Measurement of ^{3}He Elastic Electromagnetic Form Factor Diffractive Minima Using Polarization Observables

On behalf of the E12-06-121 collaboration

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d_2^n Collaboration

^{3}He Elastic Scattering Form Factors

$$\left(\frac{d\sigma}{d\Omega}\right)_{\text{exp}} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \frac{1}{1+\tau}\left[G_E^2(Q^2) + \frac{\tau}{\epsilon}G_M^2(Q^2)\right]$$

Rosenbluth Separation

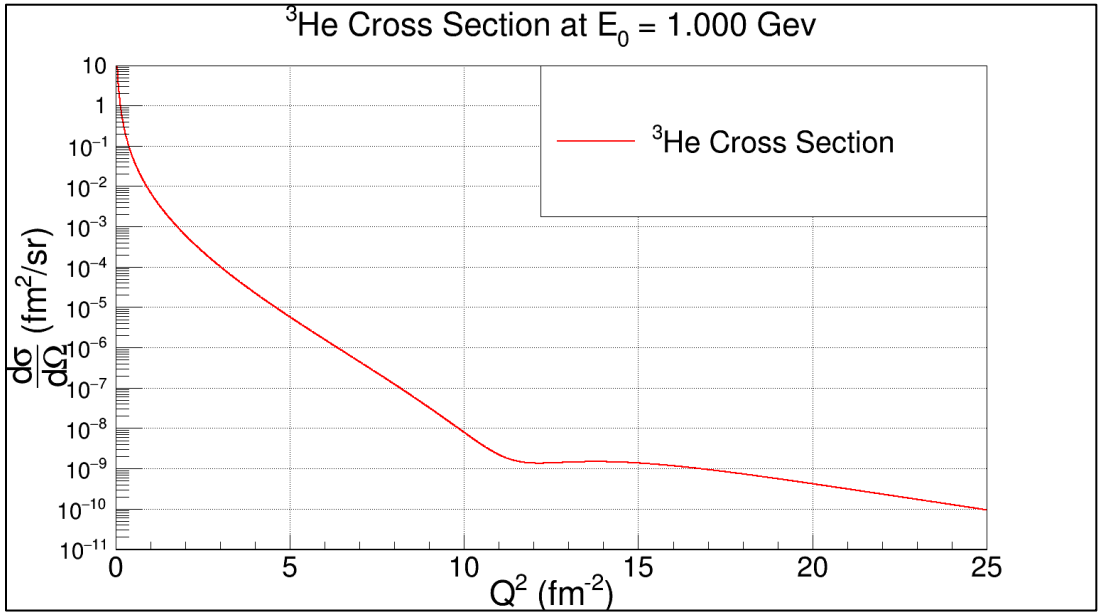
$$\left(\frac{d\sigma}{d\Omega}\right)_{\text{red}} = [\epsilon G_E^2(Q^2) + \tau G_M^2(Q^2)]$$

- G_E & G_M extracted from a linear fit of the cross section with respect to ϵ
  - G_E^2 = slope
  - τG_M^2 = intercept

$$\epsilon \equiv \left(1 + 2(1+\tau)\tan^2\left(\frac{\theta}{2}\right)\right)^{-1}$$

$$\tau \equiv \frac{Q^2}{4M^2}$$

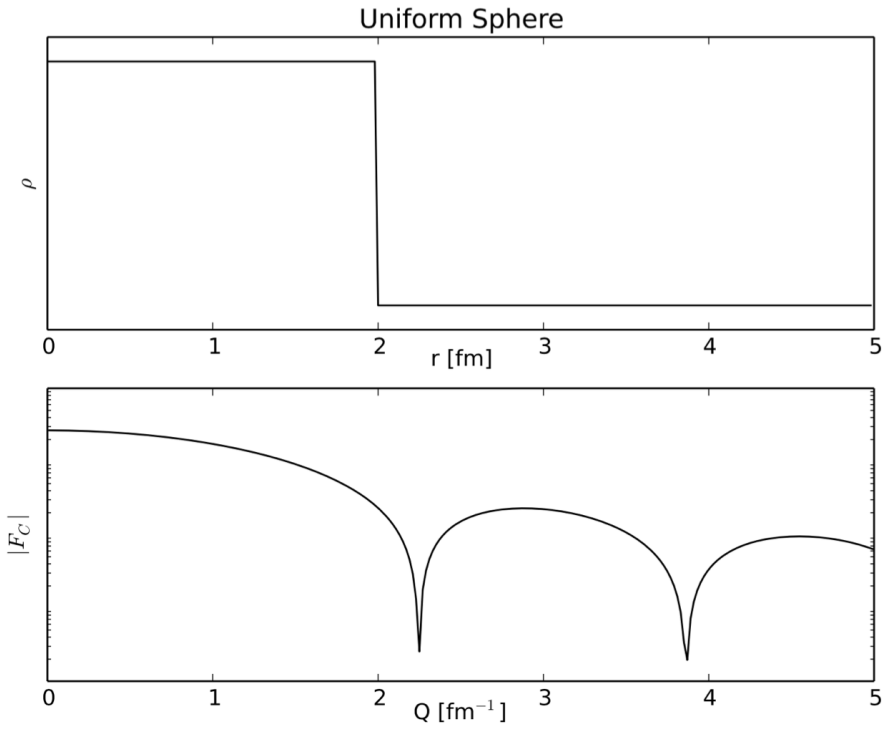
Fit to world data

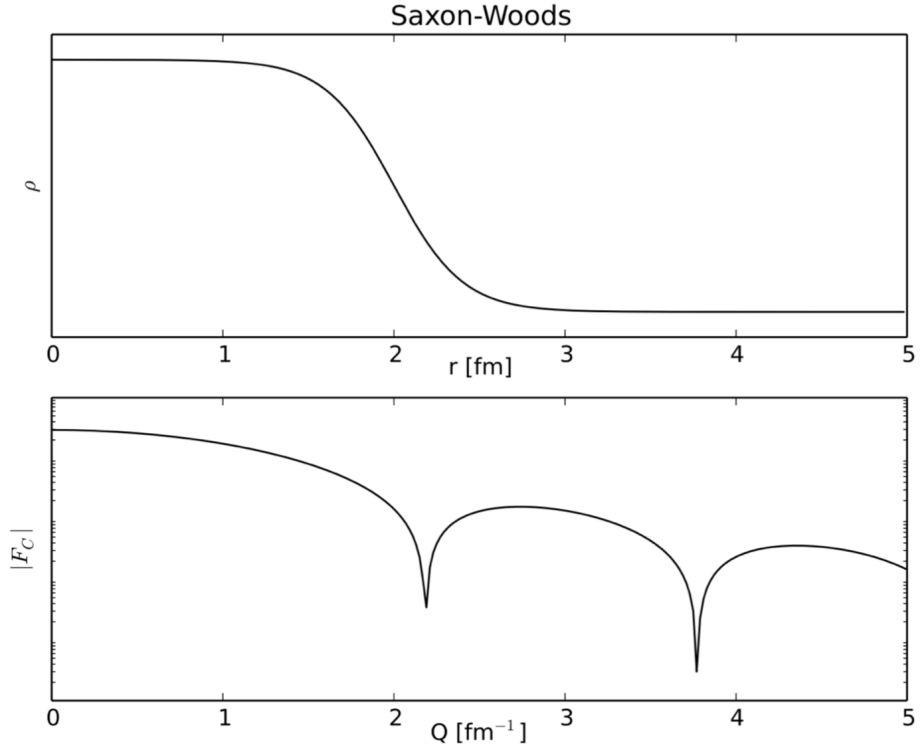


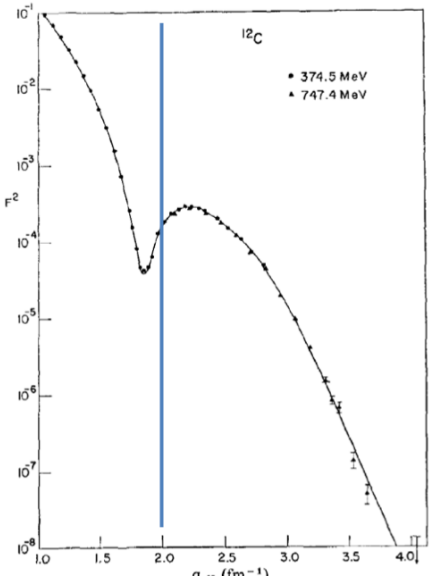
All high Q² Form Factor measurements are from unpolarized elastic scattering

Electron Scattering Charge Radii from Nuclei

Fourier Transformation of Ideal Charge Distributions.



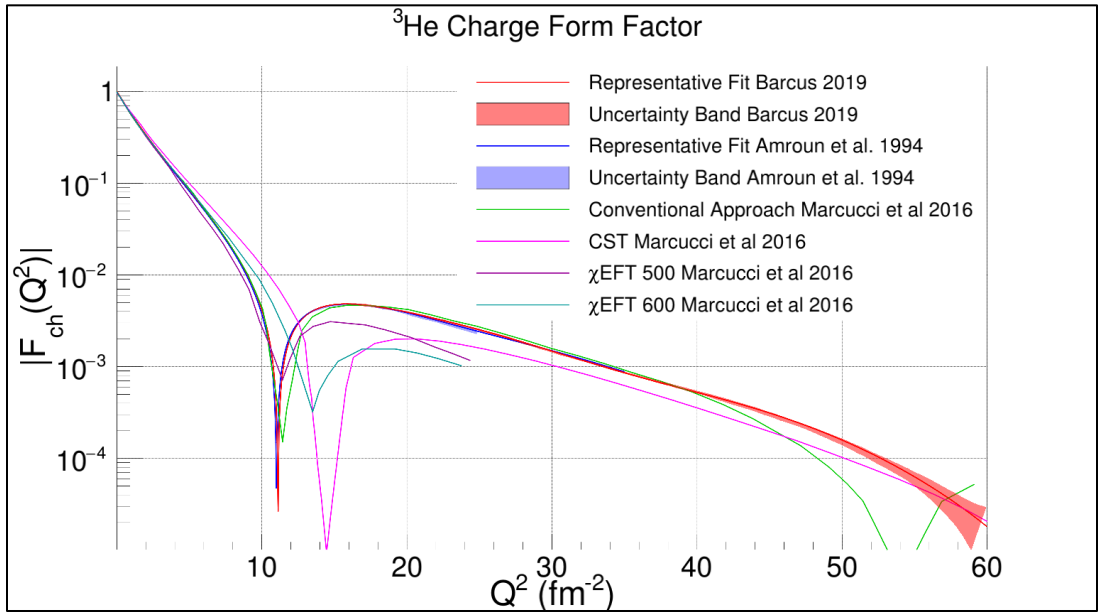


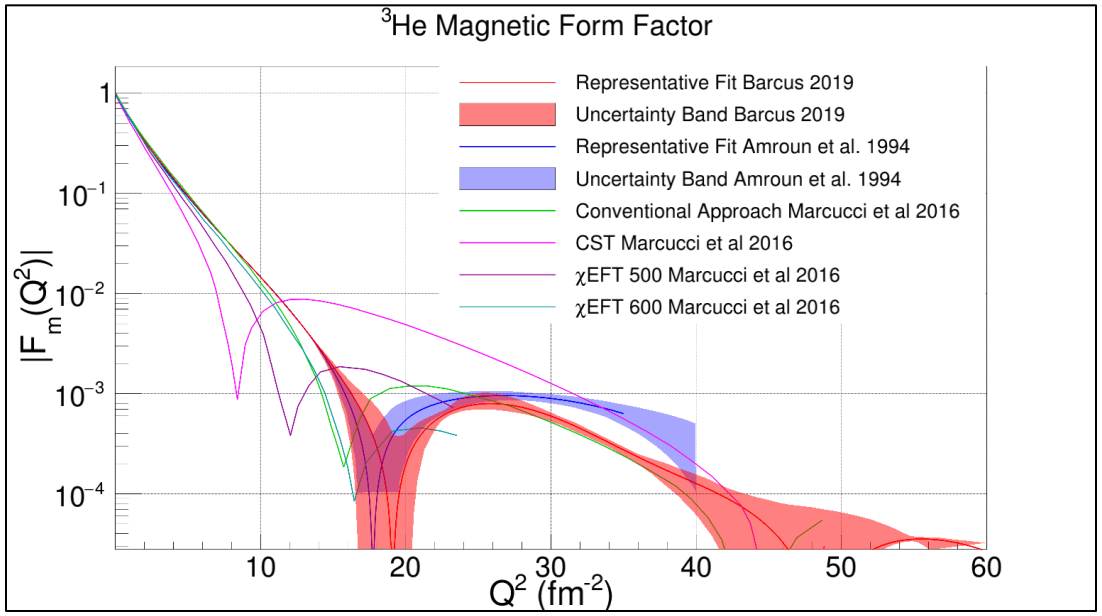


Example Plots Made By R. Evan McClellan

Slide credit to D. Higinbotham

Experimental and Theoretical Comparison



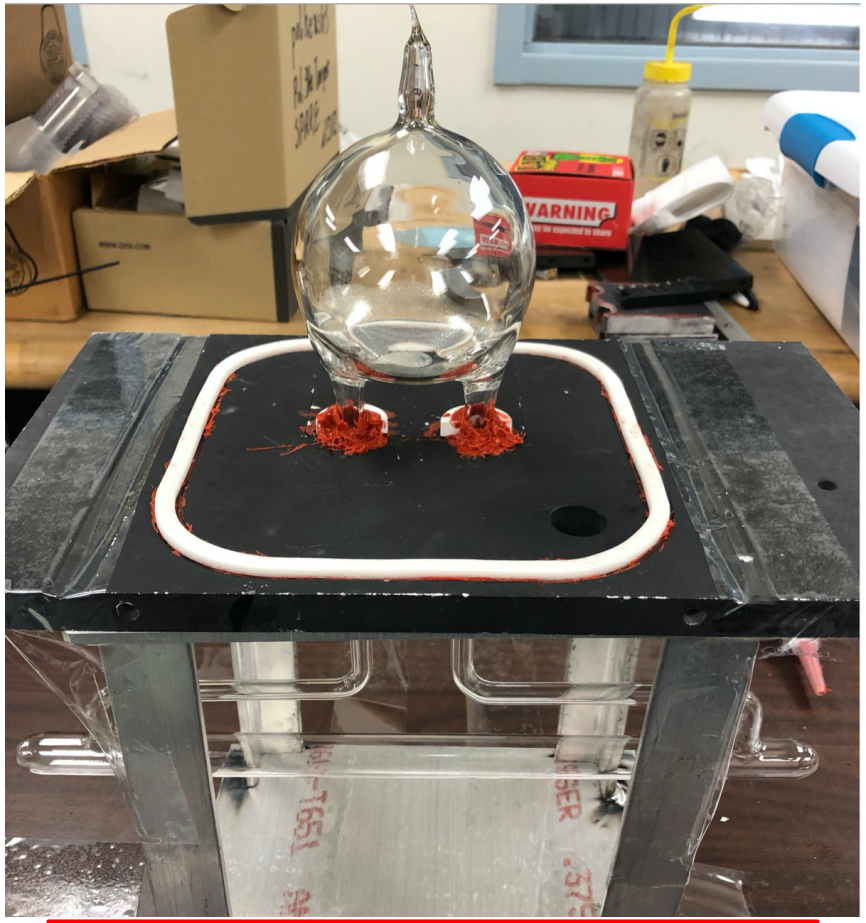


- **Discrepancies in location of minima of the magnetic form factor**
- Rosenbluth separations in diffractive minima are non-trivial
- Sharp minima from a shallow cross section minima

Polarization Measurement

- How to disentangle these differences?
  - **Double-polarization measurement**
- An independent method to constrain the ^{3}He Form Factor
- First high Q^2 elastic asymmetry measurement for ^{3}He
- Help to explain the differences between theory and experimental results

Polarized ^{3}He cell



Details of the polarized ^{3}He target can be found in Mingyu Chen's talk

Double Polarization Measurement

Polarized electron beam and polarized target

$$A_{phys} = \frac{-2\sqrt{\tau(1+\tau)}\tan\left(\frac{\theta}{2}\right)}{G_E^2 + \frac{\tau}{\epsilon}G_M^2}\left[\sin(\theta^*)\cos(\varphi^*)\,G_E\;\;G_M + \sqrt{\tau\left[1+(1+\tau)\tan^2\left(\frac{\theta}{2}\right)\right]}\cos(\theta^*)G_M^2\right]$$

$$A_{meas} = \frac{N^+ - N^-}{N^+ + N^-}$$

$$A_{meas} = P_t P_l\, A_{phys}$$

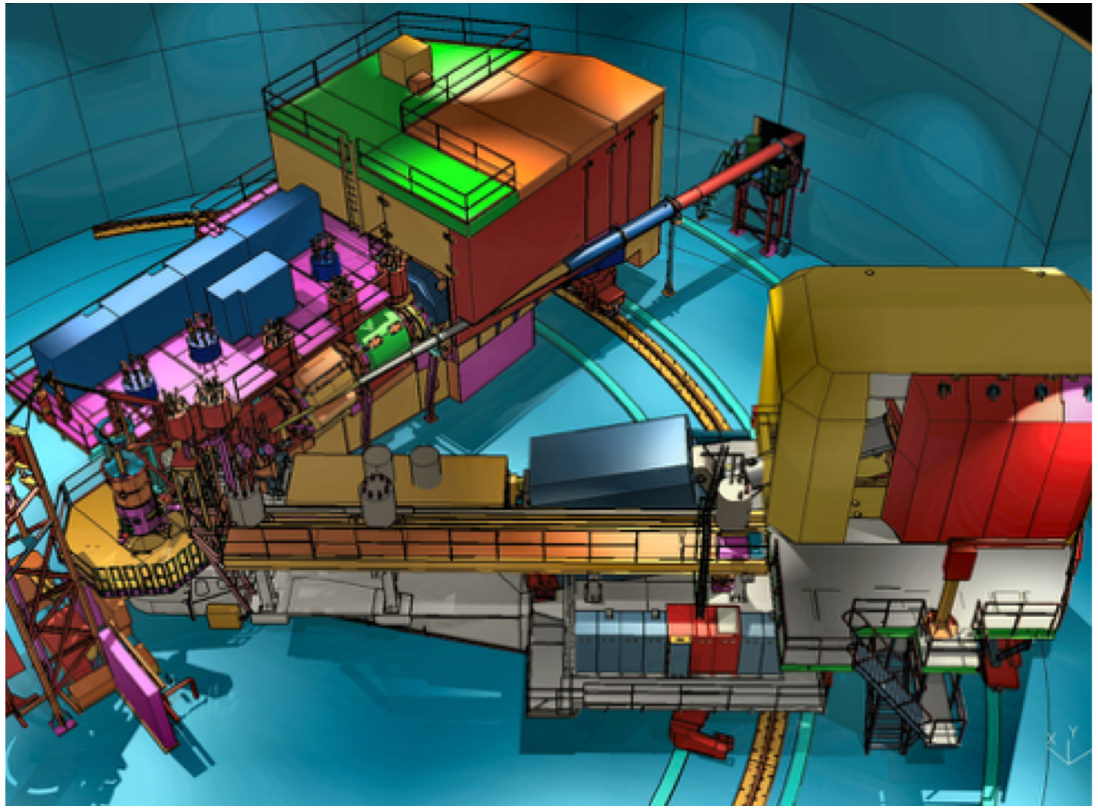
Where

θ^*& φ^* - polar & azimuthal angles of polarization vector of target

P_t&P_l - Polarization of target and electron beam

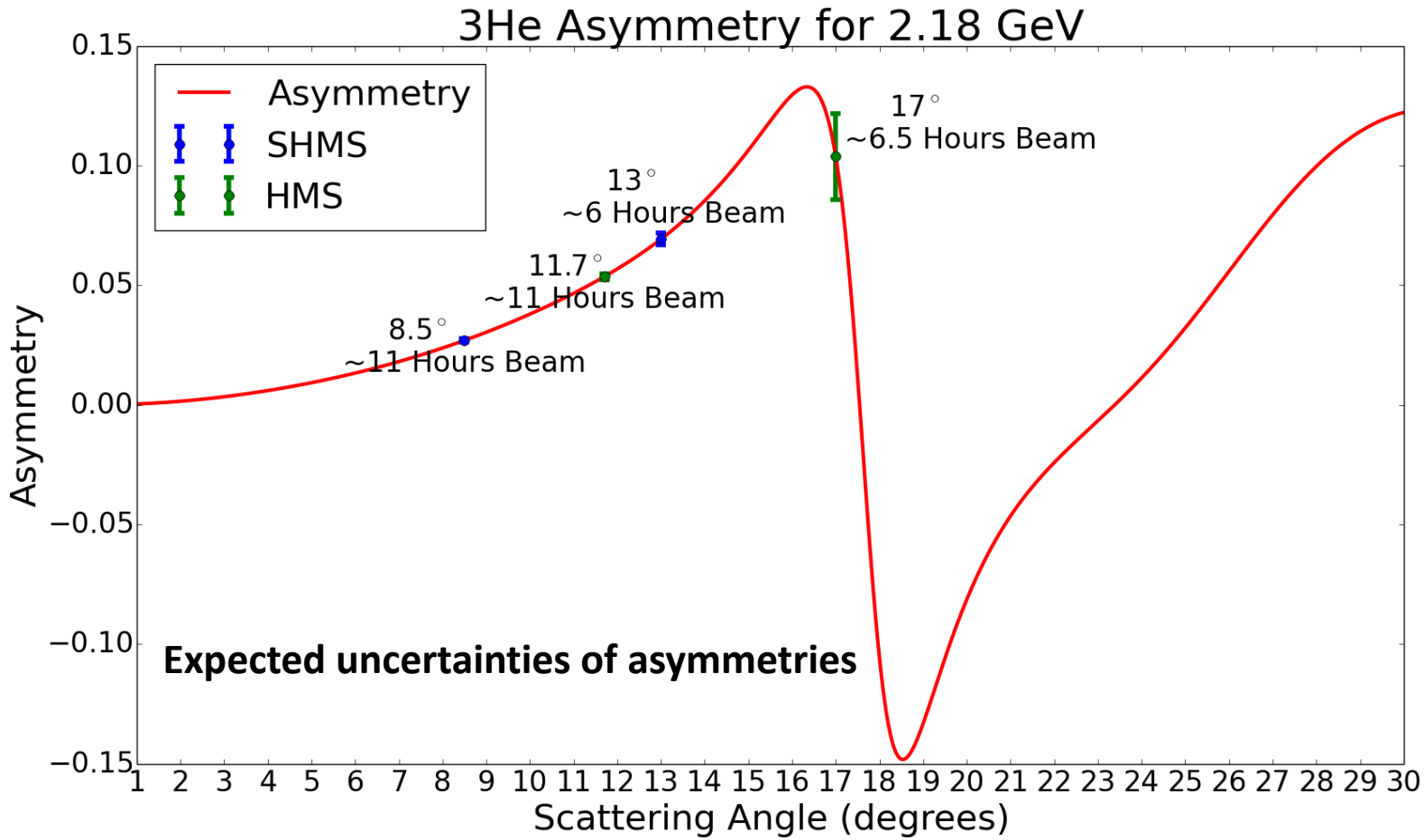
Experiment E12-06-121A

- Ran parasitically in Hall C during d_2^n
  - Configured with d_2^n planned 1st pass systematic measurements
- Target cells
  - Polarized ^{3}He cell
  - Reference ^{3}He cell
- Beam energy: 2.18 GeV
- Beam current: 30 μA (glass cells)
- Detect elastically scattered electrons independently in both HMS and SHMS
- Collected ≈17 hours of data



Measured Kinematic Points

- Will provided further constraints to global fit and better determination of ^{3}He form factors
- Proof of principle



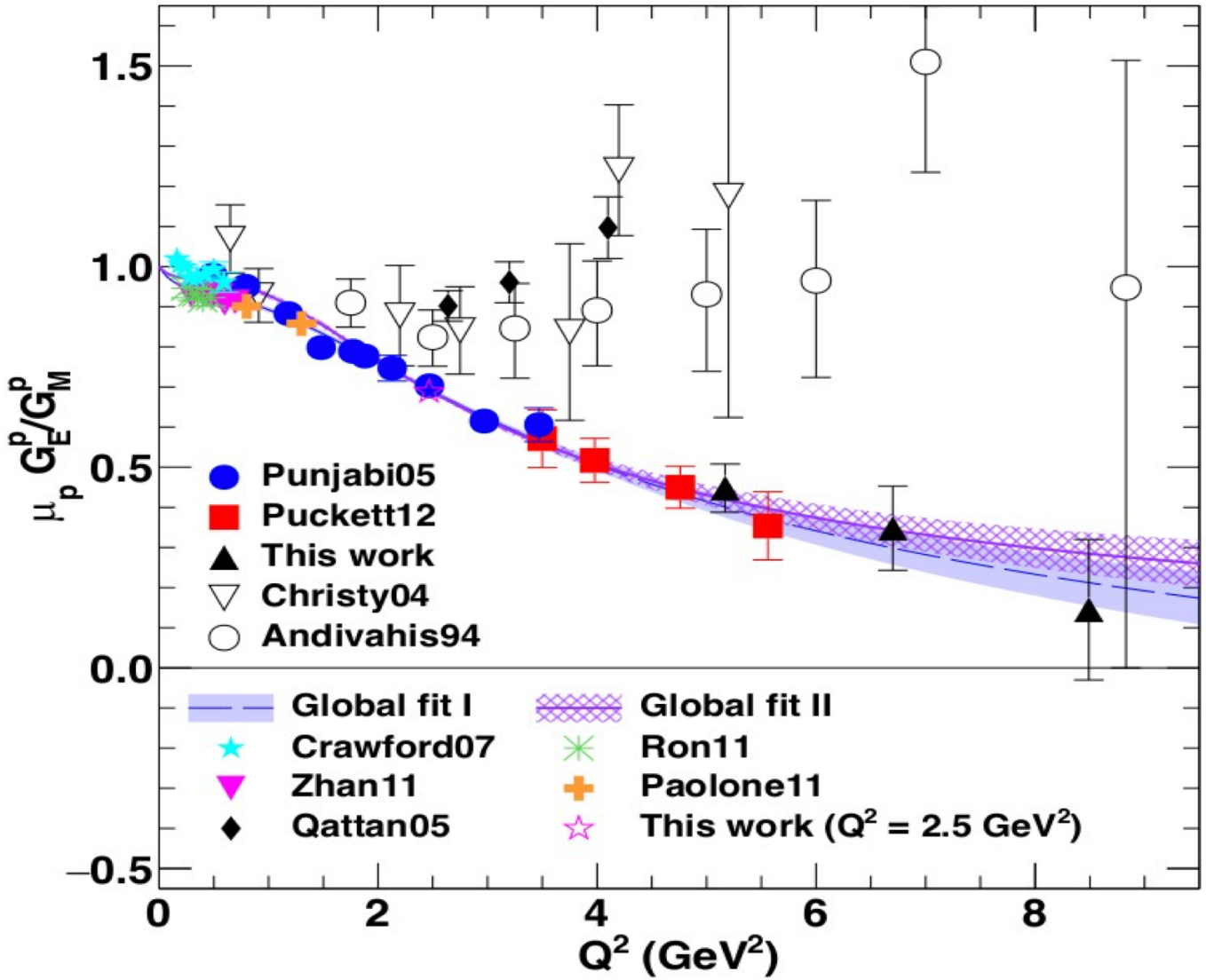
Summary

- Experiment E12-06-121A ran parasitically at the end of the d_2^n experiment during the Fall* 2020 run period
- **First high Q^2 ^{3}He elastic asymmetry points measured**
- Analysis status
  - **First Pass calibrations already preformed by A_1^n and d_2^n students!**
    - Detector Calibrations – See Talks by **Melanie Rehfuss** and **Junhao Chen**
  - Beginning stages of simulation
- Thank you to the Hall C Scientific and Technical staff as well as shift workers for their support!

Thank You

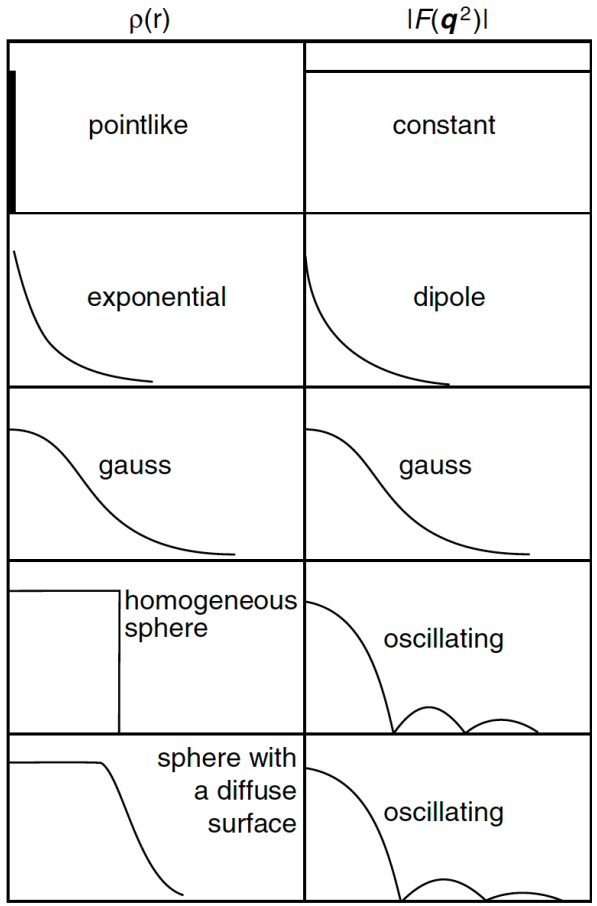
Backup

JLab Hall C GEP-III PRC 96, 055203 (2017)

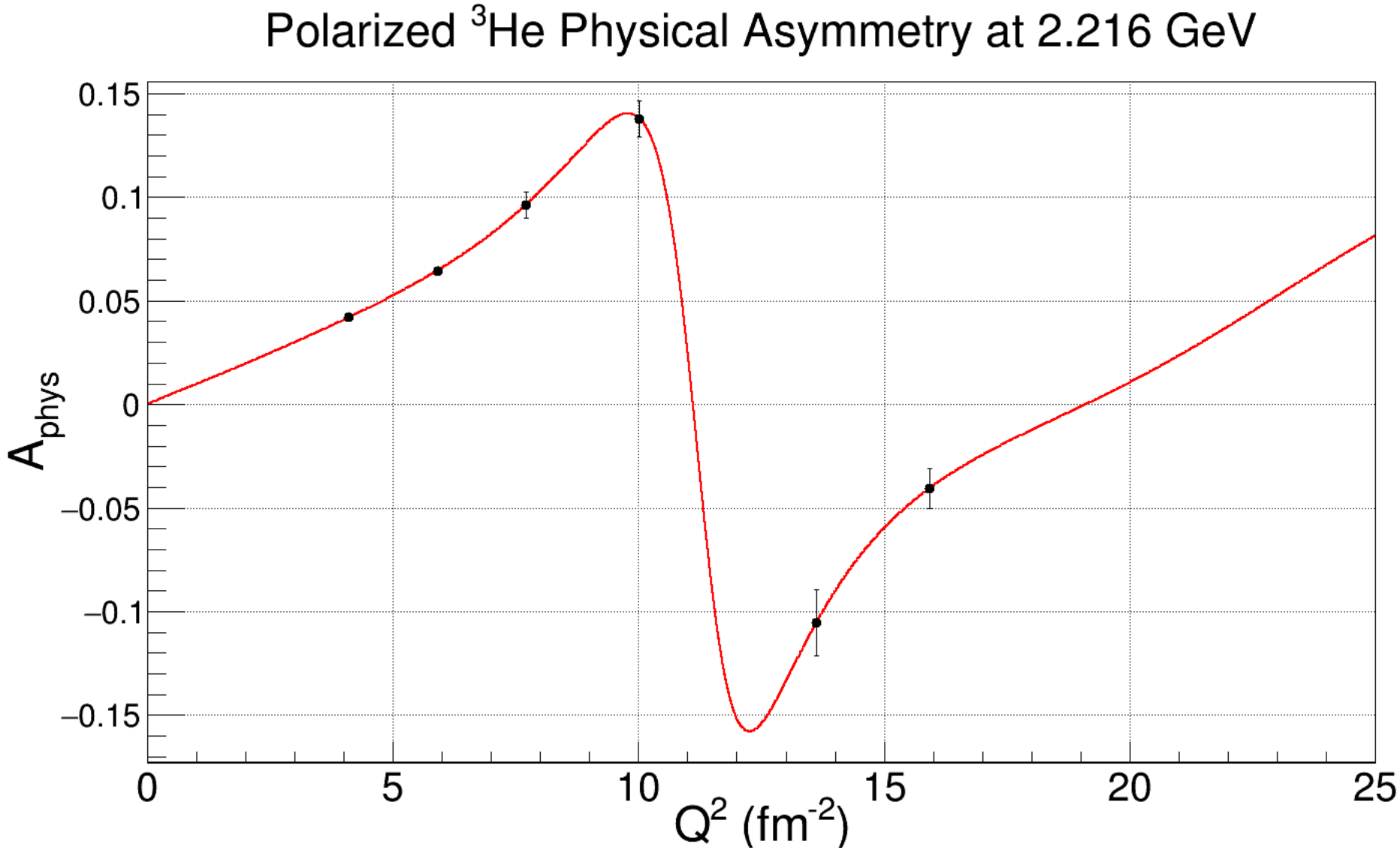


Kinematics

Spectrometer	θ [°]	P_0 [GeV]	Q^2 [fm^{-2}]
SHMS	8.5	2.12	2.60
SHMS	13.0	2.12	6.10
HMS	11.7	2.08	4.88
HMS	17.0	2.08	10.25



Particles and Nuclei


Polarized ^{3}He Physical Asymmetry at 2.216 GeV
A_{phys}
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
0
5
10
15
20
25
Q^2 (fm^{-2})