Nuclear moment studies of short-lived excited states towards the Island of Inversion.

g factor of ^{28}Mg (2^+) using TDRIV on H-like ions.

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Nuclear moments – Why?

- Nuclei with non-zero spin have magnetic dipole moment $\mu = gI\,[\mu_N]$

- Sources of nuclear magnetism:
  - orbital movement of charged particles;
  - intrinsic spin of the nucleons.

- Free-nucleons g factors:

$$g_s^{\pi} = 5.585 \qquad g_{\ell}^{\pi} = 1$$
$$g_s^{\nu} = -3.826 \qquad g_{\ell}^{\nu} = 0$$

- Magnetic moment of a nucleus:

$$\vec{\mu} = \sum_{k=1}^{A} g_{\ell}^{(k)} \vec{\ell}^{(k)} + \sum_{k=1}^{A} g_s^{(k)} \vec{s}^{(k)}$$

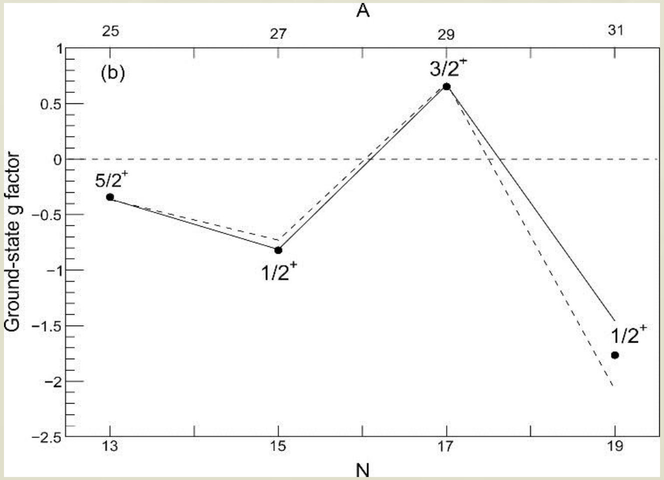
- the contribution of every nucleon

- Liquid-drop model: ***g = Z/A***

^{28}Mg – what is so exciting?

- Mg isotopes and the "Island of Inversion"
  - ^{32}Mg – first identified with high B(E2) and low E_x (2^+)

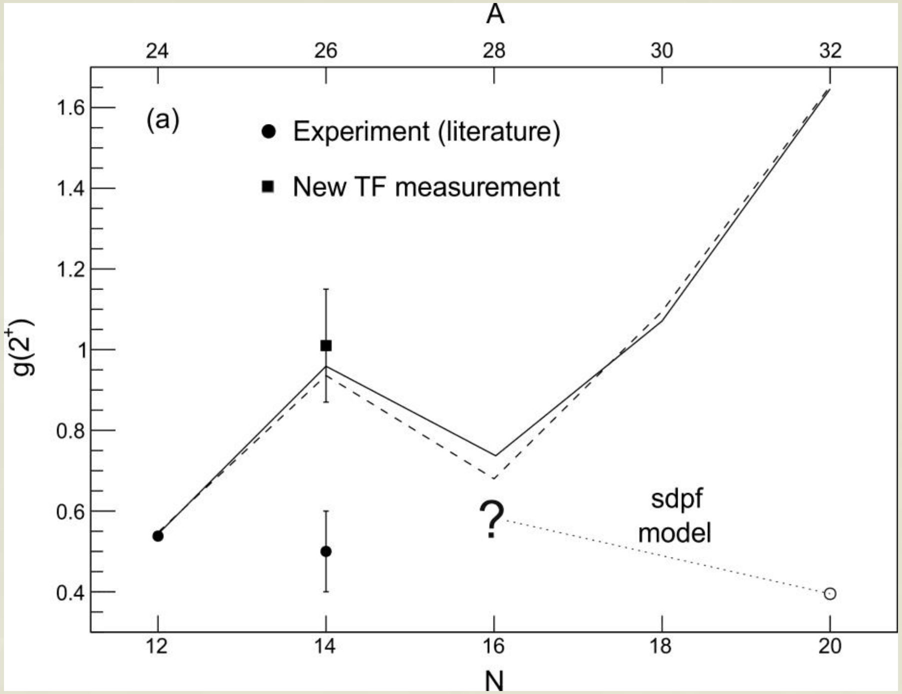
- Ground-state's moments in the Mg isotopes:



→ s.p. states, not sensitive to configuration mixing but to the odd-nucleon orbit

e.g. ^{31}Mg – magnetic moment of $1/2^+$ state well reproduced even if its energy (*sd* model space) is > 1 MeV off

Even-even Mg's (2^+ states)



- ^{26}Mg – inconsistent values in literature;
  – big uncertainties from TF measurements
- ^{24}Mg (N=Z) and ^{26}Mg ($\nu d_{5/2}$ subshell) – rather "simple" theory cases
- ^{28}Mg – ^{32}Mg – real tests for the interactions

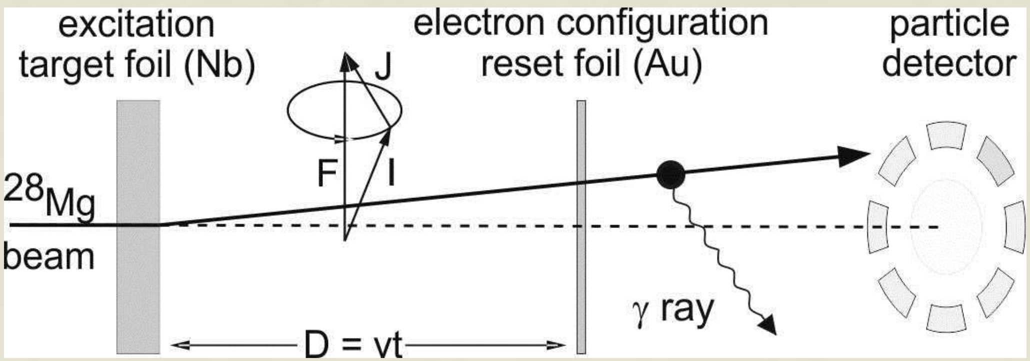
- ^{28}Mg – importance (*or not?*) of the N=16 sub-shell gap at Z=12?
- New estimations for the borders of the "Island of Inversion"
  T. Otsuka *et al.*, INPC 2016 presentation. http://inpc2016.com/abstracts/pdf/abstract_345.pdf

→necessity to include *pf* admixtures for reproducing excited states in ^{30}Mg

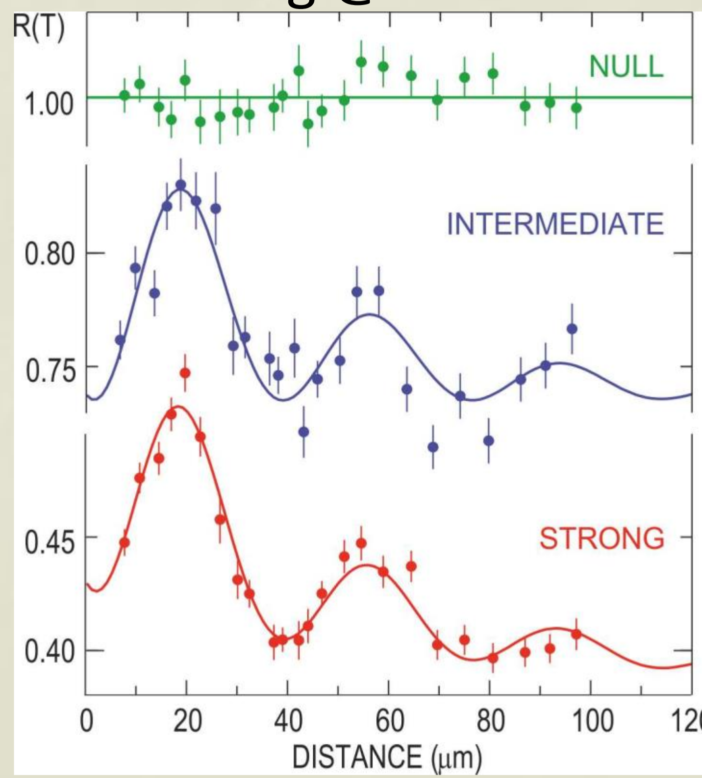
TDRIV on H-like ions

TDRIV - Interaction between the **nuclear spins** (oriented by the reaction) with the **electron spins** (random) for **well defined time** (plunger)

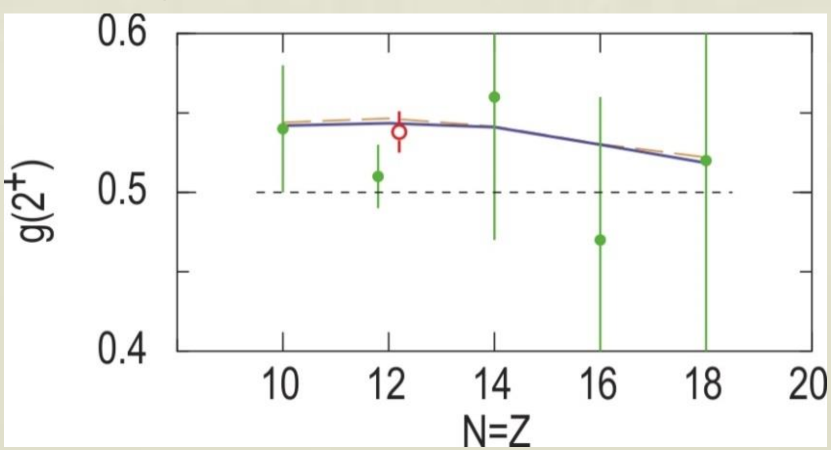
H-like ions → well defined magnetic field (*1s*): $B_{ns} = 16.7\frac{Z^3}{n^3}\left[1 + \left({}^{Z}/_{84}\right)^{2.5}\right]$



^{24}Mg @ ALTO



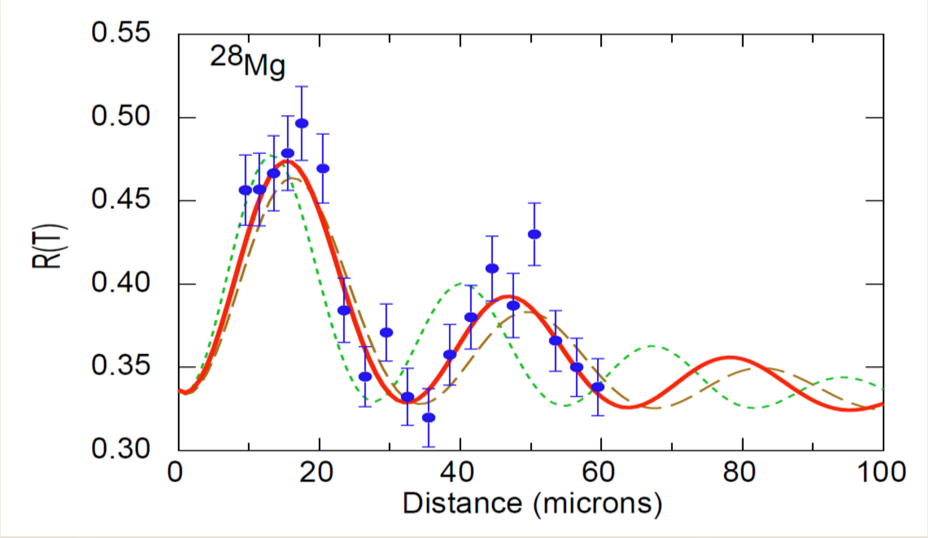
A. Kusoglu *et al.,* PRL 114, 062501 (2015)



Experimental requirements

- ^{28}Mg (~5.5 MeV/u) beam from HIE-ISOLDE:
  → $1x10^6$ – $5x10^5$ pps
- Miniball spectrometer
  → detectors @ ~90° angles
  → ~7% efficiency @ 1.4 MeV
  → Cologne Miniball plunger
- ~1000 p – γ "useful" coinc. per "segment"/distance
- 20 plunger distances

→ g(^{28}Mg) ~5% accuracy



Beam-time request

	ISOLDE yields [p/μC]	Expected yield @ Miniball [pps]	Shifts
^{28}Mg (20.9 h)	**$6x10^6$**	**$5x10^5$ - $1x10^6$**	**25**
^{22}Ne (stable)	from EBIS	~ $1x10^7$	1 week

→ **Total 25 shifts RIB + 1 week stable beam requested**

for obtaining g(2^+, ^{28}Mg) with ~5% accuracy

TAC comments

INTC #	Exp no.	setup (red: new)	Shifts (setup not counted)	isotopes	safety input (red: new elements)	Radioprotection and safety	Beam intensity/purity, targets-ion sources	General implantation and setup	REX, HIE-ISOLDE	Comments
INTC-P-478		Miniball	25	28Mg; 22Ne	Miniball		28Mg: >6e6/uC (RILIS gain vs DB); 28Al: 1e6/uC OK		Already done at REX-ISOLDE. Most probably charge state 9+. Energy ok: 5.5MeV/u	

Counts in p-γ coincidences in Miniball

- 10^6 pps ^{28}Mg (5.5 MeV/u)

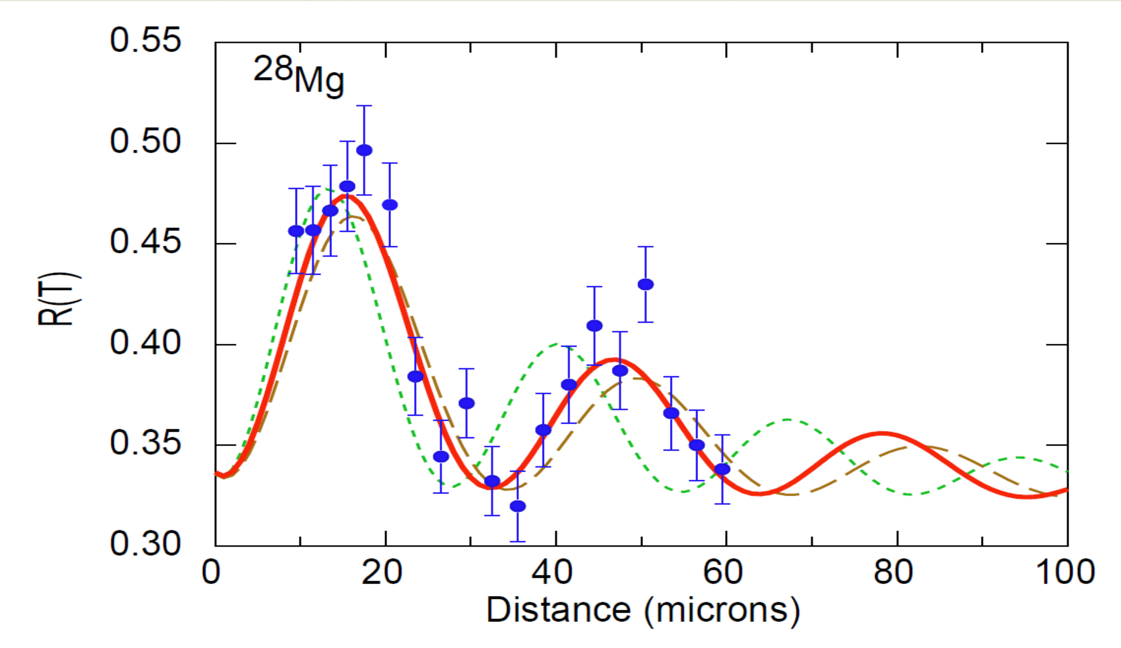
  → 10^3 p-γ produced/"segment"/hour (1/8 of CD, 28° < θ <40°)

  x 7% Miniball efficiency

  → 560 p-γ detected

  out of which 20% in "useful correlation angles"

  → 110 p-γ/hour per best Ge detectors positions

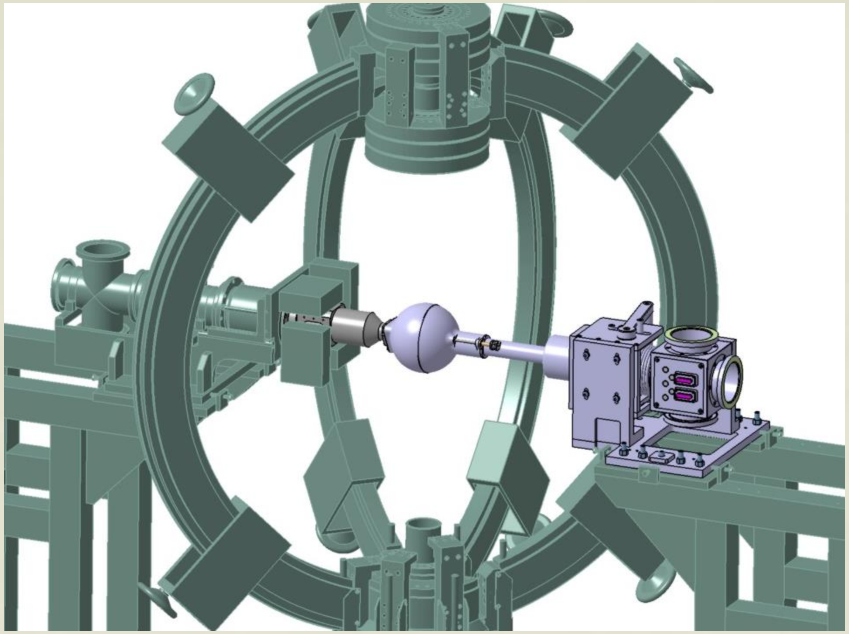


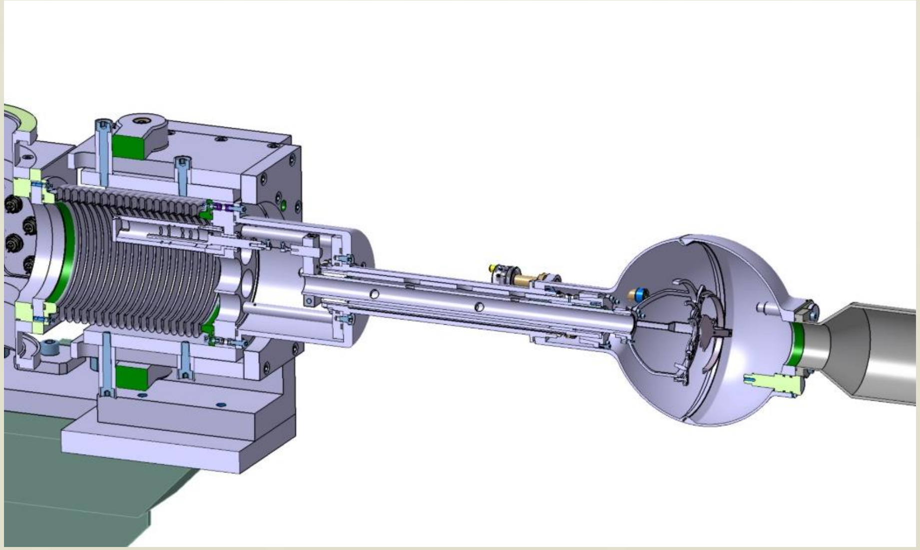
Miniball plunger availability?

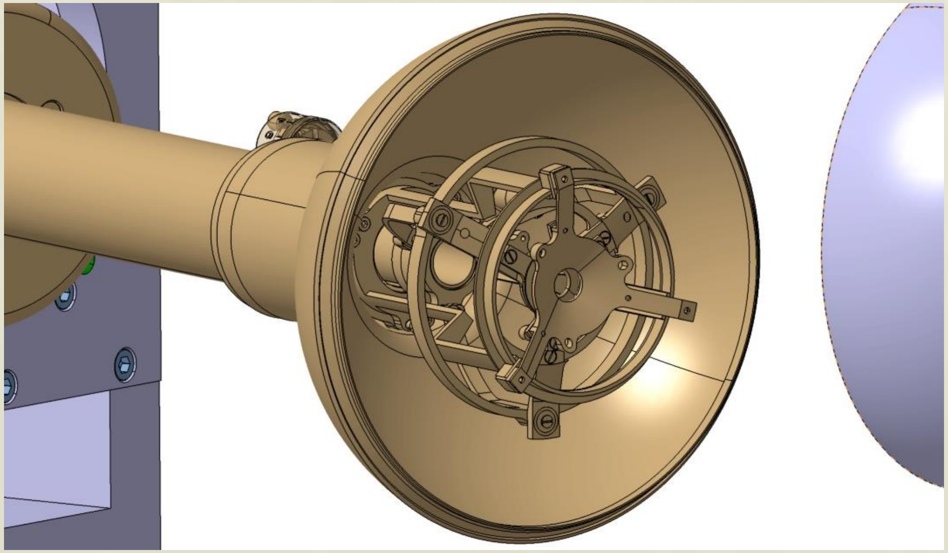
Dear Georgi,

Our mechanics workshop is manufacturing the parts for the Miniball plunger at the moment and we will finish it (including a test run in Cologne to guarantee that it works stable and reliable) definitely in time for experiments that take place next year. Thus you can submit your proposal assuming the plunger is available.

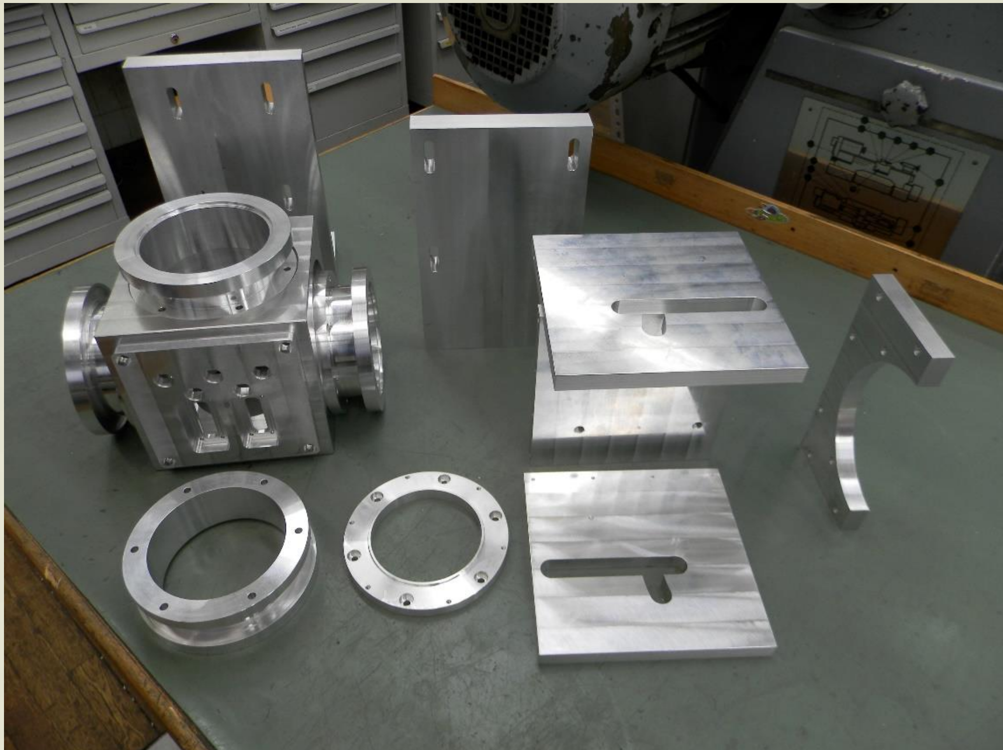
Best regards,
Christoph

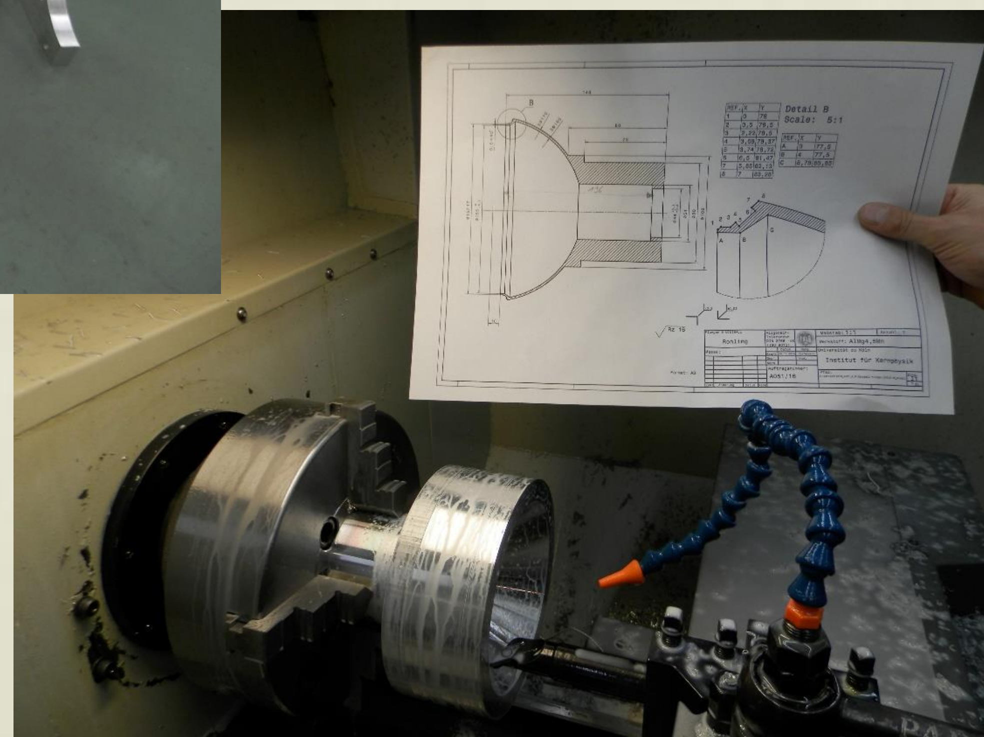




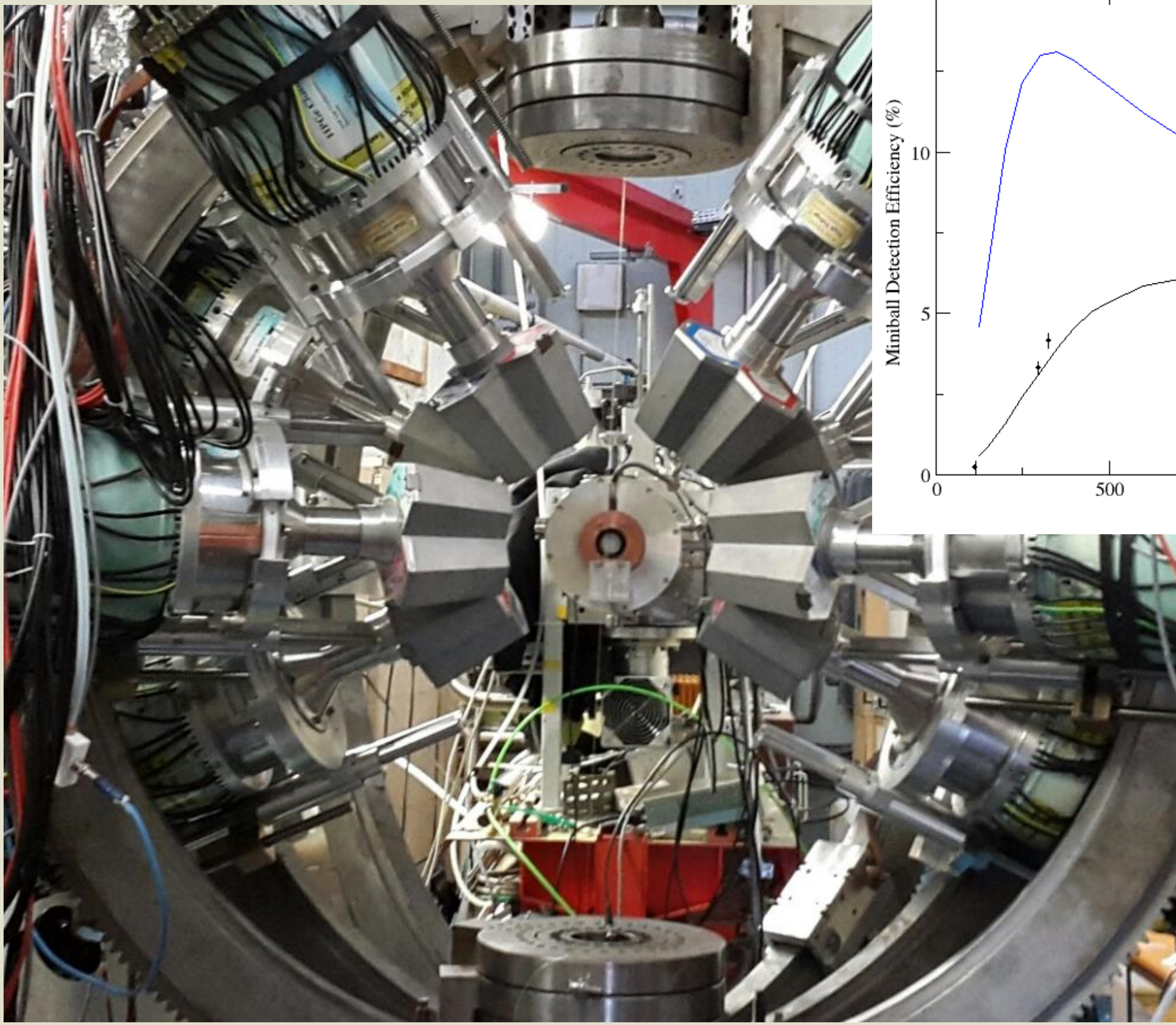


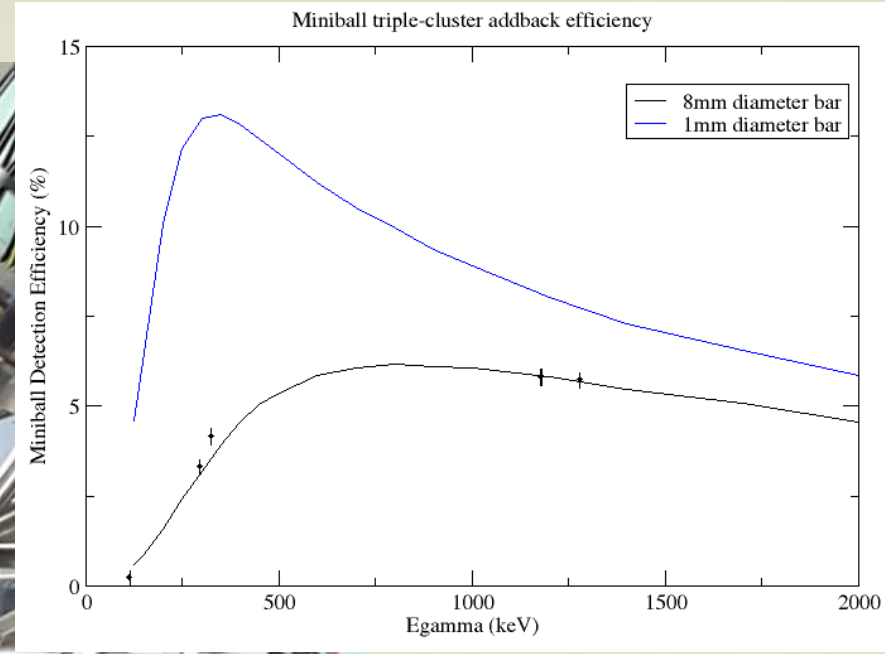
News from IKP Cologne (27/10/2016)





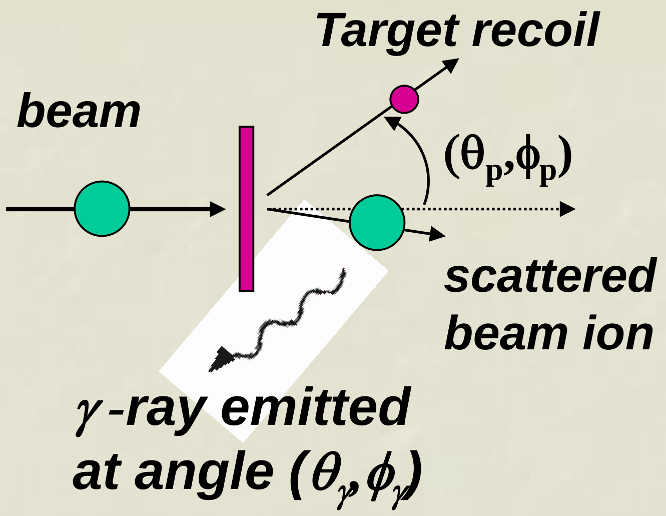
Miniball experimental efficiency (~90° configuration)

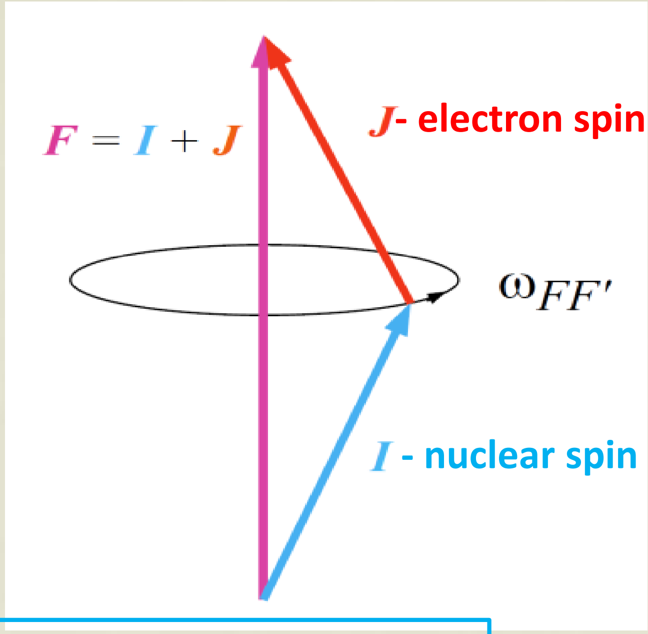




Licorne @ MINORCA

Electron-nuclear spin interaction in vacuum





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

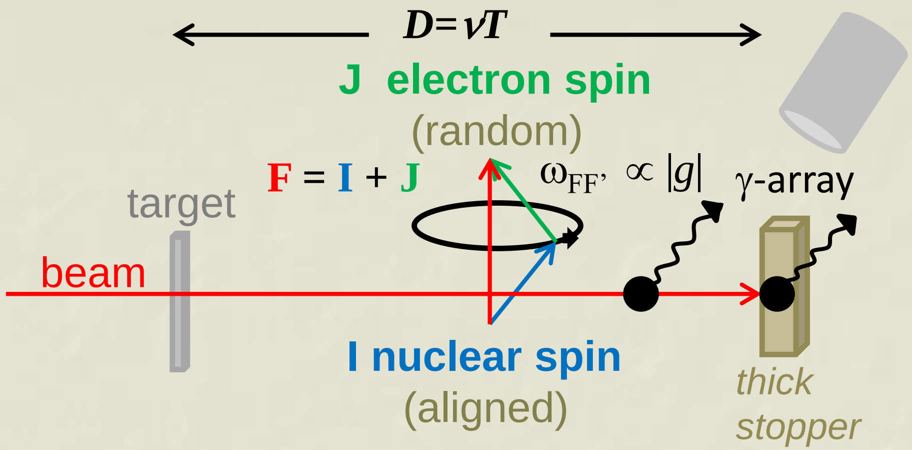
$$G_k(t) = \sum_{F,F'} C_{FF'} \exp(-\omega_{FF'} t) \qquad (0 \le |G_k| \le 1)$$

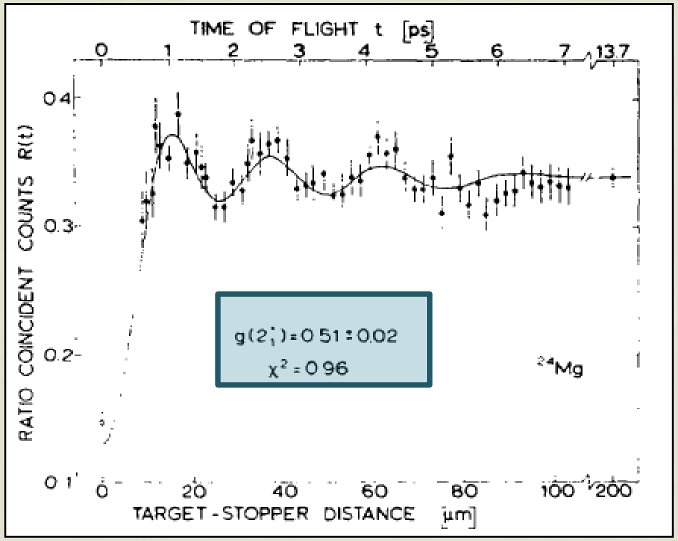
attenuation coefficients – a measure for the electron – nuclear spin interaction

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

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

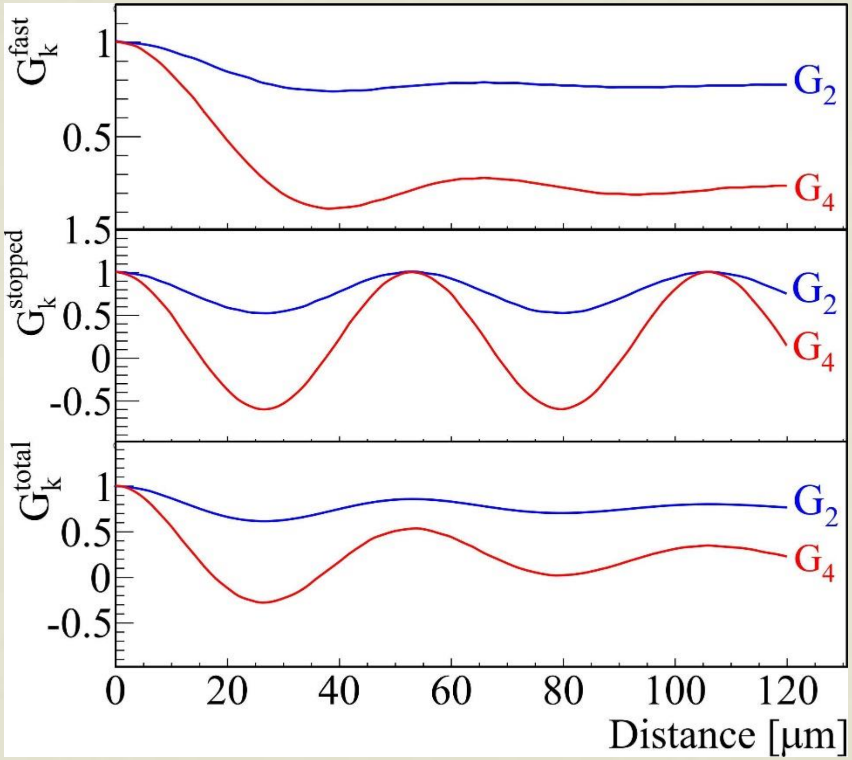
Time Dependent Recoil In Vacuum (stable beams)





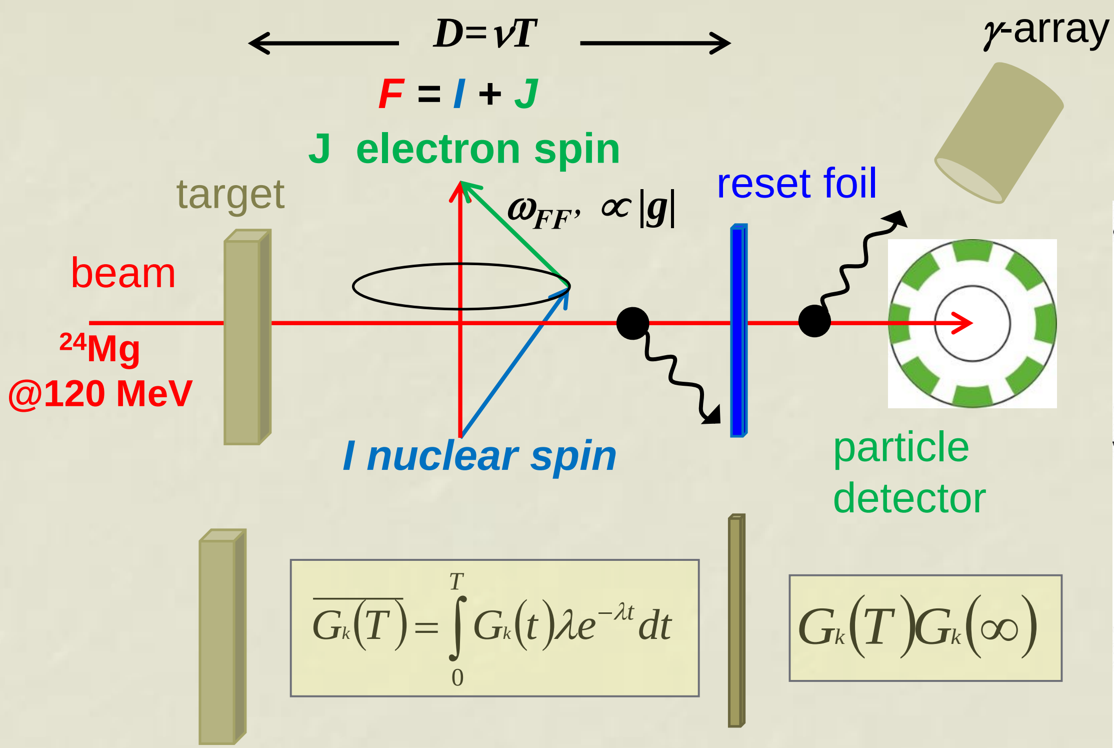
R.F. Horstman *et al.*, Nucl. Phys. **A248**, 291 (1975)

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 %)*

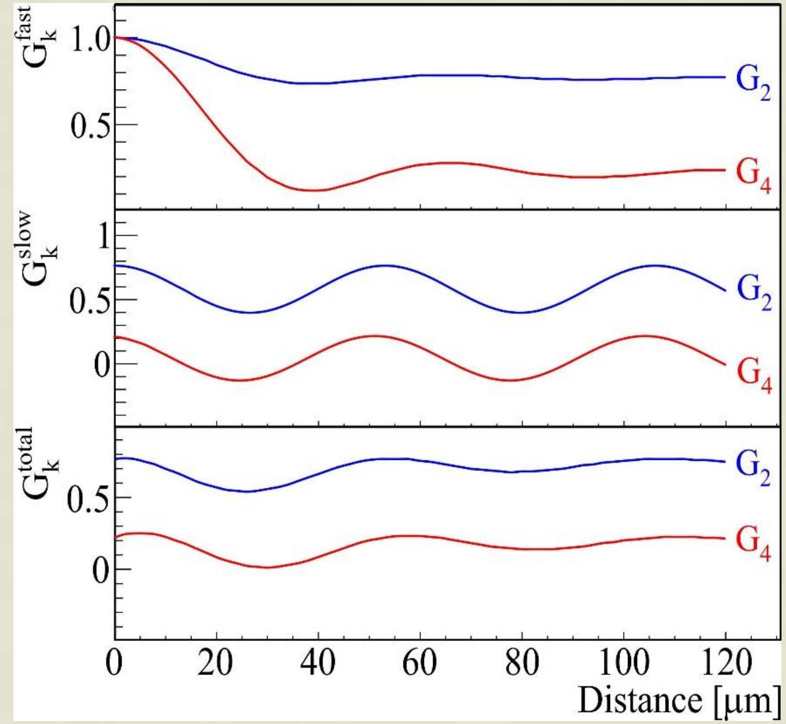
TDRIV – radioactive beam geometry



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

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

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



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)

Particle – γ correlations