LBNF - DUNE UK Project Meeting: Trigger Activities at NP04

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THE UNIVERSITY of EDINBURGH

Overview

- DUNE DAQ Triggering Mechanism
  1. How does the trigger subsystem “see” the raw data?
  2. Down sampled Raw Data – Trigger Primitives
- Triggering So Far
  1. Multiplicity Triggering (December 2021)
  2. Horizontal Muon - Track Length Triggering (June 2022)
  3. Firmware Trigger Primitive Triggering (Electronic Noise)
- Future Plans & Coming Up
  1. Michel Targeting
  2. Low Energy Event Trigger Algorithm – Template

DUNE DAQ Triggering

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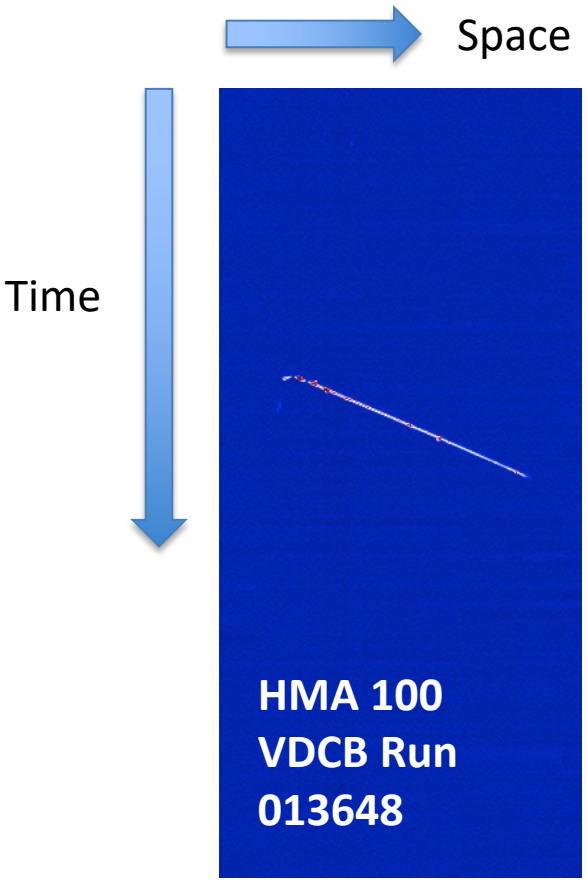

The way trigger sees the incoming data can be visualized in the following way:

1. (left) A raw event display from a **Vertical Drift Cold Box (VDCB)** run.

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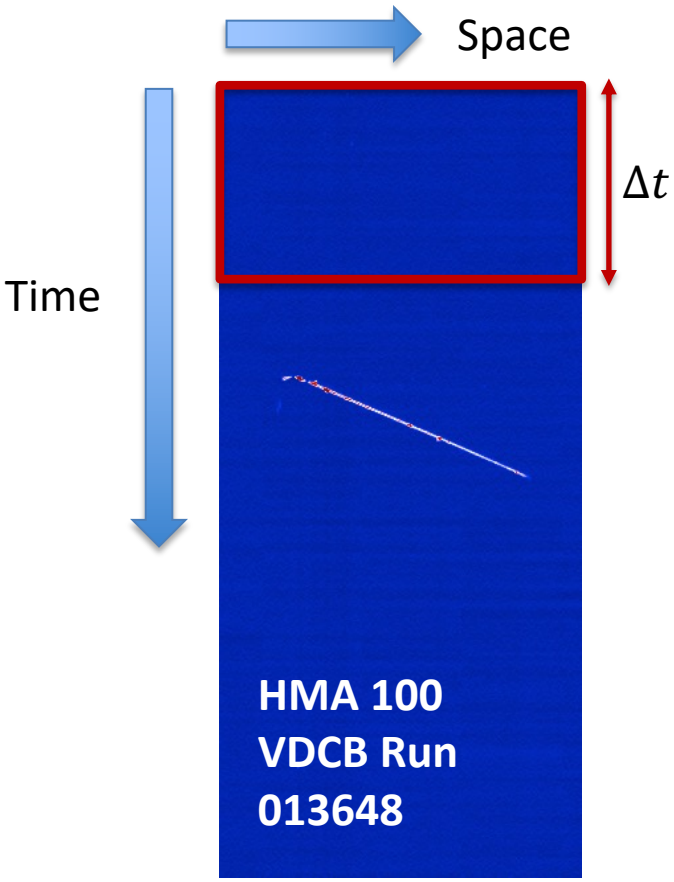

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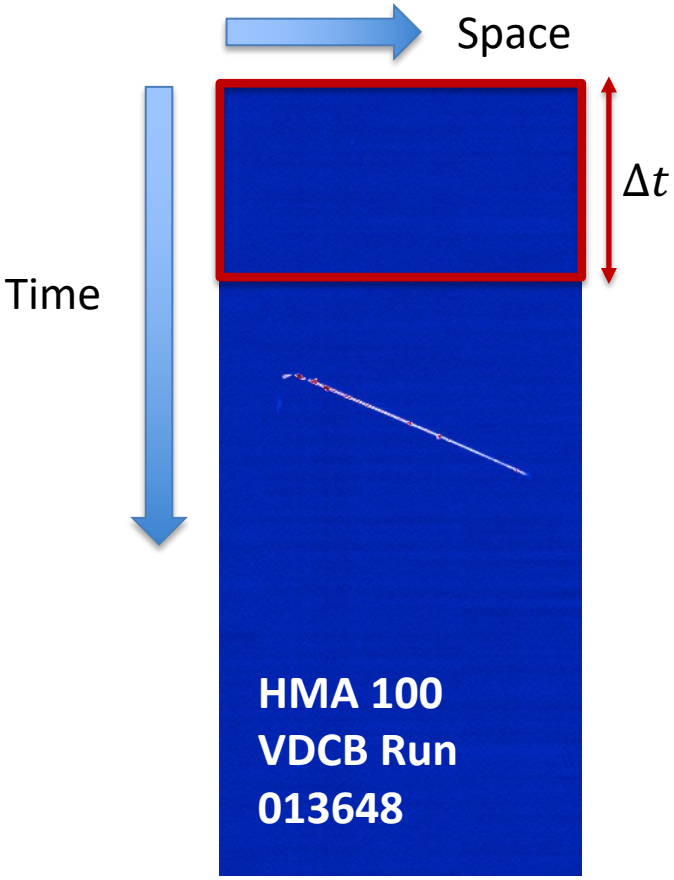

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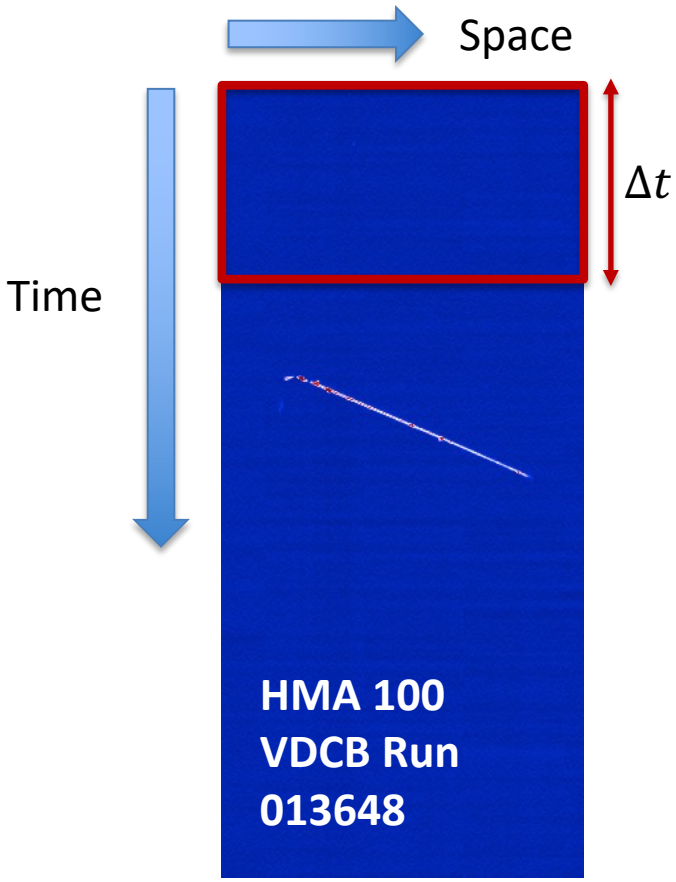

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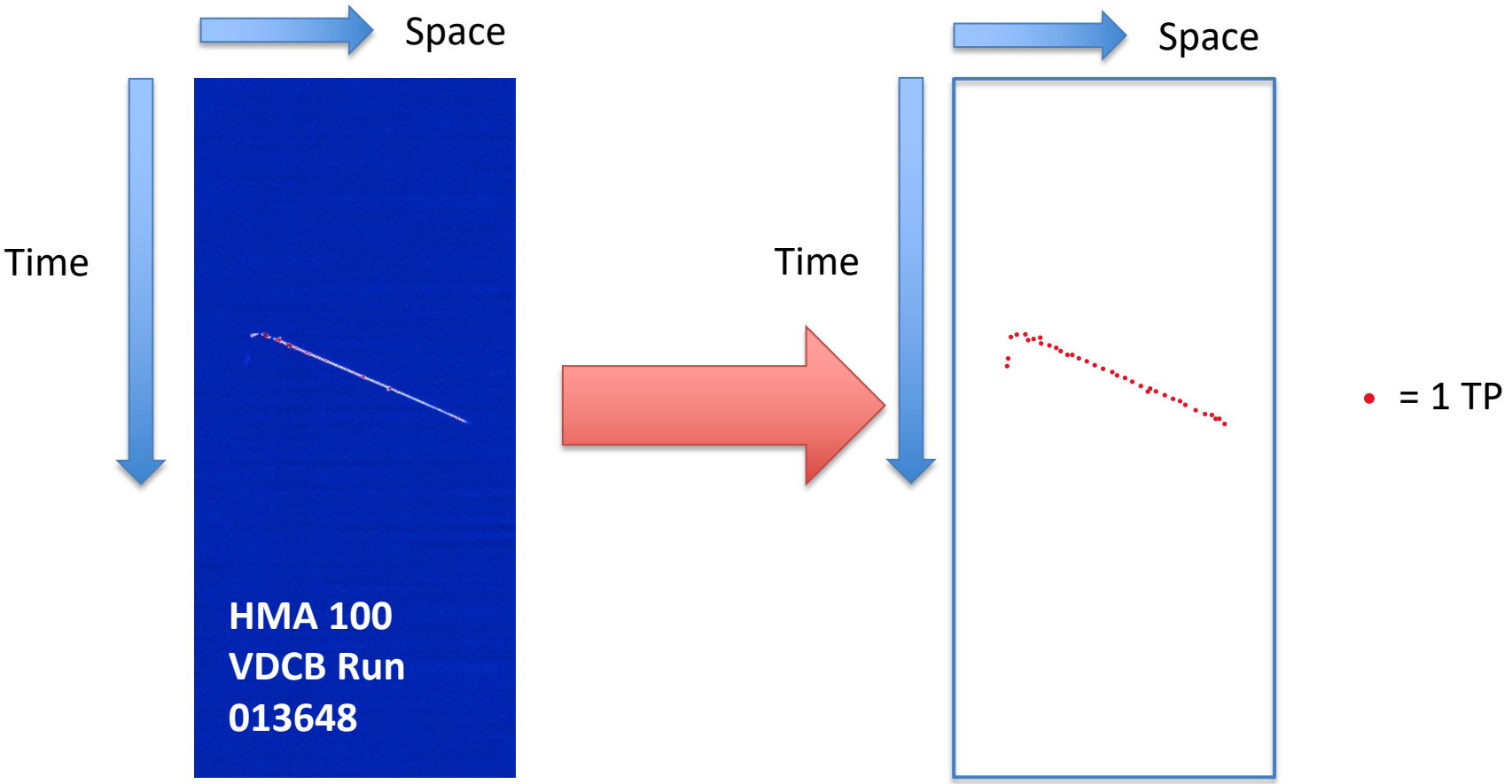
1. (left) A raw event display from a VDCB run
2. Take a window that spans all space s but fixed time interval Δt from the top of that display
3. Allow this window to slide along increasing time, so that the raw data within the window can be observed
4. Finally, turn on your algorithm checks to identify your physics event – sound the alarm!

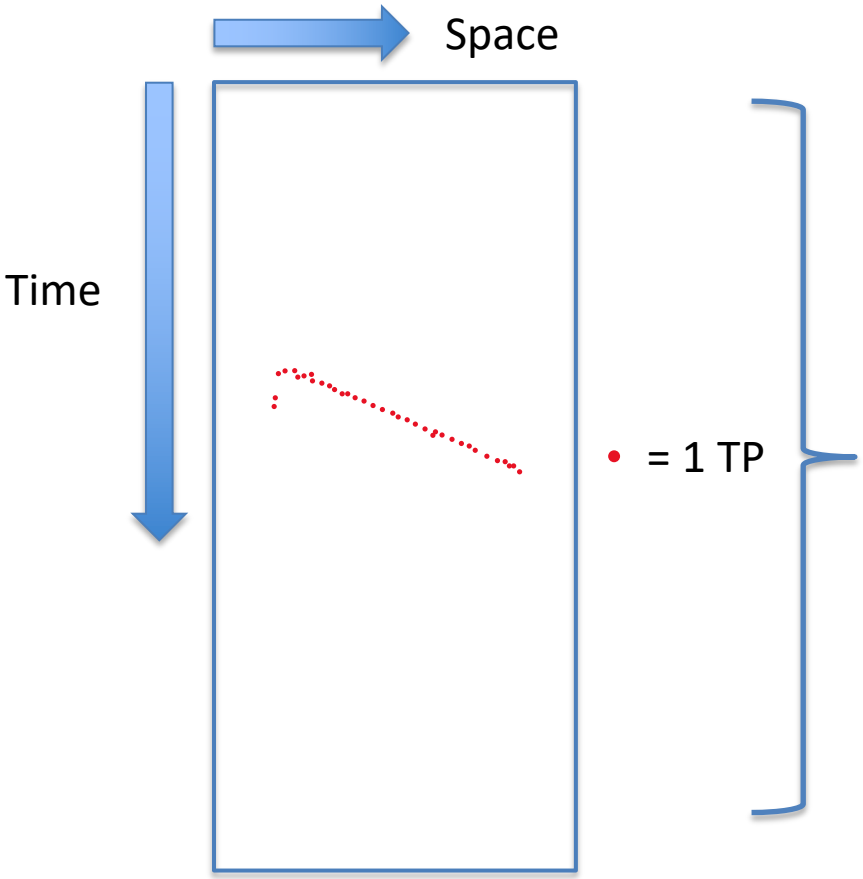
DUNE DAQ Triggering

- In practice, we don't see the raw data, but a down-sampled representation of it described in terms of Trigger Primitives (TPs).



DUNE DAQ Triggering

- What we're left with is the below. A fixed size window which is subject to a constant stream of TPs that are time-ordered.



- Start Time
- Peak ADC Time
- ADC Integral
- ADC Peak
- Offline Channel Number
- Time Over Threshold
- Detector ID
- Type

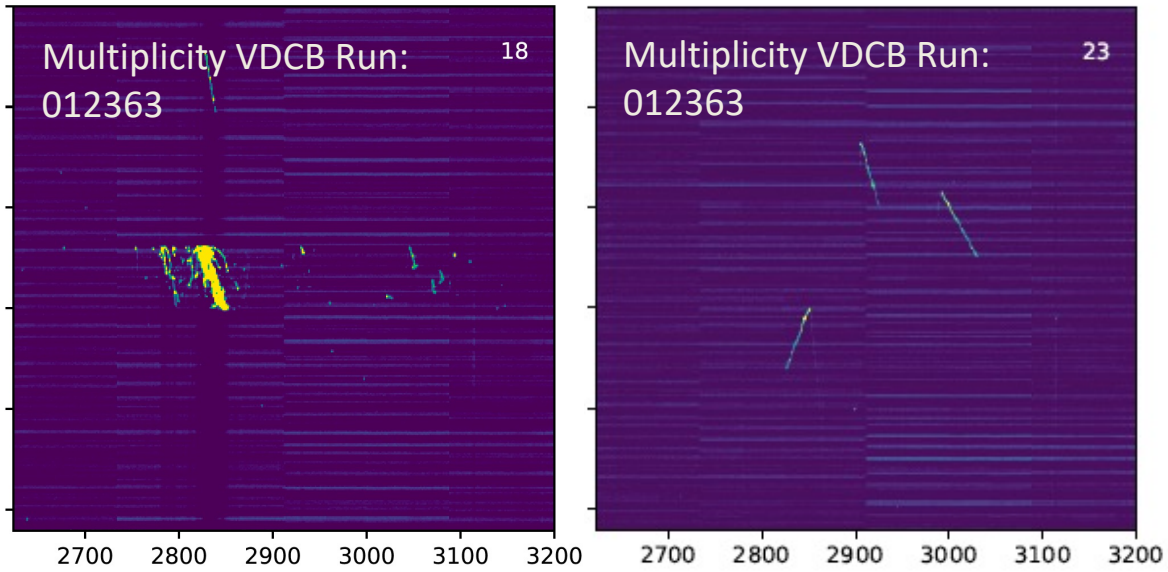
Trigger Algorithms

Triggering Terms

- Vertical Drift Cold Box = VDCB
- Trigger Record = TR – Roughly equivalent to a LArSoft Event
- Adjacency = Property of physics activity across many contiguous wire channels
- Trigger Primitive = TP – Roughly equivalent to a “Hit” in LArSoft
- Thresholds – Parameters that must be met for triggering to progress within algorithms
- HMAX = HorizontalMuonAlgorithm + Adjacency Threshold (eg HMA 60, 60 Adjacency Threshold)
- Trigger Candidate = TC

Multiplicity - December 2021

- In December 2021, the first triggering runs with software generated TPs were taken on the **Vertical Drift Cold Box (VDCB)** at EHN1, CERN.
- A simple, single parameter **channel multiplicity** algorithm was used to identify snippets of activity.

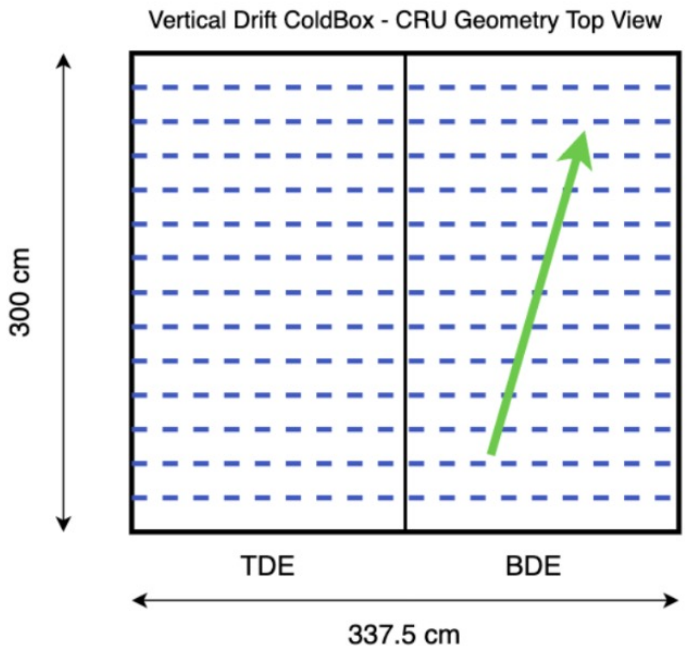


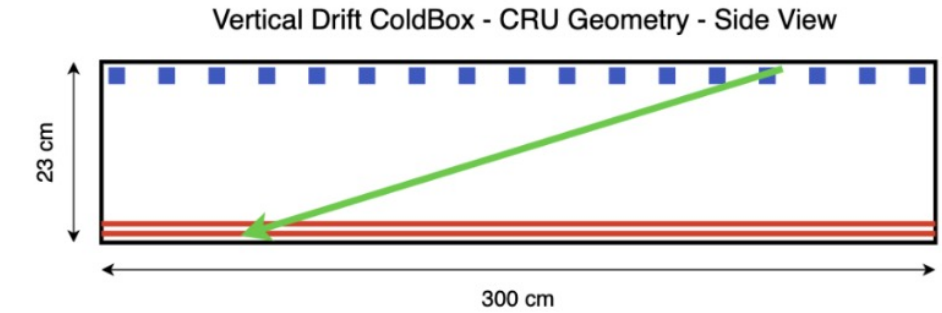
That parameter was defined to be: **the minimum number of unique channels with TPs, within the current time window** before issuing a trigger command.

Parameter	Value
Multiplicity	10
Multiplicity	15

Toward Track Triggering

- With software TP triggering demonstrated, the next goal was to identify activities with large horizontal components, filtering out the multitude of mostly vertical cosmic tracks in the VDCB.
- We introduce **adjacency** checking into our algorithm, and call it the **Horizontal Muon** algorithm.





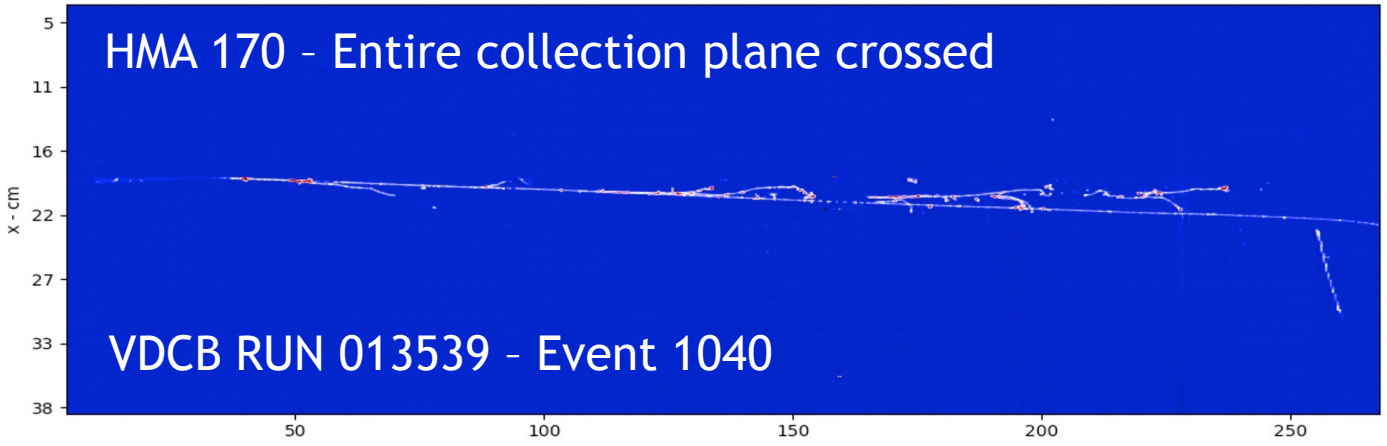
= Horizontal Muon

= Collection Wires

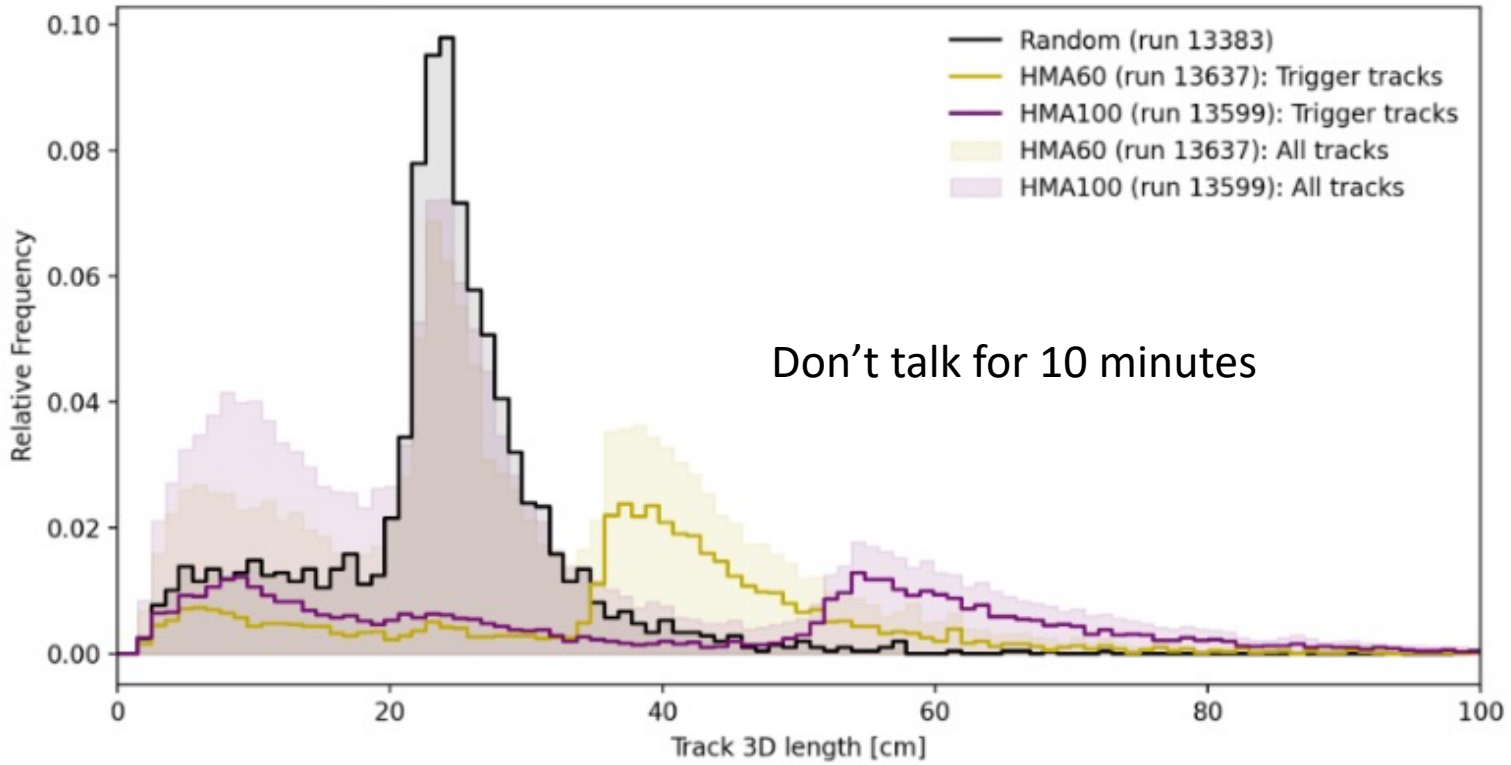
Adjacency = Minimum number of contiguous collection channels with TPs, within configured time window.

Horizontal Muon Algorithm – June 2022

Run Number	Threshold	TRs Stored	Trigger Rate (Hz)
013511	150	62	0.1
013539	170	1583	0.07
013599	100	52116	2.41
013600	60	10595	8.33
013637	60	23536	6.53
013648	100	33216	1.39



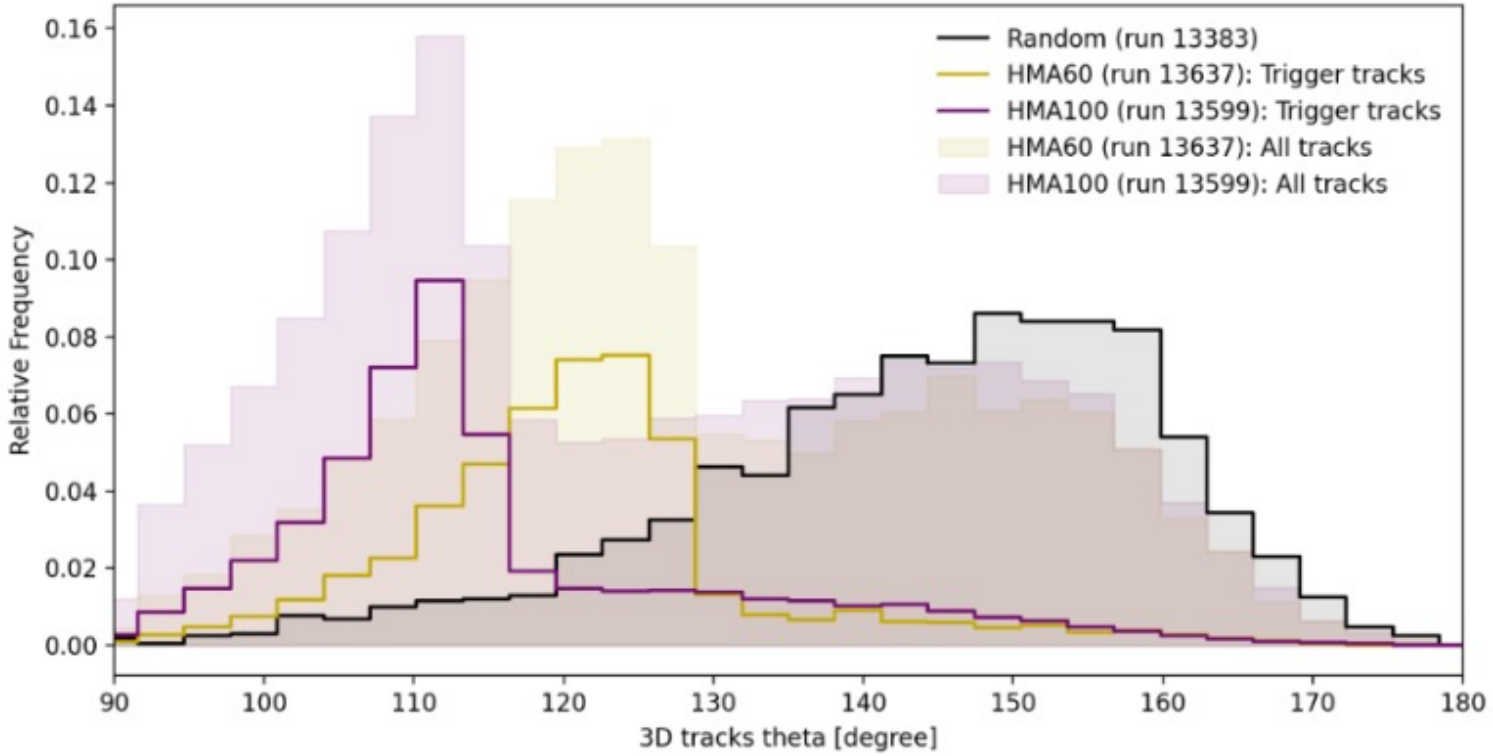
Horizontal Muon Algorithm – June 2022



Don't talk for 10 minutes

1. Small snippets of activity common to ~all triggered events
2. Peak surrounding drift length of the VDCB ~21-22cm (Vertical cosmics)
3. Following peaks for 60 wires, 100 wires

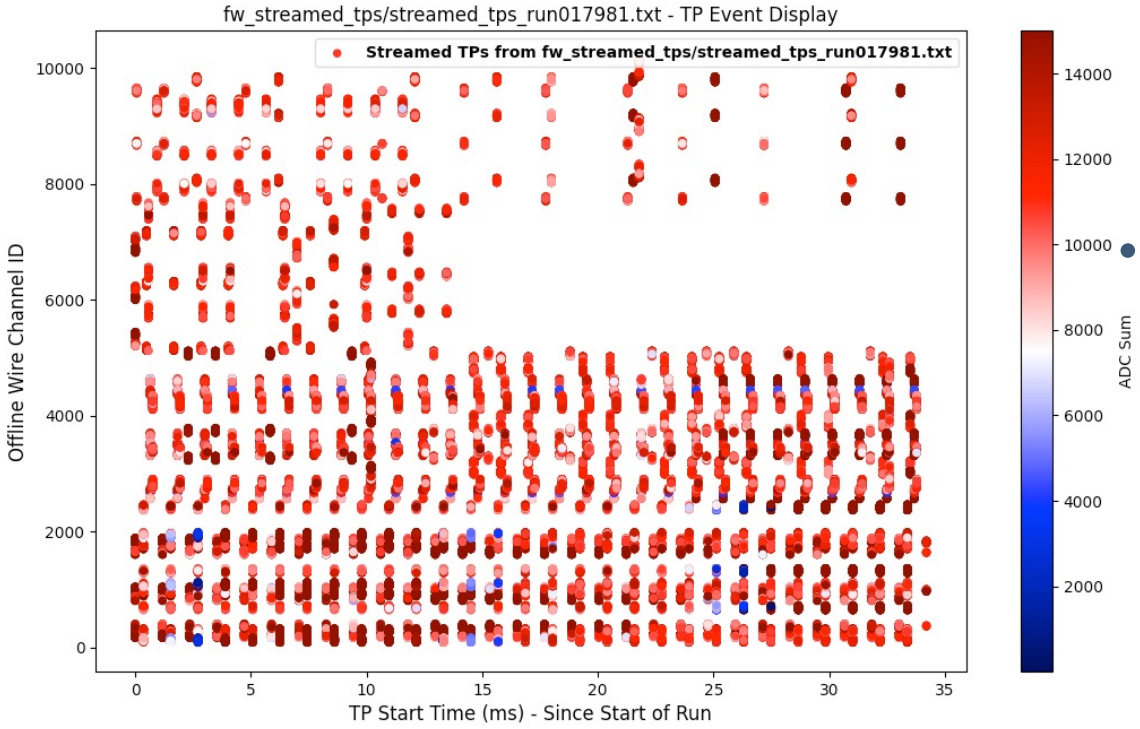
Horizontal Muon Algorithm – June 2022



1. HMA 100 – Largest horizontal components at 90 – 110°
2. HMA 60 – Second largest horizontal components 110 – 130°
3. Wide peak around 150 – 160° for random tracks approaching vertical

Firmware TPG – Triggering

- Below – Sample of Firmware produced TPs as written out by the TPStreamWriter.



- We did also manage to trigger on noise produced TPs from FW runs using the same methods mentioned above.
- These runs have helped to identify issues within the trigger system that are currently being worked on.

Future Plans & Algorithms

Coming Up…

1. Late January -> Early February Cold Box Runs
2. ProtoDUNE II -> Summer 2023 (hopefully!)

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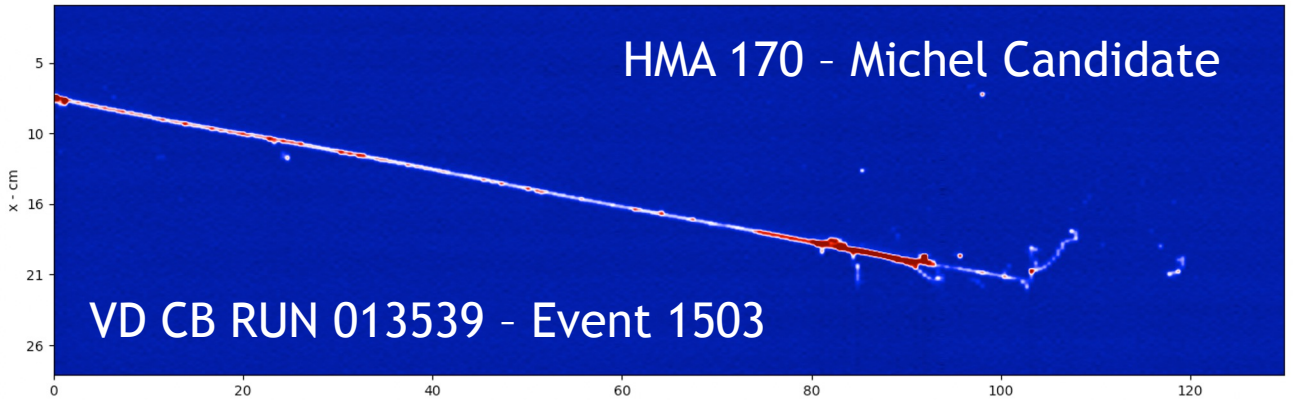
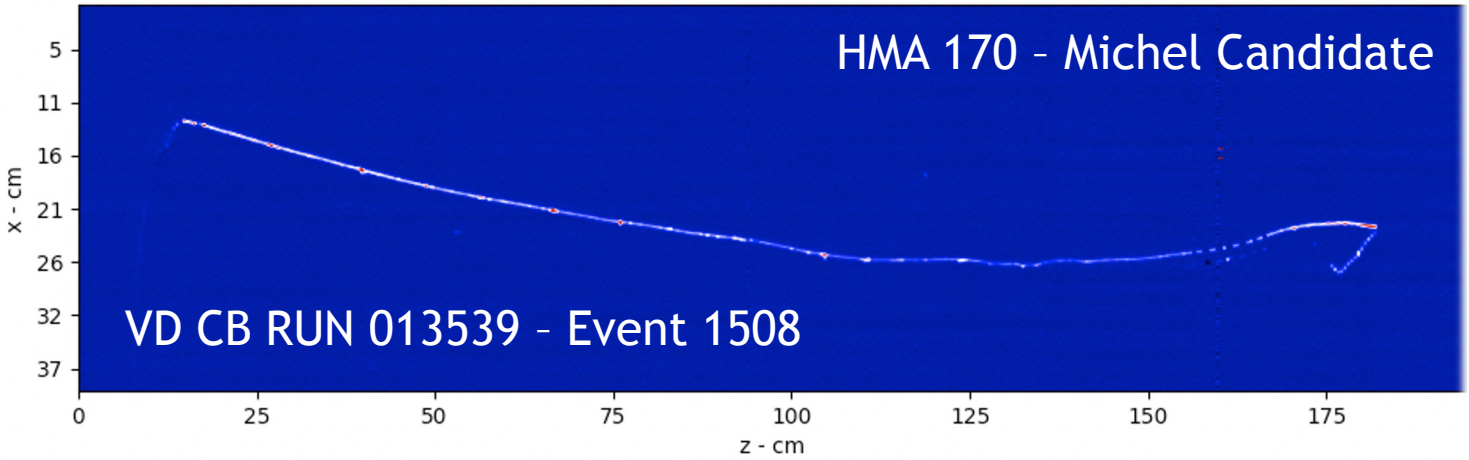
What do we have planned?

Stopping Muon – Michel Events

- The HMA runs contained some candidate Michel electron events in their TRs.





Stopping Muon – Michel Events

- There exists a template algorithm for Michel triggering, which takes the tracks triggered by the HMA, and makes two subsequent checks:

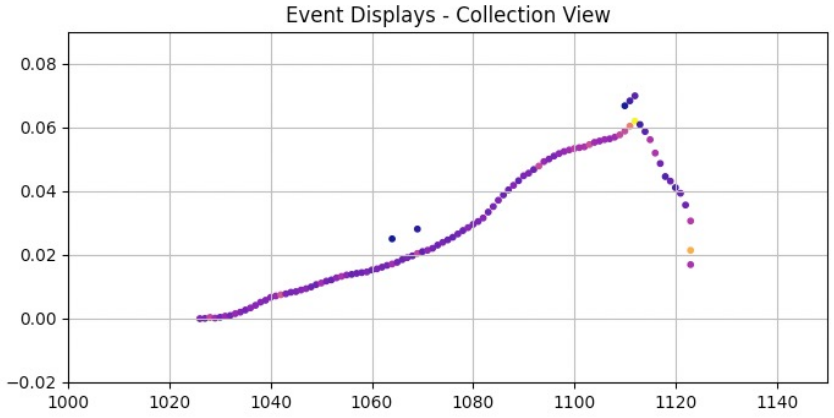
1) Bragg Peak Check

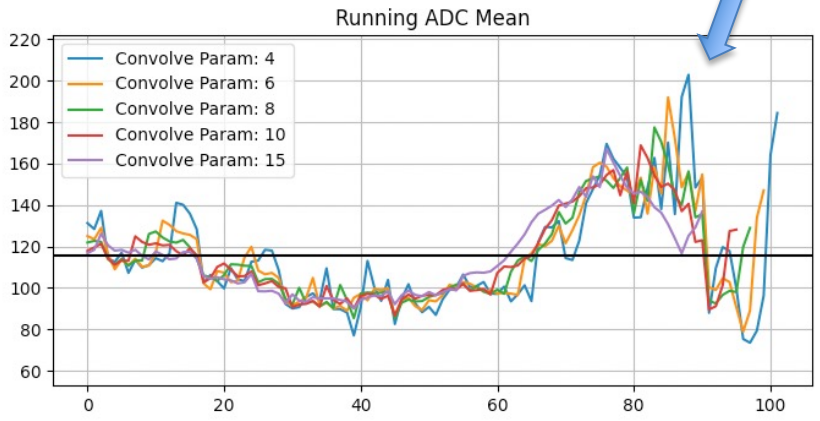
Takes a **convolution** parameter which makes it less sensitive to random fluctuations in running ADC

Bragg parameter is a threshold ADC relative to the running mean to be reached

Bragg Peak

ColdBox Simulation - 300 MeV μ^-s





Stopping Muon – Michel Events

- There exists a template algorithm for Michel triggering, which takes the tracks triggered by the HMA, and makes two subsequent checks:

2) Kink Check

Takes a **convolution** parameter which makes it less sensitive to random fluctuations in running gradient

Deviation parameter is a threshold gradient relative to the running mean to be reached

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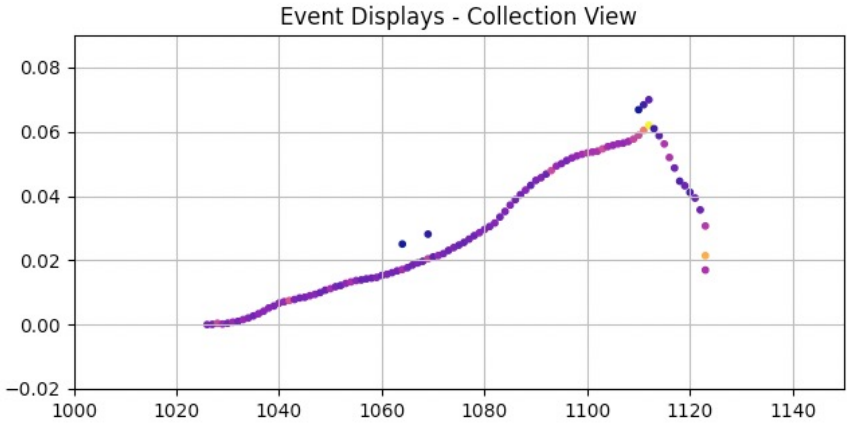

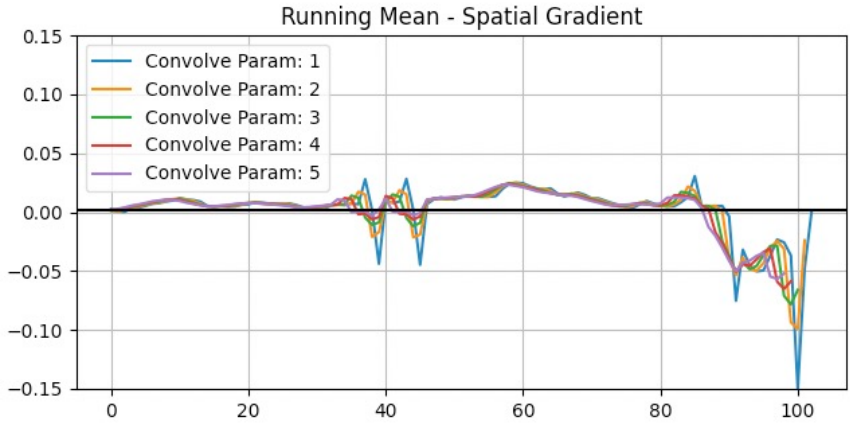

Low Energy Events

- There also exists a template algorithm which has three concurrent search windows, one for each wire plane:
  - https://github.com/DUNE-DAQ/triggeralgs/blob/develop/src/TriggerActivityMakerLowEnergyEvent.cpp

- The three windows fill up with TPs, and currently just check for a combined ADC integral, followed by a short track requirement on the collection plane (3 wires for example).

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- In the future we hope to include Photon Detection System (PDS) TPs here also, where we can check for coincident flashes alongside low ADC short tracks

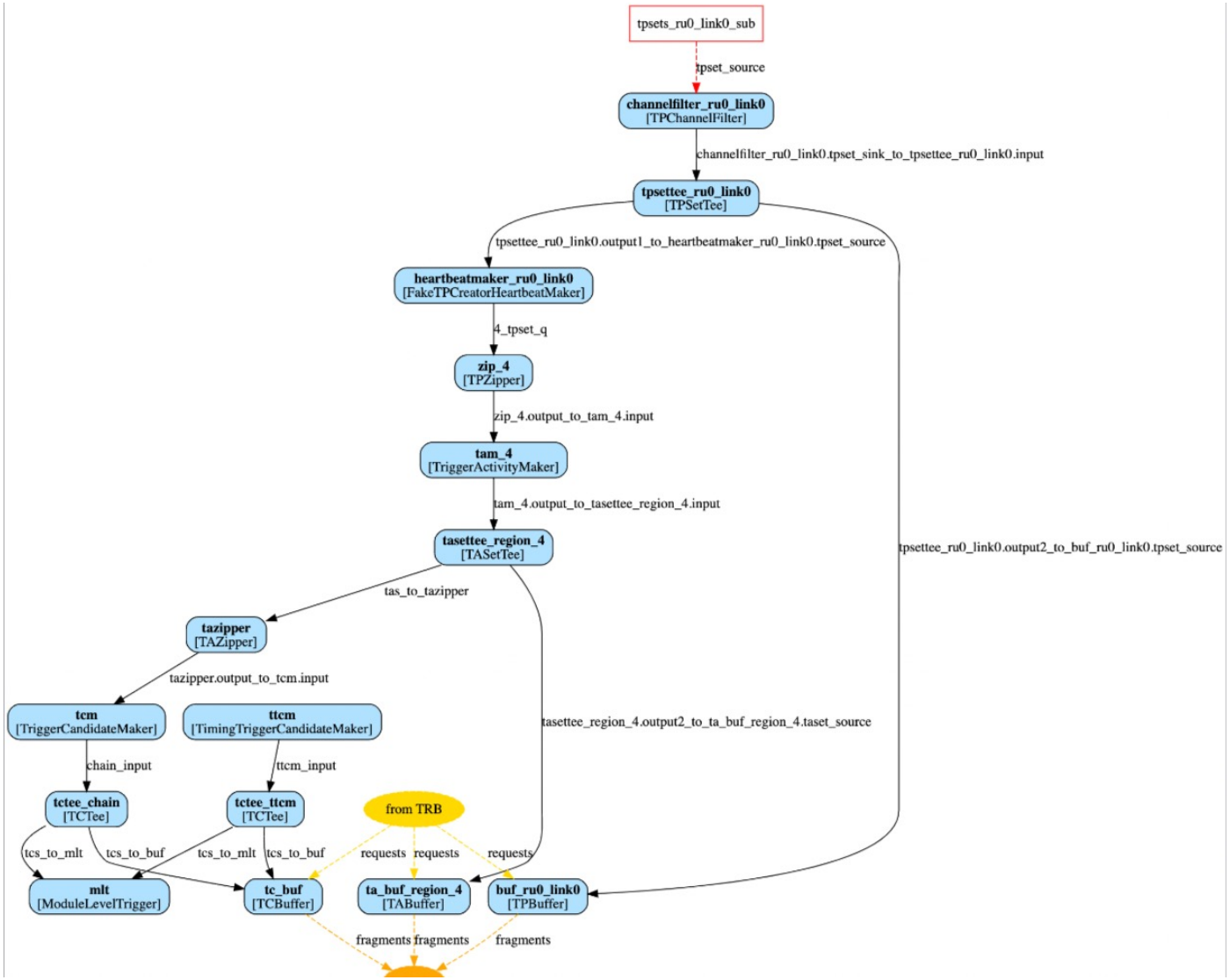
- This algorithm is here to serve as a toy model for triggering on specific event topologies!

Summary

- **TP Clustering & Triggering** – Extensively demonstrated throughout December 2021 and June 2022 runs
- **November Software TPs** – Managed well up to about 7 active links. Above this, the system struggled to keep up, and we begin to see “tardy” (late) data requests made by trigger.
- **November Firmware TPs** – Triggering on noise/pulsing worked when cardinality was manually set to 1 and extracting ADC information from 4 WIB links.
- **Future Algorithms –** Michel triggering, Low energy events etc…

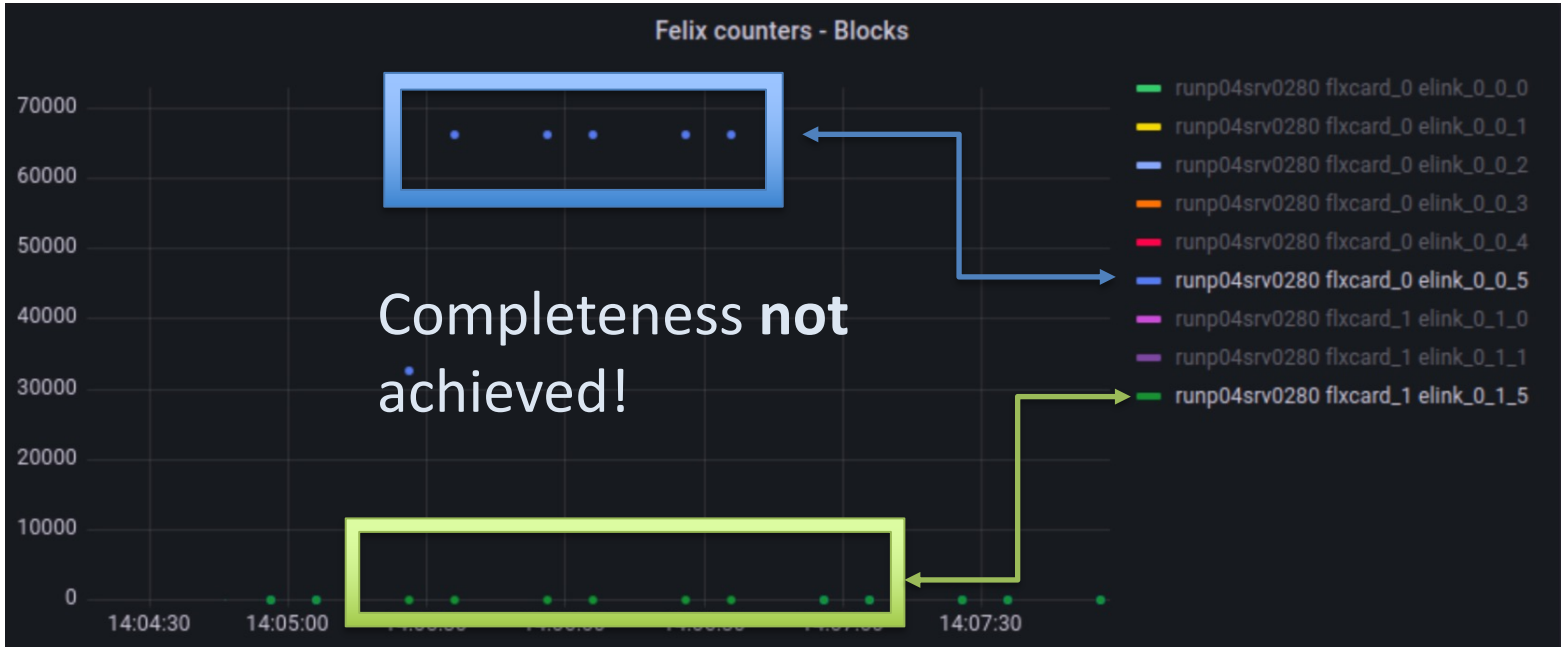
Backup Slides

Trigger System Diagram



Completeness & Cardinality

- Trigger has a configurable parameter called the **cardinality**. It is set to the number of expected TP input queues.
- We also have a measure called **completeness.** This checks that we're seeing TPs across an appropriate number of input queues.



Completeness & Cardinality

- When completeness is not achieved, all TPSets are kept in the ring buffer of the TPZipper until **stop time**.
- At this point, **all TPSets** are released and and attempt to push them all through the system at once results in many FollyQueue timeout errors.