Compact Monoenergetic Proton Generator in MeV Region Using NANOGAN

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Concept of Proton Generator

Purposes :

generating protons in MeV region with monochromatic energy for

- ◇ detector calibration
- ◇ cell irradiation
- ◇ RI production

Concept:

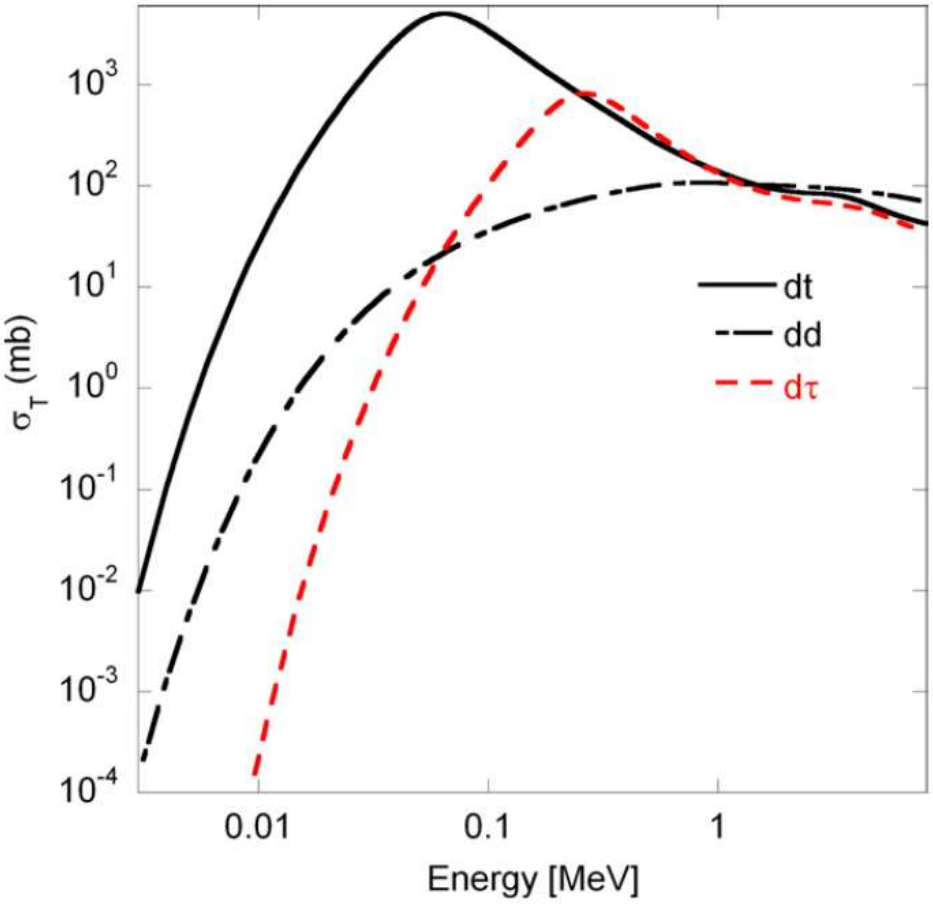
Low construction cost, compact

- ● No Accelerators like Van de Graaf or Cyclotron
- ● Use fusion reaction $^{3}He+d \rightarrow p+^{4}He$

(The proton energy is **14.67MeV**)

→Energy requirement is only several hundred keV

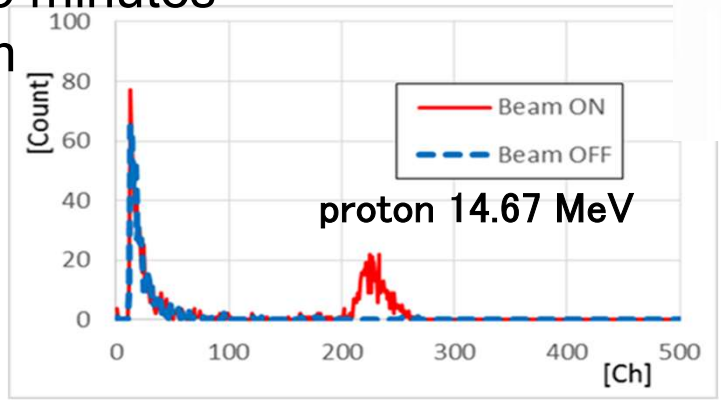
→Compact generator can be constructed with ion sources



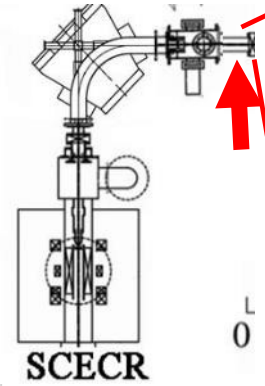
$^{3}He+d$ reaction cross section shown by dashed line
[M. Nocente et al., Nucl. Fusion 50 (2010) 055001]

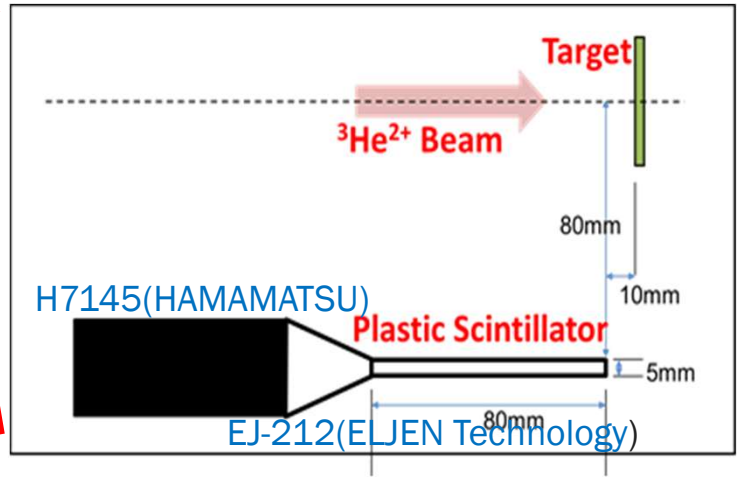
Previous Studies

Confirmation of 3He+D→P+4He reaction with deuterated polyethylene target.
[presented in ICIS'17]
499 protons / 15 minutes with $^3He^{2+}$ beam from SC-ECR (40keV (20kV), ~200eμA)



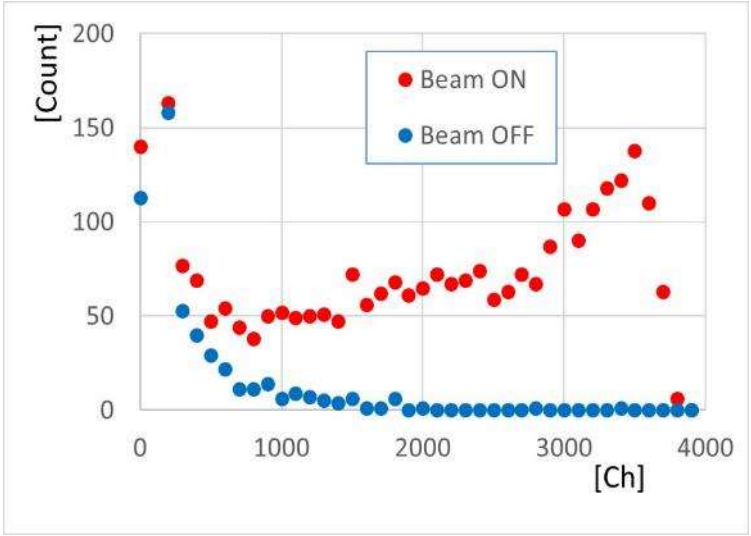
Setup in vacuum chamber



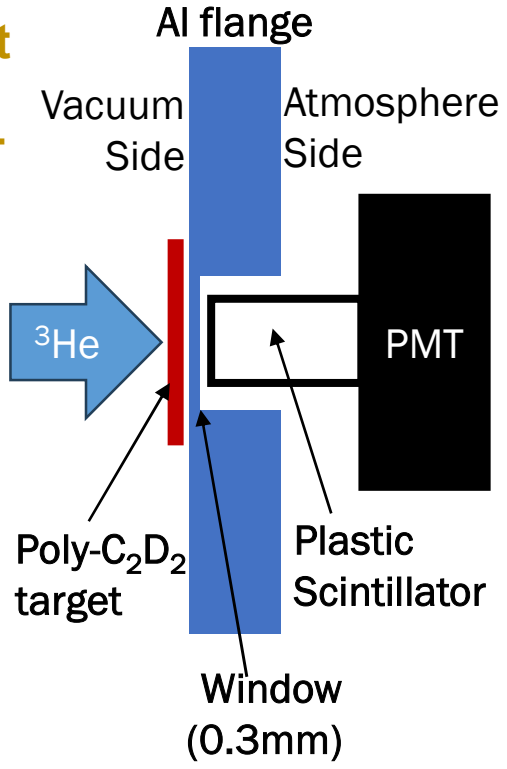


Trying to obtain protons in atmosphere through thin Al window of ϕ20mm and 0.3 mm thickness on Al flange with deuterated polyethylene target.
[presented in ICIS'19]
2204 protons / 10 minutes with $^3He^{2+}$ beam from SC-ECR (40keV (20kV), ~400eμA)

But not monochromatic

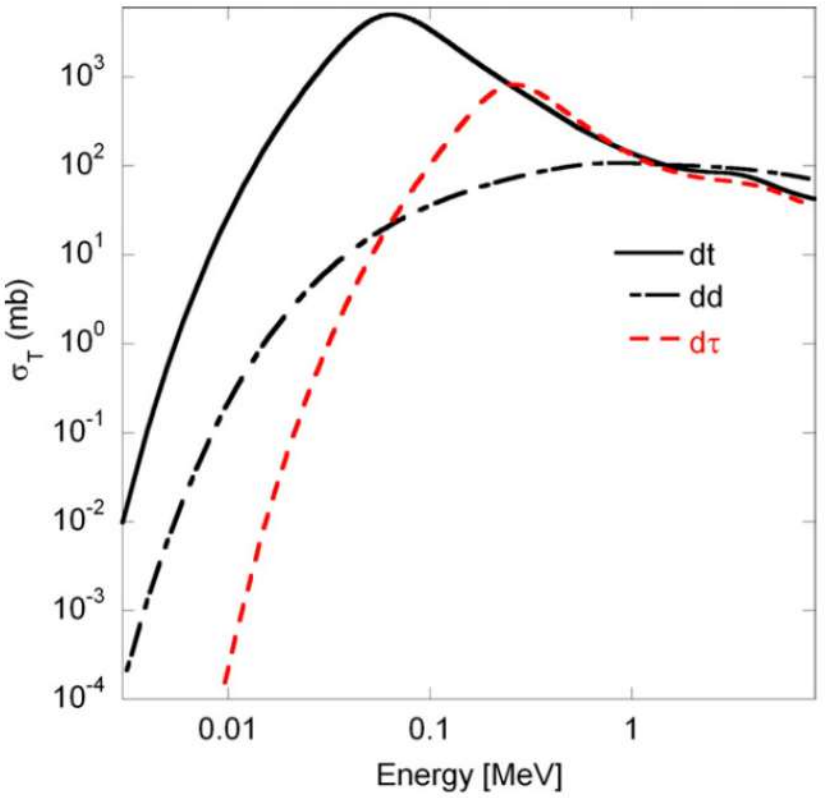


Setup at the end of LEBT



Our Goal

Generating protons in MeV region
in **atmosphere**
with **high intensity**
and **monochromatic energy**



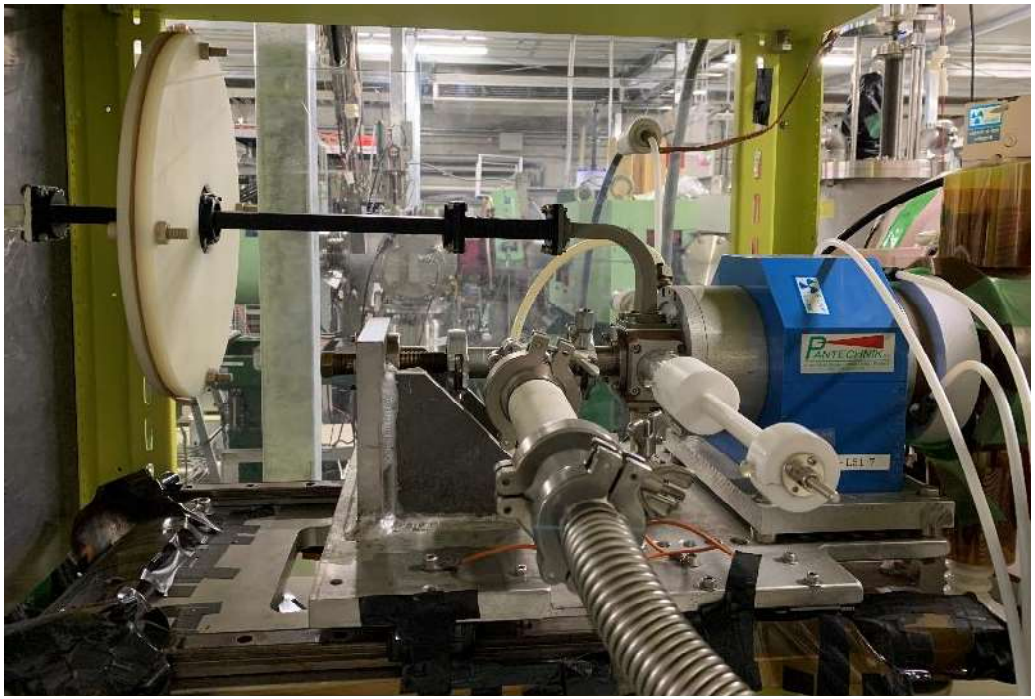
^{3}He+d reaction cross section

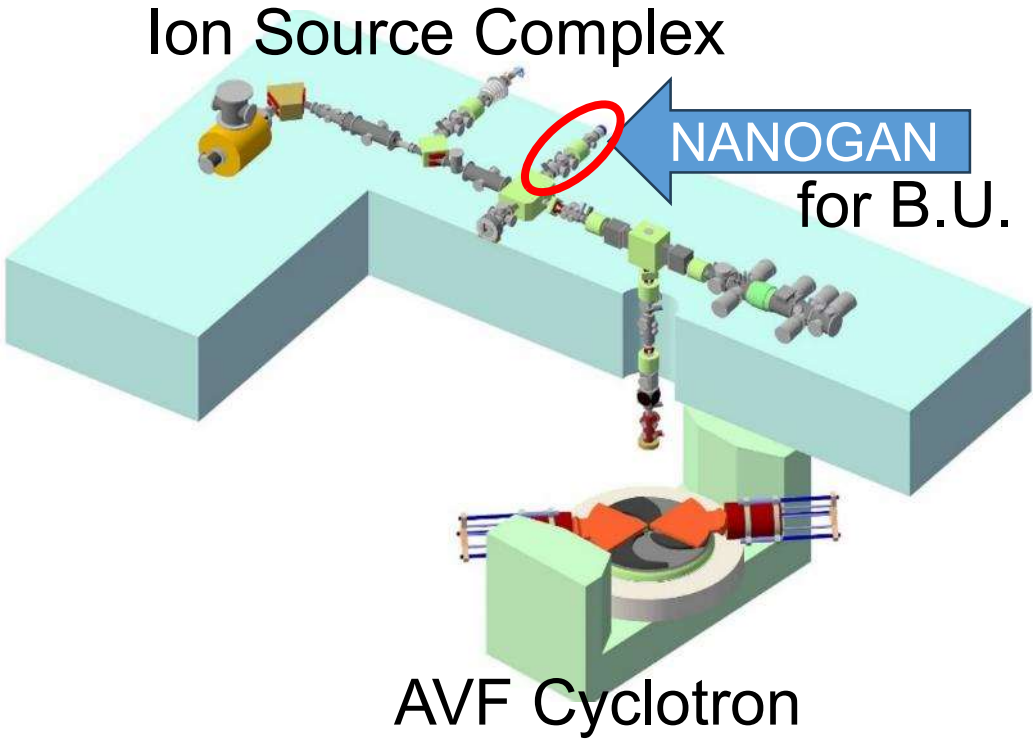
requirements:

◇ High intensity ion source
◇ High voltage acceleration for higher cross section
◇ Thin Window for less energy loss

Compact Ion Source

NANOGAN（PANTECHNIK)
10GHz permanent magnet ECR





Modification on DC cut and insulation of stand for 50kV acceleration has been done.

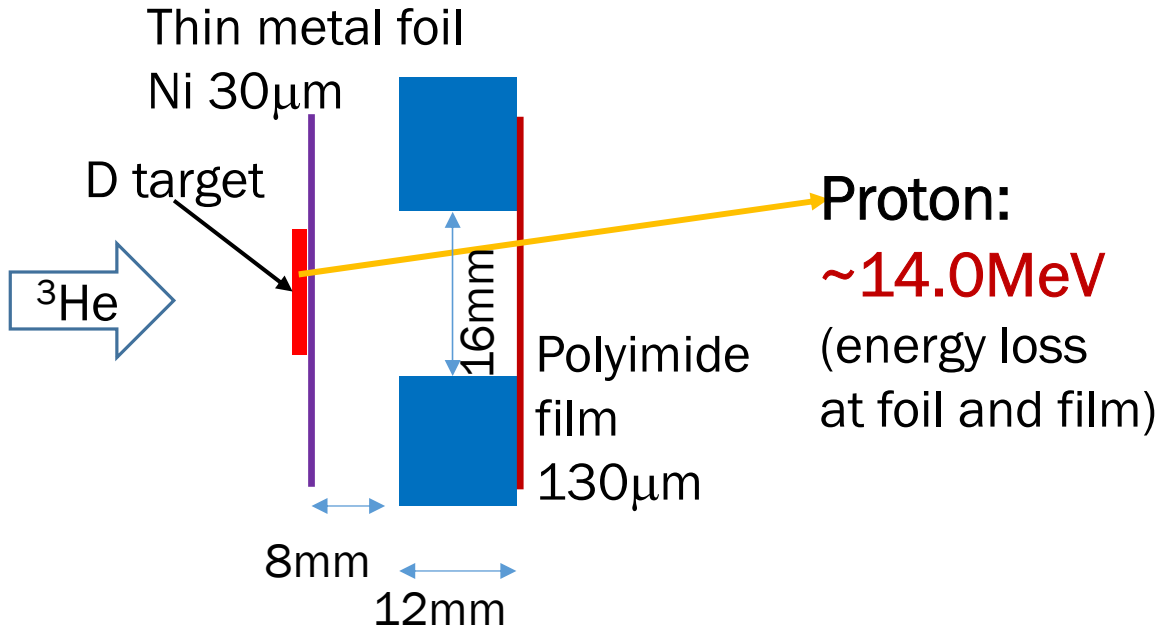
We obtained CW $^{4}He^{2+}$ beam of 800 μA with the 50kV.

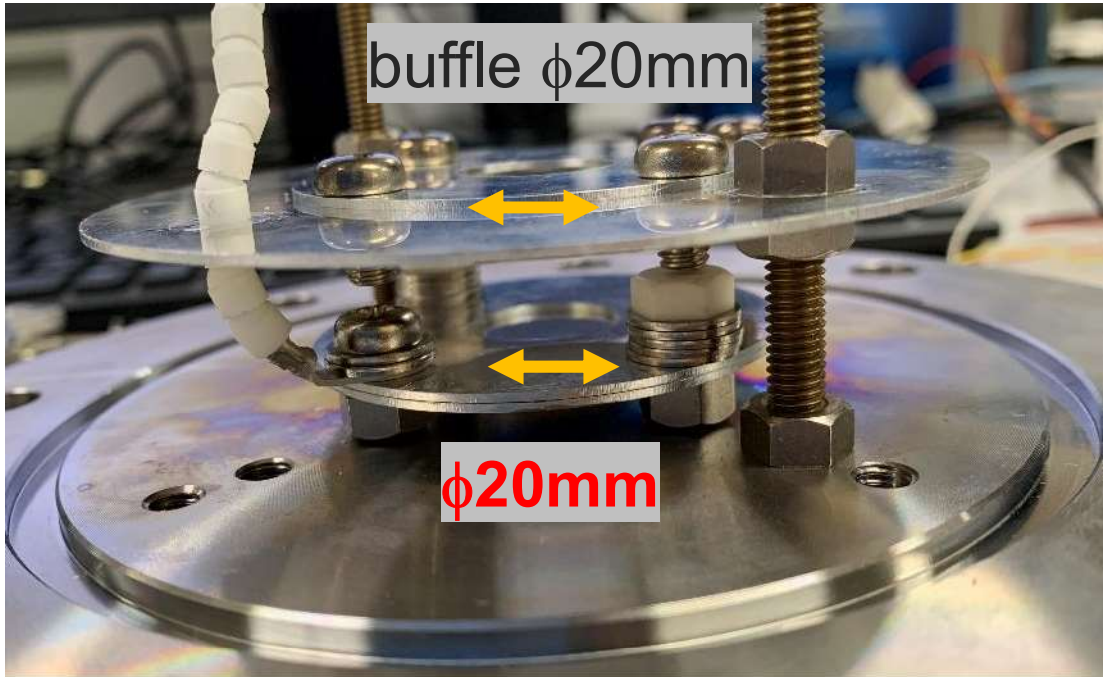
(Cf: spec. on catalog is 100μA@20kV)

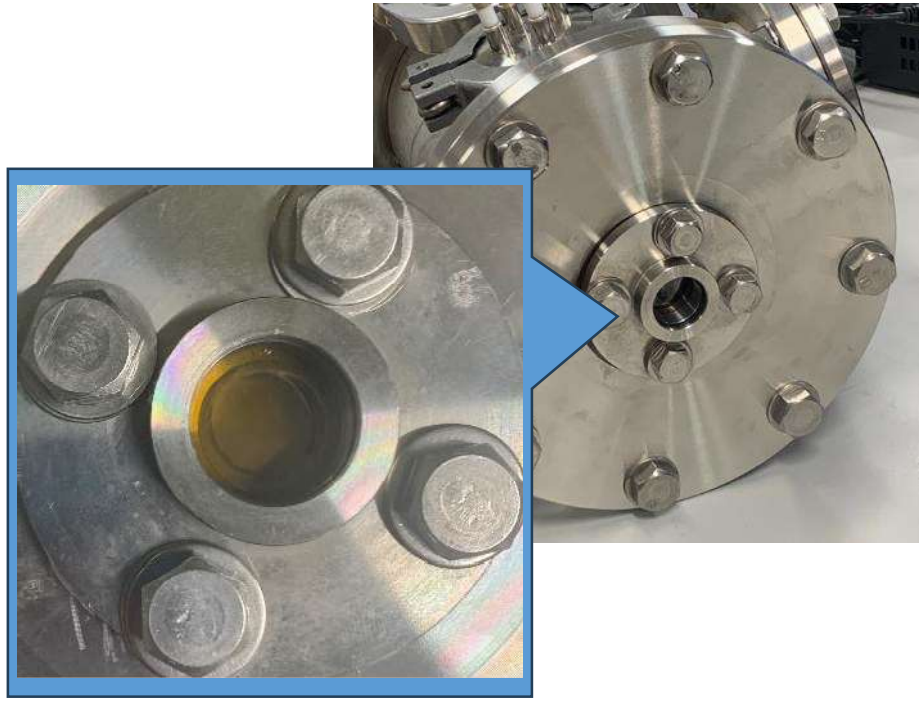
New Thin Window

Window material is
Polyimide film of 130 μm

Thin metal foil is placed
in front of the window to
protect the window from
beam heat load



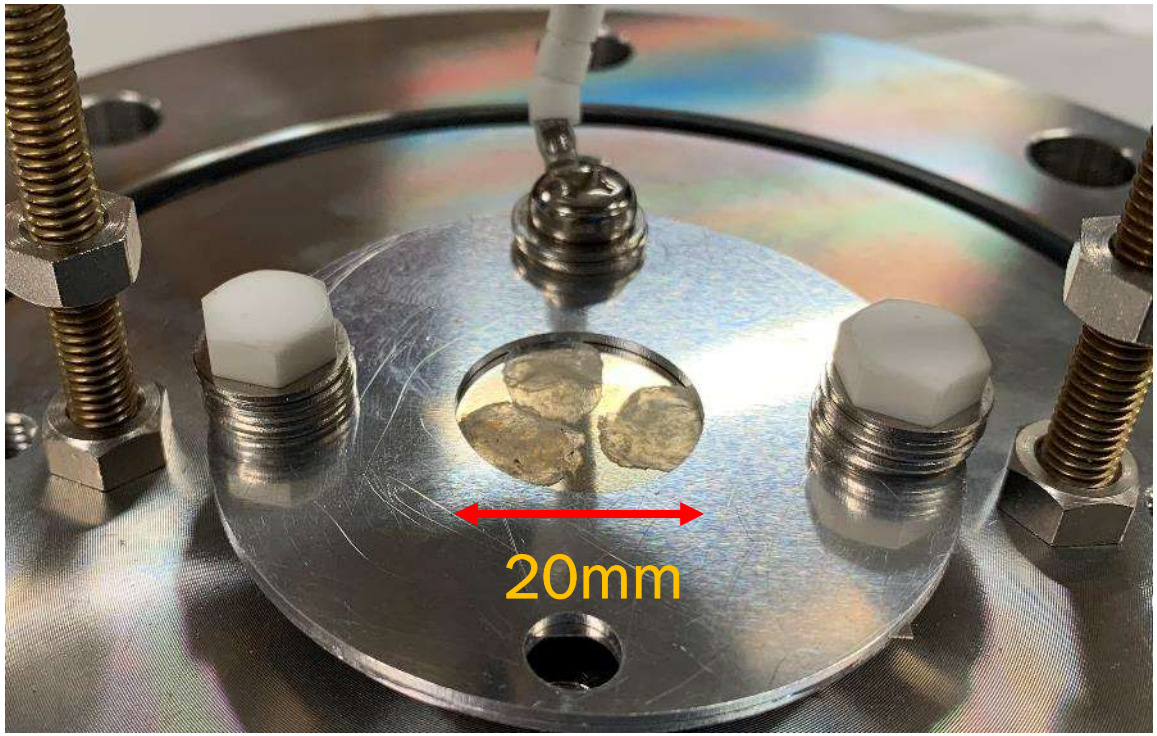




Deuteron Target

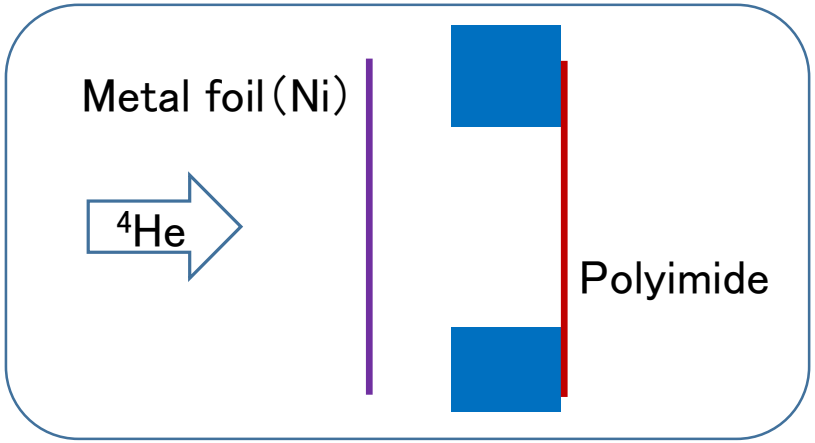
press

■Deuteron target is made of Deuterated Polyethelene (Poly-C_2D_2) using press machine.
■ Thickness is 30~50mm.
■ Targets are mounted on Ni foil.
■ Beam current was measured by Ni foil stage.



Beam Heat Load Problems in Pre-Tests

● $^{4}He^{1+}$ beam of 20kV and 3mA broke Ni foil and then Polyimide film

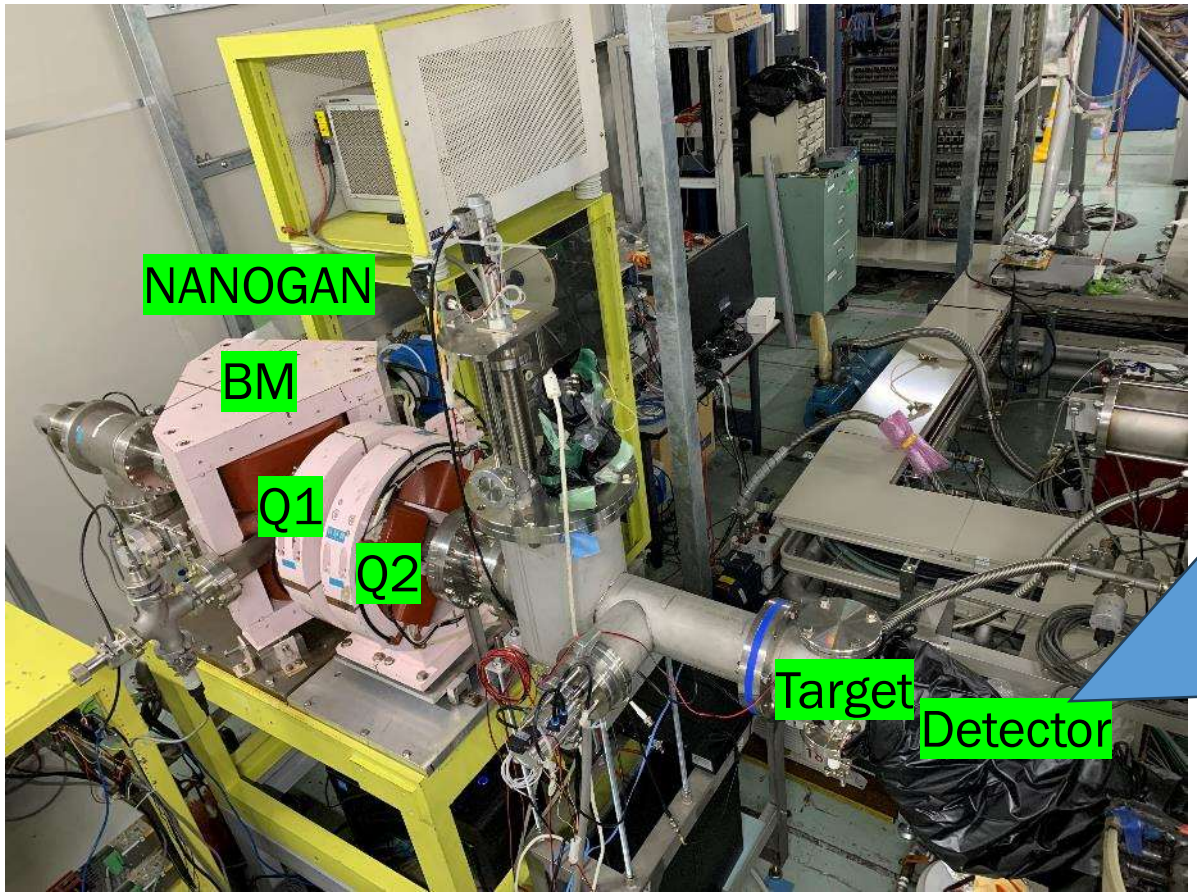


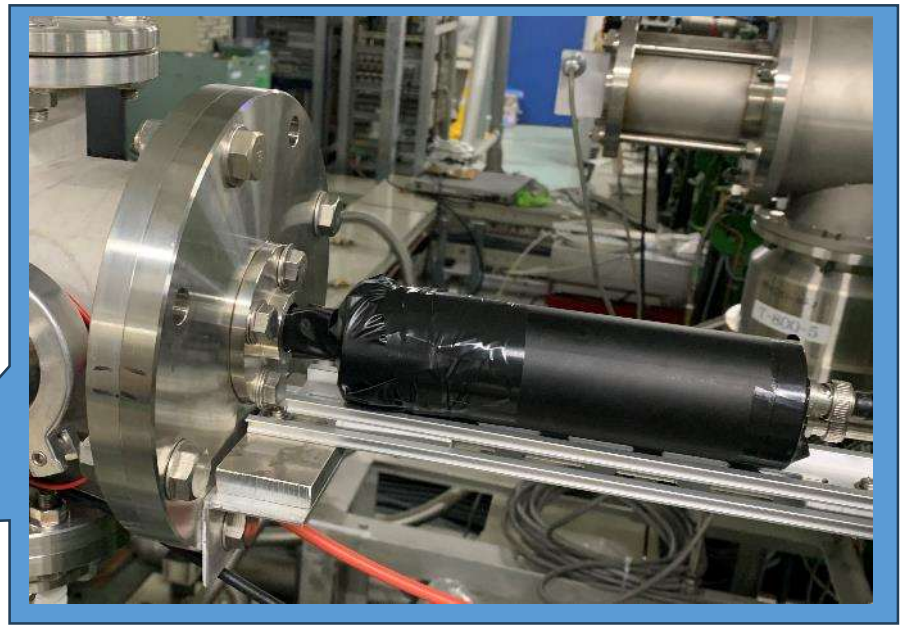
● $^{3}He^{2+}$ beam of 20kV and 0.4mA deformed target in previous SC-ECR test

→The beam current was limited to several μA this time

→cooling system will be constructed in future

Experimental Setup





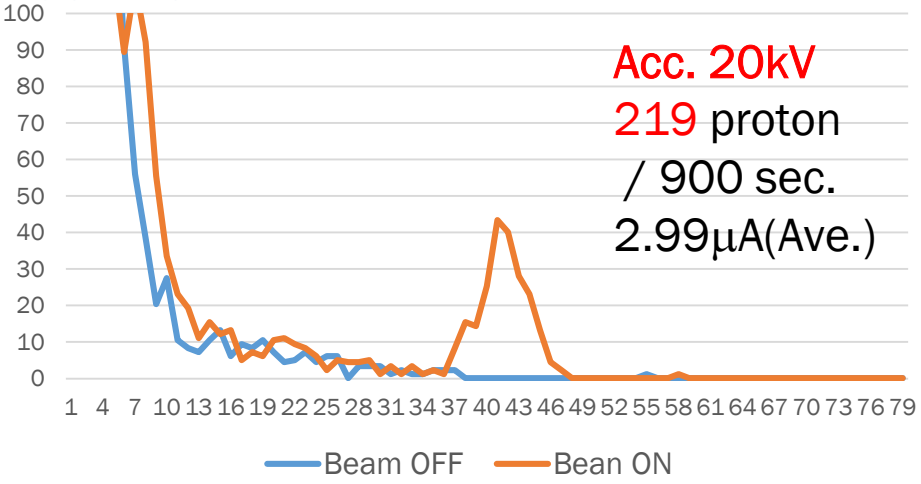
Conditions

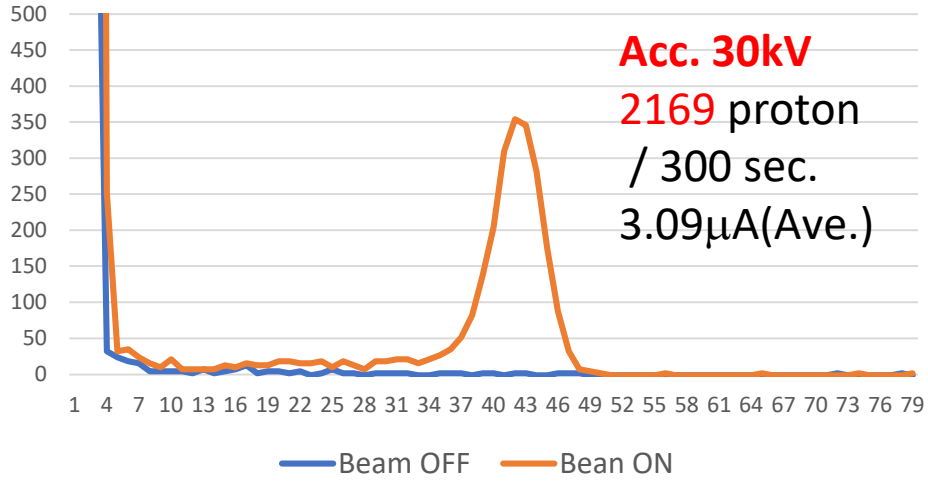
Acc. HV : 45 kV, 30 kV and 20 kV

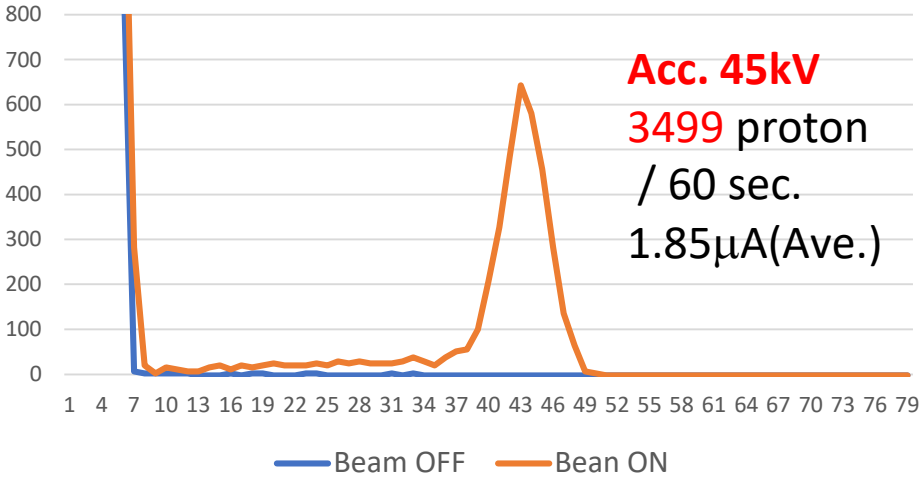
$^{3}He^{2+}$ current : 2~3eμA

Proton detector:
Plastic Scintillator
(15x15x40)
+
PMT

Results







Protons of 14.0MeV has been obtained successfully !!

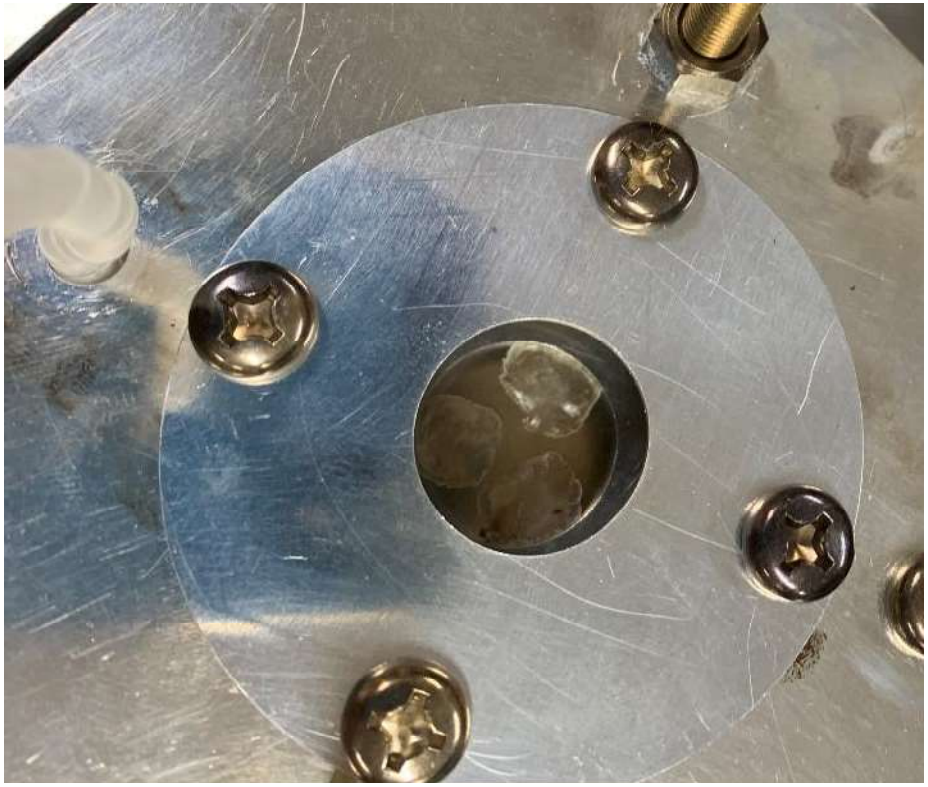
$^{3}He^{2+}$ Energy [MeV]	event rate [/sec./μA]
0.04	0.081
0.06	2.34
0.09	31.5

→Over 2.5E+4 protons / sec. will be obtained with $^{3}He^{2+}$ of 800eμA at 50kV

- ◇ detector calib. → good enough
- ◇ cell irradiation → OK
- ◇ RI production → ??

Targets after Irradiation

Before irradiation

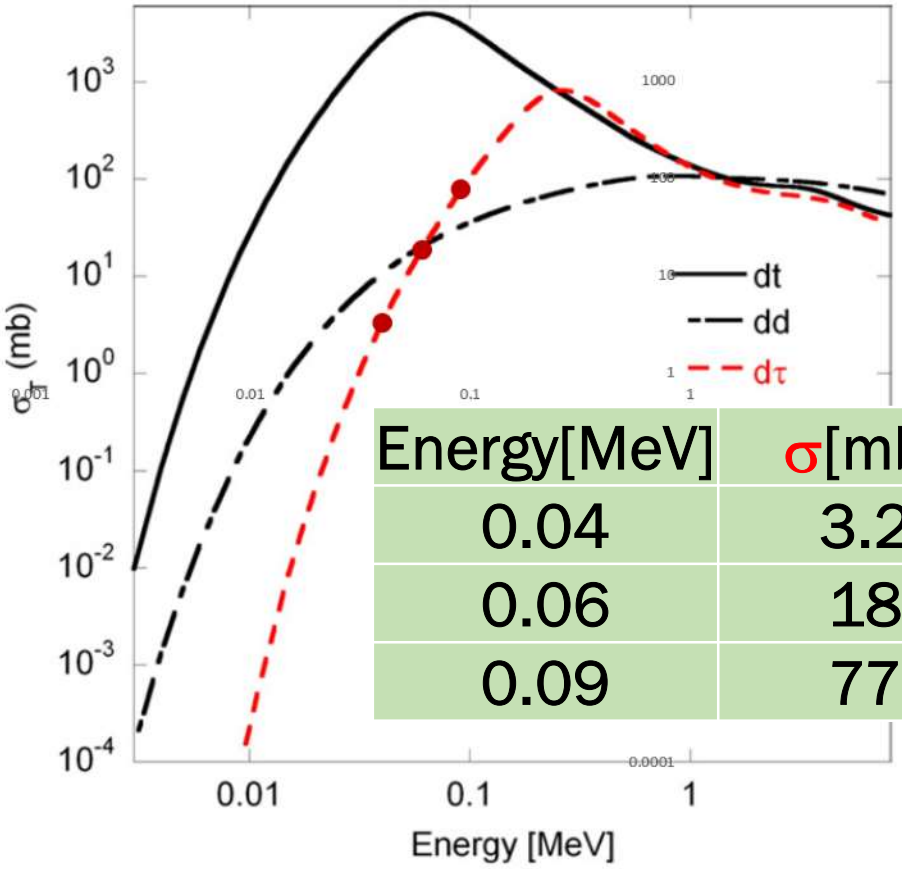


After irradiation

Deformation has not been seen
Beam unevenness has been seen

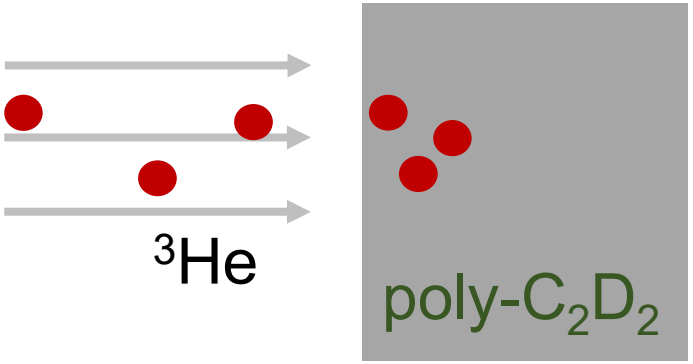
We will prepare cooling system for further study

Comparison with Reaction Cross Section



Energy[MeV]	σ[mb]
0.04	3.2
0.06	18
0.09	77

Energy [MeV]	event rate [/sec./eμA]
0.04	0.081
0.06	2.34
0.09	31.5



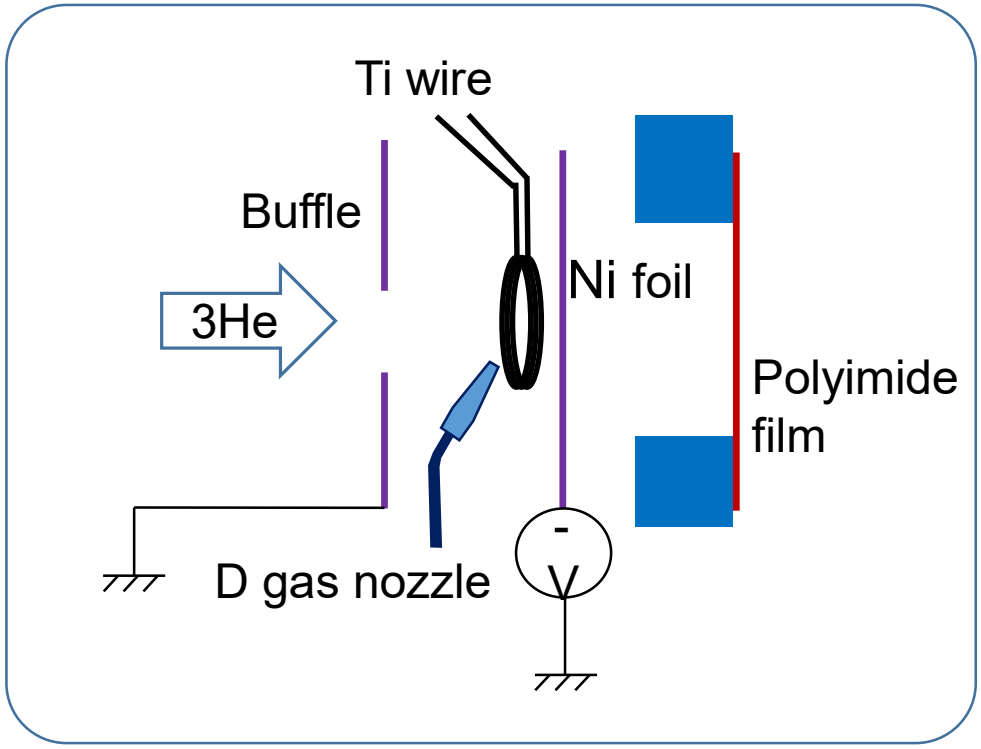
Each ratio is different due to
- The beam unevenness or less reproducibility
- Energy loss of projectile in poly-C_2D_2

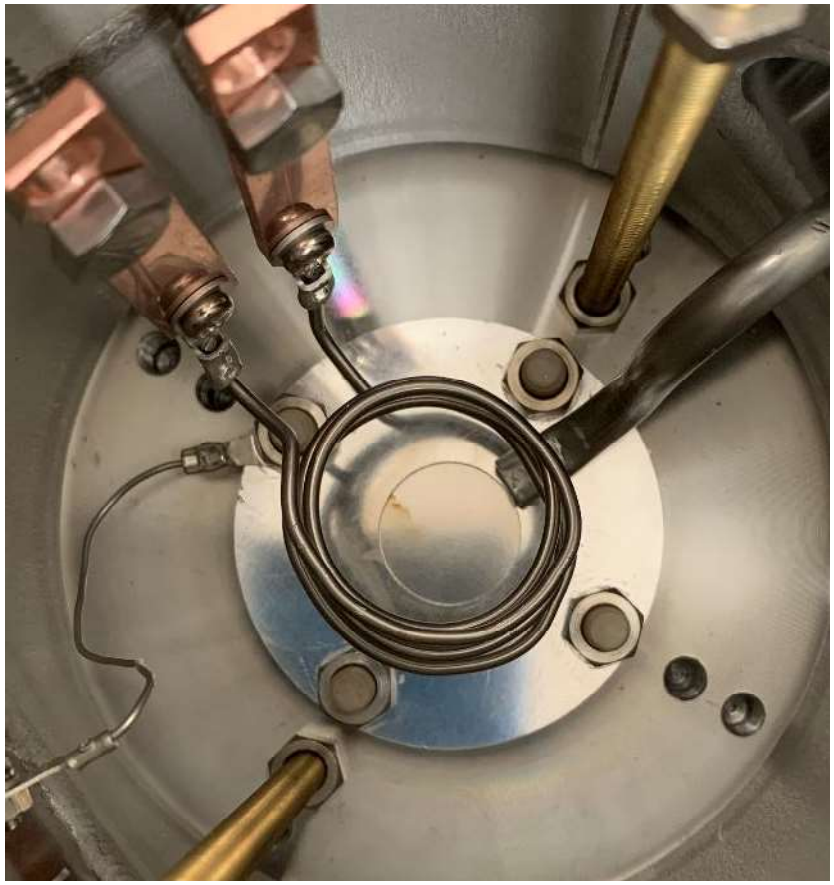
→Dense deuteron target without C may make less ionization loss and more event rate

Plan of New Deuteron Target for higher beam load

Deuteron adsorbed on Ti vapor deposition on metal foil with cooling system.

- ◆ No target deformation → OK
- ◆ Dense target → ??
- ◆ Strength against beam → ??





Summary

To constructing proton generator in MeV region with monochromatic energy with low construction cost and compactness, we selected fusion reaction $^{3}He+d \rightarrow p+^{4}He$ that the proton energy is **14.67MeV**

To obtain protons in atmosphere with high intensity and monochromatic energy, the generator should consist with

- High intensity ion source
- High voltage acceleration for higher cross section
- Thin Window for less energy loss

We obtained 31.5 protons/sec./μA in atmosphere with energy of 14MeV under condition of $^{3}He^{2+}$ beam of 45kV ~2μA and Thin target and window.

Over 2.5e+4 protons/sec. can be expected after development of new target.