3 DVCS candidate selection

3.1 Kinematic and particle identification cuts

The files used in this analysis can be found at */cache/clas12/rg-c/production/summer22/pass1/10.5gev*, and we are using the sidisdvcs train files. They already include the following kinematics cuts:

- $Q^2 > 0.95 GeV^2/C^4$
- $W > 1.95 GeV/C^2$

A first wide selection of events is made to select all potential DVCS candidates before applying any exclusivity cuts. We require at least one electron, one proton, and one photon in the event, if there are multiple, the particle with the highest momentum is selected. The requirements for each of the particles are as follows:

- An electron with $P > 1GeV$ and $-2.77 < \chi^2_{pid} < 3.37$ to select the scattered beam electron.
- A proton with $-3.39 < \chi^2_{pid} < 4.29$ to select the recoil proton.
- A photon with $P > 2GeV$ and $0.9 < \beta < 1.1$ to select a well reconstructed photon with a large enough momentum to be a DVCS candidate. We also require the electron-photon angle ($\theta_{e\gamma}$) to be larger than $6°$ to remove bremsstrahlung photons.

The χ^2_{pid} cuts are set at 3σ around the peak of the distribution (Fig. 2) and all photons with $\theta_{e\gamma} < 6°$ are added to the electron momentum (Fig. 3).

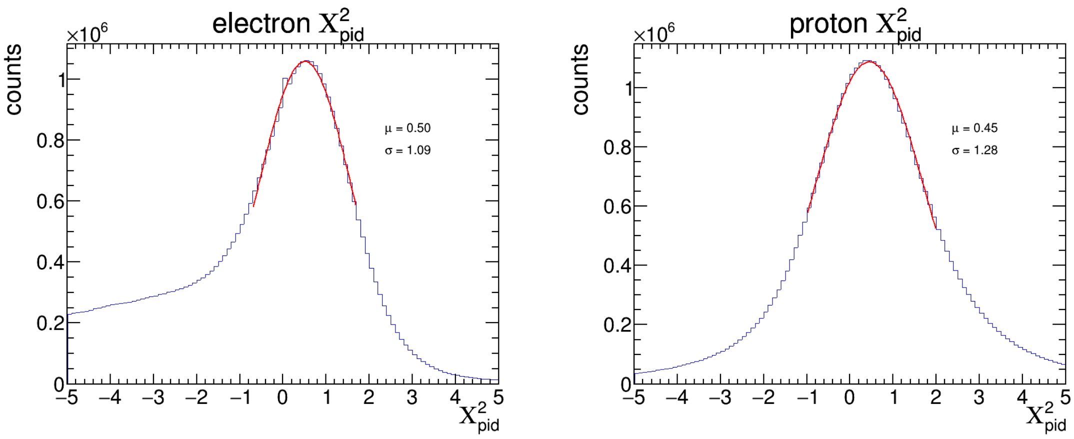

Figure 2: χ^2_{pid} distributions for electron (left) and protons (right) fitted with a gaussian.

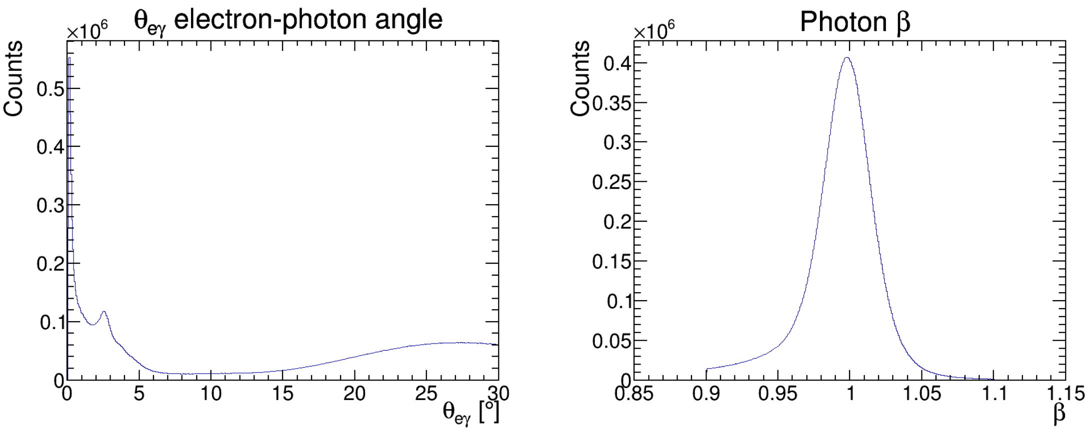

Figure 3: Left: Angle between the photon and the scattered electron, only photons with $\theta_{e\gamma} > 6°$ are selected for DVCS. Right: photon β distribution on PCAL with the $[0.9, 1.1]$ cut applied.

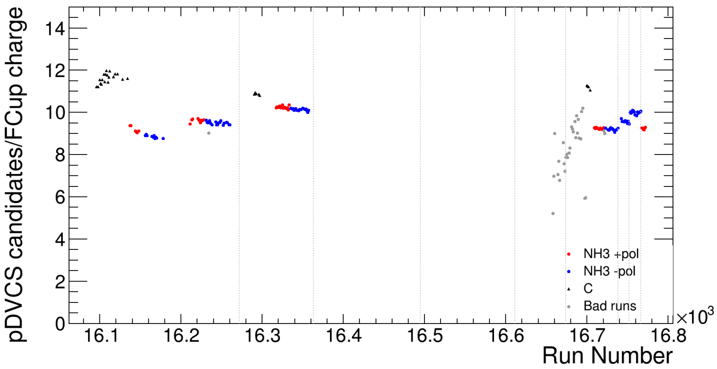

Figure 4: Ratio of the number of DVCS candidates over beam charge for each run in Summer 22 data. Grey markers are runs that were removed at the QADB selection stage or because of Hall C bleed-through.

3.2 QADB selection

The full QADB timelines are available for RGC Summer 22 data [1], we use it to select only events for which the beam and detector conditions were suitable to measure asymmetries. The following bits are required to be set to one in QADB:

- TotalOutlier
- TerminalOutlier
- MarginalOutlier
- SectorLoss
- LowLiveTime
- ChargeHigh
- ChargeNegative
- ChargeUnknown
- PossiblyNoBeam

The beam charge used in the analysis is only incremented in time bins that pass the same QADB selection criteria.
The comments in QADB for each run are also checked, and some runs have been removed at this stage because of detector issues or because tests were performed during the run. Runs 16658 to 16695 are also removed because Hall C bleed-through, the number of DVCS candidates normalized by the run beam charge is anomalous on this range Fig. 4. Issues were also noted on this run range in different physics channel and on the target performance monitoring tools.

3.3 Run list

The summer 22 run list used for the analysis is:

- NH_3 target runs with positive helicity: 16137, 16138, 16144, 16145, 16146, 16148, 16211, 16213, 16214, 16221, 16222, 16223, 16224, 16225, 16226, 16228, 16317, 16318, 16320, 16321, 16322, 16323, 16325, 16326, 16327, 16328, 16329, 16330, 16331, 16332, 16333, 16709, 16710, 16711, 16712, 16713, 16715, 16716, 16717, 16718, 16719, 16720, 16767, 16768, 16769, 16770, 16771, 16772.
- NH_3 target runs with negative helicity: 16156, 16157, 16158, 16164, 16166, 16167, 16168, 16169, 16170, 16178, 16231, 16232, 16233, 16235, 16236, 16238, 16243, 16244, 16245, 16246, 16248, 16249, 16250, 16251, 16252, 16253, 16256, 16257, 16259, 16260, 16335, 16336, 16337, 16338, 16339, 16341, 16343, 16345, 16346, 16348, 16350, 16352, 16353, 16354, 16355, 16356, 16357, 16723, 16726, 16727, 16728, 16729, 16730, 16731, 16732, 16733, 16734, 16736, 16738, 16742, 16743, 16744, 16746, 16747, 16748, 16749, 16750, 16751, 16752, 16753, 16754, 16755, 16756, 16757, 16758, 16759, 16761, 16762, 16763, 16765, 16766.

- Carbon target runs: 16096, 16098, 16100, 16101, 16102, 16103, 16105, 16106, 16107, 16108, 16109, 16110, 16111, 16112, 16113, 16114, 16115, 16116, 16117, 16119, 16122, 16128, 16134, 16290, 16700, 16701, 16702, 16704, 16291, 16292, 16293, 16296, 16297.
- CH_2 target: 16298, 16299, 16300, 16301, 16302, 16303.
- Runs with no target cell but with the liquid helium bath: 16307, 16308, 16309, 16184.
- Runs with no target cell and no liquid helium bath: 16186.

4 Fiducial cuts

4.1 DC fiducial cuts

Fiducial cuts are applied to ensure that all particles are detected in the active area of the detector, far enough from the edges to be properly reconstructed. The reconstruction of electrons and protons tracks in the forward region is done by the drift chambers (DC). A cut is applied to the *edge* variable of the track that is defined as the distance of closest approach of the track to the edge of the detector on each DC region. Two sets of cuts are defined, one for inbending and one for outbending particle. The cuts are build from the distribution of track χ^2/NDF as a function of the edge variable, choosing first a cut on region 2 then region 1 and finally region 3. The cuts are set on π^+ and π^- tracks and then checked on electron and protons Fig. 5. The cuts have been checked sector by sector and are found to be stable across all sectors (TK maybe add plots in apendix?). The final cuts and survival rates can be found in table 1.

Torus polarity	Region 1 [cm]	Region 2 [cm]	Region 3 [cm]	survival rate
Inbending	4	3	7	96%
Outbending	3	3	10	95%

Table 1: DC edge cuts in each region inbending and outbending particles. The survival rate is defined as the fraction of DVCS candidates that pass the DC fiducial cuts.

4.2 FTCAL and PCAL fiducial cuts

DVCS photons are detected in two different systems, the forward calorimeters and the forward tagger. The forward tagger calorimeter (FTCAL) is made of $15 \times 15 \times 200\text{mm}^3$ scintillating crystals organised on a disc around the beam pipe covering angles up to $\theta = 4.5°$ [5]. The inner radius of the disc is around 6.75cm and the outer radius around 17.25cm. The fiducial cut is applied to the radius of the photon in the FT defined as $r = \sqrt{x^2 + y^2}$, where x and y are the coordinates of the cluster on the detector. The cut on the inner and outer radii are set respectively at 8.25cm and 15.75cm, one crystal away from the edge. Four additional circles are cut to remove dead areas in the detector, the definition of the cuts can be found in table 2, they were taken from the RGA DVCS analysis. The fiducial cut survival rate for photons in FTCAL is 89% and the impact of the cuts in the x, y plane is shown in Fig. 7.

Centre x [cm]	Centre y [cm]	Radius [cm]
-8.42	9.89	1.6
-9.89	-5.33	1.6
-6.15	-13	2.3
3.7	-6.5	2

Table 2: Definition of the FTCAL fiducial cuts used to remove dead areas in the detector.

Photons detected in the forward calorimeters are detected in PCAL, ECIN and ECOUT. Each are made with scintilator bars running in three different directions (u,v,w) to be able to reconstruct the 2D position of the cluster. A study of the EMCAL performances in the RGC setup has been performed by T. Hayward [?], we choose to use the medium cuts outlined in the study requiring PCAL coordinates $u > 29$cm and $v, w > 14$cm. The electron sampling fraction as a function of the different PCAL coordinates and the impact of the cuts in the x, y plane are shown in Fig. 8. The survival rate of DVCS candidates after the PCAL fiducial cuts is 89%.

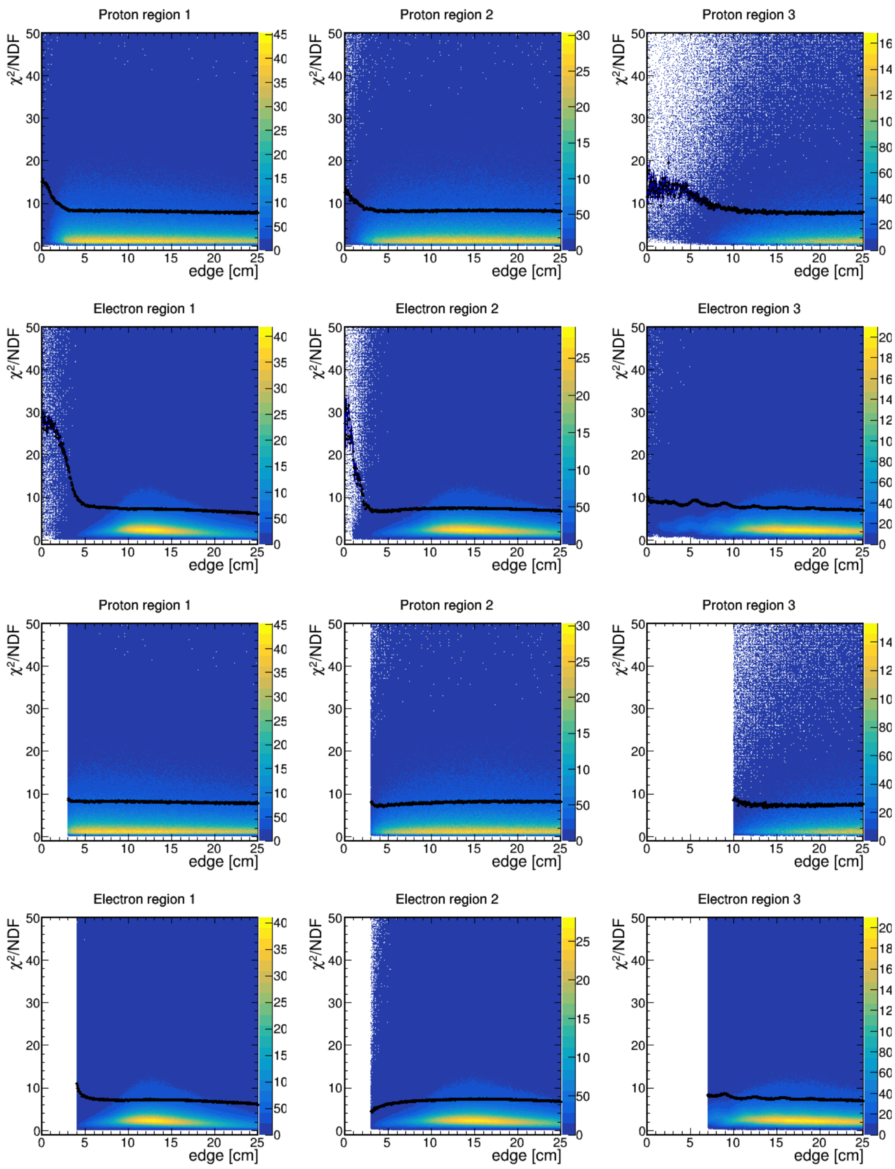

Figure 5: χ^2/NDF as a function of the edge variable for electron and proton tracks before (top) and after (bottom) fiducial cuts. The black markers show the average χ^2/NDF in each edge bin.

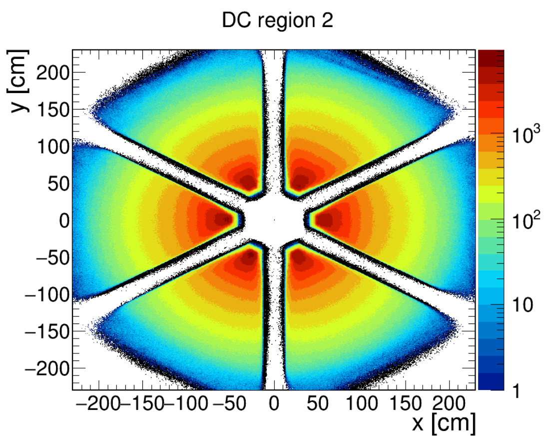

Figure 6: All tracks in the DC region 2, the black markers show tracks outside the fiducial cuts.

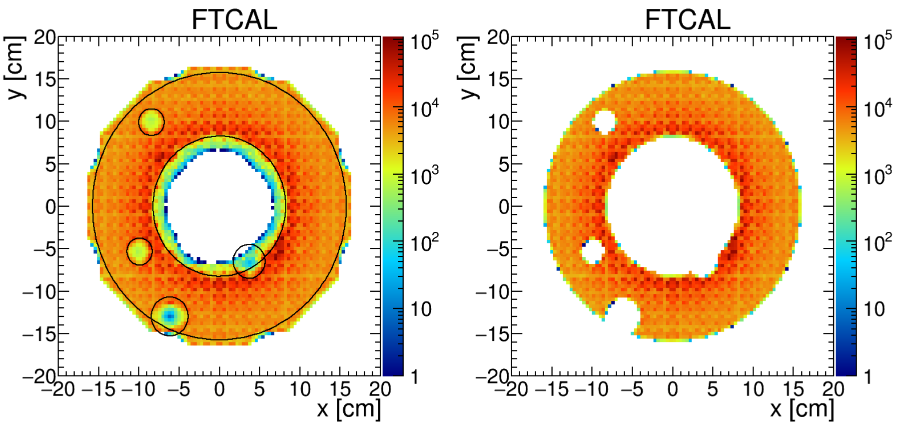

Figure 7: Left: photons in the FT, the black circles show the fiducial cuts limits. Right: photons in the FT after fiducial cuts are applied.

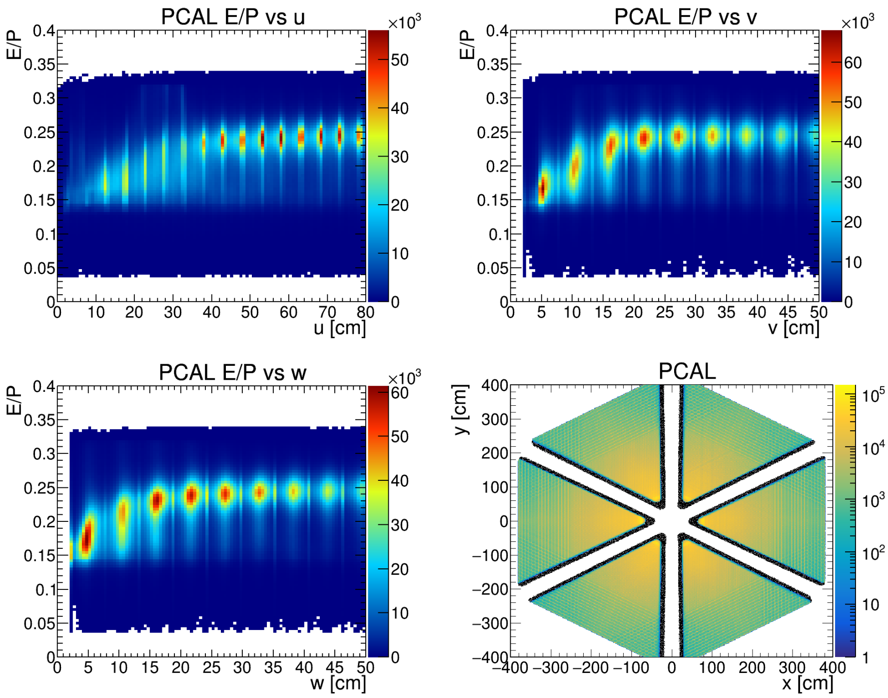

Figure 8: E/P for electron tracks as a function of u, v, w coordinates in PCAL and all photon tracks in the PCAL xy plane. The black markers show tracks outside the fiducial cuts.

7 Exclusivity cuts

The wide selection of DVCS candidates includes noise coming from inclusive processes as well as from the nuclear background present in the NH_3 target. To cut it we rely on the exclusivity of the process to define exclusivity variables, each has a set value if there are no missing particles in the interaction. The different variables probe the conservation of energy and momentum in the process, and allow us to remove events where the missing momentum is outside the detector resolution. The following exclusivity variables are used in the analysis:

- MMtot, total missing mass, mass of X in $ep \to ep\gamma X$
- ME, total missing energy, energy of X in $ep \to ep\gamma X$
- Mpt, total missing transverse momentum of X in $ep \to ep\gamma X$
- MMp, proton missing mass, $ep \to e\gamma X$
- MMg, photon missing mass $ep \to epX$
- g_cone, photon cone angle, angle between the measured photon and the expected photon computed from all the other particles in the process.
- $\Delta\phi$, difference in the trento ϕ angle computed with two different hadronic plane definitions. Hadronic plane defined with the real photon and the proton minus hadronic plane defined with the virtual photon and the proton.
- Δt difference in the proton momentum transfer variable t computed in two different ways. $\Delta t = |(P_{\text{target}} - P_p)^2 - (P_\gamma - P_{\gamma^*})^2|$.

Data taken on the carbon target cell provides a good estimate of the shape and magnitude of the nuclear background in the NH_3 target, so we plot the distributions of each exclusivity variables for both carbon and NH_3 targets and place the cuts to remove areas where the nuclear background is the largest contribution. We use two sets of exclusivity cuts, first *level2* cuts that are very broad to remove events far outside the exclusivity region, then *level3* cuts that are the final cuts used for the analysis (*level1* cuts refer to the candidate selection/fiducial cuts). Figure 13 shows the distributions of all exclusivity variables used for event selection, before and after *level3* cuts on both NH_3 and carbon targets. Table 5 details the final *level3* cuts and the intermediate *level2* cuts used for the analysis. (TK add plots bin by bin??)

Variable	*level2* cuts	*level3* cuts
MMtot [GeV^2/c^4]	$[-0.1, 0.1]$	$[-0.008, 0.01]$
MMp [GeV^2/c^4]	$[0, 3]$	$[0.5, 2.2]$
ME [GeV]	$[-1.5, 1.5]$	$[-0.5, 0.6]$
Mpt [GeV/c]	$[0, 1]$	$[0, 0.1]$
MMg [GeV^2/c^4]	$[-0.8, 0.8]$	$[-0.25, 0.3]$
g_cone [deg]	$[0, 2]$	$[0, 1]$
$\Delta\phi$ [deg]	$[-3, 3]$	$[-0.5, 0.5]$
Δt [GeV^2/c^4]	$[0, 2]$	$[0, 0.2]$

Table 5: *level2* and *level3* DVCS exclusivity cuts.

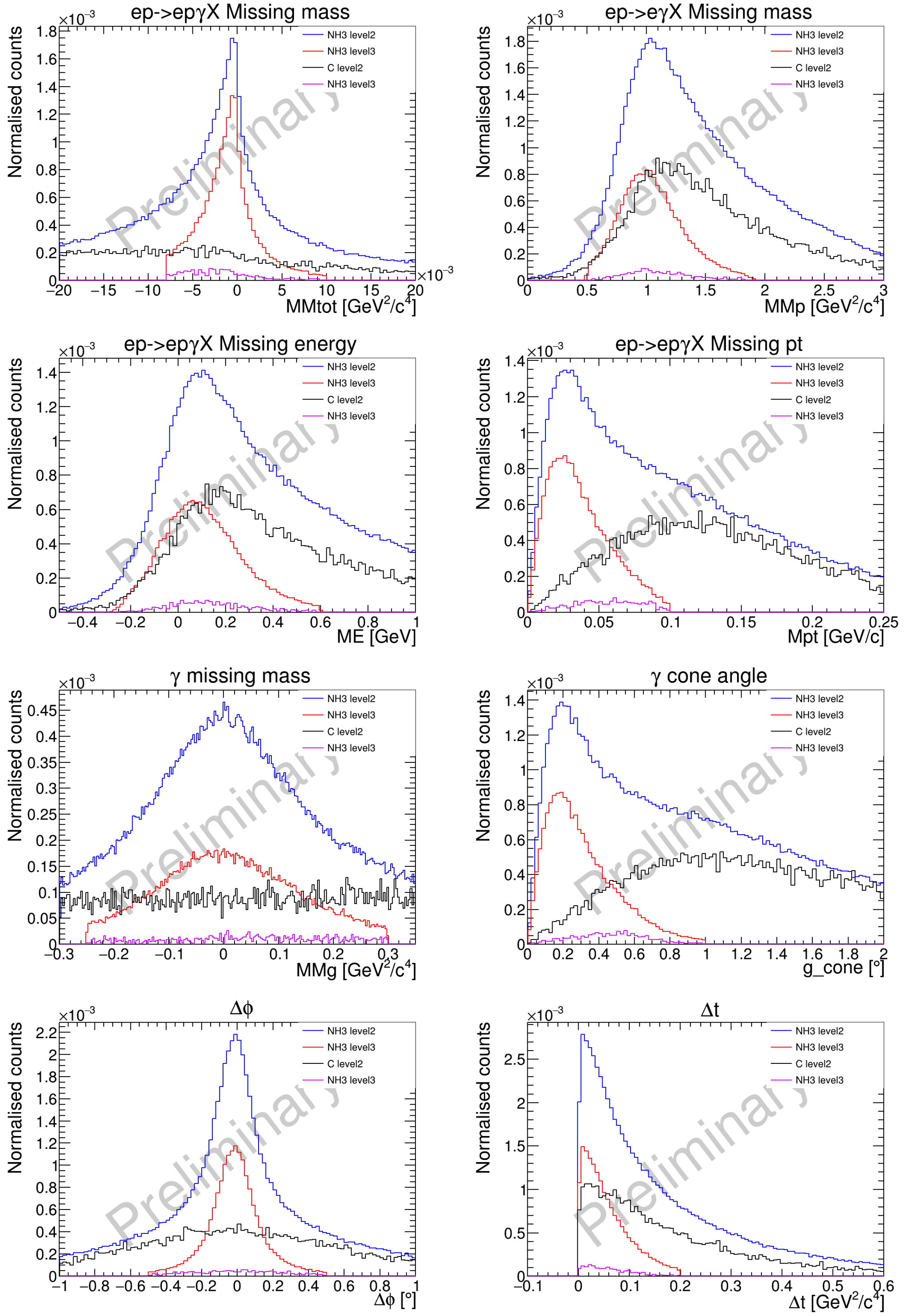

Figure 13: Distributions of all exclusivity variables used for event selection, before and after *level3* cuts on both NH3 and Carbon targets. The two datasets are normalised by the beam charge accumulated on each.