JLab 20+ DVCS Data:

A look at the Benefits

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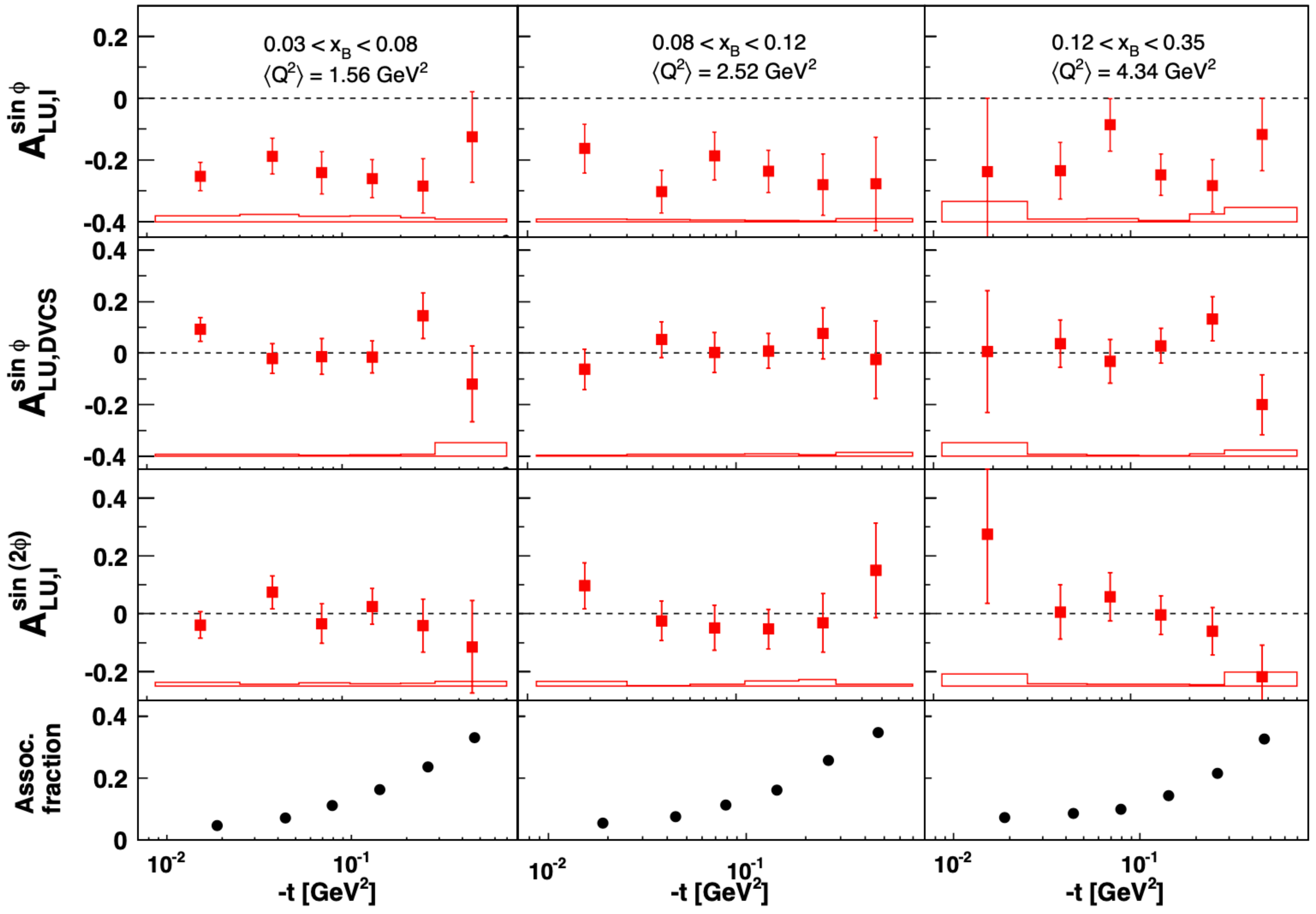
Overview

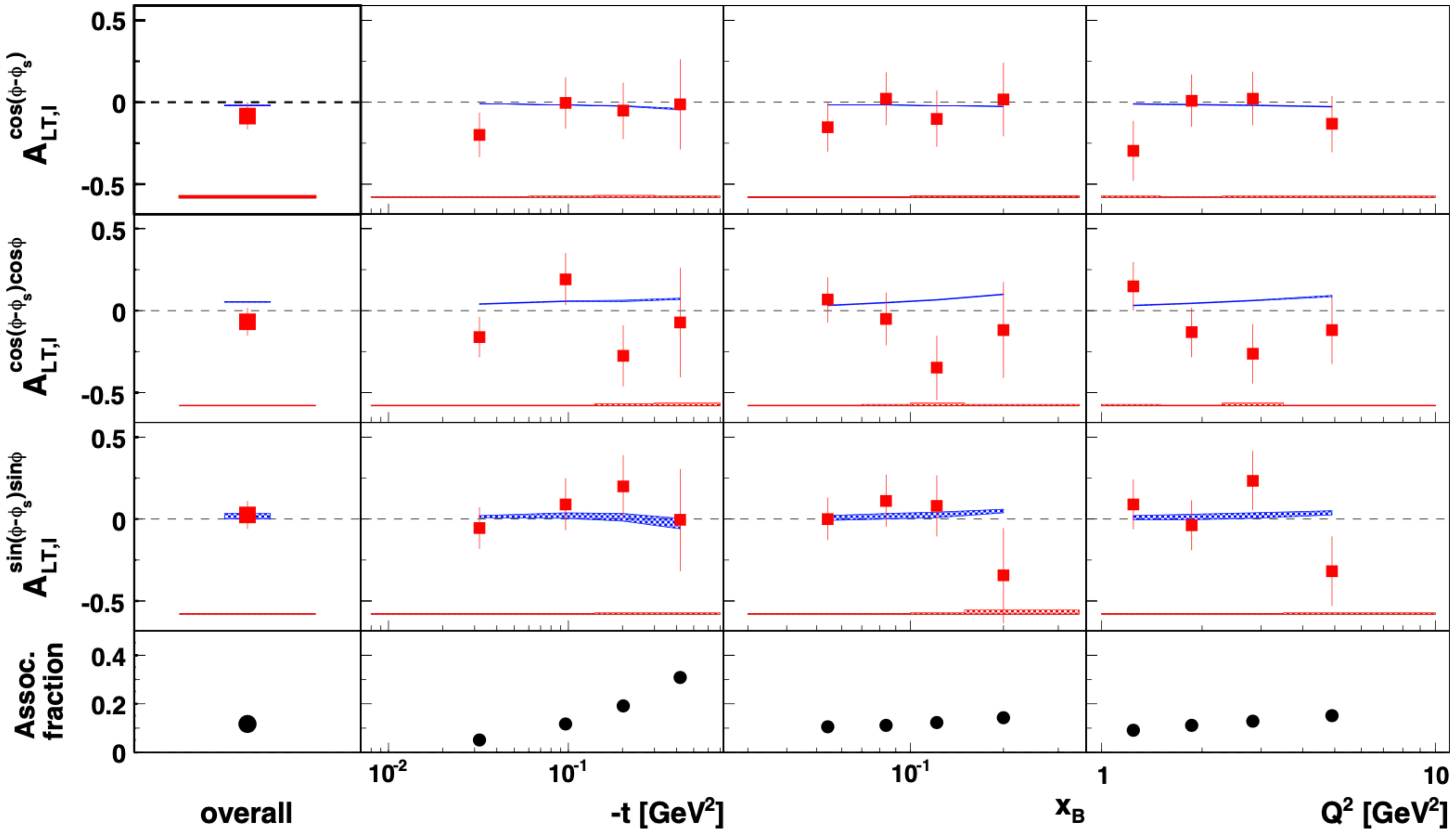
- **Review of HERMES data**
  1. Data Examples
  2. Extracted CFFs
- **JLab DVCS at 20+ GeV**
  1. Kinematics
  2. Comparison: HERMES to JLAB
  3. 20+ GeV Cross section predictions compared to 10 GeV
  4. Remarks, Compton Form Factor fitting
- **Conclusions**

First let's look at the HERMES data..

- HERMES raw data runs from 2001-2007, publications from ~2006-2012
- Exclusive study of ASYMMETRIES
- Electron and positron beams used
- Many observables measured: $A_C, A_{LU}, A_{UL}, A_{LL}, A_{UT}, A_{LT}$ totals over 14 harmonic coeff's
- Beam energy of $27.6\ \text{GeV}$
- Lower luminosity $\leq 10^{31} cm^{-2} s^{-1}$
- Most data within $0.05 \leq x_B \leq 0.2$ $2\ \text{GeV}^2 \leq Q^2 \leq 6\ \text{GeV}^2$

Examples of HERMES data



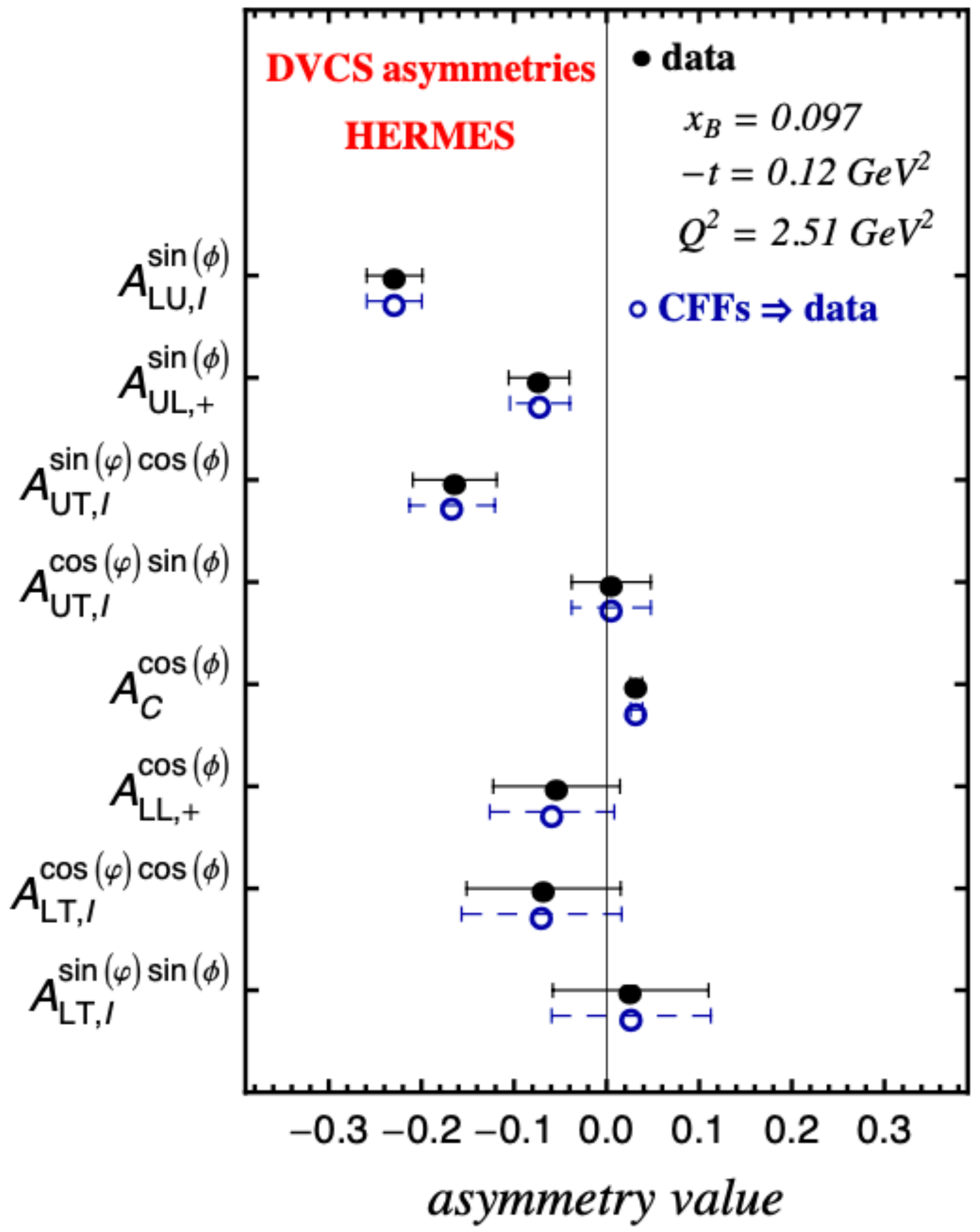


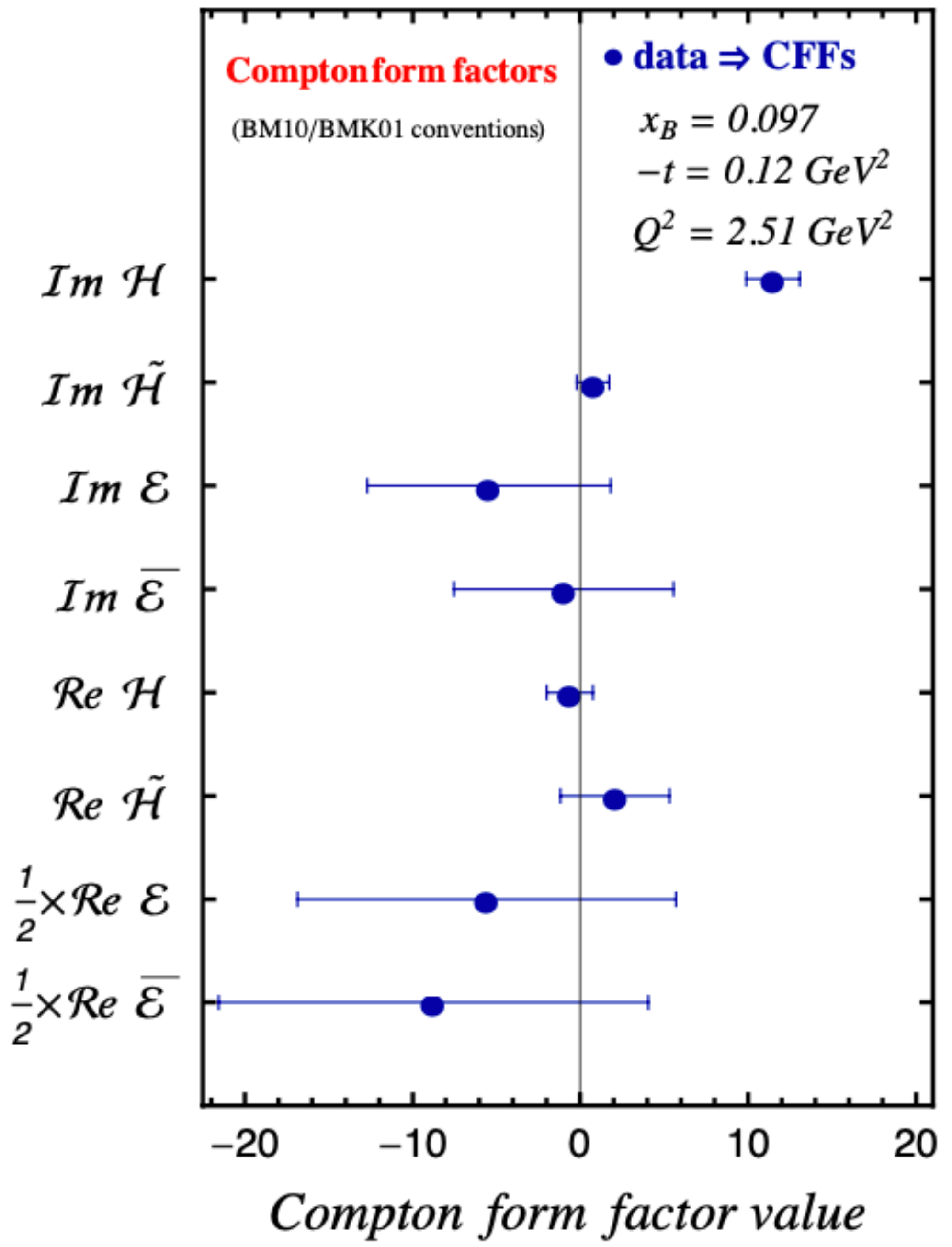
- Okay, so what does this data give us ??...

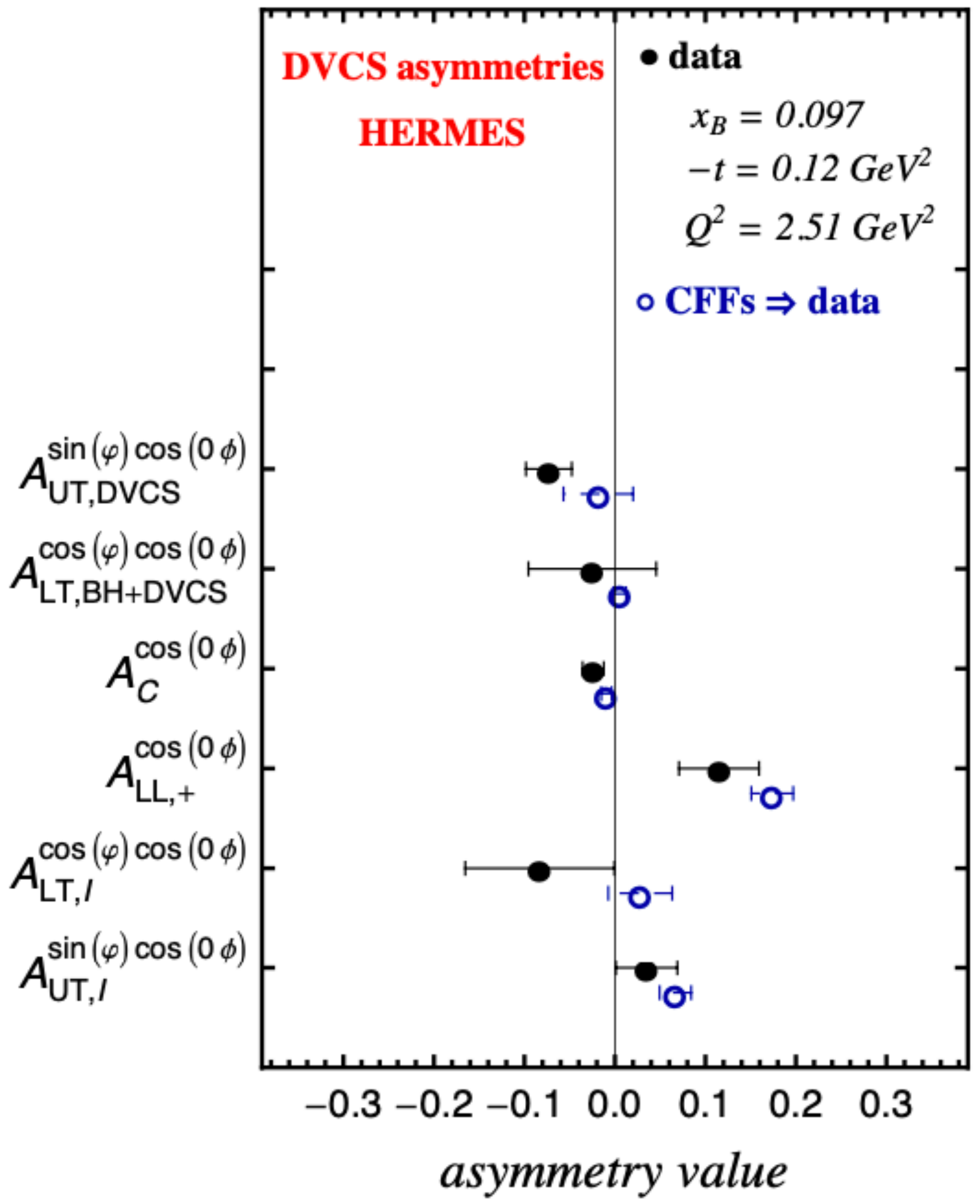
An analysis of HERMES data

e.g. Kumericki, Muller & Murray 2014:

- Extracted all 8 twist-2 CFFs using linear approximations



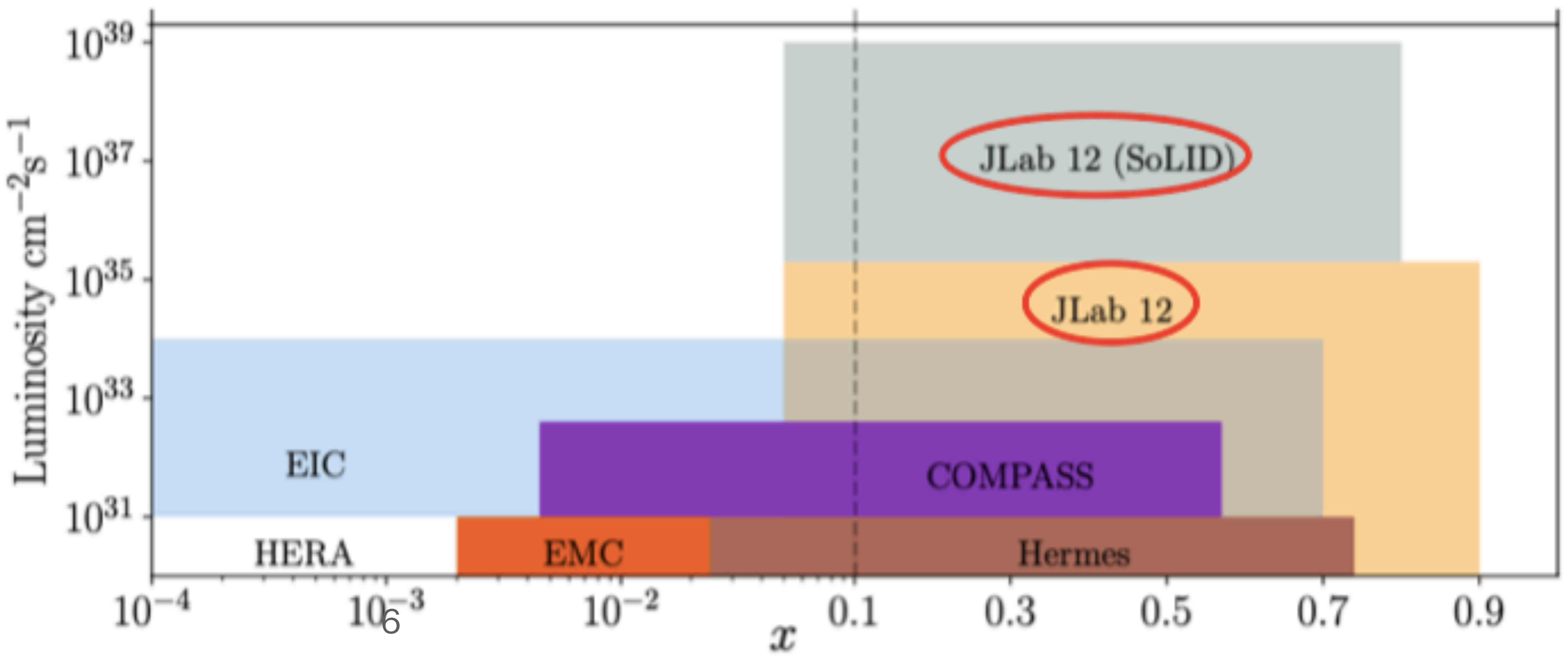




- Other, more rigorous analyses have been done, which also includes JLab data, but for this case here is a "best-case scenario" given only HERMES data

JLab 20+ GeV Data

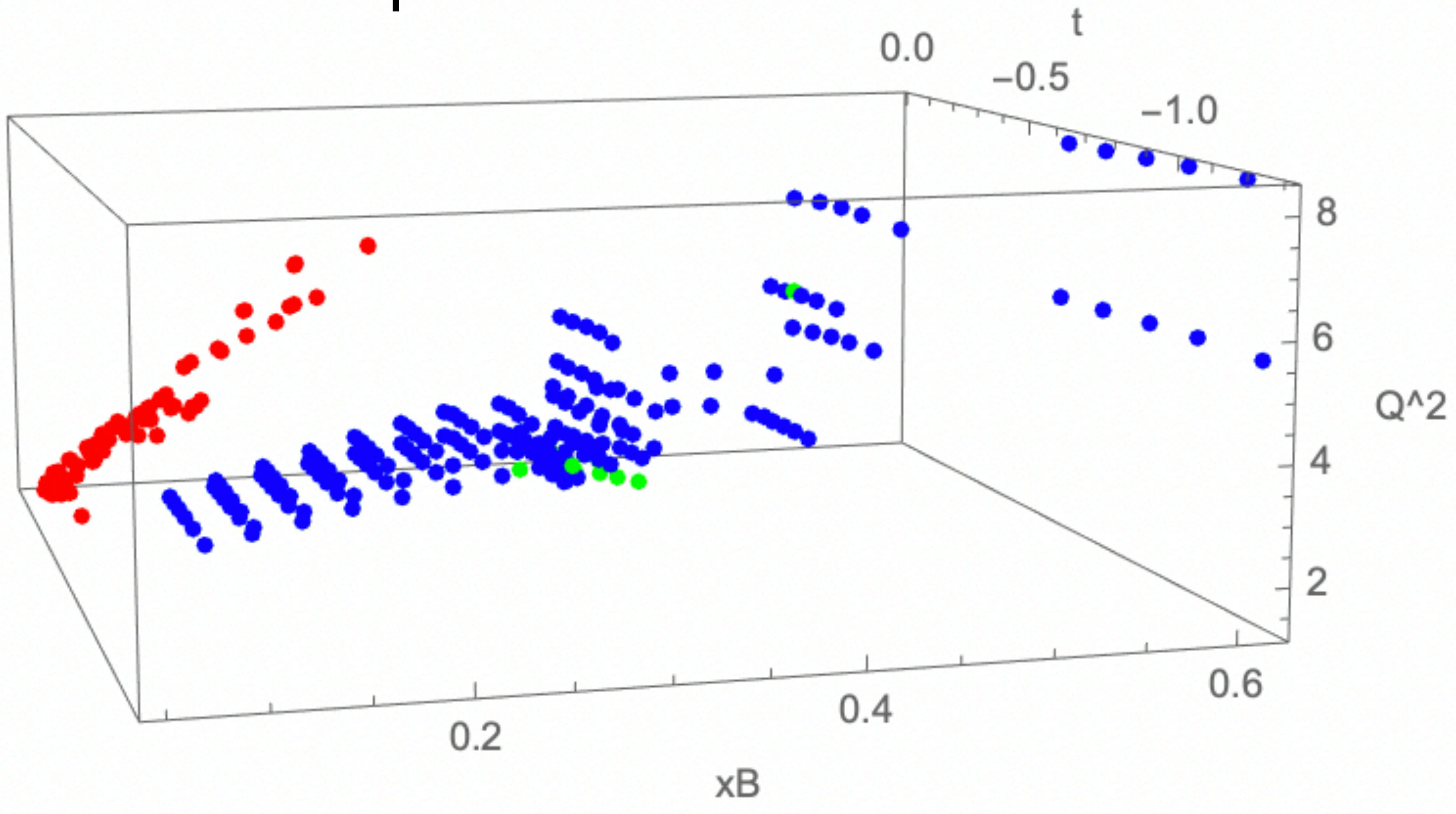
- JLab 20+ GeV can be thought of as a "super HERMES"
- Similar maximum energy (but variable!) but much higher luminosity
- Therefore, if we simply performed the same (or similar) observable measurement program, the improved statistics will allow much higher constraints on CFFs (& GPDs)

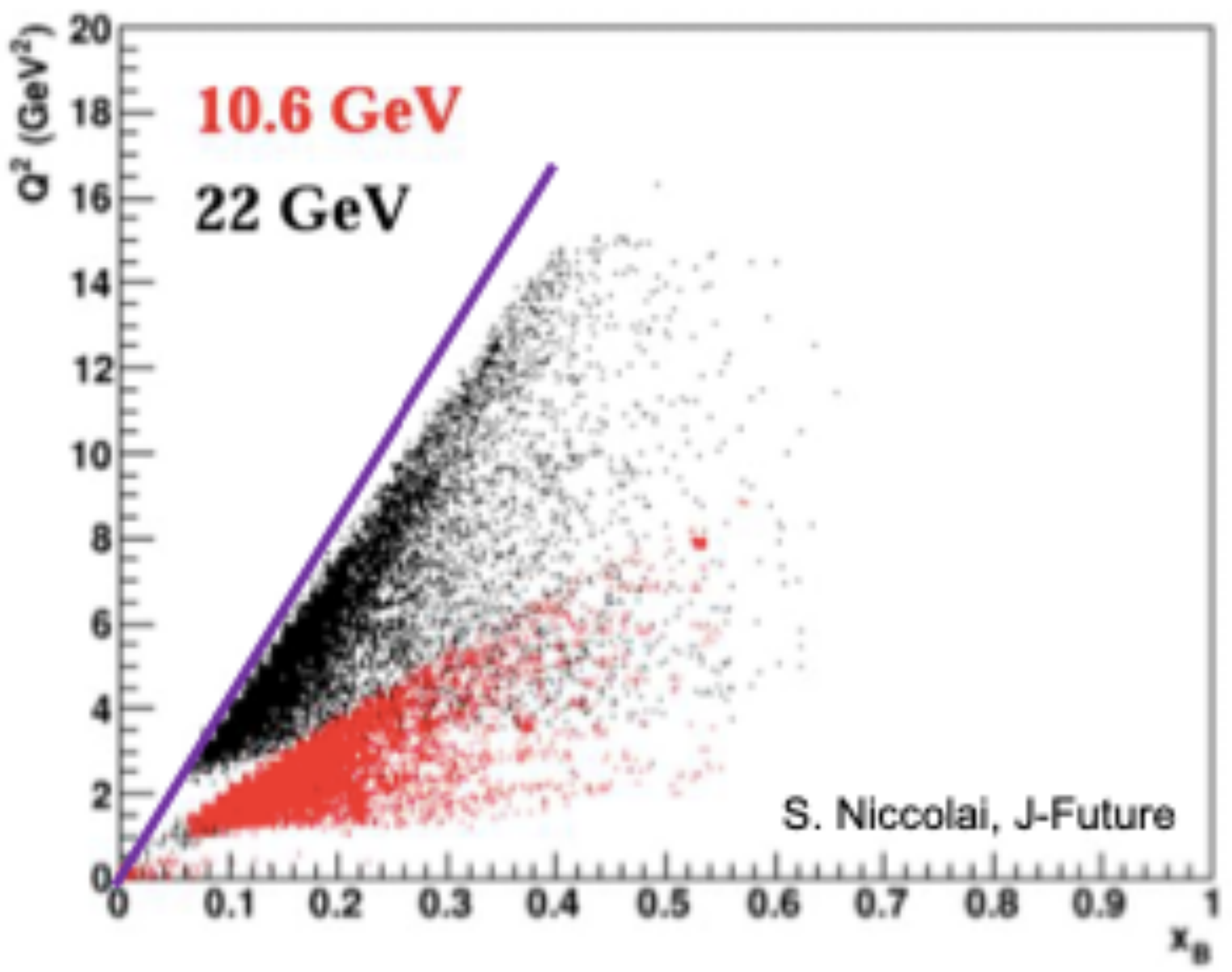


HERMES vs JLAB data

- Current HERMES data greater Q^2 coverage, but less t coverage than current JLab data
- Upgrading to 20^+ GeV will bring all that wonderful JLab precision to the HERMES kinematical space!

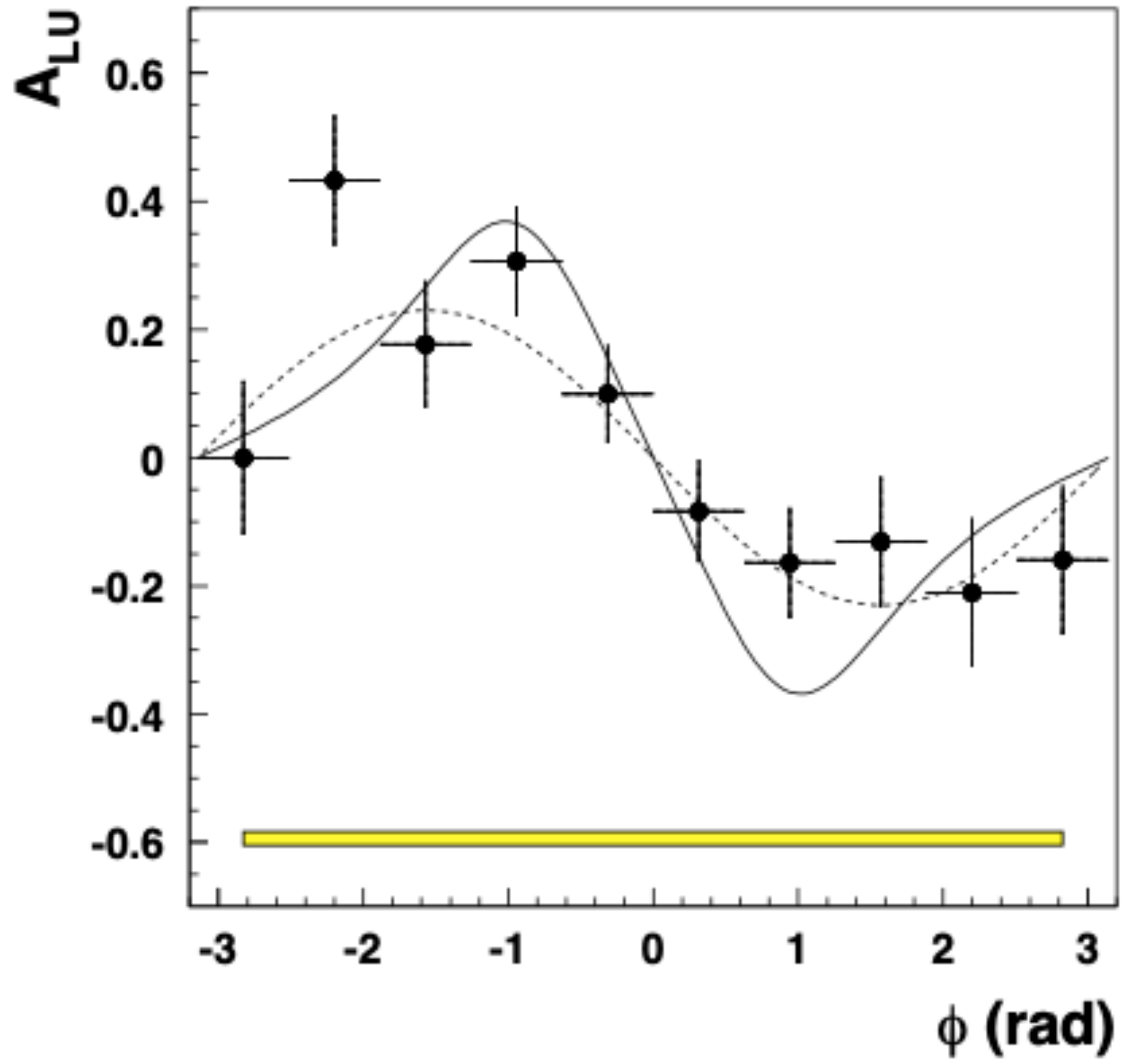
- HERMES data
- current JLAB data





Case Comparison: A_{LU}

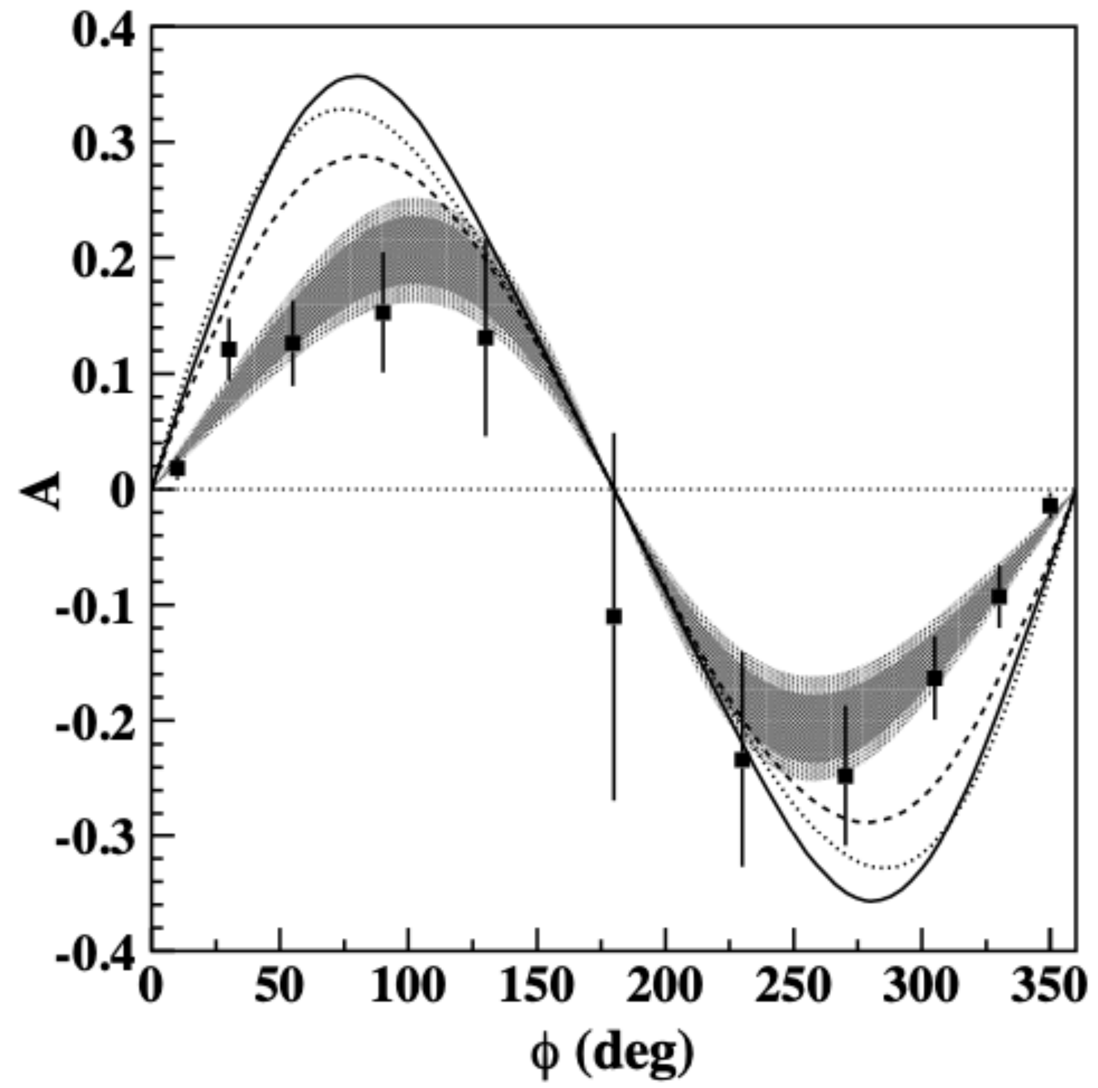
HERMES 2001



By combining the $A_{LU}^{\sin\phi}$ data in the same M_x region as was used for Fig. 3 (-1.5 < M_x < 1.7 GeV), an average value of -0.23 ± 0.04 (stat) ± 0.03 (syst) is obtained. The average values of the kinematic variables corresponding to this measurement are: $\langle x \rangle = 0.11$, $\langle Q^2 \rangle = 2.6$ GeV^2 and $\langle -t \rangle = 0.27$ GeV^2. Since the BH pro-

$$A_{LU}^{\sin(\phi)} = 0.23 \pm .04$$

CLAS 2001

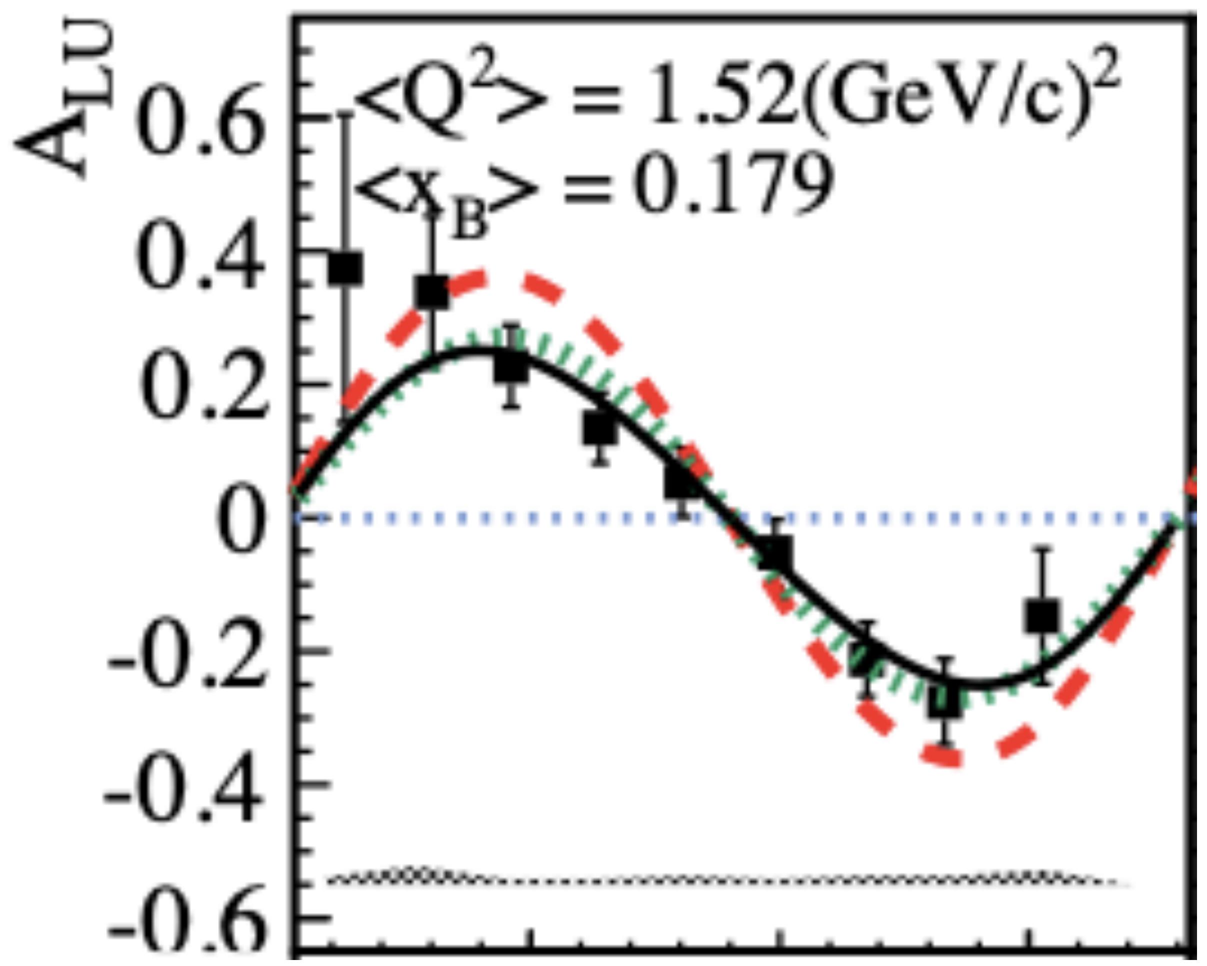


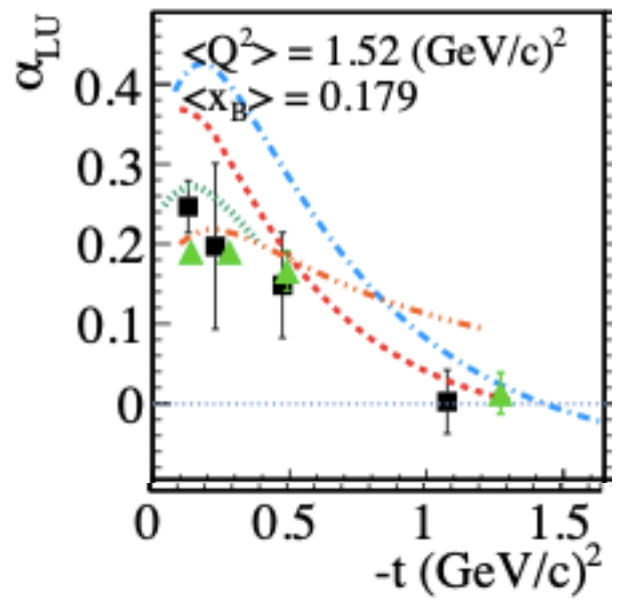
a $\sin\phi$ modulation. Curves in Figure 4 show the results of theoretical calculations from Refs. [5,11,13] at fixed values of $Q^2 = 1.25$ (GeV/c)^2, $x_B = 0.19$, and $-t = 0.19$ (GeV/c)^2. The limited experimental informa-

The data points are fitted with the function $A(\phi) = \alpha \sin\phi + \beta \sin 2\phi$. The fitted parameters are $\alpha = 0.202 \pm 0.028^{stat} \pm 0.013^{sys}$ and $\beta = -0.024 \pm 0.021^{stat} \pm 0.009^{sys}$.

$$A_{LU}^{\sin(\phi)} = 0.20 \pm .03$$

CLAS 2015





$$A_{LU}^{\sin(\phi)} = 0.25 \pm .02$$

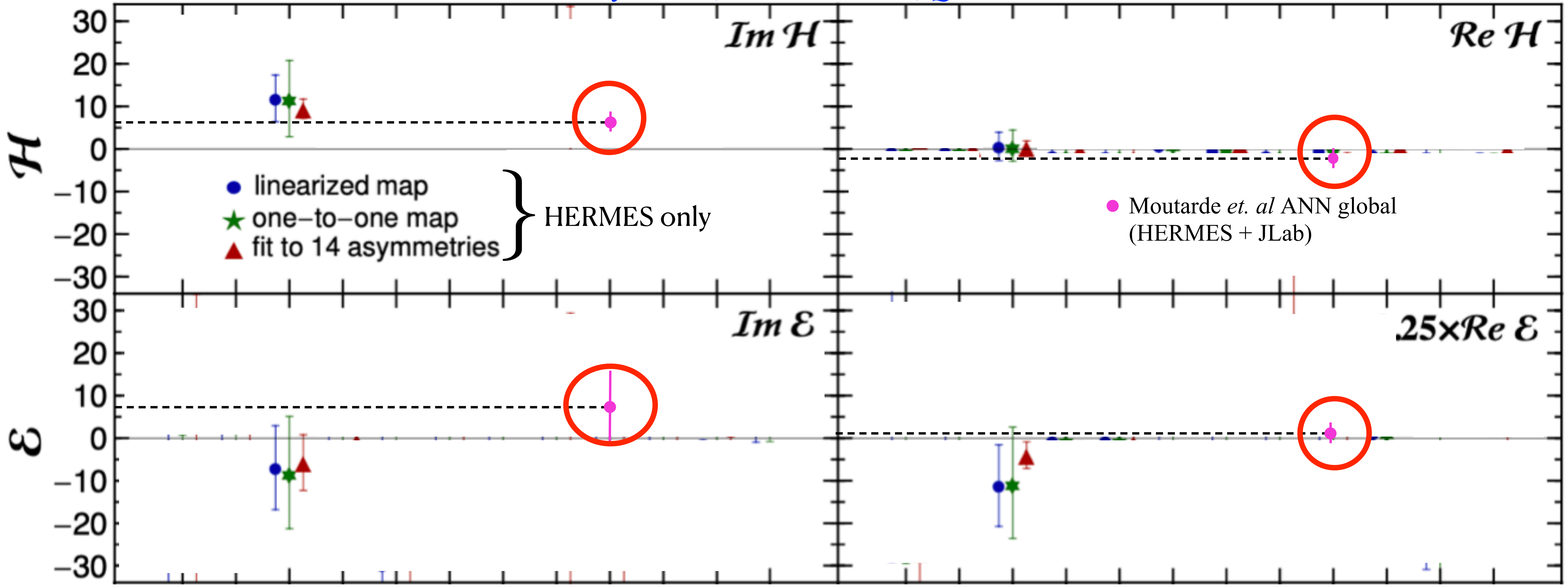
$A_{LU}^{\sin(\phi)}$ fractional uncertainty improved by factor of 2

This improvement directly translates to CFFs

Global Analyses of DVCS data

- A general global analysis should not use linear approximations
- They should either use numerical χ^2 fitting method (Guidal & Boer 2015) or NNs (Moutarde 2019)

$\xi = 0.06,\ t \approx -0.3\ \mathrm{GeV}^2,\ Q^2 \approx 2\ \mathrm{GeV}^2$



- The inclusion of higher luminosity, higher precision data results in determining CFFs (and thus GPDs) with smaller uncertainties

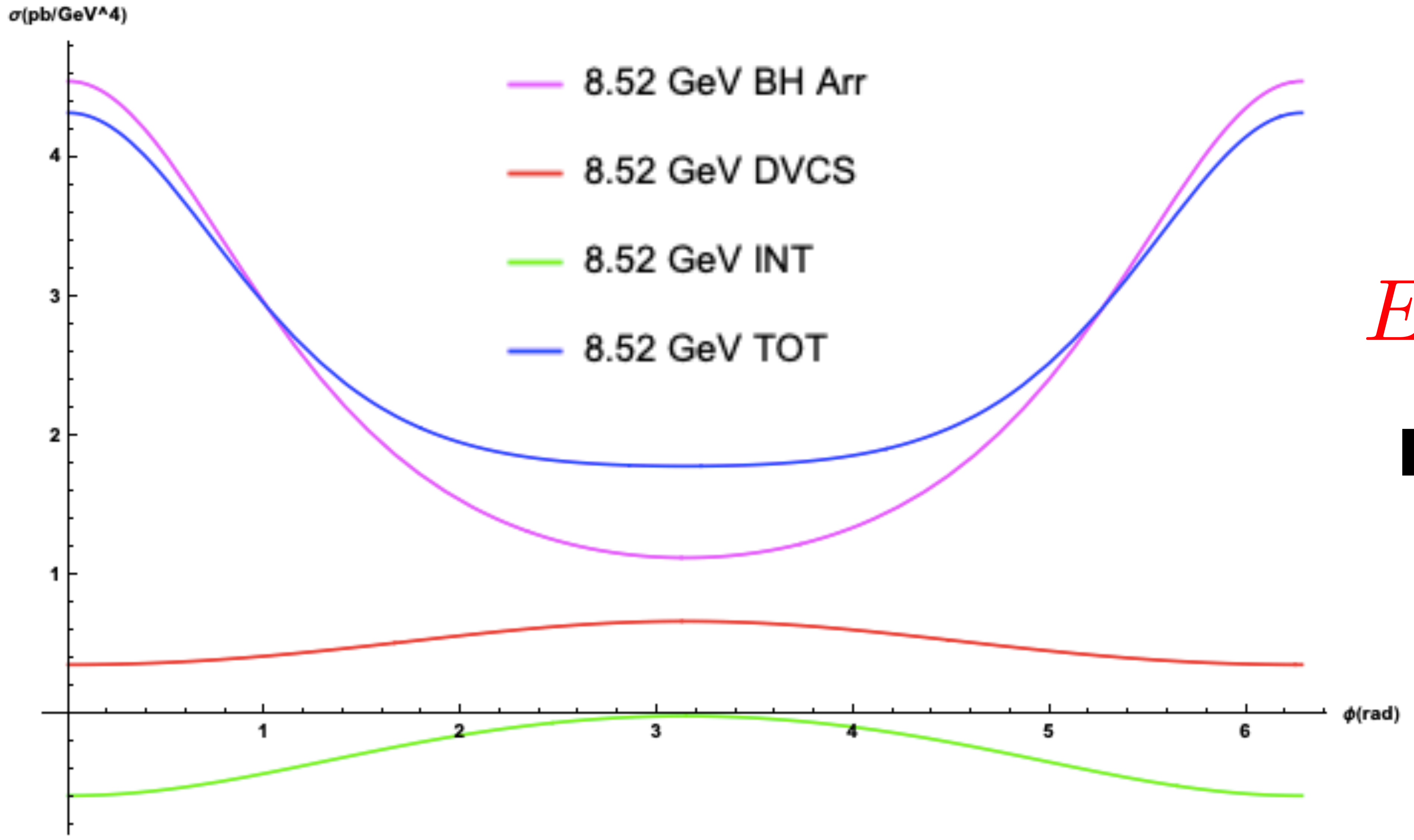
20 GeV DVCS Cross Section Predictions

- Assume the KM15 GPD model at kin. points where it agrees with JLab 12 GeV Hall A data, then predict the Bethe-Heitler (BH), DVCS and Interference cross sections at those kinematics in (E_b, ϕ, x_B, t, Q^2)
- As E_b increases (y decreases) the BH cross section decreases and so does the total cross section
- In general, the different harmonic coefficients of σ_{DVCS} & σ_{INT} behave differently with E_b, and since those cross sections make up a larger portion of the total, one can get a different ϕ dependence of the total cross section than at low energies

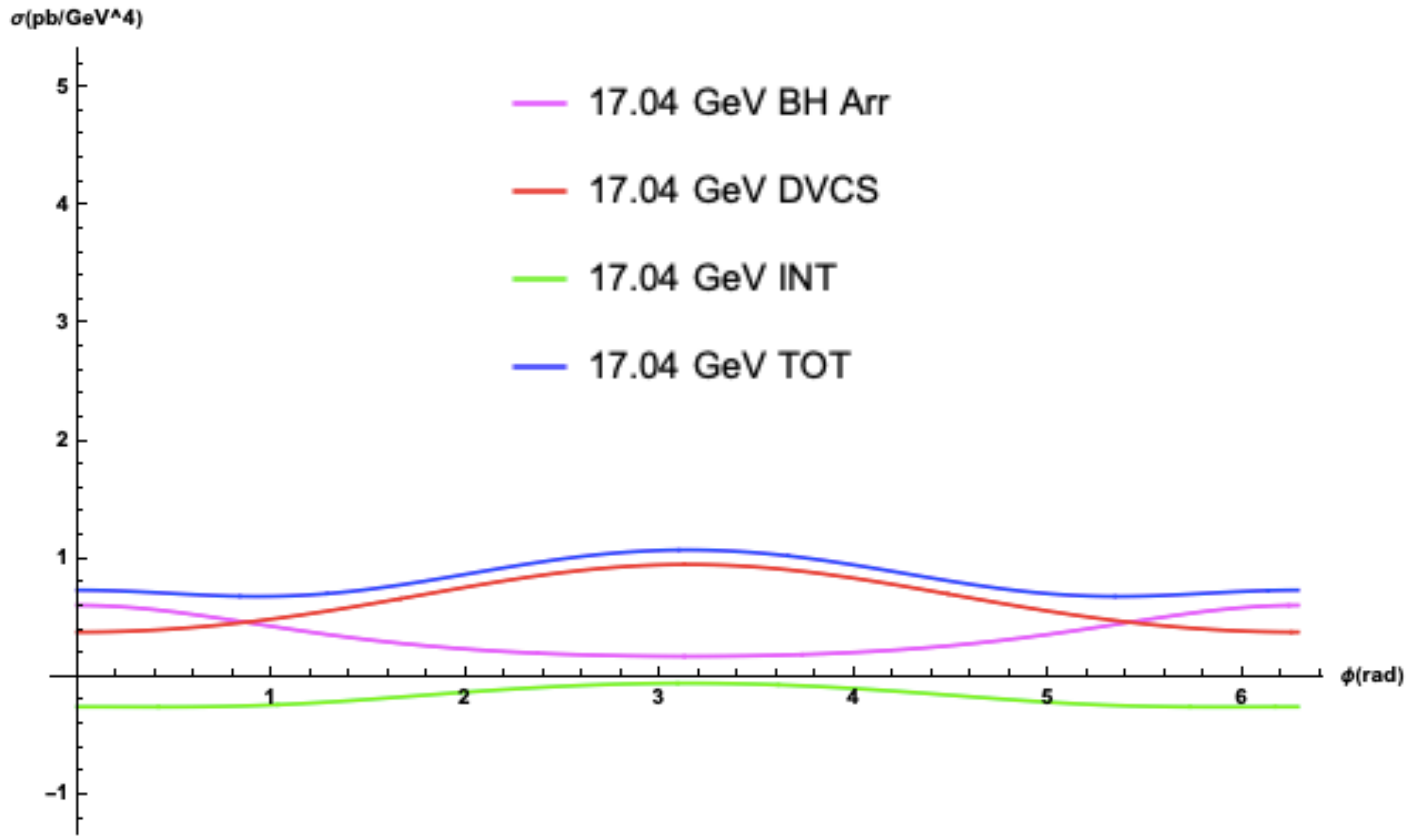
$x_B = 0.48$

$t = -0.51 \text{ GeV}^2$

$Q^2 = 5.36 \text{ GeV}^2$



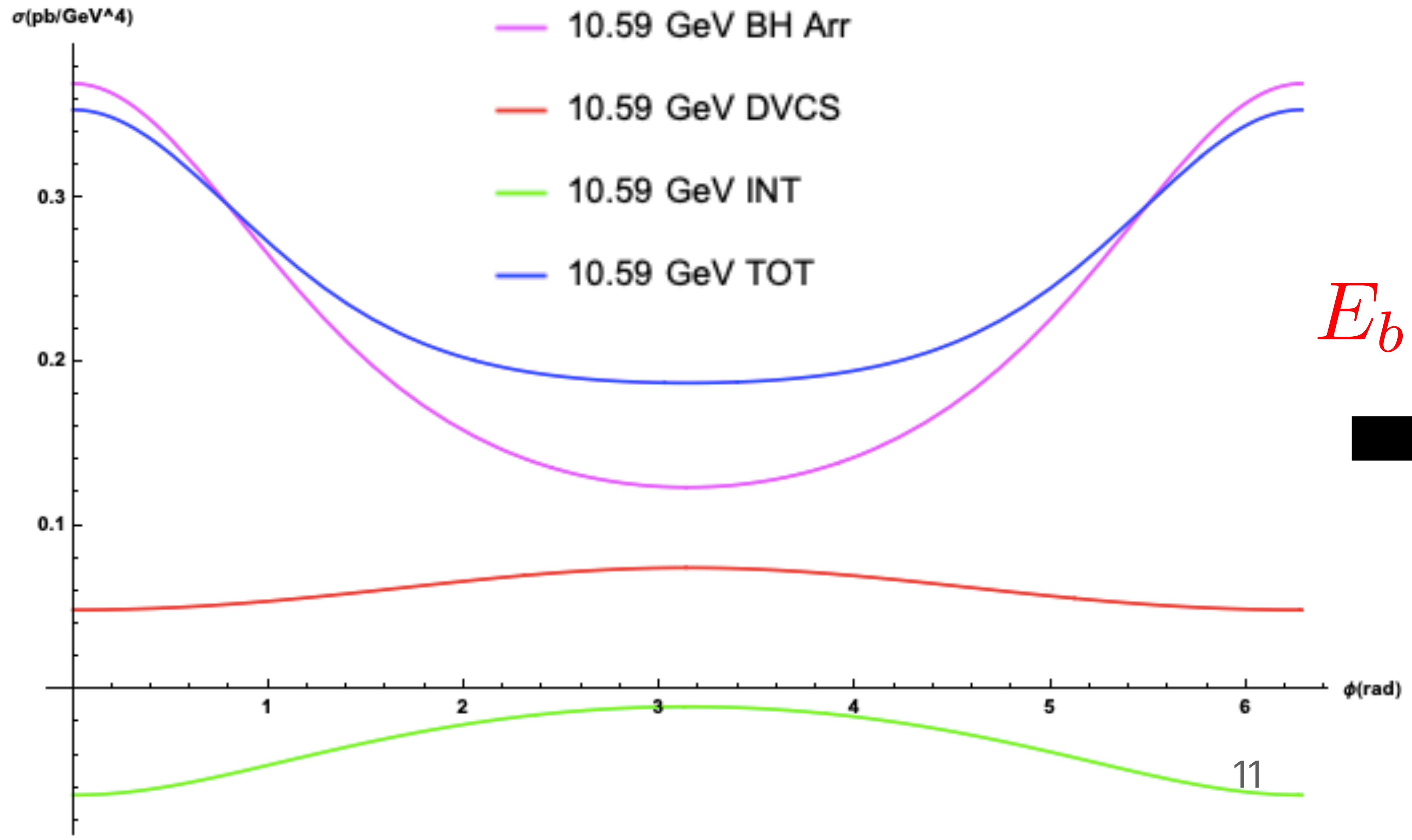
$E_b \times 2$



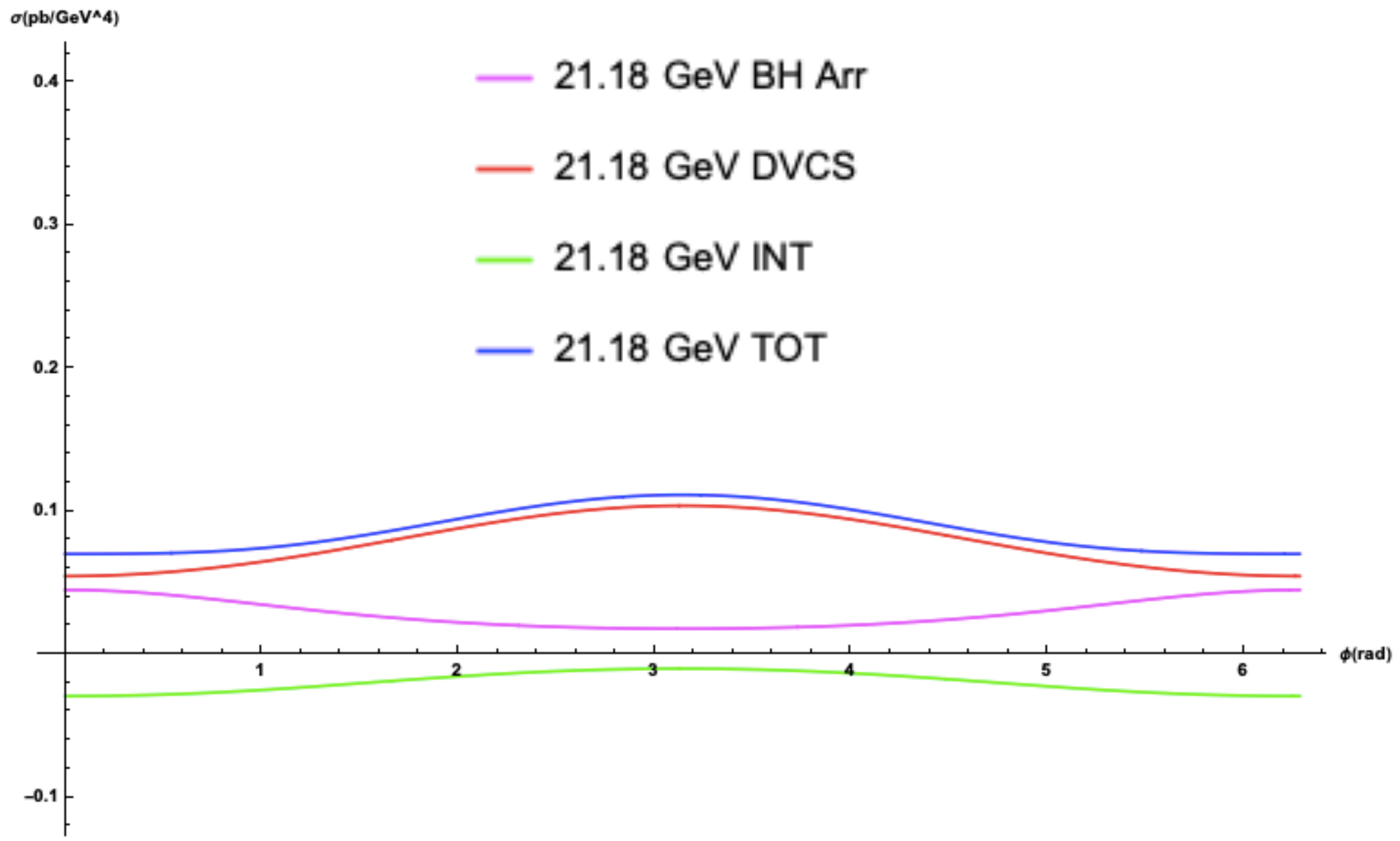
$x_B = 0.6$

$t = -0.91 \text{ GeV}^2$

$Q^2 = 8.45 \text{ GeV}^2$



$E_b \times 2$



Additional Remarks about 20 GeV

- Bethe-Heitler cross section decreases while its uncertainty remains fixed
- However, the total cross section decreases too so the benefit appears to diminish
- Having multiple beam energies (doubled by upgrade) is a great benefit for CFF extraction, as they provide additional unique constraints on CFFs

$$\sigma^{UU}_{\rm DVCS} = \frac{2\pi\Gamma}{Q^4} \sum_n h^U_n(E_b; x_B, t, Q^2)\mathcal{D}(\mathcal{F}^2)\cos(n\phi) \qquad \mathcal{F} = \mathcal{H}, \mathcal{E}, ...(x_B, t, Q^2)$$

$$\#constr \approx \textstyle\sum_{\rm pol.}(\#E_b) \times (\#harm/pol.)$$

For stable CFF extraction (unique solution): $\#constr \geq \#param$

twist 2 CFFs $\Rightarrow$ 8 param

Higher Twist Suppression

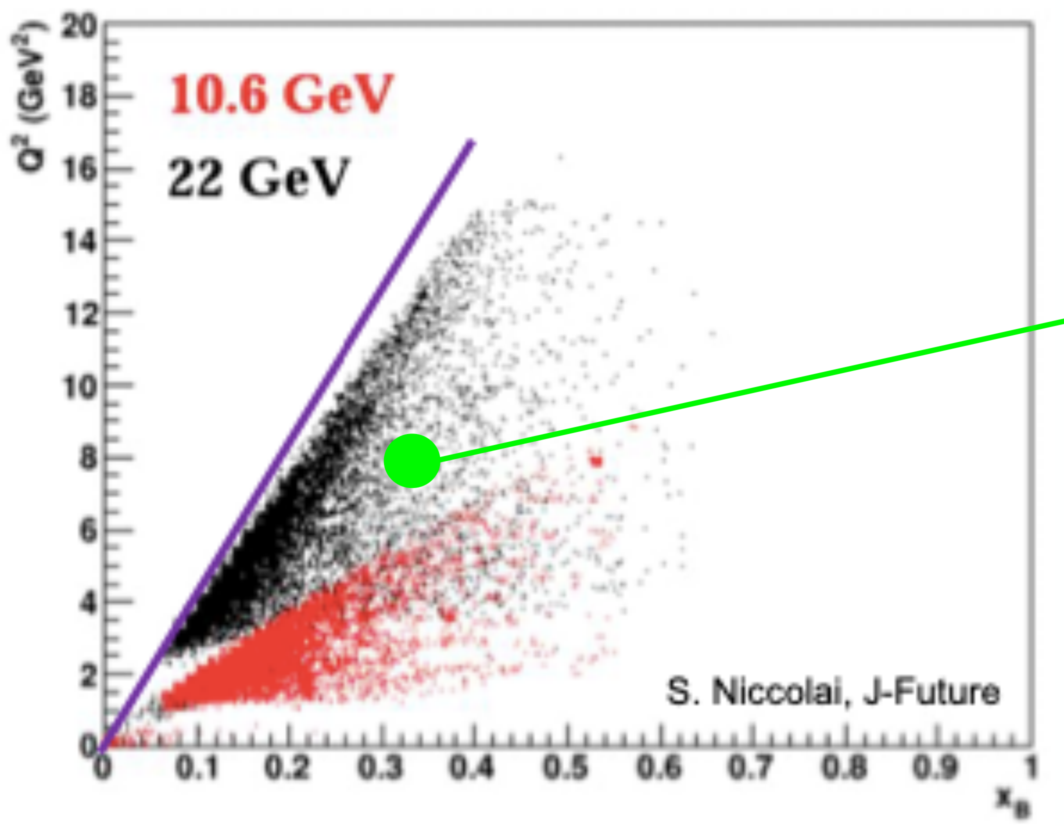
- Higher beam energy allows higher Q^2 (at a fixed x_B), which allows one to get events where higher twist effects are very small

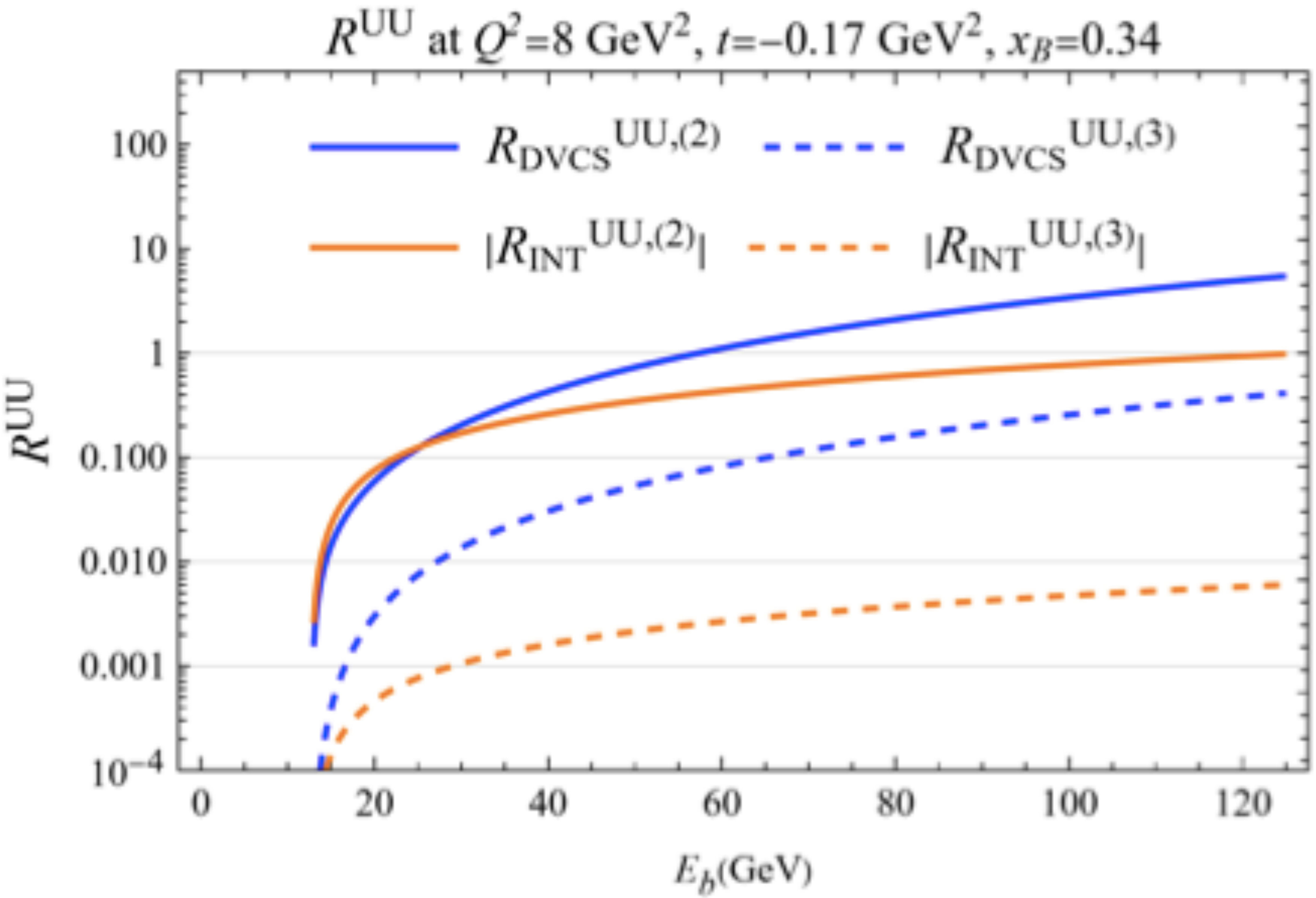
- Define ϕ-integrated cross section ratio:

$$R_i^{\mathrm{UU}}(x_B, Q^2, t) = \frac{\mathrm{d}^3\sigma_i^{\mathrm{UU}}}{\mathrm{d}x_B \mathrm{d}Q^2 \mathrm{d}|t|} \left(\frac{\mathrm{d}^3\sigma_{\mathrm{BH}}^{\mathrm{UU}}}{\mathrm{d}x_B \mathrm{d}Q^2 \mathrm{d}|t|} \right)^{-1}$$

$$i = \mathrm{DVCS, INT}$$

$$R_i^{\mathrm{UU}} = R_i^{\mathrm{UU},(2)} + R_i^{\mathrm{UU},(3)} + \cdots$$





What we need next:

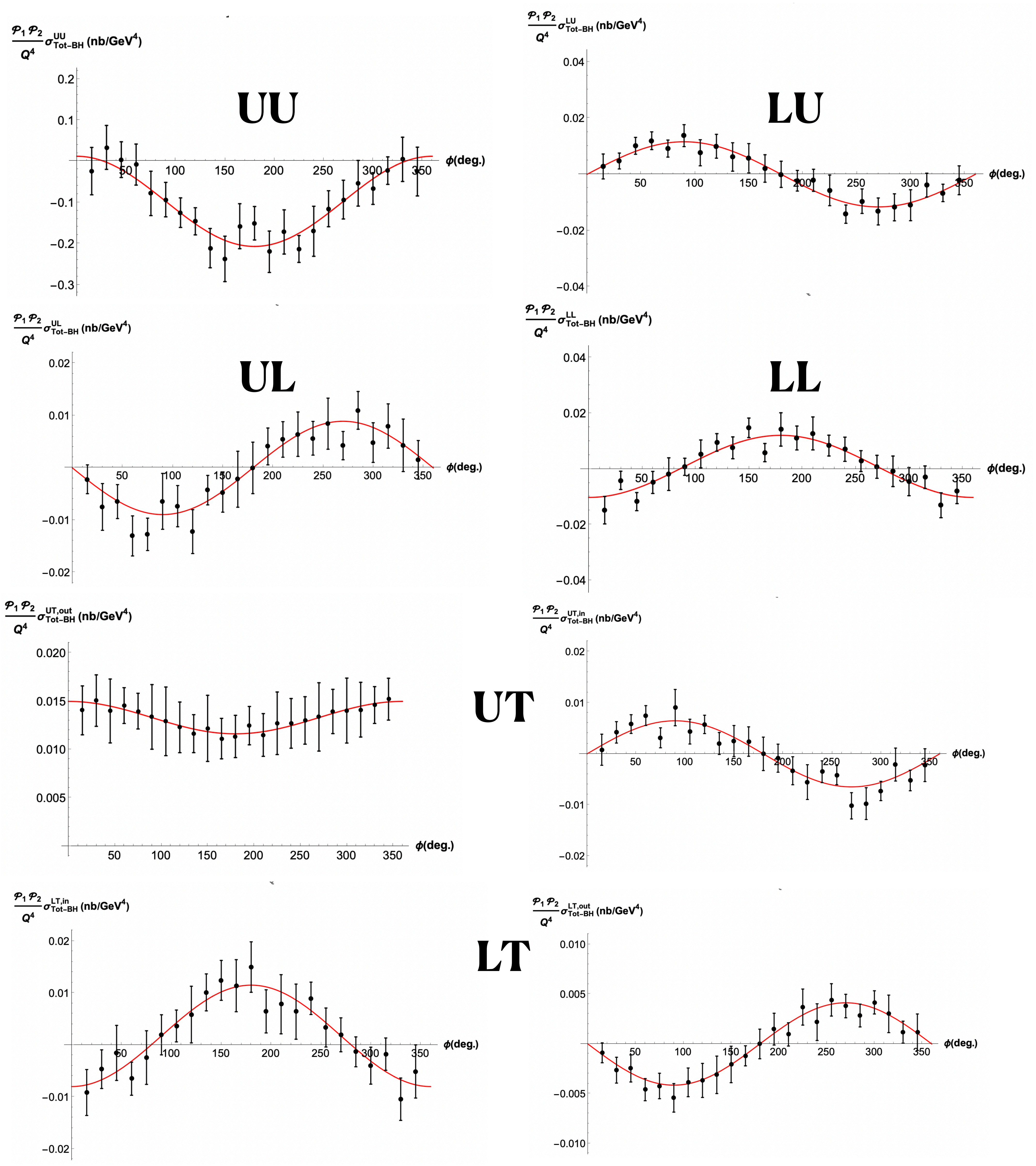
- We need MORE data:

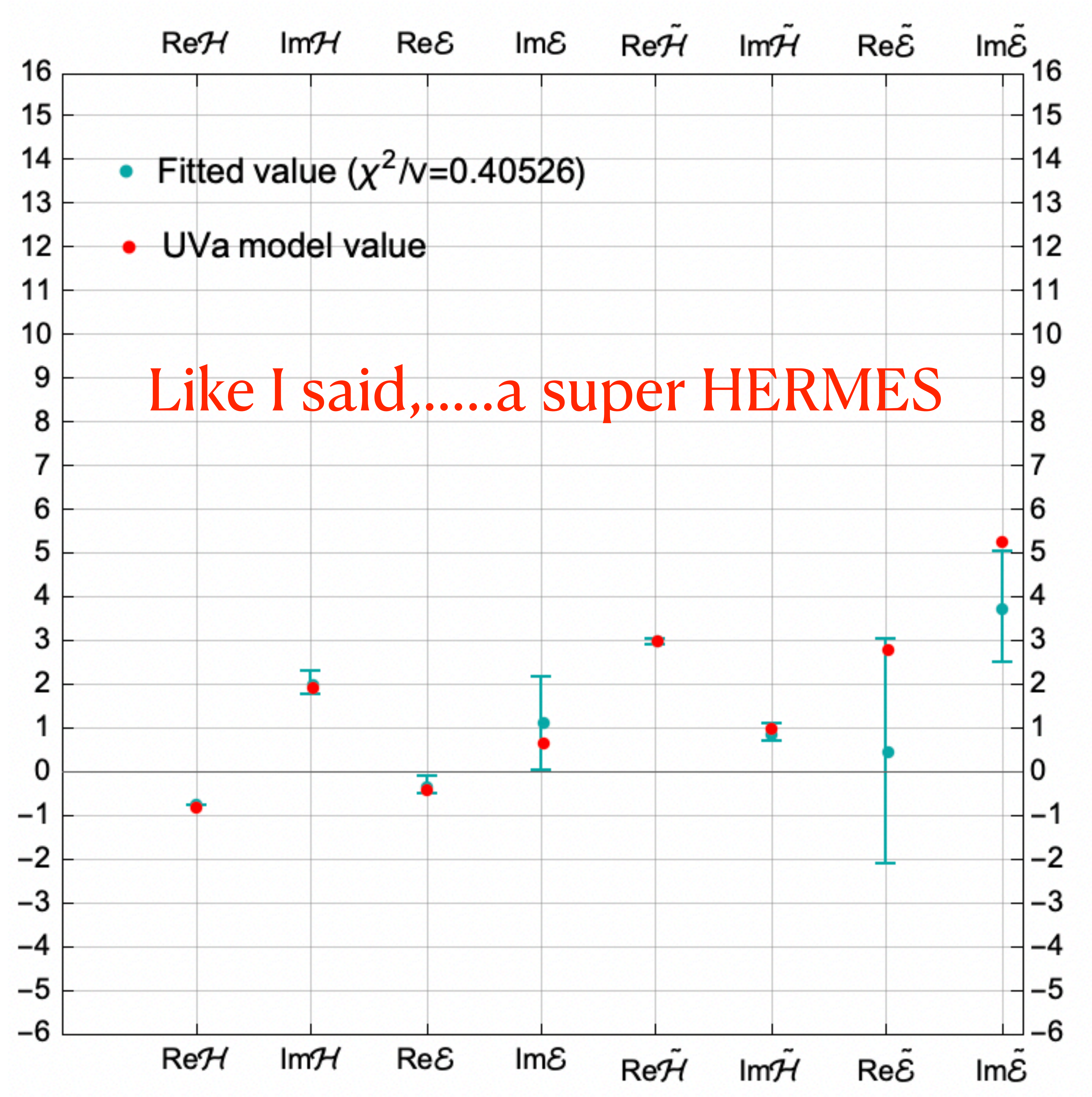
  A. More data points in general but also…
  B. More kinematical coverage in: (Q^2, x_B, t)
  C. More observable variety: UU, LU, UL, LL, UT, LT
  D. Even extend that to charge asymmetries (positrons) and even other processes like DDVCS and TCS
  E. Spread over full range of ϕ (and ϕ_S for Transverse targets)

Hall B asymmetries

- With that understood, going to 24 GeV gives additional advantages

Observable Breadth: CFF Extraction





Final Remarks

- Higher CBAF energies allows greater kinematical coverage
- This together with a broad DVEP measurement program will truly make JLAB a "super HERMES"
- Additional discrete beam energy measurements **can help one better constrain CFFs** with limited number of observables
- The higher Q^2 reach allows one to **more cleanly extract pure twist-2 CFFs** with suppressed higher twist (≥3) contributions
- Evolution effects in GPDs may be studied more fully at the higher Q^2 as well