Study of CRT Channel Map

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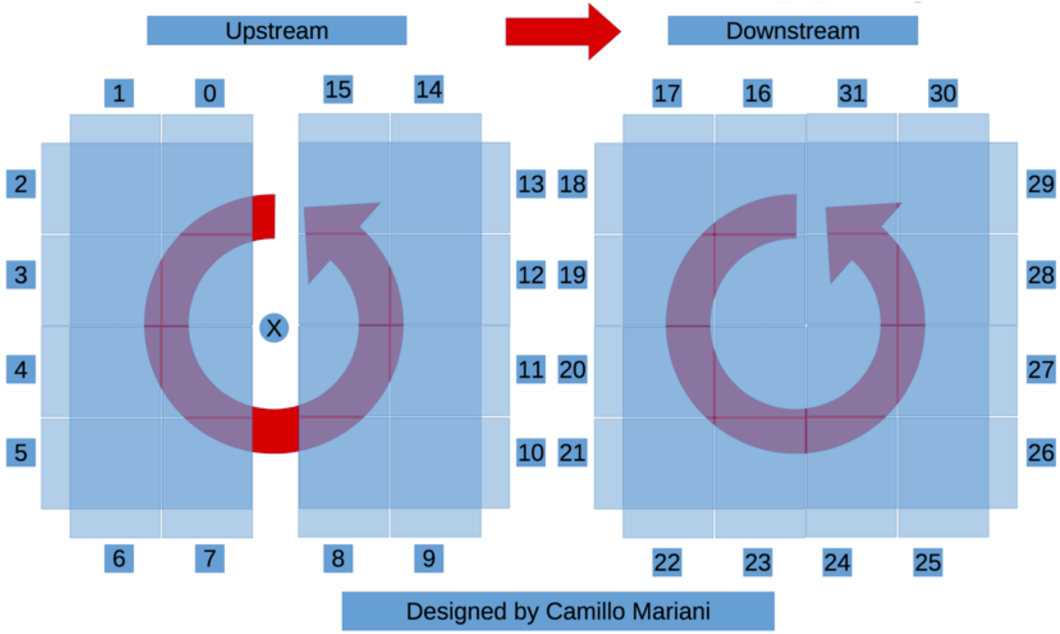
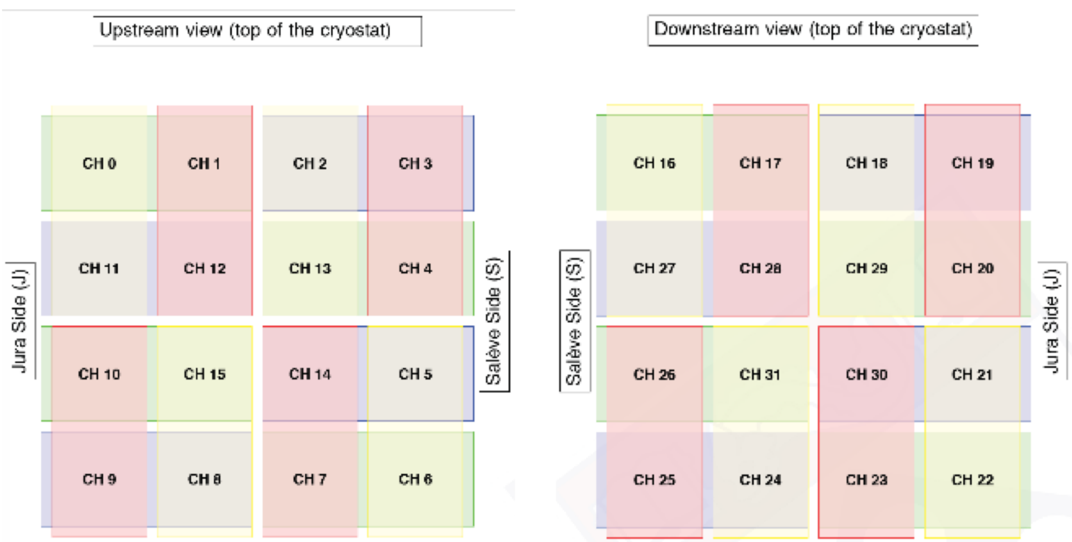
Introduction

- CRT information is very important for detector calibration.
- I have tried to look into the CRT channel map as there seems to be some confusion.
- So far I only looked CTB information, not the CRT information itself.
- I had very useful discussions with Andrew Olivier, Tom Junk, Nuno Barros, Marco Roda and Jon Sensenig.

Hardware module numbers



Pixel numbers



Coincident overlapping modules define “pixels” for trigger.

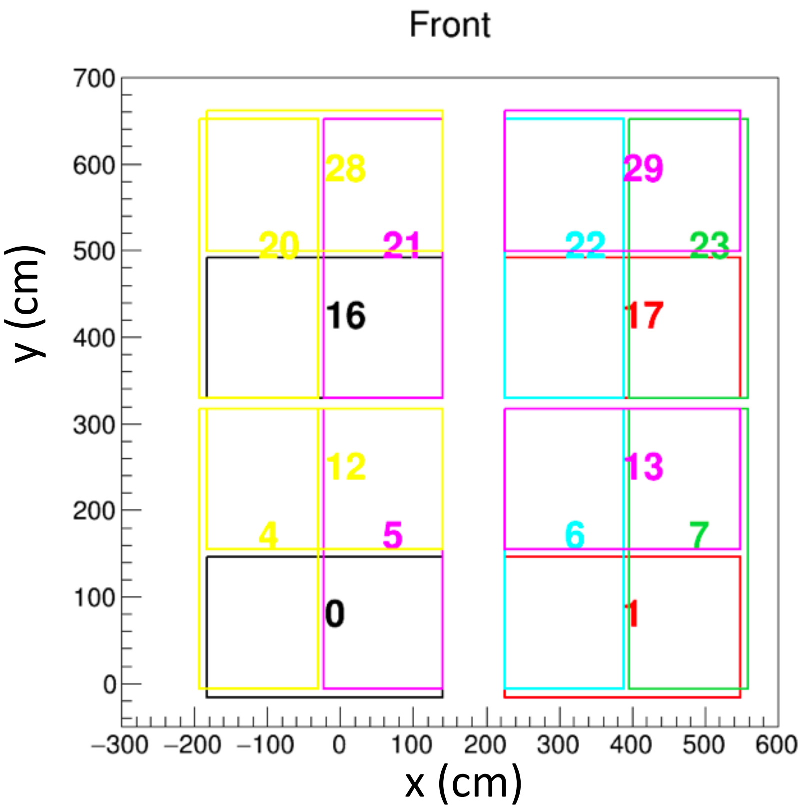
```
-- Upstream CRT panels
-- output     vertical       horizontal
crt_o(0) <= crt_in(1) and crt_in(2);
crt_o(1) <= crt_in(0) and crt_in(2);
crt_o(2) <= crt_in(15) and crt_in(13);
crt_o(3) <= crt_in(14) and crt_in(13);
crt_o(4) <= crt_in(14) and crt_in(12);
crt_o(5) <= crt_in(9) and crt_in(11);
crt_o(6) <= crt_in(9) and crt_in(10);
crt_o(7) <= crt_in(8) and crt_in(10);
crt_o(8) <= crt_in(7) and crt_in(5);
crt_o(9) <= crt_in(6) and crt_in(5);
crt_o(10) <= crt_in(6) and crt_in(4);
crt_o(11) <= crt_in(1) and crt_in(3);
crt_o(12) <= crt_in(0) and crt_in(3);
crt_o(13) <= crt_in(15) and crt_in(12);
crt_o(14) <= crt_in(8) and crt_in(11);
crt_o(15) <= crt_in(7) and crt_in(4);
-- Downstream modules
crt_o(16) <= crt_in(17) and crt_in(18);
crt_o(17) <= crt_in(16) and crt_in(18);
crt_o(18) <= crt_in(31) and crt_in(29);
crt_o(19) <= crt_in(30) and crt_in(29);
crt_o(20) <= crt_in(30) and crt_in(28);
crt_o(21) <= crt_in(25) and crt_in(27);
crt_o(22) <= crt_in(25) and crt_in(26);
crt_o(23) <= crt_in(24) and crt_in(26);
crt_o(24) <= crt_in(23) and crt_in(21);
crt_o(25) <= crt_in(22) and crt_in(21);
crt_o(26) <= crt_in(22) and crt_in(20);
crt_o(27) <= crt_in(17) and crt_in(19);
crt_o(28) <= crt_in(16) and crt_in(19);
crt_o(29) <= crt_in(31) and crt_in(28);
crt_o(30) <= crt_in(24) and crt_in(27);
crt_o(31) <= crt_in(23) and crt_in(20);
```

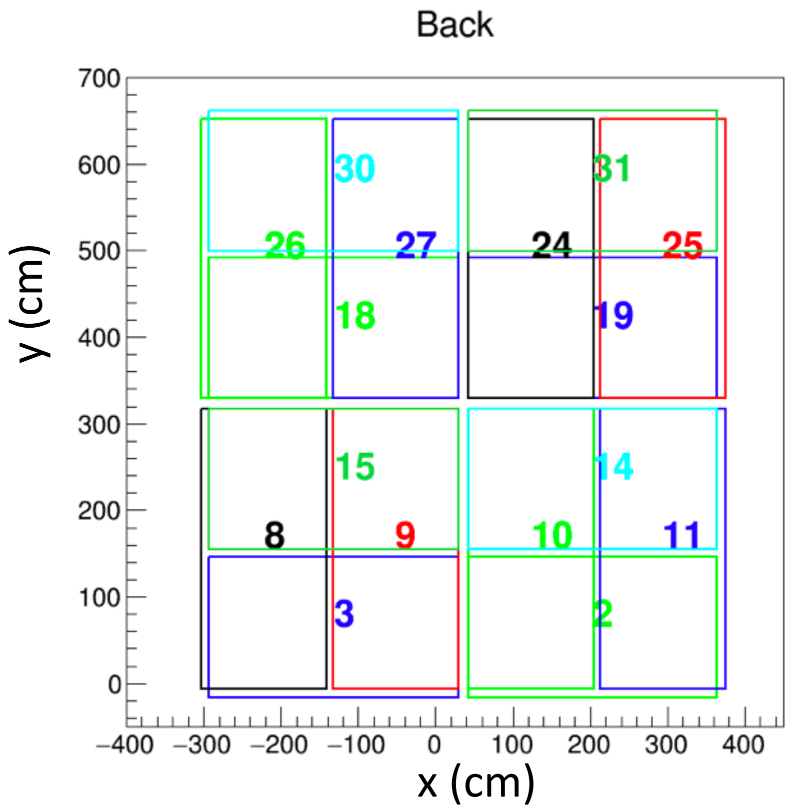
Downstream pixel map has Jura side (beam left) on the right.
=> This turns out to be wrong.

Understand the CTB information

- Select CRT triggered events (raw::RDTimeStamp::GetFlags() == 13)
- pdspctbs[i].GetChStatusAfterHLTs() gives the CRT trigger information.
- For example, in run 5785 and event 1514, the channel status is 33556480. Converting it to binary: 10000000000000100000000000, which means pixels 11 and 25 were in coincidence to produce this CRT trigger.
- Sometimes only one pixel fired
  - Run 5785 event 1669, chanel status is 512 => 1000000000. Only upstream pixel 9 fired.
- How to look at unpacked Trigger Words
  - https://wiki.dunescience.org/wiki/Look_at_unpacked_Trigger_Words

Determine pixel coordinates

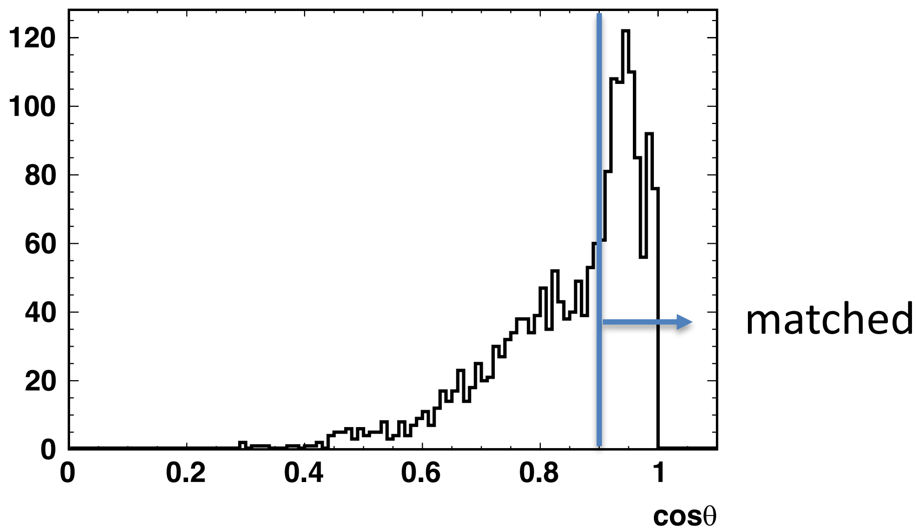


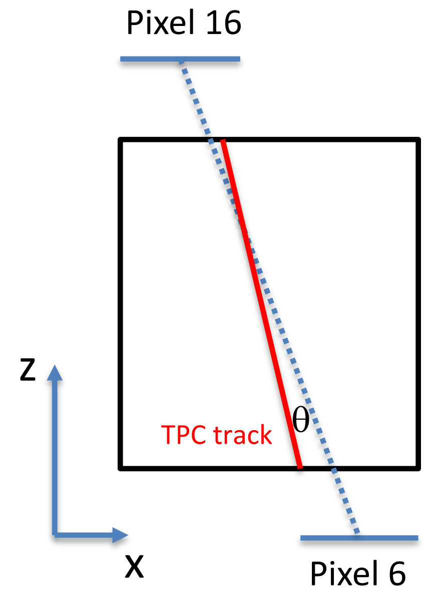


- Plot offline CRT modules using gdml.
- It is straightforward to map the online module number to offline module number.
- We can determine the pixel center coordinates based on the module geometry.

Match CRT trigger with TPC tracks

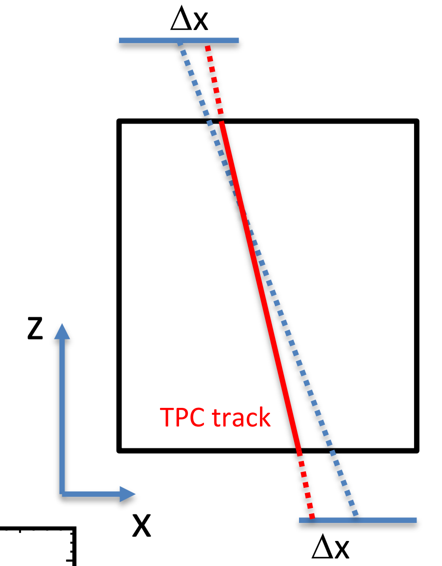
- Select events where two pixels fired (one upstream and one downstream).
  - Trigger direction is defined by the centers of the two pixels.
- Select through-going Pandora tracks (track start < 40 cm, track end > 660 cm).
- Plot the cosine of the angle between the trigger direction and track direction.

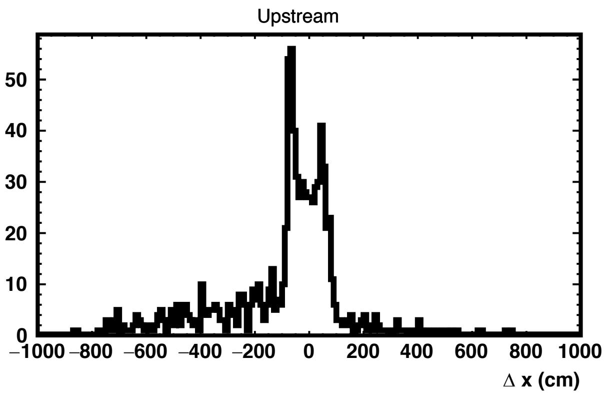


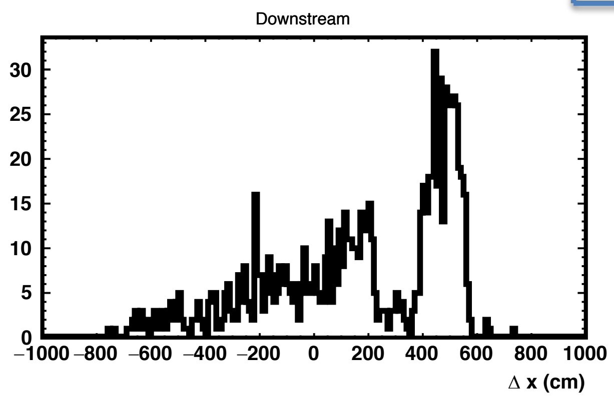


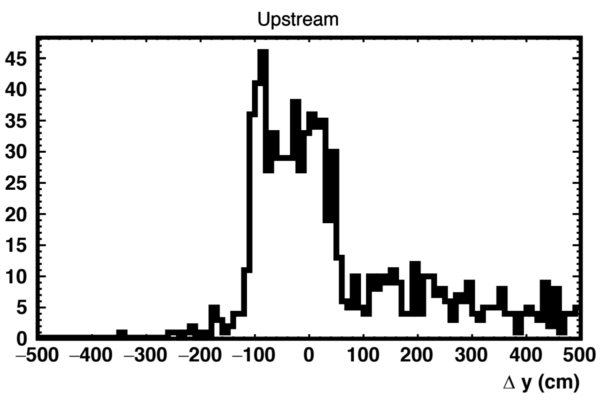
Validate pixel positions

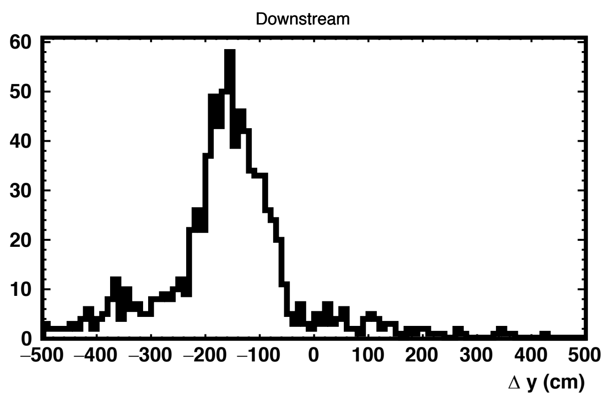
- Project the track onto the CRT module.
- Plot distance between the track projection and pixel center.





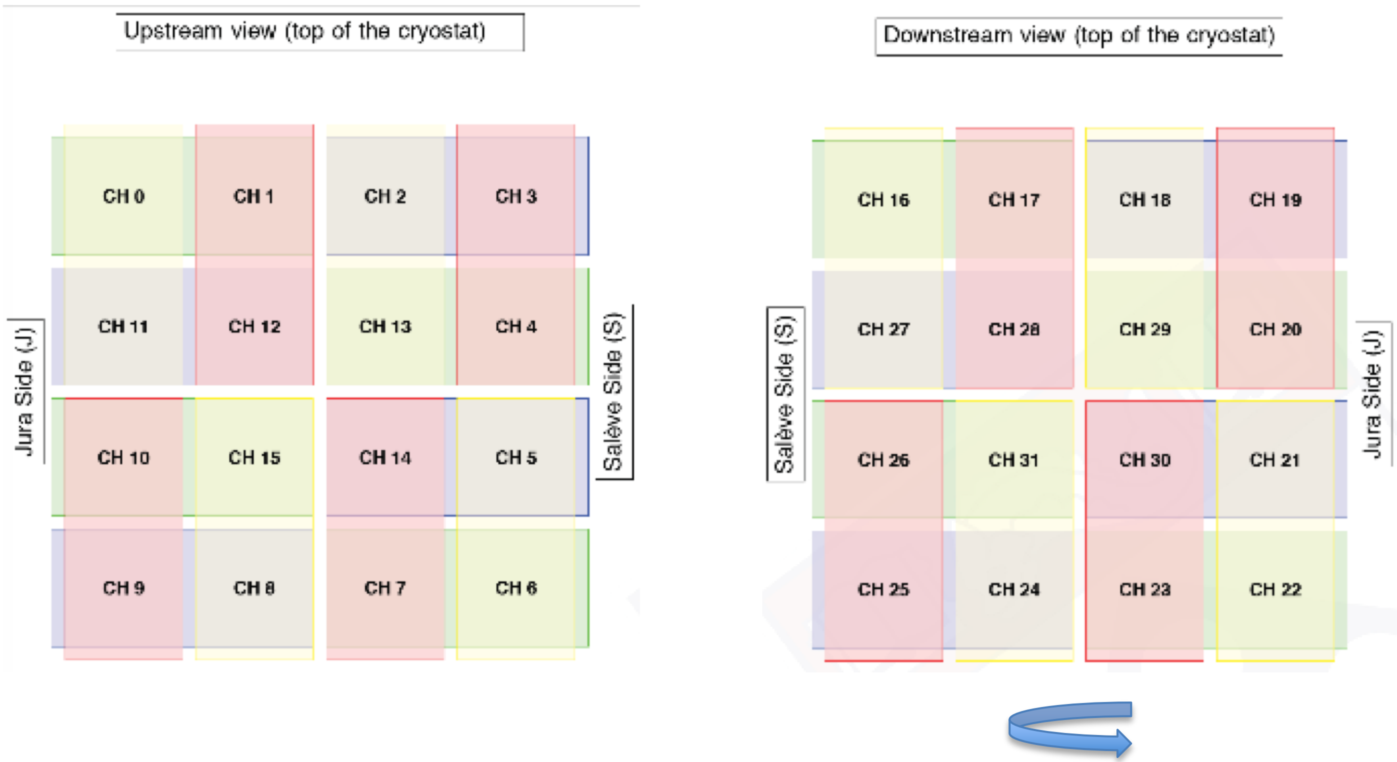






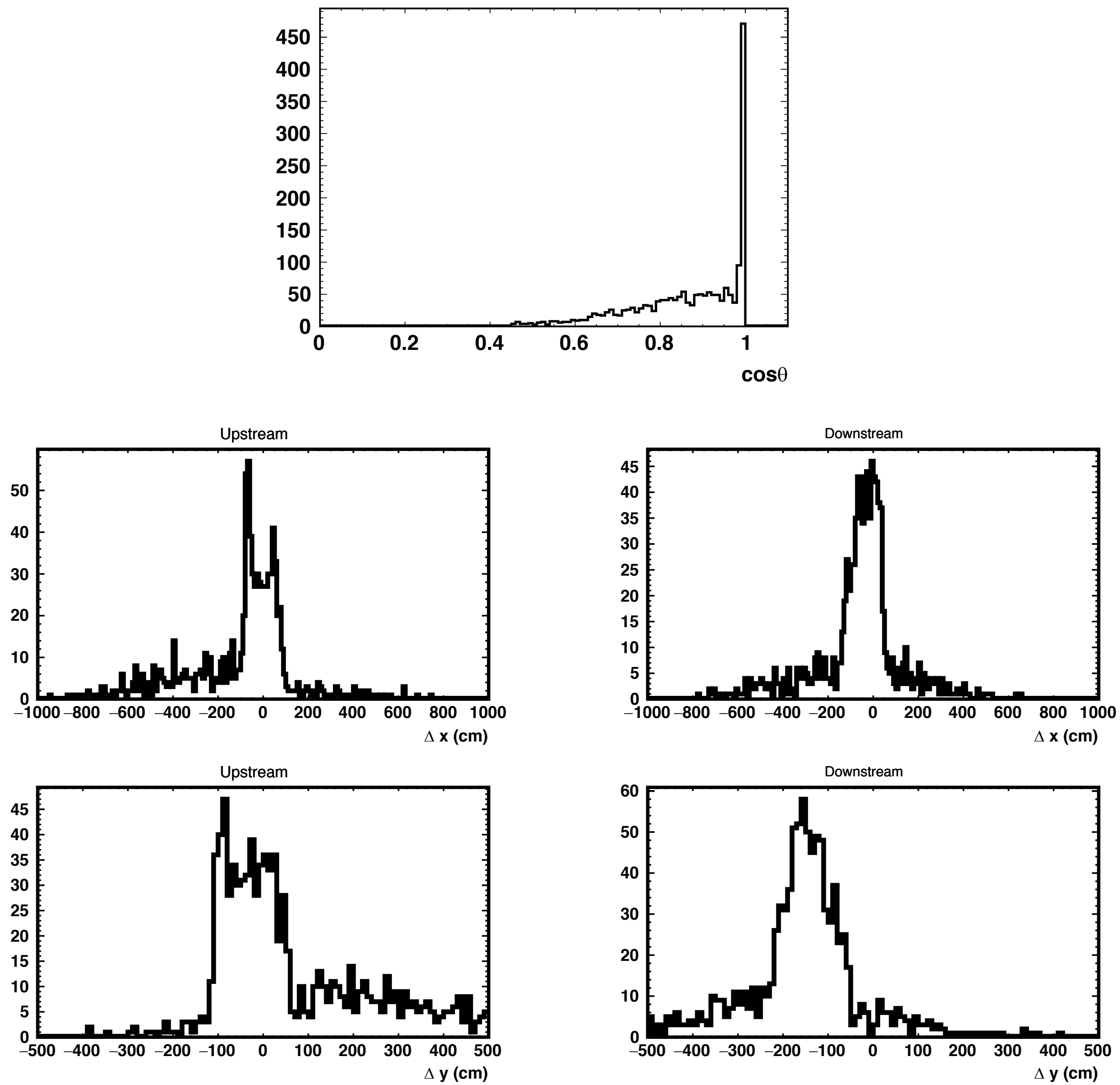
- Width should be consistent with pixel size ~1.6 m
- Upstream x looks fine.
- Upstream y looks shifted by ~50 cm.
- Downstream x ???
- Downstream y looks shifted by ~1.5 m

Downstream x positions



- Andrew thinks the downstream x direction is flipped.
- Tried to flipped the downstream pixels in the x direction and repeat the study.

After flipping the downstream x direction



- cosθ is much improved.
- x positions look much better.
- Upstream modules are ~50 cm too high.
- Downstream modules are ~1.5 m too high.
- Andrew thinks the shifts are possible and have requested measurements at CERN.

New measurements at CERN

- Per Andrew's request, Serhan Tufanli measured the CRT locations earlier today.
- In the offline geometry, all CRT modules are ~2 m above the pit floor.
- In the Serhan's measurements, the upstream CRT module is ~1.5 m above the floor and the downstream CRT module is ~0.5 m above the floor.
  - Consistent with what we saw in the data.

US

DS

CRT time offset

- I don't claim I understand this …
- Tom pointed out there is a fixed 0.25 ms offset between the beginning of TPC readout and CTB trigger.
  - This is what we requested for the beam trigger.
  - It seems to be the same for the CRT trigger.
- There may be a smaller time offset between CRT trigger and timing board reader. See Andrew's talk:
  - https://indico.fnal.gov/event/19132/contribution/4/material/slides/0.pdf
- In TPC reconstruction, we subtract a constant trigger offset 0.25 ms when converting ticks to x position.
  - This indicates the CRT tagged tracks will have the correct reconstructed x position.
  - This seems to be the case from the Δx distributions shown before.

Conclusions

- The x coordinates of CRT modules are fixed already in offline feature/crt branch.
- The CRT modules seem to be at different height than the offline geometry.
  - Confirmed by measurements. Andrew is going to update the offline geometry soon.
- More precise measurements are needed to understand the module locations
  - Important for detector calibration, e.g. SCE calibration.