Cosmic Ray Muon Data in the NOvA Far Detector

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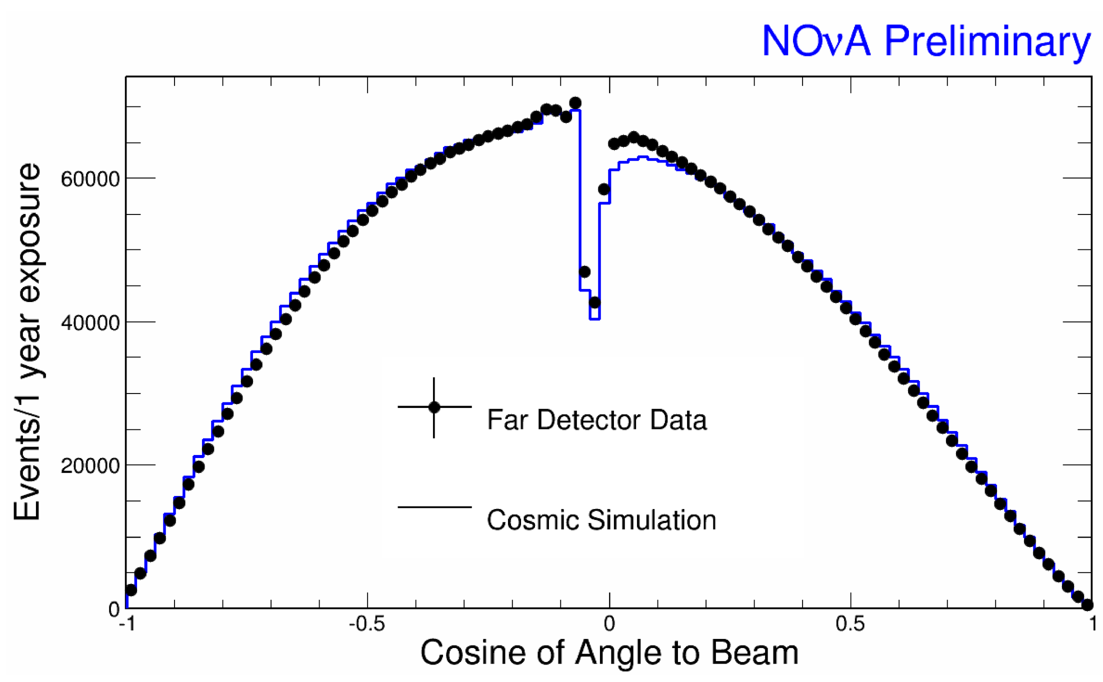
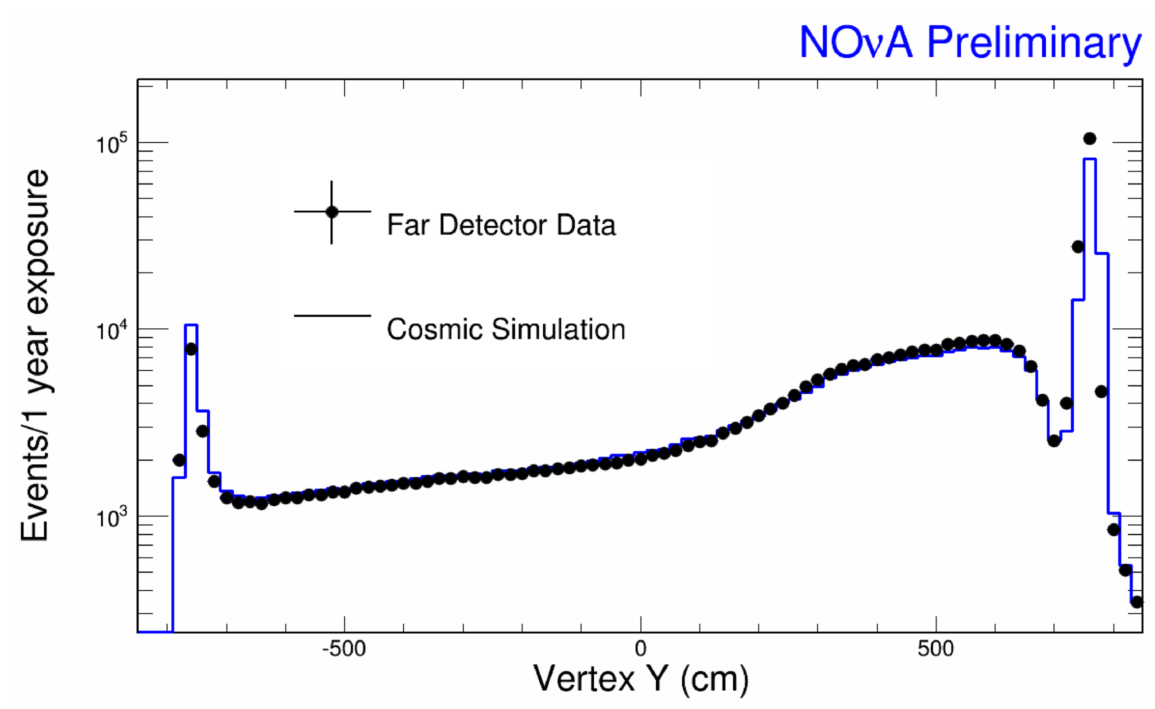
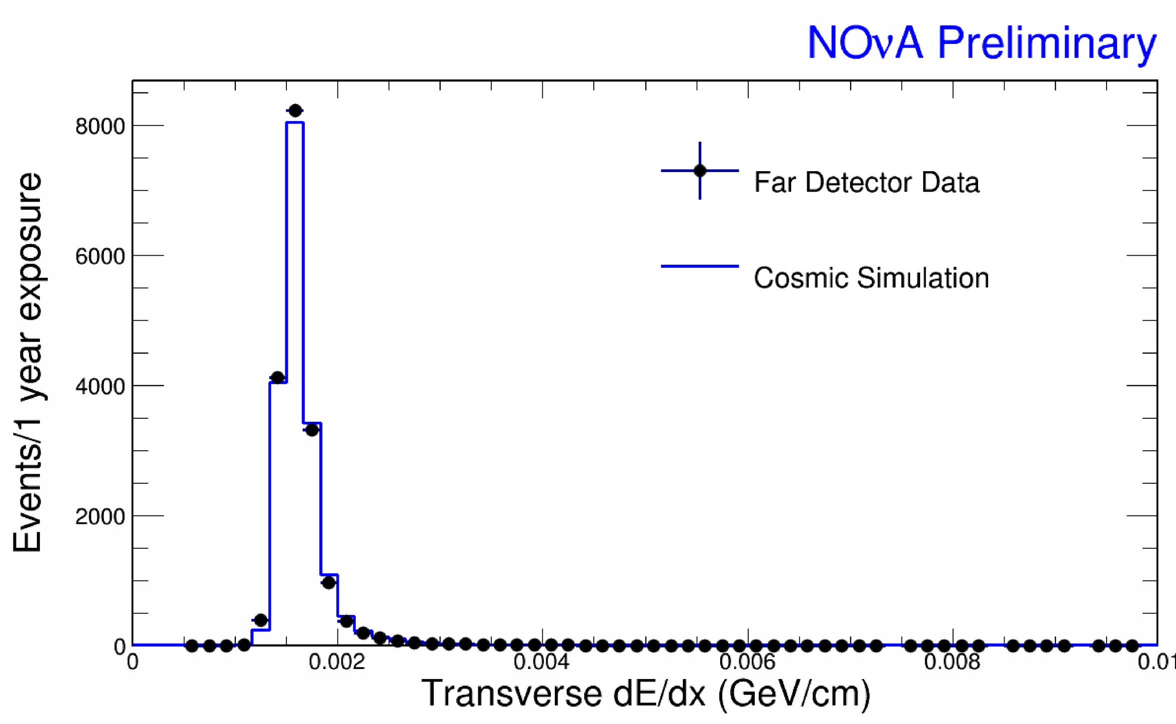
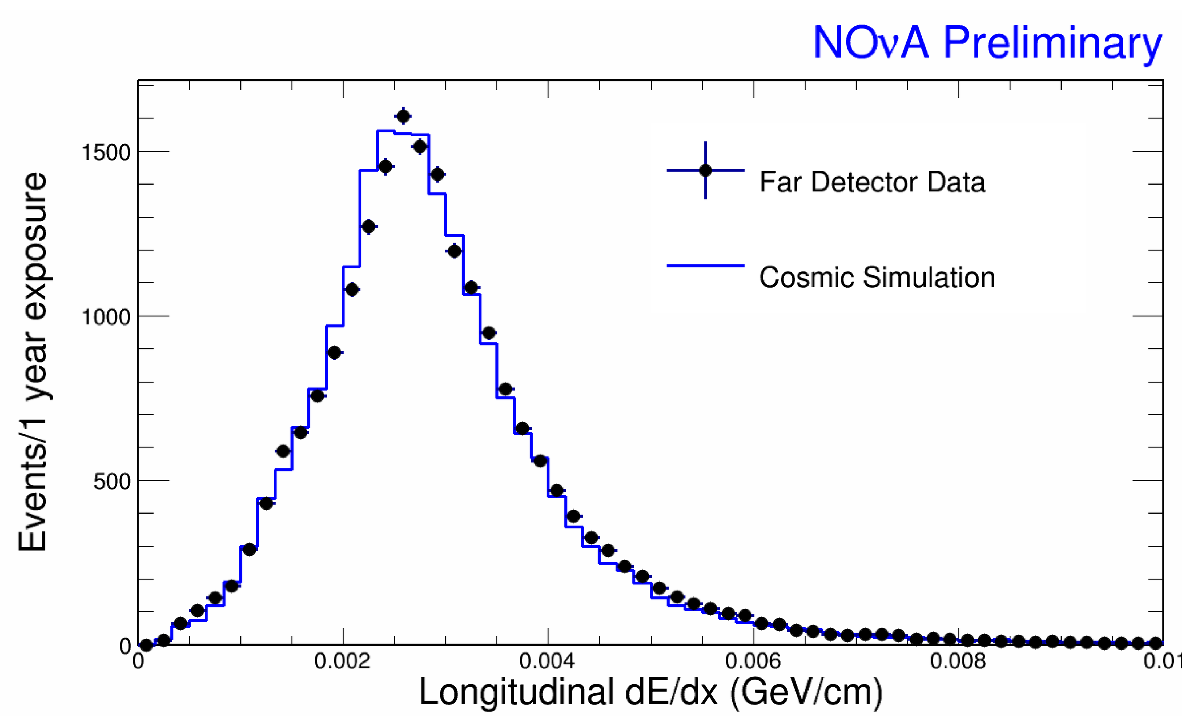
NOvA is a next generation long-baseline experiment optimized for the detection of $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillations. The Far Detector (FD) is located on the surface under 14 radiation lengths of barite and concrete overburden. Cosmic rays passing through the FD present a unique challenge in cosmic ray background rejection. We show cosmic ray data versus Monte Carlo from the NOvA FD 4 di-block partial configuration. The cosmic ray data represents approximately 30 minutes of livetime. We also demonstrate preliminary cosmic rejection levels in the signal region using these data.

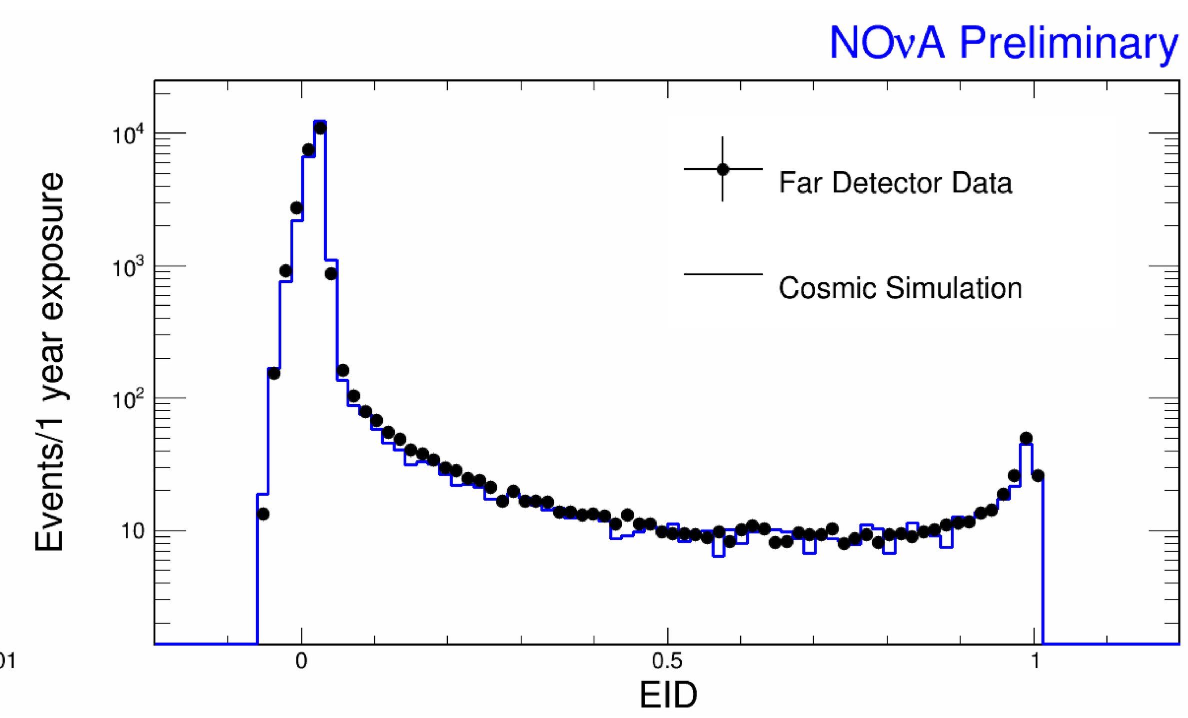


A comparison of cosmic ray muon data versus cosmic simulations using basic reconstructed quantities in a contained volume of the 4 di-block detector shows good agreement. Specifically we show the cosine of the angle of reconstructed tracks with respect to the beam direction (left) after track quality cuts and the reconstructed vertex position (right) in the Y coordinate for events more aligned with the beam direction and within a fiducial volume 80 cm from the top and 60 cm from all other walls.

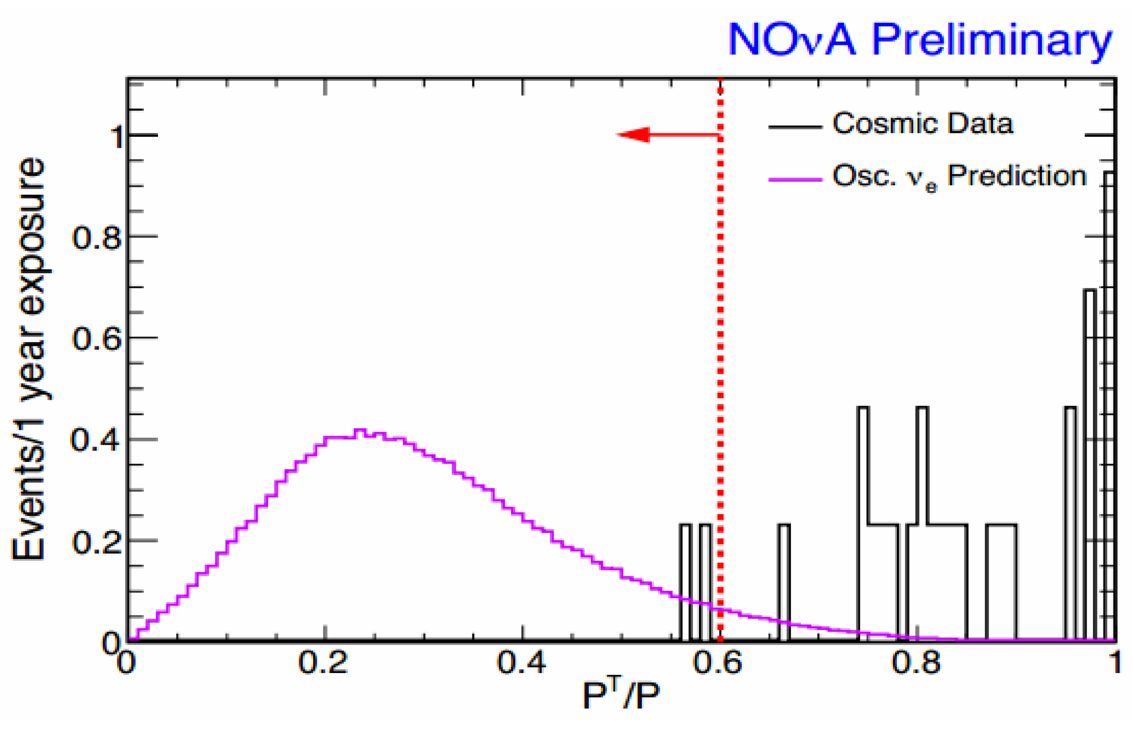






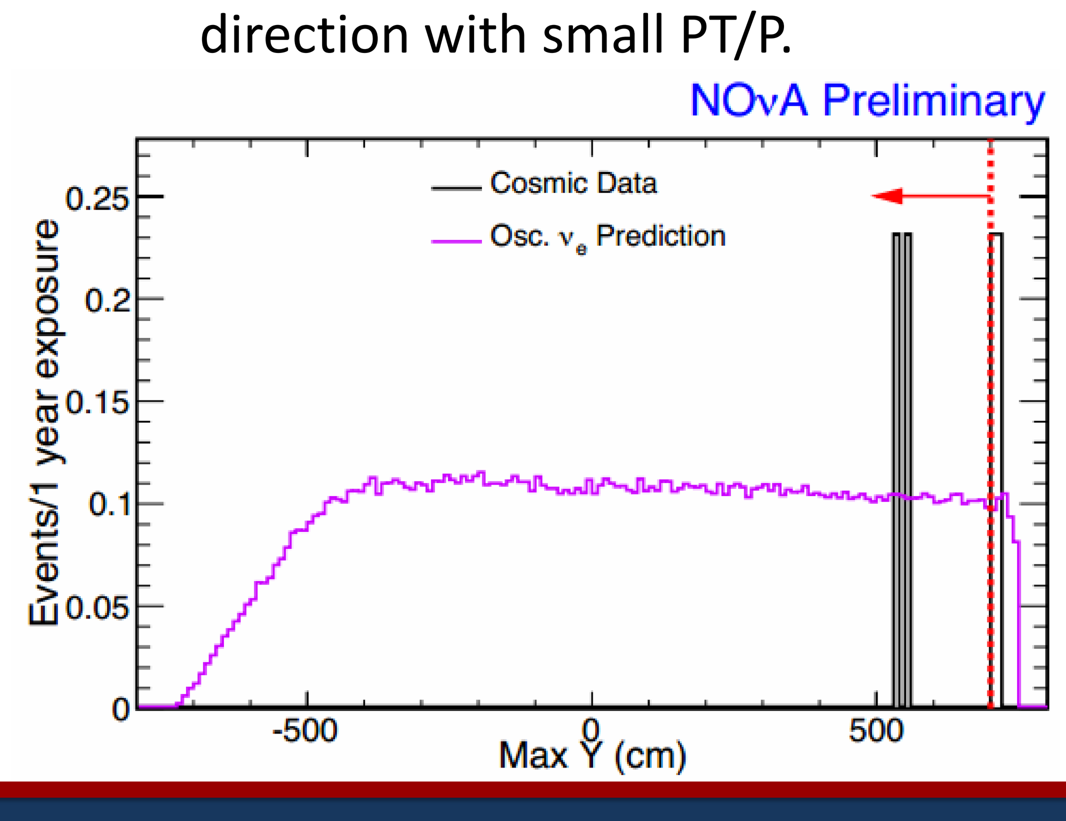


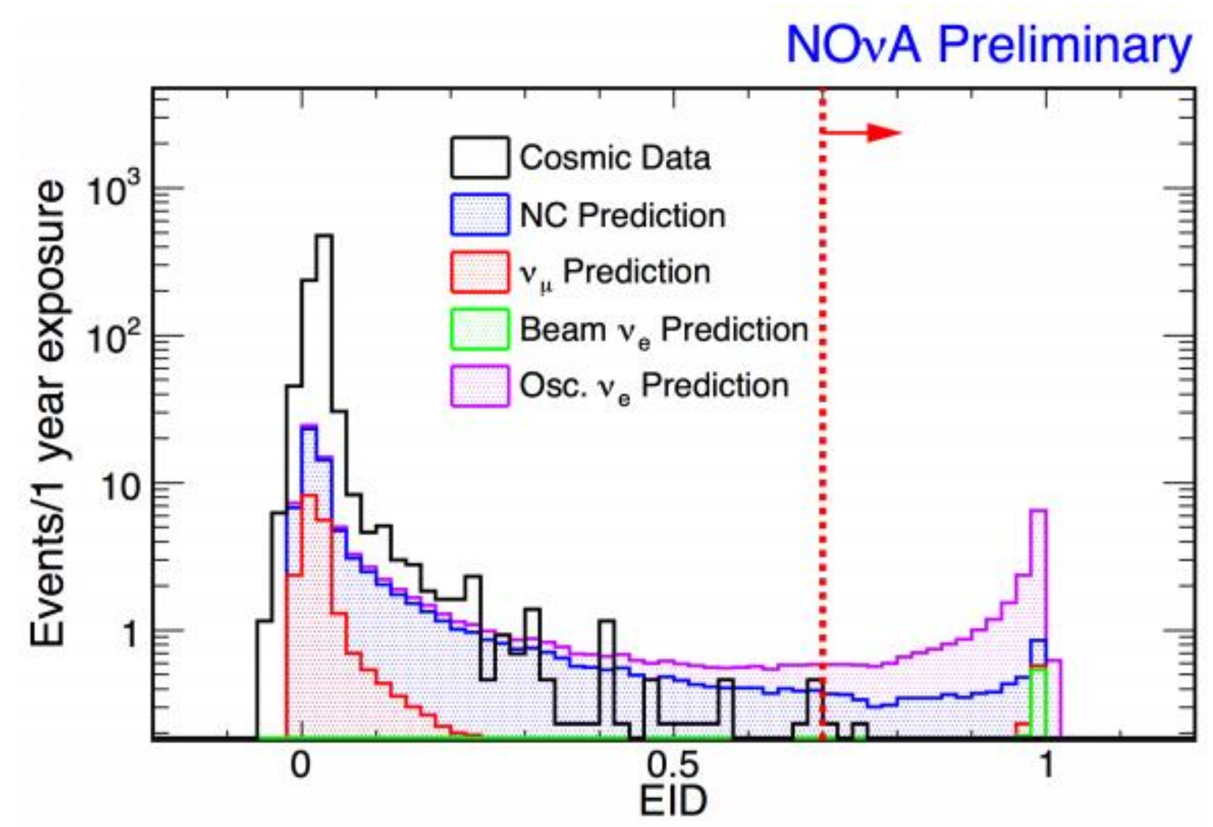
We have constructed several particle ID algorithms in order to discriminate ν_e CC events from other topologies, including cosmic rays. One of them, EID, is based on shower shape and likelihood comparisons to the confounding particles. We have benchmarked the bulk of the cosmic ray data aligned with the beam direction for these variables. Transverse dE/dX (left) is the average of total prong energy in a cell per total path length; the longitudinal dE/dX (middle), calculated plane-by-plane (first plane shown), is the total prong energy in the plane per the path length in the plane. The ν_e particle identification discriminating variable (EID) constructed from these and other shape variables is also shown (right). Events in the signal region can easily be rejected mainly with basic cuts related to steepness and distance from the top of the detector.



Applying signal-like pre-selection cuts based on data quality, energy and containment, a basic set of cosmic rejection cuts are defined, and applied to the cosmic ray sample in the 4 di-block FD. We show this sample after a cut on EID with the very few data events that pass the combined set of cuts together with the signal simulation. The ratio of event transverse momentum(PT) by event total momentum (P) (left) rejects the predominantly vertical cosmic rays with large PT/P and retains the neutrinos that go along the beam direction with small PT/P.

The Max Y distribution (right) is a measure of the larger value of the start and stop Y position of the most energetic shower thus rejects entering cosmic background close to the top of the FD. We also cut on the distance (gap) between the vertex and start point of the shower to remove misreconstructed events that can confuse the PID.





	Osc. ν_eCC	Beam Bkgd	Cosmic Bkgd
No cut	36.7	965	1.91e7
Containment & quality	24.5	114.3	55055
Cosmic rejection	21.1	82.7	843.1
ν_e selection	13.8	5.9	0.5

Using 3 basic cosmic rejection cuts we achieve excellent cosmic background rejection with 0.5 cosmic background events in one year of nominal neutrino running time of NOvA. The events that passed these cuts are mostly short, neutron-like events that are closer to the top of the detector. The figure of merit (signal/sqrt(signal+background)) for 1 year of optimal running is 3.1 after these cuts.

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