Gamma-spectroscopy of neutron-dripline nuclei ^{46}S and ^{47}S

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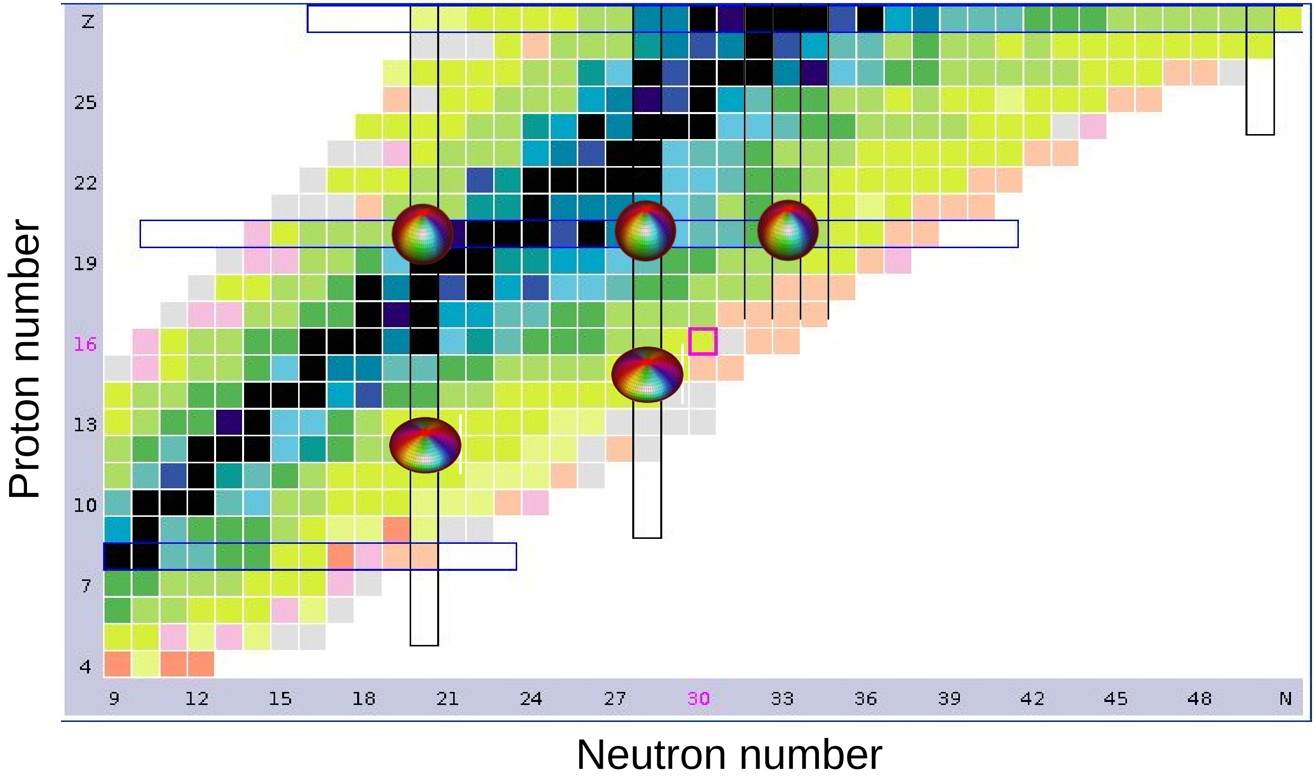
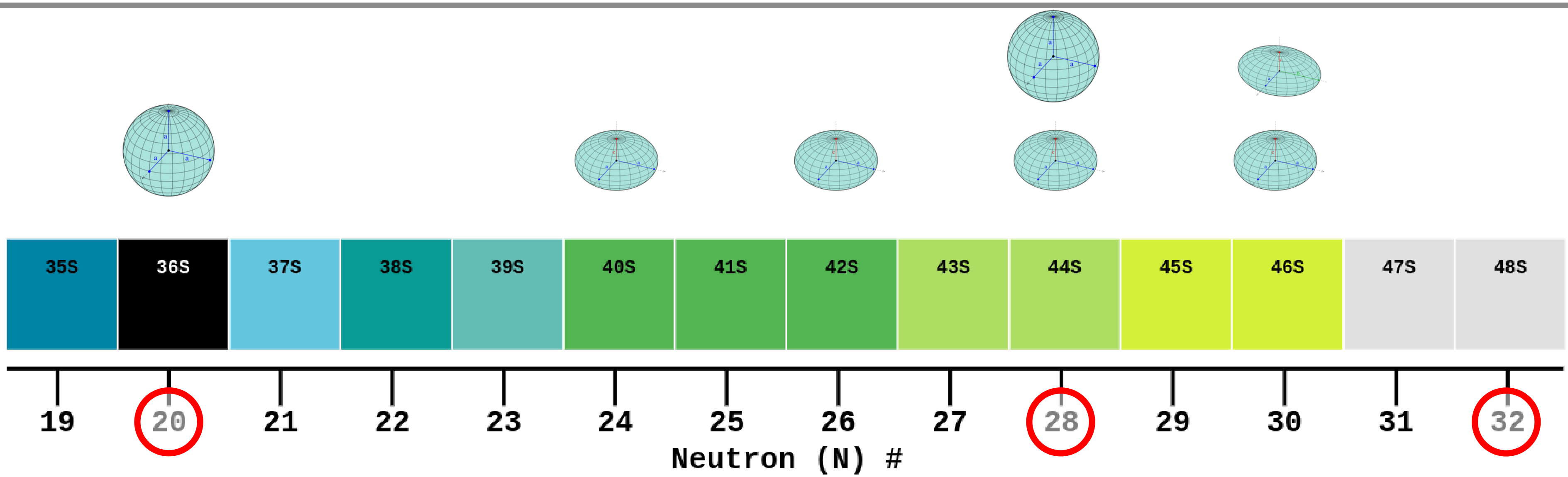
on behalf of SUNFLOWER and Seastar collaborations

Motivation



Neutron rich nuclei with A~ 30-50 exhibit interesting nuclear structure phenomena: the N=20 and N=28 neutron shell closures disappear at larger N/Z ratios, new subshell closures evolves at N=32 and 34, islands of deformation emerge, shape coexistence appears.

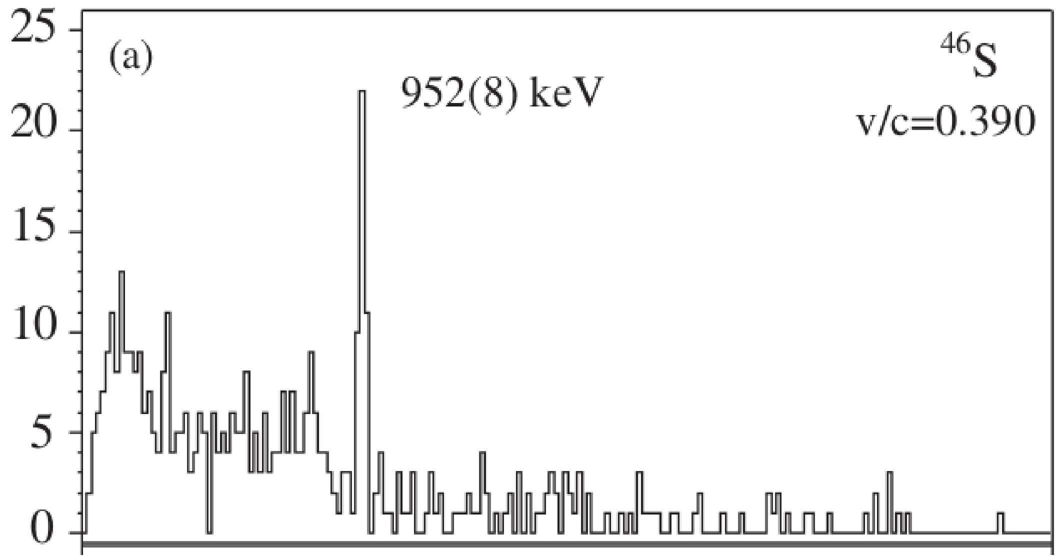
Motivation



Neutron rich Sulphur nuclei show several deformation related phenomena:

- ^{36}S with N=20 is spherical
- Midshell nuclei ^{40}S and ^{42}S have prolate shape
- ^{44}S: the N=28 shell closure disappears, belongs to the island of deformation with A~40
- ^{46}S and ^{47}S: located between the N=28 and the N=32 (sub)shell closures, appearance of triaxial shape have been predicted in ^{46}S

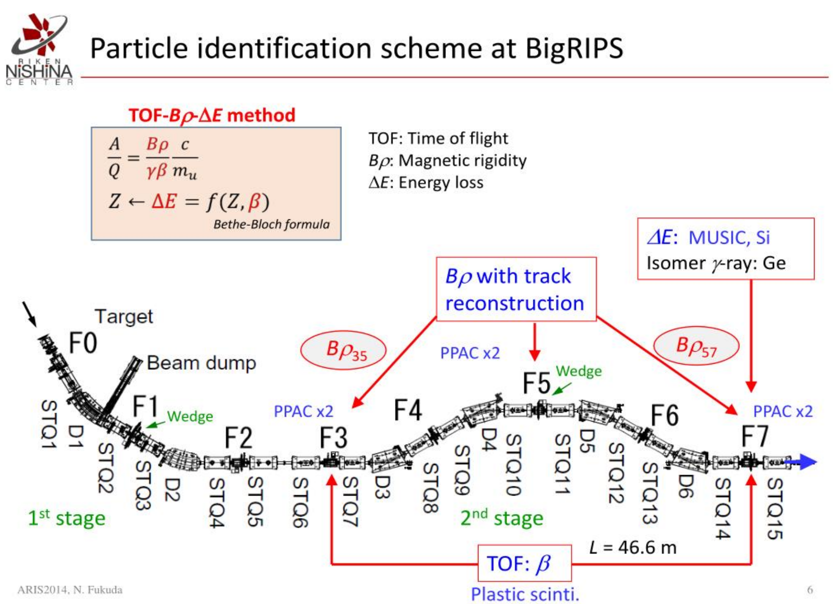
Prior information on these nuclei

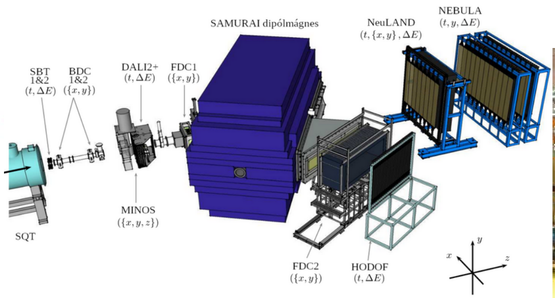


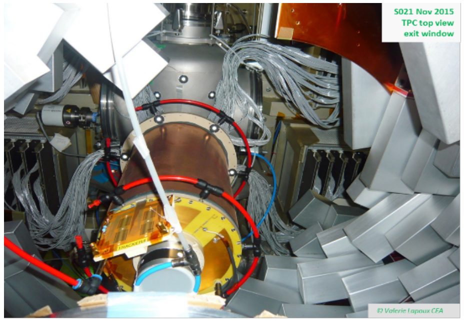
- A. Gade et. al.: In-beam gamma-ray spectroscopy of very neutron-rich nuclei: excited states in ^{46}S and ^{48}Ar,

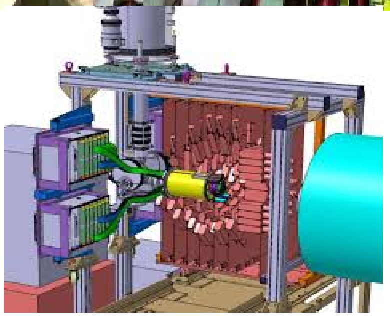
  PRL 102, 182502 (2009)
- 2^+ state of ^{46}S was found @ 952 keV
- ^{47}S there is no spectroscopic information for this nucleus

Experimental setup



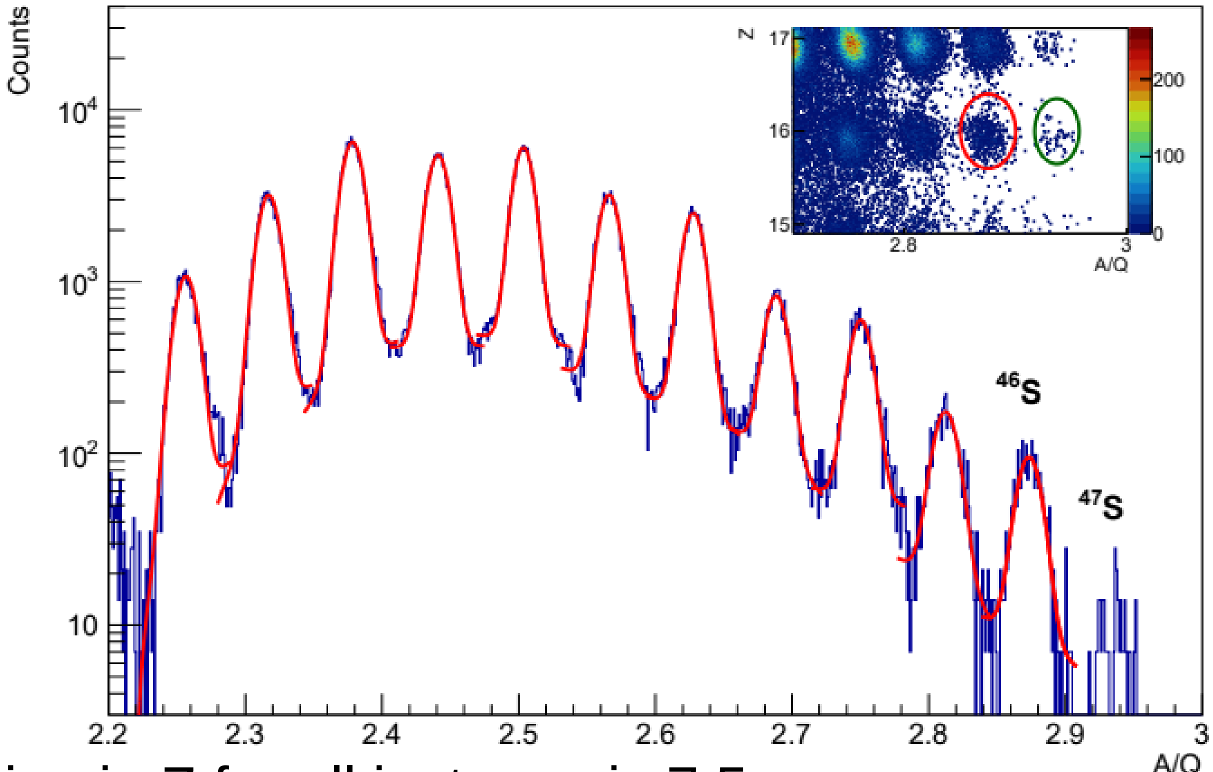






- The experiment: carried out at the RIBF at RIKEN Nishina Center.
- Data: last SEASTAR campaign optimized for nuclei around ^{56}Ca.
- Primary beam: ^{70}Zn @ 345 MeV/u with 240 pnA on ^{9}Be 10-mm thick target
- Secondary beam: BigRIPS separator A/Q identification by Bρ−ΔE−TOF
- Secondary target: MINOS 151-mm-long lH2 device + cylindrical TPC
- A/Q identification of fragments:SAMURAI spectrometer by Bρ−ΔE−TOF
- Gamma-rays: DALI2+ NaI detector array

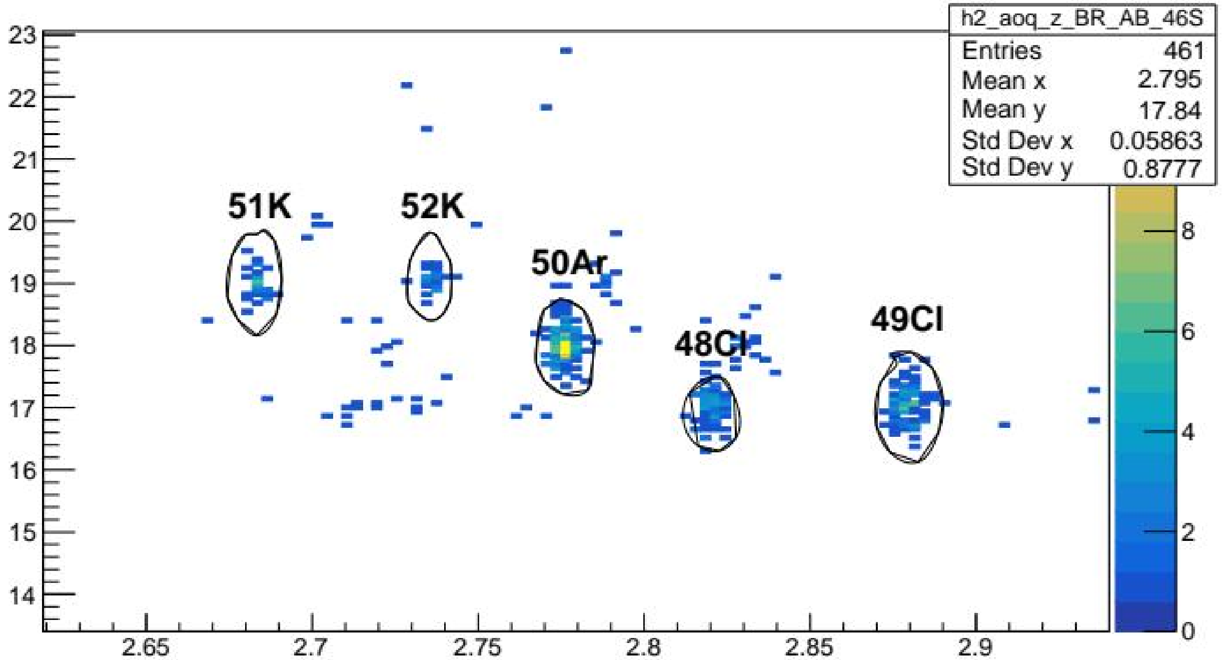
Identification of nuclei ^{46}S and ^{47}S



- separation in Z for all isotopes is 7.5 σ,
- separation in A/Q for S isotopes is 9.4 σ
- ^{46}S and ^{47}S are well separated, and unambiguously identified

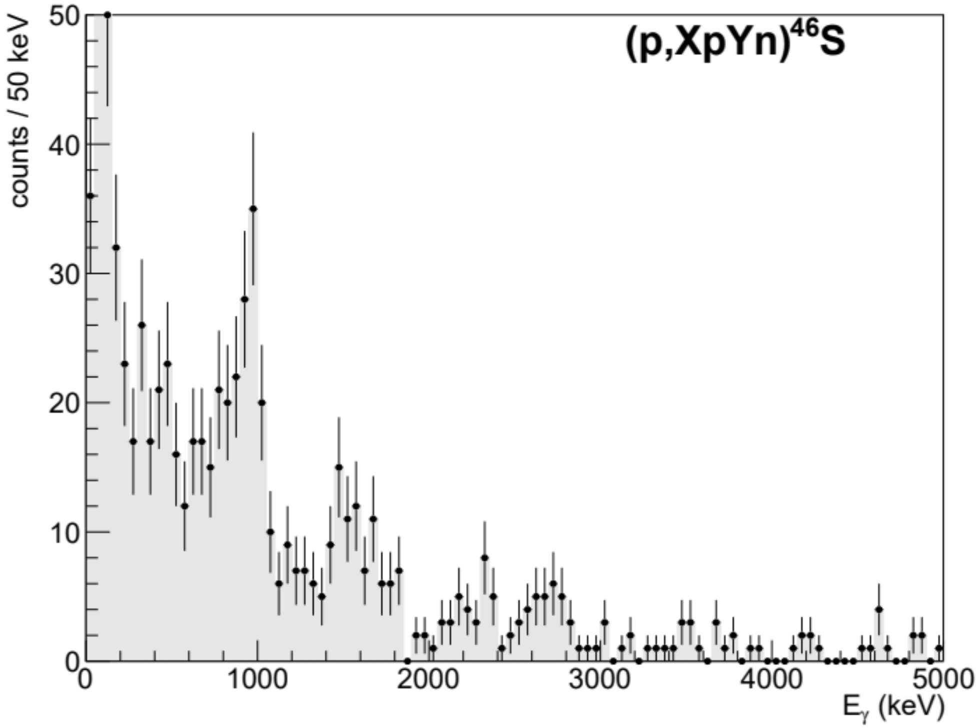
Production of ^{46}S

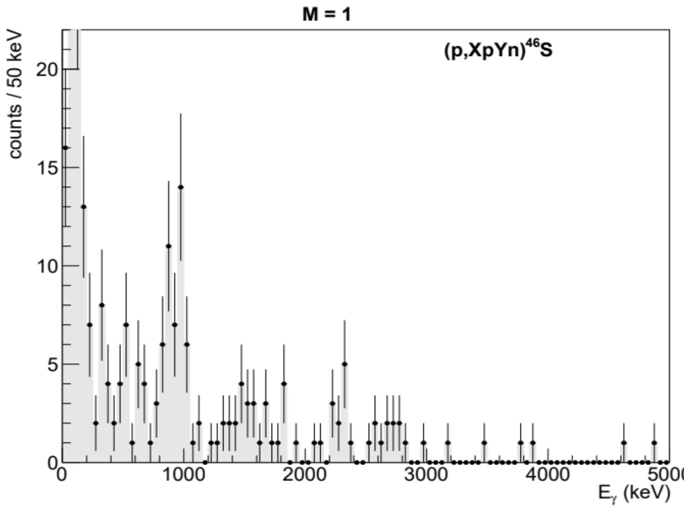
- ^{46}S were produced mainly by 2p2n, and to a lesser extent by 1p2n and 1p1n knockout reactions from ^{50}Ar, ^{49}Cl, and ^{48}Cl secondary beams
- A total of 380 events leading to ^{46}S were counted

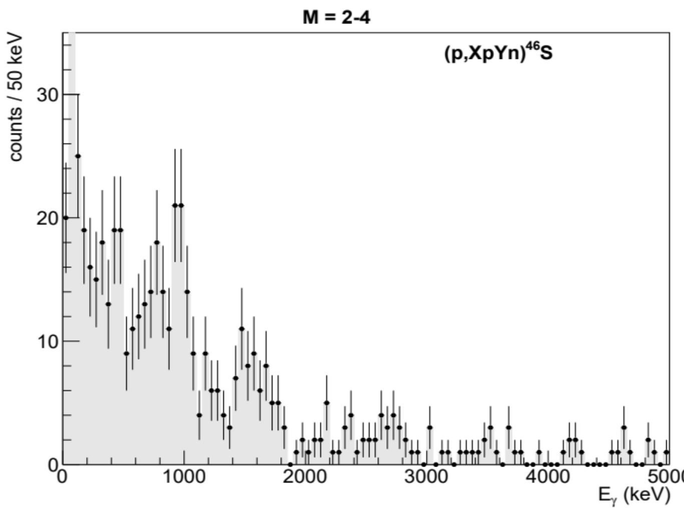


	^{46}S
^{48}Cl (p,2p1n)	66
^{49}Cl (p,2p2n)	93
^{50}Ar (p,3p2n)	162
^{51}K (p,4p2n)	35
^{52}K (p,4p3n)	24
Total	380

Gamma-ray spectra of ^{46}S

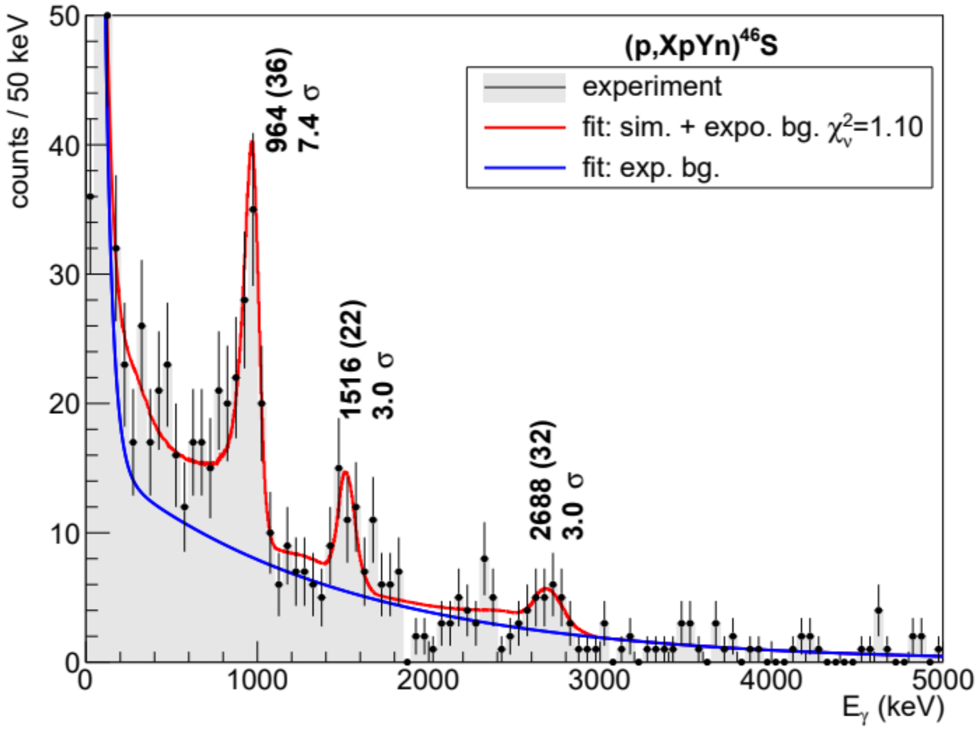


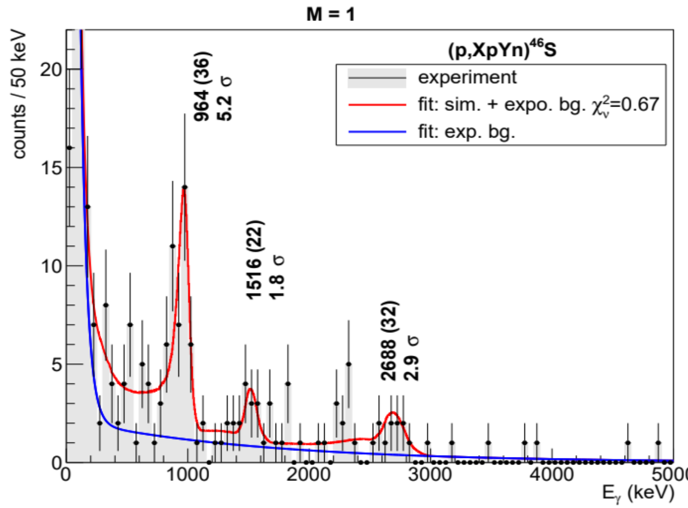


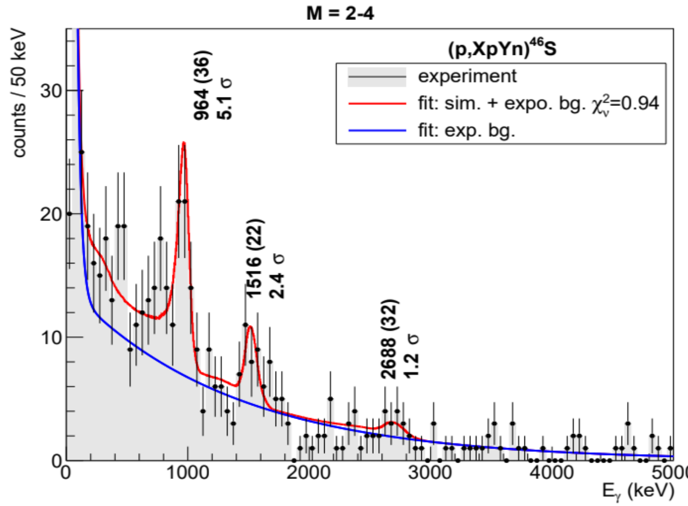


- 3 peaks: the most intense one around 950 keV, two smaller at around 1500 and 2700 keV
- M=1: peak at ~950 keV is increased
- M=2-4: peaks at ~1500 and ~2700 keV are increased, peak at ~750 keV appears

Gamma-ray spectra of ^{46}S

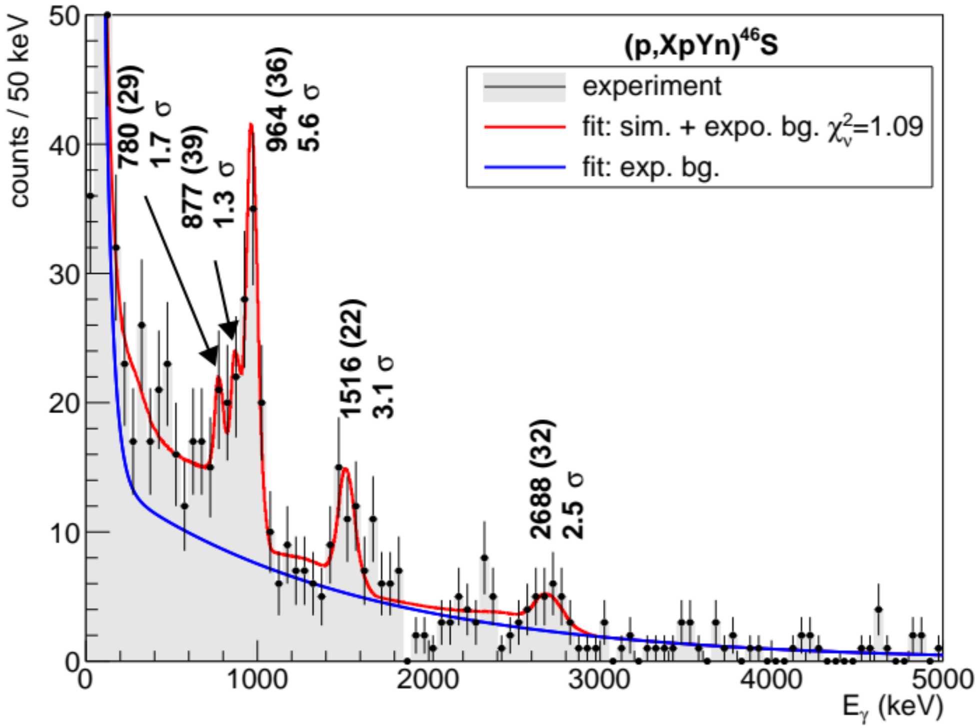


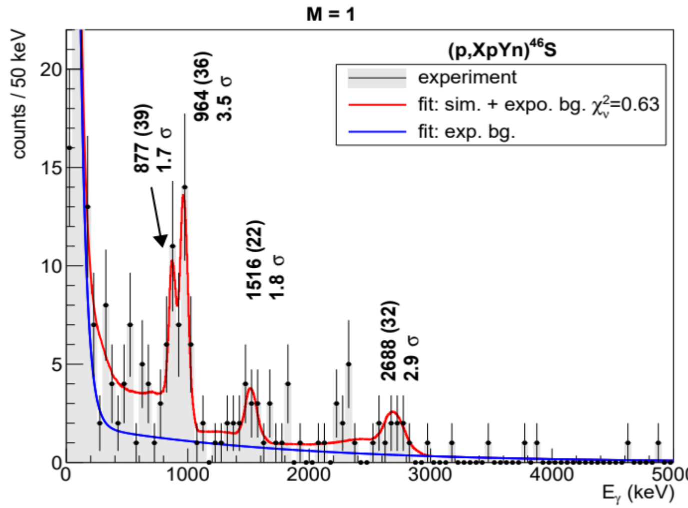


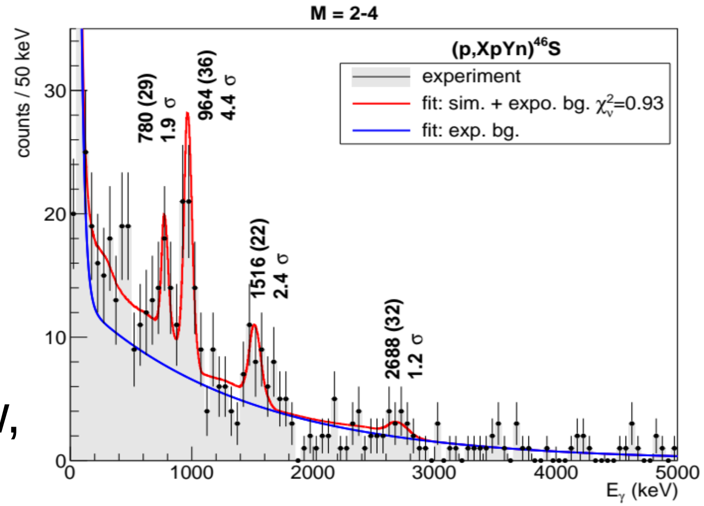


To describe the wide peak at ~950 keV at least 200 ps half life has to be assumed, but the appearance of a peak at ~750 keV in the M=2-4 spectrum contradicts this assumption.

Gamma-ray spectra of ^{46}S

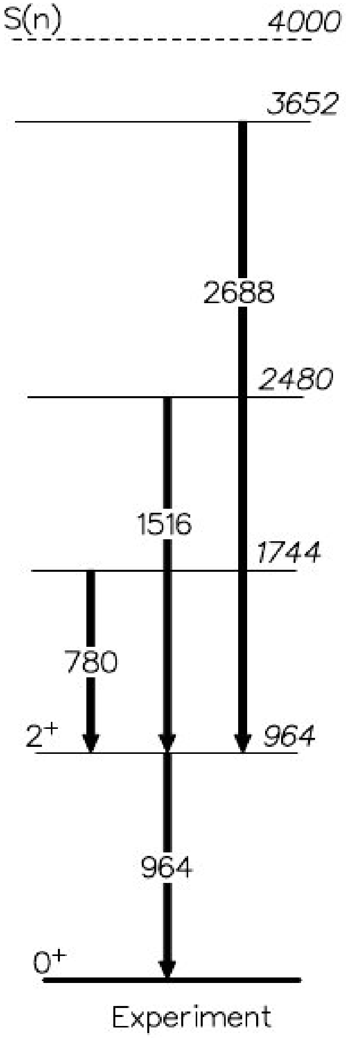






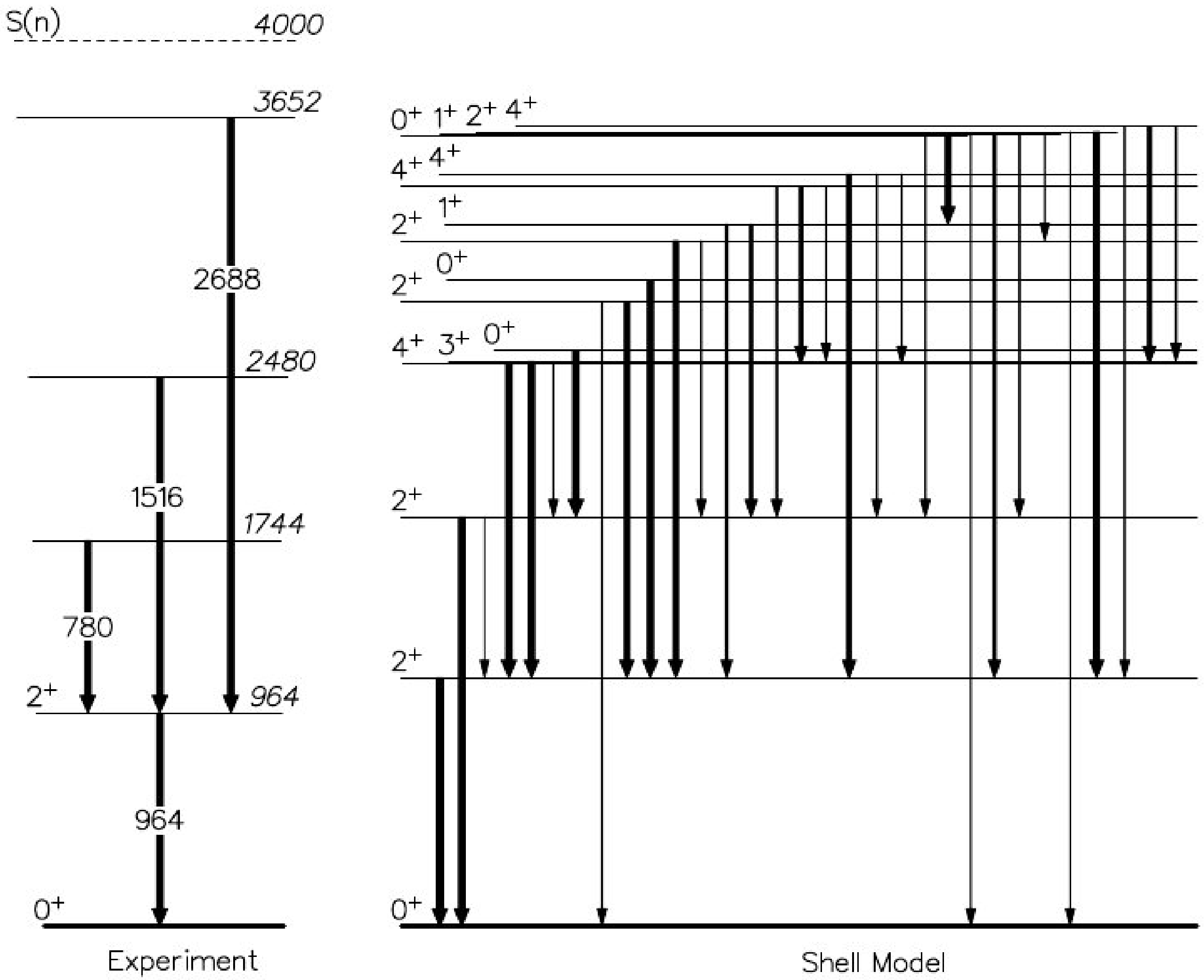
- Using prompt peaks the fit with 5 gamma line yields the best result.
- As the significance of the peak at 877 keV is low, we assign 4 peaks to ^{46}S.

Level scheme obtained for ^{46}S



- We confirm the $2^+ \rightarrow 0^+$ transition.
- Due to the low statistics we could not deduce gamma-gamma coincidence information.
- Based on increased intensity of the new transitions in the M=2-4 spectra they are placed decaying to the 2^+ state.

Comparision of experimental results to theoretical calculations for ^{46}S



Large Scale SM gives a good description.

Based on the BRs and the population of the states in multinucleon knockout reactions:

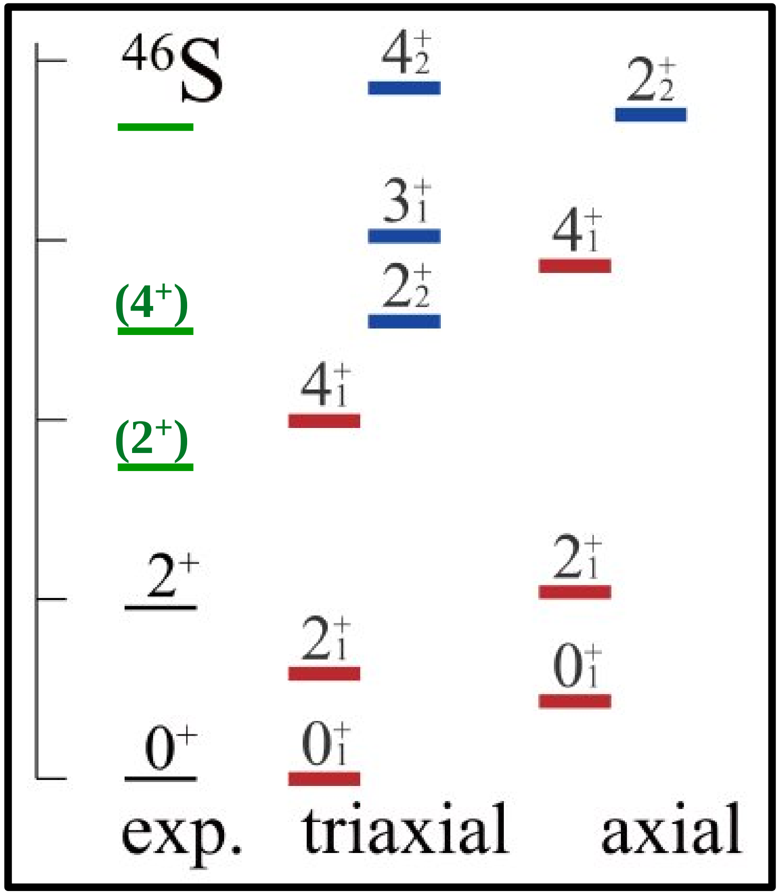
- 1744-keV state → 2^+_2
- 2480-keV state → 4^+_1
- 3652-keV state → 2^+_5

Comparision of experimental results to theoretical calculations for ^{46}S

E_{4+}/E_{2+} ratio: 2.57

- Vibrator: 3.33
- Rotor: 2.00
- Davydov-Filippov model, triaxial rotor: ~2.6

GCM calculations predict the triaxial shape beside the prolate shape.



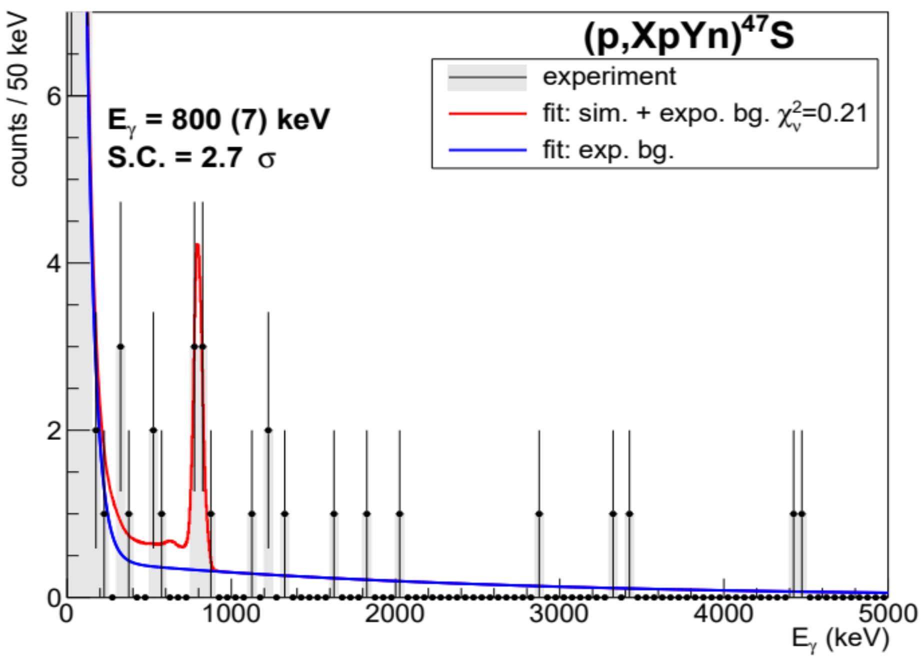
Y. Suzuki and M. Kimura, PRC 104, 024327 (2021)

Production of ^{47}S

- Secondary beam particles are similar as in the case of ^{46}S
- ^{47}S were produced from ^{48}Cl, ^{49}Cl, and ^{50}Ar via 1p, 1p1n,and 2p1n knockout reactions
- The statistics is very low, altogether 57 events could be collected

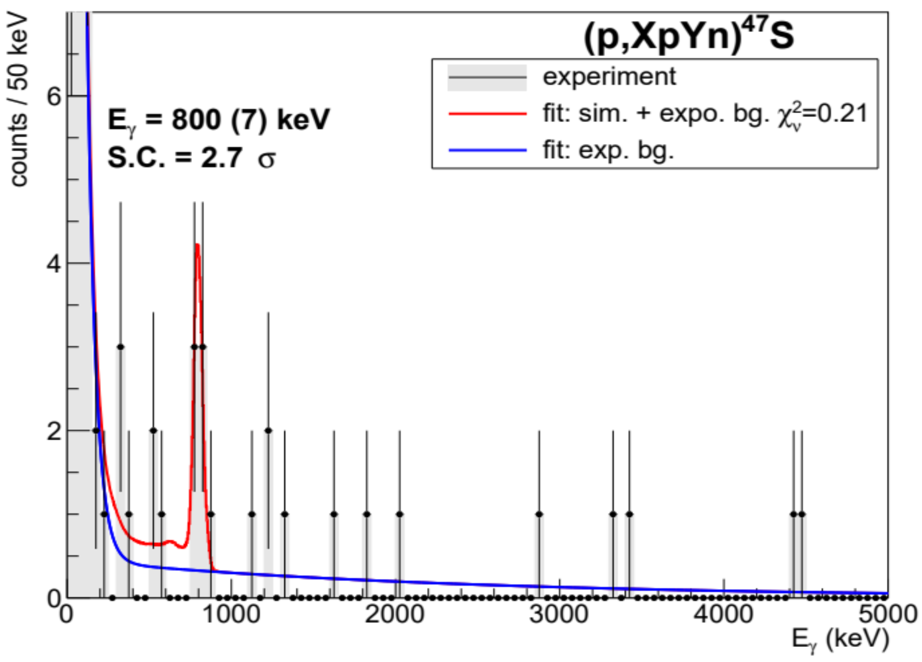
Gamma-ray spectrum of ^{47}S

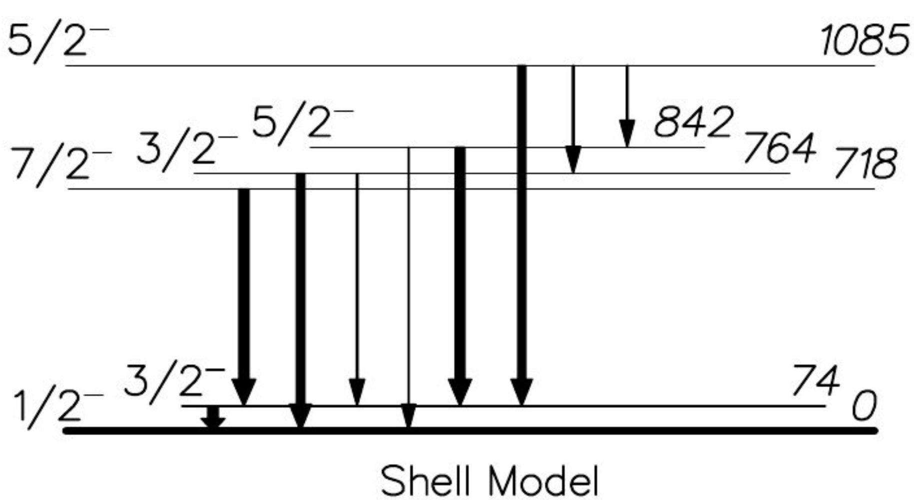
- Because of the low statistics background parameters obtained from ^{46}S
- A sharp peak at 800 keV is clearly visible in the spectrum



Gamma-ray spectrum of ^{47}S

- Because of the low statistics background parameters obtained from ^{46}S
- A sharp peak at 800 keV is clearly visible in the spectrum
- Large-scale SM calculations show that there are several possible theoretical counterparts for this transition





Summary

- Excited states of ^{46}S and ^{47}S have been studied by multinucleon knockout reactions
- New transitions have been assigned to ^{46}S establishing 3 new excited states
- ^{47}S a gamma ray has been identified to it
- Comparision of the experimental results to the theoretical calculations shows an indication for the appearance of triaxial shape in ^{46}S

Thank you for your attention!

M. Begala, D. Sohler, Z. Elekes, M. M. Juhász, Y. Utsuno, T. Otsuka, P. Doornenbal, A. Obertelli, H. Baba, F. Browne, D. Calvet, F. Château, S. Chen, N. Chiga, A. Corsi, M. L. Cortés, A. Delbart, J.-M. Gheller, A. Giganon, A. Gillibert, C. Hilaire, T. Isobe, T. Kobayashi, Y. Kubota, V. Lapoux, T. Motobayashi, I. Murray, H. Otsu, V. Panin, N. Paul, W. Rodriguez, H. Sakurai, M. Sasano, D. Steppenbeck, L. Stuhl, Y. L. Sun, Y. Togano, T. Uesaka, K. Wimmer, K. Yoneda, N. L. Achouri, O. Aktas, T. Aumann, L. X. Chung, F. Flavigny, S. Franchoo, I. Găsparić, R.-B. Gerst, J. Gibelin, K. I. Hahn, D. Kim, T. Koiwai, Y. Kondo, P. Koseoglou, J. Lee, C. Lehr, B.D. Linh, H. N. Liu, T. Lokotko, M. MacCormick, K. Moschner, T. Nakamura, S. Y. Park, D. Rossi, E. Sahin, P.-A. Söderström, S. Takeuchi, H. Törnqvist, V. Vaquero, V. Wagner, S. Wang, V. Werner, X. Xu, H. Yamada, D. Yan, Z. Yang, M. Yasuda, L. Zanetti