Studies of Cosmogenic Background to Nucleon Decay in MicroBooNE

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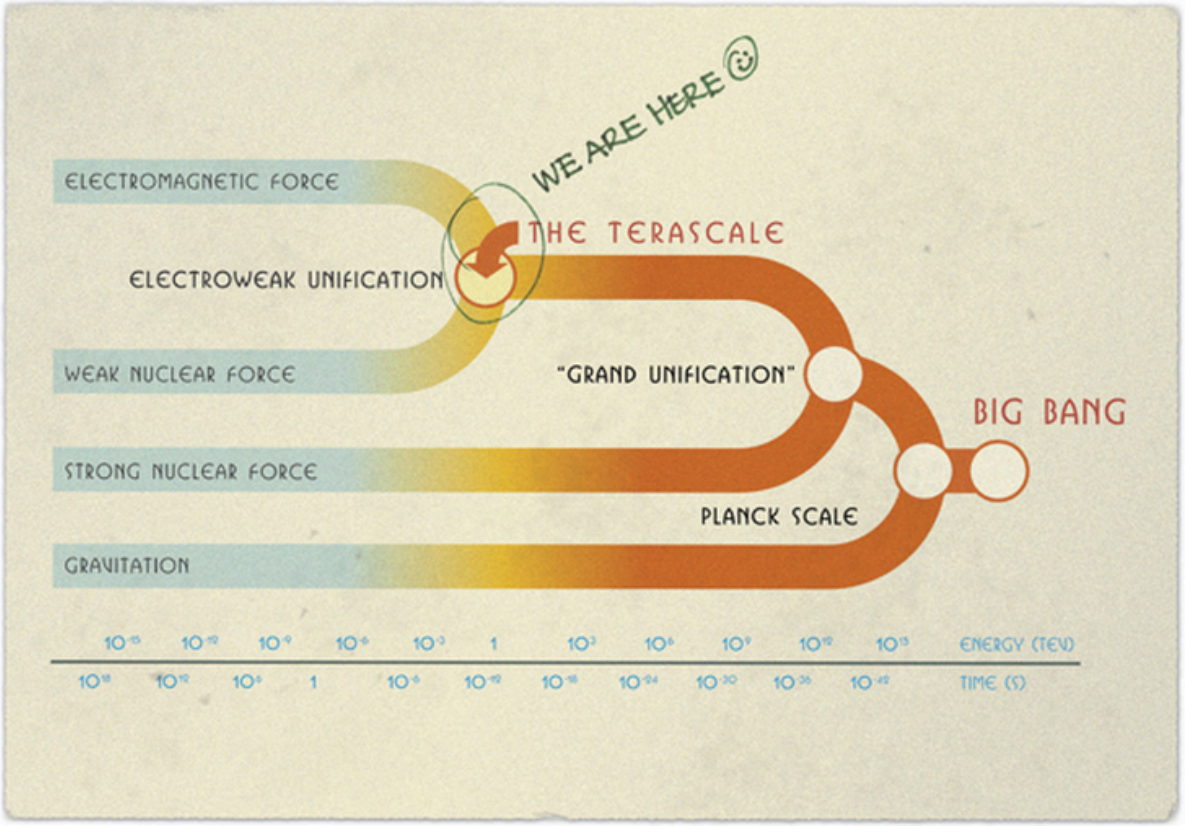
On behalf of the MicroBooNE collaboration

TAUP 2015
September 6-11, Torino, Italy

Motivations for Nucleon Decay

Every interaction in the **SM conserves baryon number**.

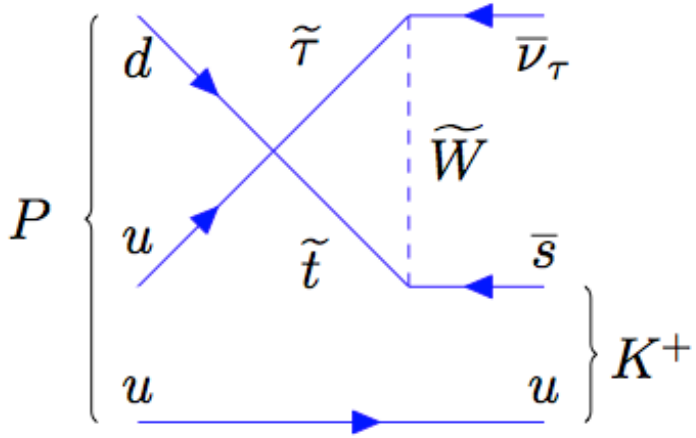
Proton (or bound neutron) **decay** can occur only as a **violation of baryon number** and it's predicted by almost every GUT.



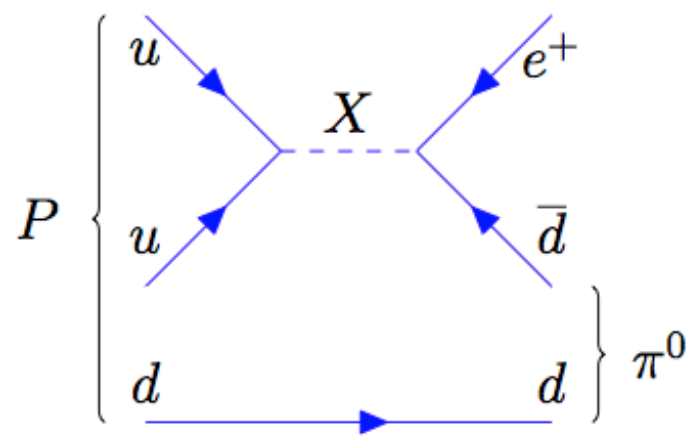
The detection of even one nucleon decay event would be a **direct evidence** of **physics BSM**, opening a window on GUTs exploration.

Not Only Golden Modes

$p \to K^+ \bar{\nu}$



$p \to e^+\pi^0$



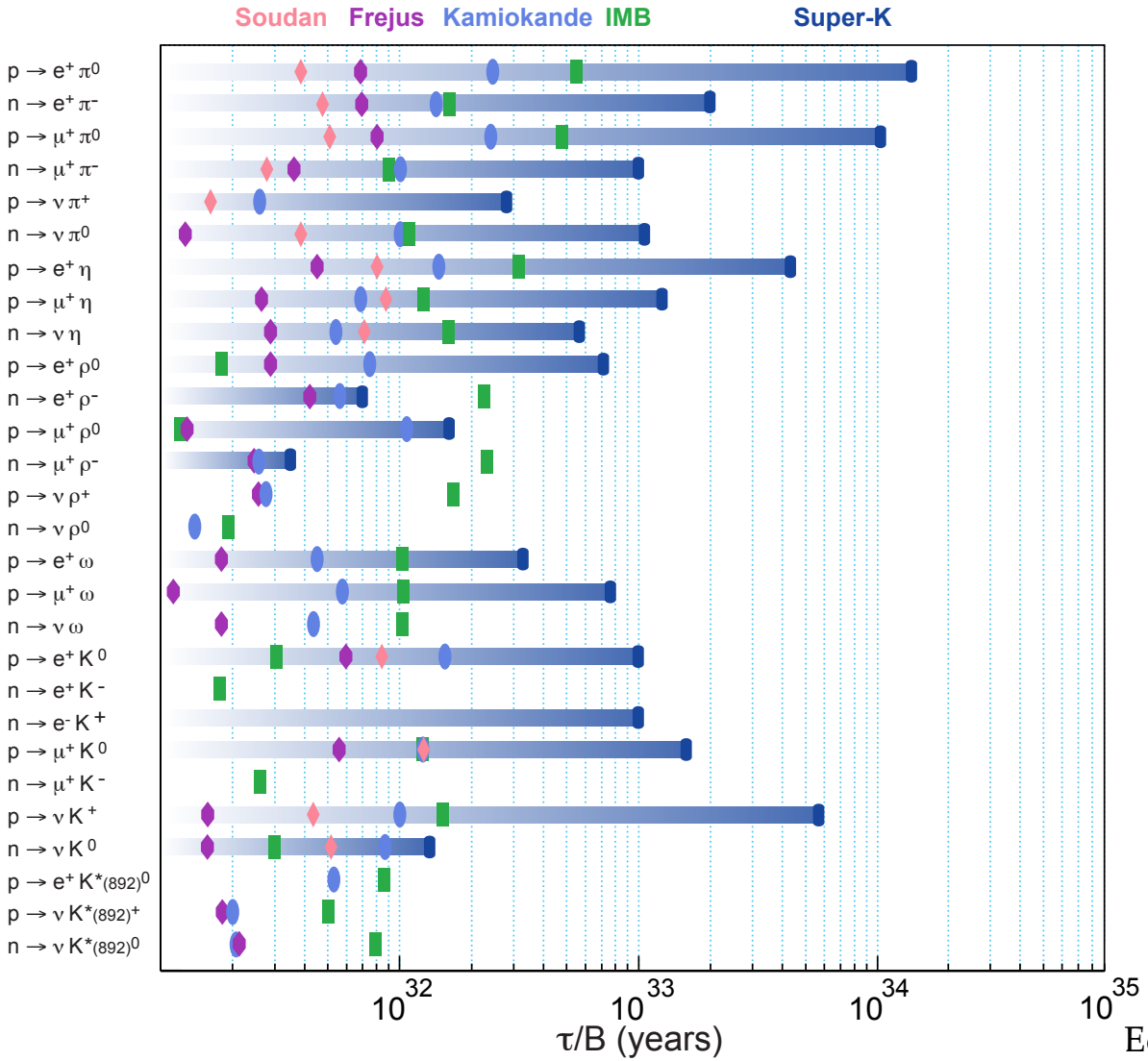
arXiv:1307.7335

… plus many others!

The discovery of a particular decay mode would constrain GUT models.

Need of experimental handle on many different predicted modes.

Experimental Limits on τ_P

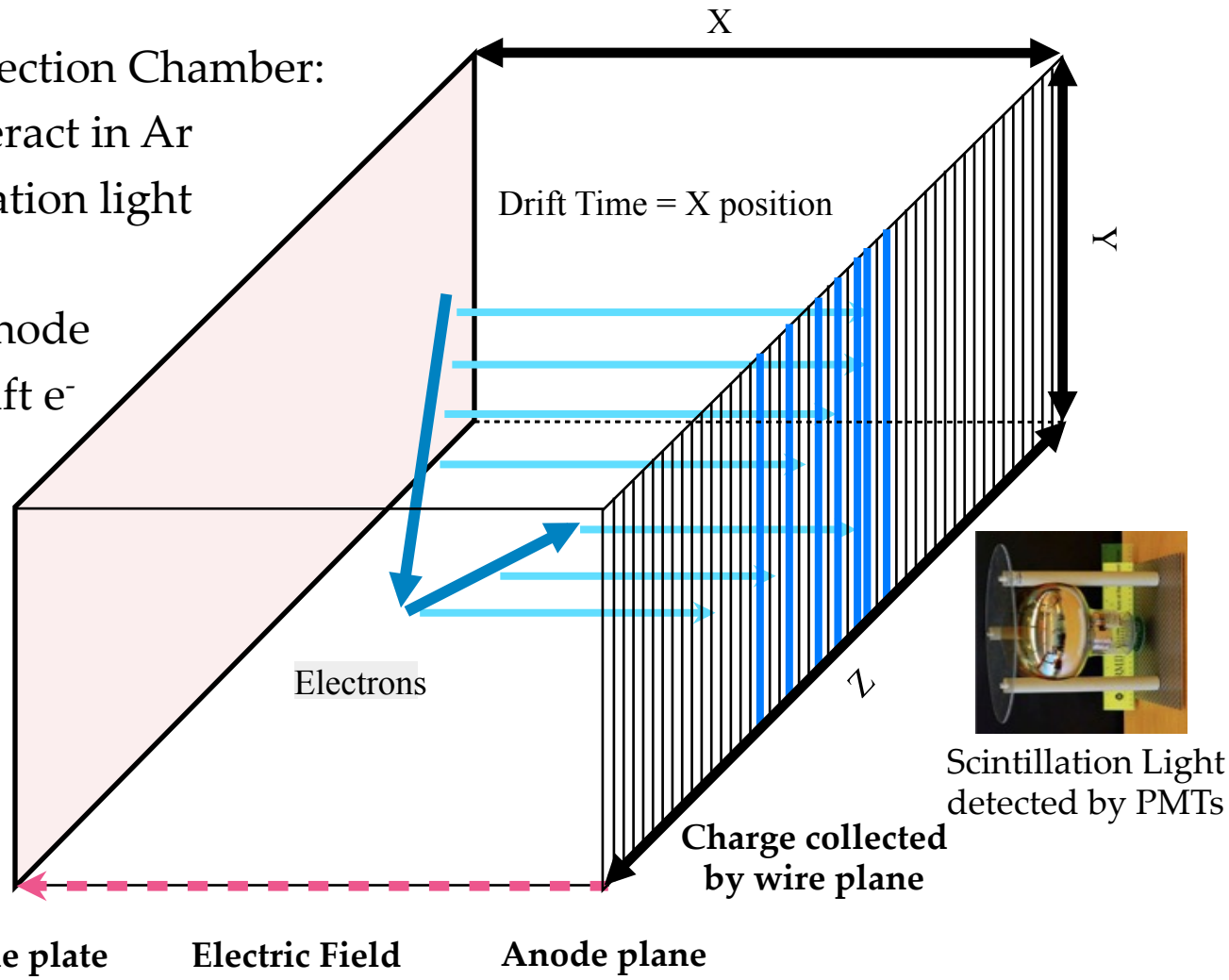


Ed. Kearns

A Tool for Many Modes: LArTPC

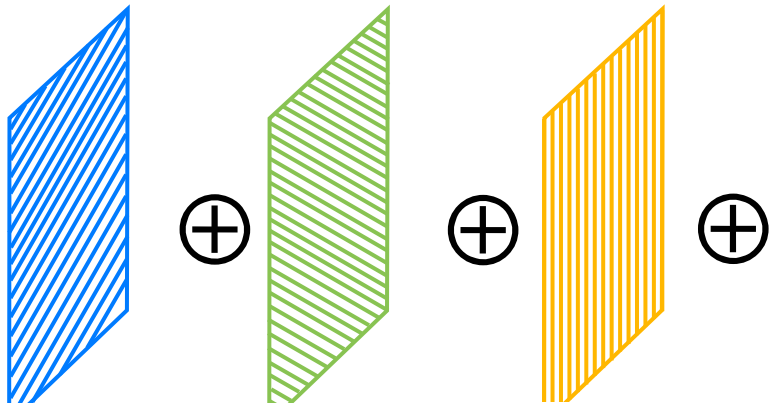
Working principles of a
Liquid Argon Time Projection Chamber:

1. Charged particles interact in Ar
    - Produce scintillation light
    - Ionize electrons
2. Ionization e^- drift to anode
3. Wire planes detect drift e^-



LArTPC Key Features for Nucleon Decay

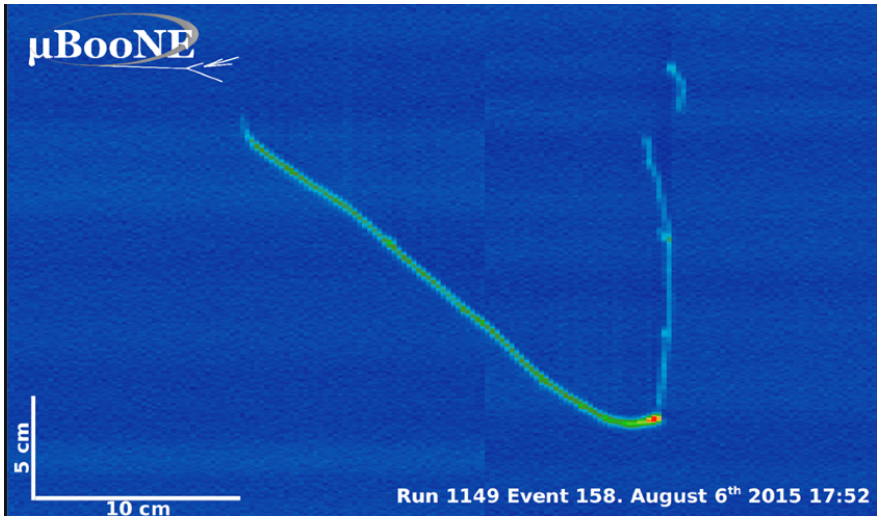
Wire pitch at the millimeter scale.



U plane induction ⊕ **V plane** induction ⊕ **Y plane** collection ⊕ Drift time = **3D imaging Millimetric Space Resolution**

Calorimetry information

One of first MicroBooNE events



Ingredients for Nucleon Decay Detection

Lots of nucleons

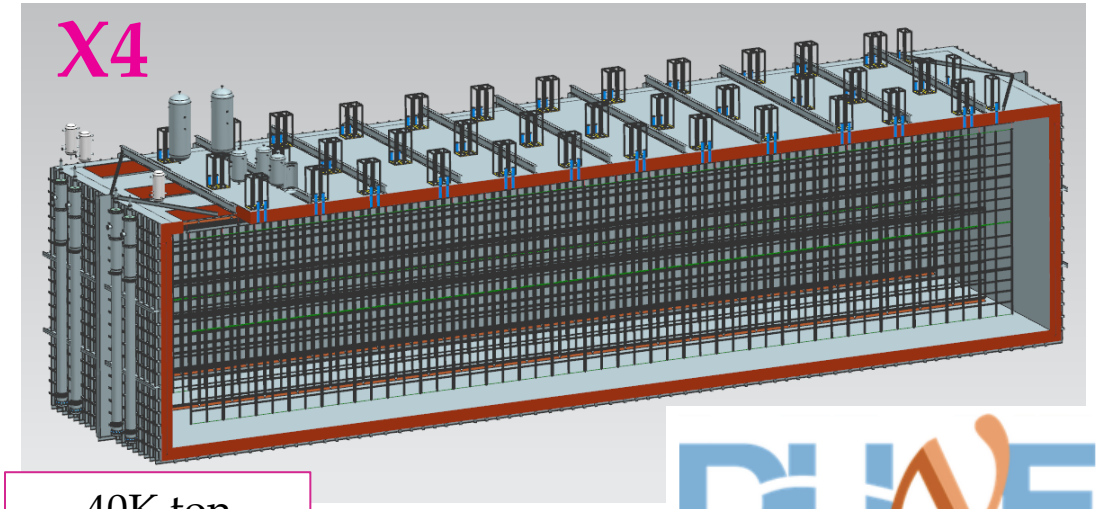
Lots of time

Low background

[so low you need to go underground?]

Future and present LArTPCs…

DUNE: Increase Nucleon Decay sensitivity in multiple channels.



40K ton active volume

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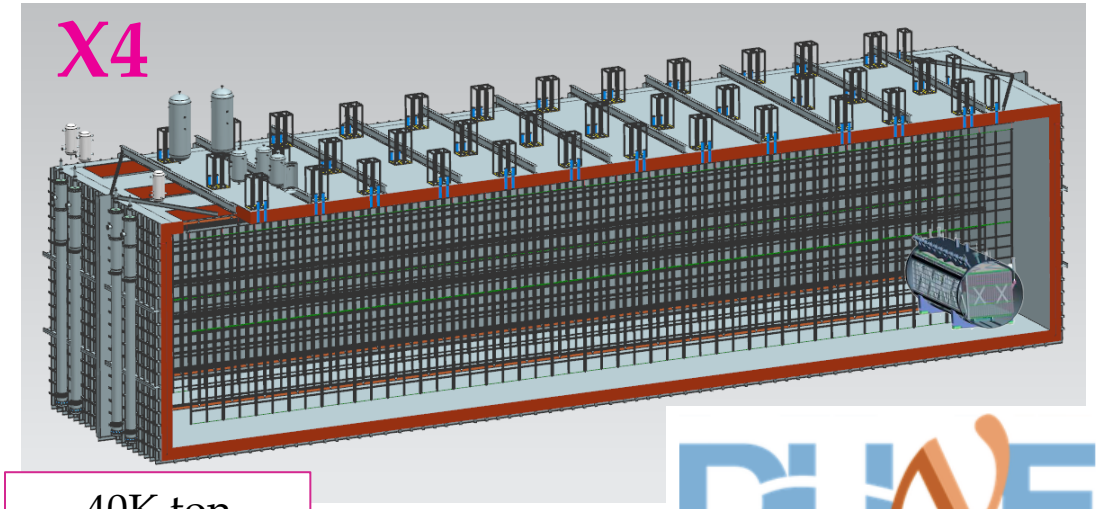

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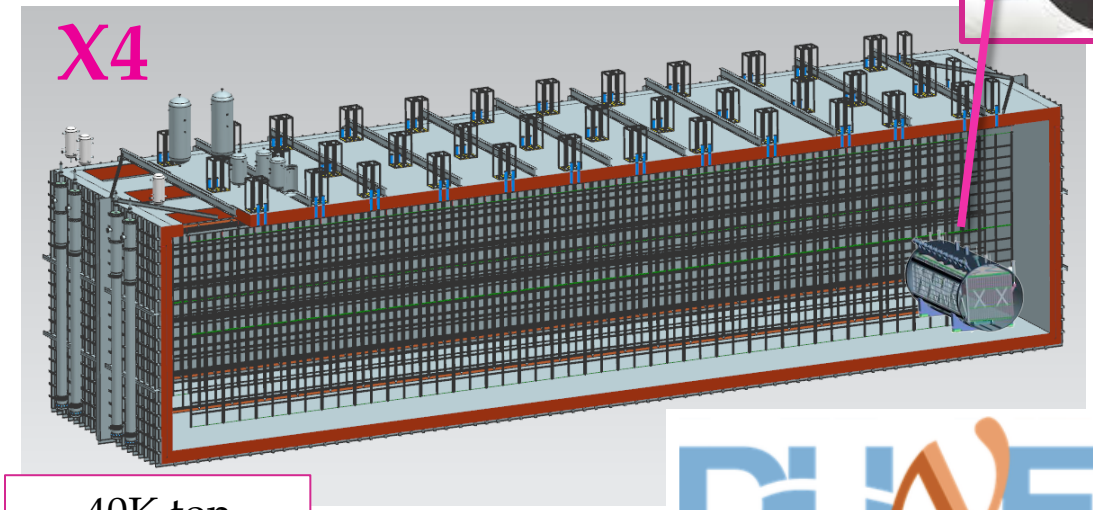
89 ton
active volume



40K ton
active volume

μBooNE

Study **Cosmogenic Backgrounds** in a LArTPC.

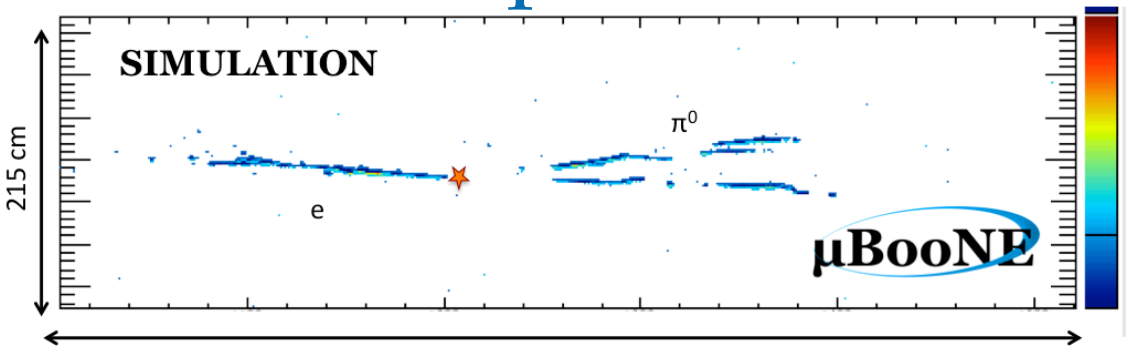
MicroBooNE and Nucleon Decay

GOAL

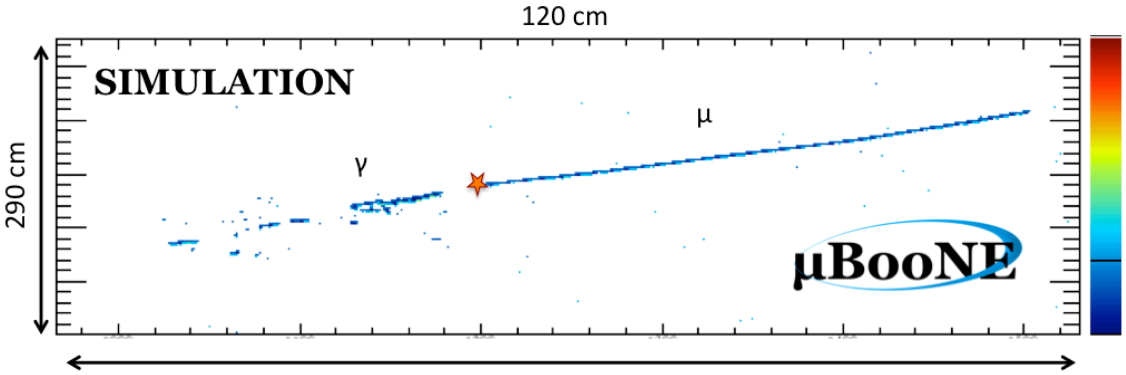
Perform a topological search of events that mimic proton decay to estimate the mis-id rate from cosmogenic sources.

1. Study the decay topologies by exploiting the variety of information provided by a LArTPC.
2. Development of a selection strategy **geared towards removal of cosmogenic backgrounds for proton decay**.

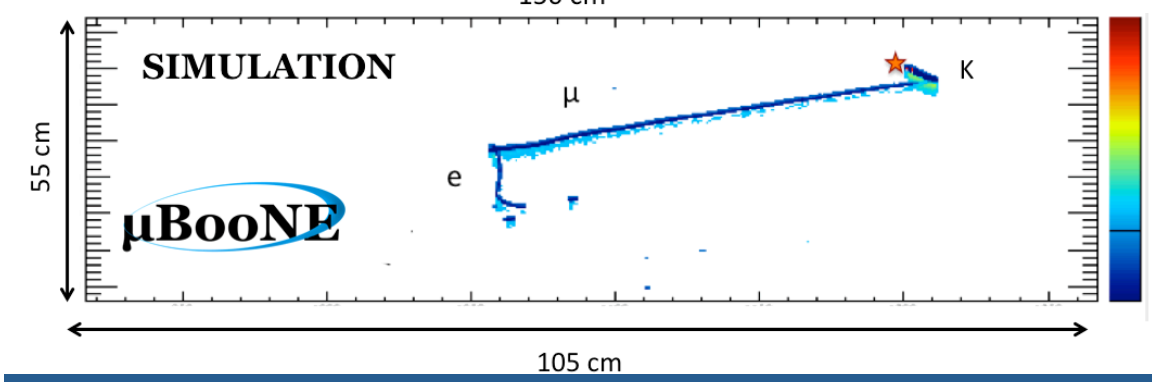
Some example modes



$p \rightarrow e^+\pi^0$
Standard candle



$p \rightarrow \mu^+\gamma$
High background channel



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Golden channel in LAr

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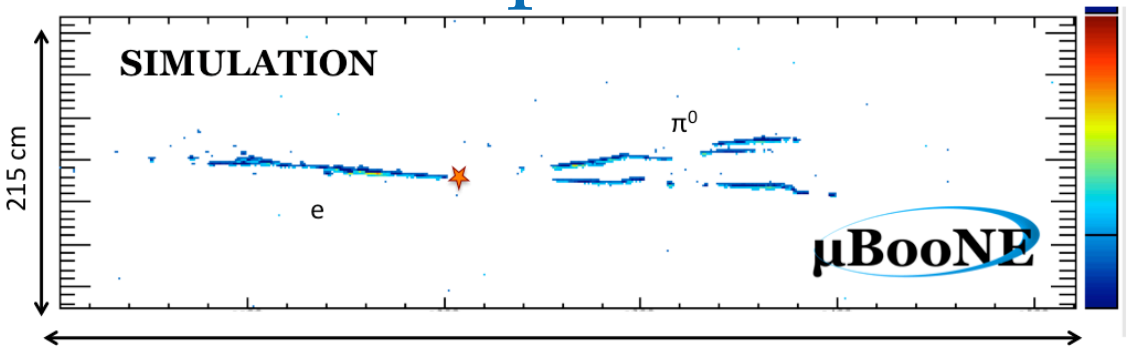

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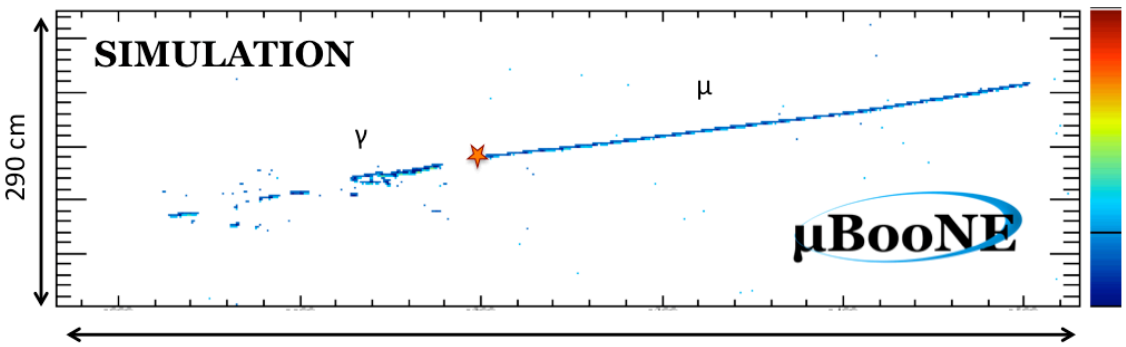

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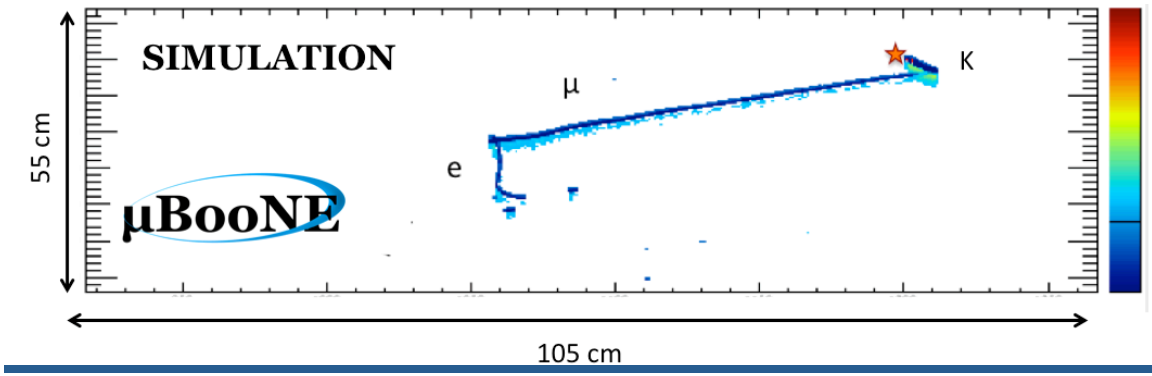

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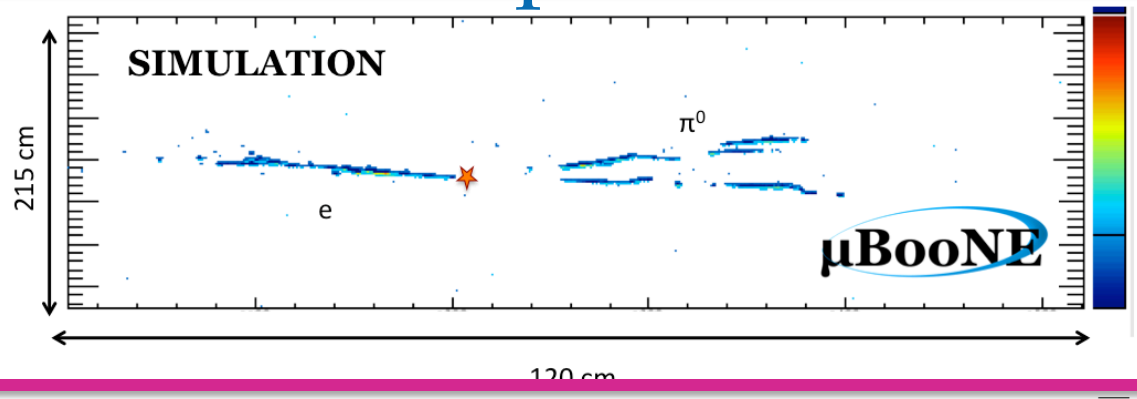

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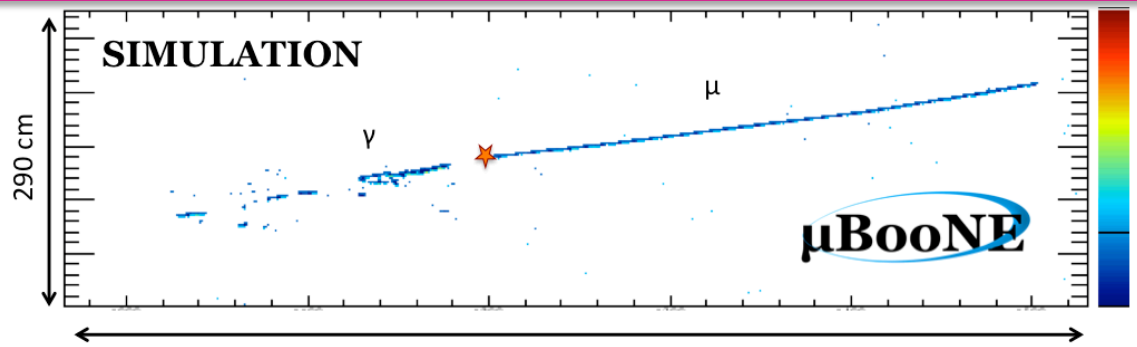

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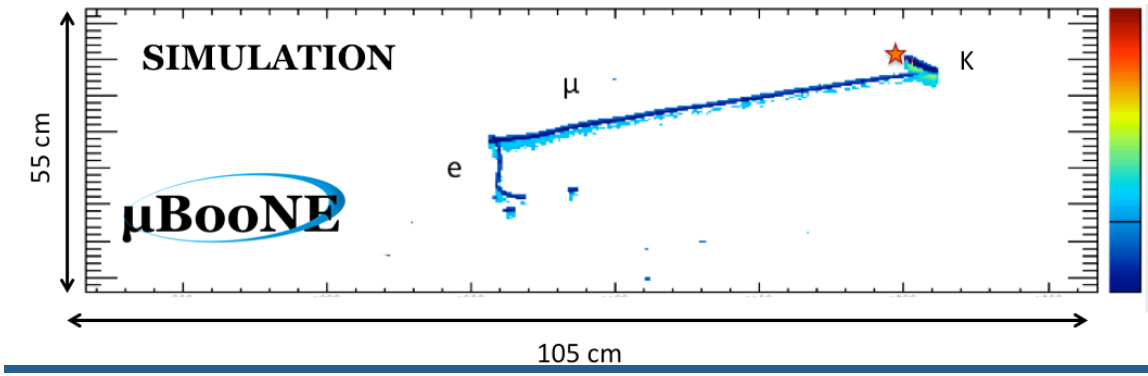

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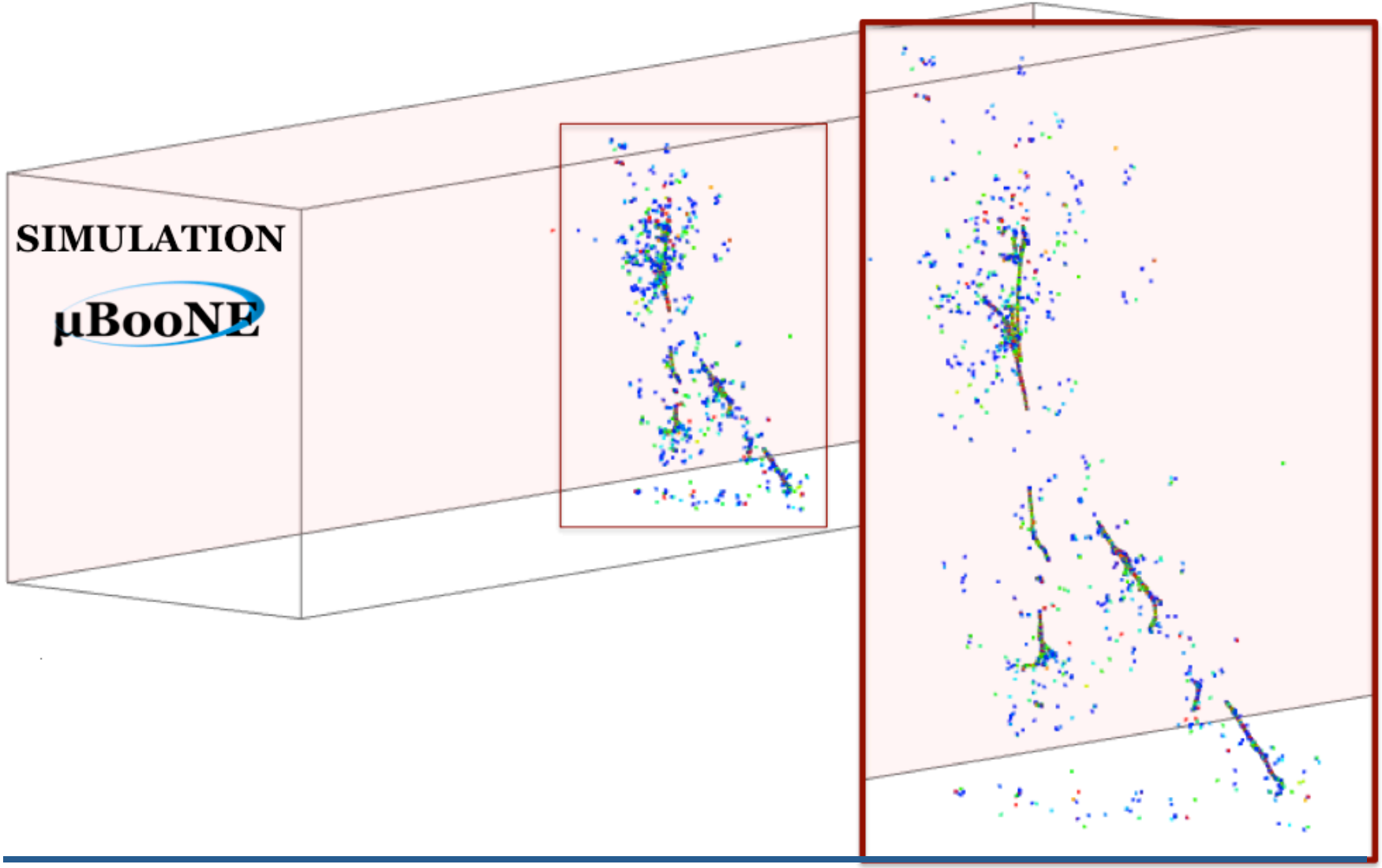
Simulated Event Display for $p \rightarrow e^+ \pi^0$



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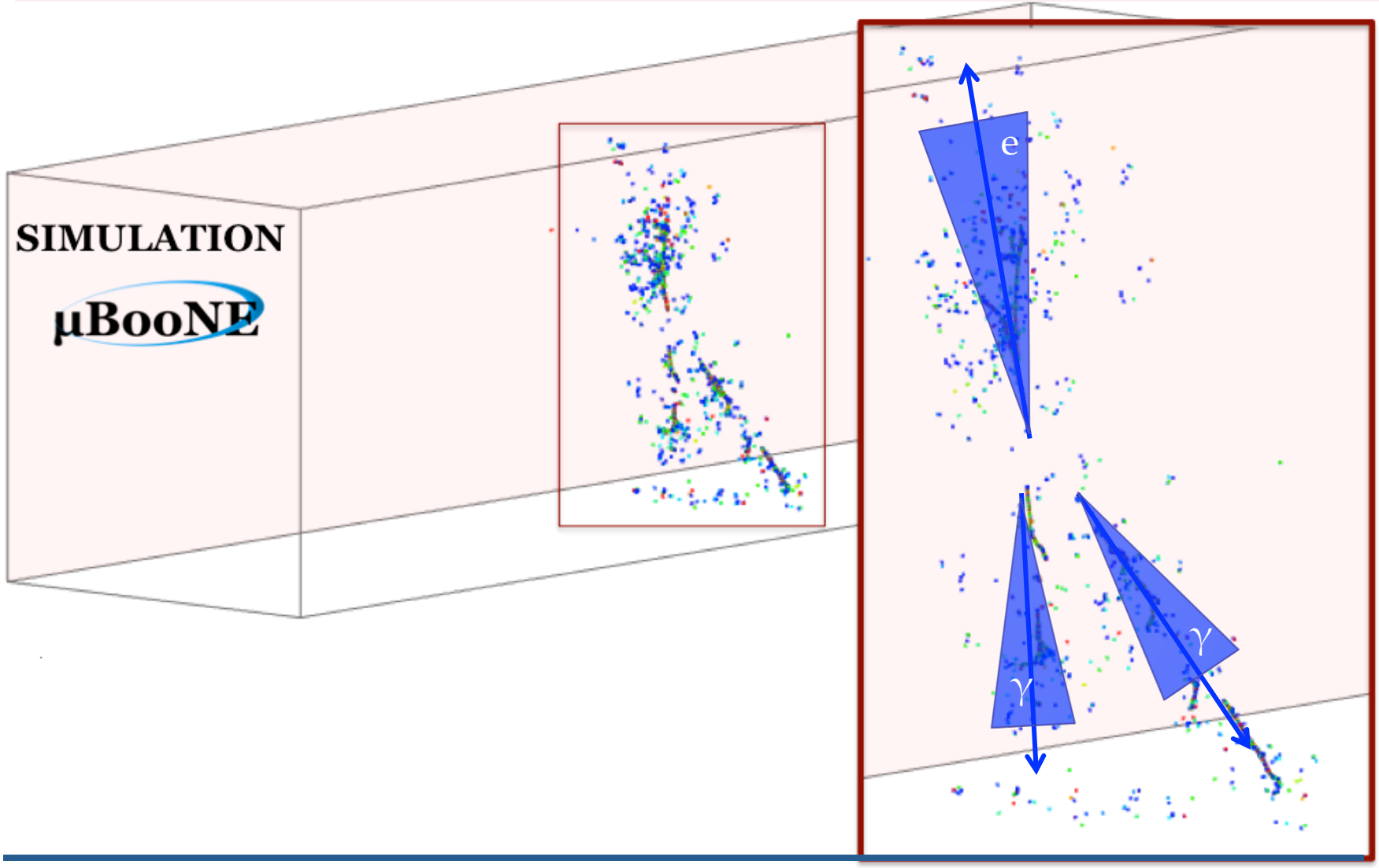


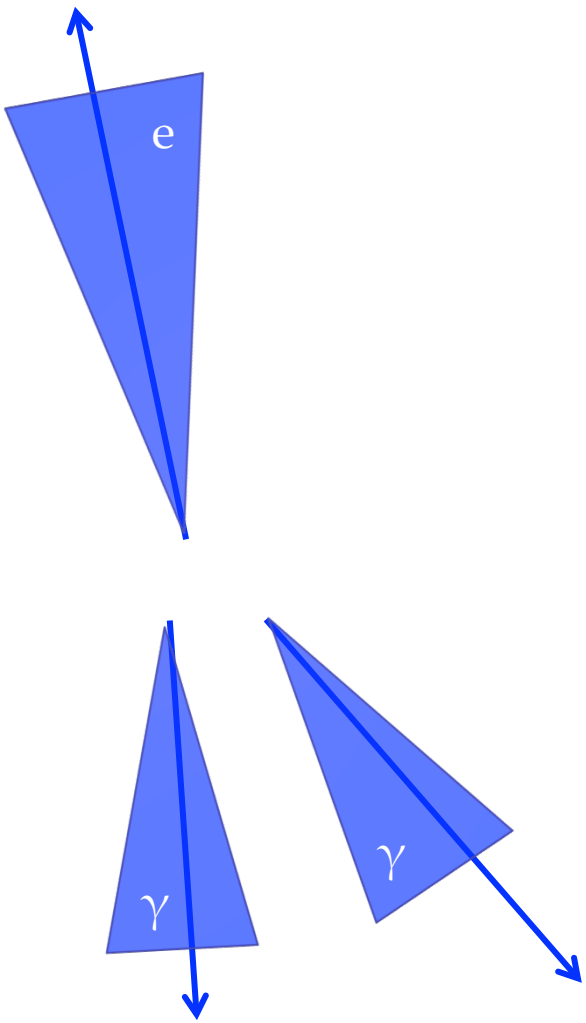
Selection strategy

Geometry selection & PID

- π^0 and e identification
- No additional vertex activity
- Proximity
- Planarity

Calorimetry selection

- Total energy deposited consistent with the proton rest mass
- Total net momentum consistent with Fermi Momentum



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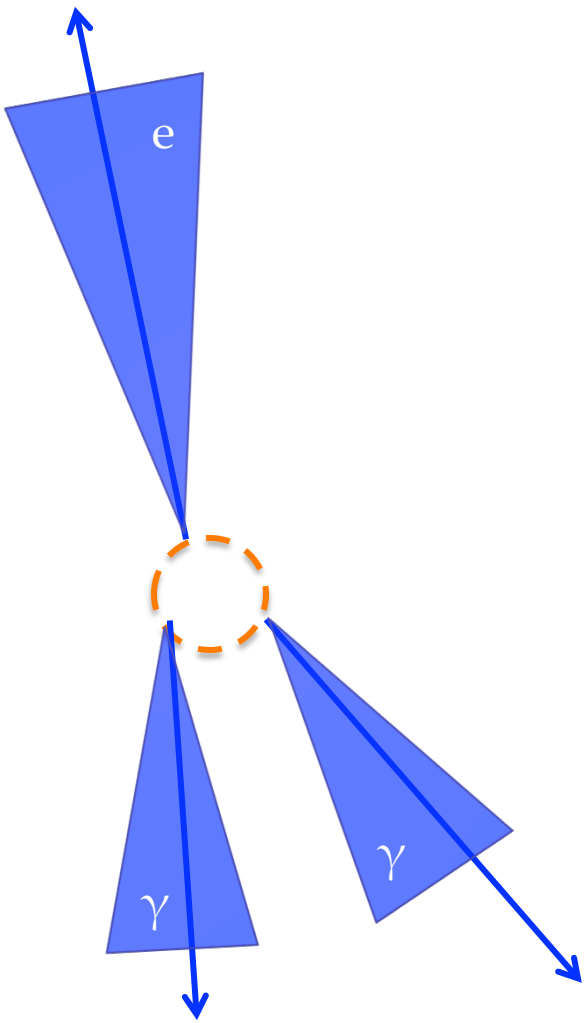

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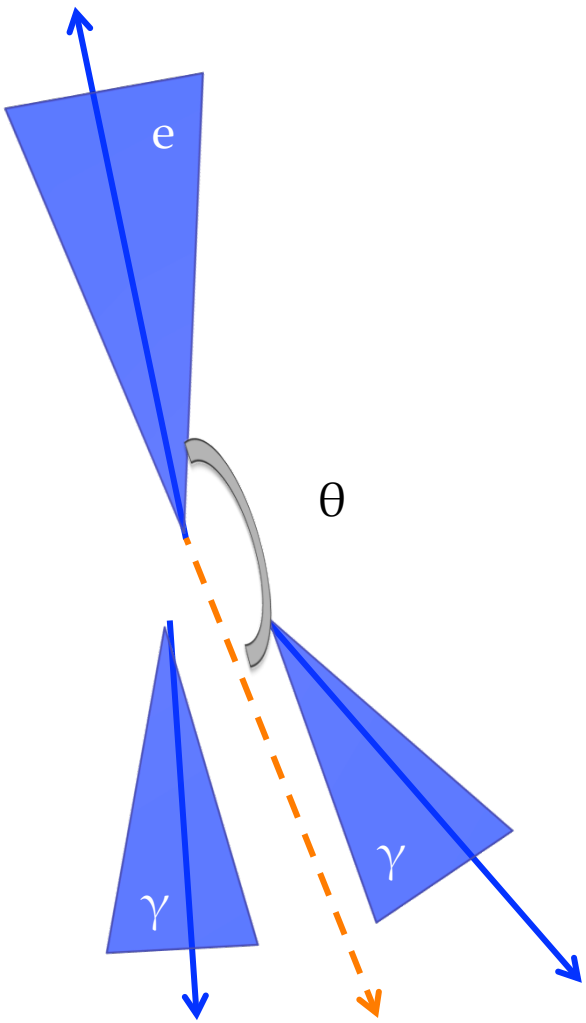
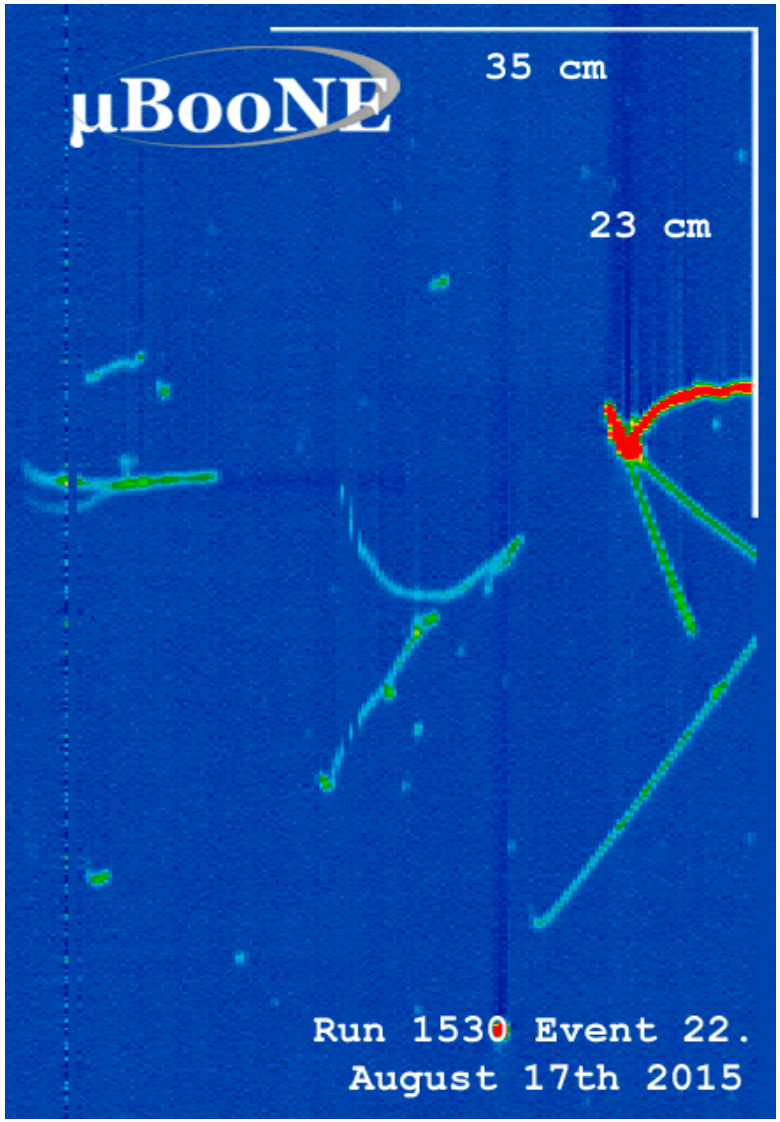


Selection strategy: Geometry & PID



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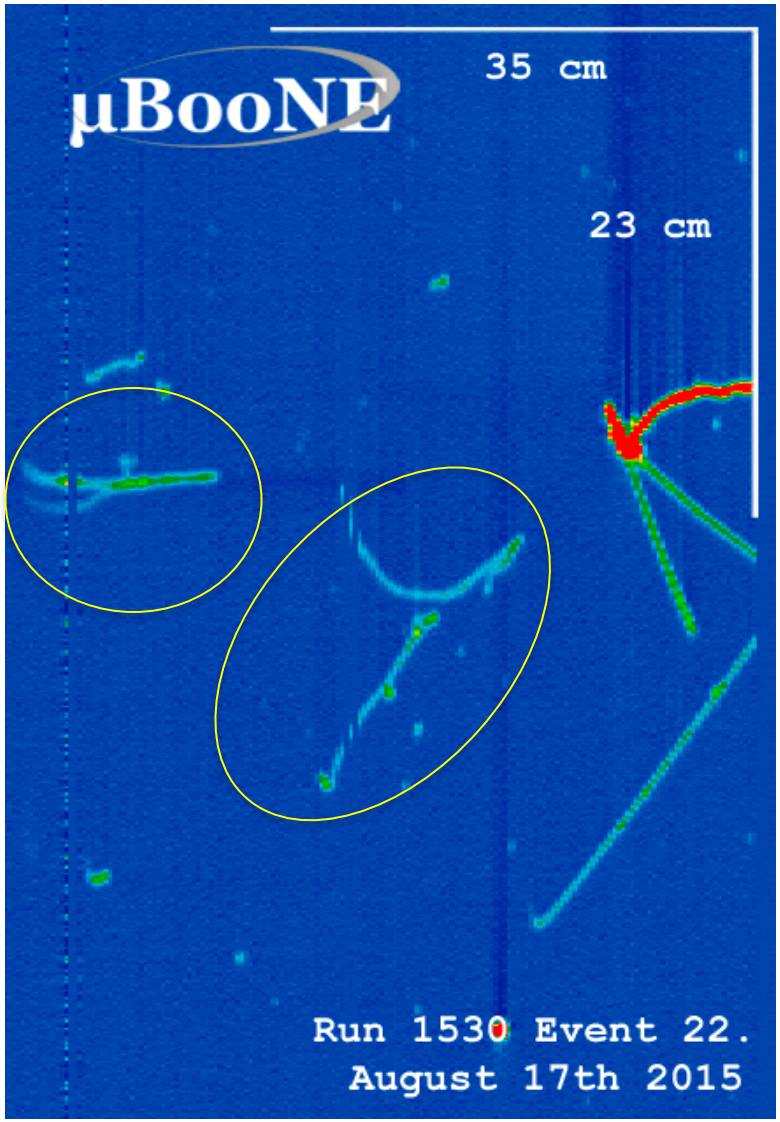

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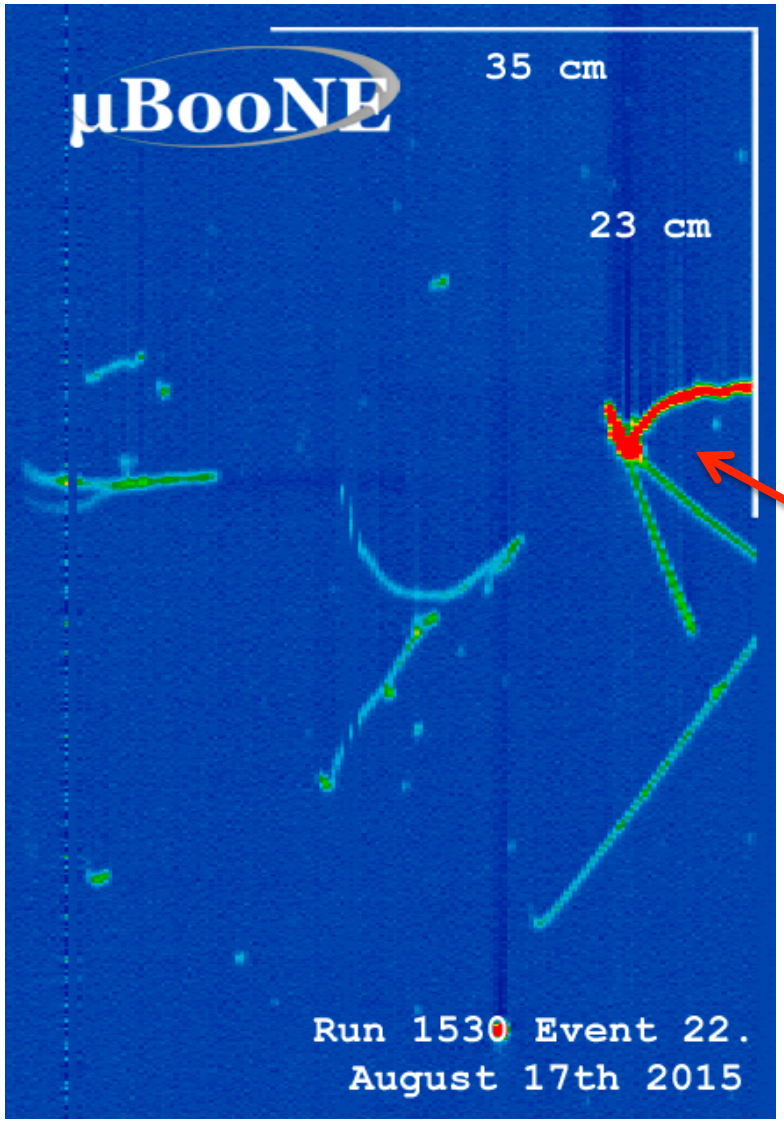

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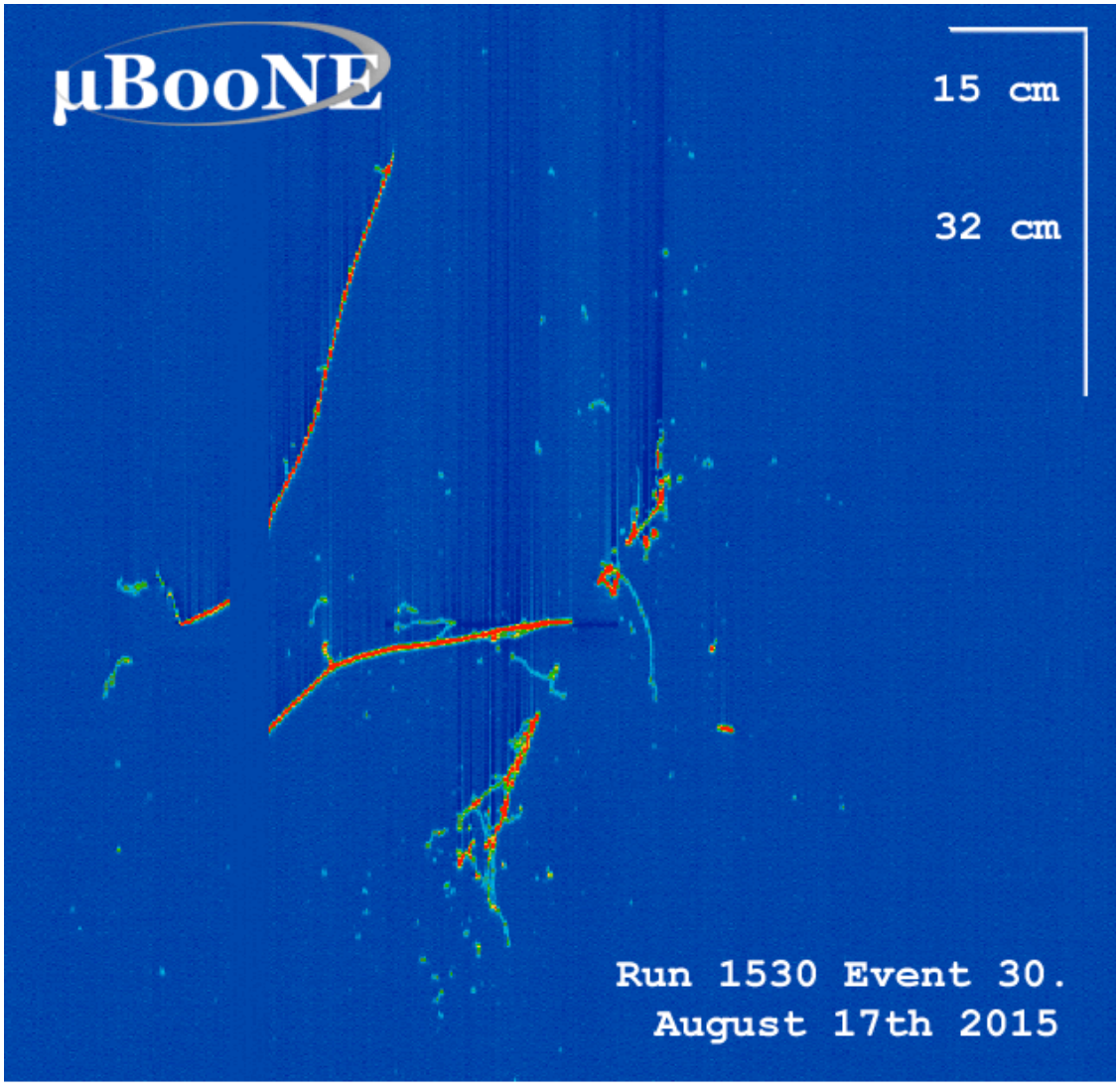

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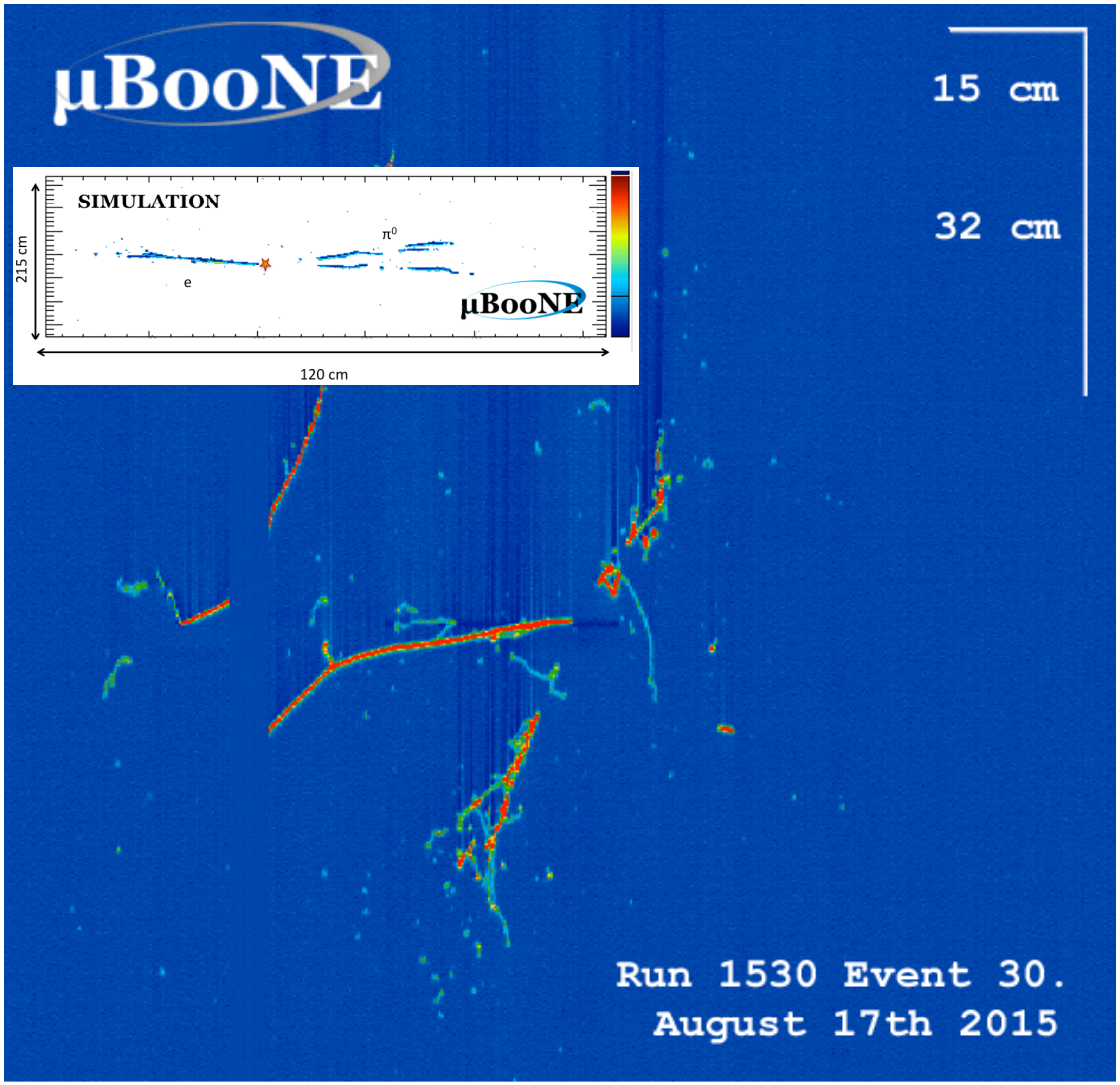

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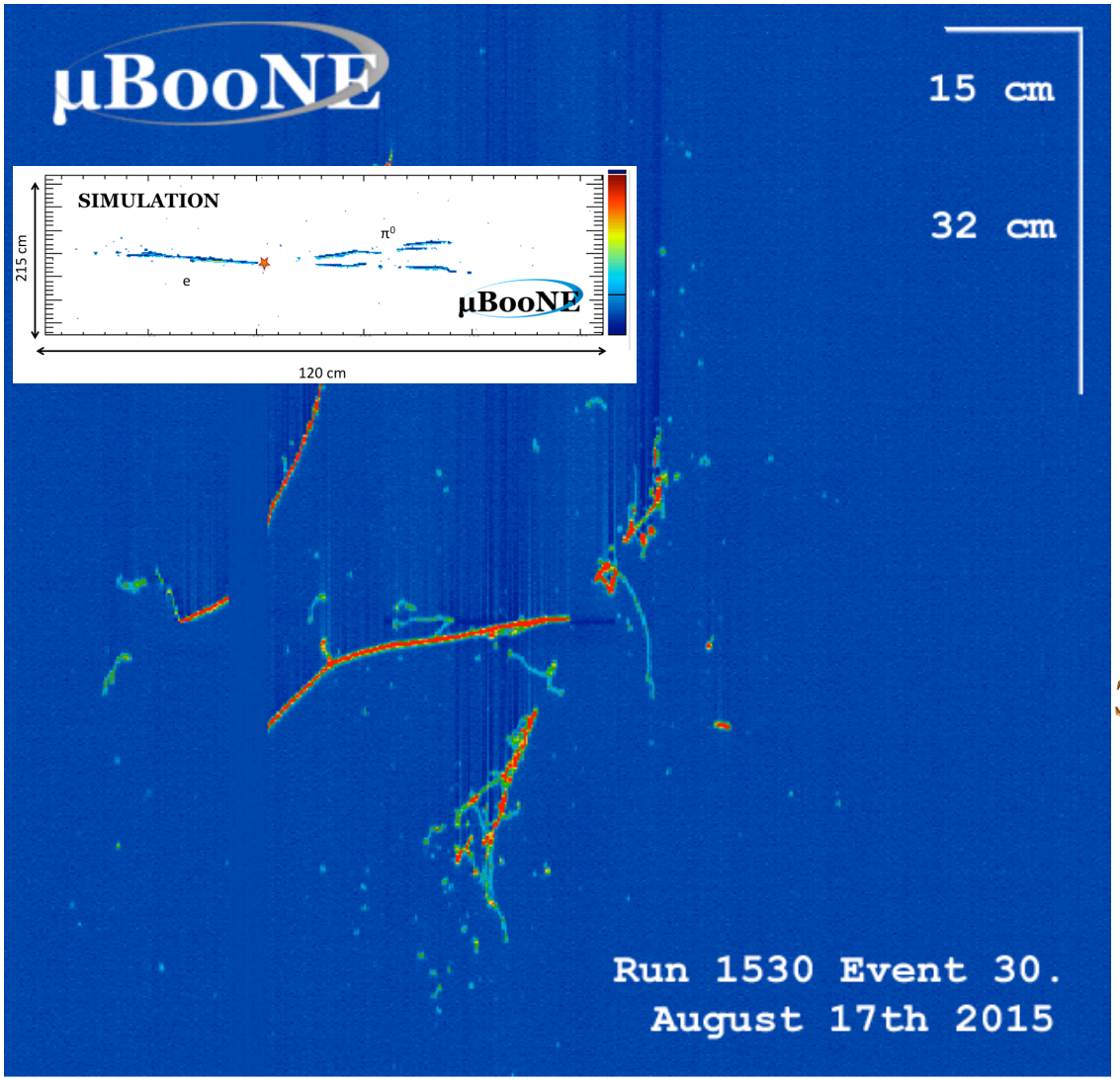

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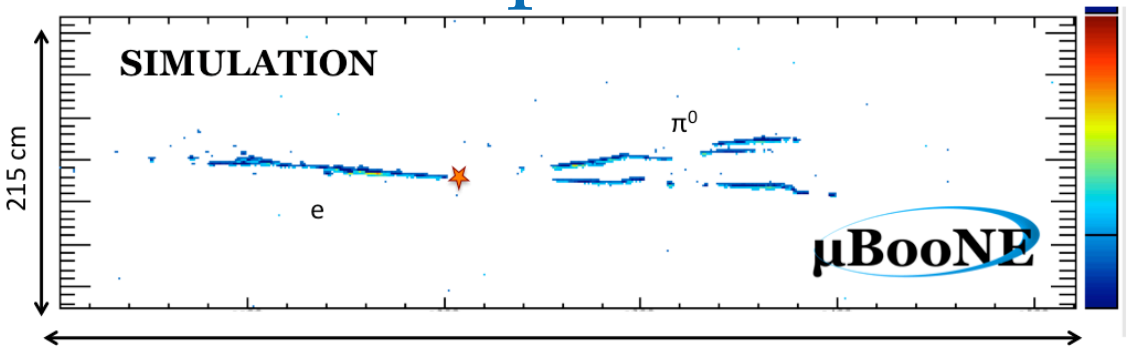
Some example modes



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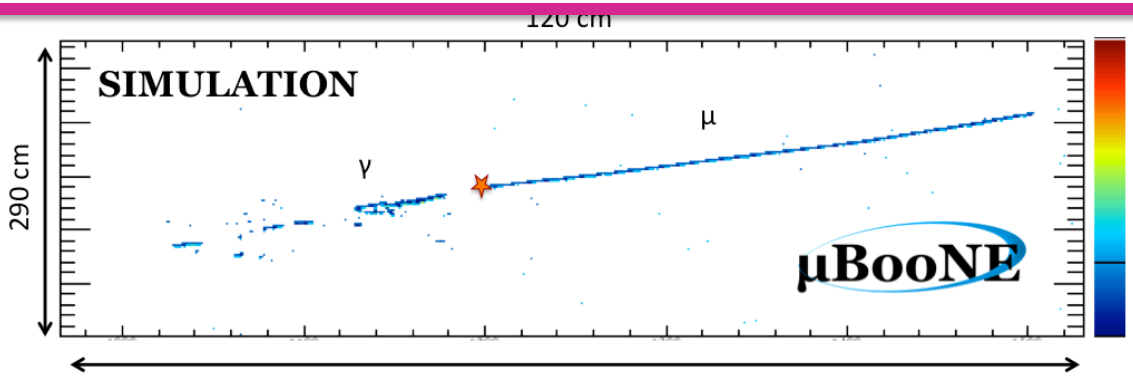
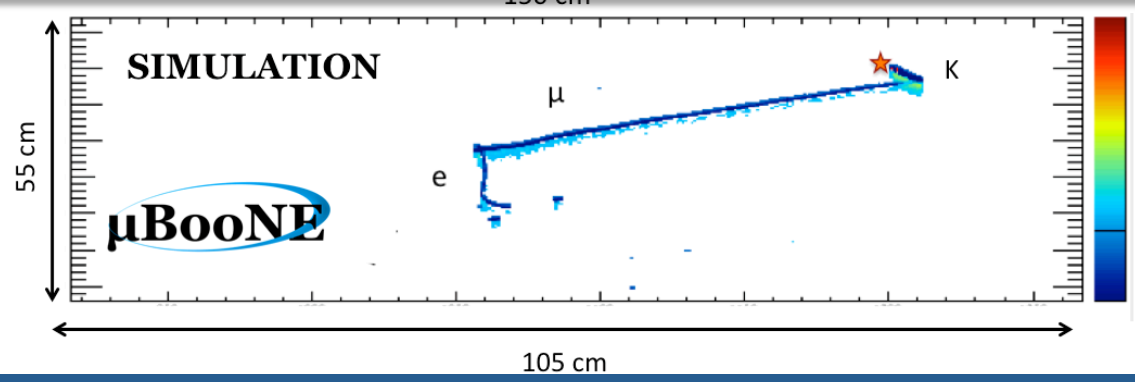


$p \rightarrow \mu^+\gamma$
High bkg channel



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Golden channel
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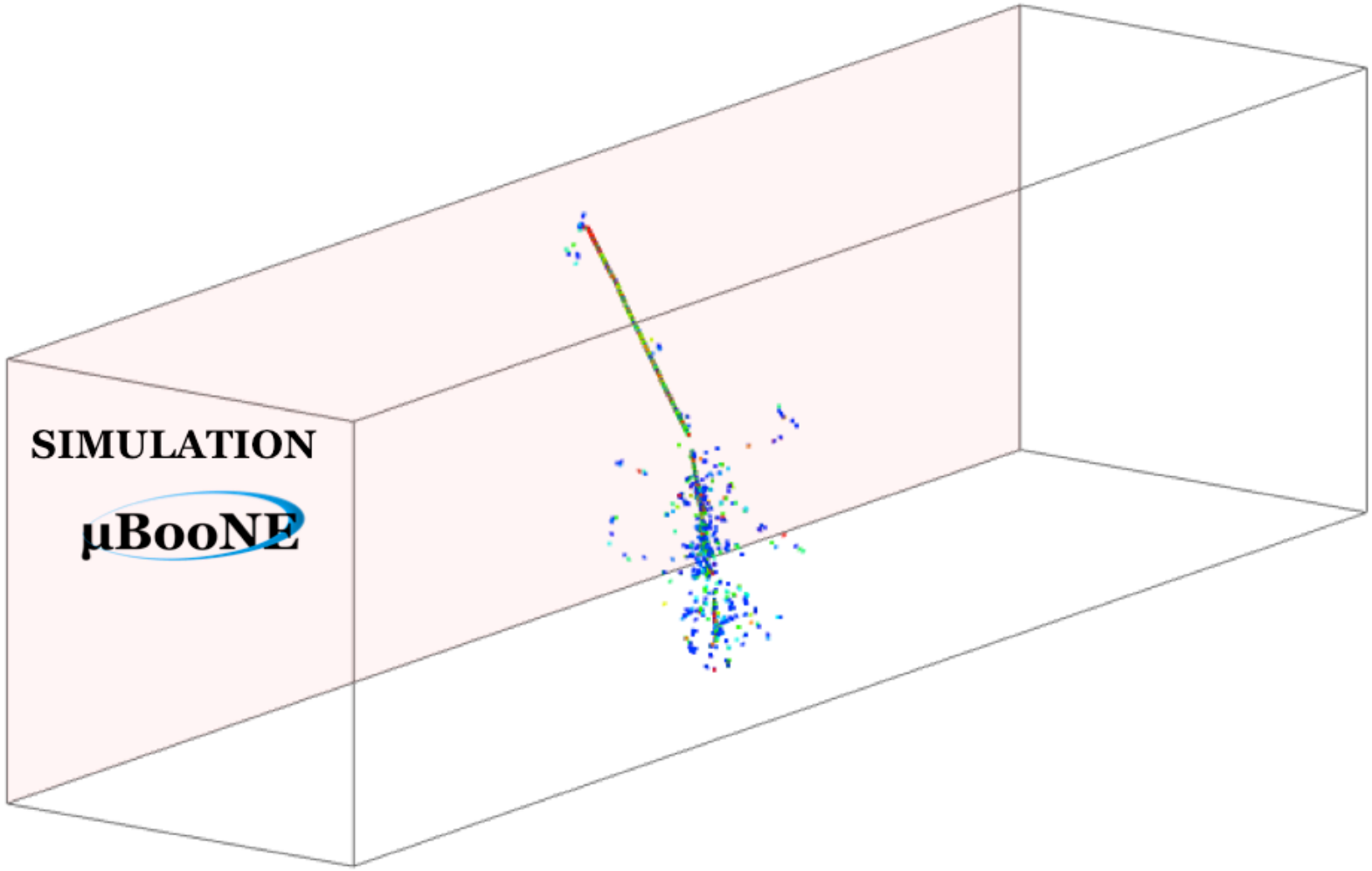
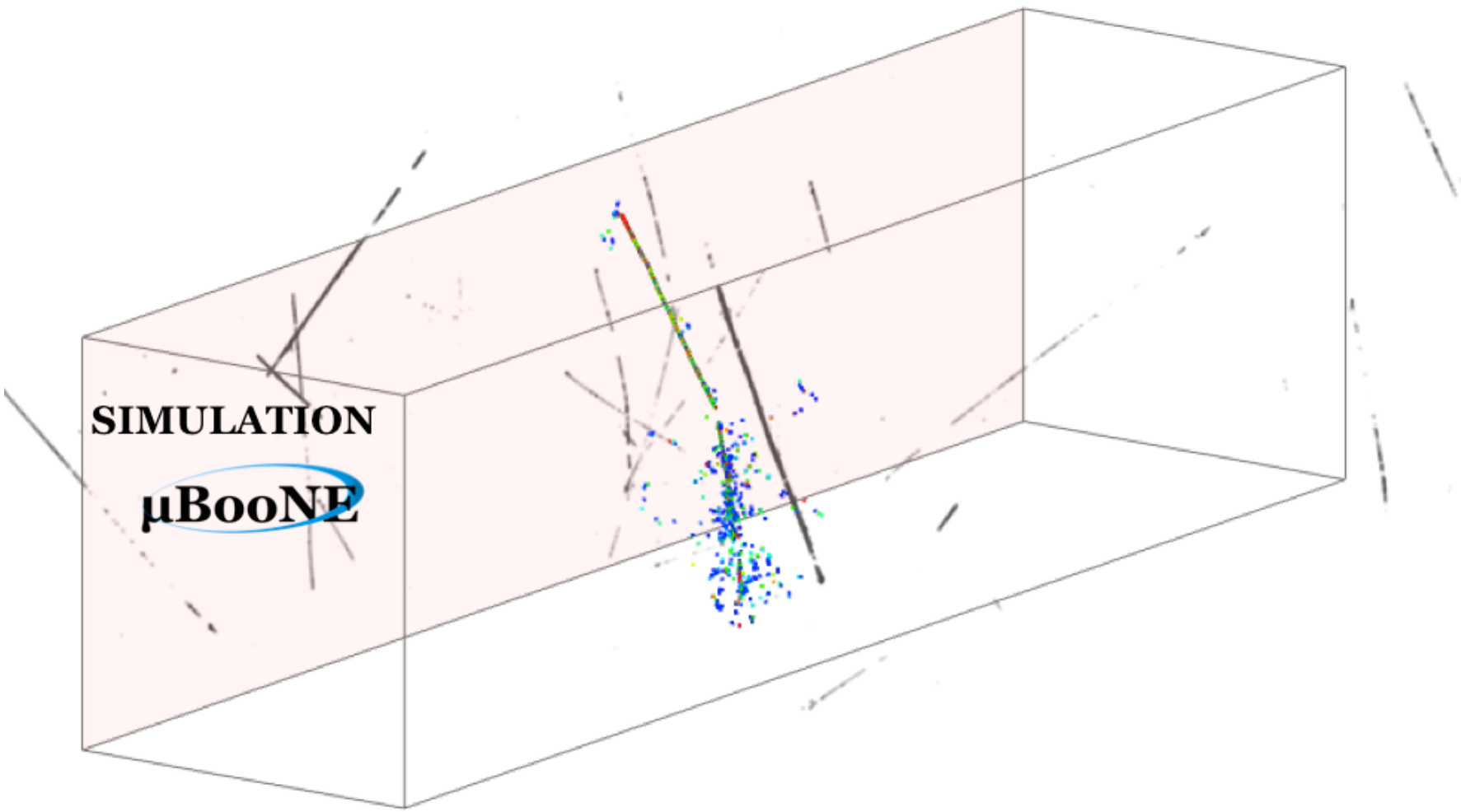
Simulated Event Display for $p \rightarrow \mu^+ \gamma$



Simulated Event Display for $p \rightarrow \mu^+ \gamma$ with cosmics data overlay



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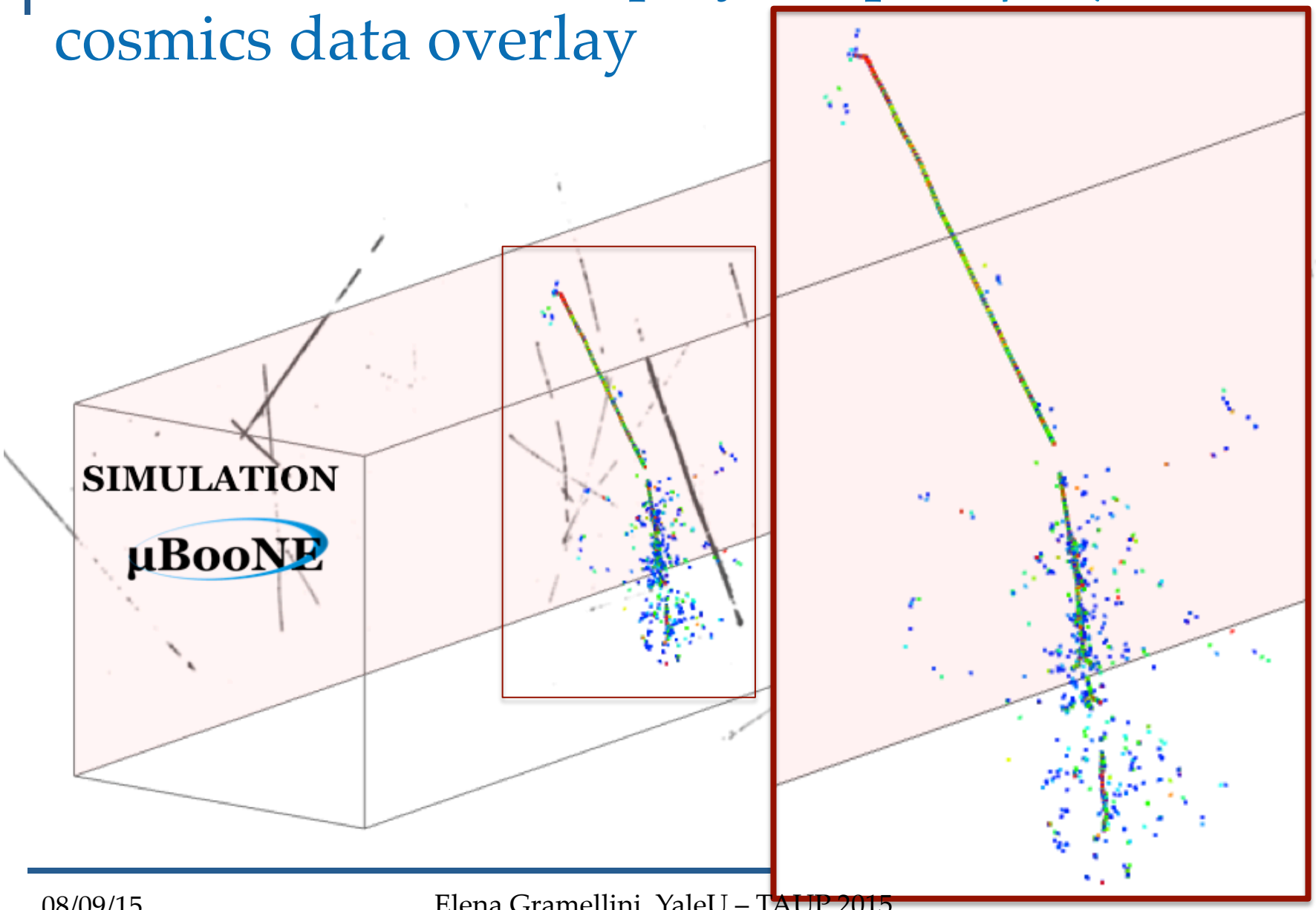

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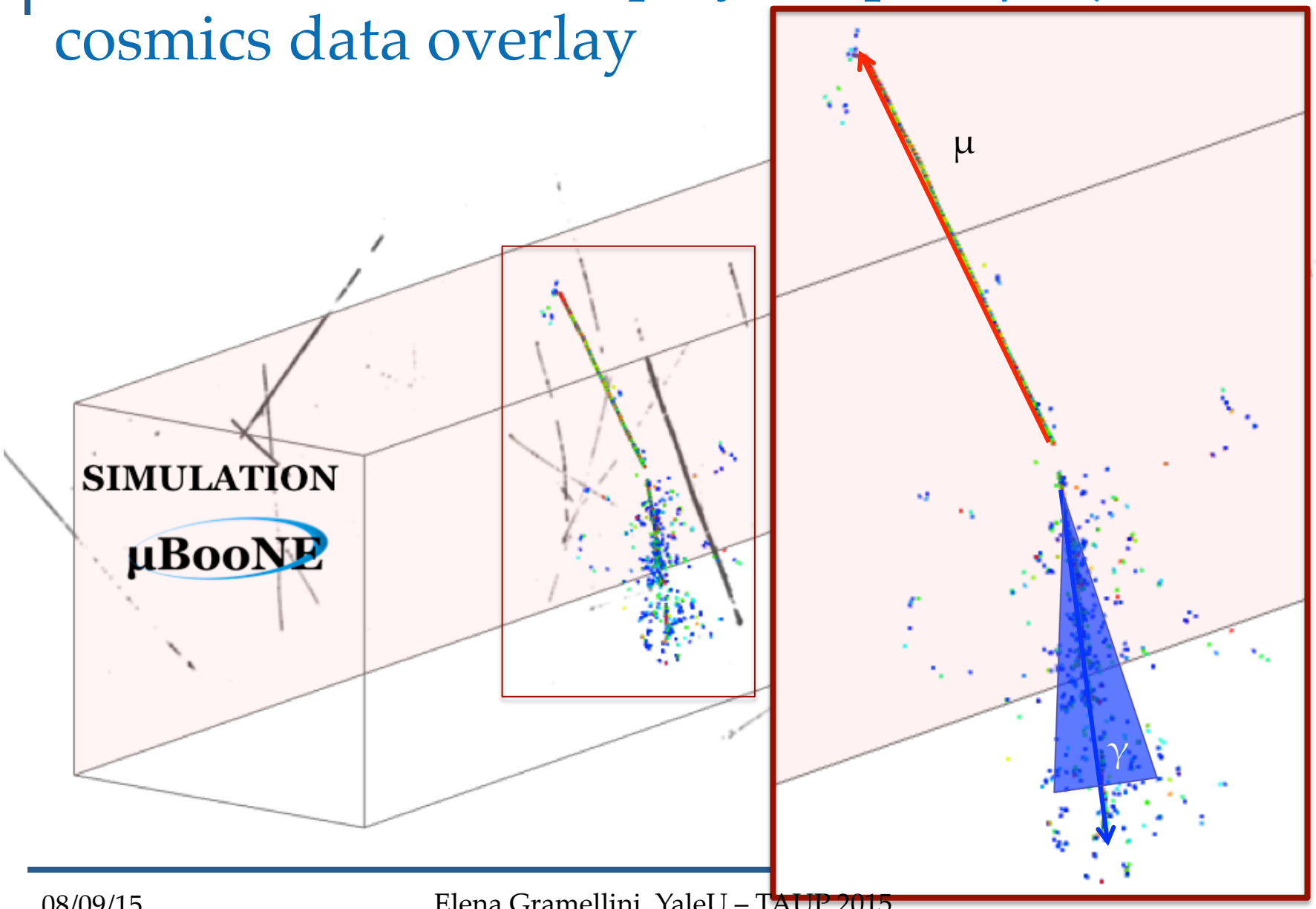

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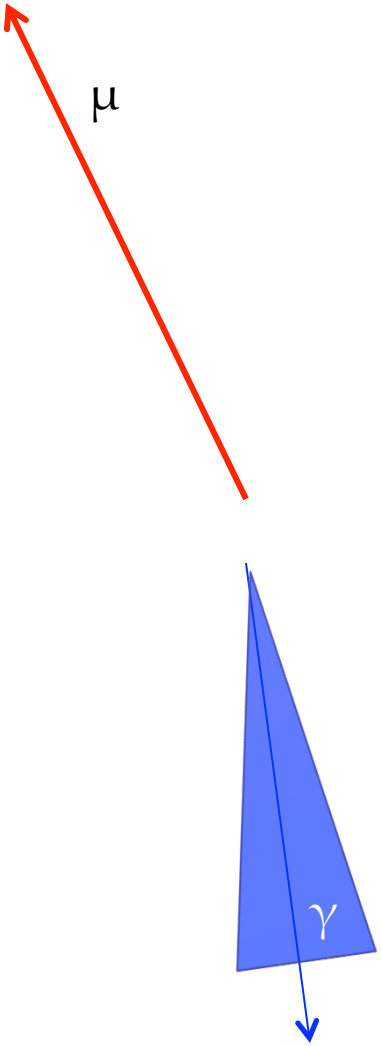

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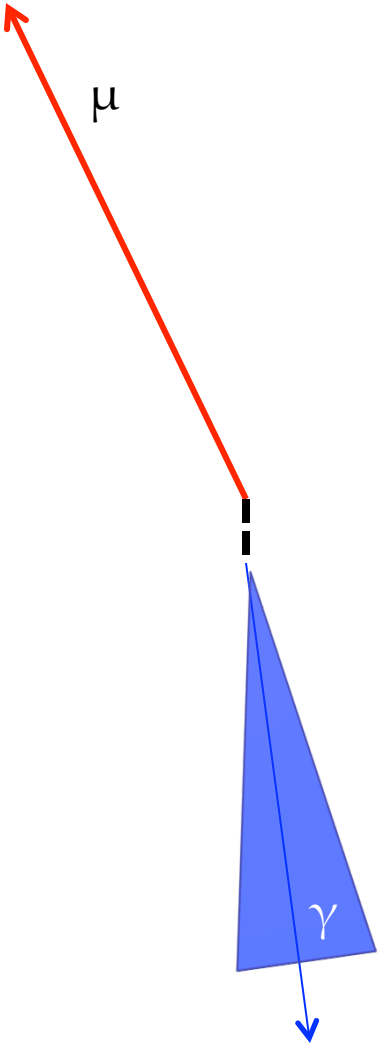

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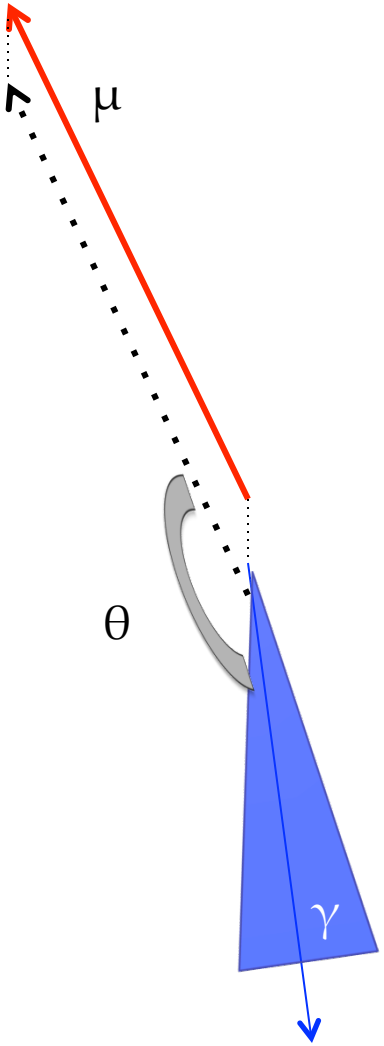

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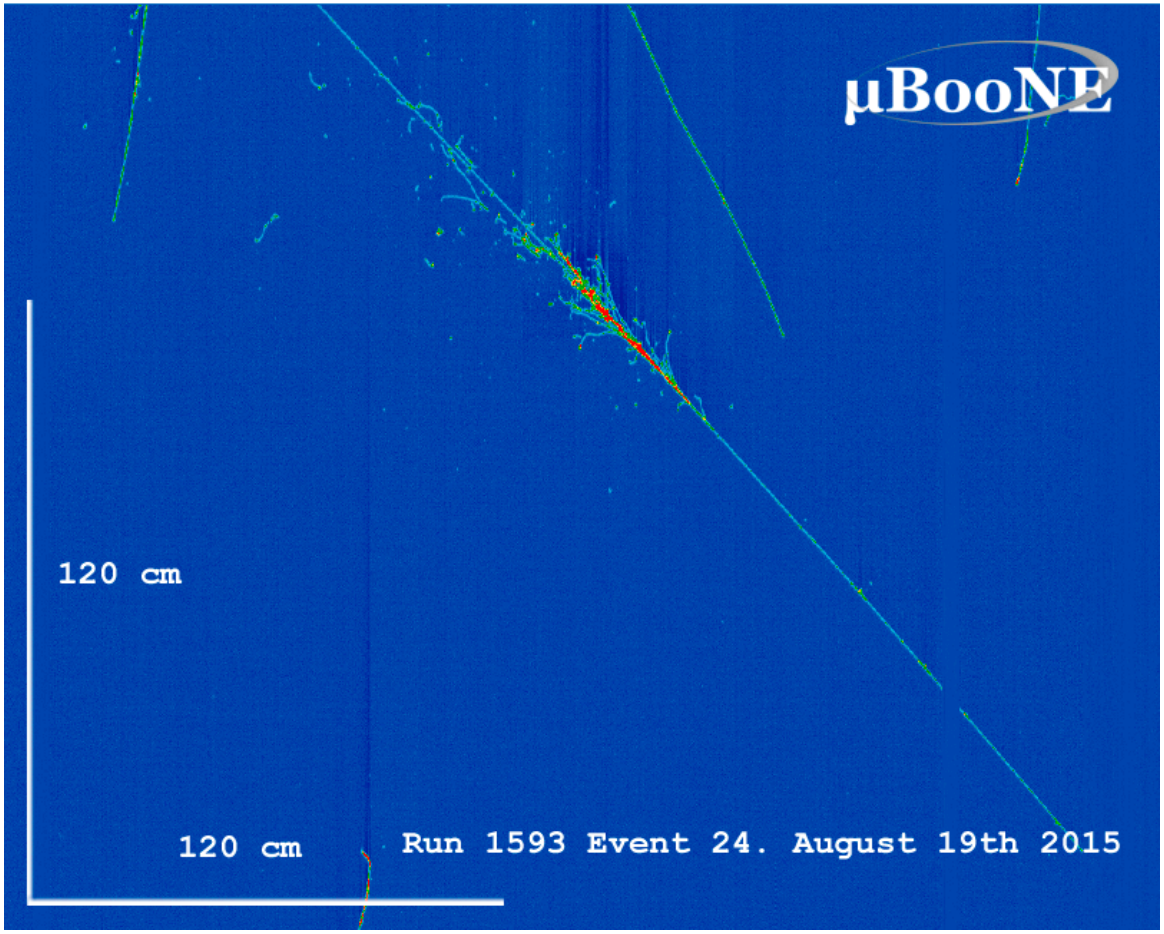

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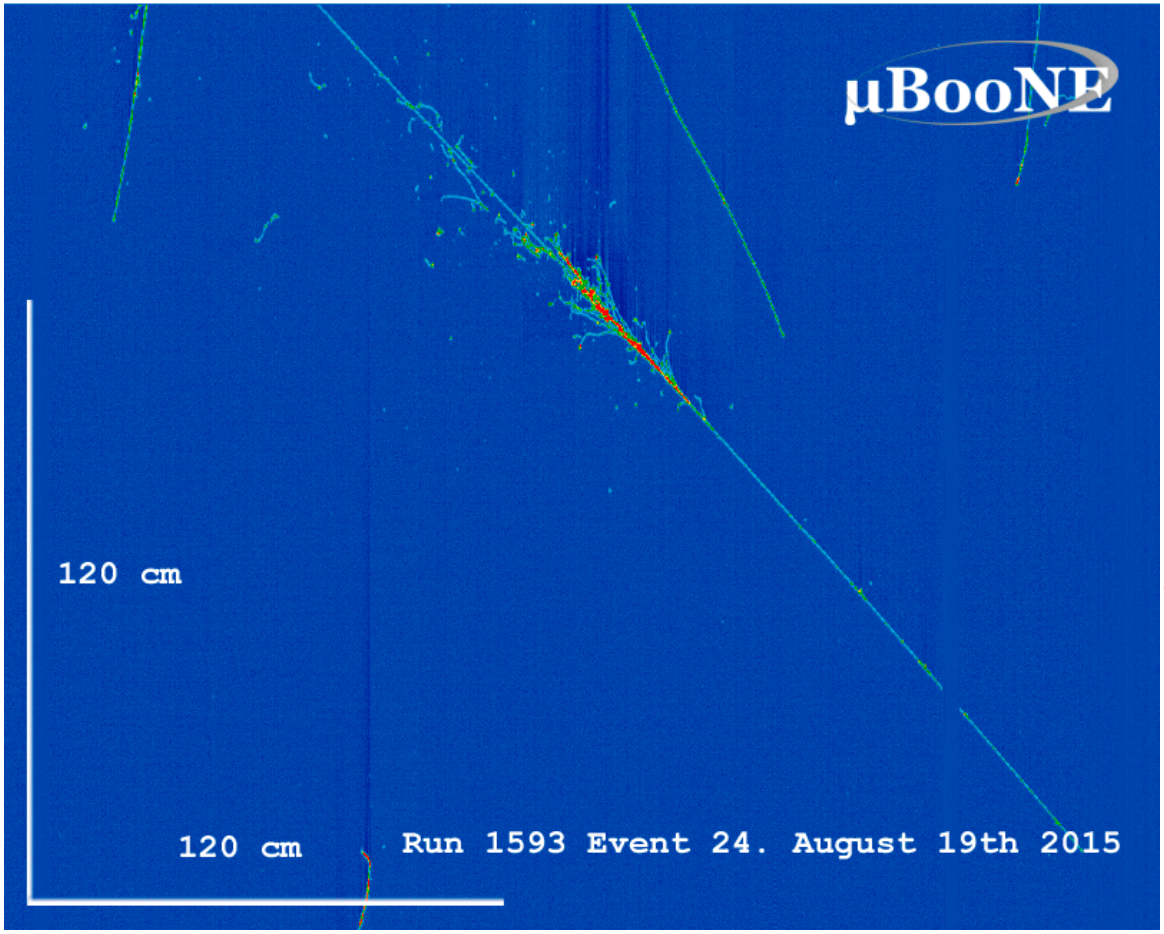

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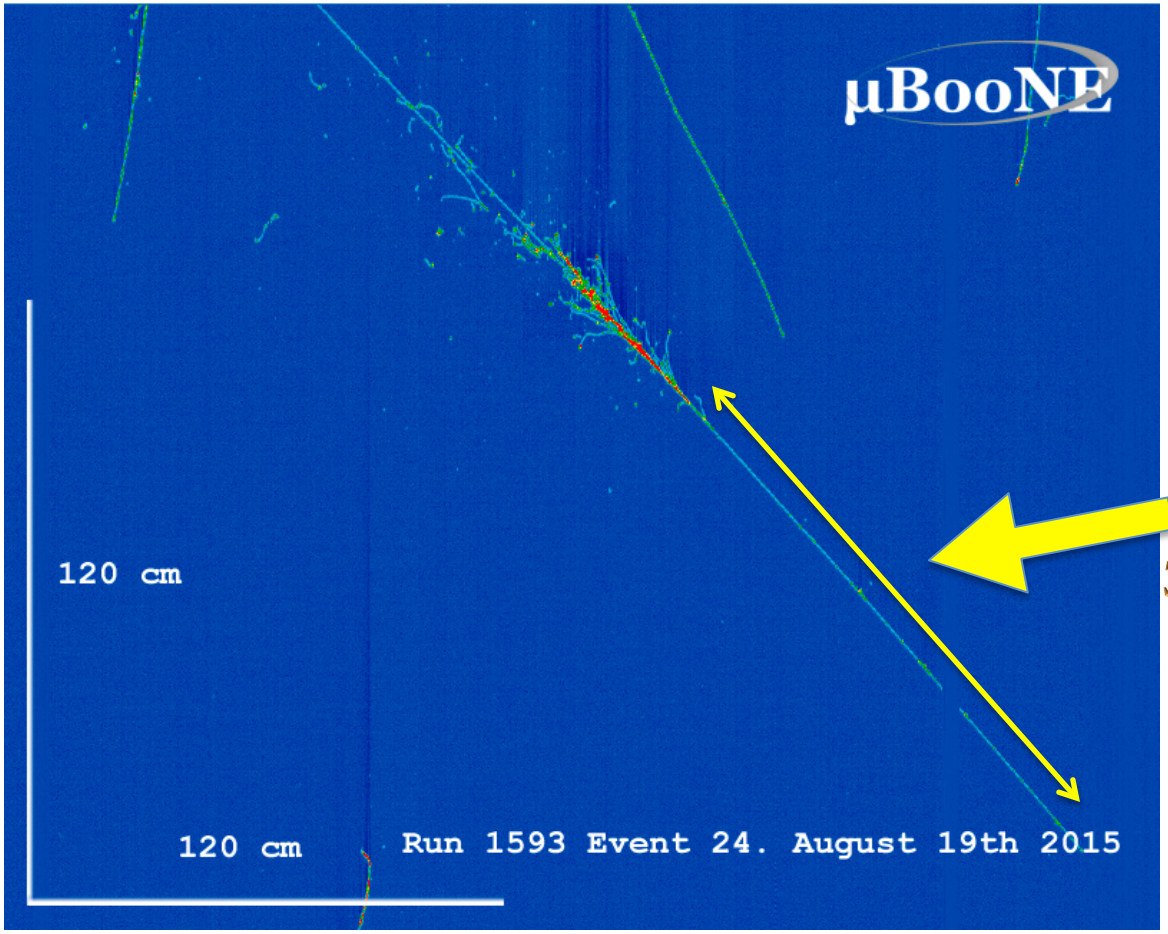

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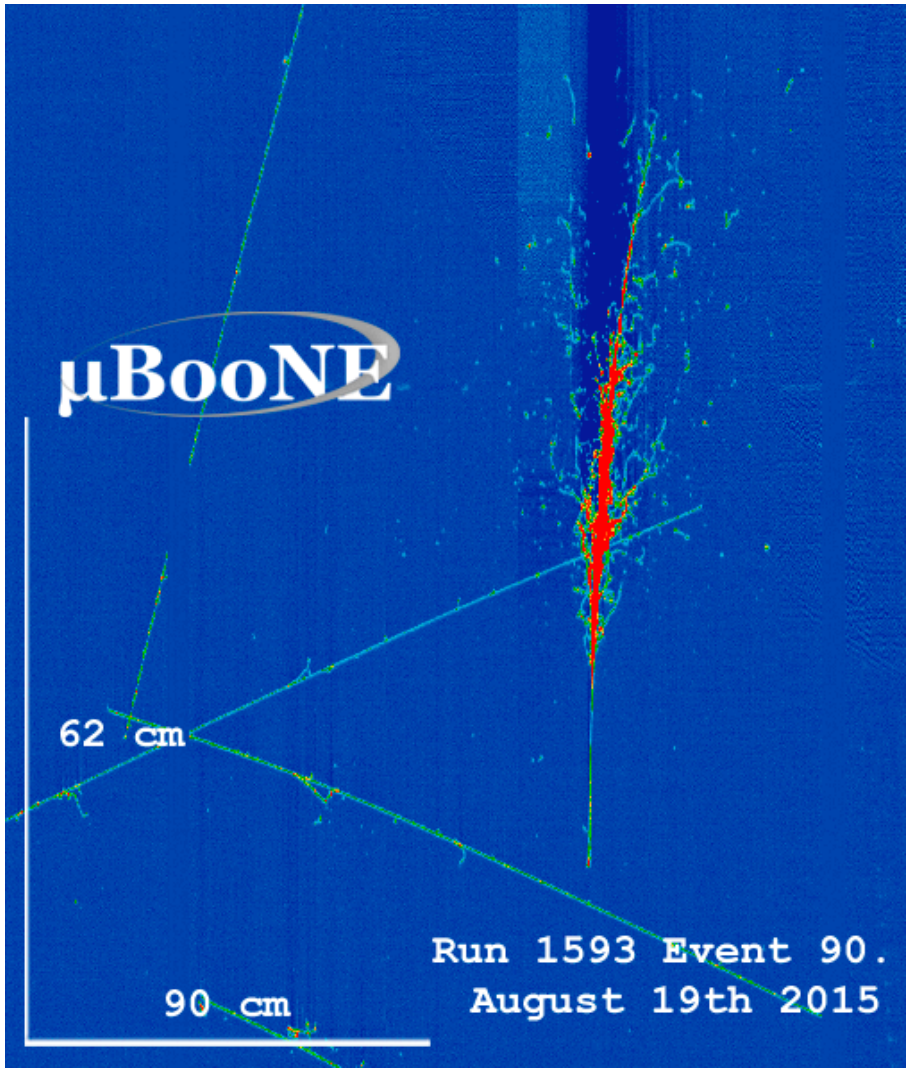

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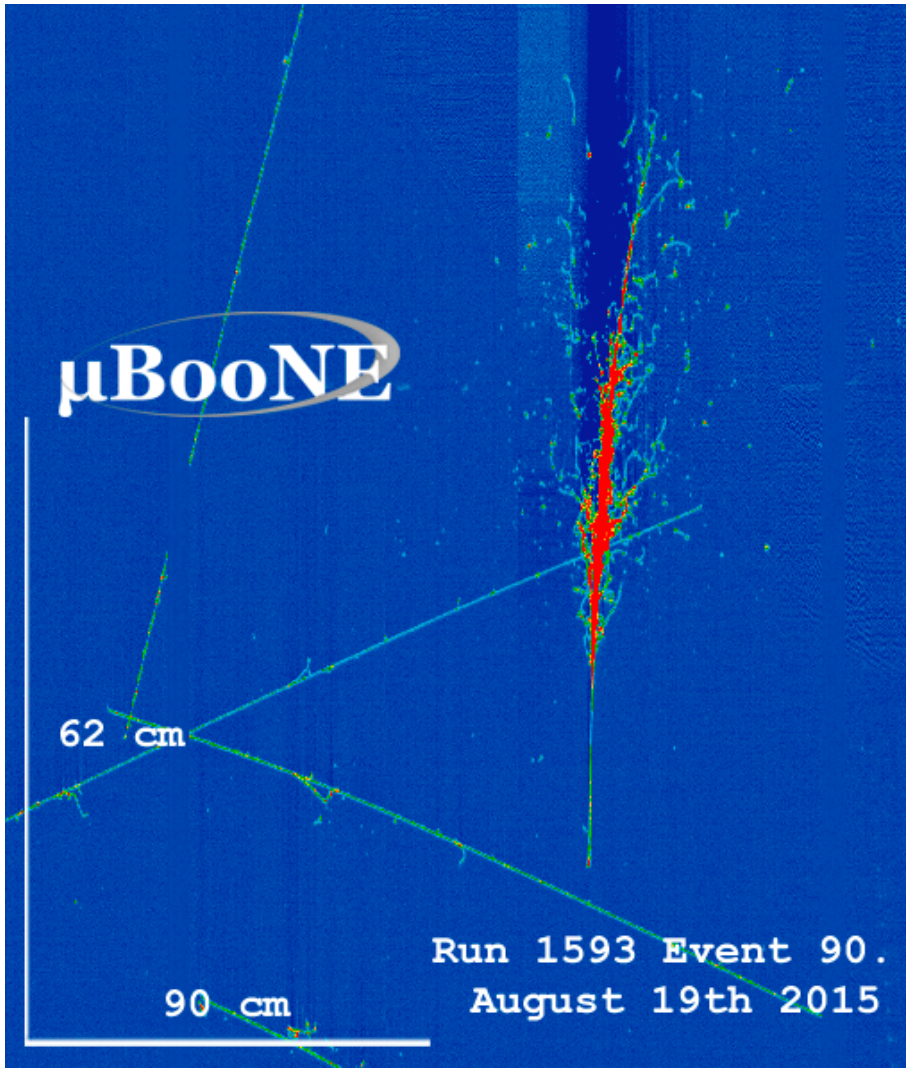

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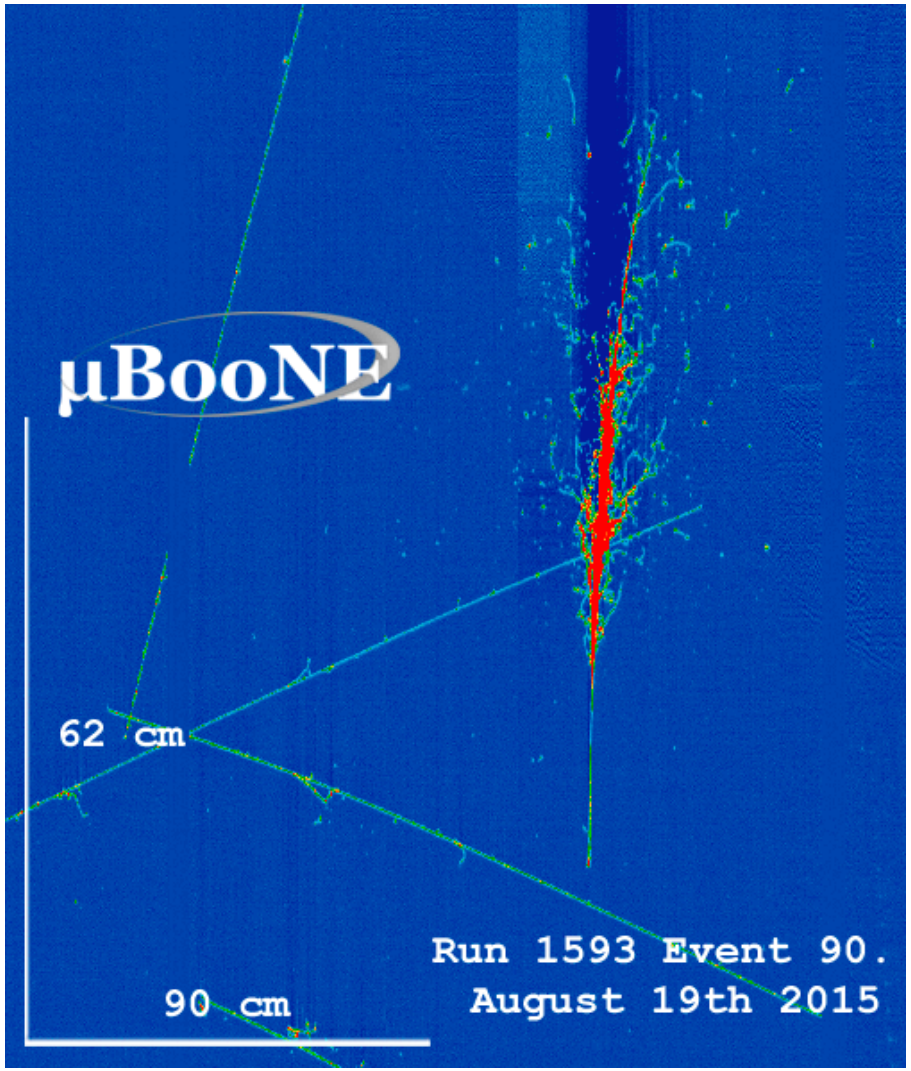
Fiducialization

Selection strategy: calorimetry



We look for events that **meet all the selection criteria**: important background.

Geometry selection & PID

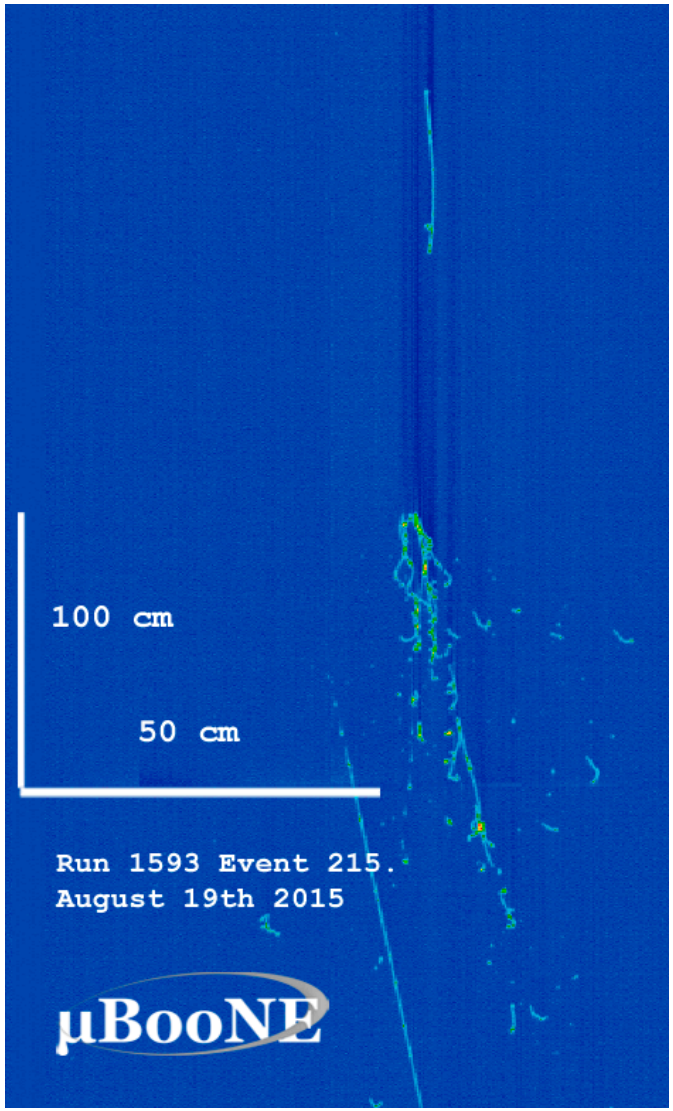
- ✔ μ/π identification
- ✖ γ identification
- ✔ No additional vtx activity
- ✔ Proximity
- 3D Planarity

Calorimetry selection

- ✖ Total energy deposited
- ✖ Total net momentum

Fiducialization

$p \rightarrow \mu^+ \gamma$ signature in 2D



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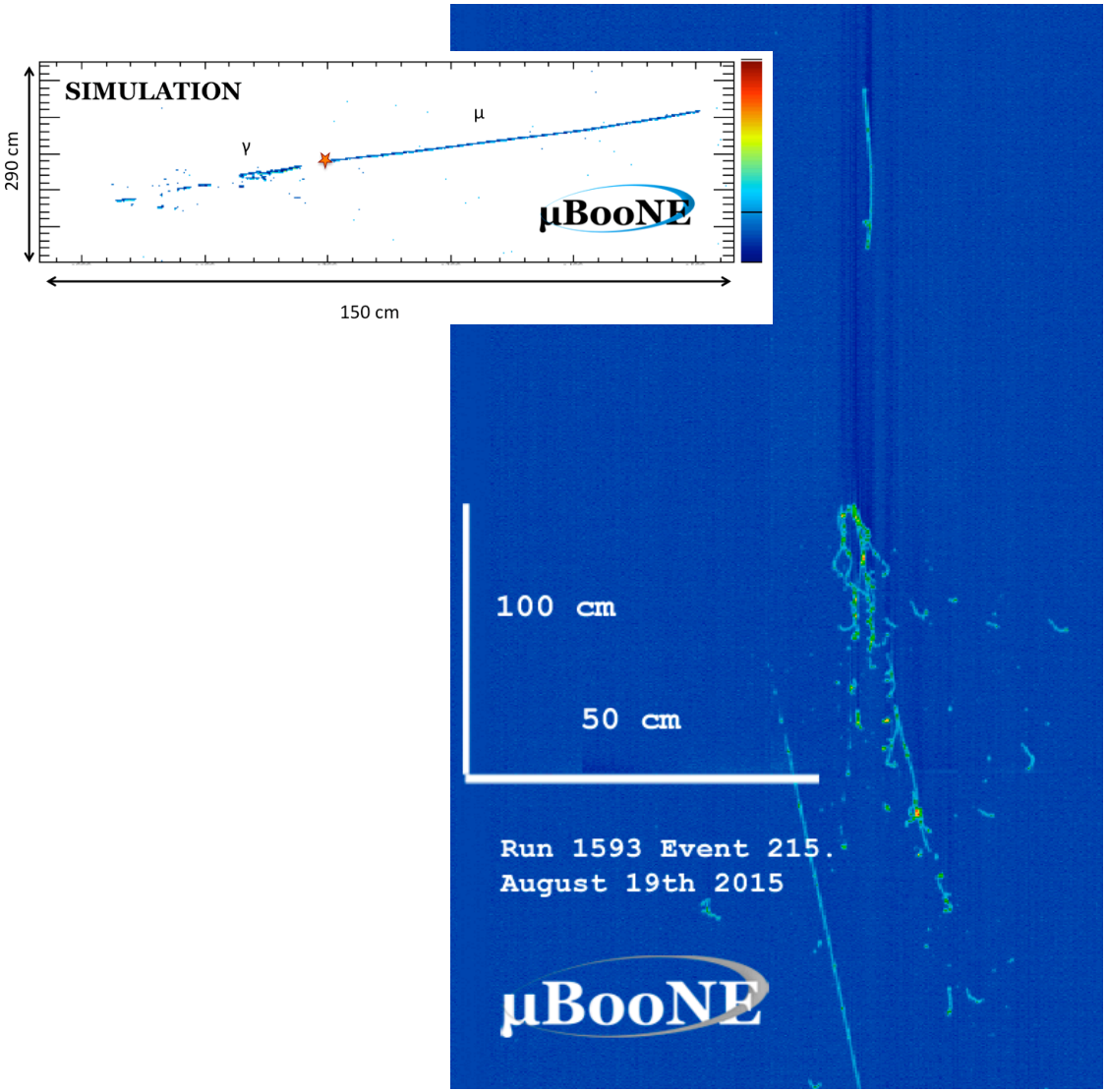

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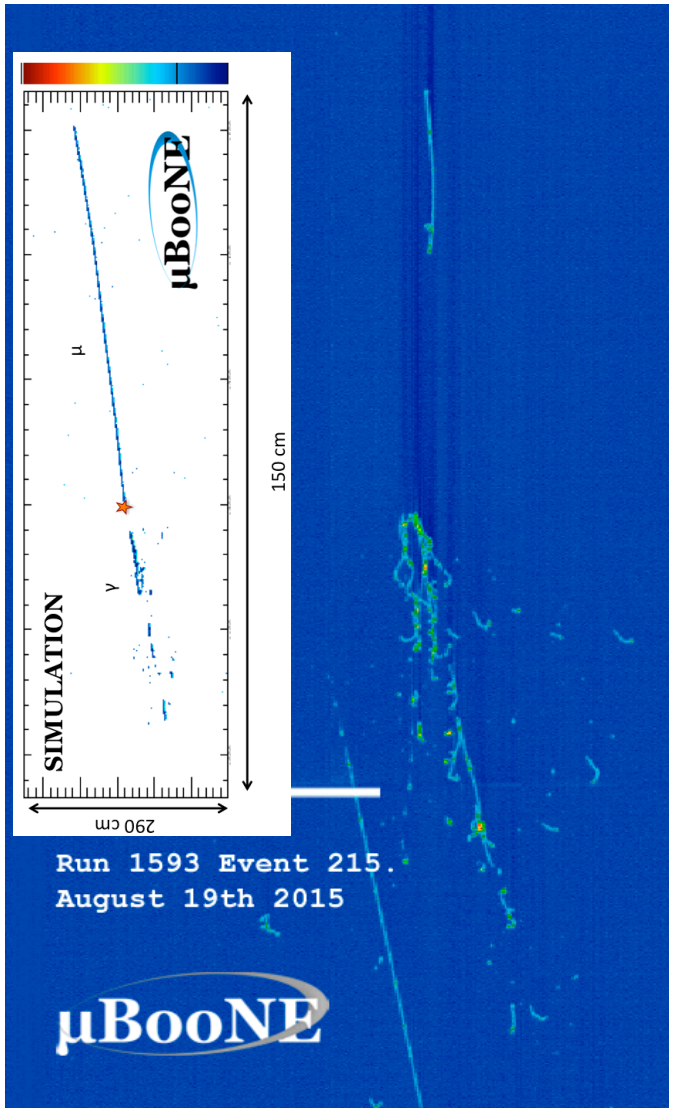

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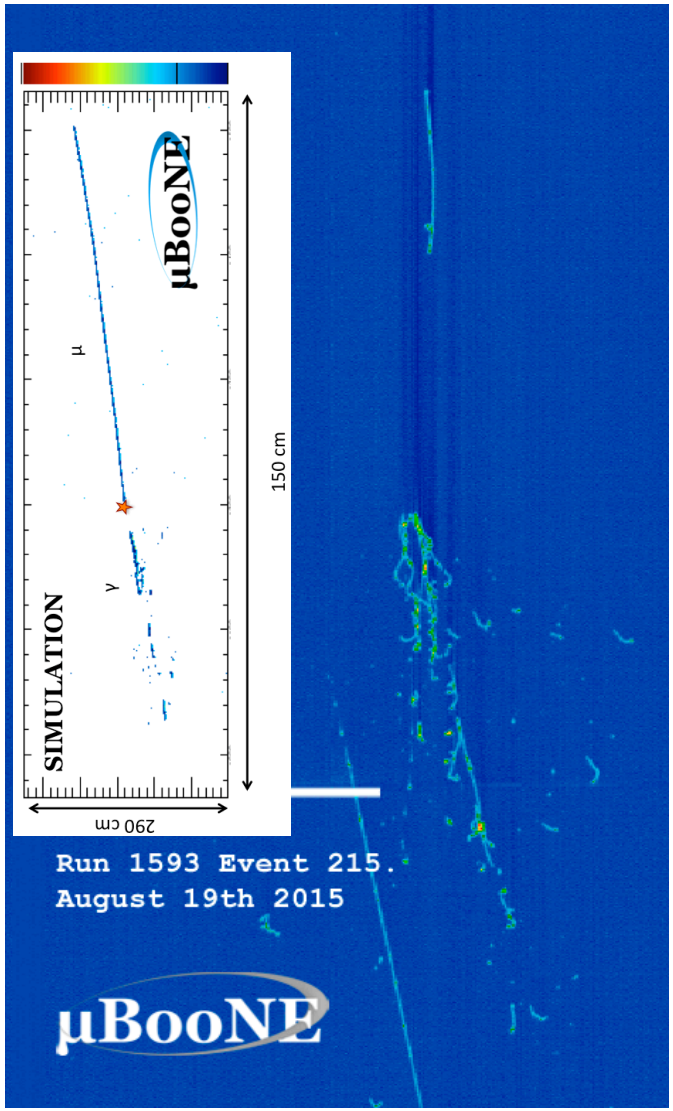

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Geometry selection & PID

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- ✔ γ identification
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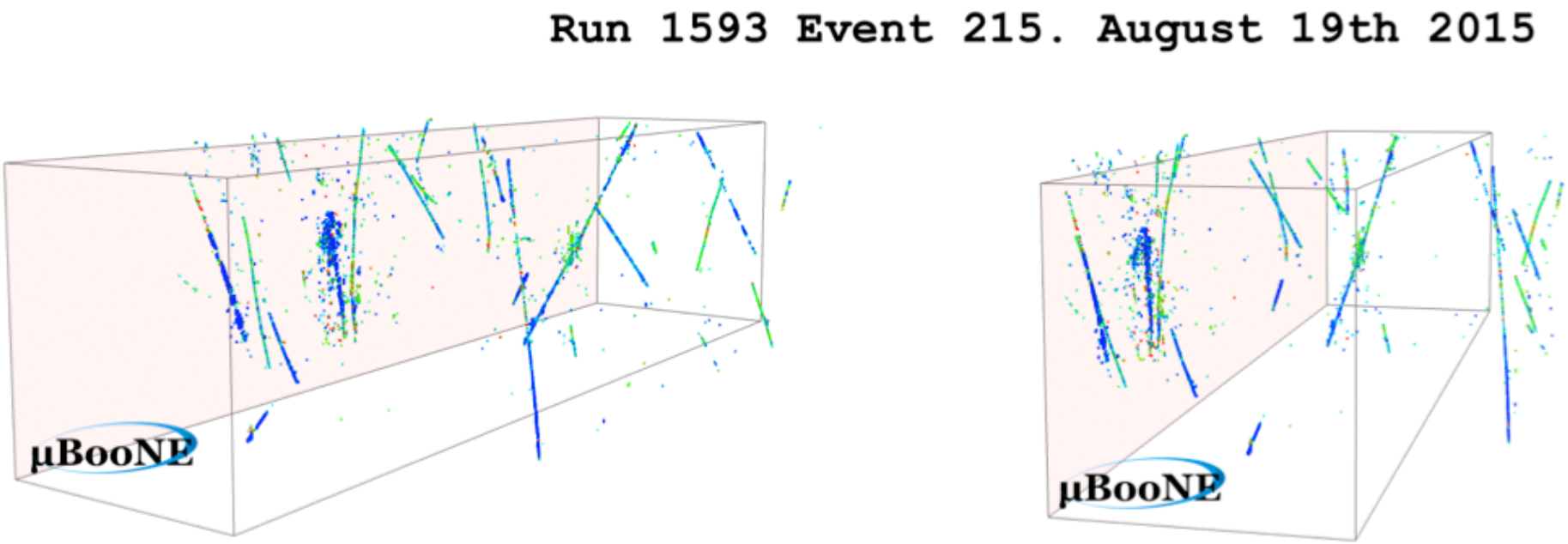
- ✔ Proximity
- 3D Planarity?

Calorimetry selection

- ✔ Total energy deposited
- ✔ Total net momentum

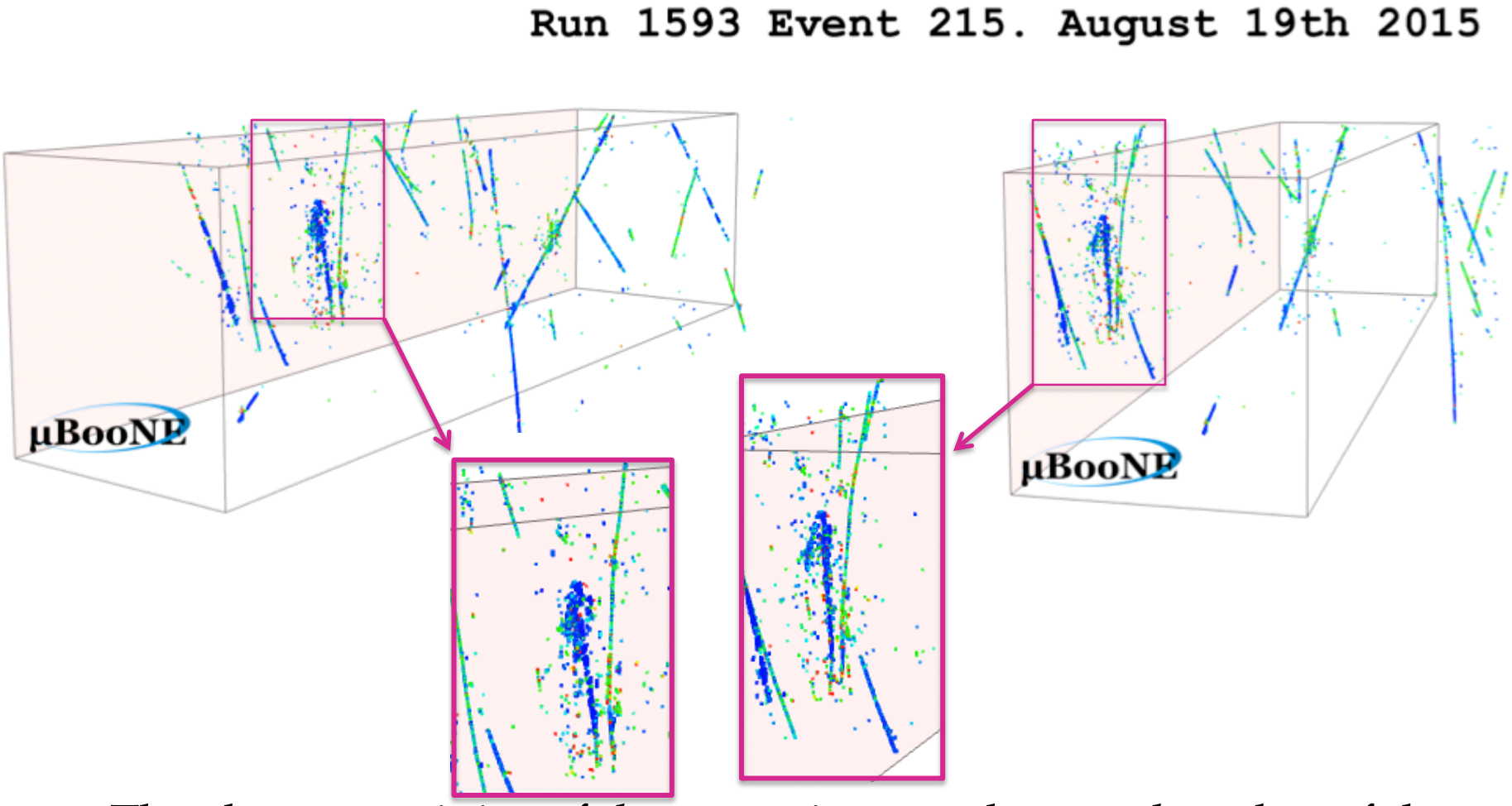
Fiducialization ?

Selection strategy: fiducialization



The shower activity of the event is very close to the edge of the TPC: event rejected by planarity and fiducialization.

Selection strategy: fiducialization



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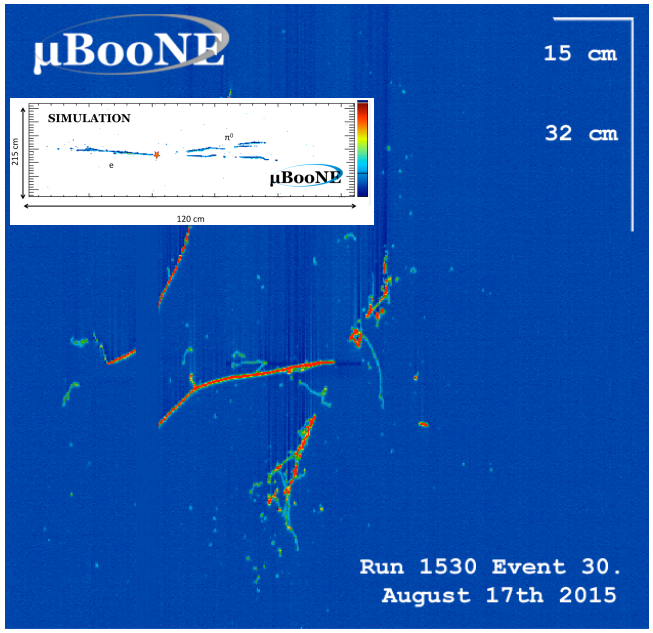
Visual summary

In the first MicroBooNE events,

we've seen…



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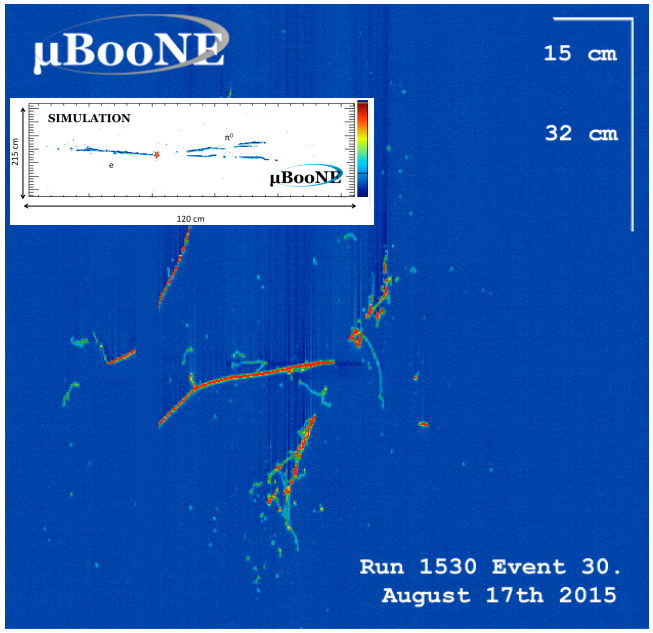

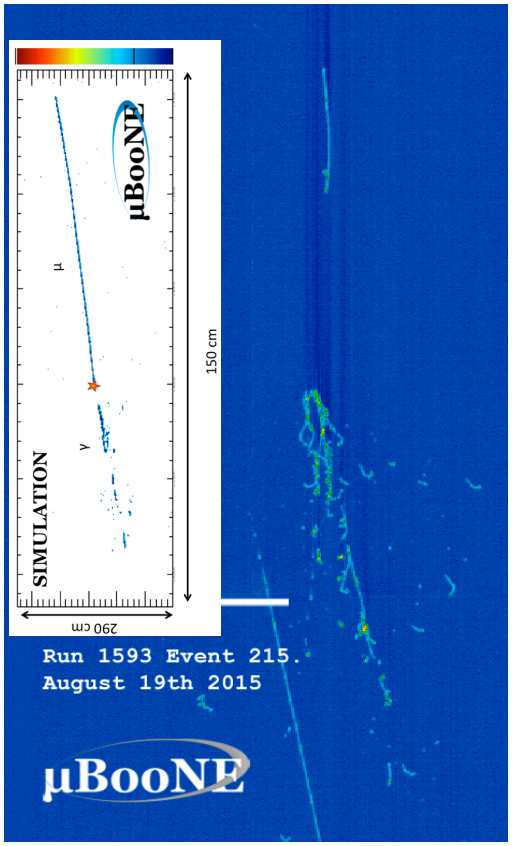

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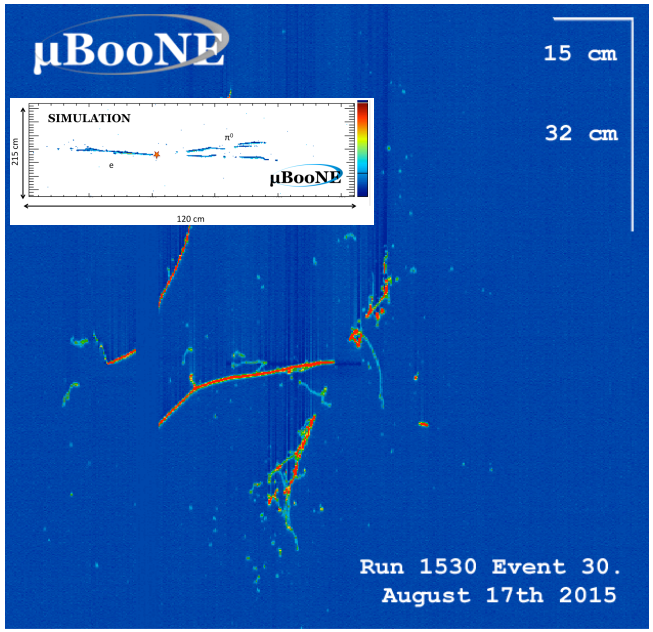
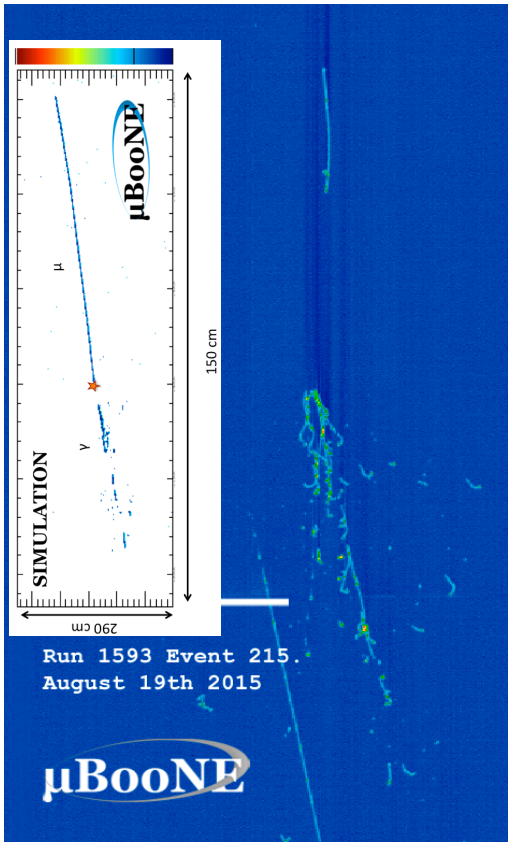
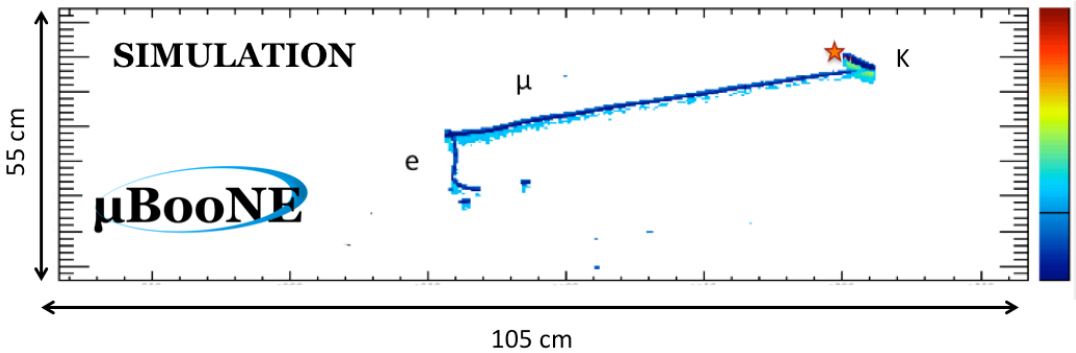




In the first MicroBooNE events, we've seen…

… and more to come!



Takeaways

Even in the initial MicroBooNE cosmics data, we are **seeing for the first time** topologies of interest for **proton decay** searches in a LAr.

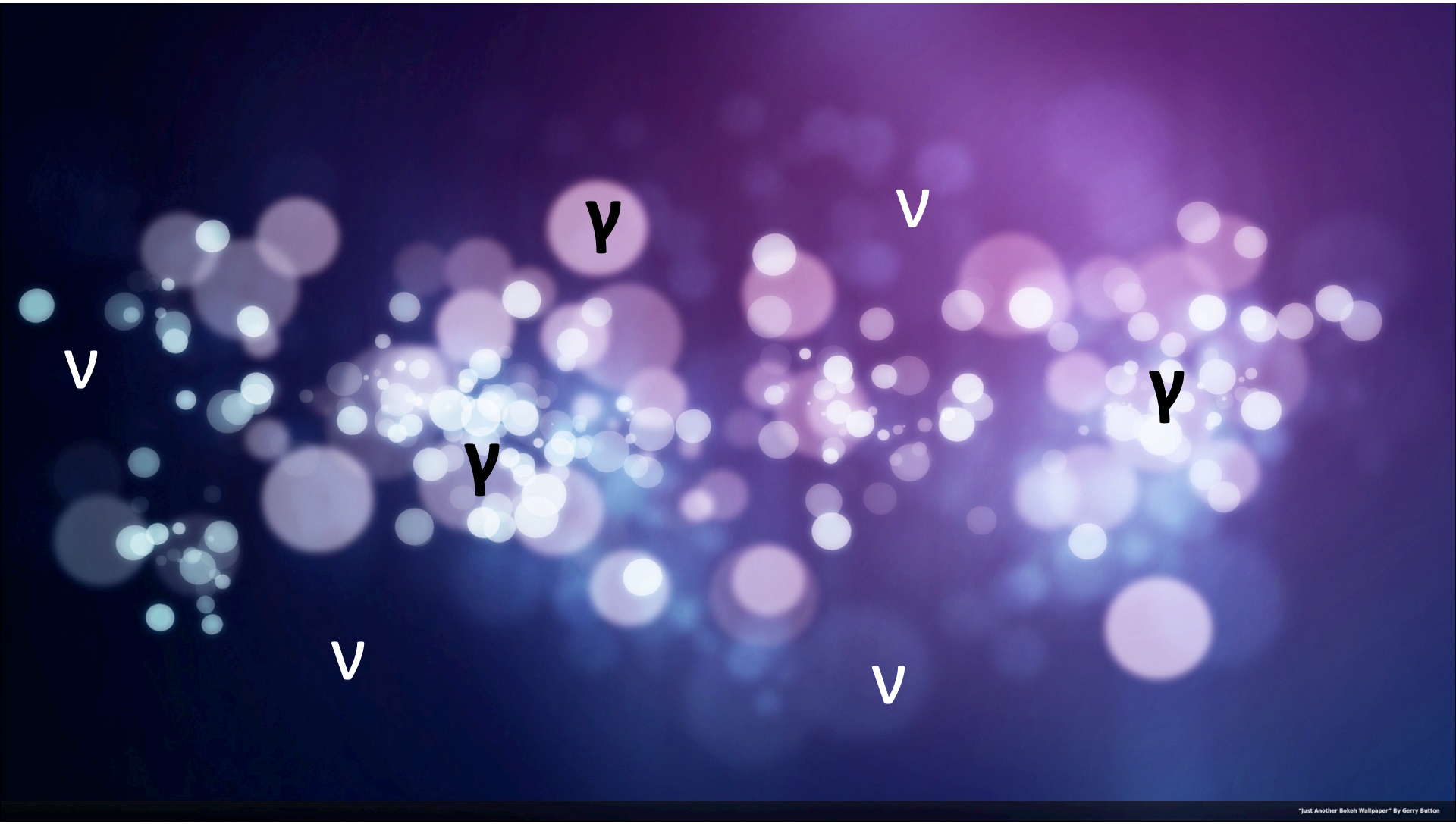
This analysis is in progress.
The goal is to produce **full characterization and analysis** of cosmogenic backgrounds mis-ID rates.

With MicroBooNE (a 100 ton scale experiment), **we can measure backgrounds**, as well as **develop strategies and reconstruction tools** critical for future LArTPCs proton decay searches.

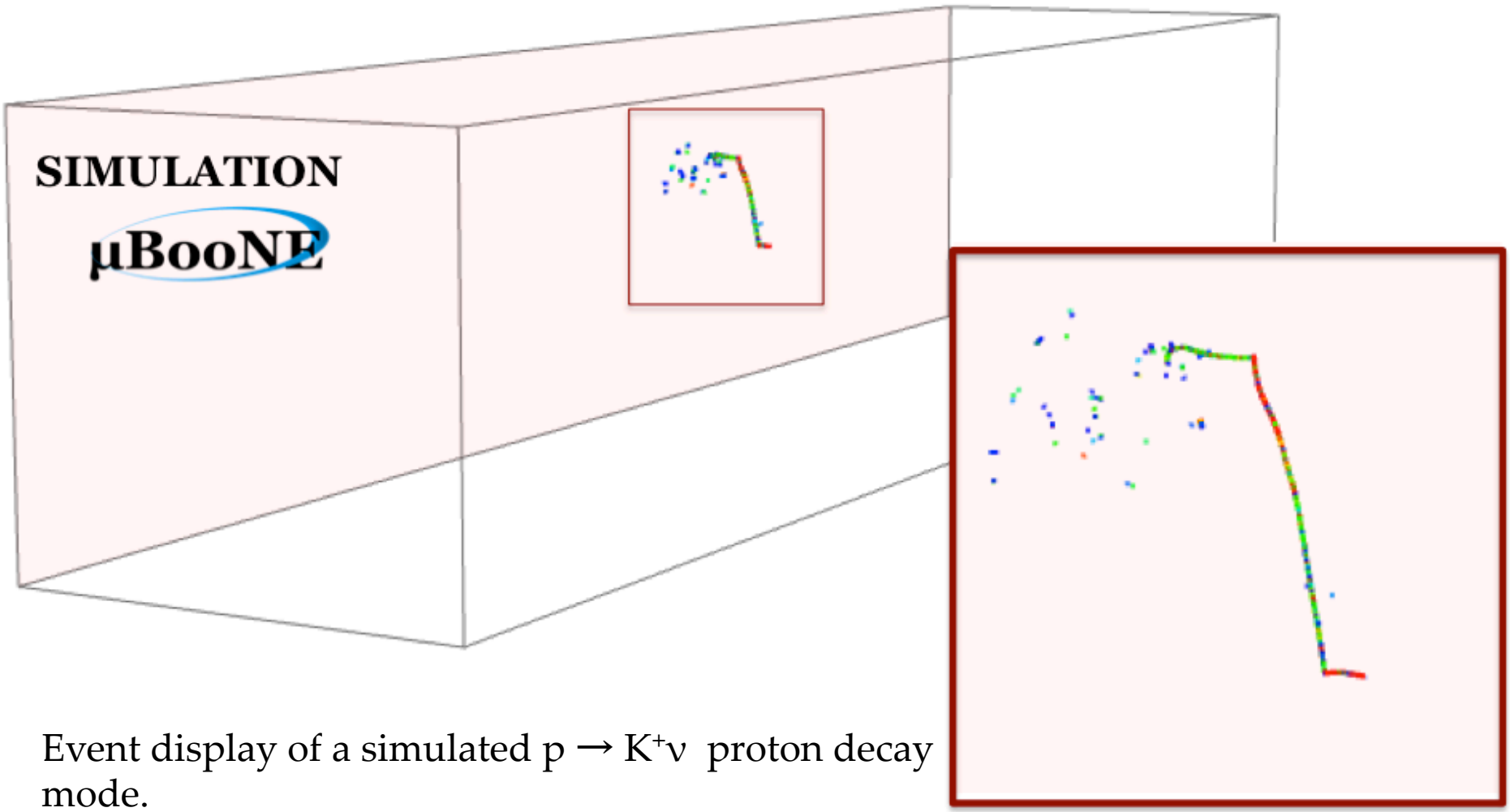
Thanks for the attention!

… if you want to hear more about MicroBooNE, don't forget to attend our run coordinator's (Matt Toups) talk tomorrow!

Back up



Simulated Event Display for the $p \rightarrow K^{+}\bar{\nu}$



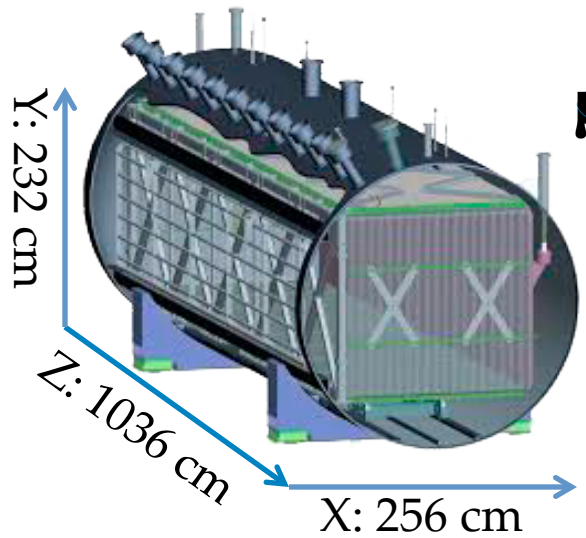
Event display of a simulated $p \rightarrow K^{+}\nu$ proton decay mode.

…What About Now?

MicroBooNE is a 170 ton LArTPC in the Booster Neutrino Beam at Fermilab.
While the mass is not sufficient to explore τ_P not already excluded. Surface position and currently taking cosmic data: perfect venue to study

Cosmogenic Backgrounds in a LArTPC.

Test the potential of LArTPC in proton decay searches.



μBooNE