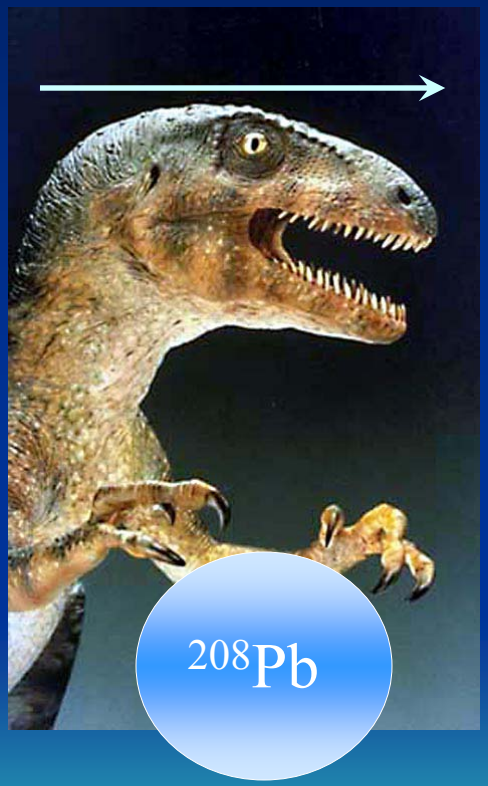
Parity Radius Experiment (PReX)

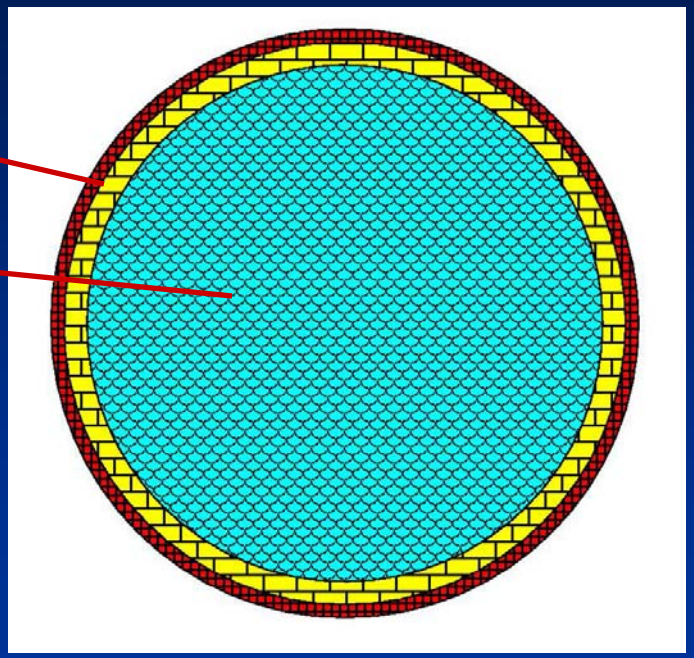


- Introduction: neutron skin of heavy nuclei.
- Parity violation and neutron densities.
- Implications for atomic physics, nuclear structure and neutron stars.

-- C. J. Horowitz, LOWq03, Halifax

N. Star Crust vs Neutron Skin

- Neutron star has solid crust over liquid core.
- Heavy nucleus has neutron skin.



^{208}Pb

Both neutron skin and solid crust are made out of neutron rich matter at similar densities.

Neutron Rich Skin

- A heavy nucleus should have a neutron rich skin because of the neutron excess and coulomb barrier which removes protons from surface.
- Thickness of skin depends on pressure of neutron rich matter as neutrons are pushed out against surface tension.
- Measuring neutron rich skin with hadronic probes is difficult because of strong interaction uncertainties.

Weak Interaction Probes Neutrons

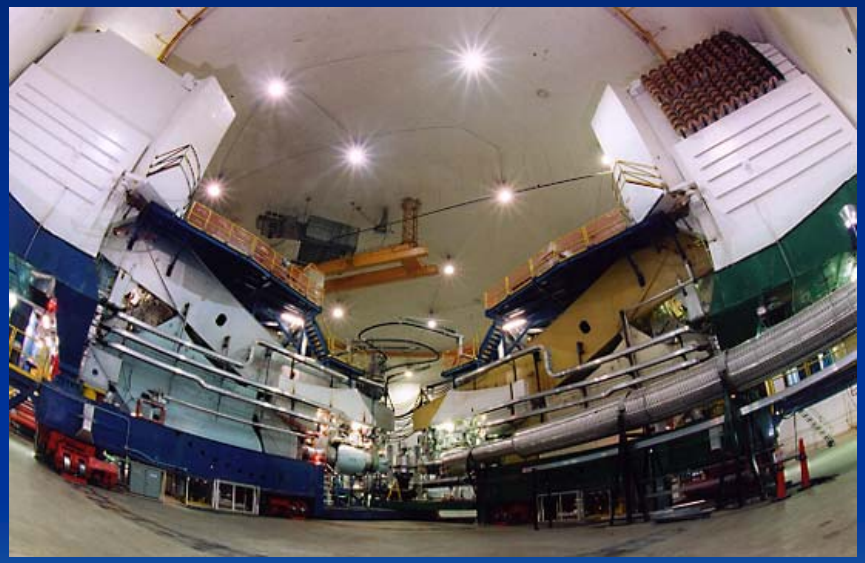
- Z^0 couples to weak charge which is weak isospin - $2\sin^2\Theta_W Q_{em}$. Add up weak charges of valence quarks:

  $Q_n = -1/2$, $Q_p = \frac{1}{2} - 2\sin^2\Theta_W \approx 0$.

- Weak charge of n $\gg$ that of p.
- Parity violating asymmetry in elastic electron scattering provides a purely electroweak probe of neutron density.

Jefferson Lab Hall A exp.

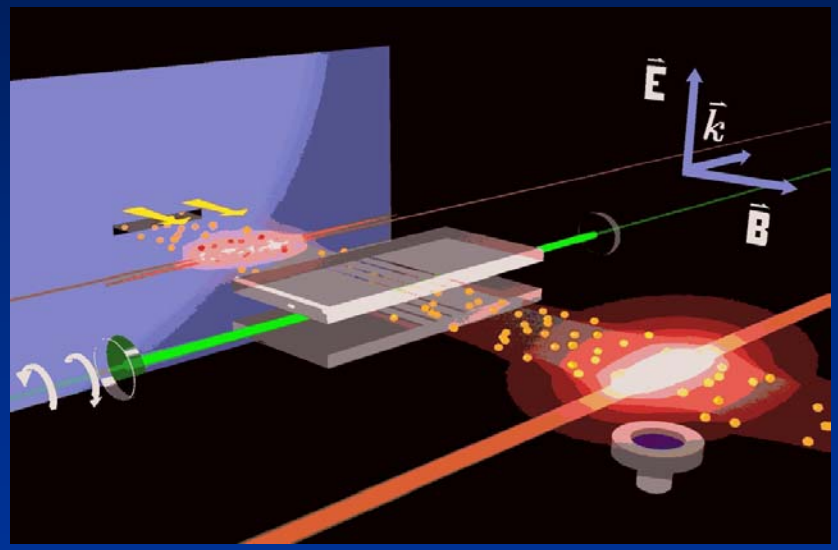
- 850 MeV e elastically scattering at 6 deg. from ^{208}Pb.
- Goal: measure A $\approx$ 0.6 ppm to 3%. This gives neutron radius to 1% ($\pm$ 0.05 Fm).
- Cleanly resolves skin R_n-$R_p \approx$ 0.2 Fm



Atomic Parity Nonconservation

Low Energy Test of Standard Model

- Depends on neutron densities.
- Cs exp. good to 0.3% but limited by 1% atomic theory.
- Not limited by R_n but future 0.1% exp would need R_n to 1%
- Future isotope ratio exp will need neutron radii differences.
- Exp with Fr isotopes at RIA?



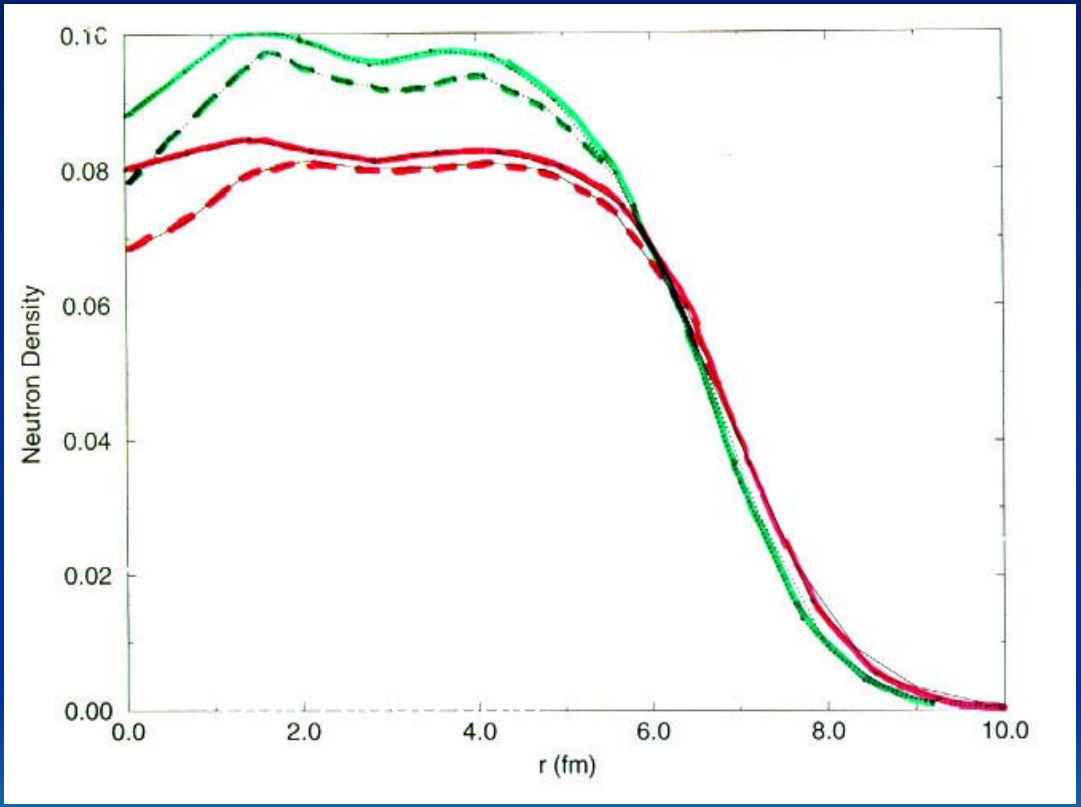
Colorado Cs Experiment

- Combine neutron radii from PV e scattering with an atomic PNC exp for best low energy test of standard model.

R-process nucleosynthesis

- N=126 shell important for nucleosyn. Slow n capture reaches N=126 at Z=82, Rapid n capture: N=126 with Z~66 (~^{192}Dy).
- Red curves use rel. mean field force, green curves use nonrel. Skyrme force. Solid, ^{208}Pb, dashed, ^{192}Dy.
- Measurement in Pb constrains force and allows much better predictions for ^{192}Dy.

Neutron density for N=126



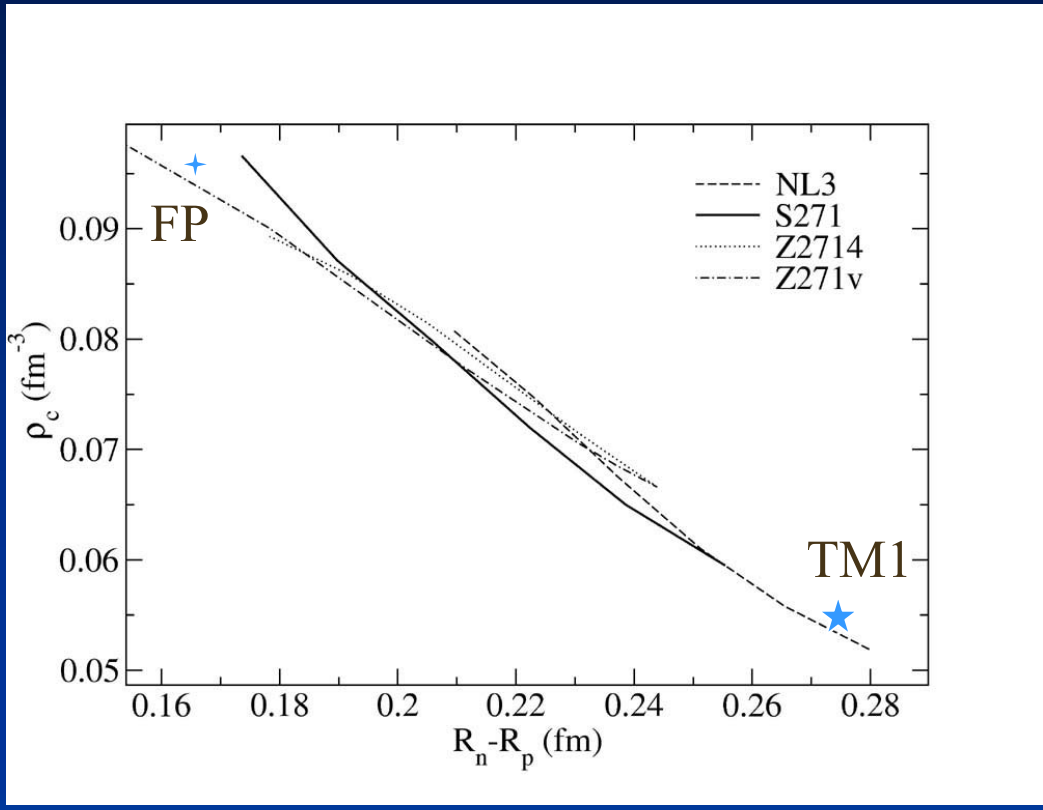
- R-process needs masses, n-capture and b-decay rates for n rich nuclei.

Liquid/Solid Transition Density

- RPA stability against small amplitude density osc. Unstable if $\varepsilon_L<0$.

$$\epsilon_L(q_0=0,q)=\det\left(1-D_L\Pi_L\right)$$

- Thicker neutron skin in Pb means energy rises rapidly with density→ Quickly favors uniform phase. Thick skin in Pb→low transition density in star.



- Matter is a uniform liquid above ρ_c and a nonuniform solid below.

Observables Sensitive to Crust

- Glitches in rotational period of pulsars from “star-quakes” in solid crust. Vela crust must contain at least 1.4% of angular momentum. Crust can’t be too thin (ρ_c or R can’t be too small).
- Thermal properties depend on heat conduction through crust.
- Solid crust can support nonaxial quadrupole deformations important for gravitational radiation. LIGO will look for signal at frequencies of known pulsars.
- ...

Pb Parity Radius Exp. Status

- Need septum magnets for spectrometers to view small angles. Being installed.
- Need to demonstrate very good control over helicity correlated beam properties during Happex II and He experiments. [Note 3% goal would be world record].
- Need to measure beam polarization to 2% or better, also Q_{Weak} needs pol. to 1%.

Parity Radius Measurement

- Provides fundamental nuclear structure information because it can be both accurate and model independent.
- Important for atomic parity tests of the standard model, nuclear structure including structure of very neutron rich nuclei, and astrophysics including neutron star properties: skin, radii, cooling...
- Measurement is challenging but feasible.
- Pb exp. is part of a robust JLAB parity program involving strange quark and standard model test measurements.
- R_n for Pb can help calibrate elastic p scattering and other strong probes. Measure matter densities of radioactive beams with p scattering.
- Using parity to calibrate p scattering is like using β decay to calibrate (p,n).