Nuclear Excitation via Electron Capture with TITAN

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NEEC

- “In the resonant process of NEEC, a free electron is captured into a highly charged ion with the simultaneous excitation of the nucleus” [1]

- Atomic electron is captured into a vacancy of a highly charged ion causing energy to be transferred to the nucleus

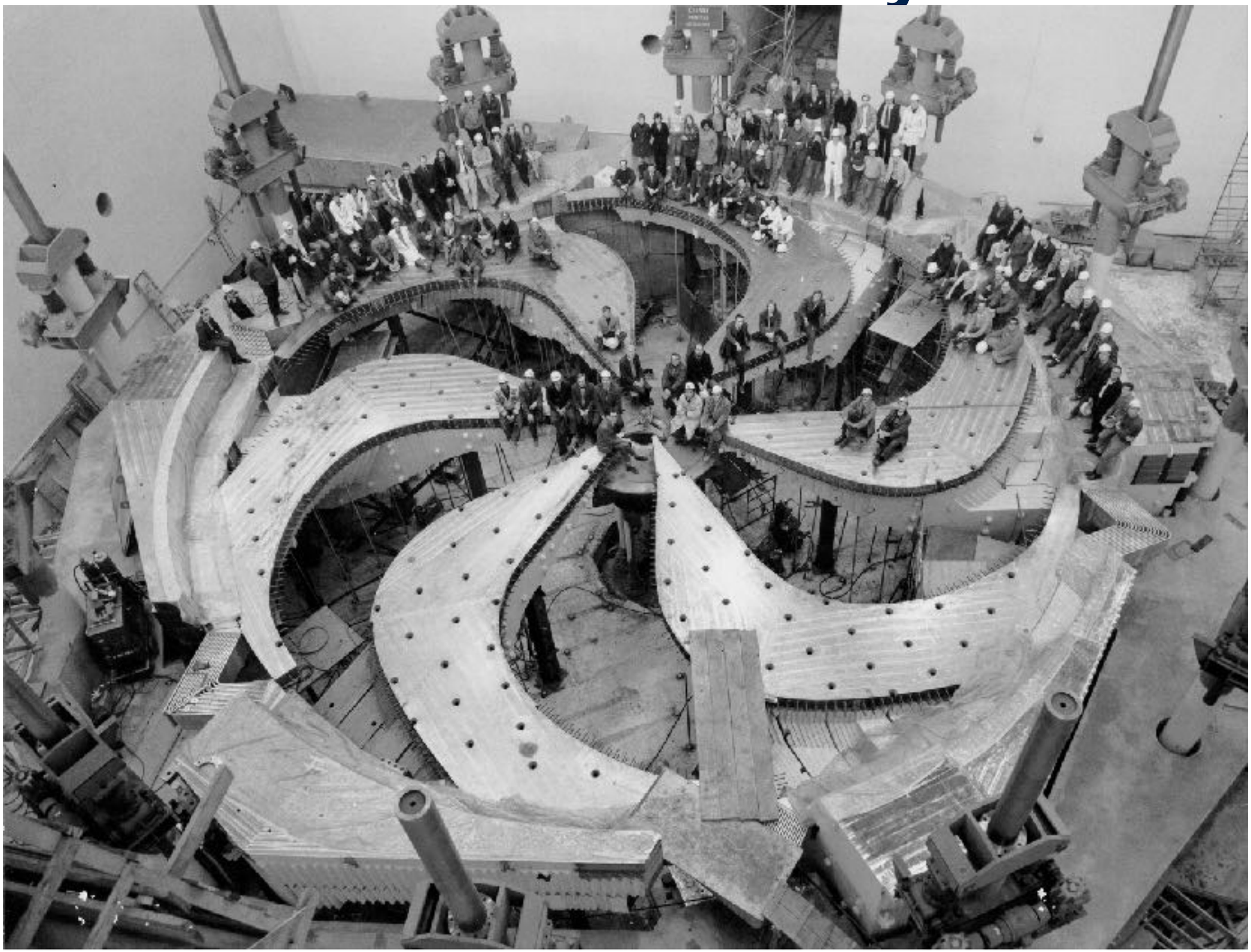
- NEEC requires that the K.E. of the captured free electron plus its binding energy must equal the difference between the two nuclear states [2]. This is a resonant process.

- NEEC was recently reported for the first time in 2018 via in beam measurement at Argonne National Laboratory in 93Mo [2]

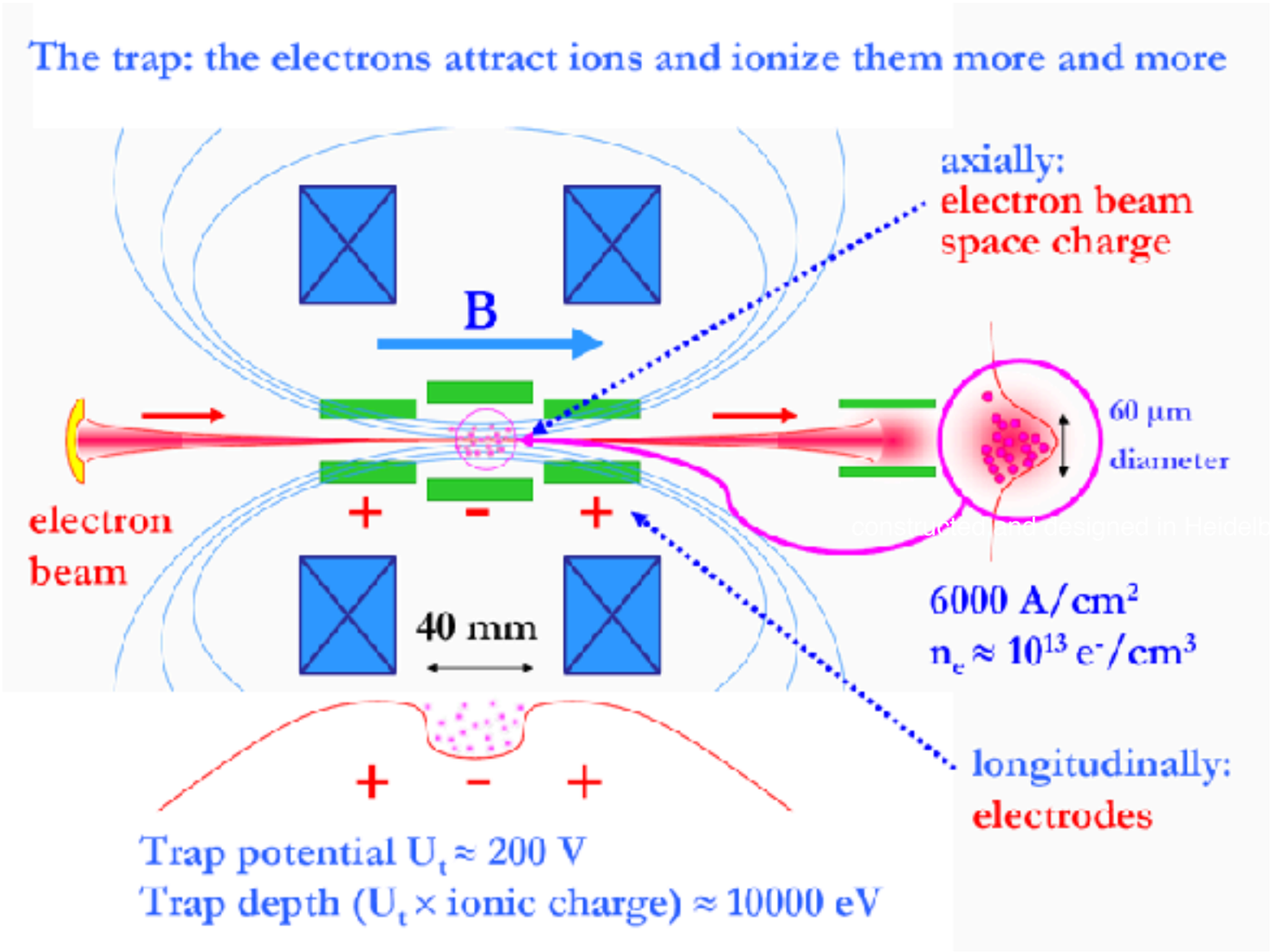
- By considering unstable nuclei for NEEC, the number of suitable cases in increased dramatically.

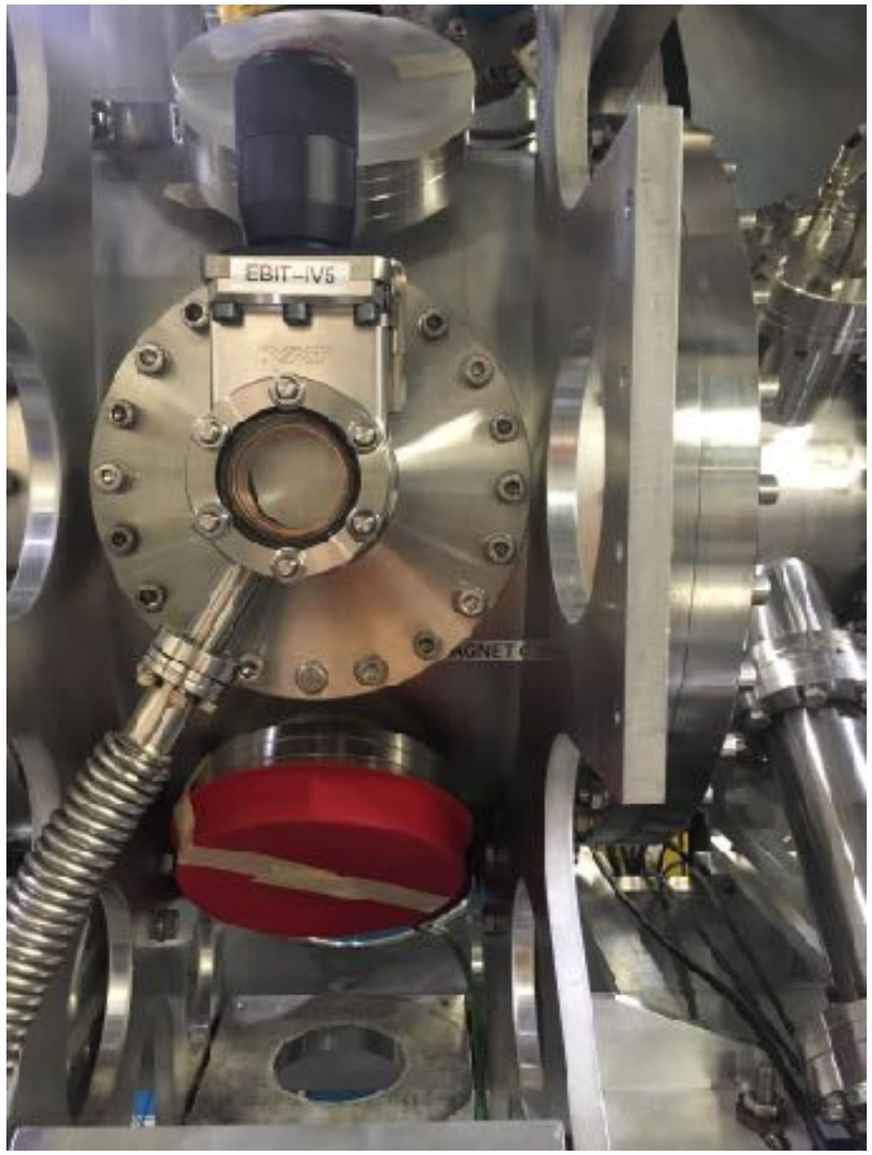
1. A. Palffy et al., Phys. Rev. Lett. **99**, 172502 (2007)
2. C. J. Chiara et al., Nature **554**, 216-218 (2018)

TRIUMF - 520MeV Cyclotron



EBIT - Electron Beam Ion Trap





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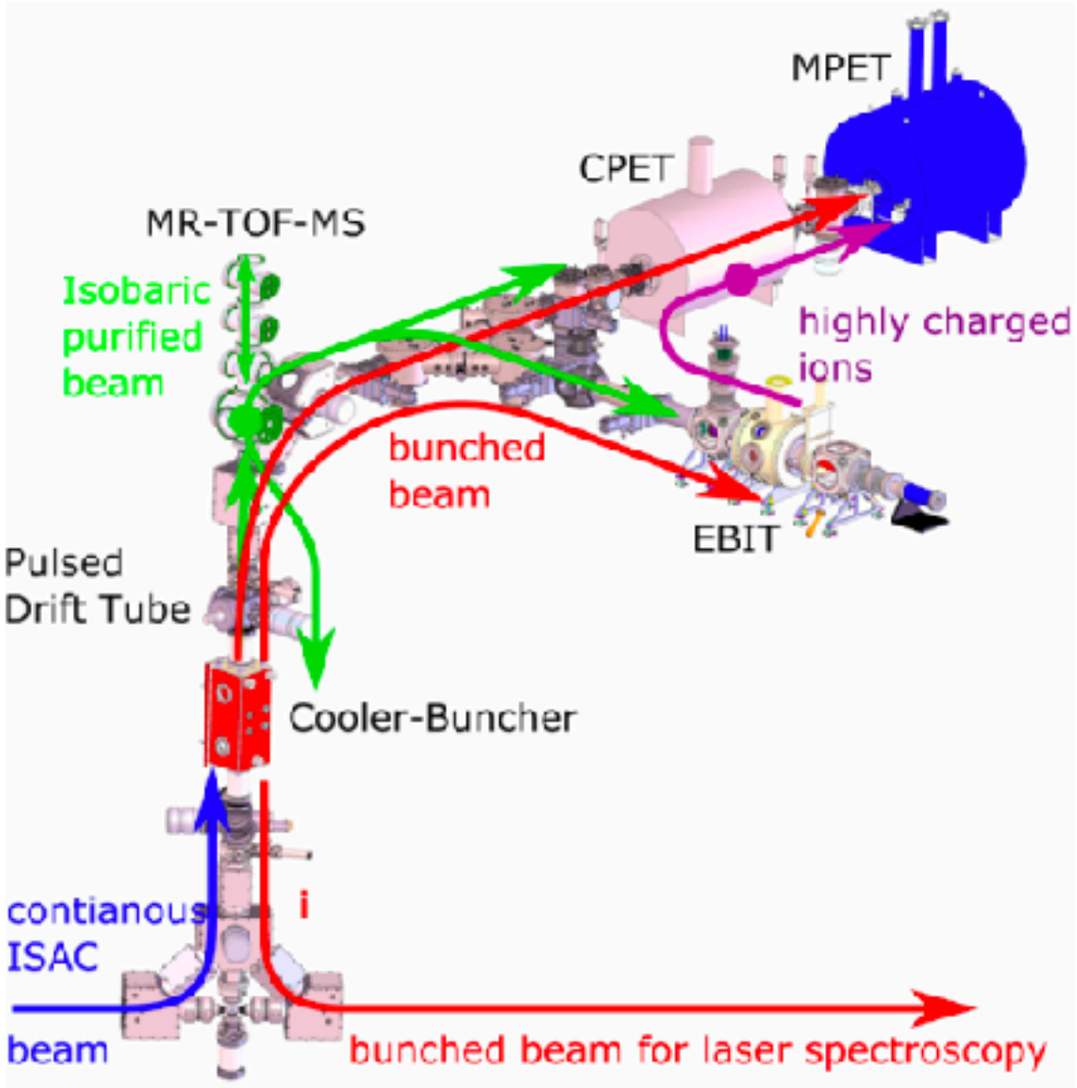
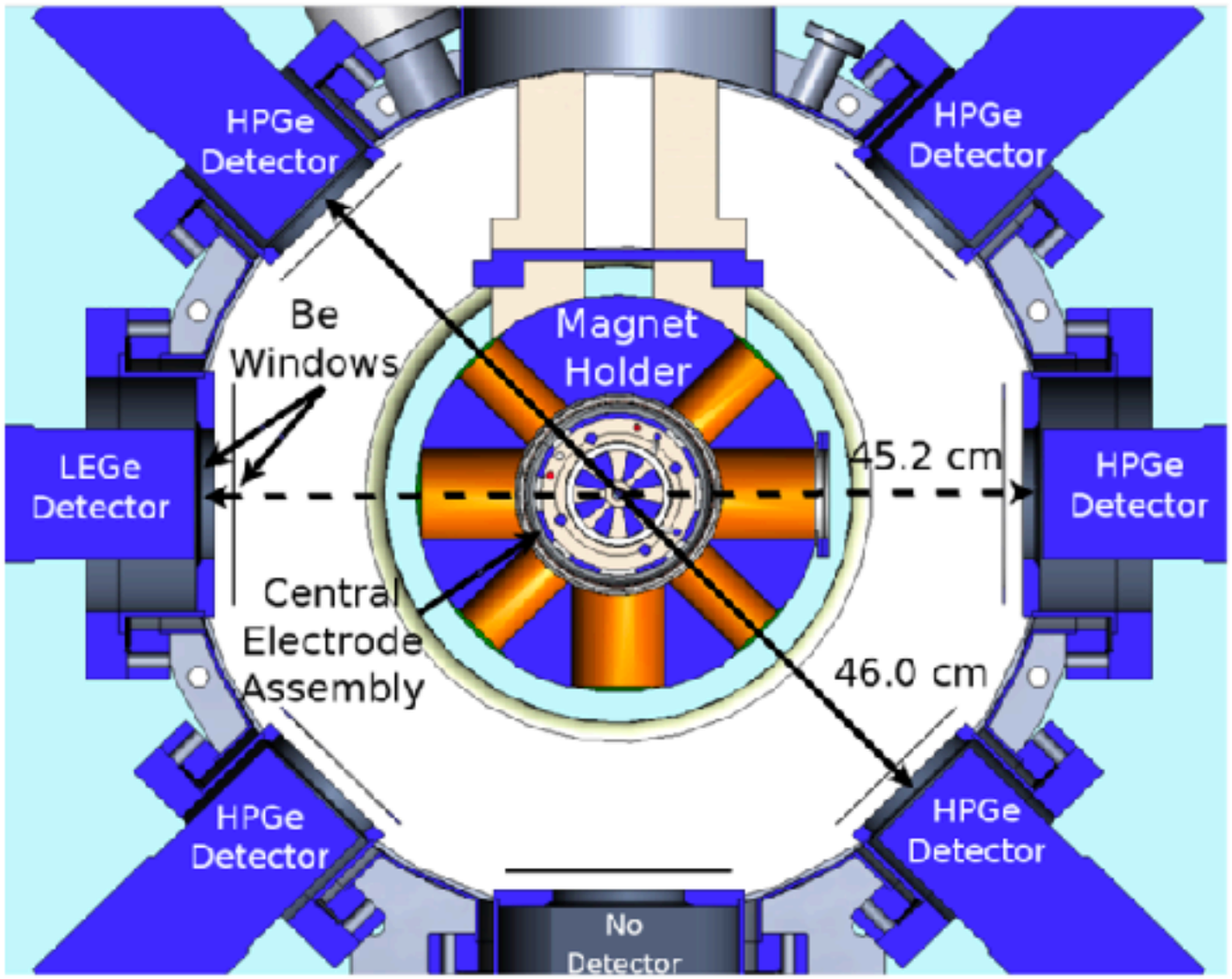
*EBIT constructed and designed in Heidelberg.

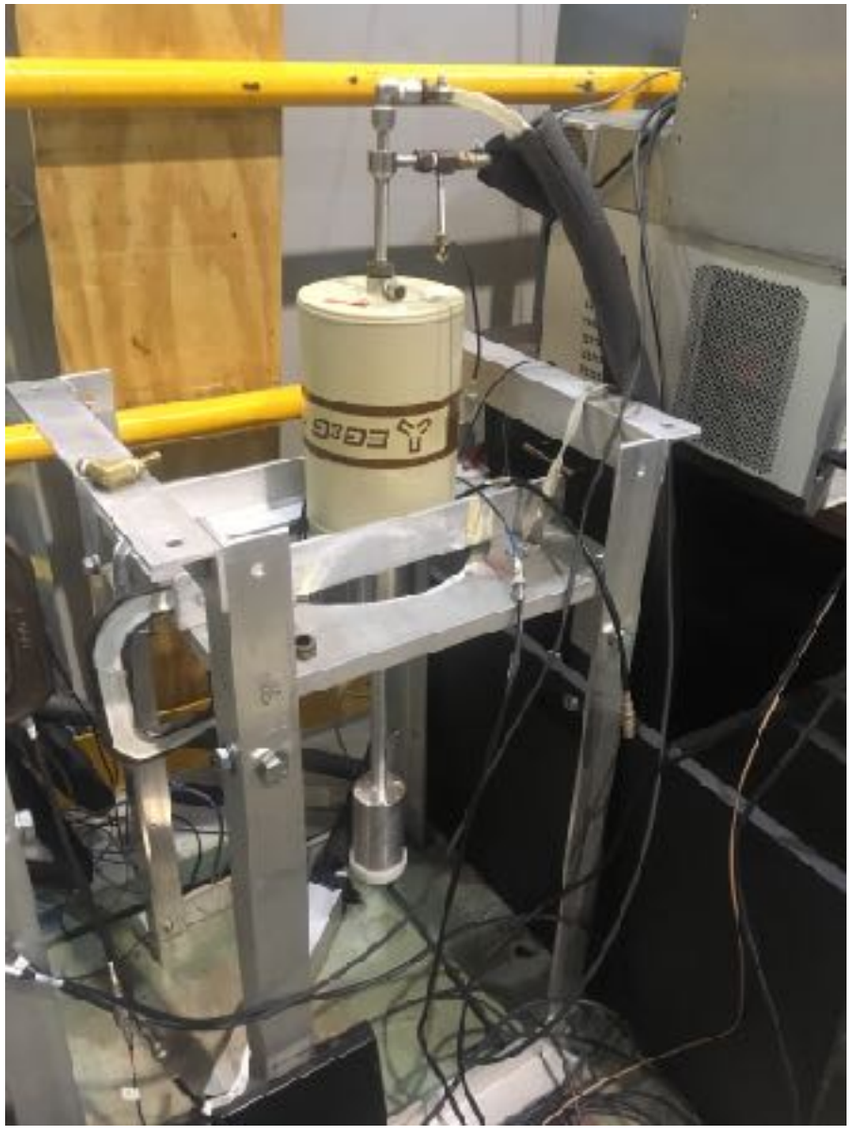
TITAN - EBIT (Electron-Beam Ion Trap)

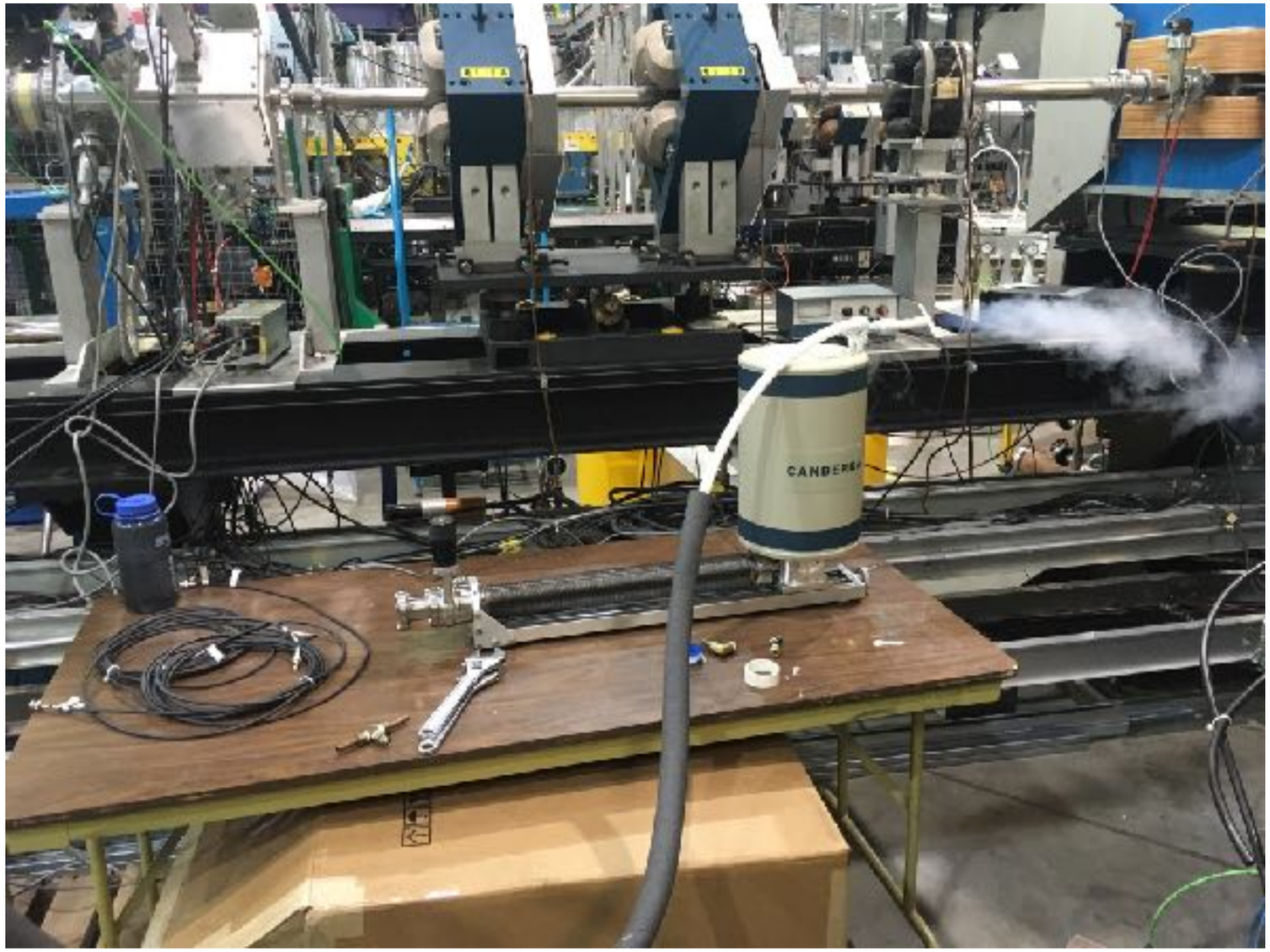




- **TITAN - TRIUMF's Ion Trap for Atomic and Nuclear Science**
- **7 access ports to house 5 HPGe's & 1 ULE-HPGe detector**
- **Geometric acceptance is ~ 2% of 4pi**

High Purity Germanium Detectors





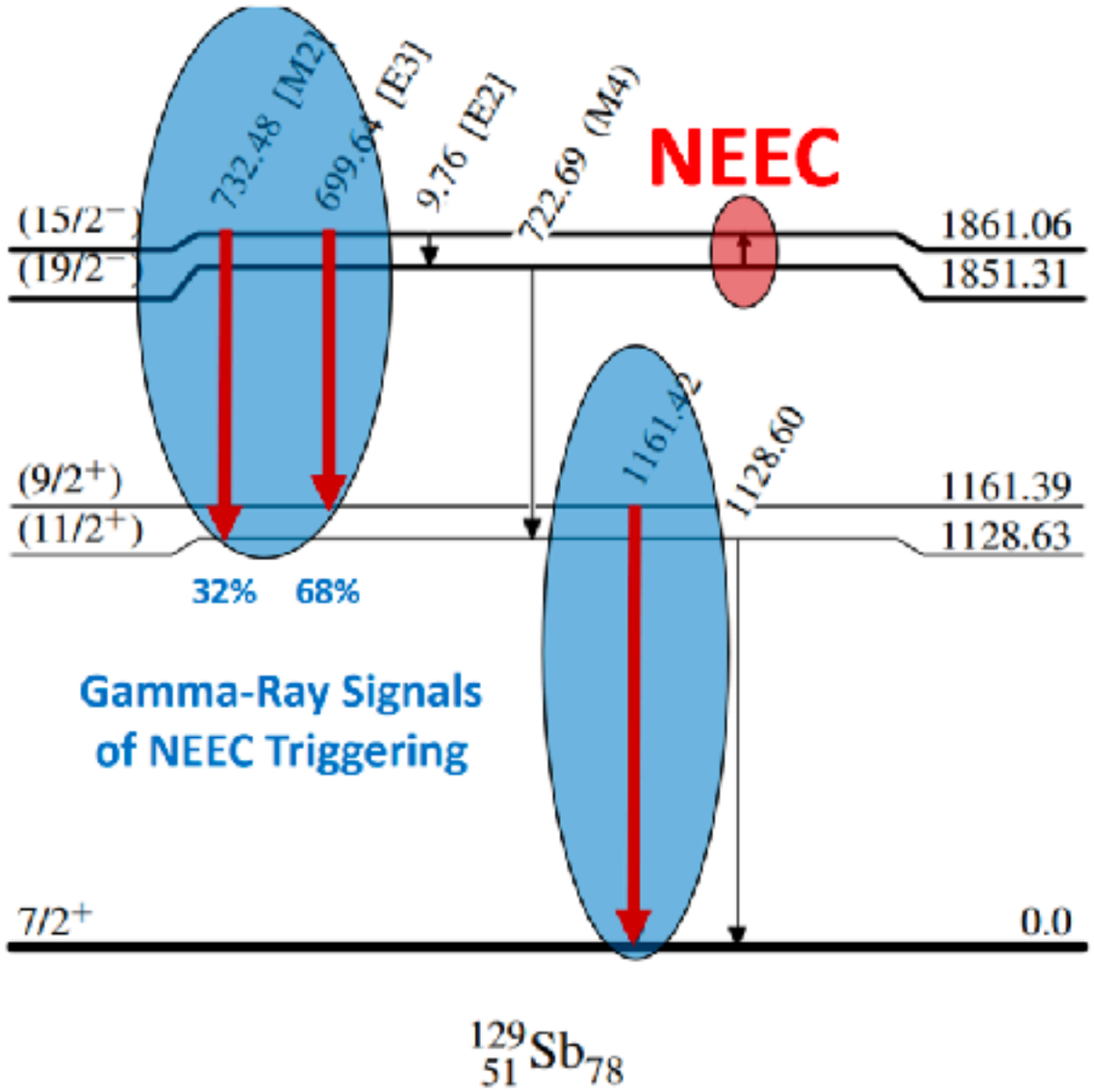
High Energy HPGe

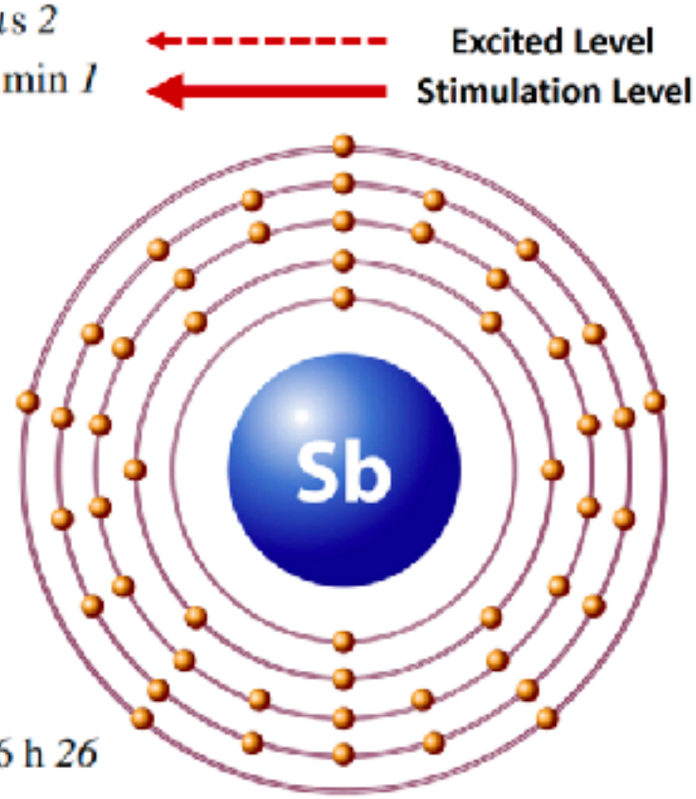
- **Sensitive to nuclear gamma rays (100 keV-> 2 MeV)**
- **Used to observe NEEC characteristic gamma rays**

Ultra Low Energy HPGe

- **Sensitive to atomic x-rays (1 keV -> 100 keV)**
- **Used to determine current charge state in EBIT**

NEEC of $^{129m1}Sb$





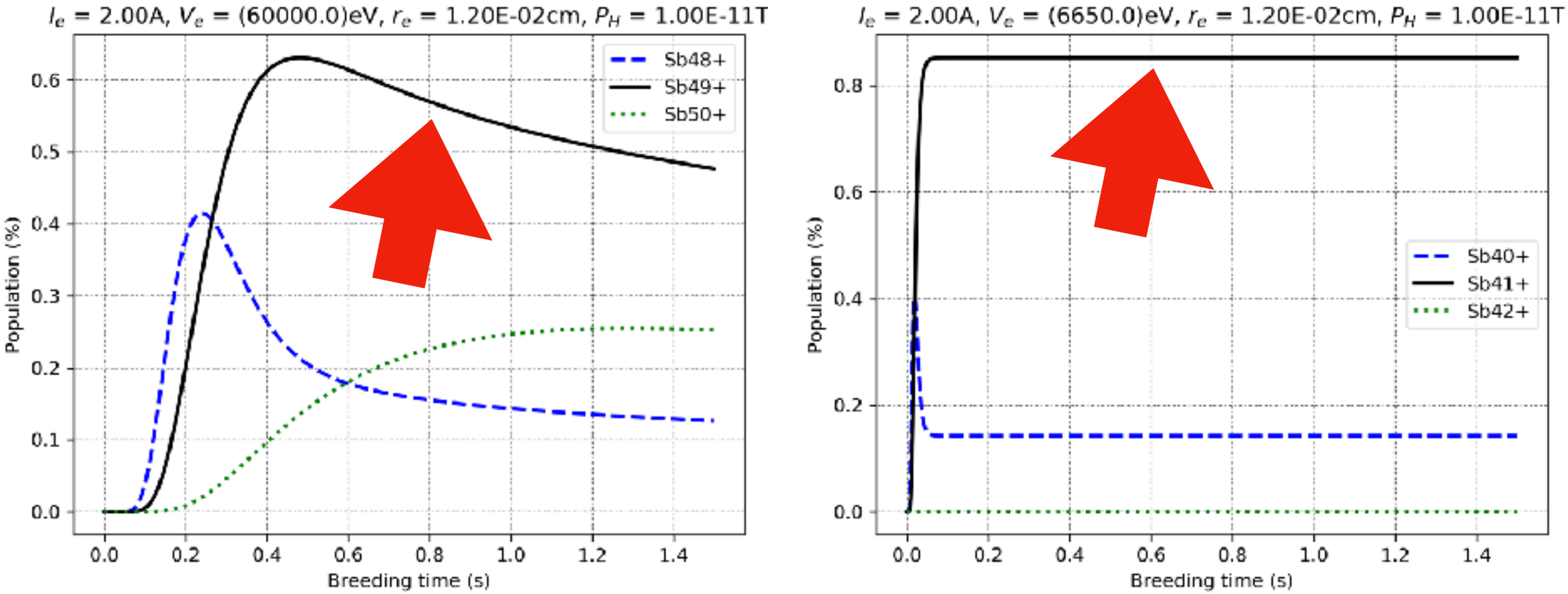
He-like case : L-shell atomic vacancy - Recombination x-section : $1.6x10^{-3}b \cdot eV$

Ne-like case : M-shell atomic vacancy - Recombination x-section : $3.0x10^{-5}b \cdot eV$

- A. Palffy, Private Communication (2018)
- K G. Leach et al., TRIUMF EEC Lett. of Intent **1865** (2019)

Charge Breeding Simulations

Antimony - 129Sb

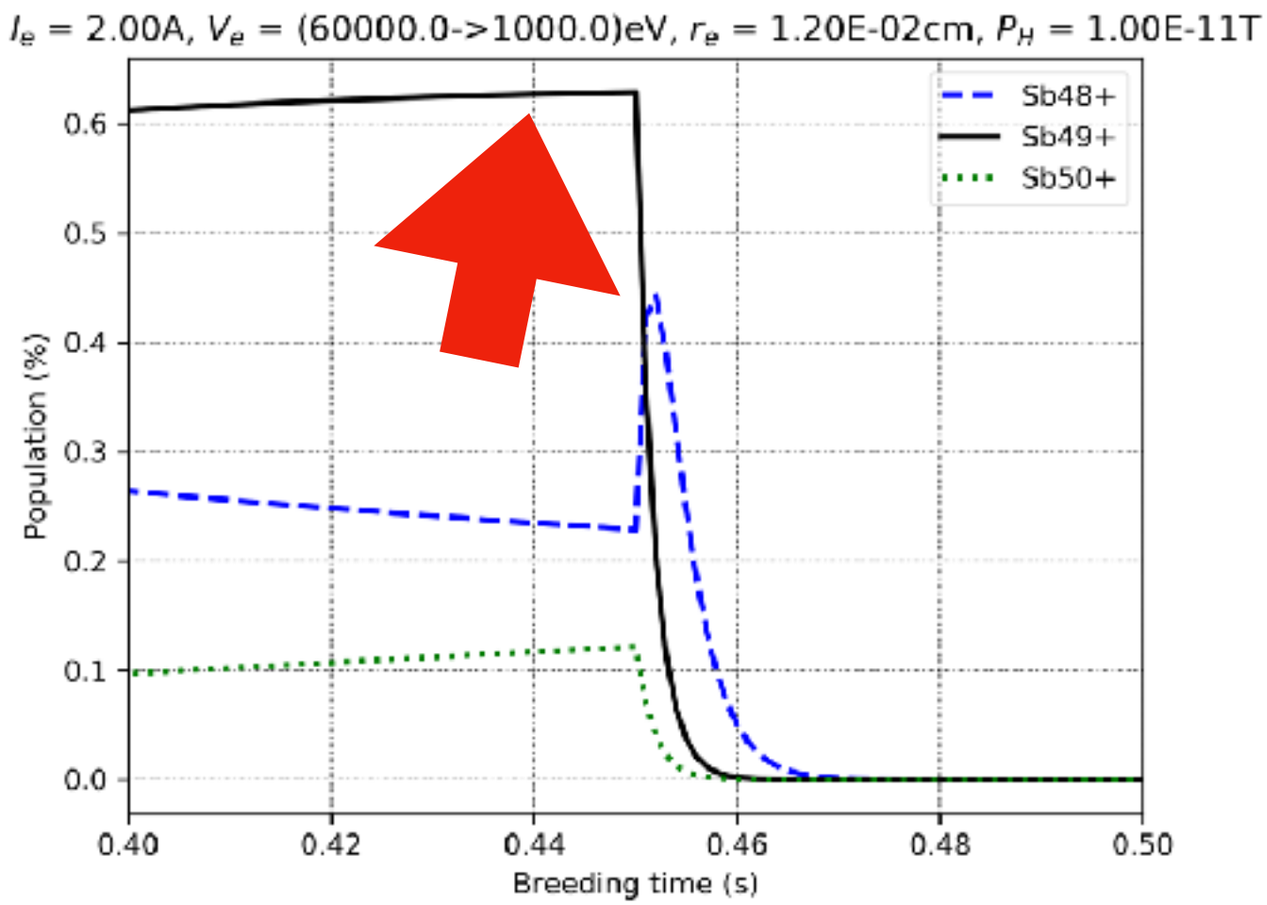


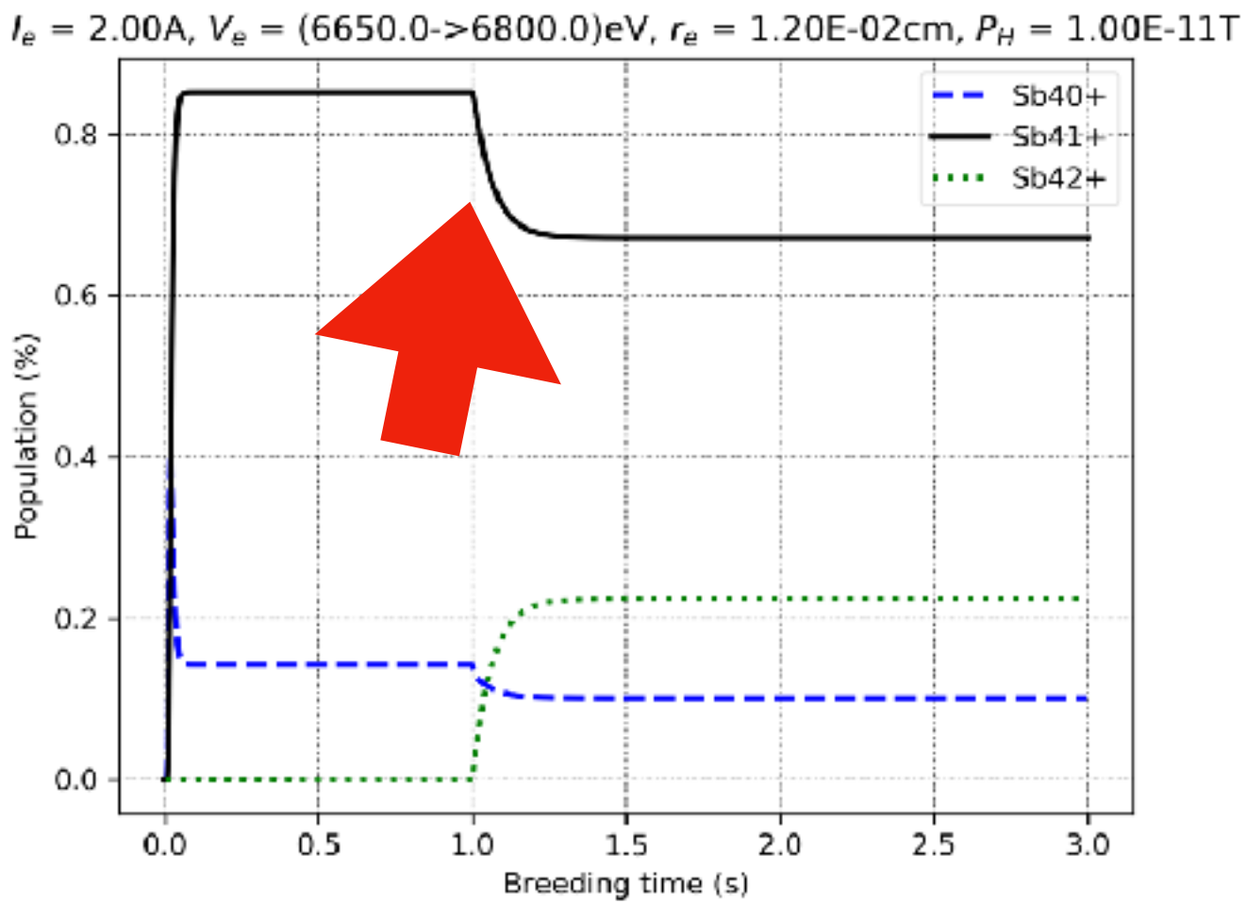
Charge breeding for the He-like (left) and Ne-like (right) cases

https://github.com/mineselectroweakgroup/ebitsim

Simulation of charge breeding w/ ebeam ramping

Antimony - 129Sb





He-like (left) - Ne-like (right)

Conclusions - work in progress

- **In the TITAN EBIT we have been able to perform decay measurements of highly charged ions**

- **This setup is ideally suited to perform controlled measurements of the NEEC process on a wide variety of stable and unstable cases**

- **New HPGe's and ULGe must be installed on TITAN**
  - **5 HPGe's will be installed in order to achieve our desired 2% of 4pi**
  - **1 - 2 ULGe's will be installed for characterization of charge state**

- **New Multi-Channel Analyzer (MCA) software is being written**
  - **Frontend and online analysis software is being developed for both the MDPP16 and GRIF16 MCA's**

- **Upgrades to the electron beam to reach higher currents**
  - **With the new electron gun currents of 2Amps should be achievable (previous ~0.5Amps)**

- **Need to determine the best way to quickly ramp the electron beam**

- **Beam development is still required for production and separation of $^{129m1}Sb$**

- **Run the experiment and take data!!**

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TITAN Collaboration

TRIUMF
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University of Notre Dame
Colorado School of Mines
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CNRS
Max-Planck-Institut für Kernphysik Heidelberg
university of groningen
kvi - center for advanced radiation technology
NRC CNRC
NSERC CRSNG
DFG Deutsche Forschungsgemeinschaft

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Available code

EBIT Charge state simulator :
https://github.com/mineselectroweakgroup/ebitsim

EBIT Charge state simulator VAGRANT instance:
https://github.com/mineselectroweakgroup/ebitsim_vagrant

CENDET - ENSDEF reader
https://github.com/mineselectroweakgroup/cendet

ROOT v6 in VAGRANT instance:
https://github.com/cnatzke/VagrantRootCERN