Radiative corrections and ^{27}Al "background"

- Comments on gamma-Z box
  - It is all Misha's discovery!
  - We need to work to a very high standard and make a measurement that, with its theoretical error, could significantly disagree with the standard model. This includes **theoretical errors that can be defended** against scathing criticism.
  - I worry about the part I forgot, or the mistake we all made. These could impact error.
  - We should be in it for the long haul. It is enough for the error to be small after appropriate documentation, calculations, or measurements.

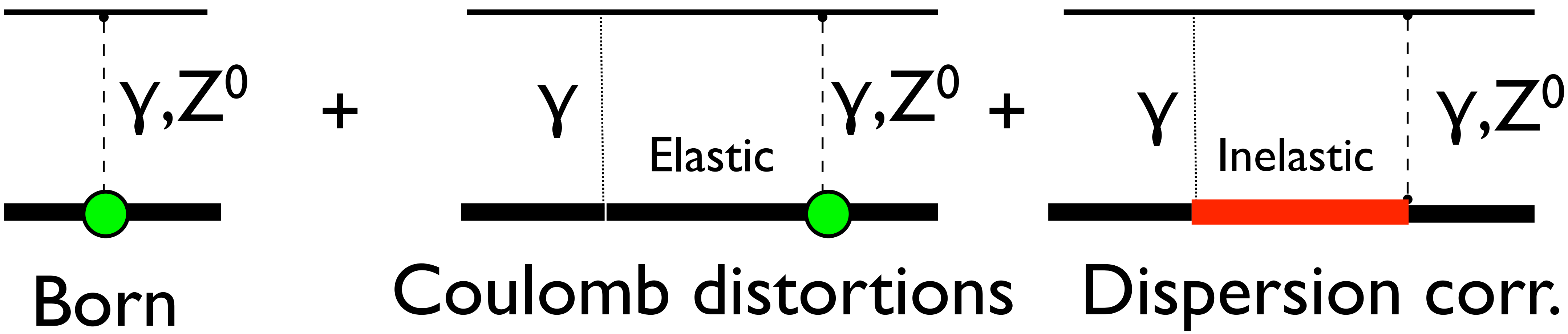
Gamma-Z box questions

- What PV (not so?)DIS measurements will best constrain the calculation? What kinematics, how many points, and to what accuracy?
- Do any of the above measurements constrain interesting hadronic structure that would further motivate an experiment?
- Can the lattice calculate anything useful to constrain the calculations?

Radiative corrections

- Increasingly important for many precision measurements.
- Can isolate some radiative corrections with only polarized electrons (no need for positrons).
- PREX, CREX, Qweak Al provide unique data sets on high Z targets. Comparing these to low Z data allows "Rosenbluth like" separations of different coulomb distortion, dispersion ... contributions vs Z. Instead of long / transverse vs angle, have coulomb distortion / dispersion contributions vs Z.
- Analyzing high Z and low Z data together can provide important additional insight even if only interested in low Z experiments.

Radiative corrections



- Coulomb distortions are coherent, order $Z\alpha$. Important for PREX (Pb has Z=82).
- Dispersion corrections order α (not $Z\alpha$). Important for QWEAK because correction is order $\alpha/Q_w \sim 10\%$ relative to small Born term (Q_w). --- M. Gorshteyn
- Both Coulomb distortion and dispersion cor. can be important for Transverse Beam Asymmetry A_n for ^{208}Pb. Note Born term gives zero by time reversal symmetry.

Coulomb Distortions for PREX

- We sum elastic intermediate states to all orders in Zα by solving Dirac equ. for e moving in coulomb V and weak axial A potentials.

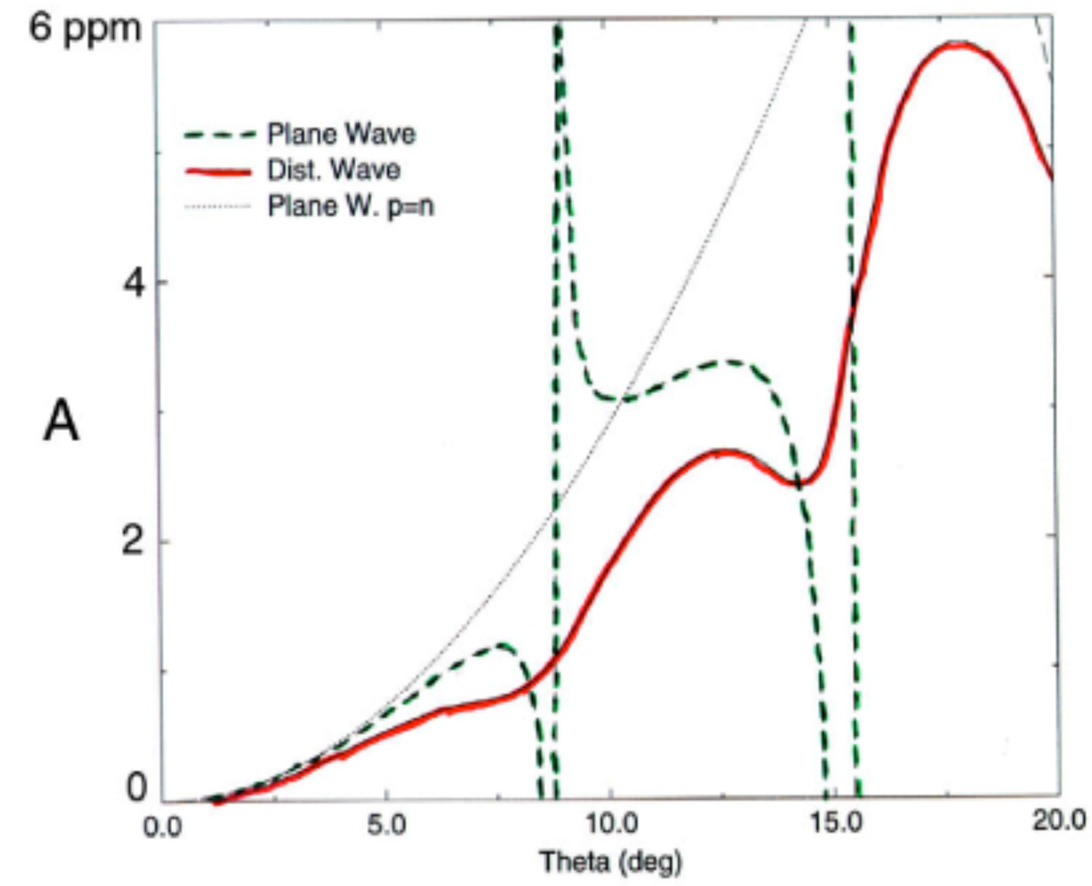
$$A \propto G_F \rho_W(r) \approx 10 \text{ eV} \qquad V(r) \approx 25\text{MeV}$$

- Right handed e sees V+A, left handed V-A

$$A_{pv} = [d\sigma/d\Omega|_{V+A} - d\sigma/d\Omega|_{V-A}]/2d\sigma/d\Omega$$

- Coulomb distortions reduce A_{pv} by ~30%, but they are accurately calculated. Q^2 shared between "hard" weak, and soft interactions so weak amplitude $G_F Q^2$ reduced.

^{208}Pb at 850 MeV

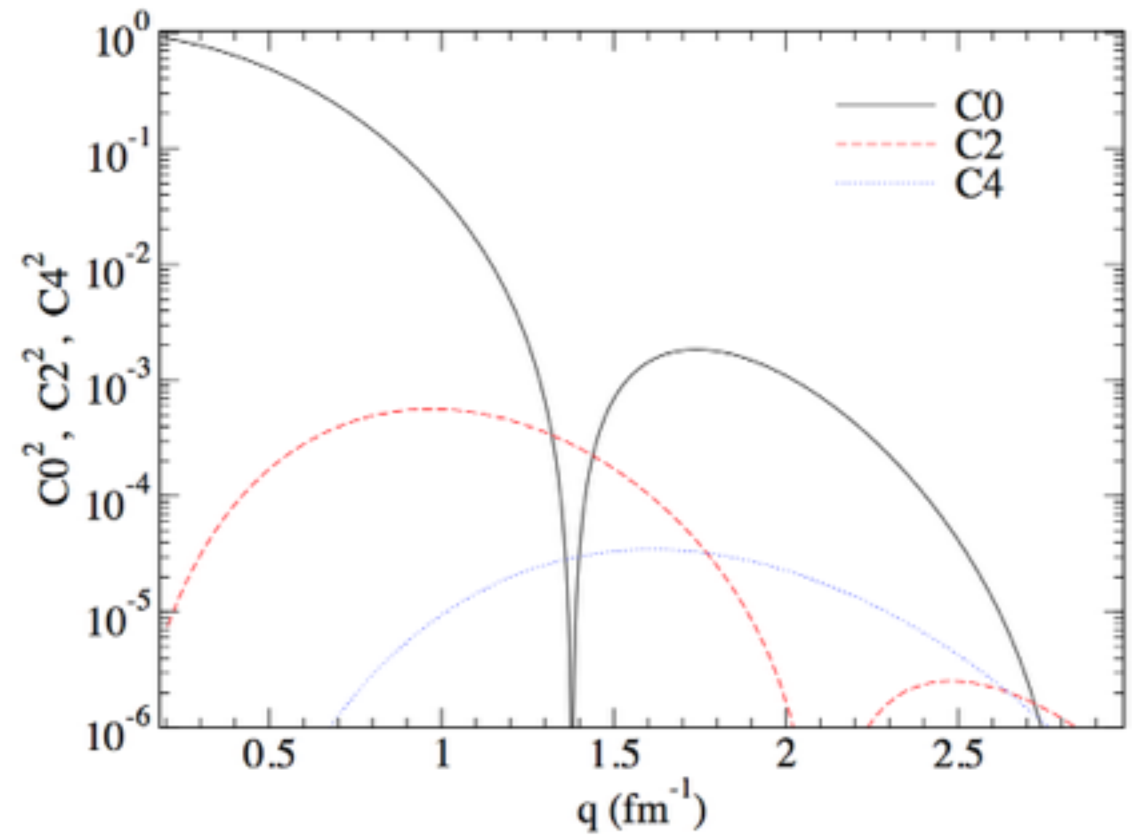


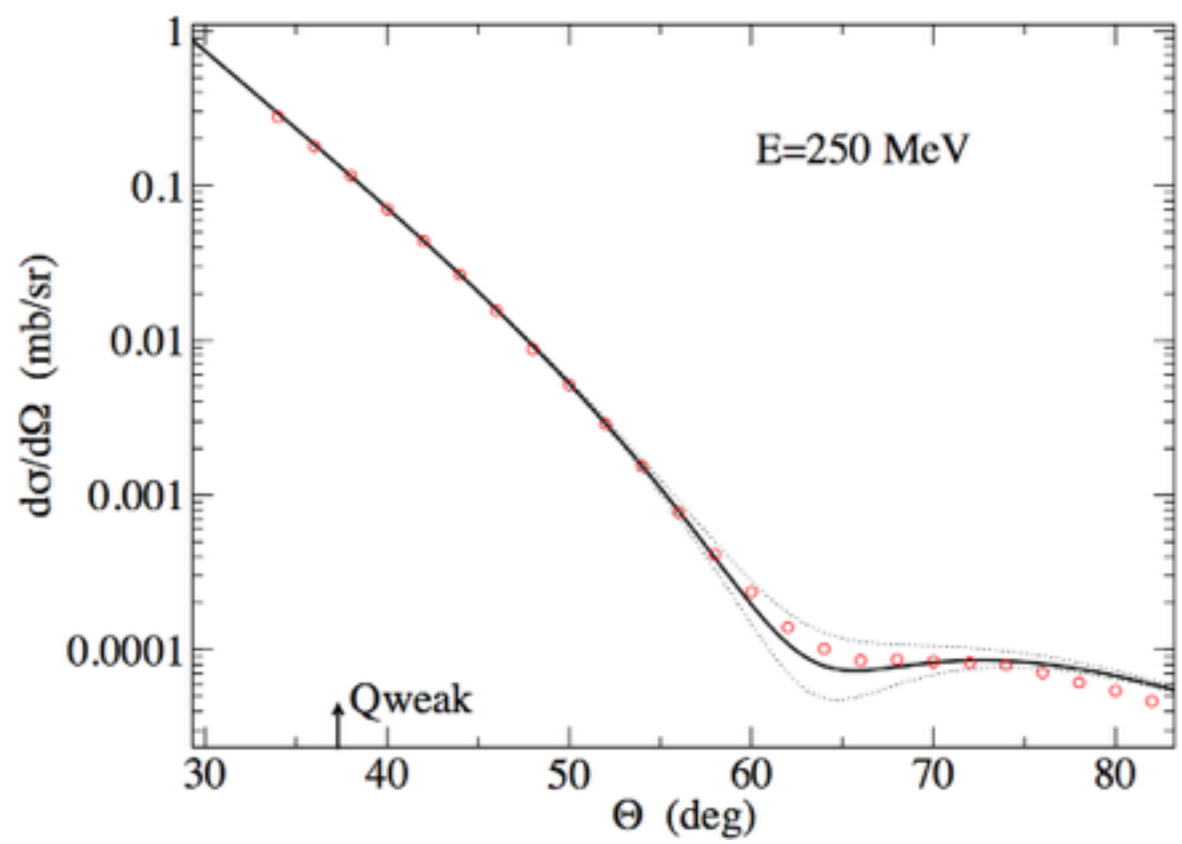
$$A_{pv} = \frac{G_F Q^2}{2\pi\alpha\sqrt{2}} \frac{F_W(Q^2)}{F_{\text{ch}}(Q^2)}$$

--- With E.D. Cooper

QWEAK ^{27}Al Preliminary

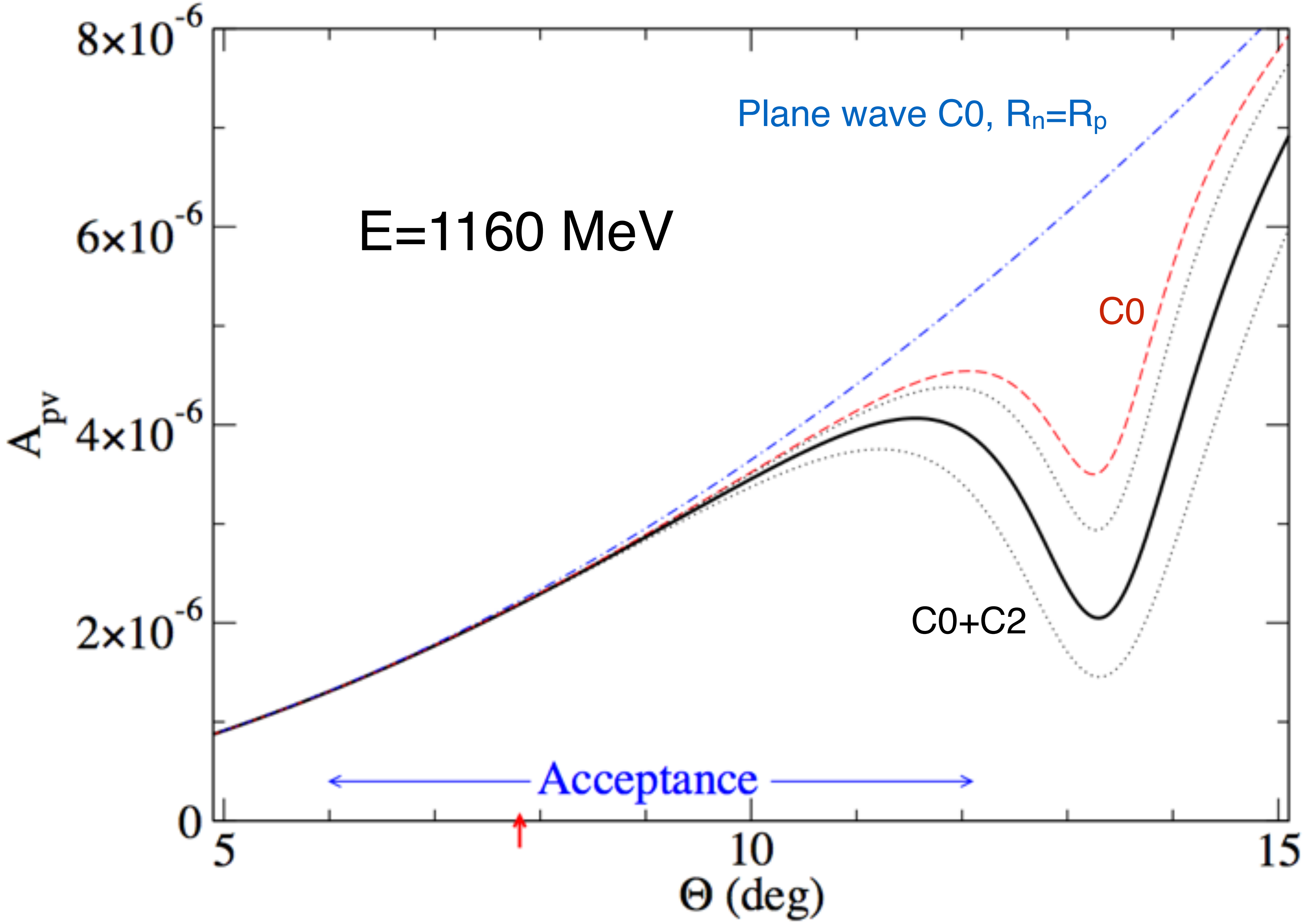
- Al windows of Q_{weak} hydrogen target important background because weak charge and A_{pv} much larger for Al than H.
- Simple RMF model of ^{27}Al, proton $1d_{5/2}$ hole using FSUgold interaction.
- Ignore small transverse and C4 multipoles.
- Full distorted wave for C0, add small C2 in Born approximation.
- Error band from multiplying C2 amplitude of hole by 0.5 and 1.5





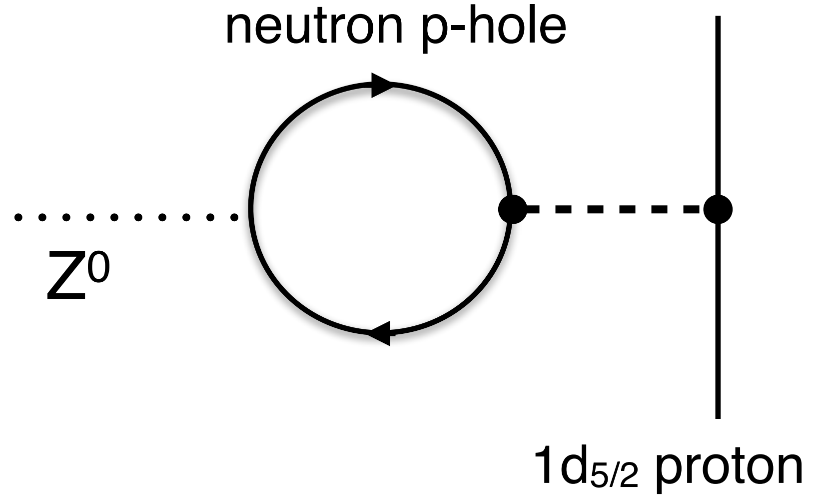
^{27}Al parity violating asymmetry

- Monopole form factor includes full coulomb distortions, while C2 (and weak C2) in Born approx.
- Coulomb distortions reduce A_{pv} (from C0) in diffraction minimum. Small at 8 deg.
- Role of C2 important for large angle part of acceptance.

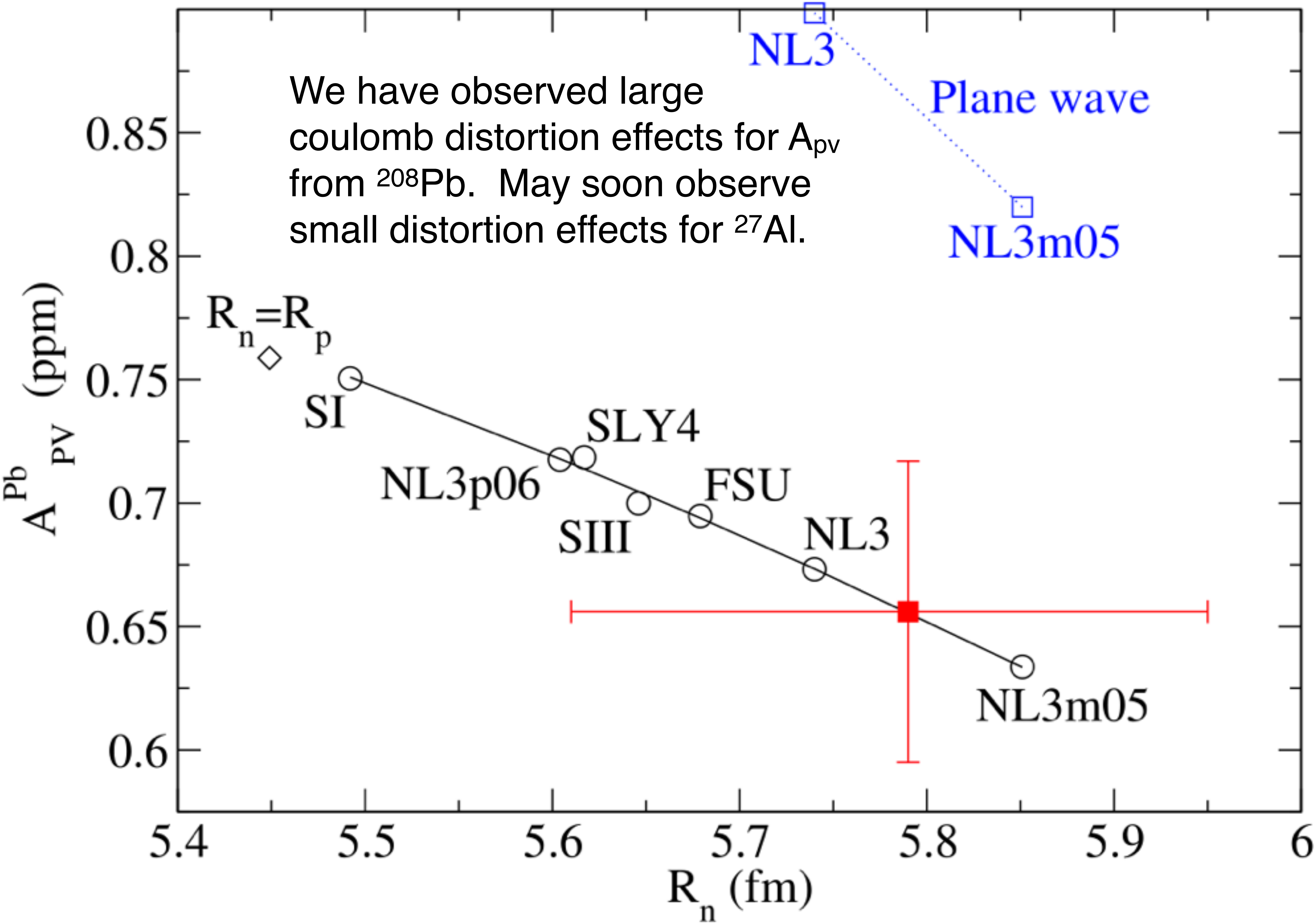


Core polarization and neutron radius

- Largest remaining nuclear structure uncertainty, near diff. minimum, likely to be core polarization where proton $d_{5/2}$ hole polarizes neutron density.
  - This has much larger weak charge then original proton hole.
  - Simple calculation would be very useful.
  - Integrate over acceptance to find final (small) uncertainty for Q_{weak} measurement.



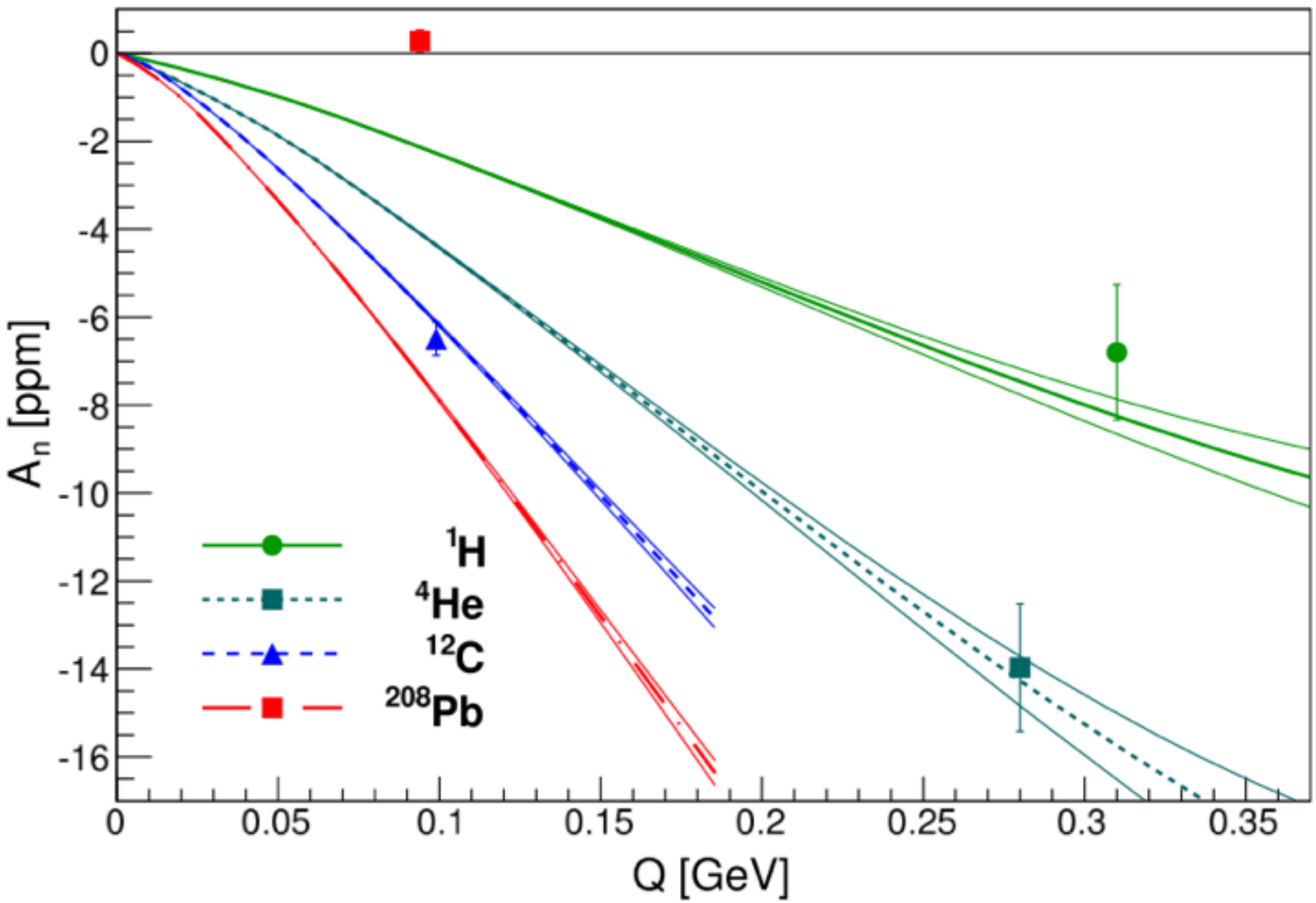
- $d\ln A_{pv}/d\ln R_n \sim 2$. 4% A_{pv} measurement gives 2% R_n measurement! Better than PREX-I (3%).
- Nuclear structure models only have very small range in R_n-R_p. Q_{weak} ^{27}Al provides important nuclear structure test. "Poor man's ^{40}Ca."


We have observed large coulomb distortion effects for A_{pv} from ^{208}Pb. May soon observe small distortion effects for ^{27}Al.
NL3
Plane wave
NL3m05
$R_n=R_p$
SI
SLY4
NL3p06
FSU
SIII
NL3
NL3m05
A^{Pb}_{PV} (ppm)
R_n (fm)
0.85
0.8
0.75
0.7
0.65
0.6
5.4
5.5
5.6
5.7
5.8
5.9
6

Transverse Beam Asymmetry A_n

- Left / Right cross section asymmetry for electrons with transverse polarization.
- Potential systematic error for PV from small trans components of beam polarization.
- A_n vanishes in Born approx (time reversal) --> Sensitive probe of 2 or more photon effects.
- Full dispersion calculations include all excited states but only for 2 photon exchange.

Measure A_n for Calcium



Theory, experiment agree for H, ^{4}He, ^{12}C, but disagree completely for ^{208}Pb.

- Measure A_n for both ^{40}Ca, ^{48}Ca during CREX to study dependence of coulomb distortions on Z and dispersion contributions on N.

C. Horowitz, Indiana U., Gamma Z box, JLAB, Dec.