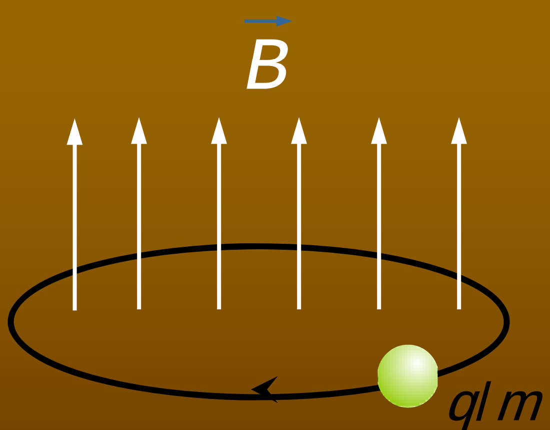
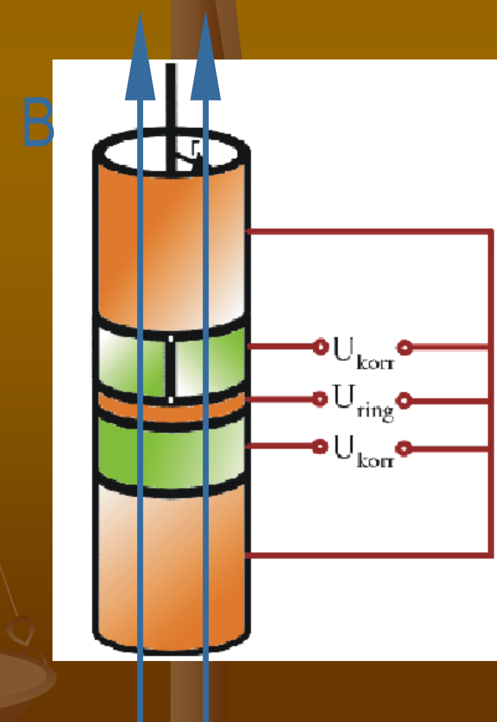
Development of VECC Cryogenic Penning Ion Trap and some planned experiments

Parnika Das

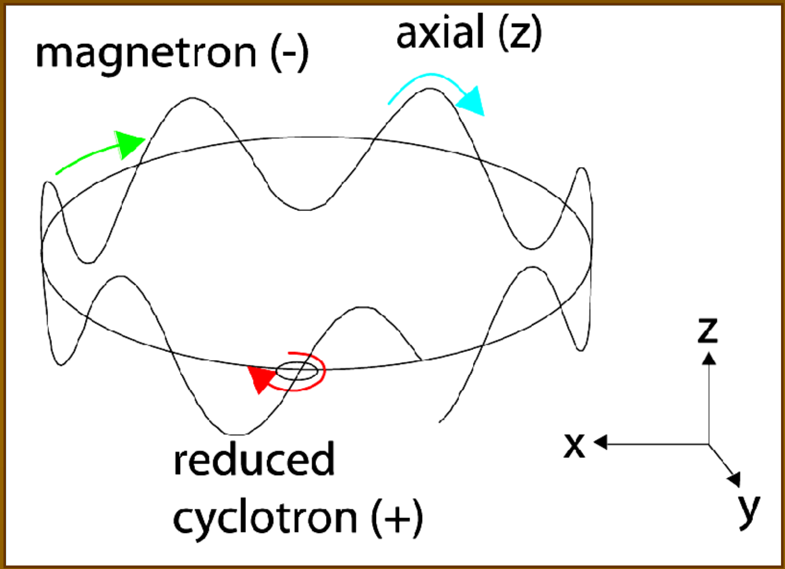
Penning Ion Trap

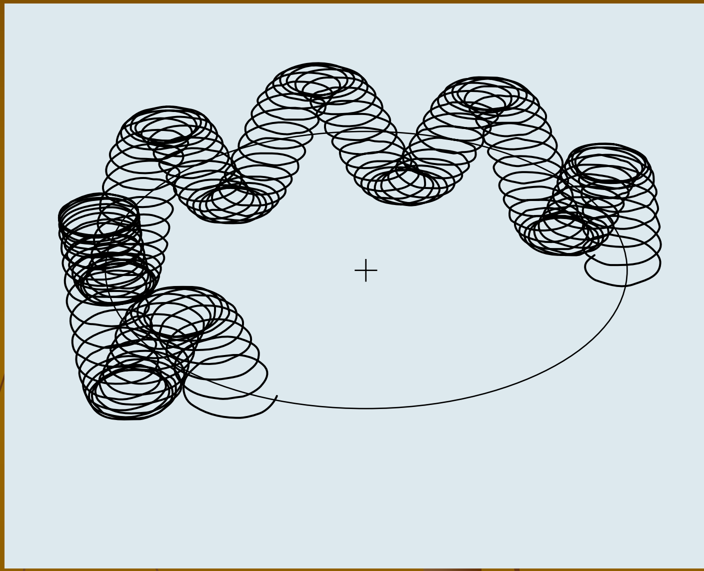
- **Strong homogeneous magnetic field**
- **Weak electric 3D quadrupole field**





Motion of an ion





Superposition of three characteristic harmonic motions:

- axial motion (frequency ν_z)
- magnetron motion (frequency ν_-)
- modified cyclotron motion (frequency ν_+)

AT VECC

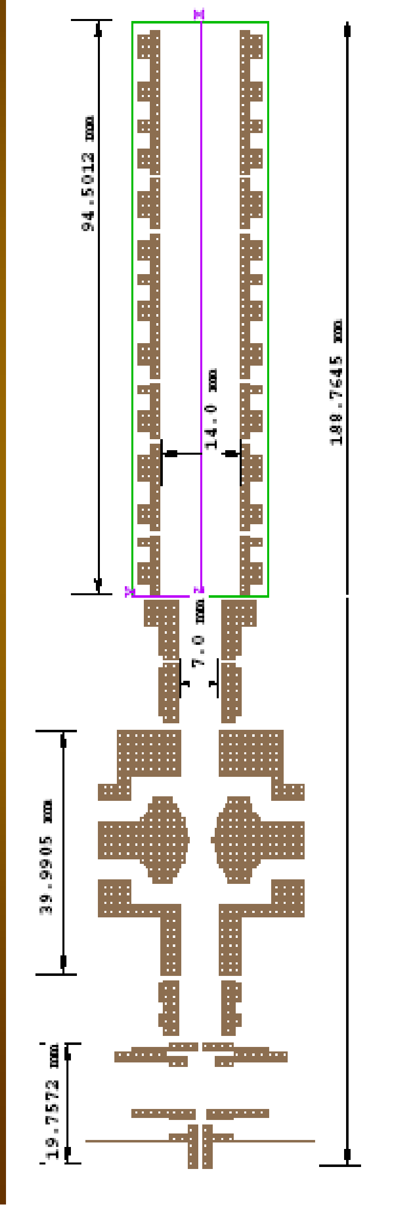
A persistent mode superconducting magnet with shim coil assembly

providing **5 Tesla** magnetic field

Uniformity **0.1 ppm** over 1cm DSV

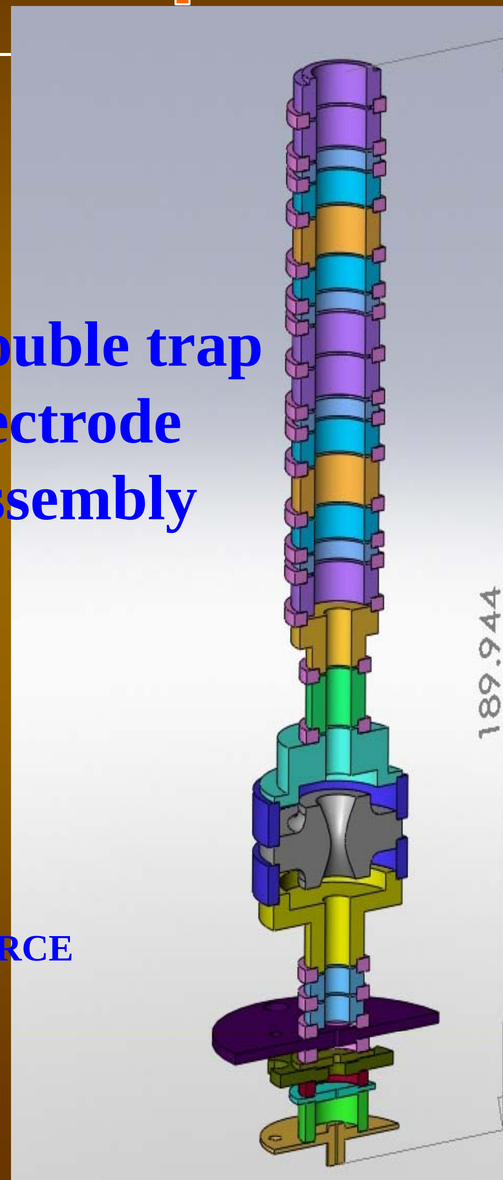
Temporal stability **~1ppb/hr**

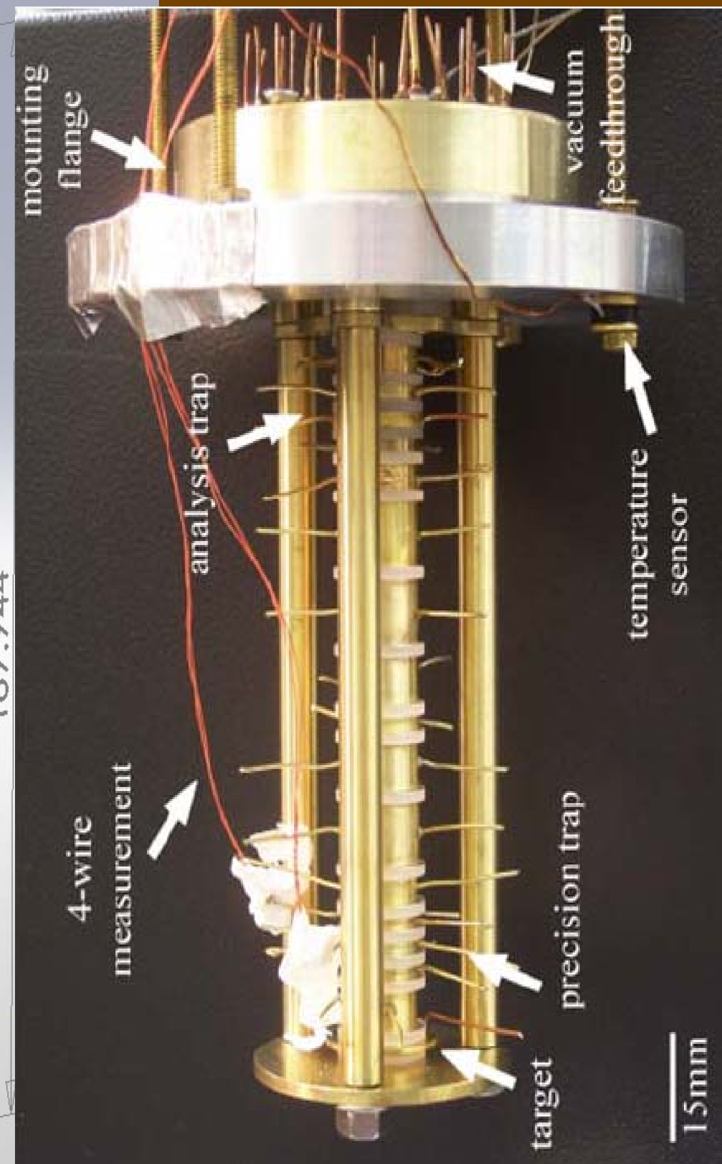
Ion source and Trap Electrode Arrangement

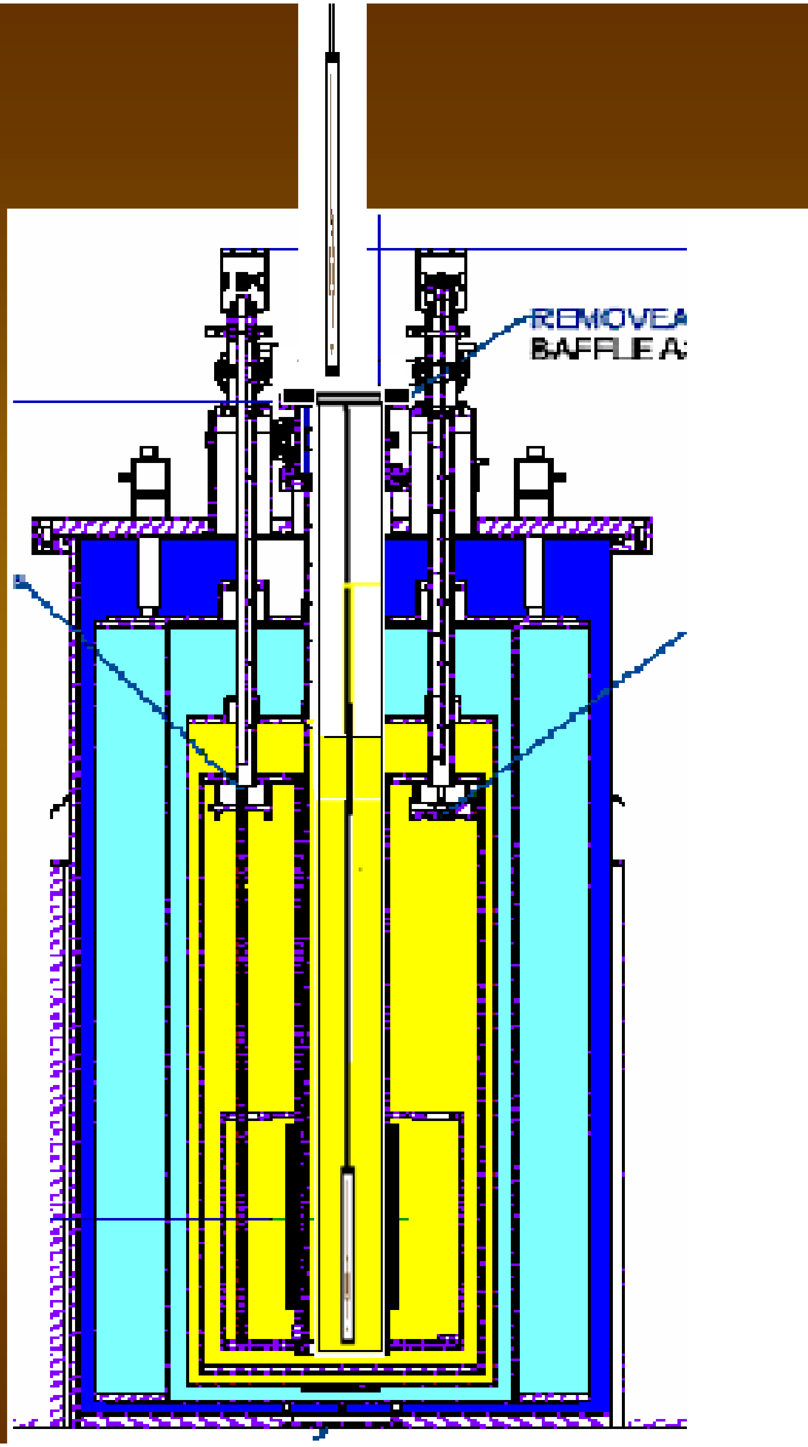


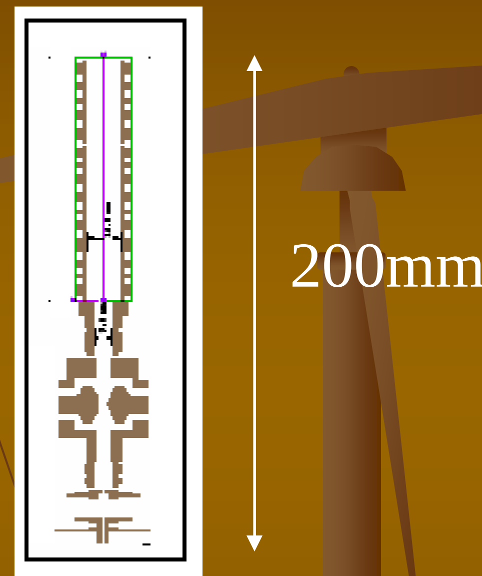
Double trap electrode Assembly

ION SOURCE









Drawing for proptotype fabrication is in progress ...

❖Decay rate measurements using VECC trap

Potential profile in the trap

TRAP electrode parameters:

r_0 =7mm
z_0 = 14mm

$$d^2 = 1/2(z_0^2 + \frac{r_0^2}{2})$$

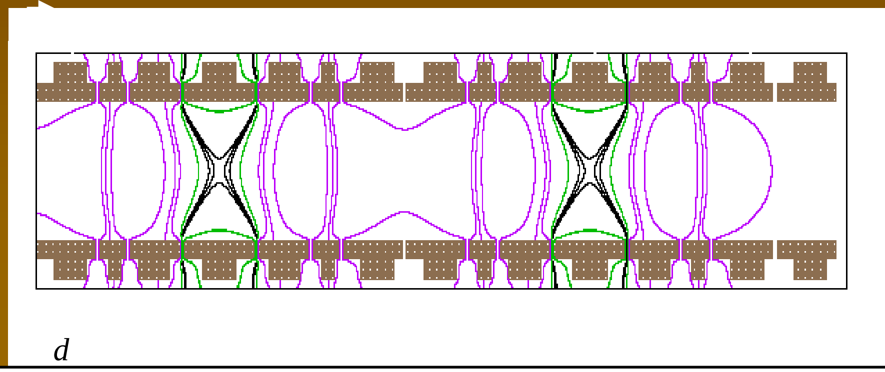
d=10.5 mm

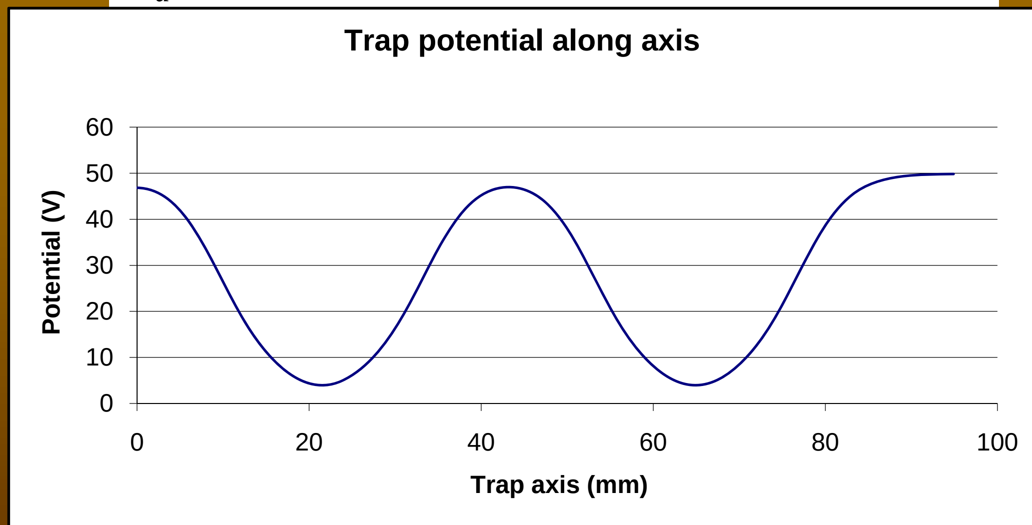
For ^{7}Be in 1+ charge state

$\omega_z \cong$ 2.4 MHz
$\omega_+ \cong$ 64 MHz
$\omega_- \cong$ 45 kHz

$$n_{\lim} = B^2 / 2\mu_0 Mc^2$$

n_{lim}=1.28×10^{10}





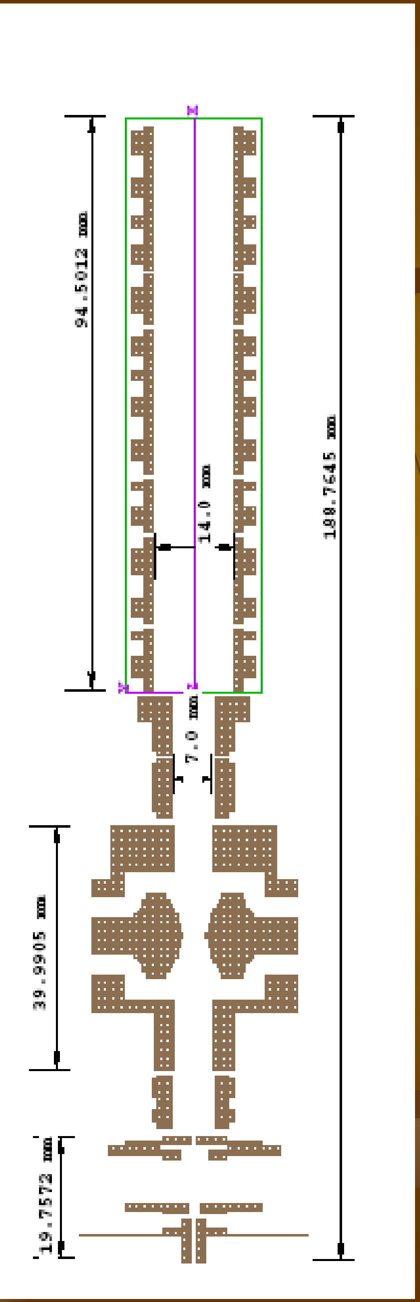
Preparation for experiments using VECC trap

Loading the TRAP with radioactive ions

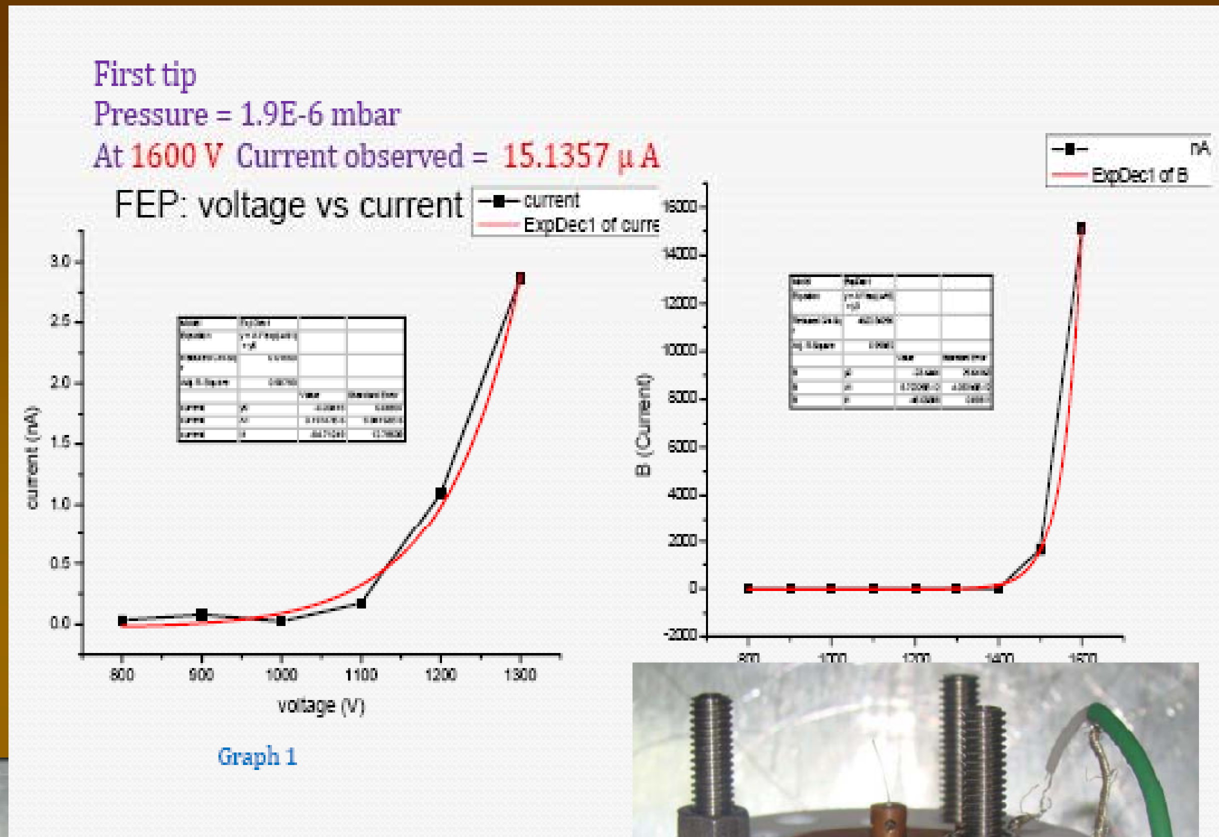
STEPS

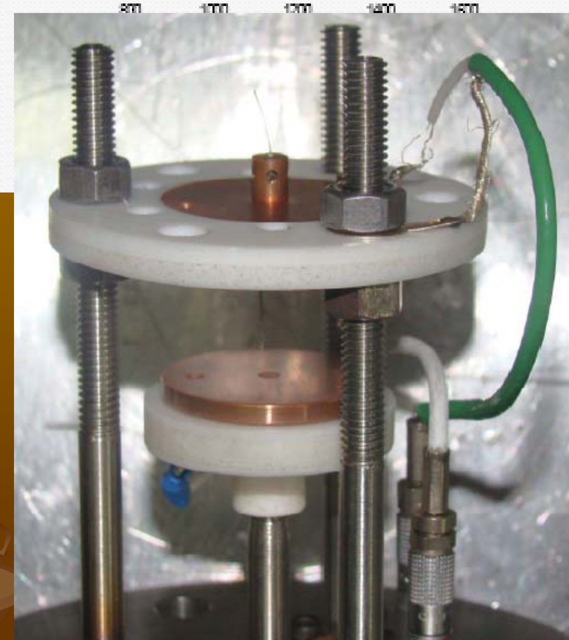
1. Production of ions of interest by a suitable nuclear reaction
2. Radiochemical separation in a carrier free form
3. Deposition on a suitable substrate
4. Regeneration of radioactive ions in at least 1+ charge state

Recently produced ^{100}Pd, radio chemically separated and deposited on a copper substrate

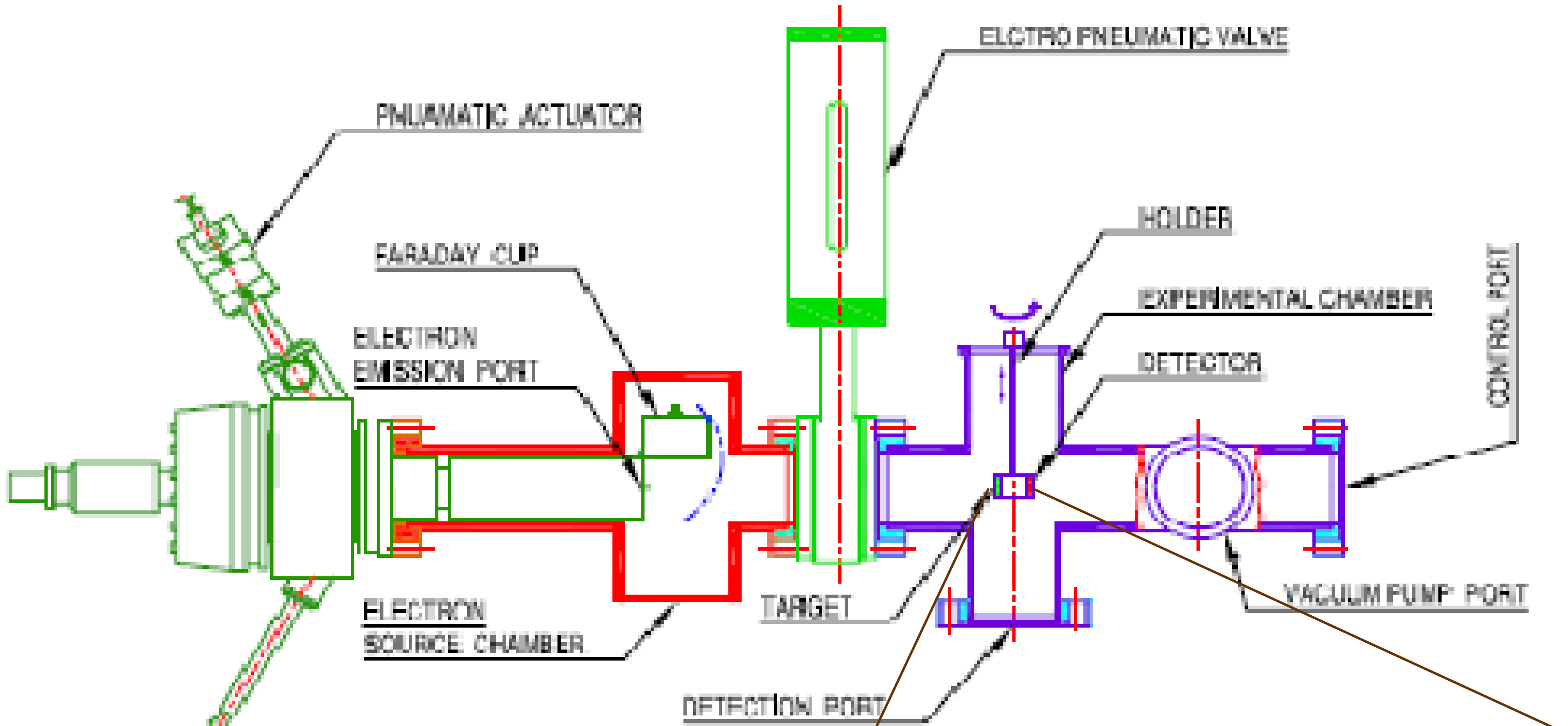


Field Emission Testing setup

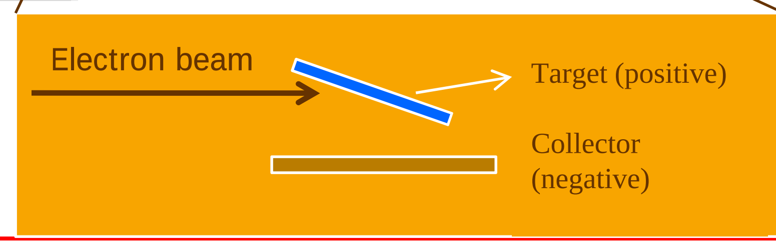




Set up for Ion regeneration study using a Electron Source

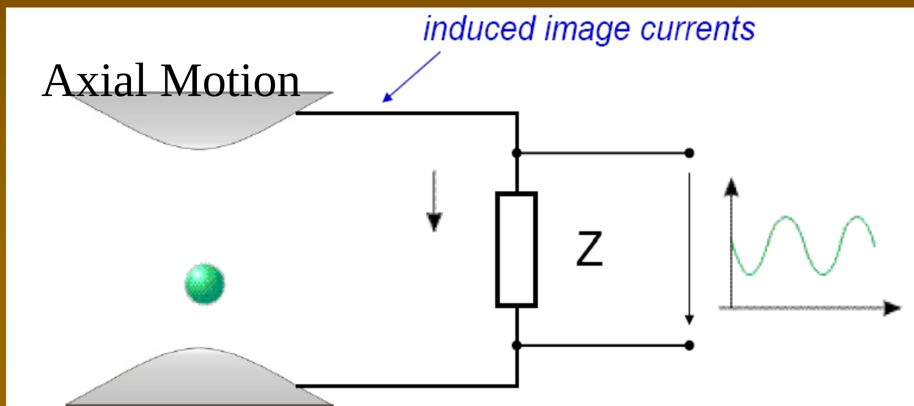


Electron Source Specifications:
Energy : 100 eV to 10 keV
Current :10 nA to 100 µA



VEC TRAP

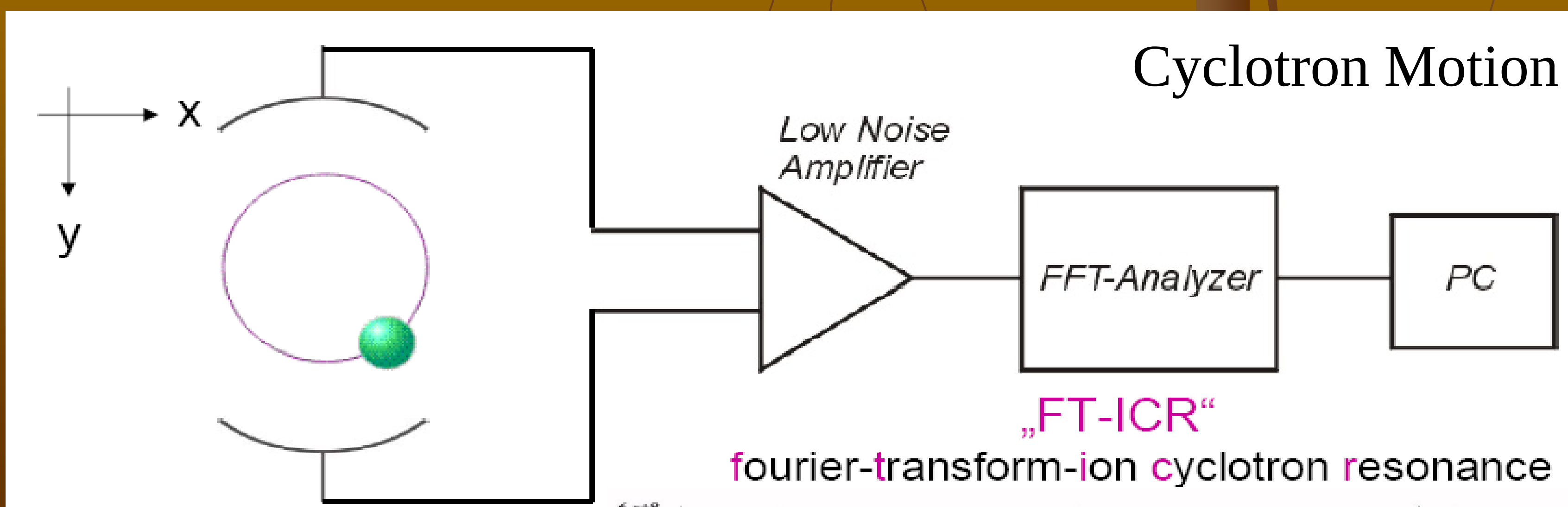
Detection by *Non destructive IMAGE CHARGE*



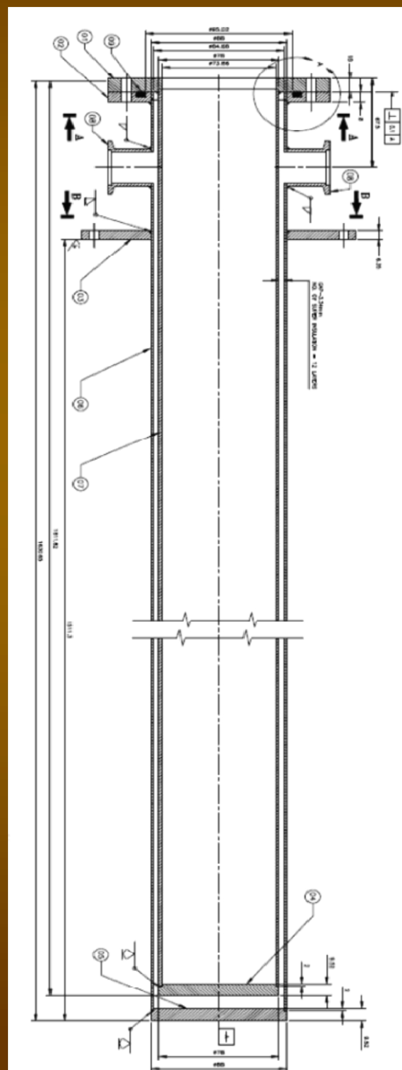
induced current:

$I_{eff} = 1/\sqrt{2} \cdot r_{ion}/D \cdot \omega \cdot q$

Broad band detection



Scan tube fabricated



Specifications:

A double walled hollow chamber of 1630.35 mm

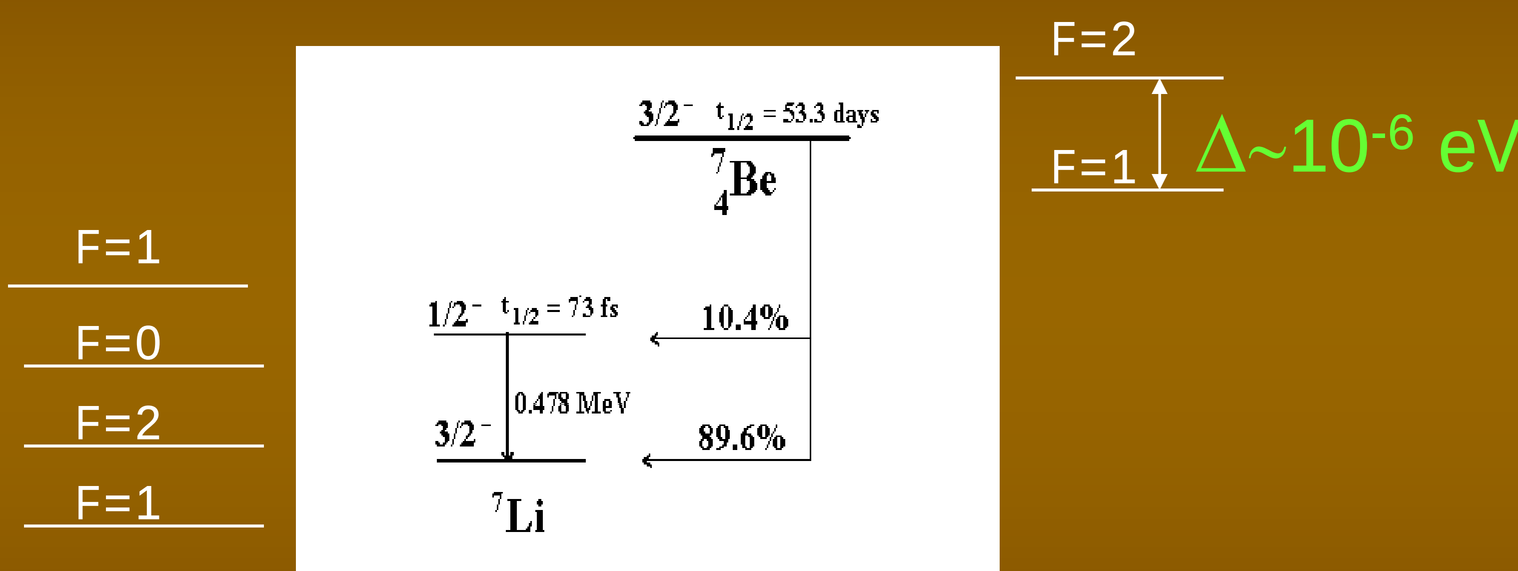
The outer chamber is a 2 mm thick hollow cylinder made of stainless steel with outer diameter is 86.9 mm

Inner chamber 3.3 mm thick cylinder with inner diameter 69.4 mm.

The outer wall of the inner cylinder is wrapped with 15 layers of super insulations and then placed inside the outer chamber and vacuum sealed to 10^{-5} mbar level.

Change in decay rate due to hyperfine interactions

Folan and Tsifrinovich [PRL **74** 499(1995)] pointed out that the electron capture rate of hydrogen like atom can be dramatically changed by hyperfine interaction at temperatures small compared to the hyperfine splitting.



- So we need to cool the system to milikelvin temperatures so thermal energy is lower than hyperfine splitting.
- In heavier nuclei hyperfine splitting will be larger, so the effect can be observed at higher temperature, but it is difficult to make them hydrogen like.

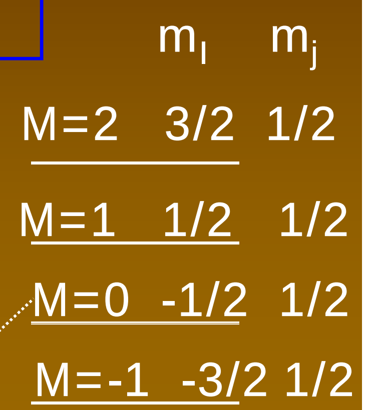
Total interaction energy in the high field limit:

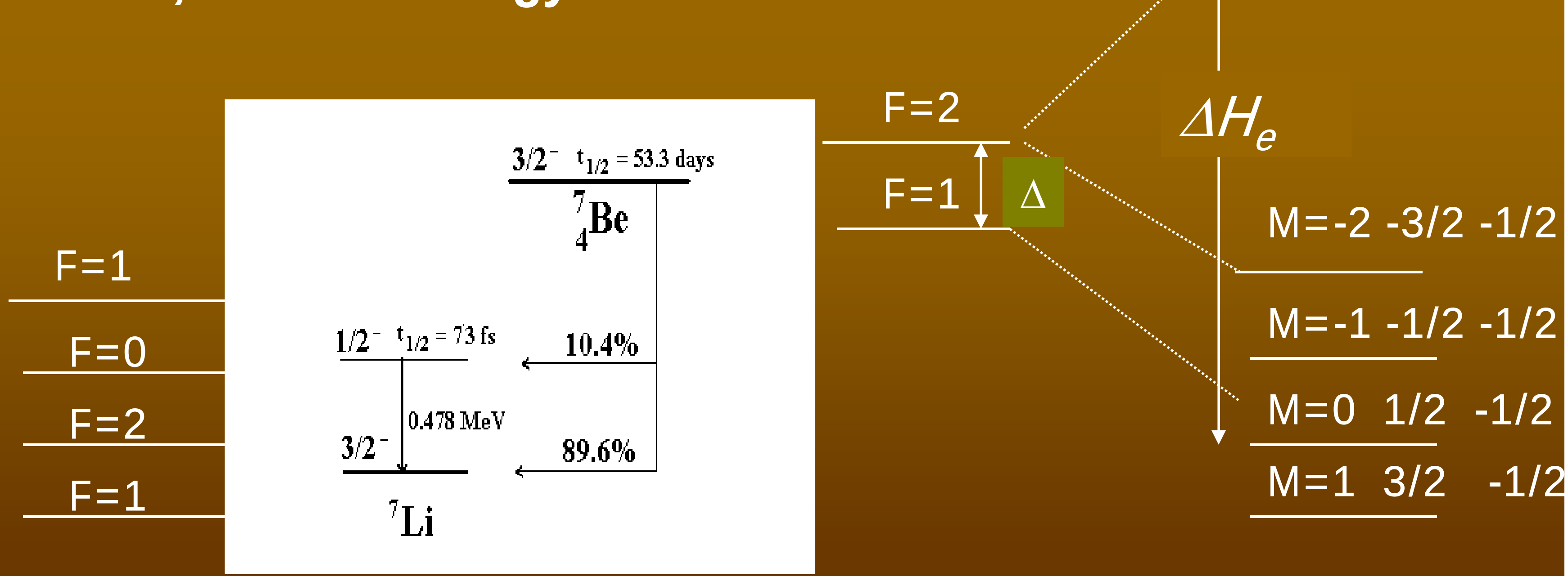
$$H_{Total} = (-m_I \cancel{g_I \mu_N} - m_J g_J \mu_B) H_e + A m_I m_J$$

Hyperfine splitting constant $A = -\frac{\mu_I H(0)}{IJ} \approx 10^{-6} eV$

$\Delta H_e \sim 6X10^{-4}\ eV \sim 100\Delta$

At 4K, thermal energy is $3.6X10^{-4}$ eV





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Thankyou