Punching Holes in Exotic Nuclei

^{208}Pb $\qquad$ ^{206}Hg

Bonnie Todd with J. Piekarewicz and P.D. Cottle
Florida State University

"Abstract"

Remove least bound *s*-shell protons in ^{48}Ca and ^{208}Pb

$\Downarrow$

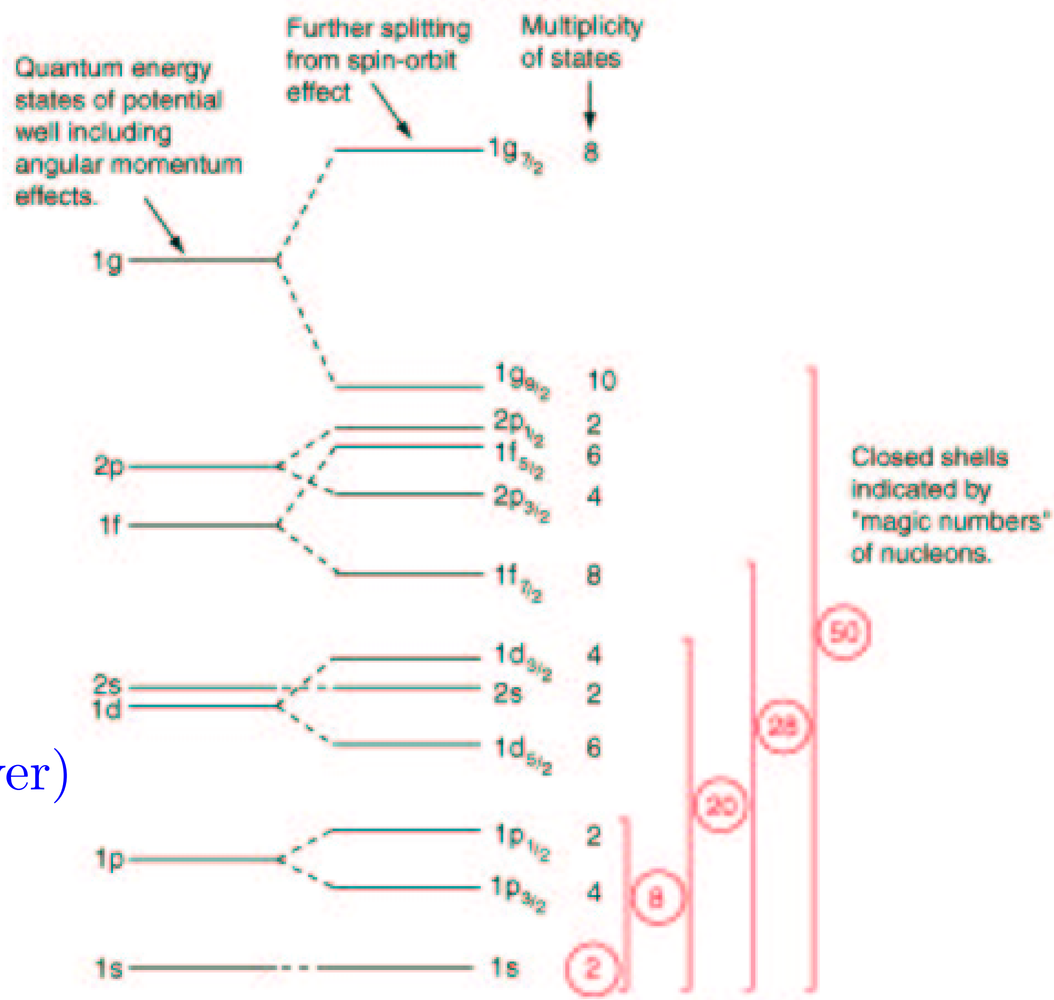
Spin-orbit collapse of *p*-shell neutrons in ^{46}Ar and ^{206}Hg

Outline

- Motivation - Magic numbers
- Related work - high-j orbits
- Background theory
- Results
- Conclusion

Motivation

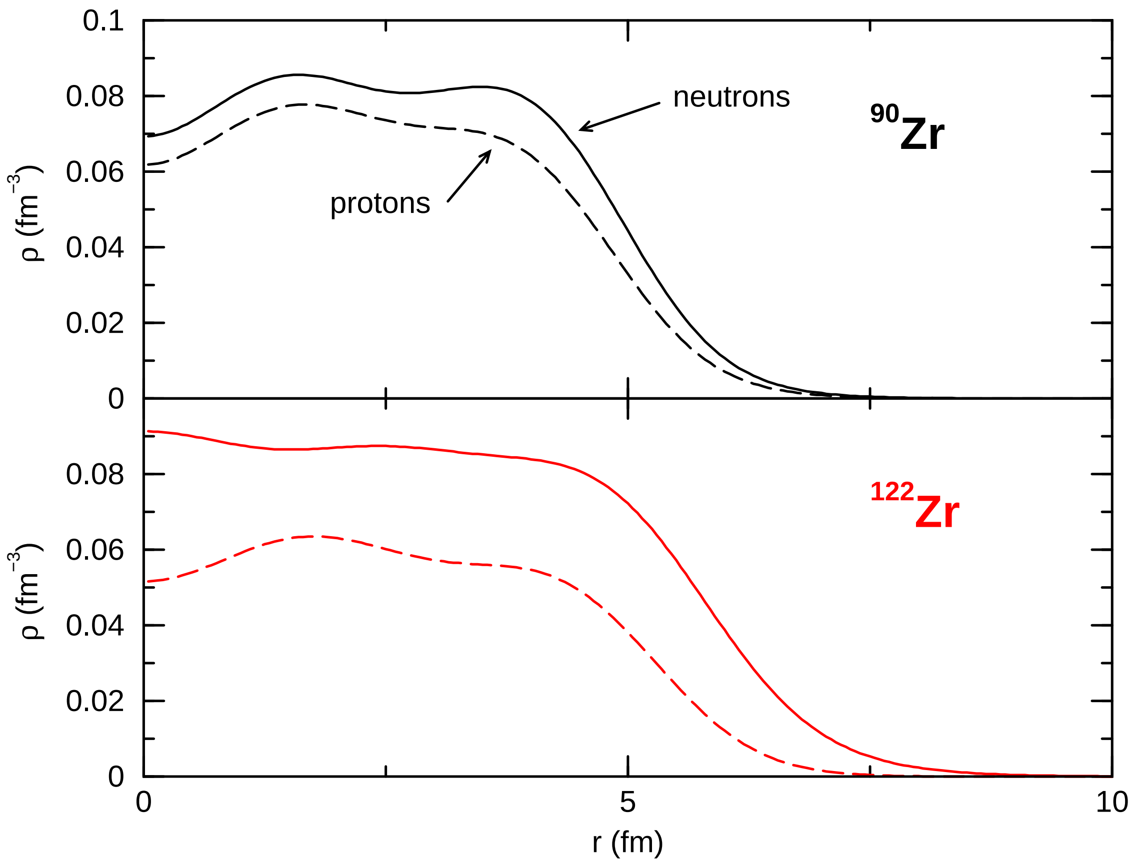
The spin-orbit effect is interesting because it is responsible for the magic numbers. (Maria Goeppert-Mayer)



Nuclear Magic Numbers: 2, 8, 20, 28, 50, 82, 126,...

Related Work

There has been interest in high-j orbits for neutron rich systems.



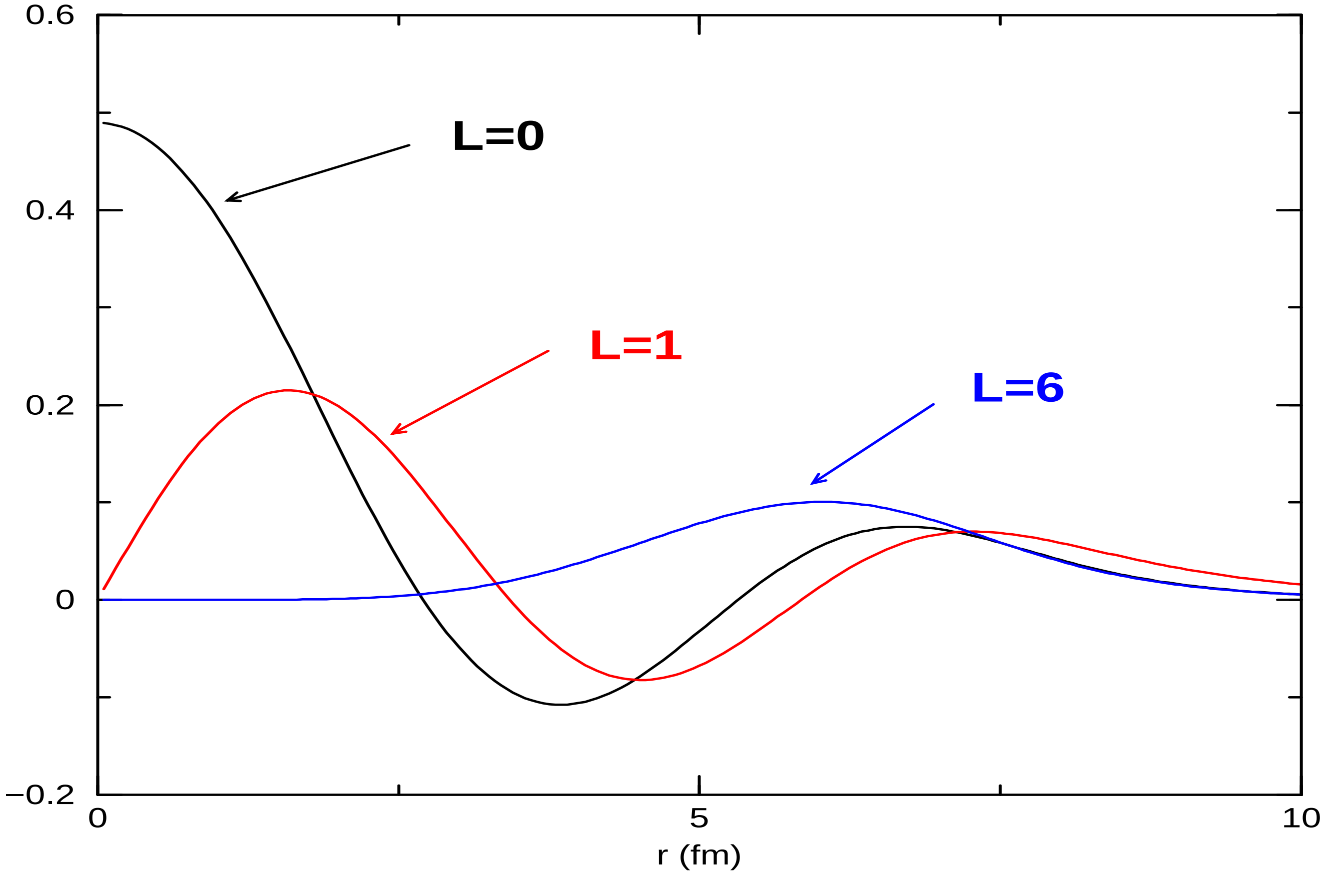
The splitting between the $1g_{9/2}$ and $1g_{7/2}$ neutron orbits is

^{90}Zr: 7.41 MeV

^{122}Zr: 5.40 MeV

- a change of 2.01 MeV.

Wavefunctions



Near the origin, the wavefunctions behave like r^ℓ. So s-shell wavefunctions have a large impact on the central region of a nucleus.

Low-j neutron orbits

What happens to the p-orbits when protons are removed from the s-shell?

To solve:

• Utilize a relativistic mean field calculation

• Estimate spin-orbit splitting by using the Schrödinger-equivalent spin-orbit potential and wavefunctions:

$$\left[\frac{d^2}{dr^2} - p^2 - \frac{\kappa(\kappa+1)}{r^2} - V_{eff}\right]u(r) = 0$$

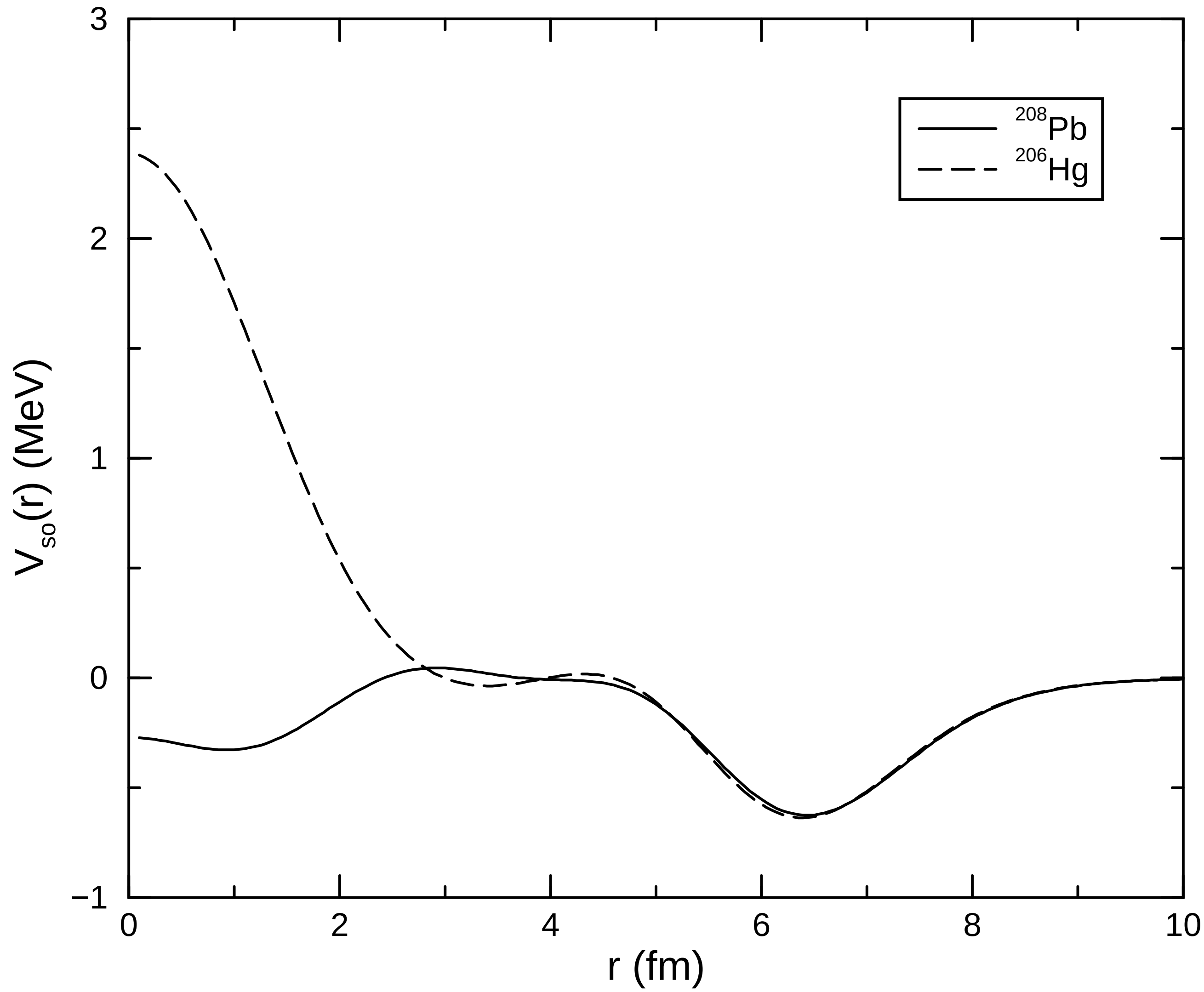
$$p^2 \equiv M^2 - E^2$$

$$V_{eff} \equiv V_C - \kappa V_{SO} + V_D$$

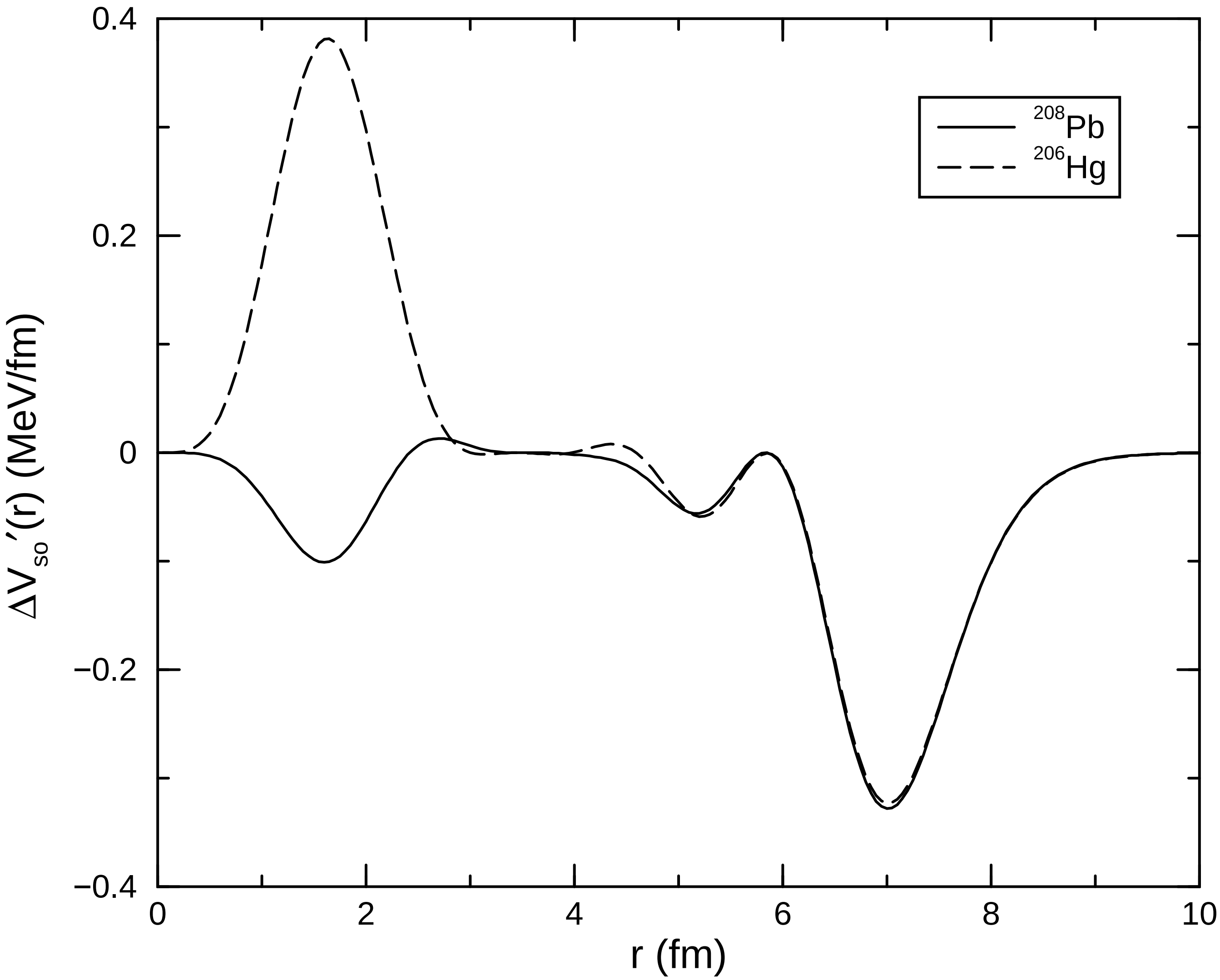
$$\Downarrow$$

$$\Delta V_{\mathrm{SO}}(r) \equiv \int_0^r dr' V_{\mathrm{SO}}(r') \left[2u^2_{p_{3/2}}(r') + u^2_{p_{1/2}}(r')\right] \; .$$

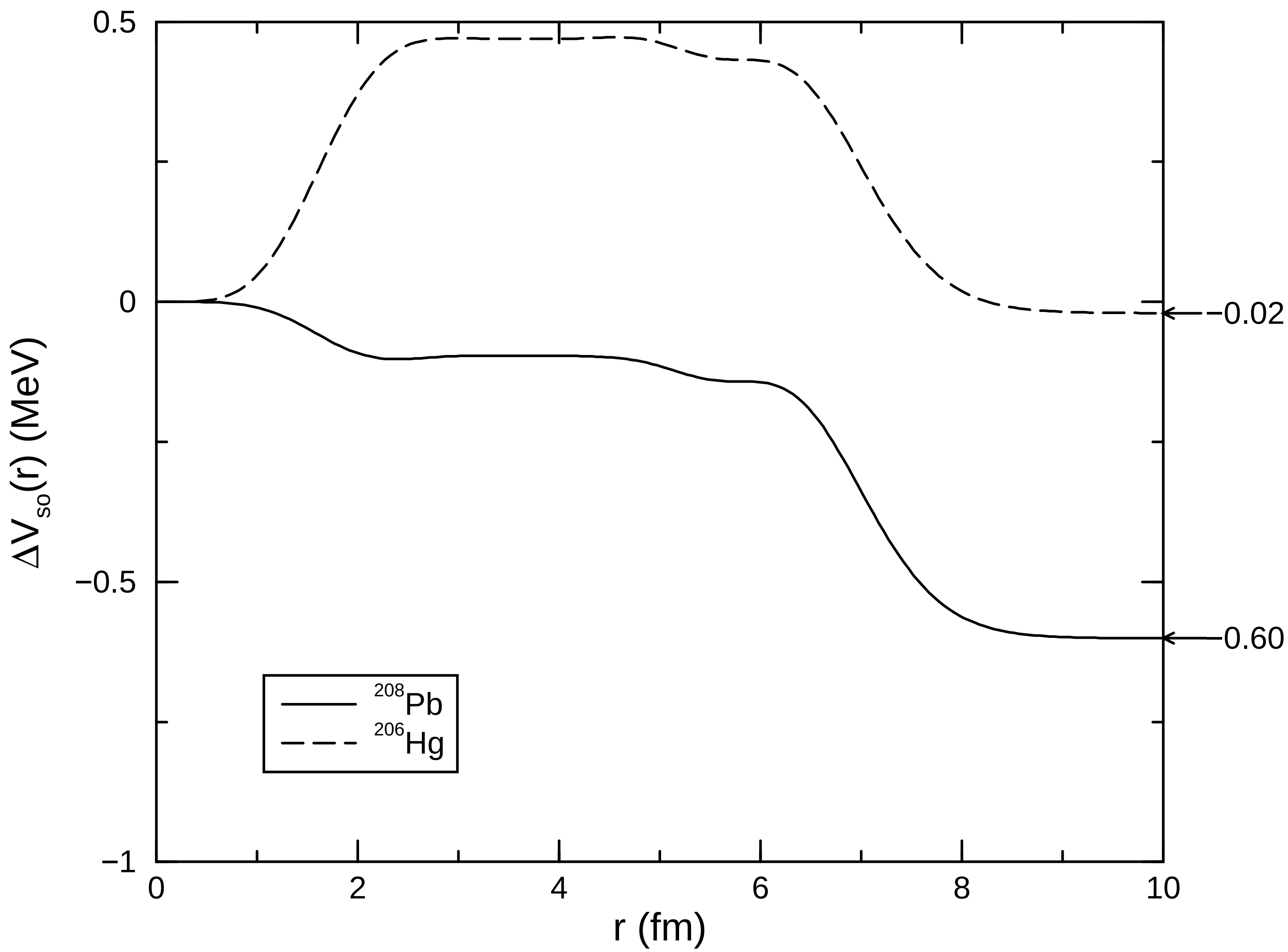
The spin-orbit results



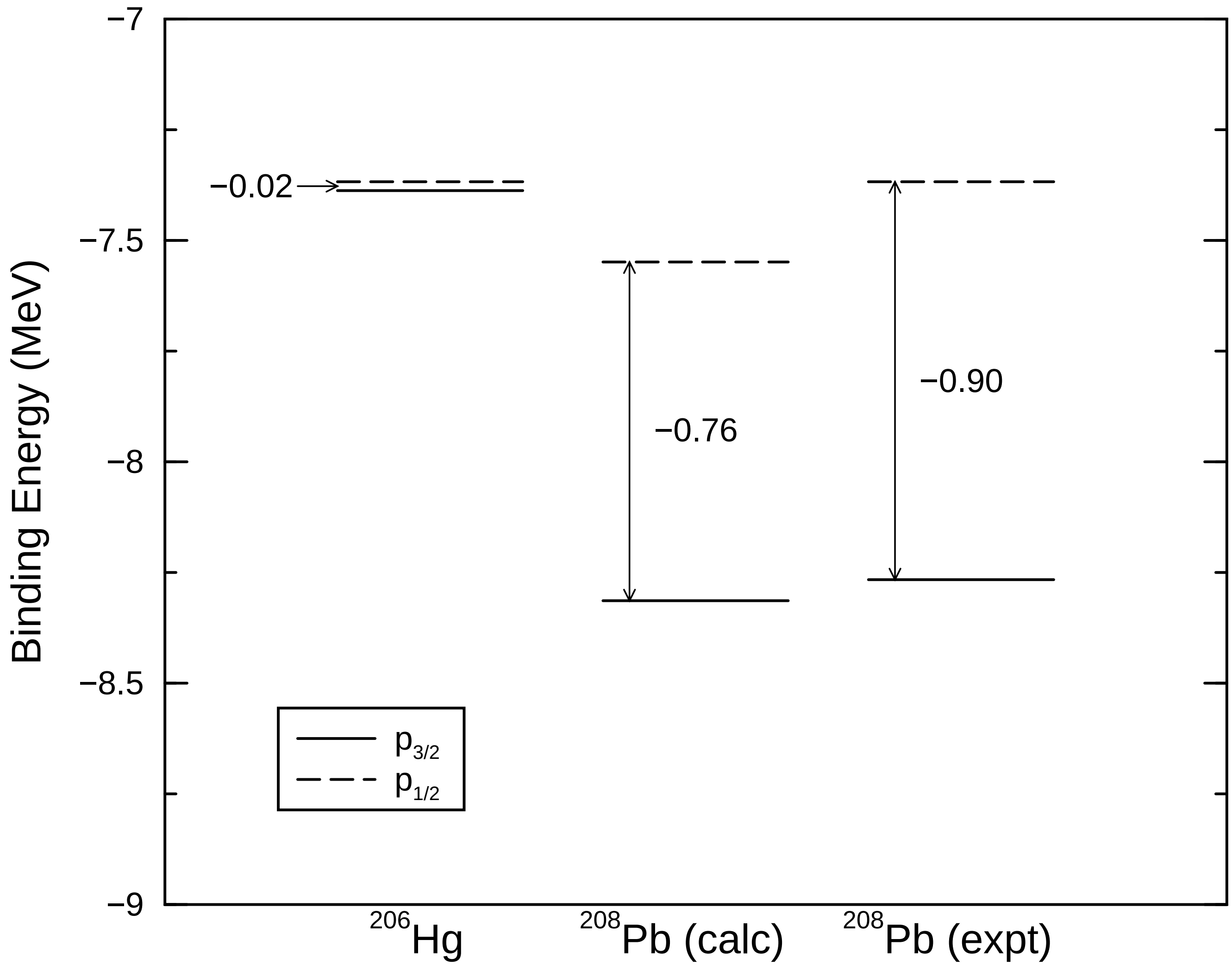
The spin-orbit results



The spin-orbit results



"Exact" calculations and experiment



Conclusion

- Studying spin-orbit is important for understanding magic numbers.

- A new source of the spin-orbit collapse for low-j neutron orbits.

- "Punching holes" (removing $s_{1/2}$ protons) causes a much smaller splitting in ^{206}Hg (^{46}Ar) between $p_{3/2}$ and $p_{1/2}$ neutron orbits than in the nearby doubly-magic nuclei ^{208}Pb (^{48}Ca).

J.Piekarewicz, Phys. Rev. C **48**, 2174 (1993).

B.G. Todd, J. Piekarewicz, and P.D. Cottle, nucl_th/0306042.