Background simulations on Charged-Lepton Flavor Violation (CLFV) in the Leptoquark framework at the EIC

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1.Introduction

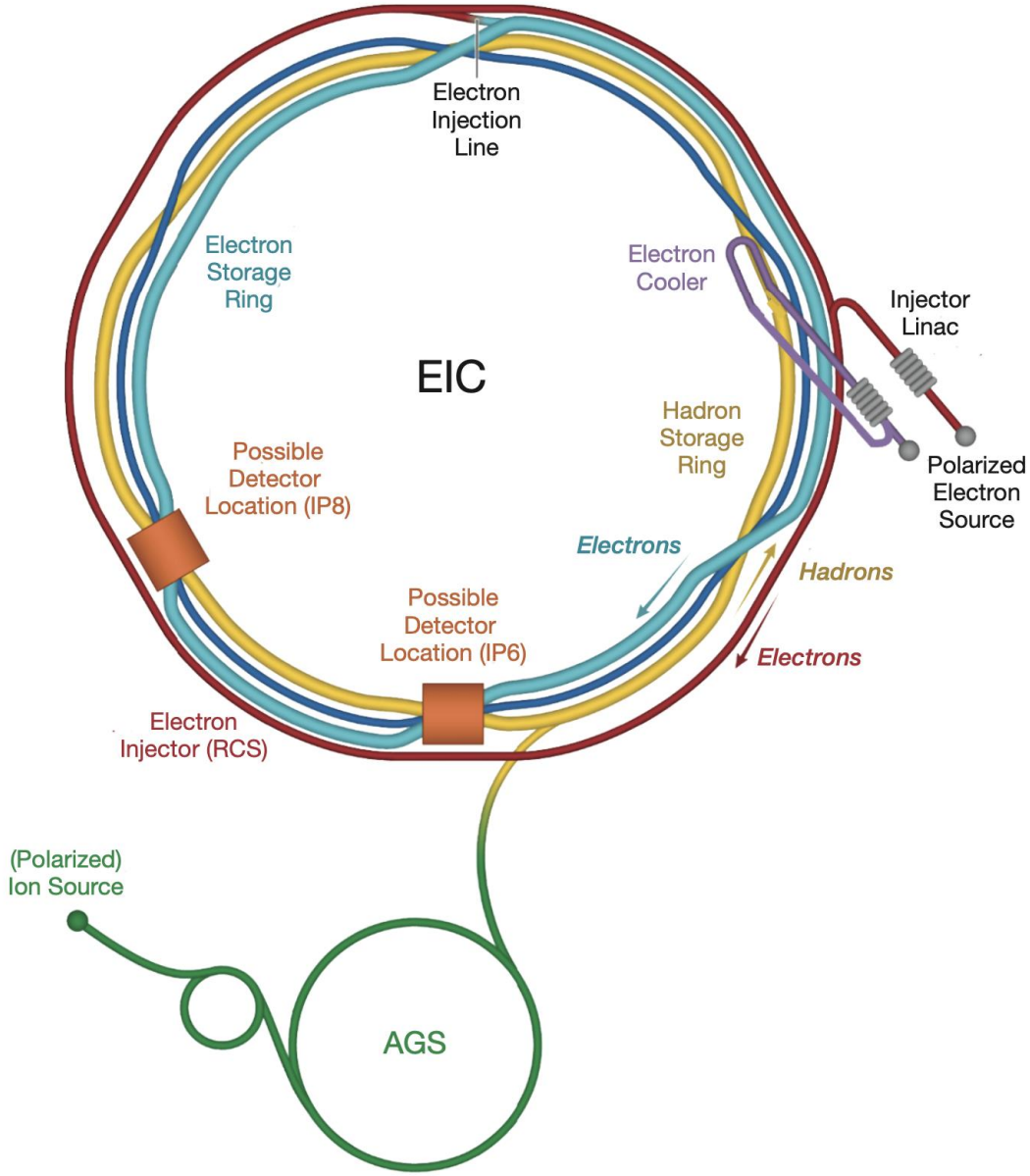
The Electron Ion Collider (EIC) will collide electrons and protons at high energies (18 GeV electron on 275 GeV protons) to increase our understanding of Quantum Chromodynamics (QCD).

The Electron-Ion Collider (EIC) will address some of the most fundamental questions in science:

- including the origin of the nucleon mass,
- the nucleon spin
- and the emergent properties of a dense system of gluons.

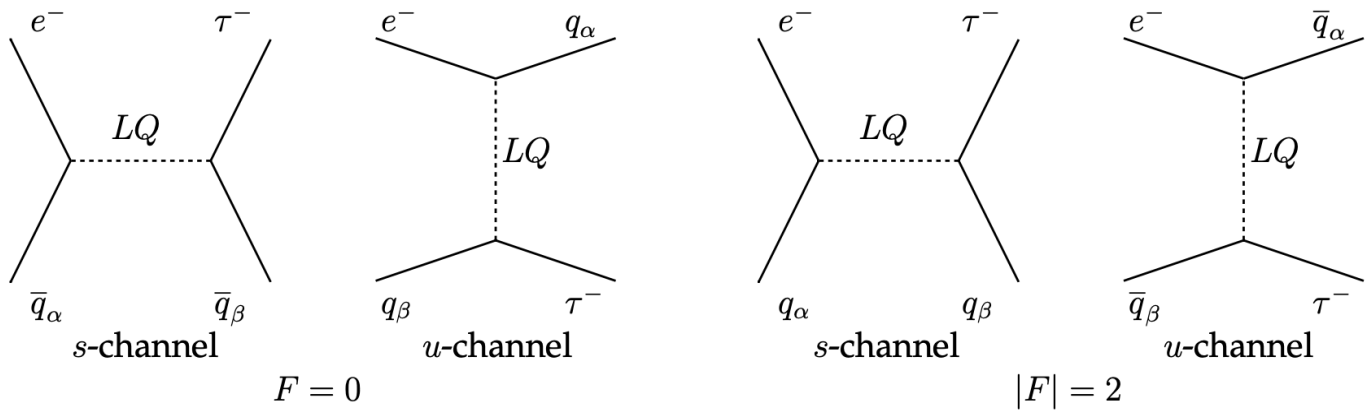
- EIC offers ability for precision studies that can significantly test Standard Model.

A leading observable in this arena is the $e- \rightarrow \tau-$ transition.



Leptoquarks: Beyond the Standard Model at the EIC

- LFV (neutrino oscillations) ⟹ CLFV ⟹ BSM Physics ⟹ LQ
- Leptoquarks are color triplet bosons that carry both lepton (L) and baryon (B) numbers, coupling leptons to quarks and mediating the $e + p \rightarrow \tau + X$ CLFV process at tree-level.
- *$e- \rightarrow \tau-$ transition is one of the best candidates for CLFV event measurements, and it is what we study here.*
- We carry out the simulation analysis for determining sensitivity to the CLFV process $e+p \rightarrow \tau +X$ in the leptoquark framework.



arXiv:1006.5063v1

2.Background Event Generation

- The tau particle does not live long enough to be measured by any detectors

- Study the potential of $e^- \rightarrow \tau^-$ conversion event by ECCE indicates that the dominant τ decay modes can be categorized:

1. "1-prong" mode
2. "3-prong" mode

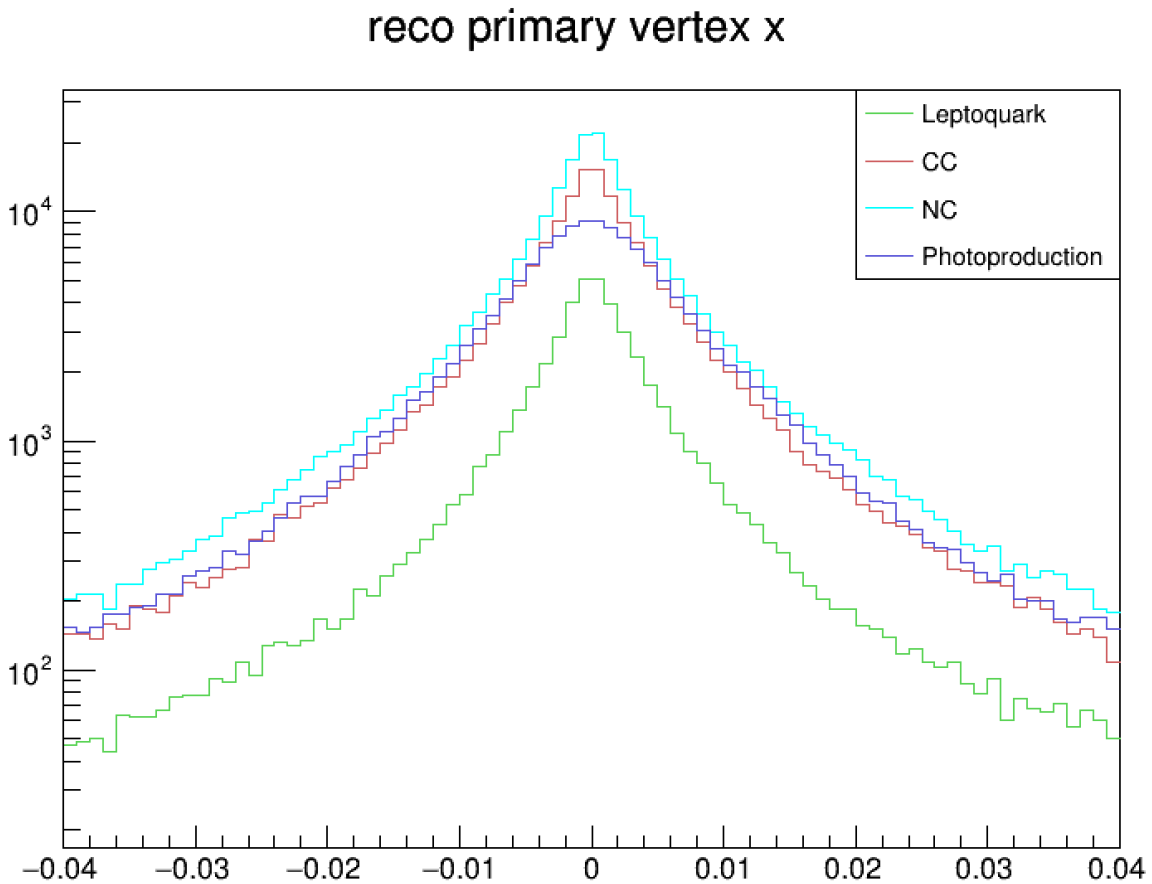
- SM background events are e + p collisions and mediated by EW interactions:

1. Charged Current Deep Inelastic Scattering (CC DIS) → **Djangoh**
2. Neutral Current Deep In- elastic Scattering (NC DIS)
3. Photoproduction → **Pythia**

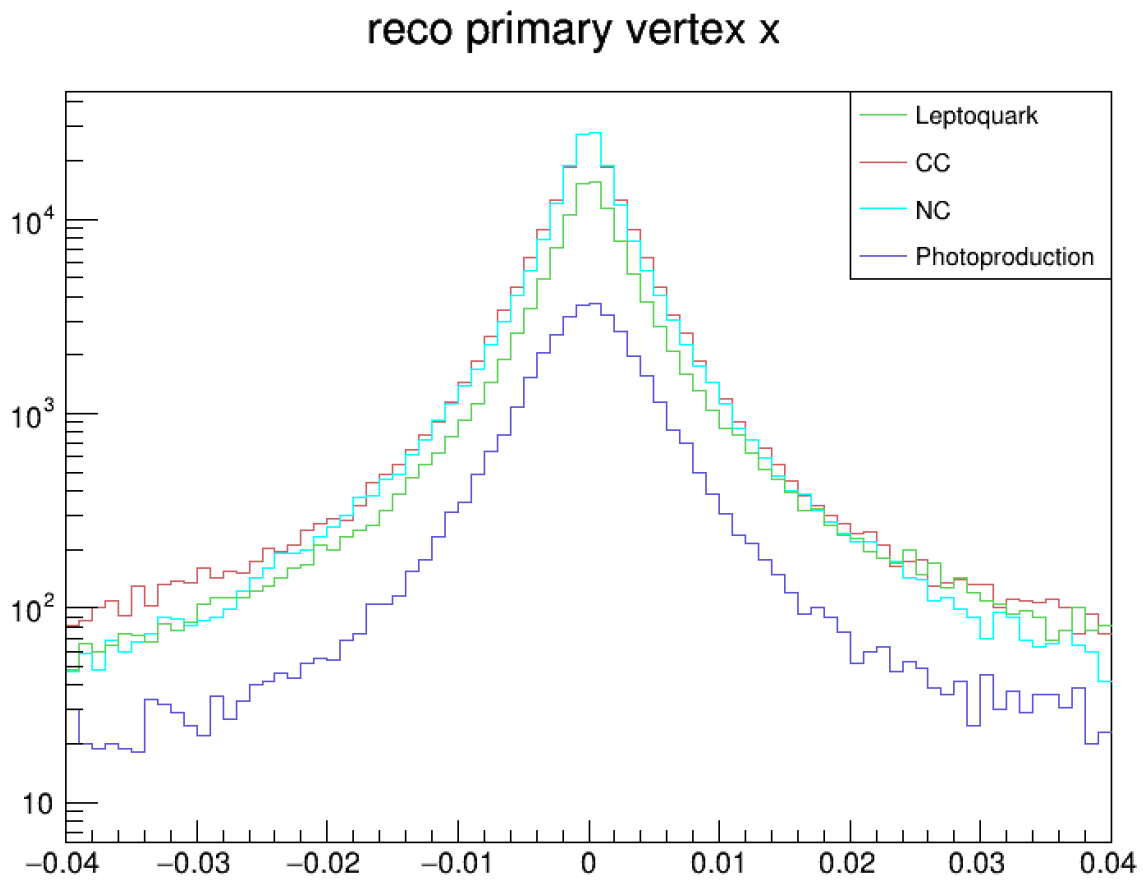
- These SM events may cause similar signal to tau particle as produced in a LQ event.

- The goal is to study CLFV at the EIC based on real detector simulations and identify such events over SM backgrounds.

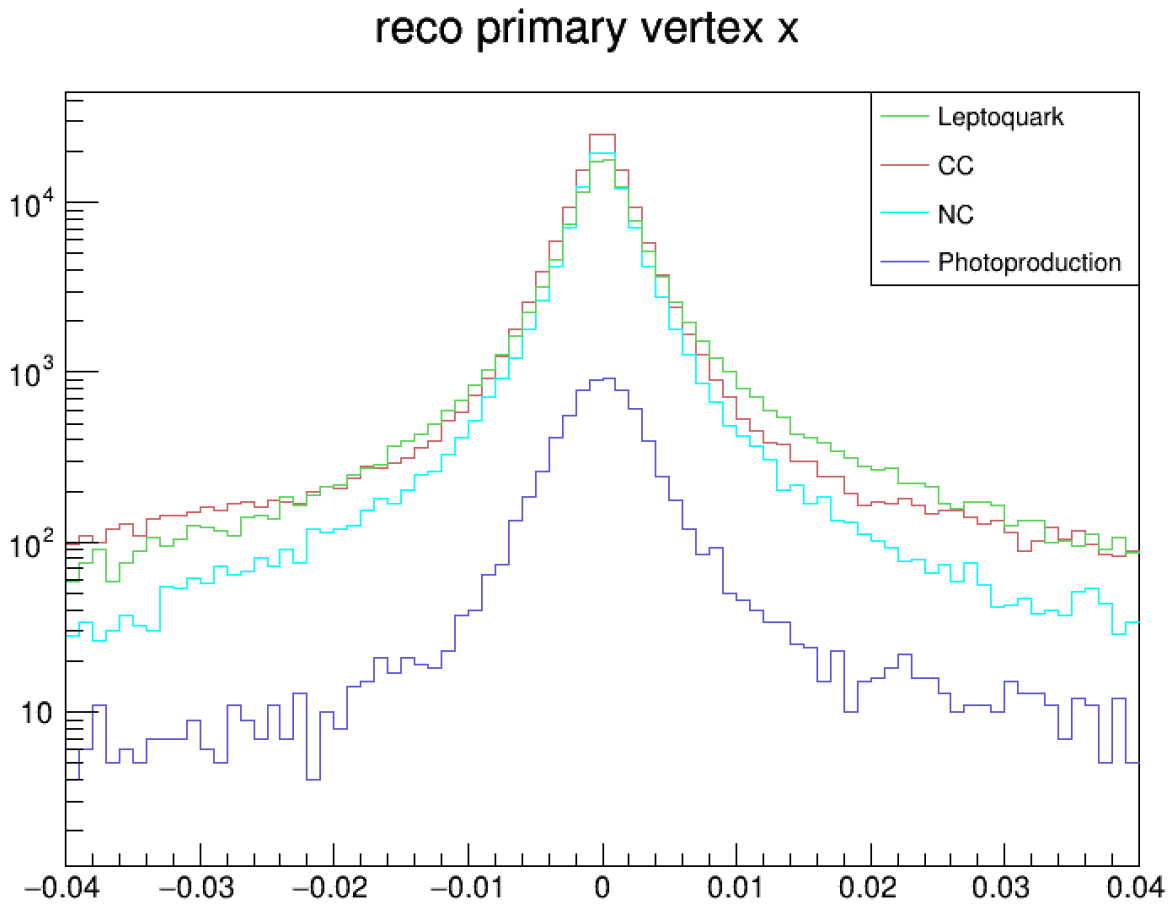
Tau decay products originates from secondary vertex which can be reconstructed from the tracks of the charged particles



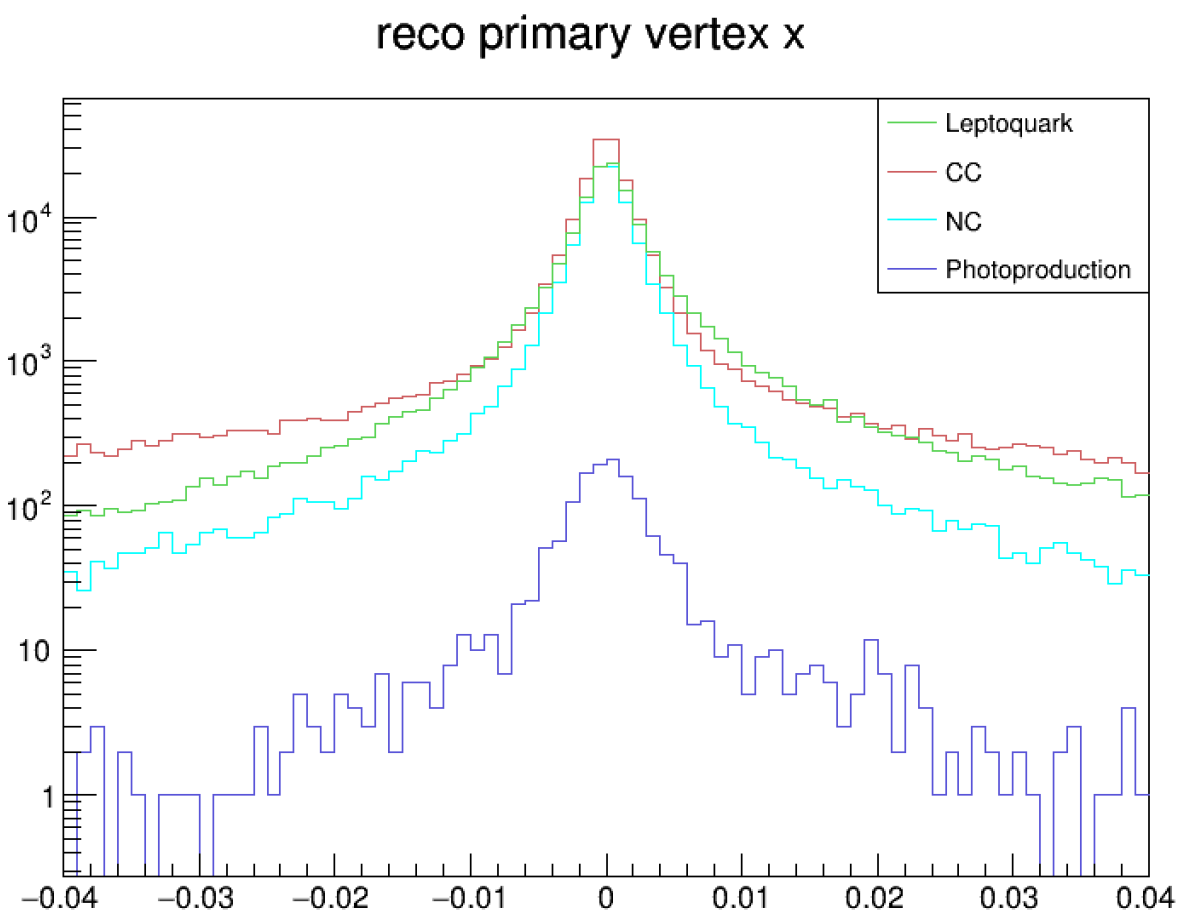
Number of tracks < 4



Number of tracks < 6

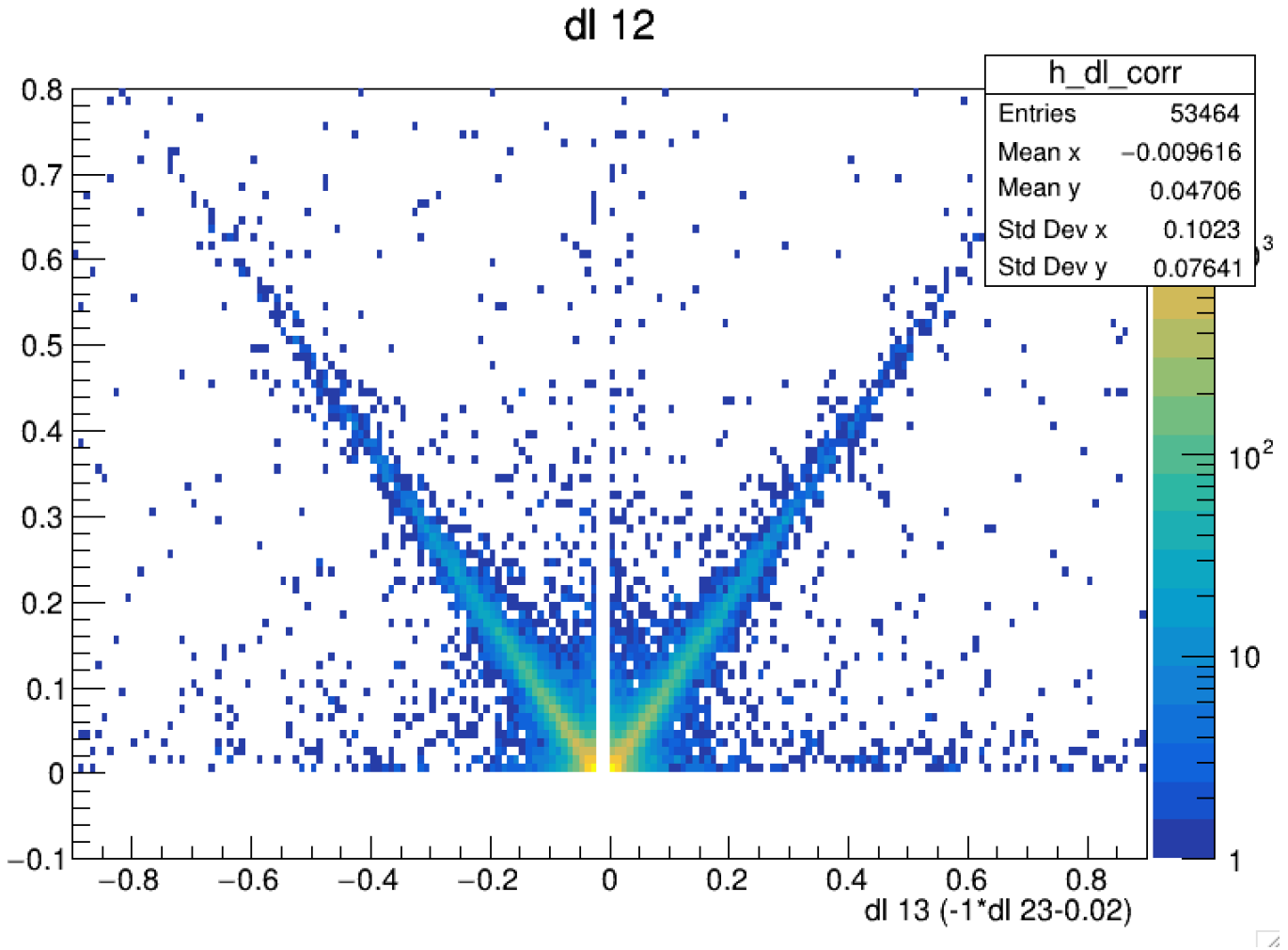


Number of tracks < 8



Number of tracks < else

To reconstruct the secondary vertex, we first look for 3-π candidates.

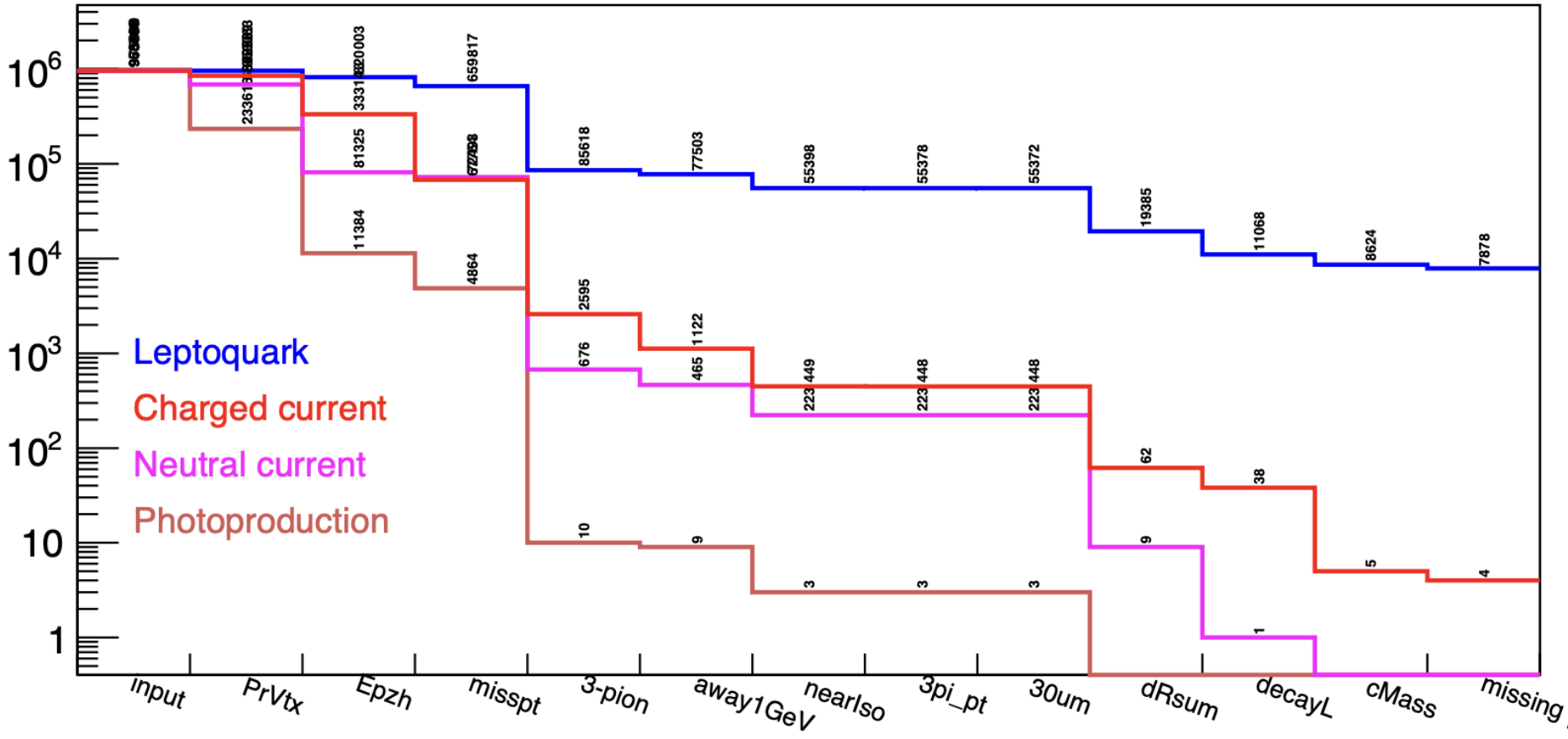


Coincidence between two of the three “intermediate” vertices (either left or right half) is usually enough to indicate a “3-prong" secondary vertex.

Coincidence among three “intermediate” vertices for 3-π event identification

Sensitivity to Leptoquarks

The sensitivity to the leptoquark signal cross section based on simulations of the 3-prong decay mode of the tau lepton



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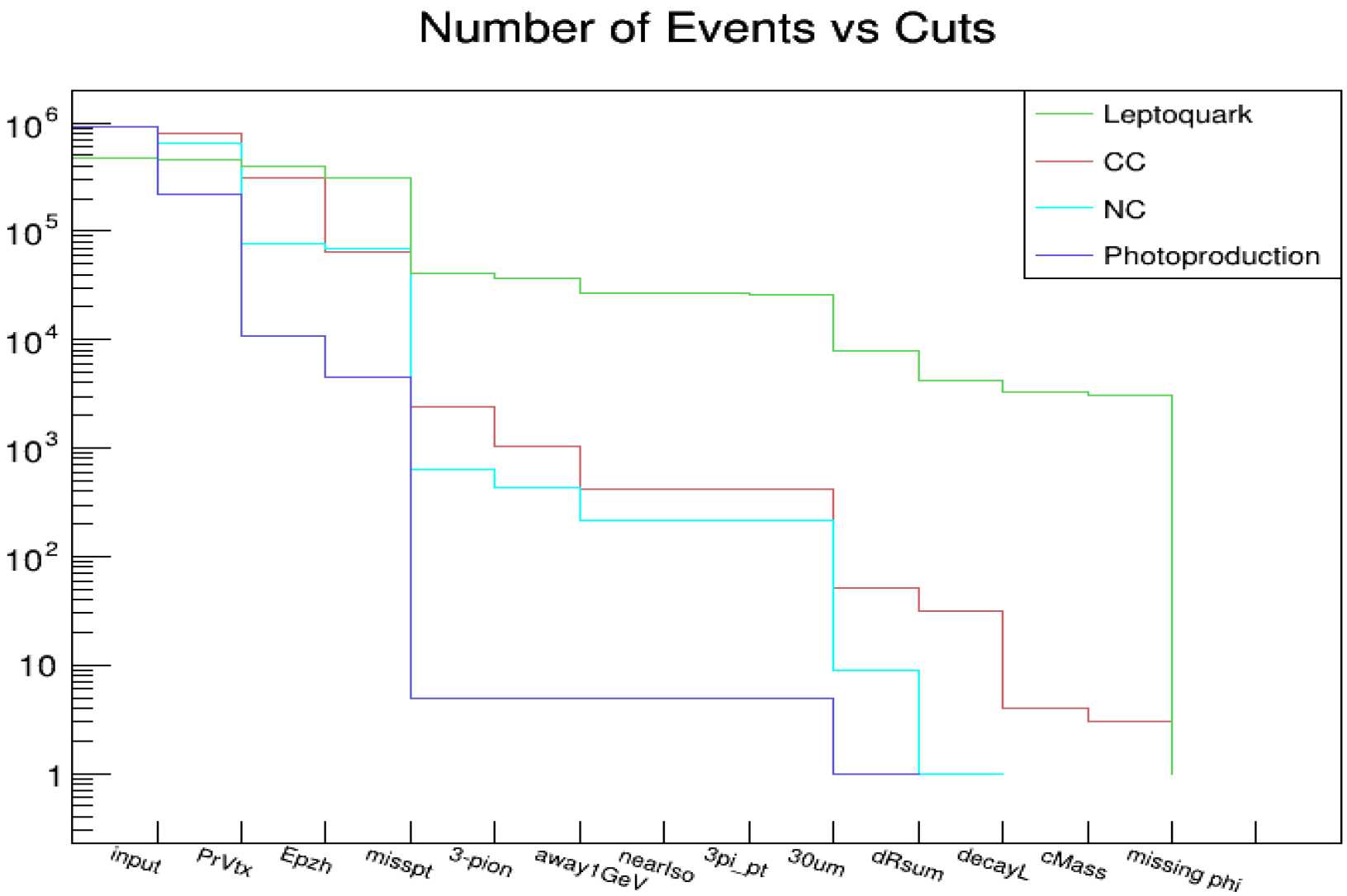
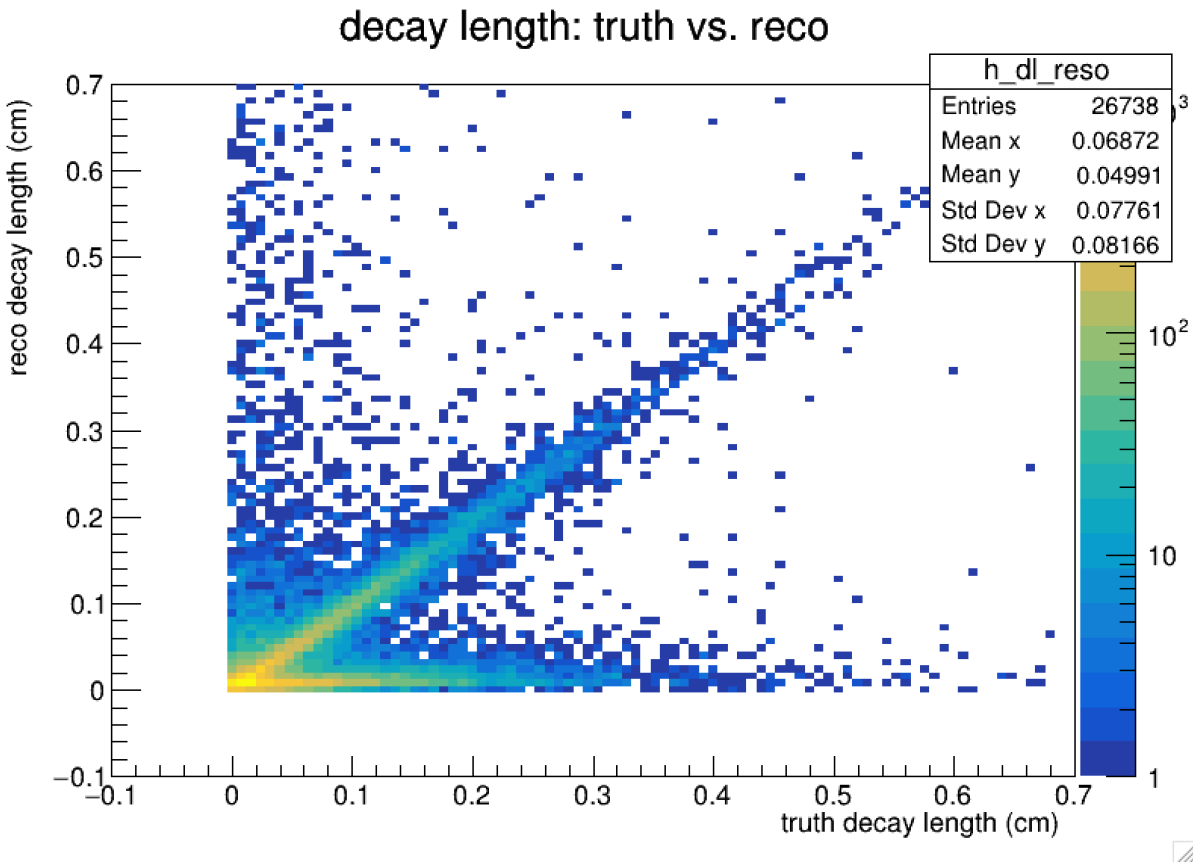
1M MC event samples are generated for each of the four processes: the leptoquark mediated signal process $e + p \rightarrow \tau + X$, and three backgrounds.

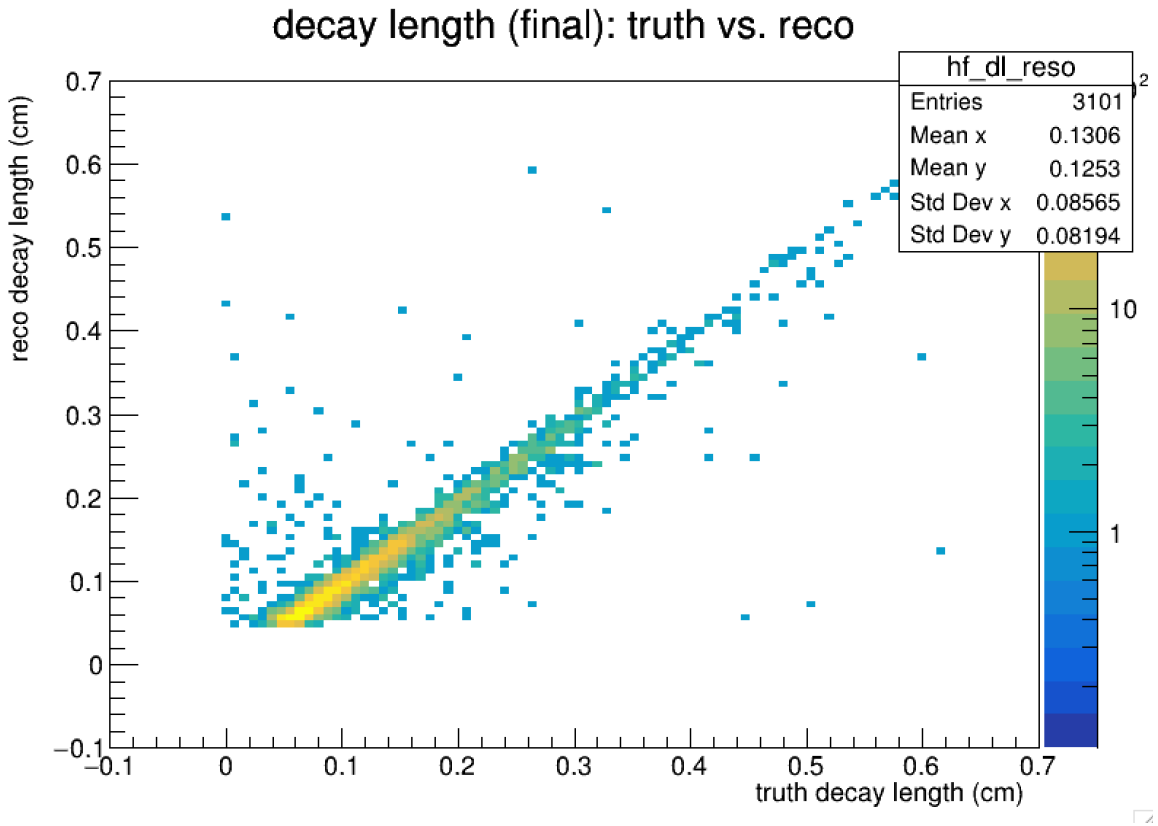
Sensitivity to Leptoquarks



the $e \rightarrow \tau$ events can be effectively selected with these preliminary cuts

using ***decayL*** as one of the event selection criteria , which is the average of the reconstructed decay lengths from three pair combinations of the 3-π candidate





comparison between the true decay length from the generator and the decay length reconstructed from tracks at the detector level

3.Conclusion

- Due to the initial state electron, the EIC is an excellent candidate for finding CLFV events.
- Study the potential CLFV event at the EIC and identification of LQ events over SM backgrounds or detection of these CLFV events at much larger rates that SM predicts would be strong evidence for BSM physics.
- Study done by ECCE thoroughly investigates only the 3-prong decay and the vertex resolution is sufficient for identifying tau decays.
- Background events survival depends on selection criteria or the performing cuts and obviously these background event affect the leptoquark sensitivity.

4.Planning for the future work

- 10 times higher statistics for background events in the Leptoquark framework
- background simulation for higher statistics must be run through real (**ePIC**) detector simulation
- Optimize selection criteria of events
- Compare S/B by using for example multivariable technique (Machine learning with ROOT) TMVA https://root.cern/manual/tmva/
- Working towards "1-prong" modes which are more demanding to identify experimentally

Thank you for your Attention!