Double-beta decay of ^{96}Zr: nuclear physics meets geology

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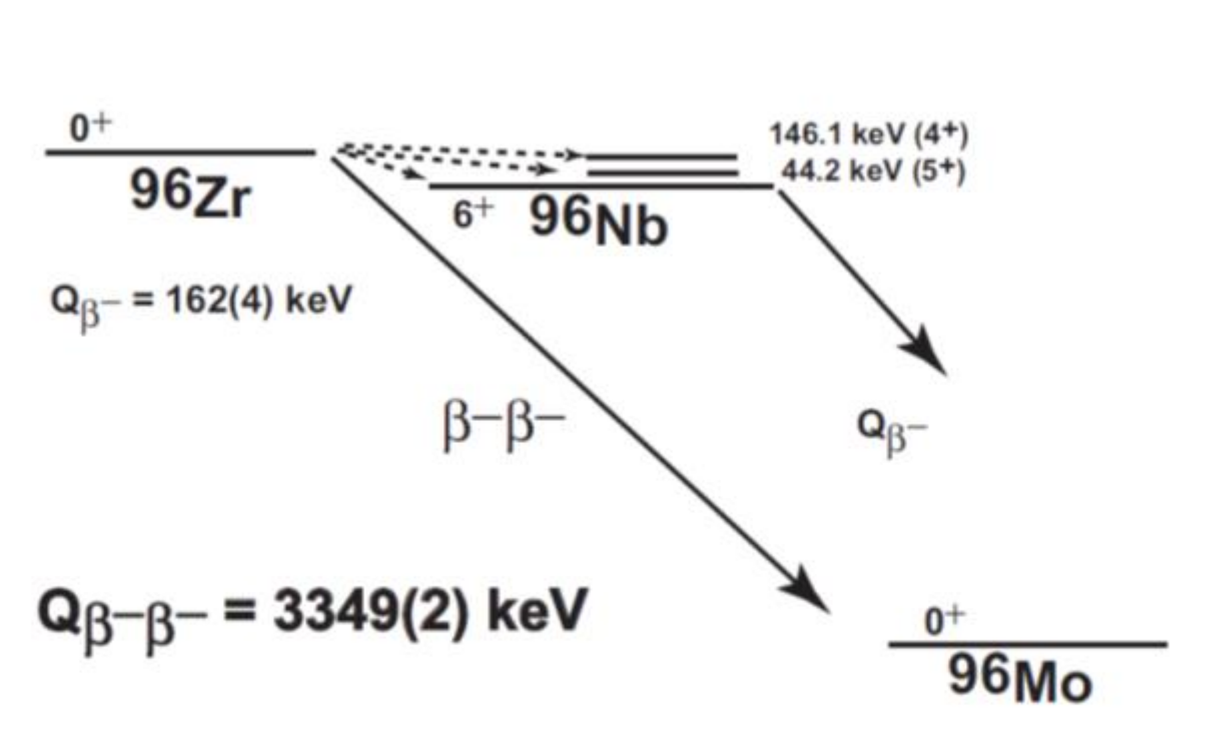
Motivation and summary

- Double-beta decay measurements give insight into properties of the neutrino, one of the least well understood particles
- Objective: Determine the half-life of the ββ-decay of $^{96}Zr \rightarrow {}^{96}Mo$
- Approach: Use two different measurements to determine different parameters related to the half-life
  - At U of Calgary: geochemical measurement of ββ-decay half-life
  - At U Jyväskylä: measure the Q-value of the decay
- Motivation: Understand a discrepancy between a direct measurement of the decay at NEMO in 2010 and the last geological measurement from 2001

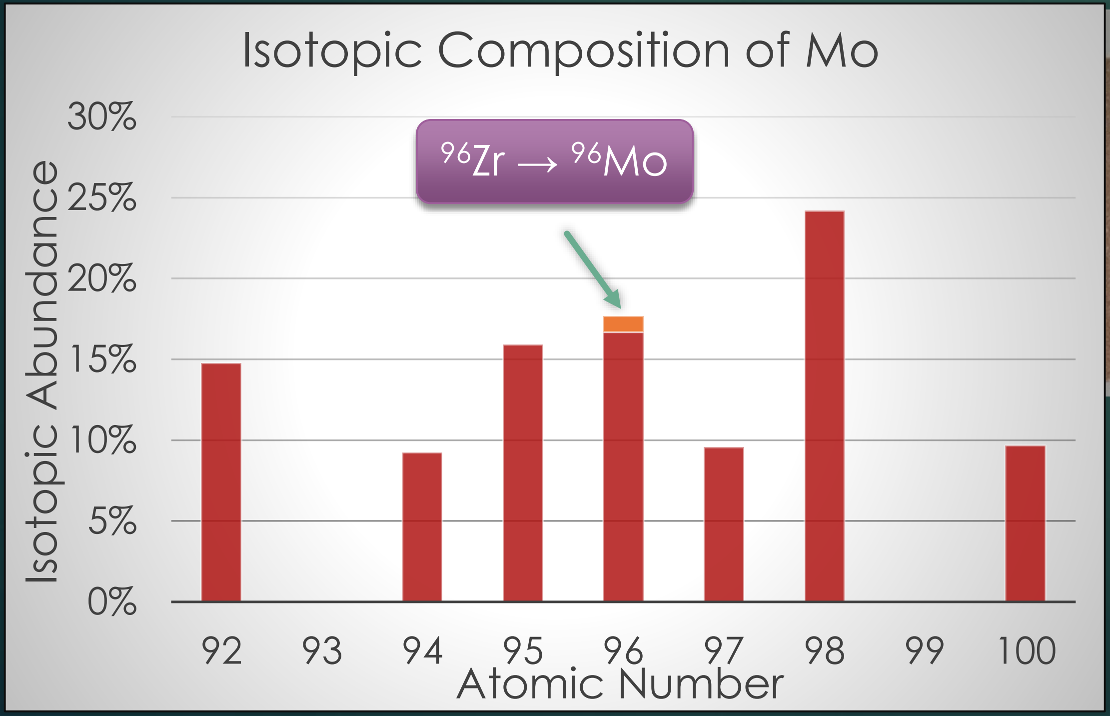
^{96}Zr decay scheme

- Geochemical measurement
  - $0.94(32) \times 10^{19}$ a
  - Wieser and DeLaeter 2001
- ββ counting measurement
  - $2.4(3) \times 10^{19}$ a
  - NEMO Collaboration 2010
- > 2σ difference!
- Competing single beta-decay half-life?
  - Theoretical half-life: ~2.6×10^{20} a
  - Dependent on Q-value of the decay



Double-beta decay half-life by stable isotope geochemistry

- Verify measurements by Wieser and DeLaeter in 2001
- Excess ^{96}Mo compared to ^{96}Zr tells us the half-life of the decay



Zircon

1.8 Ga

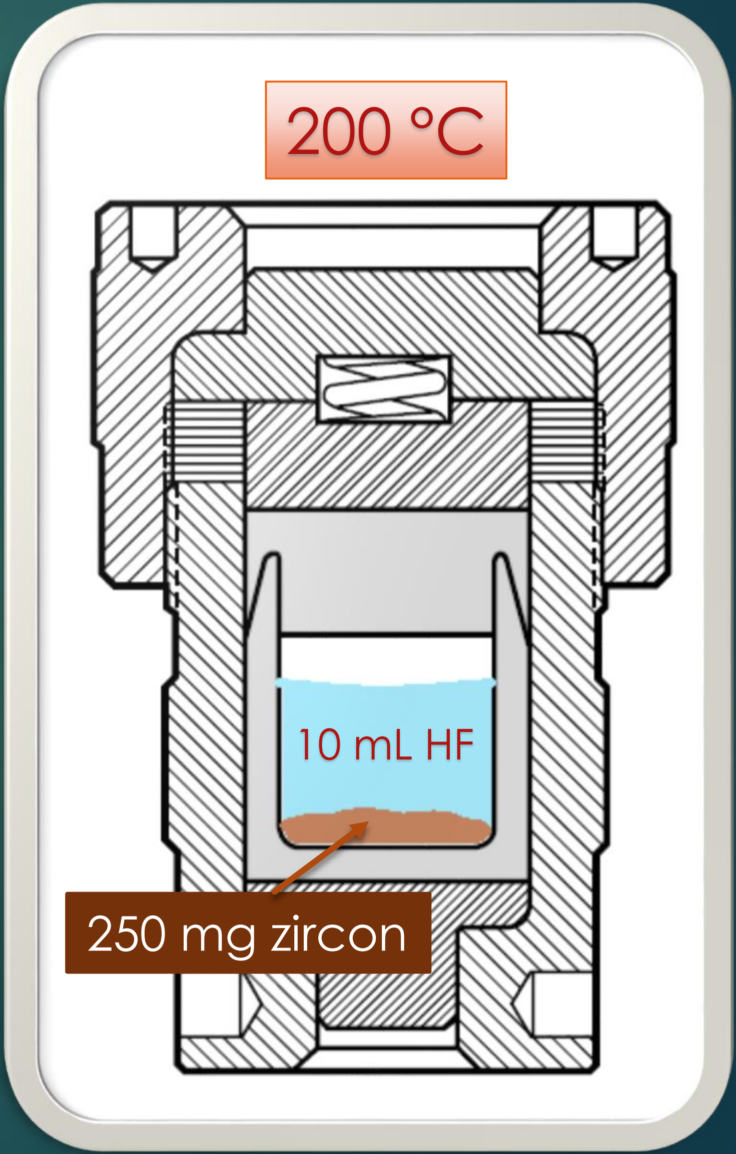
$ZrSiO_4$

2.8 % ^{96}Zr

$^{96}Zr \rightarrow {}^{96}Mo + 2e^- + 2\bar{\nu}$

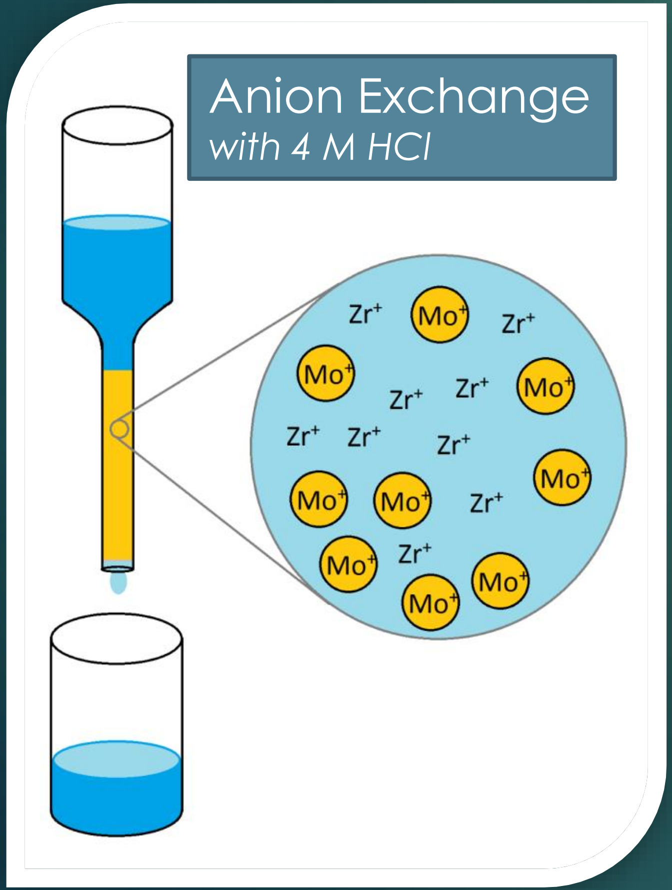
Sample preparation: Acid digestion

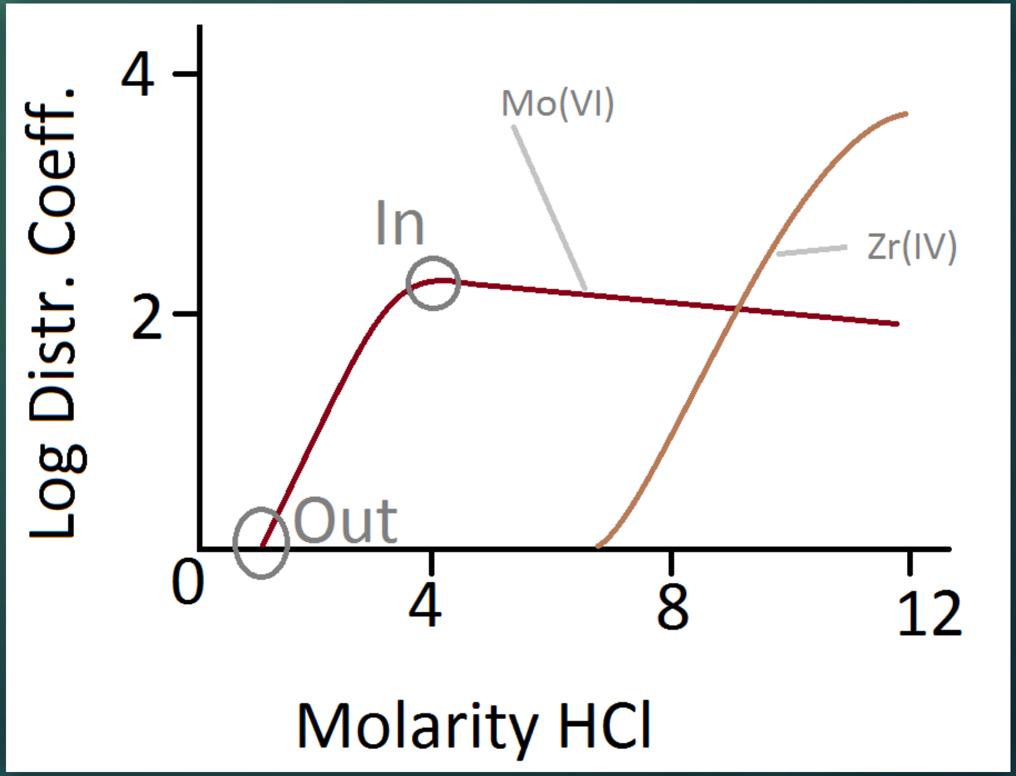
- Sample digested in high temperature concentrated HF in an acid digestion bomb



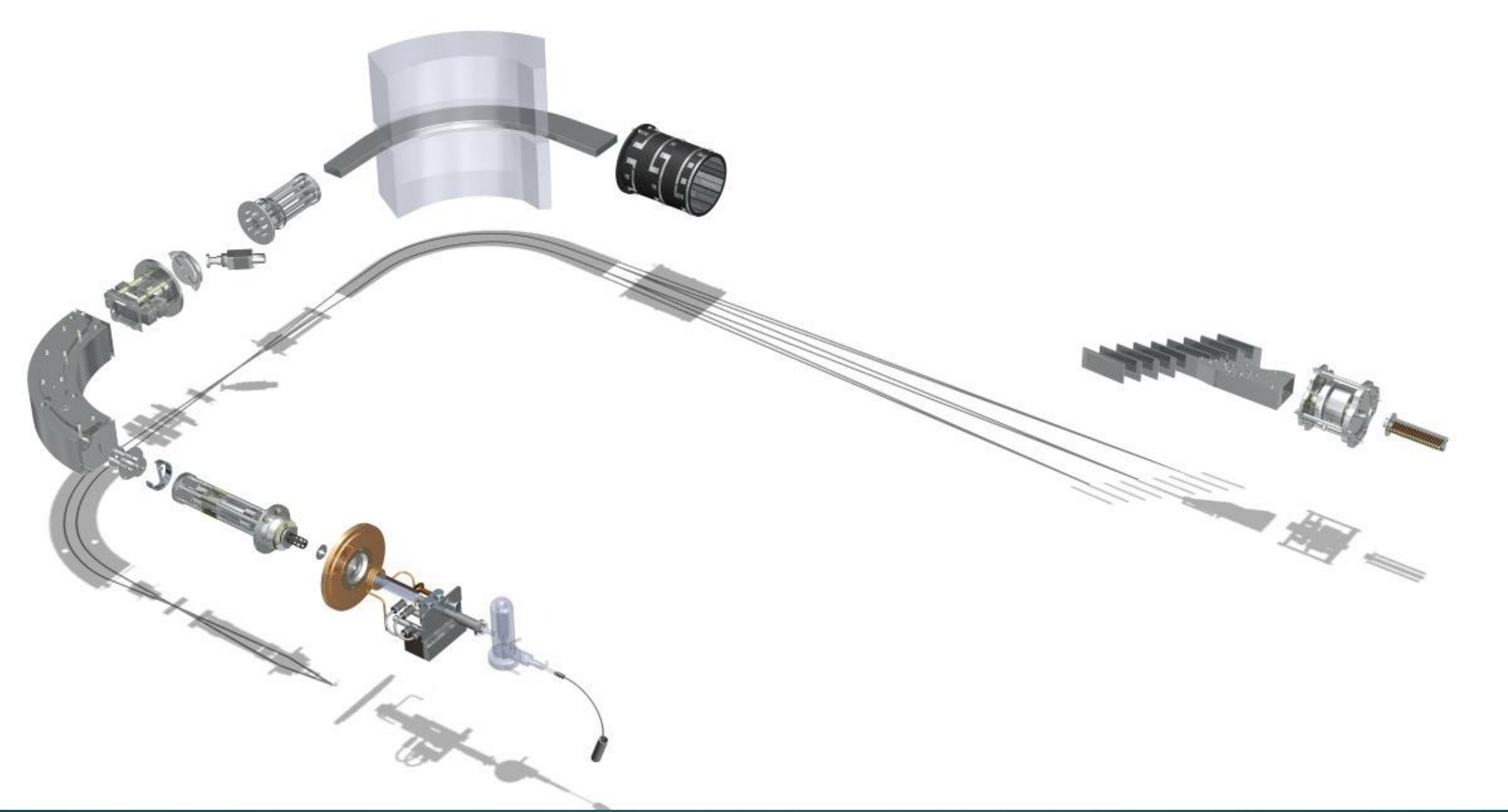
Sample preparation: Mo separation

- In order to measure ^{96}Mo, we must first separate the Mo from the Zr





Sample analysis: MC-ICP-MS



How will we improve over the previous measurement?

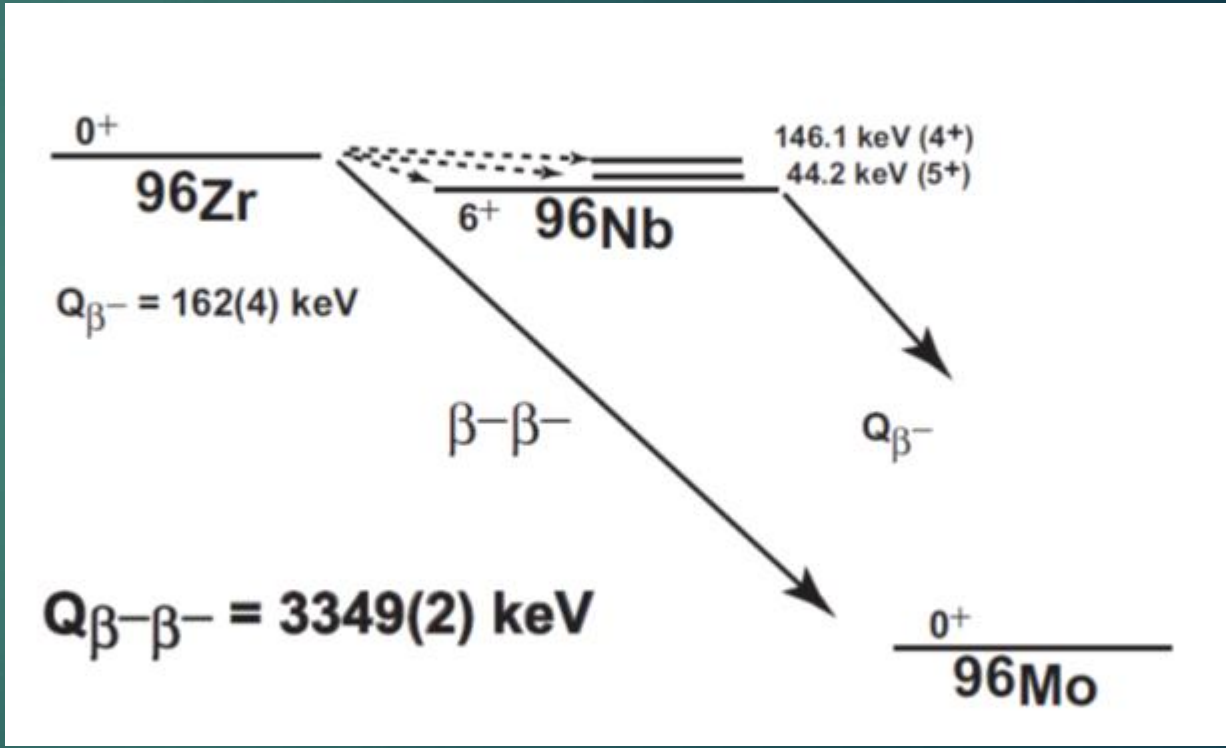
- Original measurements performed with Thermal Ionization MS

	Previous (TIMS)	New (MC-ICP-MS)
Sensitivity	100 ng Mo	10 ng Mo
Chemistry blank	10 ng Mo	1 ng Mo
Precision	1.0 ‰	0.1 ‰

- All related measurements, i.e. Zr concentration and U-Pb dating will be performed in house

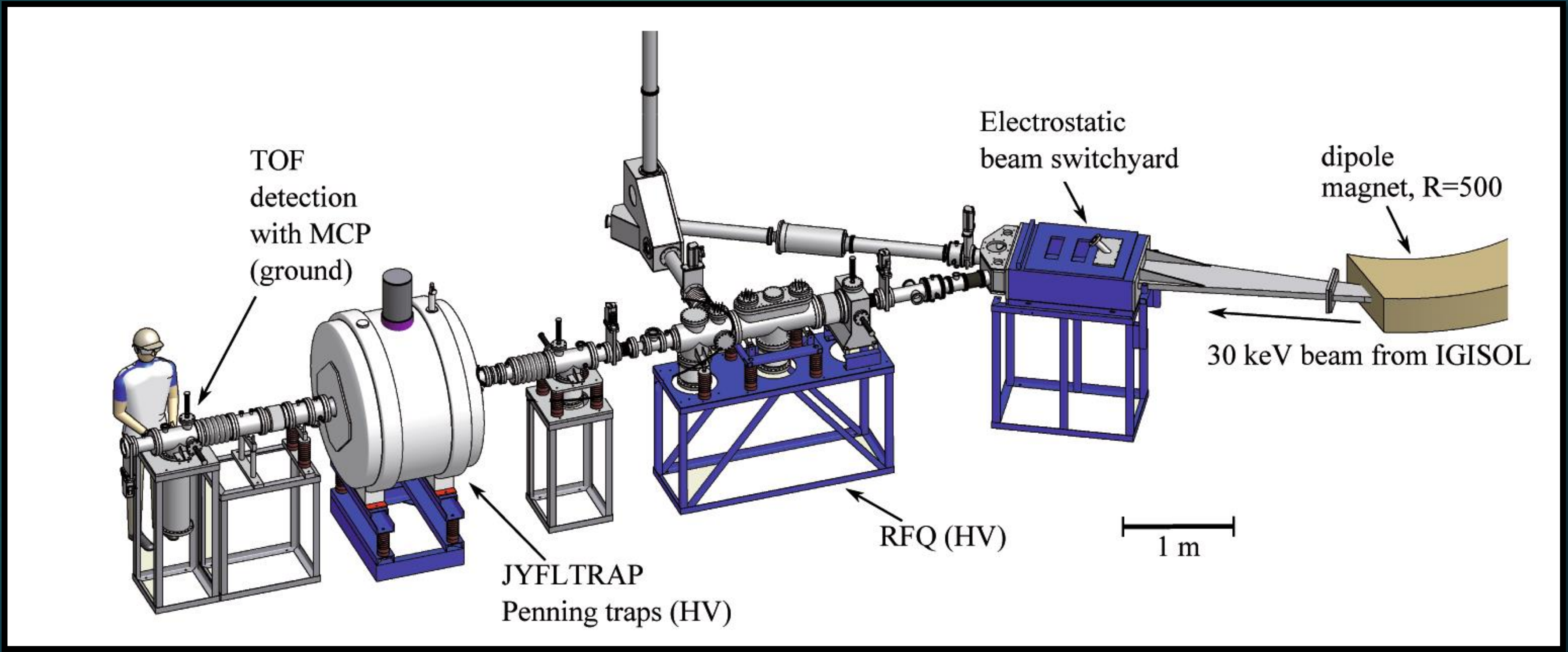
Q-value measurements at JYFLTRAP

- Geological measurements so far provide evidence for 2nd decay route
- Single β-decay half-life dependent Q-value



JYFLTRAP

- Penning trap mass spectrometer at University of Jyväskylä, Finland

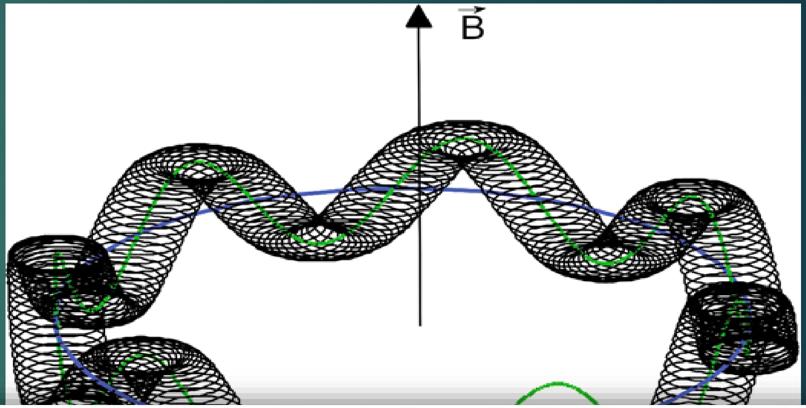


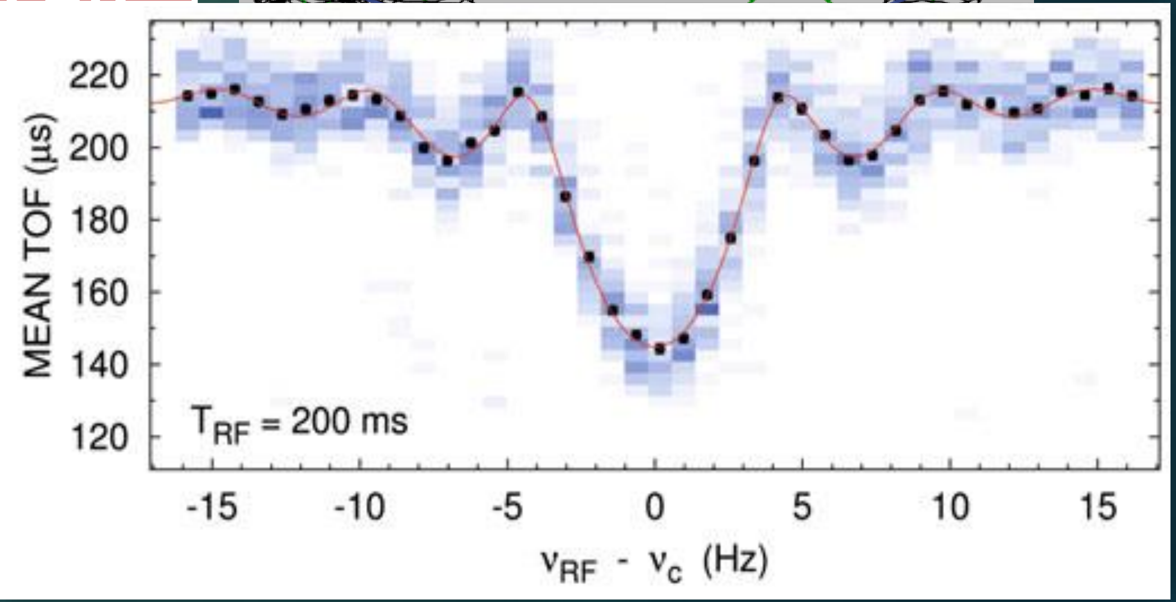
Penning trap mass measurements

- Ion motion dependent on q/m and trap parameters
  - (1) magnetron
  - (2) axial
  - (3) reduced cyclotron

$$\nu_c = \frac{q}{m}\frac{B}{2\pi}$$

- Apply RF quadrupole field
  - Excite reduced cyclotron motion
- Measure time-of-flight to determine energy gain
- Measure relative to reference isotope (i.e. ^{85}Rb) to eliminate uncertainty due to B-field





Questions we will answer

- Can we confirm the discrepancy between the NEMO direct and Wieser/DeLaeter geological measurements?
- Is a highly forbidden single-beta decay also contributing to the decay?
- If the discrepancy is confirmed, and cannot be accounted for, is this evidence for time-dependent double-beta parameters?