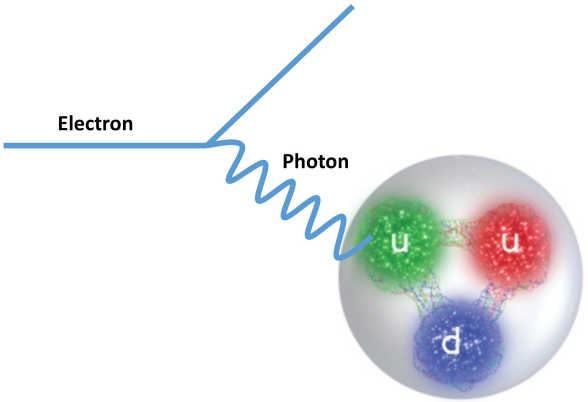
Deeply Virtual Compton Scattering on the proton at 10.6 GeV with CLAS12 at Jefferson Lab

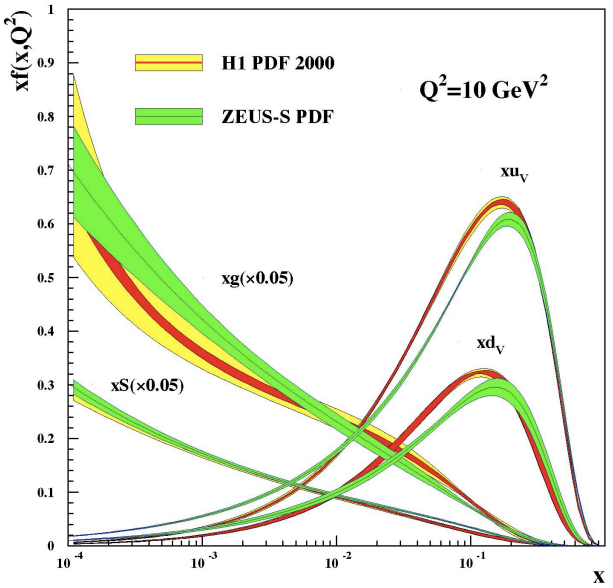
Guillaume CHRISTIAENS (CEA Saclay, University of Glasgow)
for the CLAS Collaboration

August 1, 2019

Introduction

- Scattering experiments to access the **proton structure**:
  - 1950's Form Factors: transverse spatial distributions of partons (elastic scattering)
  - 1960's Parton Distribution Functions: longitudinal momentum of partons (deep inelastic scattering)
  - 1990's **Generalized Partons Distributions (GPDs)**: correlations of longitudinal momentum and transverse position (deep exclusive processes)



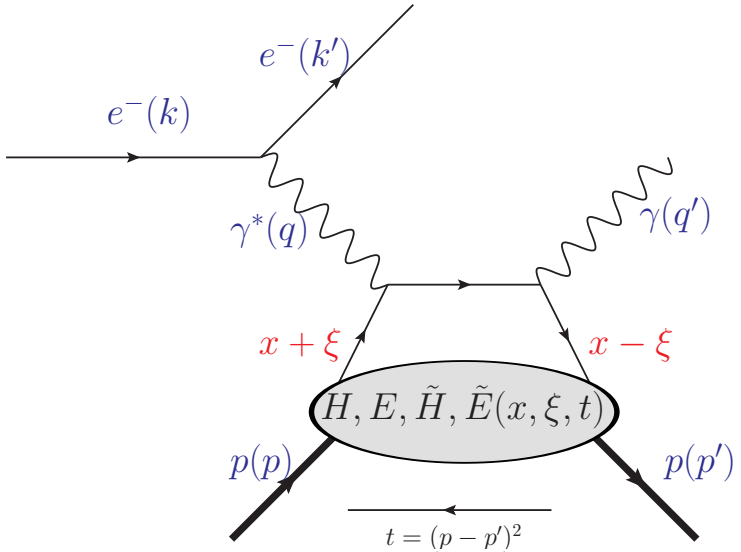


Deeply Virtual Compton Scattering

Deeply Virtual Compton Scattering

- GPDs appear in the DVCS amplitude through Compton Form Factors (CFF) such as:

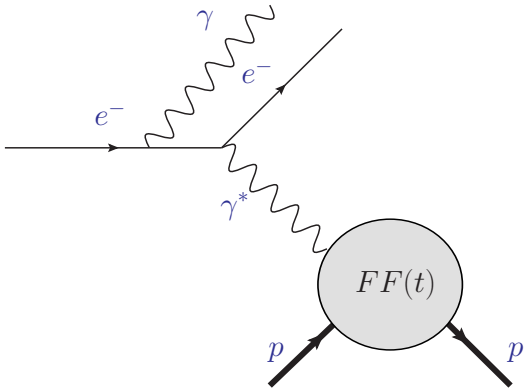
$$\mathcal{H} = \int_{-1}^{1} H(x,\xi,t)\left(\frac{1}{\xi - x - i\epsilon} - \frac{1}{\xi + x - i\epsilon}\right)dx$$



DVCS at leading order

- Experimentally we measure photon leptoproduction: interference of DVCS and Bethe-Heitler (BH)

$$\sigma(ep \to ep\gamma) = |DVCS|^2 + |BH|^2 + Interference$$



BH at leading order

Generalized Parton Distributions

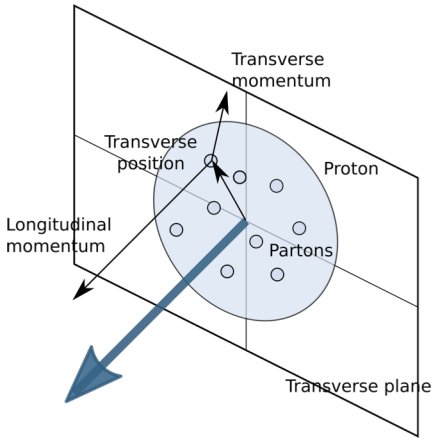
- **Tomography of the nucleon**

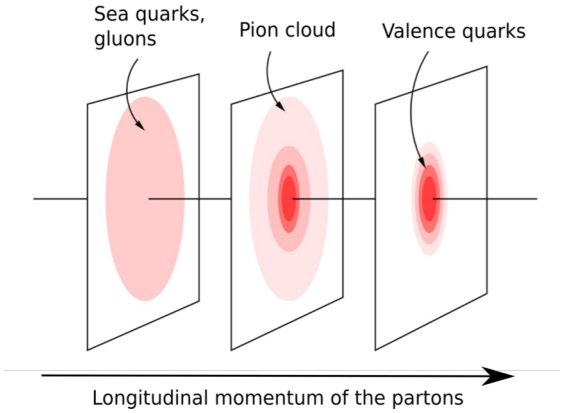
$$\rho(x, \vec{r_\perp}) = \int \frac{d^2\Delta_\perp}{(2\pi)^2} e^{-i\vec{\Delta_\perp}\cdot\vec{r_\perp}} H(x, \xi = 0, t = -\Delta_\perp^2)$$

Burkardt, 2003

$\Delta_\perp$ transverse momentum transfer

Distribution of longitudinal momentum x and transverse position $\vec{r_\perp}$





- Contribution of quark orbital angular momentum to the **proton spin**:

$$J = \int_{-1}^{1} x\Big[H(x, \xi, 0) + E(x, \xi, 0)\Big]dx$$

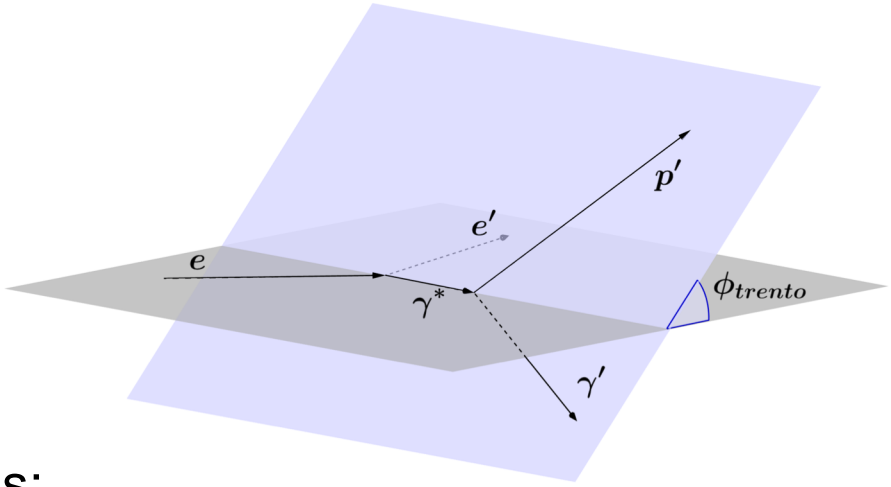
Ji, 1997

Beam-spin asymmetry

- Extraction of GPDs from DVCS with polarized lepton beam and unpolarized target

- Photon leptoproduction **beam-spin asymmetry**:

$$A_{LU} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$$



- At leading order the asymmetry is:

$$A_{LU} \simeq \frac{A \sin(\phi_{trento})}{1 + B \cos(\phi_{trento})}$$

$$A = \frac{s_1^{\mathcal{I}}}{\kappa c_0^{BH} + c_0^{\mathcal{I}}} \qquad B = \frac{\kappa c_1^{BH} + c_1^{\mathcal{I}}}{\kappa c_0^{BH} + c_0^{\mathcal{I}}}$$

κ known function of kinematical variables

$c_1^{\mathcal{I}},\ c_0^{\mathcal{I}},\ s_1^{\mathcal{I}}$ combinations of CFF

$$s_1^{\mathcal{I}} \propto Im(F_1\mathcal{H} + \xi(F_1 + F_2)\tilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E})$$

F_1, F_2 form factors

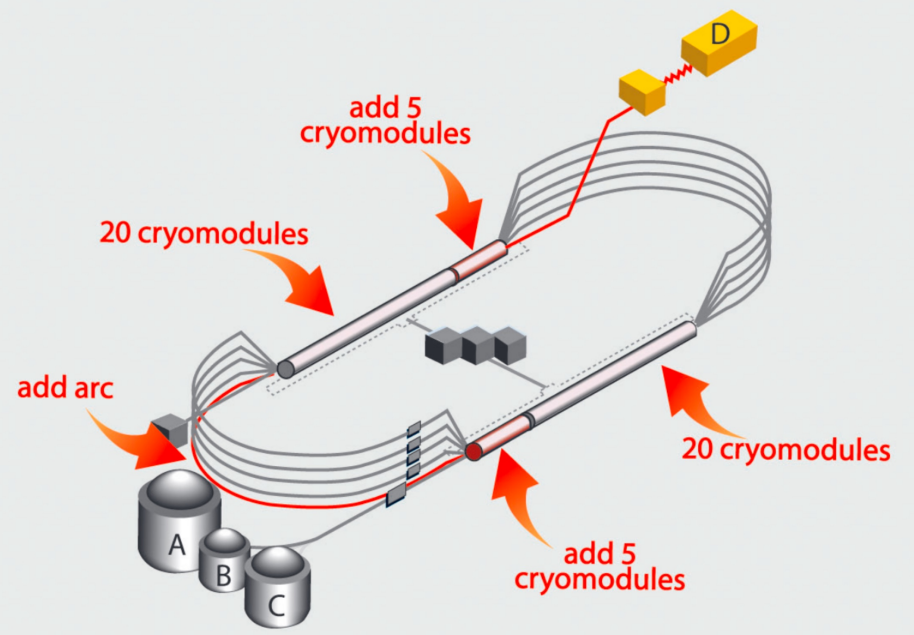
CLAS12 installation complete

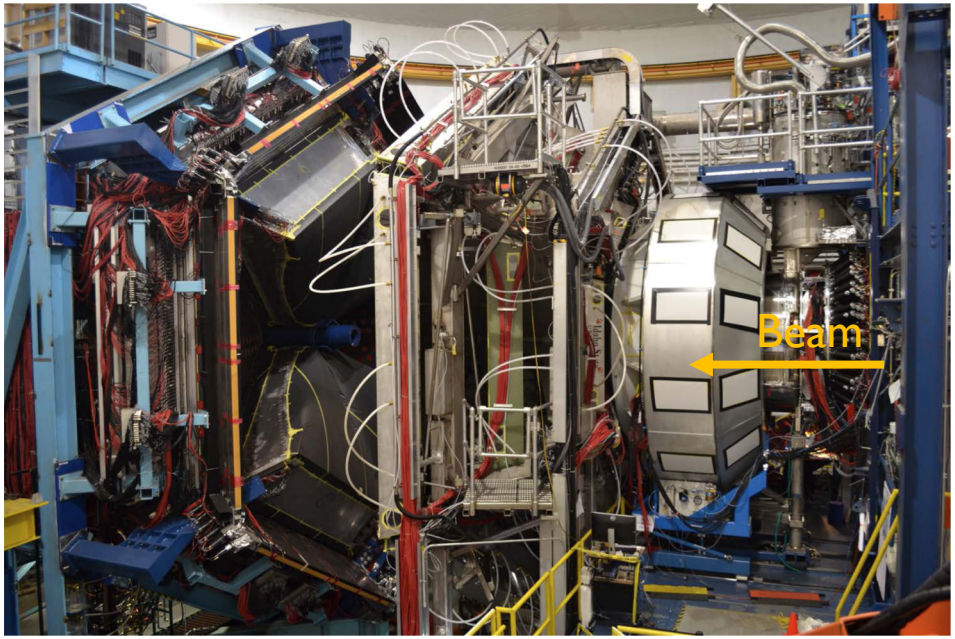
Jefferson Lab

- **CEBAF upgraded** to deliver longitudinally polarized 12GeV electron beam

CLAS12 data taking started in 2018

- **10.6 GeV electron beam**
- **Unpolarized liquid hydrogen** target





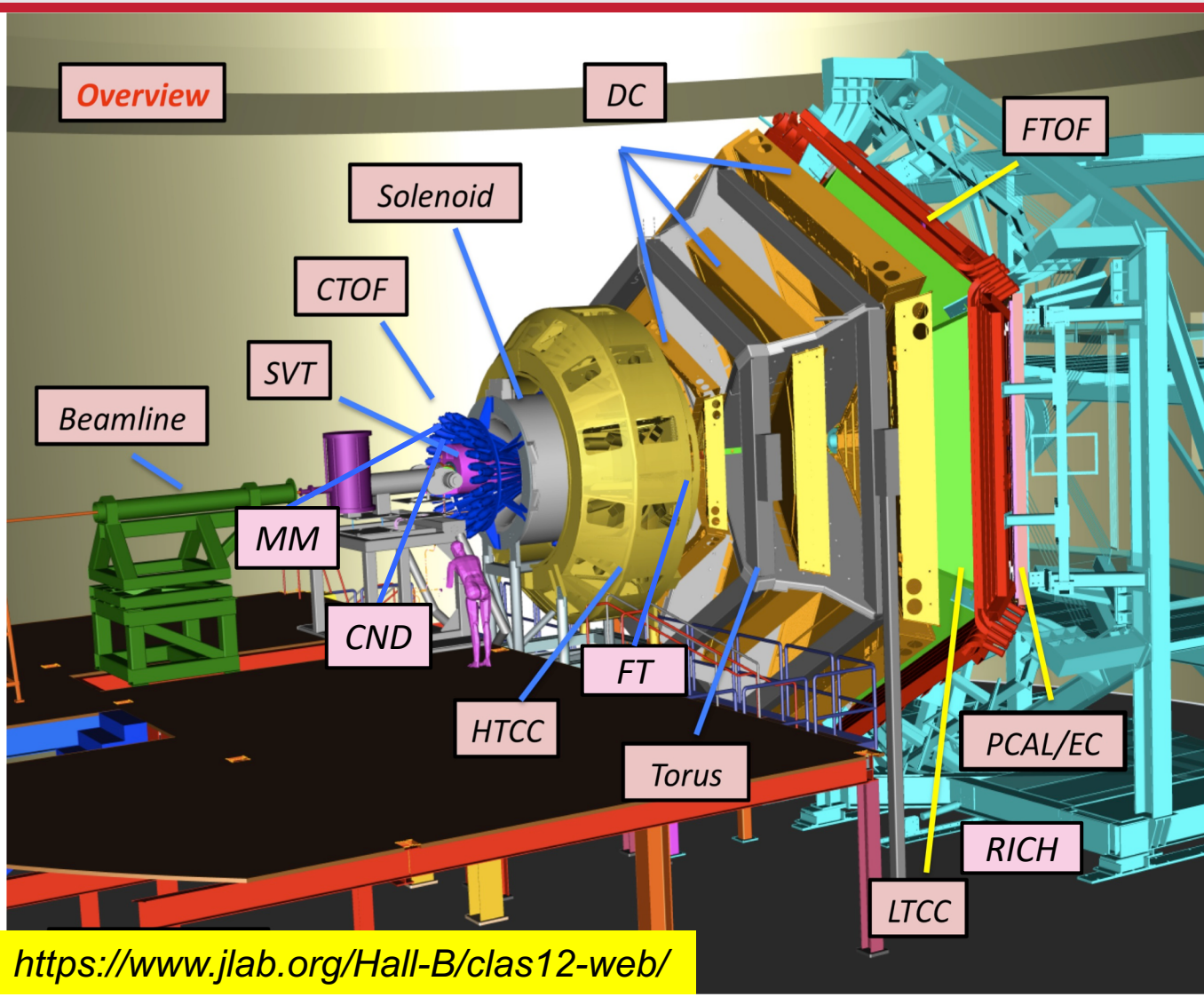
CLAS12

Forward Detector (FD):

- ***TORUS magnet***
- ***Drift chamber system***
- ***HT Cherenkov Counter***
- *LT Cherenkov Counter*
- ***Forward ToF System***
- ***Preshower calorimeter***
- ***E.M. calorimeter***
- *RICH detector*
- ***Forward Tagger***

Central Detector (CD):

- ***SOLENOID magnet***
- ***Barrel Silicon Tracker***
- ***Micromegas***
- ***Central Time-of-Flight***
- *Central Neutron detector*

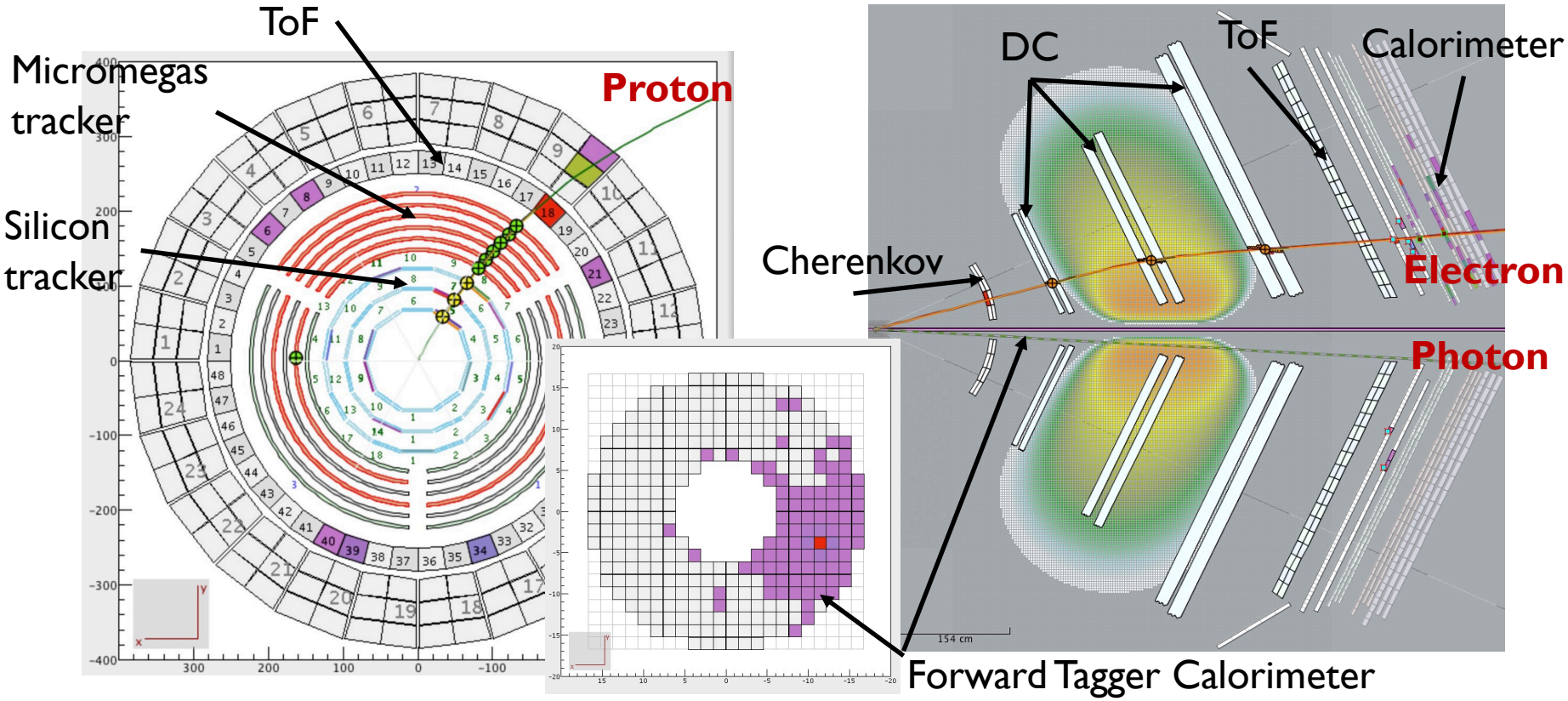


https://www.jlab.org/Hall-B/clas12-web/

DVCS event in CLAS12

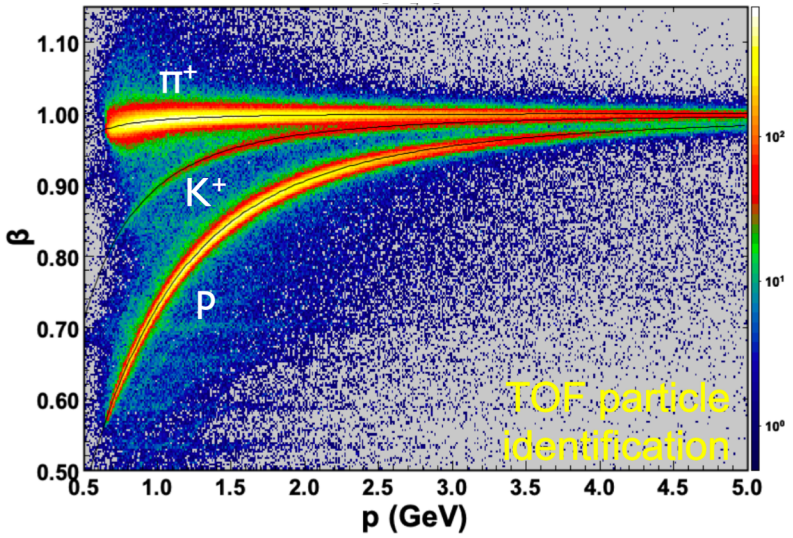
Typical DVCS event:

- Electron in the forward detector (torus, DC, ToF, Cherenkov, Calorimeter)
- Photon in the forward tagger (calorimeter)
- Proton in the central detector (solenoid, Silicon, Micromegas and ToF)



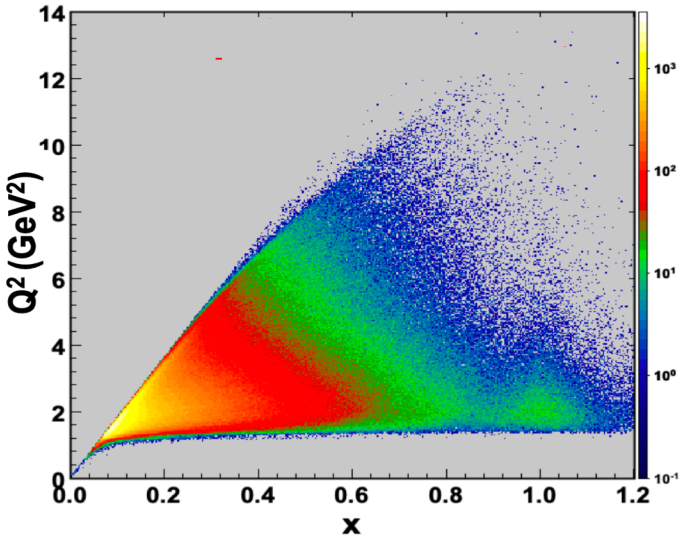
Event Reconstruction and kinematic

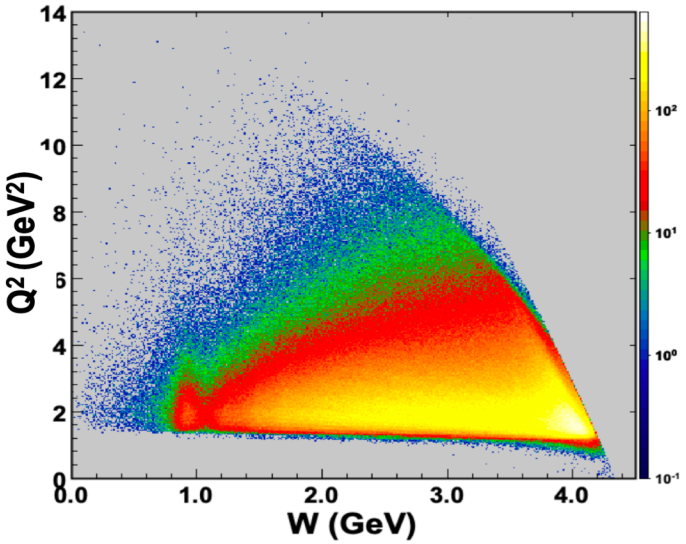
Reconstruction in the Forward Time of Flight



Positive charges
β vs momentum

Kinematic Reach
(100 min of data taking)

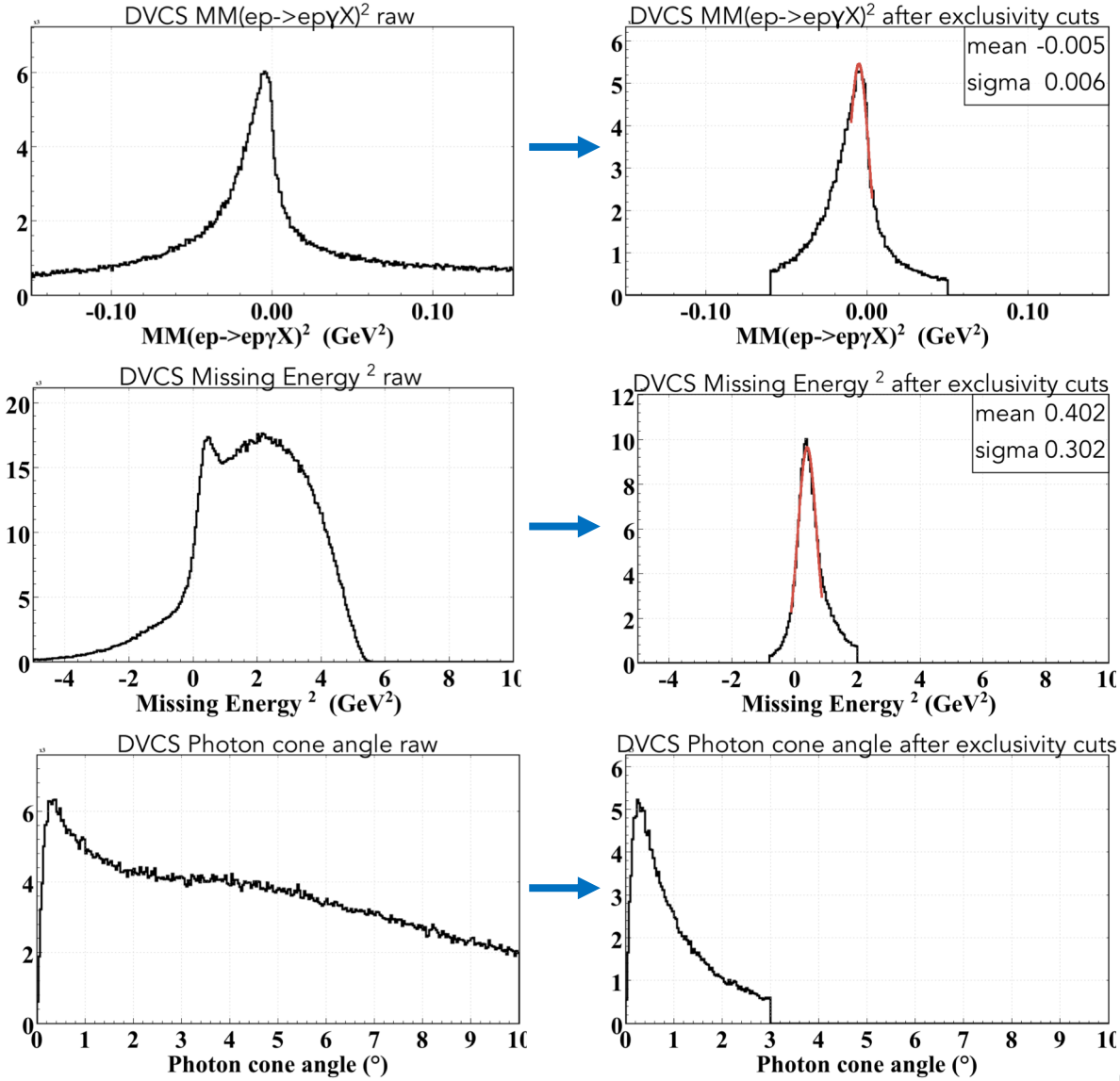




Exclusivity

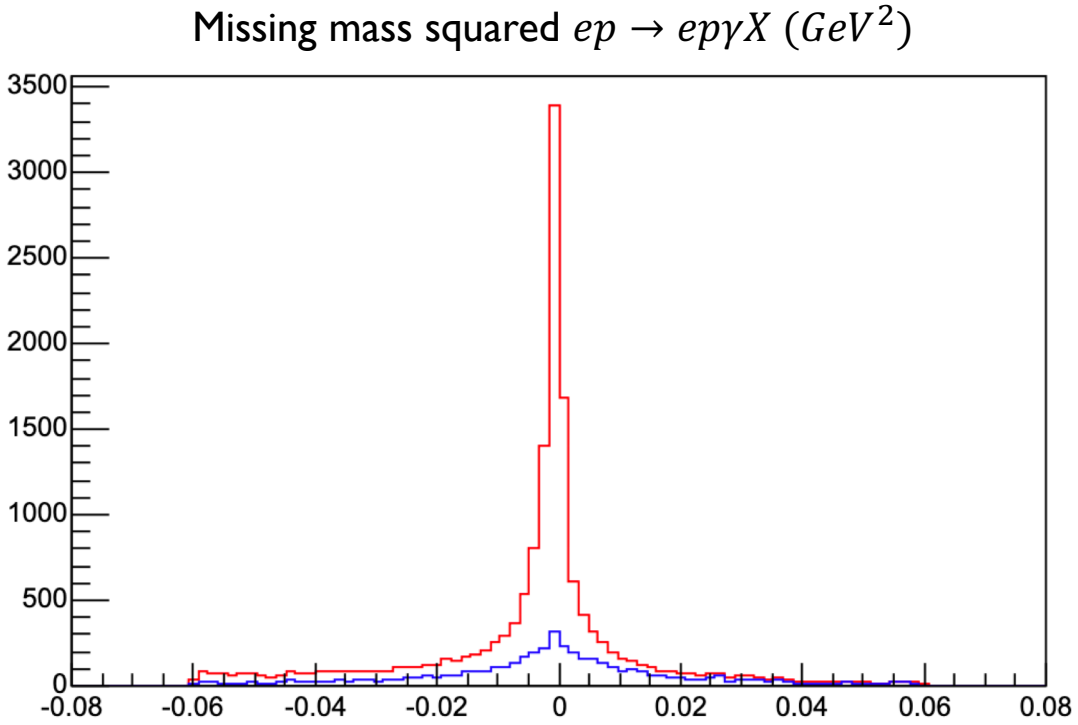
Selection of exclusive DVCS events:

- **Missing mass**
  $ep \rightarrow ep\gamma X$
- **Missing energy**
  $ep \rightarrow ep\gamma X$
- **Cone angle**: angle between measured and computed photon (using proton and electron)
- Main background:
  $ep \rightarrow ep\pi^0 \rightarrow ep\gamma\gamma$



Contamination from π^0

- Contamination can come from an **asymmetric decay of a π^0**
- Depends a lot on:
  - Kinematic region
  - Exclusivity cuts
- Several methods to estimate this contamination have been implemented



Exclusive π^0 contamination
from simulation
red: total signal, blue contamination

First look at beam-spin asymmetry

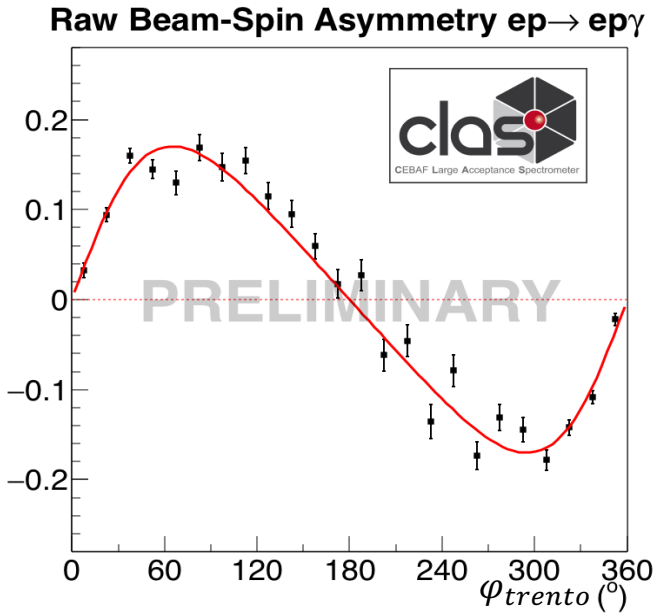
Preliminary asymmetry:

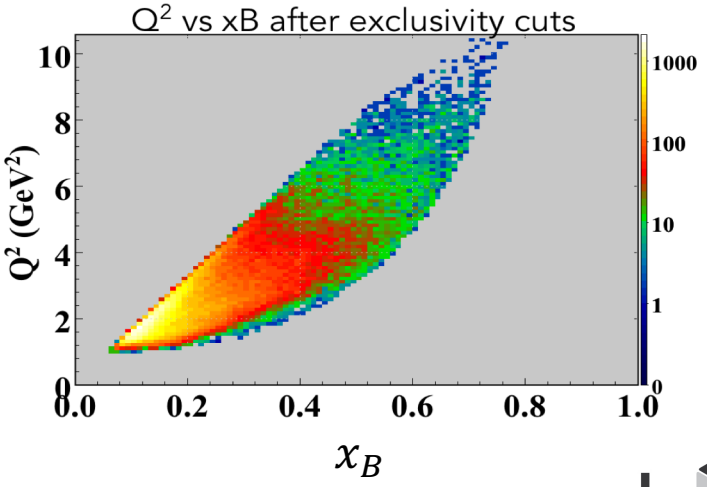
$$A_{LU} = \frac{1}{P}\frac{N^+(\phi_{trento}) - N^-(\phi_{trento})}{N^+(\phi_{trento}) + N^-(\phi_{trento})}$$

P polarization

N^+ / N^- number of events with helicity + / -

- Residual background not subtracted
- Only statistical errors
- Integrated over all kinematic domain





Summary and outlook

Guillaume CHRISTIAENS

guillaum@jlab.org

- Only 2% of expected statistic shown here
- Tuning of calibration and reconstruction for optimized performances
- Analysis in progress, on π^0 contamination, simulation, exclusivity cuts …