The TITAN Cooler Penning Trap – Status and Perspectives

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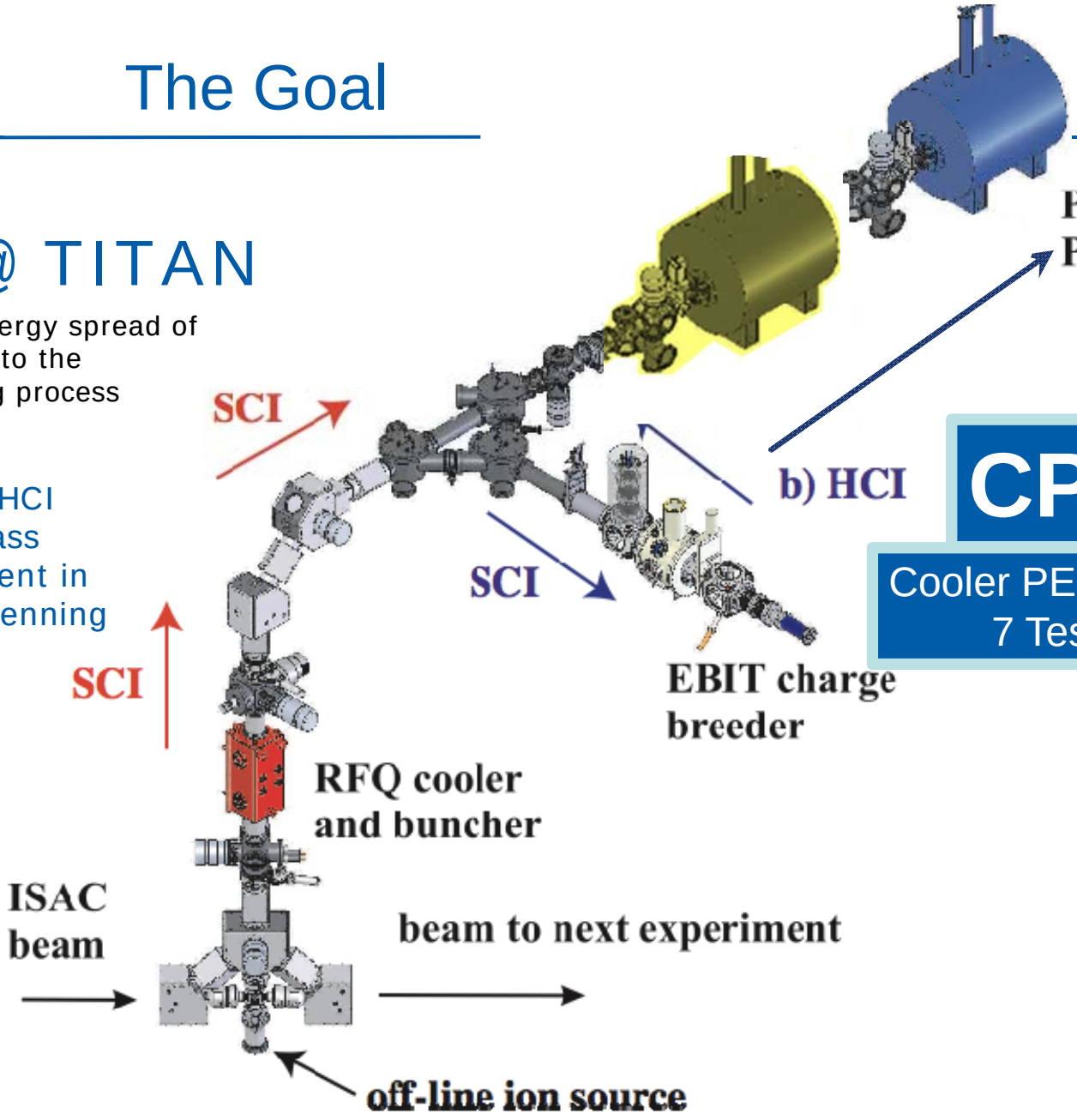
The Goal

CPET @ TITAN

Reduction of energy spread of HCI that is due to the charge breeding process in the EBIT

→ Cooling of HCI prior to mass measurement in precision Penning trap



CPET

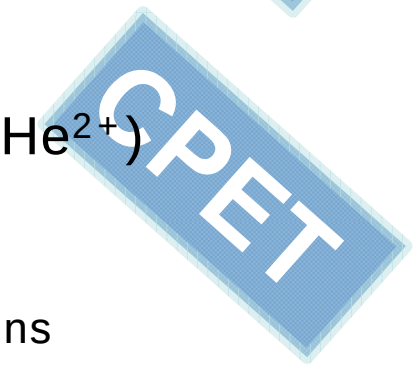
Cooler PEnning Trap
7 Tesla

Techniques for ion cooling

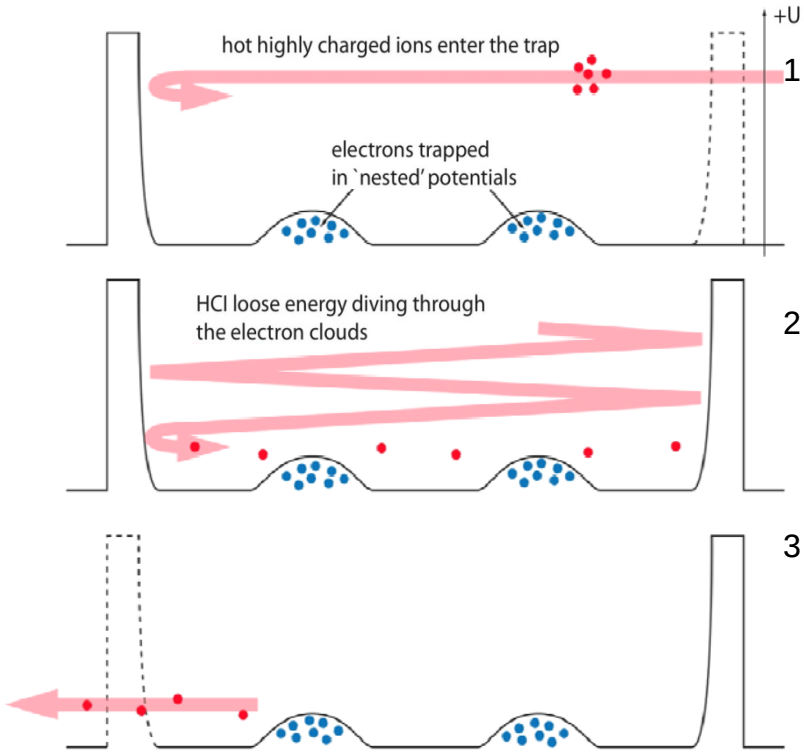
- Several techniques:
  - Buffer gas cooling (SCI)
  - Resistive cooling
  - Positron cooling (avoids recombination, but requires strong beta emitter as source)
  - Evaporative cooling, …
- CPET is investigating cooling of HCI with:
  - Electron cooling
    - Simulations and used for (anti)protons and feasibility studies for HCI at $T_i \gtrsim$ few eV/q
    - Advantage: electrons self-cool via synchrotron radiation
    - Disadvantage: electron-ion recombination

  or

  - Ion-ion cooling with light, cold ions (protons, He^{2+}) (proton cooling)
    - No recombination issues
    - But no synchrotron cooling, need initially cold light ions



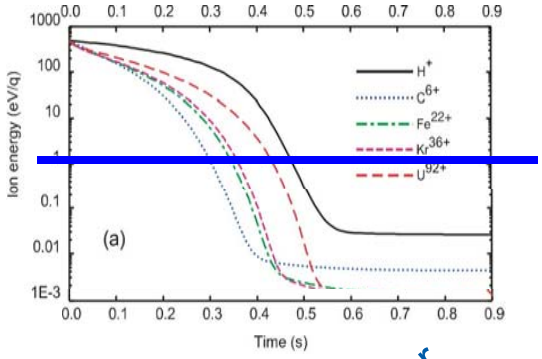
Electron cooling: scheme

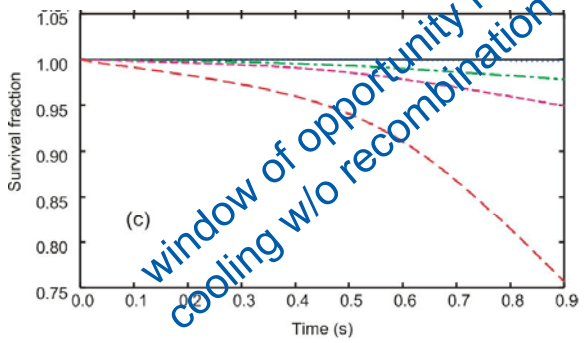


1) - Multiple electron injections
   - Multiple HCI injections

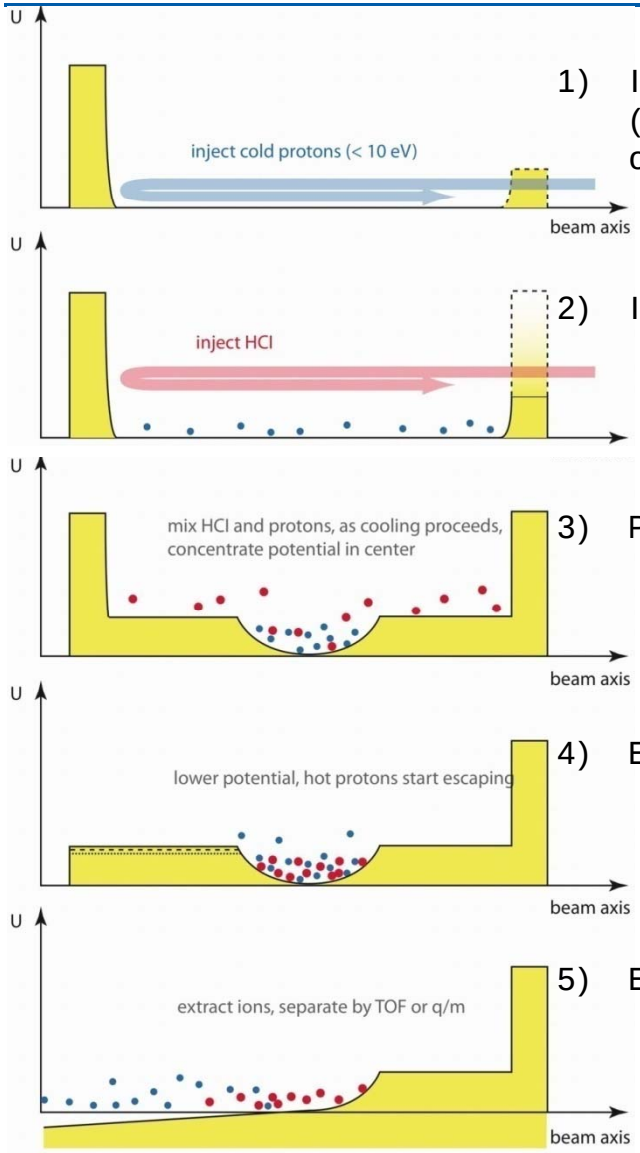
2) - Electron cooling

3) - Termination of electron cooling
   - Excitation/ detection of motions & extraction of HCI





Proton cooling: scheme



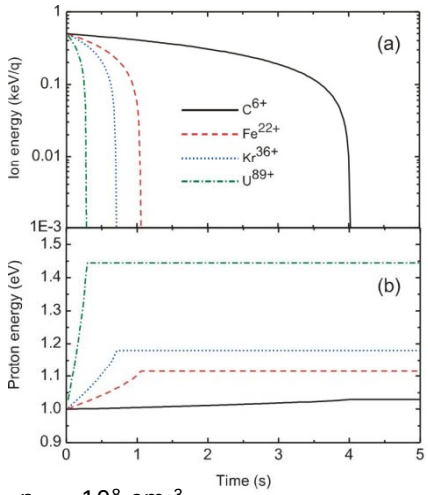
1) Injection of cold protons (possible resistive cooling of protons)

2) Injection of HCl

3) Proton cooling

4) Evaporative cooling

5) Extraction of ions

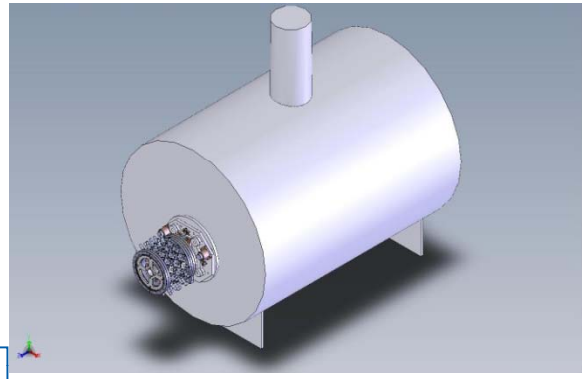


$n_p = 10^8$ cm^{-3}
$N_i/N_e = 10^{-5}$

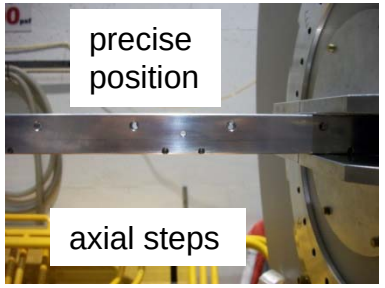
Zunjian Ke, PhD thesis, U. of Manitoba, 2008

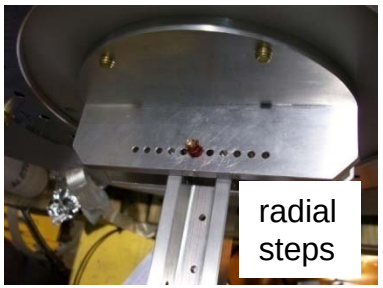
TRIUMF CPET – Cooler PEnning Trap at TITAN what we need

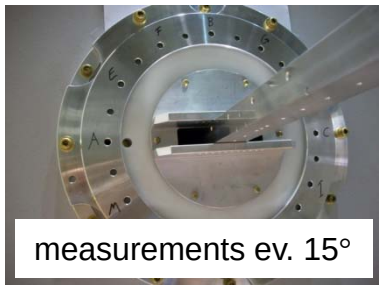
- A 7 Tesla superconducting solenoid with a compensated homogeneous magnetic field will be used

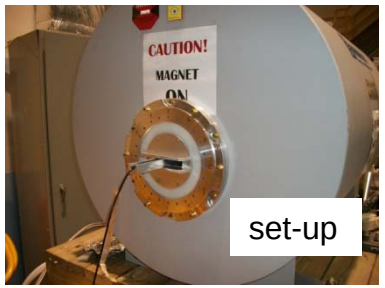


- Ongoing magnetic field mapping → next talk



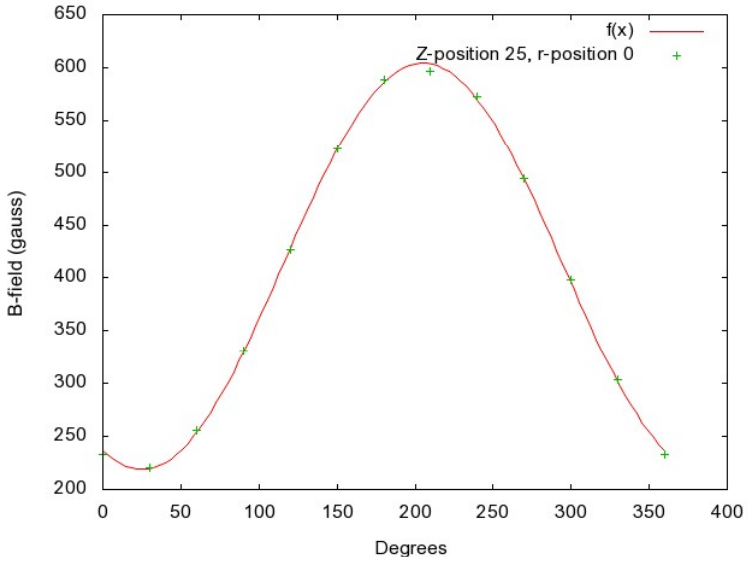






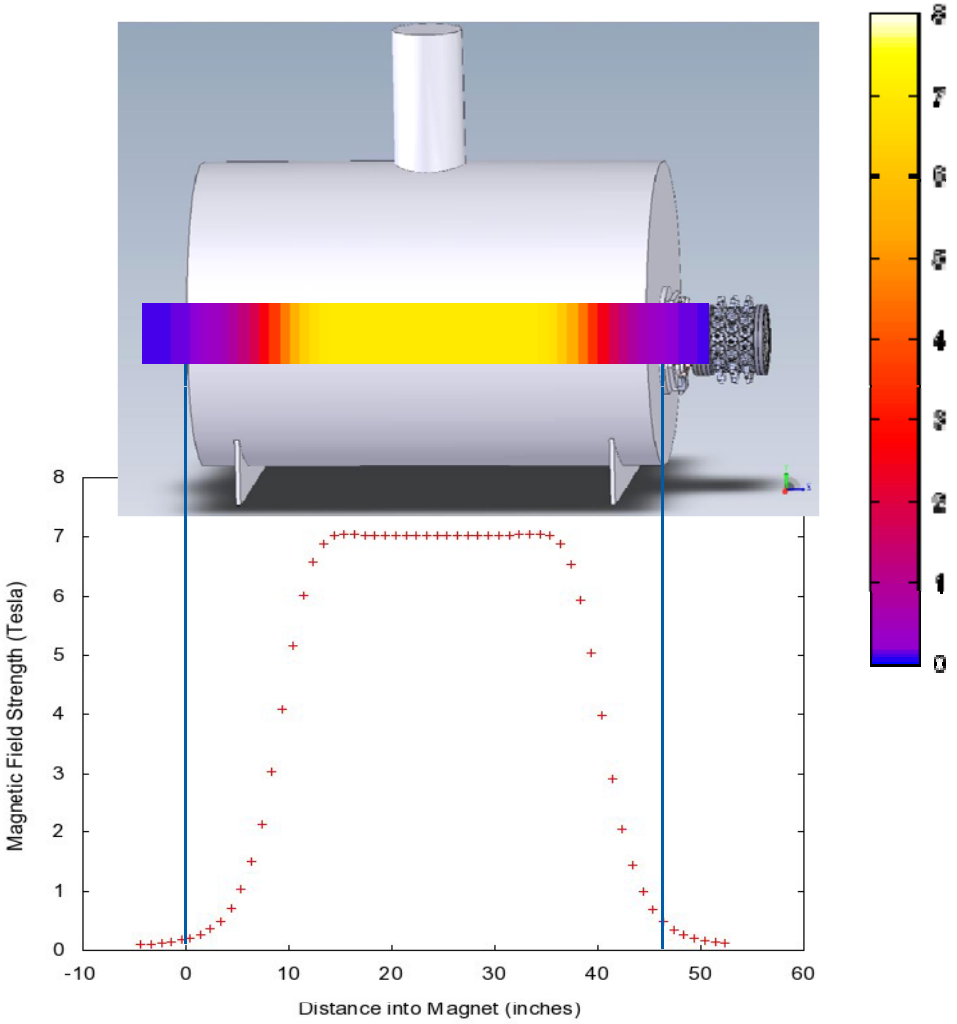
Need of B-field mapping

- Radial measurement
  - Axis of B-field



→ next talk

Undergraduate project Spencer Pasieka



- Axial measurement
  - Strength of the B-field

Need of Vacuum tests

- Vacuum requirements for HCI

- Increasing probability of charge-changing collisions with background gas
- Schlachter formular (velocity independence of cross section σ)
  - Collision rate R for charge ion in background gas (density n)

$$R = v_{\mathrm{rel}} \sigma n$$

  - ion motion dominates relative velocity between collision partners

$$R = \sqrt{2c^2 q \frac{K/q}{mc^2}} \frac{p}{kT} \sigma$$

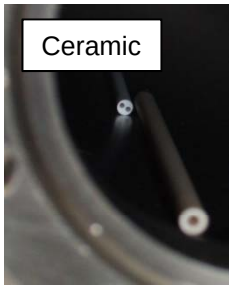
i.e.:
Ion mass of 50, charge of 20, kinetic energy K=100 eV/q,
cross section of $1*10^{-13}$ cm^2, room temperature gas

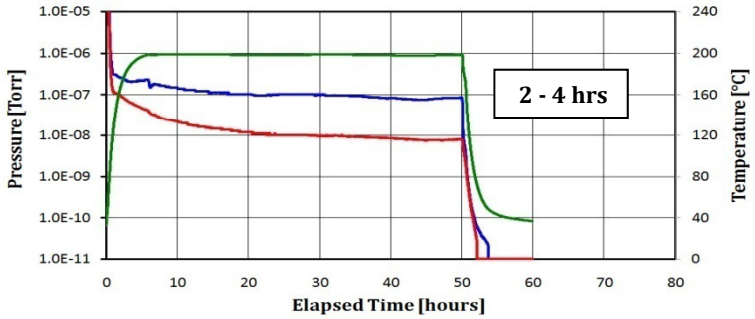
→ Results in collision rate of 2 Hz at a pressure of 10^{-10} mbar

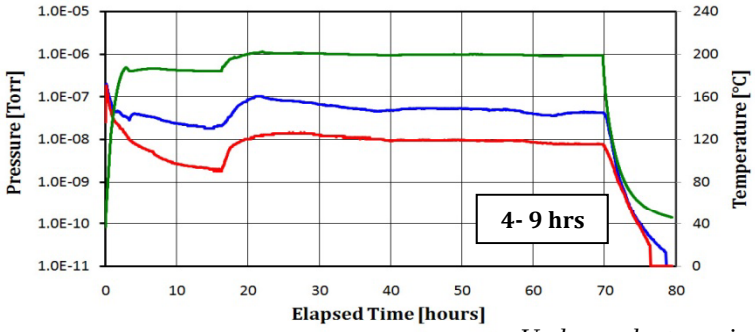
Minimum requirement for vacuum

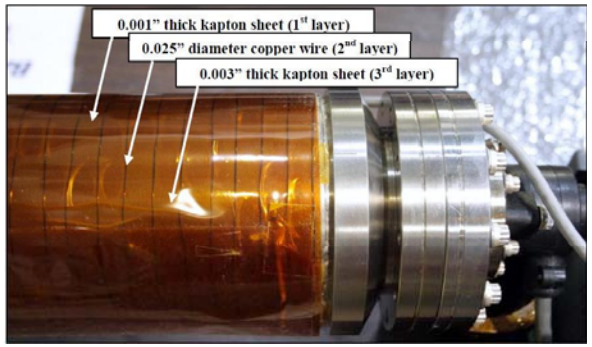
Need of Vacuum tests

- Baking of titanium tube
  - Ti: (can be activated and used as pump itself)
  - Heating with copper-wires
  - Insulation kapton foil
- Empty tube
  - After baking for several days at ~200°C:
    - p <1.5 ·10^{-11} Torr
    - Below limit of gauge controllers!



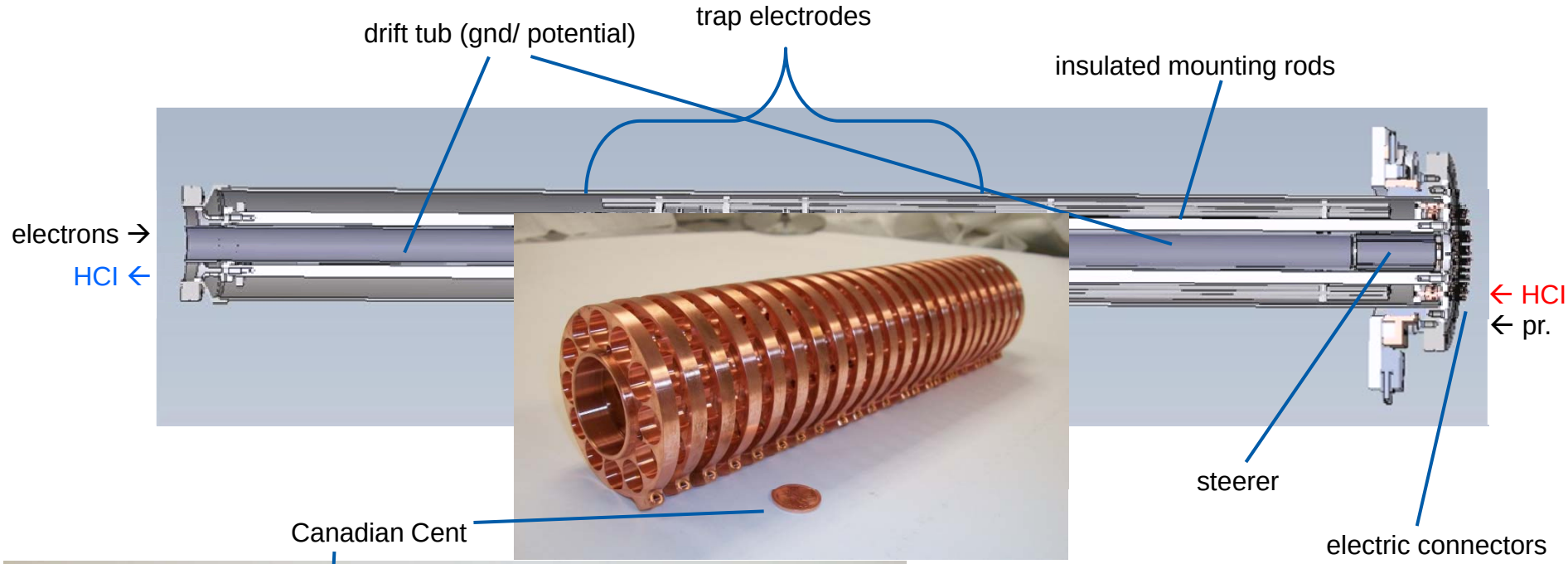






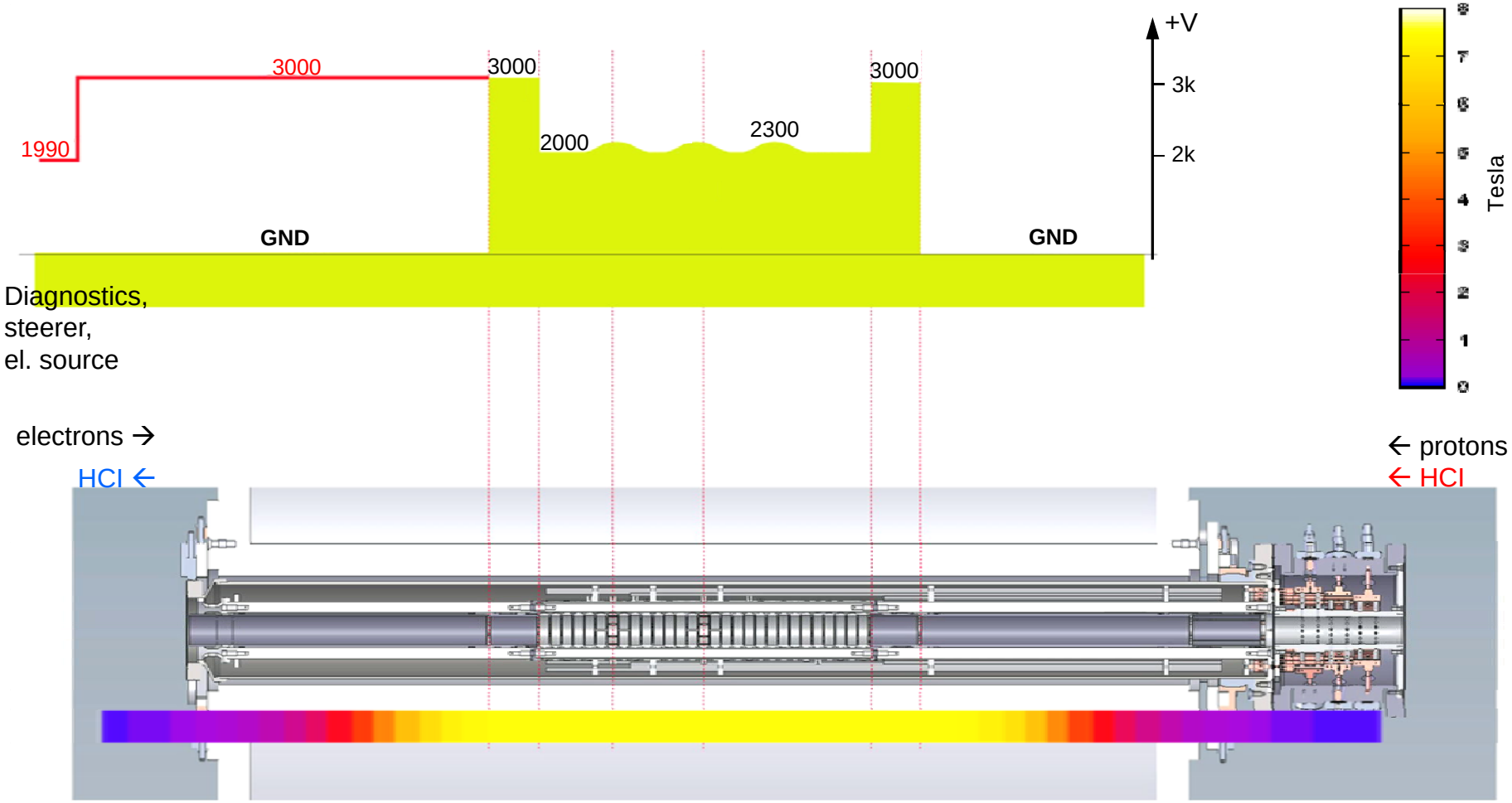
Undergraduate project Scott Foubister

CPET – Trap structure



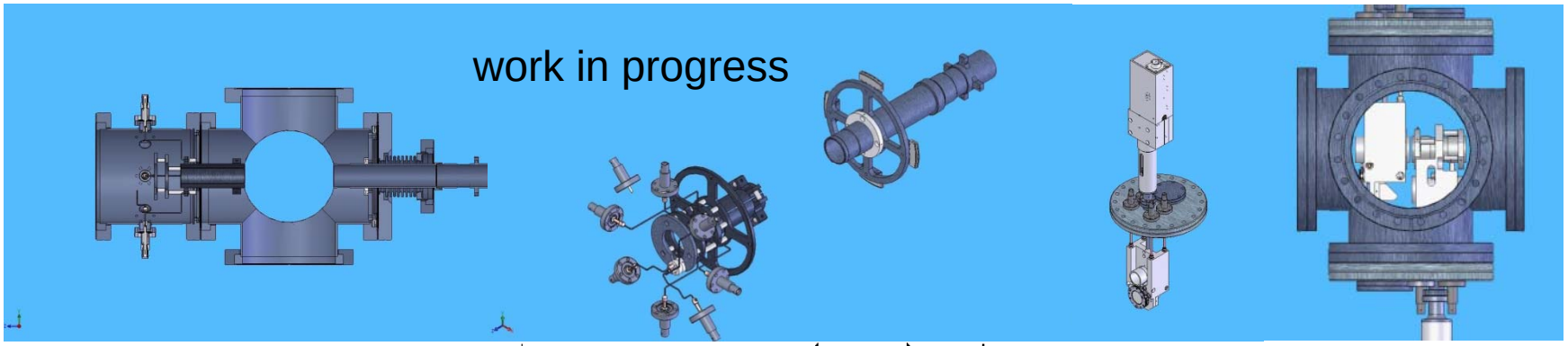
- Trap structure parts in machine shop
  - Au plating of electrodes
  - NEG coating of titanium tube for enhanced vacuum

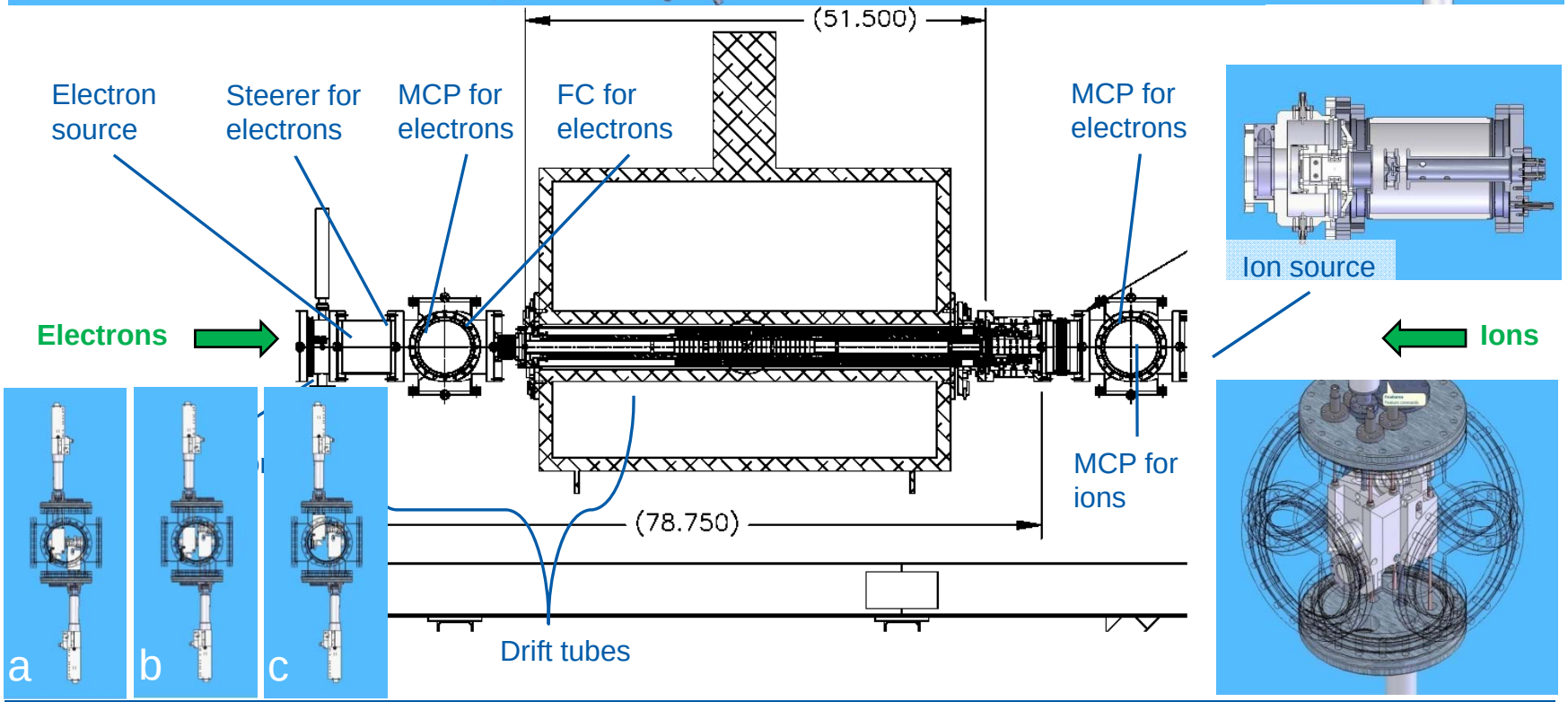
CPET – Trap structure



Outlook

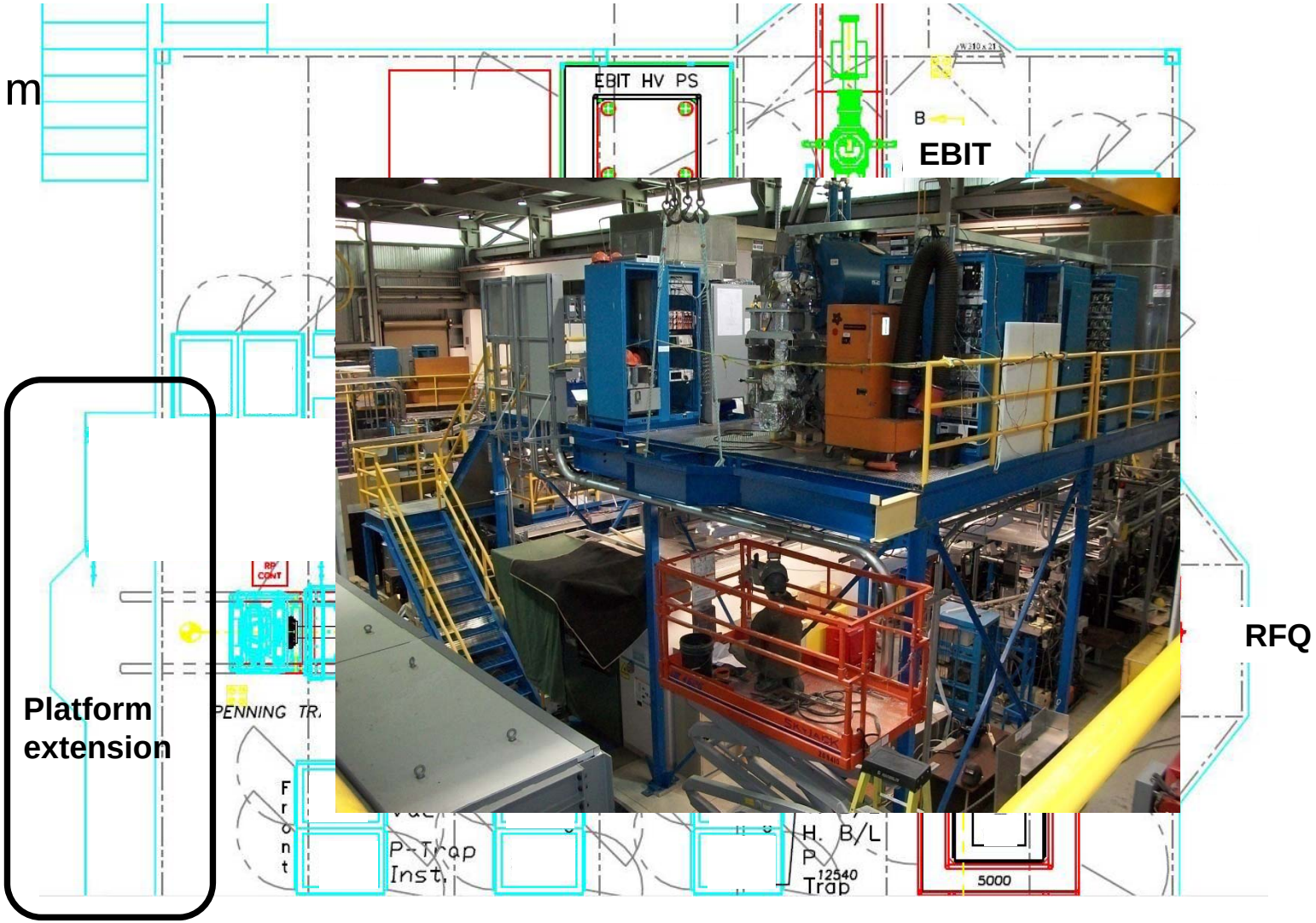
- work in progress





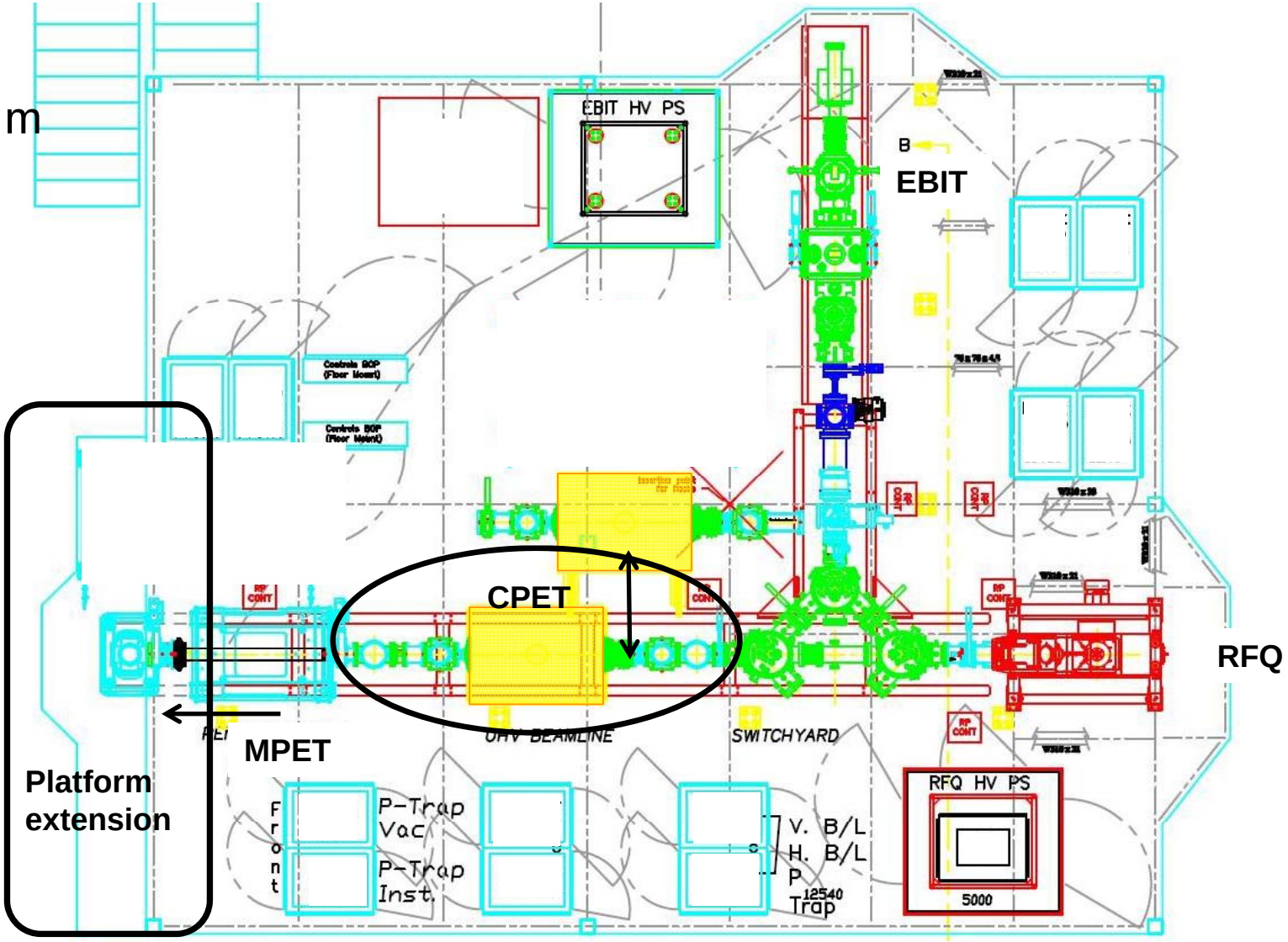
Outlook

- TITAN platform



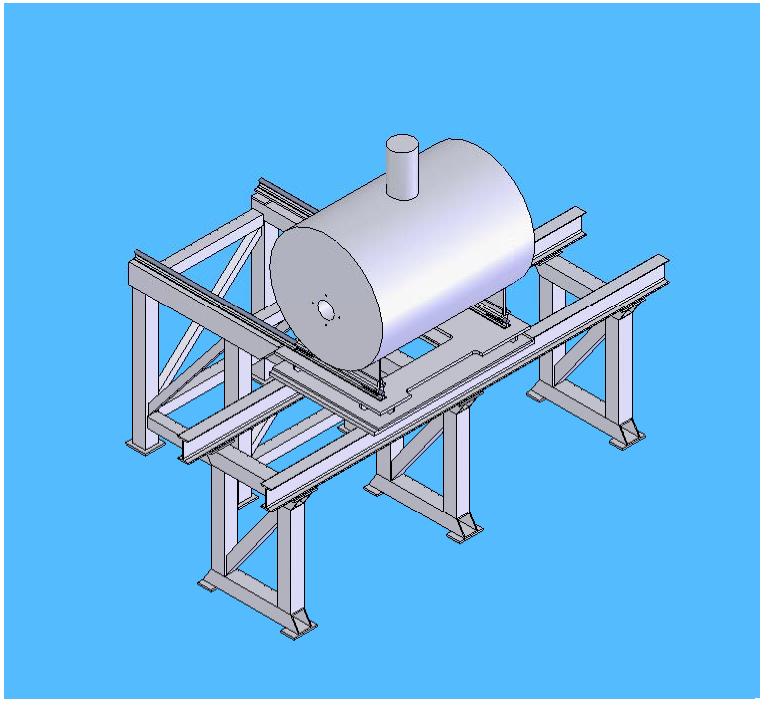
Outlook

- TITAN platform



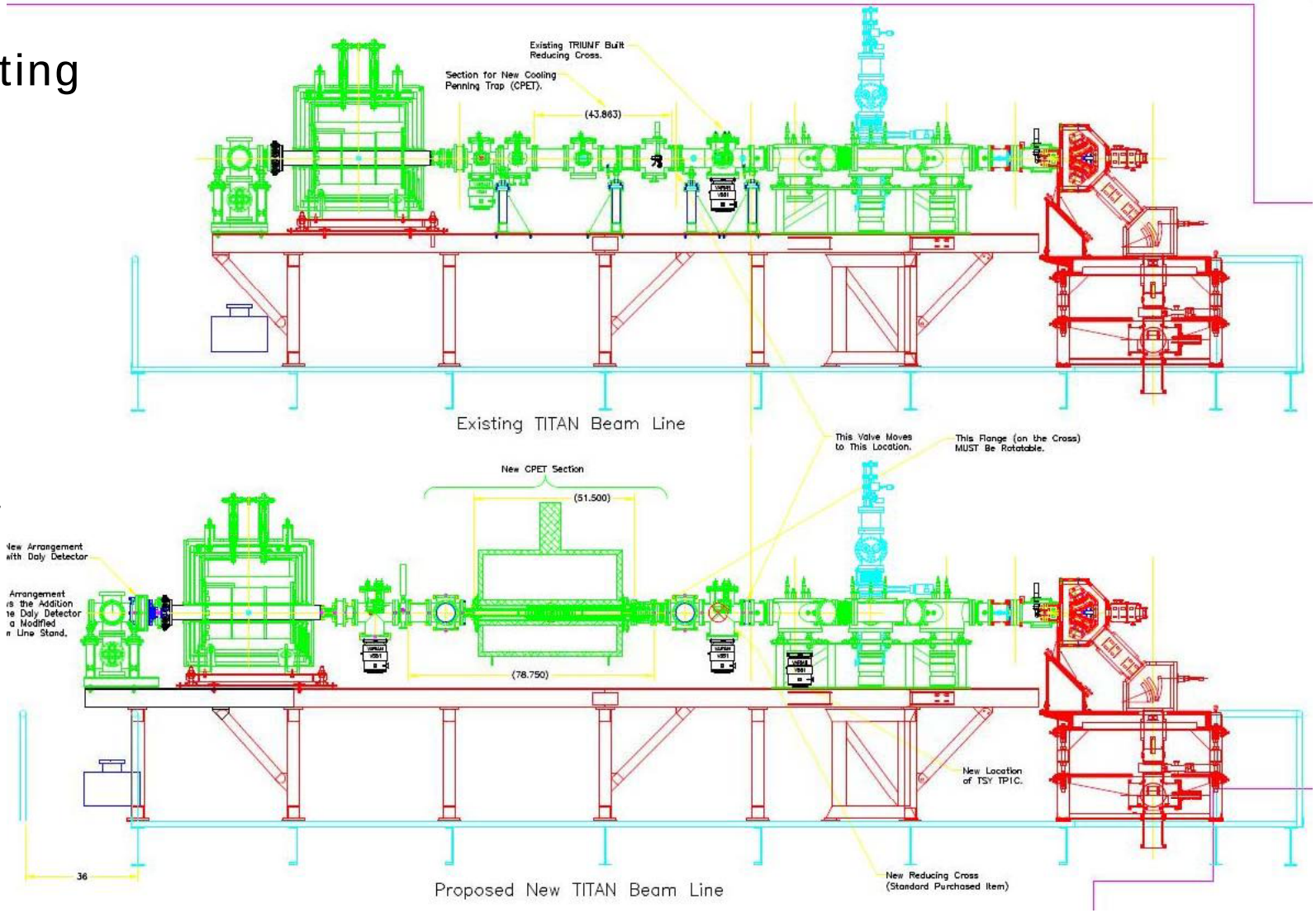
Outlook

- Sliding function
  - Removing, replacing magnet easily
  - For maintenance and optimization purposes
    - Having off-line setup for off-line test next to beam-line



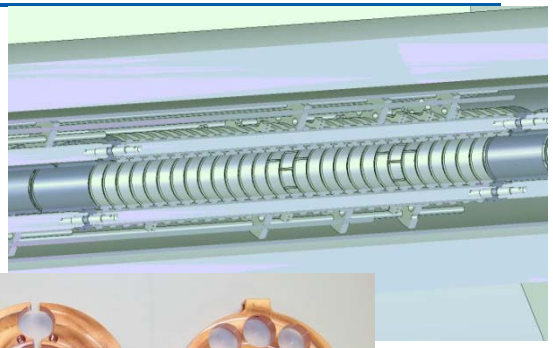
Outlook

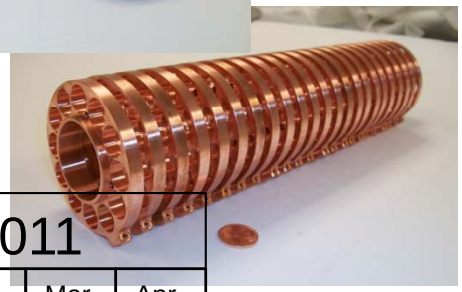
- Existing
- New



Summary & Outlook with timeline

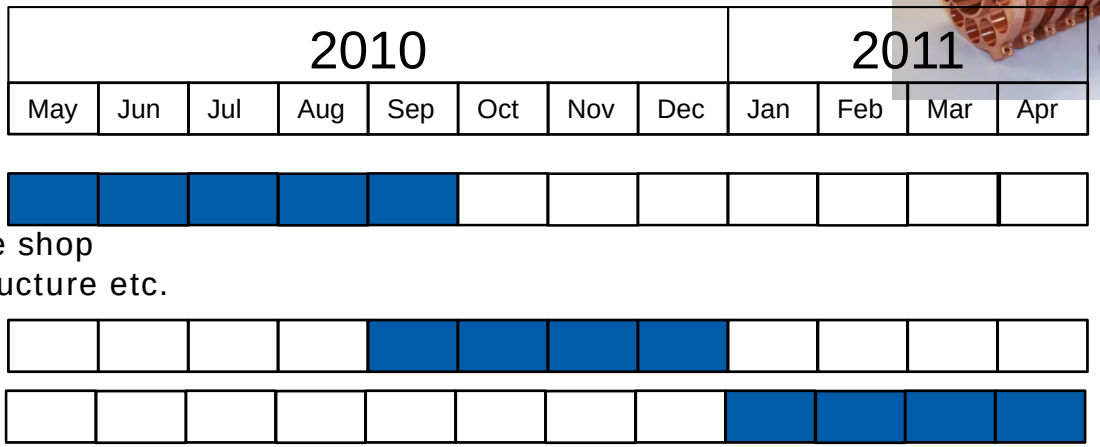
- Overall design ready…
- Build up the system for testing of proton and electron cooling
  - Proof of principle tests, emittance, etc.
  - Decision for electron or proton cooling

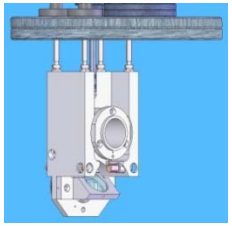




Timeline

- Extension of platform is done
- Preparations
  - Purchasing, machine shop
  - Assembly of trap structure etc.
- Off-line setup
- Insertion to final beam-line position





Few more steps to go

- Big and long TODO list
  - Getting REAs for all the design parts mentioned
    - Design office → update project plan to push
    - Machine shop
  - Long shopping list of items
    - Mechanical parts
    - Electronics parts
    - Diagnostics
    - DAQ
- Open questions:
  - Electron-gun: design, housing etc.
  - Power supplies, switches.... →electronic support
  - Proton source
  - And then the final question
    - Compare electron to proton cooling. What do we finally want to use?