

Small angle GDH E97-110

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January 30th 2019

Outline

- Experiment E97110 at Jefferson Lab:
 - Physics motivation
 - Setup
 - Analysis status:
 - Preliminary results on He^3 and Neutron
 - Summary

Gerasimov-Drell-Hearn (GDH) sum rule ($Q^2=0$, real photons)

$$I_{GDH} = \int_{\nu_{thr}}^{\infty} (\sigma^{1/2} - \sigma^{3/2}) \frac{d\nu}{\nu} \stackrel{\text{Theory prediction}}{=} \frac{-2\alpha\pi^2\kappa^2}{M^2}$$

Experimentally measured
Static property of target

$\sigma^{1/2}, \sigma^{3/2}$: photon absorption cross sections, with photon helicity anti-parallel or parallel to target spin.

κ : anomalous magnetic moment

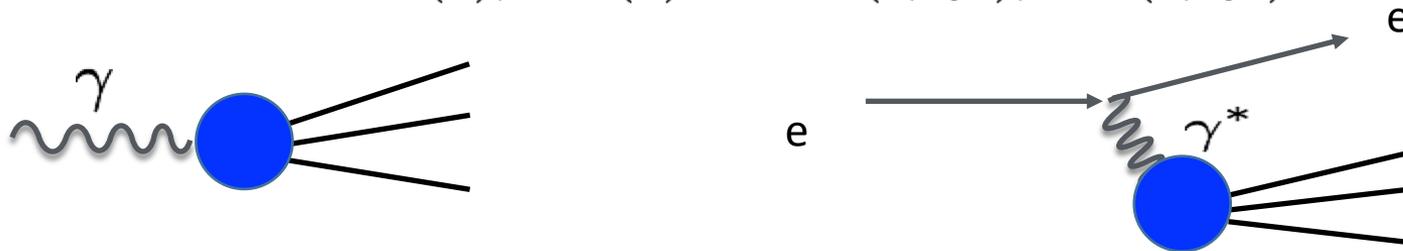
M : target's mass

Target	M (GeV)	κ	I_{GDH} (μb)
Proton	0.938	1.79	-204.8
Neutron	0.940	-1.91	-233.2
^3He	2.809	-8.38	-498.0

Generalized GDH sum rule (virtual photon, $Q^2 > 0$)

- From real to virtual photon: change photon production cross section with electro-production cross section

$$\sigma^{1/2}(\nu), \sigma^{3/2}(\nu) \rightarrow \sigma^{1/2}(\nu, Q^2), \sigma^{3/2}(\nu, Q^2)$$



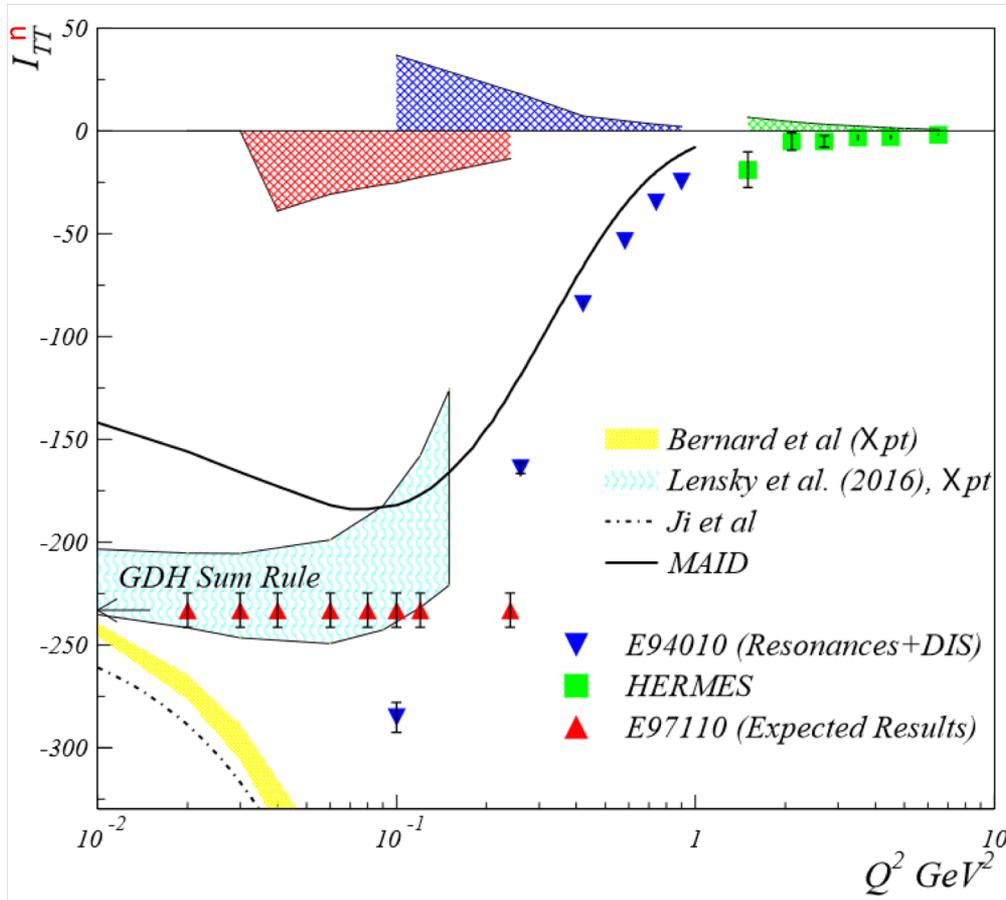
- Or rewrite it in term of Compton scattering amplitudes (by Ji and Osborne): $S_1(Q^2), S_2(Q^2)$ which are calculable in principle at all Q^2 .

$$\frac{16\alpha\pi^2}{Q^2} \int_0^1 g_1 dx = 2\alpha\pi^2 S_1$$

Chiral Perturbation Theory

Operator Production Expansion

Current data for GDH in low Q^2 region



Experiments:

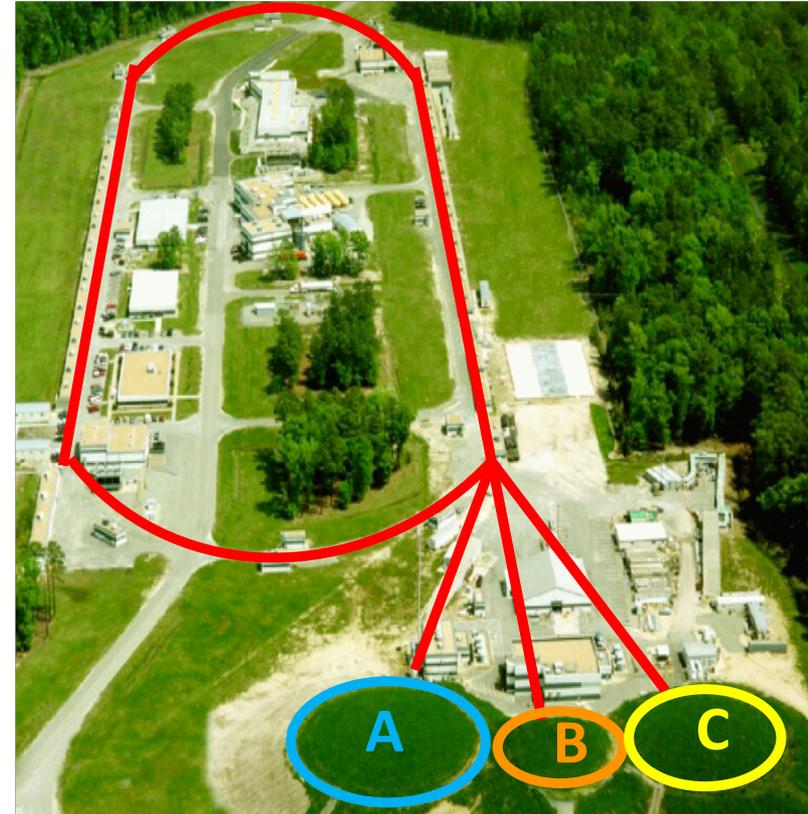
- E94010 Hall A.
- E97110 Hall A.

Show a smooth transition from partonic to hadronic regions.

We expect a sharp change in slope at $Q^2 < 0.1 \text{ GeV}^2$ → need turn over to validate GDH for real photon

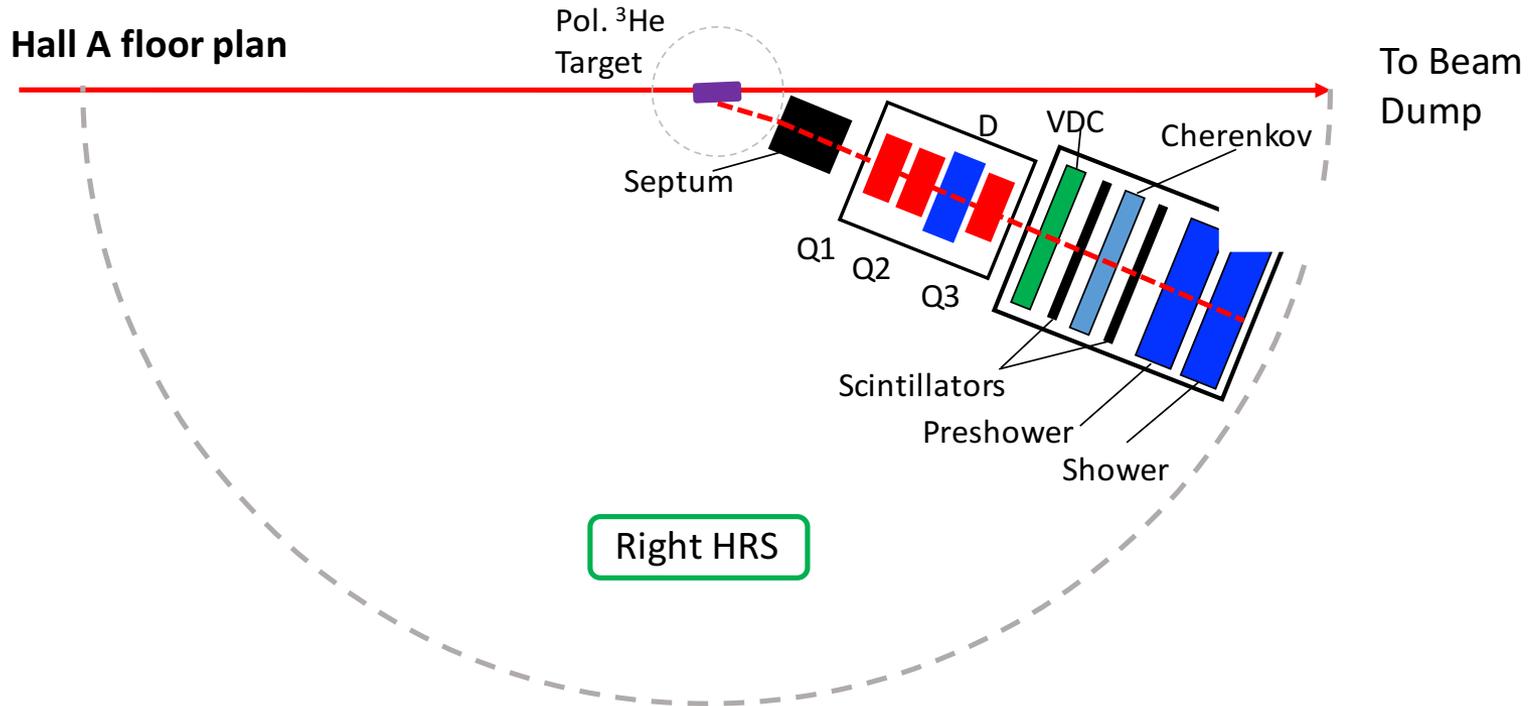
Hall A Experiment E97110

- Precise measurement of generalized GDH integral at $0.02 < Q^2 < 0.3 \text{ GeV}^2$.
- Inclusive experiment: ${}^3\text{He}(\vec{e}, \vec{e}')X$
- Measured polarized **cross section differences**.
- Continuous beam with $P_e \sim 85\%$. Two angles (6° and 9°).
- Polarized ${}^3\text{He}$: $P_t \sim 40\%$.



Spokespersons: J.P Chen, A. Deur, F. Garibaldi.
Students: J. Singh, V. Sulkosky, J. Yuan, C. Peng, N. Ton

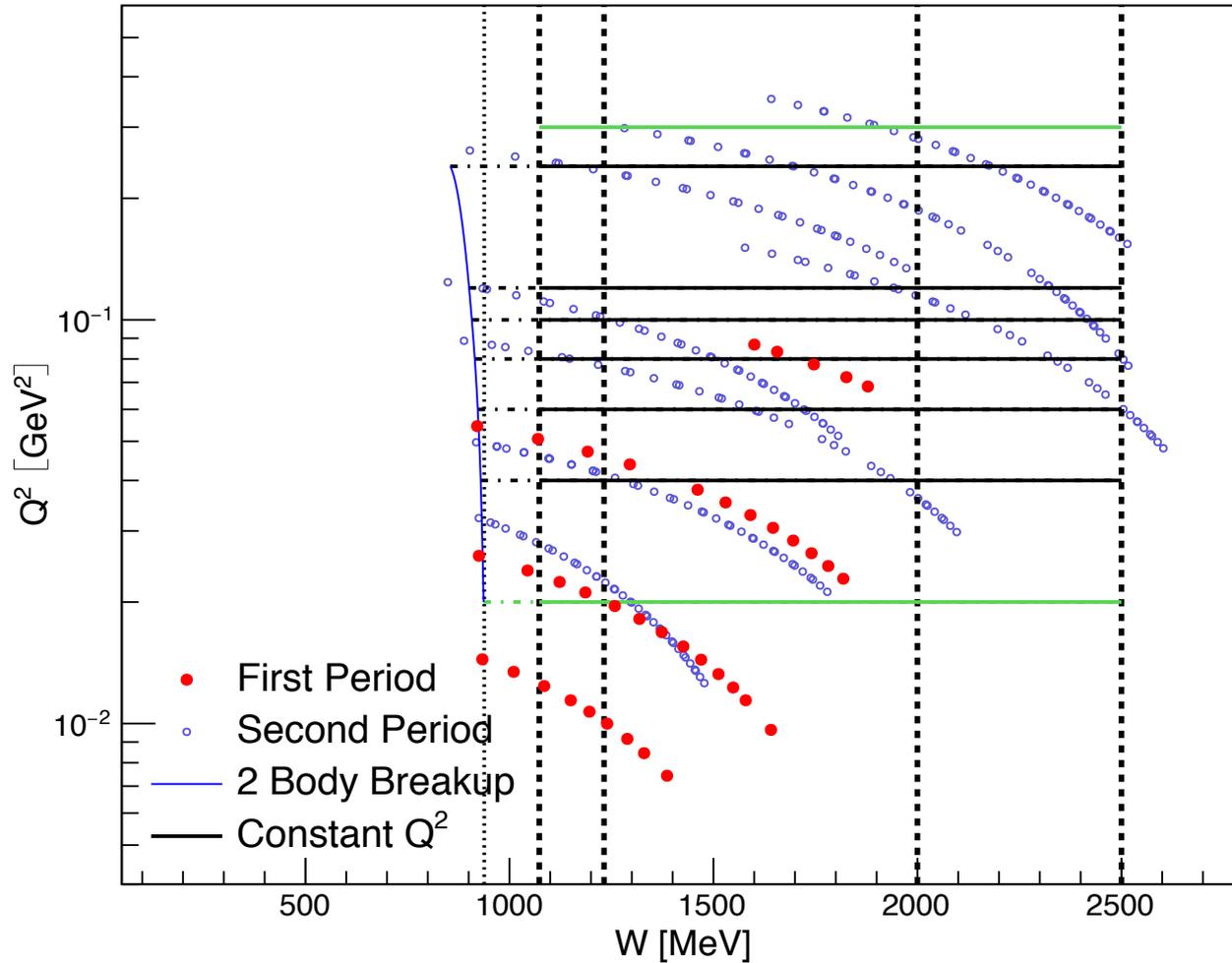
Experiment setup



$$0.02 < Q^2 < 0.3 \text{ GeV}^2$$

- **1st period:** mis-wired septum (lowest Q^2 data)
- **2nd period:** good septum

Kinematic plot for experiment



Preliminary Results

1. g_1 , g_2 on ^3He

2. Neutron:

- First moment (Γ_1), Generalized GDH
- Spin polarizabilities (γ_0 , δ_{LT})

3. ^3He :

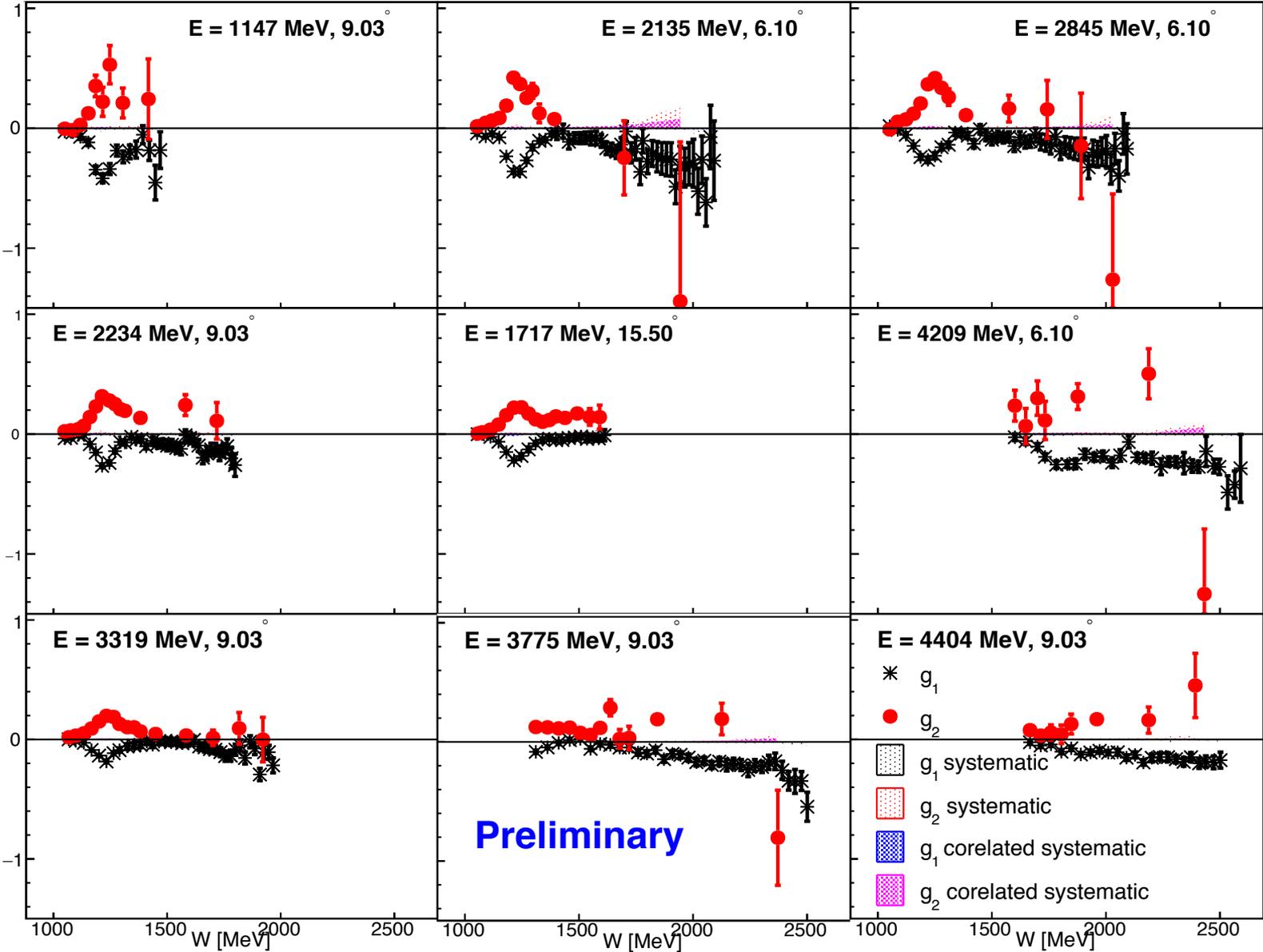
- Generalized GDH
- Spin polarizability (γ_0)

4. First period asymmetry and cross section difference results

Structure functions

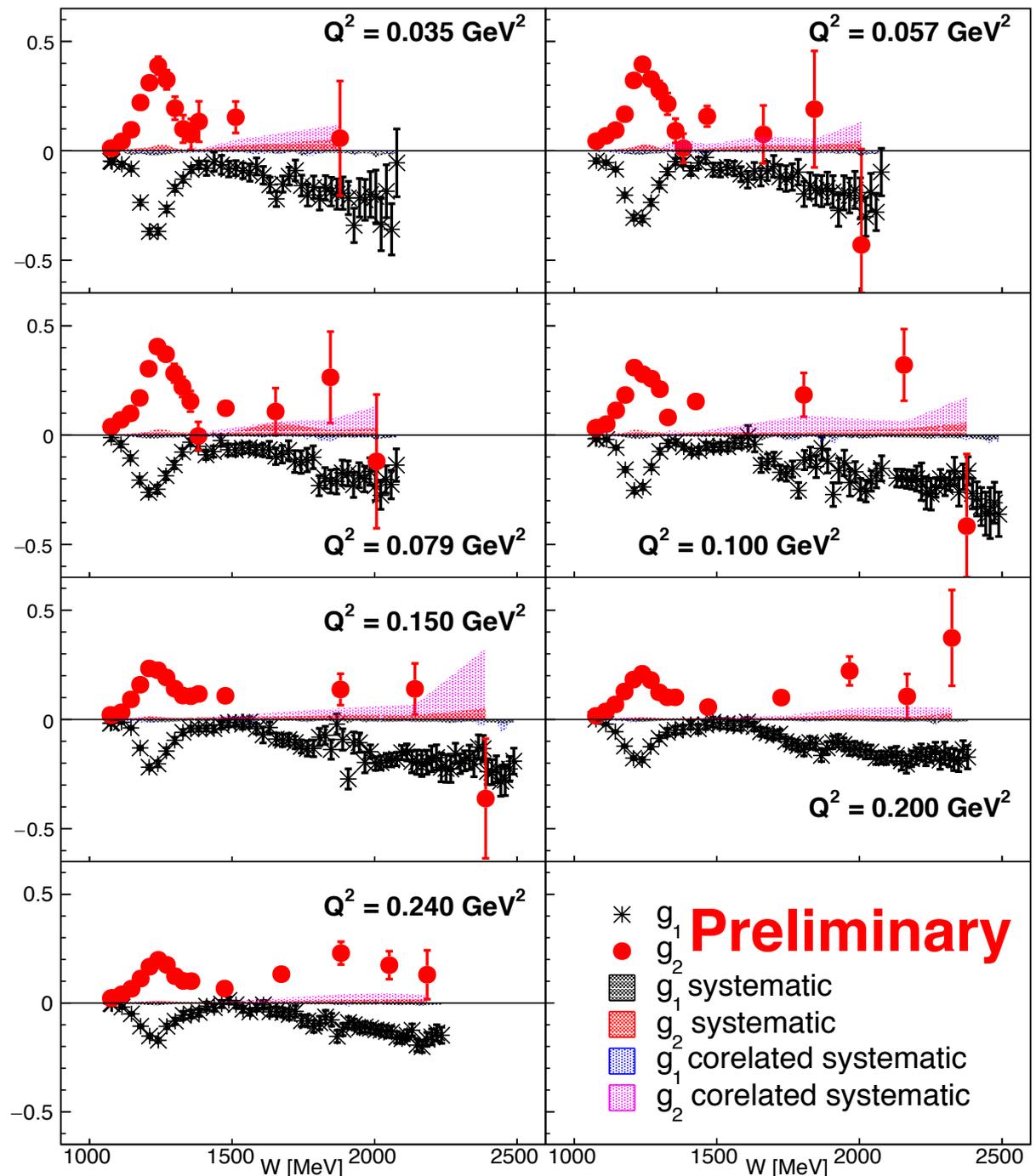
Plots from V. Sulkosky

Constant energy



➤ Structure functions at constant Q^2

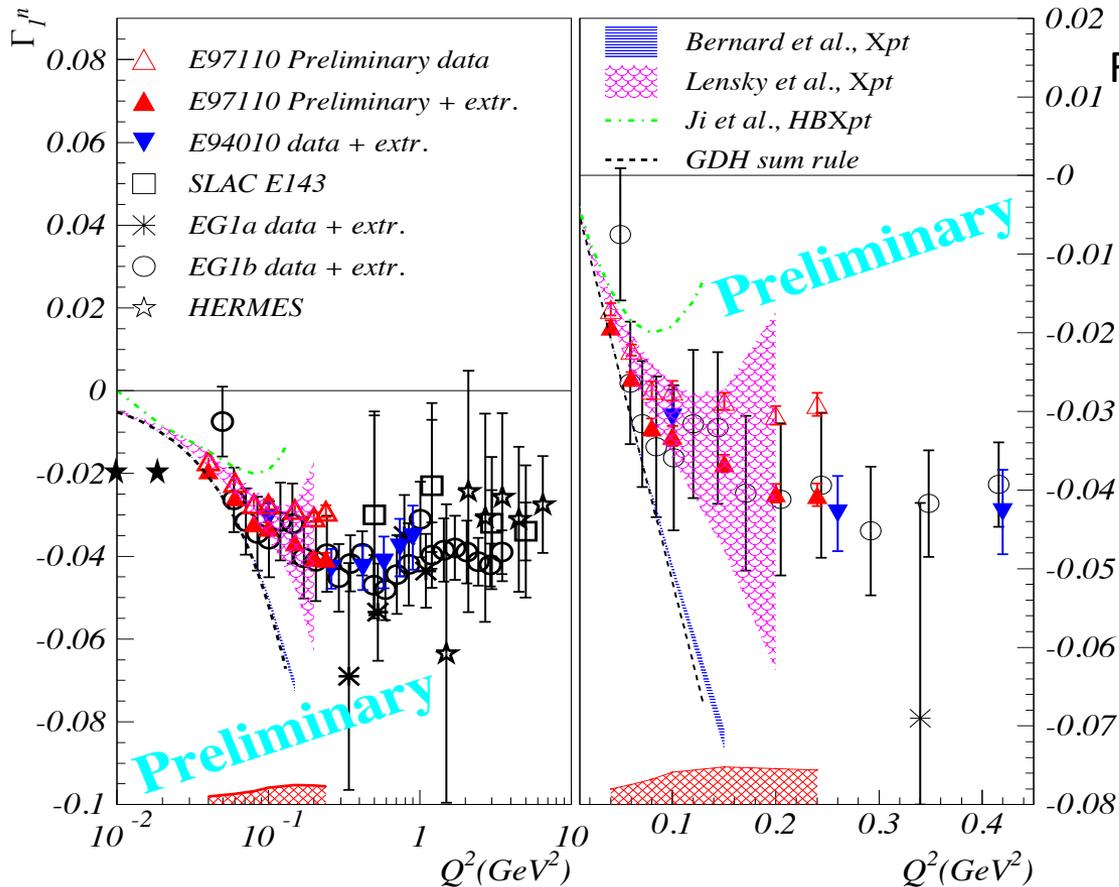
- Correlated uncertainty: correlated radiative correction uncertainty + interpolation uncertainty
- Uncorrelated: everything else



Plots from V. Sulkosky

Neutron Results

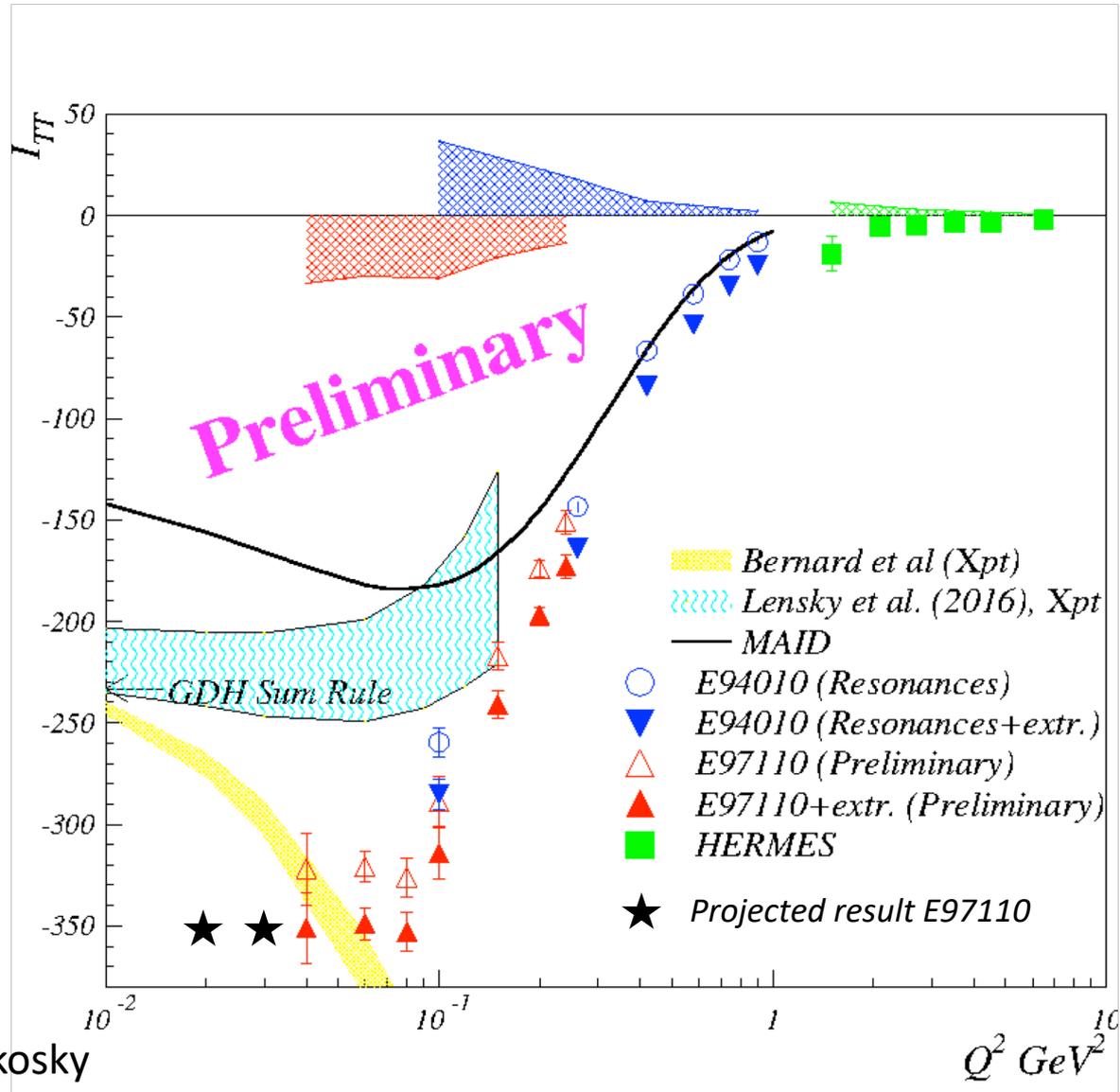
Plots from V. Sulkosky



First moment of $\Gamma_1 = \int_0^{x_0} g_1(x, Q^2) dx$

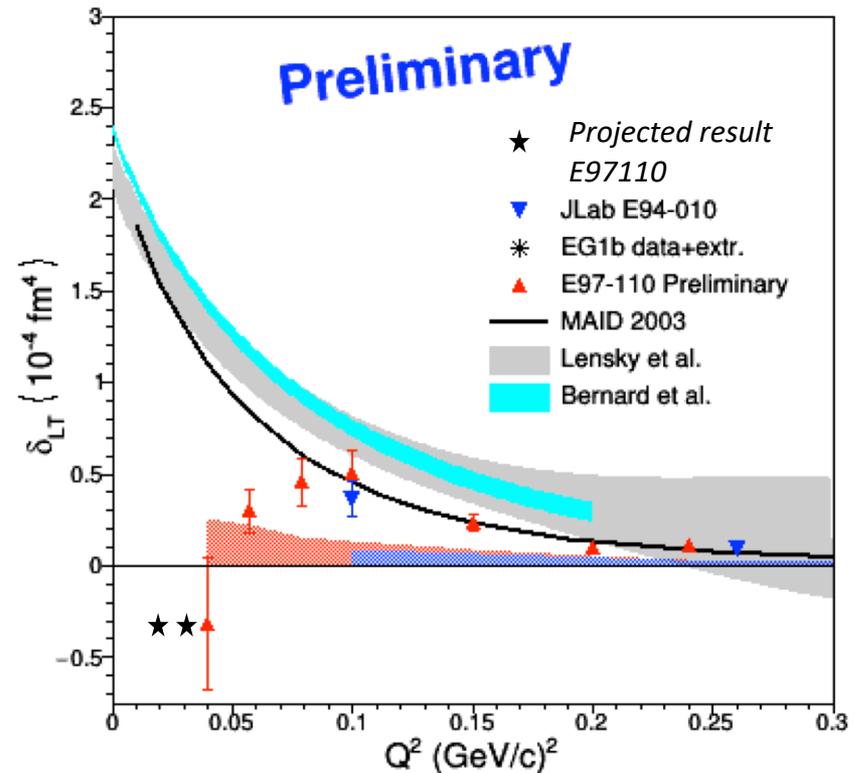
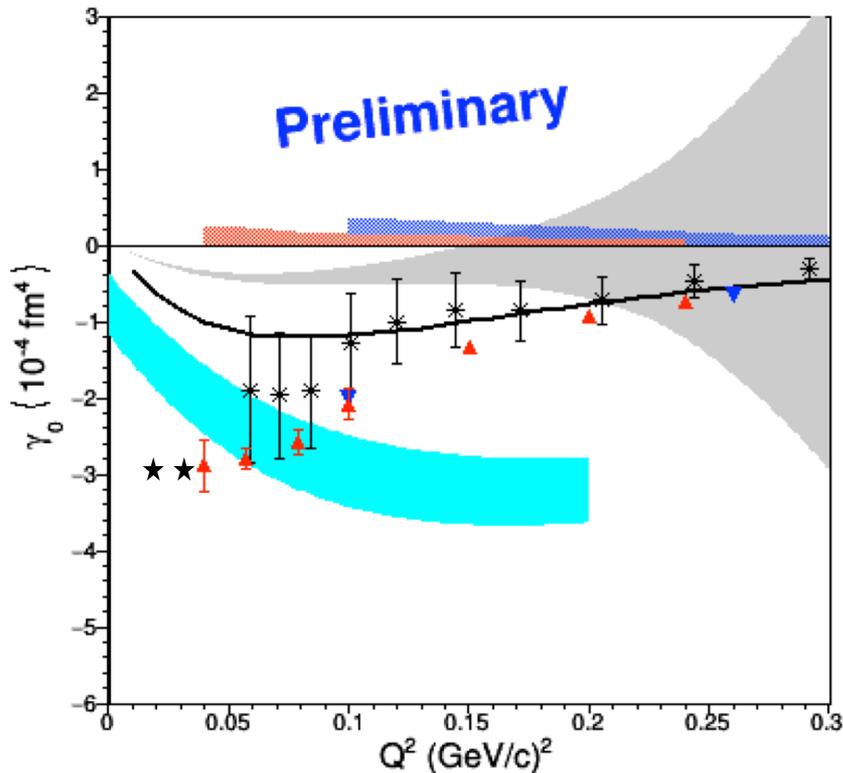
- Additional data available (**black data points**): analyze the lowest Q^2 points (first period) (on-going)

Generalized GDH on Neutron



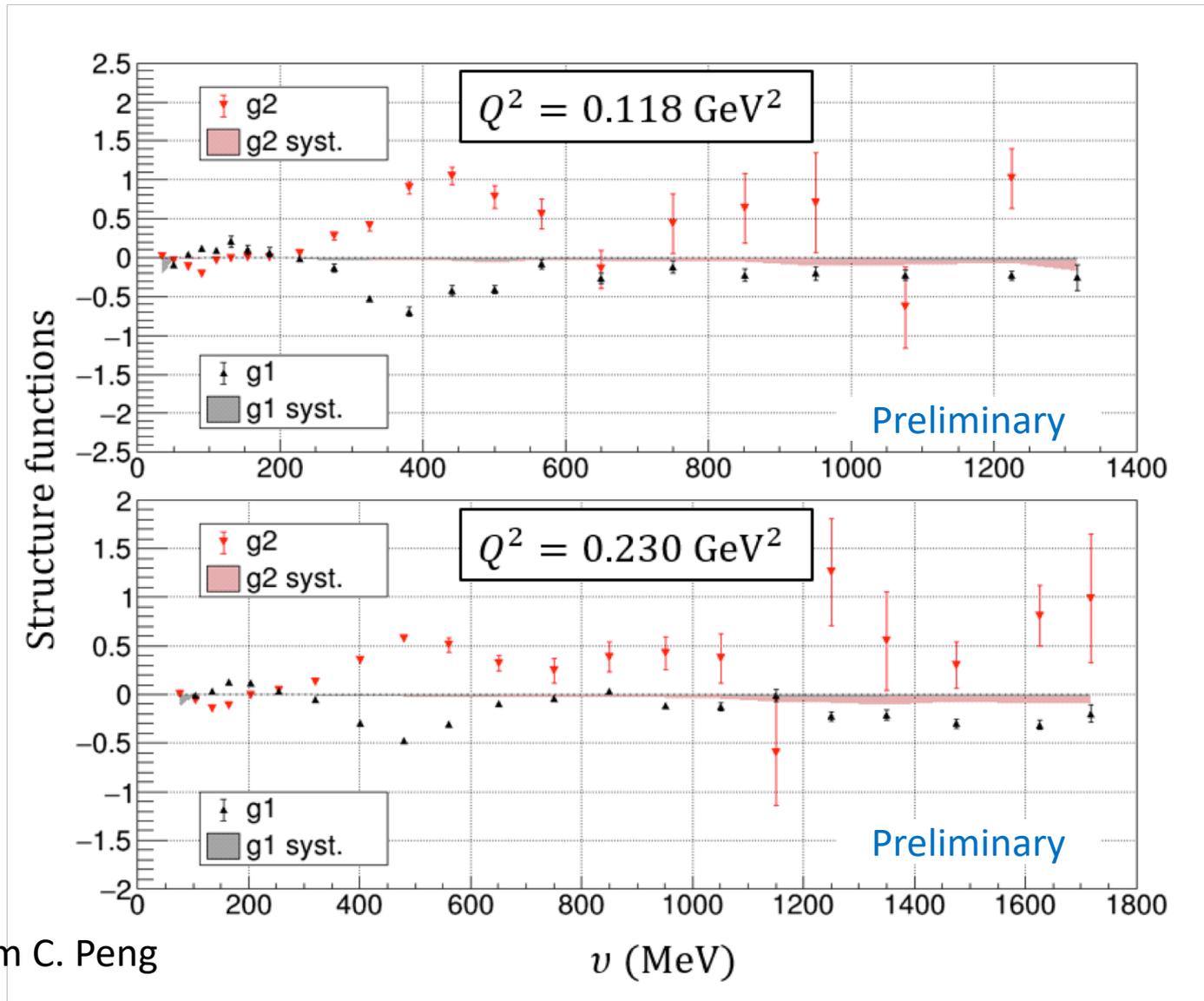
Preliminary result of Spin Polarizability from E97-110

Plots from V. Sulkosky



New data from E97-110 show a disagreement between experimental data and χ PT theoretical predictions

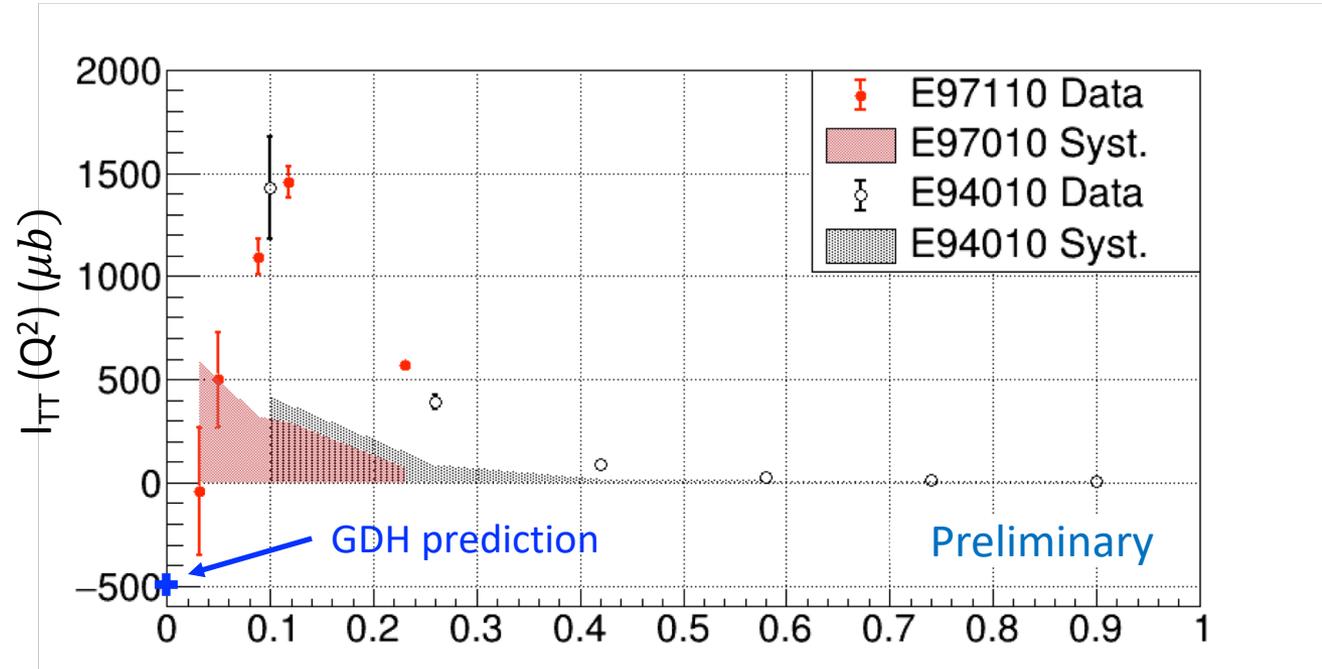
Structure functions g_1 , g_2 for ${}^3\text{He}$ (Quasi-elastic)



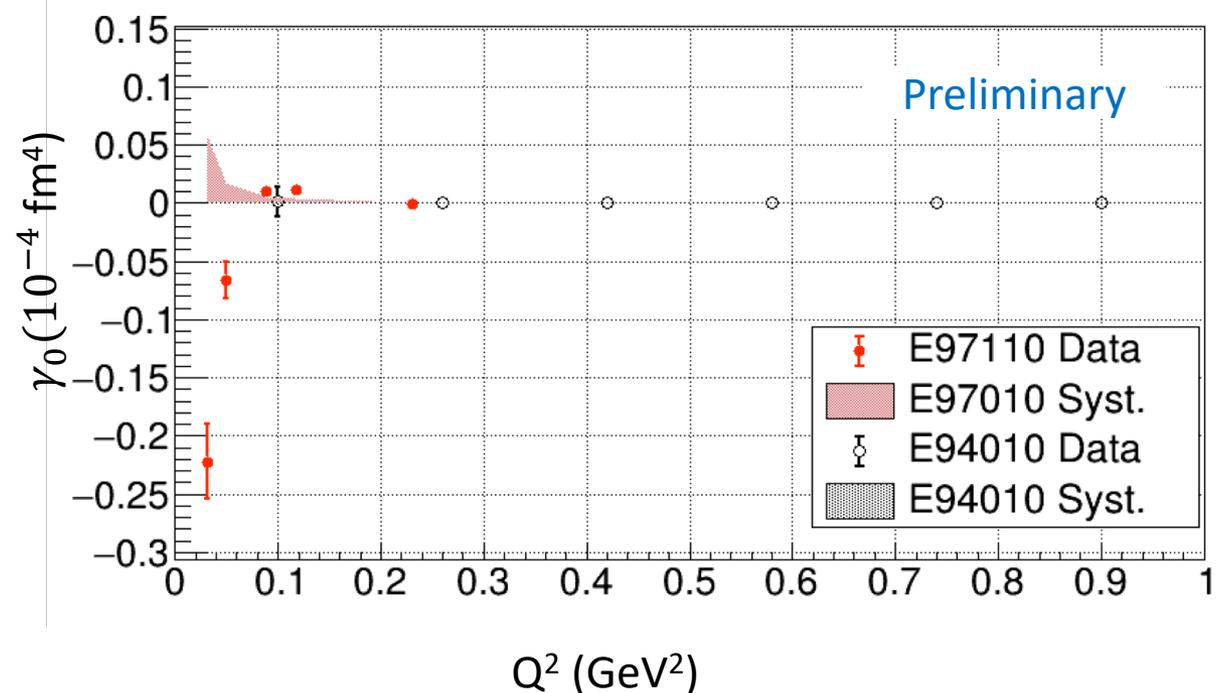
Plots from C. Peng

Generalized GDH integral

GDH sum rule for ^3He :
 $I_{\text{TT}}(Q^2 = 0) = -498 (\mu\text{b})$



Spin Polarizability γ_0

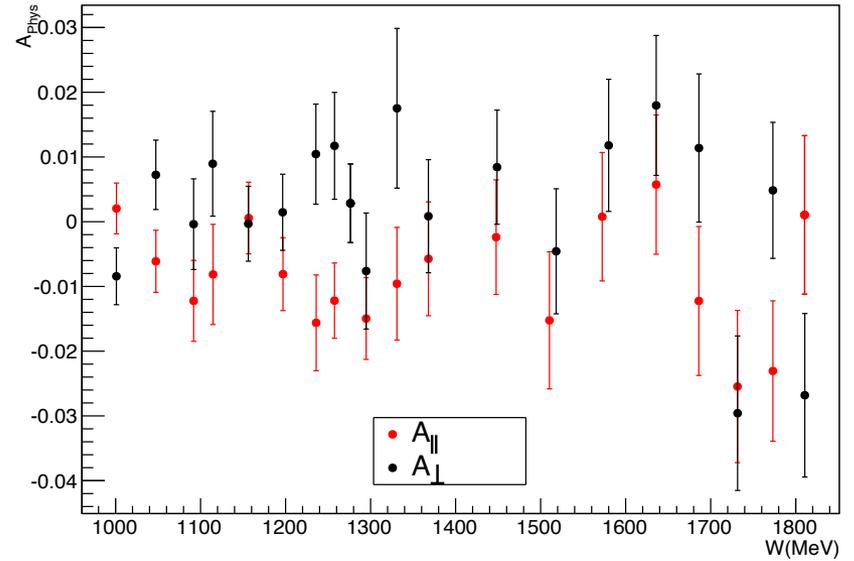
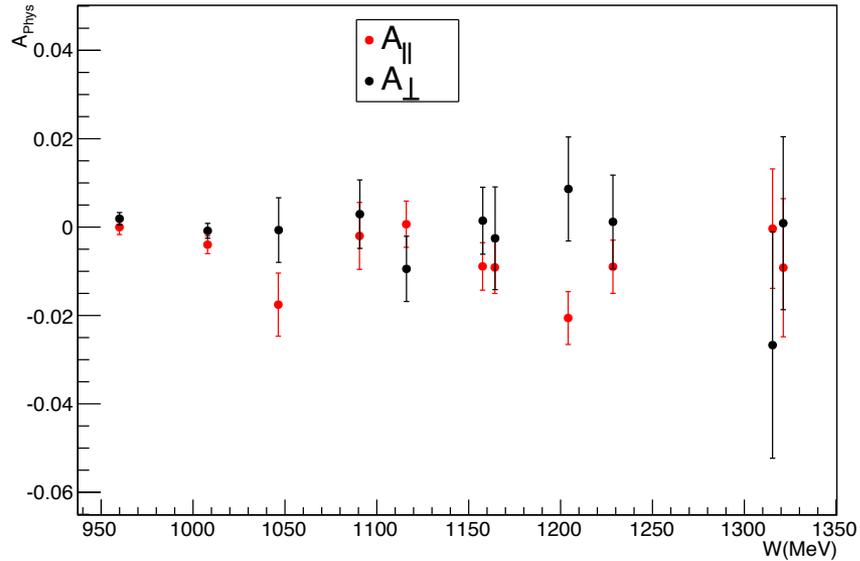


First period asymmetry and cross section difference

$A_{\perp\parallel}$ 1.1 GeV at 6 deg

Asymmetry

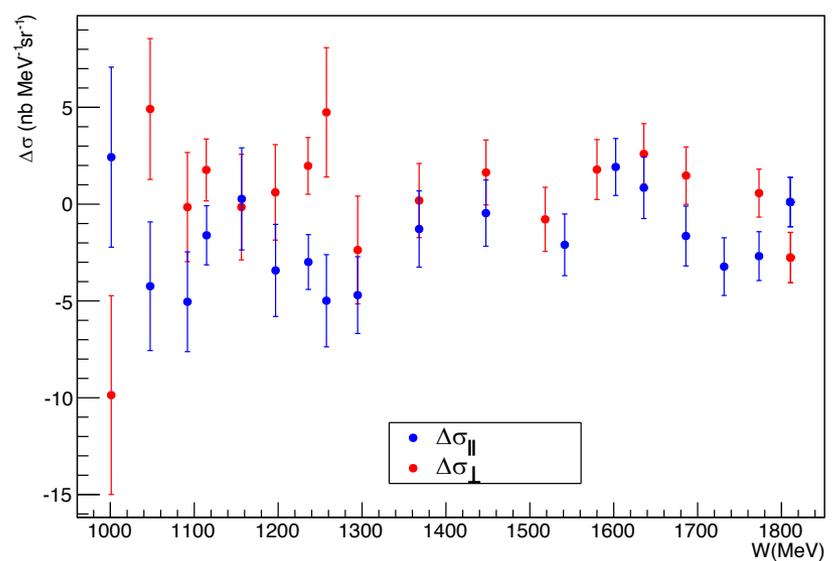
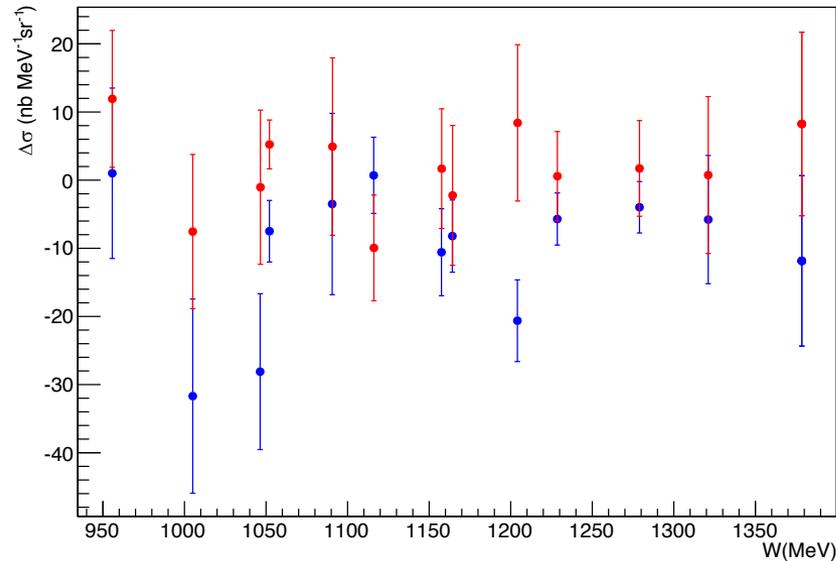
$A_{\perp\parallel}$ 2 GeV at 6 deg



$\Delta\sigma$ 1.1 GeV at 6 deg

Cross section difference

2 GeV at 6 deg



Summary

- First period analysis:
 - Extracting cross section difference for other beam energies.
 - Preliminary results on moment in 2019.
- Second period analysis.
 - Neutron results: finalizing systematics
 - He³ results: finalizing systematics
 - Neutron and He³ data soon to be published (weeks).