HELIUM-3 RESULTS FROM SAGDH EXPERIMENT

Chao Peng (Argonne National Laboratory)

For the Hall A and E97-110 Collaborations

HALL A COLLABORATION MEETING, JANUARY 30, 2020

OUTLINE

- Introduction
- Experiment E97-110
- Experiment Results

3 GDH SUM RULE

- Gerasimov-Drell-Hearn (GDH) Sum Rule

$$I^{GDH} = \int_{\nu_{th}}^{\infty} \frac{d\nu}{\nu} \left(\sigma_P(\nu) - \sigma_A(\nu)\right) = 4\pi^2 \alpha \frac{\kappa^2}{M^2} S,$$

- Spin S and anomalous magnetic moment κ
- Relate the helicity-dependent photoabsorption cross sections to static properties
- Derived from general principles

4 GDH MEASUREMENTS

- Proton, verified: Mainz, Bonn, LEGS (up to $\nu \sim 3$ GeV)
- Neutron, in progress: Mainz, Bonn, LEGS, HIGS
- Measurements on Deuteron and ^{3}He

	M[GeV]	Spin	κ	$I_{\mathrm{GDH}}[\mu$ b]
Proton	0.938	$\frac{1}{2}$	1.79	–204.8
Neutron	0.940	$\frac{1}{2}$	-1.91	–233.2
Deuteron	1.876	1	-0.14	–0.65
Helium-3	2.809	$\frac{1}{2}$	-8.38	–498.0

5 GENERALIZED GDH SUM RULES

- Generalized for virtual photon via unsubtracted dispersion relation

$$I_{TT}(Q^2) = \frac{M^2}{4\pi^2\alpha}\int_{\nu_{th}}^{\infty}\frac{K(\nu,Q^2)\sigma_{TT}(\nu,Q^2)}{\nu^2}d\nu$$

$$= \frac{2M^2}{Q^2}\int_0^{x_{th}}\left[g_1(x,Q^2) - \frac{4M^2}{Q^2}x^2 g_2(x,Q^2)\right]dx.$$

$$I_1(Q^2) = \frac{2M^2}{Q^2}\int_0^{x_{th}} g_1(x,Q^2)dx$$

$$= \frac{M^2}{4\pi^2\alpha}\int_{\nu_{th}}^{\infty}\frac{K(\nu,Q^2)}{\nu^2+Q^2}\left[\sigma_{TT}(\nu,Q^2) + \frac{Q}{\nu}\sigma_{LT}(\nu,Q^2)\right]d\nu.$$

6 FIRST MOMENT OF g_1

- First Moment of g_1

$$\Gamma_1(Q^2) = \int_0^1 g_1(x, Q^2)dx$$

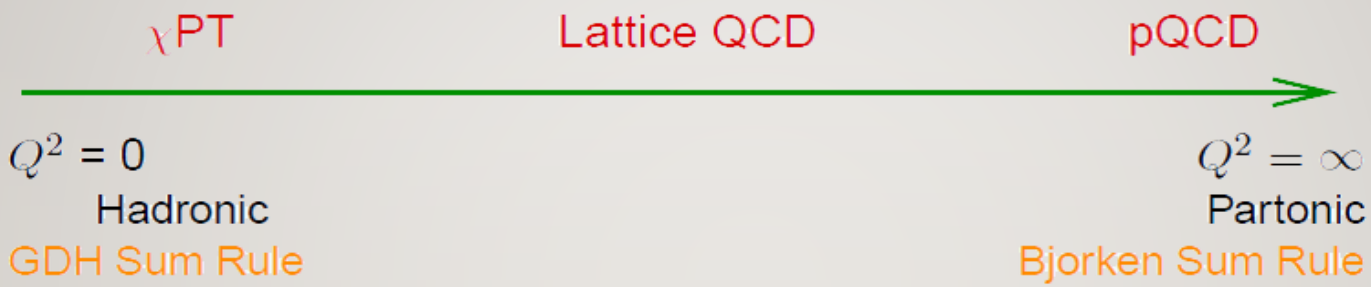
  - Connects to the total spin carried by the quarks in DIS region
  - $I_1(Q^2)$ + elastic contribution

- Bjorken Sum Rule

$$\Gamma_1^P(Q^2) - \Gamma_1^N(Q^2) = \frac{g_A}{6} + O\left(\alpha_s(Q^2)\right) + O\left(\frac{1}{Q^2}\right)$$

  - g_A, nucleon axial charge
  - Consistent with experimental result in 10%
  - Valid in DIS region

7 IMPORTANCE OF GENERALIZED GDH SUM RULES



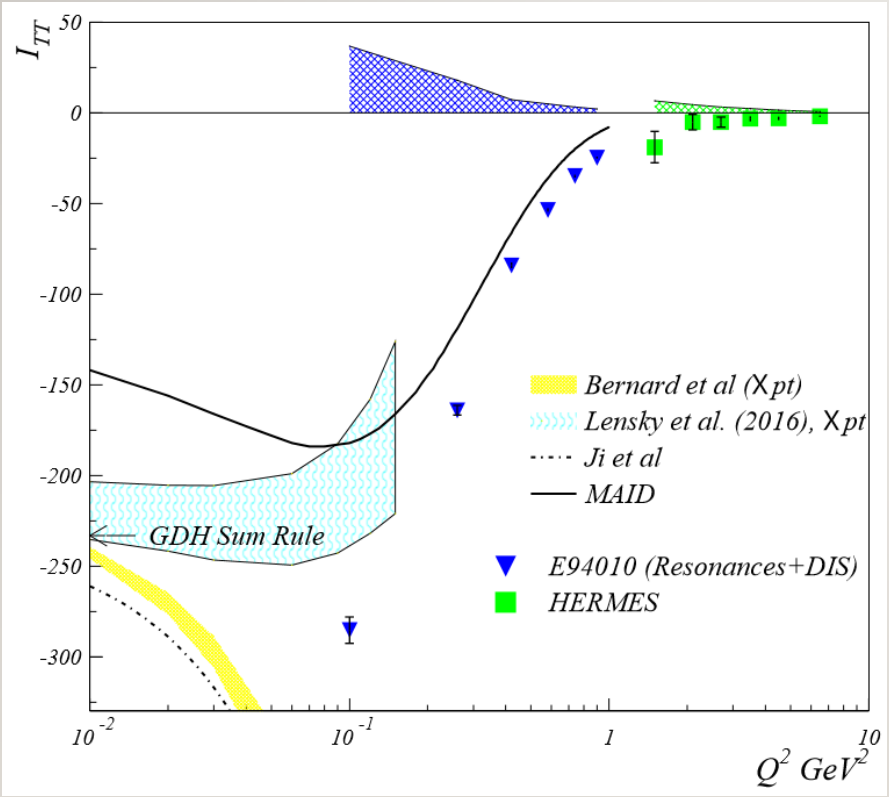
- Recover the GDH sum rule for real photons ($Q^2 = 0$)
- Connect with Bjorken sum rule ($Q^2 = \infty$)
- Relate the moments of the spin dependent structure functions to virtual Compton AMPLITUDE ($Q^2 > 0$), and test the theoretical calculations
  - Baryon Chiral Perturbation Theory (IRBChPT, RBChPT)
  - Lattice QCD
- Study the transition from non-perturbative to perturbative QCD

8 EXPERIMENTAL PROGRESS

Observable	H target	D target	^{3}He target
g_1, g_2, Γ_1 & Γ_2 at high Q^2	SLAC JLAB SANE	SLAC	SLAC JLAB E97-117 JLAB E01-012 JLAB E06-014
g_1 & Γ_1 at high Q^2	SMC HERMES JLAB EG1	SMC HERMES JLAB EG1	HERMES
Γ_1 & Γ_2 at low Q^2	JLab RSS	JLab RSS	JLab E94-010 JLab E97-103
Γ_1 at low Q^2	SLAC HERMES JLAB EG1	SLAC HERMES JLAB EG1	HERMES
Γ_1, $Q^2 << 1$ GeV^2	JLab EG4	JLab EG4	JLab E97-110
Γ_2, $Q^2 << 1$ GeV^2	JLab E08-027		JLab E97-110

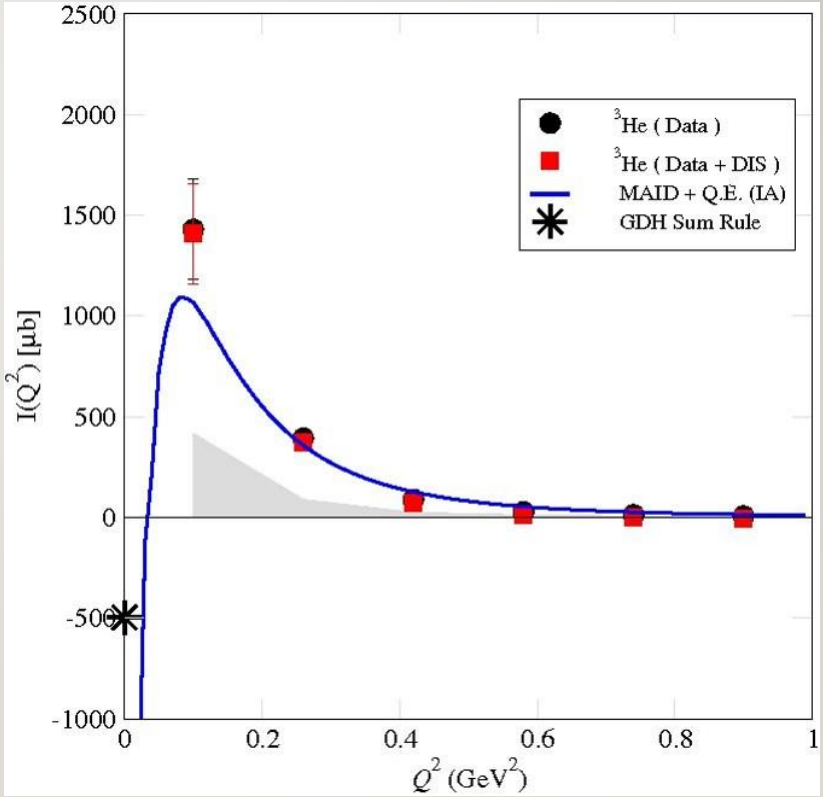
9 E94-010 RESULTS

Neutron

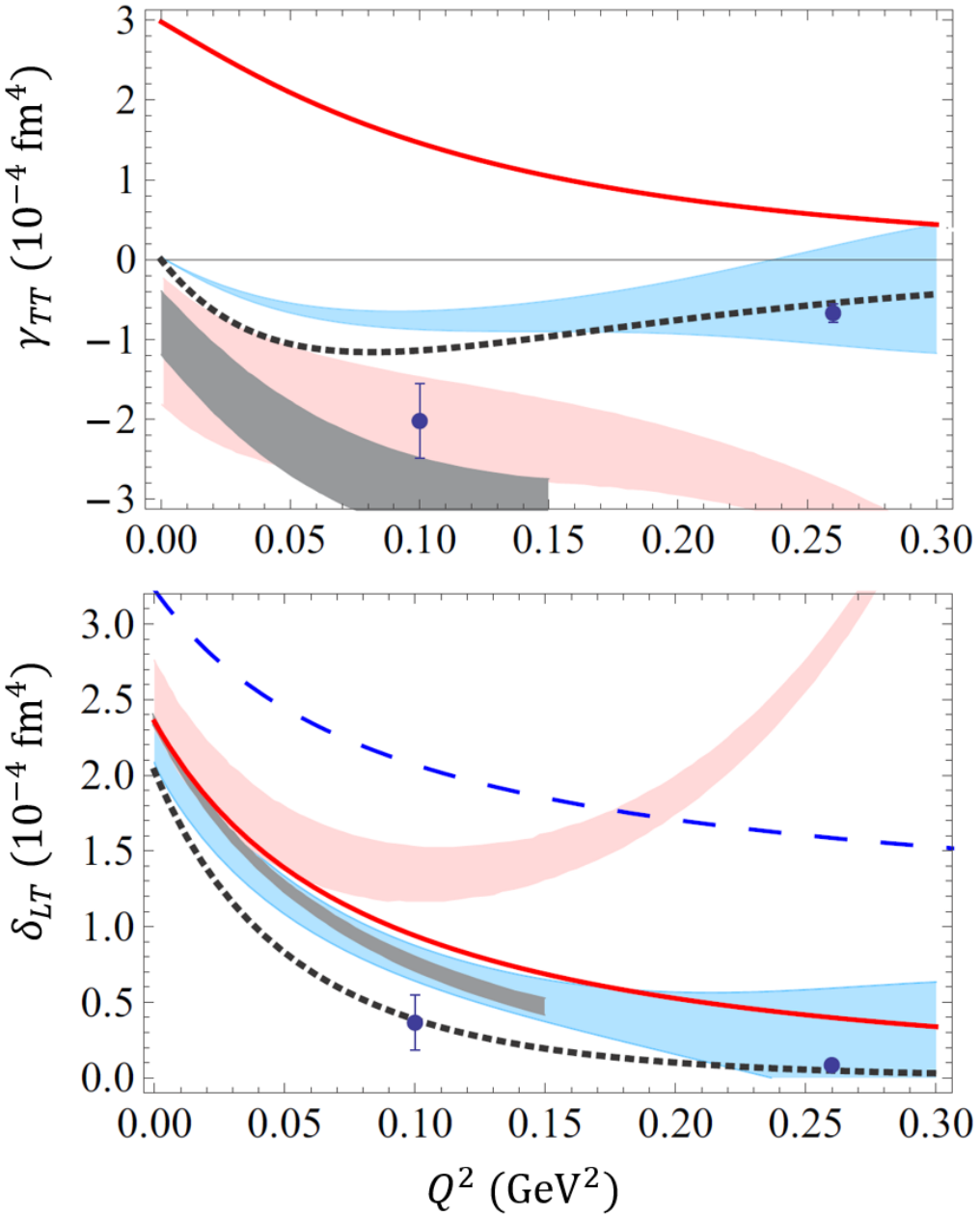


M. Amarian et al., Phys. Rev. Lett., 89:242301, 2002.

Helium-3



K. Slifer et al., Phys. Rev. Lett., 101:022303, 2008.



MAID 2007

HBChEFT
Kao *et al.* (2003)

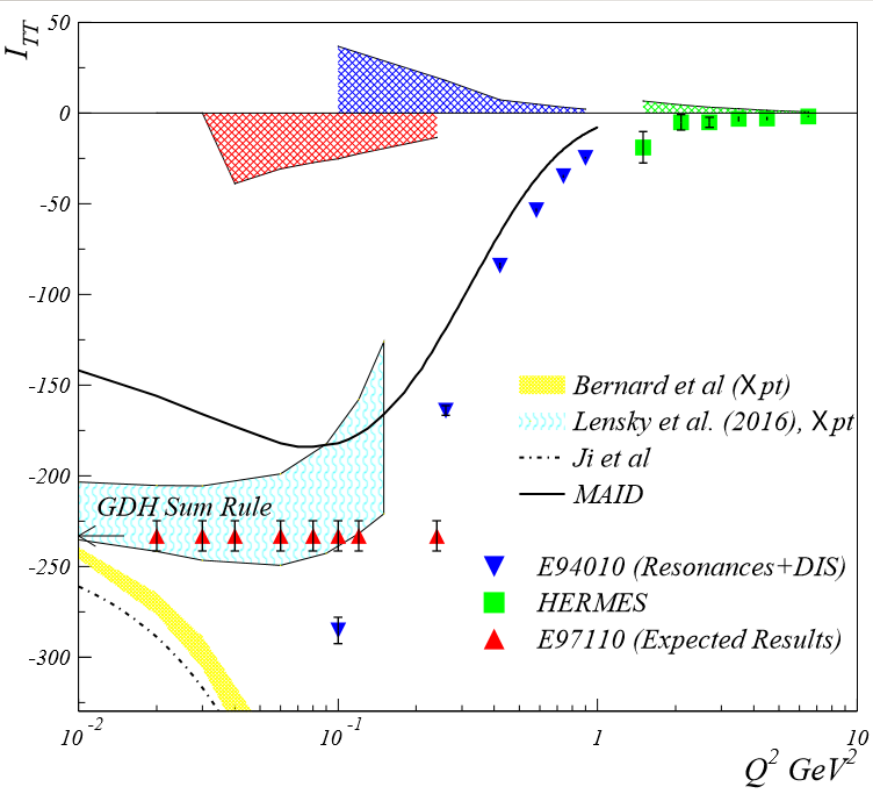
IRBChEFT
Bernard *et al.* (2003)

Covariant BChEFT
Bernard *et al.* (2013)

LO BChEFT
Lensky *et al.* (2014)

NLO BChEFT
Lensky *et al.* (2014)

11 E97-110 AT JEFFERSON LAB

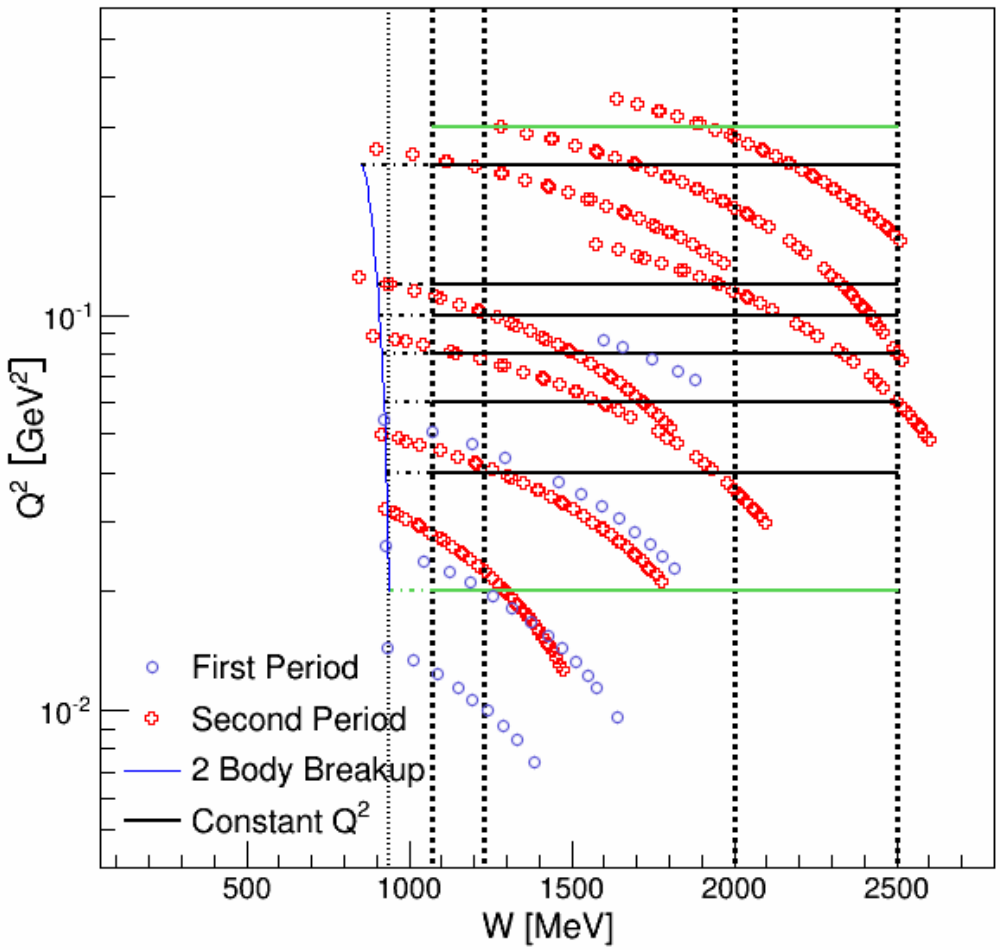


- Inclusive measurement, $^3\vec{\mathrm{He}}(\vec{e},e')X$
  - Scattering angles: 6° and 9°
  - Polarized electron beam, P_{beam} = 75%
  - Polarized ^{3}He target, P_{target} = 40%
- Measured the differences of polarized cross sections
  - Parallel (anti-parallel)
  - Perpendicular

Spokespersons: J.-P. Chen, A. Deur, F. Garibaldi

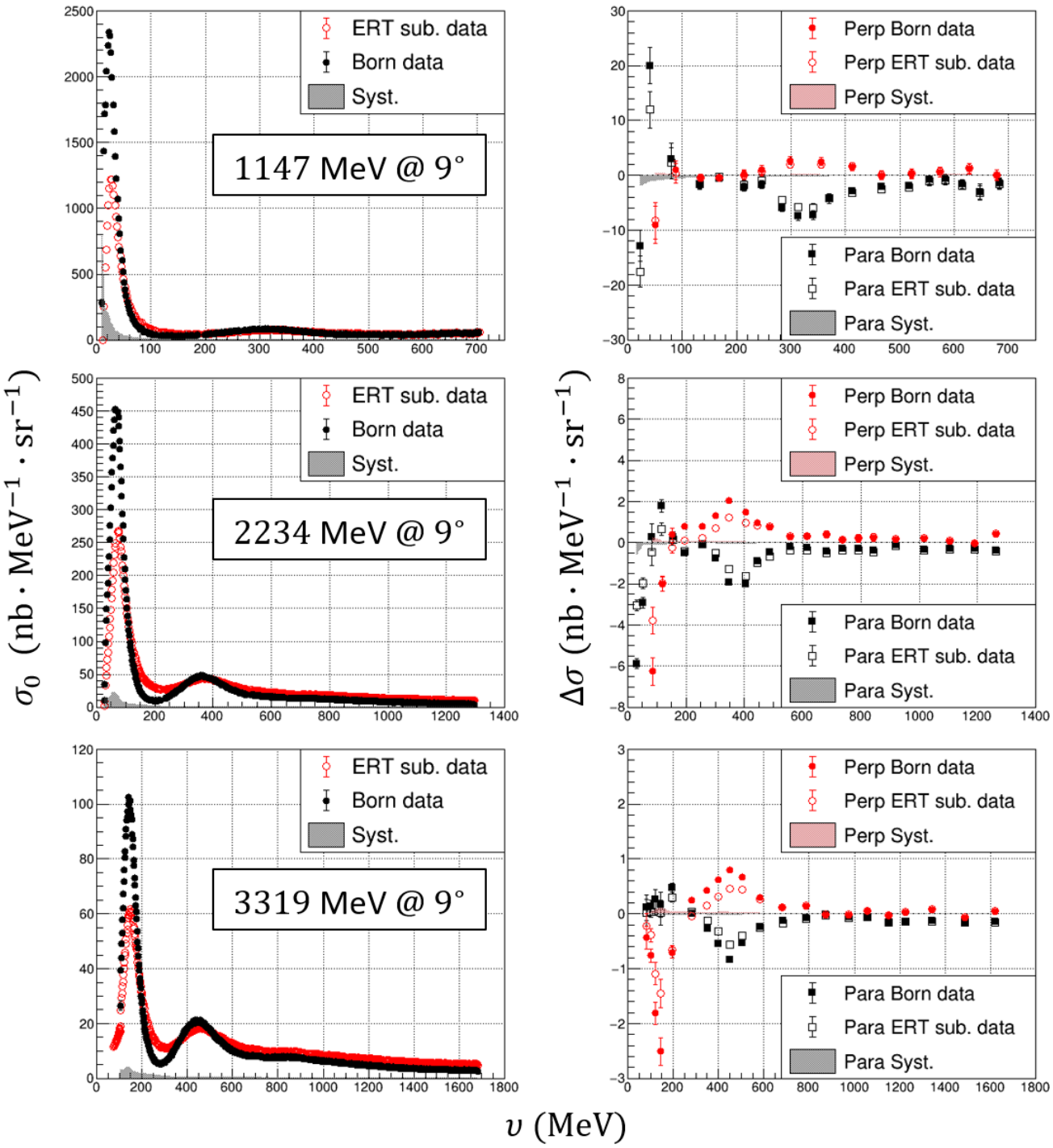
Graduate students: J. Singh, V. Sulkosky, J. Yuan, C. Peng, N. Ton

E97-110 AT JEFFERSON LAB



Target Cell	Angle	Beam Energy (MeV)
Penelope	6.10°	2134.2
Priapus	6.10°	2134.9
Priapus	6.10°	2844.8
Priapus	6.10°	4208.8
Priapus	9.03°	1147.3
Priapus	9.03°	2233.9
Priapus	9.03°	3318.8
Priapus	9.03°	3775.4
Priapus	9.03°	4404.2

CROSS-SECTIONS AND CROSS-SECTION DIFFERENCE RESULTS



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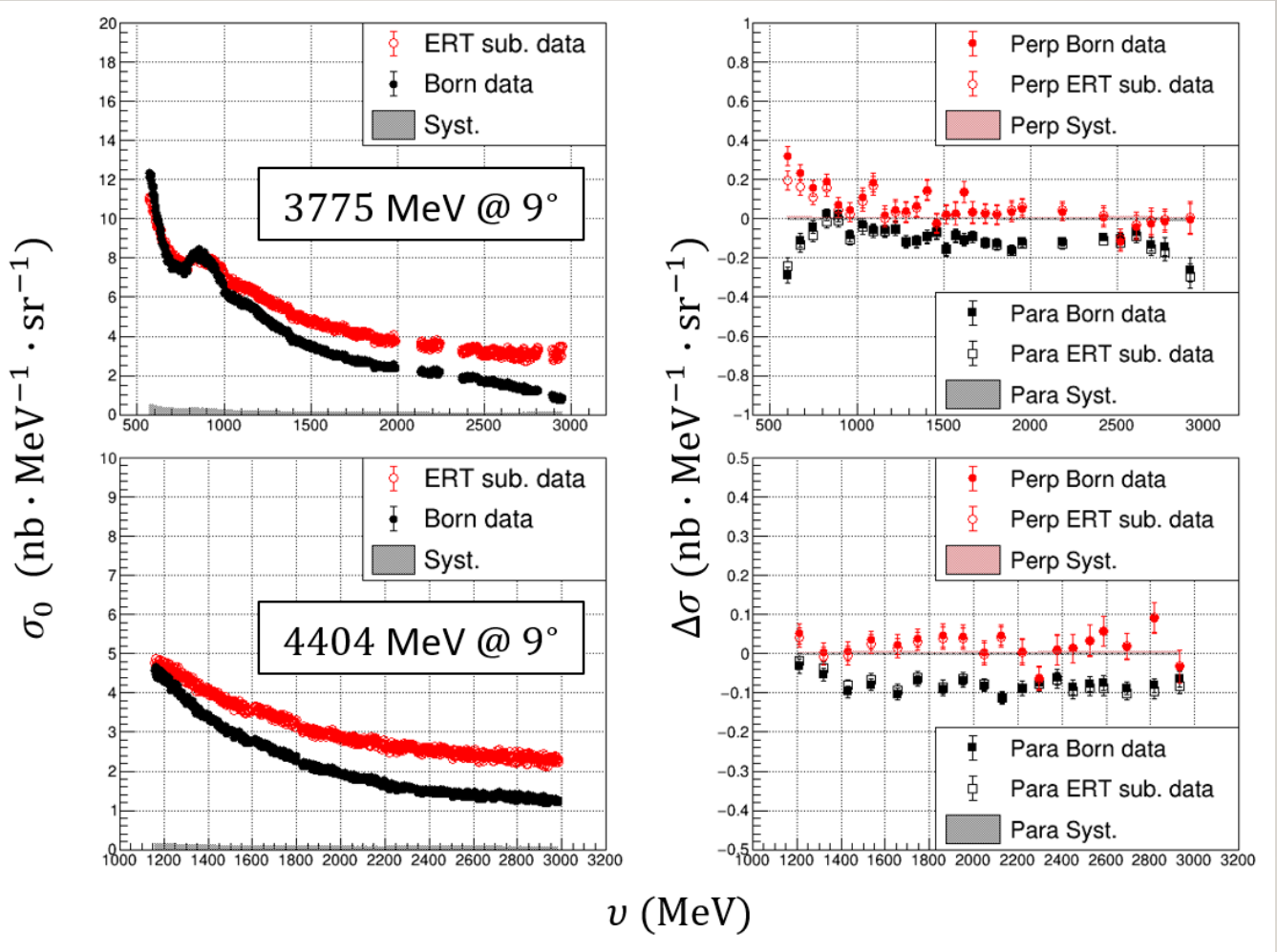

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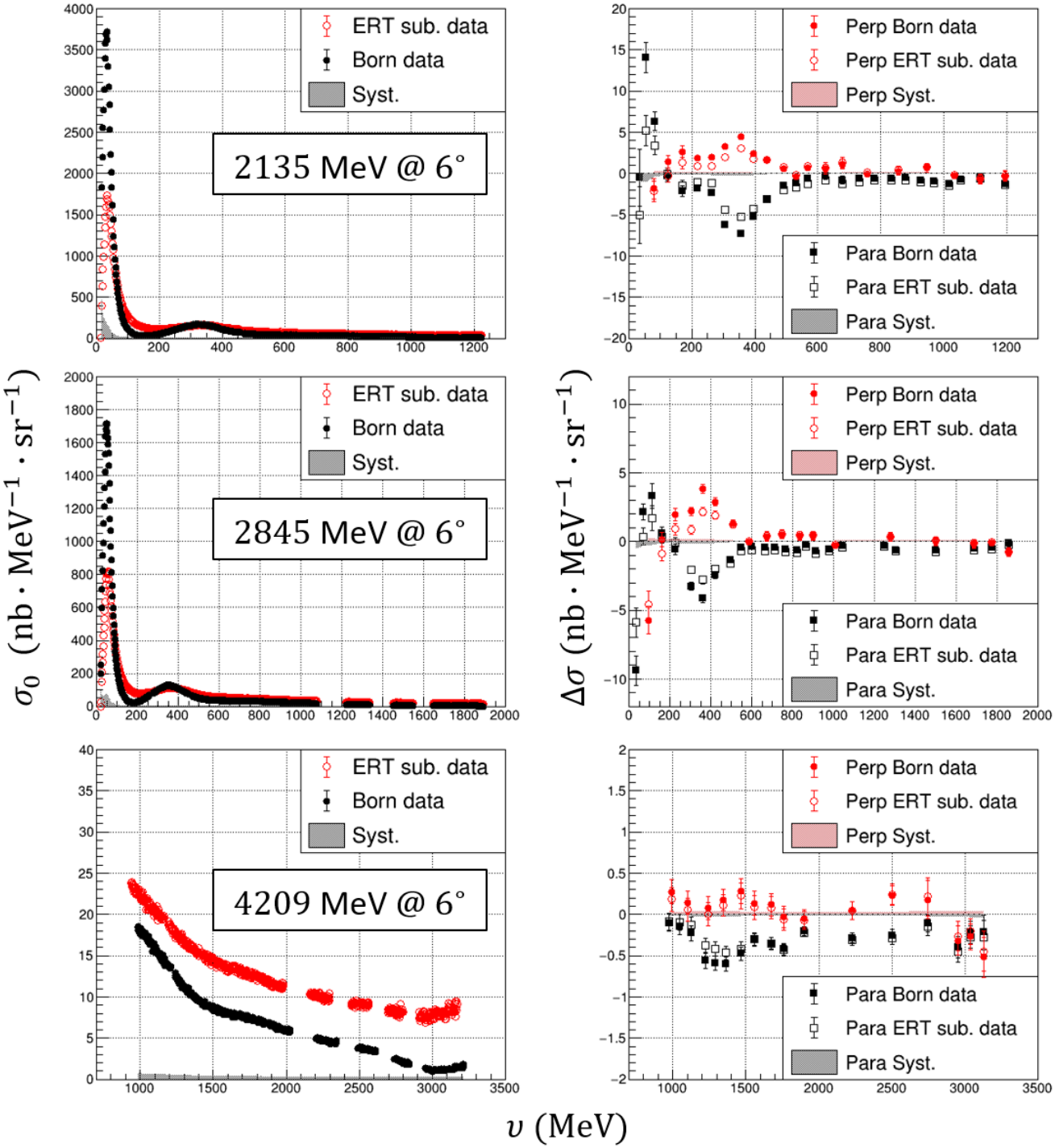
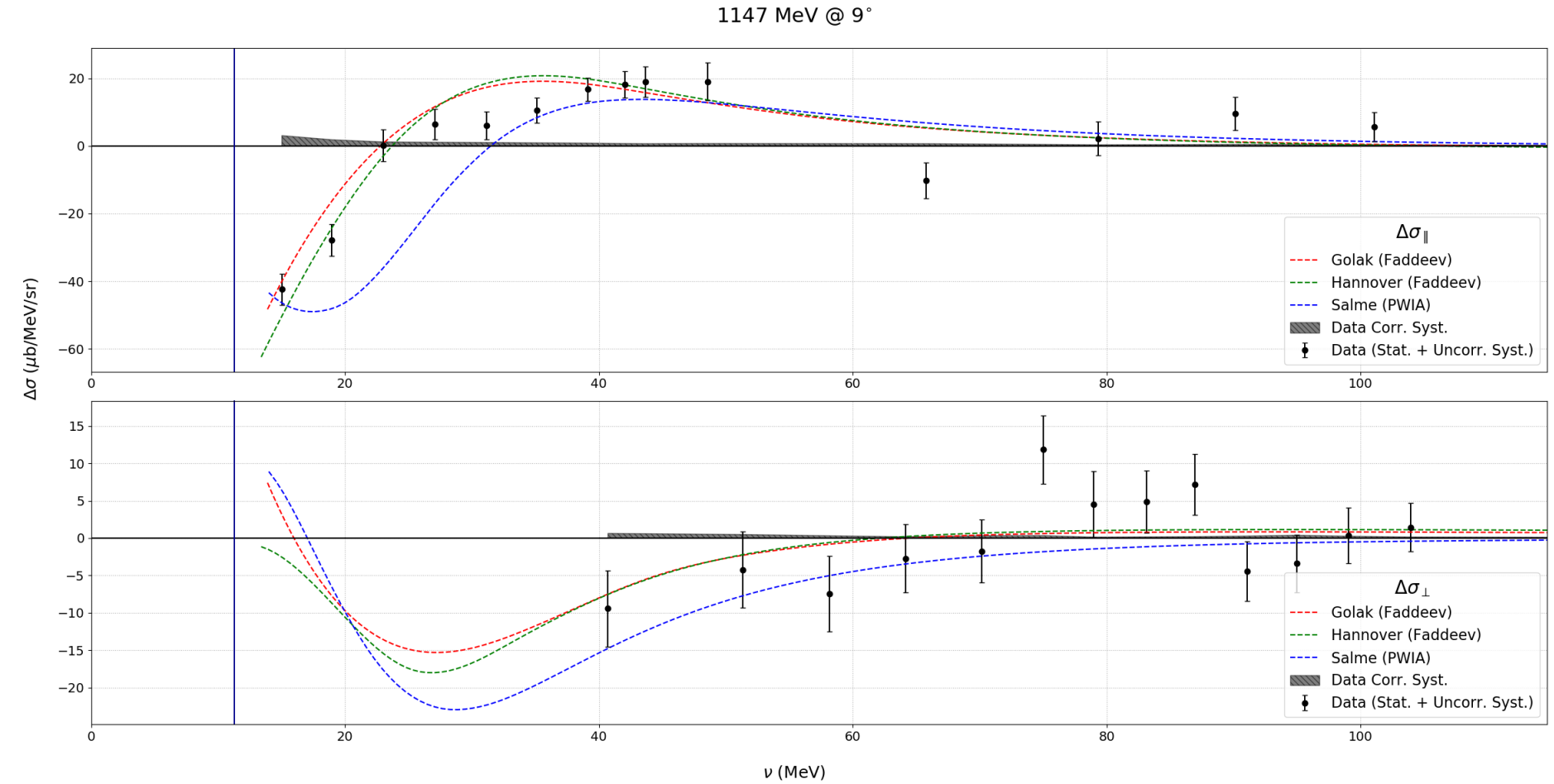


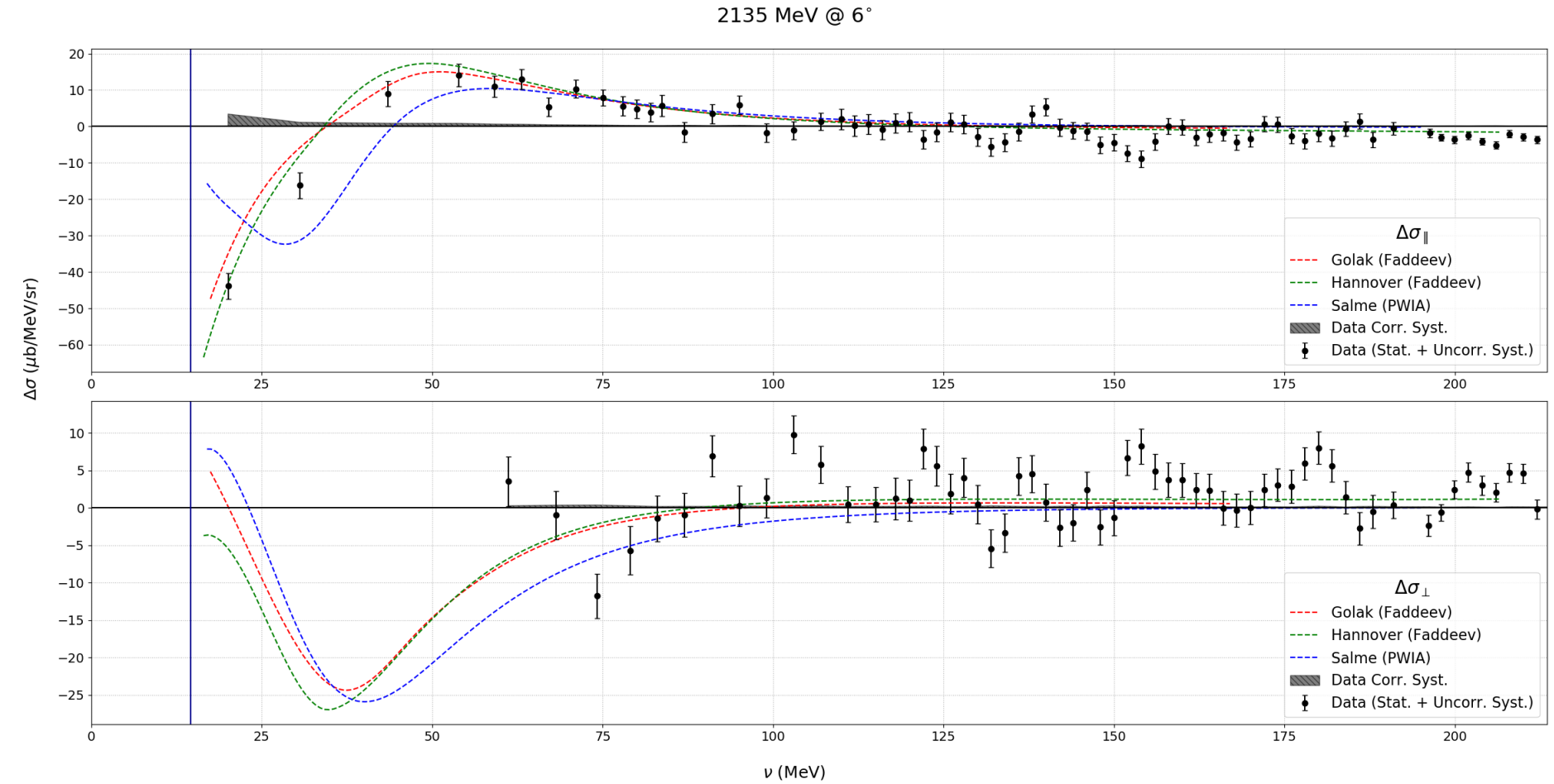
SECOND PERIOD SYSTEMATICS (V. SULKOSKY)

Source	σ_{syst} [%]
Target density	1.6
VDC Multi-tracks	< 1
Charge	1
Detector Efficiencies GC,Sh,Scint	$1.5 - 2$
Yield Stability ν-dependent	< 1.5
Acceptance	$3 - 4$
Beam polarization	3.5
Target Polarization	$3 - 5$

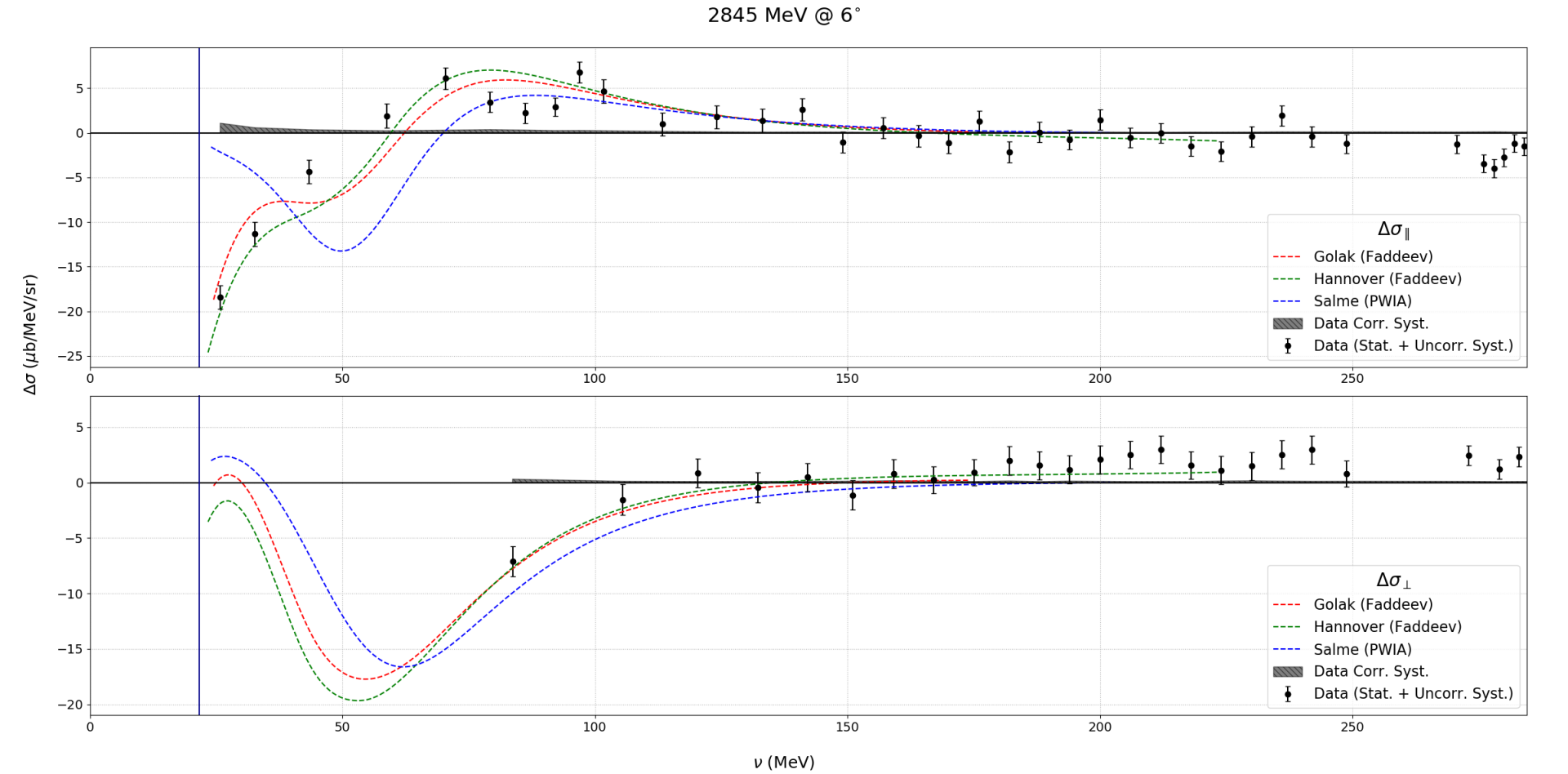
17 COMPARE WITH CALCULATIONS



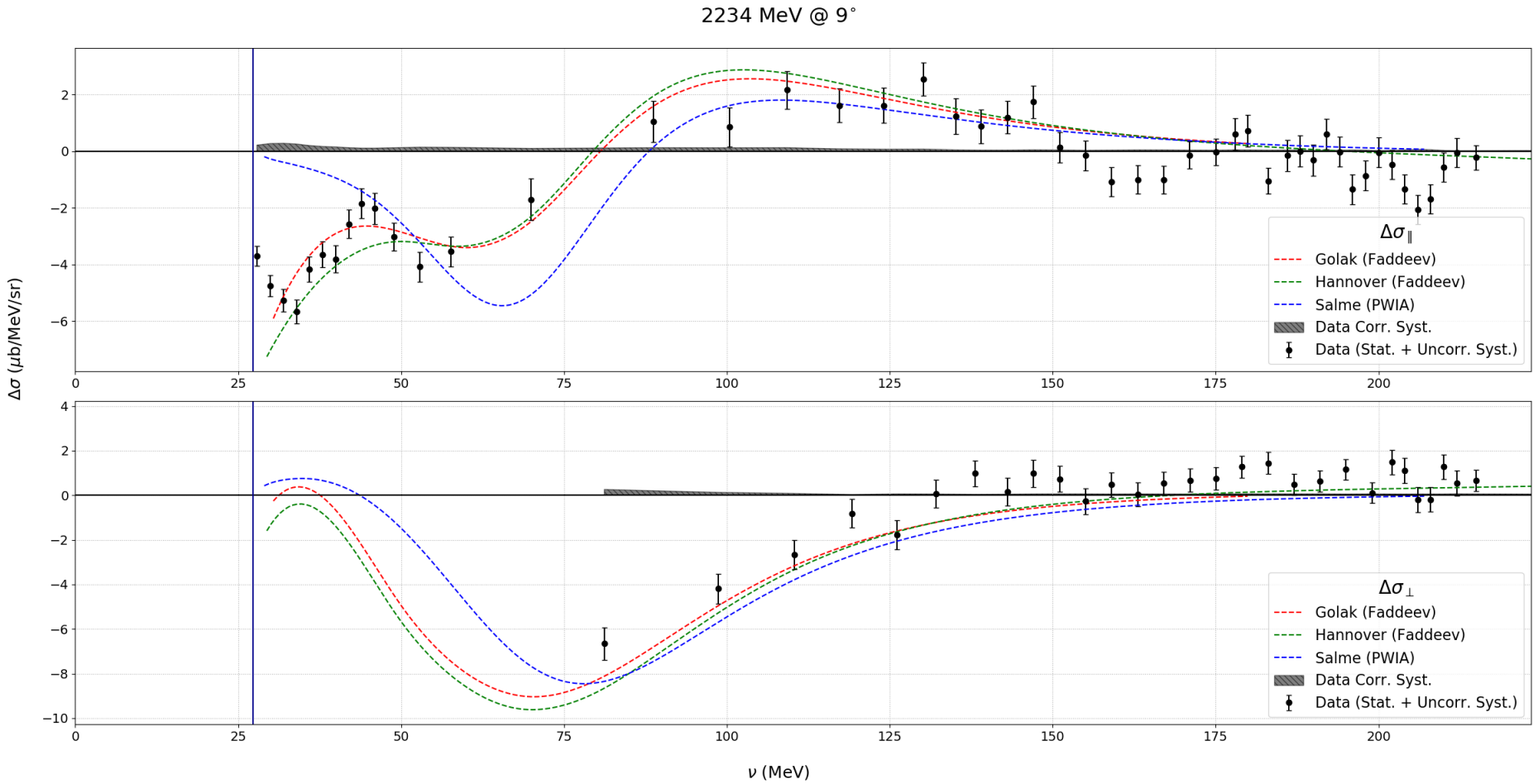
18 COMPARE WITH CALCULATIONS



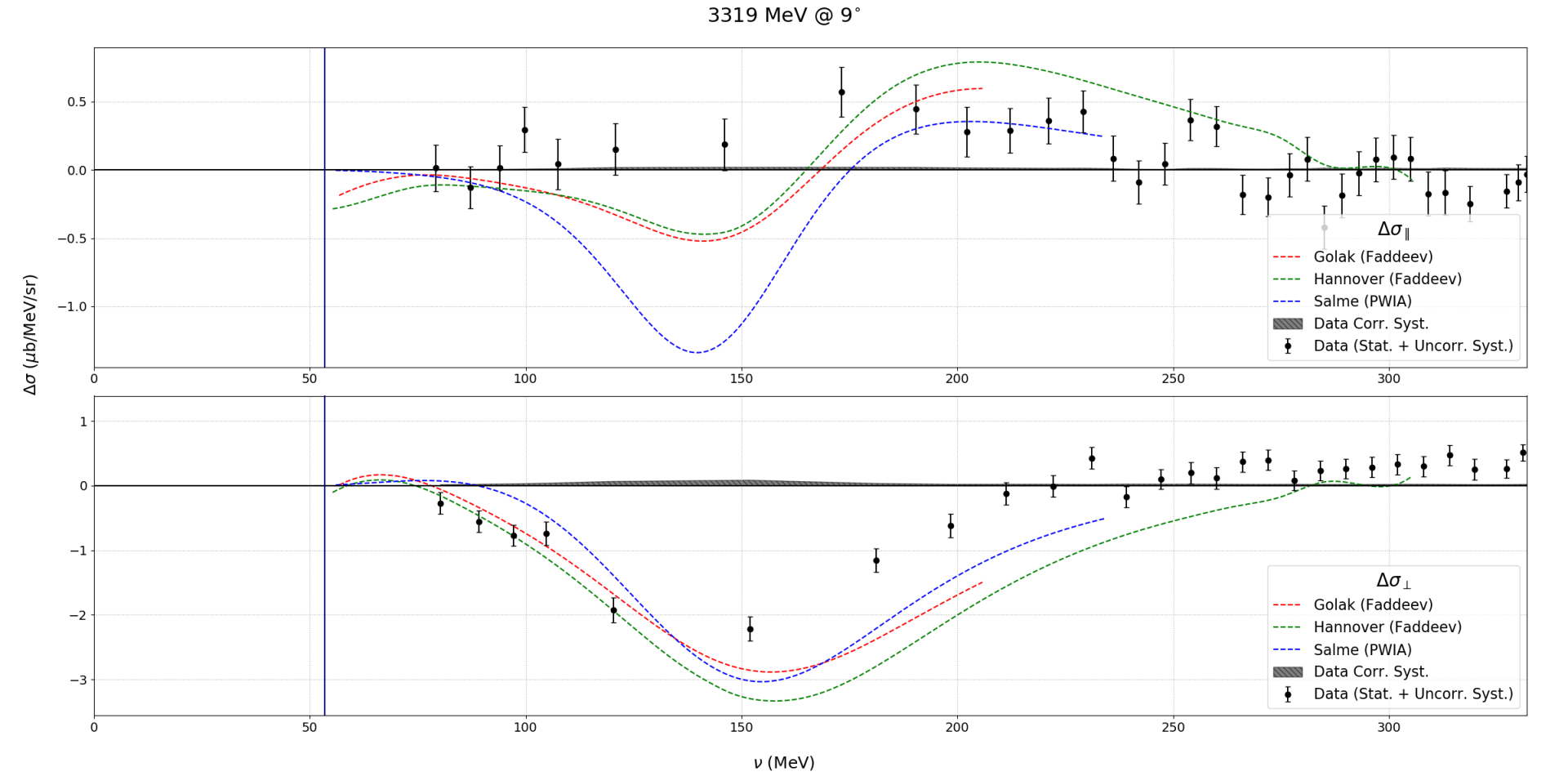
19 COMPARE WITH CALCULATIONS



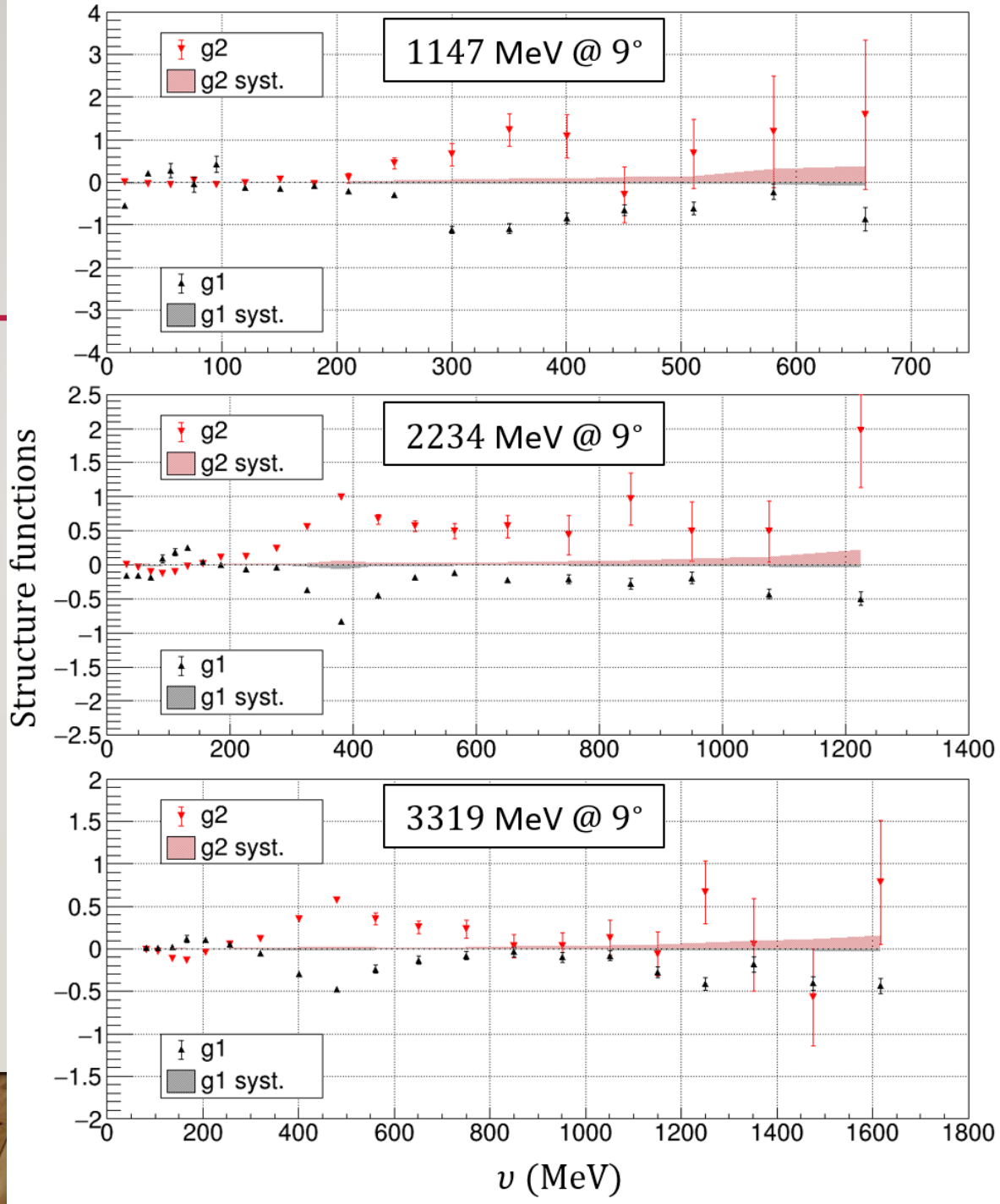
20 COMPARE WITH CALCULATIONS



21 COMPARE WITH CALCULATIONS



SPIN-DEPENDENT STRUCTURE FUNCTIONS RESULTS



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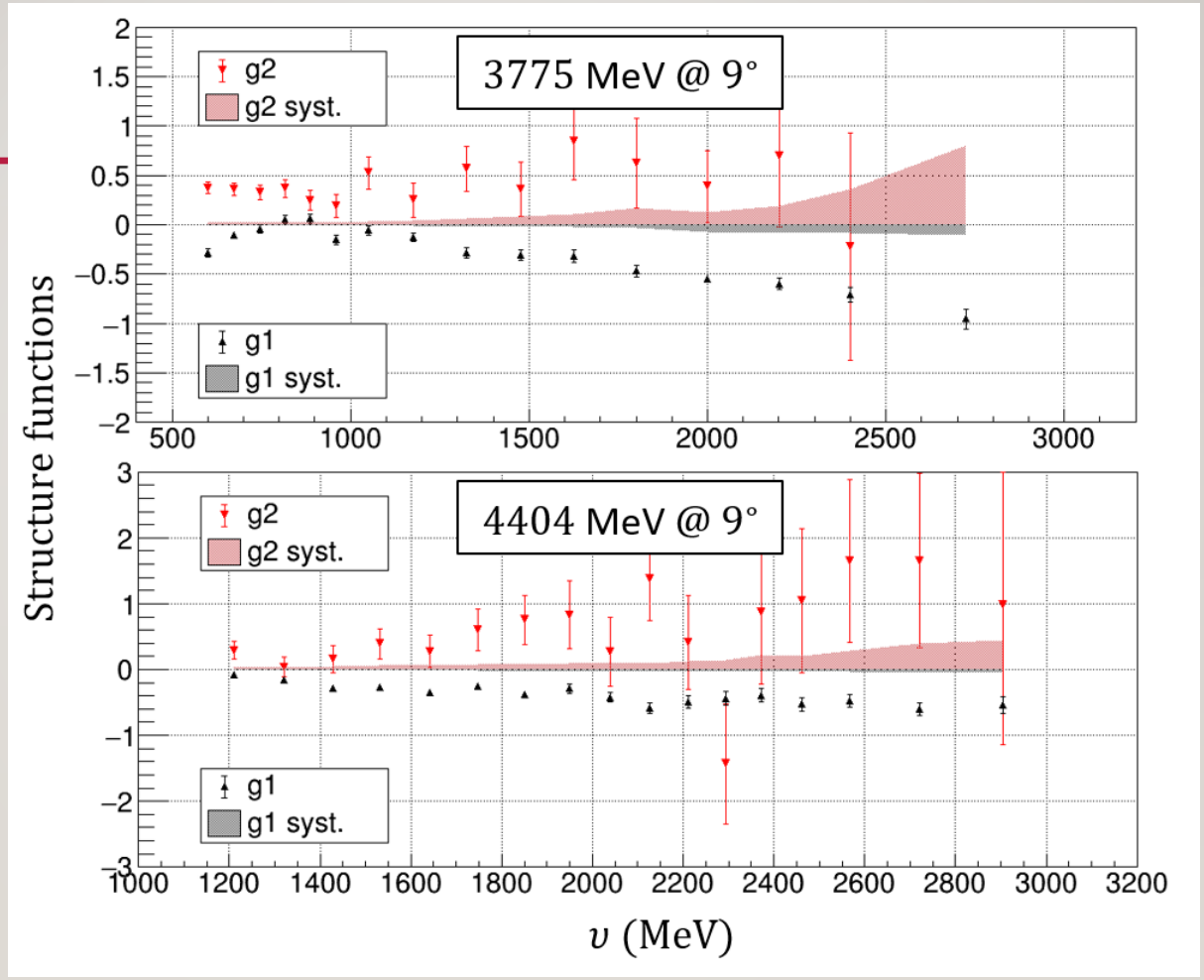

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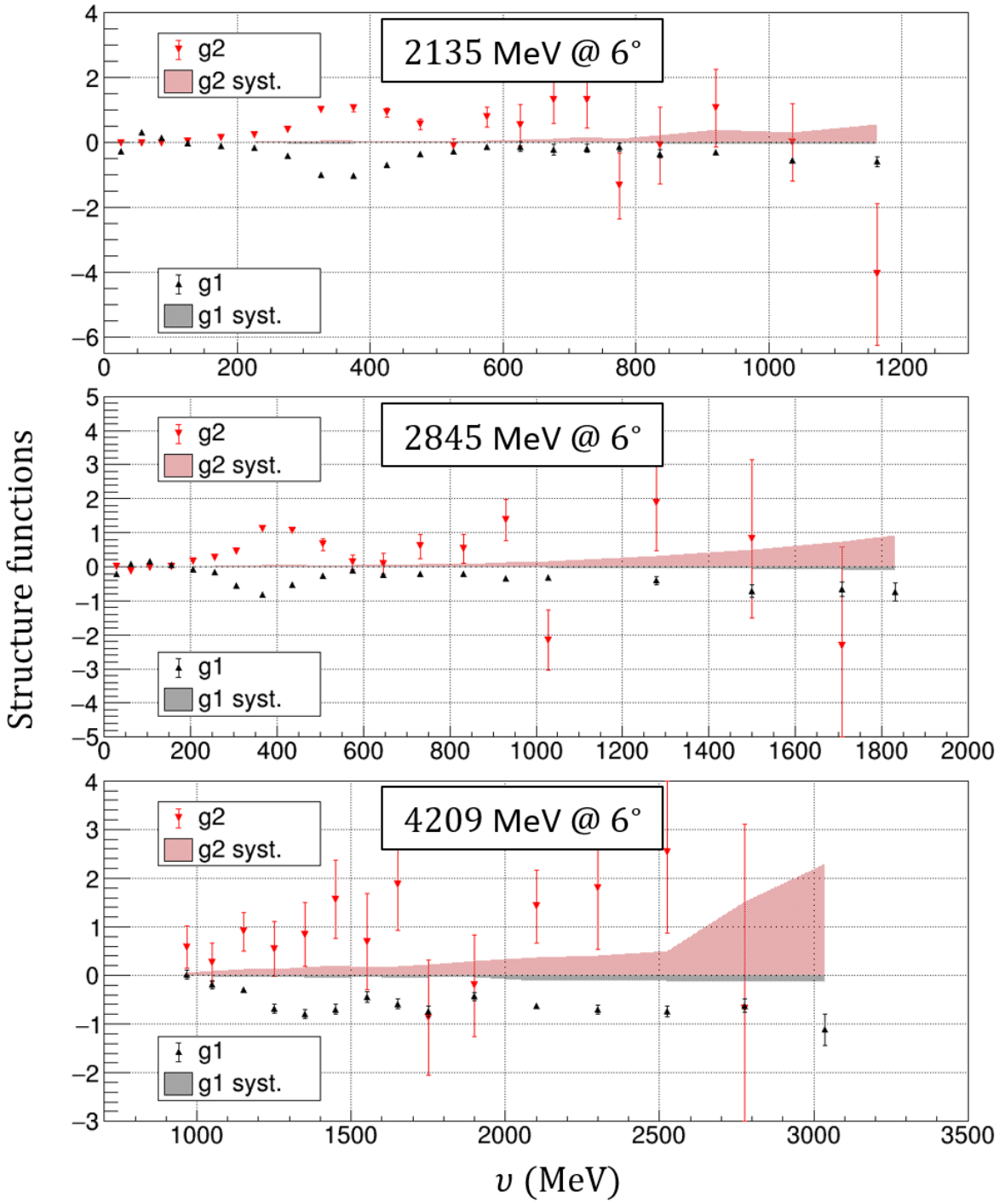


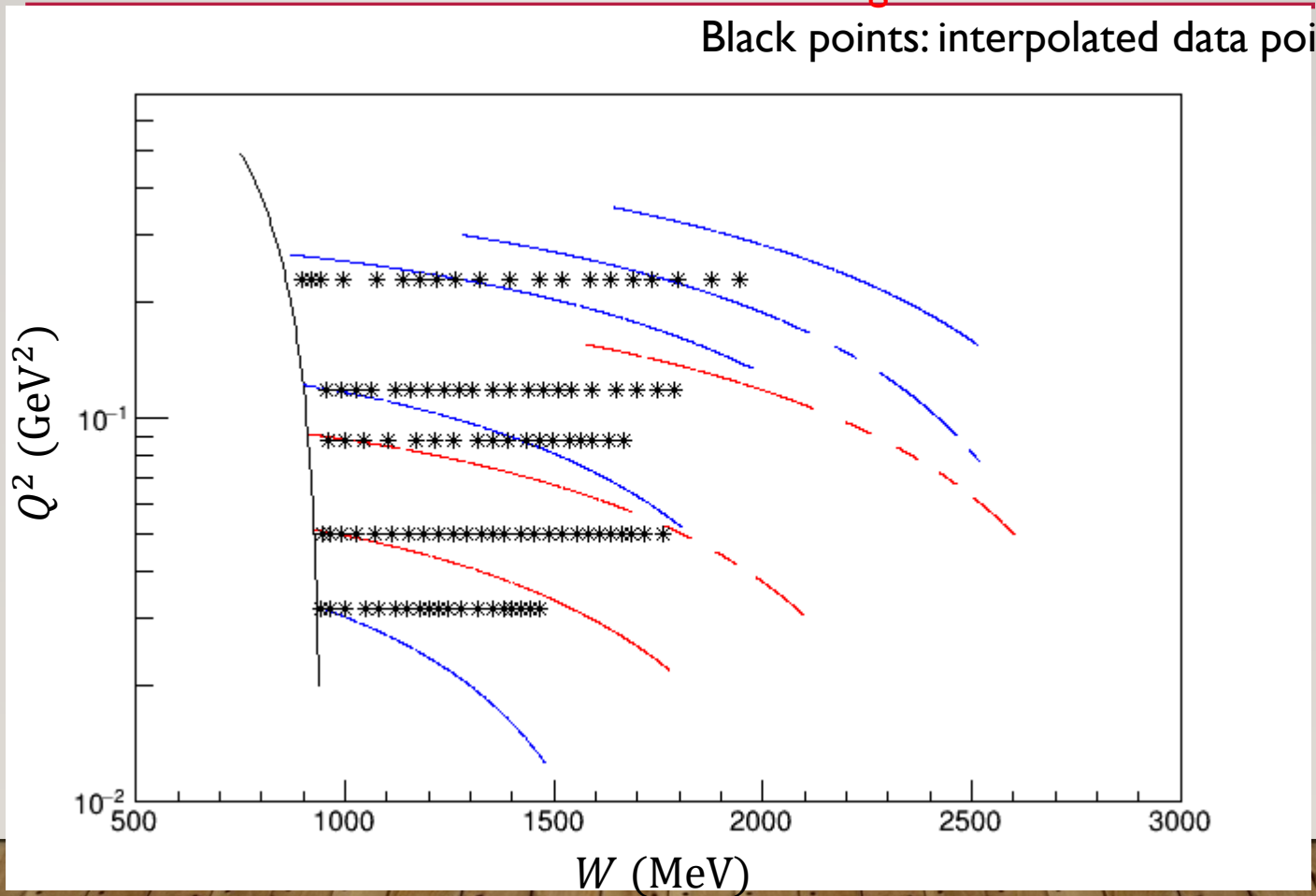
25 INTERPOLATION TO CONSTANT Q^2

$Q^2 = 0.032 \sim 0.23\ \mathrm{GeV}^2$

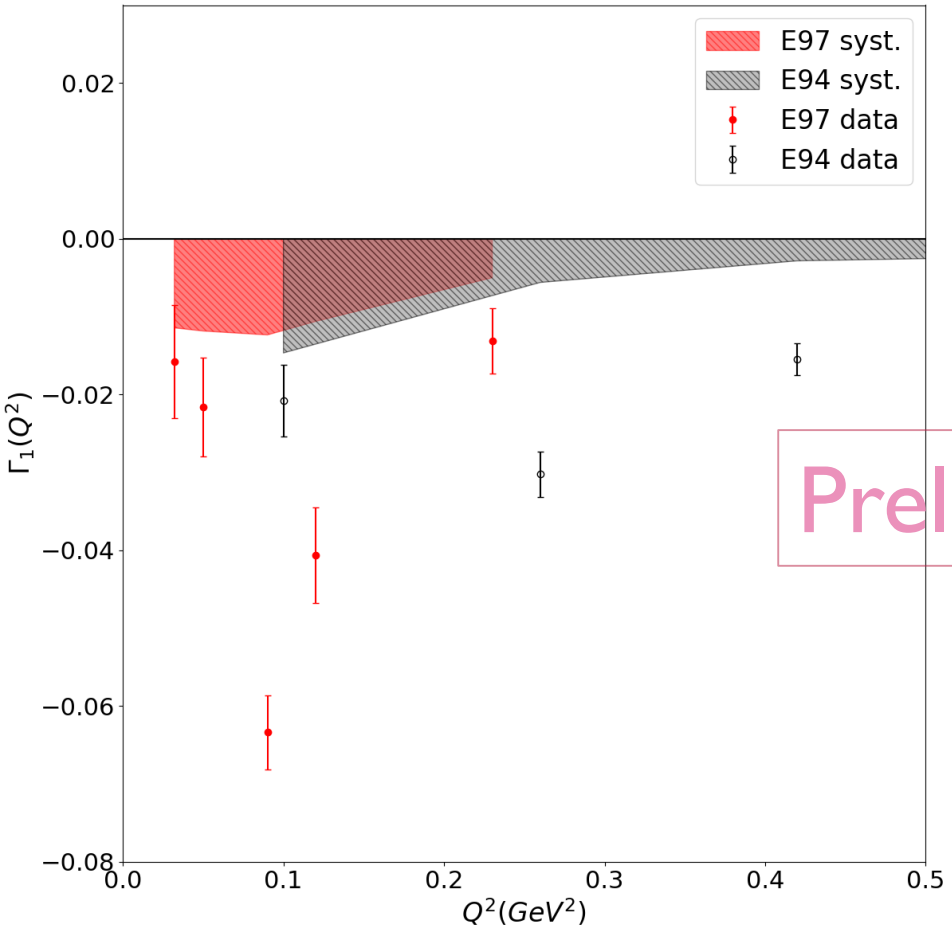
Blue: 9 degree

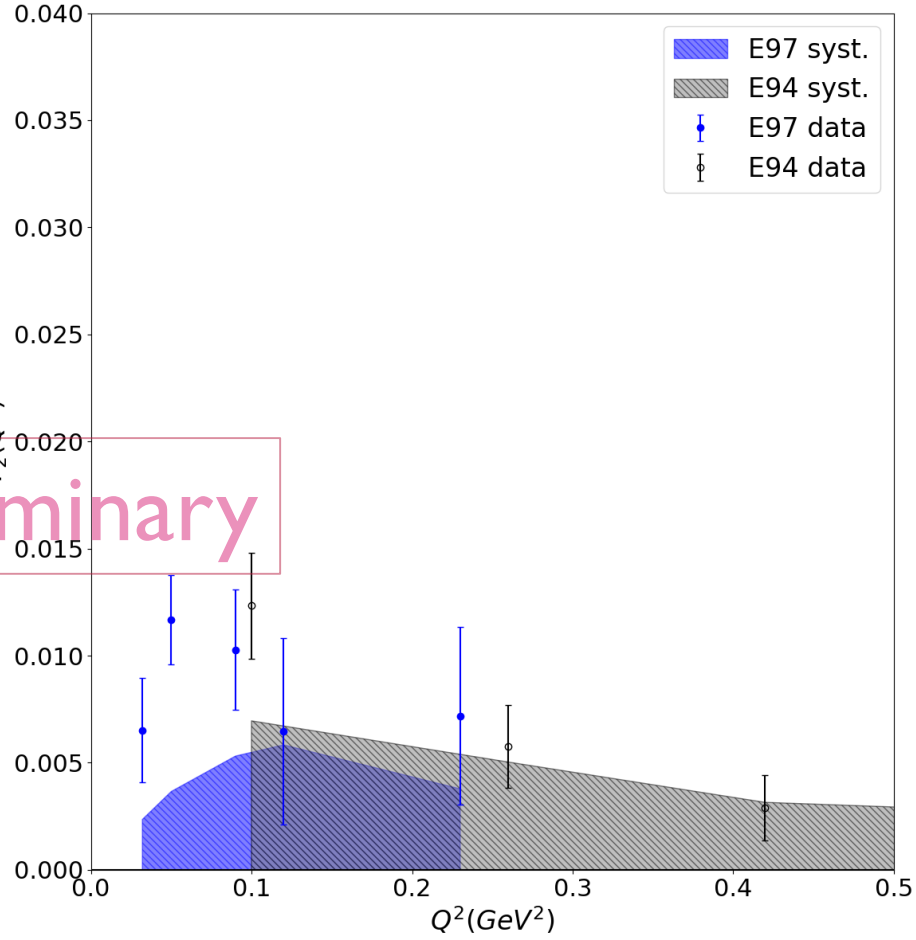
Red: 6 degree

Black points: interpolated data points



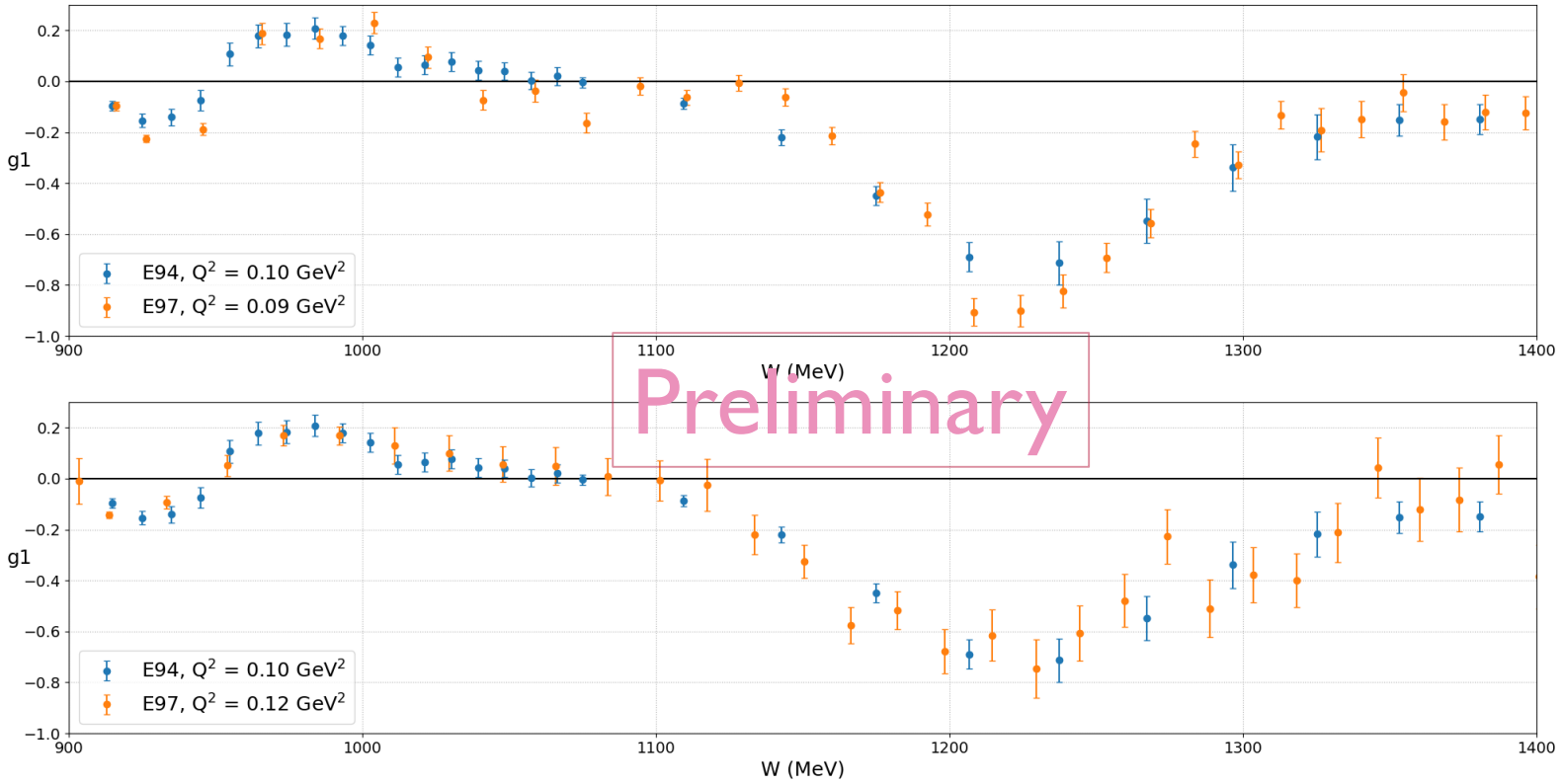
FIRST MOMENTS



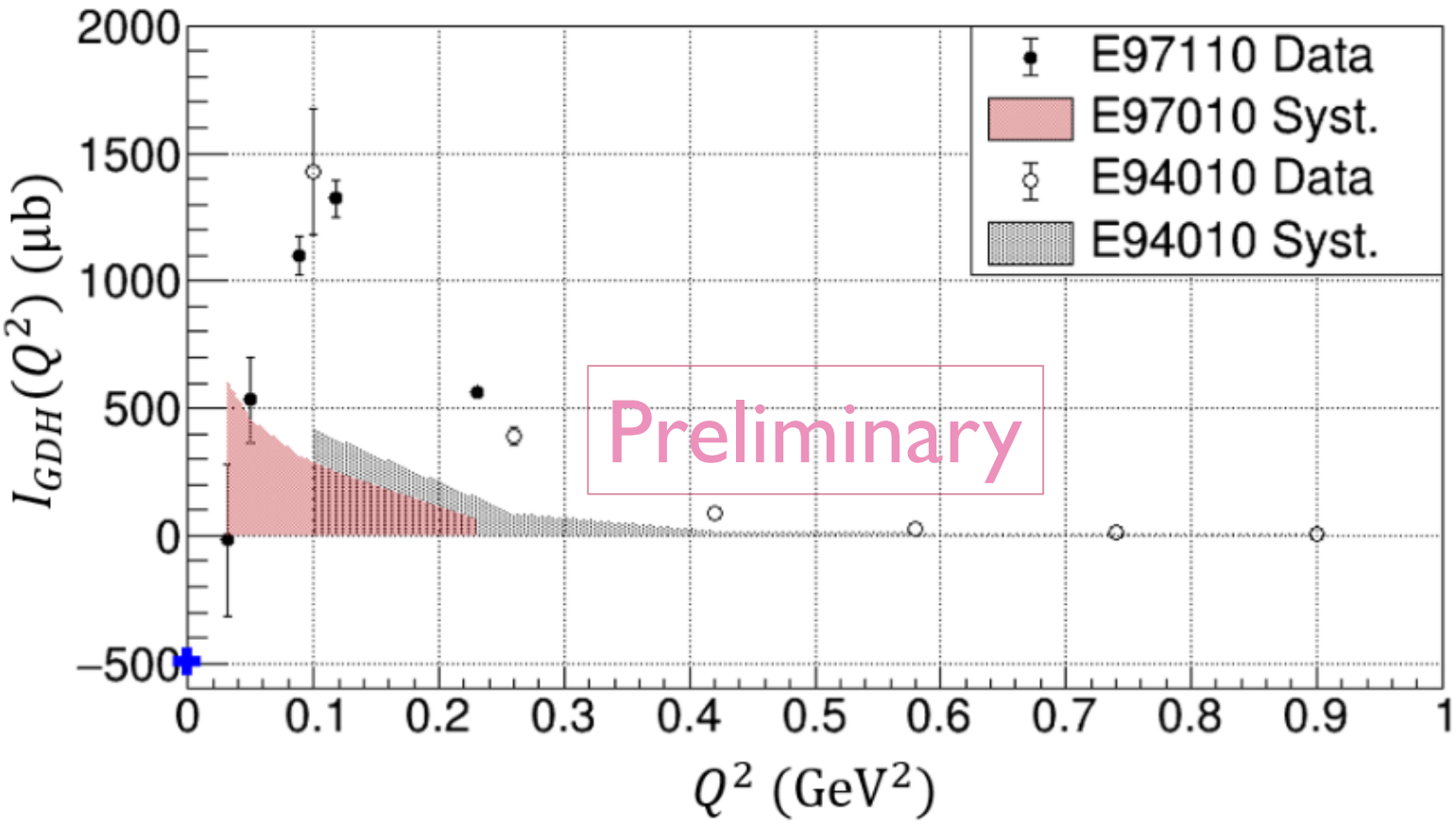


Preliminary

27 CROSS CHECK WITH E94 RESULTS



EXTENDED GDH SUM (I_{TT})



29 SUMMARY

- Good agreement with Faddeev calculation for the lowest Q^2 data points
- Helium-3 results are consistent with E94 results in the overlapping kinematic range
- Observed the expected turning point at low Q^2 for the GDH sum
- Paper is being drafted

THANK YOU