QUARTET

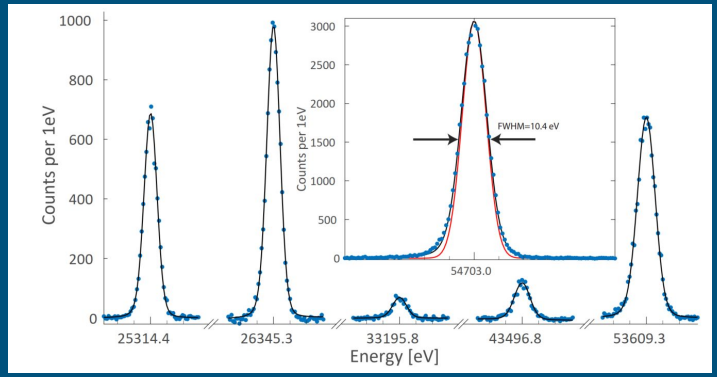
Narrowing Physics Cases

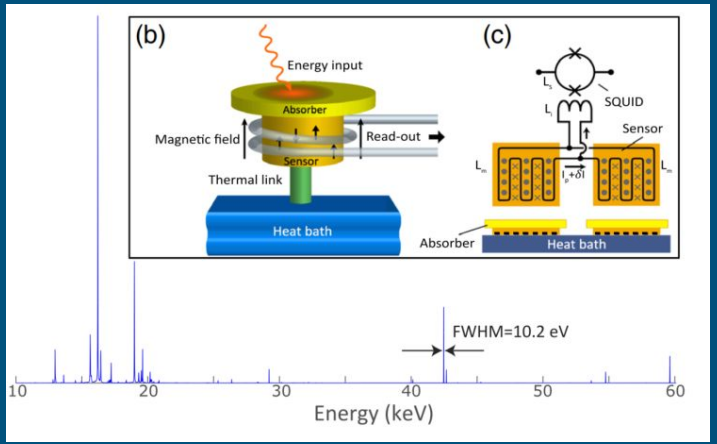
Choice of cases

maXs-30
Energy range

Isot.	E_{1S-2P} keV
^{20}Ne	207
^{19}F	169
^{16}O	134
^{14}N	102
^{12}C	75
^{11}B	52
^{9}Be	33
^{7}Li	19

maXs-30

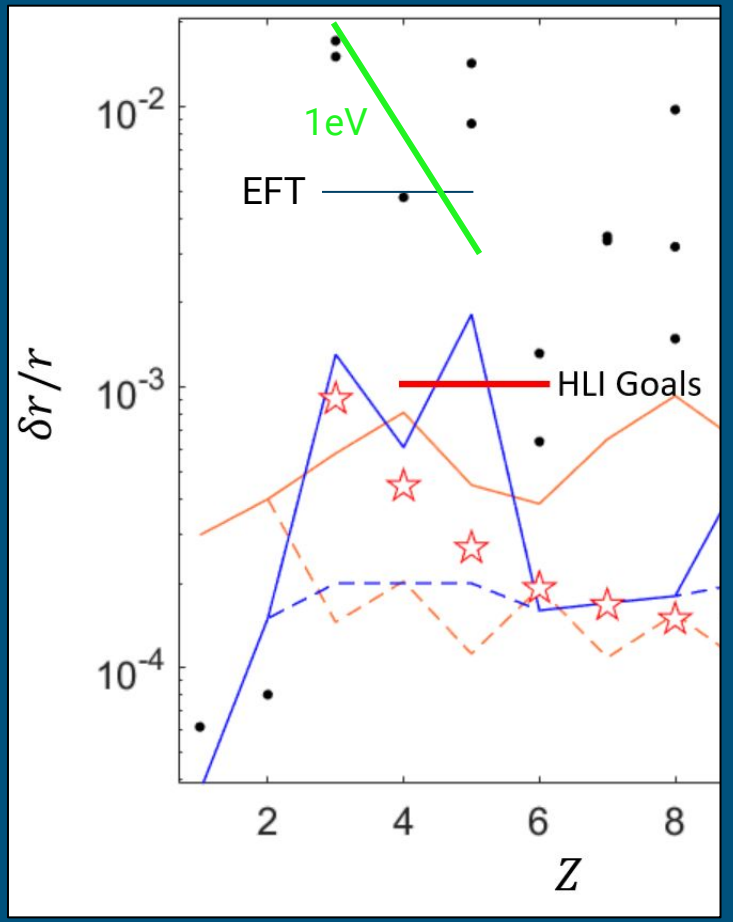




Conservative physics reach (absolute radii):

	E(2p-1s) keV	δr/r @ 1eV	δr/r scat.	δr/r EFT
Li6/7	19	2%	2%	0.5%
Be	33	0.6%	*0.5%*	0.5%
B10/11	52	**0.3%**	*1%*	0.5%

Opinion: Either sub 1eV or focus on Boron



Literature

- Measured simultaneously: Be, B, N
- BN thickness 1g/cm, 90% transparent @50keV
- Germanium resolution was 1 keV
- 6 Hours run time, ~kHz counting rates
- Stat unc ~eV, Limited to ~10eV by calibration!
- Unresolved fine-structure / Hyperfine, Isotope shifts

For similar run time, our required rates @ 10 eV resolution are ~0.1 Hz total to reach <eV statistical uncertainty

NUCLEAR CHARGE RADII
FROM MUONIC X-RAY TRANSITIONS
IN BERYLLIUM, BORON, CARBON AND NITROGEN †

L. A. SCHALLER, L. SCHELLENBERG, A. RUETSCHI and H. SCHNEUWLY
Institut de Physique de l'Université, CH-1700 Fribourg, Switzerland

Transition	Be present work 2cm³ Ge	B refs. [15,16]	B present work 2cm³ Ge
2p-1s	33402 (0.8; 10)	52259 (6)	52257 (0.7; 7)
3p-1s	39581 (1.0; 10)		61946 (1.4; 6)
4p-1s	41746 (2.2; 12)		65330 (2.8; 7)

CHARGE-DISTRIBUTION PARAMETERS, ISOTOPE SHIFTS, ISOMER SHIFTS, AND MAGNETIC HYPERFINE CONSTANTS FROM MUONIC ATOMS

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CERN, Geneva, Switzerland

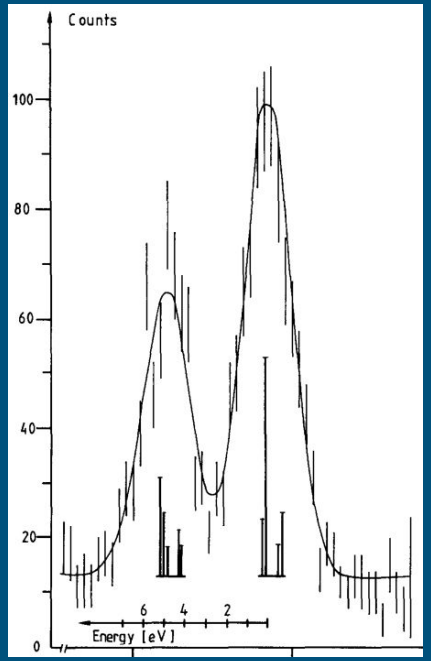
Z	Isotope	2p-1s	Ref.
2	^{4}He	8.18(4)	67WB1
		8.18(7)	71PP1
		8.228(4)	74BE1
3	^{6}Li	18.1(4)	66JK1
		18.64(7)	68HS1
	^{7}Li	18.1(4)	66JK1
		18.69(6)	68HS1

Features in spectra

- Very narrow natural linewidths.
- Isotope shifts are resolved (no need for enrichment). Less sensitive to calibration uncertainty. *Are we sure, 6Li has only 7% abundance, so you need many sigma's separation -> check with cascade code!*
- Difficult to resolve fine/hyperfine-structure (use cascade code).

	LW eV	FS eV	HFS eV
^{11}B	~0.4	6	...
^{9}Be	0.22	2.4	...
^{7}Li	0.07	0.7502(2)	4.659(9)

7Li-HFS (crystal):



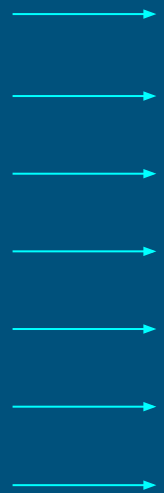
Isotope shifts:

Pair	ΔE_{2P-1S} eV
^{10,11}B	62
^{6,7}Li	50

Available close calibration lines

Gammas keV(unc. in eV):

	B (52.3 keV)	Be (33.4 keV)	Li (18.7 keV)
241Am	59.5 (0.4)	**33.2 (0.3)**	26.3 (0.2)
210Pb	47 (1)		
152Eu			
133Ba	53.2 (0.6)		
228Th			
109Cd			
57Co			14 (0.3)



Daughter x-rays keV(unc. eV)

	B (52.3 keV)	Be (33.4 keV)	Li (18.7 keV)
Np			2-22
Bi			9-16
Sm+Gd	39-50		
Cs		31-36(0.5)	
Ra			10-19
Ag			22-25
Fe			6-7 (0.01)

Play with 241Am in Heidelberg?

MMC metrology example

A New Measurement of the 60 keV Emission from Am-241 using Metallic Magnetic Calorimeters

G. B. Kim, S. T. P. Boyd, R. H. Cantor, L. A. Bernstein, S. Friedrich

September 3, 2019

Crystal spec MMC (40 eV resolution)

169Yb: 63,120.44(3) -> 241Am: 59,539.3(3)stat(3)sys

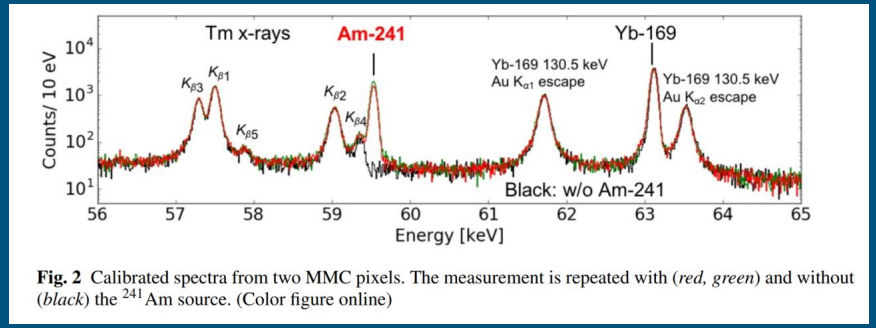
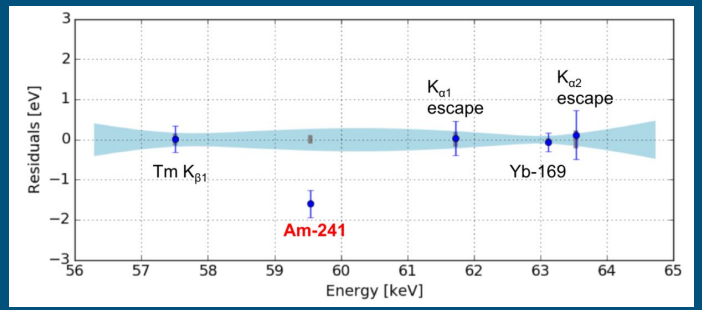


Fig. 2 Calibrated spectra from two MMC pixels. The measurement is repeated with (*red, green*) and without (*black*) the ^{241}Am source. (Color figure online)



Large difference from Literature value measured with solid-state detector without considering lineshape unc.
-> one has to be careful with literature values!

Mixed solid targets & muonic calibration:

Isot.	E_{1S-2P} keV
^{11}B	52
^{9}Be	33
^{7}Li	19

BN

LiF

“Known” to few ppm:

	E(3d-2p) keV
Be	7
B	10
C	14
N	19
O	25
F	32
Ne	39

← (Future direction, Interesting from 0.1eV)

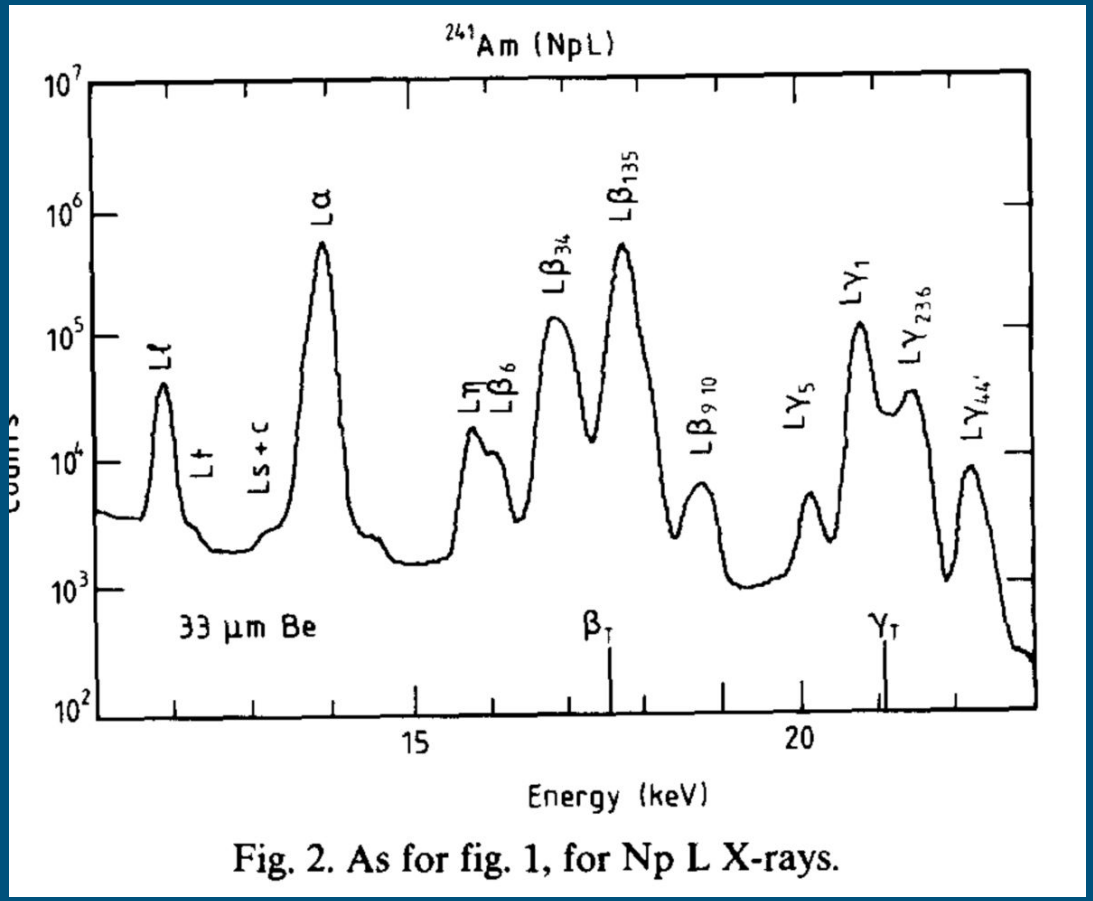
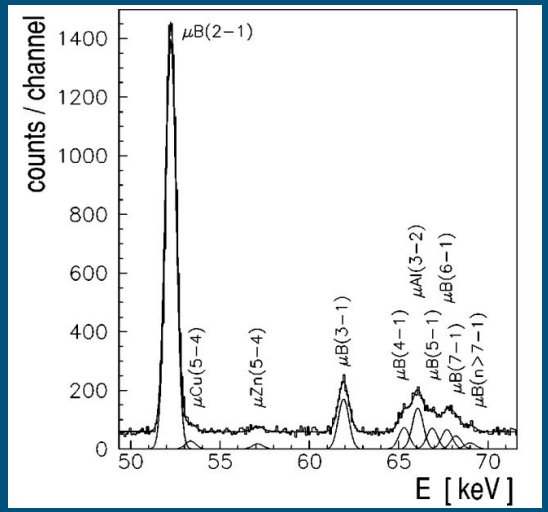
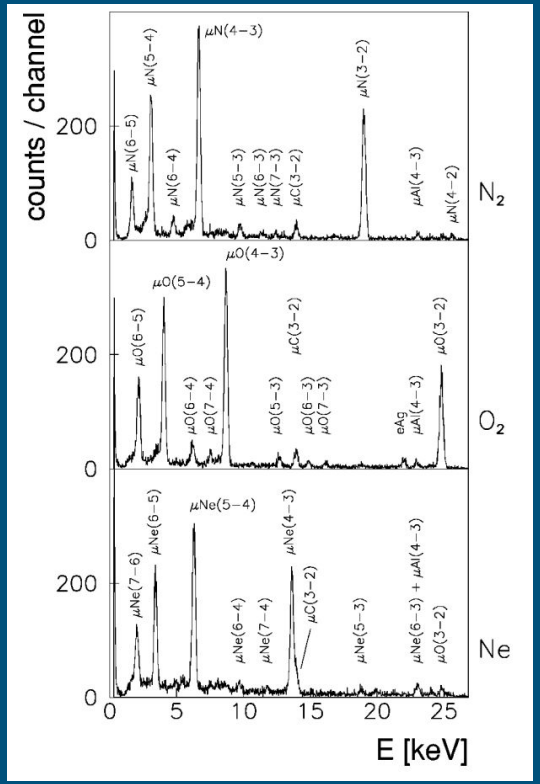
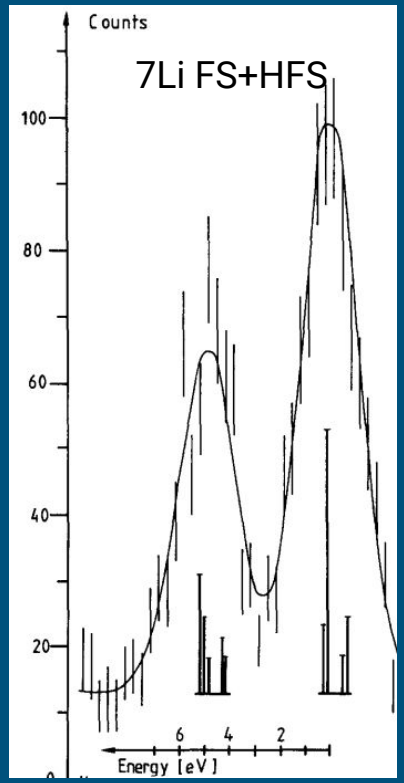


Fig. 2. As for fig. 1, for Np L X-rays.

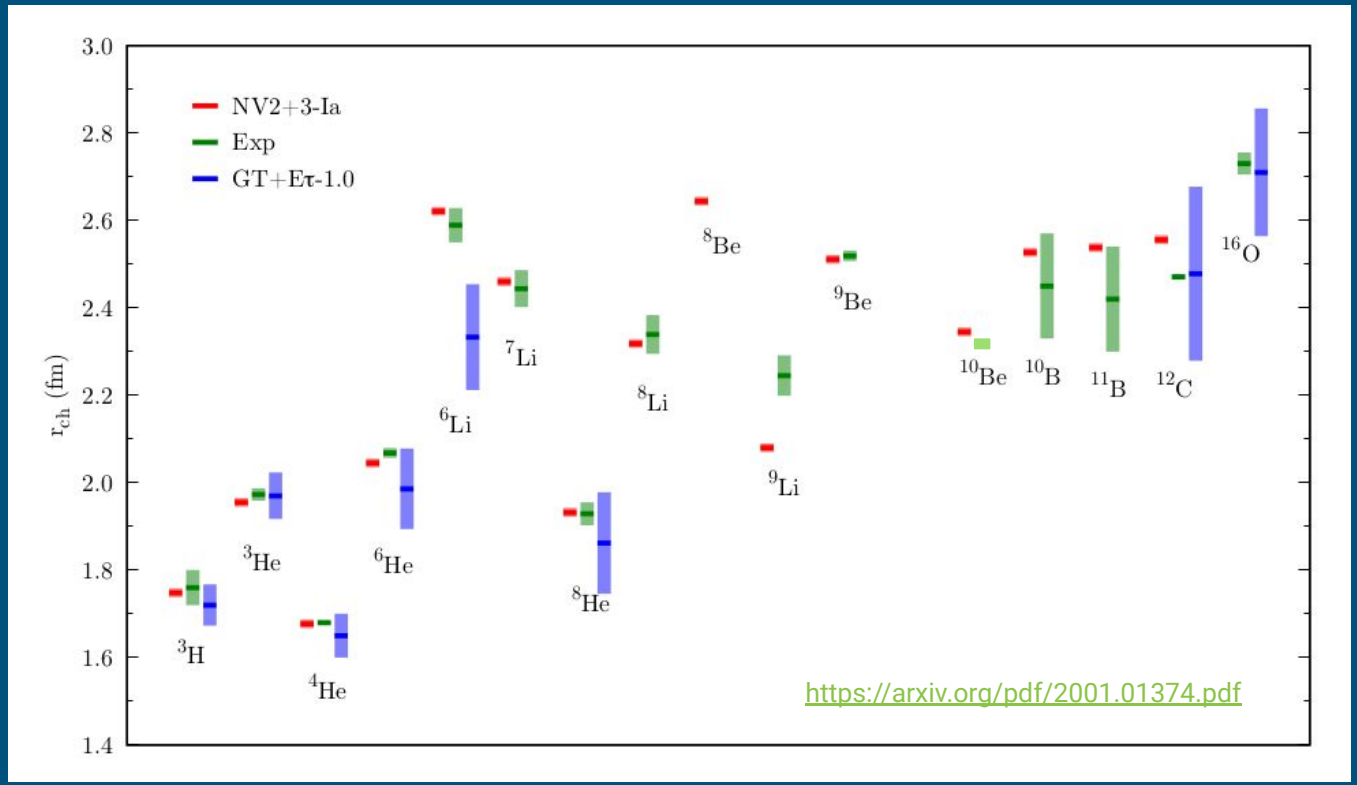
Some measured spectra:







Low Z <r2> and ab-initio/EFT/NN calculations

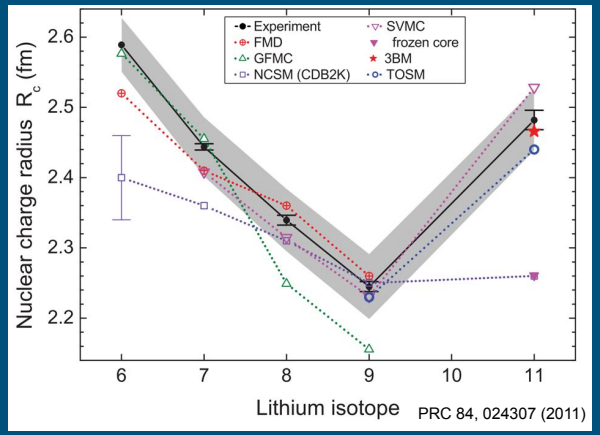


Absolute radii

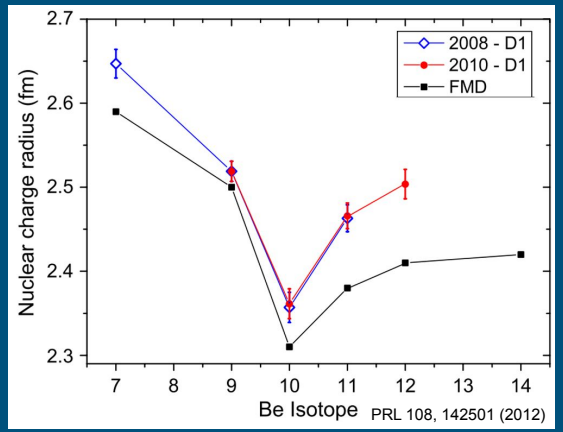
Absolute radii to anchor chains of isotope shift measurements. Test nuclear models.

Isot.	E_{1S-2P} keV	δ_{exp} eV	δ_{NP} eV	fm/keV	$\delta_r\ 10^{-3}$ fm	Gain	Good for
^{11}B	52	5 → 0.10	0.2 → 0.05	-6.7	21 → 0.8	26	Mir., HLI, Chain
^{9}Be	33	10 → 0.07	0.1 → 0.03	−16	12 → 1.3	9	Mir., HLI, Chain
^{7}Li	19	60 → 0.05	0.03 → 0.01	−47	42 → 2.4	17	Mir., Chain

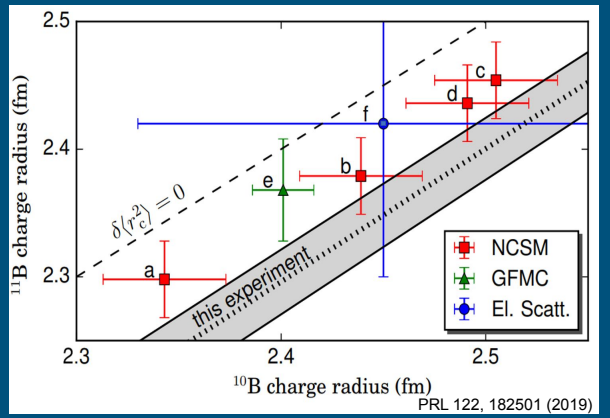
Lithium chain, limited by reference.
Can improve by factor ~20
No more grey band



Be chain, limited by reference.
Can improve by factor ~9



Improve **^{10,11}B** absolute and IS
By factor ~30
~size of blue datapoint



Up to N now accessible with No Core Shell Model with Continuum
Benchmark ab initio theory

Critical for upcoming ^{8}B measurement

Isotope shifts:

Not limited by calibration

	ΔE(2p-1s) eV	dΔr/Δr @ 1eV	dΔr fm scat.	dr/r EFT
Li6-7	50			
B10-11	62			