Transfer Experiments with T-REX at ISOLDE

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Excellence Cluster Universe

GEFÖRDERT VOM
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EURONS

REX-ISOLDE

T-REX – Si particle detector array

T-REX … Si detector array for Transfer experiments at REX-ISOLDE

- large solid angle (58% of 4π)
- position sensitive
- PID (ΔE-E): p, d, t, α,

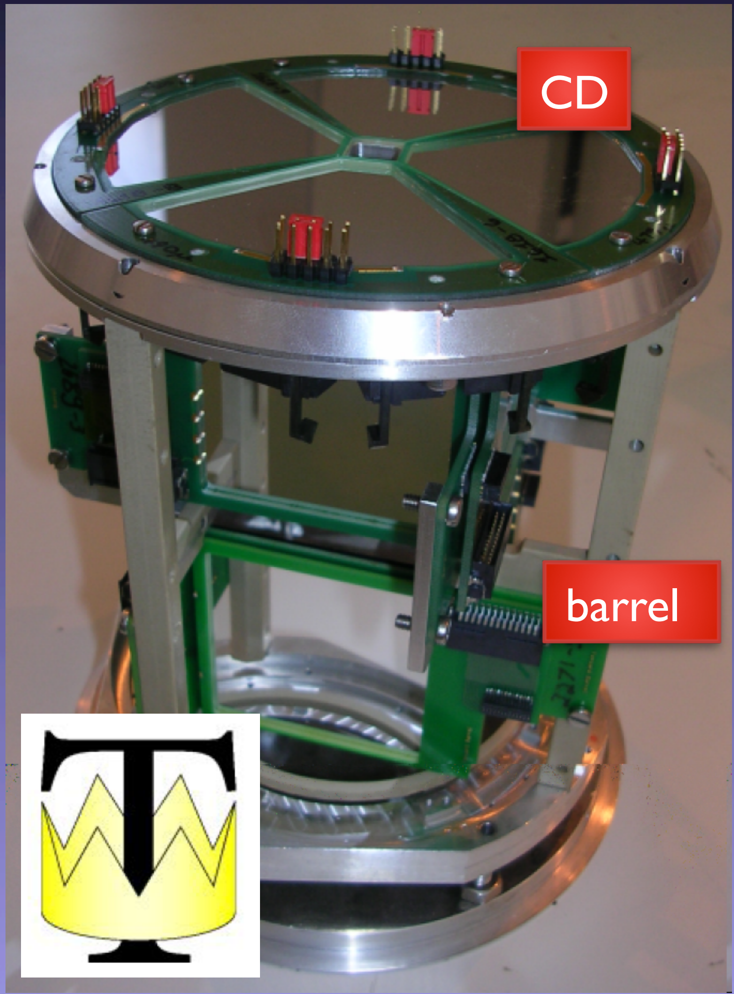
  … and e^- from β-decay (!)

Technical details:

Barrel: 140 μm ΔE / 16 resistive strips
1000 μm E / pad

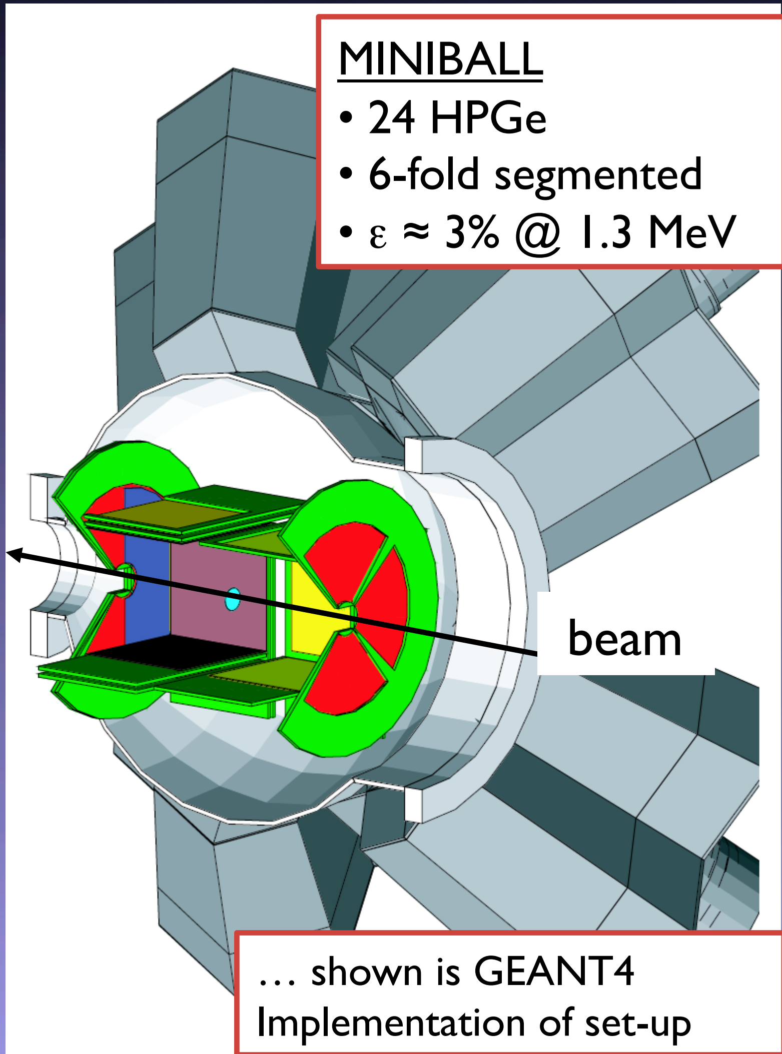
Backward CD: 500 μm ΔE / DSSSD
500 μm E / pad

V. Bildstein, K. Wimmer, Th. Kröll,
R. Gernhäuser et al.
(funded by TU München, KU Leuven,
U Edinburgh, CSNSM Orsay, TU Darmstadt)

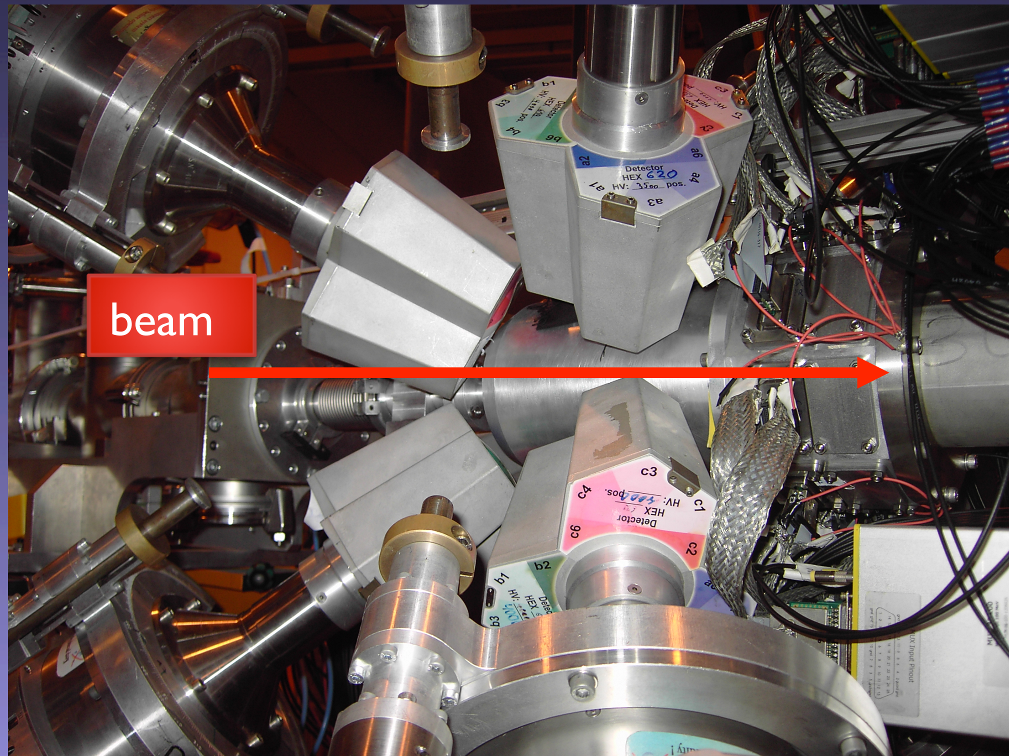


Experimental set-up: T-REX & MINIBALL

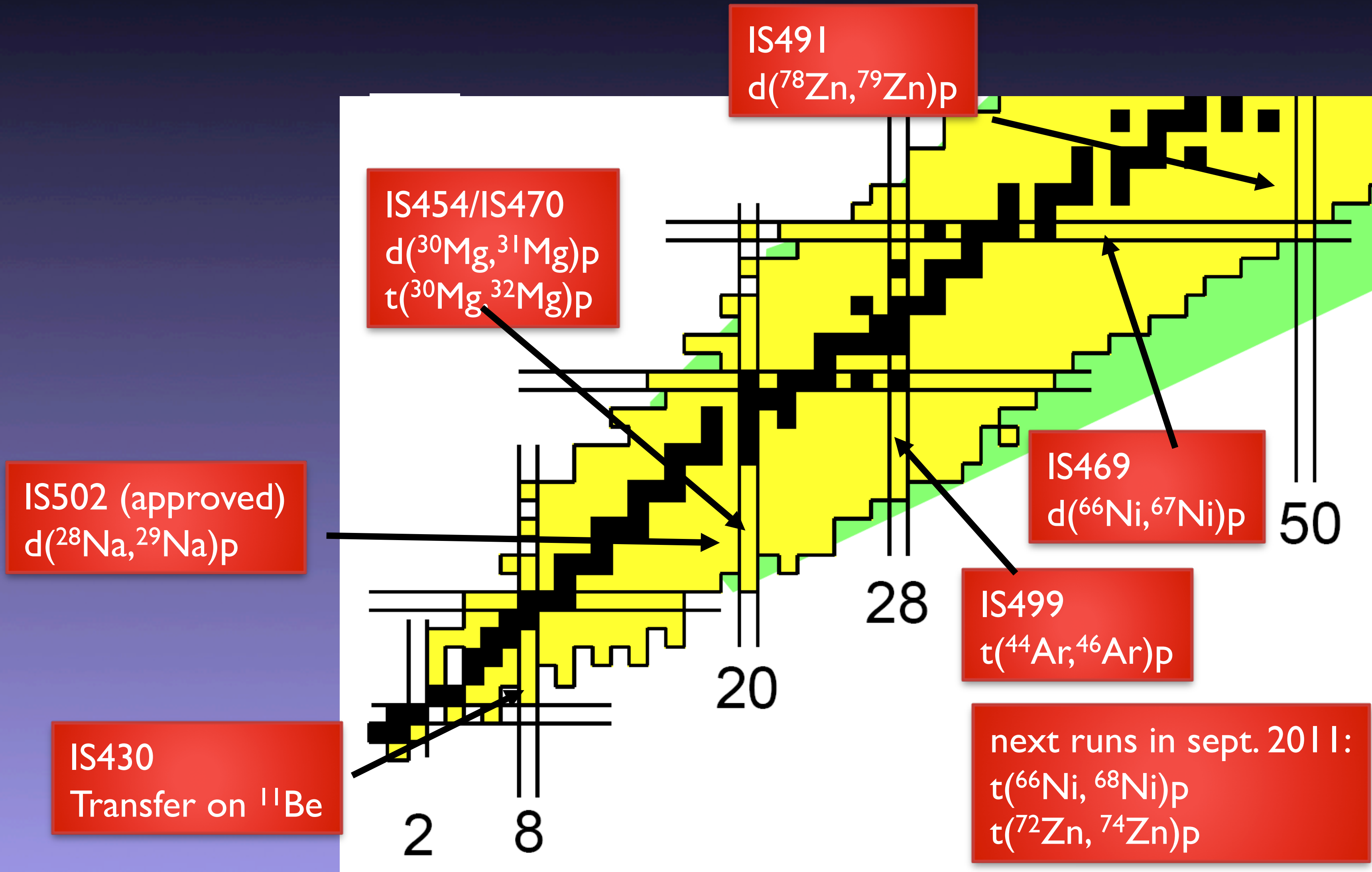
<u>MINIBALL</u>
- 24 HPGe
- 6-fold segmented
- $\varepsilon \approx 3\%$ @ 1.3 MeV



… shown is GEANT4
Implementation of set-up



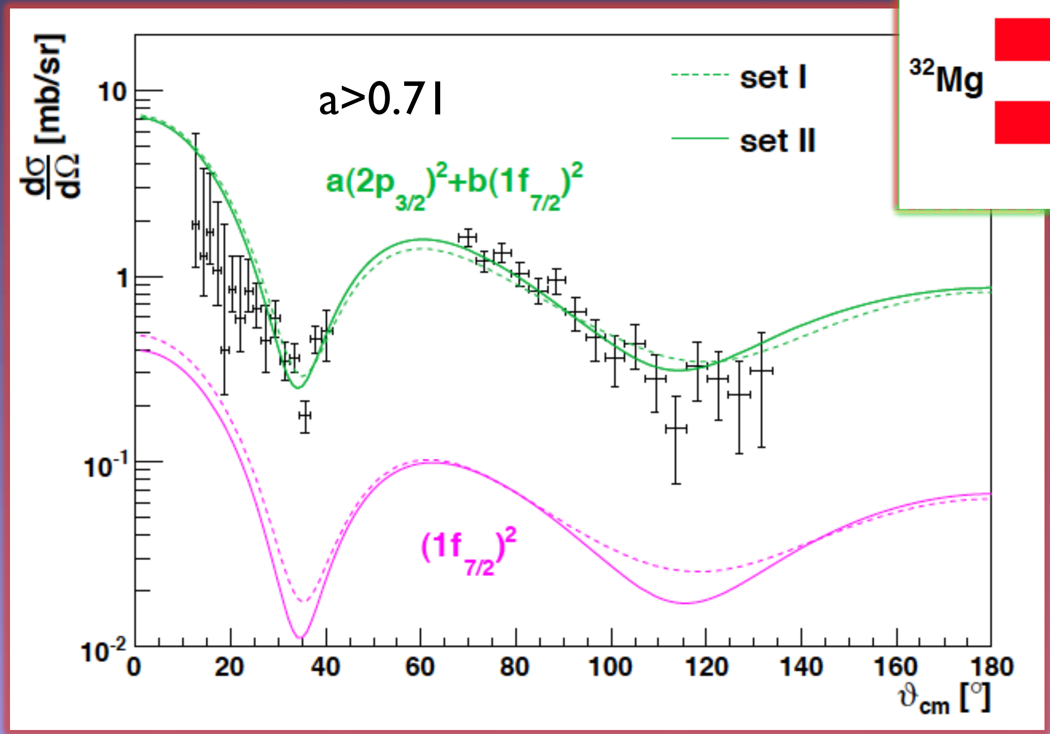
Overview of experiments done so far:
one- and two-nuceon transfer reactions

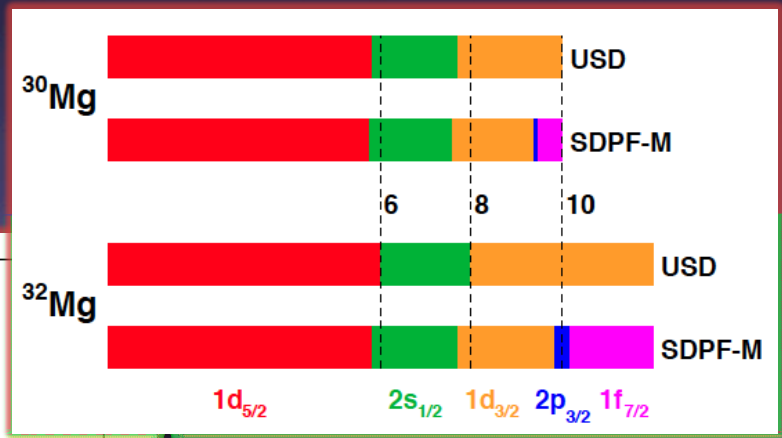


Selected for a Viewpoint in *Physics*
PRL **105,** 252501 (2010) PHYSICAL REVIEW LETTERS week ending 17 DECEMBER 2010

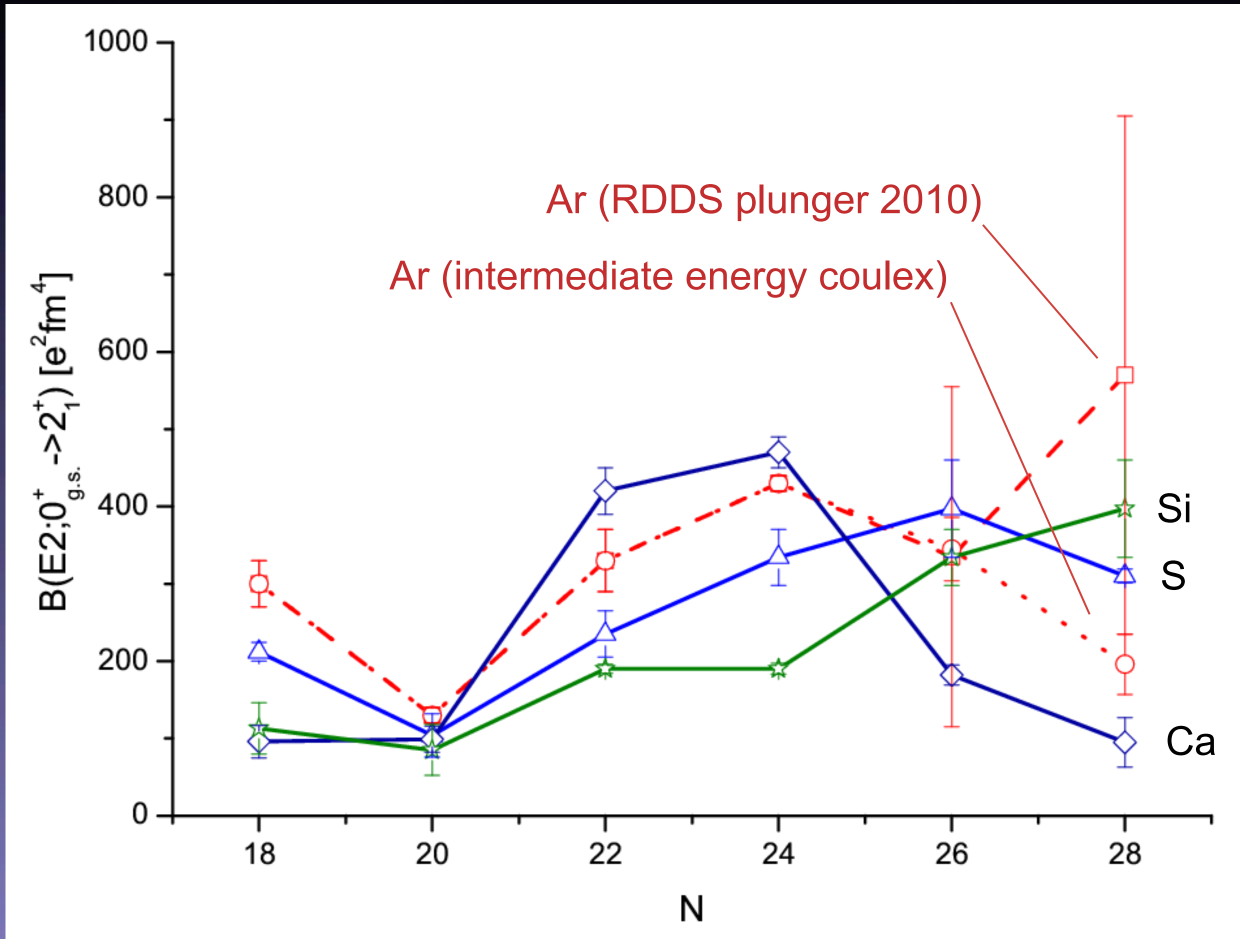
Discovery of the Shape Coexisting 0^+ State in ^{32}Mg by a Two Neutron Transfer Reaction

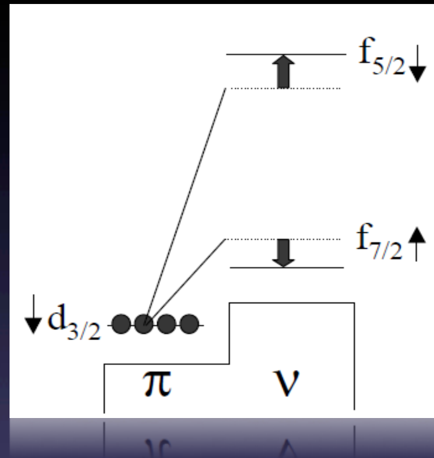
K. Wimmer,[1] T. Kröll,[1,*] R. Krücken,[1] V. Bildstein,[1] R. Gernhäuser,[1] B. Bastin,[2] N. Bree,[2] J. Diriken,[2] P. Van Duppen,[2]



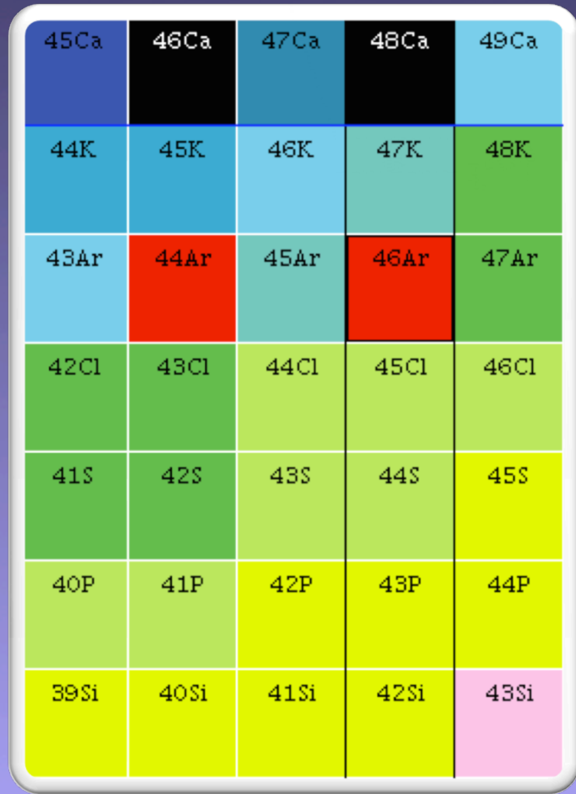


J. R. Terry et al., *Phys. Rev. C* ***77 (2008) 014316***





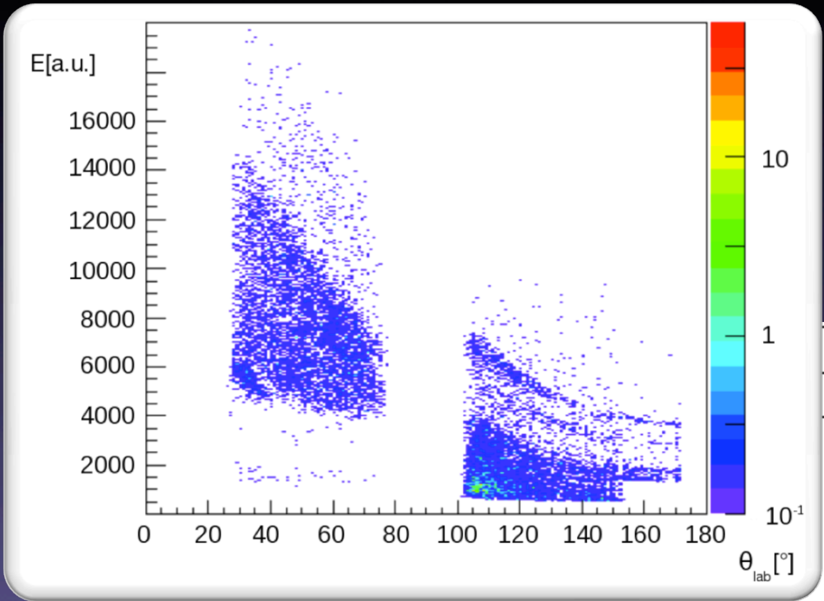
O. Sorlin, M.G. Porquet, Prog. Part. Nucl. Phys. 61, 2 (2008) 602-673

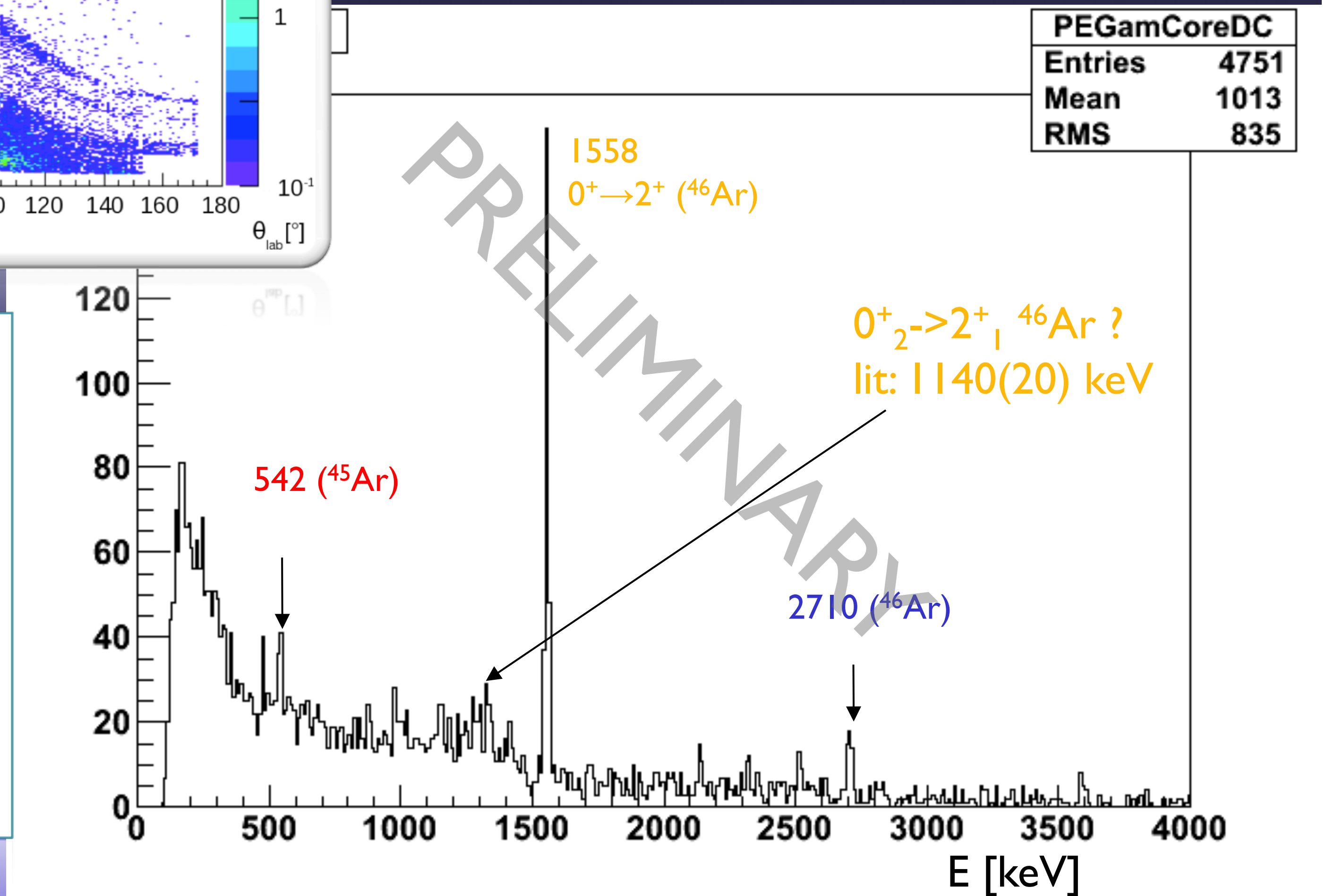


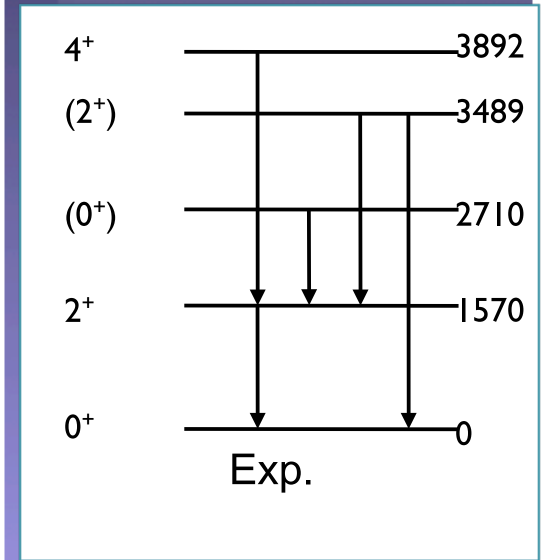
S. Raman, C.W. Nestor, and P. Tikkanen, At. Data Nucl. Data Tables 78 (2001)
X. Liang et al., Phys. Rev. C. 67 (2003) 024302
P.M. Campbell et al., Phys. Rev. Lett. 97 (2006) 112501
B. Bastin et al., Phys. Rev. Lett. 99 (2007) 022503
J.A. Winger et al., Phys. Rev. C 64 (2001) 064318
D. Mengoni et al., Phys. Rev. C 82 (2010) 024308
H.Scheit et. al., Phys. Rev Lett. 77 (1996) 3967
A. Gade et al., Phys. Rev. C 68 (2003) 014302

44Ar 2n transfer @ MINIBALL+T-REX (Ph.D thesis K. Nowak, E12, TU Munich)

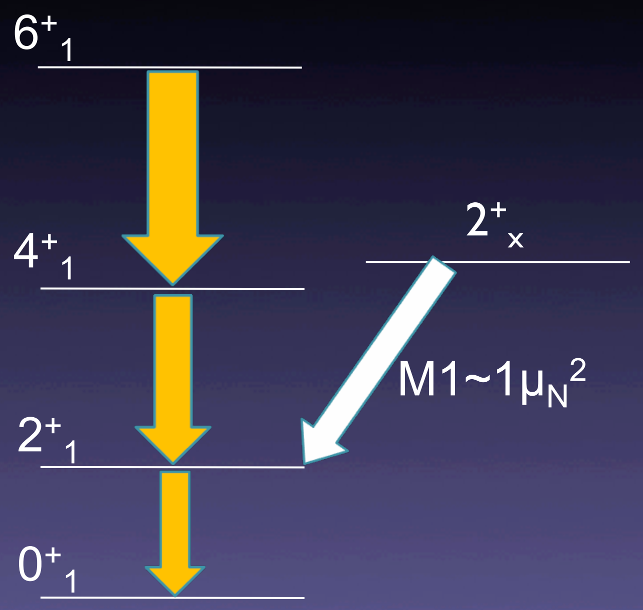
- ^{44}Ar beam: 2.16 A MeV
- beam intensity: ~1 · 10^5 part/s
- target: tritium-loaded titanium foil



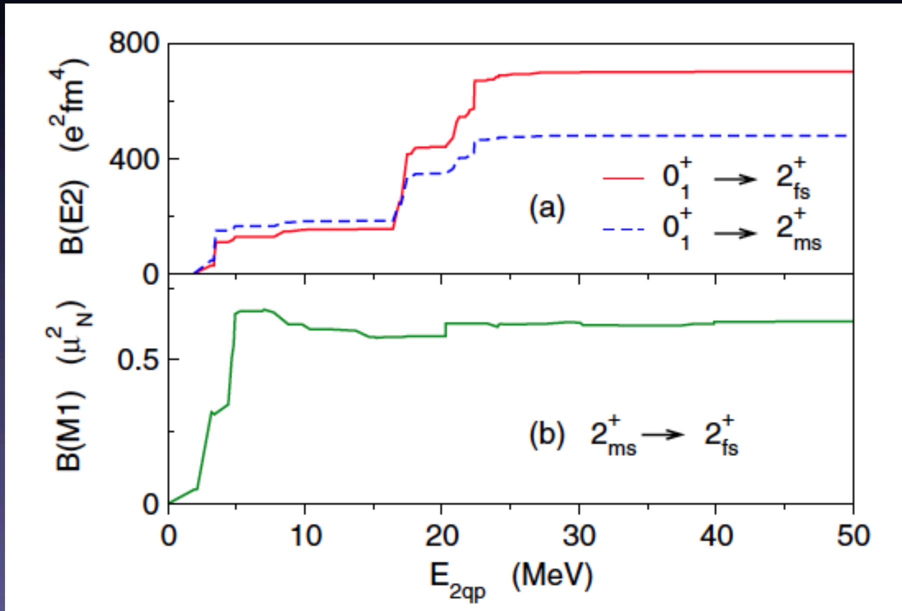




Dombradi et al., Nucl. Phys. A 727, 195 (2003) low-lying M1-strength is a "robust" feature of even-even nuclei



Nature of Mixed Symmetry State: Coupling to Quadrupole Giant Resonance is important !



(see also talk by A. Gargano: two-state mixing model)

C. Walz et al, PRL 106, 062501 (2011)

interpretations in the framework of Boson models (T. Otsuka et al, *Phys. Lett. B 76 (1978), 139)*

surface vibration for π and ν separately:

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

$$r_i(\theta,\varphi;r_0) = r_0[1 + \alpha_i^0 + \alpha_{i\mu} Y_{2\mu}(\theta,\varphi)] \,,$$

$$\rho_i[r_0] = \rho_i[r/(1 + \alpha_i^0 + \alpha_{i\mu} Y_{2\mu})]$$
$$= \rho_i[r] - r(\alpha_i^0 + \alpha_{i\mu} Y_{2\mu})\, \rho_i'(r)$$

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

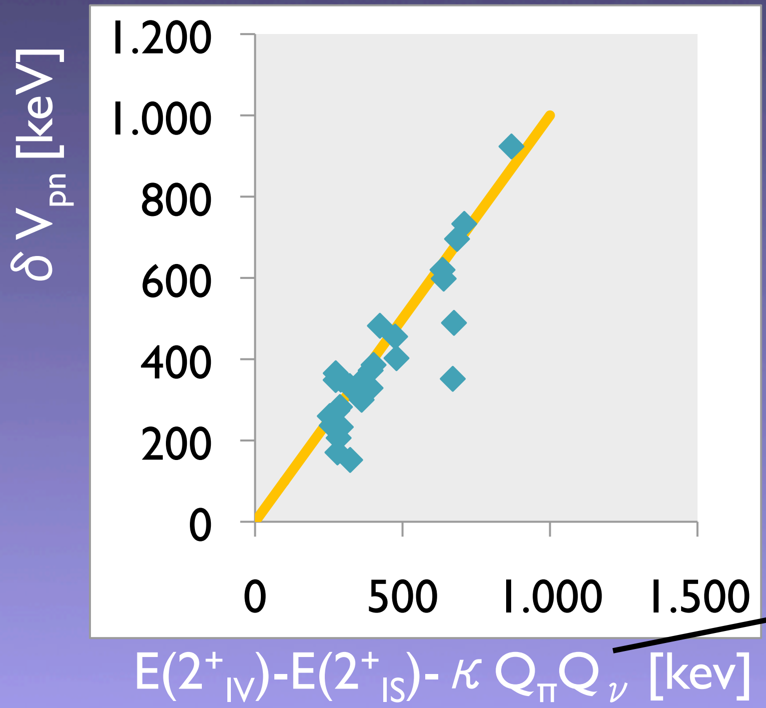
$$B = a_v A - a_s A^{2/3} - a_c \frac{Z^2}{A^{1/3}} - a_A \frac{(Z-N)^2}{A} + \delta(Z,A)$$

symmetry energy is a major uncertainty for understanding the EOS for neutron rich matter at extreme densities, like e.g. neutron stars

$$E_{sym} = \frac{1}{2} a_{sym} T^2 = \frac{1}{2}(a_{kin} + a_{int}) T^2.$$

$$\delta V_{pn}(Z,N) = ¼ \ [\{B(Z,N) - B(Z, N-2)\} - \{B(Z-2, N) - B(Z-2, N-2)\}]$$

D. Mücher, R. Krücken, J. Jolie et al. to be published



- simple measure of pn interaction in valence shell (Cakirli et al, PRL **94, 092501, 2005)**
- entering this into Bethe-Weiszäcker formula gives back mainly (~80%) the symmetry energy
- contains Wigner energy (important for N=Z): P. van Isacker et al, PRL 74, 23 (1995)
- accessible to DFT calculations → collab. P. Ring

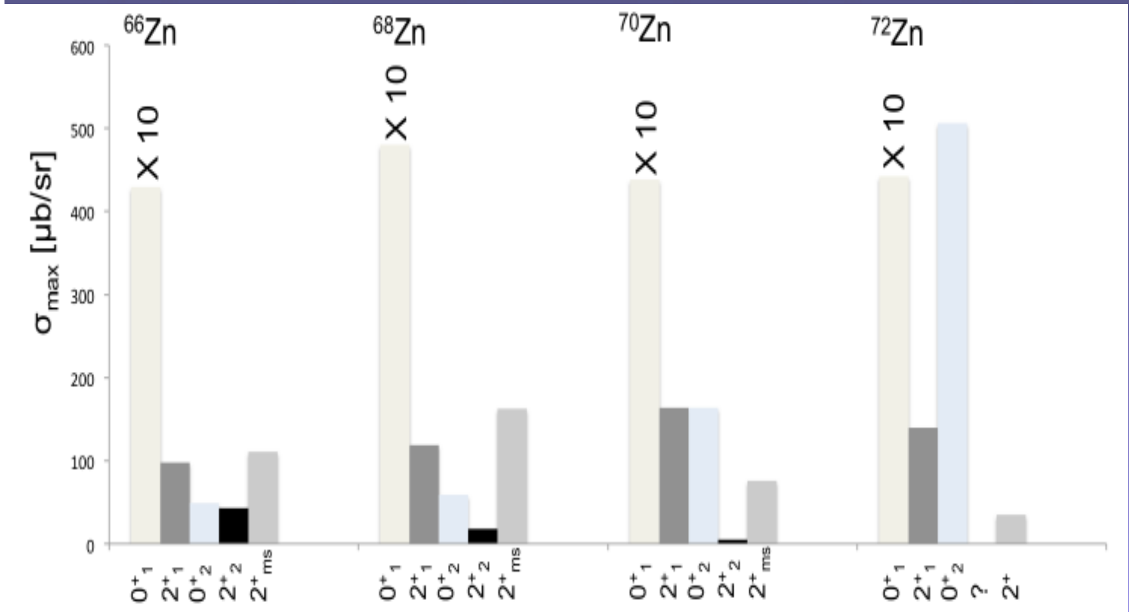
see comment from D.Vretenar (monday): collective correlations may strongly depend on nucleon number from our studies we may expect a general lowering of magnetic strength in even-even nuclei

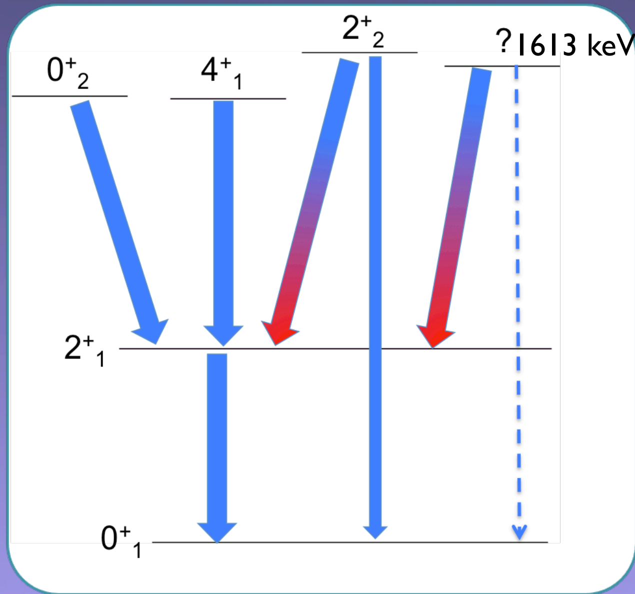
- near heavy N=Z (lowering of Wigner energy)
- in neutron-rich systems (lowering of spatial overlap of protons and neutrons)

So: how can we measure Mixed Symmetry States with RIB ?

•Coulomb excitation not successful so far (right now running at MINIBALL, CERN: IS496, ^{140}Nd), HIE-ISOLDE needed !
•MSS are often strongly excited after 2n transfer:

• IS 510: ^{72}Zn Coulex+2n transfer, scheduled in oct. 2011





^{72}Zn

Thanks for your attention!

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LMU
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Universe

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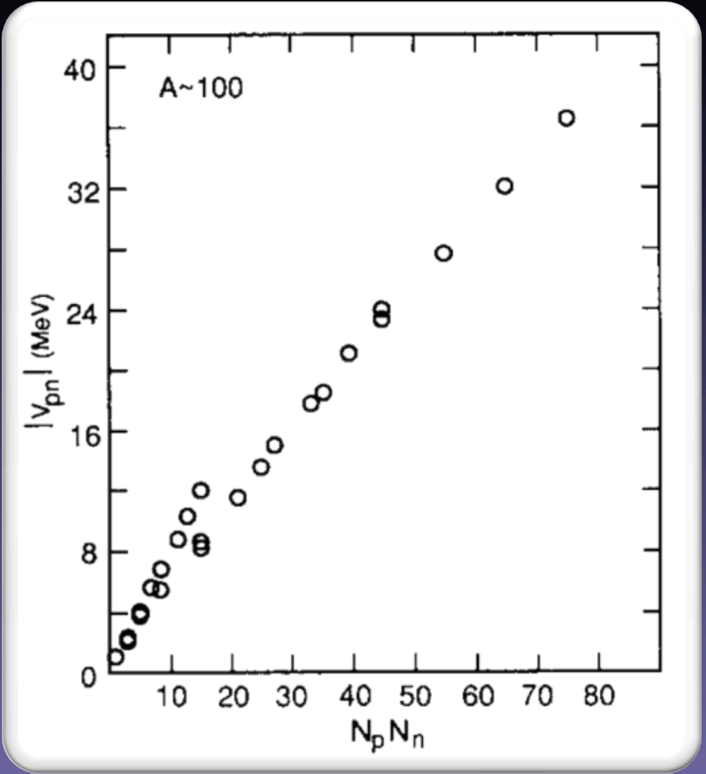
EURONS

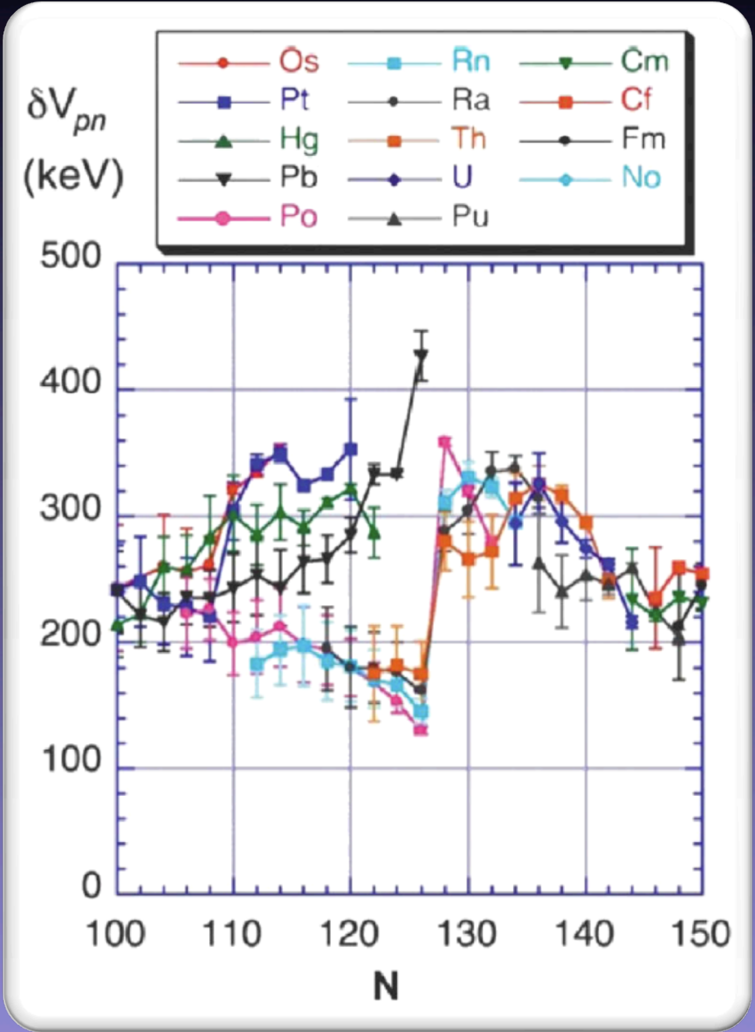
REX-ISOLDE

MINI BALL

A first phenomenologic picture



J.-Y. Zhang et al, Phys. Lett B227, 1 (1989)



R.B.Cakirli et al., PRL **94, 092501 (2005)**

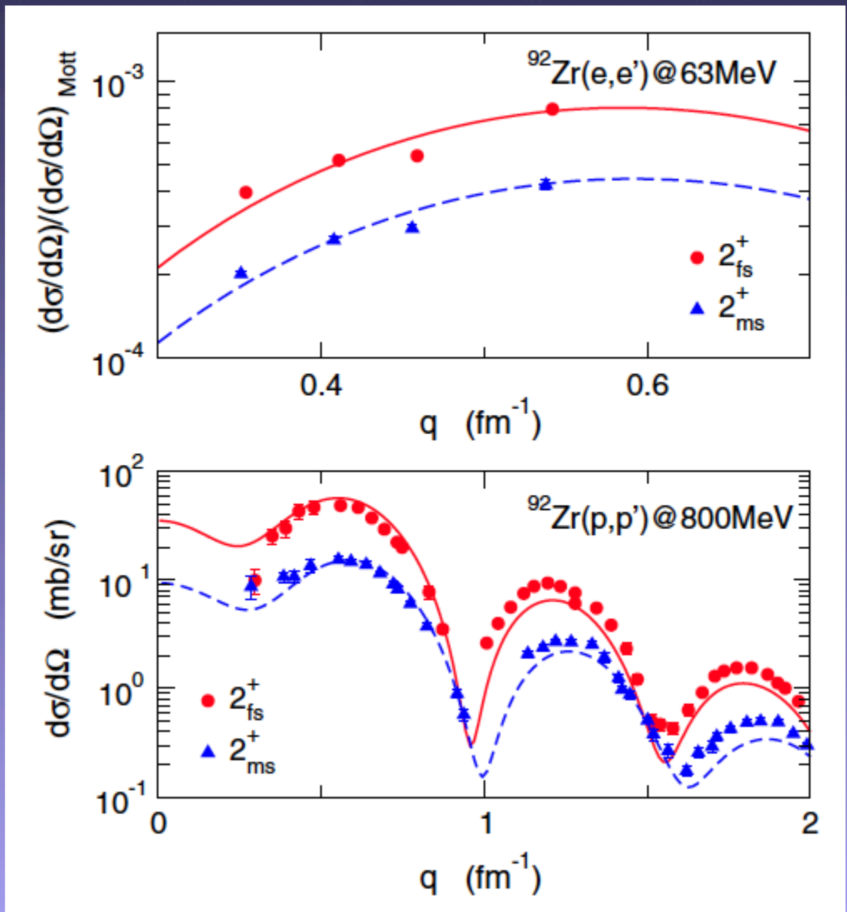
valence proton-neutron interaction roughly depends on the number of valence particles as well as on the spatial overlap of the respective shell orbits

However: the pn-interaction does not always behave so “smooth“ !

PRL 106, 062501 (2011) PHYSICAL REVIEW LETTERS week ending 11 FEBRUARY 2011

Origin of Low-Energy Quadrupole Collectivity in Vibrational Nuclei

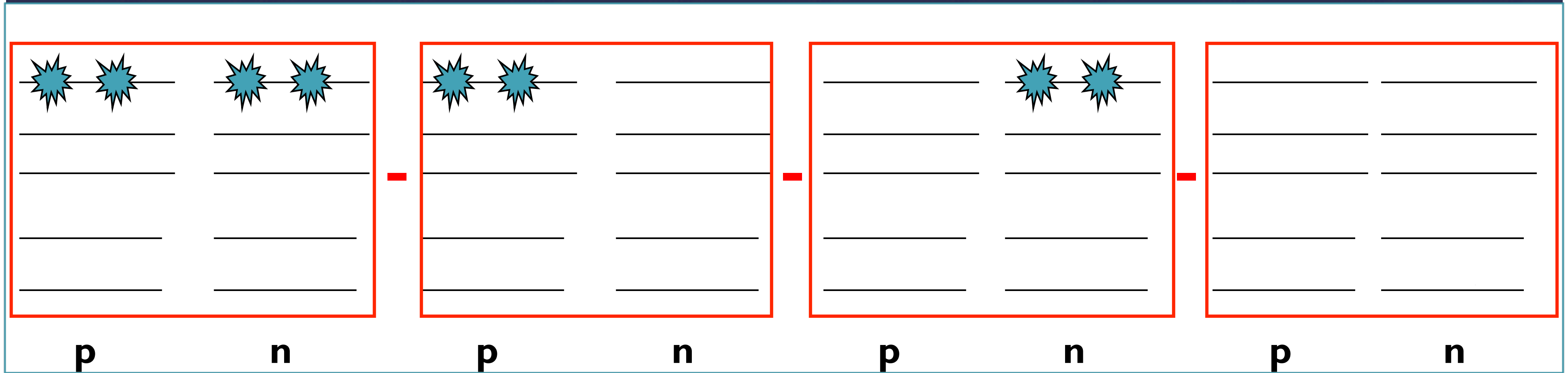
C. Walz,[1] H. Fujita,[2,3] A. Krugmann,[1] P. von Neumann-Cosel,[1] N. Pietralla,[1] V. Yu. Ponomarev,[1] A. Scheikh-Obeid,[1] and J. Wambach[1,4]



Professor Dr. Norbert Pietralla
Darmstadt Coordinator of the Helmholtz International Center for FAIR
Coordinator of the DFGCollaborative Research Center SFB634
Director
Institut fuer Kernphysik, TU Darmstadt

δVpn (Z,N) =

¼ [{B(Z,N) - B(Z, N-2)} - {B(Z-2, N) - B(Z-2, N-2)}]



Int. of last two n with Z protons, N-2 neutrons and with each other - Int. of last two n with Z-2 protons, N-2 neutrons and with each other

Bethe-Weizäcker:

δ Vpn is ominated by symmetry energy (80 %)

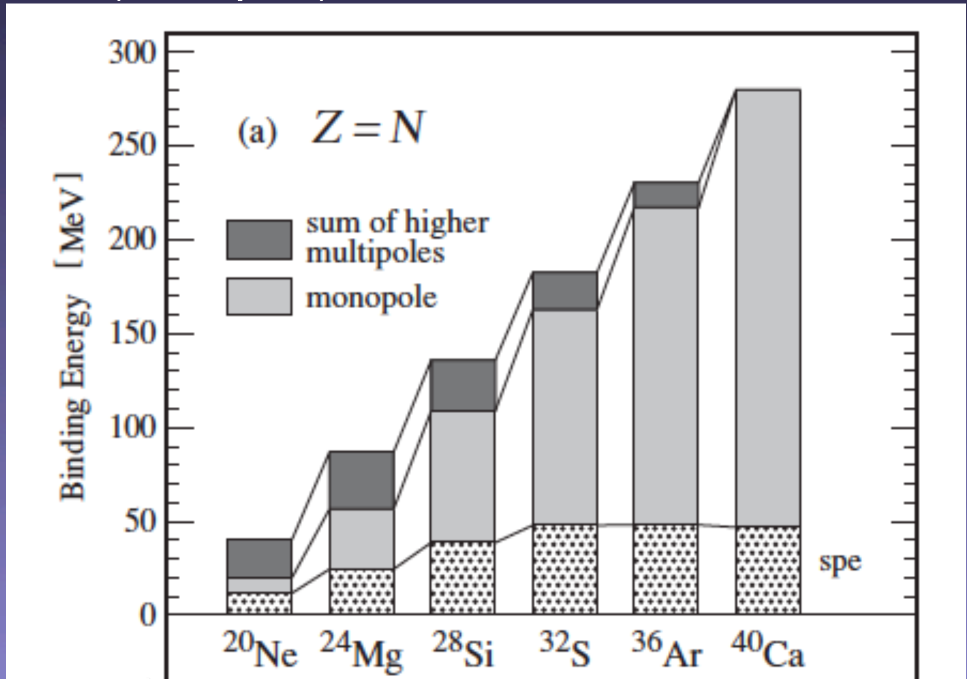
PHYSICAL REVIEW C VOLUME 59, NUMBER 3 MARCH 1999

Extension of the pairing plus quadrupole force model to $N \approx Z$ nuclei

M. Hasegawa[1] and K. Kaneko[2]
[1]Laboratory of Physics, Fukuoka Dental College, Fukuoka 814-0193, Japan
[2]Department of Physics, Kyushu Sangyo University, Fukuoka 813-8503, Japan
(Received 28 October 1998)

inclusion of a T=0 J-independent pn-interaction (monopole)

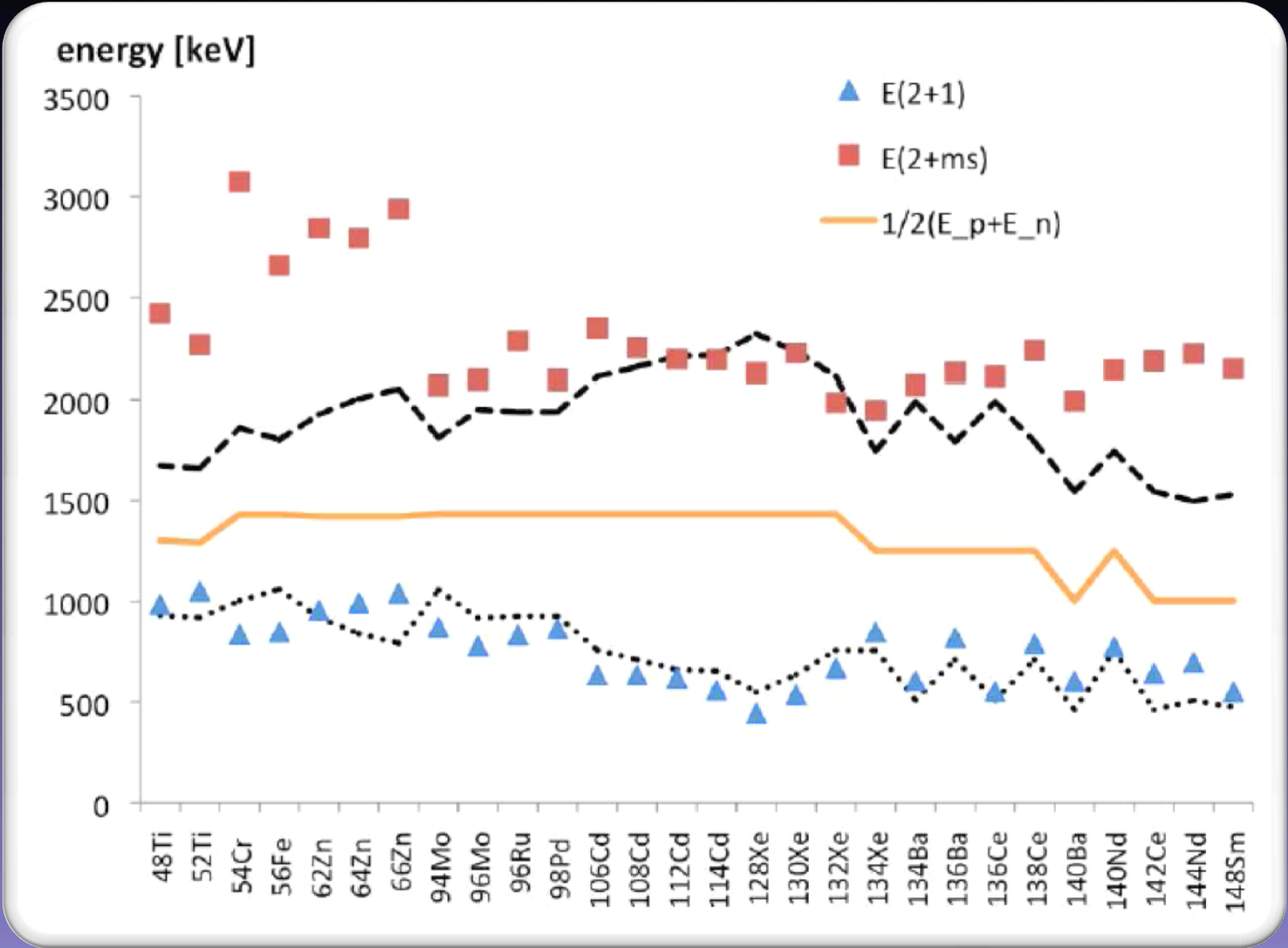
$$V_{\pi\nu}^{\tau=0} = -\frac{1}{2}k^0\left\{\frac{\hat{n}}{2}\left(\frac{\hat{n}}{2}+1\right)-\hat{T}^2\right\}$$



Heyde et al., PRC 49, 5 (1994), 2499

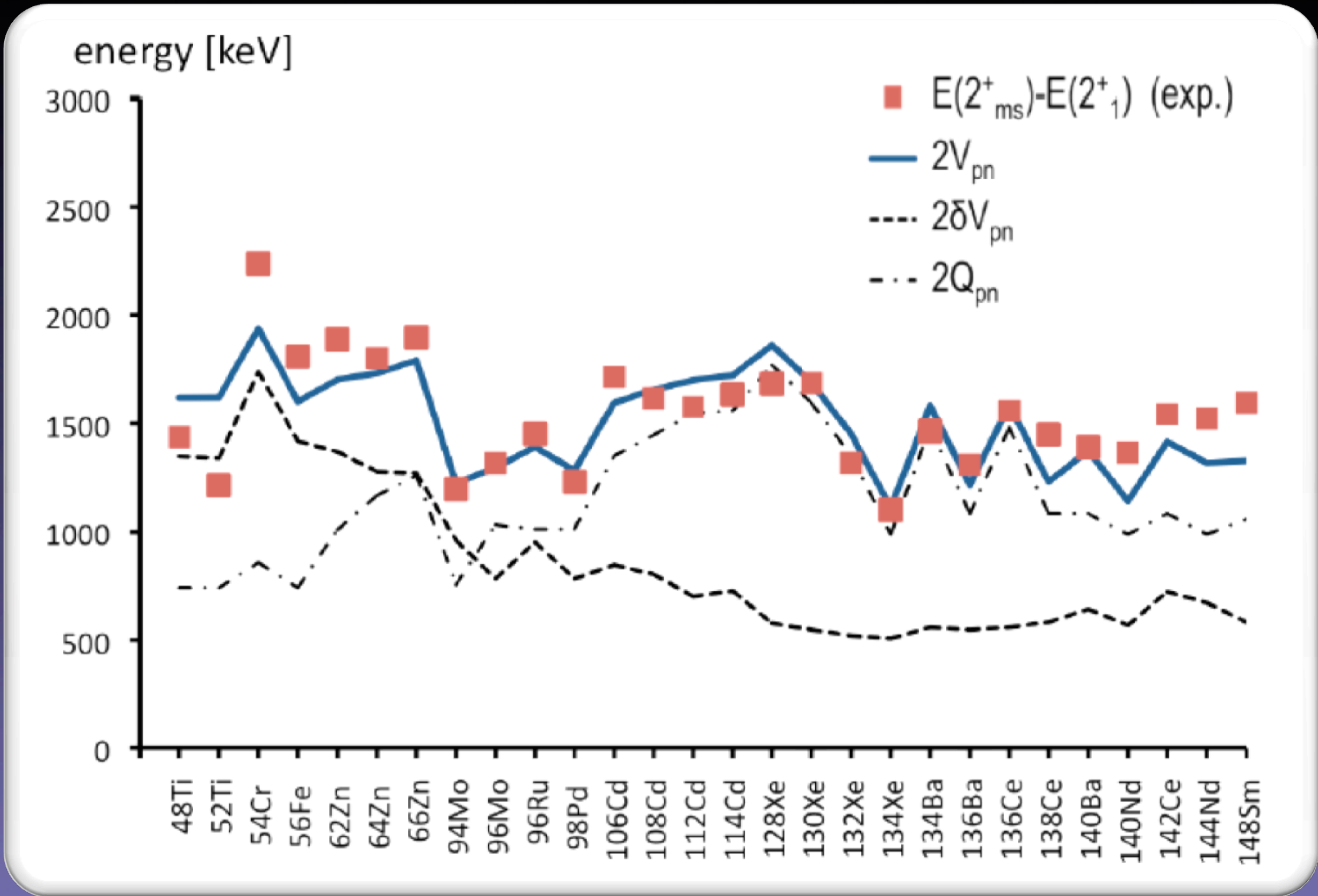
$$\delta V_{pn} = \frac{4\cdot \Sigma_J (2J+1)\langle j_\pi j_\nu ;J|V|j_\pi j_\nu ;J\rangle}{\Sigma_J (2J+1)}$$

Symmetry energy ←→ δ Vpn←→ J-independent (T=0) pn-interaction ?



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

general: lower T <-> higher pn-symmetry

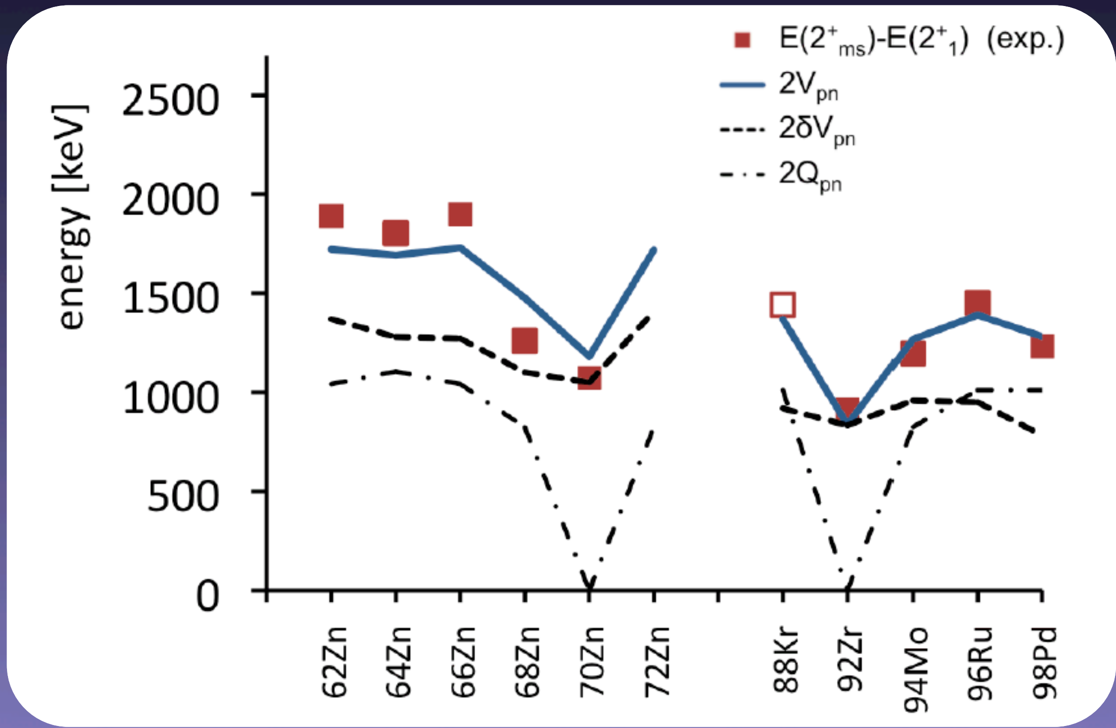


$$E(2^+_{\mathrm{ms}}) - E(2^+_1) = 2V_{pn} = \sqrt{(\epsilon_\pi - \epsilon_\nu)^2 + 4\delta V_{pn}^2 + 4Q_{pn}^2}$$

description of energies around N,Z=40: influence of subshell closure

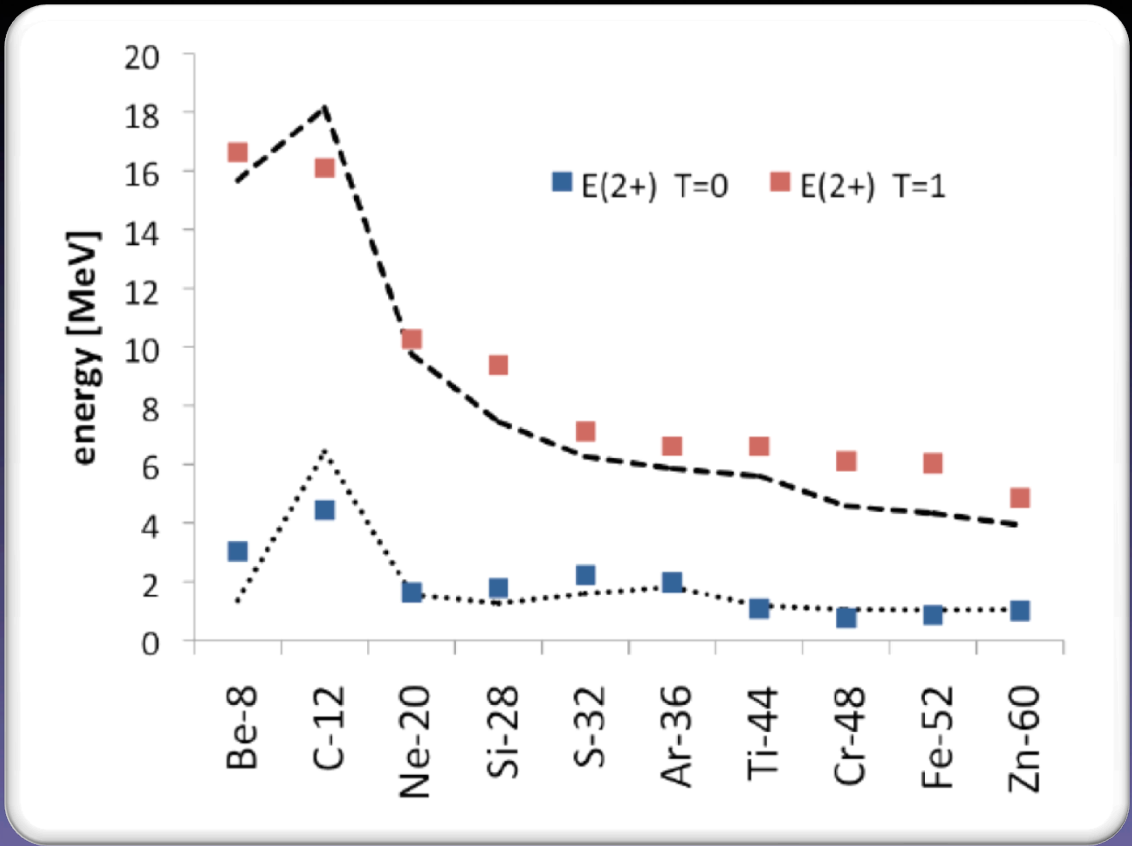
Nuclear Physics A 847 (2010) 180–206

→ the study of E(2+ms) is a very sensitive tool for the quadrupole collectivity, but only when also treating the monopole-like contributions!



$E(2^+_{ms})$ seems to be related related to the symmetry energy and is shifted to higher energies towards N=Z due to the the isovector character of these states

What happends at N=Z ??



at N=Z: strong effects of the Wigner energy: T=0 pn interaction!

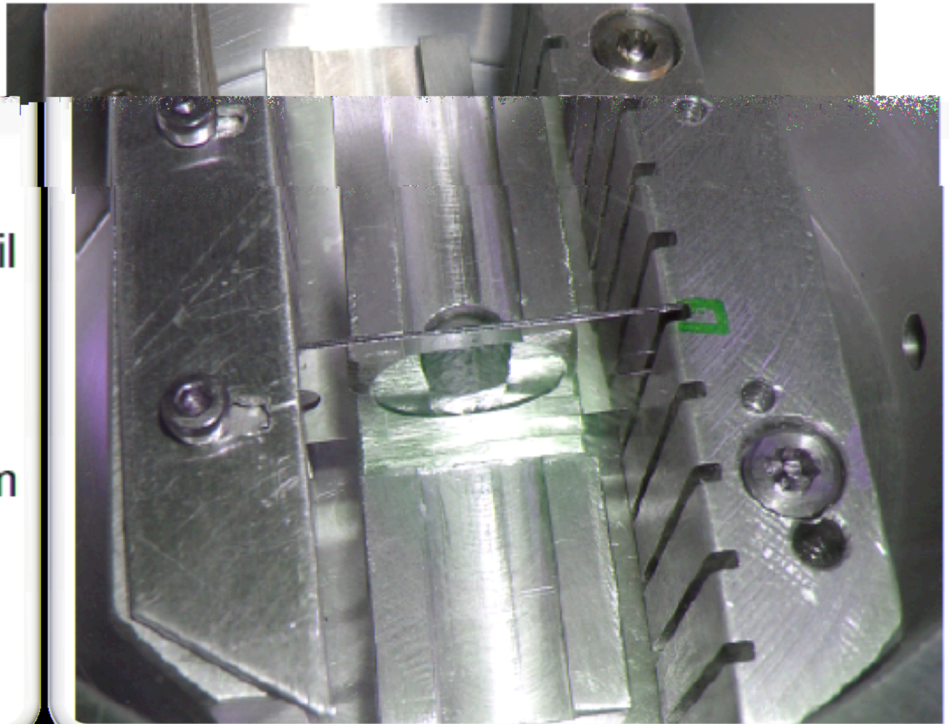
applications:

1. measurement of $E(2^+_{ms})$ is a tool to monitor the evolution of the pn interaction and to disentangle monopole and quadrupole components
2. study N=Z nuclei towards A=100: Wigner energy reduced?

→ we expect major changes(i.e. low-lying M1 trength) in the low-energy regime of exotic nuclei from these observations !

oil

m



Challenge: radioactive Tritium target

- use of Tritium loaded Titanium f
- 0.5 mg/cm^2 Ti foil
- atomic ratio H^3/Ti $\approx$ 1.5
- corresponds to 50 μg/cm^2 Tritiu
- activity $<$ 10 GBq

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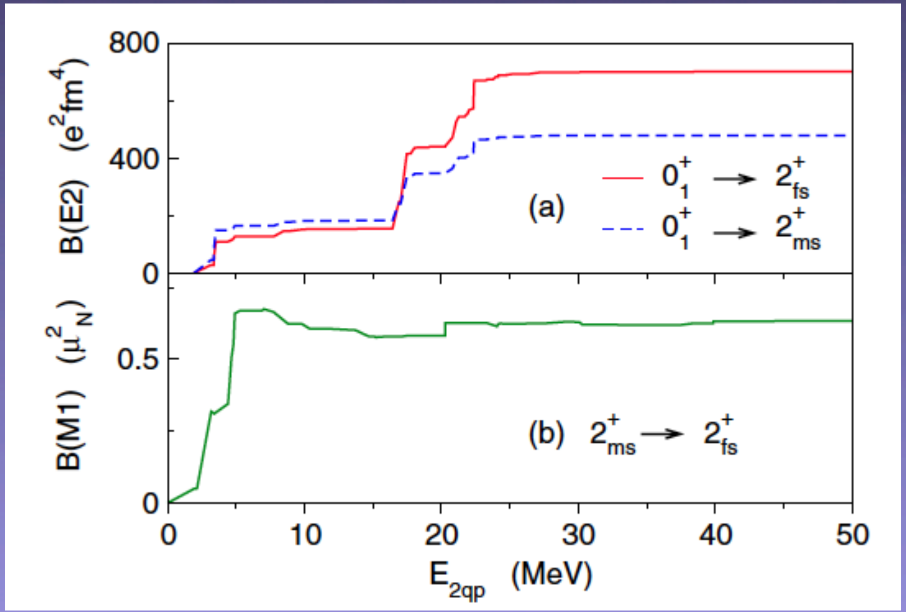
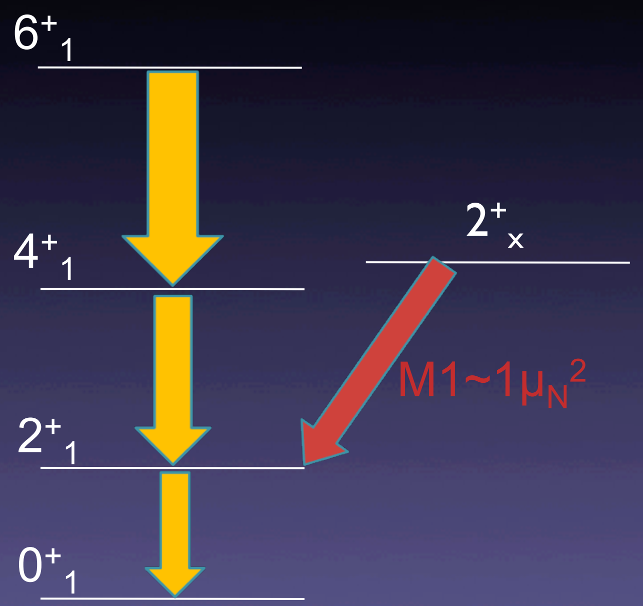
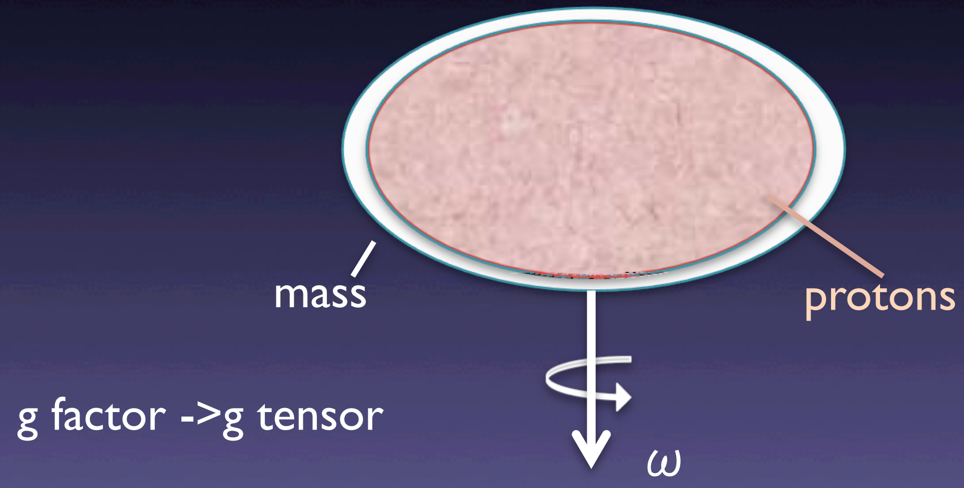
Nature of Mixed Symmetry State:
Coupling to Quadrupole Giant Resonance is important !



low-lying M1-strength is a "robust" feature of even-even nuclei



W. Greiner, Phys Rev Lett 14, 1965, 15 : different deformation of protons and neutrons



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

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