T=1/2 Mirror transitions @ DESIR

T=1/2 mirror transition:

With $T \geq |T_Z|$ and $T_Z = (N\text{-}Z)/2 = \pm\ 1/2$ (one nucleon away from N=Z line)

β^+ decay transition of the form: ${}_{Z}X_{N} \rightarrow {}_{N}Y_{Z} + e^+ + \nu$ where $Z = N+1$

groupe Noyaux Exotiques CENBG Bordeaux (France)

T=1/2 Mirror transitions @ DESIR

Motivation:

Cabbibo-**K**obayashi-**M**asukawa matrix

Unitarity test for 3 generations electroweak model

$$V_{ud}^2 + V_{us}^2 + V_{ub}^2 = 1$$

Determine V_{ud} (main term) with great precision

T=1/2 Mirror transitions @ DESIR

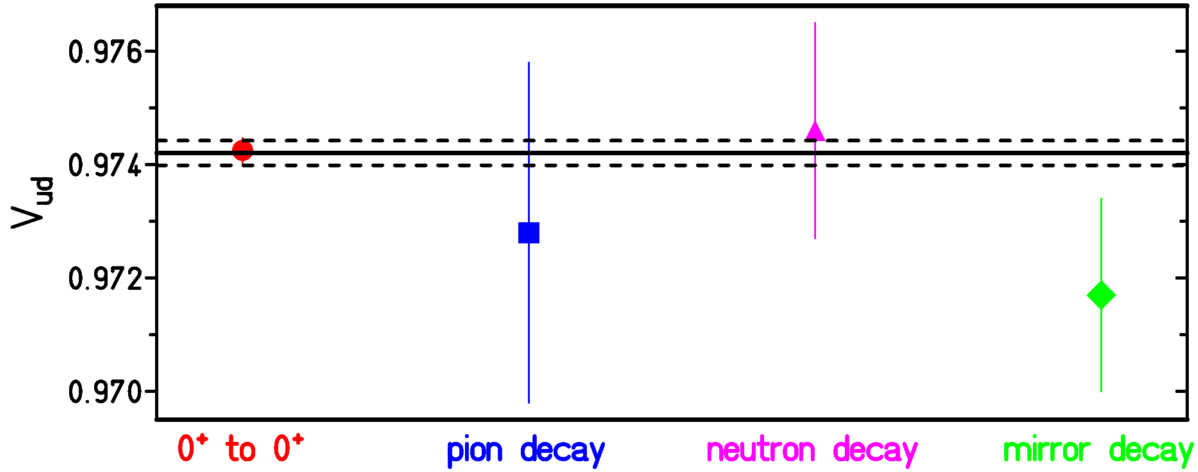
Status:

Traditional studies:

- super-allowed $0^+ \rightarrow 0^+$ transitions : 0.97425(22)
- pion decay: 0.9728(30)
- neutron decay: 0.9746(19)

Recent method:

- mirror β decay: 0.9717(17)



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T=1/2 Mirror transitions @ DESIR

Mirror transitions: the bad combination

- mix of Gamov-Teller and Fermi, like neutron decay.
- need for corrections, like pure Fermi transitions.

→ not a privileged tool to study electroweak interaction!

But it remains an independent probe...

T=1/2 Mirror transitions @ DESIR

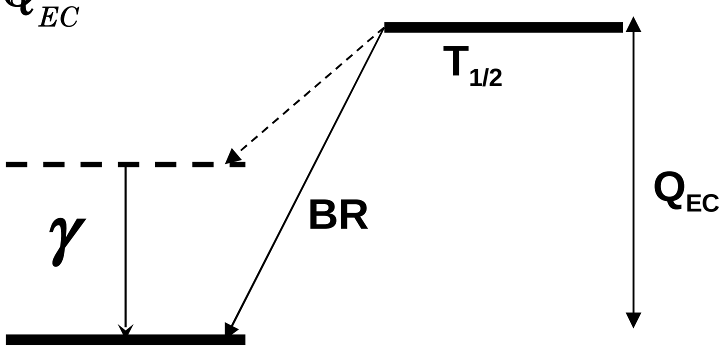
Motivation:

Theory → means to determine V_{ud} from T=1/2 mirror transitions

Ingredients:

In addition to progress in determining theoretical corrections, need to investigate :

- Gamov-Teller to Fermi ratio
- half-life $T_{1/2}$
- branching ratio BR
- Q_{EC}



$$ft = \frac{K}{g_V^2 \langle M_F \rangle^2 + g_A^2 \langle M_{GT} \rangle^2} = f(Q_{ec}) * T_{1/2} / BR$$

Corrected vector part $$Ft = f_V t (1+\delta_R')(1+\delta_{NS}^V - \delta_C^V)$$

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T=1/2 Mirror transitions @ DESIR

Comparison with *Ft* from superallowed Fermi transitions:

$$\mathcal{F}t^{0^+\to 0^+} \equiv \frac{K}{2G_F^2 V_{ud}^2 C_V^2 \left(1+\Delta_R^V\right)}$$

$$\mathcal{F}t^{\mathrm{mirror}} \equiv \frac{K}{G_F^2 V_{ud}^2} \frac{1}{C_V^2 |M_F^0|^2 (1+\Delta_R^V)[1+(f_A/f_V)\rho'^2]}$$

Mean value over available data: $\overline{\mathcal{F}t}_0 = 6173 \pm 22\ \mathrm{s}$

$$V_{ud}^2 = \frac{K}{\overline{\mathcal{F}t}_0 G_F^2 (1+\Delta_R^V)}$$

leads to $V_{ud} = 0.9717(17)$

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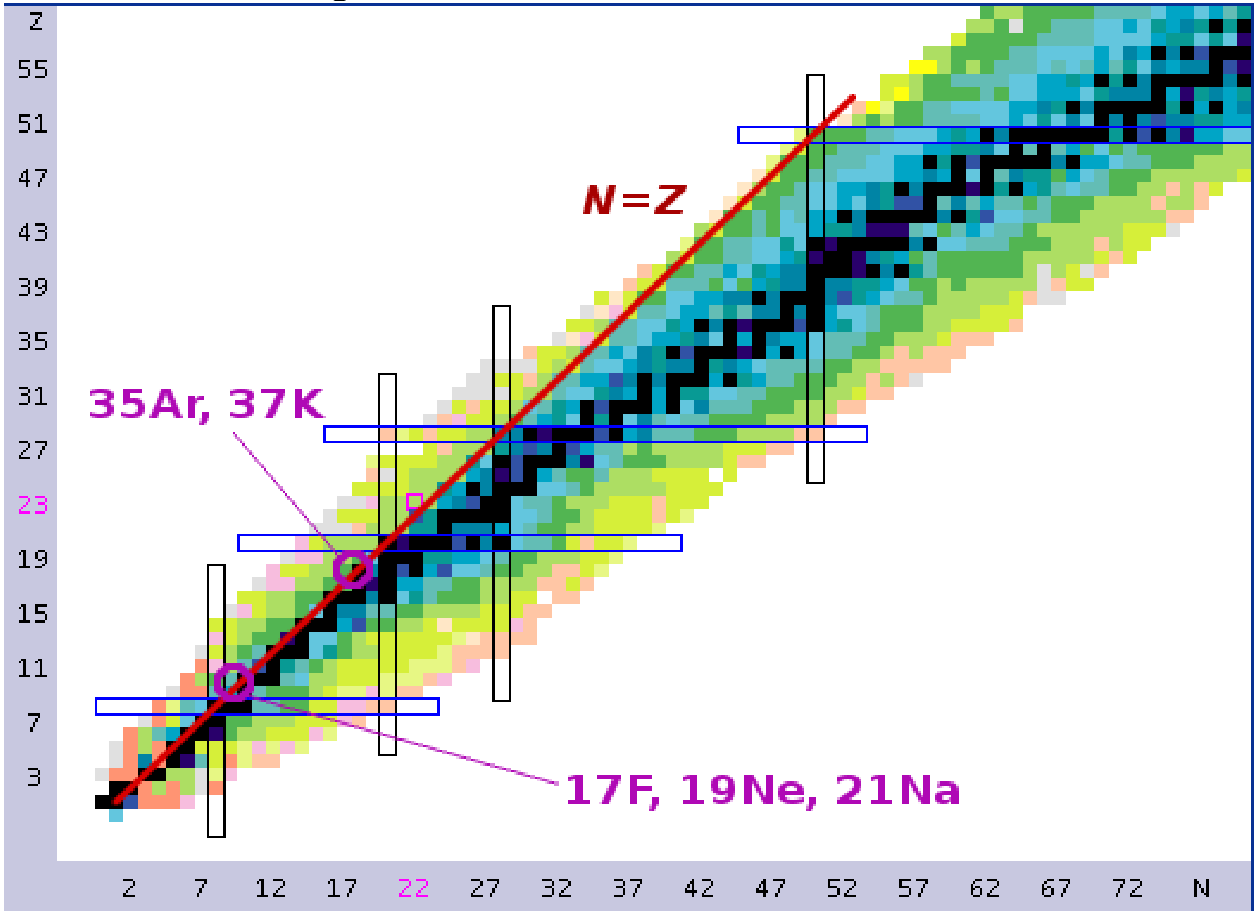
T=1/2 Mirror transitions @ DESIR

After Severijns: 35 candidates from ^{3}H to ^{83}Mo

Correlations have been measured for a few of them (beta asym, neutrino asym, beta-neutrino angular correlations) : ^{17}F, ^{19}Ne, ^{21}Na, ^{29}P, ^{35}Ar, ^{37}K



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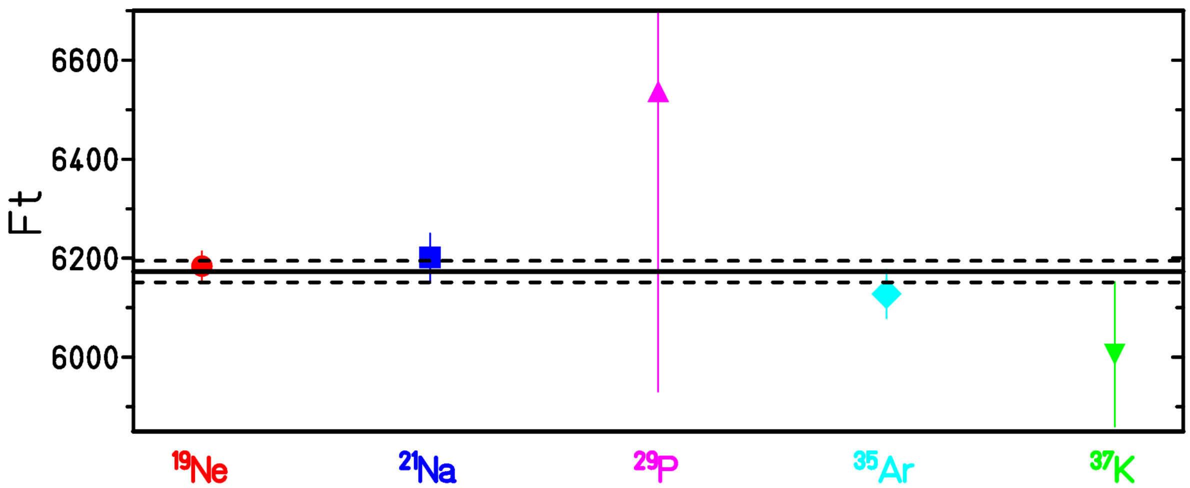
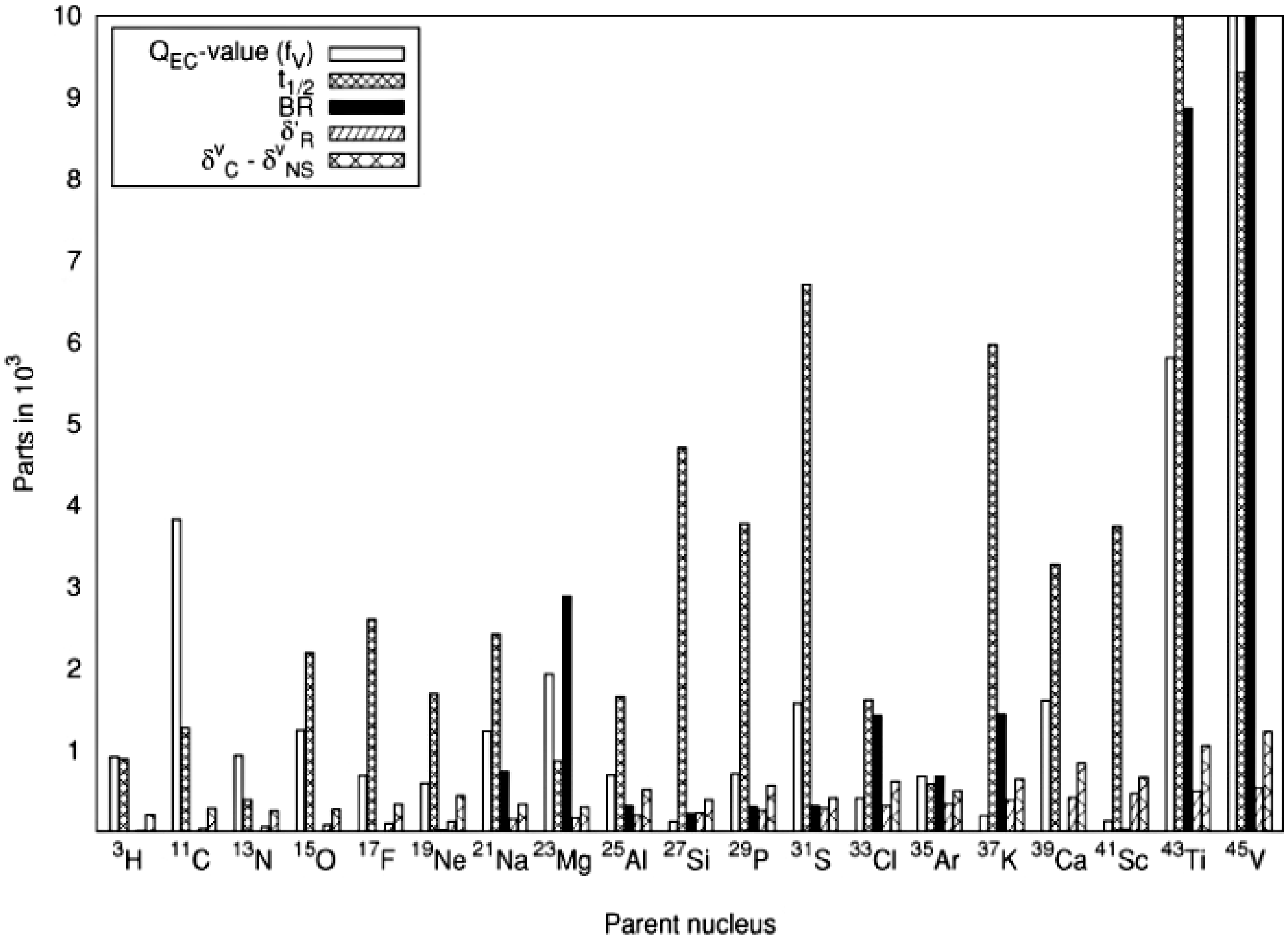
Individual Ft_0 values for five nuclei:



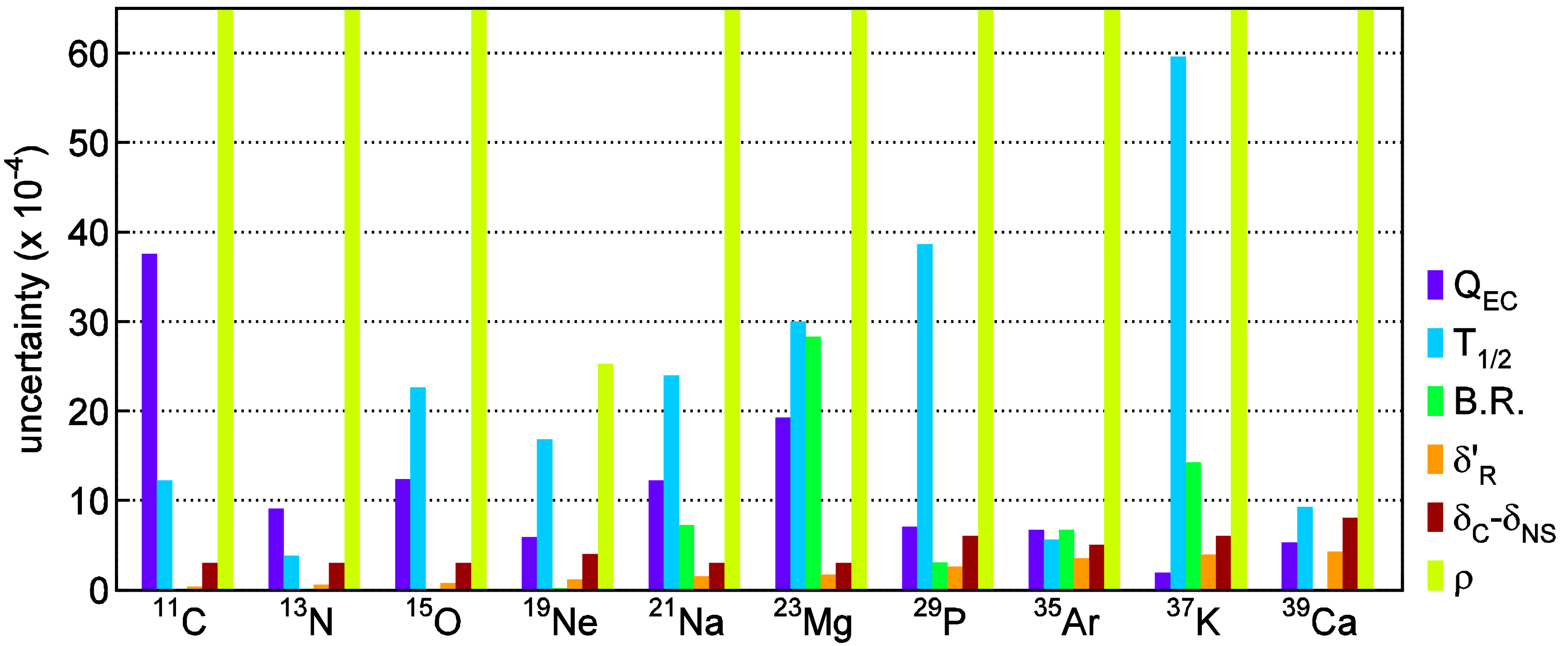
data from Naviliat-Cuncic & Severijns, PRL 102 (2009) 142302

Relative uncertainties for various nuclei:



from Severijns et al. PRC78 (2008) 055501

Relative uncertainties for various nuclei:



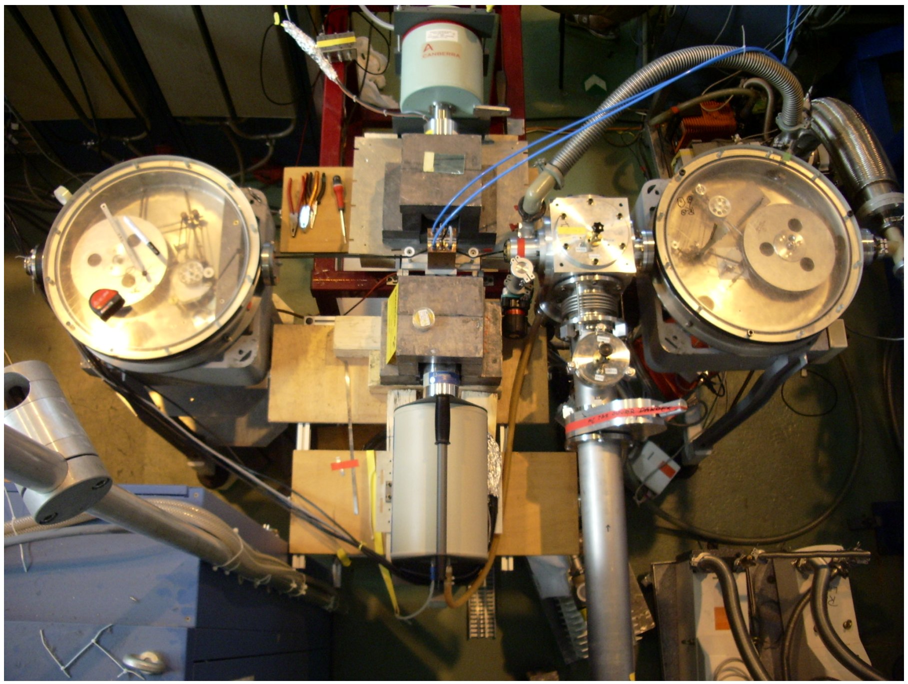
data from Severijns et al. PRC78 (2008) 055501

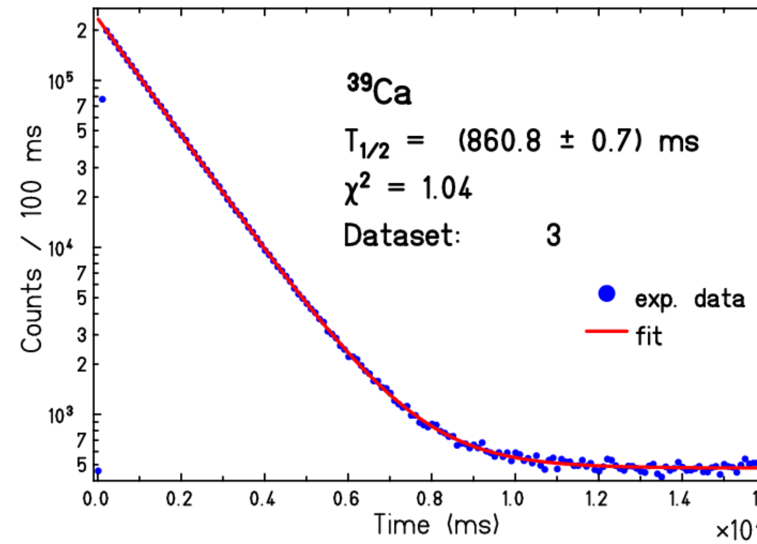
The mixing ratio is the main source of uncertainty.

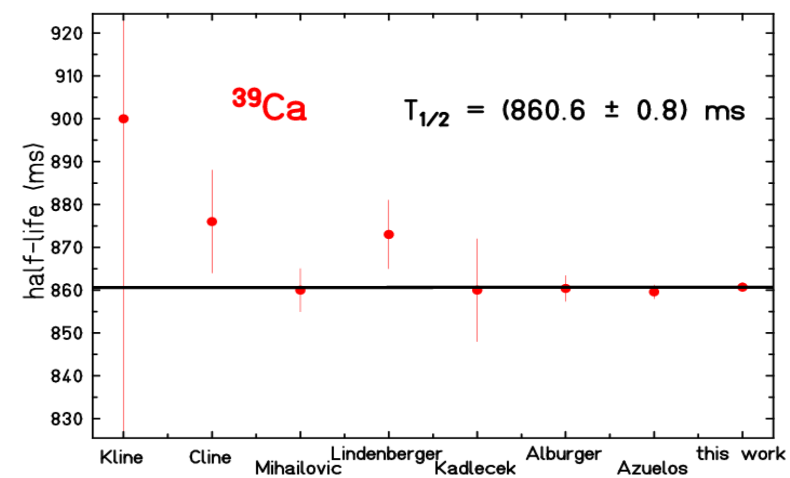
Recent experiments by our group:

^{39}Ca half-life determination (ISOLDE) 2007

^{29}P, ^{31}S (Jyväskylä, Finland) in 2009







Experimental set-up:

- mylar tape (implantation)
- germanium detectors (gamma)
- Geiger-Müller (beta)

Blank et al. DOI: 10.1140/epja/i2010-10958-2

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T=1/2 Mirror transitions @ DESIR

Interesting features of DESIR:

- several beam sources (SPIRAL1, SPIRAL2, S3)
- high intensity beam
- High Resolution Spectrometer
- ion traps

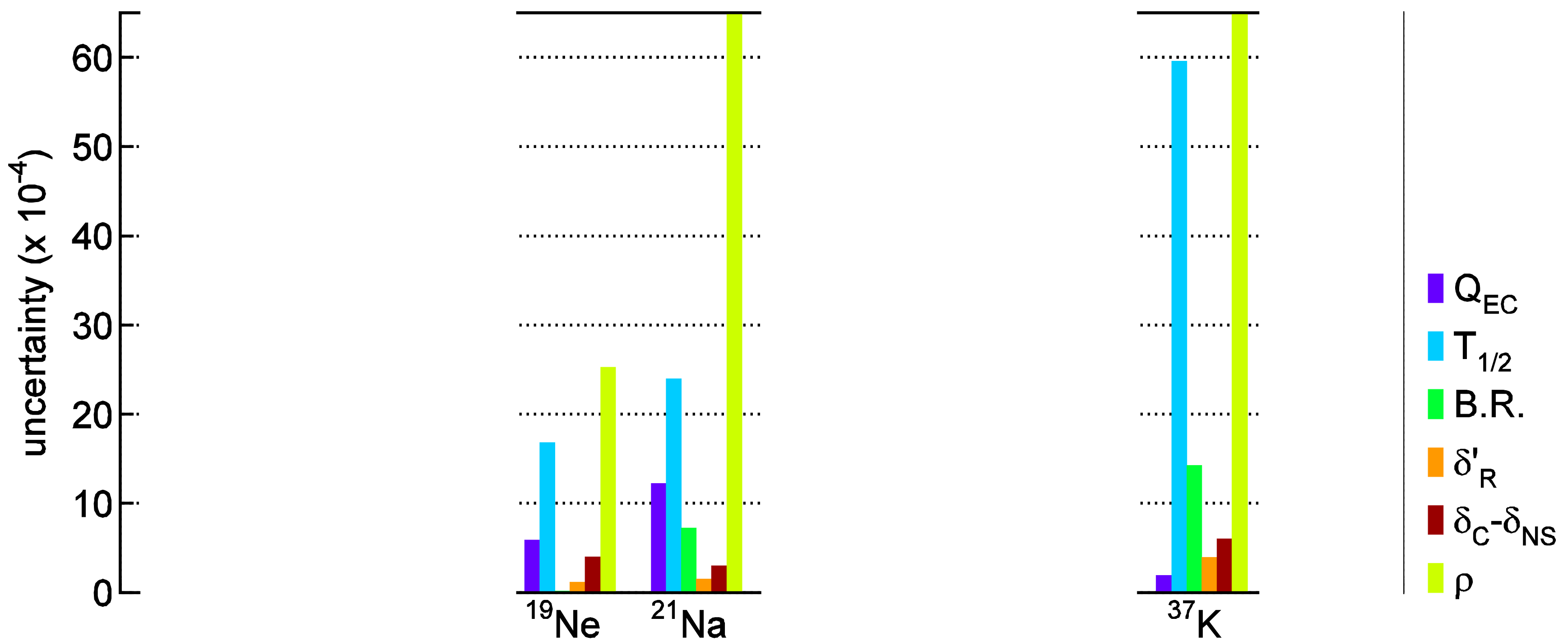
DESIRed counting rate:

For half-life measurement: between 100 and 1000 events/s

For branching-ratio determination: bet. 1000 and 10000 events/s

T=1/2 Mirror transitions @ DESIR

Nuclei for starters:



Next candidates: ^{17}F, ^{33}Cl... to be coordinated with correlation measurements.

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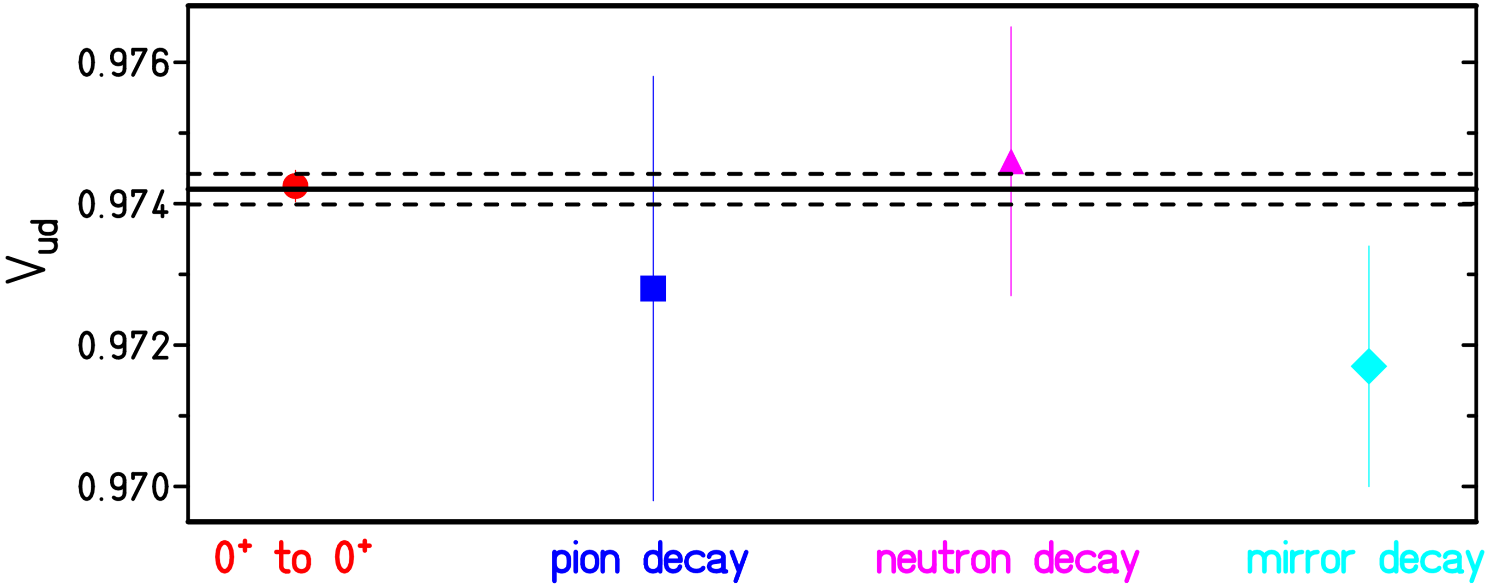
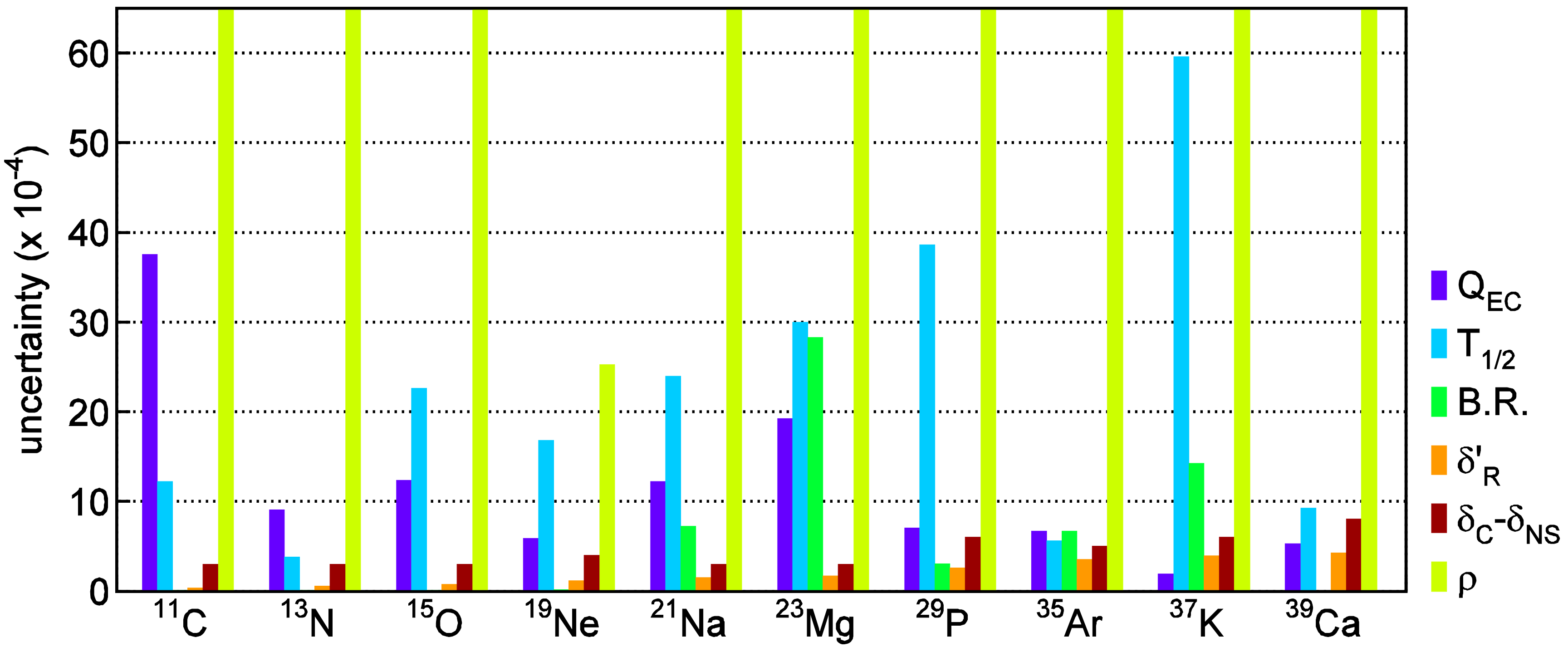
- super-allowed $0^+ \to 0^+$ transitions : 0.97425(22)
- pion decay: 0.9728(30)
- neutron decay: 0.9746(19)
- mirror β decay: 0.9717(17)





uncertainty (x 10^{-4})
60
50
40
30
20
10
0
^{11}C
^{13}N
^{15}O
^{19}Ne
^{21}Na
^{23}Mg
^{29}P
^{35}Ar
^{37}K
^{39}Ca
Q_{EC}
$T_{1/2}$
B.R.
δ'_R
δ_C-δ_{NS}
ρ

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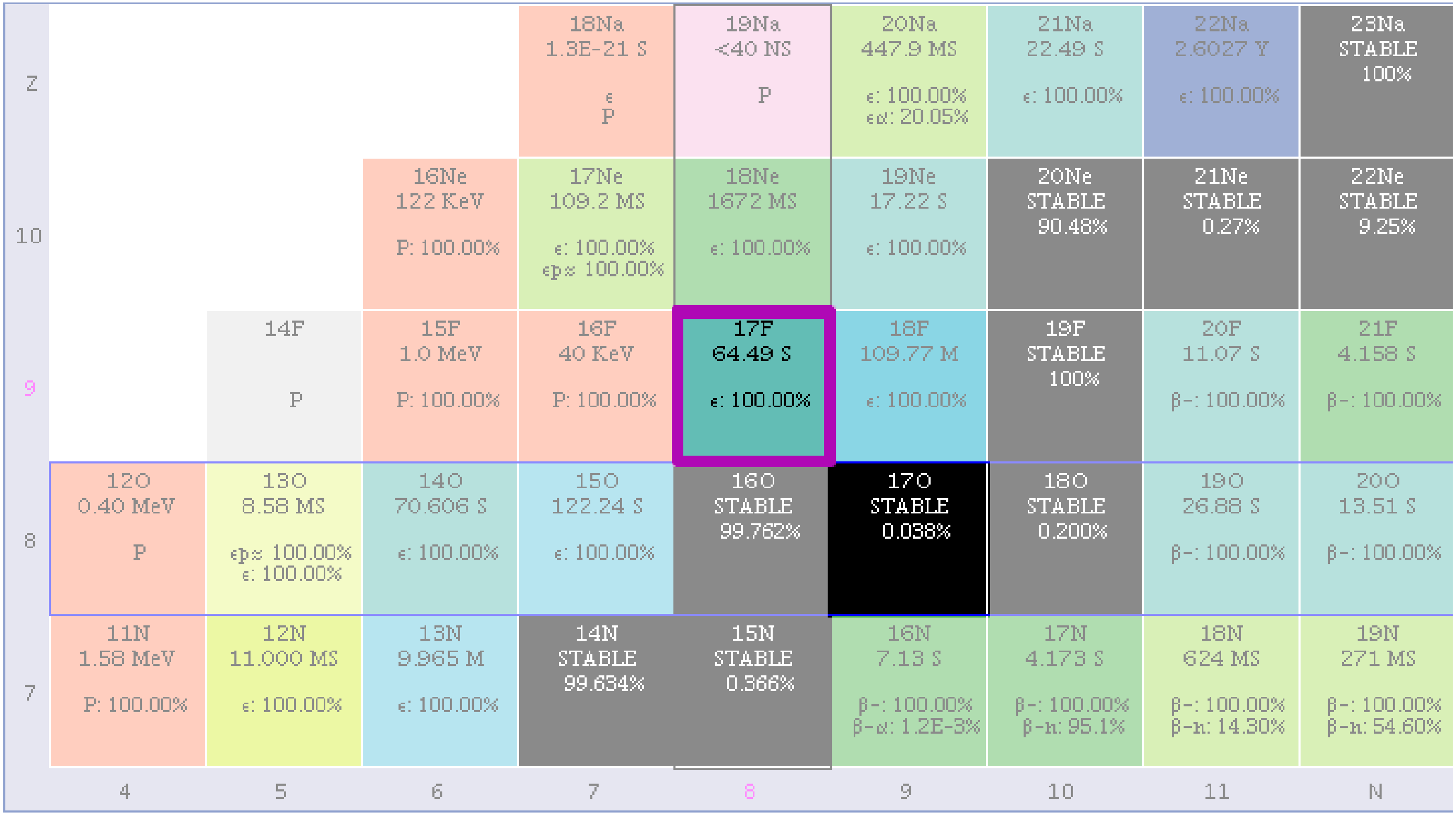

Ground and isomeric state information for $^{17}_{9}F$

E(level) (MeV)	Jπ	Δ(MeV)	$T_{1/2}$	Decay Modes
0.0	5/2+	1.9517	64.49 s *16*	ε : 100.00 %

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Z	5	6	7	8	9	10	11	12	N
Z			19Mg 2P	20Mg 90.8 MS ε: 100.00% εp≈ 27.00%	21Mg 122 MS ε: 100.00% εp: 32.60%	22Mg 3.8755 S ε: 100.00%	23Mg 11.317 S ε: 100.00%	24Mg STABLE 78.99%	25Mg STABLE 10.00%
11			18Na 1.3E-21 S ε P	19Na <40 NS P	20Na 447.9 MS ε: 100.00% εα: 20.05%	21Na 22.49 S ε: 100.00%	22Na 2.6027 Y ε: 100.00%	23Na STABLE 100%	24Na 14.997 H β-: 100.00%
10		16Ne 122 KeV P: 100.00%	17Ne 109.2 MS ε: 100.00% εp≈ 100.00%	18Ne 1672 MS ε: 100.00%	19Ne 17.22 S ε: 100.00%	20Ne STABLE 90.48%	21Ne STABLE 0.27%	22Ne STABLE 9.25%	23Ne 37.24 S β-: 100.00%
9	14F P	15F 1.0 MeV P: 100.00%	16F 40 KeV P: 100.00%	17F 64.49 S ε: 100.00%	18F 109.77 M ε: 100.00%	19F STABLE 100%	20F 11.07 S β-: 100.00%	21F 4.158 S β-: 100.00%	22F 4.23 S β-: 100.00% β-n ≤ 11.00%
8	13O 8.58 MS εp≈ 100.00% ε: 100.00%	14O 70.606 S ε: 100.00%	15O 122.24 S ε: 100.00%	16O STABLE 99.762%	17O STABLE 0.038%	18O STABLE 0.200%	19O 26.88 S β-: 100.00%	20O 13.51 S β-: 100.00%	21O 3.42 S β-: 100.00%

Ground and isomeric state information for $^{19}_{10}\mathrm{Ne}$

E(level) (MeV)	Jπ	Δ(MeV)	$T_{1/2}$	Decay Modes
0.0	1/2+	1.7514	17.22 s 2	ε : 100.00 %

A. Bacquias

Z			21Al <35 NS P	22Al 59 MS ε: 100.00% εp≈ 60.00%	23Al 470 MS ε: 100.00% εp: 0.46%	24Al 2.053 S ε: 100.00% εα: 0.04%	25Al 7.183 S ε: 100.00%	26Al 7.17E+5 Y ε: 100.00%	27Al STABLE 100%
12		19Mg 2P	20Mg 90.8 MS ε: 100.00% εp≈ 27.00%	21Mg 122 MS ε: 100.00% εp: 32.60%	22Mg 3.8755 S ε: 100.00%	23Mg 11.317 S ε: 100.00%	24Mg STABLE 78.99%	25Mg STABLE 10.00%	26Mg STABLE 11.01%
11		18Na 1.3E-21 S ε P	19Na <40 NS P	20Na 447.9 MS ε: 100.00% εα: 20.05%	21Na 22.49 S ε: 100.00%	22Na 2.6027 Y ε: 100.00%	23Na STABLE 100%	24Na 14.997 H β-: 100.00%	25Na 59.1 S β-: 100.00%
10	16Ne 122 KeV P: 100.00%	17Ne 109.2 MS ε: 100.00% εp≈ 100.00%	18Ne 1672 MS ε: 100.00%	19Ne 17.22 S ε: 100.00%	20Ne STABLE 90.48%	21Ne STABLE 0.27%	22Ne STABLE 9.25%	23Ne 37.24 S β-: 100.00%	24Ne 3.38 M β-: 100.00%
9	15F 1.0 MeV P: 100.00%	16F 40 KeV P: 100.00%	17F 64.49 S ε: 100.00%	18F 109.77 M ε: 100.00%	19F STABLE 100%	20F 11.07 S β-: 100.00%	21F 4.158 S β-: 100.00%	22F 4.23 S β-: 100.00% β-n < 11.00%	23F 2.23 S β-: 100.00%
	6	7	8	9	10	11	12	13	N

Ground and isomeric state information for $^{21}_{11}\mathrm{Na}$

E(level) (MeV)	Jπ	Δ(MeV)	$T_{1/2}$	Decay Modes
0.0	3/2+	-2.1840	22.49 s 4	ε : 100.00 %

A. Bacquias

Z		34Ca <35 NS P	35Ca 25.7 MS ϵ: 100.00% ϵp: 95.70%	36Ca 102 MS ϵ: 100.00% ϵp: 54.30%	37Ca 181.1 MS ϵ: 100.00% ϵp: 82.10%	38Ca 440 MS ϵ: 100.00%	39Ca 859.6 MS ϵ: 100.00%	40Ca >3.0E+21 Y 96.94% 2ϵ	41Ca 1.02E+5 Y ϵ: 100.00%
19	32K P	33K <25 NS P	34K <25 NS P	35K 178 MS ϵ: 100.00% ϵp: 0.37%	36K 342 MS ϵ: 100.00% ϵp: 0.05%	37K 1.226 S ϵ: 100.00%	38K 7.636 M ϵ: 100.00%	39K STABLE 93.2581%	40K 1.248E+9 Y 0.0117% β-: 89.28% ϵ: 10.72%
18	31Ar 14.4 MS ϵ: 100.00% ϵp: 63.00%	32Ar 98 MS ϵ: 100.00% ϵp: 43.00%	33Ar 173.0 MS ϵ: 100.00% ϵp: 38.70%	34Ar 844.5 MS ϵ: 100.00%	35Ar 1.775 S ϵ: 100.00%	36Ar STABLE 0.3365%	37Ar 34.95 D ϵ: 100.00%	38Ar STABLE 0.0632%	39Ar 269 Y β-: 100.00%
17	30Cl <30 NS P	31Cl 150 MS ϵ: 100.00% ϵp: 0.70%	32Cl 298 MS ϵ: 100.00% ϵα: 0.05%	33Cl 2.511 S ϵ: 100.00%	34Cl 1.5264 S ϵ: 100.00%	35Cl STABLE 75.77%	36Cl 3.01E+5 Y β-: 98.10% ϵ: 1.90%	37Cl STABLE 24.23%	38Cl 37.24 M β-: 100.00%
16	29S 187 MS ϵ: 100.00% ϵp: 47.00%	30S 1.178 S ϵ: 100.00%	31S 2.572 S ϵ: 100.00%	32S STABLE 95.02%	33S STABLE 0.75%	34S STABLE 4.21%	35S 87.51 D β-: 100.00%	36S STABLE 0.02%	37S 5.05 M β-: 100.00%
	13	14	15	16	17	18	19	20	N

Ground and isomeric state information for $^{35}_{18}$**Ar**

E(level) (MeV)	Jπ	Δ(MeV)	$T_{1/2}$	Decay Modes
0.0	3/2+	-23.0474	1.775 s 4	ε : 100.00 %

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Z		36Sc P	37Sc P	38Sc P	39Sc <300 NS P: 100.00%	40Sc 182.3 MS ε: 100.00% εp: 0.44%	41Sc 596.3 MS ε: 100.00%	42Sc 681.3 MS ε: 100.00%	43Sc 3.891 H ε: 100.00%
20	34Ca <35 NS P	35Ca 25.7 MS ε: 100.00% εp: 95.70%	36Ca 102 MS ε: 100.00% εp: 54.30%	37Ca 181.1 MS ε: 100.00% εp: 82.10%	38Ca 440 MS ε: 100.00%	39Ca 859.6 MS ε: 100.00%	40Ca >3.0E+21 Y 96.94% 2ε	41Ca 1.02E+5 Y ε: 100.00%	42Ca STABLE 0.647%
19	33K <25 NS P	34K <25 NS P	35K 178 MS ε: 100.00% εp: 0.37%	36K 342 MS ε: 100.00% εp: 0.05%	37K 1.226 S ε: 100.00%	38K 7.636 M ε: 100.00%	39K STABLE 93.2581%	40K 1.248E+9 Y 0.0117% β-: 89.28% ε: 10.72%	41K STABLE 6.7302%
18	32Ar 98 MS ε: 100.00% εp: 43.00%	33Ar 173.0 MS ε: 100.00% εp: 38.70%	34Ar 844.5 MS ε: 100.00%	35Ar 1.775 S ε: 100.00%	36Ar STABLE 0.3365%	37Ar 34.95 D ε: 100.00%	38Ar STABLE 0.0632%	39Ar 269 Y β-: 100.00%	40Ar STABLE 99.6003%
17	31Cl 150 MS ε: 100.00% εp: 0.70%	32Cl 298 MS ε: 100.00% εα: 0.05%	33Cl 2.511 S ε: 100.00%	34Cl 1.5264 S ε: 100.00%	35Cl STABLE 75.77%	36Cl 3.01E+5 Y β-: 98.10% ε: 1.90%	37Cl STABLE 24.23%	38Cl 37.24 M β-: 100.00%	39Cl 56.2 M β-: 100.00%
	14	15	16	17	18	19	20	21	N

Ground and isomeric state information for $^{37}_{19}K$

E(level) (MeV)	Jπ	Δ(MeV)	$T_{1/2}$	Decay Modes
0.0	3/2+	-24.8002	1.226 s 7	ε : 100.00 %