PRESPEC & The (Time-Dependent) Mean Field

Dr Paul D Stevenson
University of Surrey

PRESPEC Topics

1) Isomer and metastable decays and associated nuclear structure tests, including shell model configurations around magic numbers, seniority and core excitation isomers.

2) Shell model physics around 56Ni, 100Sn, 132Sn and 208Pb.

3) Beta-delayed spectroscopy of heavy, neutron-rich isotopes associated with shape evolution.

4) 'Fast-timing' measurements of nuclear states using arrays of LaBr3 detectors.

5) Measurements of decay heat and beta-delayed neutron emission probability from **fission fragments**.

6) Limits of the nuclear chart by measured by proton radioactivity

7) Studies of isospin symmetry and mixing, and B(GT) **strength measurements**.

8) Beta-delayed neutron measurements of relevance to astrophysical scenarios

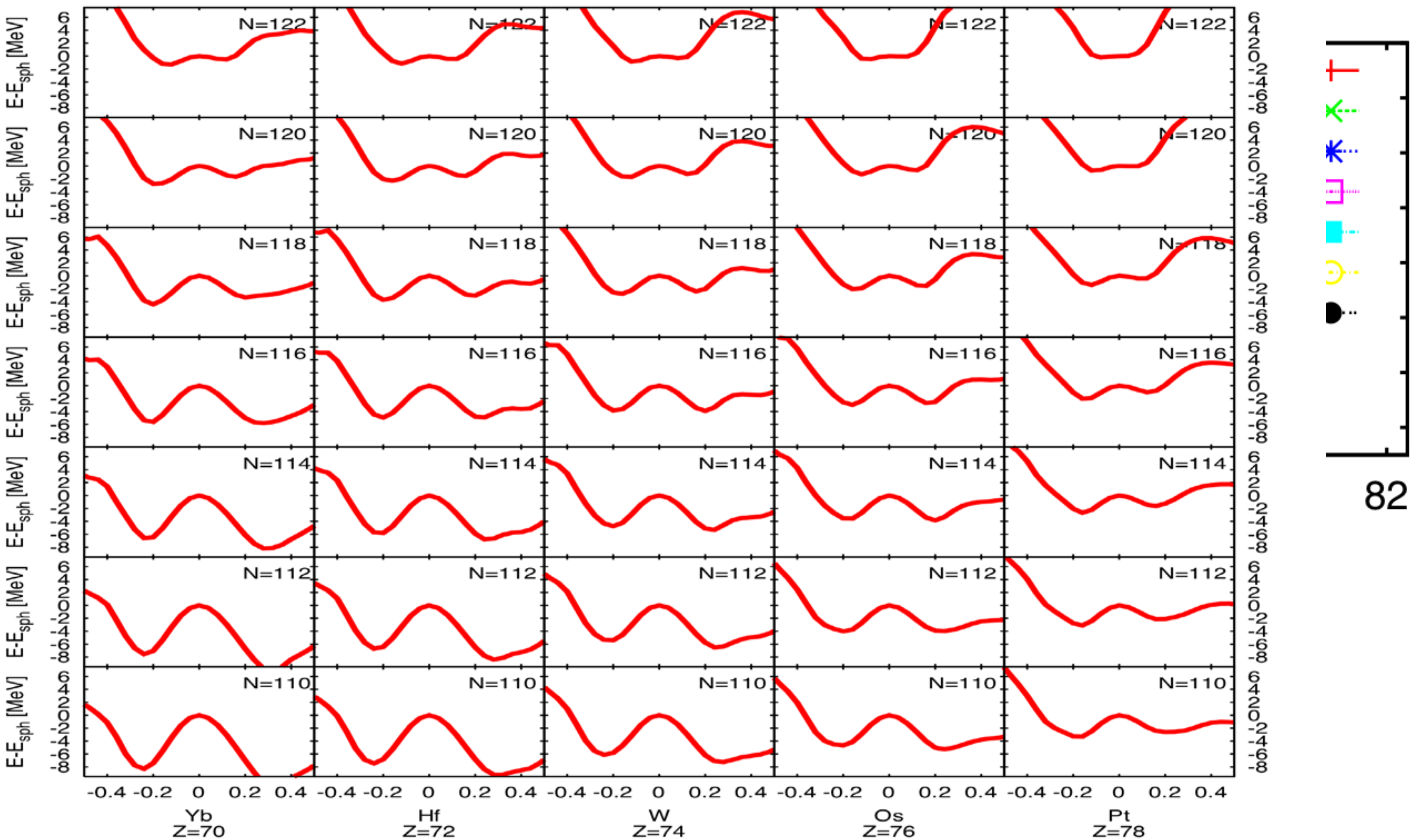
9) and others....

Theory convergence

No need to talk about “shell-model physics”

- **Effective shell model Hamiltonians from density functional theory: Quadrupolar and pairing correlations** Author(s): Rodriguez-Guzman, R; Alhassid, Y; Bertsch, GFSource: PHYSICAL REVIEW C Volume: 77 Issue: 6 Article Number: 064308 Published: 2008
- **Configuration Interactions Constrained by Energy Density Functionals,** B. Alex Brown, Angelo Signoracci, Morten Hjorth-Jensen, Journal-ref: Phys.Lett.B695:507-511,2011
- **The Negele-Vautherin density matrix expansion applied to the Gogny force,** J. Dobaczewski, B.G. Carlsson, M. Kortelainen, J. Phys. G: Nucl. Part. Phys. 37 (2010) 075106
- "**The Long Journey from Ab Initio Calculations to Density Functional Theory for Nuclear Large Amplitude Collective Motion**," A. Bulgac, J. Phys. G 37, 064006 (2010).

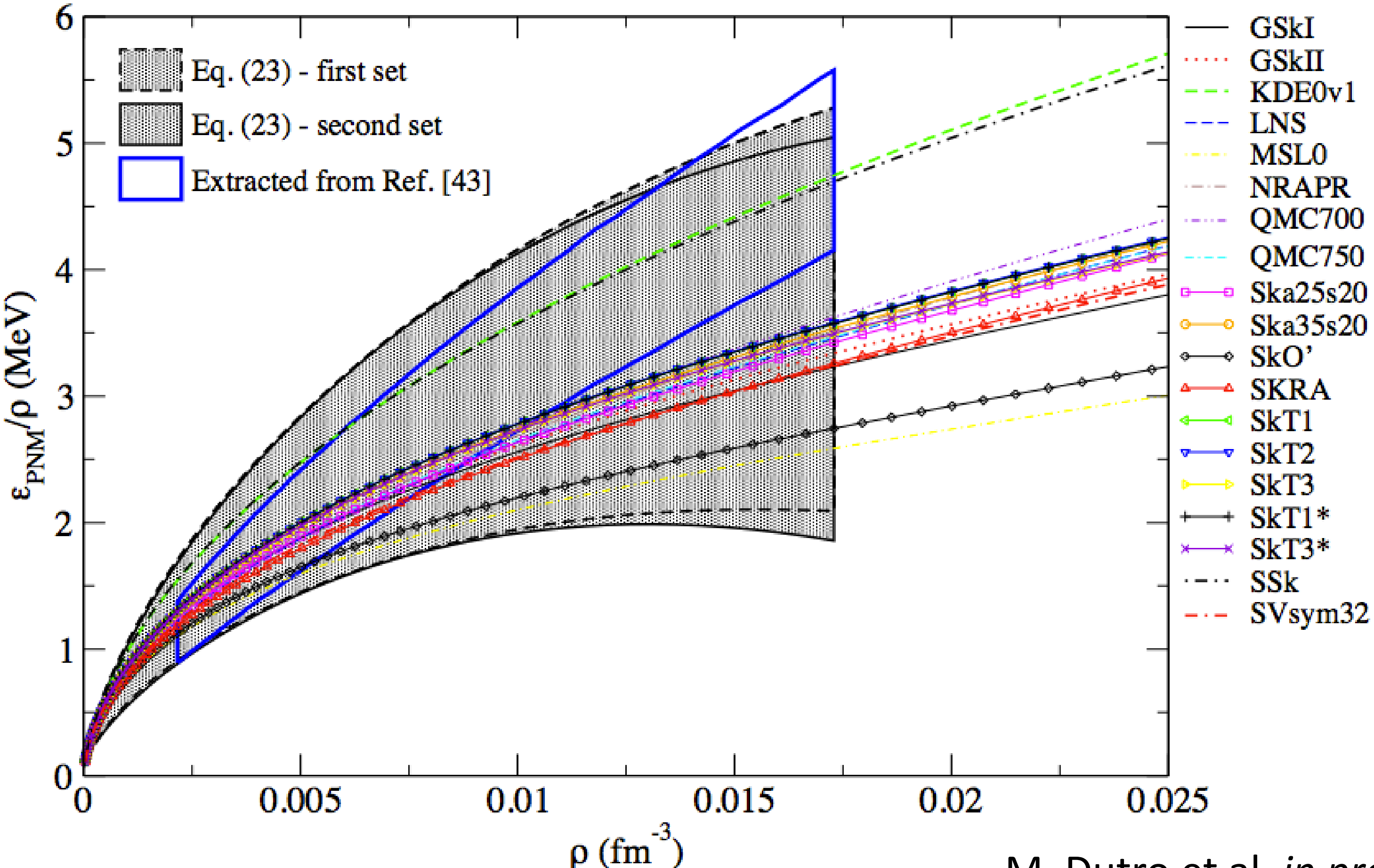
Shape evolution



But for every observable…

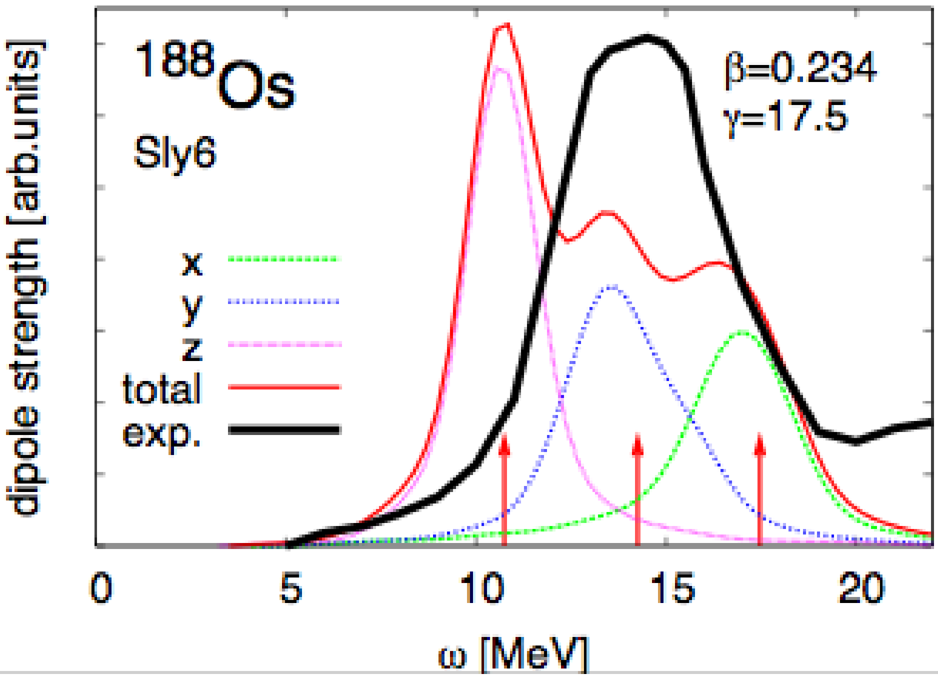
There are lots of predictions

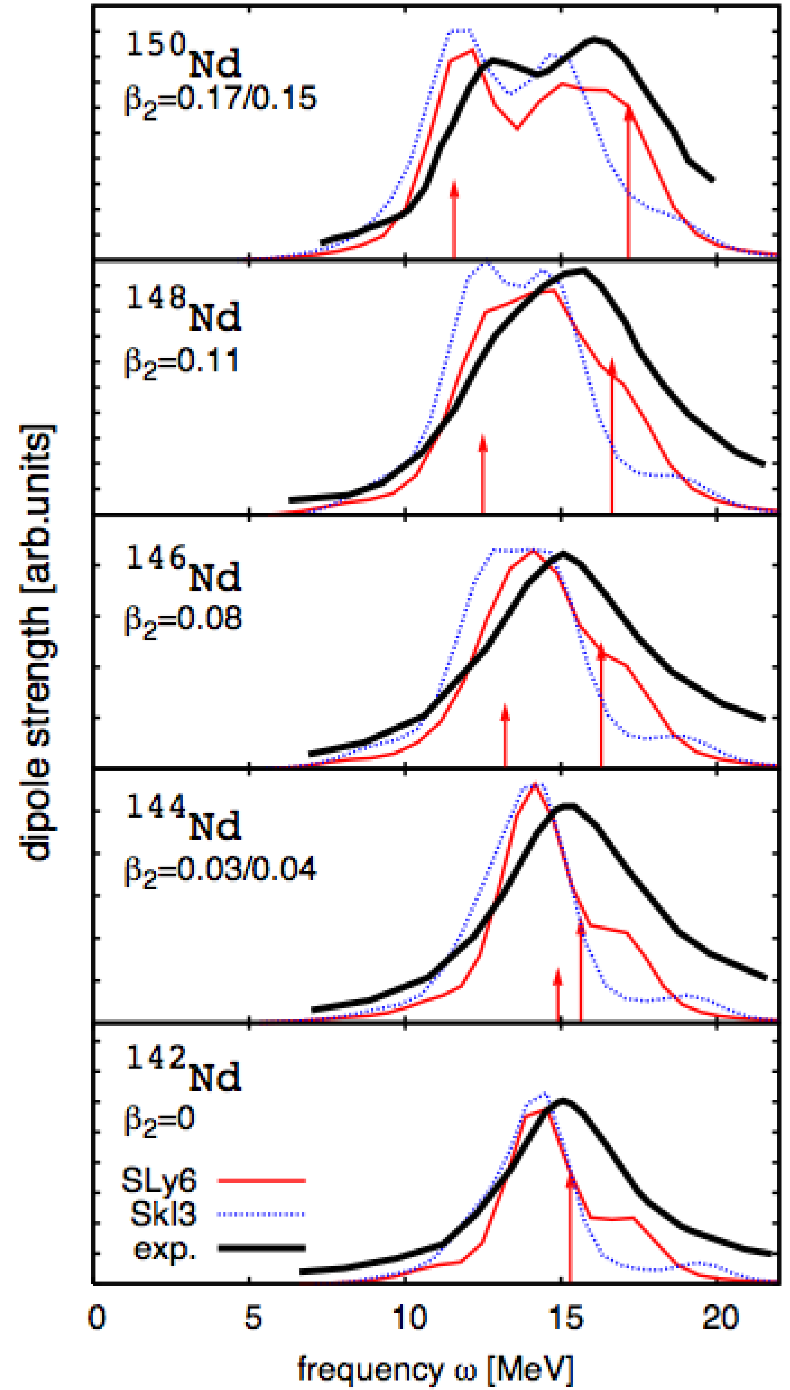
These for EoS of Pure Neutron Matter



M. Dutro et al, *in preparation*

shape evolution





J. A. Maruhn, P.-G. Reinhard, P. D. Stevenson, J. Rikovska Stone and M. R. Strayer, *Phys. Rev. C* **71**, 064328 (2005)

Skyrme Energy Functional

$$E = E_{kin} + \int d^3r \left(\mathcal{E}_{\mathsf{Sk}} + \mathcal{E}_{\mathsf{Sk}}^{(ls)} \right) + E_C$$

$$E_{kin} = \int d^3r \, \hbar^2 \, \tau$$

$$\begin{aligned}
\mathcal{E}_{\mathsf{Skyrme}} = & \int d^3r \sum_{t=0,1} \Big\{ C_t^{\rho}[\rho_0]\, \rho_t^2 + C_t^{s}[\rho_0]\, \mathbf{s}_t^2 + C_t^{\Delta\rho} \rho_t \Delta \rho_t + C_t^{\tau} (\rho_t \tau_t - \mathbf{j}_t^2) \\
& + C_t^{T} \left[\mathbf{s}_t \cdot \mathbf{T}_t - \tfrac{1}{3} (J^{(0)})^2 - \tfrac{1}{2} (J^{(1)})^2 - (J^{(2)})^2 \right] + C_t^{\Delta s} \mathbf{s}_t \cdot \Delta \mathbf{s}_t \\
& + C_t^{F} \left[\mathbf{s}_t \cdot \mathbf{F}_t - \tfrac{2}{3} (J^{(0)})^2 + \tfrac{1}{4} (J^{(1)})^2 - \tfrac{1}{2} (J^{(2)})^2 \right] + C_t^{\nabla s} (\nabla \cdot \mathbf{s}_t)^2 \\
& + C_t^{\nabla \cdot J} (\rho_t \nabla \cdot \mathbf{J}_t + \mathbf{s}_t \cdot \nabla \times \mathbf{j}_t) \Big\}
\end{aligned}$$

$$E_C = \frac{e^2}{2} \int d^3r \, d^3r' \rho_p(\vec{r}) \frac{1}{|\vec{r} - \vec{r}'|} \rho_p(\vec{r}') - \frac{3}{4} e^2 \left(\frac{3}{\pi}\right)^{\frac{1}{3}} \int d^3r [\rho_p(\vec{r})]^{\frac{4}{3}}$$

with

$$\vec{\sigma}_q(\vec{r}) = \sum_q \varphi_\alpha^{+}(\vec{r}) \hat{\vec{\sigma}} \varphi_\alpha(\vec{r})$$

$$\vec{J}_q(\vec{r}) = -i \sum_q \varphi_\alpha^{+}(\vec{r}) \nabla \times \hat{\vec{\sigma}} \varphi_\alpha(\vec{r})$$

spectroscopy of heavy, neutron-rich isotopes

E. B. Suckling and P. D. Stevenson

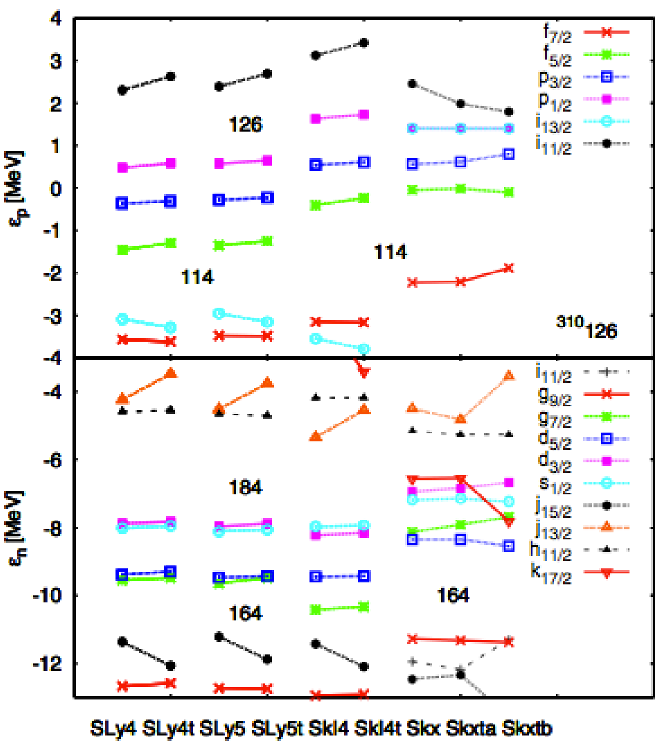


Fig. 2: (Colour on-line) Single-particle spectra of $^{310}126$ for protons (top) and neutrons (bottom) for the mean-field forces indicated with and without the tensor component.

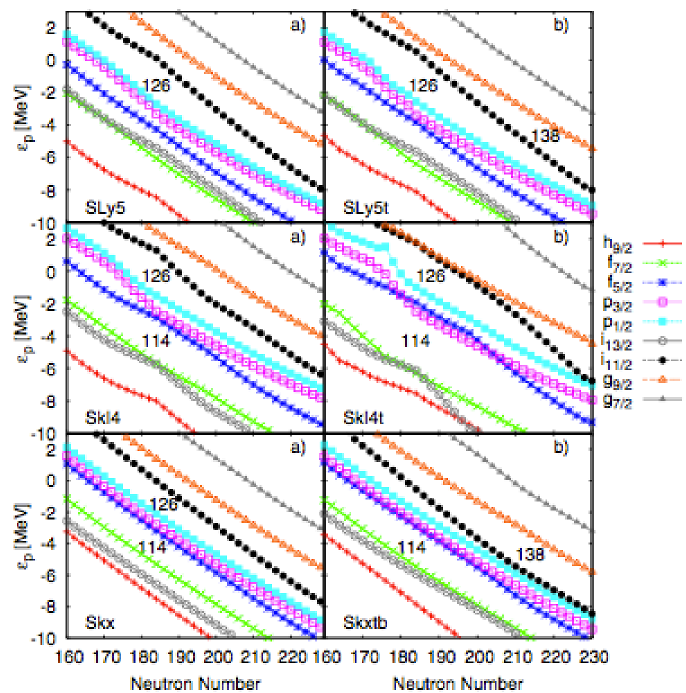


Fig. 3: (Colour on-line) Proton shell structures across the $Z = 114$ isotopes using SLy6 (a) without tensor and (b) with the tensor term.

"*The Effect of the Skyrme Tensor force on Superheavy Shell Closures*", *E. B. Suckling and P. D. Stevenson, EPL* ***90, 12001 (2010)***

Tensor terms in collisions

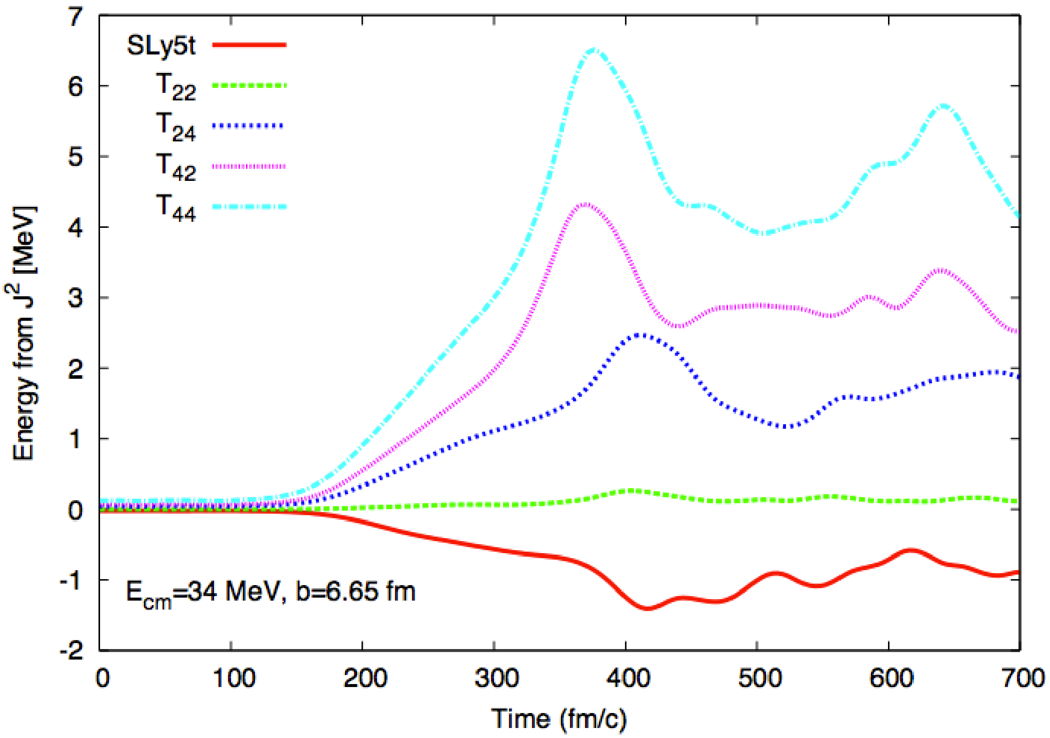
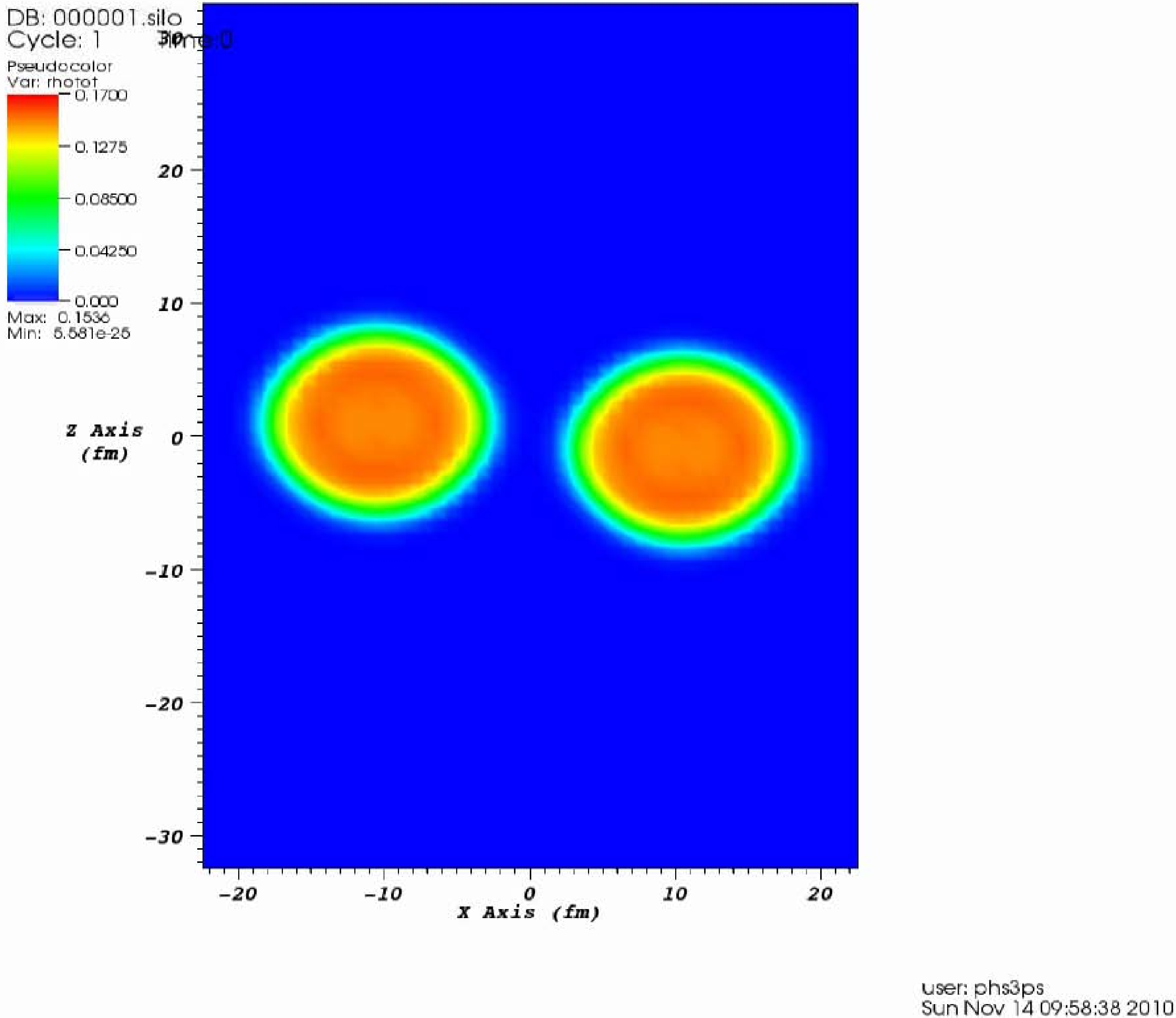


Figure 5.14: Energy contribution from the J^2 component of the Skyrme functional as a function of time for the $^{16}O + ^{16}O$ collision at $E_{cm} = 34$ MeV and $b = 6.65$ fm for different Skyrme force parameterisations.

E. B. Suckling, PhD thesis, 2011


DB: 000001.silo
Cycle: 1
Time:0
Pseudocolor
Var: rhotot
0.1700
0.1275
0.08500
0.04250
0.000
Max: 0.1536
Min: 5.581e-25
Z Axis
(fm)
30
20
10
0
-10
-20
-30
-20
-10
0
10
20
X Axis (fm)
user: phs3ps
Sun Nov 14 09:58:38 2010

Acknowledgements

Thanks to my collaborators:

J. A. Maruhn, U. Frankfurt

S. Fracasso, U. Surrey

E. Suckling, U. Surrey

A. S. Umar, U. Vanderbilt

R. Rodriguez-Guzman, Madrid

J. R. Stone, ORNL