22nd ASRC International Workshop

The investigation of the high-spin states in ^{35}S by in-beam gamma-ray spectroscopy

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OUTLINE

1. **Introduction and scientific motivation,**
2. **Experimental details,**
3. **Analysis and theoretical calculations,**
4. **Results and conclusions,**

Introduction and Scientific Motivation

- sd shells → fundamental testing ground for basic models
- Several interesting phenomena:

  clusterization,

  shape coexistence,

  proton-neutron interaction

  interplay between collective and single-particle motion.
- More experimental data is needed to improve models.

- Previously ^{35}S has been populated via:

- **$^{34}S(n,\gamma)$**
- S.Raman et.al Phys. Rev. C 32, 18 (1985).

- **$^{34}S(d,p\gamma)$**
- R.M.Freeman et. al. Nucl. Phys. A 197, 529 (1972).

- **$^{37}Cl(p,^{3}He)$**
- A.Guichard et. al. Phys. Rev. C 12, 1109 (1975).

- **$^{37}Cl(d,\alpha\gamma)$**
- Th. W. Van Der Mark et al., Nucl. Phys. A 181, 196 (1972).

- **^{35}P β^- Decay**
- E.K.Warburton et.al Phys. Rev. C 34, 1031 (1986).

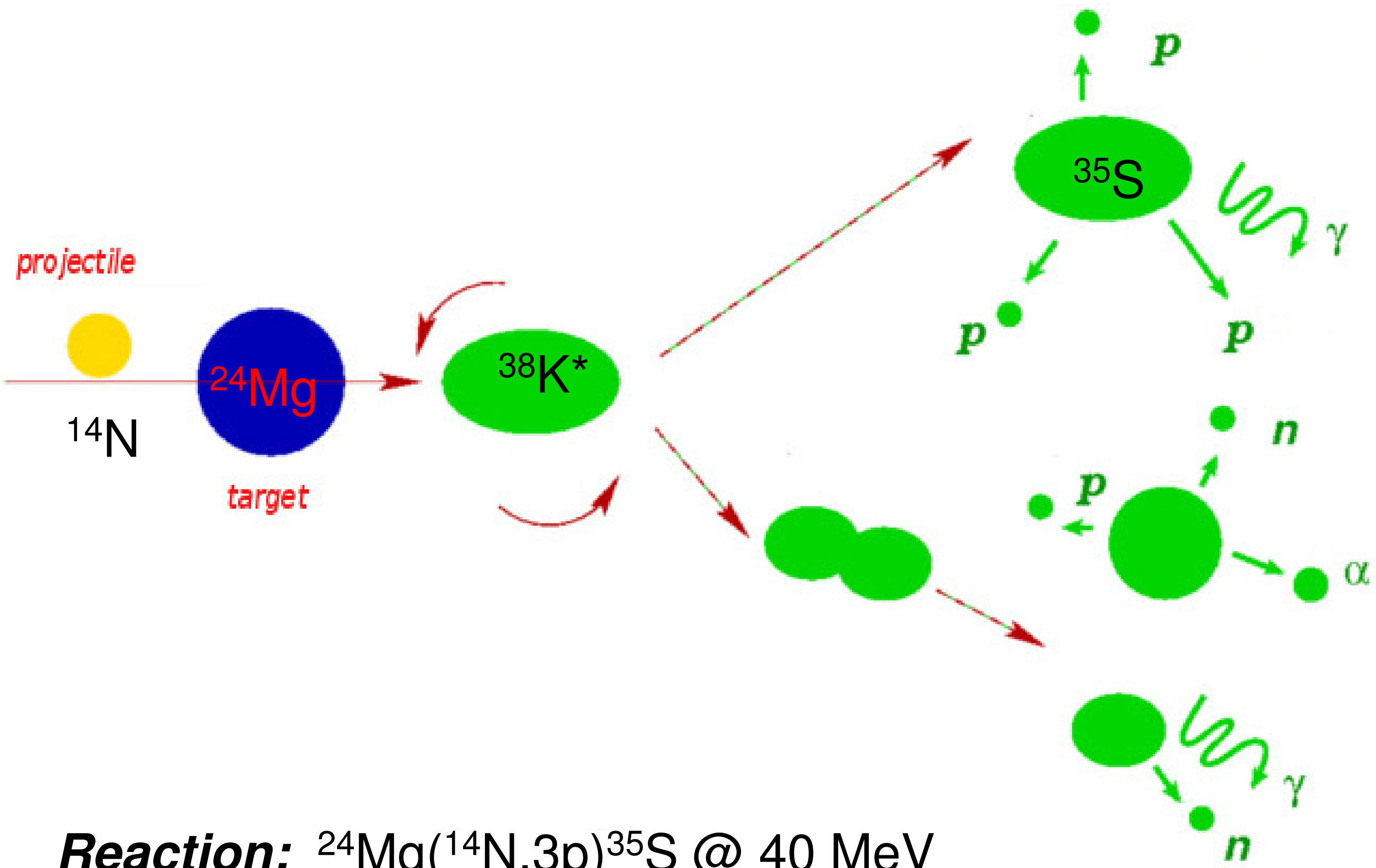
- No investigation by HI reactions,
- No efficient detection system
- Results:

  low and medium spin states up to

  $5/2^+$ for positive parity and

  $7/2^-$ for negative parity observed

Experimental details



Reaction: ^{24}Mg(^{14}N,3p)^{35}S @ 40 MeV

Target: ^{24}Mg on Au backing.

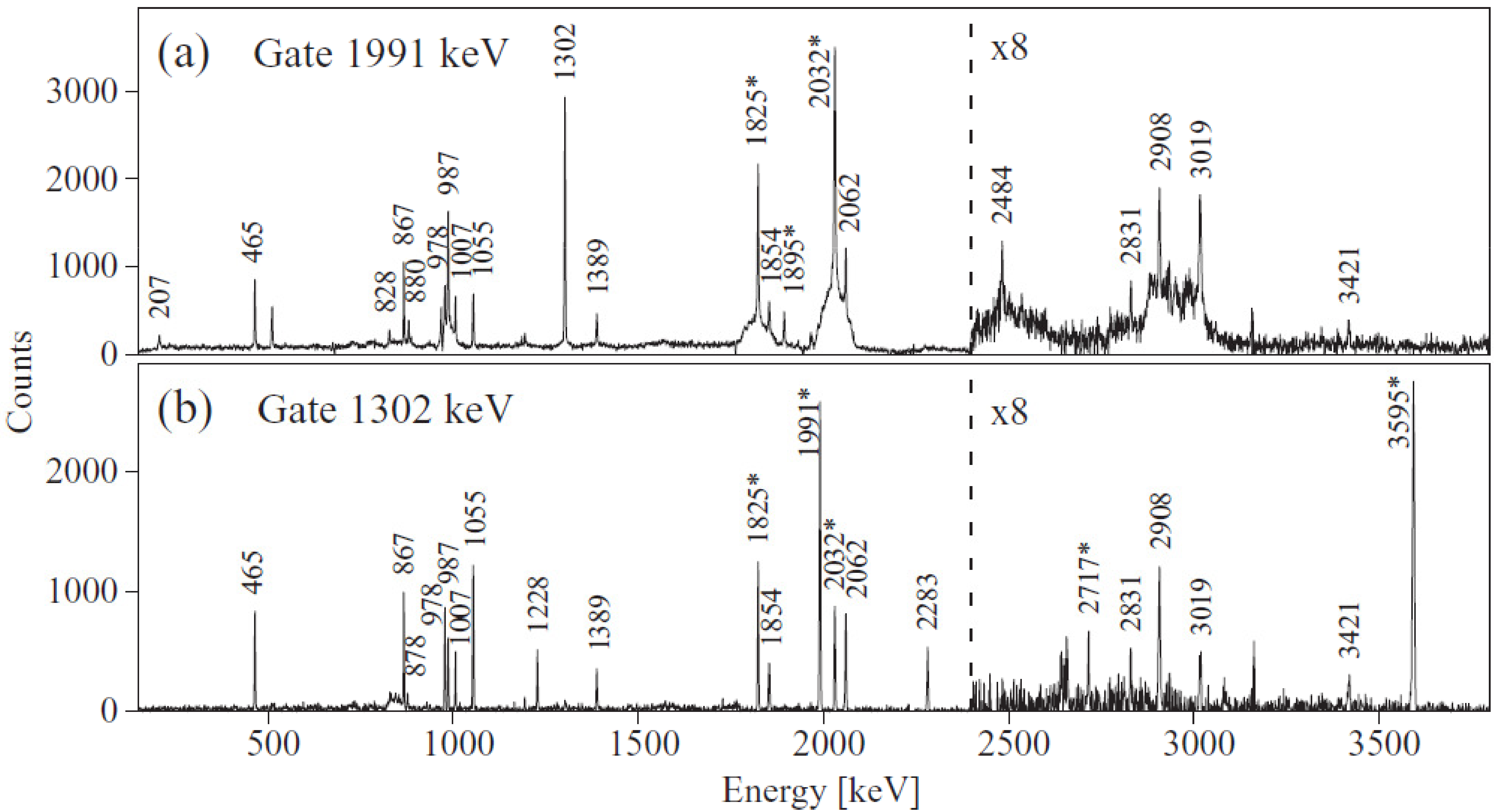
Detection: *4π-GASP array*

GASP ARRAY*

- Was located in LNL, italy
- 40 HPGe detectors with anti-Compton shield.
- GASP angles:
  34°(6), 60°(6) , 72°(4), 90°(8), 108°(4), 120°(6) and 146°(6)
- Data sorted in γ-γ-γ cube
- γ-γ matrix and seven asymmetric matrices

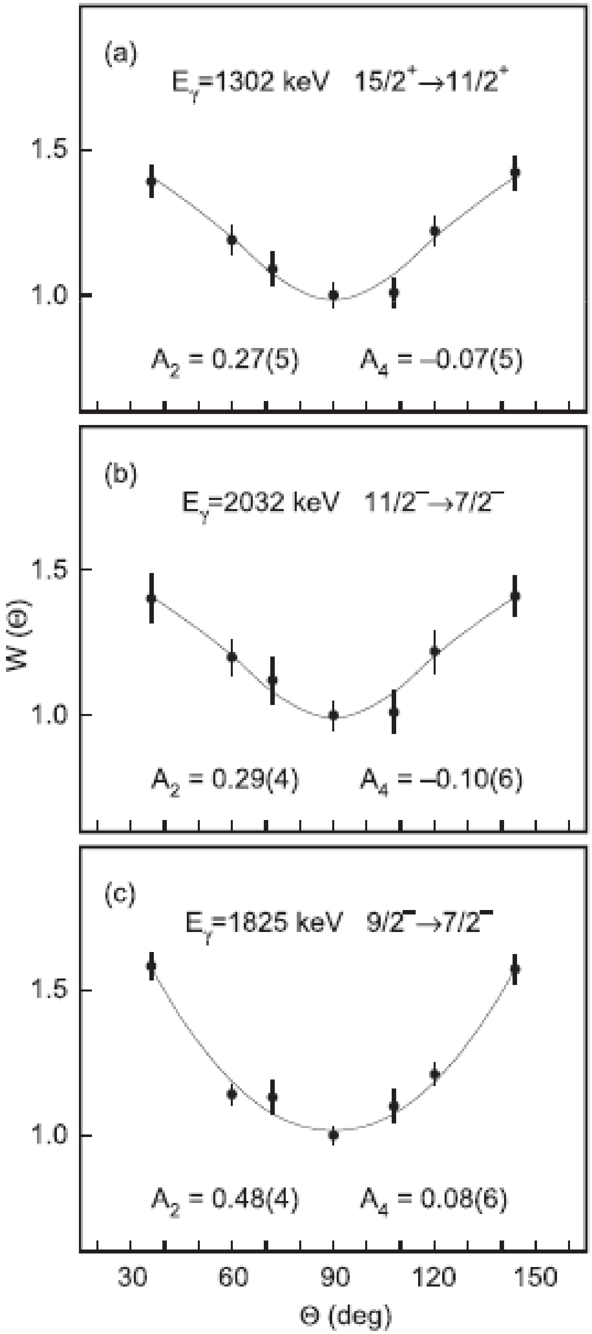
http://www.pd.infn.it/gamma/pages/activities.html

*C.Rossi Alvarez Nuc. Phys. News Vol. 3, Iss. 3, 1993



S.Aydin et.al Phys. Rev. C 89, 0143310 (2014)

Angular Distribution Analysis



- Seven asymmetric matrices used.
- **Information on the multipolarity. and mixing ratio obtained.**
- Fit→standard Legendre Polynomials $P_{2,4}(\cos\theta)$ *with* free $A_{2,4}$
- Fit→ free mixing ratio *δ and the degree of alignment σ*

For low intensity transitions

- Angular distribution measurement unfeasible,
- **Multipolarity information obtained from:**

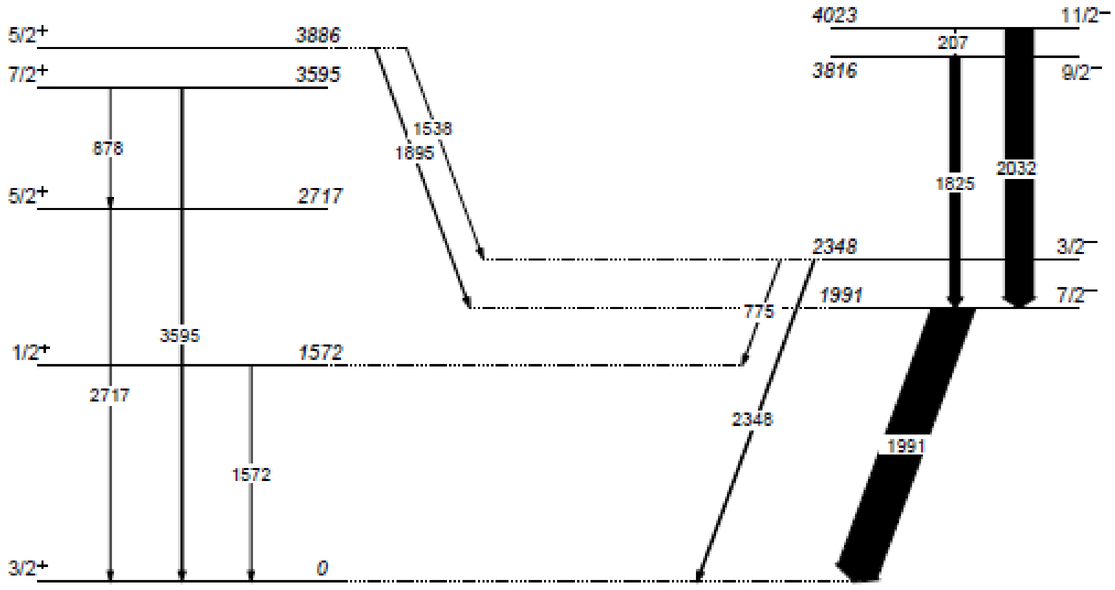
$$R_{ADO} = \frac{I_\gamma(34°) + I_\gamma(146°)}{2I_\gamma(90°)}$$

- Reference R_{ADO} is 0.8 for stretched dipole

1.4 for stretched quadrupole or ΔJ=0 pure dipole transitions

- **For mixed character, R_{ADO} depends on mixing ratio δ.**

$^{35}_{16}S_{19}$


5/2+
3886
7/2+
3595
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1572
3/2+
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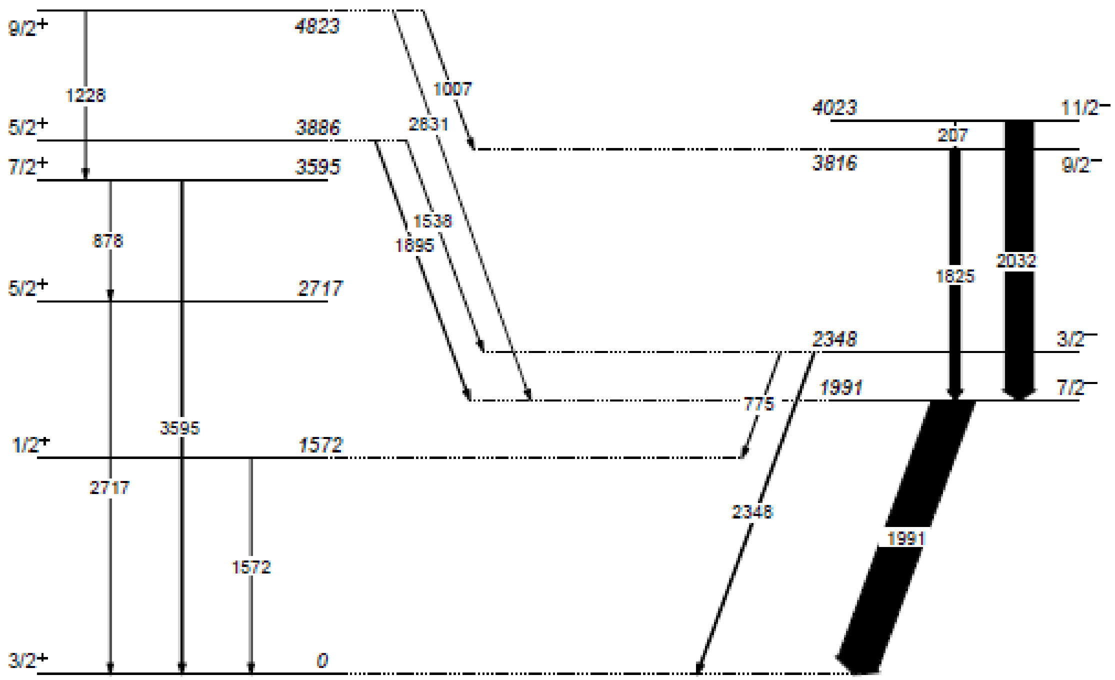
7/2−
1991

$^{35}_{16}S_{19}$



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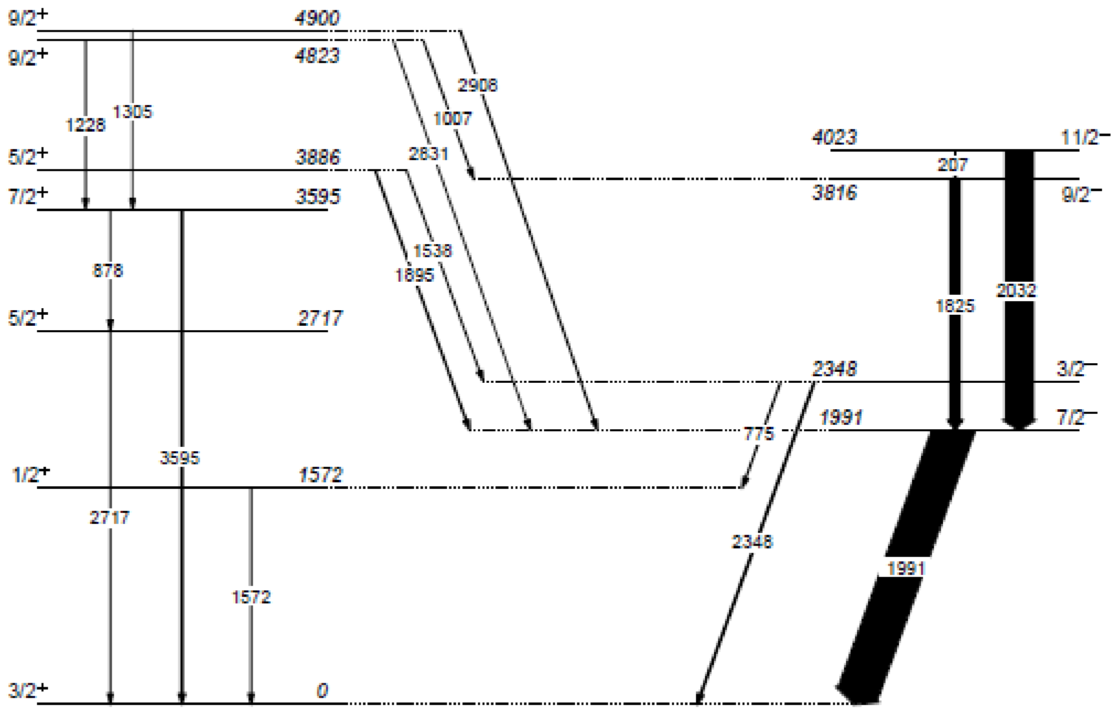
$^{35}_{16}S_{19}$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9/2+ 4823
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7/2+ 3595
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1/2+ 1572
3/2+ 0
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2348 3/2−
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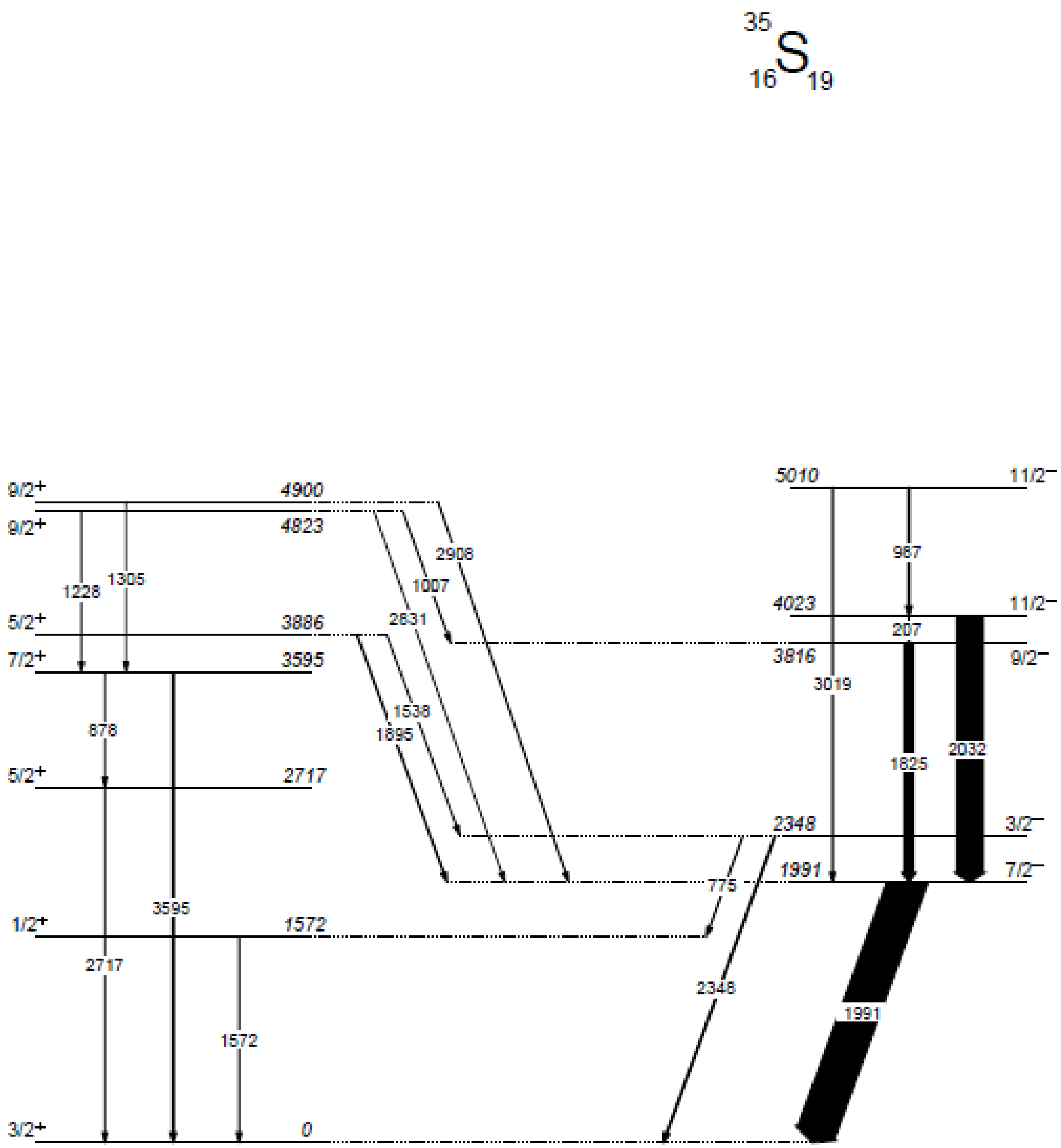

$^{35}_{16}S_{19}$
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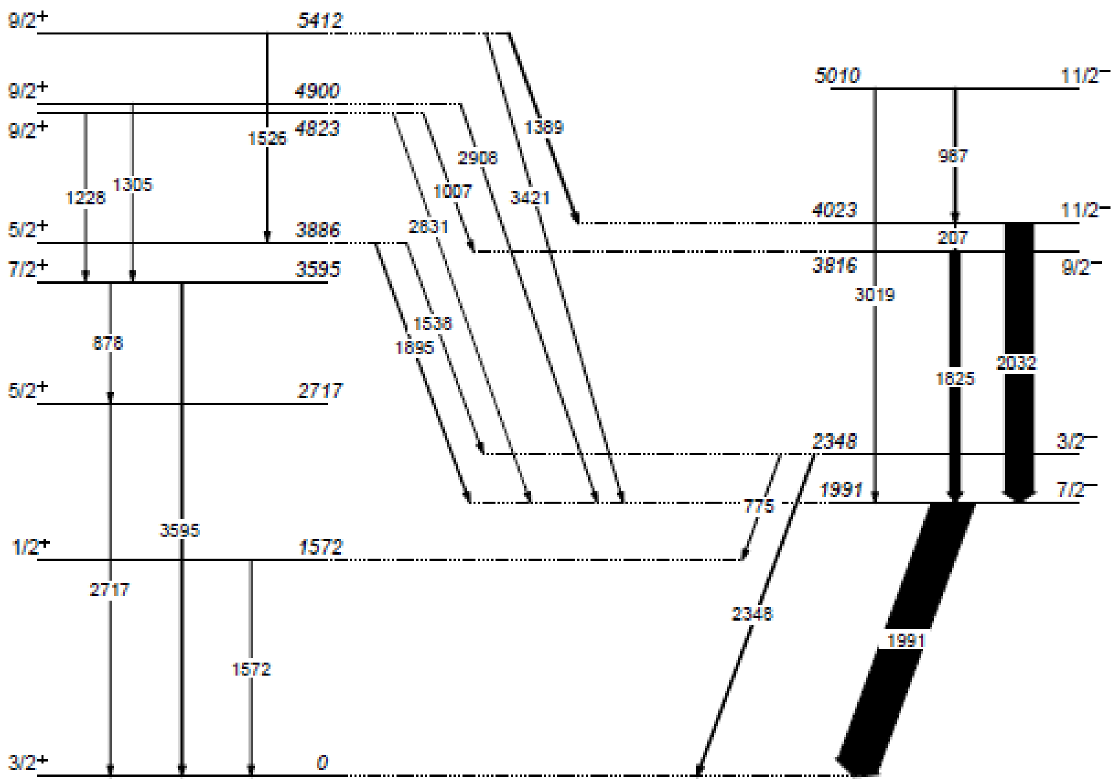
$^{35}_{16}S_{19}$



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7/2+ 3595
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3/2+ 0
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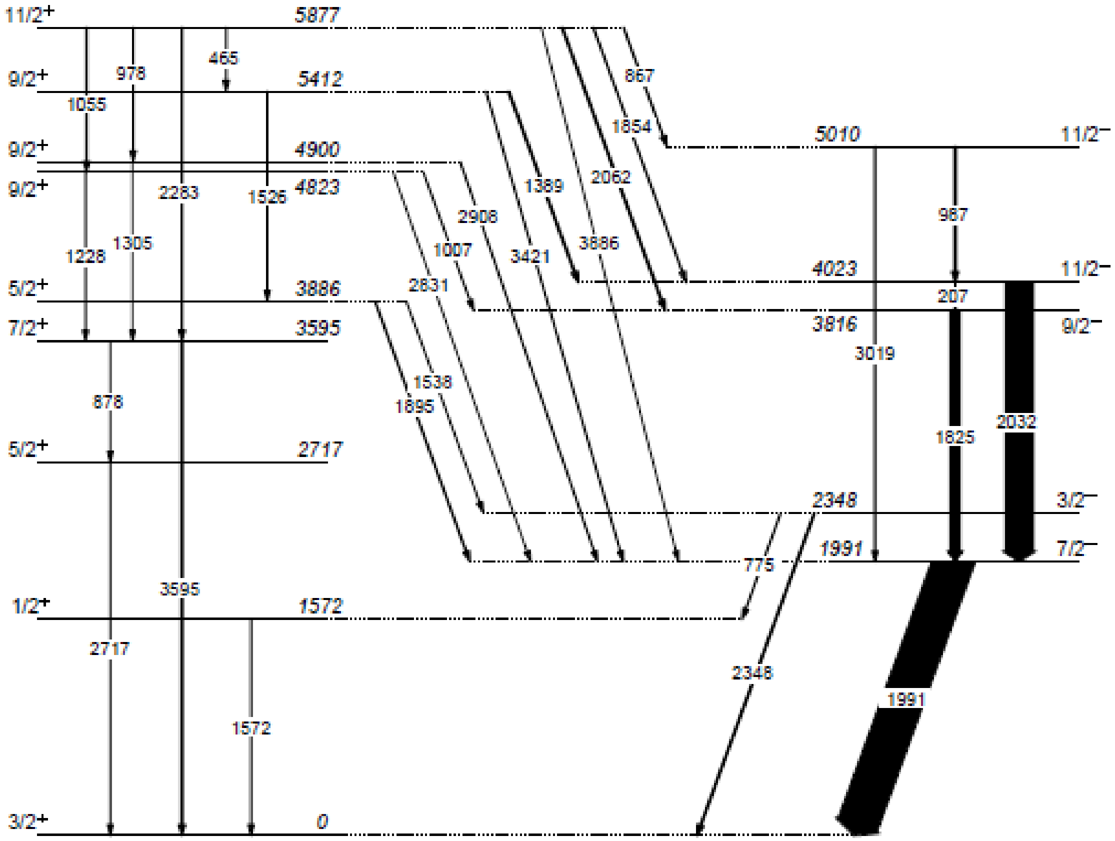
$^{35}_{16}S_{19}$



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1572
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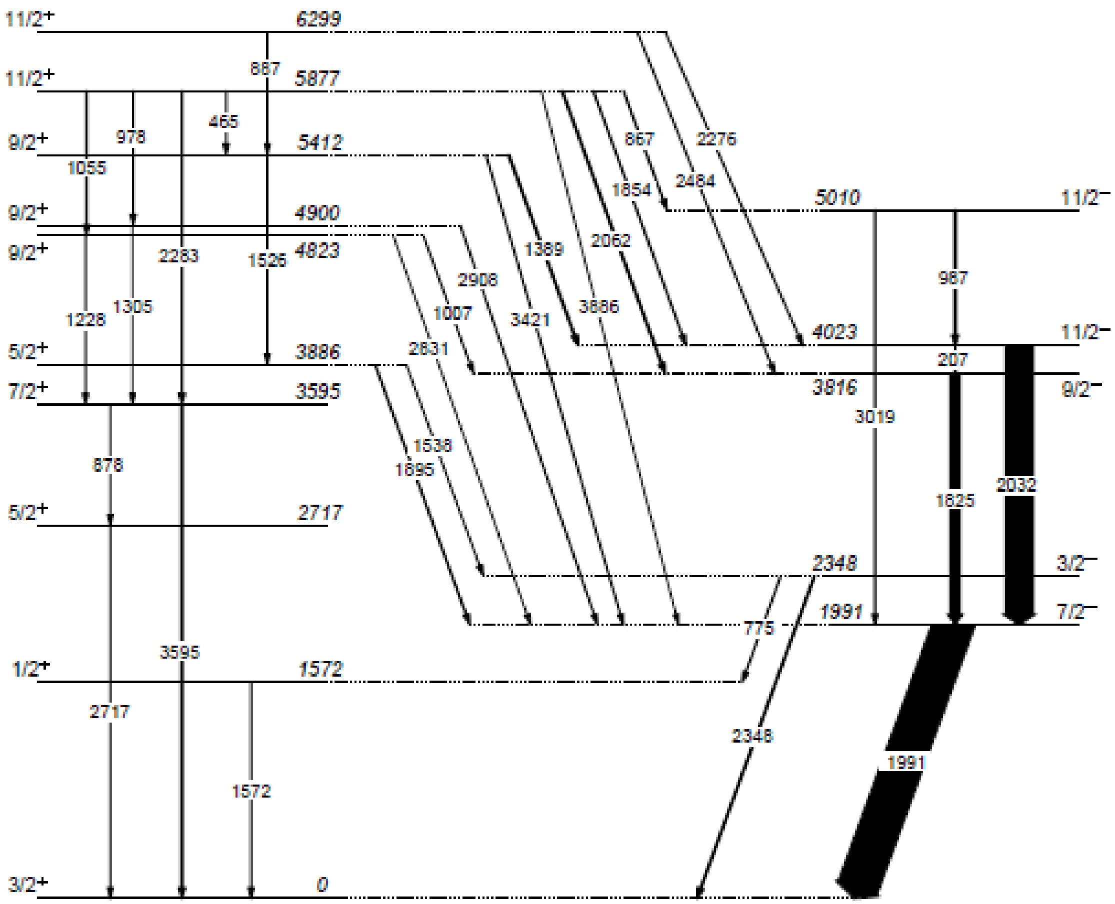
$^{35}_{16}S_{19}$



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9/2+ 5412
9/2+ 4900
9/2+ 4823
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7/2+ 3595
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3/2+ 0
5010 11/2−
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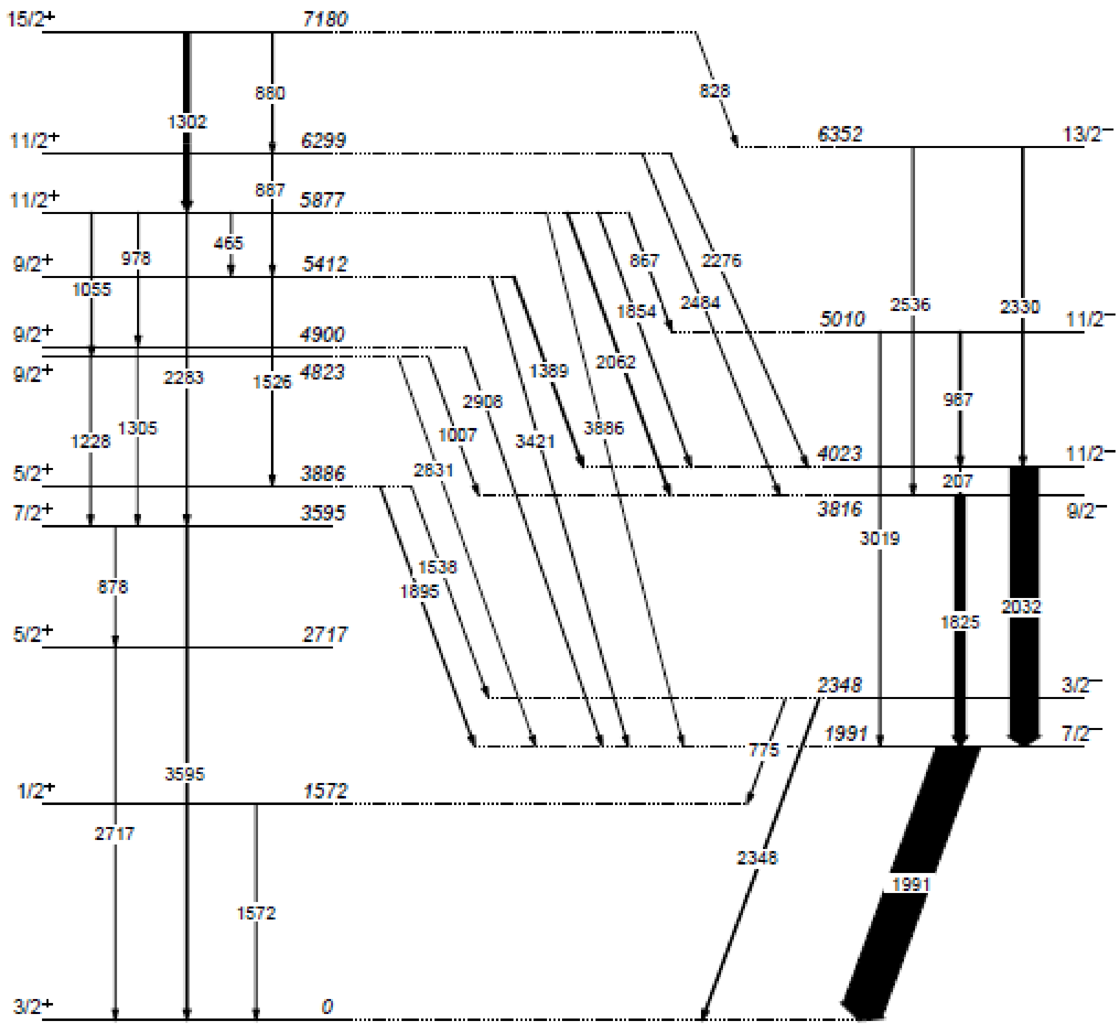
$^{35}_{16}S_{19}$



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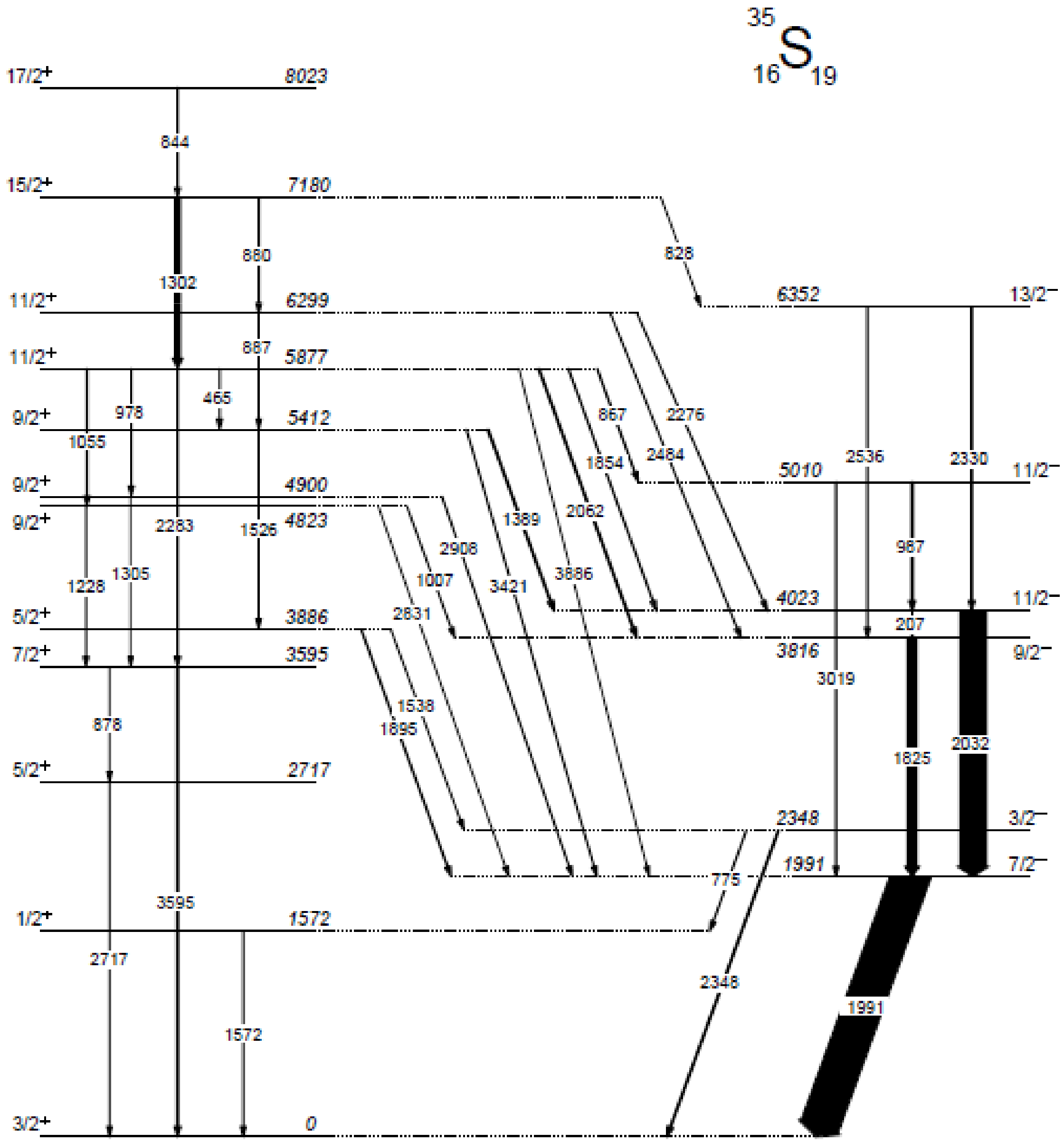
35 S 16 19
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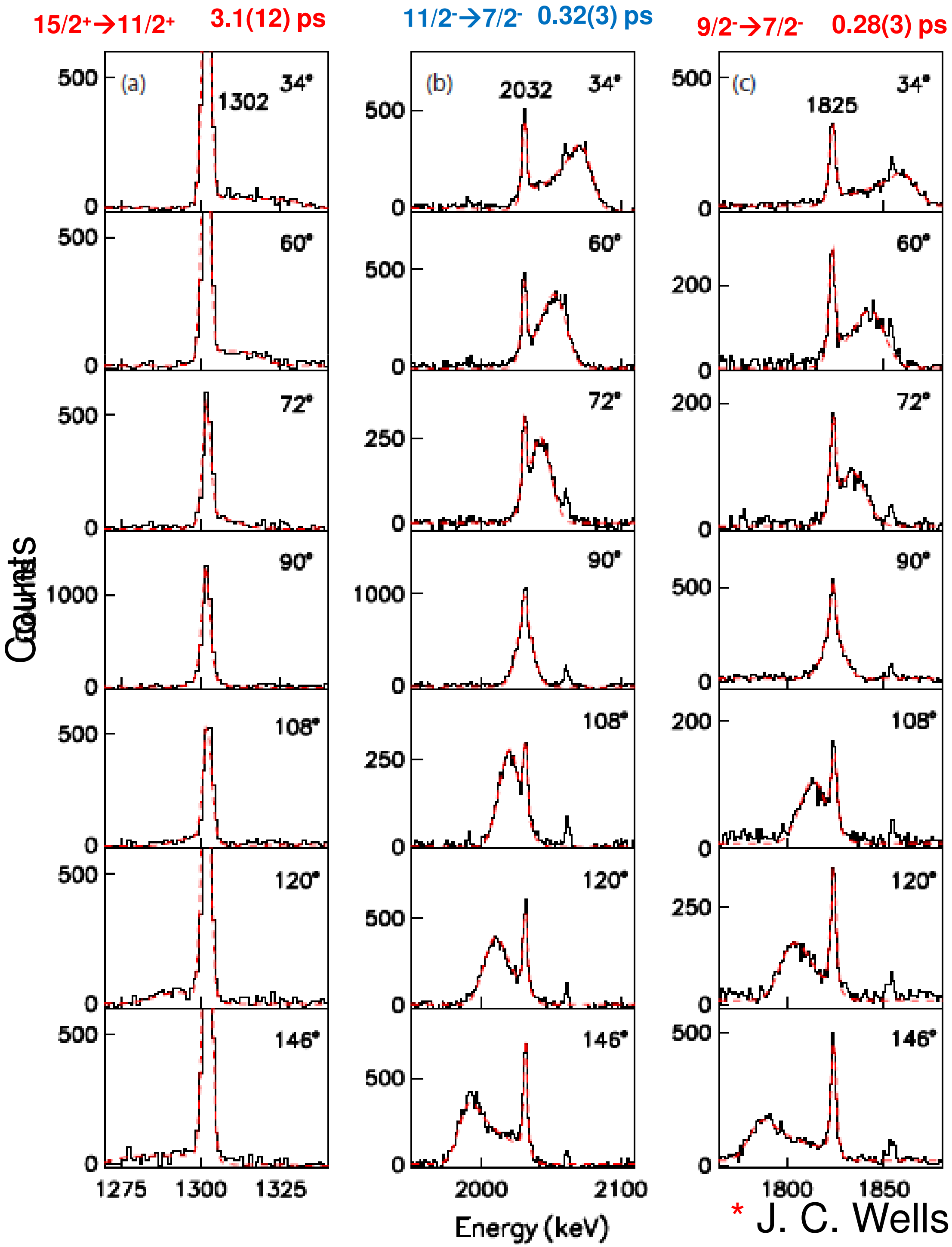
3/2+ 0

Doppler shift attenuation method (DSAM) Measurement



- 7 asymmetric matrices used.
- LINE-SHAPE *
- **Slowing down simulation by Monte Carlo**

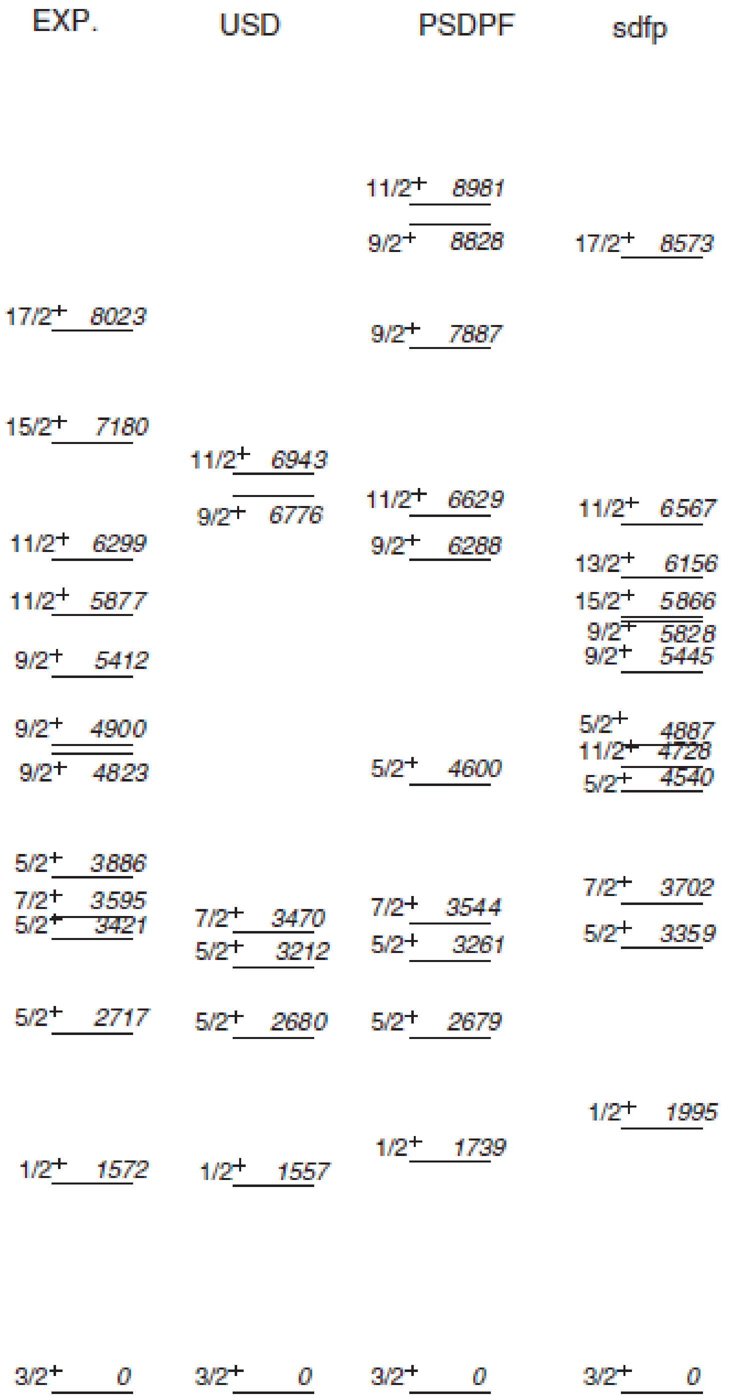
* J. C. Wells et.al., Report No. ORNL-6689, 1991, p. 44.

DSAM Measurement

Half-lives determined in the present work for excited states in ^{35}S.

E_x (keV)	J^π	$T_{1/2}$ (ps)
3816	$9/2^-$	0.28(3)
4023	$11/2^-$	0.32(3)
5010	$11/2^-$	0.45(8)
6352	$13/2^-$	0.05(1)
7180	$15/2^+$	3.1(12)
8023	$17/2^+$	0.15(4)

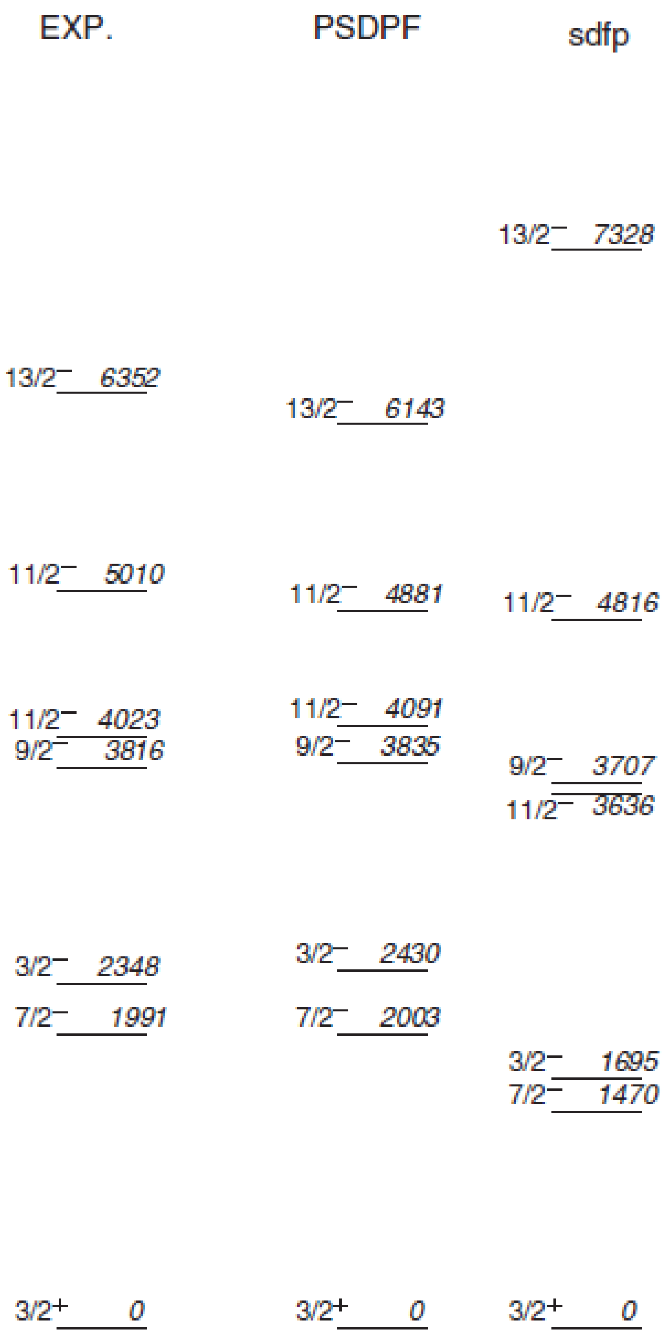
Shell Model Calculation



- Shell-model code ANTOINE* used
- Different interaction and model space
- USD** → not good for J>7/2
- PSDPF*** → full psdpf with a ^{4}He core
- sdfp**** → more than one particle-hole excitation to the *fp shell* → well prediction

* E. Caurier and F. Nowacki, Acta Phys. Pol. B **30, 705 (1999).**
B. H. Wildenthal, Prog. Part. Nucl. Phys. **11, 5 (1984).
*** M. Bouhelal et.al., Nucl. Phys. A **864, 113 (2011).**
****E. Caurier et.al., Phys. Lett. B **522, 240 (2001).**

Shell Model Calculation



- PSDPF→ Good agreement for full J≤13/2⁻
- *sdfp →results satisfactory*

Transition probabilities *B(M1) and B(E2) for negative- and positive-parity states in ^{35}S compared to SM calculations*

E_{lev}^{exp} (keV)	$T_{1/2}^{exp}$ (ps)	J_i^π	J_f^π	E_γ^{exp} (keV)	BR[b] %	$B(M1)(\mu_N^2)$ exp	USD	PSDPF	$sdfp$	$B(E2)(e^2fm^4)$ exp	USD	PSDPF	$sdfp$
1572	2.3(4)[a]	$1/2_1^+$	$3/2_1^+$	1572	100	0.004(1)	0.024	0.020	0.002				
2717	0.069(24)[a]	$5/2_1^+$	$3/2_1^+$	2717	100	0.028(10)	0.032	0.038	0.000				
7180	3.1(1.2)[b]	$15/2_1^+$	$11/2_1^+$	1302	93(2)					45(17)	7	9	31
8023	0.15(4)[b]	$17/2_1^+$	$15/2_1^+$	844	100	0.44(12)	0.72	1.134	0.002				
3816	0.28(3)[b]	$9/2_1^-$	$7/2_1^-$	1825	100	0.018(4)		0.019	0.008	23(8)		48	5
4023	0.32(3)[b]	$11/2_1^-$	$7/2_1^-$	2032	99(1)					51(5)		48	14
5010	0.45(8)[b]	$11/2_2^-$	$11/2_1^-$	987	70(3)	0.064(12)		0.040	0.020				
			$7/2_1^-$	3019	30(3)					1.5(3)		1.3	21
6352	0.05(1)[b]	$13/2_1^-$	$11/2_1^-$	2330	66(10)	0.04(1)		0.037	0.001				
			$9/2_1^-$	2536	34(5)					37(9)		26	18

[a]:N.Nica et.al Nucl.Data Sheets **113,1** (2012)

[b]: Present study

Experimental reduced transition probabilities **B(E1), B(M2),** and **B(E3)** in ^{35}S compared to shell model calculations performed with the code ANTOINE using the **PSDPF** residual interaction

E_{lev}^{exp} (keV)	$T_{1/2}^{exp}$ (ps)	J_i^π	J_f^π	E_γ^{exp} (keV)	BR[a] %	$B(E1)(e^2\text{fm}^2)$ exp	$B(E1)(e^2\text{fm}^2)$ PSDPF	$B(M2)(\mu_N^2\text{fm}^2)$ exp	$B(M2)(\mu_N^2\text{fm}^2)$ PSDPF	$B(E3)(e^2\text{fm}^6)$ exp	$B(E3)(e^2\text{fm}^6)$ PSDPF
1991	1020(50)[a]	$7/2_1^-$	$3/2_1^+$	1991	100			1.6(5)	2.11	115(86)	119
2348	0.81(14)[a]	$3/2_1^-$	$1/2_1^+$	775	27(1)	$32(6) \times 10^{-5}$	54×10^{-5}				
			$3/2_1^+$	2348	73(1)	$31(6) \times 10^{-6}$	10×10^{-7}	45(18)	0.0044		

[a]:N.Nica et.al Nucl.Data Sheets **113,1** (2012)

Results and Conclusions

- 9 new excited states
- **28 new *γ-ray transitions.***
- *Firm spin-parity assignment to four previusly known levels.*
- **Half-life for 6 states by DSAM.**
- SM prediction with different model spaces.
- **Level scheme of ^{35}S improved.**

Collaborators

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Thank you