Spin and Parity of the 4.841-MeV Level of ^{208}Pb†

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A level at 4.841 MeV in ^{208}Pb previously claimed to be 1^+ is shown to be 1^- by its large yield in inelastic α-particle scattering from ^{208}Pb.

A recent Letter[1] claimed that a state in ^{208}Pb at 4.843 MeV with a ground-state decay width of 5.1 ± 0.8 eV has spin-parity $J^\pi = 1^+$. This particular assignment is difficult to square with any theoretical[2-4] treatments of $M1$ transitions in ^{208}Pb, insofar as none of the existing calculations can account for this large $M1$ strength $[B(M1) = (3.8 \pm 0.6)(eh/2mc)^2]$ at such low excitation energy. The reasons for this difficulty are simple. The principal configurations contributing to $M1$ excitations built on the ^{208}Pb ground state are $(i_{11/2}\text{-}i_{13/2}{}^{-1})^{1^+}$ neutron particle holes and $(h_{9/2}h_{11/2}{}^{-1})^{1^+}$ proton particle holes. As these particle-hole excitations are nearly degenerate in energy, the residual interaction mixes them rather completely. One resulting eigenstate takes on the character of an isovector excitation and has a sizable $M1$ rate $[B(M1)\sim 16(eh/2m_pc)^2]$ while the other is predominantly isoscalar and has a correspondingly much slower decay rate $[B(M1)\sim 0.4(eh/2m_pc)^2]$. The isovector strength has likely been observed,[5] in previous work, at very nearly the theoretically predicted energy.[2] It would therefore be surprising to find a low-lying state with a relatively large $M1$ transition probability. However, it should be pointed out that attempts to locate the "isoscalar" 1^+ strength have been unsuccessful.[6]

A very recent theoretical paper[7] (motivated by the result of Ref. 1) including 2-particle, 2-hole configurations in the basis set describing the 1^+ states is not able to obtain any sizable component of $M1$ strength as low as 4.84 MeV in ^{208}Pb.

As there seems to be no doubt that the spin of this level[8,9] is 1, the only question remaining is to fix its parity. The parity was fixed in Ref. 1

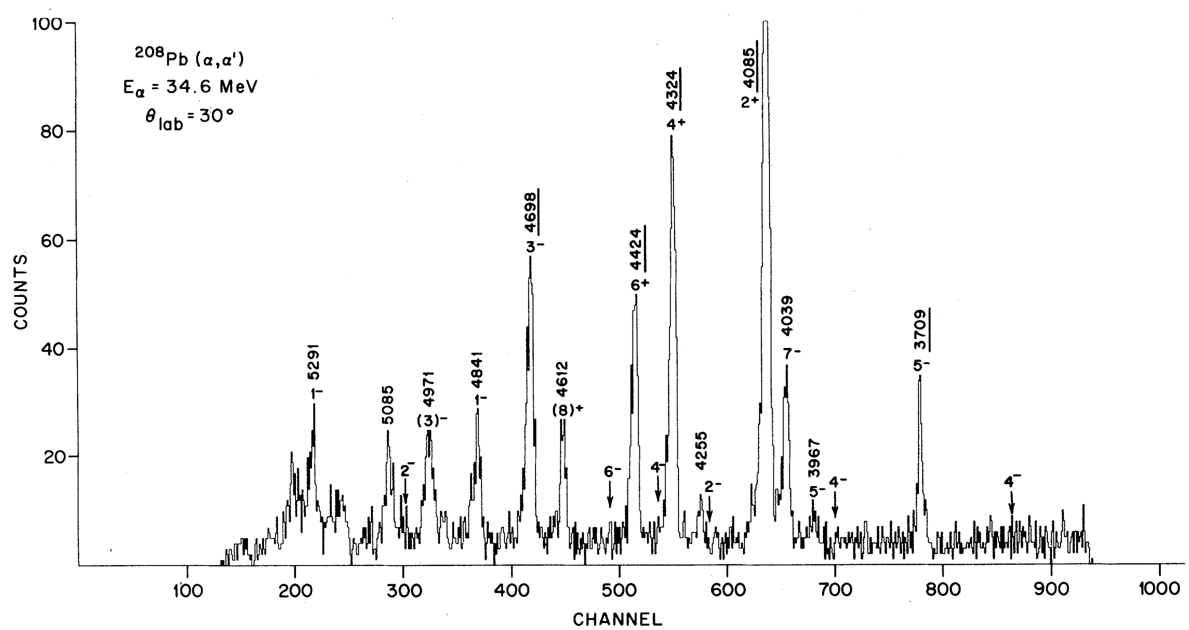

FIG. 1. The partial energy spectrum of 34.7-MeV incident α particles inelastically scattered from ^{208}Pb at 30°. The expected positions, of known unnatural parity-levels are indicated by arrows.

by measuring the linear polarization of the decaying radiation using two Ge detectors operated in coincidence as a polarimeter. The result obtained was consistent with positive parity being four standard deviations from the value expected if the parity of the 4.843-MeV level were negative.

In light of the difficulties precipitated by this result, we attempted to check the parity assignment by investigating inelastic α scattering from ^{208}Pb. One recalls in first order the excitation of unnatural parity $[(-1)^{J+1}]$ states is forbidden[10] in inelastic α scattering. If a level is weakly excited, one may not infer that its spin parity is unnatural, but strong excitation of a level is decisive evidence for its natural parity.

Figure 1 shows the energy spectrum in the region of interest for 34.6-MeV α particles inelastically scattered at 30° to the beam. The spectrum obtained, using the new Princeton University *QDDD* magnetic spectrometer, has a resolution (full width at half-maximum) of 17 keV. Yield to a level at 4.841 ± 0.005 MeV is clearly evident in this spectrum. Note the absence of yield to known[11,12] unnatural-parity states at 3.475 (4^-), 3.919 (4^-), 4.230 (2^-), 4.357 (4^-), 4.480 (6^-), and 5.036 (2^-) levels. There is a 1^- level at 5.291 MeV which also has a radiative width[8] of approximately 5.0 eV. The ratio of the integrated yield of inelastically scattered α particles to this level to the spin-1 level at 4.841 MeV is 0.9 ± 0.1 over the range of angles (20–50°) we have investigated. A recent[13] careful study of inelastic proton scattering on ^{208}Pb with 6–8-keV resolution indicated no state within 22 keV of the 4.841-MeV state and hence we believe that we are measuring yield to the same level referred to by Swann.

We must therefore conclude that the parity of the spin-1 level at 4.841 MeV is negative; this assignment presents no difficulty for current nuclear theories.

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