Operational experience of high-power production target for BigRIPS separator

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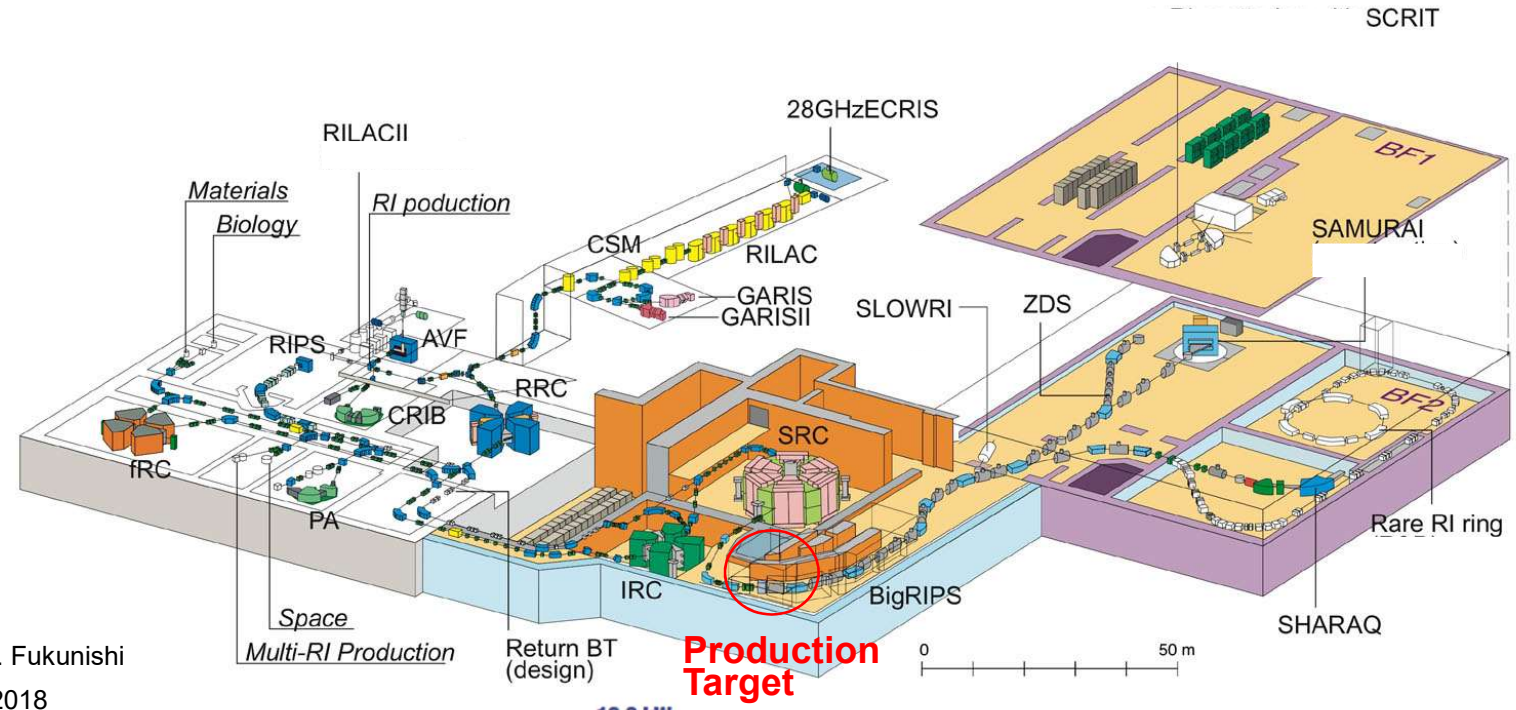
- BigRIPS target system
- Temperature monitoring
- Troubles

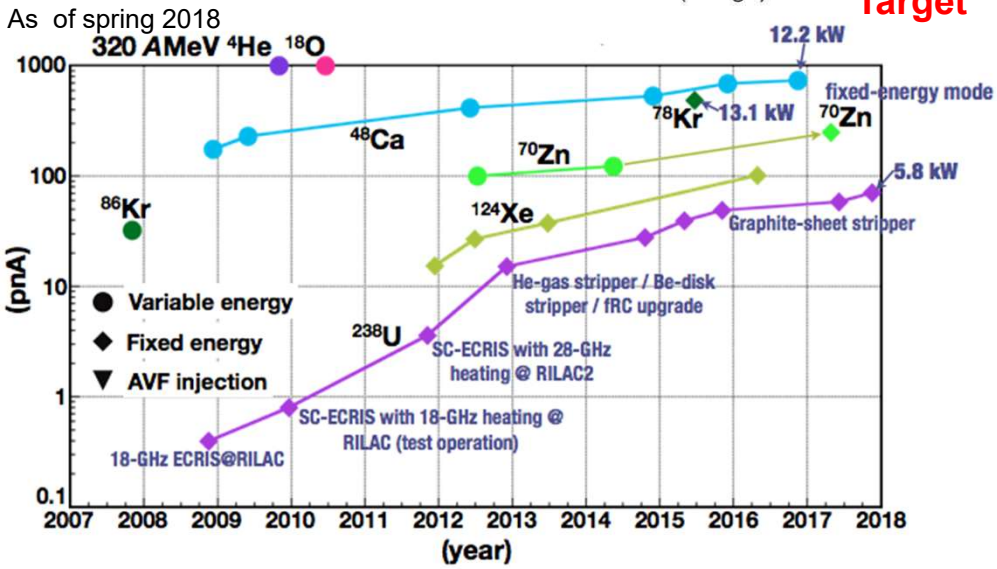
International Nuclear Target Development Society Conference (INTDS 2018)

RIKEN RI-beam factory



Courtesy of N. Fukunishi

As of spring 2018



Goal: ^{238}U 345MeV/u, 1puA : 83kW
beam spot size 1mm (FWHM),
on Be 1g/cm^2 (5.4mm) → ΔE= 24 kW

Present : ^{238}U 345MeV/A, 70pnA : 5.8 kW
→ ΔE= 1.5 kW
^{48}Ca 345MeV/A, 730pnA : 12.2 kW
^{78}Kr 345MeV/A, 486pnA : 13.1 kW
^{70}Zn 250pnA, ^{124}Xe 100pnA,
^{4}He, ^{18}O 1puA

Requirements for BigRIPS target

- Variety of the primary beam
  U ~ He : 250 ~ 345 MeV/u spot size 1mm

- Target thickness
  Be 0.1~ 30mm (depend on the experiment)

- Target material
  Be : for fragmentation (most cases)
  W : for in-flight coulomb fission of U-beam,
  high-Z material

- Many target sets
- Need to change each beam time period

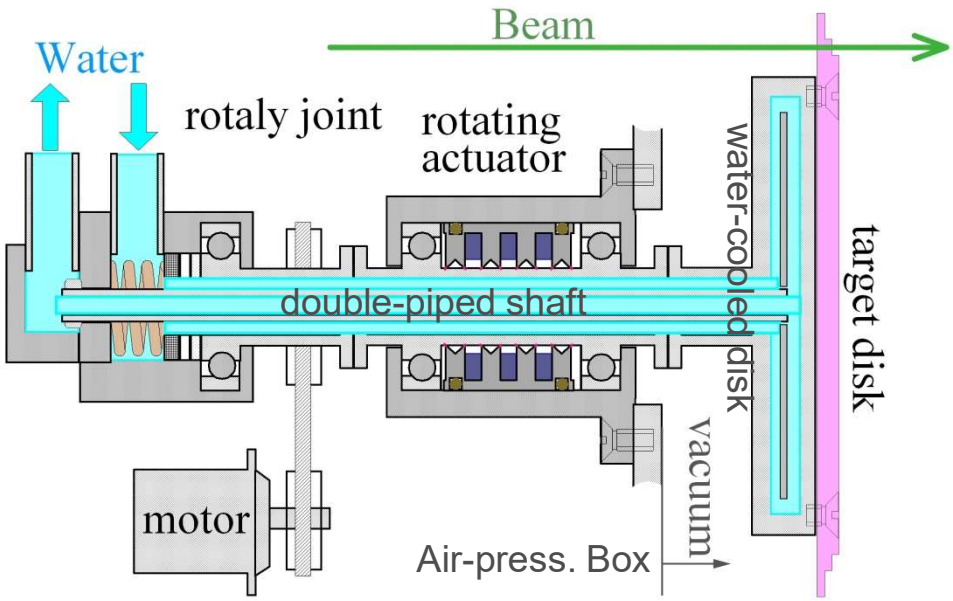
Two target systems:

○ Rotating disk target with water-cooling for high-power beams

○ Fixed target for light particles , low intensity

Rotating disk target with water-cooling

Schematic view of rotating disk target



(Components)

•Rotating solid target disk

to dissipate the heat of the beam spot

• Water-cooled disk

to remove heat from the target disk

• Rotating actuator & motor

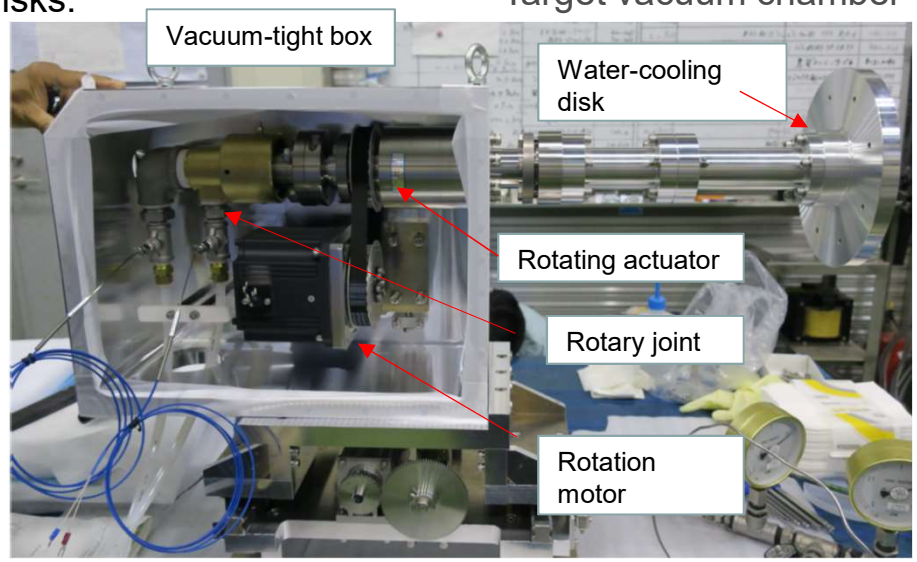
to rotate the disks in high speed ~ up to1000rpm

(currently in use: 150rpm)

•Double-piped shaft & rotary joint

to introduce cooling water into the rotating disks.

Target vacuum chamber



Designed and constructed
by Dr. A.Yoshida and Dr. T.Kubo

Target disks and removal target flange unit

Be disk

Diameter : 300 mm
Step shaped edge

For U, Xe
1 / 2 / 3 mm
2 / 3 / 4 mm
4 / 6 / 8 mm
5 / 7 / 10 mm

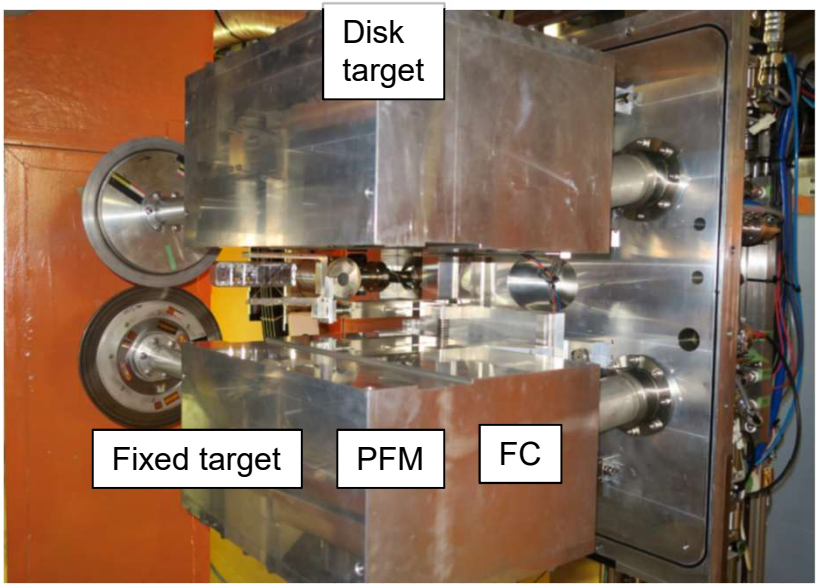
For Ca beams
10 / 15 / 20 mm
20 / 25 / 30mm

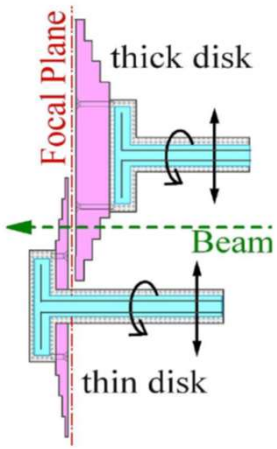
Be tapered(fixed) target

for low power beam.

Diameter :
~18 mm
Thickness :
0.1 ~ 30mm

Removal target flange unit





- We can change thickness of the target by the combination of two disks
- Heat deposit can be shared by these disks

Dose on the surface of Be target
~ 10 mSv/h (3 days after exp.)
~ 500uSv/h (two weeks after exp.)
~ 100uSv/h (two months after exp.)
(^{7}Be~(53d))

Beam and Target list used for experiments (2017)

April - July 2017						
Be 10/15/20 Be 5/7/10 Ladder: Be0.5, 1.0, 2.0. W1.5						
^{48}Ca	600pnA					
3/30 -4/2						
NewIso	^{39}Na	20				
4 day for Zn acc.						
^{70}Zn	240pnA					
4/11-5/15						
SAMURAI	^{44}Ca	1				
	^{52}Ca	10				
	^{50}Ca	15	10			
NewIso	^{66}Cu	2				
	secondry reactior	1	2	15	10	20
	^{52}Ca	10				
	^{52}Ar	10				
seaster	^{53}K	10				
	^{57}Sc	10				
	63V	10				
4 days for 238U acc.						
Be 2/3/4 Be 5/7/10 Ladder:Be 1,10,15,20,25						
^{238}U	60pnA					
5/30 -6/21						
BRIKEN	^{130}Ag	3	4			
	168Sm	3				
	^{84}Zn	2	4			
	167Sm	4				
	^{149}Xe	4				
OEDO	^{107}Pd	5				
	^{93}Zr	5				
	^{82}Cu	5				
	^{66}Cu	2				
BRIKEN	^{100}Br	2,3				
	^{115}Nb	2,3				
	^{126}Pd	3,4				
	^{132}Sn	4				
	^{78}Ge	10				
3.5 days for 18O acc.						
^{18}O	550pnA					
6/24 -7/14						
SAMURAI	^{6,8}He	25				
	p	20				

Rot: Be 10,15,20
Fix: Be1,2

Rot: Be 2,3,4, 5,10
Fix: Be 20,25

Oct. - Nov 2017			
Be 2/3/4, 5/7/10, Ladder: Be0.5,1,2,W1.5			
^{238}U	70pnA		
10/21 - 11/30			
OEDO	^{107}Pd	5	
	^{93}Zr	5	
BRIKEN	^{82}Cu	5	
PARIS	^{66}Cu	2	
BRIKEN	^{100}Br	2,3	
	^{115}Nb	2,3	
	^{126}Pd	3,4	
	^{132}Sn	4	
OEDO	^{79}Se	1	
	^{77}Se	1	
Mass ring	^{78}Ge	10	

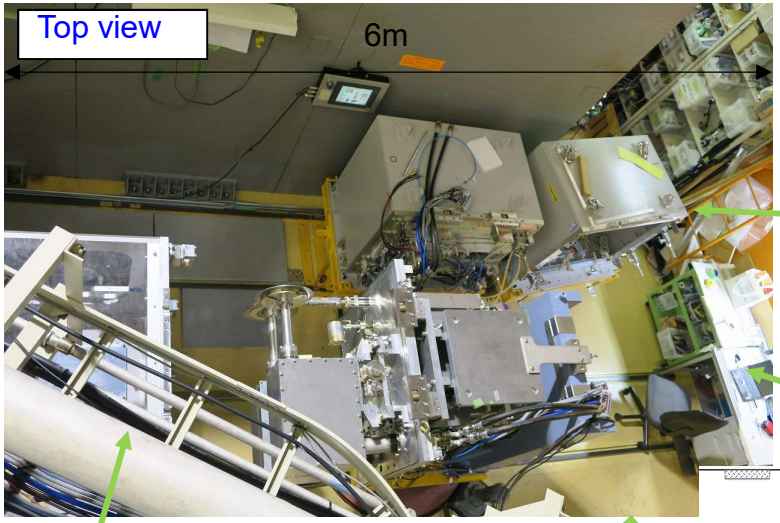
Rot: Be 2,3,4,5,10
Fix: Be 1

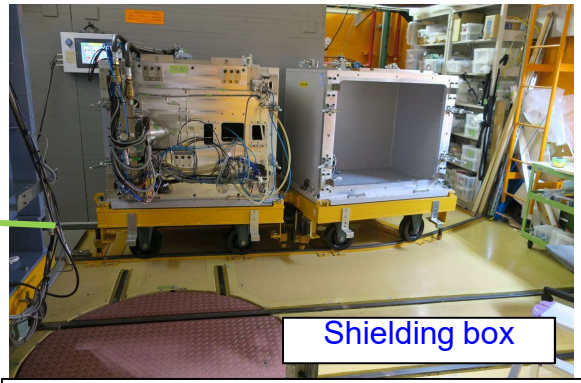
Fiscal year 2017

^{238}U 70pnA + Be 5mm → ΔE = 1.5 kW
^{48}Ca 600pnA + Be 20mm → ΔE = 2.6 kW
^{70}Zn 240pnA + Be 15mm → ΔE = 1.8 kW
^{18}O 550pnA + Be 25mm → ΔE = 0.5 kW

Full-scale operation of disk target started in fiscal 2017

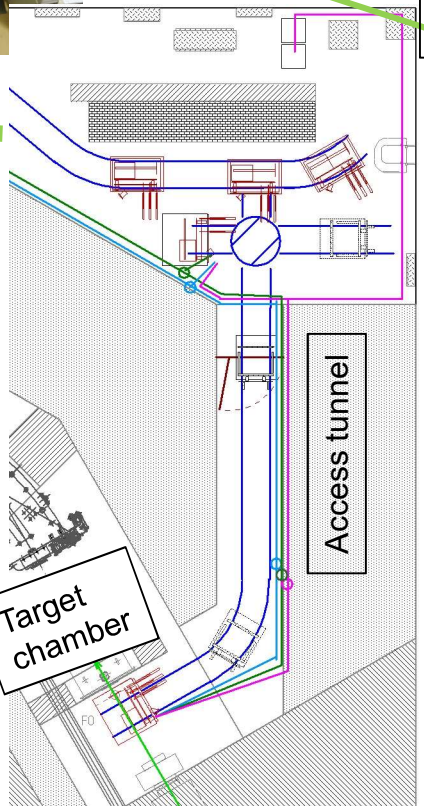
Target maintenance area

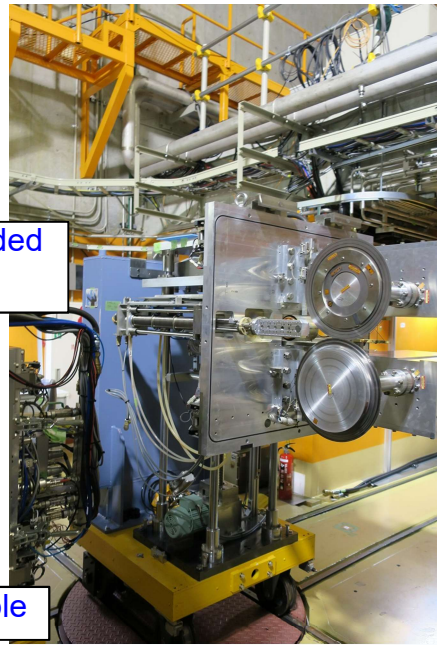




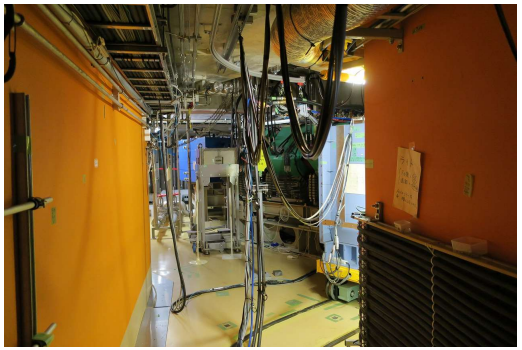
Keep the flange for over a month
3 days after exp. ～ 10mSv/h (target surface)
two months after exp. ~ 100uSv/h

Simulator chamber
assembled and checked
signals for removal flange unit

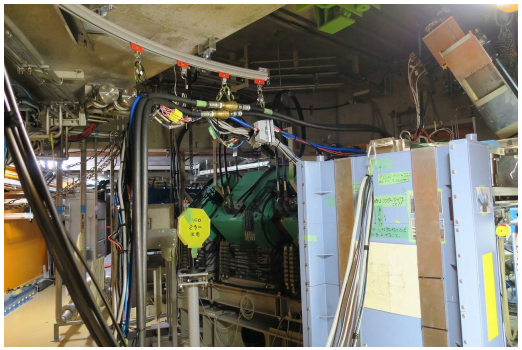




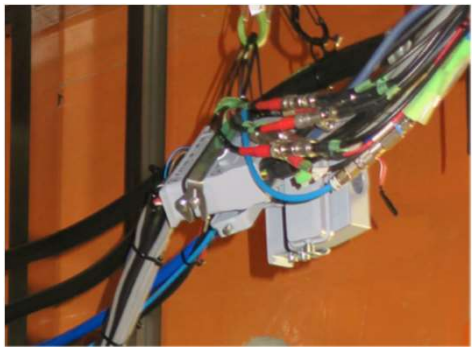
Target exchange



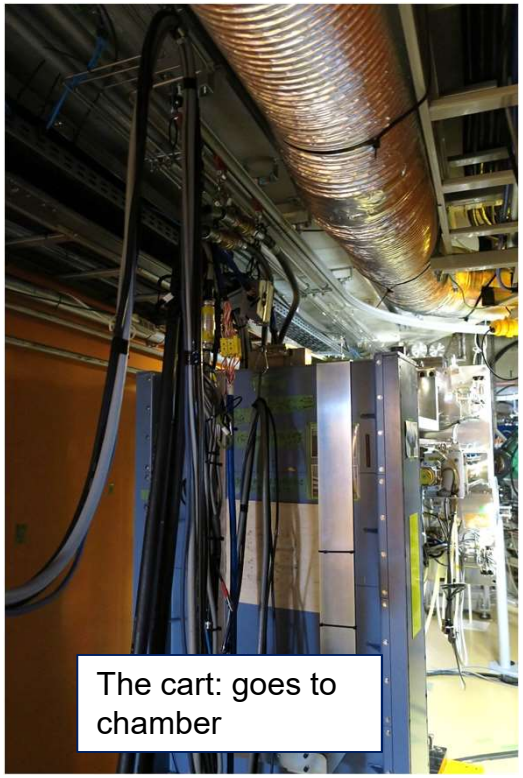
Assemble area:



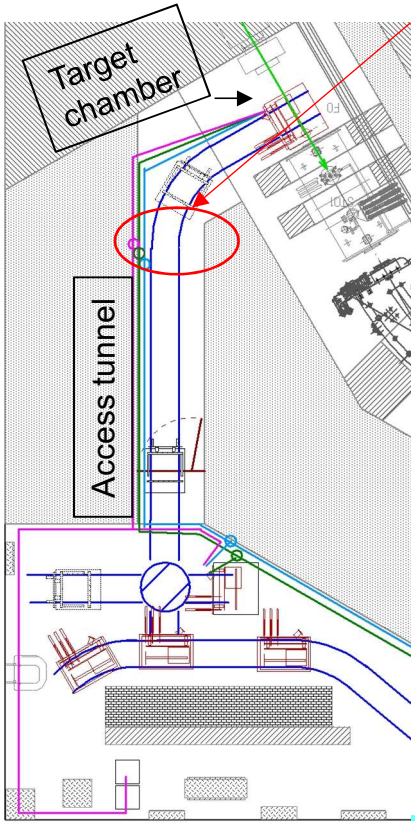
Rail for cables of flange



combitac connector



The cart: goes to chamber



Assembly/disassembly area:

・Radiation level:

4days after exp. ^{238}U 38pnA 60usV/h

2days after exp. ^{238}U 30pnA 200usV/h

→ with cart (Pb shield), 1/10 reduction

・Power cables, control cables, signal cables

→multi cable connection (combitac connector)

short time, short space

・Cooling water

Operation time for target replacement ~60 min

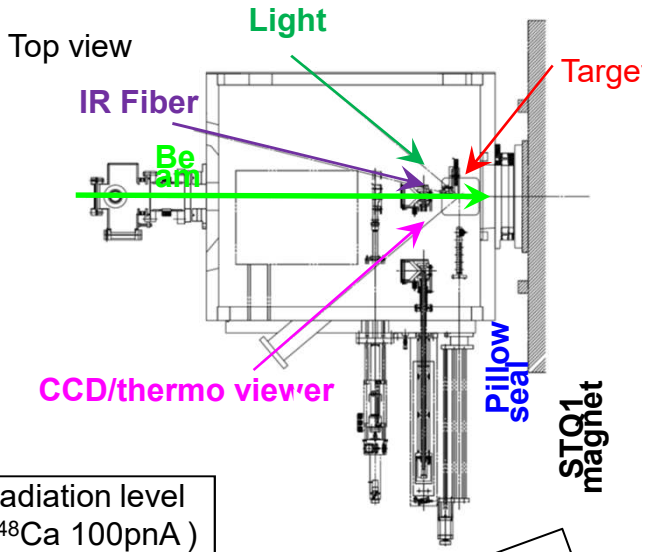
(leak~60min, vacuum in chamber ~120min.)

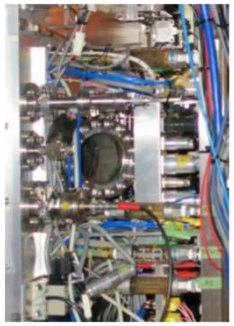
→ 4 hours

Beam spot monitors

(1) IR thermal image camera with telescope lens

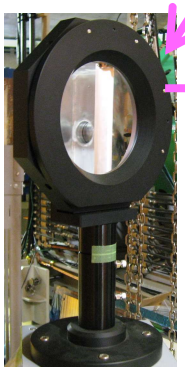
- 15m away from target chamber through 3 mirrors.
  (TVS-8502, Avio (+ TVL-85626A lens)
- Spec: range: 40～1000℃
  resolution: 0.5 x 0.5mm/1pixel
- We use this viewer just for the beginning of each beam time to check the beam spot temperature





through sapphire view port

2.5 m



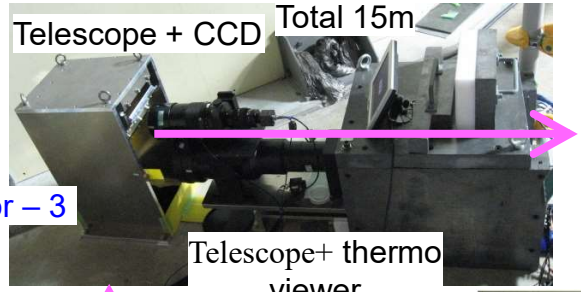
mirror - 1

along access tunnel
horizontal 8.5 m

make a hole
through the ceiling
vertical 2.5 m

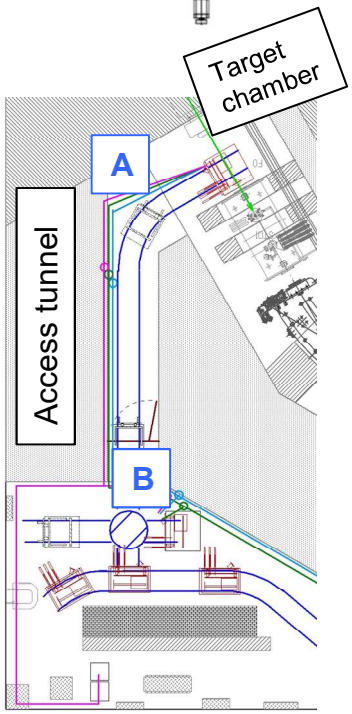
mirror – 2

mirror – 3



Radiation level
(^{48}Ca 100pnA)

γ	27μSv/h
n-slow	20μ
n-fast	530μ



Beam spot monitors

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- Installed 15m away from target chamber through 3 mirrors.
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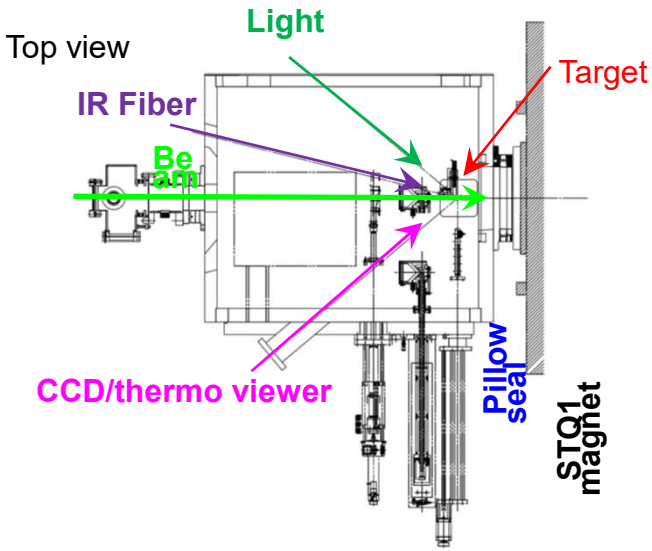
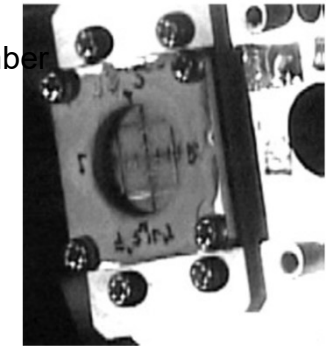
- We use this viewer just for the beginning of each beam time to check the beam spot temperature



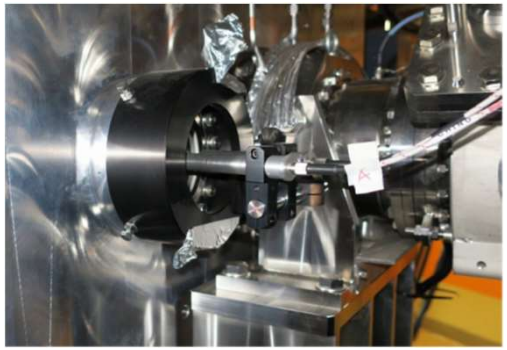
(2) CCD camera with telescope

- Installed 15m away from target chamber through 3 mirrors
  (MINTON ENTERPRISE CO. LTD MTV-23X10HE)
- Check beam spot position and size using beam viewer at sometime but during whole exp. period
- Breakdown : about once a year.



(3) IR Fiber optic radiation thermometer

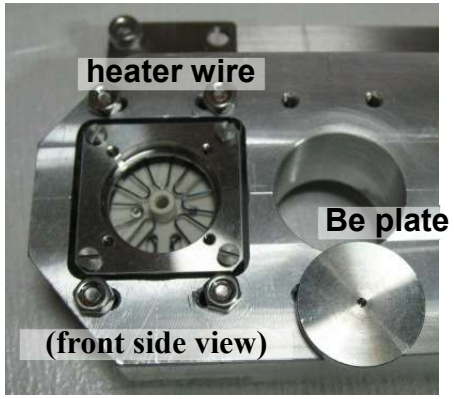
- Monitoring beam spot temperature during exp. period are available (CHINO corp. IR-FA1XK1)
- Main body: 40m away from target chamber (with quartz fiber)
- Temperature range (250～600℃)
- High-speed response (0.1msec for catalogue spec.) for beam interlock system

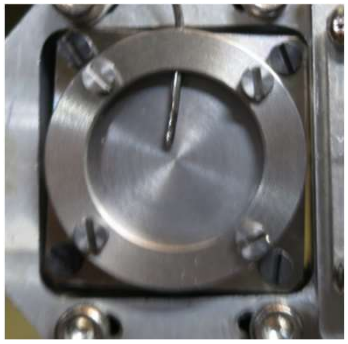


Sapphire view port & Lenz unit mounted on the Target chamber

Temperature calibration using heater

In order to reduce an ambiguity of emissivity (ε) on target surface, the thermo viewer was calibrated using a heater unit in vacuum.





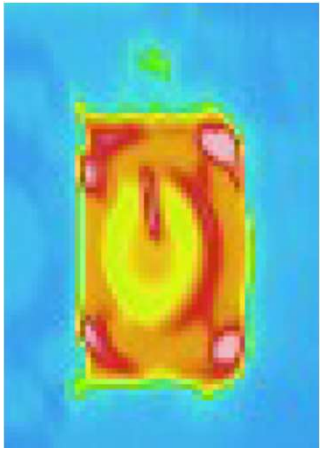
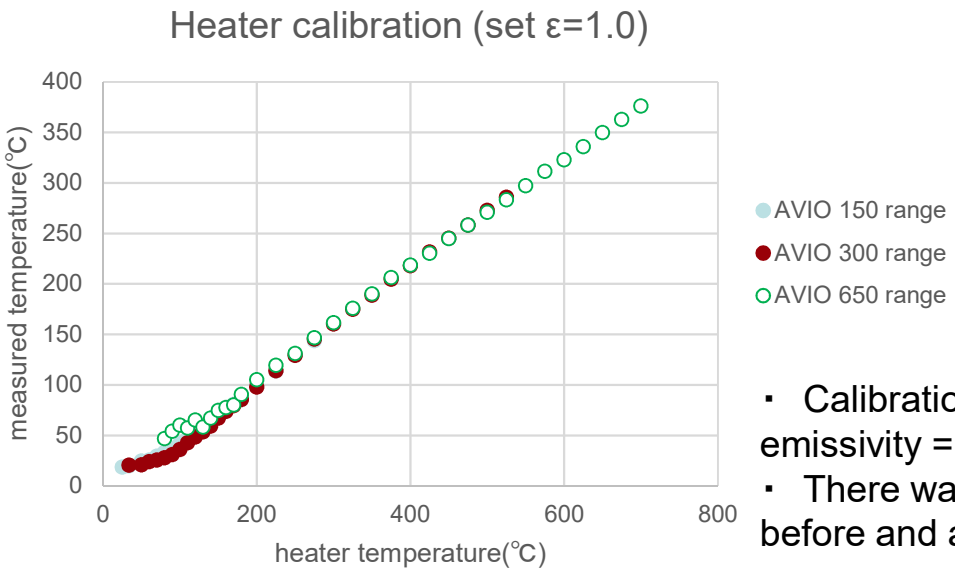


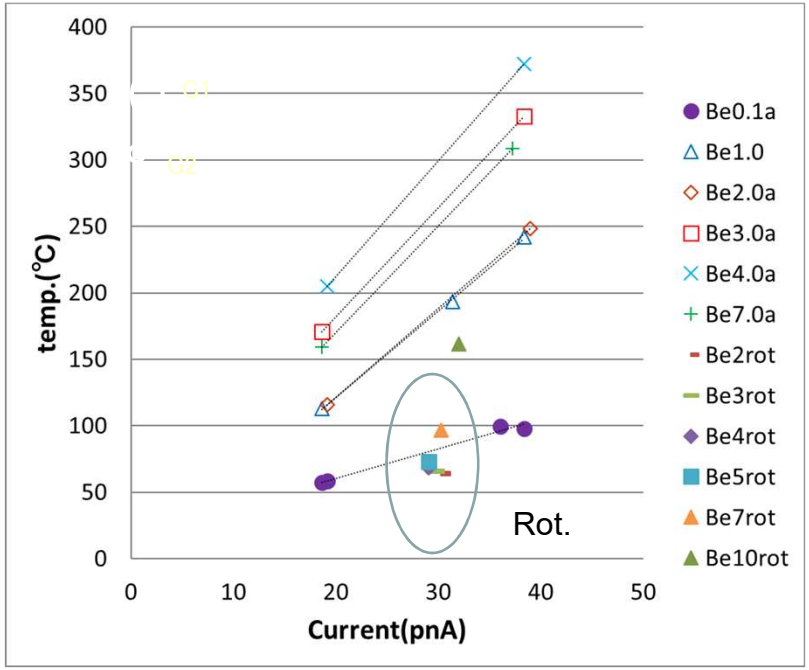
Image by thermo viewer



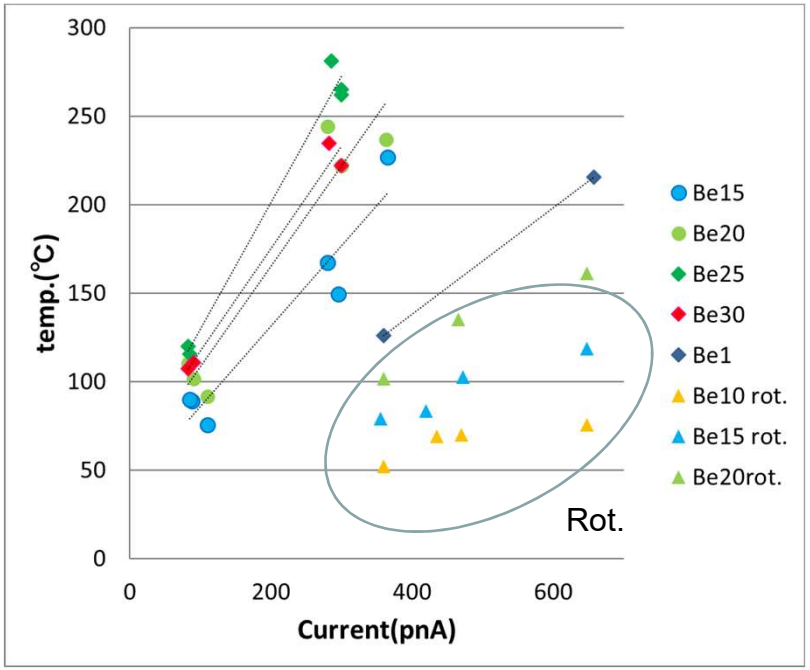
- Calibration used heater was carried out by a set emissivity = 1.0 at a temperature range of 50 to 650 degrees.
- There was little difference in the temperature calibration before and after the experiment.

Measured temperature data

$^{238}U^{86+}$ beam : 345MeV/u + Be
(fixed and disk target)

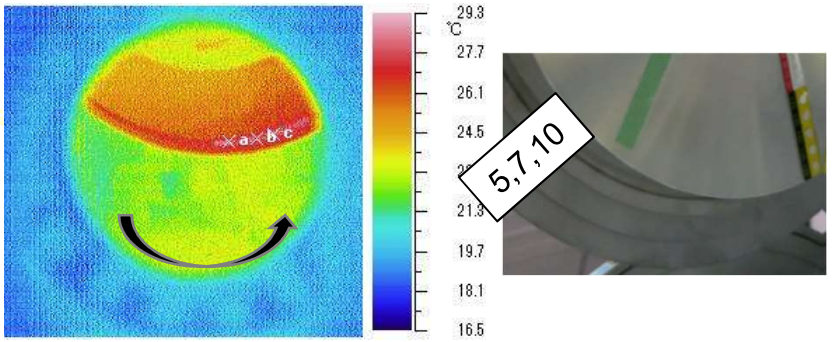


$^{48}Ca^{20+}$ beam : 345MeV/u + Be
(fixed and disk target)



Beam ^{238}U 38pnA +Be5mm
ΔE = 0.8kW

Thermo viewer
(Be5mm)



Beam ^{48}Ca 650pnA +Be20mm
ΔE = 2.8kW

Present (max.) :
^{238}U 345MeV/A, 70pnA
^{48}Ca 345MeV/A, 730pnA

Troubles

- Ladder fixed target

  Melted target Be 1, 3, 7mm case

  Water leaks from fixed target holder

  Be 30mm case

- Disk target

  No serious trouble

  → monitor: torque, temperature, rotational speed etc.

  Prepare spare items

  → motor, actuator etc.

- Issue

  How do you detect when the target breaks (melts)

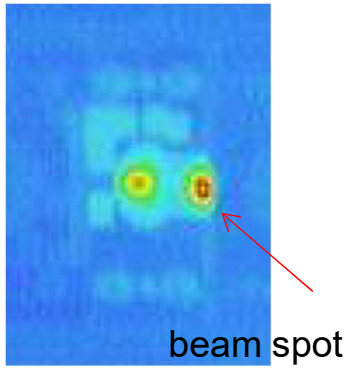
  without major trouble?

  - I do not know when the target melted.
  - The experiment was conducted until the end of the experiment.

Melted target

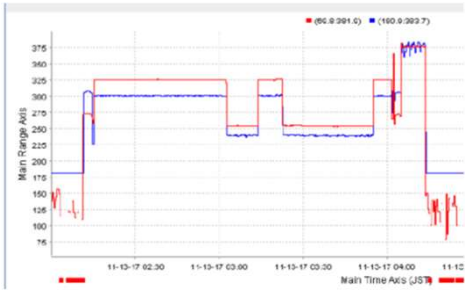
Be 1mm

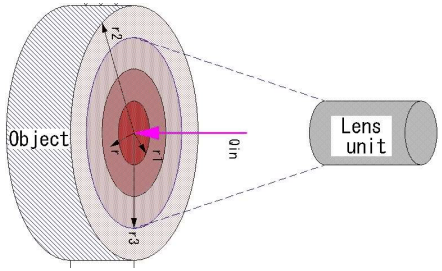
^{238}U 32 pnA 200 ℃ (AVIO)
ΔE = 0.15kW at the beginning



^{238}U 54pnA →350℃ (IR fiber)
ΔE = 0.25kW during experiments

Crack





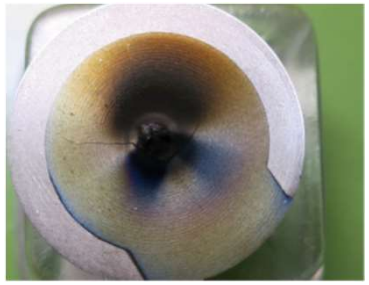
measure an average temp. in a circle of 5mm dia. on an object placed at 1120mm from the lens unit

no problem up to 30pnA in experience

→ Over 300℃ beam stops using an interlock system

Be 3mm

^{238}U 34 pnA
IR Fiber 389℃ (max)
ΔE=0.4kW



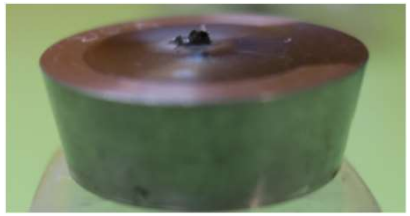
Front side

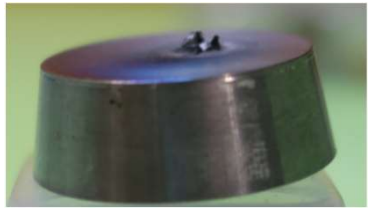
Back side

Side view

Be 7mm

^{238}U 58 pnA
IR Fiber 620℃ (max)
ΔE=1.7kW

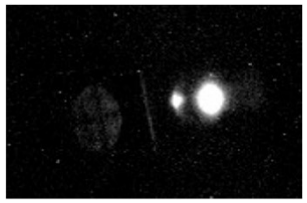




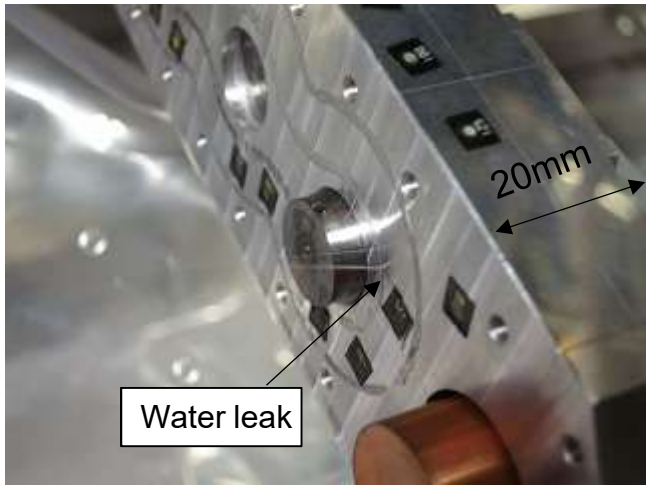
Water leakage

(Be 30mm ^{48}Ca 400pnA ΔE=2.7kW)

IR fiber over 500℃



By CCD



After scraping down the waterway,
Al plate welded by laser welding

Summary

Present status at RIBF (As of 2018 spring)

^{238}U 345MeV /u ~ 70 pnA (6 kW) + Be 5mm ΔE = 1.5 kW
^{48}Ca 345MeV /u ~ 730 pnA (12 kW) + Be 20mm ΔE = 3.1 kW
Goal: U +Be 5mm ΔE = 24kW

Present status of BigRIPS target system

- Target system
  Target exchange scheme and maintenance

- Beam spot monitoring
  Beam spot temperature of rotating disk target and fixed target.
  → Detail of beam spot temperature will be talked by Yoshida-san
- Troubles
  Melted Be target
  Walter leakage