Double beta decay in deformed nuclei

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A) Project Overview

- Neutrinoless DBD matrix elements (beyond-standard-model physics, neutrino properties)
- Prof. J. Engel, Dr. M.T. Mustonen (Dr. M. Braby, Mr. T. Schafer)
- Nuclear model code by Dr. J. Terasaki
- UNEDF SciDAC collaboration (DoE grant), NSF Teragrid

B) Science Lesson

- Nuclear model part (JT) solves the Hamiltonian for deformed nuclei (constructs and diagonalizes a huge matrix)
- DBD part (MM) will calculate the double-beta-decay matrix elements

C) Parallel Programming Model

- MPI and OpenMP
- Fortran 90/95
- ScaLAPACK
- Kraken at ORNL (Cray XT5)
- Plan: Don't touch the nuclear model part (unless necessary), program the DBD part

D) Computational Methods

- Numerical integration (1D and 2D)
- B-splines represent single-ple wfns
- Iterative minimization in the nuclear model codes
- Matrix algebra: ScaLAPACK
- Status: nuclear model codes ready, DBD part in planning

E) I/O Patterns and Strategy

- Nuclear code: one file per MPI process
- DBD code: undecided
- ~100 000 nuclear states
- Nuclear code is a chain of different programs, one's output is the next's input

F) Visualization and Analysis

- Results are mostly simple numbers (ME translates to half-life); no fancy automatic visualization
- Nuclear code part produces some easy-to-visualize data of e.g. evolution of physical variables as iteration proceeds

G) Performance

- No performance analysis yet
- Probable bottleneck: Integration over intermediate neutrino momenta contains a product of two 2D integrals (which can be tabulated to avoid calculating the same integral 10^5 times)

H) Tools

- Debugging the old-fashioned way: testing each function as soon as they are written, building from bottom up, printing out intermediate results

I) Status and Scalability

- Status: Just starting – learning how to operate the nuclear code, planning how to write the DBD part
- In principle, the time-consuming part of the DBD code should parallelize easily (large number of independent terms to be summed up in the end)

J) Roadmap

- Application of the DBD code by the end of the year
- Publishing first results early next year?
- If funding continues, adding e.g. neglected terms of the neutrino potential, short-range correlations... studying their effects