The Catholic University of America

JSA/Jefferson Lab Graduate Fellowship Program

Deeply Virtual Compton Scattering at JLab 12GeV

First Studies of the Fall 2014 Run at Hall A

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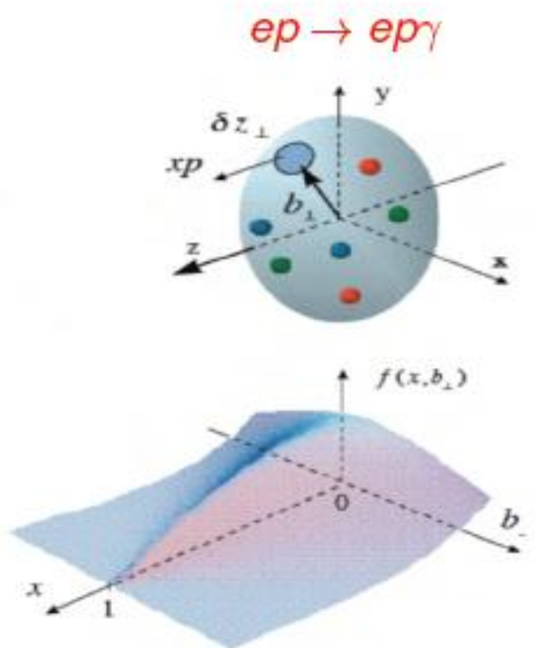
JLab Hall A DVCS Collaboration

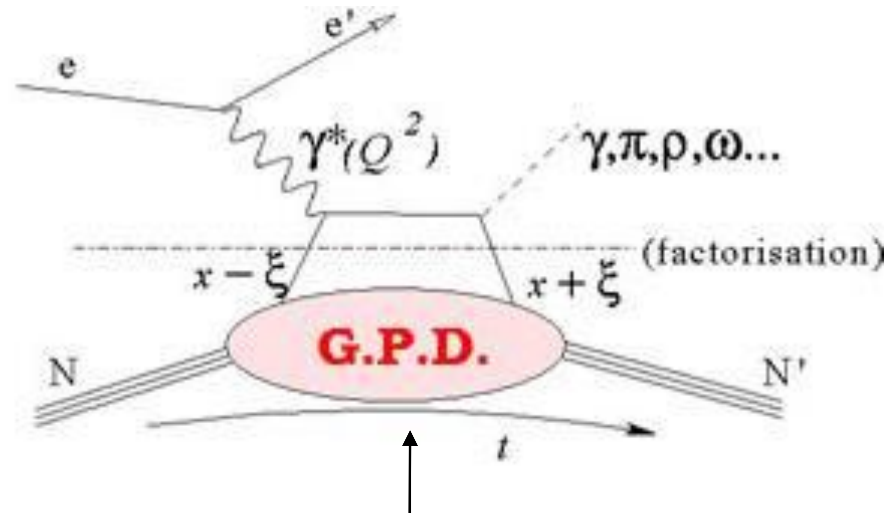
6th Workshop of the APS Topical GHP - April 11–14, 2015; Baltimore, Maryland

Topics

- Generalized Parton Distributions and Deeply Virtual Compton Scattering
- DVCS at Jefferson Laboratory, Hall A
- Instrumentation:
  - Hall A spectrometers
  - DVCS: dedicated calorimeter FPGA based data acquisition
- Preliminary studies:
  - Data acquisition deadtimes monitoring
  - Detector efficiencies
  - Preliminary missing mass checks: DVCS and π^0

Generalized Parton Distributions





GPDs describe the soft part, i.e., with non-perturbative functions.

Generalized Parton Distributions (GPD) encode information on the distribution of partons both in the transverse plane and in the longitudinal direction

Nucleon structure described by 4 GPDs:
H, E (unpolarized), $\tilde{H}$ $\tilde{E}$, polarized)

Quark GPDs E and H are connected to the elastic form factors:

$$\int_0^1 dx\, H^q(x, \xi, t, \mu^2) = F_1^q(t)$$

$$\int_0^1 dx\, E^q(x, \xi, t, \mu^2) = F_2^q(t)$$

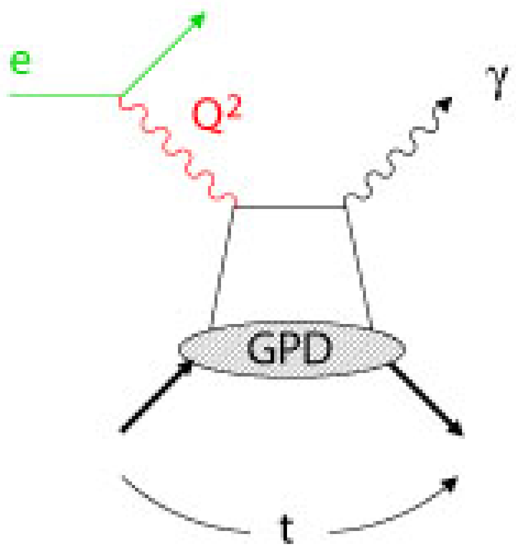
And also to usual PDFs.

https://www.jlab.org/div_dept/theory/talks/guzey08_Conn.pdf

Accessing GPDs experimentally

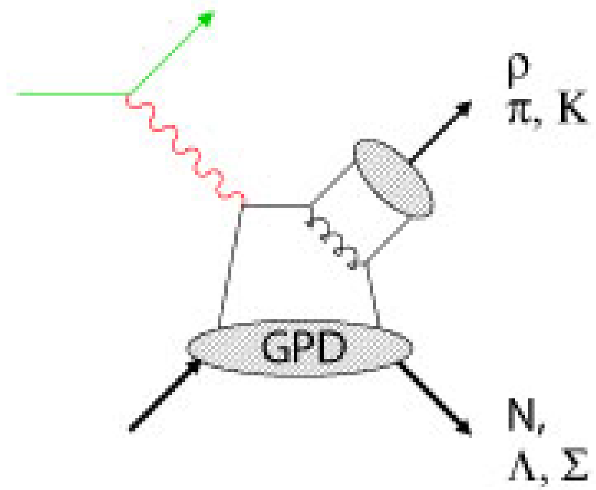
We can access GPDs through hard exclusive reactions

Deeply Virtual Compton Scattering (DVCS)



- Simplest and cleanest way to access GPDs experimentally. The spin asymmetry studies in DVCS give access to imaginary part of the scattering amplitude.
- DVCS (flavor blind) probes GPD *H* and provides additional information on singlet quarks

Deeply virtual meson production (DVMP)

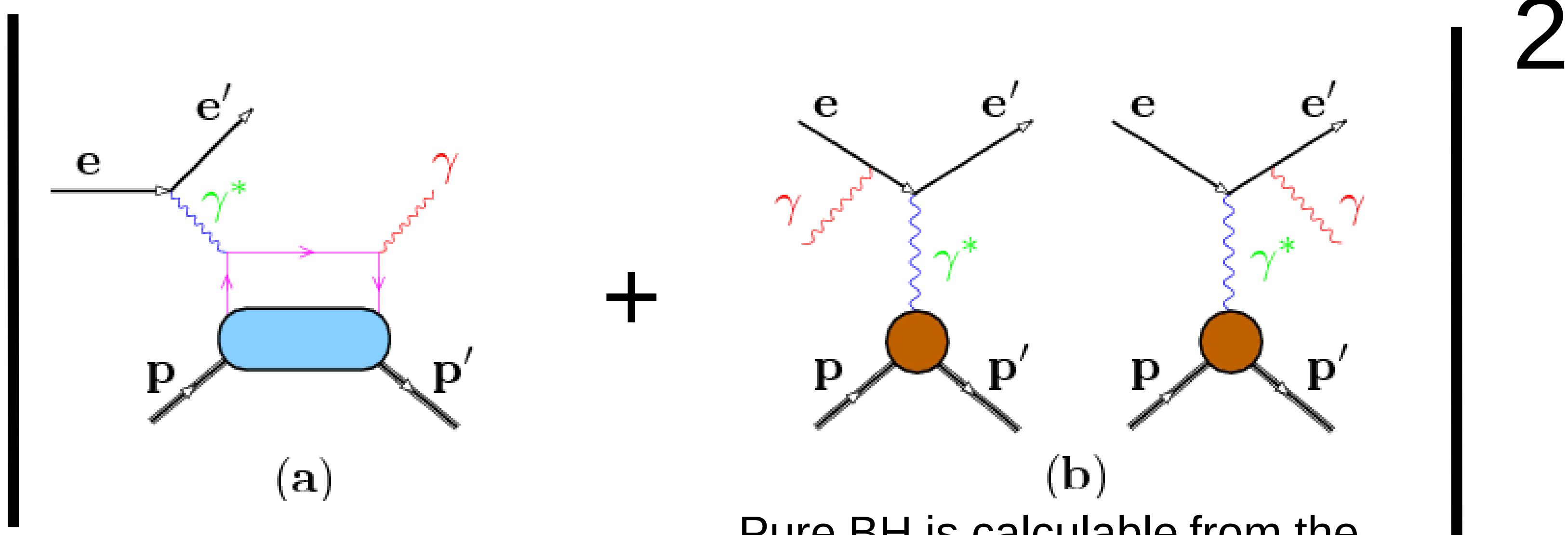


- Mesons select definite charge, spin, flavor component of GPD
- Quantum numbers in DVMP probe individual GPD components selectively
- Need good understanding of reaction mechanism
  - QCD factorization for mesons is complex (additional interaction of the produced meson)

Images: https://www.jlab.org/highlights/images/physics/dvcs.jpg

Accessing GPDs with DVCS

DVCS amplitudes interfere with E&M Bethe-Heitler:



(a)

DVCS

(b)

Pure BH is calculable from the nucleon FF

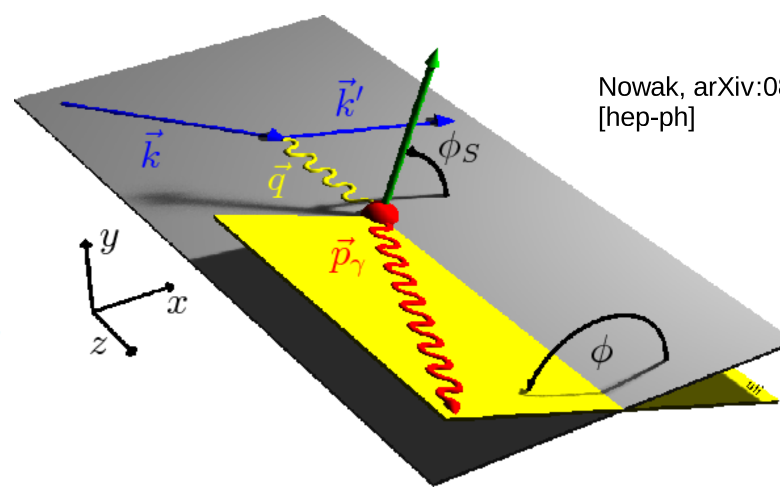
Interference term:

$$\mathcal{I} = \frac{e^6}{x_B y^3 \mathcal{P}_1(\phi_{\gamma\gamma})\mathcal{P}_2(\phi_{\gamma\gamma}) t}\left\{c_0^{\mathcal{I}} + \sum_{n=1}^{3}(-1)^n\left[c_n^{\mathcal{I}}(\lambda)\cos(n\phi_{\gamma\gamma}) - \lambda s_n^{\mathcal{I}}\sin(n\phi_{\gamma\gamma})\right]\right\}$$

DVCS^2 term:

$$\left|\mathcal{T}^{DVCS}(\lambda)\right|^2 = \frac{e^6}{y^2 Q^2}\left\{c_0^{DVCS} + \sum_{n=1}^{2}(-1)^n c_n^{DVCS}\cos(n\phi_{\gamma\gamma}) + \lambda s_1^{DVCS}\sin(\phi_{\gamma\gamma})\right\}$$

Encodes GPDs

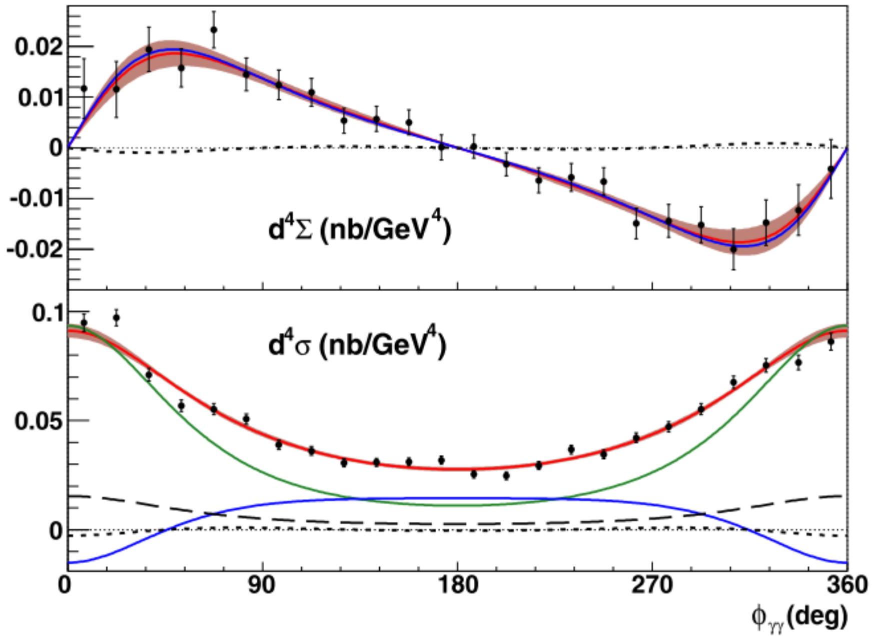


Nowak, arXiv:0812.2679 [hep-ph]

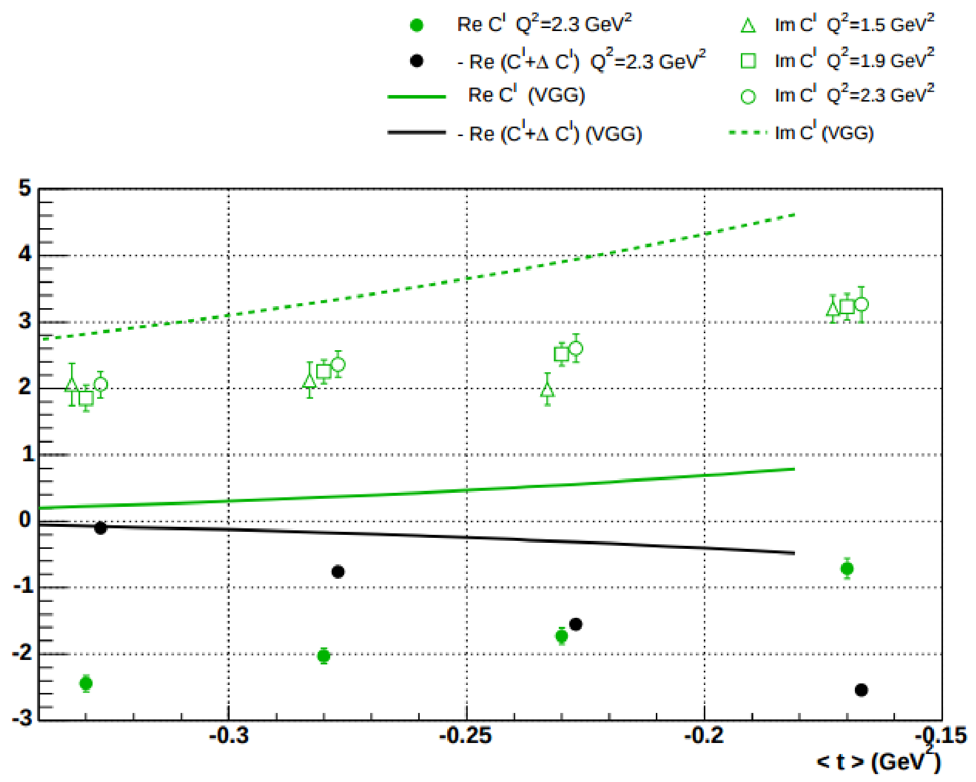
DVCS at JLab Hall A – 6 GeV

6 GeV

DVCS helicity-dependent ($d^4\Sigma$) and helicity-independent ($d^4\sigma$) cross sections measured in E00-110 for $Q^2 = 2.3\ GeV^2$ and $t = -0.28\ GeV^2$.



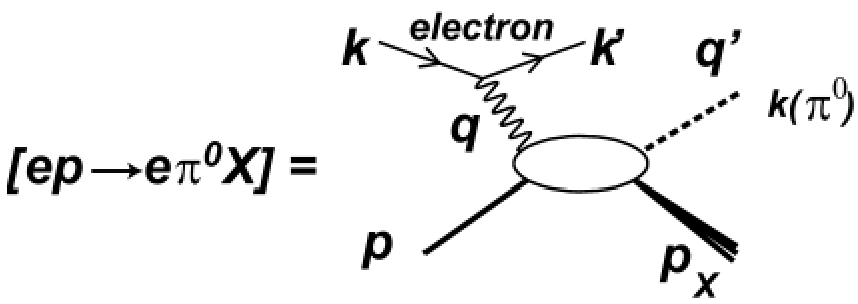
Some Fourier coefficients measured

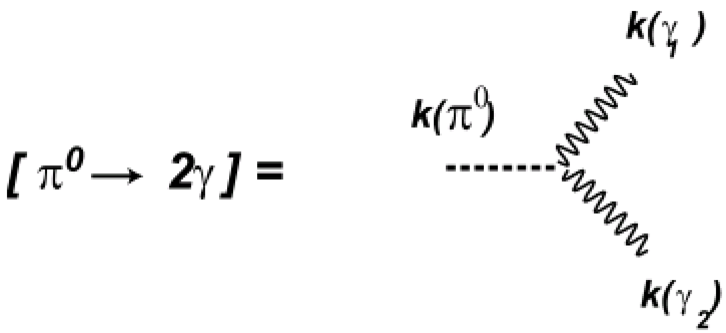


[C. Munoz Camacho et al.,2005]

π^0 electroproduction

Measurements of the same final state particles: e^- and photon

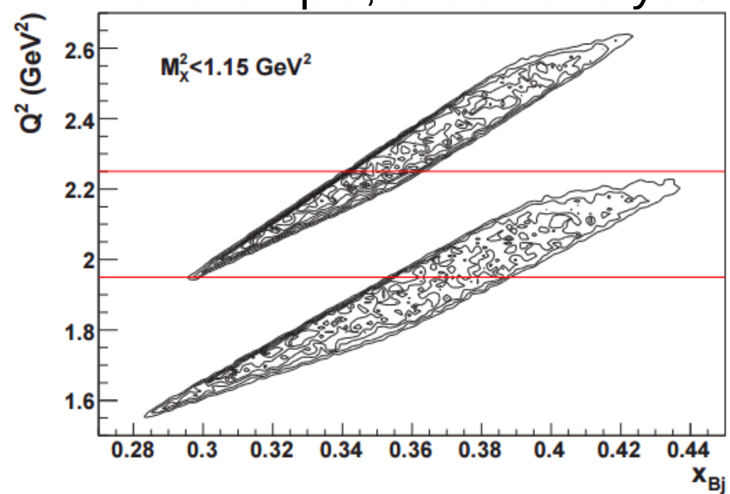




Cross section measured at same Q^2, but different epsilon, allow for L/T separation.

$$\left.\frac{d\sigma_v}{d\Omega_\pi}\right|_{unpol} = \frac{d\sigma_T}{d\Omega_\pi} + \epsilon_L\frac{d\sigma_L}{d\Omega_\pi} + \sqrt{2\epsilon_L(1+\epsilon)}\frac{d\sigma_{TL}}{d\Omega_\pi}\cos\phi_\pi + \epsilon\frac{d\sigma_{TT}}{d\Omega_\pi}\cos 2\phi_\pi$$

For example, 6 GeV analysis:



π^0 events are in the acceptance:
We will measure the π^0 electroproduction cross section in the same kinematics, that may allow for L/T separation

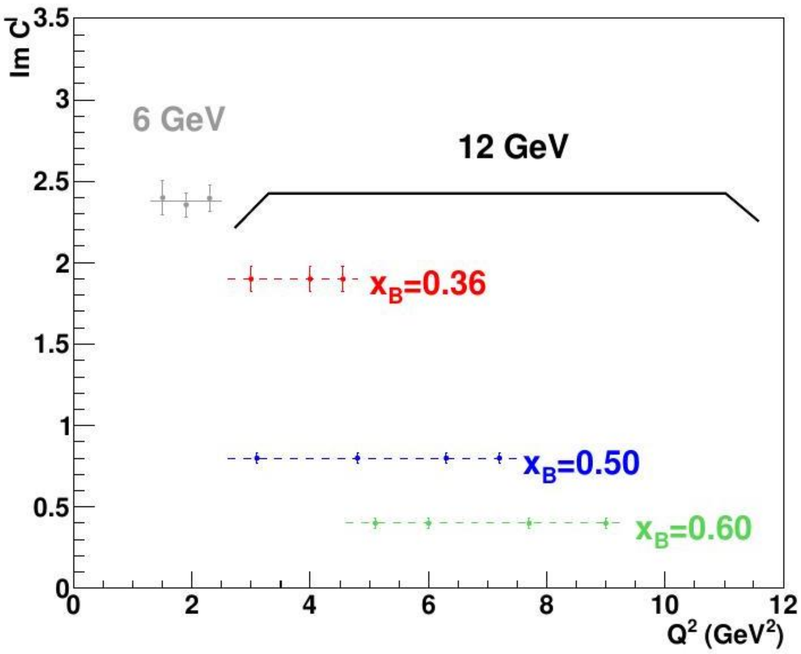
https://hallaweb.jlab.org/12GeV/experiment/E12-06-114/documents/results/e_fuchey_thesis.pdf

DVCS kinematics: JLab @ 12 GeV

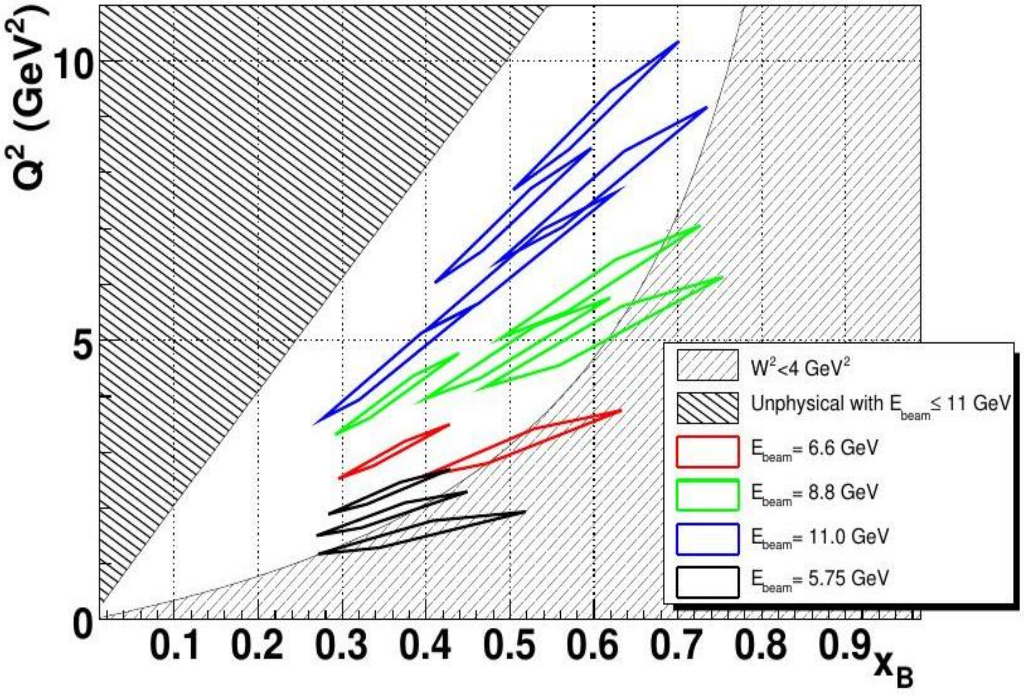
- Scaling test of DVCS cross-sections to 5% precision over large arm in Q^2
- Separation of *Re* and *Im* part of DVCS amplitude (polarized and total cross section)

3rd generation of DVCS experiments at JLab Hall A

Planned scans in Q^2 and x_{Bj}



We have a hint for leading order domination. We will expand the Q^2 and x_{Bj} scan to nail that down.



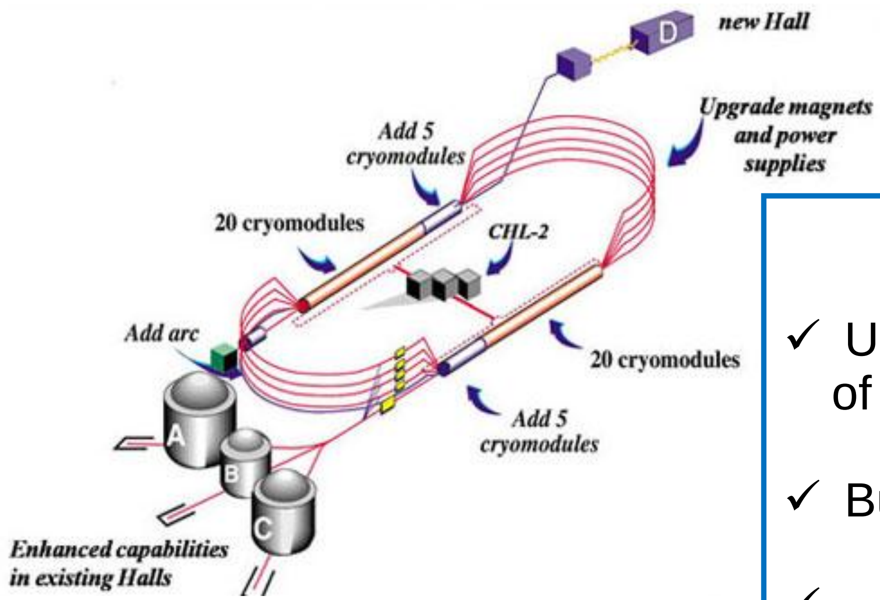
https://hallaweb.jlab.org/12GeV/experiment/E12-06-114/documents/proposals/E12-06-114_update.pdf

JLab at 12 GeV and DVCS instrumentation

Jefferson Laboratory at 12 GeV

JLab during the upgrade
Commissioning phane now!

Added new cryomodules to double the electron beam energy



<u>Upgrades:</u>

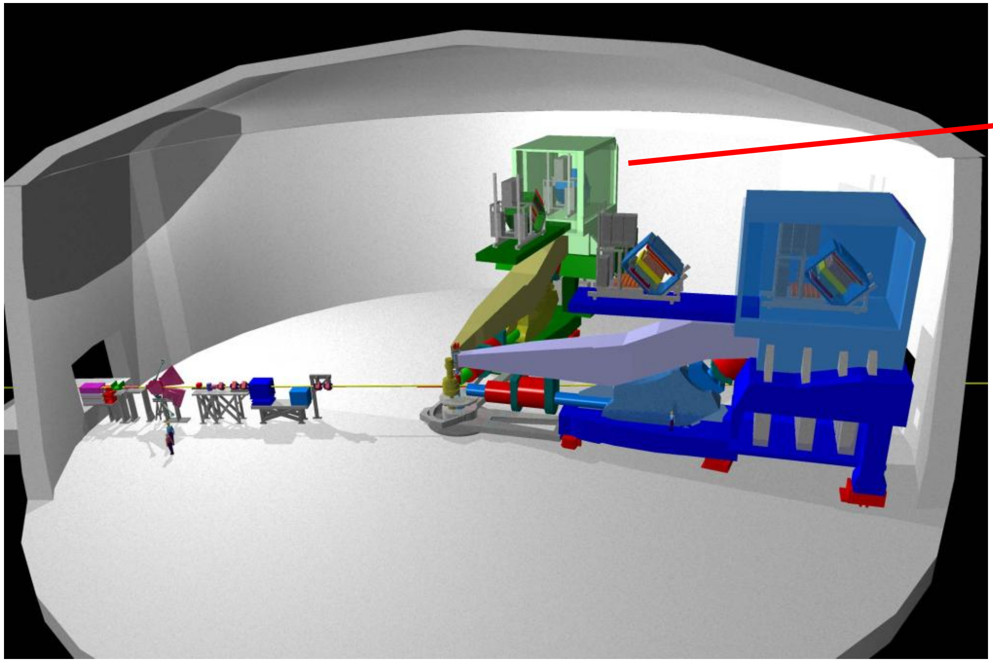
- ✓ Upgraded equipment of existing Halls
- ✓ Built Hall D (GlueX)
- ✓ …
- ❑ Commissioning phase

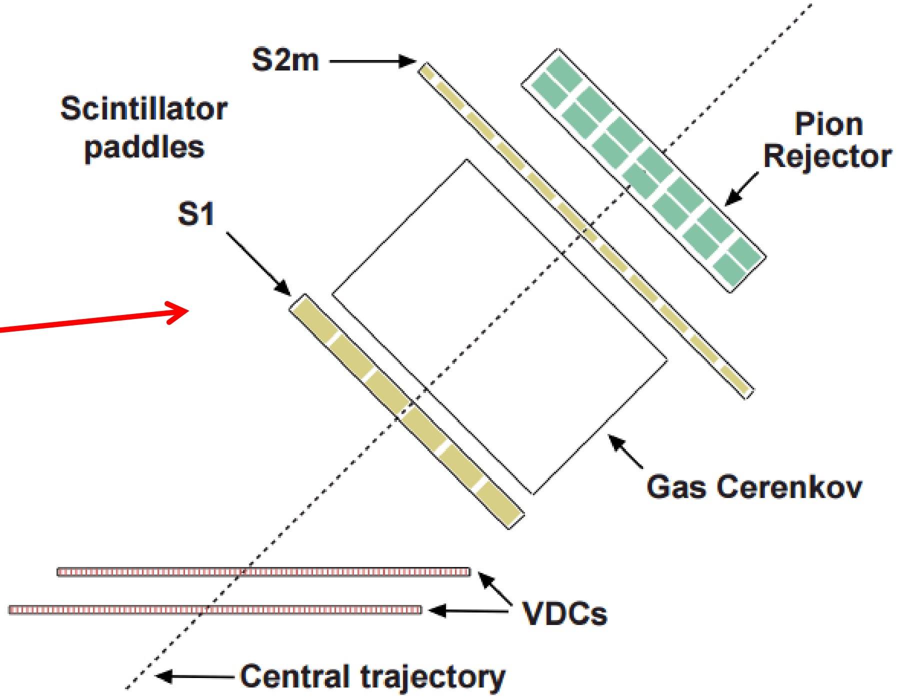
https://www.jlab.org/sites/default/files/images/12-GeV3.jpg
https://srf.jlab.org/srf/index.htm

JLab Hall A

DVCS:
We use the Left HRS to detect

Existing two High Resolution Spectrometers (HRS)

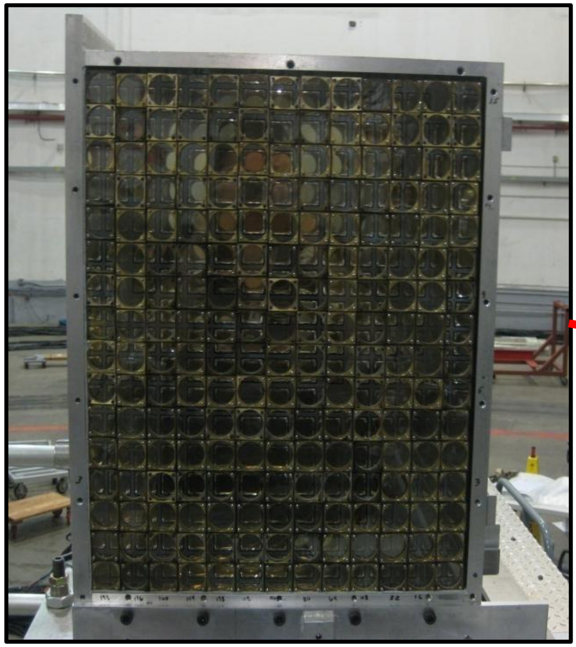




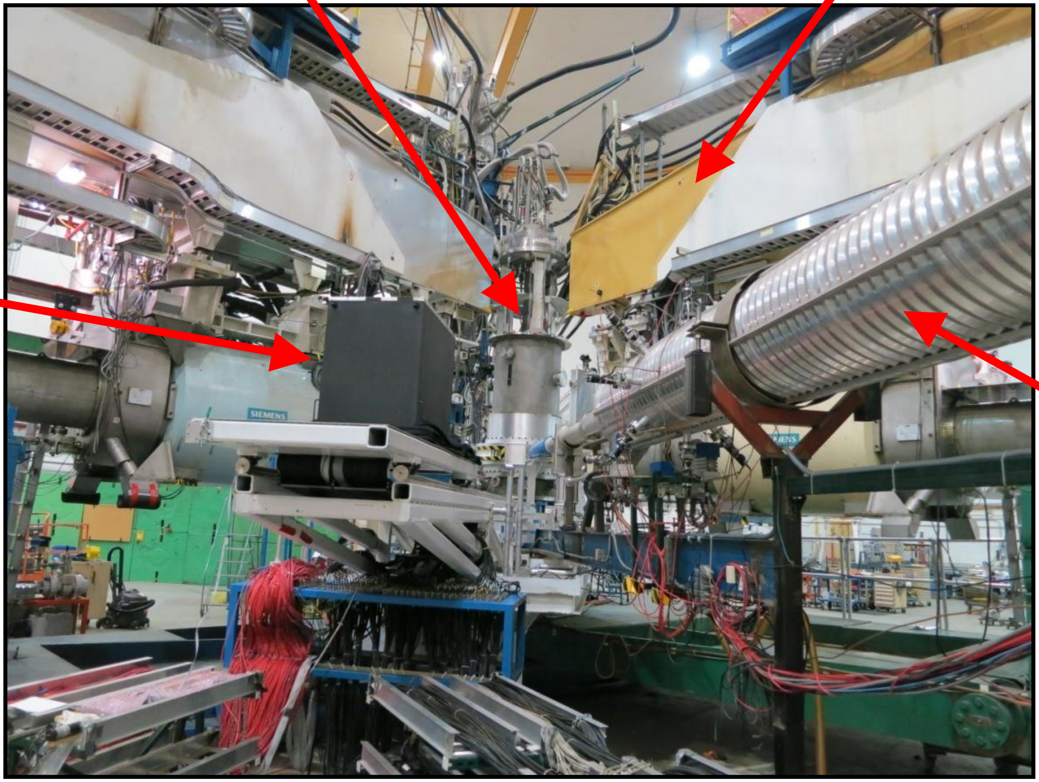
- s2m and s0: scintillators pannels for triggering
- PID: Gas Cherenkov, Pion Rejector calorimeter
- Drift chamber, FPP chamber

Dedicated detector for DVCS

DVCS calorimeter

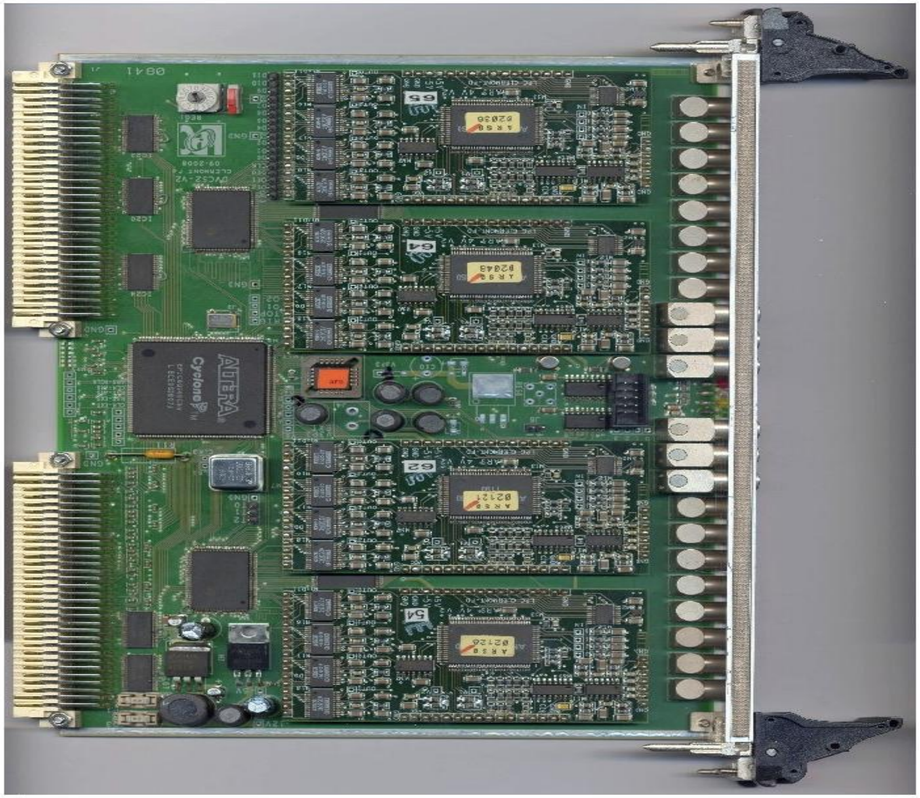


208 PbF_2 blocks calorimeter
Resolution: 3% ~ modest



Calorimeter photon energy resolution is our limiting factor in the missing mass reconstruction

Dedicated FPGA electronics for trigger and signal sampling

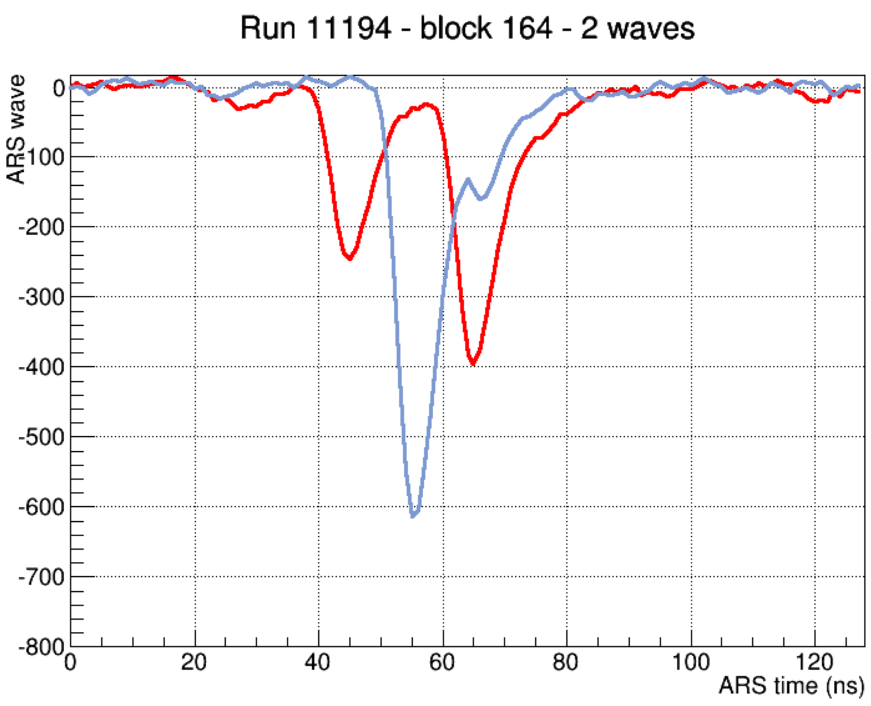


Analog Ring Sampler (ARS)

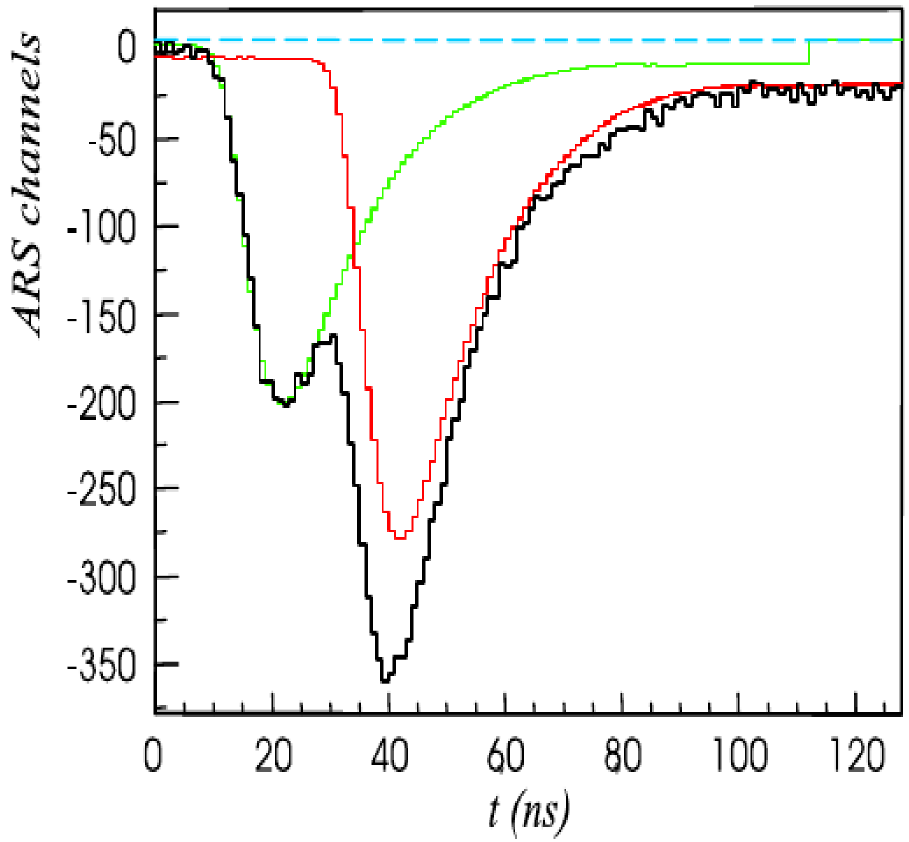
- ➢208 channels
- ➢1 GHz sampling rate
- ➢Digitalization of 128 ns window

Allows for waveform analyses and better separate pile-up events off-line

Sampling and disentangling pile-up events



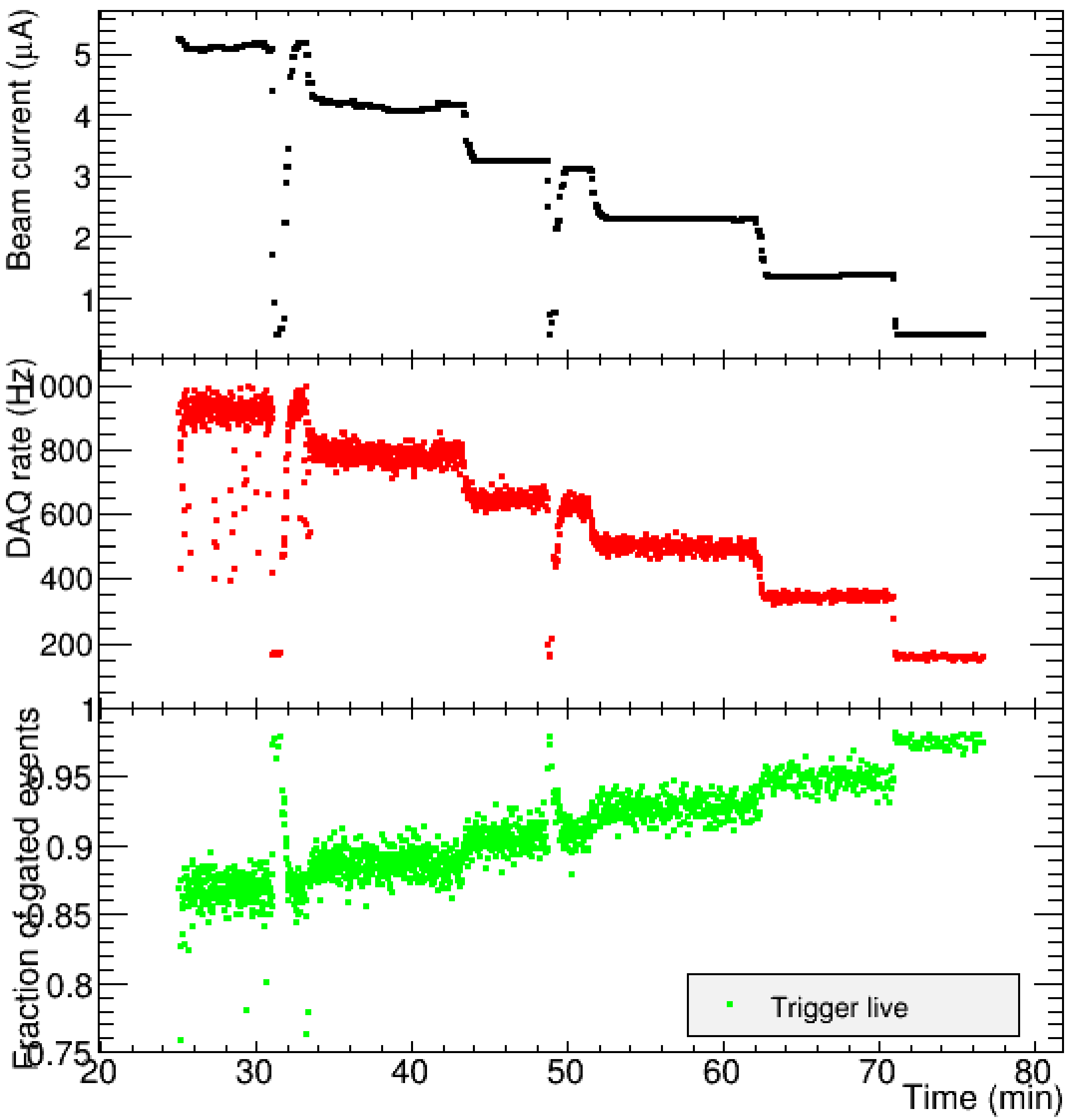
Two actual examples of pile up events Taken few days ago, during a production run



Algorithm built to fit and disentangle these events

Preliminary studies

Production runs:
Monitoring deadtimes closely



$$Yield = \frac{N_{events}}{Q \cdot \boxed{DAQ_{LIVE}} \cdot eff}$$

- DAQ deadtime is a direct normalization factor to the cross sections extractions

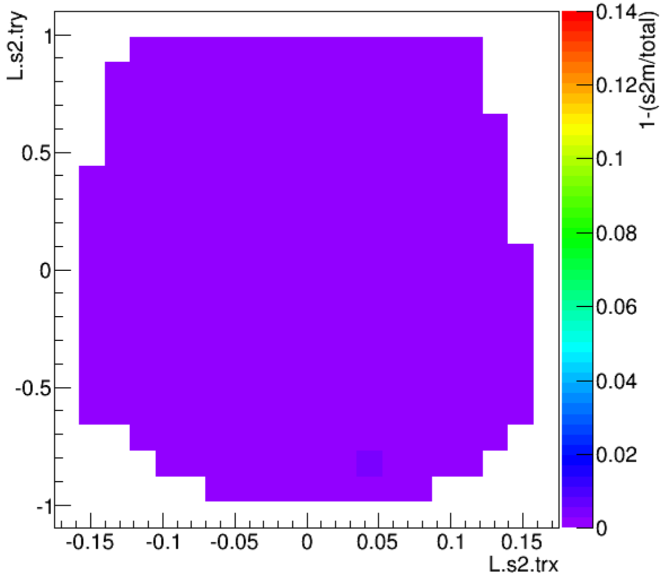
- Monitoring of DAQ deadtimes during the runs, for the calculation of deadtime weighted beam current

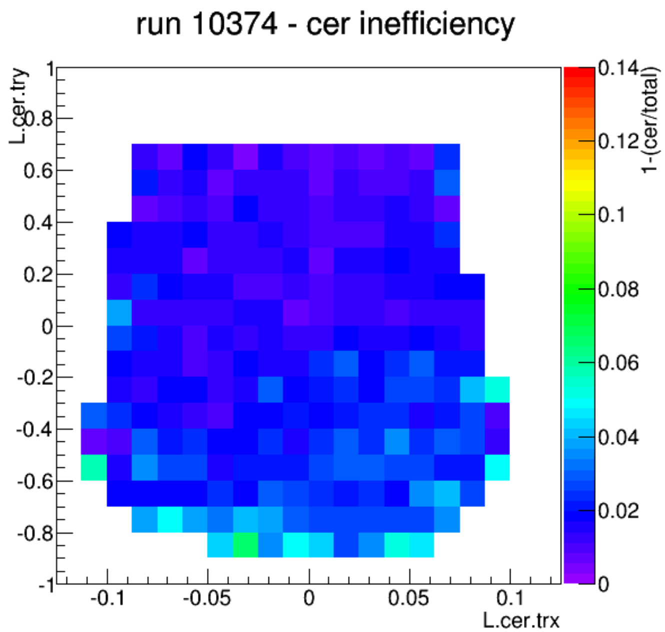
- In the example, a run taken at with several beam currents for deadtime studies.

- Few beam trips observed (will be removed later for the analysis)

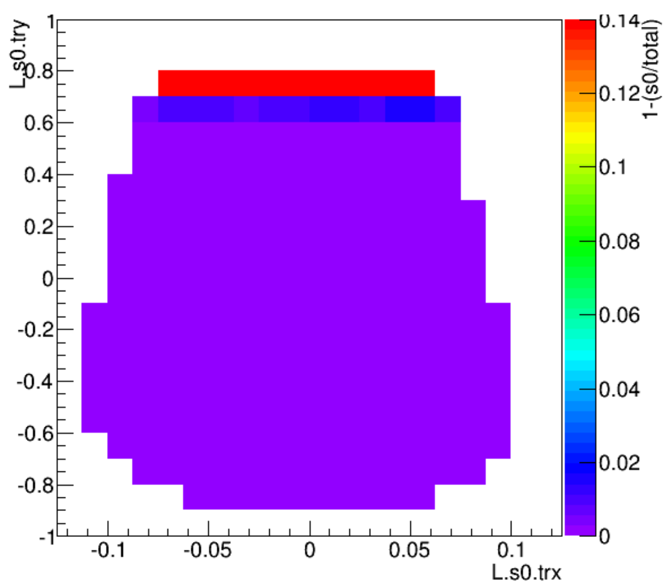
- Mean deadtime of ~5% in a production run

Monitoring details of the DAQ: Trigger efficiencies





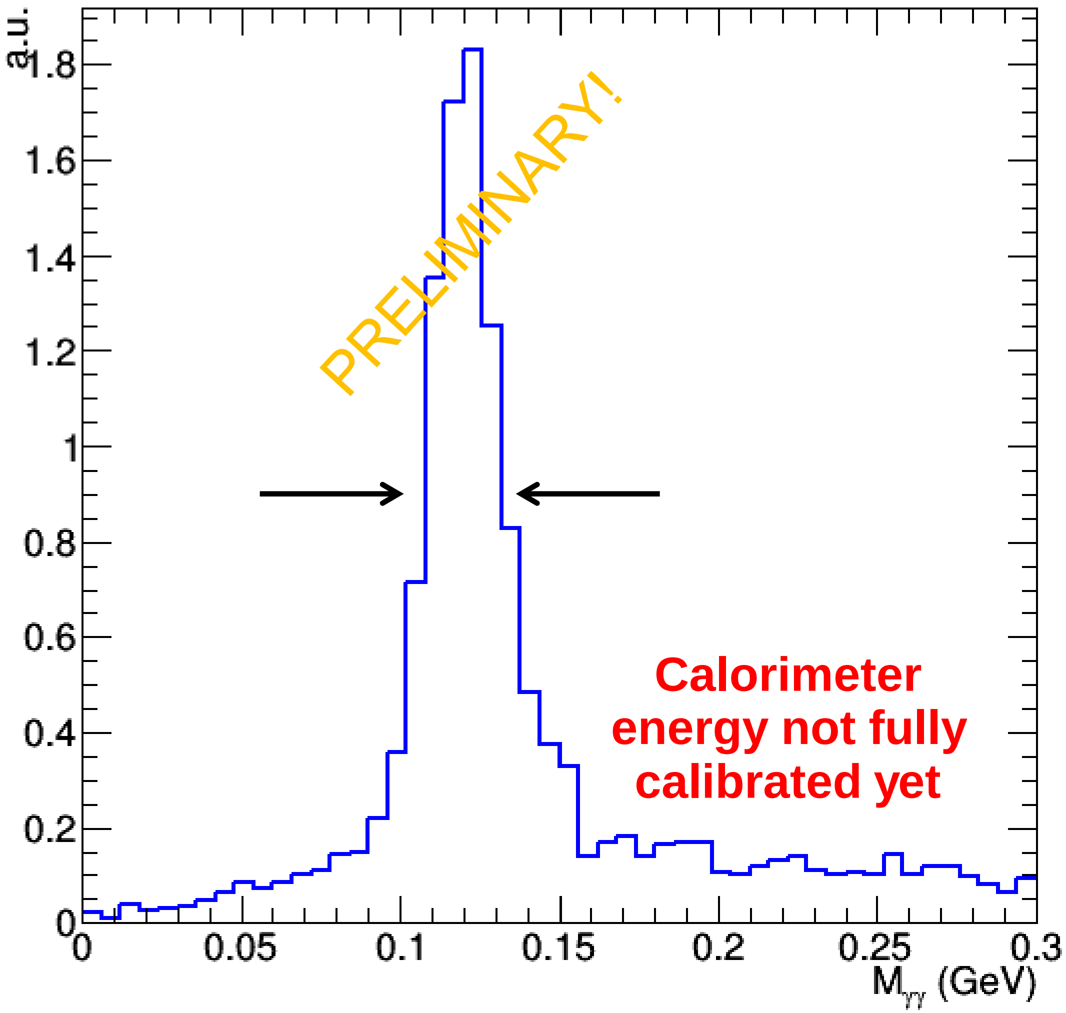
$$Yield = \frac{N_{events}}{Q \cdot DAQ_{LIVE} \cdot eff}$$



- Detector efficiencies are also a direct normalization factor to the cross sections extractions

- Monitoring trigger efficiencies for the different kinematics of the experiment

Very preliminary first data analysis 2 clusters events

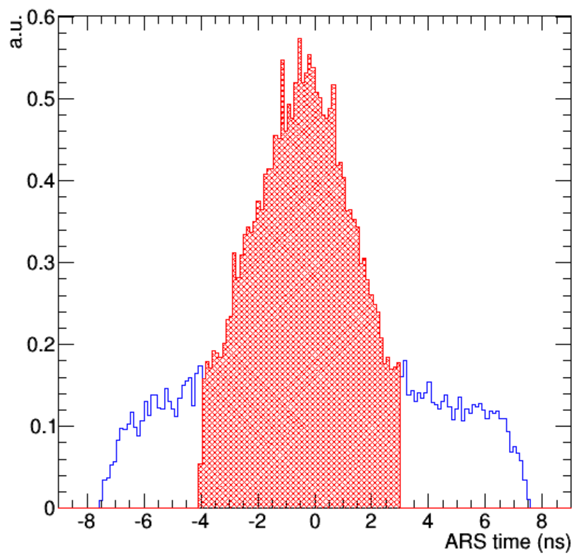


- Invariant mass reconstruction of 2 clusters events
- π^0 peaks at slightly shifted mass, since we still didn't tune all the calibration coefficients

Very preliminary analysis: One cluster events

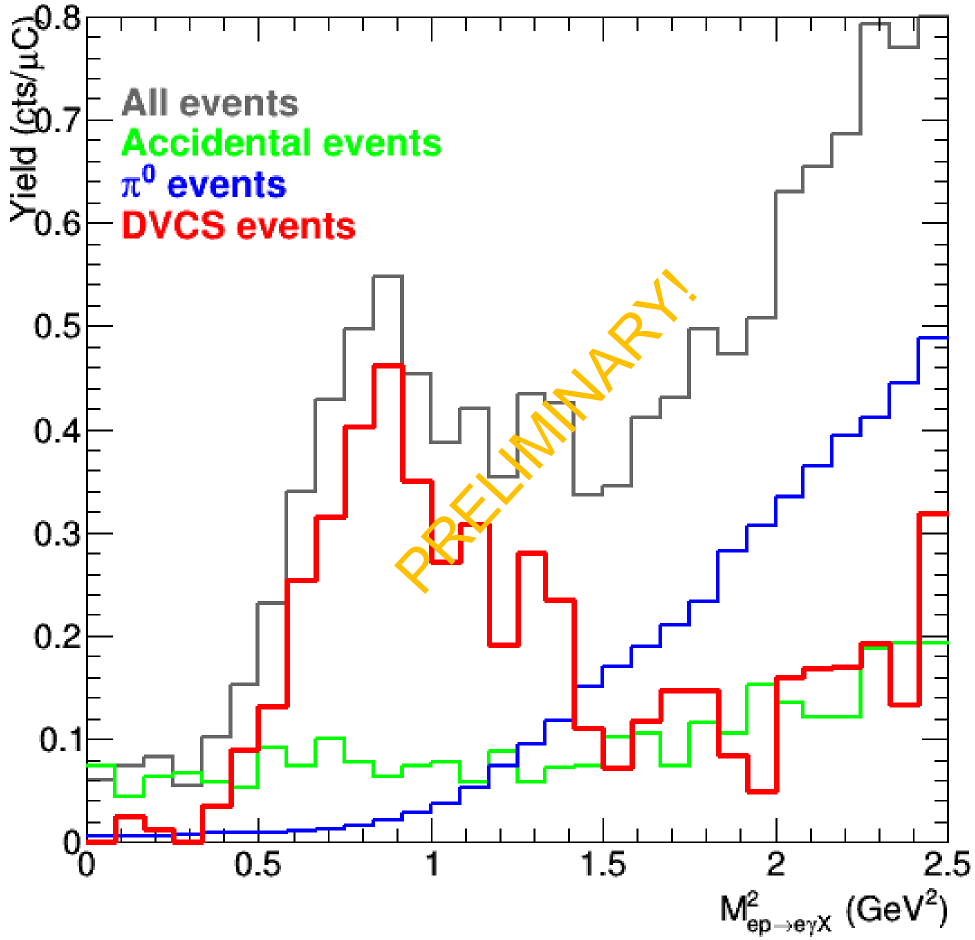
Some <u>preliminary</u> cuts applied:

- Vertex reconstructed in the target
- Photon energy above 0.6 GeV (expected DVCS range)
- PID: pion rejection
- Time of event at the calorimeter



Cut example: time of event in the calorimeter

Exclusive peak in missing mass
DVCS events



2014/2015 data taking continues...

- Running the experiment together with the JLab 12 GeV commissioning
- 100 days approved to run the DVCS experiment at JLab Hall A
- Run time already scheduled/planned for 2016
- Scaling test of DVCS cross section for leading order factorization confirmation
- Extraction of t-dependent polarized and unpolarized DVCS cross section (and π^0 electroproduction) over a wide kinematic range
    - Q^2 from 2 to 9 GeV^2
    - x_B = 0.36, 0.5, and 0.6

Thank you!

More about DVCS at Hall A at the APS meeting:
Lee Allison, “The Spring 2015 JLab Hall A Deeply Virtual Compton Scattering Run”
Sunday, April 12, 2015 - 1:30PM