Pairing Theory of the Wigner Cusp

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Subtracting the Coulomb energy from the mass of a nucleus results in what may be called the Coulomb reduced mass. In 1936, Bethe and Bacher suggested that the latter increases from $N = Z$ approximately quadratically in $N - Z$, where N and Z are the numbers of neutrons and protons. Myers and Swiatecki found in 1966 a marked deviation from this rule; for small $|N - Z|$ the Coulomb reduced mass rises more rapidly. They called the apparent extra binding energy in the vicinity of $N = Z$ the Wigner energy. It will be shown that this nonanalytic behaviour of the mass as a function of $N - Z$, referred to as the Wigner cusp, arises naturally when the pairing force is treated in the random phase approximation (RPA). In the limit of equidistant single nucleon levels the increment of the Coulomb reduced mass from $N = Z$ is approximately proportional to $T(T + 1)$, where T is the isospin, equal to $|N - Z|/2$ in the ground state of a doubly even nucleus. Excitation energies proportional to $T(T+1)$ resemble the spectrum of a quantal, axially symmetric rotor. In 1999, Frauendorf and Scheikh identified the superfluid pair gap as the deformation which gives rise to an analogous rotation in isospace. Recent work by Bentley and Frauendorf in collaboration with the speaker applied a Strutinskij renormalised independent nucleons plus pairing Hamiltonian to the description of nuclei in the the vicinity of $N = Z$. The theory includes a Strutinskij renormalisation of the RPA contribution to the total energy. This theory reproduces quite well the empirical masses in the vicinity of $N = Z$ for $A \geq 24$, including the Wigner cusps and the splitting of the lowest levels with $T = 0$ and 1 in the doubly odd $N = Z$ nuclei. While it is crucial for this result that the liquid drop symmetry energy is similar to the symmetry part of the Strutinskij counterterm to the RPA energy in being proportional to $T(T + 1)$ rather than T^2, large shell corrections modify this bulk behaviour. Apart from providing a microscopic foundation of the assumption of a $T(T + 1)$ bulk symmetry energy, the RPA contribution is of little significance for the reproduction of the data.