Exclusive Vector Meson Production at HERMES

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for the HERMES collaboration

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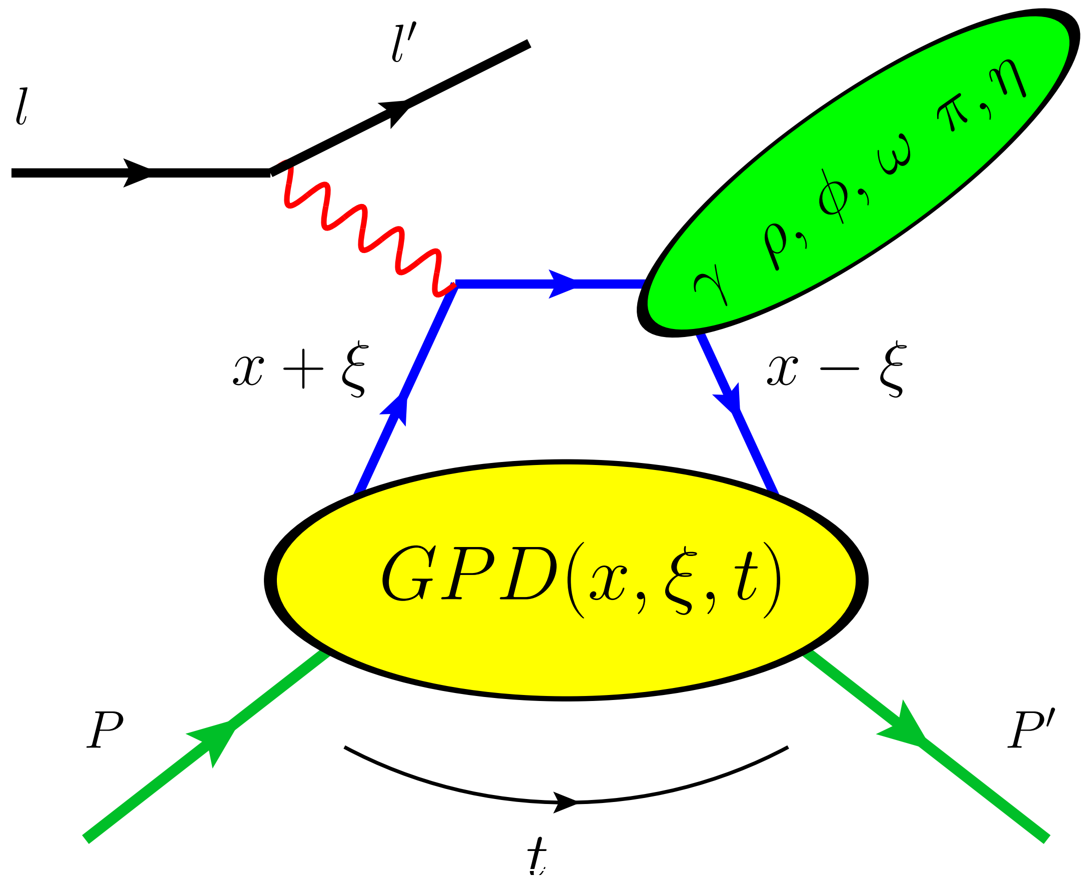
Experimental probe of GPDs ⟶ Hard exclusive Processes



Deeply Virtual Compton Scattering

- Theoretically the cleanest probe of GPDs
- Theoretical accuracy at NNLO
- GPDs are accessed through convolution integrals with hard scattering amplitude
- Experimental observables: Azimuthal asymmetries, cross sections, cross section differences.
- Amplitudes depend on all GPDs $H, E, \widetilde{H}, \widetilde{E}$

Vector Mesons

- Factorization for σ_L (to ρ_L, ϕ_L, ω_L) only
- σ_L to σ_T suppressed by 1/Q
- σ_T suppressed by $1/Q^2$
- Experimental observables: cross sections, SDMEs, azimuthal asymmetries, Helicity amplitude ratios
- At leading twist → sensitive to GPDs H and E
- Observables for different mesons provide a possibility of flavor tagging.

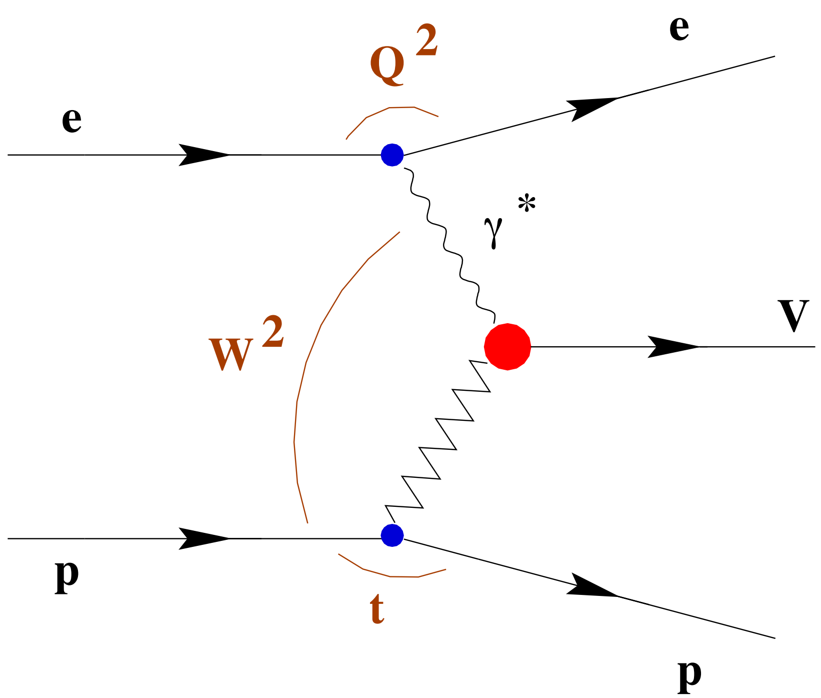
Pseudoscalar mesons

- Experimental observables: Cross sections, azimuthal asymmetries
- At leading twist → sensitive to GPDs $\widetilde{H}$ and $\widetilde{E}$

Exclusive Vector Meson Production

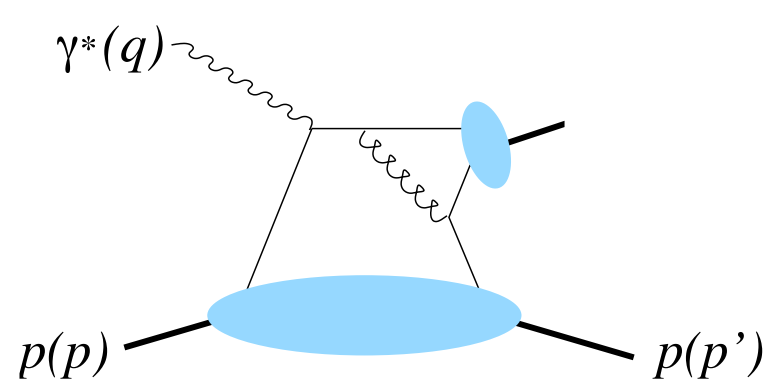
Vector Meson Dominance

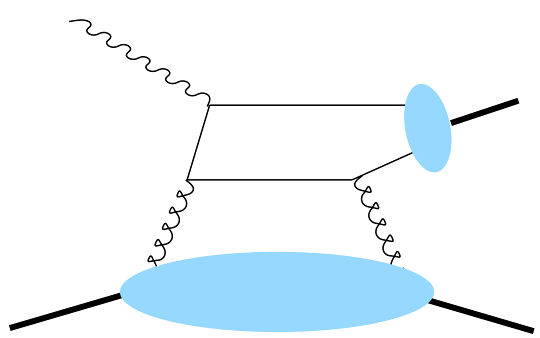
$$0 < Q^2 < few \quad GeV^2$$



pQCD

$$Q^2 \gg 1 \quad GeV^2$$





pQCD description of the process.

I) dissociation of the virtual photon into quark-antiquark pair
II) scattering of the pair on a nucleon
III) formation of the observed vector meson

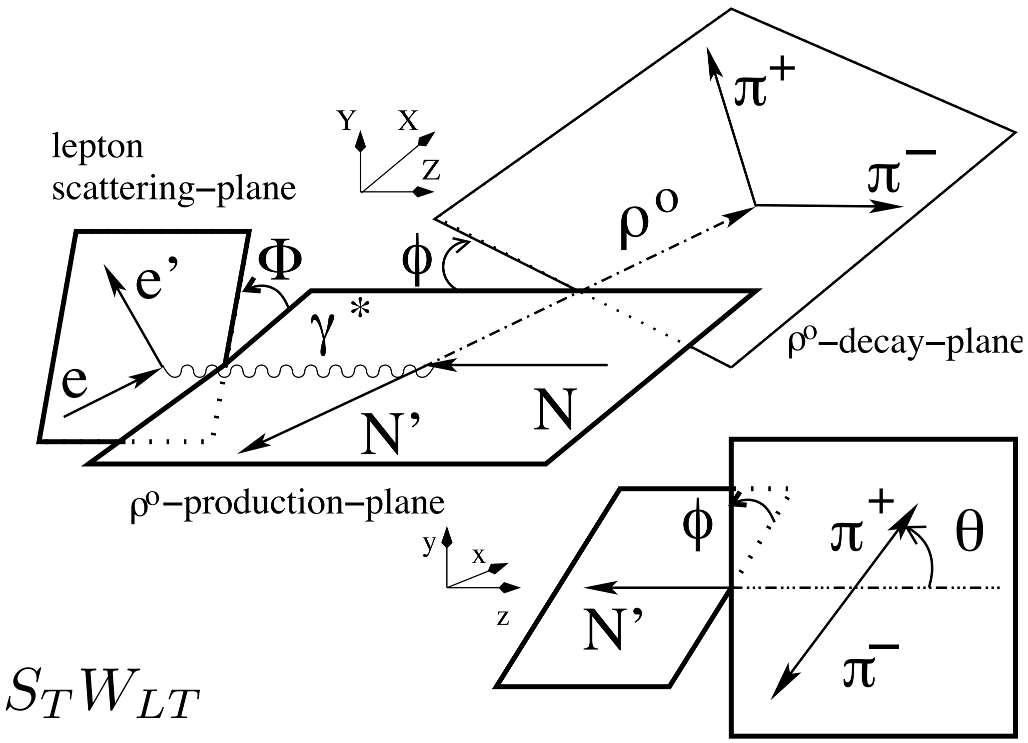
Natural Parity Exchange - described by GPDs H and E

Unnatural Parity Exchange - described by GPDs $\widetilde{H}$ and $\widetilde{E}$

Experimental Observables

Cross Section

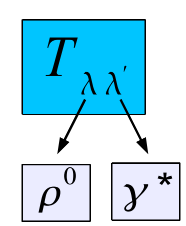
$$\frac{d\sigma}{dx_B dQ^2 dt d\Phi d\cos\theta d\phi} \propto \frac{d\sigma}{dx_B dQ^2 dt} W(x_B, Q^2, t, \Phi, \cos\theta, \phi)$$



production and decay angular distribution

$$W = W_{UU} + P_\ell W_{LU} + S_L W_{UL} + P_\ell S_L W_{LL} + S_T W_{UT} + P_\ell S_T W_{LT}$$

parameterization in terms of helicity amplitudes



or SDMES

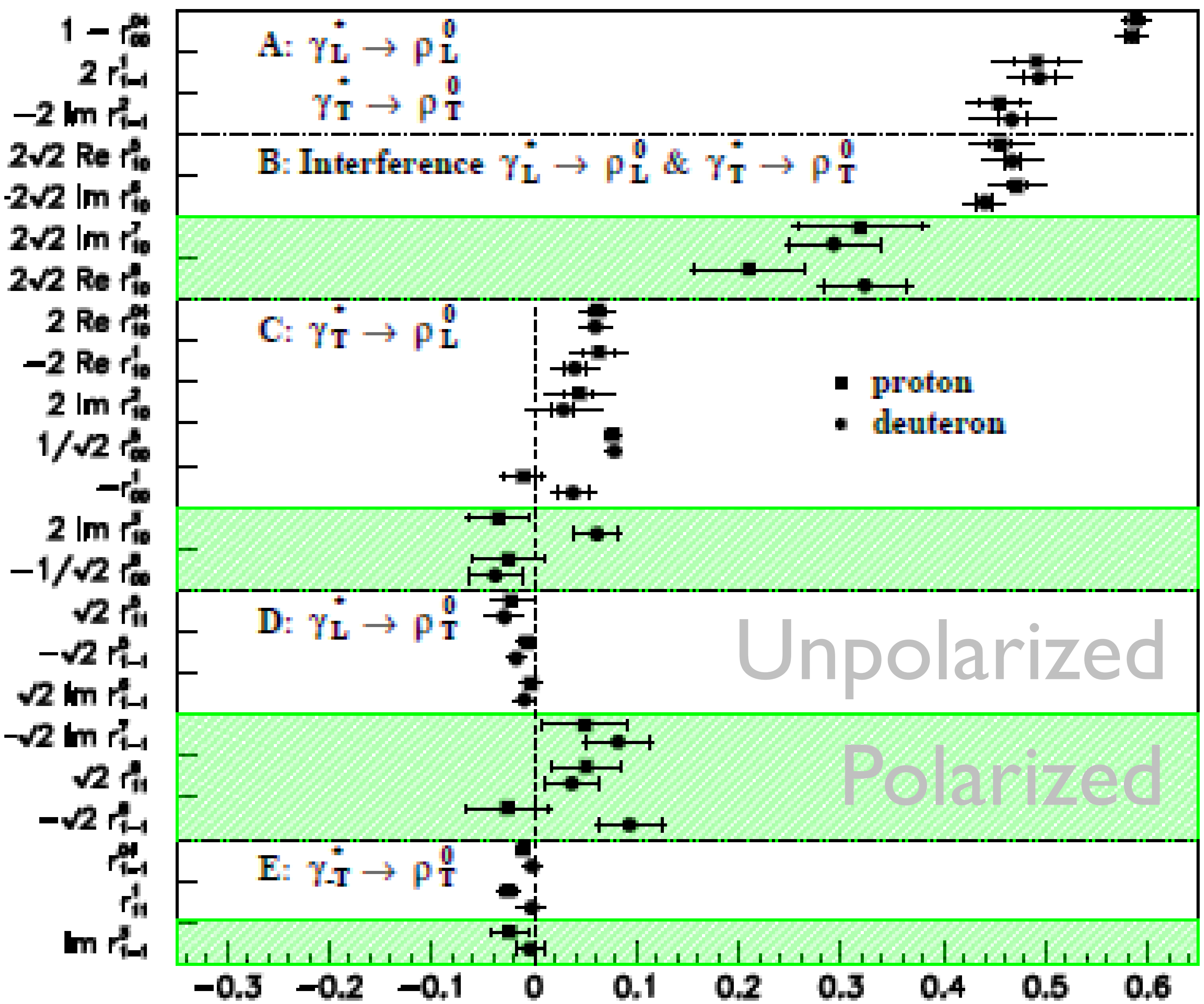
-Schilling, Wolf (1973)
-Diehl (2007)

$$W = W_{UU} + P_\ell W_{LU} + S_L W_{UL} + P_\ell S_L W_{LL} + S_T W_{UT} + P_\ell S_T W_{LT}$$

- W_{UU} → 15 SDMEs
- W_{LU} → 8 SDMEs
- W_{UT} → 30 SDMEs

SDME's ρ^0

$$|T_{00}| \sim |T_{11}| \gg |T_{01}| > |T_{10}| \geq |T_{1-1}|$$



- Selected hierarchy of NPE helicity amplitudes is confirmed
- No differences between proton and deuteron

$\gamma^*_L \to V_L$ && $\gamma^*_T \to V_T$ (Class A & B)

- SDMEs are significantly different from zero
- SDMEs of Class B are smaller than SDMEs of Class A

$\gamma^*_T \to V_L$ (Class C)

- some SDMEs are significantly different from zero (up to 10σ)
- Violation from SCHC

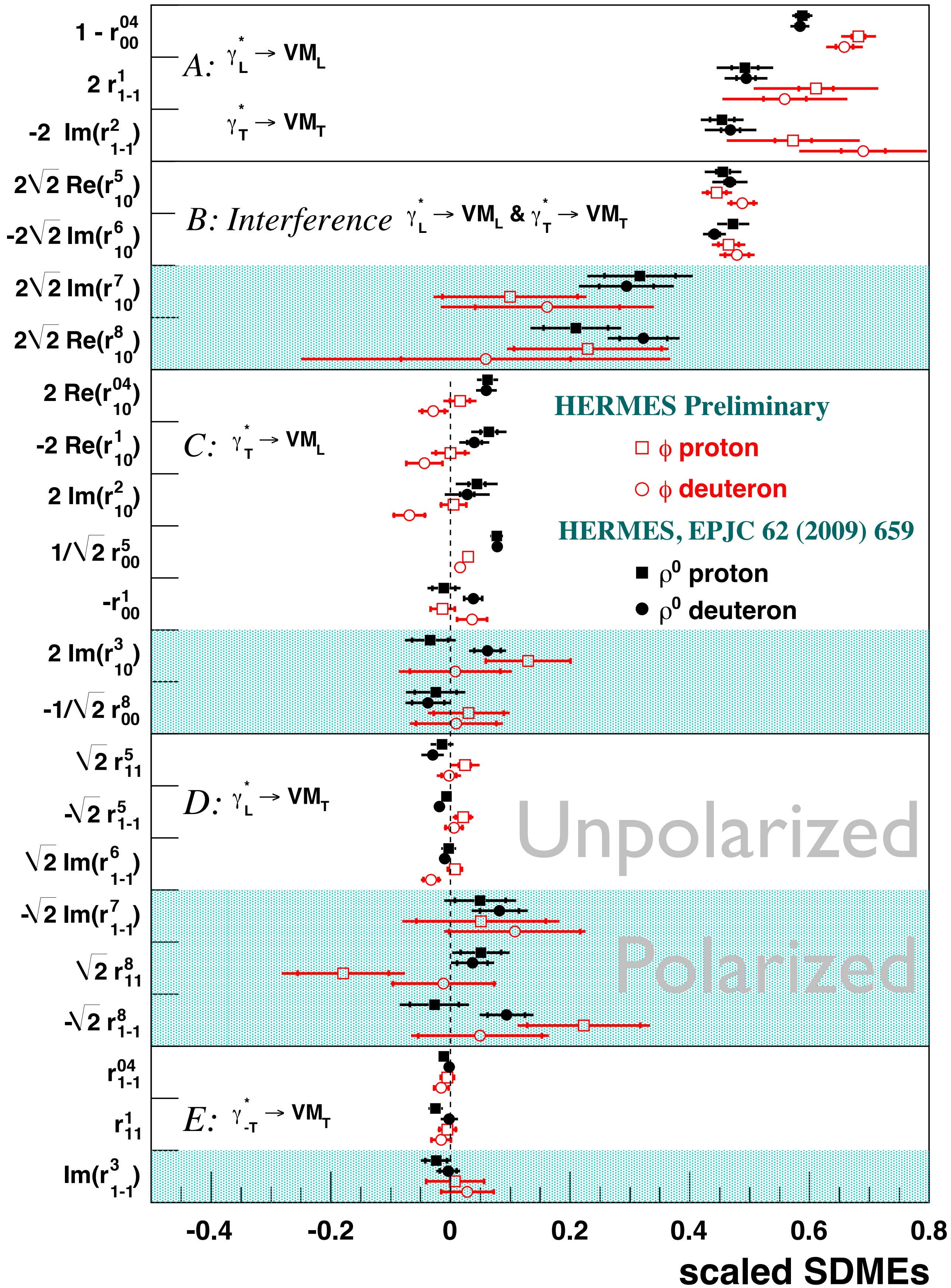
$\gamma^*_L \to V_T$ (Class D)

- Unpolarized SDMEs are slightly negative
- Polarized SDMEs are slightly positive

$\gamma^*_{-T} \to V_T$ (Class E)

- SDMEs on Deuteron are consistent with zero
- Small deviation from zero for SDMEs on hydrogen

SDMEs Φ



- Selected hierarchy of NPE helicity amplitudes is confirmed
- No significant differences between proton and deuteron

$\gamma^*_L \rightarrow V_L$ & $\gamma^*_T \rightarrow V_T$ (Class A & B)

- SDMEs are significantly different from zero
- 10-20% difference between ρ and ϕ SDMEs

$\gamma^*_T \rightarrow V_L$ (Class C)

- SDMEs are consistent with zero
- SDMEs on deuteron are slightly negative
- No strong indication of violation from SCHC

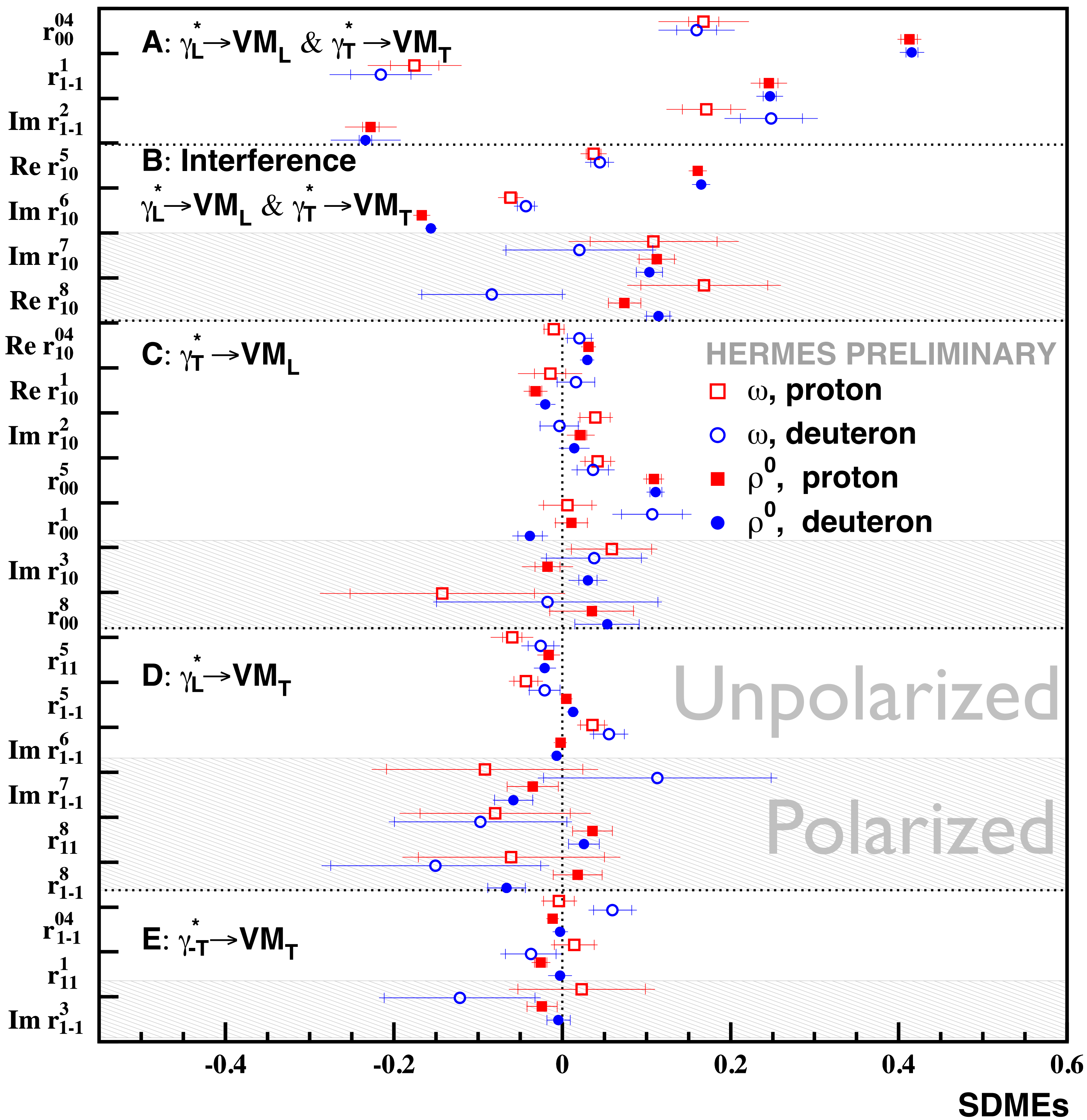
$\gamma^*_L \rightarrow V_T$ (Class D)

- Unpolarized and Polarized SDMEs are consistent with zero for both hydrogen and deuteron

$\gamma^*_{-T} \rightarrow V_T$ (Class E)

- Unpolarized and Polarized SDMEs are consistent with zero for both hydrogen and deuteron

SDMEs ω



- Selected hierarchy of NPE helicity amplitudes is not confirmed
- No differences between proton and deuteron

$\gamma^*_L \rightarrow V_L$ & $\gamma^*_T \rightarrow V_T$ (Class A & B)

- SDMEs are significantly different from zero
- Significant differences between ρ and ω SDMEs

$\gamma^*_T \rightarrow V_L$ (Class C)

- SDMEs are consistent with zero on both targets

$\gamma^*_L \rightarrow V_T$ (Class D)

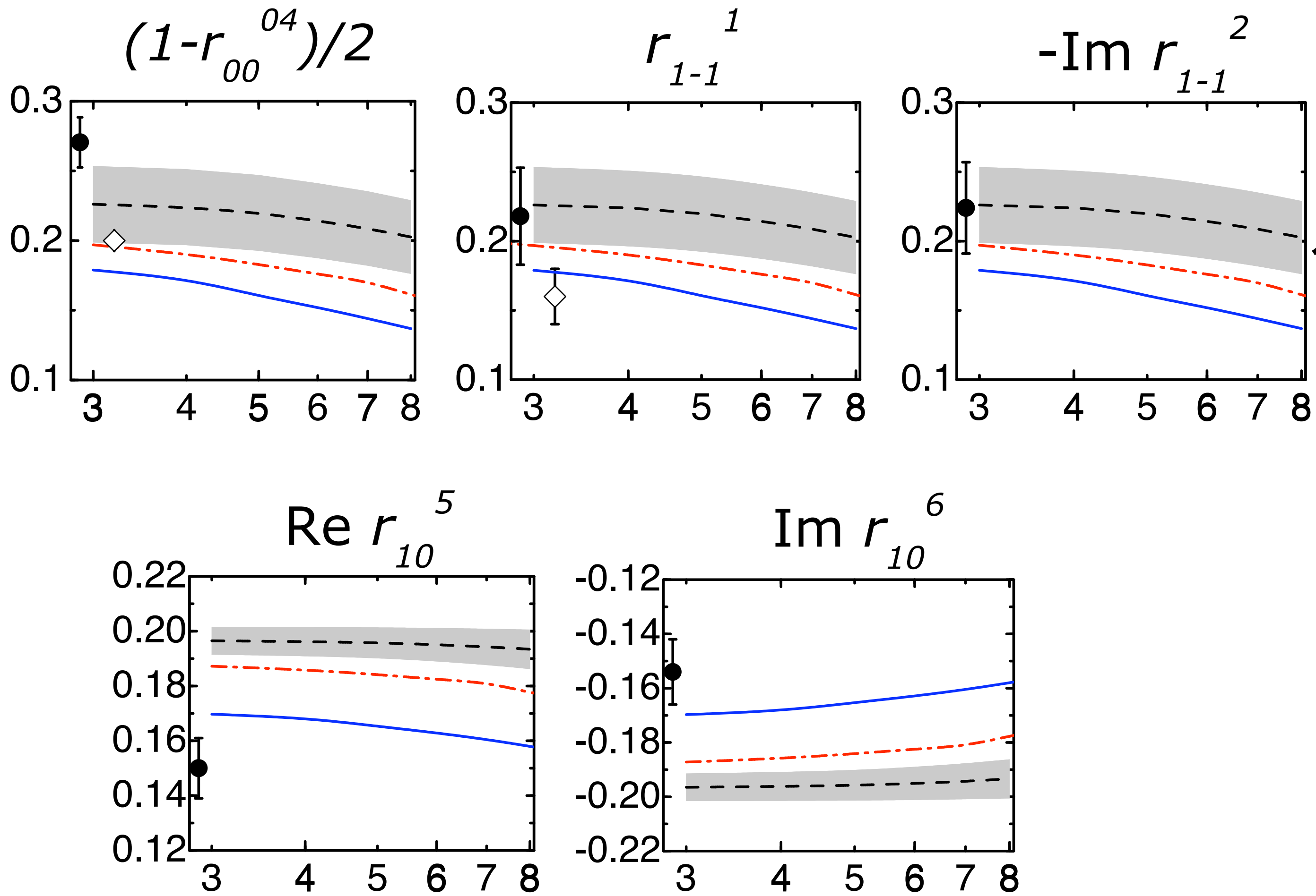
- Unpolarized SDMEs differ from zero
- Small evidence for violation from SCHC

$\gamma^*_{-T} \rightarrow V_T$ (Class E)

- Unpolarized and Polarized SDMEs are consistent with zero for both hydrogen and deuteron

Comparison with GPD models

GPD model: S.Goloskokov, P. Kroll (2007)



W=5 GeV (HERMES)
W=10 GeV (COMPASS)
W=90 GeV (H1,ZEUS)

$\gamma^*_L \rightarrow \rho^0_L$ & $\gamma^*_T \rightarrow \rho^0_T$

$$1 - r^{04}_{00}, r^1_{1-1}, -Imr^2_{1-1} \propto T_{11}$$

model is in agreement with data

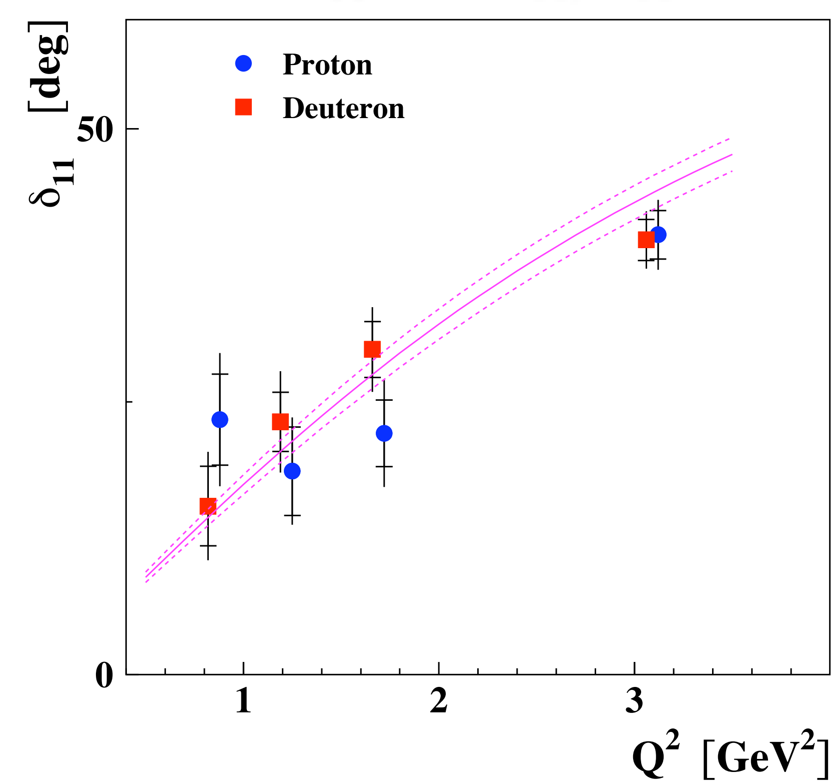
interference $\gamma^*_L \rightarrow \rho^0_L$ & $\gamma^*_T \rightarrow \rho^0_T$

model dose not describe the data
model uses phase difference
between T_{00} and T_{11}, δ_{11}=3.1 deg.

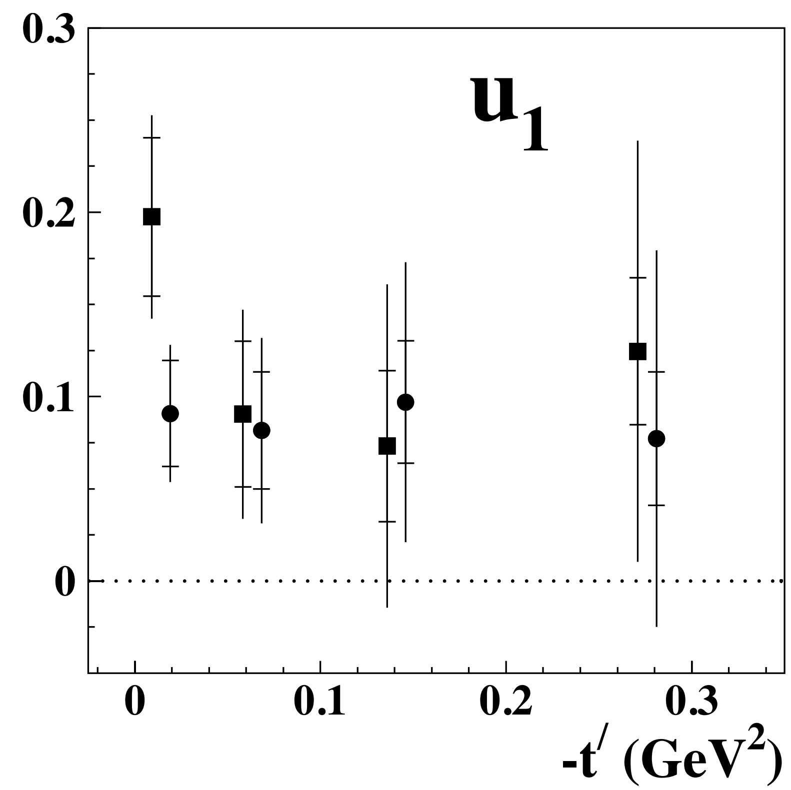
$$tan\,\delta_{11} = \frac{Im(T_{11}/T_{00})}{Re(T_{11}/T_{00})}$$

HERMES result δ_{11}=31.5 ± 1.4 deg.

Large phase difference was observed also by H1 (δ_{11}=20)



UPE Contribution ρ^0



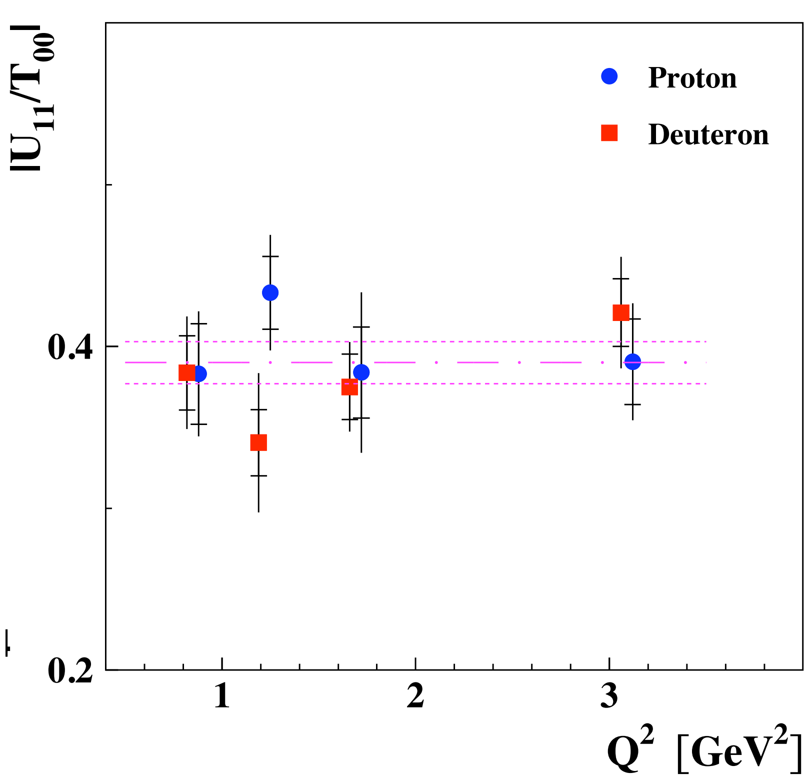
At large W^2 and Q^2 the transition should be suppressed by M/Q

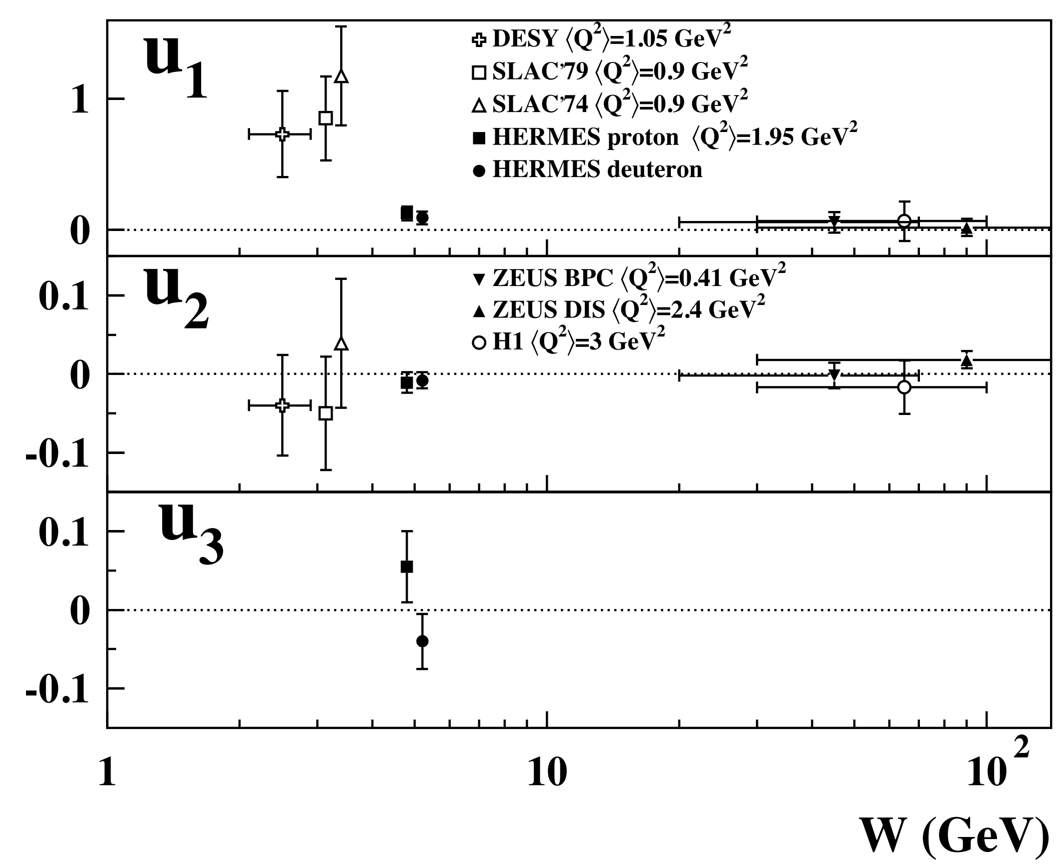
- direct helicity amplitude ratio analysis: U_{11}/T_{00}
- the combination of SDMEs is expected to be zero in case of NPE

$$u_1 = 1 - r^{04}_{00} + 2r^{04}_{1-1} - 2r^{1}_{11} - 2r^{1}_{1-1}$$

$$u_2 = r^{5}_{11} + r^{5}_{1-1}$$

$$u_3 = r^{8}_{11} + r^{8}_{1-1}$$

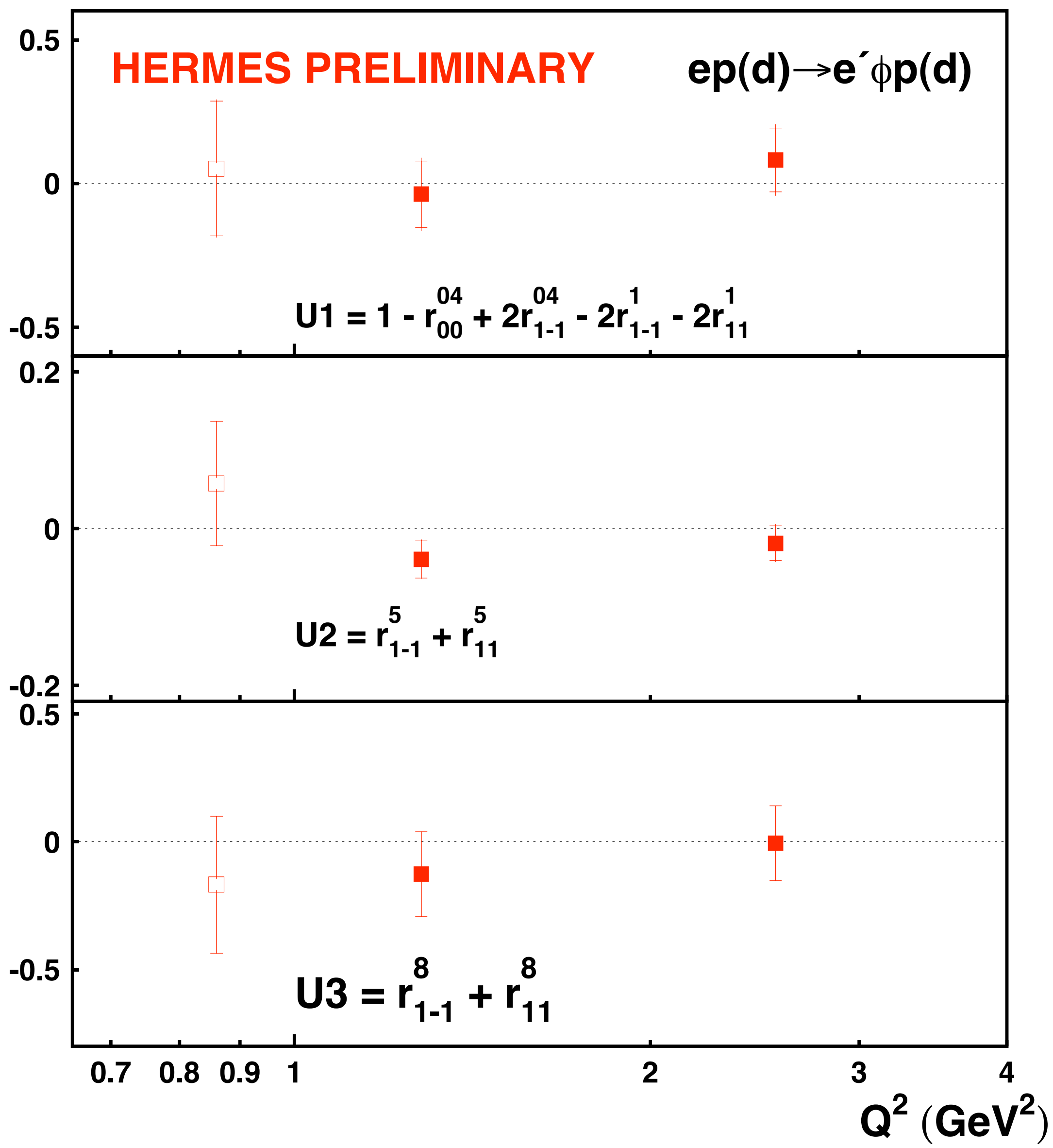


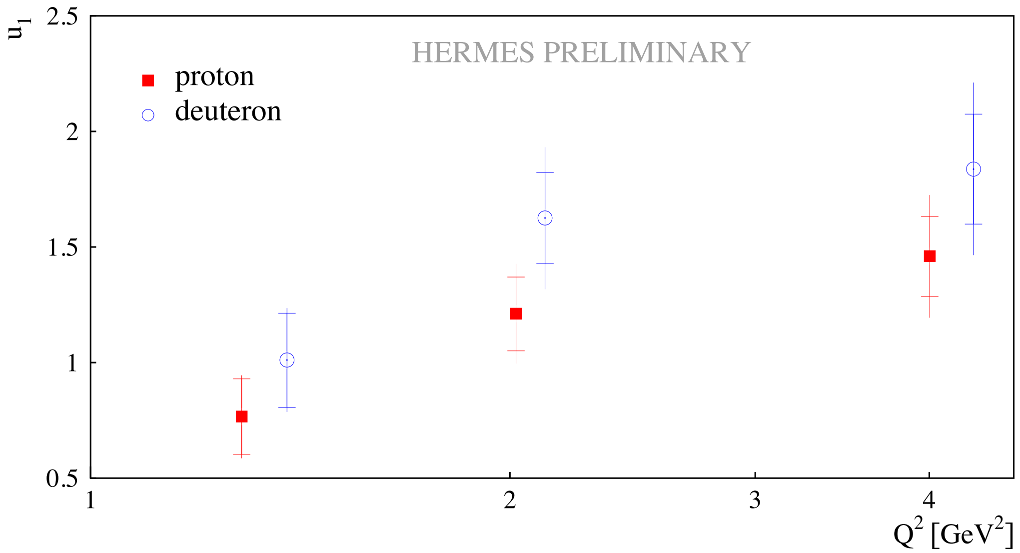


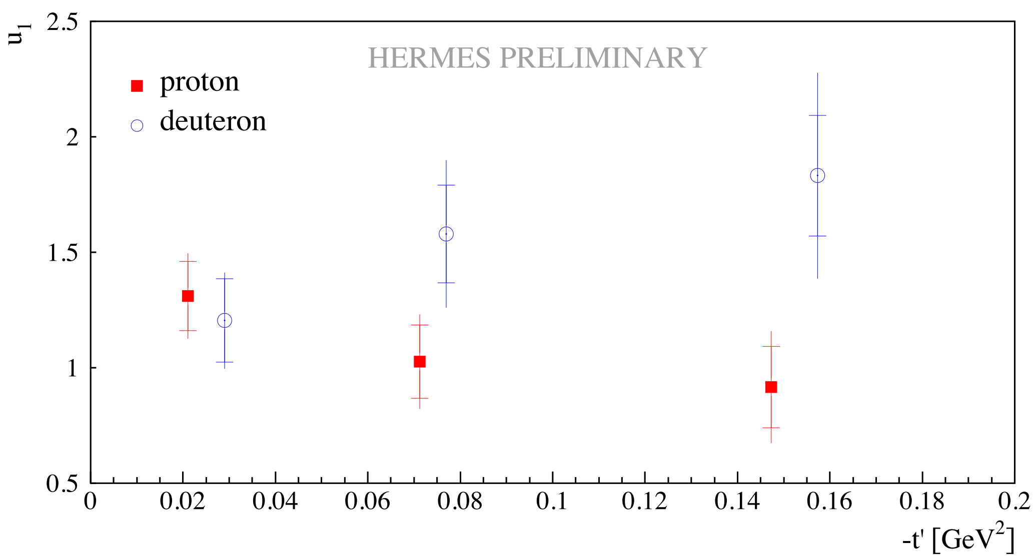
UPE Contribution Φ and ω

- u values are consistent with zero.
- Process dynamics is dominated by two-gluon exchange mechanism.

- Significantly large value for u_1
- Process dynamics is dominated by quark exchange mechanism.

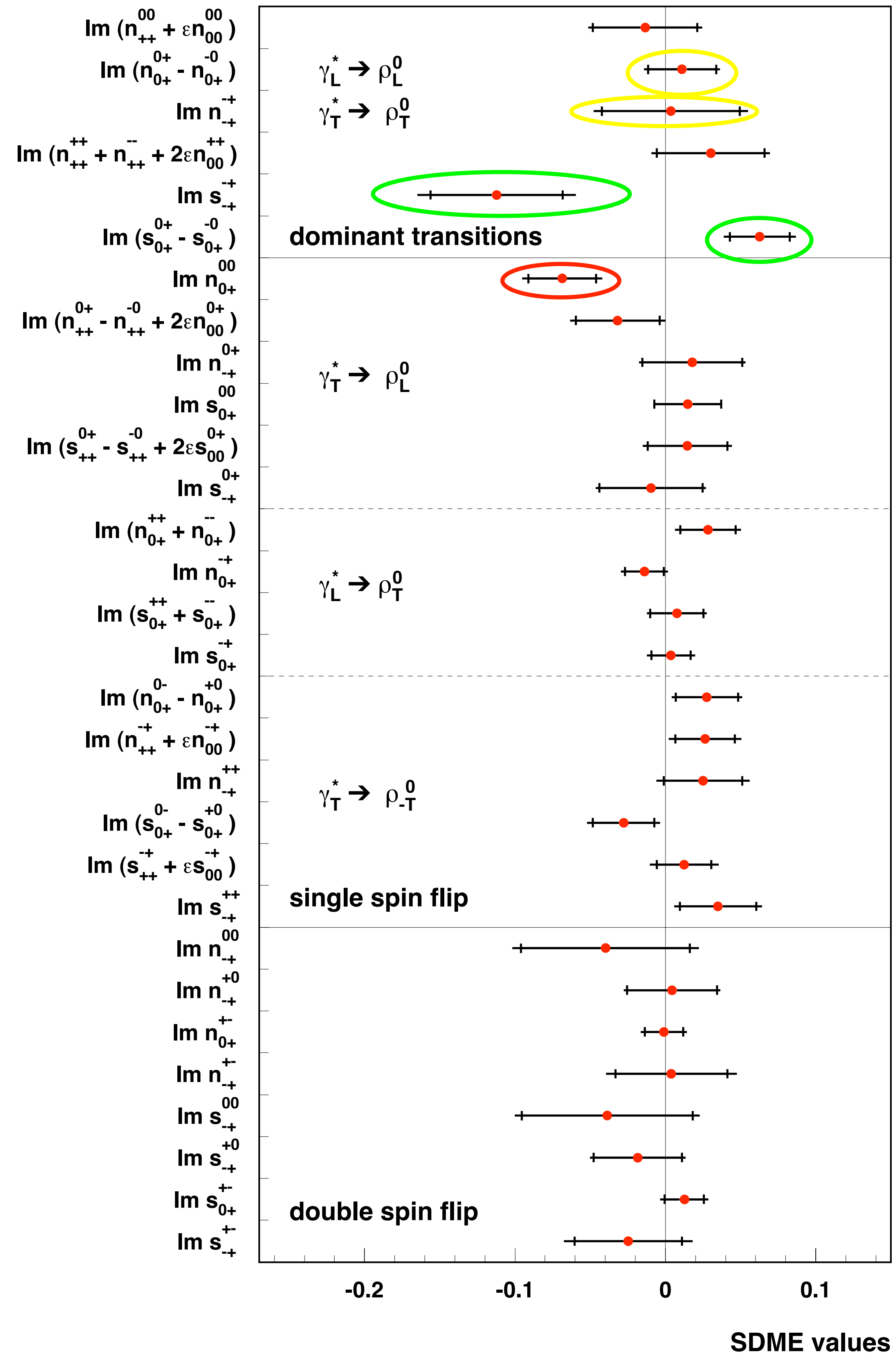






Transverse SDMEs of ρ^0

- Most of the SDMEs are consistent with zero within 1.5σ
- SDMEs $\mathbf{Im}\,(s^{0+}_{0+} - s^{-0}_{0+})$, $\mathbf{Im}\, s^{-+}_{-+}$ and $\mathbf{Im}\, n^{00}_{0+}$ differ form zero by 2.5σ
- Non - zero value for SDME $\mathbf{Im}\, n^{00}_{0+}$ - violation from SCHC
- In case of NPE - expected $s^{\nu\nu'}_{\mu\mu'} < n^{\nu\nu'}_{\mu\mu'}$
- Non - zero values for SDMEs $\mathbf{Im}\,(s^{0+}_{0+} - s^{-0}_{0+})$ and $\mathbf{Im}\, s^{-+}_{-+}$ indicate a large contribution of UPE



Transverse SDMEs of ρ^0

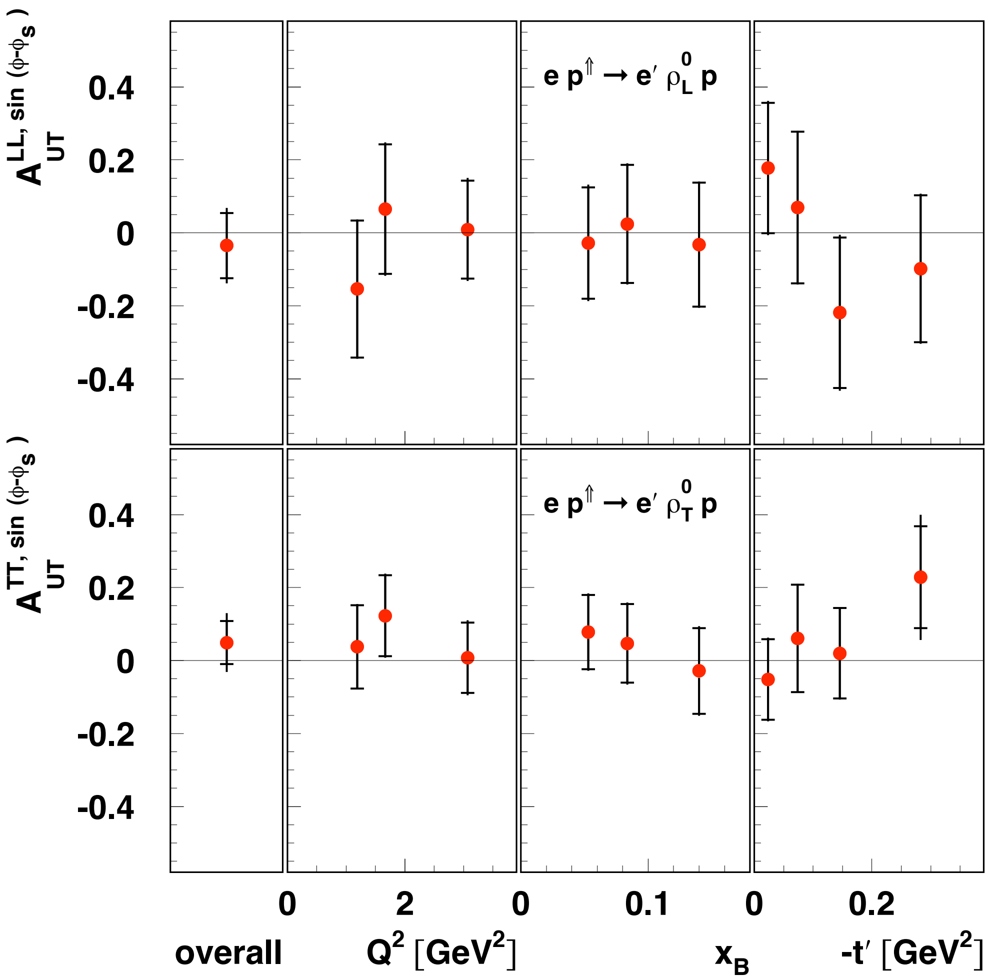
Transverse Target-Spin Asymmetry : ~ GPD E

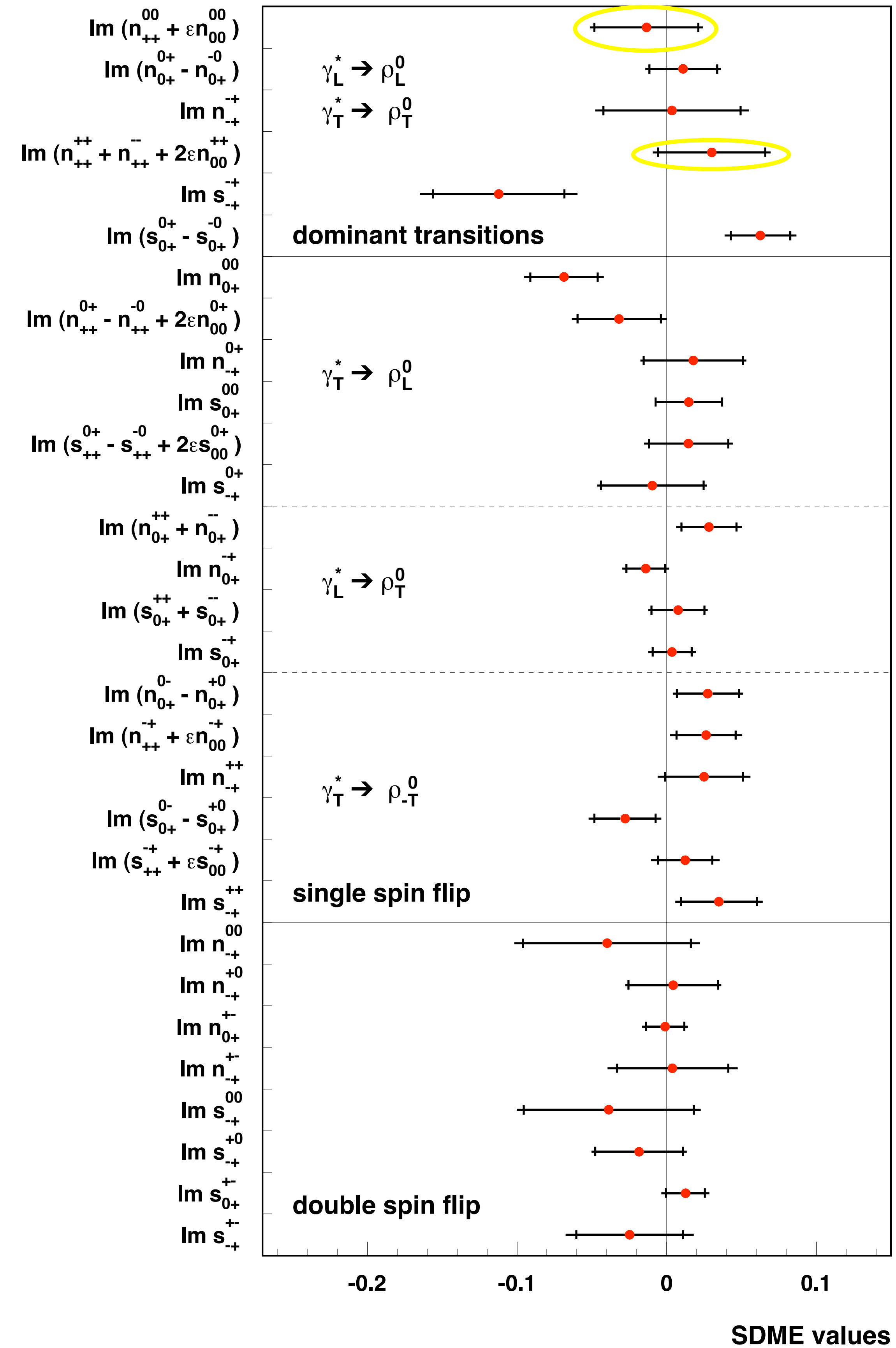
for L - L

$$A_{UT}^{LL,sin(\phi-\phi_s)} = \frac{\mathbf{Im}(n_{00}^{++} + \epsilon n_{00}^{00})}{u_{++}^{00} + \epsilon u_{00}^{00}}$$

and T - T

$$A_{UT}^{TT,sin(\phi-\phi_s)} = \frac{\mathbf{Im}(n_{++}^{++} + n_{++}^{--} + 2\epsilon n_{00}^{++})}{1 - (u_{++}^{00} + \epsilon u_{00}^{00})}$$





Results for R

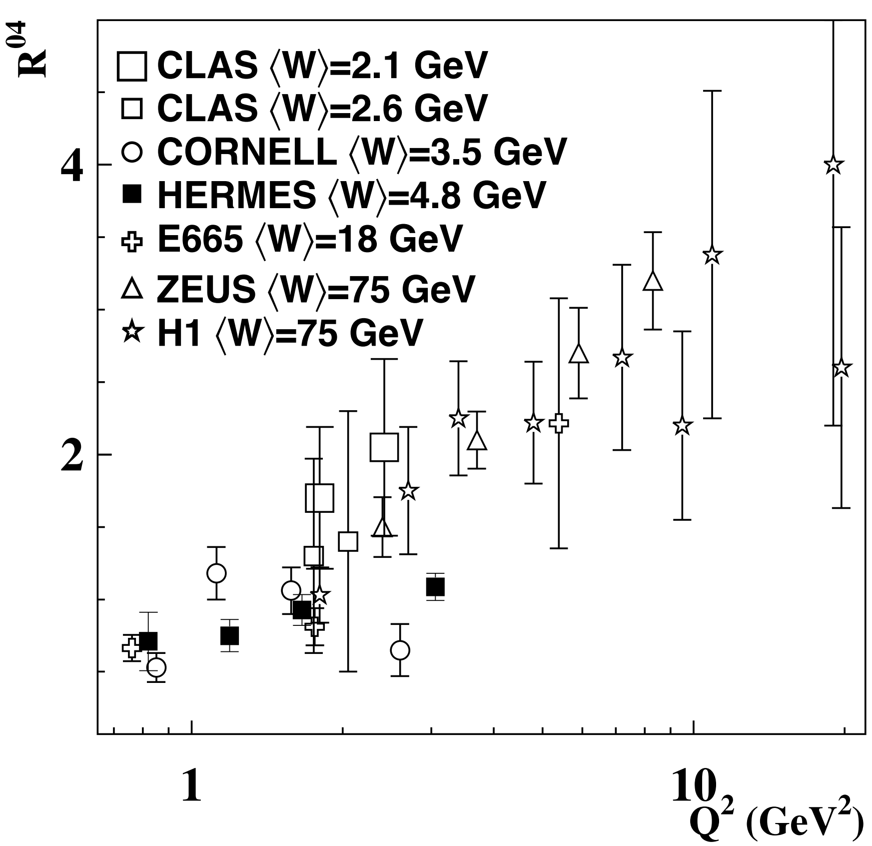
Commonly used observable $R^{04} = \frac{1}{\epsilon} \frac{r_{00}^{04}}{1 - r_{00}^{04}}$

In case of SCHC and NPE $R^{04} = R = \sigma_L / \sigma_T$

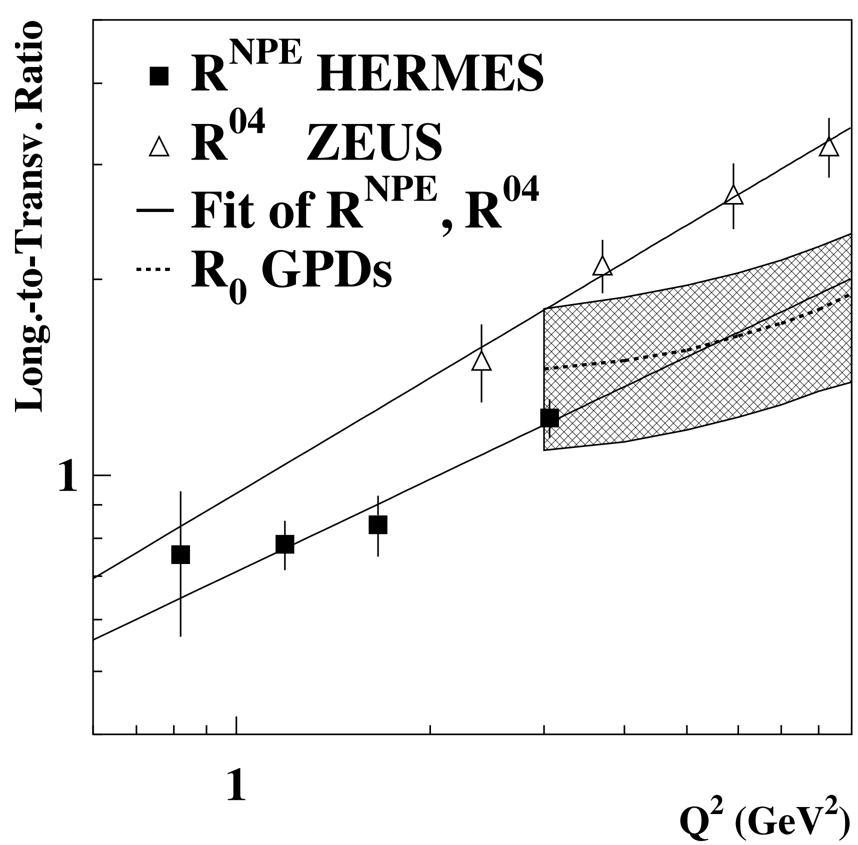
Strong W dependence for both - UPE contribution and ratio R

W dependence of the Q^2 slope can be studied $R(Q^2) = c_0 (\frac{Q^2}{M_V^2})^{c_1}$

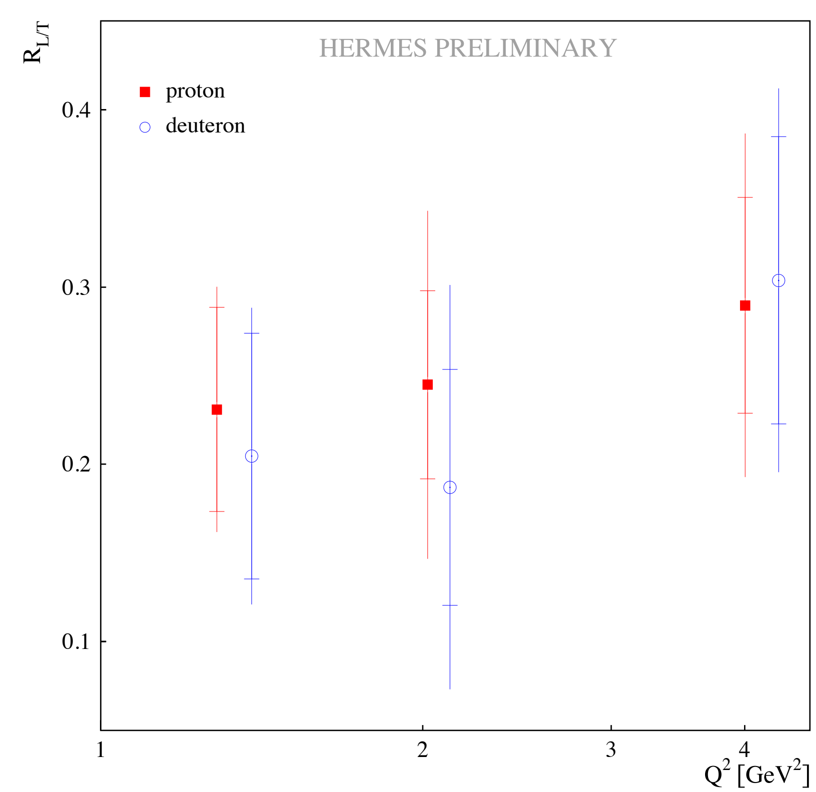
ρ^0



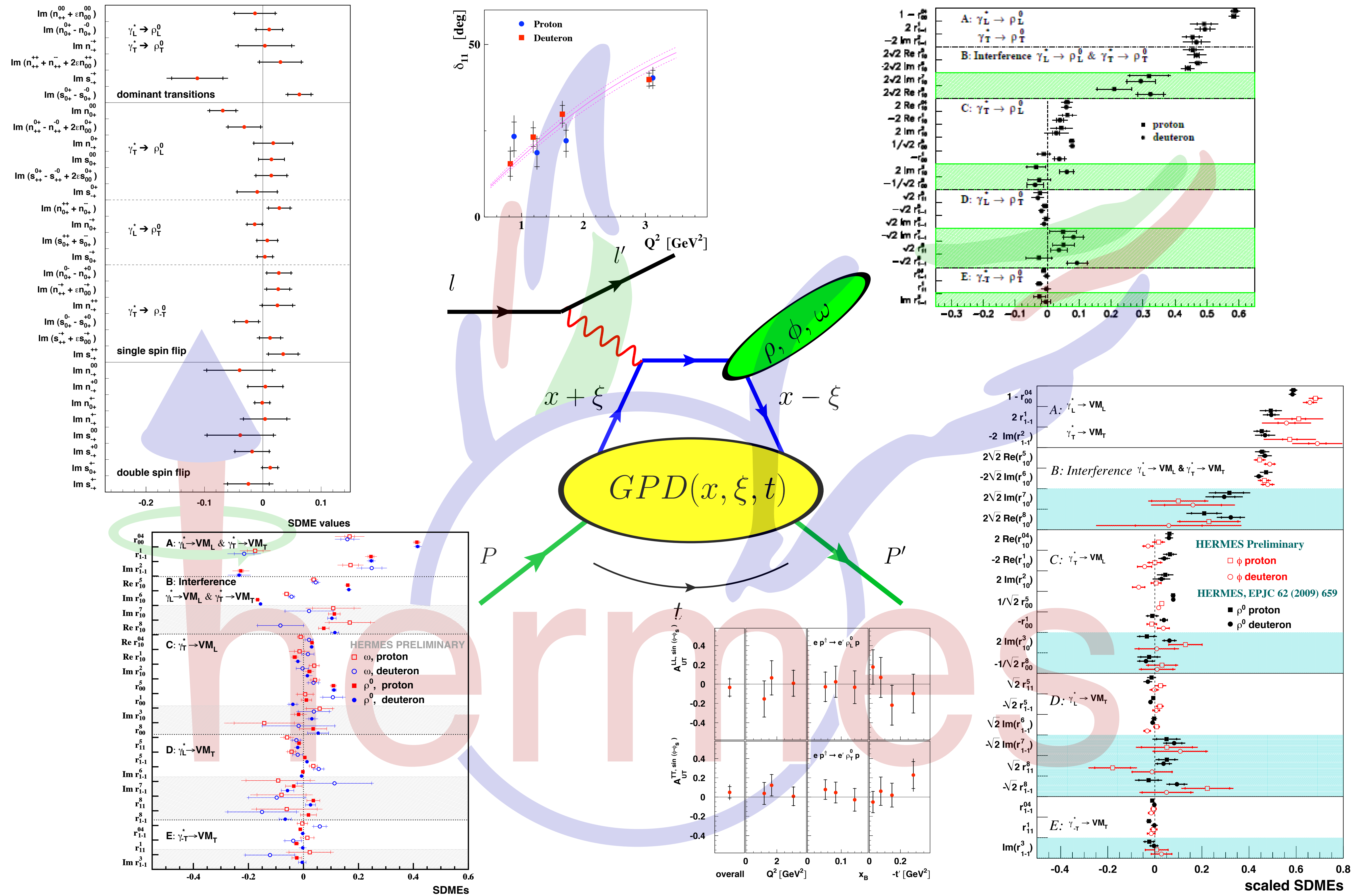
ρ^0



ω



Conclusion



dominant transitions
single spin flip
double spin flip
SDME values
δ_{11} [deg]
Proton
Deuteron
Q^2 [GeV^2]
A: $\gamma^*_L \to \rho^0_L$ & $\gamma^*_T \to \rho^0_T$
B: Interference $\gamma^*_L \to \rho^0_L$ & $\gamma^*_T \to \rho^0_T$
C: $\gamma^*_T \to \rho^0_L$
D: $\gamma^*_L \to \rho^0_T$
E: $\gamma^*_T \to \rho^0_T$
proton
deuteron
l
l'
ρ, ϕ, ω
$x + \xi$
$x - \xi$
$GPD(x, \xi, t)$
P
P'
t
HERMES PRELIMINARY
ω, proton
ω, deuteron
ρ^0, proton
ρ^0, deuteron
SDMEs
overall
Q^2 [GeV^2]
x_B
-t' [GeV^2]
HERMES Preliminary
φ proton
φ deuteron
HERMES, EPJC 62 (2009) 659
ρ^0 proton
ρ^0 deuteron
scaled SDMEs