GAMOW-TELLER BETA DECAY OF PROTON-RICH KR ISOTOPES IN A SELF-CONSISTENT APPROACH

A. PETROVICI

Institute for Physics and Nuclear Engineering, Bucharest, Romania
Institut für Theoretische Physik, Universität Tübingen, Germany

- $^{74}\mathrm{Kr} \quad \rightarrow \quad ^{74}\mathrm{Br}$

$$0^+_{ground-state} \rightarrow 1^+$$

- $^{72}\mathrm{Kr} \quad \rightarrow \quad ^{72}\mathrm{Br}$

$$0^+_{ground-state} \rightarrow 1^+$$

$$0^+_{first-excited} \rightarrow 1^+$$

within

the *complex* **EXCITED VAMPIR** variational approach

VAMPIR - Variational approaches to the nuclear many-body problem

Framework

- the model space is defined by a finite dimensional set of spherical single particle states
- the effective many-body Hamiltonian is represented as a sum of one- and two-body terms
- the basic buiding blocks are Hartree-Fock-Bogoliubov (HFB) vacua
- the HFB transformations are essentially *complex* and allow for proton-neutron, parity and angular momentum mixing being only restricted by time-reversal and axial symmetry
- the broken symmetries (s=N, Z, I, π) are restored before variation by projection techniques

Variational procedures

complex Vampir approach

$$E^s[F_1^s] = \frac{\langle F_1^s | \hat{H} \hat{\Theta}^s_{00} | F_1^s \rangle}{\langle F_1^s | \hat{\Theta}^s_{00} | F_1^s \rangle}$$

$$|\psi(F_1^s); sM\rangle = \frac{\hat{\Theta}^s_{M0} | F_1^s \rangle}{\sqrt{\langle F_1^s | \hat{\Theta}^s_{00} | F_1^s \rangle}}$$

complex Excited Vampir approach

$$|\psi(F_2^s); sM\rangle = \hat{\Theta}^s_{M0} \left\{ |F_1^s\rangle \alpha_1^2 + |F_2^s\rangle \alpha_2^2 \right\}$$

$$|\psi(F_i^s); sM\rangle = \hat{\Theta}^s_{M0} \sum_{j=1}^{i} |F_j^s\rangle \, \alpha_j^i \qquad \text{for} \quad i = 1, \ldots, n$$

$$|\Psi_\alpha^{(n)}; sM > = \sum_{i=1}^{n} |\psi_i; sM > f_{i\alpha}^{(n)}, \qquad \alpha = 1, \ldots, n$$

$$(H - E^{(n)} N) f^n = 0$$

$$(f^{(n)})^+ N f^{(n)} = 1$$

A= 70 – 90 mass region

^{40}Ca - core

model space (π, ν):

$1p_{1/2}\ 1p_{3/2}\ 0f_{5/2}\ 0f_{7/2}\ 1d_{5/2}\ 0g_{9/2}$

renormalized G–matrix (OBEP, Bonn A)

- short range Gaussians in the *nn, pp, np channels*
- monopole shifts:

$\langle 0g_{9/2}0f; T=0|\hat{G}|0g_{9/2}0f; T=0\rangle$

$\langle 1p1d_{5/2}; T=0|\hat{G}|1p1d_{5/2}; T=0\rangle$

	$f_{5/2}$	$f_{7/2}$
(ms1):	-0.590 MeV /	-0.060 MeV
(ms2):	-0.500 MeV /	-0.150 MeV
(ms3):	-0.400 MeV /	-0.250 MeV

Gamow-Teller β Decay of ^{74}Kr

CERN/ISOLDE E. Poirier et al., Phys.Rev. C69(2004)034307

$$^{74}\mathrm{Kr} \rightarrow {}^{74}\mathrm{Br}$$

$Q_{EC} = 3.140 \pm 0.060$ *MeV*

$$0^+_{ground-state} \rightarrow 1^+$$

The amount of mixing for the ground-state of ^{74}Kr.

	o-mixing	p-mixing
ms1	56(2)(1)(1)%	35(3)(1)(1)%
ms2	39(2)(1)(1)%	51(3)(1)(1)%
ms3	28(1)(1)%	65(3)(2)%

The amount of mixing for the lowest calculated 1^+ states of ^{74}Br (ms1).

o-mixing /p-mixing
94(3)(3)%
61(35)(2)(1)%
89(3)(2)(2)(1)(1)(1)%
44(28)(19)(4)(1)(1)(1)%
97%
69(19)(5)(2)(2)%
70(7)(3)(2)(1)(1)(1)%4(3)(2)(2)%
9(3)% 25(24)(11)(10)(3)(2)(2)(1)(1)(1)(1)(1)(1)(1)%
7(1)(1)% 71(8)(5)(1)(1)(1)(1)(1)%
43(12)(9)(7)(7)(3)(3)(2)(2)(2)(1)(1)(1)(1)(1)(1)(1)%
57(3)(2)(1)(1)(1)(1)%13(5)(4)(2)(2)(1)(1)(1)(1)%
26(1)(1)% 36(20)(4)(3)(2)(1)(1)(1)%
21(21)(14)(14)(6)(5)(4)(2)(2)(1)(1)(1)(1)(1)(1)%
1%26(20)(8)(7)(6)(5)(4)(3)(2)(2)(2)(1)(1)(1)(1)(1)(1)(1)(1)(1)(1)(1)%
2(1)(1)(1)% 36(14)(12)(6)(6)(5)(4)(2)(2)(1)(1)(1)(1)(1)(1)%
10(2)(2)(1)(1)% 27(13)(11)(9)(3)(3)(2)(2)(2)(2)(1)(1)(1)(1)(1)(1)(1)(1)%
50(16)(9)(5)(3)(3)(2)(2)(2)(1)(1)(1)% 2(2)%
33(21)(12)(8)(5)(5)(3)(3)(2)(2)(1)(1)% 1(1)(1)%
1(1)%34(18)(13)(9)(4)(3)(2)(2)(2)(2)(1)(1)(1)(1)(1)(1)%

The amount of mixing for the lowest calculated 1^+ states of ^{74}Br (ms2).

o-mixing /p-mixing

94(3)(1)%
61(35)(2)%
46(29)(17)(3)(1)(1)%
91(2)(2)(1)(1)(1)(1)%
97(1)%
40(37)(14)(4)(1)%
69(28)(1)(1)%
54(20)(11)(6)(1)(1)%2%
46(27)(9)(6)(2)(2)(1)(1)(1)(1)(1)%
5% 65(16)(4)(1)(1)(1)(1)%
49(8)(8)(5)(5)(4)(4)(3)(2)(2)(2)(1)(1)(1)%
29(14)(11)(10)(9)(7)(7)(2)(2)(1)(1)(1)(1)(1)(1)%
1% 61(19)(7)(2)(1)(1)(1)(1)(1)(1)(1)%
57(11)(8)(5)(3)(3)(1)(1)(1)(1)(1)(1)(1)(1)(1)%
78(6)(2)(1)(1)(1)(1)(1)(1)% 1(1)(1)(1)%
3% 33(23)(10)(7)(6)(5)(3)(2)(2)(1)(1)%
31(10)(10)(6)(6)(5)(3)(3)(3)(2)(2)(2)(2)(2)(1)(1)(1)(1)(1)(1)(1)(1)(1)(1)(1)%
(1)1% 25(19)(14)(7)(6)(5)(4)(4)(2)(2)(2)(2)(1)(1)%
2% 42(10)(9)(6)(5)(4)(4)(3)(3)(3)(1)(1)(1)(1)(1)(1)%
28(19)(13)(10)(7)(4)(3)(1)(1)(1)% 3(1)(1)(1)(1)(1)(1)%
23(16)(14)(6)(5)(4)(2)(1)(1)(1)(1)% 12(3)(2)(1)(1)(1)(1)%
(1)1% 28(13)(12)(10)(6)(5)(3)(3)(3)(2)(1)(1)(1)(1)(1)(1)(1)%
51(16)(11)(3)(3)(3)(2)(2)(2)(1)(1)% 1(1)(1)%
25(19)(11)(10)(8)(8)(3)(3)(2)(2)(1)(1)(1)(1)% 2(1)%

The amount of mixing for the lowest calculated 1^+ states of ^{74}Br (ms3).

o-mixing /p-mixing

61(35)(2)%
94(4)(1)%
48(31)(15)(2)(2)(1)%
92(3)(1)(1)(1)(1)(1)%
94(2)(2)%
76(16)(3)(2)(1)%
2(2)%63(10)(10)(3)(3)(1)(1)(1)(1)(1)%
45(42)(5)(1)% 2(1)(1)%
2(1)(1)% 64(15)(3)(2)(2)(2)(1)(1)(1)(1)(1)(1)%
45(19)(15)(13)(1)(1)(1)%1%
67(21)(3)(2)(2)(1)(1)(1)%
2% 54(16)(12)(2)(2)(1)(1)(1)(1)(1)(1)(1)(1)(1)(1)%
53(12)(5)(4)(4)(3)(2)(2)(2)(2)(2)(2)(2)(1)(1)(1)(1)%
41(26)(7)(7)(3)(2)(1)(1)(1)(1)(1)(1)(1)(1)(1)(1)(1)%
32(26)(16)(5)(5)(3)(2)(2)(2)(1)(1)(1)%
20(19)(10)(8)(7)(6)(4)(4)(3)(2)(2)(2)(2)(2)(2)(1)(1)(1)(1)(1)%
52(24)(11)(4)(1)(1)(1)(1)%1%
36(10)(8)% 16(13)(3)(2)(2)(2)(1)(1)(1)%
31(18)(9)(8)(6)(6)(3)(2)(2)(2)(2)(1)(1)(1)(1)(1)(1)(1)(1)%
41(11)(8)(7)(6)(5)(4)(3)(2)(2)(1)(1)(1)(1)(1)(1)(1)(1)(1)%
1%33(13)(7)(7)(6)(5)(4)(4)(4)(3)(2)(1)(1)(1)(1)(1)(1)(1)(1)%
61(7)(7)(6)(3)(2)(1)(1)(1)(1)(1)% 2(1)(1)(1)(1)%
42(9)(7)(4)(2)(2)(1)(1)(1)% 4(4)(3)(2)(2)(2)(1)(1)(1)(1)(1)(1)(1)%
25(20)(13)(12)(8)(5)(3)(3)(2)(1)(1)(1)(1)(1)% 3(1)(1)%
57(12)(10)(2)(2)(1)% 11%
3(1)% 25(19)(14)(6)(6)(5)(4)(3)(2)(1)(1)(1)(1)(1)(1)(1)(1)(1)(1)%
1(1)(1)(1)% 38(9)(8)(7)(5)(5)(5)(4)(2)(2)(2)(1)(1)(1)(1)(1)(1)%
1%23(16)(9)(7)(5)(4)(4)(4)(3)(3)(2)(2)(2)(2)(2)(1)(1)(1)(1)(1)(1)%

Spectroscopic quadrupole moments Q_2^{sp} (in efm^2) for the lowest calculated 1^+ states of the ^{74}Br nucleus (ms1).

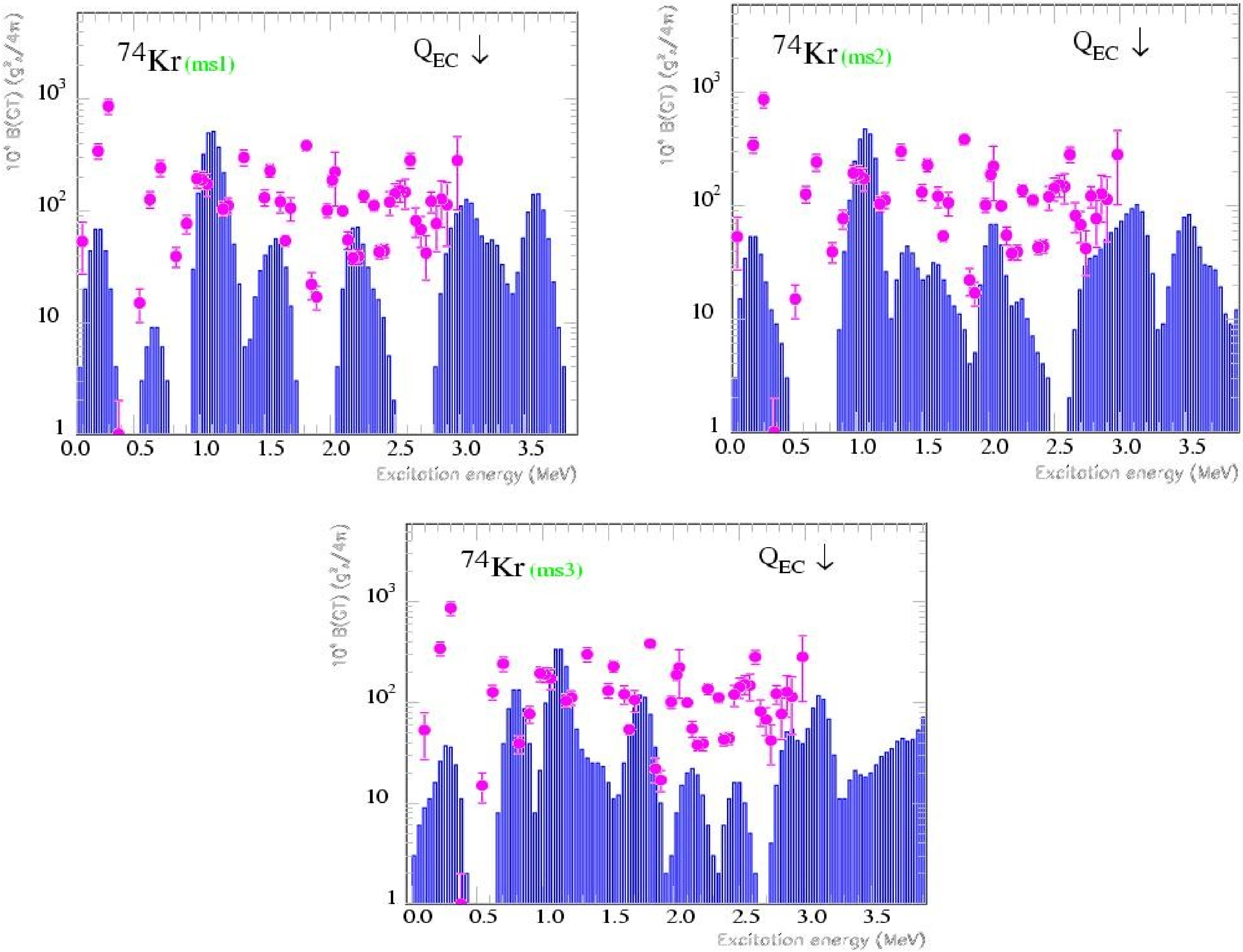
1^+_I	1^+_{II}	1^+_{III}	....							
48.6	-49.4	46.6	-46.7	-47.7	45.1	45.3	47.7	-56.6	33.2	-38.2
-40.1	42.0	-50.7	-58.1	-52.4	-51.0	16.7	-22.0	-50.9	-50.5	-48.5
-43.4	37.2	45.0	-40.3	-34.3	26.2	39.2	41.0	-44.5	-49.0	40.9
-51.3	-39.8	-42.3	14.4	18.4	37.9	41.0	-37.4	15.0	-40.4	29.3
-39.3	41.5	-54.2	-52.3	38.4	-47.6	-45.3	-8.4	-1.4	-41.4	-48.2
40.3	48.7	-40.6	43.1	-24.0	46.0	-45.3	-61.4	-54.8	-55.0	-16.1

Spectroscopic quadrupole moments Q_2^{sp} (in efm^2) for the lowest calculated 1^+ states of the ^{74}Br nucleus (ms2).

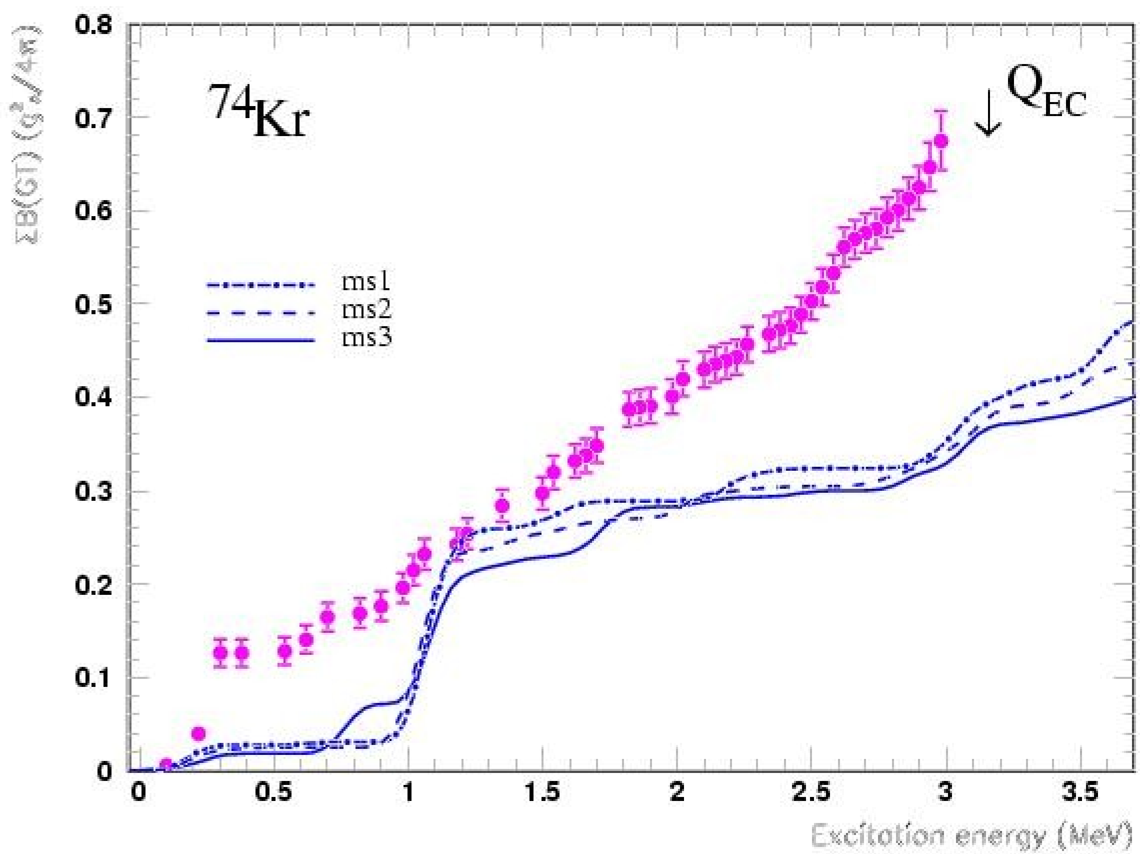
1^+_I	1^+_{II}	1^+_{III}	....							
48.5	-49.0	-47.6	47.0	-48.5	48.2	44.1	45.4	-51.7	-53.1	42.5
-43.3	-50.8	40.0	-50.2	-52.5	-55.0	-50.8	-50.5	42.4	-49.1	-46.1
47.6	-44.1	-44.2	-43.7	40.9	35.6	34.3	-31.5	-47.3	-45.3	39.5
-51.4	42.4	-53.4	-47.3	-44.0	35.9	-46.5	39.9	-44.1	-59.6	-48.5
33.8	38.4	-44.4	40.8	-43.4	7.6	-3.8	33.0	-51.7	-46.1	-45.2
33.3	-34.7	-14.7	5.6	44.4	14.6	-12.2	-62.2	44.9	-44.2	-52.2
40.3	-55.1	-52.2	46.6	33.3	-15.5					

Spectroscopic quadrupole moments Q_2^{sp} (in efm^2) for the lowest calculated 1^+ states of the ^{74}Br nucleus (ms3).

1^+_I	1^+_{II}	1^+_{III}	....							
-49.3	48.4	-48.7	47.1	-49.5	47.8	-48.0	40.9	-51.3	45.5	-49.8
-51.3	45.0	-50.1	-51.4	-44.9	38.1	-53.7	-49.6	-50.9	44.7	6.6
-3.4	-47.3	-52.1	-46.2	-52.0	4.9	-11.9	-43.4	-45.4	38.9	-27.5
16.7	39.2	-44.9	30.9	-42.0	-42.5	-45.3	-52.9	-44.2	-27.3	28.1
-0.1	-4.7	-45.8	39.4	-37.3	-45.4	32.0	39.6	-40.3	-41.4	30.4
-43.5	-24.2	20.6	41.9	13.0	-16.0	38.4	-34.4	25.8	-55.7	-15.5
14.5	-52.2	40.9	35.2	29.1	2.7	-15.9	4.7			



74Kr(ms1)
QEC
Excitation energy (MeV)
74Kr(ms2)
QEC
Excitation energy (MeV)
74Kr(ms3)
QEC
Excitation energy (MeV)



^{74}Kr
$\downarrow Q_{EC}$
ms1
ms2
ms3
ΣB(GT) ($g_A^2/4\pi$)
Excitation energy (MeV)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
0.5
1
1.5
2
2.5
3
3.5

Gamow-Teller β Decay of ^{72}Kr

CERN/ISOLDE   I. Piqueras, Eur. Phys. J. A16(2003)313

$$^{72}\mathrm{Kr} \quad \rightarrow \quad ^{72}\mathrm{Br}$$

$$Q_{EC} = 5.040 \pm 0.375 \text{ MeV}$$

$$0^+_{ground-state} \rightarrow 1^+$$

$$0^+_{first-excited} \rightarrow 1^+$$

The amount of mixing for the lowest two 0^+-states of the ^{72}Kr nucleus (ms3).

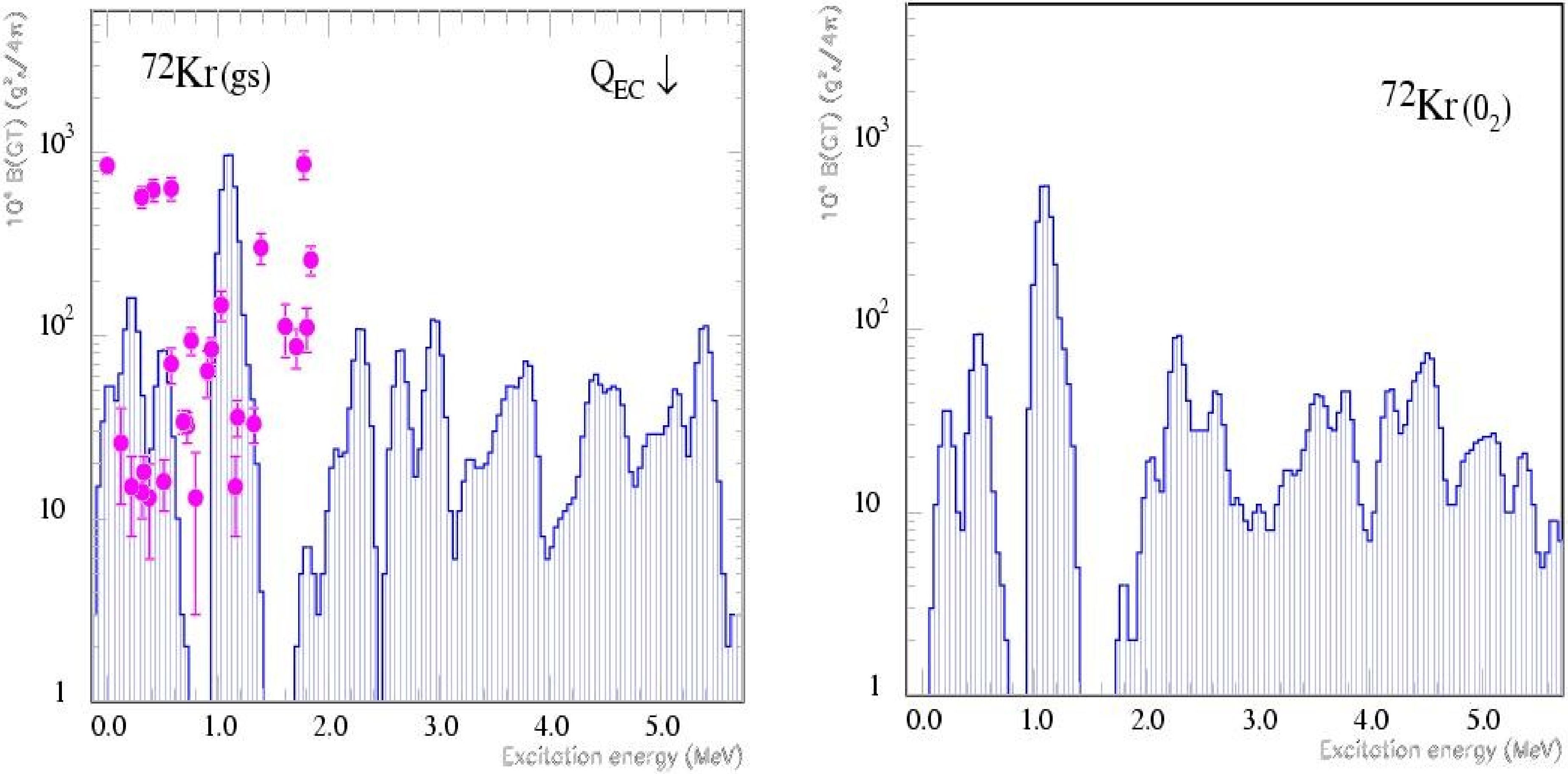
$I\,[\hbar]$	o-mixing	p-mixing
0^+_1	64(2)%	29(2)(1)(1)%
0^+_2	35(2)%	57(3)(1)(1)%

The amount of mixing for the lowest calculated 1^+ states of ^{72}Br (ms3).

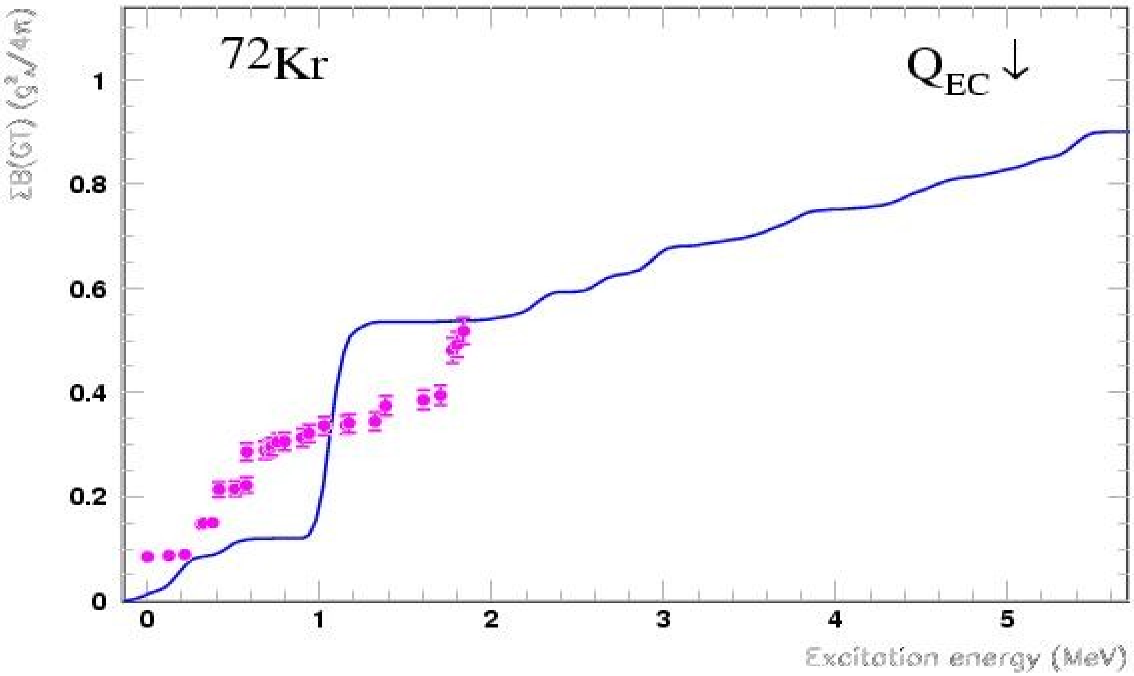
o-mixing /p-mixing
85(13)%
80(12)(5)%
1%89(2)(2)(2)(1)(1)%
82(4)(3)(2)(2)(1)(1)(1)%
81(15)(1)(1)%
77(5)(3)(3)(2)(2)(2)(1)(1)%
44(26)(9)(7)(5)(1)(1)(1)(1)%
37(30)(13)(8)(3)(1)(1)(1)(1)%
76(20)(1)(1)%
77(7)(1)(1)(1)% 4(2)(1)%
8(1)% 29(28)(20)(2)(2)(1)(1)(1)(1)(1)(1)(1)(1)%
38(14)(12)(12)(8)(2)(2)(2)(1)(1)(1)(1)(1)(1)(1)%
44(16)(9)(6)(6)(4)(3)(3)(2)(1)(1)(1)(1)%
67(15)(7)(3)(1)(1)(1)(1)%
54(21)(8)(7)(2)(1)(1)(1)% 2%

Spectroscopic quadrupole moments Q_2^{sp} (in efm^2) for the lowest calculated 1^+ states of the ^{72}Br nucleus (ms3).

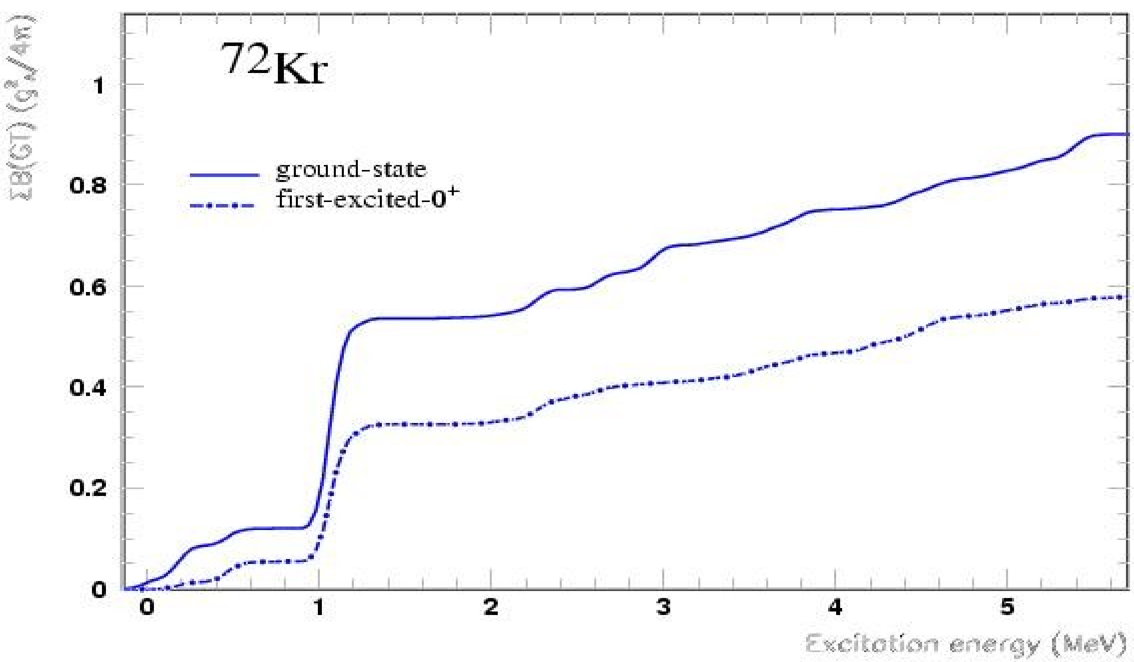
1^+_I	1^+_{II}	1^+_{III}	....							
48.6	48.8	-50.2	-49.7	46.6	45.7	-51.7	-50.2	-49.6	47.3	38.9
-41.5	-48.7	-47.6	45.8	42.8	-53.3	-55.4	44.0	40.1	-44.4	-49.9
-50.3	41.4	-48.2	23.8	-28.2	42.2	-44.1	-46.5	42.8	-44.4	-46.8
-45.8	-16.8	5.7	-10.0	19.4	-36.5	-46.7	11.5	-33.5	39.4	-44.7
42.2	-46.5	-45.2	-45.9	38.5	44.2	25.0	-30.8	-43.4	34.0	-38.9
-34.5	41.7	2.8	23.9	6.1	20.1	14.3	41.2	-52.5	-48.3	46.2
39.0	-44.8	-45.5	44.6	35.5	-45.5	-47.5	8.3	-36.3	42.8	-45.2
48.3	44.8	1.2								



72Kr(gs)
Q_EC ↓
10^4 B(GT) (g²A/4π)
10³
10²
10
1
0.0
1.0
2.0
3.0
4.0
5.0
Excitation energy (MeV)
72Kr(0₂)
10^4 B(GT) (g²A/4π)
10³
10²
10
1
0.0
1.0
2.0
3.0
4.0
5.0
Excitation energy (MeV)



^{72}Kr
$Q_{EC}\downarrow$
ΣB(GT) (g²A/4π)
Excitation energy (MeV)



^{72}Kr
ground-state
first-excited-0$^+$
ΣB(GT) (g²A/4π)
Excitation energy (MeV)

Summary and outlook

- the Gamow-Teller β decay of ^{74}Kr was investigated for the first time within the complex Excited Vampir variational approach, describing consistently the shape-coexistence and –mixing in both parent and daughter nucleus

- the first results concerning the Gamow-Teller strength distribution as well as the accumulated strength for both the ground state and the first-excited 0+ state of ^{72}Kr are obtained in a self-consistent approach. A good agreement with available data is revealed.

- the uncertainties in the effective interaction require systematic investigations

In collaboration with:

K. W. Schmid, Amand Faessler

Tuebingen University, Germany

O. Radu

National Institute for Physics and Nuclear Engineering,
Bucharest, Romania