Deeply Virtual Compton Scattering Cross Section from the Neutron at the CLAS12 experiment

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CLAS Collaboration Meeting

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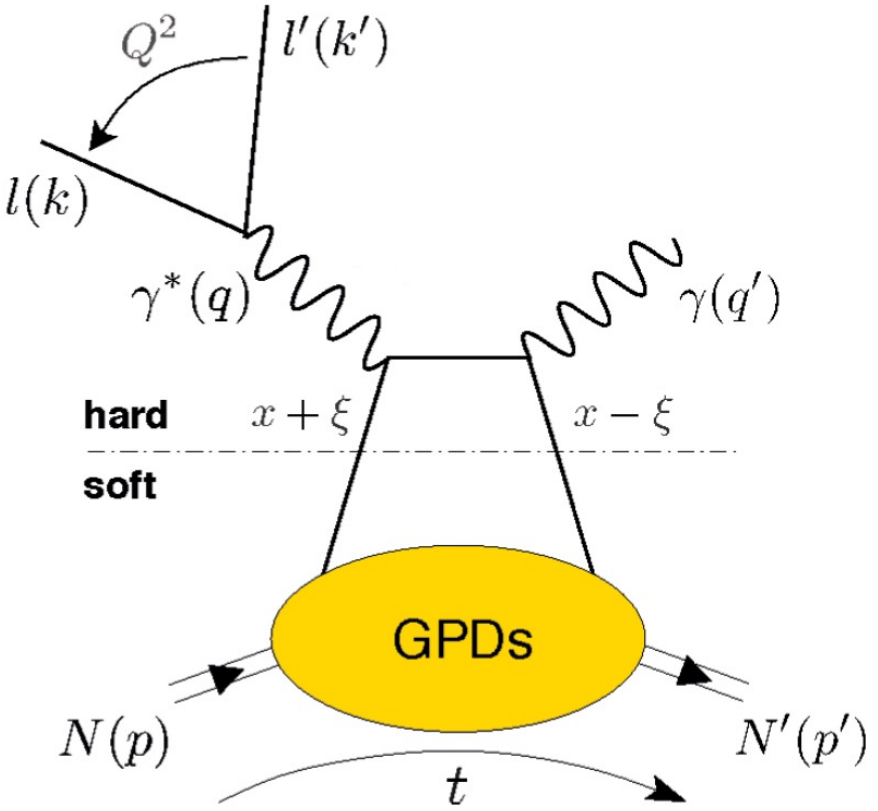
Outline

- Motivation
- Data and MC samples
- PID and fiducial cuts
- Select nDVCS data
- Distributions of nDVCS variables
- Next to do

Motivation

- The study of multi-dimensional partonic structure of nucleons can provide important information to probe non-perturbative QCD
- Generalized Parton Distributions (GPDs) relate transverse position of partons to longitudinal momentum
- The Deeply Virtual Compton Scattering (DVCS) is one of the cleanest channels to access GPDs
- The measurement of DVCS cross-section from the neutron can provide unique information on GPDs



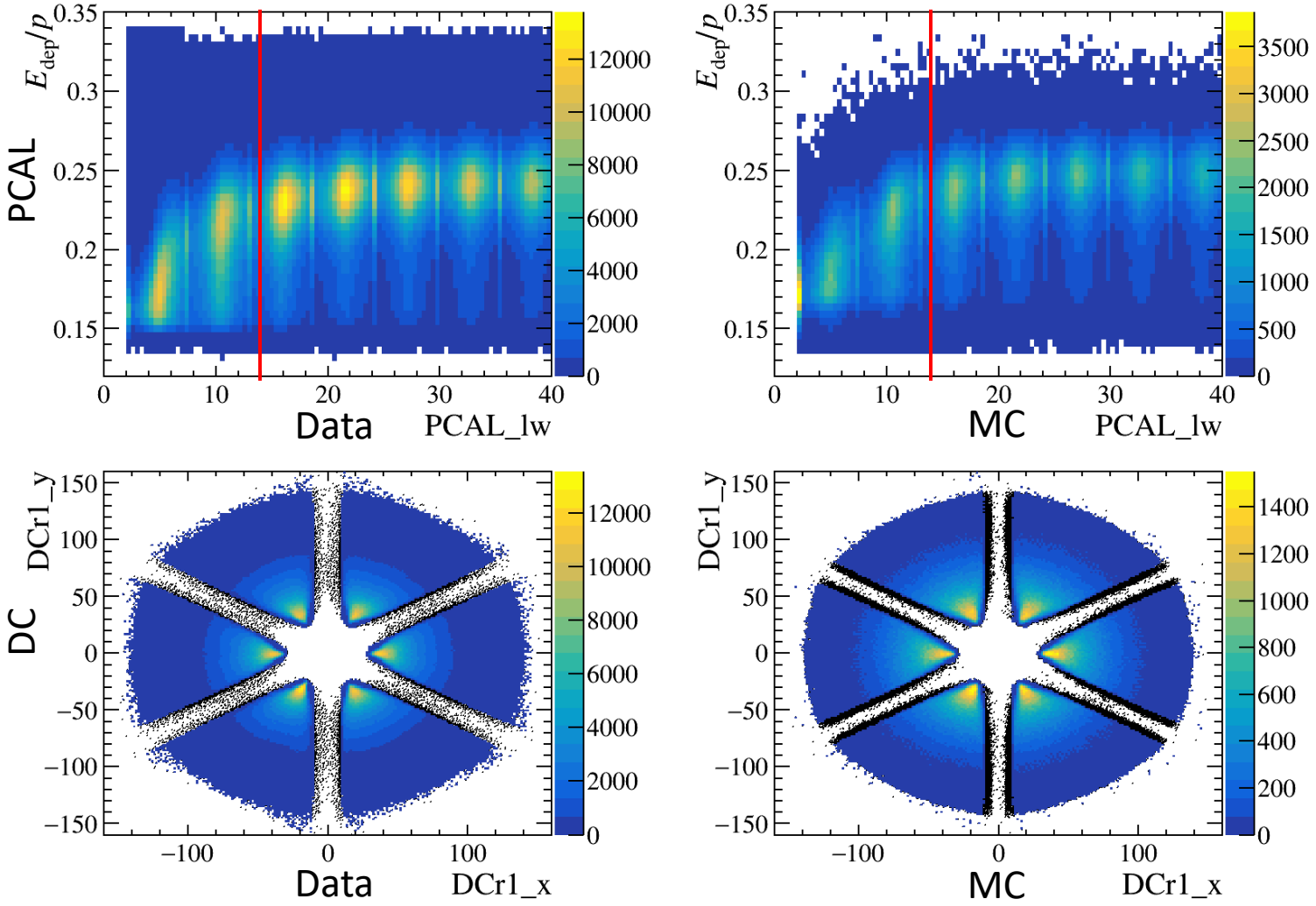
Data and MC samples

- Data
  - RGB data, collected by the CLAS12 detector in 2019 spring
  - 10.6/10.2 GeV electron beam scattering off an unpolarized liquid deuterium target
  - 232 runs (run number 6202 - 6603)
- MC
  - 100M DVCS events (nDVCS: 23M events)

Configuration	rgb_spring2019	Software Ver.	gemc/5.4 coatjava/10.0.2
MC Gen Ver.	2.33	Magnetic Field	tor-1.00_sol-1.00
Generator	genepi	Bkg merging	50nA_10599MeV
Target Position	-3.0 cm	Target Length	5 cm
Generator Opt.	--EBeam 10.6 --process 0 -- targ_A 2 --targ_Z 1		

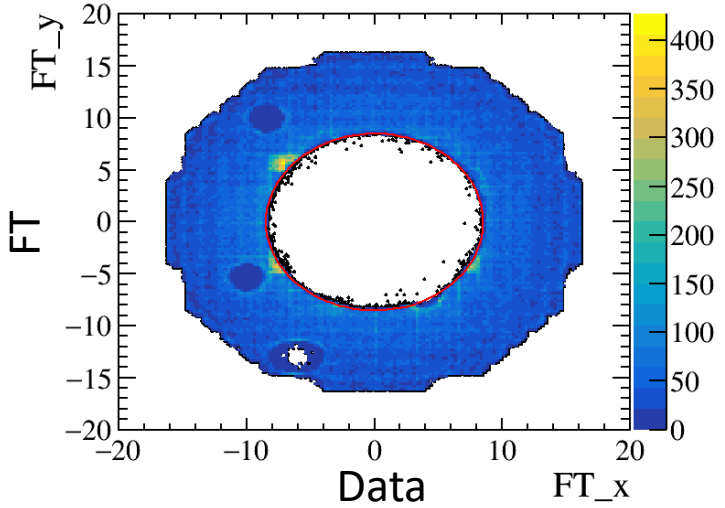
Electron selection

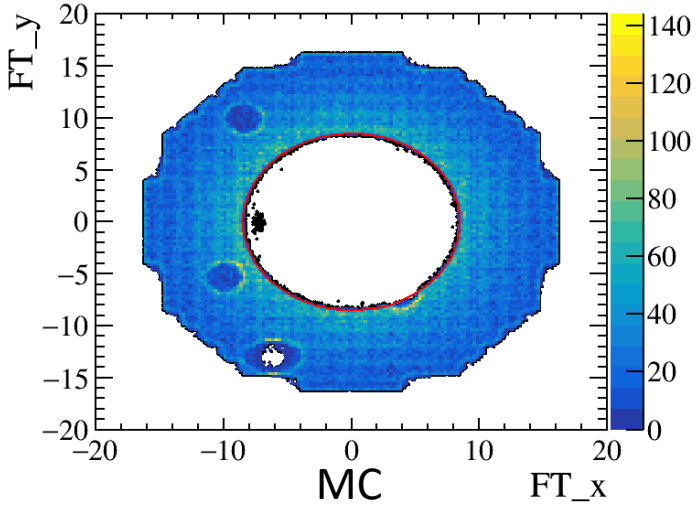
- $q = -1$
- $\mathrm{pid} = 11$
- $p_e > 1\ \mathrm{GeV}$
- Reconstructed in FD
- Fiducial cut
  - PCAL:
    $\mathrm{lv} > 14 \text{ and } \mathrm{lw} > 14$
  - DC: region 1-3
    $\mathrm{edge} > 6$

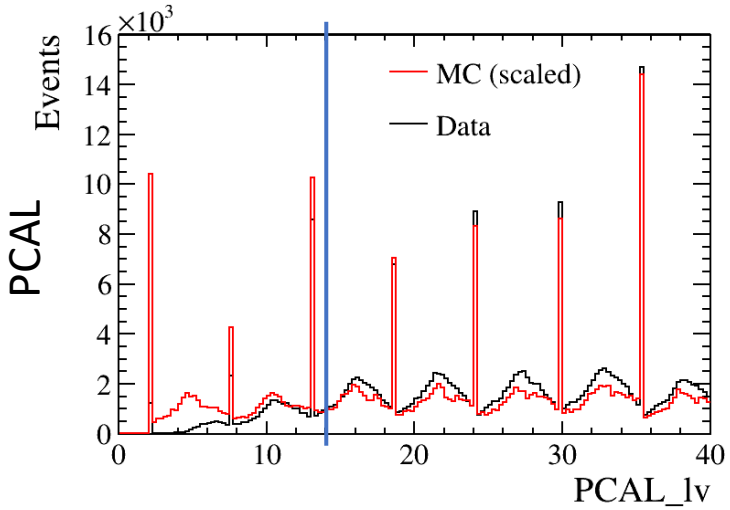


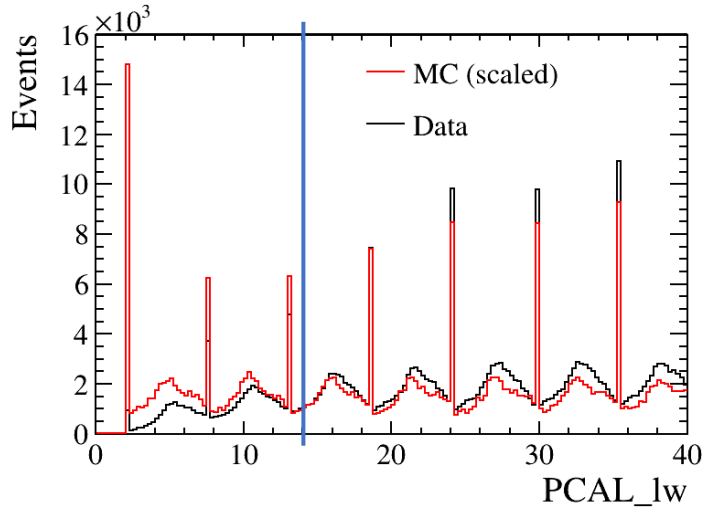
Photon selection

- $q = 0$
- $\mathrm{pid} = 22$
- $p_\gamma > 2\ \mathrm{GeV}$
- Reconstructed in FT
  - Fiducial cut
    $x^2 + y^2 > 72$
- Reconstructed in FD
  - Fiducial cut (PCAL)
    $\mathrm{lv} > 14 \text{ and } \mathrm{lw} > 14$









Neutron selection

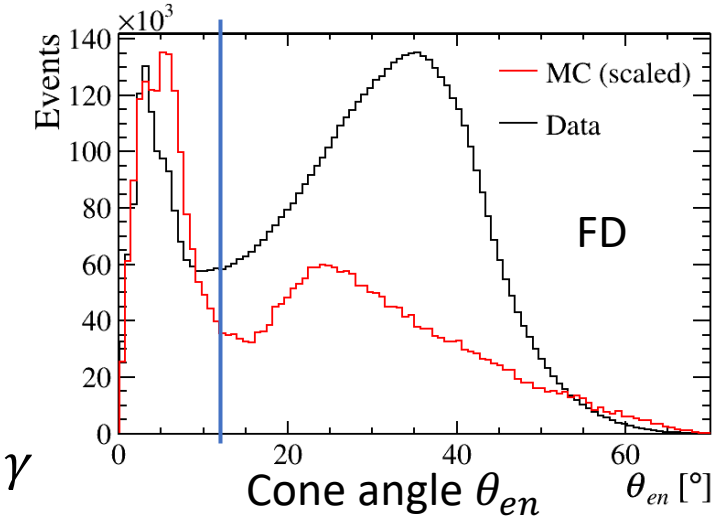
- $q = 0$
- $\mathrm{pid} = 2112$
- $p_n > 0.3$ GeV
- Reconstructed in FD
  - Remove misidentified e^-, γ

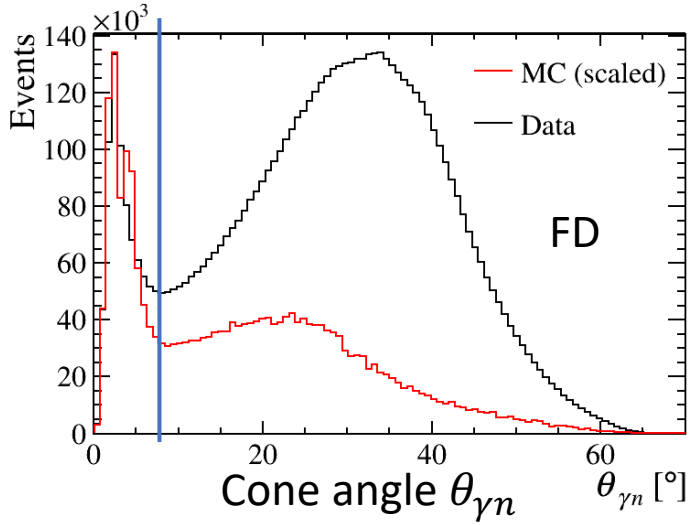
    $\theta_{en} > 12°$ and $\theta_{\gamma n} > 7°$
  - Fiducial cut

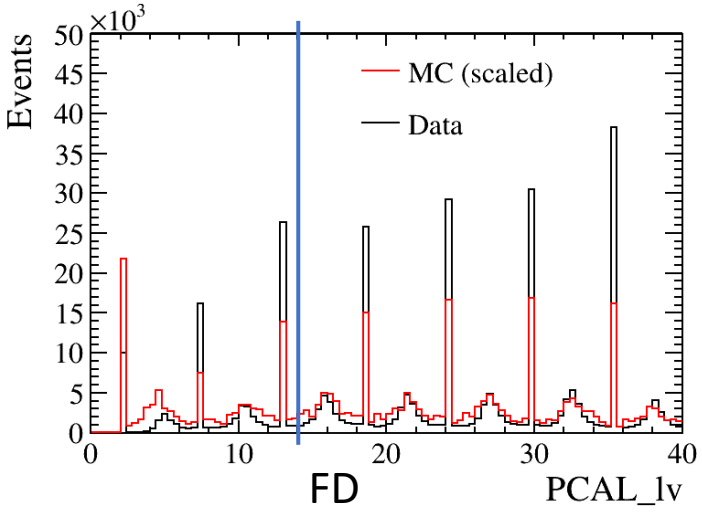
    $\mathrm{lv} > 14$ and $\mathrm{lw} > 14$

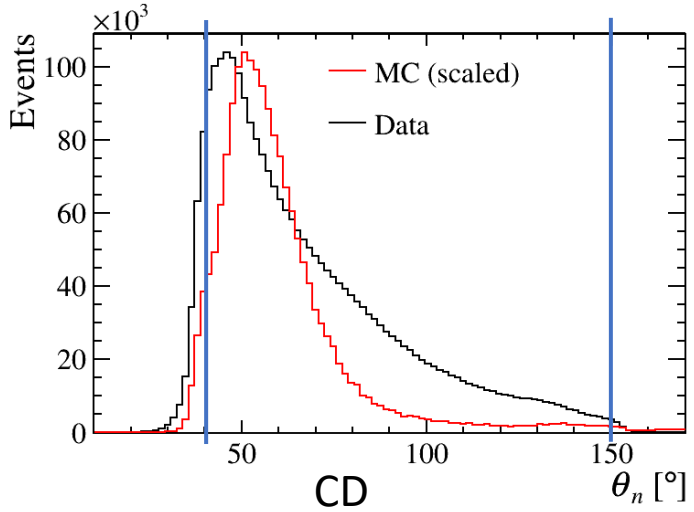
    for PCAL or ECin or ECout
- Reconstructed in CD
  - Fiducial cut

    $40° < \theta_n < 150°$





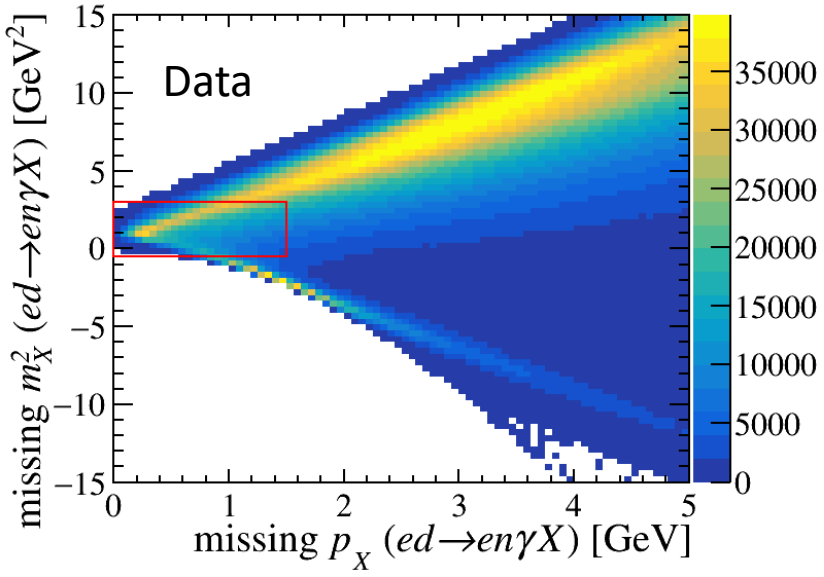


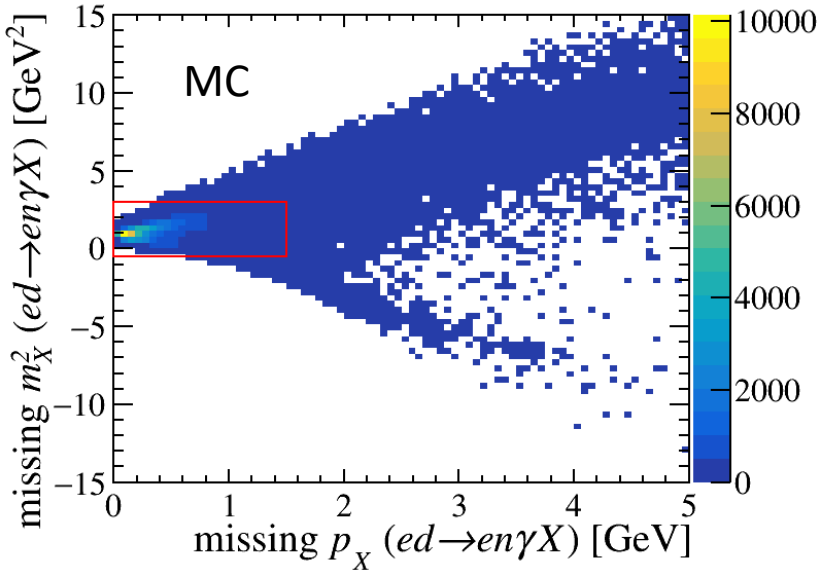


The data and MC distributions are different because MC is nDVCS while data contains lots of channels at this stage.

Select nDVCS data

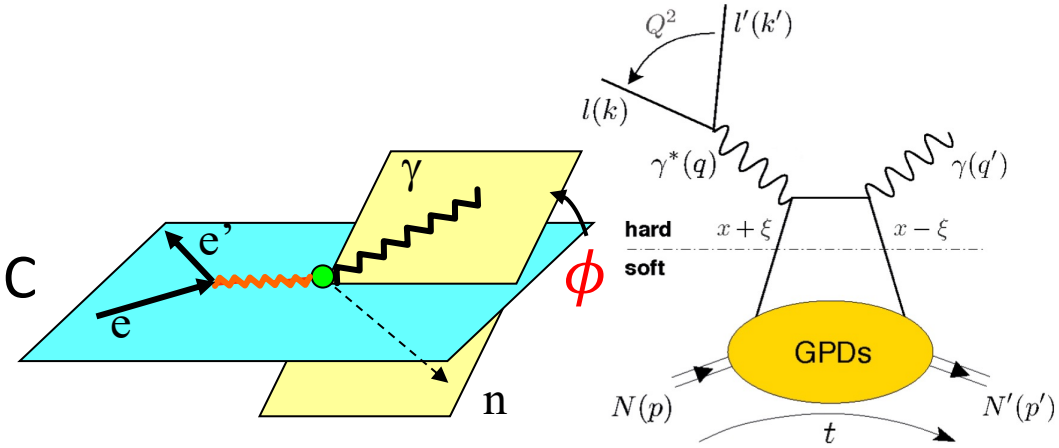
- Select events with at least one electron, one neutron and one photon
  - For cases with more than one combination, select the one with the smallest χ^2-like quantity (defined using exclusivity variables that peak at zero)
- Reaction kinematics: $Q^2 > 1\ \mathrm{GeV}^2$, $W > 2\ \mathrm{GeV}$, $t > -1.9\ \mathrm{GeV}^2$
- Apply pre-selection on missing m_X^2 and p_X of $ed \to en\gamma X$
  - To reduce events from other channels mostly
  - Pre-selection: $-0.5 < m_X^2 < 3\ \mathrm{GeV}^2$, $0 < p_X < 1.5\ \mathrm{GeV}$

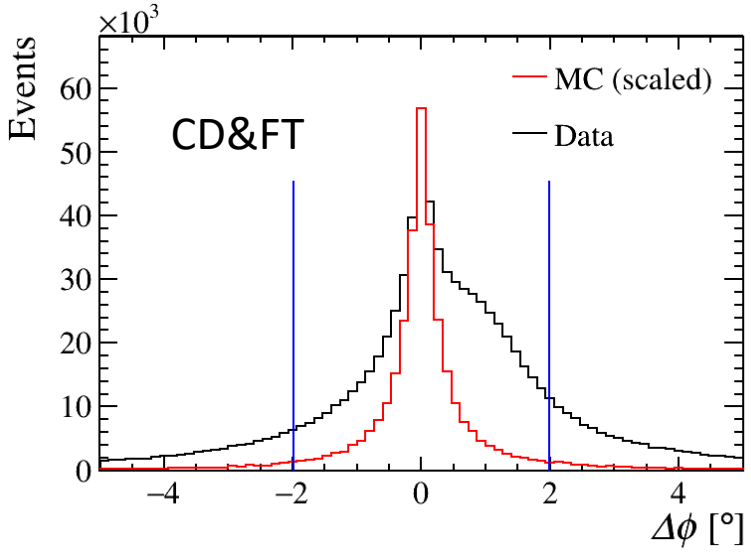




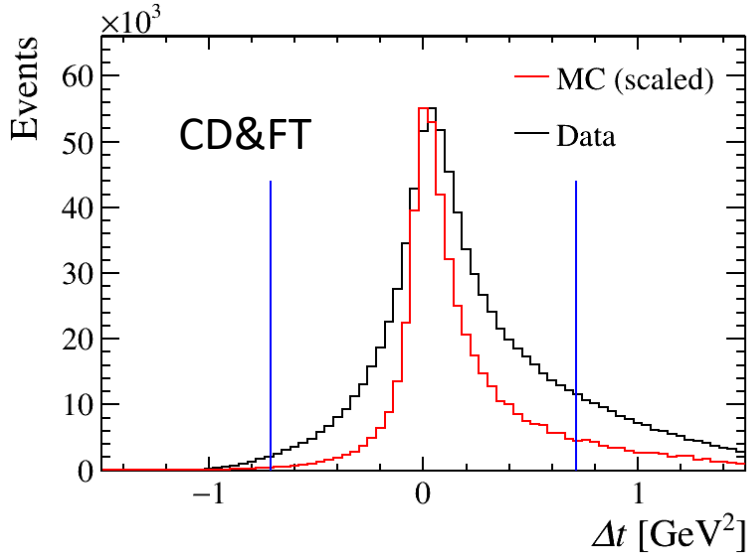
Exclusivity selection

- Criteria determined by comparing data and MC
  - $\sim 2\sigma$ of the MC distribution
- CD&FT (n in CD & γ in FT)





$|\Delta\phi| < 2.0°$



$|\Delta t| < 0.7\ \mathrm{GeV}^2$

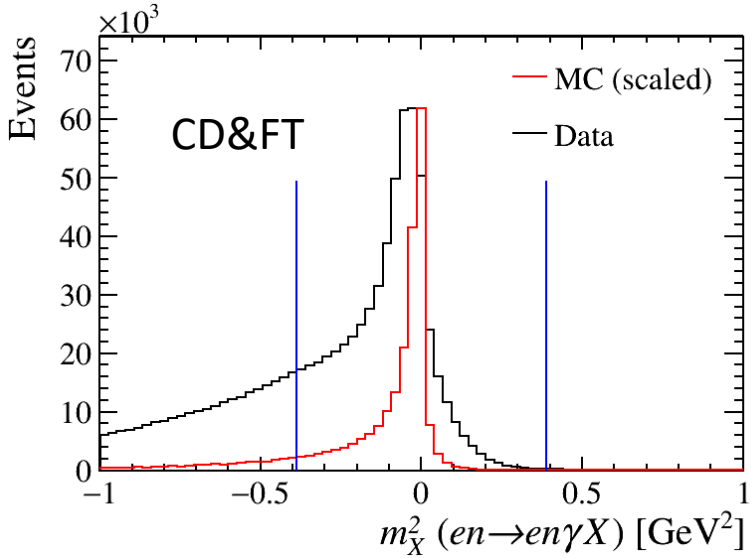
- $\Delta\phi$: difference in ϕ between
  - hadronic plane formed by the neutron and the virtual photon
  - hadronic plane formed by the neutron and the outgoing photon
- Δt: difference in t between
  - t calculated by the neutron
  - t calculated by the photon

Other topologies (CD&FD, FD&FT, FD&FD) are presented in backup slides

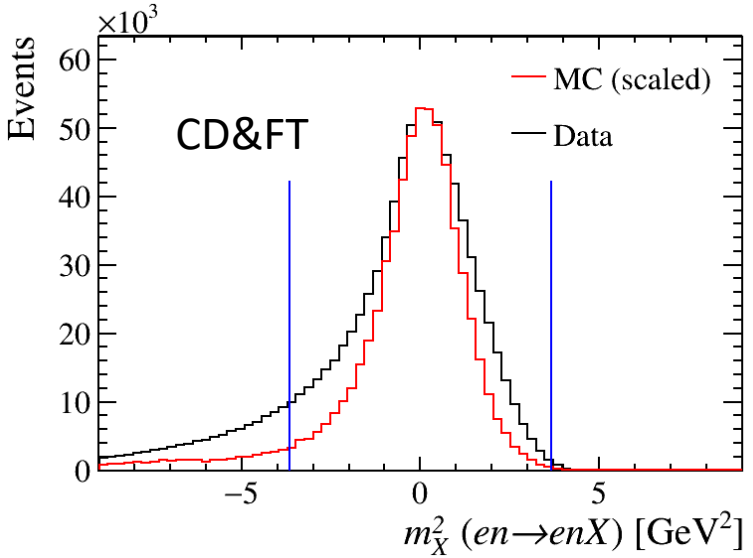
Exclusivity selection

- Criteria determined by comparing data and MC
  - $\sim 2\sigma$ of the MC distribution
- CD&FT (n in CD & γ in FT)

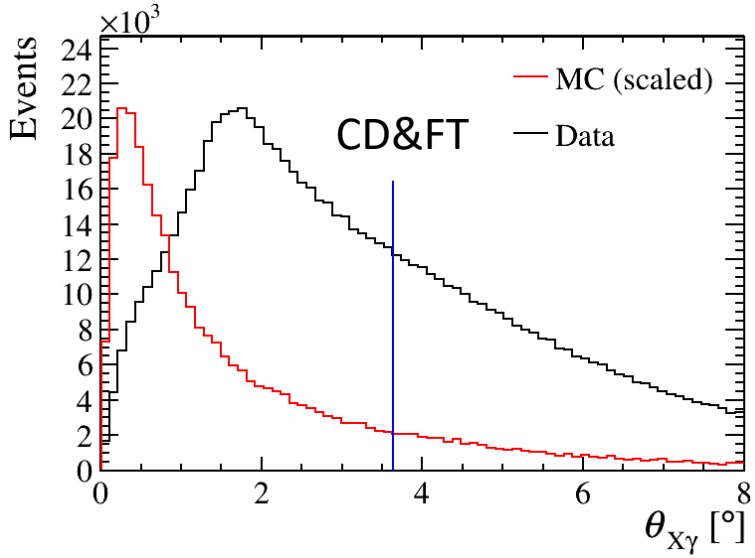
- $\theta_{X\gamma}$: cone angle formed by the missing photon X ($en \rightarrow enX$) and the outgoing photon γ



$|m_X^2| < 0.4\ \mathrm{GeV}^2$



$|m_X^2| < 3.7\ \mathrm{GeV}^2$



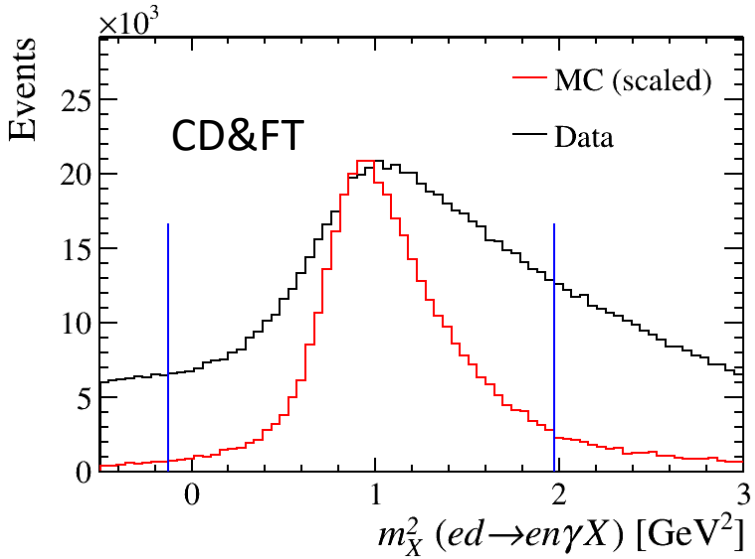
$\theta_{X\gamma} < 3.6°$

The data and MC distributions are very different

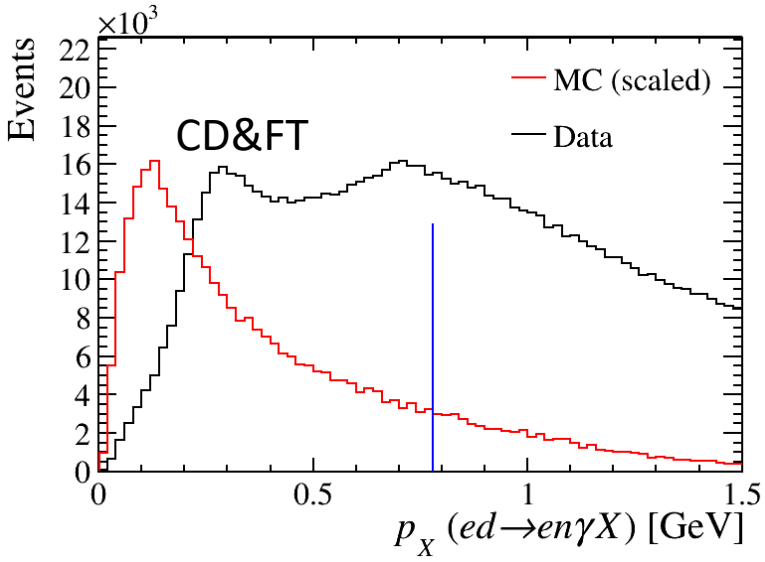
- ➢ mainly due to the protons that are misidentified as neutrons, discussed in the later slides, and due to the π^0 contamination

Exclusivity selection

- Criteria determined by comparing data and MC
  - $\sim 2\sigma$ of the MC distribution
- CD&FT (n in CD & γ in FT)



$-0.1 < m_X^2 < 2.0\ \mathrm{GeV}^2$



$p_X < 0.8\ \mathrm{GeV}$

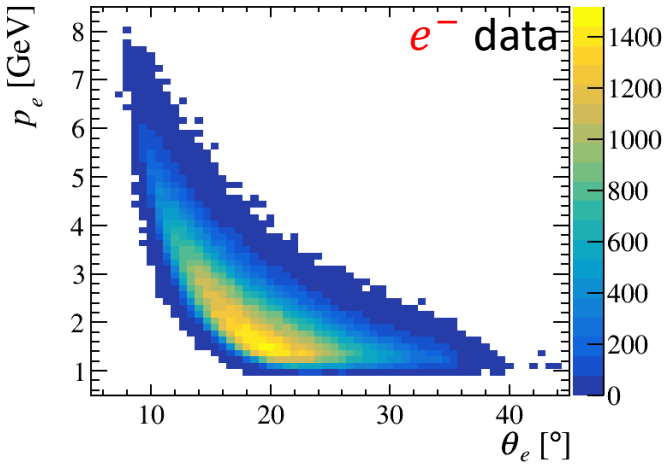
- Exclusivity cuts for CD&FT
  - $|\Delta\phi| < 2.0°$
  - $|\Delta t| < 0.7\ \mathrm{GeV}^2$
  - $\left|m_X^2\right| < 0.4\ \mathrm{GeV}^2\ (en \to en\gamma X)$
  - $\left|m_X^2\right| < 3.7\ \mathrm{GeV}^2\ (en \to enX)$
  - $\theta_{X\gamma} < 3.6°\ (en \to enX)$
  - $-0.1 < m_X^2 < 2.0\ \mathrm{GeV}^2$ $(ed \to en\gamma X)$
  - $p_X < 0.8\ \mathrm{GeV}\ (ed \to en\gamma X)$
- After the selection
  - $N = 2.74\times10^5$ for CD&FT

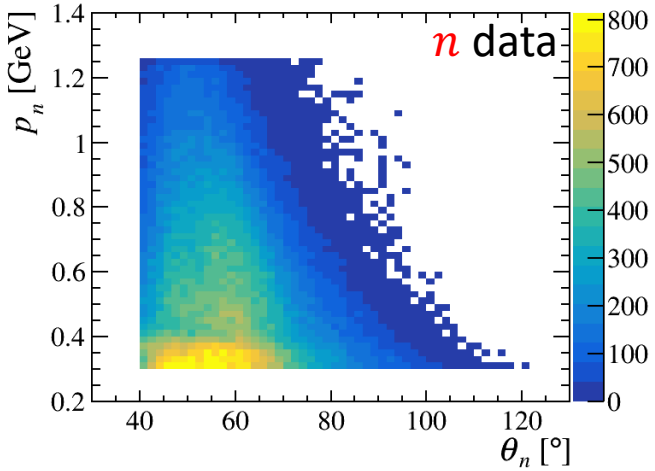
The data and MC distributions are very different

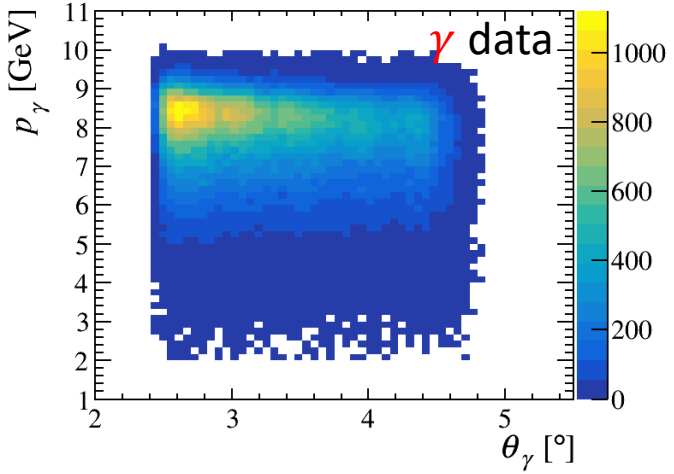
➢ mainly due to the protons that are misidentified as neutrons, discussed in the later slides, and due to the π^0 contamination

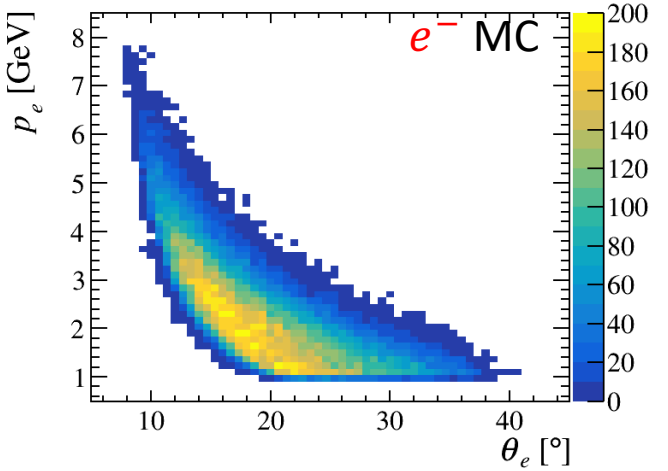
Particle kinematics after the selection

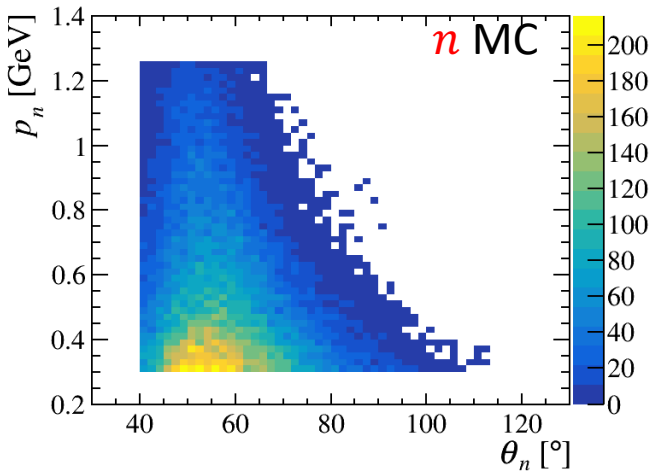
- CD&FT (n in CD & γ in FT)

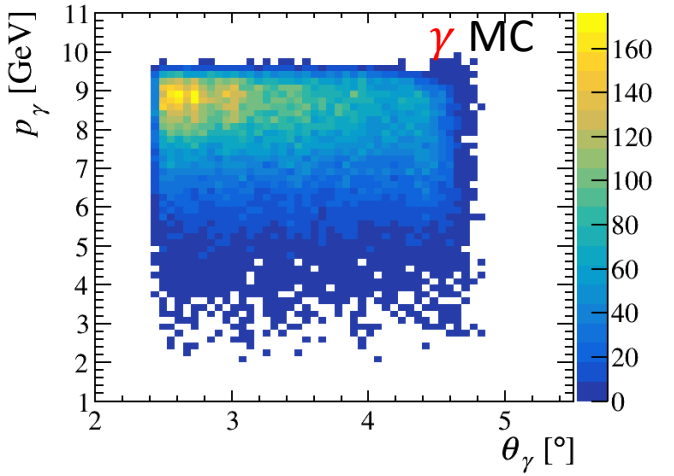








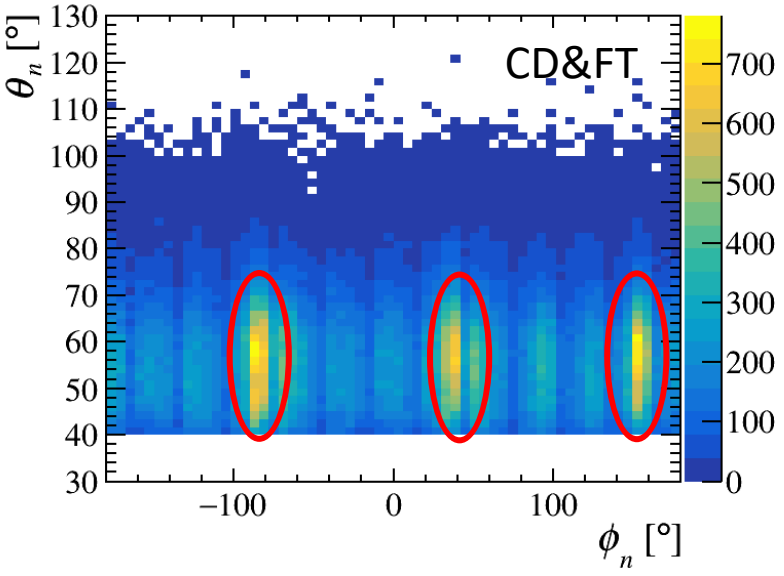




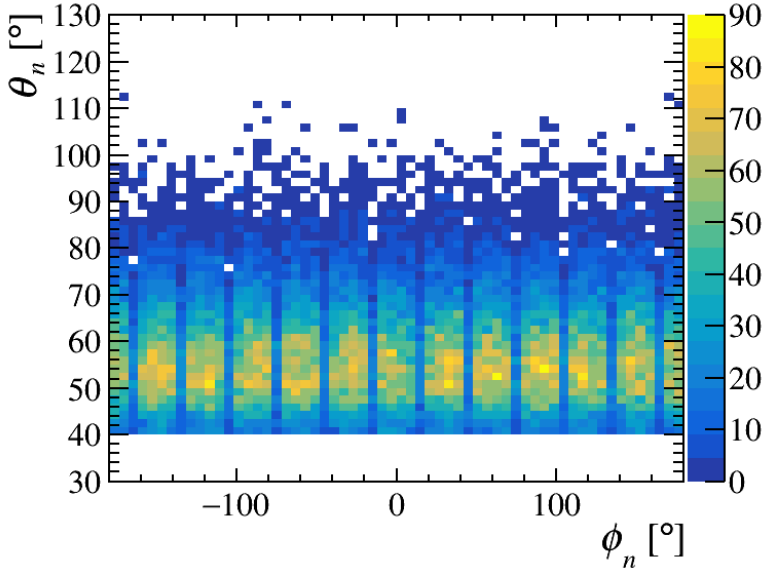
Proton misidentified as neutron

- The tracking system (CVT) in CD has dead or low-efficiency regions
- Protons: no tracks in CVT but hits in CND
  - ➢Misidentified as neutrons
- Reproduce distributions in MC mixing pDVCS and nDVCS

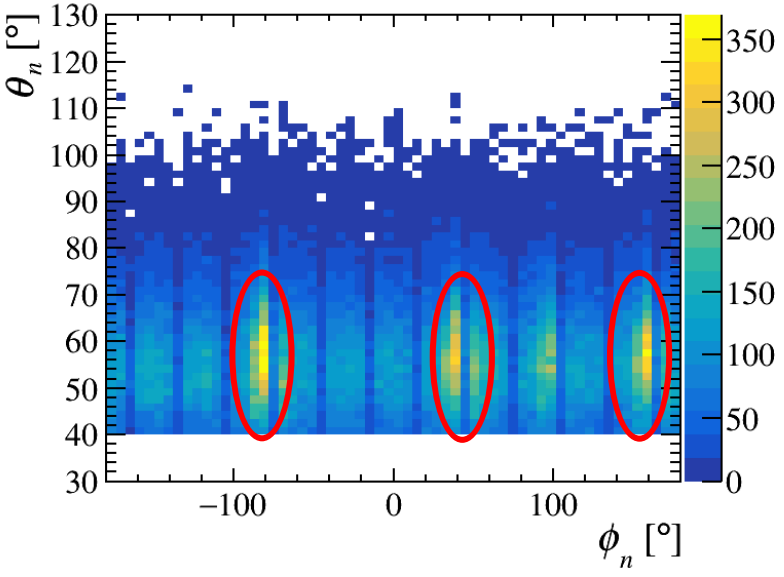
Data



Only nDVCS MC

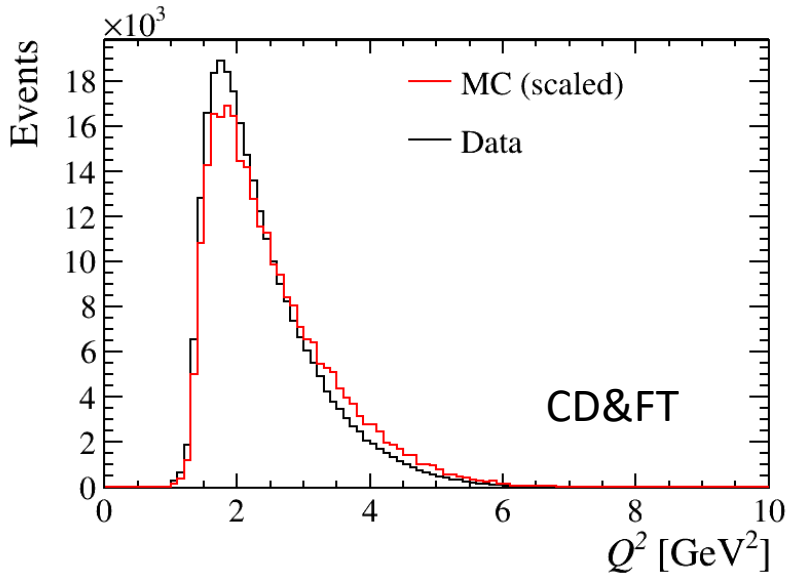


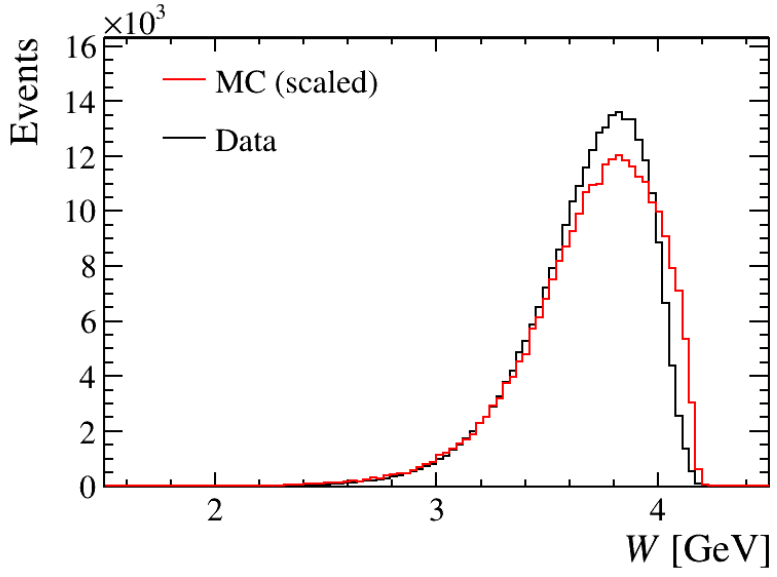
Mix pDVCS and nDVCS MC

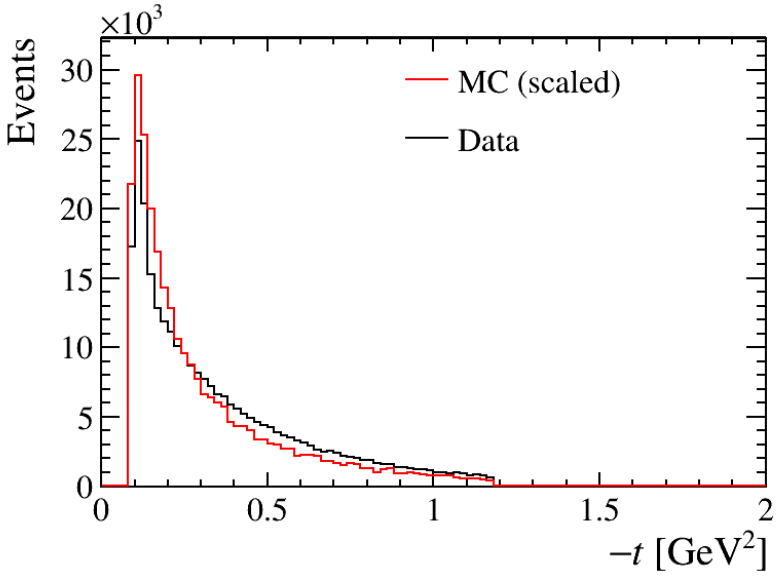


Distributions of nDVCS variables for CD&FT

- Remain backgrounds:
  - Proton misidentified as neutron
    - To be reduced by TMVA
  - π^0 production
    - The study of π^0 production MC is ongoing







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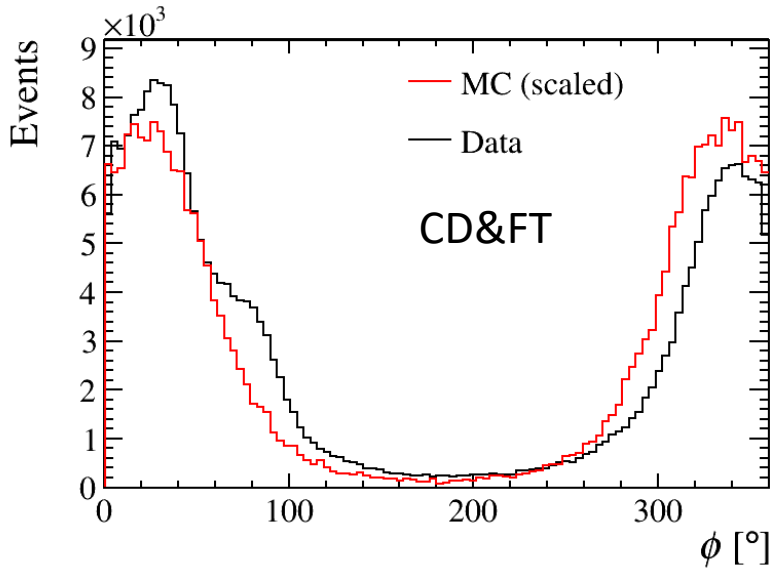
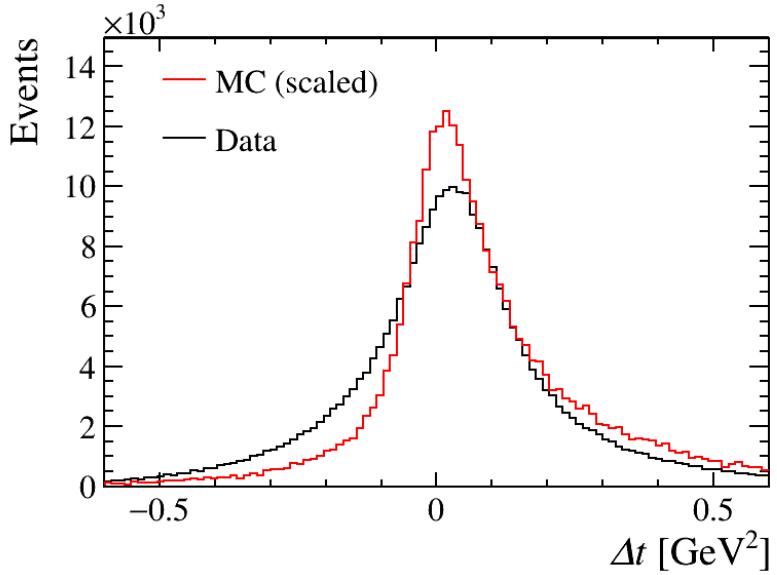
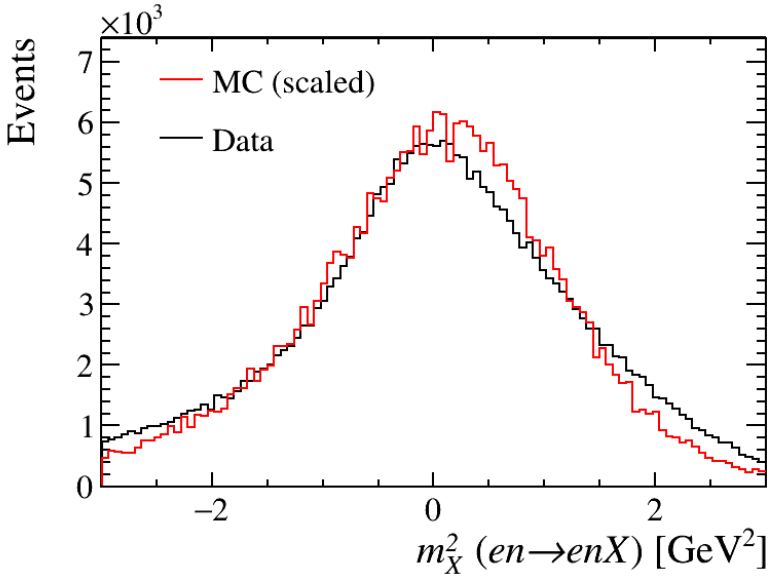
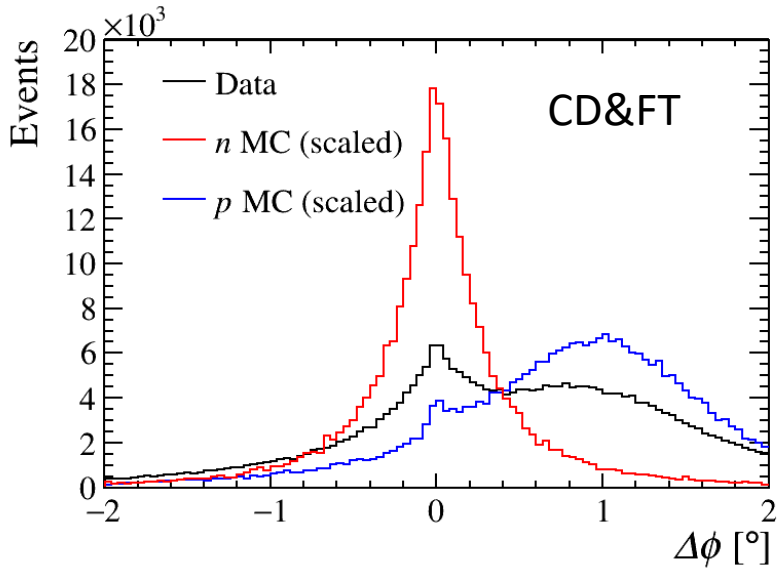


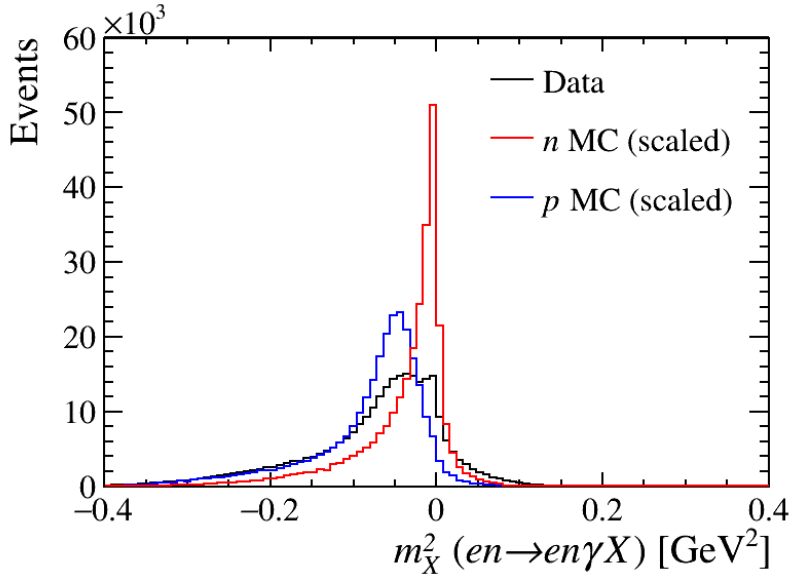


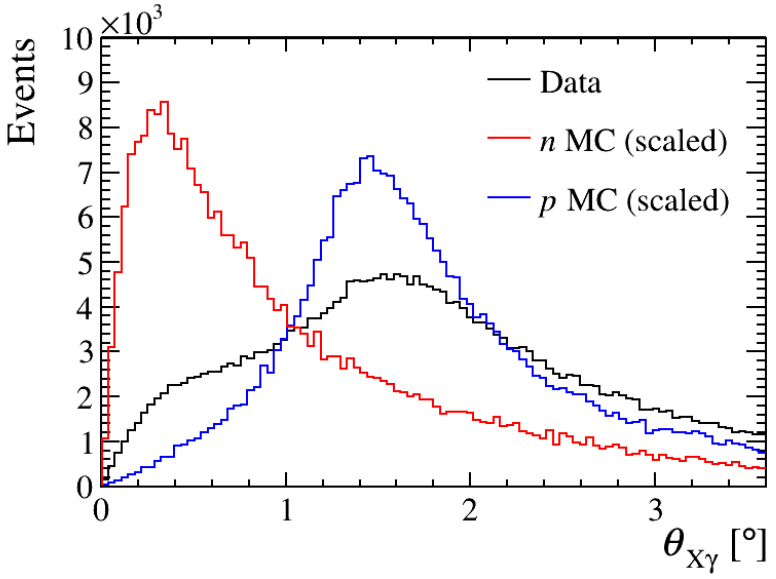


Distributions of nDVCS variables for CD&FT

- Remain backgrounds:
  - Proton misidentified as neutron
    - To be reduced by TMVA
    - p MC distribution: pDVCS but reconstructed as nDVCS events
  - π^0 contamination

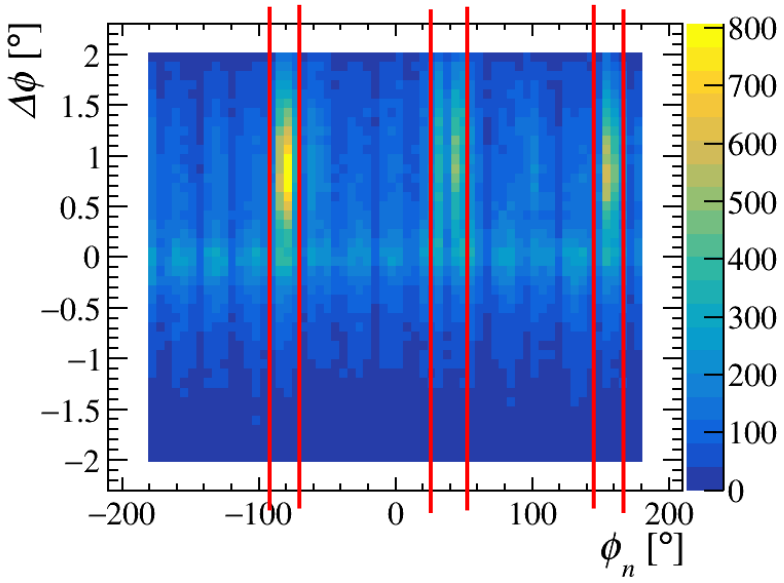




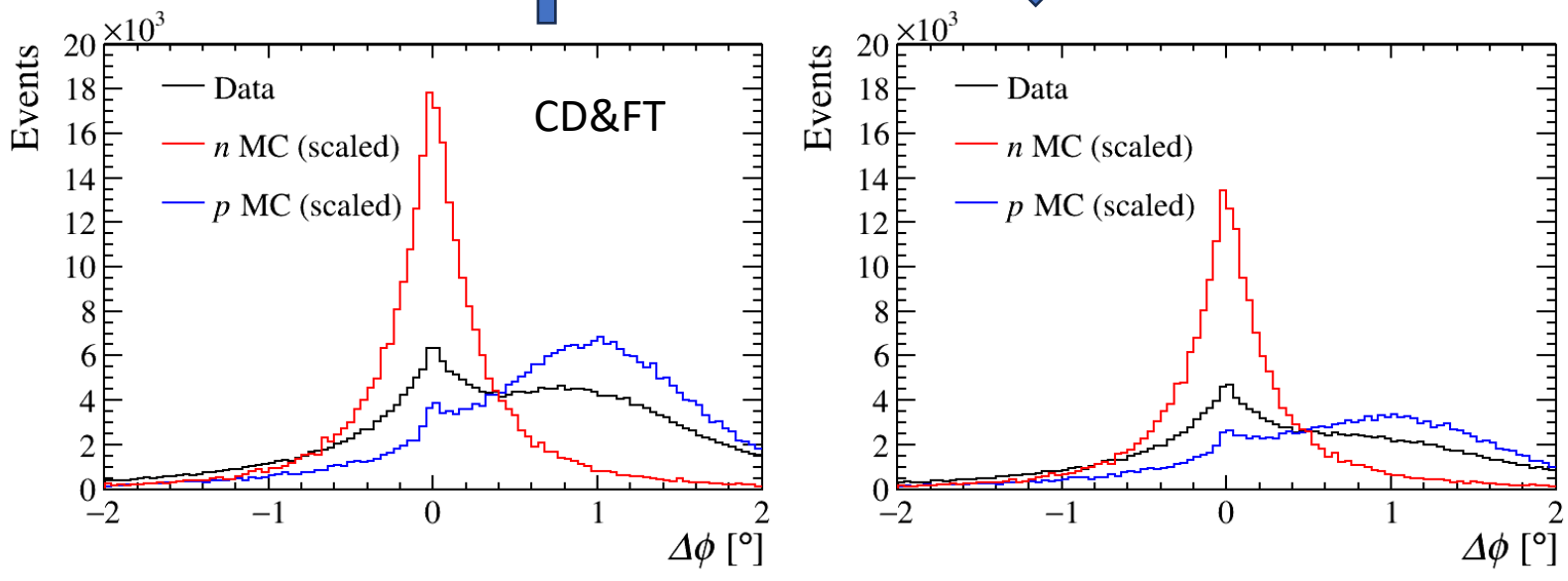


Distributions of nDVCS variables for CD&FT

- Remain backgrounds:
  - Proton misidentified as neutron
    - Plain cut of ϕ_n is not enough to remove protons
    - Need to be reduced by TMVA
  - π^0 contamination

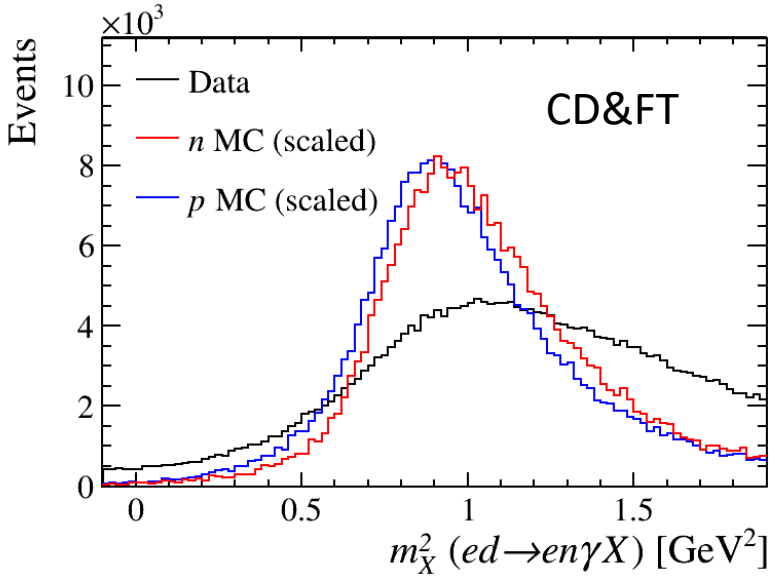


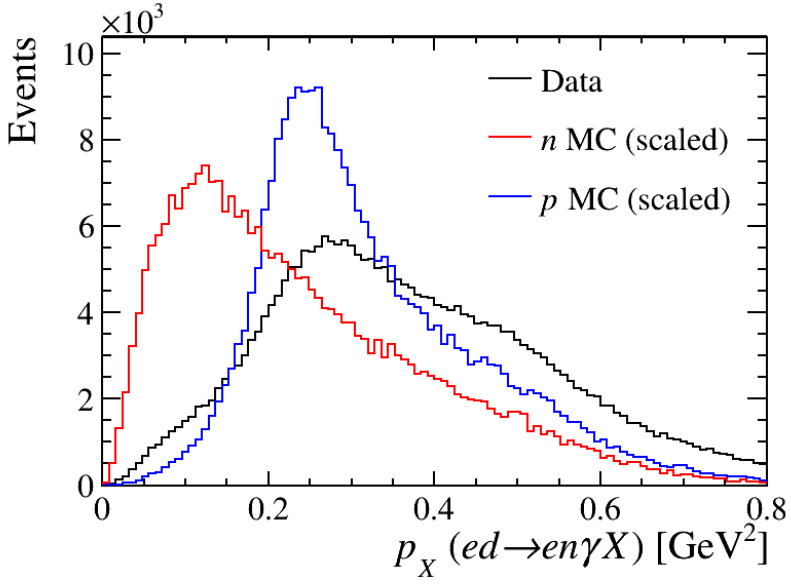
Plain cut of ϕ_n



Distributions of nDVCS variables for CD&FT

- Remain backgrounds:
  - Proton misidentified as neutron
    - To be reduced by TMVA
    - p MC distribution: pDVCS but reconstructed as nDVCS events
  - π^0 contamination
- Need momentum correction for neutron





Next to do

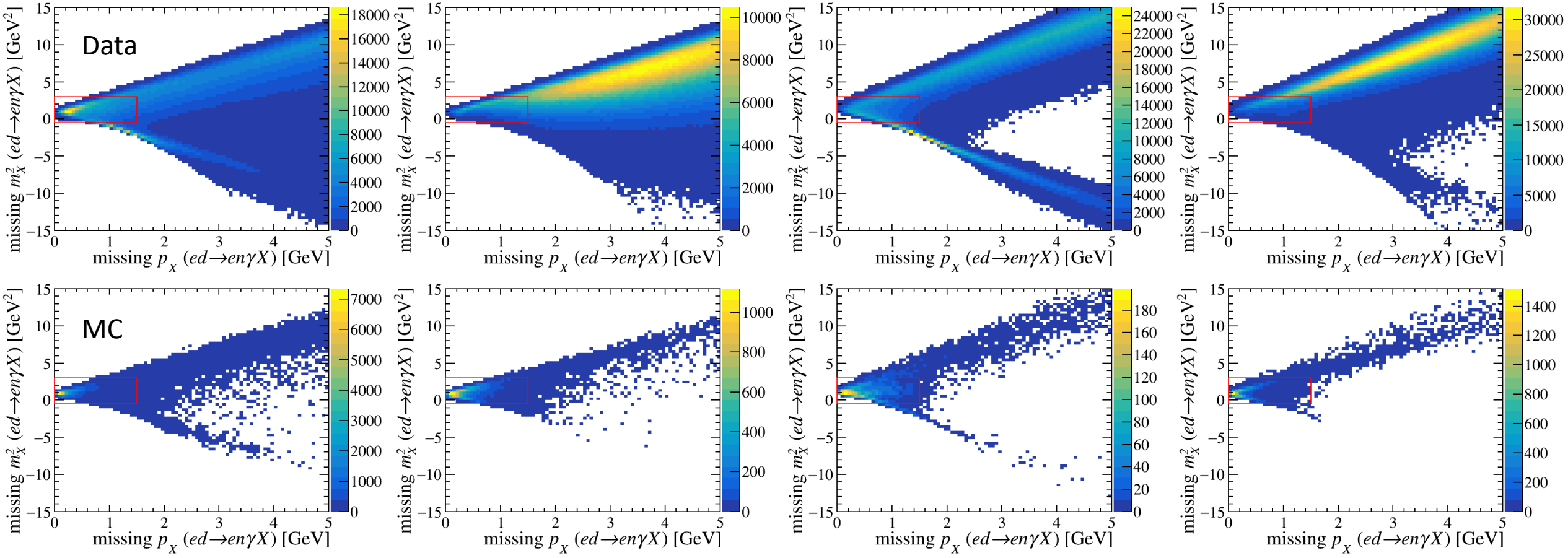
- Tune the selection criteria for each topology
- Momentum corrections
- Subtract backgrounds of misidentified-proton by TMVA
- Subtract π^0 production background
- Determine the efficiency and acceptance
- Extract the integrated luminosity
- Estimate the systematic uncertainties

Thank you!

Backup slides

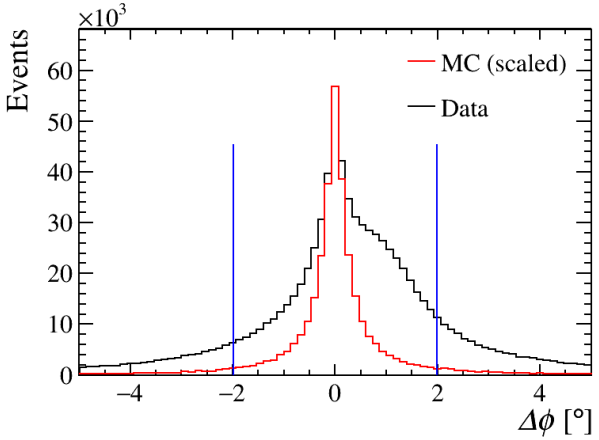
Pre-selection on missing m_X^2 and p_X of $ed \rightarrow en\gamma X$

CD&FT CD&FD FD&FT FD&FD

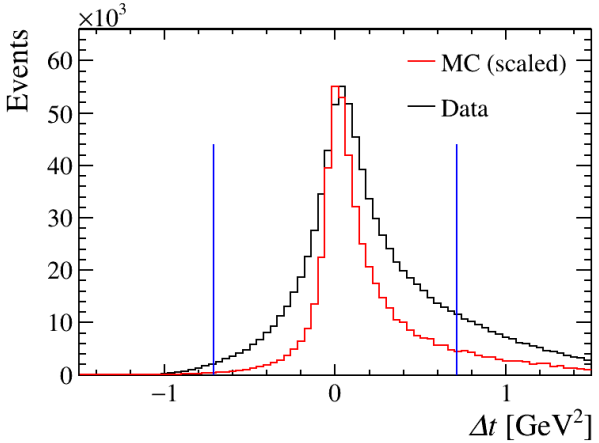


Exclusivity selection

CD&FT

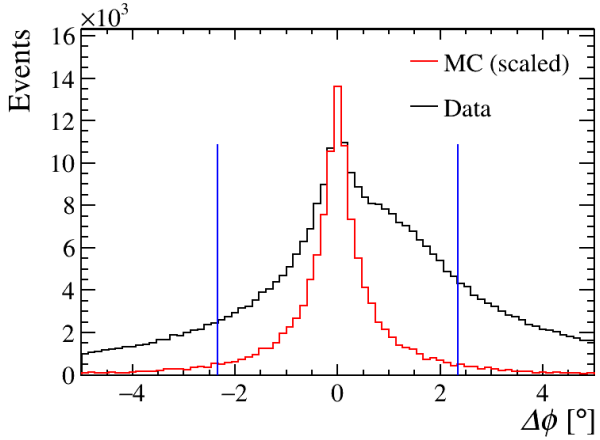


$|\Delta\phi| < 2.0$

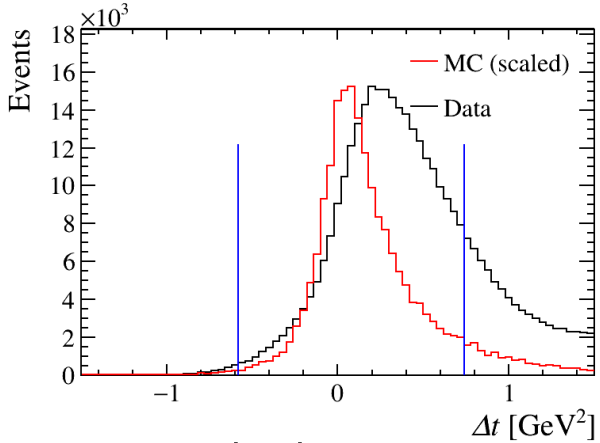


$|\Delta t| < 0.7$

CD&FD

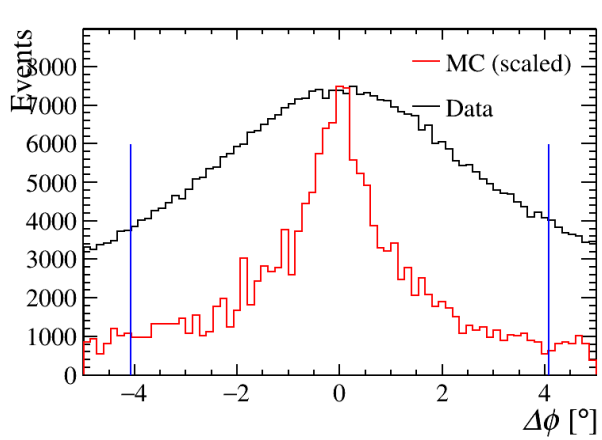


$|\Delta\phi| < 2.3$

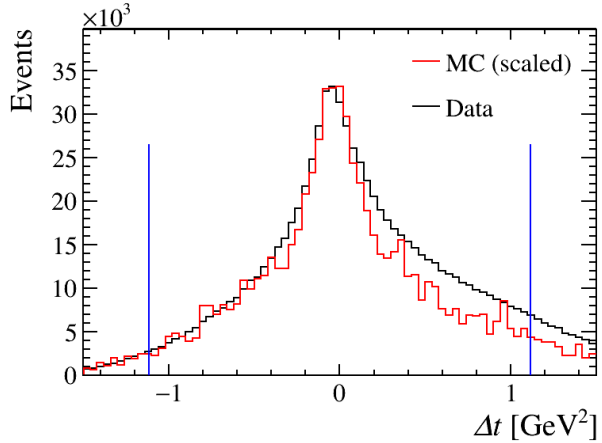


$|\Delta t| < 0.6$

FD&FT

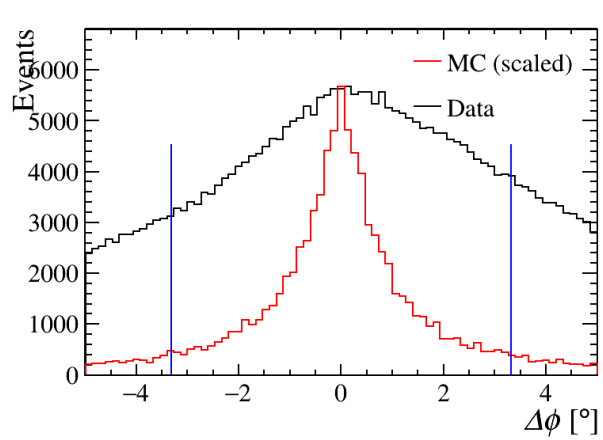


$|\Delta\phi| < 4.1$

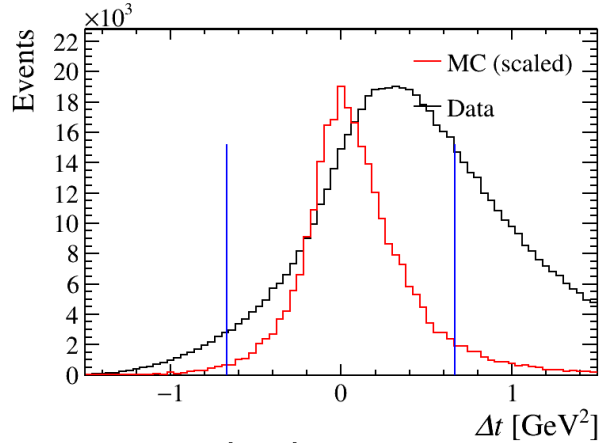


$|\Delta t| < 1.1$

FD&FD



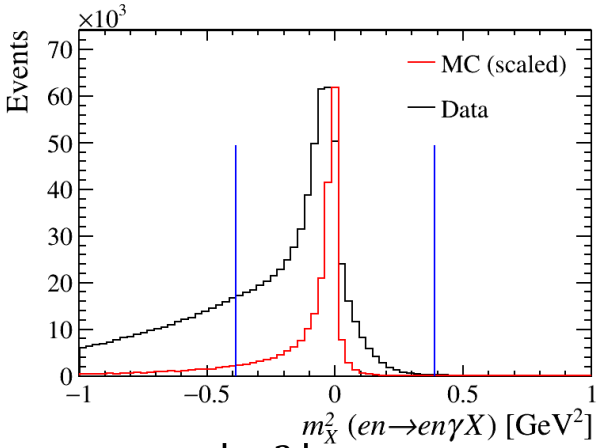
$|\Delta\phi| < 3.3$



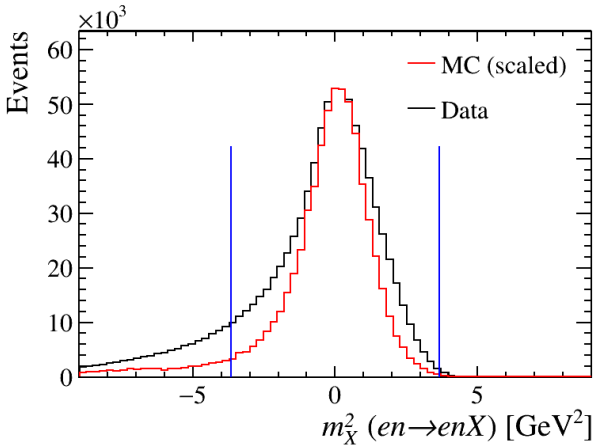
$|\Delta t| < 0.7$

Exclusivity selection

CD&FT

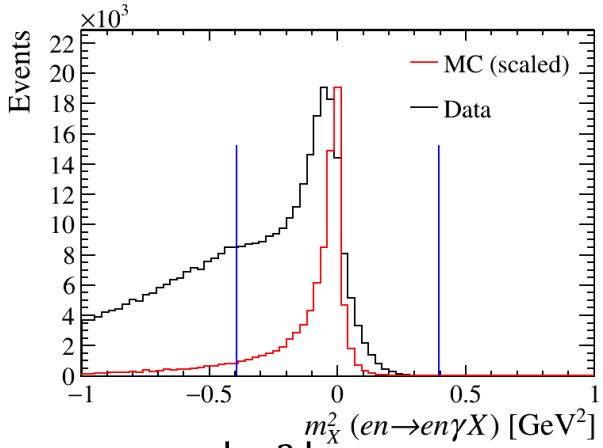


$|m_X^2| < 0.4$

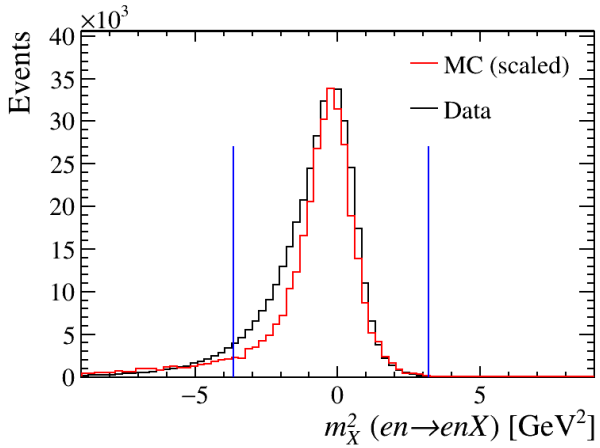


$|m_X^2| < 3.7$

CD&FD

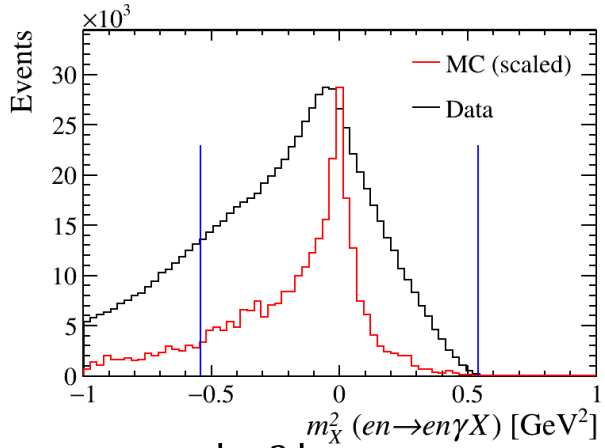


$|m_X^2| < 0.4$

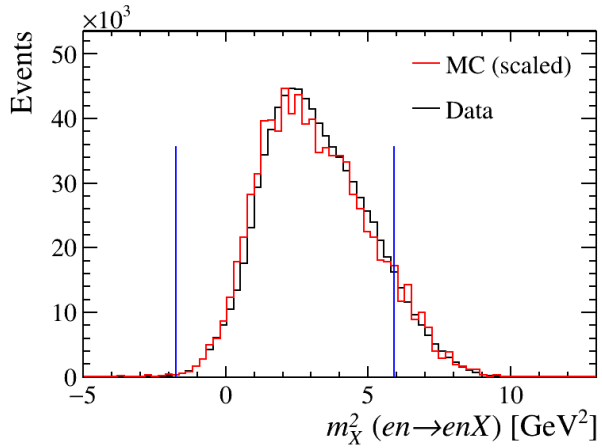


$-3.7 < m_X^2 < 3.2$

FD&FT

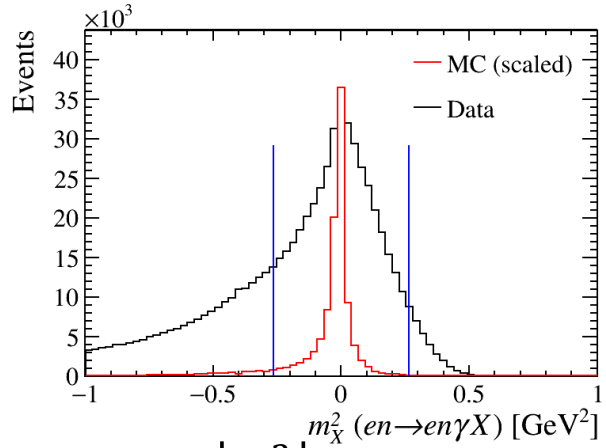


$|m_X^2| < 0.5$

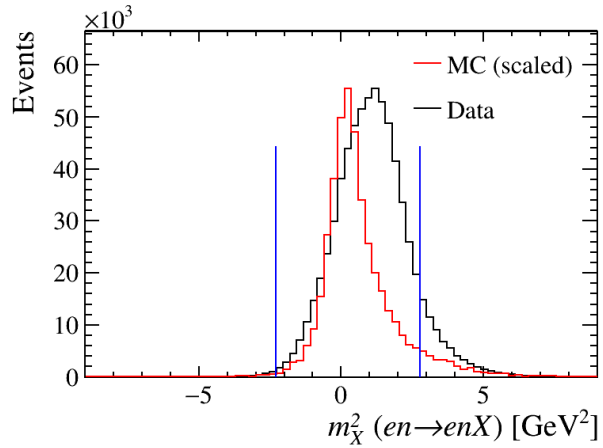


$-1.7 < m_X^2 < 5.9$

FD&FD



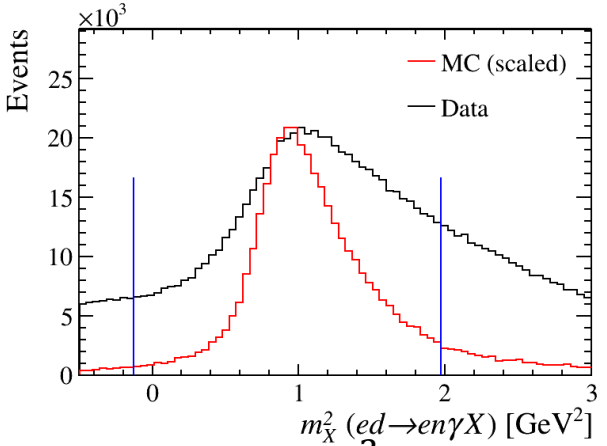
$|m_X^2| < 0.3$



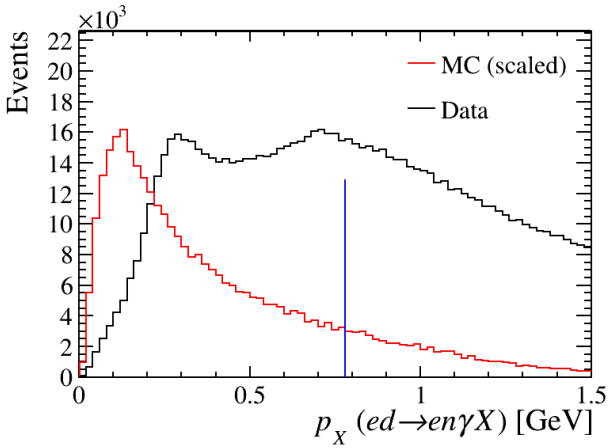
$-2.3 < m_X^2 < 2.8$

Exclusivity selection

CD&FT

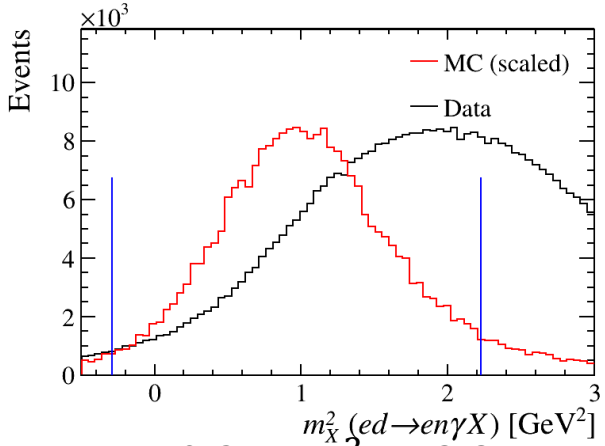


$-0.1 < m_X^2 < 2.0$

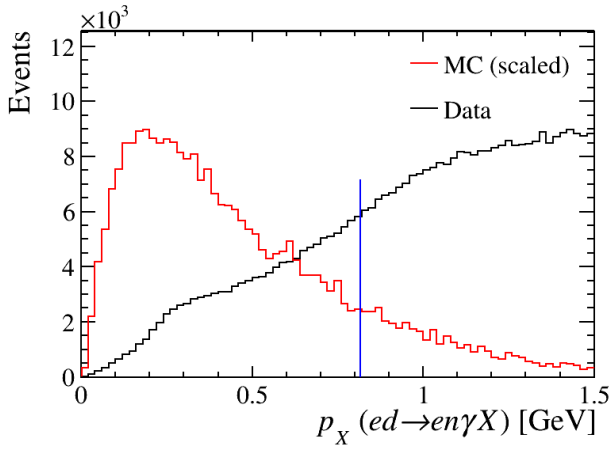


$p_X < 0.8$

CD&FD

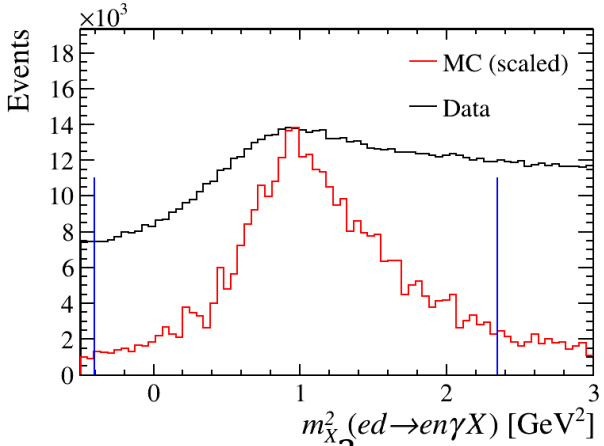


$-0.3 < m_X^2 < 2.2$

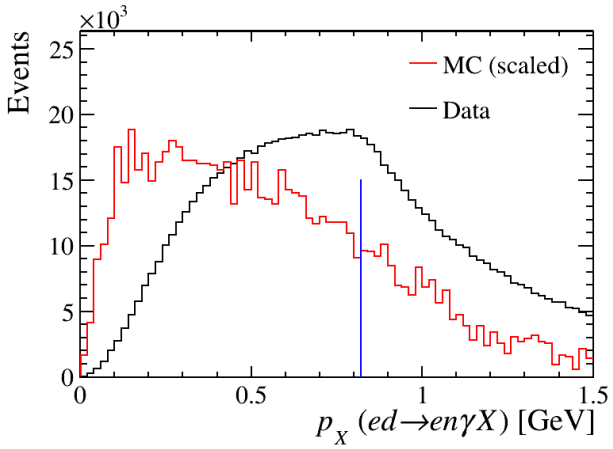


$p_X < 0.8$

FD&FT

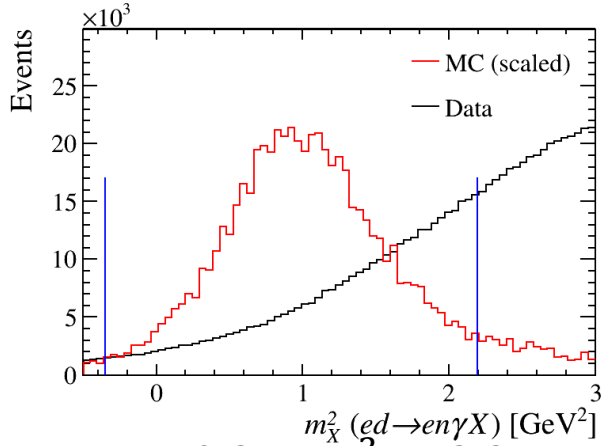


$-0.4 < m_X^2 < 2.3$

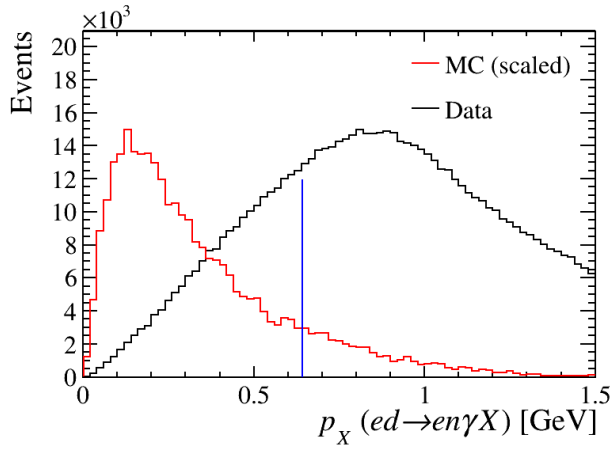


$p_X < 0.8$

FD&FD



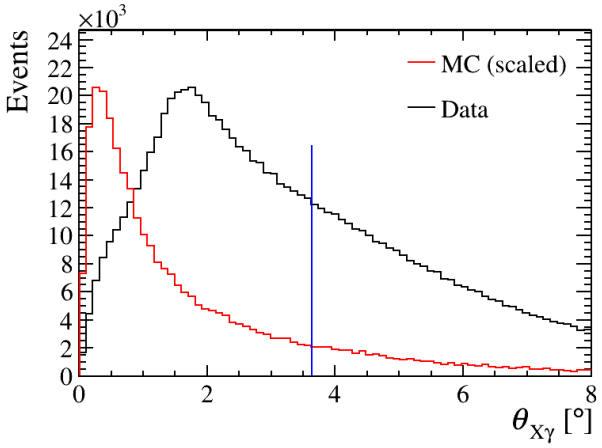
$-0.3 < m_X^2 < 2.2$



$p_X < 0.6$

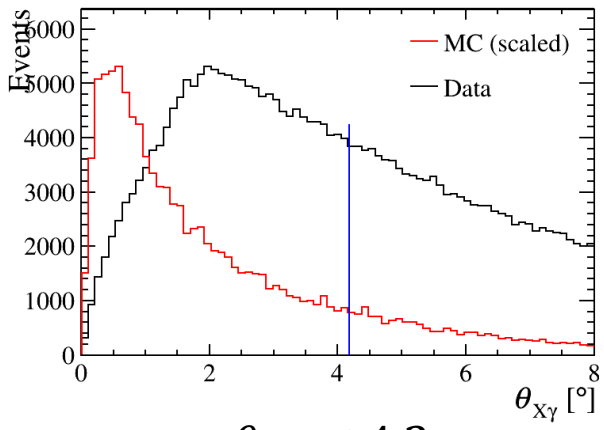
Exclusivity selection

CD&FT



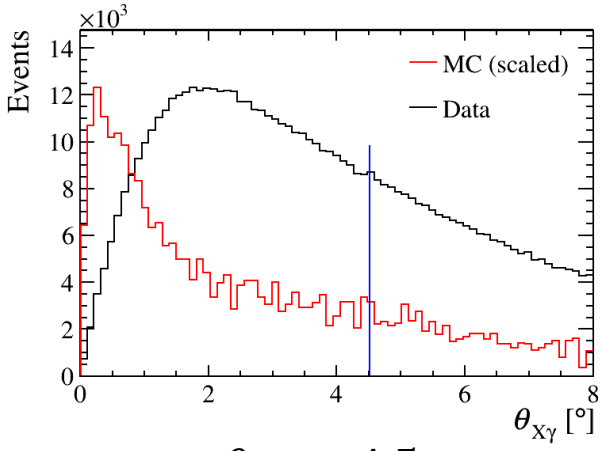
$\theta_{X\gamma} < 3.6$

CD&FD



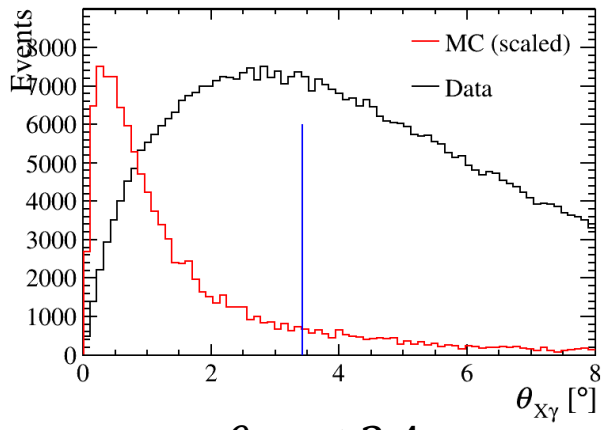
$\theta_{X\gamma} < 4.2$

FD&FT



$\theta_{X\gamma} < 4.5$

FD&FD



$\theta_{X\gamma} < 3.4$

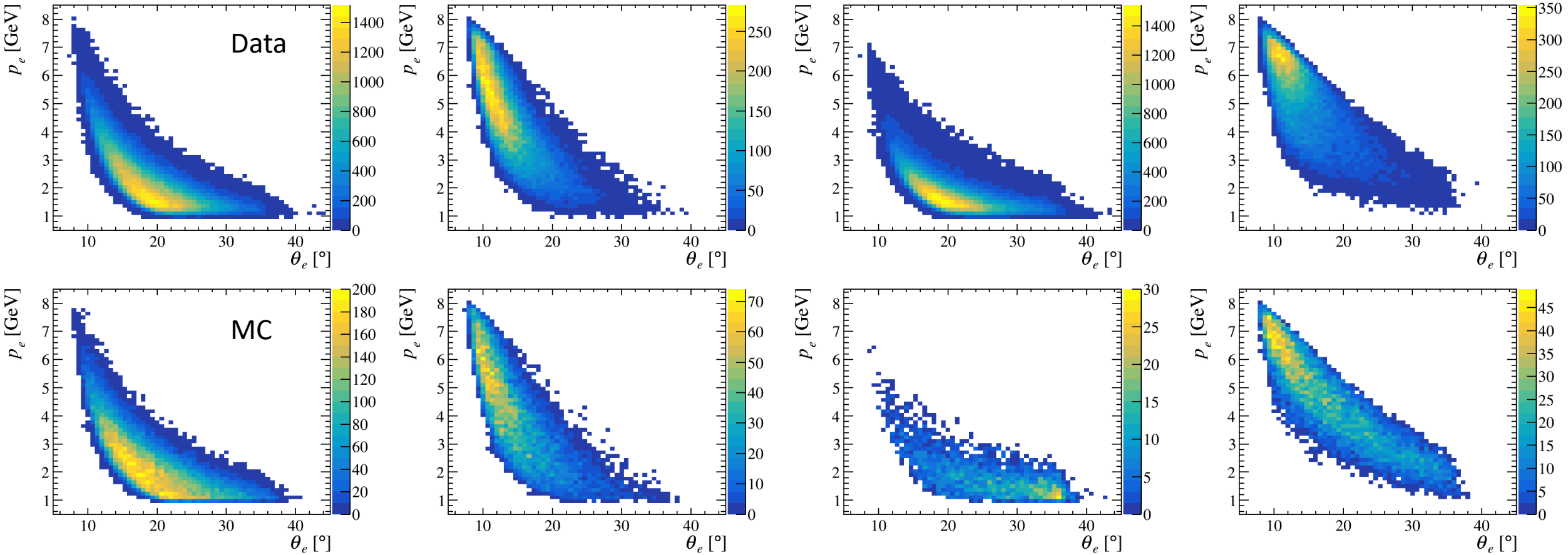
Electron kinematics

CD&FT

CD&FD

FD&FT

FD&FD



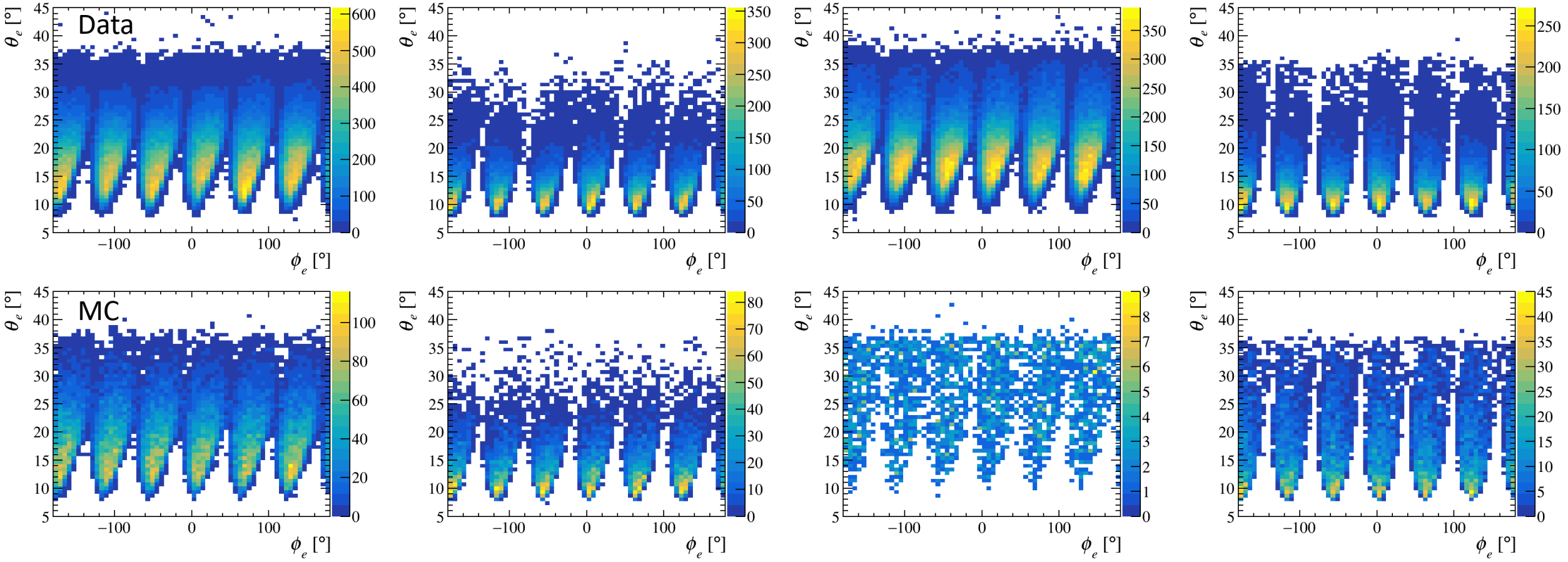
Electron kinematics

CD&FT

CD&FD

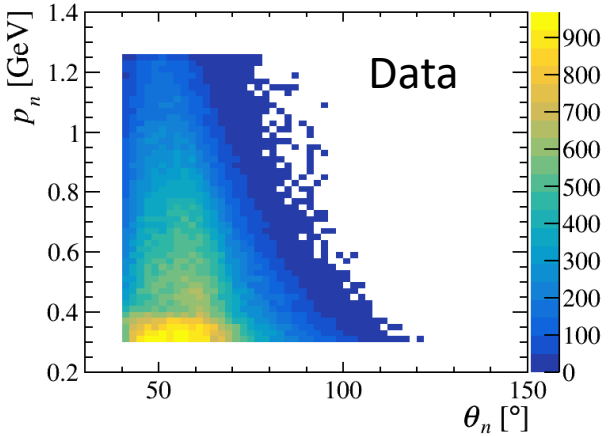
FD&FT

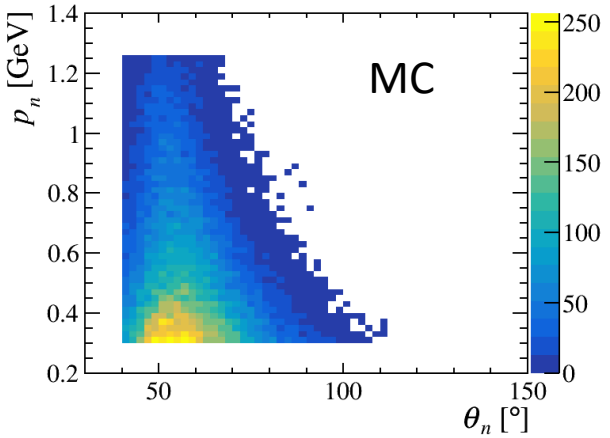
FD&FD



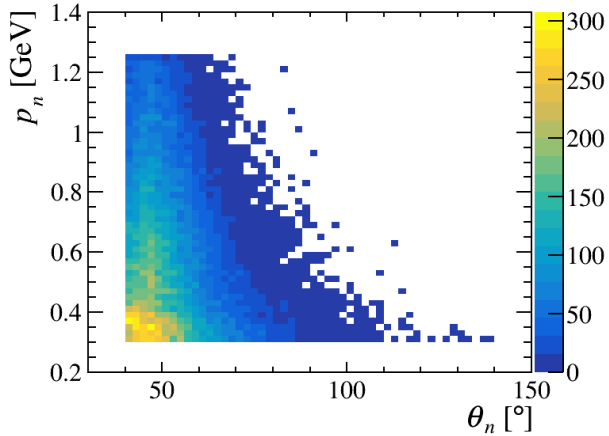
Neutron kinematics

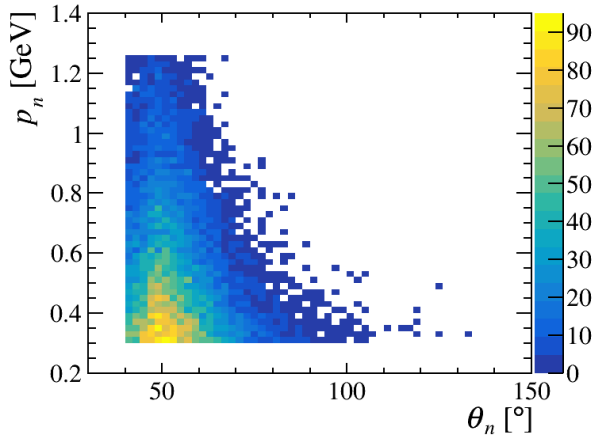
CD&FT



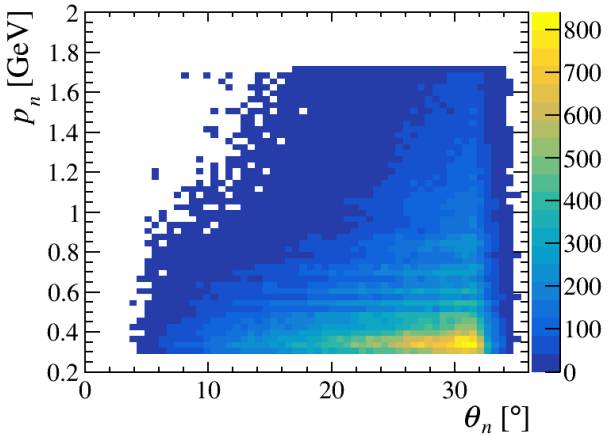


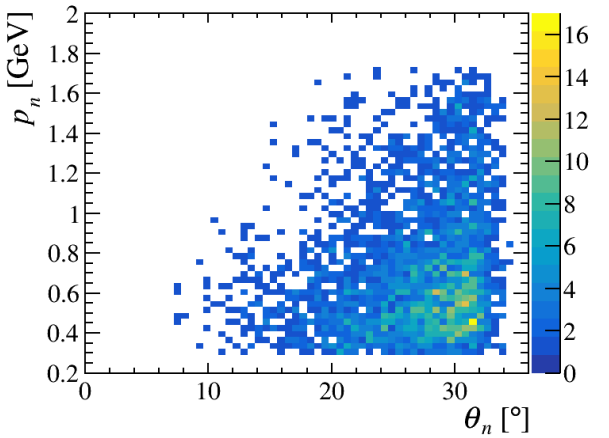
CD&FD



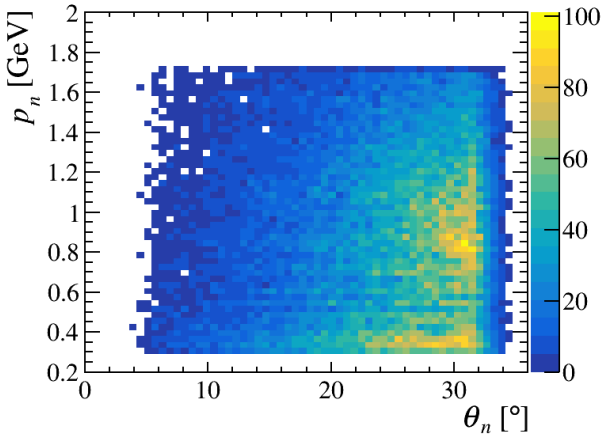


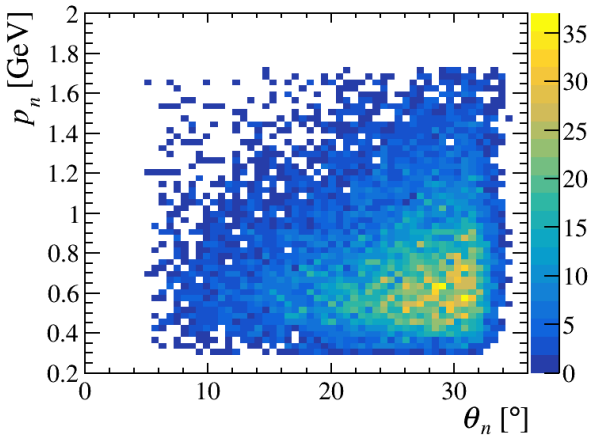
FD&FT





FD&FD





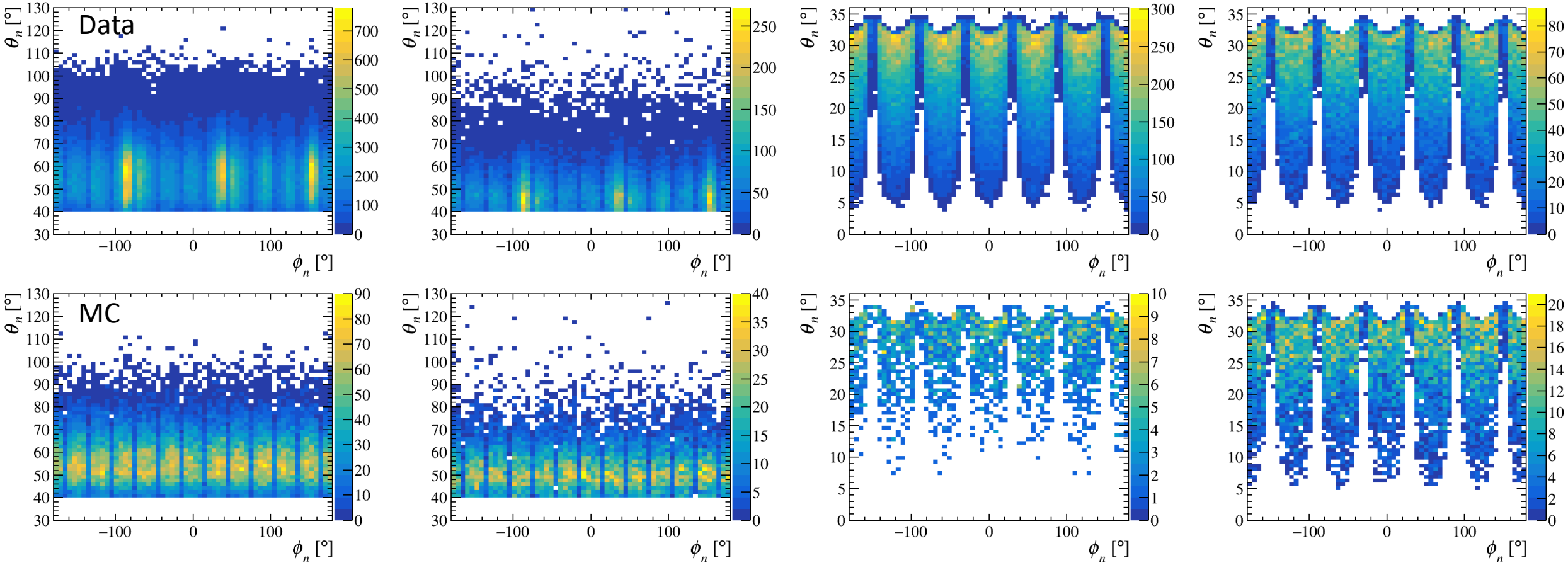
Neutron kinematics

CD&FT

CD&FD

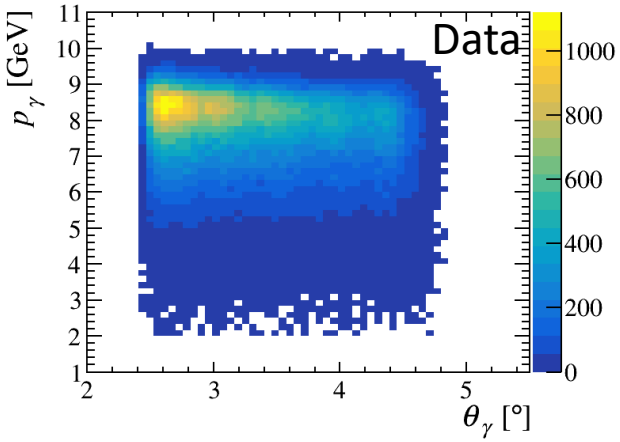
FD&FT

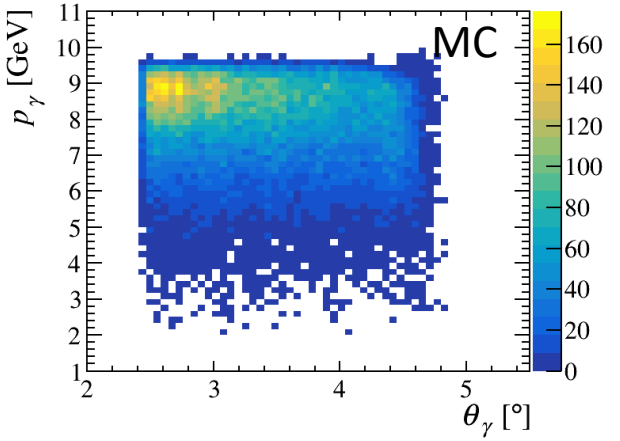
FD&FD



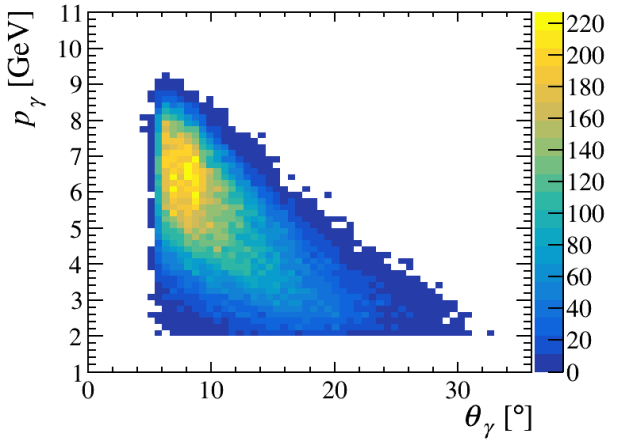
Photon kinematics

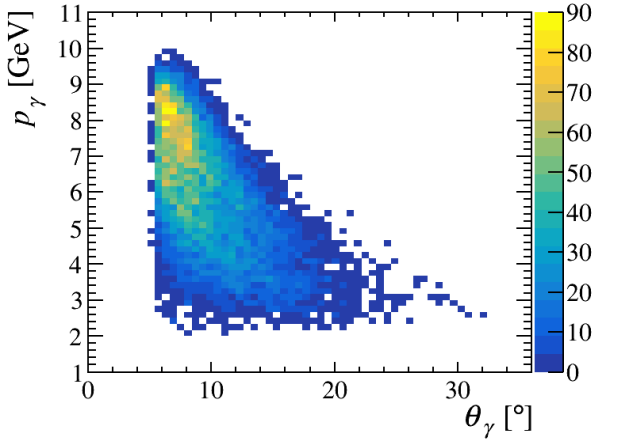
CD&FT



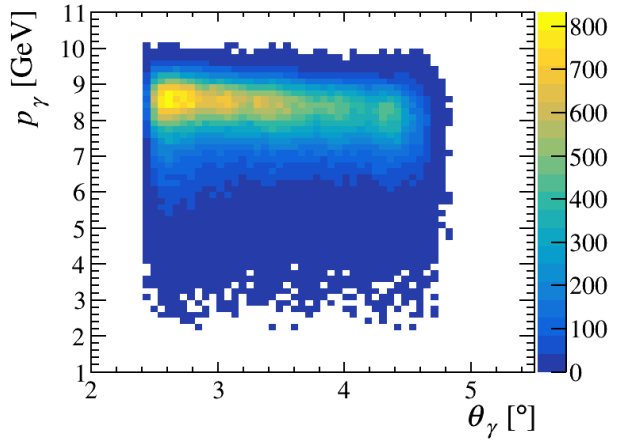


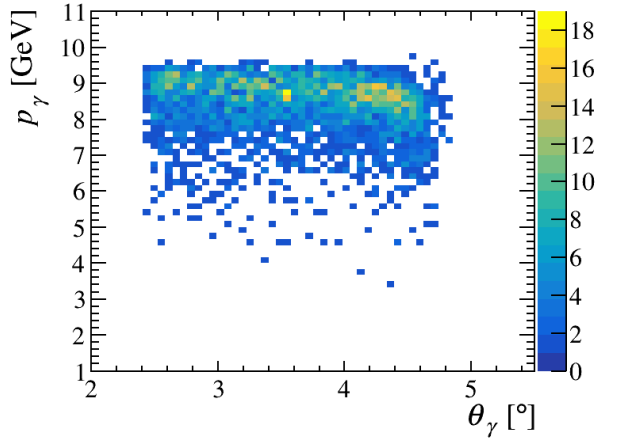
CD&FD



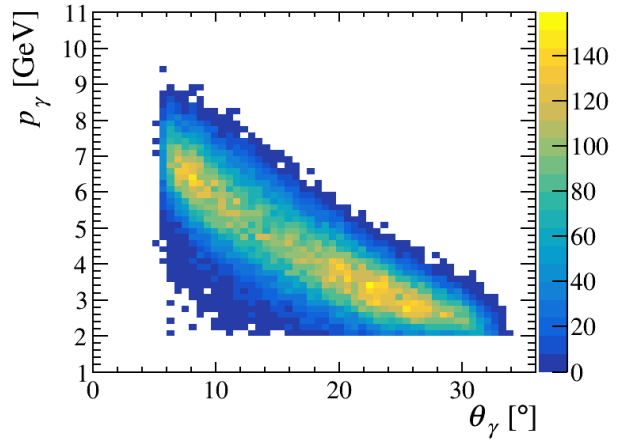


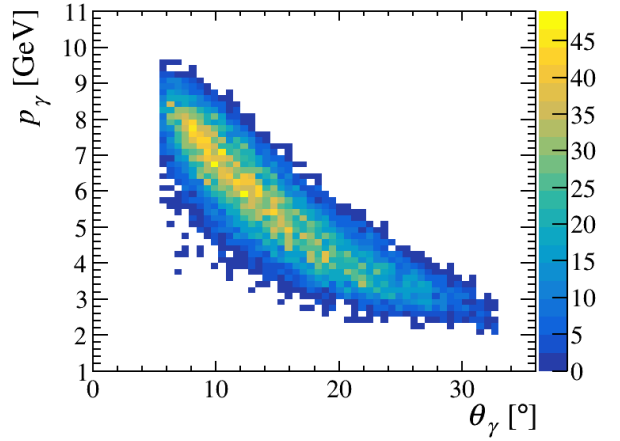
FD&FT





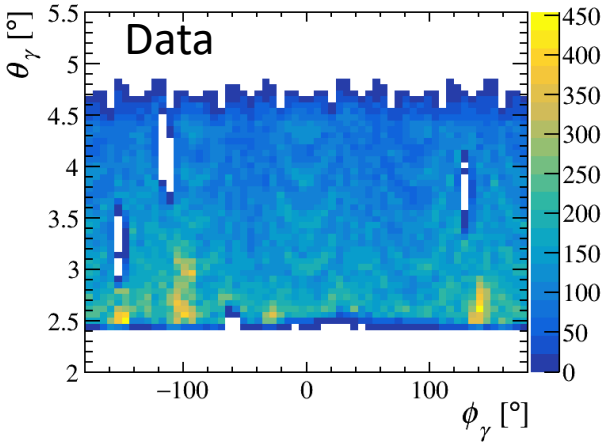
FD&FD



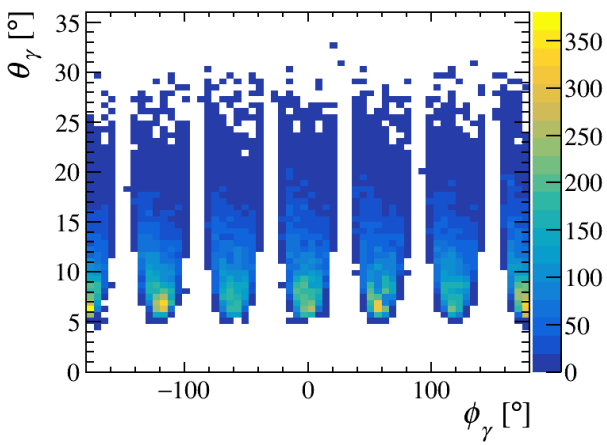


Photon kinematics

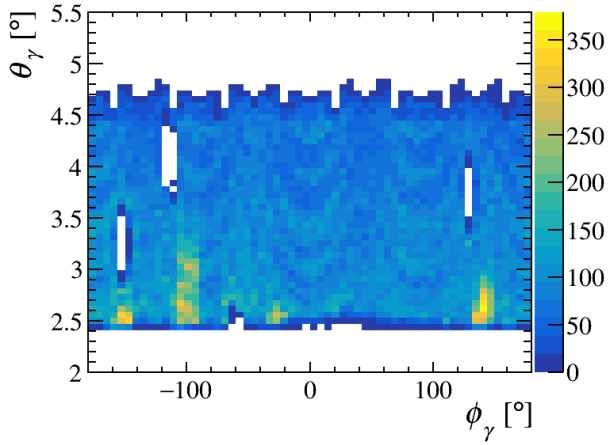
CD&FT



CD&FD



FD&FT



FD&FD