An Automated Deep Learning ν_e Reconstruction for MicroBooNE

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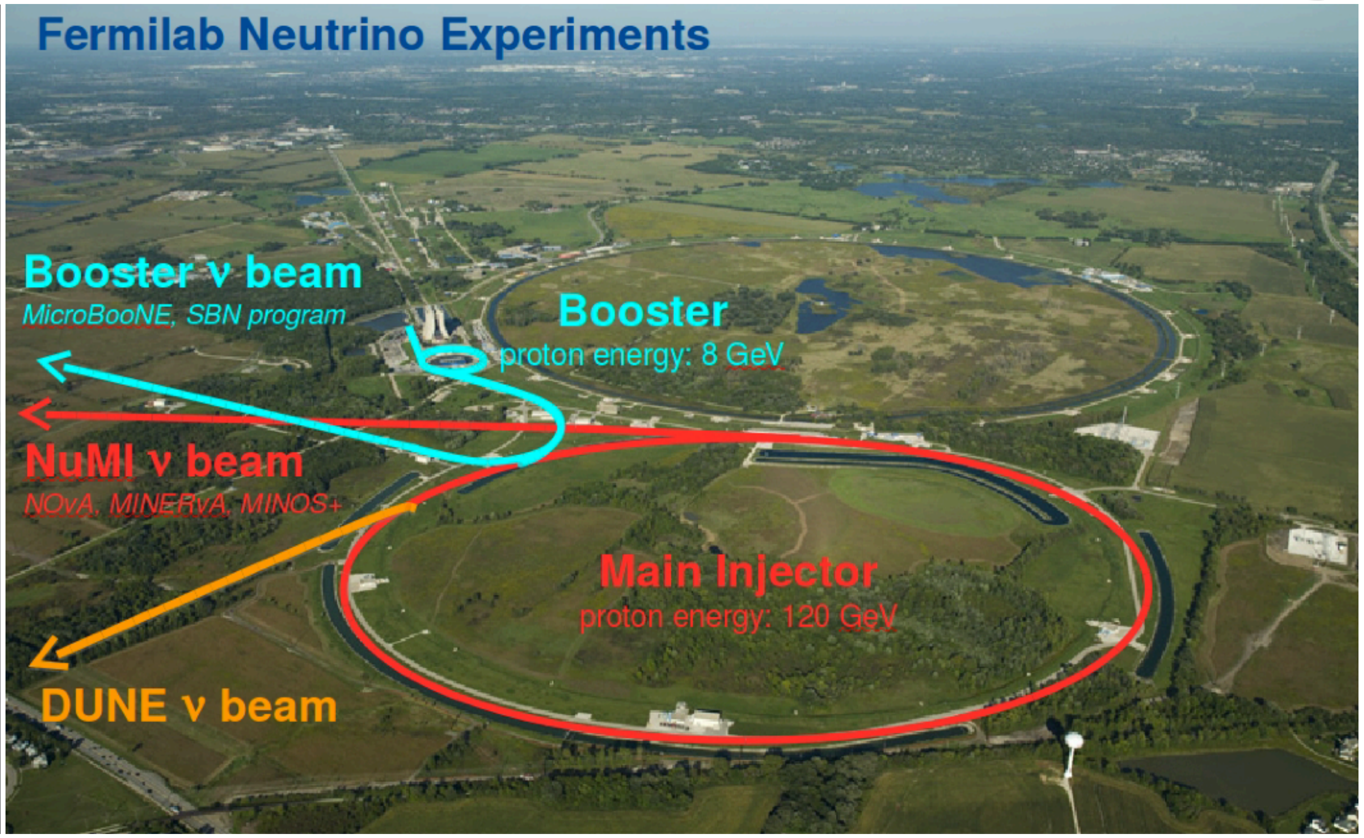
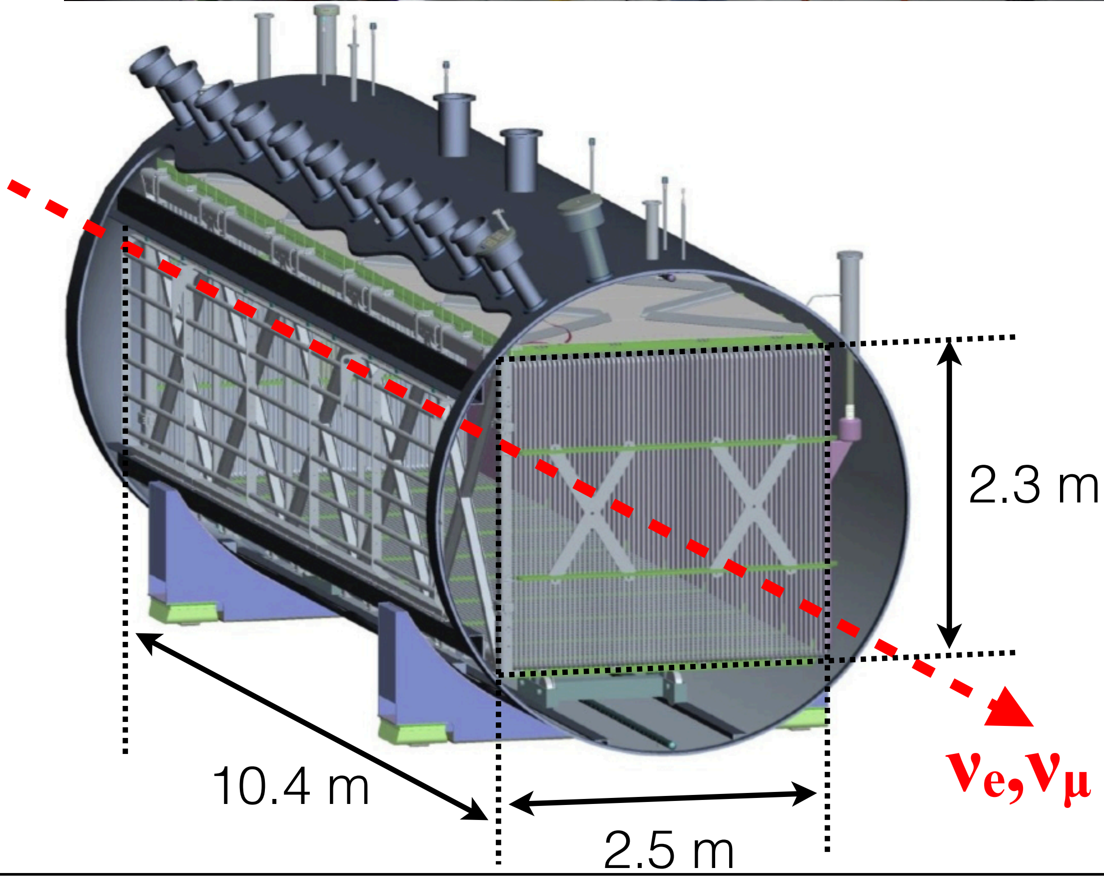
for MicroBooNE and the Deep Learning Group

05/09/2017

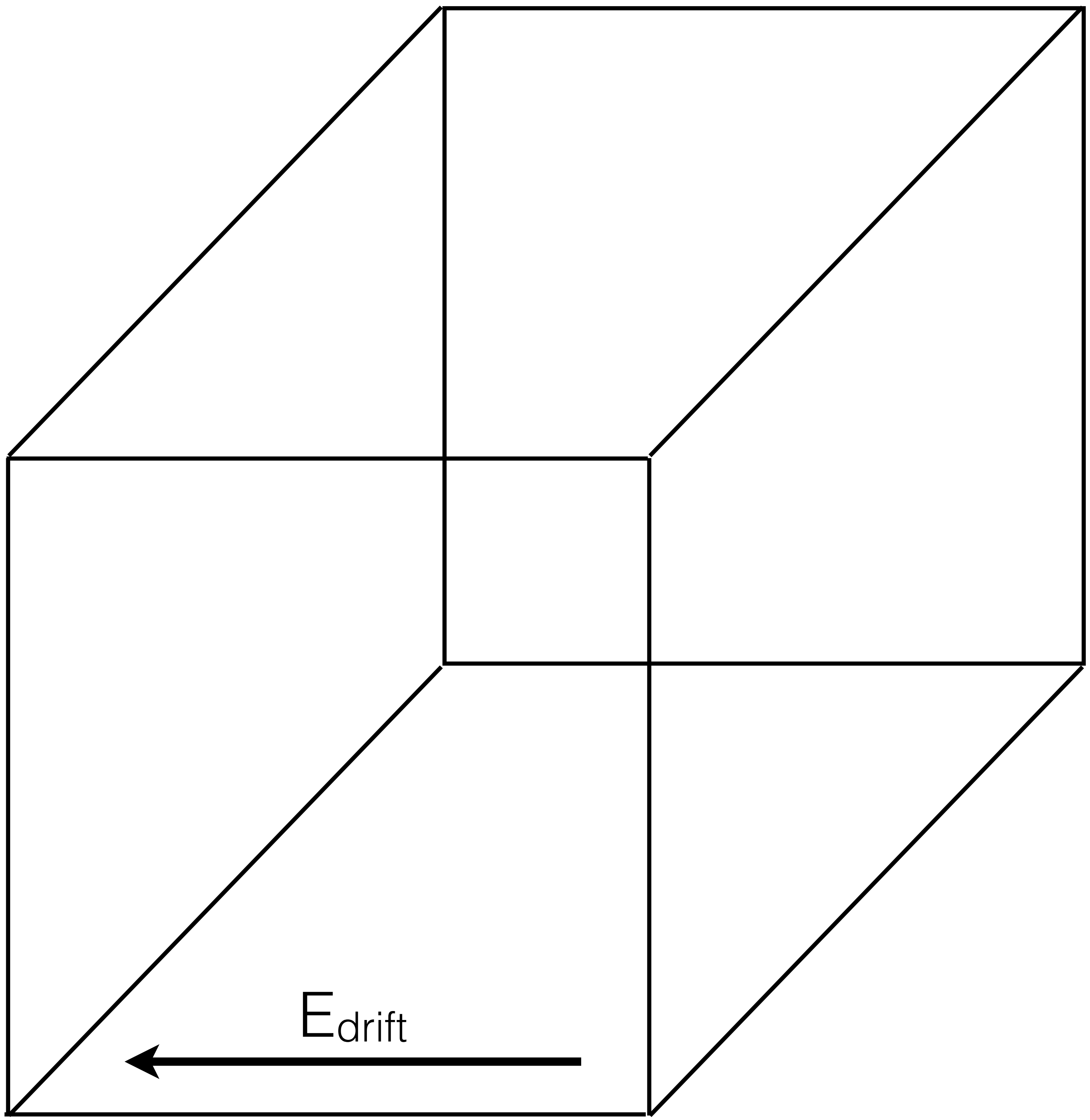
The MicroBooNE Detector





- **Micro Boo**ster **N**eutrino **E**xperiment
- ~90 tons LArTPC
- $\nu_\mu \longrightarrow \nu_e$ appearance experiment
- Booster Neutrino Beam-line
- >97% detector up time
- 5.0x10^{20} POT (proposal: 6.6x10^{20} POT)

LArTPC Operation



"Design and Construction of the MicroBooNE Detector", [JINST 12, P02017 (2017)]

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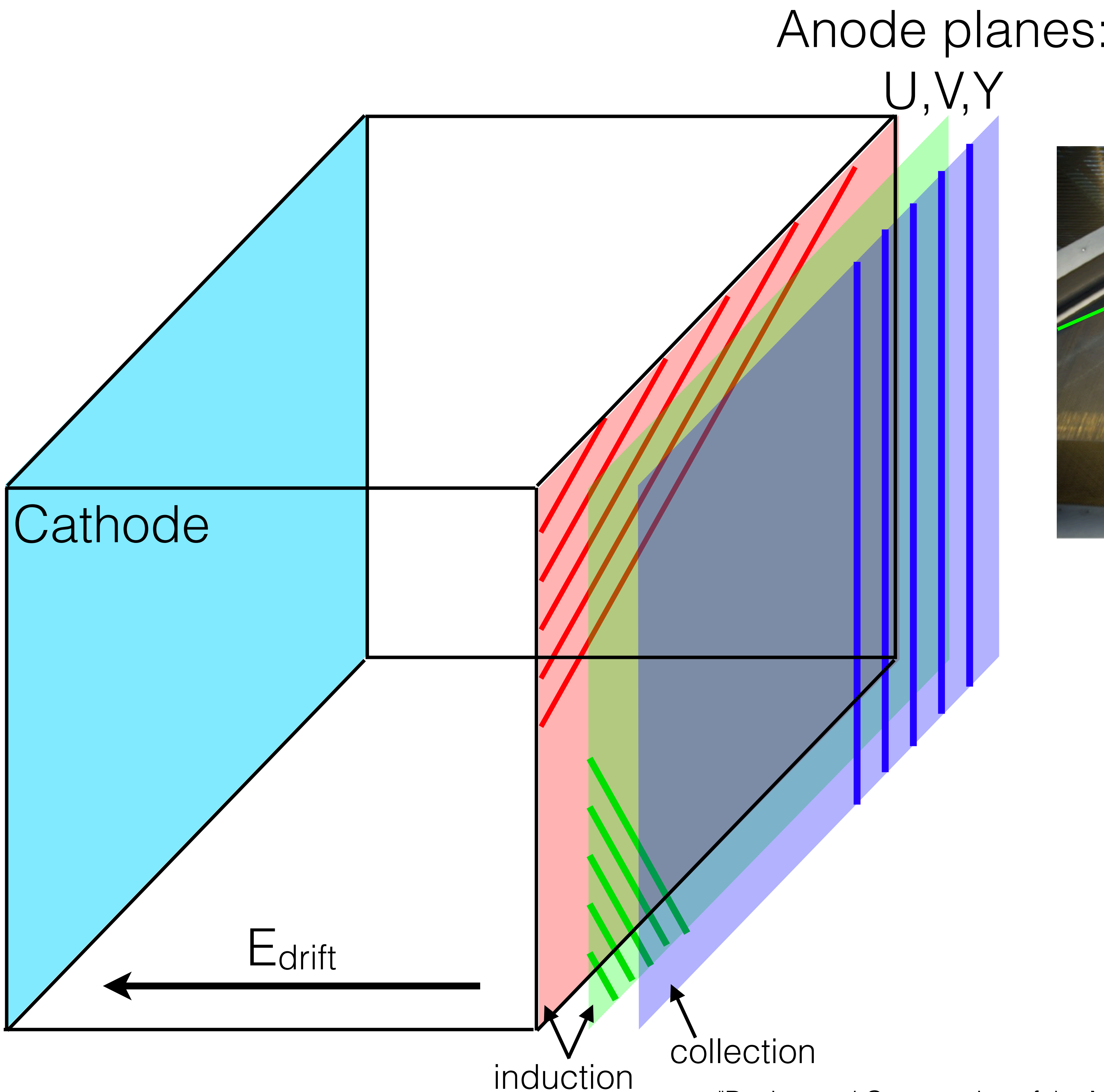

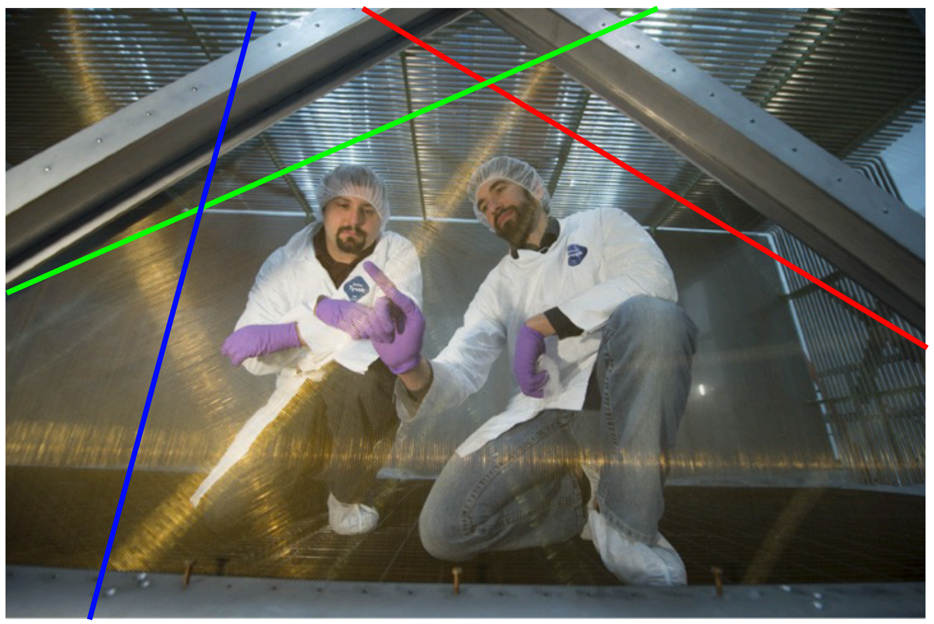

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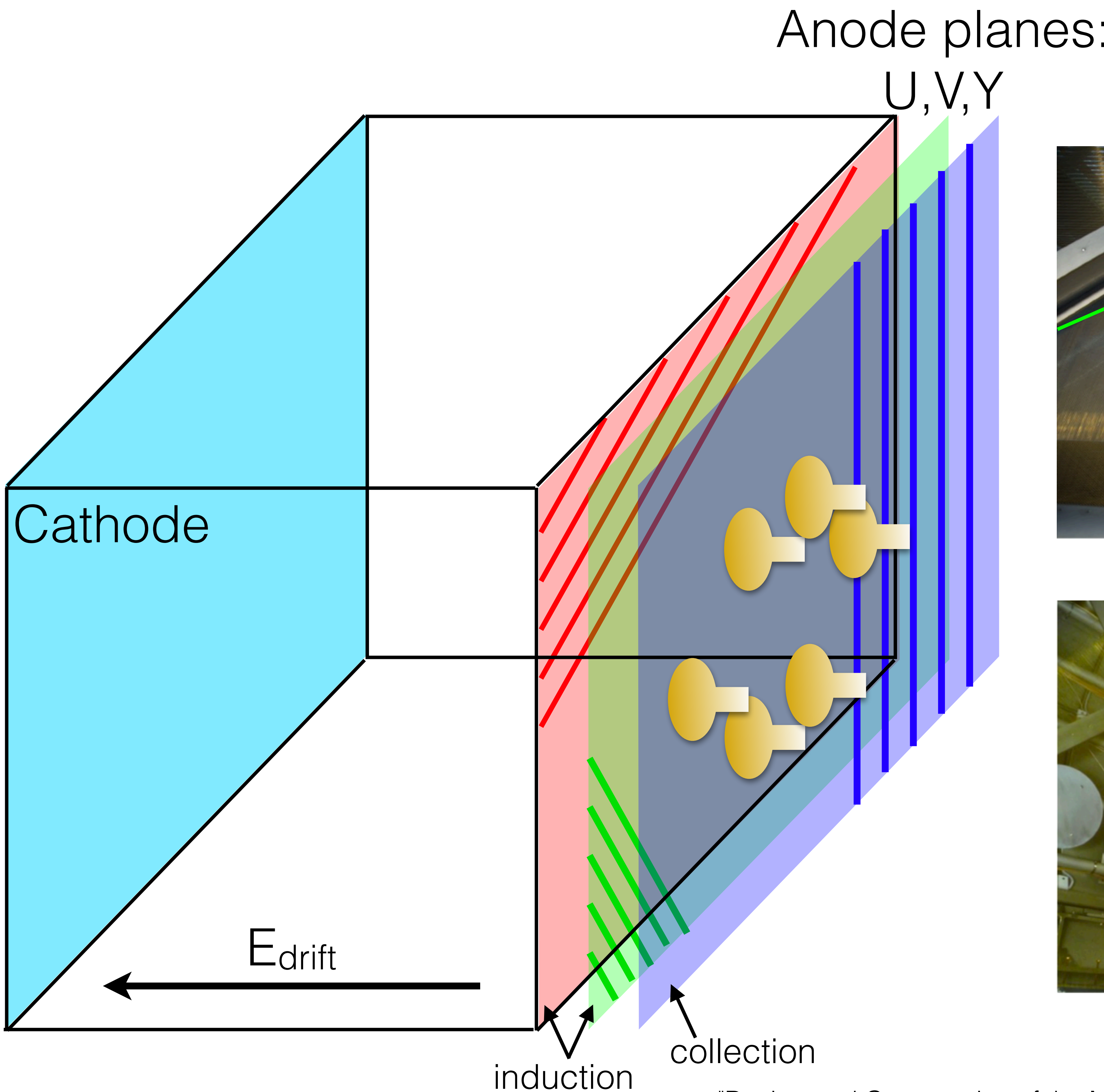

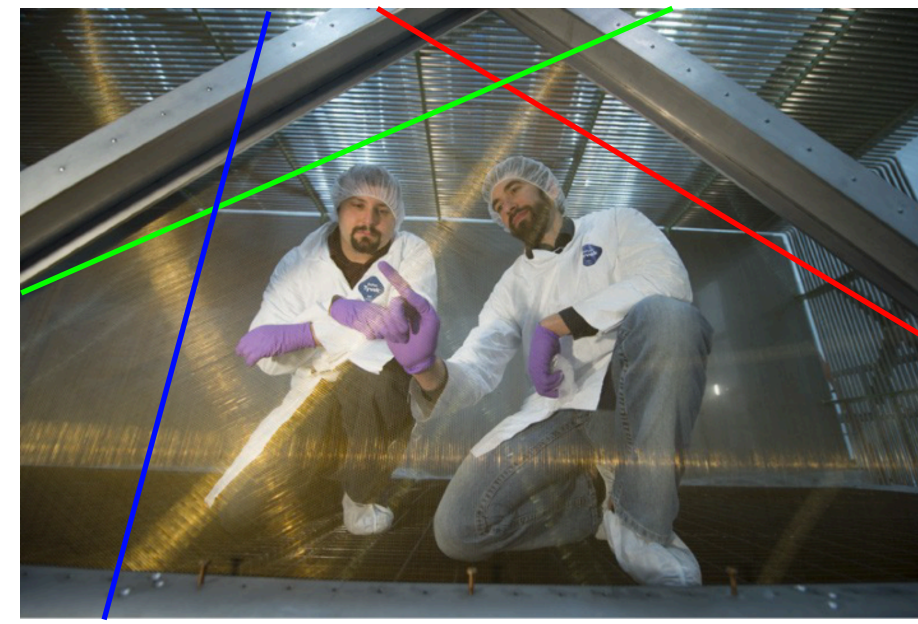

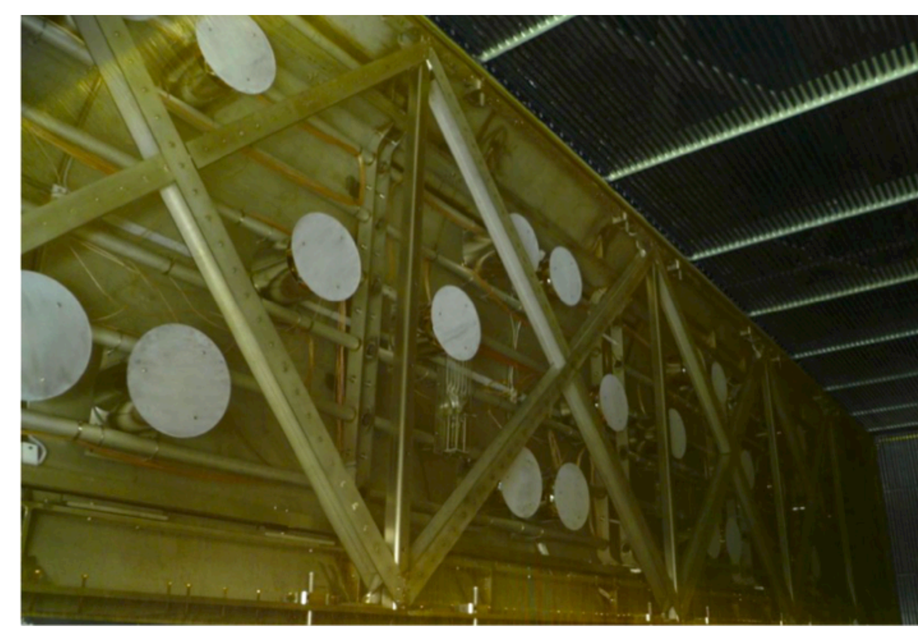

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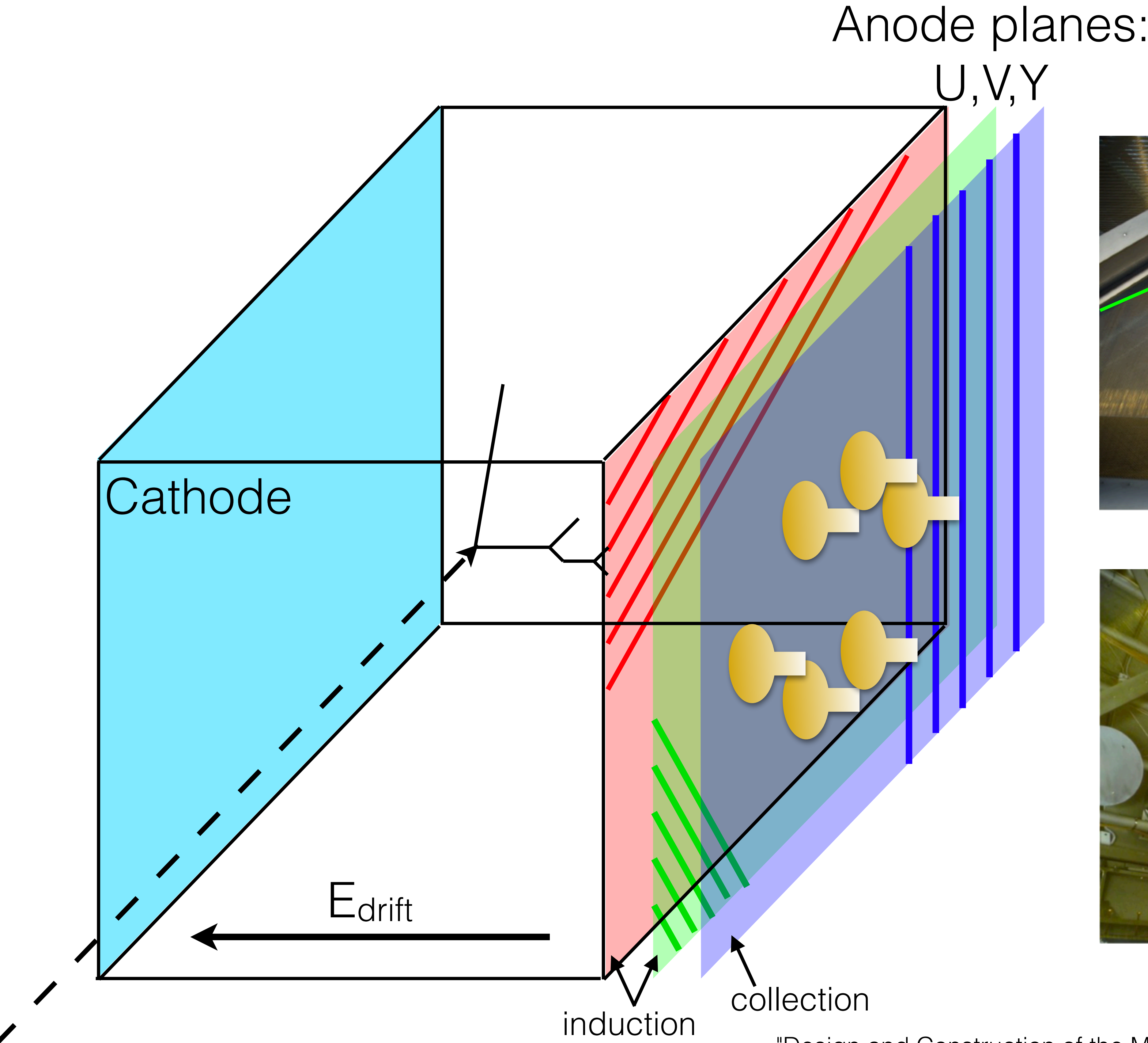

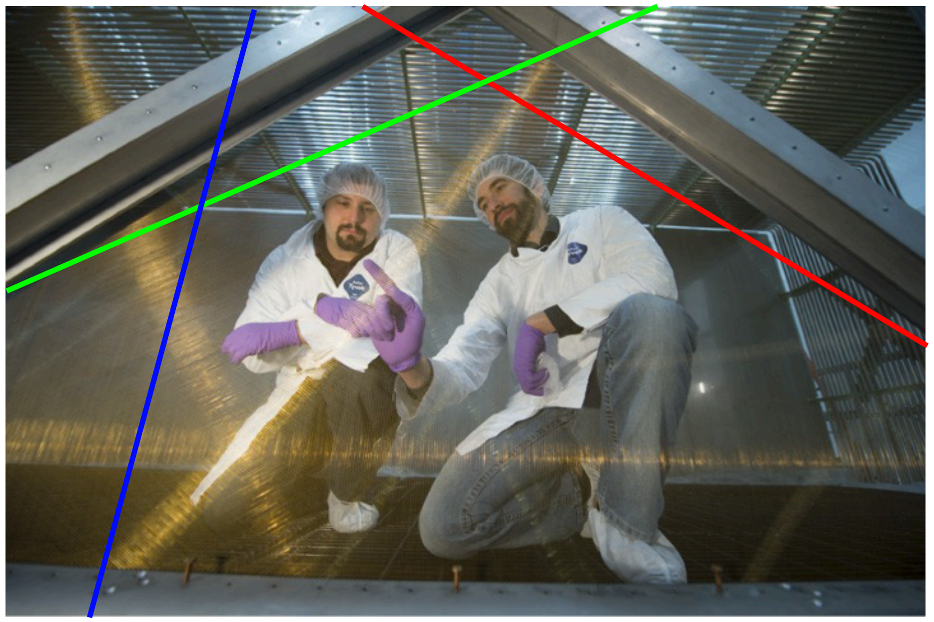

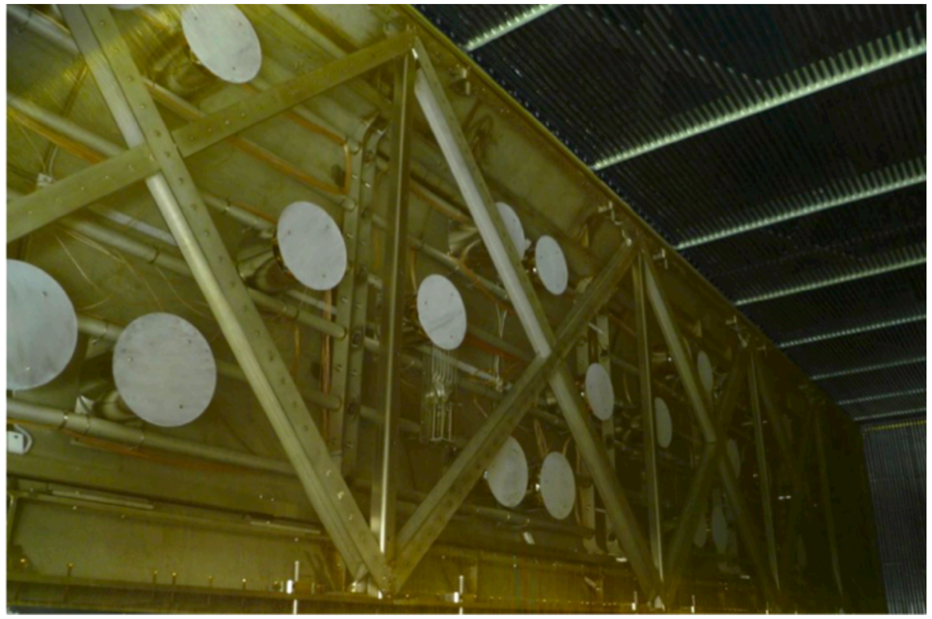

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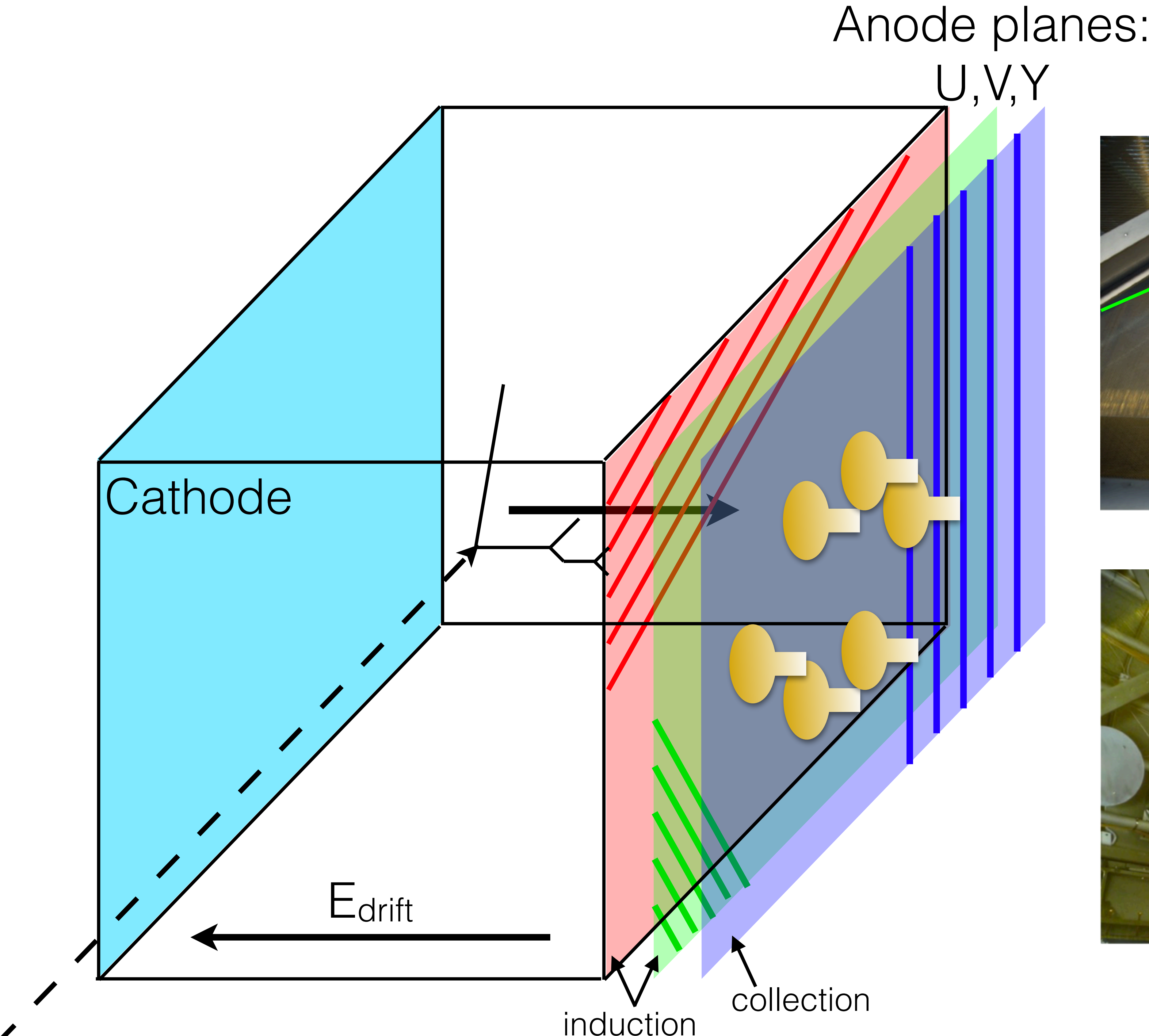

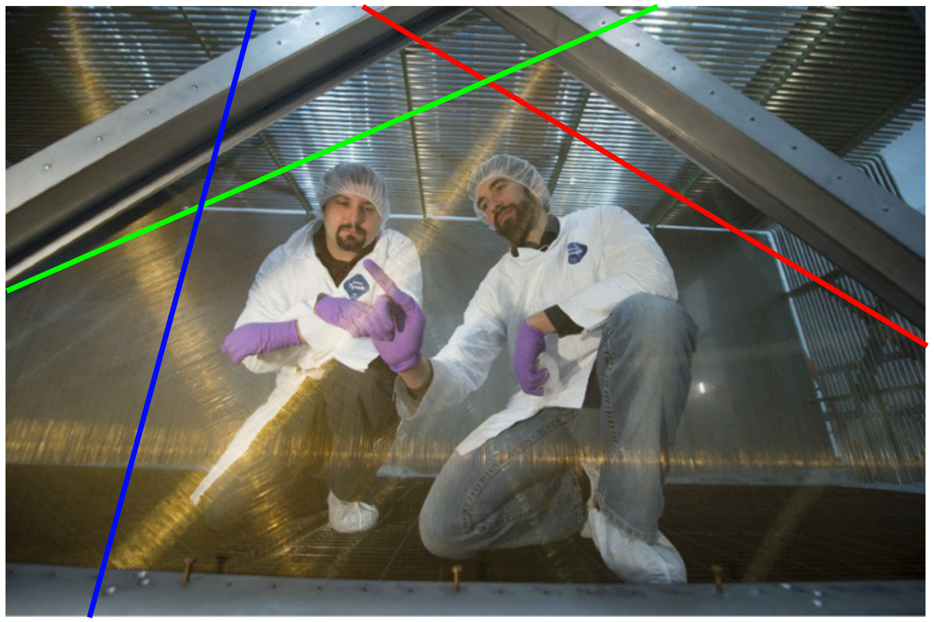

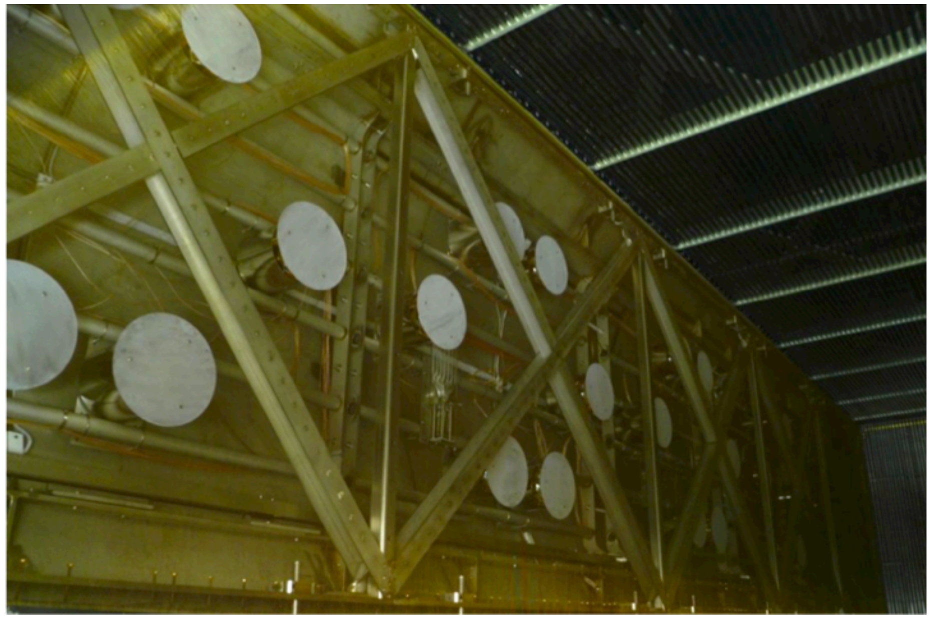

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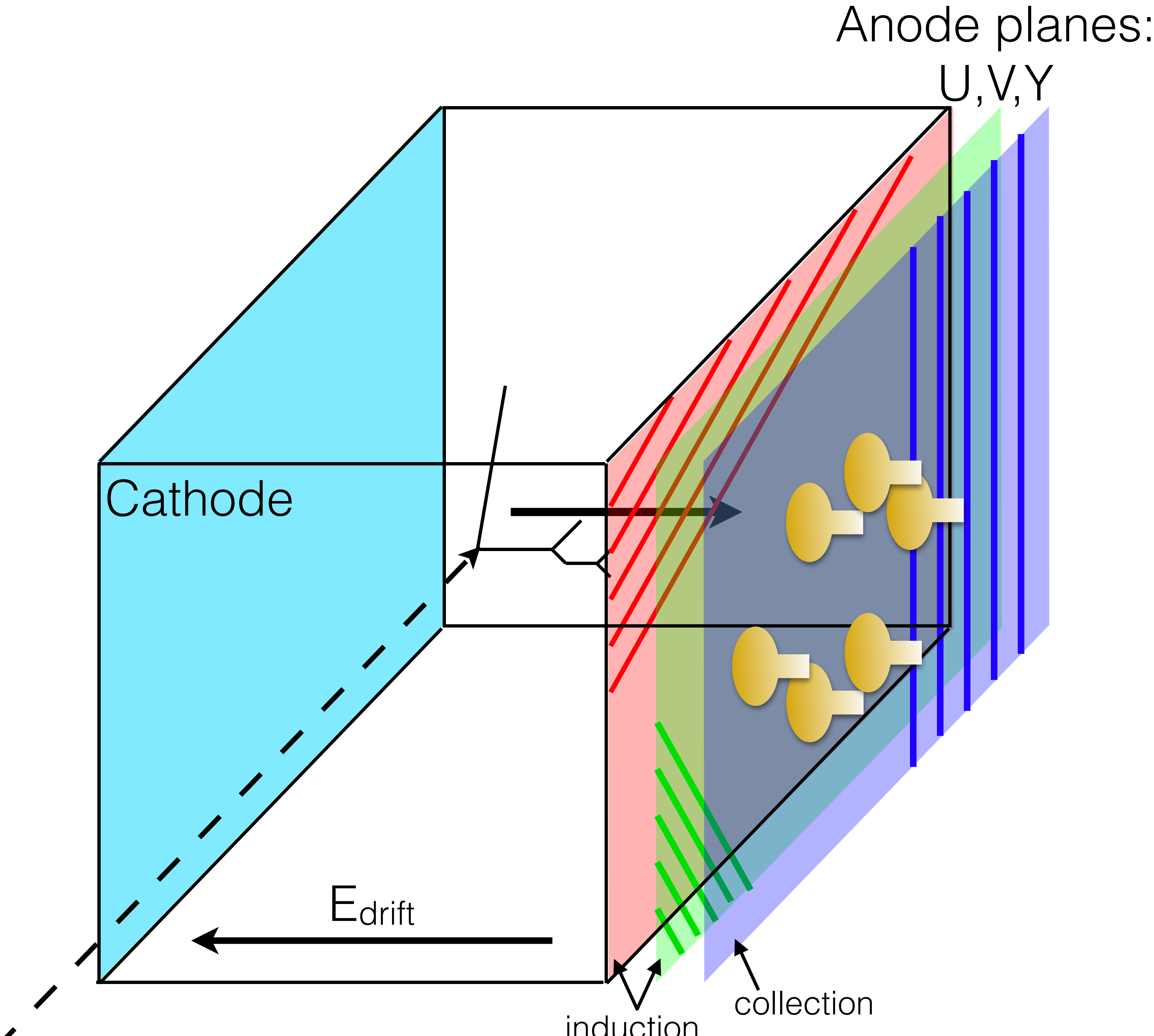
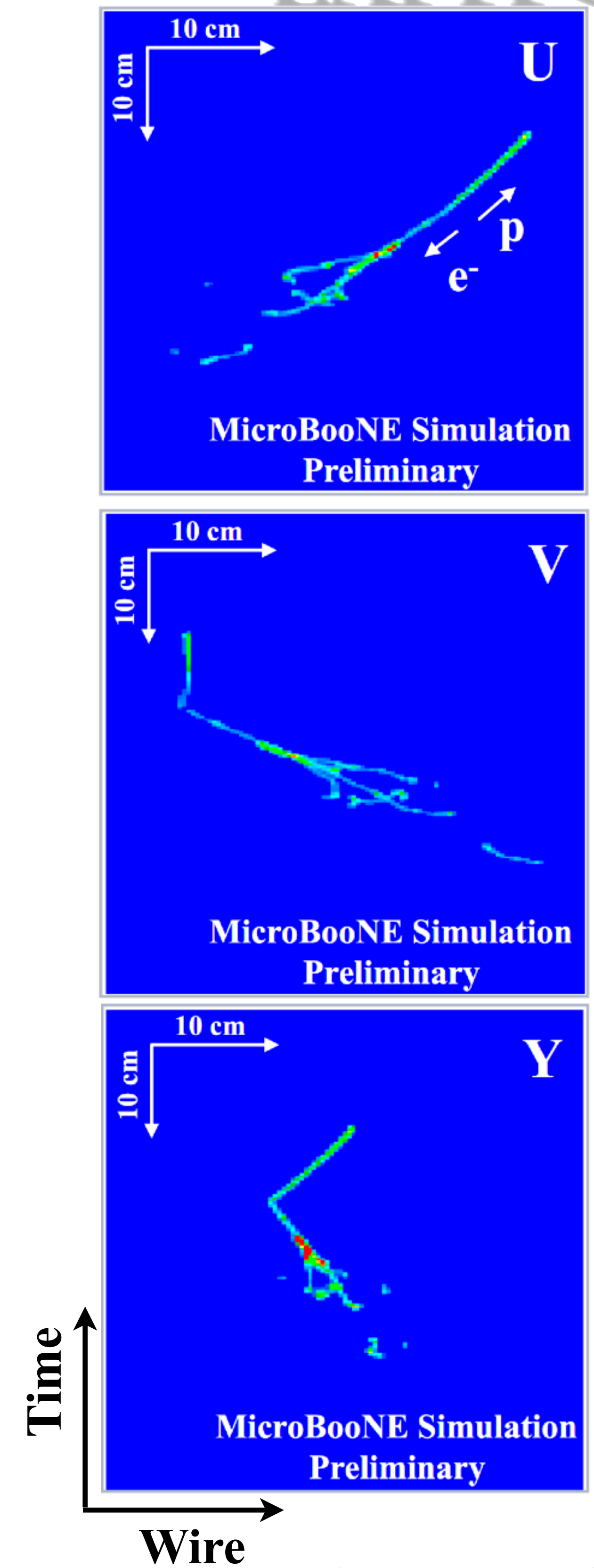
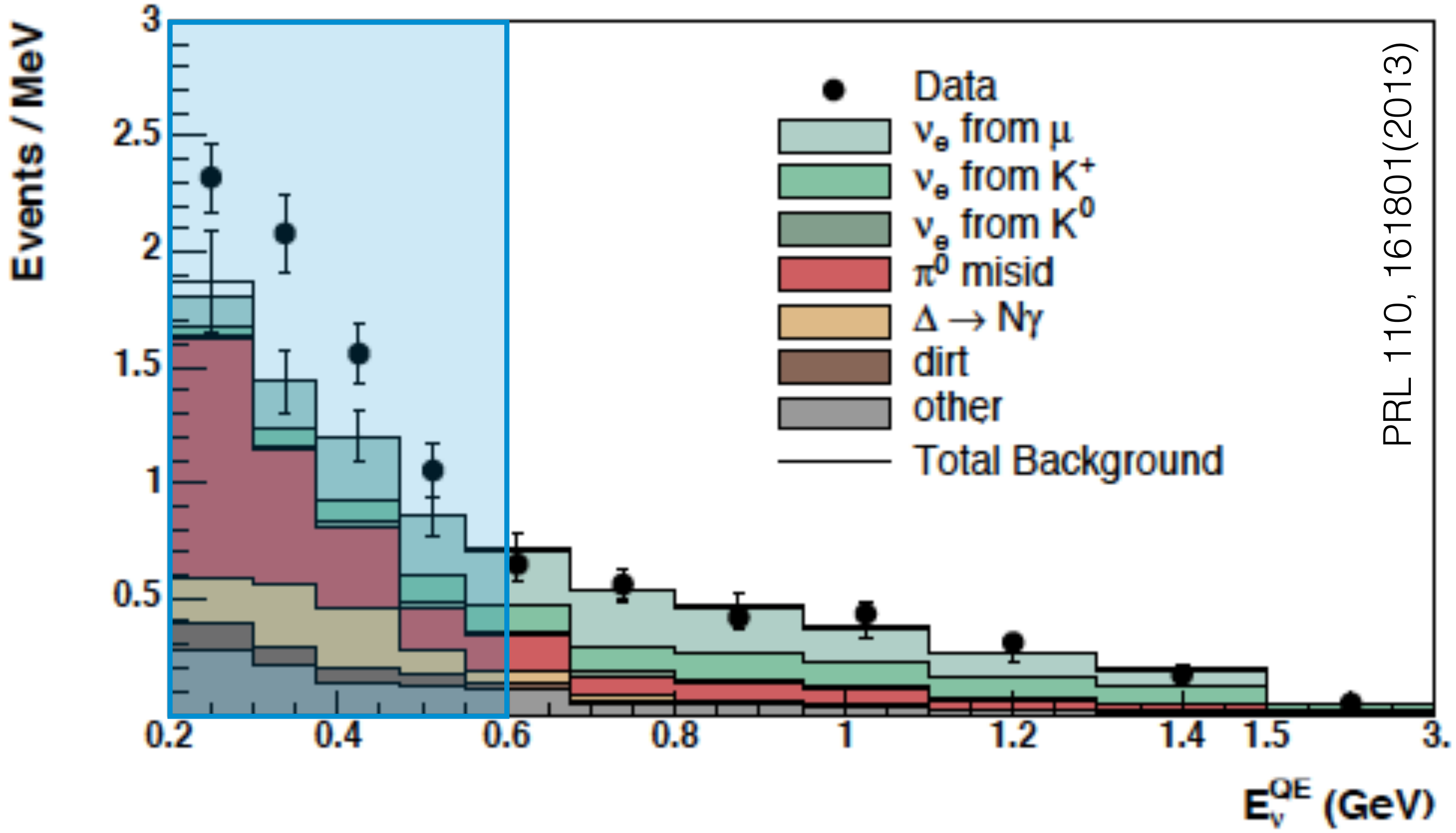
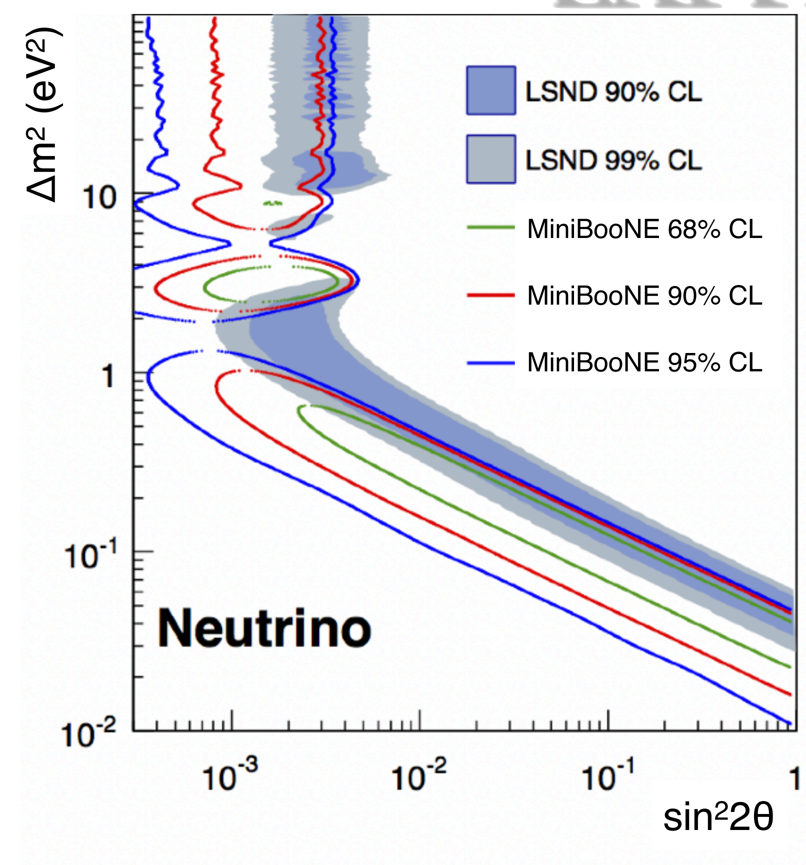




"Design and Construction of the MicroBooNE Detector", [JINST 12, P02017 (2017)]

MiniBooNE Low Energy Excess

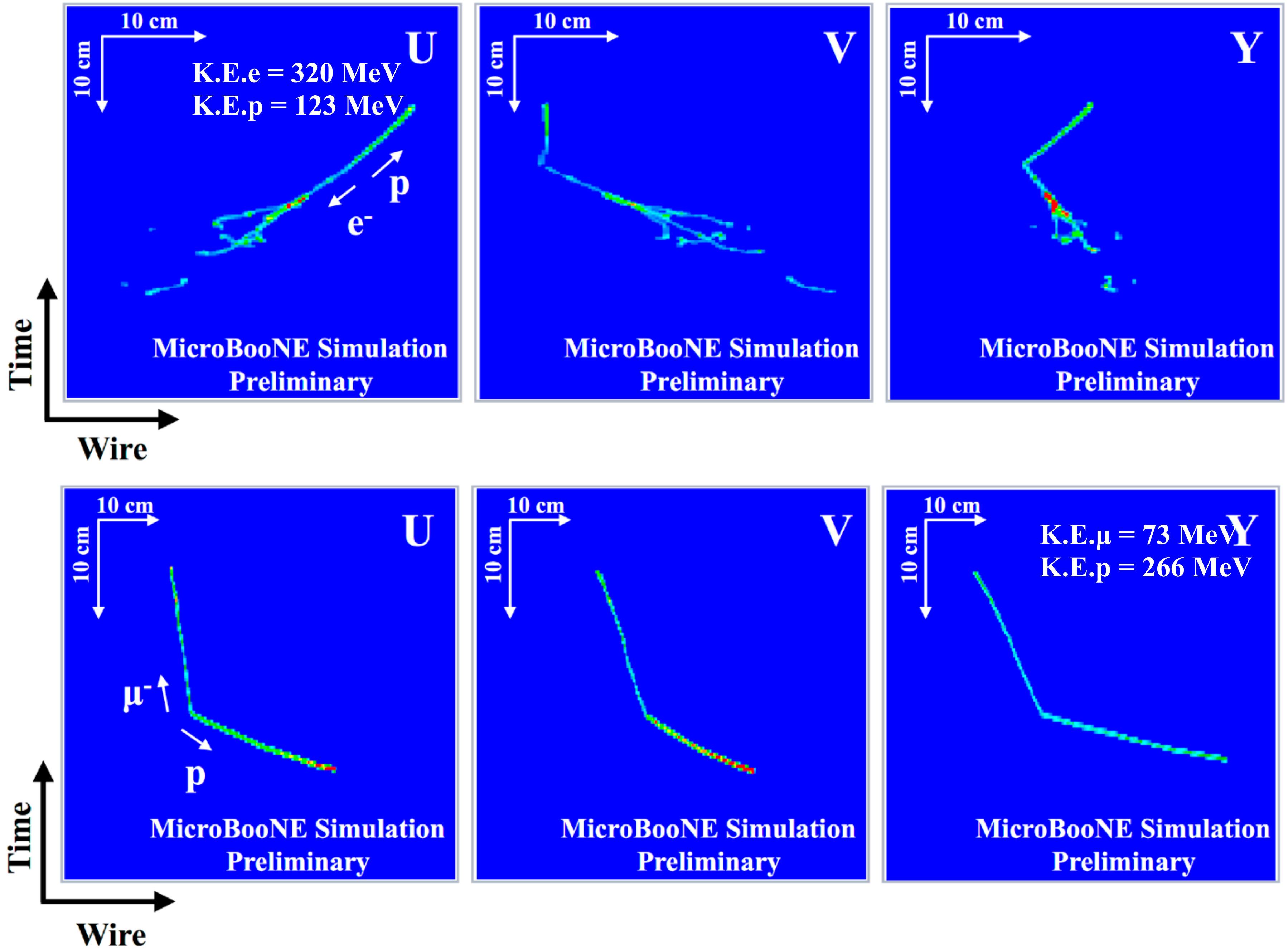




- MiniBooNE saw a 3σ ν_e-like excess within [200-600] MeV
- MiniBooNE's neutrino result is in tension with a global 3+1 model fit

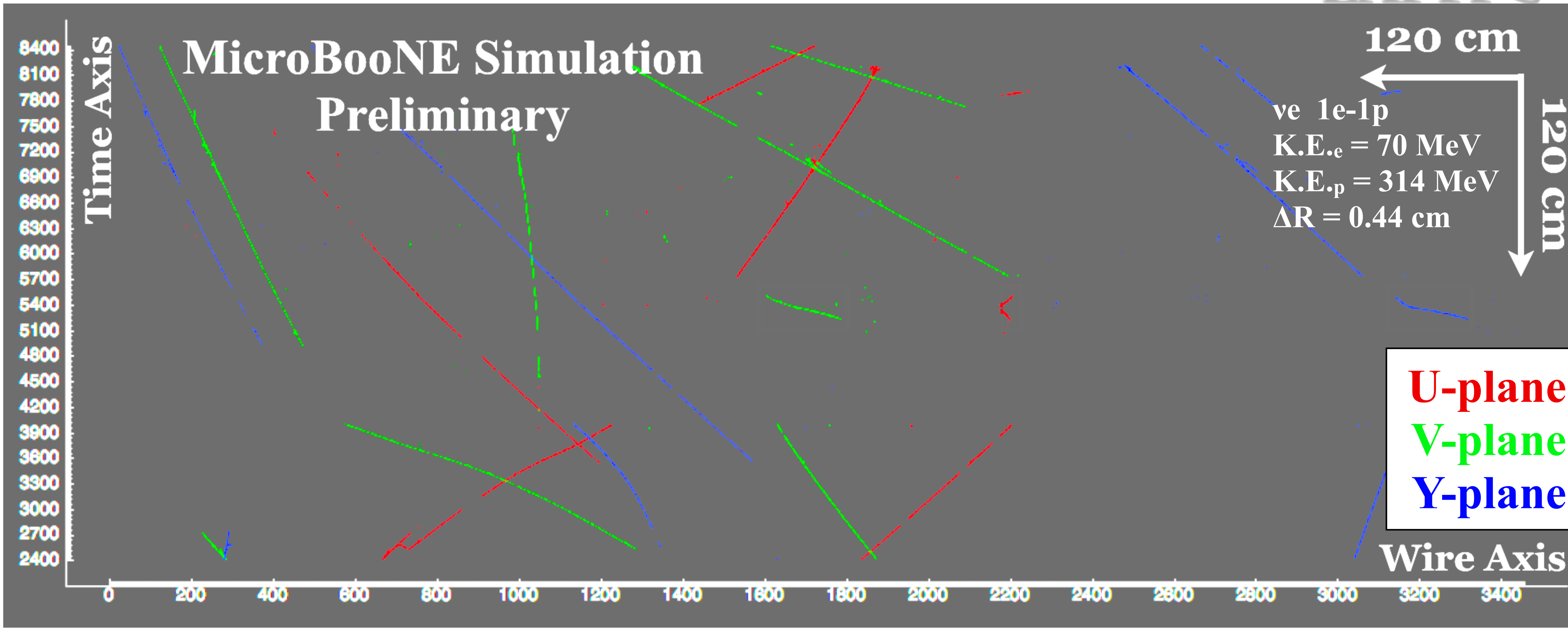
- MiniBooNE
  - significant BG fraction from γ/e^- mis-ID
  - statistical error ≈ systematic error
- MicroBooNE
  - Same beam
  - Similar baseline
  - Statistic-dominated

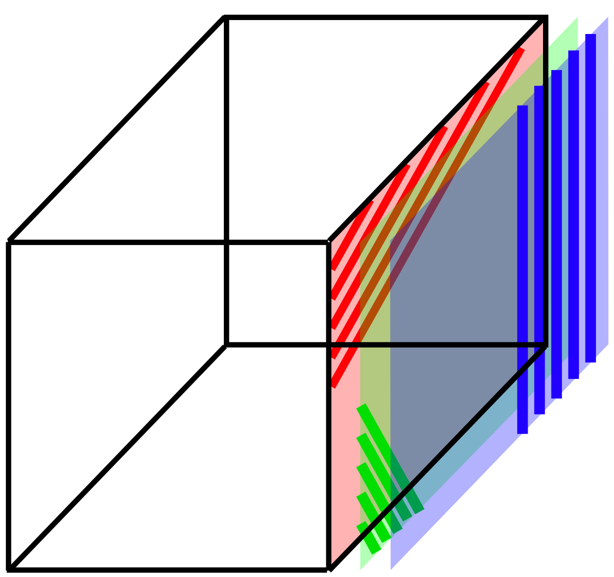
1L-1p Event Topology



- Only 1 proton > 60 MeV & 1 lepton > 35 MeV
- "Golden" events : low BG (~only intrinsic ν_e constrained with ν_μ)

A Couple of Events





- One colour per wire plane
- Time on the Y-axis
- Tracks appear on all three planes
- Can you find the neutrino?

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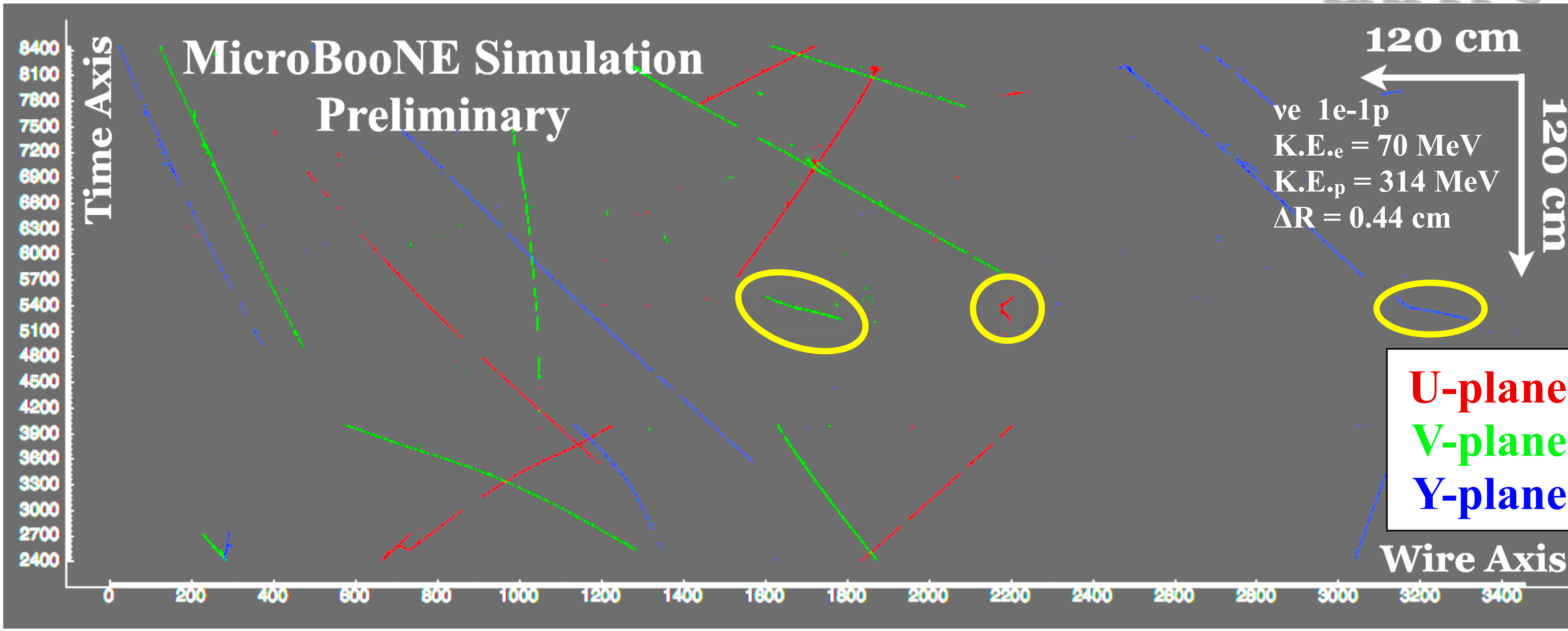

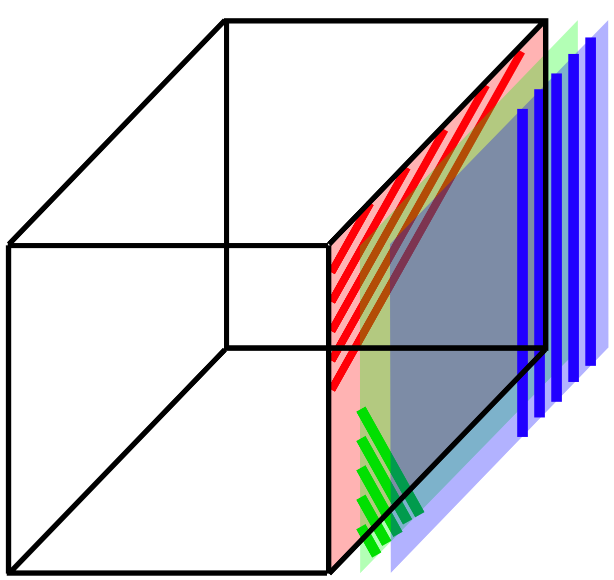

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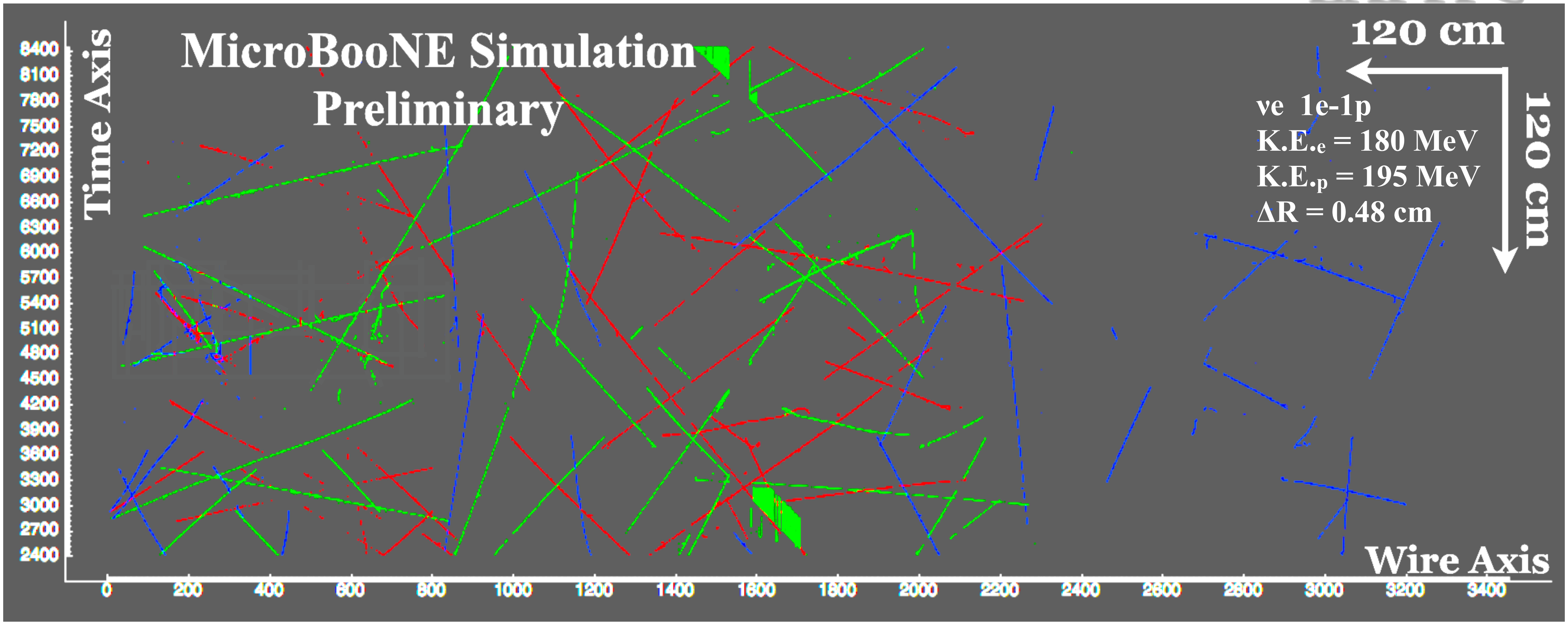


- MicroBooNE operates at the surface ⇒ a lot of cosmics!
- Can you find the neutrino?
  (Hint : ~20 cm in a 10.4m x 2.5m detector)
- Goal : sort through the cosmic and reconstruct ν_e events

Reconstruction Chain

PMT pre-cuts

↓

Cosmic Tag & ROI finding

↓

Track/Shower Pixel Labelling

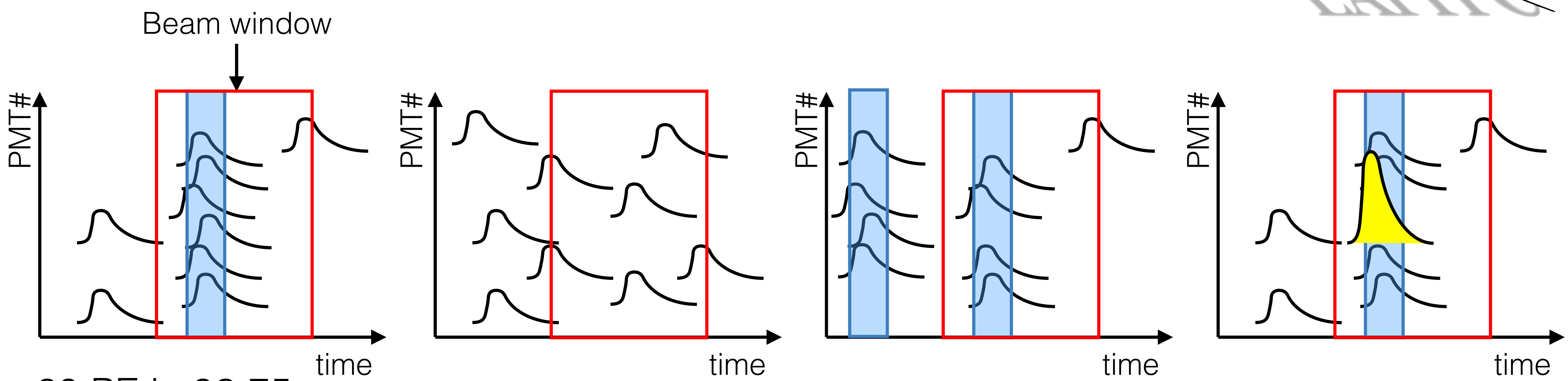
↓

3D Vertex Reco

↓

Particle ID

PMT precuts



20 PE in 93.75 ns

No signal 2 μs before beam

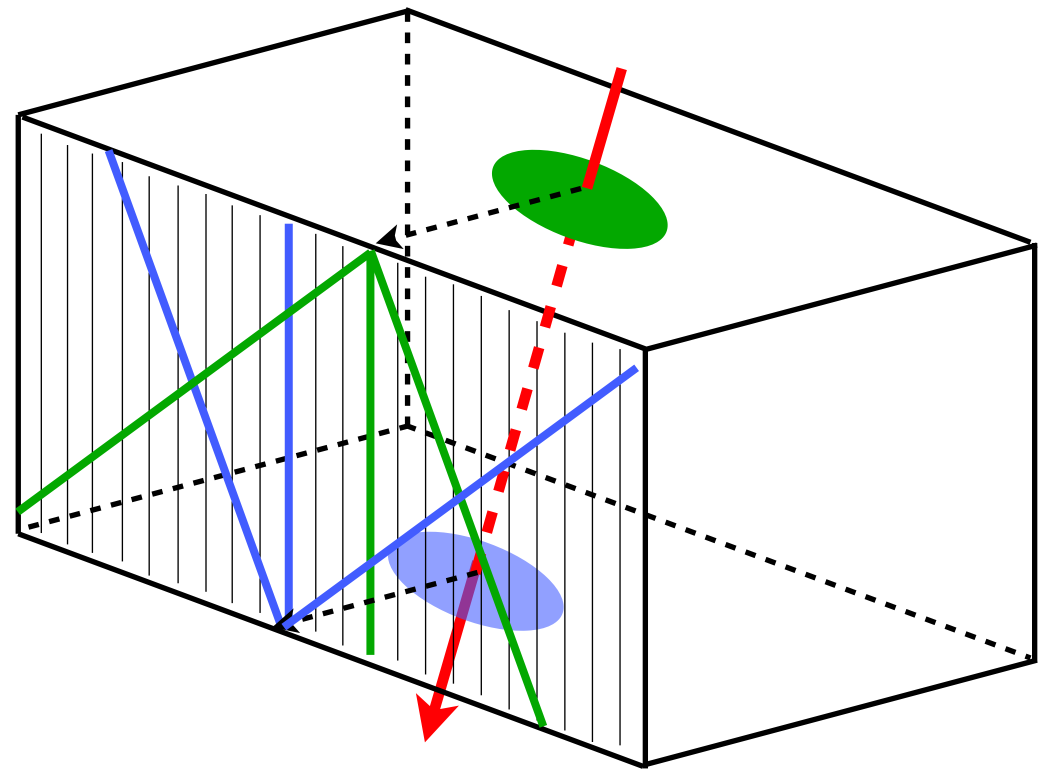
Max single PMT light <60% total light

PMT cuts used to reject :

- Random single PE noise
  - no time correlation between PE pulses
- Cosmic Background
  - pre-window cut rejects Michel electron from beam window
- PMT-based noise
  - max fraction of light collected by a single PMT

Efficiency >96%
Background rejection > 75%

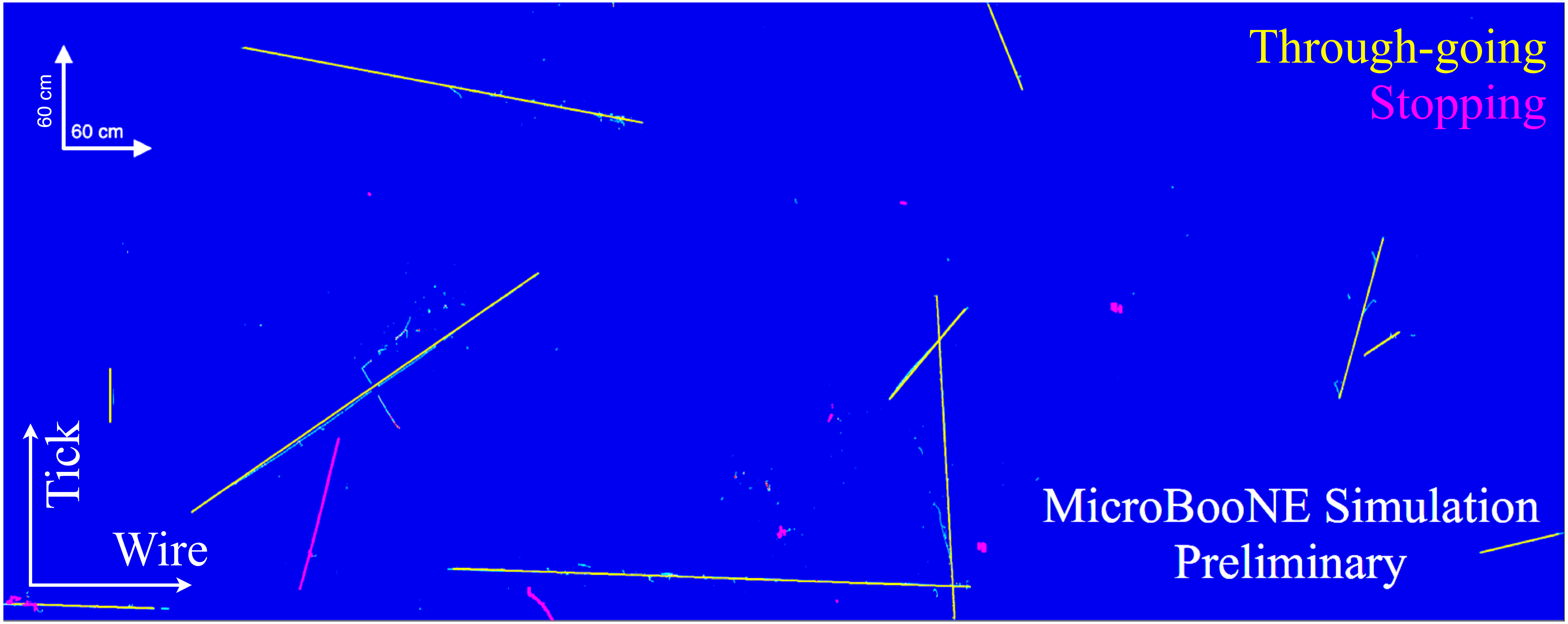
Cosmic Pixel Tagging



- Cosmic and other BG cross from the exterior of the TPC
- Un-contained ν events have tracks crossing to the outside

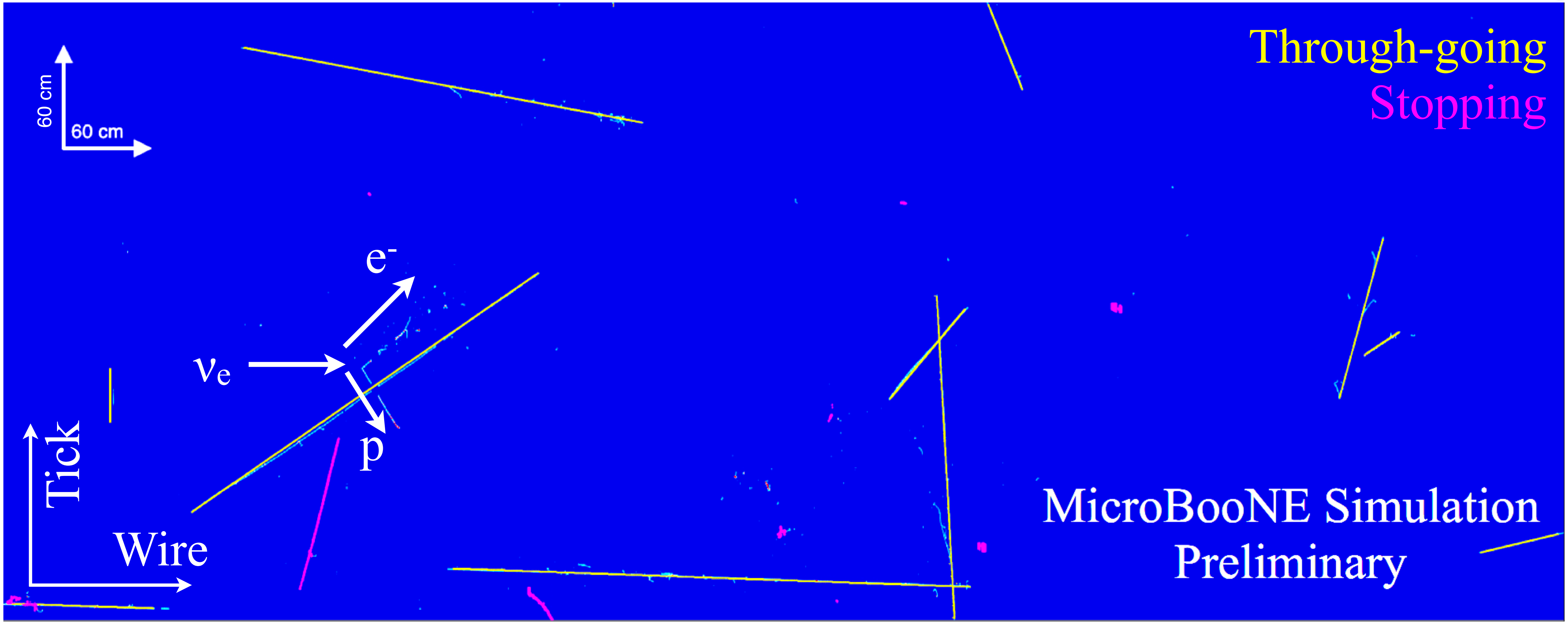
- Identify edge-crossing tracks
- Connect the end-points by following the charge with a 3D path finding algorithm.

Cosmic Pixel Tagging



- Y-plane event display
- Overlay yellow pixels on top of through-going muons
- Overlay magenta pixels on top of stopping muons
- Un-tagged :
  - some cosmic remnants
  - ν_e 1e-1p event
- Draw 3D Region of Interest (ROI) around non-tagged pixels

Cosmic Pixel Tagging



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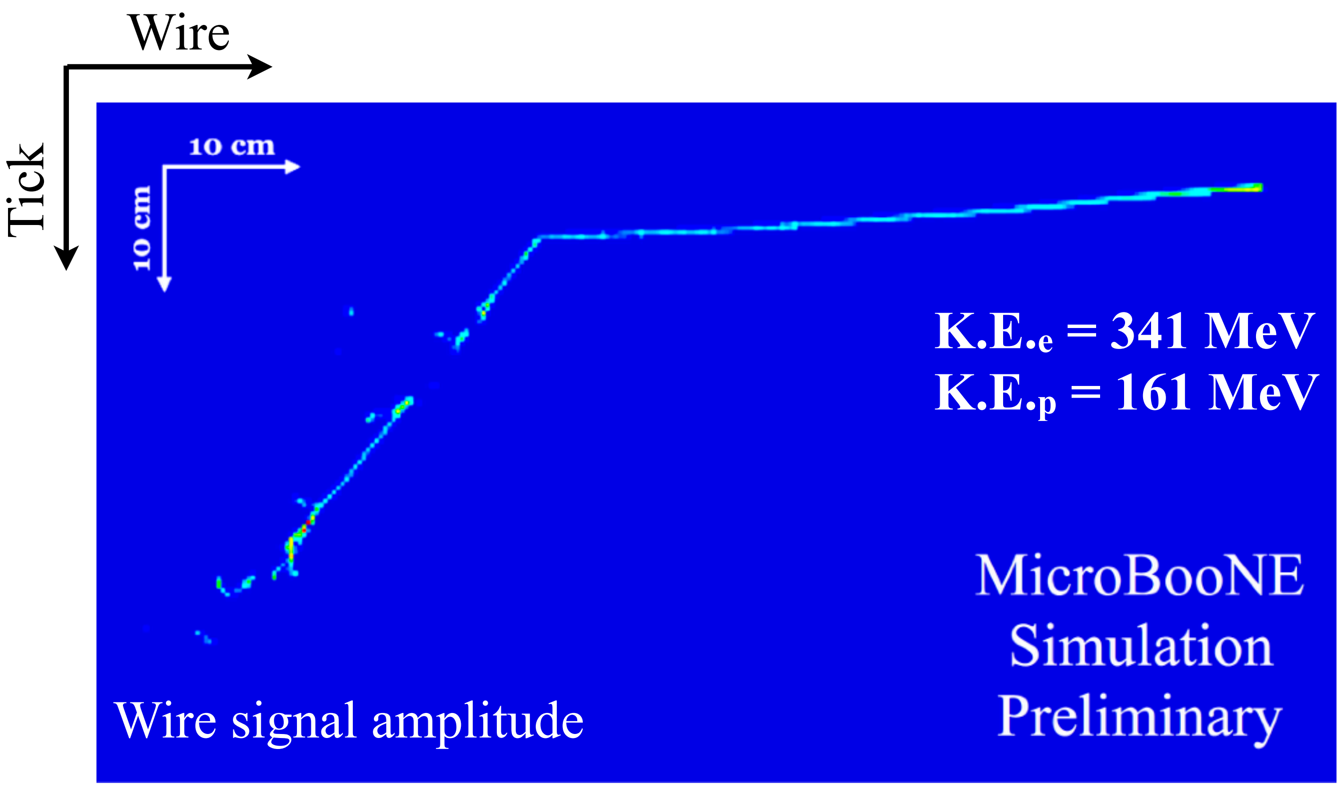
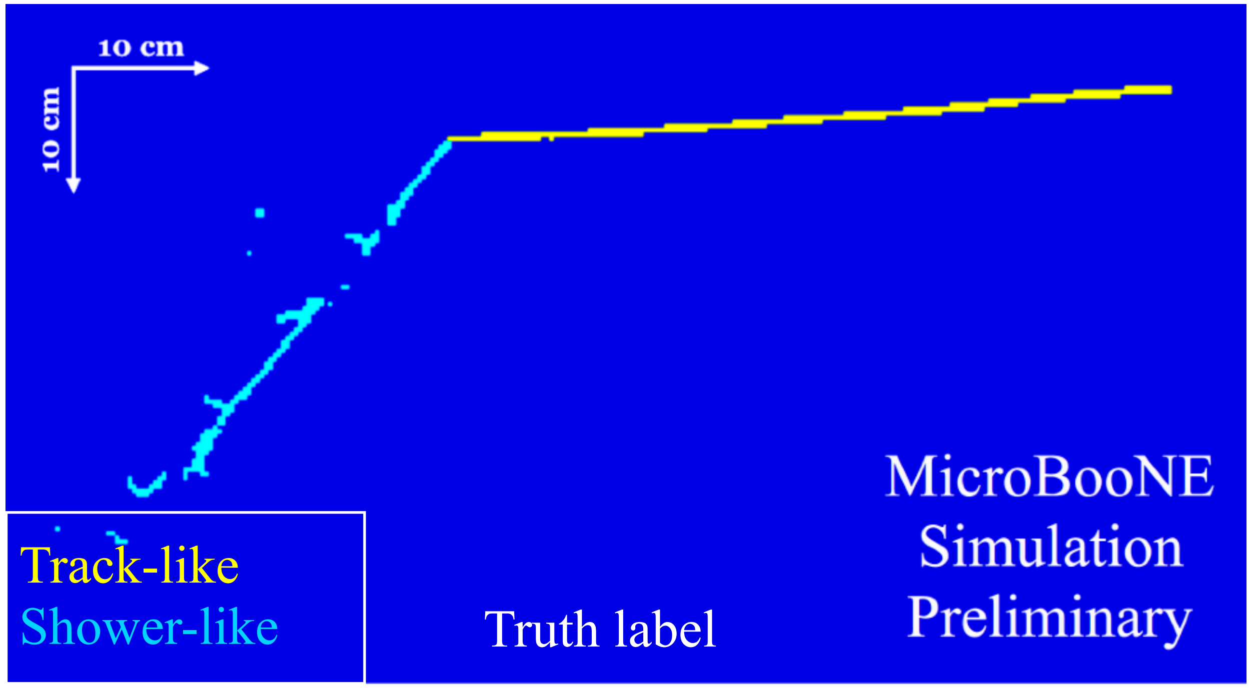
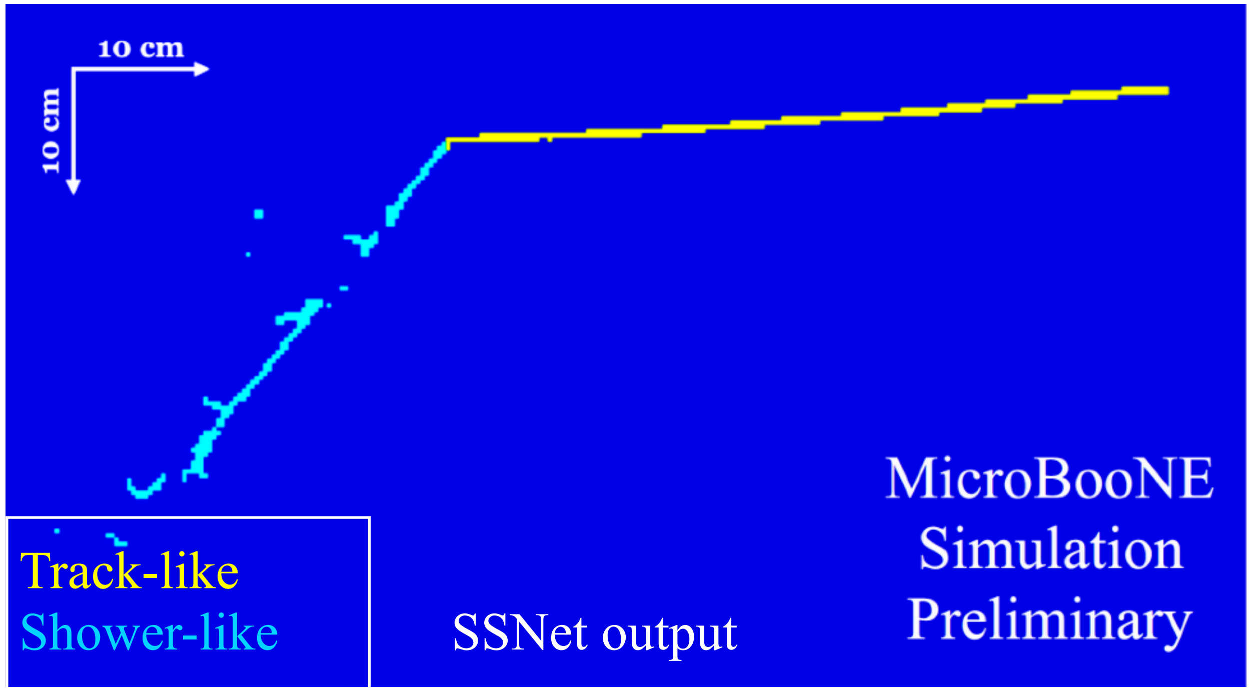
Track/Shower Pixel Labelling

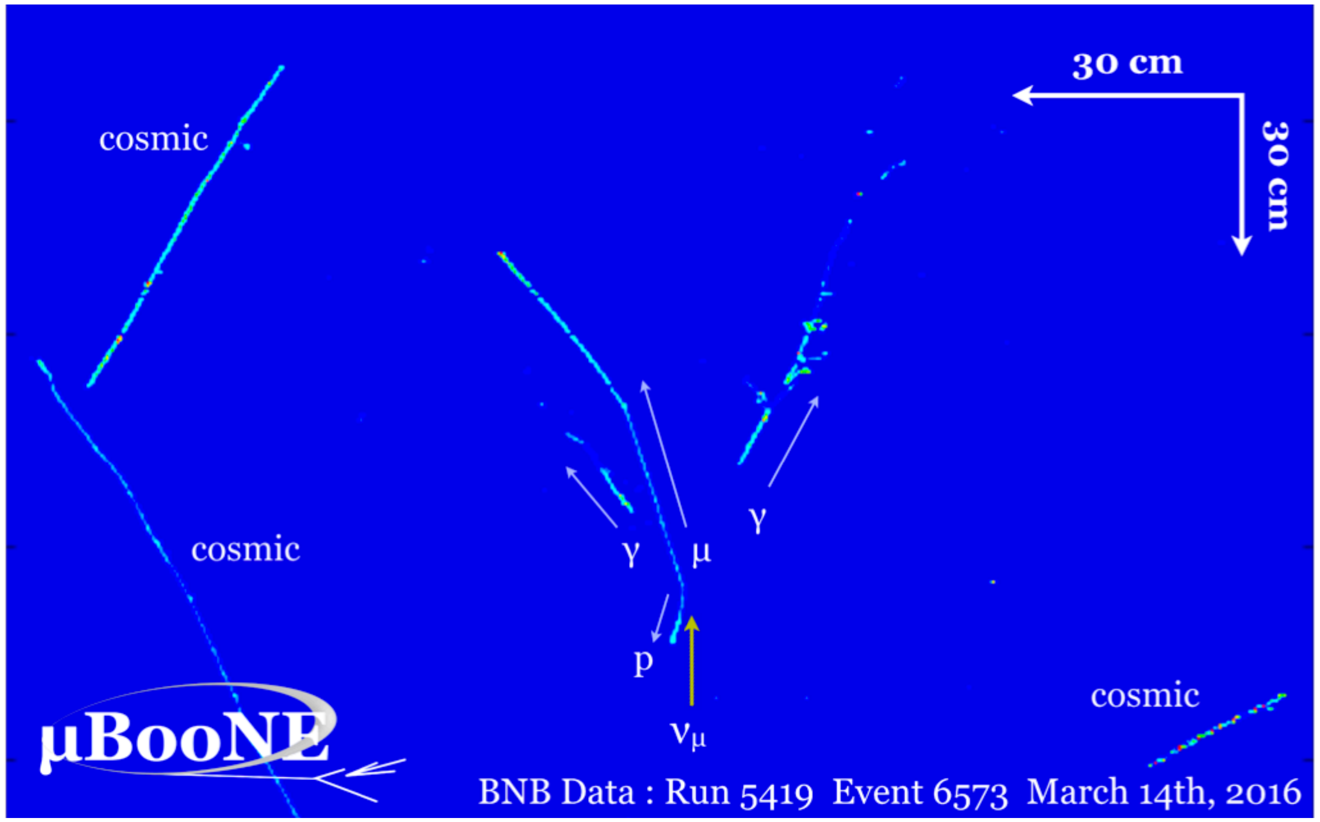


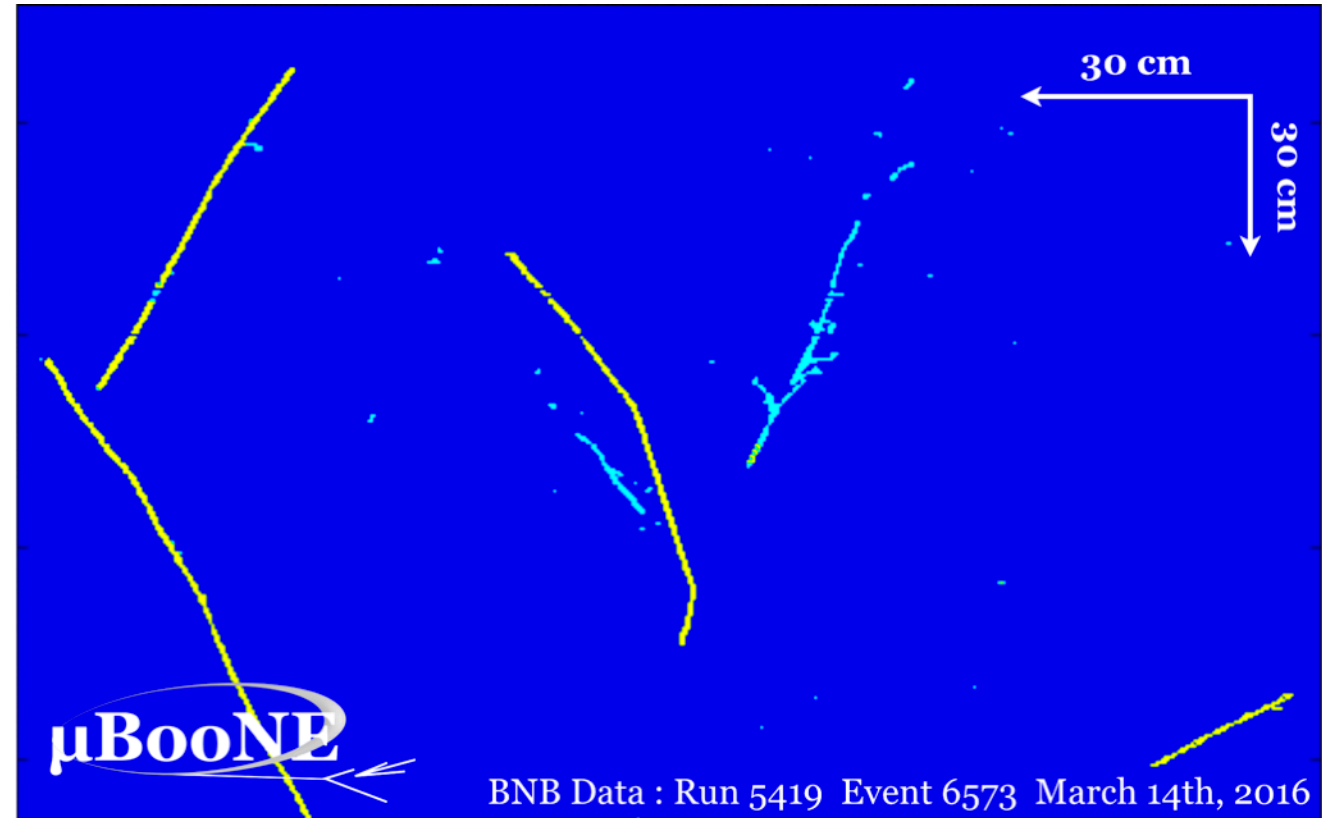
- Goal : separate track and shower to make 3D Vertex reconstruction and track/shower clustering more efficient
- Use SSNet to label pixels as "background", "track", or "shower"





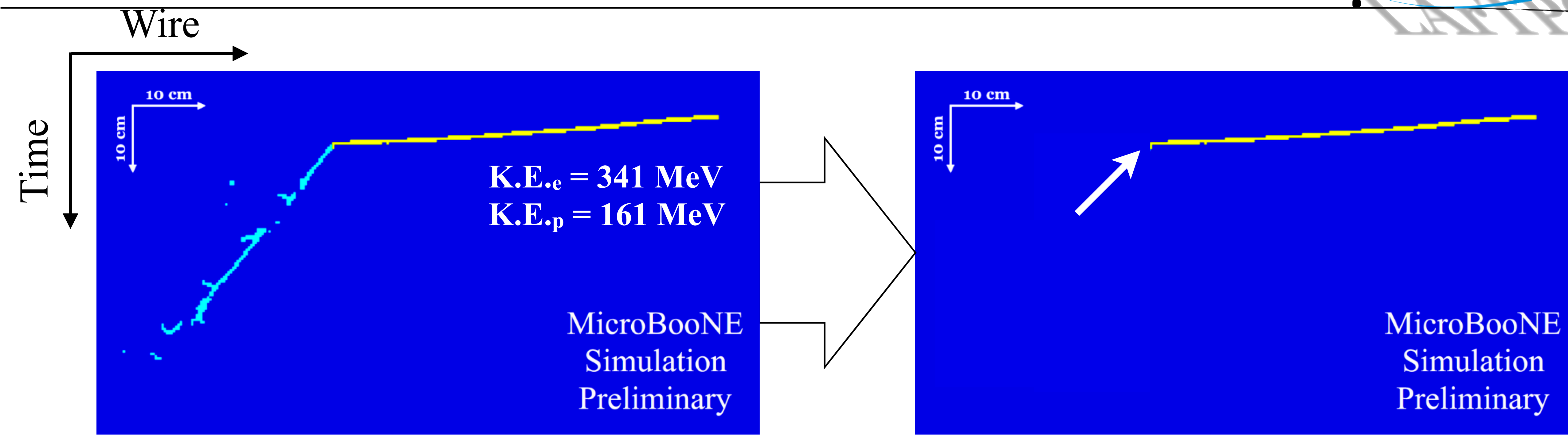
SSNet vs Data





- As a sanity check, the SSNet can be ran over a CCπ^0 selection (MICROBOONE-NOTE-1006-PUB)
- Here the proton and muon are correctly classified as track
- The two γ showers are recognised, but the beginning of one is classified as track

3D Vertex Reconstruction

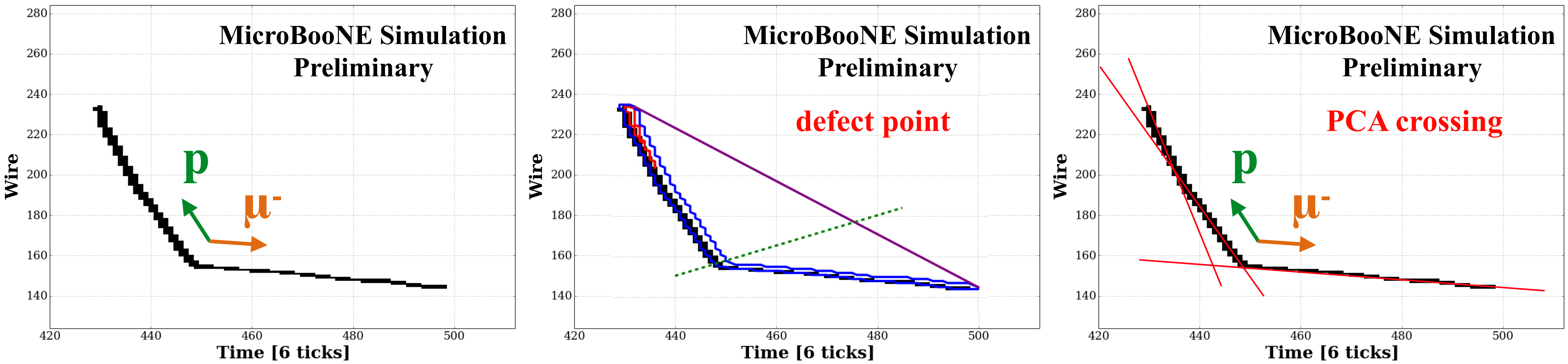


If track and shower are found (e.g. ν_e sample)

- remove shower pixels
- Find potential vertex candidate on track parts
- Add vertex for best-matching 3D point at the track/shower merging

3D Vertex Reconstruction

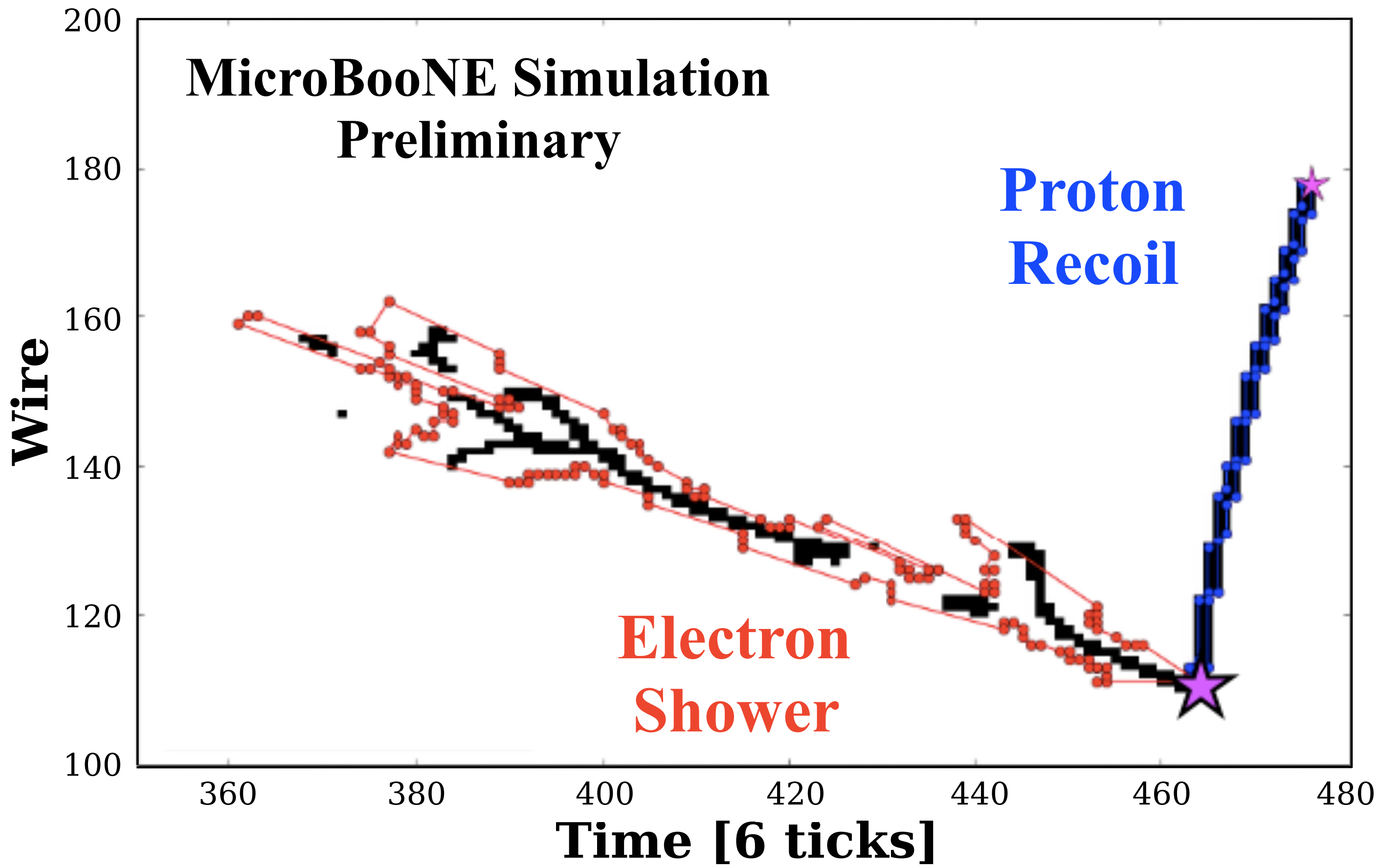
μBooNE



Track-only vertex (e.g. ν_{μ} normalisation sample)

- 2D vertex seed for each plane view
  - Defect points
  - **P**rincipal **C**omponent **A**nalysis line crossing
- Match in 3D

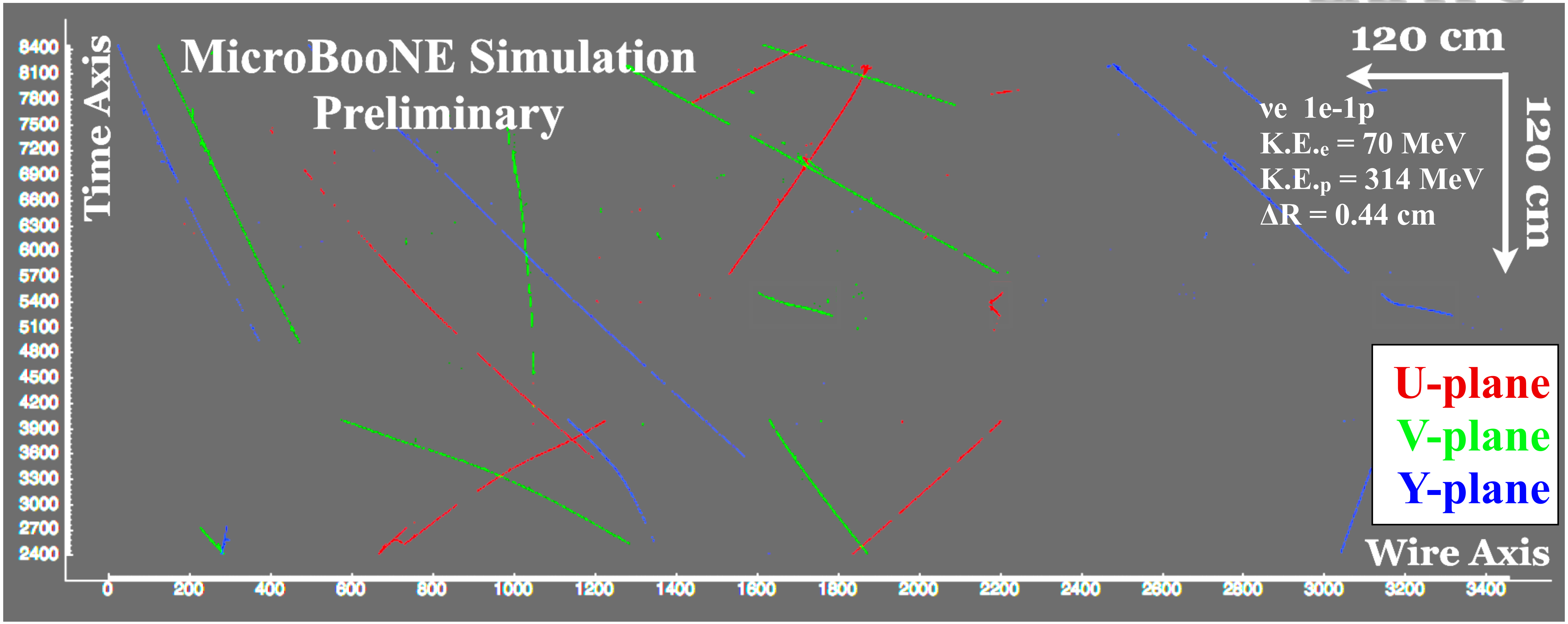
Particle ID



particle	correct ID
e^-	77.8 ± 0.7 %
γ	83.4 ± 0.6 %
μ^-	89.7 ± 0.5 %
π^0	71.0 ± 0.7 %
p	91.2 ± 0.5 %

- After 3D vertex reconstruction:
  - 3D vertex point
  - Clusters of pixels attributed to a single track/shower
- Feed individual particle to a CNN-based particle ID (HiRes GoogLeNet)
- MicroBooNE 1st publication!
  ("Convolutional Neural Networks Applied to Neutrino Events in a Liquid Argon Time Projection Chamber", JINST 12, P03011 (2017))

Reconstructed Events



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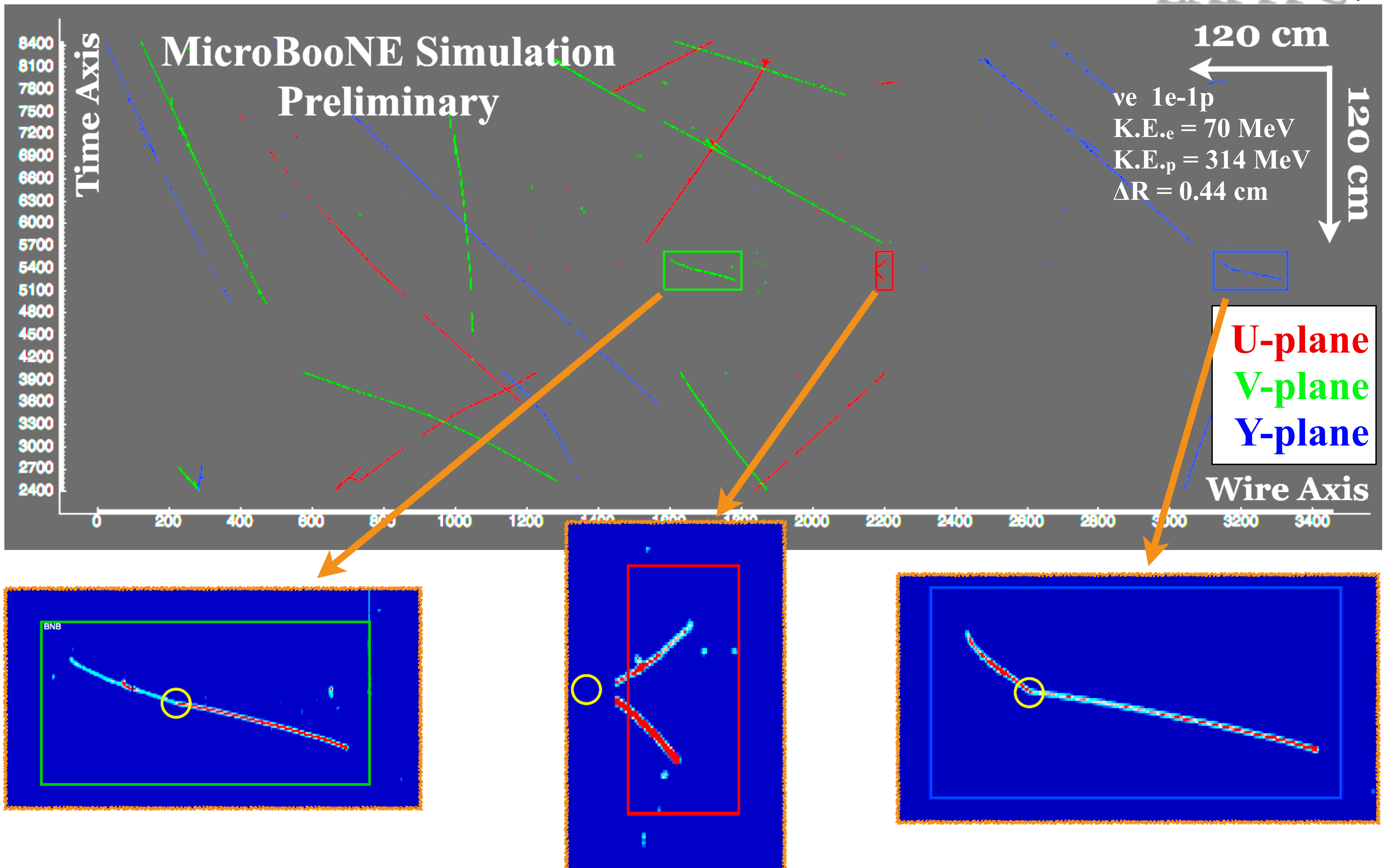

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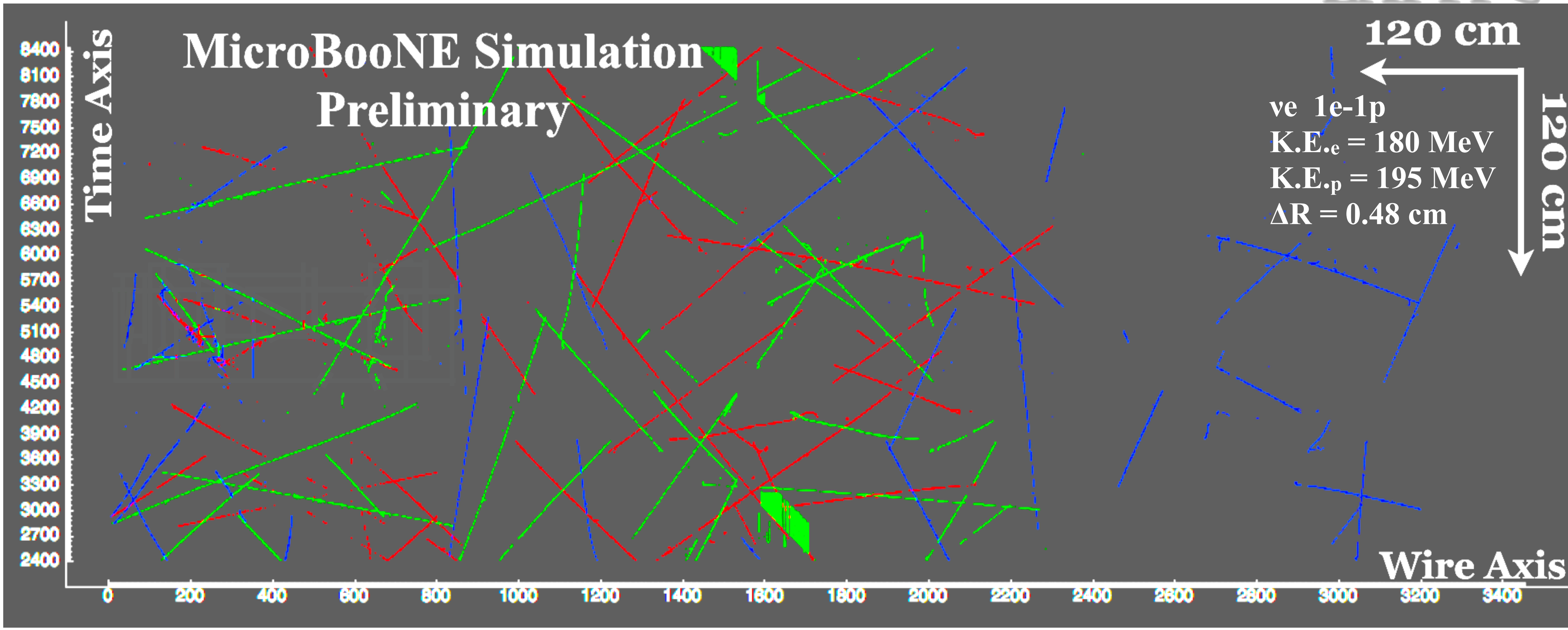

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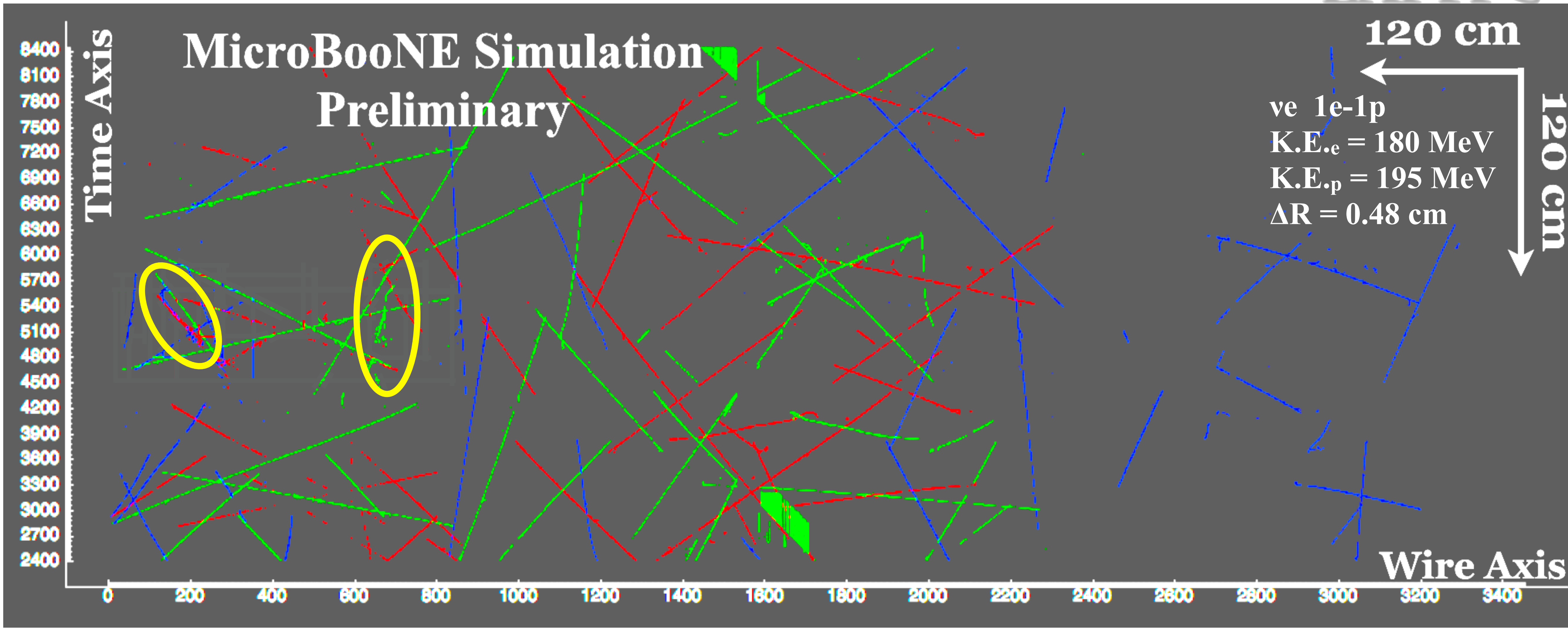

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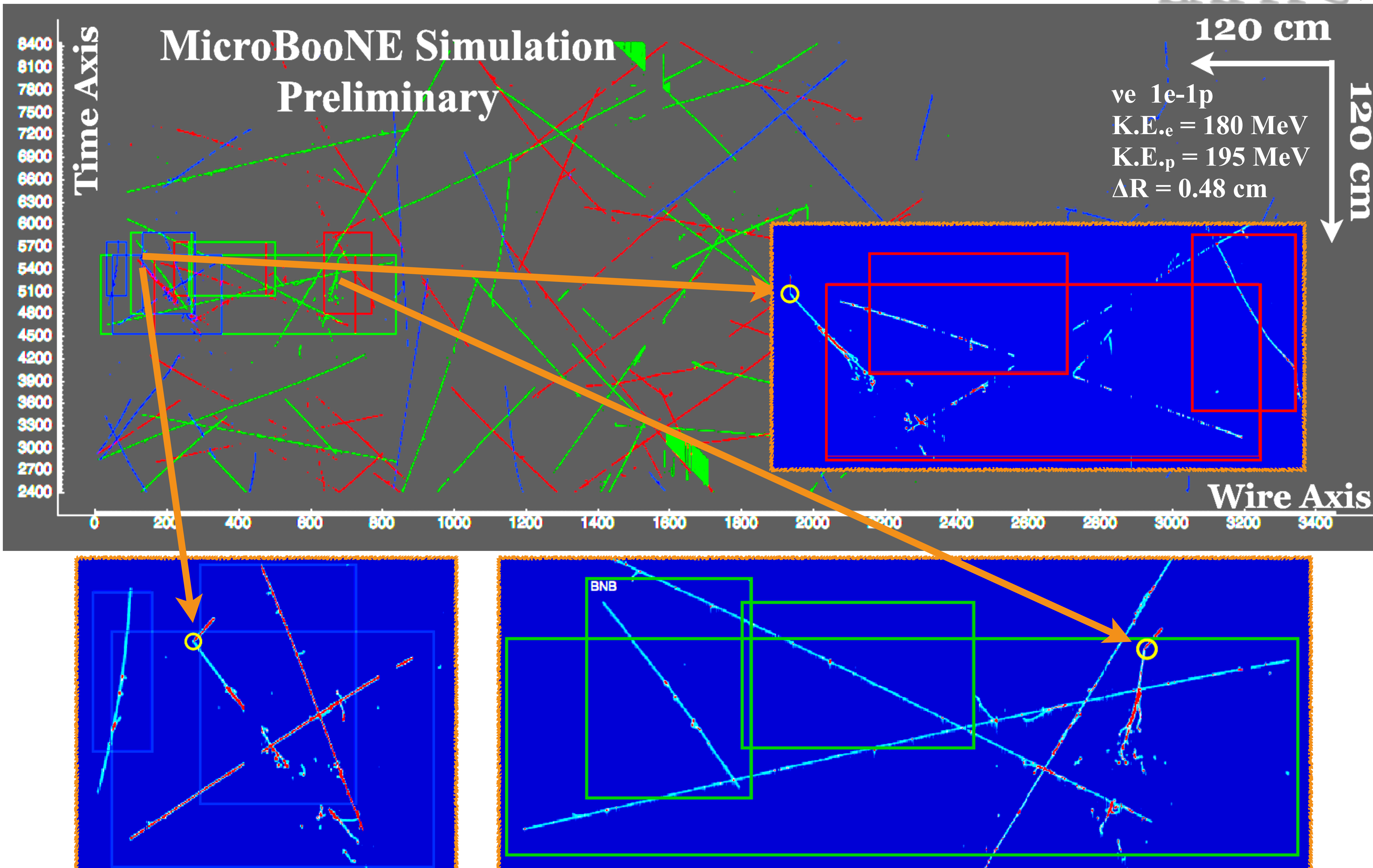

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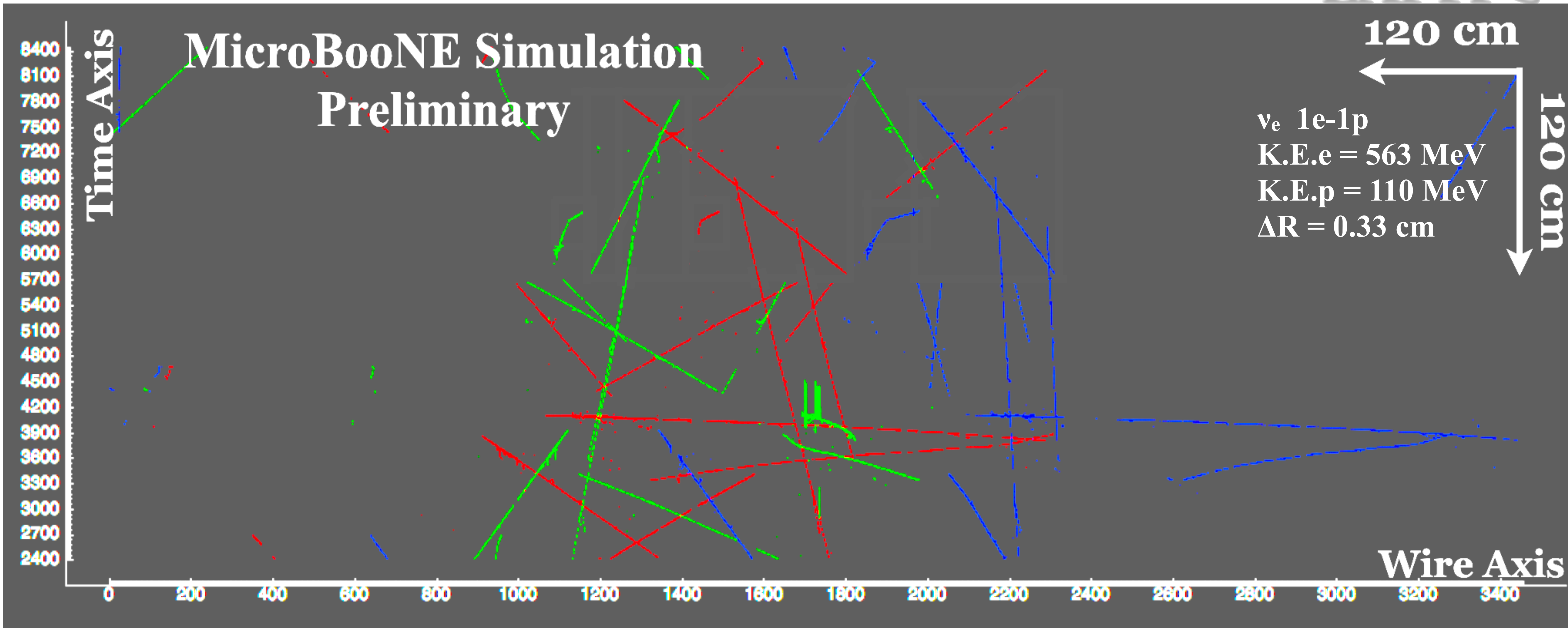

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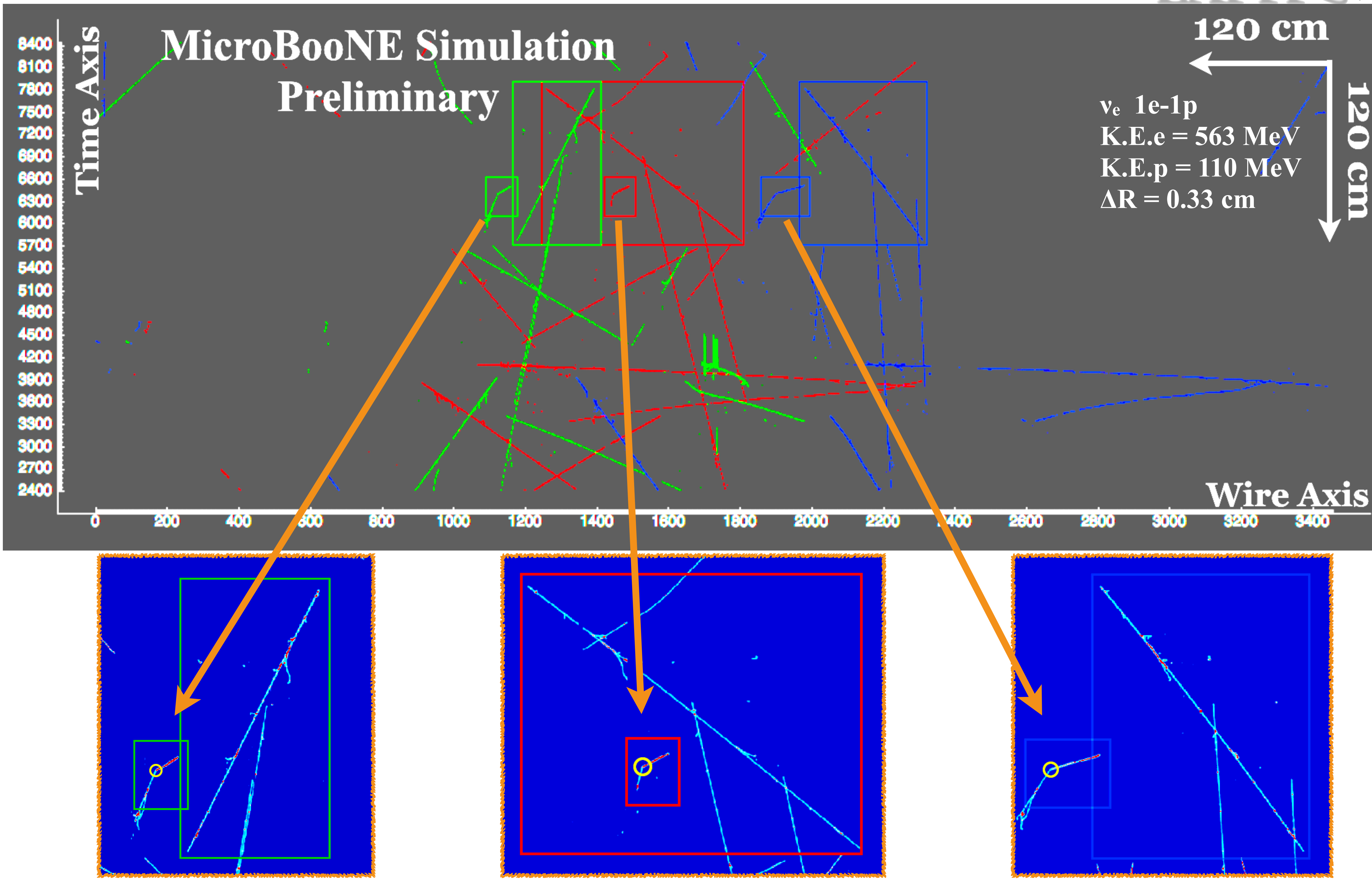

Summary

- Fully automated reconstruction chain for low energy events
  - Methods for cosmic background rejection
  - Finds the neutrino interaction
  - Separates individual tracks/showers
  - Reconstructs 3D vertex
  - ID individual particles
- 3D track and shower reconstruction coming soon:
  - dE/dx, event selection
  - Physics!

Thank You!