Study of proton emitting light nuclei: Spectroscopy of the unbound nucleus ^{18}Na, and $^{19}Mg(2p)$

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e521aS collaboration

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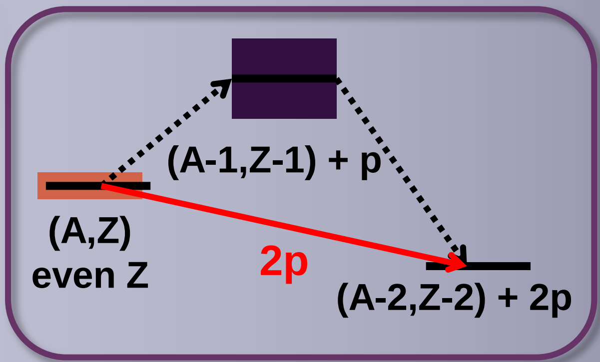
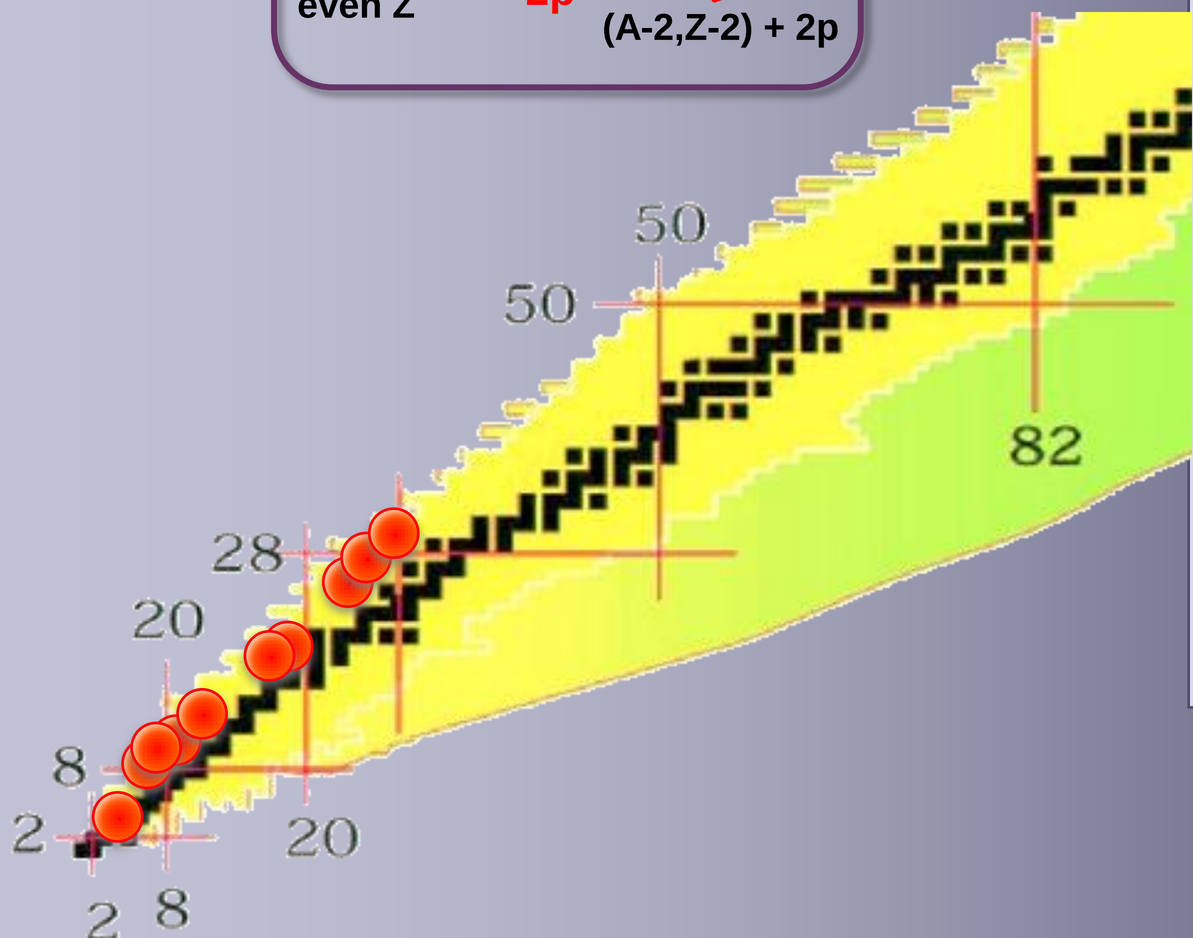
Two proton radioactivity





Predictions

Goldansky et al, NP (1960)
Grigorenko et al NPA (2003)

^{6}Be, ^{12}O, ^{16}Ne

Bochkarev *et al,* NPA (1989)
Kryger *et al,* PRL (1995)

^{45}Fe, ^{48}Ni, ^{54}Zn ...

Giovinazzo et al PRL (2002)
Blank et al PRL (2005) …

^{19}Mg

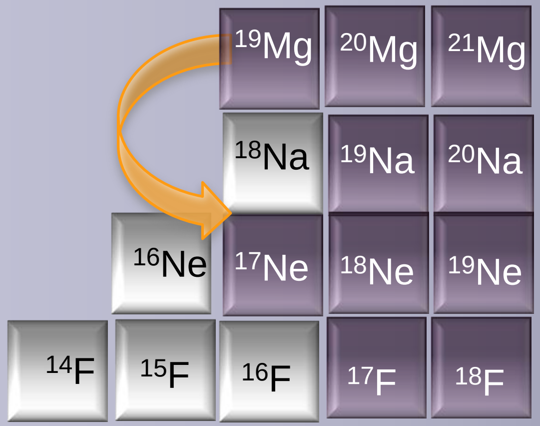
Mukha *et al,* PRL (2007)

^{19}Mg : two-proton radioactivity status

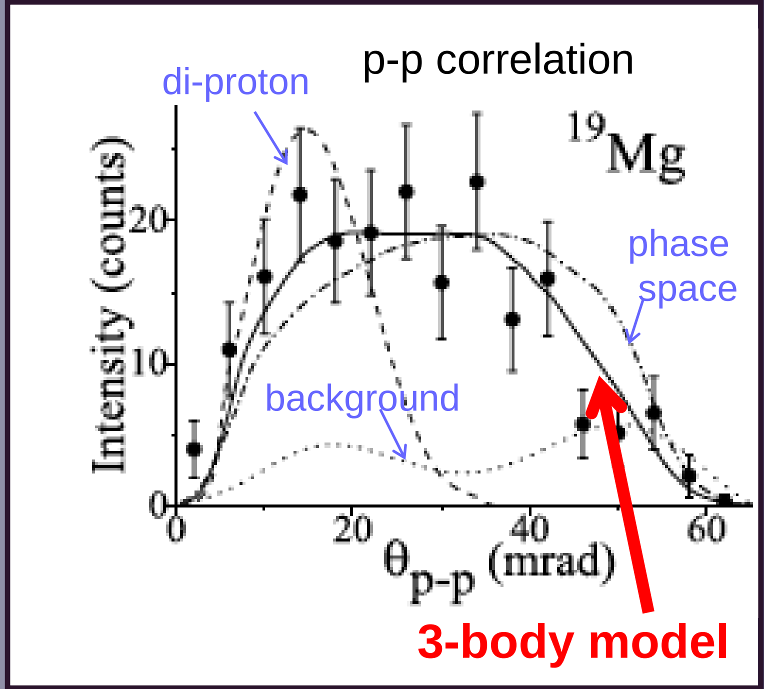
I. Mukha *et al*, PRL (2007)

$Q_{2p}(^{19}Mg)$ = 0.750 (50) MeV

$T_{1/2}$ (^{19}Mg) = 4.0 (15) ps



I. Mukha *et al*, PRC (2008)



Agreement for dominant (88%) *d*-wave configuration

^{19}Mg = ^{17}Negs + $\pi(d5/2)^2$

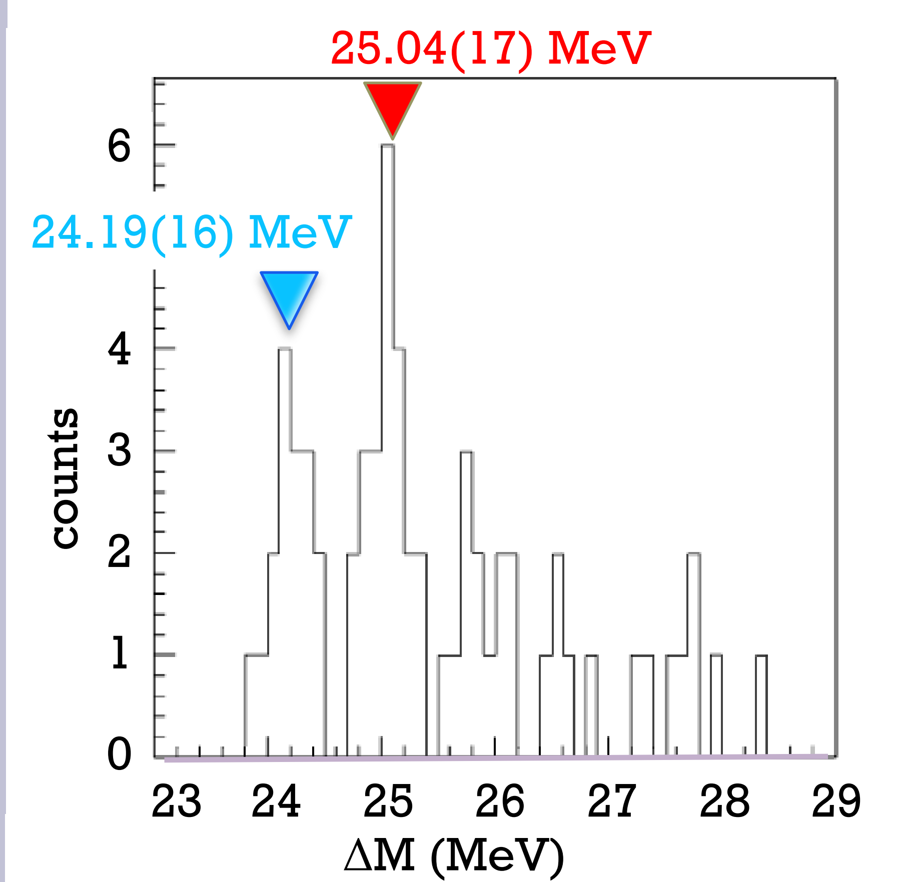
The same interaction describes ^{18}Na and ^{19}Mg

^{18}Na is only intermediate nucleus measurable

The case of ^{18}Na

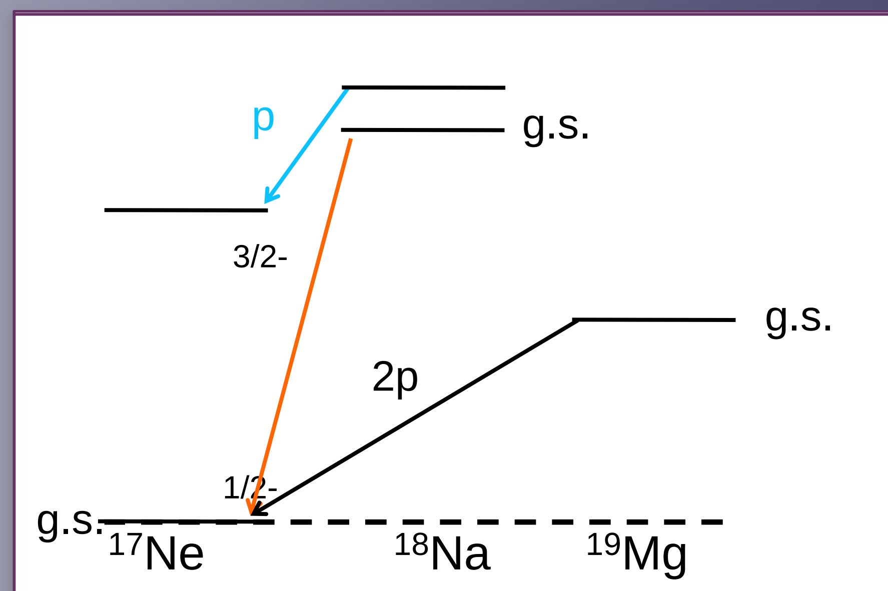
Stripping of ^{20}Mg

T. Zerguerras *et al*, EPJA 20 (2004)



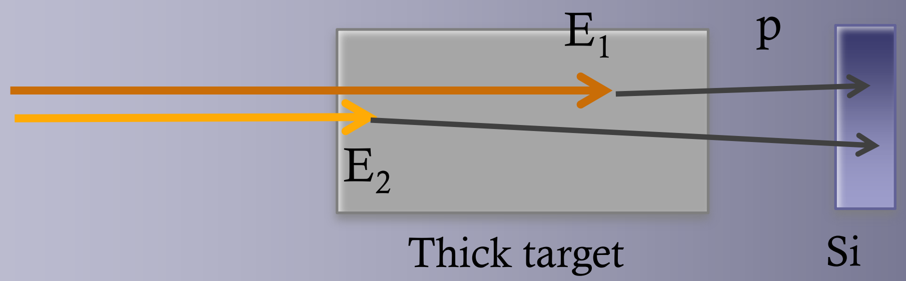
Mass predictions

ΔM = 25.3 MeV G. Audi
ΔM = 25.67 MeV IMME
ΔM = 25.76 MeV Kelson-Garvey



Experimental method : Resonant elastic scattering

V.Z. Goldberg et al, Phys At. Nucl (1997)

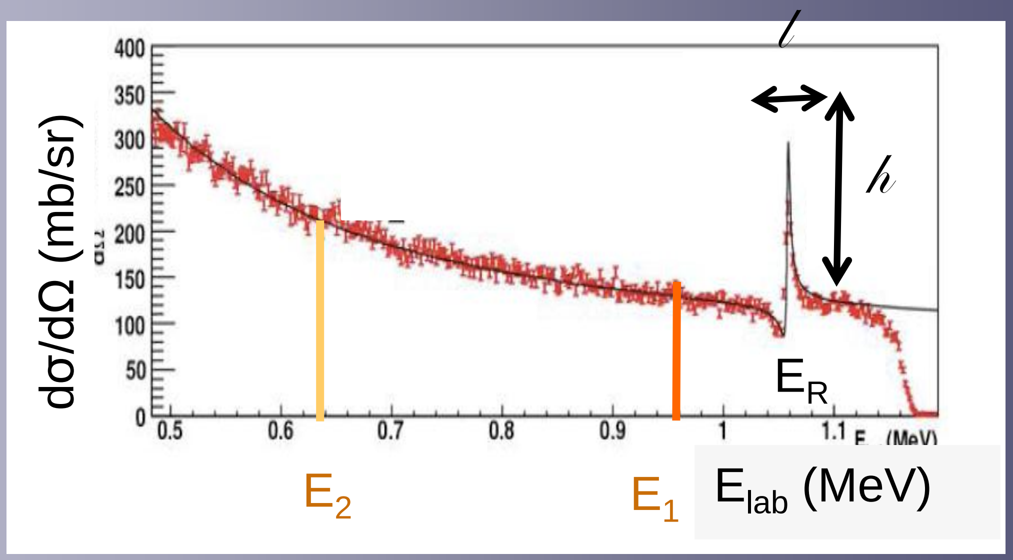


$$E_R = E_x - S_p$$

$$l \propto \Gamma_{tot}$$

$$h \propto \frac{\Gamma_p}{\Gamma_{tot}}$$

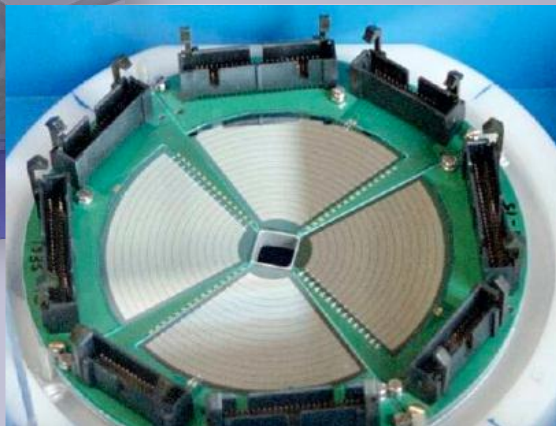
$$\text{shape} \rightarrow J^{\pi}$$

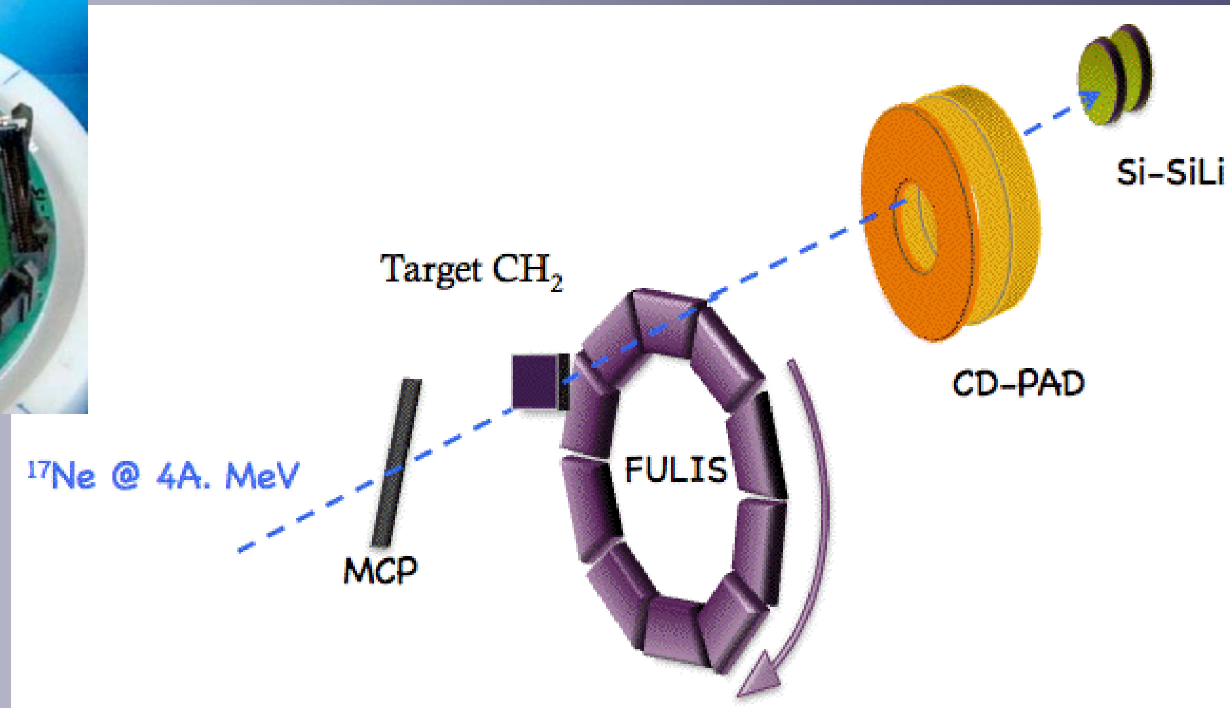


I. Stefan Ph. D. Thesis

- High cross section
- Good energy resolution

Experimental set-up @ GANIL



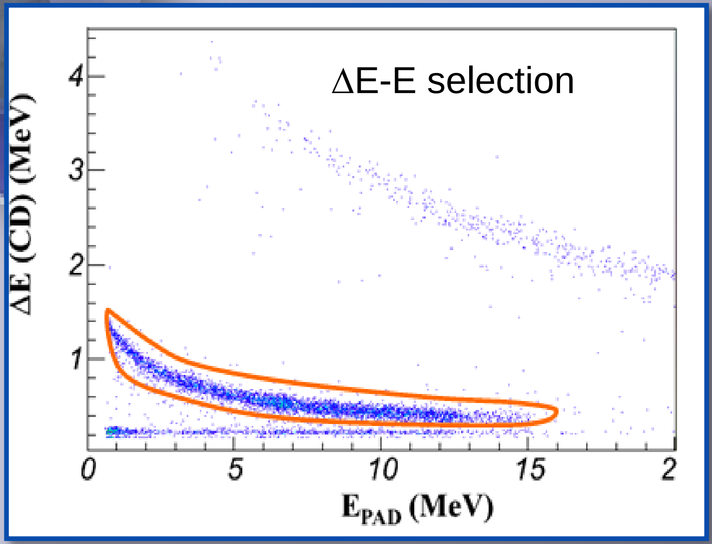


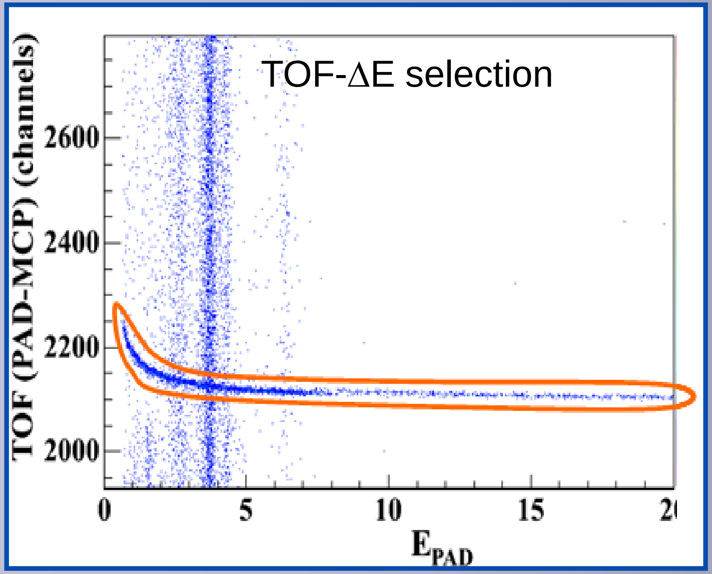
- SPIRAL Beams : ^{17}O / ^{17}Ne @ 4 A.MeV, 10^4pps
- Beam purity ~ 100%

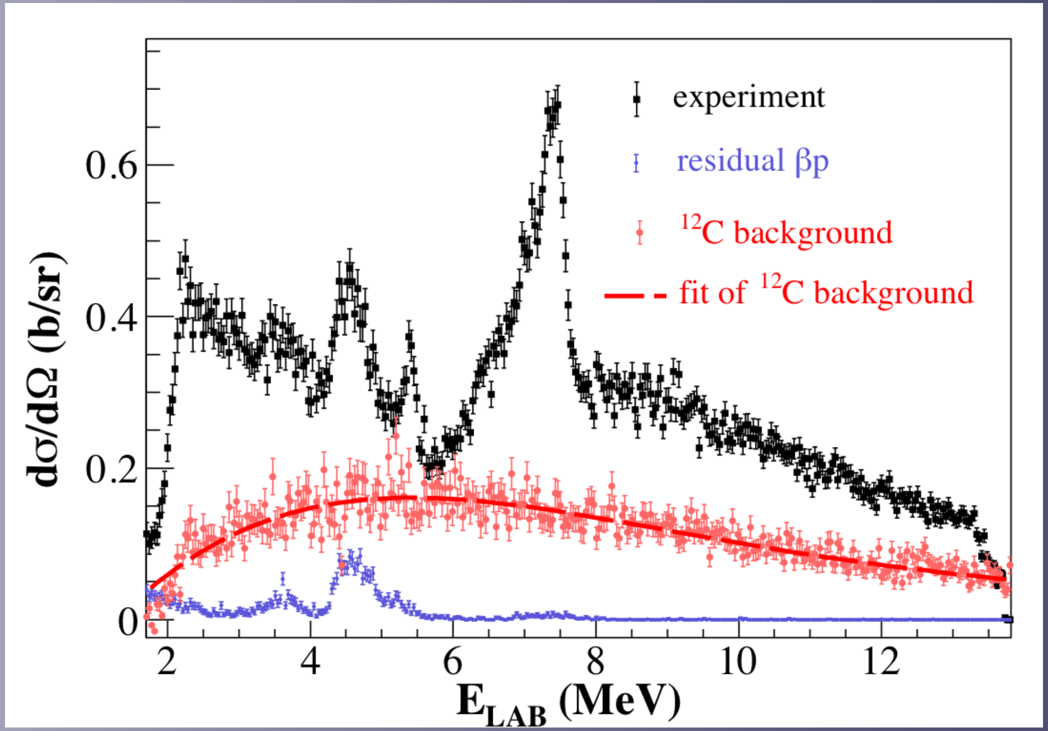
- Targets : CH_2 (100μm) / ^{12}C (125μm)

- ^{17}Ne $T_{1/2}$ = 0.1 s decays by βp (90%) and also βα (10%)
  -> Rotation of target 1000 r/min
  -> MCP time signal (efficiency ~100%)

Resonant elastic scattering in lab







Analysis with R-Matrix formalism
5 x 6 = 30 parameters

Theoretical calculations for ^{18}Na

^{18}Na states	θ^2 ^{17}Ne g.s. $1d_{5/2}$	θ^2 ^{17}Ne g.s. $2s_{1/2}$	θ^2 ^{17}Ne$^*(3/2^-)$ $1d_{5/2}$	θ^2 ^{17}Ne$^*(3/2^-)$ $2s_{1/2}$
1_1^-	-	0.086	0.921	0.183
2_1^-	0.644	-	0.311	0.042
0_1^-	-	0.759	-	-
1_2^-	-	0.654	0.031	0.027
2_2^-	0.004	-	0.507	0.028
3_1^-	0.621	-	0.109	-

N. Smirnova

Shell model

The first 6 low lying states can be described by:

^{18}Na = ^{17}Ne$_{gs}$ $\otimes$ p

^{18}Na = ^{17}Ne* (3/2-) $\otimes$ p

States predicted

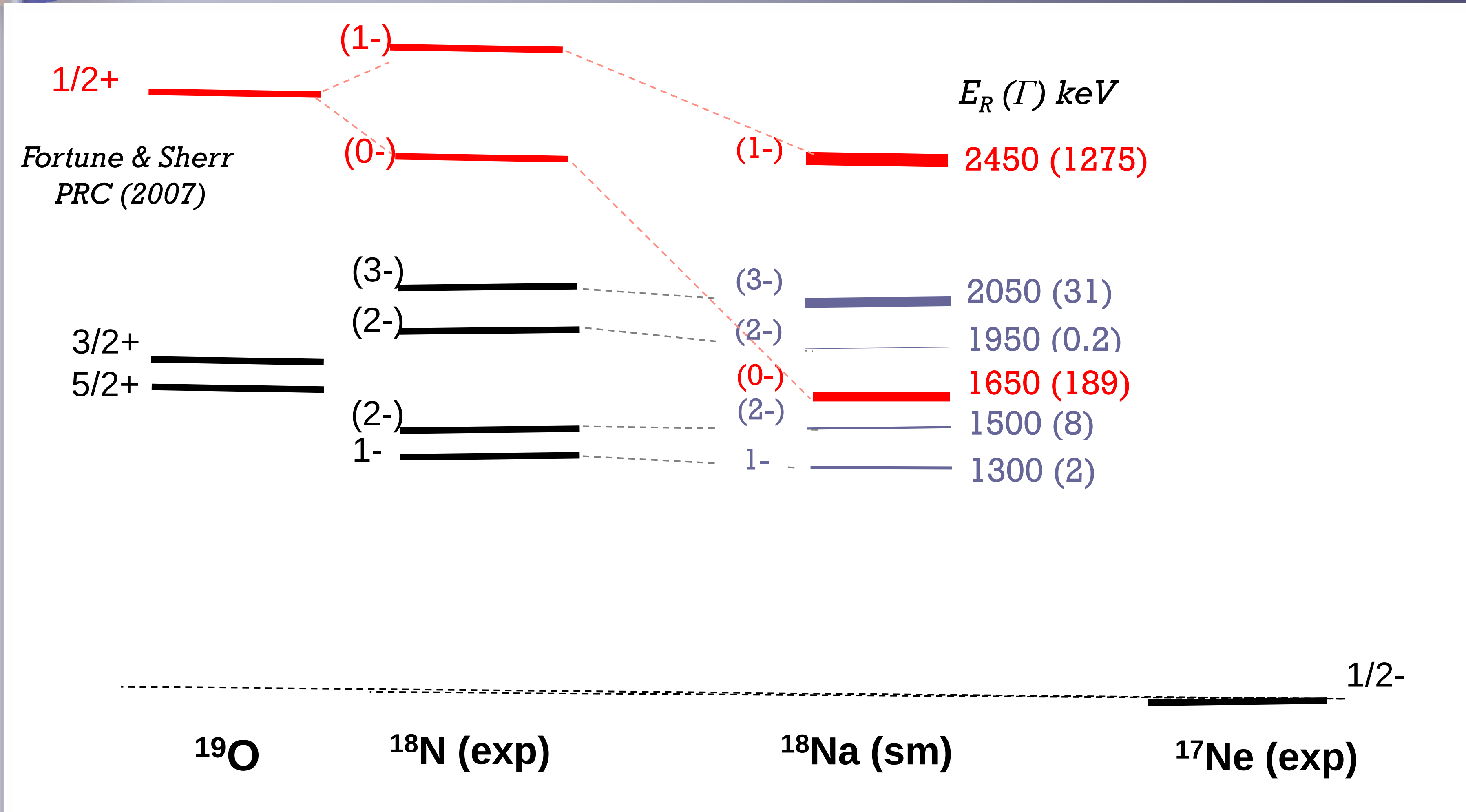
Idem for the mirror nucleus

^{18}N = ^{17}N$_{gs}$ $\otimes$ n

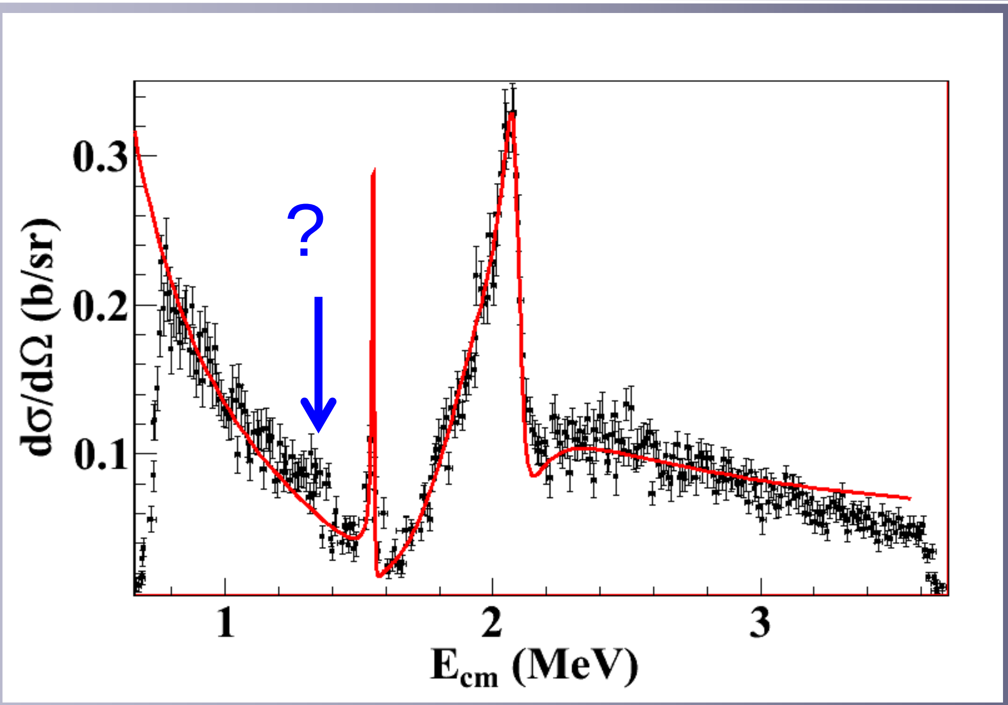
^{18}N = ^{17}N* (3/2-) $\otimes$ n

Mirror states fitted

Theoretical calculations for ^{18}Na

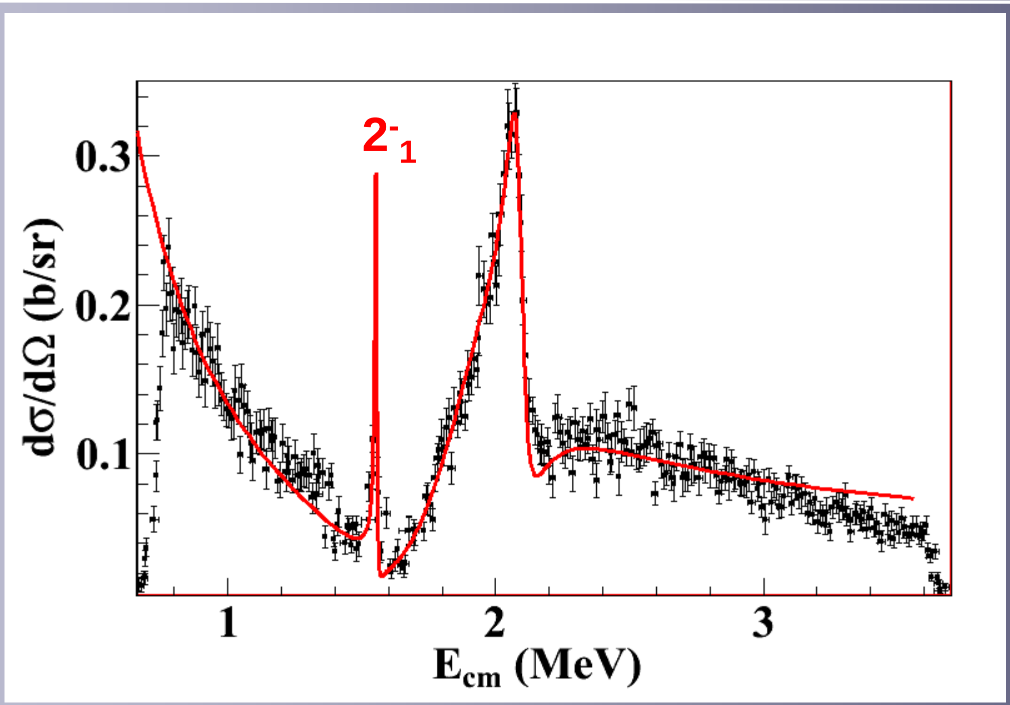


R-matrix fit of excitation function



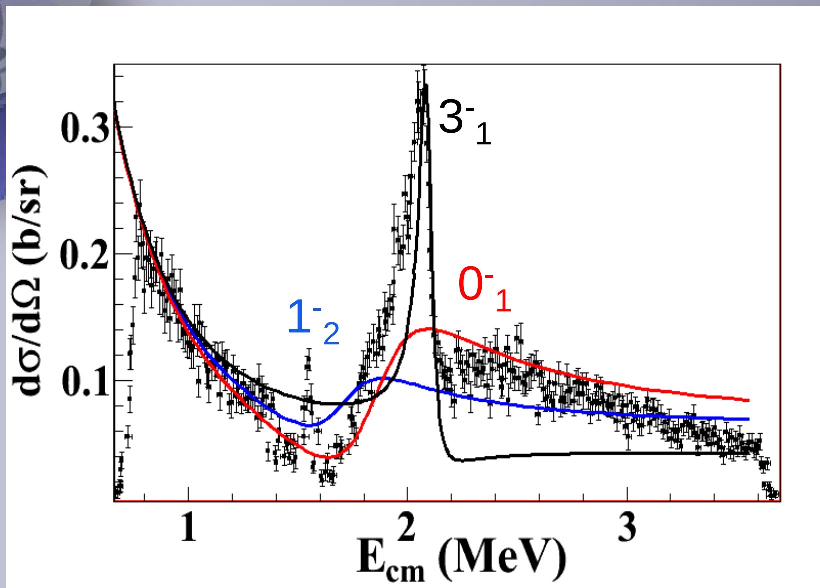
State in^{18}Na	Er(th) (keV)	Γ (keV) ^{17}Ne g.s.	Γ (keV) ^{17}Ne 3/2-	**Er(exp) (keV)**	**Γ(keV) g.s.**	**Γ (keV) ^{17}Ne 3/2-**
1_1^-	1300	2	0	**1362 ?**	**<1**	**<1**

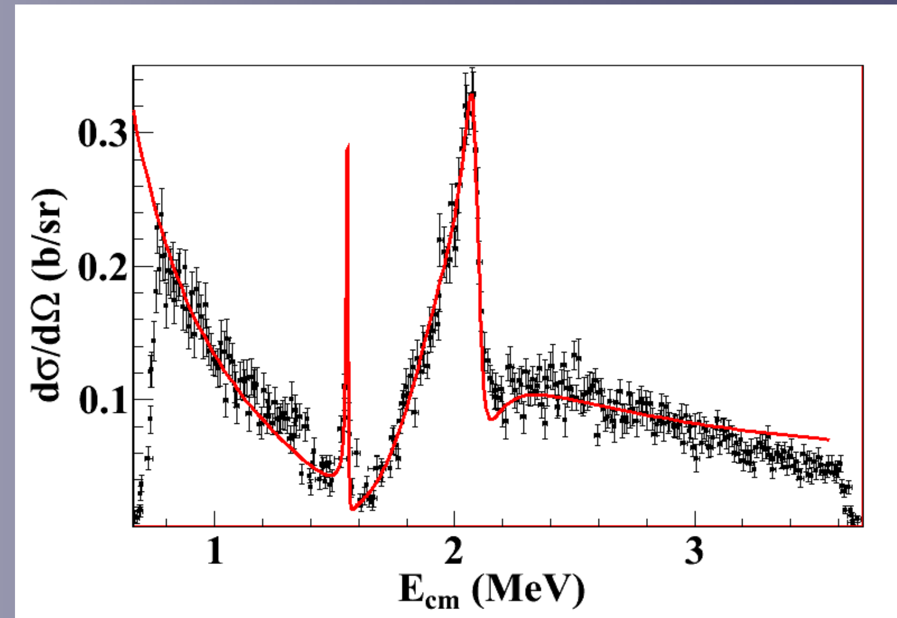
R-matrix fit of excitation function



State in[18]Na	Er(th) (keV)	Γ (keV) ^{17}Ne g.s.	Γ (keV) ^{17}Ne 3/2-	**Er(exp) (keV)**	**Γ(keV) g.s.**	**Γ (keV) ^{17}Ne 3/2-**
1_1^-	1300	22	0	**1362 ?**	**<1**	**<1**
2_1^-	1500	8	0	**1552(5)**	**9(3)**	**<1**

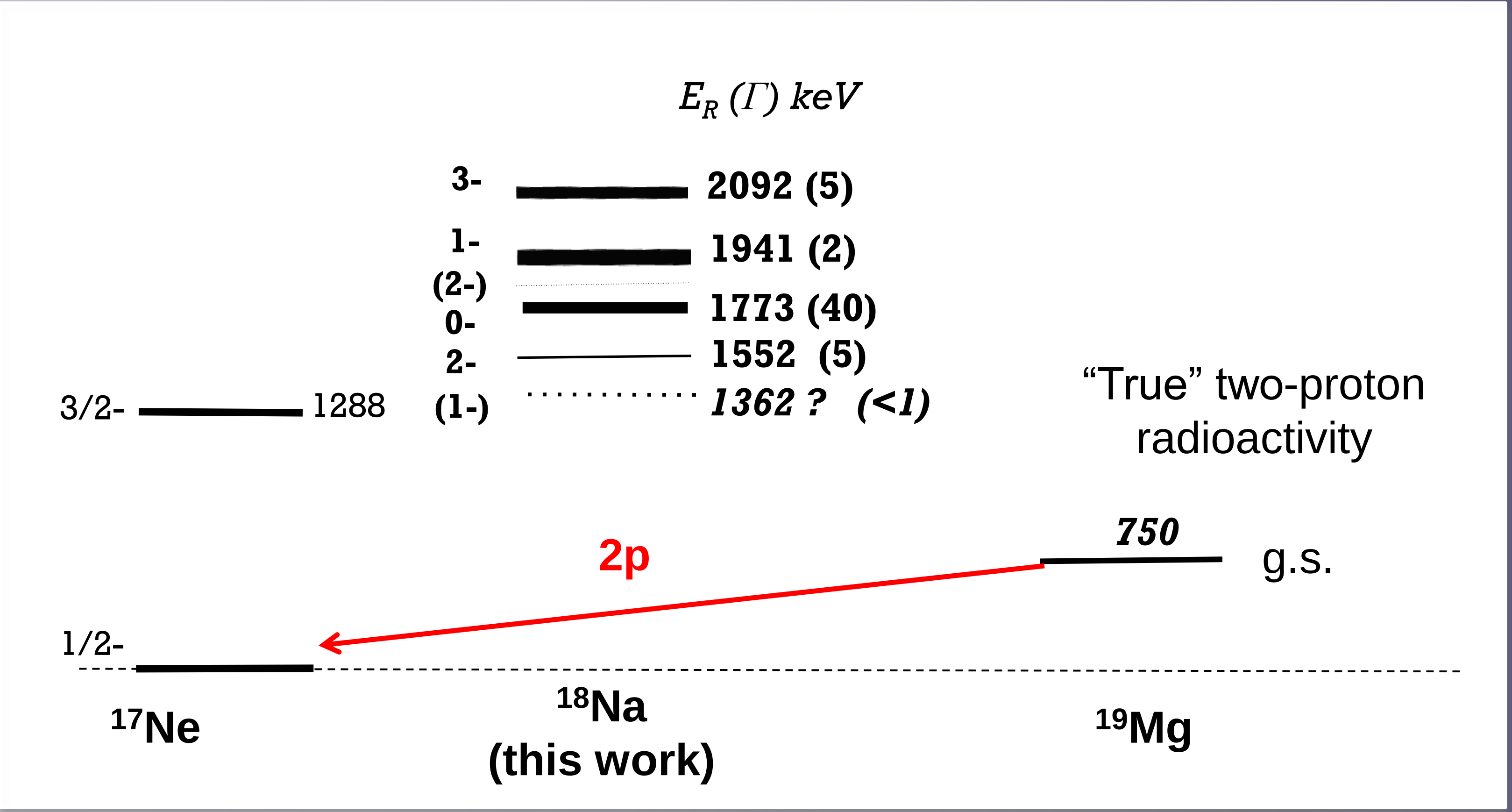
R-matrix fit of excitation function



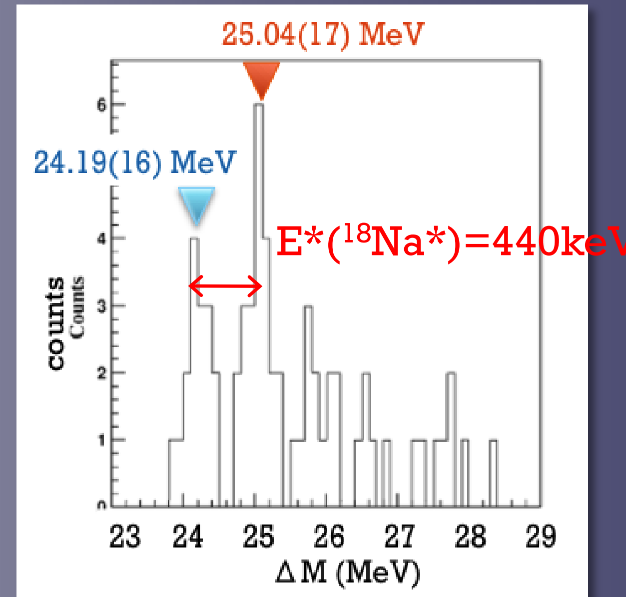


State in^{18}Na	Er(th) (keV)	Γ (keV) ^{17}Ne g.s.	Γ (keV) ^{17}Ne 3/2-	**Er(exp) (keV)**	**Γ(keV) g.s.**	**Γ (keV) ^{17}Ne 3/2-**
1_1^-	1300	22	0	**1362 ?**	**<1**	**<1**
2_1^-	1500	8	0	**1552(5)**	**9(3)**	**<1**
0_1^-	*1650*	189	0	**1773(40)**	**479 (200)**	**<50**
2_2^-	1950	0.2	5	***1827 ?***	**<1**	**<1**
1_2^-	*2450*	1275	4.8	**1941**	**551(100)**	**20(5)**
3_1^-	2050	31	0.015	**2092**	**53(5)**	**<100**

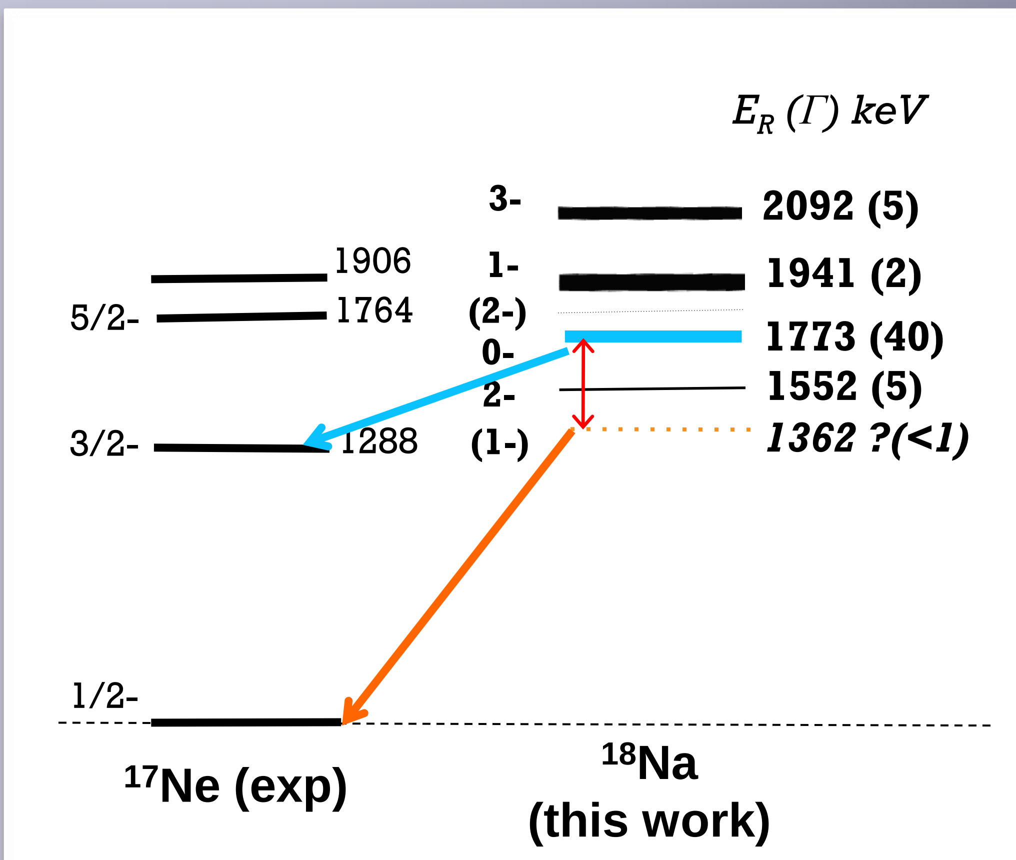
Level scheme for ^{18}Na



Level scheme for ^{18}Na



Zerguerras et al, EPJA (2004)



State in ^{18}Na	Er(exp) (keV)	Γ(keV) g.s.	Γ (keV) ^{17}Ne $_{3/2-}$
1_1^-	*1362 ?*	*<1*	*<1*
2_1^-	1552(5)	9(3)	<1
2_2^-	*1827 ?*	<1	<1
0_1^-	1773(40)	479 (200)	<50
1_2^-	1941	551(100)	20(5)
3_1^-	2092	53(5)	<100

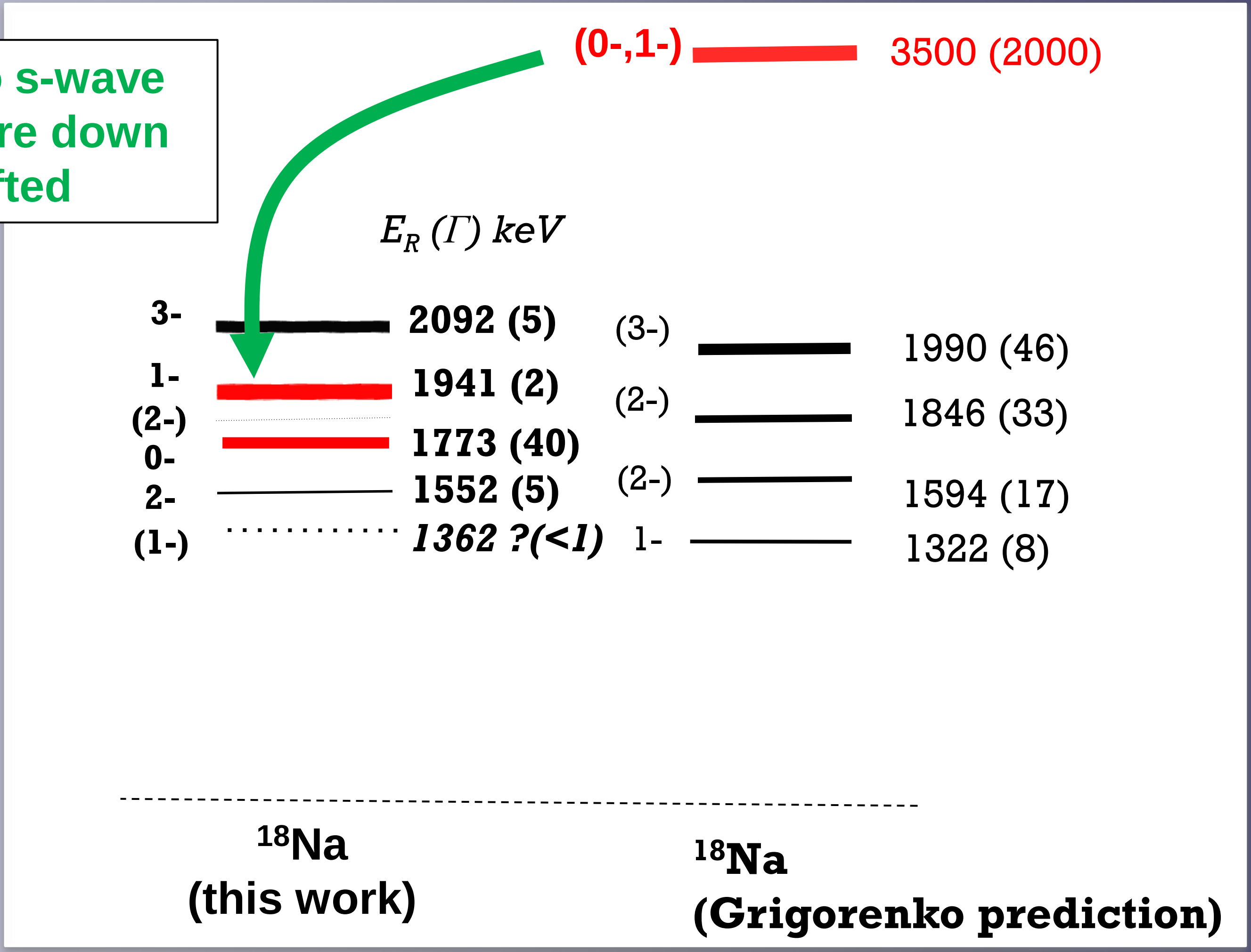
Lifetime of ^{19}Mg

Grigorenko, NPA (2003)
Best agreement with d-wave configuration

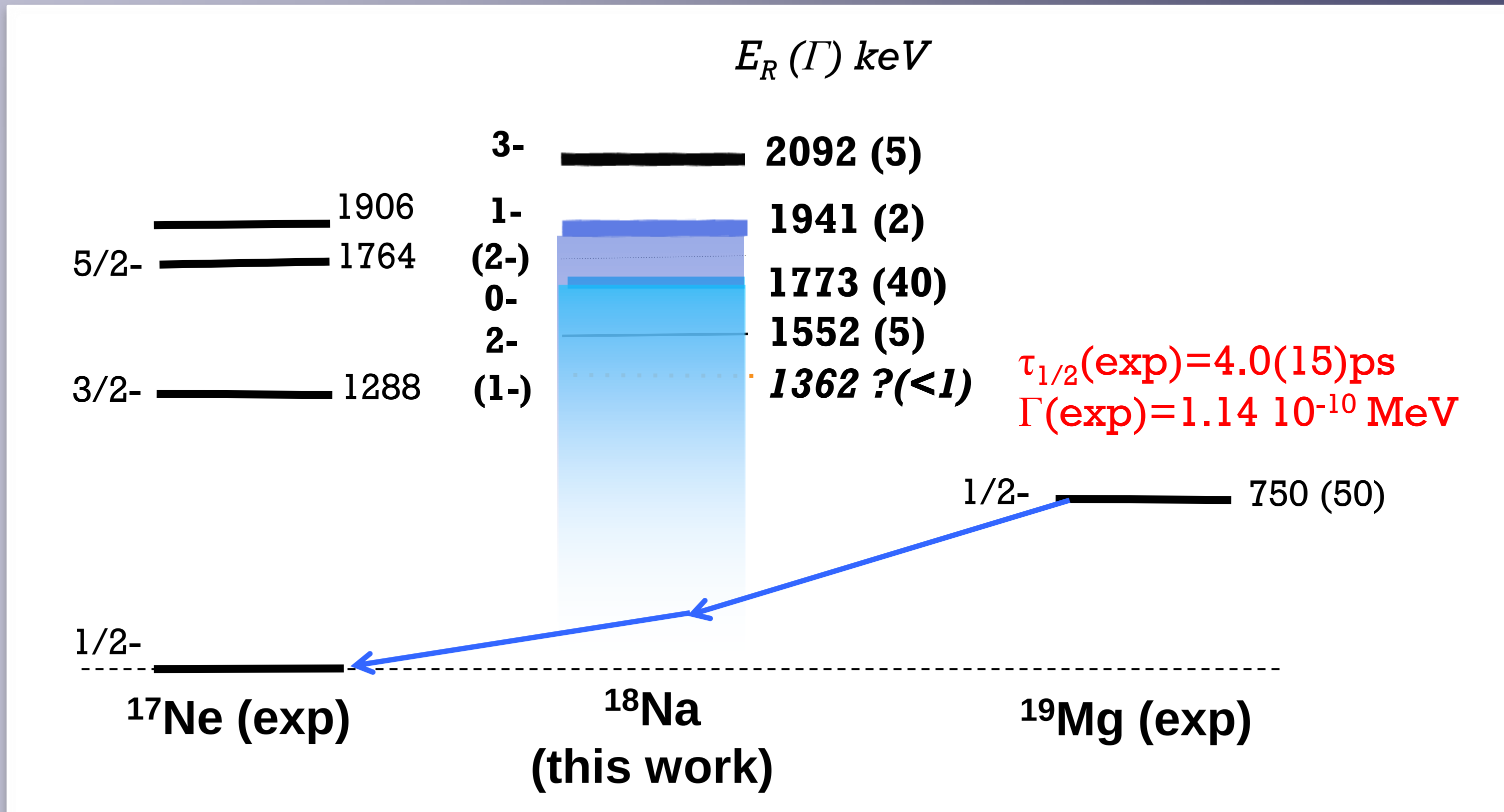
$\tau_{1/2}$(exp)=4.0(15)ps

The two s-wave states are down shifted

Effect on ^{19}Mg lifetime ?



Lifetime of ^{19}Mg for sequential decay



Decay l=0 via 1_1^- Γ=6.6 10^{-11}s

via 0_1^- Γ=2.4 10^{-10}s

via 1_2^- Γ=4.1 10^{-10}s

} >Γ(exp)

Suppression of s-wave configuration in ^{19}Mg
➔ **d-wave dominant**

Shell Model

$$\theta^2 \left(|^{18}\mathrm{Na}_{(0_1^-)} > \oplus |\pi 2s_{1/2} > \right) = 0.0956$$

- L.V. Grigorenko, I.G. Mukha and M.V. Zhukov, Nucl.Phys. A, 713 (2003) 372.
- R.A. Kryger *et al*, *Phys. Rev. Lett.*, *74* (1995) 860.

Lifetime of ^{19}Mg for sequential decay

Distance traveled by the first proton before the emission of the second one

$$T(E) = \frac{\hbar\Gamma}{(E - E_0)^2 + \Gamma^2/4}.$$

Collision time

A.I Baz, Ya. Zel'daricIt and A. M. Perelomov

SCATTERING, REACTIONS and DECAY
in NONRELATIVISTIC QUANTUM MECHANICS

d = 5 fm

$$T(E) = \frac{\hbar}{\Gamma(E)}$$

d = 5000 fm

Who is true?

E521as collaboration

*M. Assie et al   Physics Letters B, Volume 712, Issue 3,
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M. Assié[1,2], F. de Oliveira Santos[1], T. Davinson[3], F. de Grancey[1], L. Achouri[4], J. Alcántara-Núñez[5], J.-C. Angélique[4], C. Borcea[6], L. Caceres[1], I. Celikovic[7], V. Chudoba[8,9], D.Y. Pang[1], C. Ducoin[10], M. Fallot[11], O. Kamalou[1], J. Kiener[12], Y. Lam[13], A. Lefebvre-Schuhl[12], G. Lotay[3], J. Mrazek[14], L. Perrot[2], A. M. Sánchez-Benítez[15], F. Rotaru[6], M-G. Saint-Laurent[1], Yu. Sobolev[14], N. Smirnova[13], M. Stanoiu[6], R. Stanoiu[6], I. Stefan[2], K. Subotic[7], P. Ujic[1,7], R. Wolski[8,16], P.J. Woods[3]

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