ProtoDUNE-BSM: Detector Simulation

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ProtoDUNE-BSM Collaboration Meeting

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Introduction and Outline

- We would like to develop a **trigger** that minimises cosmic backgrounds
- Want to know if BSM events, such as HNL decays, could be **reconstructed** and **selected**
- Need a **simulation** of interesting events in ProtoDUNE with a full **detector response**
- Began working with Animesh to **simulate HNL decay products** in **ProtoDUNE Horizontal Drift (HD / NP04)** and the **detector response**

HNL Simulation

- Salvador has provided **HEPEVT** format files for **HNL** decays in **ProtoDUNE-HD**
- Describes decays of $\mathbf{HNL} \rightarrow \boldsymbol{\mu^{-}\pi^{+}}$ and $\mathbf{HNL} \rightarrow \boldsymbol{e^{-}\pi^{+}}$
- HNL **mass** is **1003 MeV**
- Many lines of this:

```
933483 2
1 211 0 0 0 0 -0.216739 0.294149 9.01554 9.02402 0.13957 -1781.7 -1124.93 -2291.14 0.0
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PDG Code

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No mother or daughter particles

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X, Y and Z momentum and total energy

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Particle mass (GeV)

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Initial X, Y, and Z position (mm, later convert to cm)

Particles come from the same decay vertex, so they should be the same

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Time of particle production

HNL Simulation

- A **LArSoft producer module** has been written to **generate** these events in ProtoDUNE

  `HepMCFileGen_module.cc`

- Use the **HEPEVT** file as an input and assume the **ProtoDUNE-HD geometry**
- Run:

  `lar –c run_hepmcfilegen.fcl`

- HNL decays are then generated!

Detector Simulation

- Events are generated, now simulate the ProtoDUNE-HD detector response
- First simulate particle production and propogation with **GEANT4**

```
lar –c standard_g4_protodunehd.fcl –s gen.root
```

- Then simulate the **detector response** (charge on wires etc…)

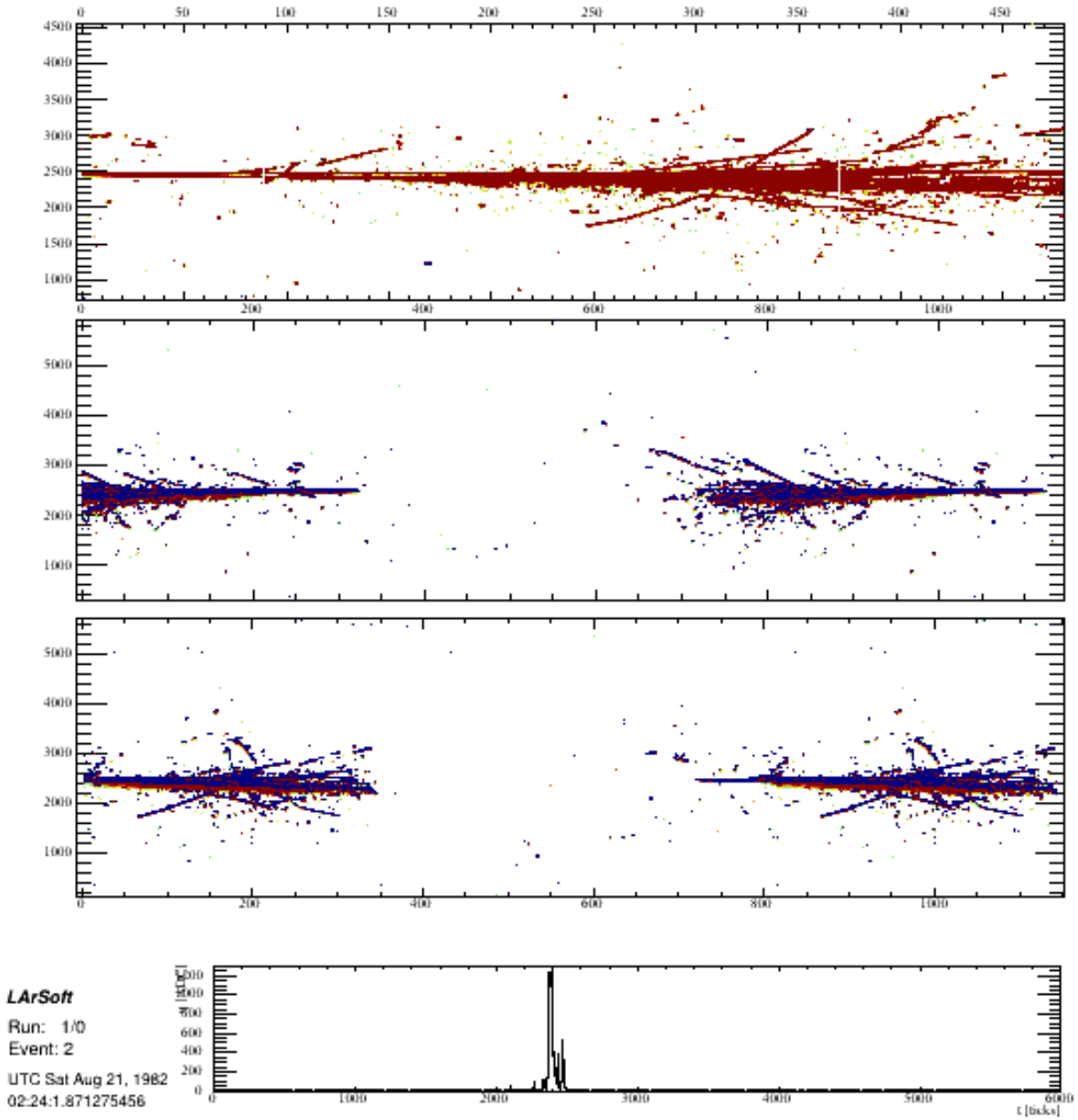
```
lar –c standard_detsim_protodunehd.fcl –s g4.root
```

- Finally apply **reconstruction algorithms** (not yet considering, but runs without error)

```
lar –c standard_reco_protodunehd.fcl –s detsim.root
```

Event Displays

- Simulated HNLs are **very high energy**
- Very high energy decay products – big showers!
- This event has
  - 29 GeV μ^-
  - 30 GeV π^+

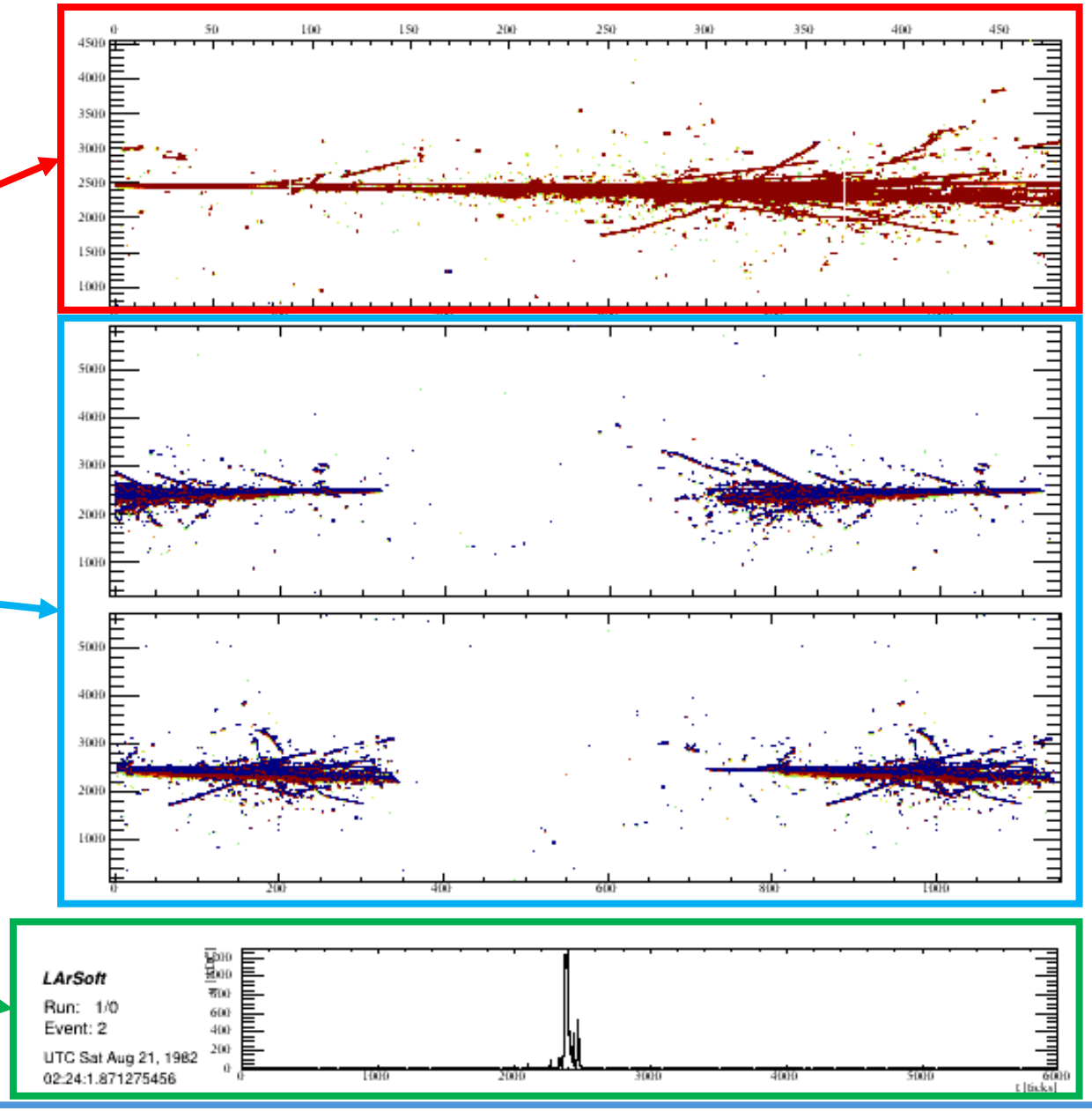


Event Displays

Collection Plane

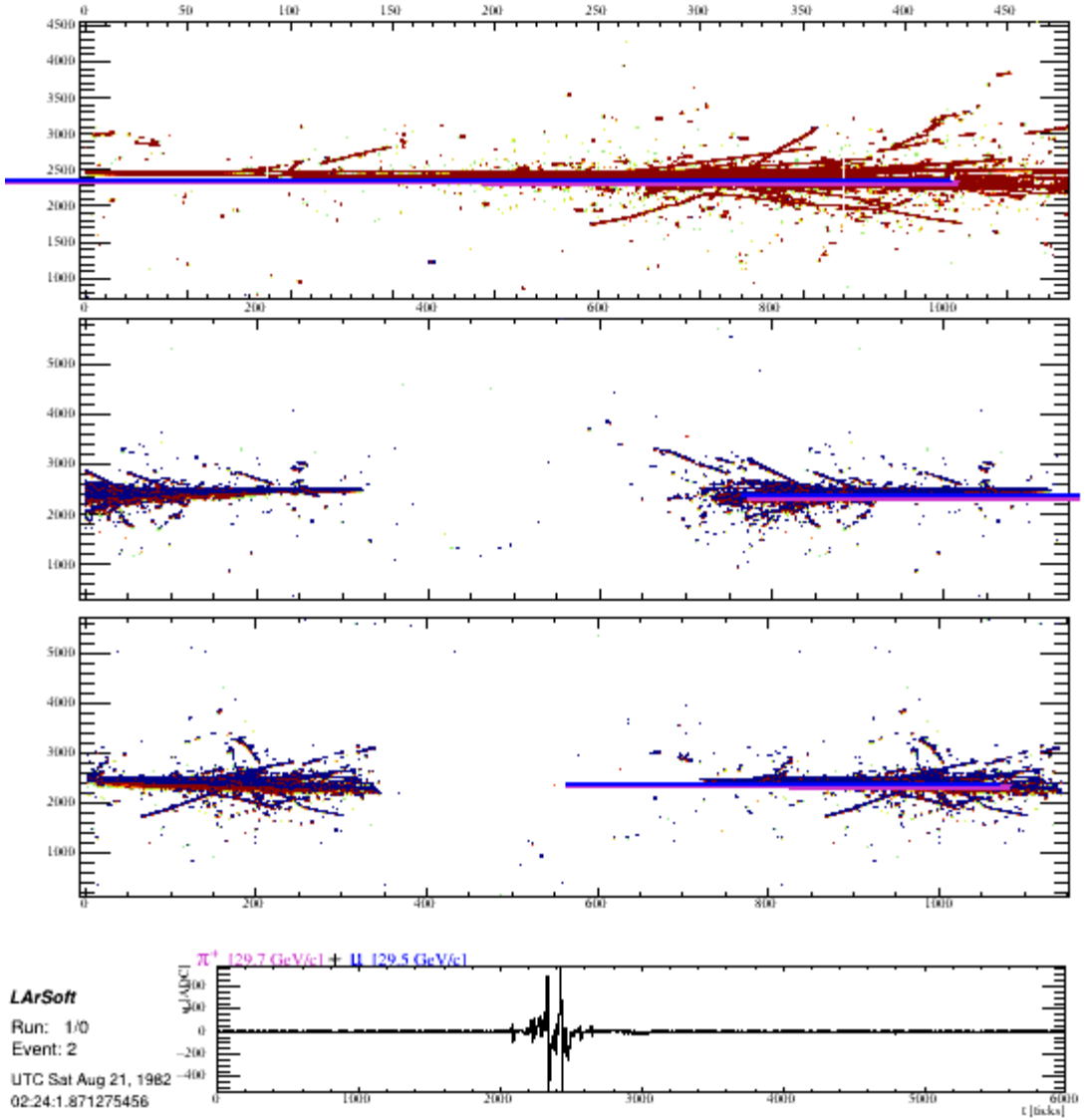
Induction Planes

Individual wire response



Event Displays

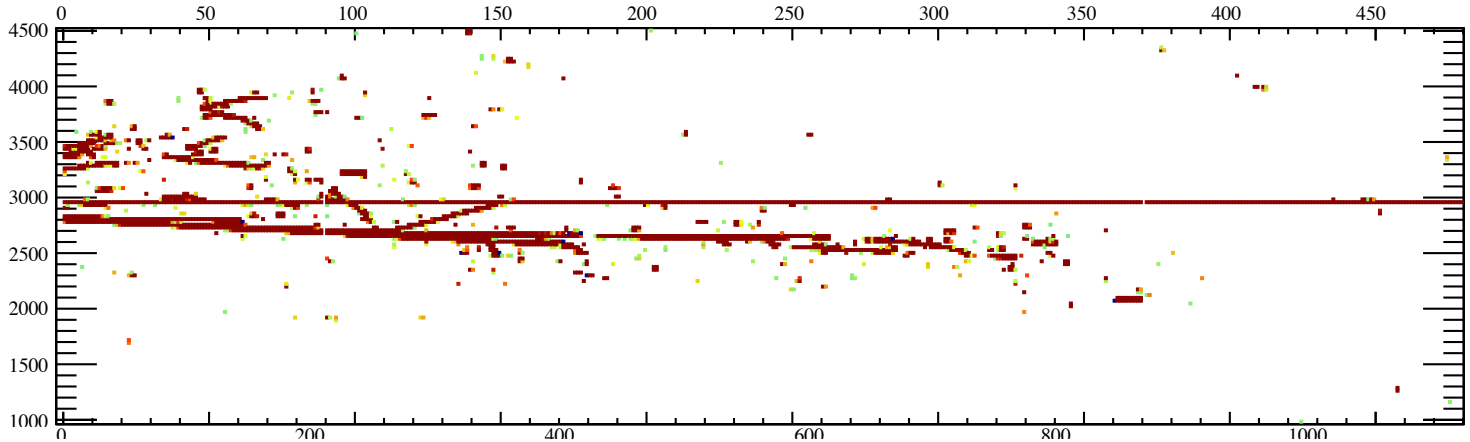
- LArSoft can draw true lines for the path of the generated particles
- *Mostly* line-up with the energy deposits in the detector… may need some investigation
- This event has
  - 29 GeV μ^-
  - 30 GeV π^+



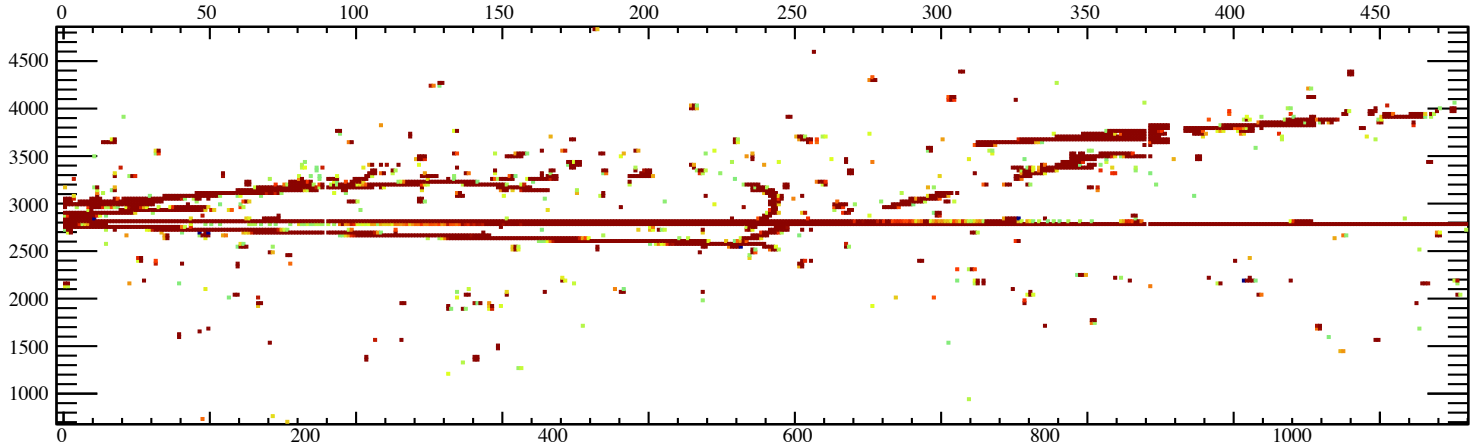
Event Displays

- Very **high energy pions** could be **challenging** to recontruct
- Look at events with lower (**< 10 GeV**) pion energy
- Event **not as messy** – easier for reconstruction to handle?

Collection Plane: 98 GeV μ^- and 8.3 GeV π^+

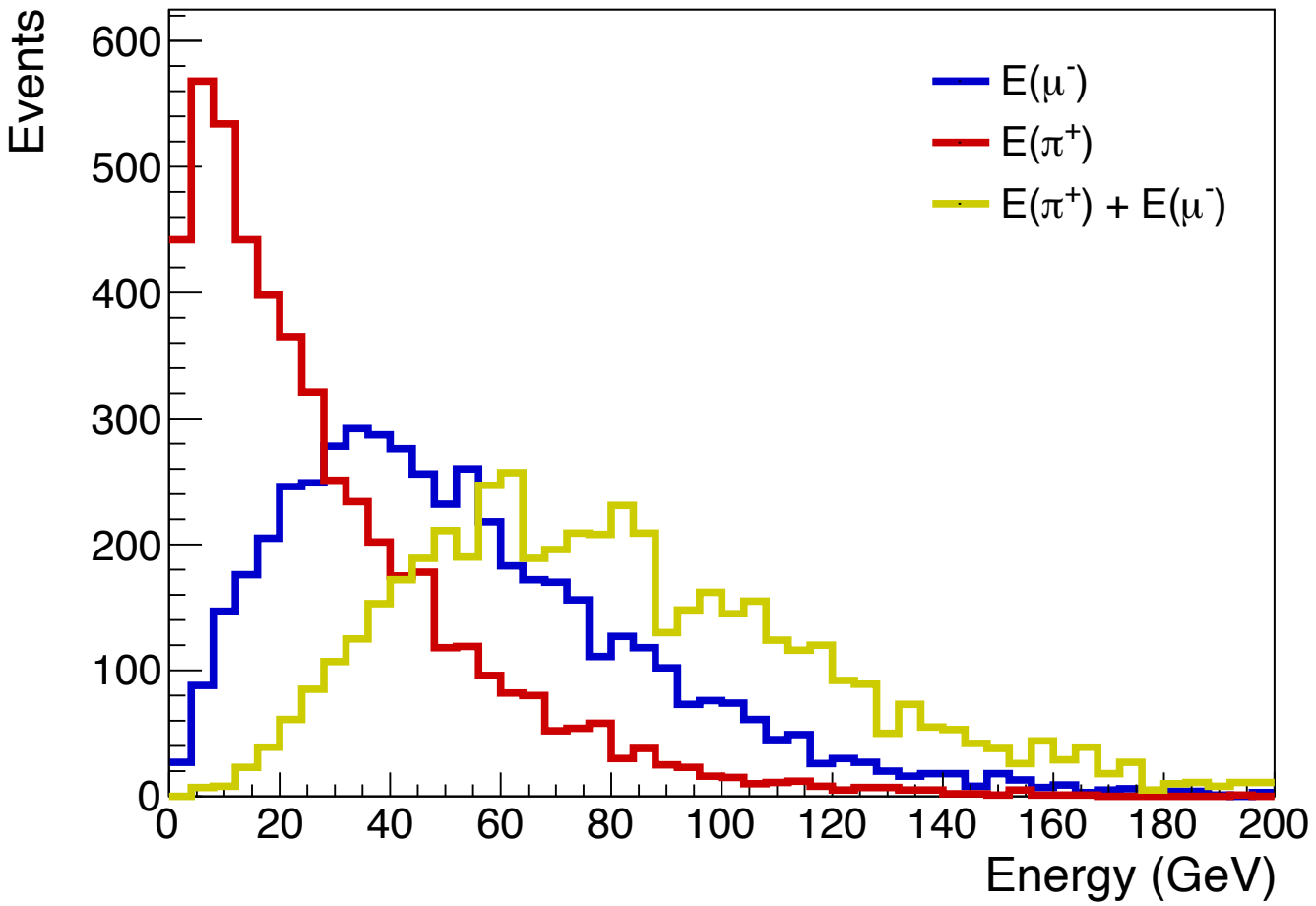


Collection Plane: 10.7 GeV μ^- and 9.0 GeV π^+



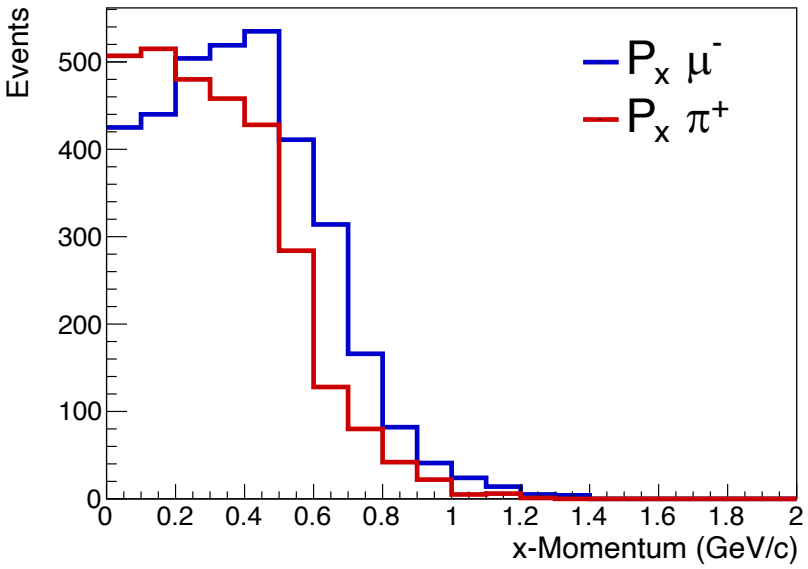
HNL Decay Truth Information

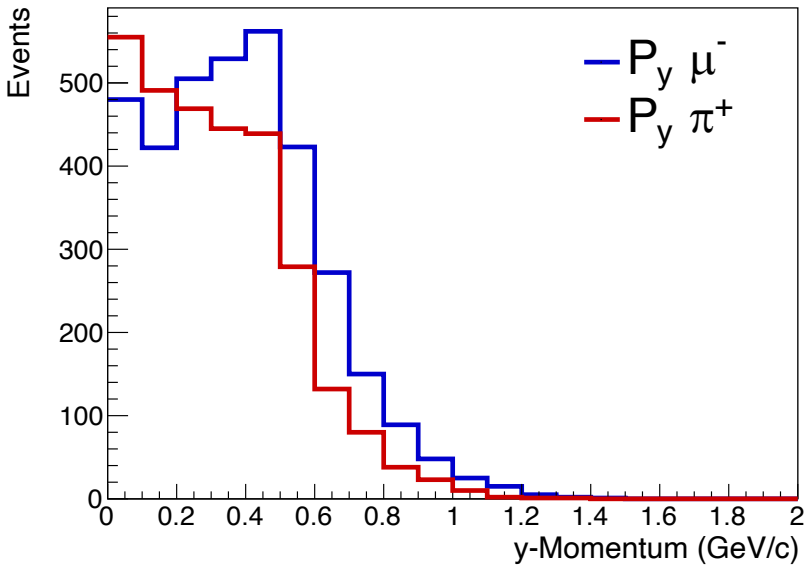
- Plot **truth information** from the event generator
- Different energy distributions for **lepton** and **pion**
- Combined energy of pion and muon ~ **HNL energy**
- Does this match our expectations based on the generated HNL flux? (Hopefully, yes)

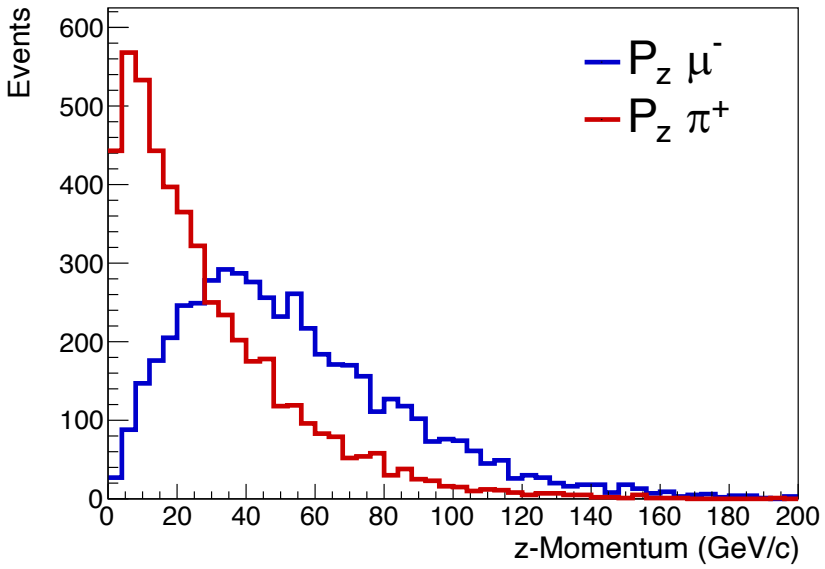


HNL Decay Truth Information

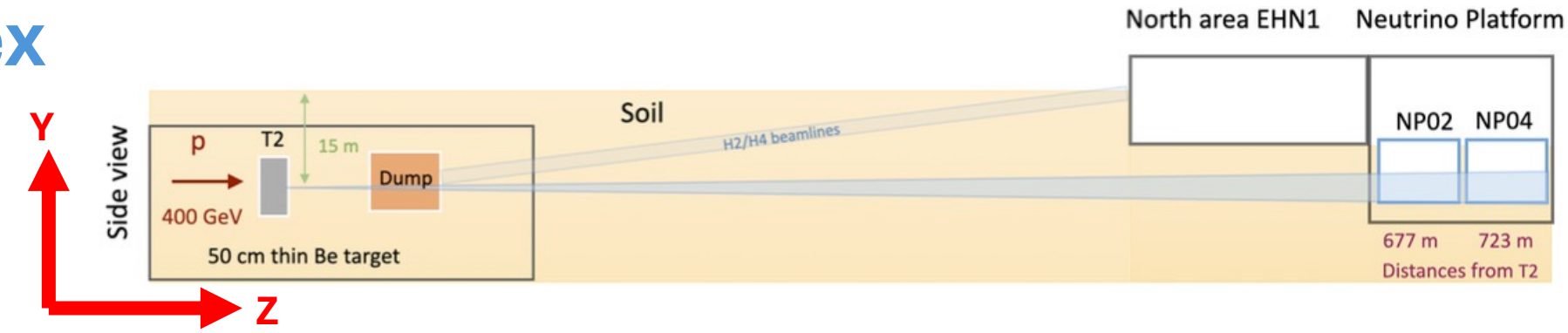
- Almost all the **momentum** of the HNL (and therefore the decay products) is in the **z-direction** – **parallel to the beam**
- Very **low momenta** in **x** and **y** planes



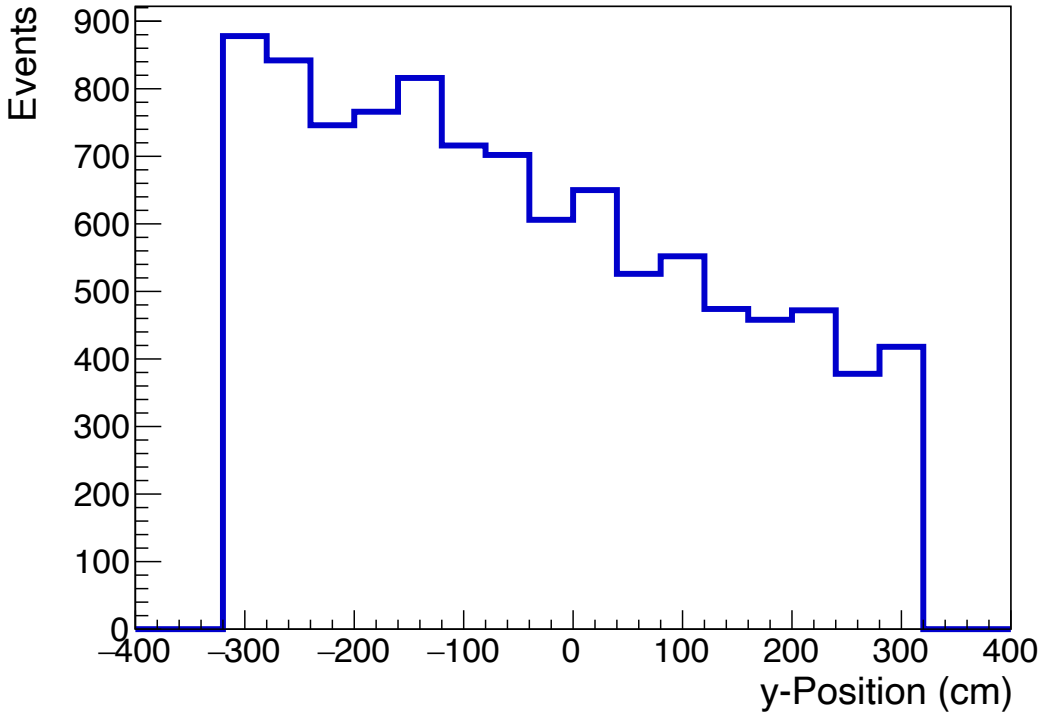




Decay Vertex



- The **beam axis** from T2 points at the **lower half** of ProtoDUNE HD
- We see more HNL decays in the lower half **(-ve Y)** of ProtoDUNE than in the upper half **(+ve Y)**
- This seems sensible?



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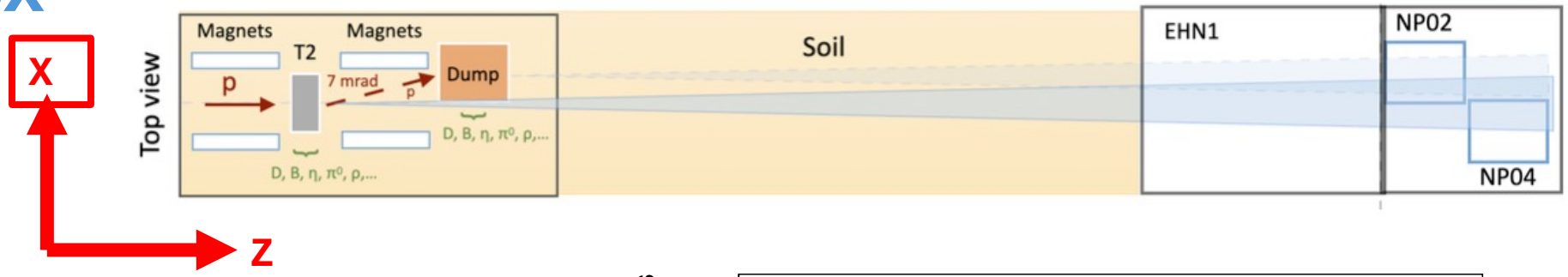
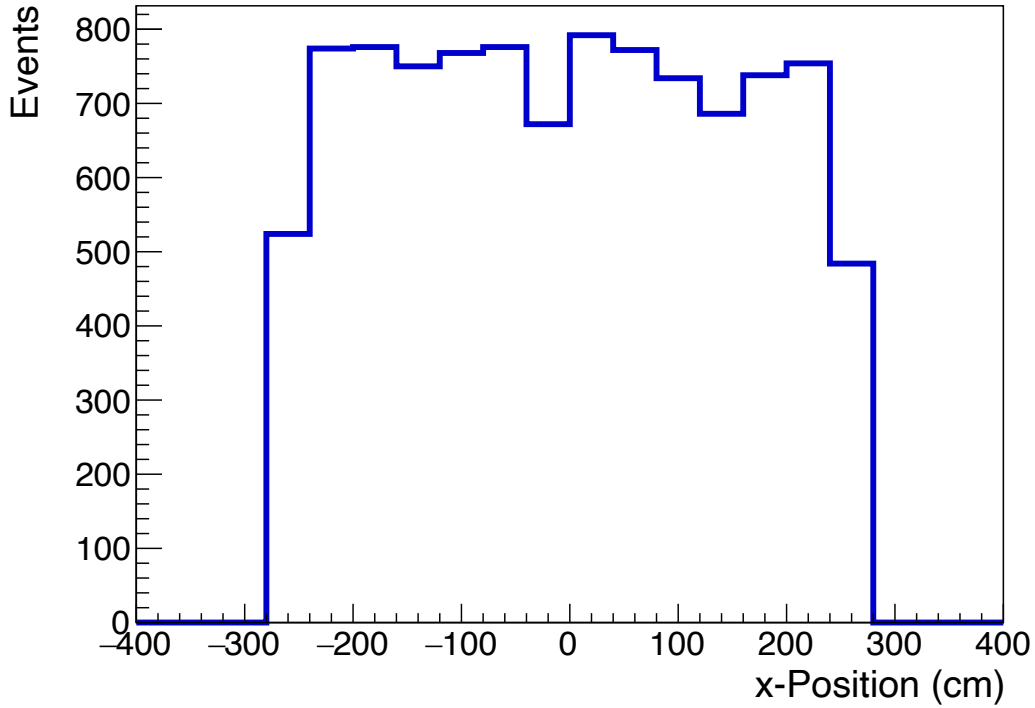


- The **beam axis** from T2 also does not point at centre of ProtoDUNE in the **X-plane**
- Our distribution of vertices in the **x-plane is flat**
- Is this expected? Naively expected a similar distribution to the Y-plane



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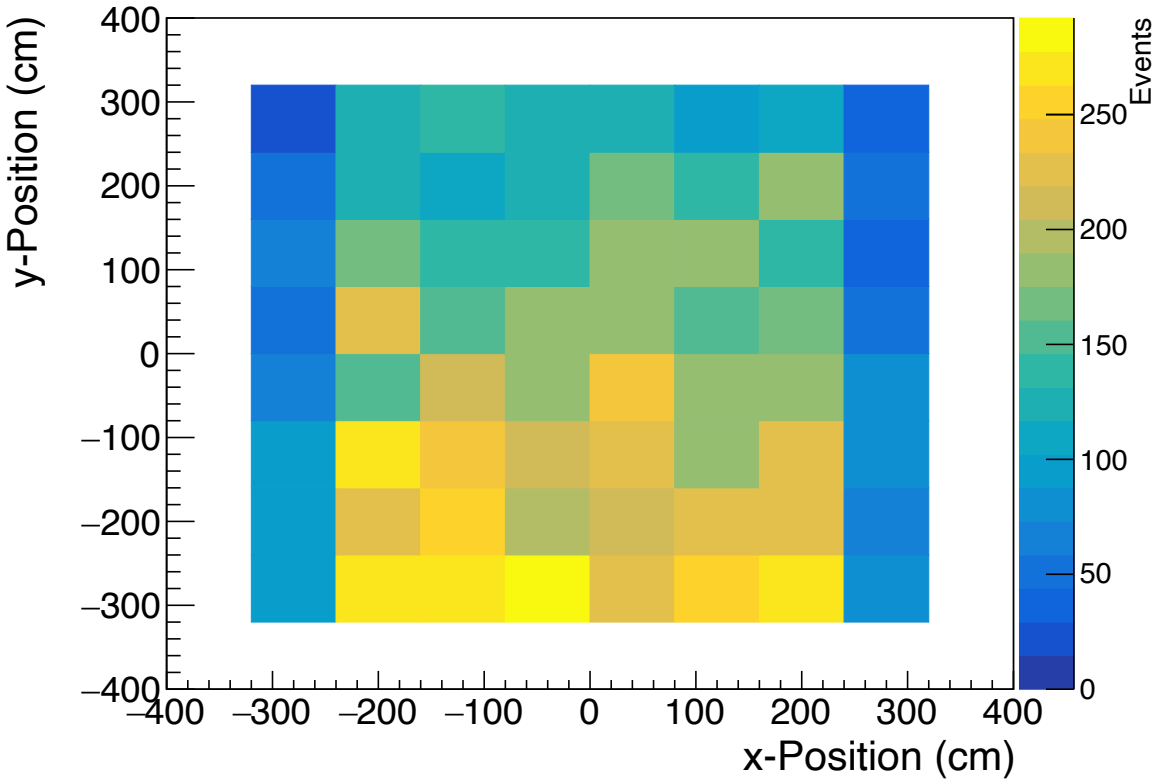
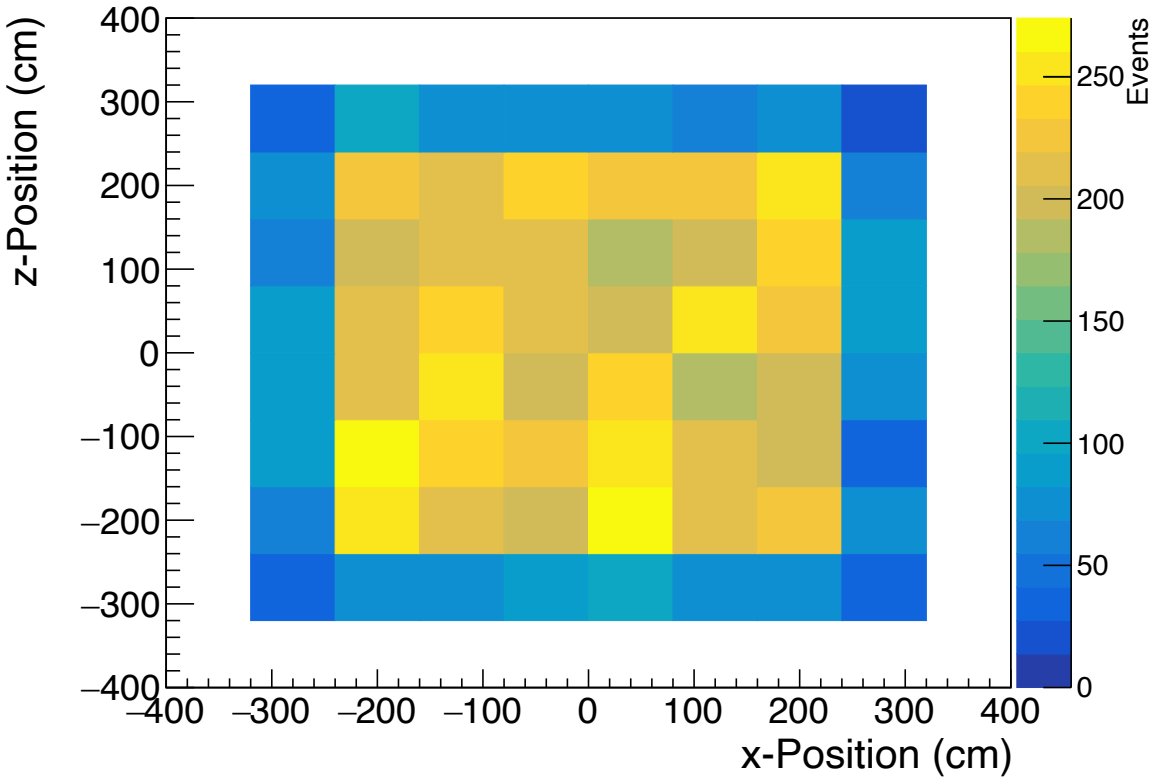


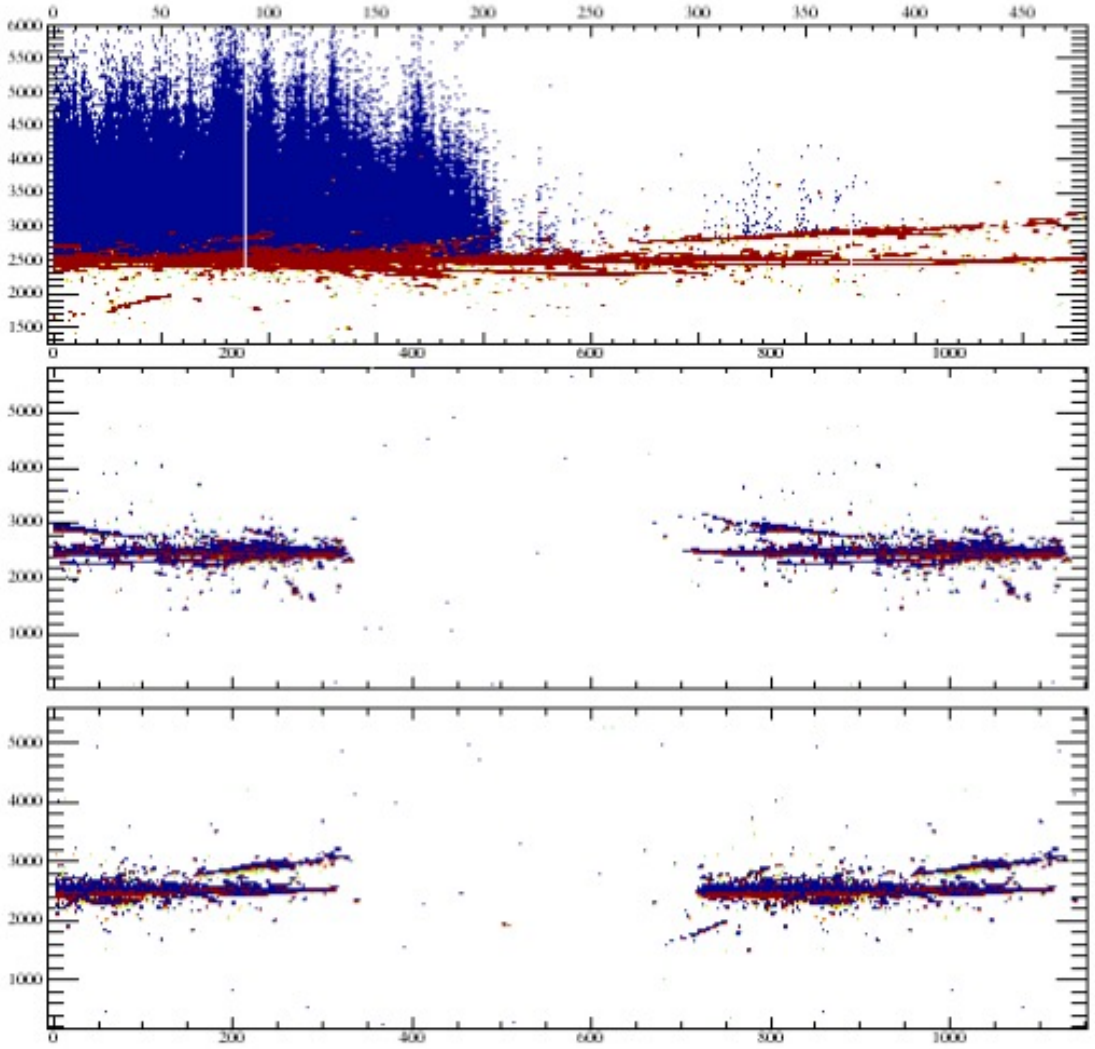


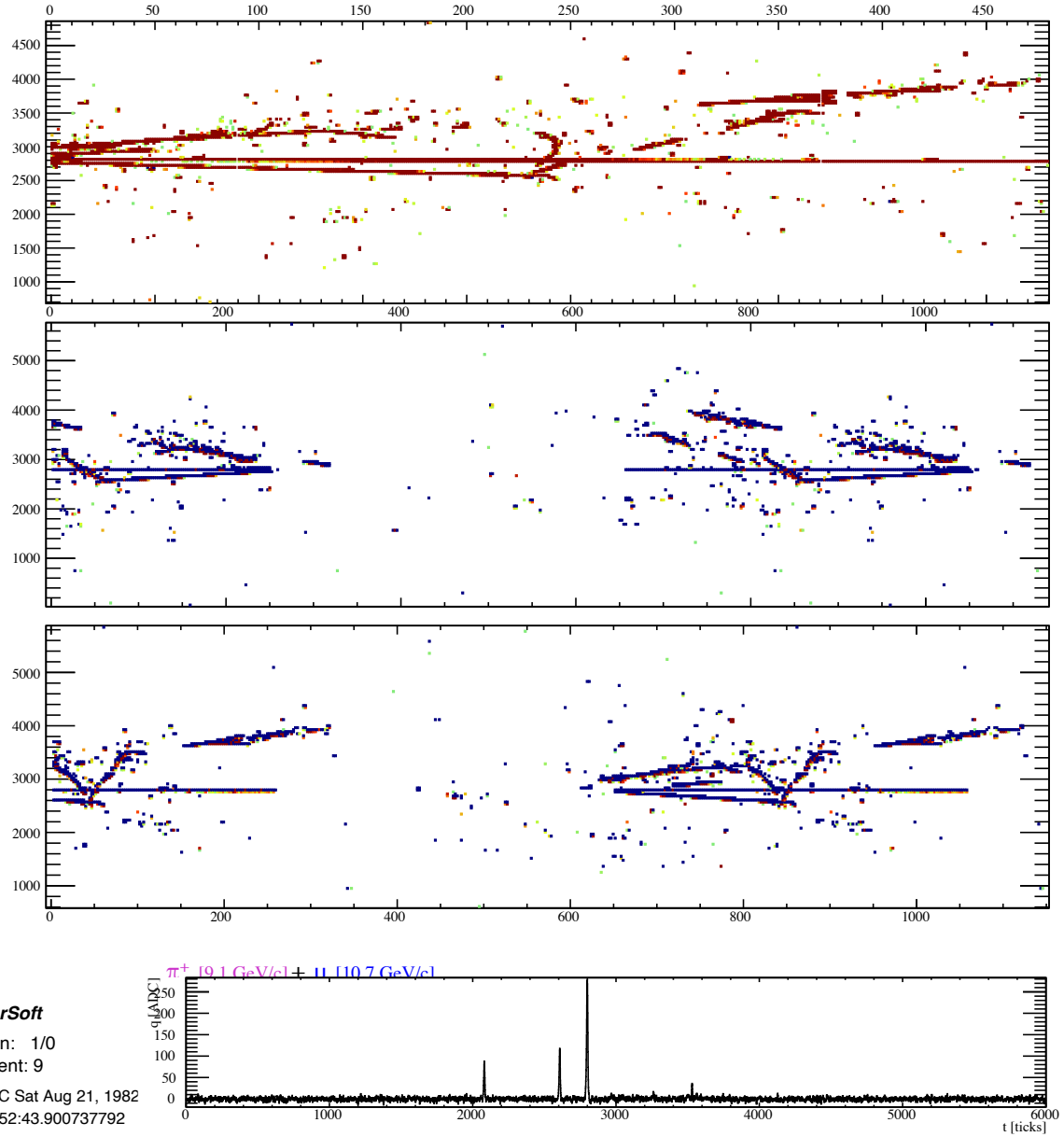
Conclusions and Next Steps

- LArSoft module can **generate HNL decays in ProtoDUNE** horizontal drift
- Full **detector simulation** for those events
- Reconstruction seems to be working as well – this needs more investigation though
- Next steps:
  - Attempt reconstructing tracks/showers with Pandora in LArSoft
  - Develop an analyser module
  - Detector simulation for neutrinos?

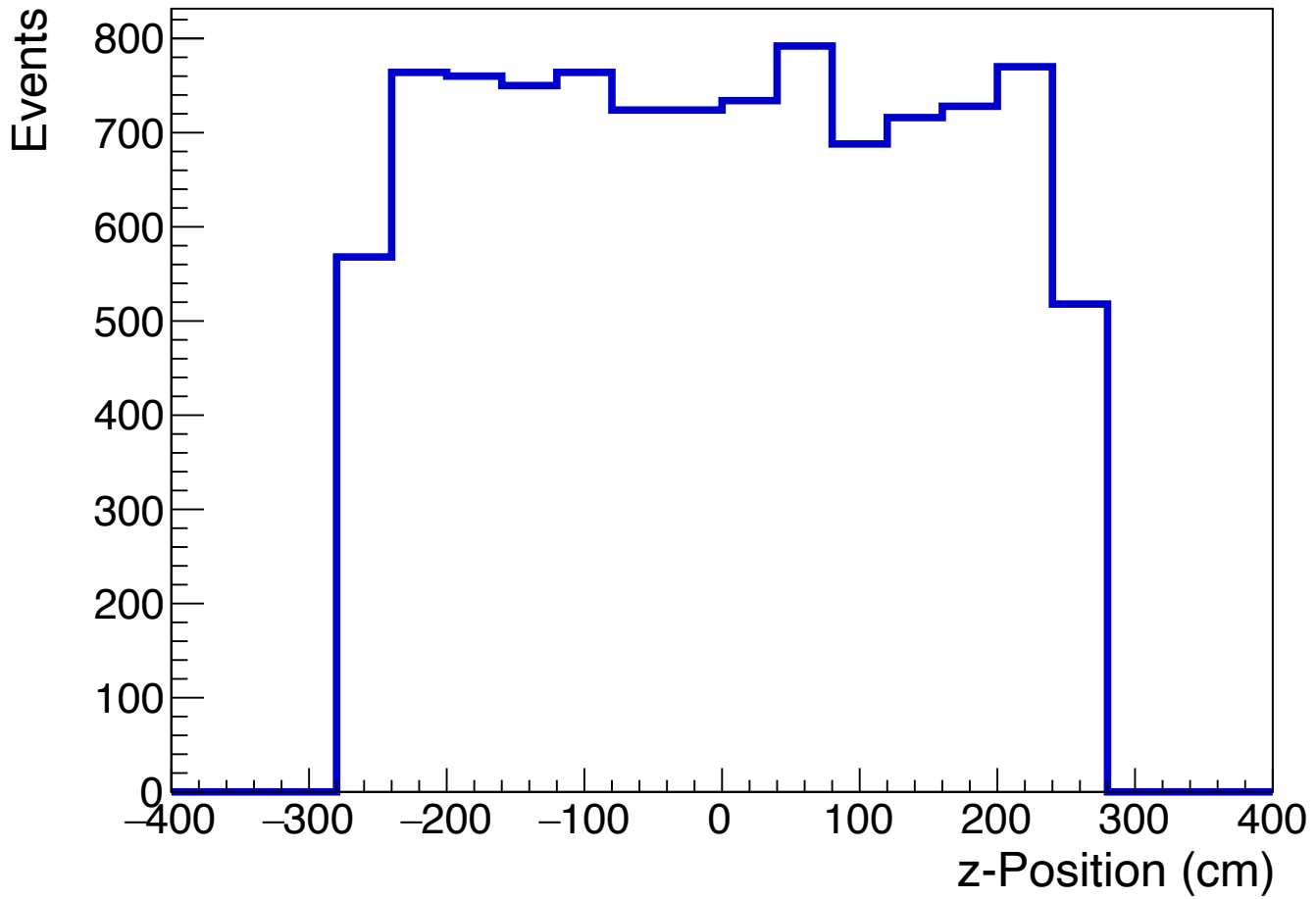
Thank you for listening!

Backup: More Events





Backup: More Momenta/Position



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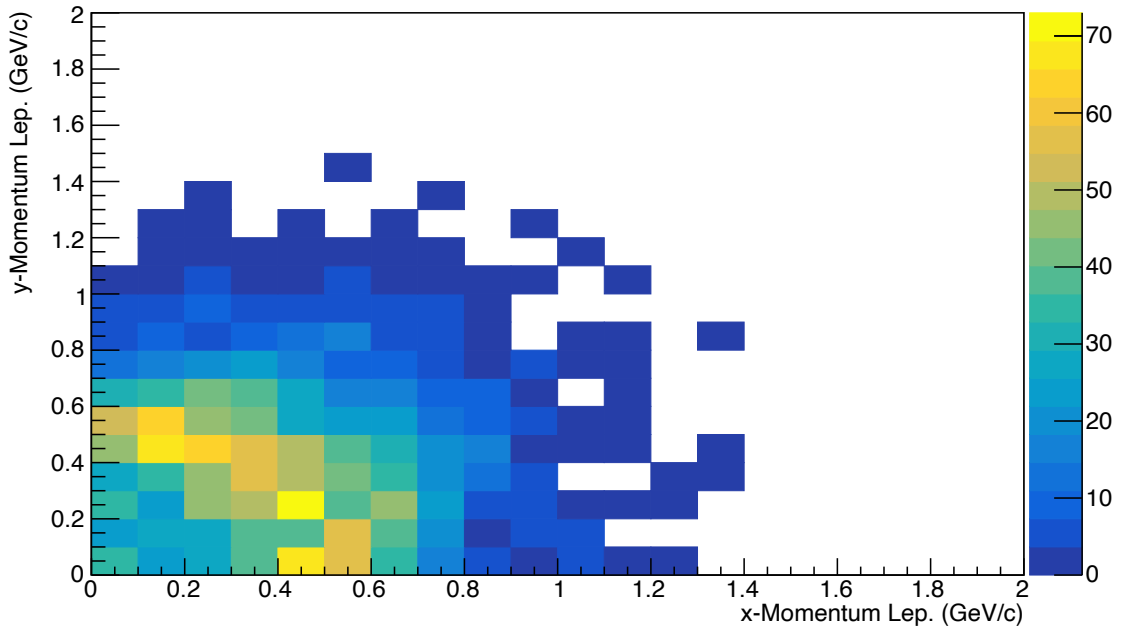

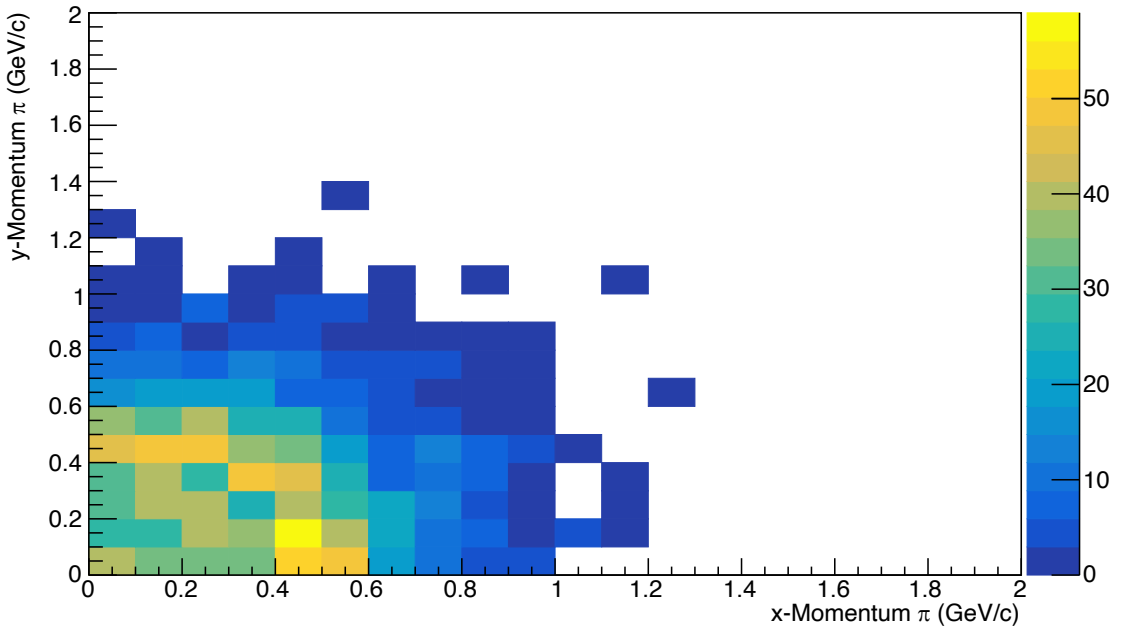

Backup: Reconstruction

Reco hit on wire – seems to be working