Towards Precise Nuclear Charge Radii of Silicon Isotopes Using Muonic X-ray Spectroscopy

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The nuclear charge radii of silicon isotopes provide valuable input for searches for physics beyond the Standard model and for constraining the neutron equation of state. Therefore, laser spectroscopy on $^{28\text{-}32}$Si has recently been performed [1] and is planned for other isotopes in the near future. However, for extraction of the nuclear charge radii from laser spectroscopy, the mass and field shift parameters are needed, and currently, they are poorly known, and different models provide inconsistent trends. Hence, these parameters need to be re-evaluated, which can be achieved by using the King plot method combined with the determination of the nuclear charge radius of three silicon isotopes ($^{28,\ 29,\ 30}$Si) by using muonic x-ray spectroscopy.

Muonic x-ray spectroscopy exploits the large mass of the muon, which is ≈ 207 times larger than that of an electron. This leads to a significant reduction in the Bohr radius by a factor of $\frac{m_\mu}{m_e}$ and an increase in the binding energy by the same factor. Consequently, the increased sensitivity to nuclear structure effects, particularly finite size effects by a factor $\approx 10^7$, allows for precise extraction of absolute nuclear charge radii. This provides crucial input for laser spectroscopy, which can then be used to constrain the slope of the symmetry energy for the equation of state and for searches of physics beyond the Standard model.

In this contribution, we report on preliminary results from the muonic x-ray spectroscopy campaign performed in 2024 at the Paul Scherrer Institute. The experiment employed the GIANT HPGe detector array [2], enabling extraction of the x-ray transitions. This work is part of the broader effort by the MuX/ReferenceRadii collaboration at PSI, which is reviving the field of x-ray spectroscopy in muonic atoms [3]. Our focus in this contribution is the determination of charge radii for $^{28,\ 29,\ 30}$Si.

[1] Kristian König *et al.*. Nuclear charge radii of silicon isotopes. Phys. Rev. Lett. (2024) 132:162502.

[2] Lars Gerchow *et al.*, Germanium array for non-destructive testing (GIANT) setup for muon-induced x-ray emission (MIXE) at the paul scherrer institute. Review of Scientific Instruments (2023) 94(4).

[3] M.Heines *et al.*. A comparative study of target fabrication strategies for microgram muonic atom spectroscopy, Sci Rep 15 (2025) 6939.