MOPAB404

A low emittance compact proton injector for a proton therapy facility

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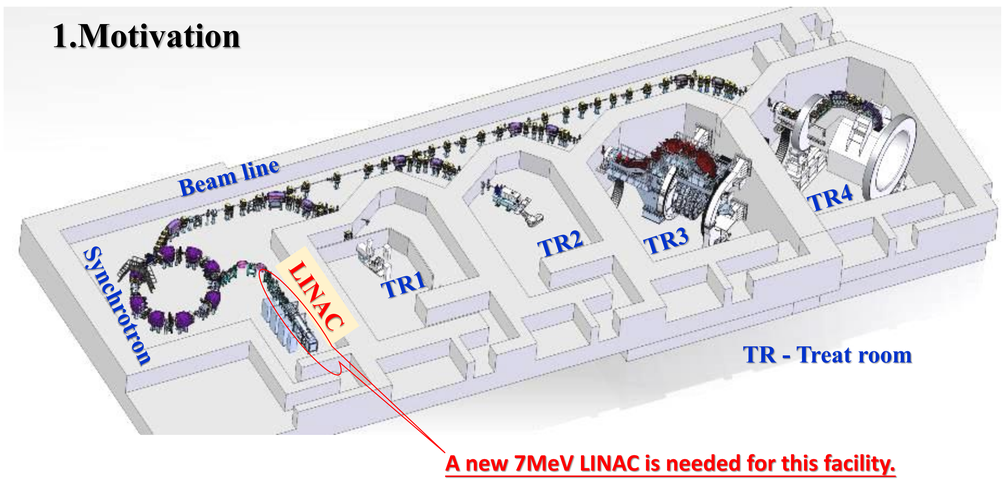
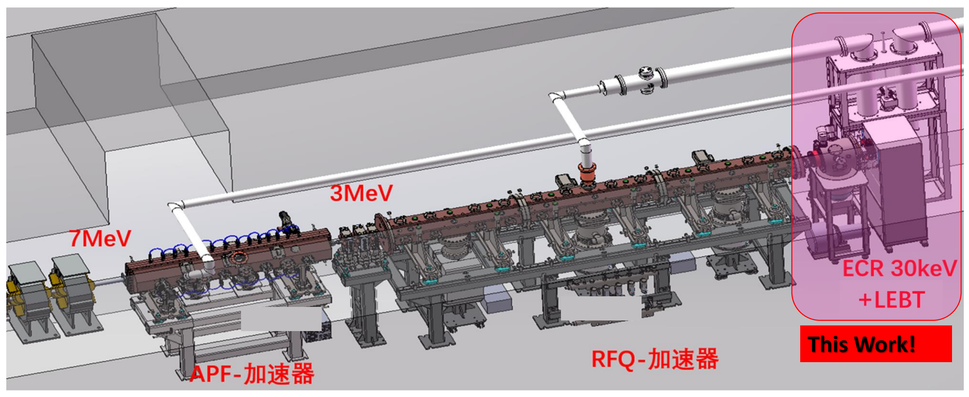
Abstract To meet the requirements of a Proton Therapy Facility funded by National Key Research and Development Program of China, a new compact ion source-LEBT integrated proton injector was developed at Peking University (PKU). It consists of a typical PKU permanent magnet compact 2.45 GHz ECR ion source (PMECRIS) and an electrostatic LEBT (low energy beam transport) with an electrostatic lens, a beam chopper, a set of beam steers, an ACCT, a bellow, an e-trap and a valve. A 1200 L/s molecular pump is adopted to maintain the vacuum for this integrated injector. The total length from RF matching plane to RFQ front flange is about 450 mm. Chopper is used to shorten the pulse length from ms to μs with sharp edges. Test results of this PMECR source prove that it has the ability of delivering a proton beam with current from 10 mA to 90 mA with duty factor of 3%(100Hz/0.3ms) and its rms emittance less than 0.1π mm·mrad at 30 keV. The acceptance tests of this integrated injector have been performed with a 30 keV hydrogen beam. A required proton current of 18 mA with ripple wave less than ±0.1 mA successfully passed through a Ø20 mm aperture diaphragm at RFQ entrance flange. Its rms emittance is about 0.06 π mm·mrad.

1.Motivation



Overall View of the Proton Treatment Device at Shanghai Ruijin Hospital.

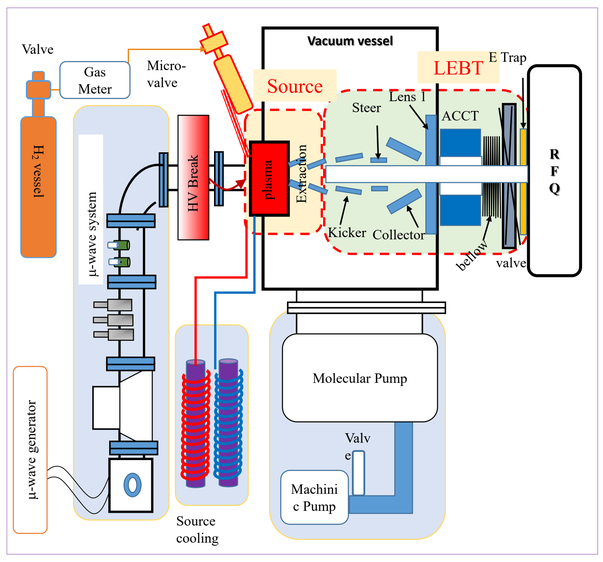


The Schematic View of this 7 MeV LINAC

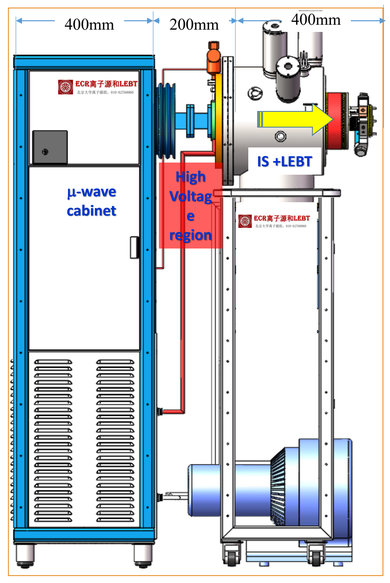
2. Proton injector setup

Table: Parameters required by this LINAC

Content		Parameters	Unit	Mothed
Ion type		H^+		H_2
Energy		30±0.1	keV	PKU PMECRIS + Electrostatic Lens
Peak Current	Ion source	20~30	mA	
	LEBT	>18	mA	
Beam stability(LEBT)		±1	mA	
Emittence (RMS, Norm)		≤0.2	π mm·mrad	
Repeat frequency		0.5~10	Hz	Pulsed Plasma + Kicker
Pulsed Length		40~100	μs	
Raise edge		≤2.0	μs	

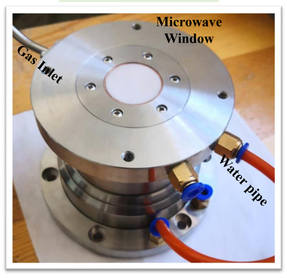


The diagram of proton injector



3. Details of this proton injector

Source body



- **Source Body**

PKU Compact Permanent magnet 2.45GHz ECR ion source.

Outside Dimension: ϕ100 mm × 100 mm

- **Extraction System**

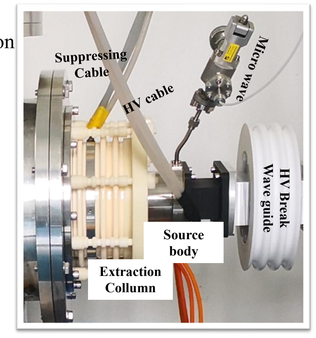
A three-electrodes system.

Outside Dimension: ϕ200 mm × 110 mm

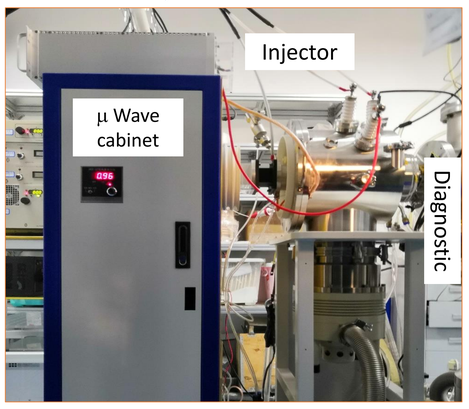
- **Integrated source**

Outside Dimension: ϕ200 mm × 150 mm

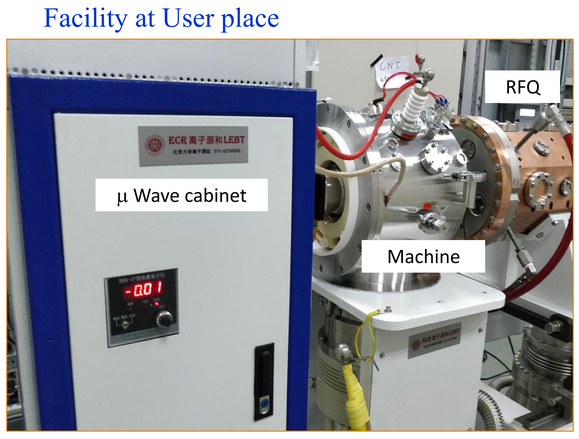
Integrated source



Facility at PKU



Facility at User place



4. Commissioning Results

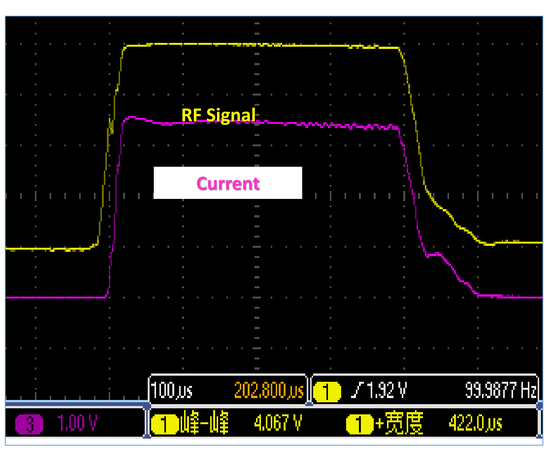
➢ Results from Ion Source

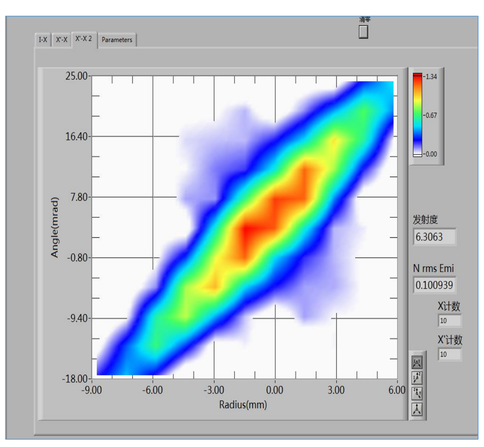
- **Operation Parameters**

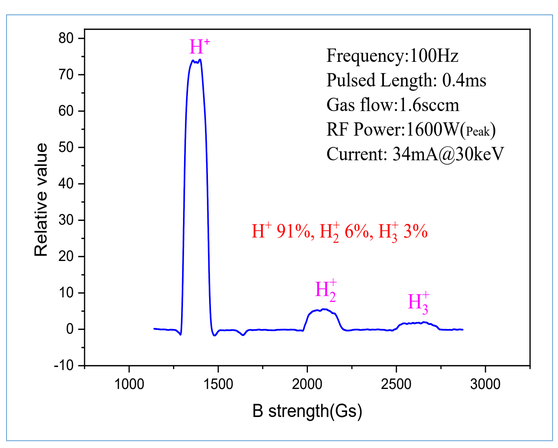
Frequency: 100 Hz
Pulse Length: 0.3 ms
Gas flow：0.7sccm-2.3sccm
Extraction Voltage:30 kV
Suppressing Voltage: -2 kV

- **Test results**

10 mA to 90 mA
rms emittance is ~0.1π·mm·mrad
H+ faction:>90%







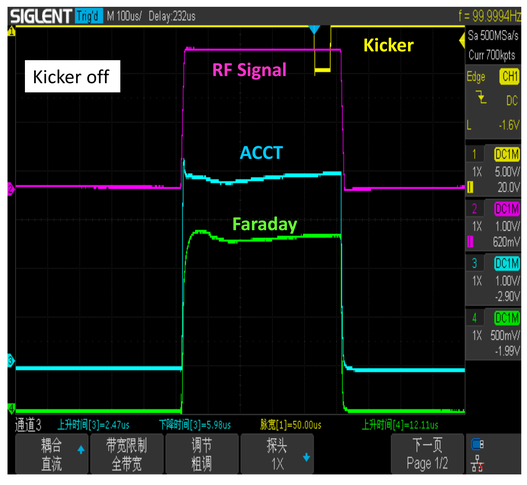
➢ Results at the entrance of RFQ

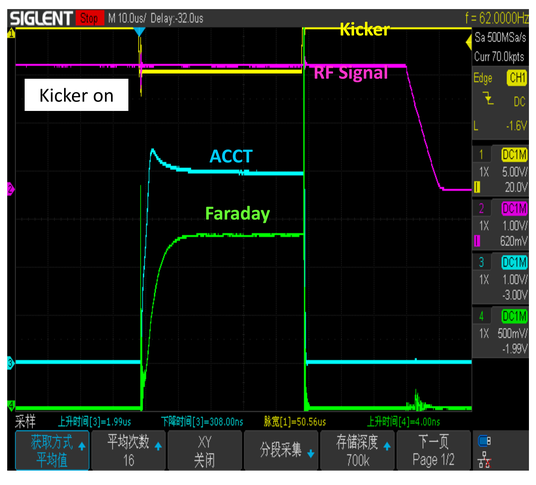
- **Setting Parameters:**

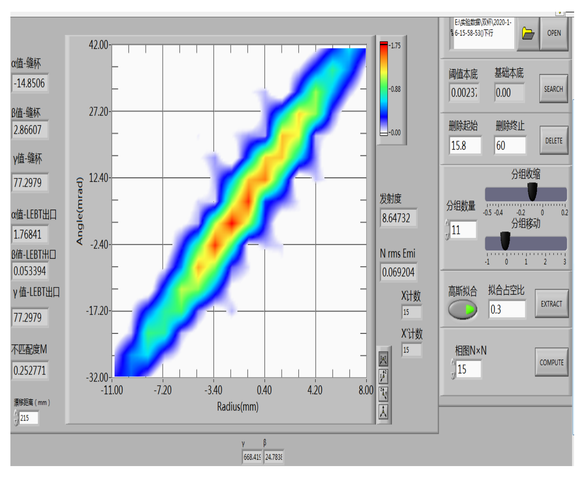
Frequency： 0.5 Hz to 100 Hz
Pulse length before chopper : 0.3 ms - 1ms
Pulse length after chopper: 40 μs - 100 μs
RF power(peak): 1 kW to 2.6 kW
Gas mass flow: 0.7 sccm to 2.3 sccm
Extraction Voltage: 30 kV
Suppressing Voltage: -2 kV

- **Commissioning Results**

Current at ACCT: 10 mA to 30 mA.
rms emittance: < 0.1π·mm·mrad
beam rise edge: < 2 μs.
Beam transmission efficiency: > 95%.
No steer is needed for beam calibration.







5. Summary

A proton injector was developed at PKU for P-RT facility. It was based on a combination of a PKU type compact permanent magnet 2.45 GHz ECR ion source and an E-LEBT. Beams produced by this injector match the requirement of RFQ facility. RFQ commissioning in on the way.

Acknowledgment

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