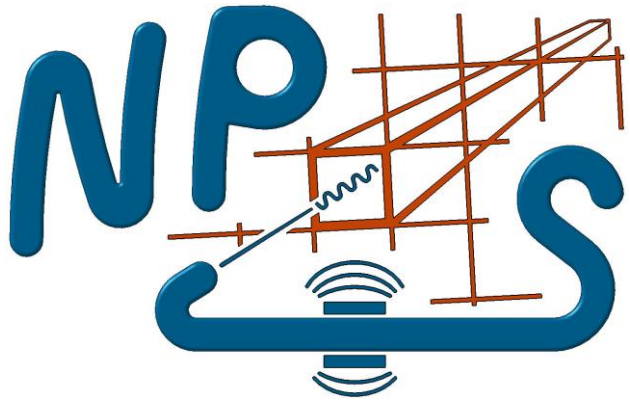

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Deeply Virtual Compton Scattering Using a Neutral Particle Spectrometer in Hall C

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June 12, 2024

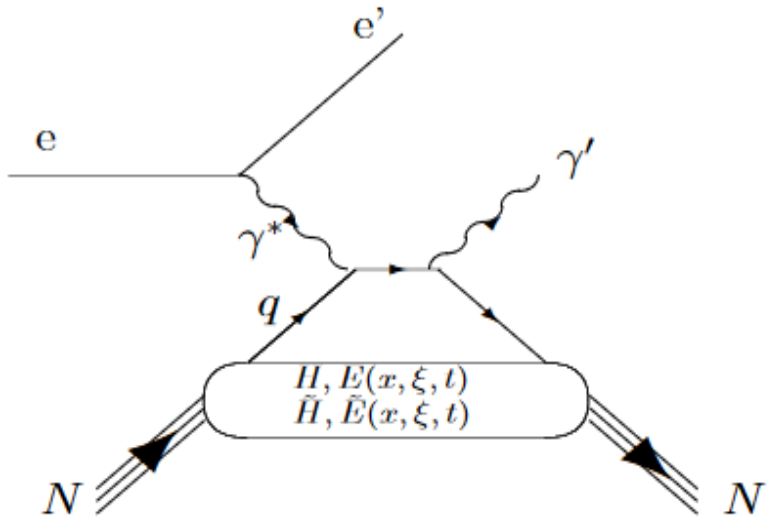
Theory: Internal Structure of the Nucleon

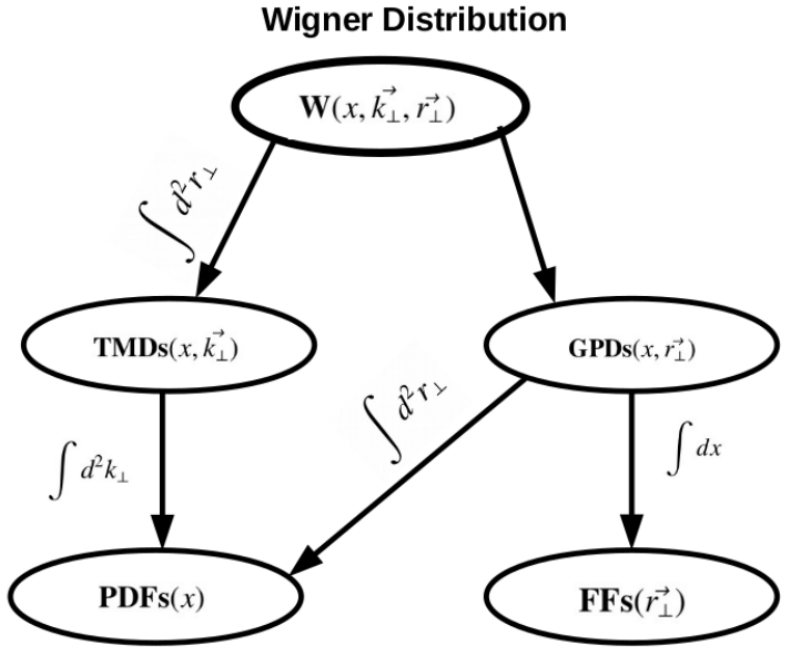
- GPDs develop multidimensional picture of internal nucleon structure

Process	What we get	Info encoded
Elastic scattering ($eN \rightarrow e'N'$)	Form factors	Spatial distribution of electric charge
Deep inelastic scattering (DIS) ($eN \rightarrow e'X$)	Parton distribution functions (PDFs)	Longitudinal momentum distribution of partons
Deeply virtual Compton scattering (DVCS) ($eN \rightarrow e'N'\gamma$)	Generalized parton distributions (GPDs)	Both spatial and momentum distributions of partons

Theory: DVCS and GPDs

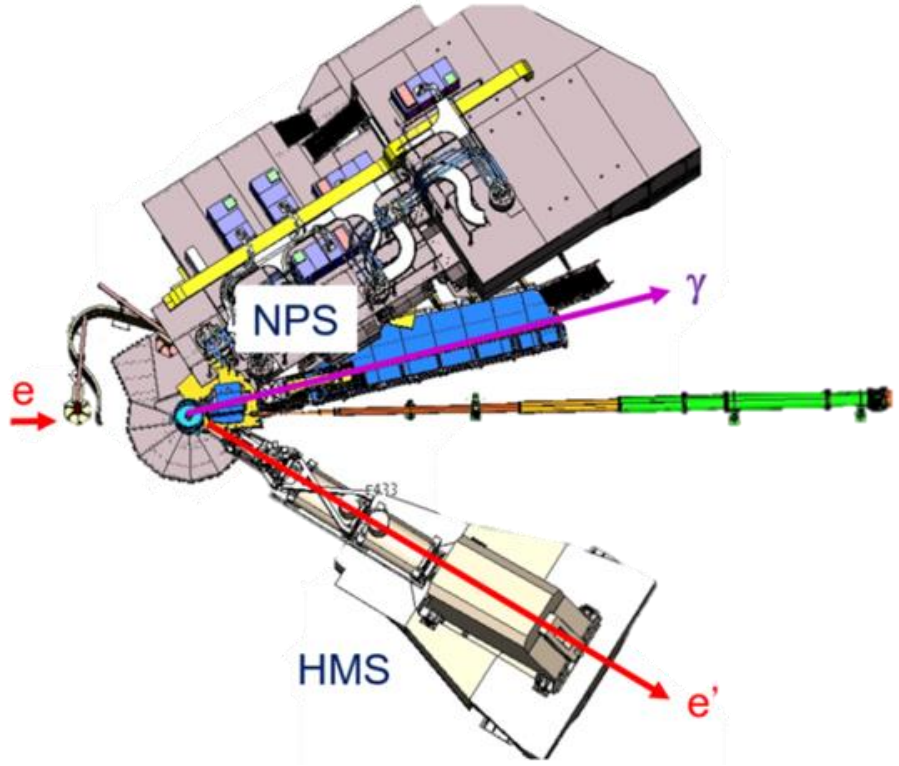
- DVCS is the simplest probe for accessing GPDs
  - Measure Compton form factors, then deconvolve into GPDs





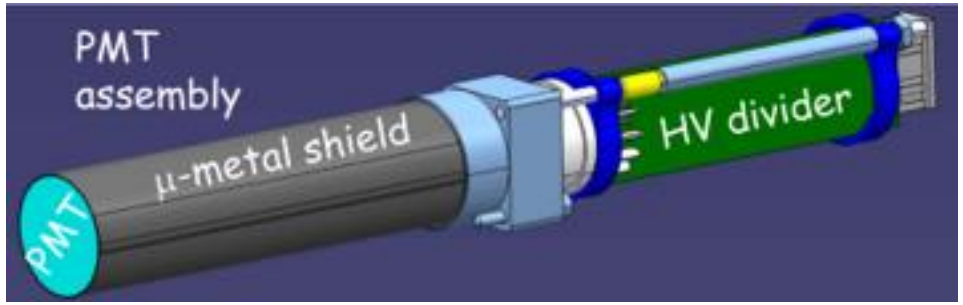
Experimental Setup

- 3 experiments running from September 2023 to May 2024
- DVCS is eN → e'N'γ
  - Electron in HMS
  - N not detected; identified by missing mass
  - Photon in NPS

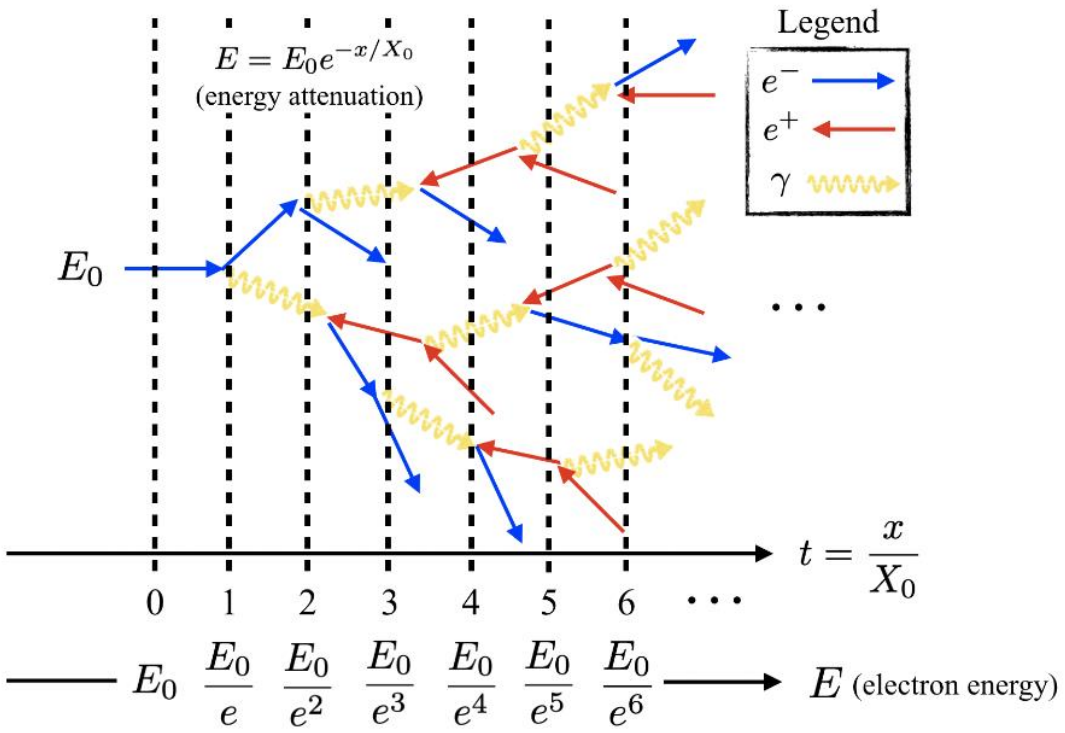


Neutral Particle Spectrometer (NPS) Calorimeter

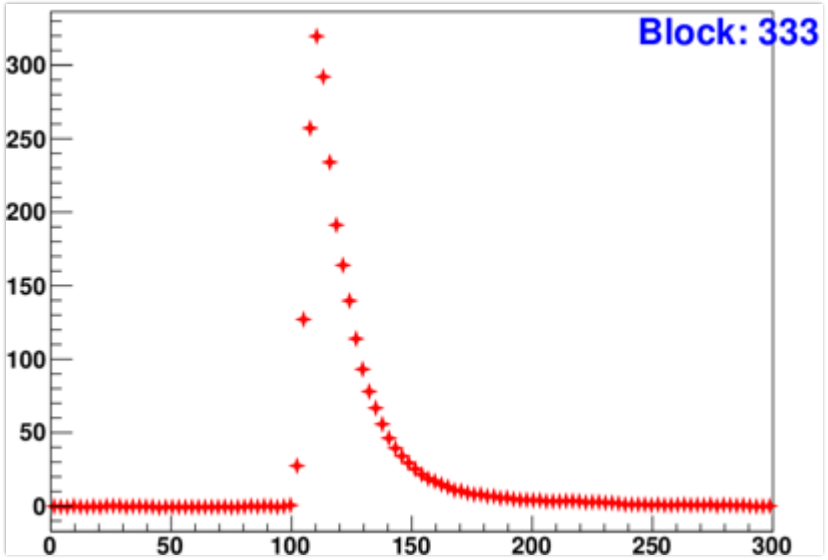
- 1080 (30x36) channels with $PbWO_4$ crystal blocks and PMTs
  - Resistant to radiation damage
  - High light yield
  - High energy resolution
- All channels able to perform well at very high luminosity (~7.5×10^{37} cm^2/s)



Waveform and Energy Resolution



- Clustering



- Flash analog to digital converters (fADCs) on every channel
  - 250MHz sampling rate
  - Allows reconstruction of pulse waveforms

DISCLAIMER!

Everything after this is preliminary

Validating Luminosity and HMS Acceptance with DIS Analysis

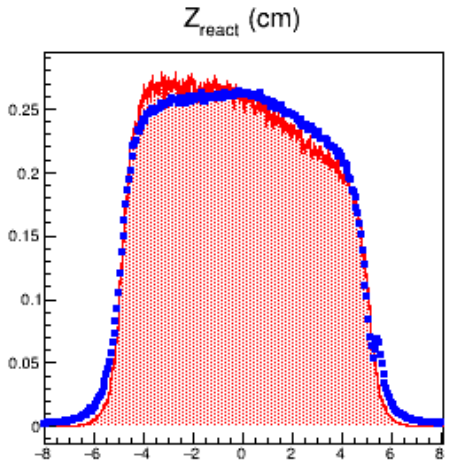
- Interested in measuring experimental DIS cross section
  - Well-understood at these kinematics
  - Compare yield of DIS events to MC simulation

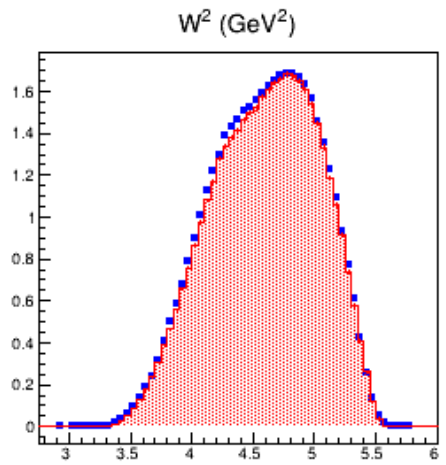
- MC process:
  - Generate events – flat distribution across HMS acceptance
  - Apply radiative corrections
  - Weight events according to DIS cross section

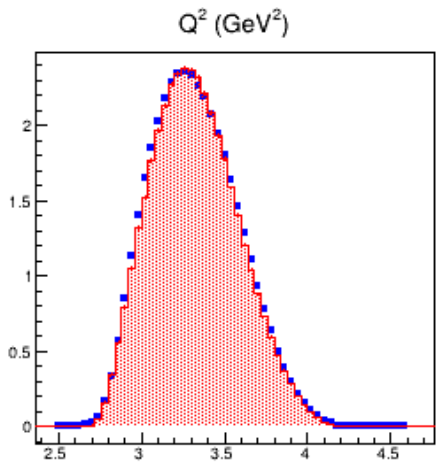
- Data process:
  - Apply cuts to select for electron events
  - Apply detector corrections
  - Remove background contributions

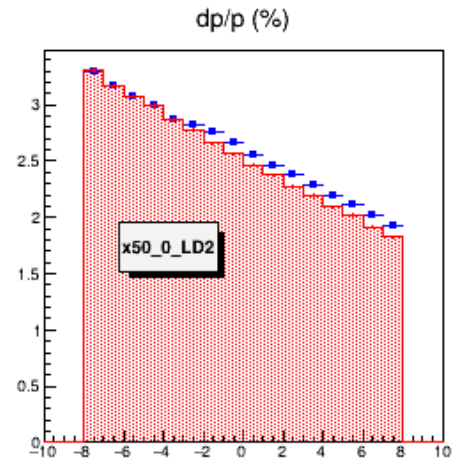
DIS Analysis: Deuterium

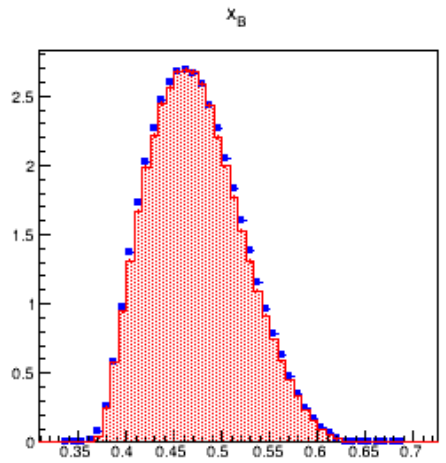
102.9% of expected yield

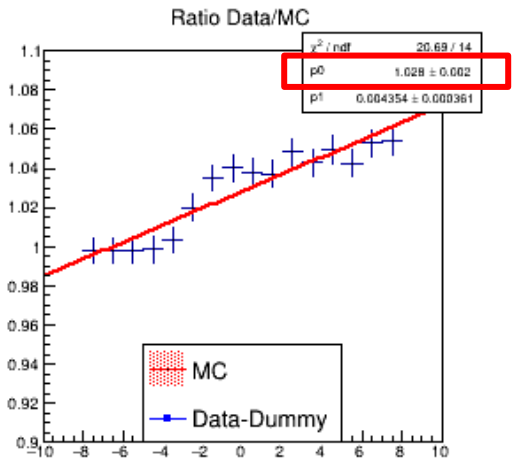






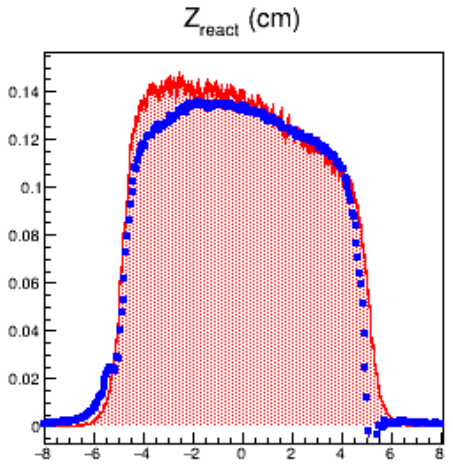


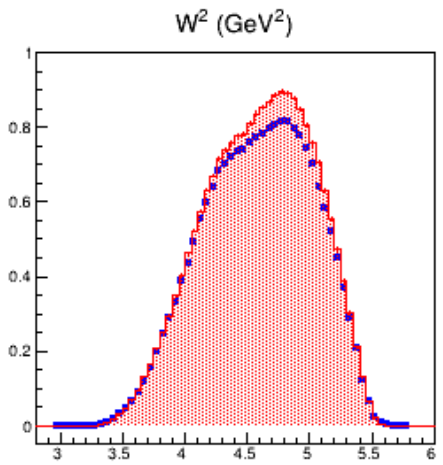


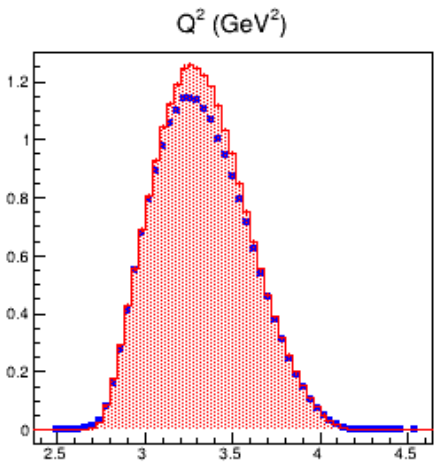


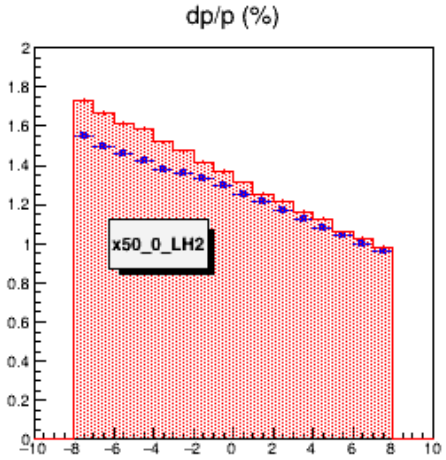
DIS Analysis: Hydrogen

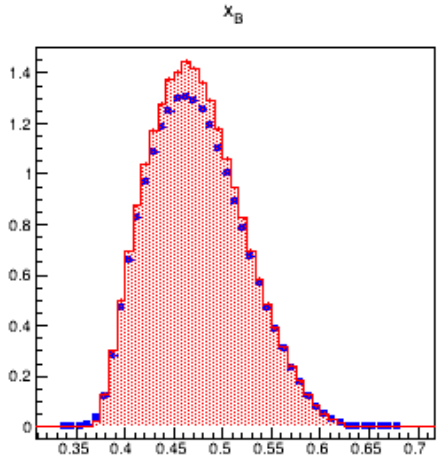
94.1% of expected yield

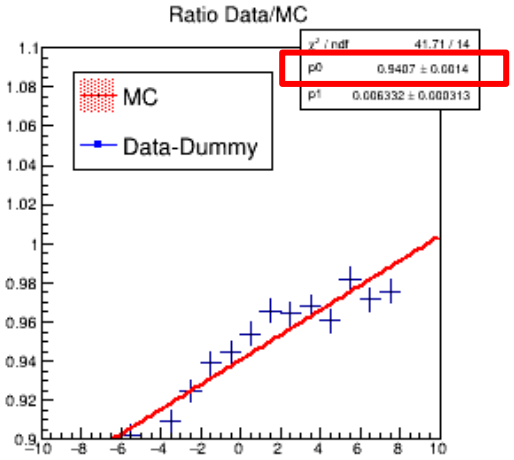












Target Issues?

LH2				
Kinematic	Target Cell	Fan Speed	Pressure	DIS Data yield/ Predicted MC yield
KinC_x60_4	Loop 2	58Hz	25psi	62.3%
KinC_x36_4	Loop 2	58Hz	25psi	60.0%
	Loop 2	42Hz	25psi	70.1%
	Loop 3	58Hz	25psi	64.0%
	Loop 3	42Hz	25psi	73.6%
	Loop 3	42Hz	30psi	79.6%
KinC_x25_3	Loop 3	42Hz	30psi	73.9%
	Loop 3	42Hz	35psi	76.4%
	Loop 3	40-41Hz	40psi	81.2%
KinC_x50_0	Loop 3	42Hz	40psi	94.1%
	Loop 3	40Hz	40psi	93.6%
	Loop 3	36Hz	40psi	96.0%
	Loop 3	32Hz	40psi	95.5%

Summary

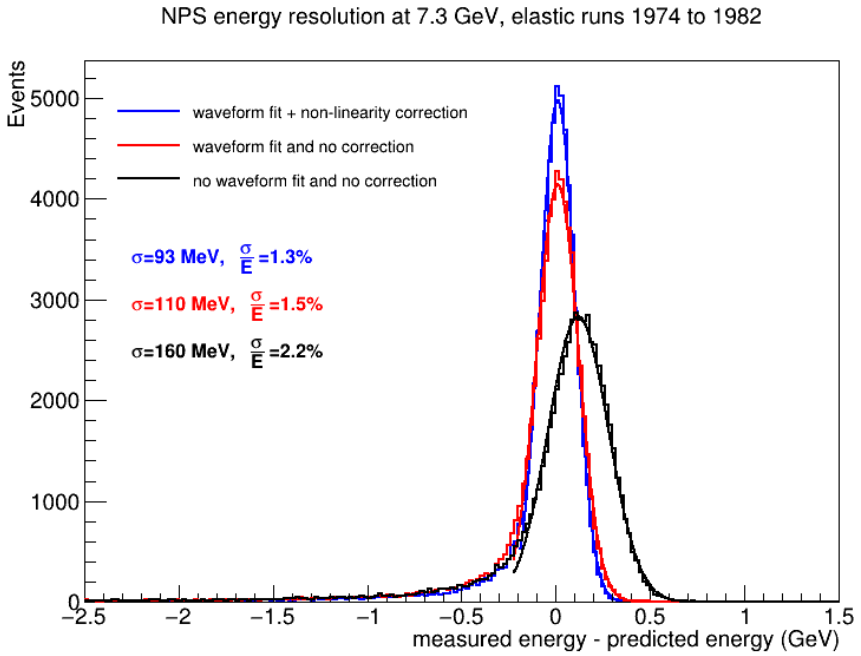
- DVCS is one of the cleanest probes of GPDs, leading to a more comprehensive picture of the internal structure of the nucleon
- The NPS experiments in Hall C took DVCS data for several months and aim to precisely measure GPDs using the high energy resolution of the NPS
- Preliminary analysis indicates NPS is performing well and is in line with making these precision measurements

- Analysis ongoing to characterize issues with LH2 target and properly model discrepancies

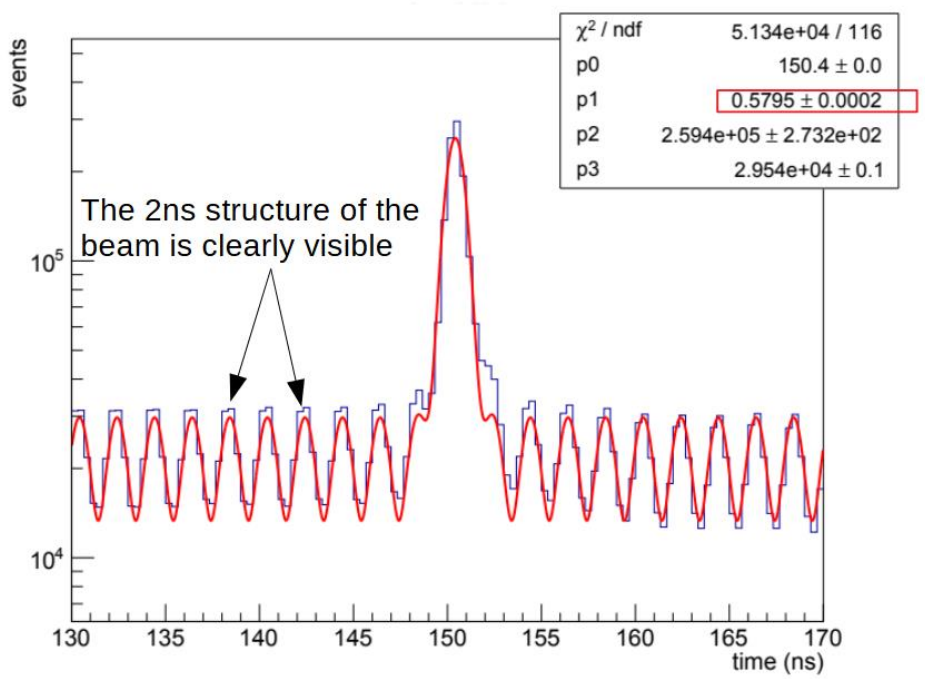
Bonus Slides!

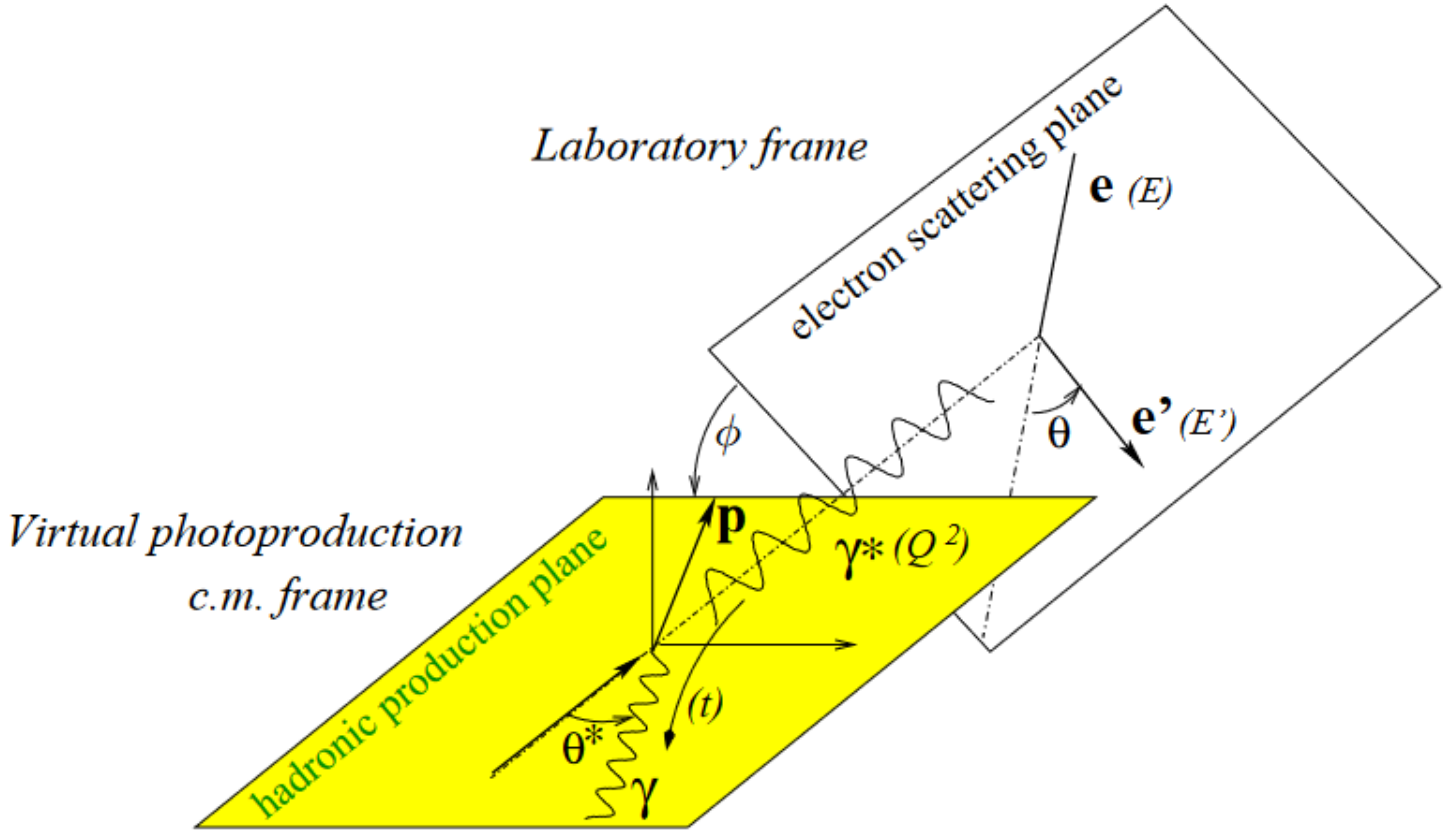
NPS Resolutions

Energy Resolution



Time Resolution





DVCS BH

$$\sigma(ep \to ep\gamma) \propto \left| \quad + \quad + \quad \right|^2$$

Theory: DVCS Cross Section

- DVCS is the simplest probe for accessing GPDs
- DVCS is not the only eN → e'N'γ process
  - Contribution from Bethe-Heitler process
- $\sigma(eN \to e'N'\gamma) = |DVCS|^2 + |BH|^2 + \textit{Interference}$
  - $|BH|^2$ calculable from QED w/ FFs
  - Interference terms separable from beam energy dependence and angle φ

Clustering Method

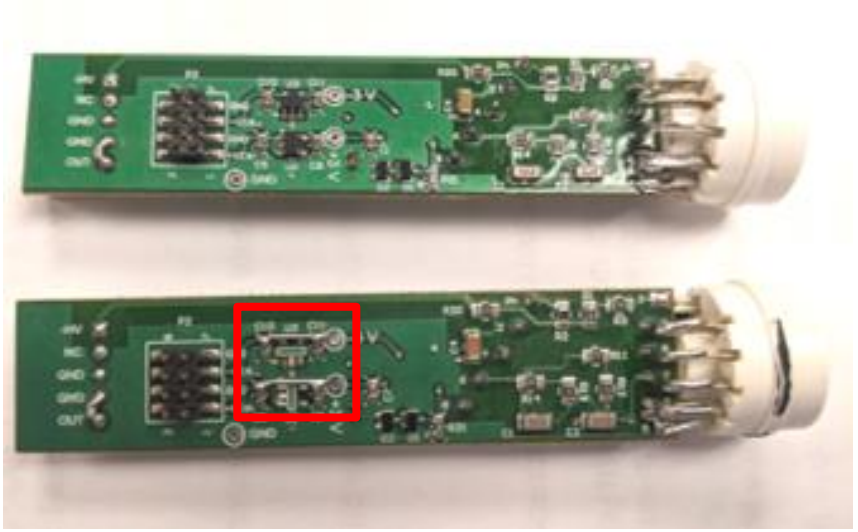
			0.2		
			3.0	1.0	0.2
0.3	0.2	0.4	7.0	2.0	0.2
2.0	8.0	1.0	0.4		
0.2	0.6	0.3	0.2		

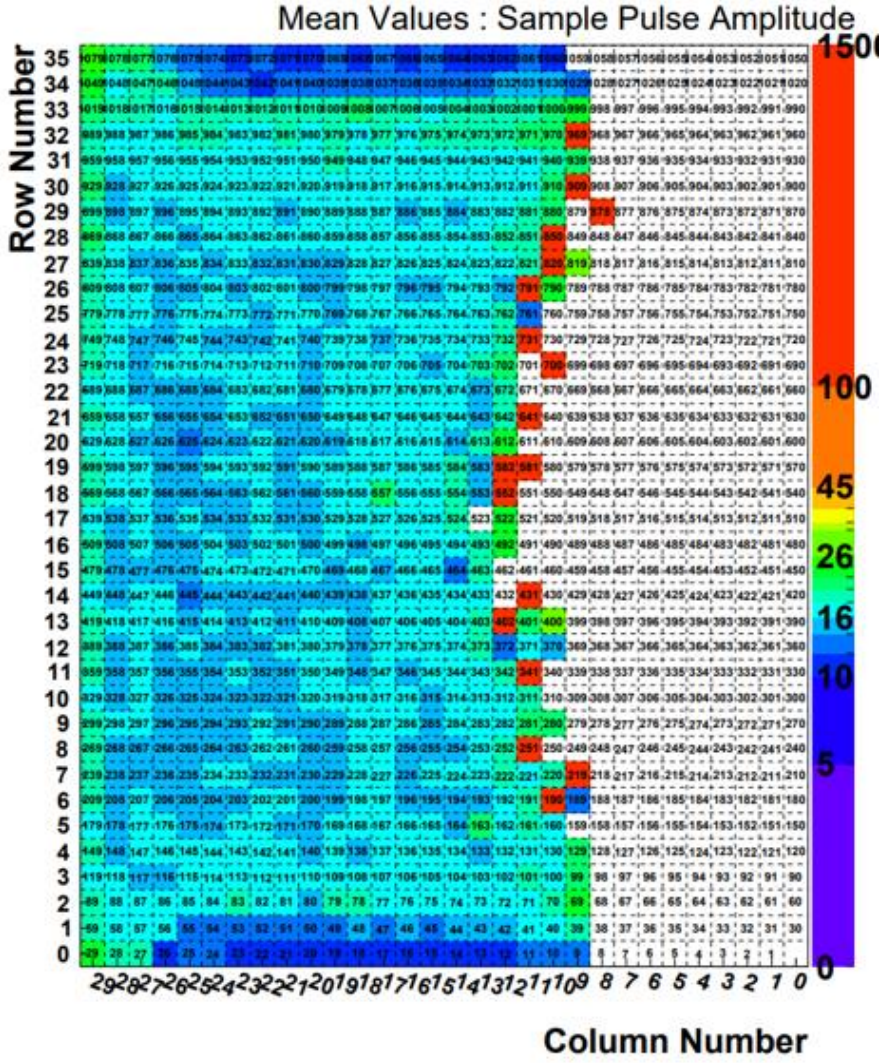
			3.0		
			7.0	7.0	2.0
8.0	8.0	8.0	7.0	7.0	2.0
8.0	8.0	8.0	7.0		
8.0	8.0	8.0	1.0		

			7.0		
			7.0	7.0	7.0
8.0	8.0	8.0	7.0	7.0	7.0
8.0	8.0	8.0	7.0		
8.0	8.0	8.0	8.0		

$$x = \frac{\sum_i w_i \, x_i}{\sum_i w_i} \qquad w_i = \max\left\{0, \left[W_0 + \ln\left(\frac{E_i}{E}\right)\right]\right\}.$$

Radiation Damage





DIS Hydrogen/Deuterium Yield Ratio