What methods we could use depends on the detector setup. All the proposed calibration methods use the TPCs themselves (limited to the projection of the instrumented region, and the spatial displacement is integrated along the drift)

- Anode-to-anode crossing tracks,
  - Access the entire detector volume
  - Require a detector that is instrumented with high completeness.
  - No requirement on the light signal.
- “True tracks” provided by external system (scintillation panels for example)
  - Need to know the relative positions between the systems well to provide a base of the coordinate system
  - Similar to the anode-to-anode crossing tracks
  - Unlikely to have the setup
- Track ends
  - Only able to map the vicinity of the detector boundary
  - Potentially can work with a small fraction of the readout
  - No requirement on the light signal.
- Radioactive signals from LAr
  - Outcome should be similar to the method using track ends
  - Strong dependence on the charge-light matching to provide T0 and the charge, light readout threshold. (Challenging but demonstrated good performance near the light detectors in 2x2 single modules; therefore, currently limited to the area near the light detectors)
  - Potentially can leverage the density distribution of the radioactive activities for the whole detector
- UV light and the cathode targets
  - Delivery of the additional setup
  - Probe the cathode exclusively

Experience with 2x2/SingleMods:

Experience with the 2x2 single modules is directly transferable to FSD.
(Similar analogy for 2x2 and ND-LAr)

- Using anode-to-anode crossing tracks to examine the entire detector volume
  - Anode-to-anode tracks provide two “true-position” anchor points for the true tracks.
  - The coverage of the detector, and the statistics.
- Using track ends to map the neighbour of the detector boundary
  - Need to set a predefined neighbour area to select the tracks
  - Gives pseudo 3d mapping, as you don't know the relative position, you project to the side. The track end is not easily mappable from 2d to 3d.
- Using radioactive signals from LAr
  - Similar to scan with the track ends
  - Use this as a cross check for track ends.
  - Pipe line is there, but not clear if this quantifiable. It is unclear how to

interpret the heat map.
    - Deliverable of CSU
- The observed maximum spatial distortion is O(1cm).

Experience with the 2x2 single modules is directly transferable to FSD.

- Currently going through and updating the machinery of extracting the spatial displacement map with the latest "*ndlar_flow*" which is used for data processing and calibration for ND-LAr-like detectors. (L. Triller, AJ Nielsen, S. Fogarty)
- Similarities and differences of the electric field study between 2x2 single modules and FSD:
    - For surface operation, FSD will in principle see larger space charge effect (to be quantified) than 2x2 single modules given it is much bigger and has longer drift window
    - X cm field shaping zinc stripes and Y cm gaps. Need large statistics to bin finely or match the bins around there to examine the spatial displacement near the fieldshell panels.
    - On the side of the TPCs, the electric field shaping is provided by the "rings" and the light detectors, while the light detectors shield the fieldshell and probably dominate the effect. May not be sensitive to the fieldshell design.

Reason - Design requirement of spatial distortion. < 5% distortion throughout fiducial volume.

Goal of this effort is:

1. Anode-to-Anode crossing track.
2. Track ends.
3. Do we need to impose a requirement on track straightness? Can MIP track straightness be determined with PCA. These tools exist in rock muon selection. Or, should this be the ability to reconstruct straight tracks. This could be input for track selection for A-to-A tracks.

Issues:

1. Resources - people
2. Infrastructure - There are packages(flow), the work is to collect everything Dan and Alex did. Make sense of it, and plug it into flow. At this stage, do not look beyond distortions.
3. Simulation for comparison (does it add much or is it worth using singlemod). Geometry?

Notes on what is needed for:

1 - Anode-to-Anode crossing track

AJ has looked into A-to-A from Dan; seemed to be using endpoint, rather than continuous track. Seems like no ref to DBScan.

Yifan: The first step is clustering (exists in flow). Then track. Then track ends, then selection (unique to this), and then mapping. After selection there will be tuning for 3D map. Need a more general track-end selection, which leads into boundary mapping. After A-to-A how do you get a 3d distortion map; needs optimization and distortion map - pipeline is not in the flow. Need this for a set of plots.

AJ: with Dimario selection code, A-To-A added, his based code was already finding tracks. His selections would give detector-crossing tracks.

Yifan: part 1 is track clustering (can reuse), part 2 selection can diverge from rock-muon selection. Consider A-To-A, and track end as separate analysis with common clustering.

AJ has a functional map tool based on track ends at anodes.

2 - Track ends

General end selection needed. Track ends. Is to map the detector boundary, should be using A/C crossing (knowing the caveat that it comes with a smearing). If there is a light matched event, any track crossing the boundary can be used. Once you have clustering, this is easy, can check LRO trigger, or if at boundary. Clustering can be taken from an existing project. Track-end selection needs writing. Mapping simple after selection.

People & Tasks:

AJ at 2.5 days per week

Continue with A2A for 2x2.
Validate against Dan & Alex's work.
Work to optimise a 3D distortion map.
Will start working on track end, data currently being run over, not light matching

Brooke 1.5 days per week

Develop a general selection tool for track ends. Initial application 2x2. Two cases: light matched crossing any boundary, or crossing anode/cathode.

Liz at 1 day per week

A2A
Stay high level with AJ's A2A effort. Regularly check in to discuss plans and understand the method.

Write a plan for porting to FSD.

TrackEnds
Work with Brooke to develop general selection tool

Meeting notes 17th

AJ: also have code for track endpoints in X and YZ. Only using charge, no light. Position along drift determined from prompt hits from charge with DBSCAN to cluster hits, forced to cross boundaries. Based on DeMario's work.

Code shared with Liz and Brooke. To produce general tool. Starting with dimension change.

Brooke: has NERSC account. And flow setup.

AJ: plotting code needs updating. Also have A2A plotting code, same code baseline as faces. Faces came from A2A.

Meeting notes 24th

Brooke has coded from AJ, can run and reproduce plots from AJ. Next step is to go into the selection code and add in light matching.

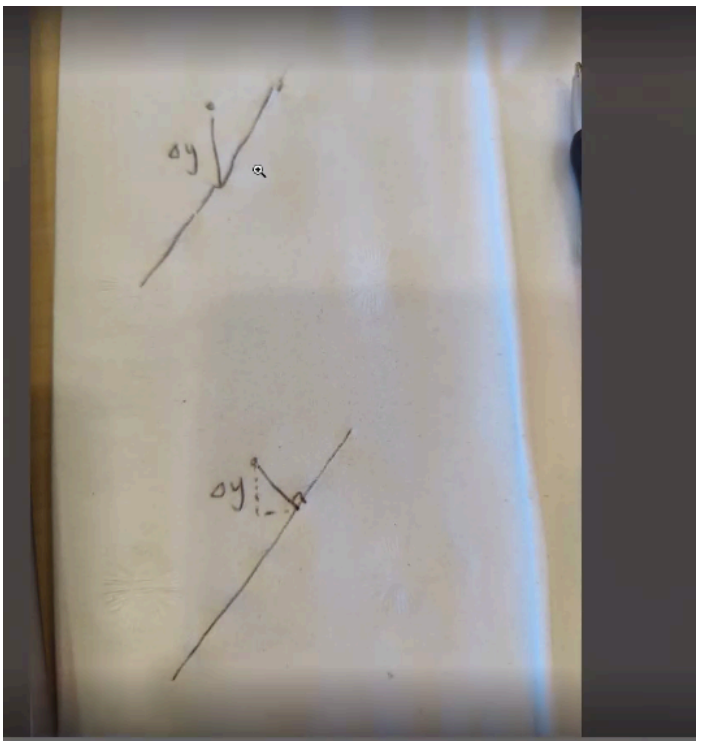
Andrew Light matching is ongoing. Light system triggers are available to the entire DAQ, but light charge matching is all offline as written separately. This has been on priority list for a while, the idea is to build something MLreco can use. *"What can we do now?" That's a good question for Livio and Yifan.*

Andrew also see LE effort from CSU
https://indico.fnal.gov/event/65626/contributions/296743/attachments/180071/246397/2x2%20Low%20Threshold%20Runs%20Analysis.pdf

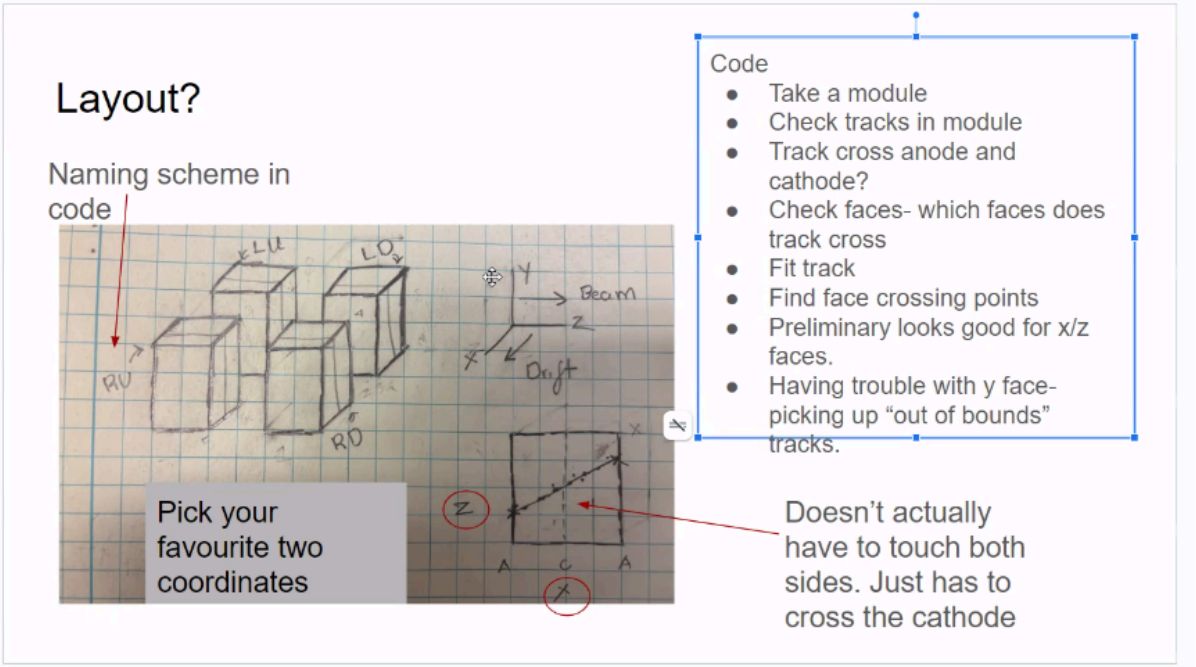
For next week: try to work on A/C ends.

AJ, not a lot new for different types of analysis, has been working on Bern cosmic data. Verification of previous work. Had been working in method of upper image, and finding the difference in y. But the lower method has been suggested by Yifan.

Yifan, the lower one is more robust to angular dependence, but stats dependent, because features can still happen in the bottom one. One thing to alter next is how many stats needed to observe features. One thing to take care of is whether plotting from ref frame of hit instead of truth, because then averaging different hits is fine in ref frame of hits. But, with charge weighting, it might be easier to consider hits as separate points and average at bin level.



Brooke, had code ready to run over files, but grid down. Want to confirm coordinates.



X is flipped, z is off by 3 degrees. Had requirement of cathode & anode crossing. Will include only cathode or anode.

Yifan, check external trigger when crossing. Beam or light can be used. LRO timing is associated to CRO already. Charge event has the attribute of external triggers.

Brooke, have been plotting the crossings. Map the track ends for all faces.

7th meeting

AJ, Sorry for my broken mic, I was just saying that I don't have much to updat about right now, I'm rerunning my plotting code to plot the proper 1D differences in x/y/z right now along with some other statistics (my other non-DUNE project took up a lot of my time in the last week)

Brooke, plotting crossing anodes or cathode, started looking at external triggers. Just want to understand correctly, in the HD5 files there is TS start and TS end. Want one hit/one external trigger in a given time frame. Which should we look at?

Yifan, TS is the start and end time of the event. Check one external trigger then go through charge signals and do clustering. Should give tracks. The information should give one cluster in this event. Need to talk to Dimario, to add in information of how many clusters you get. If one, keep, if more or zero then throw away. For plot style, I gather this is a scatter plot, the uboone is a very specific plot, the style is not informative here. Do not show edge in a way the show's surface, show in histograms not scatter. Put y as a vertical axis. Show surface not frame.

Brooke, next step is to implement tracks with an external trigger.

Yifan, another thing is to look at plot and understand features. Conclusion will be the extent of distortion at the detector edge.

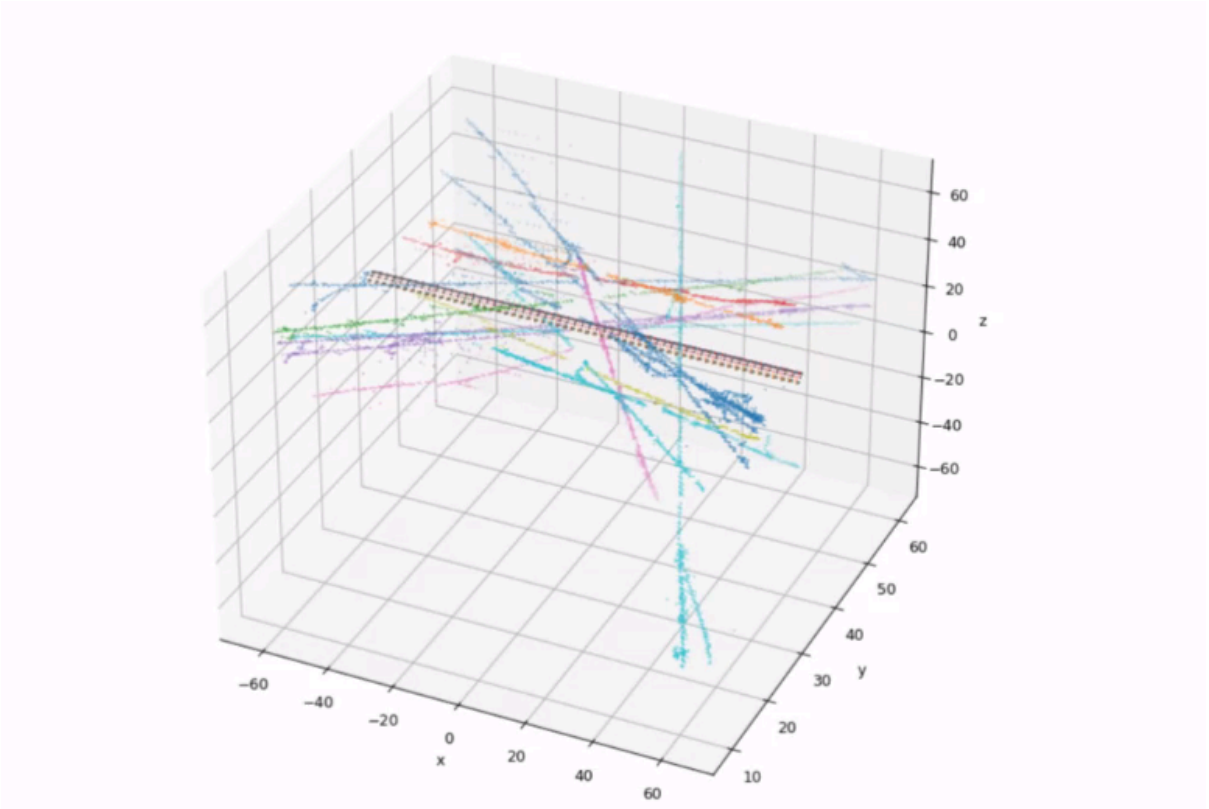
Brooke, using cad from docdb, now working to this orientation wrt beam. In 2x2 nominal HV feature seen crossing modules.

Francosis, a constant pixel might project from TPC out into another, could be noisy channel.

Brooke, added external trigger matching, if track meets conditions for signal external trigger, without crossing plane, it is added. It only adds 3 or 4 tracks. Have a temp external trigger matching.

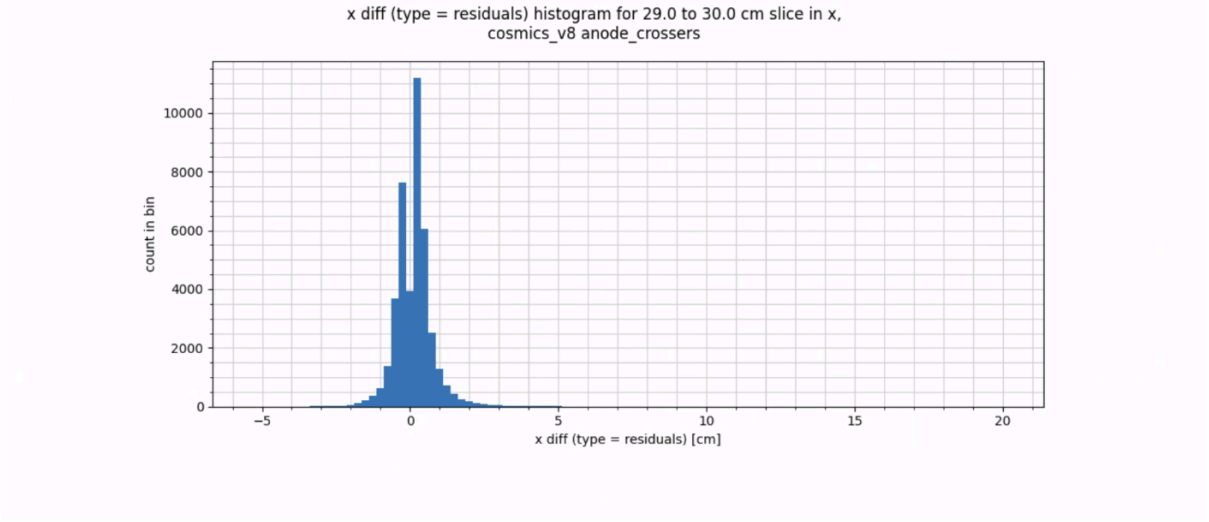
AJ, implemented Yifan's xyz correctly. Running on Bern data, can reproduce Dan's work.
Looking at tracks starting within 3 cm, to get the number of tracks, which is important for Brooke. Also looking therta_x,_*y*_z.

AJ, when using full tracks. There were spots in Y, where there is no data. At the faces. Check if holes are due to selection.



AJ Updates 8/14/24

Histogram of residual values w/ xdiff (or xdiff, ydiff, zdiff) for specific slices, with 0.25cm bin width for each histogram - example below



Notes Yifan x Liz x Kendall 8/20/2024

What are the steps to get 2x2 software working in FSD? What checks do we need to do along the way?

List:

Understand where and how much spatial distortion is seen

- Geometry
    - Yifan helps us find a LArPix geometry file
    - Kendall and Liz investigate the geometry
    - Validate by comparing to previous analyses details.
    - Talk to AJ and Brooke to check where the geometry appears in their code.
        - Are they extracting it from flow or from some other source?
- 3D points
- Event display
- Samples
    - Sample: external triggers
        - What's available hardware wise
    - Sample: Geometric triggers
    - Combined analysis of multiple samples

- Survey TPC boundaries - track endpoints (isolate edgemost hits) and see where they appear w.r.t. geometry
- Survey TPC volume -
    - Similar to AJ now, and what Dan and Alex did for Module 0
    - Identify true tracks
    - Then, associate hits 3D points to the true track line

- Decide if we want to do spatial correction, or do further spatial investigation
    - Do we need to add features to the simulation?
    - Or, necessary for paper or FSD approval
    - Based on 2x2, this may not be necessary. But if it's a large effect.
- Conversion from spatial to field as possible extension
    - Use case will be apply correction for recombination

Detailed transcript:
https://www.evernote.com/shard/s435/sh/a6308d43-85fd-2ce7-a857-3dc59ec2d626/1Pip8k2EScjgU0cNJ3CGCTFDQNTUN8Et_2mvjgGCB3SeJ8KJiln4Em6YQA

This is the reflow location:
https://github.com/DUNE/2x2_sim/wiki/Reflow-File-Locations (e
This is the larpix geometry:
https://github.com/DUNE/larnd-sim/blob/develop/larndsim/pixel_layouts/multi_tile_layout-3.0.40.yaml

https://github.com/DUNE/larnd-sim/blob/a16f14a6d1c1f3bec8d983026559d51e93f37523/larndsim/consts/detector.py#L278-L294

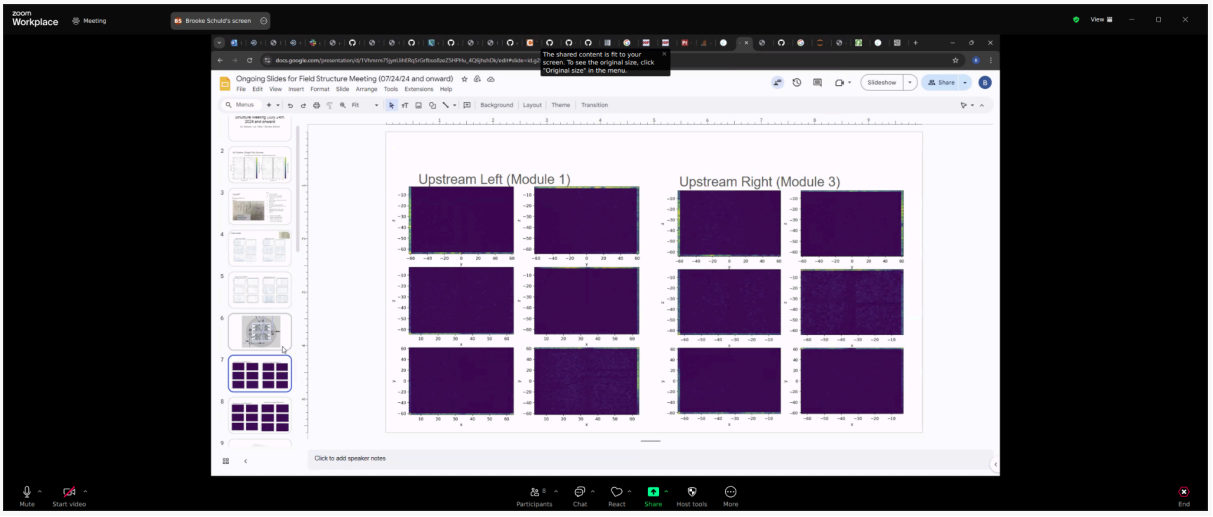
Notes from August 21st:

AJ discussing with Pedro raw angles of track, trying to think hot to define the angle properly. The angle was defined was the difference with the line end to end with the y difference with the projected distance in the x-z plane. But this gives only -90 to 90. But a vector along positive y could be angle 0, or negative could be 180. Will post sketch later. Would be something.

Brooke, question for Yifan: mentioned somethignin slack about working from boundaries. Can this be clarifies

Yifan, most of the plot is hollow, the boundary is only the edge. Want to see the surface.

This is a multiplicity plot



Brooke, cuts 2 cm from the wall.

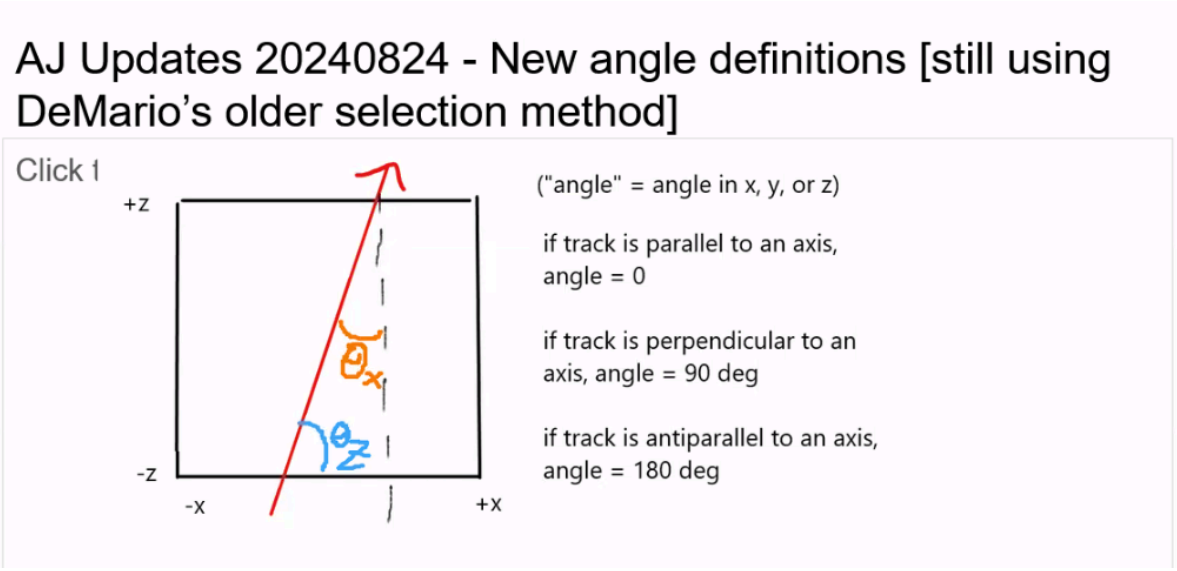
Yifan wants a surface projection plot. Look for the hit, and consider the distance to the surface. That will give a sense of how far the track ends are from the TPC. At a surface, the track end is not necessarily ending at the actual wall.

Brooke, only using beam on data from July 8th. ~30k tracks.

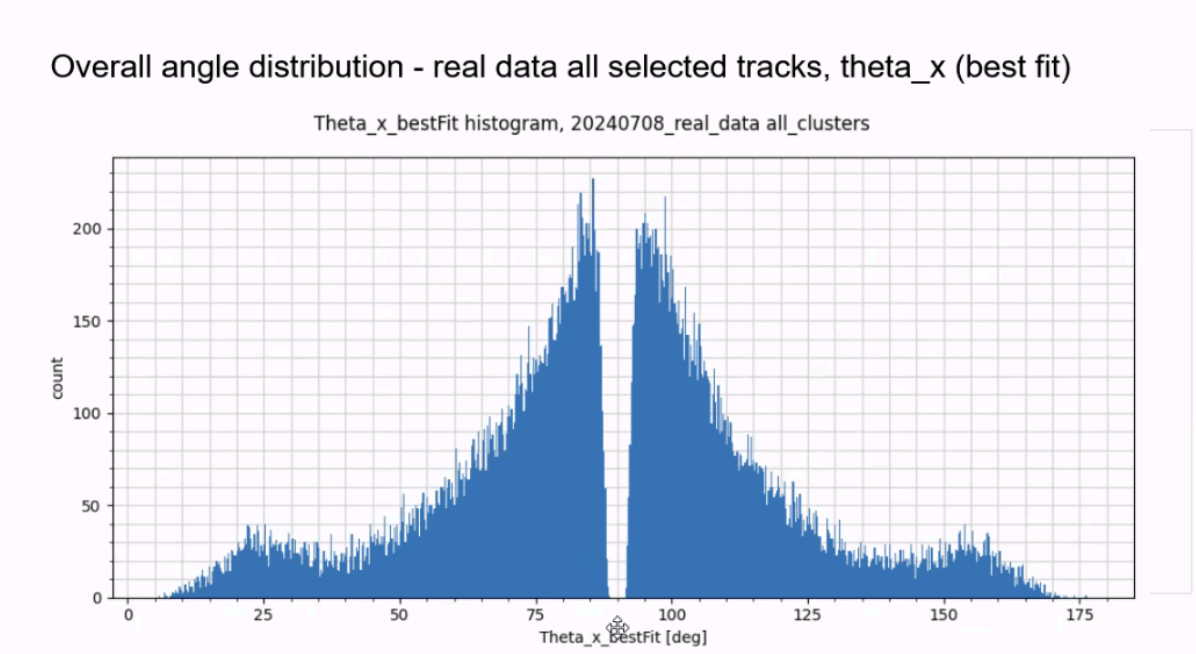
Yifan, guess some surfaces have more hits because of phase space. Can use data for all events, not just beam, will need to set threshold. Will provide a link. Also useful for AJ.

Meeting 28th

AJ, got the overall theta X,Y,Z angles.

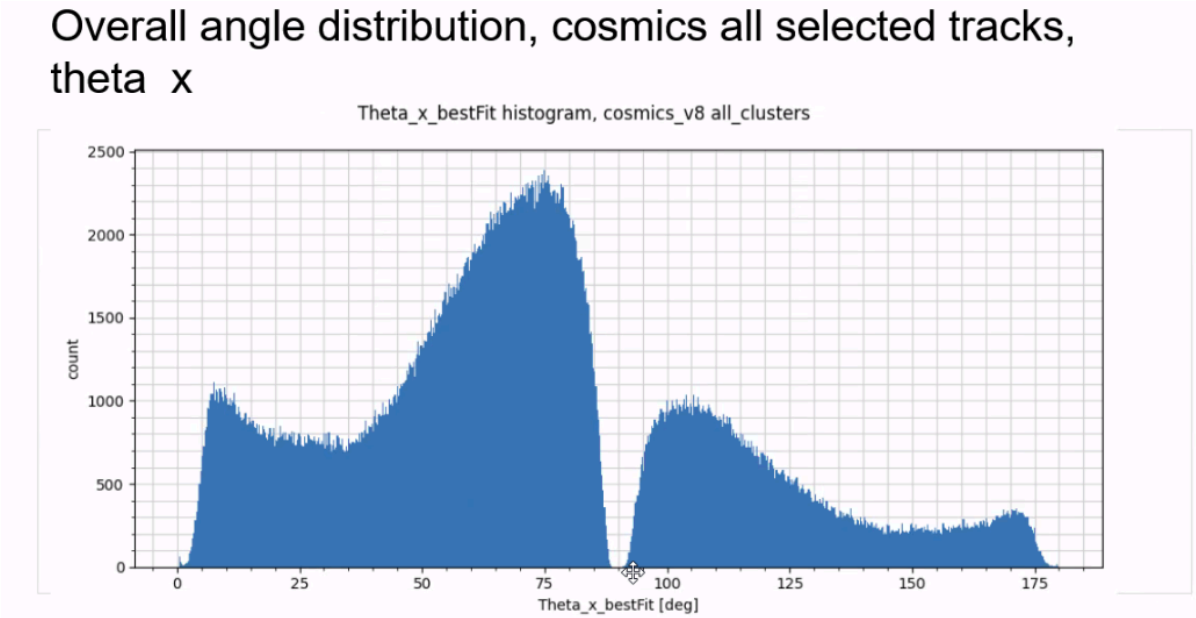


If a track is parallel to an axis the angle wrt that coordinate is 0, if it was perpendicular an axis it is 90.
Do have the distro for faces of the detector, will have it for cathodes soon.
A start point has a smaller z value than an end point.



Interesting that there is nothing at 90 (perpendicular to X axis). This plot shows all selected tracks, not just anode-anode. Need to compare with Dimario and check definitions.

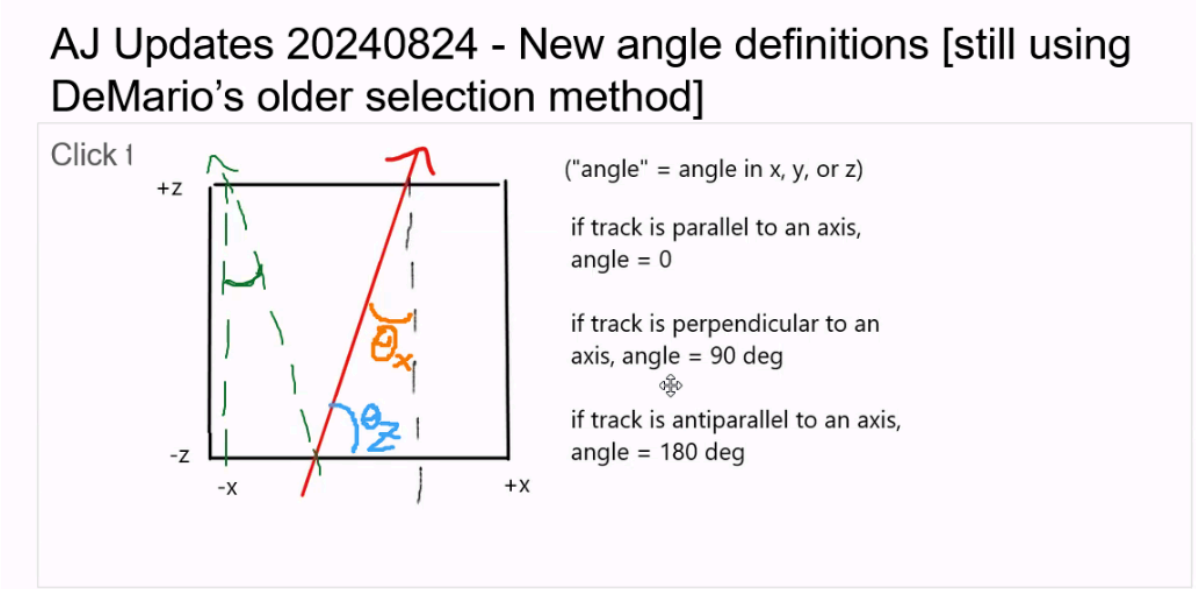
For cosmics using Bern data.



Sorting all hits in track wrt to smallest Z(2x2) or largest Y(cosmics).

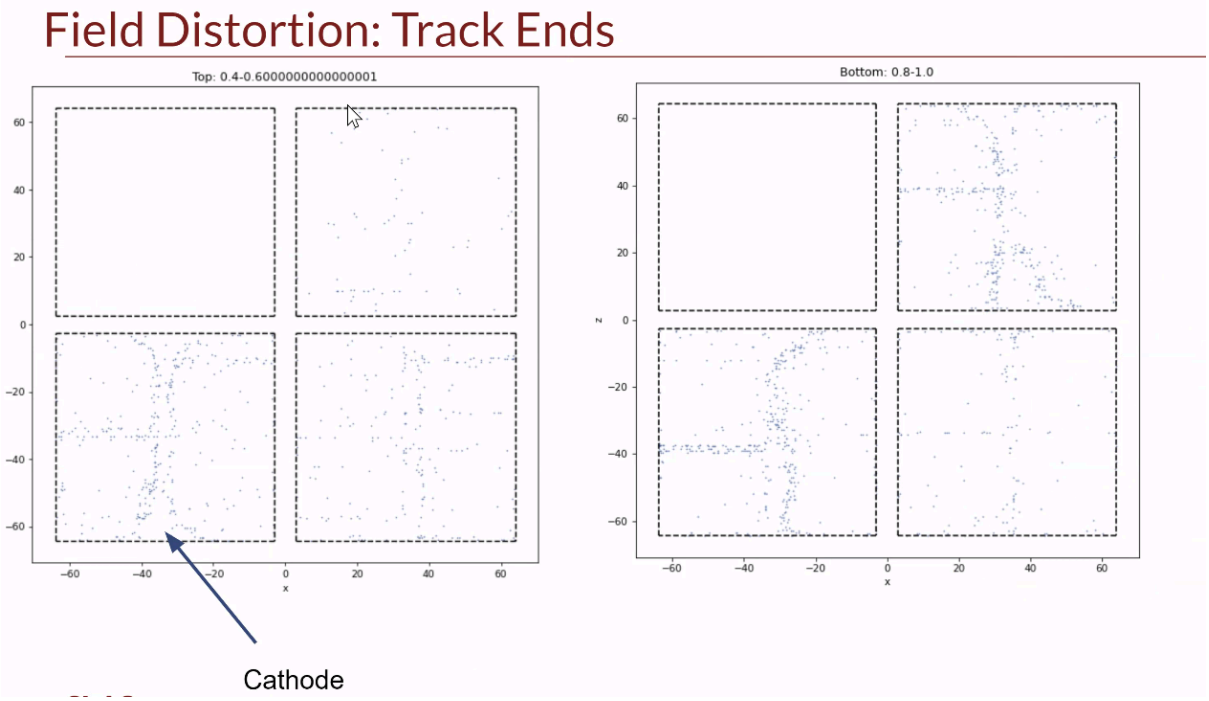
Yifan, left and right does not give more information, why not collapse into 90, instead of 180.

Aj for a directional tell:



Yifan, to get some information from the angle, what you are plotting is the distro of the track, but to be informative, you can have the angle of segments wrt to PCA. Suspect all segments are along the PCA line. Can define the angle wrt the PCA line, which could be interesting, look for systematic differences along the PCA. And these angles with respect to global coordinates.

Brooke, july 8th data, only tracks crossing top and bottom:



Meeting September 18

AJ: There has been some work on reflowing the July data. Issues with hits out of bounds that seem like they correspond to noisy pixels, not sure if fixed in reflow.
Cosmic needs to rerun.

Yifan: just to clarify the out of time hits, are most of them noise, if understood correctly a large fraction out of time due to T0, but some from noise. Are we talking about the same thing?

AJ: some noise, some T0 (track out of bounds). Too look for out of bounds, looking at everything including the beam.

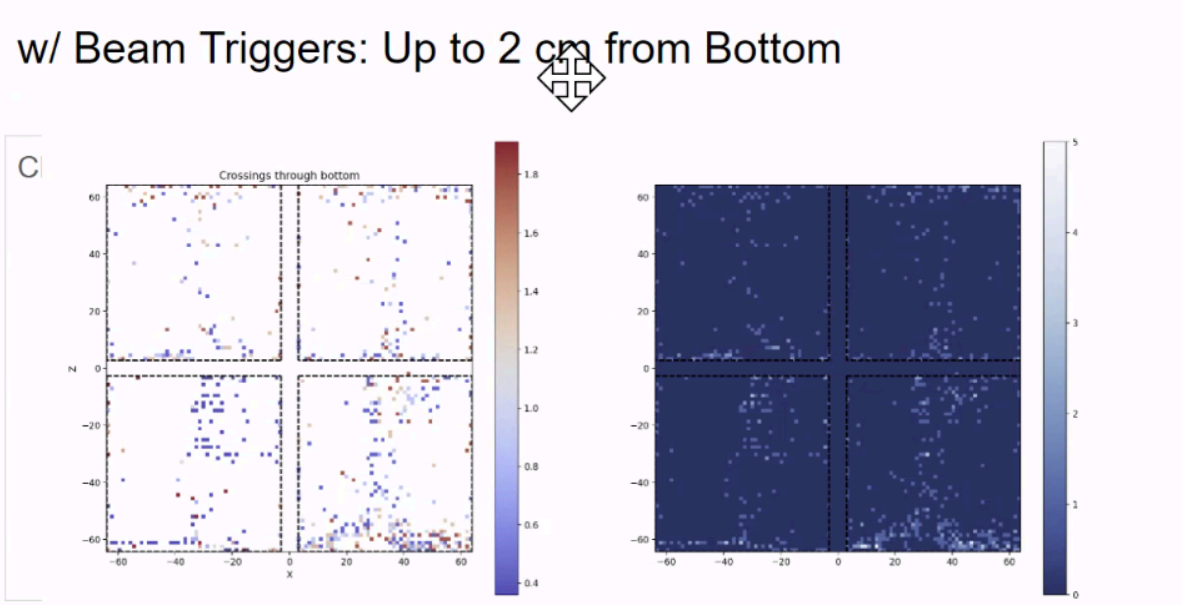
Brooke: all events with beam triggers. Extended cut up to 2 cm. Selecting 700 tracks.

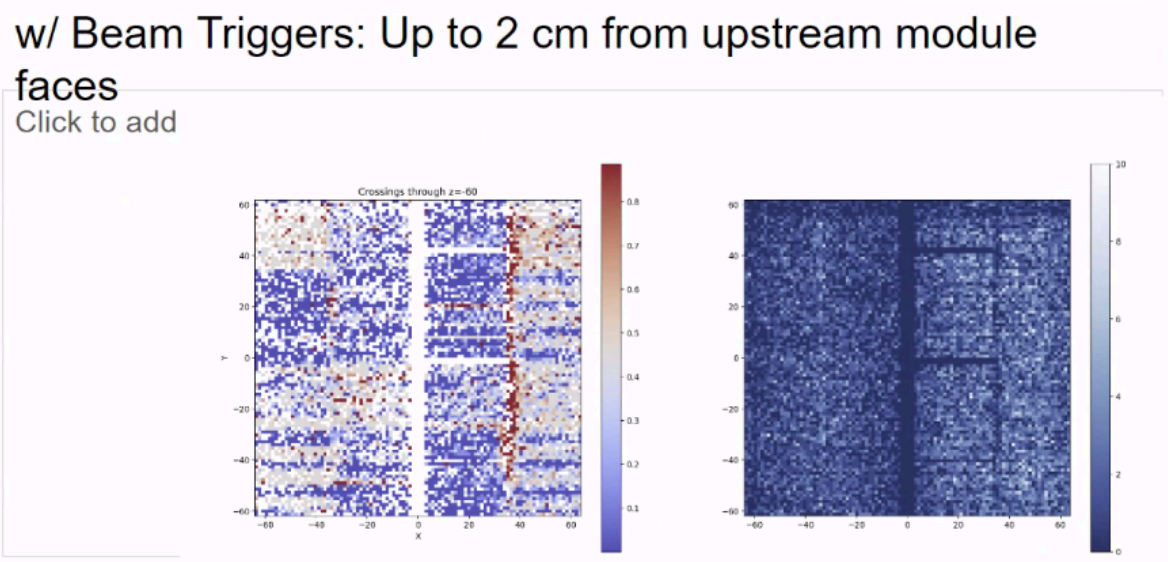
Yifan: 700 in time crossing, for what run time.

Brooke: all data in the beam flowed folder. July 8 and 10.

Yifan: remind the criteria.

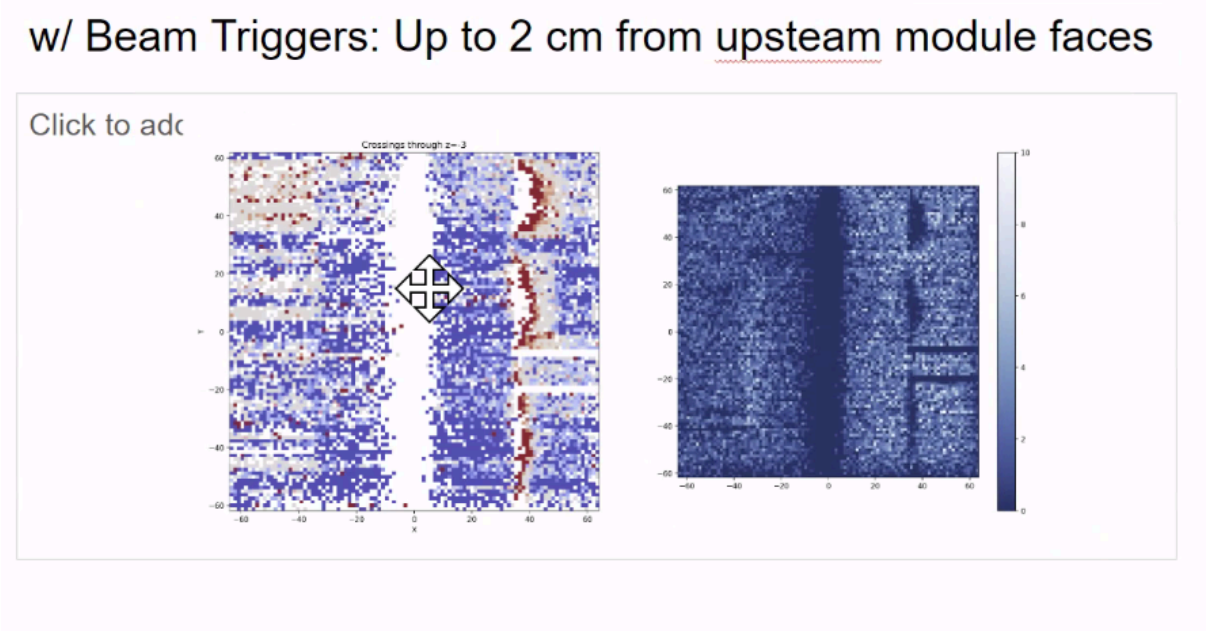
Brooke: rock muon, crossing on anode. Looking now at those exit through the bottom.



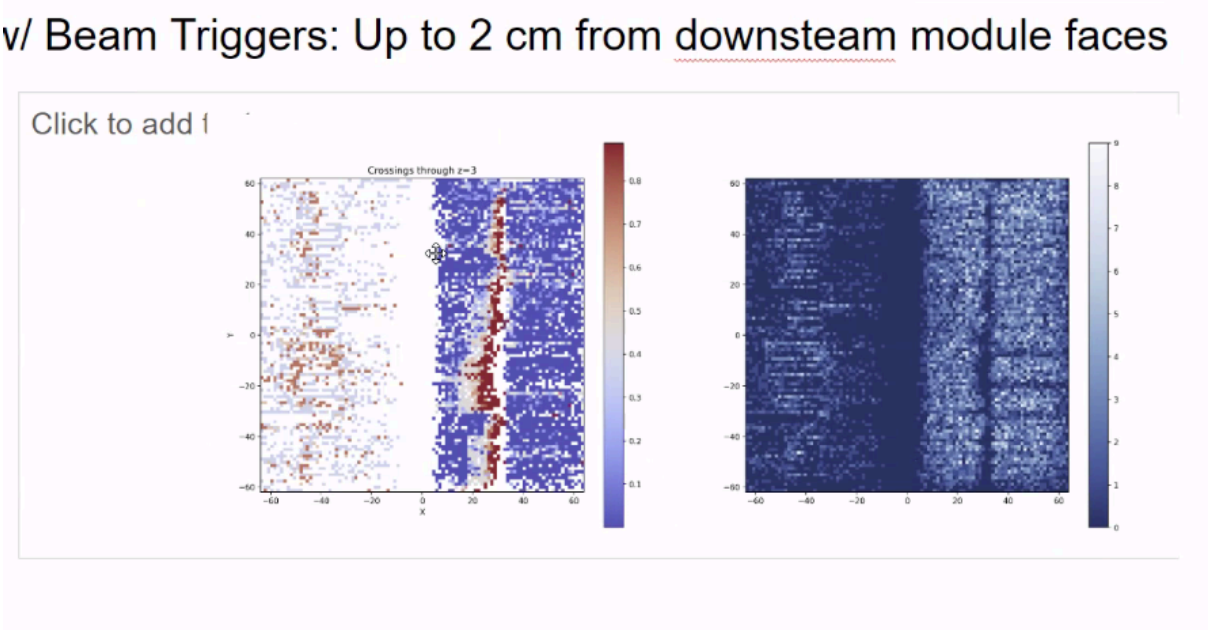


Yifan, do you have dX? Looking at Z shows distance to wall so this is the 2 extremes of the I would also be interested to see the x slices. Clost to cathode and close to anode.

AJ: have added code to plot at cathode. Need to resend to Brooke.



Yifan, huge blank in the middle, similarly with:



Yifan, have you checked hit number wrt to pixel.

AJ: has map, can send later.

Yifan: gap is alarming. Need to make sure geometry is centred where we think it is.

Some of this looks like light RO, wait for slice in X

Track defined as have cluster from rock muon

Yifan: look for tracks in red zone and plot the entire event. All hits.

Yifan: to do this for FSD: need a matrix to understand what is better: e.g. how straight the track is. No

matrices exist. Not a matrix. Need a criteria to decide what is or isn't good. A quantitative way to decide what is going on. E.g for assessing full volume, all voxles must be below a certain variation and absolute value below X. can also look at track level and assess straightness of track. Also, something we should compare to single module, compare the scale.

Get plan start

From Yifan:

Skeleton of the field analysis FSD

1. Data processing (Matt): run the data through ndlar_flow; get the pedestal, larpix operating voltage and the geometry
2. Analysing the hits:
    a. Detector contour:
        i. From hits directly
        ii. From track ends
            1. Charge clustering
            2. Determine a cluster is track-like
            3. Find the track ends
            4. Determine what is considered as the vicinity of the detector boundary
        iii. Cathode from the crossing tracks
    b. "Cosmic muon" straightness
        i. Identify tracks (largely overlap with 2/a/ii)
            1. One and only one external trigger per TPC
                a. Will the light detectors from both tpcs trigger together?
                b. How the trigger is forwarded to the pacmans
            2. Charge clustering
            3. Fit a line
            4. Remove non-track like objects
        ii. Calculate straightness (How the b./i./4. interfering this part)
            1. Average distance from hits to the line
            2. Accumulative angular changes
            3. Second axis of the PCA fit
    c. Survey the full detector volume with the anode-to-anode (AA) tracks
        i. Identify the AA tracks (largely overlap with 2/a/ii)
        ii. Calculate the residuals with respect to the detector positions

See separate PDF for comment chain.