Electron Ion Collider Simulated Detection of Lepton Flavor Violation via Displaced Tau Vertex

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The Electron Ion Collider

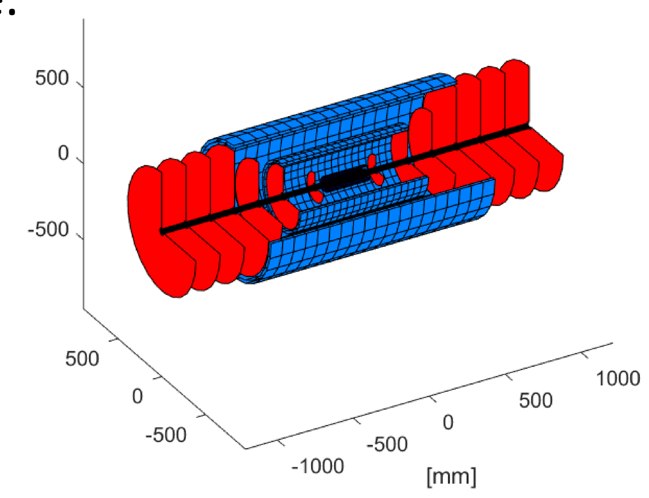
The Electron-Ion Collider (EIC) is a planned future facility for fundamental research in Nuclear Physics. It will consist of intense electron and ion beams that collide at high center-of-mass energies ranging from 20 to 140 GeV. These collisions allow us to probe the inner structure of the atomic nucleus as well as to study the strong force and its carrier, the gluon.

The collider may also be used to study lepton flavor violation, a theorized phenomenon that has yet to be observed. I adapted a detector response simulation package for use with the EIC in order to simulate detection of events with displaced vertices. Such events may indicate a beam electron transitioning into a tau lepton, an example of lepton flavor violation. The tau lepton is unstable and will decay after a short time and flight path, and the point of decay may be observed as a displaced vertex.

Methods

I used Monte Carlo simulations to determine if and how the particle-tracking detector at the EIC would detect displaced tau vertices from tau-decay and therefore lepton flavor violation. The detector response was modeled with the “LiC Detector Toy 2.0” package [3], originally developed for detector response studies at the International Linear Collider. I adapted the package for EIC studies by allowing events with varying number of tracks with Monte Carlo generated collision event parameters.

In this study, I used an all-silicon detector model, consisting of barrel layers surrounding the beamline complemented with disks orthogonal to the beamline. Combined, the barrel layers and disks can track particles over a wide range at polar angles between 5 and 175 degrees with respect to the beamline.

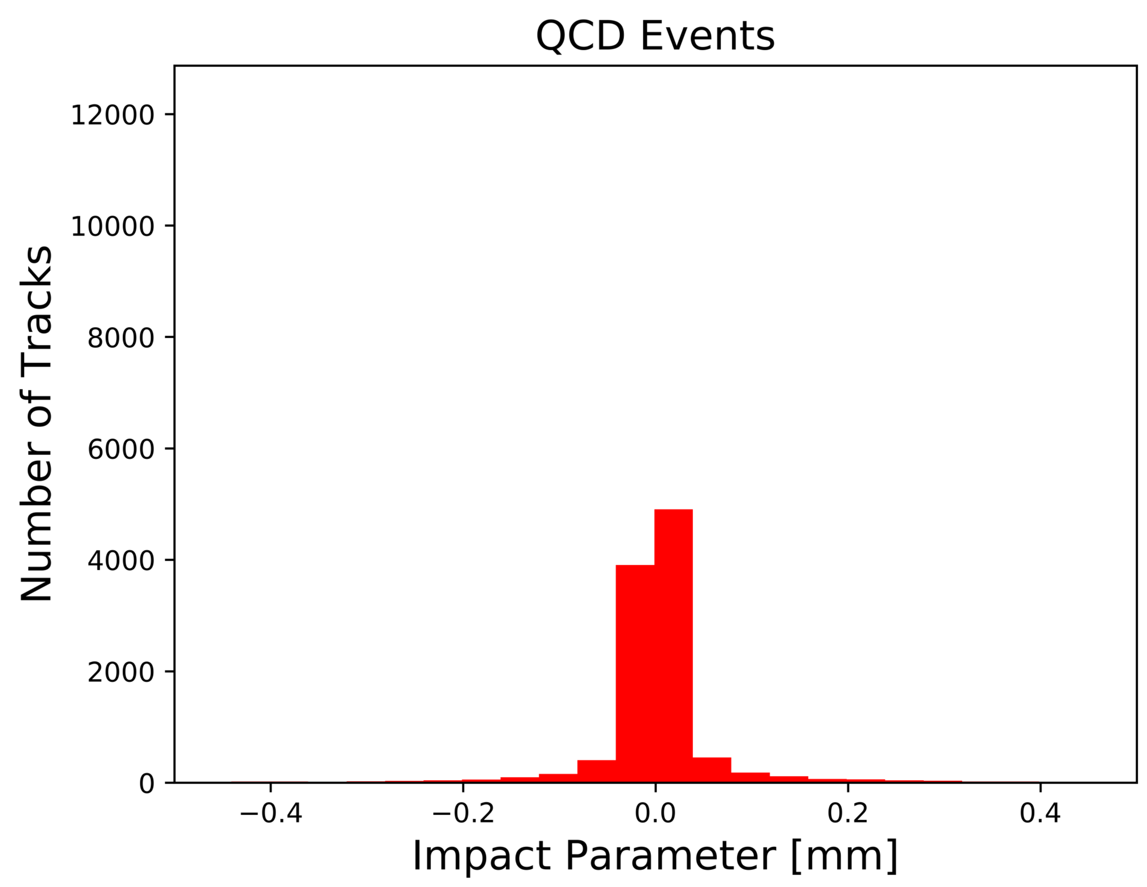


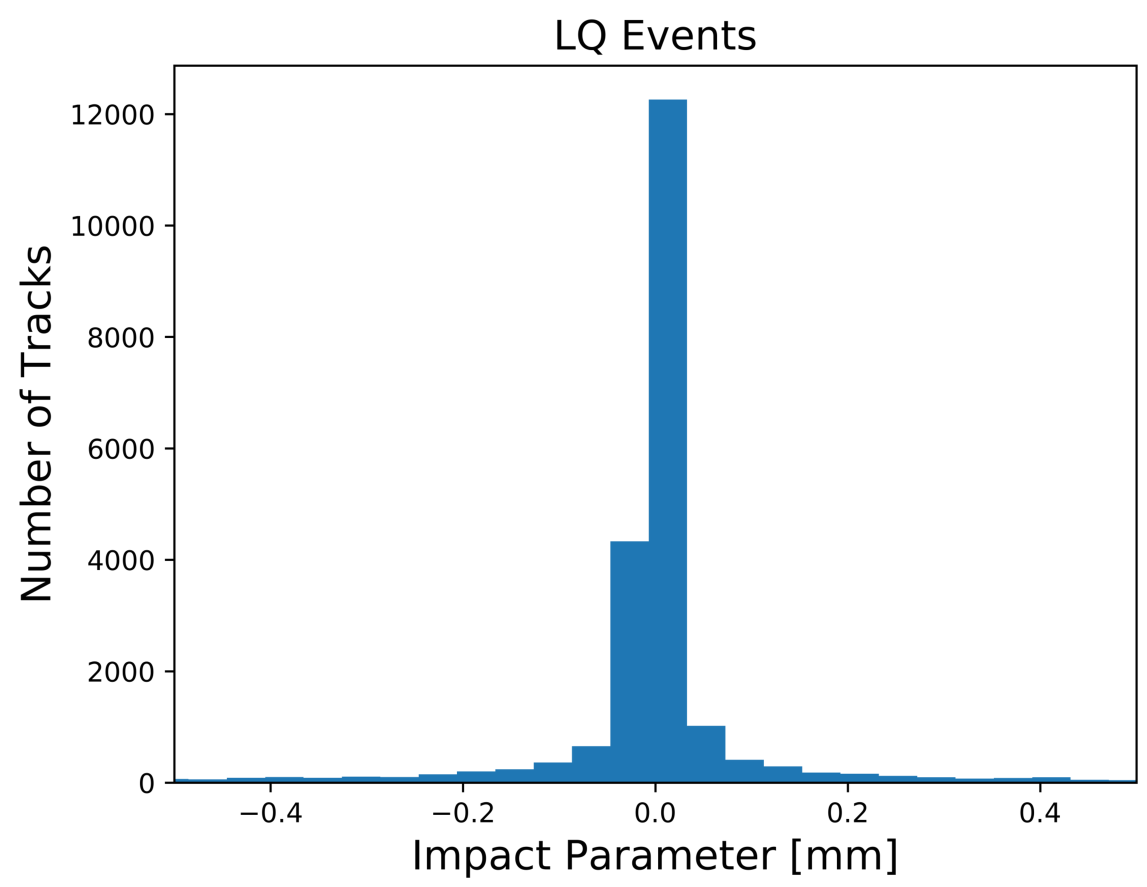
3D Model of Detector Configuration [3]

I used event generators LQGENEP [1], a leptoquark generator for electron-proton scattering, and PythiaeRHIC [2], a QCD event generator. In this simulation the electron beam energy is set to 20 Gev, the proton beam energy is set to 250 GeV and the assumed leptoquark mass is 100 GeV. In LQGENEP events the scattering yields a tau lepton that subsequently decays. The trajectories of the decay particles are displaced due to the tau lifetime and flight path.

Results

These histograms show the impact parameters from an equal sample of PythiaeRHIC events (left) and LQGENEP events (right). the vertex of each track is defined as the impact parameter between the track’s trajectory and the line (0,0,z) where z runs along the length of the detector.





Conclusions

- The single track impact parameter distributions have similar widths and tails but differ by a scale factor. The simulated LQ events from LQGENEP have a larger number of tracks per event than the QCD events. This characteristic may be used in discriminating such events.
- Future work could investigate if this can be used to suppress QCD backgrounds in search for new physics such as lepton flavor violation.
- The next step in this project is to extend the reconstruction from single-track impact parameters to the reconstruction of a true secondary vertex by combining tracks.

Acknowledgements

I would like to thank my advisor, Ernst Sichtermann for taking me on last summer as a research assistant at LBNL. I would also like to thank my Stony Brook mentor, Joanna Kiryluk who allowed me to continue my work at Berkeley from Stony Brook.

References

[1] L. Bellagamba (2001) LQGENEP [Fortran]. http://cpc.cs.qub.ac.uk/summaries/ADOY

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