Deeply Virtual Compton Scattering at 10.6 GeV with CLAS12 at Jefferson Lab

Guillaume CHRISTIAENS (CEA Saclay, University of Glasgow)

for the CLAS Collaboration

Friday, October 26, 2018

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 (GPD)**: correlations of longitudinal momentum and transverse position (deep exclusive processes)
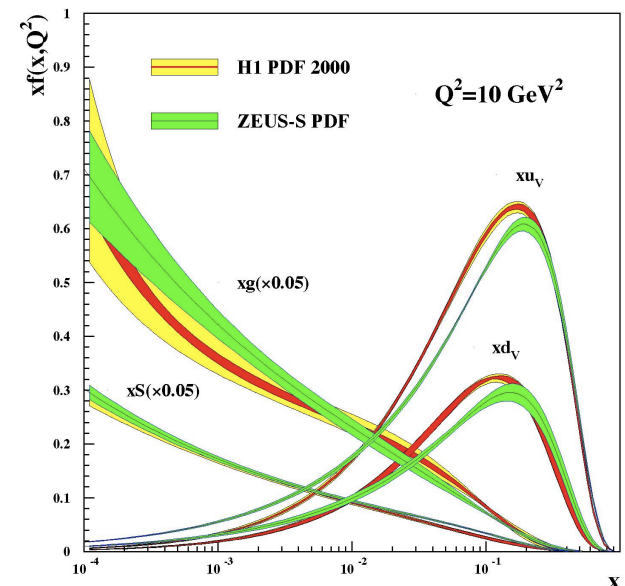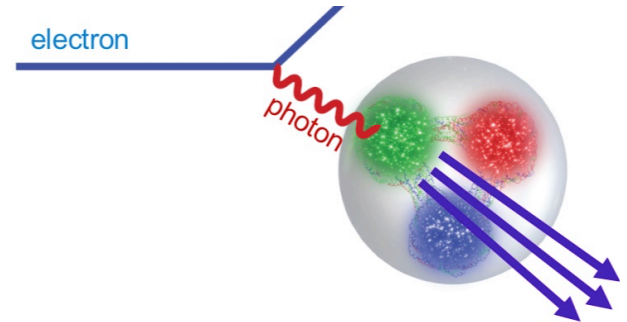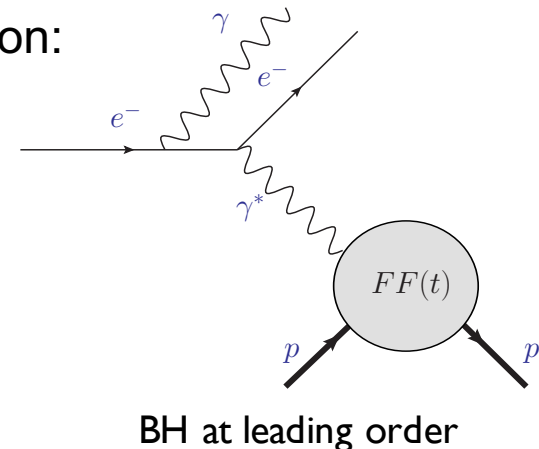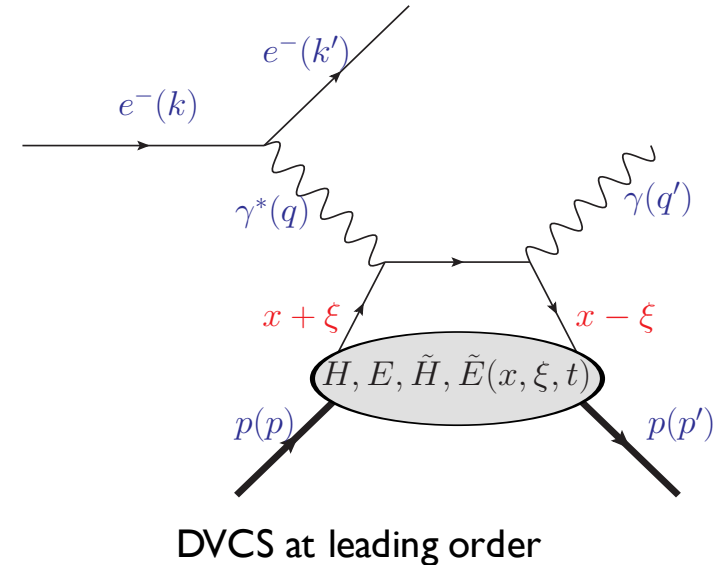
Deeply Virtual Compton Scattering

Deeply Virtual Compton Scattering

- GPD 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 Beithe-Heitler (BH)

$$\sigma_{(ep \to ep\gamma)} = |DVCS|^2 + |BH|^2 + Interference$$
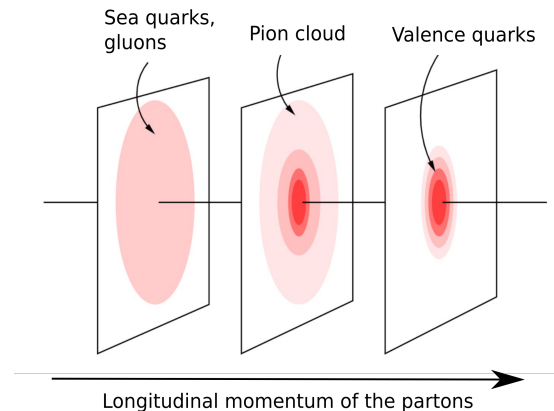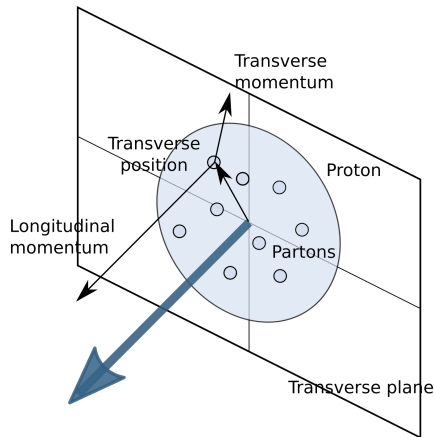
BH at leading order

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

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

$$J = \int_{-1}^{1} x\Big[H(x, \xi, 0) + E(x, \xi, 0)\Big]dx$$
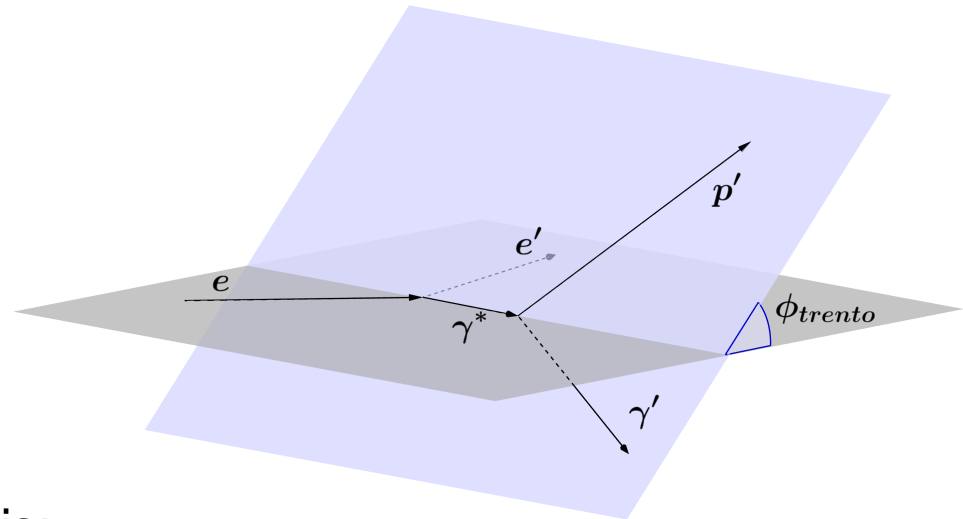
Ji, 1997

Beam-spin asymmetry

- Extraction of GPD 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:

$$A_{LU} \simeq \frac{A \sin(\phi_{trento})}{1 + B \cos(\phi_{trento})} \qquad A = \frac{s_1^{\mathcal{I}}}{\kappa c_0^{BH} + c_0^{\mathcal{I}}} \qquad B = \frac{\kappa c_1^{BH} + c_1^{\mathcal{I}}}{\kappa c_0^{BH} + c_0^{\mathcal{I}}}$$

$c_1^{\mathcal{I}}, \ c_0^{\mathcal{I}}, \ s_1^{\mathcal{I}}$ combinations of CFF $\qquad s_1^{\mathcal{I}} \propto Im(F_1\mathcal{H} + \xi(F_1 + F_2)\tilde{\mathcal{H}} - kF_2\mathcal{E})$
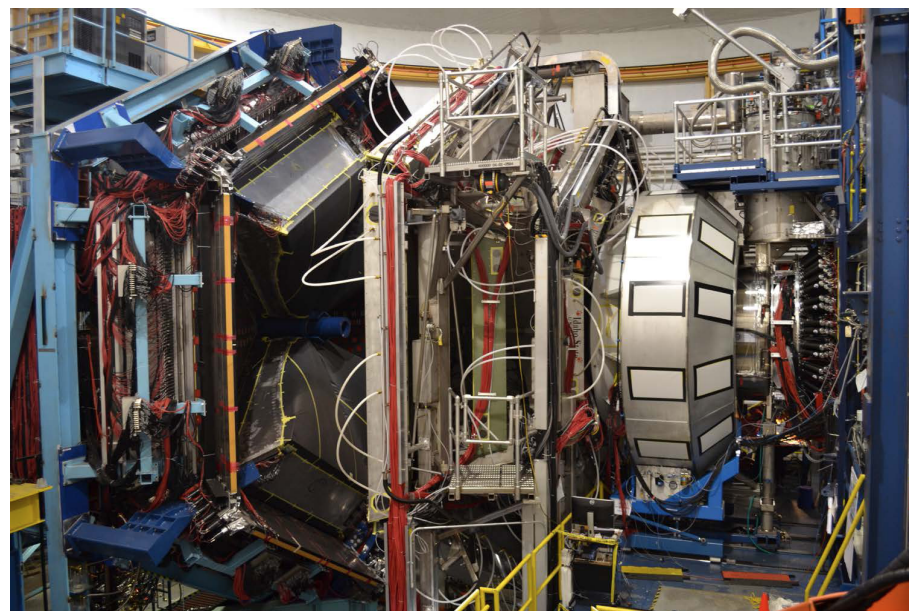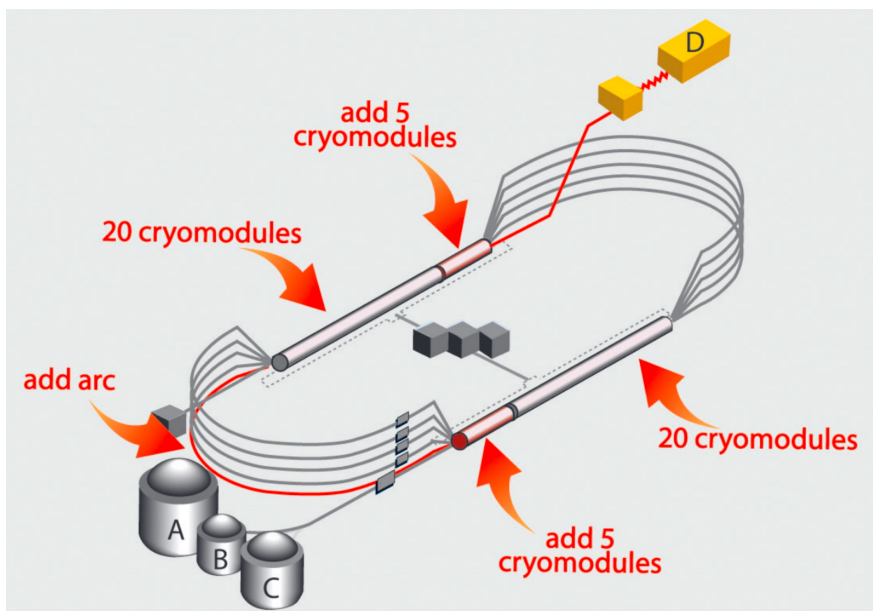
CLAS12 installation complete

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

CLAS12 data taking started in 2018
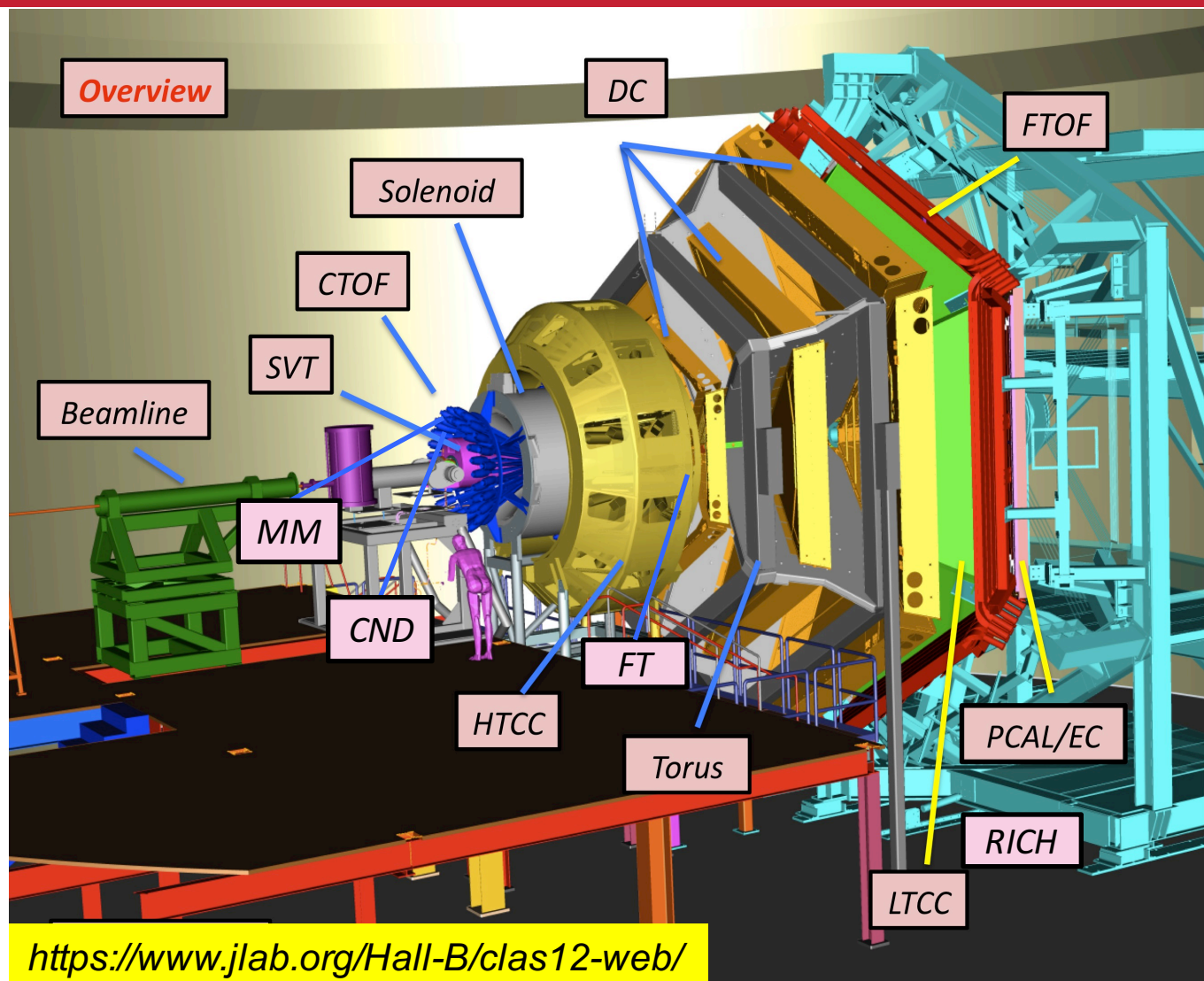- **10.6 GeV electron beam**
- **Unpolarized liquid hydrogen** target

add 5 cryomodules

20 cryomodules

add arc

20 cryomodules

add 5 cryomodules

A B C D

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*
- Neutron detector

Overview

DC · FTOF · Solenoid · CTOF · SVT · Beamline · MM · CND · HTCC · FT · Torus · PCAL/EC · RICH · LTCC

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, Silicium, Micromegas and ToF)
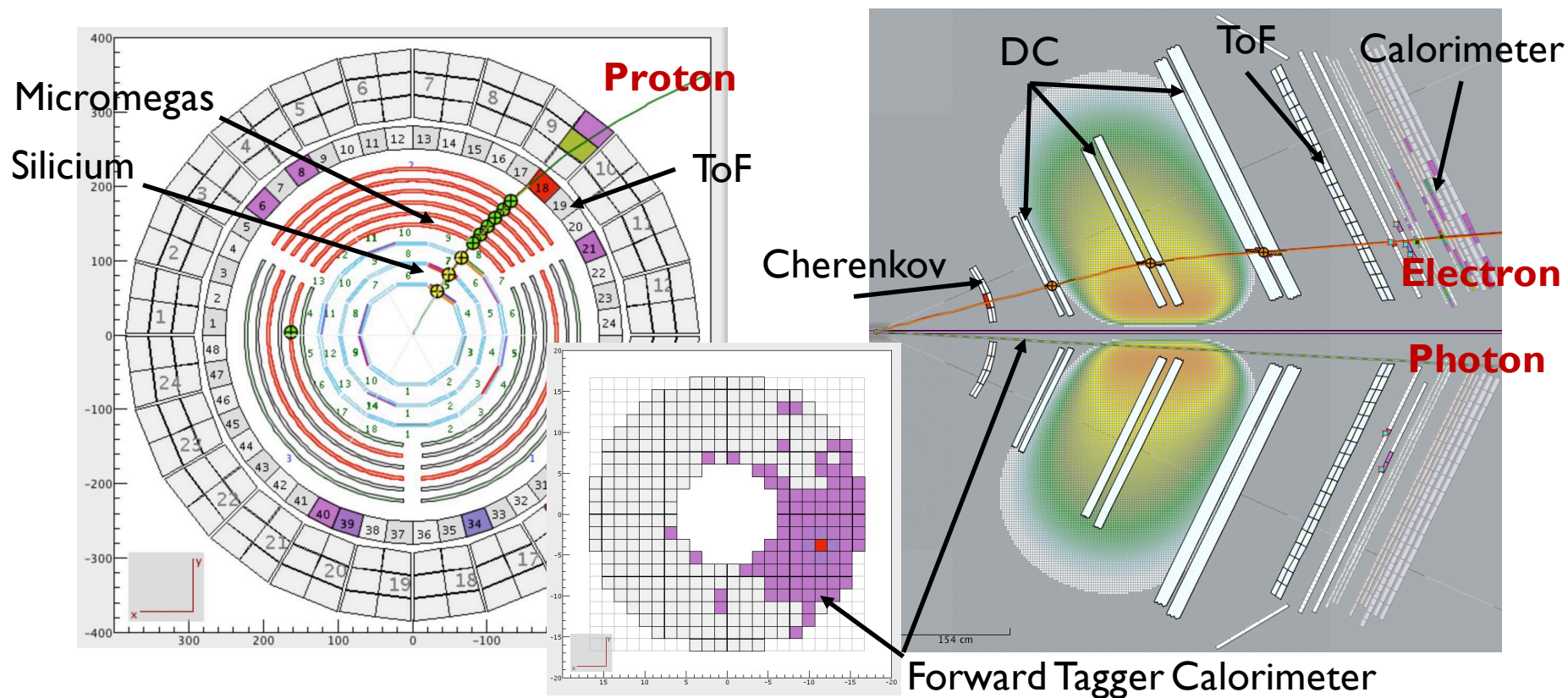
DVCS kinematic and particle selection

- **High energy electron**
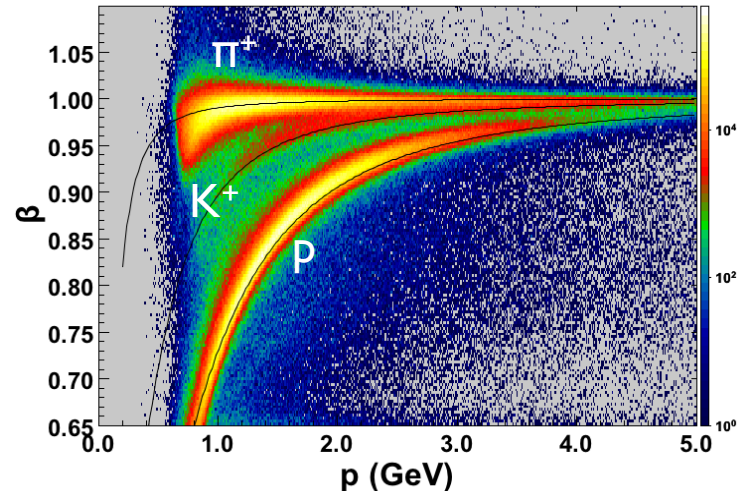
$$E_{elec} > 2\ GeV$$
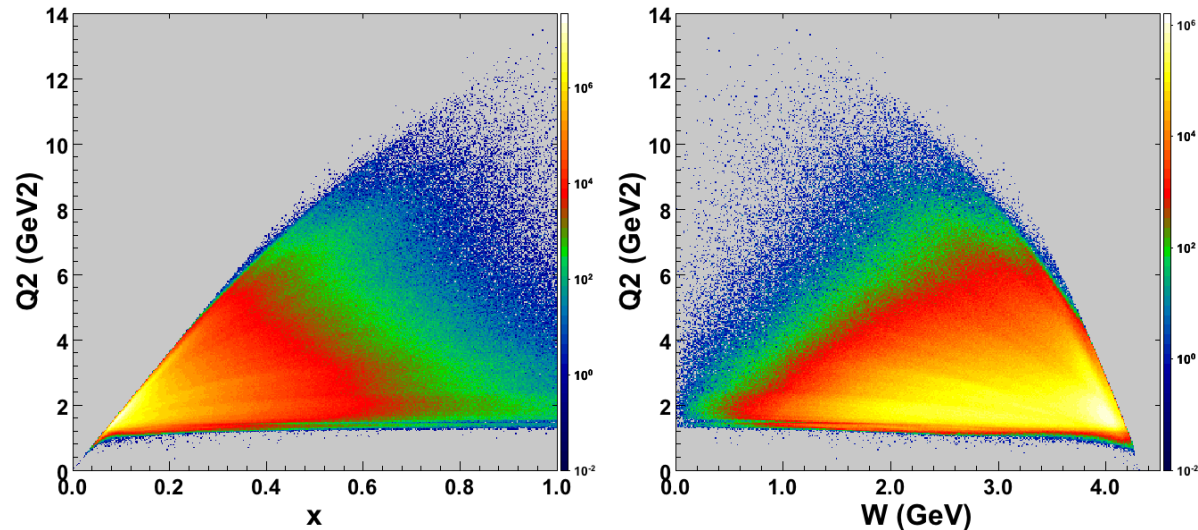
- **High energy photon**

$$E_{phot} > 3\ GeV$$

- **Proton**

- **Kinematical cuts**

$$Q^2 = -q^2 > 1\ GeV^2$$

$$W^2 = (p + q)^2 > 4\ GeV^2$$

Positive charges β vs momentum P

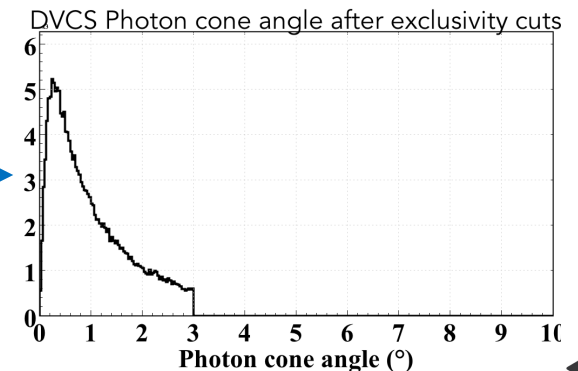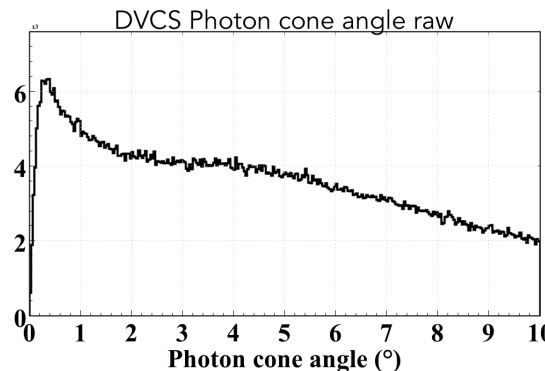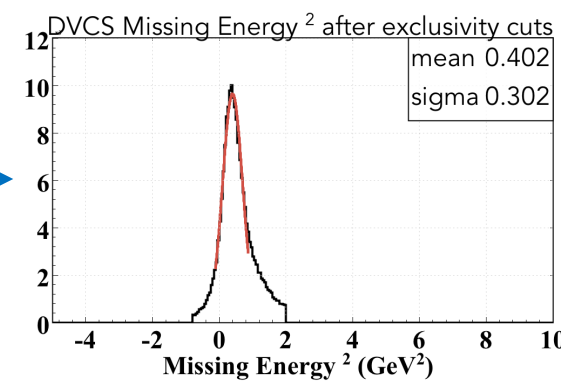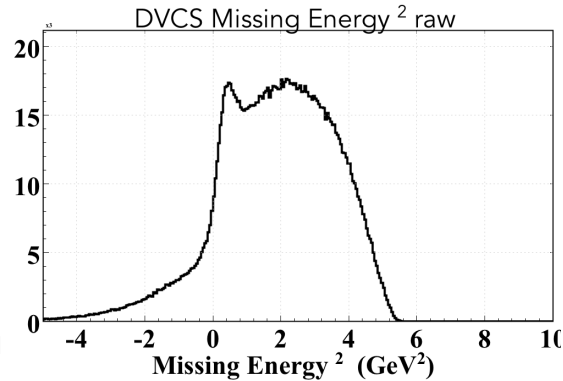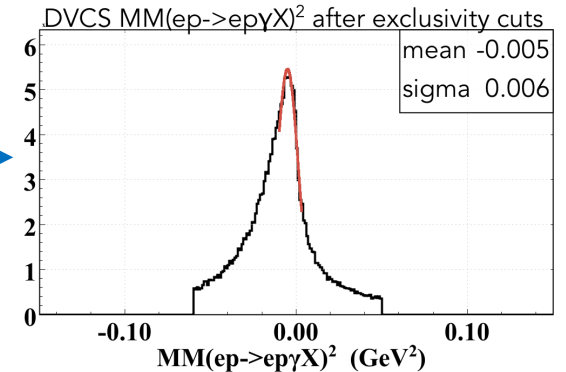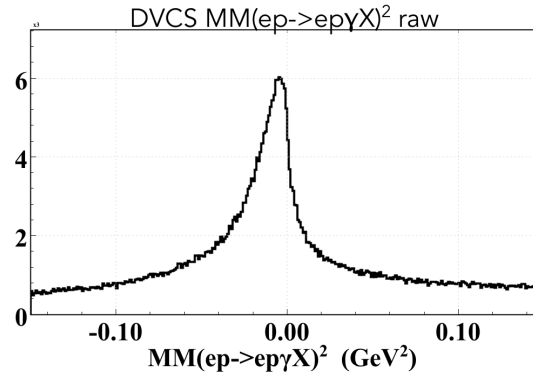Raw electrons kinematics

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:
  $$ep \rightarrow ep\pi^0 \rightarrow ep\gamma\gamma$$

DVCS MM(ep->epγX)² raw

DVCS MM(ep->epγX)² after exclusivity cuts
mean -0.005
sigma 0.006

DVCS Missing Energy ² raw

DVCS Missing Energy ² after exclusivity cuts
mean 0.402
sigma 0.302

DVCS Photon cone angle raw

DVCS Photon cone angle after exclusivity cuts

First look at beam-spin asymmetry
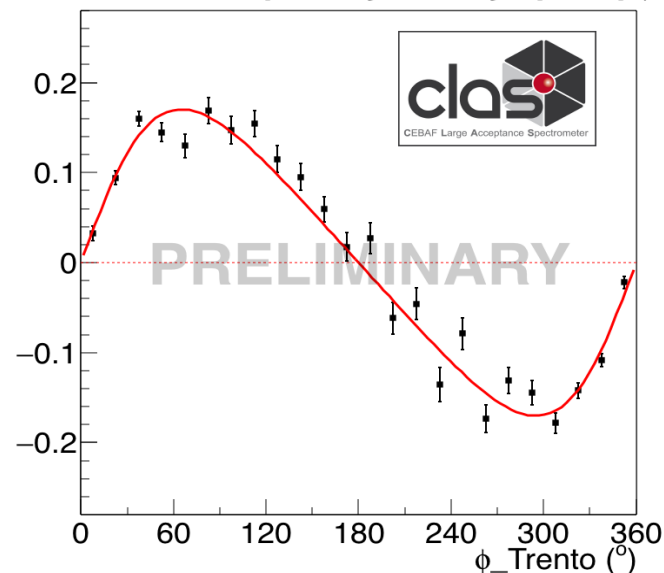
Preliminary asymmetry:

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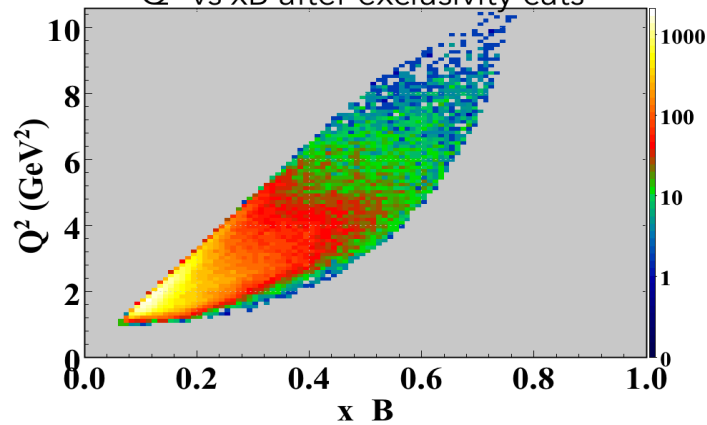
P polarization

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

- Residual background not yet subtracted

- Only statistical errors

- Integrated over all kinematic domain

Raw Beam-Spin Asymmetry ep→ epγ

PRELIMINARY

ϕ_Trento (^{o})

Q^2 vs xB after exclusivity cuts

Q^2 (GeV^2)

x_B

Summary and outlook

- Data taking still ongoing (data here are around 2% of approved beam time)

- DVCS extraction and preliminary asymmetry

- Outlook:

  - Work in progress, for instance, π^0 contamination not yet removed

  - CFF extraction with global fits

Raw Beam-Spin Asymmetry ep→ epγ