NIRS HIMAC

Present status of HIMAC ECR ion sources

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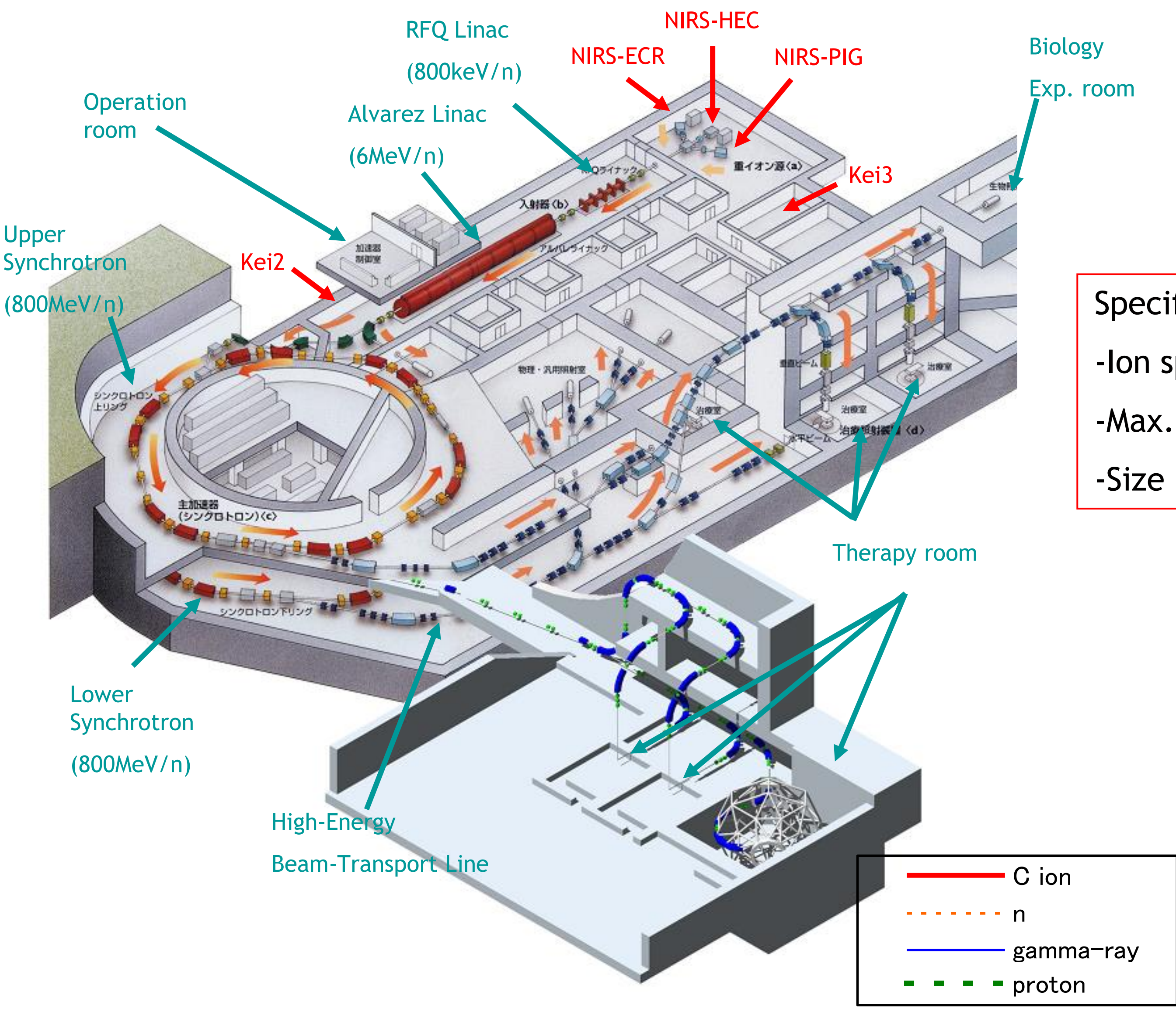
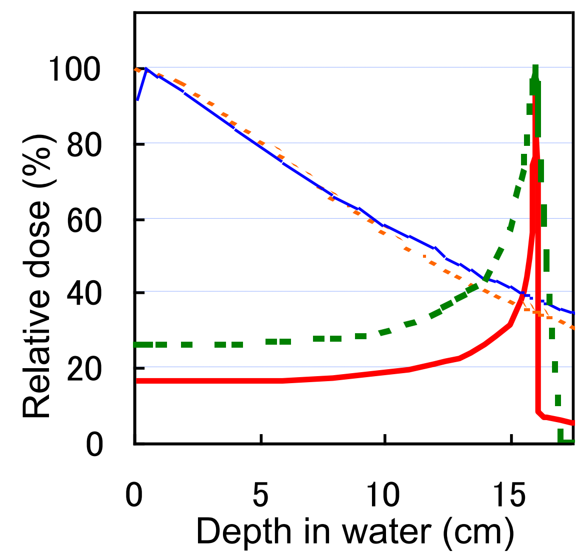
2 Accelerator Engineering Corporation (AEC), Japan

Heavy Ion Medical Accelerator in Chiba (HIMAC)

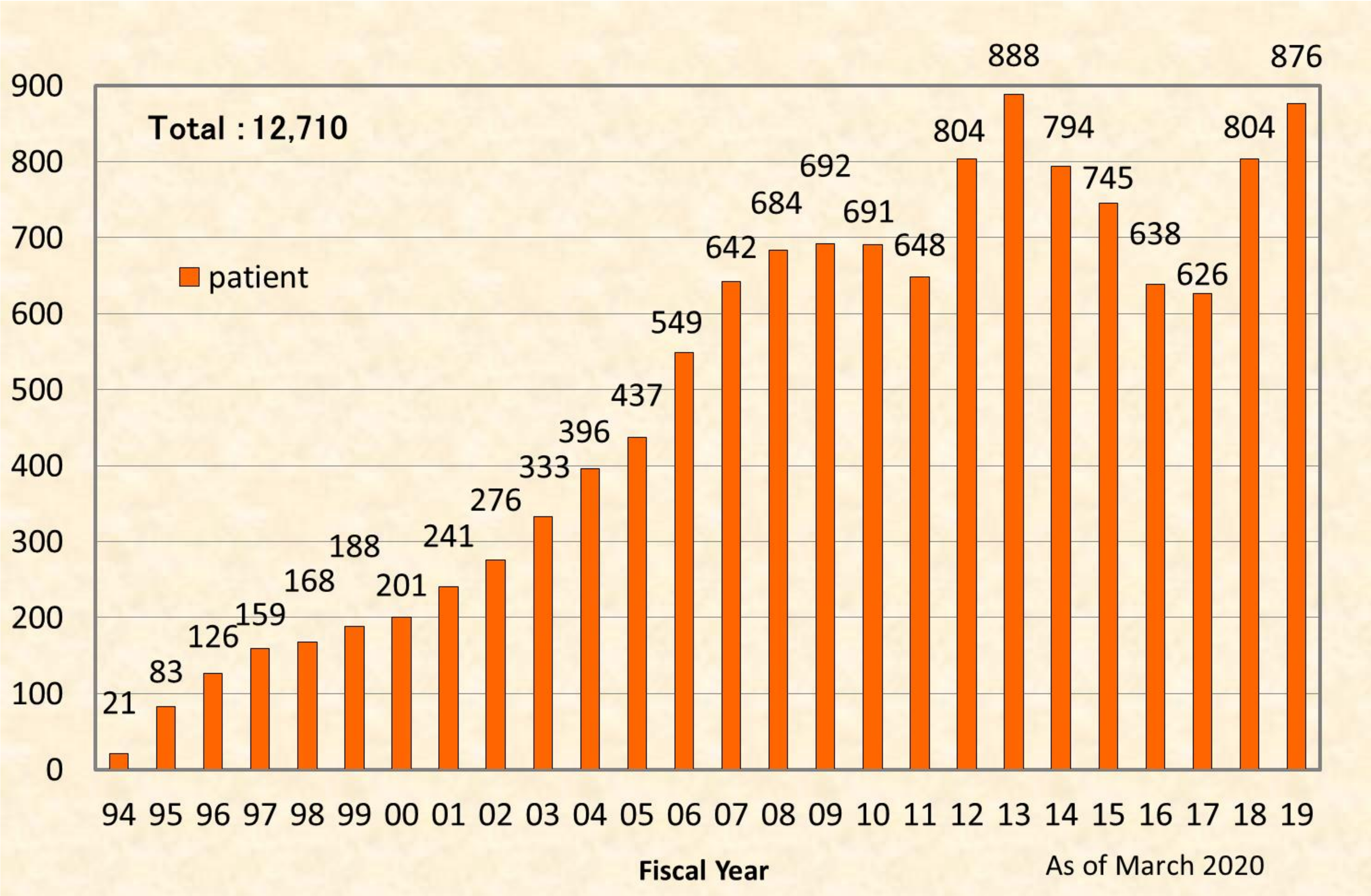


Specifications

-Ion species	He-Si
-Max. energy	800 MeV/n
-Size	70 m(W), 120 m(L), 30 m(H)



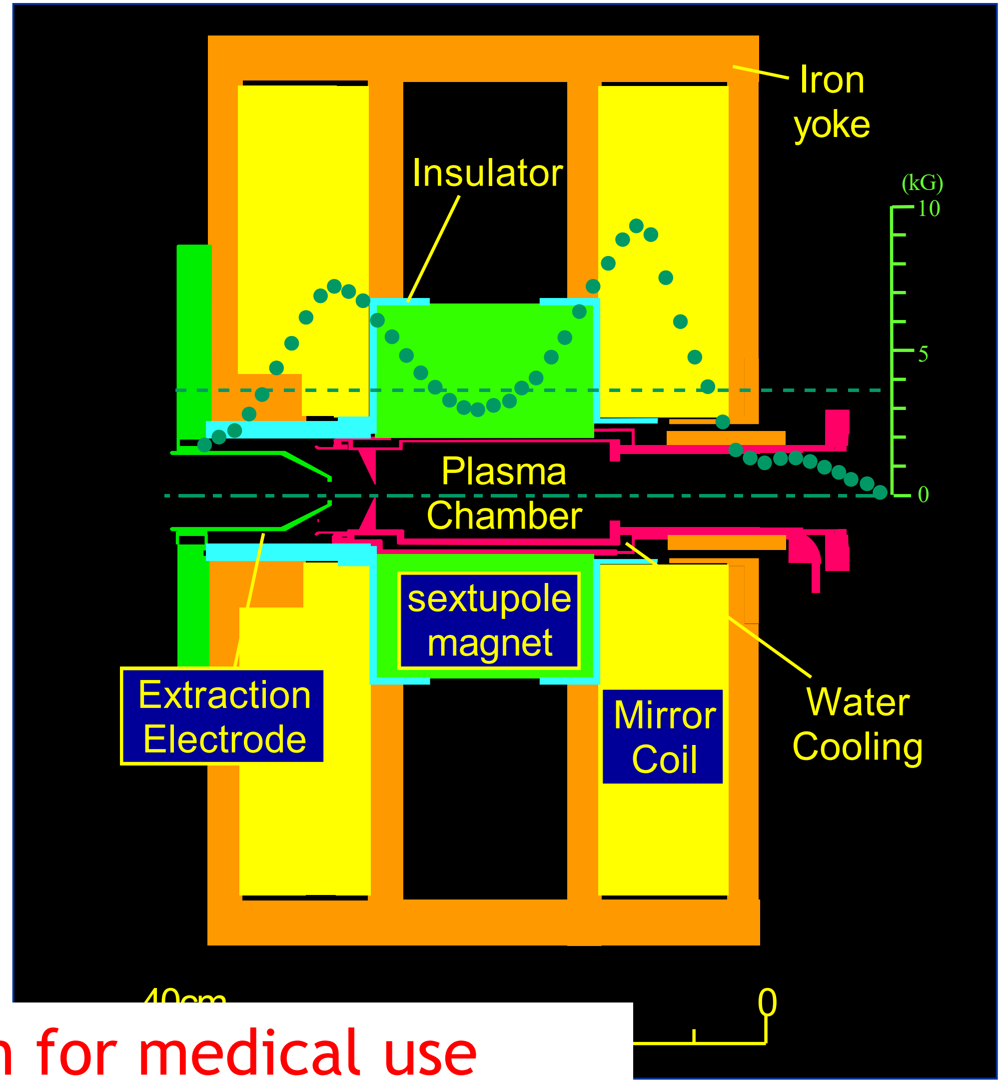
Patient Enrolled in Carbon Ion Therapy at QST (June 1994～ March 2020)

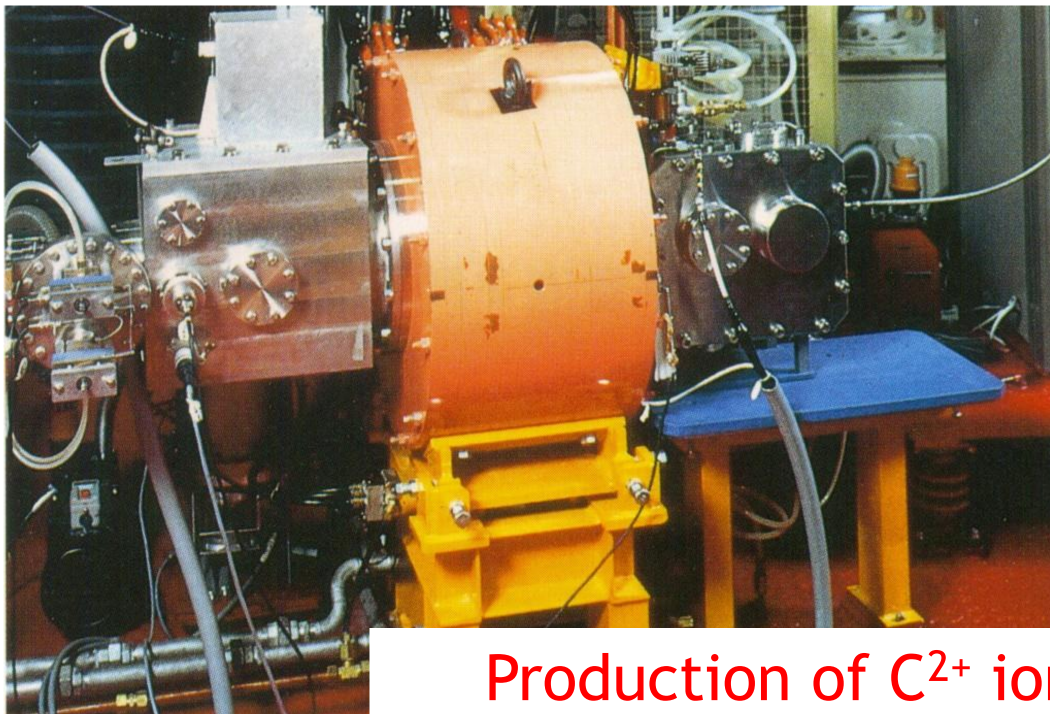


10 GHz NIRS-ECR ion source

- TWT Amp., 9.75-10.25 GHz, 1 kW
- Mirror field: 0.93 T / 0.76 T
- Axial field: 0.8 T
- Extraction voltage: 25kV max.
- C^{4+}: 430 μA (C^{2+}: 200 μA for therapy)

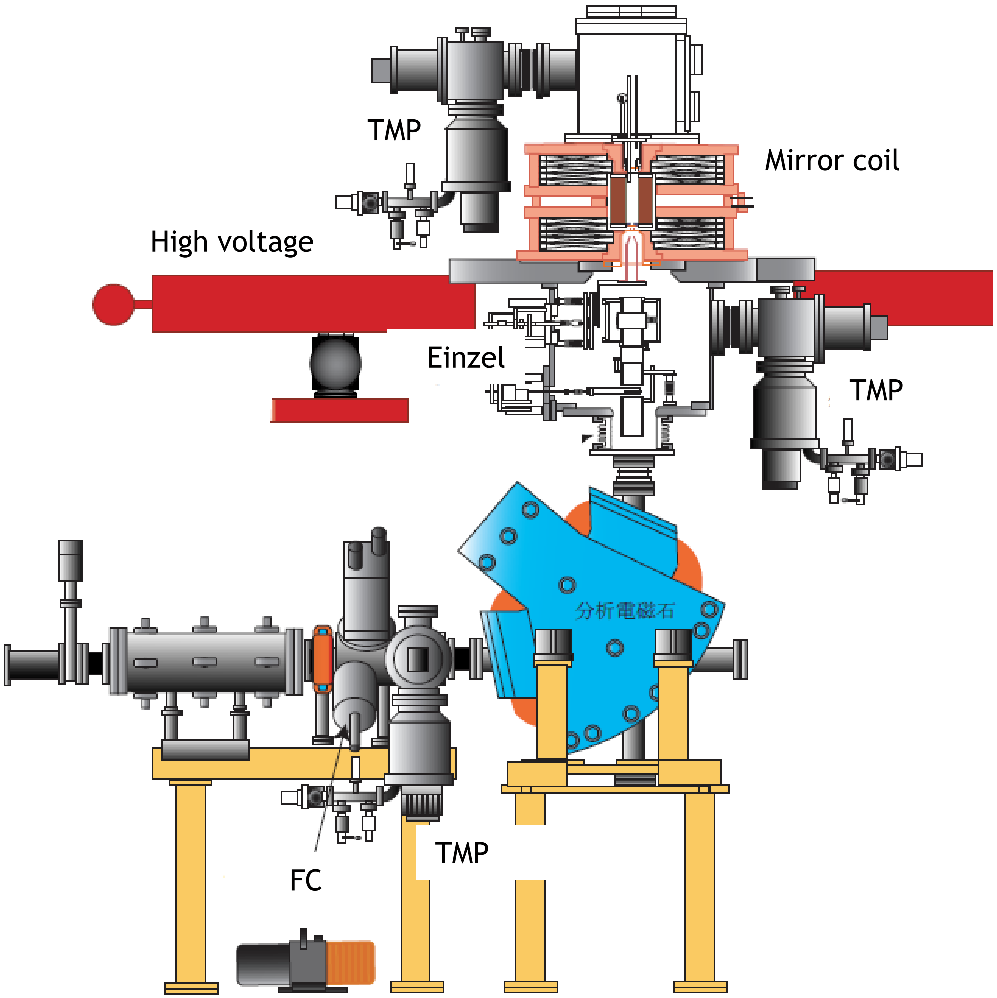
Schematic View Of NIRS-ECR

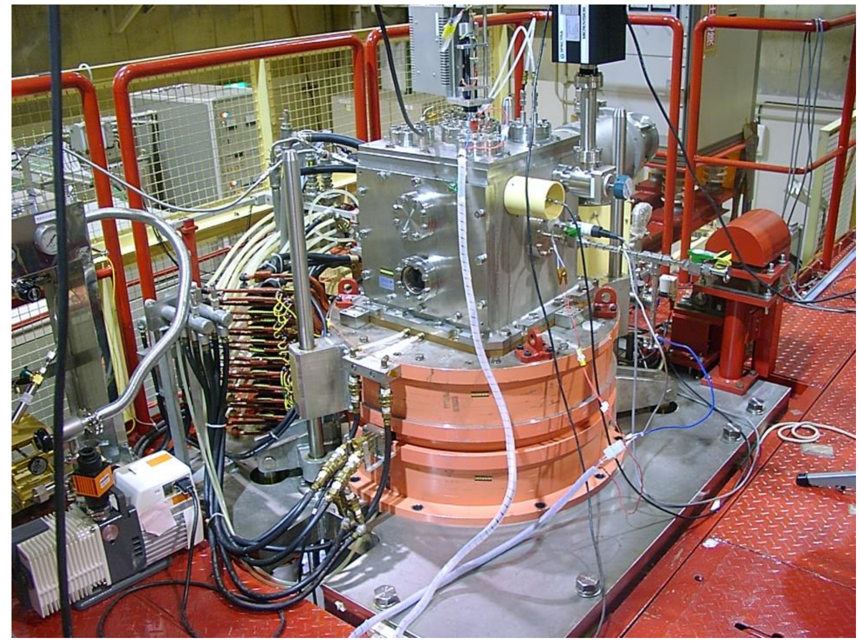




Production of C^{2+} ion for medical use

18 GHz NIRS-HEC source





KLY: 18 GHz, 1400 W

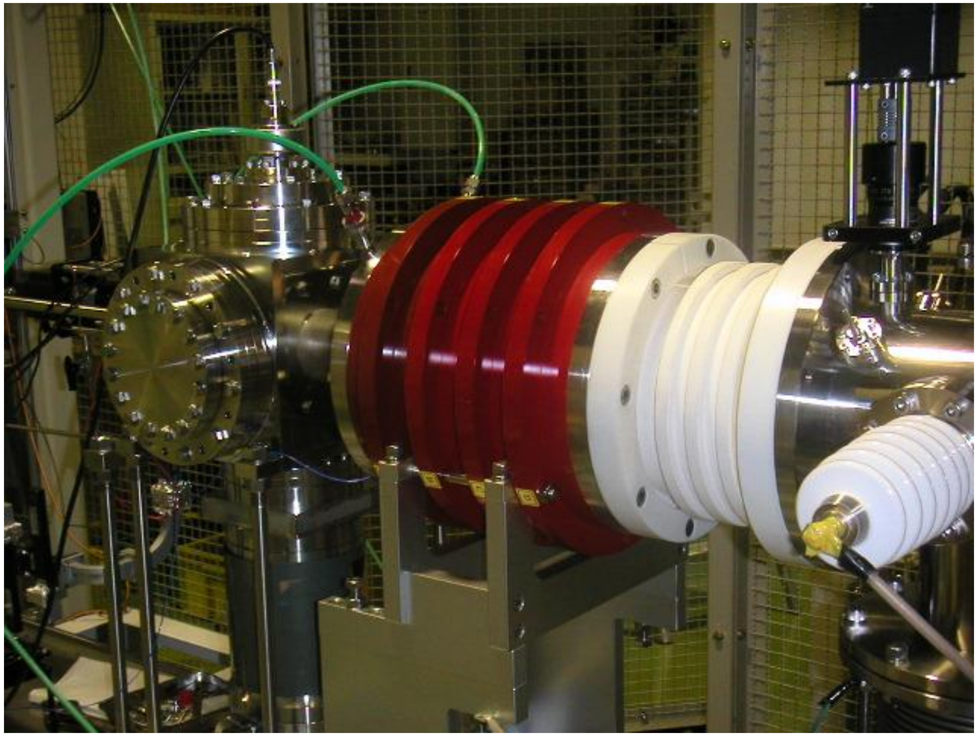
TWTA: 17.10 – 18.55, 1200 W

Extraction voltage : 60 kV max.

Production of heavy ions (Ar, Fe, Kr, Xe)
for biological and physical experiment

NIRS HIMAC

Prototype ion source for carbon ion radiotherapy (Kei2-source)



Production of C^{4+} ion for biological experiment in HIMAC

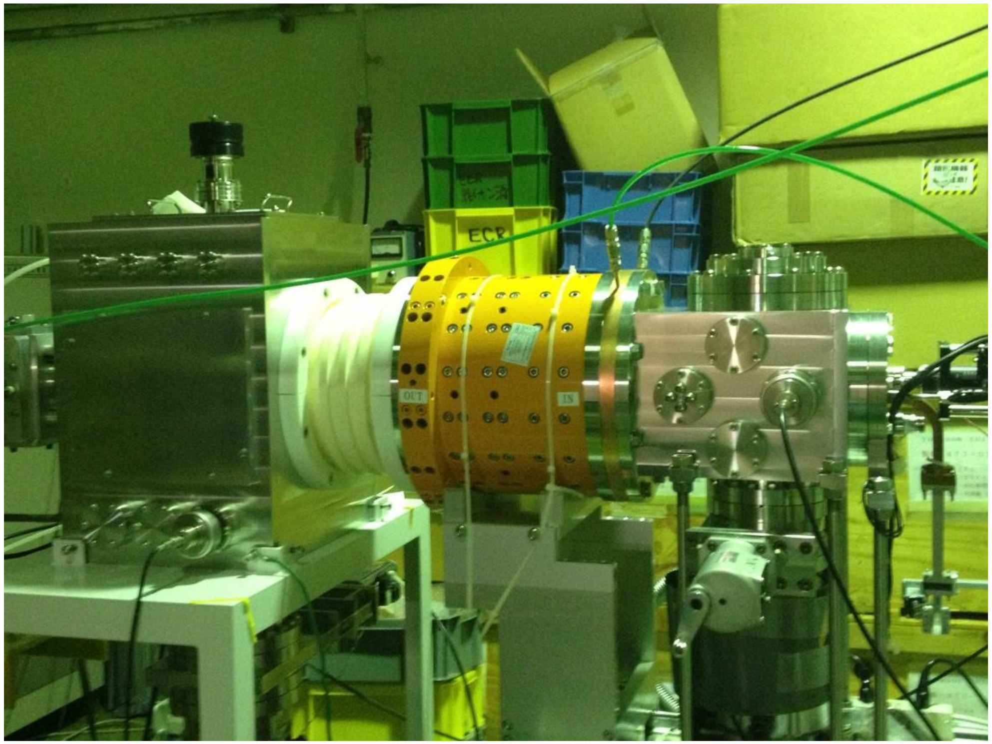
All permanent magnet

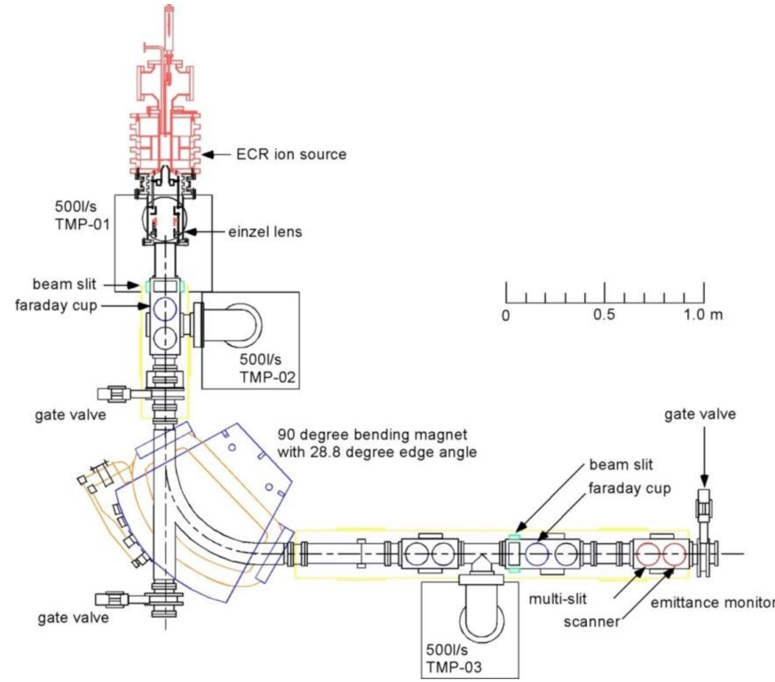
- Mirror field: 0.84 T / 0.55 T
- Radial field: 0.75 T

Extraction voltage: 30 kV max.

Commercial model (Kei series):Gunma, Saga, Kanagawa, Osaka, Yamagata -> under operating

Prototype ion source for various ion production (Kei3-source)





All permanent magnet

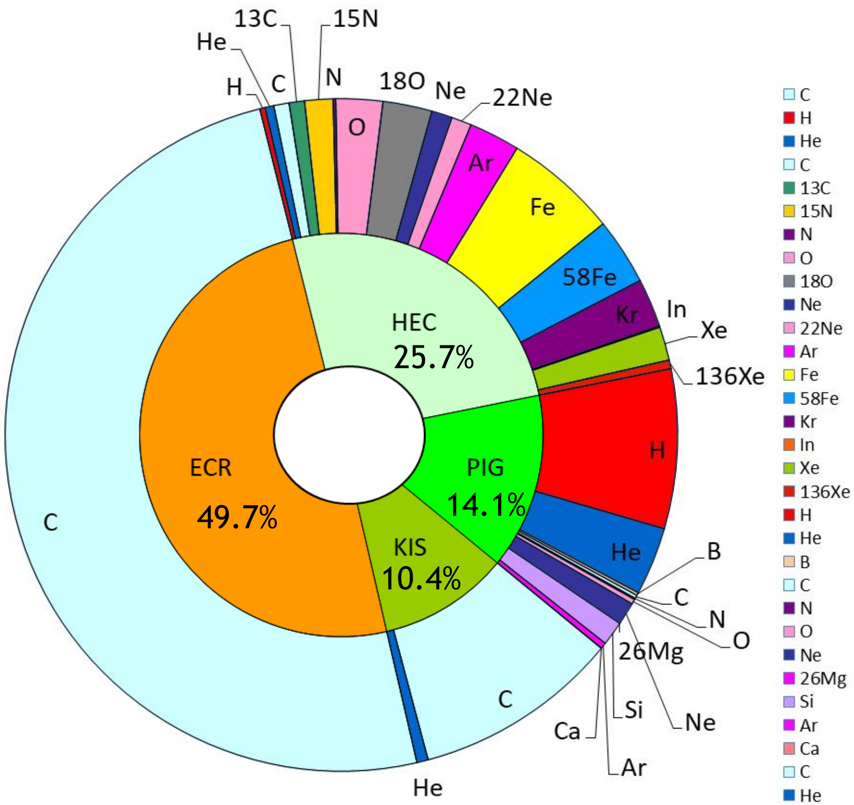
- Mirror field: 0.84 T / 0.55 T
- Radial field: 0.75 T

Extraction voltage: 30 kV max.

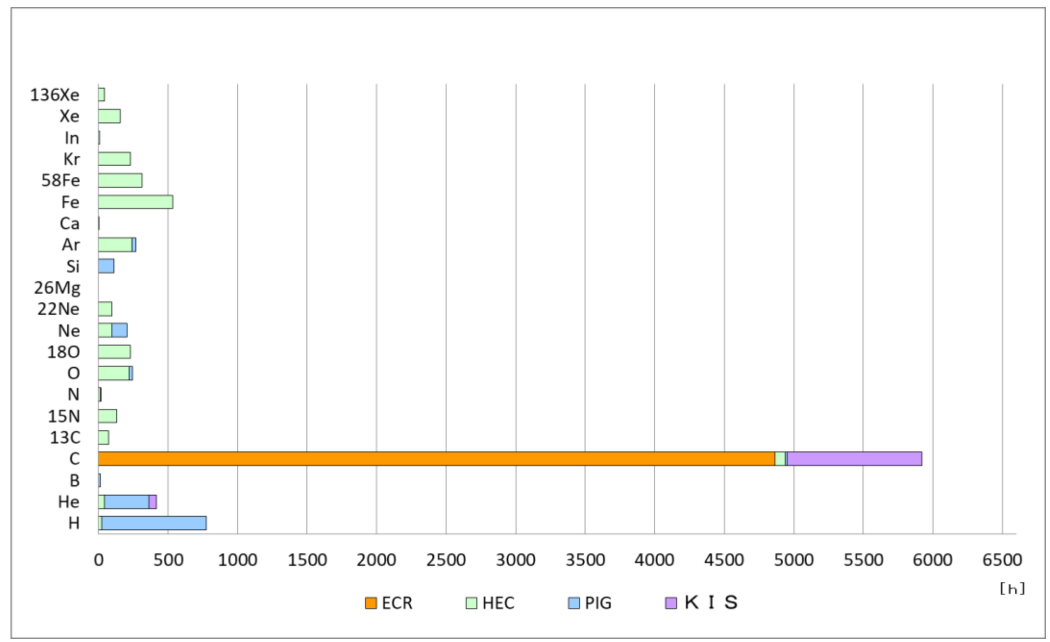
Development of ECR ion source (two frequency heating, gas mixing…)

Operation of ion sources at HIMAC in 2019

ECR: 10 GHz NIRS-ECR, HEC: 18 GHz NIRS-HEC
PIG: NIRS-PIG, KIS: 10 GHz Kei2-source



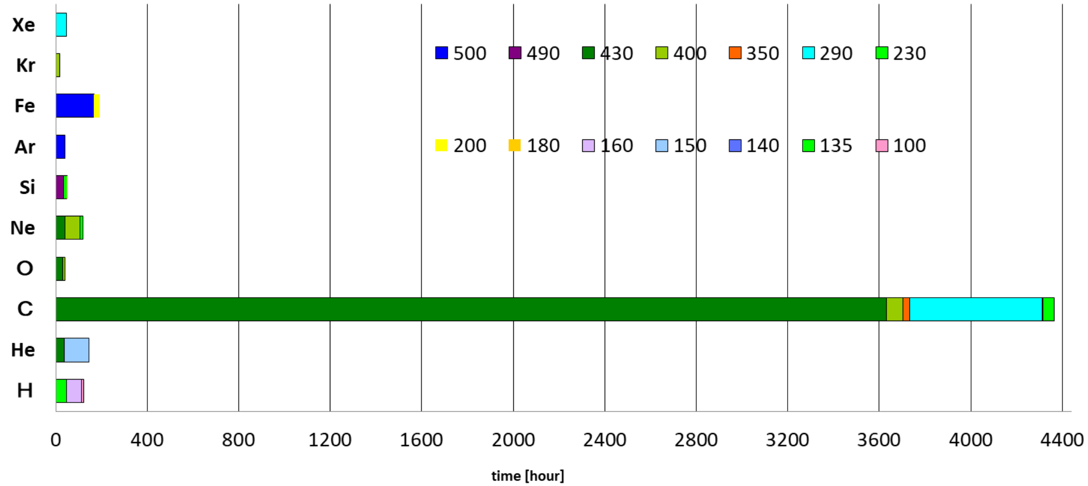
Ratio of operation time and ion species in 2019



Operation time of various ion species in 2019

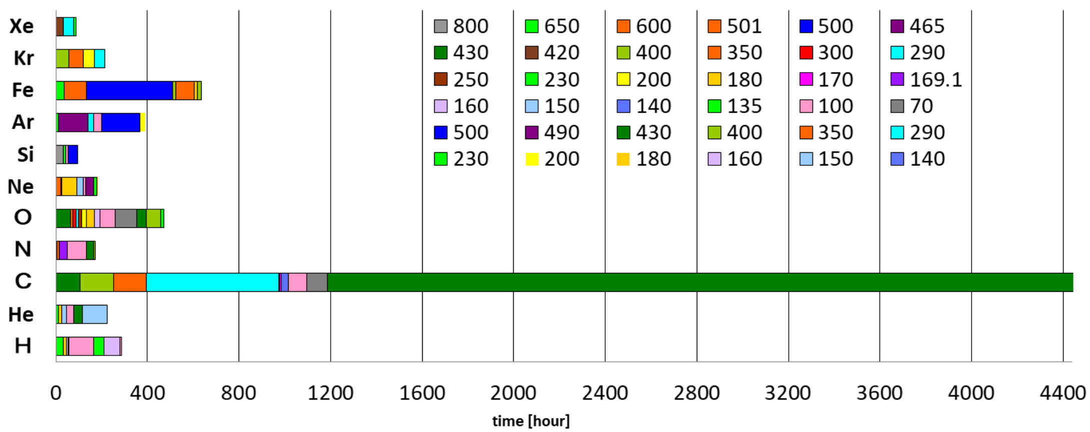
- Total operation time of ion sources were 9786.16hour in 2019.
- ECR produce C ion for medical use,
- HEC: Heavy ion, isotopic gas, PIG: light ion, spattering, KIS: carbon, He
- Operation time of carbon was 5923.04 hour (ECR: med., KIS, HEC, PIG: exp.)

Operation time of HIMAC synchrotron



Upper synchrotron ring

- Carbon for medical use and few bio. Phys. experiment
- Beam energy for medical use is 56-430 MeV/n
- Other ion used for biological and physical experiment



Lower synchrotron ring

- Biological and physical experiment
- Iron and Oxygen are used a lot next to carbon

NIRS
HIMAC

Development of 18 GHz NIRS-HEC

Gas switching at NIRS-HEC for multi-ion irradiation

- pulsed gas by solenoid valve
- production of He^{+}, C^{2+}, O^{3+}, Ne^{4+}
- beam switching

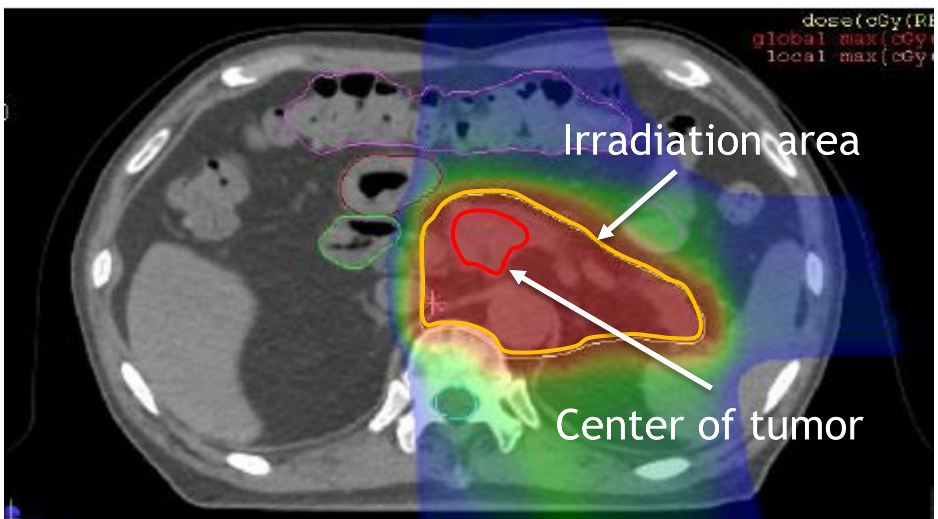
Production of Indium and Tin ion at 18 GHz NIRS-HEC

- In: $In(C_5H_5)$
- Sn: $Sn(i\text{-}C_3H_7)_4$

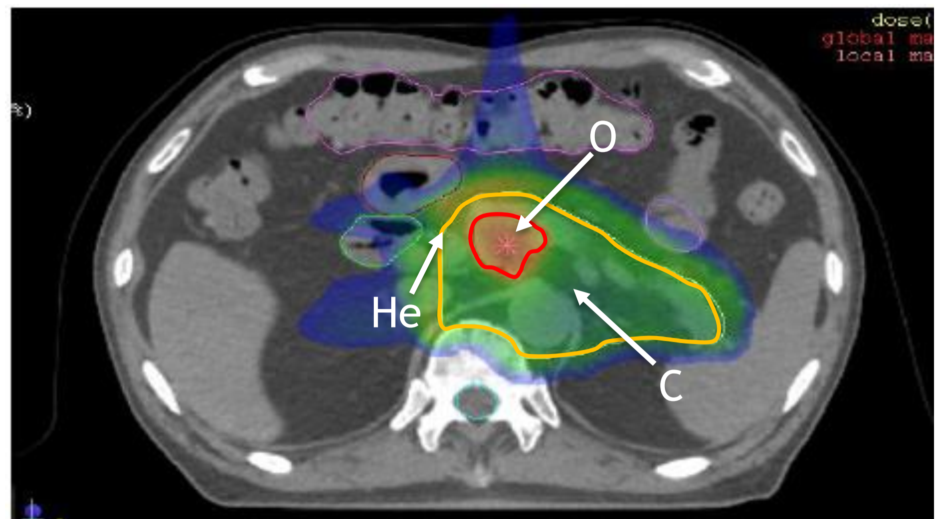
Multi-ion irradiation

- Multi-ion irradiation: Optimization of ion species by irradiation area
  - Center of tumor: Neon, Oxygen (higher biological effect than carbon)
    -> Suppression of cancer recurrence
  - Around the center of the tumor: Carbon
  - Near normal tissue: Helium (lower biological effect than carbon)
    -> Reducing side effects

Dose distribution with He, C, O at pancreas



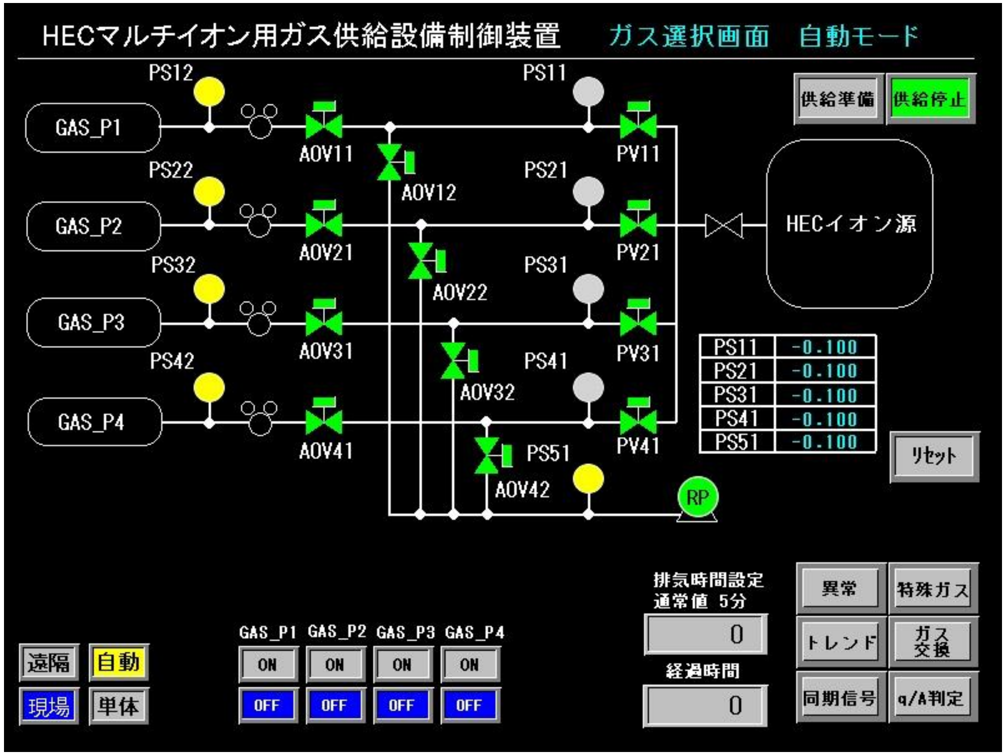
Distribution of LET with He, C, O at pancreas



Ion source: production of He, C, O, and Ne ion

T. Inaniwa et al., Physics in Medicine and Biology, 62, p.5180 (2017).

Gas switching system



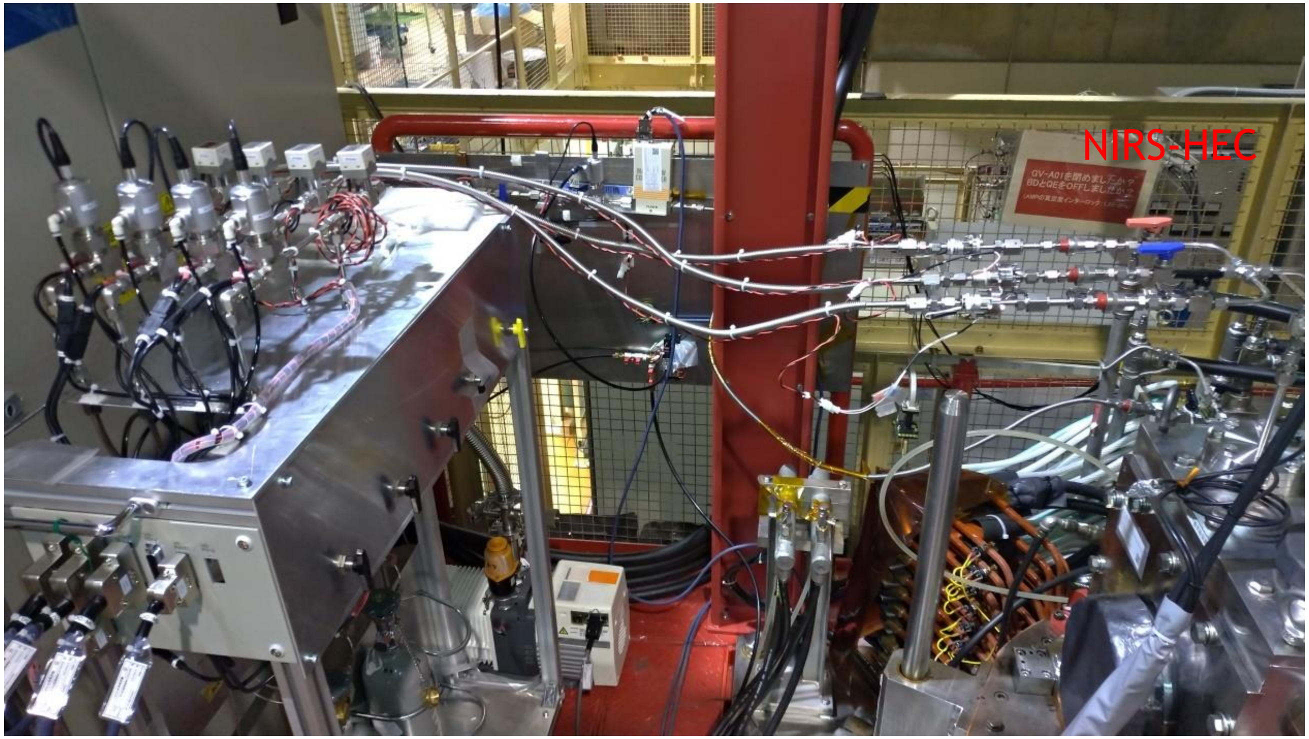
Material for ion production

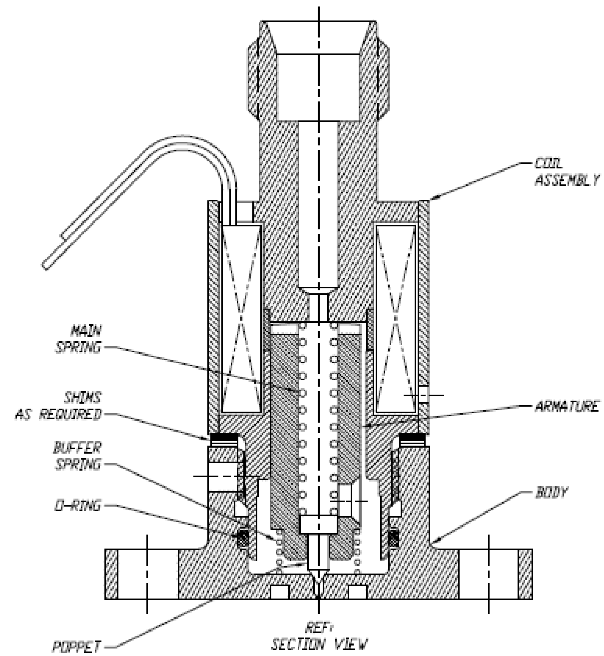
He: He^{2+}

CO_2: C^{2+}, O^{3+}

Ne: Ne^{4+}

Gas switching system





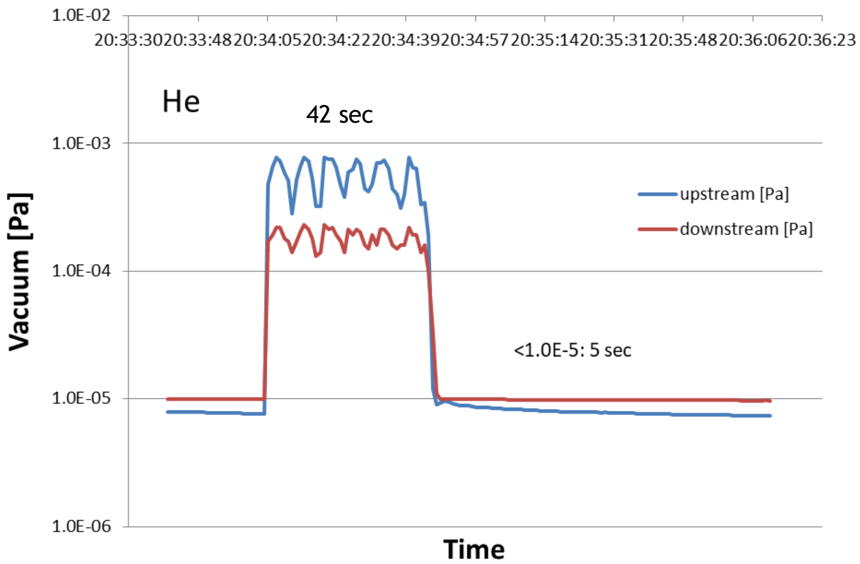
Material for ion production

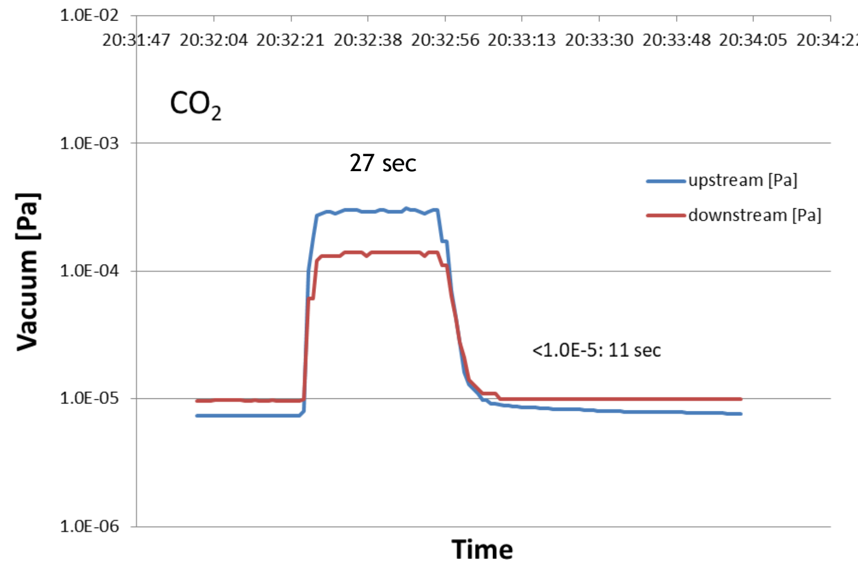
He: He^{2+}

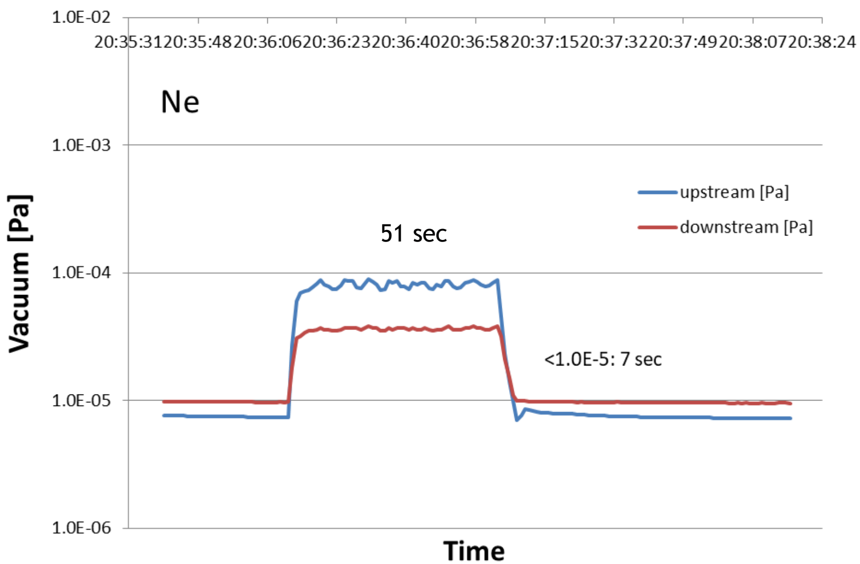
CO_2: C^{2+}, O^{3+}

Ne: Ne^{4+}

Exhaust time of gases

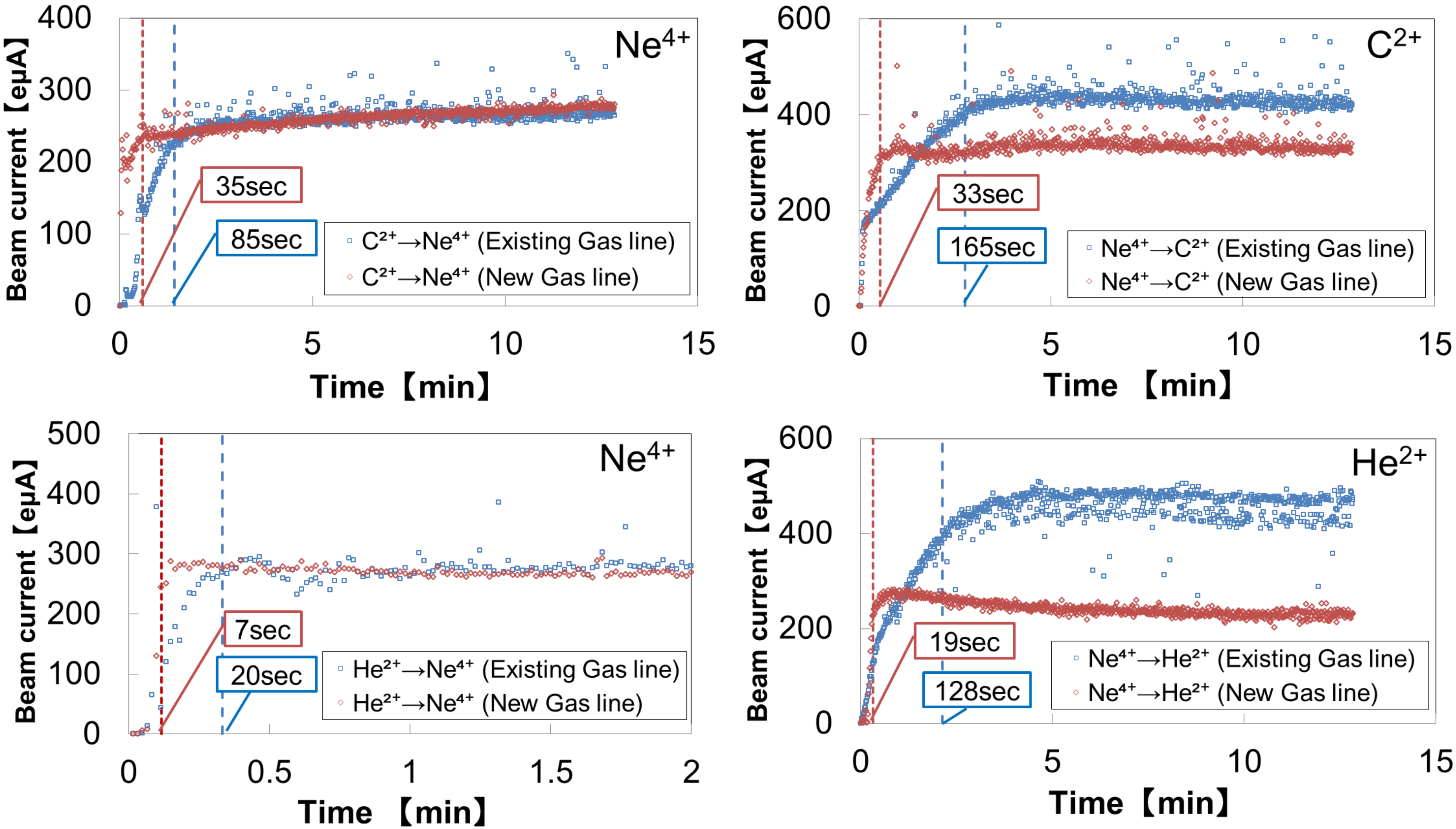






	Pulse width [msec]	Repetition [Hz]	Pressure [MPa]	Time to 1.0E-5 Pa [sec]
He	0.12	1.2	0.00	5
CO_2	0.3	1.2	-0.05	11
Ne	0.25	1.2	0.00	7

Beam switching time



Development of ECRIS

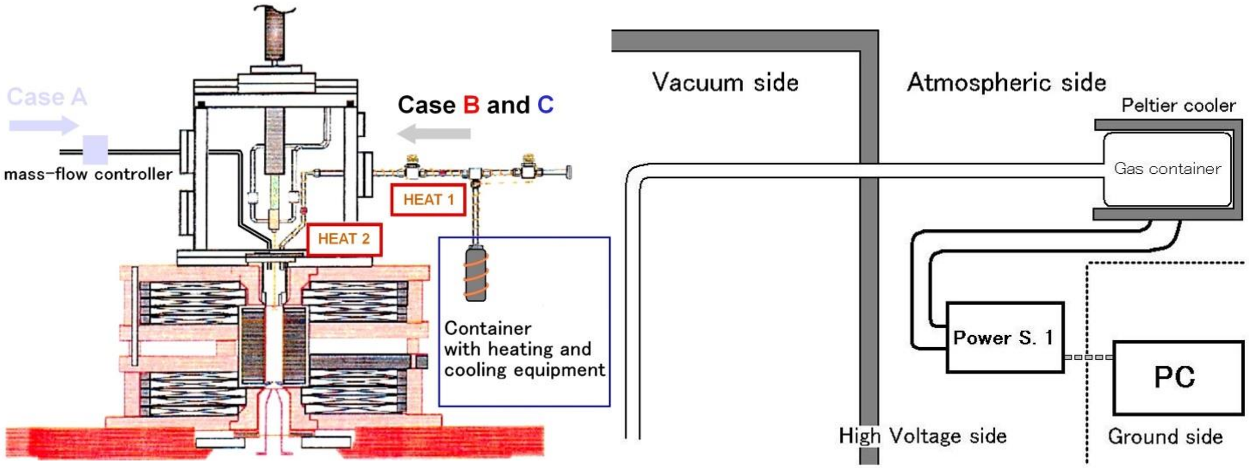
Gas switching at NIRS-HEC for multi-ion irradiation

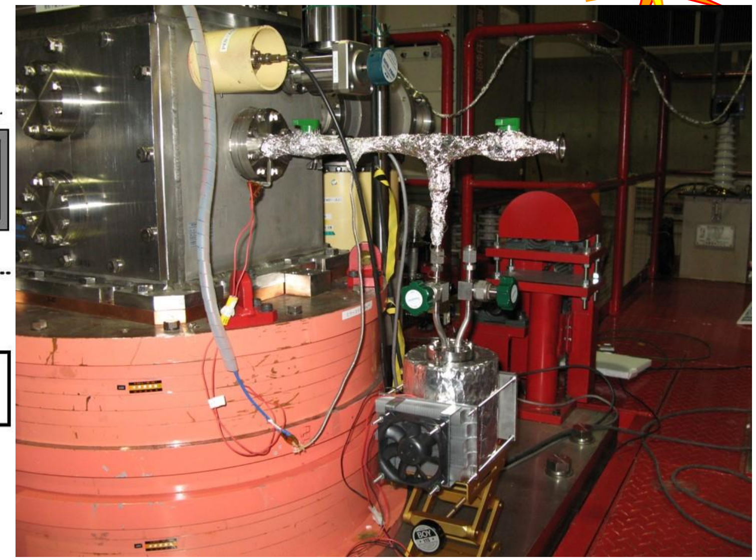
- pulsed gas by solenoid valve
- production of He^{+}, C^{2+}, O^{3+}, Ne^{4+}
- beam switching

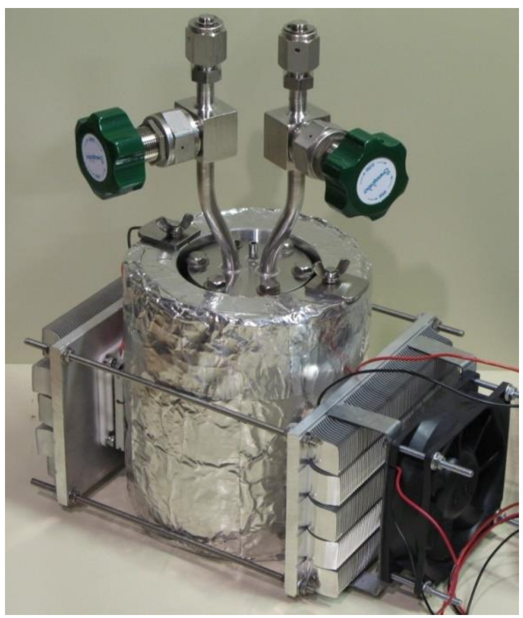
Production of Indium and Tin ion at NIRS-HEC

- In: $In(C_5H_5)$
- Sn: $Sn(i\text{-}C_3H_7)_4$

Production of Indium and Tin ion







Peltier cooler for MIVOC

0-room temperature

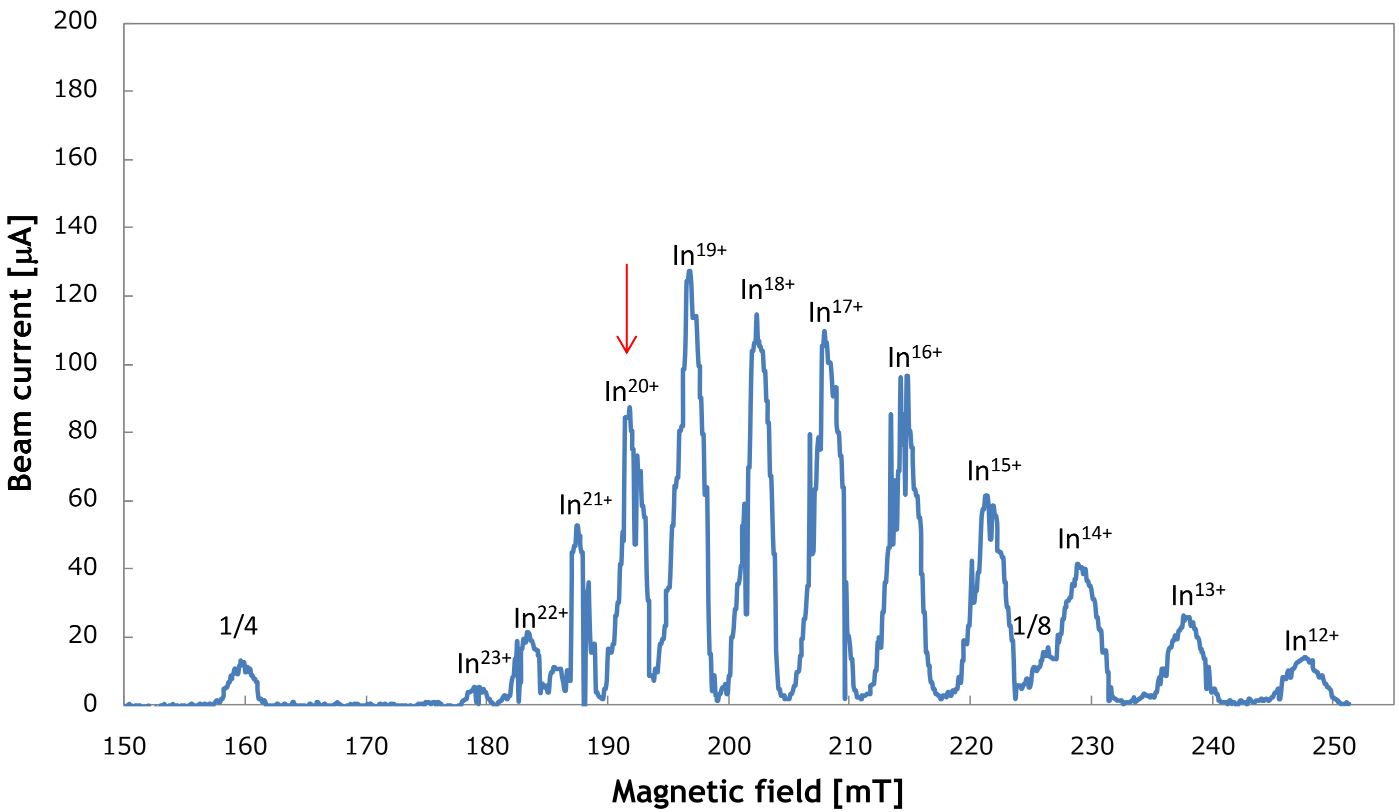
W. Takasugi RSI 81, 02A329 (2010)

Material

In: $In(C_5H_5)$

Sn: $Sn(i\text{-}C_3H_7)_4$

Production of Is ion from In(C_5H_5)

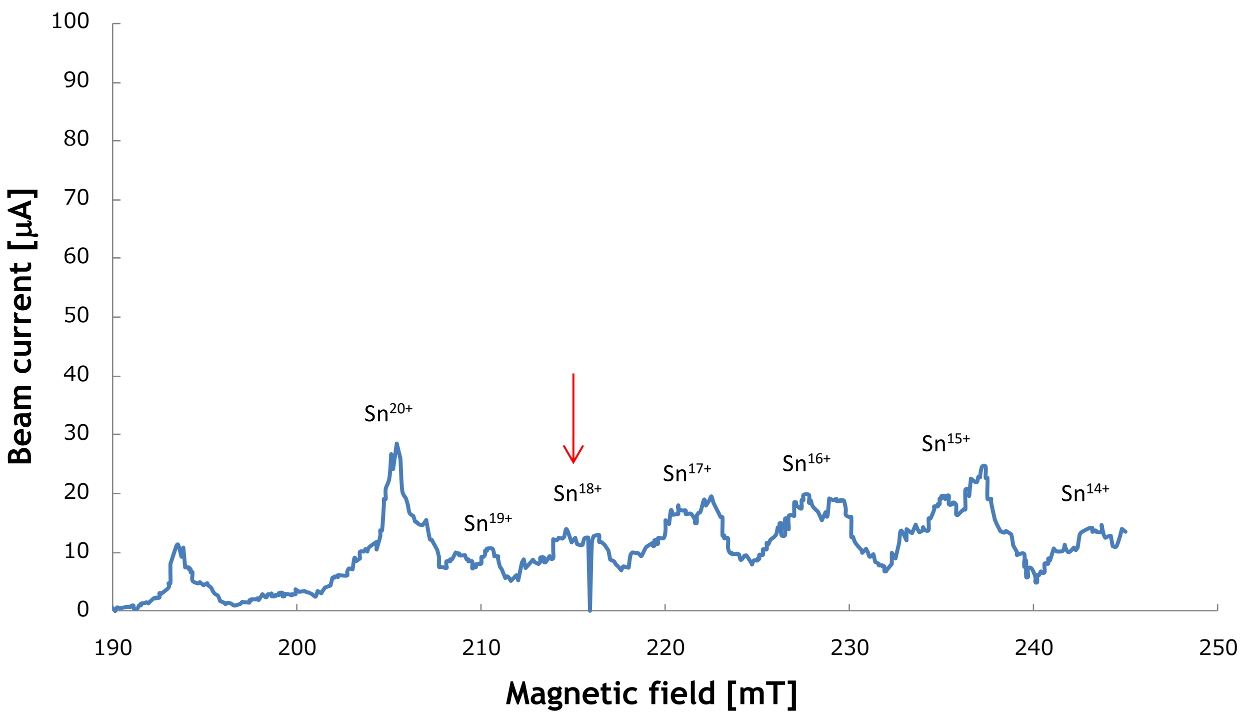


DEVICE	UNIT	PRESET	
TG1_D	msec	152.39	
TG1_W	msec	12	
TG2_D	msec	152.4	
TG2_W	msec	11.9	
M_GFL	cc/min	0.08	O2
S_GFL	cc/min	0	
AMP1:F	W	1200	
AMP2:F	W	600	
LENS_D	kV	7.2	
MRR1	A	865	
MRR2	A	570	
EXT_D	kV	31	
AG_D	kV	46	
BD	V	100	
TEMP	Degree C	6.2	
BA	mT	187.48	
SLTA02	mm	10	
SELF	sec	0.412	

Optimized for 20+

$^{115}In^{20+}$: 90 μA

Production of Sn ion from $Sn(i\text{-}C_3H_7)_4$



DEVICE	UNIT	PRESET	
TG1_D	msec	0	
TG1_W	msec	75	
TG2_D	msec	0	
TG2_W	msec	75	
M_GFL	cc/min	0	O2
S_GFL	cc/min	-	
AMP1:F	W	950	
AMP2:F	W	200	
LENS_D	kV	6	
MRR1	A	865	
MRR2	A	550	
EXT_D	kV	32	
AG_D	kV	53.333	
BD	V	100	
TEMP	Degree C	9.2	
BA	mT	215.71	
SLTA02	mm	5	
SELF	sec	0.412	

Optimized for 18+

$^{120}Sn^{18+}$: 15 μA

not separation

Conclusion

Operation in 2019

- Total operation time: 9786hour
- Without big trouble (discharge, operation mistake)

Development of ECRIS

- Gas switching at NIRS-HEC for multi-ion irradiation
  - production of He^{+}, C^{2+}, O^{3+}, Ne^{4+}
  - switching time: 7-35 sec
- Production of Indium and Tin ion at NIRS-HEC
  - $^{115}In^{20+}$: 90 μA
  - $^{120}Sn^{18+}$: 15 μA (?)

Thank you

Heavy ion radiotherapy facilities worldwide