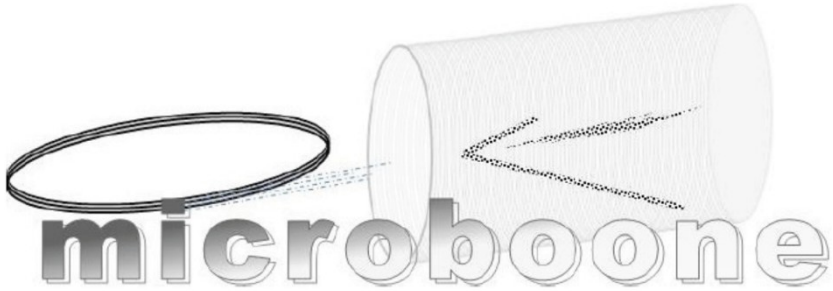


Image Processing Techniques applied to Liquid Argon Time Projection Chamber(LArTPC) Data

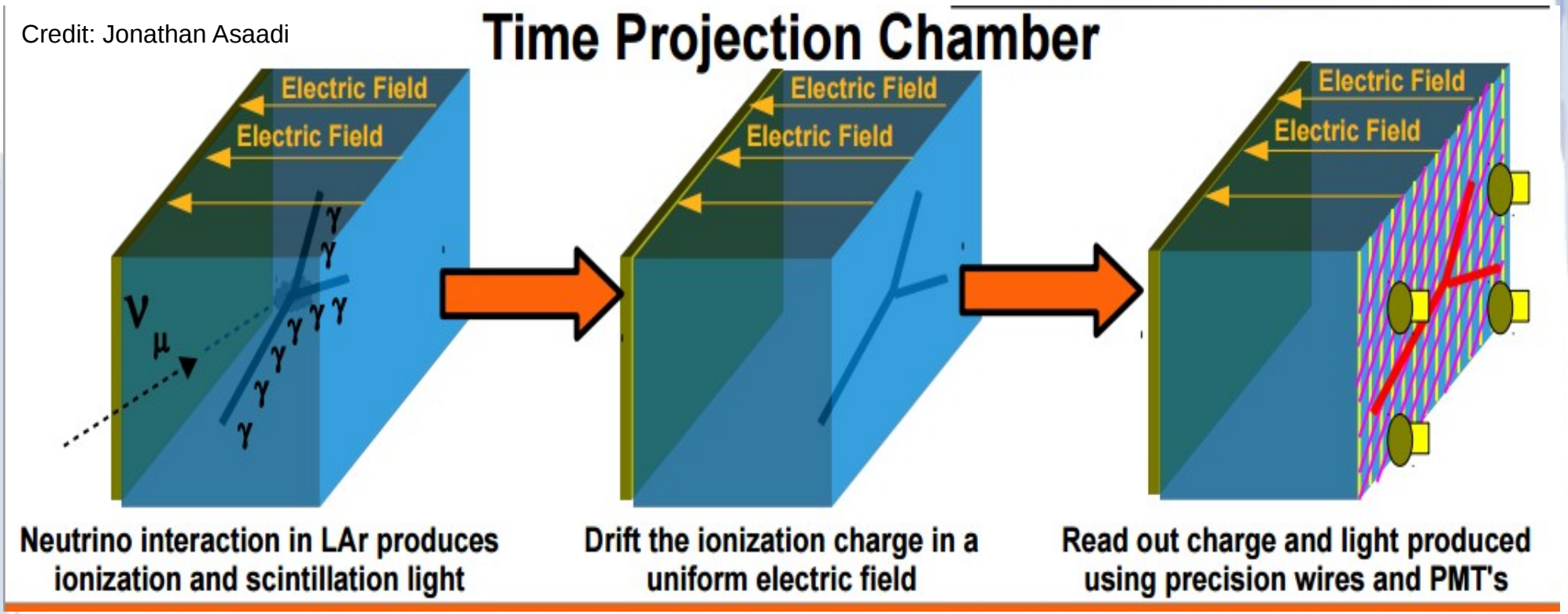
Jessica Esquivel
On Behalf of the MicroBooNE Collaboration
Syracuse University
Advisor: Mitch Soderberg

Outline

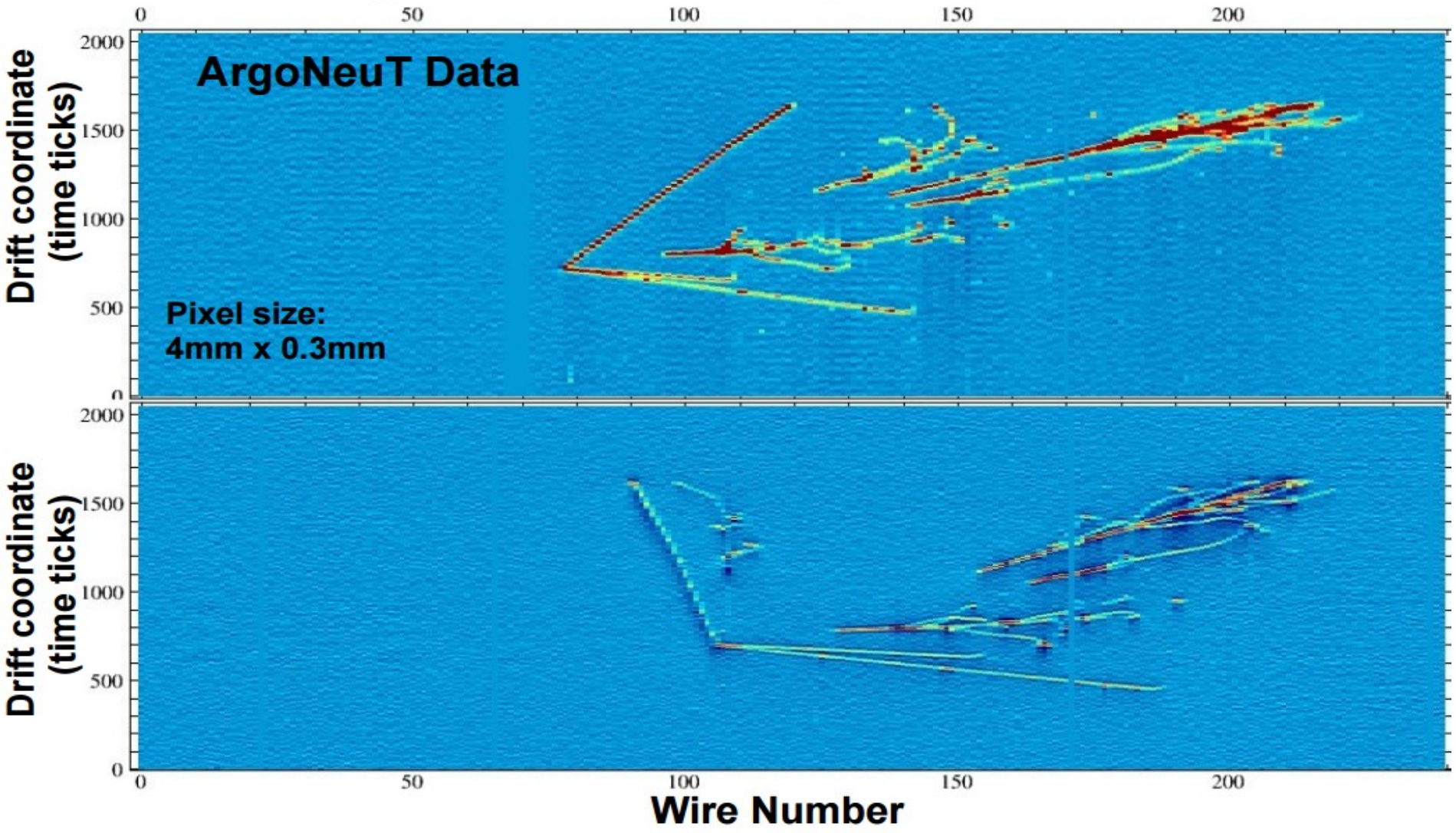
- LArTPC Technology
- MicroBooNE Overview
- What is Image Processing?
- Image Processing on MicroBooNE Data
- Future Directions

LArTPC Technology

Credit: Jonathan Asaadi

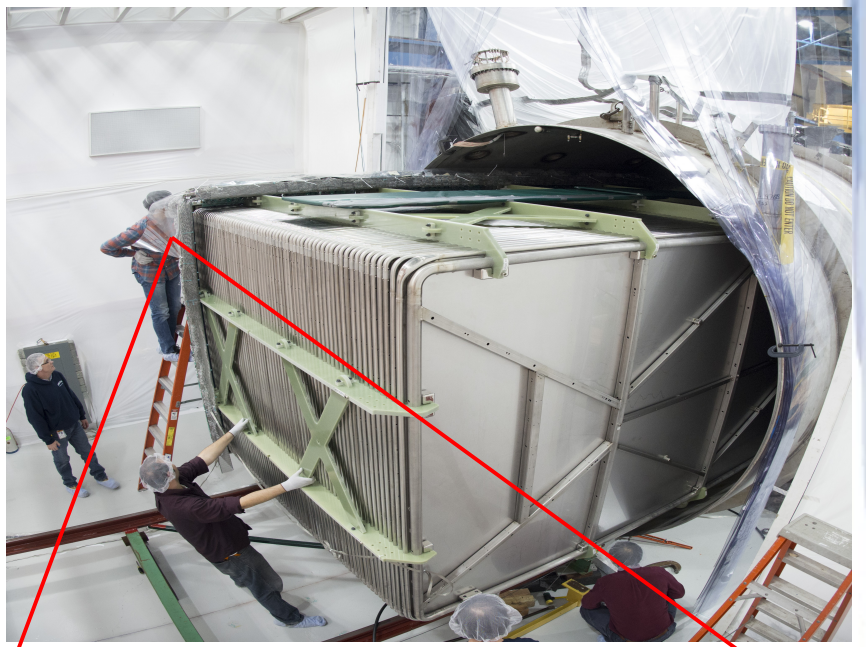


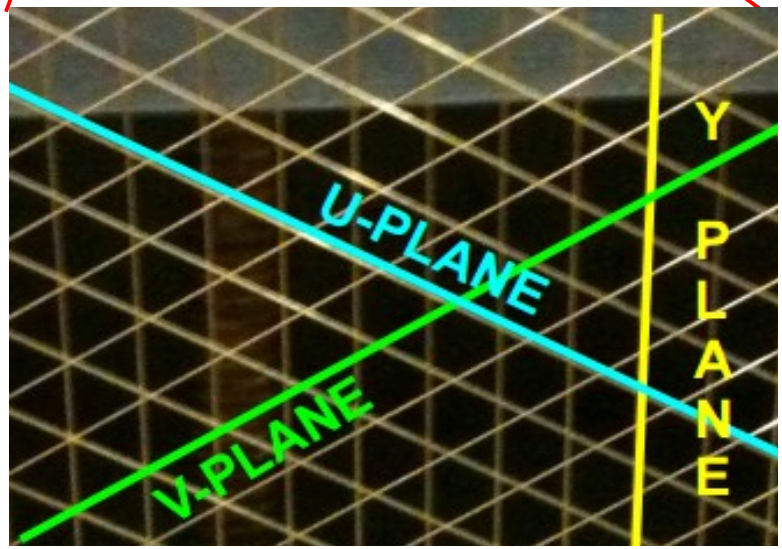
LArTPC Technology



MicroBooNE Overview

- MicroBooNE is a 150 ton(cryostat) ~90 ton LArTPC
- TPC dimensions
  - 10.3m long*2.3m tall*2.5m wide(drift distance)
- 8256 wire channels
  - 3456 Collection channels
    - Wires oriented vertically
  - 4800 Induction channels
    - Wires oriented +/-60 degrees
- 32 8” PMT's
  - For initial time of event and cosmic background removal





What is Image Processing?

- MicroBooNE has traditional reconstruction tools implemented
- Any form of signal processing in which both the output and input are images
- Examples of Image Processing Techniques
  - Gaussian Smoothing
  - Edge Detection
  - Contours
  - Pattern Recognition

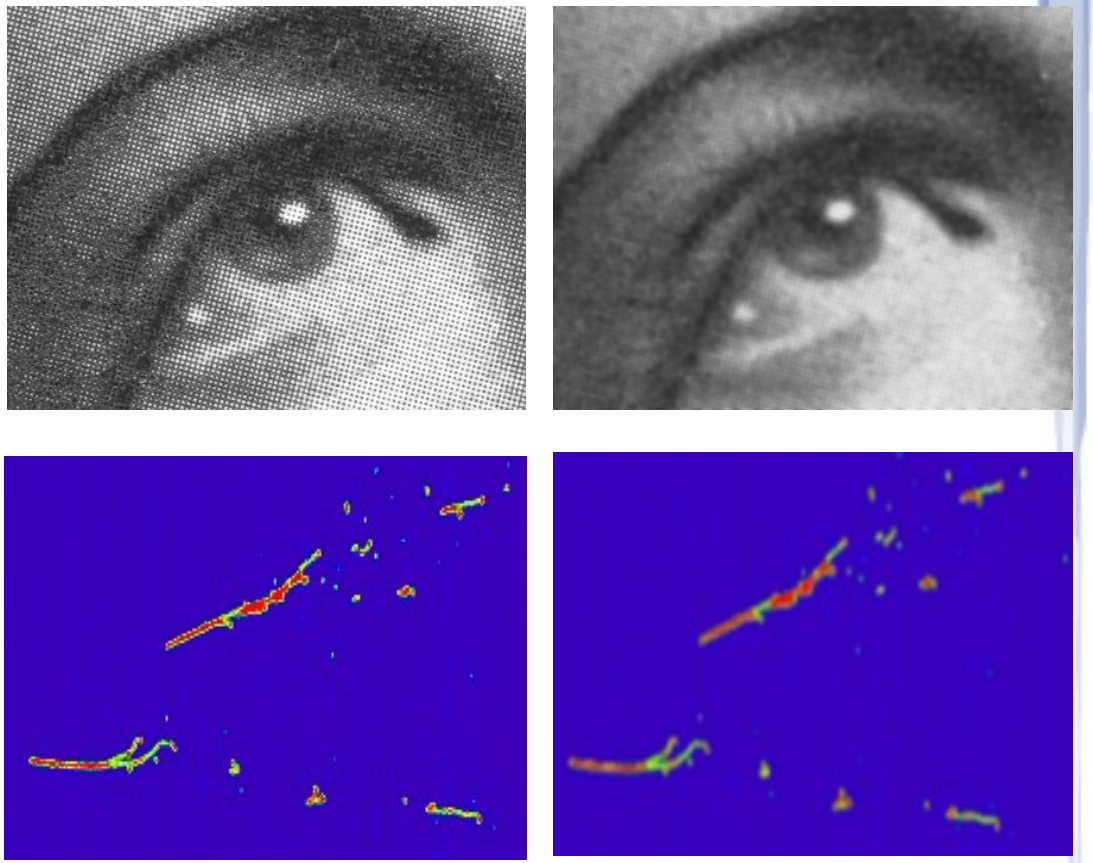
What is Image Processing: MicroBooNE

- Because LArTPC data offer very high resolution, it is possible to run image processing techniques over the “images”
- Each “pixel” would be a single ADC value for a single wire channel and time-tick
- It would start from wire information to include the largest amount of information
- Gaussian smoothing would be implemented on the image
- The Canny Edge Detection Algorithm could then be used to run on each event in each plane
- Next, the Contour Algorithm could then be run to find a Region of Interest(ROI)

What is Image Processing: Gaussian Smoothing

- Gaussian smoothing is convolving the image with a Gaussian function to reduce noise and discretized pixels.
- For MicroBooNE events, this would be used to decrease detector noise and make ADC values continuous to decrease the likelihood of false edges.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$



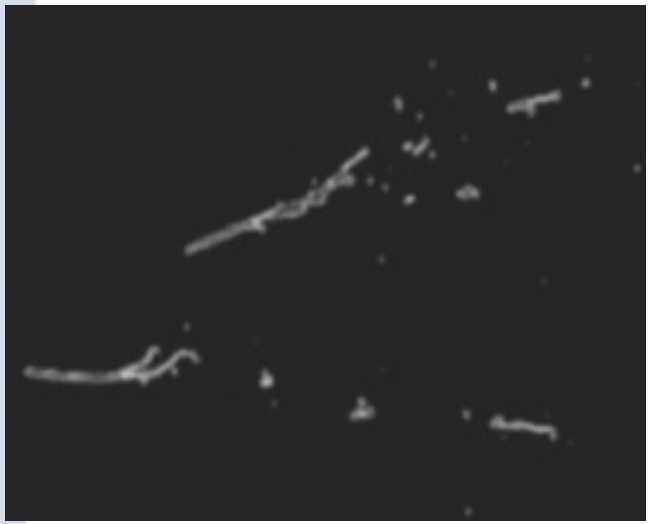
Π^0 event with Momentum of 561MeV

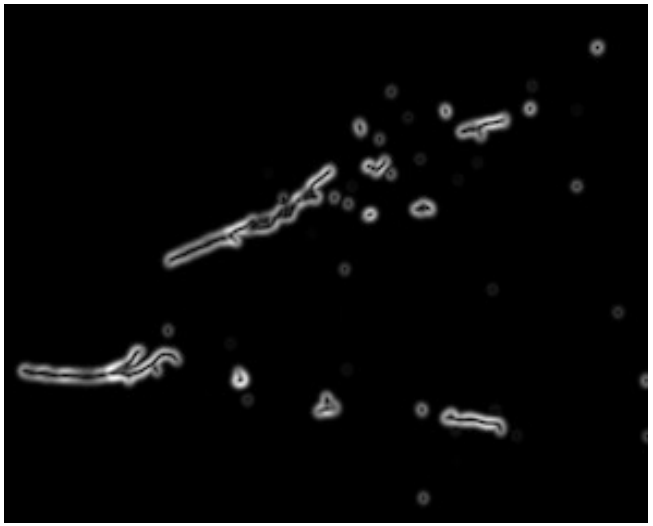
What is Image Processing: Canny Edge Detection

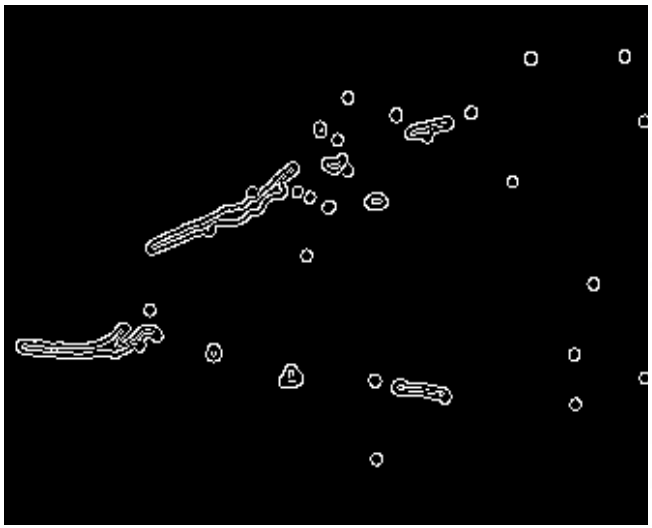
Gaussian Smoothing

Intensity Gradient

Hysteresis

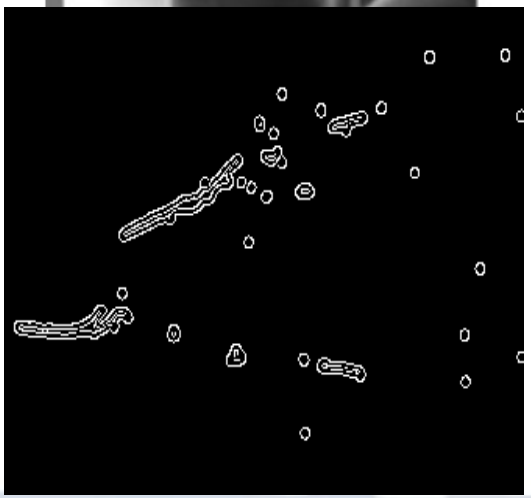






What is Image Processing: Contours

- An outline bounding the shape/form or in this case event is used to get a Region of Interest
- For MicroBooNE, it is used to outline the whole event to create a bounding box and therefore a ROI.



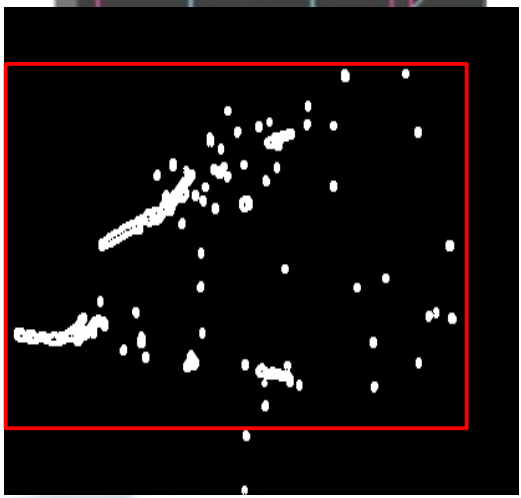


Image Processing on MicroBooNE Monte Carlo Data

Original Event: 1.5GeV Electron Neutrino with Cosmic Overlaid

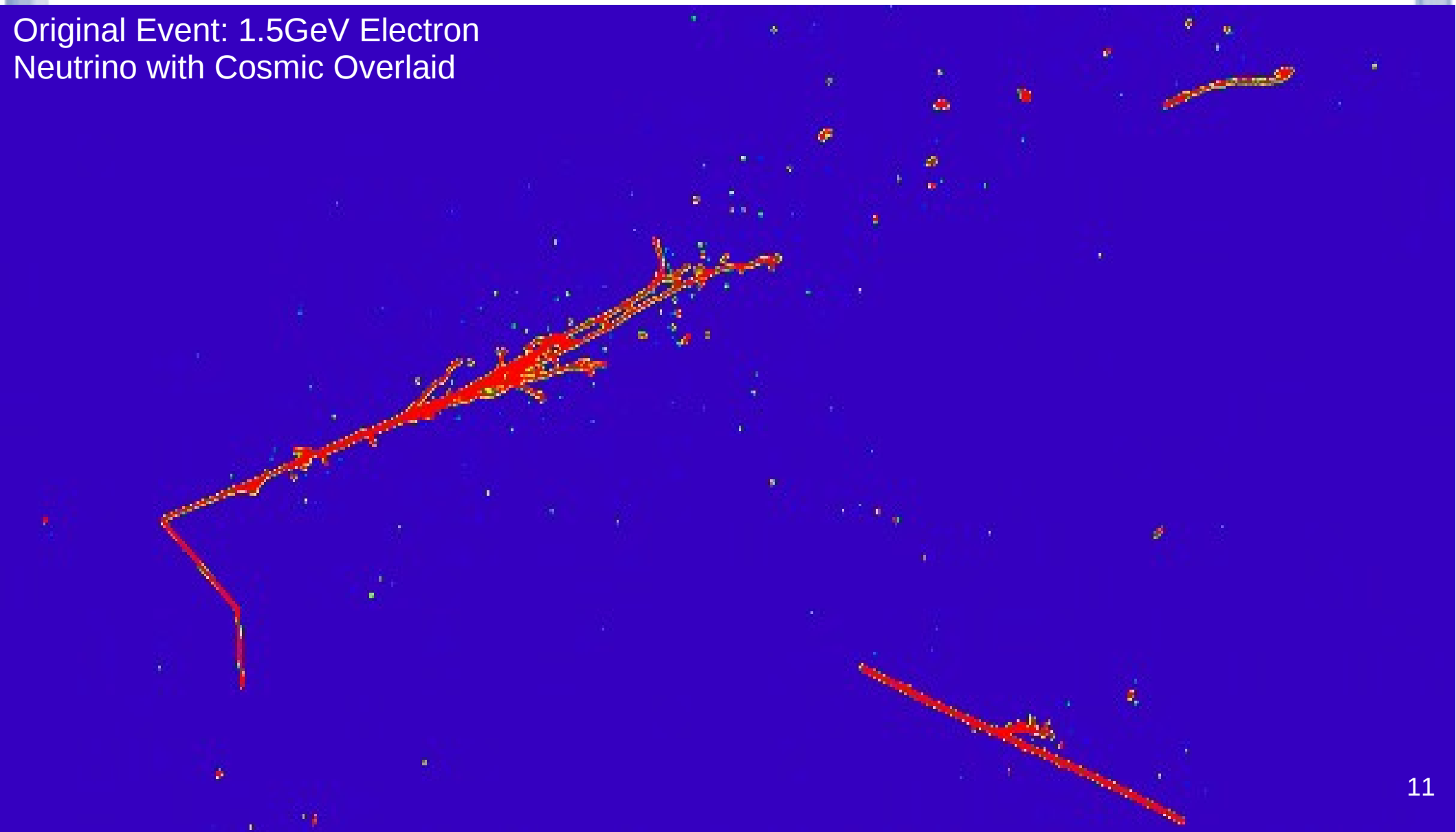


Image Processing on MicroBooNE Monte Carlo Data

Edge Detected Event: 1.5GeV Electron Neutrino with Cosmic Overlaid

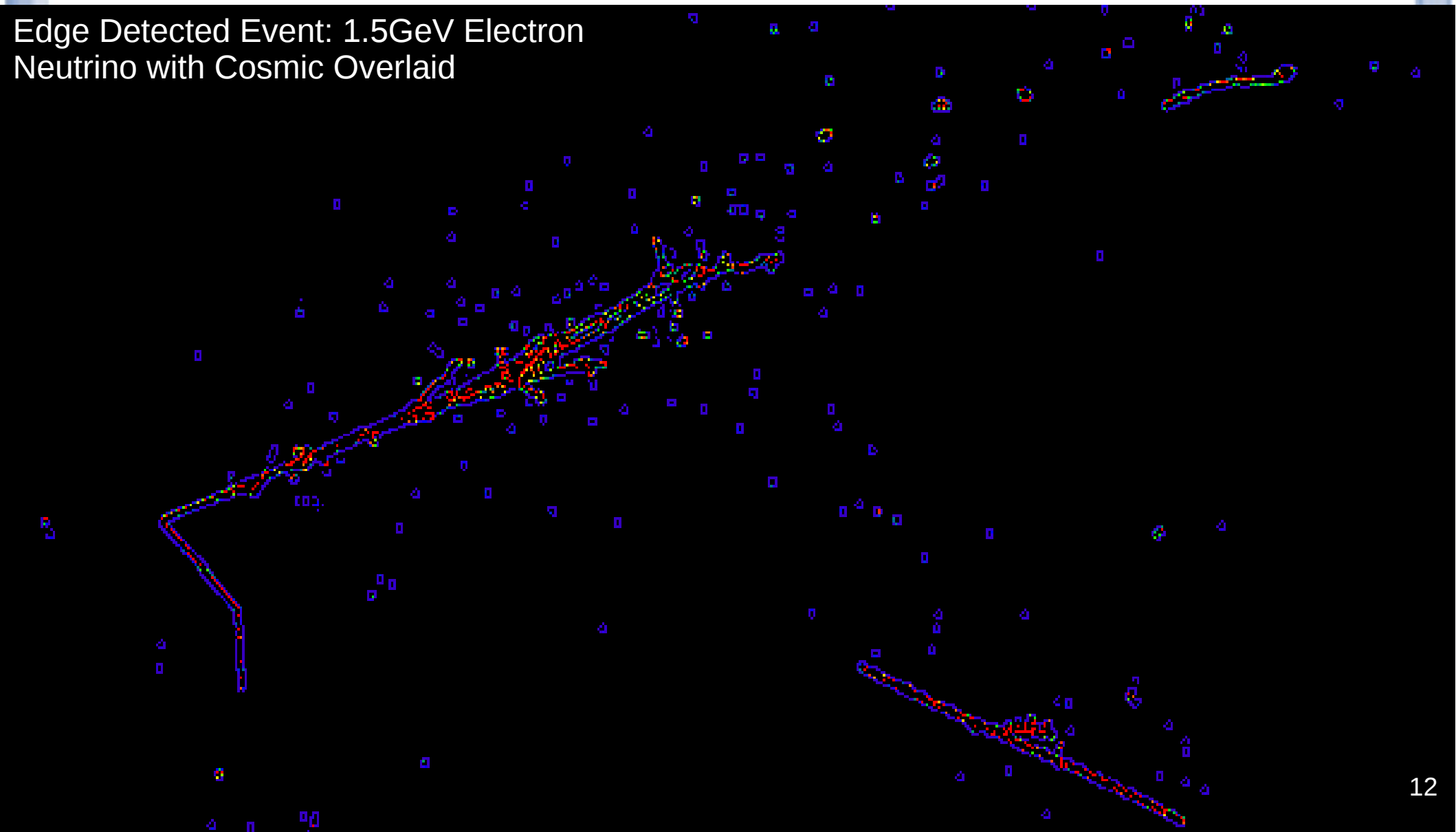


Image Processing on MicroBooNE Monte Carlo Data

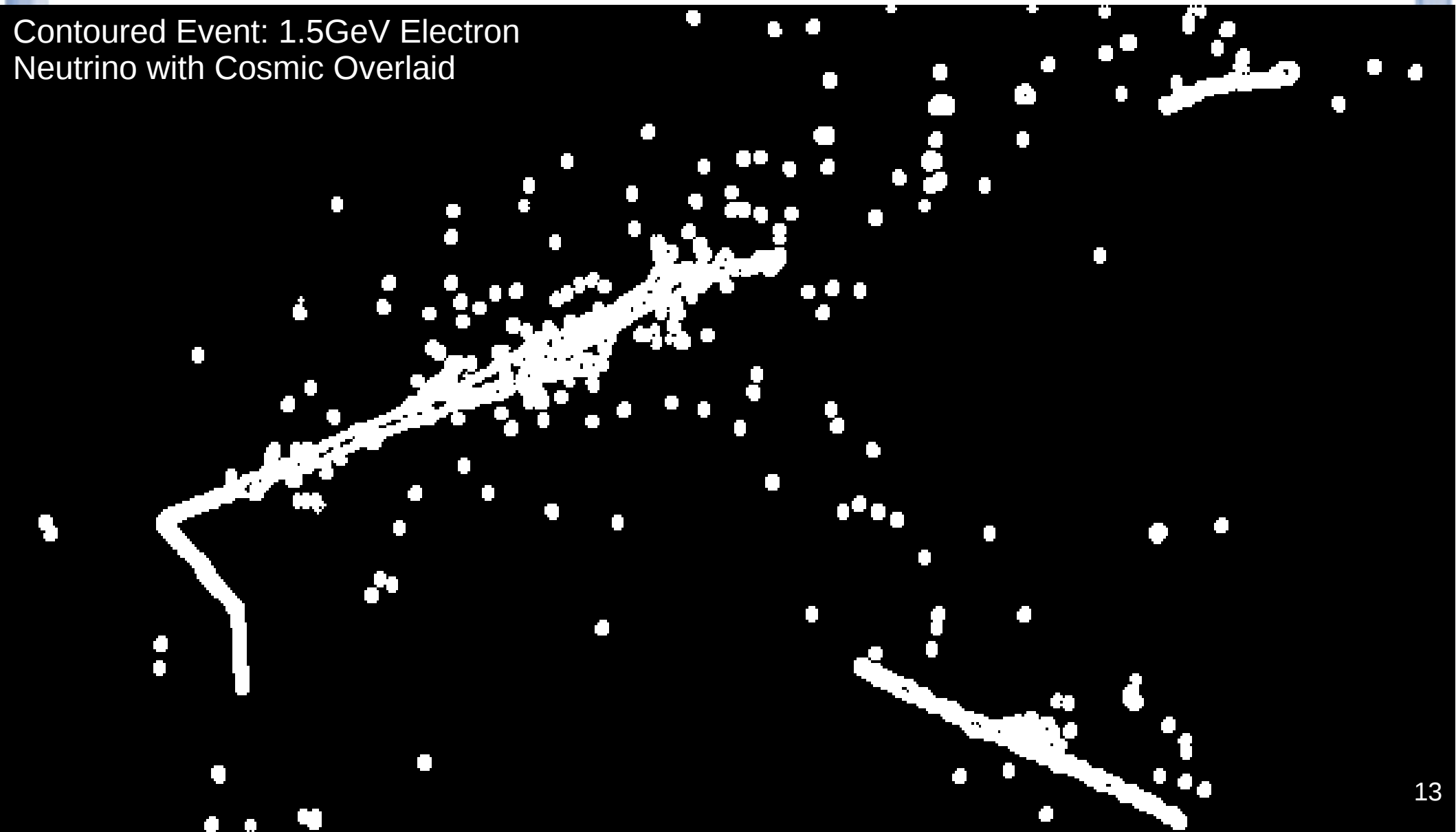


Image Processing on MicroBooNE Monte Carlo Data

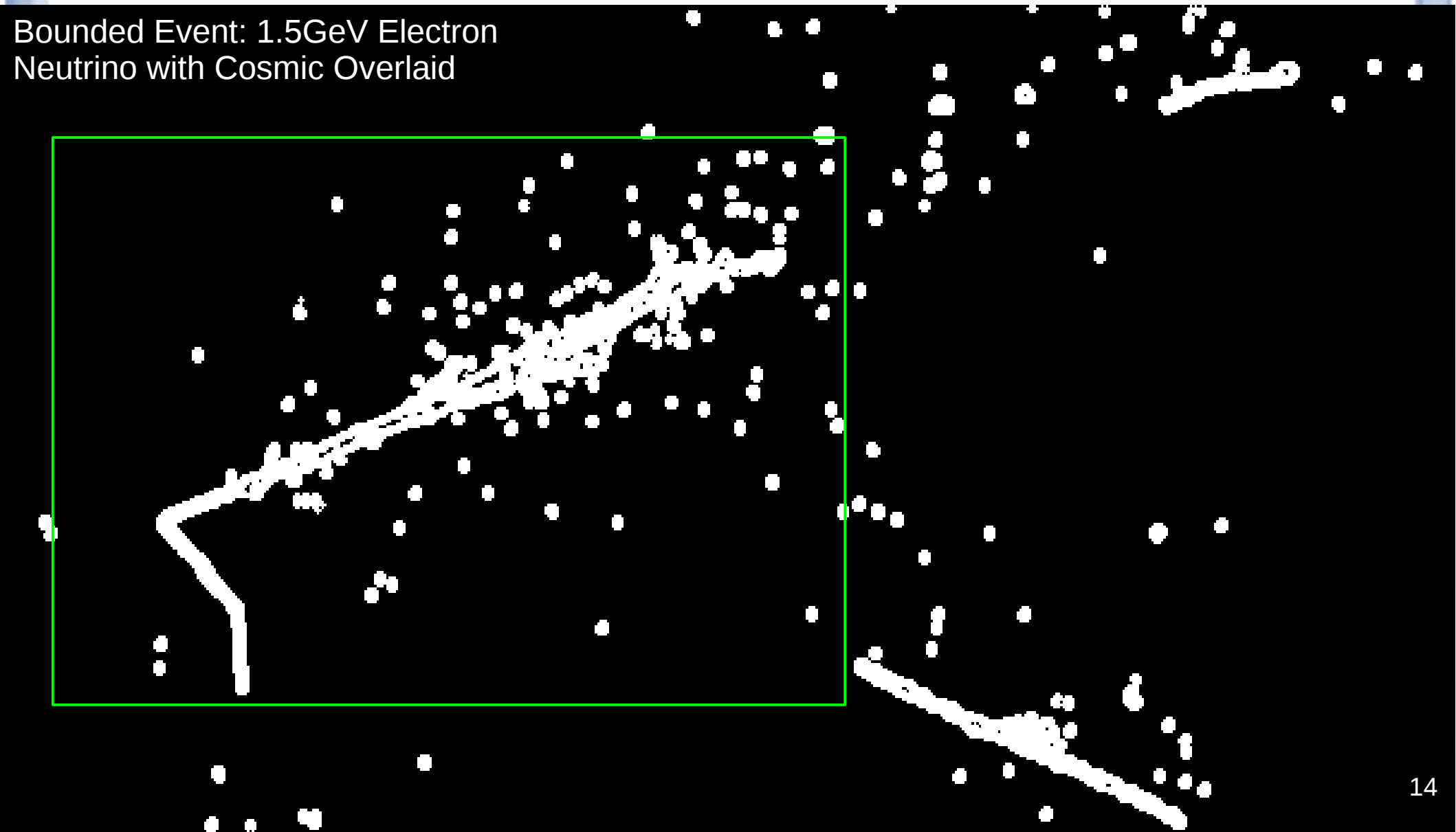


Image Processing on MicroBooNE Monte Carlo Data

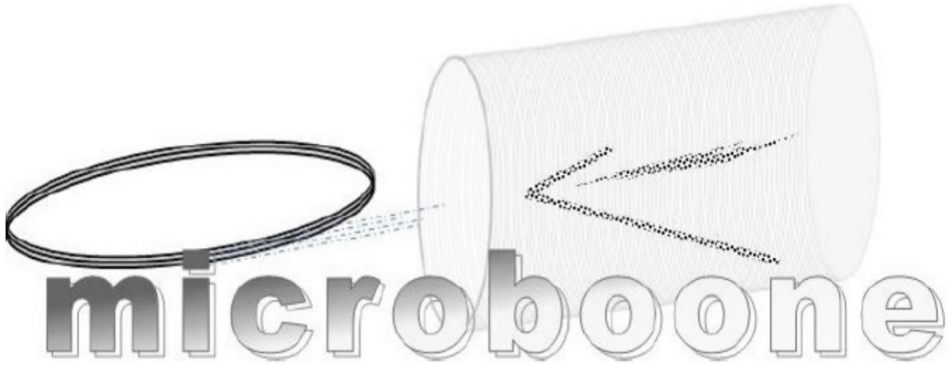
Original World View Event: 1.5GeV
Electron Neutrino with Cosmic Overlaid

Future Directions

- The next step would be to use pattern recognition to identify different event topologies
  - Facebook uses pattern recognition to tag people. Similar algorithm can be used for LArTPC events
  - Would be used on a set of known events (i.e. shower-like or track-like) to train the algorithm, then would be used on unknown events
  - Similar approaches have been taken by the ICARUS collaboration:
    - Image Segmentation in Liquid Argon Time Projection Chamber Detector http://arxiv.org/pdf/1502.08046v1.pdf

Future Directions

- Image Processing Techniques can be beneficial to LArTPC data.
- Whether in conjunction with reconstruction algorithms or as a separate reconstruction tool there is merit to driving ahead with this.
- MicroBooNE will begin taking data soon so this process can be tested on real data


microboone

Questions?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Backup Slides

LArTPC Technology

- Since Neutrinos interact via the weak force, Neutrino Detectors need to be:
  - Big
  - Dense
  - Sensitive to neutrino Interactions

	He	Ne	Ar	Kr	Xe	Water
Boiling Point [K] @ 1atm	4.2	27.1	87.3	120.0	165.0	373
Density [g/cm^3]	0.125	1.2	1.4	2.4	3.0	1
Radiation Length [cm]	755.2	24.0	14.0	4.9	2.8	36.1
dE/dx [MeV/cm]	0.24	1.4	2.1	3.0	3.8	1.9
Scintillation [γ /MeV]	19,000	30,000	40,000	25,000	42,000	
Scintillation λ [nm]	80	78	128	150	175	

Credit: Mitch Soderberg, Jonathan Assadi

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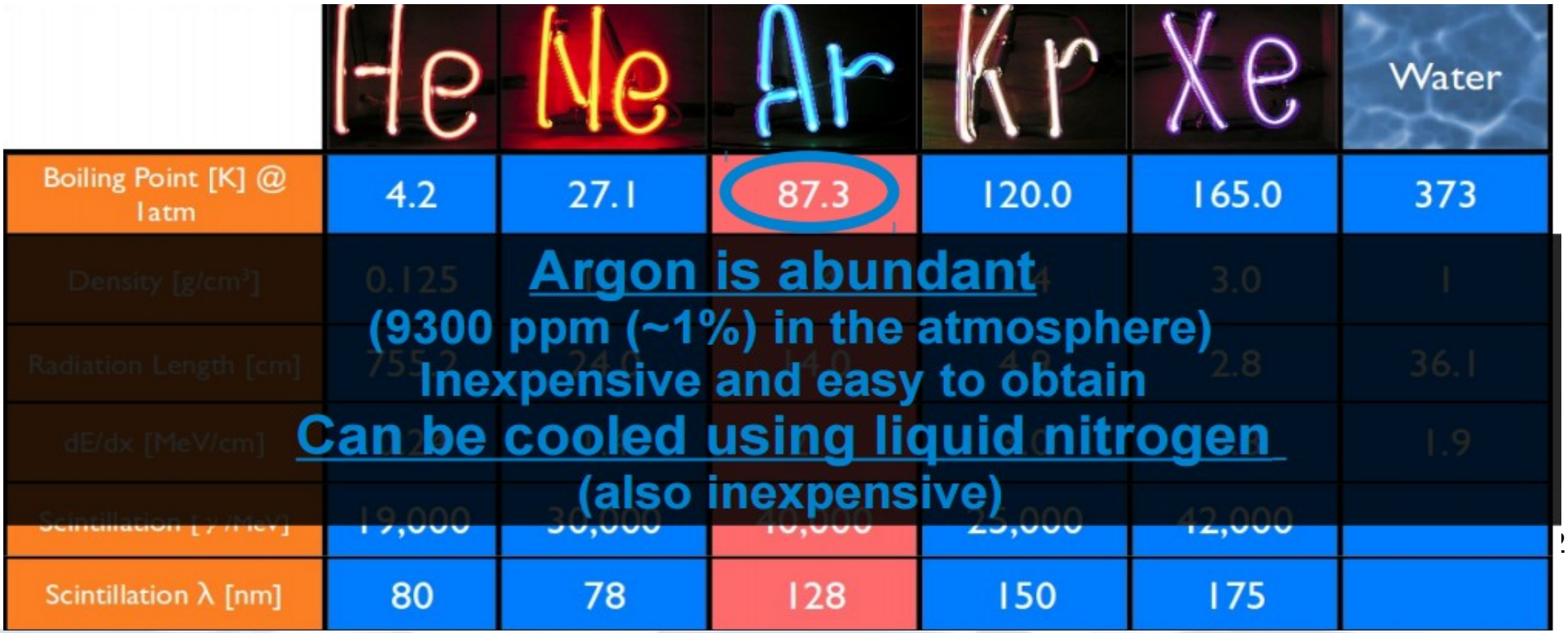

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Argon is abundant
(9300 ppm (~1%) in the atmosphere)
Inexpensive and easy to obtain
Can be cooled using liquid nitrogen
(also inexpensive)

Credit: Mitch Soderberg, Jonathan Assadi

LArTPC Technology

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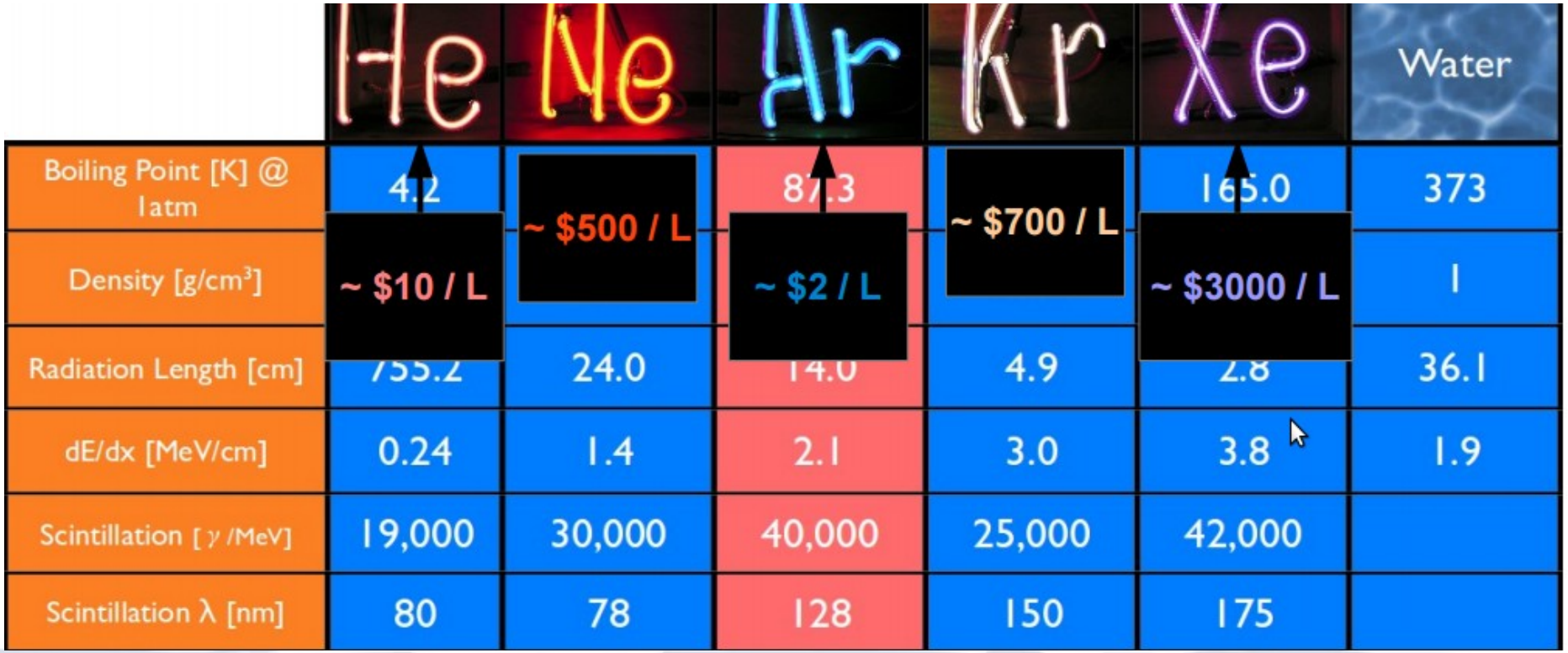

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Argon is dense
(almost one and a half times more dense than water)

Credit: Mitch Soderberg, Jonathan Assadi

LArTPC Technology

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Argon ionizes easily (55,000 electrons / cm)

Credit: Mitch Soderberg, Jonathan Assadi

LArTPC Technology

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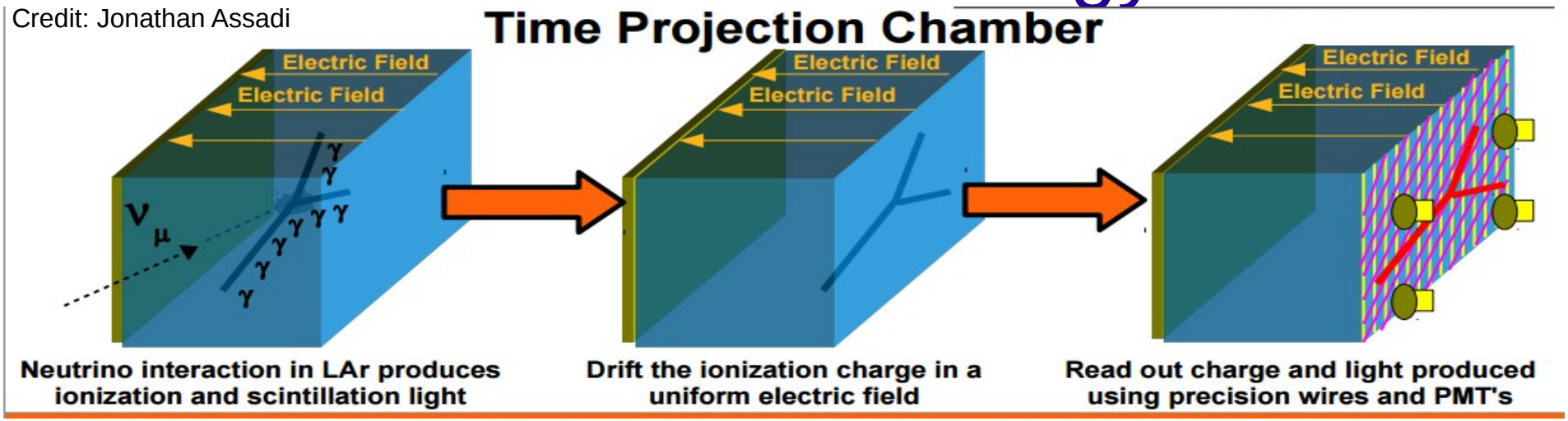
Produces lots of scintillation light
(and is transparent to the light it produces)

Credit: Mitch Soderberg, Jonathan Assadi

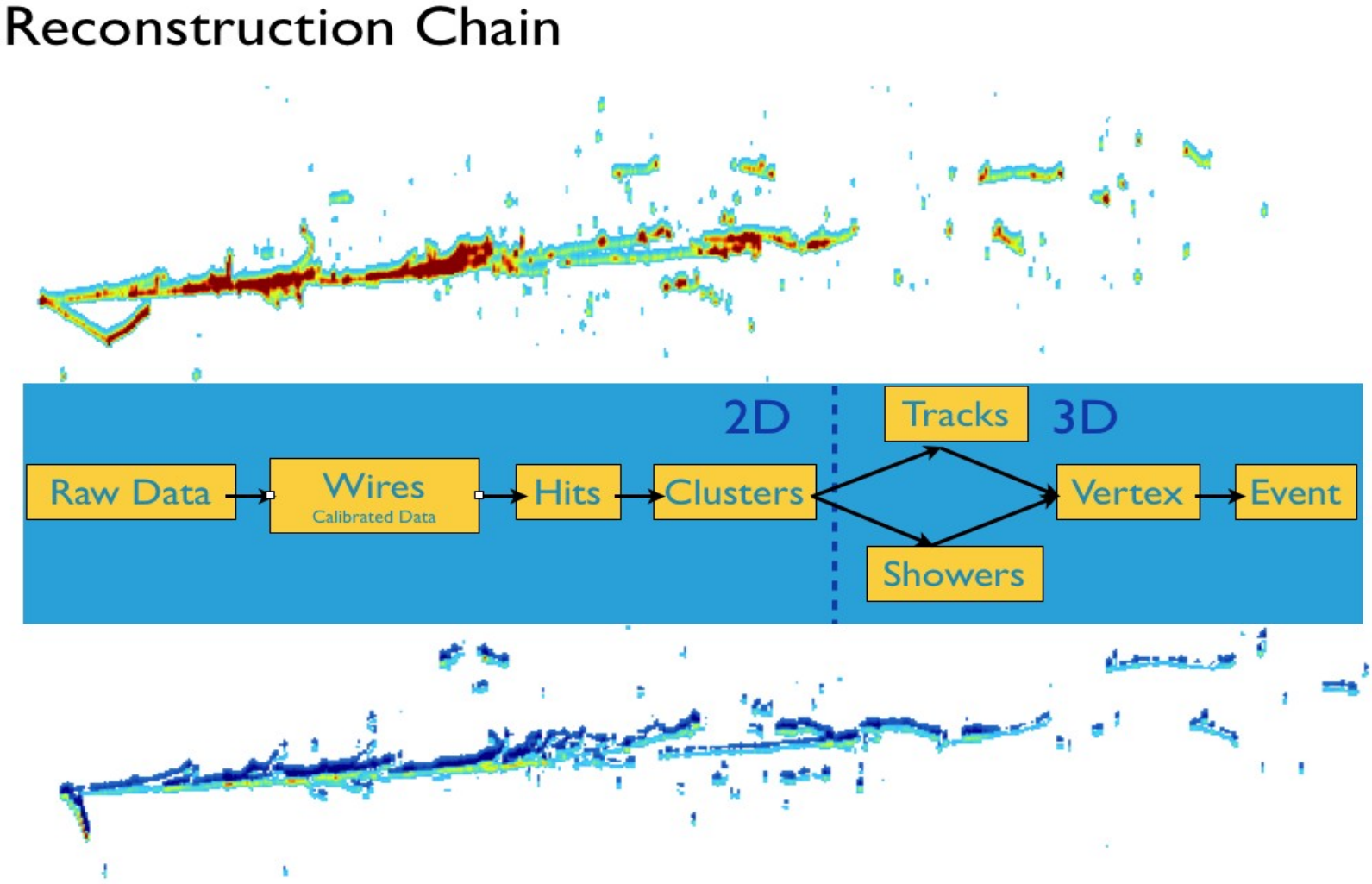
LArTPC Technology

Credit: Jonathan Assadi

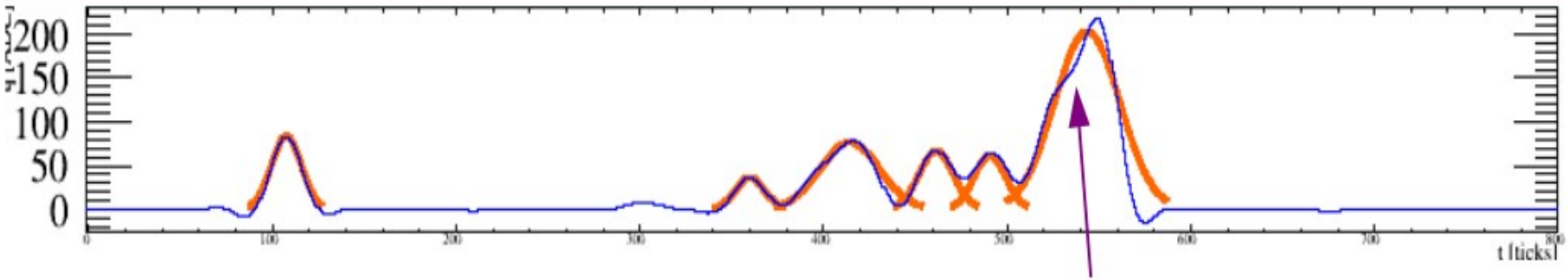


- Charged particles from a neutrino-Argon interaction ionize the argon as they move through the volume
- The interaction also produces scintillation light which is collected with PMTs and gives the initial time of event.
- The ionization then drifts toward wire-planes and creates signals on the collection and induction planes, and the ionization is collected on the collection plane
- Using the charge collected on the wire planes and the drift time we can project the event back into the volume to get a 3D reconstructed image

Reconstruction Chain



Reconstruction Chain: Challenges



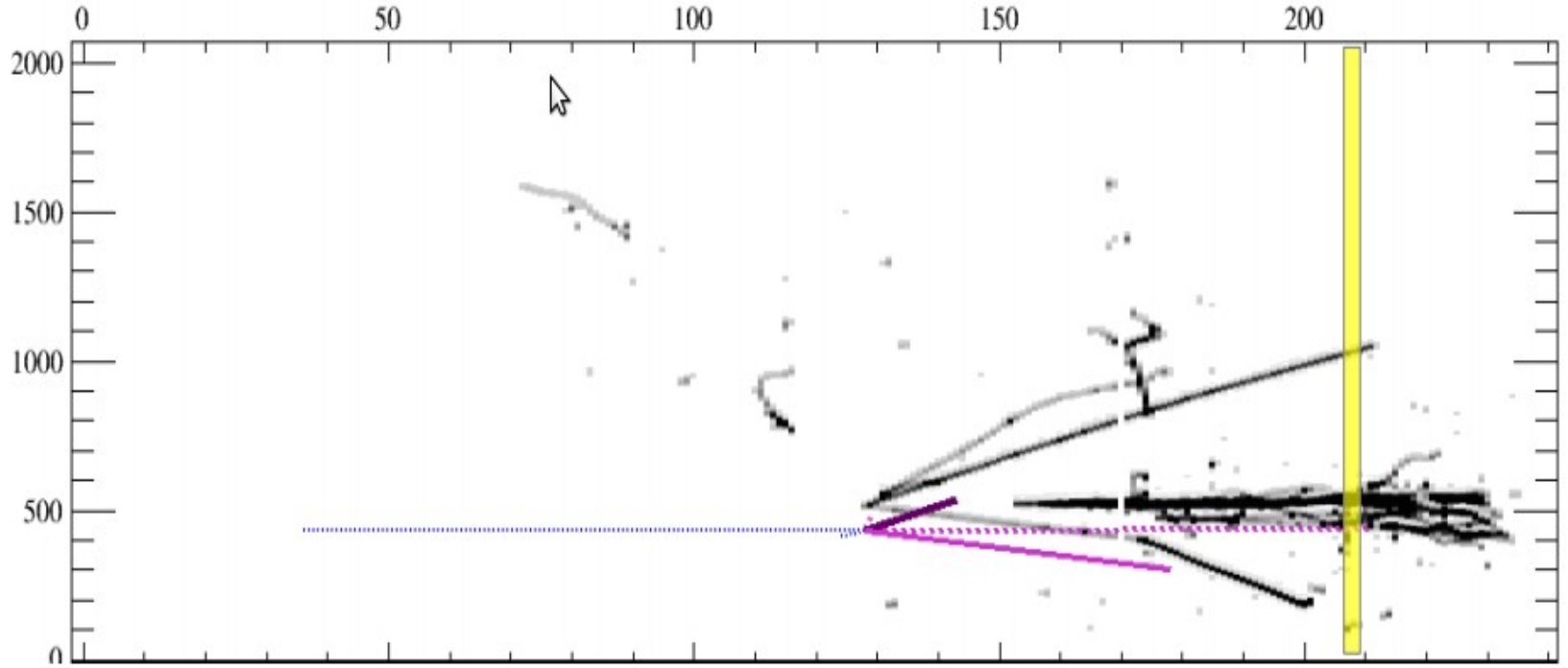


Image Processing on MicroBooNE Data: Muon Event

Collection

Induction 0

Induction 1

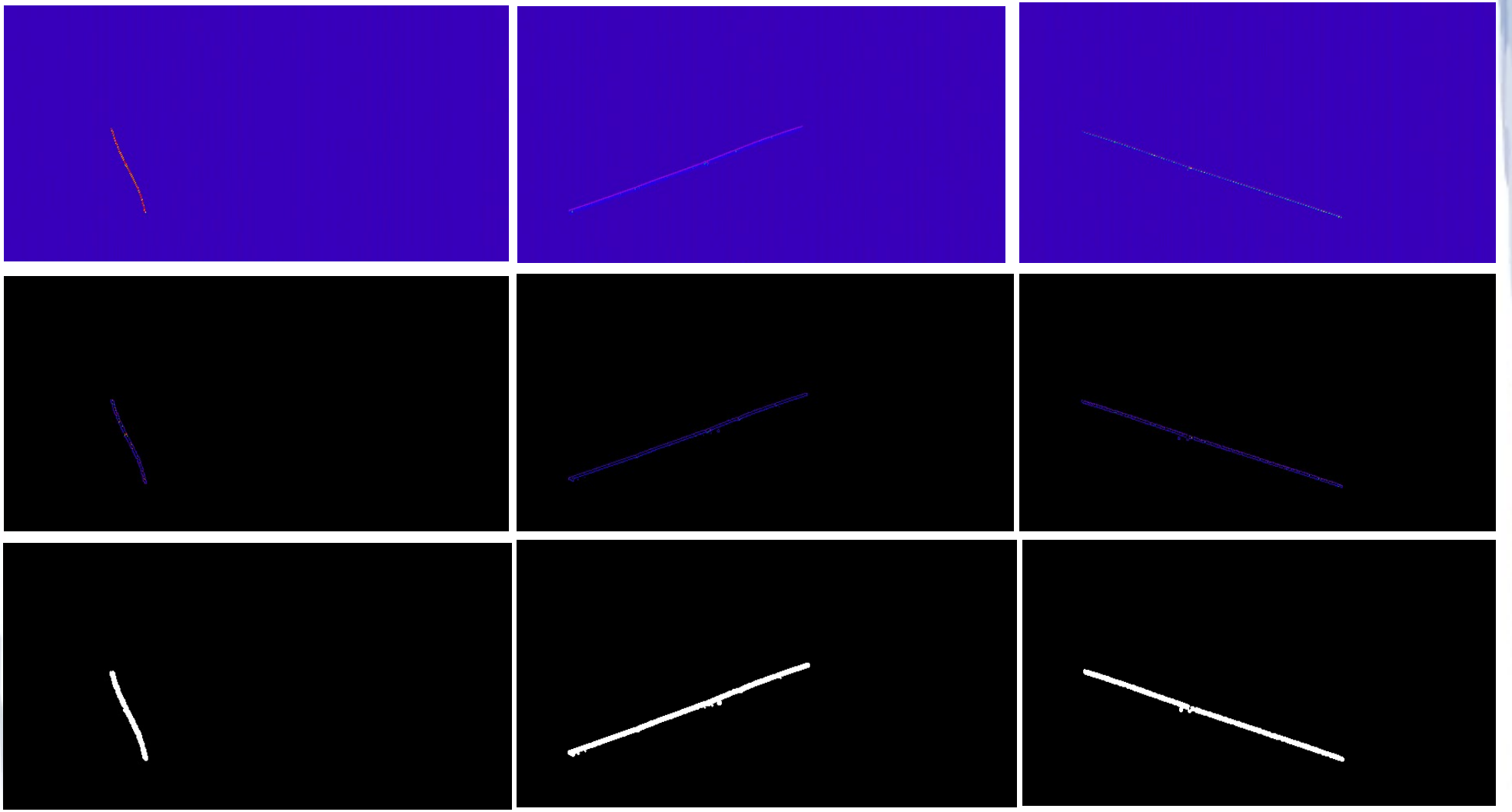


Image Processing on MicroBooNE Data: Pi0 Events

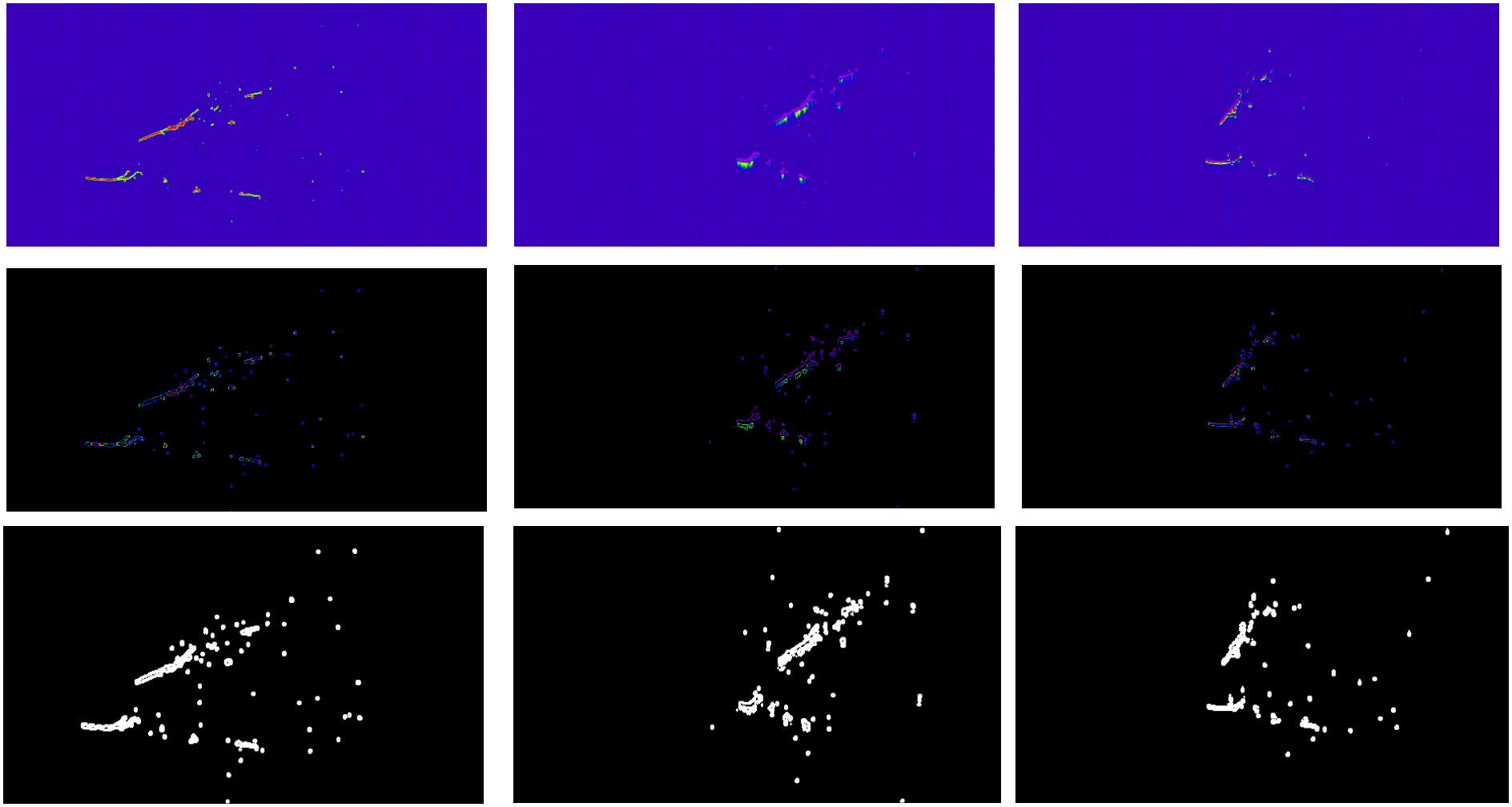


Image Processing on MicroBooNE Data

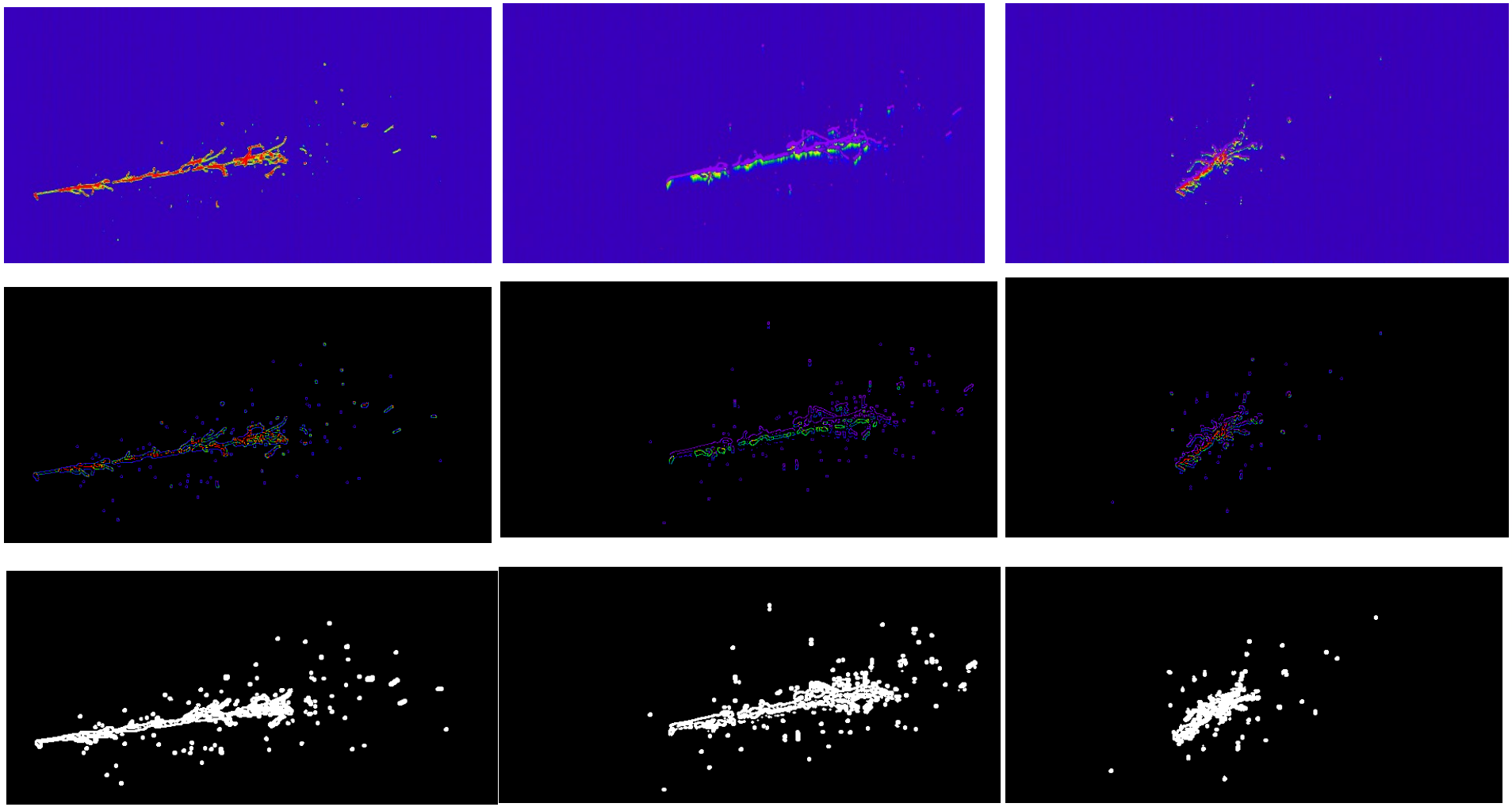


Image Processing on MicroBooNE MonteCarlo Data

Original Event: Electron neutrino 1.170GeV CC Quasi- Elastic in the Collection Plane

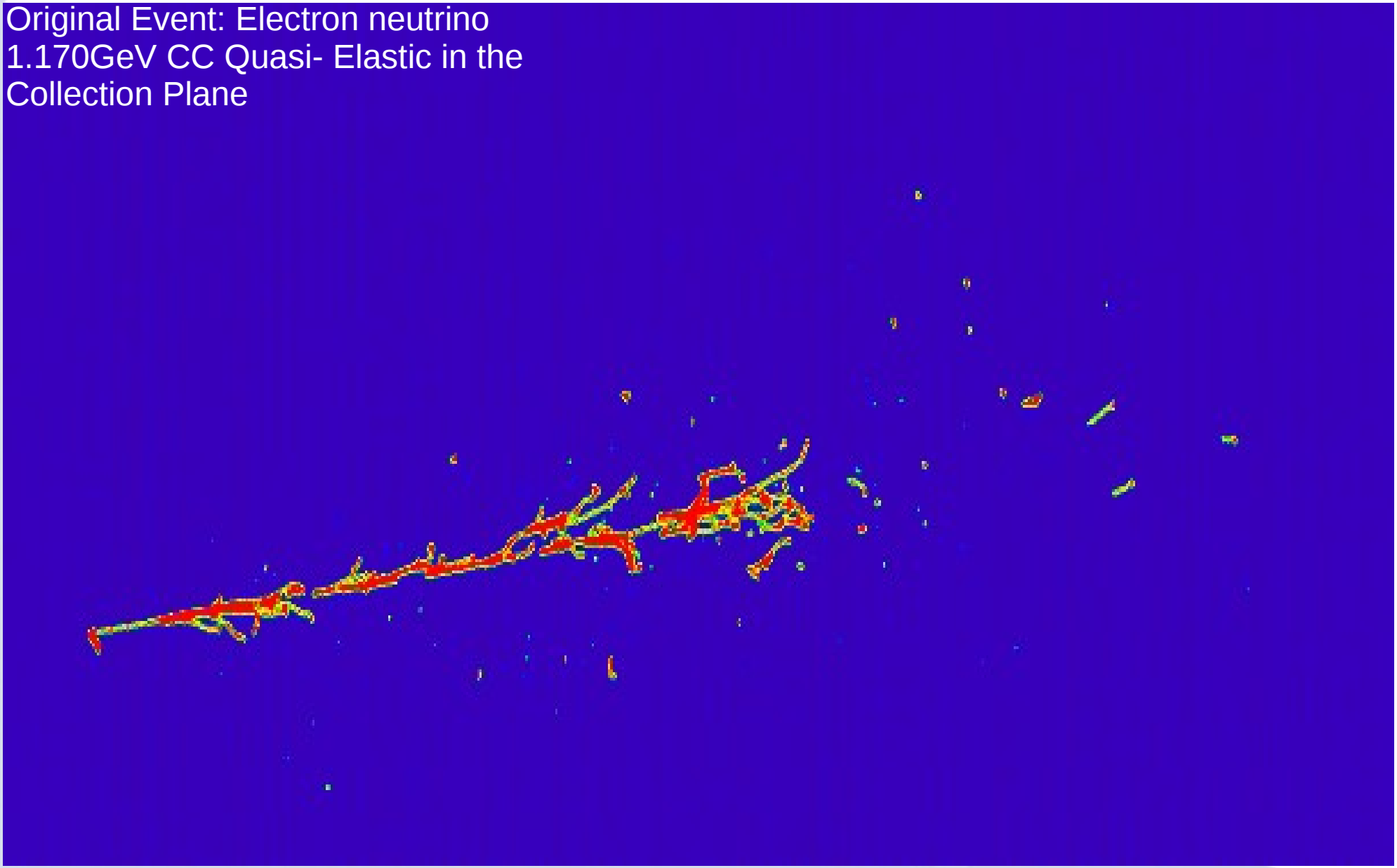


Image Processing on MicroBooNE MonteCarlo Data

Canny Event: Electron neutrino 1.170GeV CC Quasi- Elastic in the Collection Plane

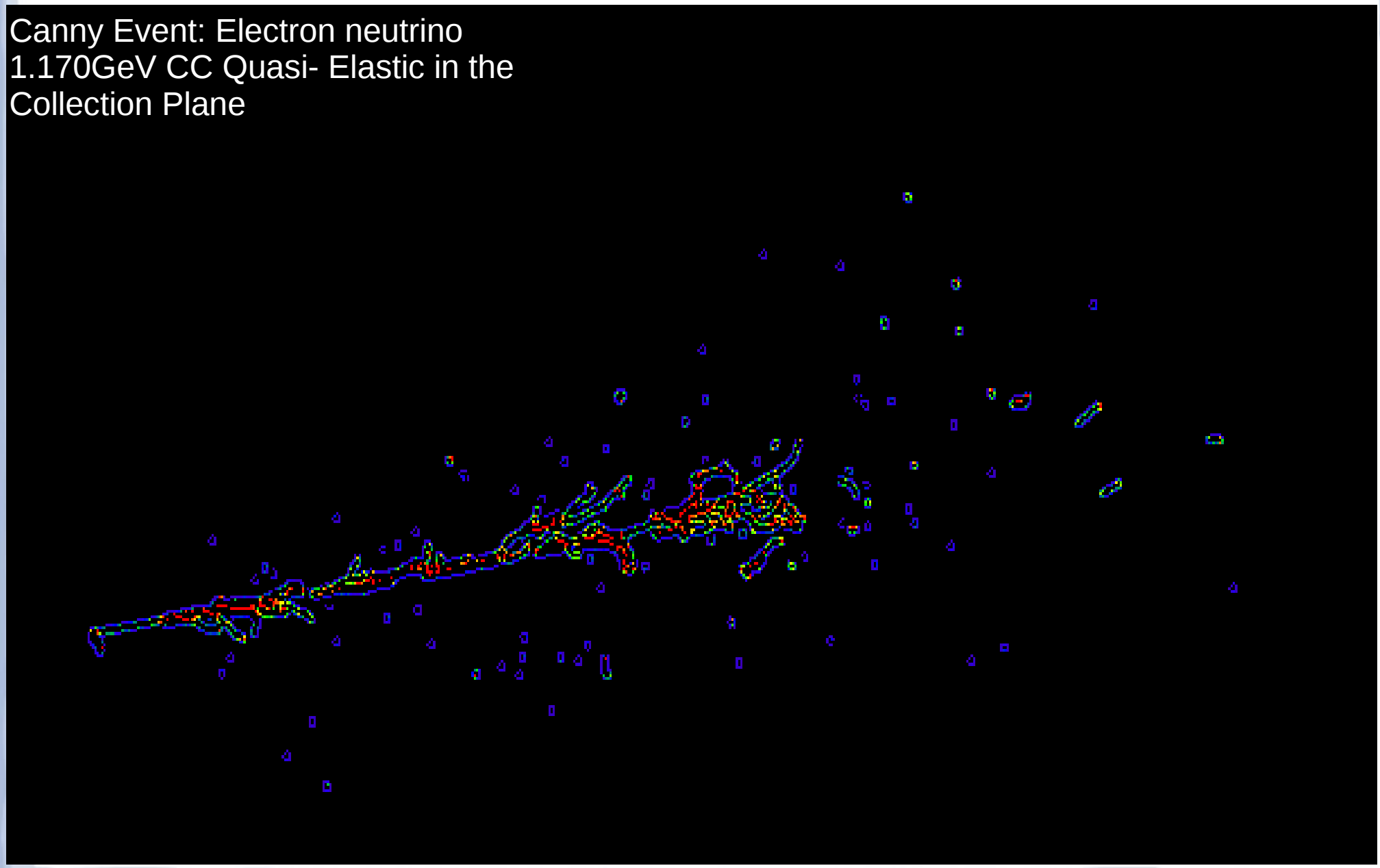


Image Processing on MicroBooNE MonteCarlo Data

Contoured Event: Electron neutrino 1.170GeV CC Quasi- Elastic in the Collection Plane

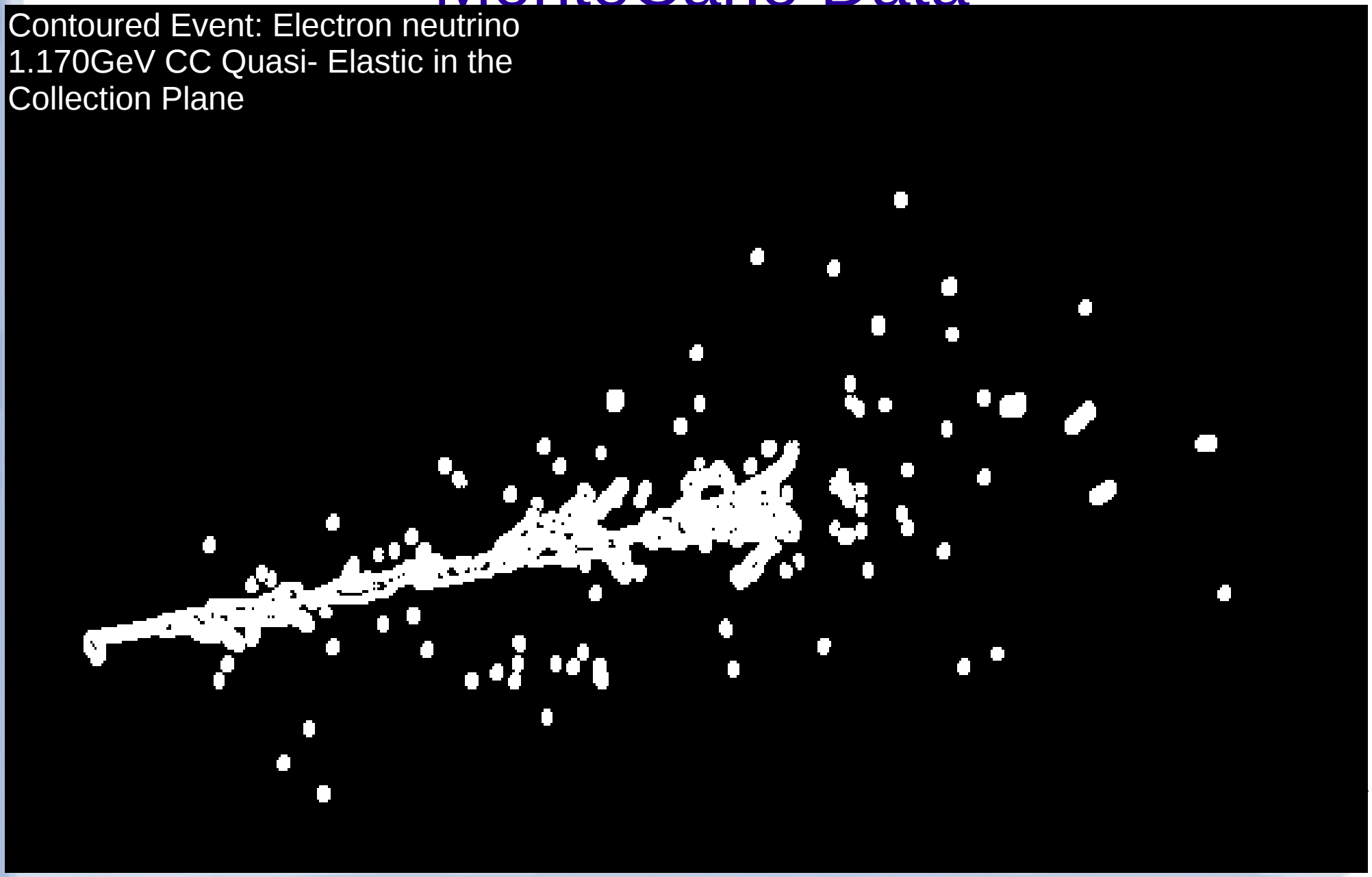


Image Processing on MicroBooNE MonteCarlo Data

Bounded Event: Electron neutrino 1.170GeV CC Quasi- Elastic in the Collection Plane

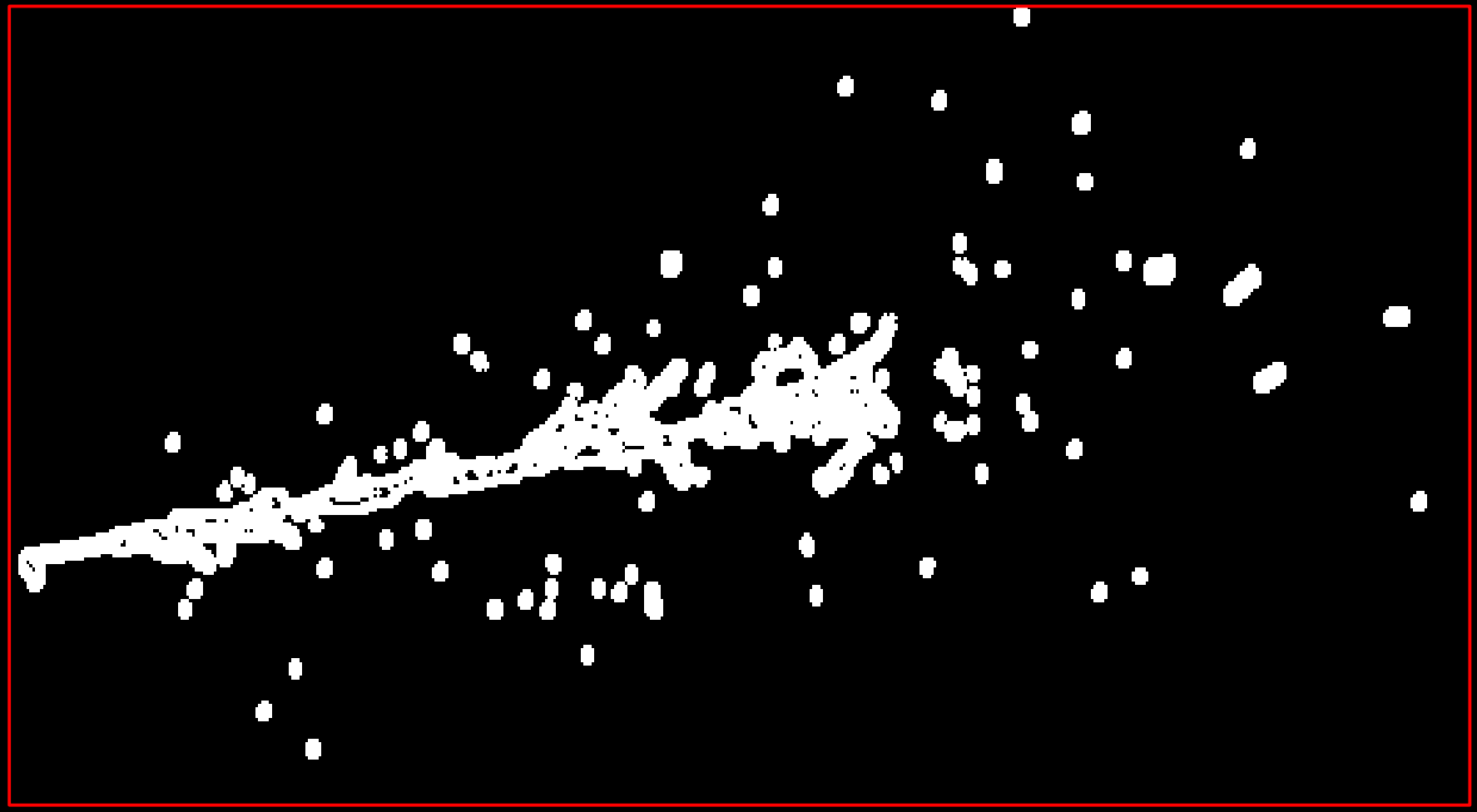


Image Processing on MicroBooNE MonteCarlo Data: World View