GERDA

Support for GERDA

The Shell Model Occupancies in ^{76}Ge and ^{76}Se and background reactions

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GERDA Collaboration

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bmb+f - Förderschwerpunkt
Astroteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

Kepler Center for Astro and Particle Physics

the mass of the neutrino

Neutrino oscillations:

mass is finite

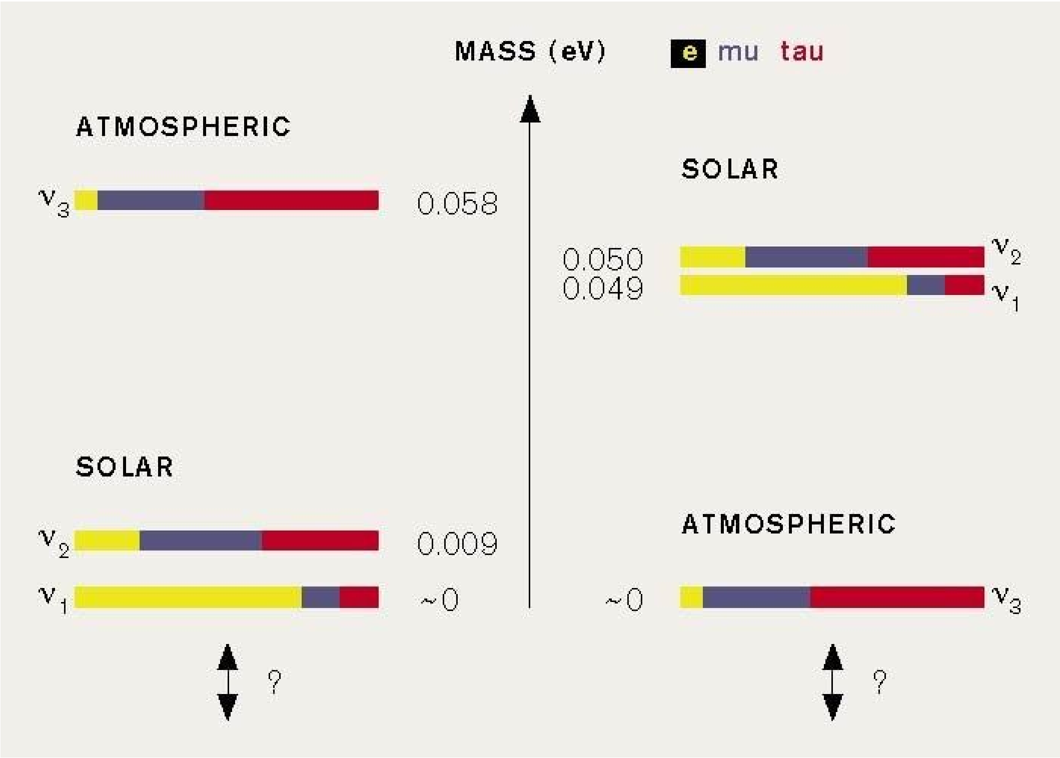
(Suzuki, INPC07)

$\Delta m^2_{solar} = 8{,}2\ 10^{-5}\ eV^2$

$\Delta m^2_{atm} = 2{,}7\ 10^{-3}\ eV^2$

$\Delta m^2_{23} > 0$ normal

$\Delta m^2_{23} < 0$ inverted



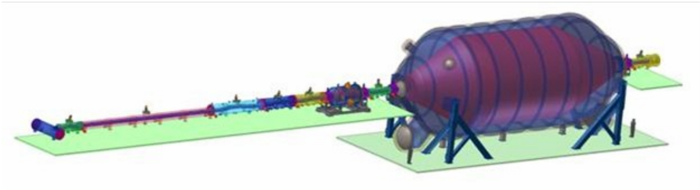
still need:

- absolute mass scale
- hierachy

Tritium β decay

Mainz & Troitsk $m_e \sim 2{,}2$ eV

KATRIN/Mare → 0,2 eV



neutrinoless double beta decay

Aim at support for $2\beta 0\nu$ experiments

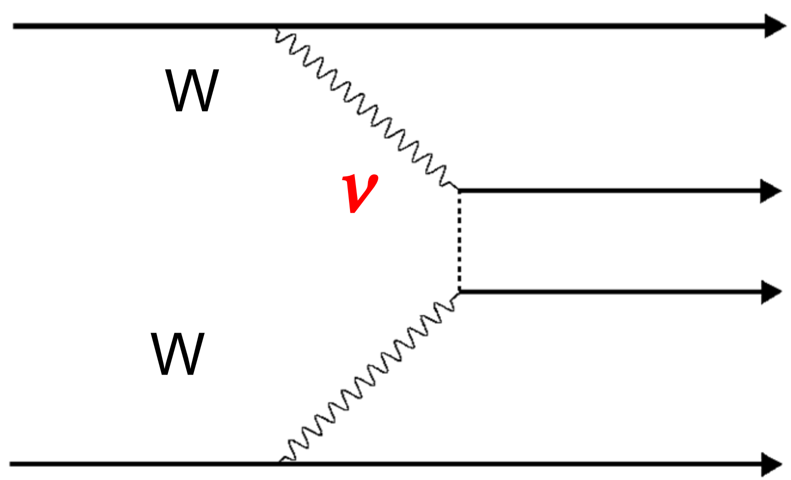
GERDA experim.

$$1/\tau = G(Q)\,\|M_{nucl}\|^2\,<m_{ee}>^2$$

Phase space factor ($\sim Q^5$;choose (A,Z))

Nuclear matrix element (theory input)

Effective Majorana mass (hierachy)



Content

Aim at support for $2\beta0\nu$ experiments

GERDA experim.

$$1/\tau = G(Q)\,||M_{nucl}||^2 <m_{ee}>^2$$

Tübingen: (^{76}Ge, ^{76}Se)

- neutron capture — identify background veto

neutron elastic scattering (TÜ+DD)

- transfer reactions — nuclear structure for matrix elements

back of the envelope

assume background free; $T_{1/2} \gg t$;

For half-lifes of $T_{1/2} = 10^{25}$ yrs

$N_{\beta\beta} / t = 1$ event/yr

$$T_{1/2} = \ln 2 \cdot (N_A/A) \cdot M \cdot (N_{\beta\beta} / t)^{-1}$$

This is about 10 moles of isotope, implying ~kg

for ^{76}Ge : 2,1 kg @ 86% enriched

Now you only can loose:

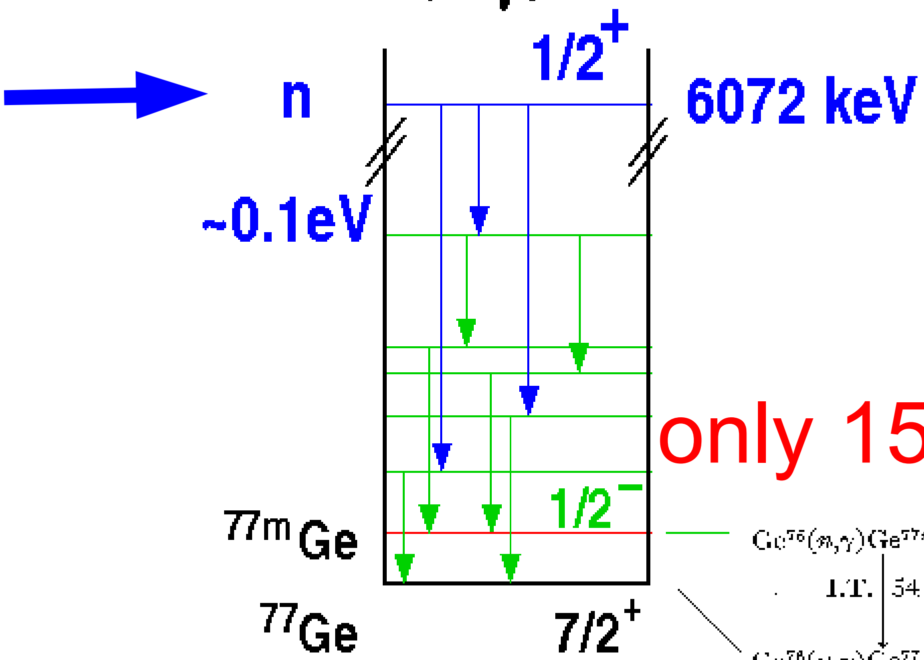
nat. abundance a, efficiency ε, background B, ...

neutron capture

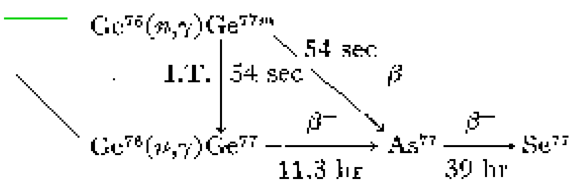
2 photon lines: 2041(prompt) & 2037 (delayed) keV close to $Q_{\beta\beta}$=2039keV

2 experiments: thermal (< meV, FRM-II) & astro (25 keV, FZK)

76 Ge(n,γ) 77Ge



only 15% known



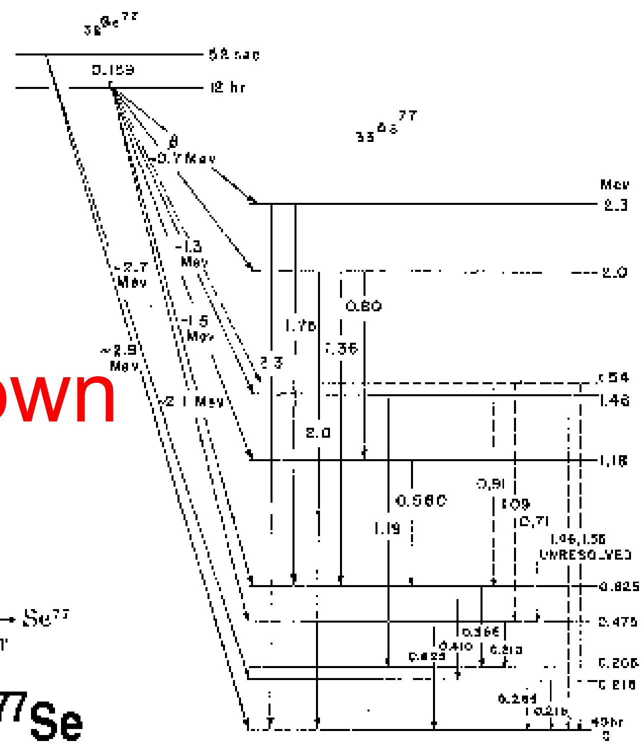


Fig. 6. Decay scheme of $_{32}Ge^{77}$.

$^{77}Ge \xrightarrow{\beta} {}^{77}As \xrightarrow{\beta} {}^{77}Se$

Q_β = 2703 690 keV

neutron capture in GERDA

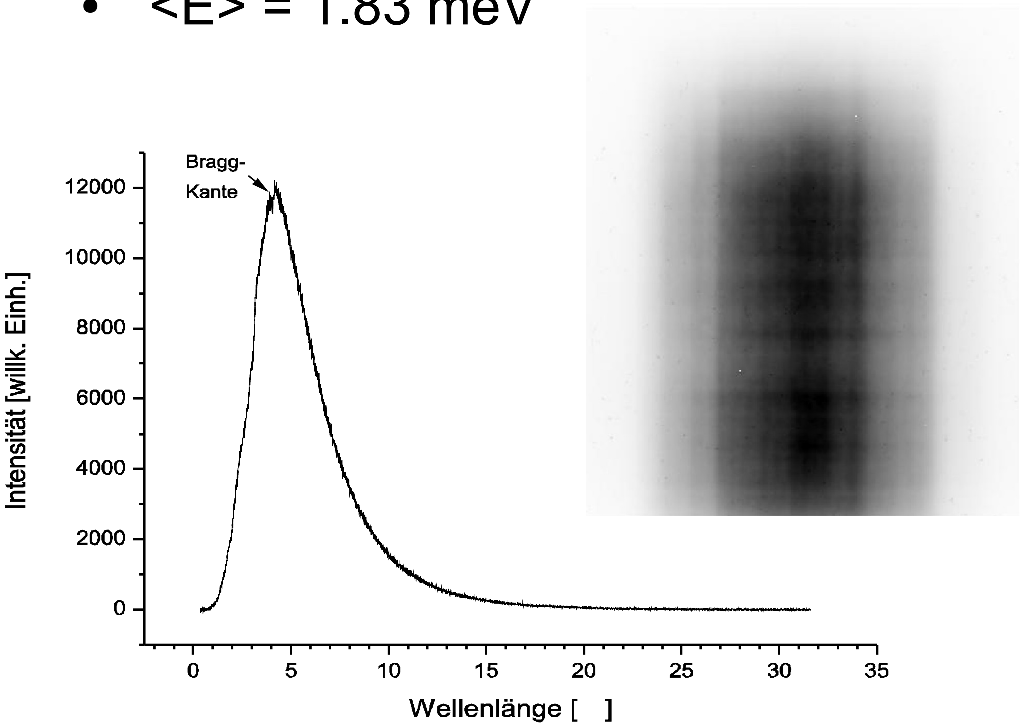
~1 n-capture/(kg y) (MC simulation)

⇒ Possible background in the region of interest (2039 keV)

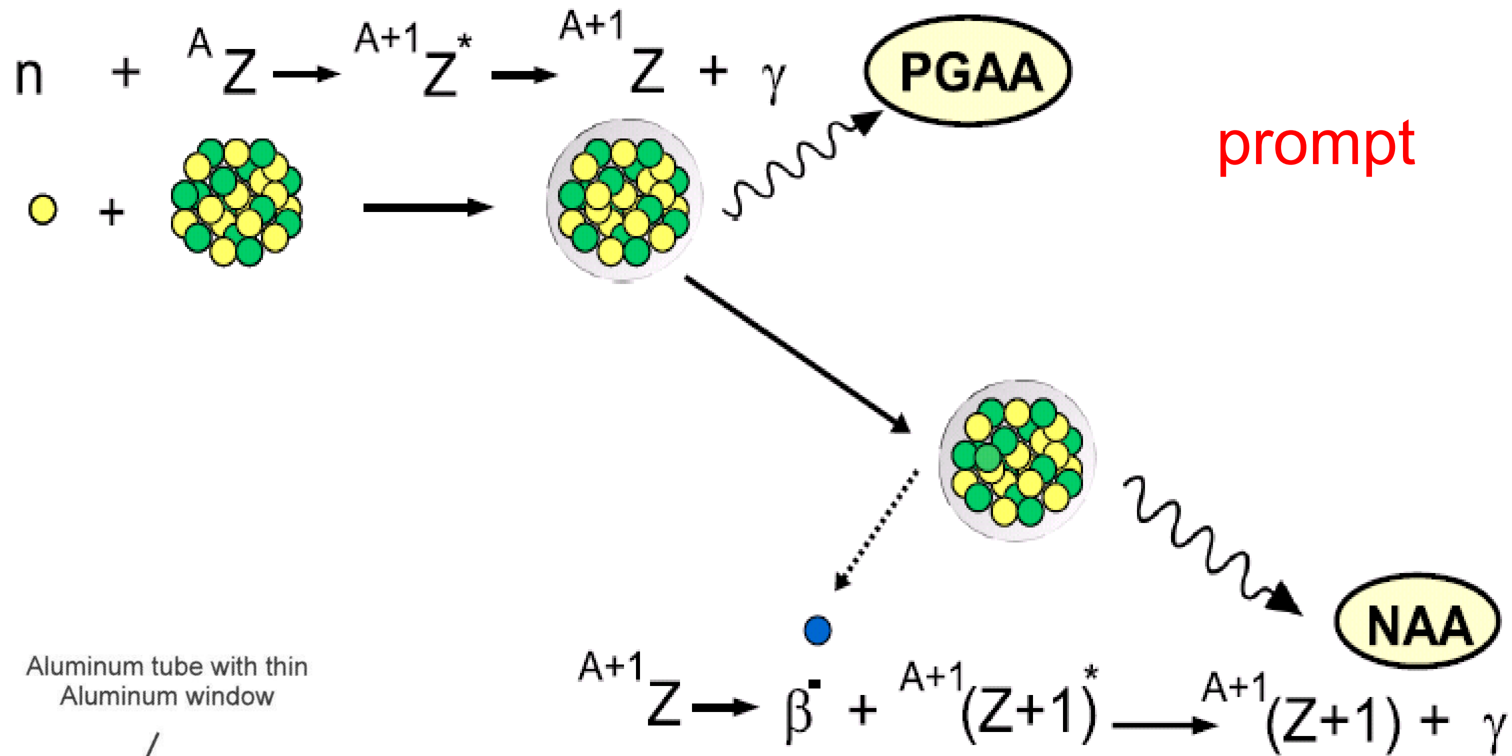
Source	γ-ray Background in ROI	Rejection method	β- Background in ROI	Rejection method
Prompt Gamma Rays	Peak? Compton scattering	multisite events	X	X
β-Decay of ^{77}Ge	Peak (2037.76 keV) Compton scattering (E_{max}=2353.4 keV)	multisite events	Continuous (E_{max}=2486.5 keV)	detection of prompt gamma rays
β-Decay of ^{77m}Ge	X (E_{max}=1676.5 keV)	X	Continuous (E_{max}=2861.7 keV)	detection of prompt gamma rays
β-Decay of ^{77}As	X (E_{max}=682.9 keV)	X	X (E_{max}=682.9 keV)	X

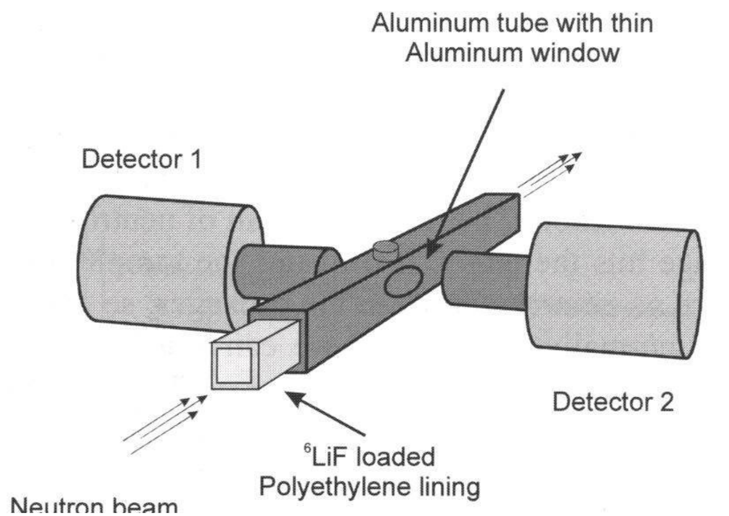
the neutron source FRM II

- 7.83 x 10^9 n/(cm^2 s^1)
- <λ_n> = 6.7 Å
- <E> = 1.83 meV



the reaction



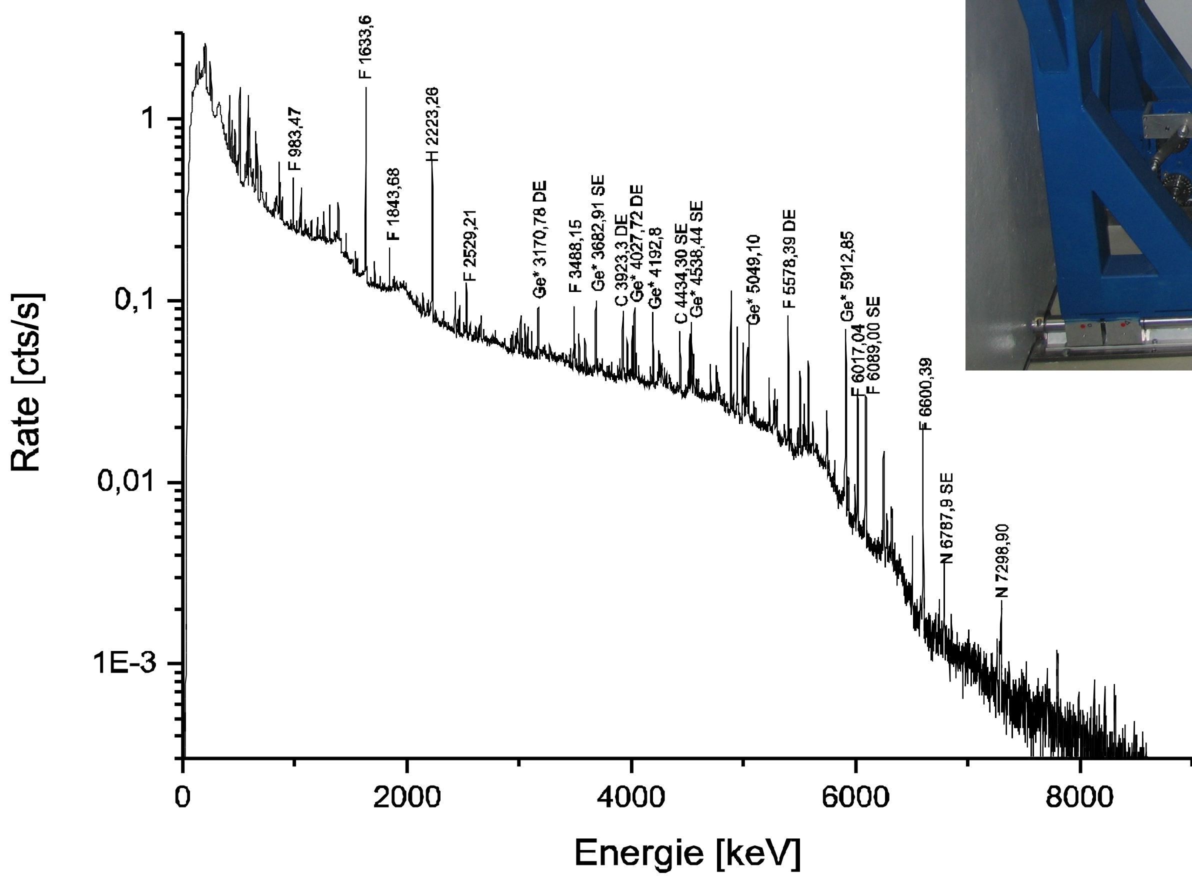


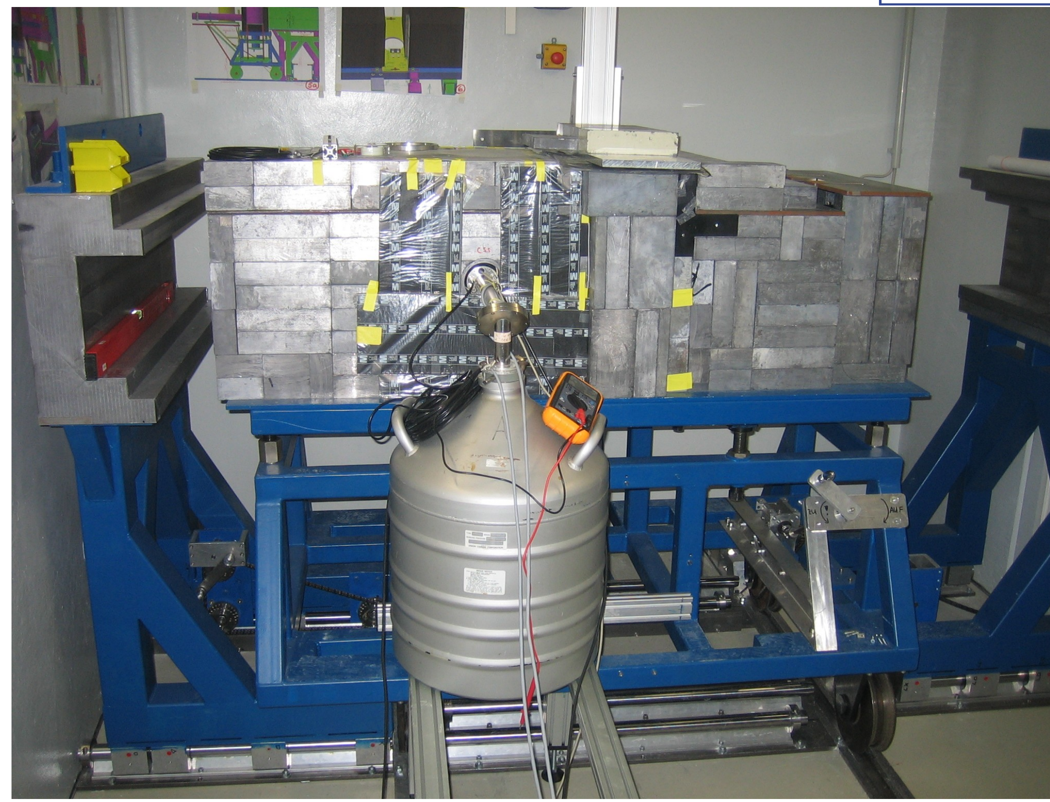
coincidence technique for study of decay schema

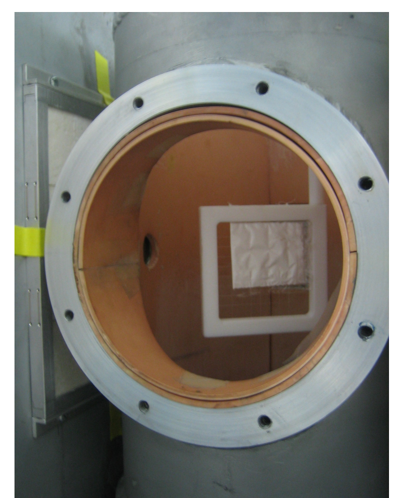
the reaction

m ~ 300 mg of enriched GeO_2

Irradiation time > 50 000 s

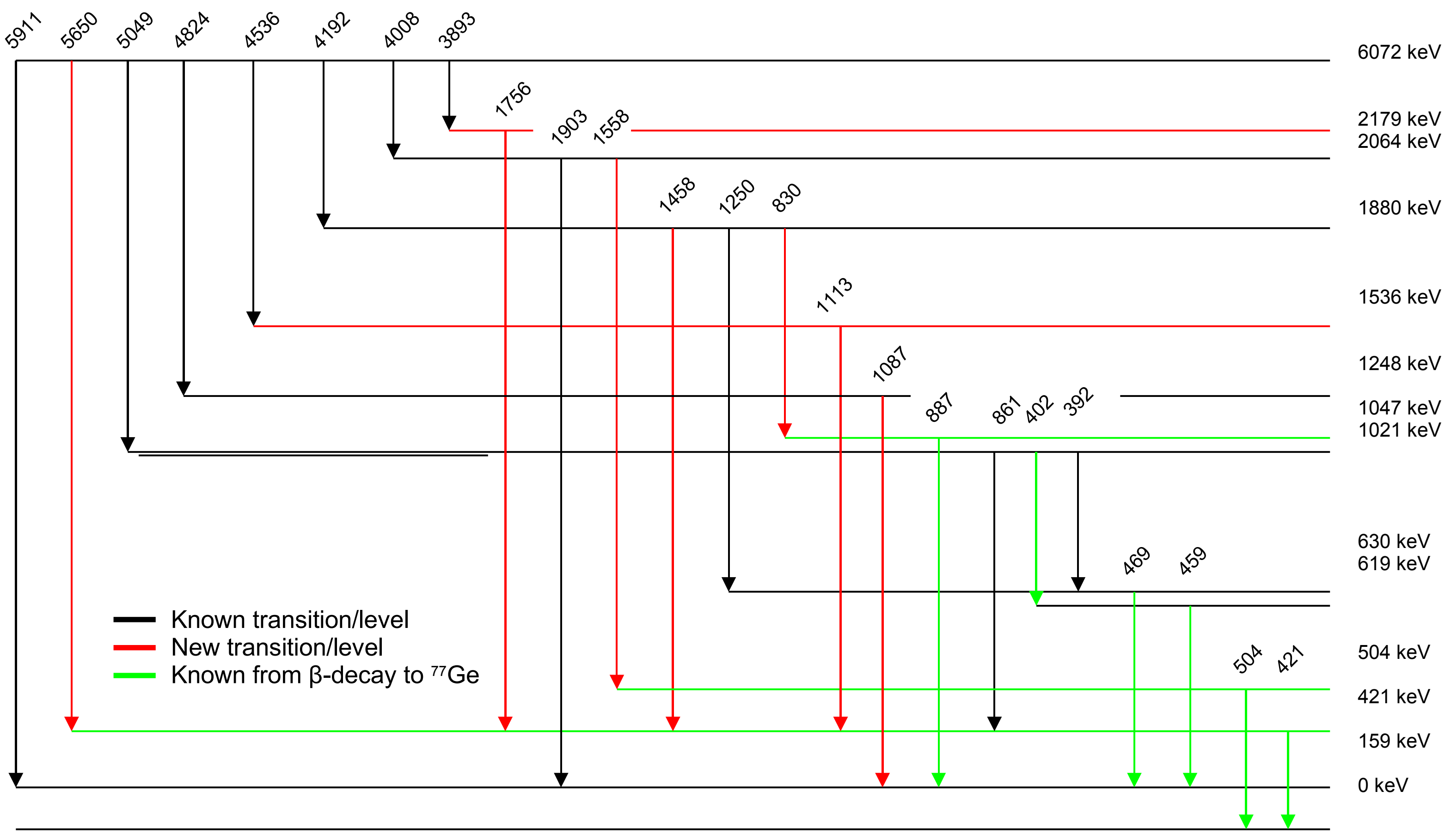




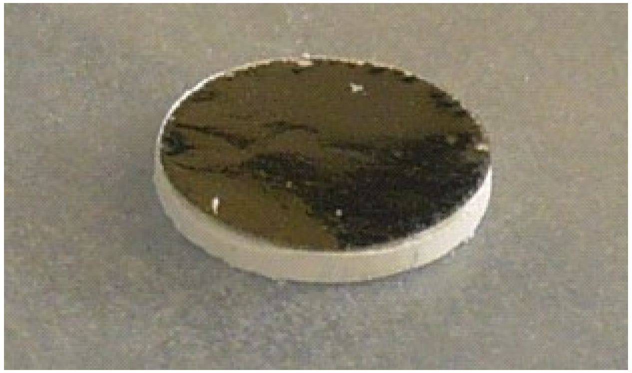


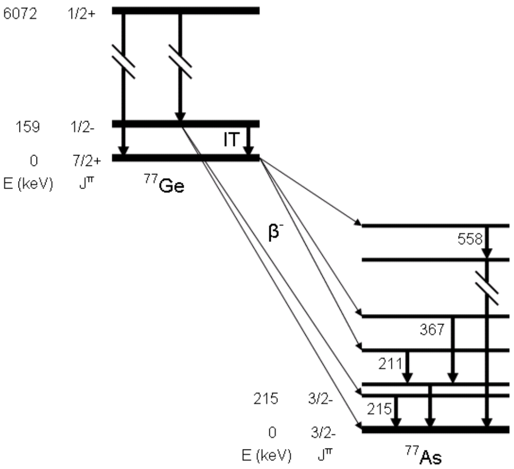
P. Grabmayr

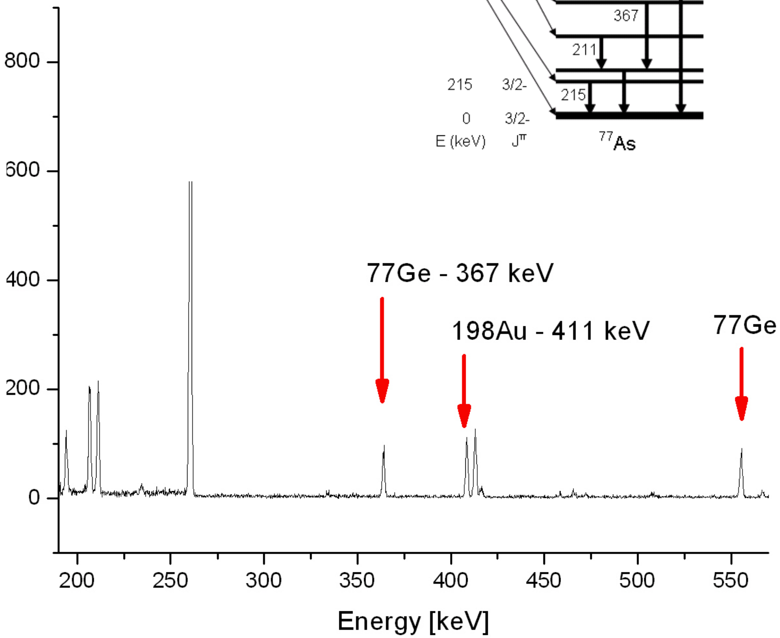
first look at coincidence data

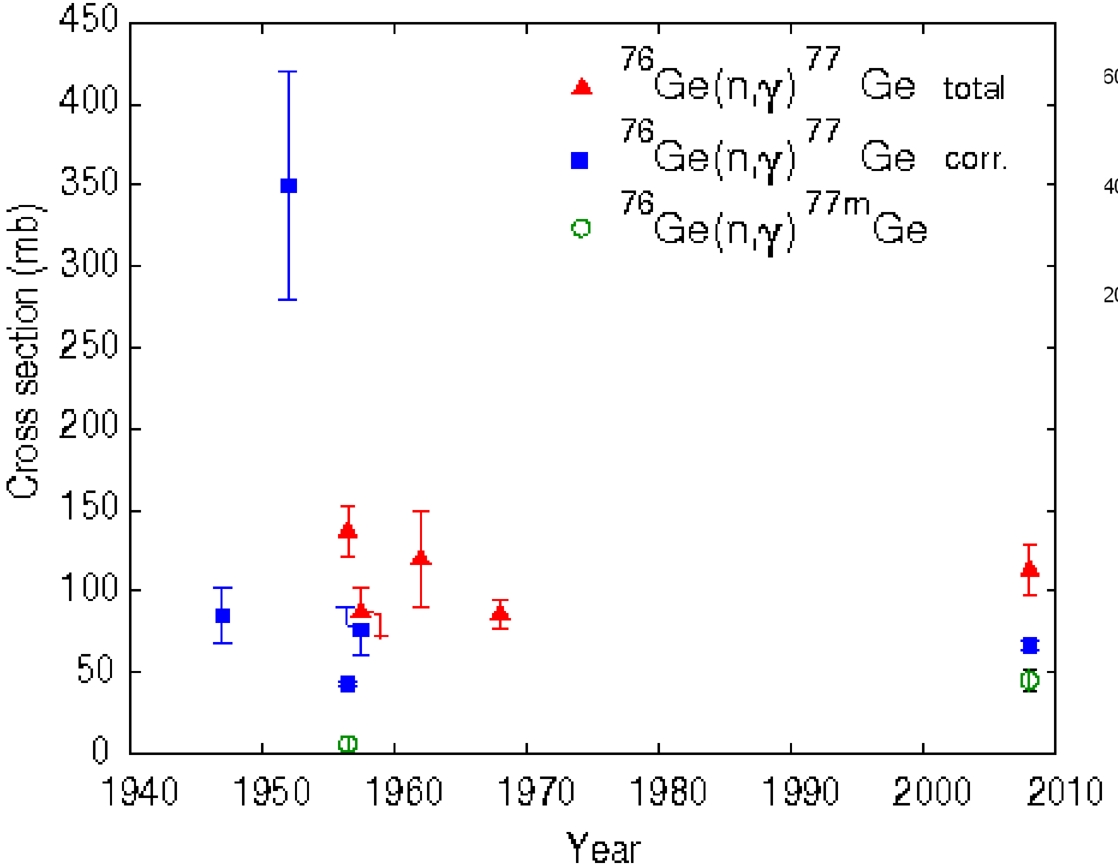


total capture cross section









neutron capture

2 photon lines: 2041(prompt) & 2037 (delayed) keV close to $Q_{\beta\beta}$

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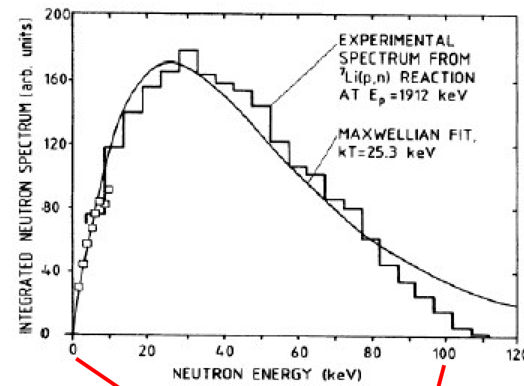
IOP PUBLISHING JOURNAL OF PHYSICS G: NUCLEAR AND PARTICLE PHYSICS

J. Phys. G: Nucl. Part. Phys. 35 (2008) 014022 (5pp) doi:10.1088/0954-3899/35/1/014022

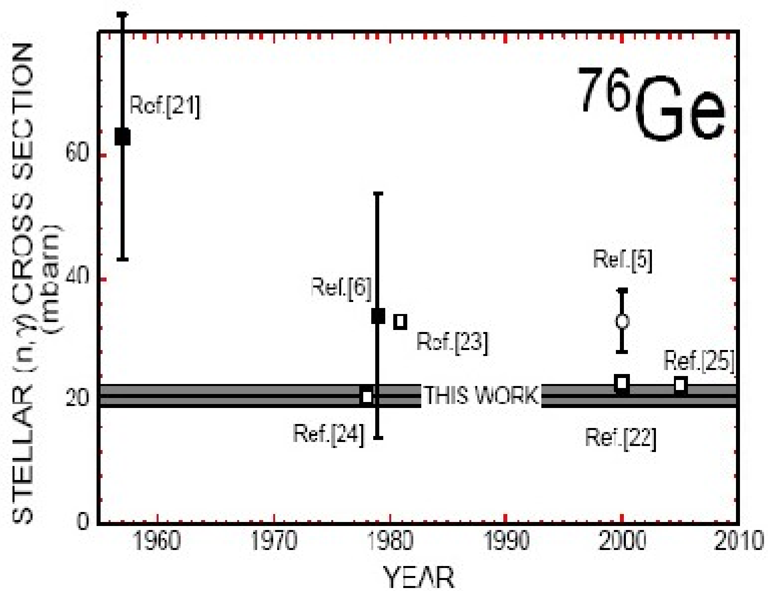
Neutron capture cross section of ^{76}Ge

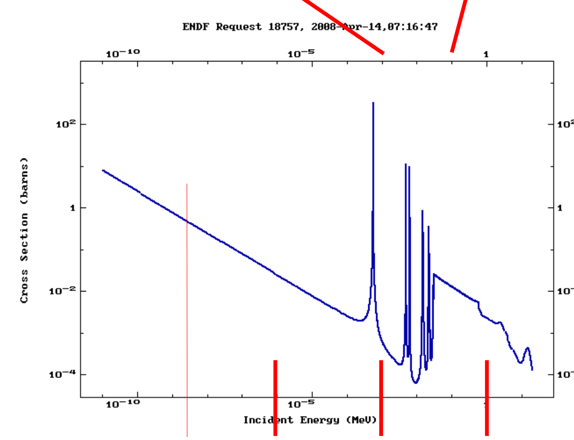
J Marganiec[1,2], I Dillmann[1], C Domingo Pardo[1], P Grabmayr[3] and F Käppeler[1]



new publication

$\sigma^{gs} + \sigma^{m}$





Content

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$$1/\tau = G(Q)\,\|M_{nucl}\|^2 <m_{ee}>^2$$

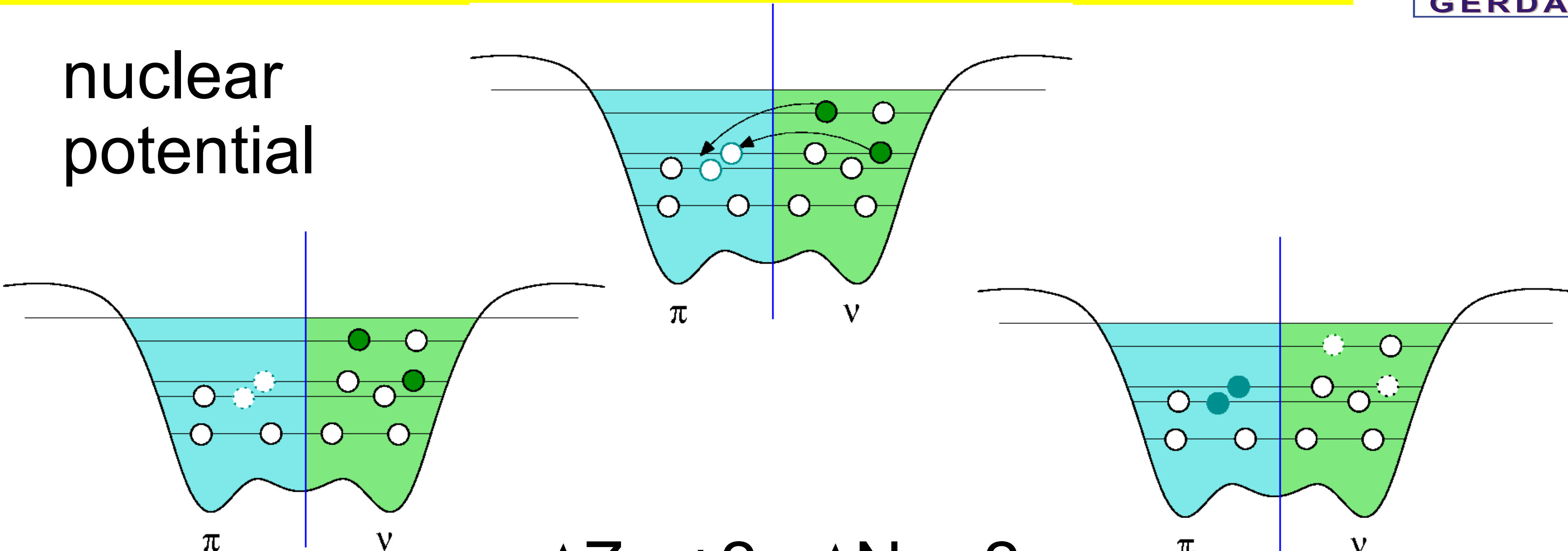
Tübingen: (^{76}Ge, ^{76}Se)

- neutron capture — identify background veto

  neutron elastic scattering (TÜ+DD)

- transfer reactions — nuclear structure for matrix elements

ββ-decay in the Shell Model



ΔZ= +2   ΔN= -2

$^{76}Ge_{44}$ → $^{76}Se_{42}$

V. Rodin: calculations of ME

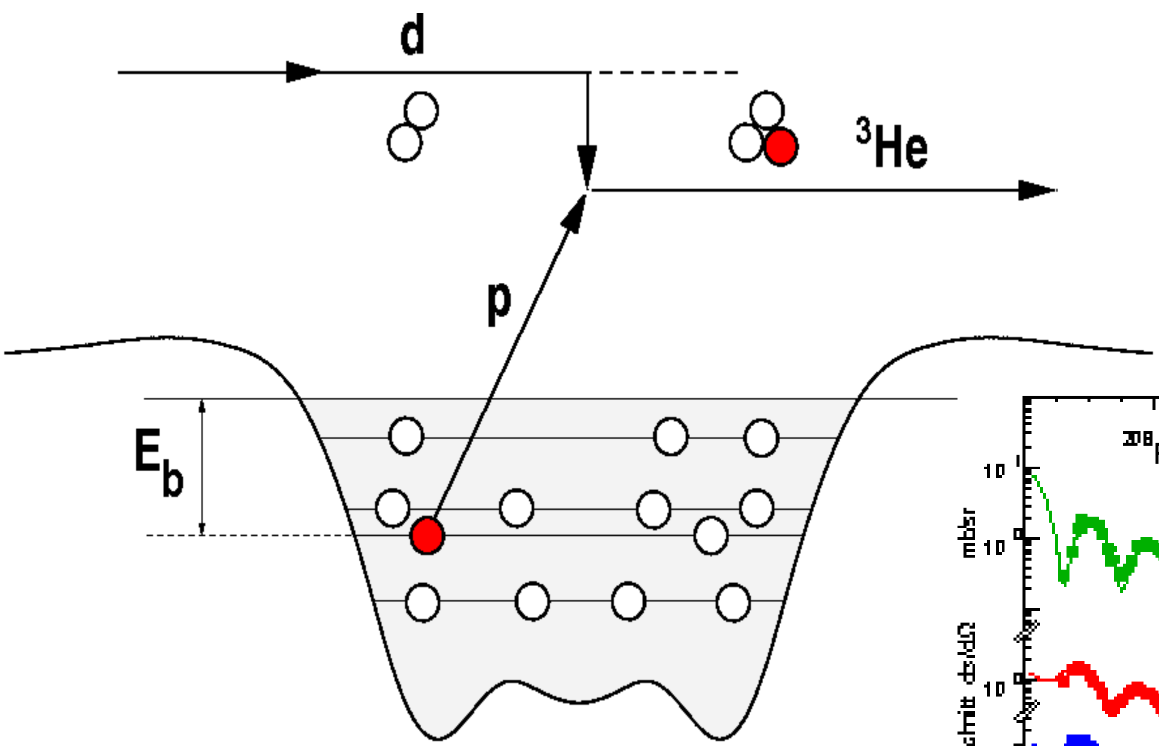
no reaction for direct comparison

clarify structure of initial and final nucleus

transfer reactions

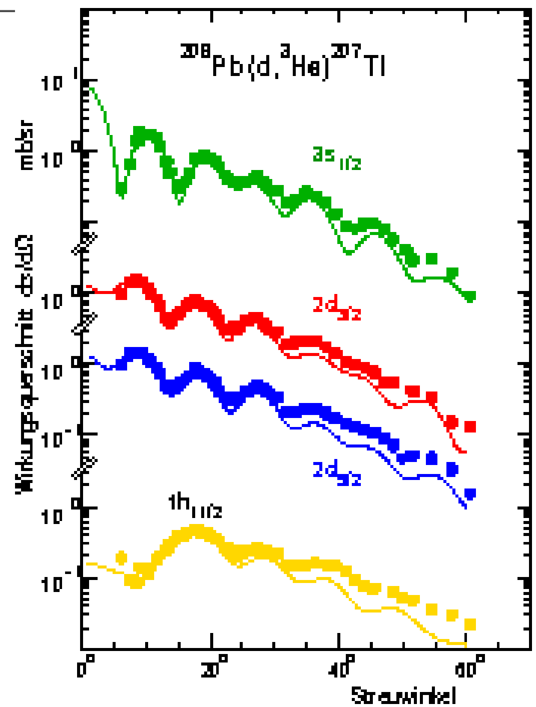
remove or add a single nucleon

sudden approximation



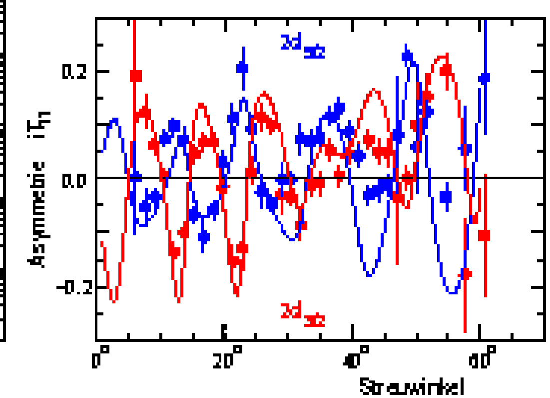
energy of ^{3}He : E_b

strength: number of π in orbital

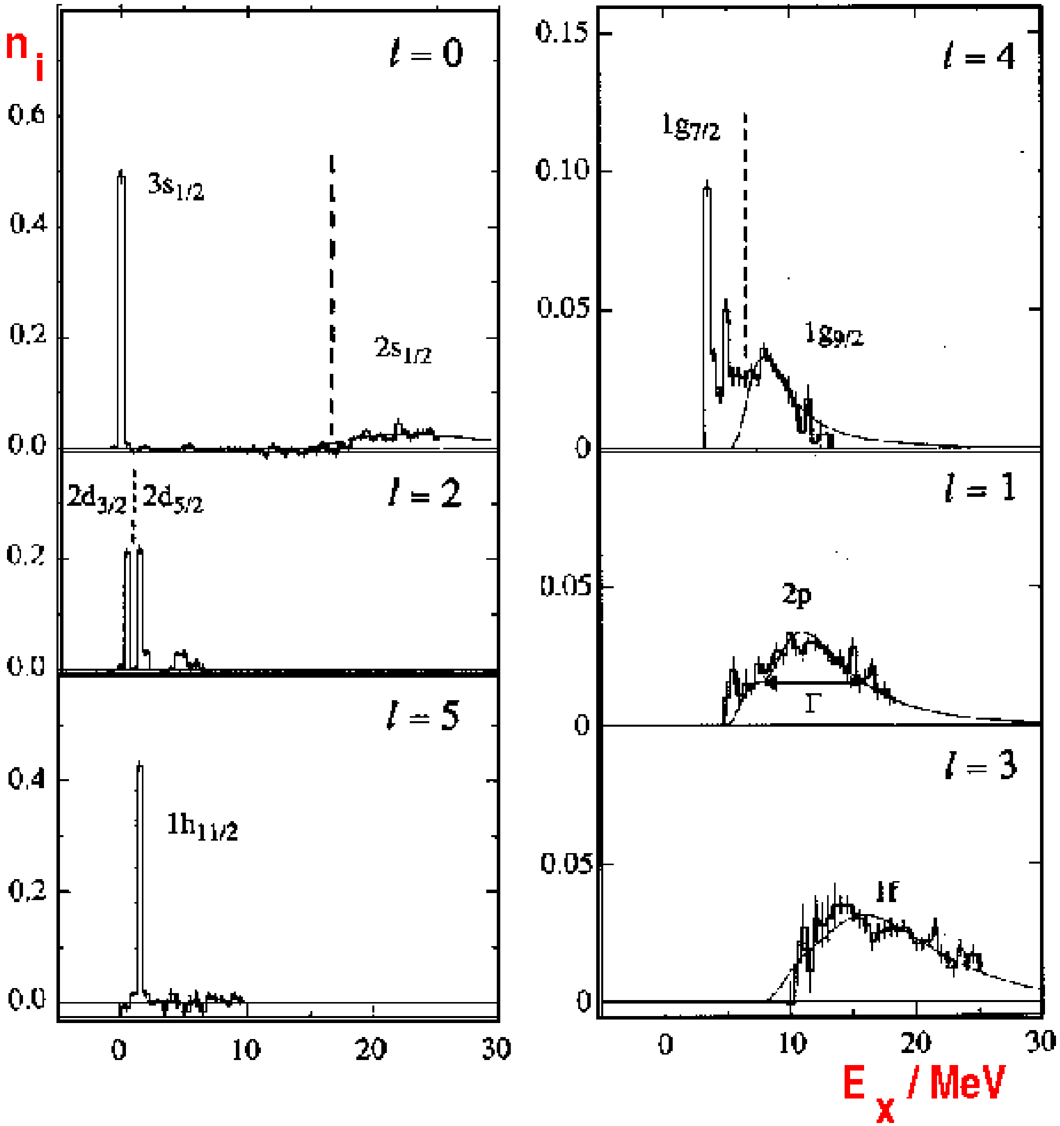


polarised deuterons

$j = l \pm s$

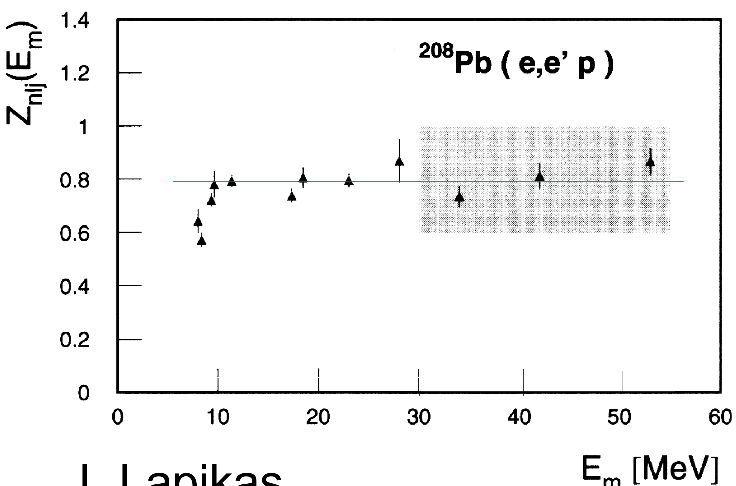


(e,e'p) knockout reaction



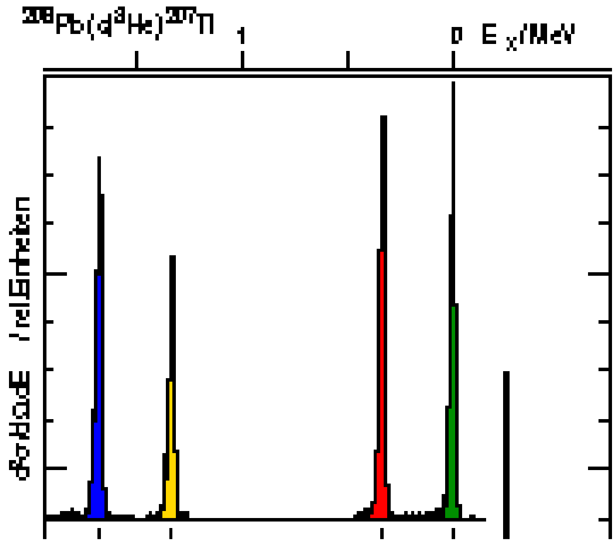
^{208}Pb

ENM Quint etal, NIKHEF



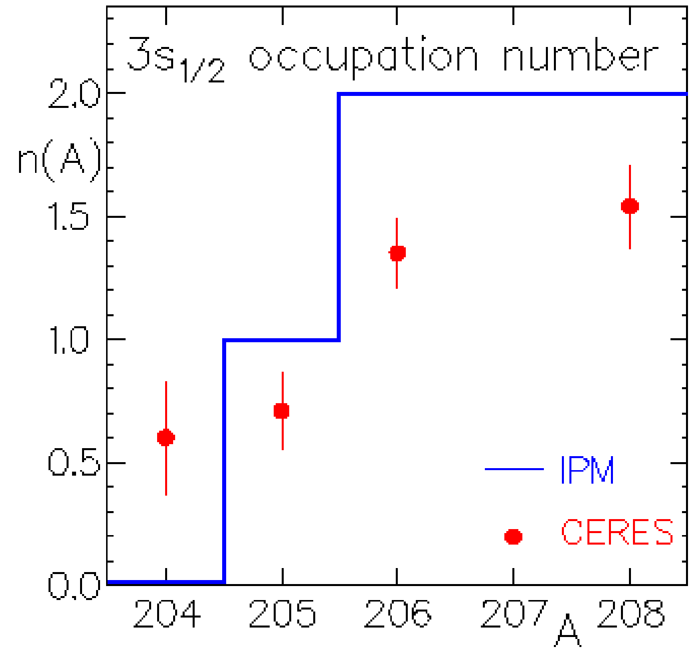
L.Lapikas

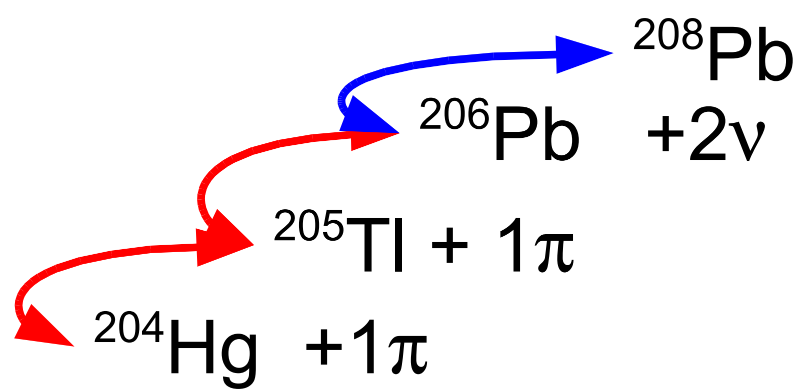
Independent Shell Model



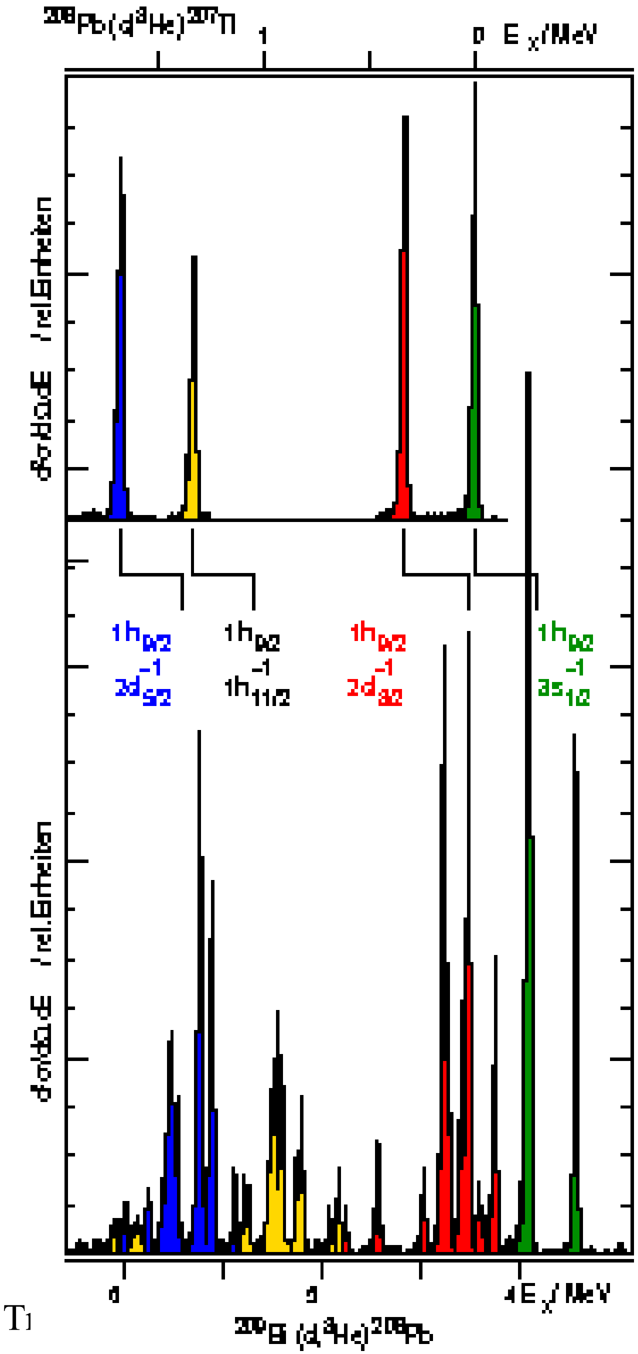
^{208}Pb

PG, PNPP 29(1991)251





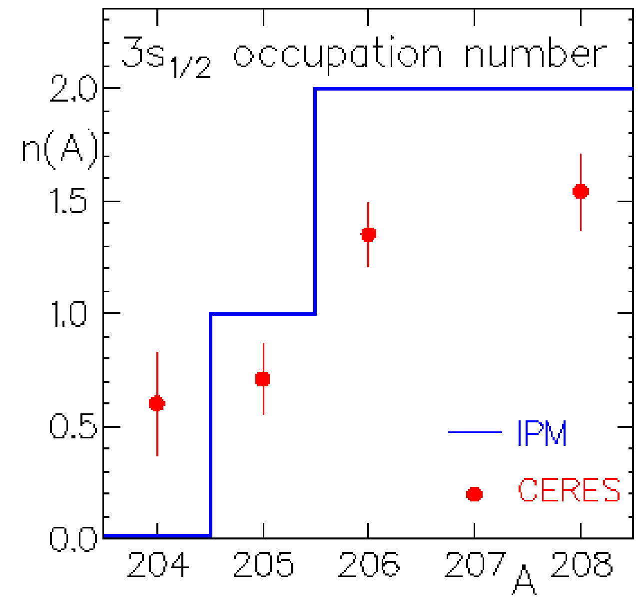
Independent Shell Model

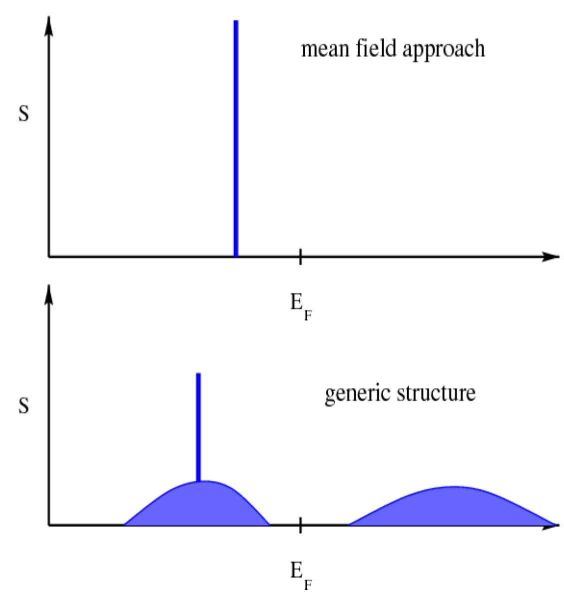


^{208}Pb

^{209}Bi

PG, PNPP 29(1991)251





P. Grabmayr

some sum rules

strength determined in comparison to DWBA

$$G^{-} = C^2S/(2\boldsymbol{j}+1) = N\,\sigma_{epx}/\sigma_{DWBA}$$

parameter dependent

full orbital has 2***j***+1 particles

pickup strength $G^{-} = 1$ if orbital is full

stripping strength $G^{+} = 1$ if orbital is empty

$$G^{+} + G^{-} = 1$$

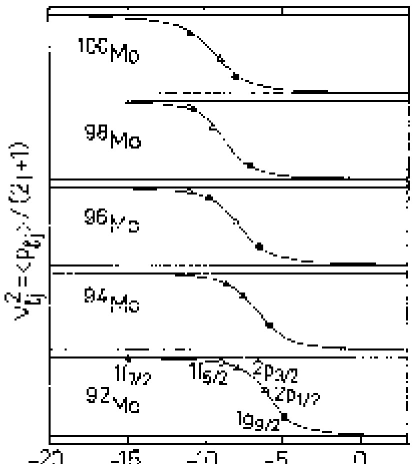
French & McFarlane Sum Rule

independent of DWBA,

however all strength must be detected

occupancies

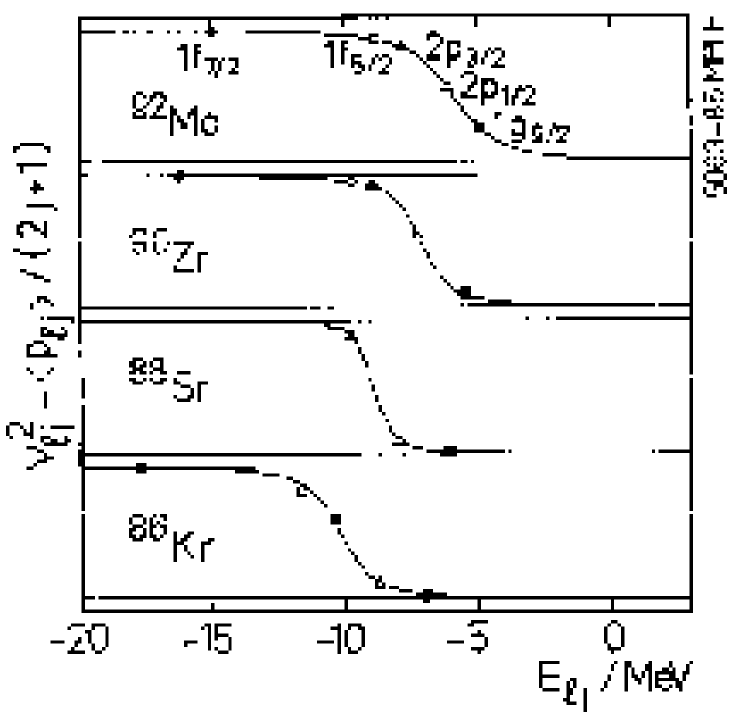
G.Mairle etal, NPA543,NPA455

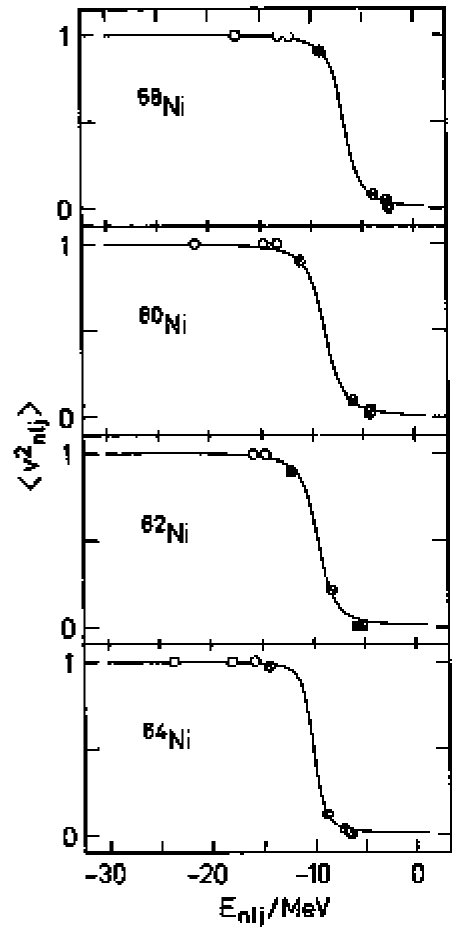


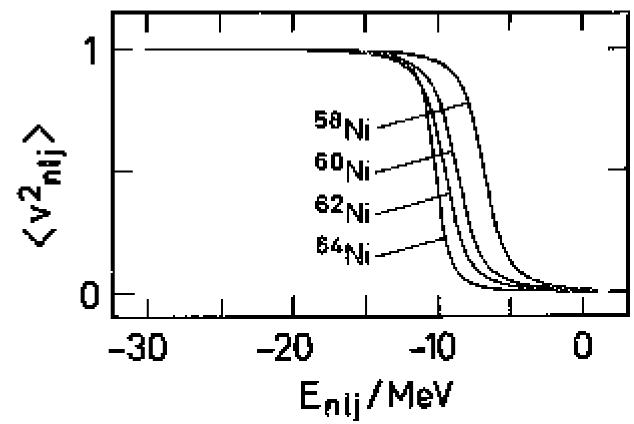
$$v_{njl}^2 = \frac{1}{2(2j+1)}\left[G^- + (2j+1-G^+)\right]$$

BCS

$$v_{njl}^2 = \frac{1}{2}\left[\frac{1-(E_{nlj}-E_F)}{\sqrt{(E_{njl}-E_F)^2+\Delta^2}}\right]$$







previous measurement

INVESTIGATION OF THE LEVEL SCHEMES OF ^{73,75,77}As VIA THE (^{3}He, d) REACTION

M. SCHRADER, H. REISS, G. ROSNER and H. V. KLAPDOR
Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Received 22 December 1975
(Revised 6 February 1976)

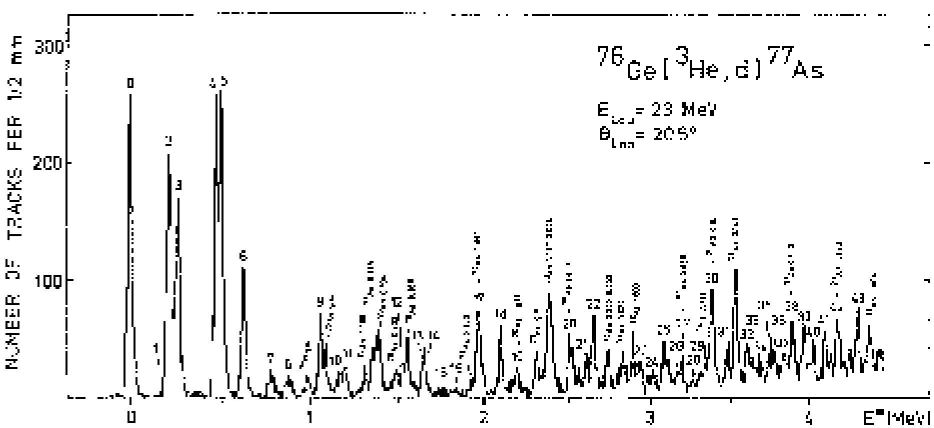
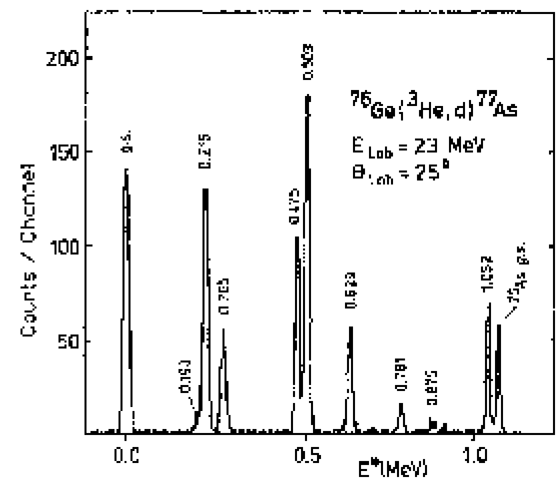
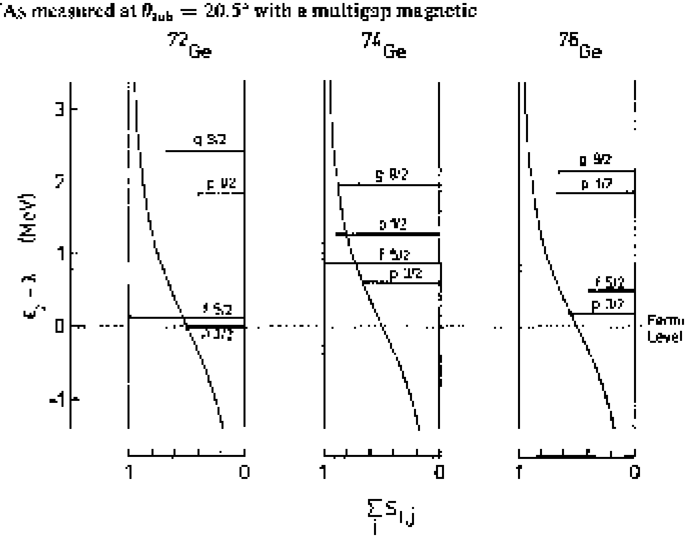


Fig. 2. Spectrum of the reaction ^{76}Ge(^{3}He, d)^{77}As measured at θ_{Lab} = 20.5° with a multigap magnetic sp





no absolute strength
no comparison to inverse

proton orbitals

precise relative measurements

targets: ^{74}Ge, ^{76}Ge, ^{76}Se, ^{78}Se

thickness: Rutherford scattering @ 10MeV α

reactions: (d,^{3}He) and (^{3}He,d)

beam of 80 MeV deuterons & ^{3}He

cyclotron @ RCNP, Osaka

Gran Raiden

solid angle: α-source with solid state detector

wire chamber efficiencies

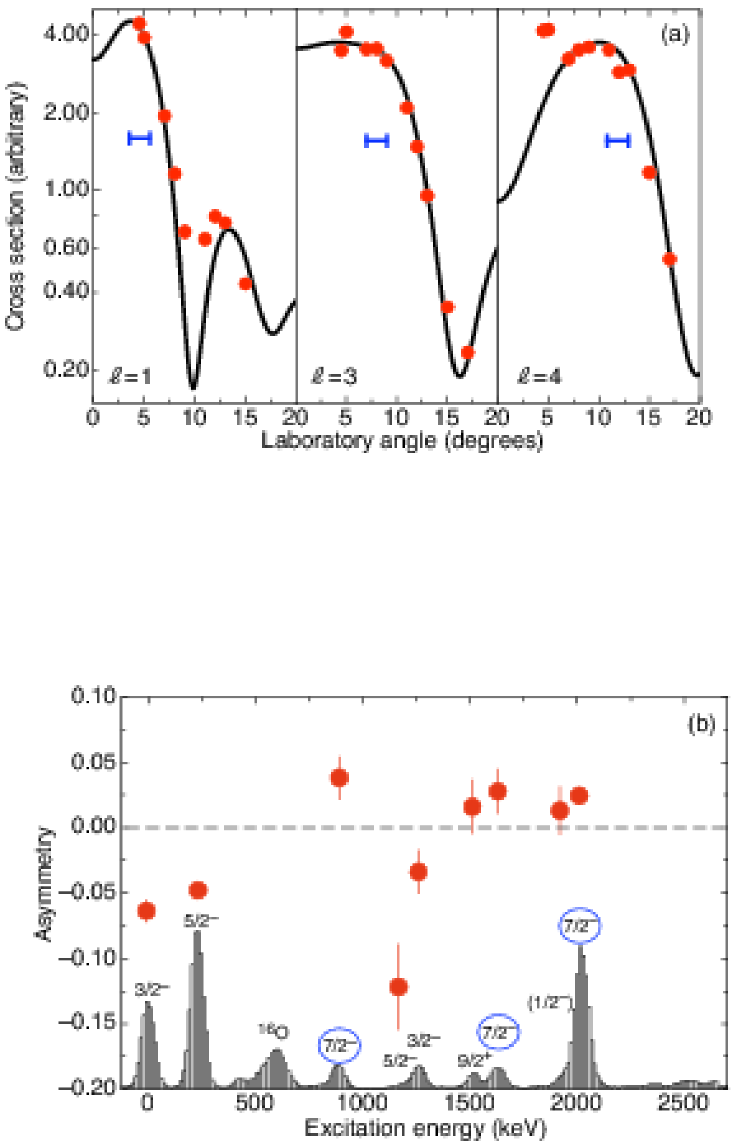
luminosity monitoring with 2nd spectr. LAS

polarised deuterons (beam polarimeter)

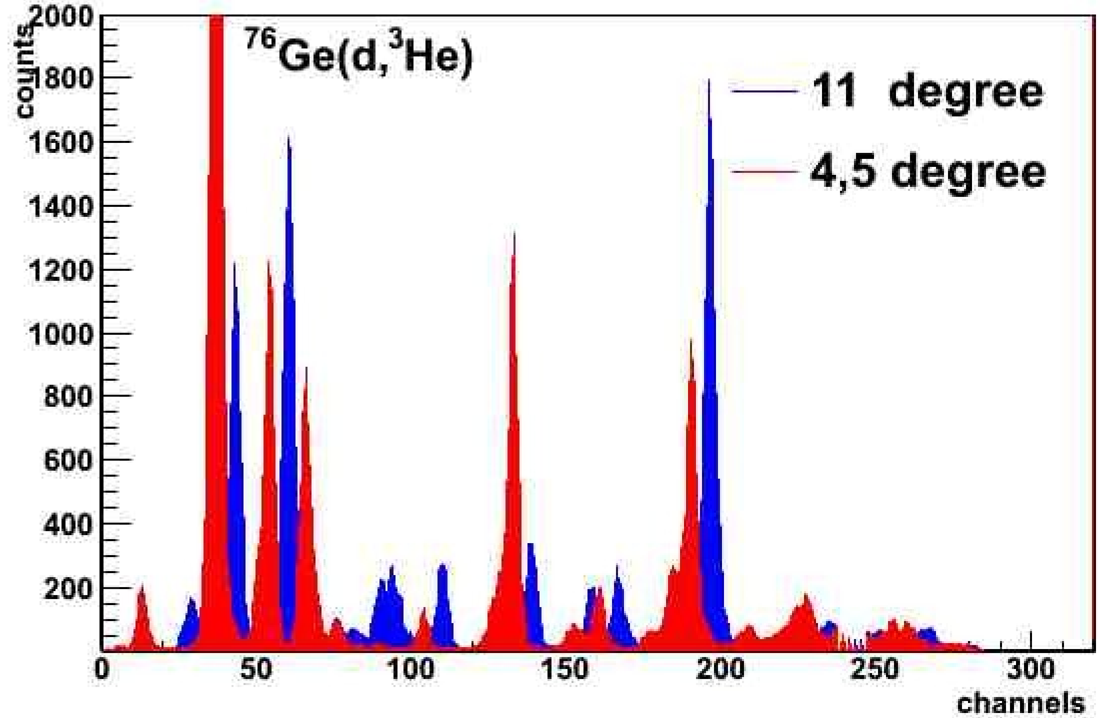
DWBA: use a single parameter set


SUMITOMO

proton transfer



B.Kay, J. Schiffer, S. Freeman etal



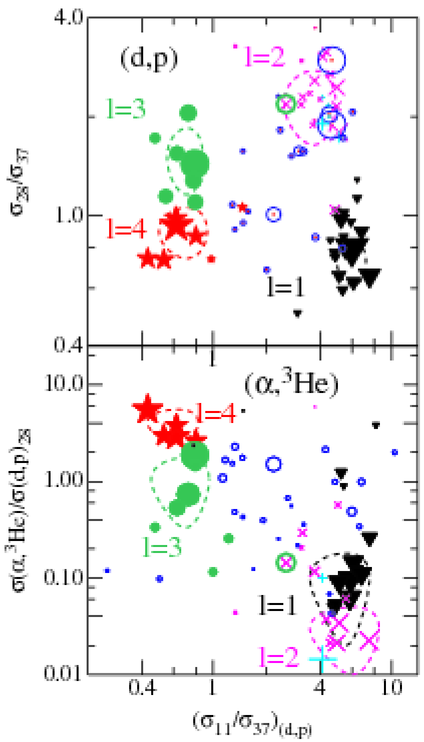
in (^{3}He,d) not the full strength found

neutron vacancies (1-occ.)

PRL **100,** 112501 (2008) PHYSICAL REVIEW LETTERS week ending 21 MARCH 2008

Nuclear Structure Relevant to Neutrinoless Double β Decay: ^{76}Ge and ^{76}Se

J.P. Schiffer,[1,*] S.J. Freeman,[2] J.A. Clark,[3] C. Deibel,[3] C.R. Fitzpatrick,[2] S. Gros,[1] A. Heinz,[3] D. Hirata,[4,5] C.L. Jiang,[1] B.P. Kay,[2] A. Parikh,[3] P.D. Parker,[3] K.E. Rehm,[1] A.C.C. Villari,[4] V. Werner,[3] and C. Wrede[3]



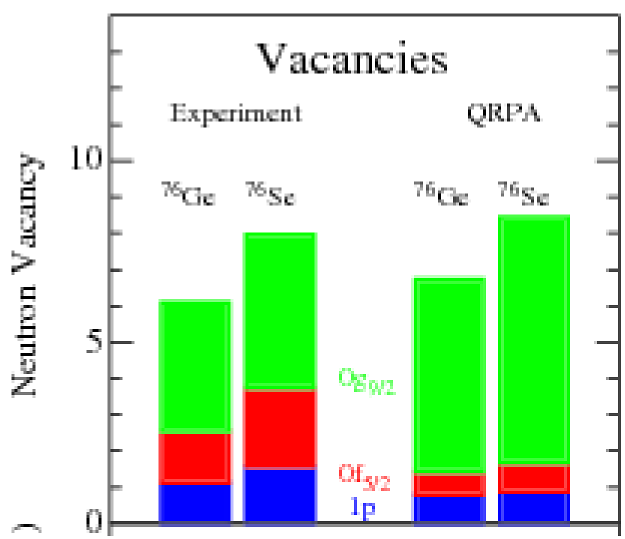
shell closure @ N=50

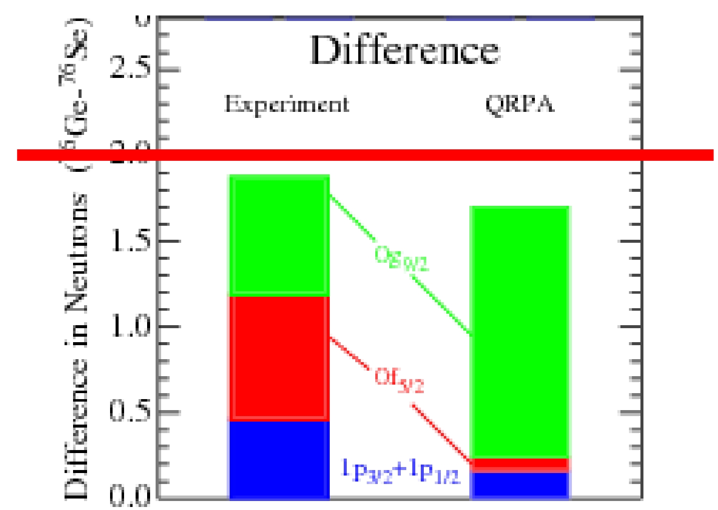
$\nu(^{76}Se) = 6$

$\nu(^{76}Ge) = 8$

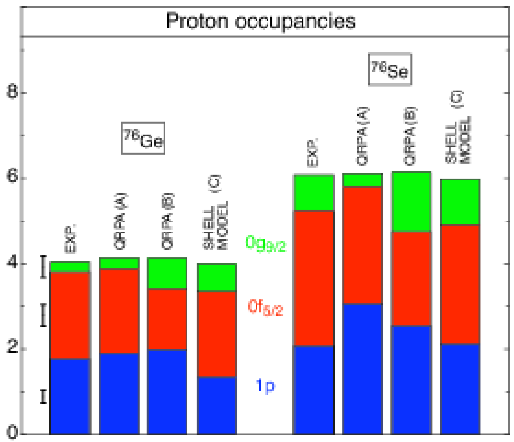
(d,p) (p,d)

(α,^{3}He) (^{3}He,α)





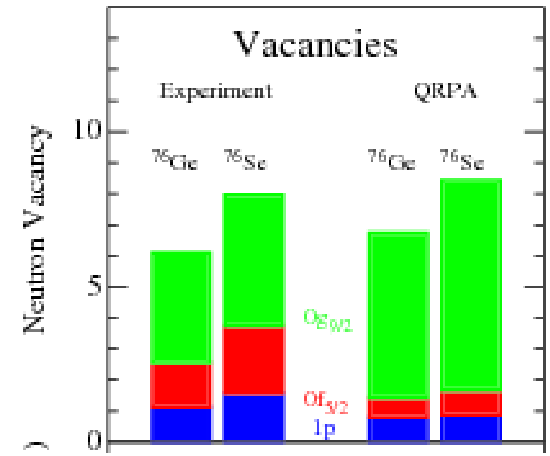
differences in occupancy



A) V.A. Rodin etal
NPA766 (2006) 107

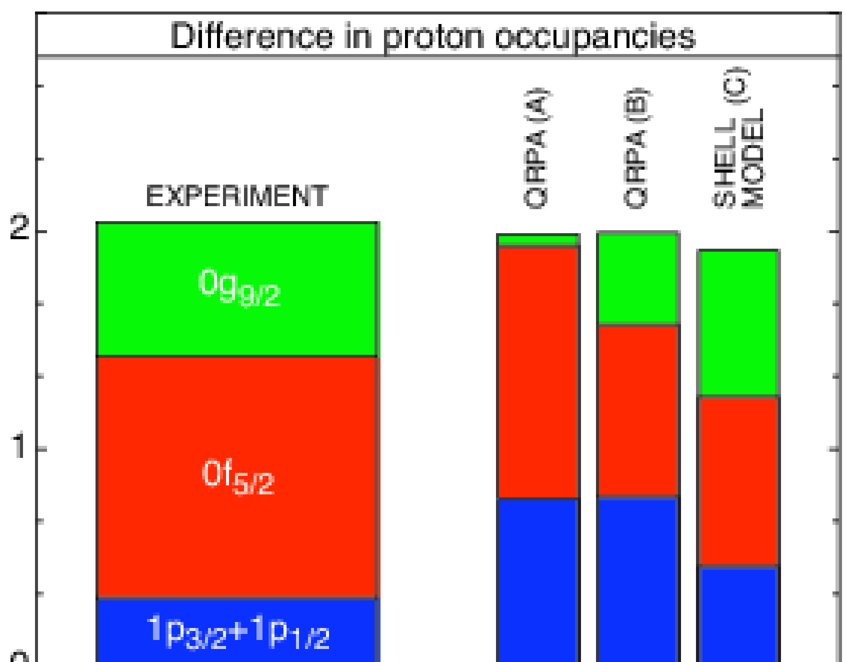
B) J. Suhonen and O. Civitarese
PLB668 (2008) 277

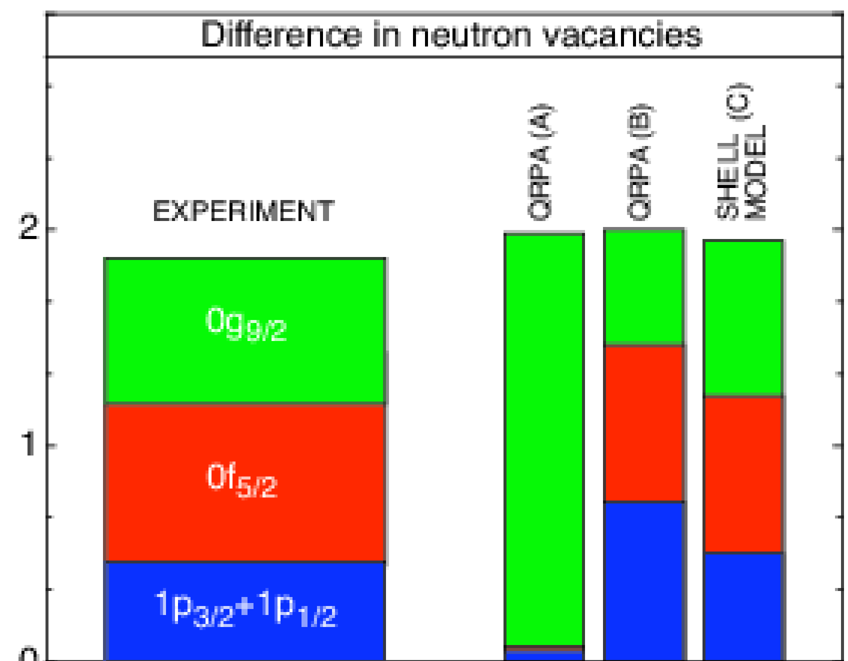
C) E. Caurier etal
PRL 100 (2008) 052503
+ A.Poves (priv.comm.)



protons

neutrons





summary

rare event search

question of understanding the background

neutron capture

control reactions for interpretation

proton transfer