Nuclear Charge Radii of Mg Isotopes by Laser Spectroscopy with Combined Fluorescence and β-decay Detection

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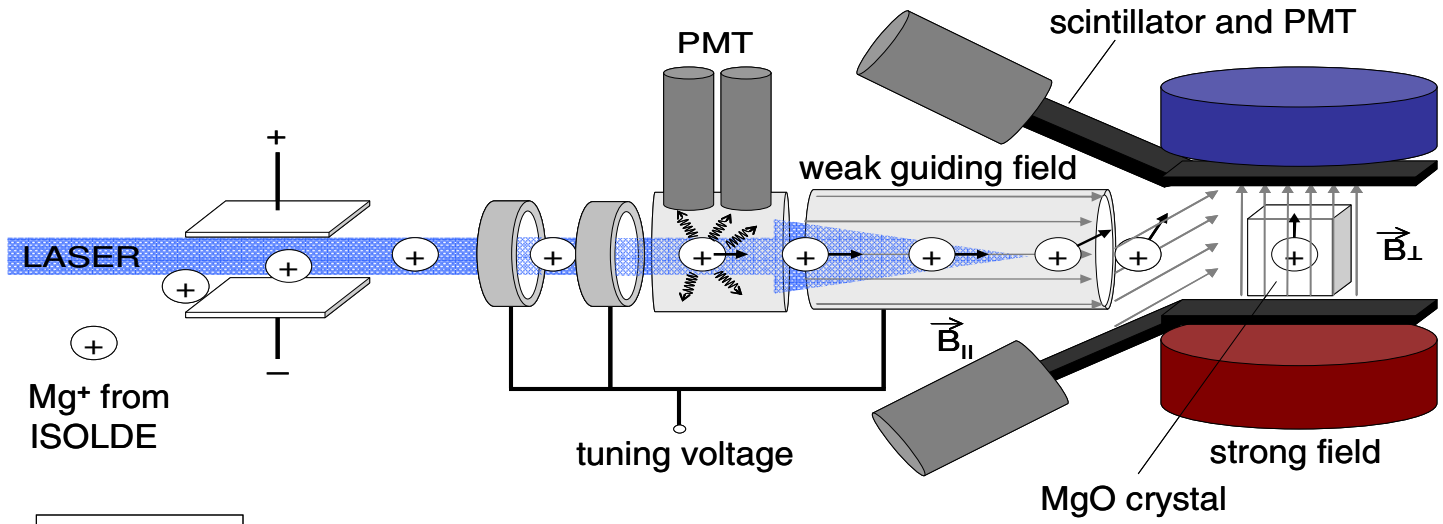
The β detection method



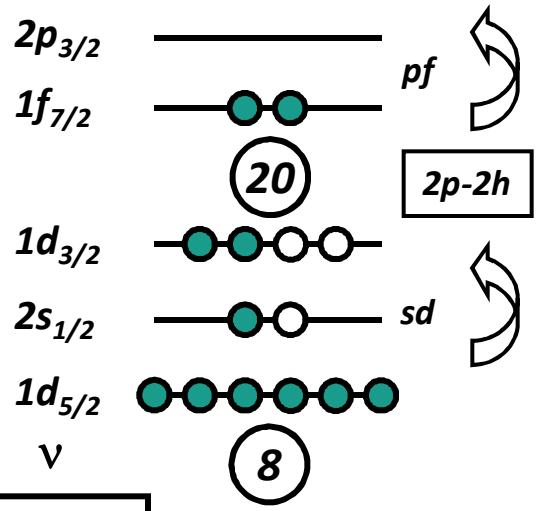
acceleration → deflection → Doppler tuning → optical pumping → β-asymmetry detection

Doppler tuning → optical detection

Shell Structure of Mg Isotopes - „Island of Inversion“

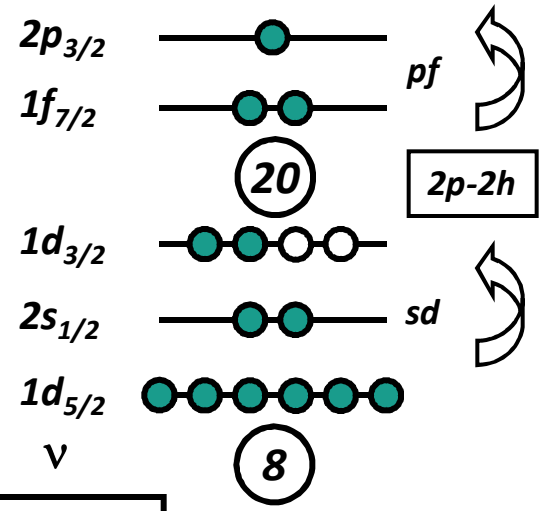
$\mu = -0.88355(15)\mu_N$
$\mu_{Theory} = -0.84\mu_N$
$\mu_{Schmidt} = -1.9\mu_N$

^{31}Mg (Z=12, N=19)

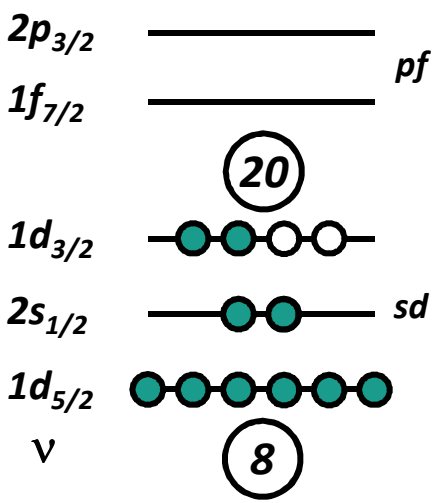


$\mu = -0.7456(5)\ \mu_N$
$\mu_{Theory} = -0.71\mu_N$
$\mu_{Schmidt} = -1.9\mu_N$

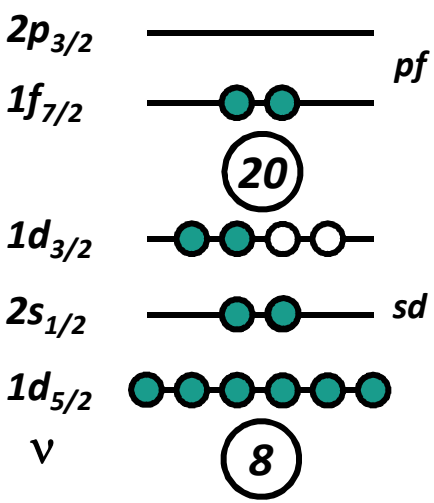
^{33}Mg (Z=12, N=21)



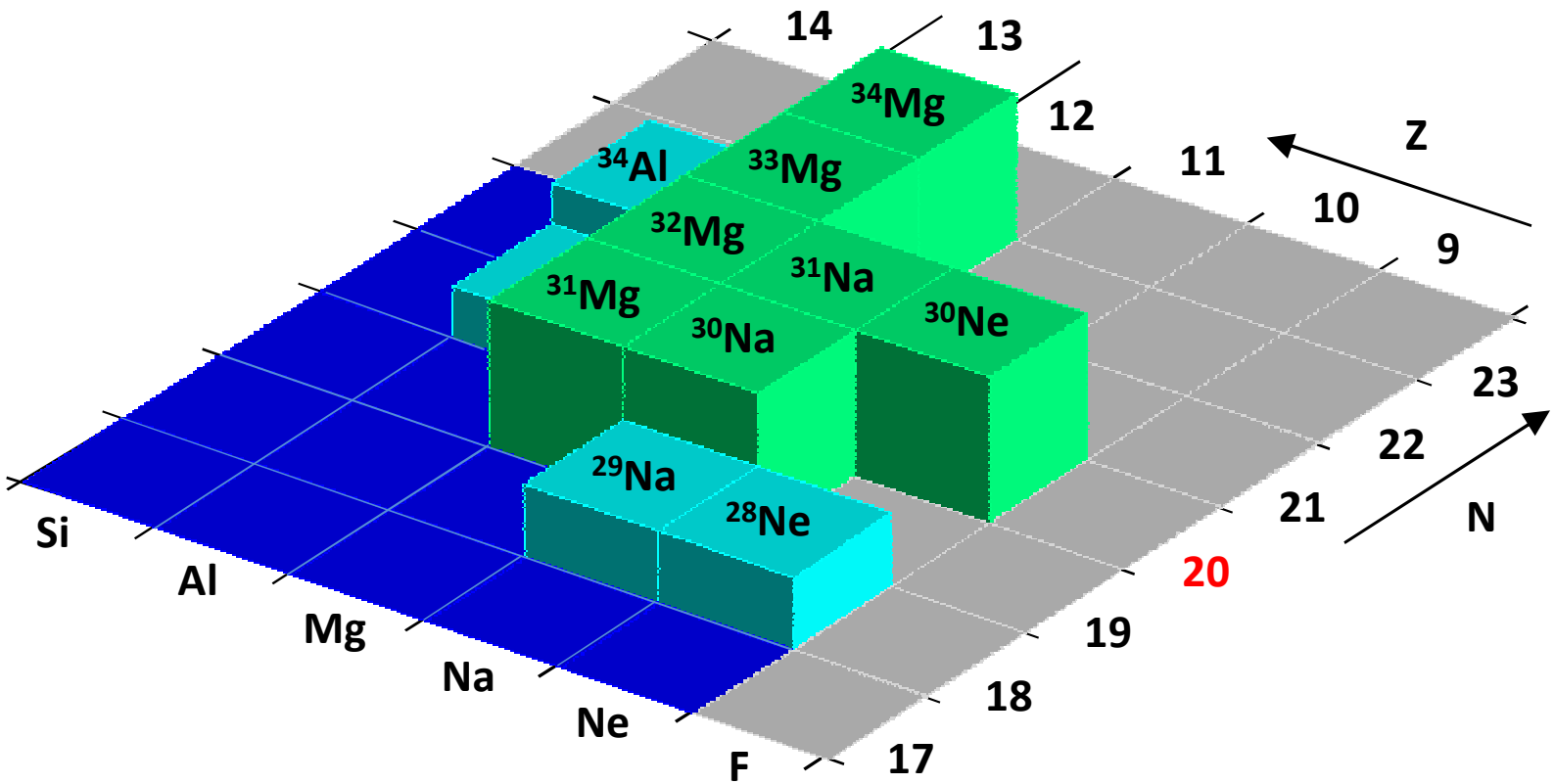
^{30}Mg (Z=12, N=18)



^{32}Mg (Z=12, N=20)

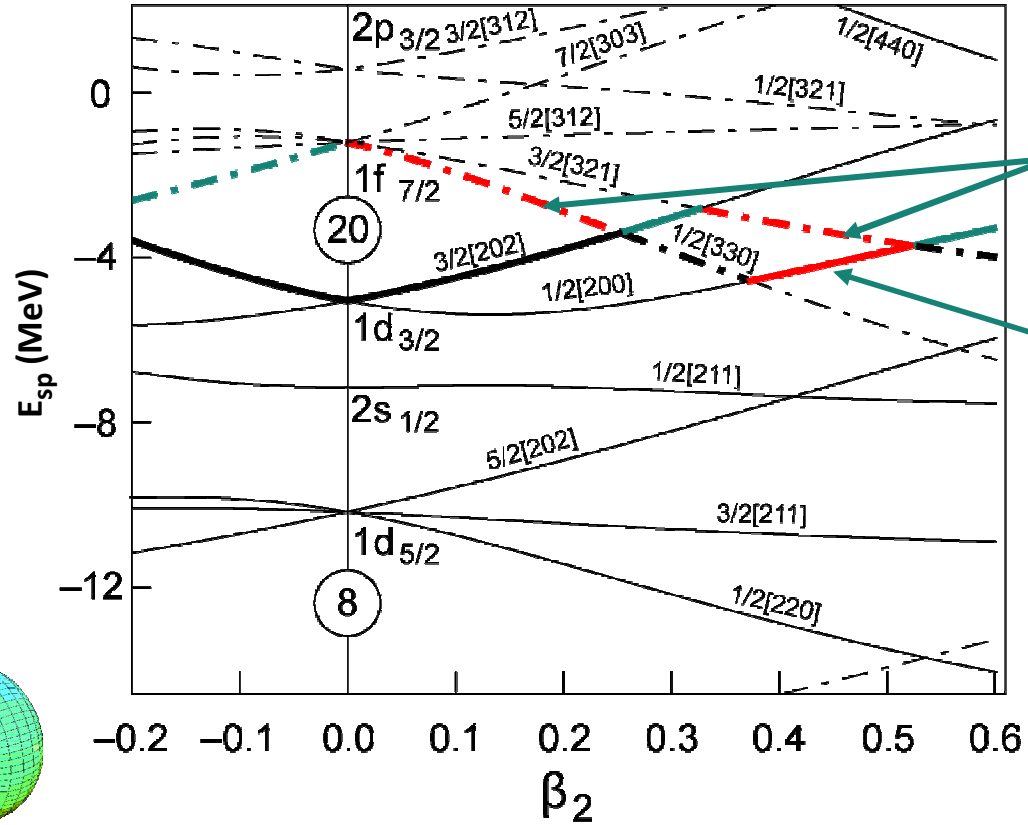


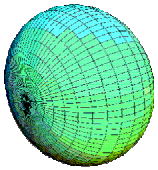
The Island of Inversion an Island of Deformation?

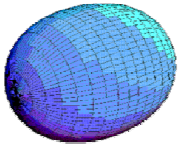


The "island of inversion" in terms of the SPHERICAL shell model.
The height of the boxes represents the amount of particle-hole configurations present in the ground-state wave functions.
(*analogous to a figure from* P. Himpe *et. al.*, Phys. Lett. B **658**, 203 (2008).**)**

Does Deformation Explain the ^{31,33}Mg spins and moments?







^{33}Mg, $I^{\pi} = 3/2^{(-)}$

1/2[330]: μ = -0.76 μ_N

3/2[202]: μ = +0.80 μ_N

3/2[321]: μ = -0.32 μ_N

^{31}Mg, $I^{\pi} = 1/2^{+}$

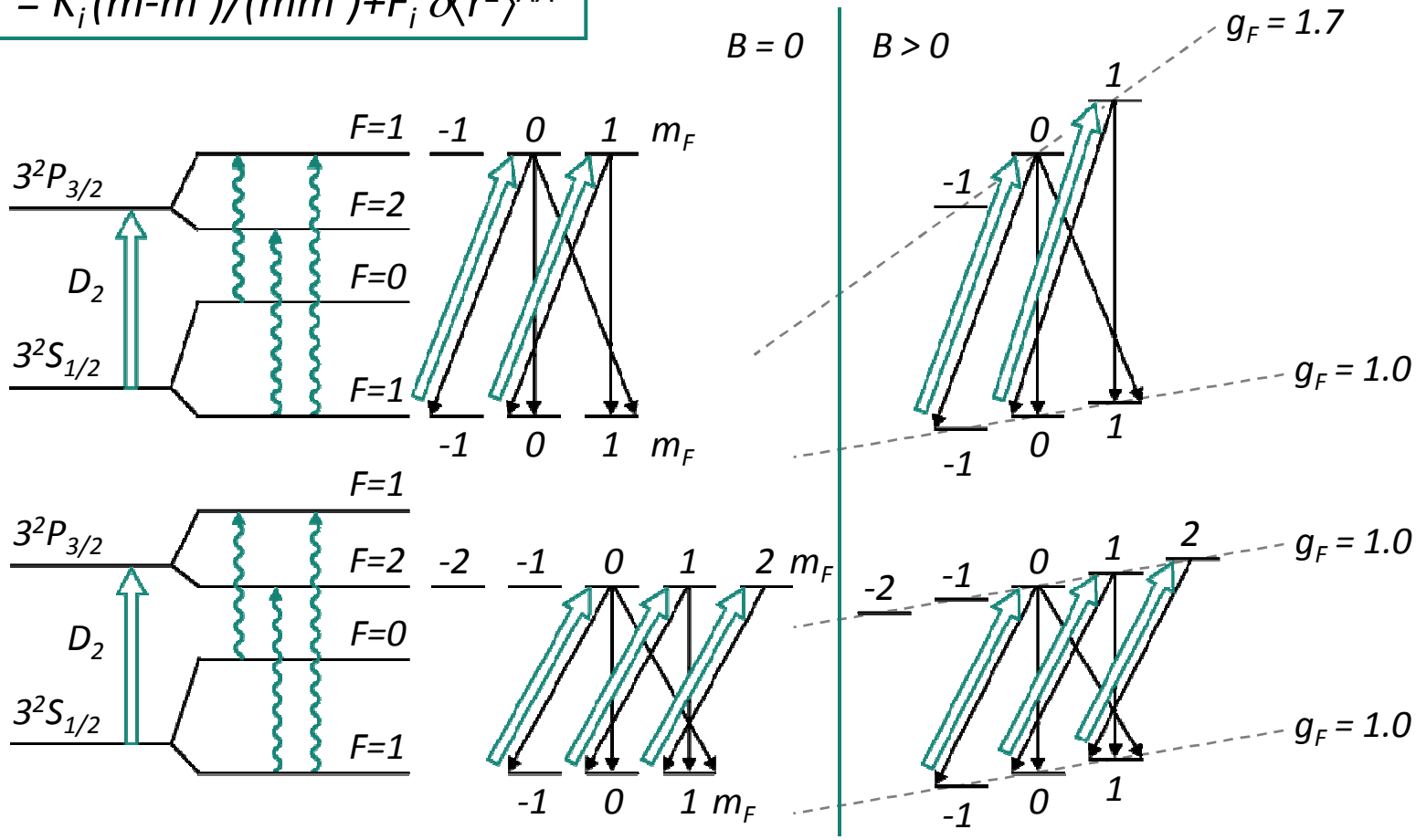
1/2[200]: μ = -0.86 μ_N

^{31}Mg	***μ = -0.88355(15)μ_N***
^{33}Mg	***μ = -0.7456(5)μ_N***

- ***Q_S(^{31}Mg)=0. Quadrupole-moment measurements of ^{29,33}Mg - not feasible;***
- ***Necessity of a common observable for all isotopes in order to detect the transition to a deformed configuration;***

Isotope shifts by β detection

$$\delta\nu_i^{AA'} = K_i(m-m')/(mm') + F_i\,\delta\langle r^2\rangle^{AA'}$$



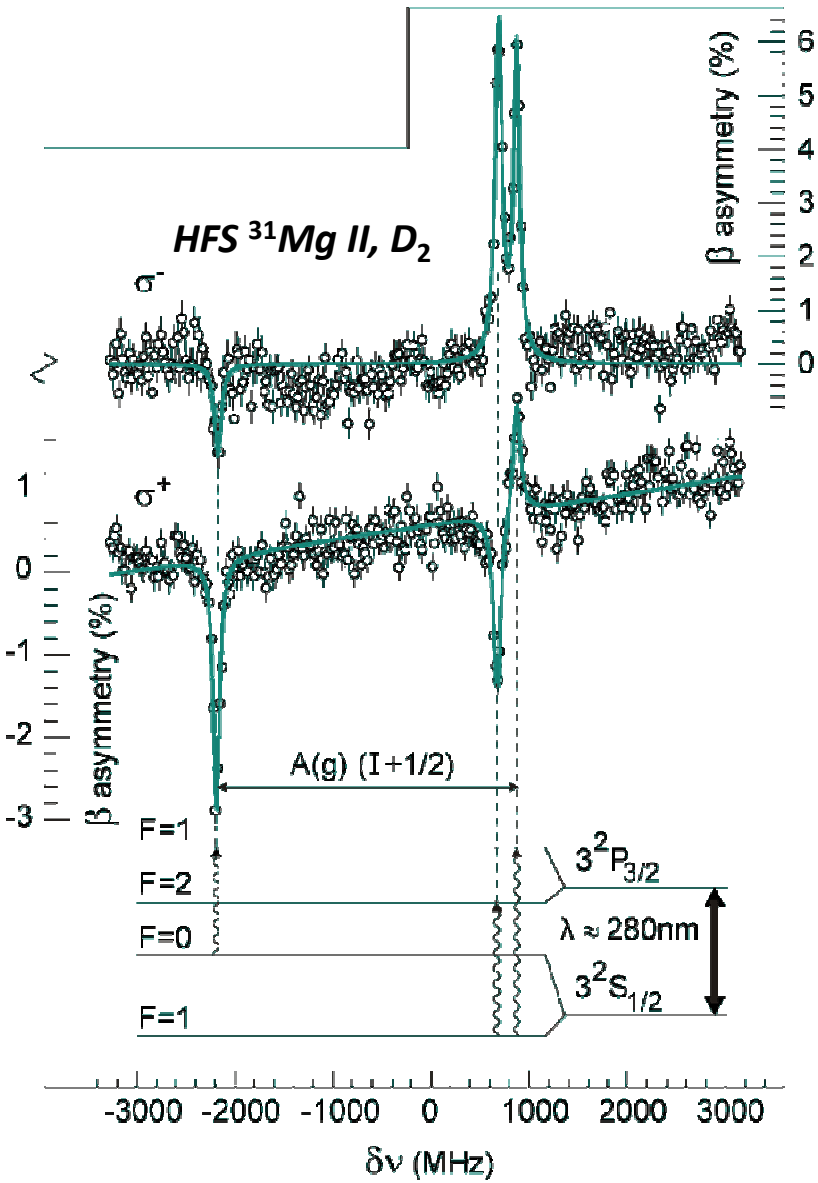
Influence of the guiding field on the atomic lines:

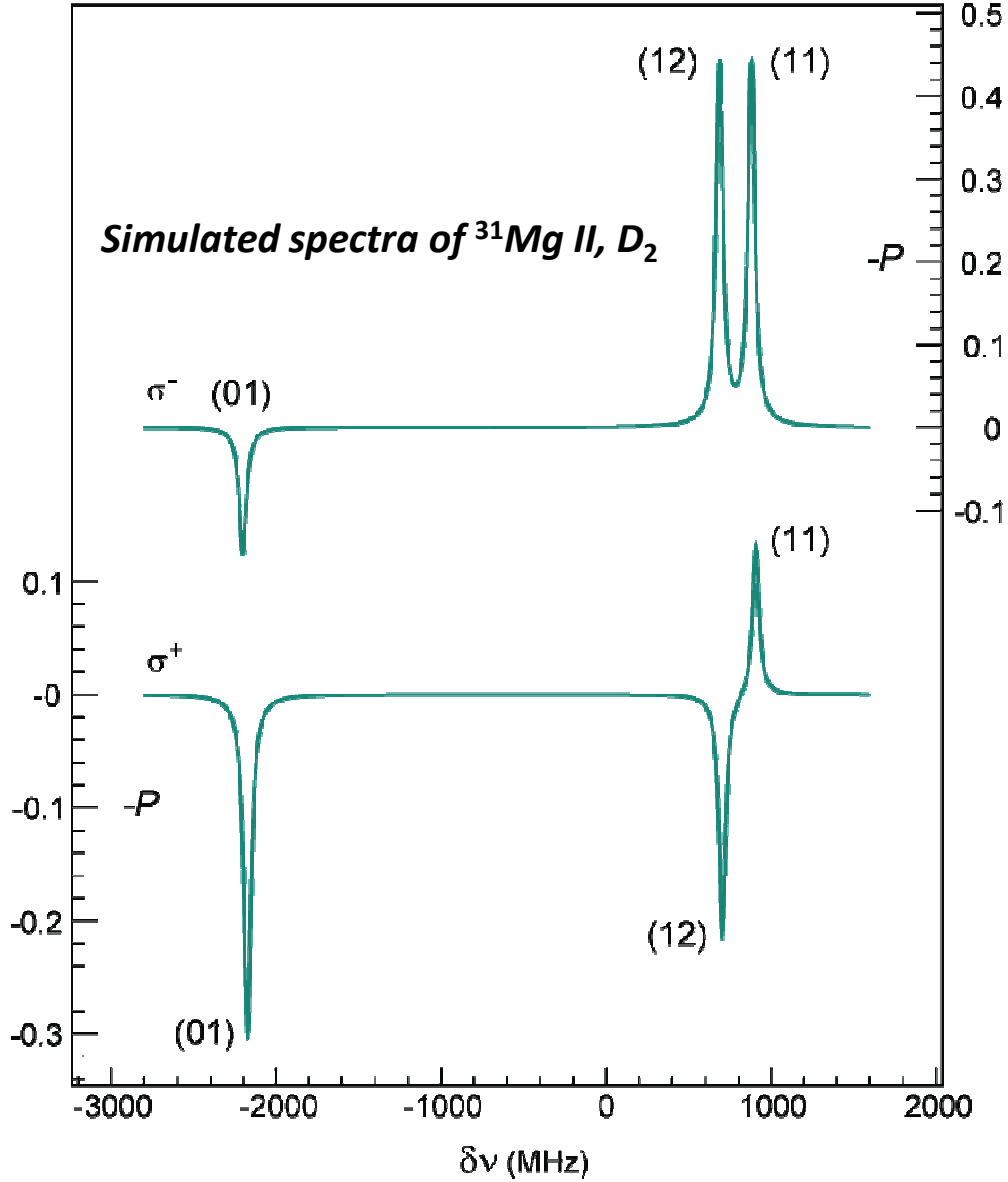
- *shift*
- *broadening*

One can solve numerically the rate equations and quantitatively describe these effects.

M. Keim *et al.*, Eur. Phys. J. A **8**, 31 (2000).

Isotope shifts by β detection

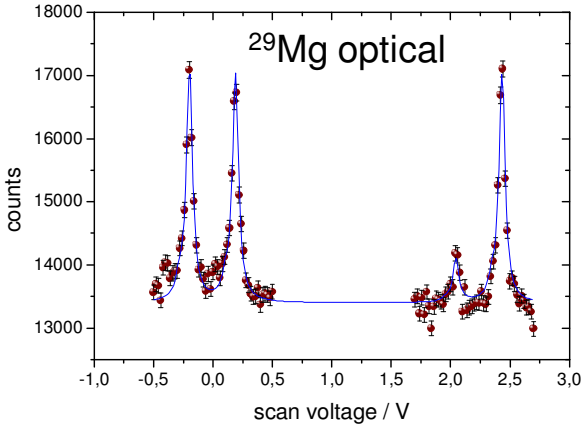


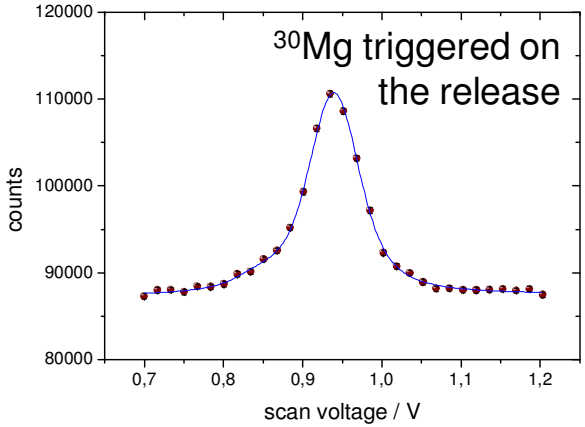


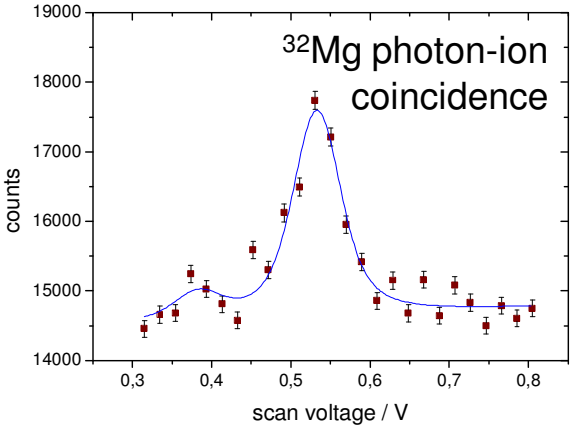
M. Kowalska *et al.*, Phys. Rev. C **77**, 034307 (2008).

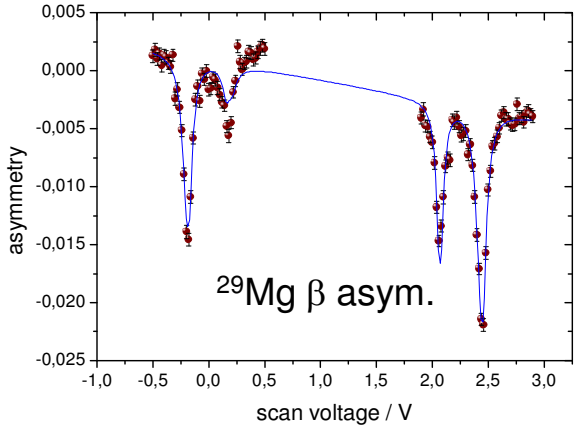
First use of β detection for isotope-shift measurments

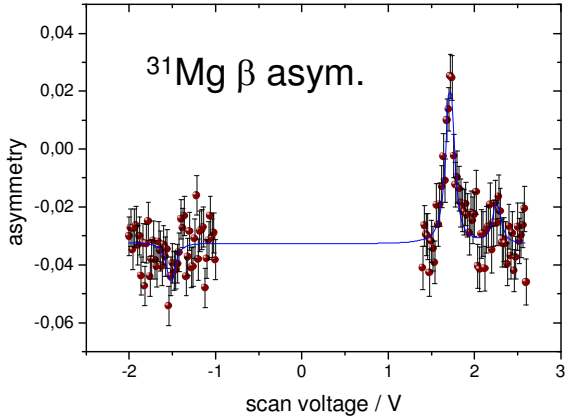
Preliminary Results on ^{24}Mg - ^{32}Mg from September 2009











^{29}Mg	1.2×10^6 ions/μC
^{30}Mg	4.6×10^5 ions/μC
^{31}Mg	1.5×10^5 ions/μC
^{32}Mg	4.2×10^4 ions/μC
^{33}Mg	5.3×10^3 ions/μC

^{21}Mg	3×10^3 ions/μC
^{21}Na	4×10^8 ions/μC

Proof of principle:
^{29}Mg optical and β detection are consistent!

Charge radii of Magnesium Isotopes

radii from muonic data

Fricke et al., Phys. Rev. C45 (1992) 80

Isotope shifts

King plot

K_{SMS}=367,3(3) GHz u

$\delta\langle r^2\rangle$

theoretical calculation

electronic factor F

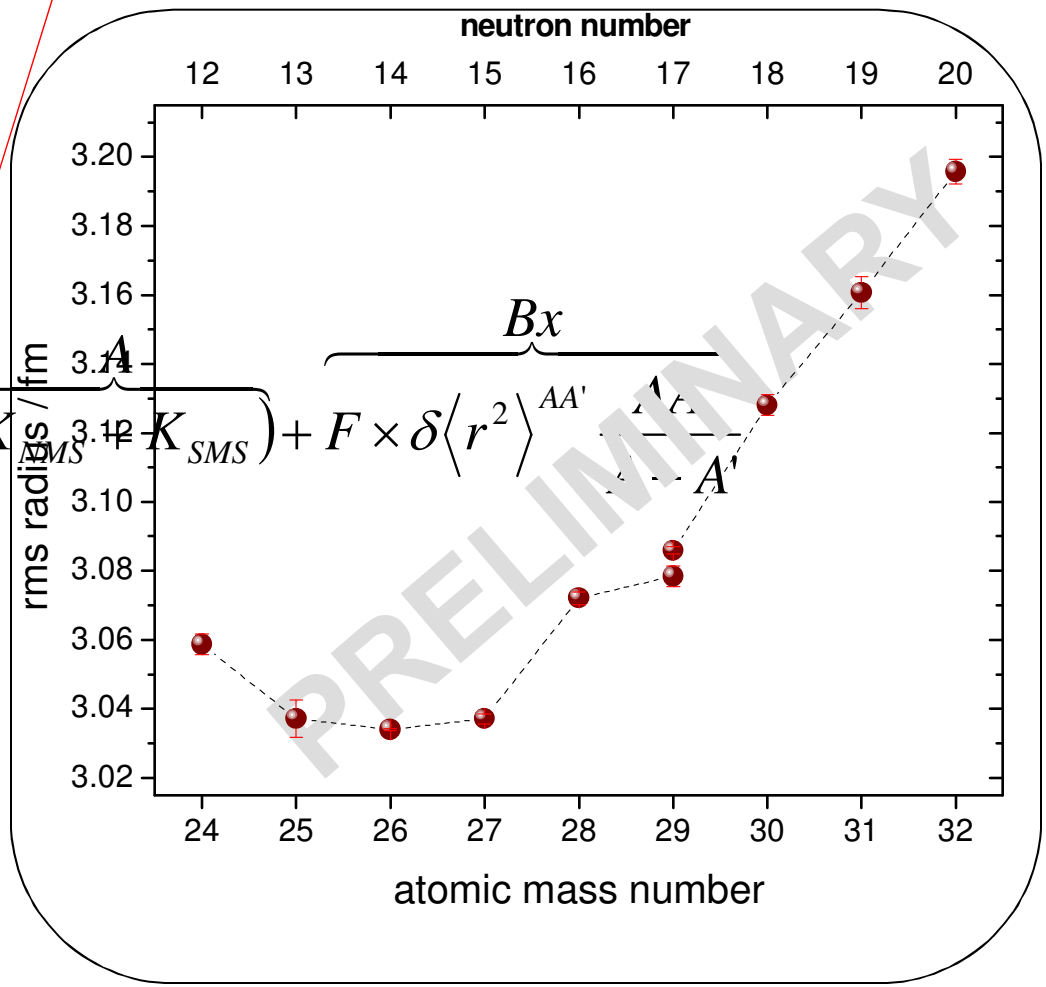
Berengut et al., Phys. Rev. A68 (2003) 022502

reference radius:

r_C (^{26}Mg) =3.034(2) fm

Fricke et al., Phys. Rev. C45 (1992) 80

$$\delta\nu_{IS}^{AA'} \times \frac{AA'}{A-A'} = \overbrace{\left(K_{AMS} + K_{SMS}\right)}^{A} + \overbrace{F \times \delta\langle r^2\rangle^{AA'}}^{Bx} \times \frac{AA'}{A-A'}$$



Discussion: PRELIMINARY

Isotope shift ^{24}Mg-^{26}Mg: 3077(2)(9) MHz -in agreement with trap measurement: 3084.905(93) MHz

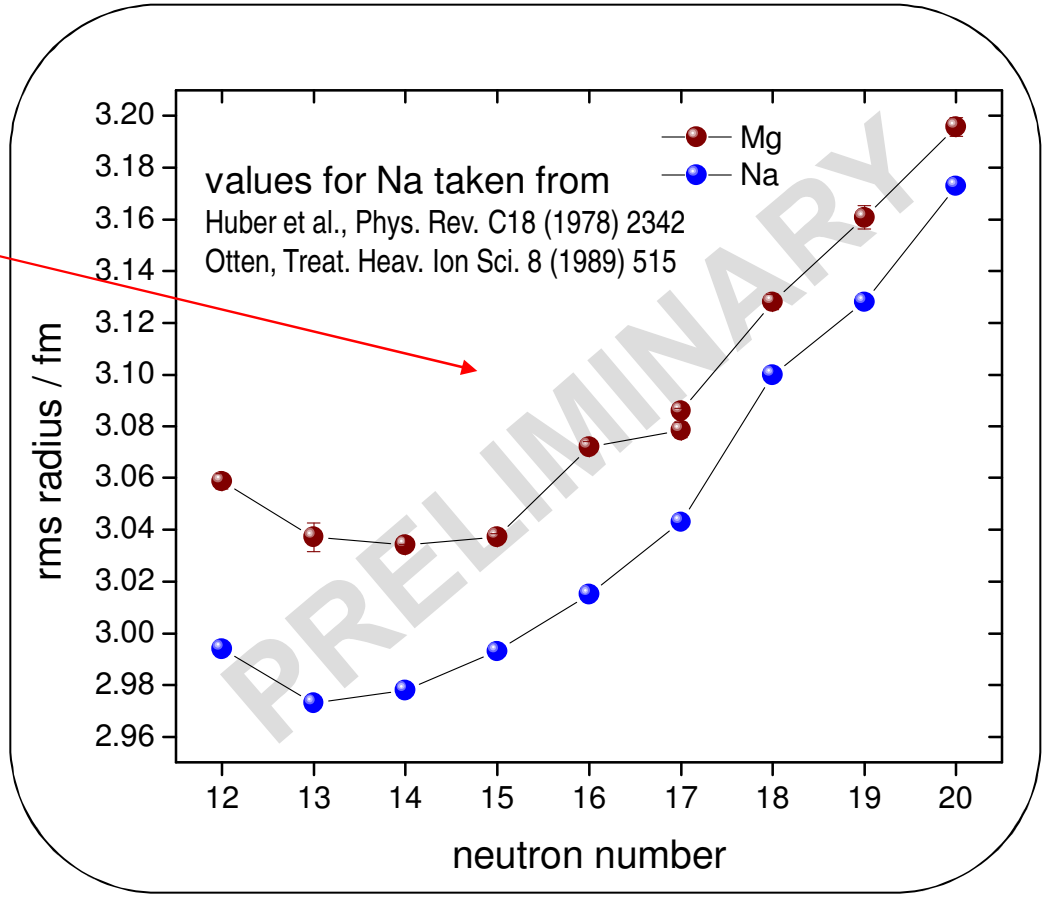
Batteiger et al. Phys. Rev. A80 (2009) 022503

radii

- Mg and Na reveal similar trend
- Indication for an effect at ^{30}Na and ^{31}Mg

$$\gamma^N = \frac{2\delta\langle r^2\rangle^{N,N-1}}{\delta\langle r^2\rangle^{N+1,N-1}} \quad N\ odd$$

Isotope	γ
^{31}Mg	0.958
^{29}Mg	0.489
^{27}Mg	0.164



staggering parameter <1, well within the known systematics