Exclusive π^0 studies for calorimeter resolutions

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1 Inroduction

Considering the very small mass of neutral pion with respect to the energies at EIC, these kinematics studies are the same for DVCS.

2 Exclusive π^0 studies for 20×250 GeV^2

The opening angle between the two photons of an exclusive π^0 is the smallest when the π^0-decay is symmetric with respect to the π^0-momentum.

At a given Q^2 and x$_B$, the π^0-momentum is the highest for t=tmin. In order to have a first idea about possible limitations from the electromagnetic calorimeter, I have studied the smallest opening angle for exclusive π^0 at t=tmin over the Q^2-x$_B$ phase space.

It is not a Monte-Carlo simulation but simple kinematics studies. The plots have been produced by assuming electron energy 20 GeV and proton energy at 250 GeV.

2.1 Electron coverage

Here are the electron momentum/rapidity distributions as a function of Q^2 and x$_B$. I have required to have y>0.01 and y<0.95. I have assumed that the maximal scattering angle we can detect for the electron is 140 degrees.

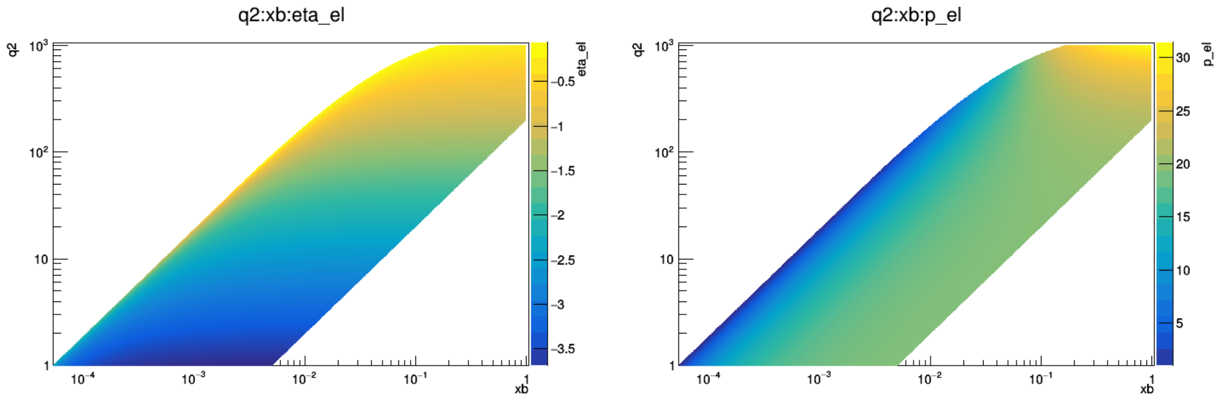

FIGURE 1 – Rapidity (Left) and momentum (right) of scattered electron as function of Q^2 and x_B.

2.2 π^0 kinematics

The tmin-π^0 is generated by having it collinear to the virtual photon exchanged between the proton and the electron.

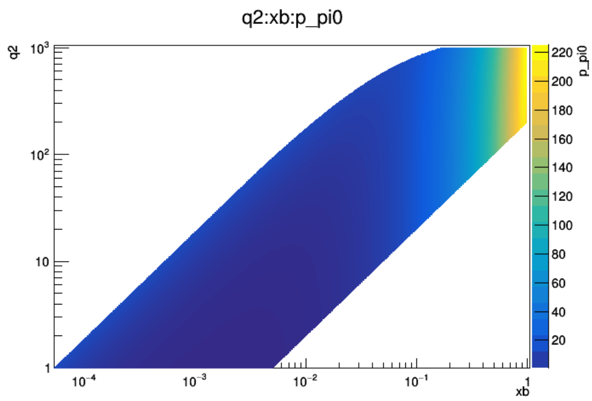

FIGURE 2 – Exclusive π^0-momentum distribution over Q^2 and x_B pahse space.

As Q^2 increases, the π^0 is more backward and its momentum slightly increases. The highest momentum is reached at 225 GeV for the highest x_B and highest Q^2.

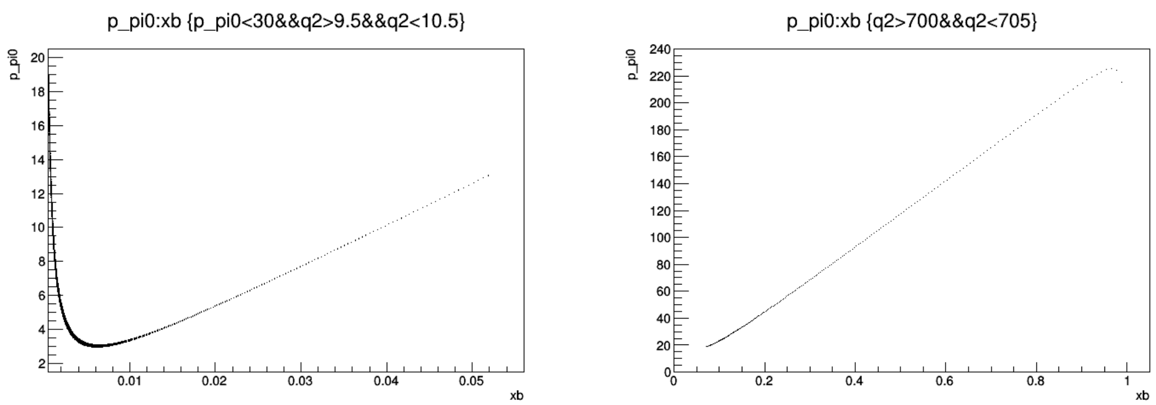

FIGURE 3 – Exclusive π^0-momentum distribution as a function of x_B for $Q^2 \sim 10$ GeV^2 (Left) and $Q^2 \sim 700$ GeV^2 (Right).

The π^0-momentum has a minimum as function of x_B for Q^2 less than 600 GeV^2, and then becomes a monotonic increasing function of x_B for higher Q^2 values.

The opening angle between the two photons highlights the minimum of momentum as function of x_B for Q^2 below 600 GeV^2. The π^0 with highest momentum are going in the forward endcap.

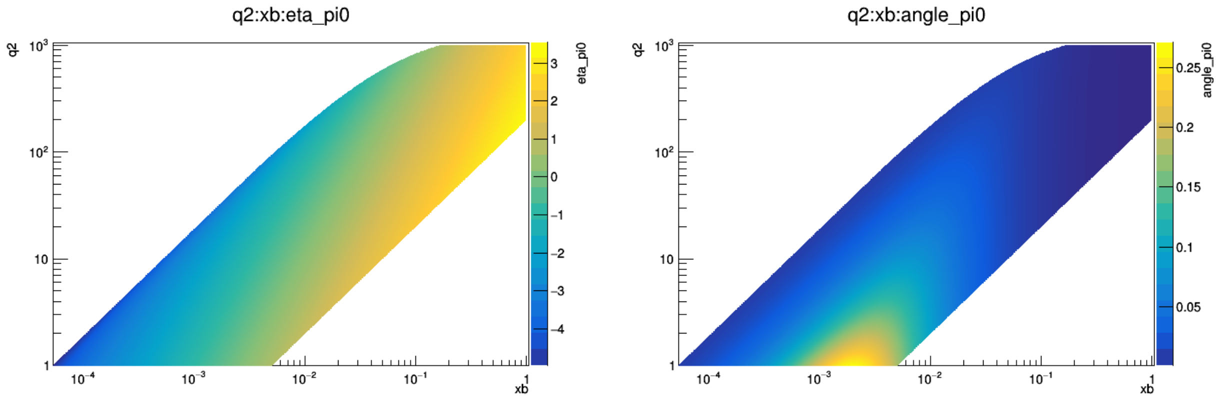

FIGURE 4 – Rapidity (Left) and minimal opening angle between photons (Right) of an exclusive π^0 at t=tmin over the Q^2/x_B phase space.

2.3 Recoil proton kinematics

Here are the momentum and rapidity of the tmin-recoil proton.

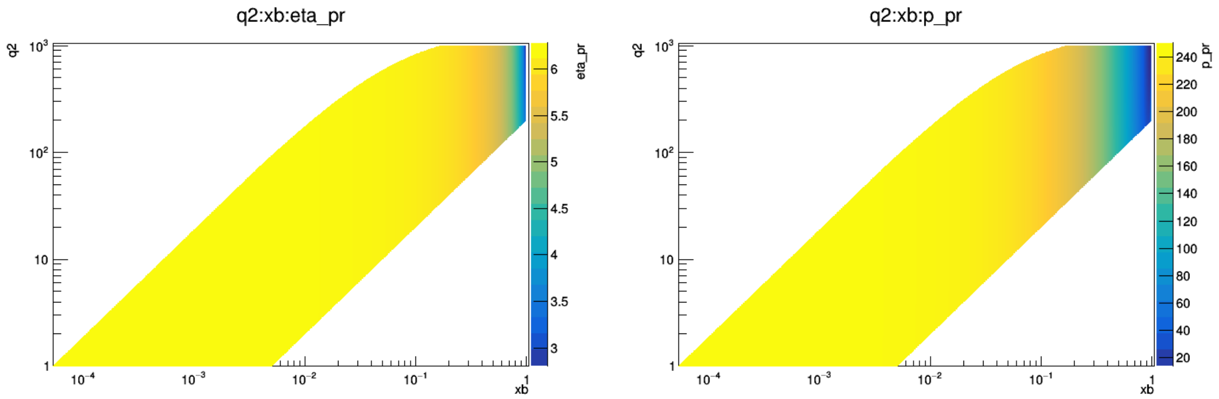

FIGURE 5 – Rapidity (Left) and momentum (right) of recoiled proton as function of Q^2 and x_B.

Without much surprise, the proton is going forward and its momentum is not much affected except at high x_B, where the π^0 is getting very energetic.

3 Exclusive π^0 studies for 5×100 GeV^2

The very high x_B region is more easily accessible at lower $\sqrt{s}$-configuration. Following the dvcs studies performed and summarized on the wiki, I considered a lepton beam energy at 5 GeV and a hadron bean energy at 100 GeV.

3.1 Electron coverage

Here are the electron momentum/rapidity distributions as a function of Q^2 and x_B. I have required to have y>0.01 and y<0.95. I have assumed that the maximal scattering angle we can detect for the electron is 140 degrees.

3.2 π^0 kinematics

The tmin-π^0 is generated by having it collinear to the virtual photon exchanged between the proton and the electron.

As Q^2 increases, the π^0 is more backward and its momentum slightly increases. The highest momentum is reached at 78 GeV for the highest x_B and highest Q^2.

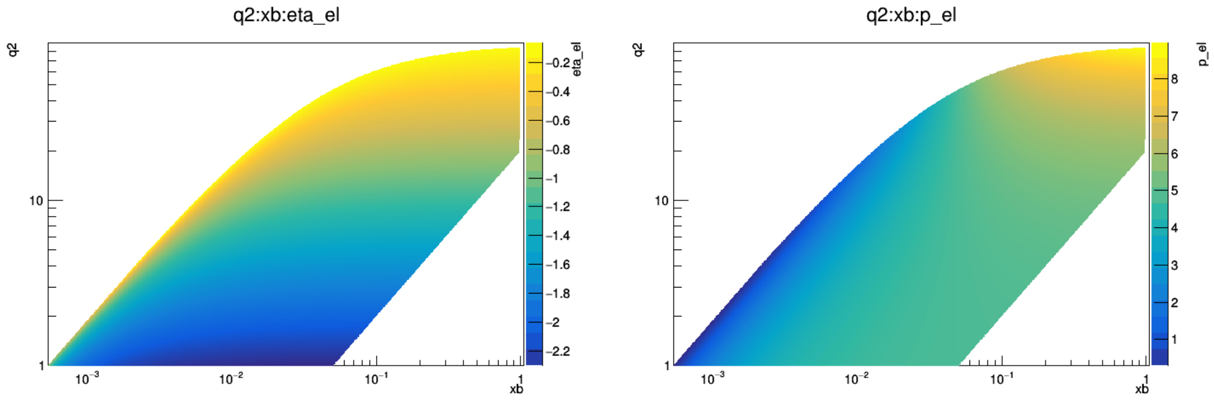

FIGURE 6 – Rapidity (Left) and momentum (right) of scattered electron as function of Q^2 and x_B.

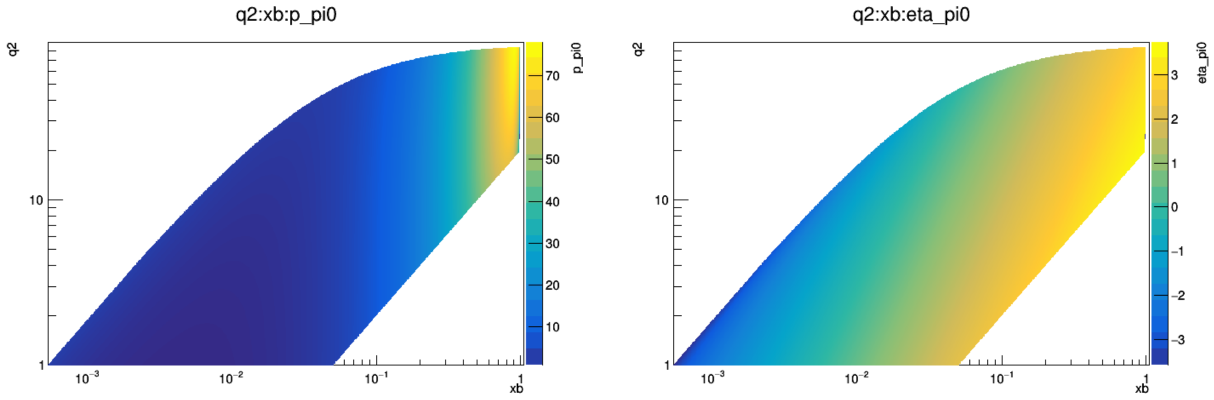

FIGURE 7 – Exclusive π^0-momentum and rapidity distribution over Q^2 and x_B pahse space for t=tmin.

As previously shown, the π^0-momentum has a minimum as function of x_B for Q^2 less than 30 GeV^2, and then becomes a monotonic increasing function of x_B for higher Q^2 values.

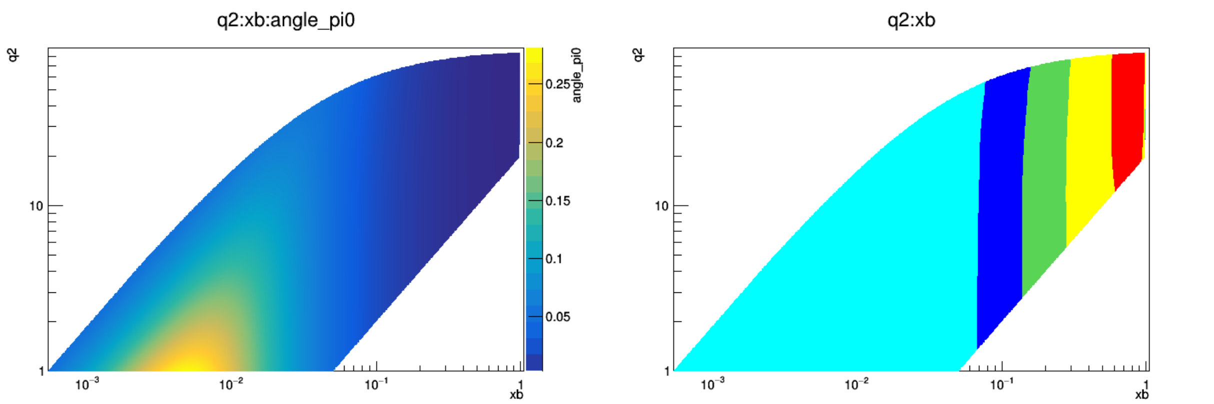

FIGURE 8 – Minimal opening angle (Left) and kinematic coverage corresponding to different thresholds (Right) in minimal opening angle (Right) of an exclusive π^0 at t=tmin. Here is the legend for the figure on the right :

— Red : Opening angle smaller than 0.005 rad.
— Yellow : Opening angle between 0.005 and 0.01 rad.
— Green : Opening angle between 0.01 and 0.02 rad.
— Dark blue : Opening angle between 0.02 and 0.04 rad.
— Light blue : opening angle larger than 0.04 rad.

The π^0 with highest momentum are going in the forward endcap and the 2-γ identification remains challenging.

3.3 Recoil proton kinematics

Here are the momentum and rapidity of the tmin-recoil proton.

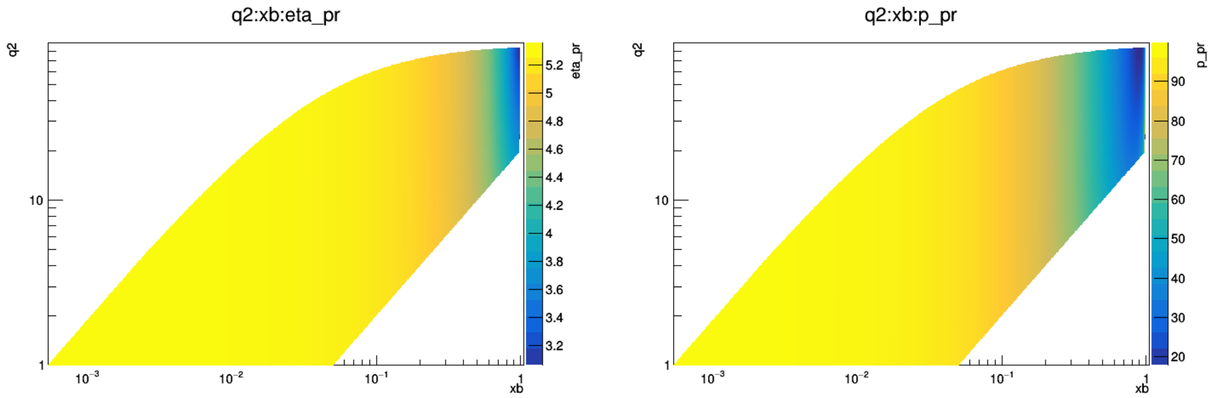

FIGURE 9 – Rapidity (Left) and momentum (right) of recoiled proton as function of Q^2 and x_B.

Without much surprise, the proton is going forward and its momentum is not much affected except at high x_B, where the π^0 is getting very energetic.

4 Limitations for high x_B and high Q^2

It seems clear that the most energetic π^0s are expected in the hadron endcap or in the very forward part. Even if we consider the configuration 5×100 GeV^2, the maximum energy of these π^0s is still of 78 GeV. If the hadron endcap calorimeter cannot resolve opening angle smaller than 0.01 rad, a significant area of the phase space will not be accessible for both processes DVCS and π^0 .

For x_B >0.1 and $Q^2 \sim 10$ GeV^2, there is no doubt that there will be exclusive π^0 whose number may not be negligible regarding the DVCS events.

5 Persective

I want to emphasize that DVCS cannot be studied if we cannot study the π^0. From the plots above, we can then determine how much of the phase space we lose for a given granularity of the calorimeter at tmin. A global study as a function of t must be performed since the π^0 momentum (and consequently the minimal opening angle between the two photons) decreases.

I would recommend to do as much minimum-biased studies as possible. Models may not be reliable in this terra incognita (Gluon Transversity GPD models do not have much π^0 data in this region to be constrained). Concerning the π^0, the first predictions in the valence region were underestimating the cross section by an order of magnitude.

I would even extend this warning to DVCS as well but for another reason : The Bethe-Heitler has very steep kinematical dependences and varies by several order of magnitude. But we are interested in DVCS. So we need to make sure we are not tuning the experimental setup to study Bethe-Heitler dominated kinematics (Which are most of the events you will get easily from a generator including Bethe-Heitler) : We must keep our mind as open as possible to collect DVCS data in regions never explored so far.