ρ^0-Meson Helicity Amplitude Ratios at HERMES

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DIS 2011

Outline

- SDMEs vs. **H**elicity **A**mplitude **R**atios (HARs)
- Comparisons to theoretical expectations
- Unnatural Parity Exchange for ρ^0 at HERMES
- Review

Helicity Amplitudes

$$F_{\lambda_V \lambda_\gamma} = T_{\lambda_V \lambda_\gamma} + U_{\lambda_V \lambda_\gamma}$$

Helicity Amplitude

Natural Parity Exchange Contribution

Unnatural Parity Exchange Contribution

Key: 0 indicates longitudinal helicity

±1 indicates transverse helicity

Helicity Amplitudes

$$F_{\lambda_V \lambda_\gamma} = T_{\lambda_V \lambda_\gamma} + U_{\lambda_V \lambda_\gamma}$$

Helicity Amplitude

Natural Parity Exchange Contribution

Unnatural Parity Exchange Contribution

Assume nucleon flip amplitudes negligible for NPE

Sum over nucleon amplitudes for UPE

Helicity Amplitudes

Hard Exclusive Meson Leptoproduction:

$e\ p \rightarrow e\ p\ \rho^0$

$|T_{00}|^2 \approx |T_{11}|^2 >> |U_{11}|^2 > |T_{01}|^2 >> |T_{10}|^2 \ldots$

D. Yu. Ivanov and R. Kirschner,
Phys. Rev. D 58, 114026 (1998)

- Predicted by theory & confirmed at HERMES

- Extract NPE amplitudes as ratios to $|T_{00}|$:

$$t_{VY} = |T_{VY}/T_{00}|$$

SDMEs vs HARs

$$\rho_{\lambda_V \mu_V} = \frac{1}{2\mathcal{N}} \sum F_{\lambda_V \lambda_\gamma} \vartheta_{\lambda_\gamma \mu_\gamma} F^{*}_{\mu_V \mu_\gamma}$$

Sum of all Helicity Amplitudes

Where does the disagreement originate?

Helicity Amplitude Ratios allow direct comparison with theory!

SDMEs vs HARs

- HARs form a basis for the set of SDMEs

➡ ρ^0 SDMEs are already extracted

A. Airapetian et al, EPJC 62 (2009) 659-694

- Check of HARs: extract SDMEs from HARs (it's the same data set)

A. Airapetian et al, EPJC (in press), arXiv:1012.3676

- More precise SDMES due to fewer fit parameters

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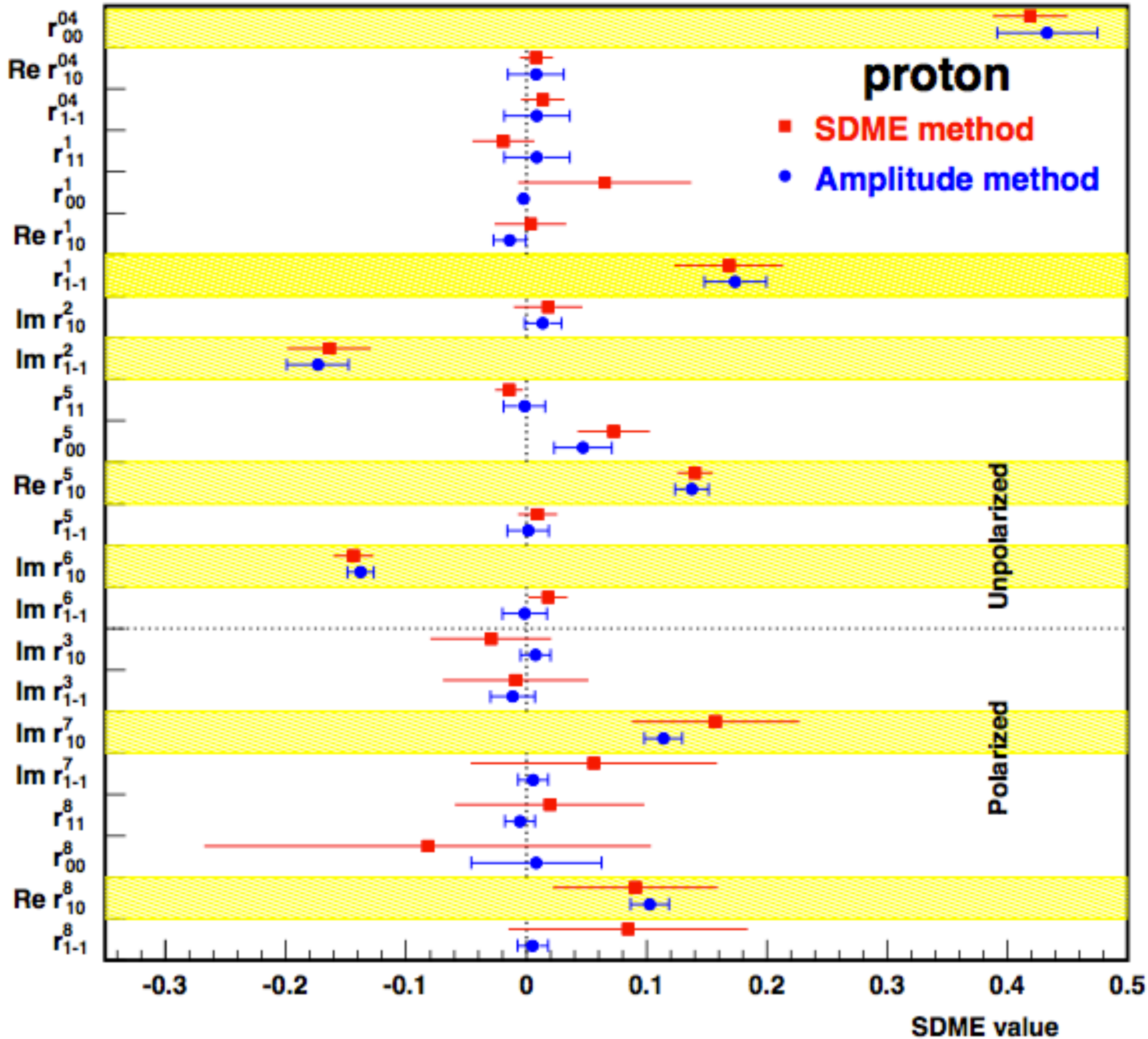
SDMEs for ρ^0



Kinematic Dependences of HARs

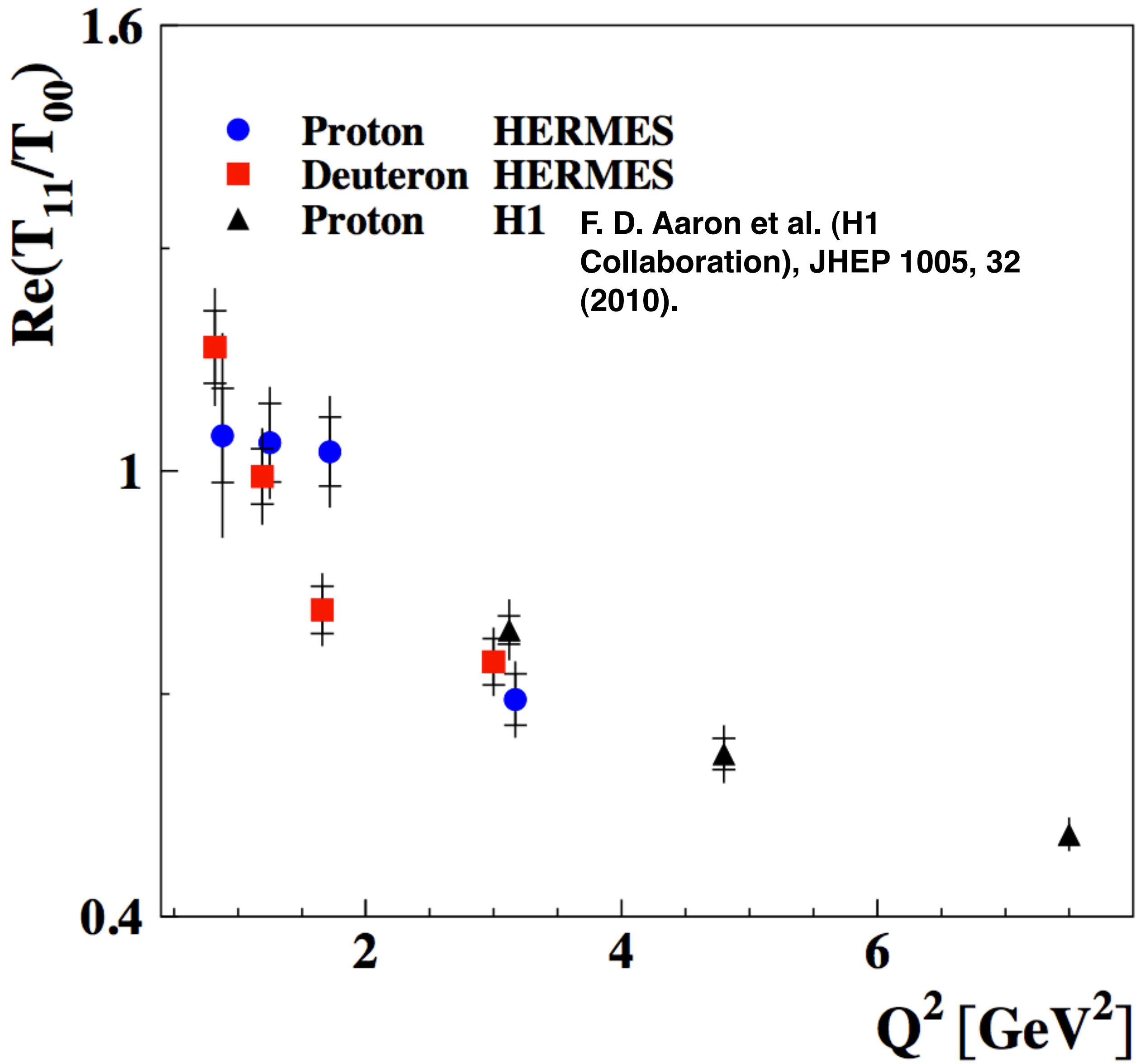
Behaviour of NPE

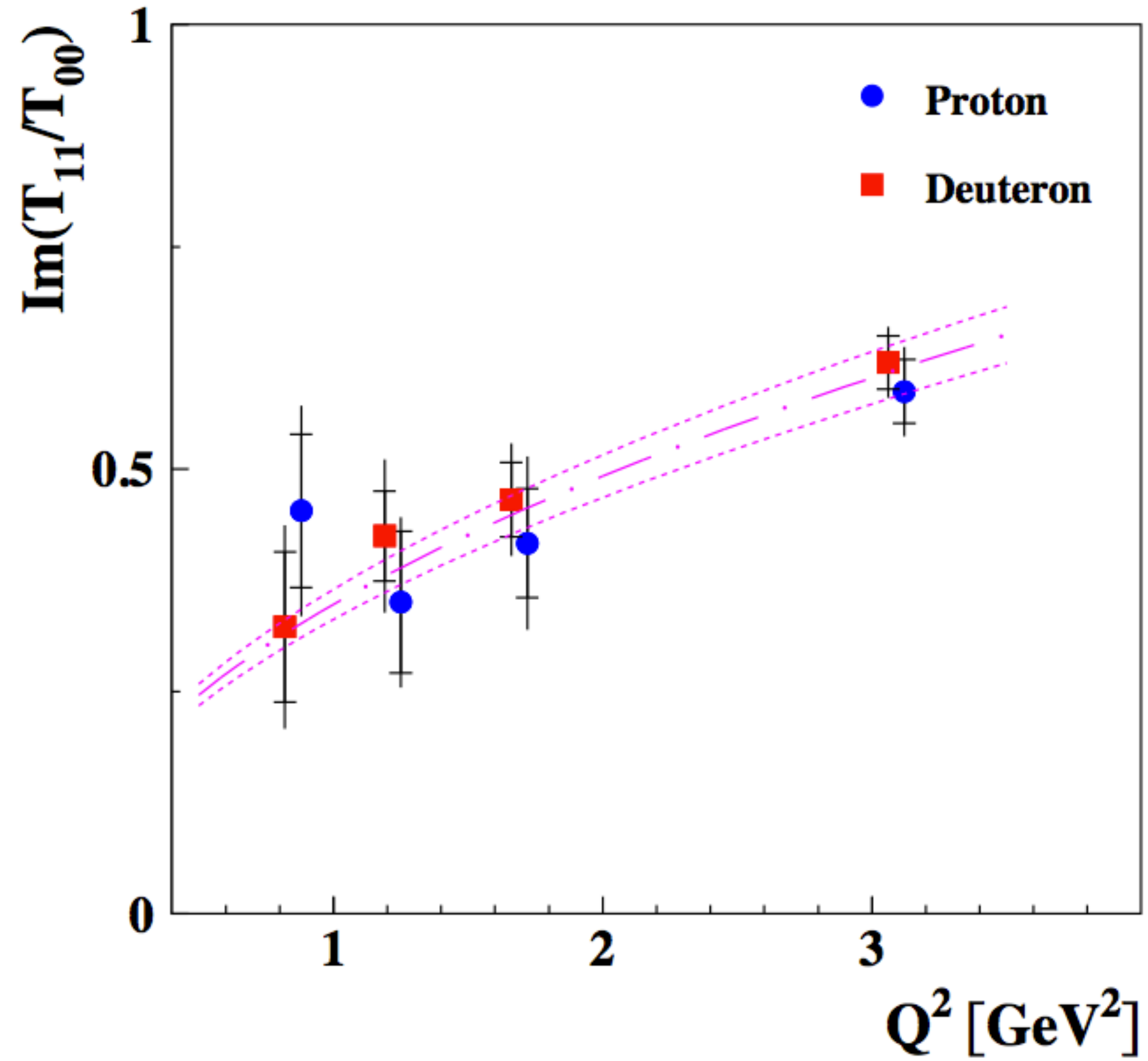
$$|T_{00}|^2 \approx |T_{11}|^2 >> |U_{11}|^2 > |T_{01}|^2 >> |T_{10}|^2 \ldots$$

- T_{00} should behave as a constant at small *t'*
- t_{11} may expect a 1/Q dependence from pQCD

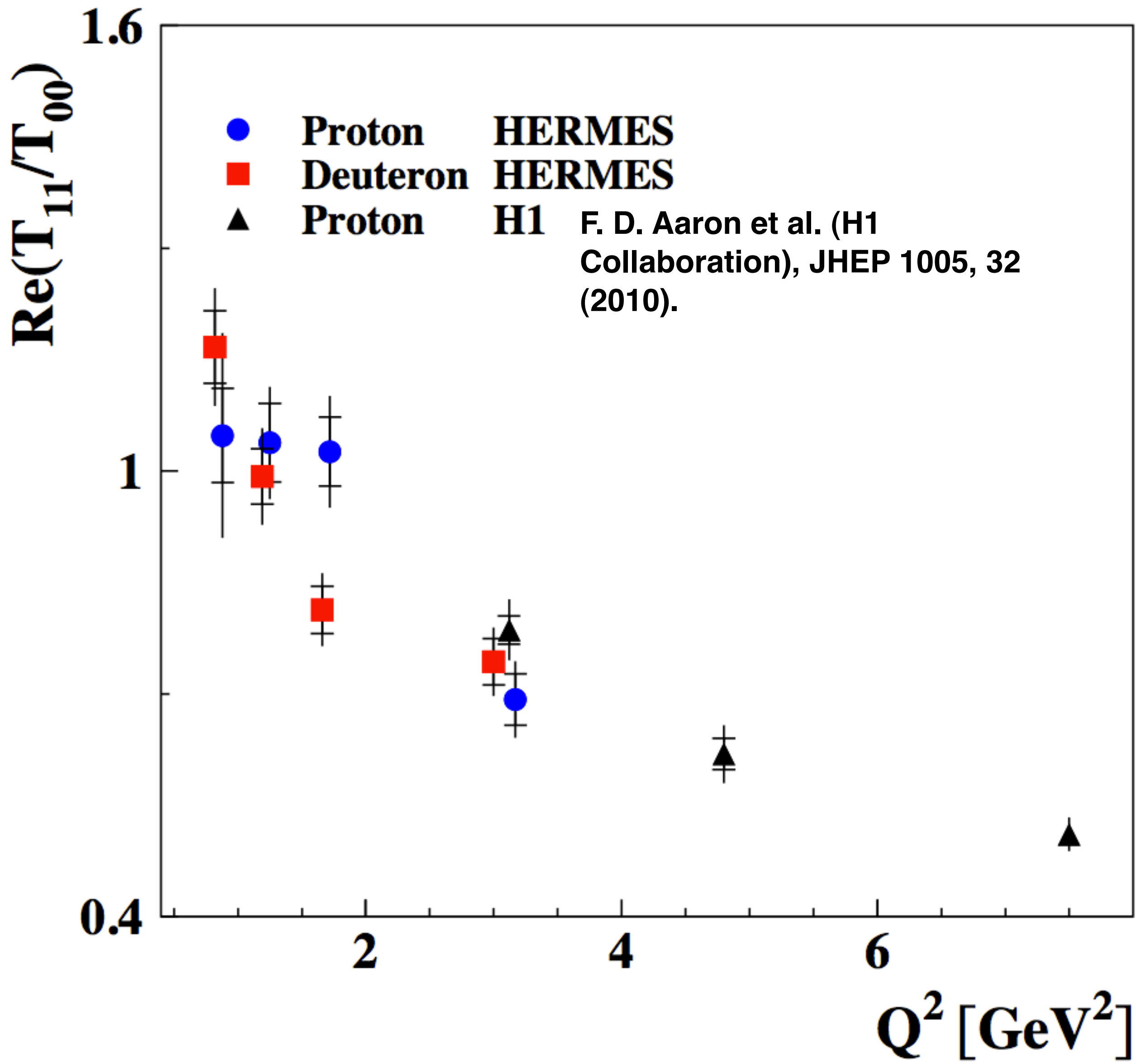
D. Yu. Ivanov and R. Kirschner, Phys. Rev. D 58, 114026 (1998)

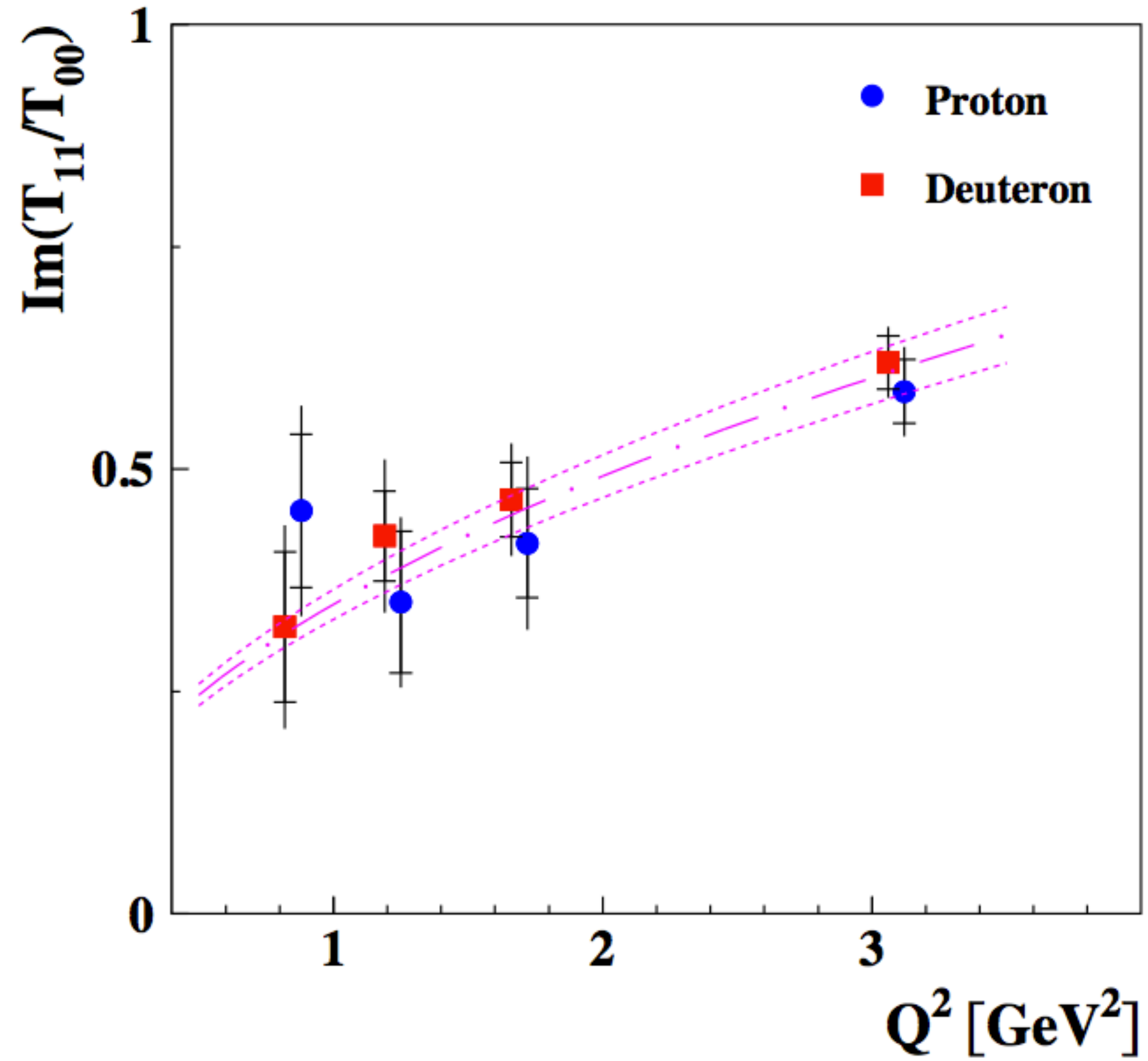
- Real and Imaginary parts examined separately





Kinematic Dependence of t_{11}





Real Part follows a/Q with a=1.11±0.03GeV as expected!

Imaginary Part follows bQ with b=0.34±0.02GeV^{-1} (fit has no basis in theory)

Phase Differences of HARs

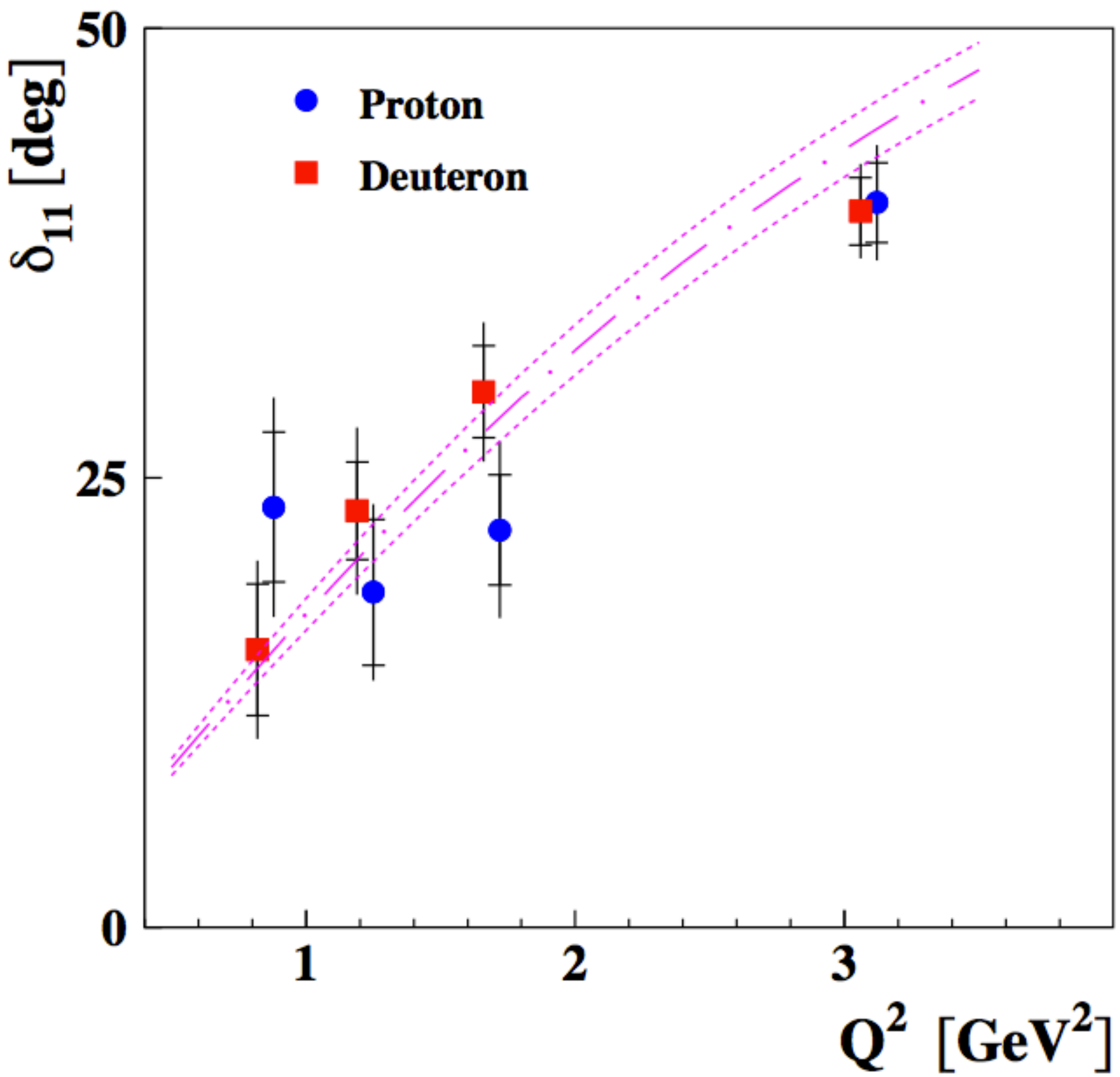
- GPD model predicts small phase difference for $\tan(\delta_{11})=\mathrm{Im}(t_{11})/\mathrm{Re}(t_{11})$

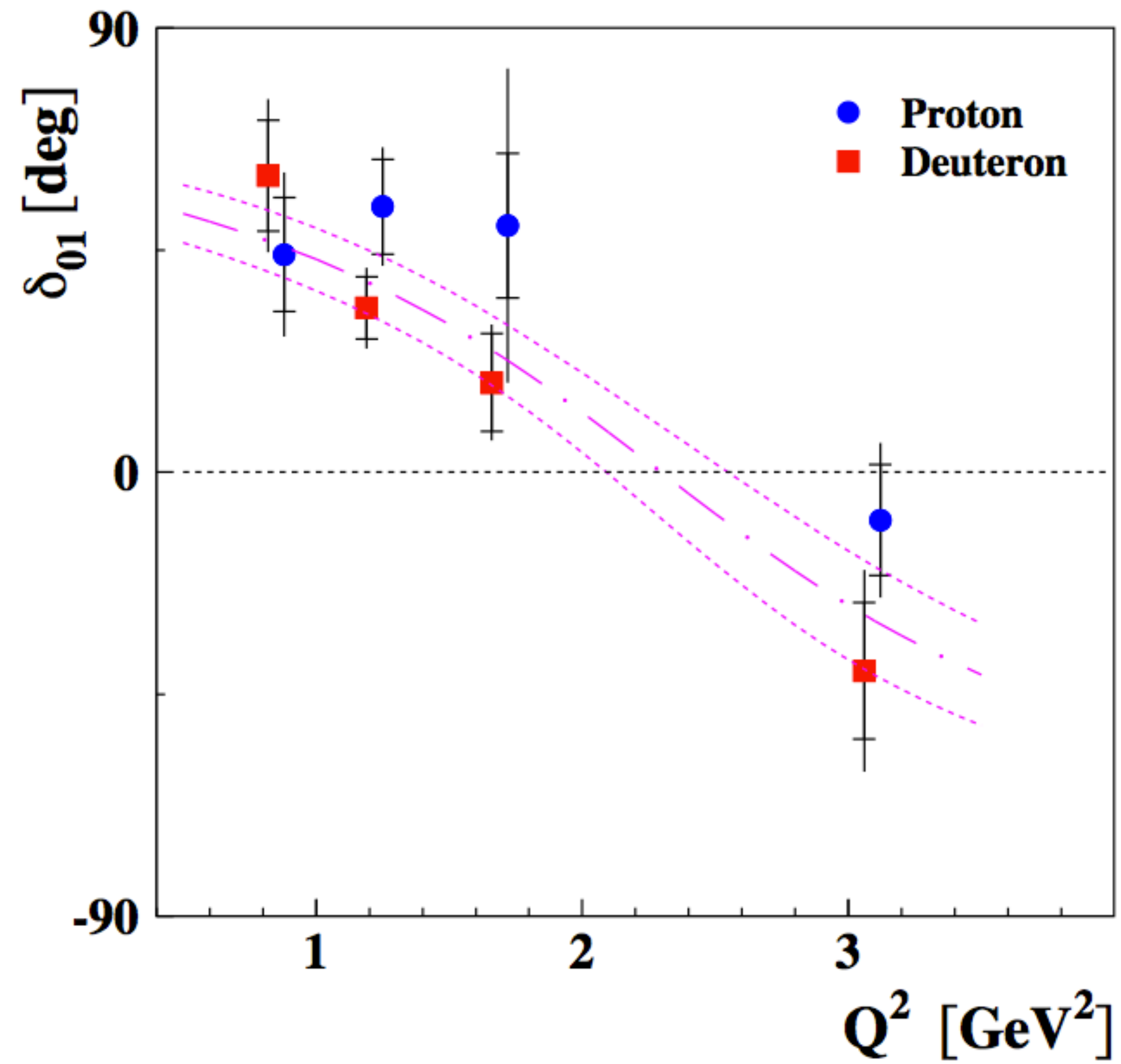
S. V. Goloskokov and P. Kroll, Eur. Phys. J. C 53, 367 (2008)

- t_{01} is expected to be the largest SCHC-violating amplitude and δ_{01} should be constant

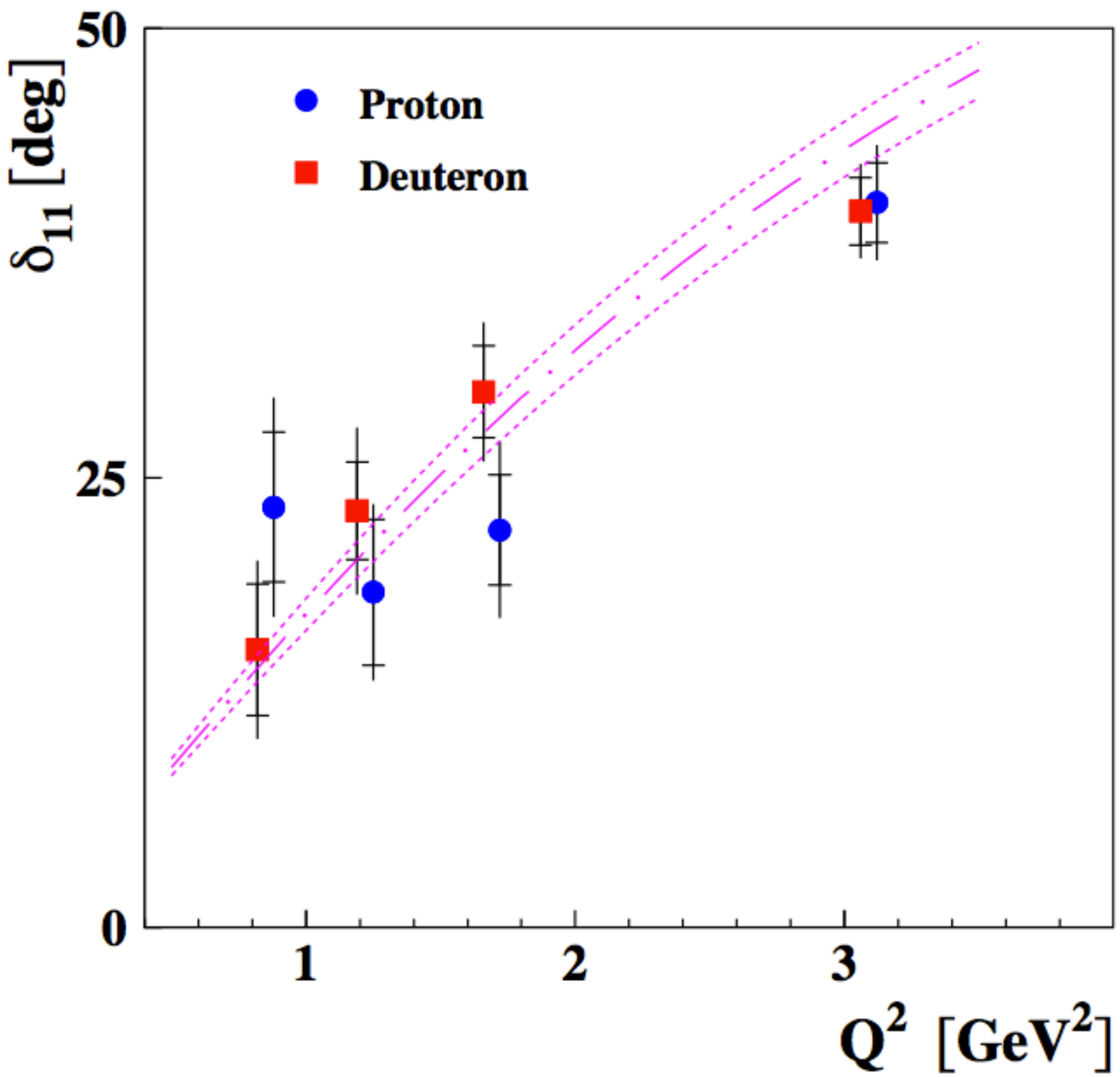
D. Yu. Ivanov and R. Kirschner, Phys. Rev. D 58, 114026 (1998)

Phase Difference of HARs



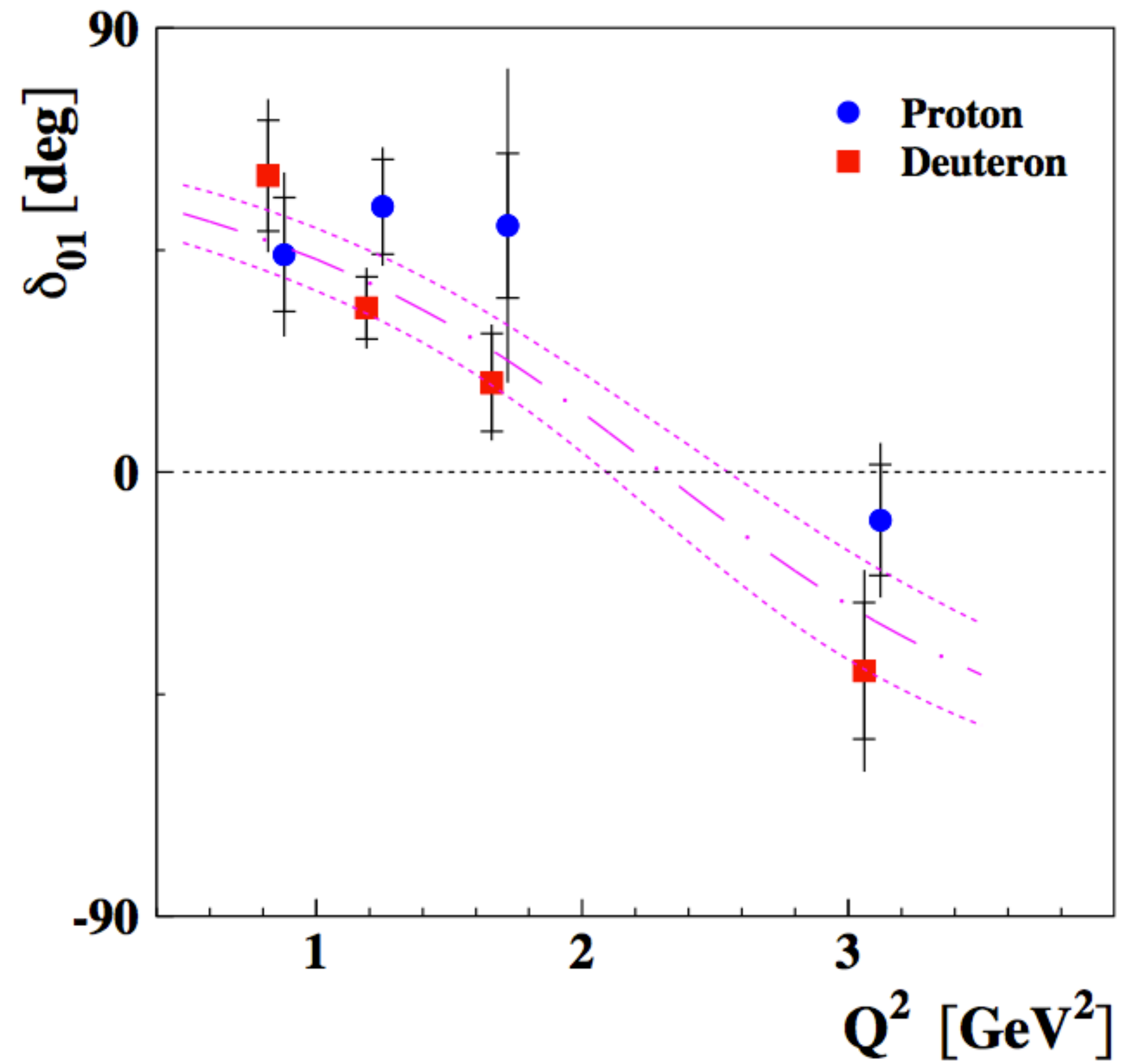


Large value contradicts GPD-based models



Should be a constant

(Neither Re(t_{01}) nor Im(t_{01}) follow theoretical dependence predictions!!!)



N.B: Fits have no basis in theory

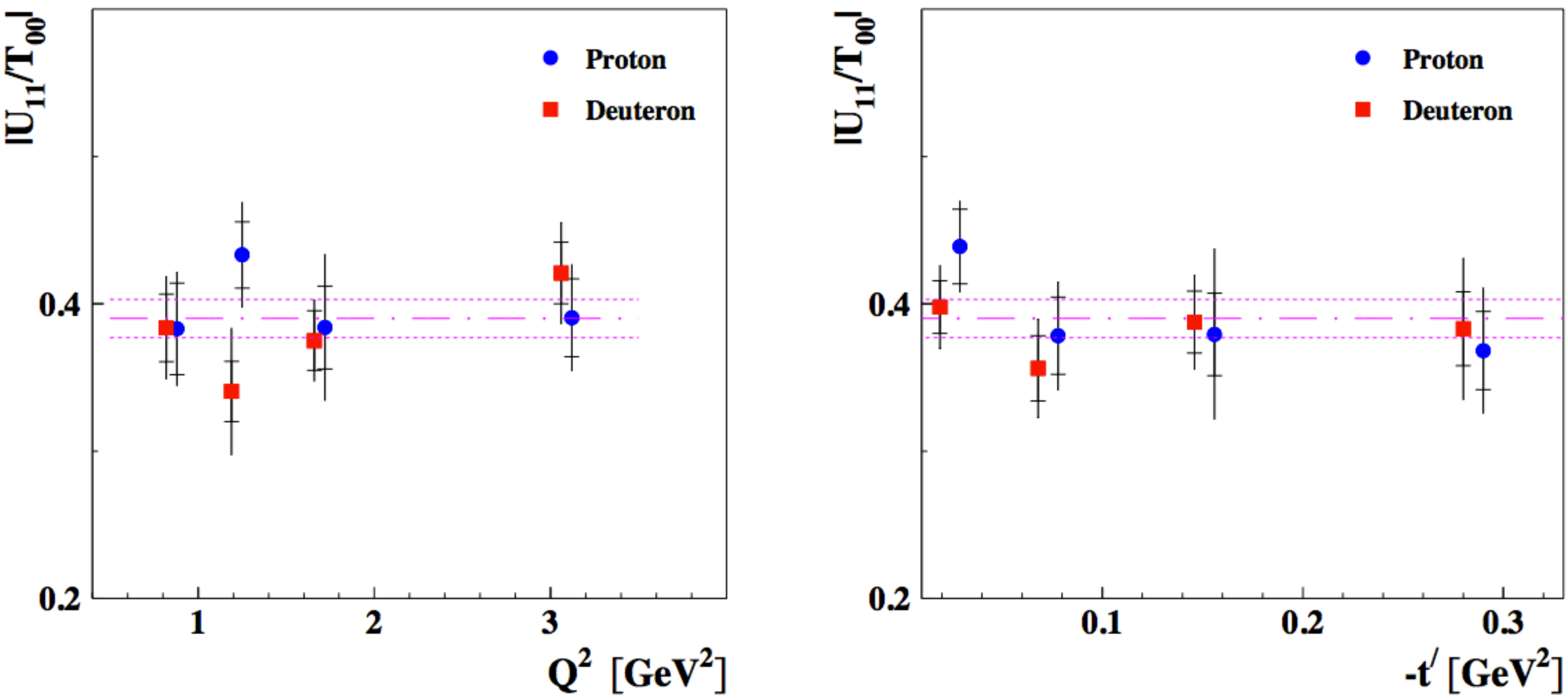
Helicity Amplitude Hierarchy

Behaviour of UPE

$$|T_{00}|^2 \approx |T_{11}|^2 >> |U_{11}|^2 > |T_{01}|^2 >> |T_{10}|^2 \ldots$$

- $u_{11} = |U_{11}|/|T_{00}|$ should be small ($u_{11} \approx 0.2$) but visible (only) for ρ^0 at HERMES!
- May naively expect a $1/Q$ dependence in u_{11}
- UPE is one-pion exchange => may also see some influence of the pion-pole at small *t?*

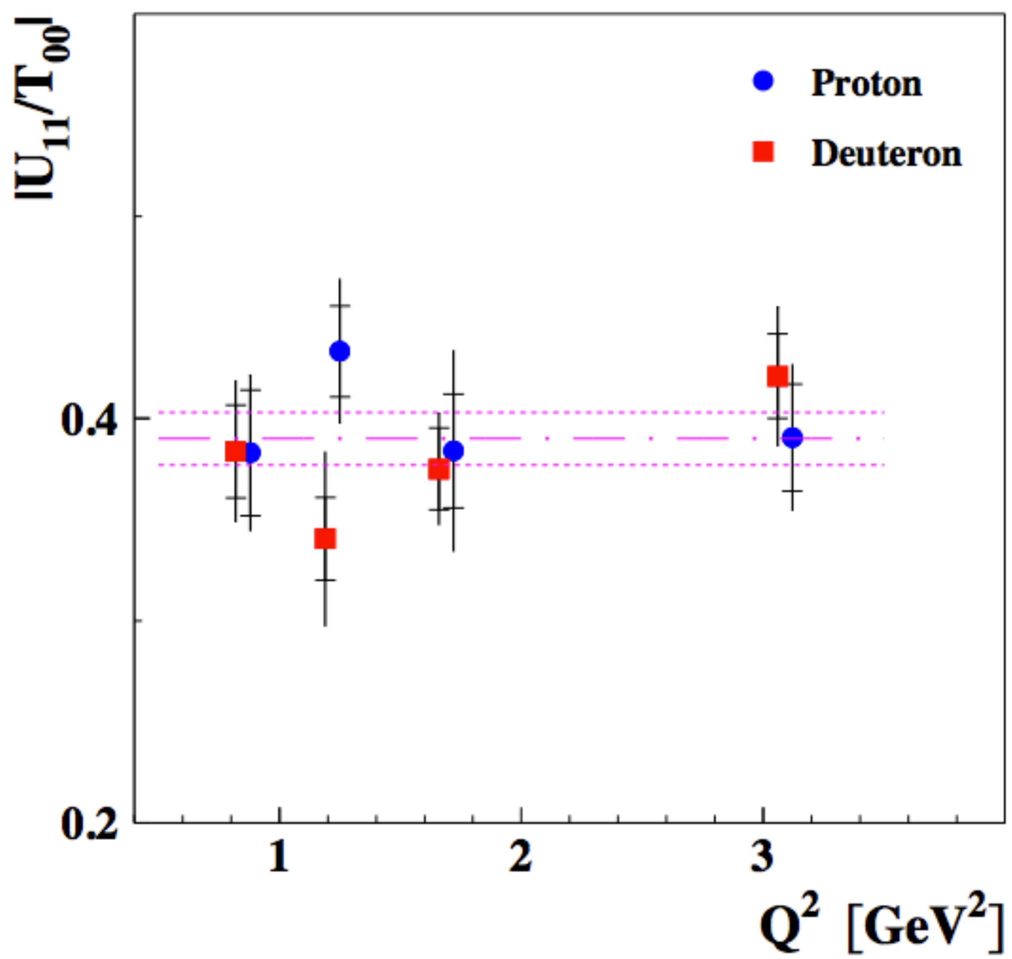
Unnatural Parity Exchange

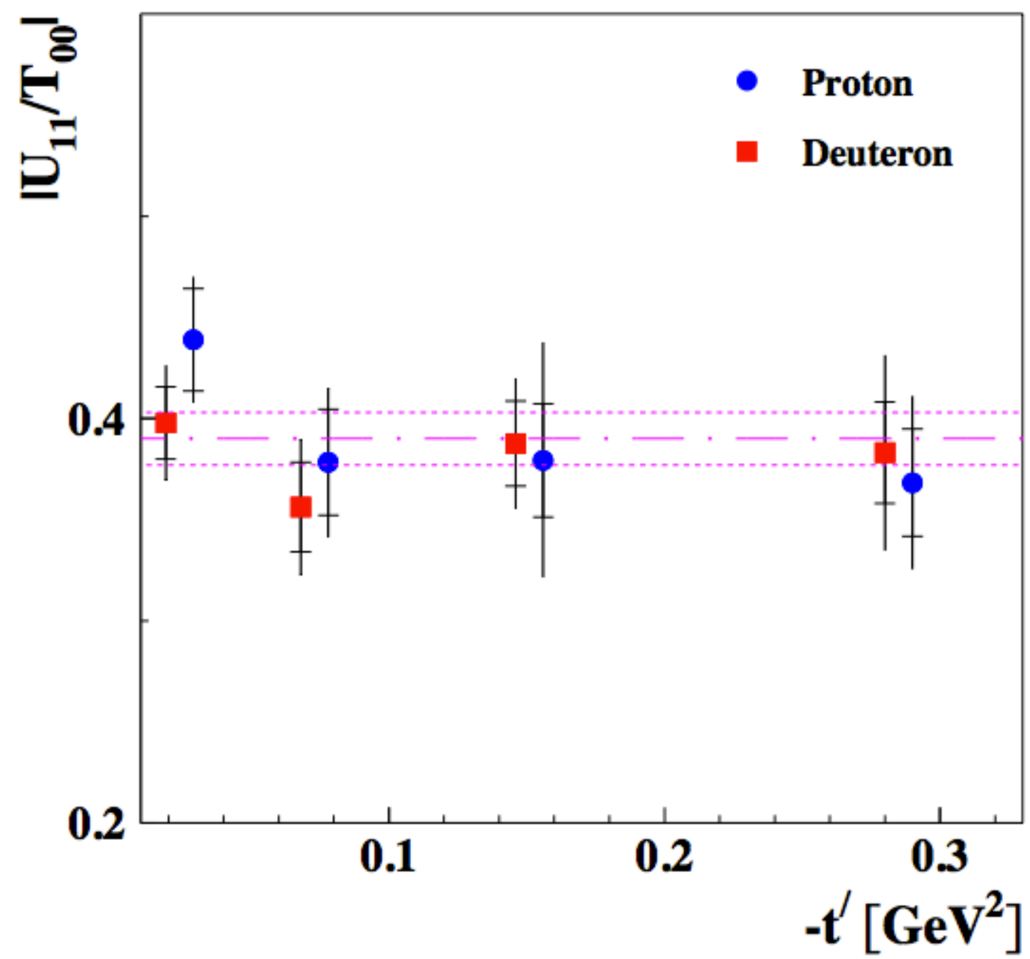


Unnatural Parity Exchange

No dependence on Q^2!

No dependence on t'!





Existence established to 20σ (integrated extraction)

Magnitude of U_{11} is 2.5x smaller than T_{00}

Unnatural Parity Exchange

- No dependence on Q^2 may be because HERMES is far from the asymptotic region ?

- No dependence on t'

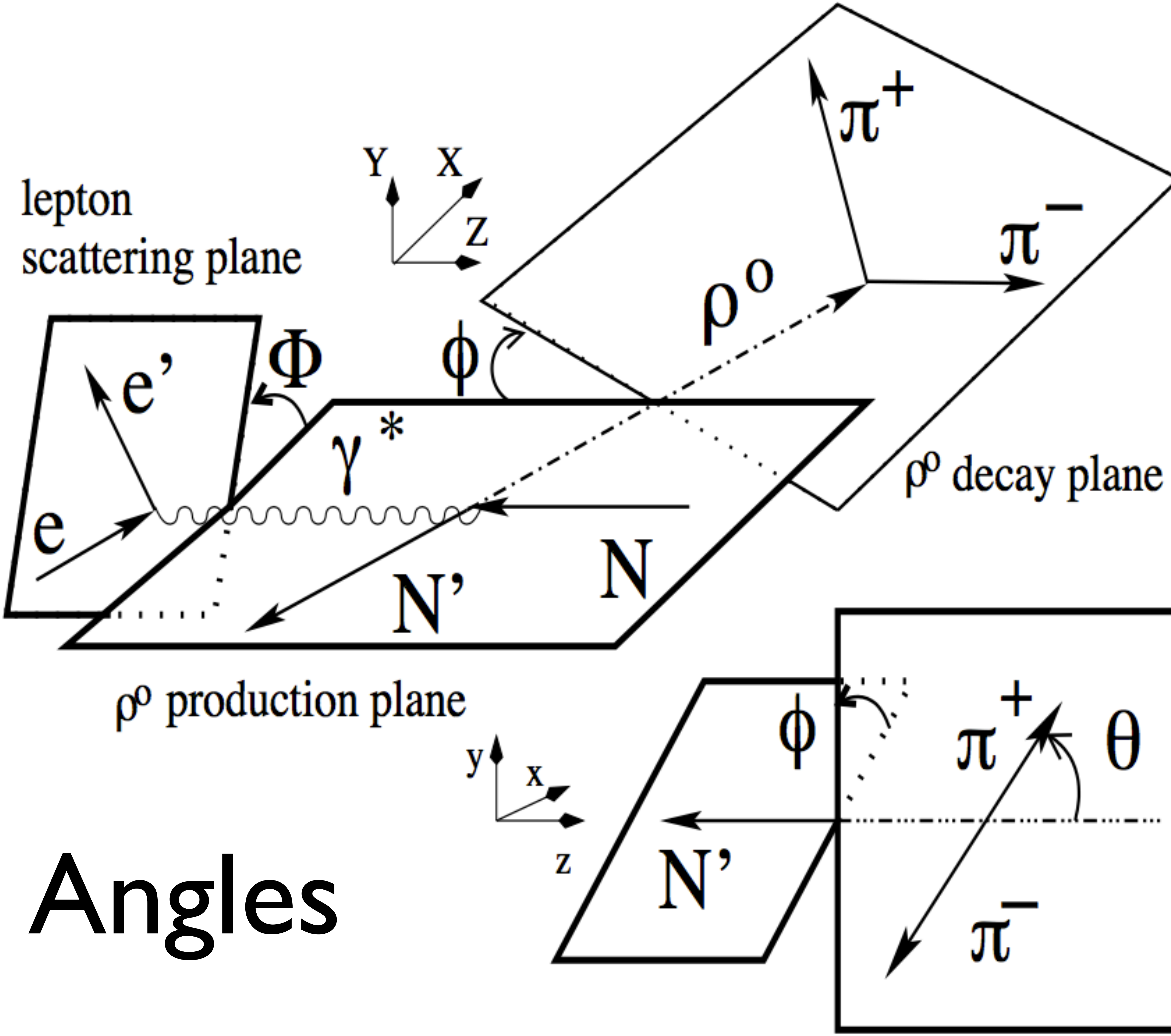
➡ Too far from pion-pole ?

➡ U_{11} not dominated by one-pion exchange ?

➡ An underlying dependence of T_{00} on t' ?

Review

- Polarized SDMEs can be determined more precisely from a fit of HARs than they can be through direct extraction
- Some kinematic dependences and phase differences of HARs are contrary to theory expectations, but are compatible with H1!
  (No W^2 dependence?)
- Unnatural Parity Exchange has been strongly established at HERMES for ρ^0 mesons although the kinematic dependences are not well understood



lepton
scattering plane
Y
X
Z
π⁺
π⁻
ρ°
Φ
ϕ
e'
γ*
e
N
N'
ρ° decay plane
ρ° production plane
ϕ
π⁺
θ
y
x
z
N'
π⁻

Angles

SDMEs vs HARs

$$\mathcal{W}^U(\Phi,\phi,\cos\theta) = \frac{3}{8\pi^2}\Bigg[\frac{1}{2}(1-r^{04}_{00}) + \frac{1}{2}(3r^{04}_{00}-1)\cos^2\theta - \sqrt{2}\mathrm{Re}\{r^{04}_{10}\}\sin 2\theta\cos\phi - r^{04}_{1-1}\sin^2\theta\cos 2\phi$$
$$- \epsilon\cos 2\Phi\Big(r^1_{11}\sin^2\theta + r^1_{00}\cos^2\theta - \sqrt{2}\mathrm{Re}\{r^1_{10}\}\sin 2\theta\cos\phi - r^1_{1-1}\sin^2\theta\cos 2\phi\Big)$$
$$- \epsilon\sin 2\Phi\Big(\sqrt{2}\mathrm{Im}\{r^2_{10}\}\sin 2\theta\sin\phi + \mathrm{Im}\{r^2_{1-1}\}\sin^2\theta\sin 2\phi\Big)$$
$$+ \sqrt{2\epsilon(1+\epsilon)}\cos\Phi\Big(r^5_{11}\sin^2\theta + r^5_{00}\cos^2\theta - \sqrt{2}\mathrm{Re}\{r^5_{10}\}\sin 2\theta\cos\phi - r^5_{1-1}\sin^2\theta\cos 2\phi\Big)$$
$$+ \sqrt{2\epsilon(1+\epsilon)}\sin\Phi\Big(\sqrt{2}\mathrm{Im}\{r^6_{10}\}\sin 2\theta\sin\phi + \mathrm{Im}\{r^6_{1-1}\}\sin^2\theta\sin 2\phi\Big)\Bigg],$$

$$\mathcal{W}^L(\Phi,\phi,\cos\theta) = \frac{3}{8\pi^2}\Bigg[\sqrt{1-\epsilon^2}\Big(\sqrt{2}\mathrm{Im}\{r^3_{10}\}\sin 2\theta\sin\phi + \mathrm{Im}\{r^3_{1-1}\}\sin^2\theta\sin 2\phi\Big)$$
$$+ \sqrt{2\epsilon(1-\epsilon)}\cos\Phi\Big(\sqrt{2}\mathrm{Im}\{r^7_{10}\}\sin 2\theta\sin\phi + \mathrm{Im}\{r^7_{1-1}\}\sin^2\theta\sin 2\phi\Big)$$
$$+ \sqrt{2\epsilon(1-\epsilon)}\sin\Phi\Big(r^8_{11}\sin^2\theta + r^8_{00}\cos^2\theta - \sqrt{2}\mathrm{Re}\{r^8_{10}\}\sin 2\theta\cos\phi - r^8_{1-1}\sin^2\theta\cos 2\phi\Big)\Bigg].$$

$$r^{04}_{00} \simeq \{\epsilon + |t_{01}|^2\}/N\,,$$
$$\mathrm{Re}\{r^{04}_{10}\} \simeq \mathrm{Re}\{\epsilon t_{10} + \frac{1}{2} t_{01}(t_{11} - t_{1-1})^*\}/N\,,$$
$$r^{04}_{1-1} \simeq \mathrm{Re}\{-\epsilon|t_{10}|^2 + t_{1-1}t^*_{11}\}/N\,,$$
$$r^{1}_{11} \simeq \mathrm{Re}\{t_{1-1}t^*_{11}\}/N\,,$$
$$r^{1}_{00} \simeq -|t_{01}|^2/N\,,$$
$$\mathrm{Re}\{r^{1}_{10}\} \simeq \frac{1}{2}\mathrm{Re}\{-t_{01}(t_{11} - t_{1-1})^*\}/N\,,$$
$$r^{1}_{1-1} \simeq \frac{1}{2}\{|t_{11}|^2 + |t_{1-1}|^2 - |u_{11}|^2\}/N\,,$$
$$\mathrm{Im}\{r^{2}_{10}\} \simeq \frac{1}{2}\mathrm{Re}\{t_{01}(t_{11} + t_{1-1})^*\}/N\,,$$
$$\mathrm{Im}\{r^{2}_{1-1}\} \simeq \frac{1}{2}\{-|t_{11}|^2 + |t_{1-1}|^2 + |u_{11}|^2\}/N\,,$$
$$r^{5}_{11} \simeq \frac{1}{\sqrt{2}}\mathrm{Re}\{t_{10}(t_{11} - t_{1-1})^*\}/N\,,$$
$$r^{5}_{00} \simeq \sqrt{2}\mathrm{Re}\{t_{01}\}/N\,,$$
$$\mathrm{Re}\{r^{5}_{10}\} \simeq \frac{1}{\sqrt{8}}\mathrm{Re}\{2t_{10}t^*_{01} + (t_{11} - t_{1-1})\}/N\,,$$
$$r^{5}_{1-1} \simeq \frac{1}{\sqrt{2}}\mathrm{Re}\{-t_{10}(t_{11} - t_{1-1})^*\}/N\,,$$
$$\mathrm{Im}\{r^{6}_{10}\} \simeq -\frac{1}{\sqrt{8}}\mathrm{Re}\{t_{11} + t_{1-1}\}/N\,,$$
$$\mathrm{Im}\{r^{6}_{1-1}\} \simeq \frac{1}{\sqrt{2}}\mathrm{Re}\{t_{10}(t_{11} + t_{1-1})^*\}/N\,,$$

$$\mathrm{Im}\{r^{3}_{10}\} \simeq -\frac{1}{2}\mathrm{Im}\{t_{01}(t_{11} + t_{1-1})^*\}/N\,,$$
$$\mathrm{Im}\{r^{3}_{1-1}\} \simeq -\mathrm{Im}\{t_{1-1}t^*_{11}\}/N\,,$$
$$\mathrm{Im}\{r^{7}_{10}\} \simeq \frac{1}{\sqrt{8}}\mathrm{Im}\{t_{11} + t_{1-1}\}/N\,,$$
$$\mathrm{Im}\{r^{7}_{1-1}\} \simeq \frac{1}{\sqrt{2}}\mathrm{Im}\{t_{10}(t_{11} + t_{1-1})^*\}/N,$$
$$r^{8}_{11} \simeq -\frac{1}{\sqrt{2}}\mathrm{Im}\{t_{10}(t_{11} - t_{1-1})^*\}/N\,,$$
$$r^{8}_{00} \simeq \sqrt{2}\mathrm{Im}\{t_{01}\}/N\,,$$
$$\mathrm{Re}\{r^{8}_{10}\} \simeq \frac{1}{\sqrt{8}}\mathrm{Im}\{-2t_{10}t^*_{01} + t_{11} - t_{1-1}\}/N\,,$$
$$r^{8}_{1-1} \simeq \frac{1}{\sqrt{2}}\mathrm{Im}\{t_{10}(t_{11} - t_{1-1})^*\}/N$$

$$N = N_T + \epsilon N_L,$$
$$N_T \simeq |t_{11}|^2 + |t_{01}|^2 + |t_{1-1}|^2 + |u_{11}|^2,$$
$$N_L \simeq 1 + 2|t_{10}|^2.$$

SDMEs in terms of HARs!!!