Intense Ion beam Source and LEBT for JUNA Project

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Outlines

- Background and significance
- Design and fabrication of Ion source and LEBT
- Preliminary commissioning results
- Future work plan

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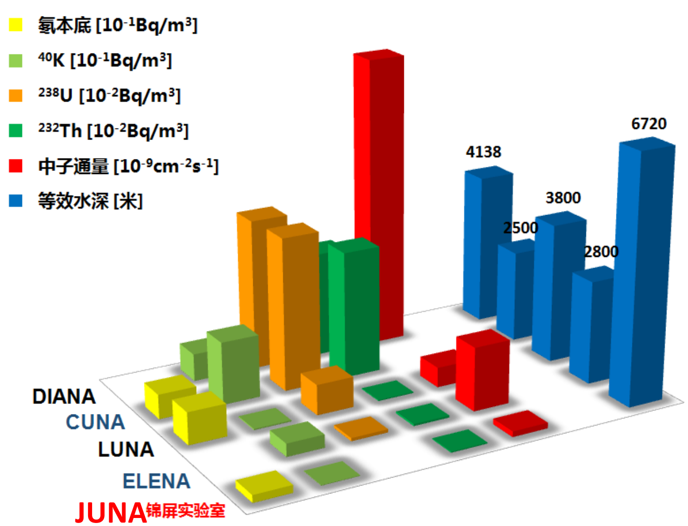
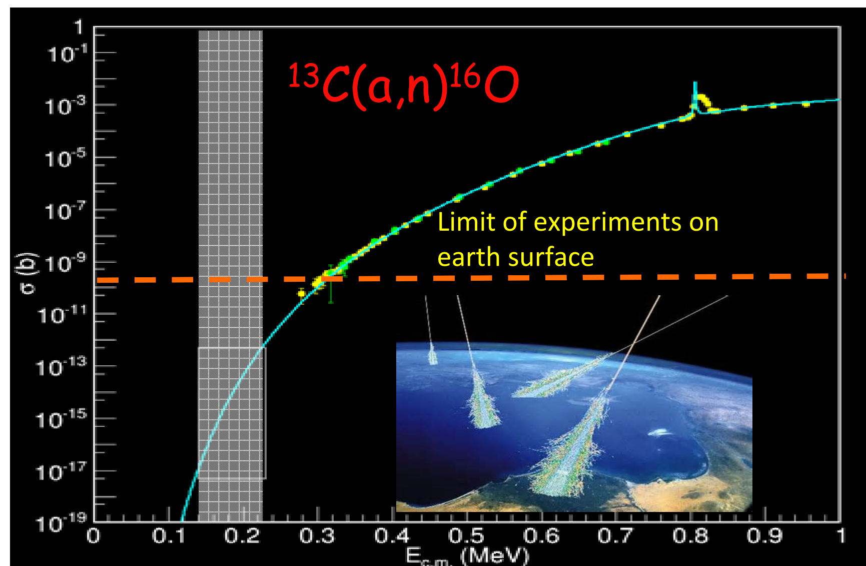
Background and Significance

Key reactions of very low cross sections at stellar energy :

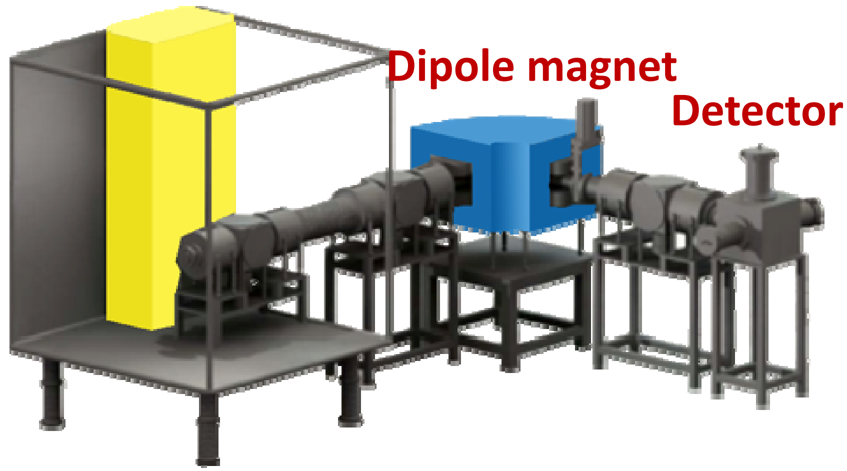
- $^{12}C(\alpha, \gamma)^{16}O$
- $^{13}C(\alpha, n)^{16}O$
- $^{25}Mg(p, \gamma)^{26}Al$
- $^{19}F(p, \alpha)^{16}O$



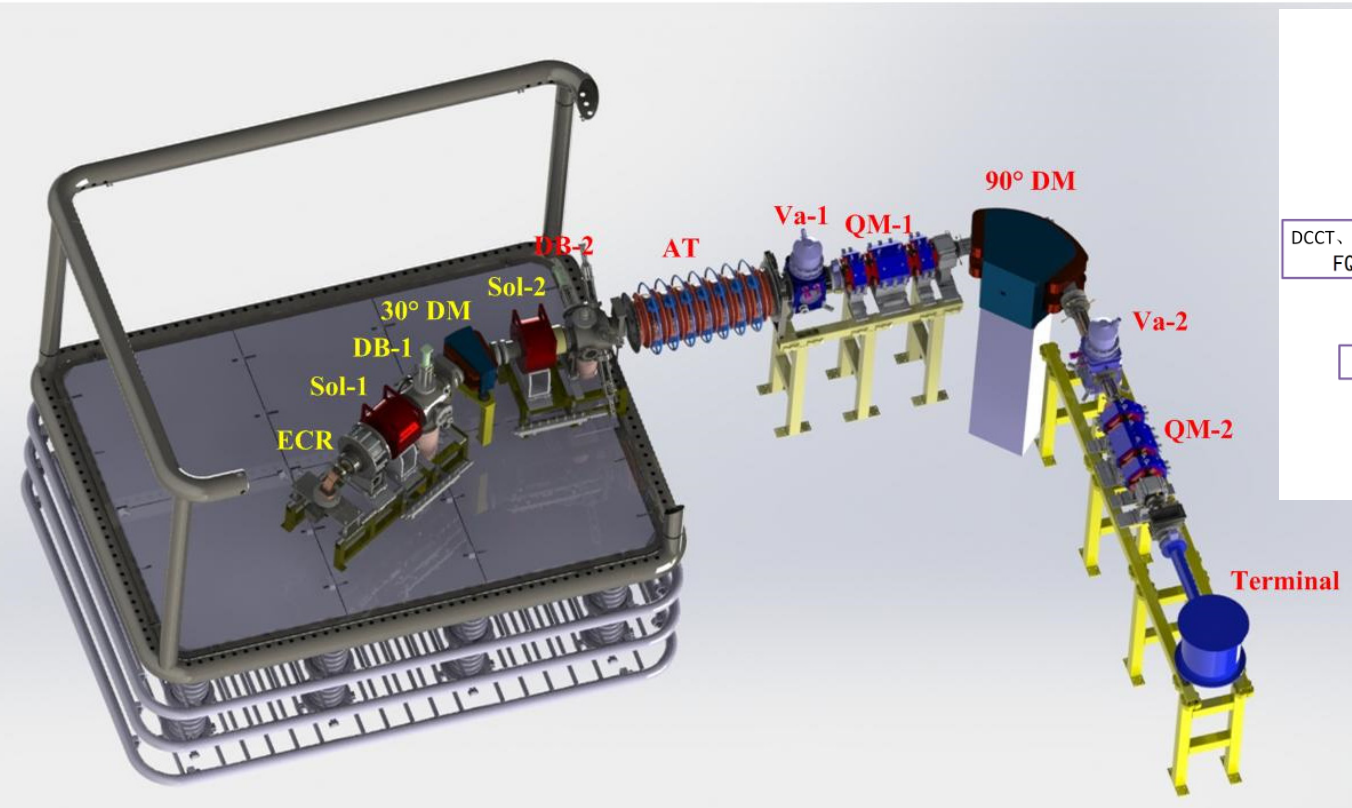


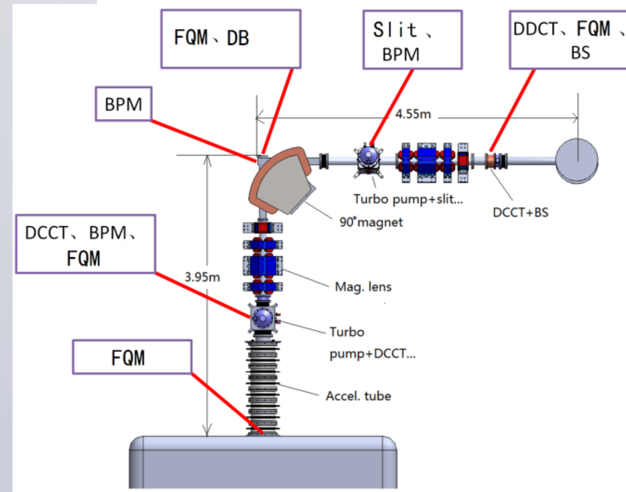
Project Challenges

- **Production of intense He^{2+}**
- **Control of beam contaminations**
  - Unwanted beams of same M/Q
  - Radiation caused by lost beam
- **Construction of the platform for underground operation**
- **Wide energy beam transmission**
  - 70~800 keV



Accelerator design



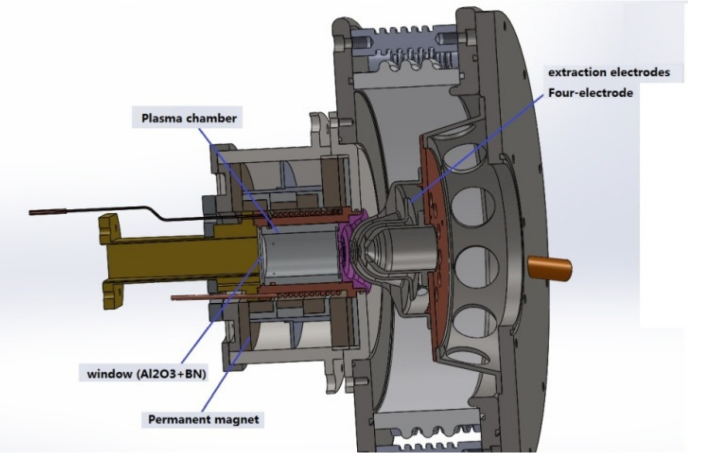


Beam Diagnostic Units

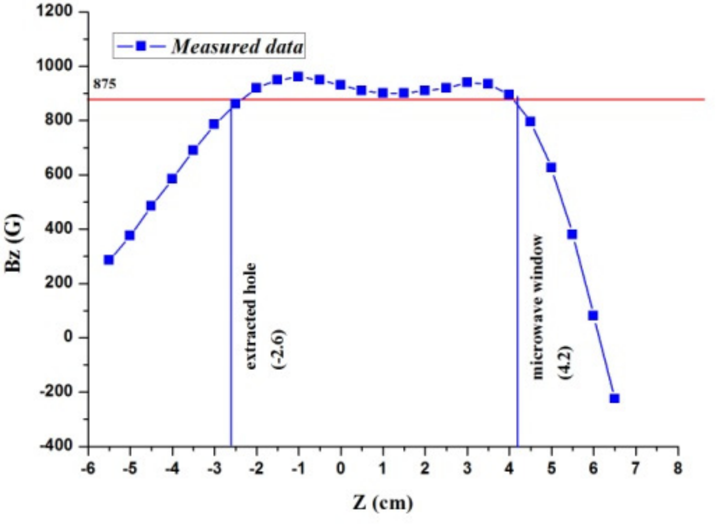
		JUNA 400 kV accelerator	LUNA 400 kV accelerator	DIANA 400 kV accelerator	CASPAR project
Source type		2.45 GHz ECR source	RF source	2.45 GHz ECR source	RF source
Beam currents	H^+	10 mA	1 mA	100mA	0.1 mA
	He^+	10 mA	0.5 mA	50mA	0.1 mA
	He^{2+}	2.5 emA			
Beam energy		70~800keV	20~400keV	50~400keV	1MeV

Ion source and LEBT design

Parameters	Values
Beam Energy (keV/q)	30~50
Frequency (GHz)	2.45
P_{rf} (kw)	0.3~1.5
Extraction system	3-electrode
n.rms emittance (π.mm.mrad)	<0.2
Beam Intensities (emA)	
H^+	> 10
He^+	> 10
He^{2+}	~2.5

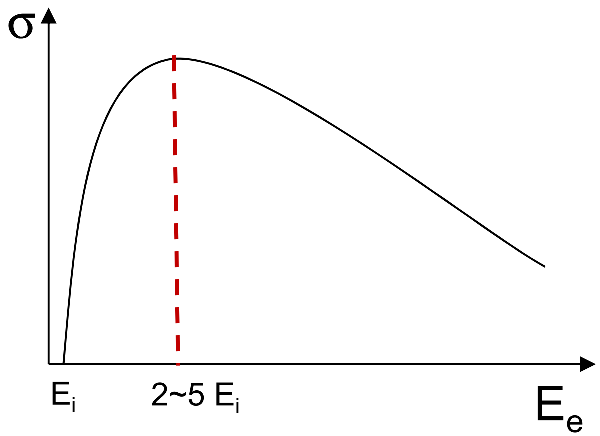


- **Conventional Design**
- high performance NdFeB N50M
- ID=Ø120 mm， OD=Ø 144
- Plasma chamber: Ø50 mm╳70mm



Axial field distribution of the ion source

Ion source and LEBT design



He^{+} generation:

e + He→ He^{+} +2e

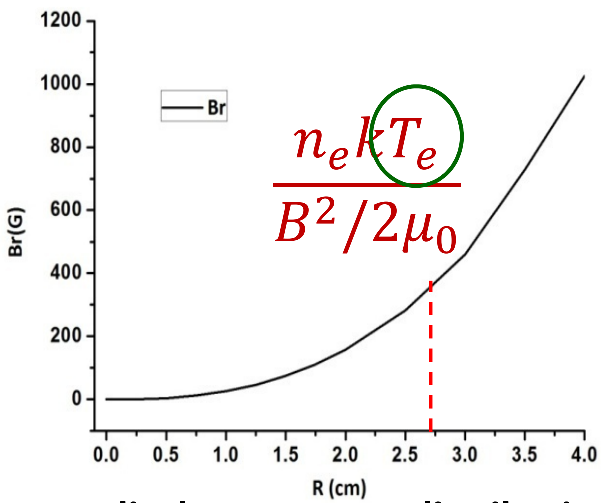
E=24.6 eV

He^{2+} generation:

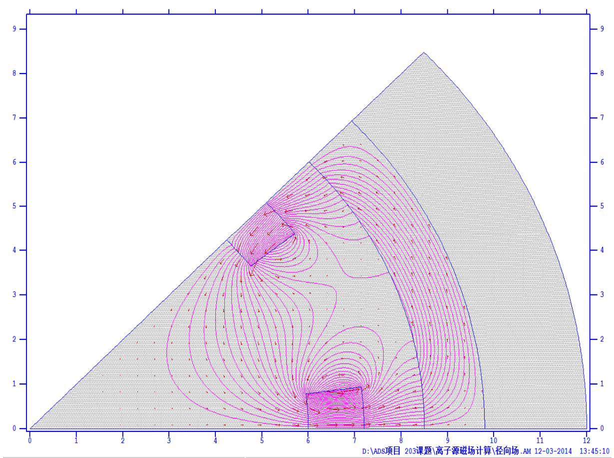
e + He^{+} → He^{2+}+2e

E=54.4 eV

He^{2+} production: $Te_{opt.}$ ~ 100-200 eV



Radical component distribution



1/8 Octupole magnet simulation

➤**Solution:**

- **Radial magnetic confinement to enhance T_e, and enhance the production of He^{2+}**
- **Flexibility in structure design: Octupole magnet could be disassembled**

Ion source and LEBT design

Perspectives in LEBT Design:

- Beam optics matching for Downstream Accelerator-Acc. Column
  - High transmission efficiency
  - Beam optics
    - 2 sets of correctors for beam errors
    - 2-solenoid→Twiss parameters control
    - 30~50 kV extraction HV for different Acc. Column HV
- Minimize contamination
  - 30° dipole magnet
    - Dump unwanted beam at low energy and far away from target area
    - Minimize beam loss of unwanted beam in Acc. Column
  - Water cooling beam dump
- Lower the platform current load
  - Separate He^{2+} from He^{+}
- Beam diagnostics and control for experiments
  - Beam quality
  - Beam intensity

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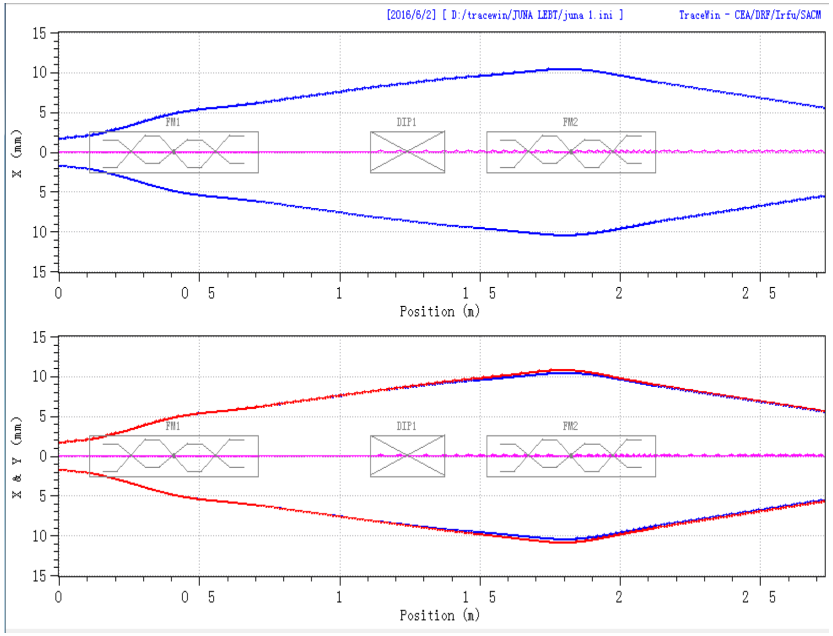
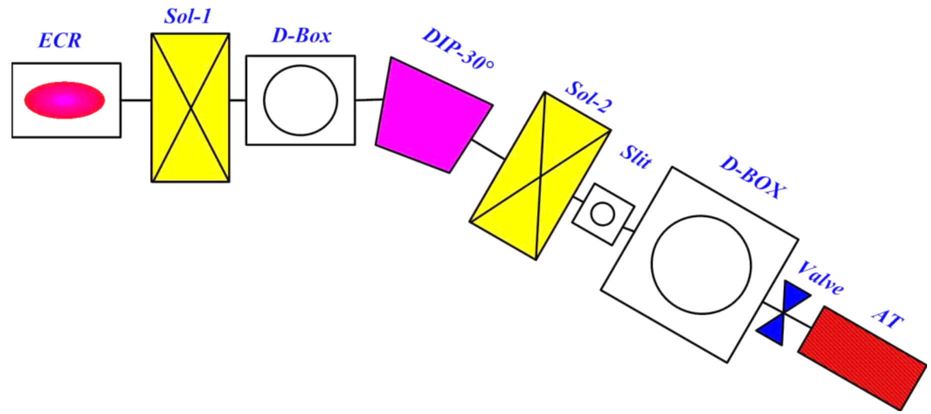
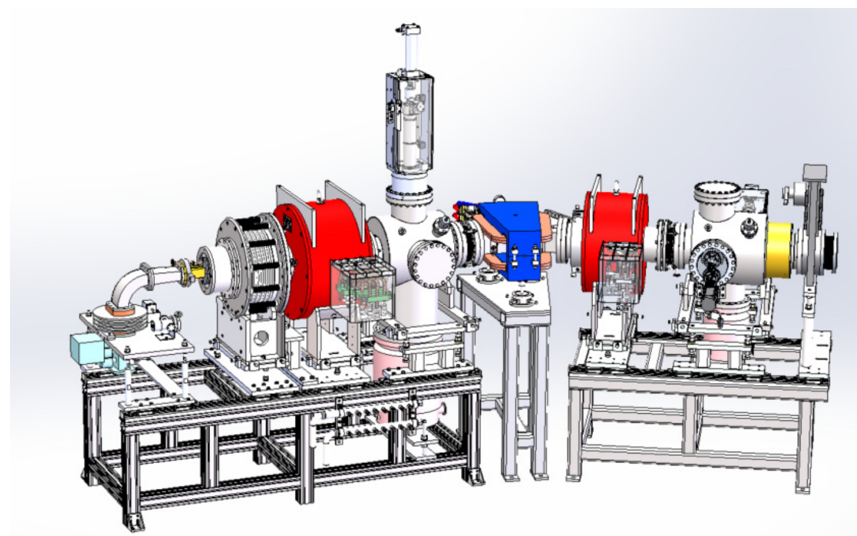
Ion source and LEBT design



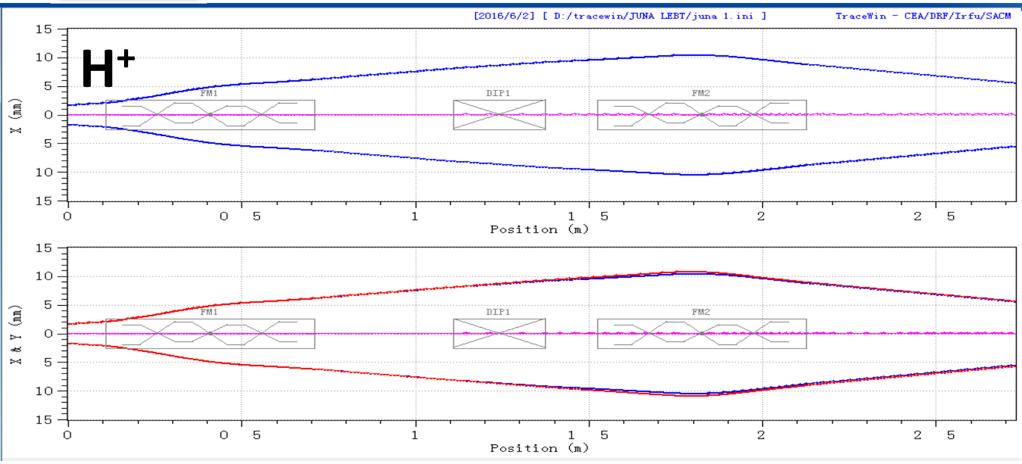
10 emA H^+@50 keV

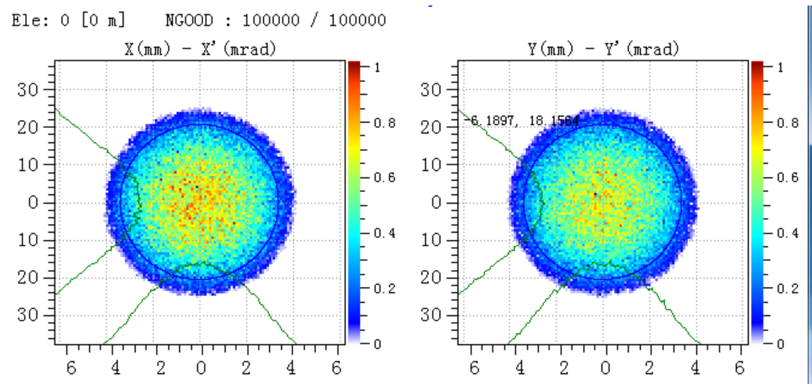




Layout of ion source and LEBT

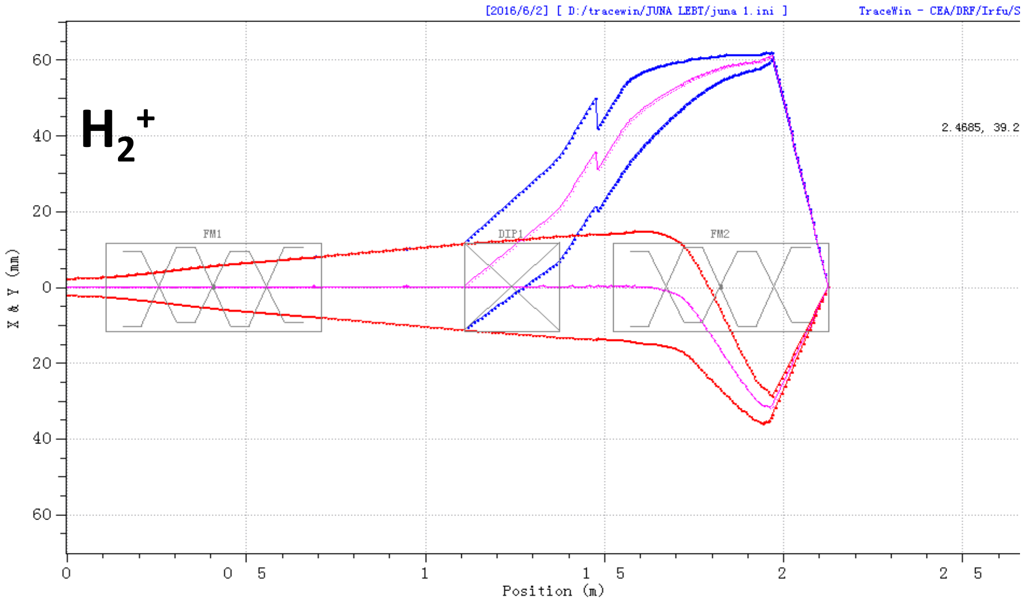
Simulation of LEBT-proton beam



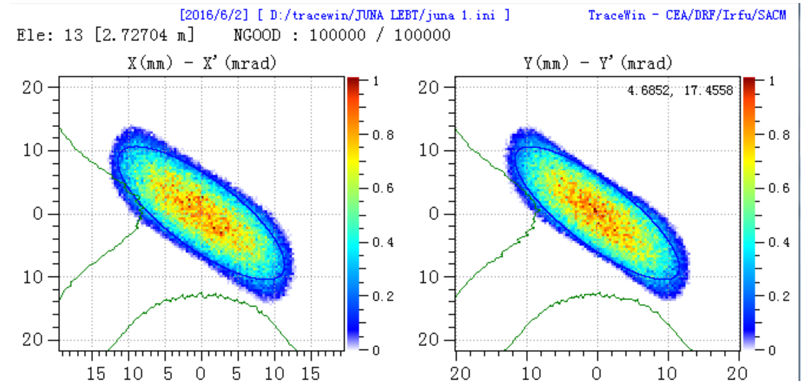


➢Initial parameters α=0 β=0.165 mm/mrad,

ε_{NRMS}=0.18 π mm.mrad, SCC=90%



➢Tracewin calculation for filtering H_2+ particle out of 10emA H^+ beam

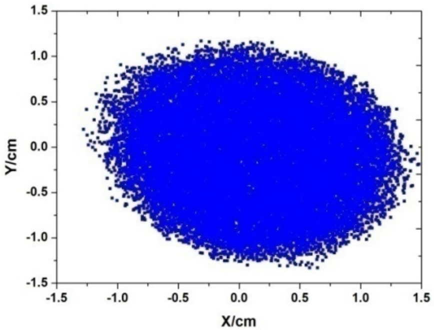


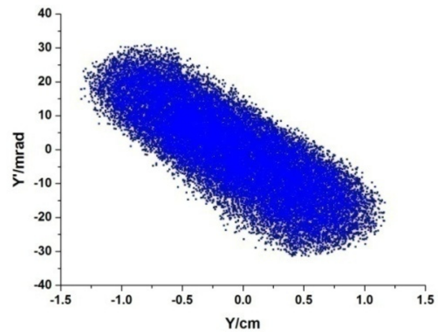
➢2-D emittance of proton beam at the LEBT exi

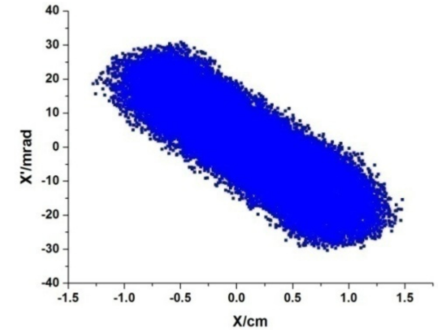
•α=1.22, β=1.63 mm/mrad,

ε_{NRMS}=0.195 π mm.mrad

Simulation of LEBT-He^{2+} beam



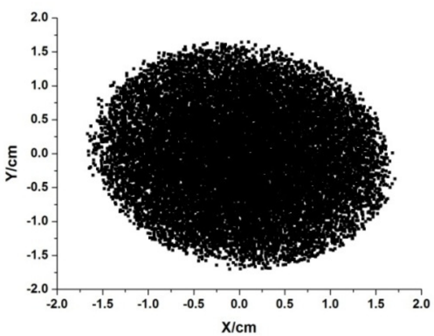


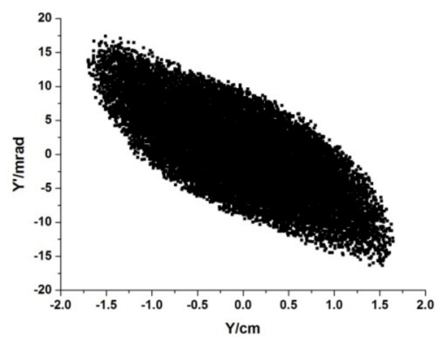


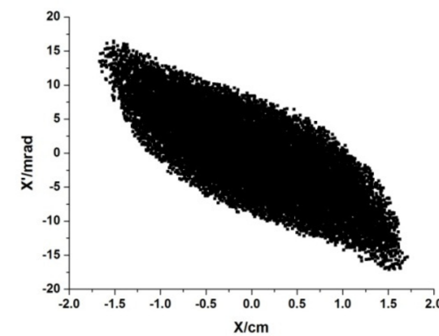
➢Trace particle He^{2+}, energy 30kV, 90%, B sol1=2310G,Bsol2=1550G

X α=1.49, β=0.08 cm/mrad,4ε=0.086 cm.mrad

Y α=1.34, β=0.07 cm/mrad,4ε=0.092 cm.mrad





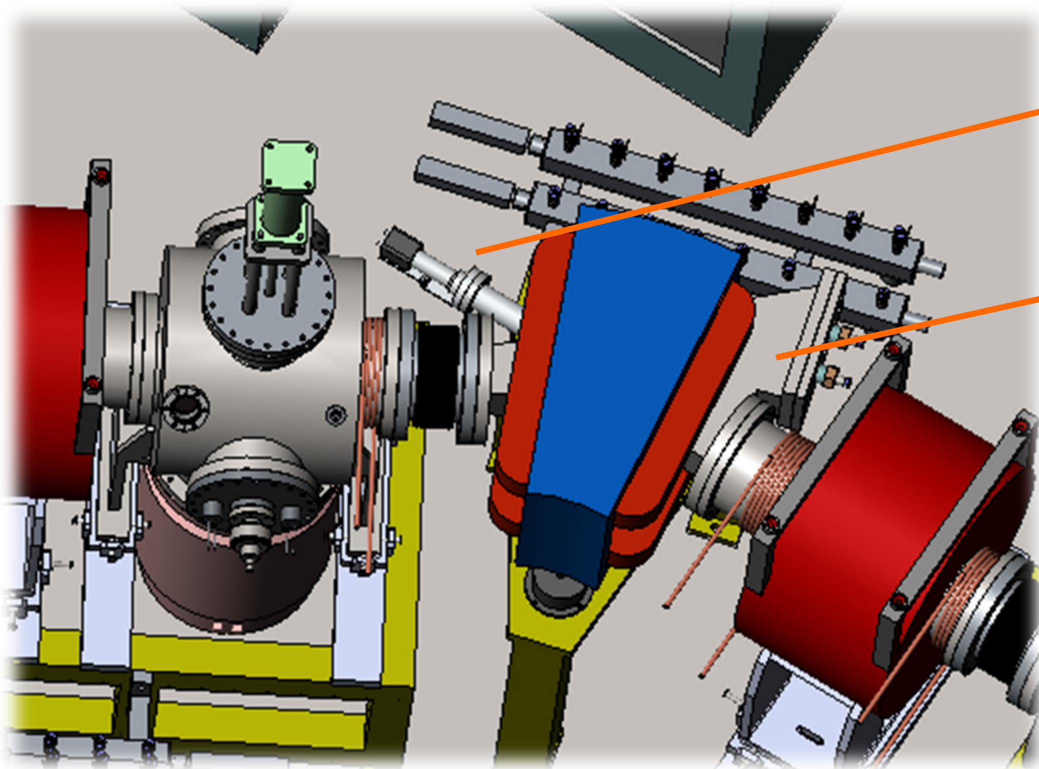


➢Trace particle He^{2+}, energy 50kV, current=5emA, 90%, sol-1=3830G,S2=2690G

X α=1.2, β=0.18 cm/mrad,4εrms=0.079cm.mrad

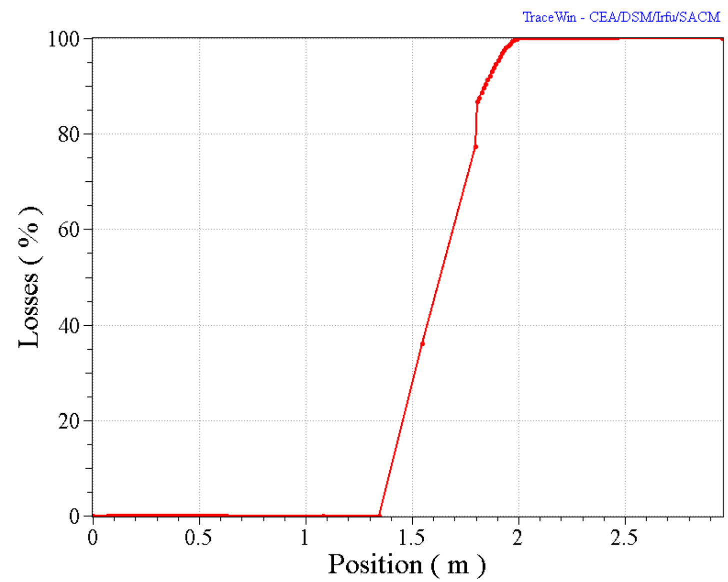
Y α=1.10, β=0.17cm/mrad,4εrms=0.084 cm.mrad

Ion source and LEBT design



Filtering beam contaminants:

- D^+ out of H^+ beam
- He^+ out of He^{2+} beam

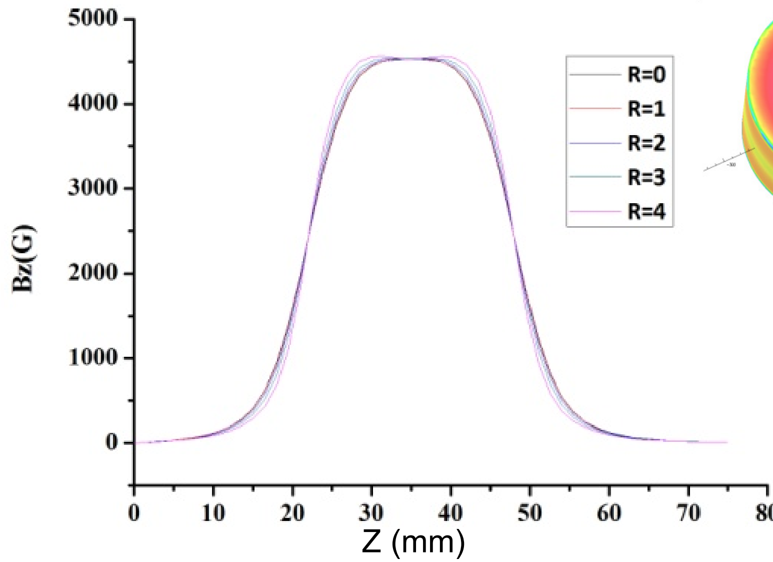


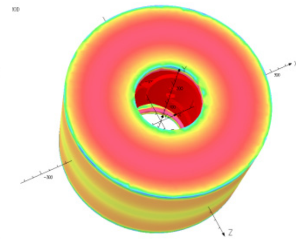
Unwanted beam loss simulation

Ion source and LEBT design

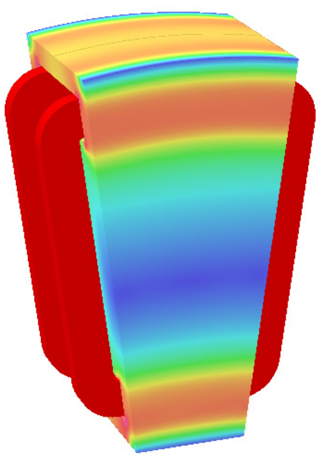
Solenoid Design:

- Large bore design
- Minimize spherical aberration
- Corrector coils integrated





Axial fields $B_z(z,r)$ at radii of 0-4cm for the solenoids

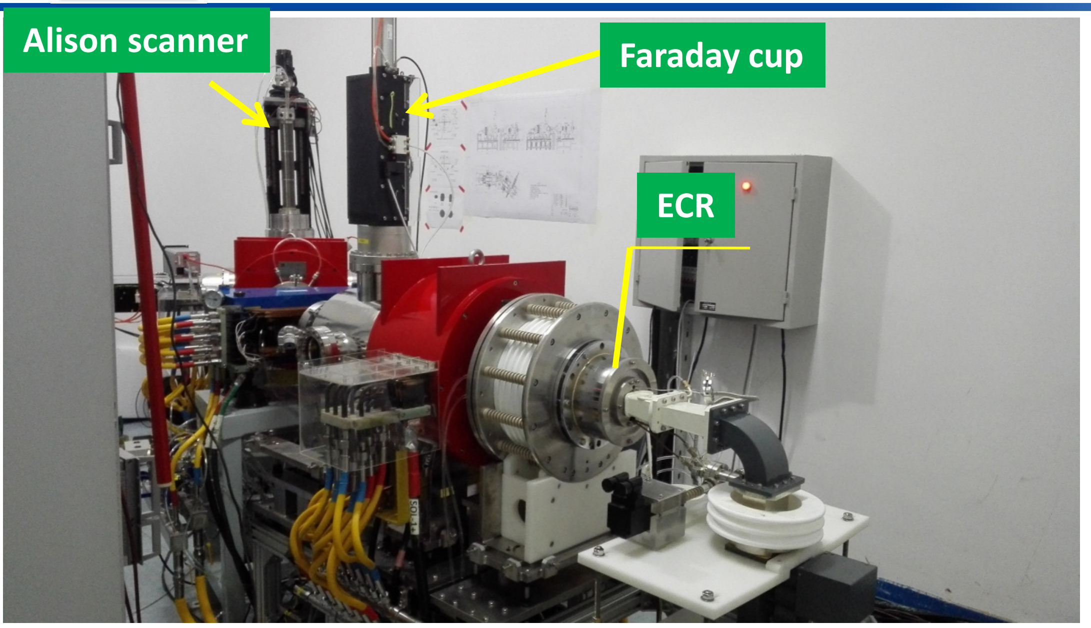


H type dipole
Bending angle: 30°
Radius: 510mm
Good field: ±75mm
Edge angle: 7.5°
Max magnetic intensity: 1400 G
Integral length: 268 mm
Air gap : 100 mm
Uniformity of integral field: ±1.5/1000

Dipole Magnet

- Compact
- Less influence to beam quality
- Accommodate to platform size

Fabrication of the ion source and LEBT



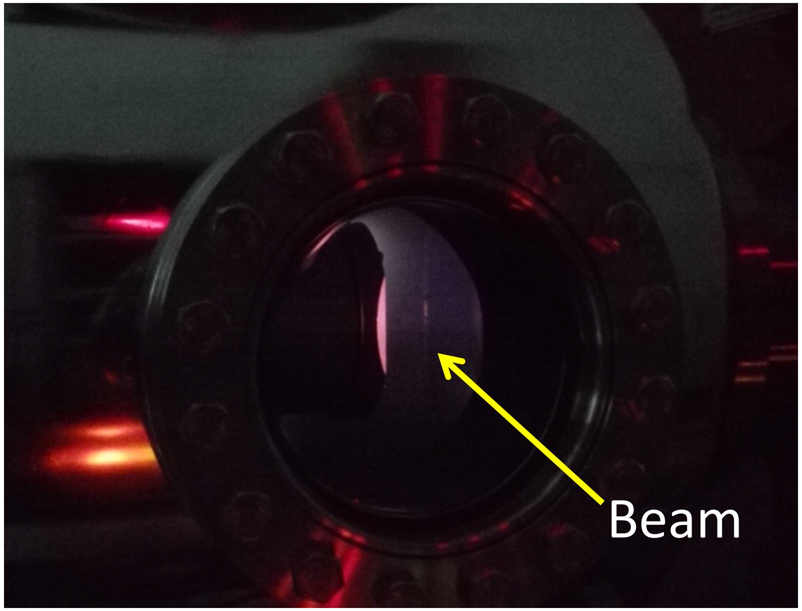
➢LEBT

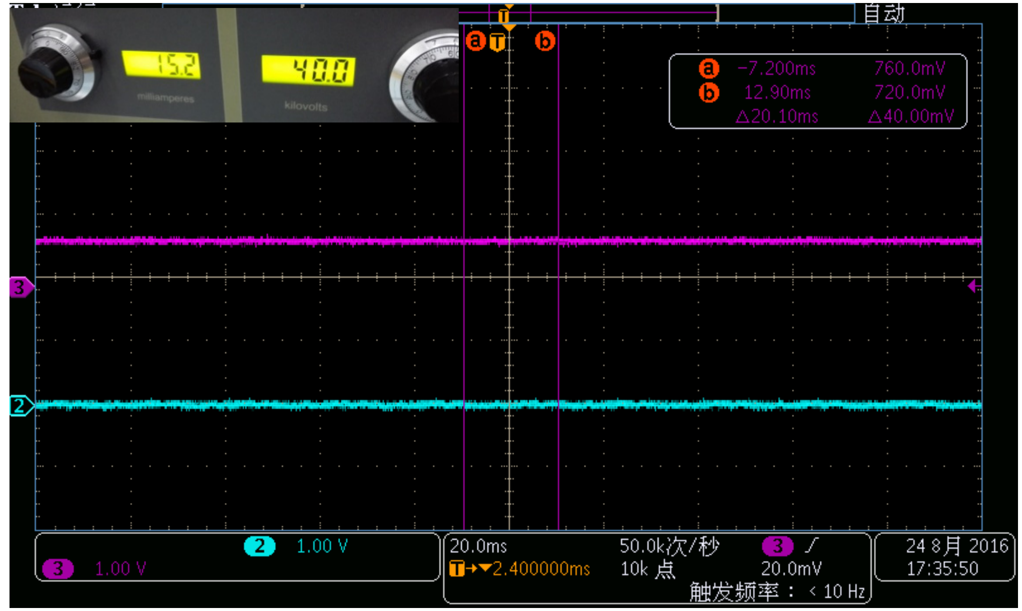
- Two solenoids ,two diagnostic boxes, one 30 degree analyzing magnet and one set of slit
- July 20th , the alignment of LEBT was finished
- August 9th, the first beam , total beam current is 15emA

➢ECR ion source

- Compact all-permanent magnet
- Apr. 20th , integrated the source body
- June 9th, discharge chamber assembly

Commissioning results





➢View of helium beam through the quartz window

➢Current waveforms of the extraction beam measured with FC unit

- Operated in CW mode
- Total beam 15.2 mA/40kV
- Extraction hole of 5mm

Future work plan

- The beam emittance for x-x’, y-y’ at the LEBT exit will be tested in Lanzhou at the end of oct. 2016
- The ion source and LEBT will be fabricated and tested in Beijing in the middle of November, 2016
- The underground commissioning of the accelerator will be in the Jun. 2017

Summary

- The present development of Ion Source and LEBT can meet the basic requirements of JUNA Project
- The LEBT design is flexible and feasible for the project purposes
- Backup plan for He^{2+} production is made
- The first commissioning of the 2.45GHz and LEBT for JUNA was in AUG. 2016.
- The 16emA He beam was produced with the energy of 50kV
- Specific issues need to be address:
  - Beam current of He^{2+}
  - Beam quality for experimental needs

Thanks for your attentions!