QUASI-ELASTIC PROTON SCATTERING ON ^{28}Si and ^{34}S at 1.0 GeV

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This experiment continues our program of nuclear structure studies with (p, 2p) and (p, np) reactions. Earlier, we investigated the 1P-shell nuclei (^{6,7}Li, ^{9}Be, ^{10,11}B, ^{12}C and ^{16}O) /1,2/ as well as some of the 2S—1d shell nuclei (^{24,25,26}Mg, ^{27}Al, ^{32}S, and ^{40}Ca) /3,4/. It was demonstrated that the observed structure of single-particle states was sensitive to nuclear deformation.

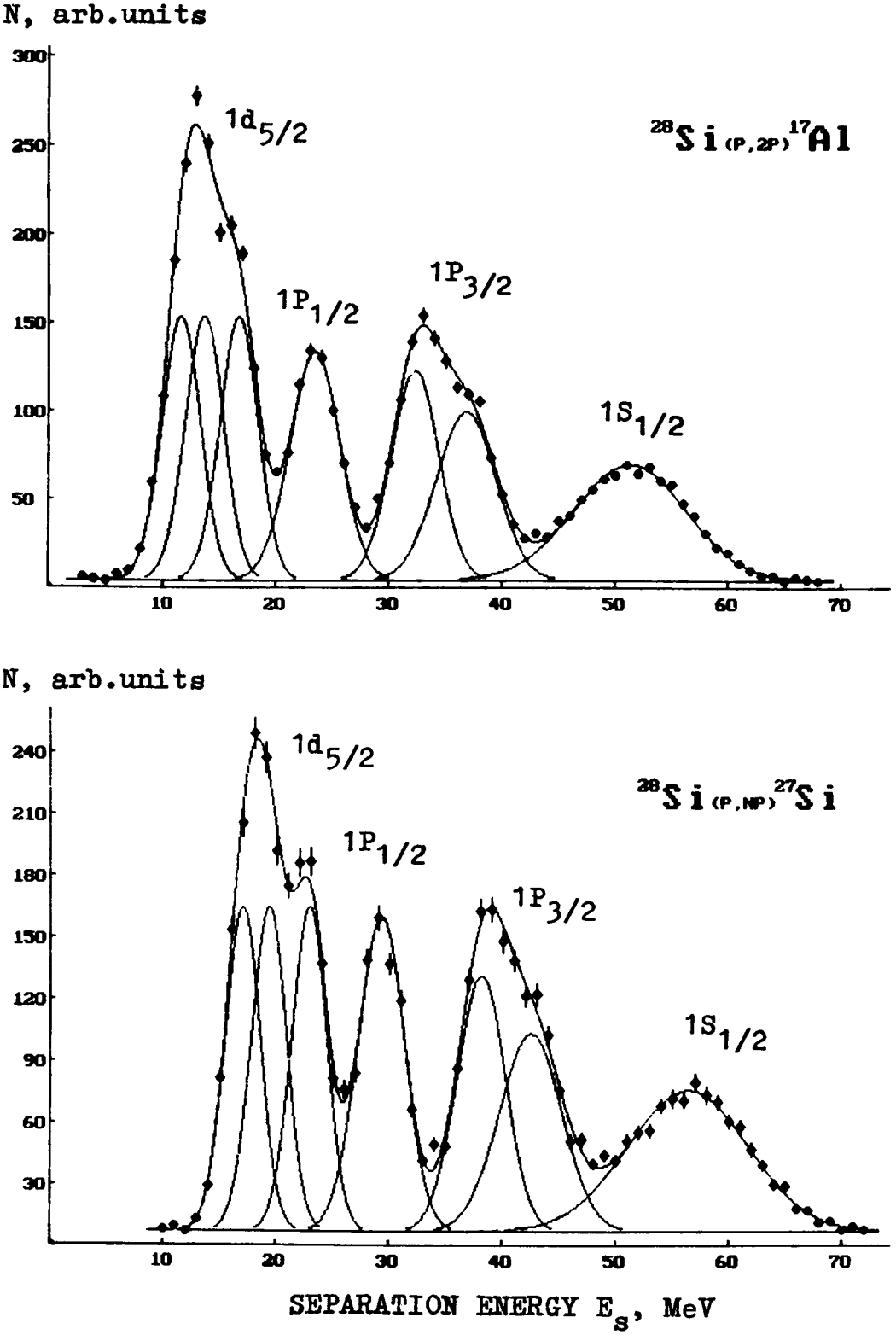
N, arb.units
300
250
200
150
100
50
1d5/2
1P1/2
1P3/2
1S1/2
28Si(p,2p)17Al
10
20
30
40
50
60
70
N, arb.units
240
210
180
150
120
90
60
30
1d5/2
1P1/2
1P3/2
1S1/2
28Si(p,np)27Si
10
20
30
40
50
60
70
SEPARATION ENERGY Es, MeV

Fig. 1

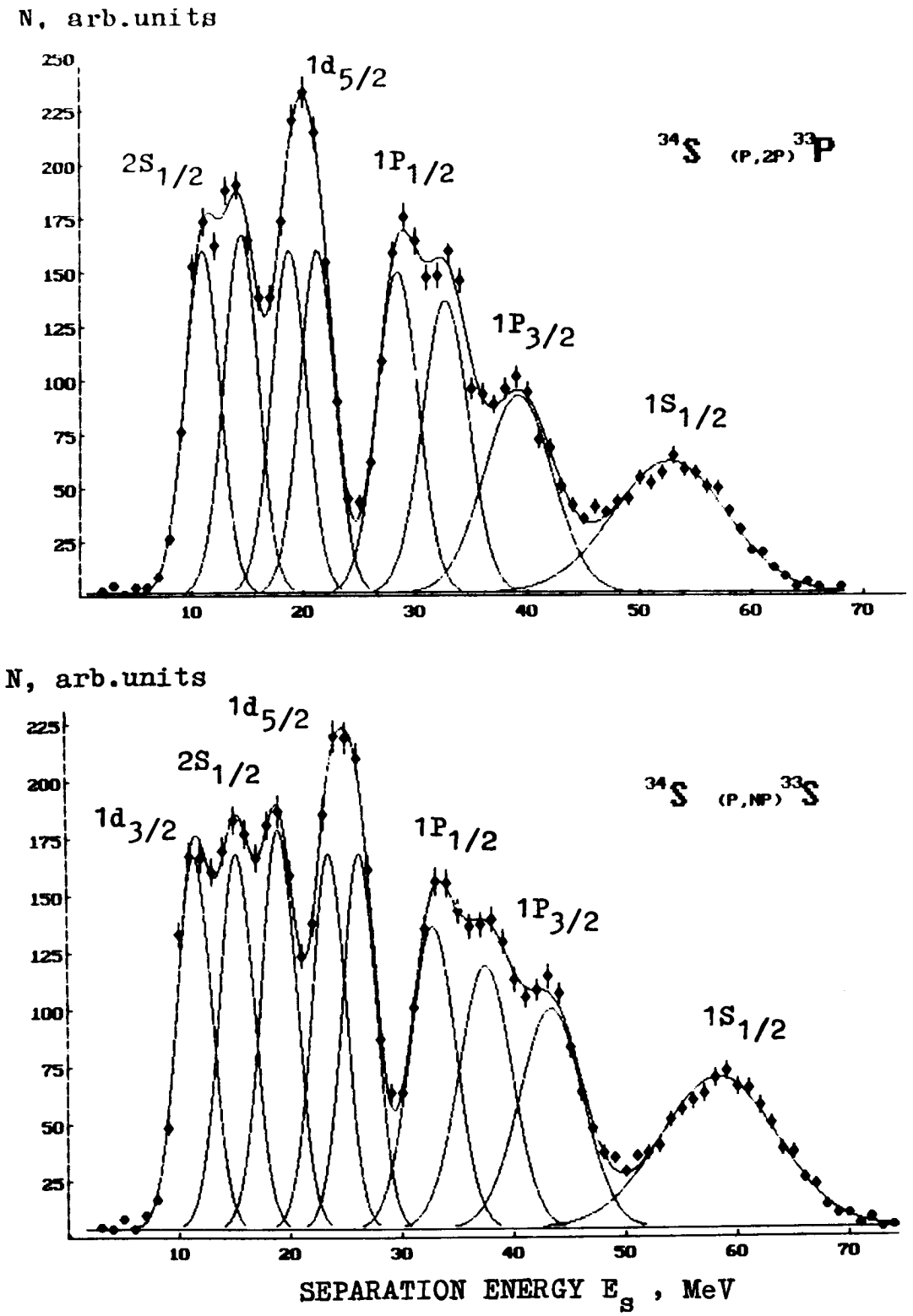
N, arb.units
250
225
200
175
150
125
100
75
50
25
10
20
30
40
50
60
70
1d5/2
2S1/2
1P1/2
1P3/2
1S1/2
34S (P,2P) 33P
N, arb.units
225
200
175
150
125
100
75
50
25
10
20
30
40
50
60
70
1d5/2
2S1/2
1d3/2
1P1/2
1P3/2
1S1/2
34S (P,NP) 33S
SEPARATION ENERGY Es , MeV

Fig. 2

Nuclear models predict the appearance of negative nuclear deformation (oblate nuclear shapes) in some of the 2S-1d shell nuclei. According to these models, negative static deformation may take place when the $1d_{5/2}$-shell is filled completely including the subshell $\Omega^{\pi}=5/2^{+}$ which originates from the $1d_{5/2}$-shell splitting in the axial nuclear potential. In particular, the Hartree-Fock calculations show that the negative and positive deformation should be almost energy-equivalent in ^{25}Mg, while in ^{27}Al the oblate shape is expected to be energy-preferable. This situation should remain until the $2S_{1/2}$-shell filling restores the prolate shape of the nucleus.

However, our experiments with ^{24,25,26}Mg, ^{27}Al, and ^{32}S have shown that the single-particle states in all these nuclei were consistent with axially symmetric positive deformation of the nuclear potentials. Similar contradiction between theory and experiment was observed in heavy nuclei /5/. No explanation for such behaviour of the nuclear shapes being found, the problem remains open.

This situation stimulated further investigation of the 2S—1d nuclei. Here we present the measured separation energy spectra for protons and neutrons in ^{28}Si and ^{34}S (fig. 1 and fig. 2). One can see the difference in the structure of these spectra that proved to be quite important. In the ^{34}S spectra (fig. 2), all three 1P-shell levels are equidistant, and this is what one should expect in the case of positive deformation of the nuclear potential. On the other hand, the positions of the 1P-levels in ^{28}Si are not equidistant (fig. 1). The $1P_{1/2}$-level is quite separate from the $1P_{3/2}$-levels that can be interpreted as a manifestation of the negative deformation of the nuclear potential in this nucleus. Such a conclusion is supported by a quantitative analysis in the framework of a semi-selfconsistent model /6/. In fact, it follows from this analysis that the proton and neutron densities in ^{28}Si both have negative deformation with nearly equal deformation parameters:

$$\beta_p \approx \beta_n \approx -0.23 .$$

To study the observed effect in greater details, we plan to perform the (p,Np) — scattering experiment with all stable silicon isotopes.

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