Coherent Deeply Virtual Compton Scattering off deuterium with CLAS12 at Jefferson Lab

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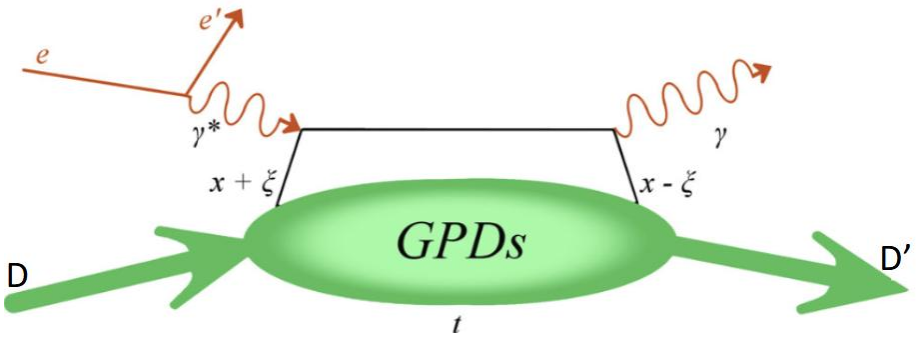
Motivations

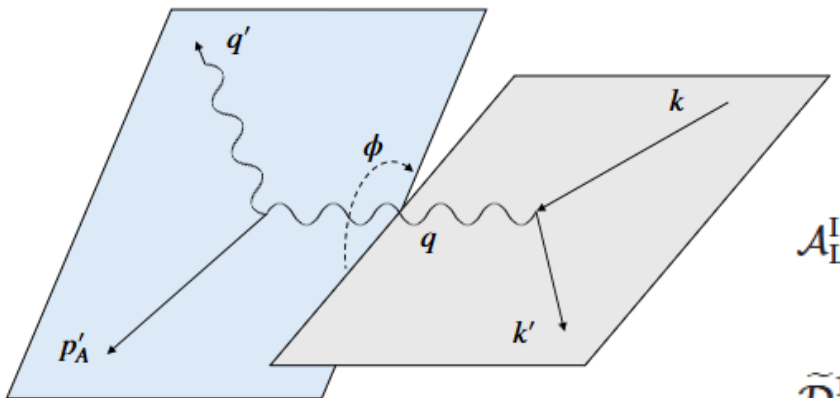
- Generalised Parton Distribution of the deuteron (GPDs)
  - Informations about the partons' position and momentum in the deuteron
  - 9 GPDs expected for the deuteron (only 4 in protons)

- GPDs can be studied in Deeply Virtual Compton Scattering (DVCS)
- Physics observable : Beam Spin Asymmetry (BSA)
- Final state : $e^- + d \rightarrow e^- + d + \gamma$
- This analysis follows up on the studies carried out by Angela Biselli and her students



DVCS and GPD's

- We work with polarized beam and unpolarized target to extract BSA
- BSA in coherent DVCS of the deuteron is sensitive to 3 of the 9 GPD's
- BSA is measured as a function of the ϕ angle between the leptonic and hadronic plane



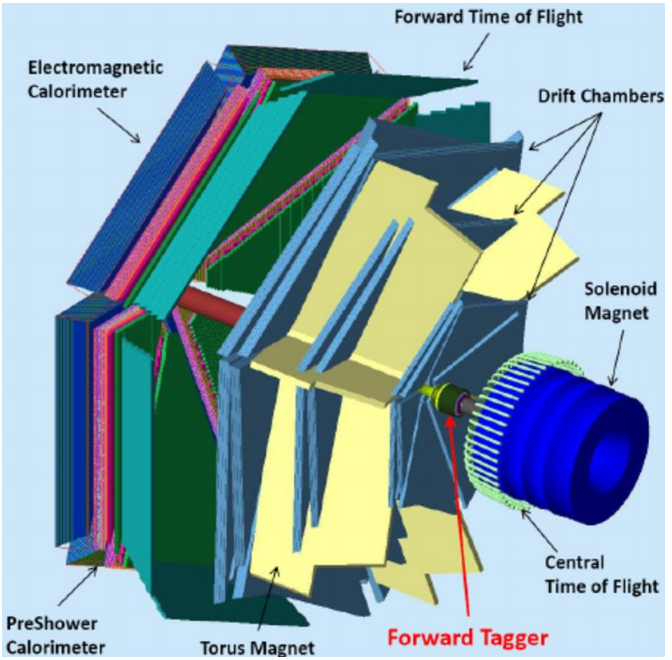
$$A_{LU}(\phi) = \frac{1}{P}\frac{N^+ - N^-}{N^+ + N^-}$$

$$\mathcal{A}^{\mathrm{I}}_{\mathrm{LU}}(\phi) \simeq -\frac{x_D(2-y)\sqrt{\frac{-t}{Q^2}(1-y)}}{2-2y+y^2}\,\mathrm{Im}\widetilde{\mathcal{D}}^{1,1}_{\mathrm{U}}\sin\phi$$

$$\widetilde{\mathcal{D}}^{1,1}_{\mathrm{U}} \equiv \frac{3G_1\mathcal{H}_1 - 2\tau[G_1\mathcal{H}_3 + G_3(\mathcal{H}_1 - \frac{1}{3}\mathcal{H}_5)] + 4\tau^2 G_3\mathcal{H}_3}{3G_1^2 - 4\tau G_1 G_3 + 4\tau^2 G_3^2}$$

CLAS12 data

- Data used :
  - RGB data from spring 2019 and spring 2020
  - Pass2 data
  - 10.2, 10.4 and 10.6 GeV data with torus magnet inbending
  - 85% polarized beam
- Configuration
  - CLAS12 + Forward Tagger (FT)



Analysis overview

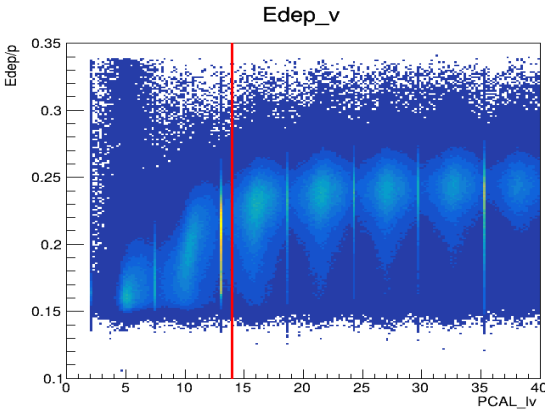
- Particle identification using CLAS12 PID, plus additional PID and fiducial cuts
- Construct all possible combination of final state particles and select the one yielding exclusivity variables closer to the nominal DVCS ones:

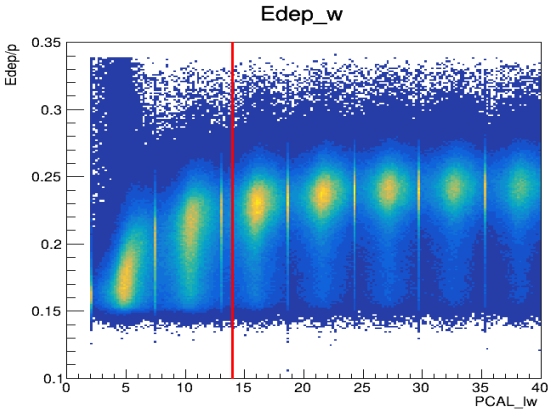
$$e^- + d \rightarrow e^- + d + \gamma$$

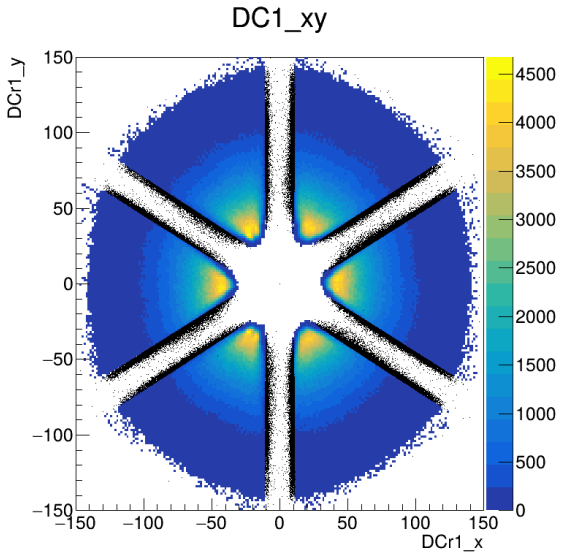
- Channel identification cuts on using exclusivity variables informed by Monte-Carlo simulations
- π^0 background subtraction
- Extraction of the asymmetry

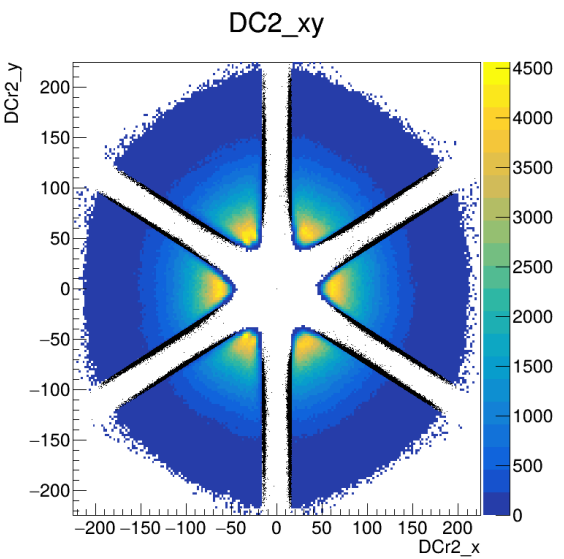
Electron identification

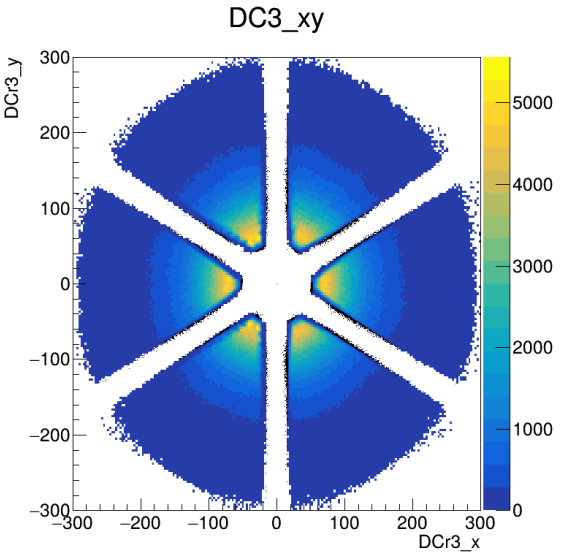
- PID = 11
- PCAL : v and w > 14cm
- DC : edge > 6cm





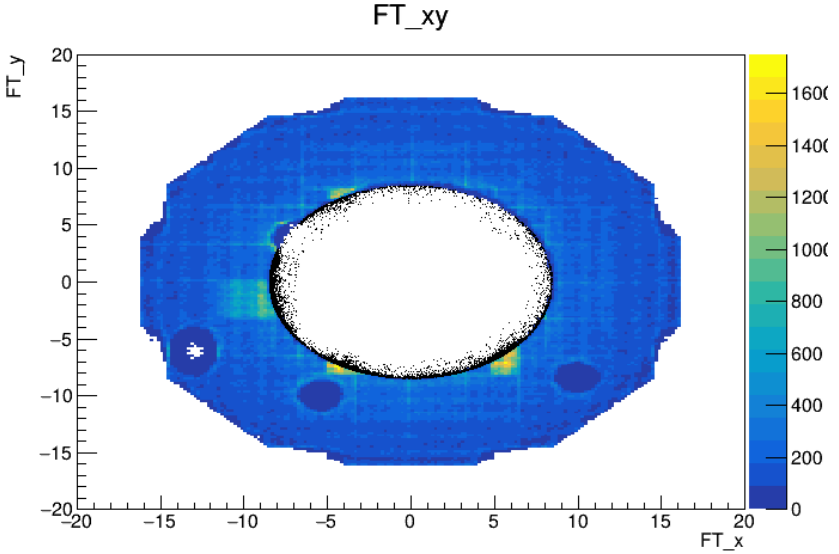


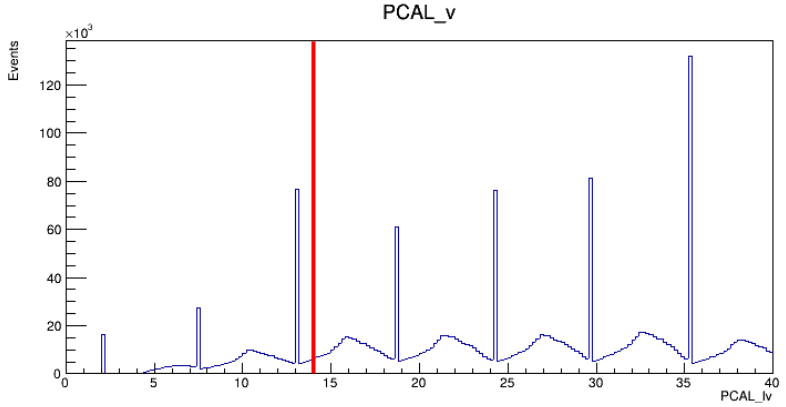


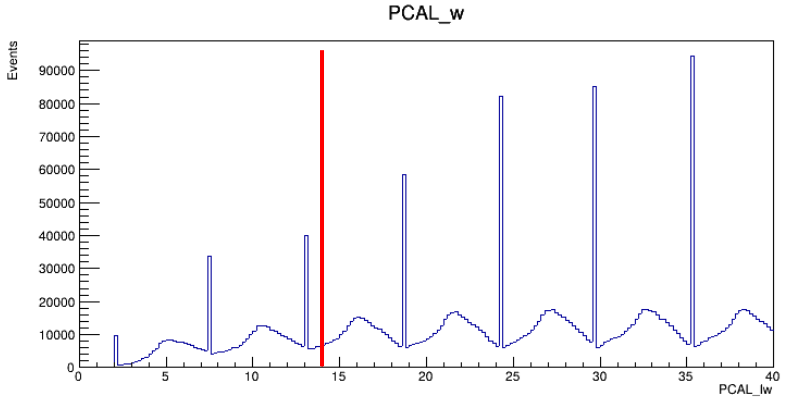


Photon identification

- PID = 22
- In FD : PCAL v and w > 14cm
- In FT : $x^2 + y^2 > 72cm^2$







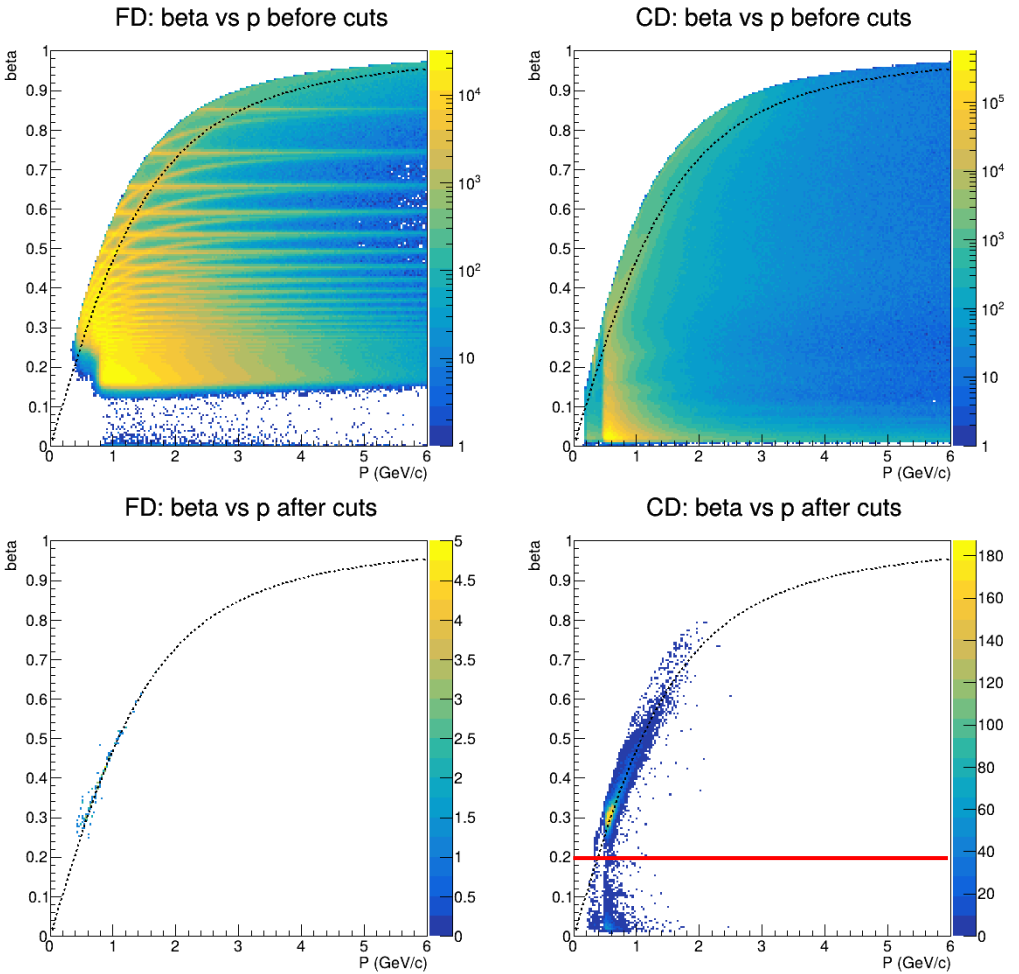
Deuteron identification

PID = 45

$\beta > 0.2$

DVCS deuterons are mainly in the CD

Exclusivity cuts remove all the accidental background



Channel identification

$Q^2 > 1.5$ GeV

$W > 2$ GeV

γ energy > 1.5 GeV

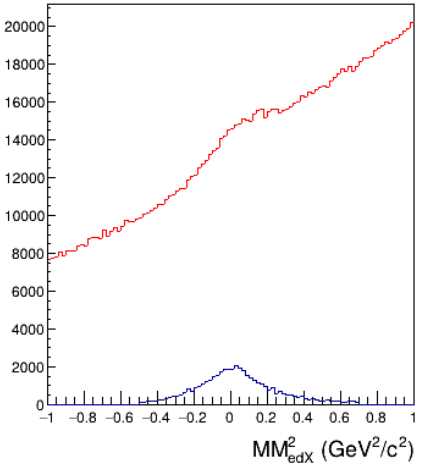
e^- momentum > 1 GeV

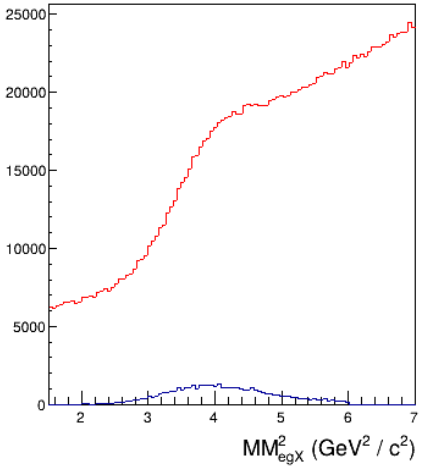
Exclusivity cuts on the following variables

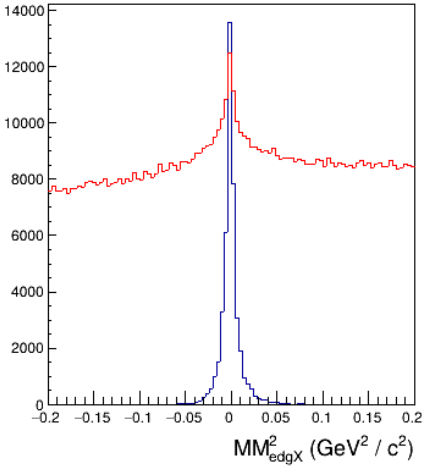
- Missing masses :
  - $e^- + d \rightarrow e^- + d + \gamma + X$
  - $e^- + d \rightarrow e^- + d + X$
  - $e^- + d \rightarrow e^- + \gamma + X$
- $p_\perp$, Δt, $\Delta\phi$, $\theta(\gamma, X)$
- Different sets of cuts used for γ in FT/FD

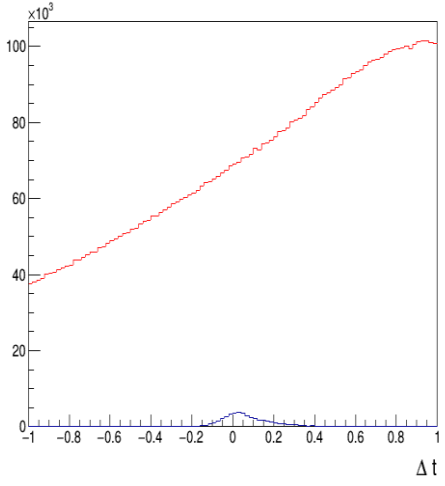
Exclusivity variables before (red) and after (blue) exclusivity cuts

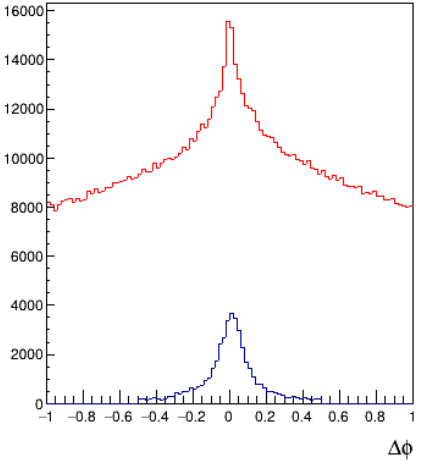
Data after cuts is shown scaled by a factor 5

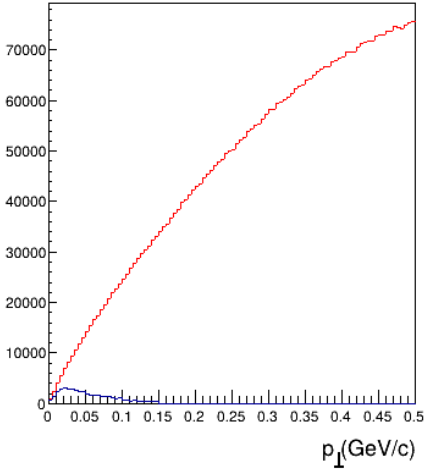


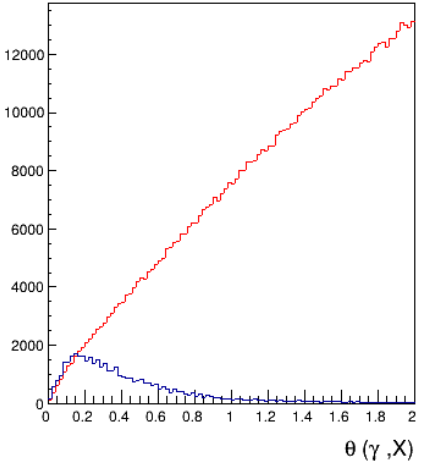










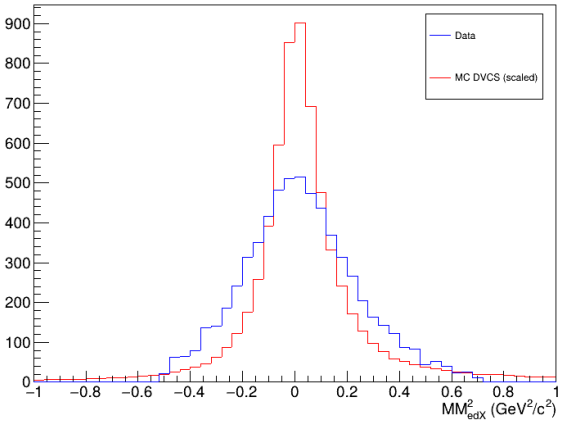


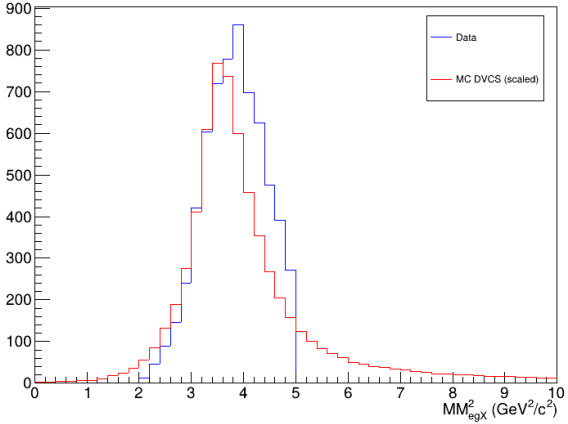
Monte-Carlo

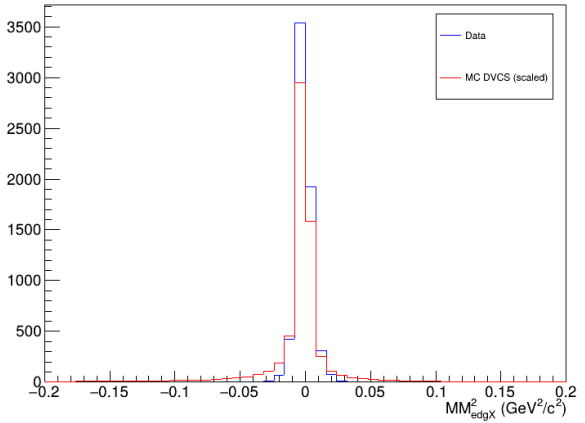
- Event generator:
  - fsgen12 from S. Stepanyan
  - Phase-space + reasonable Q^2 distribution

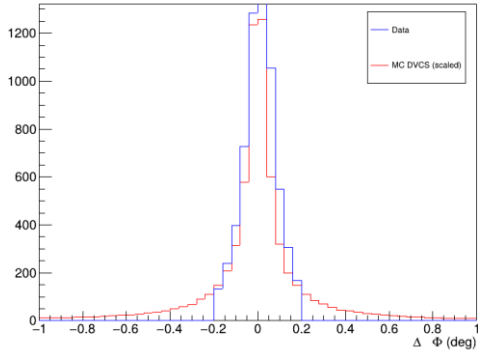
- Full simulation (gemc + coatjava) using RGB settings
- DVCS and π^0 events were generated

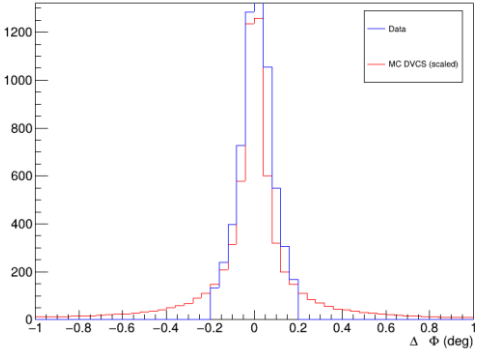
DVCS comparison with Monte-Carlo

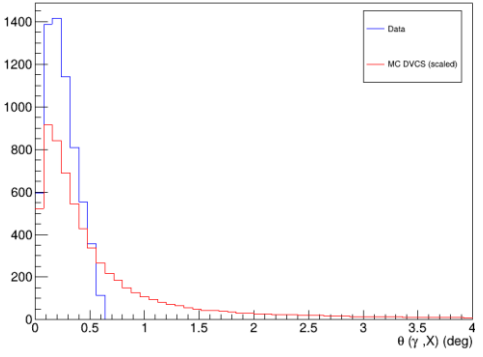


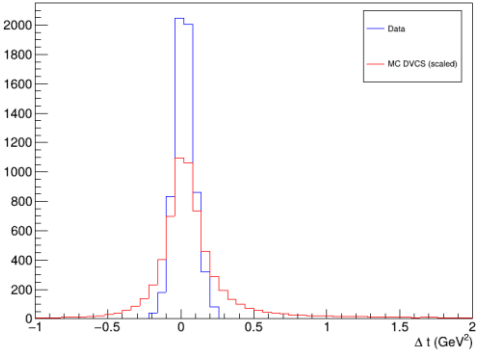






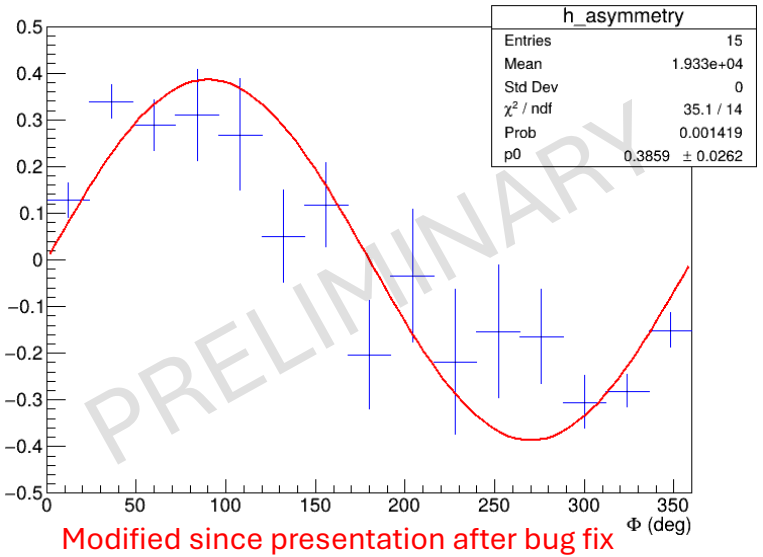






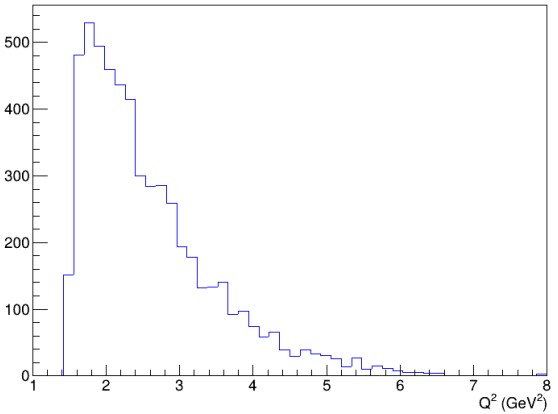
Asymmetry

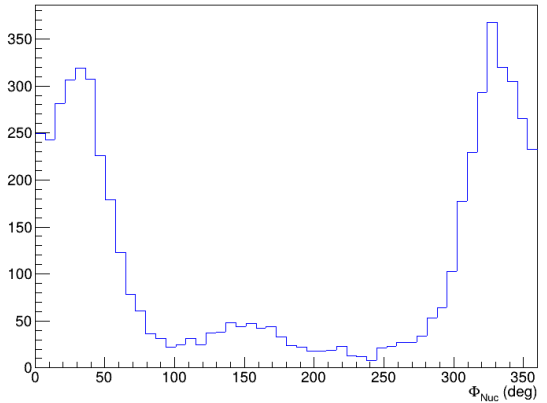
Raw BSA integrated over all kinematics

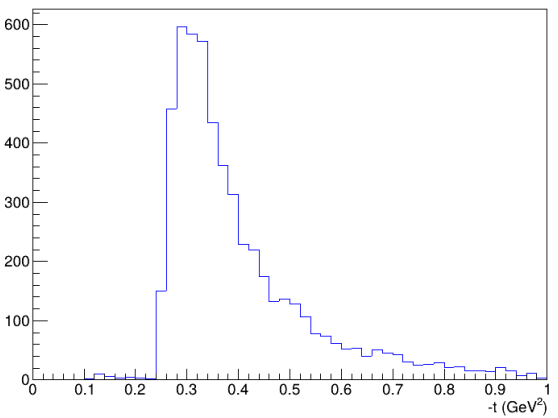


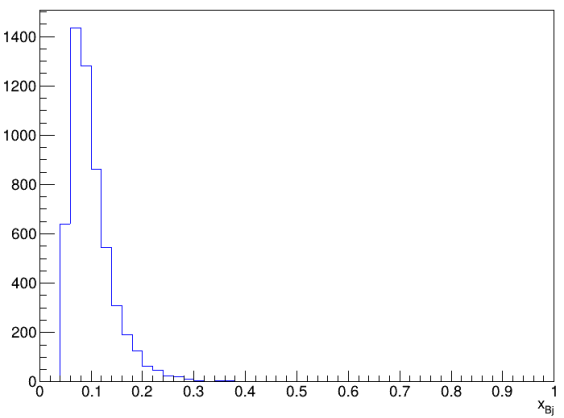
Modified since presentation after bug fix

Fit function : $A^*\sin(\Phi)$







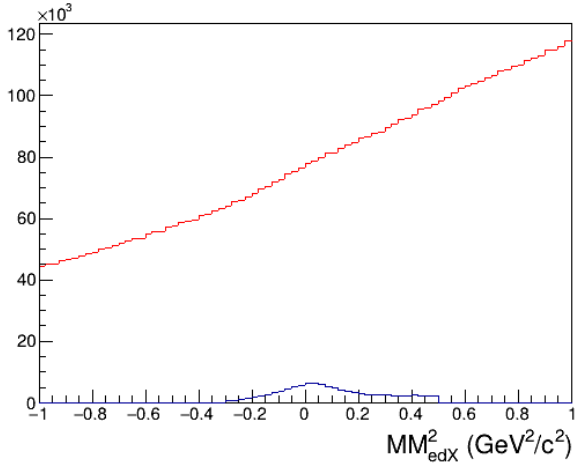


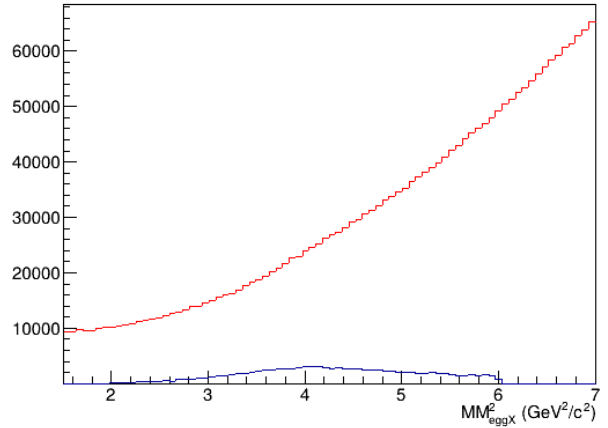
π^0 background subtraction

- Description of the method:
  - Estimate the ratio of partially reconstructed $\mathrm{ed}\pi^0(1\gamma)$ decays (misinterpreted as DVCS) to fully reconstructed $\mathrm{ed}\pi^0$ decays in MC
  - Multiply this ratio by the number of reconstructed $\mathrm{ed}\pi^0$ in data to get the number of $\mathrm{ed}\pi^0(1\gamma)$ in data
  - Subtract this number from DVCS reconstructed event candidates in data for each kinematical bin

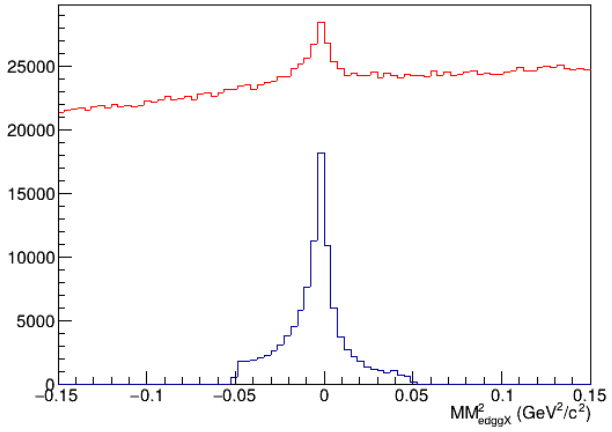
$$\mathrm{ed}\pi^0(1\gamma)_{\,\mathrm{DATA}} = \mathrm{ed}\pi^0{}_{\,\mathrm{DATA}} \times \frac{\mathrm{ed}\pi^0(1\gamma)_{\,\mathrm{MC}}}{\mathrm{ed}\pi^0{}_{\,\mathrm{MC}}}$$

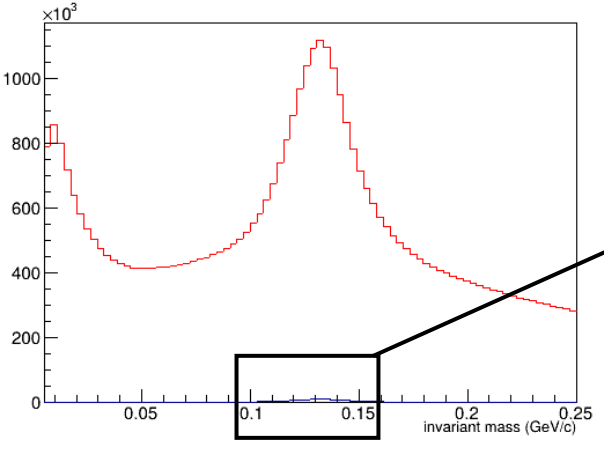
π^0 channel selection before (red) and after (blue) exclusivity cuts

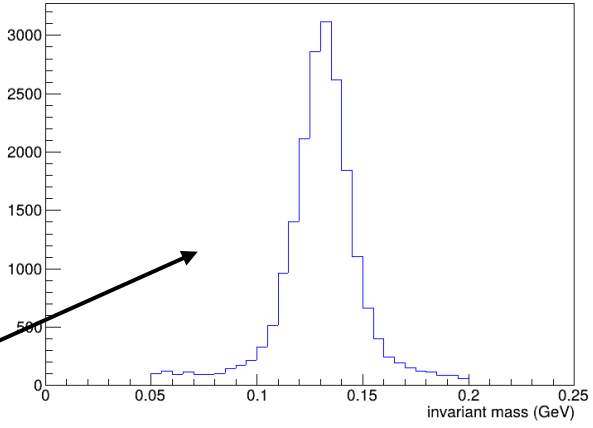




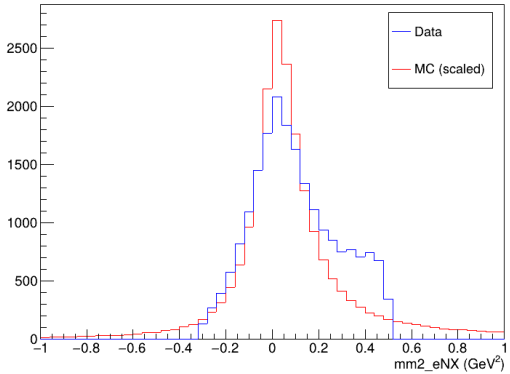
Data after cuts is shown scaled by a factor 5

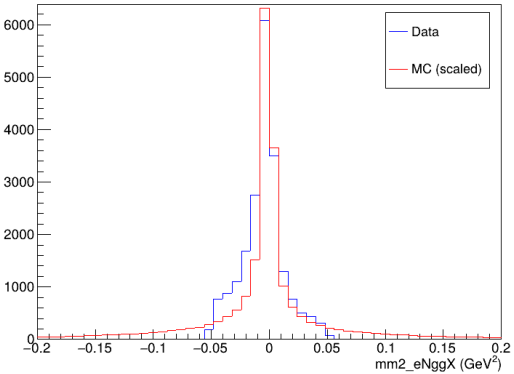


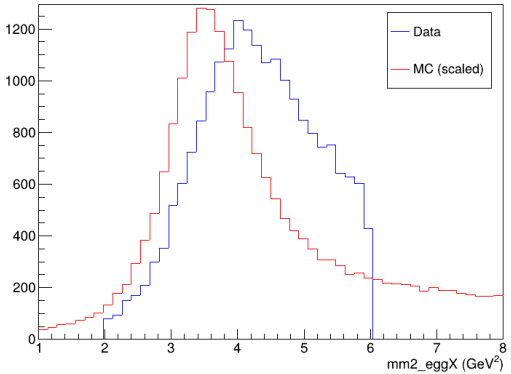


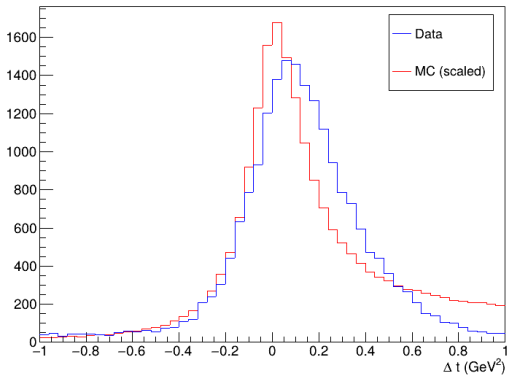


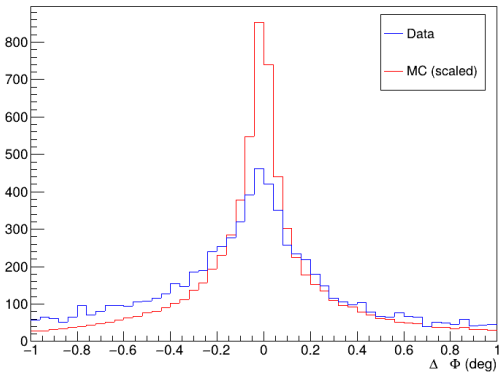
π^0 comparison with Monte-Carlo

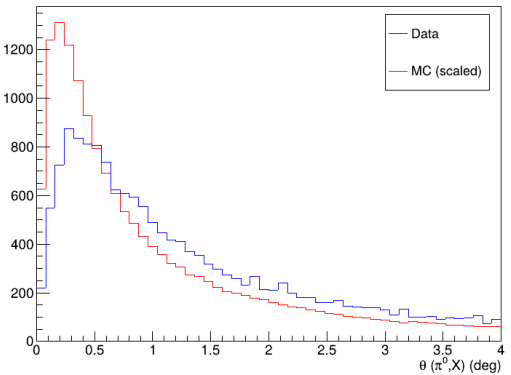


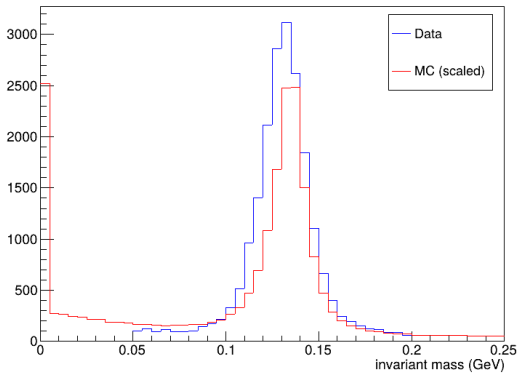












Next steps

- Get asymmetry with π^0 background subtracted
- Refine cuts
- Estimate systematic errors
- Optimize binning
- Write analysis note