Spectroscopic Factors in the Pb region from a unique phenomenological nuclear and spin-orbit potential

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spectroscopic factors and bound state potential

- usual bound state method:
  central WS potential + spin orbit (surface peaked)
  + hard core Coulomb
  fix geometry, adjust depth to E_B

  suggested procedure: [G. Mairle & PG, EPJ A9 (2000) 313]

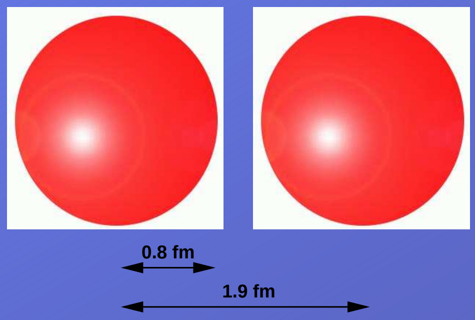
- local state-independent potential
- spin-orbit potential: Thomas type

$$V_{s.o.} = -\frac{1}{2}\left(\frac{\hbar}{m_\pi c}\right)^2 \lambda \, \frac{1}{r} \, \frac{dV_N(r)}{dr} \; (\ell \cdot s)$$

- Coulomb potential from charge distribution

Independent particles ↔ correlations

Nuclear structure



Independent particle model (IPM) surprising success;explains ground state properties (spin, parity, excitation energies,...)

Shell model

$$\sum V_{ij} = \sum V_i + V_{\text{res}}$$

IPM+Corr.

CERES (P. Grabmayr)

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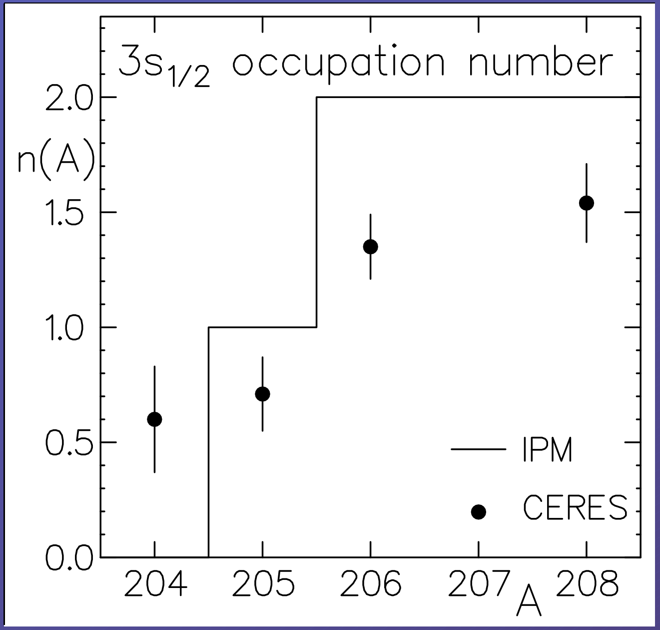
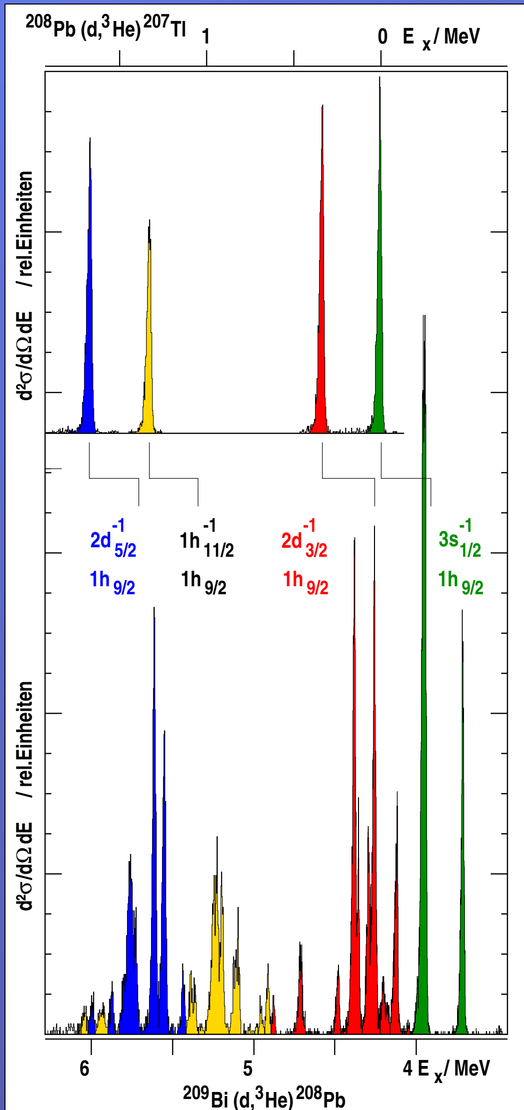
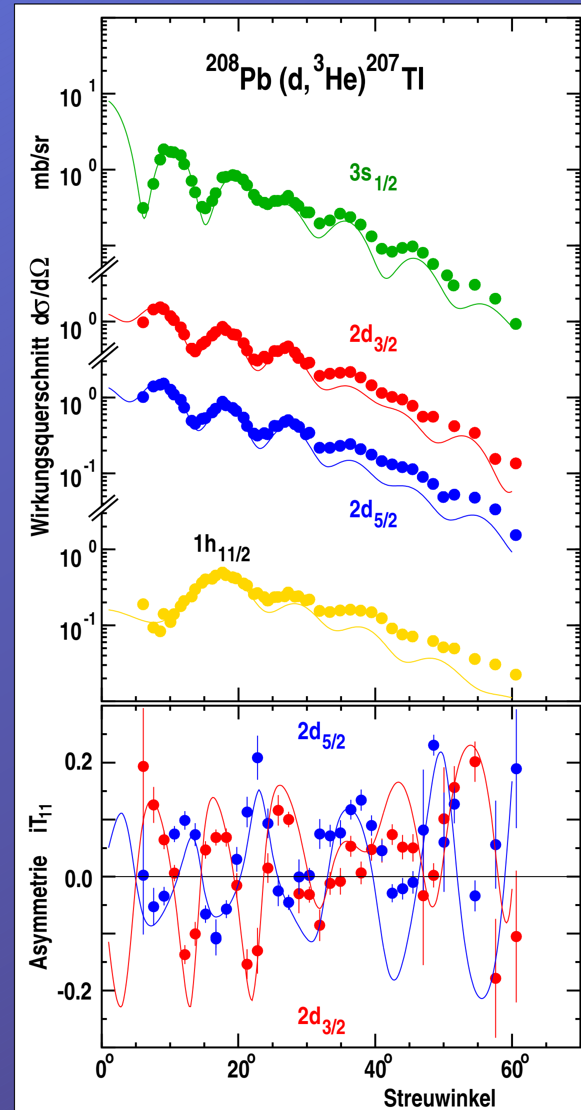


^{208}Pb(d,^{3}He) and ^{209}Bi(d,^{3}He)

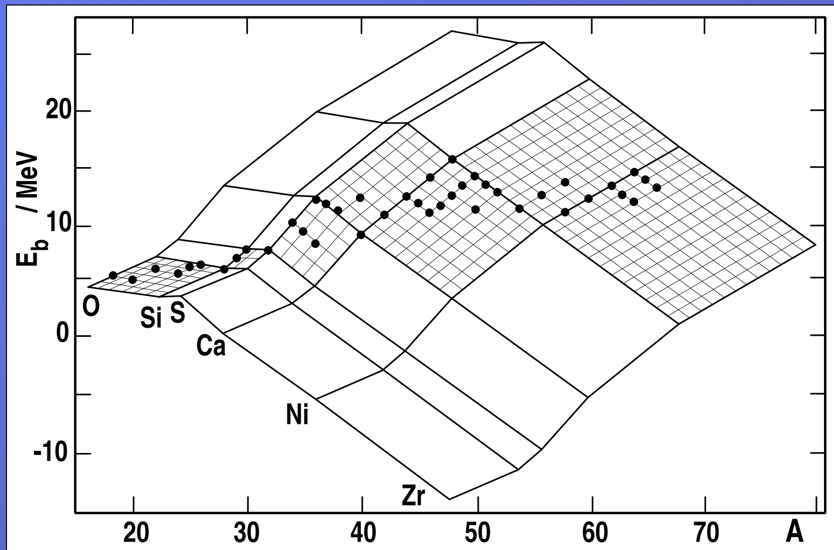




Phys. Blätter 55 (1999) 35,

Nucl. Phys. A469 (87) 285

spin orbit interaction



G. Mairle

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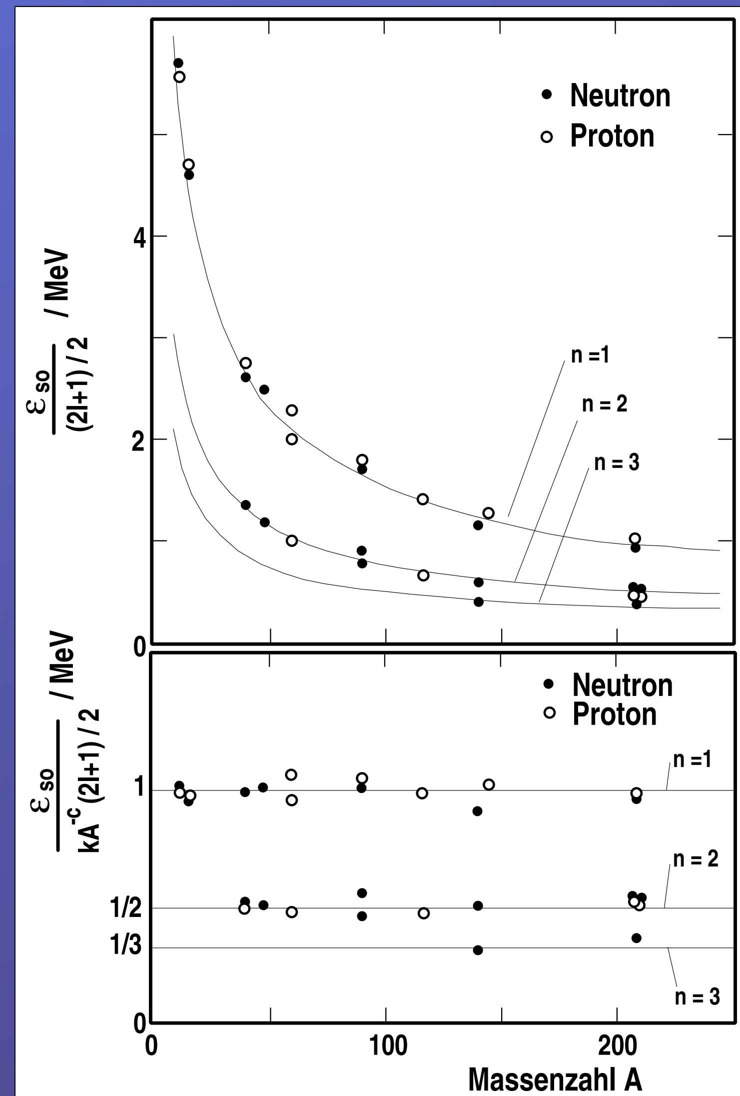
$$\varepsilon_{so} = E_{n\ell}^{J=\ell-\frac{1}{2}} - E_{n\ell}^{J=\ell+\frac{1}{2}}$$

$\varepsilon_{so}(n\ell, A) = \frac{2\ell+1}{2}\,\frac{1}{n}\,kA^{-c}$

k=23.3 MeV

c=0.58 (c=2/3 in H.O.)



numerical procedure

$V(r) = V_C(r) + V_N(r) + V_{so}(r, \ell s)$

SP energies (undisturbed by V_{so}):

$$
\begin{aligned}
E(n\ell) &= E(n\ell_J = \ell + 1/2) \; + \; \varepsilon_{so}(n\ell)\frac{\ell}{(2l+1)} \\
&= E(n\ell_J = \ell - 1/2) \; - \; \varepsilon_{so}(n\ell)\frac{(\ell+1)}{(2l+1)}
\end{aligned}
$$

adjust V_N for $E(n\ell)$ and V_{so} for ε_{so}

however:

$$V_{so} = -\frac{1}{2}\left(\frac{\hbar}{m_\pi c}\right)^2 \lambda \, \frac{dV_N(r)}{dr} \; (\ell \cdot s)$$

numerical procedure

first order perturbation calculation:

1. start with V_N^0 (e.g. WS-type)
2. solve Schrödinger eq. for $\Psi^0(r)(n\ell) \rightarrow R(n\ell)$ and $E^0(n\ell)$
3. calculate

$$\varepsilon_{so} = \frac{(2\ell+1)}{2} \left(\frac{\hbar}{m_\pi c}\right)^2 \lambda \int_0^\infty \frac{1}{r} \frac{dV_N(r)}{dr} R^2(n\ell) r^2 dr$$

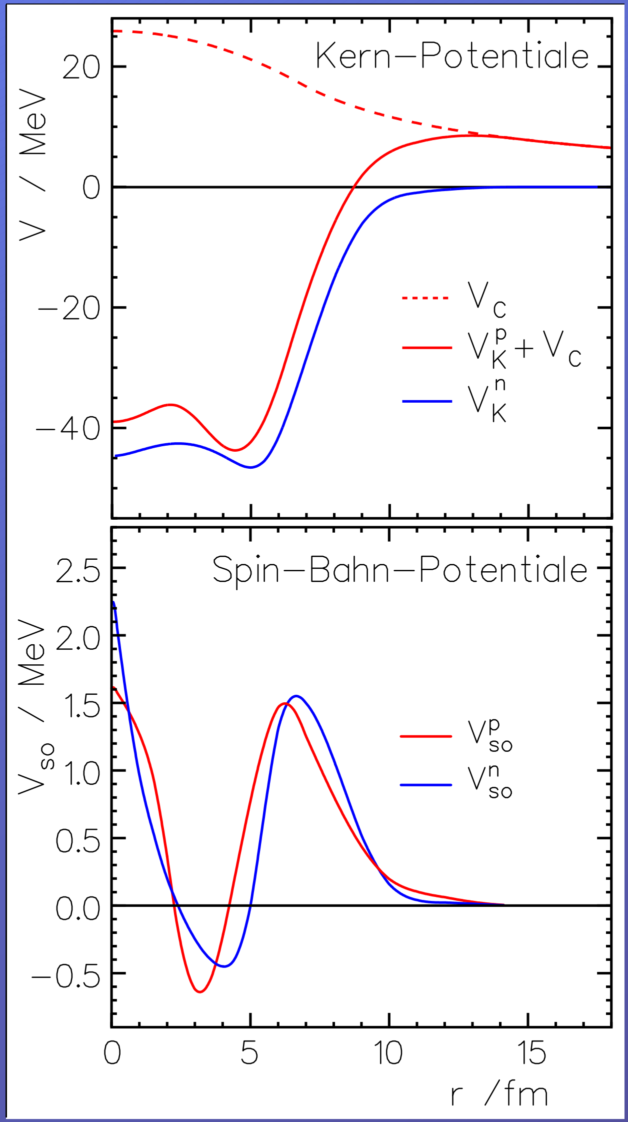
   and modify $V_{so} \sim \frac{1}{r}\frac{dV_N}{dr}$ to reproduce ε_{so}^{exp}

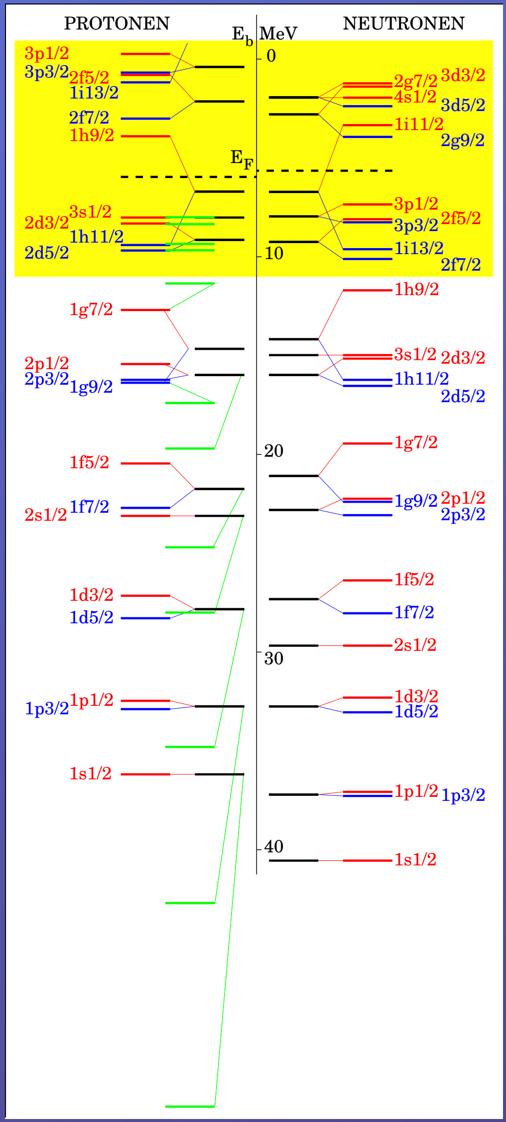
4. reconstruct $V_N(r) = \int r \, V_{so}(r) \, dr$
5. difference $V_N^0(r) - V_N(r) \longrightarrow \Delta E(n\ell)$
6. new V_N^1, V_{so}^1 provide $\Psi^1(r)$ for iteration

rms deviations Δ for valence shells:

protons	16 keV
neutrons	25 keV

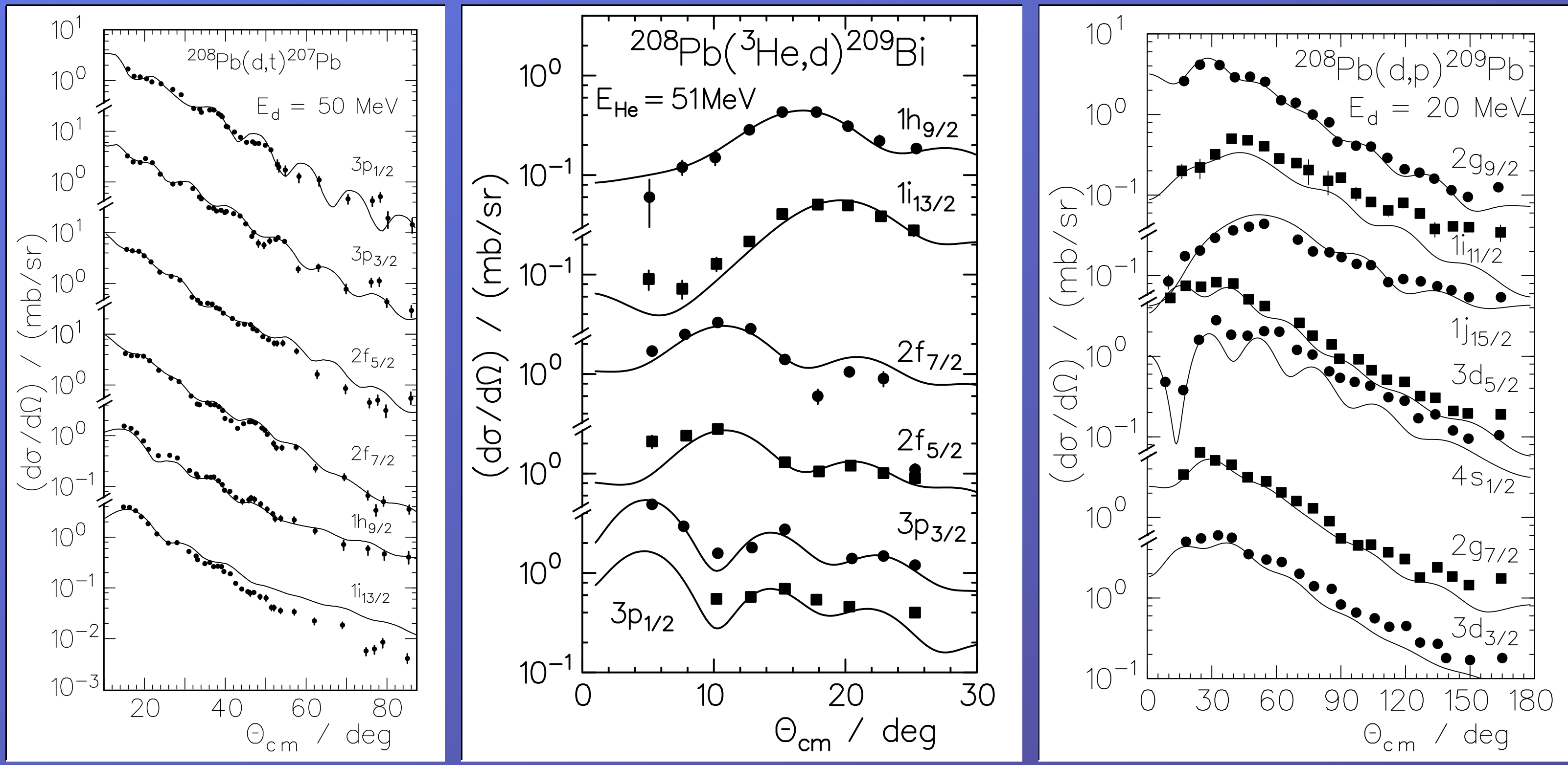
potentials and s.p. energies



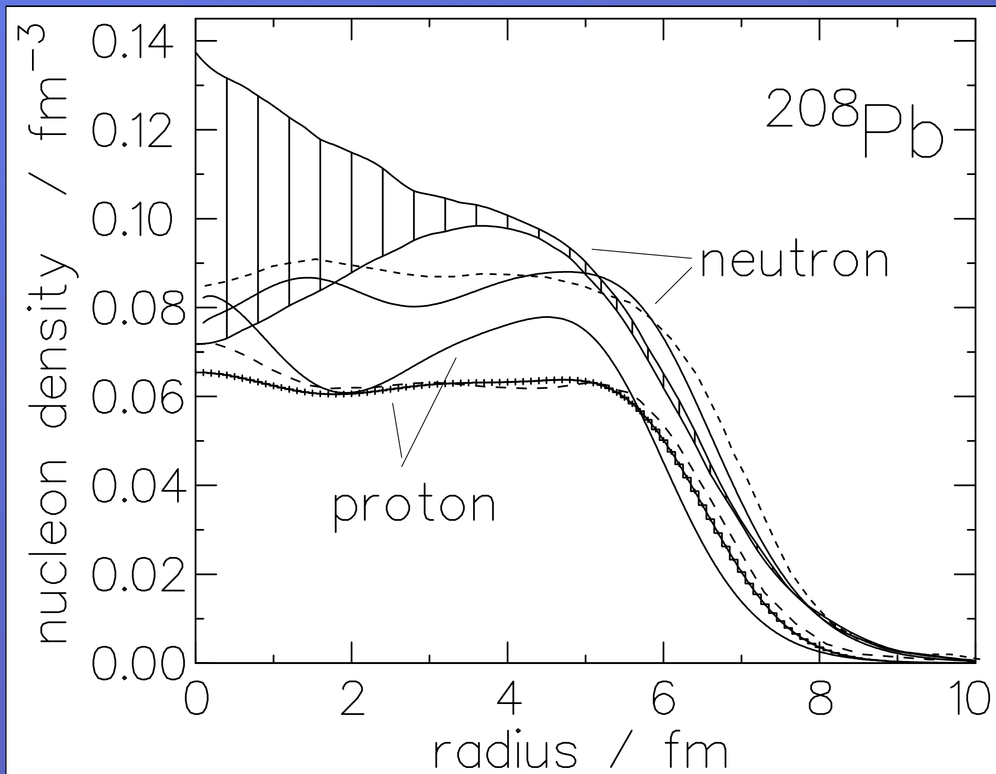


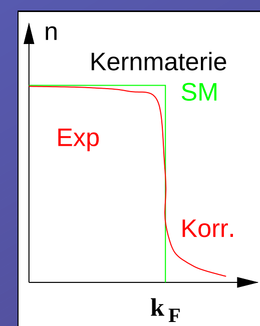
M.van Batenberg, L. Lapikas, ^{208}Pb(e,e′p)

s.p. transfer from ^{208}Pb: $S' \sim 0.6 - 0.7$



proton and neutron densities in ^{208}Pb





rms radii:

orbit	present	Sprung	Woods
$\pi\ \ 3s_{1/2}$	5.419 fm	5.37 fm	5.25 fm
$\pi\ \ 2d_{5/2}$	5.498 fm	5.49 fm	5.37 fm
$\nu\ \ 2f_{7/2}$	6.198 fm	6.05 fm	5.92 fm

Summary

- unique, local and state-independent potential $V_N \leftrightarrow V_{so}$
- reproduction of s.p. energies ($\Delta E < 25$ keV)
- spectroscopic factors $S \sim 0.6$ - 0.7
- density, radii

[G. Mairle & PG, EPJ A9 (2000) 313]

searching consistent V for ^{40}Ca, Zr, Sn