Isospin breaking and $\langle r^2_{\text{charge}}\rangle^{\frac{1}{2}}$ of $^{38\text{m}}$K

An observable related to isospin breaking of the initial and final states can be related to triplets of isobaric charge radii Seng and Gorchtein Phys Lett B 2023 (Ref. 2)
The Coulomb potential being r^2 inside of nuclei leads e.g. to a picture of purely Coulomb isospin breaking going through the isovector monopole resonance Auerbach, Loc NPA 2022

Isospin symmetry relates this contribution to δ_C and isobaric triplet $\langle r^2_{\text{charge}}\rangle^{\frac{1}{2}}$:

$$\Delta M_B^{(1)} \equiv \frac{1}{2}(Z_1\langle r_{\text{ch},1}\rangle^2 + Z_{-1}\langle r_{\text{ch},-1}\rangle^2) - Z_0\langle r_{\text{ch},0}\rangle^2$$

Seng Gorchtein Eq. 22

Only triplet with $\langle r^2_{\text{charge}}\rangle^{\frac{1}{2}}$ known is A=38:
^{38}Ca 3.467(1) fm, $^{38\text{m}}$K 3.437(4) fm, ^{38}Ar 3.4028(19) fm
$\Rightarrow \Delta M_B^{(1)}$ = -0.03(54) fm^2; models span 0.42 to 0.04 fm^2

So making $\langle r^2_{\text{charge}}\rangle^{\frac{1}{2}}$ of $^{38\text{m}}$K 2-3x better using 4S $\rightarrow$ 4P makes it as good as the other two

An order of magnitude better $^{38\text{m}}$K using 4S $\rightarrow$ 5P is needed to enable $\sim$ 10% tests of ISB

Estimation of $\Delta M_B^{(1)}$ and $|\Delta M_B^{(1)}/(AR^2/2)|$ from different models.

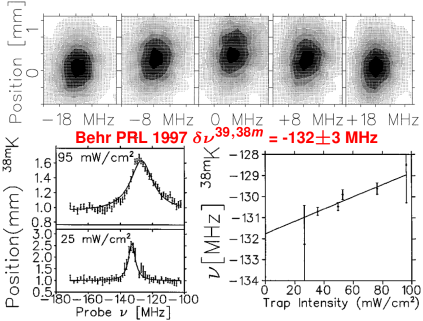
Transitions	$\Delta M_B^{(1)}$ (fm^2)				
	WS	DFT	HF	RPA	Micro
^{26m}Al $\rightarrow$ ^{26}Mg	-0.12	-0.12	-0.11	-0.05	-0.03
^{34}Cl $\rightarrow$ ^{34}S	-0.17	-0.21	-0.16	-0.06	-0.04
^{38m}K $\rightarrow$ ^{38}Ar	-0.15	-0.42	-0.15	-0.07	-0.04

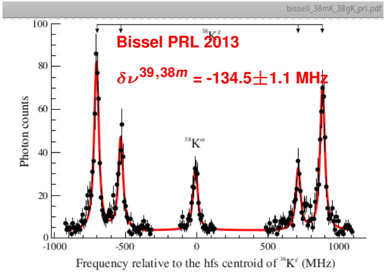
Towner'20 Satchula'16 Ormand Brown'95

We hope to interest the ab initio nuclear theory community to calculate $\langle r^2_{\text{charge}}\rangle^{\frac{1}{2}}$ along with ISB

The isospin doublet tests don't need quite as much accuracy:

^{38m}K $\langle r^2_{charge} \rangle^{\frac{1}{2}}$ methods



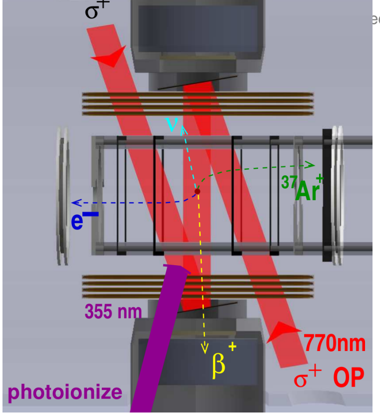


To optically pump our atoms better, we have improved all metrology

Fenker NJP 2016:

- **trap light off**
- **B < 50 mG**

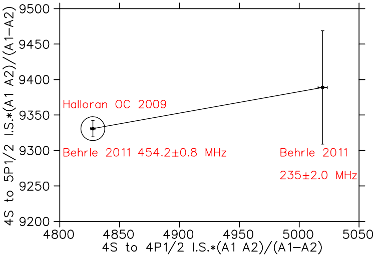
Will measure ^{37}K resonances for S1188– it removes 1 fit parameter determining our nuclear spin



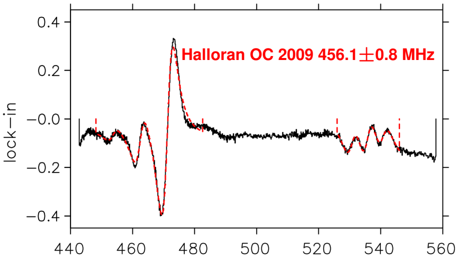
polarization by atomic techniques. Then we will be ready to measure ^{38m}K again. We should achieve the natural linewidth Γ= 6 MHz, with goal < 0.1 Γ accuracy

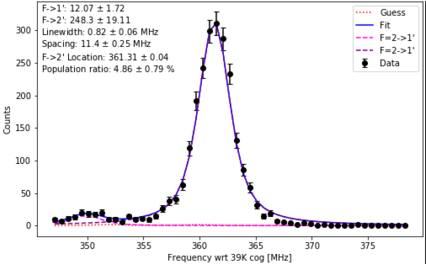
TRINAT plans in $4S_{1/2} \rightarrow 5P_{1/2}$: Γ = 1.1 MHz for 0.1 MHz accuracy

$4S_{1/2}$ to $5P_{1/2}$ K_{SMS}:
Behrle et al. semiempirical (from optical isotope shift, muonic atoms...):
~~−39~~$\pm$5 GHz-amu (Ref. 18)
Optical I.S. precision needs improvement to test theory:
Sahoo (preliminary):
-22 $\pm$ 4 GHz-amu



From a stable alkali metal dispenser, we plan to trap ^{40}K to try to reduce its optical isotope shift error from 2 MHz to less than 0.5 MHz, to make a better test.





^{41}K Trap $5P_{1/2}$ photoions
F. Klose TRINAT co-op 2022
FWHM $<$1.9 MHz

Once that metrology is demonstrated, we would be ready to measure ^{38m}K wrt ^{39}K to 0.1 MHz with TRINAT.