Signal simulation in LArSoft using point sources

(also called, regrettably, “2D”)

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LArSoft Coordination Meeting

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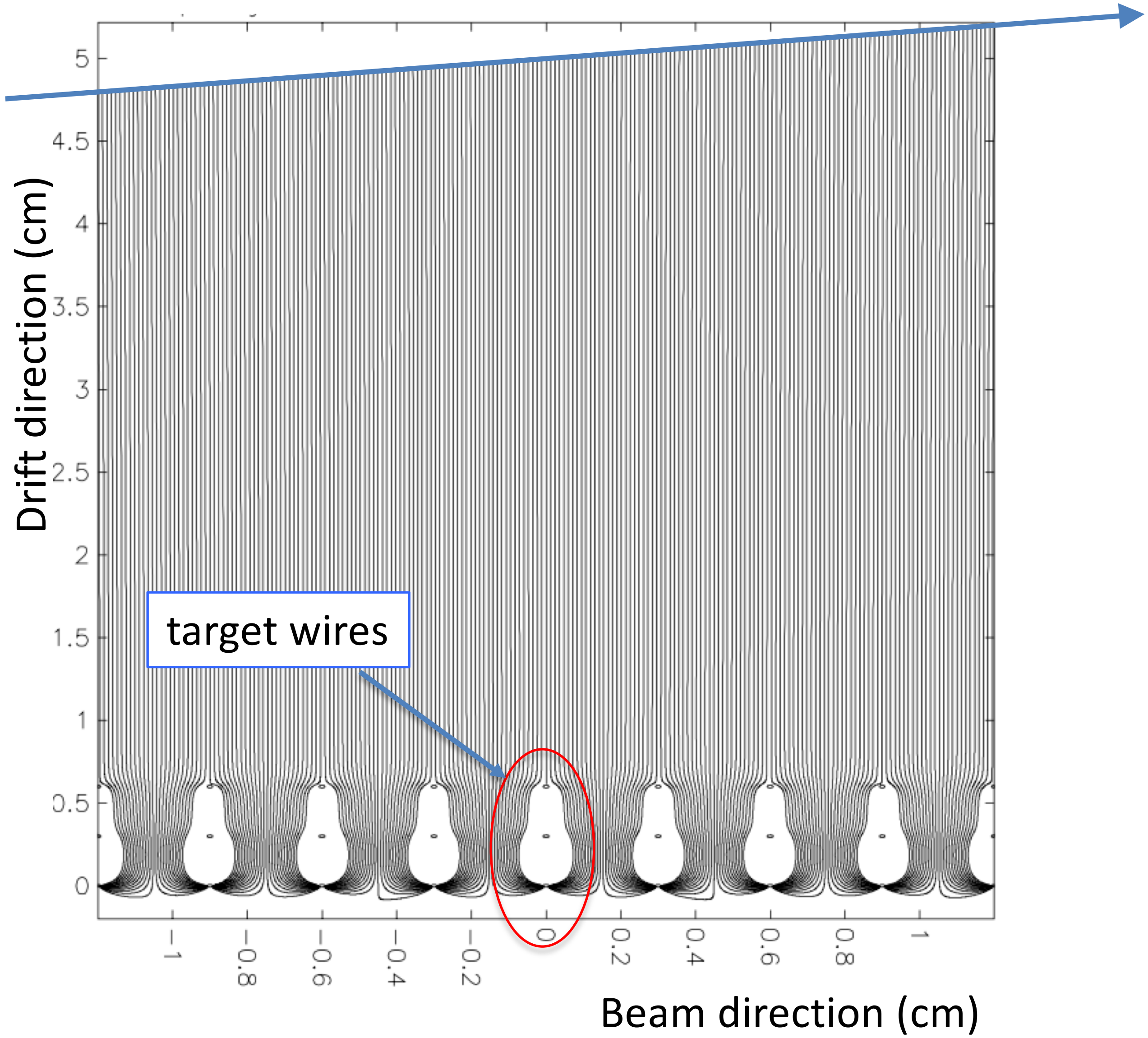
What we have now: "1D"* simulation



The current simulation uses responses averaged over a cell, generated by a track at a small fixed angle.

Responses are reported on the "target" wires.

"2D Garfield": Wires are all parallel (⊥ to the picture plane) and equally spaced.

"1D " refers to response with respect to time only, ignoring the dynamic effects on adjacent wires (space).

But.. the underlying geometric model is "2D" (Sorry…)

What’s missing

- The generating track is uniform in charge deposition, is at a fixed angle, and is essentially infinite. The resulting response functions:
  - don’t handle the ends of real tracks correctly.
  - don’t account for non-uniform charge deposition along the track.
  - are incorrect for tracks at angles (in the y/z plane) different from the one used to generate the response, especially for tracks at large angles.
  - are completely wrong for drift electrons generated inside or behind the anode. Apparently we currently simply ignore these in the simulation.

Refinement: “2D” simulation

Simulate the charge distribution more accurately by treating each cluster of electrons as generating the response to a point source, not to a generic track. Keep track of the response to each source on the “target” wire and an appropriate number of adjacent wires.

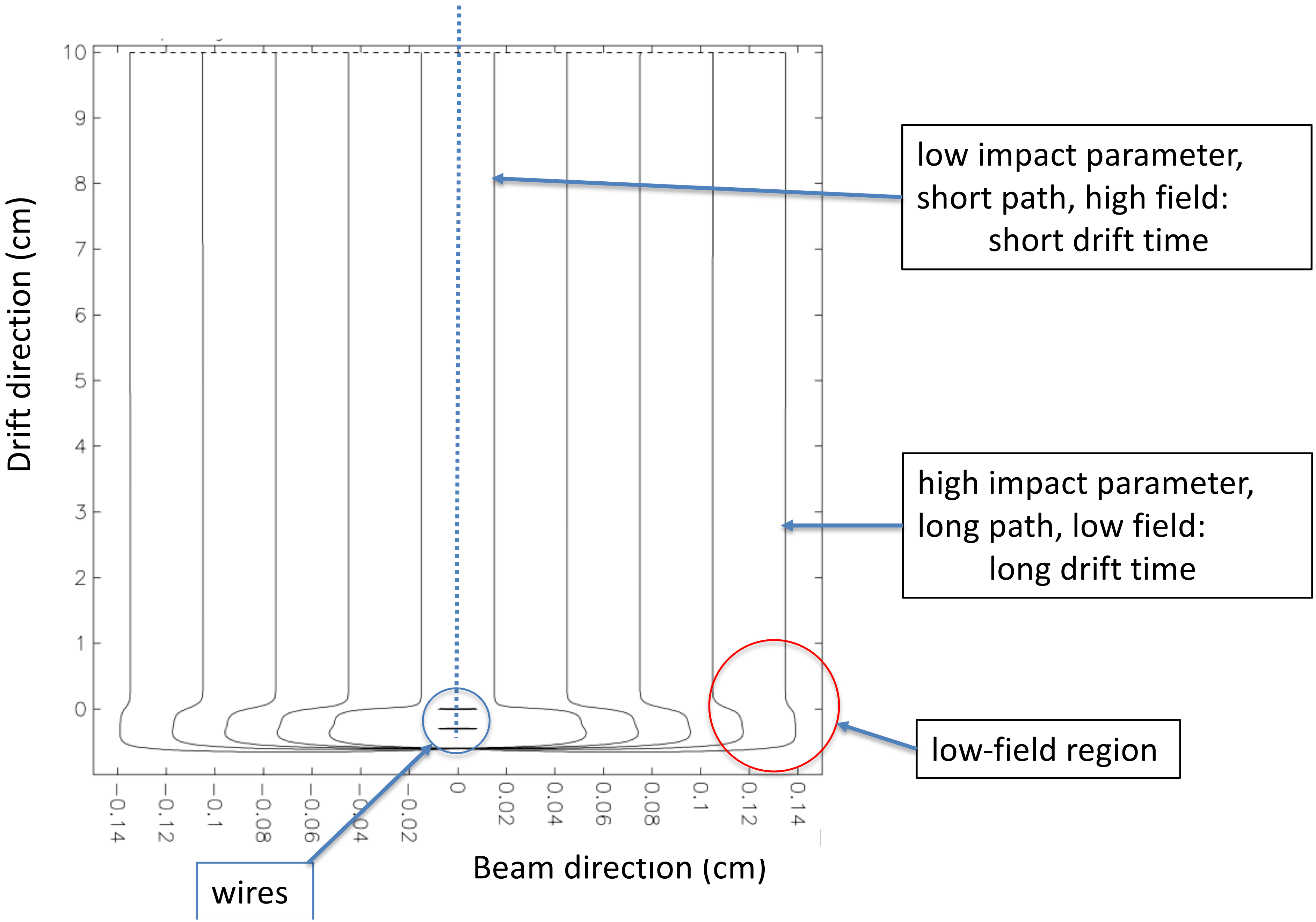
So each track will be modeled by a set of “points” (currently one per GEANT step), each of which invokes a response on the target wire and adjacent wires. The actual response is just the sum of all the point responses.

There are several ways to go about this. We started with this one because it seemed straight-forward.

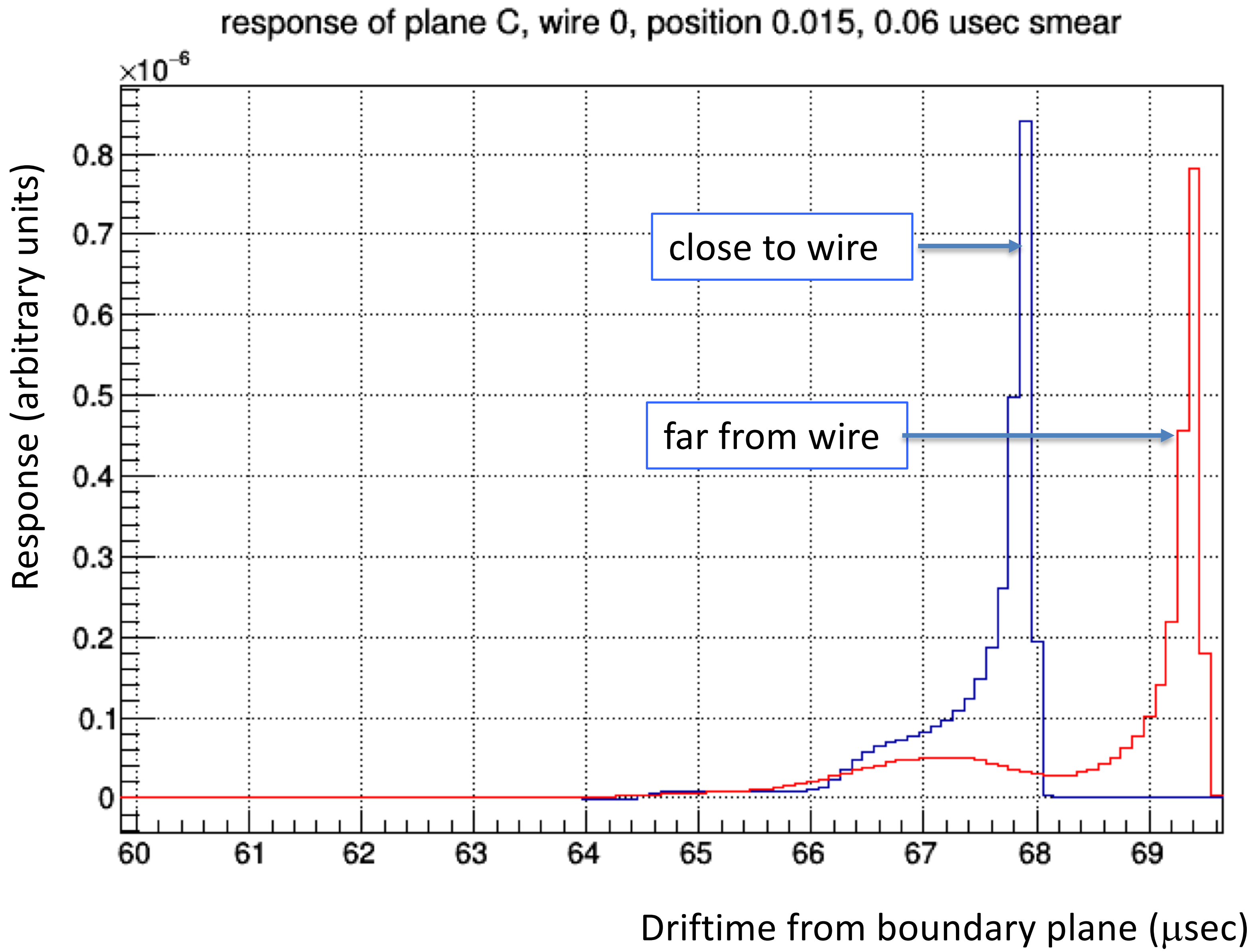
The strategy

- We divide the drift volume in two parts, separated by a plane at constant distance from the anode (10 cm for now):
  - The bulk, with constant uniform field and therefore constant drift velocity. We choose the boundary plane so that charge drifting in this region produces negligible response.
  - The region near and within the anode.
- In the first region, the drift time is simply the drift distance to the plane divided by the drift velocity.
- In the second region, we develop a library of point source responses, and choose the one to use for each point on the track, based on the initial impact parameter of the drift line with respect to the target wire. The responses provide the charge deposited as a function of drift time from the boundary plane.
- The recorded response function is the one from the point source, shifted in time by the drift time in the bulk.

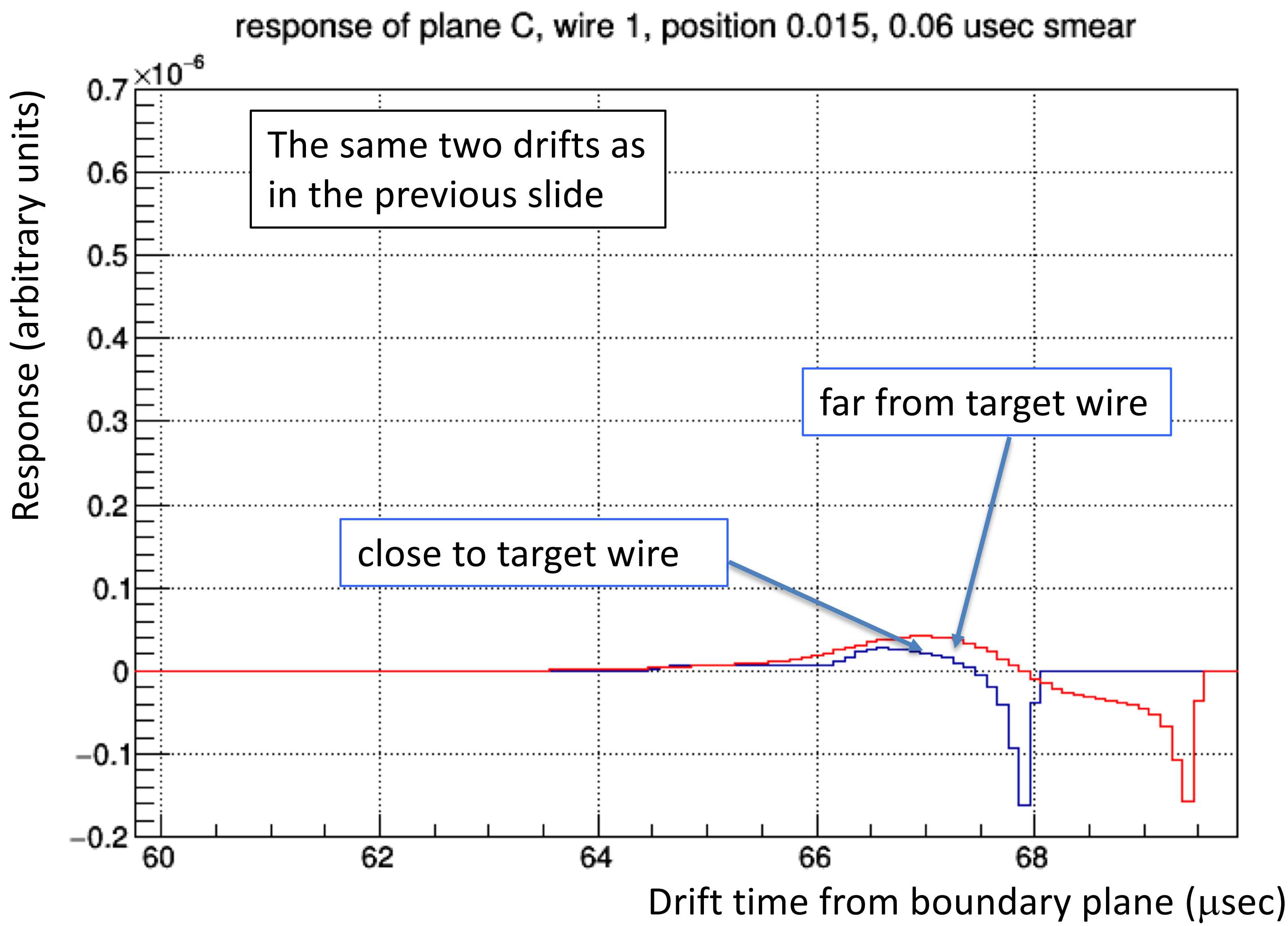
Ten drift paths in a cell



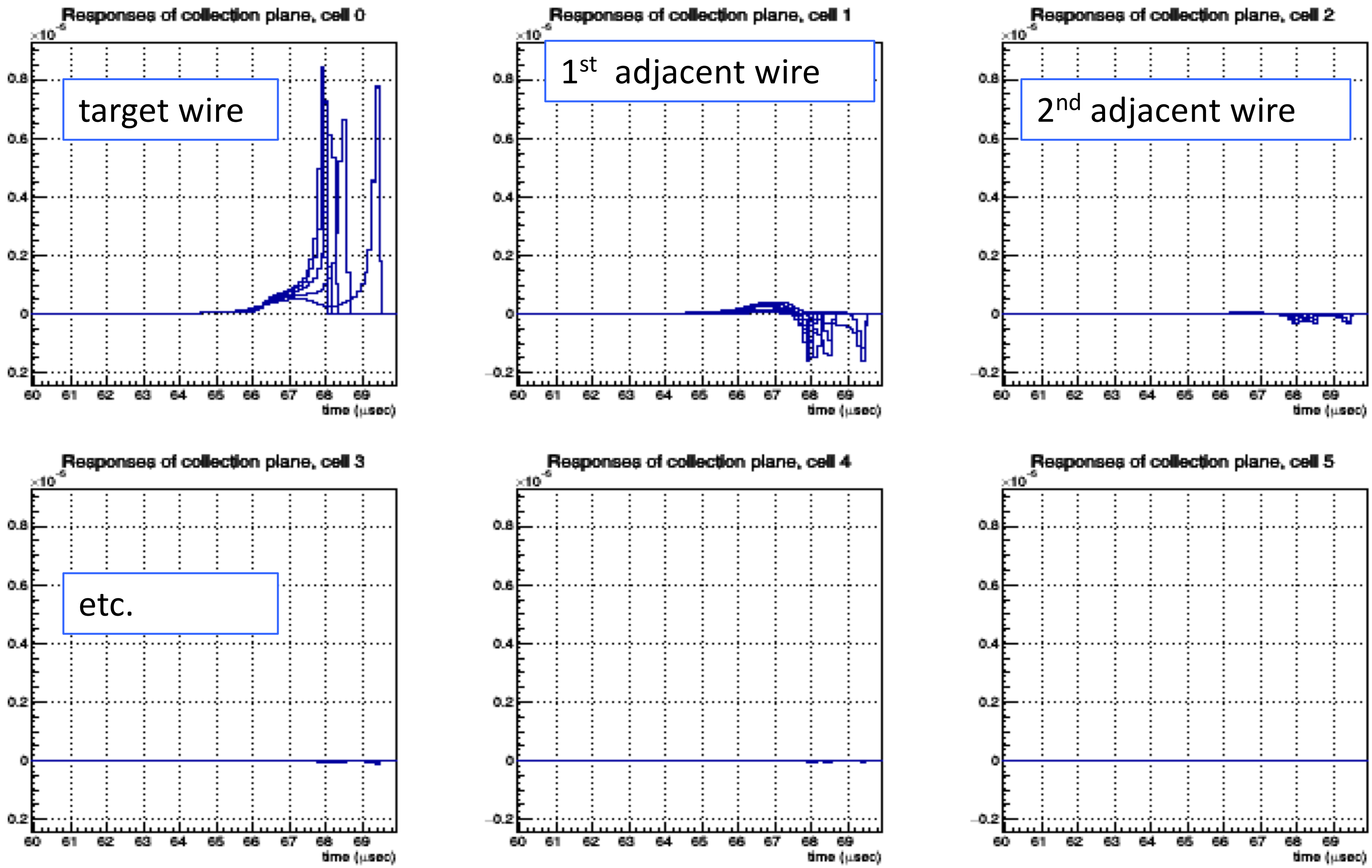
Example responses (target wire)



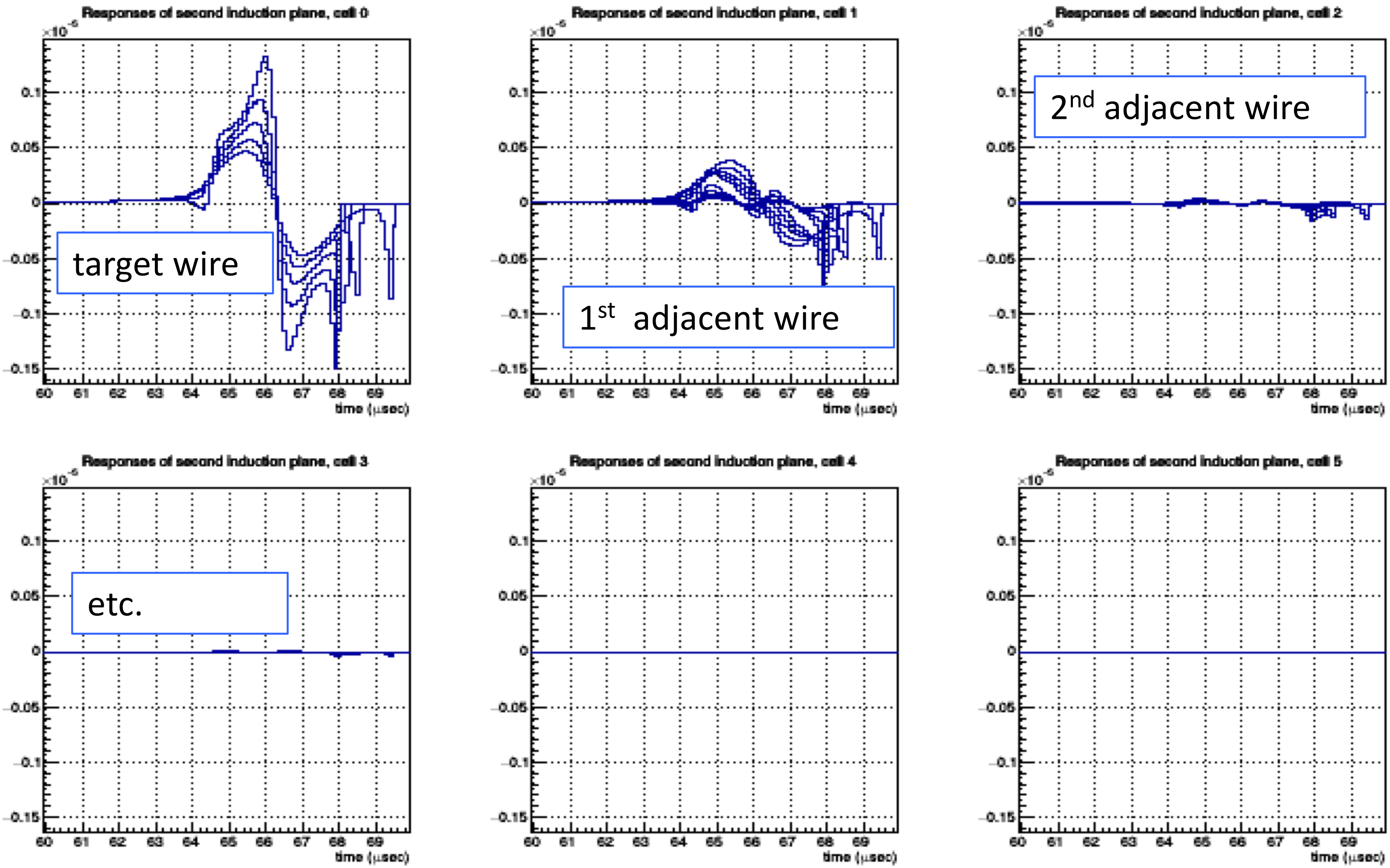
Example responses (adjacent wire)



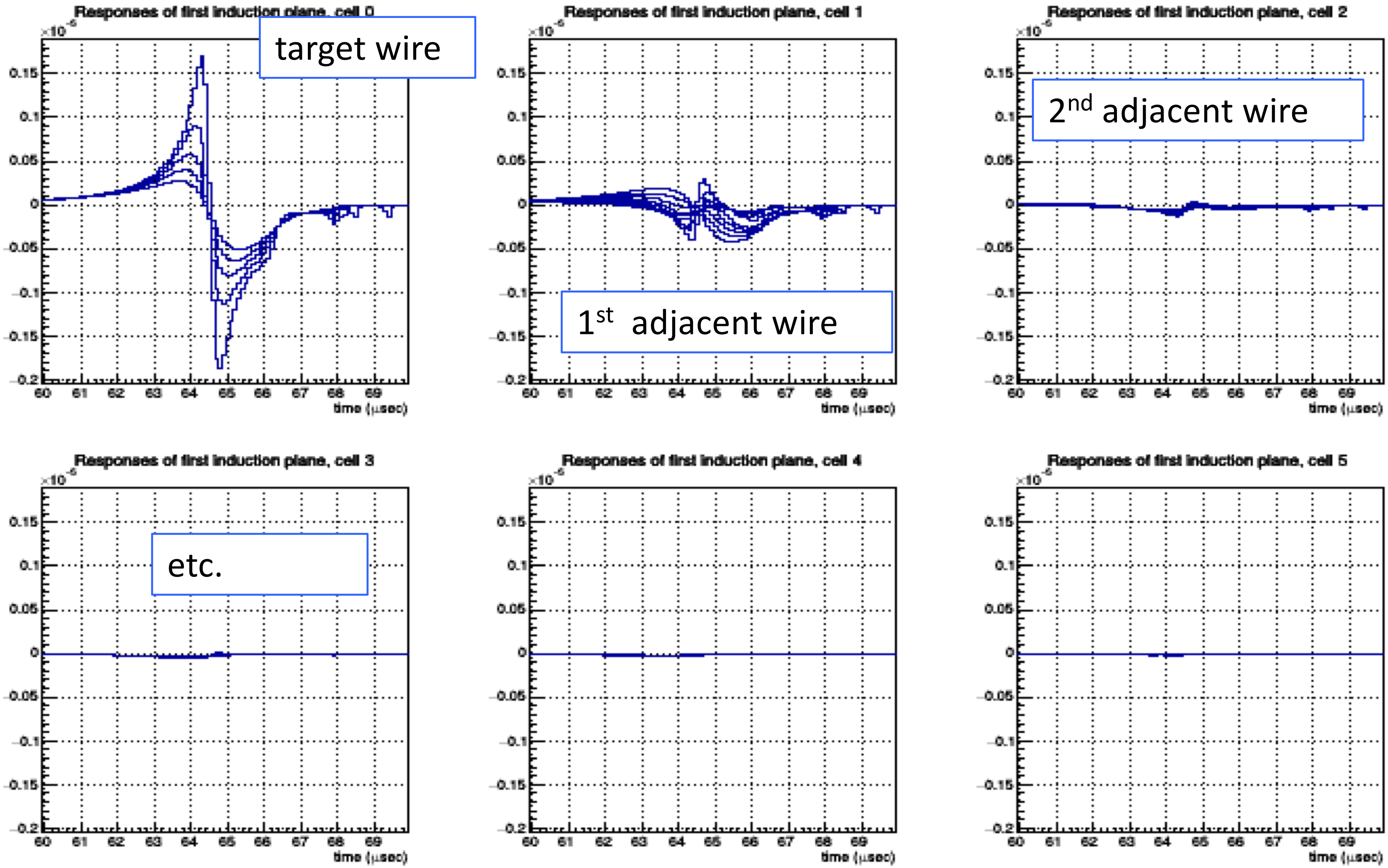
Full set of responses, collection plane



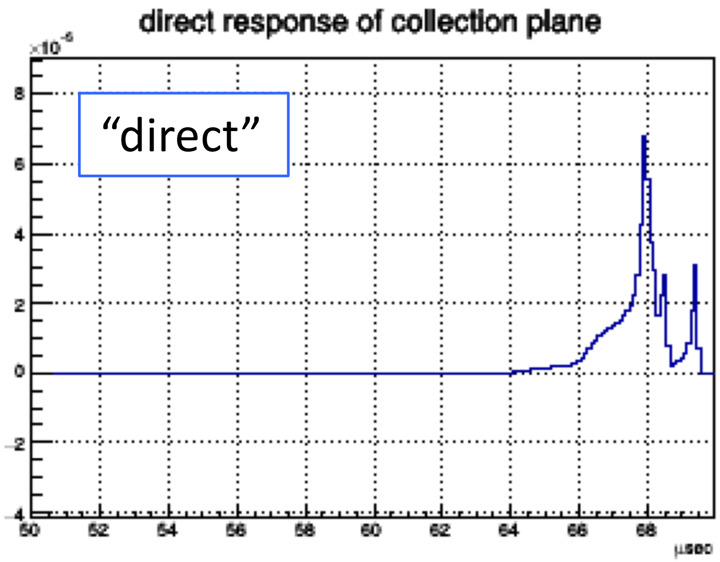
Full set of responses, 2nd induction plane

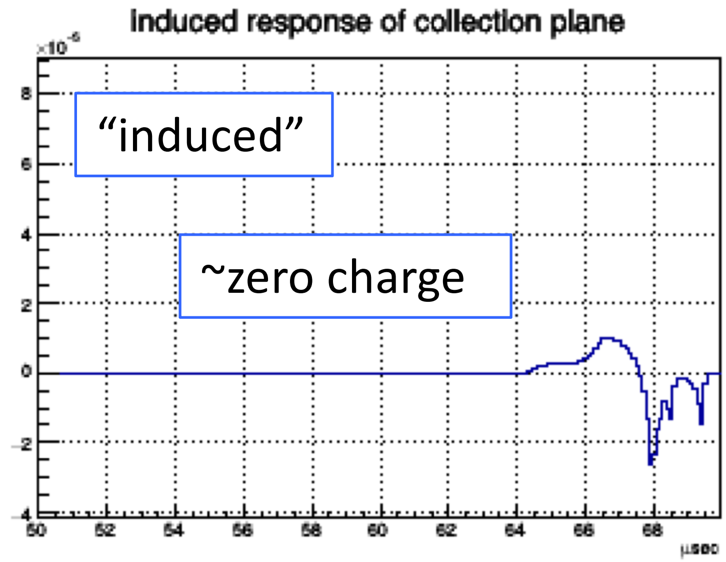


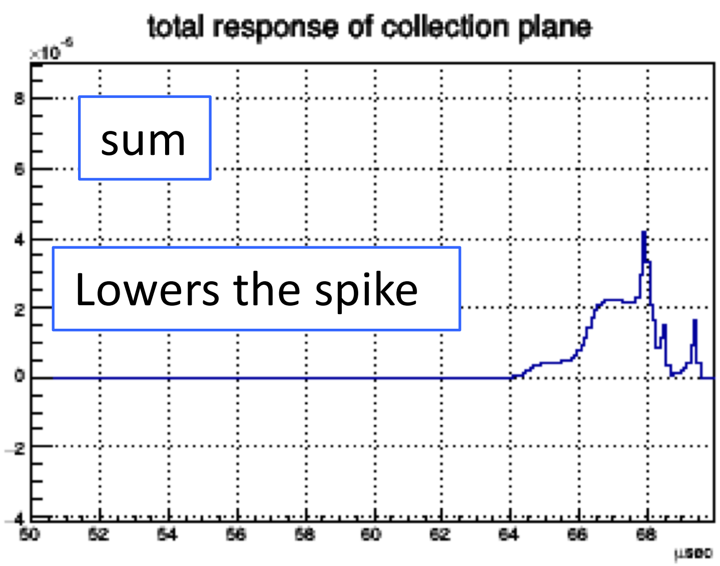
Full set of responses, 1st induction plane

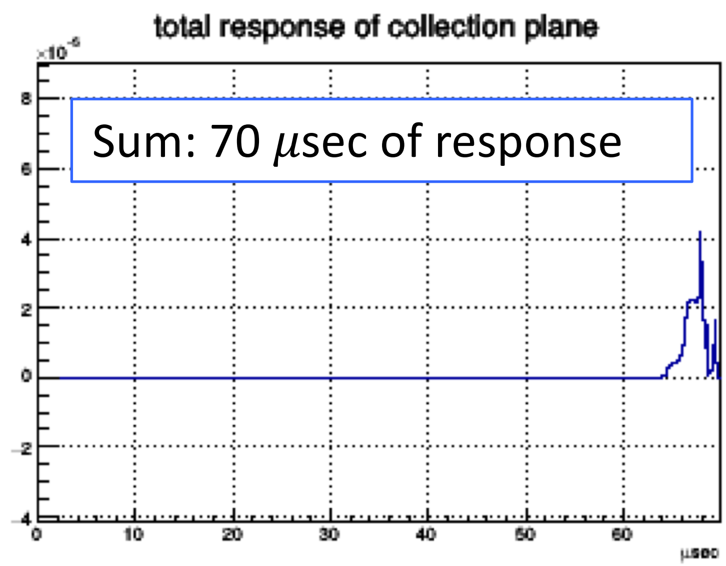


Full response of collection plane wire to 0° track



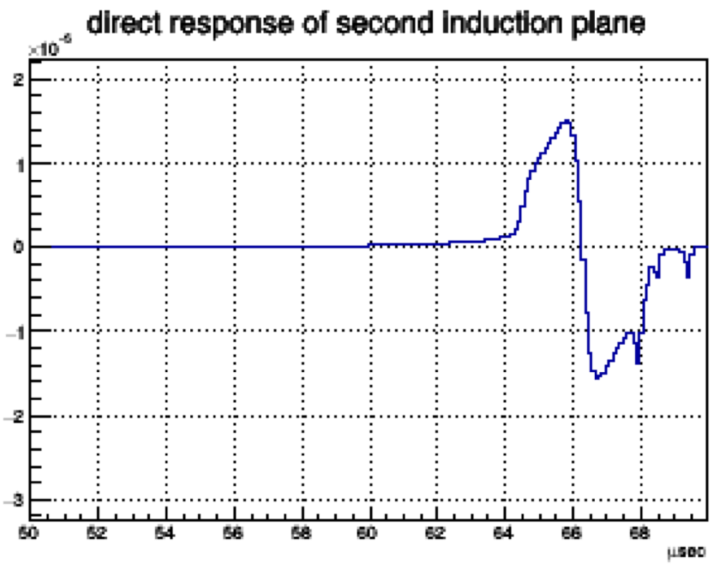


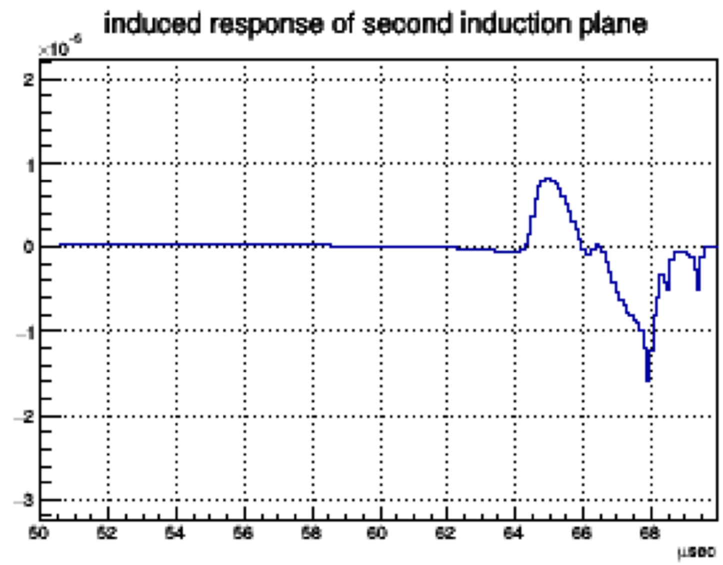


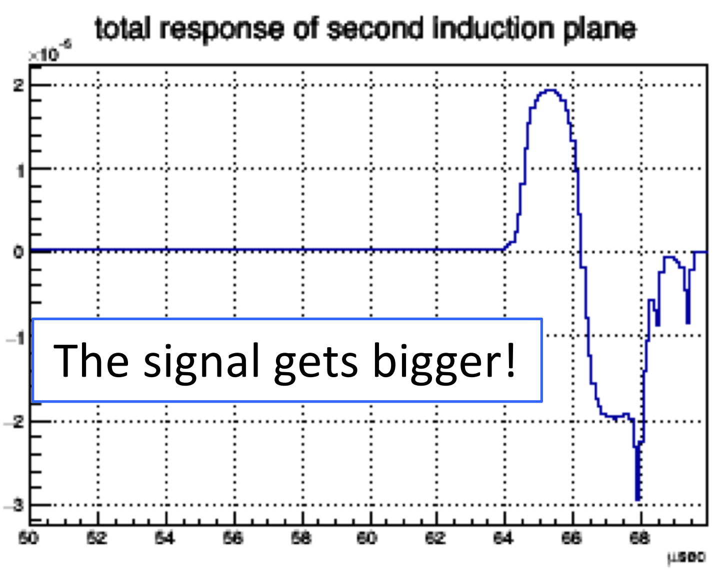


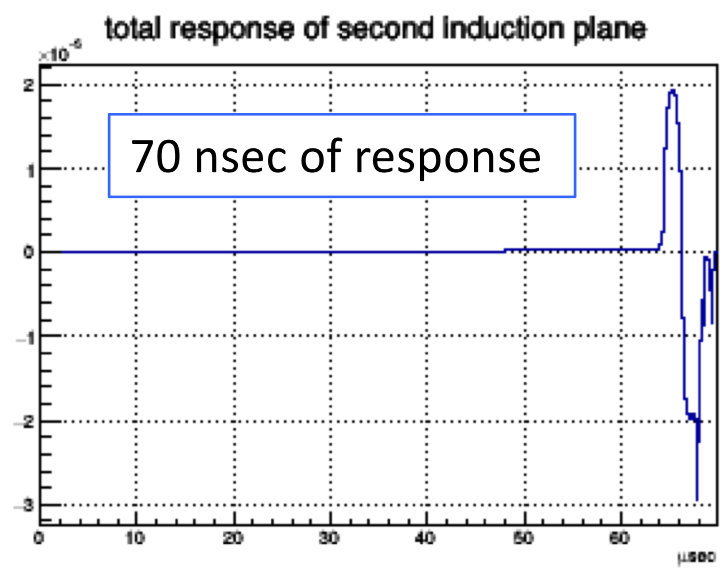
"Direct" is also induced, but by paths that end in the target cell.

Full response of 2nd induction plane wire to 0° track

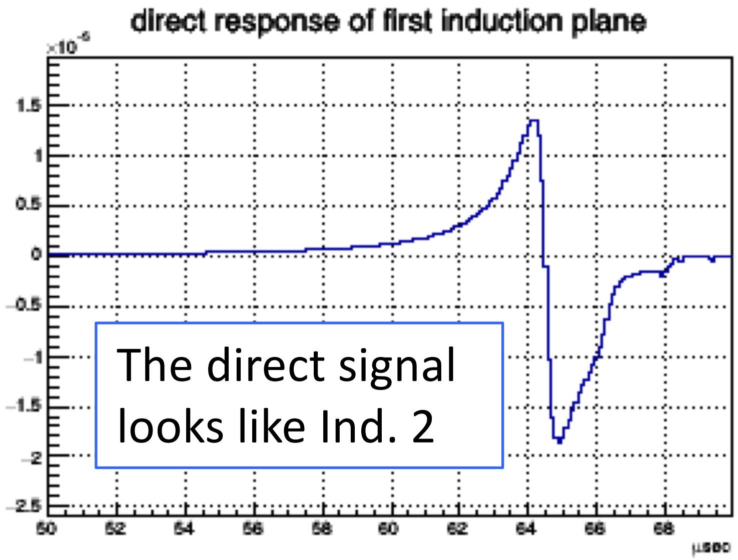


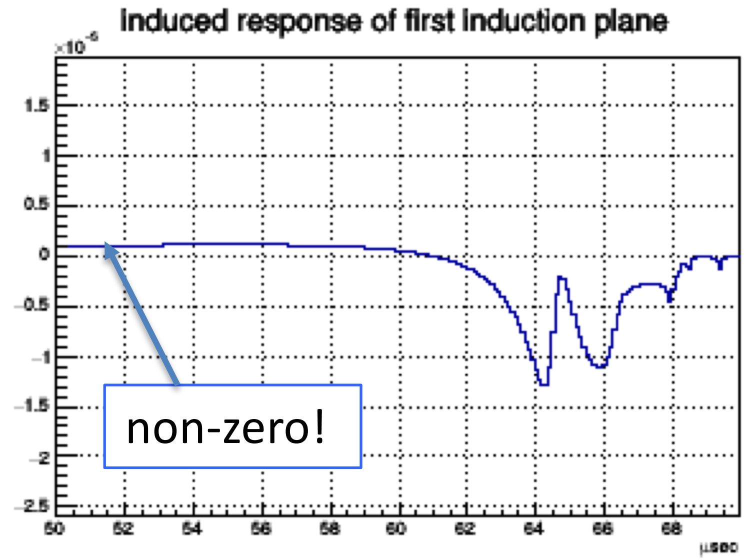


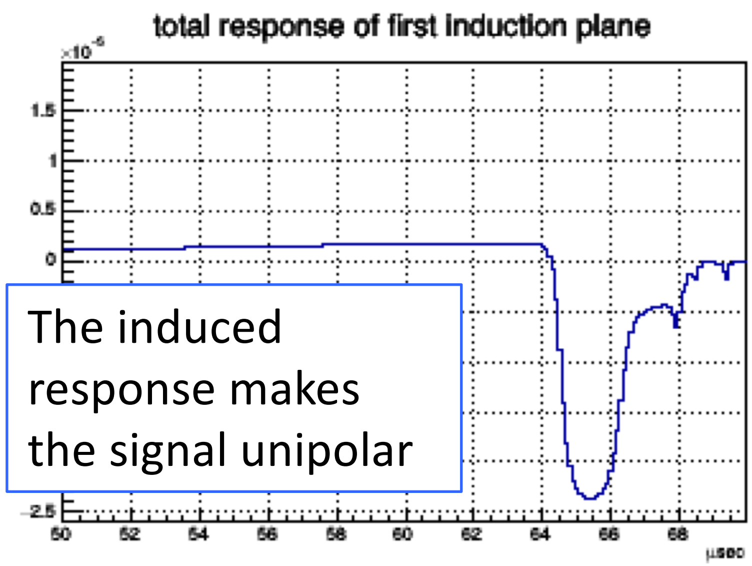


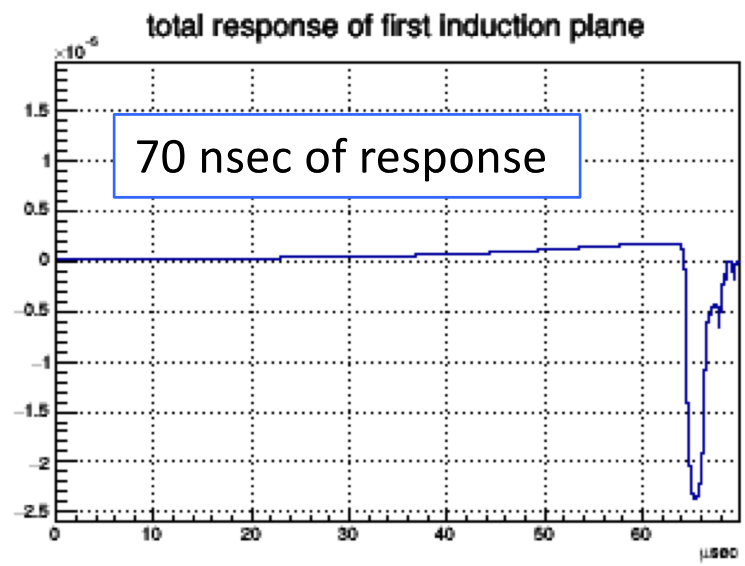


Full response of 1st induction plane wire to 0° track









The ends of the track

In the bins just beyond the end of the track, we should see a response due to the induced signal from the drifting electrons in the last real bins.

(Do we see these effects in the real data, after convolution with the electronic response and the effects of diffusion?)

Also the last (or first) bin of the track should have a lower signal than nominal, because the track traverses half the cell on average.

Tracks in the anode, and beyond

Currently, our responses are useless in the anode region, and indeed, we ignore drift electrons that start below the first induction plane.

But with the new point responses, if charge is released at or behind the 1st induction plane, (or, in fact, anywhere in the second block) we can simply "remove" the leading (long drift time) bins from the response, and use the remaining bins directly.

We know the relation between time and position on the drift path in this region, and can use this to find the correct starting point for the response for a given point on the drift path.

In principle, this technique can be extended to the region behind the collection plane. We may be able to use this effect to explore the field in this region.

Where we are

- It looks like we can improve the simulation using these point sources to:
  - better model the responses as a function of angle.
  - better simulate at the ends of tracks.
  - potentially understand the response of tracks going through the anode.
- But is it right? Can we measure/verify these effects?
  - Look for "ghost" hits beyond the ends of the track in data.
  - See how well we model the angular dependence.
  - Study anode-piercing tracks in detail.
- Tracy has this running in LArSoft!