SLENA 2008

School-cum-Workshop on
Low Energy Nuclear Astrophysics

SINP Kolkata, February 19-22, 2008

A 500 kV High Current Accelerator for FRENA

D. Kanjilal

IUAC, New Delhi 110067

Aim:

Underground low energy ion beam facility -

Compact facility with -

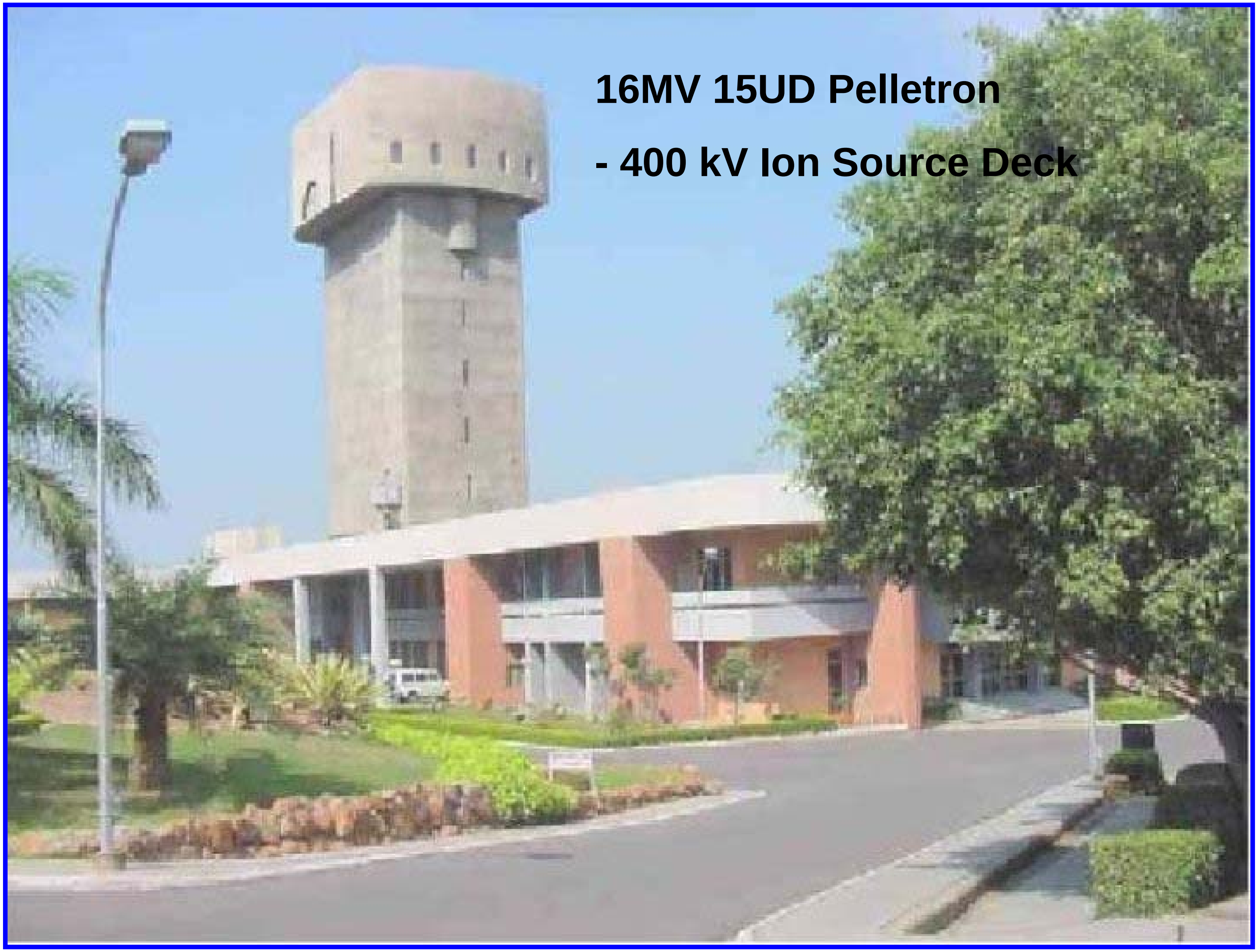
High flux (mA) ion beams tens of keV to a few MeV

Minimum power/water consumtion– Minimum load to air conditioning/cooling system

Ion beam system may run for months/years unattended

Flexibility in operation and any beam species

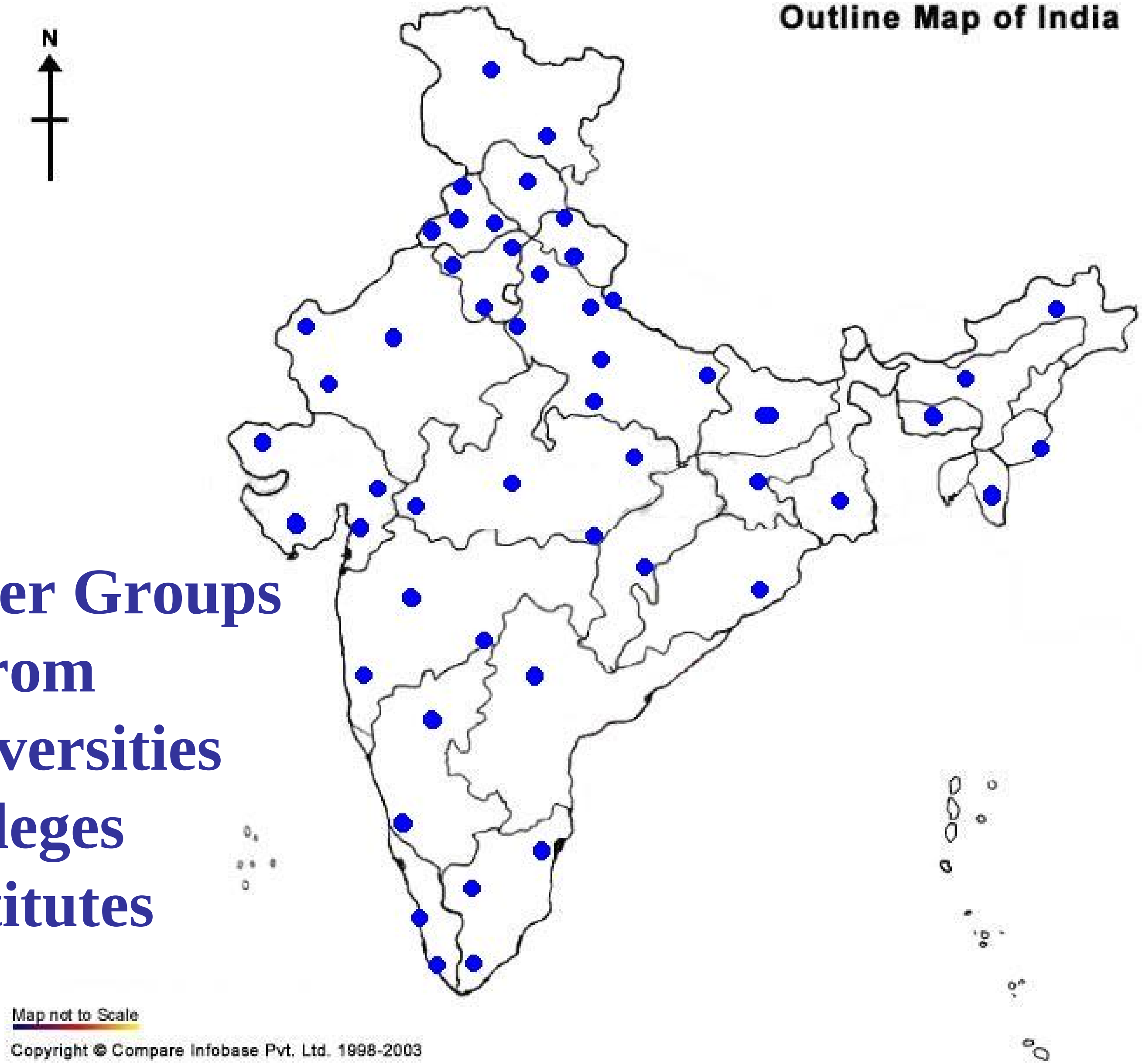
Negligible polution and danger



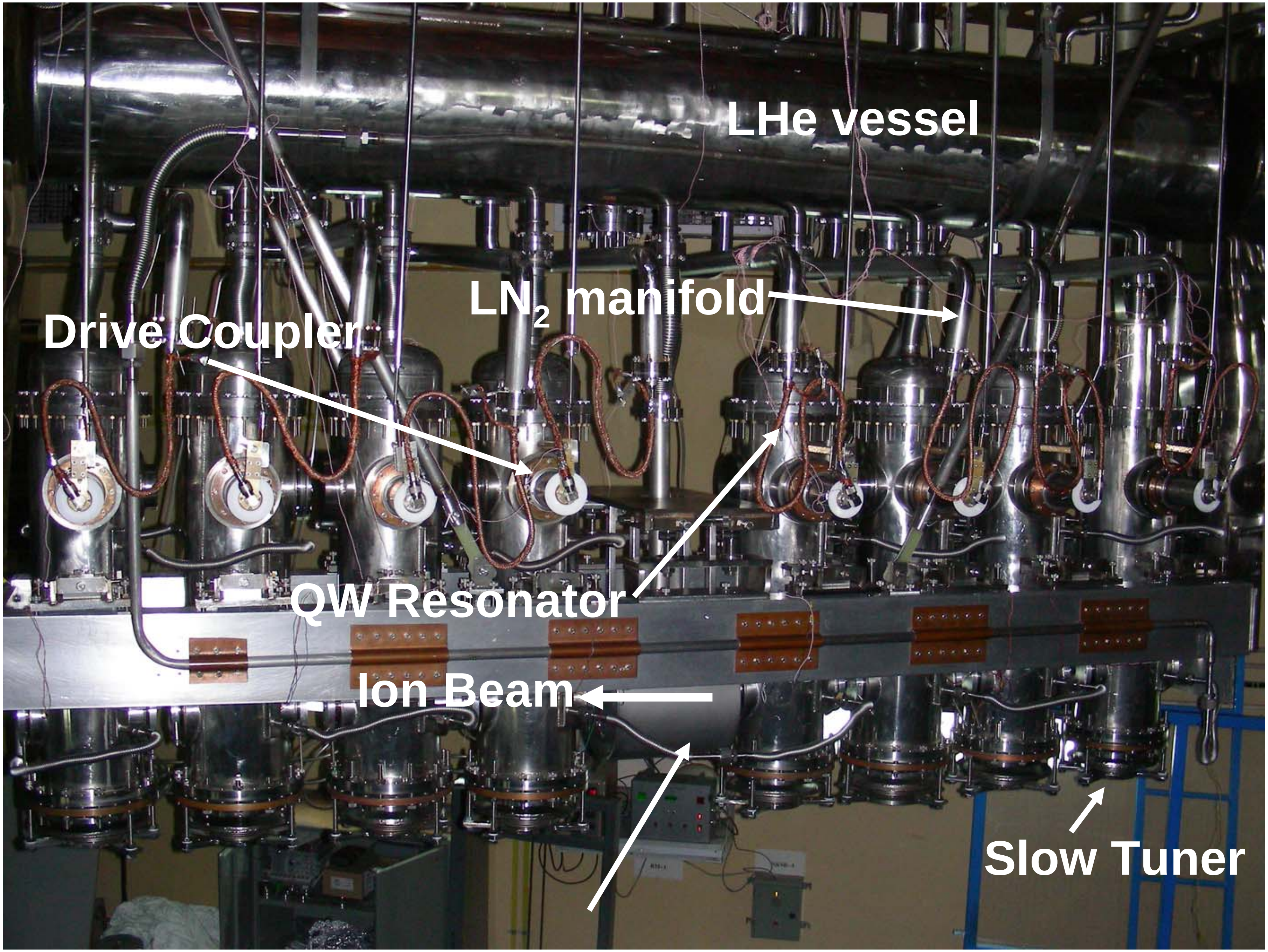
Inter-University Accelerator Centre (IUAC), New Delhi

D.Kanjilal et al, Nucl. Instr. Meth. A 328, 97 (1993).

Ion Beam User Community of IUAC

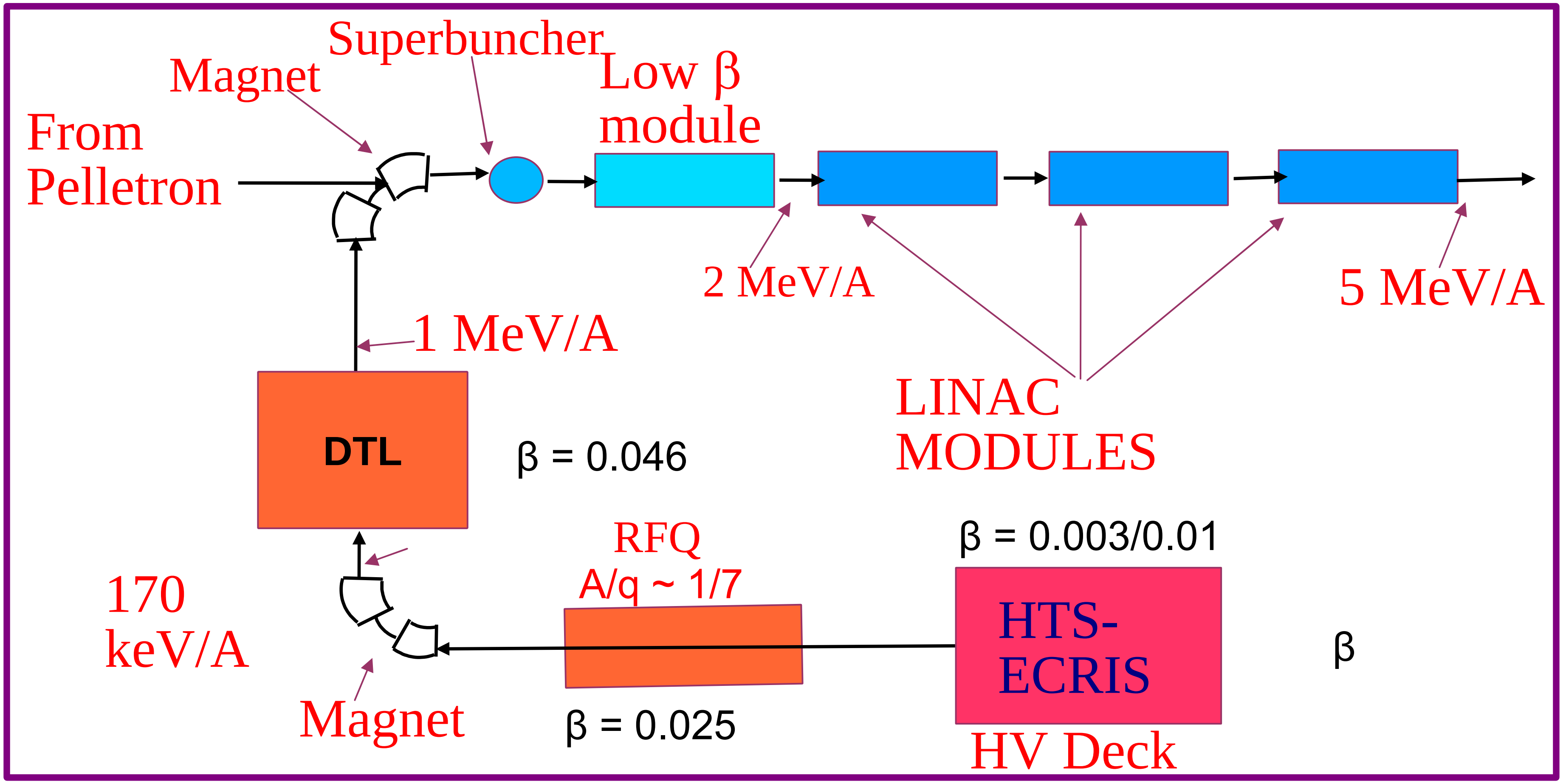


310 User Groups
from
76 Universities
44 Colleges
45 Institutes



Resonators of the first Linac module (E_{av}~3.6 MV/Resonator)

HTS-ECRIS based High Current Injector for LINAC



Alternate high performance ECRIS based injector for superconducting LINAC

Electron cyclotron resonance (ECR):

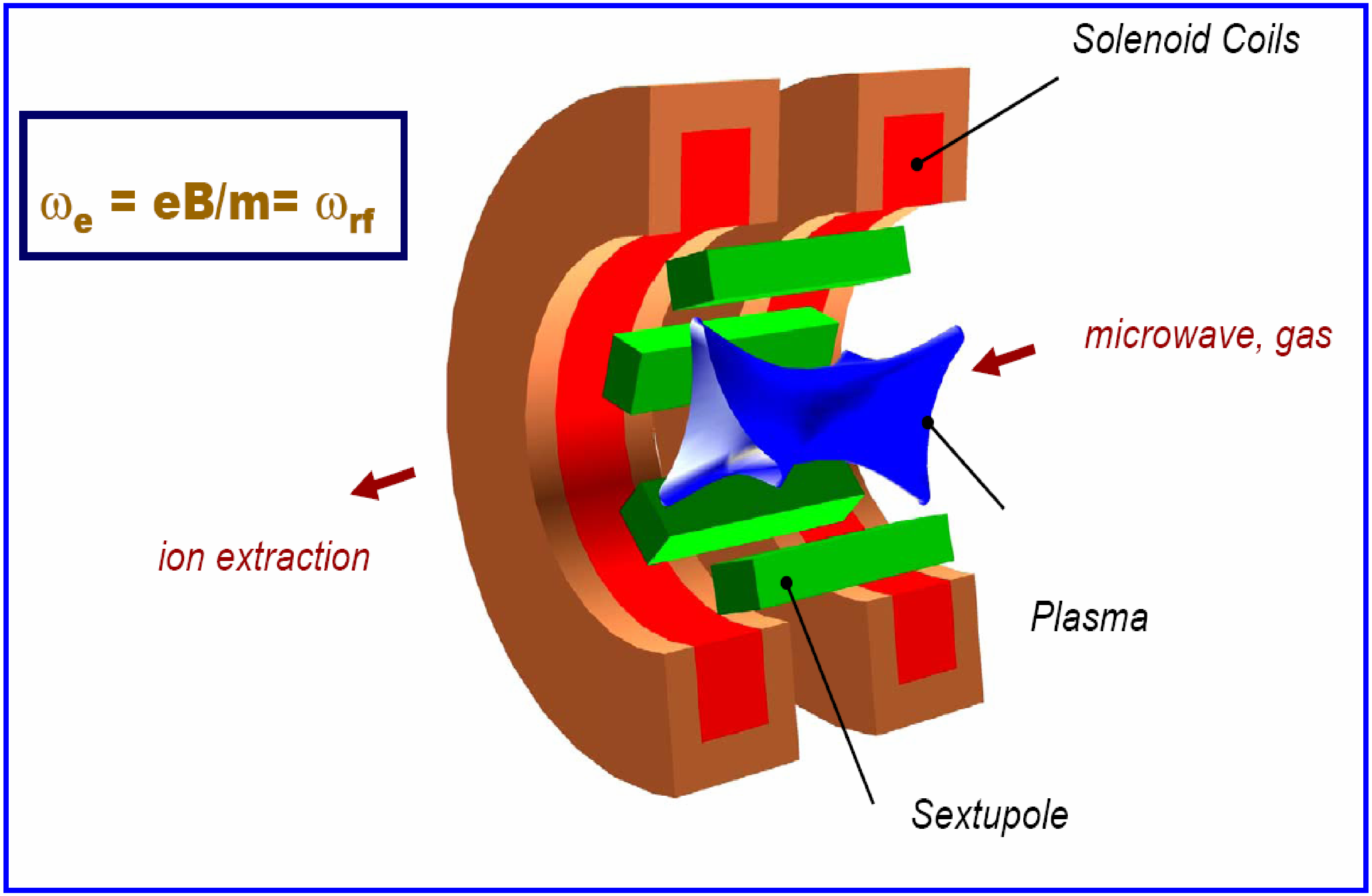
An electron in a static and uniform magnetic field will move in a circle due to the Lorentz force. The circular motion may be superimposed with a uniform axial motion, resulting in a helix, or with a uniform motion perpendicular to the field, resulting in a cycloid in the presence of an electrical field. The angular frequency ($\omega = 2\pi f$) of this ***cyclotron* motion** for a given magnetic field strength B is given (in SI units) by

$$\omega_{ce} = \frac{eB}{m}$$

.

where e is the elementary charge and m is the mass of the electron. For the commonly used microwave frequency 2.45 GHz and the bare electron charge and mass, the resonance condition is met when B = 875 G = 0.0875 T.

Principle of Electron Cyclotron Resonance Ion Source (ECRIS)



The ECR ion source makes use of the Electron Cyclotron Resonance to heat a plasma.

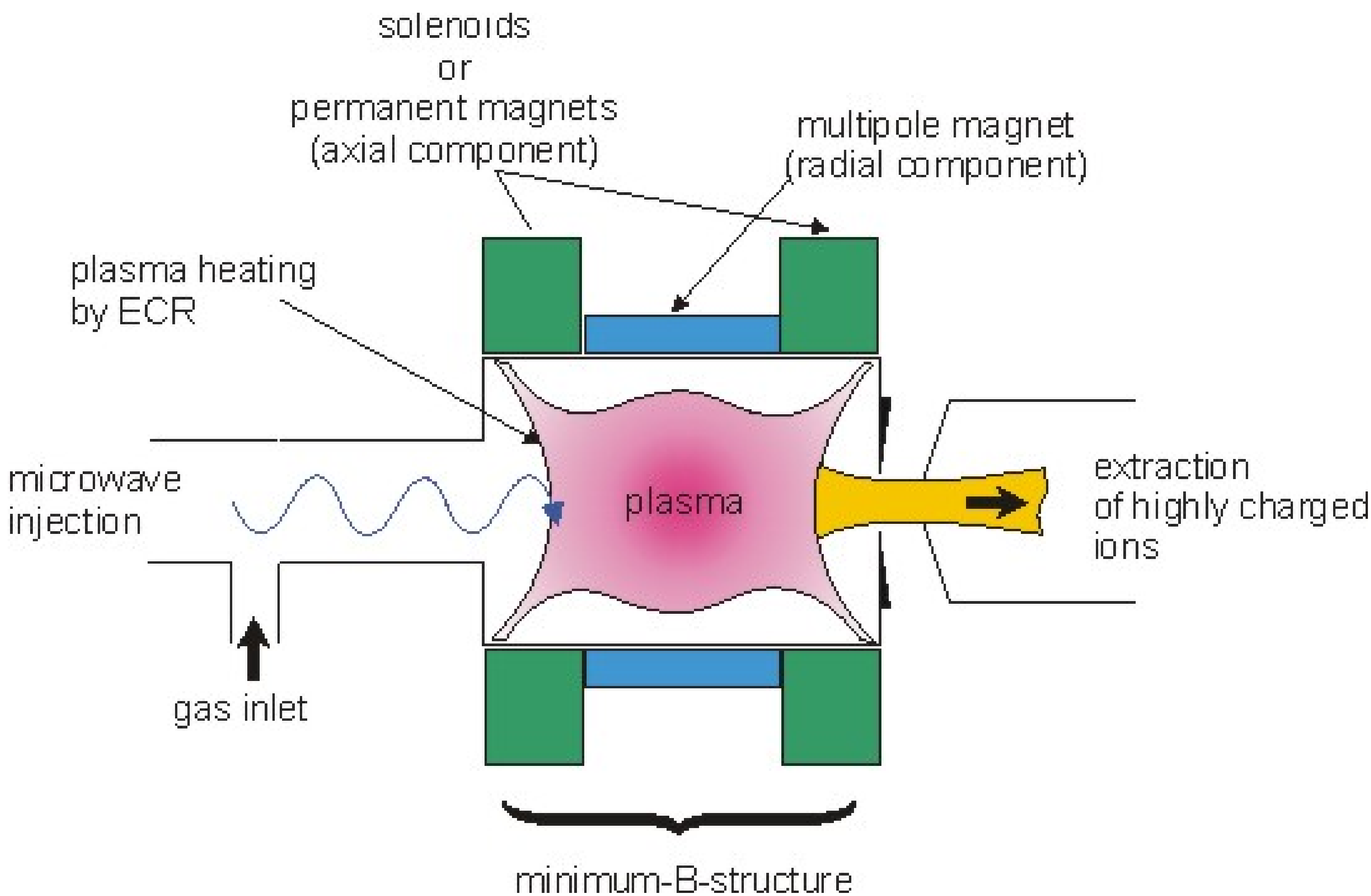
Microwaves are injected into a volume, at the frequency corresponding to the Electron Cyclotron Resonance defined by a magnetic field applied to a region inside the volume.

The volume contains a low pressure gas. The microwaves heat free electrons in the gas which in turn collide with the atoms or molecules of the gas in the volume and cause ionization.

ECR ion sources are able to produce H+ and D+ ions with high intensities of more than 100 mA in DC mode using a 2.45 GHz UHF Transmitter.

For multiply charged ions, the ECR ion source has the advantage that it is able to confine the ions for long enough for multiple collisions to take place (leading to multiple ionization) and that the low gas pressure in the source avoids recombination.

Some of the industrial fields would not even exist without the use of this fundamental technology, which makes Electron Cyclotron Resonance ion and plasma sources one of the enabling technologies of today's world.



Creation of ECR plasma and extraction of ion beam

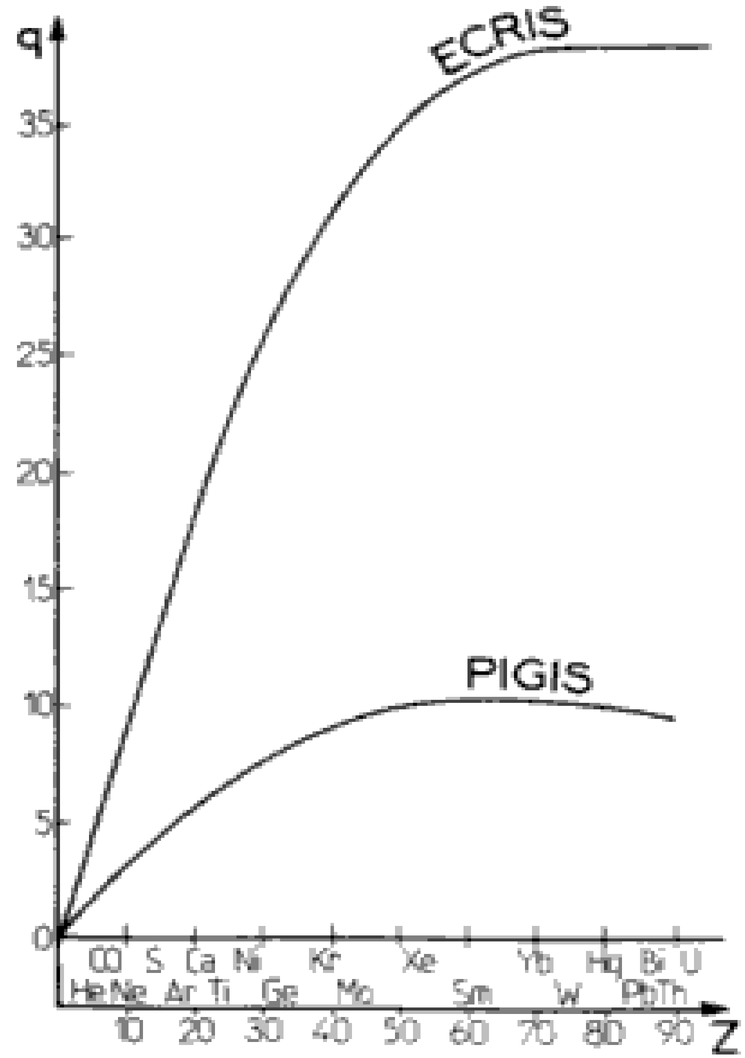
Many diverse applications are based on ECR technology:

- Cancer treatment, where ECR ion sources are crucial for proton or carbon therapy with negligible fluctuation of ion beam current,

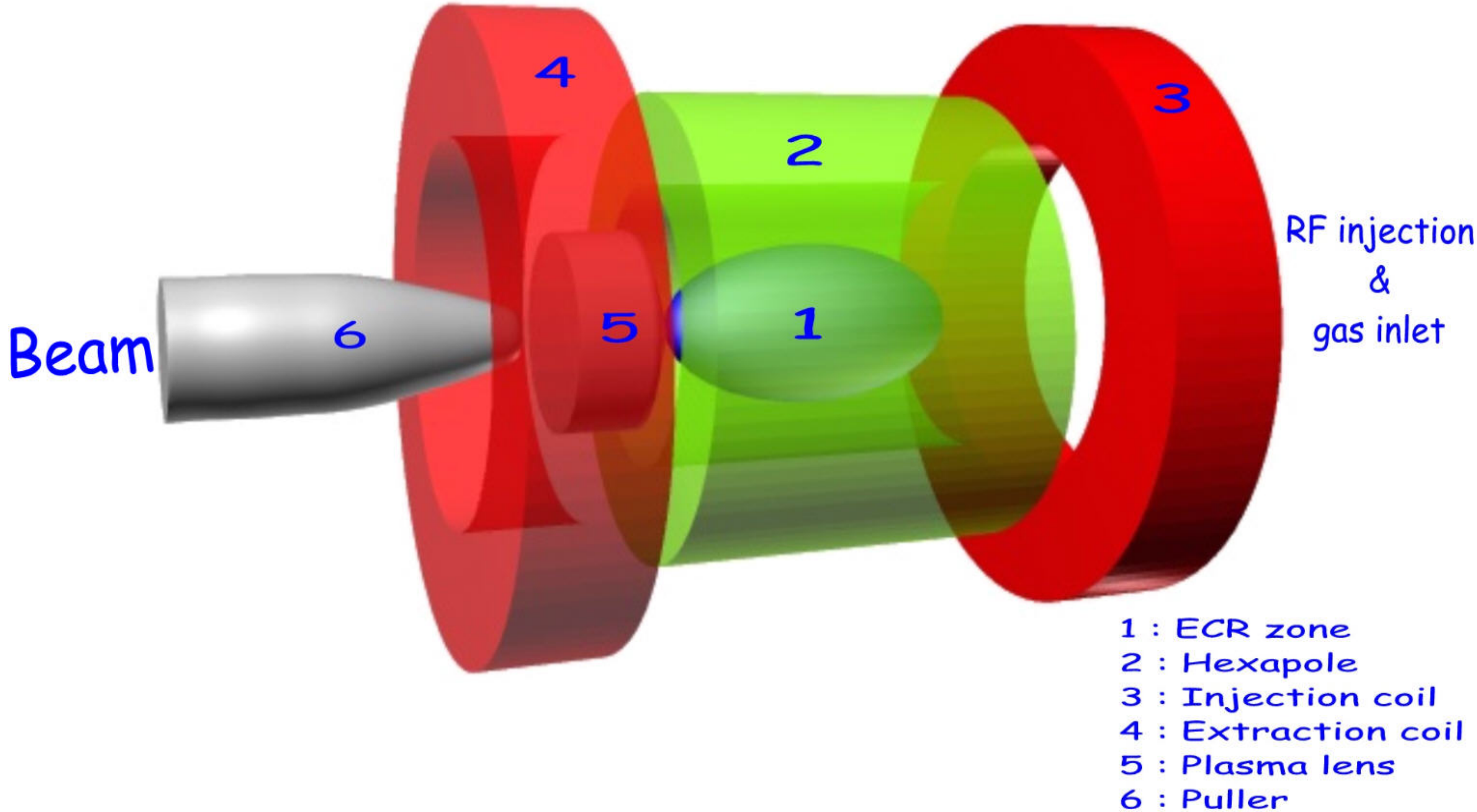
- Advanced semiconductor manufacturing, especially for high density DRAM memories, through plasma etching or other plasma processing technologies,

- Ion source of particle accelerators and radio-active ion charge breeding,

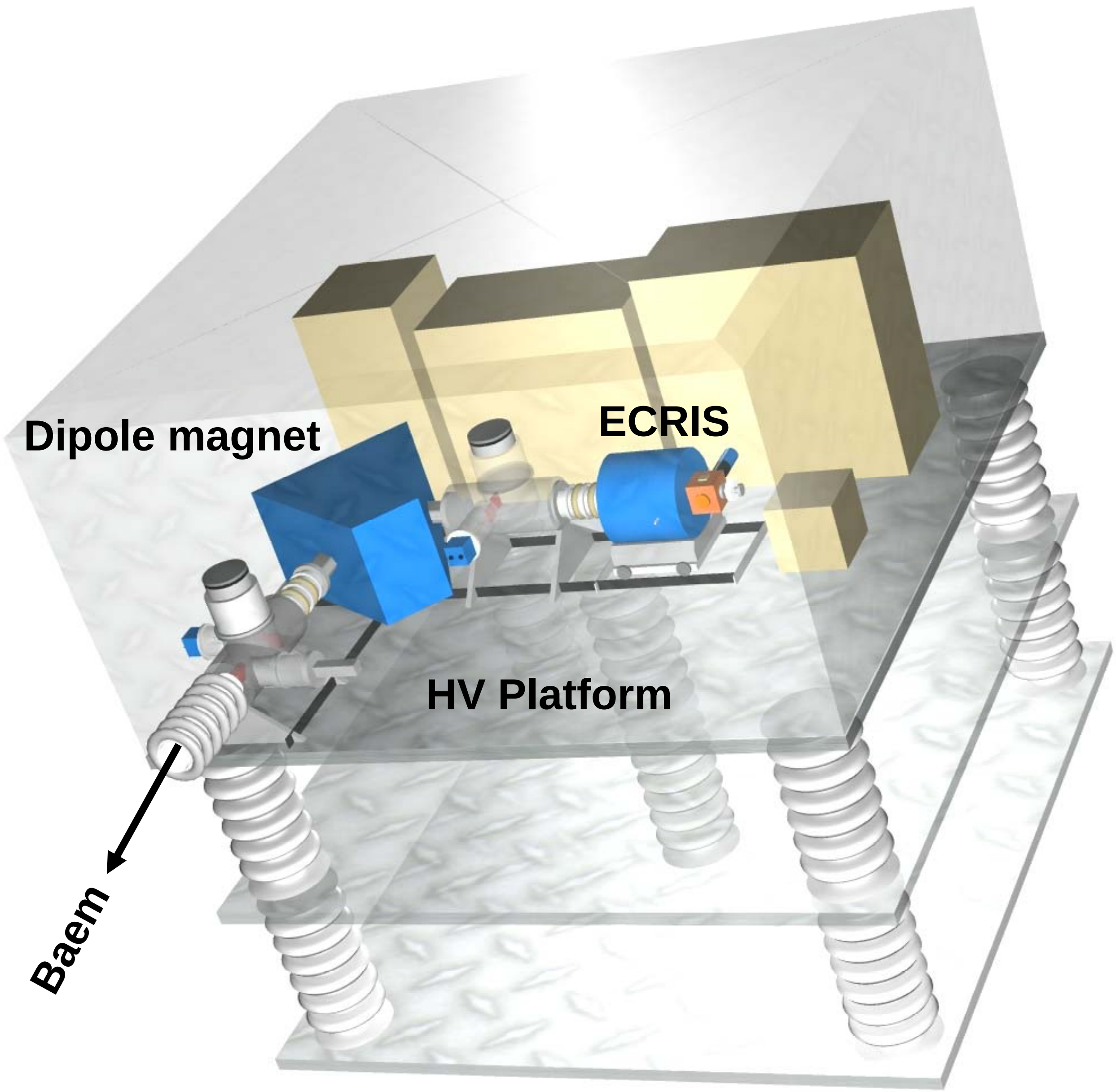
- High quality coating.



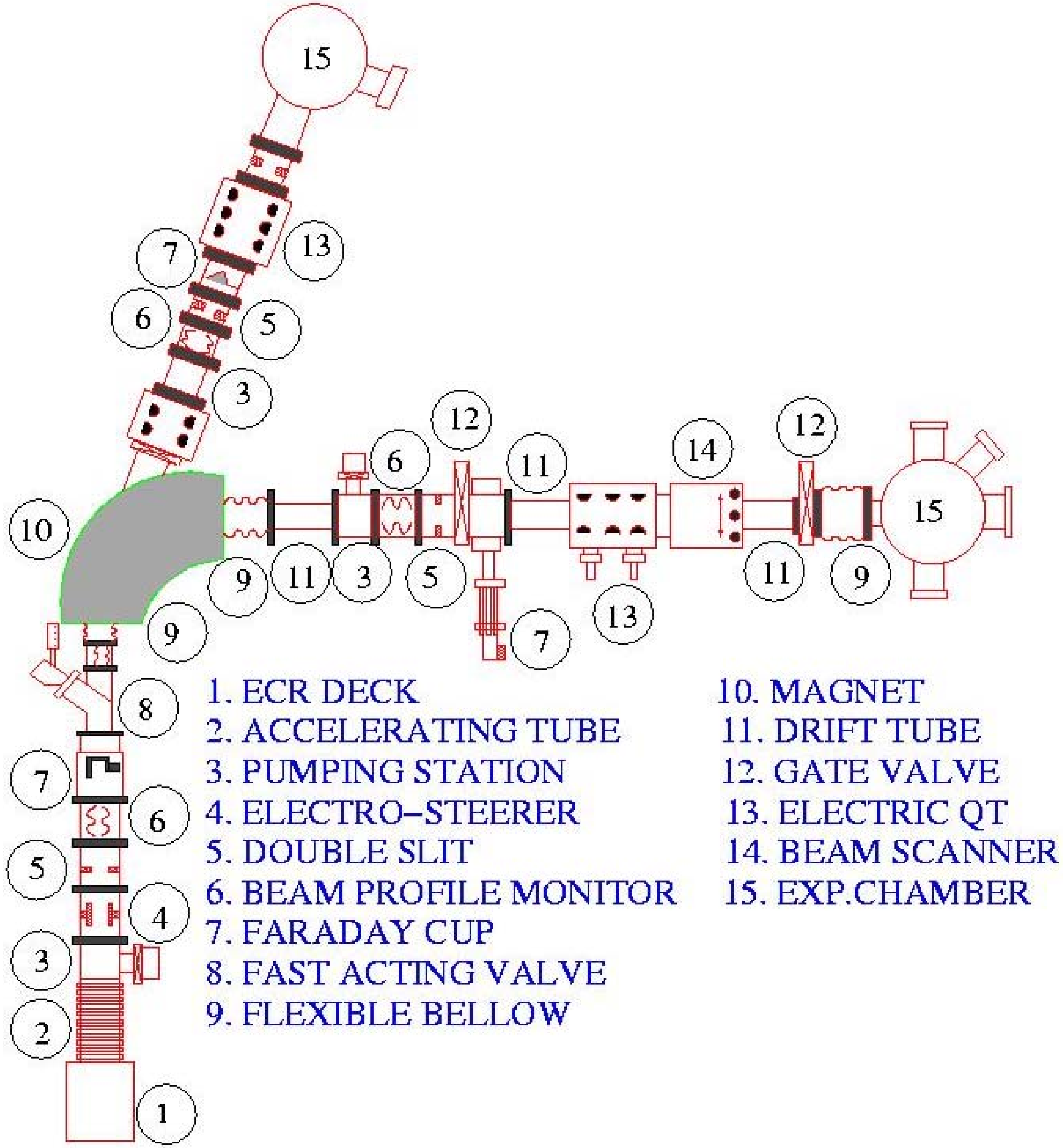
Comparison of charge states available from PIGIS and ECRIS



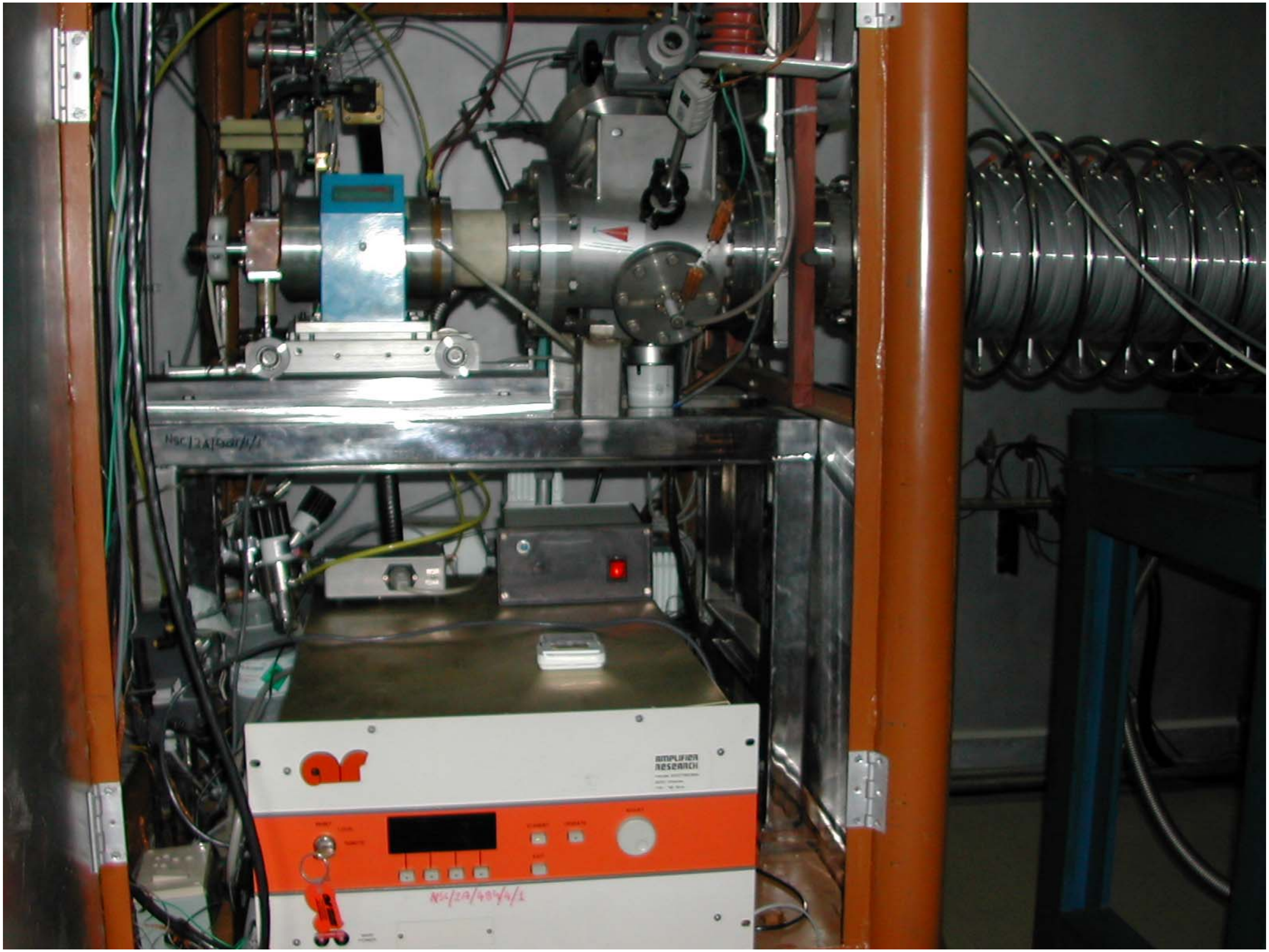
All permanent magnet (NdFeB) ECRIS



ECRIS on a high voltage platform

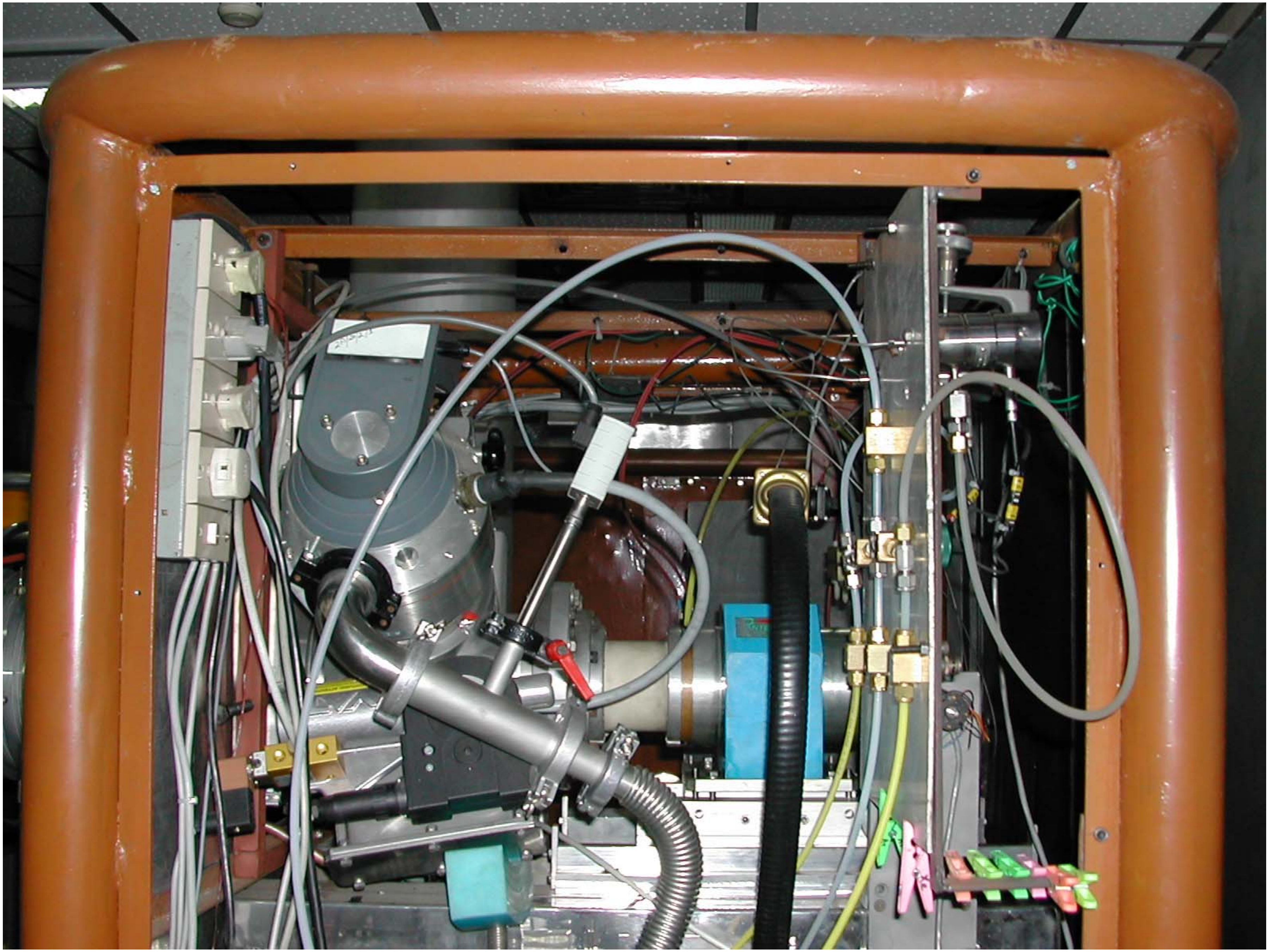


Schematic of the low energy ion beam facility

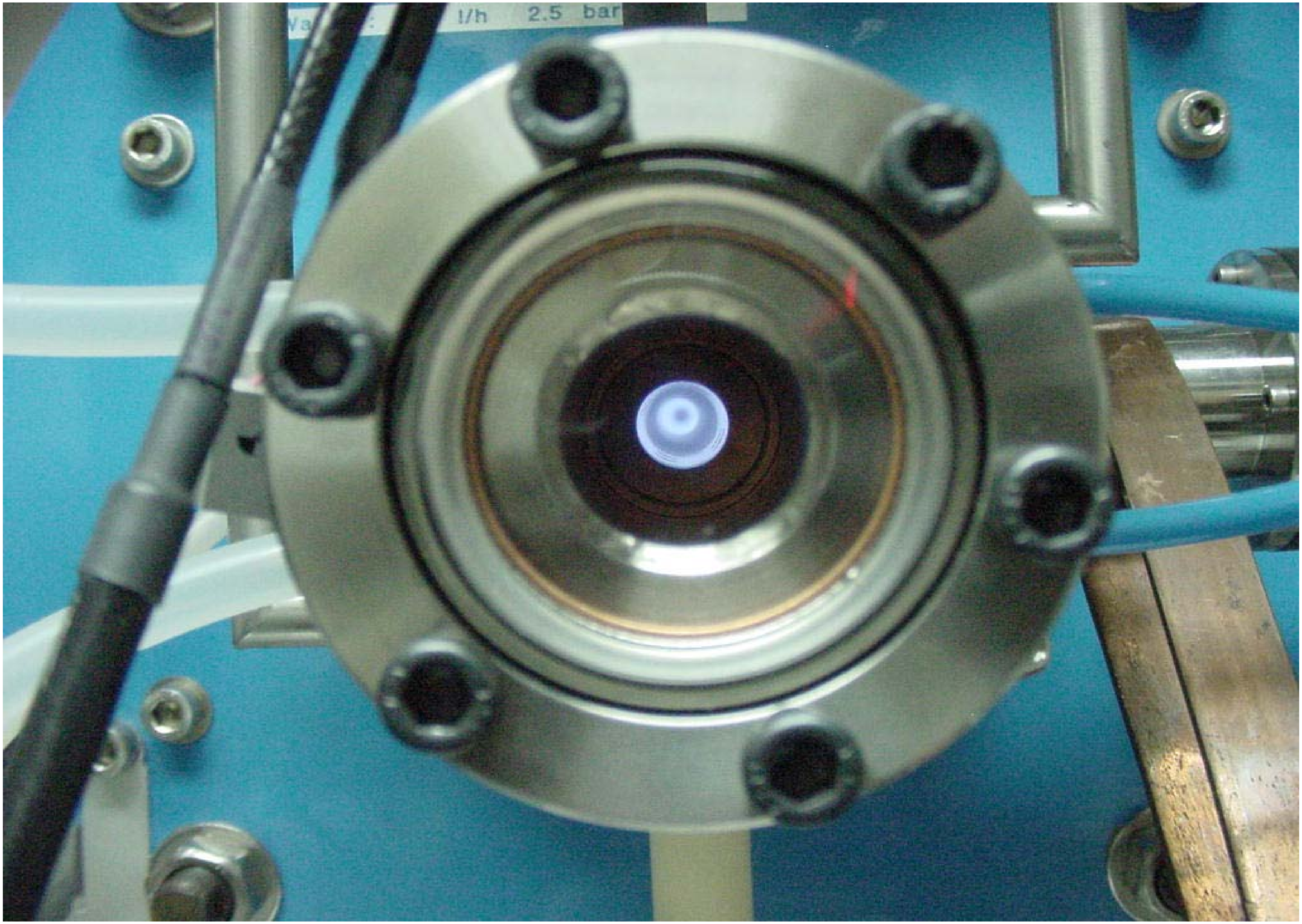


TWT Amplifier, ECRIS on HV Deck followed by Accelerating Tube.

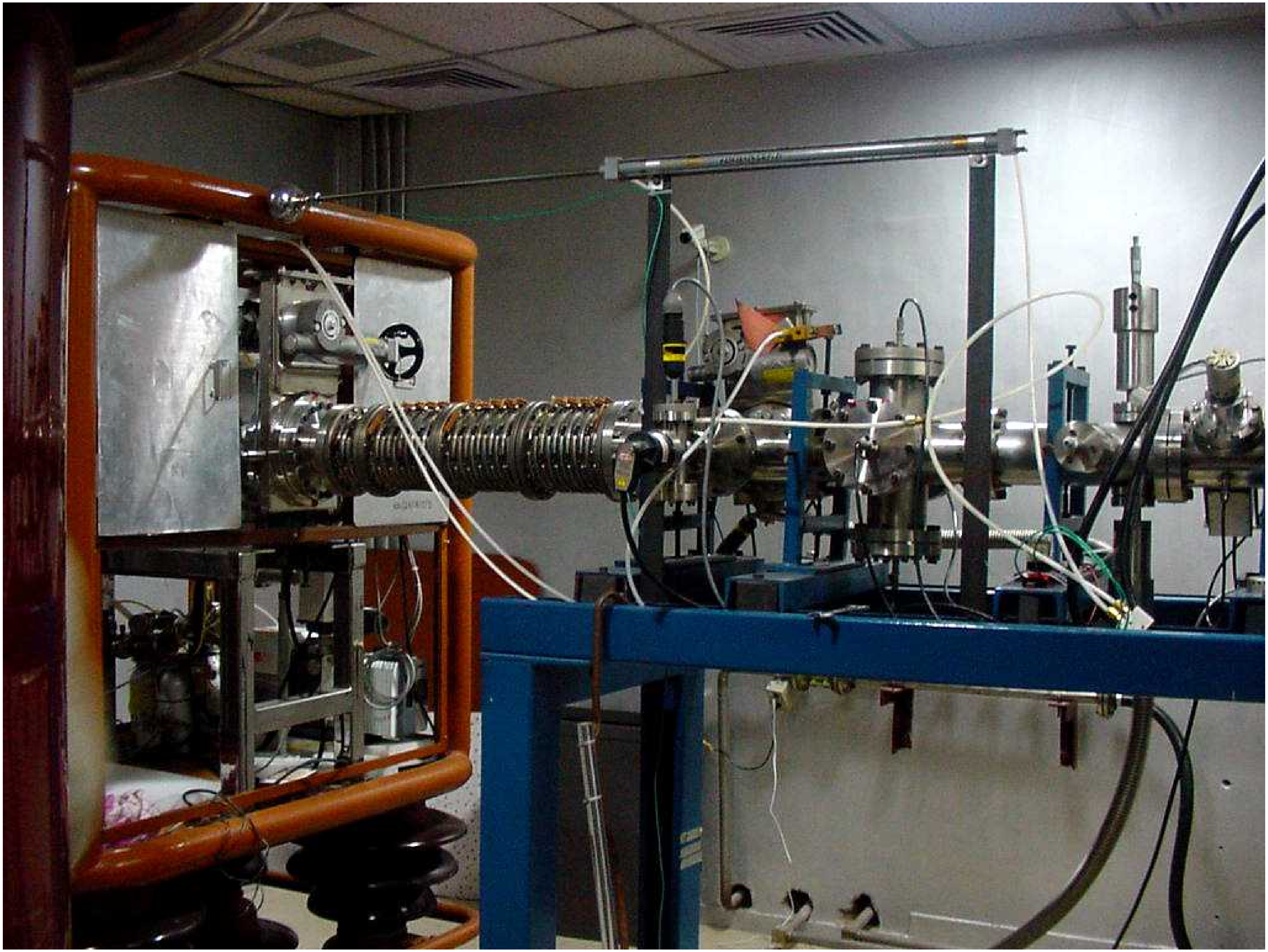
D. Kanjilal et.al., Ind. J. of Pure and Appl. Phys. 39, 25 (2001)



HV Platform with ECRIS, TP, Gas system, UHF Transmitter etc



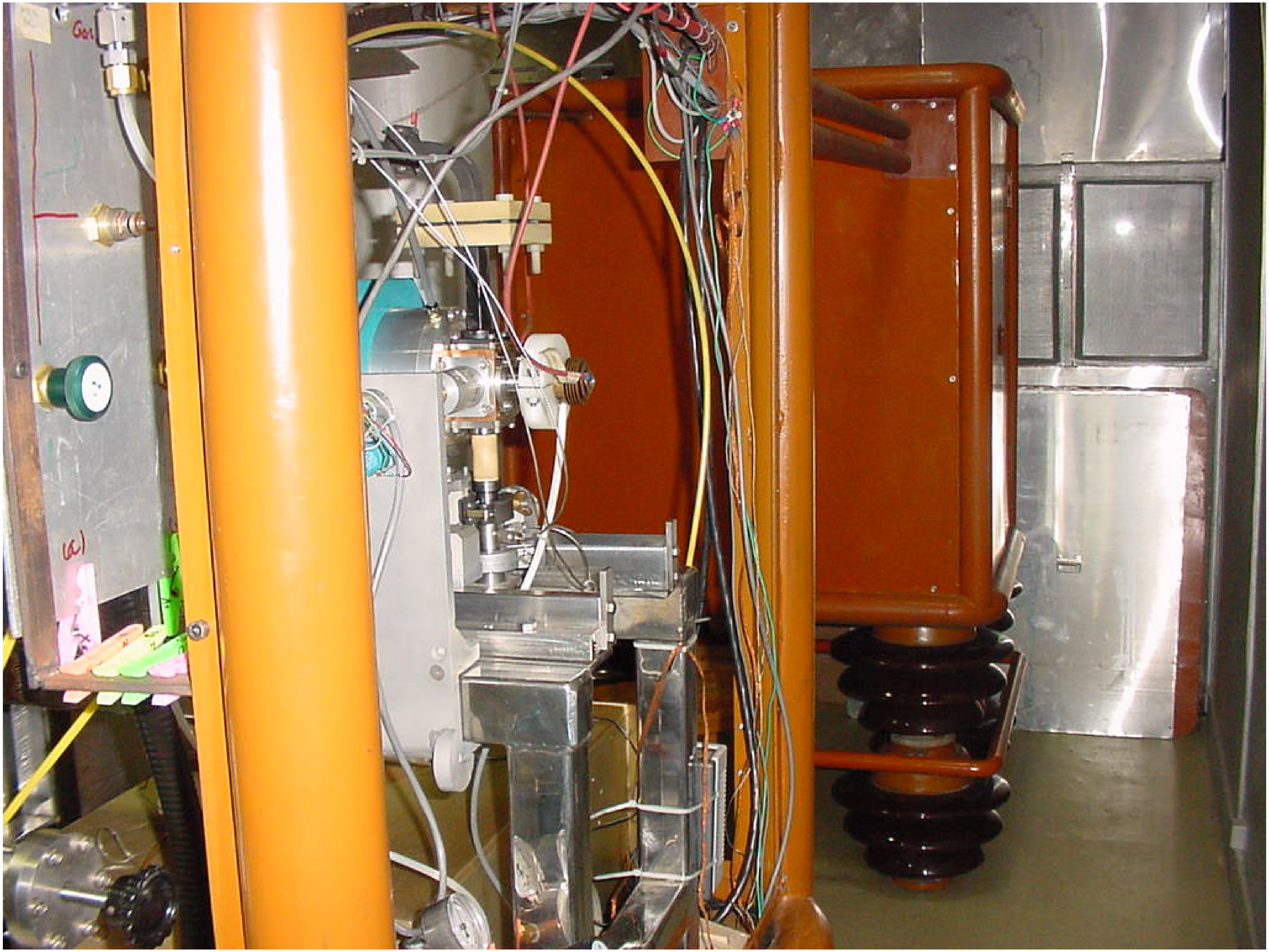
View of Plasma generated in the ECR source



Acceleration from the high voltage Platform

Extracted beam accelerated across HV Platfom to ground potential

G .K. Padmashree, et al, Rev. of Sci. Instrum. ***75****, 5094 (2004).*



Insulation stand for high voltage platform

Isolation Transformer supplying power to the HV platform

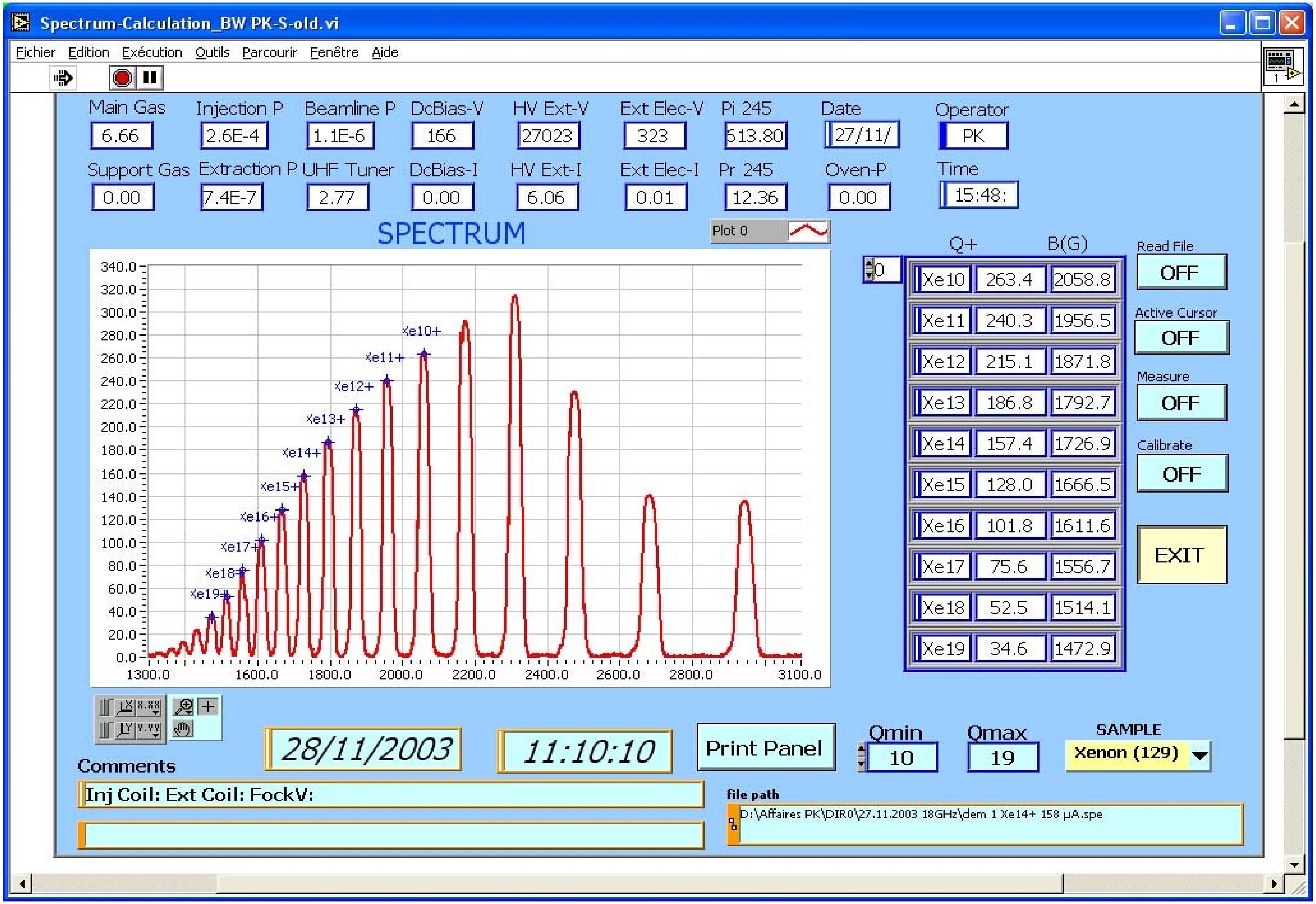
High Voltage Power Supply for biasing the platform

Control System with fiber optics communication for HV platform

P. Kumar et.al., Nucl. Instr. and Meth. B, 252, 354 (2006).

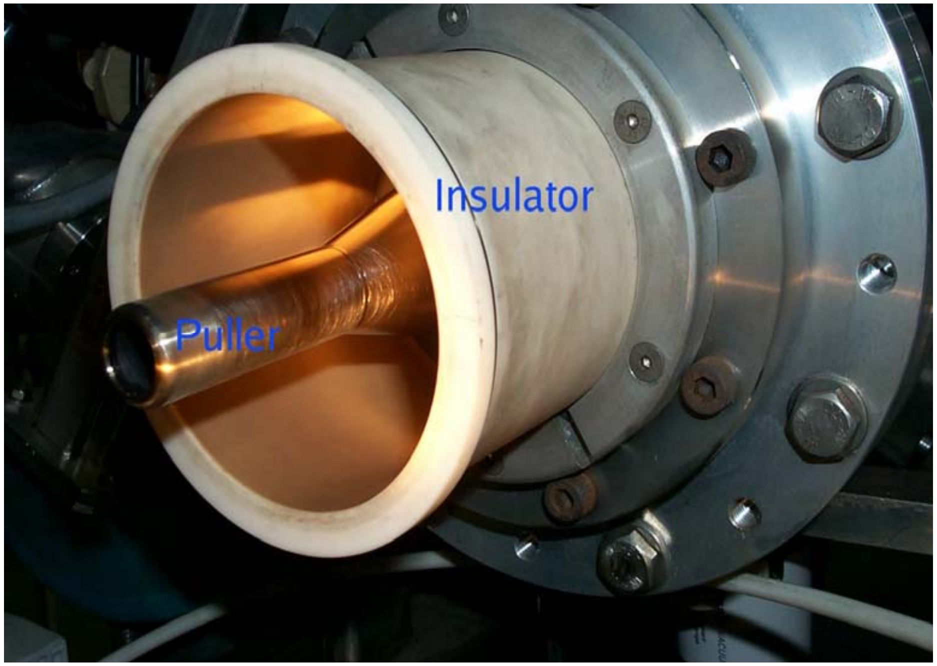
Analyzed beam focused by EQP and subsequently scanned

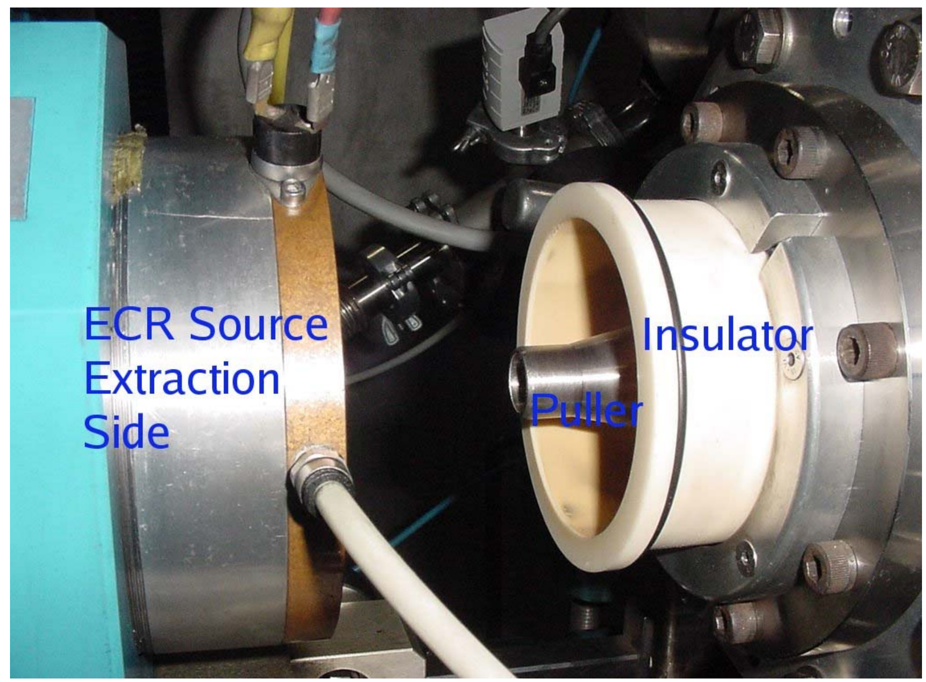
Ar Mass Analysed Spectrum



Spectrum-Calculation_BW PK-S-old.vi
Fichier Edition Exécution Outils Parcourir Fenêtre Aide
Main Gas 6.66
Injection P 2.6E-4
Beamline P 1.1E-6
DcBias-V 166
HV Ext-V 27023
Ext Elec-V 323
Pi 245 513.80
Date 27/11/
Operator PK
Support Gas 0.00
Extraction P 7.4E-7
UHF Tuner 2.77
DcBias-I 0.00
HV Ext-I 6.06
Ext Elec-I 0.01
Pr 245 12.36
Oven-P 0.00
Time 15:48:
SPECTRUM
Plot 0
Xe10+
Xe11+
Xe12+
Xe13+
Xe14+
Xe15+
Xe16+
Xe17+
Xe18+
Xe19+
Q+
B(G)
Xe10 263.4 2058.8
Xe11 240.3 1956.5
Xe12 215.1 1871.8
Xe13 186.8 1792.7
Xe14 157.4 1726.9
Xe15 128.0 1666.5
Xe16 101.8 1611.6
Xe17 75.6 1556.7
Xe18 52.5 1514.1
Xe19 34.6 1472.9
Read File OFF
Active Cursor OFF
Measure OFF
Calibrate OFF
EXIT
28/11/2003
11:10:10
Print Panel
Qmin 10
Qmax 19
SAMPLE Xenon (129)
Comments
Inj Coil: Ext Coil: FockV:
file path
D:\Affaires PK\DIR0\27.11.2003 18GHz\dem 1 Xe14+ 158 µA.spe

Xe Spectrum

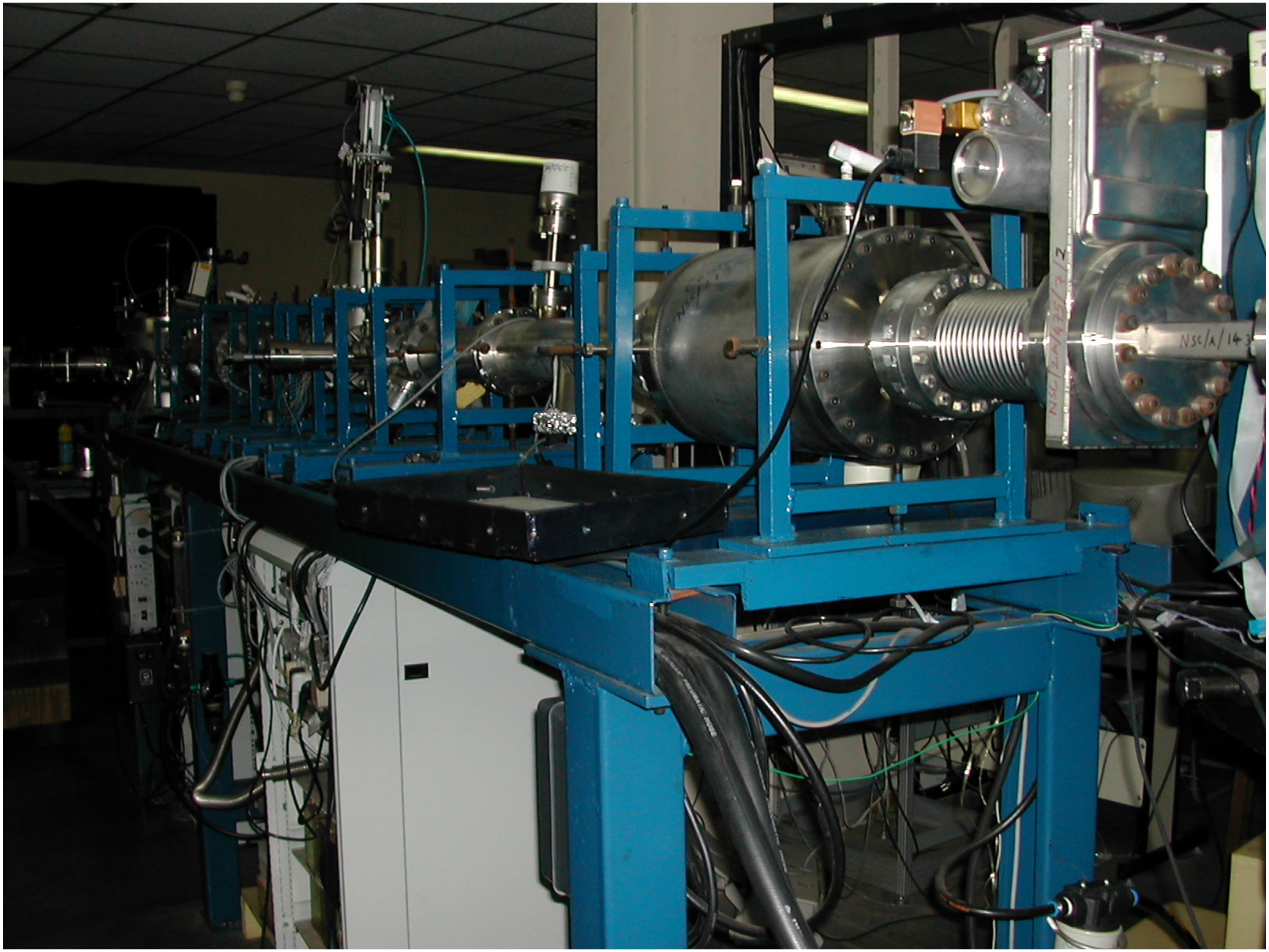




Extraction of ion from ECR plasma

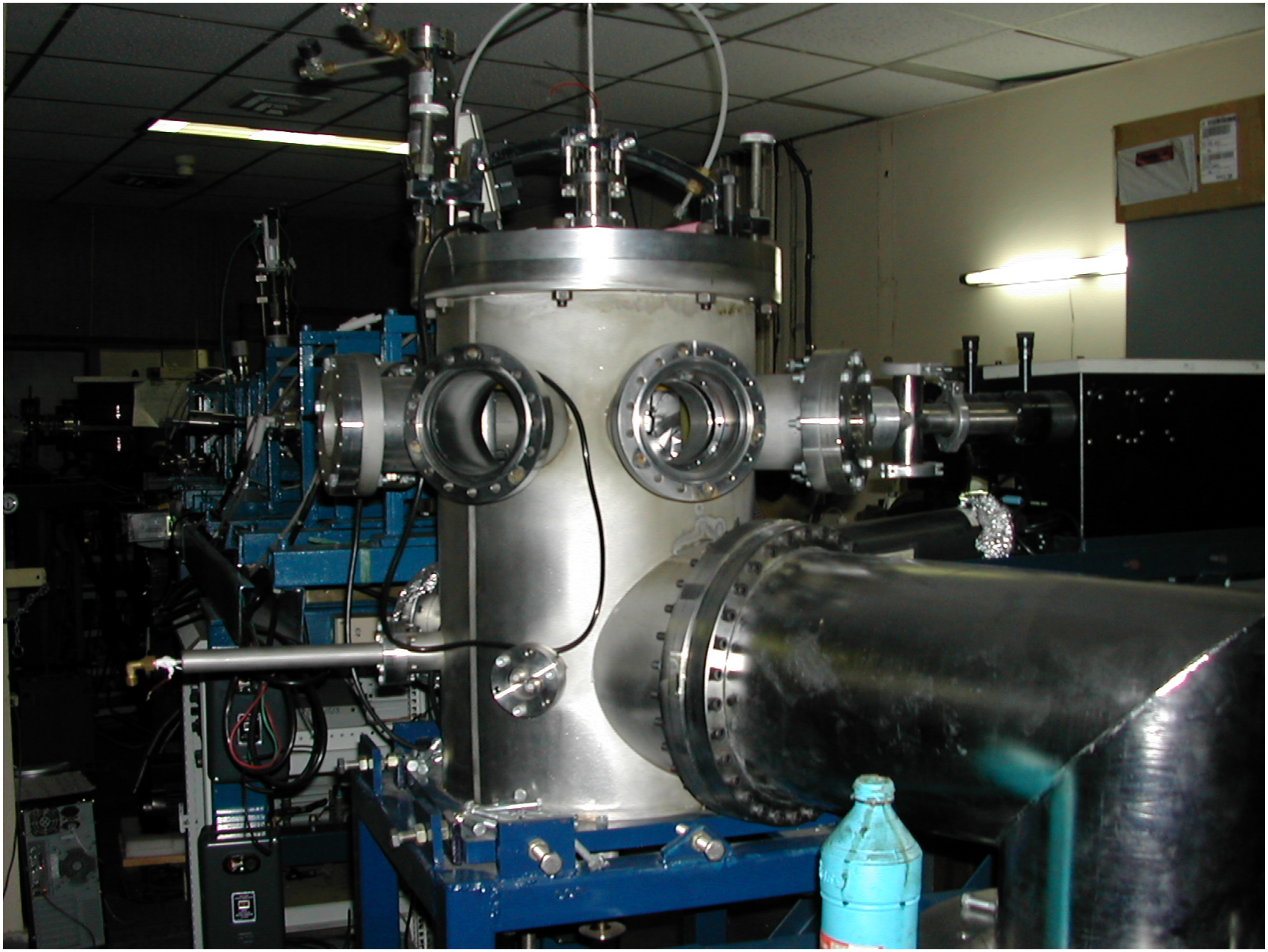
Experimental facilities of LEIBF Beam Line

*Sankar De et al, Phys. Rev. Lett. **97**, (2006) 213201*

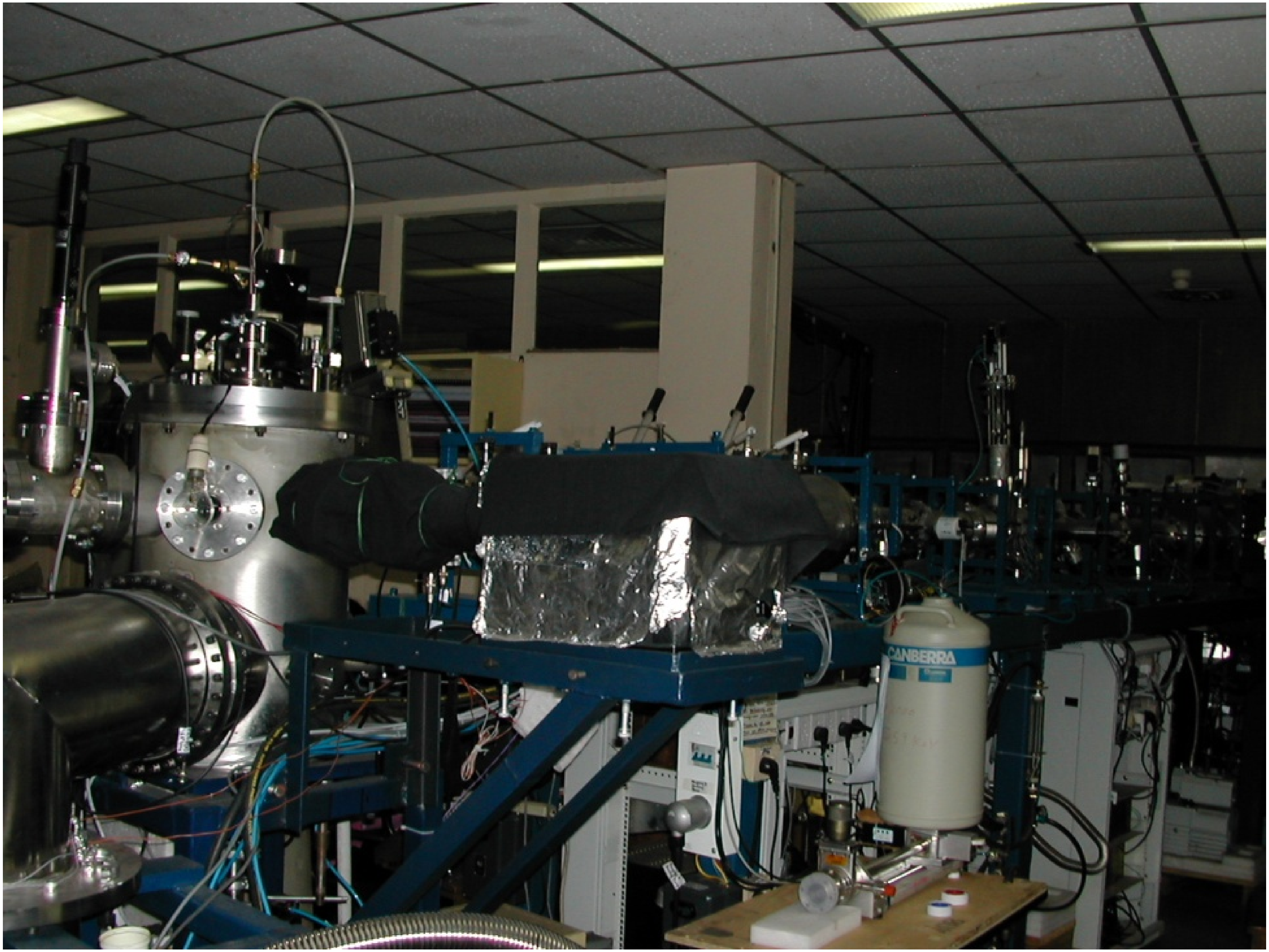


Second beam line for ion-cluster interaction

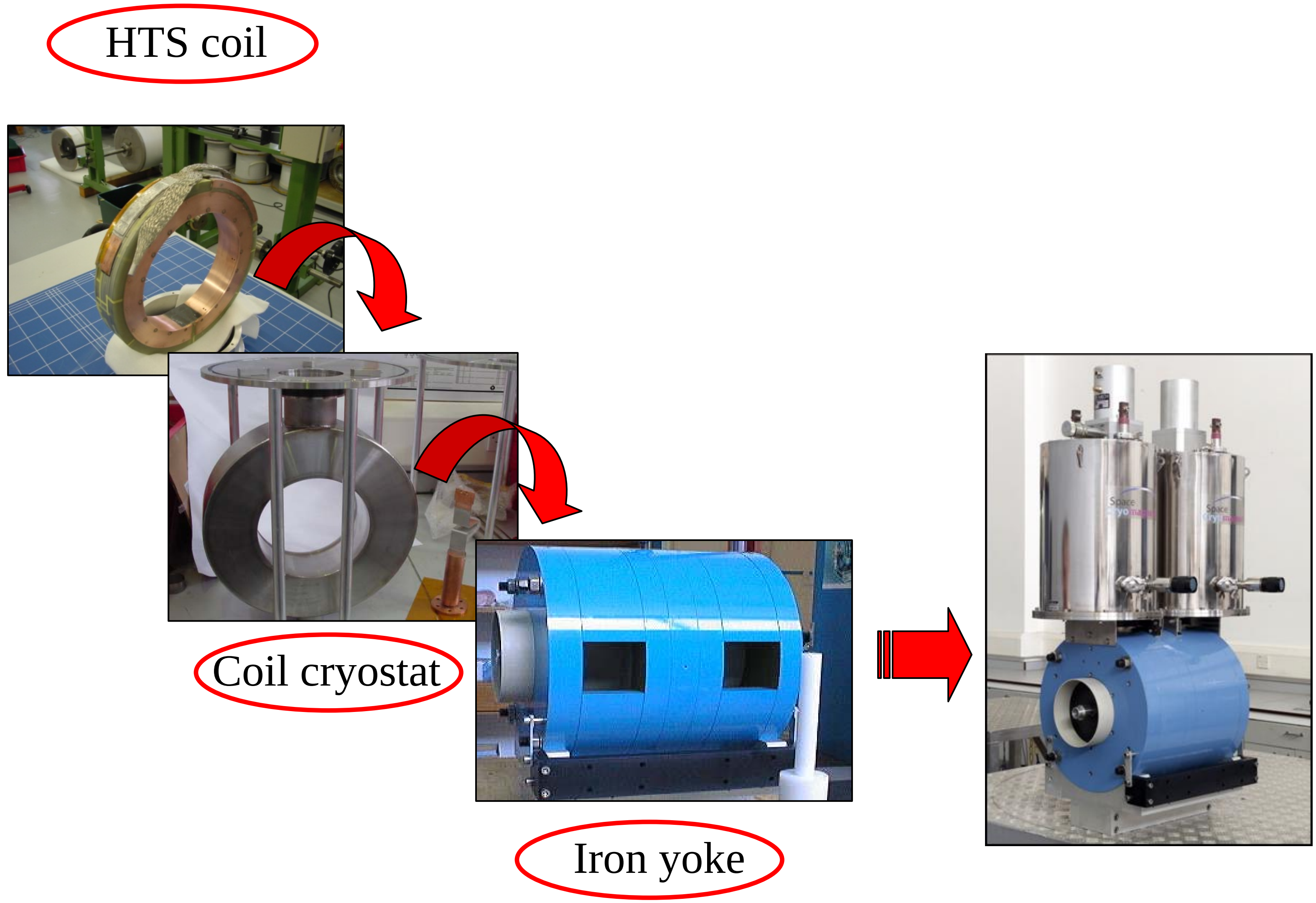
G .K. Padmashree, et al, Rev. of Sci. Instrum. ***75****, 5094 (2004).*



Experimental System on Ion – Micro-Droplet interaction

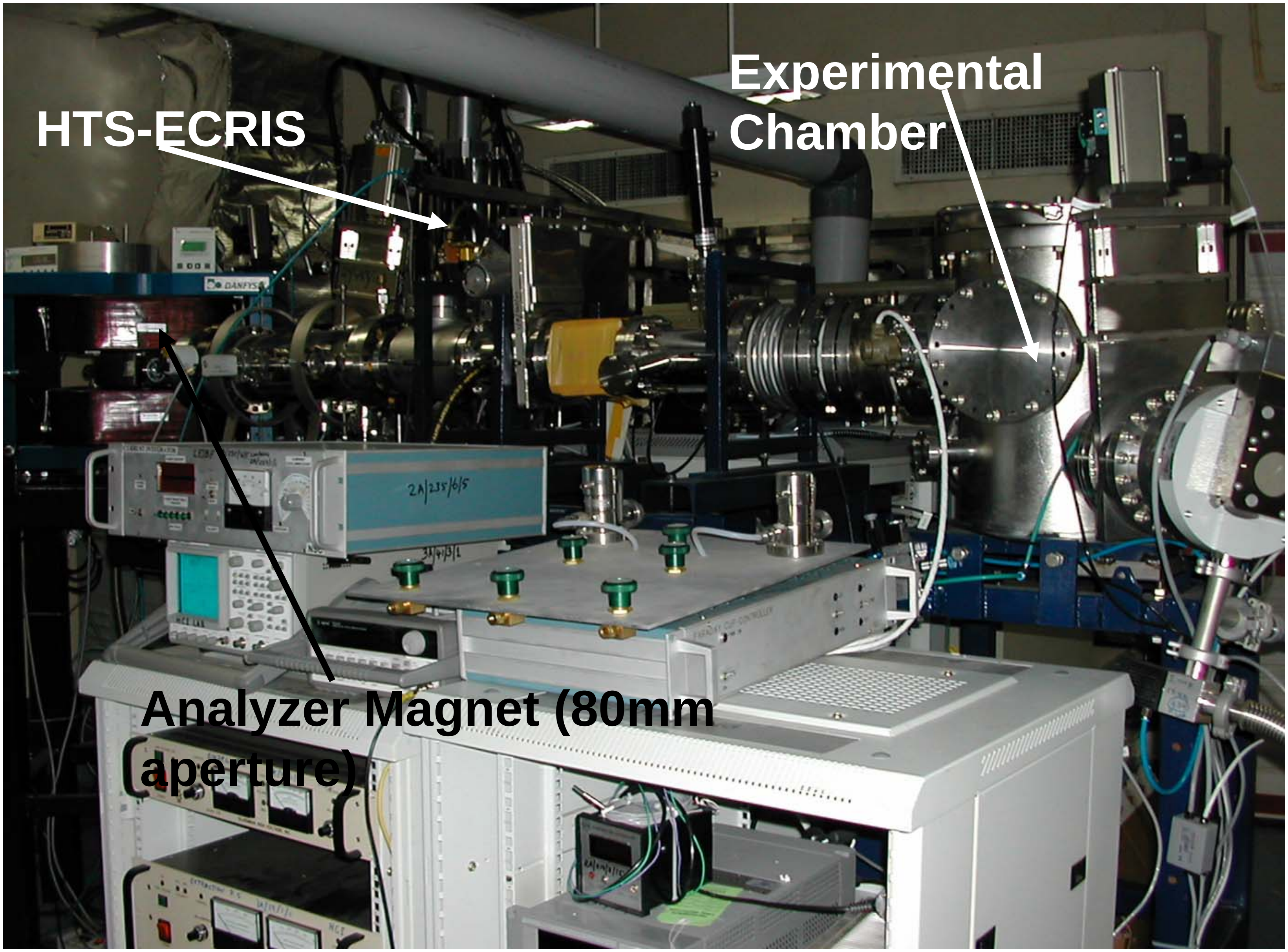


Simultaneous measurement of optical and x-ray emission



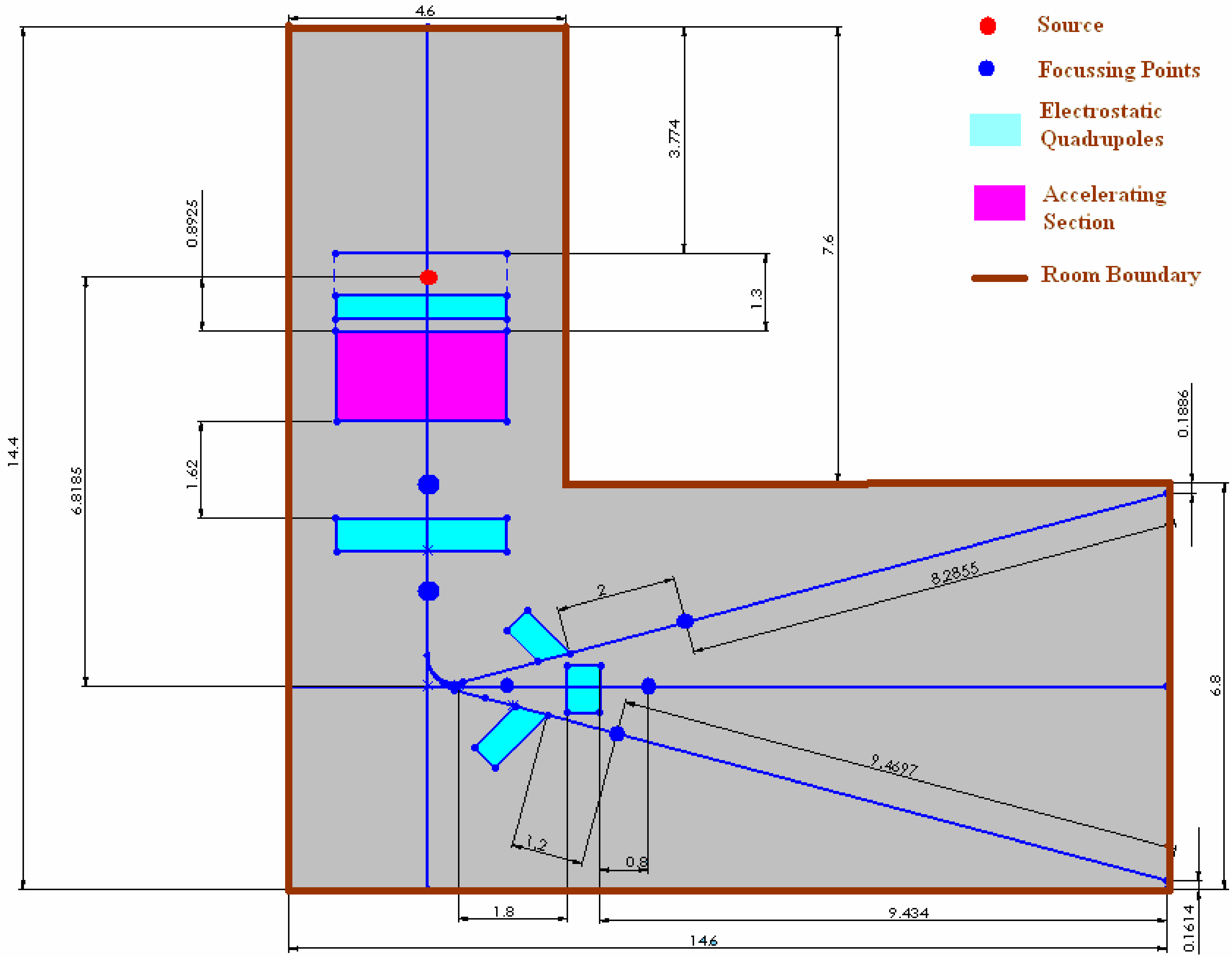
Various Stages of Development of ECRIS

D. Kanjilal et al, Rev. Sci. Instr. **77,** 3317(2005).



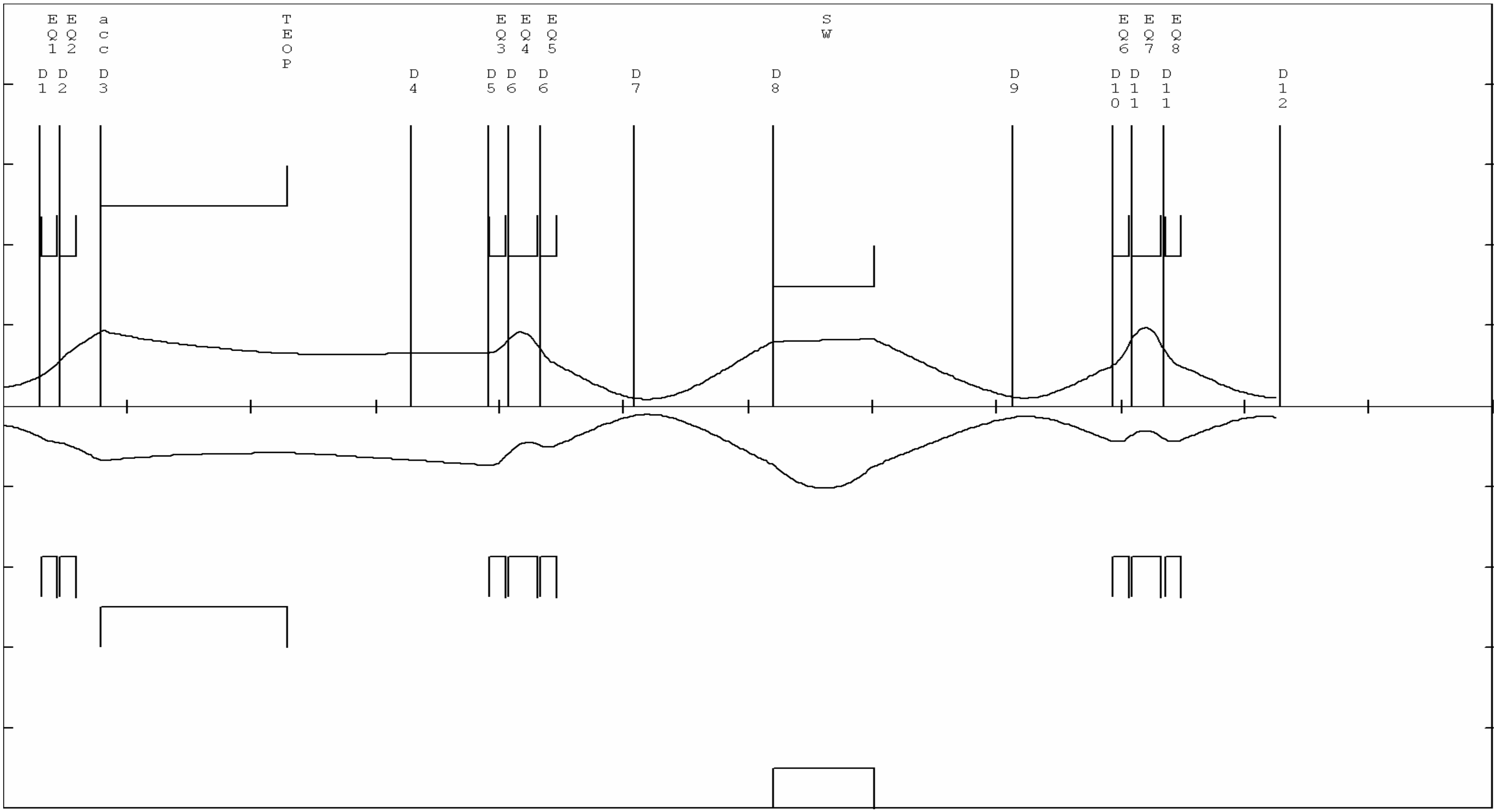
HTS-ECRIS with Experimental Chamber (Operation >22000 hrs)

D. G. O. Rodrigues, D. Kanjilal et al, Rev. Sci. Instr. (in press)

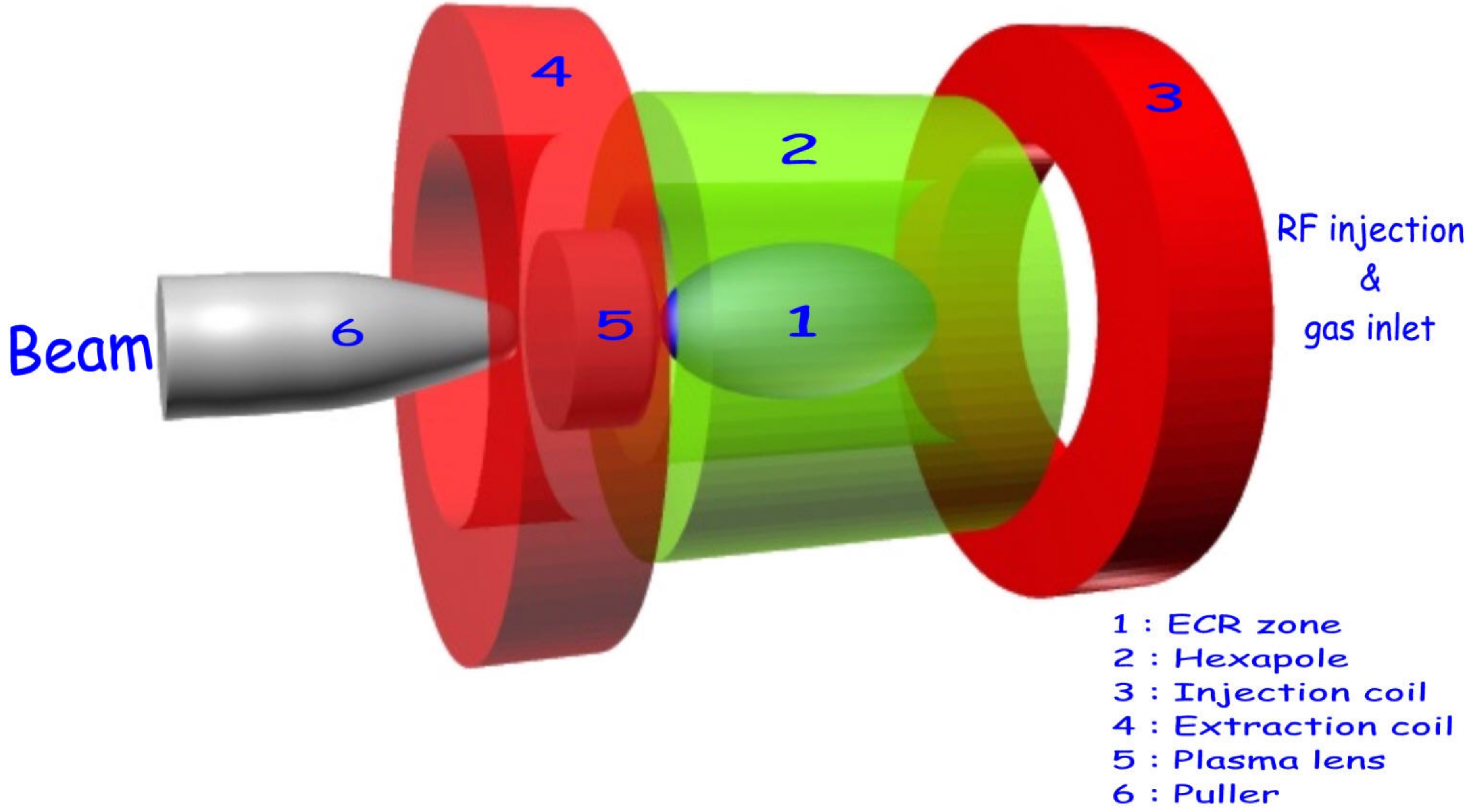


Layout of HV Platform & Beam Lines

Beam Parameters: M/Z = 96, Emittance = 100 π mm-mrad



Beam Optics of 90 degree Beam Line



ECR plasma confined in space

Beams of heavy Metals/Solids

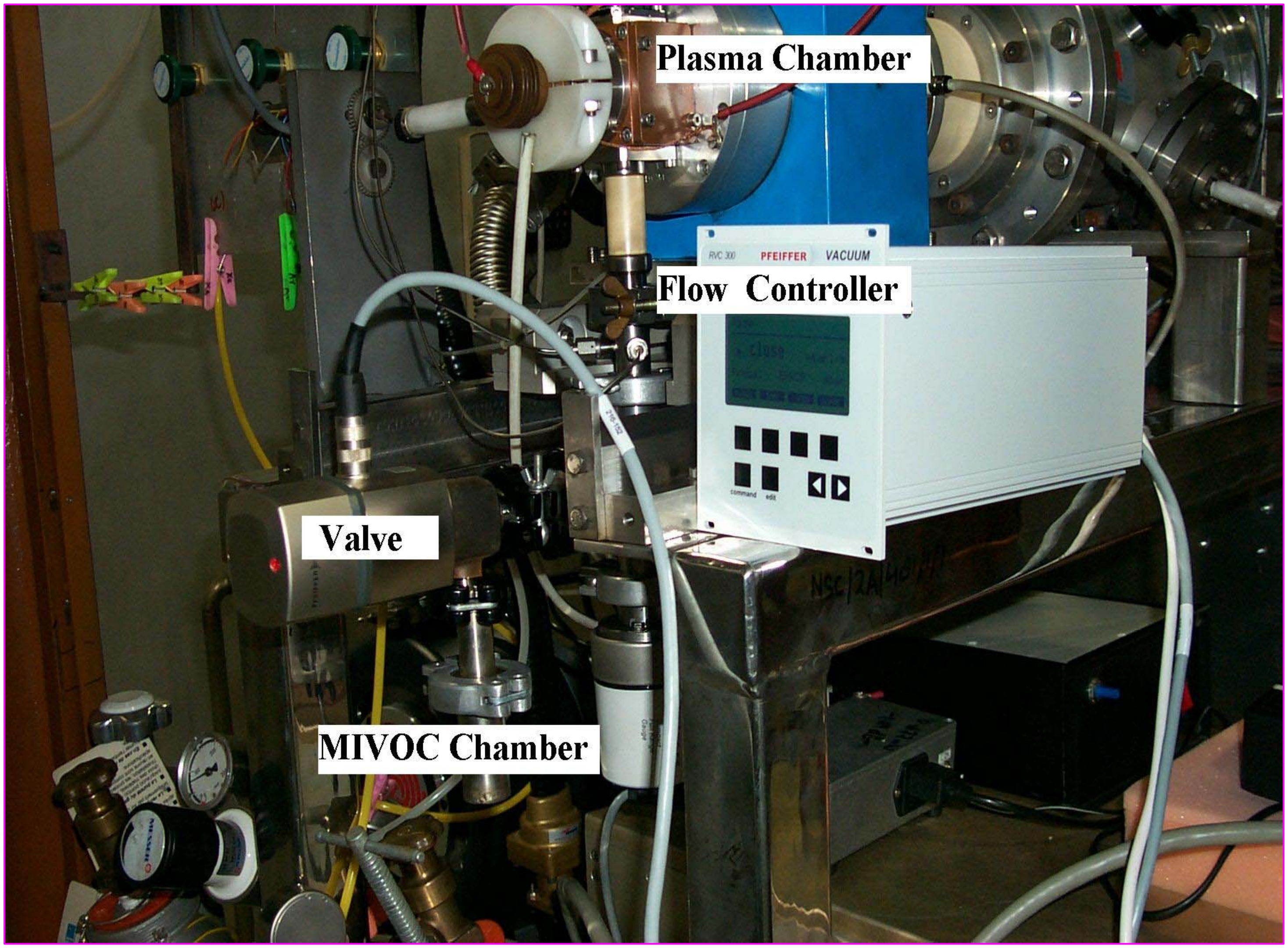
MIVOC (Metal Ions using Volatile Compounds) technique:

A new system developed for extracting metal ions using MIVOC technique.

It is used for extracting
-Fe beam using ferrocene compound [$Fe(C_5H_5)_2$] which has a vapor pressure of 1.7×10^{-3} torr at 20^0C and
-Si beam extracted using chlorotrimethylsilane [$Si(CH_3)_3Cl$].

Beams of As, Ge, Zn and Au were developed using **micro-oven.**

MIVOC Method (Metal Ions using Volatile Compounds)



Conclusion

The stable beam may be available for several months without any degradation in beam current.

➔ Ideal for long term experiments.

Tens of mA proton beam can be extracted and accelerated.

A few of high intensity beams available immeditely are:

Proton, deuteron, helium, carbon, nitrogen, oxygen, fluorine, neon, sulfur, argon, xenon, krypton etc.

UPS *backed up by* ***Generator*** *will ensure* ***continuous*** *experiments for several months if not years without maintenance of ECR ion source.*

Credit: NASA - Sun emerging from behind the Earth.