Recent activities at the ORNL Multicharged Ion Research Facility (MIRF)

Fred W. Meyer

Physics Division
Oak Ridge National Laboratory

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UT-BATTELLE
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Timeline of the Multicharged Ion Research Facility (MIRF)

- *ORNL ECR ion source, since 1984, dedicated to atomic collisions physics, MIRF established*
- *CAPRICE ECR ion source, since 1992*
- MIRF upgrade project

Extend upper energy limit to 250xq keV by placing new all permanent magnet ECR ion source on 250 kV high voltage platform

- *expands capabilities of present experiments*
- *opens door to new areas of study*
- completed 2005

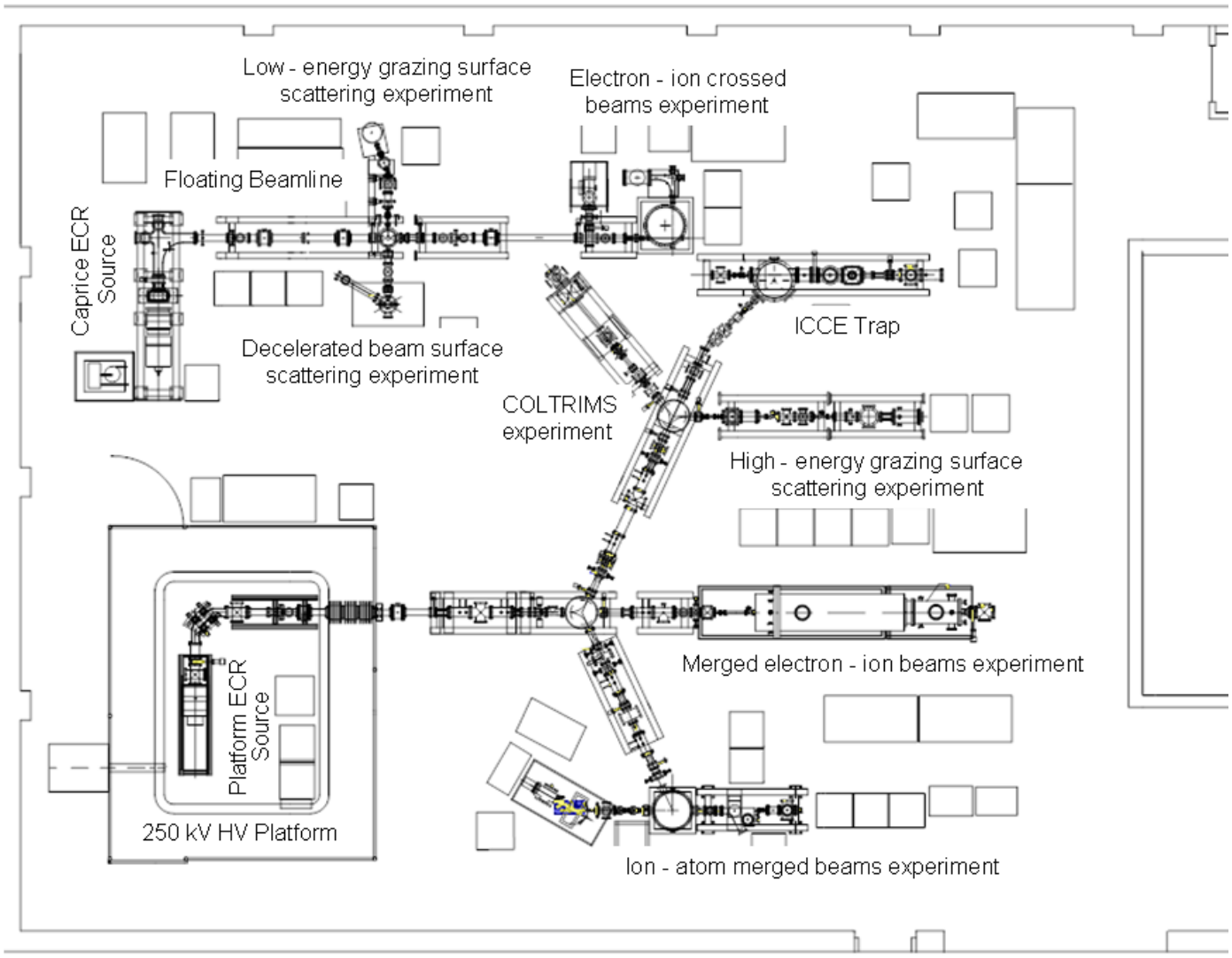
Extend lower energy limit to few eVxq by injecting CAPRICE beams into a floating beamline

- *efficient extraction and beam transport with subsequent deceleration at experimental end station*
- *simplifies present decelerated beams surface scattering experiment*
- *makes possible new experiments at very low energies*
- completed 2007

Develop linear electrostatic trap end station

- *fragmentation imaging for in-situ collisions of cold molecular ions with electrons and neutrals*
- Multisecond trapping lifetimes achieved Oct 2009

Present MIRF layout



Atomic Collision Studies at MIRF

Electron Collisions (Electron X-beam, MEIBEL, ICCE)

- Excitation and ionization of atomic ions
- Dissociation and ionization of molecular ions
- Ion beam excited state populations
- Dielectronic recombination of atomic ions
- Dissociative recombination of molecular ions
- Collisions with cooled ions (fragment imaging)

Heavy Particle Collisions (Merged beam , ICCE, COLTRIMS)

- Charge exchange between neutral atoms and molecules and atomic and molecular ions
- Very low relative velocities for heavy projectiles
- X-ray emission measurements of low energy CEX by HCI
- Highly charged ion neutralization during large angle projectile scattering
- Projectile excited state characterization
- Molecular dissociation
- Collisions with cooled ions (fragment imaging)

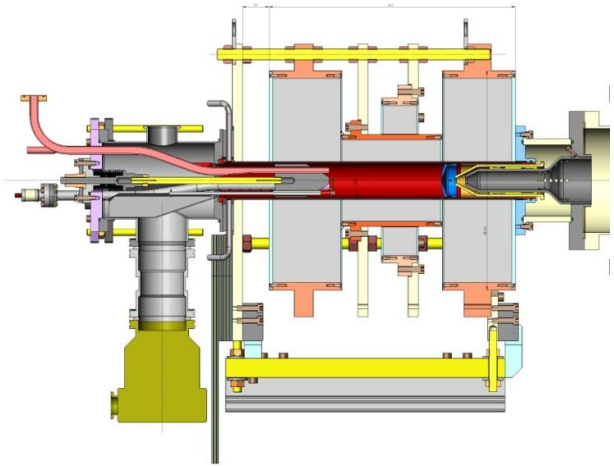
Low Energy Ion-Surface Scattering

- Chemical sputtering of graphite by low-energy D ions
- Neutralization of highly-charged ions in interactions with conducting and insulating crystals
- Charge-state distributions of scattered ions and neutrals
- “Soft” Molecular dissociation
- C-14 Detection

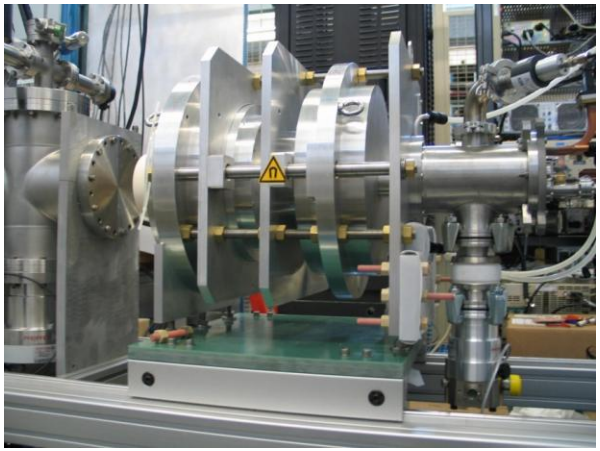
High Energy Ion-Surface Scattering

- Multicharged ion transmission/neutralization in nanocapillaries
- Multicharged projectile neutralization in grazing surface interactions
- Projectile excitation during grazing interactions with periodic (insulator) lattices
- Molecular dissociation interactions

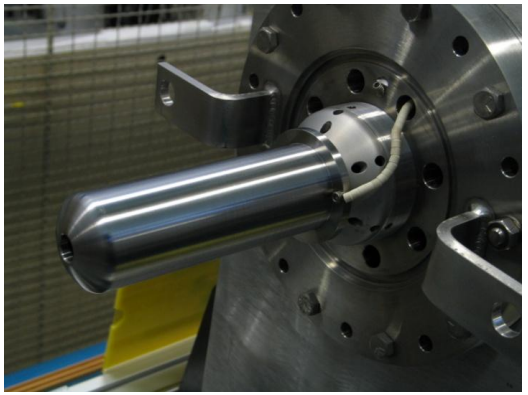
HV platform permanent magnet ECR ion source (Denis Hitz & Grenoble group)



0.9 T Tesla hexapole
1.8 Tesla w/ iron plug
12.5 – 14.5 GHz
750 W TWT
Ar: 8+ 510 μA; 11+ 90 μA
Xe: 20+ 25 μA; 30+ 1 μA
O: 1-3+ 700 μ A; 7+ 90 μA

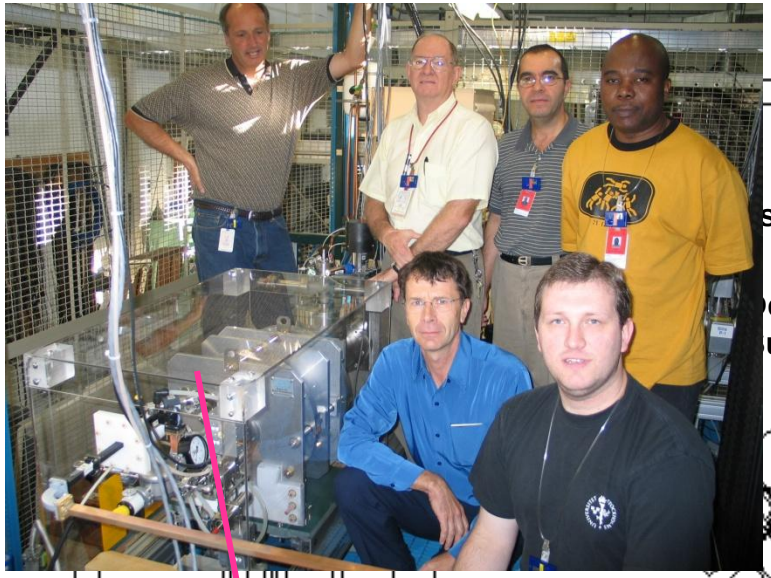


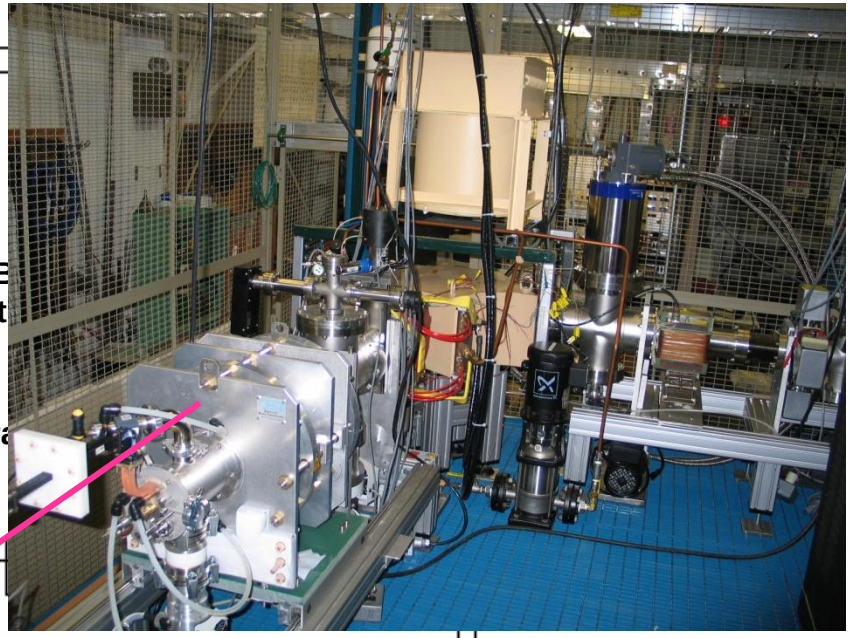
Relocation of TP
to reduce B field

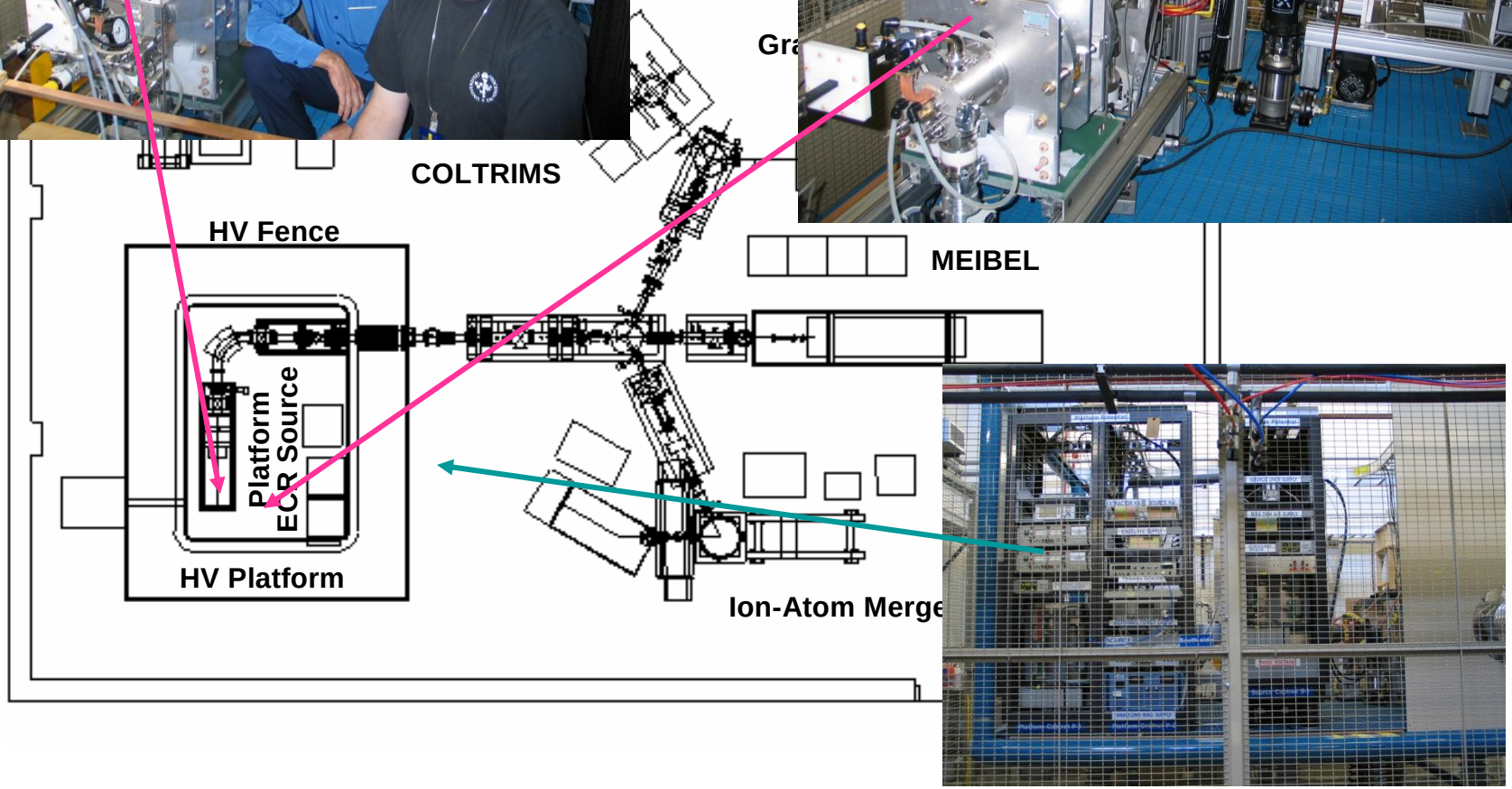


Modified Pierce geometry puller
to reduce insulator sputtering

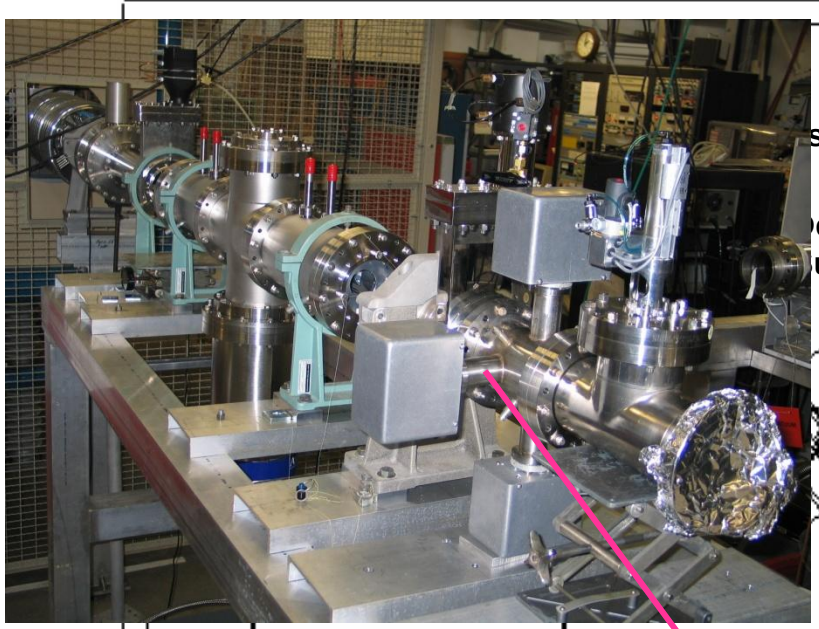
High voltage platform layout

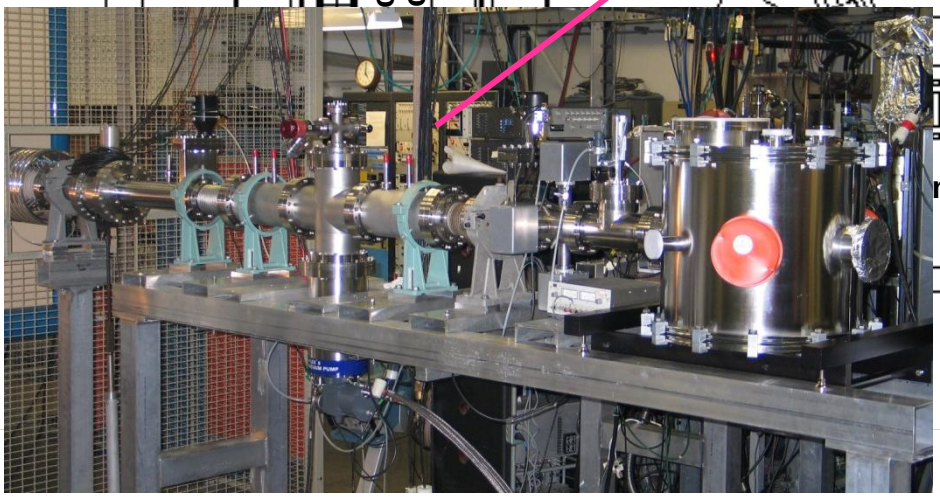




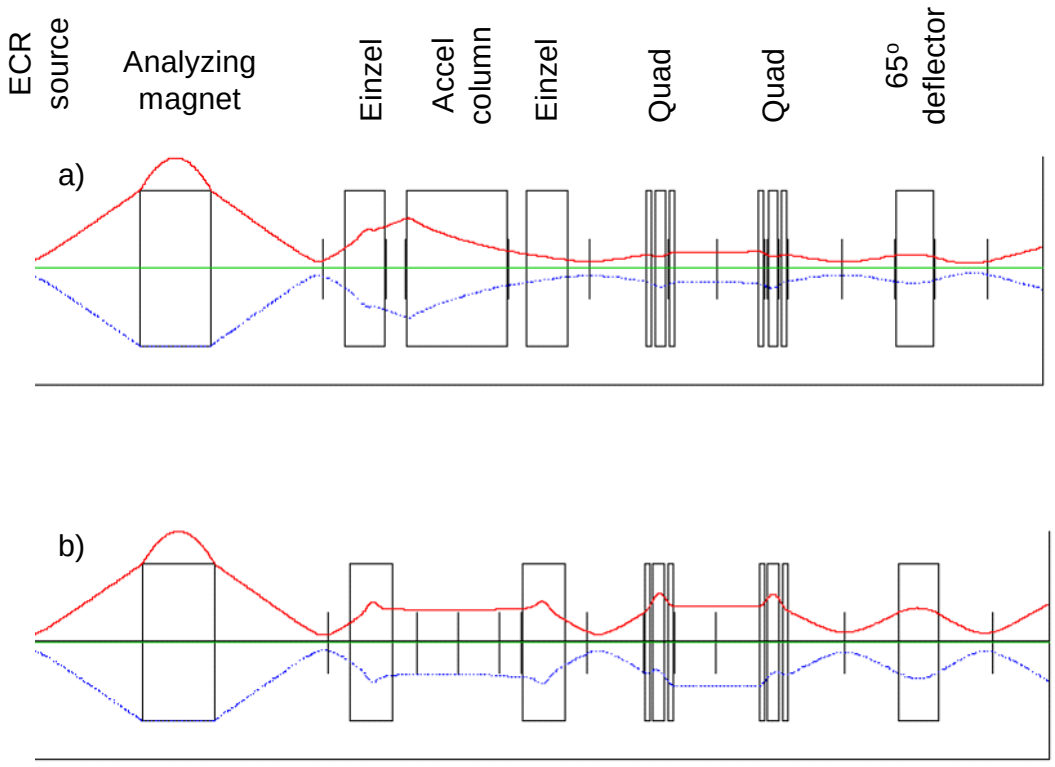


High energy beam line elements





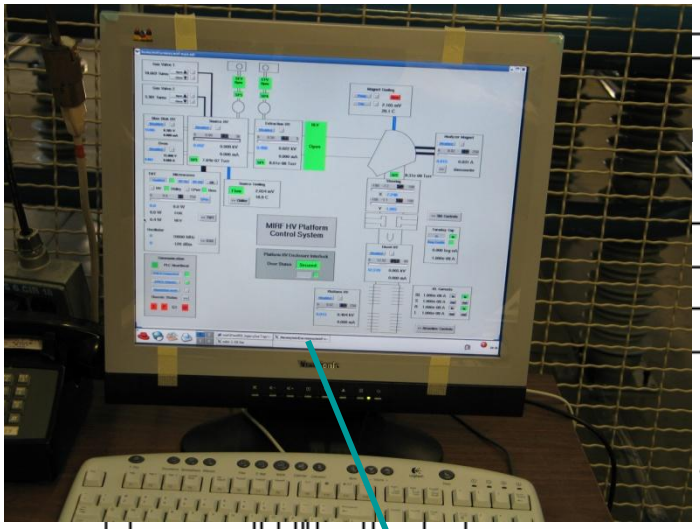
>90% transmission to end stations from 20 – 270 kV



High energy beam envelope:
- accel column provides main focusing strength for waist to waist beam transport

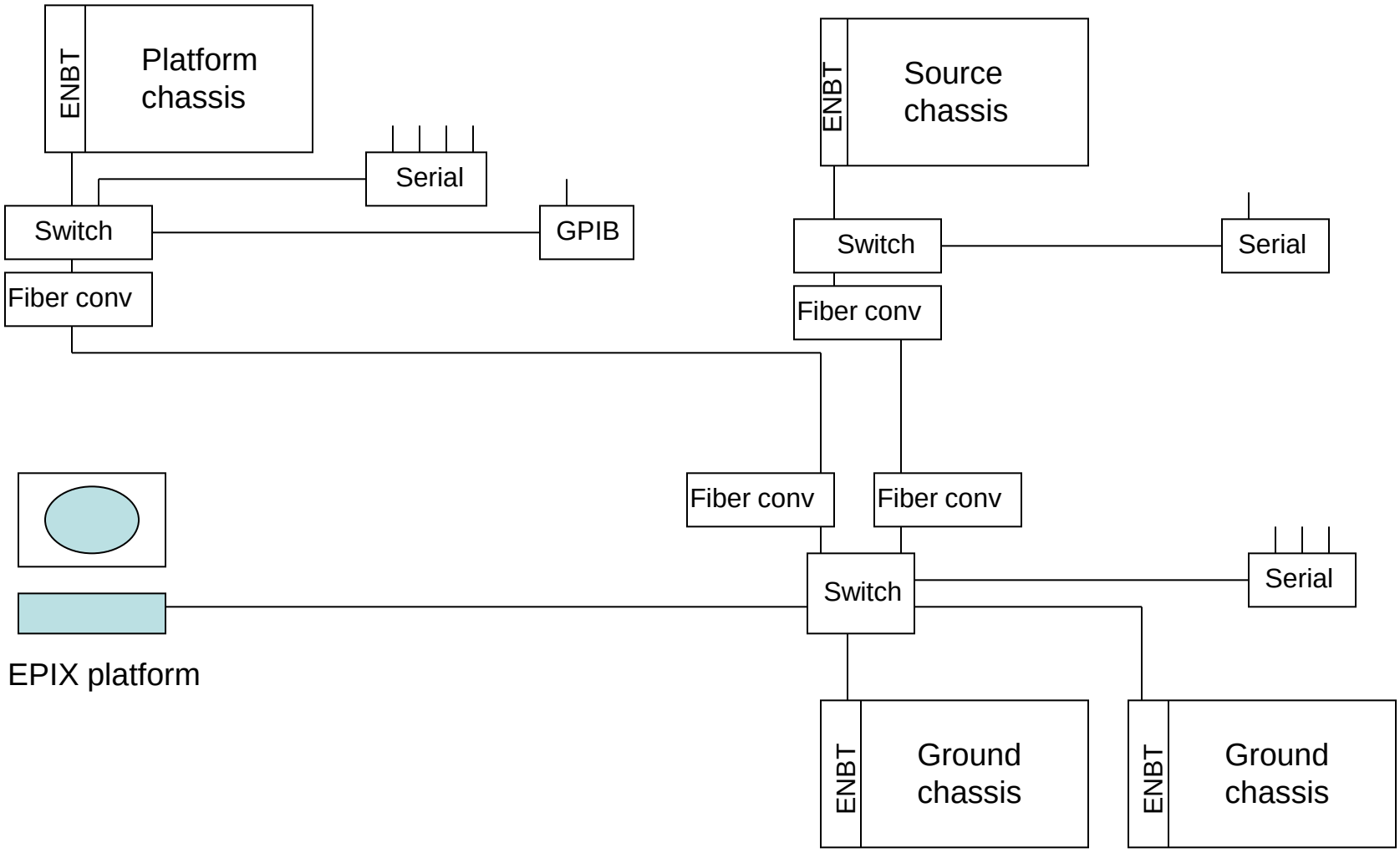
Low energy beam envelope:
- 2 einzel lenses provide waist to waist beam transport

Platform and high energy beam line control system (A-B ControlLogix/EPICS)

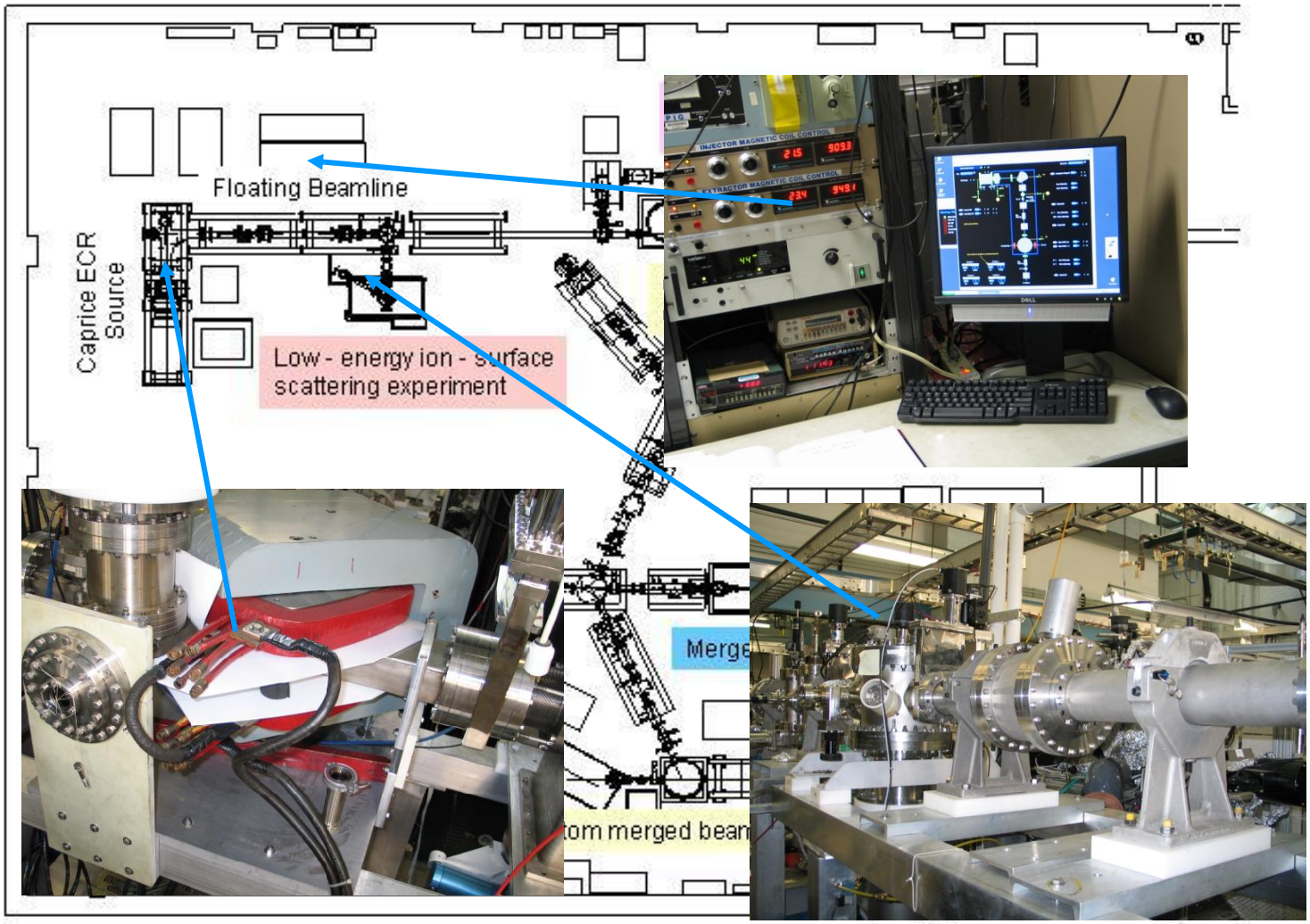


Ground chassis

Ethernet bridges among ControlLogix Chassis and to EPIX PC

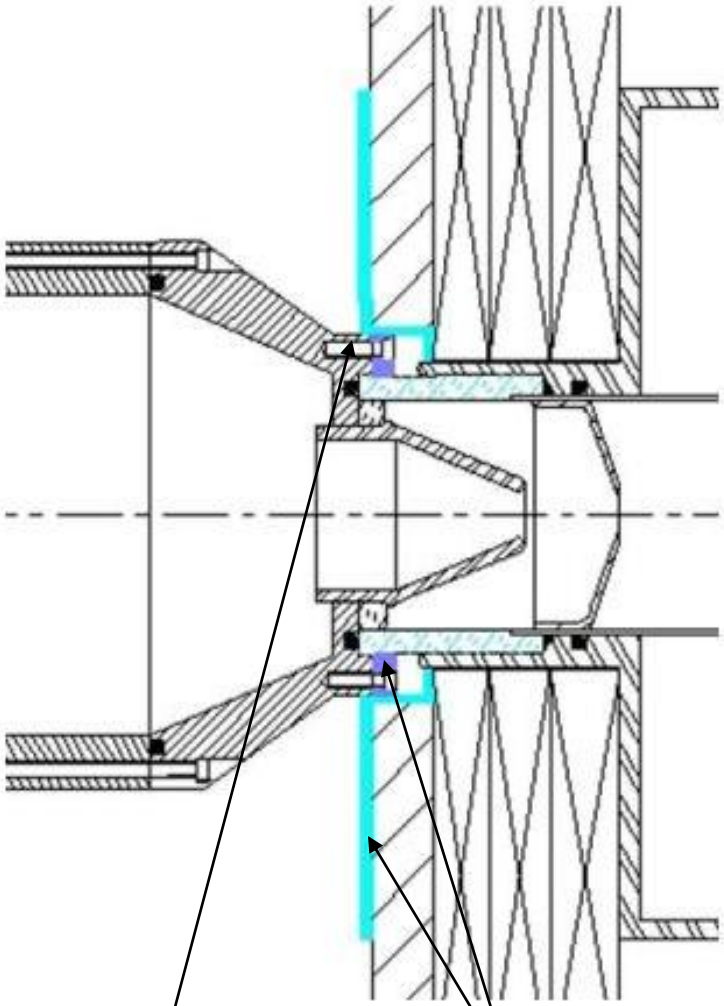


The floating beam line injected by CAPRICE



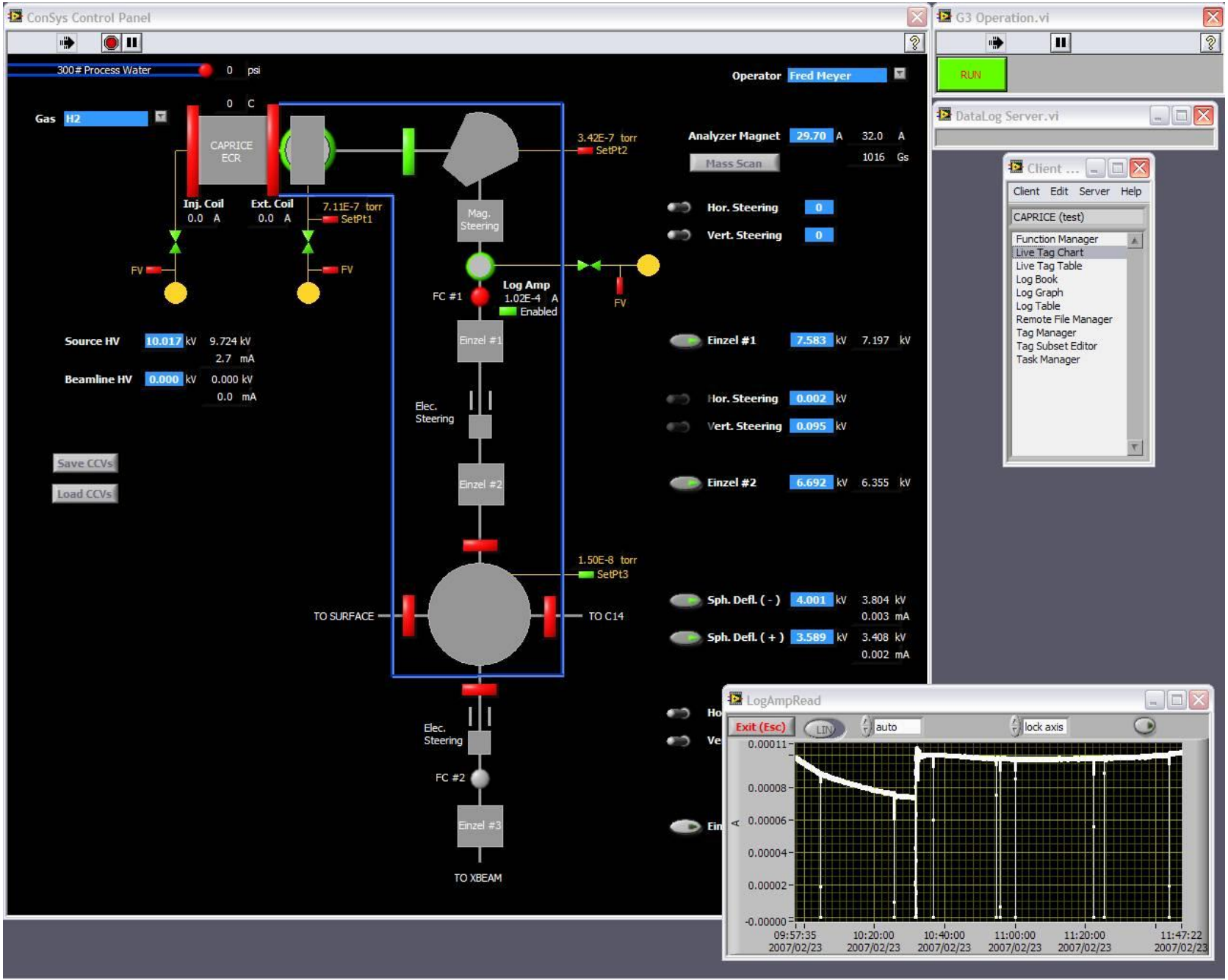
Low energy floating beam line HV isolation details

- Beamline supports on insulating Delrin blocks
- All pumps (1 DP, 1 TP, and 2 cryopumps) and ion gauges at ground potential, isolated from beamline HV by Delrin DC breaks
- All vacuum gate valves at HV: valve solenoids at ground potential
- 3.2 mm thick Teflon sheet between vacuum box and magnet for HV isolation

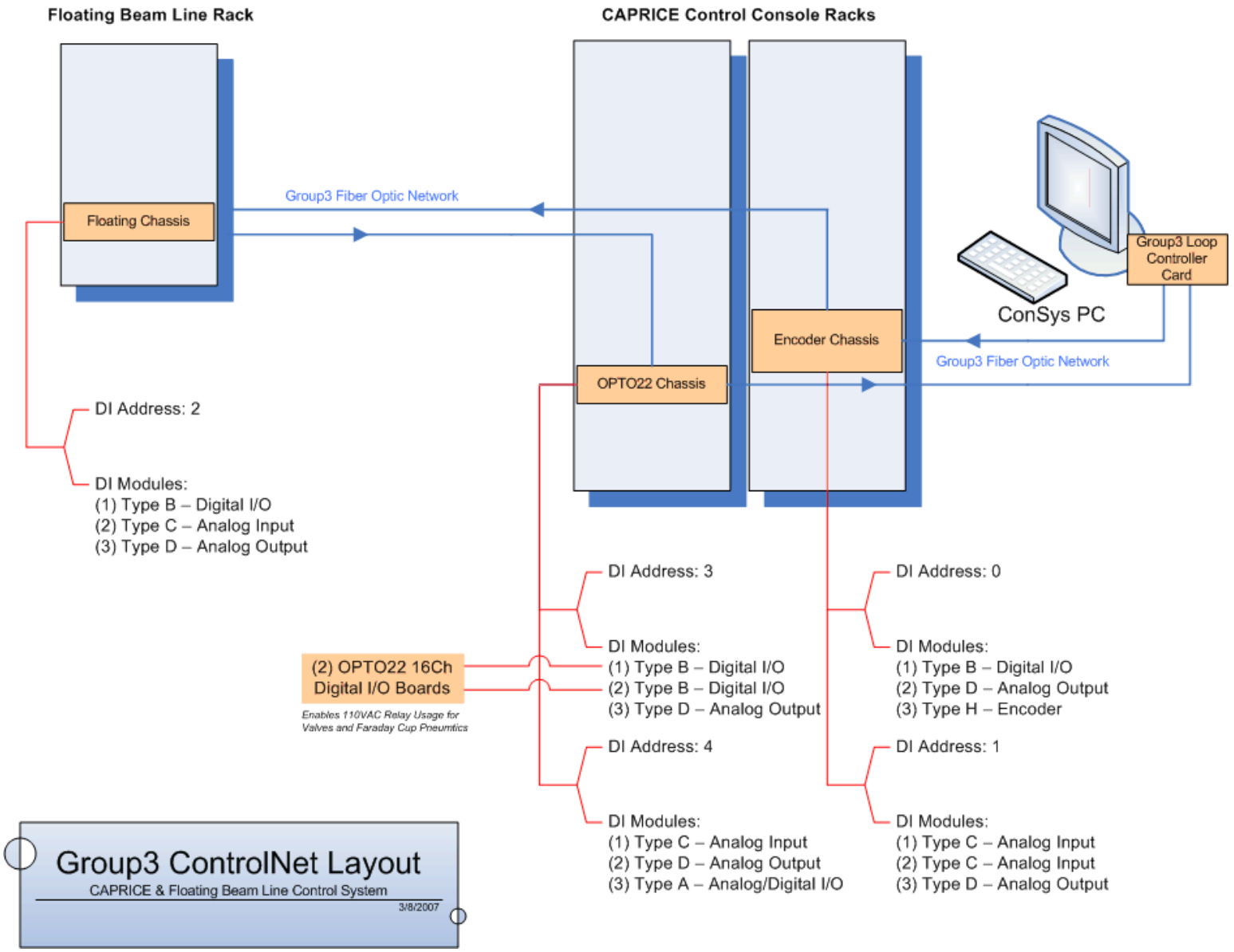


HV insulation of the ECR source extraction region enhanced by two added Delrin insulators, and nylon bolts

Floating beam line and ion source control screen with charting feature enabled



CAPRICE / Floating Beam Line Control System Network Diagram

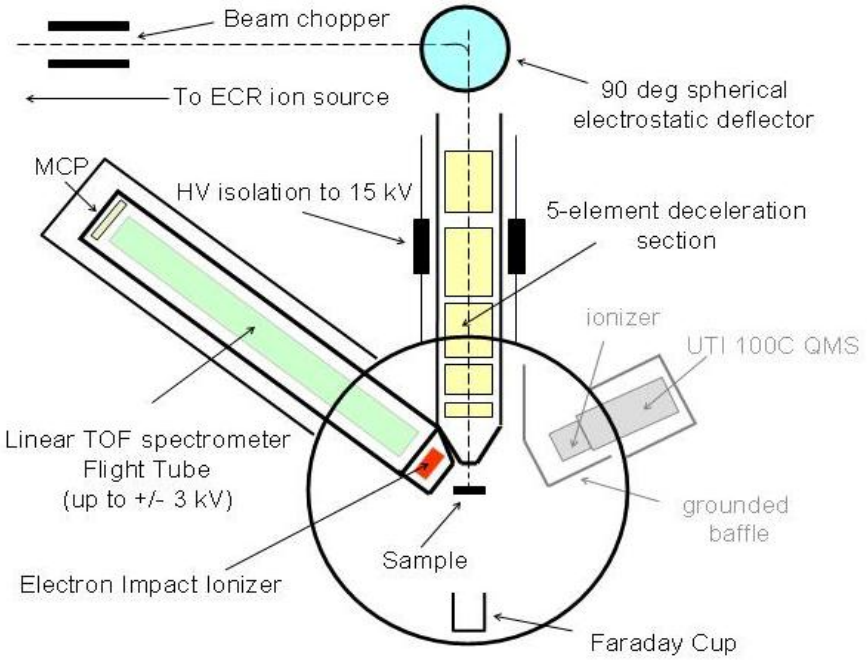


Low energy beam line - Control System Features

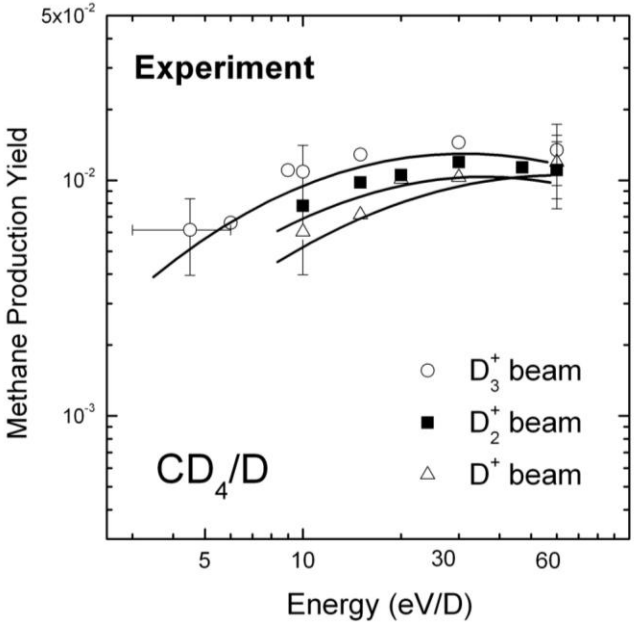
- Group3 ControlNet fiber-optically-linked distributed control system
- Small intelligent outstations (Device Interfaces or DI's) contain I/O boards
- A Loop Controller (LC) card handles communications on the fiber loop
- Group3 virtual instruments (VI) for LABVIEW handle all set-up tasks, and access all I/O data in LC
- Implements open source LuaVIEW data logging package

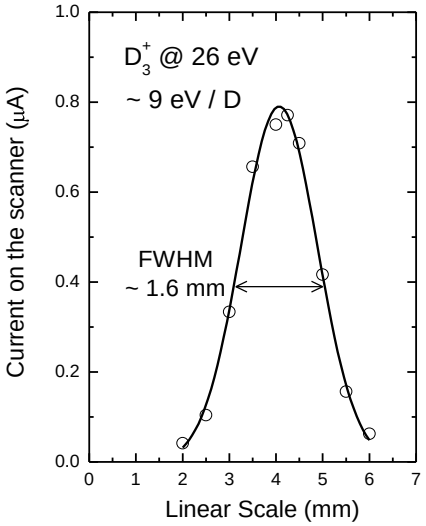
    process variables (tags) logging using time-, event-, or threshold-based algorithms
    alarms or warnings if limit values are exceeded
    mass scan utility
    charting functions
    control variable save and restore functions

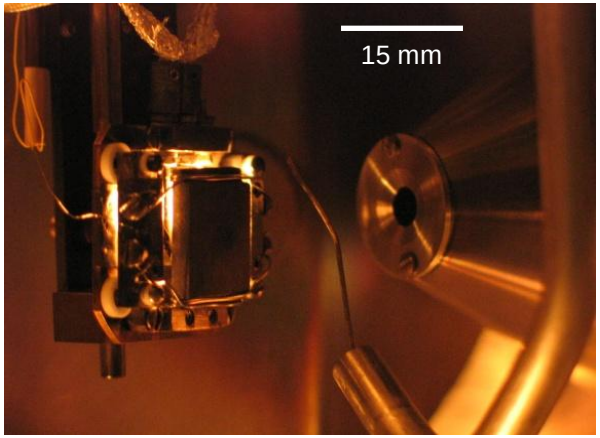
Low energy sputtering experiment needs well characterized, intense molecular ion beams



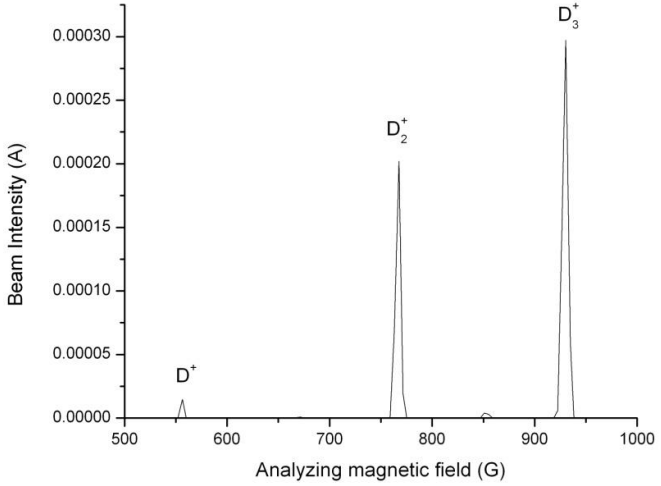
Chemical sputtering of graphite



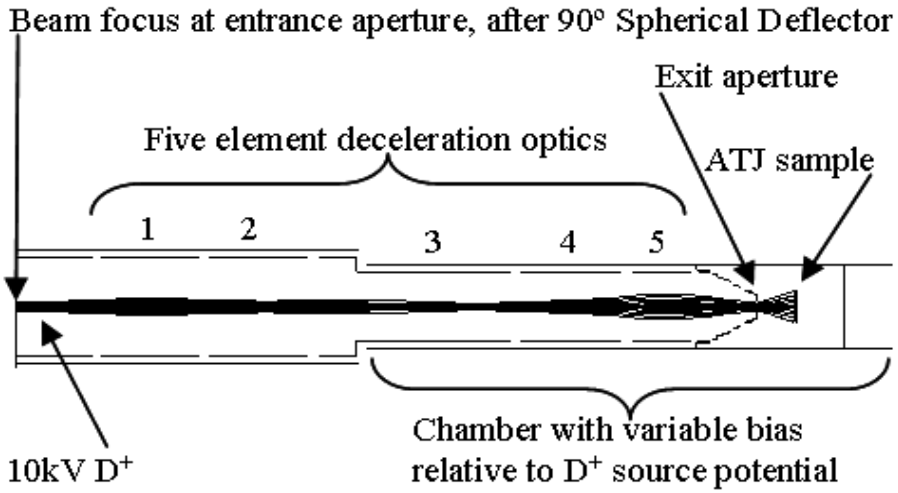




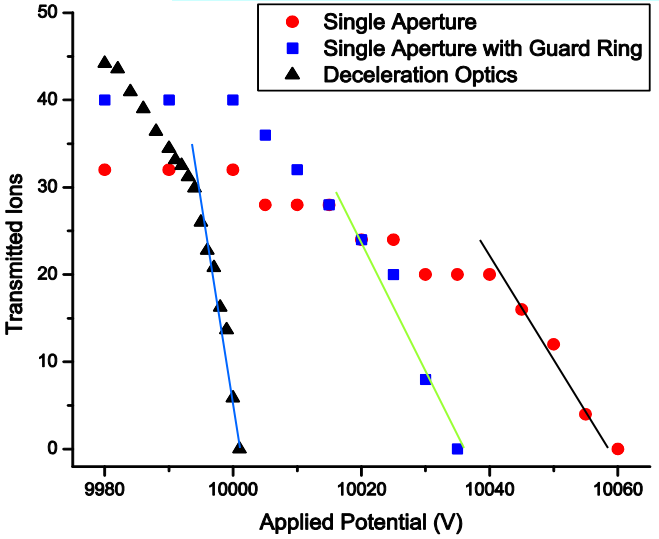
At high source pressure D_3^+ beam from CAPRICE dominates

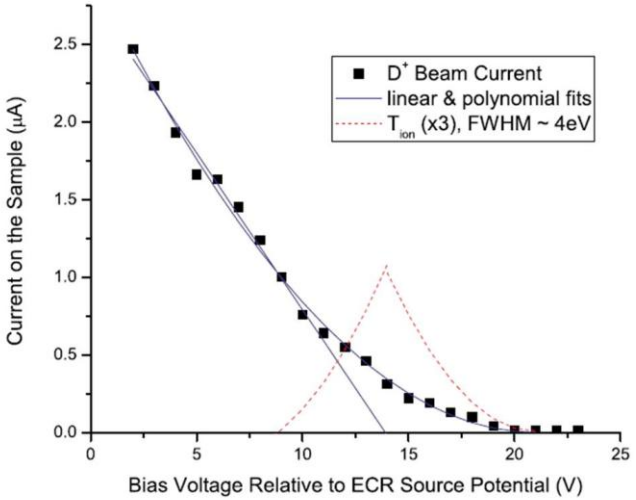


Correction for the ECR plasma potential is crucial for low energy experiments



Deceleration of 10 keV ion beam



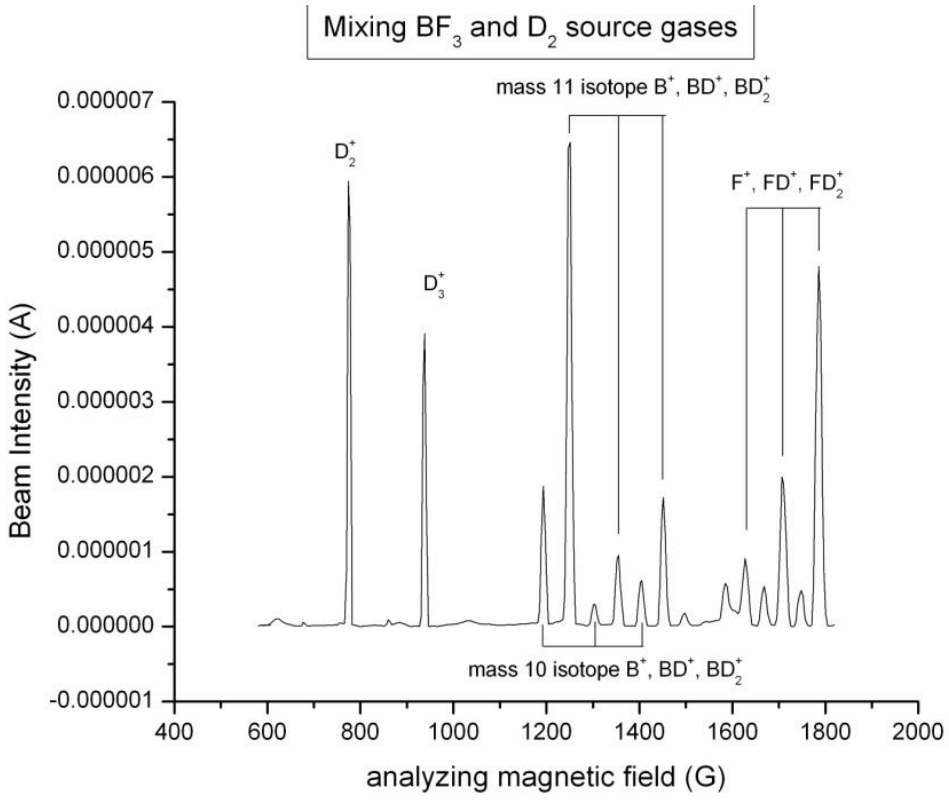


Abscissa intercept of linear region gives plasma potential estimate of *13.5 V*; difference between linear fit and actual retardation curve gives ion energy spread estimate of *4 V FWHM*

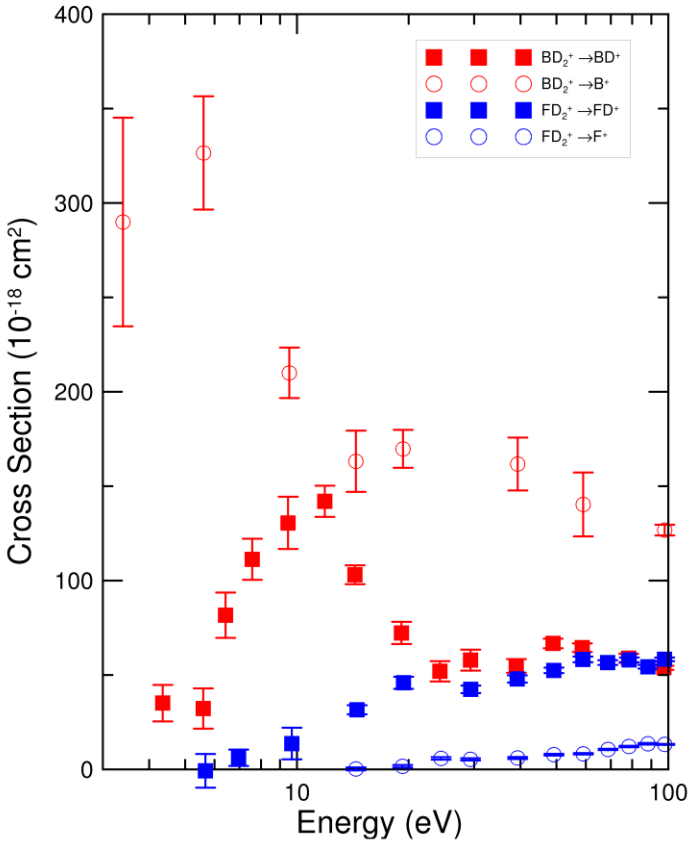
Values depend on source conditions !

ECR source chemistry produces molecular ion species for Electron X-beam Experiment

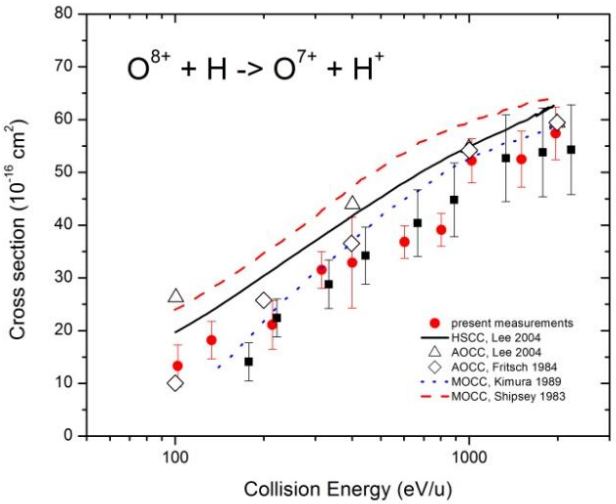
CAPRICE ECR source

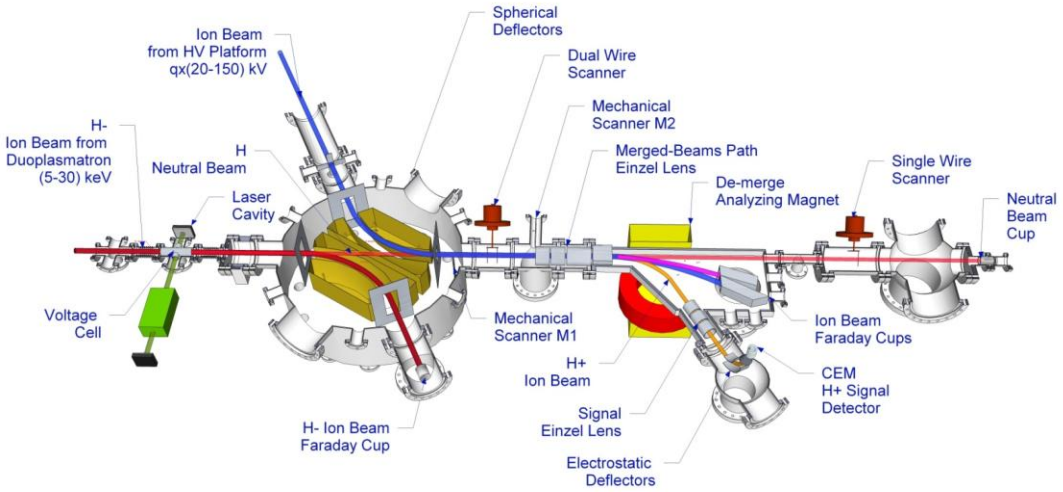


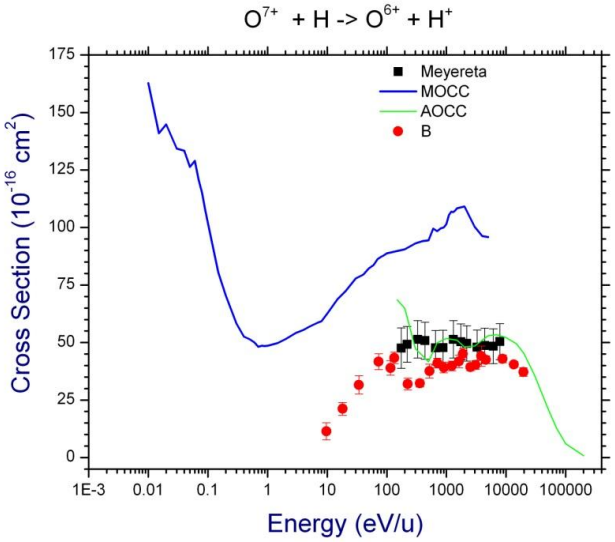
Electron impact dissociation of BD_2^+, FD_2^+

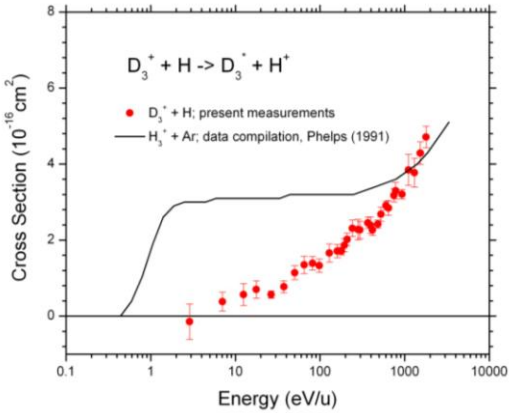


Ion-atom Merged Beams Experiment uses multi-charged as well as molecular ion beams

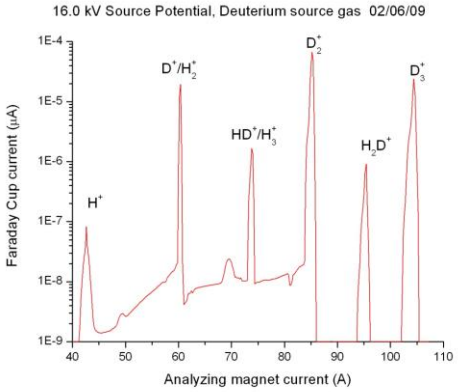








Platform ECR source



Discharge in extraction region limits max source pressure, and therefore max D_3^+ current

*The new **I**on **C**ooling and **C**haract**E**rization (ICCE) Trap End Station*

- *lifetime studies of excited molecular and multi-charged ions*
- *neutral fragment imaging*
- *studies of dissociative recombination and capture of molecular ions*