# Magnetic moment in self - conjugate $^{24}$Mg. Towards high-precision measurements of picosecond excited states with RIB.

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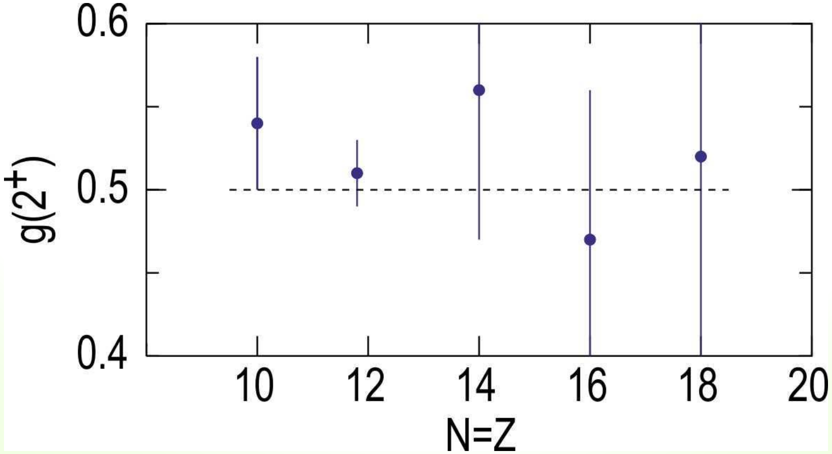
- Physics motivation

*Why do we need high-precision measurements of nuclear moment?*

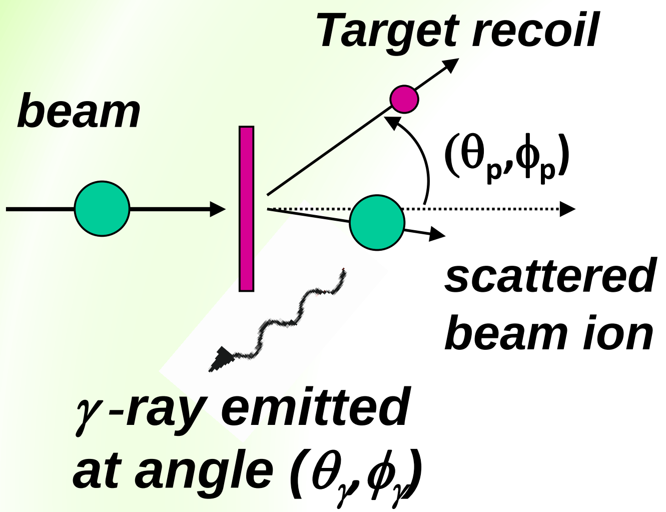
- Time Dependent Recoil In Vacuum (TDRIV) on H-like ions
  - *Experimental approach for stable ions*
  - *Peculiarities for RIB studies*
  - *g factor of $^{24}$Mg – revisited. **Prove of principle and physics results***
- Conclusions and perspectives

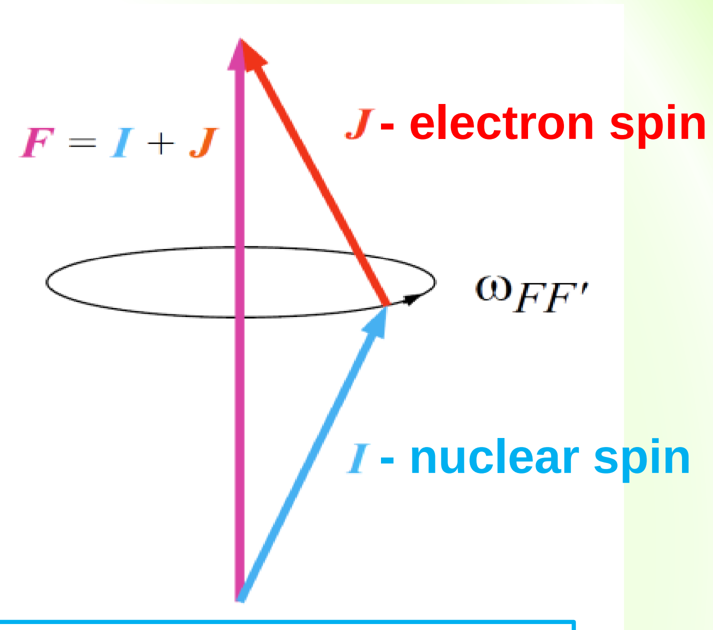
# Physics motivation

- g factors in self-conjugated nuclei – expected to be equal to 0.5
- Shell-model calculations – a sizeable departure from g=0.5 (up to 10%) for $2^+$ states in $^{20}$Ne – $^{36}$Ar (W. A. Richter, S. Mkhize, and B. A. Brown, Phys. Rev. C 78, 064302 (2008).)
- Experimental values – "consistent" with g=0.5



# Electron-nuclear spin interaction in vacuum




$$W(\theta_p,\theta_\gamma) = \sum_{k,q} \sqrt{2k+1}\,\rho_{kq}(\theta_p) G_k F_k Q_k D_{q0}^{k*}(\phi_\gamma - \phi_p, \theta_\gamma, 0)$$

$$G_k(t) = \sum_{F,F'} C_{FF'} \exp(-\omega_{FF'} t)$$

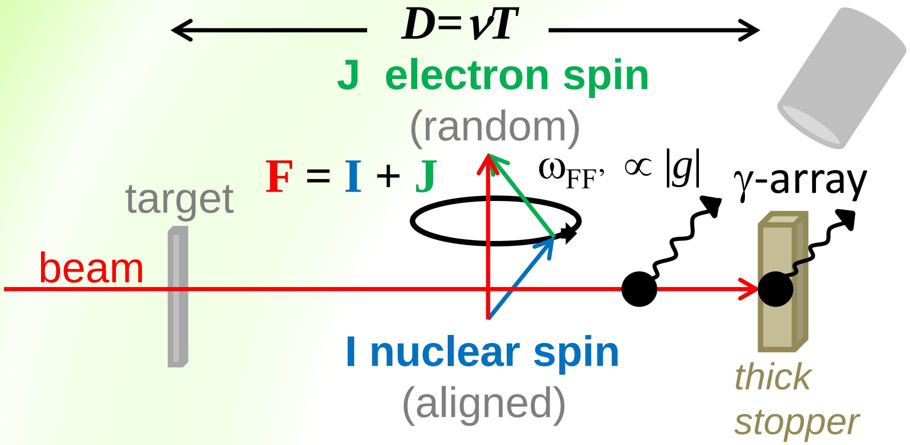
$$(0 \le |G_k| \le 1)$$

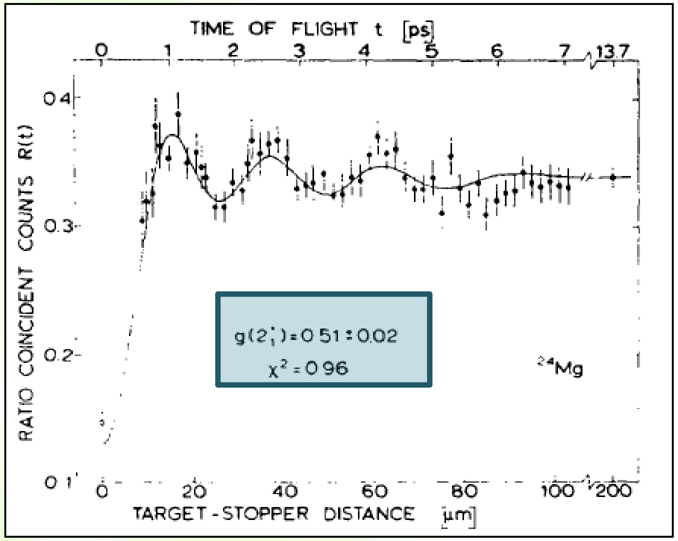
attenuation coefficients – a measure for the electron – nuclear spin interaction

$$\omega_{FF'} = \{F(F+1) - F'(F'+1)\} \frac{\mu_N B}{2\hbar J} g$$

interaction frequency - depends on I and J – **single frequency for J=1/2**

# Time Dependent Recoil In Vacuum (stable beams)

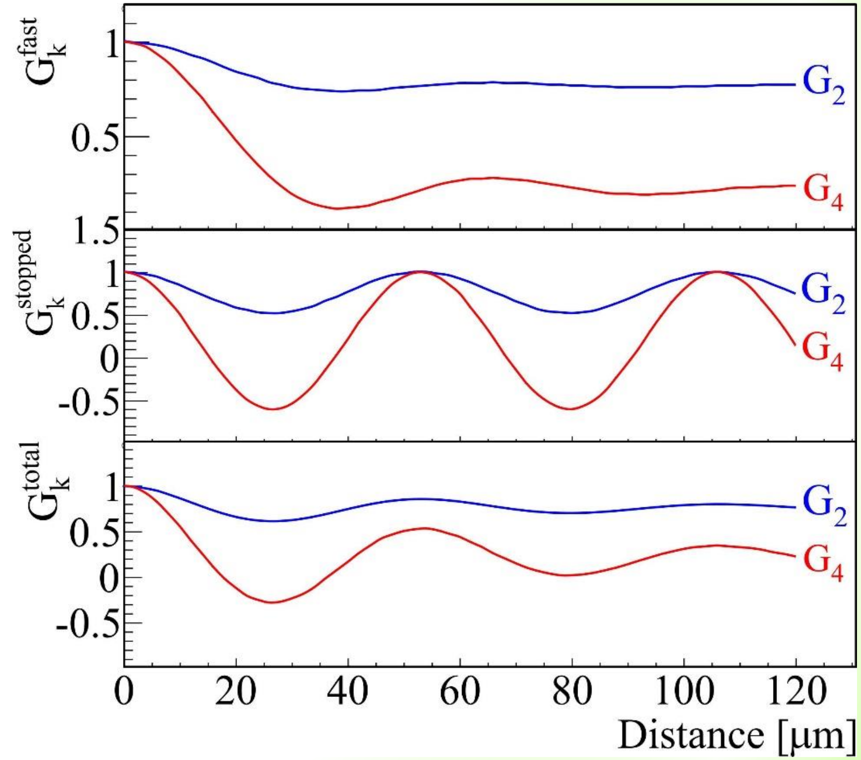



R.F. Horstman *et al.*, Nucl. Phys. **A248**, 291 (1975)

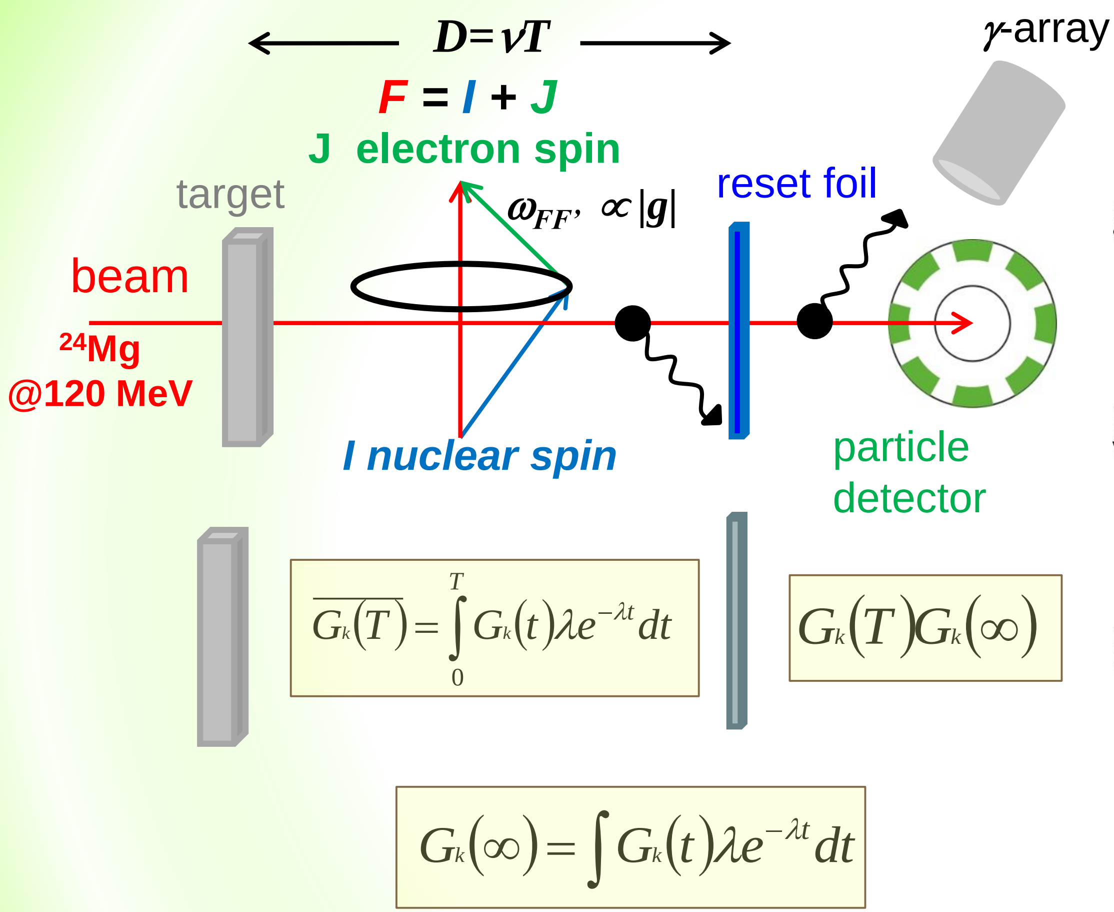
**H-like ions**

attenuation factor




- ***magnetic field*** *for H-like ions – can be calculated from first principles!*
- *pure H-like charge state could not be achieved (~15 %)*

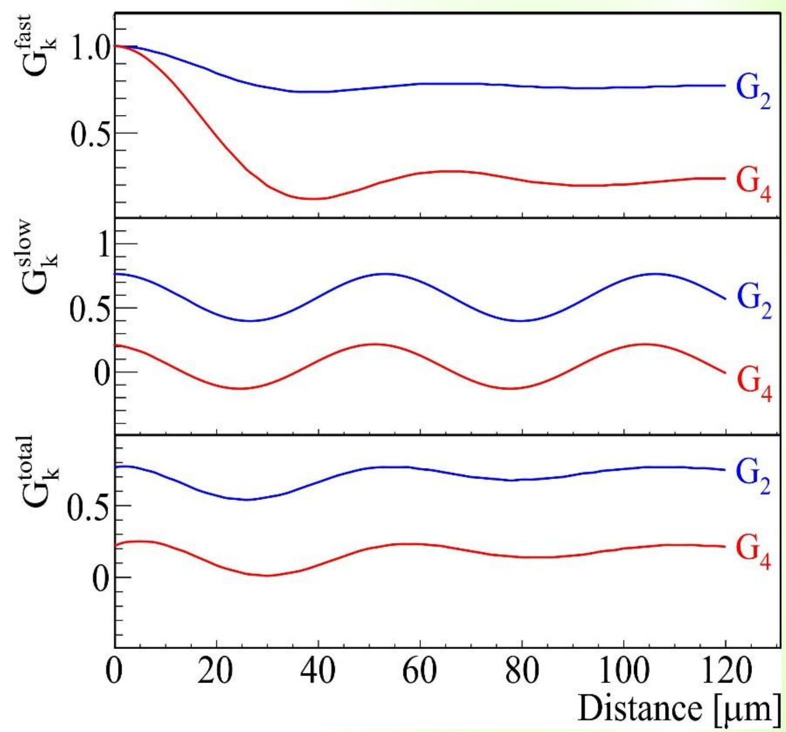
# TDRIV – radioactive beam geometry




$$\overline{G_k(T)} = \int_0^T G_k(t)\lambda e^{-\lambda t}dt$$

$$G_k(T)G_k(\infty)$$

$$G_k(\infty) = \int G_k(t)\lambda e^{-\lambda t}dt$$

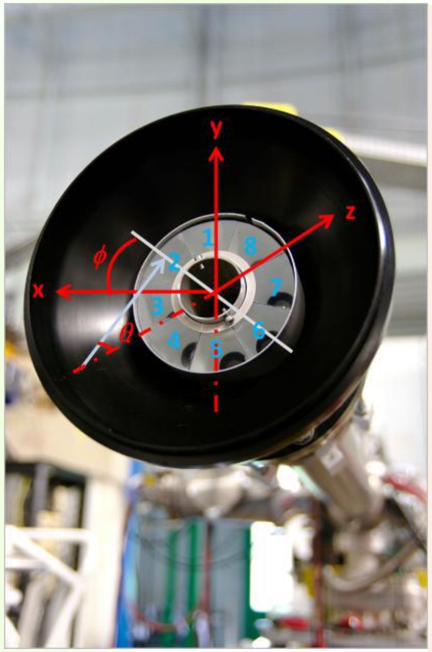


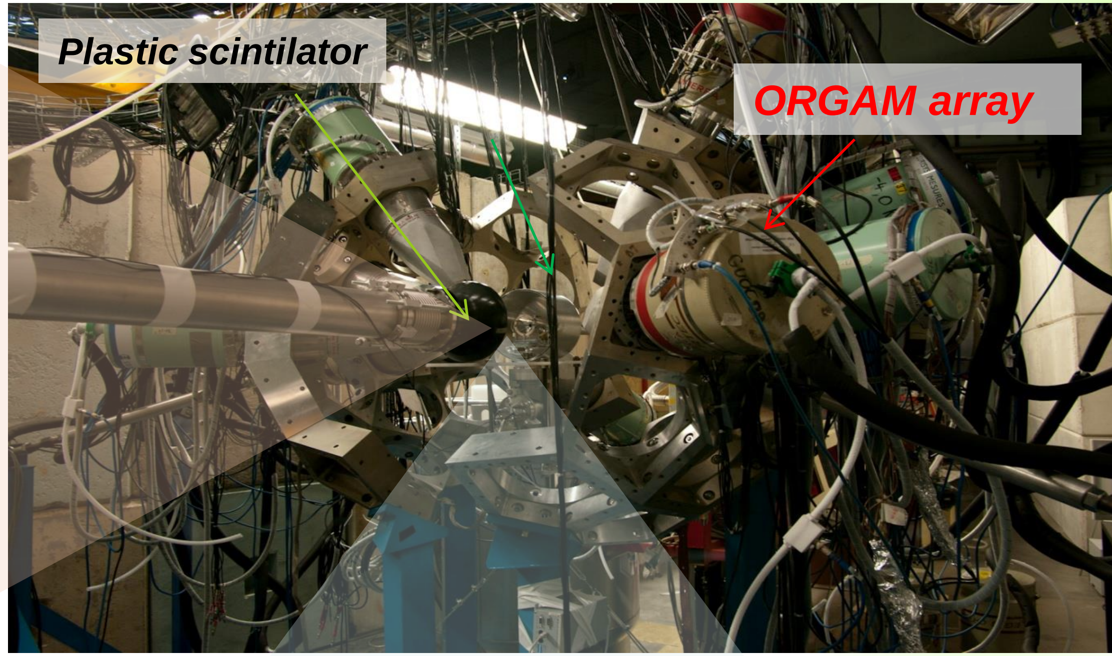

***A.E. Stuchbery et al., Phys. Rev. C71, 047302 (2005).***

The same oscillation frequency can be found even after the reset foil

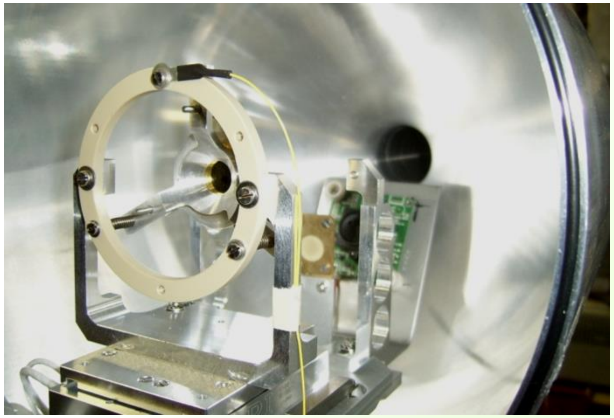
(with some damping of the amplitude due to the hard-core attenuation)

# Experimental setup @ ALTO




- ✓ 13 HPGe @ θ= 46.5°, 72.1°, 85.8°, 94.2°, 108.0°, 133.6°, 157.6°
- ✓ 8-fold segmented annular detector
- ✓ Orsay Universal Plunger System (OUPS)

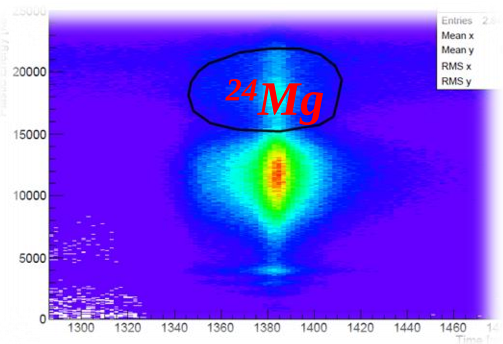


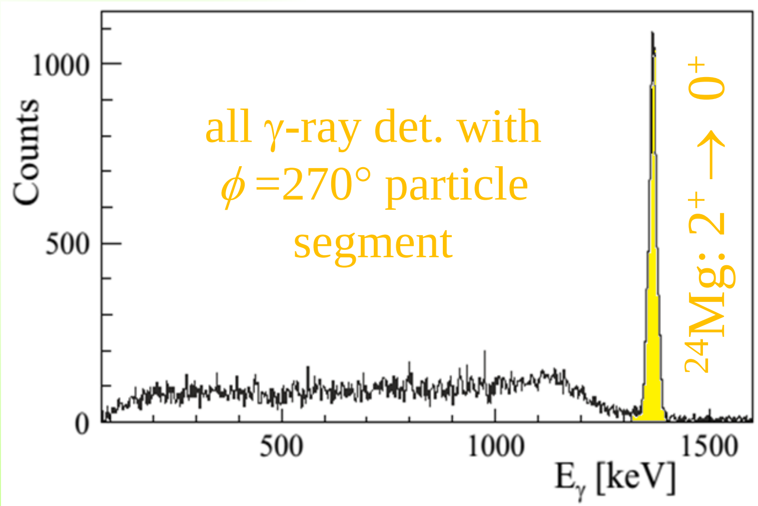
OUPS

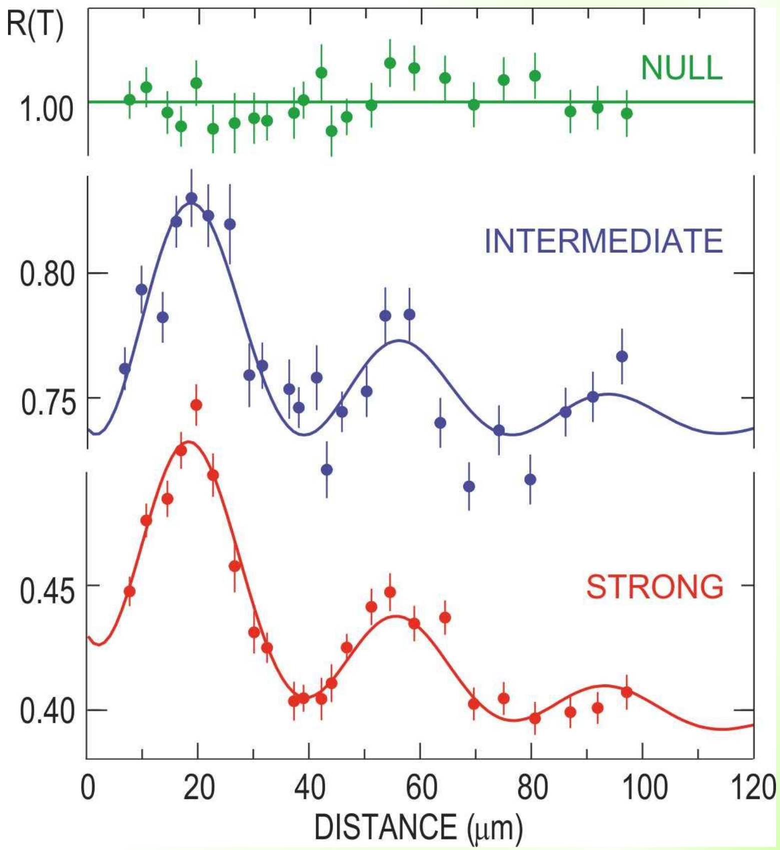
# Experimental details

beam: $^{24}$Mg @120 MeV, 0.3 pnA
target: 2.4 mg/cm$^2$ $^{93}$Nb
reset foil: 1.7 mg/cm$^2$ $^{197}$Au
distances: 24
time: ~2 h/distance

$$R(T) = \left( \prod_{i=1}^{n} \frac{W_i^{\uparrow}(T)}{W_i^{\downarrow}(T)} \right)^{1/n}$$



# Physics results

**Our result:**

PRL 114, 062501 (2015), A. Kusoglu et al.

**→ $|g(2^+)|$ $^{24}$Mg = 0.538 (13)**

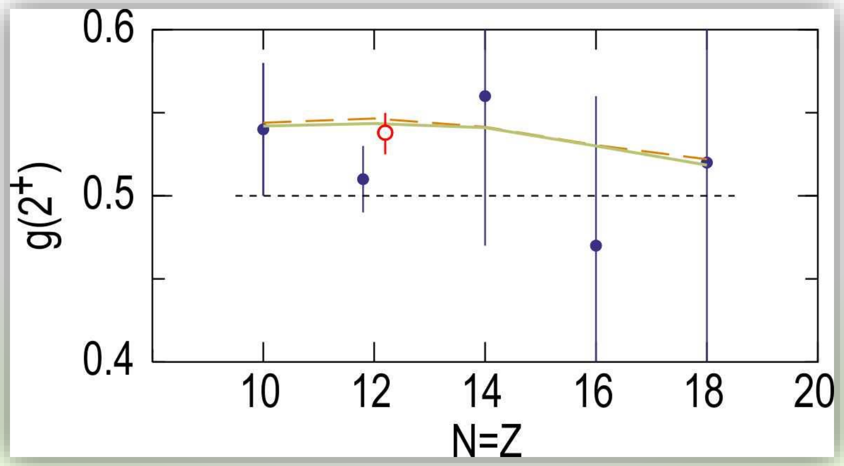
Previous measurement:

$|g(2^+)|$ = 0.51 (2)

R.F. Horstman et al., NPA 248, 291 (1975)

**sd shell-model calculations including:**

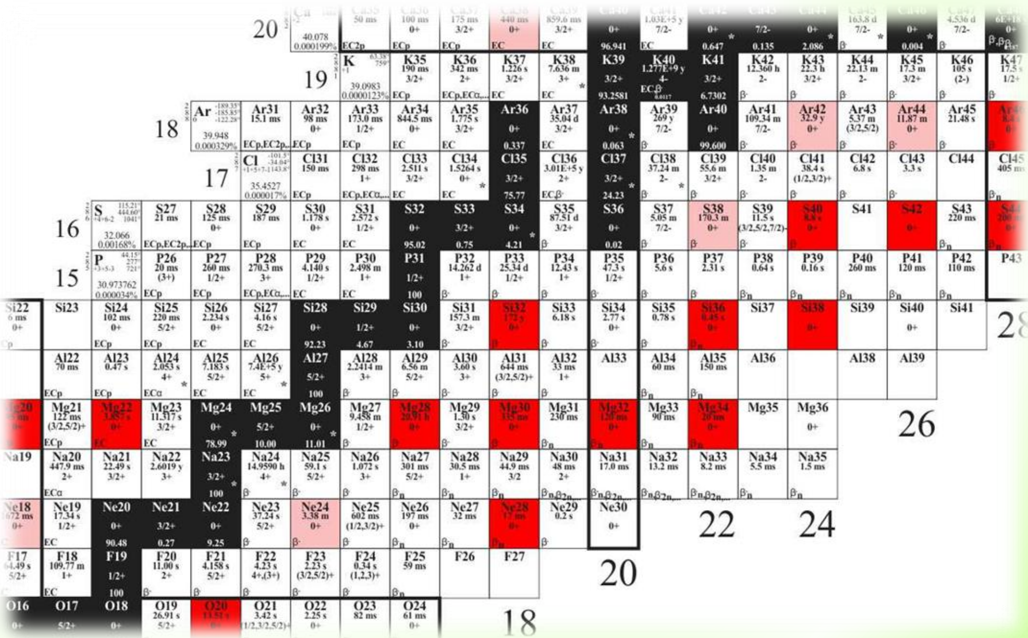
- configuration mixing
- isospin mixing
- meson-exchange currents → **$g(2^+, {}^{24}\text{Mg})_{USDB}$=0.544**



# Conclusions and perspectives

- **High-accuracy experimental results** on nuclear moments are needed for **testing the nuclear theories**
- TDRIV (on H-like ions) can provide **high accuracy**, **model independent**, measurements of short-lived excited states using **RIB**

- First RIB study?
  - e.g. $^{28}$Mg case:
    - $10^6$ pps
    - γ-efficiency – 10 – 15%
    - 7 – 10 days of beam



# Collaboration

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