High-precision laser spectroscopy of helium-like carbon

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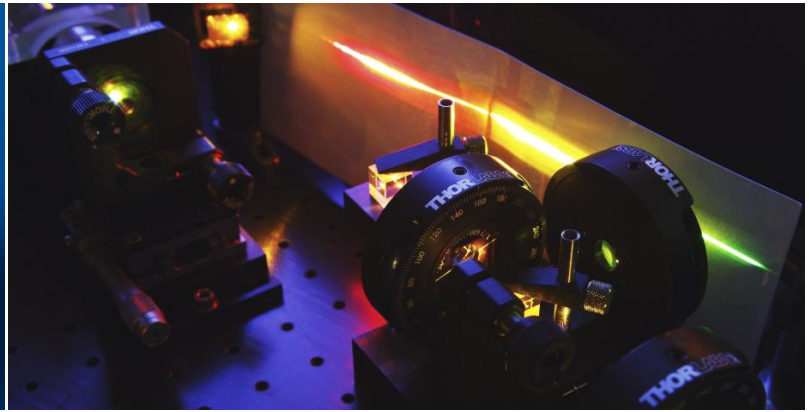

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ALA

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Nuclear charge radii

$$\left\langle r_c^2 \right\rangle = \frac{1}{Z} \int \mathrm{d}^3 r \; r^2 \rho_c(\vec{r})$$

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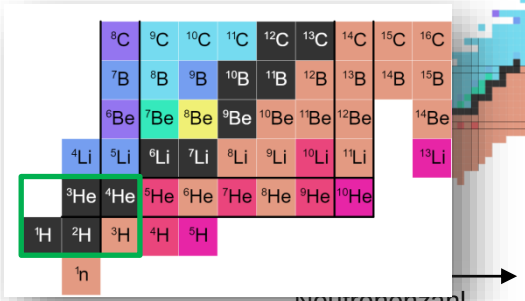
Stable Nuclei

- Elastic electron scattering
- Muonic atom spectroscopy
- Laser spectroscopy

$$\rightarrow \; R_c^A = \sqrt{\langle r_c^2 \rangle}$$



Radioactive Nuclei

- Collinear Laser Spectroscopy
- (Collinear) Resonant Ionization Spectroscopy

$$\rightarrow \; R_c^{A'} = \sqrt{\left(R_c^A\right)^2 + \delta \left\langle r_c^2 \right\rangle^{AA'}}$$

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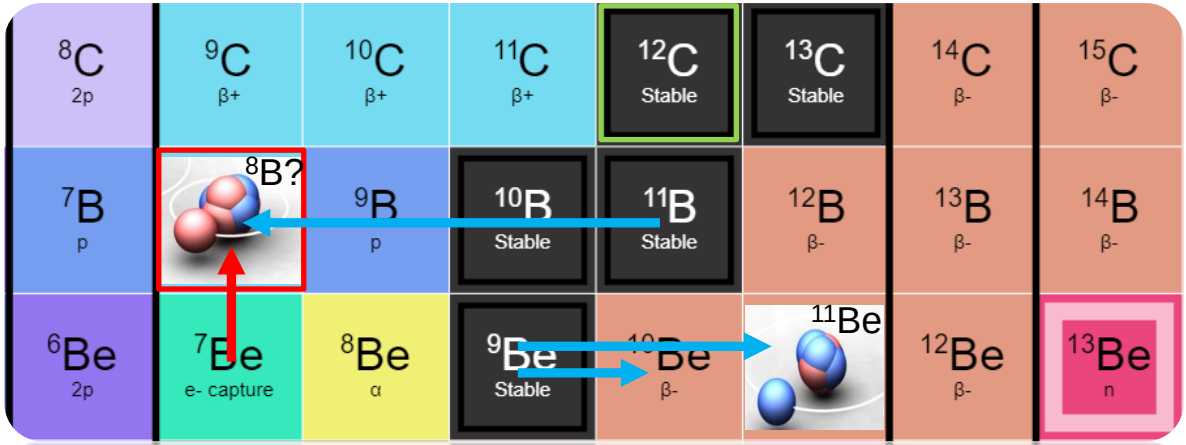
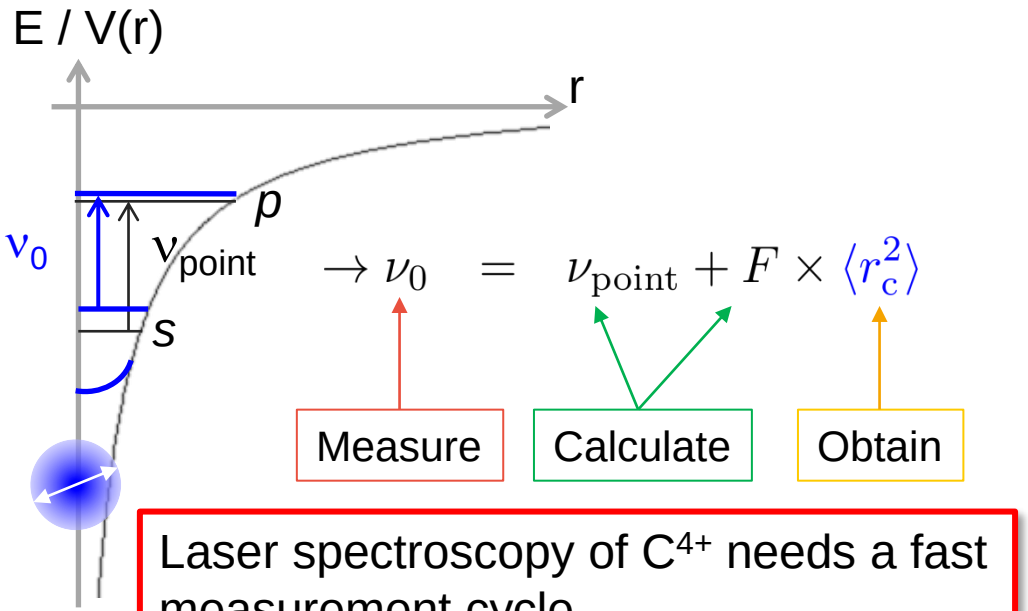
Halo nuclei

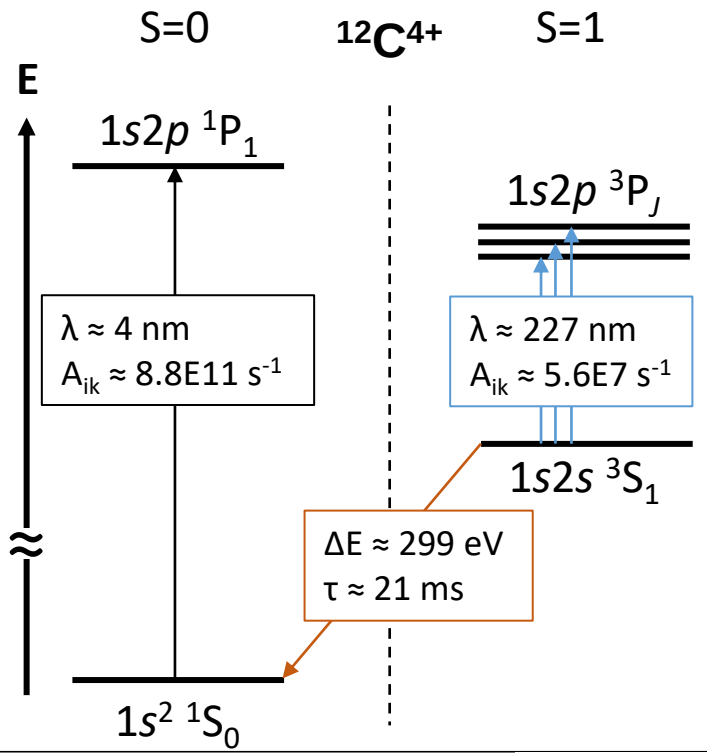


To gain information about the proton halo of ^{8}B, we need reliable and accurate reference radii for ^{9}Be and ^{10,11}B on equal footing

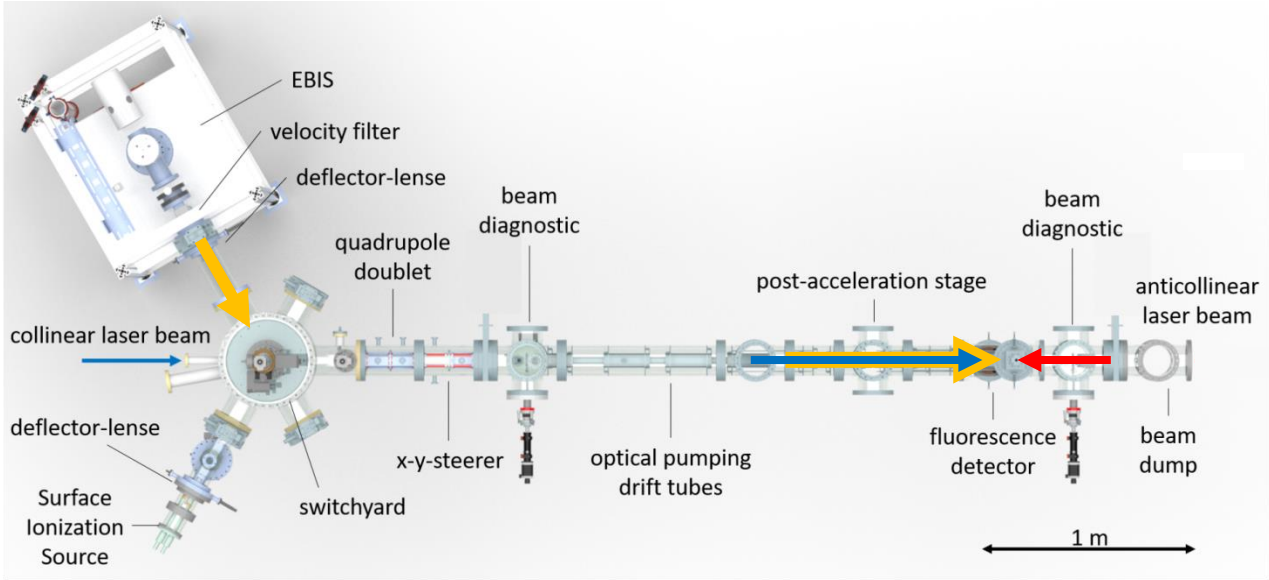
How to obtain an all-optical nuclear charge radius?

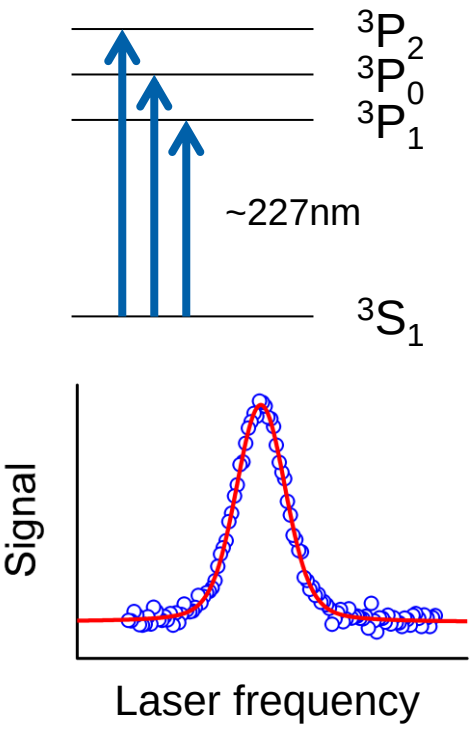


Laser spectroscopy of C^{4+} needs a fast measurement cycle
→ Collinear Laser Spectroscopy



Laser spectroscopy of He-like ions

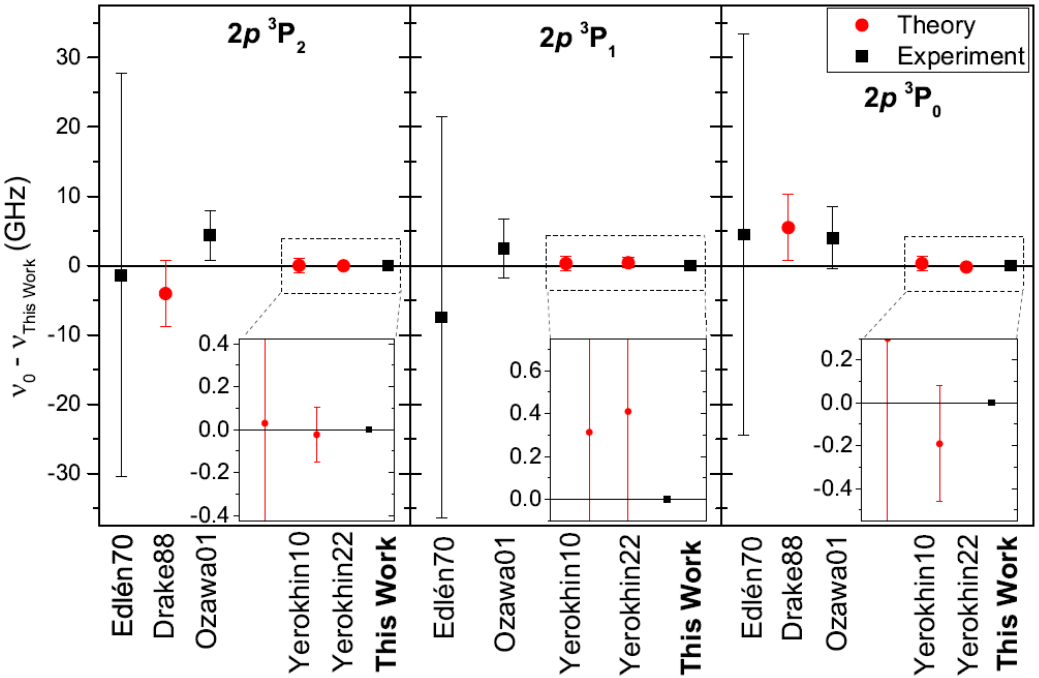


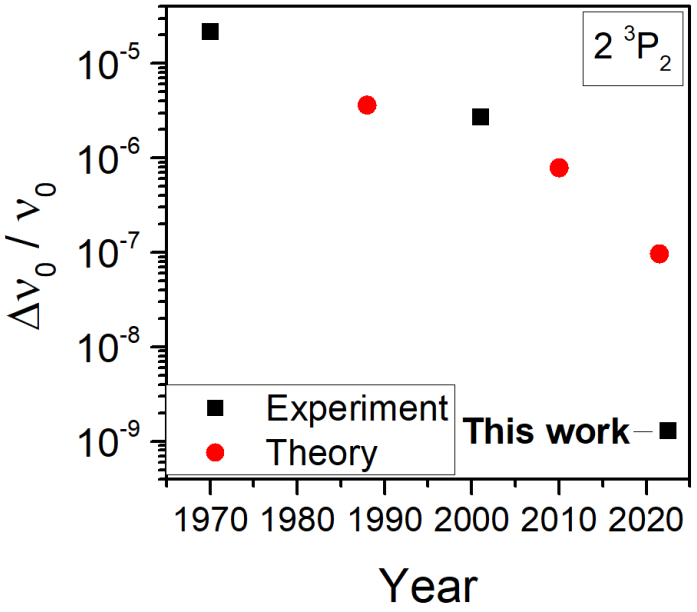


$$\left.\begin{aligned} \nu_c &= \nu_0\gamma(1+\beta) \\ \nu_a &= \nu_0\gamma(1-\beta) \end{aligned}\right\} \quad \nu_c \cdot \nu_a = \nu_0^2\gamma^2 \cdot (1+\beta)(1-\beta) = \nu_0^2$$

Results & Comparison to literature

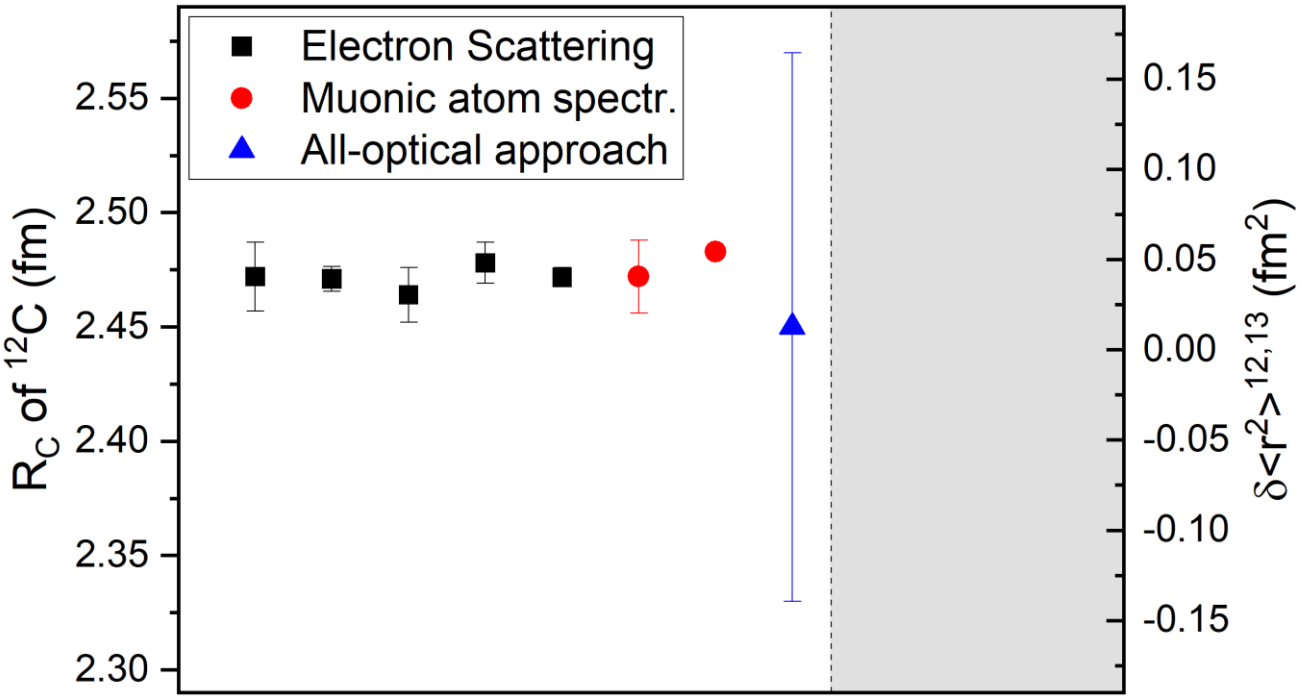
$$\rightarrow \nu_0 \quad = \quad \nu_{\text{point}} + F \times \langle r_c^2 \rangle$$





PRL 131, 243001 (2023) & PRA 108, 062809 (2023)

All-optical nuclear charge radius of ^{12}C



Imgram et al., PRL 131, 243001 (2023)

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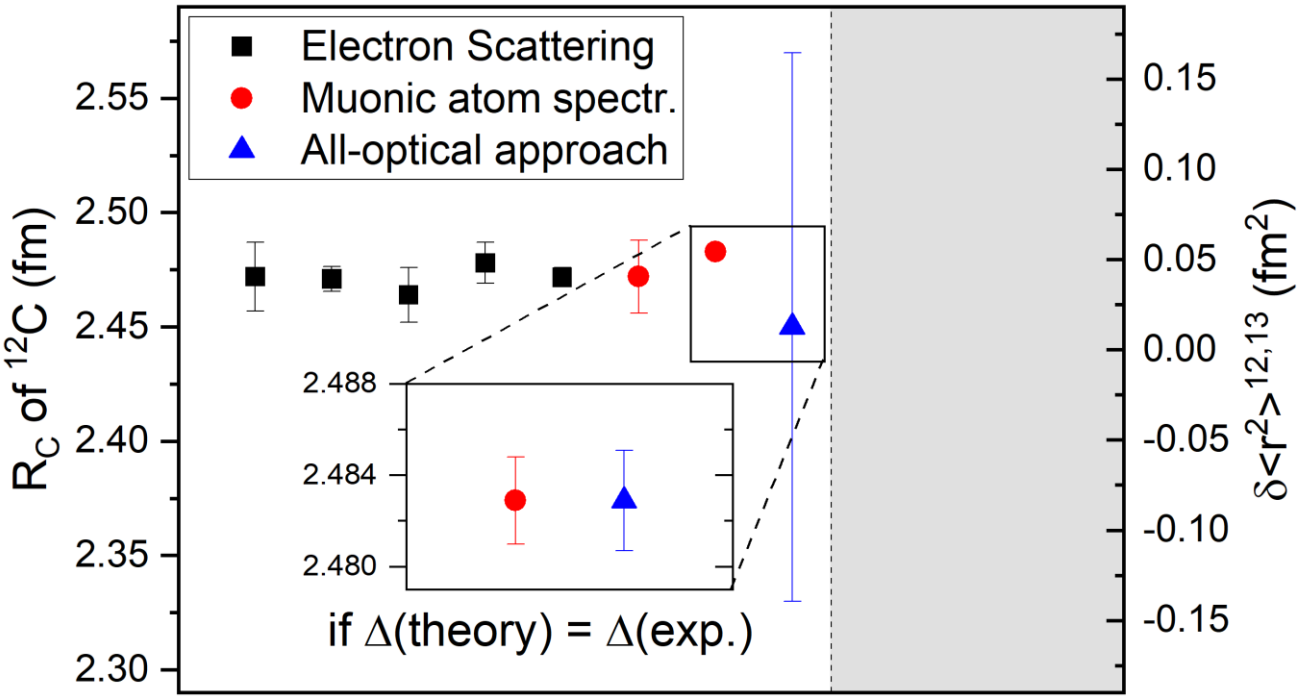

Imgram et al., PRL 131, 243001 (2023)

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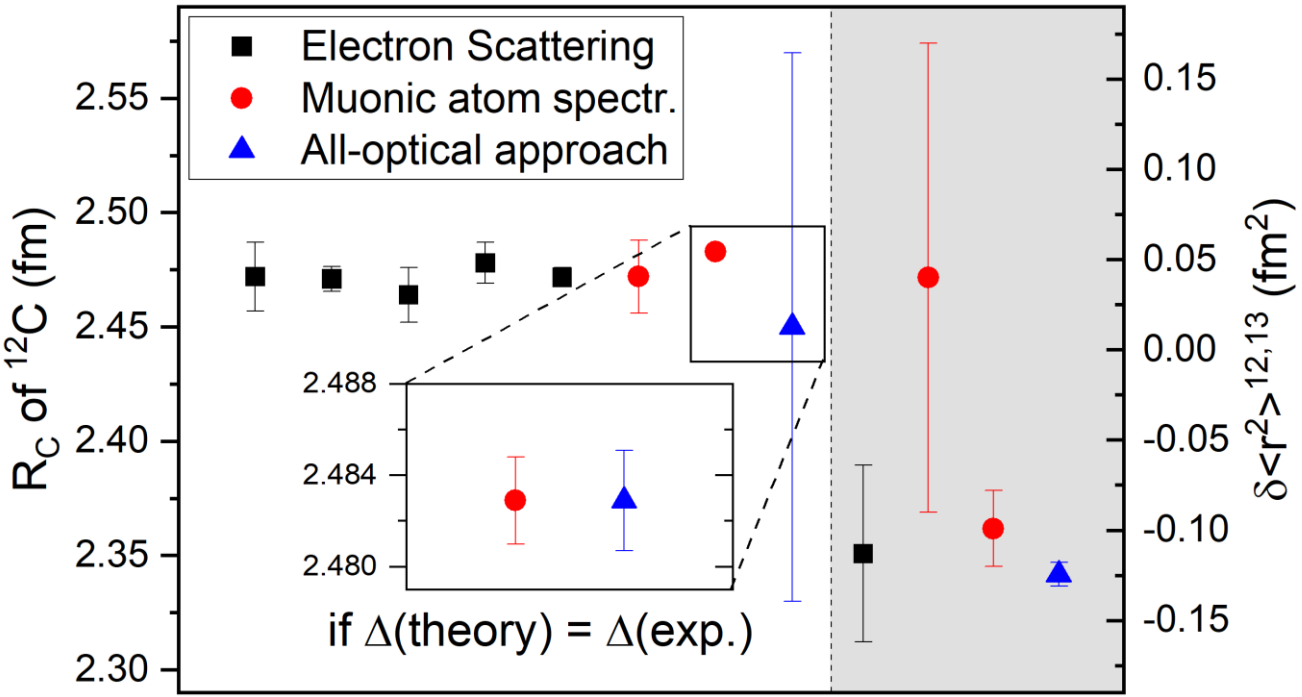

Imgram et al., PRL 131, 243001 (2023) Mueller et al., in prep.

- **Improved** previous experiments by **>3 orders** of magnitude
- **All-optical** nuclear charge radius of ^{12}C → more work needed for competitive all-optical R_C
- **First** high-precision laser spectroscopy in C isotope chain → **$\delta\langle r^2\rangle$ in C chain**

Outlook to future measurements

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Stable isotopes at COALA

- $^{14}C^{4+}$ (in preparation)
  → long-lived isotope offline feasible
- $^{10,11}B^{3+}$ (2024 - 2025)
  → Reference and $\delta\langle r^2\rangle$ extraction
- $^{9}Be^{2+}$ (>2024)
  → Feeding of Be^{+} into EBIS needs further development

Radioactive isotopes at ISOLDE

- $^{7}Be^{2+}$ (QP moment & Zemach radius)
  → influence in $^{7}Be(p, \gamma)^{8}B$ reaction rate
- $^{8}B^{3+}$
  → consistency check with Argonne NL
- $^{12,13,14}B^{3+}$
  → Radii across N=8 shell closure
- $^{15,16}C^{4+}$
  → similar to B

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Thank you for your attention!

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DFG Deutsche Forschungsgemeinschaft

SFB 1245

Federal Ministry of Education and Research

HFHF Helmholtz Forschungsakademie Hessen für FAIR

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

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