Outside-In Tracking Ideas

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7/29/11

- This talk will be very simple, possibly even naïve, and reasonably short.
- Bad news: I will write no code based on the ideas I talk about.
- Good news: I will write no code based on the ideas I talk about.

The obvious

- Much of the raison d'être of a LArTPC involves an accurate characterization of event activity (i.e. short, sometimes highly ionizing tracks) around the vertex.
- The problem: we don't find these tracks well enough with what we got.

Outside-In Tracking

- Complications:
  - The vertex region is cluttered with lots of hits. The clustering gets confused.
  - Hits overlap frequently near the vertex, and the most highly ionizing contribution (typically from the shortest track) wins.
  - The line finding and cluster finding algorithms are "geometric": they ignore known physics effects like multiple Coulomb scattering (MCS) and energy loss.
- Idea: simplify by looking "outside" the vertex region first. Then work your way back "in" taking into account MCS.

Some observations

- Our code finds long tracks with high efficiency.
- If we stick to the “downstream” part of the track, we make few mistakes (modulo delta rays).
- We have a package, Kalman, that can be used to test whether a set of hits belongs to a track, consistent with the intrinsic resolution, MCS, and dE/dx (physics, not geometry!).

Demystifying Kalman

- Hit positions depend on the underlying trajectory (what we want), intrinsic resolution (from e.g. wire pitch, diffusion, drift speed variations, electronics), and MCS.
- The MCS contribution is complicated. A scatter before wire N affects all downstream wires with n>N (correlating the measurement errors); plus the amount of scatter depends on p.
- The Kalman filter technique is a fast numerical method that incorporates the physics of intrinsic resolution and MCS into track fitting without having to deal with a big correlated error matrix among all the hits. It allows hits to be efficiently added to a track one at a time.
- It is very widely used in the collider world and elsewhere.
- If the track is long enough, Kalman can provide a decent p estimate.

Let the long tracks rule

- For each view, use the 50%(a guess) most downstream hits on the longest track found by the existing 2D tracker.
- Use Kalman to back-propagate the track and iteratively add upstream hits along the track consistent with MCS.
- Once this process finishes, take the track's hits out of the event.
- Re-run the 2D tracker chain with the reduced hit list. Find the longest remaining track, and repeat until no more tracks are found.
- Match the 2D track candidates.

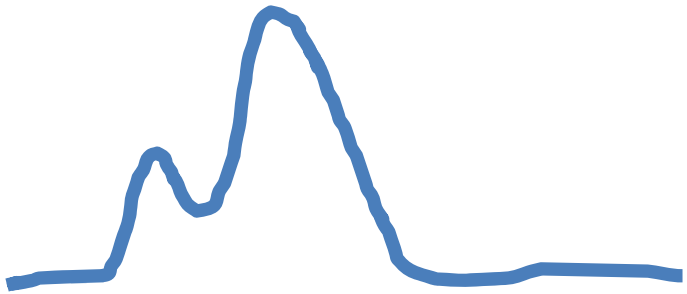
Hopes

- We pick up all the hits on the long tracks near the vertex, giving us better vertexing.
- We de-clutter the vertex region by removing the hits from the long tracks, thus reducing the confusion for the track finding on the remaining short tracks.
- We use a more physical (less geometrical) procedure to assign hits to tracks.

Hit finding

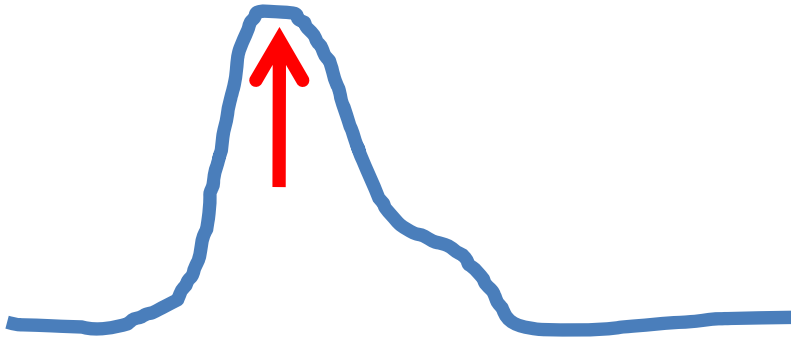
- Our preliminary studies indicate we may need to be more aggressive with hit finding around the vertex.
- In this scheme, we use long tracks as an enforcer: anything that looks like it belongs to the trajectory of a long track gets put on that track.

Overlapping Hits-- I



- Brian's studies indicate that this pattern (with a dip) reliably indicates two overlapping hits. Noise rarely mimics the signal.
- But the amplitudes can be misleading. The left "MIP" signal can be the "higher quality" hit; i.e., the one we can unambiguously put it on a long track as it extrapolates back to the vertex.

Overlapping Hits-- II

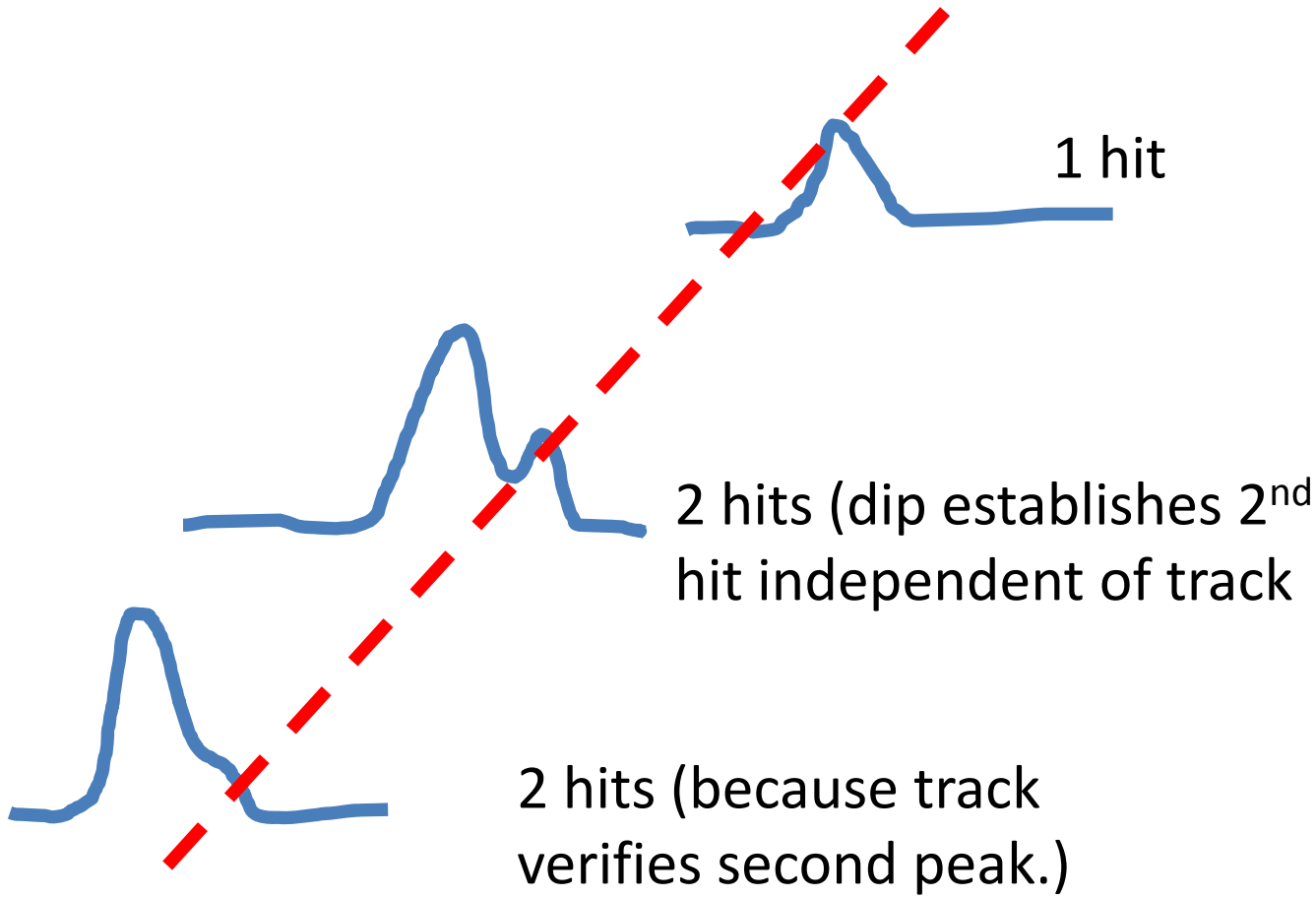


- Brian's studies indicate that this pattern cannot be reliably assumed to be two hits.
- This counts as a single hit, with the time assigned to the position of the maximum (red arrow).
- This algorithm causes long track hits to be lost near the vertex.
- If the buried second peak aligns with a back-propagated muon track, it may be the higher quality hit.

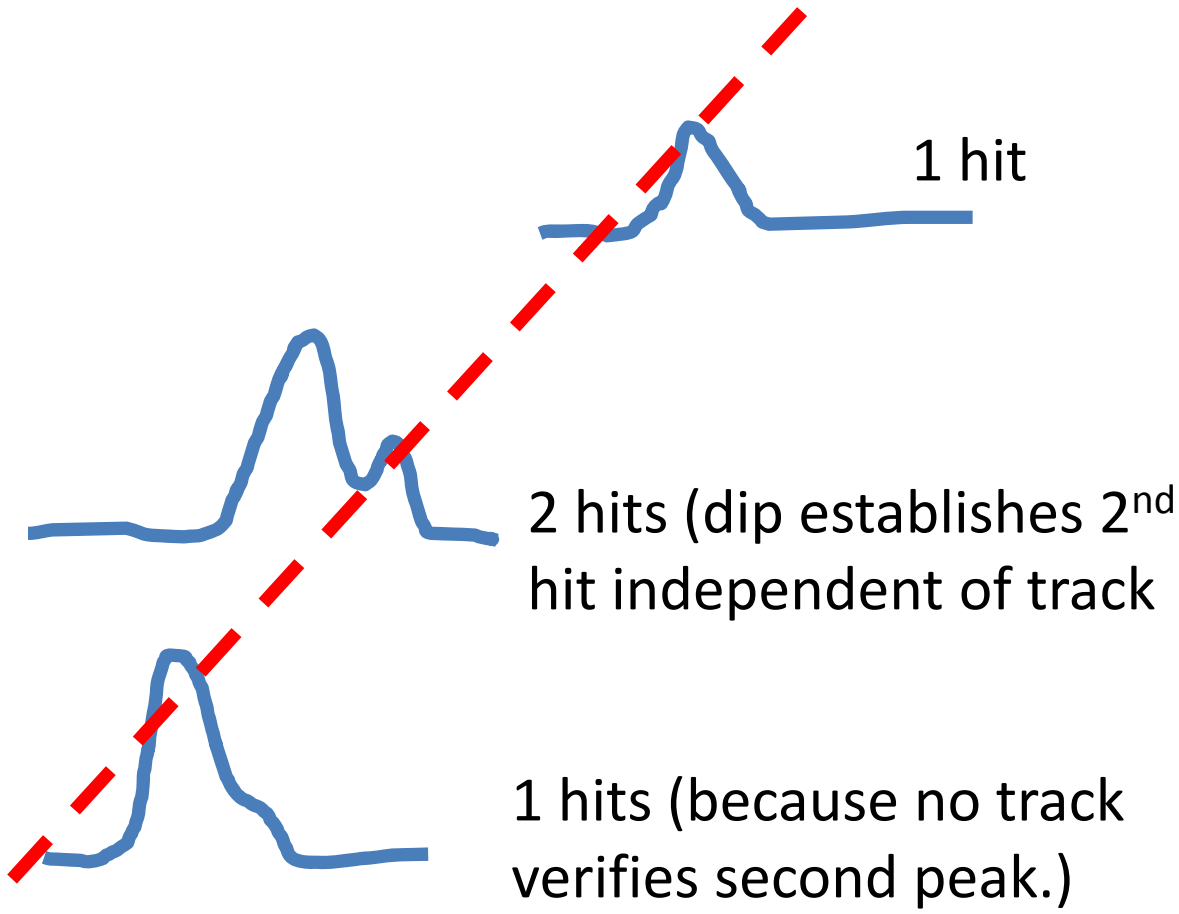
Queries

- Can we always fit to two peaks, even when a dip does not exist?
- We could then use the “shoulder peaks” if a long track back-propagates to its location.
- Can we create revised hit lists.
  - Assume apriori that single peaks hits == 1 hit
  - But save information from a 2-peak fit.
  - If a long track back-propagates to a 1 peak hit to a position consistent with that of its 2nd peak in the fit, split the hit in two.

Cartoon depiction



Cartoon depiction-- 2



Plans

- “We” (Saima) will explore the outside-in idea. Saima’s analysis topic needs good tracking around the vertex.