A Clean Measurement of the Neutron Skin of ^{208}Pb Through Parity Violating Electron Scattering

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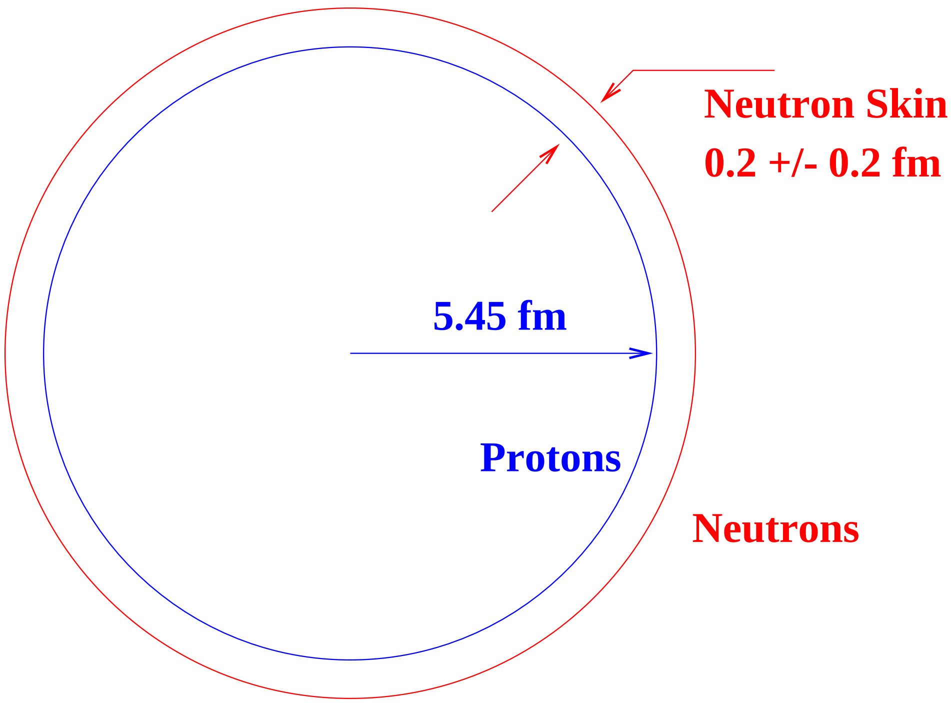
Neutron Skin



$\rightarrow$ Is $R_n > R_p$?

Why Electron Scattering ?

- Electron Scattering is a Clean Probe:

- Interaction well-known
- Sample entire nuclear volume
- Electromagnetic sees mainly Protons

- Z^0 of Weak Interaction:

Same advantages & couples mainly to neutrons

$$Q_p^Z \sim 1 - 4\sin^2\theta_W, \quad Q_n^Z \sim 1$$

- Parity Violating Asymmetry:

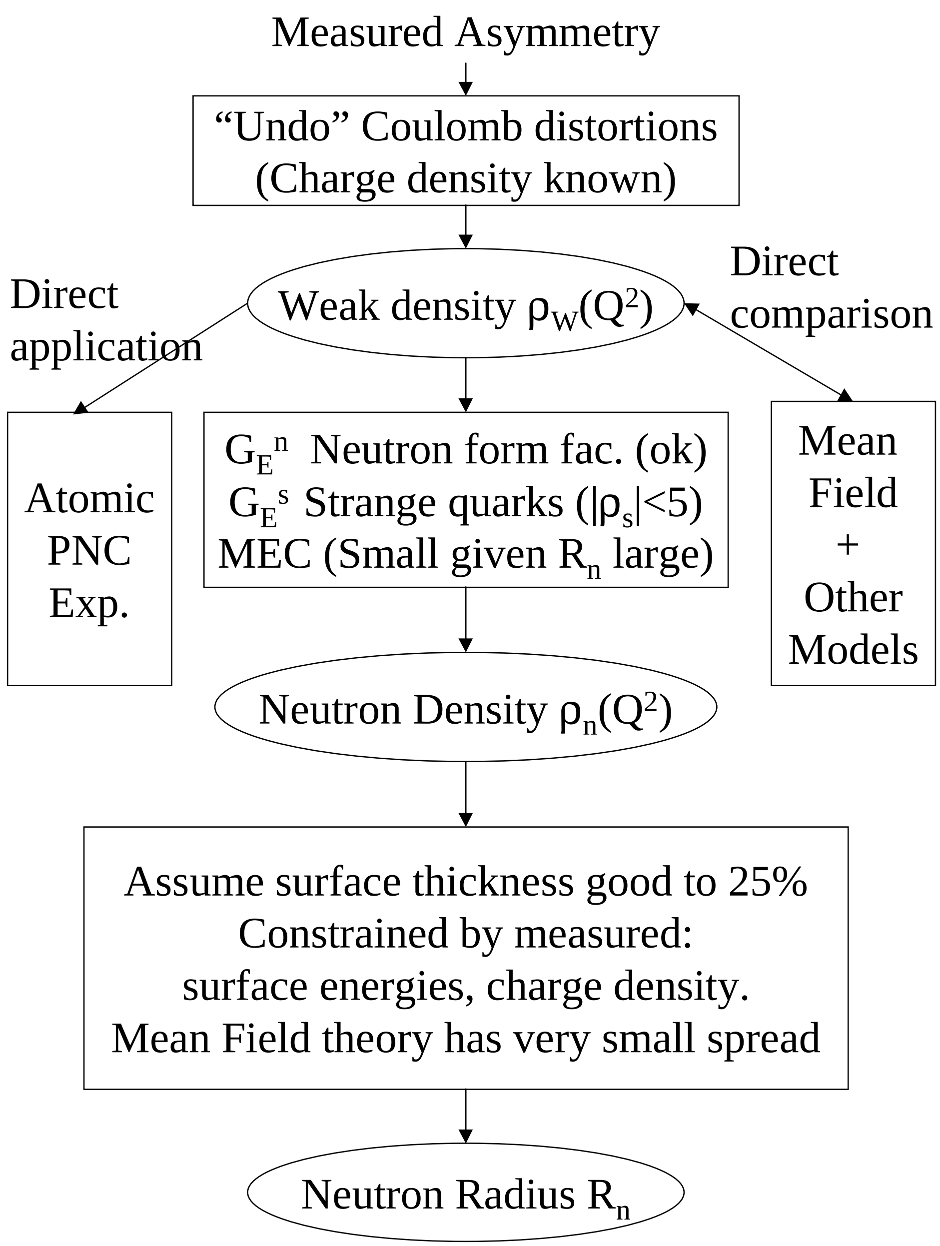
$$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

- PWIA:

$$A = -\frac{G_F Q^2}{4\pi\alpha\sqrt{2}} \{1 - 4\sin^2\theta_W - \frac{F_n(Q^2)}{F_p(Q^2)}\}$$

$$\frac{\delta A}{A} = 3\% \rightarrow \frac{\delta R_n}{R_n} = 1\%$$

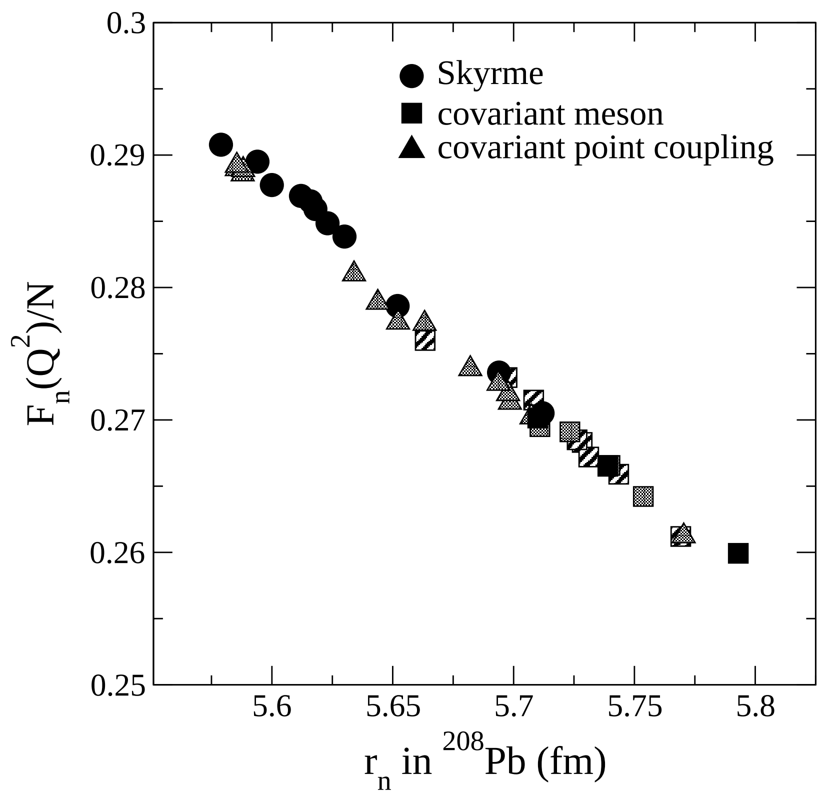
Physics Data Analysis



Neutron Radius from Form Factor

R. J. Furnstahl nucl-th/0112085

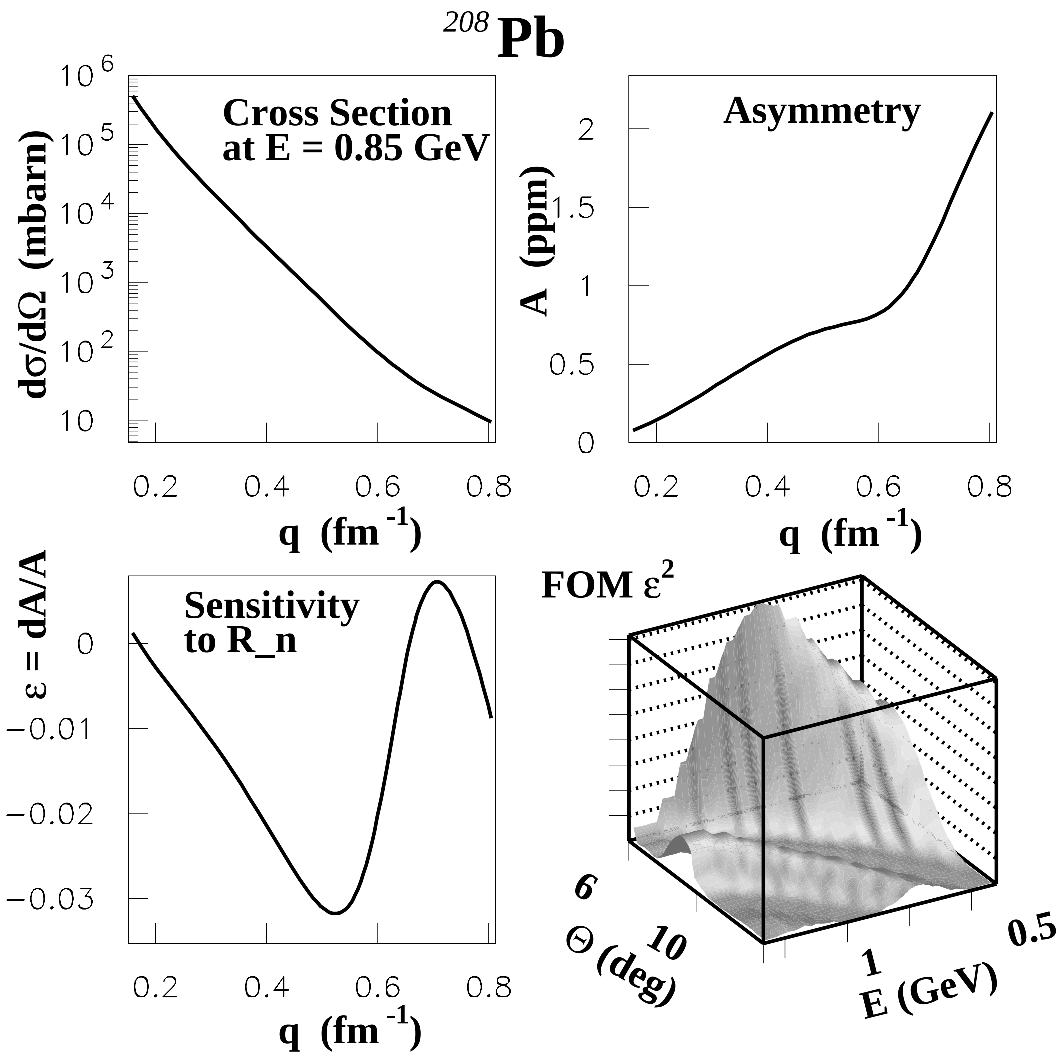
Neutron Radii in Mean-Field Models



$\rightarrow$ Measurement at one Q^2 Measures R_n

Choice of Kinematics : Lead

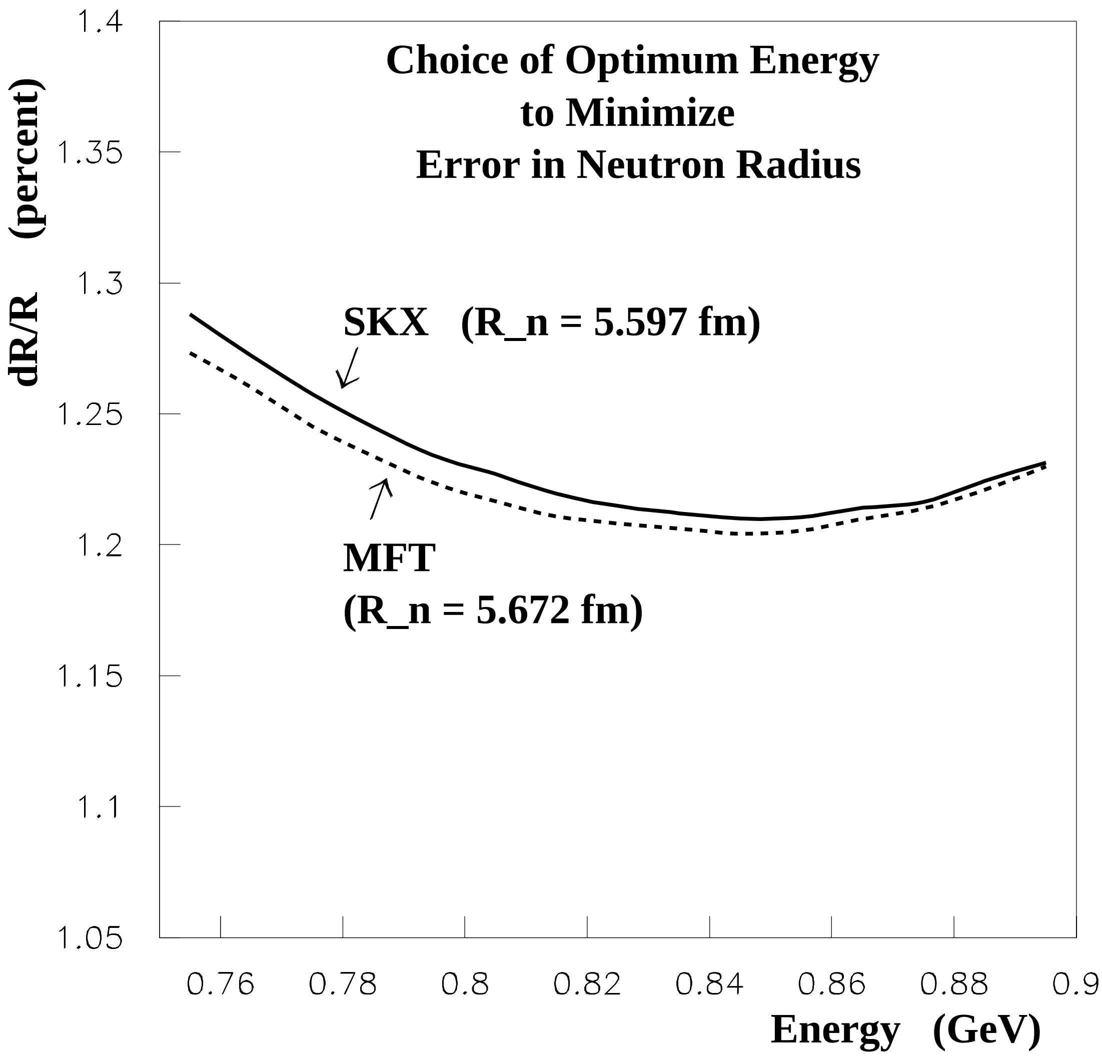
- Easy to isolate elastic electrons (2.6 MeV to 1st excited state)
- Doubly Magic – Simple, well-known structure (good 1st calibration of theory)



Optimum for ^{208}Pb : 0.85 GeV, $\theta = 6^\circ$, $q = 0.45$ fm^{-1}

Accuracy of R_n from Lead

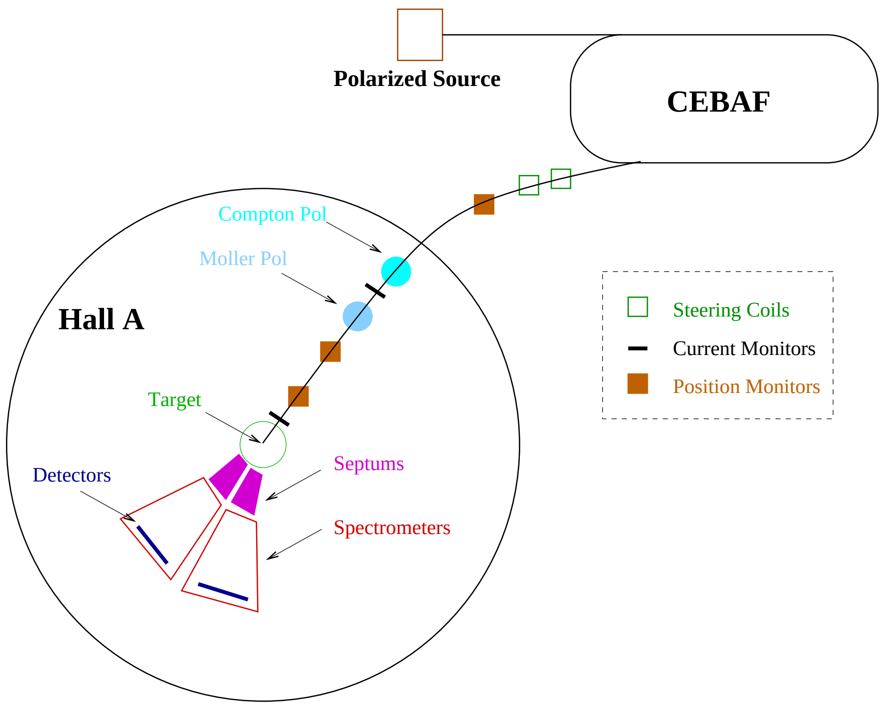
(Polarization accuracy 2% assumed)



$\rightarrow$ Insensitive to R_n or to model ($i.e.$ to shape)

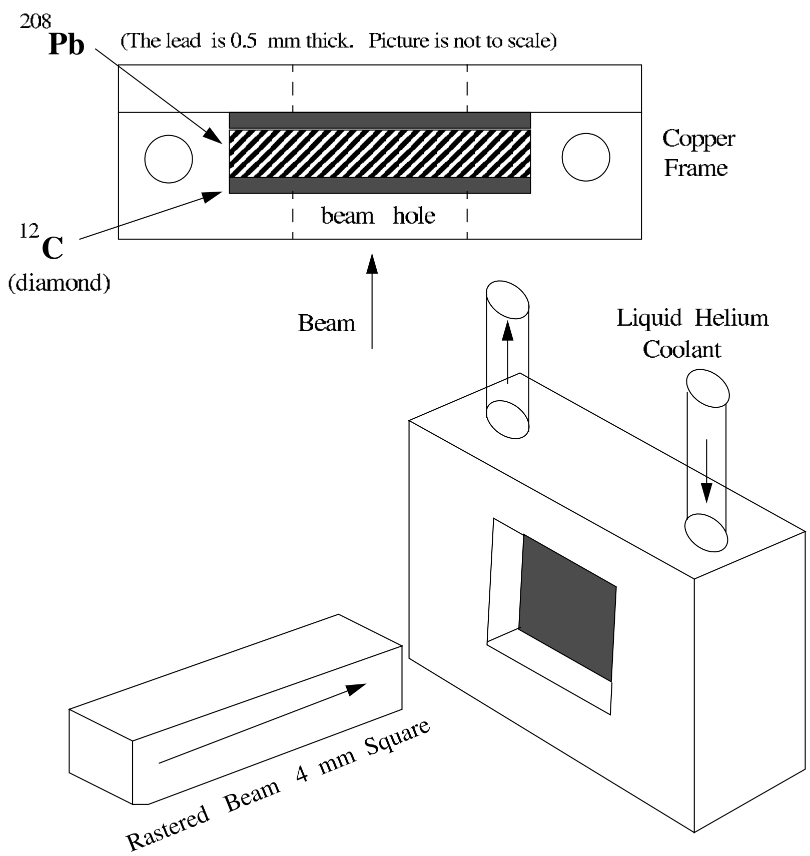
Proposed JLab ^{208}Pb Experiment

JLab Proposal E-00-003, R. Michaels, P. Souder, and G. Urciuoli, spokespersons (2000)



Measured Asymmetry ($p_e A$)	0.51 ppm
Beam Energy	850 MeV
Beam Current	50 μA
Target	10% $r.l.$ Pb
Scattering Angle	6°
Required Statistical Accuracy	3%
Energy Cut (due to detector)	4 MeV
Detected Rate (each Spectrometer)	860 MHz
Running Time	30 days

High Power (40 Watt) Lead Target



DIAMOND BACKING

- → Very High Thermal Conductivity
- → Negligible Systematic (^{12}C)

Systematic Errors

Statistical Goal 15 ppb or 3%

- Want Systematics $\lesssim$ 1 ppb
  - Averages over a 1-month run:
    - Charge Asymmetry $\lesssim 100 \pm 10$ ppb
    - Position Differences $\lesssim 1 \pm 0.1$ nm
  - Controls and Feedbacks at Polarized Source
  - Setup of Beam to Dampen Position Difference
  - Cavity Beam Position Monitors
- Normalization $\lesssim$ 2%
  - Q^2 Determination at 6° – 0.3% systematic error
  - Polarization to 1% (or at least 2%)
- Backgrounds (inelastic, ^{12}C)
- Pedestals and Nonlinearities

Accurate Polarimetry

Can we achieve 1% error (or at least 2%) ?

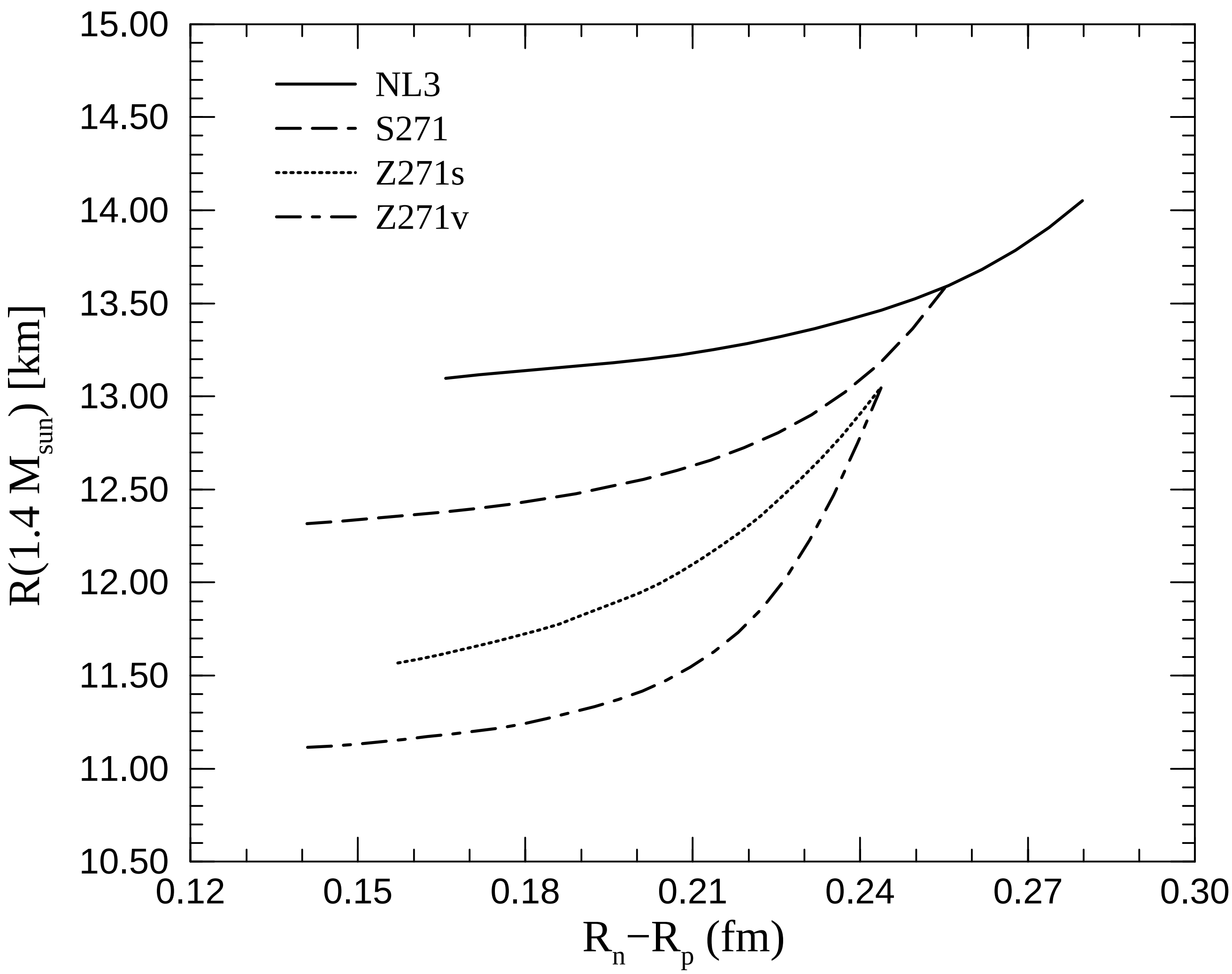
Strategies:

- Møller accuracy 3% limited by target foil polarization.
- Compton Polarimeter at 6 GeV ($\sim$1%) $\rightarrow$ calibrate Møller.
- Use calibrated Møller at lower energies.
- Use Compton to monitor polarization during run.
  ($\sim$1% relative per day)
- Upgrade Compton Polarimeter to green laser.
- Cross check versus Mott and other Halls' Møllers.

Relationship of R_n to Neutron Stars

C. J. Horowitz, J. Piekarewicz, Phys. Rev. Lett. 86, 5647 (2001)

C. J. Horowitz, J. Piekarewicz, Phys. Rev. C64, 062802 (2001)



$\rightarrow$ Do quark stars exist? (NY Times, April 11)

Summary

- R_n is Fundamental to Nuclear, Atomic, and Astrophysics
- State-of-Art Control of Systematics Required
- Polarimetry is Crucial
- Strategy: HAPPEX II and HAPPEX ^{4}He as “Dry Run” for Pb Parity