# Magnetic strength and shell evolution in light nuclei

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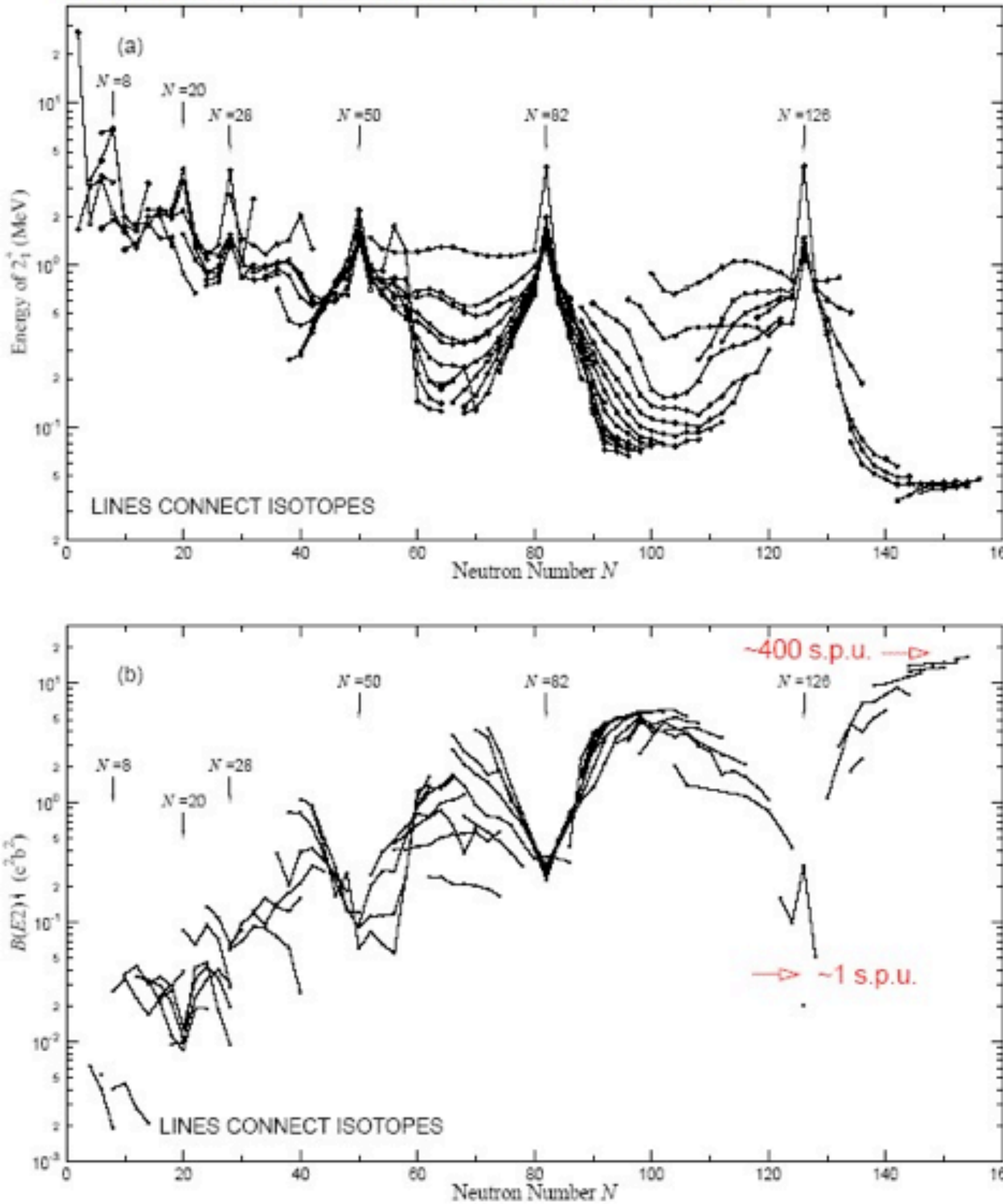
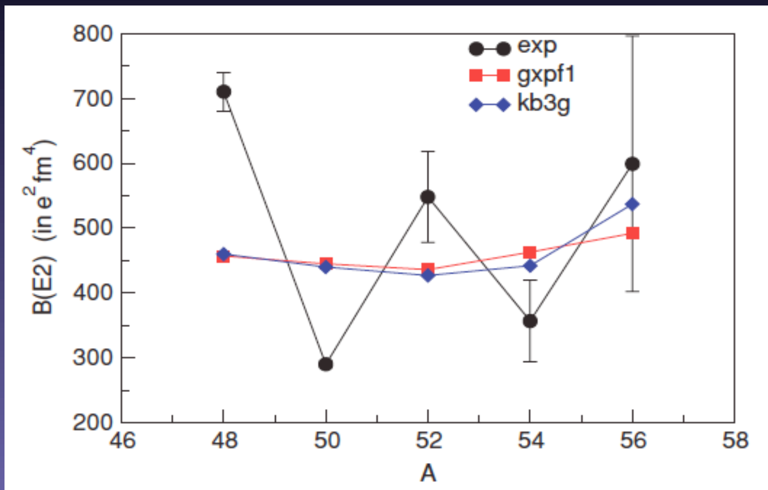
Excellence Cluster Universe

Technische Universität München

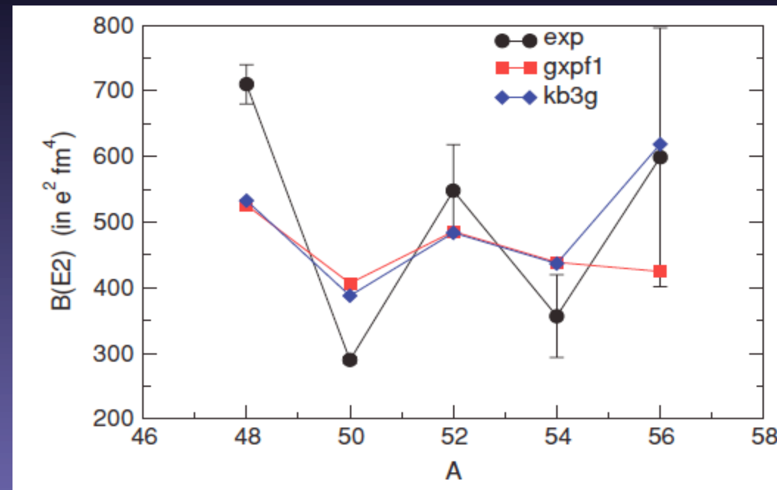
S. Raman et al., Atomic Data & Nuclear Data Tables 78, 1



# B(E2) values off n-rich Ti-isotopes: are neutrons closed at N=34 ?



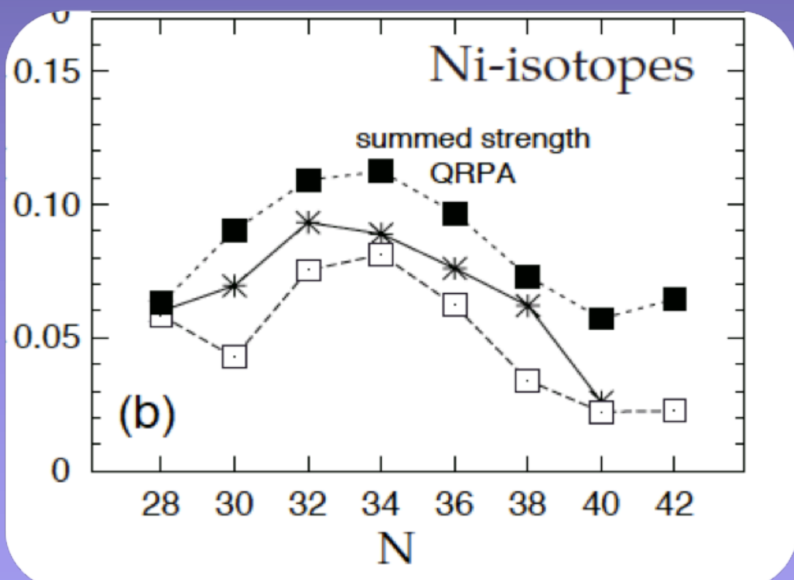

$Q_\pi$=1.5e, $Q_\nu$=0.5e



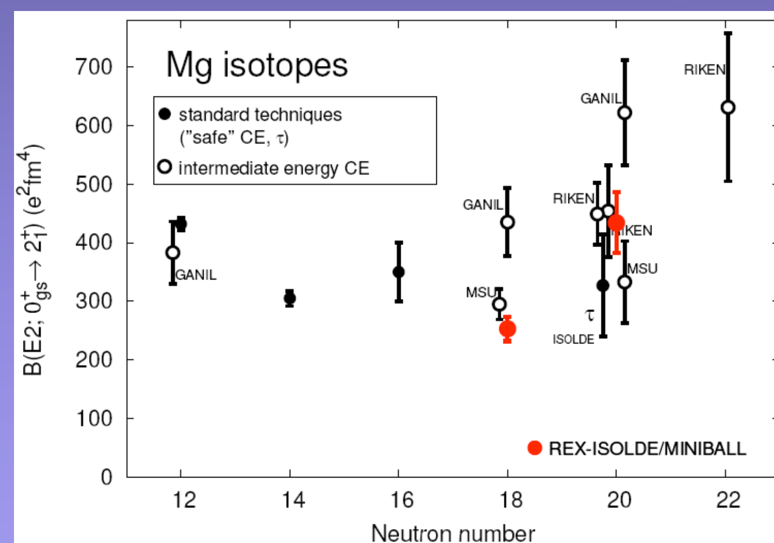

$Q_\pi$=1.15e, $Q_\nu$=0.8e

A. Poves, F. Nowacki, E. Caurier PRC 72, 047302 (2005)

B(E2;0+->2+) (e2b2)




K. Langanke et al., Phys. Rev. C, 67, 044314 (2003)

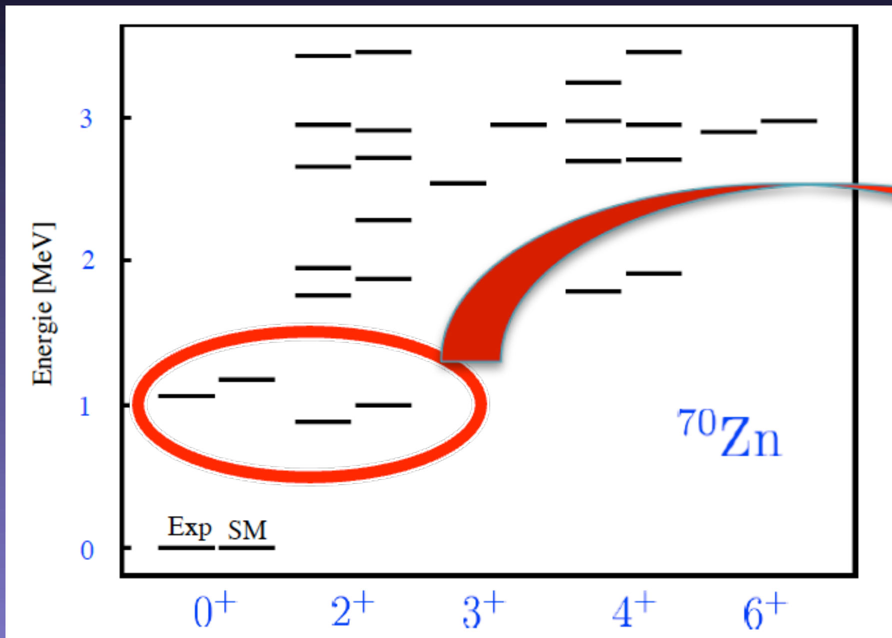


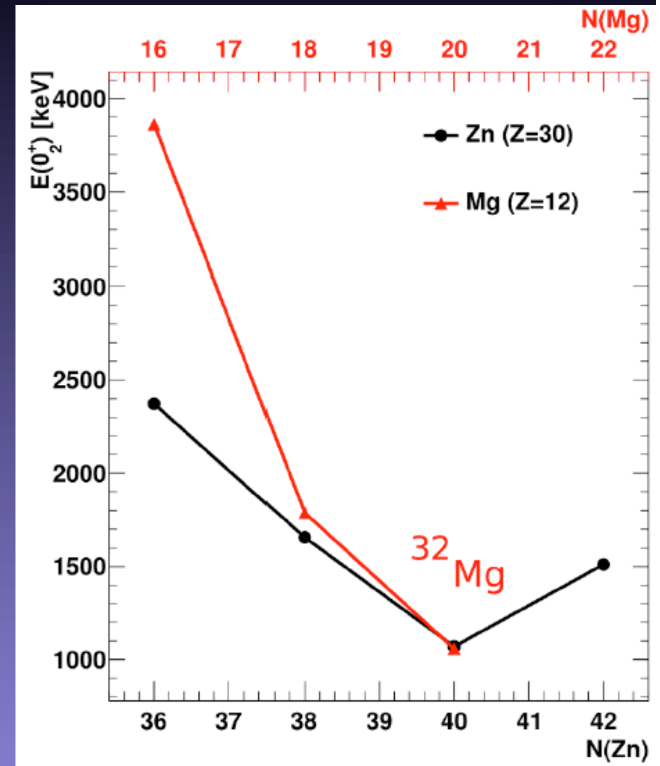

$$gs = \alpha\,(fp)^2 - \beta\,(sd\ \text{shell})\,, \quad 0_2^+ = \beta\,(fp)^2 + \alpha\,(sd$$

K. Wimmer et al., Phys. Rev. Lett. 105, 2525
(2010)
H. T. Fortune, Phys. Rev. C 84, 024327 (20

# $^{70}$Zn: yet another „Island of Inversion“ ?

A. F. Lisetskiy, priv. communication




$f_{5/2}$ $p_{3/2}$ $p_{1/2}$ $g_{9/2}$ for p+n
jj4c interaction (B. A. Brown)

| $J^\pi$ | A | $\pi(f_{5/2})$ | $\pi(p_{3/2})$ | $\nu(f_{5/2})$ | $\nu(p_{3/2})$ | $\nu(p_{1/2})$ | $\nu(g_{9/2})$ |
|---|---|---|---|---|---|---|---|
| $0^+_1$ | 0.146 | 0 | 2 | 4 | 4 | 2 | 2 |
| | 0.083 | 0 | 2 | 6 | 4 | 2 | 0 |
| | 0.065 | 2 | 0 | 4 | 4 | 0 | 4 |
| | 1.0 | 0.61 | 1.04 | 4.35 | 3.53 | 1.27 | 2.85 |
| $0^+_2$ | 0.298 | 0 | 2 | 6 | 4 | 2 | 0 |
| | 0.076 | 2 | 0 | 4 | 4 | 0 | 4 |
| | 0.054 | 0 | 2 | 5 | 3 | 2 | 2 |
| | 1.0 | 0.54 | 1.17 | 4.95 | 3.54 | 1.44 | 2.07 |

if „closed“ configuration on top of $0^+_2$: g $(2^+)$ large !

shell model:

$g(2^+_1)=0.276$, configuration „6 4 2 0“ < $10^{-10}$
$g(2^+_2)=0.10$, configuration „6 4 2 0“ < $10^{-10}$
g(2+ )=0.88 configuration „6 4 2 0“ largest!
(18

| $I^\pi_i$ | Exp’t. | FPD6 *fp* | KB3 *fp* | GXPFA *fp* | JJ4B $p_{3/2}f_{5/2}p_{1/2}g_{9/2}$ |
|---|---|---|---|---|---|
| $2^+_1$ | +0.38(2)[a] | +1.52 | +1.83 | +1.89 | +0.276 |

DM et al, Phys. Rev. C 79, 0543

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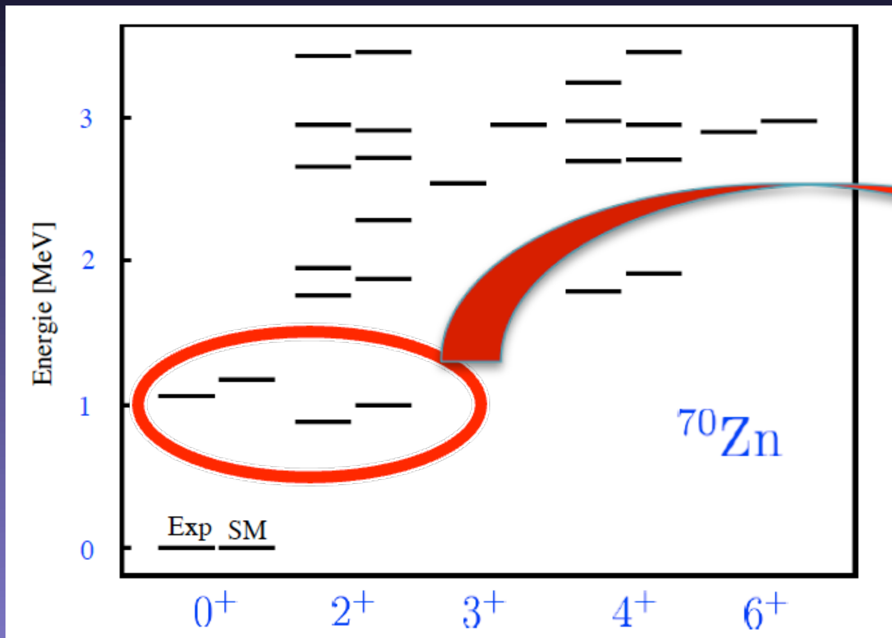
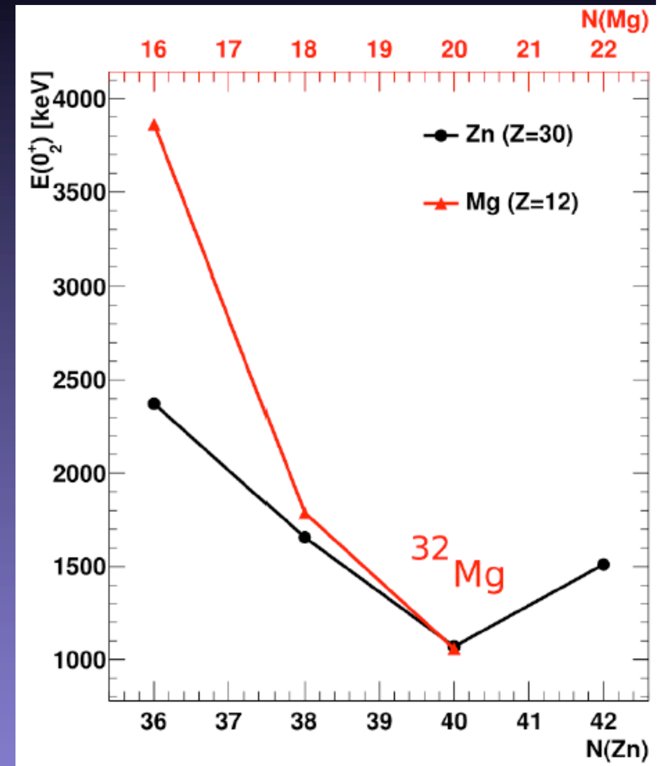
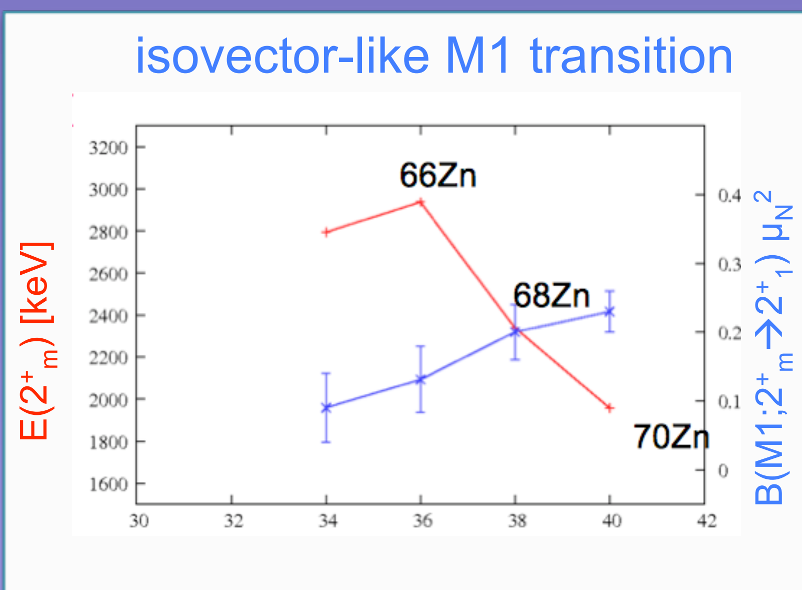
A. F. Lisetskiy, priv. communication




shell model: $B(M1;2^+_m \rightarrow 2^+_1) = 0.18\ \mu_N^2$

if „closed“ configuration on top of $0^+_2$: g $(2^+)$ large !

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| $I_i^\pi$ | Exp't. | FPD6 $fp$ | KB3 $fp$ | GXPFA $fp$ | JJ4B $p_{3/2}f_{5/2}p_{1/2}g_{9/2}$ |
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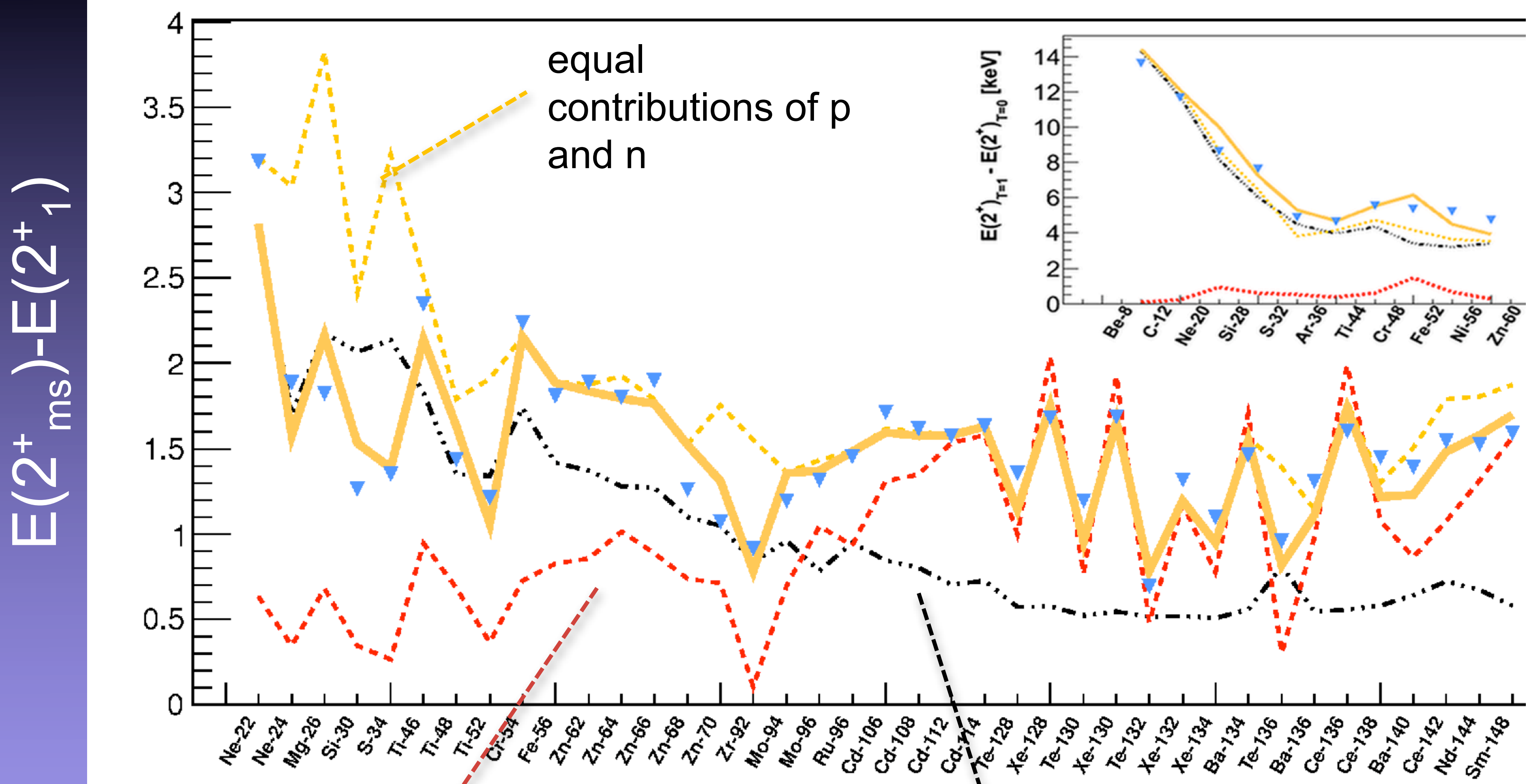
DM et al, Phys. Rev. C 79, 0543

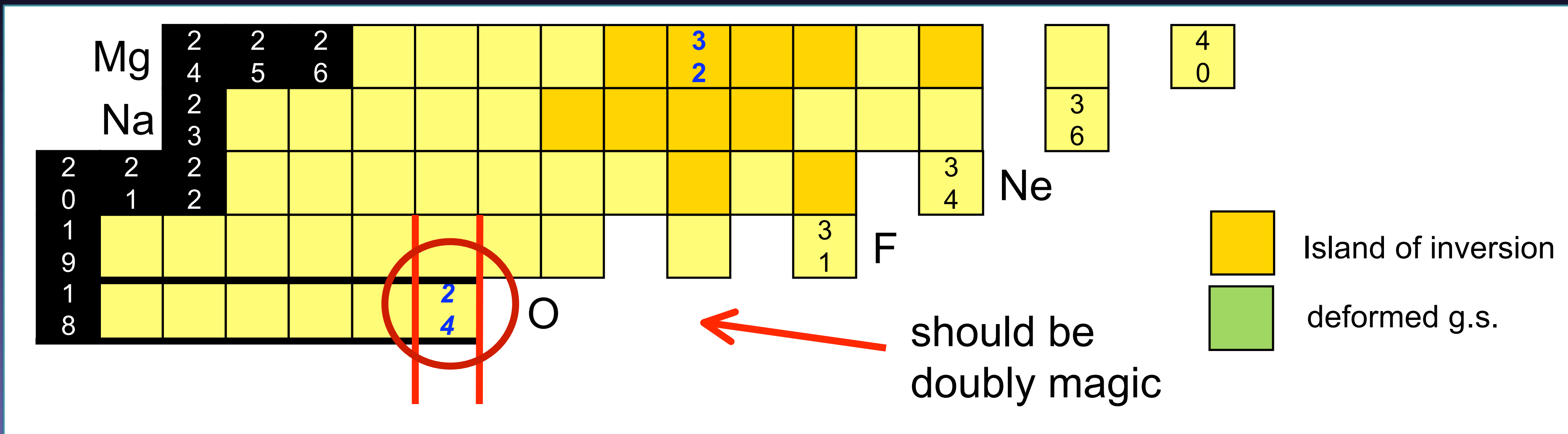


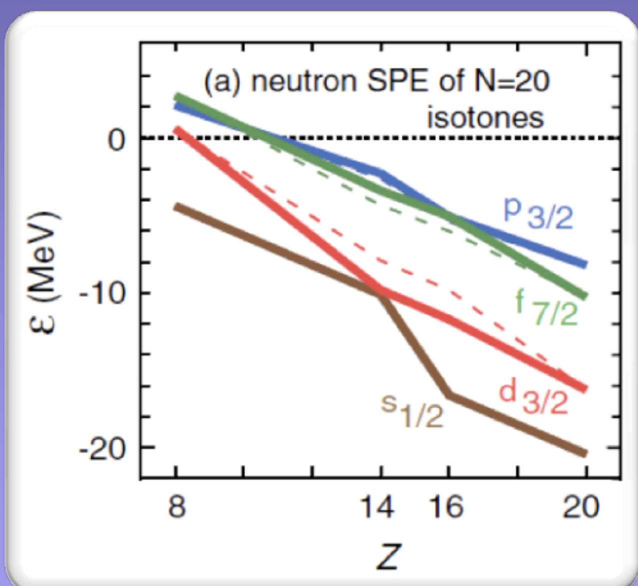

$$Q_{\pi\nu} = -\tilde{\kappa}\cdot\sqrt{\langle 0_I^+ | E2 | 2_I^+ \rangle^2 - \langle 0_I^+ | E2 | 2_{II}^+ \rangle^2}$$

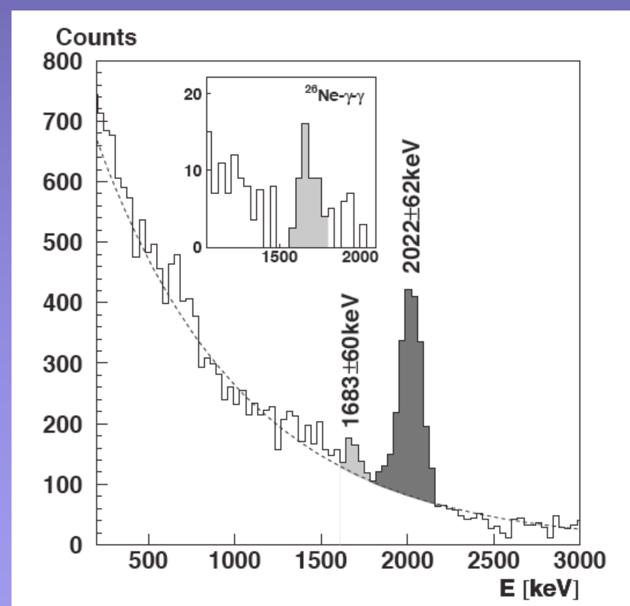
Symmetry-energy

$$\delta V'_{pn} = \frac{4\sum_J (2J+1)\langle j_\pi j_\nu, J|V|j_\pi j_\nu, J}{(2j_\pi+1)(2j_\nu+1)}$$

# Mixed Symmetry States at the dripline




N=16 (24O) is closed, 28O unbound !

→ effect on semi-magic 26Ne?

$^{26}$Ne, Coulomb Excitation @ RIKEN

J. Gibelin et al., PRC 75, 057306 (2007)

shell model: $2^+_2$ has isovector character

$^{26}$Ne:

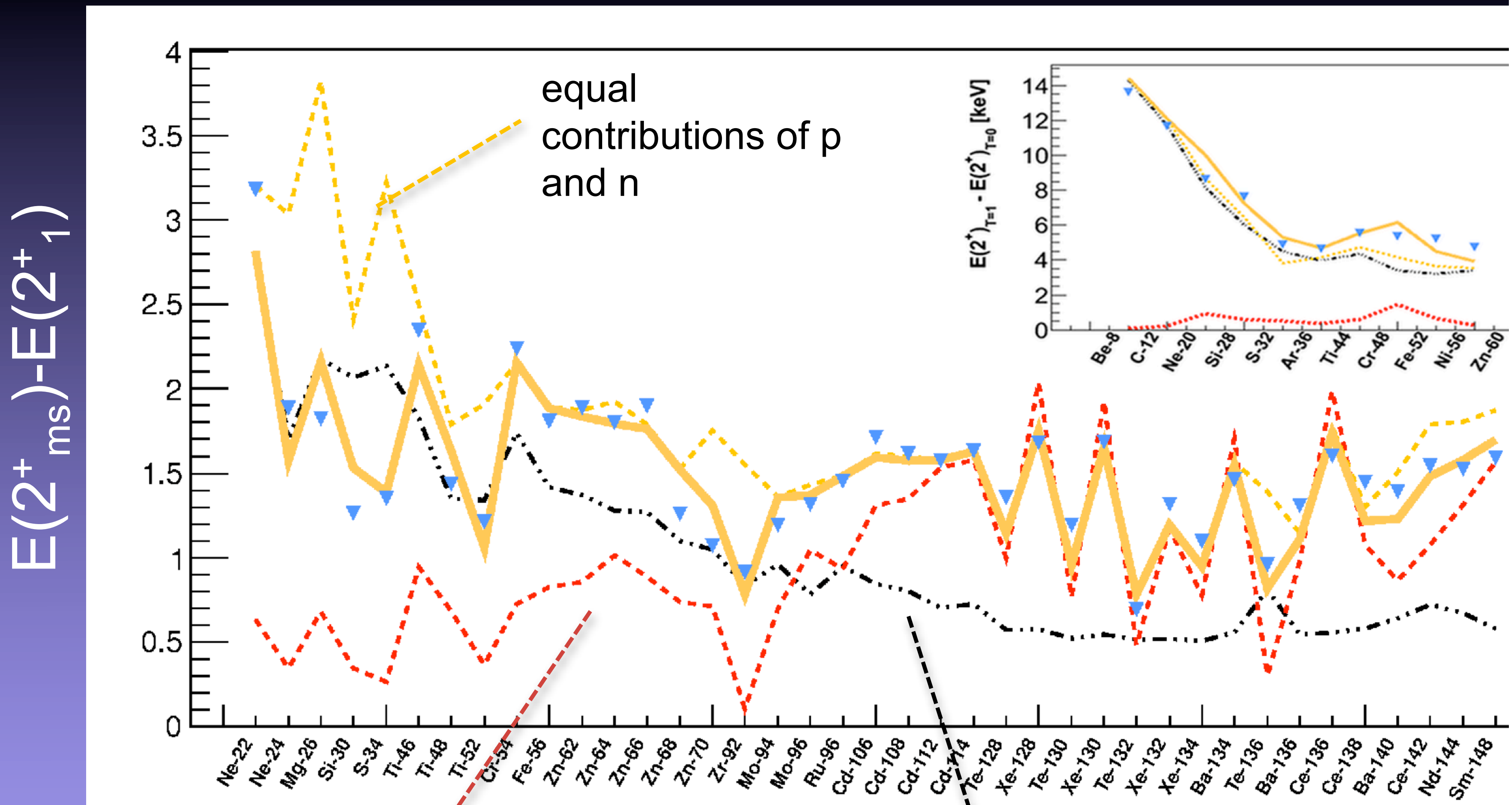
$E(2^+_1)$=2.02 MeV

$E(2^+_2)$=3.69 MeV

B(E2)=6.18(8) W.

we obtain single minimum with $|\varepsilon_\pi - \varepsilon_\nu|$ = 2.5 MeV

$^{24}$O: $E(2^+_1)$=4.72 MeV (unbound)



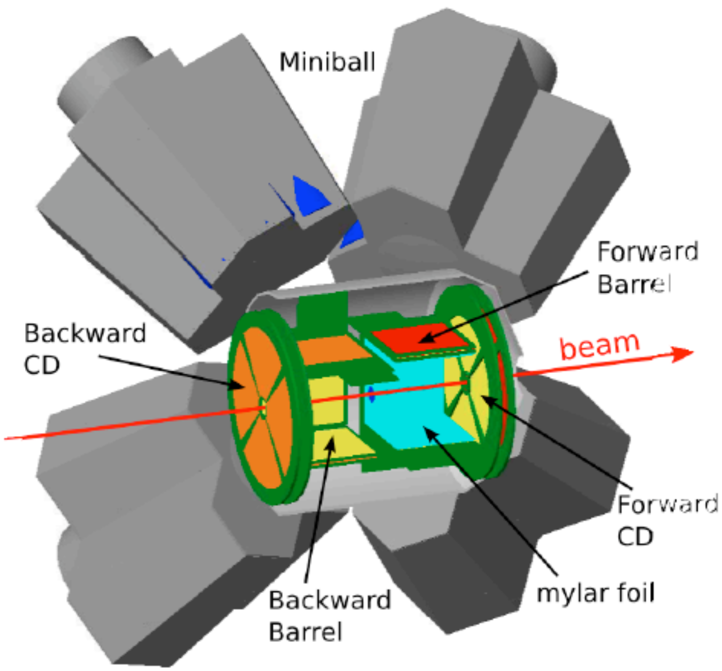

$$Q_{\pi\nu} = -\tilde{\kappa}\cdot\sqrt{\langle 0_I^+ |\, E2\, | 2_I^+\rangle^2 - \langle 0_I^+ |\, E2\, | 2_{II}^+\rangle^2}$$

Symmetry-energy !

$$\delta V'_{pn} = \frac{4\sum_J (2J+1)\langle j_\pi j_\nu, J|V|j_\pi j_\nu, J}{(2j_\pi+1)(2j_\nu+1)}$$

# Experimental setup: T-REX + MINIBALL

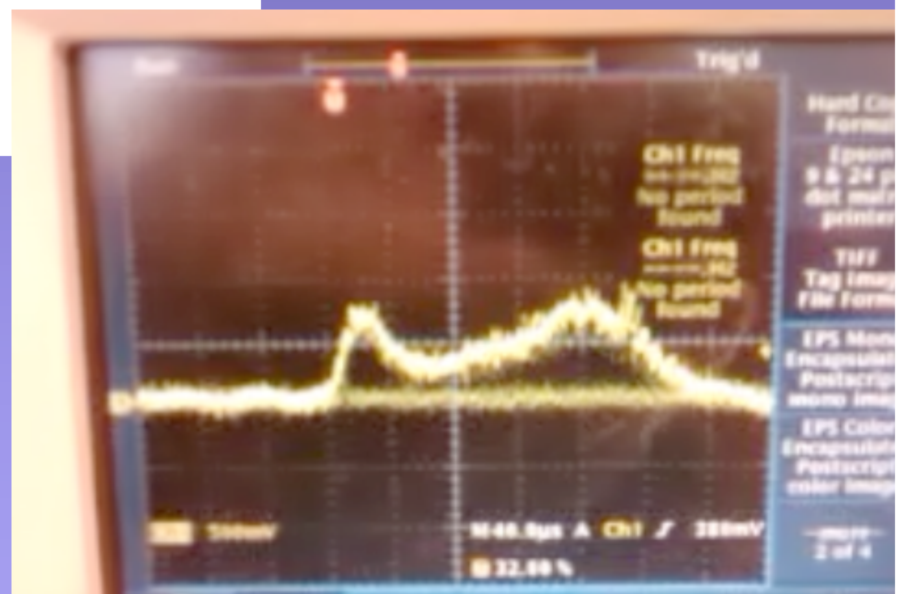
- Target: 40 $\mu$g/cm$^2$ $^3$H (2n- and 1n-transfer) contained in a 500 $\mu$g/cm$^2$ Ti-foil (Coulex)
- Fully equipped T-REX allows to combine Coulex and transfer experiments.




- Segmented $\Delta E - E$ Si-telescopes for particle identification (p, d, ...)
- 12 $\mu$m mylar protection foil in front of Forward Barrel
- Segmented Forward CD for Coulex
- MINIBALL for $\gamma$-rays

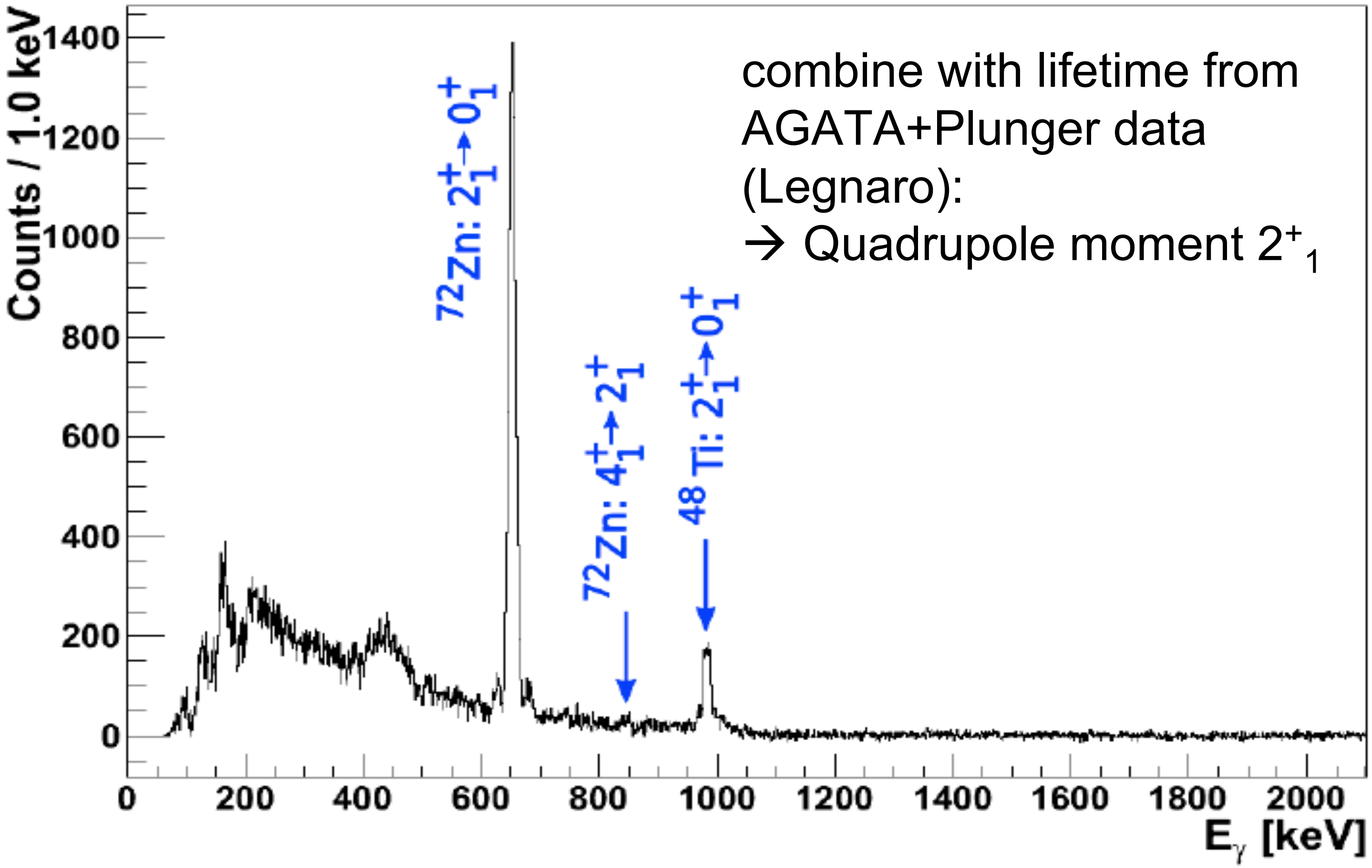
Analysis of IS510 by S. Klupp, E12, TU Munich

high-intensity ($10^7$ /s on ta
$^{72}$Zn beam:
issue with „flash" of secon
electrons in T-REX:
solved using high-power
tritium-target-ladder (+300



Analysis of IS510 by Stefanie Klupp, E12, TU

# Coulex: First results




combine with lifetime from AGATA+Plunger data (Legnaro):

→ Quadrupole moment $2^+{}_1$

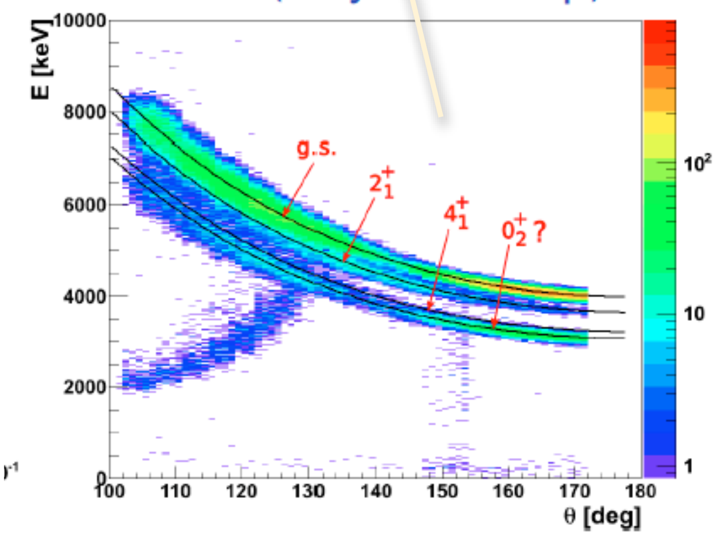
$1.95 \cdot 10^4$ counts in the $^{72}$Zn($2^+_1 \rightarrow 0^+_1$) transition in 72h measurement time!

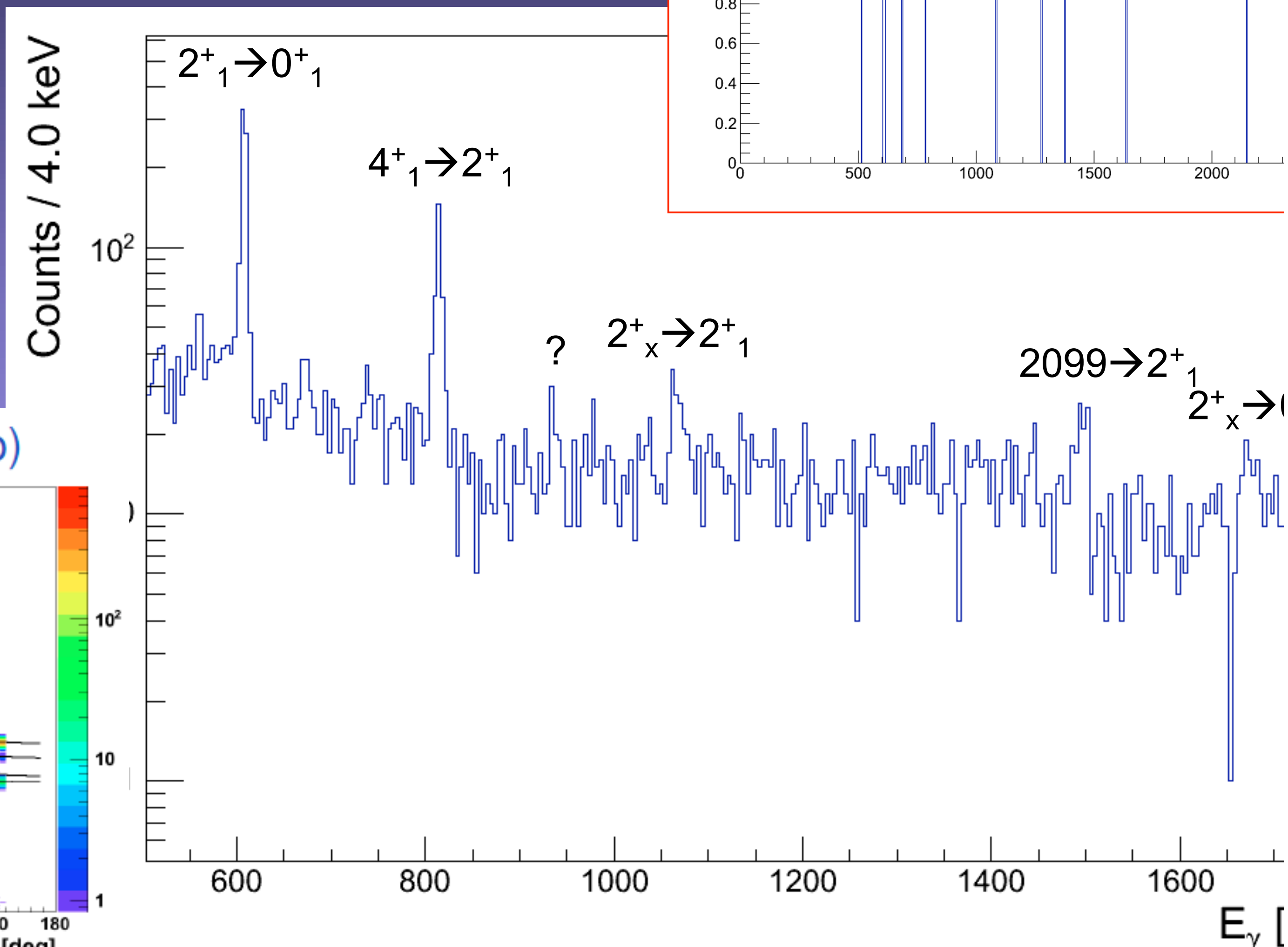
# MINIBALL-spectra of $^{74}$Zn after 2n transfer, gated on protons

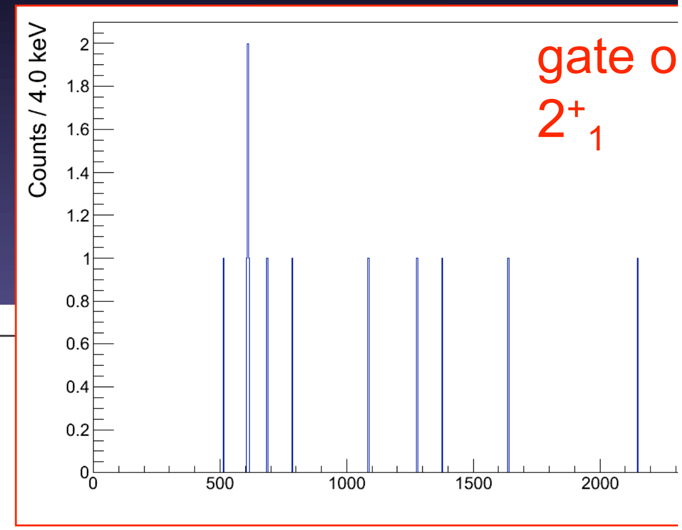
Analysis of IS510 by Stefanie Klupp, E12, TU Munich

upgrade of T-REX needed for HIE ISOLDE

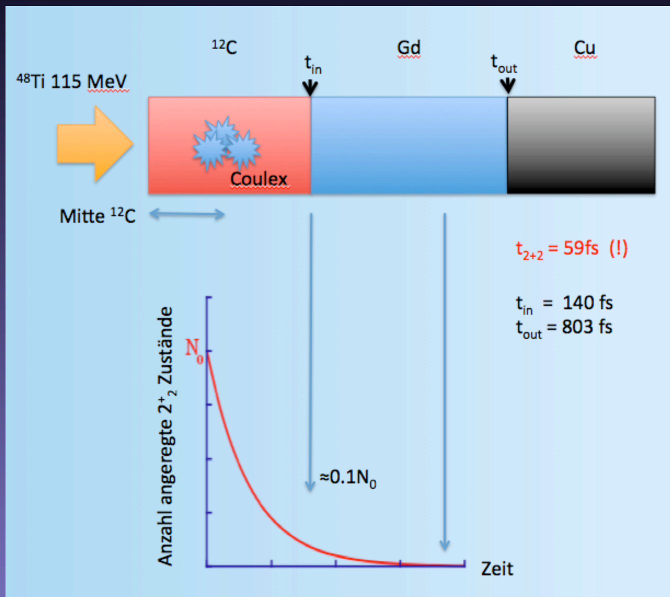
Simulation (only transfer p)



# Can we measure magnetic moments of short-lived $2^+_{ms}$ states?

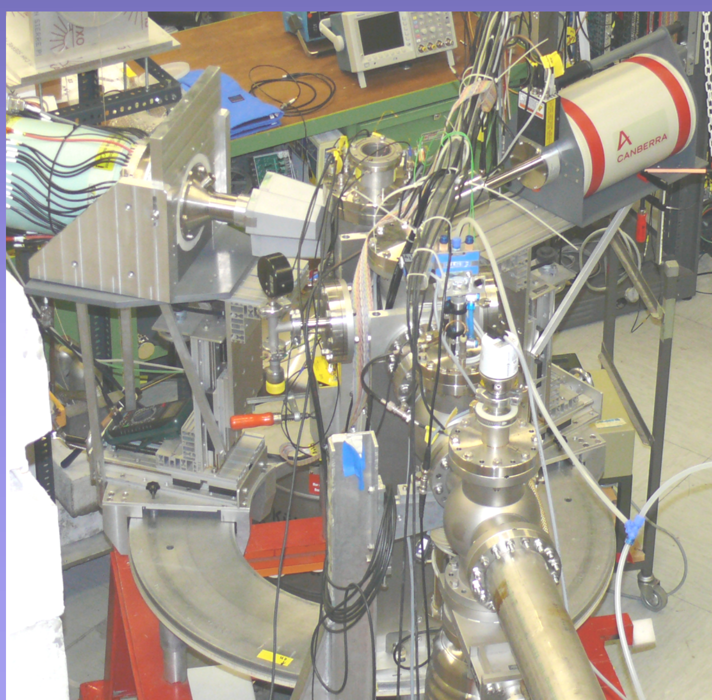


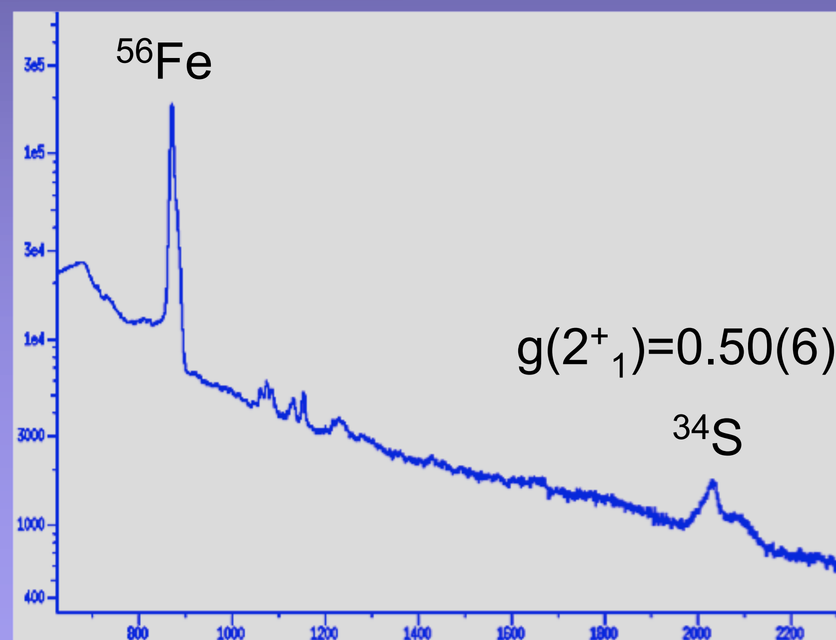

Scintillator: LYSO (Cerium-doped Lutetium Yttrium Orthosilicate)
collab. Prof. S. Ziegler, medical physics, TU Munich

\+ (i.e. glue)

Avalanche Photodiode (Hamamatsu S8664)

no radiation damage after $10^{10}$ events, 100 kHz rate)



Proposal for MINIBALL @ MLL Munich (15 MeV Tandem)

topics:

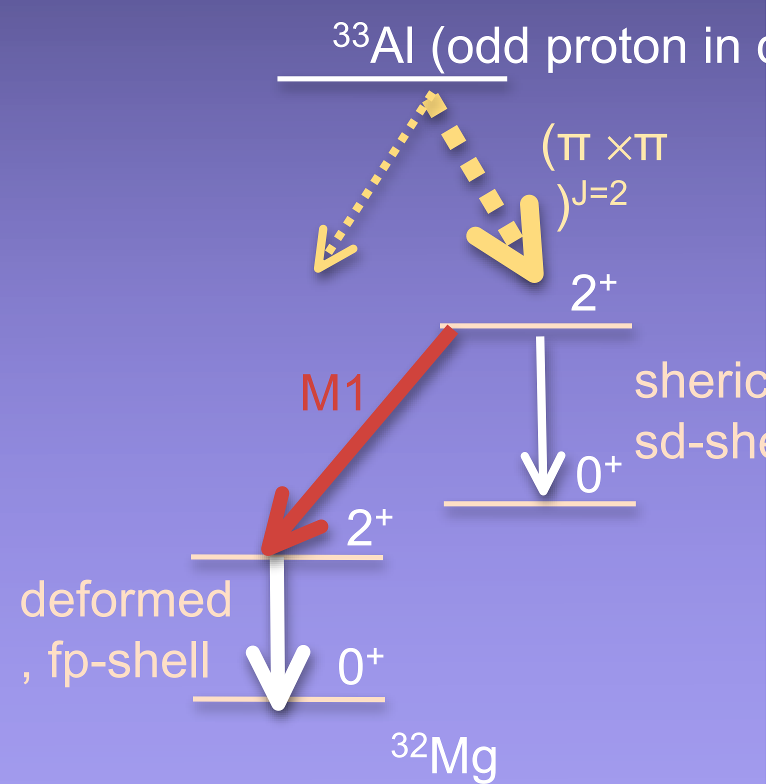
- normalisation measurements using Recoil in Vacuum after Coulex (in prep. for e.g. HIE-ISOLDE) (A. Jungclaus, Madrid)
- magnetic moments of ultra-fast states (DM)
- Lifetimes of astrophysical relevant states using cooled 3He targets (S. Bishop, E12 Munich)
- X-ray multiplicities of evaporation residues (W. Henning)

Setup:

- 4 MINIBALL triple cluster detector (72 Segments)
- trigger: all segments; Mesytec Shaper
- readout: Mesytec ADC; multievent readout

Working on a possible proposal for AGATA @ GSI:

identify $2^+$ state build on $0^+_2$ for nucleus in the „island of inversion)
($^{32}$Mg, neutron-rich Fe)



# Thanks for your attention !

E12 (TUM)

R. Krücken, W. Henning, R. Gernhäuser, K. Nowak, S. Klupp, H. Schmeiduch, S. Reichart, M. Bendel, L. Maier, C. Herlitzius, S. Bishop

IS 510 (ISOLDE)

D. Mücher[1], R. Krücken[1], K. Wimmer[1], V. Bildstein[1], M. Albers[2], L. Bettermann[2], A. Blazhev[2], S. Bönig[3], J. Eberth[2], C. Fransen[2], R. Gernhäuser[1], K. Gladnishki[4], S. Das Gupta[5], K. Hadynska[7], M. Hass[8], J. Iwanicki[7], J. Jolie[2], A. Jungclaus[9], V. Kumar[8], T. Kröll[3], J. Leske[3], G. Lo Bianco[5], P. Napiorkowski[7], B.S. Nara Singh[6], K. Nowack[1], R. Orlandi[9], J. Pakarinen[10], N. Pietralla[3], G. Rainovski[4], M. Scheck[3], K. Singh[8], J. Srebrny[7], M. von Schmid[3], K. Wrzosek-Lipska[7], N. Warr[2], M. Zielinska[7], and the REX-ISOLDE collaboration

and

N. Pietralla, M. Scheck (TU Darmstadt)

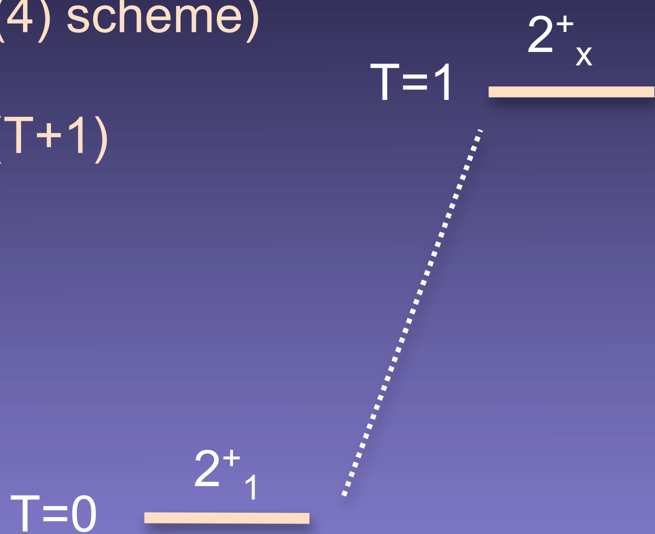
G. Rainowski (Sofia)

A. Jungclaus (Madrid)

# Maybe we can learn from the Isospin formalism ?

monopole Majorana exchange operator (Wigner, SU(4) scheme)

$M=\Sigma_{i<j} P_{i\,j} \approx T(T+1)$




even-even N=Z nucleus

Isospin: protons and neutrons behave the same.

algebra: $SU_T(2)$

energy difference: (a)symmetry energy $T(T+1)$ (+extra binding from Wigner energy)

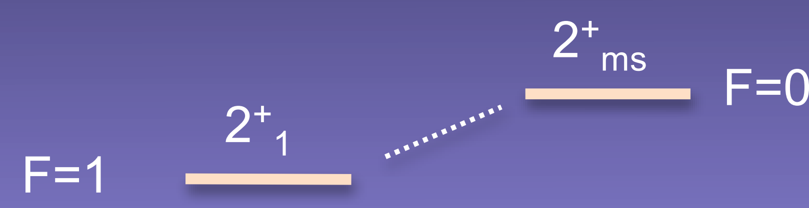
origin: high T <–> high permutation symmetry in charge <–> low symmetry in space+spin

$F \cdot F = N - N_\pi N_\nu + [(T \cdot T)^2 - T_0^4 - 2nT_0$

2 protons and 2 neutrons in same orbi

F=0 <–> T=1

F=1 <–>T=0 (+ 20% T=2)




even-even N≠Z nucleus

F-Spin: proton-bosons and neutron bos behave the same

algebra: $SU_F(2)$

energy difference: (a)symmetry energy

$$E_s = K(Z-N)^2/A$$

$$= \int [K(\rho_p - \rho_n)^2/(\rho_p + \rho_n)]\, d\tau$$

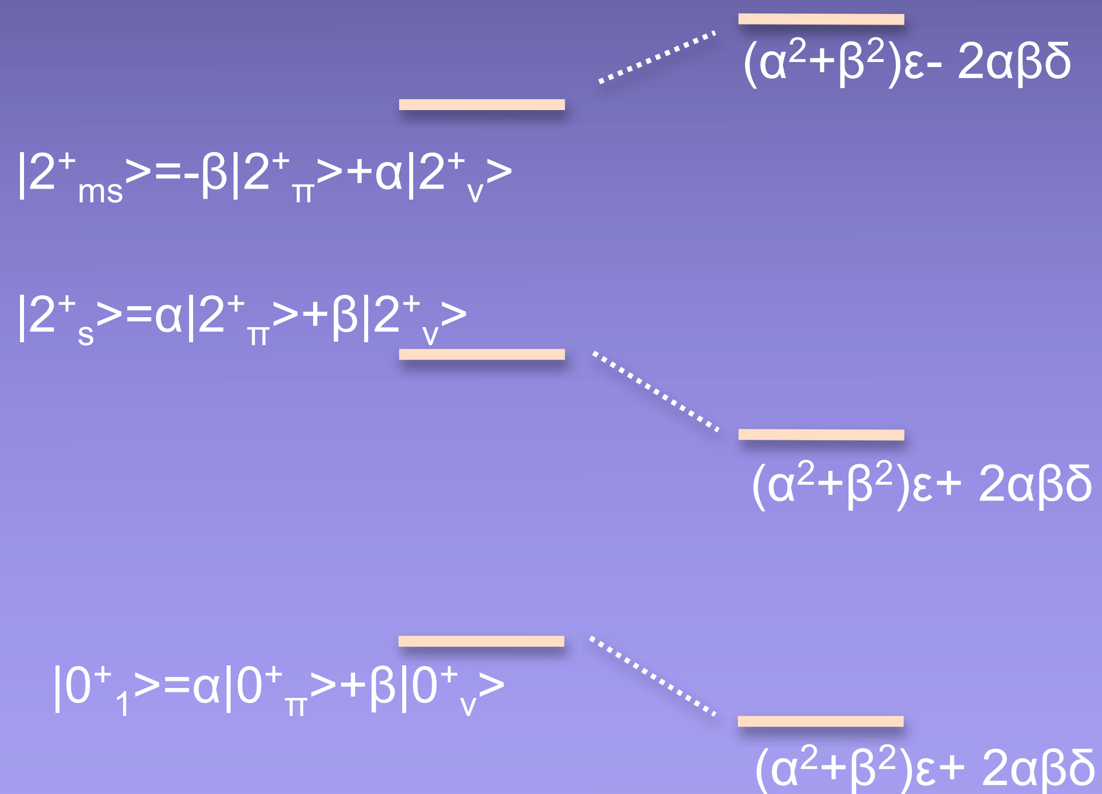
A. Faessler et al, Phys. Lett 166B, 4 (1985)

$$V_{pn} = \sum_{j_p j_n j'_p j'_n J M} \langle j_p j_n | V_{pn} | j'_p j'_n \rangle_J A^\dagger(j_p j_n J M) A(j'_p j'_n J M).$$

$$f^{(0)}(j_p j_n, j_p j_n) = \frac{\sum_J (2J+1) \langle j_p j_n | V_{pn} | j_p j_n \rangle_J}{\sqrt{(2j_p+1)(2j_n+1)}}$$

$< J^+_\rho \,|\, M_{\rho\rho} \,|\, J^+_\rho > = \text{const.}$

$< J^+_\rho \,|\, M_{pn} \,|\, J^+_{\rho'} > = \text{const.}$




shift due to monopole:

$E(2^+_{ms}) \rightarrow E(2^+_{ms}) + 4\alpha\beta\delta$

complete mixing:

$\alpha\beta = 1/2$

$E(2^+_{ms}) \rightarrow E(2^+_{ms}) + 2\delta$

$< 0^+_\pi \,|\, M_{pn} \,|\, 0^+_\nu > = \delta$

K. Heyde, J. Sau, PRC 33, 3 (1986), p. 1050

seniority u=2 shell-model states, single-j:

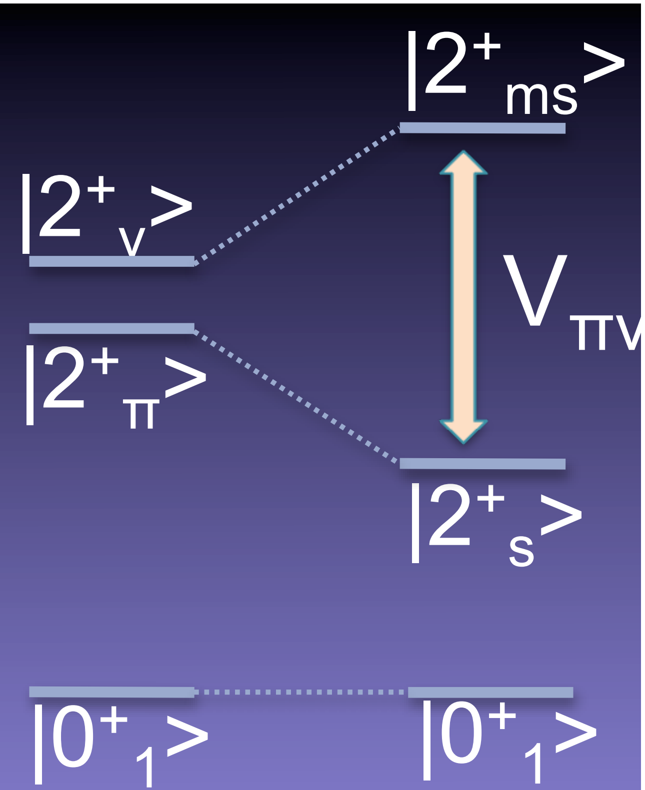
$$2^+_\pi \;=\; (j_\pi)^{n_\pi}{}_{=2}\,;2^+\;(j\;)^{n}{}_{=0}\,;0^+\;\;2^+$$

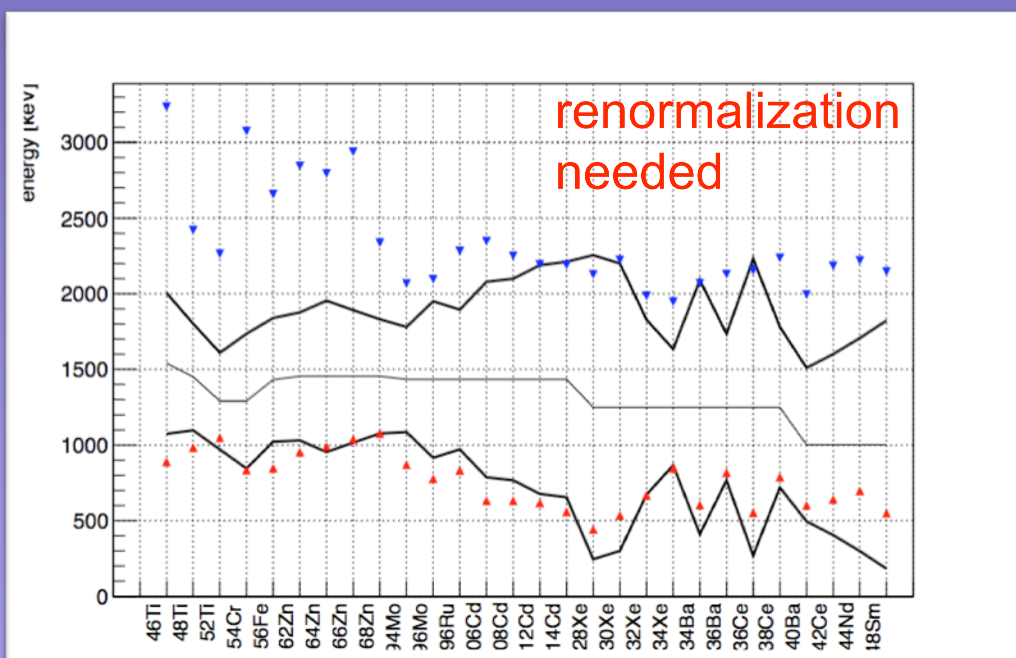
$$2^+ \;=\; (j_\pi)^{n_\pi}{}_{=2}\,;0^+\;(j\;)^{n}{}_{=0}\,;2^+\;\;2^+$$

switch on interaction:

$$V_\pi \;=\; 2^+_\pi \,/ -\; Q_\pi \cdot Q\;\;/2^+$$

$$E(2^+_{ms}) - E(2^+_1) \;=\; \frac{1}{4}(\;_\pi - \;)^2 + \;Q_\pi Q$$

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A. Faessler et al, Phys. Lett 166B, 4 (1985)

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seniority u=2 shell-model states, single-j:

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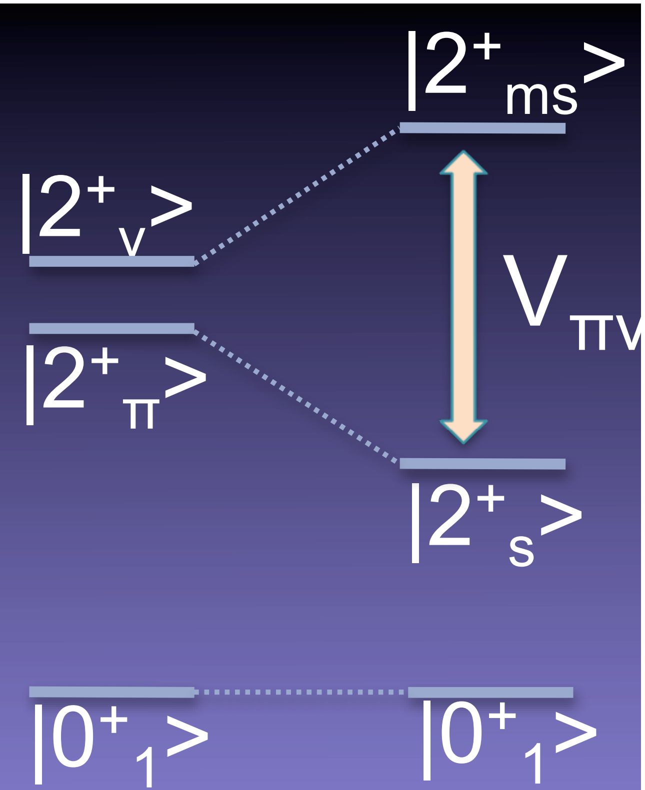
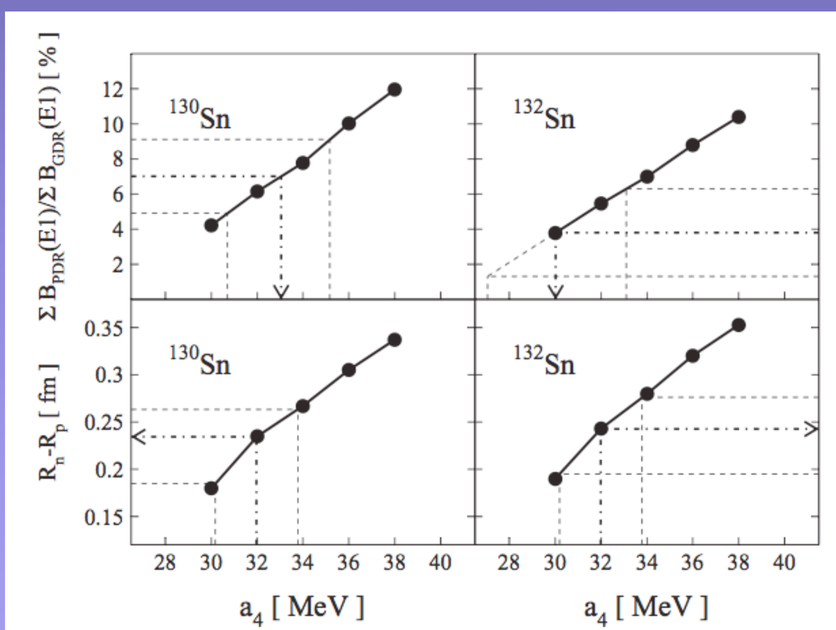
switch on interaction:

$$V_\pi \;=\; 2^+_\pi\,/-\ \ Q_\pi\cdot Q\ \ /2^+$$

$$E(2^+_{ms}) - E(2^+_1) = \frac{1}{4}(\ _\pi - \ \ )^2 + \ \ Q_\pi Q$$




A. Klimkiewic et al, PRC 76, 051603(R) 2007

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A. Faessler et al, Phys. Lett 166B, 4 (1985)