^{208}Pb Radius Experiment (PREX)

In a heavy nucleus like ^{208}Pb the difference between the neutron radius R_n and the proton radius R_p is believed to be several percent. This neutron skin has not been well established experimentally in stable nuclei. We plan to measure the neutron charge radius R_n (i.e. the RMS radius of neutrons in a nucleus) in a clean and model independent way analogous to the classic measurements [1] of the proton radius R_p and with unprecedented accuracy as suggested originally by Donnelly, Dubach, and Sick [2]. Experimentally R_n is rather poorly known – to probably only 5% [3]. Indeed the best estimates of R_n appear to come from nuclear theory where models have been constrained primarily by data *other than* neutron radii. Therefore, a measurement of R_n will provide a powerful independent check of basic nuclear theory. In addition, R_n measures the density dependence of the symmetry energy of neutron rich nuclear matter, which will constrain neutron star theory [5].

The PREX experiment (E03-011) measures the parity violating asymmetry in elastic scattering $A = (\sigma_R - \sigma_L)/(\sigma_R + \sigma_L)$. This asymmetry arises due to the the interference of the Z^0 boson amplitude of the weak neutral interaction with the photon amplitude. The asymmetry is sensitive mainly to the neutron radius R_n because the weak charge of the neutron is much larger than that of the proton. In PWIA, the relationship between the asymmetry and the neutron form factor is $A_{LR} = \frac{G_F Q^2}{4\pi\alpha\sqrt{2}}\left[1 - 4\sin^2\theta_W - \frac{F_n(Q^2)}{F_p(Q^2)}\right]$ where $F_n(Q^2)$ and $F_p(Q^2)$ are the neutron and proton form factor of the nucleus. Thus A_{LR} is approximately proportional to the ratio of neutron to proton form factors. In the above we used PWIA to illustrate. To achieve 1% accuracy requires corrections for Coulomb distortions, by Horowitz [4].

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