Performance of the Low Charge State Laser Ion Source in BNL

Masahiro Okamura, James Alessi, Edward Beebe, Michael Costanzo, Leonard DeSanto, James Jamilkowski, Takeshi Kanesue, Robert Lambiase, Daniel Lehn, Chong-Jer Liaw, Daniel McCafferty, John Morris, Robert Olsen, Alexander Pikin, Deepak Raparia, Andrew Steszyn, Shunsuke Ikeda (BNL, Upton, Long Island, New York)

LIS has been spoken badly: poor stability
uncontrollable emittance

What is “laser ion source”?

Are these really true??

Or just deceitful rumors??

Stability of an ion source

Stability of plasma heating process

Material of chamber

Gas pressure

Micro wave

Laser

Seeding gas

Magnet stability

Oven temperature

Target

Electron stream

Discharge

Magnetic field

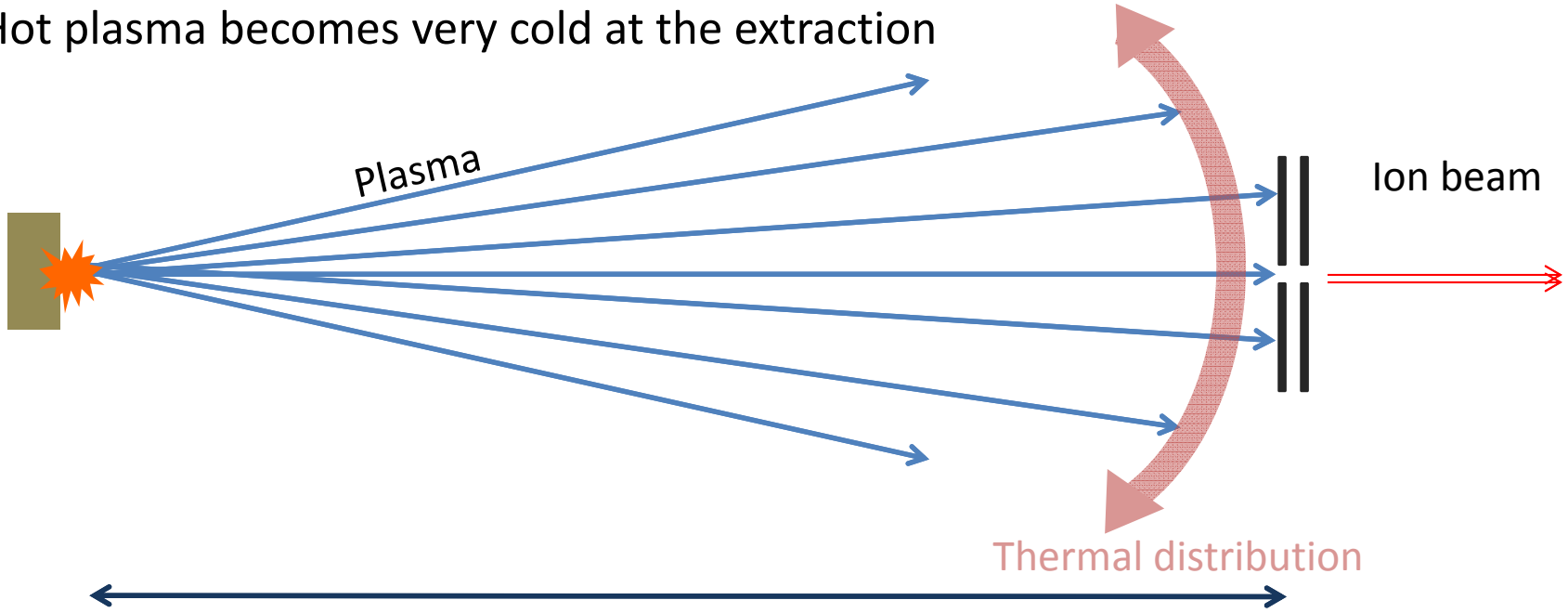
Drift tube voltage

We need just two actors in the play.
Laser & target

Emittance (brightness)

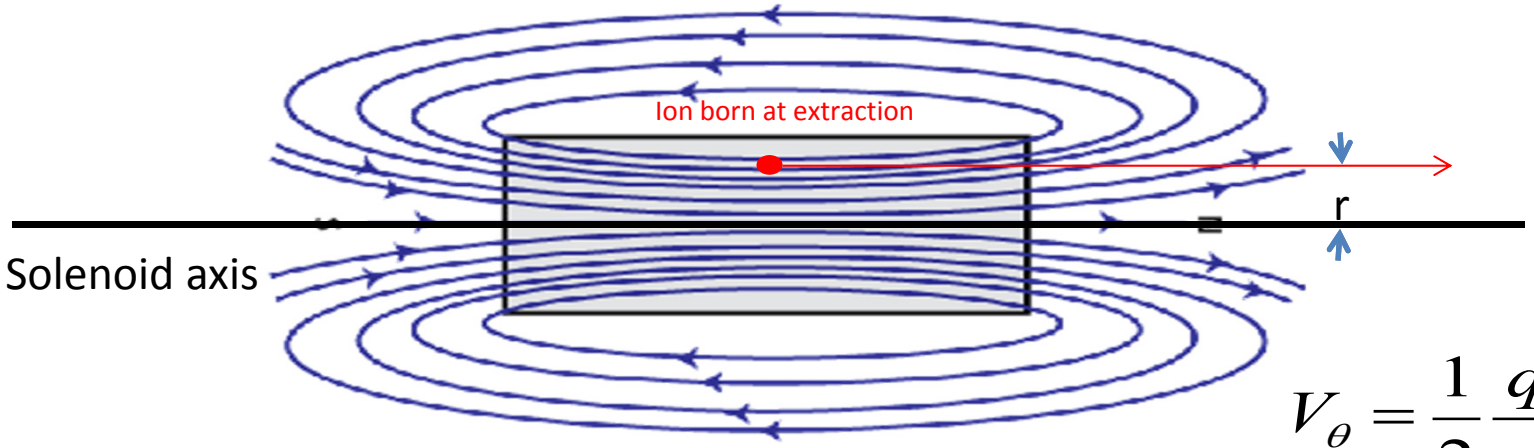
- Plasma temperature
- Magnetic field at extraction
- Uniformity of plasma at sheath

Hot plasma becomes very cold at the extraction



7.5 mm / 3300 mm → 0.13 degree

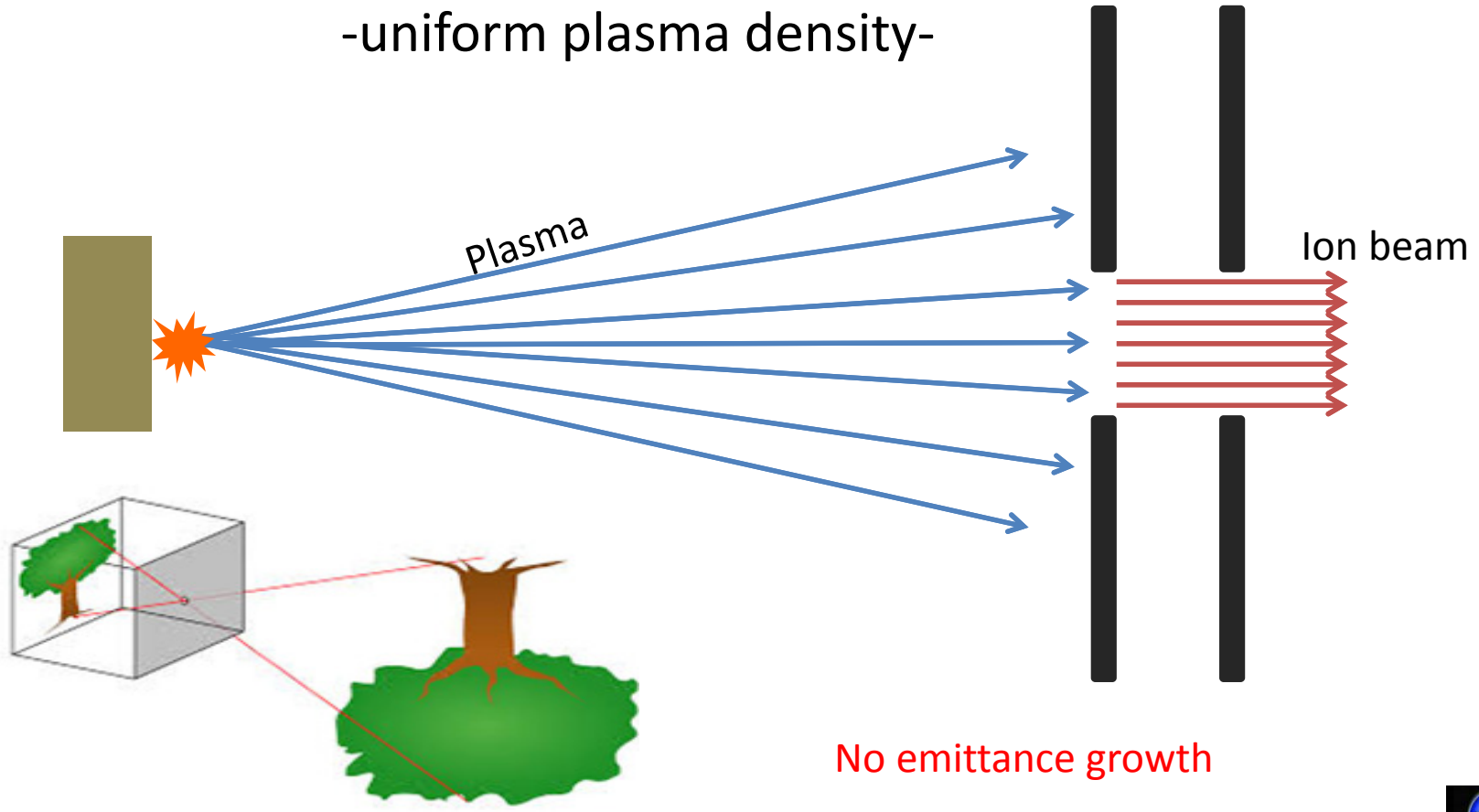
Magnetic field at extraction point increases emittance.



$$V_\theta = \frac{1}{2}\frac{q}{m} B_z r$$

No magnetic field in laser ion source

Pin point ionization
-uniform plasma density-



No emittance growth

BROOKHAVEN NATIONAL LABORATORY

NASA

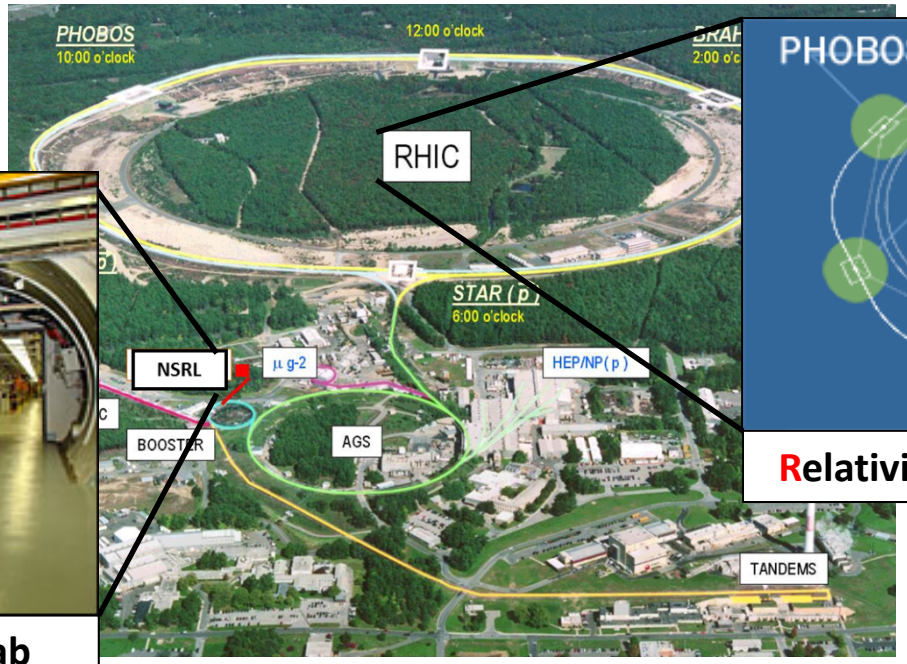
Laser ion source provides stable high brightness heavy ion beams.

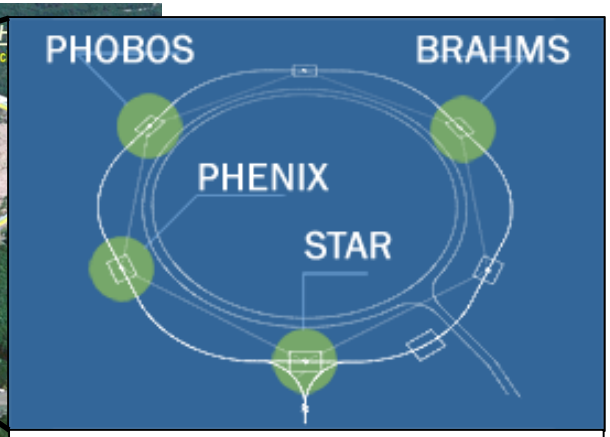
Time line of the project named as LION

2007 Stable production of Low charge state beam was established.
2009 The project was approved by NASA. Solenoid guiding filed was tested.
2010 Funded. RHIC-EBIS was completed.
2014 The first beam was delivered to EBIS.
2015 Upgraded to provide beams to NSRL and RHIC simultaneously.

We are providing beams to

NASA Space Radiation Lab

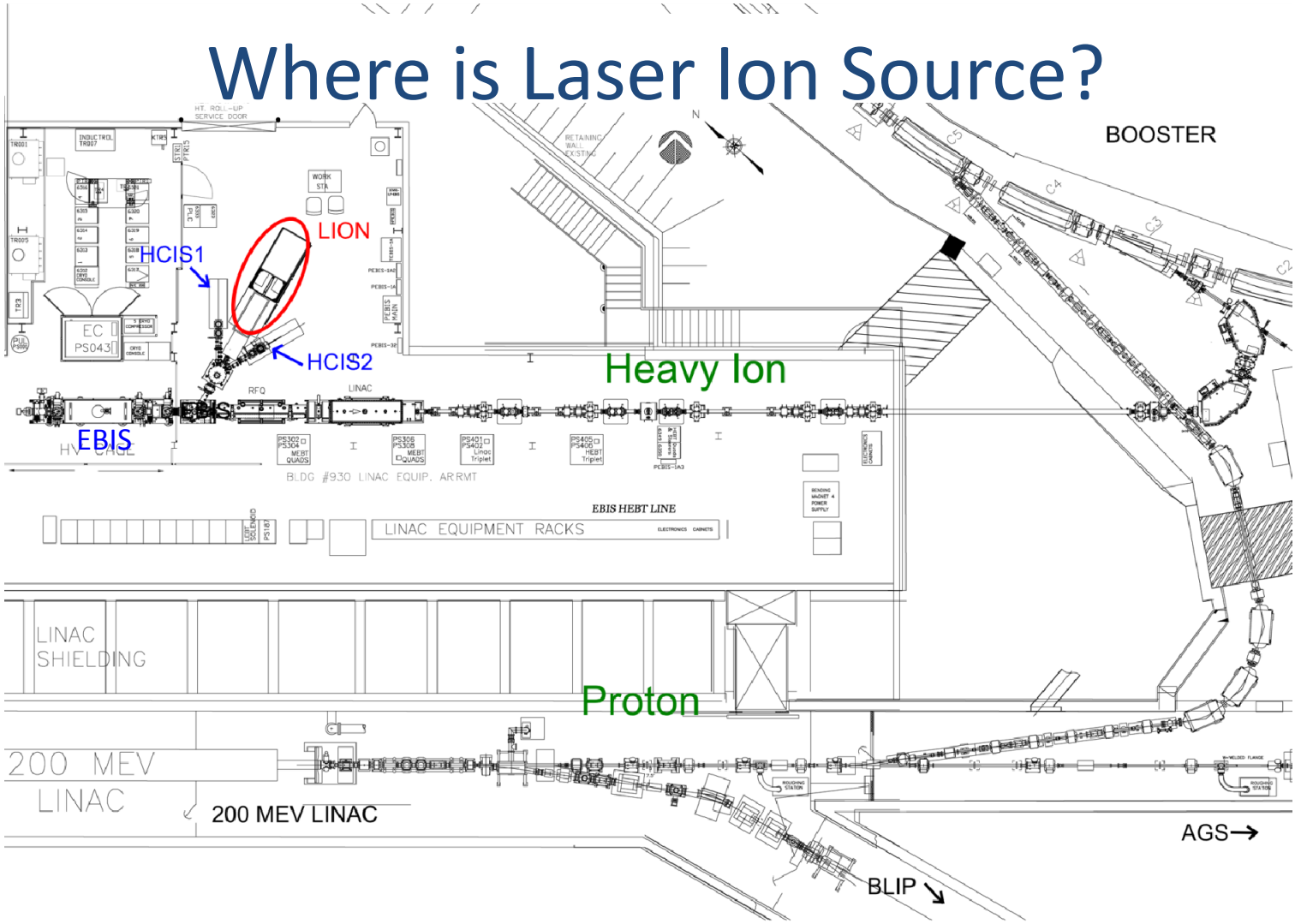




Relativistic Heavy Ion Collider

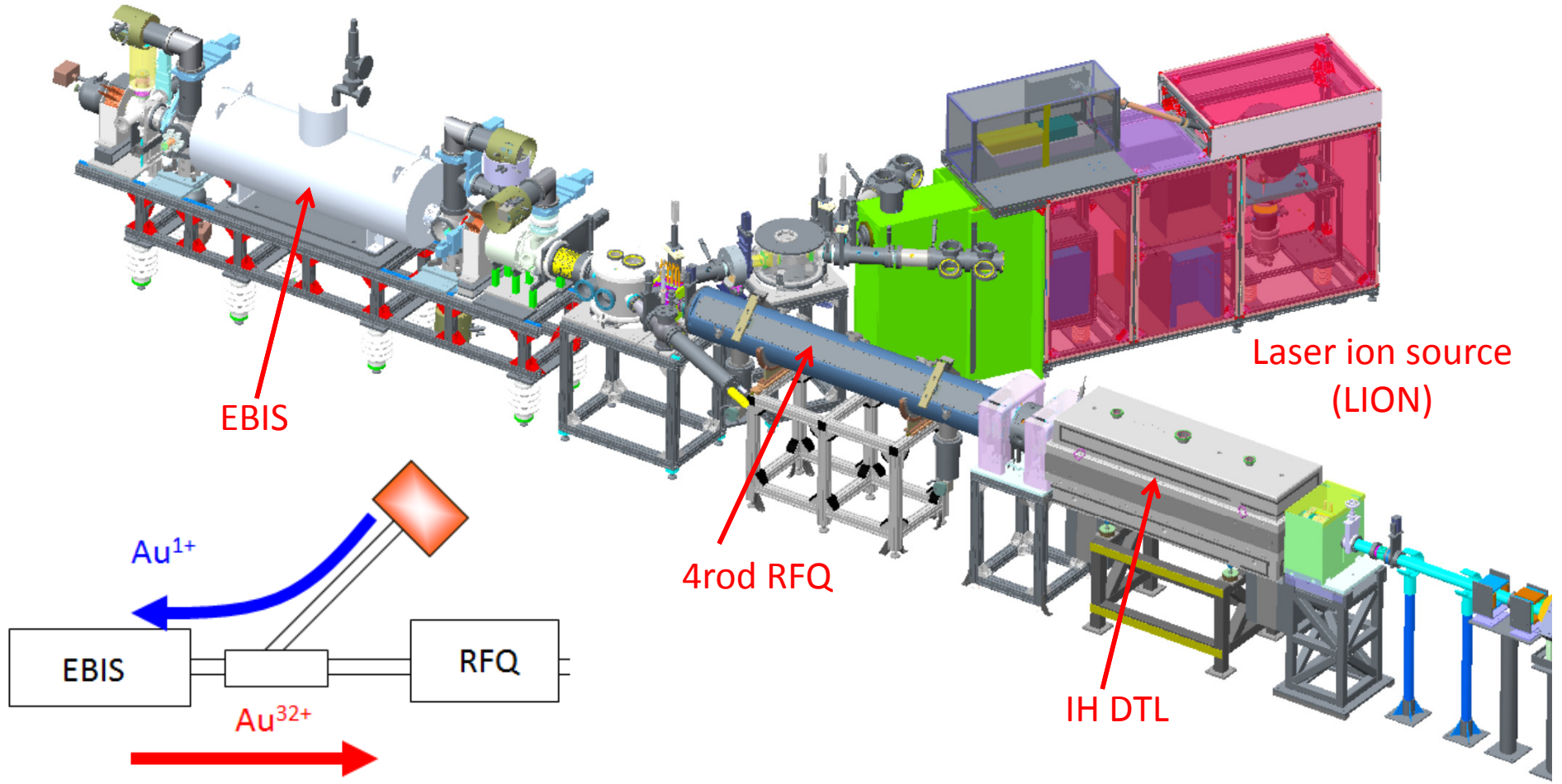
	NSRL	RHIC
For what?	Simulate galactic cosmic rays	Create quark gluon plasma
species	All kinds of cosmic rays	Au
energy	Fe ~1GeV/n	100GeV/n

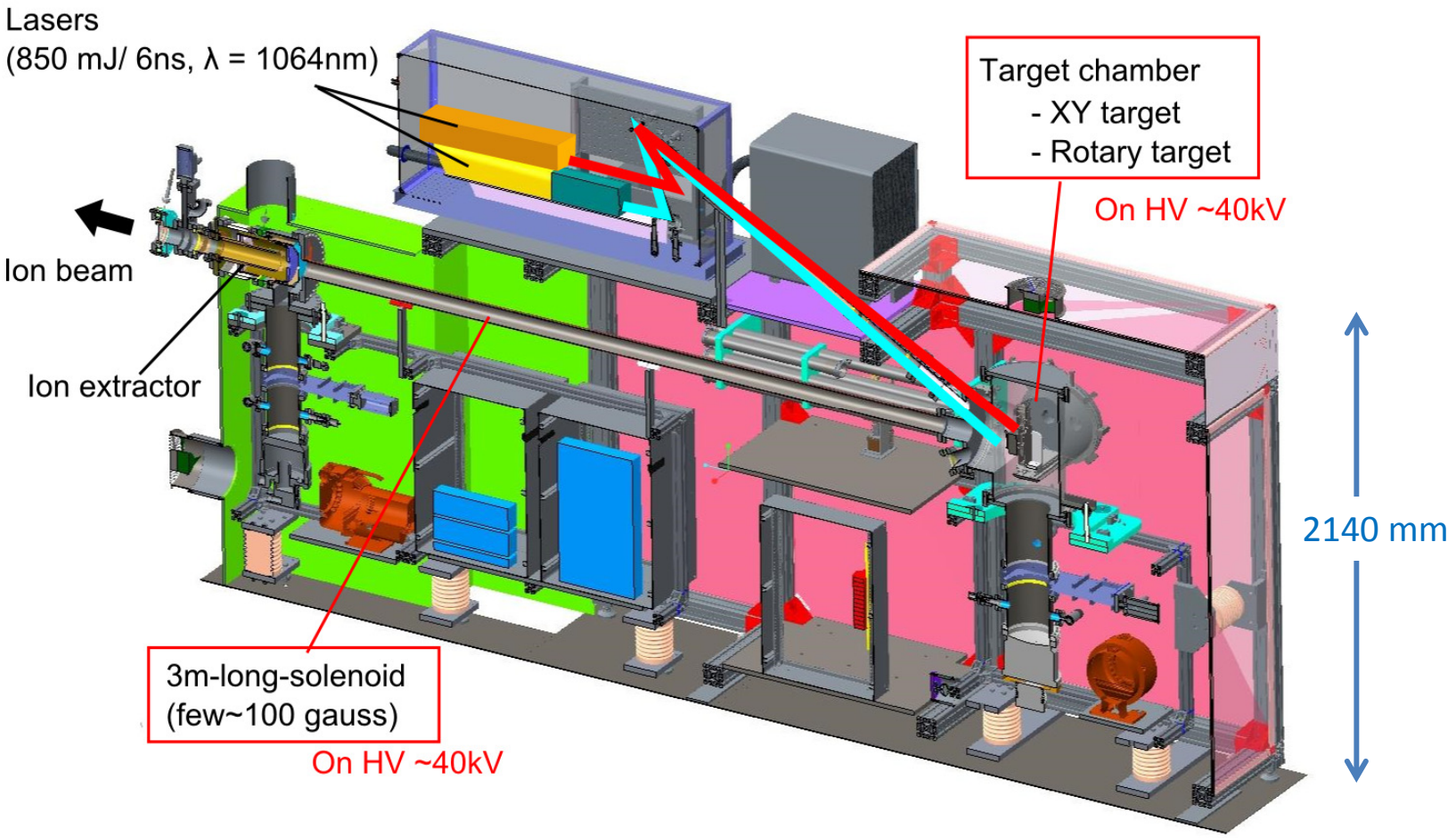
Where is Laser Ion Source?



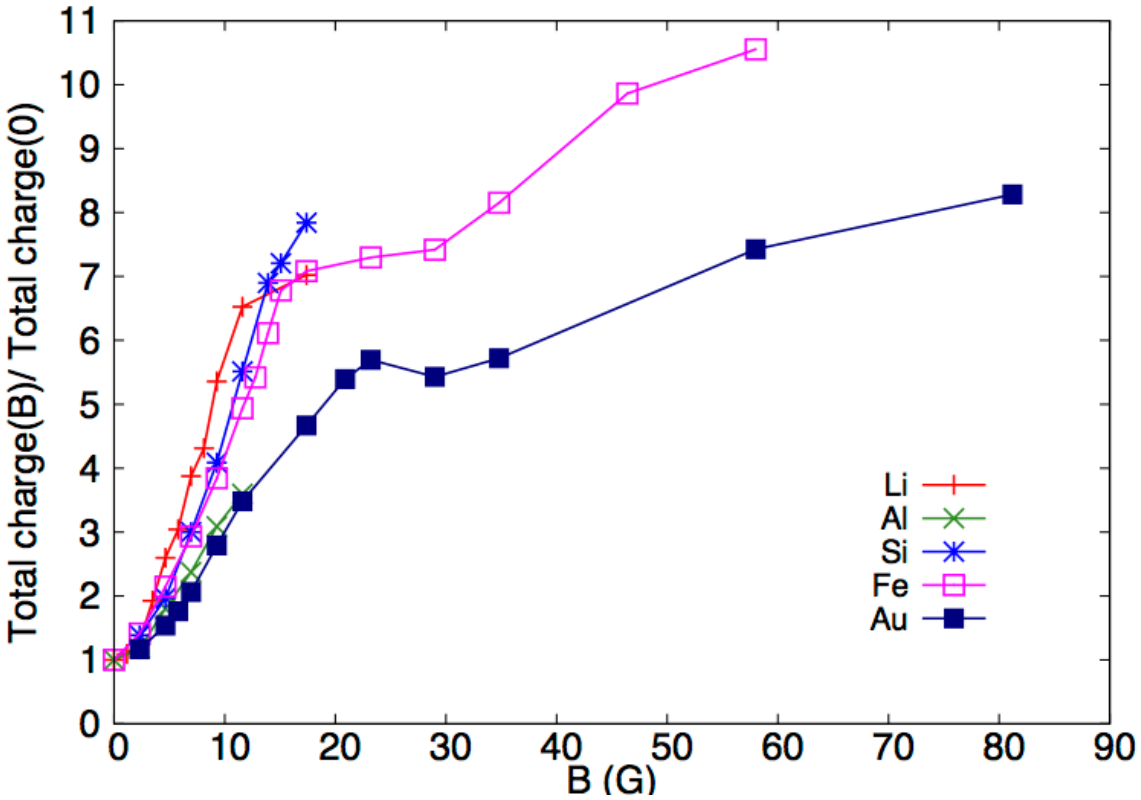
BROOKHAVEN NATIONAL LABORATORY

NASA

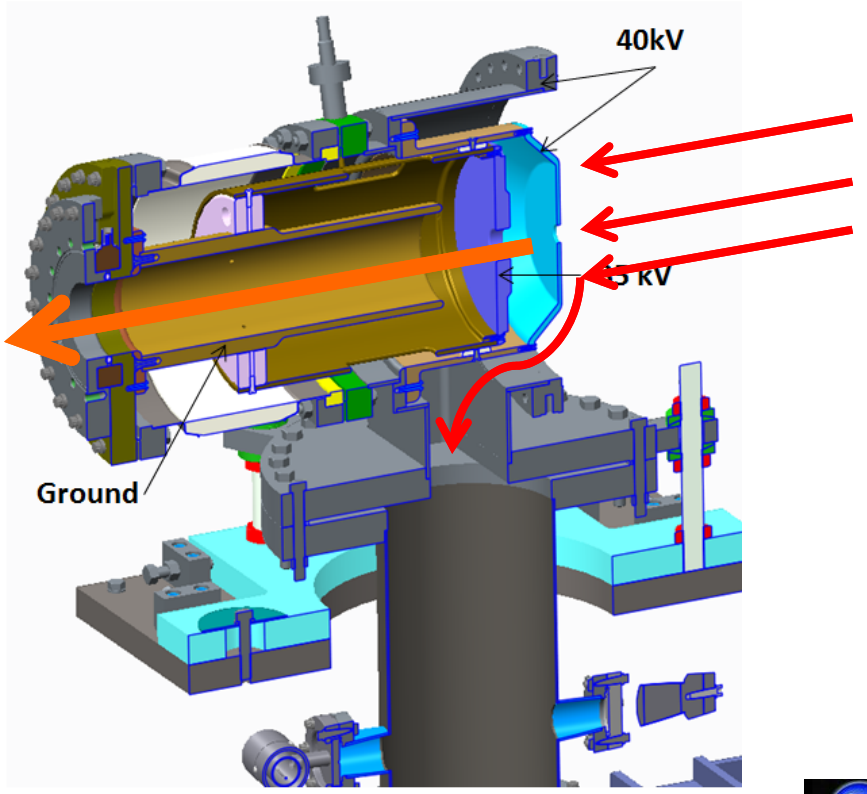

EBIS
4rod RFQ
IH DTL
Laser ion source
(LION)
Au1+
EBIS
RFQ
Au32+

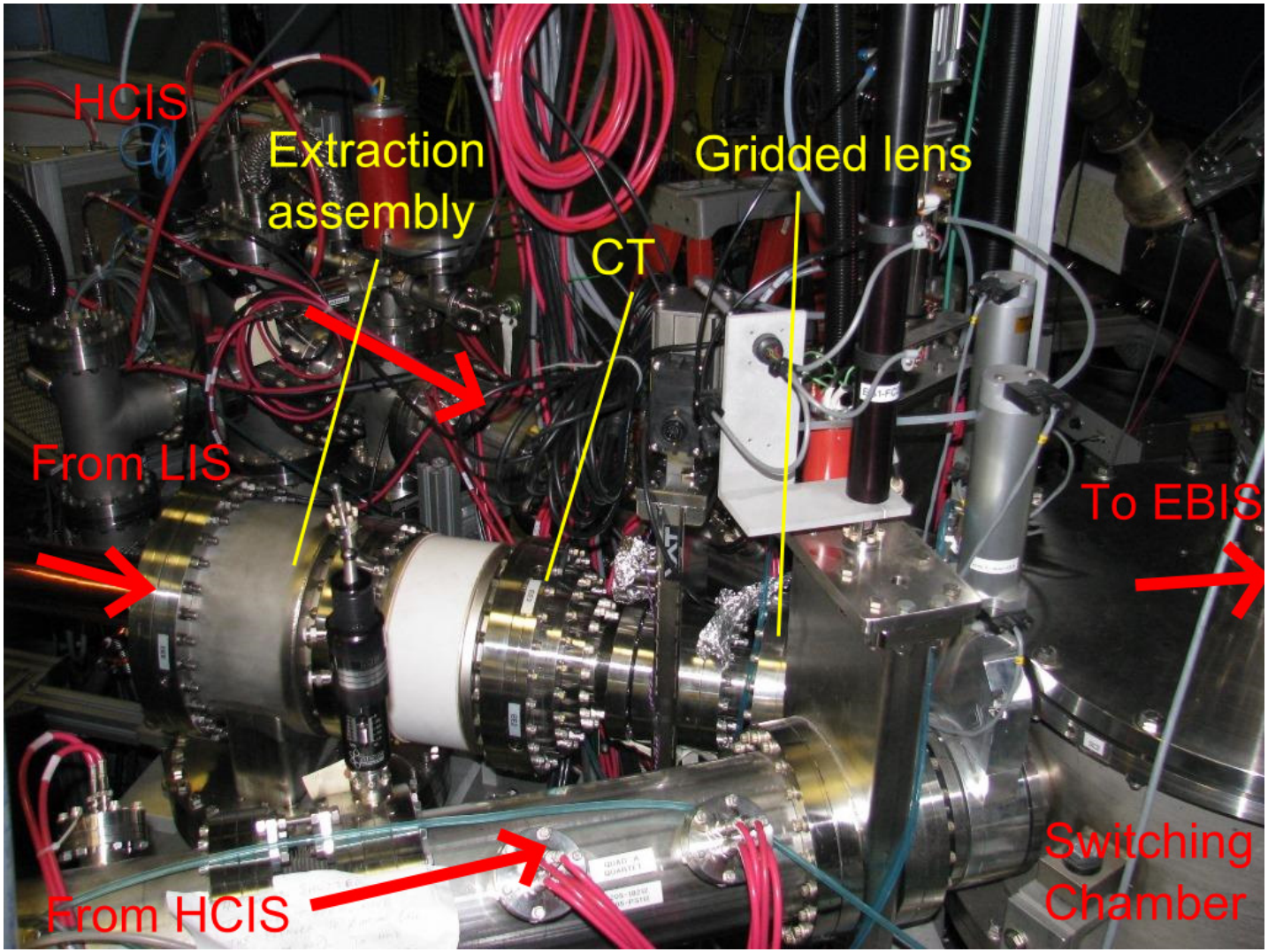

Lasers
(850 mJ/ 6ns, λ = 1064nm)
Target chamber
- XY target
- Rotary target
On HV ~40kV
Ion beam
Ion extractor
2140 mm
3m-long-solenoid
(few~100 gauss)
On HV ~40kV

Effect of the 3 m solenoid on total extracted charge



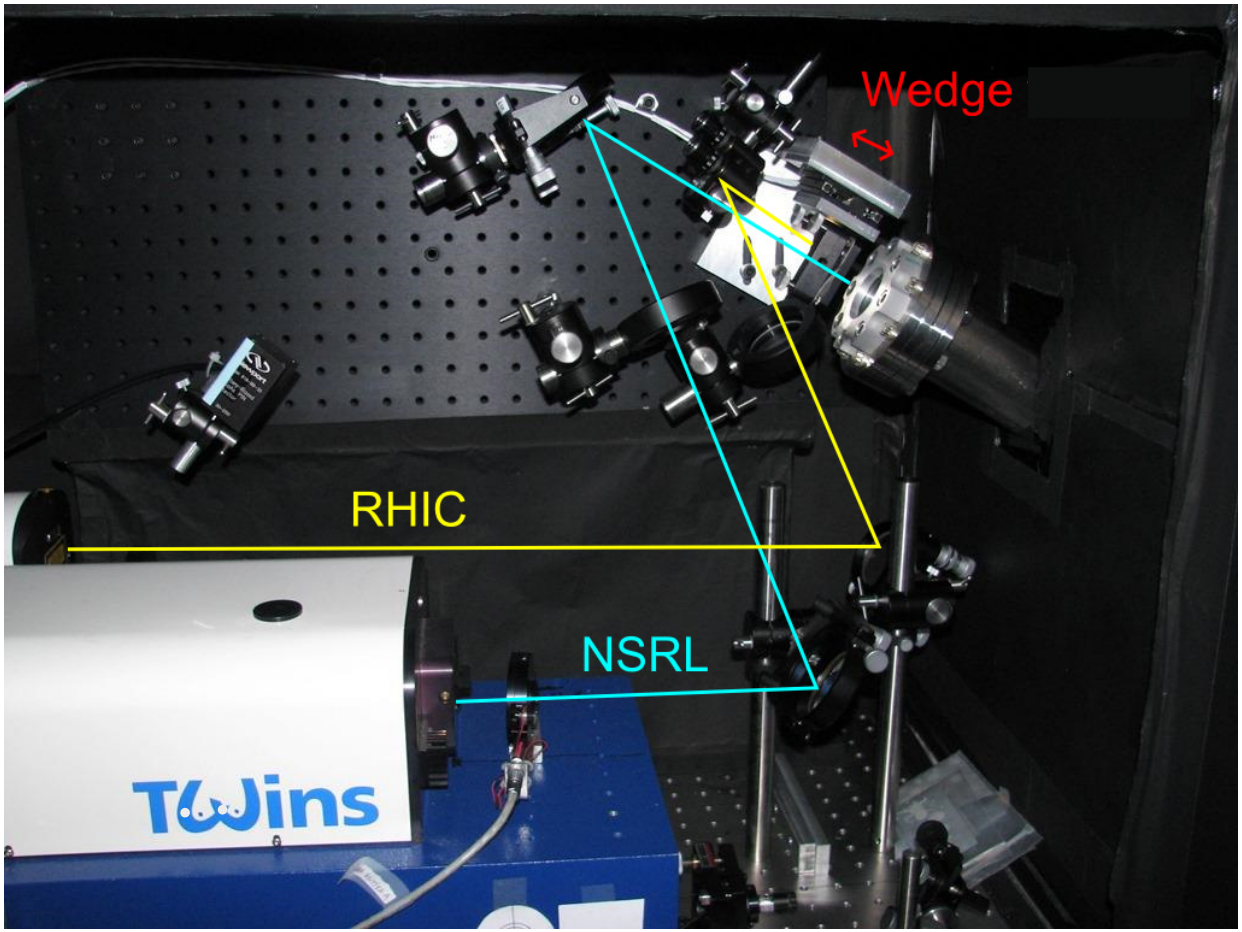
The Extraction Electrode





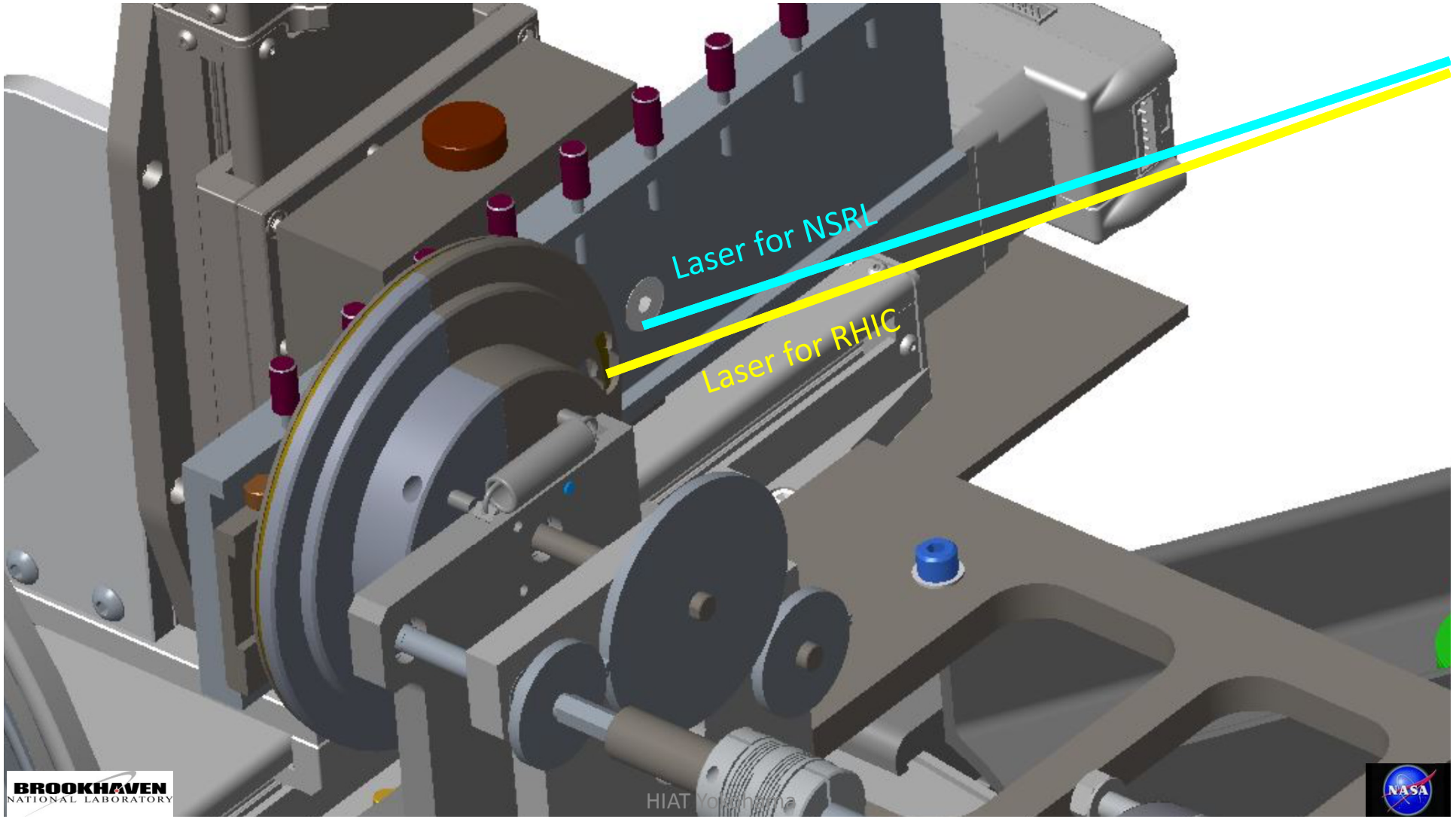
BROOKHAVEN NATIONAL LABORATORY

NASA



Typical timing sequence:
The entire accelerator complex is triggered at a signal of every 5 seconds.

Within a period of 5 seconds:
RHIC accepts 8 laser pulses at 200 ms interval.
NSRL needs 1 laser pulse.

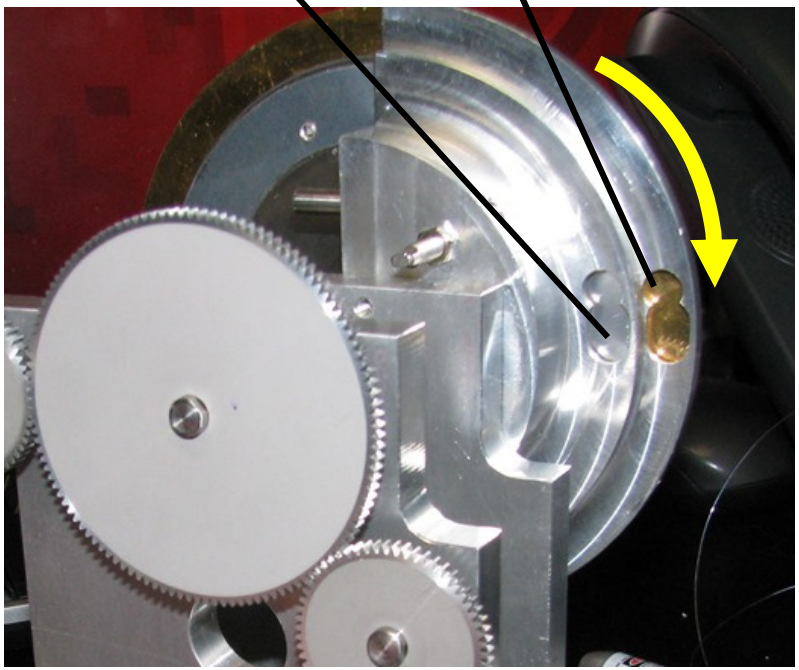

Laser for NSRL
Laser for RHIC
BROOKHAVEN
NATIONAL LABORATORY
NASA

Rotary target

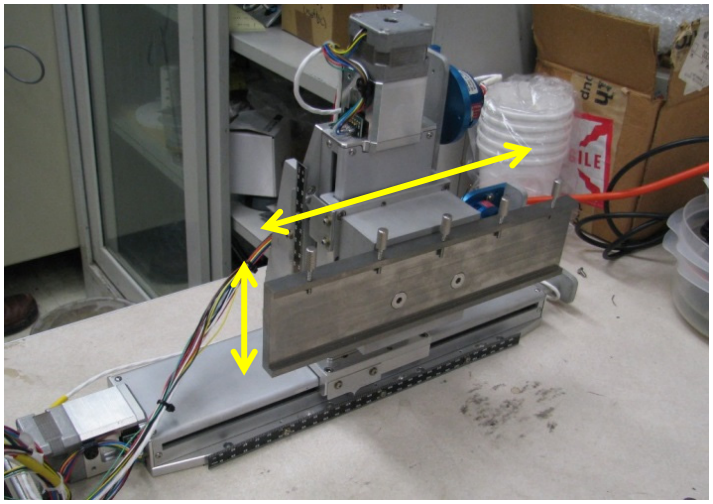
(Run15~)

Au (O.D. 120 mm)

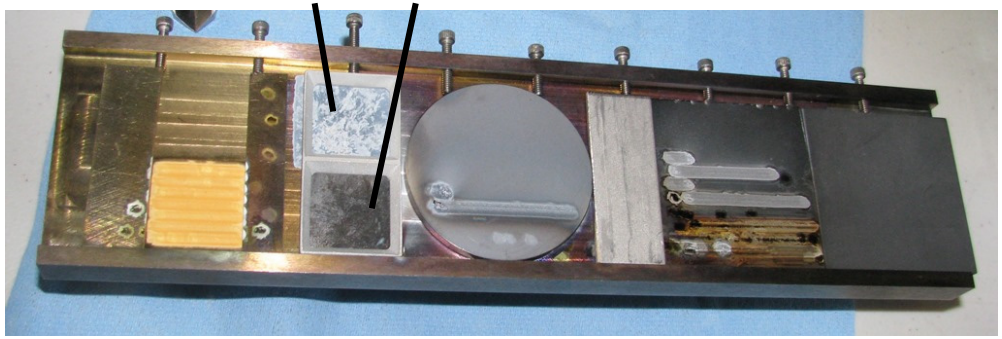
Al



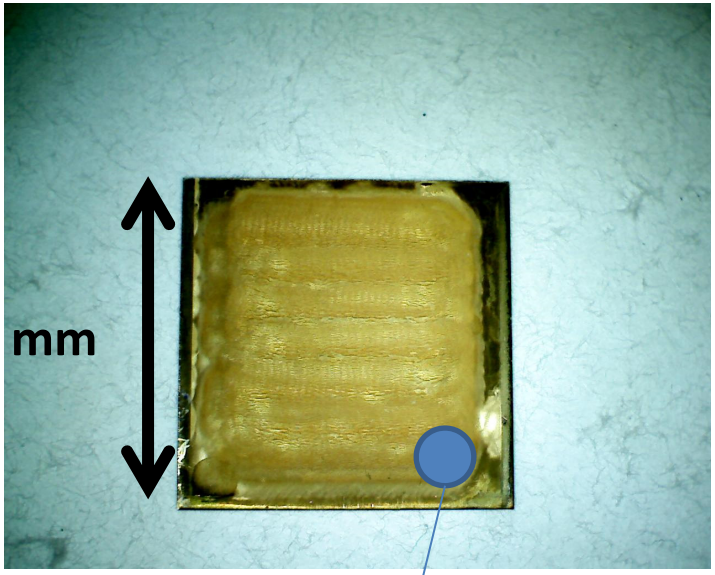
XY target



Al Au Li Ca Si Ti Fe C

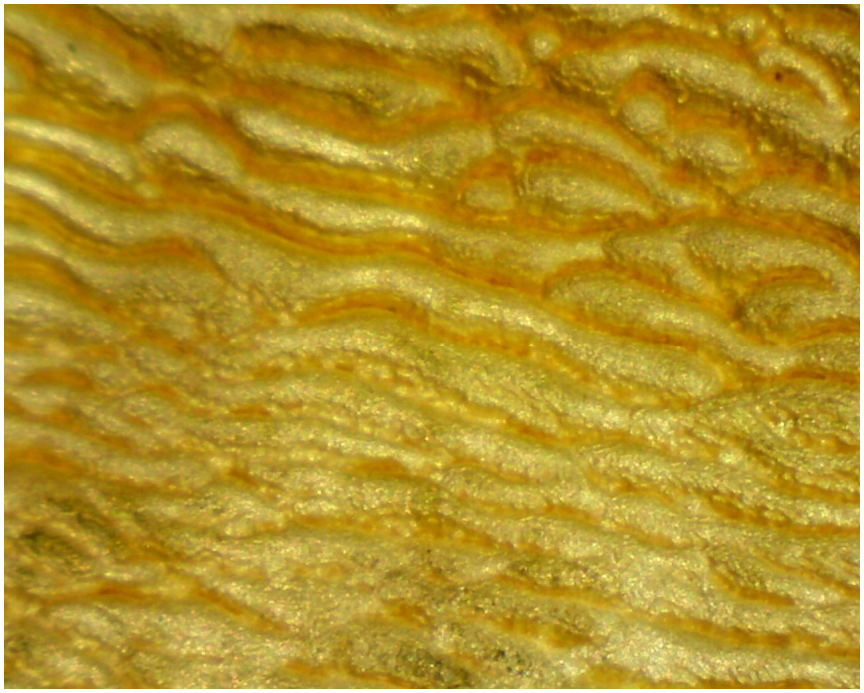


Gold target after Run 14



Laser spot size ~ ϕ 4.5mm

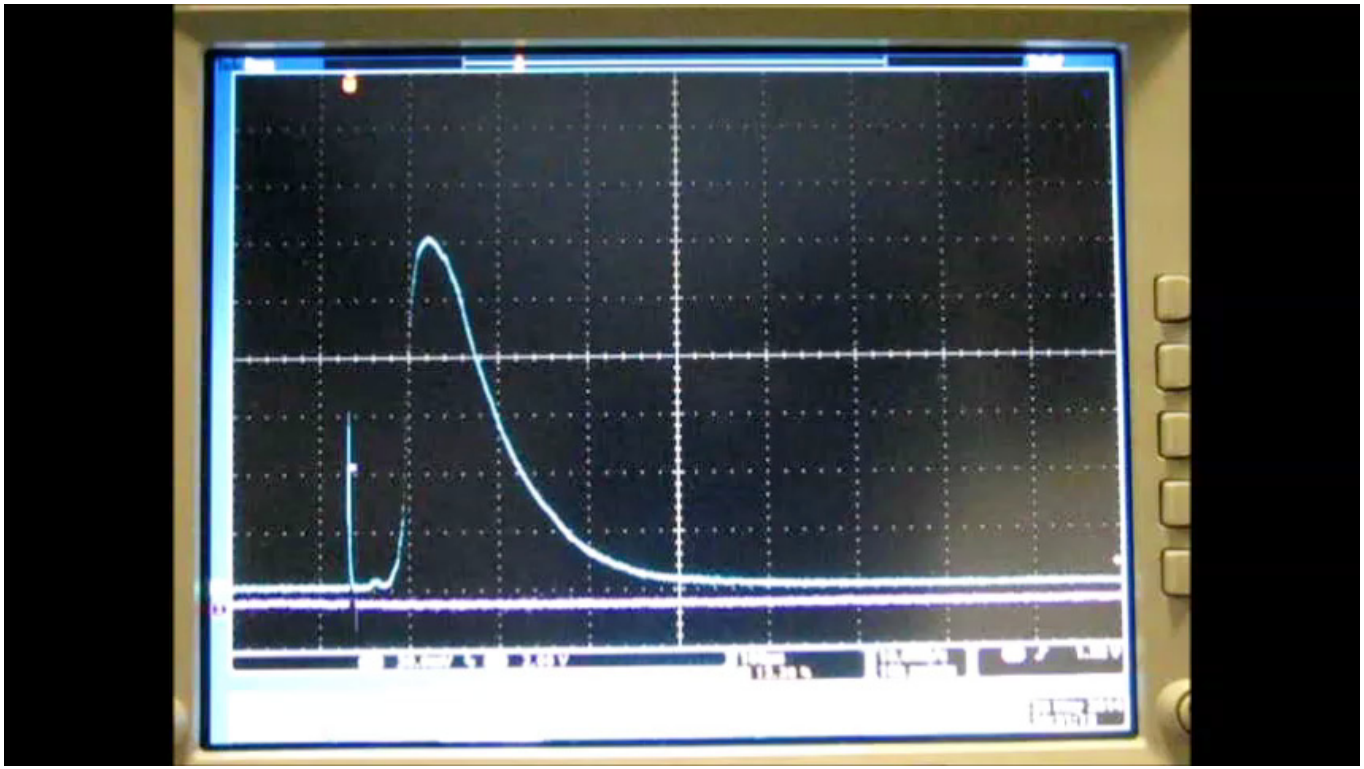
Top



Bottom

- Beam current was decreasing because of surface condition
- Solenoid was used to compensate beam current (~10 gauss)

Fast switching of ion species



- Repetition rate 1 Hz
- Switching between Au (lower current) and Ti (higher current)

Beams delivered by the LION

		Li	C	Al	Ca	Si	Ti	Fe	Ta	Au
Run14 (since March 25, 2014)	NSRL (days)		2			11	1	18	1	3
	RHIC (days)									33
Run15	NSRL (days)	1	3		1	19	4	30		6
	RHIC (days)			24						96

NSRL: 8h/day
RHIC: 24h/day

Summary

- Laser Ion Source for RHIC-EBIS (LION) was installed during Run14.
- Since RUN-14, LION has been used to deliver solid based primary ions.
- Run-15, most of all the solid based beam were provided by the LION for both RHIC and NSRL.
- Intensively used for real operation with a very good stability.
- LION has provided Li, C, Al, Si, Ca, Ti, Fe, Ta, Au.
- Species can be changed within a few seconds.
- High brightness, 0.043 π mm mrad rms (Au 120 μA), stable beams for a long time operation was demonstrated in BNL.

Summary

- Laser Ion Source for RHIC-EBIS (LION) was installed during Run14.
- Since RUN-14, LION has been used to deliver solid based primary ions.
- Run-15, most of all the solid based beam were provided by the LION for both RHIC and NSRL.
- Intensively used for real operation with a very good stability.
- LION has provided Li, C, Al, Si, Ca, Ti, Fe, Ta, Au.
- Species can be changed within a few seconds.
- High brightness, 0.043 π mm mrad rms (Au 120 μA), stable beams for a long time operation was demonstrated in BNL.

Thank you for your attention.