Triple configuration coexistence in ^{44}S

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Introduction

A familiar series

2, 8, 20, 28, 50, 82, 126

- Stable magic nuclei have higher binding energy per nucleon.
- **Magic numbers** are related to shell closure (in stable nuclei)
- Shell closure $\rightarrow$ spherical symmetry (of ground state).

Nuclear shell model

The shells are effects of an average potential analogous to the ones observed in atoms.
The nuclear many-body problem, Ring and Schuck, 1980.

A single particle Hamiltonian can be used ... at least for some very special nuclei.

The simplest case

Potential = (isotropic H.O.) + (L^2 term) + ($L \cdot S$ coupling)

Shell model prediction of *magic* numbers

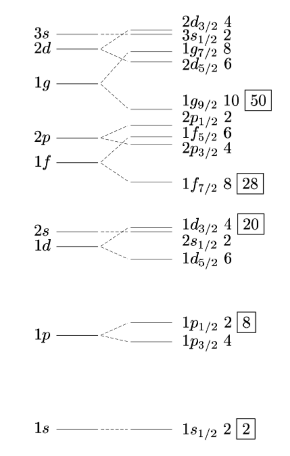

Figure: Taken from http://en.wikipedia.org/wiki/File:Shells.png

Things change away from stability.

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"Semi-magic" ^{44}S (**N=28**, Z=16): an example of shell breaking.

Where is ^{44}S?

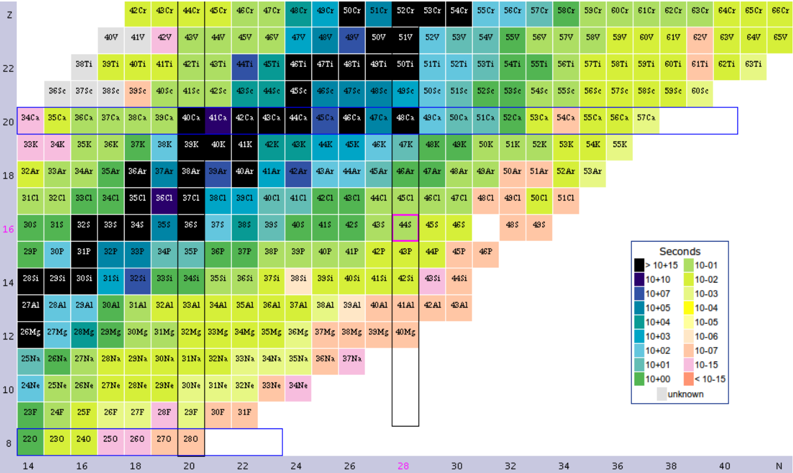

Figure: Taken from http://www.nndc.bnl.gov.

Previous experimental works on ^{44}S

1997, Glasmacher et al.
Collectivity in ^{44}S.

- Coulomb excitation to populate the 1st exc. state 2_1^+.
- $E_{exc}(2_1^+) = 1297(18)$ keV.
- $B(E2, 0^+_{g.s.} \rightarrow 2_1^+) = 314(88)\ e^2\text{fm}^4$.

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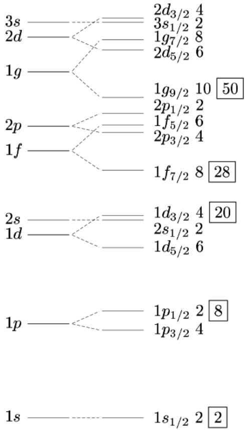
Introduced intruder configuration



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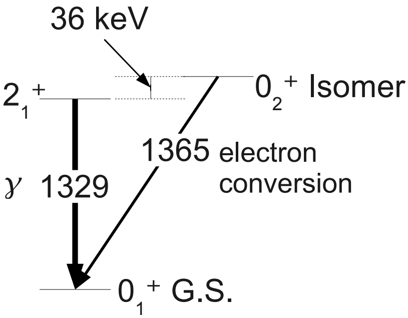
2005, Grevy et al.
Observation of the 0_2^+ state in ^{44}S.



- **Isomeric** 0^+ state and 1st exc. state 2_1^+ were observed.

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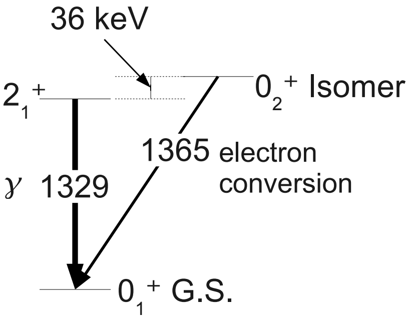

- Isomeric 0^+ state and 1st exc. state 2_1^+ were observed.
- 0_2^+ half-life of 2.3(3)μs and exc. energy of 1365(1) keV. **Comparison**: half-life of 2_1^+ is $\sim$ 2.4 ps ($10^{-6}\mu$s).

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2010, Force et al.
Prolate-spherical shape coexistence at N=28 in ^{44}S.

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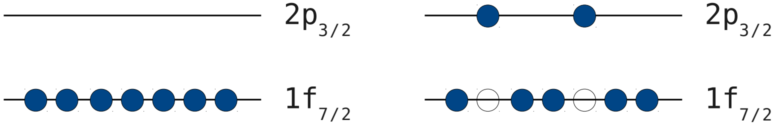
This study highlights the interaction between the "normal" configuration and the intruder configuration.



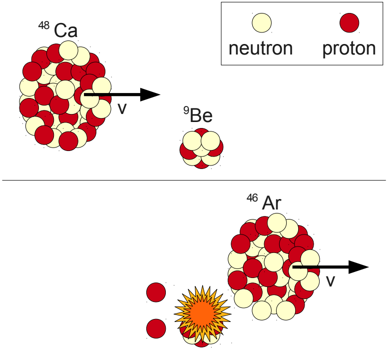
Getting ^{44}S via 2p-KO

Experiment done at NSCL, Michigan, USA in 2009

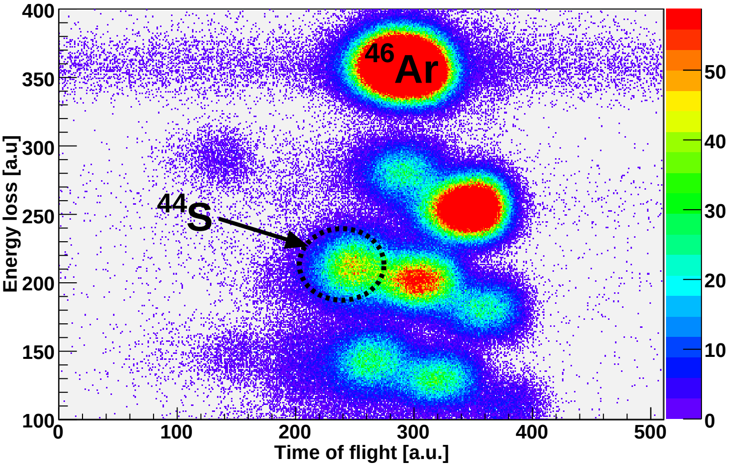
- ^{48}Ca(^{9}Be,X)^{46}Ar $\rightarrow$ ^{46}Ar(^{9}Be,X)^{44}S*

Peripheral collision

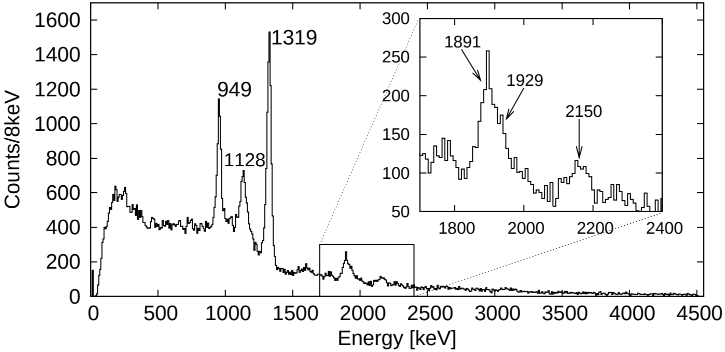
smaller steps $\rightarrow$ less background



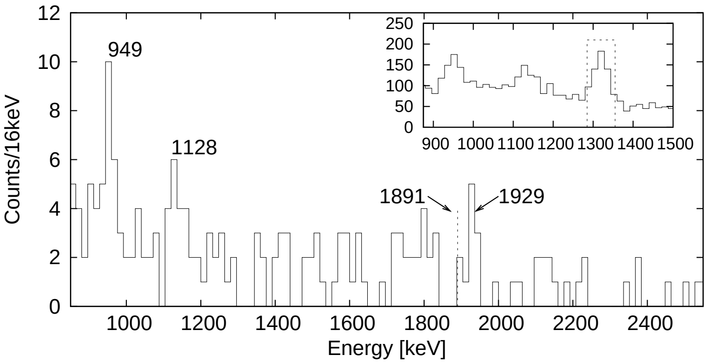
Particle identification (using S800)



singles-γ spectrum (using SeGA)



$\gamma\gamma$ matrix



γ spectrum and $\gamma\gamma$ matrix

Advantage of 2-proton knockout reaction:

Parallel momentum distributions

Parallel momentum distributions

Reference

Two-nucleon knockout spectroscopy at the limits of nuclear stability. (PRL 2009)
E.C. Simpson, J.A. Tostevin, D. Bazin, B.A. Brown and A. Gade

" ... the residue parallel momentum distributions in these reactions offer a clear spectroscopic signal of the angular momentum of the pair of nucleons removed, and thus of the **residue final state spins** ..."

Parallel momentum distribution **made simple**

The higher the J of the recoil particle, the wider its parallel momentum distribution.

Example: $2p$ removal from $^{28}\mathrm{Mg}$ to $^{26}\mathrm{Ne}$ (calculations)

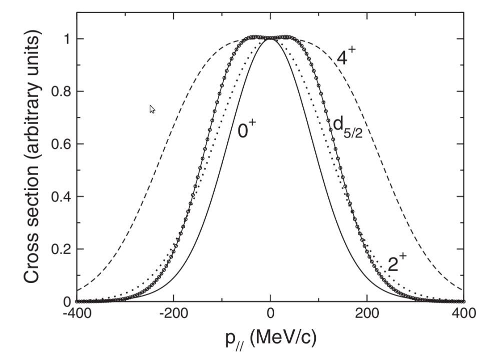
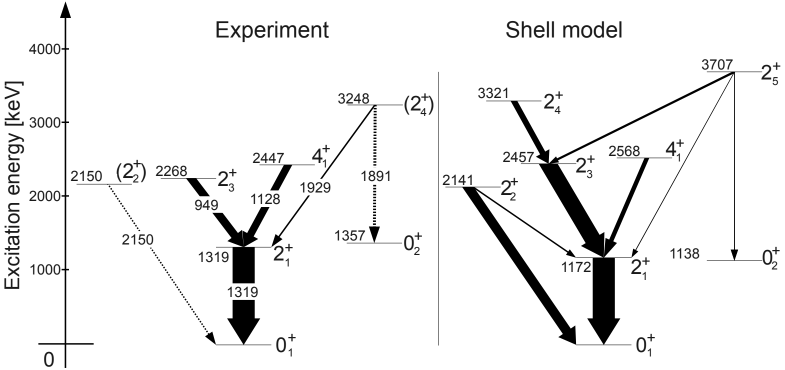


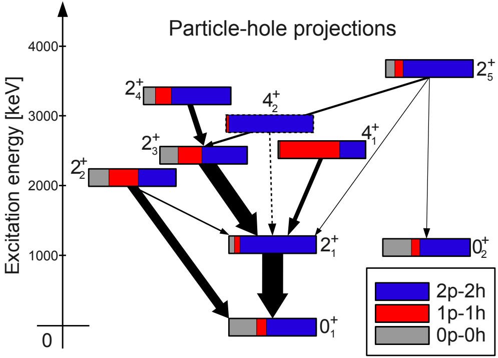
Image taken from: E.C. Simpson et al., 2009.

Level scheme



SDPF-U effective interaction from F. Nowacki and A. Poves Phys. Rev. C 79, 014310 (2009)

P-H projections



- 4^+_2 predicted with $\sigma < 1\mu$b. For 4^+_1, $\sigma \approx 32\mu$b.
- Comparison with lineshape simulations suggest half-life $\sim$50 ps.

Summary

- Magic numbers can be reproduced by simple SM (stable nuclei).
- In some cases (^{44}S), far from stability shells "breaks" (deformation).
- For ^{44}S, we reported 5 previously unobserved γ-rays transitions (3 spin assignments)
- New level scheme was proposed using the reported 0_2^+.
- SM (SDPF-U) predictions are consistent with exp. $E_{exc} < 2.7$ MeV.
- Fundamentally diff. conf. 4_1^+ (1p-1h). Suggestion of half-life $\sim$50 ps (to be measure).
- The tree coexisting neutron-configurations are then: 2p-2h for the *deformed* 0_1^+, 1p-1h for the 4_1^+ and 0p-0h for the isomeric state 0_2^+.

Thank you.