Stripping of Heavy Ion Beams Using Laser Ablated and Pinch Plasmas

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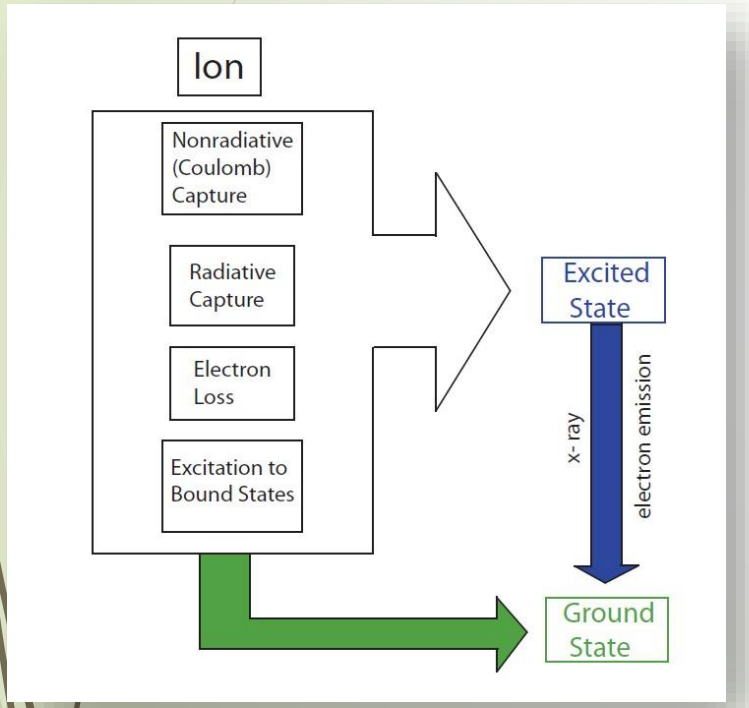
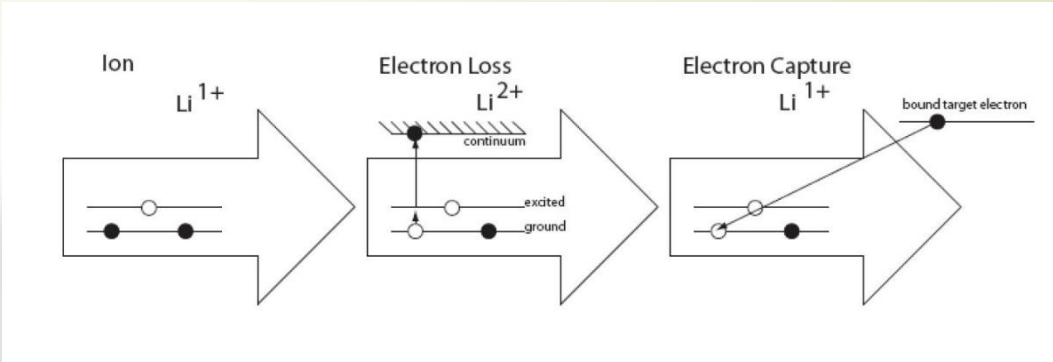
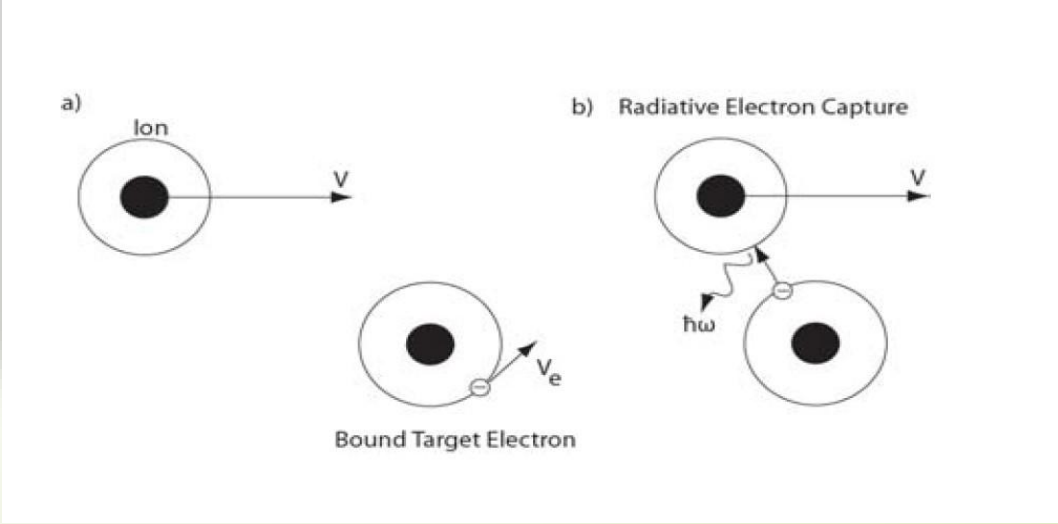
INTRODUCTION / MOTIVATION

- Interaction of heavy ions with plasma is important for research in fields like warm dense matter (WDM), laboratory astrophysics and inertial confinement fusion (ICF),where high repetition rates of ion beam pulses are of advantage as a driver
- Use of a plasma as an efficient stripper are of importance to our High Current Injector Programme (HCI) at IUAC, New Delhi as well as upcoming projects at FAIR
- Experiments are planned to be carried out using highly ionised plasmas for stripping of heavy ions

SOME GENERALITIES

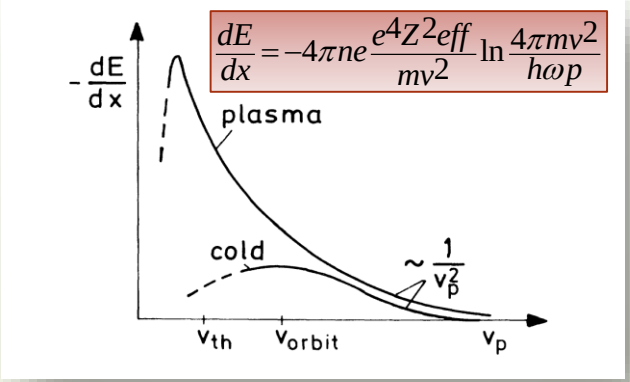






FOIL/GAS STRIPPING Vs PLASMA STRIPPING

- Gas stripping does not reach sufficiently high charge states
- Foil strippers have difficulties in long lifetime (radiation damage, sputtering, thermal and mechanical stresses due to irradiation, quality of ion beams is degraded more than from gaseous media)
- Plasma stripping (can solve) solves both the problems very well

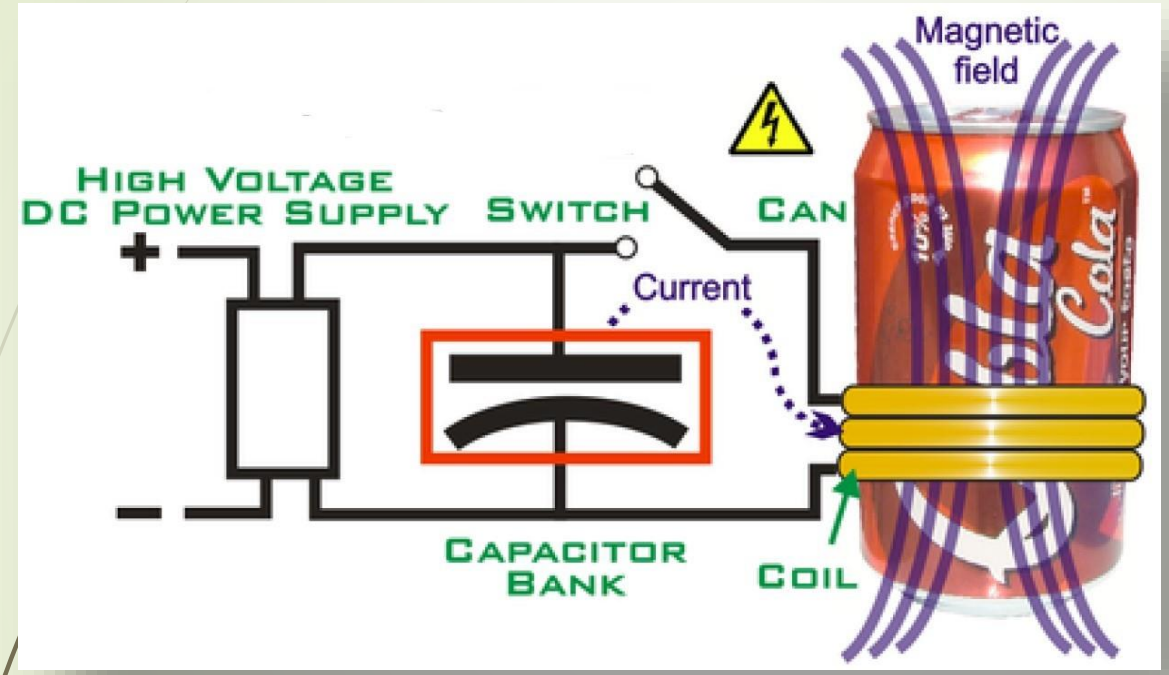


G.D.Alton et et al., Phys.Rev. A 45,5957(1992)

- In plasmas and cold matter, charge states of a projectile ions are determined are determined by ionisation and recombination processes in the target
- Cross sections for electron capture in plasmas are much smaller than those in cold matter because there are fewer bound electrons in the plasma.
- Therefore, ions in a highly ionised plasma can reach much higher states than in cold matter(Here, a hydrogen plasma is most suitable)

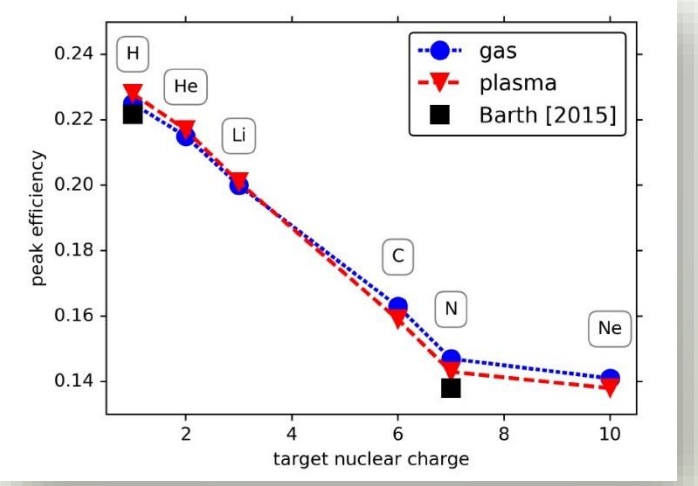
(For projectile energies > 0.1 MeV/u, cross sections for bound electron capture and radiative electron capture increase as the projectile energy decreases)

PINCH PLASMAS



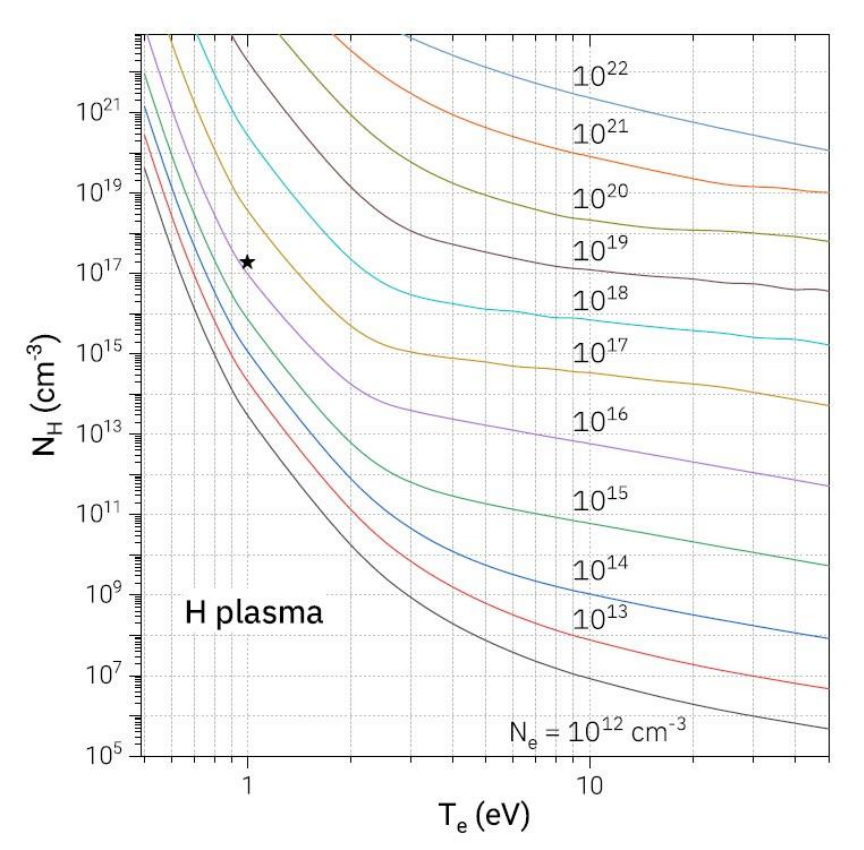
CURRENT STATE OF THE ART

- Z pinch plasma ---disadvantage is the electrode erosion effect and lifetime is reduced
- Induction ignition of plasma ----an axial magnetic field extends
- IAP at University of Frankfurt –researching on various alternatives to Z pinch (spherical theta pinch and spherical screw pinch experiments were performed)



O.S.Haas et et al., Proceedings of LINAC 2016, East Lansing, MI, USA , p.248
W. Barth *et al.*, "U28+-intensity record applying a H2-gas stripper cell", *Phys. Rev. STAB*, vol. 18, p. 040101, Apr. 2015

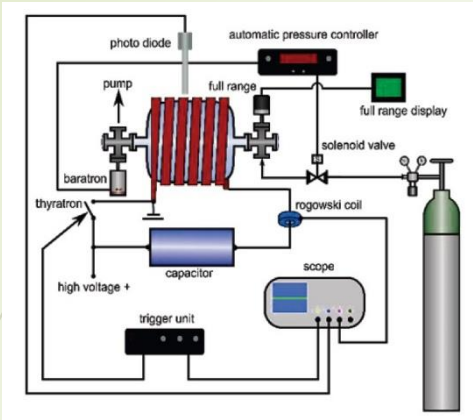
ESTIMATES OF THE FLYCHK CODE

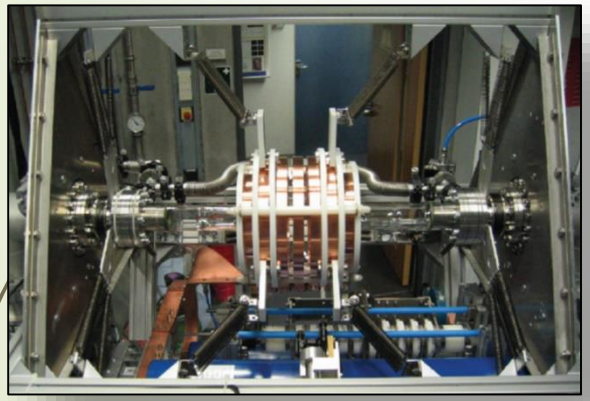


N_H= (1.9 ± 0.7) · 1017 cm−3 at T_e=
1 eV and N_e= 1.9 · 1016 cm−3.

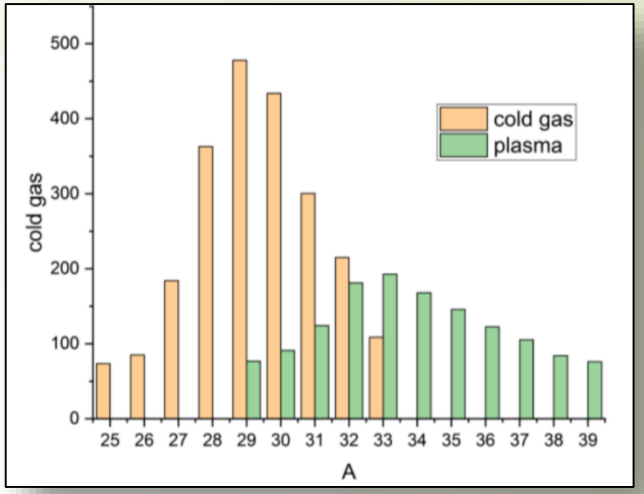
V.P Shevelko et et al., NIM B 502, 37(2021)
H,K,Chung et al., High Energy Density Physics 1, 3(2005)

EXPERIMENTAL SETUP AT GSI (UNIVERSITY OF FRANKFURT)





View of the Spherical Theta Pinch device : beam tests at GSI, Darmstadt, Germany

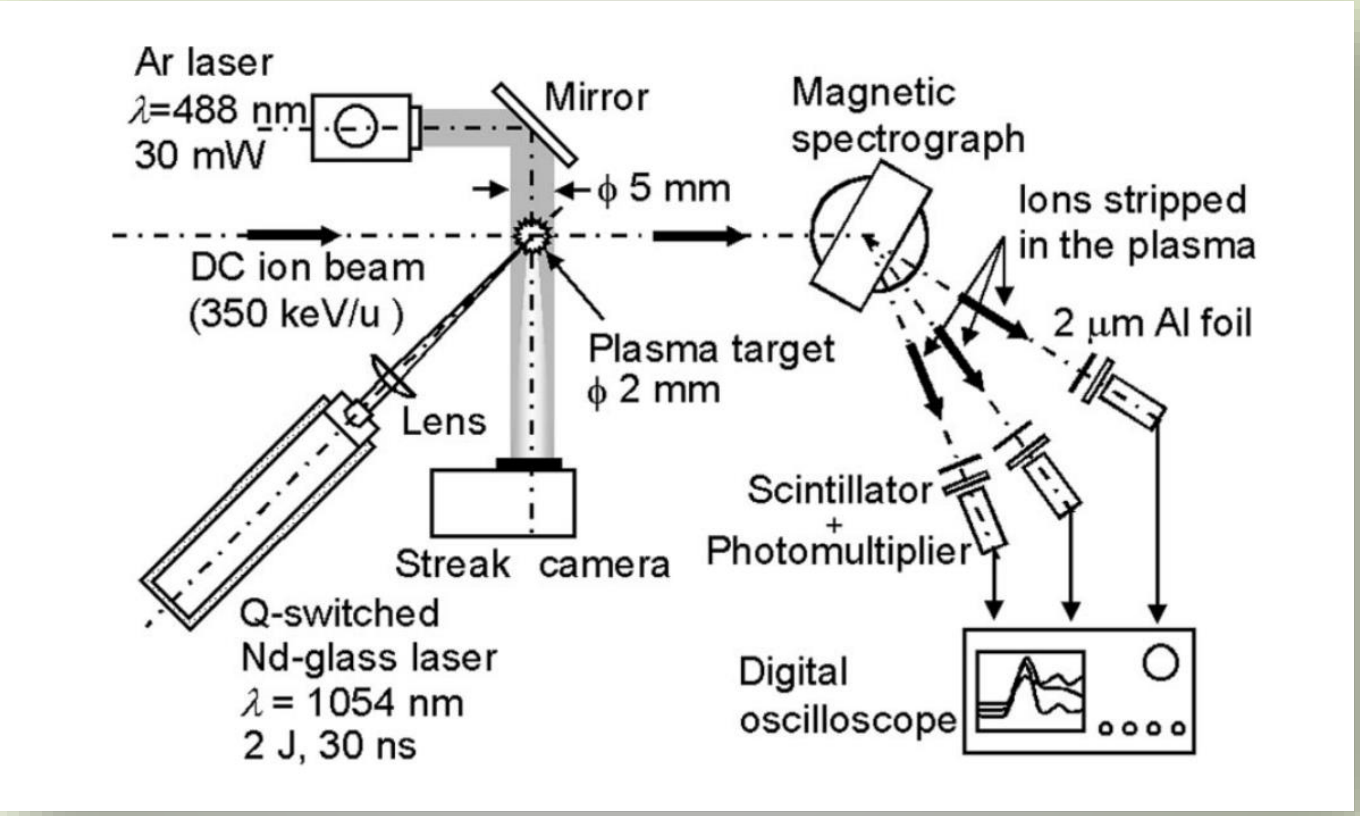


Charge state distribution of a 3.6 MeV/u Au^{26+} beam after passing through a hydrogen plasma in comparison to a cold gas

K,Cistakov et et al., IPAC 2019, Melbourne, Australia ; doi:10.18429/JACoW-IPAC2019-THPMP006

DISADVANTGES OF DISCHARGE PLASMAS

- A small amount of non-ionised species is sufficient to reduce the charge state distribution in discharge plasmas.
- The interaction between projectiles and cold gases used to produce the discharges at the boundaries of the plasma is unavoidable
- Motions of low energy projectiles are also affected by the strong magnetic field caused by the discharge currents (observed in the last experiment at GSI, by the Frankfurt Plasma Physics Group)
- **Alternatively, a laser produced plasma is another possible option**



Electron density distributions measured using laser beam refraction → simpler than conventional interferometric techniques

K.Shibata et et al., J.Appl.Phys., 91, 8, 4833(2002)

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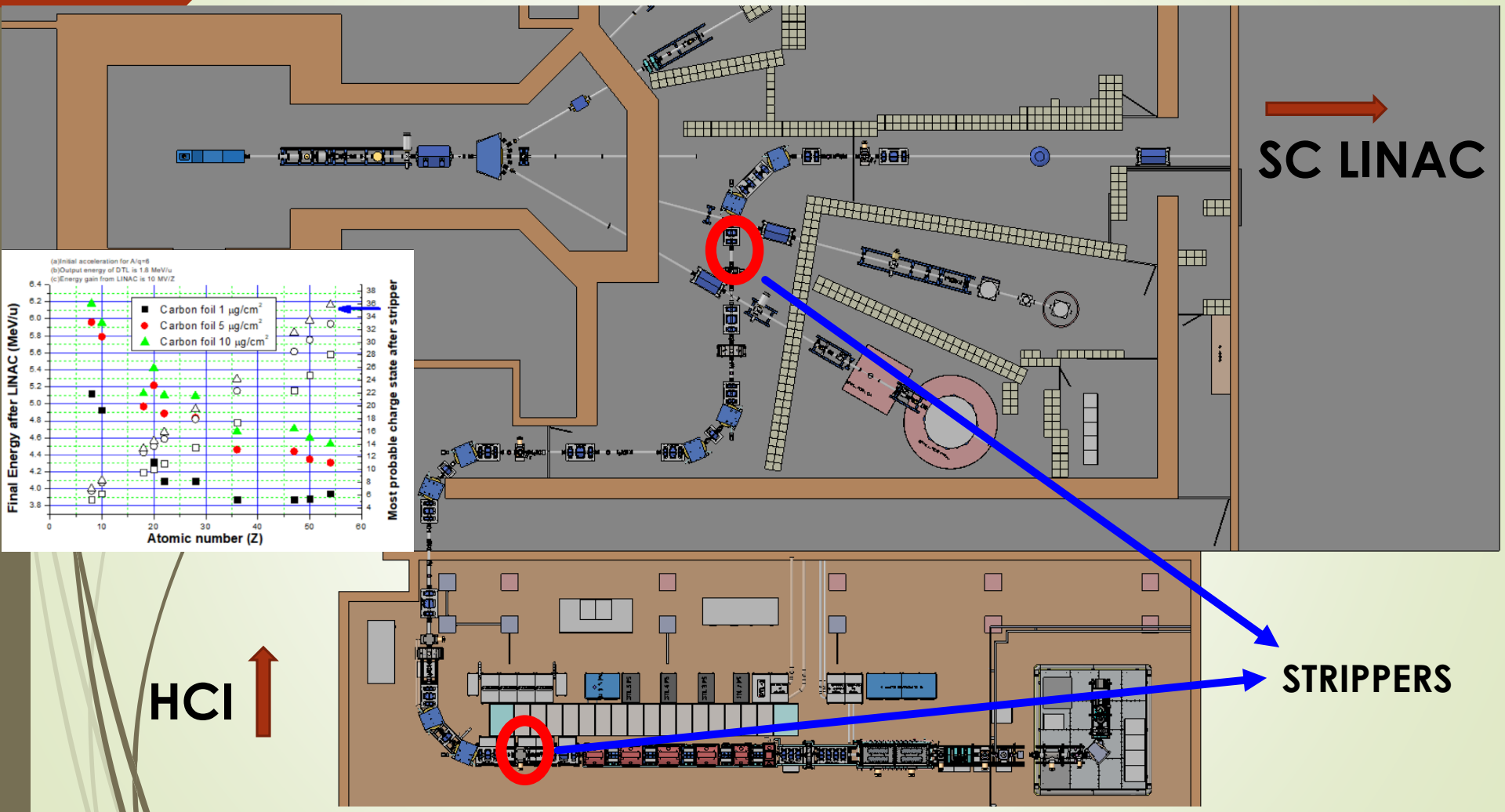
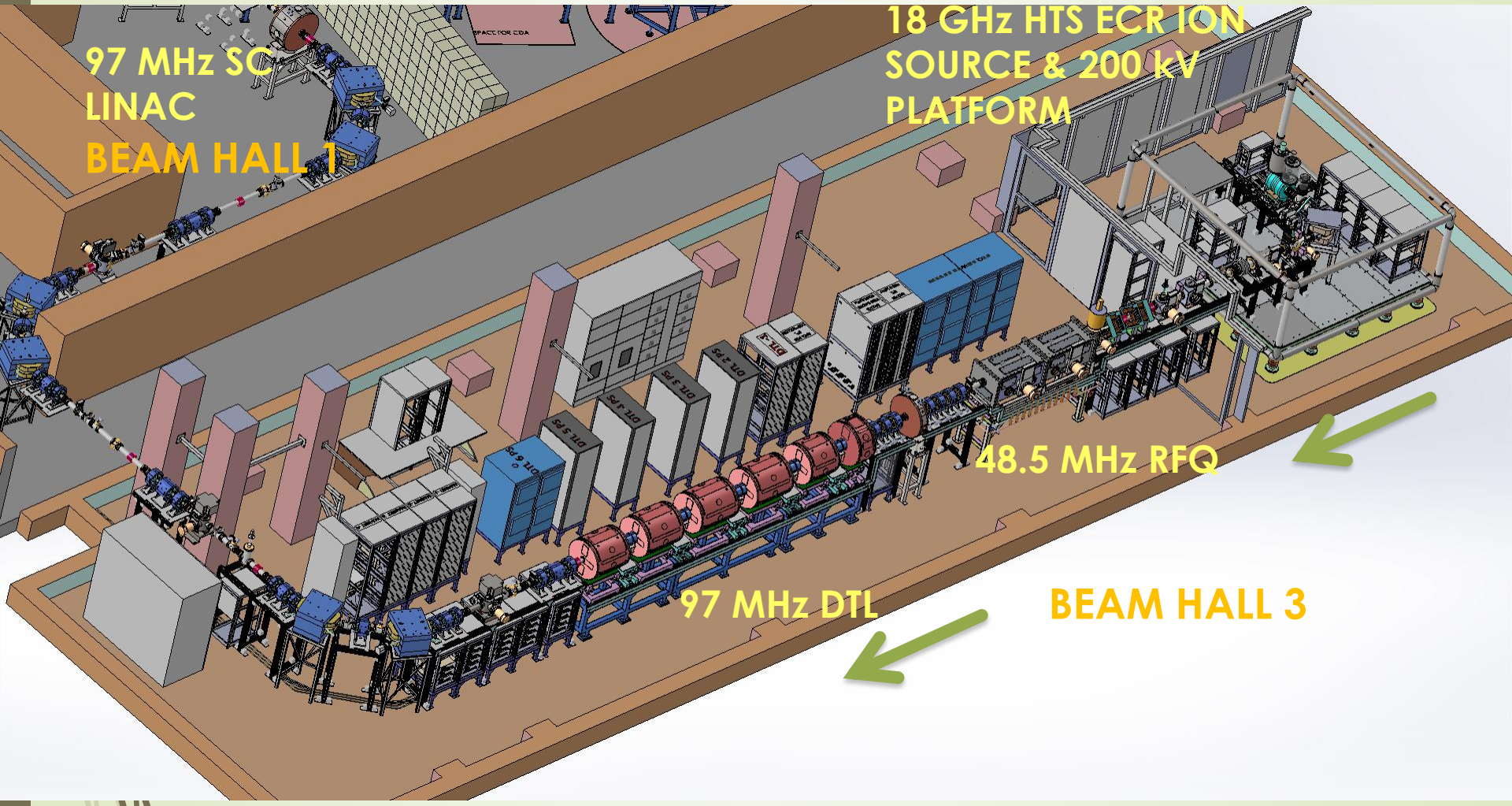
LAYOUT OF HIGH CURRENT INJECTOR (HCI)



HIGH CURRENT INJECTOR (HCI) BEAMLINE



Thank You for your Kind Attention