Nuclear moment studies in transfer reactions with the ORGAM spectrometer

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Programme instead of contents

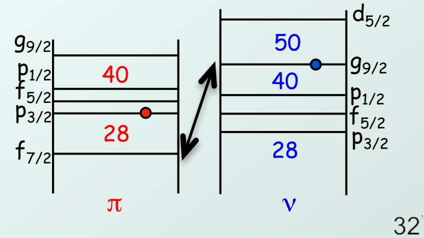
❶ *measure the quadrupole moment (Q_s) of isomeric state in ^{66}Cu using (D,p) reaction on a Cu_2O host*

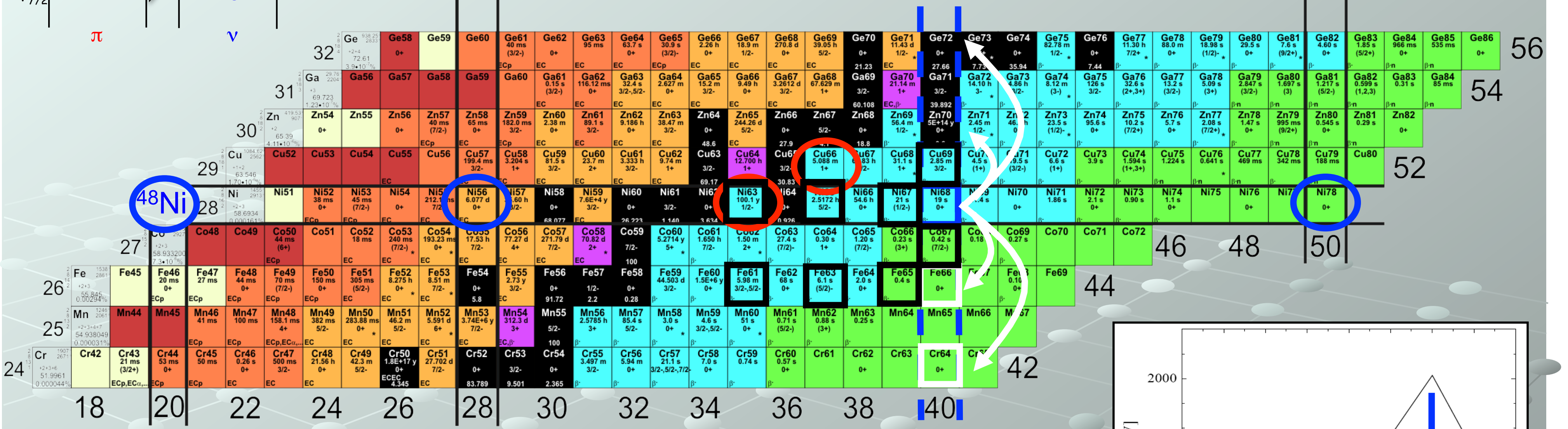
❷ *investigate the possibility of using MNT reactions for the population and nuclear moment studies of isomeric states in ^{66}Cu and ^{63}Ni (techniques to be developed for RIBs)*

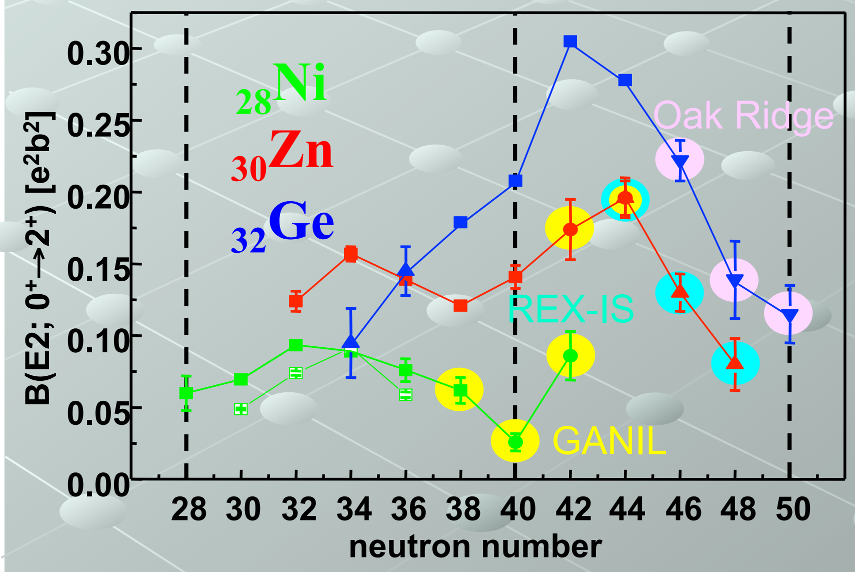
❸ *determine the EFG of Cu and Ni in Zn via quadrupole moment measurement using MNT reactions on a Zn target*

- ➲ *allow the determination of the nuclear spin orientation in MNT reactions*
- ➲ *employ MNT reactions for (quadrupole) moment measurements + RIBs*
- ➲ *study more exotic isotopes (e.g. Ni region)*

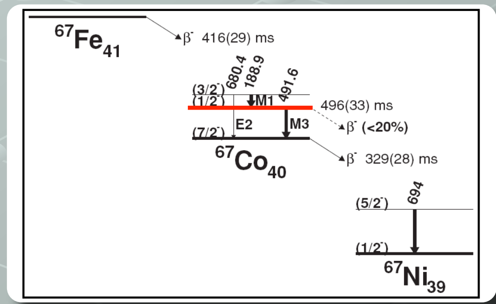
The ^{68}Ni region - deformation



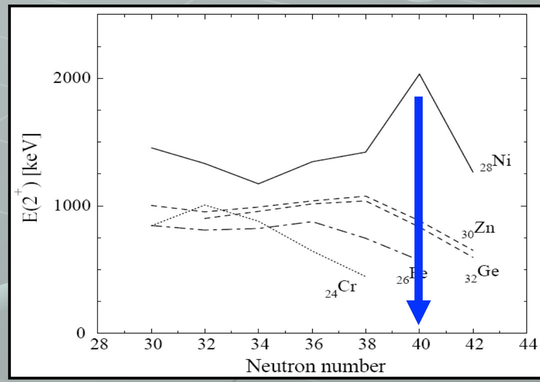




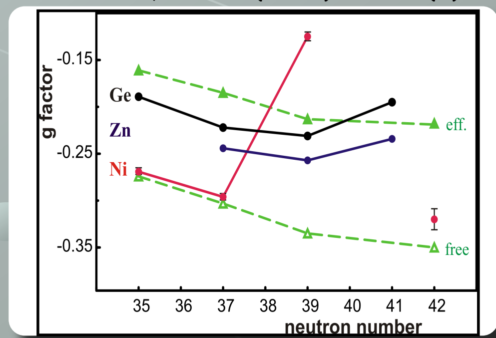
O. Sorlin, PRL **88** (2002) 092501, S. Leenhardt, EPJ A **14** (2002) 1, O. Perru, PhD thesis (2004), E. Padilla-Rodal, PRL **94** (2005) 122501, J. Van de Walle, PRC **79** (2009) 014309, D. Pauwels, PhD thesis (2009)



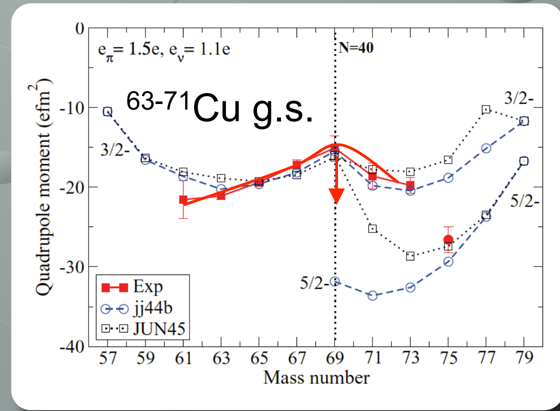
D. Pauwels, PRC **78** (2008) 041307(R)



O. Sorlin, EPJ A **16** (2003) 55

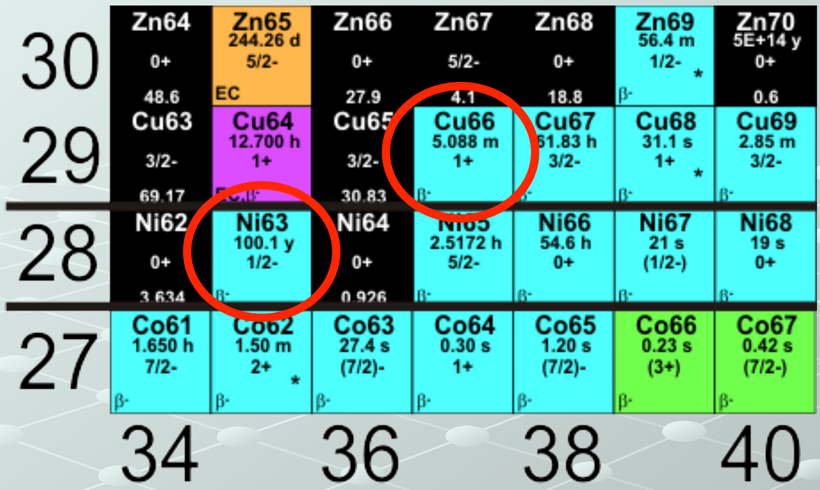


Georgiev, EPJ A **30** (2006) 351, JPG **28** (2002) 2993

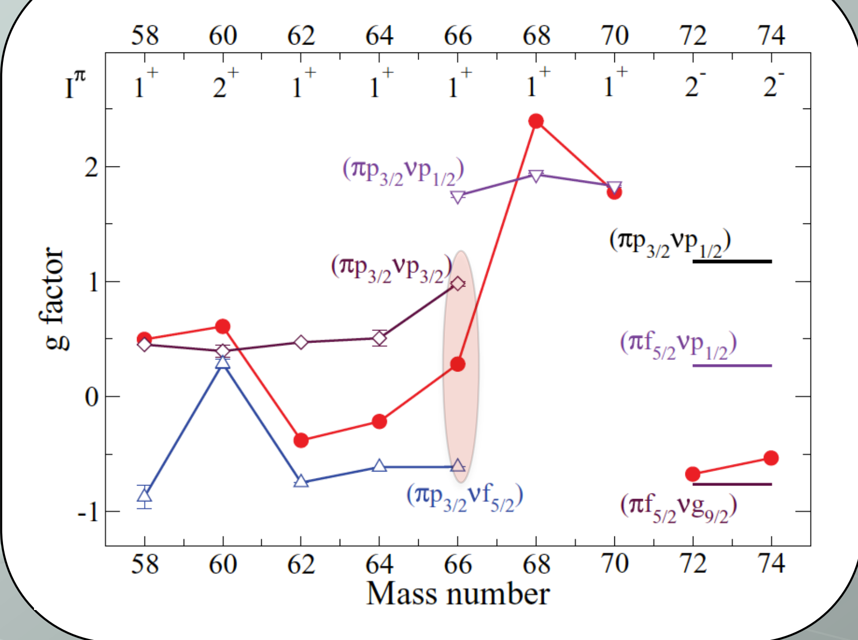


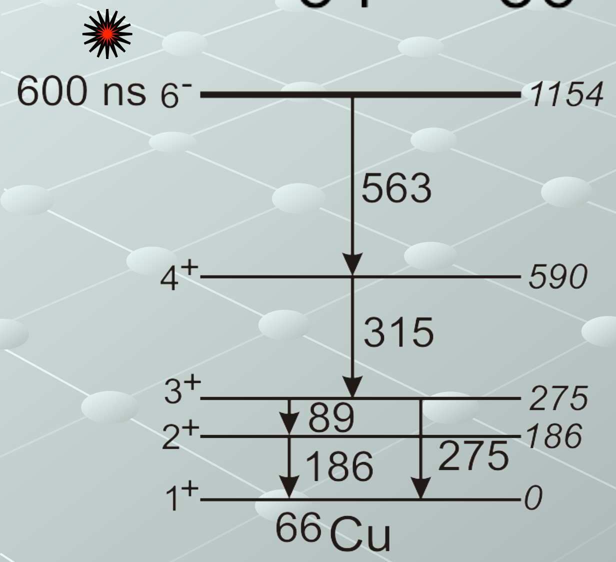
P. Vingerhoets, PRC **82** (2010) 064311

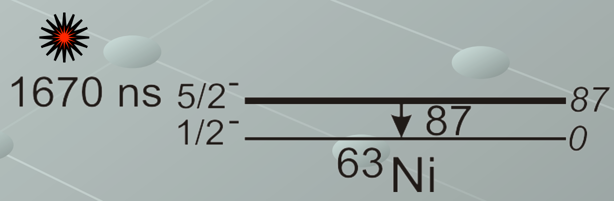
Quadrupole moments of ^{66}Cu and ^{63}Ni



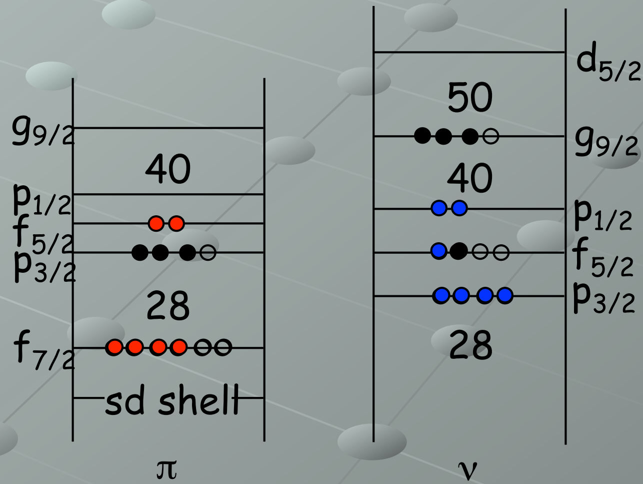
P. Vingerhoets, PRC **82** (2010) 064311







J. Bleck, NPA 197 (1972) 620, PLB 32 (1970) 41



$\pi p_{3/2} \otimes \nu g_{9/2}$

➲ *test the influence of $\pi f_{5/2}$ orbital on deformation*

➲ *test the influence $\nu g_{9/2}$ orbital on deformation*

Quadrupole moments and experimental technique

nuclear moments

magnetic

$$\mu = gI\mu_N$$

- nuclear s.p. structure
- purity wave function

quadrupole

$$Q = e\sum_{k=1}^{A}(3z_k^2 - r^2)$$

- collective properties
- nuclear deformation

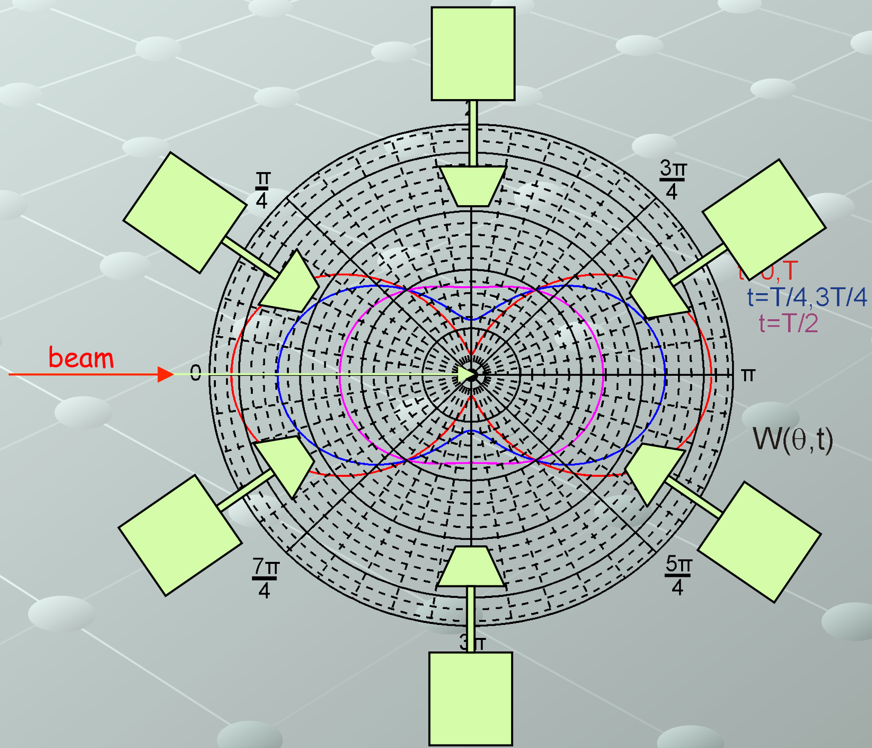
Quadrupole moment

EFG

$$\nu_Q = \frac{eQ_s V_{zz}}{h}$$

Observed quadrupole frequency

$$\nu_Q^0 = \frac{3\nu_Q}{4I(2I-1)}(\text{int } I), \nu_Q^0 = \frac{6\nu_Q}{4I(2I-1)}(\textit{half} \text{ int } I)$$



$$R(t) = \frac{W(0^0,t) - W(90^0,t)}{W(0^0,t) + W(90^0,t)}$$

$$W(\theta,t) = \sum_k A_k B_k G_{kk}(t) P_k(\cos\theta)$$

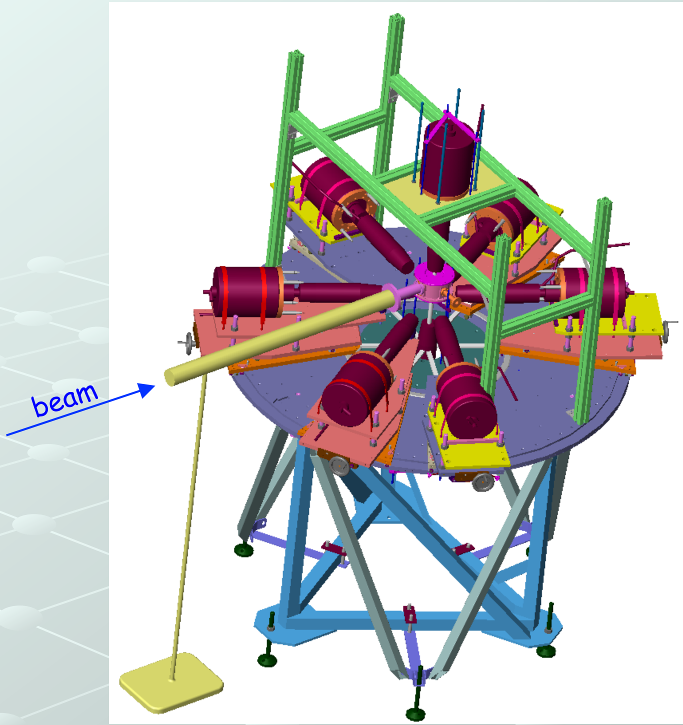
Perturbation factors

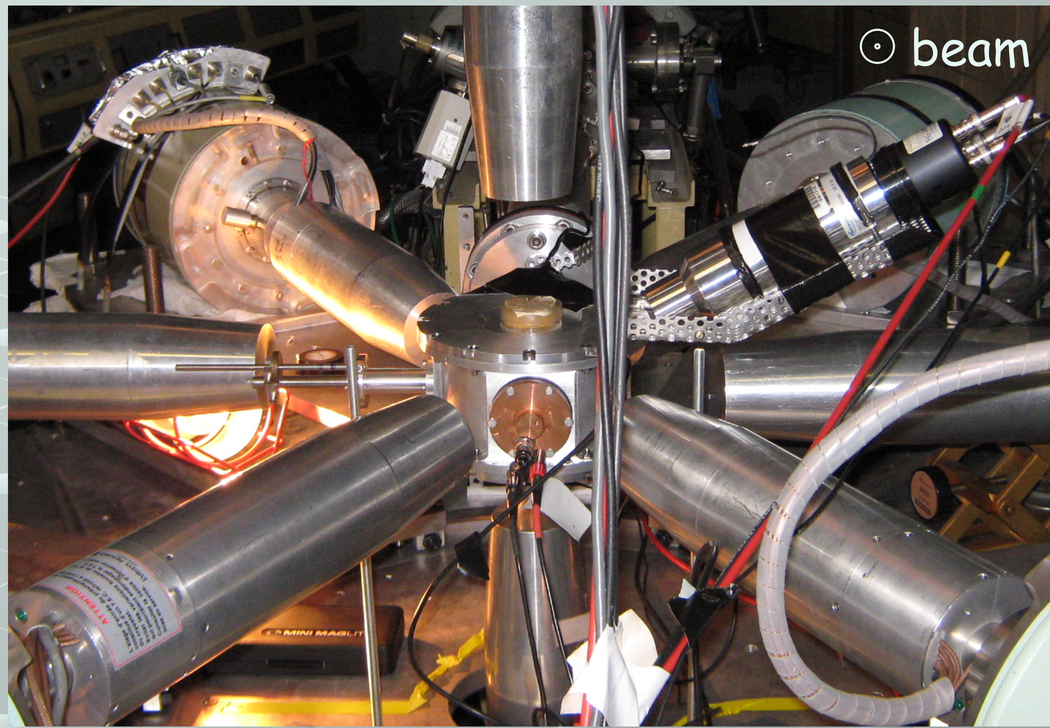
Orientation coefficients

Angular distribution coefficients

Time Dependent Perturbed Angular Distribution technique **(TDPAD)**

Experimental setup @ Tandem Orsay



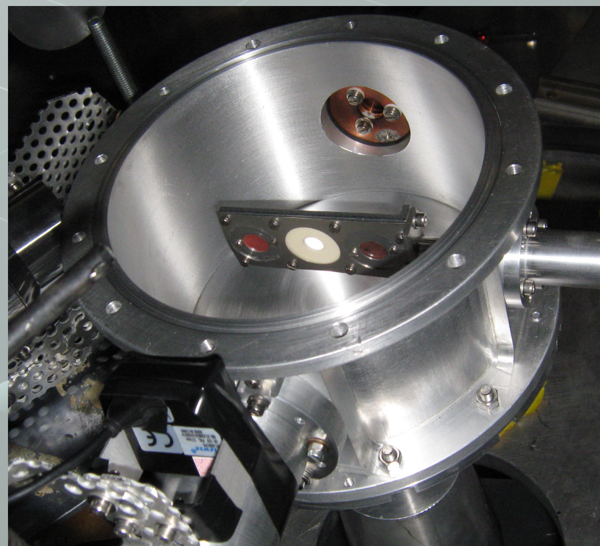


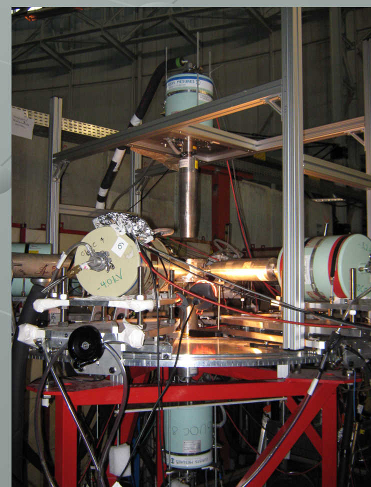
6 MeV ^{2}H beam
on Cu_2O polycrystalline target host
-> (D,p) reaction, 0.4 pnA

NQR: ^{63}Cu in Cu_2O (295 K)
ν_Q=26.001(1) MHz
(De Wijn, PR 150 (1966) 200)

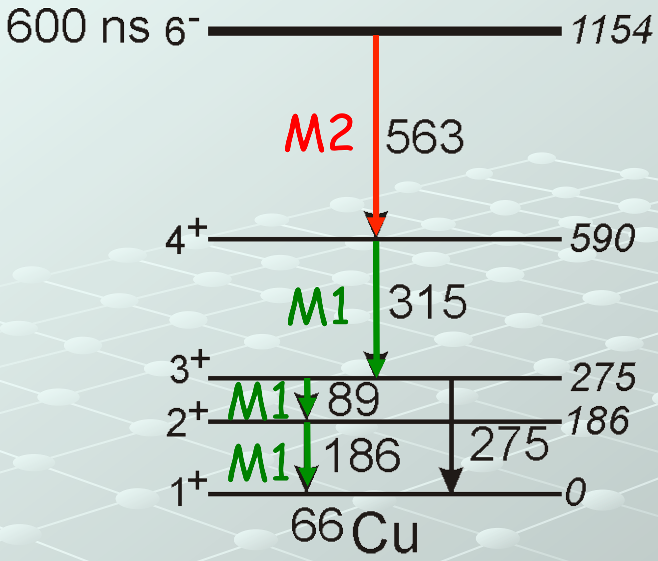
|Qs| (3/2$^-$, ^{63}Cu) = 0.211(4) b
(Stone, ANDT 90 (2005) 75)
Muonic X-ray hyperfine structure

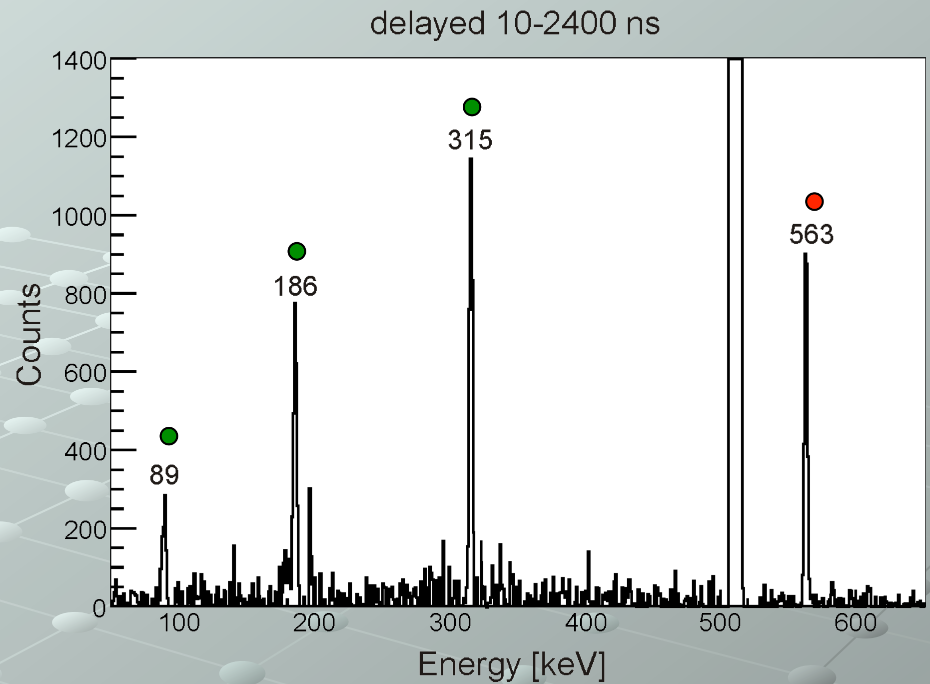
=> Vzz =102.1e20(1) V/m^2

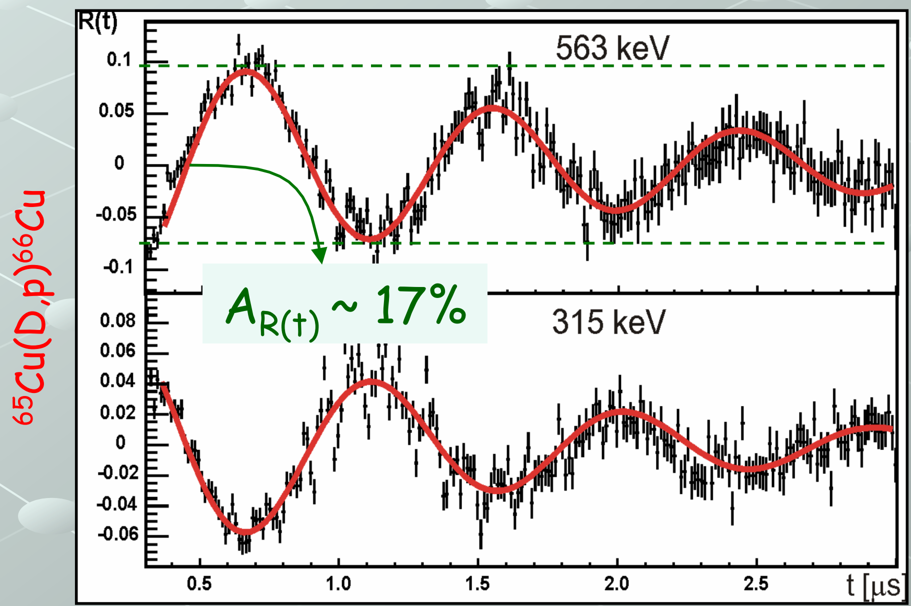




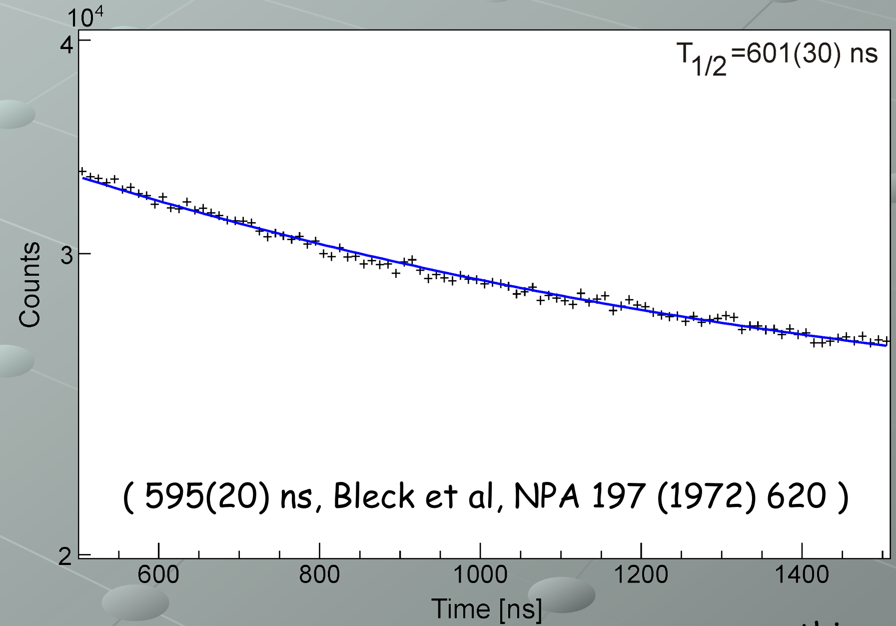
Experimental observations





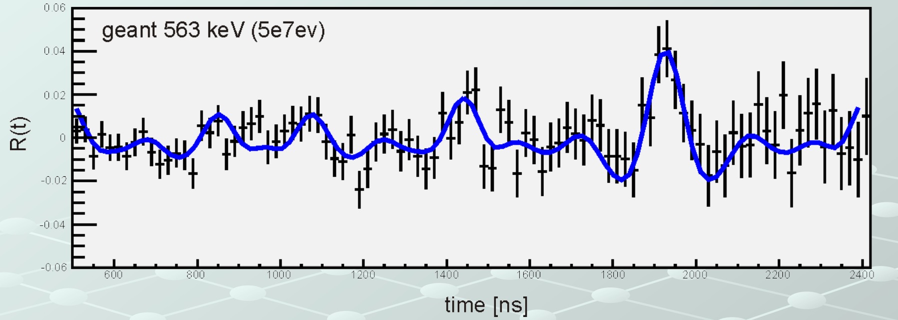


experiment N-SI-4 Orsay Tandem



this work

Experimental results



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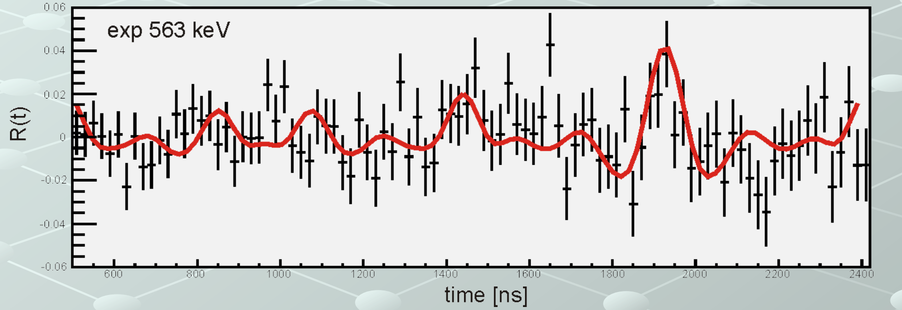
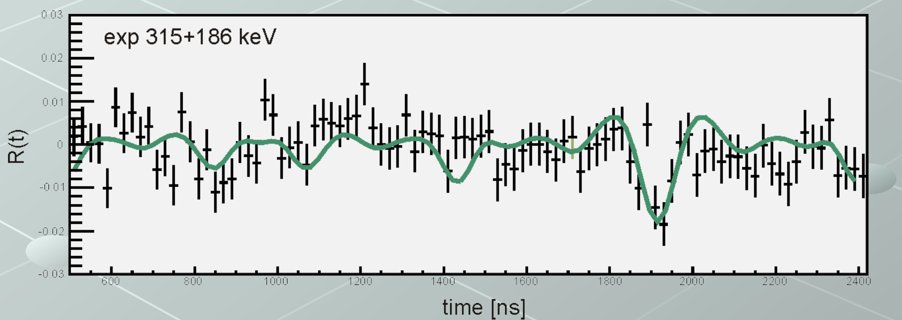
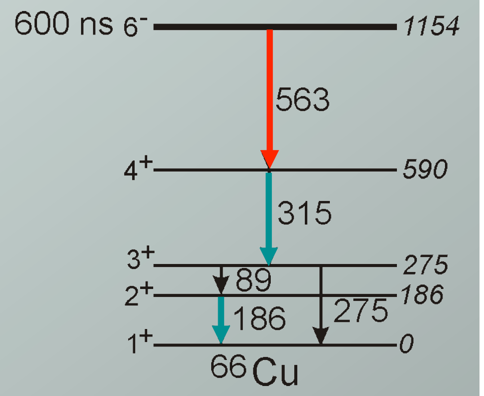


experiment



experiment



A_2=-0.4 / A_4=-0.2
B_2=-0.2 / B_4=0.02

$Amp^{563}{}_{exp}$~4%

A_2=0.3; 0.4 / A_4=0
B_2=-0.1 / B_4=0.01

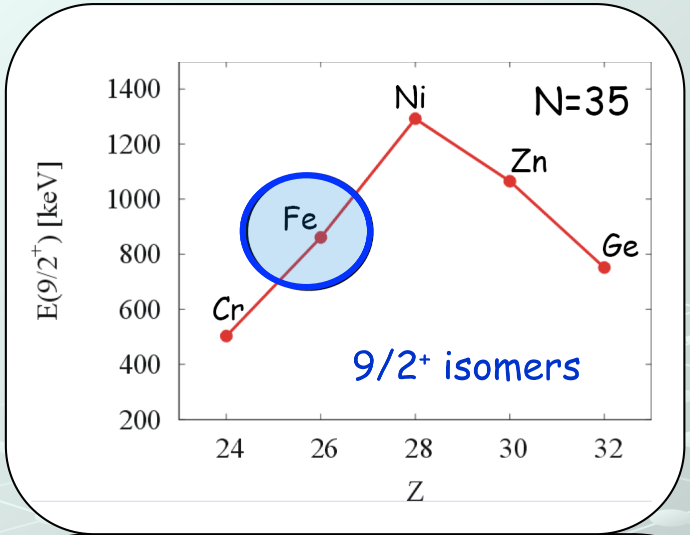
$Amp^{315,186}{}_{exp}$~2%

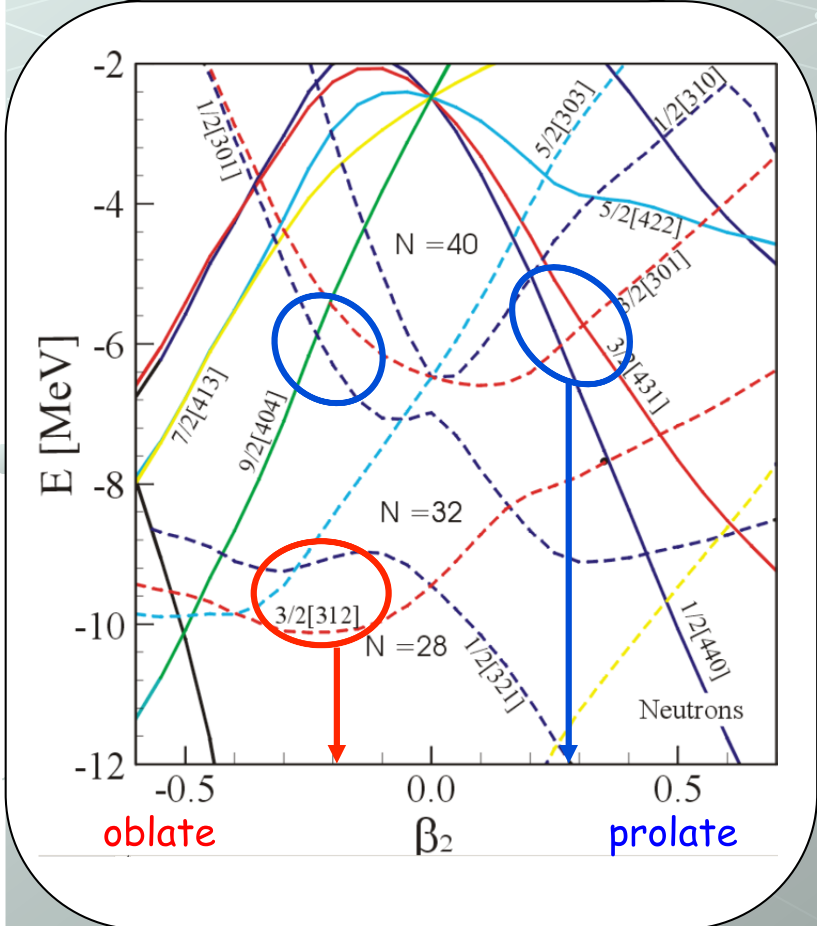
$W(\omega_0,t)=W(Amp,\cos(n\omega_0),t)$
$Amp=Amp(A_2,A_4,B_2,B_4,G_{22},G_{44})$
n=4,5,7,9,11,12,16,...

$$G_{kn}=\sum_n s_{kn}\cos(n\omega_o t)$$

ω_0=3.27(20) MHz, $|Q_s|$ = 186(12) mb = 18.6(12) efm^2

Q_s & β





$|Q_s(^{61}Fe, 9/2^+)| = 41(6)$ efm²
$\beta_2 = -0.21$ or $\beta_2 = +0.24$
N. Vermeulen et al,
PRC 75 (2007) 051302(R)

<u>relative to</u>:
$Q_s(^{57}Fe, 3/2^-) = +15$ efm²
G. Martinez-Pinedo et al.,
PRL 87 (2001) 062701

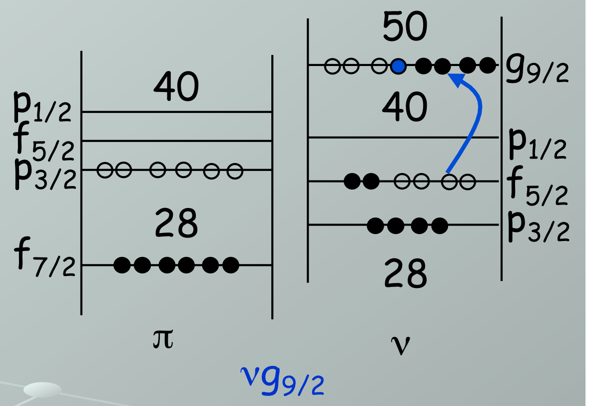
<u>fixed to</u>: $\beta_2 = +0.24$
N. Hoteling et al,
PRC 77 (2008) 044314

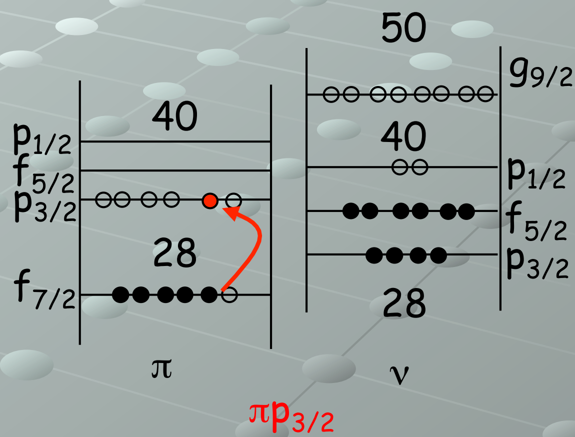
$Q_s(^{63}Cu, 3/2^-) = -21.1(4)$ efm²
$\beta_2 = -0.189(13)$
R.M. Sternheimer
Z. Naturforsch. 41a (1986) 24

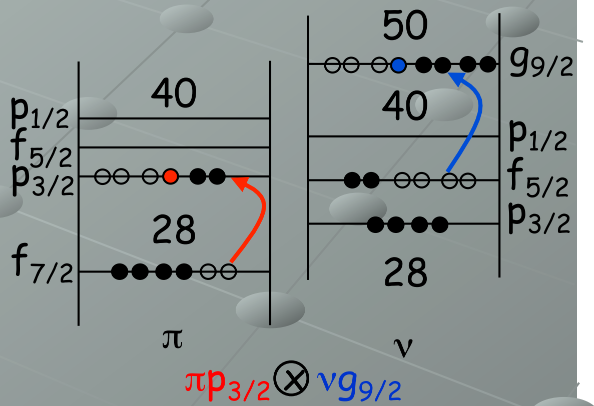
$Q_s(^{65}Cu, 3/2^-) = -19.5(4)$ efm²
$\beta_2 = -0.171(12)$
R.M. Sternheimer
PRA 6 (1972) 1702

p × n

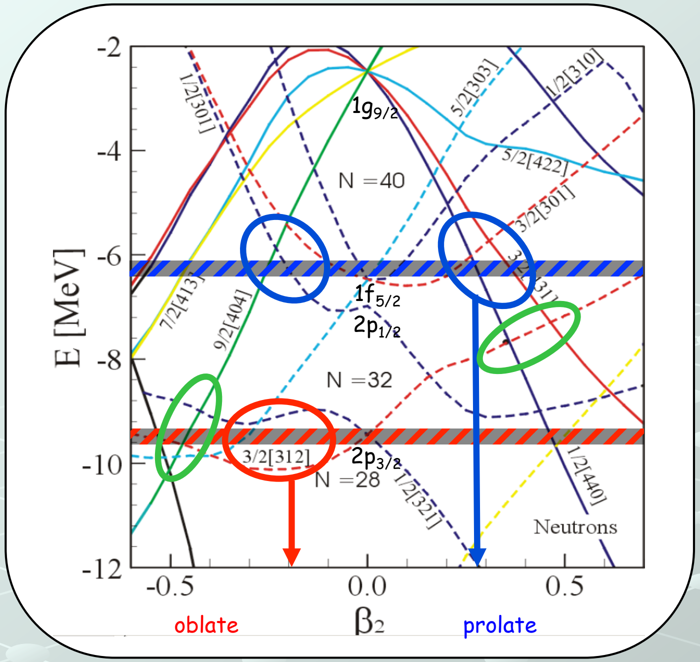
$|Q_s(^{66}Cu, 6^-)| = 18.6(12)$ efm²
this work







$Q({}^{66}_{29}Cu_{37}, 6^-)$



$^{61}Fe_{35}(9/2+)$: $\nu g_{9/2}$

$^{65}Cu_{36}(3/2-)$: $\pi p_{3/2}$

$^{66}Cu_{36}(6-)$: $\pi p_{3/2} \otimes \nu g_{9/2}$

μ: NPA 197 (1972) 620

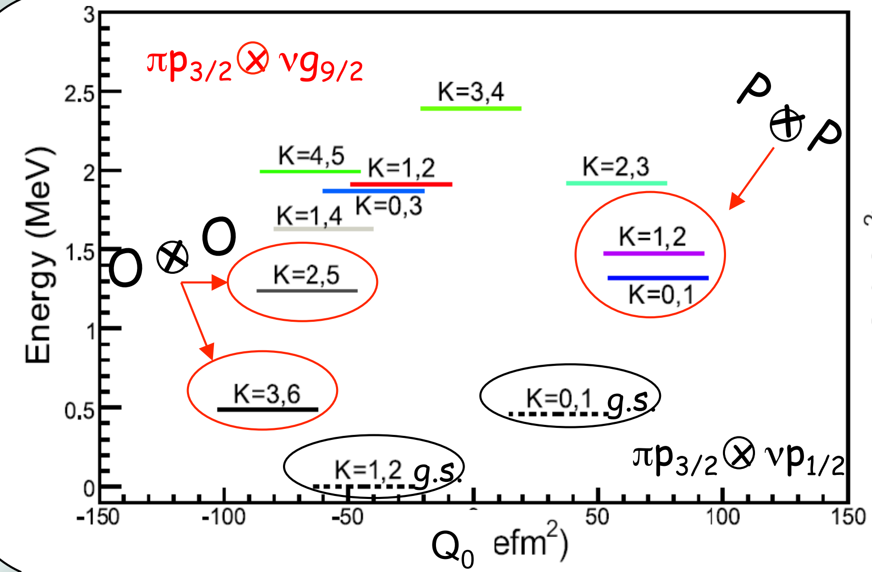
$|Q_s(^{61}Fe_{35}, 9/2^+)|$ = **41(6)** efm^2
β_2= -0.21 or β_2= **+0.24**
PRC 75 (2007) 051302(R)

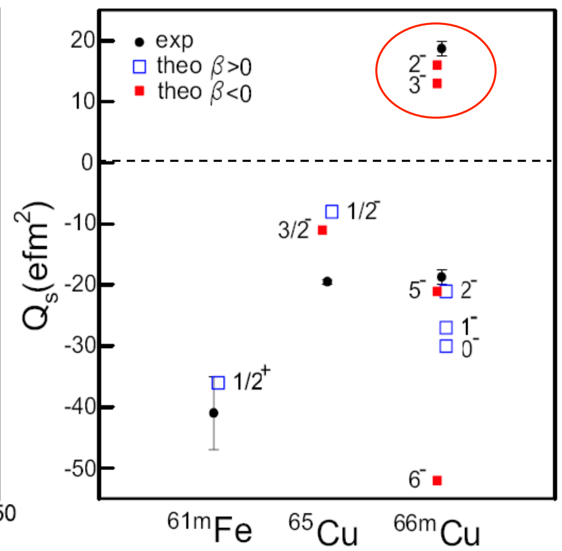
Q_0= +115 efm2 (K=1/2$^+$)
β_2= **+0.24** Q_s= **-41(6)** efm^2
PRC 77 (2008) 044314

$|Q_s(^{66}Cu, 6^-)|$ = **18.6(12)** efm^2
this work

$Q_s(^{65}Cu_{36}, 3/2^-)$= **-19.5(4)** efm^2
β_2= **-0.171(12)** (K=3/2$^-$ MF)
PRA 6 (1972) 1702

$K_\pi=3/2^-$ x $K_\nu=9/2^+$ => K=3$^-$
β_2= -0.18, Q_0= -80 efm^2
$\Rightarrow Q_s$= 18.6(12) efm^2
(oblate x oblate => **oblate**)





$K_\pi=3/2^- \otimes K_\nu=9/2^+$ => K=3$^-$,6$^-$
$K_\pi=3/2^- \otimes K_\nu=7/2^+$ => K=2$^-$,5$^-$

$K_\pi=1/2^- \otimes K_\nu=1/2^+$ => K=0$^-$,1$^-$
$K_\pi=1/2^- \otimes K_\nu=3/2^+$ => K=1$^-$,2$^-$

$$Q_s = \frac{3(K^\pi)^2 - I(I+1)}{(I+1)(2I+3)} Q_0$$

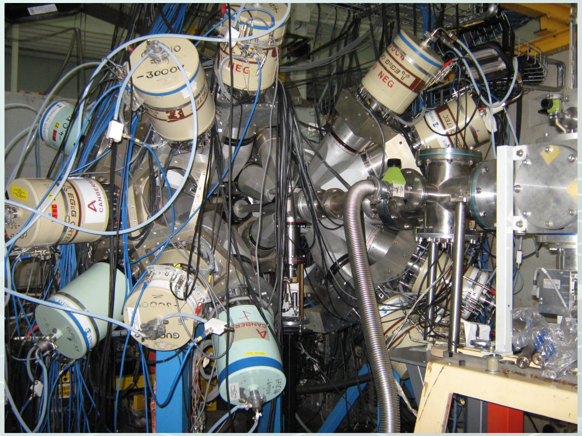
Mean-field HFB in AS/D1N Gogny force with simultaneous pn blocking, Gaussian-overlap approximation:

-> $\pi p_{3/2}$ -> K_π =1/2$^-$, 3/2$^-$,

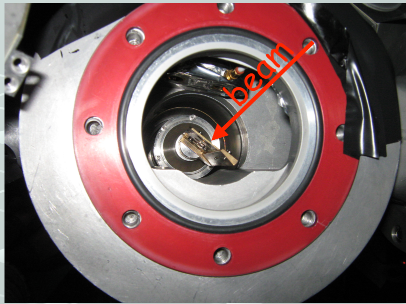
-> $\nu g_{9/2}$ -> K_ν =1/2$^+$, 3/2$^+$, 5/2$^+$, 7/2$^+$, 9/2$^+$

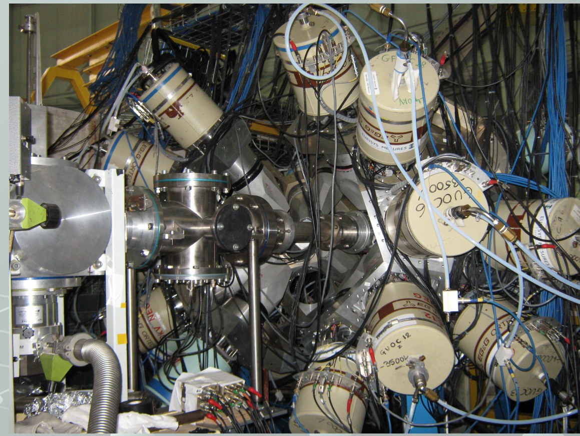
F. Chappert et al, PLB 668 (2008) 420,
J.P. Blaizot et al, NPA 591 (1995) 435, R. Lozeva et al, PLB 694 (2011) 316

MNT studies @ Tandem Orsay

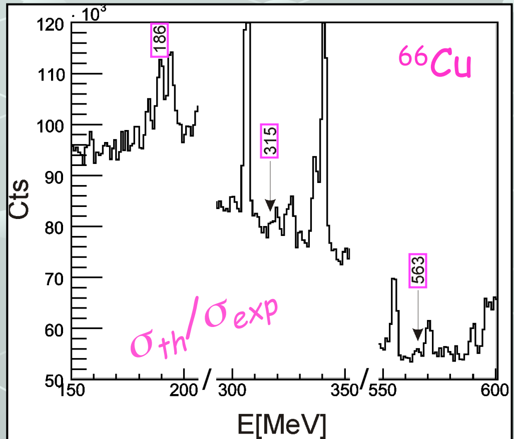


Zn(S,O,Cl,X)^{66}Cu,^{63}Ni





R. Lozeva et al, AIP 1224 (2010) 143



$^{36}_{16}S_{20}$ E_{beam}^{LAB} [MeV]	$^{18}_{8}O_{10}$ E_{beam}^{LAB} [MeV]	$^{37}_{17}Cl_{20}$ E_{beam}^{LAB} [MeV]
1.1 E_{CB}	1.1 E_{CB}	1.1 E_{Cb}
	1.2 E_{CB}	1.25 E_{CB}
1.4 E_{CB}	1.4 E_{CB}	
@ $^{66,68,70}_{30}Zn_{36,38,40}$ targets	@ $^{66,68,70}_{30}Zn_{36,38,40}$ targets	@ $^{66,68,70}_{30}Zn_{36,38,40}$ targets

S. Szilner code GRAZING (A. Winther, NPA 572 (1994) 191)

σ[mb] \ comb	^{36}S+^{66}Zn	^{18}O+^{68}Zn	^{37}Cl+^{68}Zn
^{66}Cu	5.9e-1	4.9e-1	3.9e-1
^{63}Ni	2.4e-3	3.7e-4	1.8e-3

-> determine cross sections
-> feasibility towards RIBs

Collaborators Q studies

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