

Electroweak radiative corrections to e-nucleus scattering for MESA

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e-Nucleus Scattering at MESA

- Parity violating electron-nucleus scattering
- Carbon experiment: “Atomic parity without the atom”
- Lead experiment and neutron stars
- Beam normal single-spin asymmetry: “pure radiative correction”

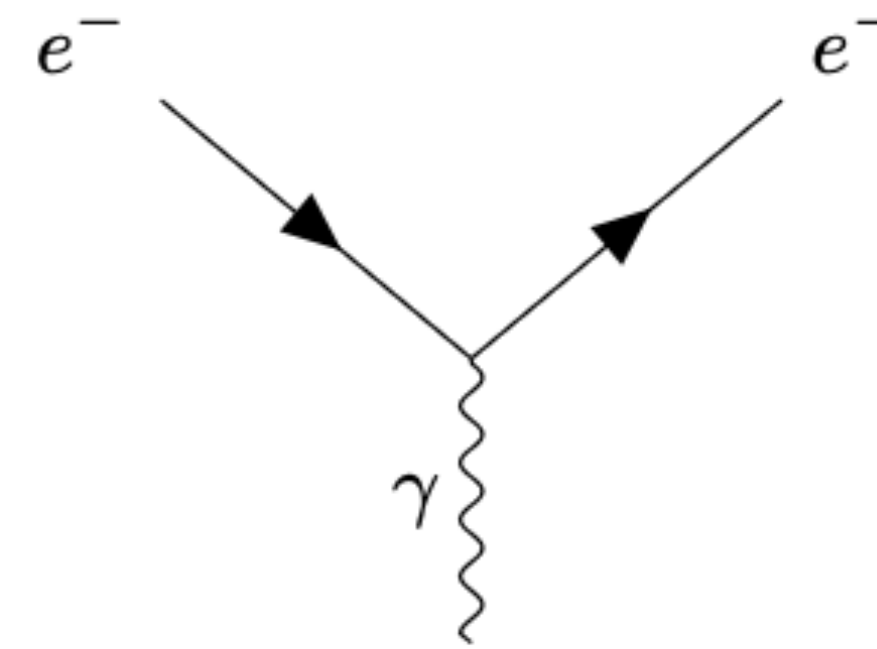
Parity Violating Asymmetry A_{pv} for e-Nucleus Scattering

- A_{pv} is fractional difference in cross section for + and - helicity electrons.

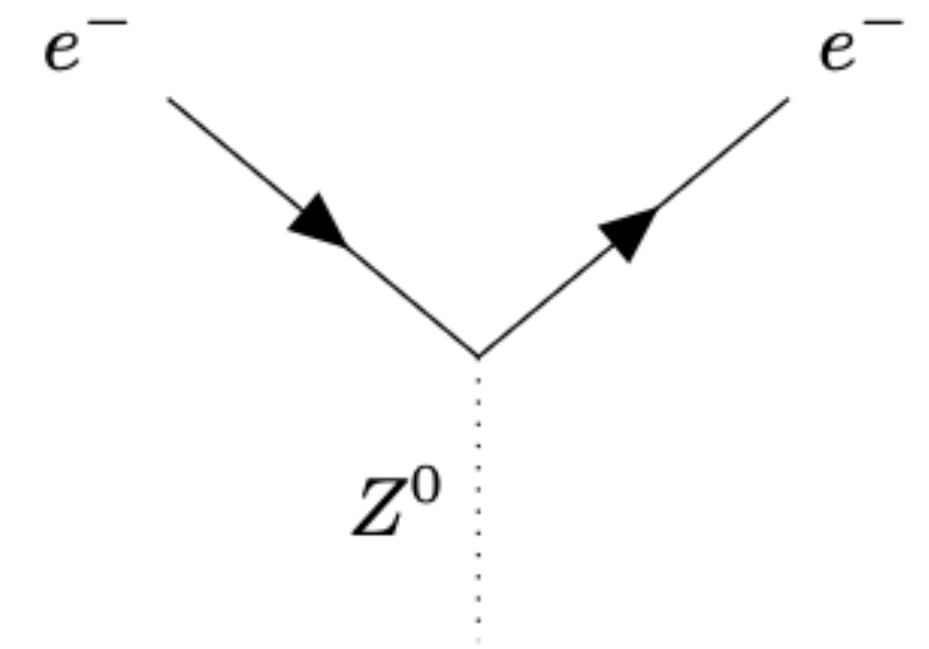
$$A_{pv}^b \equiv \frac{d\sigma_+/d\Omega - d\sigma_-/d\Omega}{d\sigma_+/d\Omega + d\sigma_-/d\Omega} = \frac{G_F Q^2}{4\pi\alpha\sqrt{2}} \frac{|Q_{wk}|}{Z} \frac{F_{wk}(Q^2)}{F_{ch}(Q^2)}$$

- In 2nd Born approx we include radiative corrections to both weak and E+M amplitudes.

$$A_{pv}^{(2)} = A_{pv}^b \left(\frac{1 + v_\pi^a(Q^2) + v_{vs}^a(Q^2)}{1 + v_\pi(Q^2) + v_{vs}(Q^2)} \right)$$

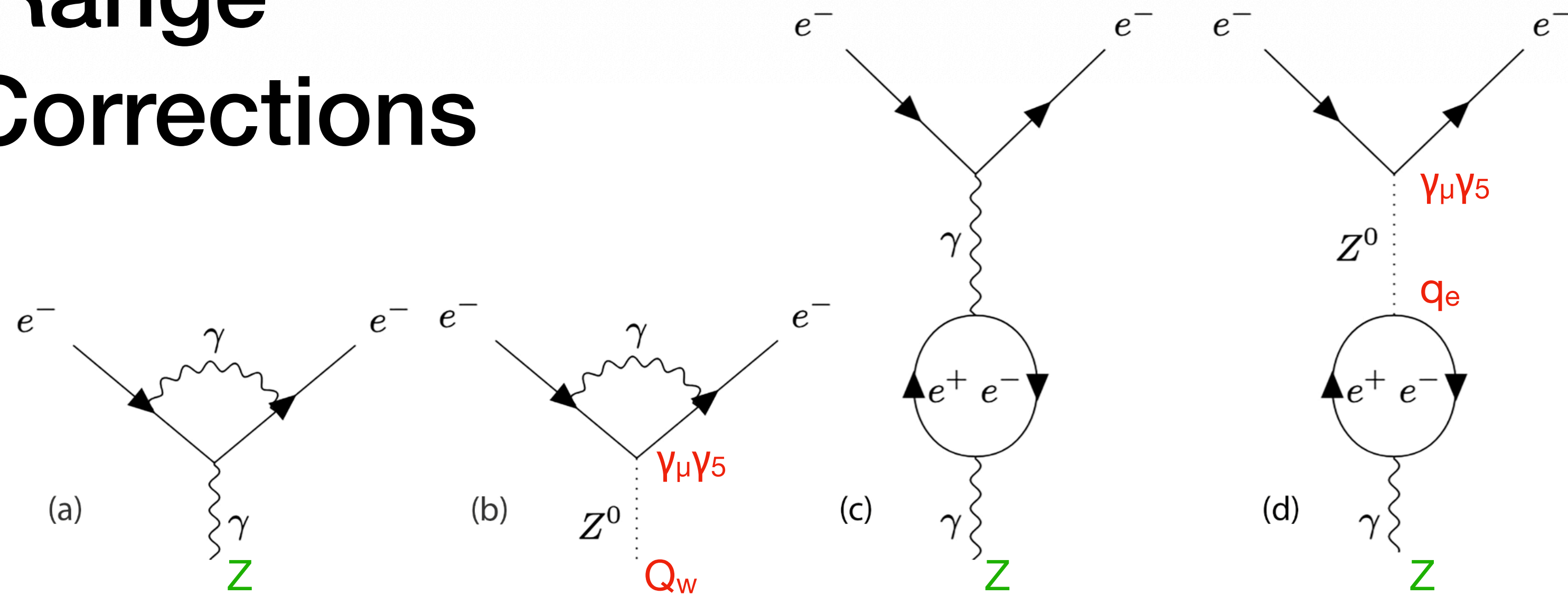


(a) One photon exchange.



(b) Z^0 -boson exchange.

Long Range Radiative Corrections



Vertex

Weak vertex

Vacuum pol.

Weak vac. pol.

- Radiative corrections to the electron arm for PV scattering from a spin zero nucleus. -> PREX (^{208}Pb), CREX (^{48}Ca), ^{12}C and MREX(^{208}Pb) at MESA.
- Vector vertex or Axial-vector vertex are order $(\alpha/2\pi)\ln^2(Q^2/m^2) \sim 10\%$
- Vac. pol. order $(\alpha/2\pi)\ln(Q^2/m^2) \sim 1\%$. Weak vac pol -> small weak charge of e.

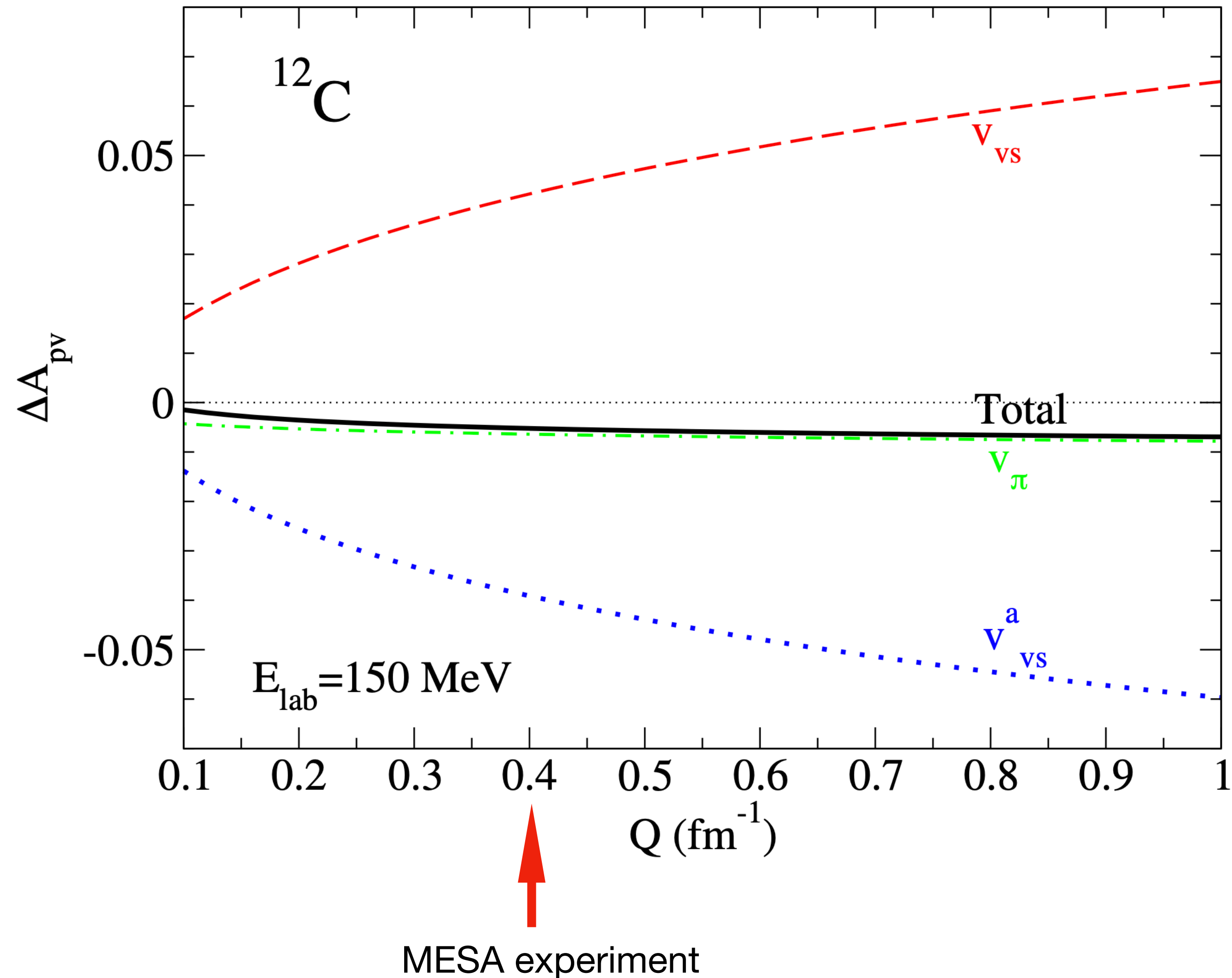
Carbon Experiment

Measure weak charge of ^{12}C .
 “Atomic parity without the atom”

Correction	2nd Born (%)	Eikonal (%)
v_{vs}	4.19	4.22
v_{vs}^a	-4.07	-3.91
v_{π}	-0.65	-0.64
$v_{vs} + v_{vs}^a + v_{\pi}$	-0.53	-0.52

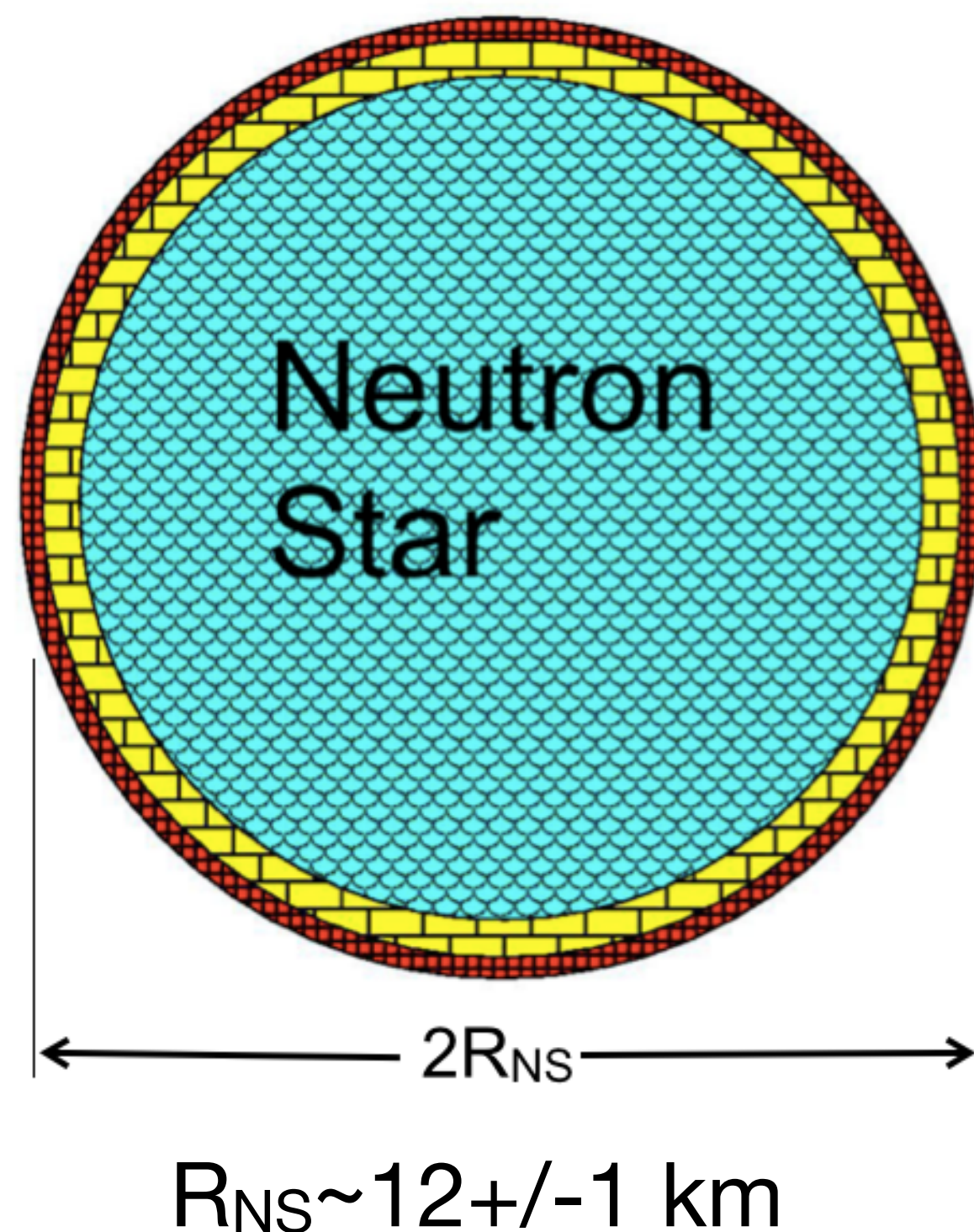
Goal: measure A_{pv} to 0.3% needs very good polarimeter.

0.5% correction from vac polarization relevant but not problematic.



^{208}Pb and Neutron Stars

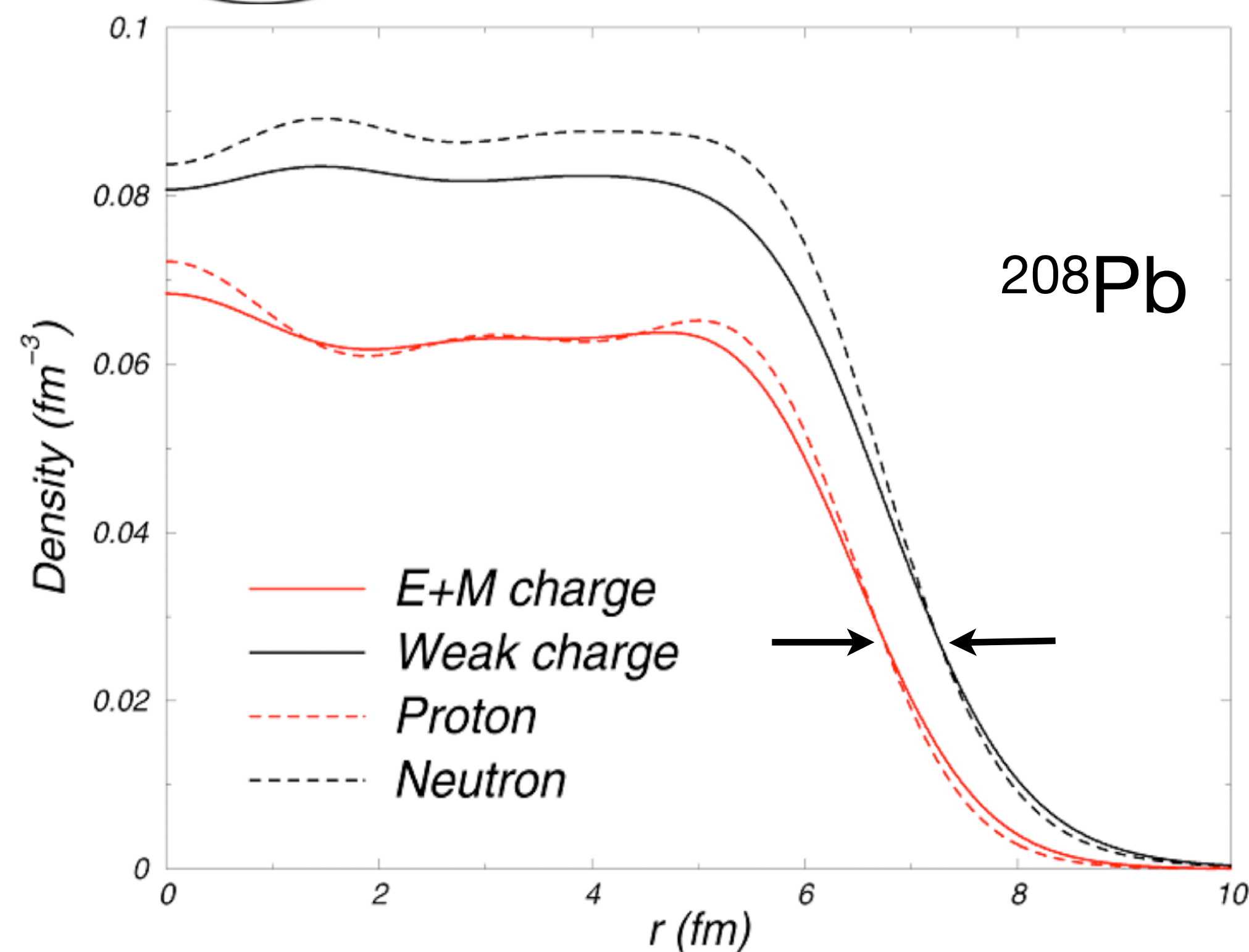
- Pressure of neutron matter pushes neutrons out against surface tension $\Rightarrow R_n - R_p$ of ^{208}Pb correlated with P of neutron matter ($P \sim 6 \pm 2 \text{ MeV/fm}^3$).
- Radius of a neutron star also depends on P of neutron matter.
- Measurement of R_n (^{208}Pb) in laboratory has important implications for the structure of neutron stars.



PREX at JLAB

$$R_W = 5.800 \pm 0.075 \text{ fm}$$

$$(R_{ch} = 5.503 \text{ fm})$$



Neutron star is 18 orders of magnitude larger than Pb nucleus but both involve neutron rich matter at similar densities with the same strong interactions and equation of state.

Coulomb distortions for ^{208}Pb

$$[\boldsymbol{\alpha} \cdot \boldsymbol{p} + (V_{\text{ch}} + \Delta V_{\text{ch}}) \pm (A + \Delta A) + \beta m] \Psi = E \Psi$$

Milstein+Sushkov v_{π}

Roca-Maza+Jakubassa-Amundsen $v_{\nu s}$

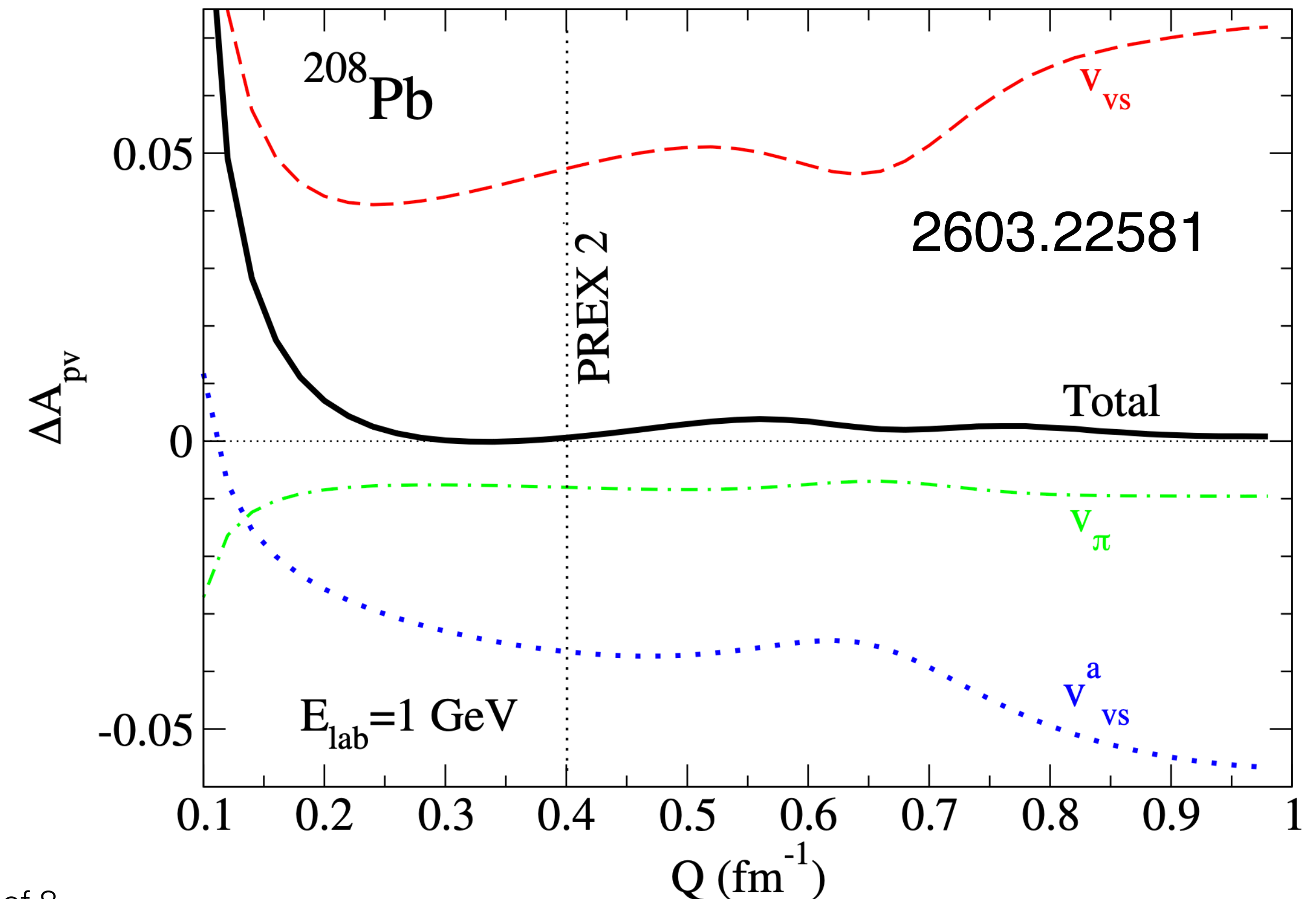
CJH Reed + CJH

$$A(r) = \frac{G_F}{2^{3/2}} \rho_{wk}(r)$$

Solve Dirac eq. for e in Coulomb plus weak potentials. Include radiative corrections in ΔV and ΔA

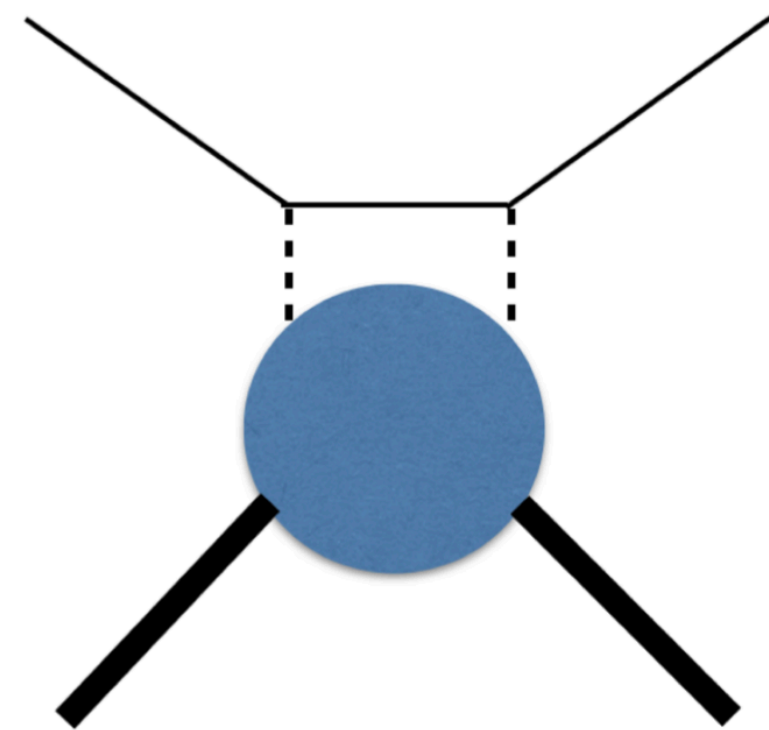
Correction	^{208}Pb (1 GeV)	
	2nd B. (%)	Eik. (%)
$v_{\nu s}$	4.19	4.73
$v_{\nu s}^a$	-4.07	-3.66
v_{π}	-0.65	-0.80
$v_{\nu s} + v_{\nu s}^a + v_{\pi}$	-0.53	0.06

Total small, not an issue for MREX



Beam normal single-spin asymmetry

- Left-right asymmetry for transversely polarized electrons. Vanishes at tree-level due to time-reversal. Nonzero result is “pure radiative correction”.



- M. Gorchtein calculates gamma-gamma box via dispersion relation. Predicts no strong Z dependence. Agrees for C, Ca. Observe anomaly for Pb where $A_n \sim 0$.
- New JLAB experiment to run early 2027. A_n for Z=6, 20, 40, 50, 74, 79, 82. Also Mainz measurements

