Dispersion Corrections to electron-nucle(on/us) interaction

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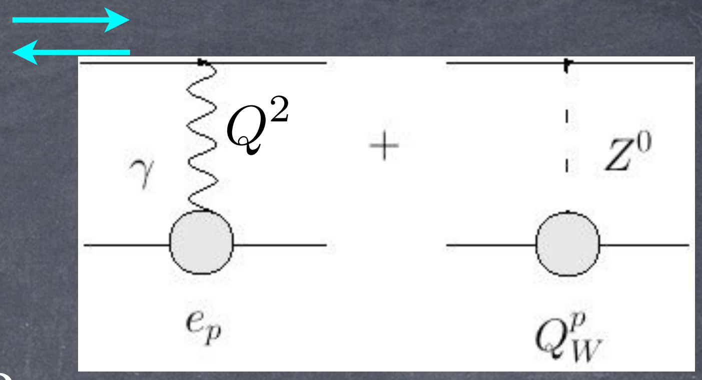
Outline

- γZ-box from forward dispersion relations: status and uncertainty (hmm... uncertainties)
- Dispersion corrections on nuclei: Nuclear polarizability contribution to Lamb shift
- Beam normal spin asymmetry - dispersion vs. Coulomb distortions
- Implications and further things to do

Elastic e-p scattering with polarized e^- beam



low Q^2, $\epsilon \to 1$

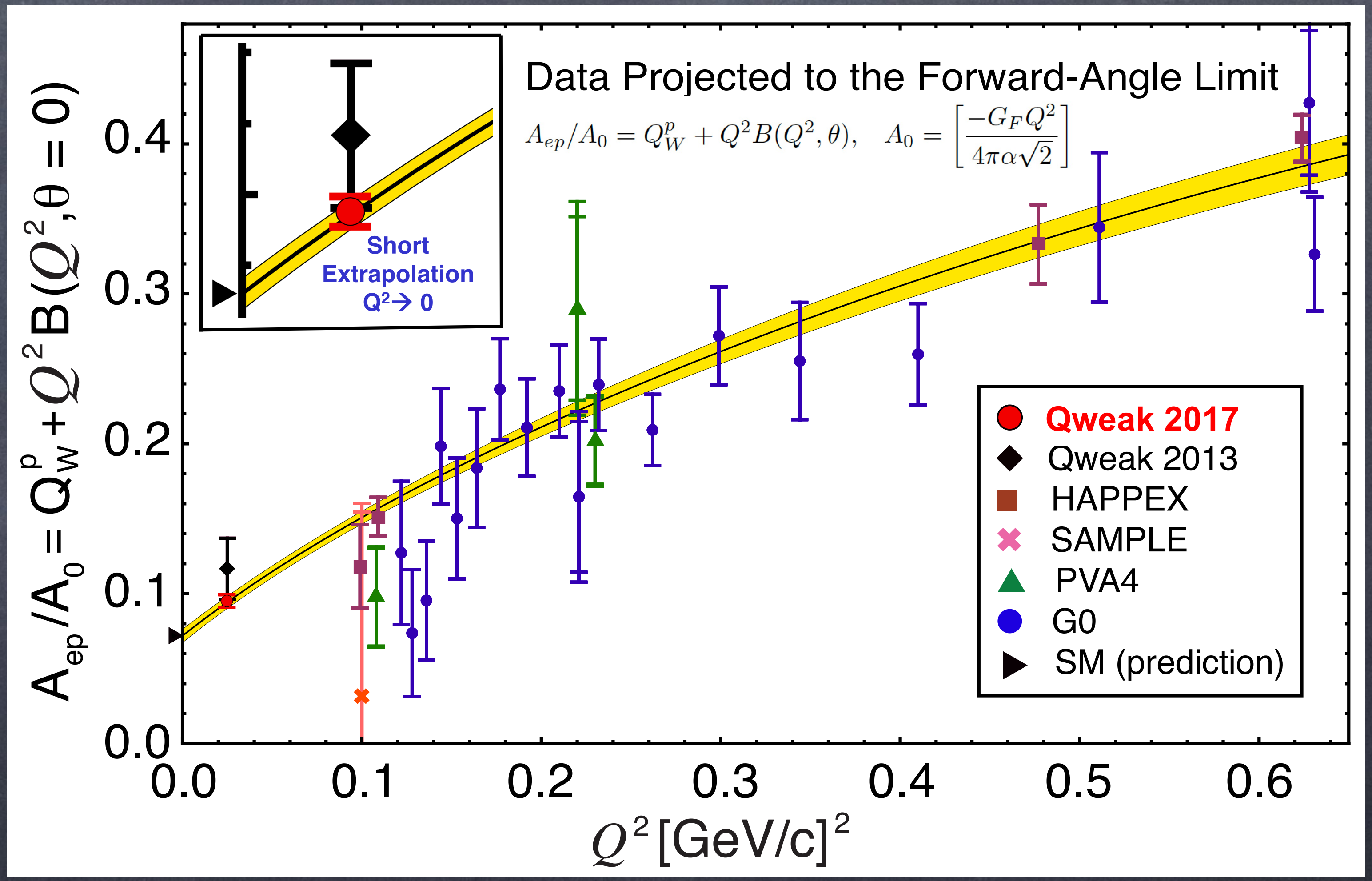
$$A^{PV}(\epsilon, Q^2) = -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left[Q_W^p + Q^2 B(Q^2)\right]$$

Exp.: Get Q_W^p to couple %

Why: see Michael's talk

How: see Wouter's talk

Young et al, '07;
Androic et al, '13
Caballero et al, '14

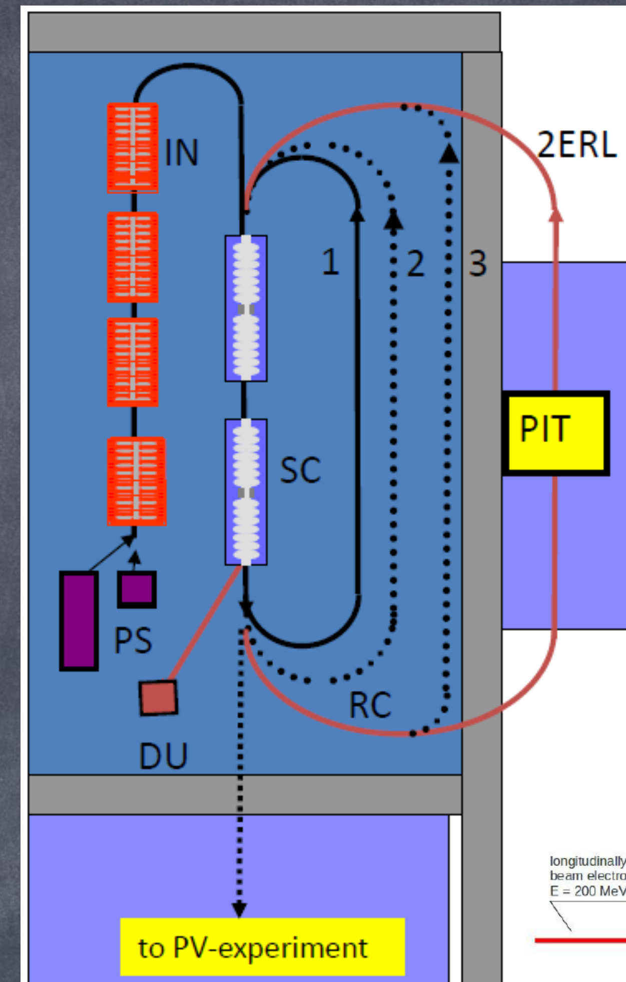


Extrapolation from Q^2=0.03 GeV^2 to 0 still needed;

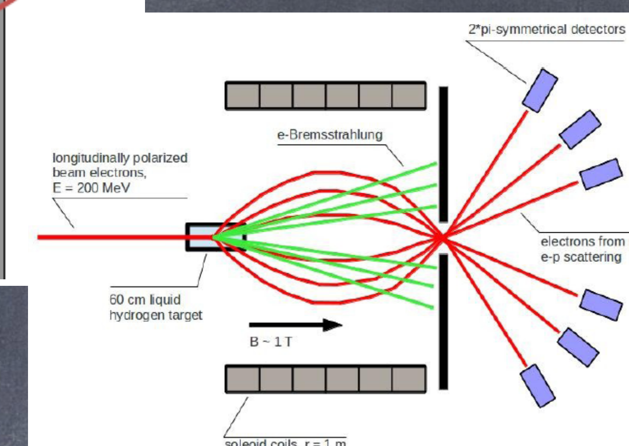
Main contributor: $\tau\ \mu_p^Z\ \mu_p^\gamma$ known modulo μ_s (<10%)

Slight sensitivity to Lattice (μ_s=0) vs PVES data ($\mu_s \neq 0$) but not a big deal

Q-Weak @ MESA/P2:



Frank's talk



Main exp. - hydrogen target
E = 155 MeV (150 μA)
Scattering angle: 20±10 deg
Polarization degree 85±0.5%
Q^2 = 0.0022-0.005 GeV^2

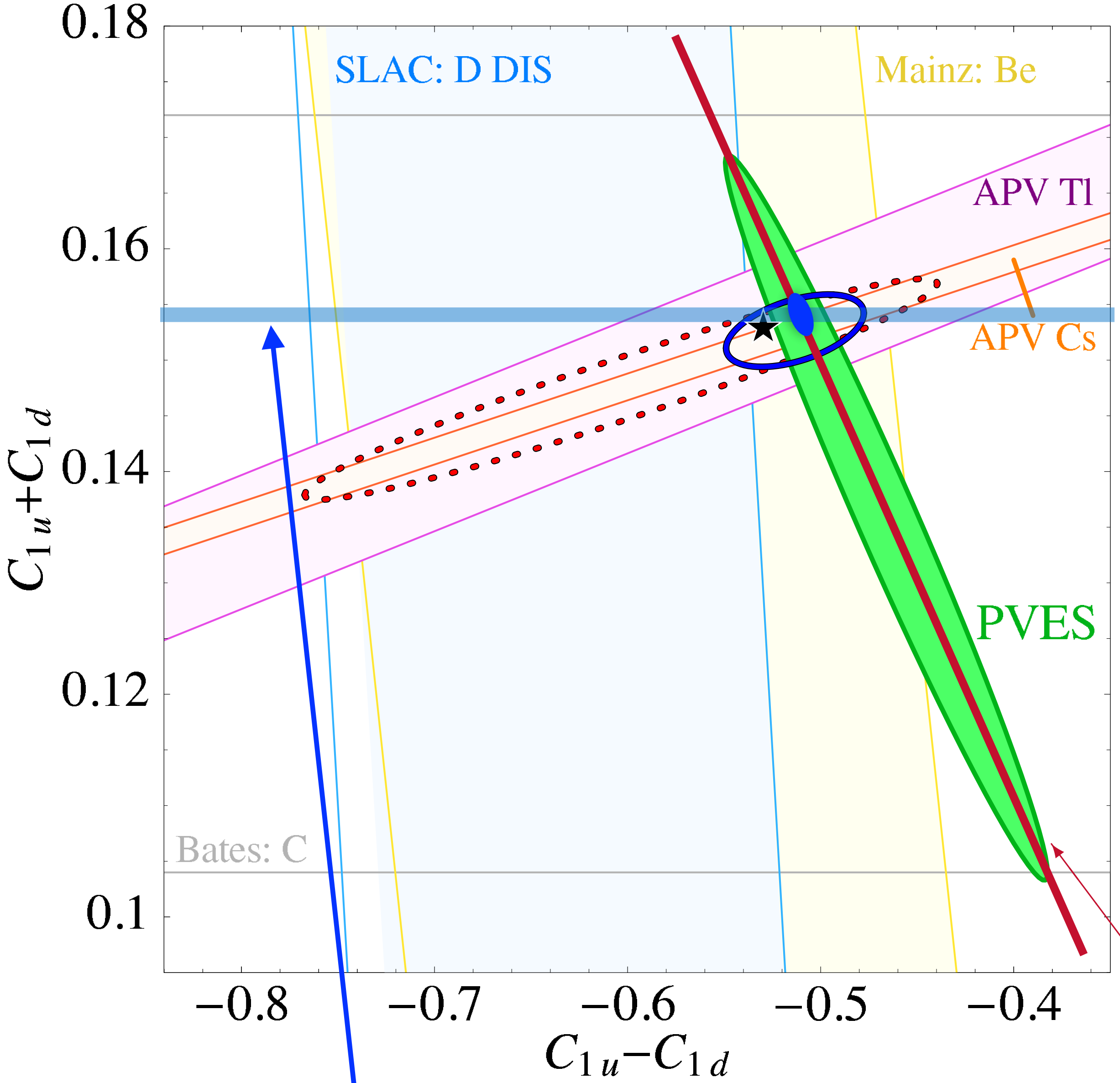
Theory + Exp. uncertainty - 1.8%

Precision goal: $\Delta \sin^2\theta_W(\mu = 0.005) = 3.7 \times 10^{-4} (0.16\%)$

Compare to LEP1, SLC $\Delta \sin^2\theta_W(\mu = M_Z) = 2.1 \times 10^{-4}$

Additional run - Carbon-12 target - measures directly $\sin^2\theta_W$
Test with an easier target (preceding the p-experiment)
Interesting physics case if precision ~0.3%

Impact of MESA (H and C12) on SM tests



A more general approach
for extensions of the Standard Model:

model independent coupling constants,
effective low-energy 4-fermion interaction

C_{1f}: $A_e \otimes V_f$, C_{2f}: $V_e \otimes A_f$

SM prediction (black star):

$$C_{1f} = -I_f + 2Q_f \sin^2\theta_W$$

$$(C_{1u} - C_{1d} = -1 + 2\sin^2\theta_W,$$

$$C_{1u} + C_{1d} = \tfrac{2}{3}\sin^2\theta_W)$$

$$Q_W(p) = -2(2C_{1u} + C_{1d})$$

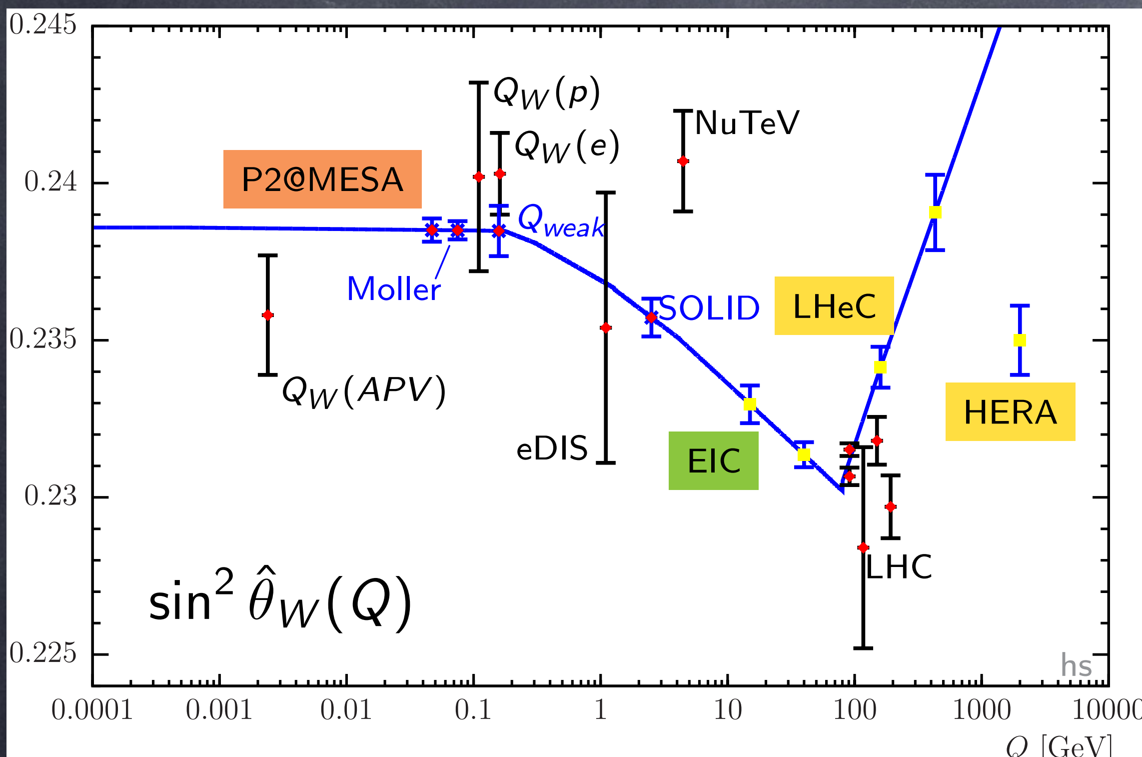
Mainz P2: $\Delta Q_W(p) = \pm 0.0097$ (2.1 %)

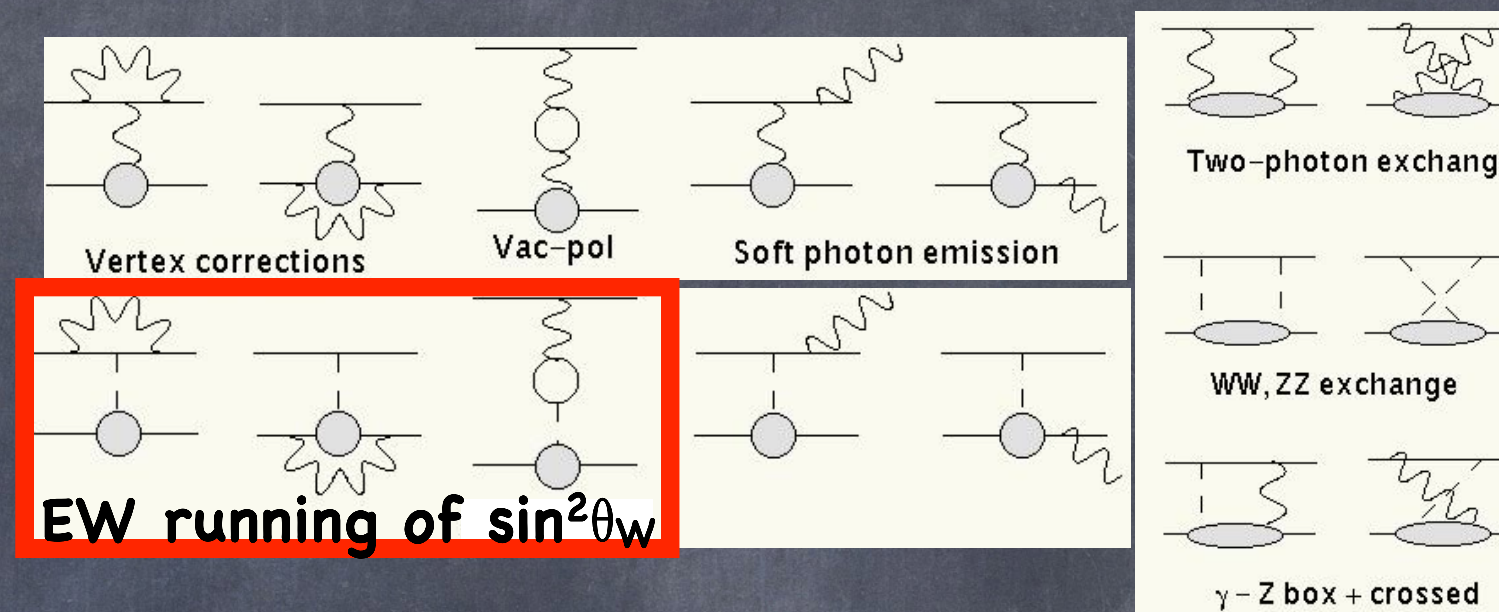
MESA C12: $\Delta Q_W(C12) = 18\Delta(C_{1u}+C_{1d}) = \pm 0.0086$ (0.3%)

Tree level: $Q_W^p = 0.072$, measure to 1% - abs. 10^{-4} accuracy

Radiative corrections at order $\alpha/\pi = 0.0023$...

EW corrections: $\alpha/\pi\ \mathrm{Log}(M_Z^2/M_p^2)$ - can be large





Erler et al. 2003, 2005

Hadronic structure effects are under control

$$Q_W^p = \boxed{(1+\Delta_\rho+\Delta_e)(1-4\sin^2\hat\theta_W+\Delta_e') + \Box_{WW} + \Box_{ZZ}} + \boxed{\Box_{\gamma Z}}$$

Marciano and Sirlin, '83, '84, '85; Ramsey-Musolf, '99

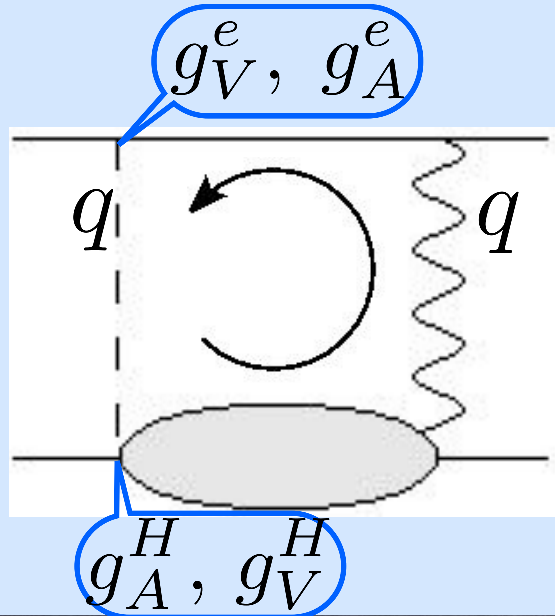
MG, Horowitz '09

$k^\mu = (E, \vec{k})$

$Q^2 = -q_\mu q^\mu \geq 0$

$W^2 = (p+q)^2$

$p^\mu = (M, \vec{0})$



Forward dispersion relation for

$$\Box_{\gamma Z} = g_V^e \Box_{\gamma Z_A} + g_A^e \Box_{\gamma Z_V}$$

Lower blob: forward interference Compton tensor

$$W^{\mu\nu} = \left(-g^{\mu\nu} + \frac{q^\mu q^\nu}{q^2}\right) F_1^{\gamma Z} + \frac{\hat{P}^\mu \hat{P}^\nu}{(pq)} F_2^{\gamma Z} - \epsilon^{\mu\nu\alpha\beta} \frac{p_\alpha q_\beta}{(pq)} F_3^{\gamma Z}$$

$$\mathrm{Re}\Box_{\gamma Z_V}(E) = \frac{2E}{\pi} \int_0^\infty dQ^2 \int_{W_\pi^2}^\infty dW^2 \left[A F_1^{\gamma Z}(W^2, Q^2) + B F_2^{\gamma Z}(W^2, Q^2)\right]$$

$$\mathrm{Re}\Box_{\gamma Z_A}(E) = \frac{2}{\pi} \int_0^\infty dQ^2 \int_{(M+m_\pi)^2}^\infty dW^2\, C F_3^{\gamma Z}(W^2, Q^2)$$

Inclusive PV data
- little available

Until that - value at E=0 was used (atomic PV)

$\mathrm{Re}\Box_{\gamma Z_A}$ contains large log from $Q^2 \sim M_Z^2$

Mild energy dependence expected

$\mathrm{Re}\Box_{\gamma Z_A}(0) \neq 0$

$\mathrm{Re}\Box_{\gamma Z_V}(0) = 0$

γZ_A - value & uncertainty

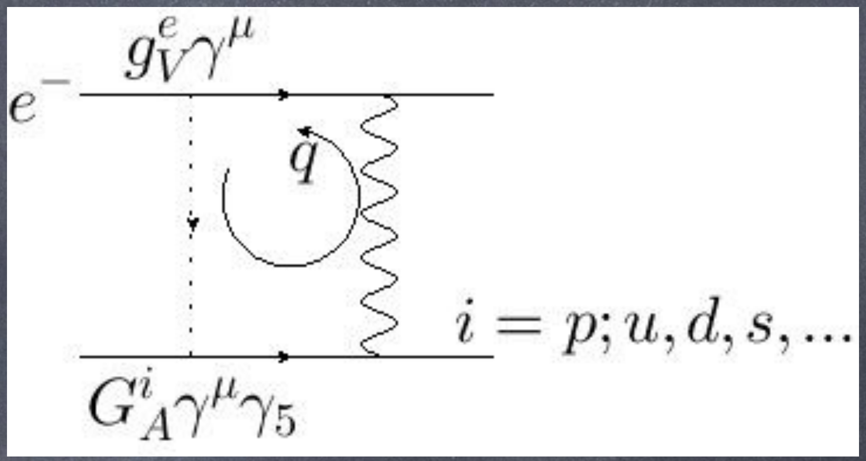
Peter's talk

$$\mathrm{Re}\,\Box_{\gamma Z_A}(E) = \alpha_{em}(1-4\sin^2\theta_W)\frac{2}{\pi}\int_0^\infty dQ^2\int_0^\infty dW^2\,C(E,W^2,Q^2)F_3^{\gamma Z}(W^2,Q^2)$$

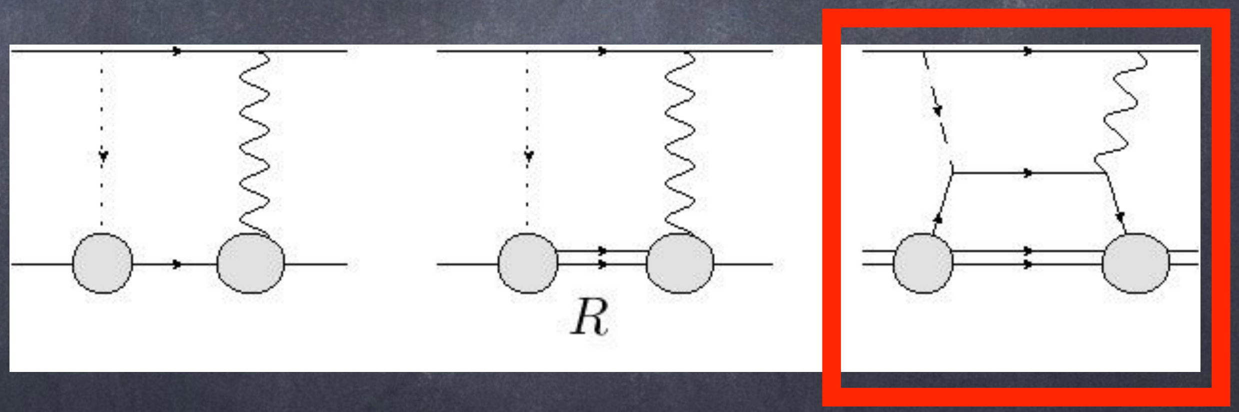
Need F_3 for $0<Q^2<\infty$, $M<W<\infty$

Marciano, Sirlin '84:

large log from $q \simeq M_Z$ - perturbative

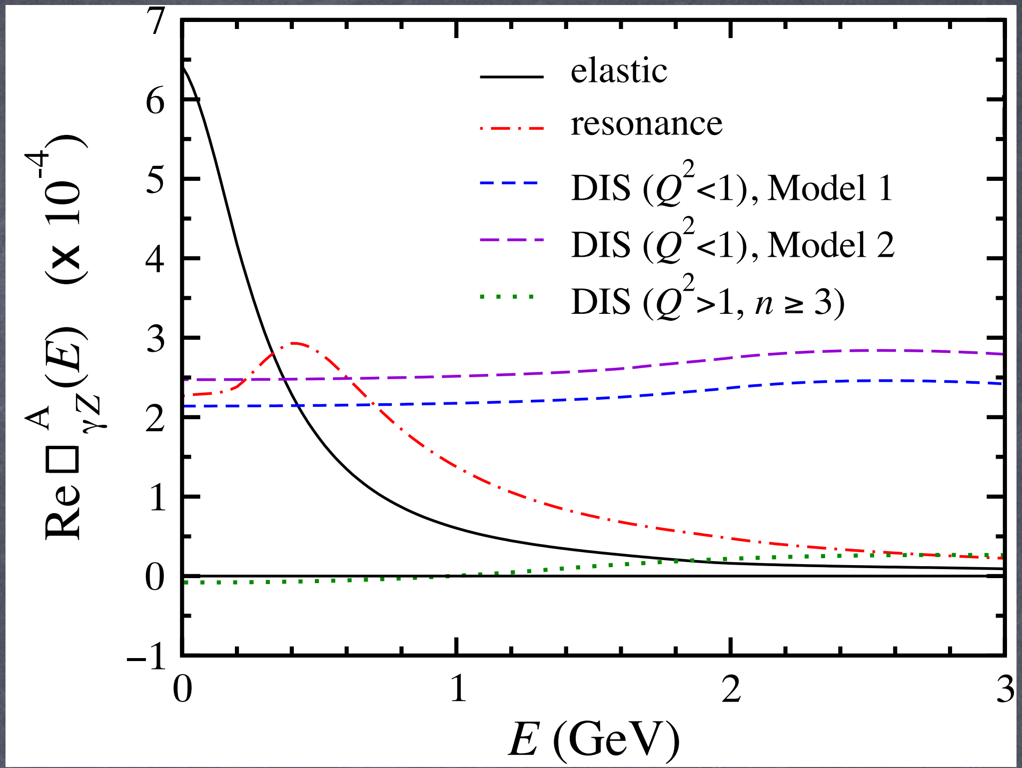


Above some scale Λ:
model-independent



$$\begin{aligned}\mathrm{Re}\,\Box_{\gamma Z_A}(E) &= \frac{5\alpha_{em}}{2\pi}(1-4\sin^2\theta_W)\left[\log\frac{M_Z^2}{\Lambda^2}+C_{\gamma Z}(\Lambda)\right] \\ &= 0.0043 \pm 0.0005\end{aligned}$$

Blunden et al, 2011: checked the old result, included SM running: $\alpha_{QED}(Q^2)$, $\alpha_s(Q^2)$, $g_V^e(Q^2)$



Resonances: generally small

$$\Box^A_{\gamma Z}(E=0) = 0.0052(5) \;\rightarrow\; \Box^A_{\gamma Z}(E=0) = 0.0044(4)$$

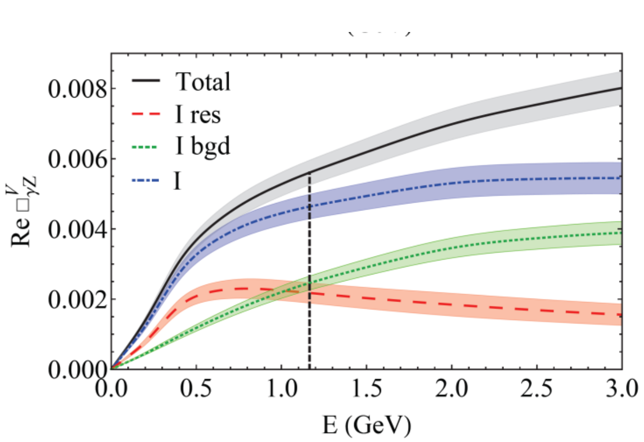
Energy behavior very weak (large log dominates)

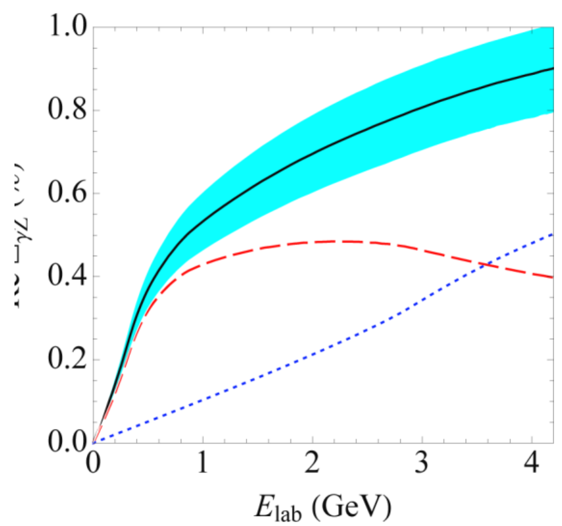
γZ$_V$ - value & uncertainty

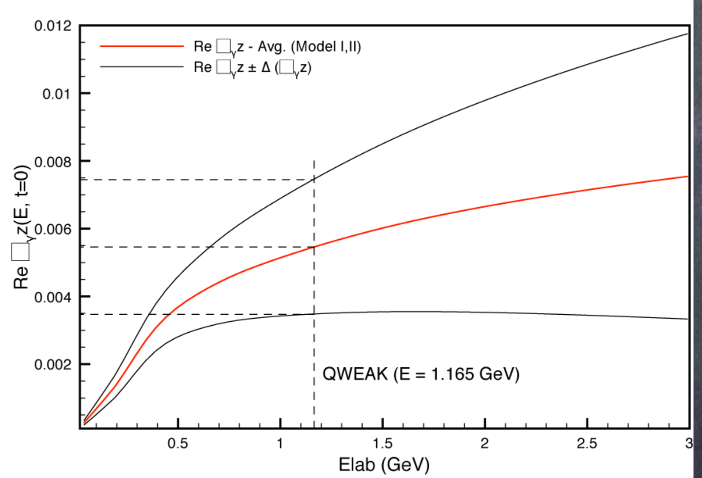
$$\mathrm{Re}\Box_{\gamma Z_V}(E) = \frac{2E}{\pi}\int_0^\infty dQ^2 \int_{W_\pi^2}^\infty dW^2 \left[A F_1^{\gamma Z}(W^2,Q^2) + B F_2^{\gamma Z}(W^2,Q^2)\right]$$

In absence of direct input:
use em data + isospin rotation + error estimate

Hall *et al.*	Carlson and Rislow	Gorchtein *et al.*
PRD 88, 013011 (2013)	PRD 83, 113007 (2011)	PRC 84, 015502 (2011)







$$\mathrm{Re}\Box^V_{\gamma Z}(E = 1.165\ \mathrm{GeV})$$

$$(5.6 \pm 0.36)\times 10^{-3} \quad (5.7 \pm 0.9)\times 10^{-3} \quad (5.4 \pm 2.0)\times 10^{-3}$$

Central value agrees; Steep energy dependence

Q-Weak energy: effect 7.6% of Q_W^p

$$Re\,\Box^V_{\gamma Z}(E = 1.155\,\mathrm{GeV}) = (5.4 \pm 2.0) \times 10^{-3}$$

Uncertainty: 2.8% of Q_W^p = 37% of γZ_V-box

MESA/P2 energy: effect 1.8% of Q_W^p

$$Re\,\Box^V_{\gamma Z}(E = 0.180\,\mathrm{GeV}) = (1.3 \pm 0.3) \times 10^{-3}$$

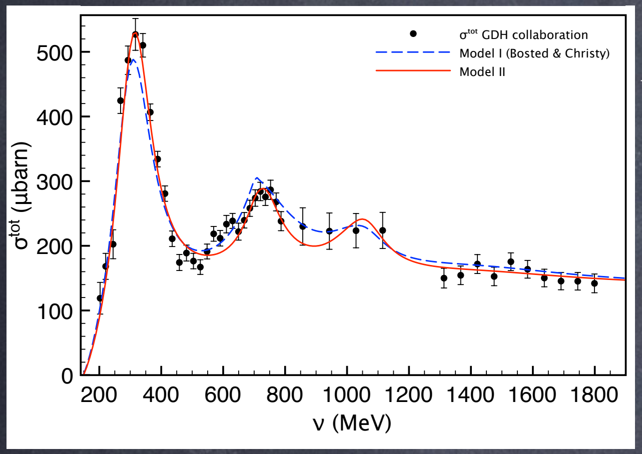
Uncertainty: 0.4% of Q_W^p = 23% of γZ_V-box

MG, Horowitz, Ramsey-Musolf 2011

Let's walk through the sources of
input; model-dependence; error estimate

Model dependence of γZ_V

$\sigma^{\gamma^* p \to X}$



Model-dependent

Definite spin, flavor states

$M_{\gamma^* p \to H_{S,I}}$

Model-dependent

Weak Isospin (flavor) rotation

$M_{Z^* p \to H_{S,I}}$

Dispersion Relation

γZ-box

PVES;

Atomic PV;

Sum rule

Where do we need input, and how precise?

Depends on the energy

$$\mathrm{Re}\,\Box_{\gamma Z_V}(E) = \frac{2E}{\pi}\int_0^\infty dQ^2 \int_0^\infty dW^2\, C(E, W^2, Q^2)\mathrm{DATA}$$

Q-Weak energy: E=1.165 GeV

	W < 2GeV	W < 4GeV	W < 5GeV	W < 10GeV	All W
$Q^2 < 1$ GeV^2	4.8%	6.1%	6.2%	6.3%	6.3%
$Q^2 < 2$ GeV^2	5.2%	6.5%	6.7%	6.8%	6.9%
$Q^2 < 3$ GeV^2	5.3%	6.7%	6.8%	7.0%	7.1%
All Q^2	5.3%	6.9%	7.2%	7.5%	7.6%

Where do we need input, and how precise?

Depends on the energy

$$\mathrm{Re}\,\Box_{\gamma Z_V}(E) = \frac{2E}{\pi}\int_0^\infty dQ^2 \int_0^\infty dW^2\, C(E, W^2, Q^2)\mathrm{DATA}$$

Mainz/MESA energy: E = 155 MeV

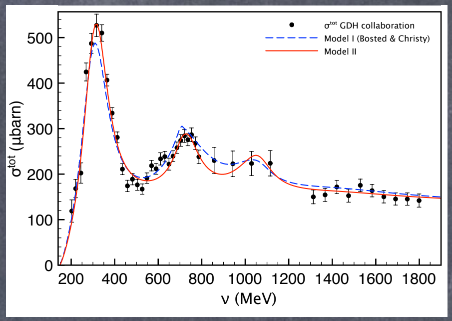
	W < 2GeV	W < 4GeV	W < 5GeV	W < 10GeV	All W
$Q^2 < 1$ GeV²	1.35%	1.55%	1.57%	1.59%	1.60%
$Q^2 < 2$ GeV²	1.41%	1.63%	1.65%	1.67%	1.68%
$Q^2 < 3$ GeV²	1.42%	1.65%	1.67%	1.71%	1.72%
All Q^2	1.43%	1.69%	1.73%	1.78%	1.8%

Step #1: check the spin and flavor state ID

Parametrization of the inclusive data by Christy & Bosted

$1.1\ \mathrm{GeV} < W < 3.1\ \mathrm{GeV},\ 0 < Q^2 < 8\ \mathrm{GeV}^2$

$\sigma^{\gamma^* p \to X}$



Definite spin, flavor states

$M_{\gamma^* p \to H_{S,I}}$

Data -> 7 resonances
+ background (HE contribution continued into res. region)

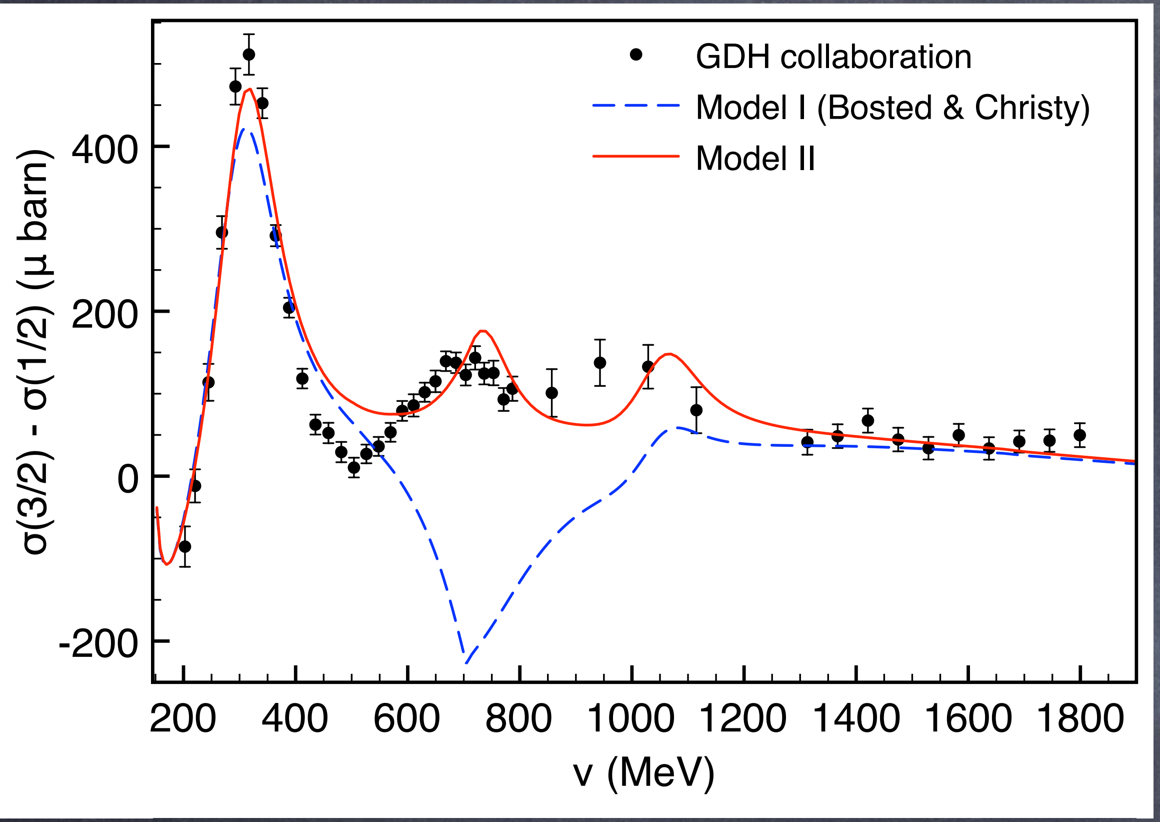
This parametrization is used by the three groups

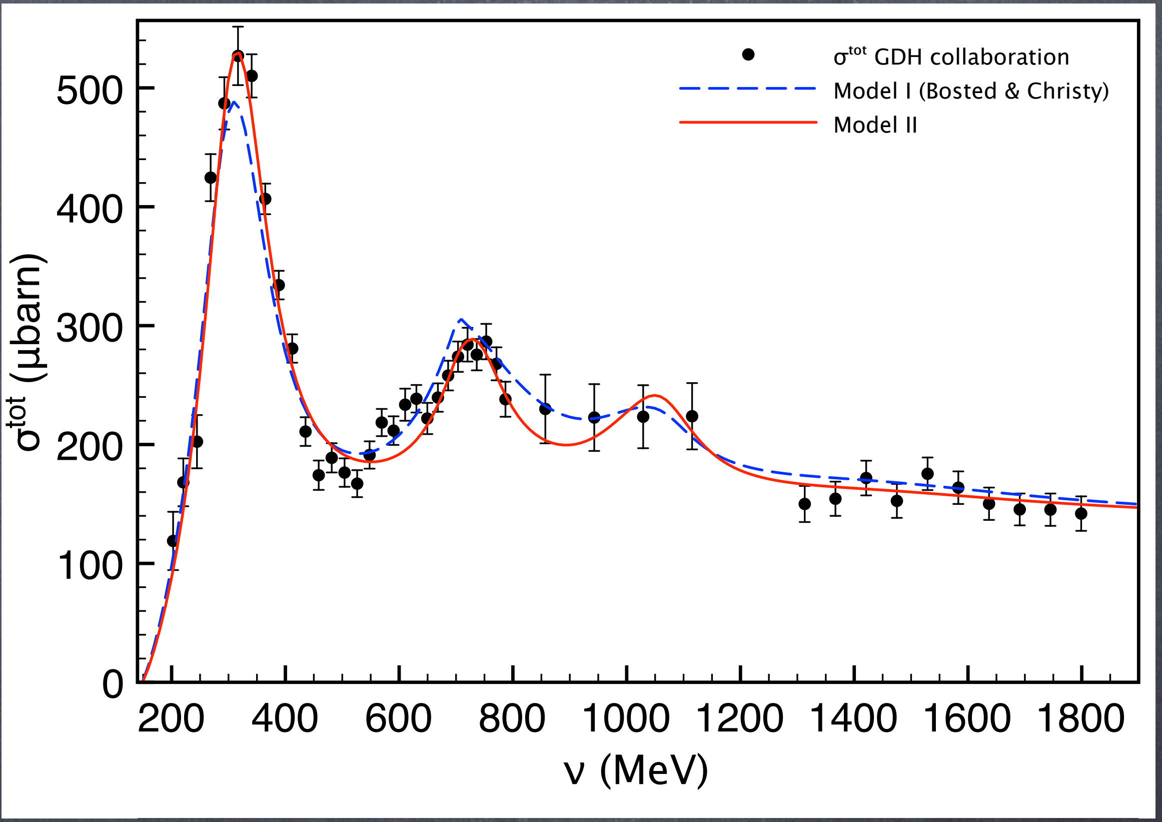
Can be a common bias?

ID and parameters of resonances should be (critically) assessed

Spin-1/2,3/2 resonances contributions to the helicity cross section
Data - from GDH collaboration (Mainz, Bonn)

Ahrens et al, '00; '01; Dutz et al, '03





S11(1535) <-> D13(1520)

MG, X. Zhang arXiv:1501.05357

Flavor ID = Resonance ID - according to the PDG

$(\times 10^{-3})$	$P_{33}(1232)$	$P_{11}(1440)$	$D_{13}(1520)$	$S_{11}(1535)$	$S_{11}(1650)$	$F_{15}(1680)$	$F_{37}(1950)$
C & B	1.23 ± 0.12	0.06 ± 0.02	0.18 ± 0.03	$0.29^{+0.34}_{-0.17}$	$0.06^{+0.14}_{-0.06}$	0.04 ± 0.01	0.40 ± 0.36
PDG	1.23 ± 0.12	0.12 ± 0.03	0.31 ± 0.05	$0.06^{+0.08}_{-0.04}$	$0.06^{+0.14}_{-0.06}$	0.04 ± 0.02	0.39 ± 0.36

$$0.53^{+0.34}_{-0.17} \rightarrow 0.50^{+0.10}_{-0.07}$$

Further reduction - mainly F37(1950)
Should be possible: it is in the right place, strength about right,
proton and neutron strength is very close - quantum numbers OK
Reasonable to assume that at least 50% of F37 is really F37

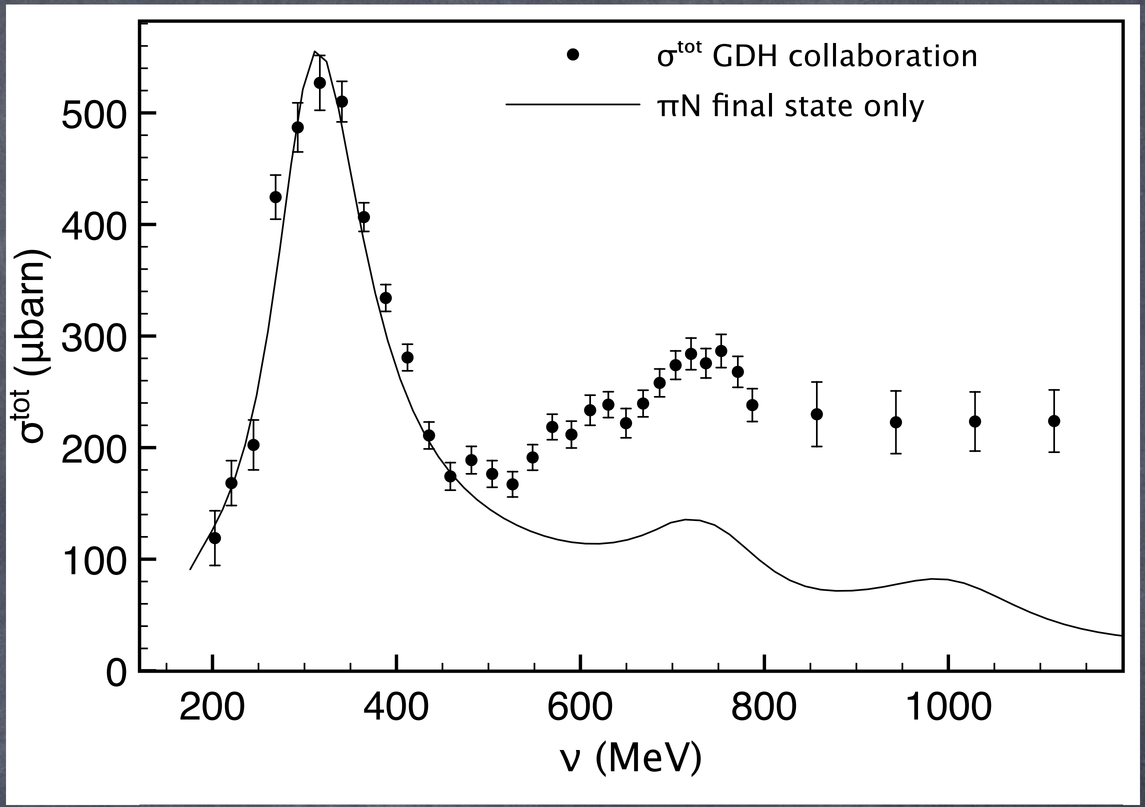
$$\Sigma_{res}^{OLD} = 2.24^{+0.53}_{-0.43} \qquad \Sigma_{res}^{NEW} = 2.21^{+0.25}_{-0.23}$$

Uncertainty on the resonance contribution is halved.

"Last" caveat in the resonance region:
strangeness contribution to N->N* transitions

But certainly can do better in the threshold - Delta region

MG, Spiesberger, Zhang 2016



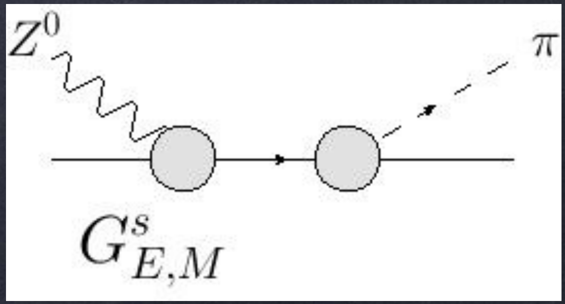
Only pion-nucleon final state:
isospin, W and Q dependence
are known!
Amplitude & PW analysis (MAID)

Weak NC pion multipoles from MAID

$$\begin{aligned} A^{\pi^+ n} &= \sqrt{2}(A^0 + A^-) \\ A^{\pi^- p} &= \sqrt{2}(A^0 - A^-) \\ A^{\pi^0 p} &= A^+ + A^0 \\ A^{\pi^0 n} &= A^+ - A^0 \end{aligned}$$

$$\begin{aligned} A_Z^{\pi^+ n} &= -A_\gamma^{\pi^- p} + (1 - 4\sin^2\theta_W)A_\gamma^{\pi^+ n} - \sqrt{2}A_s \\ A_Z^{\pi^- p} &= -A_\gamma^{\pi^+ n} + (1 - 4\sin^2\theta_W)A_\gamma^{\pi^- p} - \sqrt{2}A_s \\ A_Z^{\pi^0 p} &= A_\gamma^{\pi^0 n} + (1 - 4\sin^2\theta_W)A_\gamma^{\pi^0 p} - A_s \\ A_Z^{\pi^0 n} &= A_\gamma^{\pi^0 p} + (1 - 4\sin^2\theta_W)A_\gamma^{\pi^0 n} + A_s \end{aligned}$$

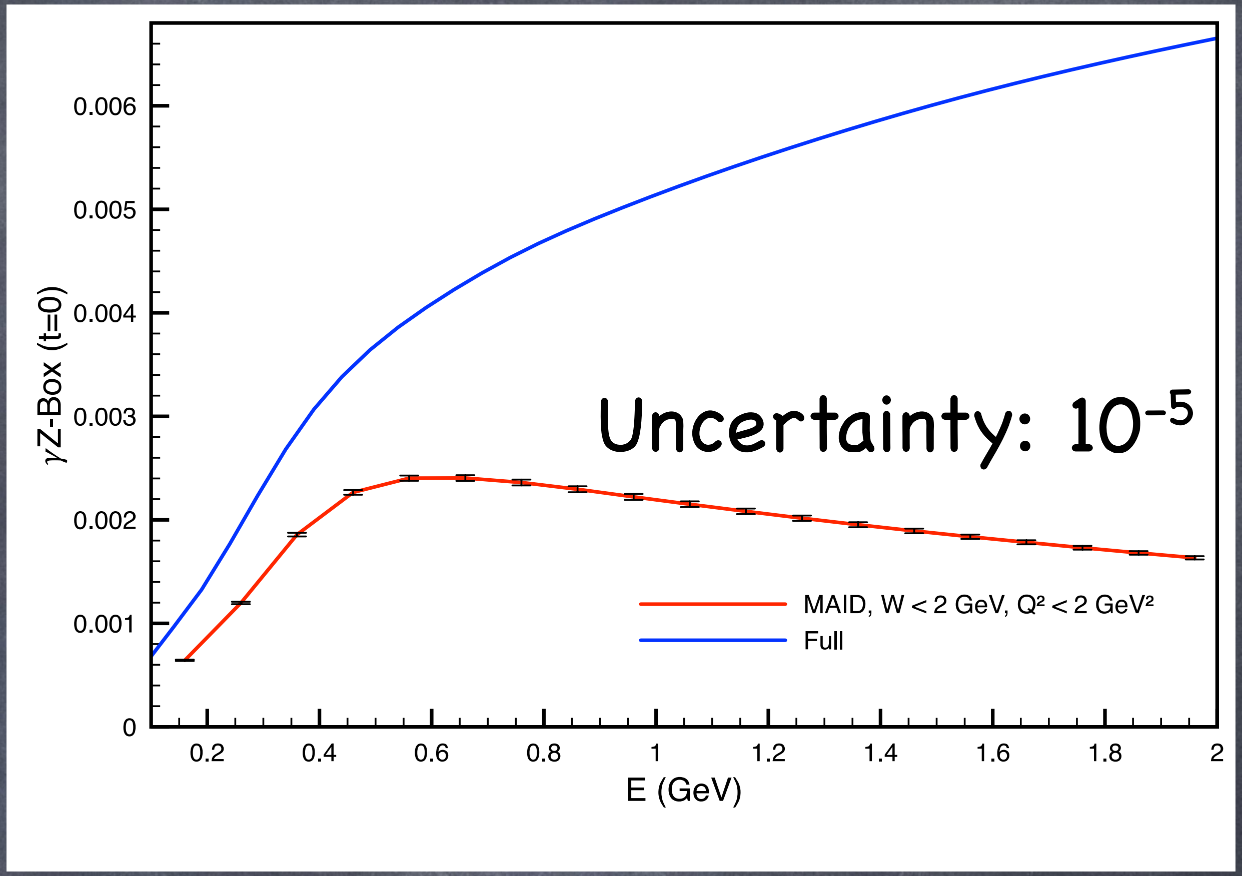
A_s - the only uncertainty;
Pions and Δ: no strange content (isovector)!
Can quantify: strange form factors



Take strange form factors
from global analyses
e.g., Armstrong, McKeown 2012

$$G_M^s(Q^2) = (0.29 \pm 0.21) G_D(Q^2)$$

$$G_E^s(Q^2) \approx (-0.08 \pm 0.08) Q^2 G_D(Q^2)$$

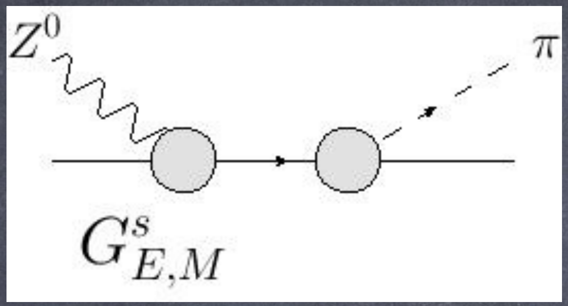


Systematical uncertainty:
strangeness - relative 1%

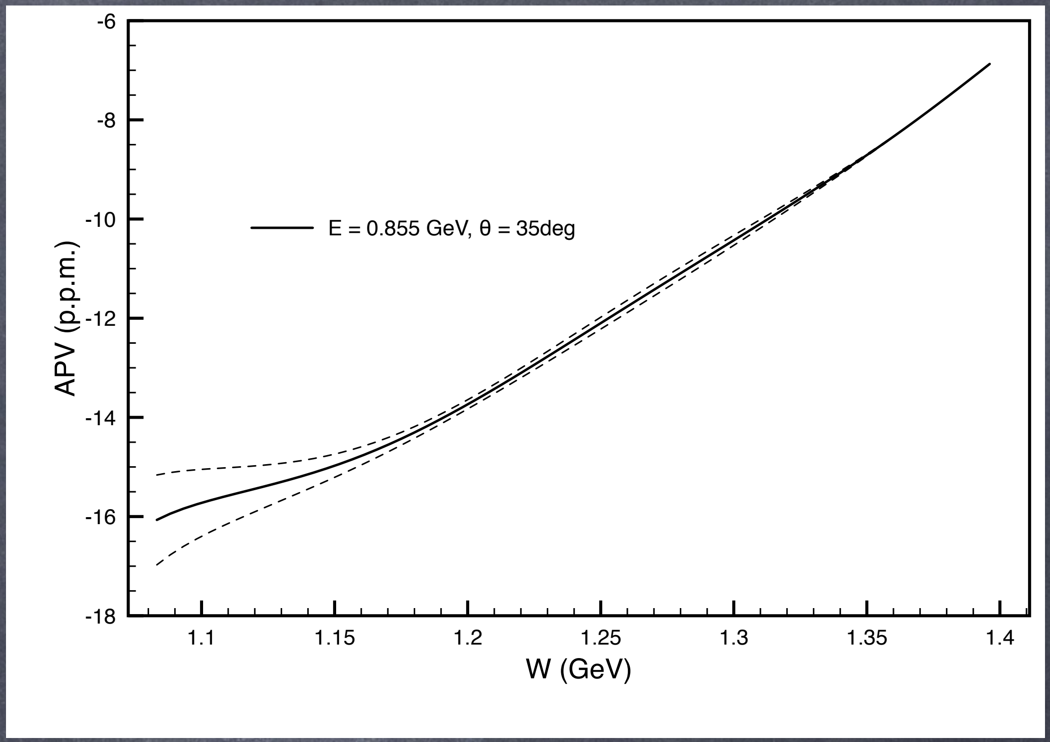
Statistical uncertainty (e.-m. data)
- typically 2-5%

Half the γZ_V in P2 kinematics:
can be computed with few % error!

Can use inelastic PVES data below Delta to extract strangeness?

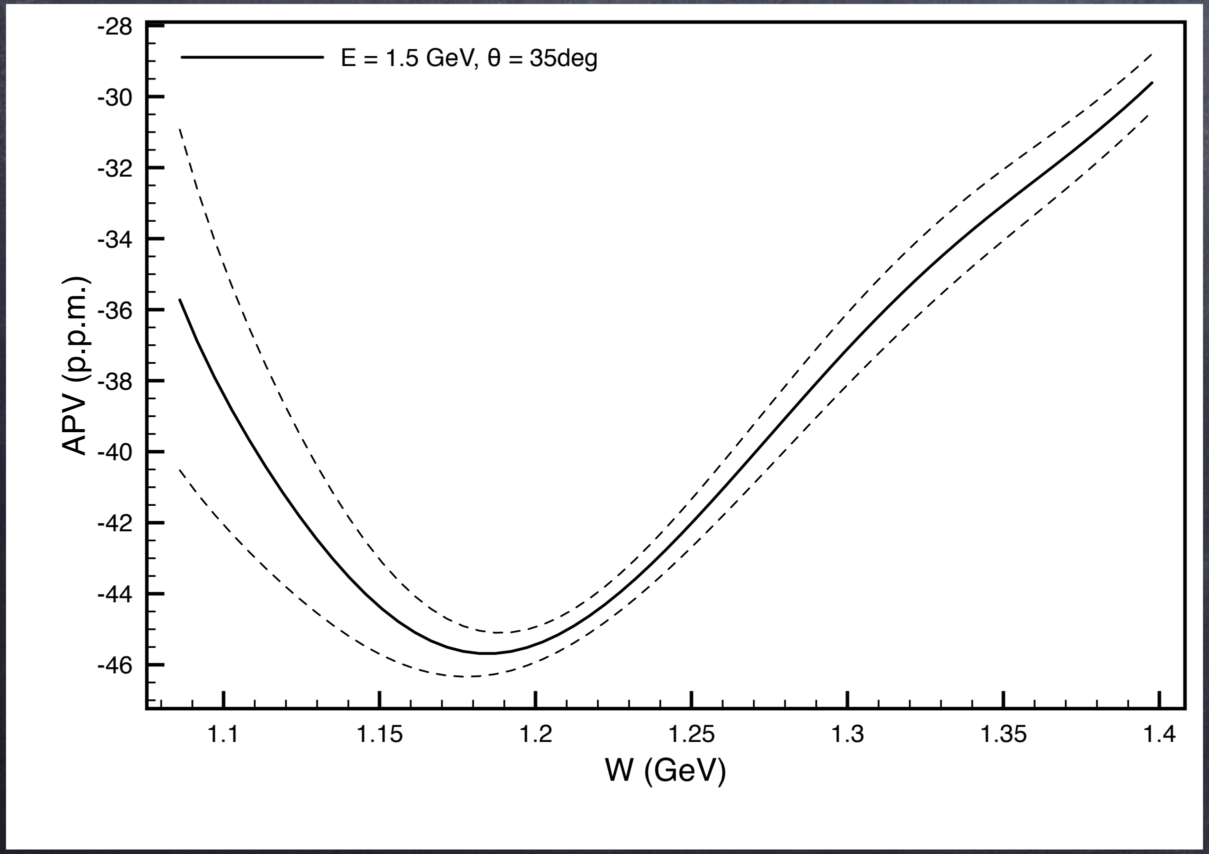


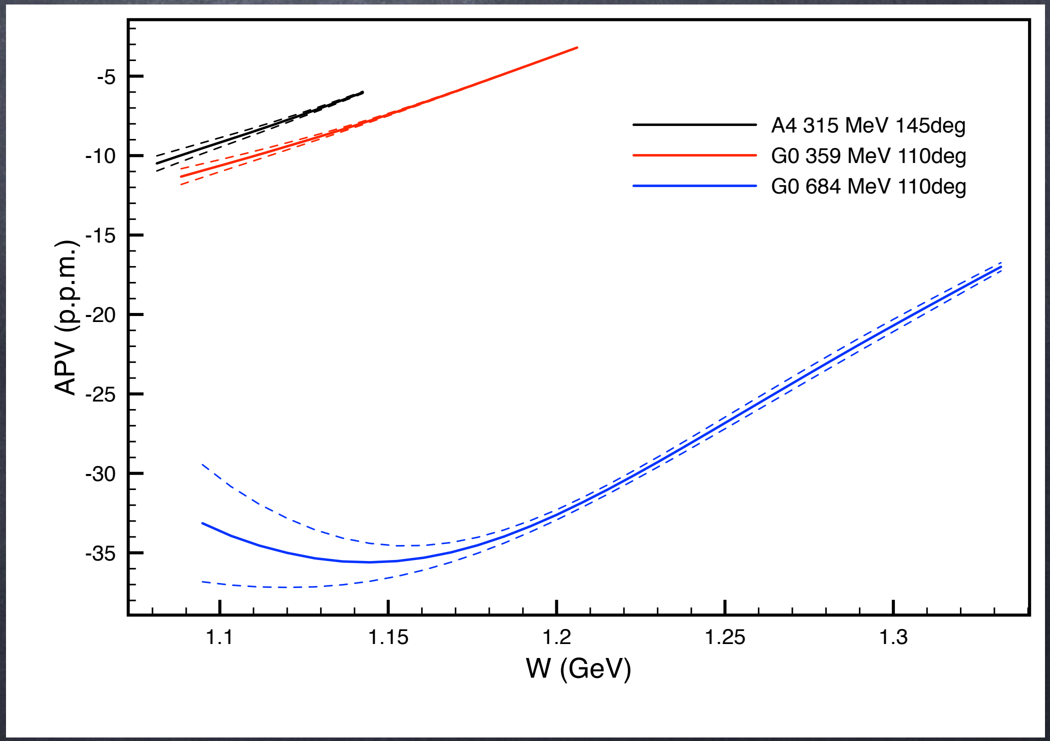
MG, Spiesberger, Zhang 2016



Effect depends on kinematics: not too small Q^2, W between threshold and the Δ

A4@Mainz - data on tape;
Large asymmetries to ~few %

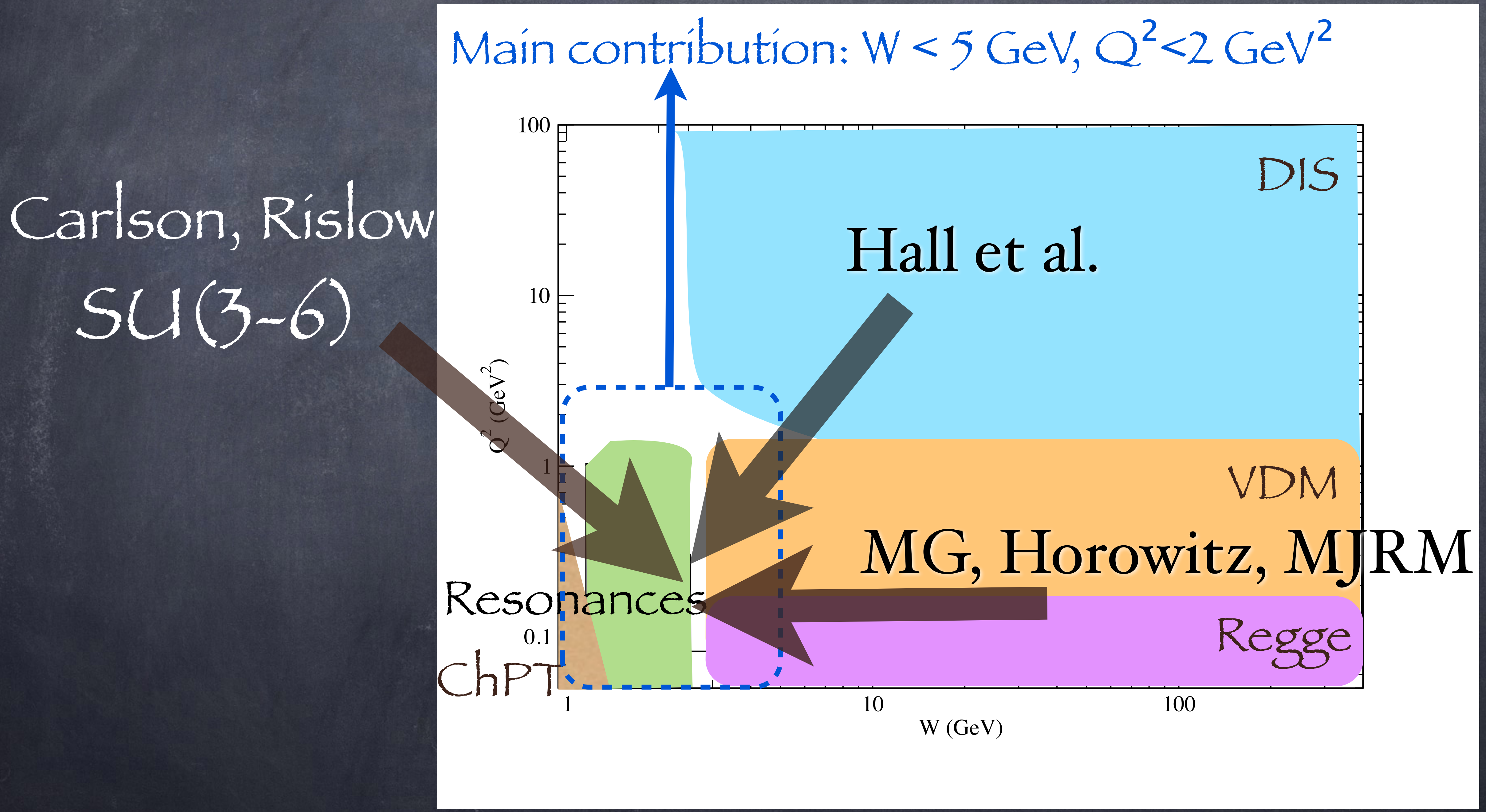




Isospin decomposition of the background

Similarities of the three evaluations: isovector dominance

Differences of the three uncertainty estimates:
estimates for isoscalar (strange) from different physics pictures



Carlson, Rislow - not data-driven procedure (but reasonable error)

Where do we need input, and how precise?

Depends on the energy

$$\mathrm{Re}\,\Box_{\gamma Z_V}(E) = \frac{2E}{\pi}\int_0^\infty dQ^2 \int_0^\infty dW^2\, C(E, W^2, Q^2)\mathrm{DATA}$$

Q-Weak energy: E=1.165 GeV

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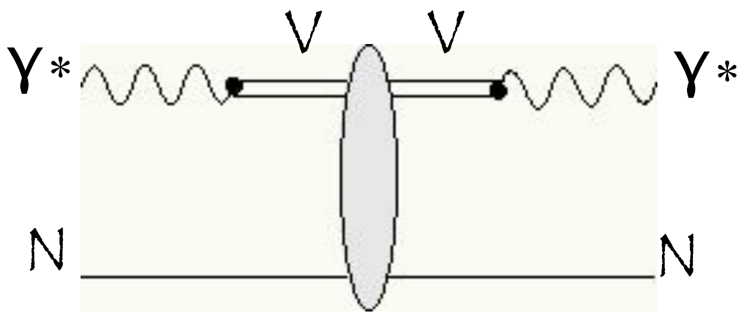
All Q^2	5.3%	6.9%	7.2%	7.5%	7.6%

Isospin rotation of e.-m. data: background

Vector Dominance Model (VDM)

$$|\gamma^*\rangle = \sum_V C_{\gamma^* V} |V\rangle \qquad V = \rho,\ \omega,\ \phi$$



$$\sigma^{\gamma p}_{tot} = \sum_{V=\rho,\omega,\phi} \frac{4\pi\alpha}{f_V^2} \sigma_{Vp}$$

Elastic Vp cross section - independent of V

VM decay constants $\frac{4\pi}{f_V^2} = 0.4545, 0.04237, 0.05435 \quad (\rho, \omega, \phi)$

VDM sum rule: $$\sigma_{tot}(\gamma p) = \sum_{V=\rho,\omega,\phi} \sqrt{16\pi \frac{4\pi\alpha}{f_V^2} \frac{d\sigma^{\gamma p \to Vp}}{dt}(t=0)}$$

Measured experimentally

HERA: NPB' 02 ZEUS: Z.Phys.'95,'96, PLB'96

$139 \pm 4\ (\mu b) \leftrightarrow 111 \pm 13\ (\mu b)$ at $W = 70$ GeV

Generalized VDM - continuum contribution $$\sigma^{\gamma p}_{tot} = \sum_{V=\rho,\omega,\phi} \frac{4\pi\alpha}{f_V^2} \sigma_{Vp} + \sigma_{Cp}$$

Finite Q² - straightforward for V, phenomenological for continuum

Rescale the background according to

$$\frac{\sigma^{\gamma^* p\to Zp}}{\sigma^{\gamma^* p\to \gamma^* p}} = \frac{\frac{g_V^{I=1}}{e_{I=1}} + \frac{g_V^{I=0}}{e_{I=0}}\frac{\sigma^{\gamma^* p\to \omega p}}{\sigma^{\gamma^* p\to \rho p}} + \frac{g_V^{s}}{e_{s}}\frac{\sigma^{\gamma^* p\to \phi p}}{\sigma^{\gamma^* p\to \rho p}} + \frac{X'}{\sigma^{\gamma^* p\to \rho p}}}{1 + \frac{\sigma^{\gamma^* p\to \omega p}}{\sigma^{\gamma^* p\to \rho p}} + \frac{\sigma^{\gamma^* p\to \phi p}}{\sigma^{\gamma^* p\to \rho p}} + \frac{X}{\sigma^{\gamma^* p\to \rho p}}}$$

VDM: identify X(X') with continuum

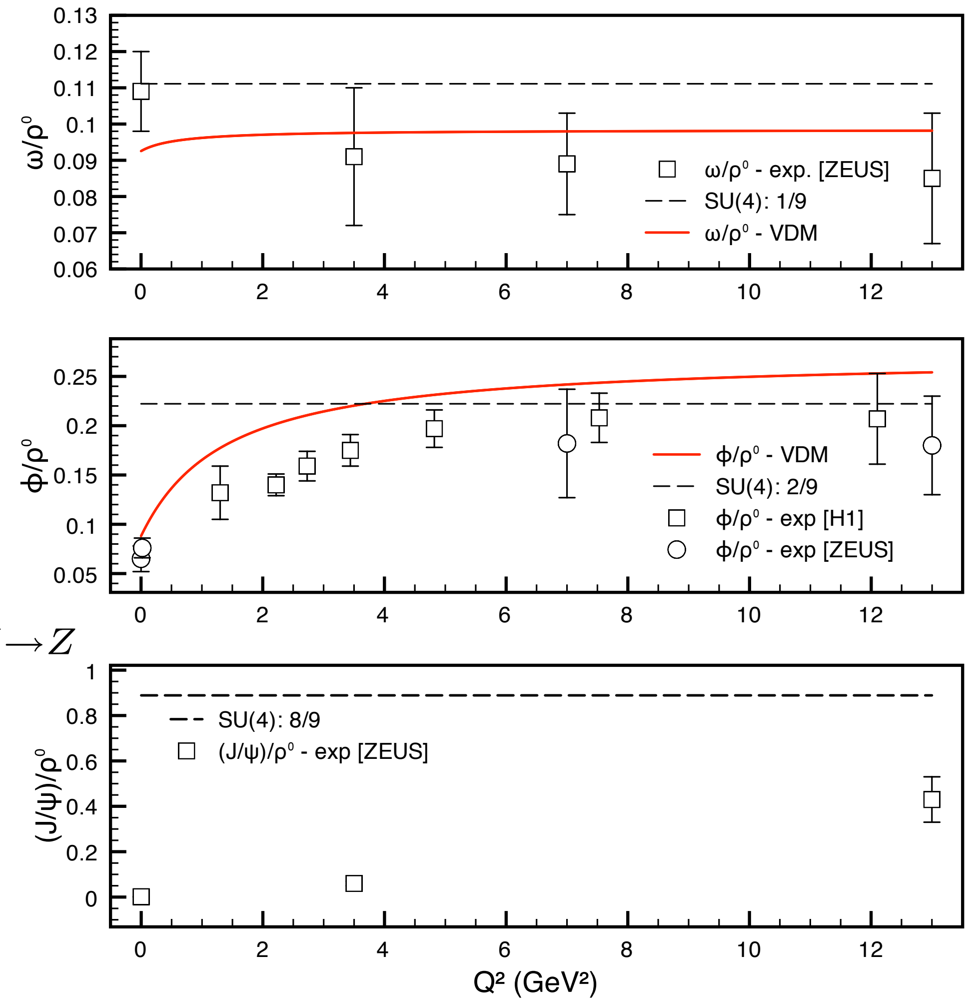
$$\frac{\sigma^{\gamma^* p\to Vp}}{\sigma^{\gamma^* p\to \rho p}} = \frac{r_V}{r_\rho}\frac{m_V^4}{m_\rho^4}\frac{(m_\rho^2+Q^2)^2}{(m_V^2+Q^2)^2}$$

Uncertainty estimate - from data!

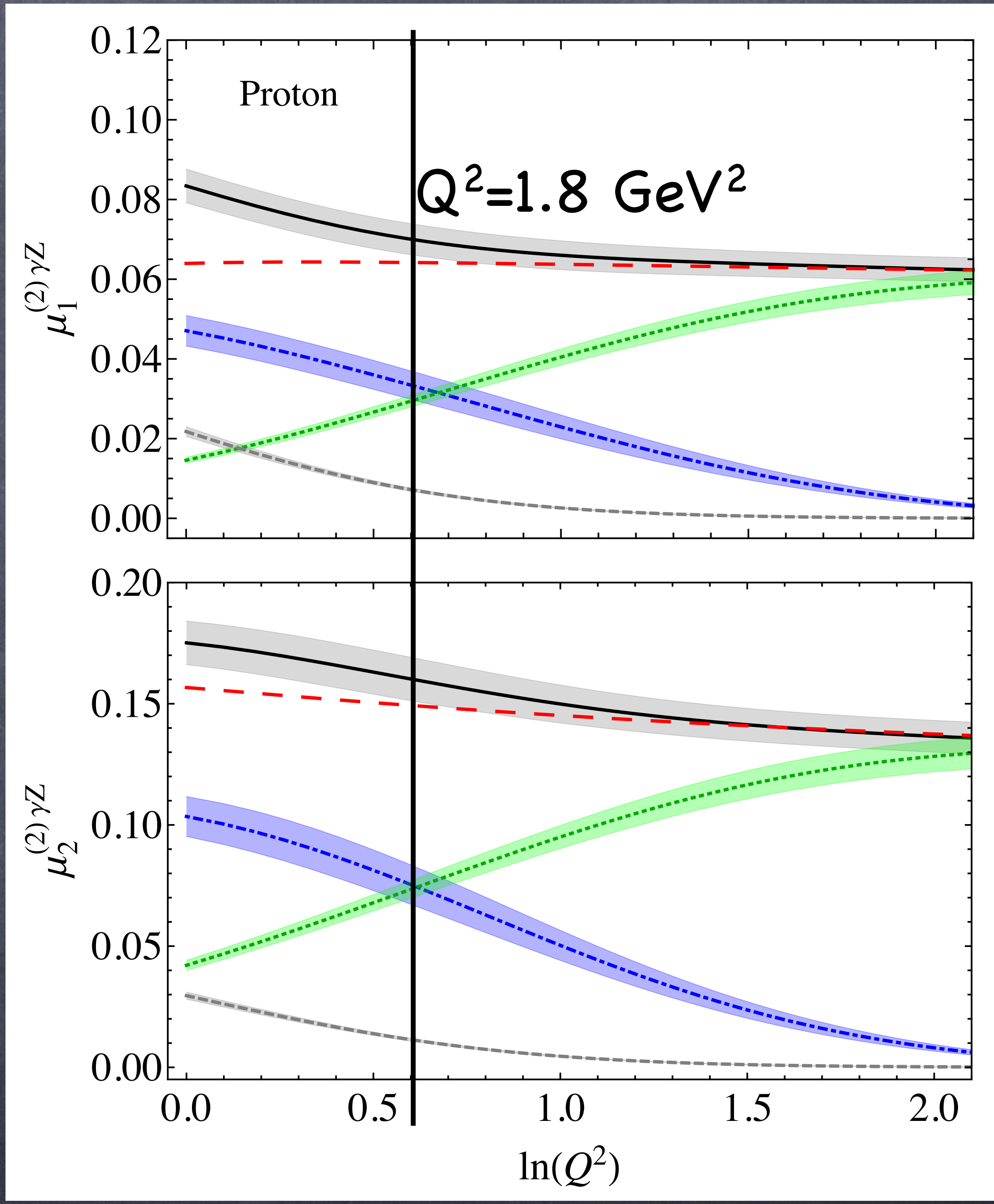
$$\Delta\xi_{Z/\gamma}^{V,Model\ A} = \left[\left(\frac{\sigma^{\gamma^*\to V}}{\sigma^{\gamma^*\to\rho}}\right)^{exp} - \left(\frac{\sigma^{\gamma^*\to V}}{\sigma^{\gamma^*\to\rho}}\right)^{Model\ A}\right]\sigma^{\gamma^*\to V\to Z}$$

Continuum - 100% uncertainty

Exp. data: W = 40-120 GeV



Blunden et al. '13: matched the continuum contribution X onto DIS
Constrained it at substantial Q^2, identified the uncertainty with the latter - reduced the uncertainty significantly



Blunden et al. '15: addressed their uncertainty estimate with duality.

I would disagree on the interpretation of their results: the deviation clearly states the failure of duality (in the model) at Q^2<1.8 GeV^2 - the uncertainty band should be inflated at lower Q^2

Q^2<1.8 GeV^2 is what matters for γZ-box
Uncertainty estimate comes from beyond

To me there's a loophole here
This is the source of discrepancy in the uncertainty estimate

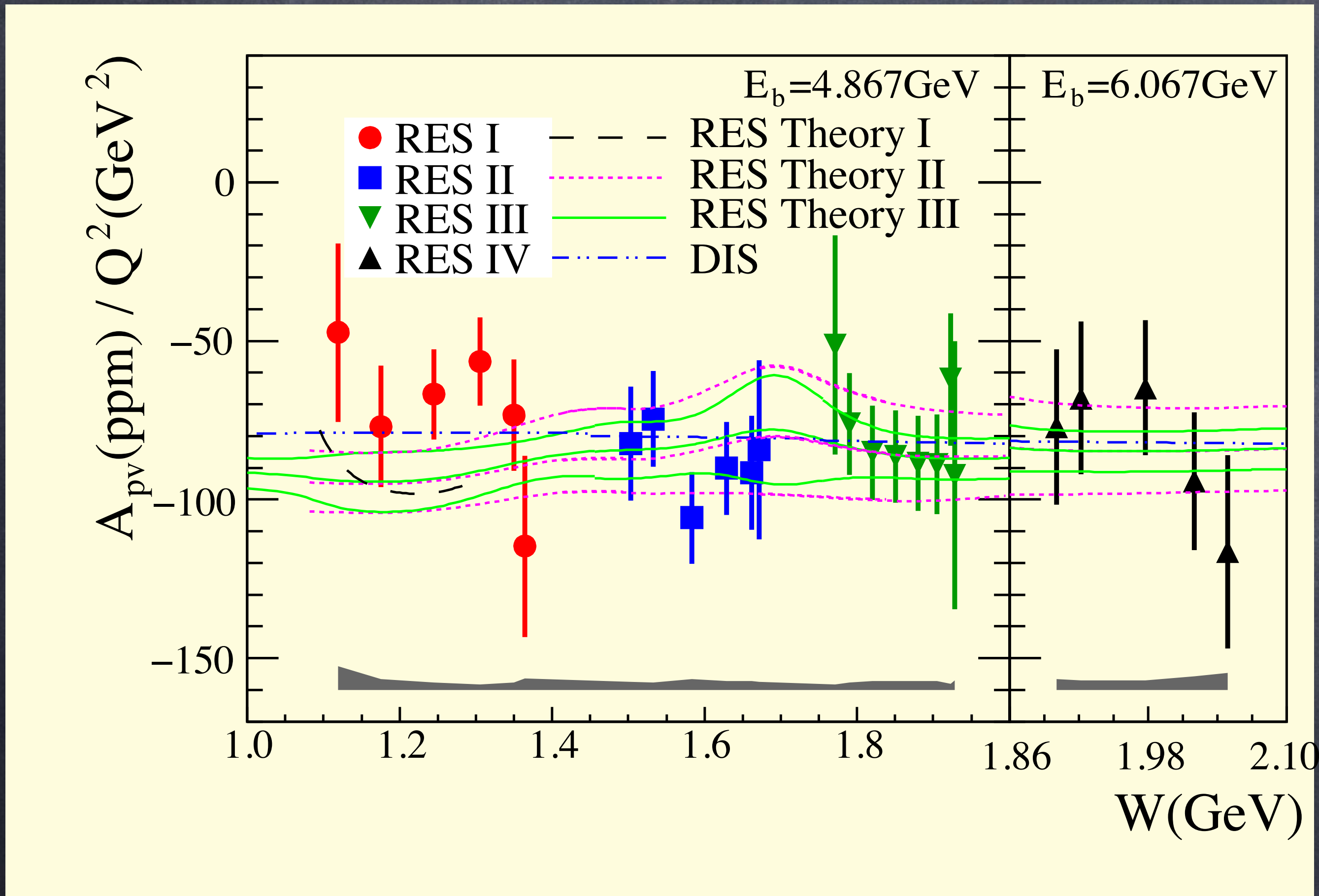
Impact of inelastic PVES data

If we are given new data, what do we do with it?

Complete kinematics precision data on the needed target - we're done

Some data on the needed target - informative, maybe not exhaustive

Some data on a random target - more like reality



Wang et al. [Hall A], '13
PVDIS on deuteron

Still useful!
D target more sensitive to large strangeness N->N* transition FFs
- seems no such effects

Most red points (central values) are outside of the theory band - is this uncertainty conservative?

How can we extend dispersion correction calculations to nuclei?
Context: C-12 @ MESA; PV in atoms; γW-box for 0^+-0^+ beta decay

Hadronic part of the spectrum - correct for Fermi motion (redistribution of strength - small effect on the integrated quantities)

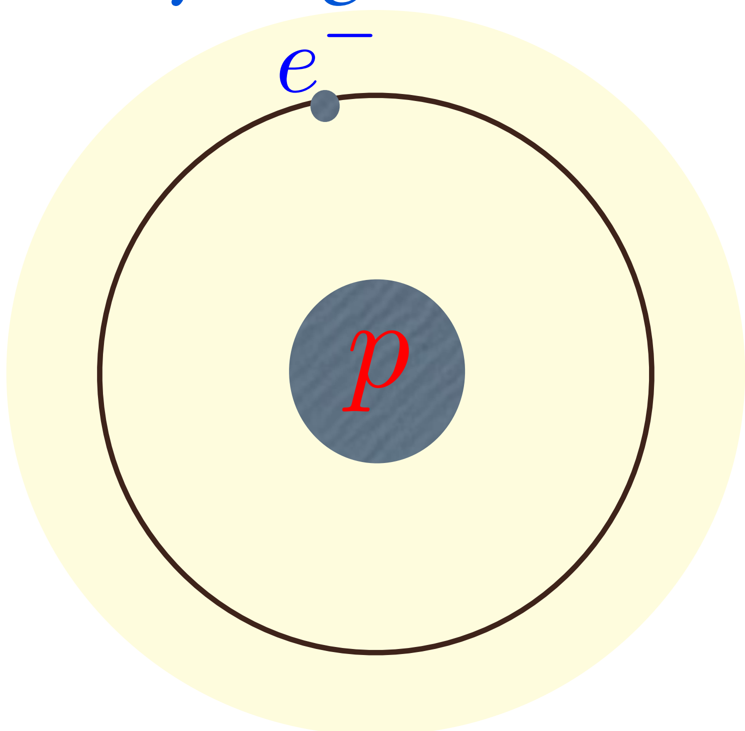
Nuclear "polarizabilities" - substantially new contribution, potential surprises

Insights:

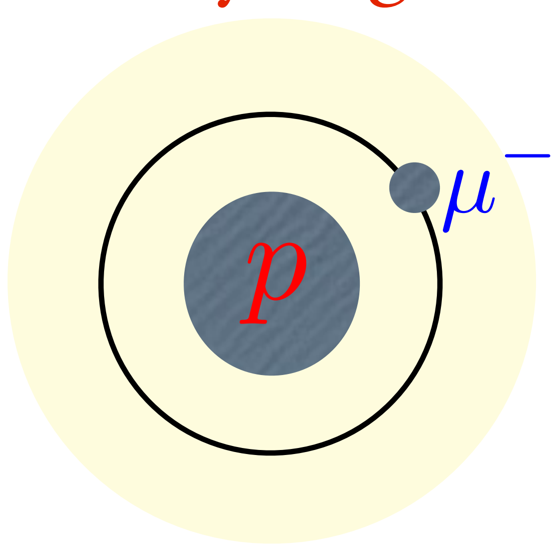
- em-box calculations for Lamb shift in light muonic atoms
- Beam normal asymmetry on nuclei in forward regime

Muonic vs Electronic Hydrogen

Hydrogen atom



muonic Hydrogen atom



SM: the only difference is the mass

Bohr radius $$\frac{R_{\mu-H}}{R_{e-H}} = \frac{m_e}{m_\mu} \approx \frac{1}{200}$$

$$\Delta E^{FS,\,e-H}_{2P_{3/2}-2S_{1/2}} = -8.1 \times 10^{-7}\, r_E^2 \,(\mathrm{meV})$$

$$\Delta E^{FS,\,\mu-H}_{2P_{3/2}-2S_{1/2}} = -5.2275(10)\, r_E^2 \,(\mathrm{meV})$$

Better sensitivity to radius;
but also more prone to polarizing the nucleus

μ-H Lamb shift Measurement CREMA Coll.

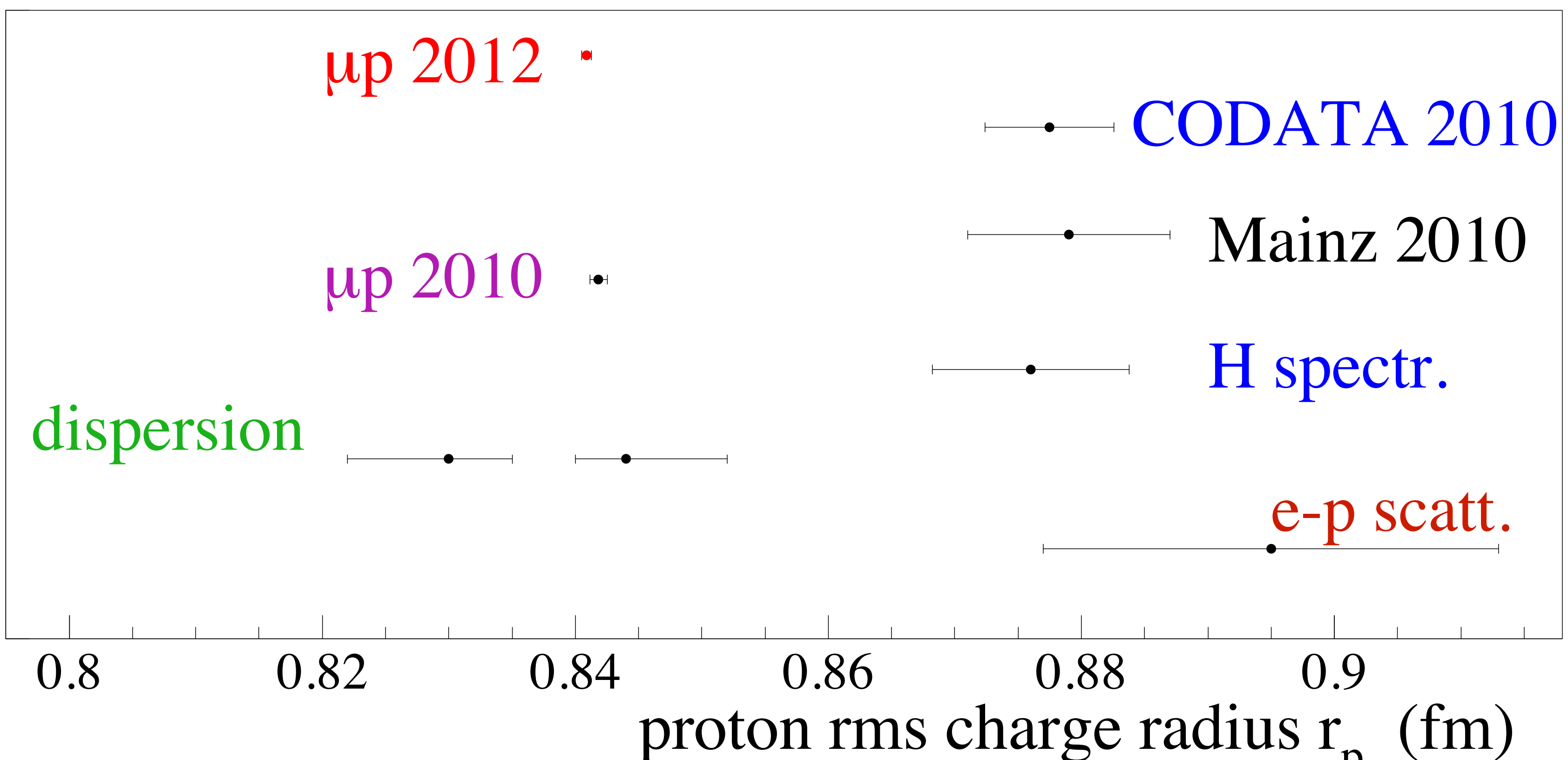
$\nu(2S_{1/2}^{F=1} \to 2P_{3/2}^{F=2})$ = 49881.88(76) GHz R. Pohl *et al.*, Nature 466, 213 (2010)

49881.35(64) GHz

$\nu(2S_{1/2}^{F=0} \to 2P_{3/2}^{F=1})$ = 54611.16(1.04) GHz A. Antogini *et al.*, submitted (2012)

Proton charge radius: r_{p} = 0.84089 $(26)_{\mathrm{exp}}$ $(29)_{\mathrm{th}}$ = 0.84089 (39) fm

$\mu\mathrm{p}$ theory: A. Antogini *et al.*, arXiv :1208.2637 (atom-ph)



"Missing" correction - 300 μeV;

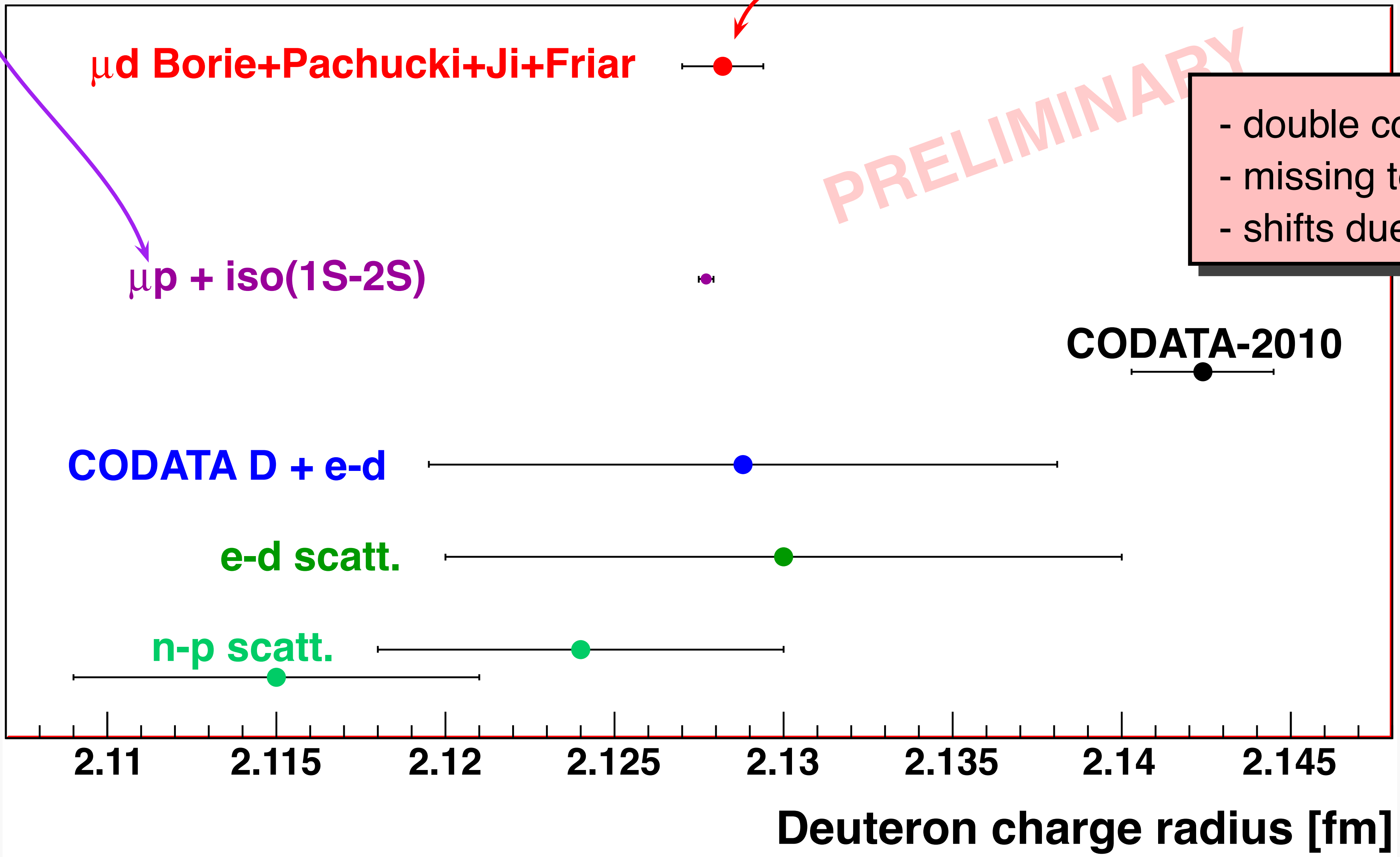
Exp. AND theory precision - μeV or less

Deuteron radius from μd and μp (**preliminary**)

H-D iso-shift: $r_d^2 - r_p^2 = 3.820\,07(65)\ \mathrm{fm}^2$
μp : $r_p = 0.84087(39)\ \mathrm{fm}$
$\Rightarrow r_d = 2.12771(22)\ \mathrm{fm}$

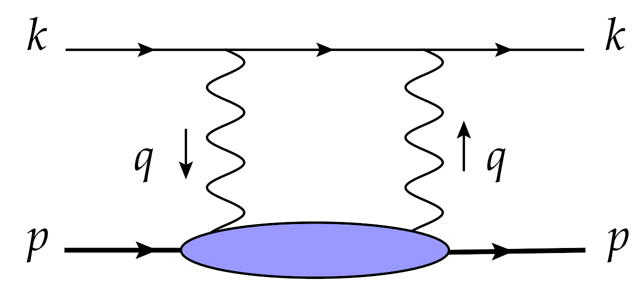
Directly from μd spectroscopy using μd polarizabiliy with ± 0.03 meV

- double counting (th)?
- missing terms (th)?
- shifts due to close levels (exp)?



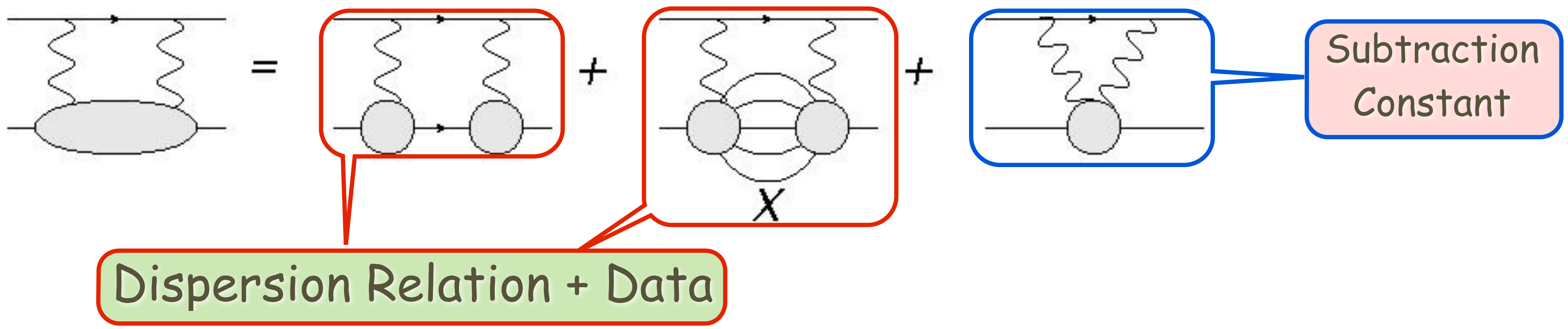
2γ exchange contribution to Lamb shift

Finite size and TPE - short range effects in atom; indistinguishable remove TPE to get the radius right



inelastic structure fn. F_1, F_2

2γ-box from forward dispersion relations



For μH - the proton pol. correction ~ 0.1 of discrepancy (and uncertainty is much smaller yet)

MG et al. '13,'14
Carlson et al, '14

For μD - the nuclear pol. correction 6x larger than the discrepancy (uncertainty - large in DR - lack of data in needed kinematics)

Way out: motivate the experimentalists to measure the missing data
Elastic eD-scattering in Mainz took inelastic data within their deuteron radius experiment
- now under analysis

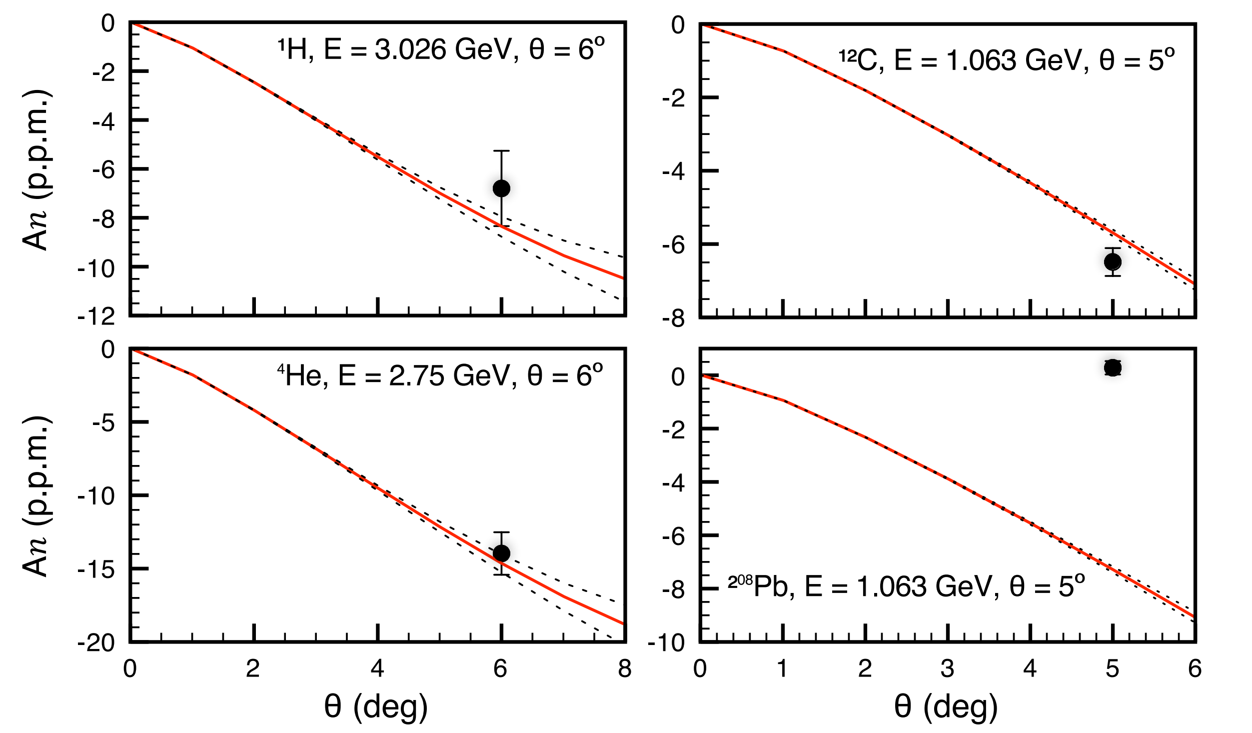
Made the physics case in Carlson et al. '14

E_{lab}, θ_{lab}	Exp. precision	$\delta(\Delta E^{\mu D}_{2S-2P})$ in μeV	$\delta(\Delta E^{eD}_{1S-2S})$ in kHz
180 MeV, 30°	2%	740	12
	1%	370	6
180 MeV, 22°	2%	390	6.32
	1%	195	3.16
180 MeV, 16°	2%	211	3.36
	1%	110	1.68
80 MeV, 16°	2%	67	1.08
	1%	48	0.78

- Nuclear polarizability contribution to precision measurements: potentially important; may be hard to calculate - require cooperation between theory and experiment;
Valuable insight from nuclear models & EFT (light nuclei)

- Cross-check using the beam normal asymmetry? Not straightforward:

$$\alpha_E = \frac{1}{2\pi^2}\int \frac{d\omega}{\omega^2}\sigma_T(\omega)$$



Abrahamyan et al. [HAPPEX and PREx], 12

$$B_n \approx -\frac{1}{4\pi^2}\frac{m_e\sqrt{Q^2}}{E^2}\ln\left(\frac{Q^2}{m_e^2}\right)\frac{e^{-BQ^2}}{F_C(Q^2)}\int_{\omega_\pi}^{E} d\omega\omega\sigma_{\gamma N}^{tot}(\omega)$$

KK's talk

B_n less sensitive to lower part of the nuclear spectrum;
But we can learn about the interplay between Coulomb distortions and dispersion corrections
- work in progress with Xavi Roca Maza

Implications and things to do:

- Forward $\gamma\gamma$-,γZ-,γW-boxes from dispersion relation - only need data
- (Almost) no data available for γZ-,γW- structure functions: model

- Re-evaluation of the VDM sum rule at JLab energies rather than HERA - what happens to the γZ-box uncertainty?

- γZ-box: non-forward calculation for MESA - could affect the global fit for $B(Q^2)$ - requires γZ- and $\gamma\gamma$-boxes;

- Extend γZ-box calculations to spin-0 nuclei
- γW-box calculations for superallowed beta decays
- γW-box for n beta decay - weak pion production

Work in progress on all items!

- Insights from B_n - input, techniques...

- Close cooperation between theory and experiment

April 23 - May 4 2018: Scientific program "Bridging the Standard Model to New Physics with Parity Violating program at MESA"

Organizers: Jens Erler, Hubert Spiesberger, MG

Topics:

Weak mixing angle at low energy with MESA

Neutron beta decay with TRIGA

Parity violation in atoms

Precision low-energy tests in a global context

Keynote speakers:

Bill Marciano, Paul Langacker, Michael Ramsey-Musolf, John Hardy, Vincenzo Cirigliano, Krishna Kumar, Chuck Horowitz, Adrzej Czarnecki, David Armstrong, Paul Souder, Frank Maas, Dima Budker, Werner Heil