Contamination study for the PI-LIST ion source

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High-Purity Radioactive Ion Beam Production: The Laser Ion Source & Trap LIST

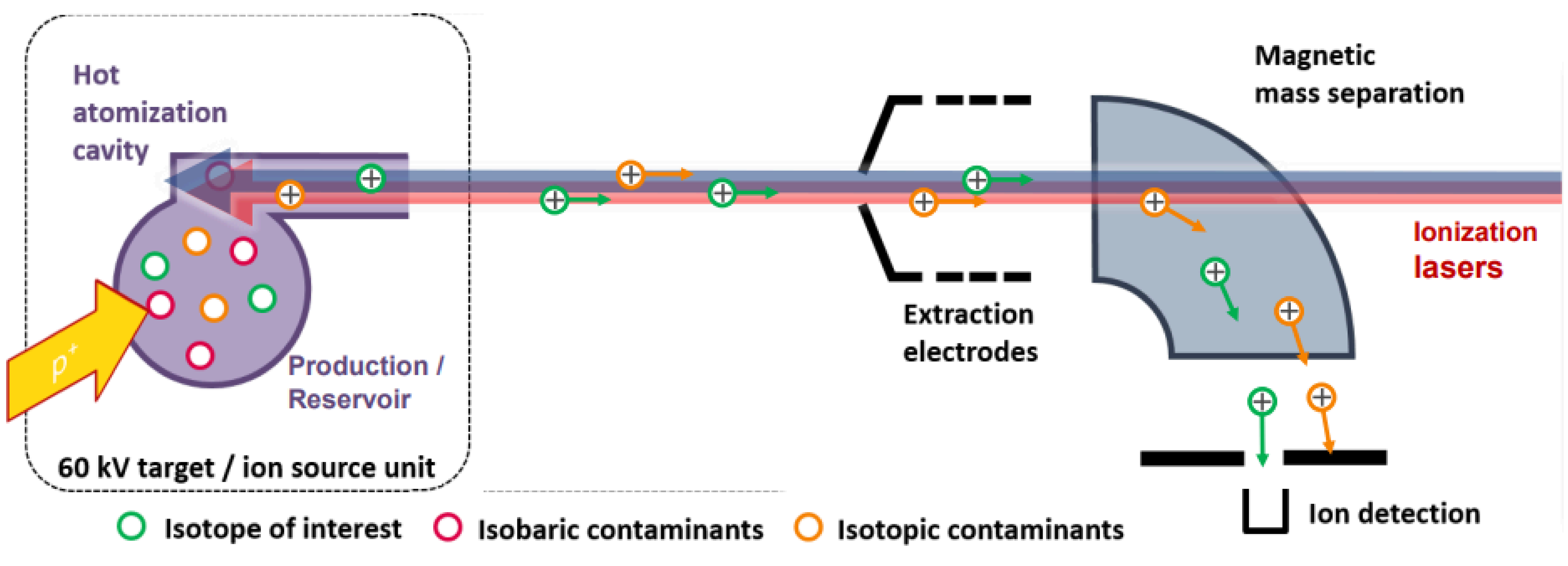

Figure 1. ISOLDE's resonance ionization laser ion source RILIS

Resonance Ionization Laser Ion Sources (RILIS) [1] provide high selectivity and efficiency in producing isotopically enriched radioactive ion beams (RIBs) at facilities like CERN–ISOLDE [2]. By utilizing wavelength-tunable lasers, RILIS (Figure 1) can precisely target and ionize specific electronic shell transitions, ensuring only the desired elements are affected. This technique enables detailed studies of nuclear properties, including spin, magnetic and electric moments, and changes in mean-squared charge radii.

The Laser Ion Source and Trap (LIST) at ISOLDE further improves beam purity by spatially separating the laser ionization region from the hot atomization cavity, thereby reducing isobaric contamination. Developed in collaboration with Johannes Gutenberg University (JGU), LIST was first successfully applied to hyperfine structure studies in neutron-rich polonium.

"Sub-Doppler" in-source laser spectroscopy: PI-LIST

In hot cavity laser ion sources, experimental resolution is typically limited by **Doppler broadening**, which can reach several GHz. The Perpendicularly Illuminated Laser Ion Source and Trap (PI-LIST) addresses this challenge by creating a crossed laser and atom beam environment, effectively targeting and minimizing lateral velocity classes to achieve sub-Doppler resolution.

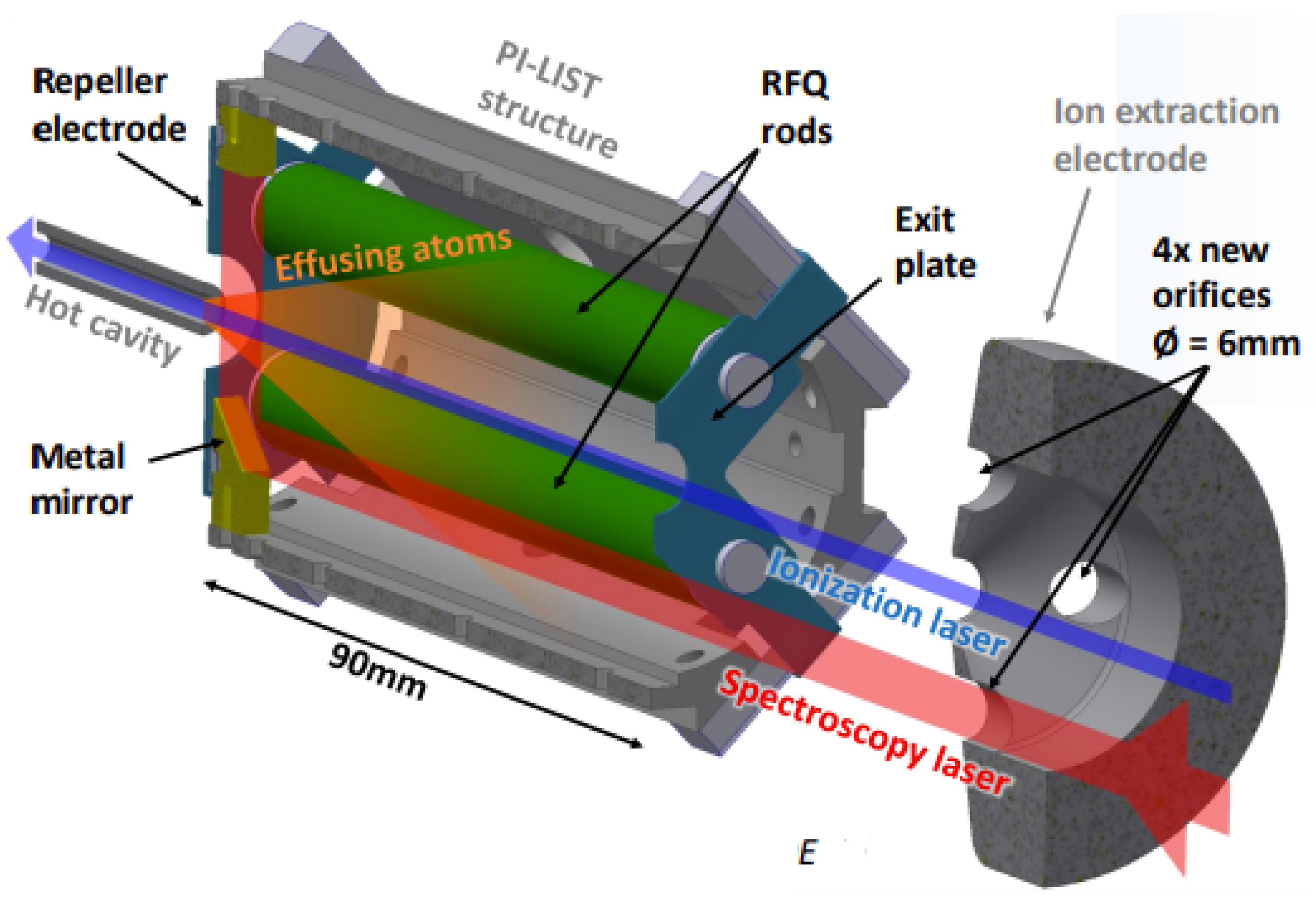

Figure 2. CAD model of the PI-LIST as installed at ISOLDE

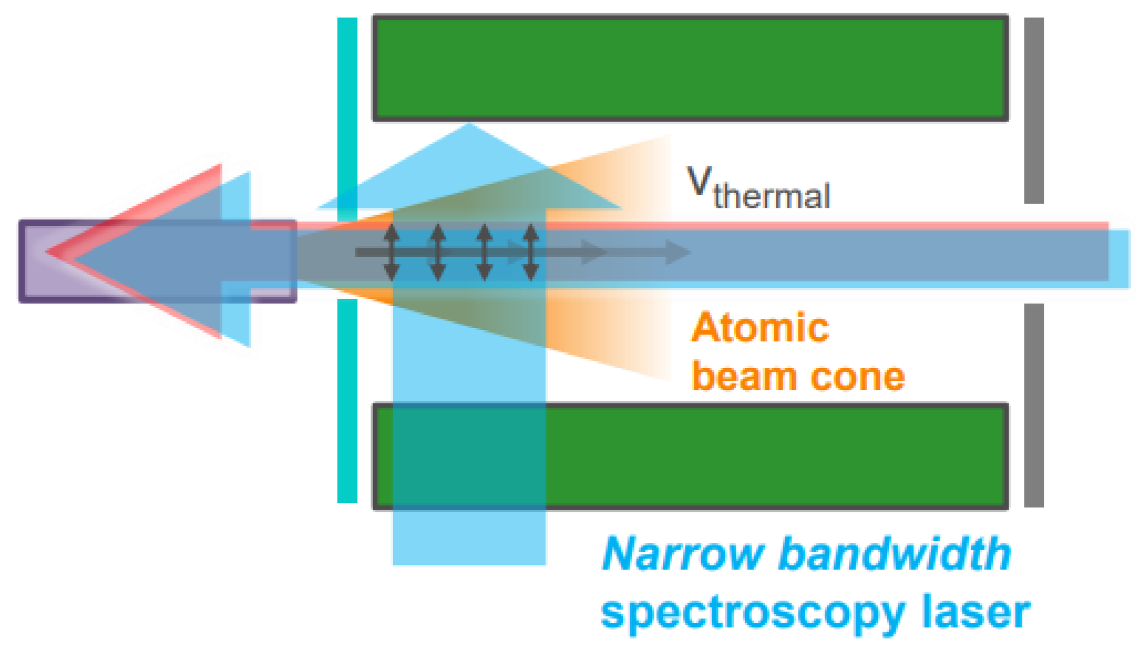

Figure 3. Narrow bandwidth spectroscopy laser

Integrated successfully at ISOLDE in 2022 [3], PI-LIST has demonstrated significant advancements:

- **Resolution Gain:** Improved by an order of magnitude, achieving 100 – 200 MHz resolution.
- **Efficiency:** Approximately 0.01%, compared to the 10% efficiency of standard RILIS.

PI-LIST's sub-Doppler resolution capabilities enable precise nuclear structure investigations, particularly within the EU network LISA (Laser Ionization and Spectroscopy of Actinides). This has facilitated detailed studies of neutron-rich actinium, advancing our understanding of complex nuclear phenomena.

Ongoing Developments

In the initial ISOLDE LIST campaigns [Fink2013Fink2015] and during the 2022 PI-LIST experiment (Figure 5), significant quantities of francium were detected despite employing modes designed to suppress non-laser ions [4]. Given francium's low ionization potential (IP = 4.1 eV) and its proximity to the hot cavity, it is hypothesized that francium is surface-ionized at the repeller due to insufficient thermal insulation.

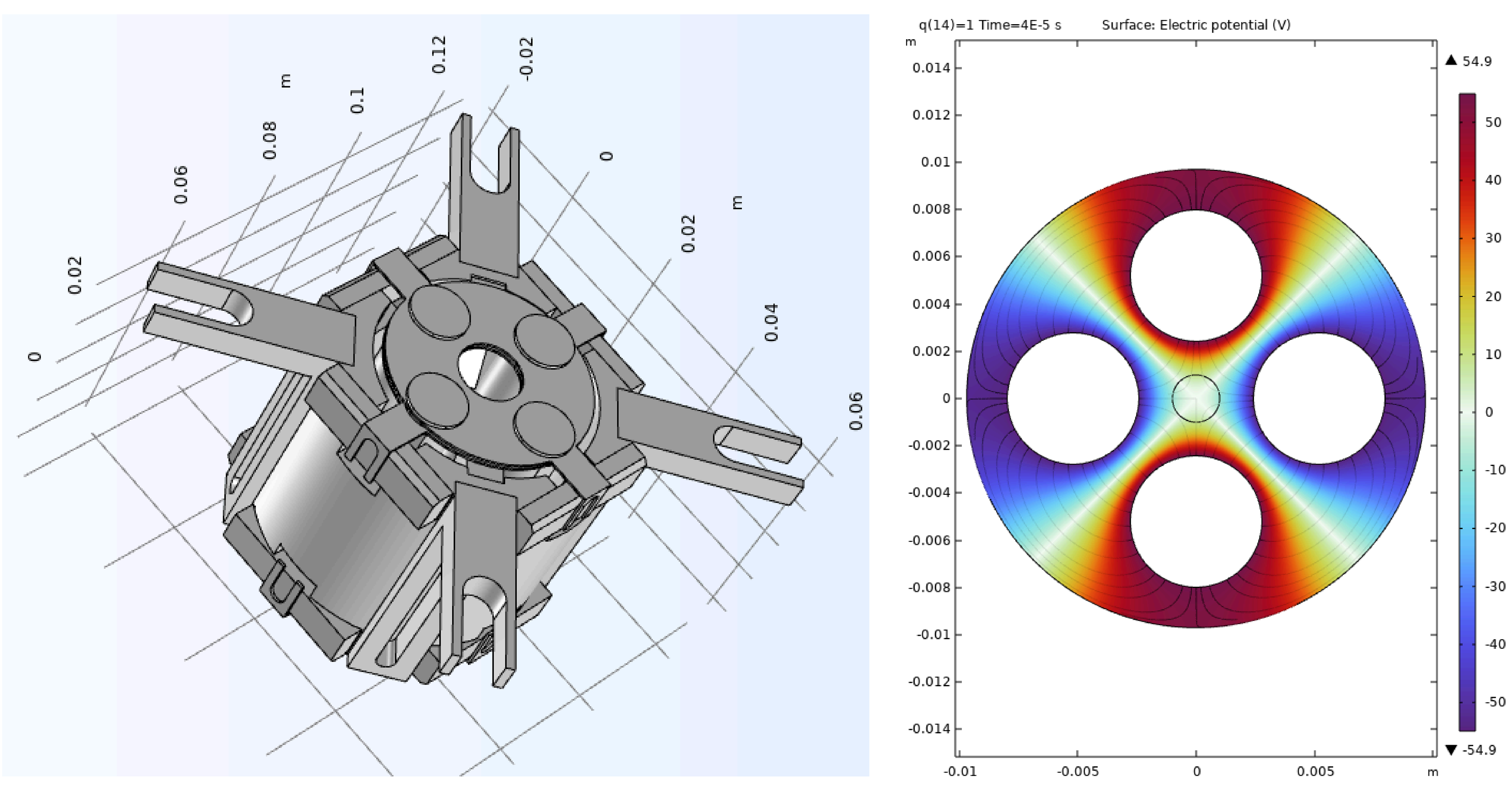

Figure 4: COMSOL simulation showing part geometry and the distribution of electric potential.

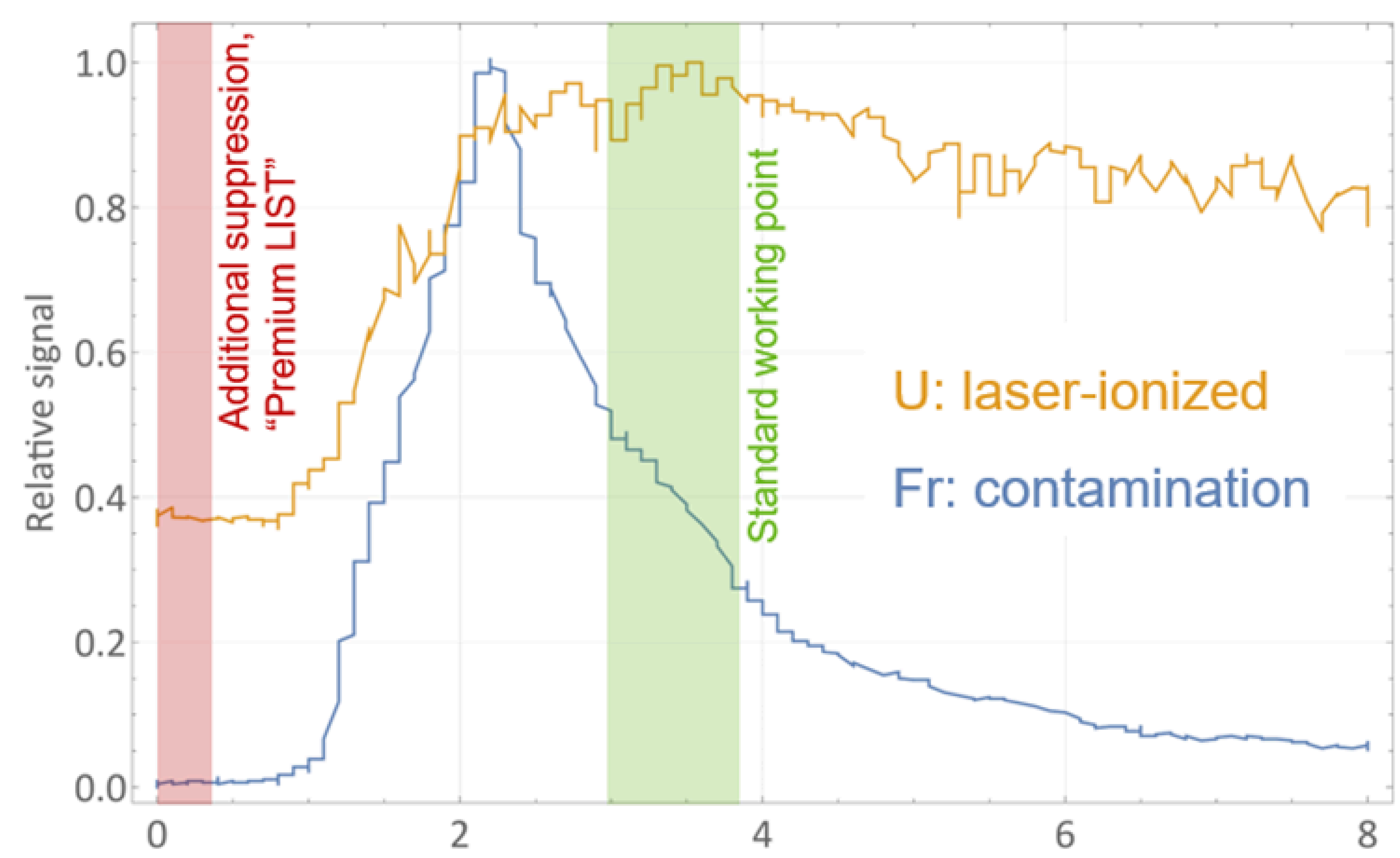

Figure 5: Dependence of laser-ionized (U) and non-laser related contamination (Fr) on the RFQ voltage amplitude in LIST mode

The detection of francium contamination adversely affects the precision of our measurements. To address this issue, we are conducting simulations using COMSOL to evaluate potential solutions, including repeller coatings, machining, or 3D printing with materials of lower work function, and enhanced thermal insulation as shown in Figure 4. These measures aim to mitigate contamination and improve the accuracy of our experimental results.

Contacts and References

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1] V. Fedosseev et al., J. Phys. G 44 084006 (2017) [2] R. Catherall et al., J. Phys. G 44 094002 (2017) [3] R. Heinke et al., NIM B 541, 8-12 (2023) [4] A. AH Jaradat et al., 1st year PhD report (2023)