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## Introduction

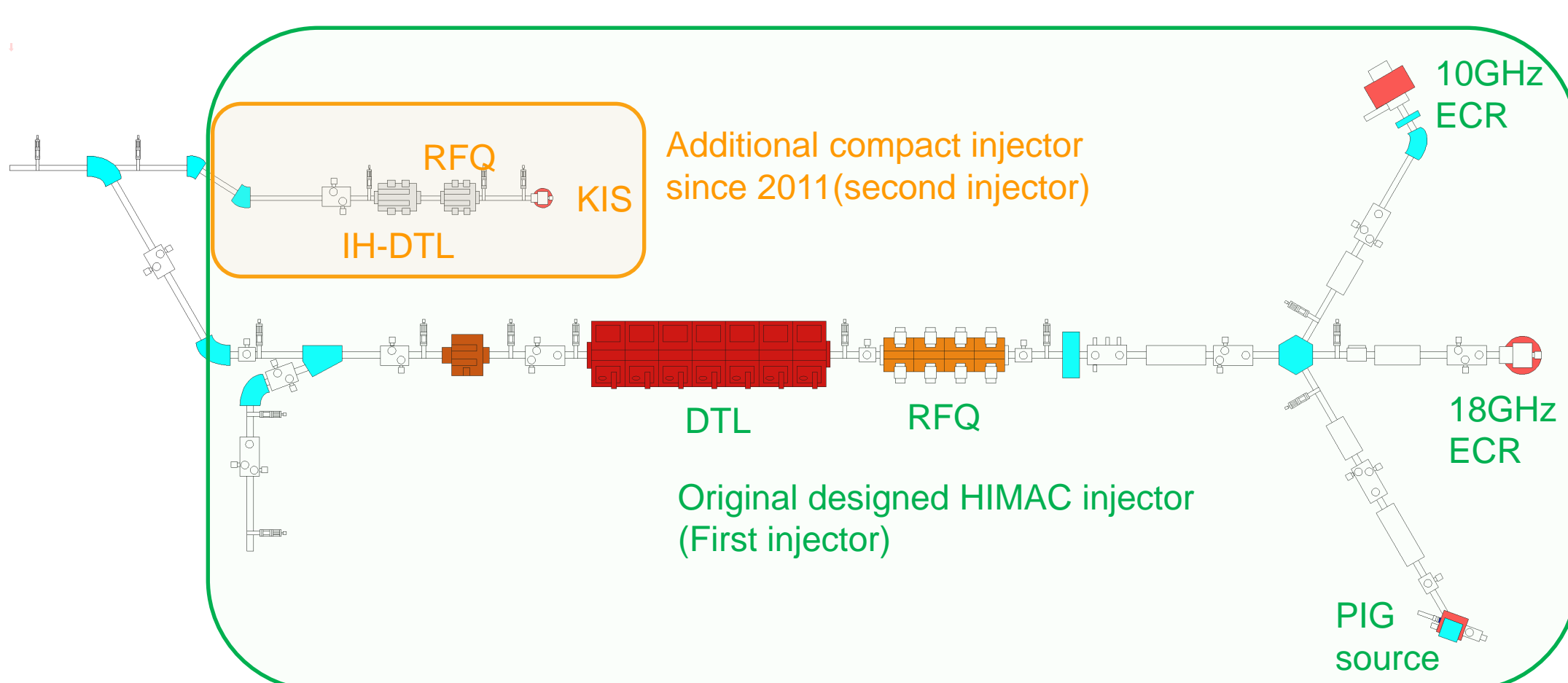
Carbon-ion radiotherapy using Heavy Ion Medical Accelerator in Chiba (HIMAC) has been carried out since 1994. Over 11000 cancer patients have been treated with carbon beams having energies of between 56-430 MeV/u. The HIMAC has two injectors and provides heavy-ion beams for medical and experimental purposes.

The first injector consists of two ECR type ion-sources (ECR, HEC), one PIG type ion-source (PIG), the RFQ linac and the DTL. This injector provides carbon-ion beam for cancer therapy, and concurrently provides various ion beams such as H, He, Fe, Xe for biological and physical experiments. The 10 GHz NIRS-ECR ion-source produces the carbon ion for cancer therapy, while the 18 GHz NIRS-HEC ion-source produces C to Xe ions for experimental use. Light ions such as H and He, moreover, B and Si ions are produced from solid materials with sputtering method by the NIRS-PIG ion-source.

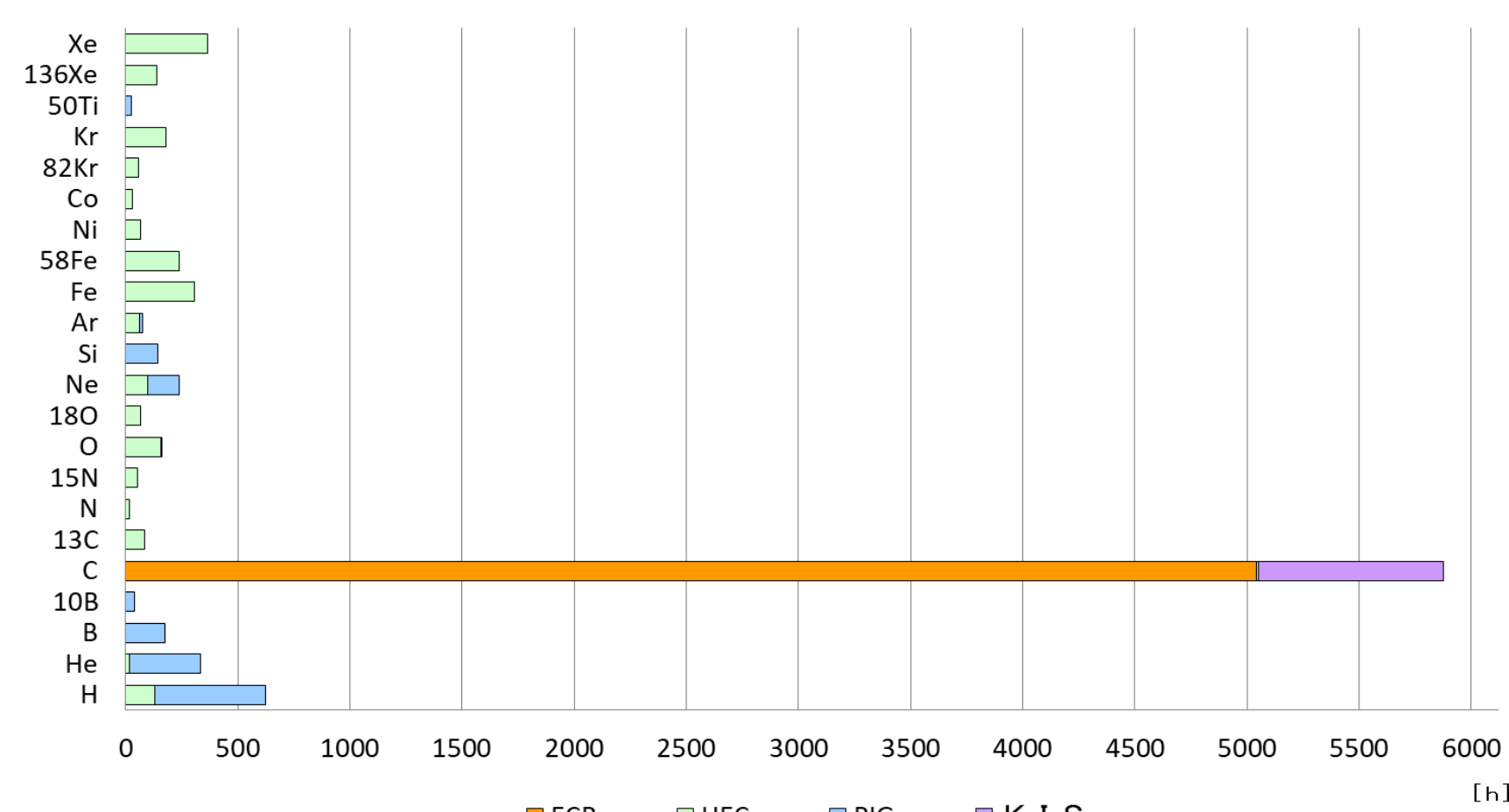
The second injector consists of the compact ECR ion-source with all permanent magnets (KIS), the RFQ linac and the Alternating-Phase-Focused Interdigital H-mode Drift-Tube-Linac (APF IH-DTL). This injector mostly provides carbon-ion beams for experimental use.

## Operation of HIMAC injector in 2017

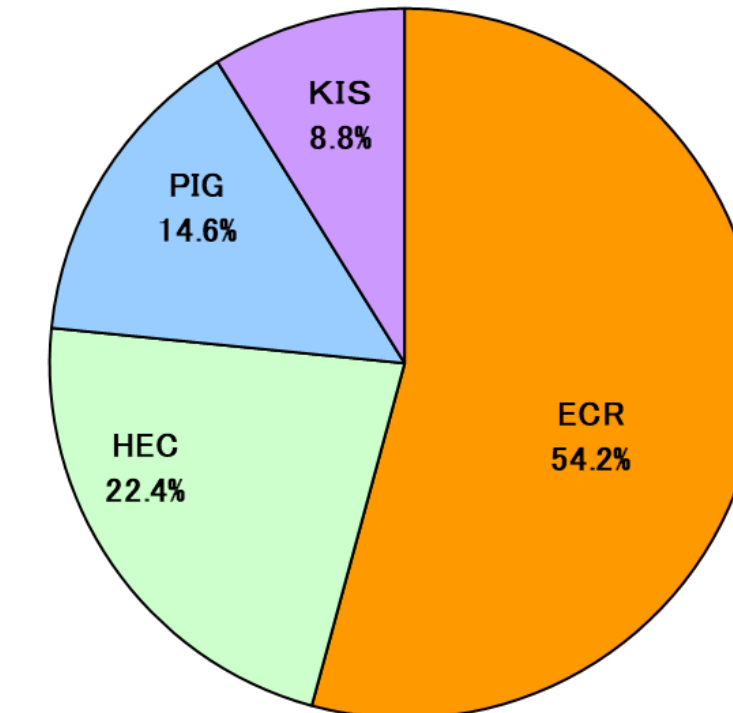
The HIMAC injector was produced various ion beam for medical and experimental use. Total operation time of injector was 9299.53 hour in 2017. Operation time of the carbon was higher than other ion species. Operation time of ECR and KIS sources for carbon ion production were 5042 and 822 hour. The carbon bean from ECR was used for medical use. Boron and silicon ions were produced by PIG with spattering method. We can operate the PIG source during 1 week without maintenance. Iron, krypton and xenon were produce by HEC. Operation time of Fe, Kr and Xe were 306, 179 and 364 hour, respectively. Ions of isotope such as <sup>13</sup>C, <sup>15</sup>N, <sup>18</sup>O and <sup>58</sup>Fe were also produced at NIRS-HEC.



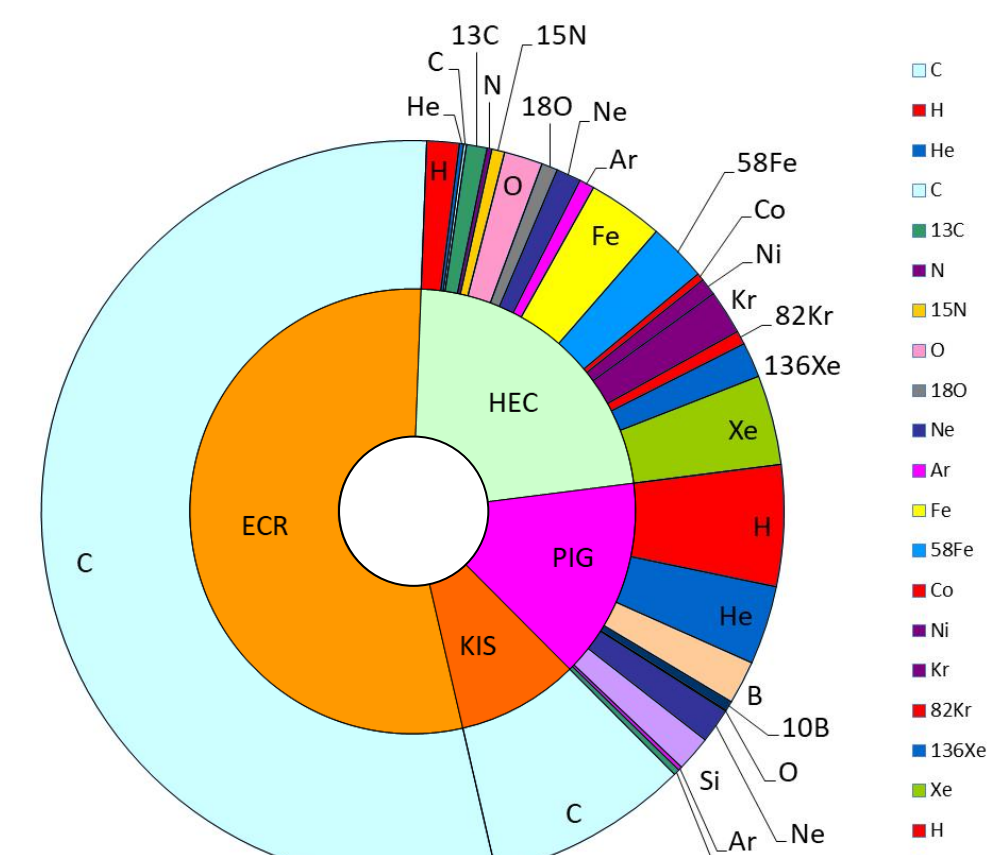
Layout of HIMAC injector



Operation time of various ion species in 2017



Operation ratio of ion source

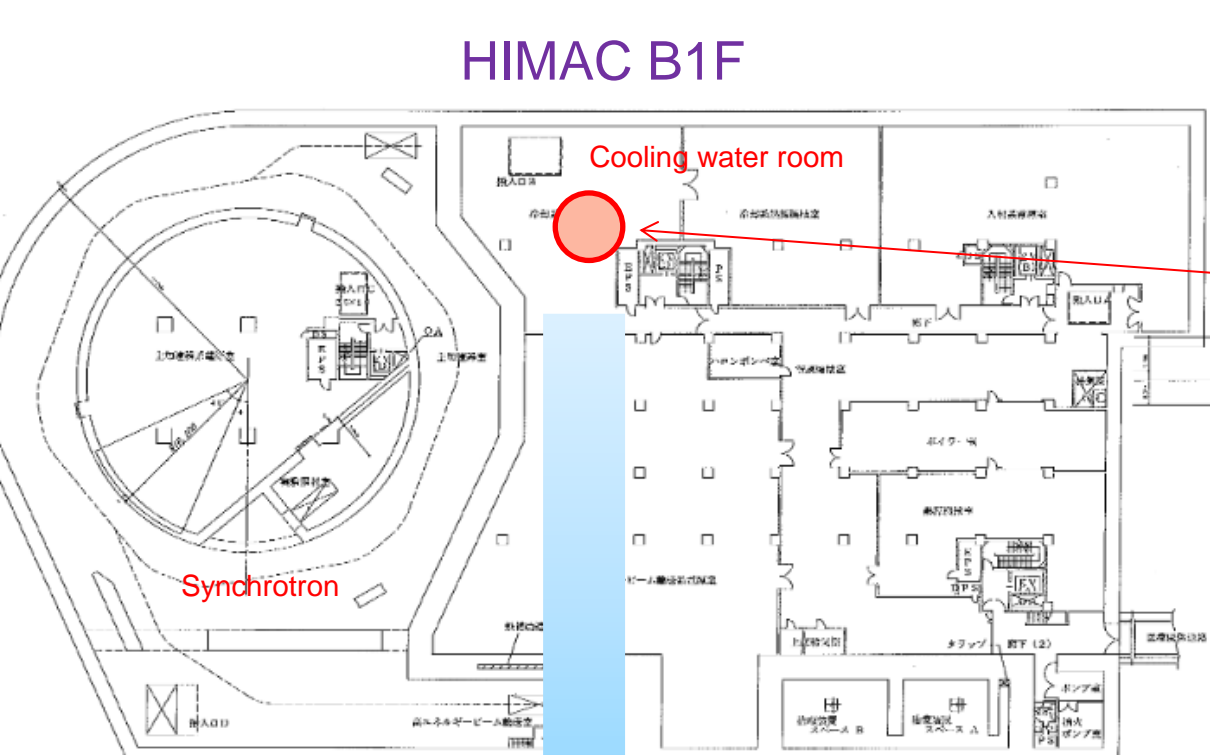


Ratio of ion species

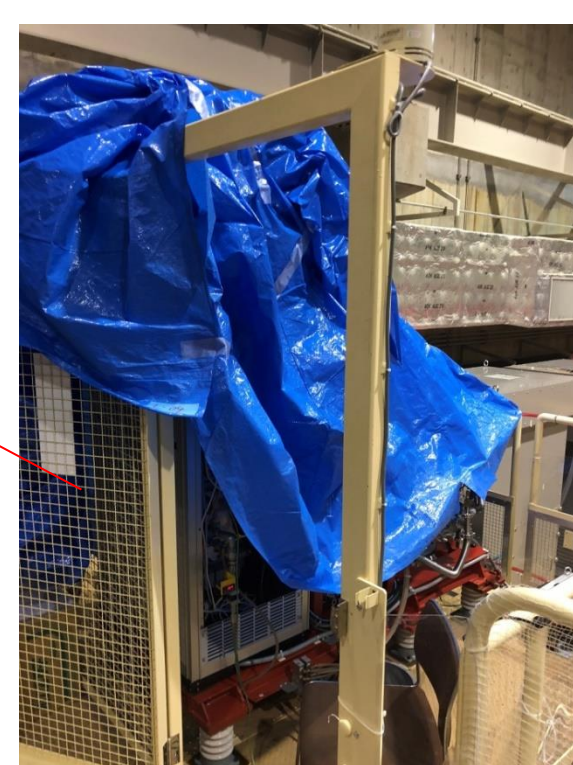
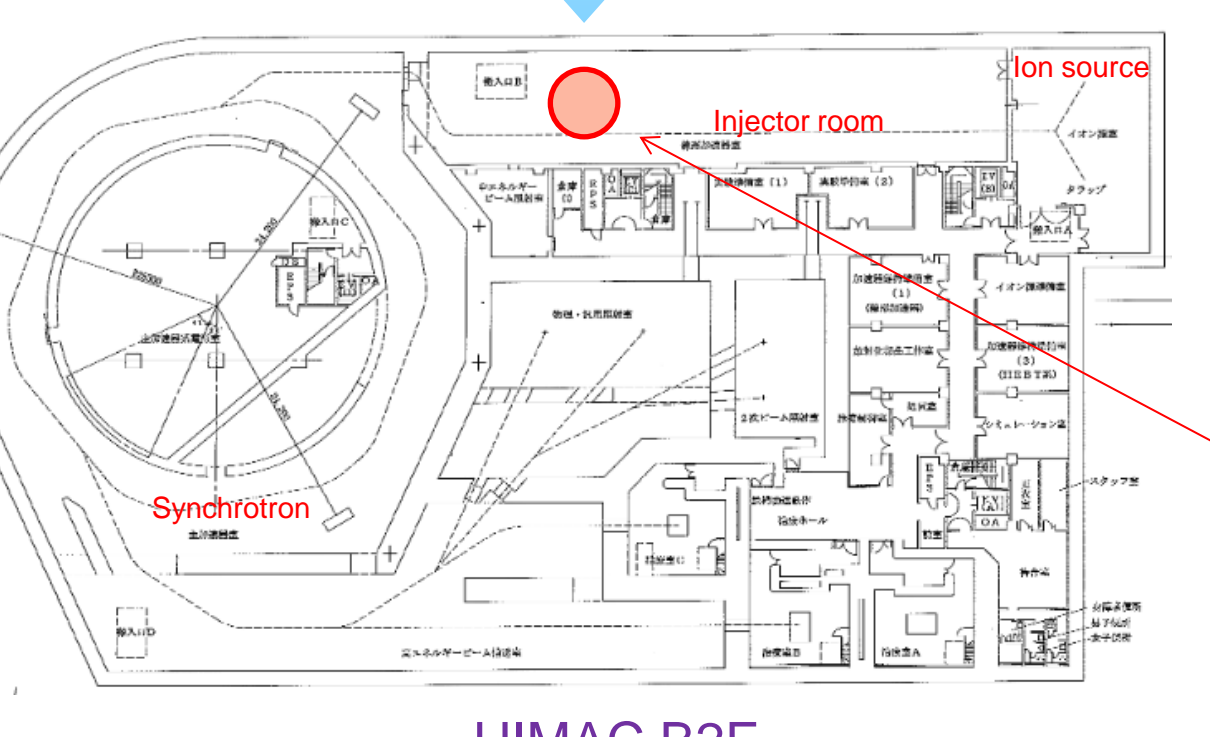
## Trouble of HIMAC injector in 2017 (aging problem)

### Rain in the injector room

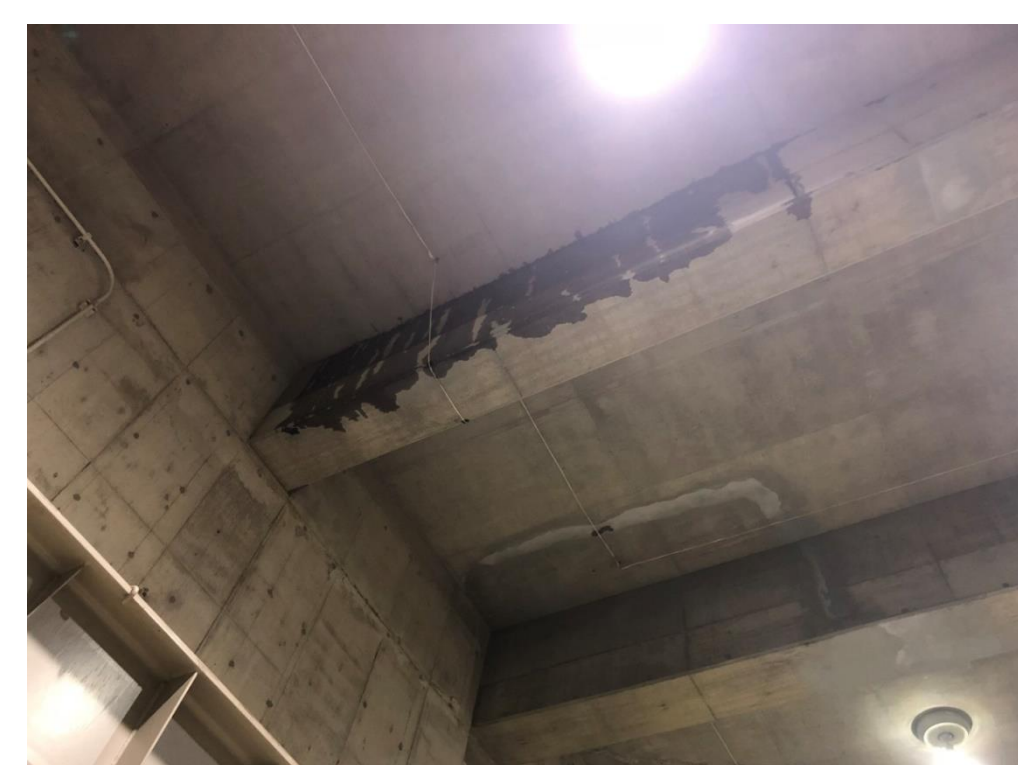
There was water leak from pump for cooling water. The water go through the concrete to other floor of injector room.



Pump for cooling water



KIS with rain coat



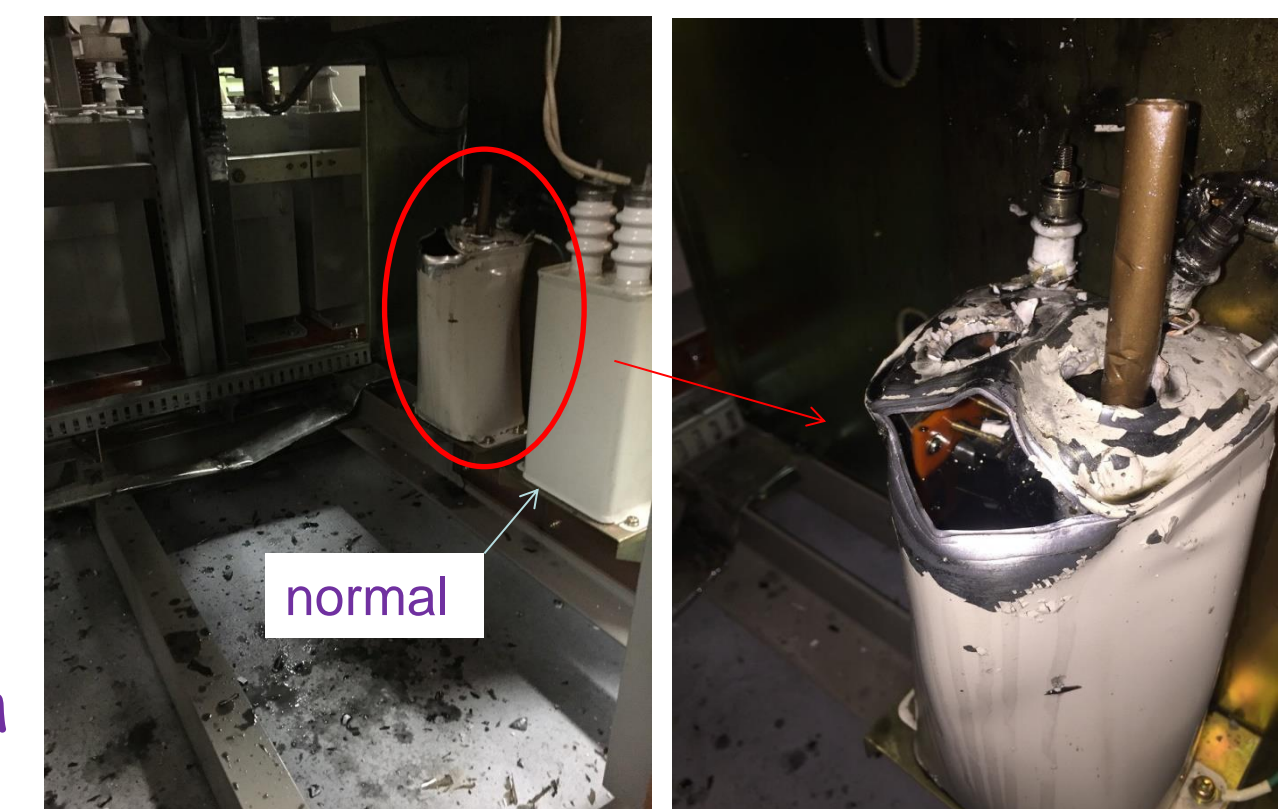
Ceiling of injector room

### Other problems

There were 26 cases of trouble about aging. Total number of trouble for which an exchange of a parts were 82 cases in 2017.

### Explosion of transformer

Transformer (500V/2000V) in power supply for plate of tube at DTL was broken due to decreasing of insulation. Maximum insulation voltage is 20 kV.



Explosion of transformer

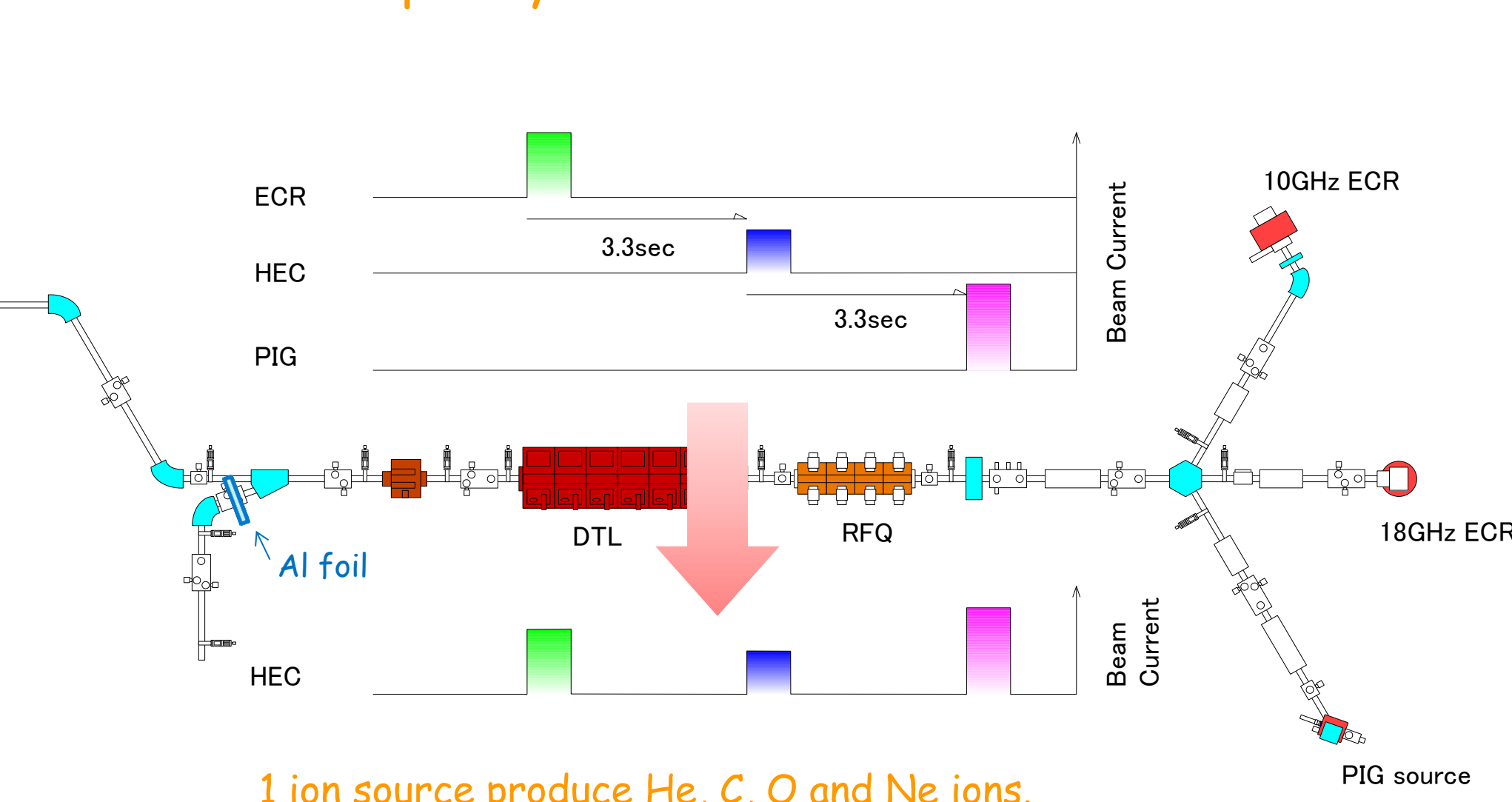
No.	Date	Item	No.	Date	Item
1	2017/4/3 21:39	sensor for air cooling in High Power Amp. (HPA) for DTL	14	2018/3/11 18:00	battery of motherboard for control PC
2	2017/4/17 13:30	fan in HPA for DTL	15	2018/3/11 18:15	controller for TMP
3	2017/5/22 14:00	connector of cooling water line for beam line	16	2018/3/11 19:00	video card for control PC
4	2017/6/2 6:50	Turbo Molecule Pump (TMP)for ECR ionsource	17	2018/3/23 15:00	solenoid valve for gate valve
5	2017/7/21 19:30	controller for TMP	18	2018/3/23 15:00	solenoid valve for gate valve
6	2017/7/25 20:00	bellows for faraday cup at PIG	19	2018/3/26 14:00	transformer for IH-DTL
7	2017/8/2 9:40	touch screen for control PC	20	2018/3/26 15:00	video card for control PC
8	2017/8/2 16:24	display monitor for control of HEC	21	2018/3/26 15:00	video card for control PC
9	2017/8/4 14:00	air leak from O ring	22	2018/3/27 10:00	battery of motherboard for control PC
10	2017/12/3 5:07	solenoid valve for gate valve	23	2018/3/27 10:00	battery of motherboard for control PC
11	2018/1/18 15:02	air leak from hose of cooling water	24	2018/3/27 10:00	battery of motherboard for control PC
12	2018/1/22 14:00	bellows for faraday cup at PIG	25	2018/3/28 14:00	Fuse for power supply of mirror coil at ECR
13	2018/3/11 17:10	HDD for control PC	26	2018/3/30 10:00	condenser of control unit for QM

## Development for multi-ion irradiation at HIMAC injector

The multi-ion irradiation with dose distribution and Liner Energy Transfer (LET) optimization is being studied at NIRS. Helium, carbon, oxygen and neon ions are considered as ion species for multi-ion irradiation. We considered the switching method with only one ion source.

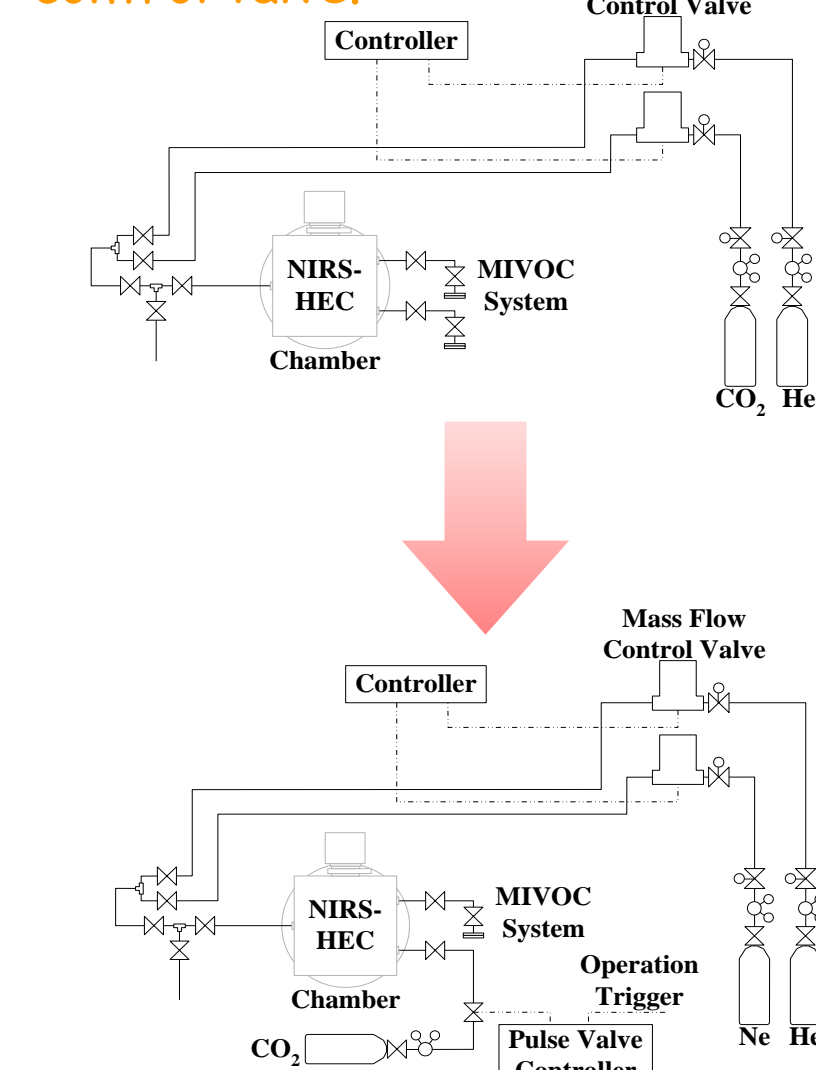
The solenoid valve was set in CO<sub>2</sub> line. The helium and neon gases were regulated by piezo valve (Mass Flow Control valve: MFC). We have to wait about 10 minutes for stable beam current of He<sup>2+</sup> by using MFC. There were residual CO<sub>2</sub> gas in the gas line and vacuum chamber. In the case of solenoid valve, wait time is about 3 minutes. The solenoid valve opens 120 msec before the microwave ignition. Pulse width was 0.22 msec. The influence of residual CO<sub>2</sub> gas is big to the production of He<sup>2+</sup> ion. The gas pulsing method is effective in a changing ion species.

We checked impurity of accelerated He<sup>2+</sup> beam at HIMAC injector. An ion is separated using differences in an energy loss on ion species when an ion passes a thin foil. We checked impurity of accelerated He<sup>2+</sup> beam

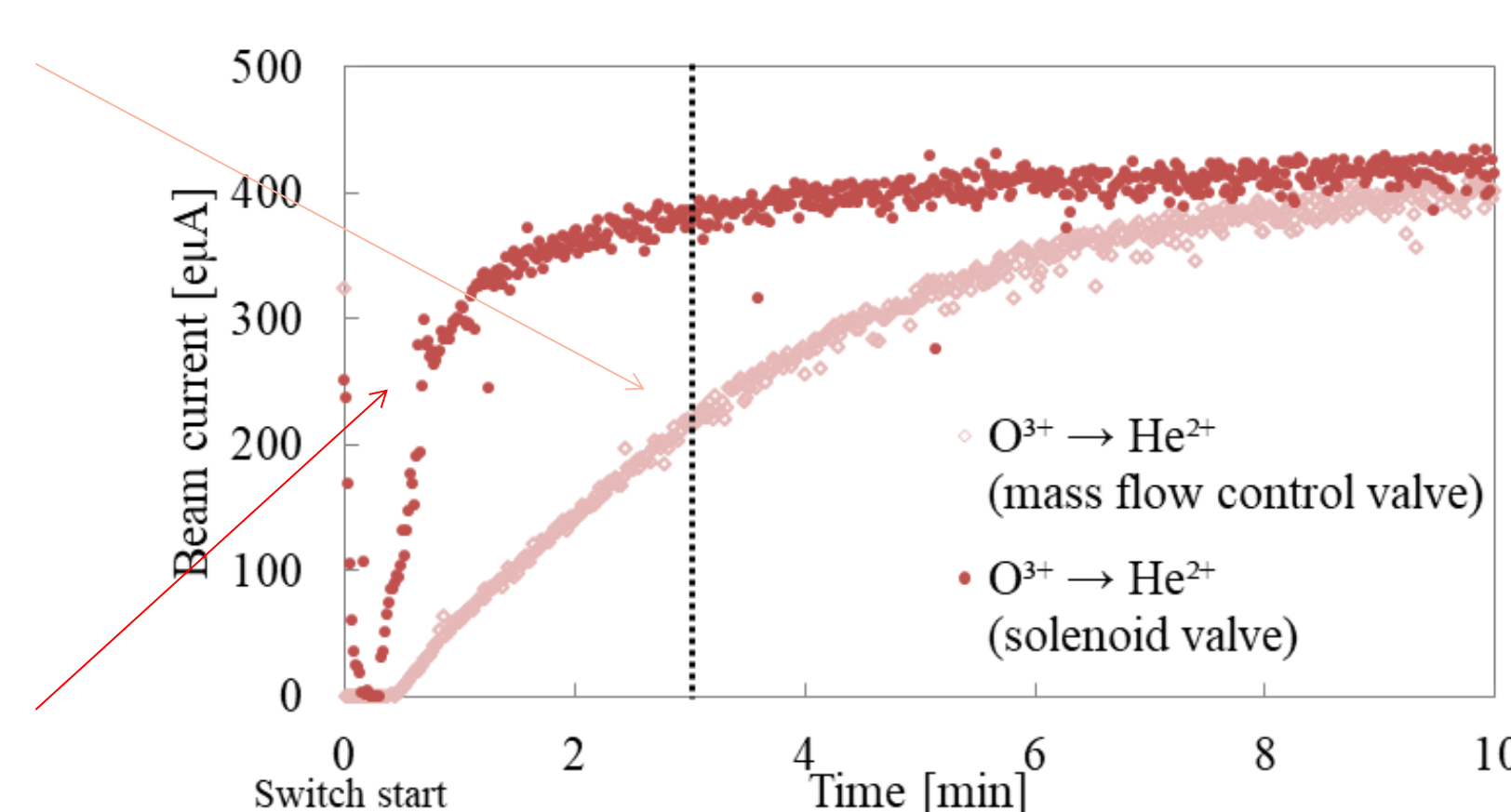


1 ion source produce He, C, O and Ne ions.

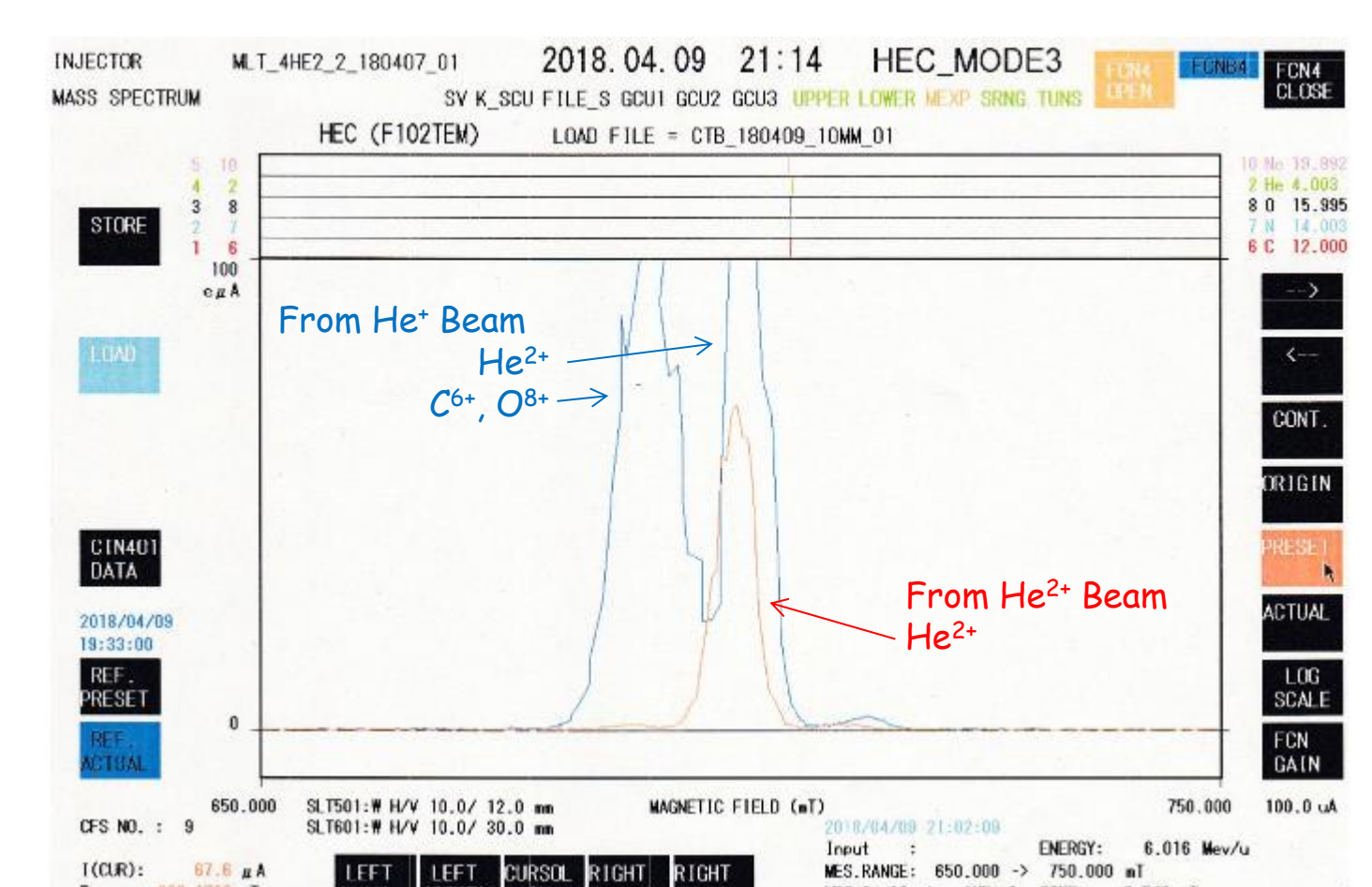
Original gas piping diagram with mass flow control valve.



Modified gas piping diagram with solenoid valve.



The reproducibility of He<sup>2+</sup> at the switching of O<sup>3+</sup> with mass flow control valve or gas pulsing method.



The beam spectrum from He<sup>+</sup> and He<sup>2+</sup> at after the HIMAC injector.