



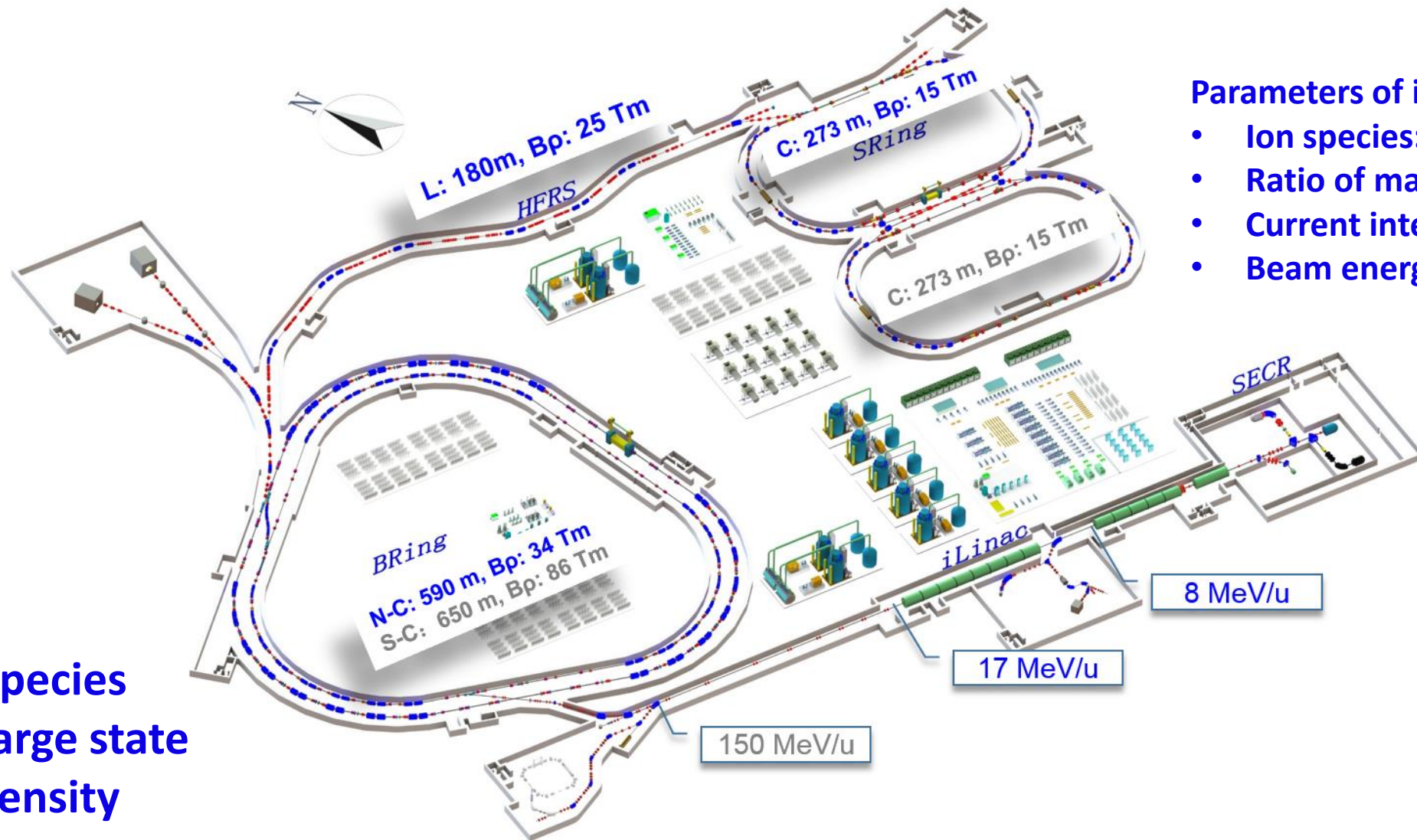
High intensity high reliability laser ion source development at IMP

Huanyu Zhao

Institute of Modern Physics, Chinese Academy of Sciences



- ❑ Applications of laser ion sources
- ❑ High intensity high charge state ion pulse production with LIS
- ❑ Repeatability of laser-produced ion pulses in short term
- ❑ Extension of operation duration for LIS
- ❑ Summary

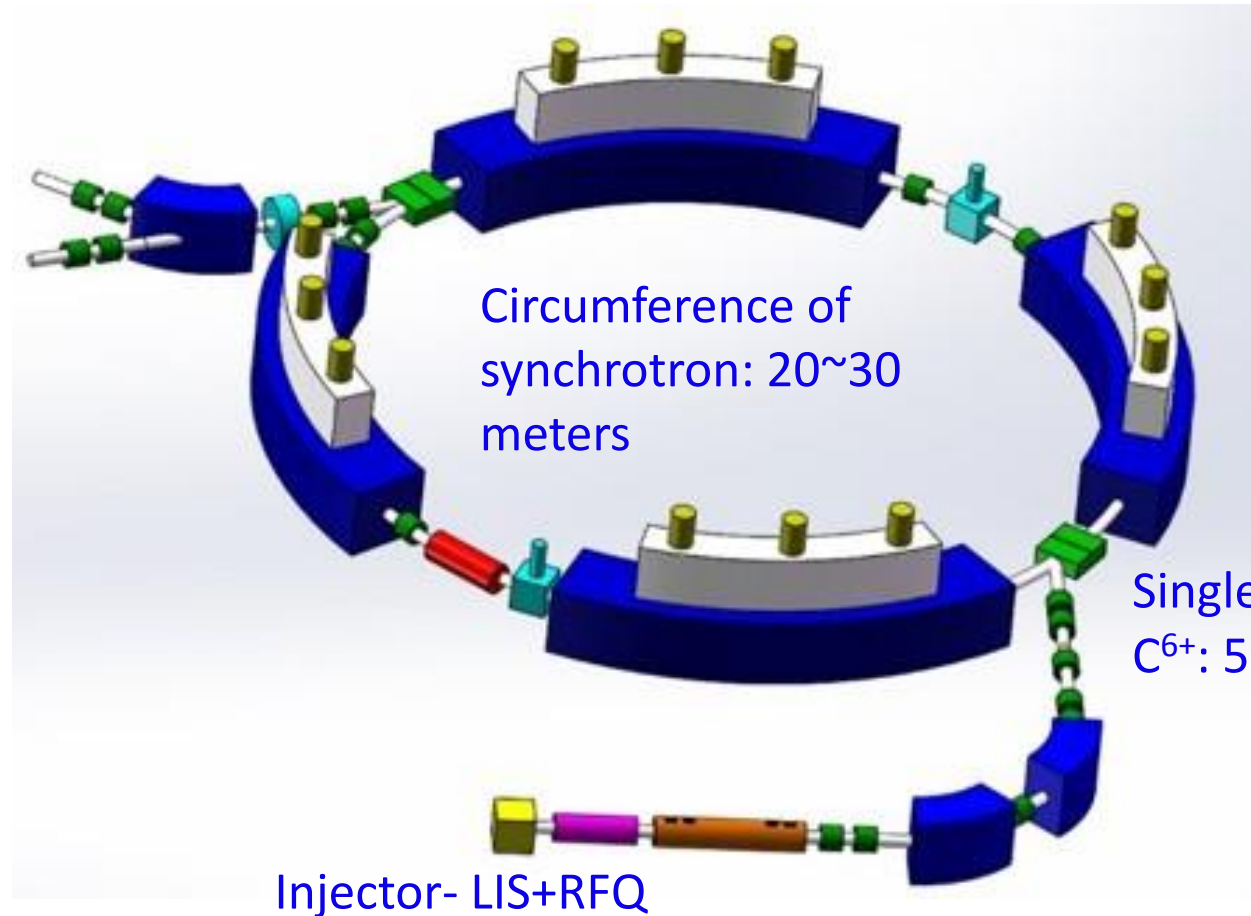


Parameters of ion sources

- Ion species: C~U
- Ratio of mass to charge: 2~7
- Current intensity: 1~50 μA
- Beam energy: 14 keV/u

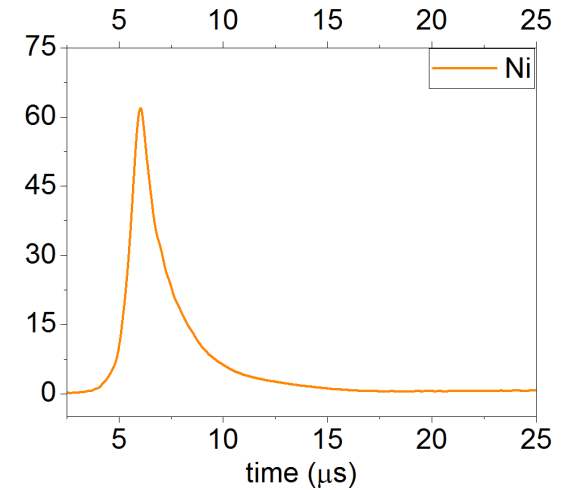
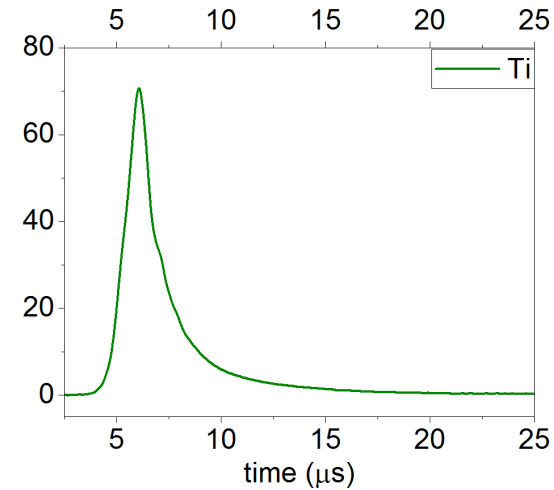
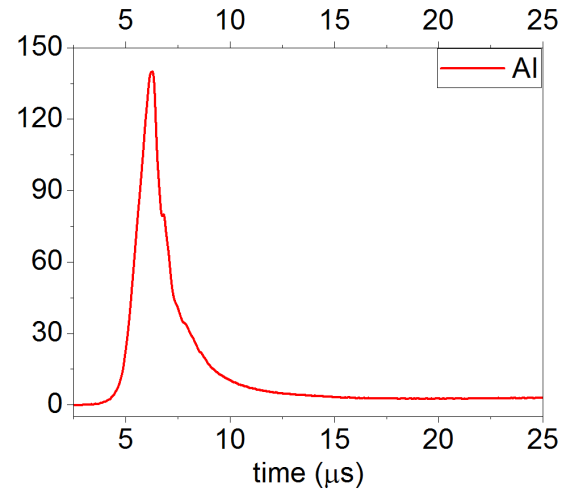
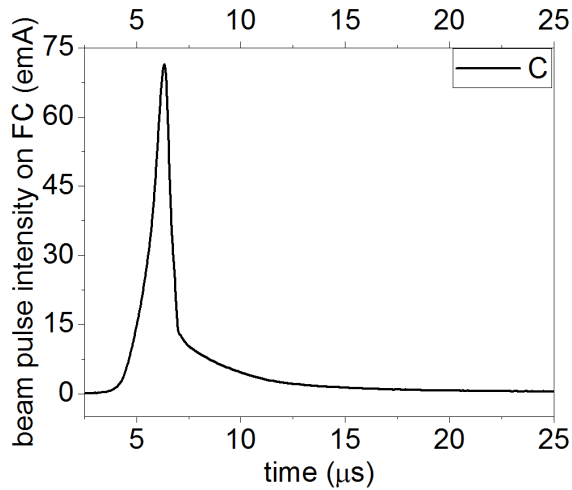
- All ion species
- High charge state
- High intensity

Compact carbon cancer therapy facility

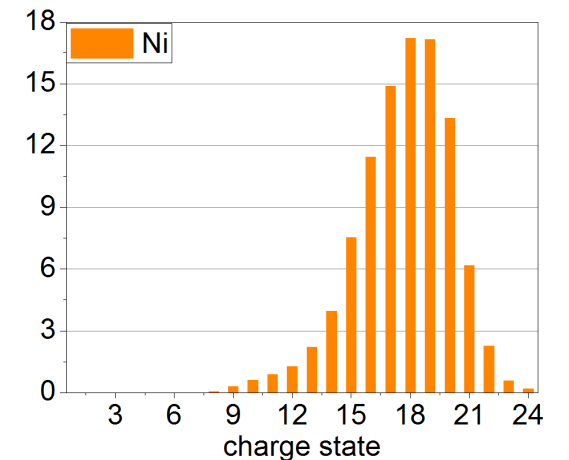
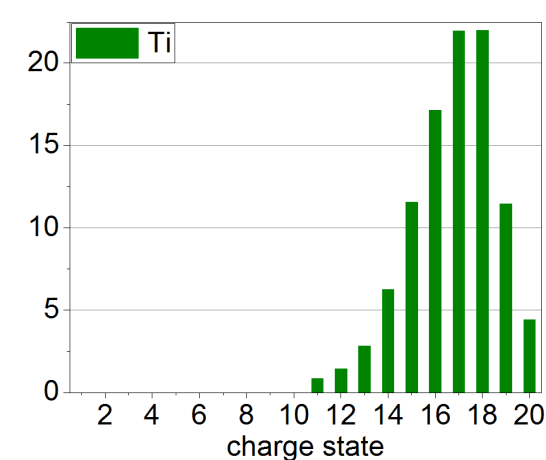
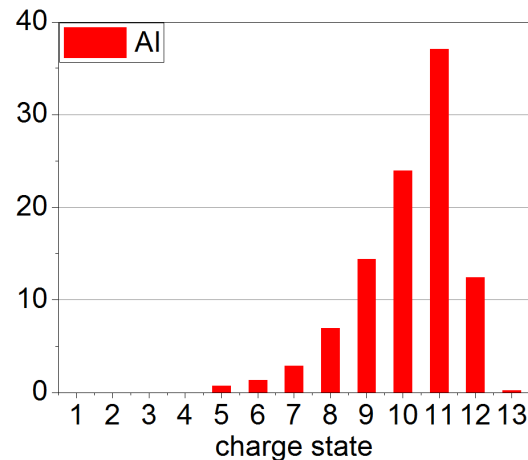
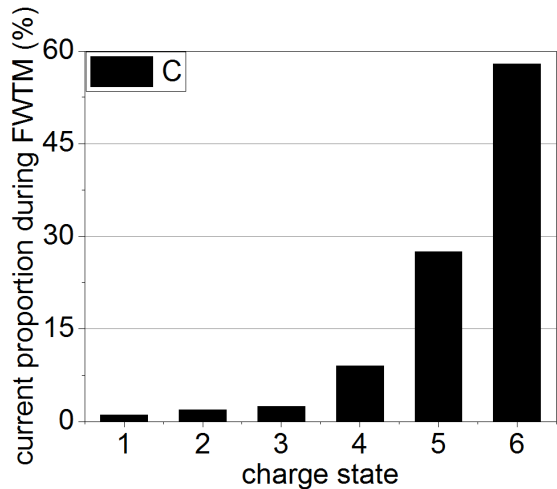


based on Direct Plasma Injection Scheme (DPIS)

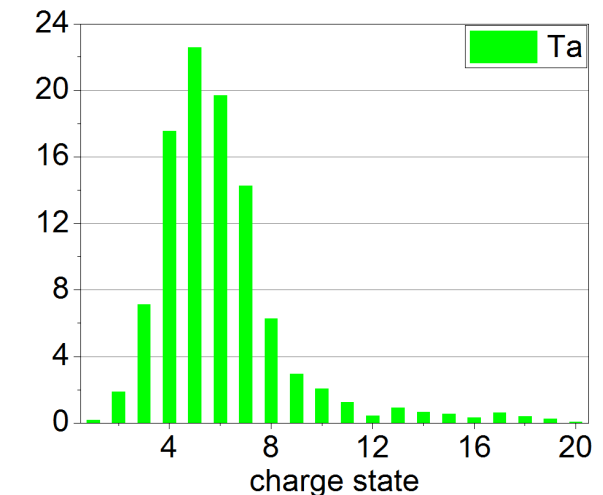
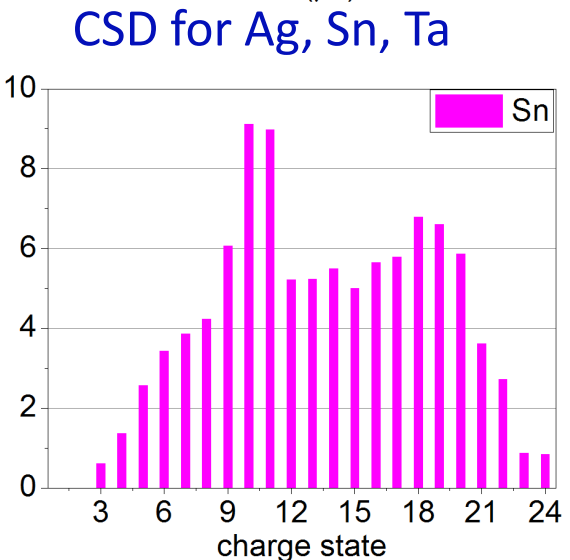
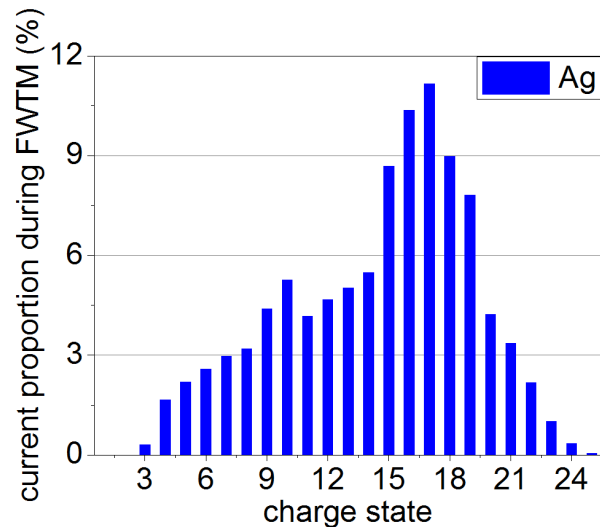
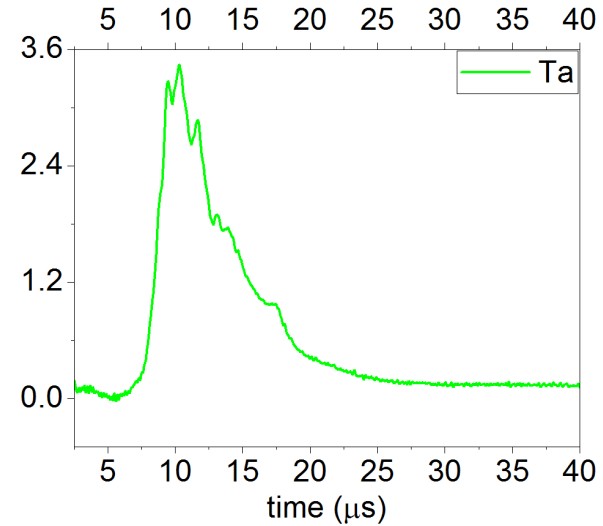
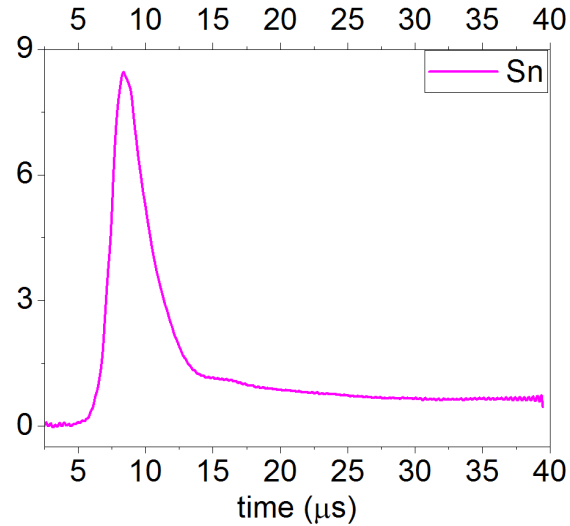
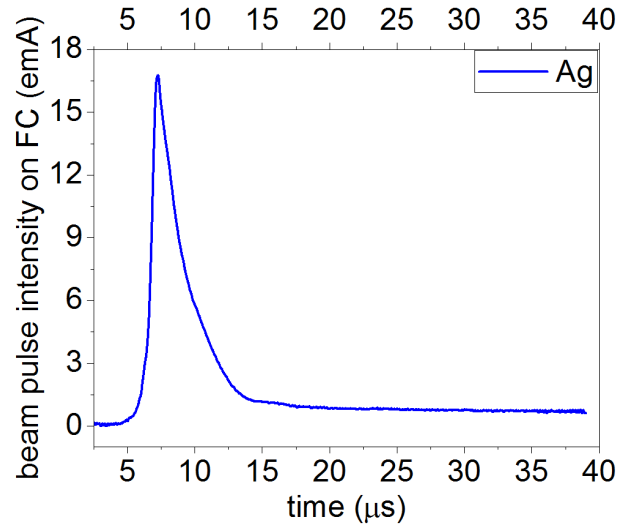
Total current intensities for C, Al, Ti, Ni @ 3 m away from targets



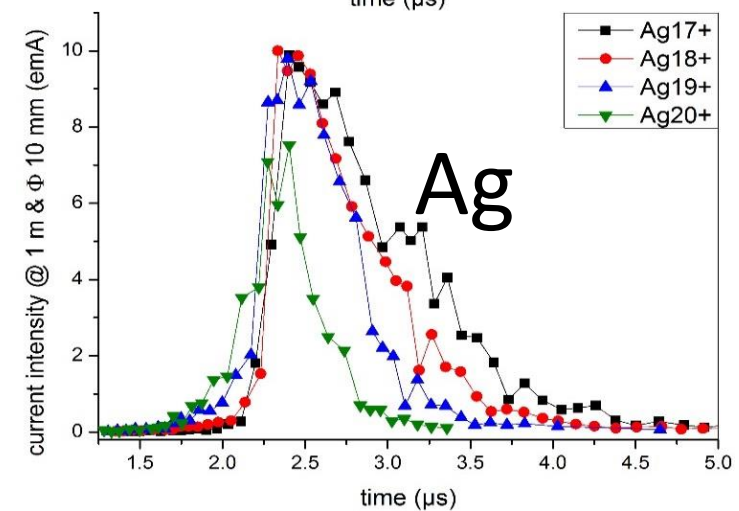
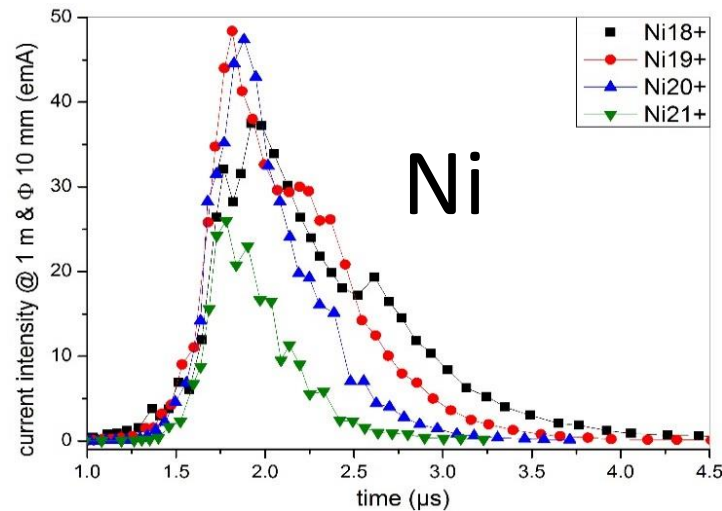
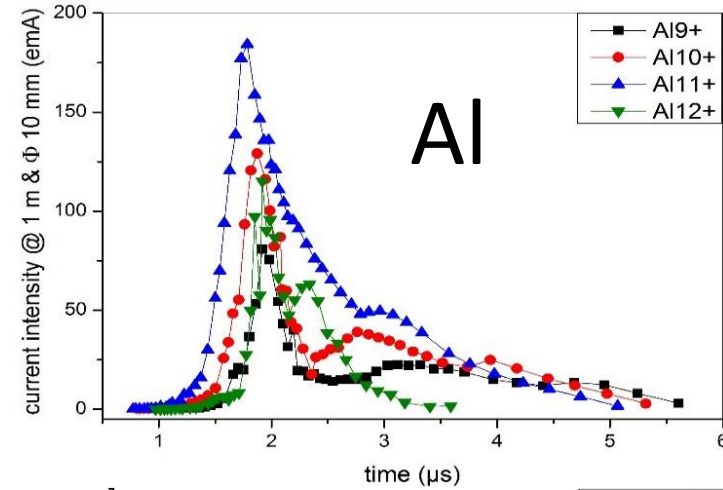
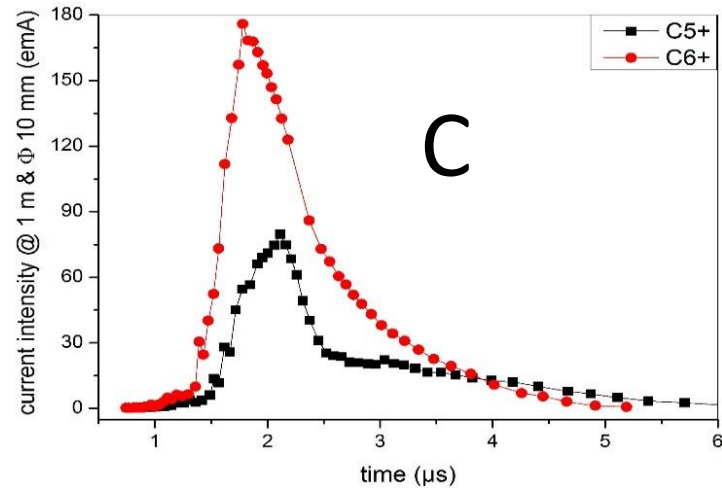
CSD for C, Al, Ti, Ni

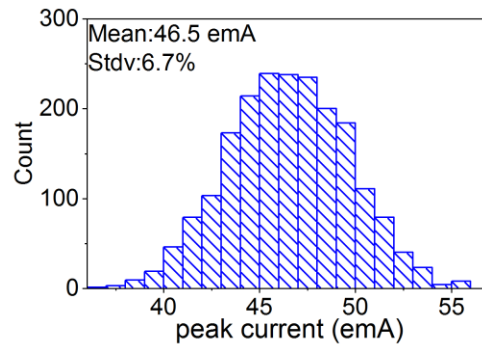
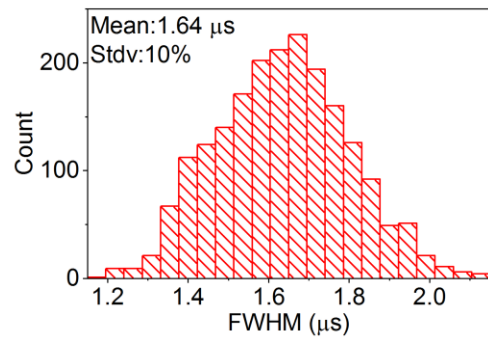
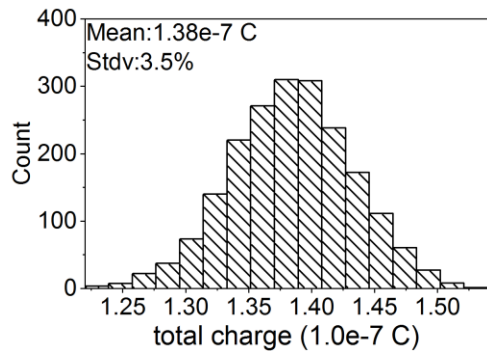
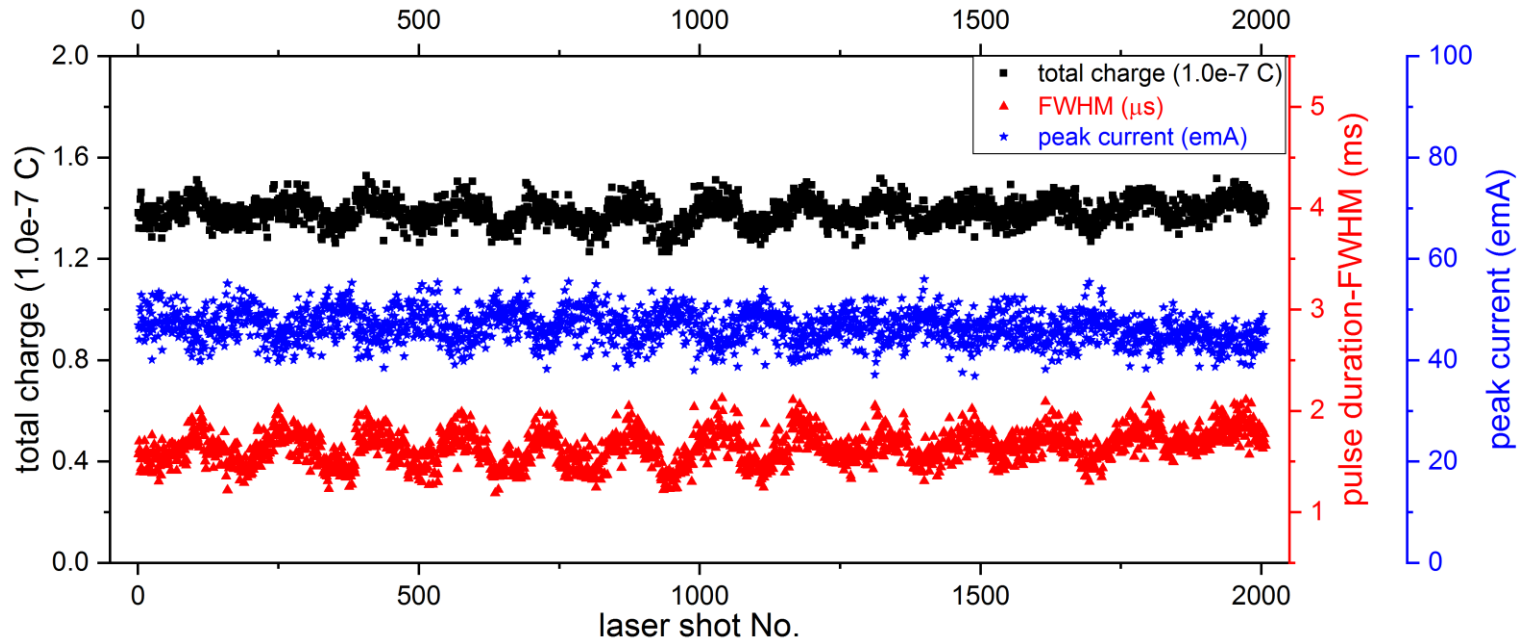


Total current intensities for Ag, Sn, Ta @ 3 m away from targets

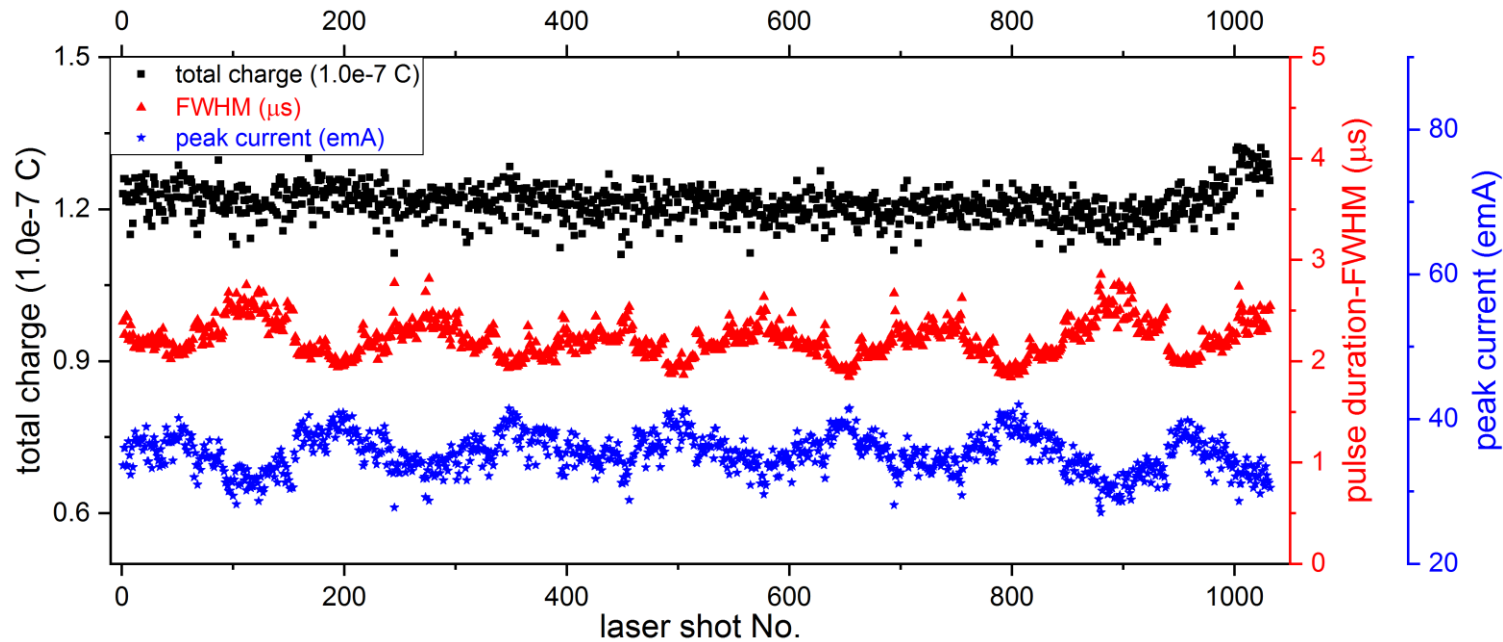


Absolute yields of HCIs with different charge states, normalized to $\phi 10$ mm aperture @ 1 m away from target

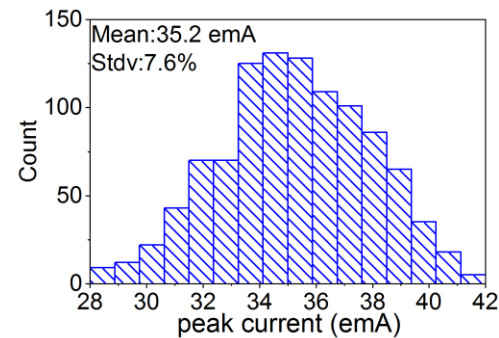
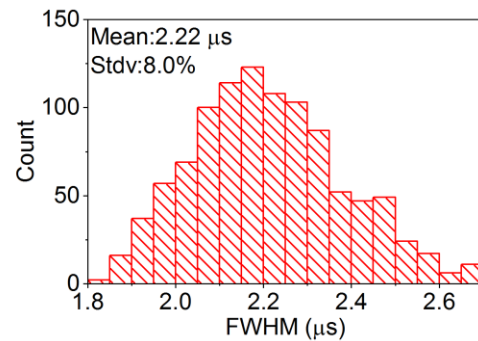
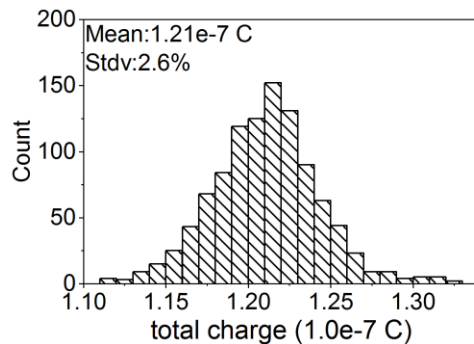


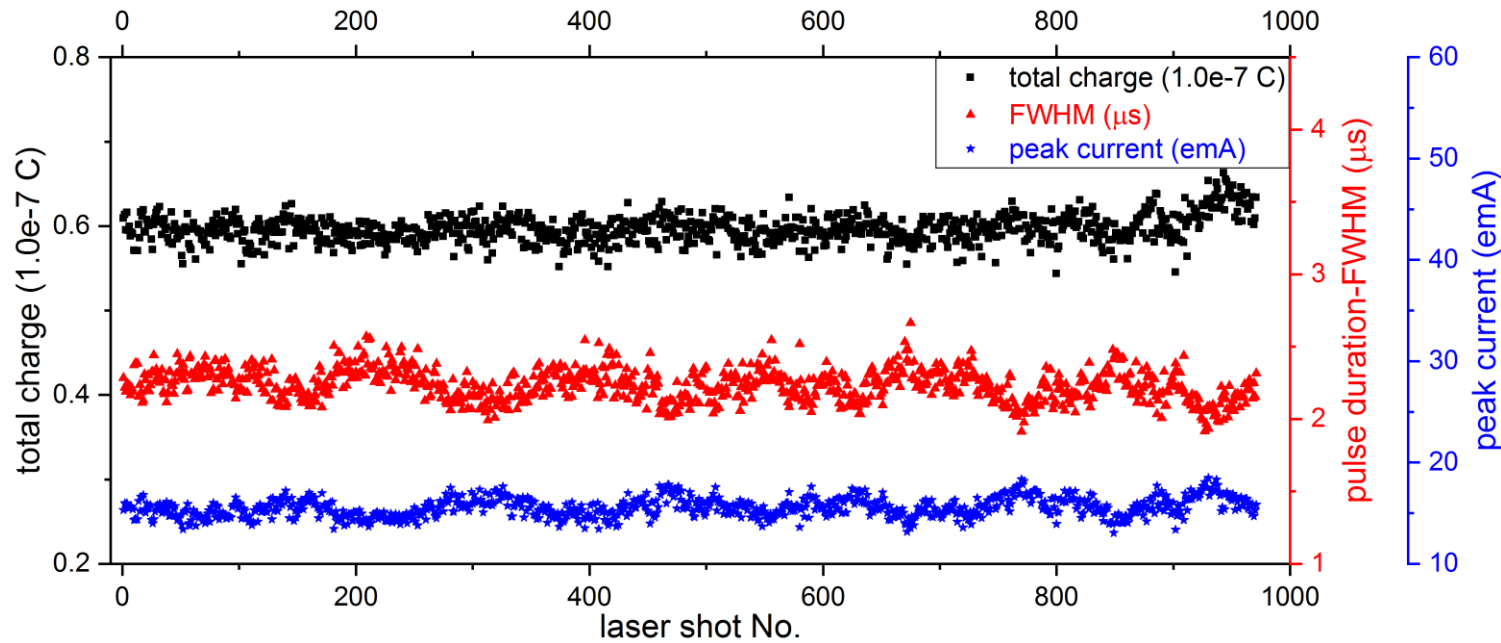


- ◆ Laser intensity @ focal spot: $\sim 10^{14} \text{ Wcm}^{-2}$
- ◆ 2000 C ion pulses
- ◆ Repetition rate: 0.33 Hz
- ◆ Duration: ~ 2 hrs
- ◆ Deviation of Q_{total} : 3.5%
- ◆ Deviation of I_{peak} : 6.7%
- ◆ Deviation of τ : 10%

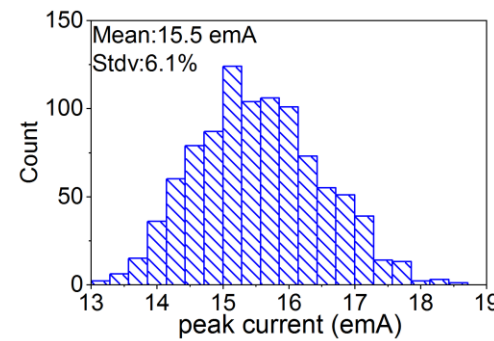
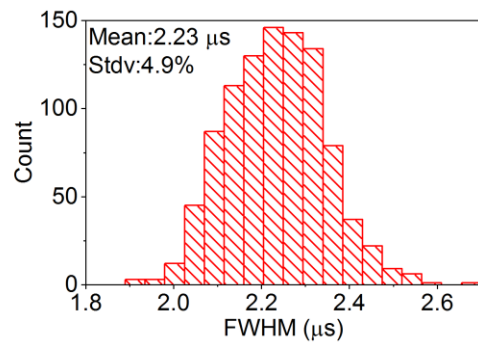
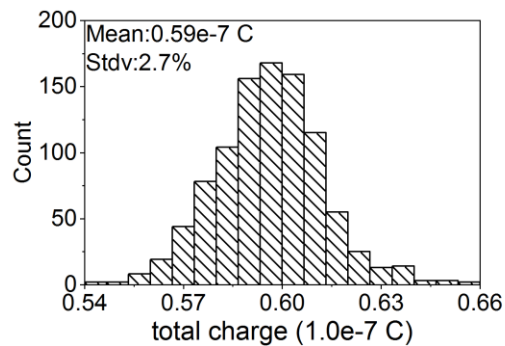


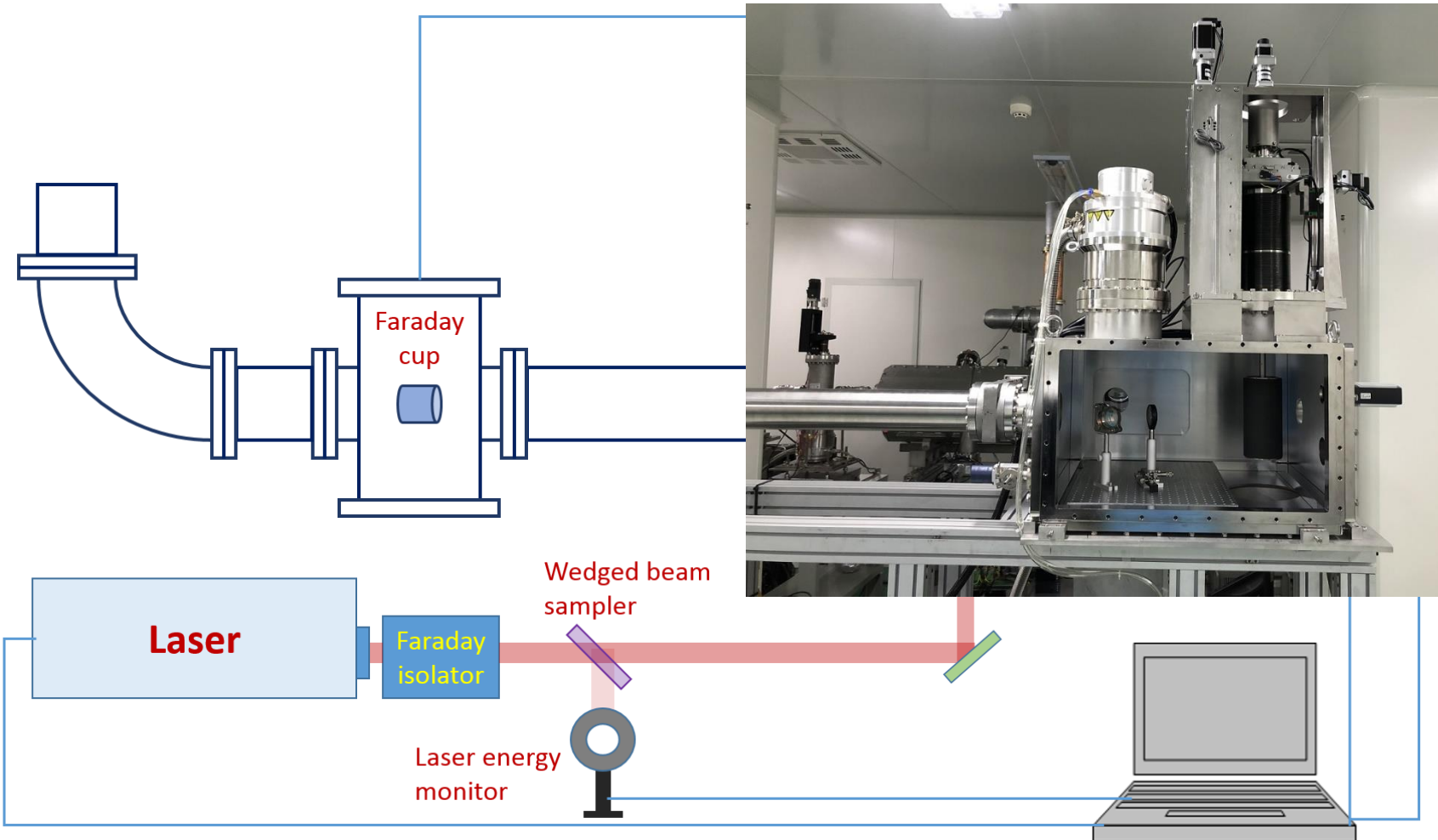
- ◆ Laser intensity @ focal spot: $\sim 10^{14}$ Wcm⁻²
- ◆ 1000 Al ion pulses
- ◆ Repetition rate: 0.33 Hz
- ◆ Duration: \sim 1 hr
- ◆ Deviation of Q_{total} : 2.6%
- ◆ Deviation of I_{peak} : 7.6%
- ◆ Deviation of τ : 8.0%



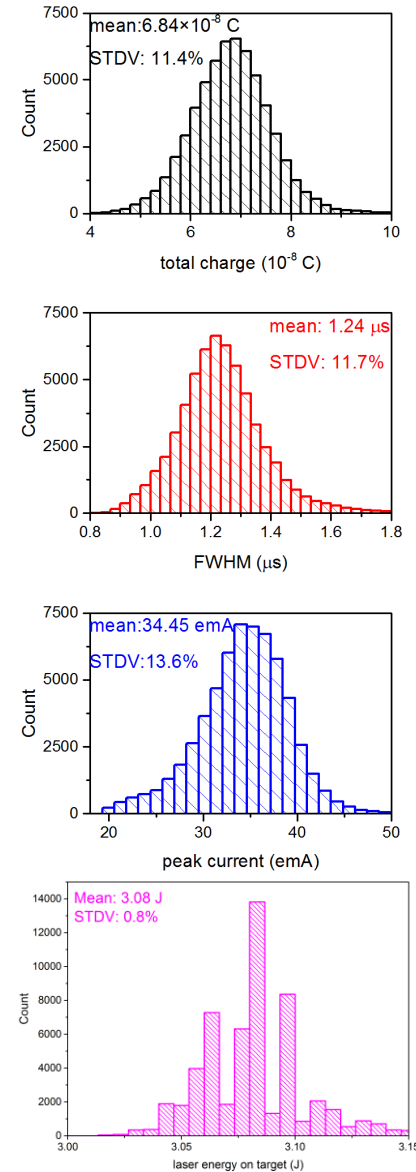
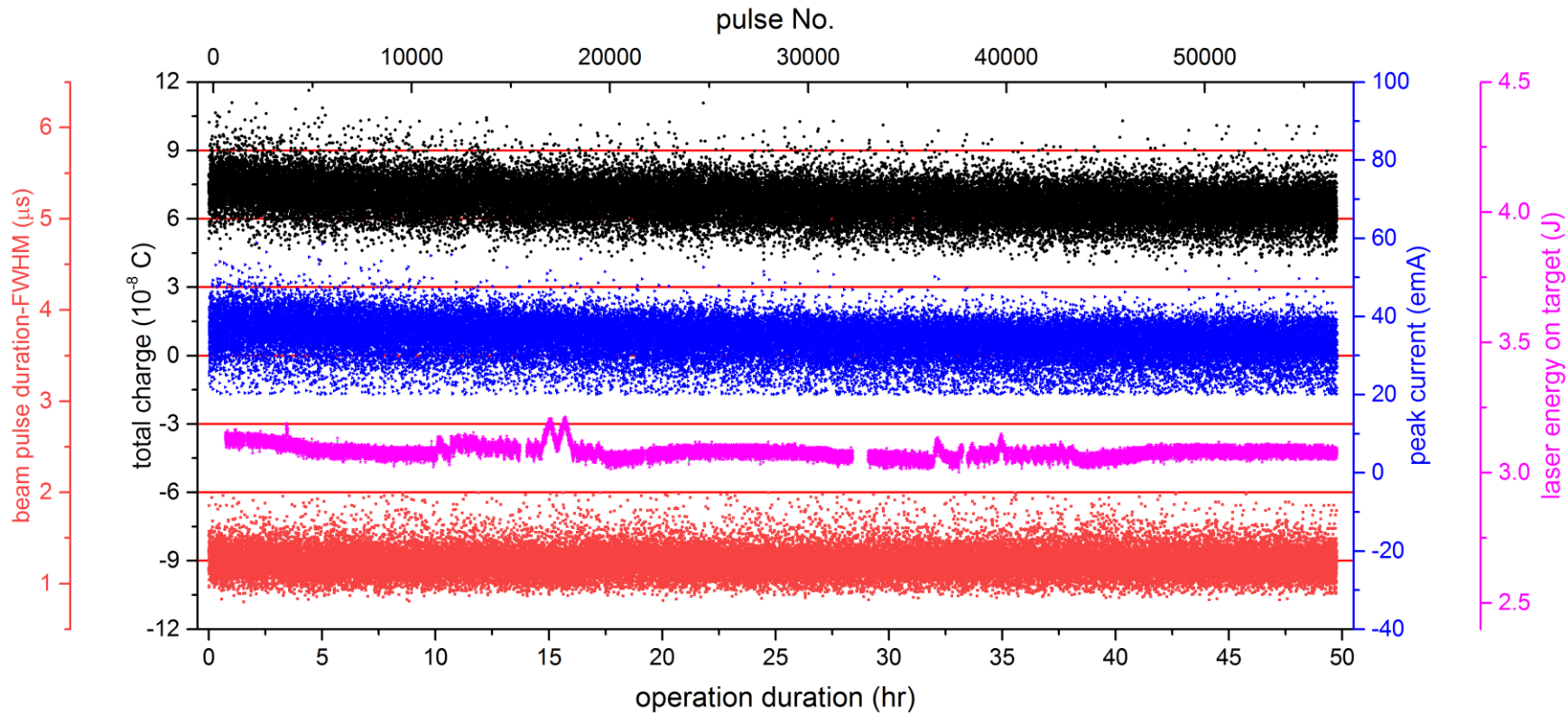


- ◆ Laser intensity @ focal spot:
 $\sim 10^{14} \text{ Wcm}^{-2}$
- ◆ 1000 Al ion pulses
- ◆ Repetition rate: 0.33 Hz
- ◆ Duration: $\sim 1 \text{ hr}$
- ◆ Deviation of Q_{total} : 2.7%
- ◆ Deviation of I_{peak} : 6.1%
- ◆ Deviation of τ : 4.9%

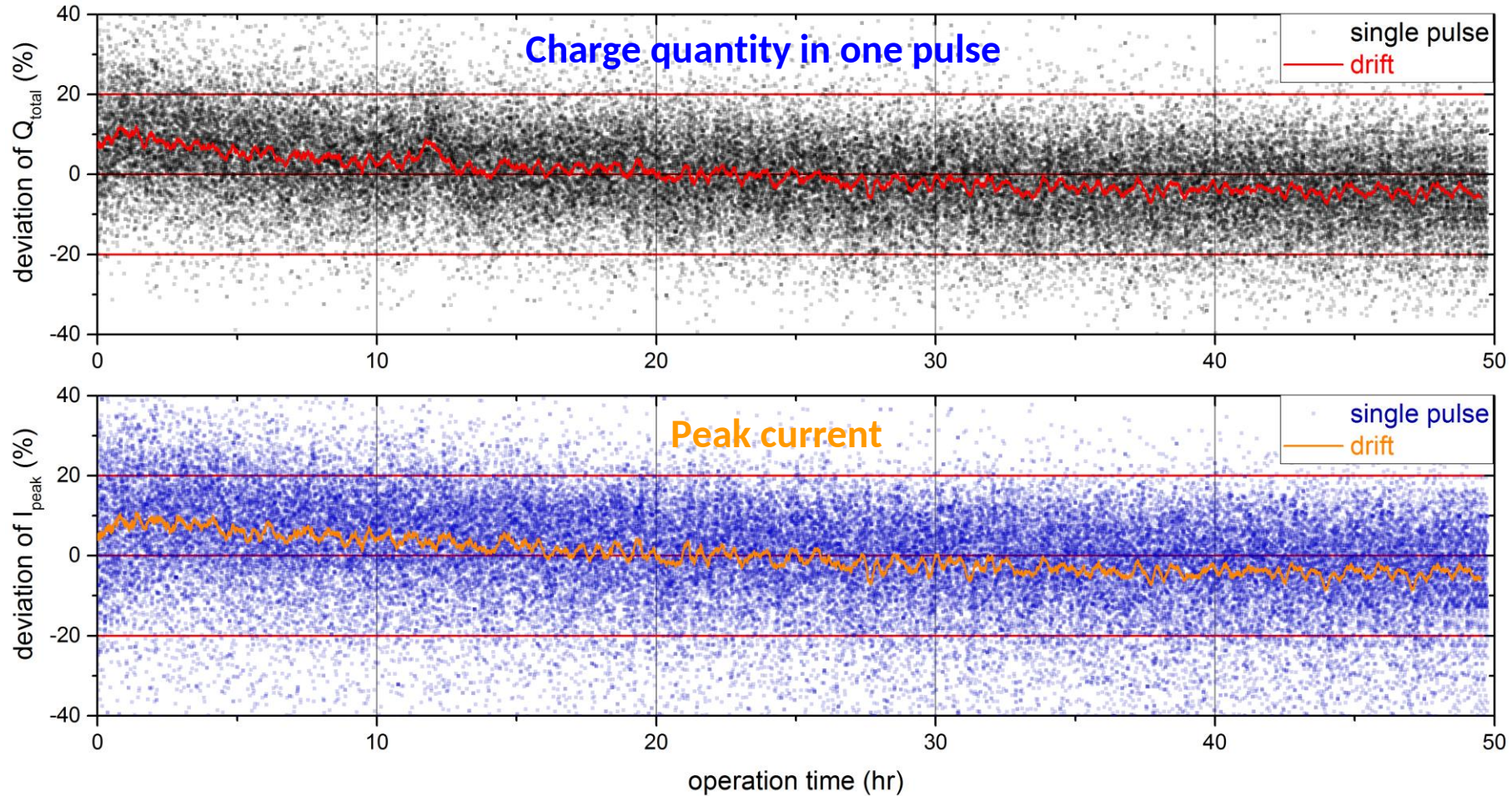




- **4-axis movement of target**
3-axis (X, Y, Z)+ rotation
Extended range of motion
- **Target: cylindrical or flat bulk**
Much larger surface area
sustaining operation of
several to dozens of hours
- **In-situ monitoring of laser energy**
- **Real-time display of ion pulse in the control system**

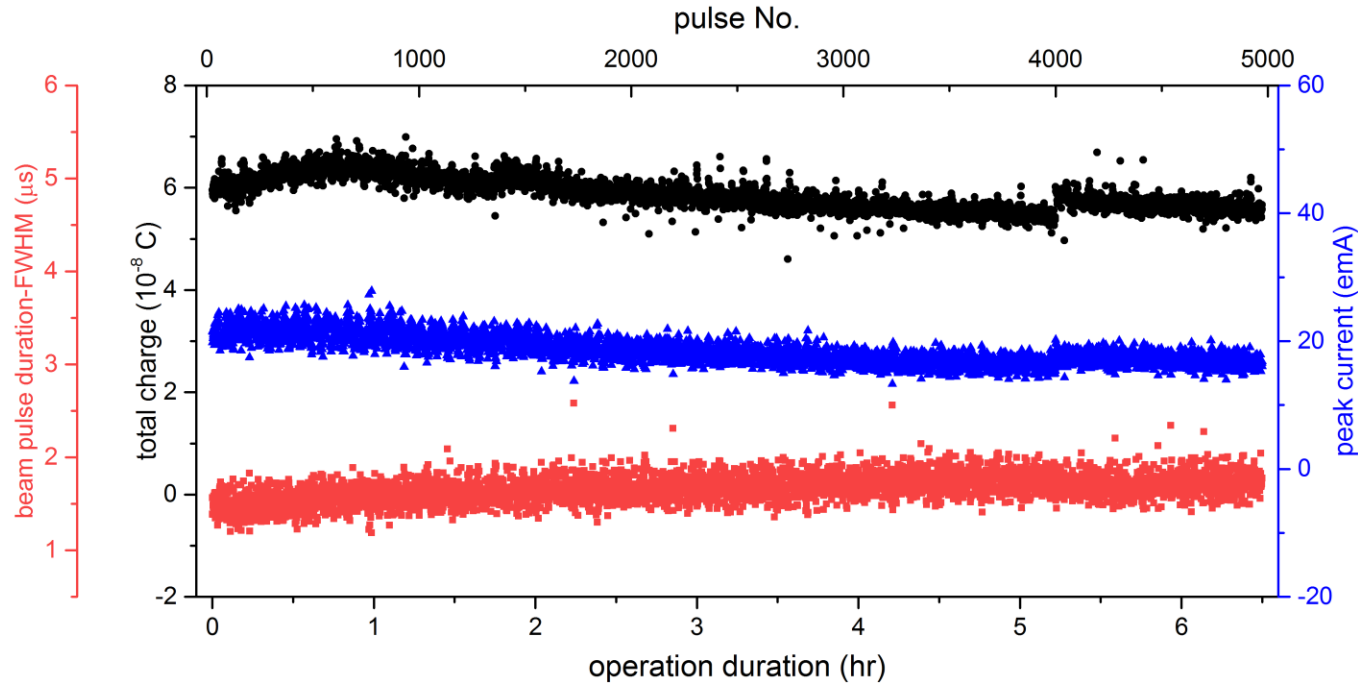


Fluctuation of laser energy: caused by unstable temperature during night



Drift lines: calculated as rolling average over consecutive 300 pulses

Q_{total} & I_{peak} drift slowly with lapse of operation time, until 30 hrs later, the values tend to stabilize
 Drift caused by degeneration of the optics in chamber



Repeatability: Cylindrical vs planar target

Standard deviation	Cylindrical target (each group composed of 4800 pulses- same pulse number with planar target)						Planar target
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	
σ_Q	10.8%	10.5%	10.6%	11.0%	10.8%	11.1%	5.3%
σ_{I_p}	13.7%	12.9%	12.8%	13.0%	13.0%	13.1%	11.6%
σ_t	11.4%	11.8%	11.7%	11.8%	12.0%	11.7%	8.3%

- ❑ High intensity high charge state ions have been produced from light to medium-mass elements with a 8-J laser, and for the production of high charge state ions from heavy elements (atomic number > 100), more powerful laser is needed.
- ❑ The continuous operation of LIS for several to tens of hours has been realized, with the shot-to-shot repeatability of the main ion pulse parameters better than 13%.
- ❑ Some measures need taking to solve the pollution of the optics in the target chamber, so that to get long-term stability of LIS.



Thanks for your attention!