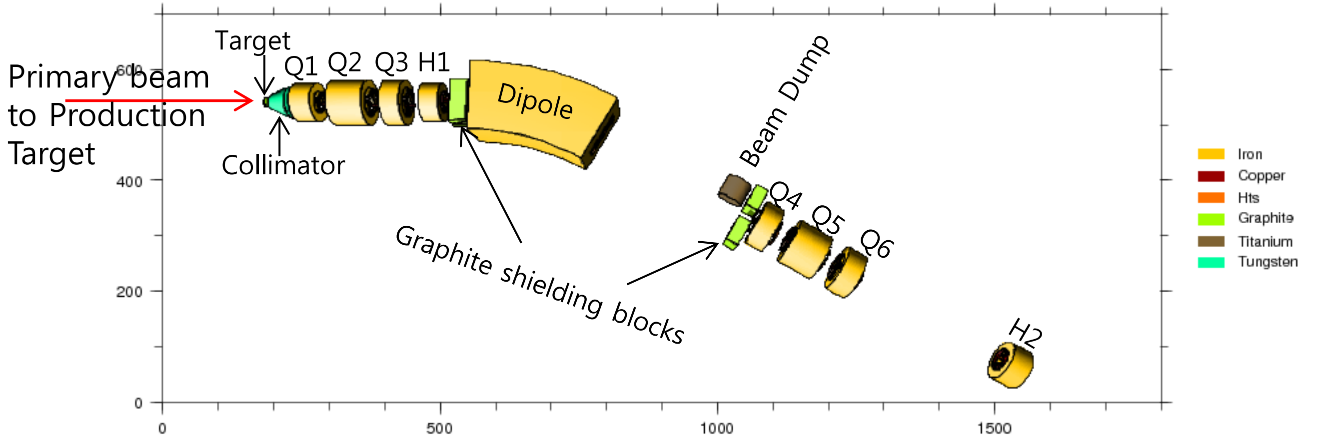


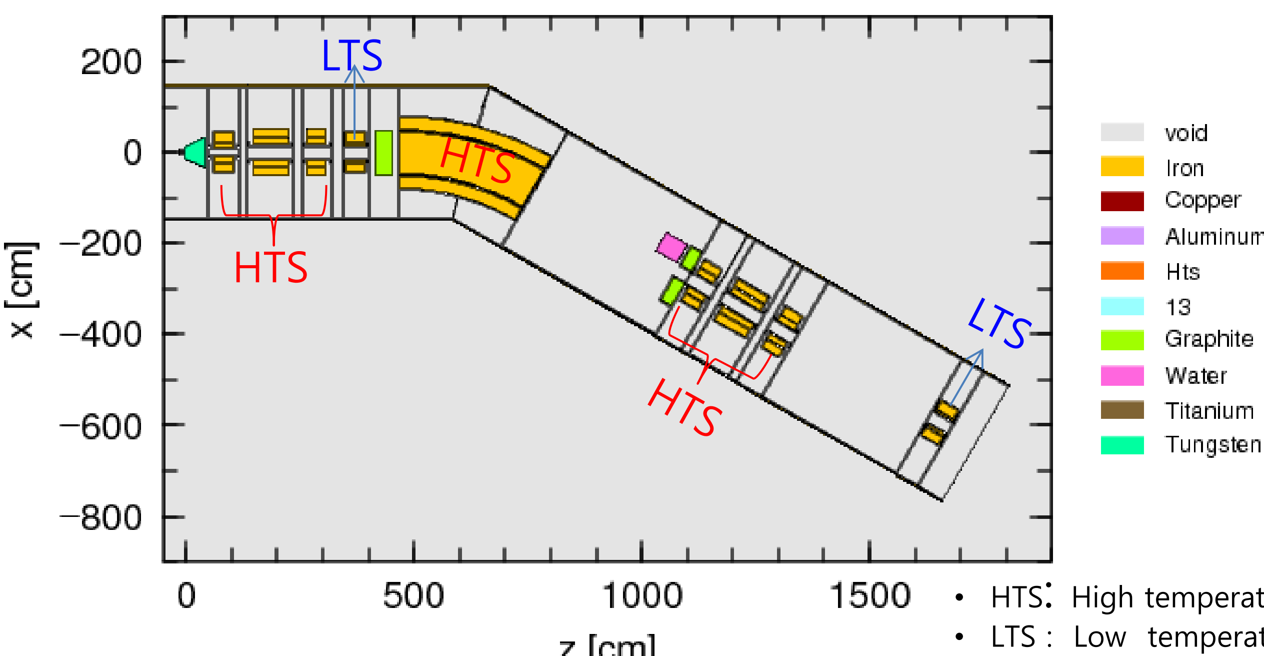






Model for PHITS Calculation





Raon resource summary

resource	description
computing 30 node	Node[01-30]
CPU	2.9Ghz (16core per node)
Memory	64G(4G per core)
shared filesystem	/home(84TB)

Calculation condition

version: PHITS2.64

- Heavy ion:JAM/QMD+GEM
- Neutron(E>20MeV) :JAM/QMD+GEM
- Neutron(E≤20MeV) :ENDF/B-VI, ENDF/B-VII. JENDL-3.3,JENDL-4.0

- HTS: High temperature superconducting
- LTS : Low temperature superconducting

HTS Coil specification & Design

KOREA ELECTROTECHNOLOGY RESEARCH INSTITUTE

◆ Basic specifications of HTS coil

- Operating temperature : ~ 50 K
- Operating current : Amount equivalent to the field gradient of 15 T/m (< critical current of HTS coil)
- Coils shape : Racetrack, Pancake
- Number of HTS coils : 1~4 single pancake (or, 1~2 double pancake)
- **HTS wire** : **2^{nd} Generation HTS Tape** (**ReBCO coated conductor- GdBCO was used for the PHITS calculation**) (width of tape = 12 mm)
- Electric insulation between turns : Metal insulation (**stainless steel tape**)

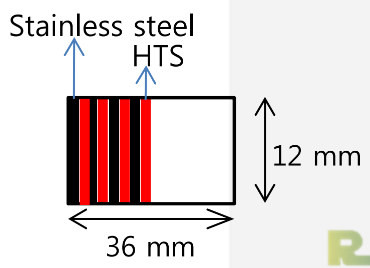
◆ HTS wire

- Two candidates : SuperPower, SuNam

◆ Number of HTS coils, Critical current and Operating current

-Basic shape of HTS coil

- **Cross-sectional dimension of single pancake = 36 mm X 12 mm** (considering the acceptability in the yoke space)
- HTS tape : 12 mm width x 0.1 mm thickness
- Thickness of stainless steel insulator = 0.05 mm



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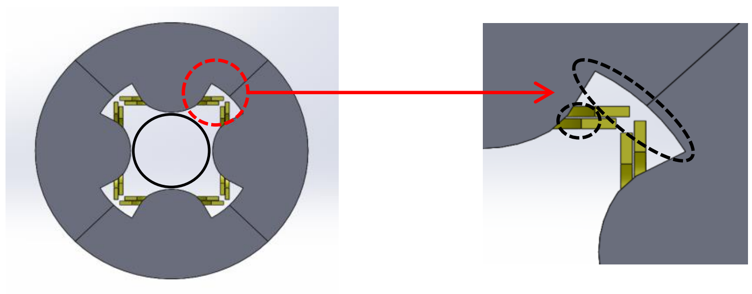
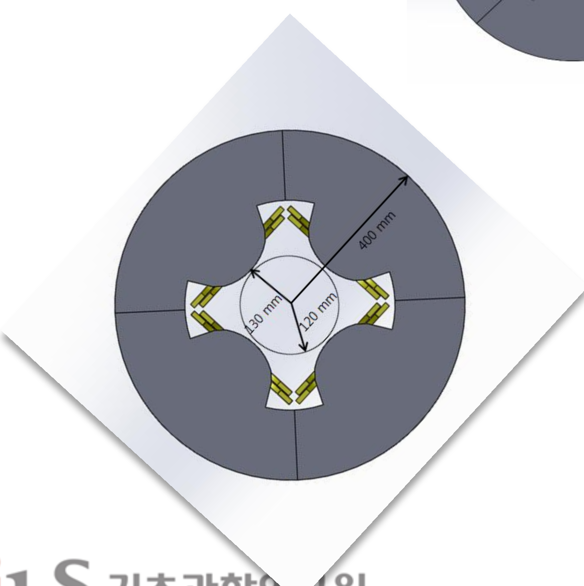
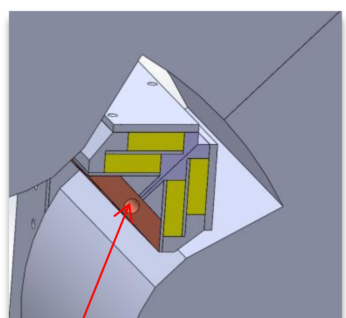
RISP

Iron Yoke Design

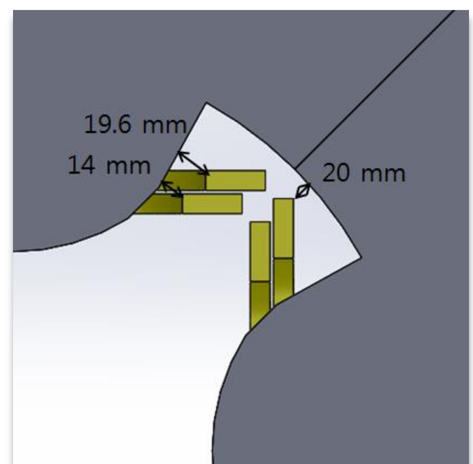
- **Shape of iron yoke**
  1. Magnetic field performance of magnet (Field gradient, uniformity…)
     → Dominantly **depends on the shape of Iron Yoke**
  2. **Space** for thermal insulation, mechanical structures for coil support and GHe cooling channels.
     → Size and shape of the space also affects the performance of magnet





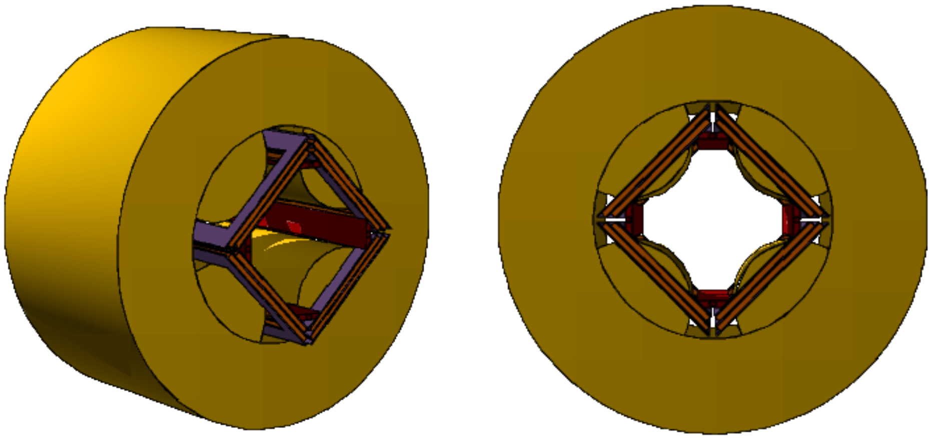


GHe cooling channel

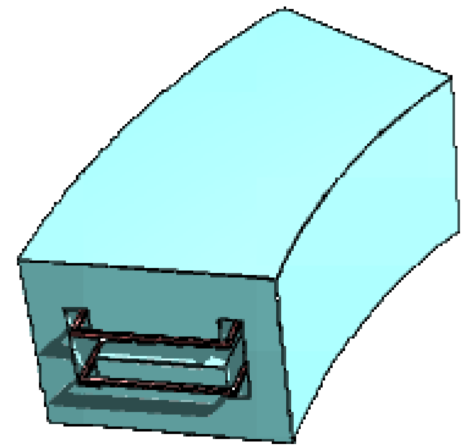


Magnet Model for PHITS calculation

Quadrupole

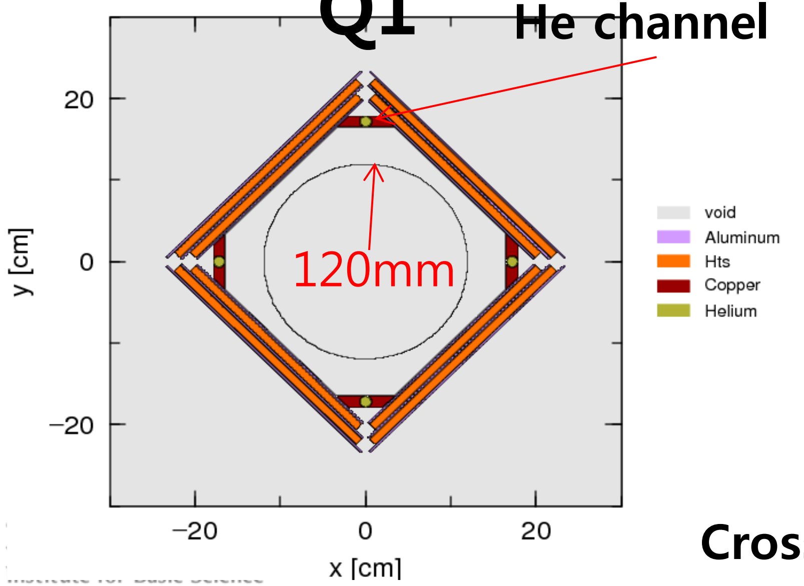


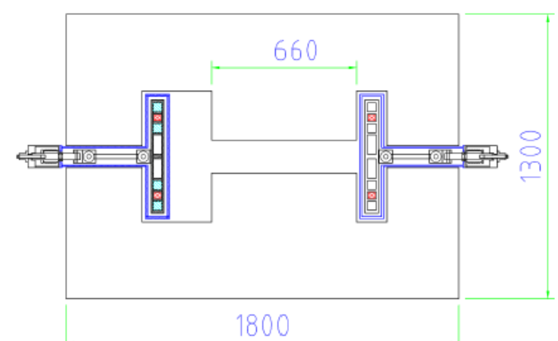
Dipole



Q1

He channel

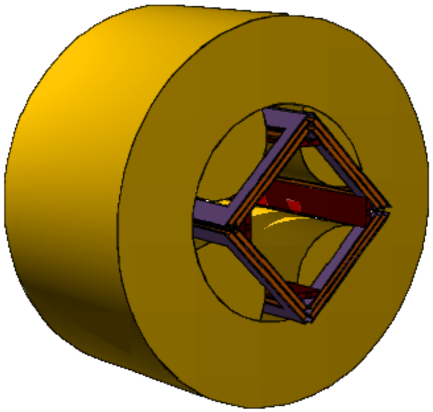


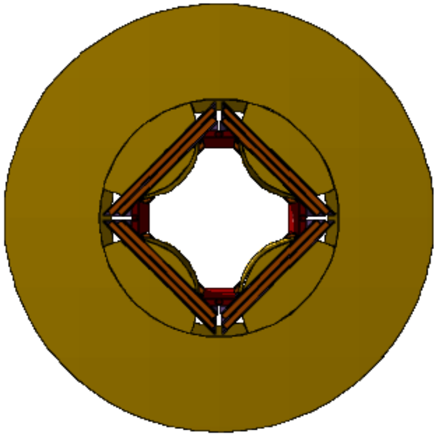


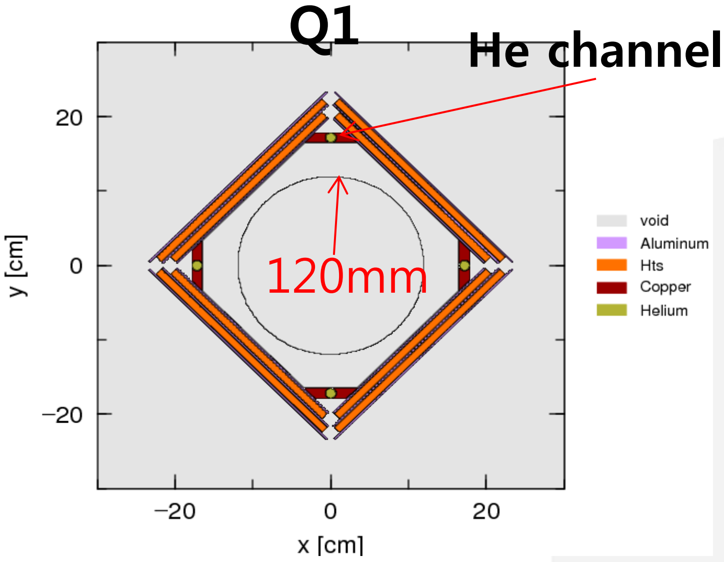
Cross sectional view

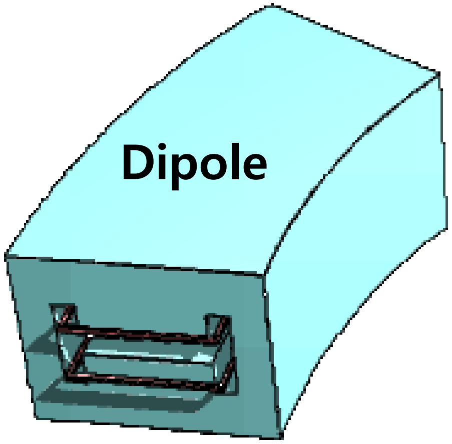
Magnet Model for PHITS calculation

Quadrupole







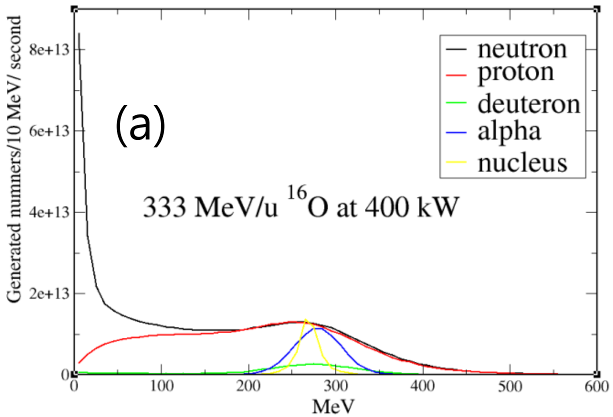


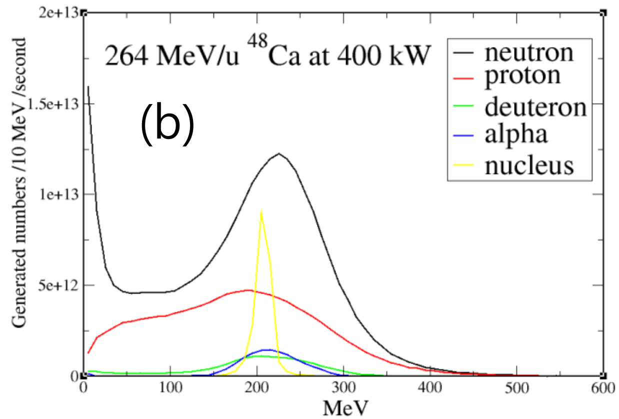
Used Primary beams and conditions

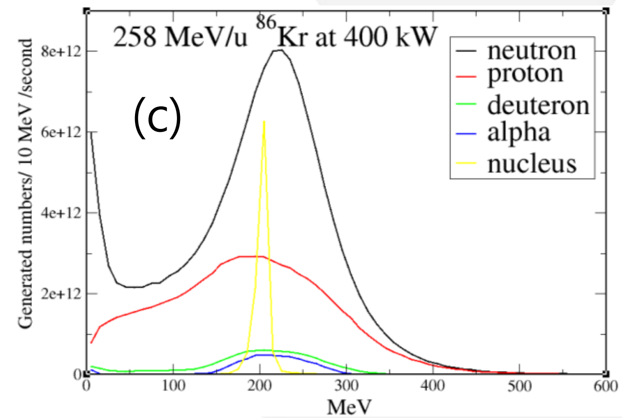
Primary beam	Projectile energy (MeV/u)	Graphite Target thickness (cm)	Beam intensity (pps)	wanted RI Frag.
^{16}O	333	2.298	4.692×10^{14}	^{12}N
^{48}Ca	264	0.752	1.973×10^{14}	^{16}C
^{86}Kr	258	0.406	1.127×10^{14}	^{77}Co
^{238}U	200	0.136	5.252×10^{13}	^{132}Sn
^{238}U	400	0.374	2.626×10^{13}	^{132}Sn

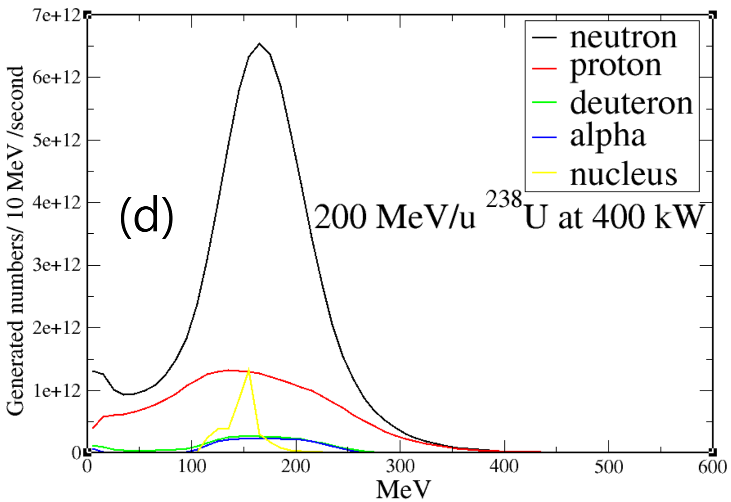
Target thickness, beam intensity, magnetic field were obtained from LISE++

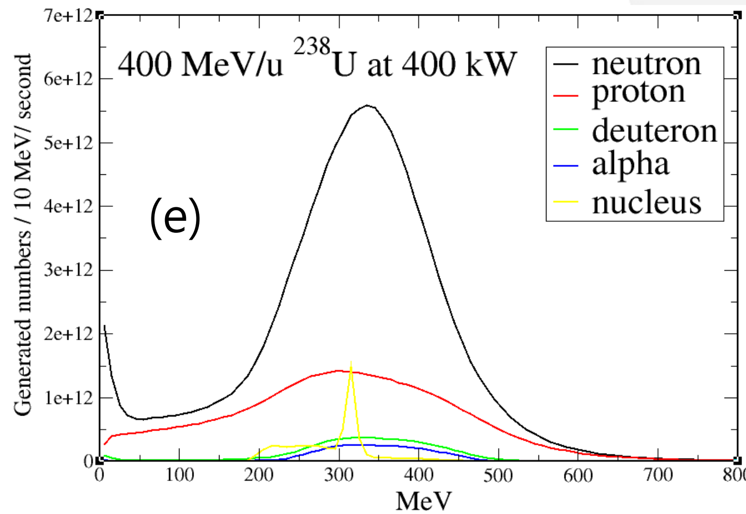
Particles and Nuclei from the Target



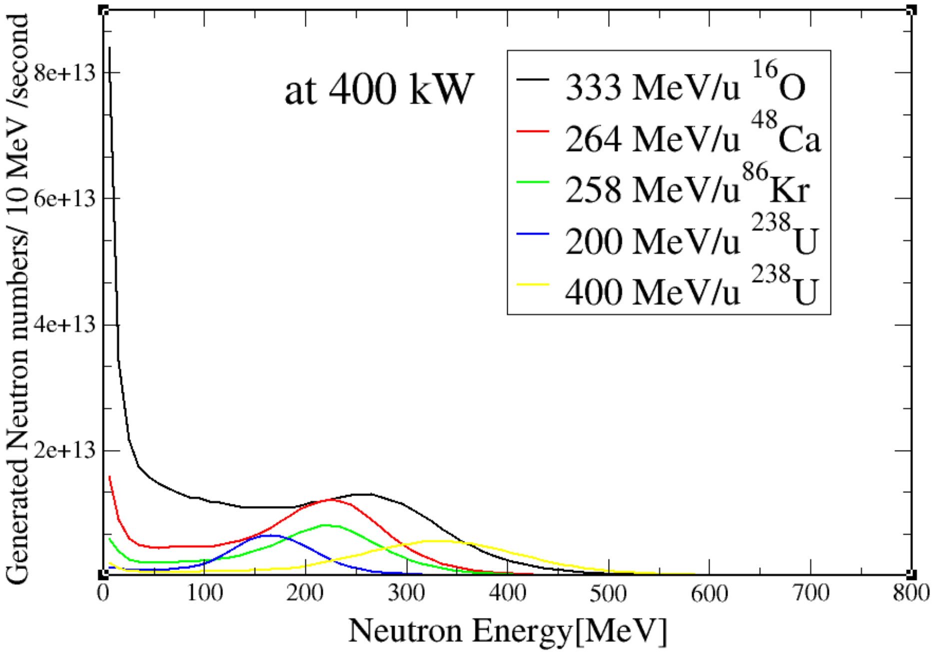


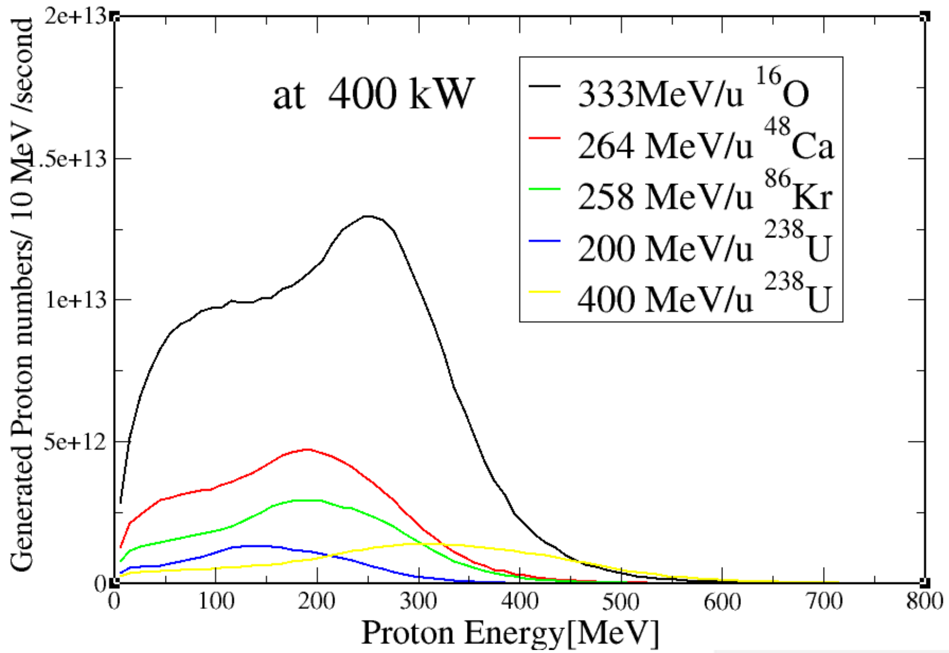






Neutrons and Protons from the Target





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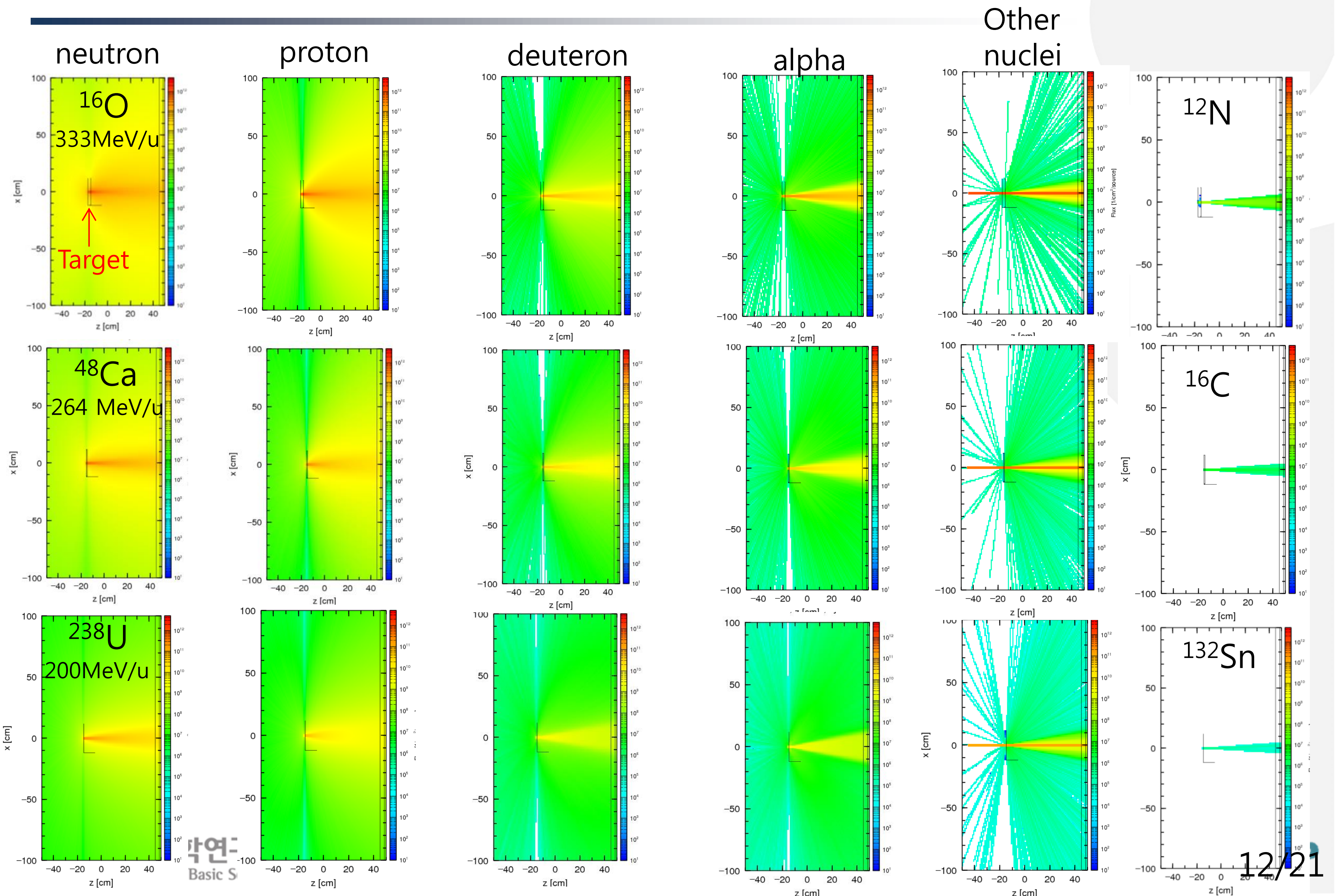
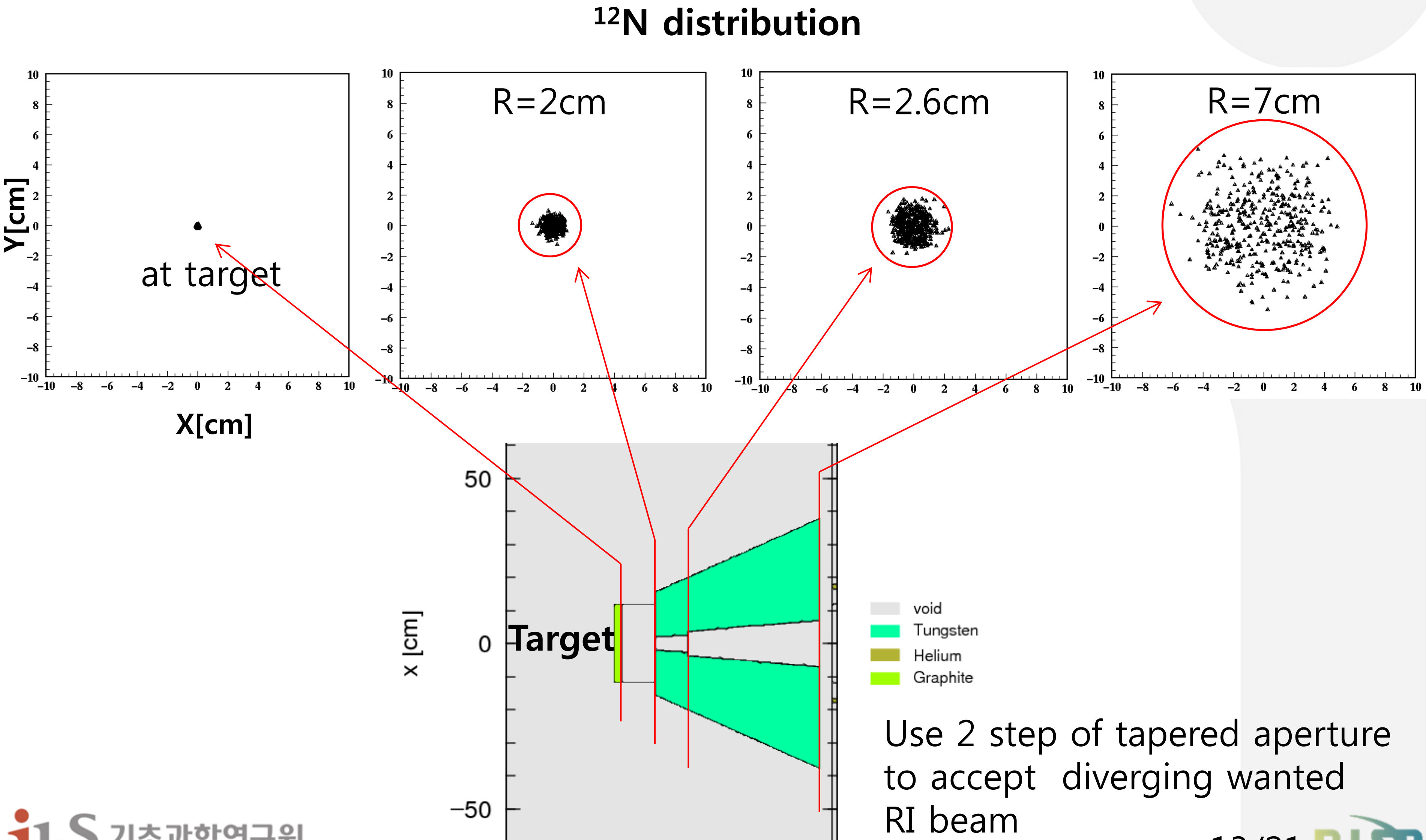
RISP

Flux Distribution[1/cm²/second]

at 400 kW



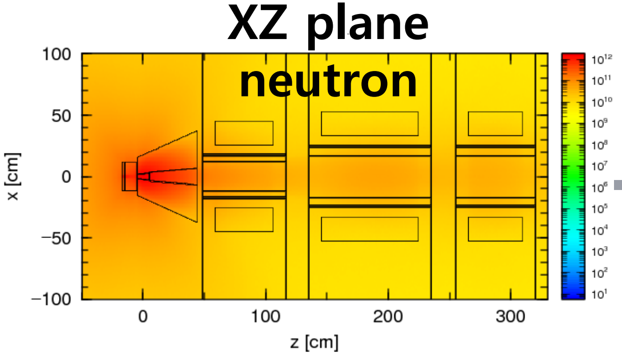
Collimator aperture(^{16}O beam for ^{12}N)

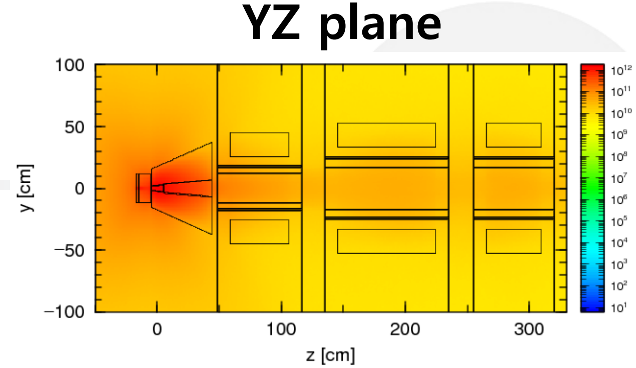


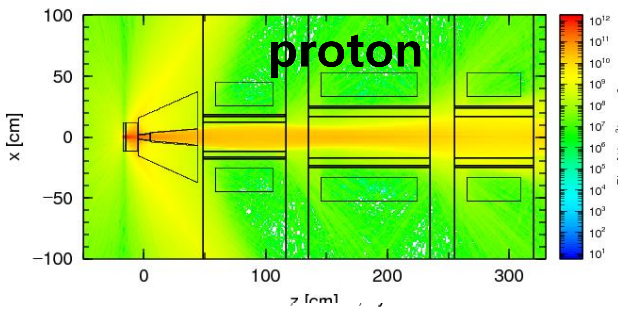
Use 2 step of tapered aperture to accept diverging wanted RI beam

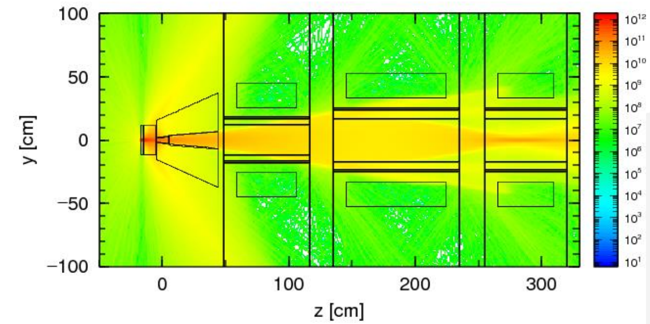
Target Area

with collimator







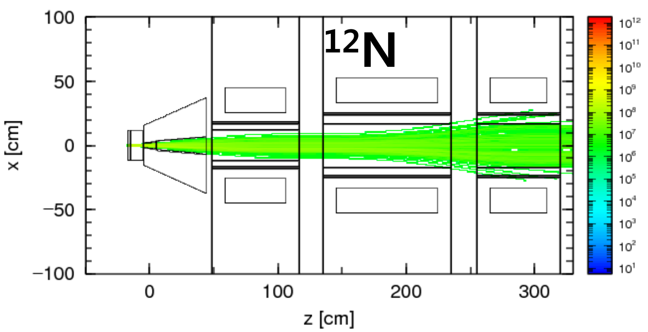


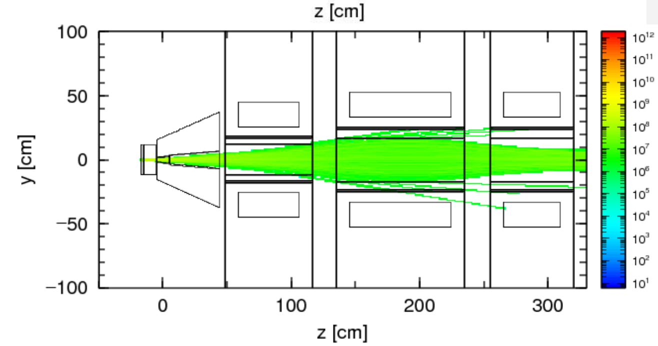
333MeV/u

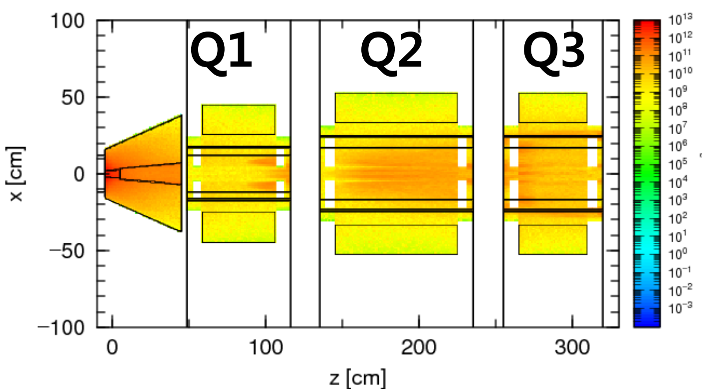
^{16}O at 400 kW

Flux Distribution

[1/cm^2/second]

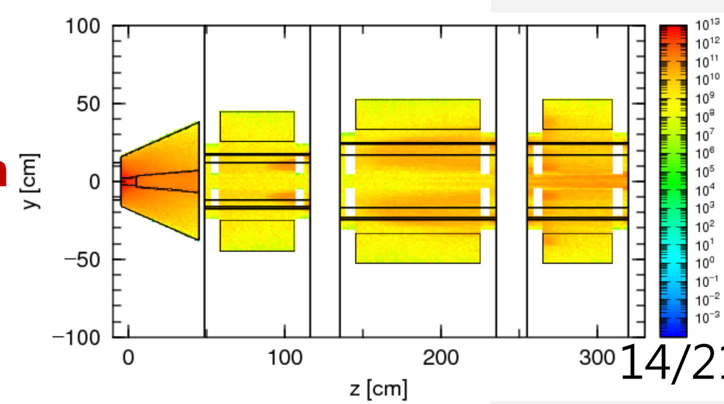






Heat deposition Distribution

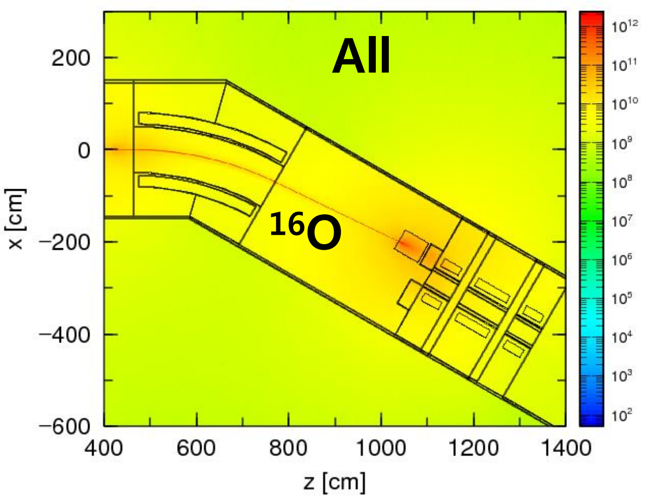
[MeV/cm^3/second]

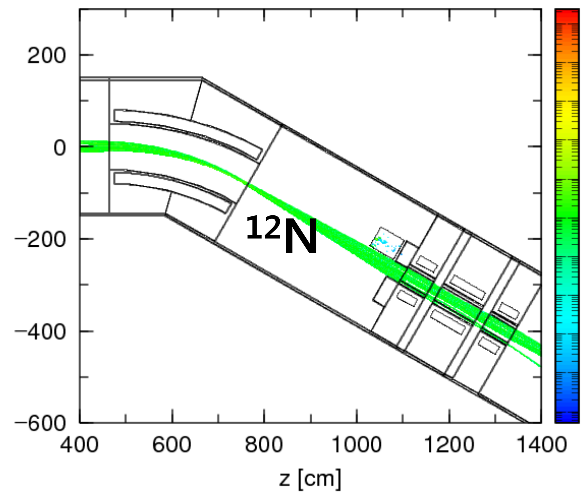


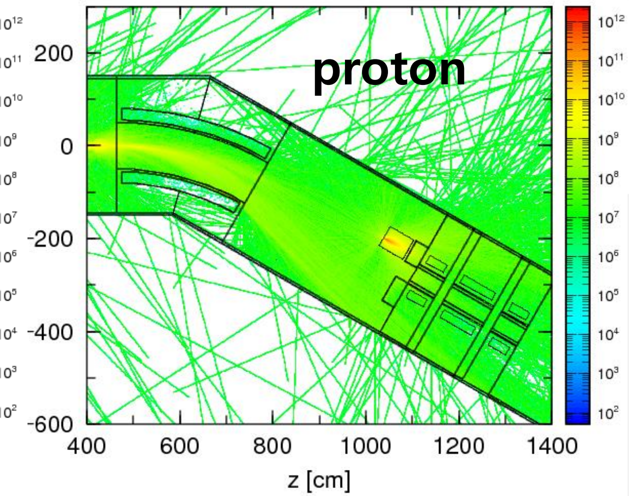
Dipole and Beam Dump area

For 333 MeV/u, ^{16}O at 400 kW

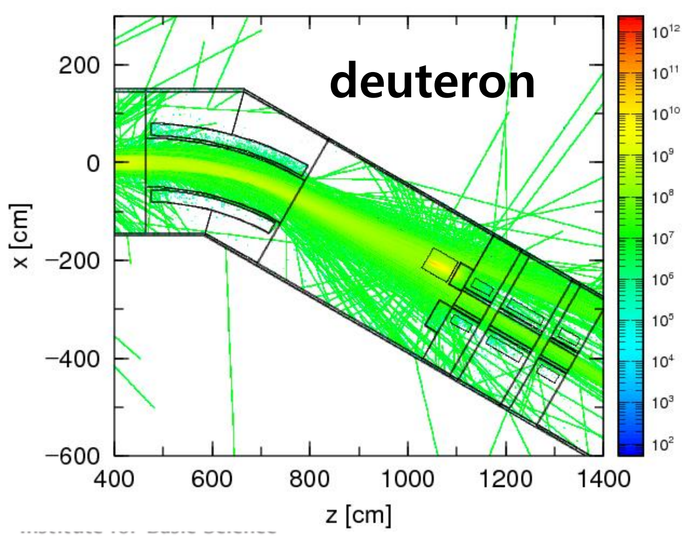
Flux Distribution[1/cm²/second]



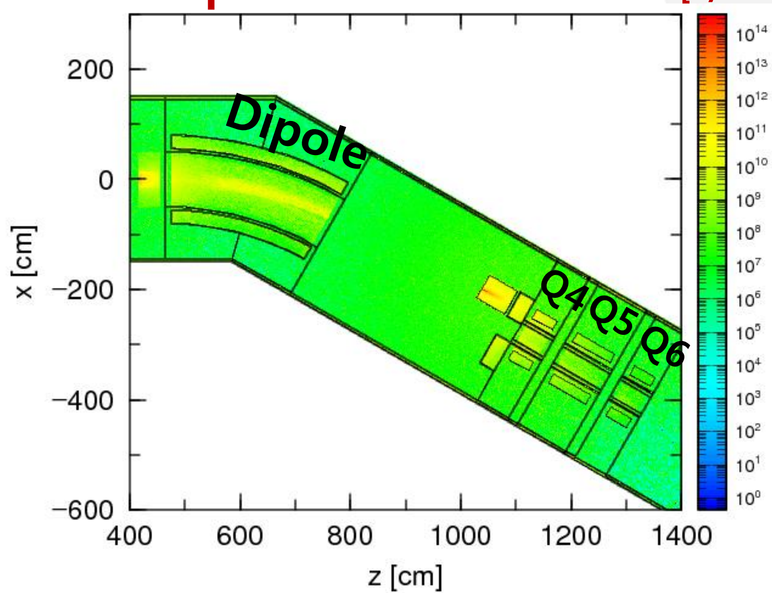




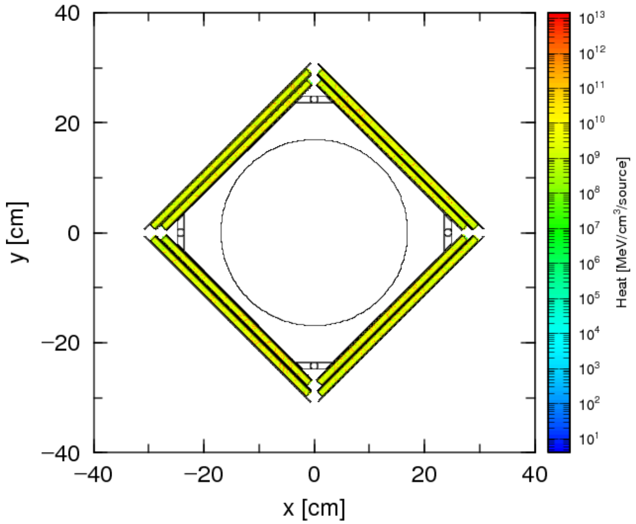
Flux Distribution[1/cm²/second]

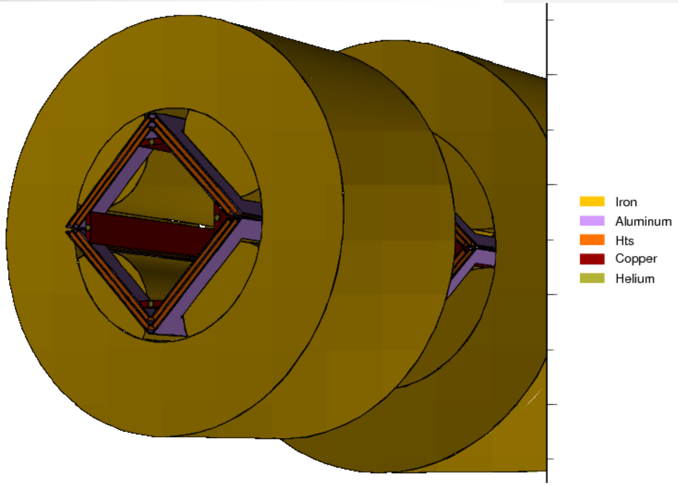


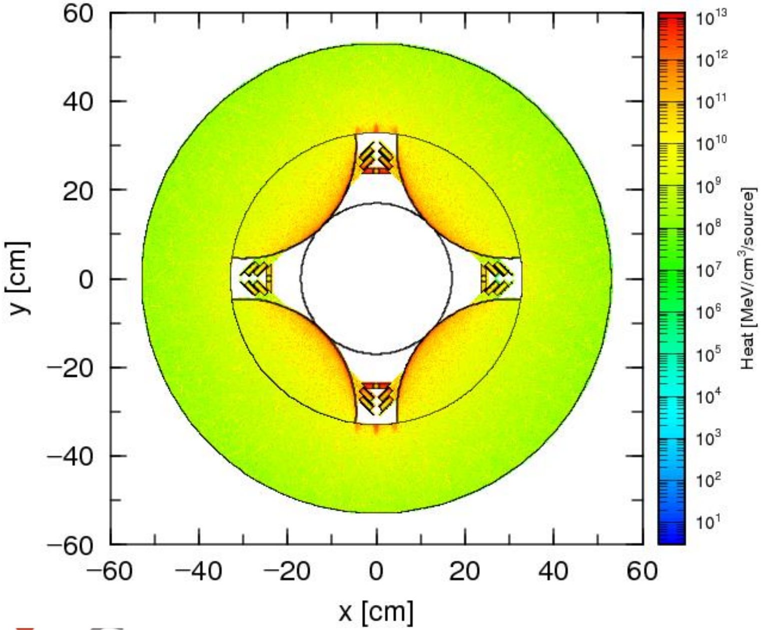
Heat Deposition Distribution[1/cm³/second]

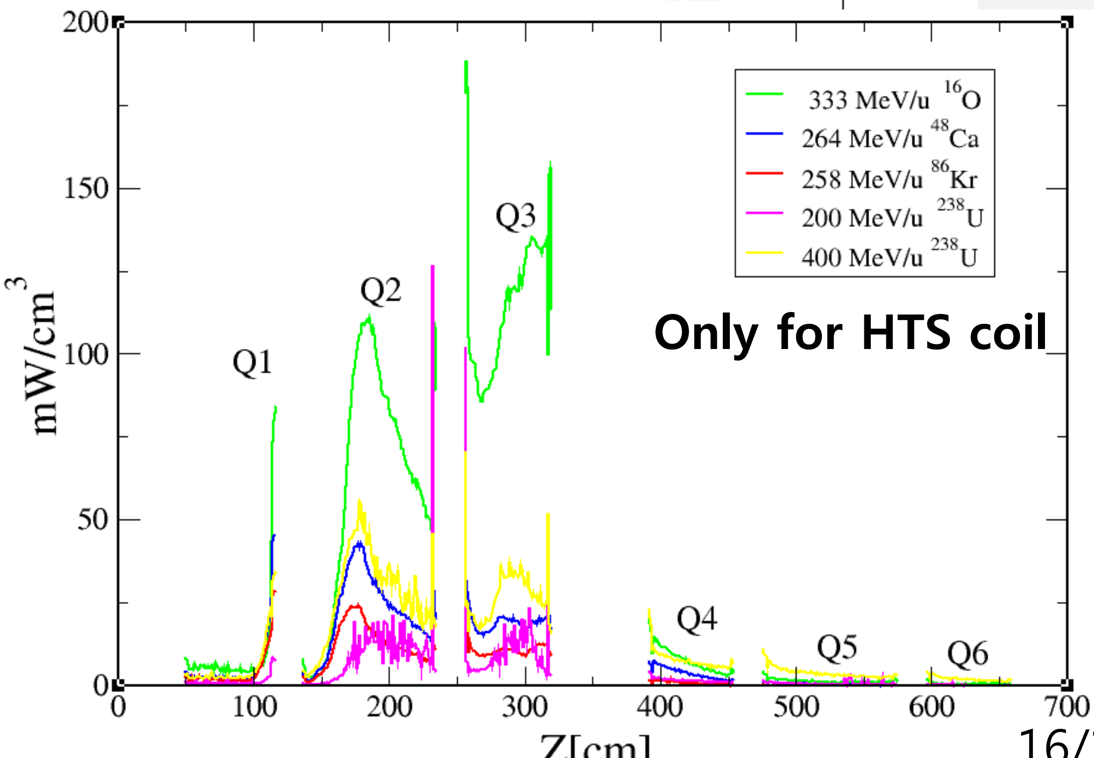


Deposited Heat Distribution and Power Density



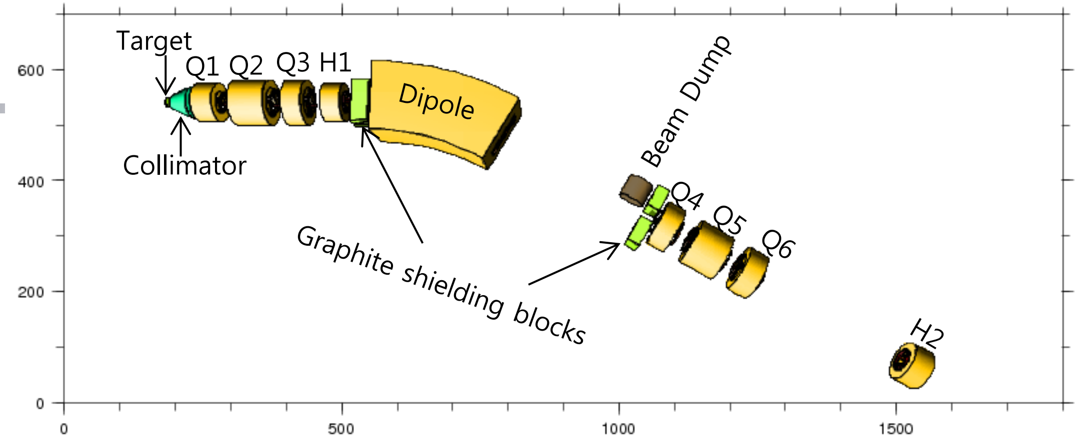


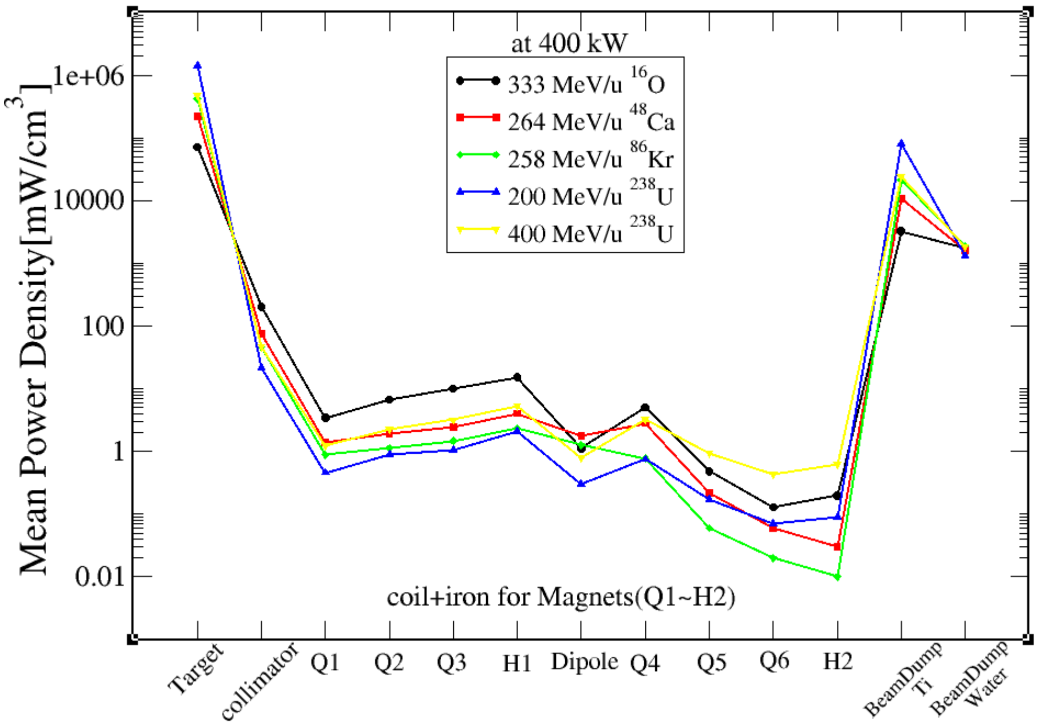




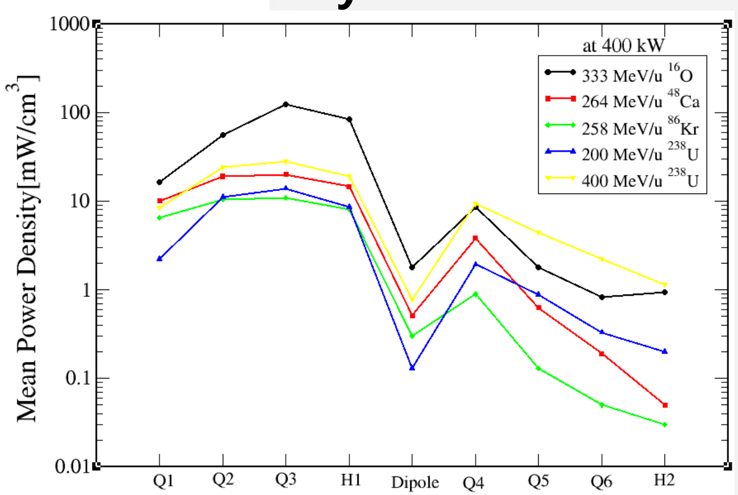
Only for HTS coil

Mean Power Density[mW/cm³]



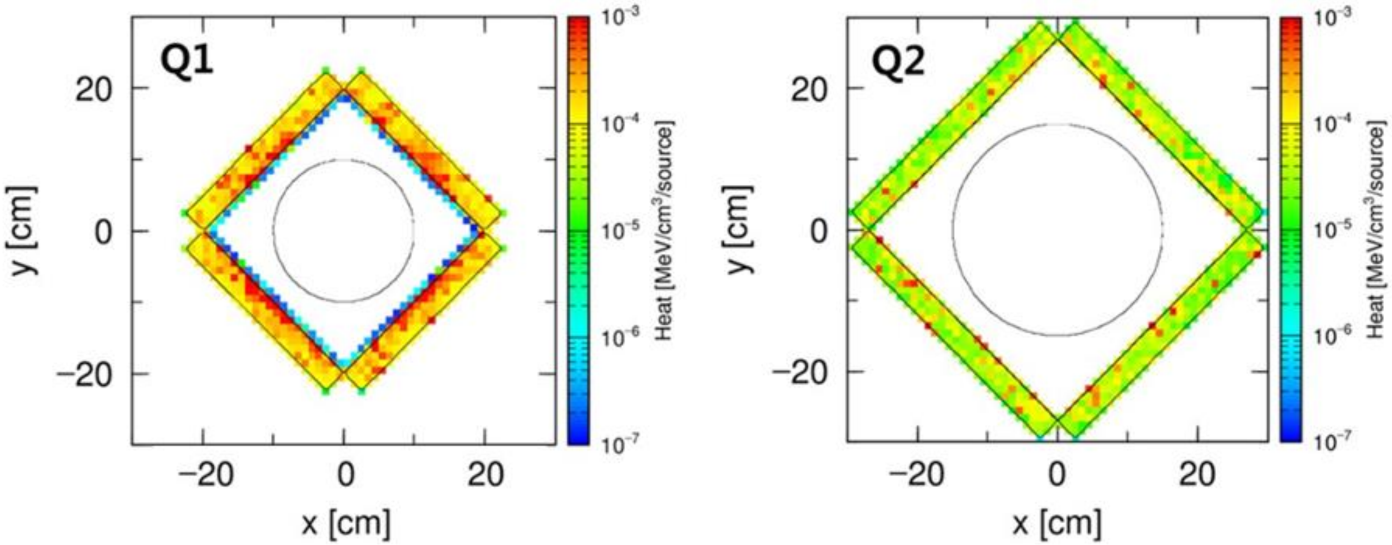


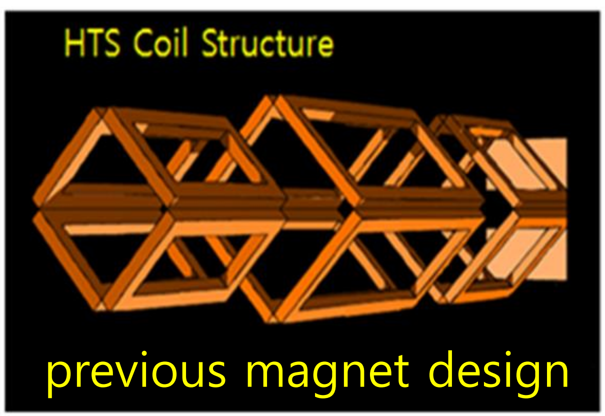
Only for Coils



How to extract Peak power density of HTS coils ?

For 400 kW, 200MeV/u ^{238}U

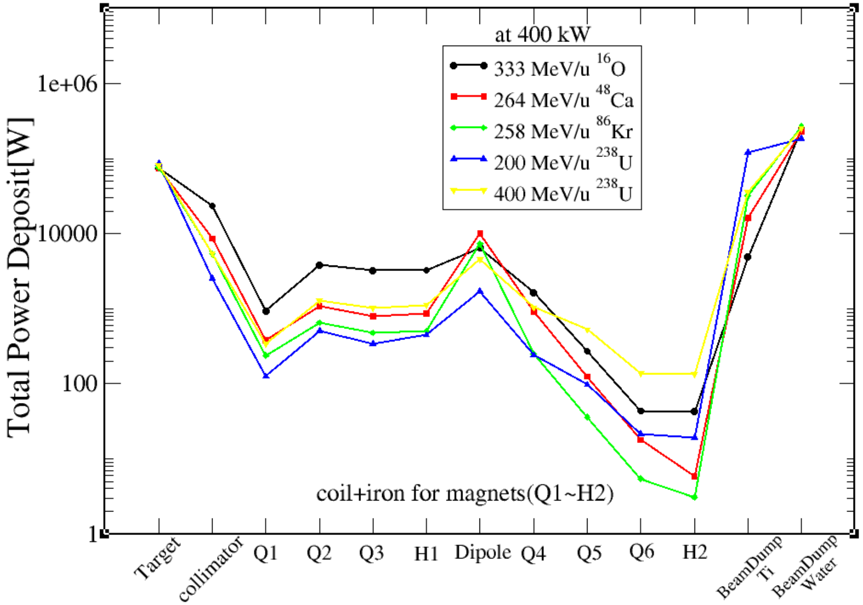




averaging the beam energy in the mesh of 1 cm square in the transverse direction and of 1 cm in the beam direction

Peak power density calculation is ongoing with new design

Total Power Deposit[W]



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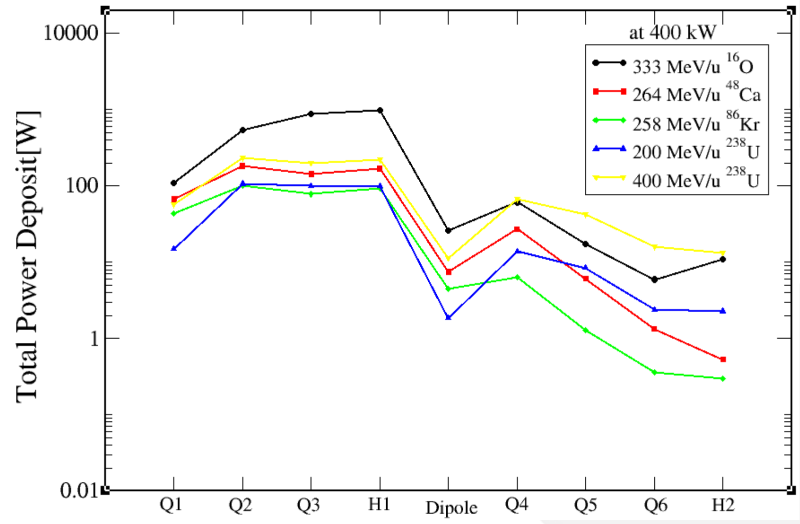
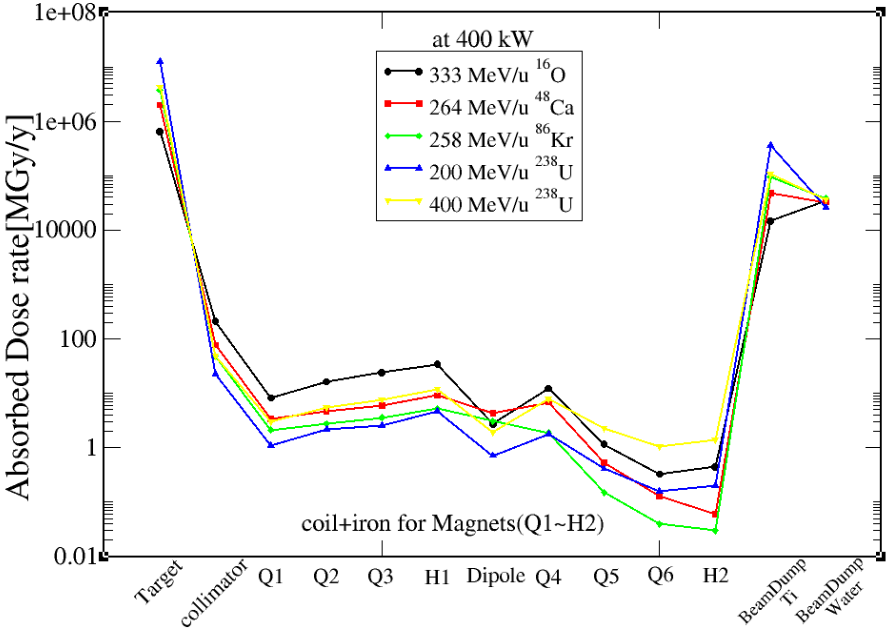
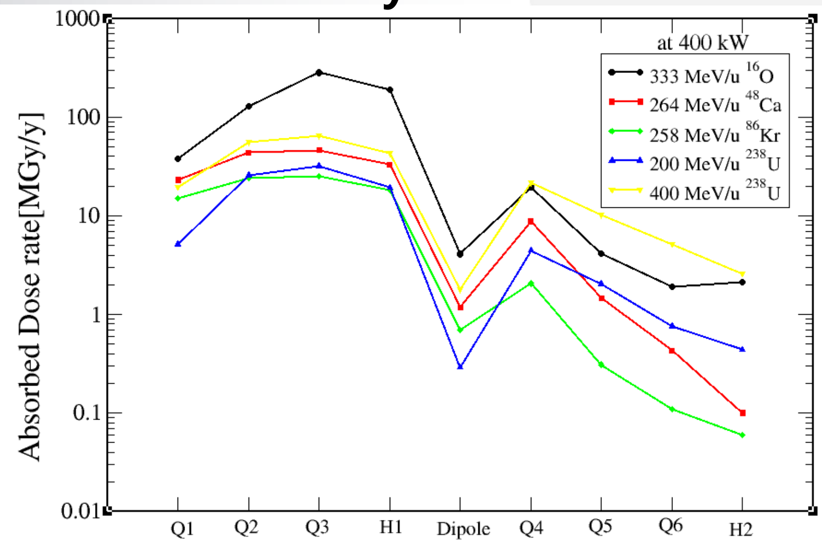


Beam ion	Target [kW]	Collimator [kW]	Coil [kW]	Iron [kW]	Beamdump (Ti+Water)[kW]	Target + Beamdump [kW]
^{16}O	74.26	23.50	2.63	17.06	4.90+ 246.45	325.60
^{48}Ca	75.05	8.65	0.61	13.73	16.21+228.36	319.62
^{86}Kr	76.08	5.34	0.33	9.12	31.68+268.17	375.94
^{238}U_200	86.07	2.52	0.35	3.15	119.85+185.13	391.05
^{238}U_400	80.45	5.40	0.86	9.29	35.81+ 252.54	368.79

Absorbed Dose Rate[MGy/y]



Only for Coils



Radiation resistance:100MGy
operation time : 5600hrs/year

HTS Coil Lifetime [y]

Magnets	^{16}O	^{48}Ca	^{86}Kr	^{238}U_200	^{238}U_400
Q1	2.6	4.3	6.7	19.5	5.1
Q2	0.8	2.3	4.1	3.9	1.8
Q3	0.4	2.2	4.0	3.1	1.5
Dipole	24.4	84.7	142.9	344.8	56.2
Q4	5.1	11.4	48.5	22.5	4.6
Q5	24.2	68.5	322.6	49.3	9.8
Q6	52.4	232.6	909.1	131.6	19.4

Summary

- Radiation Transport calculation was performed for the components of target and beam dump area of RISP IF separator system using PHITS code

- The production yields of particles and nuclei at the target and their flux distribution and heat deposition on the components are checked for the ^{16}O, ^{48}Ca, ^{86}Kr, 200 MeV/u ^{238}U and 400 MeV/u ^{238}U beams

- Total power deposition for the each component was extracted

- Absorbed dose rate and HTS coil life time were obtained from the mean power density
  → The calculation of peak power density is ongoing.

- In target area, to protect first quadrupole triplet(Q1 ~ Q3) much stronger shielding is needed

Thank you very much for your attention!