

GENIE Events in LAr and GAr

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DUNE Near Detector Workshop, CERN

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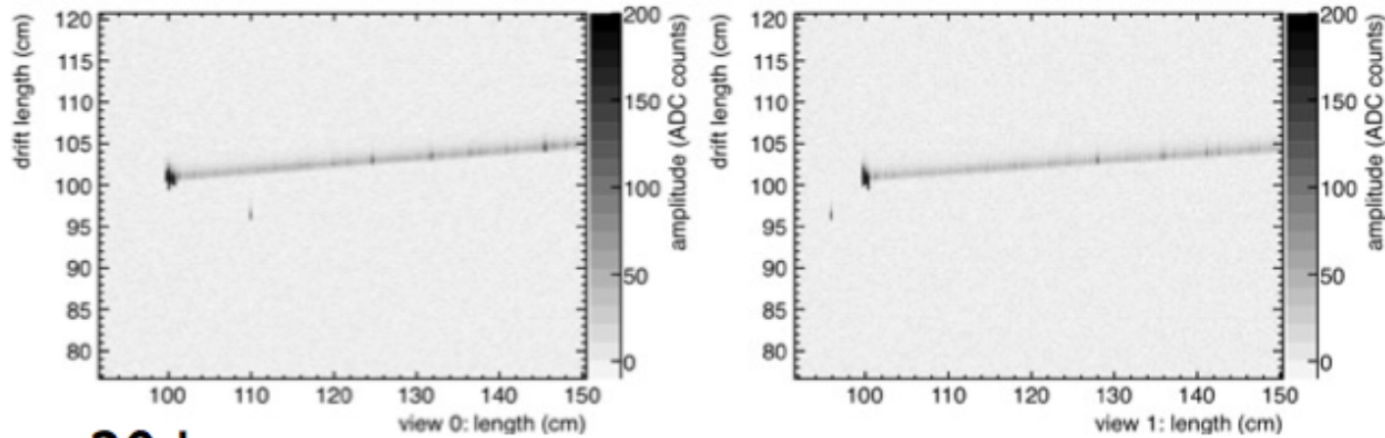
Suggestions from Jen

- GAr has longer tracks for the same momentum: lower threshold for detection
- Differential measurements easier in GAr than LAr for low-energy recoils
- Run some GENIE MC and look at a few events' MC Truth. Suggested CC 1 pi and multi-pi events.
- Try with a magnetized GAr detector. 0.5 T

Example from the LBNO ND Description Technote

E. Noah, A. Curioni, Y. Karadzhov, T. Stainer, A. Blondel

liquid Ar



Ar gas 20 bar

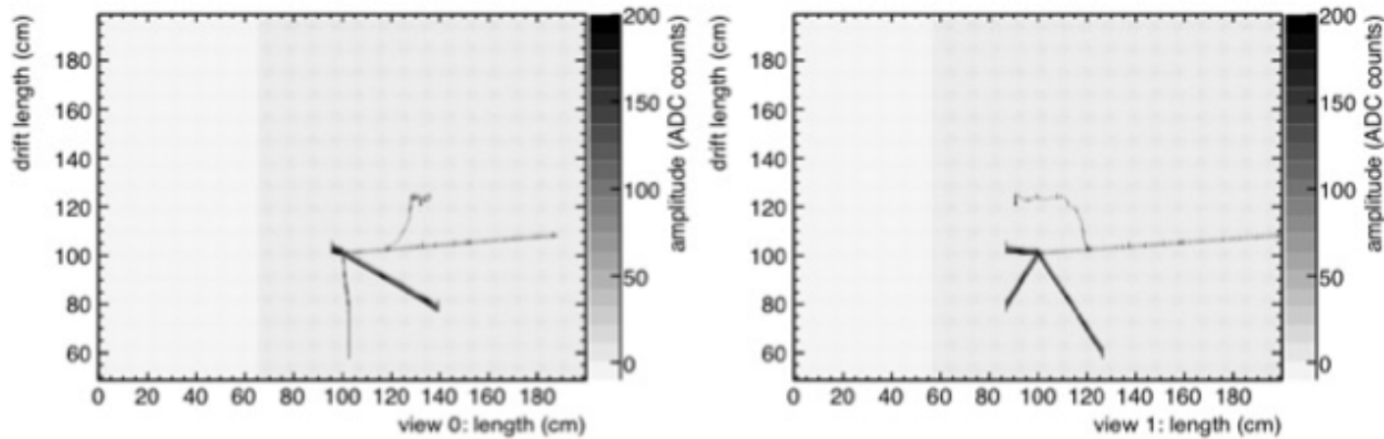


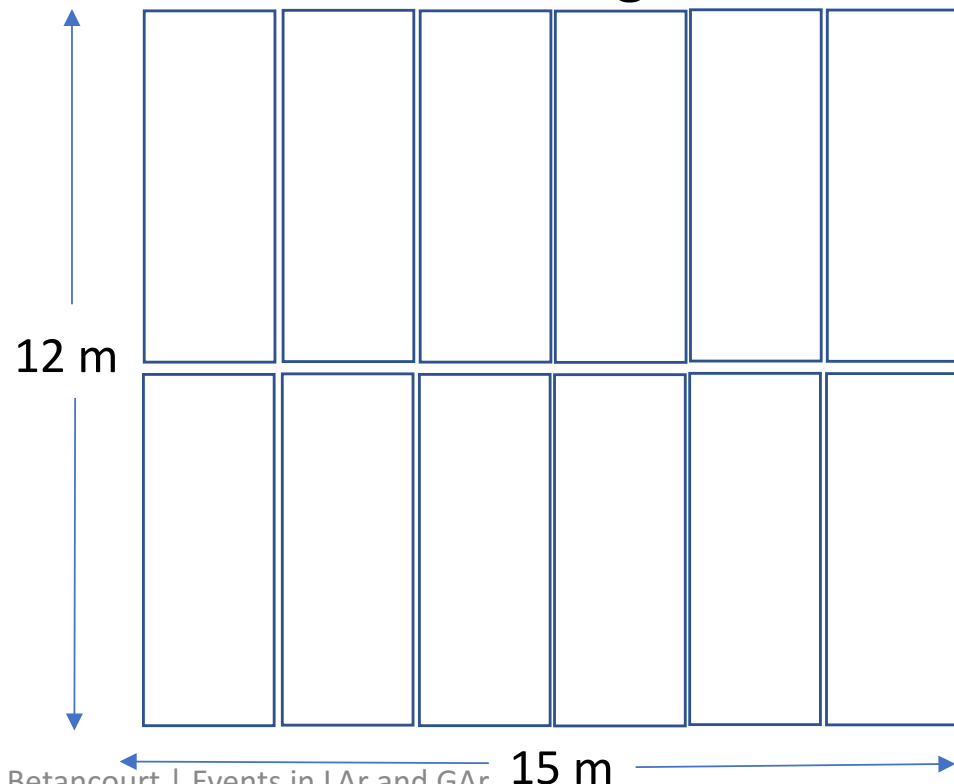
Figure 6: Comparing quasi-elastic charged current interactions in liquid and gas argon. The three protons from the interaction vertex are apparent in the GAr TPC, but cannot be resolved in the LAr.

Using LArSoft for this

- There's already a GENIE and GEANT4 interface
- Convenient geometry: 1x2x6 Far Detector Workspace.
- Too big! Each APA is 6 m high and 2.5 m wide, 2x 3.6m drift total: 7.2 m x 12 m x 15 m
- LAr with density 1.4 g/cm^3 , or GAr with 0.0178 g/cm^3

3.6 meters of active volume
on either side of the APA's

Solution to the too-big problem:
just show a subset of the event

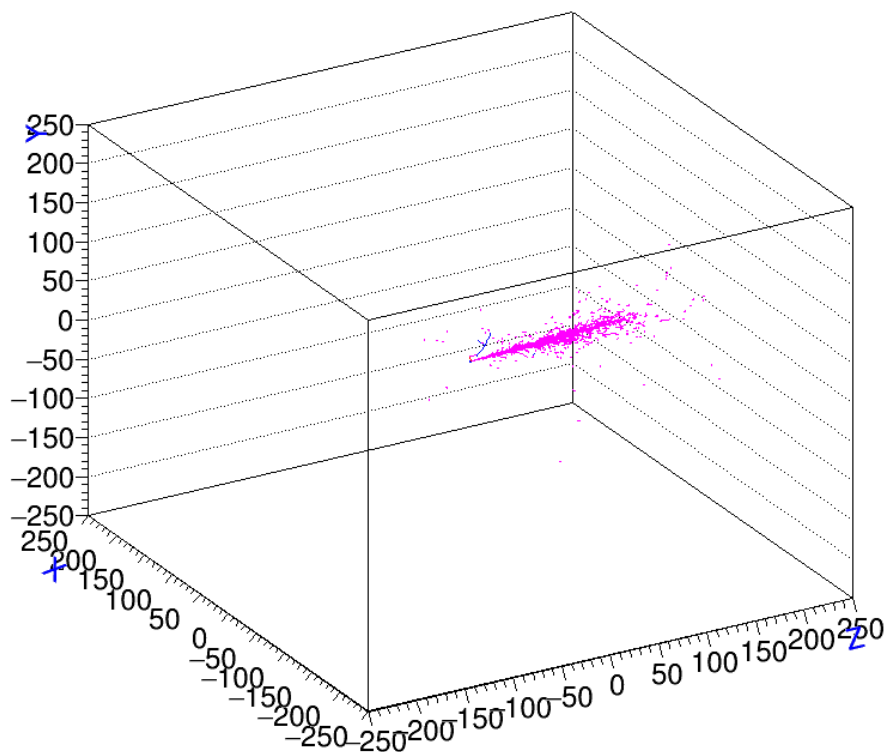


GENIE and Event Displays

- Ran GENIE with ν_e events (CC+NC) with the DUNE ND spectrum.
- Ran GEANT4 to simulate Unmagnetized LAr and GAr+magnetic field (0.5 tesla, along x)
- Used gallery to make displays of MCParticle trajectory points
- Trimmed the events to ± 250 cm in each direction from the primary vertex
- Colors:
 - Black: muons
 - Blue: protons
 - Red: charged pions
 - Magenta: electrons
 - Cyan: charged kaons
 - Green: neutrons (when shown)

First Event: ν_e CC+3p+1 charged pi

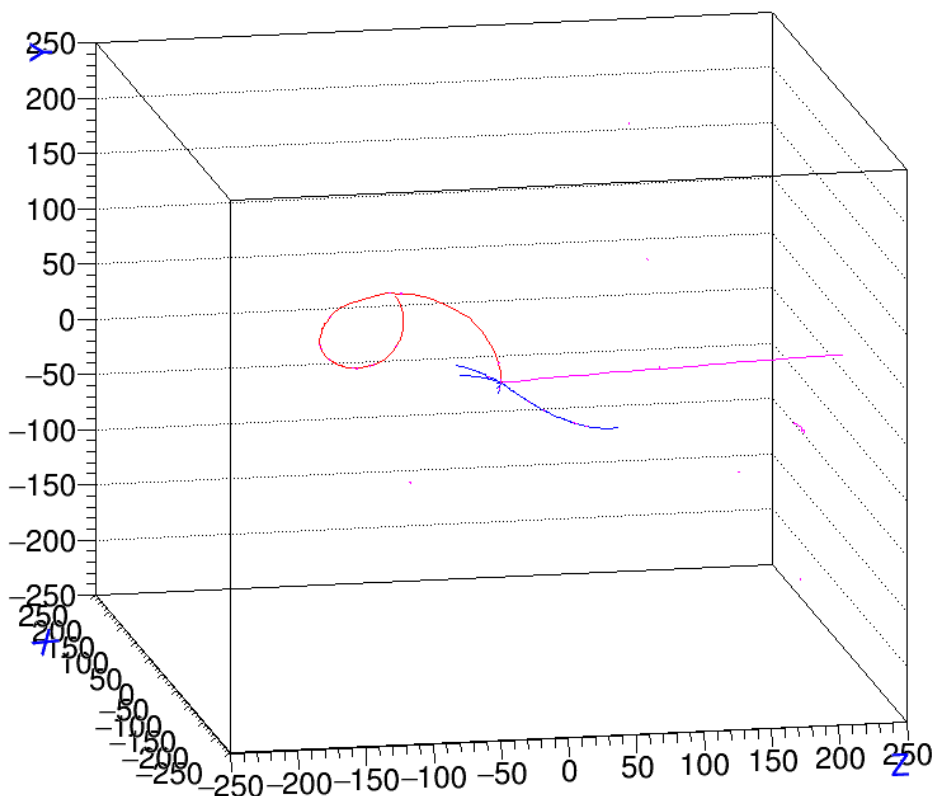
LAr



Axis scale: cm

Black: muons
Blue: protons
Red: charged pions
Magenta: electrons

GAr + 0.5 T BField



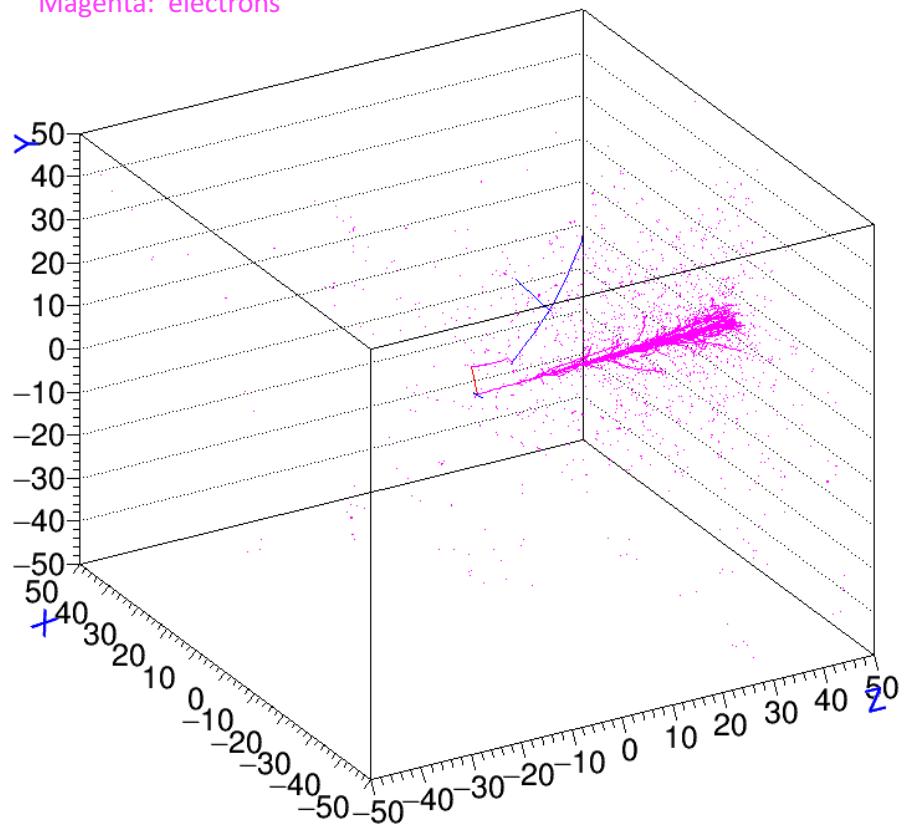
Hadronic activity more visible
in GAr. Electron not contained.

First Event: Zoom-In LAr

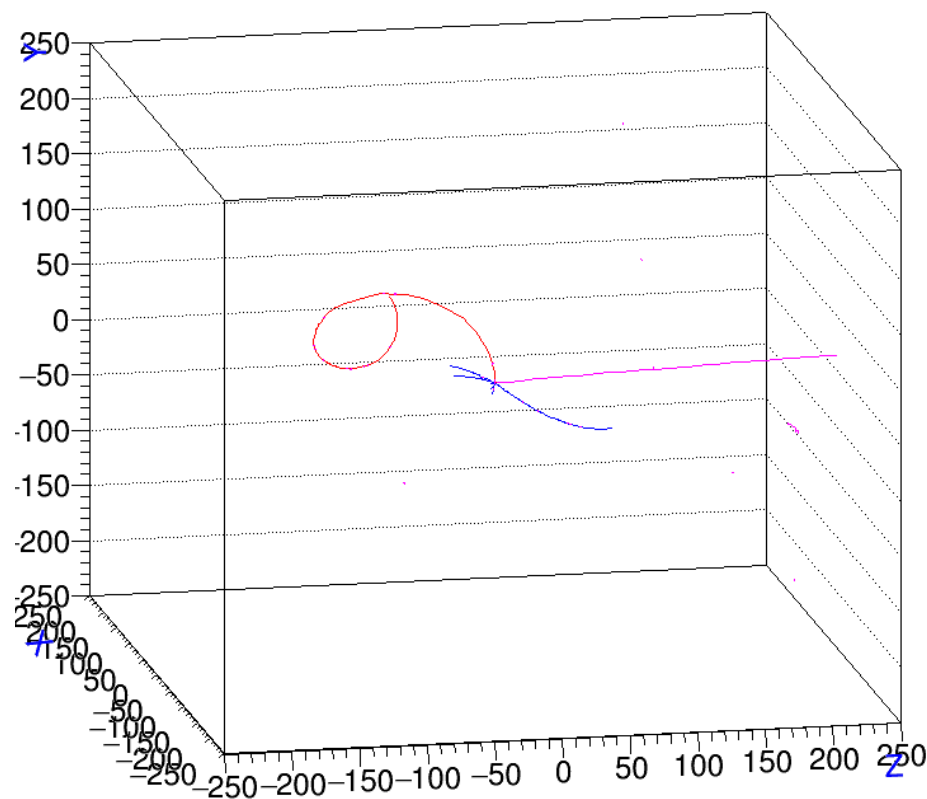
It was pointed out last time that LAr should be zoomed in a bit. Choose factor of 5

Blue: protons
Red: charged pions
Magenta: electrons

LAr



GAr + 0.5 T BField

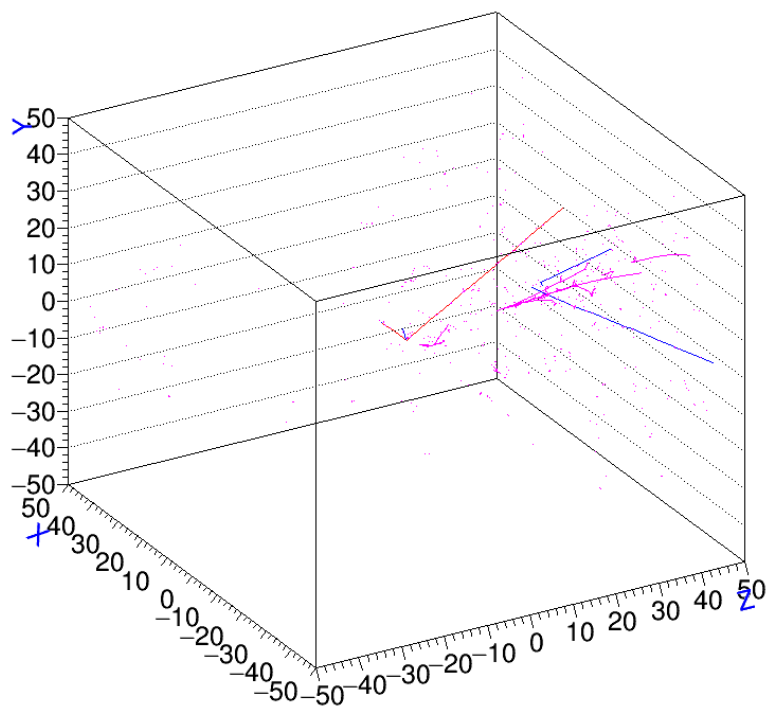


Same initial GENIE four-vectors. Extra proton(s) in LAr from a neutron scatter

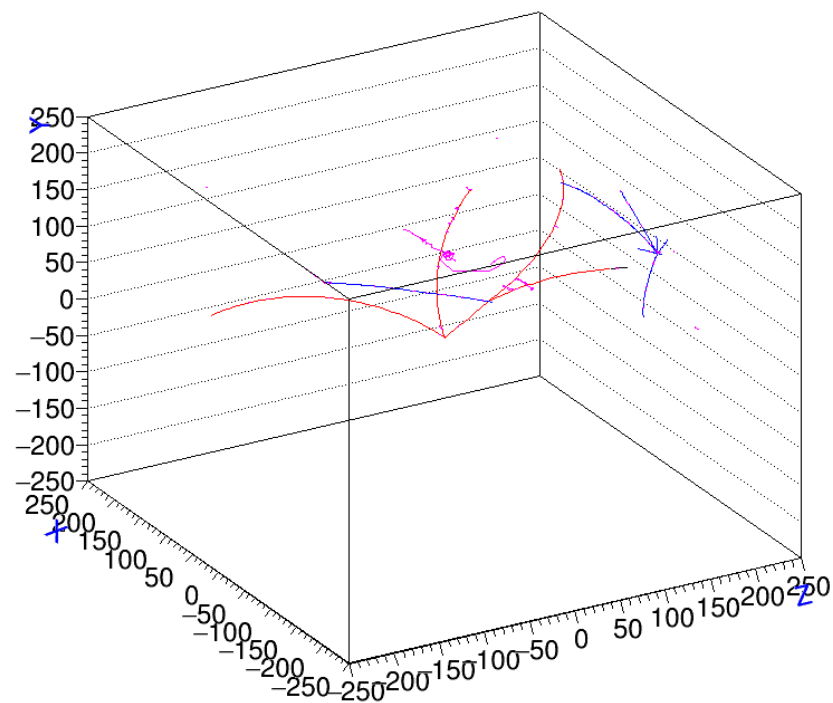
Second Event: Neutral Current

Blue: protons
Red: charged pions
Magenta: electrons

LAr



GAr + 0.5 T BField

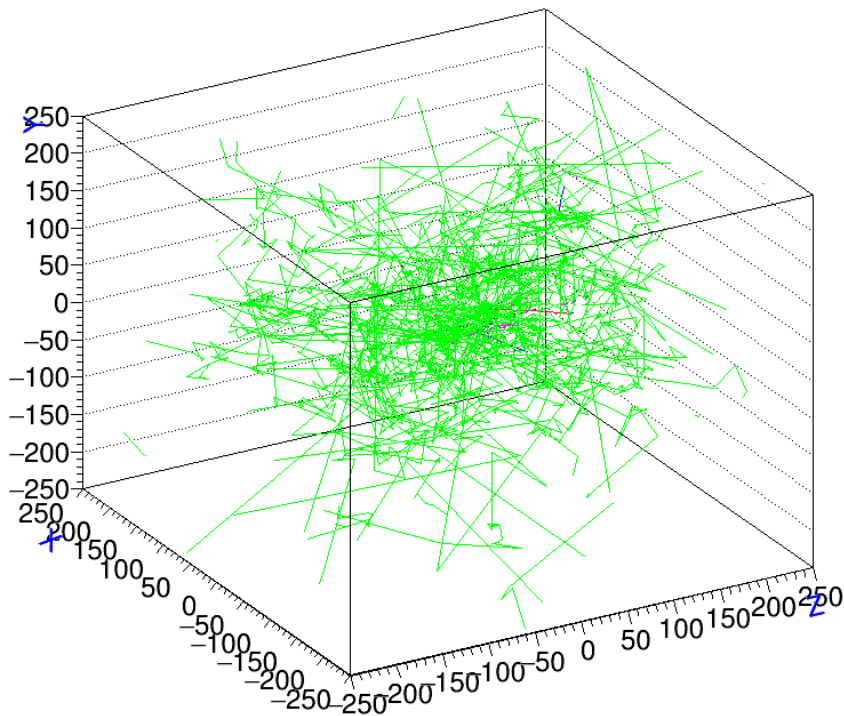


Possibly with a pizero

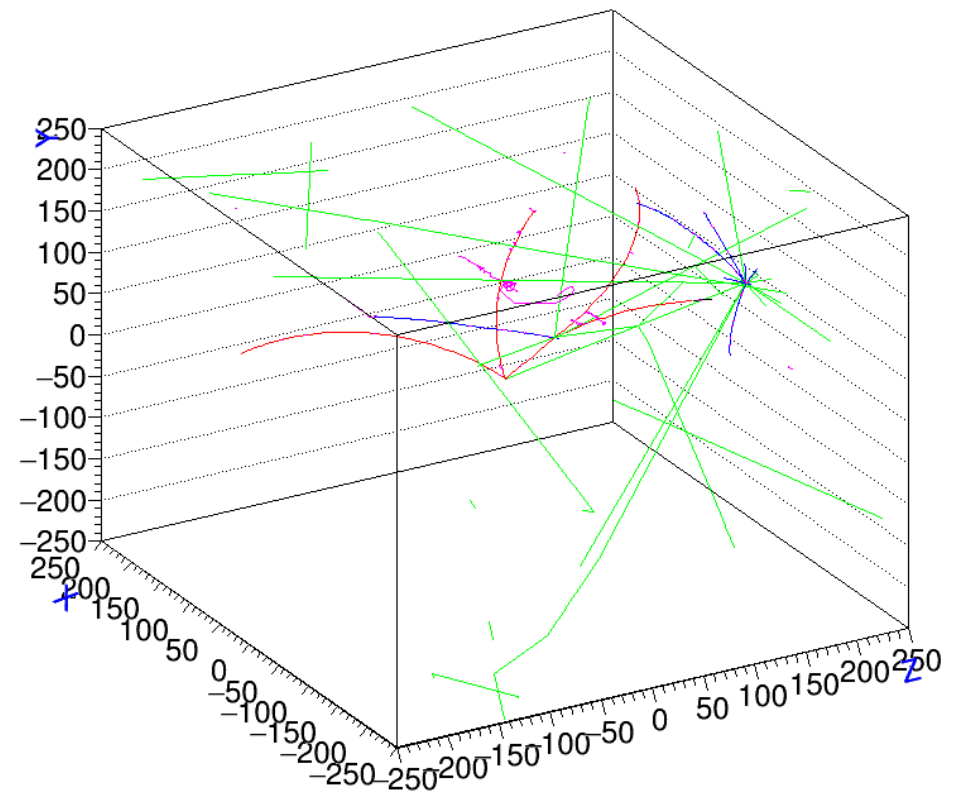
Second Event, Showing Neutrons

Blue: protons
Red: charged pions
Magenta: electrons
Green: Neutrons

LAr



GAr + 0.5 T BField



zoomed-out LAr. Zoom-in is also cluttered.

Neutrons are responsible for displaced hadronic activity in both detectors

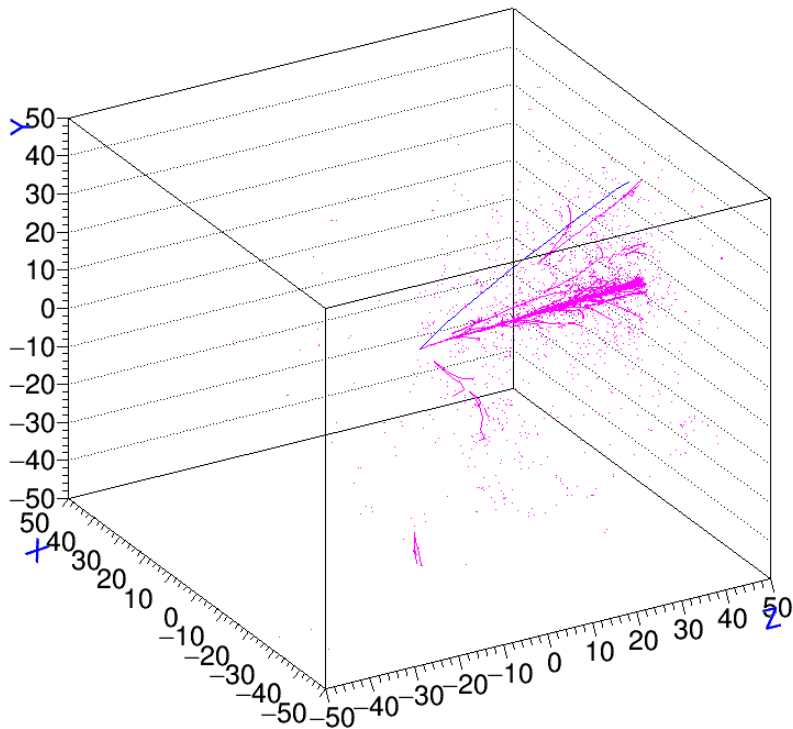
Third Event: Clean ν_e CC

Blue: protons

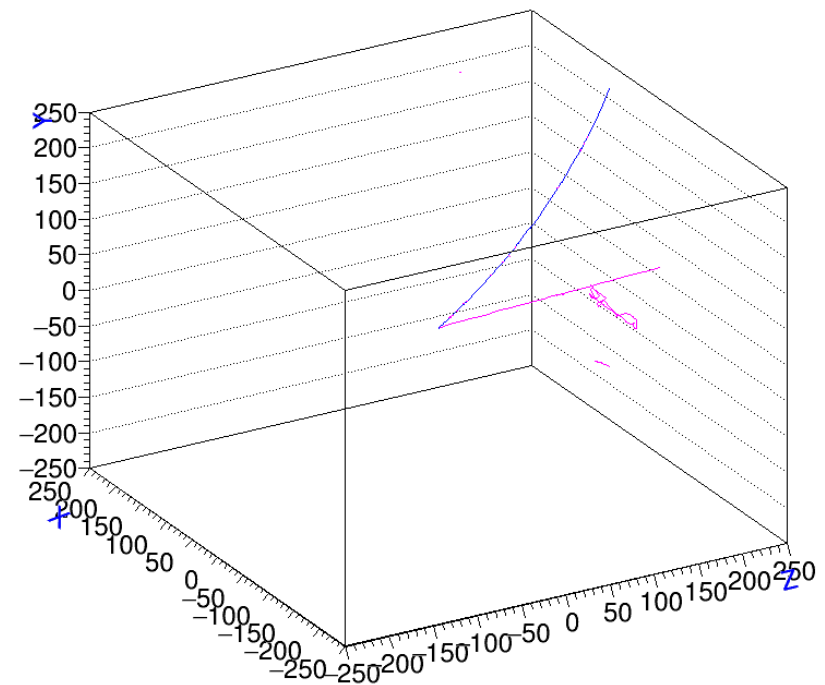
Red: charged pions

Magenta: electrons

LAr



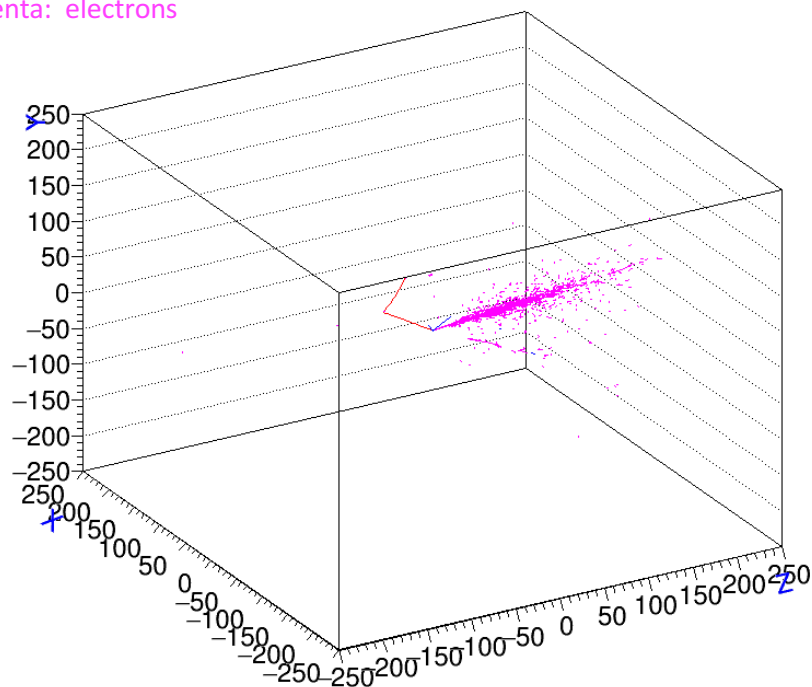
GAr + 0.5 T BField



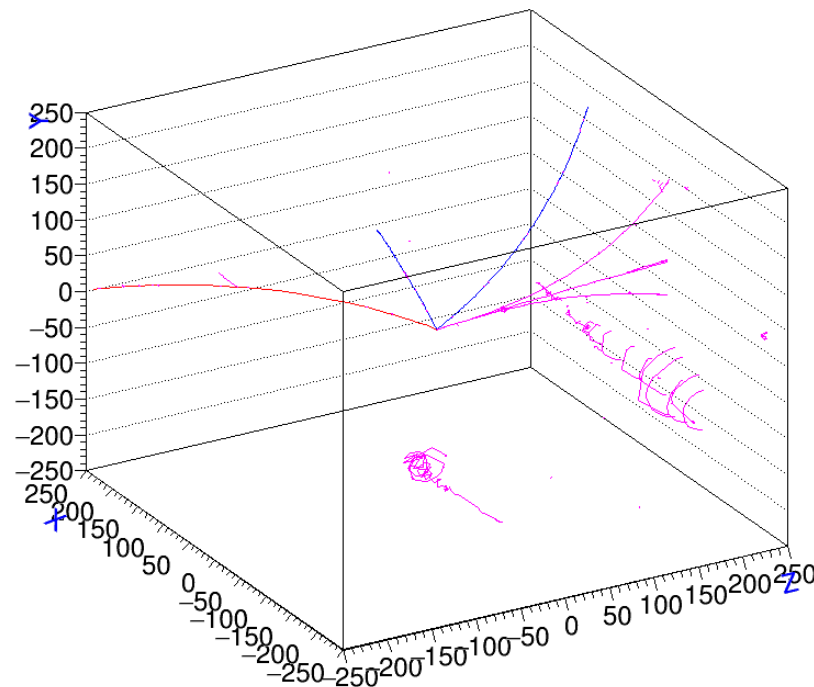
Fourth Event: "Trident" in GAr

Blue: protons
Red: charged pions
Magenta: electrons

LAr



GAr + 0.5 T BField



Even in GAr, the electron starts showering early and the sign can be ambiguous.
In colliders, we called these "Trident" events

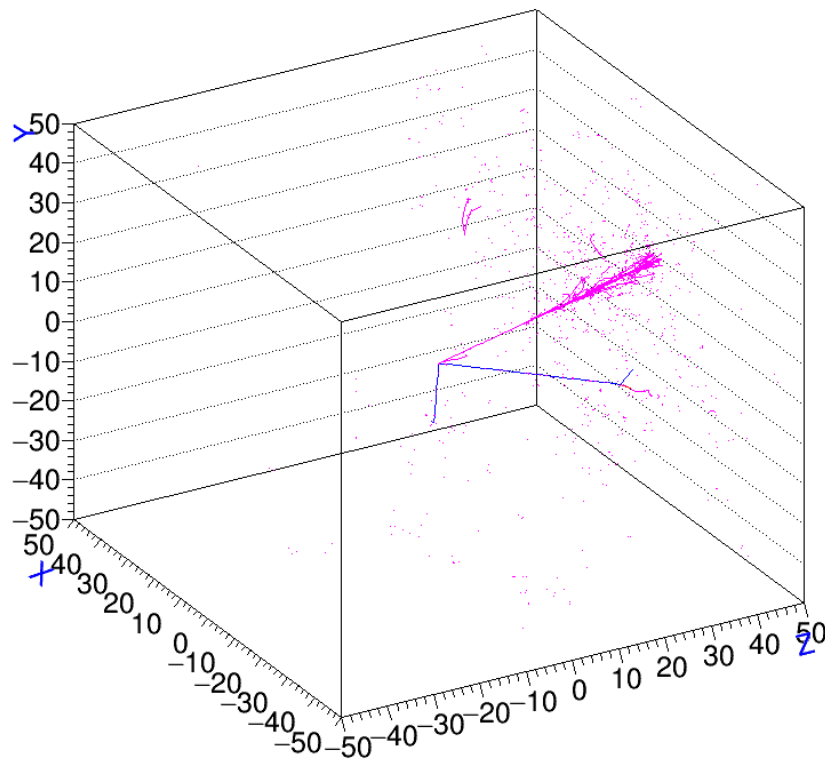
Fifth Event

Blue: protons

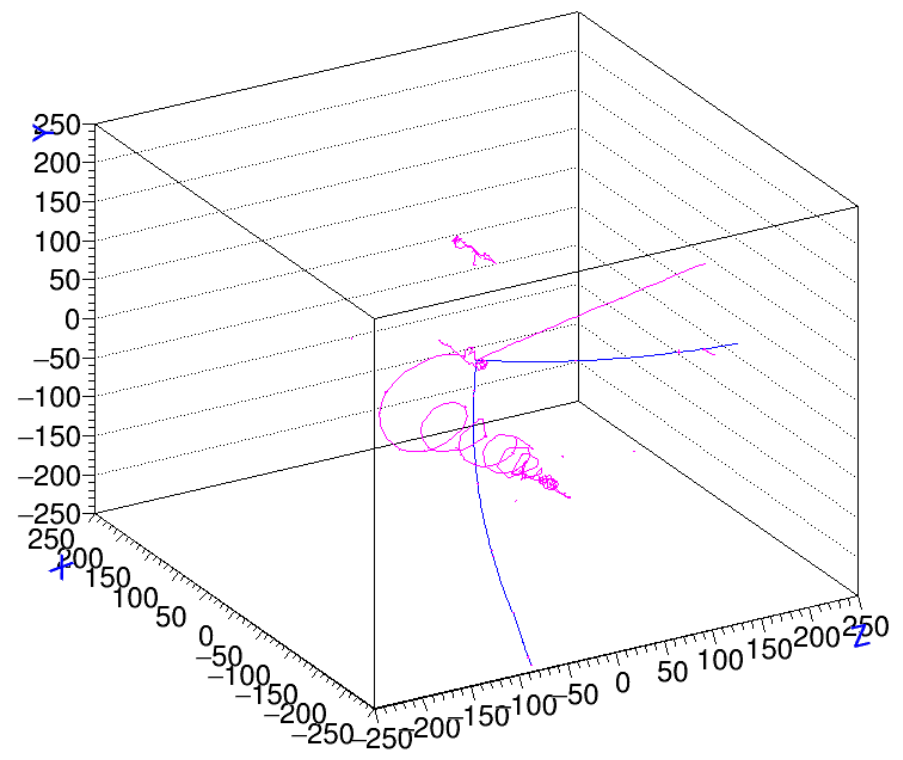
Red: charged pions

Magenta: electrons

LAr



GAr + 0.5 T BField



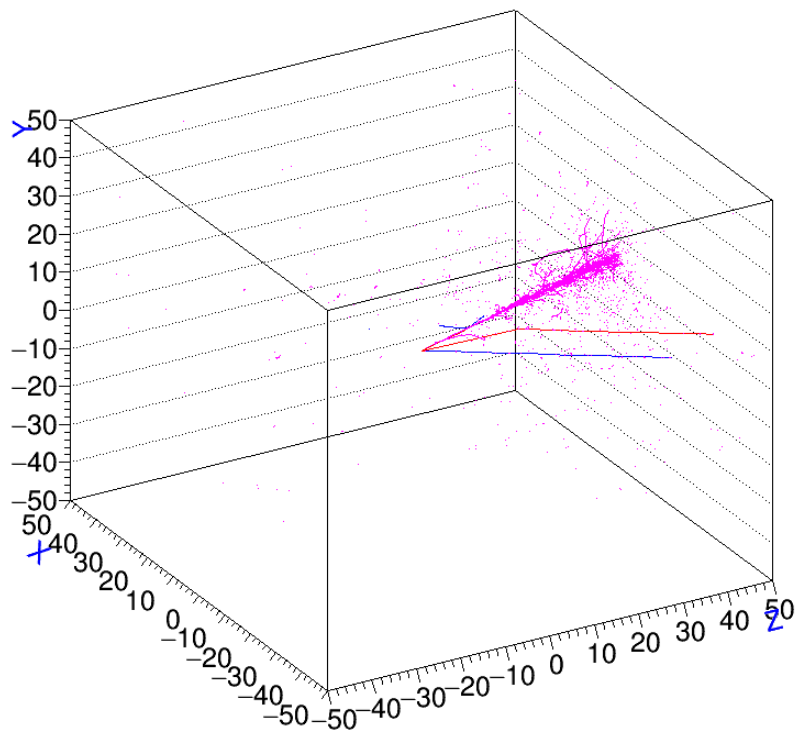
Sixth Event: Showering in GAr

Blue: protons

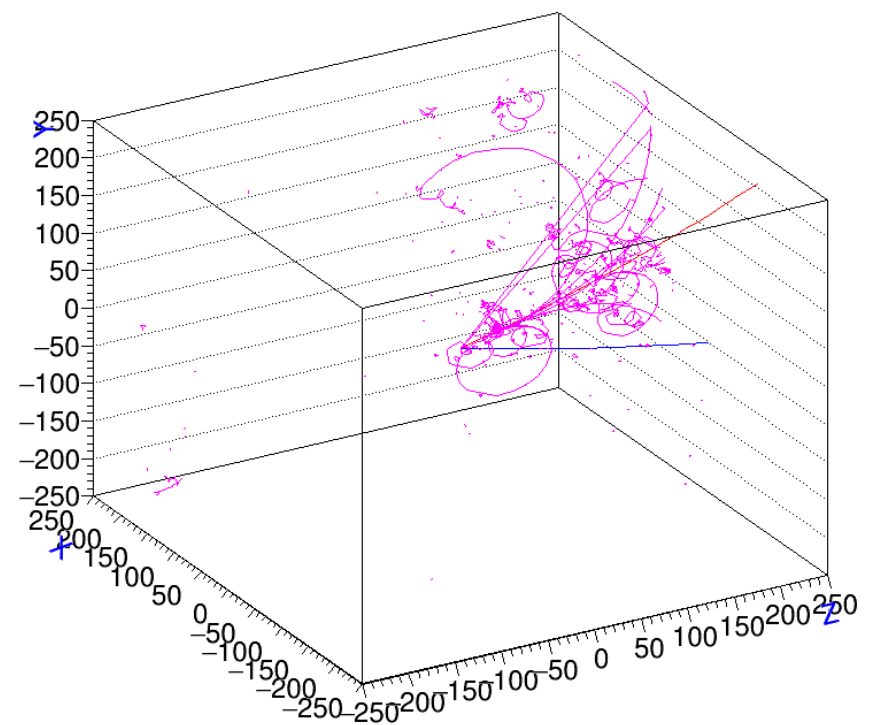
Red: charged pions

Magenta: electrons

LAr

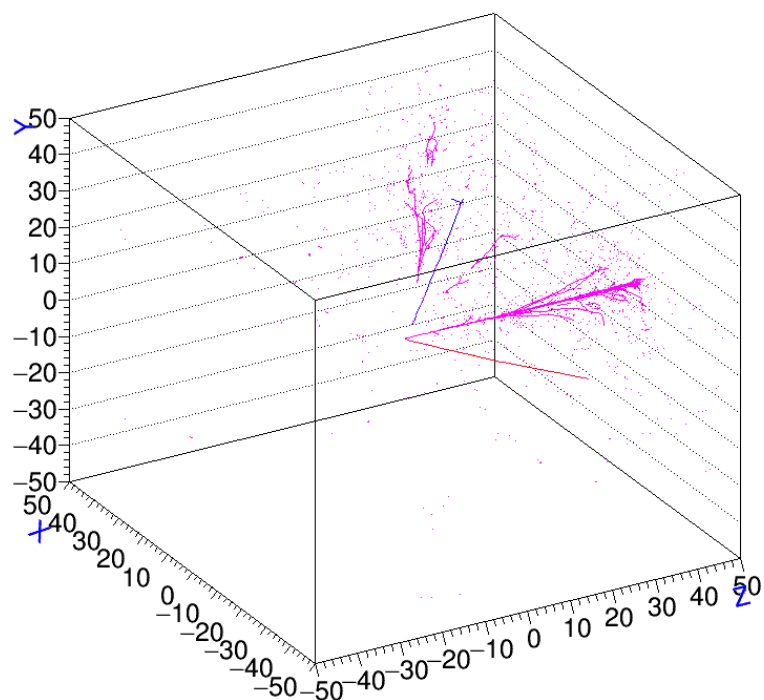


GAr + 0.5 T BField

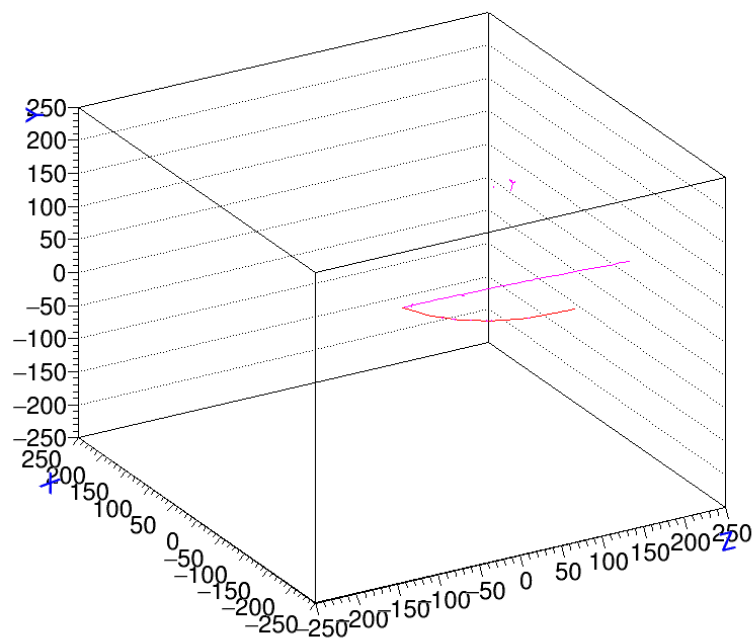


A Clean ν_e CC

LAr



GAr + 0.5 T BField

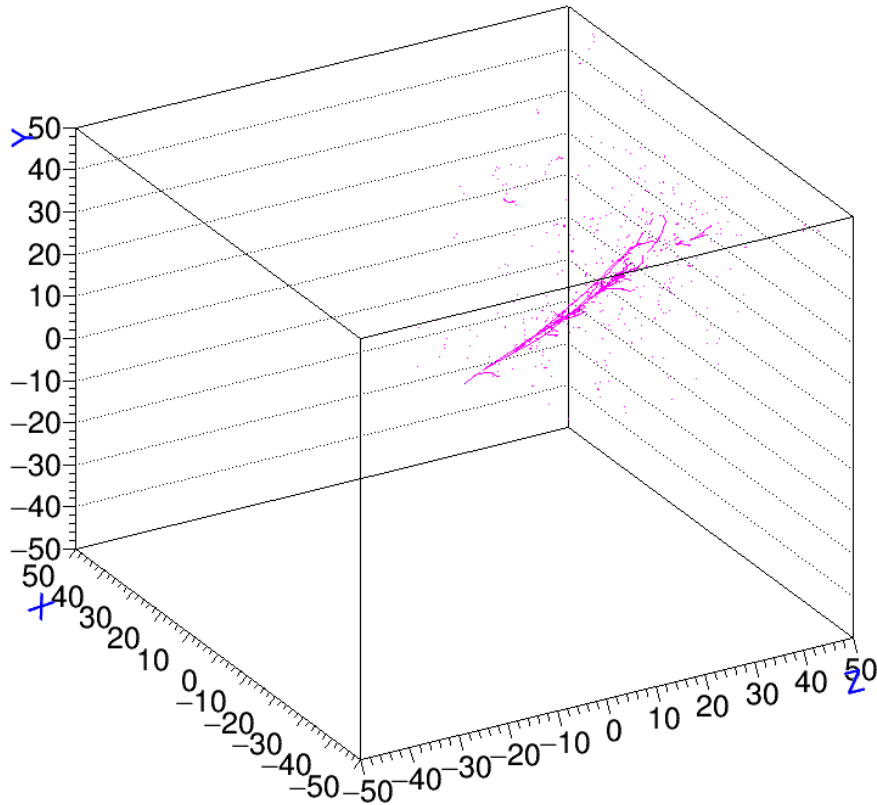


Blue: protons
Red: charged pions
Magenta: electrons

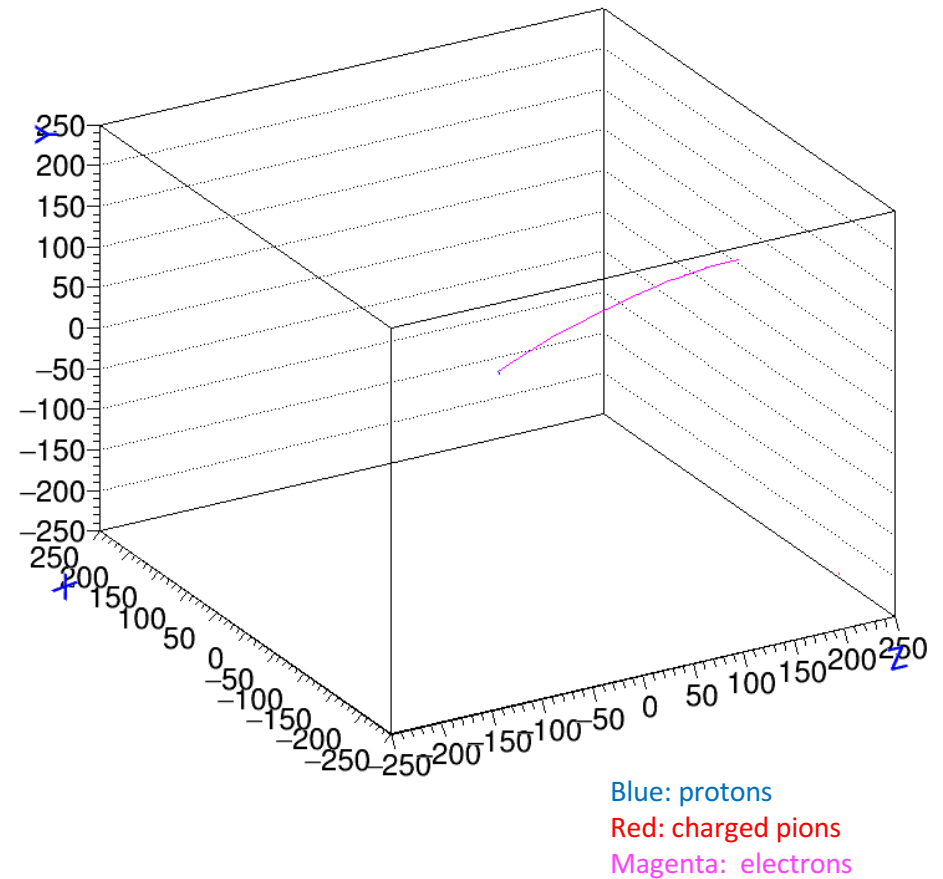
Photons from pizero decay did not convert in GAr. Need ECAL!
Also a neutron knocked off the proton in LAr but not GAr

Sometimes you only get the lepton

LAr



GAr + 0.5 T BField

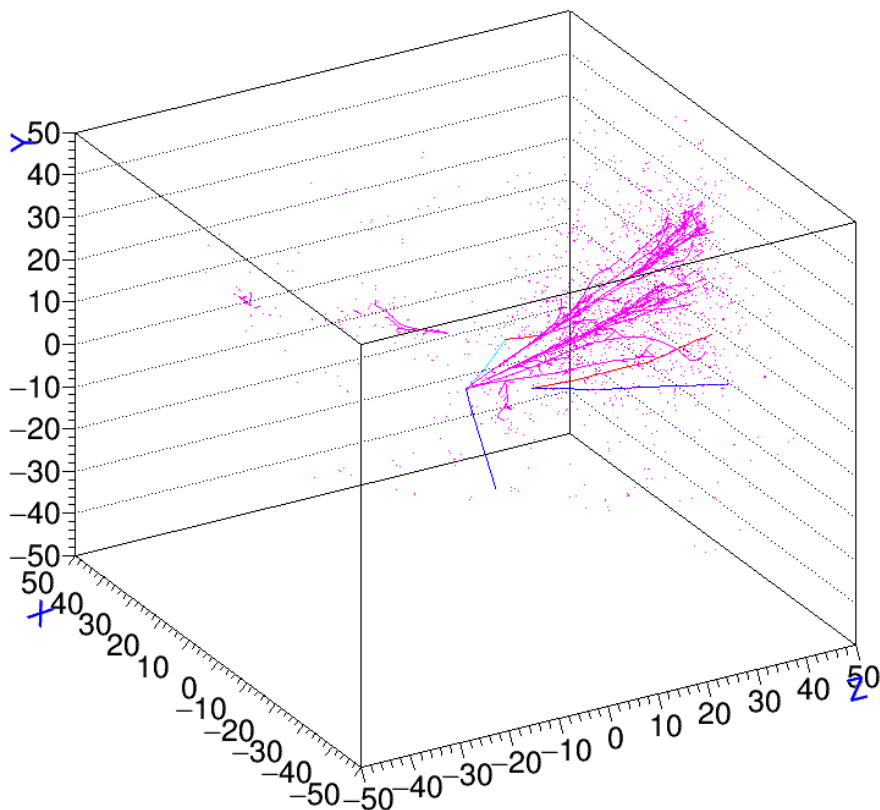


Question: This might have more NC background – photon conversion + nothing

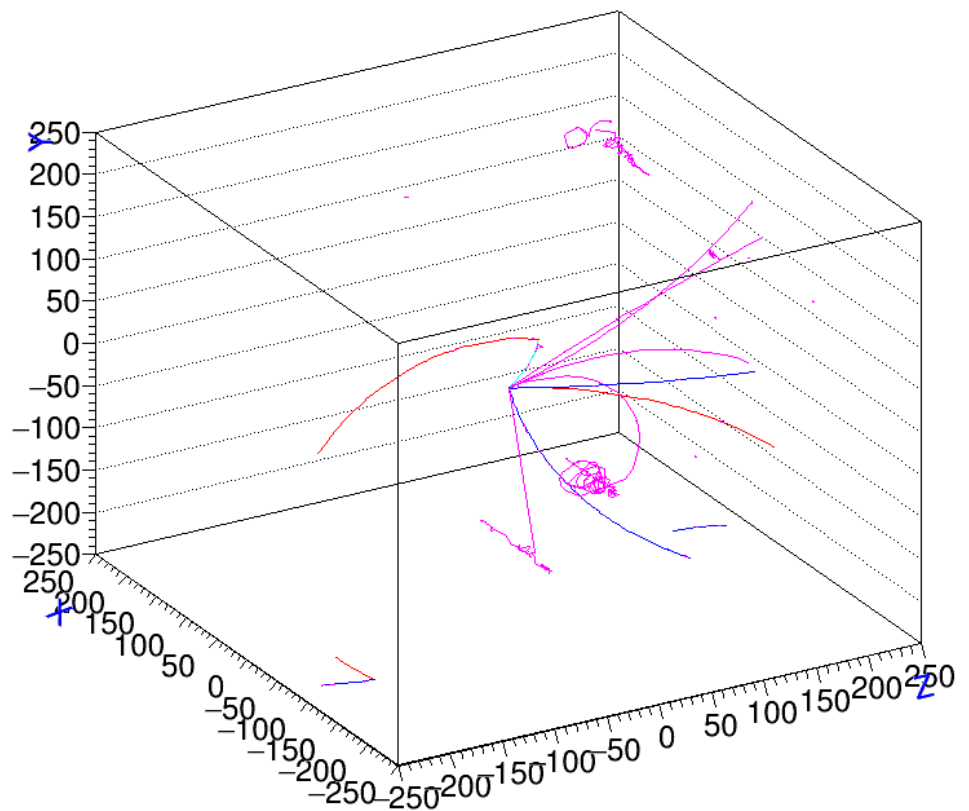
An Event with a Charged Kaon

Blue: protons
Red: charged pions
Magenta: electrons
Cyan: charged kaons

LAr

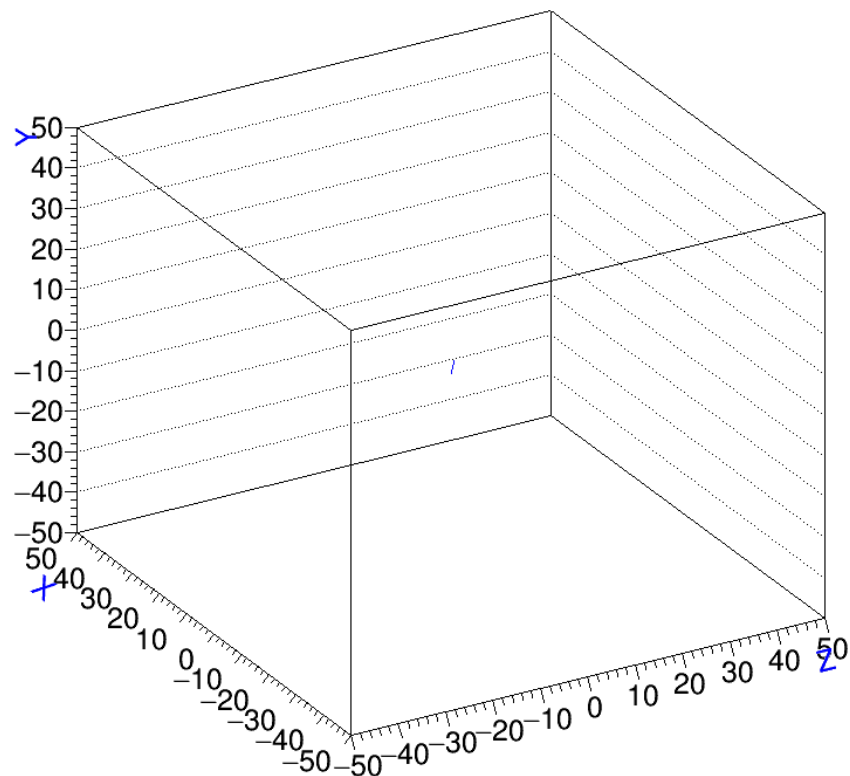


GAr + 0.5 T BField

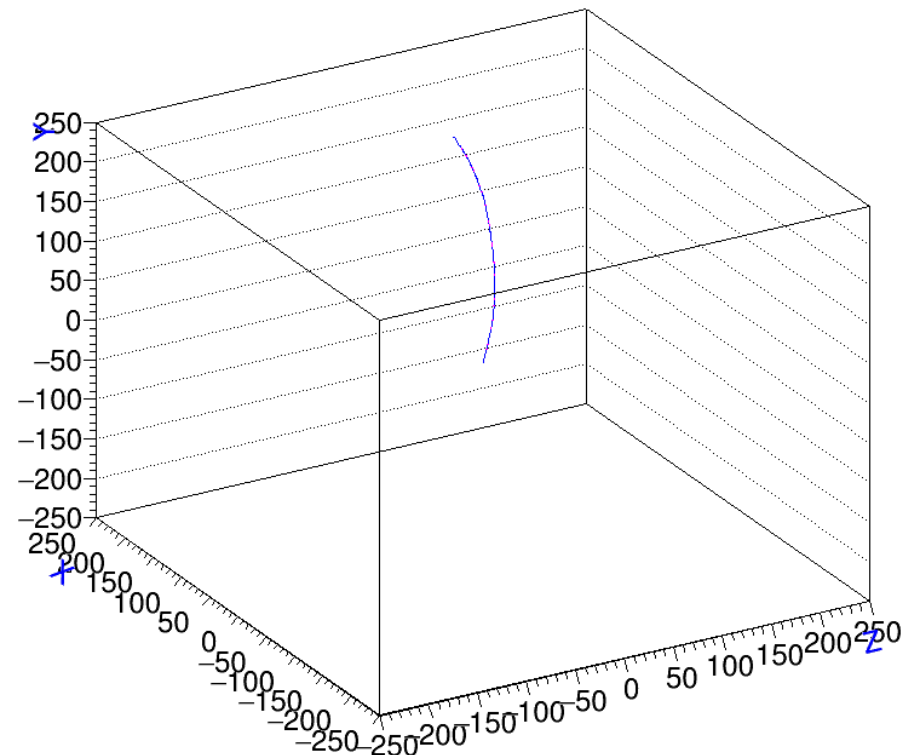


Another NC Event

LAr



GAr + 0.5 T BField



Blue: protons

Red: charged pions

Magenta: electrons

Another NC Event (in the ν_μ sample) with Lots of Hadronic Activity

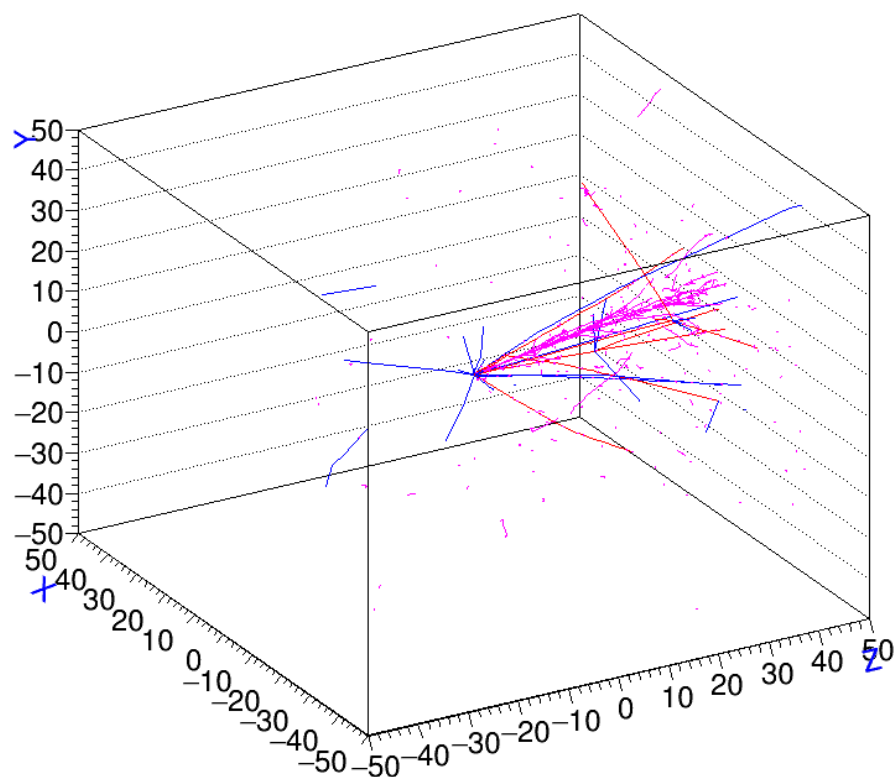
Black: muons

Blue: protons

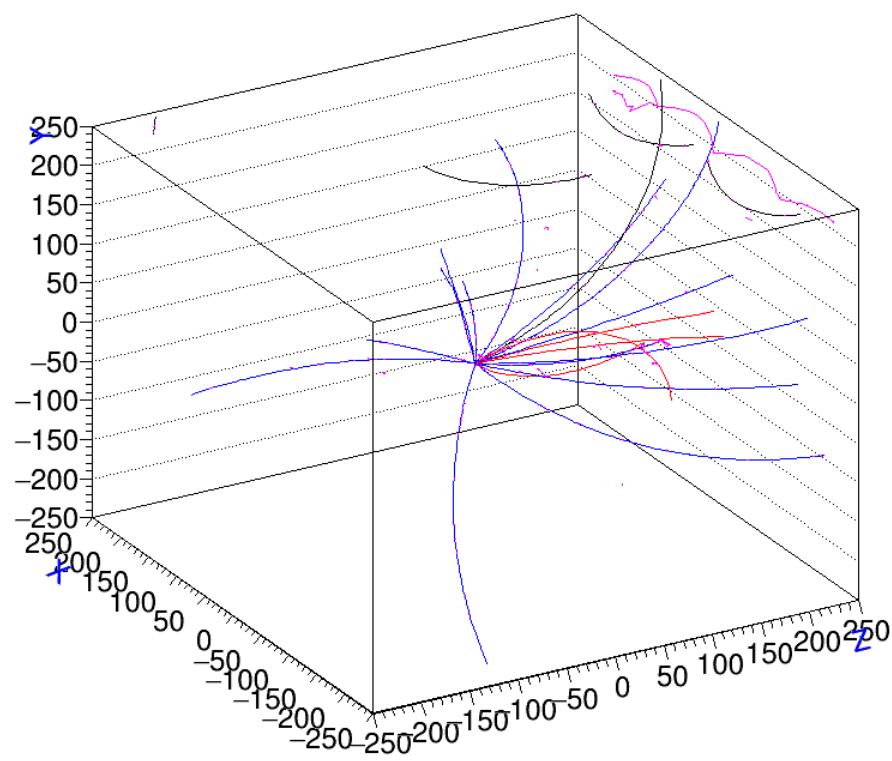
Red: charged pions

Magenta: electrons

LAr



GAr + 0.5 T BField



Muons from Pion Decay in GAr

Black: muons

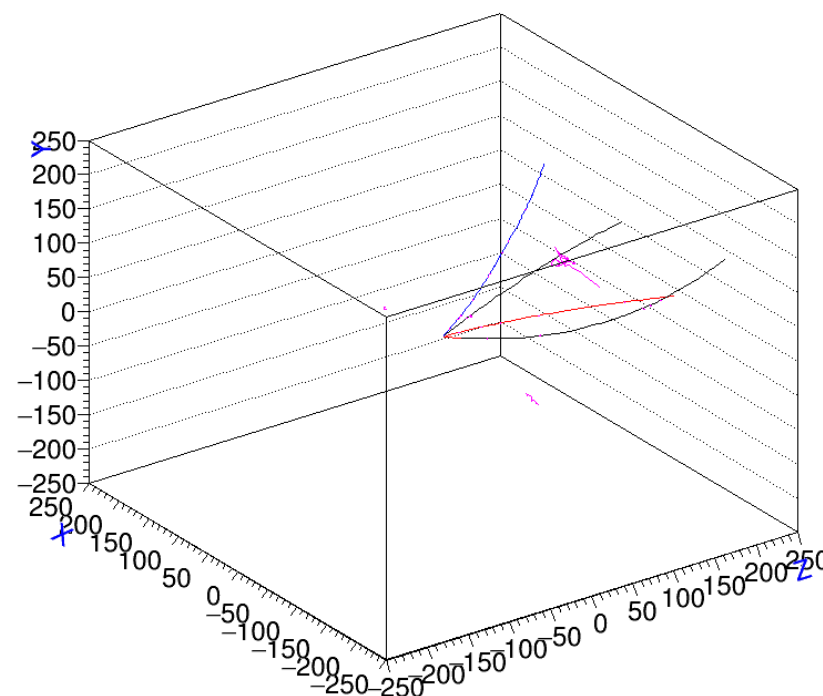
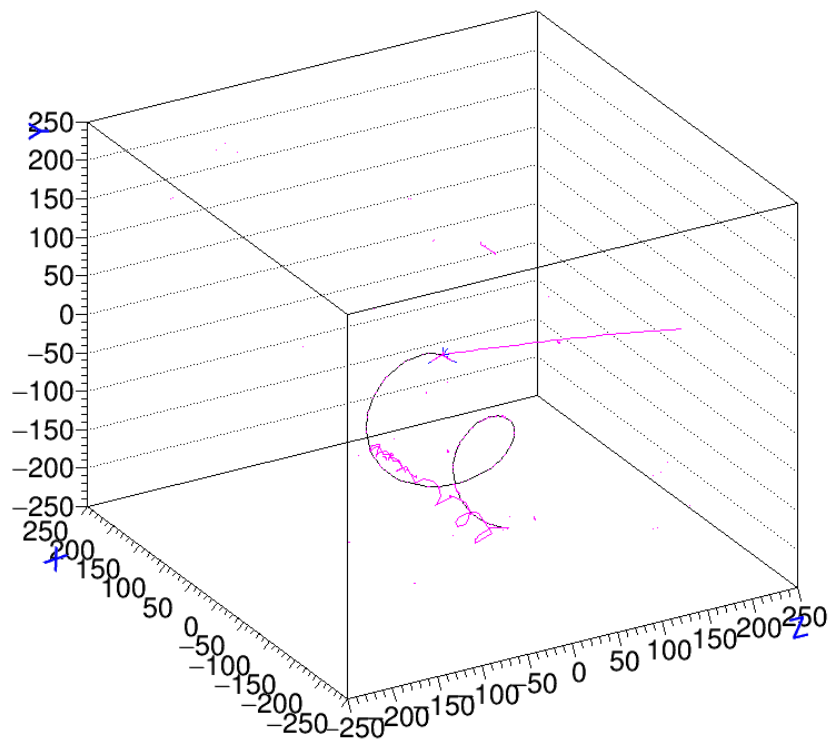
Blue: protons

Red: charged pions

Magenta: electrons

GAr + 0.5 T BField

GAr + 0.5 T BField



ν_e CC event with a muon and a Michel e.
Probably pion decay at rest near the vertex

ν_μ CC event with two muons! You can see
the pion track before it decays into
one of them

Comments

- Track lengths are great for low-energy particles in GAr compared with LAr
- With a drift velocity of 5 cm/ μ s, Michel electrons will appear displaced from a stopping muon by an average of 10 cm.
- Separation of μ^\pm from π^\pm over the momentum range of interest will require muon chambers outside of the GAr
- ECAL is necessary for π^0 measurement, and help with showering electrons. GArTPC+ECAL will make independent measurements of rates of events with π^0 s in them.
- Containment not expected in 5 m cube of GAr
- Very low-energy particles may turn around and go back in the B field before hitting the ECAL
- Low-energy particles spiral around magnetic field lines. Pileup of signals on just a few pads? Saturation? They spread out in time though.
- Fewer neutrons will interact in GAr – calorimeter can help?