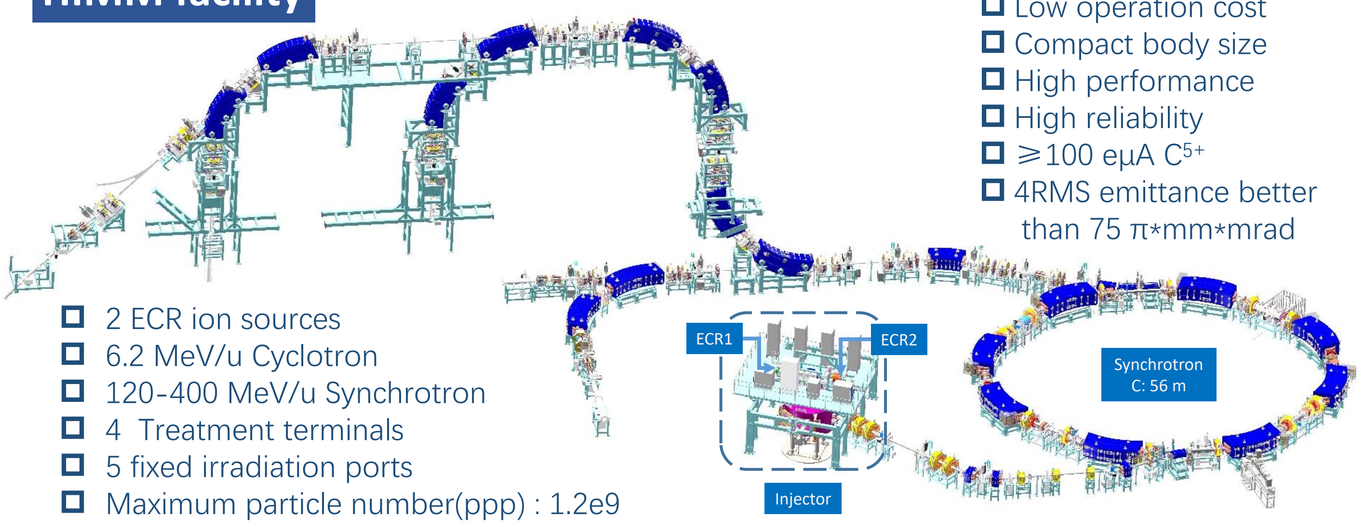
Operation with the LAPECR3 ion source for cancer therapy accelerators

J. Q. Li[1,2] , Y. Cao[1], X. Z. Zhang[1], J. D. Ma[1], G. Jin[3], L. T. Sun[1,2] and H. W. Zhao[1,2]
[1]Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China
[2]School of Nuclear Science and Technology, University of Chinese Academy of Sciences, Beijing 100049, China
[3]Lanzhou ion therapy co., Ltd (LANITH), Lanzhou 730000, China
Author e-mail address: lijiaqing@impcas.ac.cn

Abstract

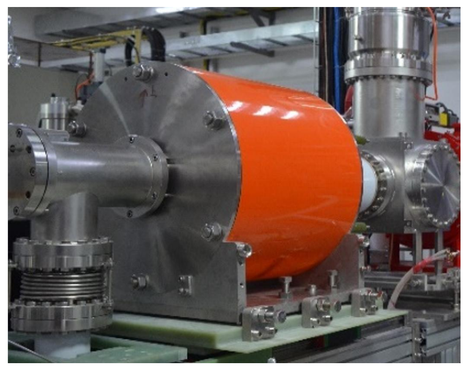
An all-permanent magnet electron cyclotron resonance ion source-LAPECR3 (Lanzhou All Permanent magnet Electron Cyclotron Resonance ion source No.3) had been developed as the C^{5+} ion beam injector of Heavy Ion Medical Machine (HIMM) accelerator facility since 2009 in China. The first HIMM demo facility was built in Wuwei city in 2015, which had been officially licensed to treat patients in early 2020. The facility has been proven to be very effective, and more than 1400 patients have been treated so far. In order to prevent ion source failure, each facility employs two identical LAPECR3 ion sources. At present, there are eight HIMM facilities are under construction or in operation, and more than 16 LAPECR3 ion sources were built. In order to improve the performance of the ion source for long term operation, some techniques were employed to optimize source performance and to avoid the damage of key equipment. The poster will introduce the operation status of LAPECR ion sources at these HIMM facilities and present the latest results of carbon beam production.

HIMM facility



- 2 ECR ion sources
- 6.2 MeV/u Cyclotron
- 120-400 MeV/u Synchrotron
- 4 Treatment terminals
- 5 fixed irradiation ports
- Maximum particle number(ppp) : 1.2e9

- Low operation cost
- Compact body size
- High performance
- High reliability
- ⩾100 eμA C^{5+}
- 4RMS emittance better than 75 π*mm*mrad

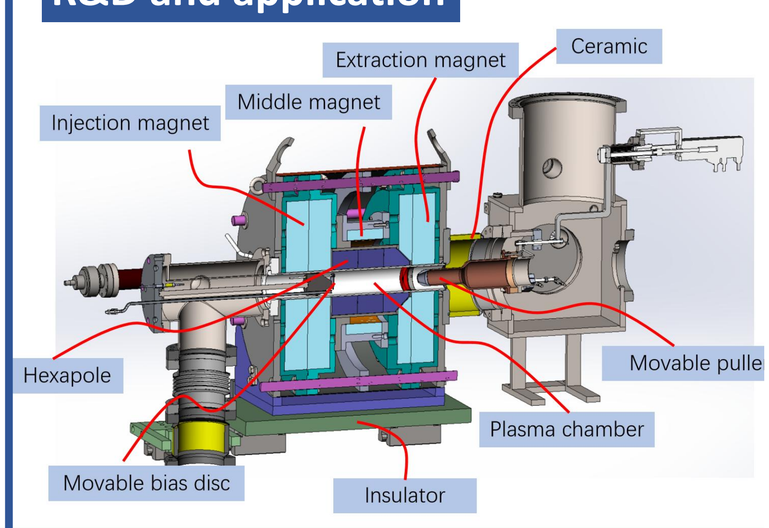


LAPECR3 ion source

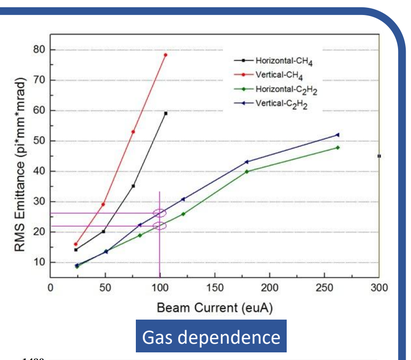
Species	Value
RF (GHz)	14.5
B_{inj} (T)	1.8
B_{ext} (T)	0.9
Bmin (T)	0.4
Br (T)	1.13
Lmirror (mm)	170
Lecr (mm)	64
Dchamber (mm)	50
HV (kV)	≤30
Beam mode	CW/PULSE
Body size (mm)	Φ450*380

Key parameters of LAPECR3 ion source

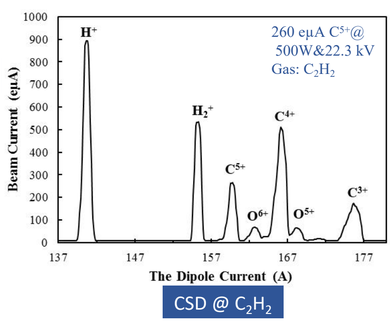
R&D and application



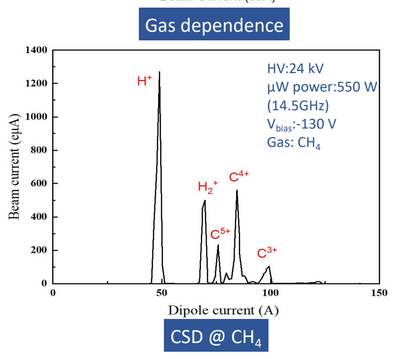
- Employment of the clear gas (CH_4) to avoid carbon contamination and to improve beam stability
- Bigger insulator ceramic to improve gas flow conductivity
- Movable puller electrode to optimize beam extraction
- Movable bias disk to affect microwave feeding
- Secondary particles shielding to prevent secondary particles pollution on the wall of ceramic



Gas dependence

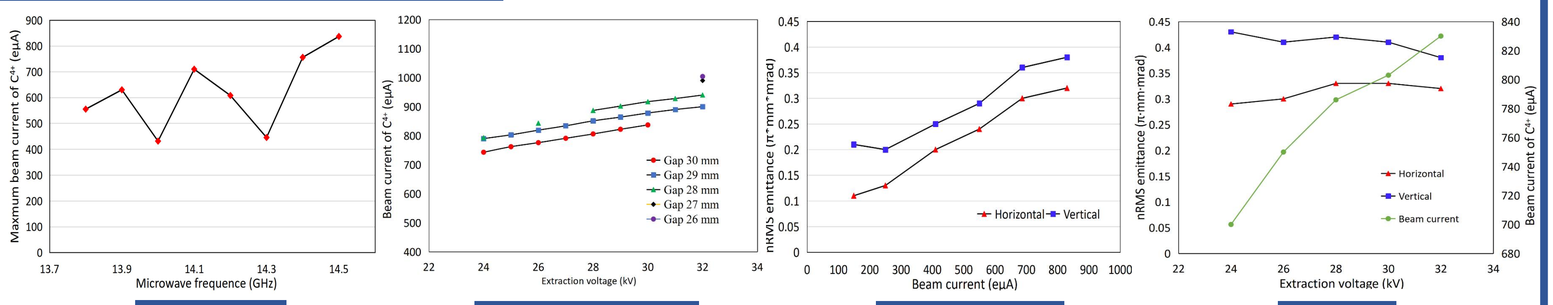


CSD @ C_2H_2

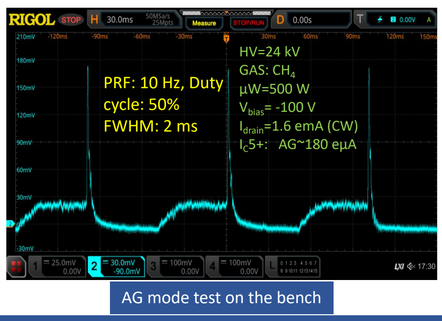


CSD @ CH_4

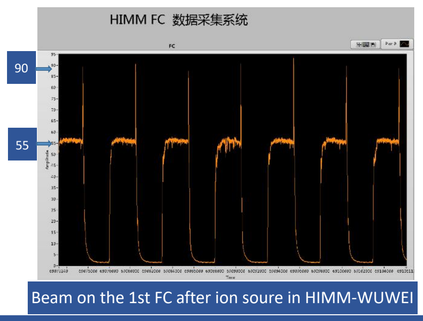
Intense C^{4+} beam production



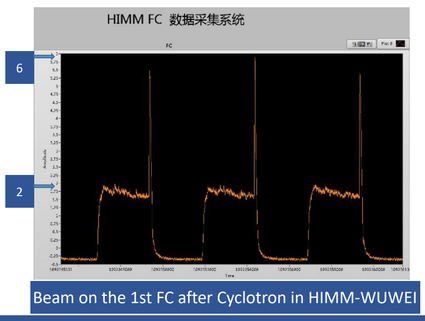
After glow mode application in HIMM



AG mode test on the bench



Beam on the 1st FC after ion soure in HIMM-WUWEI



Beam on the 1st FC after Cyclotron in HIMM-WUWEI

Routine operation

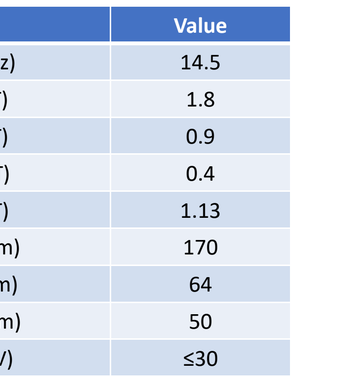
Working day	Weekend	Public holiday
Treatment	Maintenance/QA	Standby

Carbon contamination after one month@C_2H_2

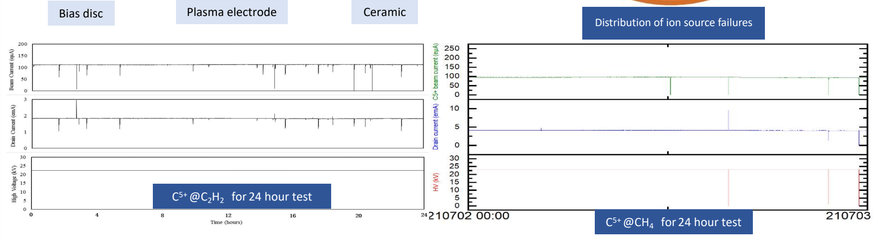
Bias disc | Plasma electrode | Plasma chamber | Ceramic

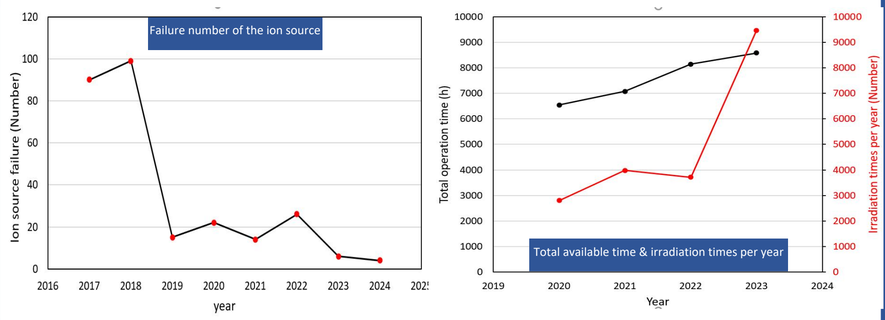
Carbon contamination after one month@CH_4

Bias disc | Plasma electrode | Ceramic



Distribution of ion source failures





	2020	2021	2022	2023
Treatment time (h)	3678.35	3929.7	3311.92	4191.33
Irradiation times	2806	3983	3717	9469
Failure time (h)	200.97	217.42	207.13	179.58
Total abailable time (h)	6543.03	7078.58	8144.87	8580.42
Beam availability	**74.6%**	**80.8%**	**92.9%**	**97.9%**
Beam utilization rate	56.2%	55.5%	40.6%	48.8%

Summary

- The employment of CH_4 gas has significantly extended the lifetime of the ion source.
- After Glow mode operation of the ion source could be an effective method to improve the performance of the injector.
- More than 1400 patients have been treated so far, and the maximum irradiation times per year up to 9000.
- The maintenance interval of the ion source exceeds 200 days in HIMM facility.
- There are a total of 8 HIMM facilities either in operation or under construction.

Institute of Modern Physics
Chinese Academy of Sciences