Possibility of using EBIT for Exotic Nuclear Physics

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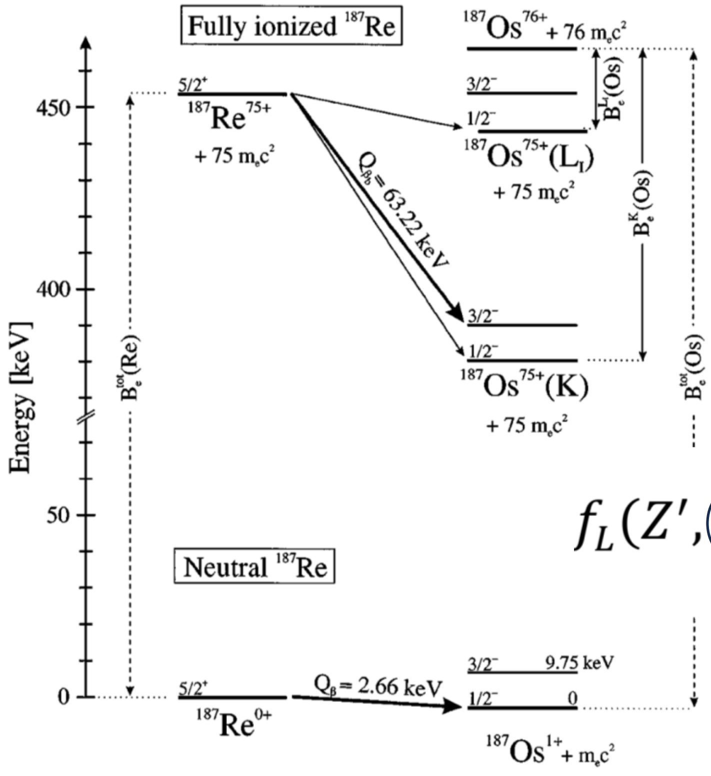
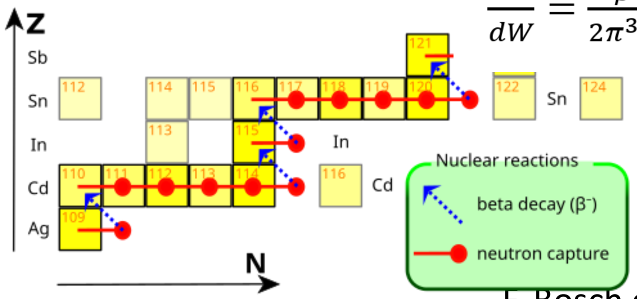
11/July/2025

Charge state effect on beta decay



$$f_L(Z', Q)\, t_{\frac{1}{2}} = \frac{(ln2)2\pi^3\hbar^7}{g^2 m_e^5 c^4 \left|M_{if}^L\right|^2}$$

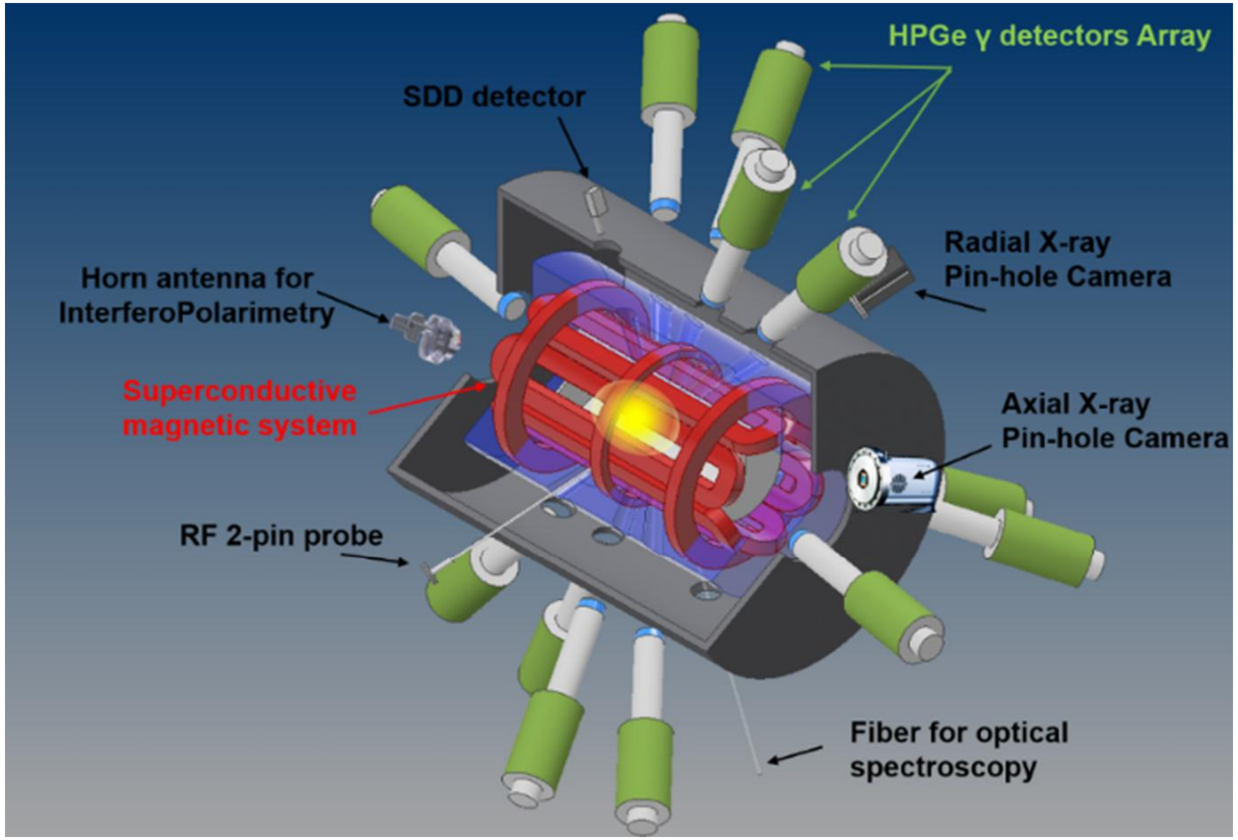
$$\frac{dN}{dW} = \frac{G_\beta^2}{2\pi^3} F(Z,W)\, pW(W_0 - W)^2 C(W) X(W)$$

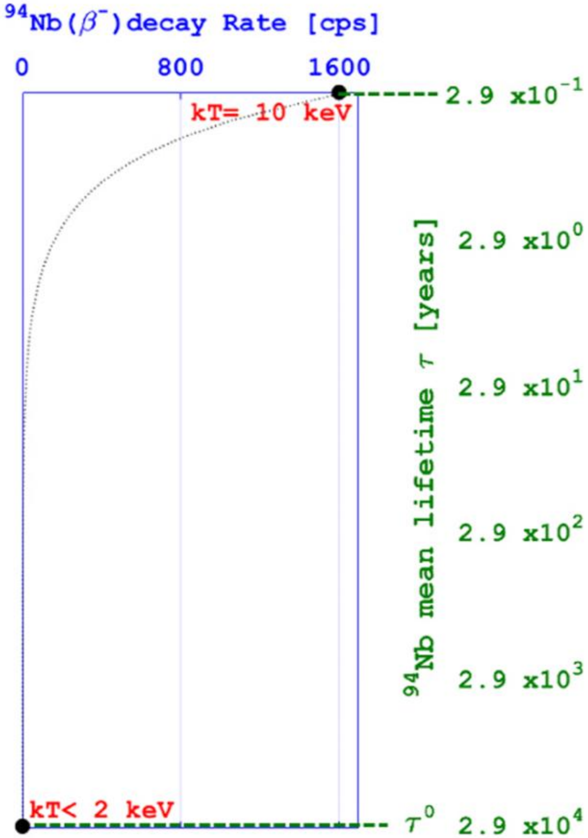


- Screening effect known to alter T1/2, beta energy distribution
- Reaction Q-value change Q=ΔB_{Nucl}+ΔB_{Elec} => beta decay (T1/2, kEβ distribution, kEβ end point) property could be changed
- Additional correction screening effect need to be considerd
- Beta decay lifetime change 42 Gyr→35 yr when fully stripped
- 2. beta decay can occur for stable isotope due to bining energy e.g. ^{163}Dy (stable), $^{163}Dy^{66+}$->$^{164}Ho^{66+}$
- Stellar environment plasma
- Astrophysical s-process modeling
- E.g. $^{53\text{-}56}$Fe isotope expected T1/2 2 order of magnitue

F. Bosch et al., Phys. Rev. Lett. 77, 5190 (1996)
Phys. Rev. Lett. 69, 2164 (1992)
Jing-Jing Liu and Dong-Mei LiuRAA2018 Vol. 18 No. 1, 8

Screening effect study-PANDORA project



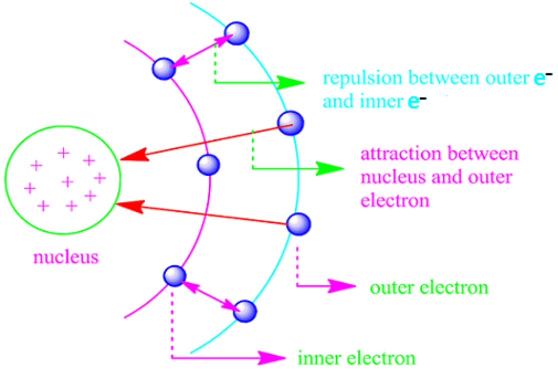


$$f_L(Z',Q)t_{\frac{1}{2}} = \frac{(ln2)2\pi^3\hbar^7}{g^2 m_e^5 c^4 \left|M_{if}^L\right|^2}$$

- T1/2 measurement in plasma inside EBIT
- Low efficiency compensated by the conical hole in the EBIT cryostat & many HPGe detectors

David Mascali and Domenico Santonocito, EPJ web of conference, 275, 01014 (2023)

Screening effect study on beta decay



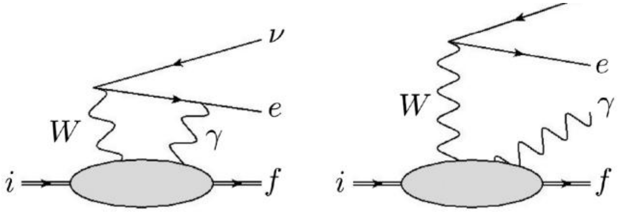


FIG. 1. $\mathcal{O}(\alpha)$ Feynman diagrams that open up the forbidden nuclear transition at $|\mathbf{q}| = 0$.

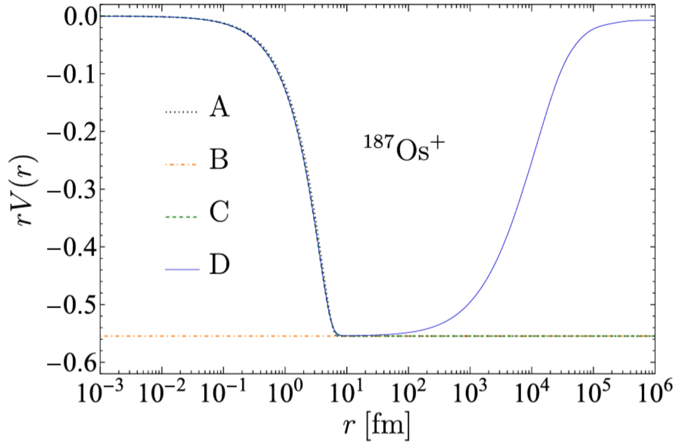
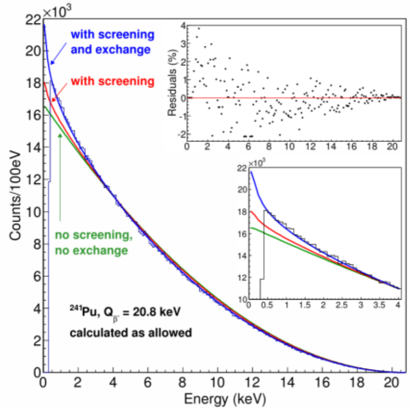
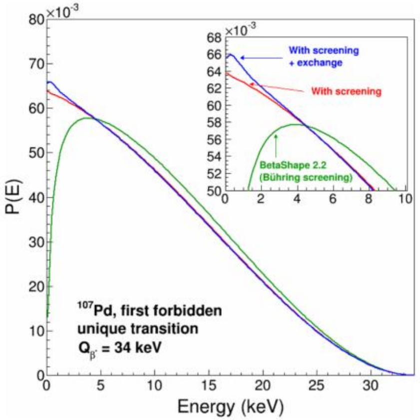


FIG. 1. The electrostatic potential for $^{187}Os^{+}$ as function of r, where the emitted electron is located, in four different approximation schemes: (A) The final nucleus as an uniform charged sphere. (B) A point-like final nucleus. (C) The final nucleus as a charged sphere filled with protons following a Fermi distribution. (D) The same as the preceding case but the atomic electron screening is taken into account.

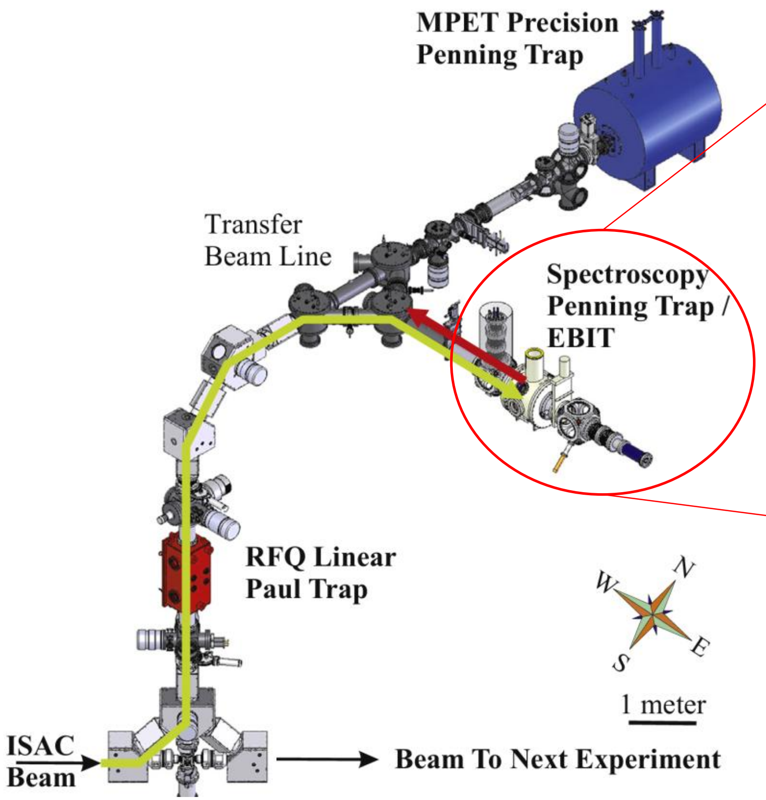


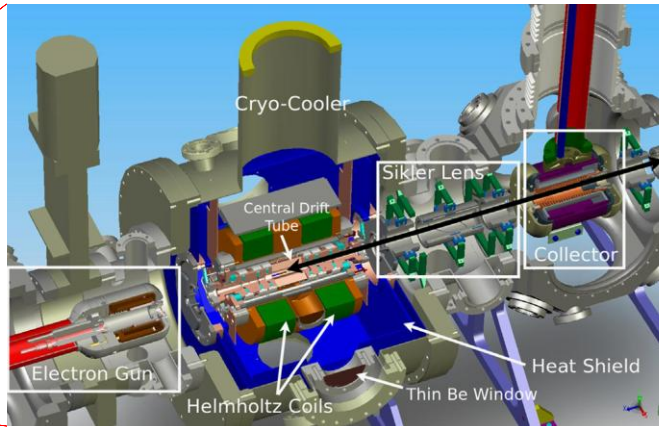


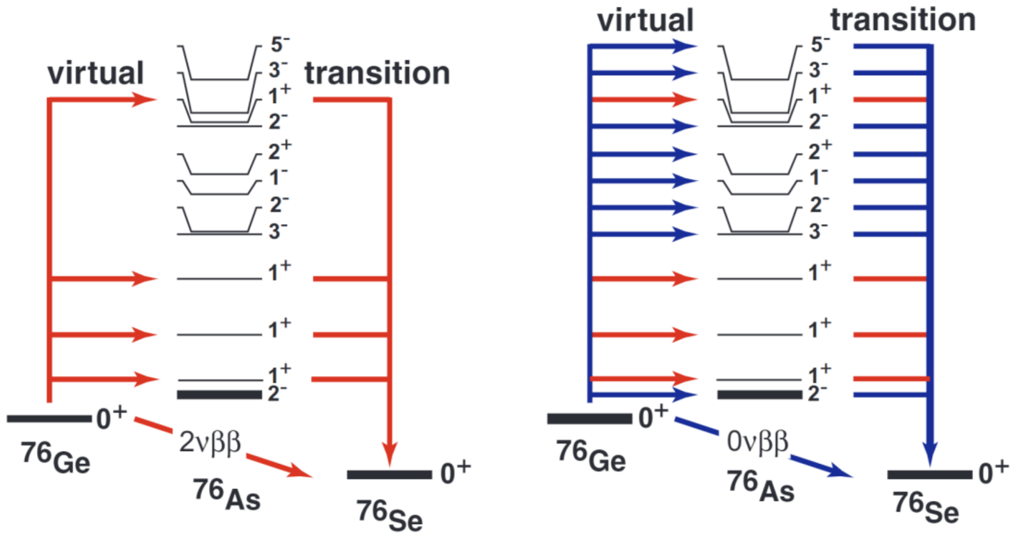
- 1.Forbidden beta decay gained new interest to study beyond standard model.
- 2. Neutrino mass study very low Q-value e.g. ^{187}Re-> ^{187}Os
- Screening effect significantly alter the partial decay rates in the forbidden beta decay

Chien-Yeah Seng et al., PRL 134, 081805 (2025)
O. Nitescu R. Dvornický and F. Šimkovic PHYSICAL REVIEW C109,025501(2024)
X. Mougeot, Applied Radiation and Isotopes 201 (2023) 11101

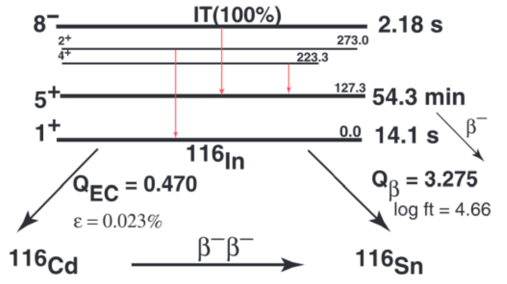
EBIT as trap: 2β decay study in trap TRIUMF case





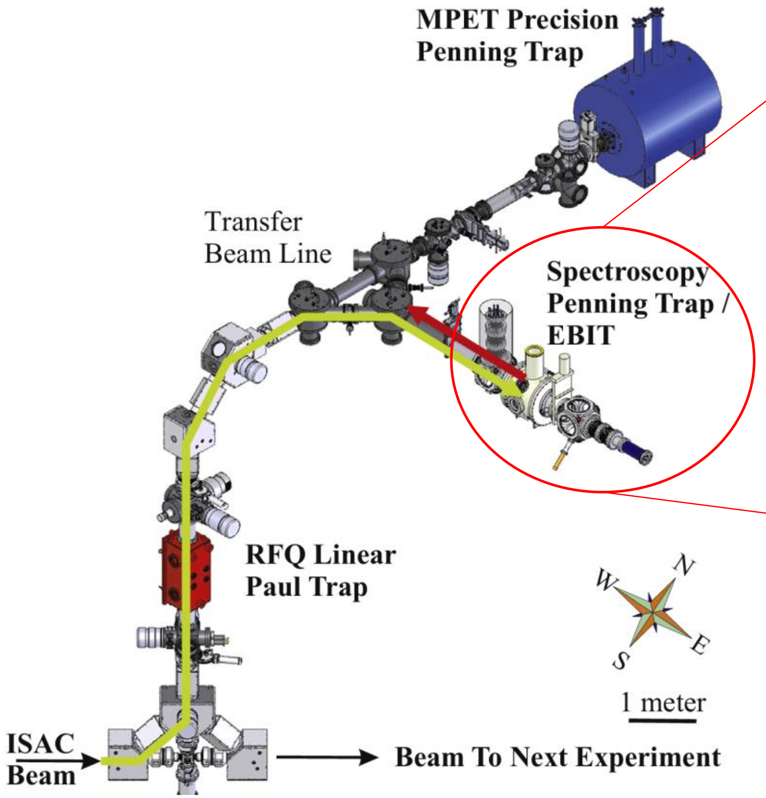


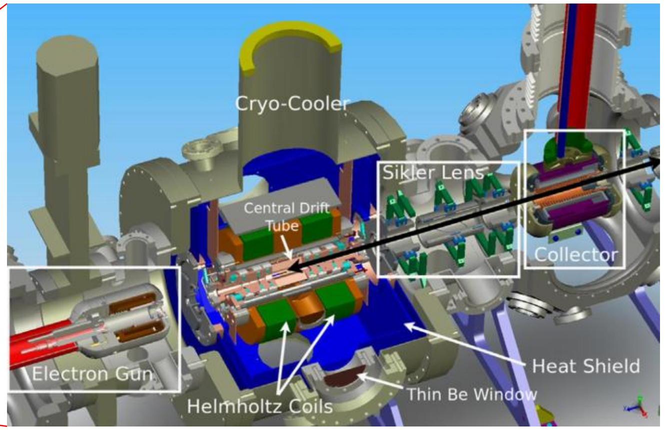
500mA electron gun
6T Helmholtz magnet
q=30+ can be reached

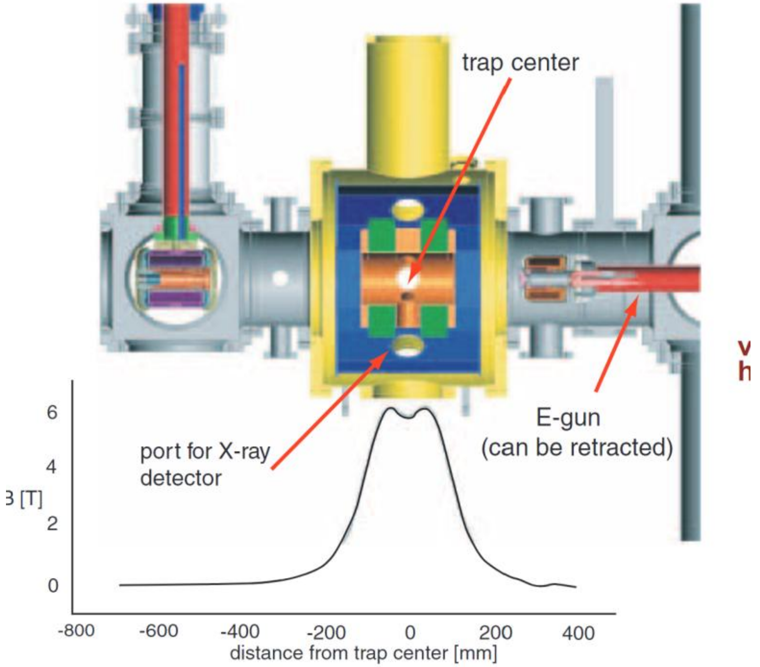


- Double-beta decay expected to be different with/without presence of neutrino.
- Find very mweak transition only possible in neutrinoless double beta decay
- Precision branching ratio of double beta-decay EC isotopes requires β background-free measurement -> EBIT storage
- Initially, EBIT as trapping ->separate collection due to ion trapping time issue

EBIT as trap: 2β decay study in trap TRIUMF case







K.G. Leach et al. NIM A 780 (2015) 91–99

500mA electron gun
6T Helmholtz magnet
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- Double-beta decay expected to be different with/without presence of neutrino.
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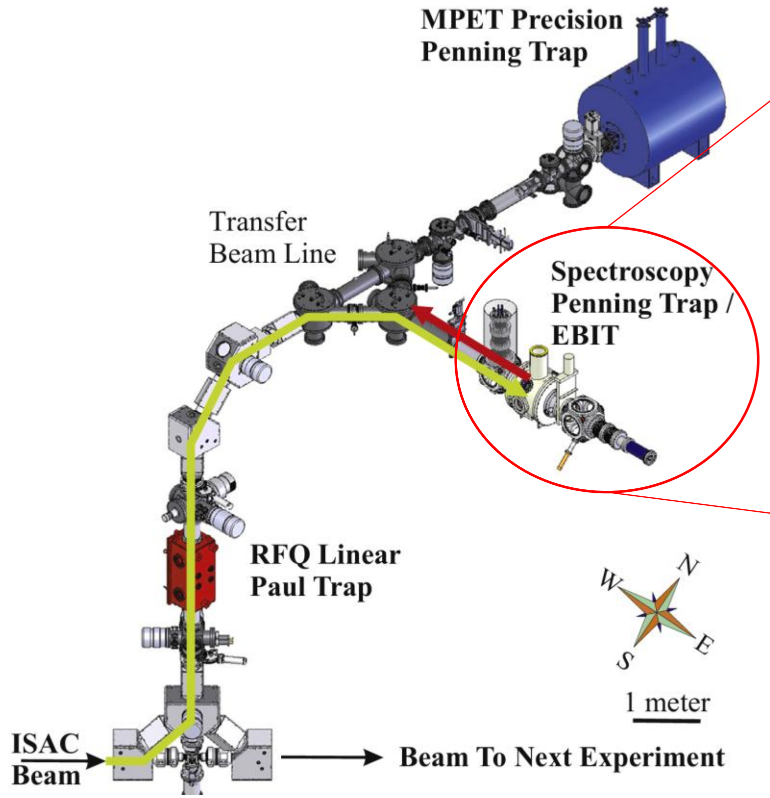
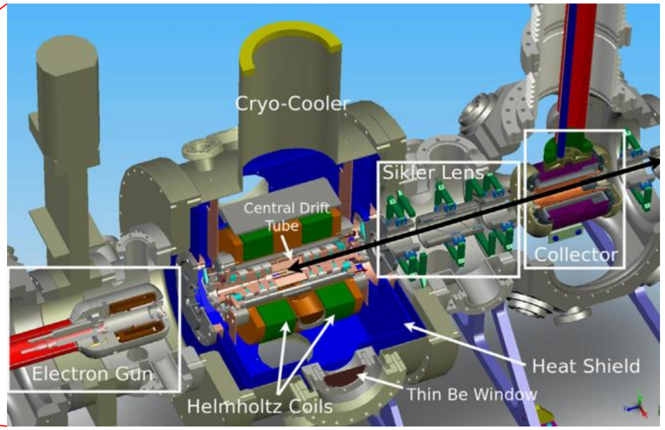
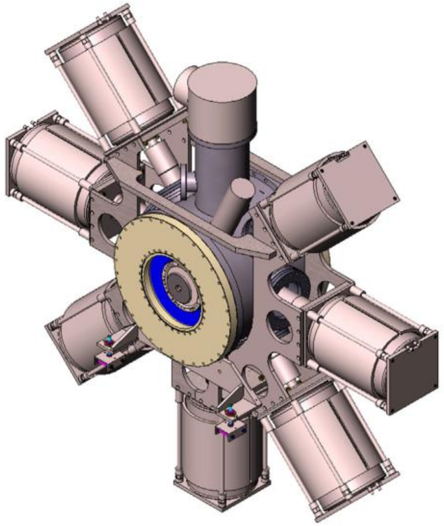
EBIT as trap: 2β decay study in trap







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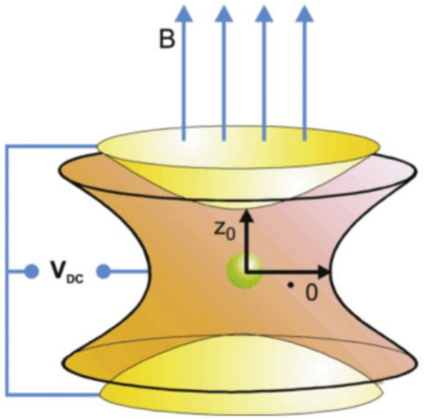
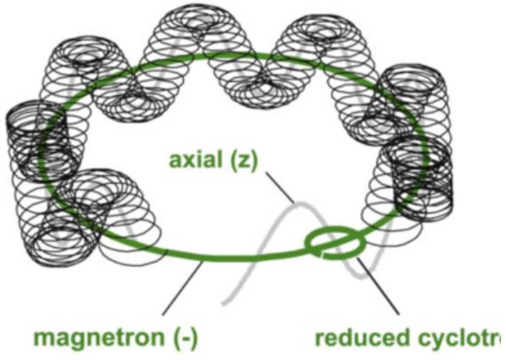
Precision mass measurement with EBIT





$$\frac{\delta m}{m} \approx \frac{m}{TqB\sqrt{N}}$$

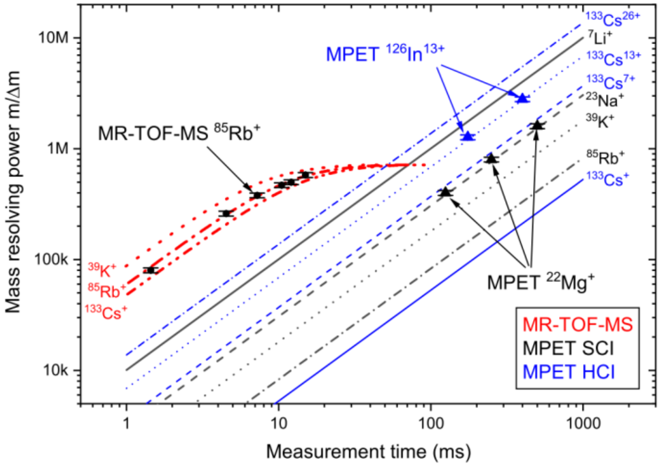


Fig. 3 Mass resolving power FWHM routinely reached with the spectrometers at TITAN for different mass-over-charge ratios. The lines show predictions for MPET and MR-TOF based on Eqs. 3 and 10, respectively. The symbols indicate representative resolving powers reached during online experiments

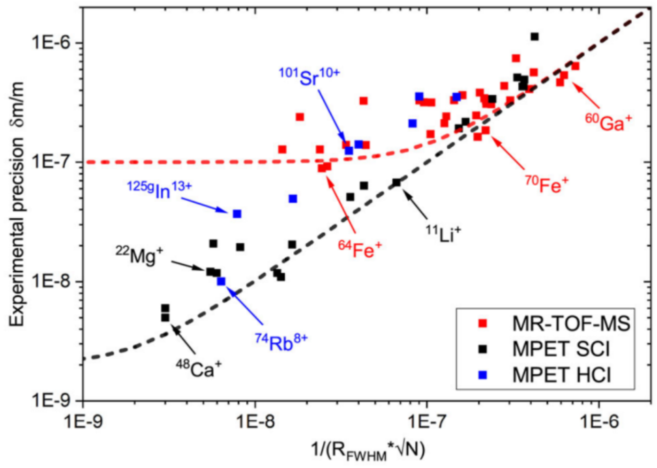


Fig. 4 Precision reached during MPET (SCI vs HCI) and MR-TOF-MS mass measurements in compassion to the respective expected precision based on mass resolving power and number of detected ions. The dashed lines show performance predictions assuming a perfect spectrometer with systematic uncertainties of 2×10^{-9} for MPET and 1×10^{-7} for MR-TOF-MS. A selection of different measurement results are shown

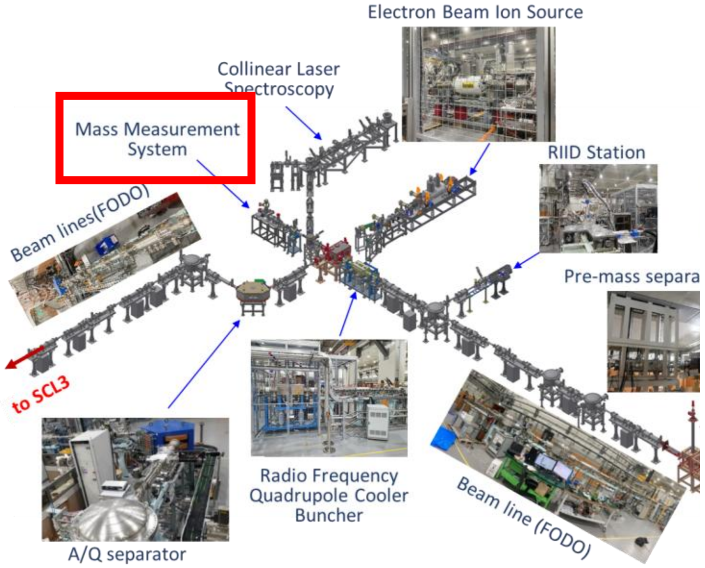
- Already case @ TRIUMF TITAN
- Precision increase proportional to the charge state
- EBIT charge breeding with even 2+,3+ could bring factor 2-3 better resolution
- Difficulty maintaining charge state for long term measurement
- Ultra-high vacuum (10^-12 torr) & cryo temperature required

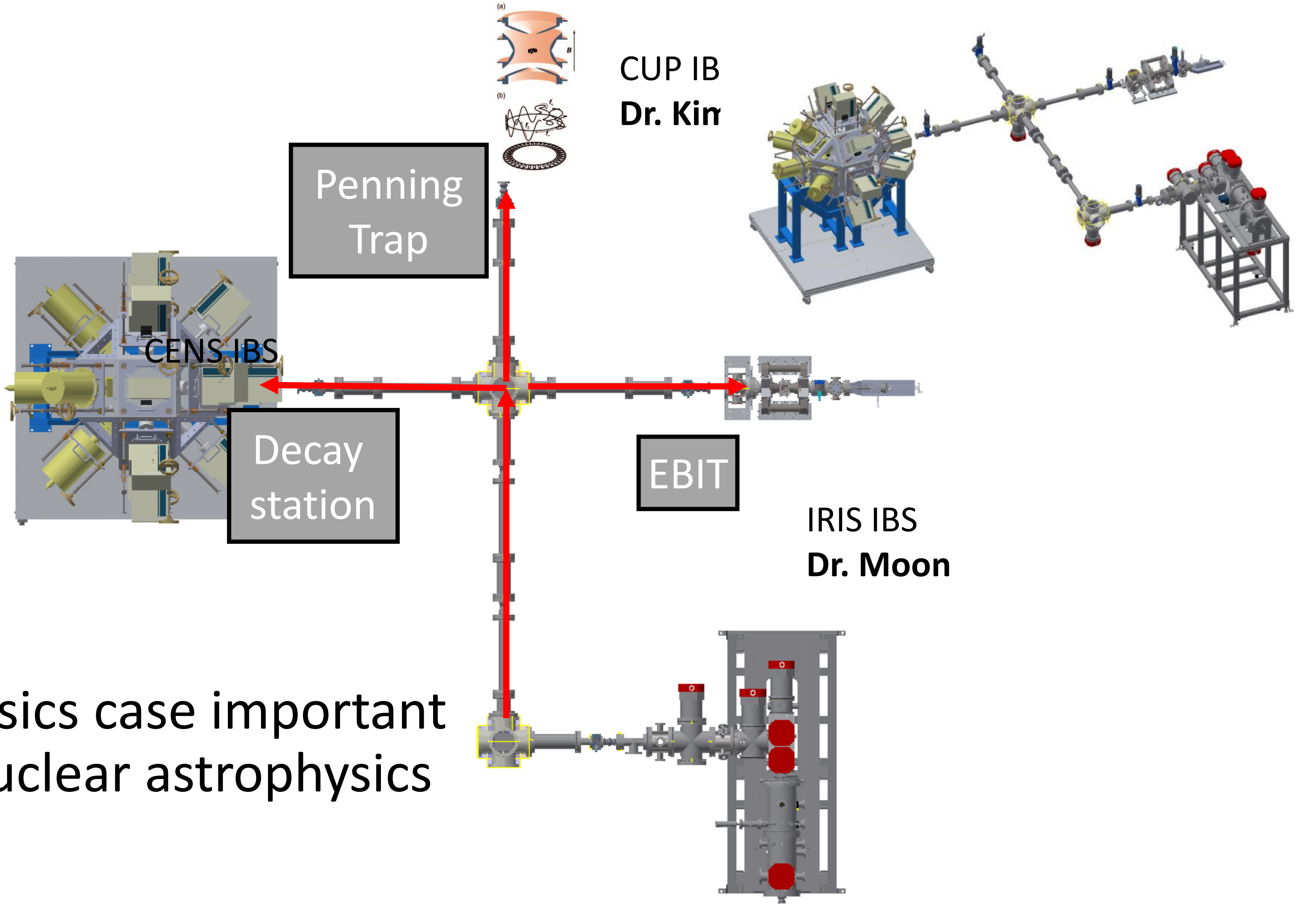
  Construction He gas cooling no longer can be done
- Future project for penning trap

Anna A. Kwiatkowski et al., Eur. Phys. J. A (2024) 60:87

Low energy beam line for Decay & mas spectroscopy

Concept





- EBIT can bring new physics case important for nuclear physics & nuclear astrophysics