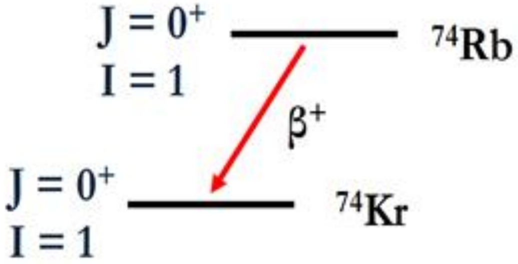
^{19}Ne

1/2^{-} lifetime measurement

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

- Isospin symmetry and selection rules
- Isospin preservation
- Isospin mixing in nuclei
- Conclusions

Superallowed Fermi beta decays



$$0^+ \rightarrow 0^+, \Delta I = 0$$

Superallowed Fermi beta transitions

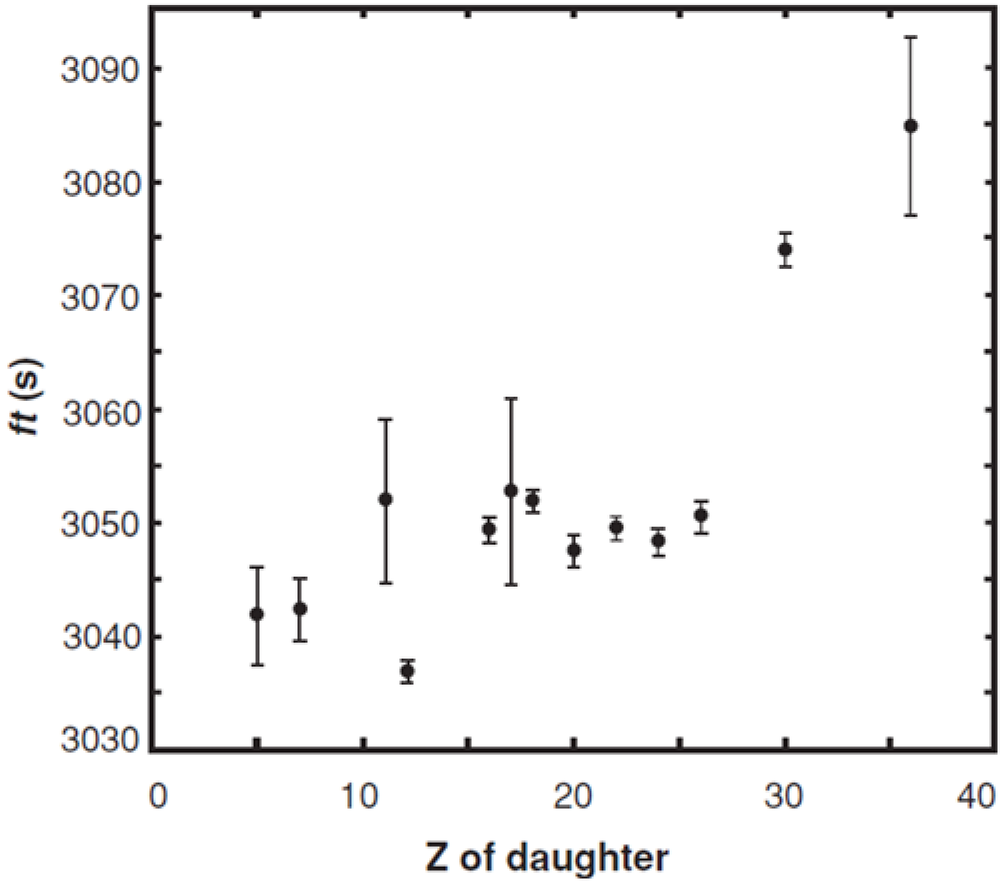
↓

ft depends only on universal quantity.
It **<u>should</u>** be indiependent on the nuclear mass.

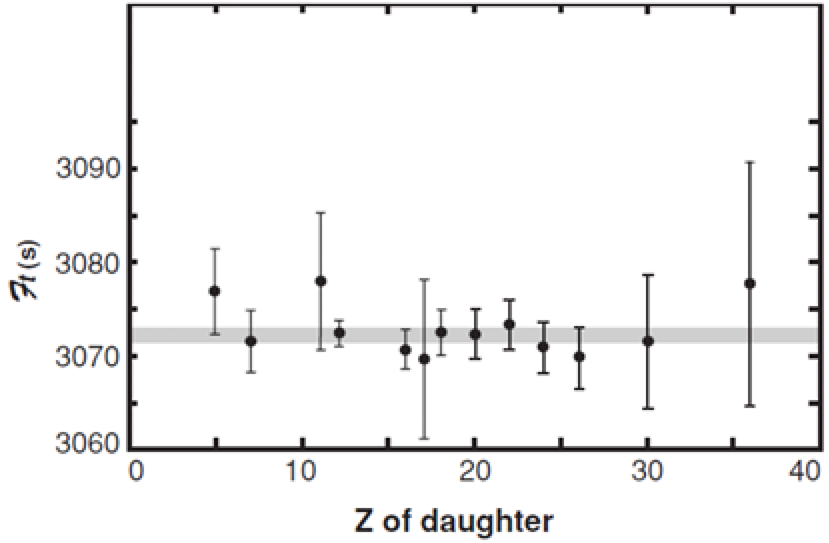
Universality of the vector coupling constant Gv

$$ft = \frac{K}{|M_F|^2 G_V^2} = \frac{K}{|M_F|^2 G_F^2 V_{ud}^2}$$

Measuring ft values in several nuclei one can extract <ft>
→ <Gv> & <Vud> & unitarity of CKM



Superallowed $0^+ \rightarrow 0^+$ Fermi beta decays



$$\mathcal{F}t \equiv ft(1+\delta'_{\mathrm{R}})(1+\delta_{\mathrm{NS}}-\boxed{\delta_{\mathrm{C}}})$$

radiative corrections

experiment

Isospin breaking correction

Electromagnetic Transition Probabilities

PHYSICAL REVIEW VOLUME 114, NUMBER 4 MAY 15, 1959

γ-Transitions Between Corresponding States in Mirror Nuclei

G. MORPURGO
Istituto di Fisica dell'Università, Parma, Italy
Istituto Nazionale di Fisica Nucleare, Laboratori di Frascati, Frascati, Italy

(Received December 22, 1958)

- **E1 ($\Delta T=0$) transitions in N=Z nuclei are forbidden**
- **E1 transition in mirror pairs have identical strength**
  - **Pure isovector character**
  - **Isospin symmetry validity with increasing A and Z**

Isospin mixing

- The presence of the **Coulomb interaction** inside the nucleus causes a **mixing** between states with different isospin (**isospin mixing**)
- In a perturbative way the mixing probability in the nuclear ground state is defined as:

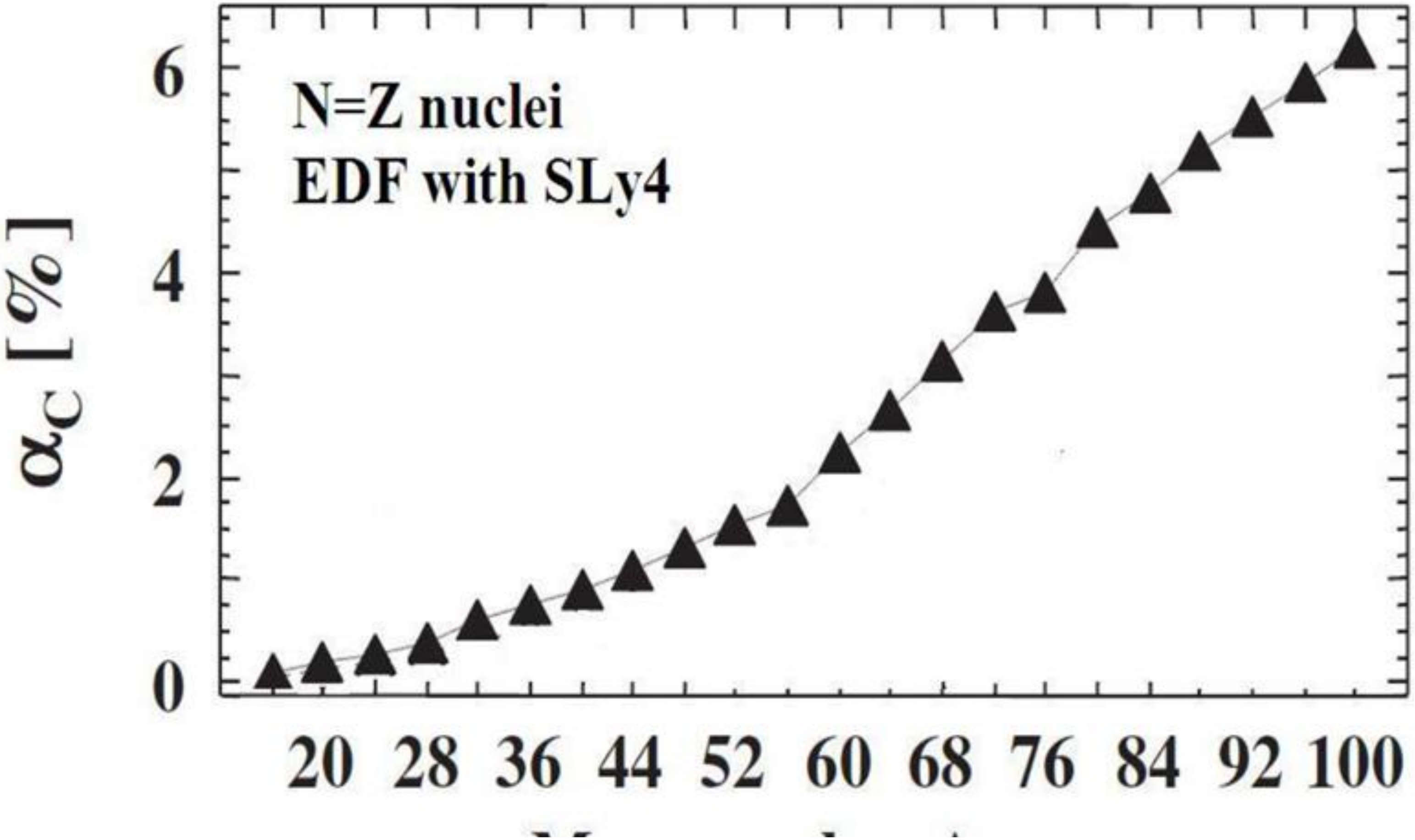
Mixing parameter

$$\alpha^2 = \frac{|\langle I=1|H_c|I=0\rangle|^2}{\Delta E^2}$$

$$|A\rangle = \beta|0\rangle + \alpha|1\rangle$$

Isospin mixing

Satula et al.,
PRL 103 (2009)



Mixing parameter

$$\alpha^2 = \frac{|\langle I=1|H_c|I=0\rangle|^2}{\Delta E^2}$$

$$|A\rangle = \beta|0\rangle + \alpha|1\rangle$$

Transition probabilities in ^{31}P and ^{31}S: A test for isospin symmetry

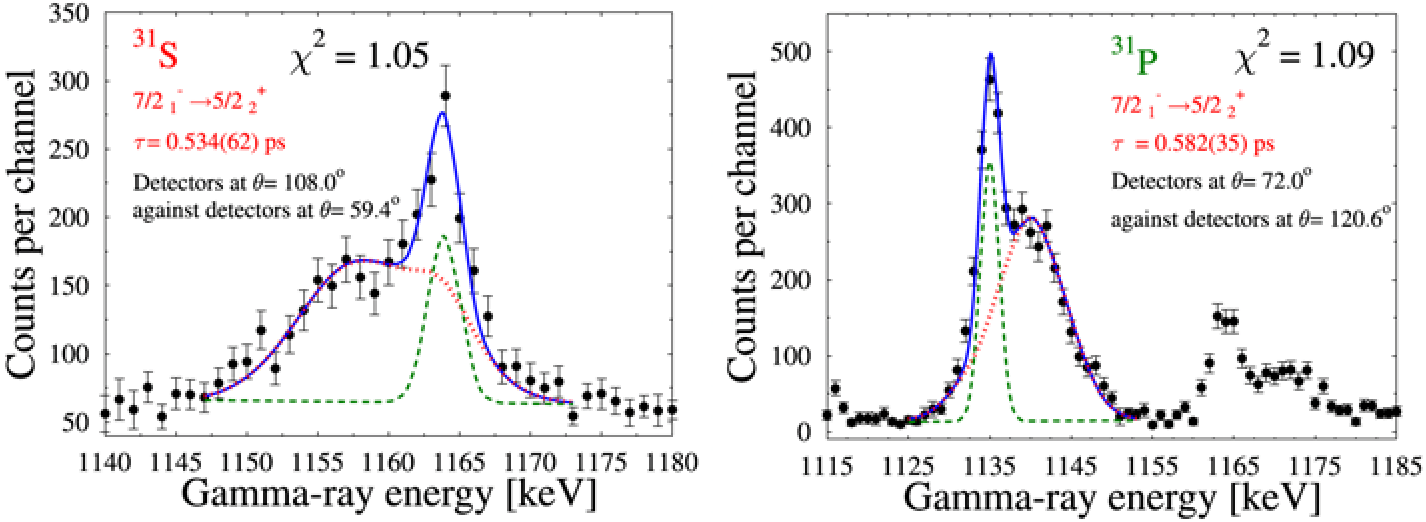
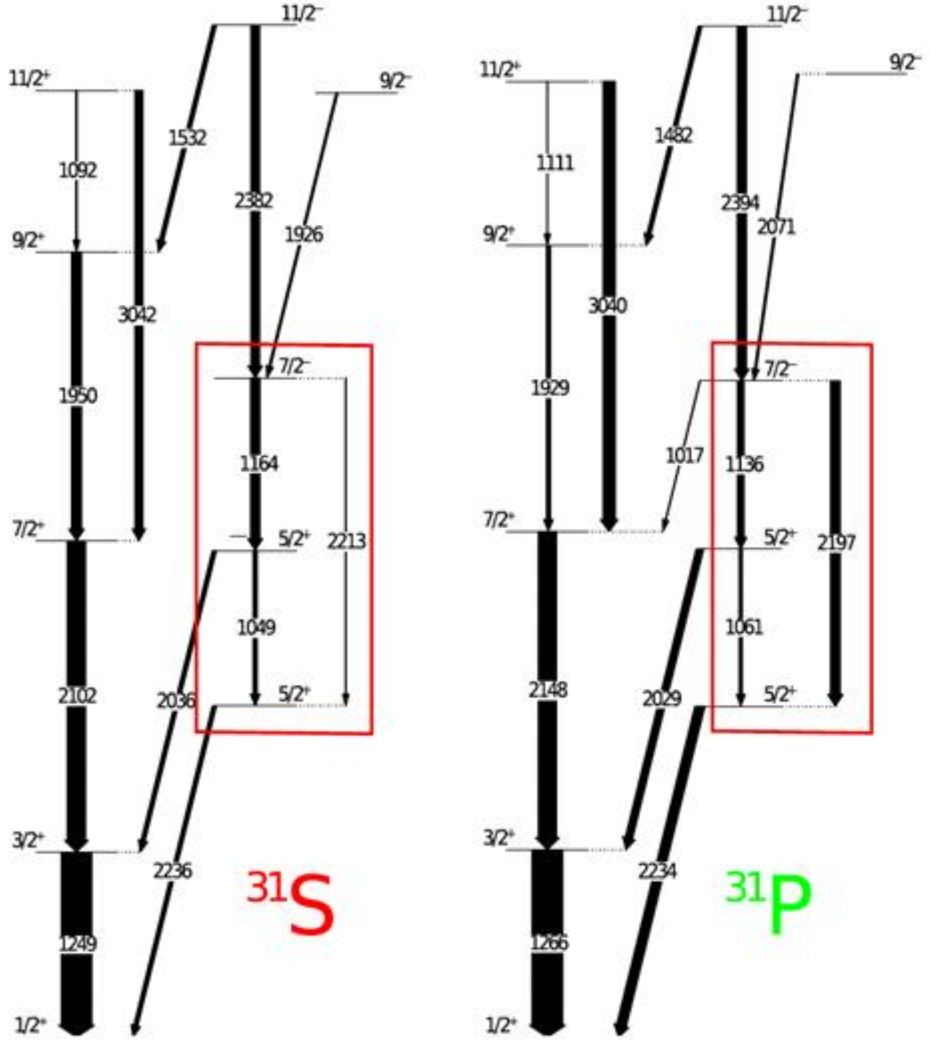


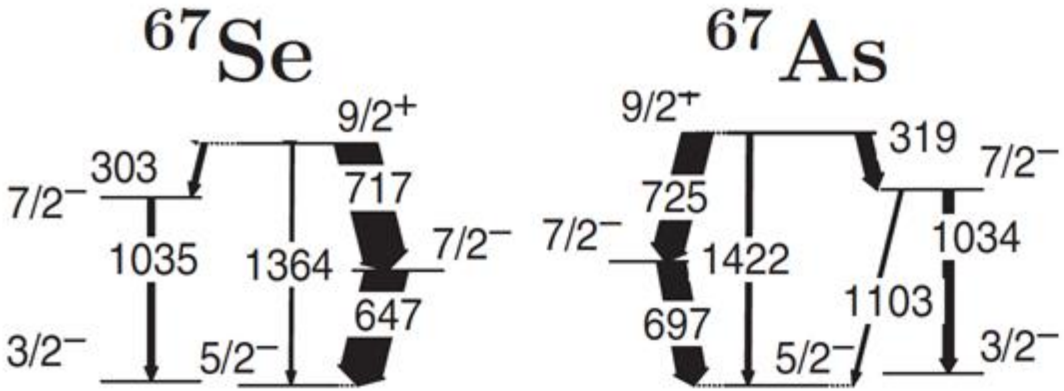
Table 1

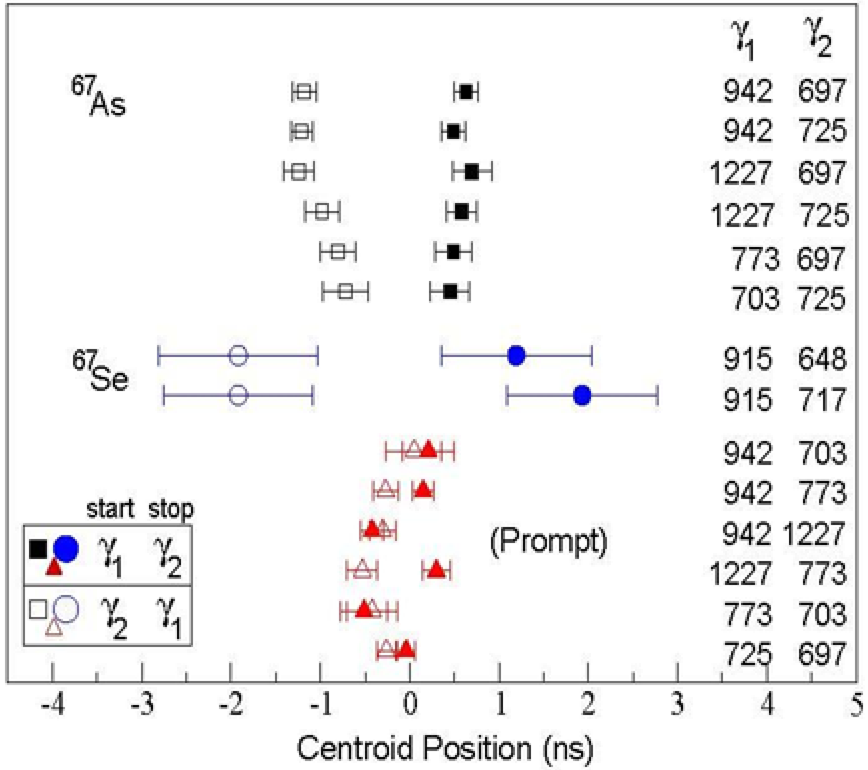
Branching ratios, multipole mixing ratios and electromagnetic transition properties. The first section concerns the decay of the $7/2^-$ state in ^{31}P with the corresponding lifetime reported, the second one that of the mirror state in ^{31}S. The first column presents transitions by their initial and final angular momentum and parity assignments I^{π}_{k}, the experimental γ energies are given in the second column. The experimentally derived branching ratios, multipole mixing ratio M2/E1, theoretically calculated and experimentally derived values of the B(E1) and B(M2) from the present dataset and B(E1) in Ref. [2] are presented in the following columns.

Transition	E_f (keV)	Br. ratio %	δ	$B(E1)_{th}$	B(E1)	B(E1) [2]	B(M2)	$B(M2)_{th}$
				e^2 fm^2			μ_N^2 fm^2	
^{31}P, $\tau = 597(45)$ fs								
$7/2^-_1 \rightarrow 5/2^+_2$	1135.6	37.0(1)	−0.03(7)	2.2×10^{-4}	$2.7(2) \times 10^{-4}$	$2.9(5) \times 10^{-4}$	22(11)	2.8
$7/2^-_1 \rightarrow 5/2^+_1$	2197.0	58.1(1)	−0.03(3)	2.4×10^{-4}	$0.58(4) \times 10^{-4}$	$0.52(4) \times 10^{-4}$	1.3(24)	2.5
$7/2^-_1 \rightarrow 7/2^+_1$	1016.4	4.9(1)	-		$0.5(1) \times 10^{-4}$	-	-	
^{31}S, $\tau = 543(49)$ fs								
$7/2^-_1 \rightarrow 5/2^+_2$	1163.9	99(1)	−0.07(8)	7.9×10^{-4}	$7.2(7) \times 10^{-4}$	$3.9(8) \times 10^{-4}$	307(+586−307)[a]	1.9
$7/2^-_1 \rightarrow 5/2^+_1$	2213.0	< 1(1)	-	6.9×10^{-4}	$<2.2 \times 10^{-4}$	$<1.15 \times 10^{-6}$	-	6.1



Mirror 67 at GAMMASPHERE





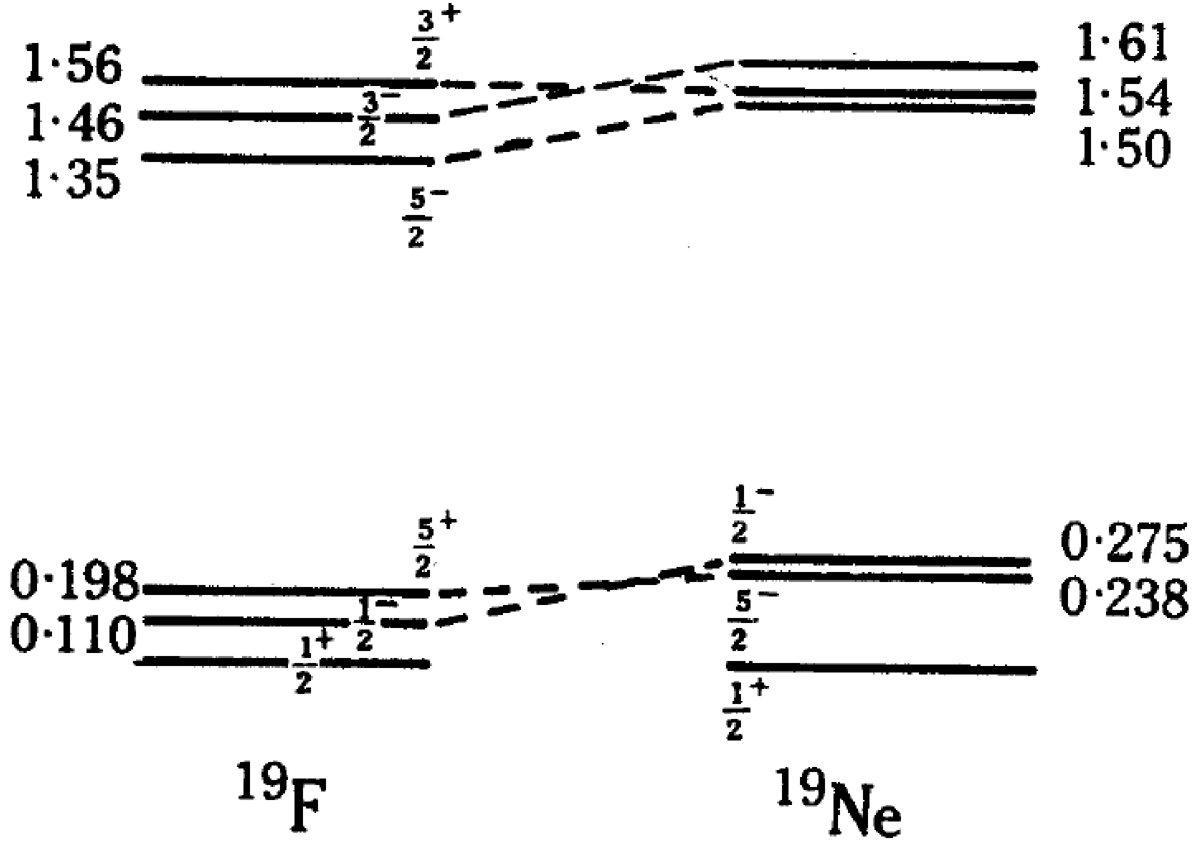
The Coulomb interaction, **mixing in a different way the level wave functions** in the two mirror nuclei, is presumably at the origin of the observed asymmetries. Its effect could be enhanced when a pair of levels having equal J^{π} lie, accidentally, close together. For example, this could have been the case for the **two 7/2$^-$ levels lying between 640 and 1100 keV in ^{67}As and ^{67}Se**

: **IS/IV~ 0.35(20)**

Nucleus	E_γ (keV)	Branching Ratio	R_{ADO} 162.7°/90°	δ	δ^2 (average)	B(E1) (w.u.)	B(M2) (w.u)
^{67}As	725	0.59(2)	0.28(4)	$-0.16^{+0.08}_{-0.13}$	0.044(38)	$1.3(4)\cdot10^{-6}$	0.5(4)
^{67}Se	717	0.77(16)	1.7(6)	$0.47 < \delta < 3.49$	6.19(5.97)	$0.5(4)\cdot10^{-6}$	7(6)
^{67}As	319	0.30(1)	0.50(11)	$0.004^{+0.144}_{-0.064}$	0.011(11)	$8.2(2.4)\cdot10^{-6}$	7(7)
^{67}Se	303	0.09(5)	not avail.	not avail.	not avail.	$1.3(9)\cdot10^{-6}$	< 108
^{67}As	1422	0.12(2)	1.14(58)†	> -0.19	not avail.		$< 0.08(3)$
^{67}Se	1365	0.14(8)	not avail.	not avail.	not avail.		$< 0.05(4)$

Measure **isospin mixing at the g.s.** using pure E1 between J=1/2 states

- Mirror 13: ^{13}N $1/2^-$ g.s.
  The 1/2+ is **proton unbound**
  34 keV wide
- Mirror 15: ^{15}O $1/2^-$ g.s.
  The 1/2+ is **fast** 8(1) fs
- Mirror 19: ^{19}Ne has a $1/2^+$ g.s.
  lifetime 61 ps → **plunger**
- Mirror 29: ^{29}P 1/2+ g.s.
  The 1/2- is **proton unbound**
  16 keV wide
- Mirror 31: ^{31}S 1/2+ g.s.
  The 1/2- is not identified > 8 MeV



Goal

- Measure ~ 60 ps lifetime of $1/2^-$ with precision comparable to previous measurement: 5%.
- ***Most precise direct measurement of isospin purity in states that are being use for the calculation of V_{UD} element of the CKM matrix***.
- Possible outcome:
  (a) Previous measurement **is disproven** an isospin mixing will be quantified with **impact in the unitarity** of the CKM matrix.
  (b) In case the B(E1) obtained for ^{19}Ne will be compatible with that of its mirror ^{19}F, this will be the **best experimental constrain to isospin mixing** setting a stringent upper limit.

Past measurement

- $^{20}Ne(^3He, ^4He)$
  32 MeV 2.5 pnA
  Oxford University Van de Graaff accelerator

- One 15 cc Ge(Li) detector = 1/20 of a single AGATA crystal

PHYSICAL REVIEW C VOLUME 2, NUMBER 4 OCTOBER 1970

Nuclear Lifetime of the Ne^{19} 275-keV Level

K. Bharuth-Ram,* R. D. Gill, and K. P. Jackson
Nuclear Physics Laboratory, Oxford, England
and
B. Povh
Physikalisches Institut der Universität, Heidelberg, Germany
and
E. K. Warburton†‡
Nuclear Physics Laboratory, Oxford, England, and Brookhaven National Laboratory, Upton, New York 11973
(Received 21 May 1970)

The mean life of the 275-keV second excited state of Ne^{19} was measured to be 61.4 ± 3.0 psec. The $He^3(Ne^{20}, \alpha)Ne^{19}$ reaction and the gas-target recoil-distance technique were used. The 275-keV state decays by $E1$ emission to the ground state. The strength of this $E1$ transition is equal within errors to that of the mirror transition in F^{19}. This result is discussed.

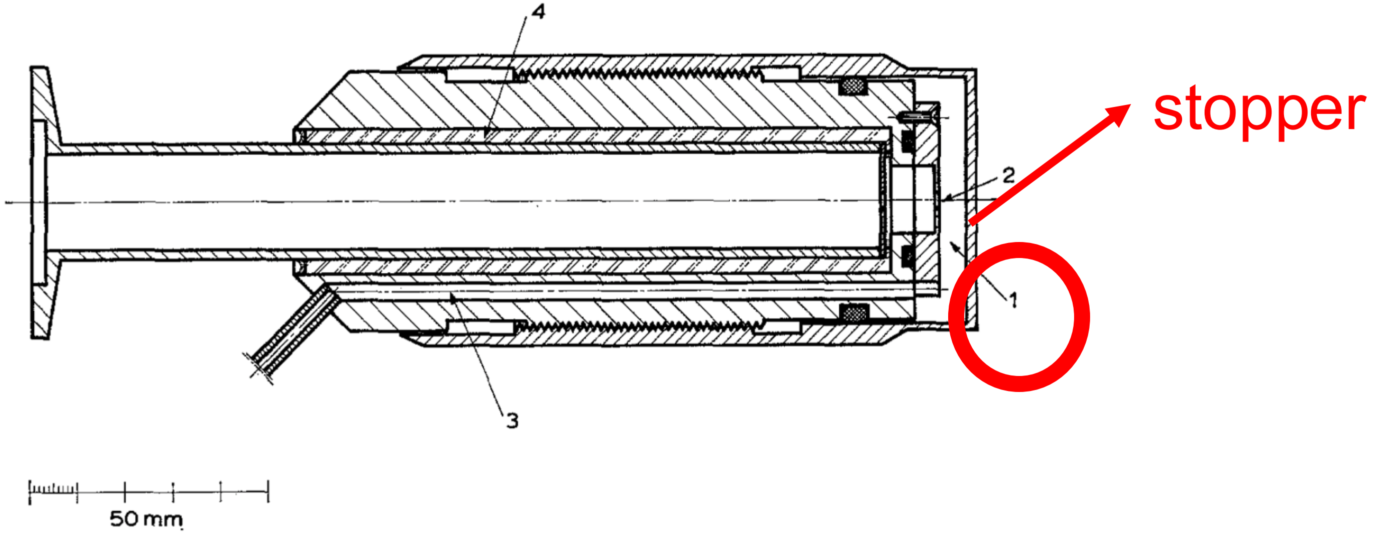


Fig. 1. Target chamber for the lifetime measurement. The beam enters the gas target (*1*) through the thin Ni window (*2*). The gas is fed into the chamber through the hole (*3*). The chamber is electrically insulated from the rest of the pipe by the insulating layer (*4*)

Past measurement

- $^{20}Ne(^{3}He, ^{4}He)$
  32 MeV 2.5 pnA
  Oxford University Van de Graaff accelerator
- One 15 cc Ge(Li) detector = 1/20 of a single AGATA crystal

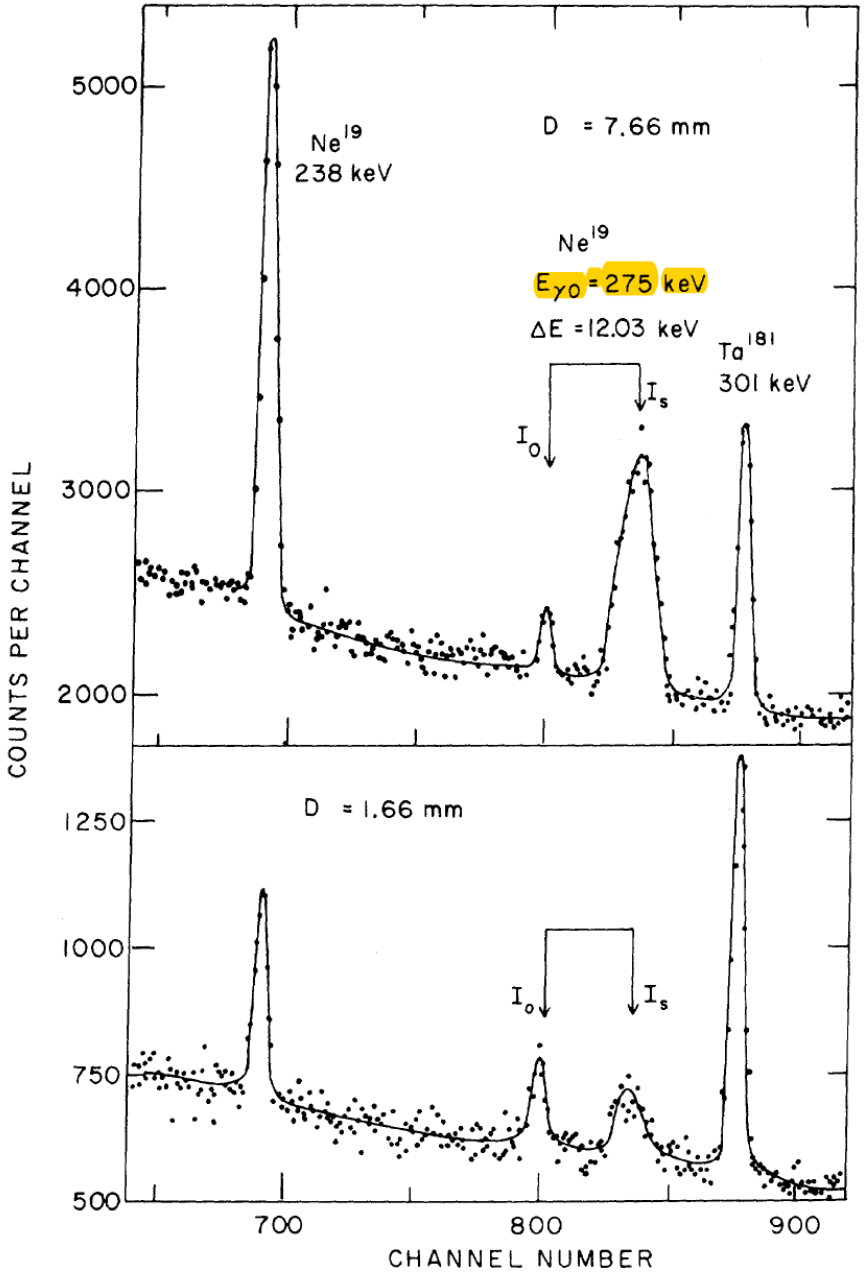
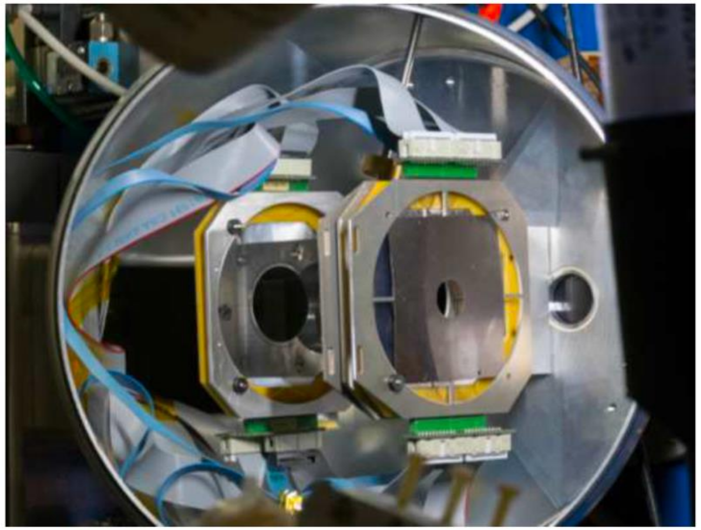
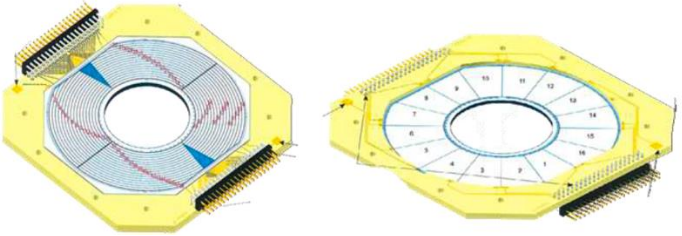


FIG. 1. The γ-ray spectra obtained at $D = 1.66$ and 7.66 mm. The solid lines are drawn through the points by hand.

$^{20}Ne(d,t)\ ^{19}Ne$





- ^{20}Ne beam at **8 AMeV**
- Ti deuterated target on a plunger device
- **Sauron detector** covers 25-45 degrees
  - Target pushed backward so that we cover 17-30 degree
- AGATA as backward as possible

→ Gain a factor 400 in gamma efficiency

→ Adding a gamma-triton coincidence
+ feeding under control

TAC comments

- Can you specify the angles of TRACE? → **Sauron**
- This kind of target has never been tested with Plunger.
- AGATA cannot be put backward, but at 90° with respect to TRACE. → **with Sauron it is possible**
- Could you afford to reduce the energy of the beam keeping reasonable cross-section? **Done: 8 instead of 10 AMeV**
- Can it be reasonable to postpone this experiment to 0° campaign? …

Thanks

Mirror 19: selection rule respected

19Ne

E(level) (keV)	XREF	J^π(level)	$T_{1/2}$(level)	E(γ) (keV)	I(γ)	M(γ)	Final Levels	
0.0	A CDE G IJKLM	1/2+	17.22 s 2 % ε = 100					
238.27 11	DE G JKLM	5/2+	18.0 ns 5	238.3	100	E2	0.0	1/2+
275.09 13	DE G J L	1/2-	42.6 ps 21	275.1	100	E1	0.0	1/2+
1507.56 30	DE G J L	5/2-	0.97 ps 40	1232.5 1269.3	88 3 12 3	E2 E1	275.09 238.27	1/2- 5/2+
1536.0 4	DE G JKL	3/2+	19 fs 8	1260.9 1297.7	5 3 95 3	E1 M1	275.09 238.27	1/2- 5/2+
1615.6 5	DE G J L	3/2-	99 fs 21	1340.5 1377 1616	70 4 10 3 20 3	M1 E1 E1	275.09 238.27 0.0	1/2- 5/2+ 1/2+

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	
238.27	$5/2^+$	238.3	100	0.0	$1/2^+$	E2	B(E2)(W.u.)=13.2 5
275.09	$1/2^-$	275.1	100	0.0	$1/2^+$	E1	B(E1)(W.u.)=0.00106 5
1507.56	$5/2^-$	1232.5	88 3	275.09	$1/2^-$	E2	B(E2)(W.u.)=58 20
		1269.3	12 3	238.27	$5/2^+$	E1	B(E1)(W.u.)=0.000057 25
1536.0	$3/2^+$	1260.9	5 3	275.09	$1/2^-$	E1	B(E1)(W.u.)=0.0010 7
		1297.7	95 3	238.27	$5/2^+$	M1	B(M1)(W.u.)=0.50 28
1615.6	$3/2^-$	1340.5	70 4	275.09	$1/2^-$	M1	B(M1)(W.u.)=0.063 16
		1377	10 3	238.27	$5/2^+$	E1	B(E1)(W.u.)=0.00036 14
		1616	20 3	0.0	$1/2^+$	E1	B(E1)(W.u.)=0.00045 14

lifetime of ½- in 19Ne: https://journals-aps-org.ezproxy.cern.ch/prc/abstract/10.1103/PhysRevC.2.1210

19F

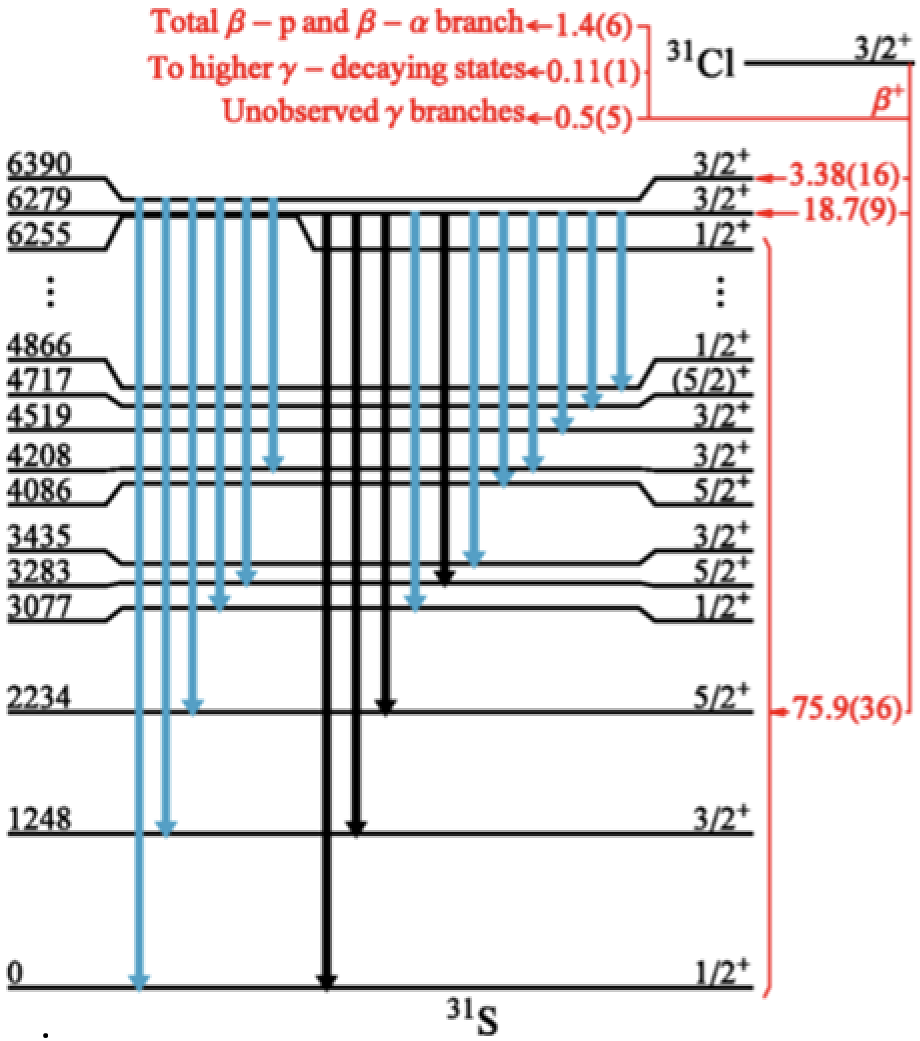
E(level) (keV)	XREF	J^π(level)	$T_{1/2}$(level)	E(γ) (keV)	I(γ)	M(γ)	Final Levels	
0.0	E GH KLMNOPQRST XYZa cdefghijklmnopqrstuv	1/2+	STABLE					
109.894 5	E G K MN R T Y abcd f i r t v	1/2-	0.591 ns 7	109.9	100	E1	0.0	1/2+
197.143 4	DE H KLMN RST YZa cdef i k m r t	5/2+	89.3 ns 10	87.3 197.1	<0.06 100	 E2	109.894 0.0	1/2- 1/2+
1345.67 13	E GH LMN R T Y a cdef j	5/2-	2.86 ps 4	1148.5 1235.8	3.2 10 96.8 10	E1 E2+(M3)	197.143 109.894	5/2+ 1/2-
1458.7 3	GH MN R Y bcdef i m t	3/2-	62 fs 14	113.0 1261.6 1348.8 1458.7	<0.2 10.7 5 68.8 9 20.5 7	 E1 M1+E2 E1+(M2)	1345.67 197.143 109.894 0.0	5/2- 5/2+ 1/2- 1/2+
1554.038 9	E LMN RST XYZa cdef i k m r t	3/2+	3.5 fs 21	95.3 208.4 1356.9 1444.2 1554.0	<0.14 <0.011 92.6 2 4.85 12 2.55 10	 M1 E1 M1	1458.7 1345.67 197.143 109.894 0.0	3/2- 5/2- 5/2+ 1/2- 1/2+

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	δ	Comments
109.894	$1/2^-$	109.9	100	0.0	$1/2^+$	E1		B(E1)(W.u.)=0.0012 1
197.143	$5/2^+$	87.3	<0.06	109.894	$1/2^-$			
		197.1	100	0.0	$1/2^+$	E2		B(E2)(W.u.)=6.95 8
1345.67	$5/2^-$	1148.5	3.2 10	197.143	$5/2^+$	E1		B(E1)(W.u.)=0.0000069 23
		1235.8	96.8 10	109.894	$1/2^-$	E2+(M3)	0.0 7	B(E2)(W.u.)=21.6 4
1458.7	$3/2^-$	113.0	<0.2	1345.67	$5/2^-$			
		1261.6	10.7 5	197.143	$5/2^+$	E1		B(E1)(W.u.)=0.00081 19
		1348.8	68.8 9	109.894	$1/2^-$	M1+E2	0.248 20	
		1458.7	20.5 7	0.0	$1/2^+$	E1+(M2)	0.01 3	B(E1)(W.u.)=0.0010 2
1554.038	$3/2^+$	95.3	<0.14	1458.7	$3/2^-$			
		208.4	<0.011	1345.67	$5/2^-$			
		1356.9	92.6 2	197.143	$5/2^+$	M1		B(M1)(W.u.)=2.3 14
		1444.2	4.85 12	109.894	$1/2^-$	E1		B(E1)(W.u.)=0.0044 26
		1554.0	2.55 10	0.0	$1/2^+$	M1		B(M1)(W.u.)=0.043 25

Why isospin mixing 3/3: supernova nuclesynthesis

- Isospin Mixing used for spin parity assignement:

"observed the β-delayed γ decay of a ^{31}S state at Ex=6390.2(7) keV, with a 30P(p,γ)31S resonance energy of Er=259.3(8) keV, in the middle of the 30P(p,γ)31S Gamow window for peak nova temperatures. **This state exhibits isospin mixing with the nearby isobaric analog state at Ex=6279.0(6) keV, giving it an unambiguous spin and parity of 3/2+** and making it an important l=0 resonance for proton capture on ^{30}P"



Isospin Mixing Reveals 30P(p,γ)31S Resonance Influencing Nova Nucleosynthesis
M. B. Bennett, et al. Phys. Rev. Lett. 116, 102502 – Published 8 March 2016

Why isospin mixing 3/3: NeNa cycle

- We wish to report our observation of beta-delayed proton emission from Al proceeding via its isobaric analog state (IAS) in Mg (E*=7.795 MeV, 1 =5/2+, T=3/2).
- 23Al is the lightest nucleon-stable member of the A =4n+ 3, T,=—3I2 mass series, and the only member of this series in which delayed proton emission from the IAS is potentially observable. We detected this group at a laboratory energy Elab = 223 +- 20 keV, representing the lowest-energy identified proton group observed to date. Proton decay from the IAS does not conserve isospin, and can therefore only occur due to isospin mixing. A comparison between the proton width of the 23Mg IAS determined in the present work and the prediction of a full 1s-Od configuration shell model calculation which includes isospin mixing of the IAS **indicates the observed isospin mixing is stronger by a factor of -10 than predicted by shell model.**