UNIVERSITY OF CAMBRIDGE

DEEP UNDERGROUND NEUTRINO EXPERIMENT

ProtoDUNE Update

Leigh Whitehead

5th July 2022

DUNE UK Meeting

Introduction

- ProtoDUNE is now a rather ambiguous name
  - We have three detectors to think about!

- ProtoDUNE-SP

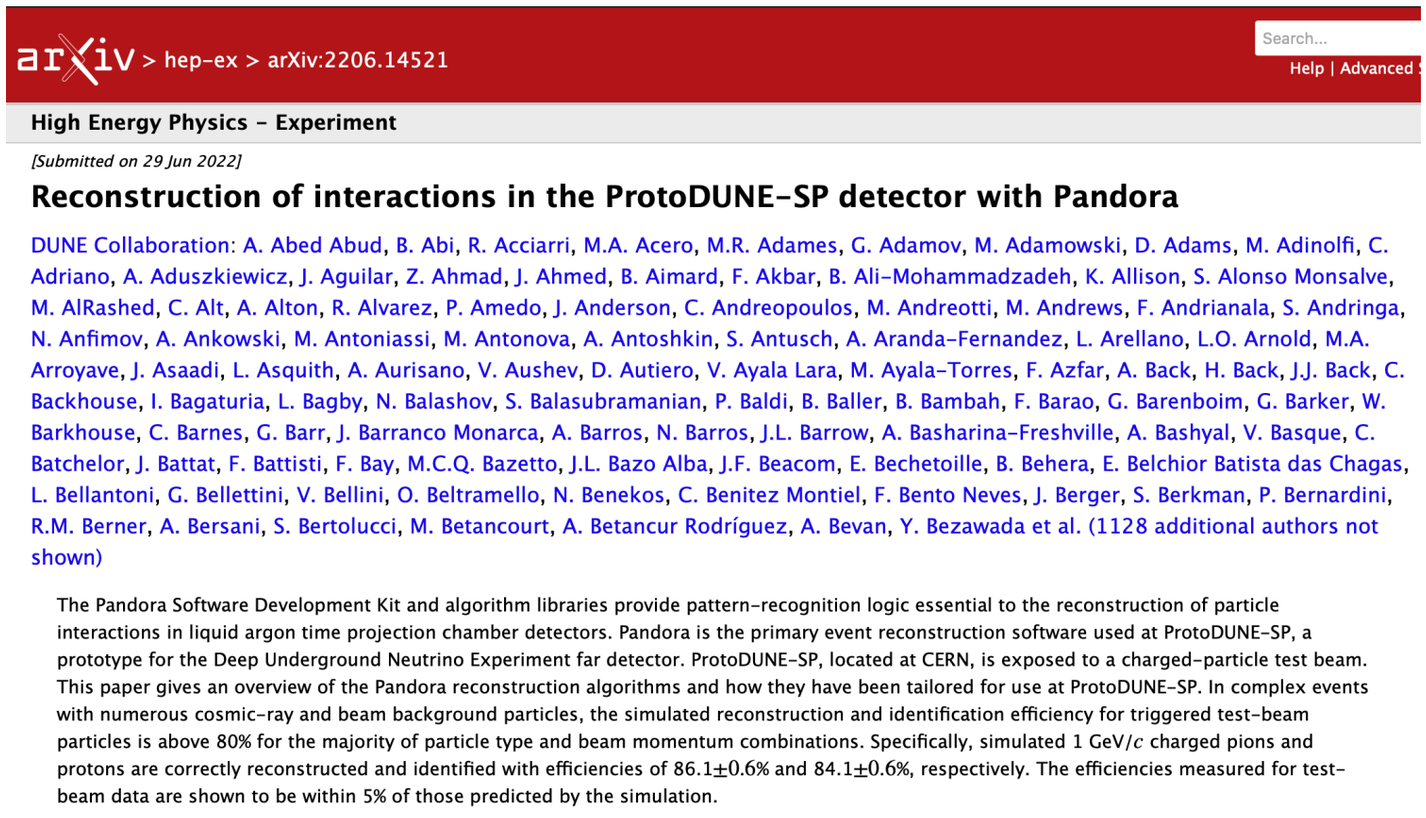
- ProtoDUNE-HD

- ProtoDUNE-VD

- The event reconstruction for all three of these detectors falls under DUNE's ProtoDUNE DRA physics group
  - Convenors: Tingjun Yang and Leigh Whitehead
  - ProtoDUNE-HD Offline Coordinator: Jake Calcutt

ProtoDUNE-SP

- As far as the event reconstruction goes, we can consider ProtoDUNE-SP as finished
  - Final data production was done last year, no plans for reprocessing
  - Comprehensive paper written and posted to the arXiv (finally!)
  - Now submitted to EPJC - let's hope for a smooth review process



arXiv > hep-ex > arXiv:2206.14521

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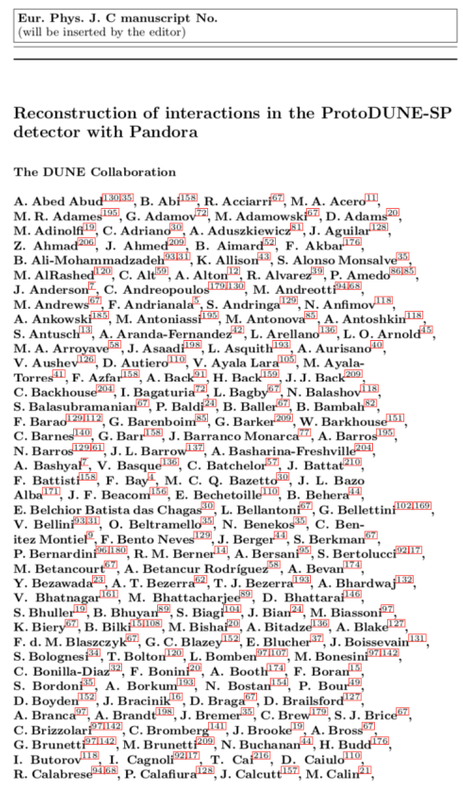
High Energy Physics – Experiment

[Submitted on 29 Jun 2022]

Reconstruction of interactions in the ProtoDUNE-SP detector with Pandora

DUNE Collaboration: A. Abed Abud, B. Abi, R. Acciarri, M.A. Acero, M.R. Adames, G. Adamov, M. Adamowski, D. Adams, M. Adinolfi, C. Adriano, A. Aduszkiewicz, J. Aguilar, Z. Ahmad, J. Ahmed, B. Aimard, F. Akbar, B. Ali-Mohammadzadeh, K. Allison, S. Alonso Monsalve, M. AlRashed, C. Alt, A. Alton, R. Alvarez, P. Amedo, J. Anderson, C. Andreopoulos, M. Andreotti, M. Andrews, F. Andrianala, S. Andringa, N. Anfimov, A. Ankowski, M. Antoniassi, M. Antonova, A. Antoshkin, S. Antusch, A. Aranda-Fernandez, L. Arellano, L.O. Arnold, M.A. Arroyave, J. Asaadi, L. Asquith, A. Aurisano, V. Aushev, D. Autiero, V. Ayala Lara, M. Ayala-Torres, F. Azfar, A. Back, H. Back, J.J. Back, C. Backhouse, I. Bagaturia, L. Bagby, N. Balashov, S. Balasubramanian, P. Baldi, B. Baller, B. Bambah, F. Barao, G. Barenboim, G. Barker, W. Barkhouse, C. Barnes, G. Barr, J. Barranco Monarca, A. Barros, N. Barros, J.L. Barrow, A. Basharina-Freshville, A. Bashyal, V. Basque, C. Batchelor, J. Battat, F. Battisti, F. Bay, M.C.Q. Bazetto, J.L. Bazo Alba, J.F. Beacom, E. Bechetoille, B. Behera, E. Belchior Batista das Chagas, L. Bellantoni, G. Bellettini, V. Bellini, O. Beltramello, N. Benekos, C. Benitez Montiel, F. Bento Neves, J. Berger, S. Berkman, P. Bernardini, R.M. Berner, A. Bersani, S. Bertolucci, M. Betancourt, A. Betancur Rodríguez, A. Bevan, Y. Bezawada et al. (1128 additional authors not shown)

The Pandora Software Development Kit and algorithm libraries provide pattern-recognition logic essential to the reconstruction of particle interactions in liquid argon time projection chamber detectors. Pandora is the primary event reconstruction software used at ProtoDUNE-SP, a prototype for the Deep Underground Neutrino Experiment far detector. ProtoDUNE-SP, located at CERN, is exposed to a charged-particle test beam. This paper gives an overview of the Pandora reconstruction algorithms and how they have been tailored for use at ProtoDUNE-SP. In complex events with numerous cosmic-ray and beam background particles, the simulated reconstruction and identification efficiency for triggered test-beam particles is above 80% for the majority of particle type and beam momentum combinations. Specifically, simulated 1 GeV/c charged pions and protons are correctly reconstructed and identified with efficiencies of 86.1±0.6% and 84.1±0.6%, respectively. The efficiencies measured for test-beam data are shown to be within 5% of those predicted by the simulation.



Eur. Phys. J. C manuscript No.
(will be inserted by the editor)

Reconstruction of interactions in the ProtoDUNE-SP detector with Pandora

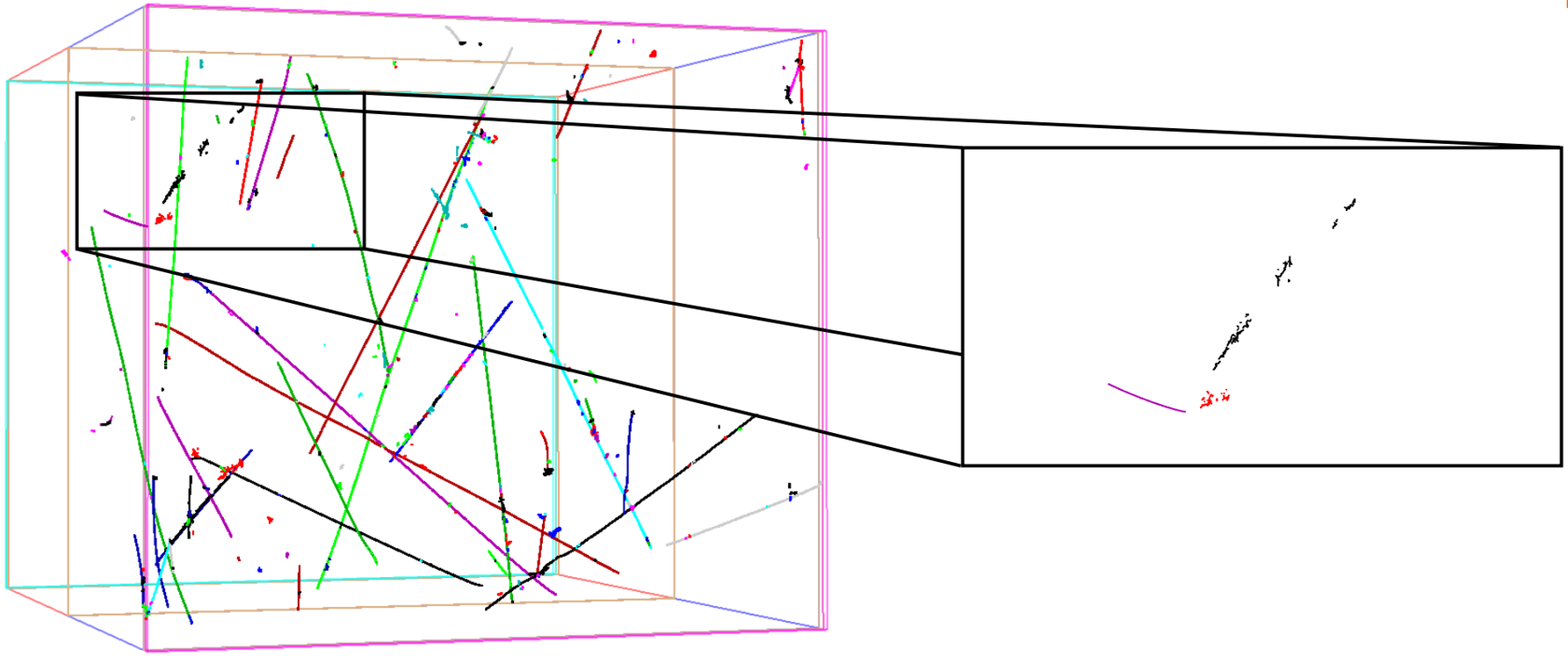
The DUNE Collaboration

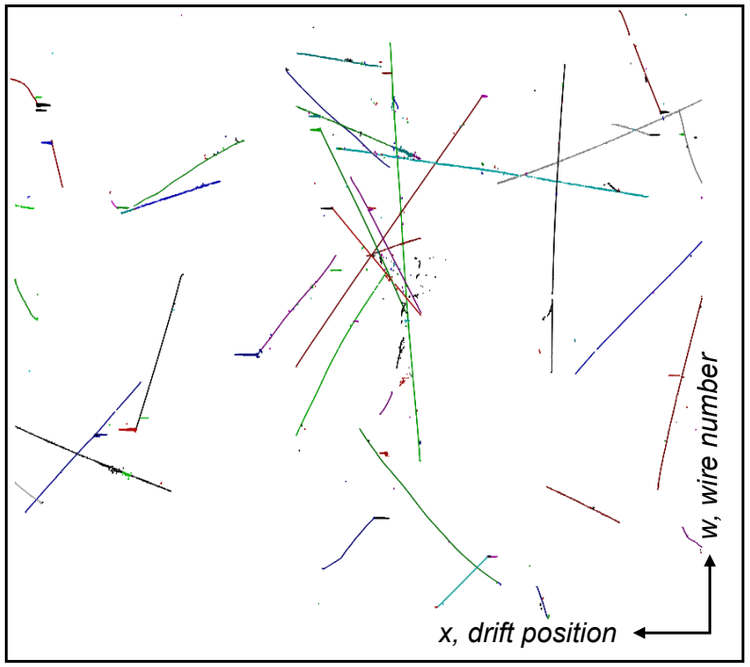
A. Abed Abud[130,135], B. Abi[158], R. Acciarri[67], M. A. Acero[11], M. R. Adames[195], G. Adamov[72], M. Adamowski[67], D. Adams[20], M. Adinolfi[19], C. Adriano[30], A. Aduszkiewicz[81], J. Aguilar[128], Z. Ahmad[206], J. Ahmed[209], B. Aimard[52], F. Akbar[176], B. Ali-Mohammadzadeh[93,131], K. Allison[43], S. Alonso Monsalve[35], M. AlRashed[120], C. Alt[59], A. Alton[12], R. Alvarez[39], P. Amedo[86,85], J. Anderson[7], C. Andreopoulos[179,130], M. Andreotti[94,168], M. Andrews[67], F. Andrianala[5], S. Andringa[129], N. Anfimov[118], A. Ankowski[185], M. Antoniassi[195], M. Antonova[85], A. Antoshkin[118], S. Antusch[13], A. Aranda-Fernandez[42], L. Arellano[136], L. O. Arnold[45], M. A. Arroyave[58], J. Asaadi[188], L. Asquith[193], A. Aurisano[40], V. Aushev[126], D. Autiero[110], V. Ayala Lara[105], M. Ayala-Torres[41], F. Azfar[158], A. Back[91], H. Back[159], J. J. Back[209], C. Backhouse[204], I. Bagaturia[72], L. Bagby[67], N. Balashov[118], S. Balasubramanian[67], P. Baldi[24], B. Baller[67], B. Bambah[82], F. Barao[129,112], G. Barenboim[85], G. Barker[209], W. Barkhouse[151], C. Barnes[140], G. Barr[158], J. Barranco Monarca[77], A. Barros[195], N. Barros[129,61], J. L. Barrow[137], A. Basharina-Freshville[204], A. Bashyal[7], V. Basque[136], C. Batchelor[57], J. Battat[210], F. Battisti[158], F. Bay[4], M. C. Q. Bazetto[30], J. L. Bazo Alba[171], J. F. Beacom[156], E. Bechetoille[110], B. Behera[44], E. Belchior Batista das Chagas[30], L. Bellantoni[67], G. Bellettini[102,169], V. Bellini[93,131], O. Beltramello[35], N. Benekos[35], C. Benitez Montiel[9], F. Bento Neves[129], J. Berger[44], S. Berkman[67], P. Bernardini[96,180], R. M. Berner[44], A. Bersani[95], S. Bertolucci[92,117], M. Betancourt[67], A. Betancur Rodríguez[58], A. Bevan[174], Y. Bezawada[23], A. T. Bezerra[62], T. J. Bezerra[193], A. Bhardwaj[132], V. Bhatnagar[161], M. Bhattacharjee[89], D. Bhattarai[146], S. Bhuller[19], B. Bhuyan[89], S. Biagi[164], J. Bian[24], M. Biassoni[97], K. Biery[67], B. Bilki[15,108], M. Bisha[20], A. Bitadze[136], A. Blake[127], F. d. M. Blaszczyk[67], G. C. Blazey[152], E. Blucher[37], J. Boissevain[131], S. Bolognesi[34], T. Bolton[120], L. Bomben[97,107], M. Bonesini[97,142], C. Bonilla-Diaz[32], F. Bonini[20], A. Booth[174], F. Boran[15], S. Bordoni[35], A. Borkum[193], N. Bostan[154], P. Bour[19], D. Boyden[152], J. Bracinik[16], D. Braga[67], D. Brailsford[127], A. Branca[97], A. Brandt[198], J. Bremer[35], C. Brew[179], S. J. Brice[67], C. Brizzolari[97,142], C. Bromberg[141], J. Brooke[19], A. Bross[67], G. Brunetti[97,142], M. Brunetti[209], N. Buchanan[44], H. Budd[176], I. Butorov[118], I. Cagnoli[92,117], T. Cai[216], D. Caiulo[110], R. Calabrese[94,168], P. Calafiura[128], J. Calcutt[157], M. Calin[21],

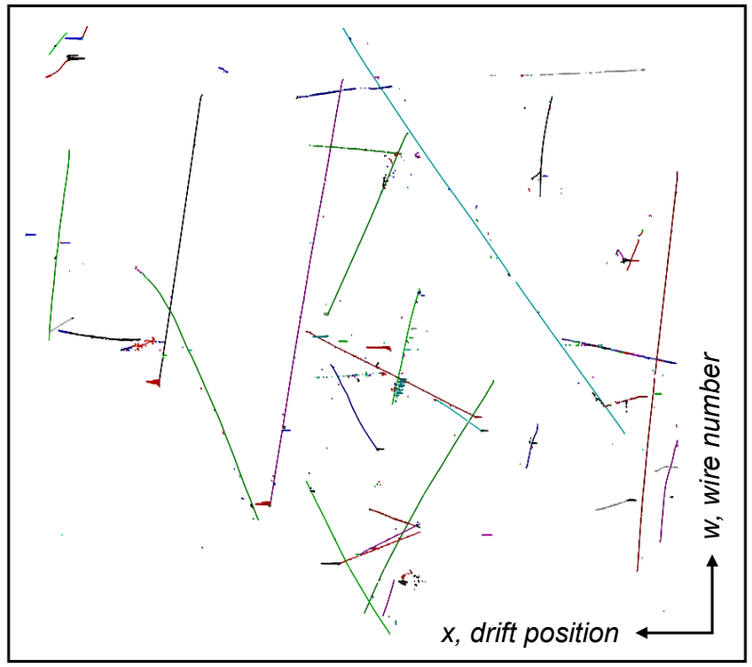
arXiv:2206.14521v1 [hep-ex] 29 Jun 2022

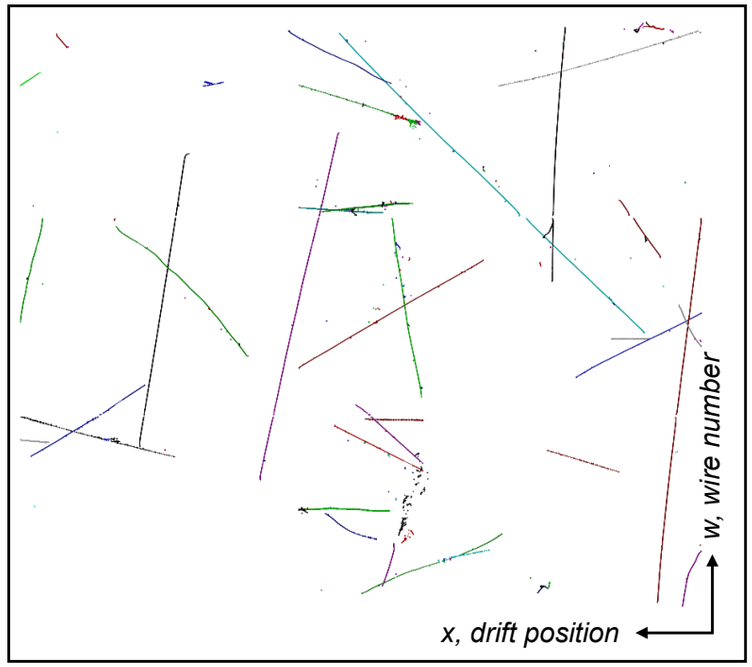
https://arxiv.org/abs/2206.14521

ProtoDUNE-SP









ProtoDUNE-HD

- ProtoDUNE-HD is the successor to ProtoDUNE-SP

- Key differences for event reconstruction:
  - There are now only four APAs
    - Two will be upside down to test the hanging mechanism for these APAs
  - The APAs start 1.4m farther downstream compared to ProtoDUNE-SP
  - New cold electronics
    - Hopefully this will be a transparent change for the event reconstruction

- The above differences mean the coordinate system has changed
  - Maintain the definition that the bottom of the upstream end of the cathode is the origin
  - The new origin is at (0.0, -7.2, 144.93) in ProtoDUNE-SP coordinates

ProtoDUNE-HD

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- Detector should be switched on by the end of October
  - Most likely won't have beam time this year
  - Expected beam will start in May 2023 (after CERN's winter break)

- We still need to be ready for cosmic data in October!

Detector geometry

- We have a first version of the geometry in LArSoft now

- It has quite a few missing features, but gives us something to use
  - The two upside-down APAs aren't upside down
  - The beam plug is very approximate but should be in the right place
  - I think the field cage may be incomplete
  - X-ARAPUCAs currently using the old design (from ProtoDUNE-SP)

- Good enough to get started with
  - Detector is roughly the right size and in roughly the right place

Current software status

- Beam simulation interface
  - Minor change to adjust for a change of coordinate system
  - Otherwise appears to work out-of-the-box

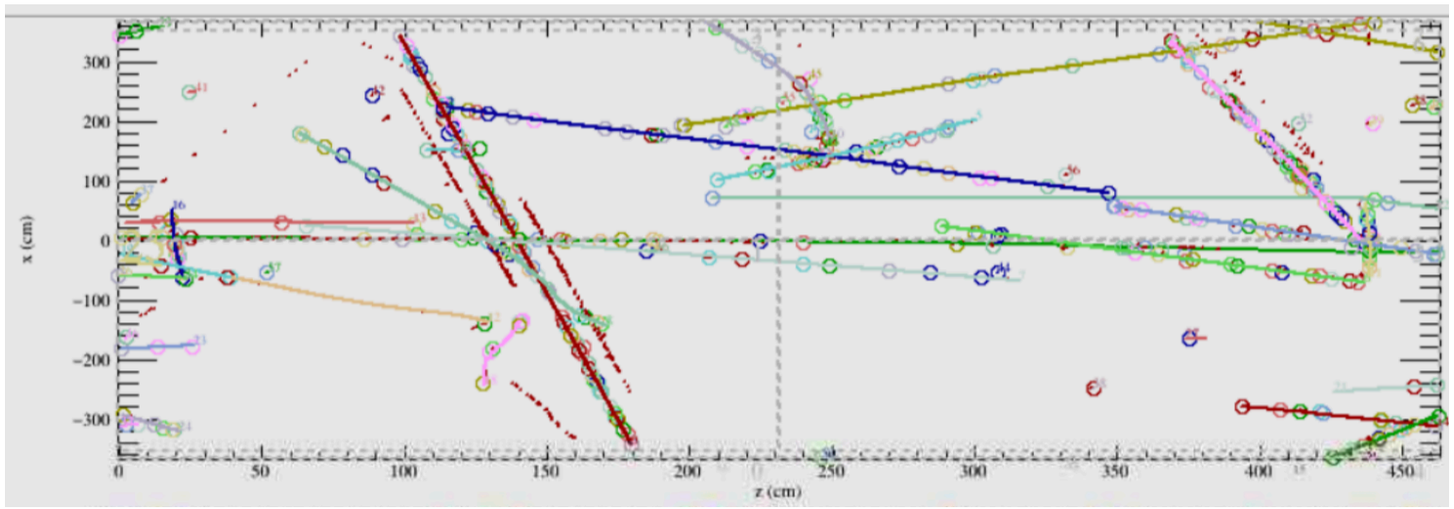
- LArG4
  - Seems to work mostly out of the box

- Detsim
  - TPC simulation running with same configuration as ProtoDUNE-SP
  - Currently no optical system hits produced

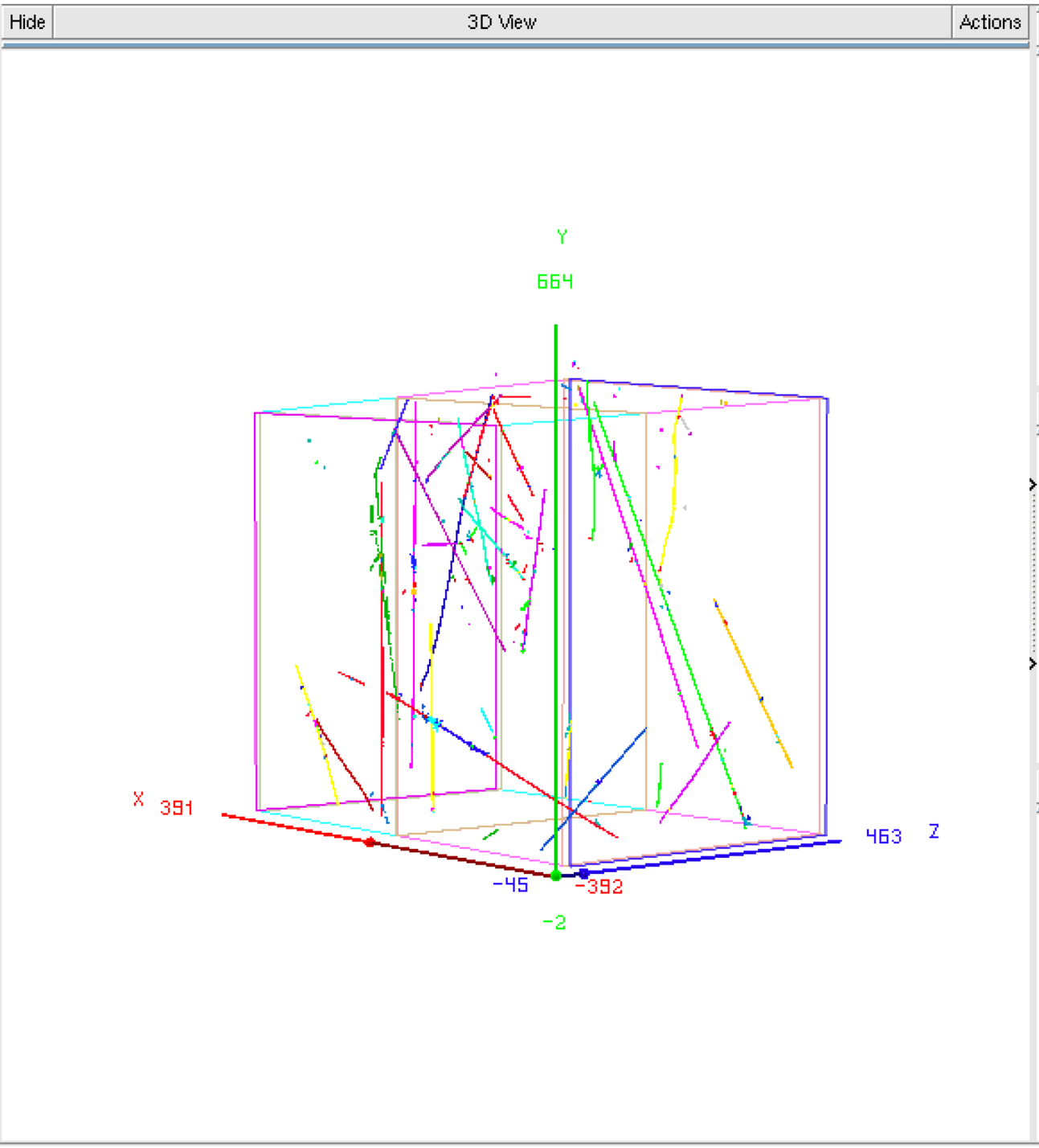
- Pre-Pandora reco
  - Data preparation and WireCell running with ProtoDUNE-SP config

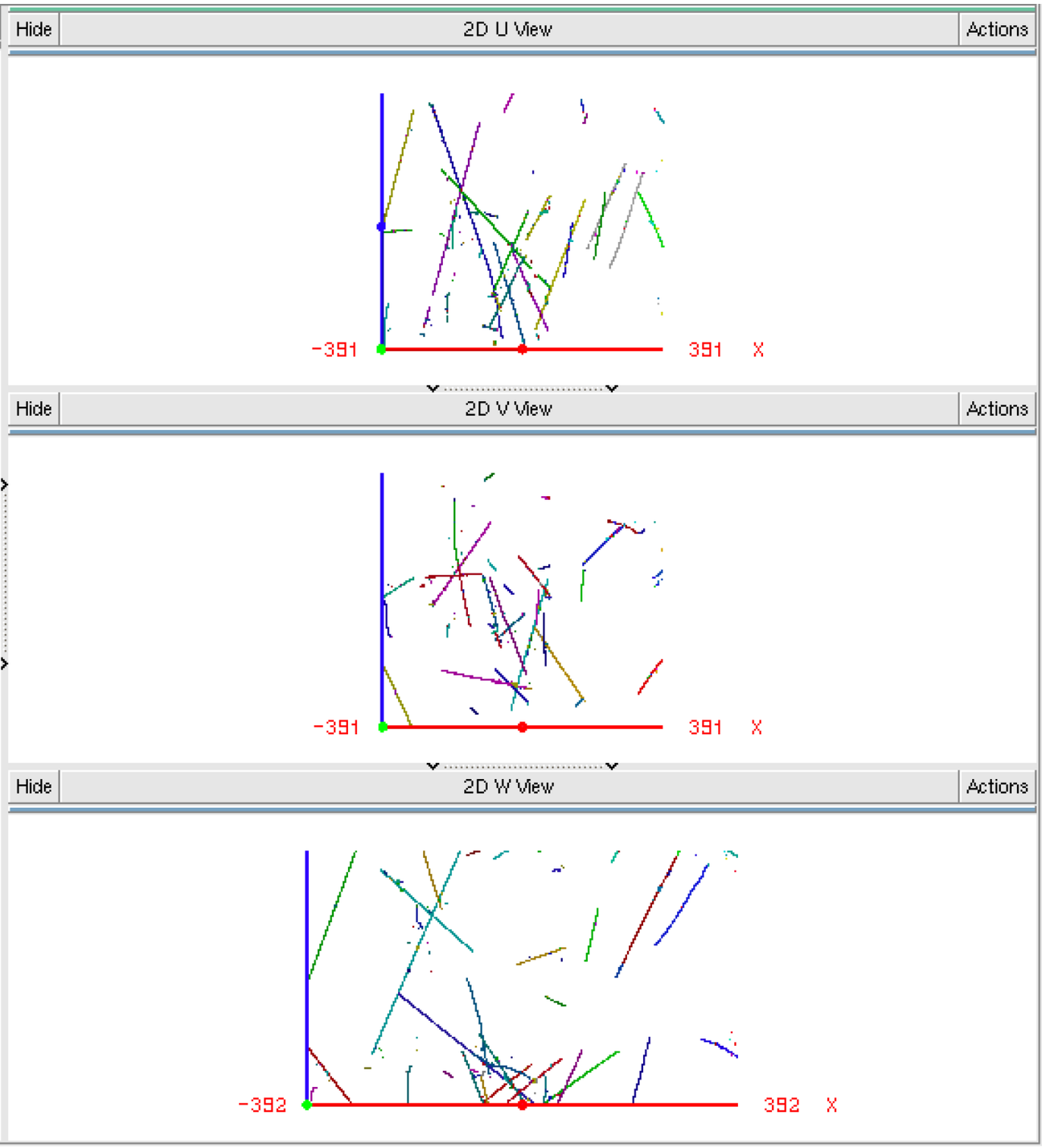
Pandora tests

- I will show a few event displays here
  - They represent the simplest tests we could do for now
- Use the ProtoDUNE-SP configuration with no changes
  - New Pandora geometry for ProtoDUNE-HD exported from LArSoft
- It works!
  - Straight out of the box we see reconstructed particles
  - The first event showed a nice stitched cosmic ray

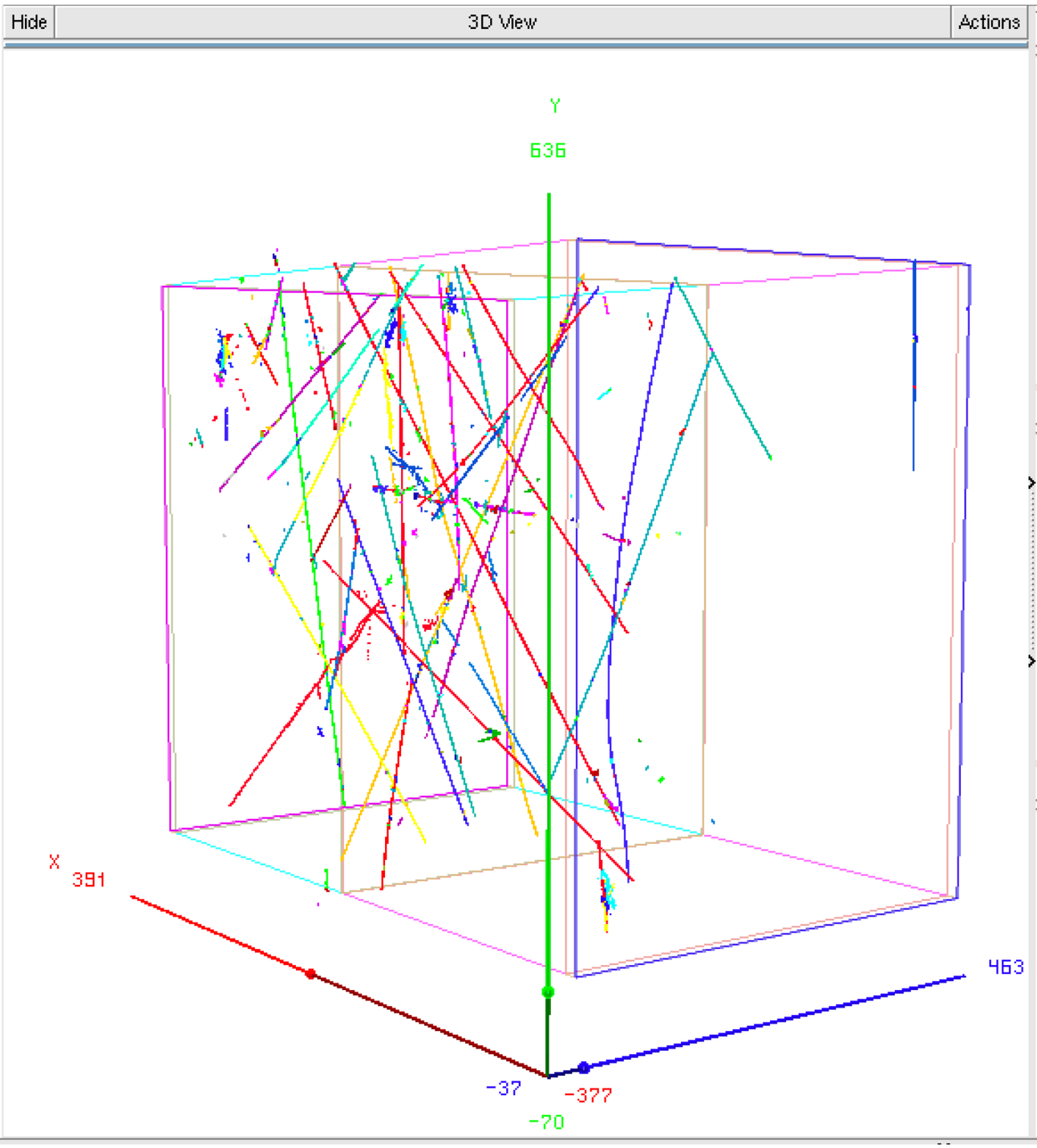


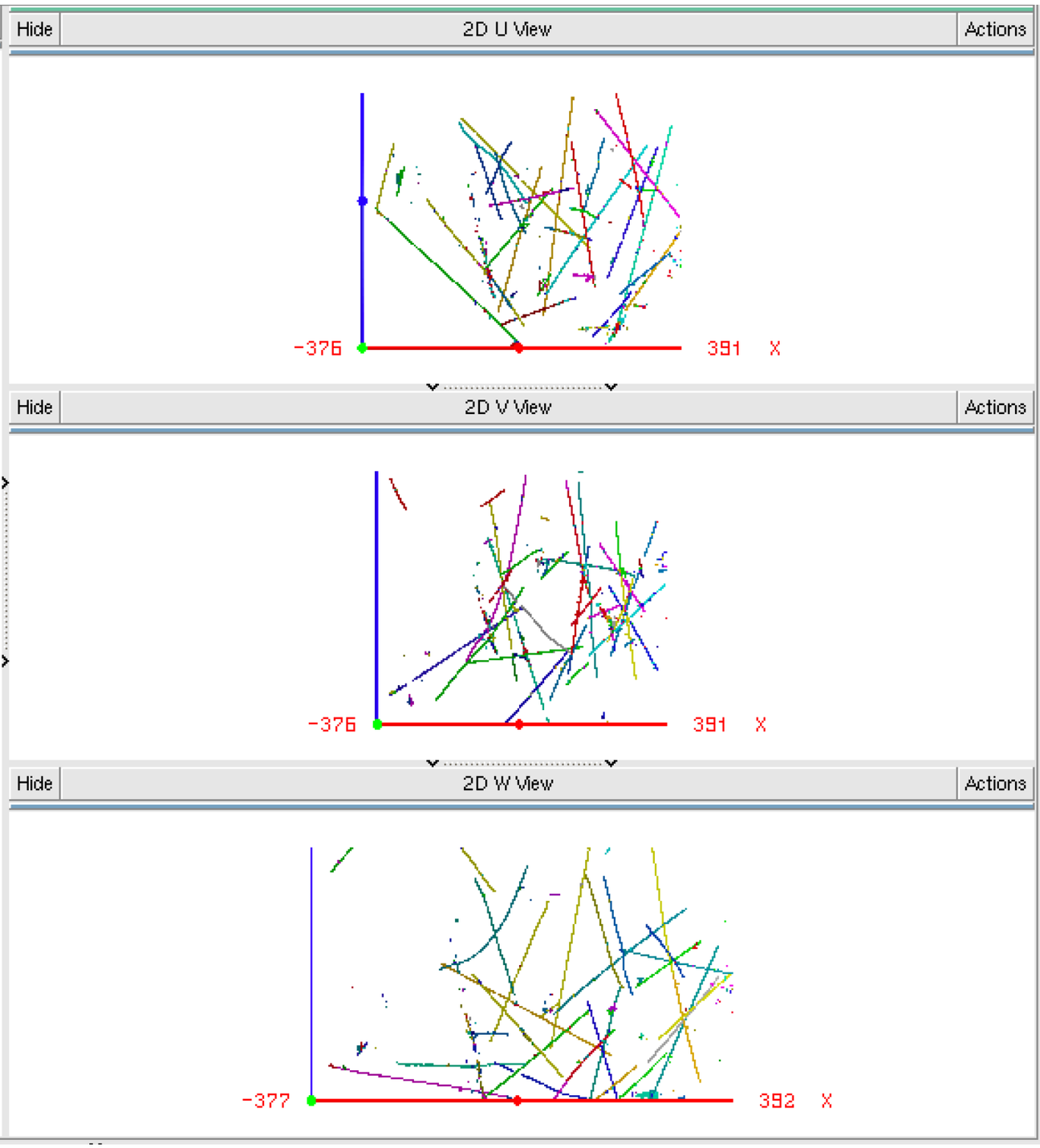
1 GeV/c pion + cosmic





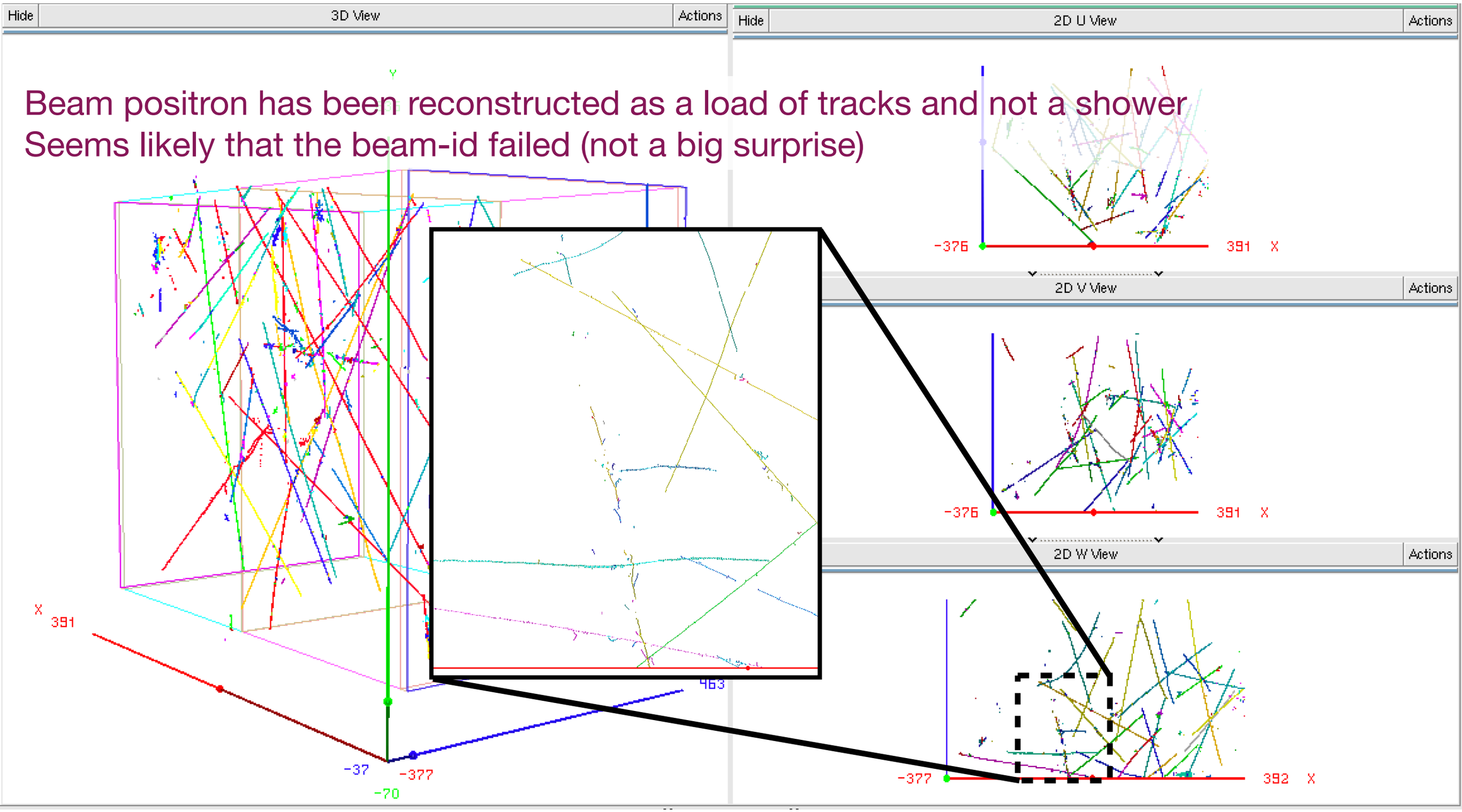
1 GeV/c positron + cosmics



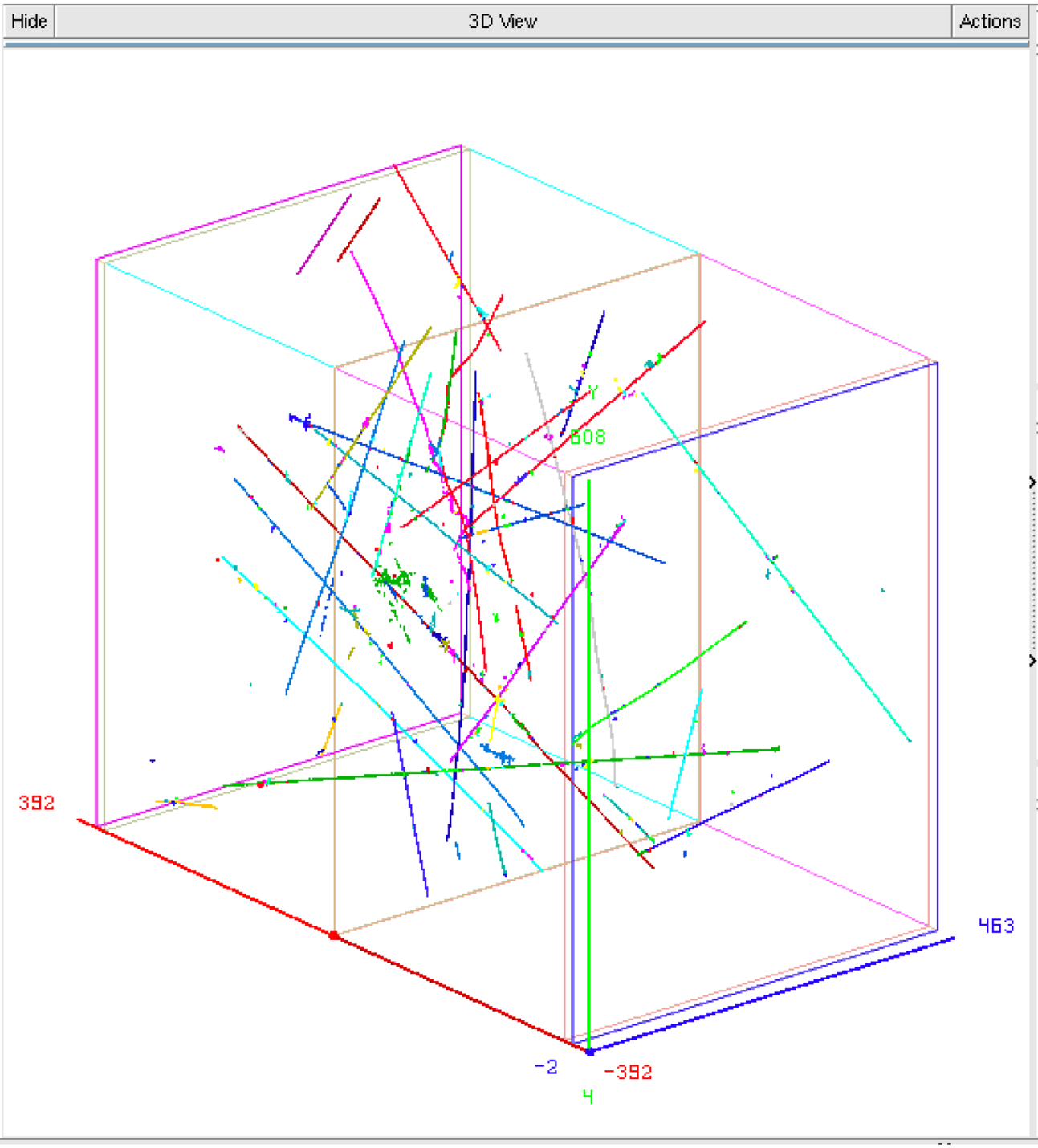


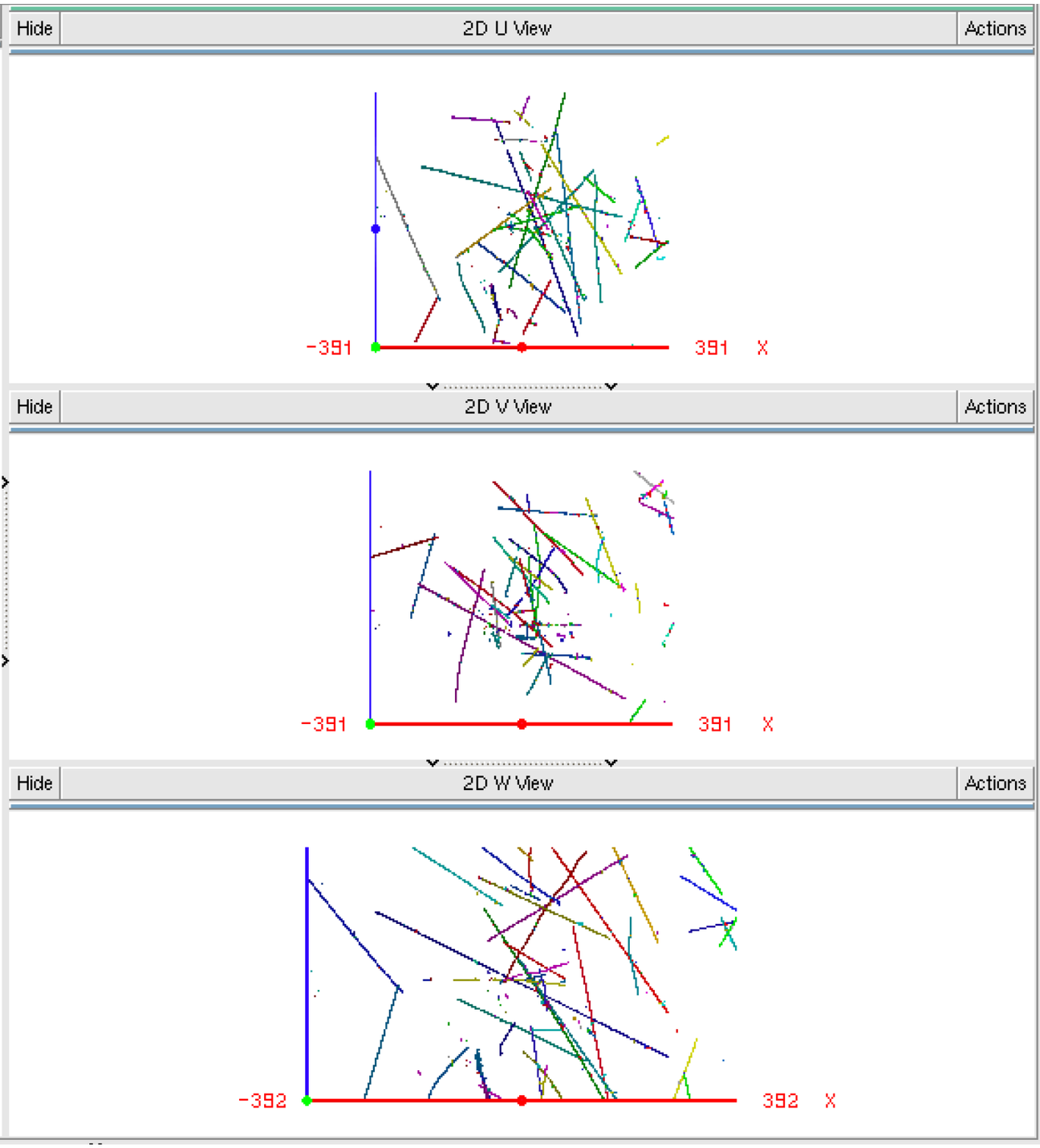
1 GeV/c positron + cosmics

Beam positron has been reconstructed as a load of tracks and not a shower
Seems likely that the beam-id failed (not a big surprise)



1 GeV/c positron + cosmics

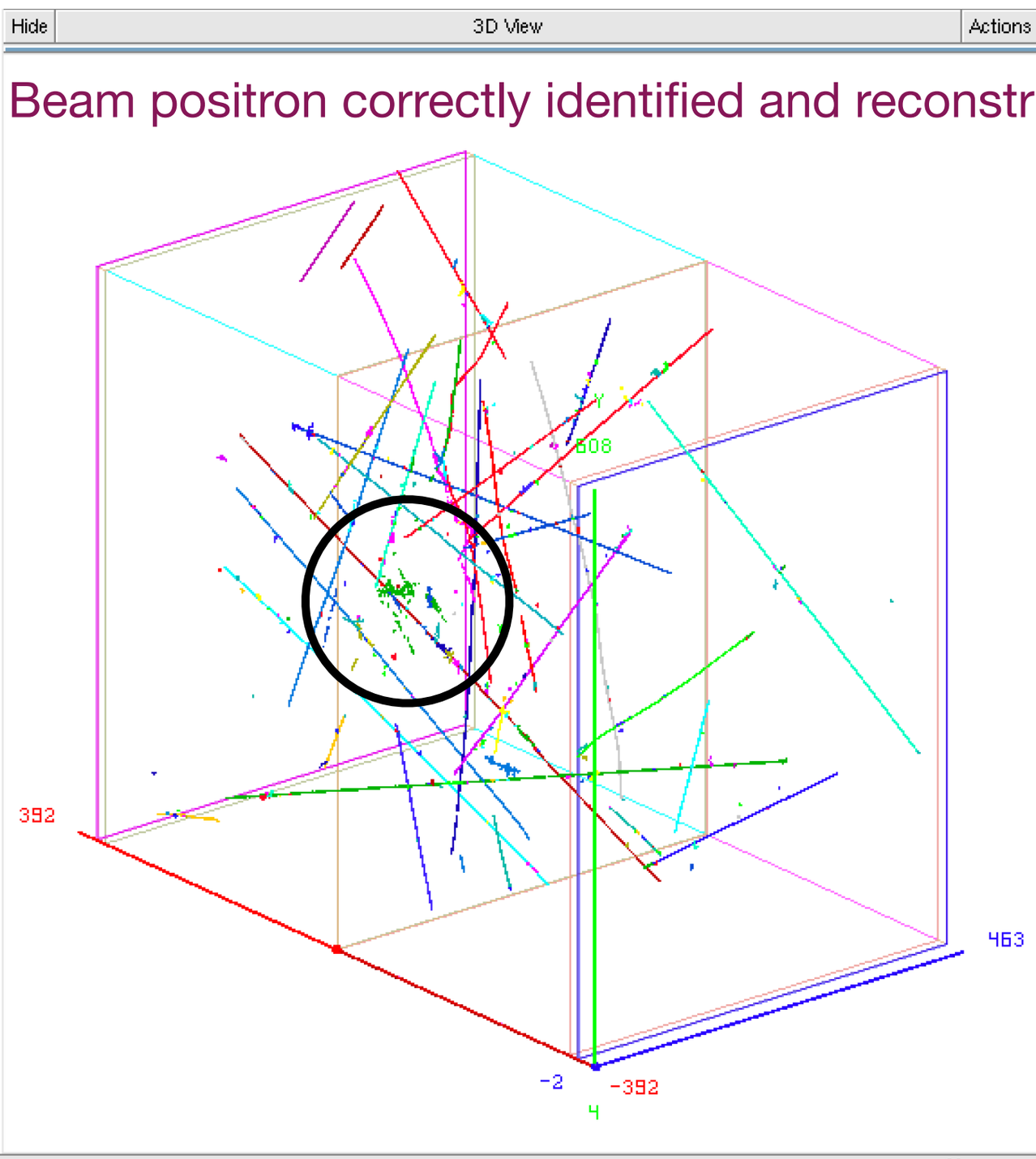


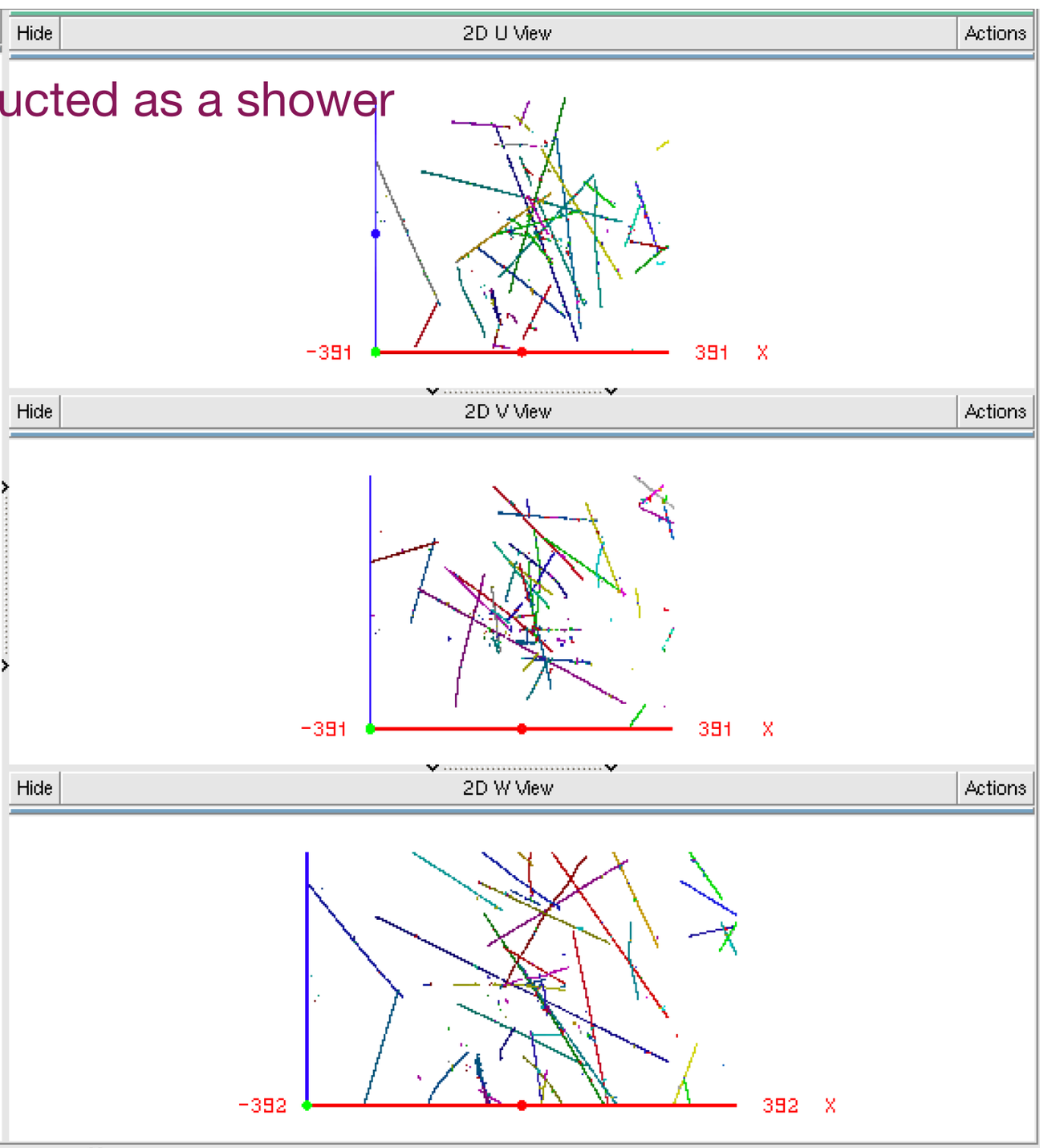


1 GeV/c positron + cosmics

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Beam positron correctly identified and reconstructed as a shower





Pandora for ProtoDUNE-HD

- I would like to include some of the new features in the default reconstruction for ProtoDUNE-HD
  - It's role should be to test the (new) FD algorithms

- Deep learning streaming
  - Small test on ProtoDUNE-SP simulation seemed promising
  - Important to be able to test the CNN on data!

- More use of calorimetry information

- Beam particle ID
  - Previous attempts to improve the BDT for ProtoDUNE-SP didn't really make much progress
  - New ideas? Perhaps this could actually be simplified?

ProtoDUNE-VD

- ProtoDUNE-VD will be housed in the ProtoDUNE-DP cryostat
- Design still seems to be evolving
  - But seems like there will be 2 CRPs
- There will be a 3rd convenor for the DRA group with expertise for ProtoDUNE-VD
  - To be announced (very) soon
- In terms of event reconstruction, I imagine we can use what has been developed for the vertical drift far detector

Summary

- ProtoDUNE-SP paper finally appeared on the arXiv!
  - Submitted to EPJC

- Work has started on ProtoDUNE-HD
  - Reconstruction looks to work OK from first event displays
  - Clearly need to study actual metrics soon
  - Decide the list of algorithms that will form the default reconstruction
  - Retune the different BDTs

- It will be a busy few months to ensure that we are ready for when ProtoDUNE-HD starts up

- We can expect ProtoDUNE-VD on a longer time scale than HD
  - Perhaps the middle of next year?