unchanged wave function is in contrast to collective rotation. Instead, collective rotation is characterised by small angular momentum contributions from a large number of particles, i.e. the wave functions of these particles change slowly with increasing angular momentum.

What has been said above implies that only deformed nuclei can rotate collectively and, if the nucleus is axially symmetric, the only possible rotation axis is perpendicular to the symmetry axis. For collective rotation, it is then also possible to define *one* moment of inertia, $\mathscr{J}$, leading to the following Hamiltonian

$$H_{\text{rot}} = \frac{\mathbf{R}^2}{2\mathscr{J}}$$

where $\mathbf{R}$ is the collective angular momentum. For pure collective rotation the total angular momentum (often referred to as the total spin) $\mathbf{I}$ is equal to $\mathbf{R}$. The spectrum then takes the form

$$E_I = \frac{\hbar^2}{2\mathscr{J}} I(I+1).$$

As only deformed nuclei exhibit rotational spectra, it should be possible to determine which nuclei are deformed from the occurrence of rotational bands. In practice, really pure rotational bands are never realised in nuclei but instead, rotations and vibrations are more or less mixed. Even so, with a not very strict definition of a rotational band, it becomes possible to define approximately which nuclei are deformed as exemplified in fig. 11.1.

The moment of inertia $\mathscr{J}$ can be extracted from measured rotational bands. The values for deformed nuclei in the rare earth region are exhibited in fig. 11.2 together with calculated values. The experimental values are generally 25–50% of the rigid body values and can be calculated with any accuracy only when pairing correlations are introduced (appendix 14B). A simpler way to get an estimate of $\mathscr{J}$ is within the two-fluid model (see e.g. Rowe, 1970) where it is assumed that only nucleons outside the largest possible central sphere give any contribution to $\mathscr{J}$ (problem 11.1).

It was discussed in chapter 6 how the valence particle outside a spherical core determines the ground state angular momentum. This is thus a typical single-particle effect and, similarly, several valence particles may partly or fully align their angular momentum vectors to build higher spin states. Also, in deformed nuclei, similar non-collective components may be present and in this chapter we will discuss the low-energy spectra of more or less well-deformed nuclei as a mixture of single-particle and collective components where the latter are treated macroscopically. With increasing spin it becomes necessary to consider the single-particle contribution from more particles