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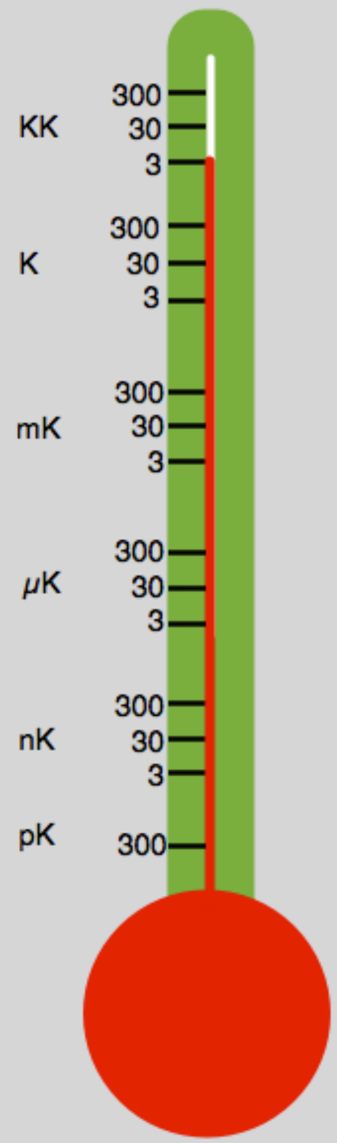
A Cooler Penning Trap to cool highly charged and short-lived isotopes at TITAN



Cool'13, Mürren
Switzerland

Usman Chowdhury

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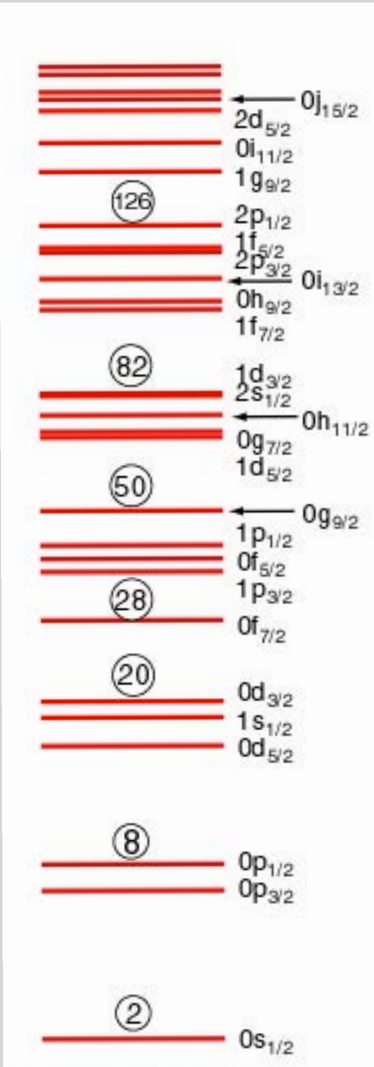
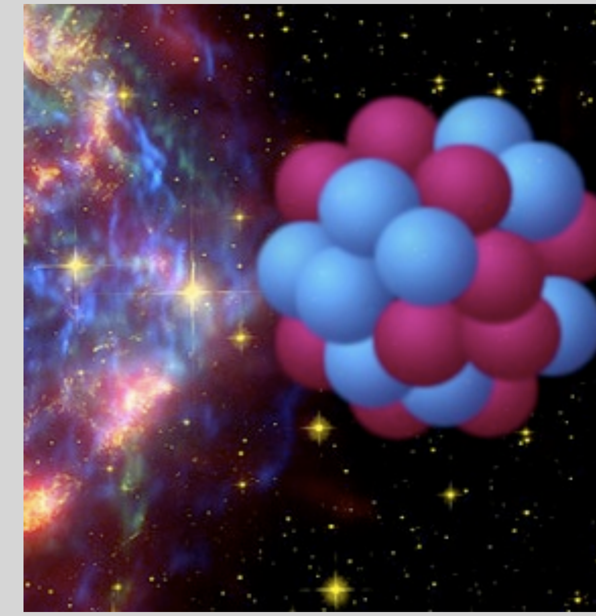
&
Department of Physics & Astronomy
University of Manitoba



Shell Model of Nuclei

Precision mass measurement



- Explaining astrophysical phenomena ($\delta m/m \approx 10^{-7}$)

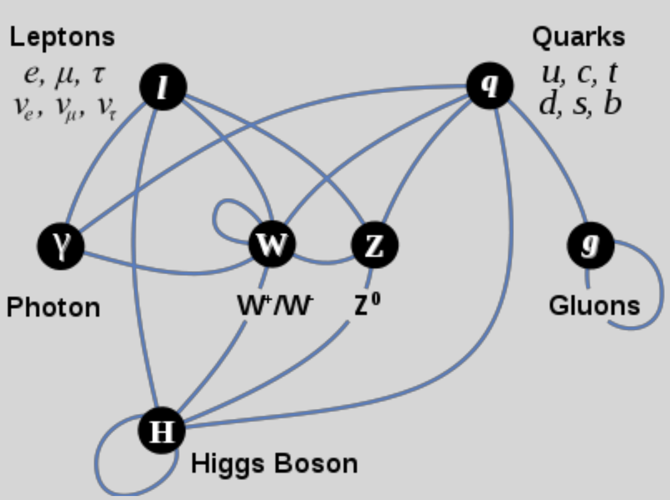
  r-process, rp-process, wait time

- Test of nuclear models ($\delta m/m \approx 10^{-7/8}$)

  Shell model, sub-shell closures

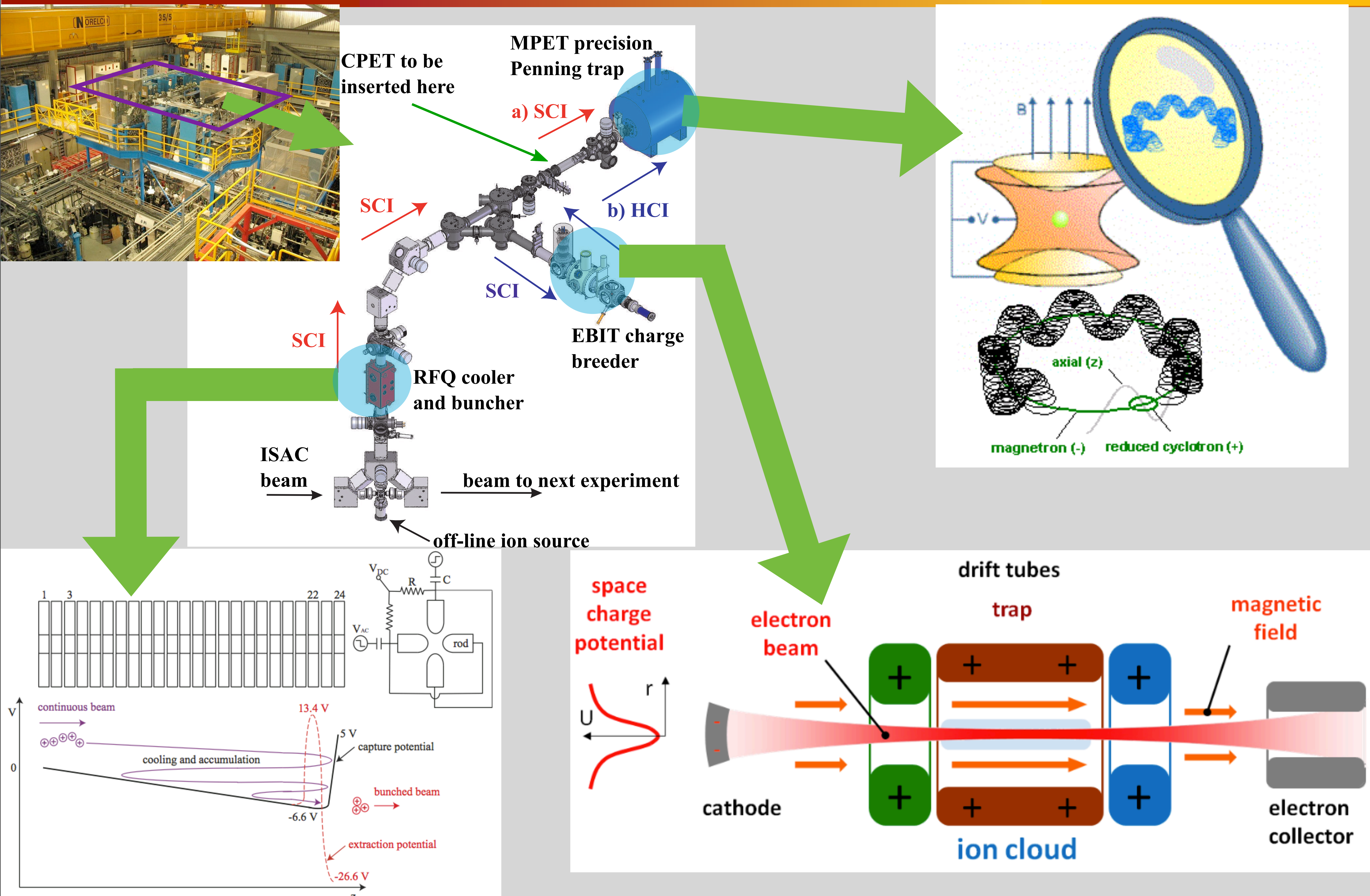
- Metrological standard fixing ($\delta m/m \approx 10^{-10}$)

  Fundamental constants: charge, mass standard.



- Test of the Standard Model ($\delta m/m \approx 10^{-8/11}$)

  CVC hypothesis, unitarity of CKM matrix.


CPET to be inserted here
MPET precision Penning trap
a) SCI
SCI
b) HCI
SCI
SCI
EBIT charge breeder
RFQ cooler and buncher
ISAC beam
beam to next experiment
off-line ion source
B
V
axial (z)
magnetron (-)
reduced cyclotron (+)
1
3
22
24
V_{DC}
R
C
V_{AC}
rod
V
0
z
continuous beam
13.4 V
5 V
capture potential
cooling and accumulation
bunched beam
-6.6 V
extraction potential
-26.6 V
drift tubes
trap
space charge potential
electron beam
magnetic field
U
r
cathode
ion cloud
electron collector

Scope of improved mass measurement

Given

$$\frac{\delta m}{m} \approx \frac{m}{q \times |\vec{B}| \times T_{RF} \times \sqrt{N}}$$

Significantly improvable with EBIT+CPET HCI

Technical and monetary challenges

Restricted by the half life

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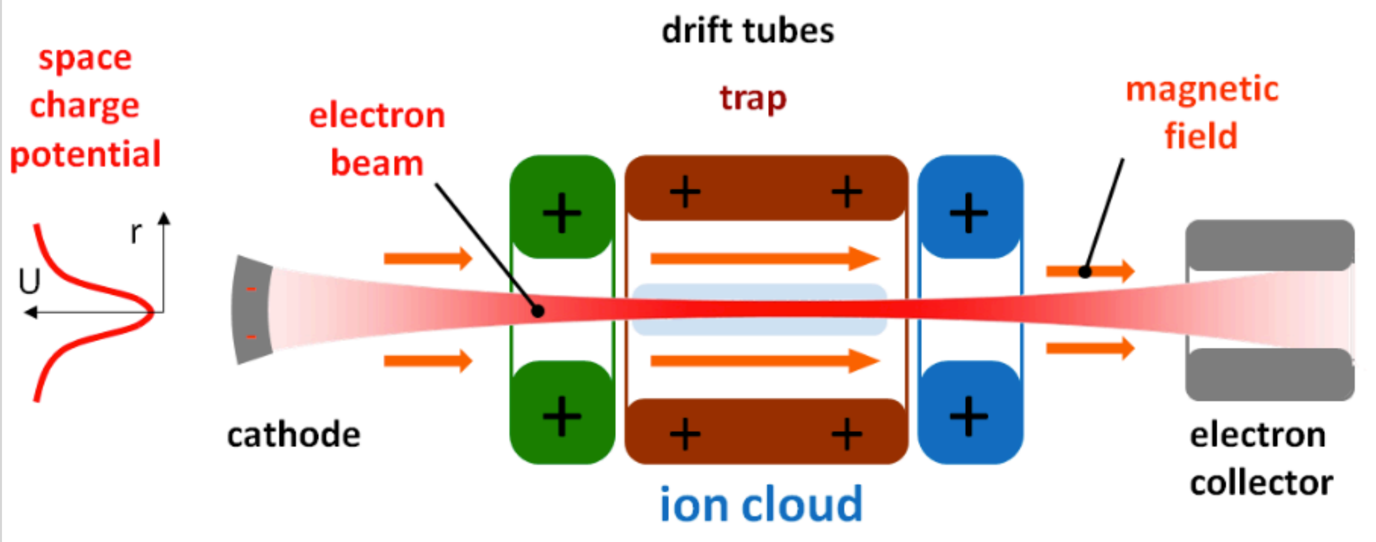
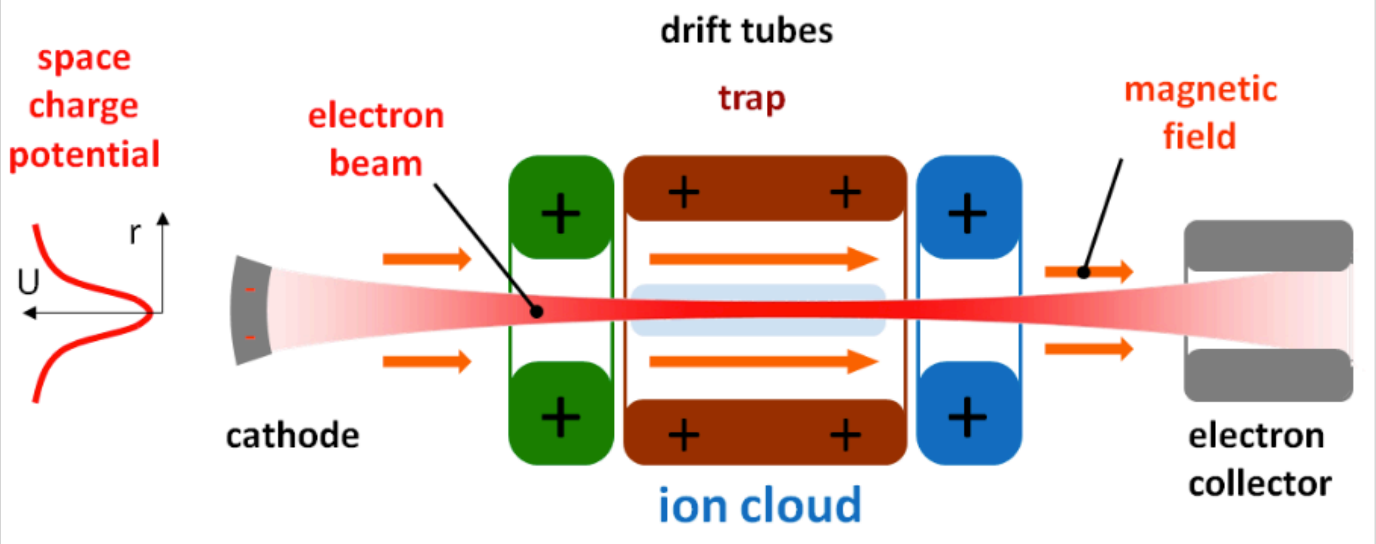
Why CPET?



- Problem arises due to:
  - Charge breeding → > 10 eV/q energy spread, increase in uncertainty.
  - Residual gases → contaminants with similar q/m.
- CPET will solve these problems:
  - Will reduce the energy spread → will use sympathetic cooling.
  - Will be able to clean the contaminants → can apply different frequencies.

Why CPET?



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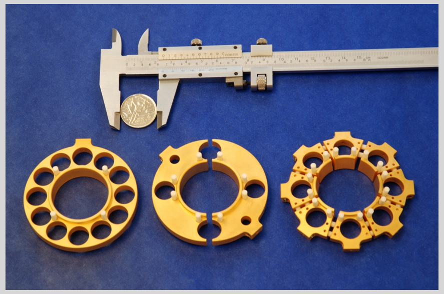
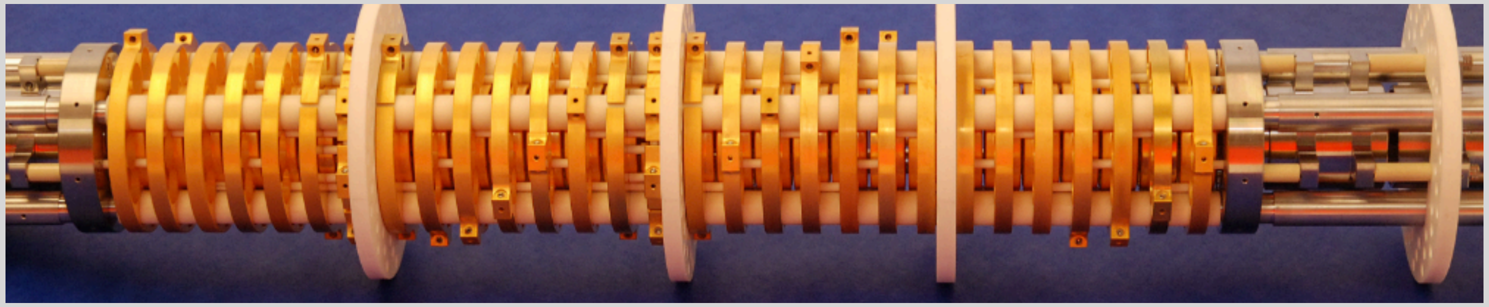
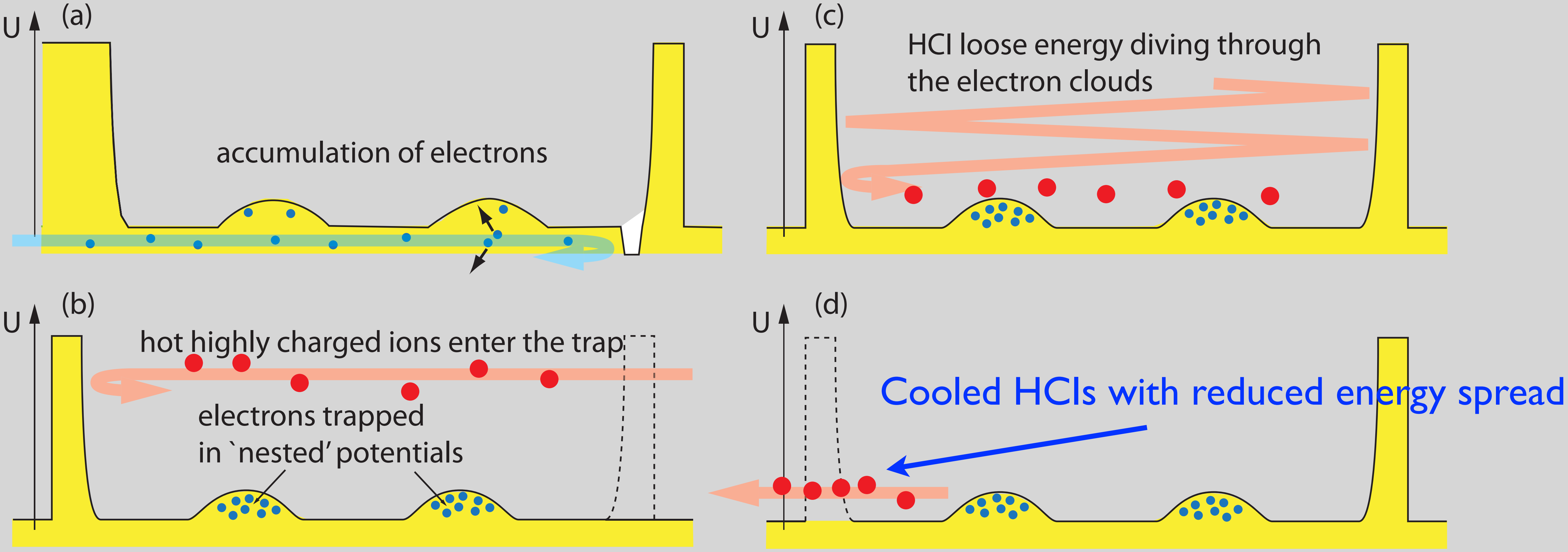
achieved through electron or proton cooling

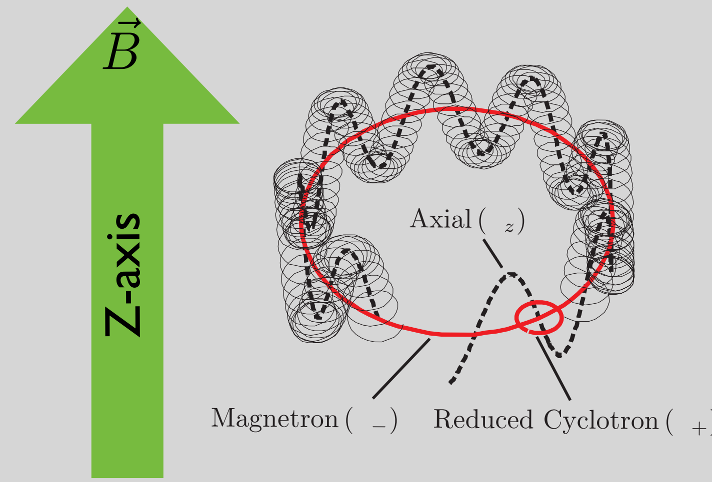
CPET cooling







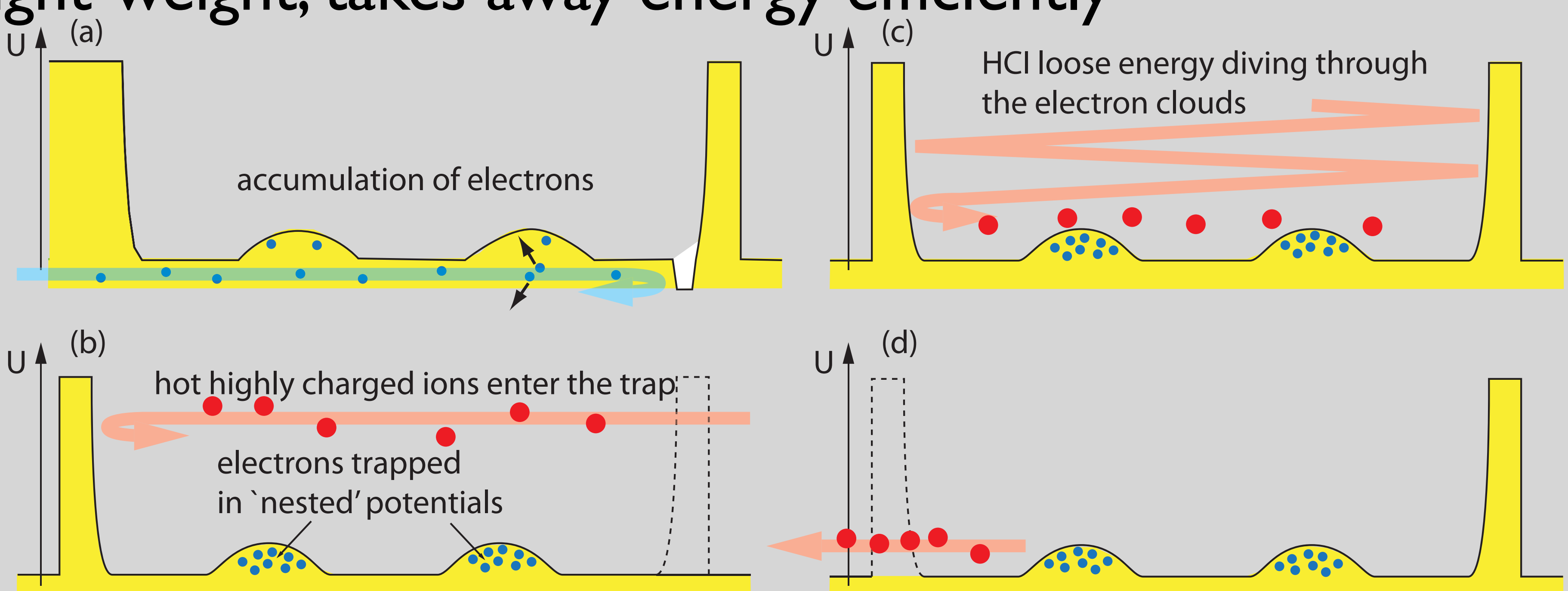
Electron cooling



- Electron's self-cooling in magnetic field helps using them perpetually

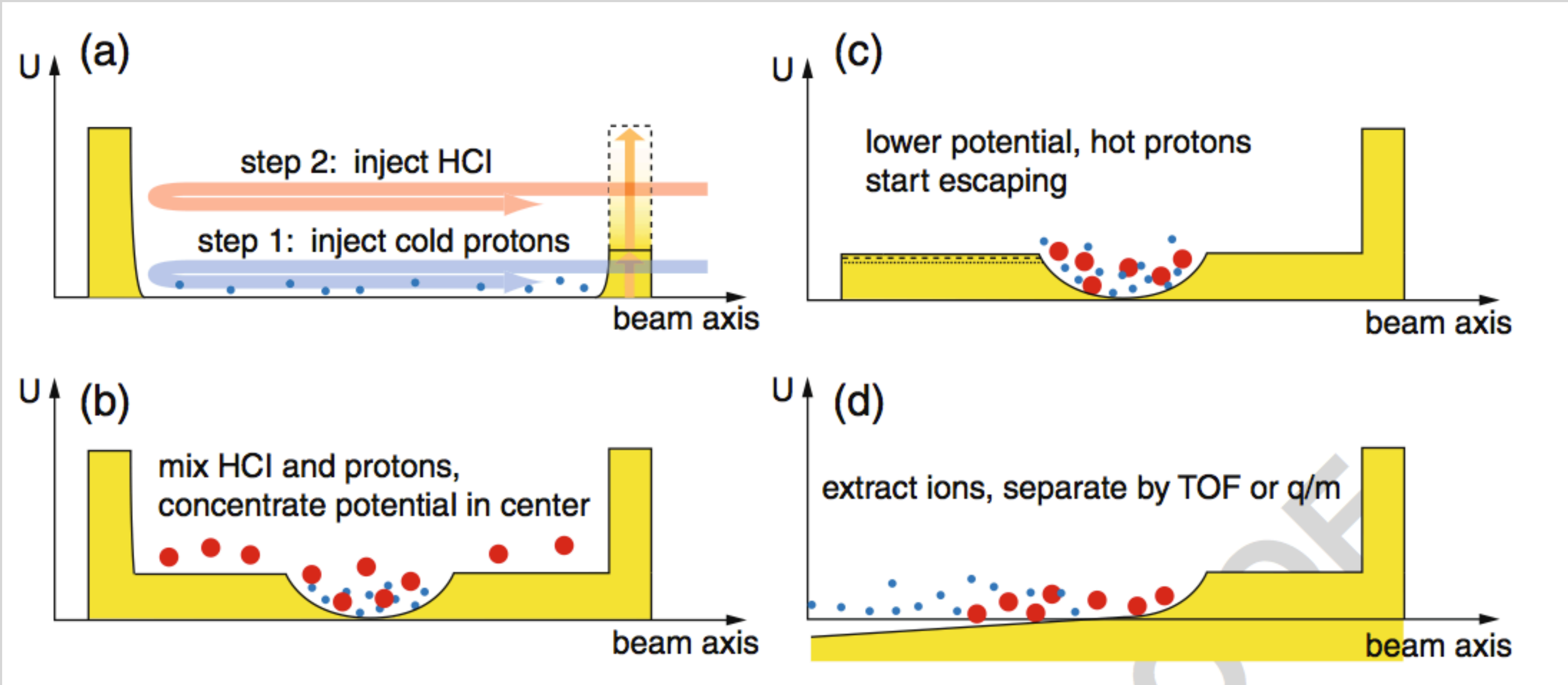
$$P = \frac{e^4}{6\pi\epsilon_0 m^4 c^5} E^2 B^2$$

- Being light-weight, takes away energy efficiently



Proton cooling

- In principle same as electron cooling.
- Advantages:
    - There is no recombination problem as in case of electron cooling.
    - Loading from off-axis is easier.
- Disadvantage
    - No significant self cooling because of heavy mass (~2000 times more than that of electron).



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CPET simulation

- Simulation shows that cooling of HCIs is possible within a fraction of second.

$n_e \approx 10^7/cm^3$

$N_i/N_e = 10^{-4}$

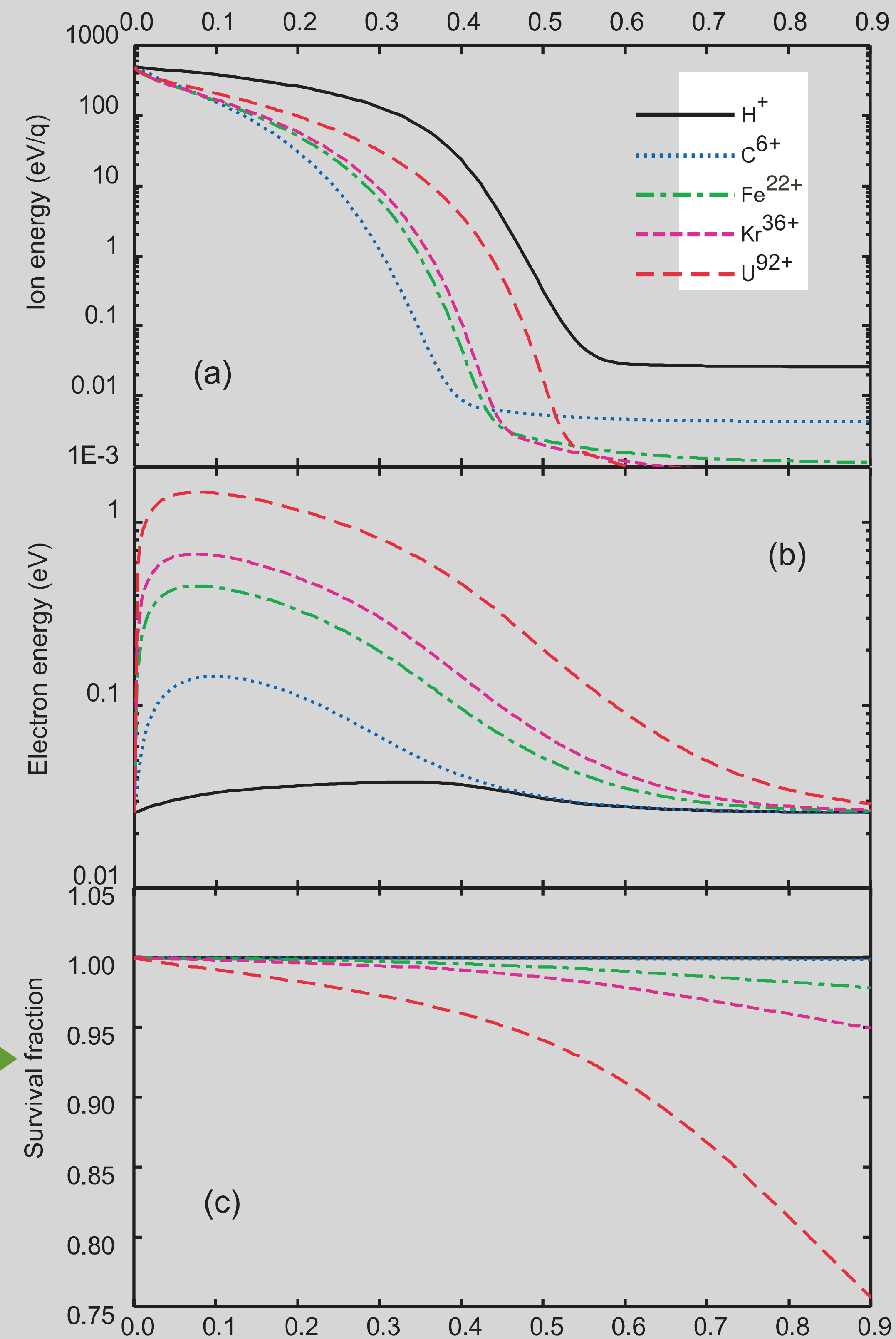
$T_{res} = 300K$

- Electrons self-cool via synchrotron radiation and absorbs energy from HCIs.

$\sim 4/B^2$

- Not too many ions lost due to the recombination during the cooling process.

$\frac{dP}{dt} = -P[\alpha_{RR}(T) + \alpha_{DR}(T) + \alpha_{TR}(T)]n_e$



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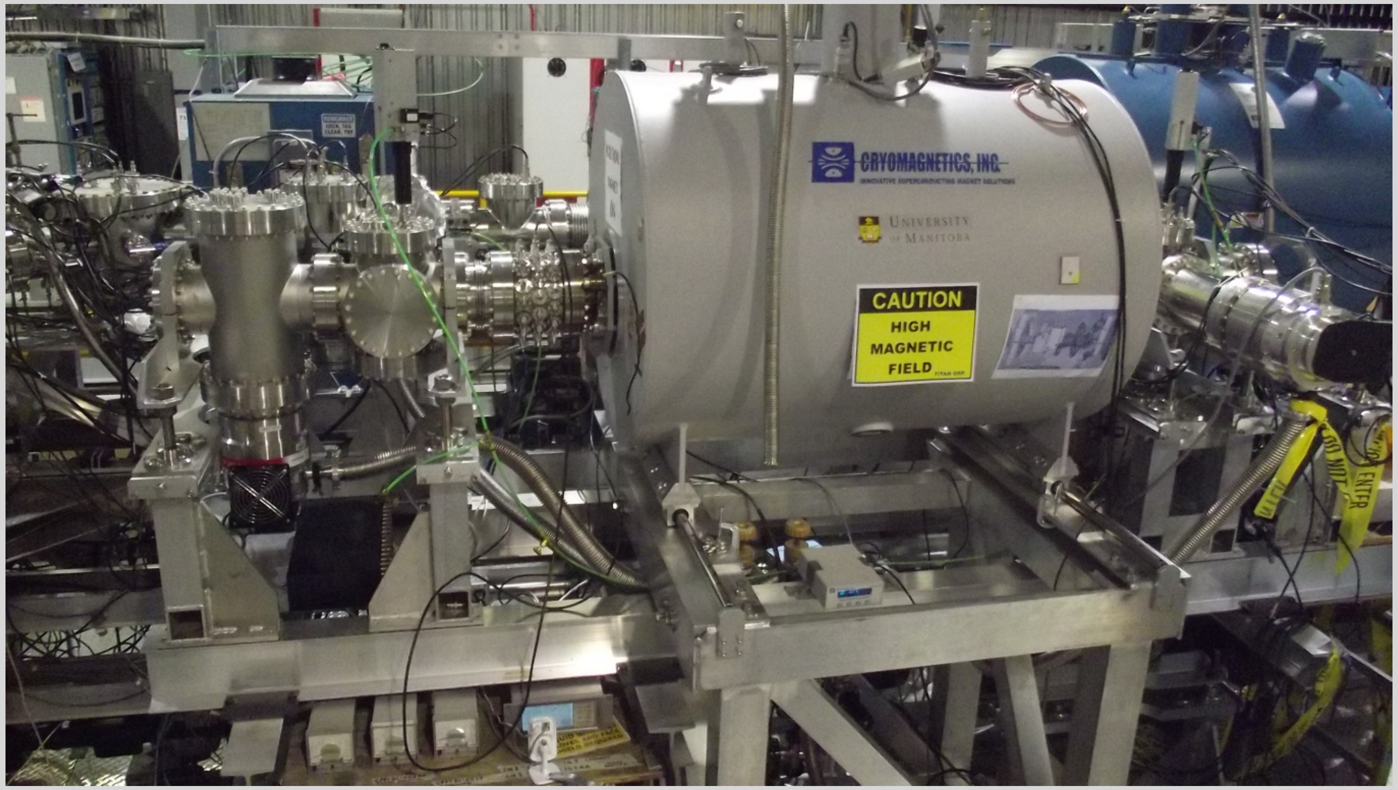
Current status

- Offline set-up is almost complete. Ion source is ready to be installed.

- Systematic tests with electron source are in progress.

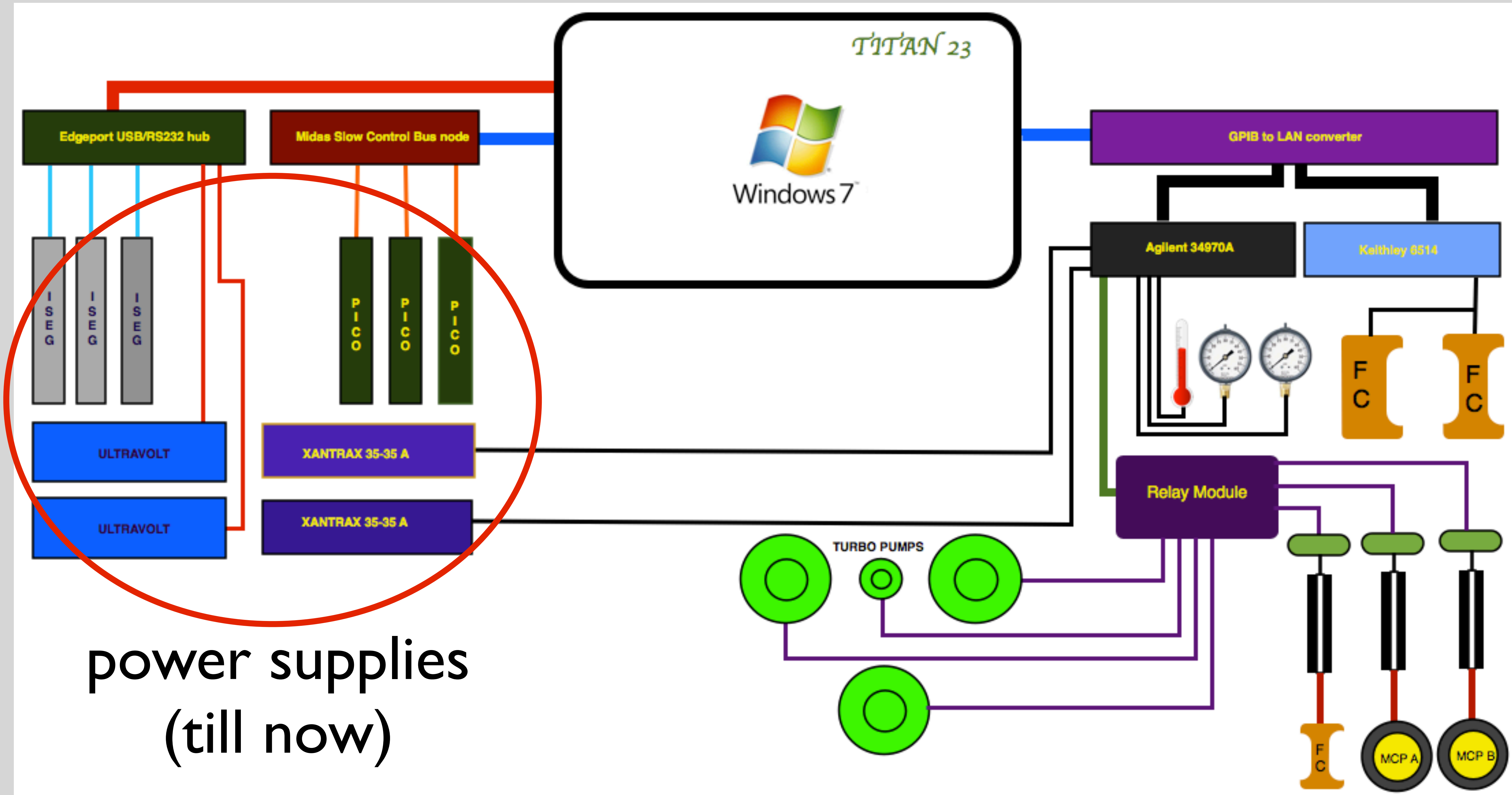
- High transmission efficiency was observed.

- Trapping effort is in progress.

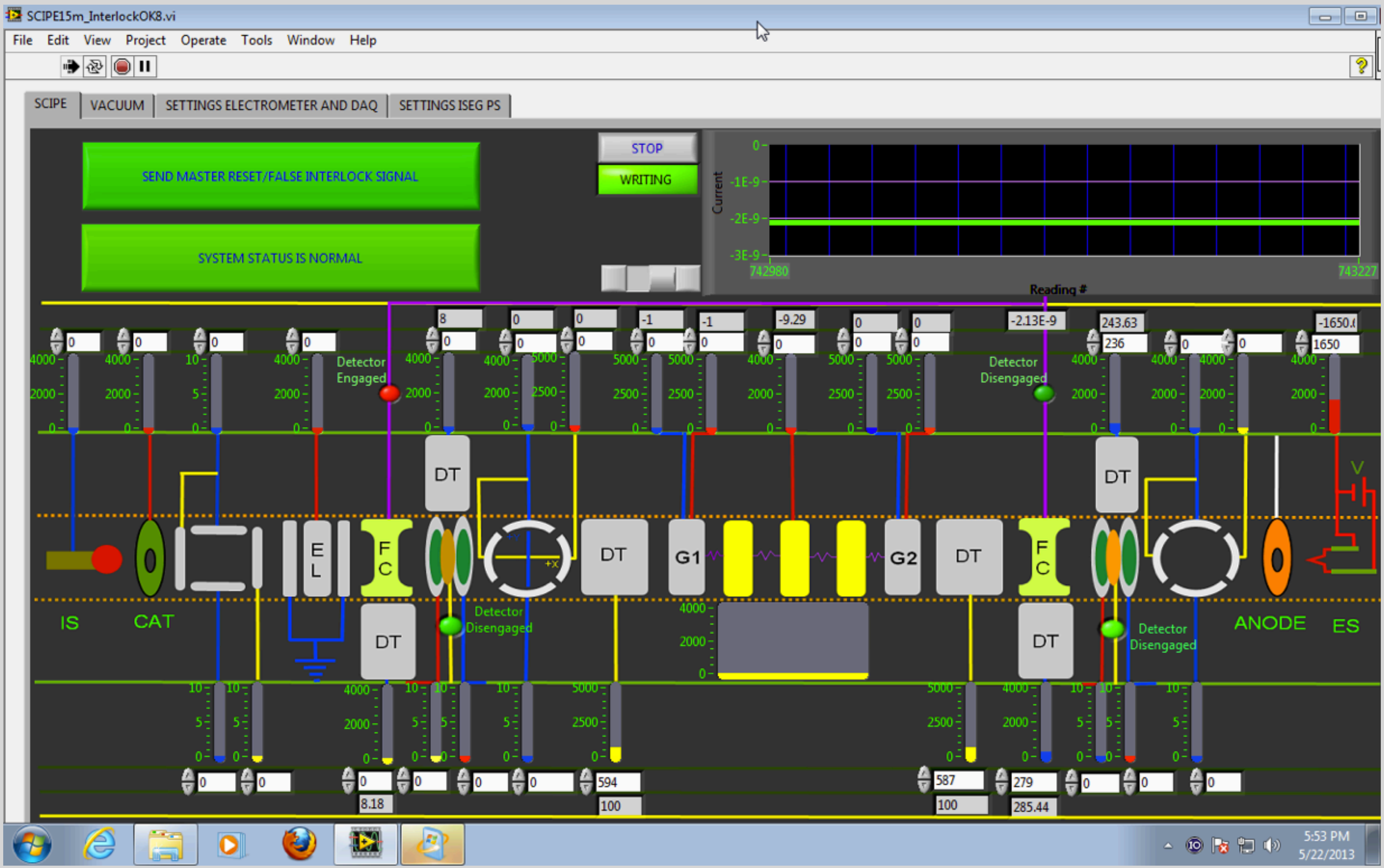


May 2013

CPET control system



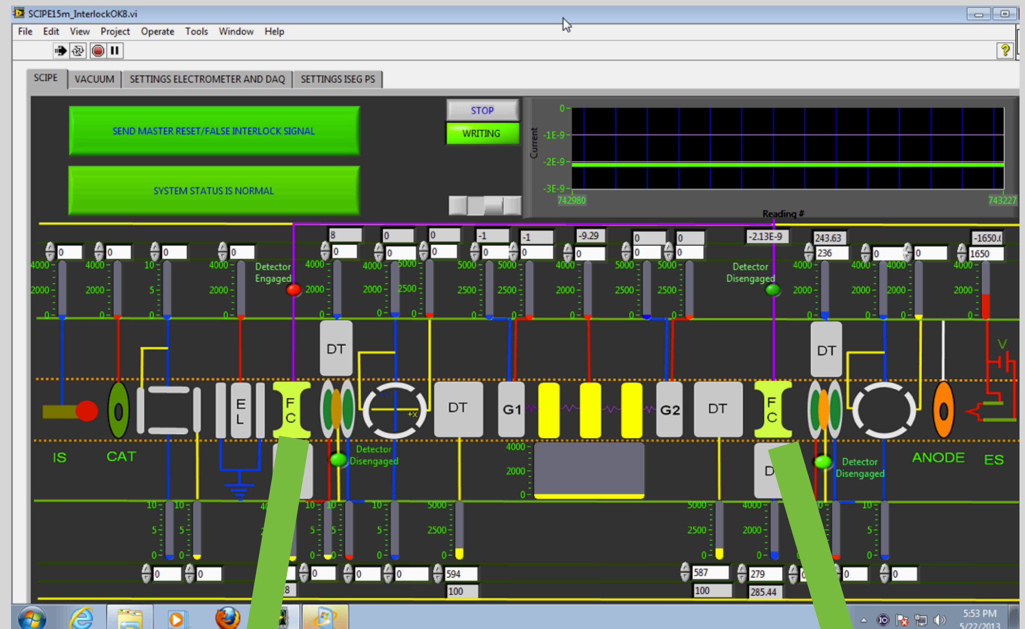
LabView interface

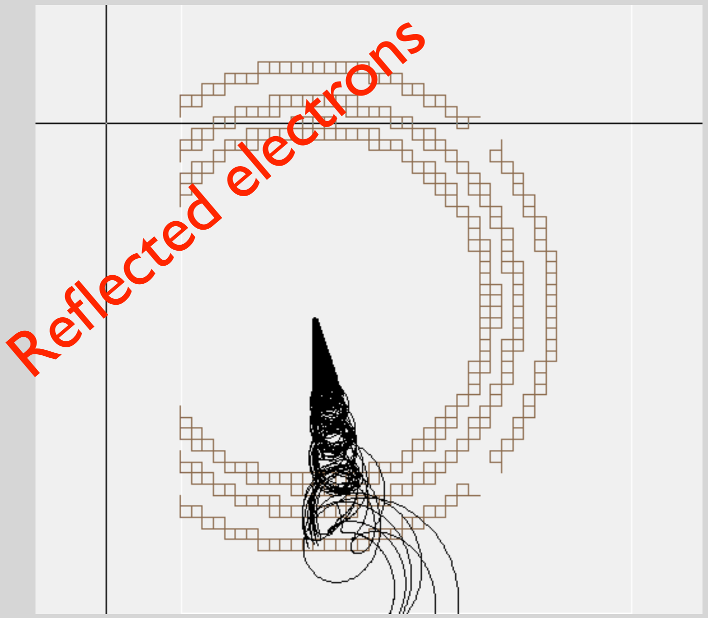


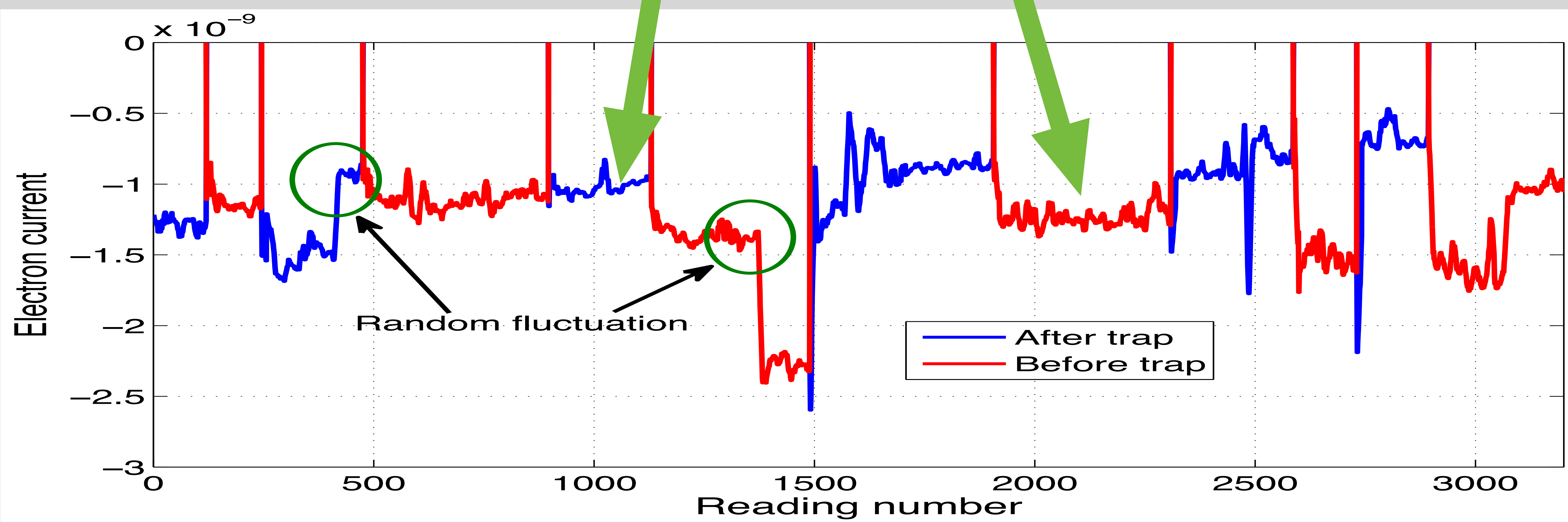
Electron through high magnetic field

Magnetic mirror

$$\left(\frac{v_{e_{\parallel}}}{v_{e_{\perp}}}\right)_{critical} = \frac{B_{max} - B_{min}}{B_{min}}$$

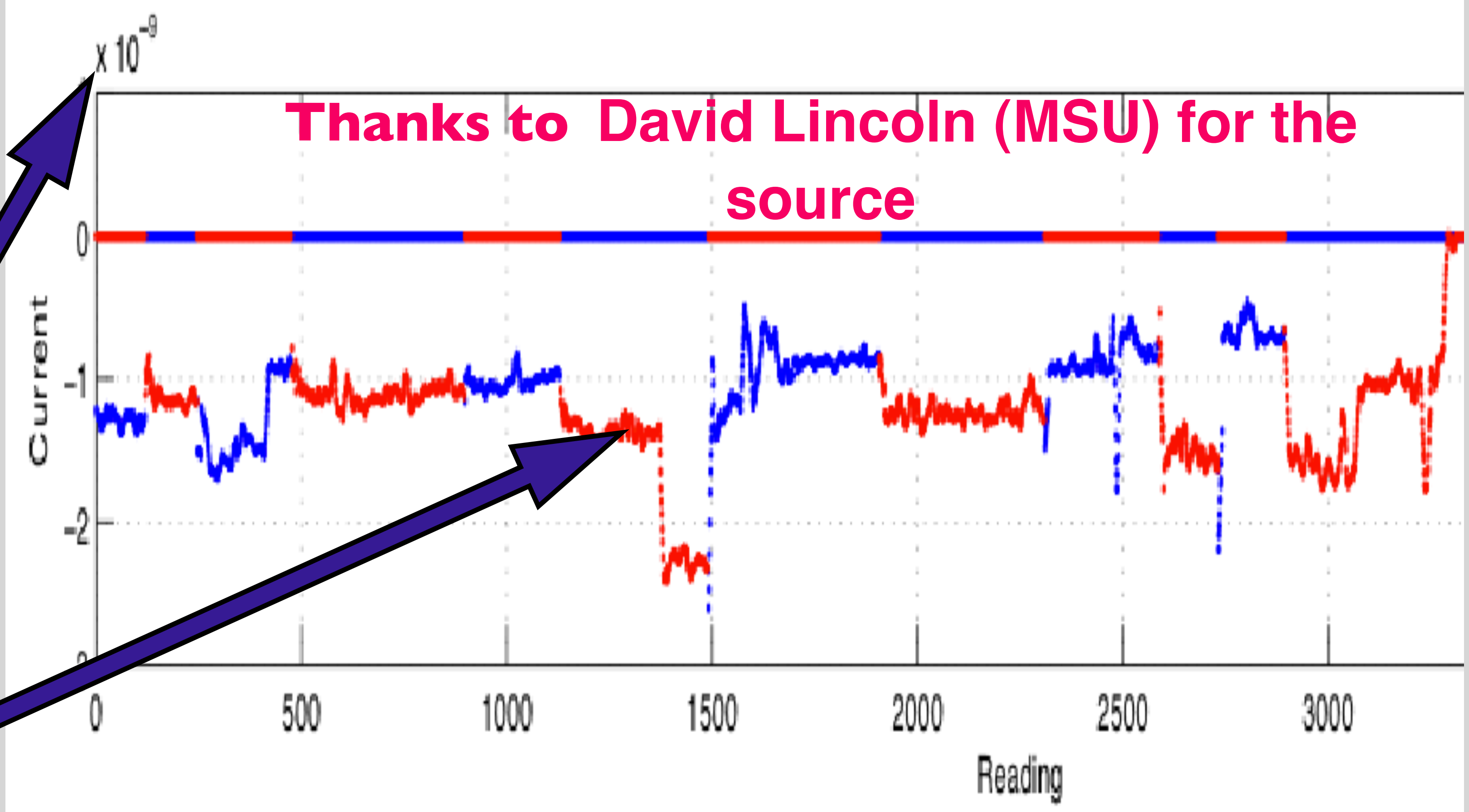






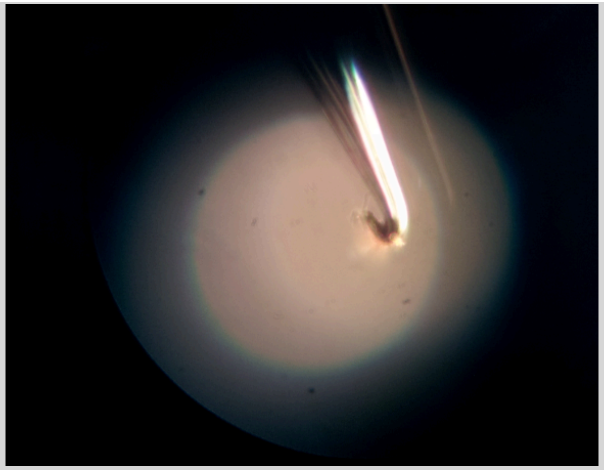
Tests with FET

- Ideal for primary tests like shot through and on-axis injection test.
- Very low current (sub μA maximum).
- Difficult to condition.
- Inherent instability in current.



Never gave electron

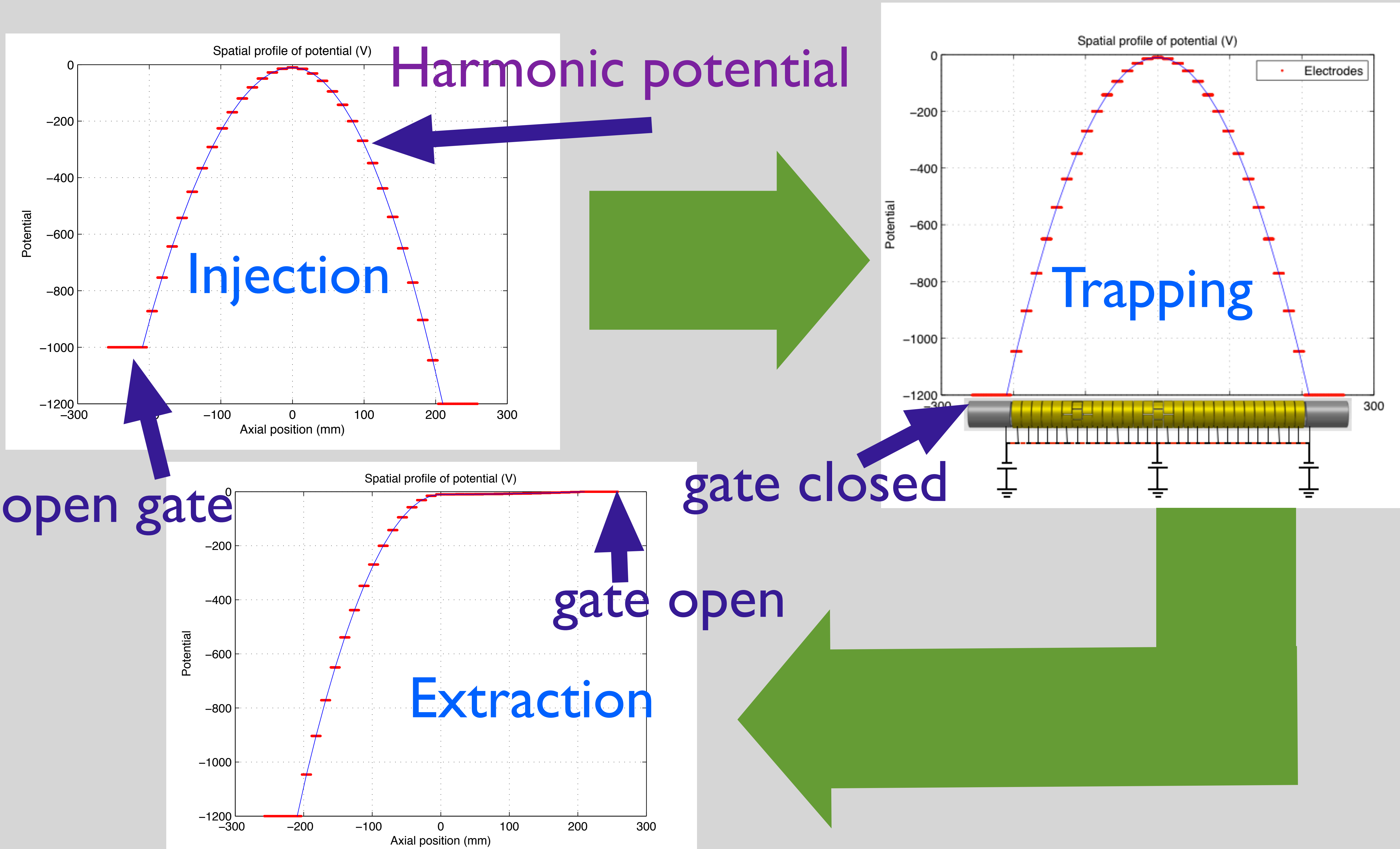
Bad tips



Burned tip

Solution: * Using thermionic filament with higher and stable current (~10μA).

Electron plasma in a harmonic potential



Next steps

- Electron trapping.
- Electron cloud optimization and trapping in nested traps.
- Ion injection and efficiency test.
- Ion trapping.
- Simultaneous trapping of ion and electron.
- Cooling ions with artificial energy spread.
- Commissioning CPET.

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Canada Foundation for Innovation
Fondation canadienne pour l'innovation

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THANK YOU!

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