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ArgonCube

# ProtoDUNE-ND: Detector Physics Studies

Bi-Weekly Near Detector Meeting
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# The ProtoDUNE-ND Concept

- ArgonCube 2x2 Demonstrator on-axis in NuMI medium energy neutrino beam at Fermilab (MINOS-ND hall)
- Perform detector physics studies that will
  - inform the final DUNE ND design choices
  - help developing reconstruction tools in preparation for DUNE
- Possibility to reconfigure ProtoDUNE-ND in order to accommodate any future prototypes of other DUNE ND subdetectors, and test the DUNE-PRISM concept
- Details in [DUNE-doc-12571-v1]

# Stand-alone 2x2 Detector Physics Studies

- Bern (February to March 2019):
  - LAr purity maintenance
  - extraction and re-insertion of modules
  - data is triggering on cosmic muons
- In NuMI at Fermilab (2020):
  - demonstrate how well ArgonCube performs in a high multiplicity environment
  - combining light and charge signals
  - fast neutron identification
  - reconstruction in a modular environment
  - desirable to include and test movable cryogenic system (DUNE-PRISM)

# Stand-alone 2x2 Simulation

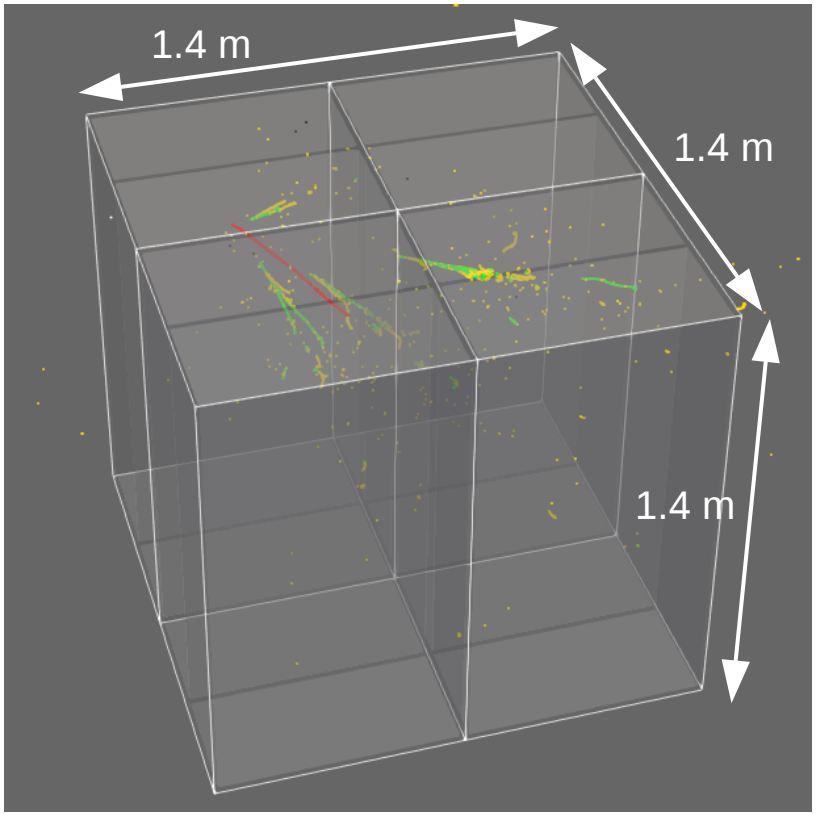
Simulations in order to check feasibility of these studies:

- High statistics GENIE Monte Carlo samples

  → compare basic properties of neutrino interactions in LBNF and NuMI ME beamlines

- GEANT4 LAr simulation based on ArgonBox* (2x2 geometry is not simulated)

  → basic understanding of event shape and containment in 2x2



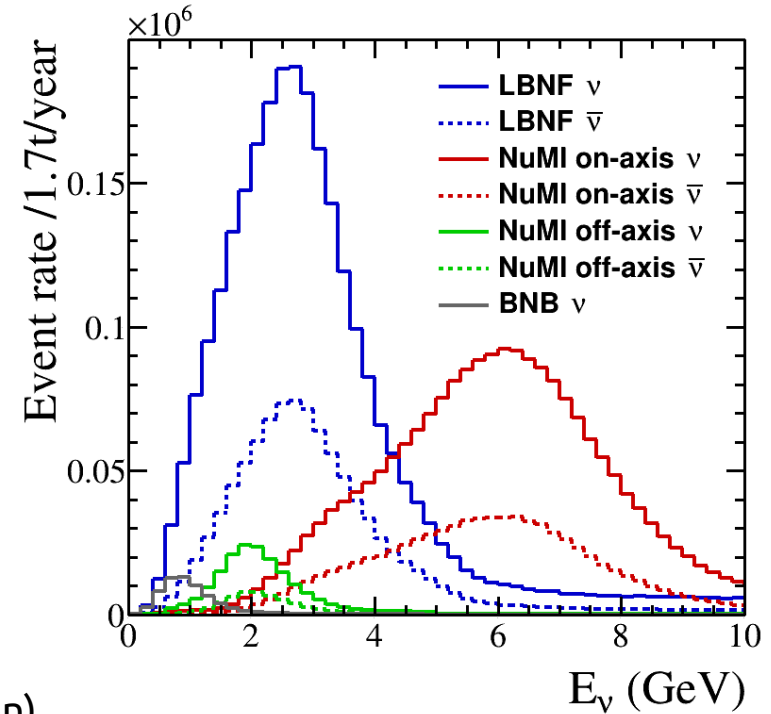

*https://github.com/dadwyer/argon_box

# Neutrino Flux Study

Expected yearly interaction rates in the ArgonCube 2x2 Demonstrator produced with GENIE*:

→ On-axis NuMI medium-energy beam provides a rate close to that of the future LBNF beamline

→ MINOS-ND hall is the ideal location for this prototype




*(v2.12.10 with “ValenciaQEBergerSehgalCOHRES” configuration)

# NuMI ME vs. LBNF Neutrino Beamline

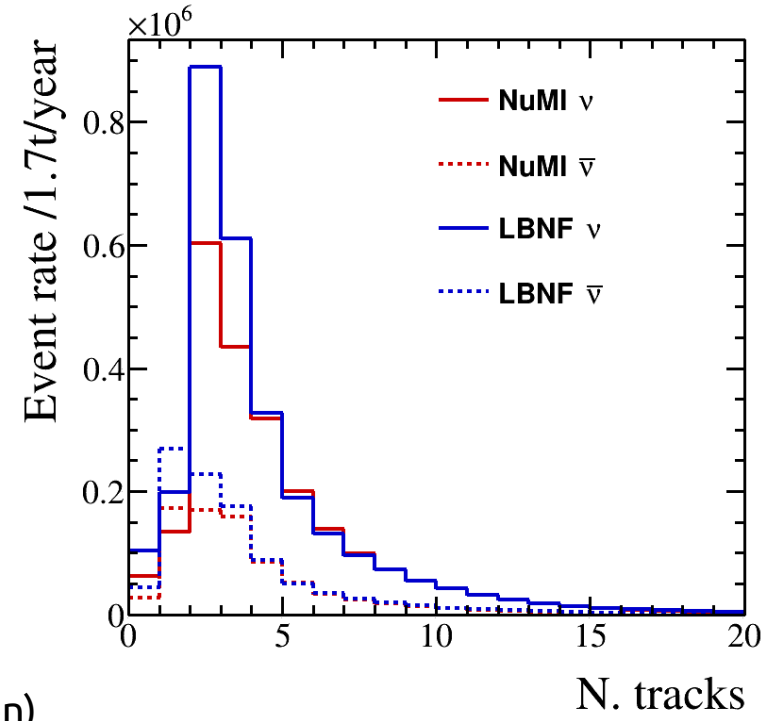
Expected yearly rates of minimum and highly ionizing particles in the ArgonCube 2x2 Demonstrator produced with GENIE*:

- Track multiplicities are similar

  → scale of reconstruction problem is similar

- Energy distributions of all particles are slightly broader for the NuMI ME flux

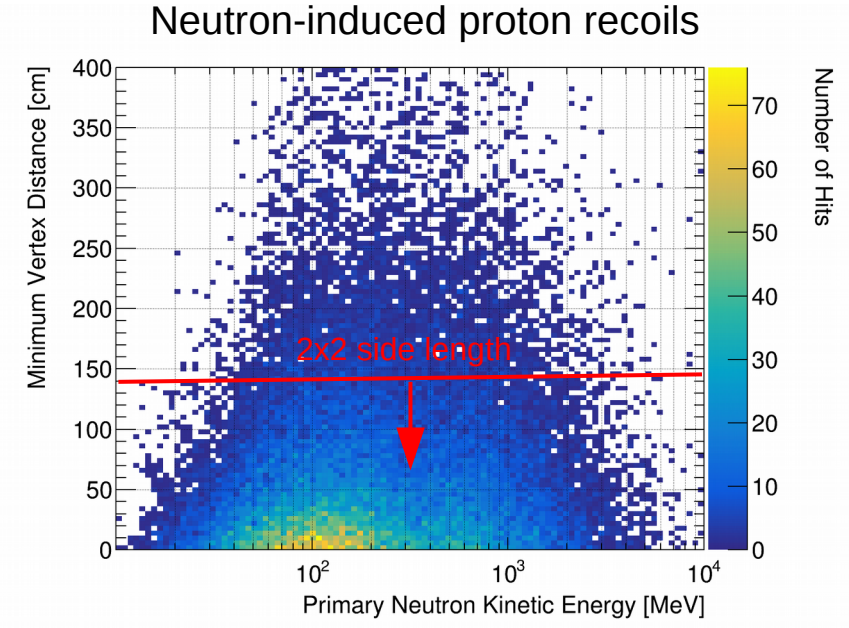
  → significant number of events with kinematics typical for LBNF




*(v2.12.10 with "ValenciaQEBergerSehgalCOHRES" configuration)

# Fast Neutron Identification

- Fast neutrons may carry away a significant fraction of the neutrino energy
  - Neutrino oscillations are a function of neutrino energy
- Neutron-induced recoils show up as detached energy deposits
- Investigate how well charge and light signals can be combined




Many neutron-induced proton recoils will be contained within the 2x2 Demonstrator.

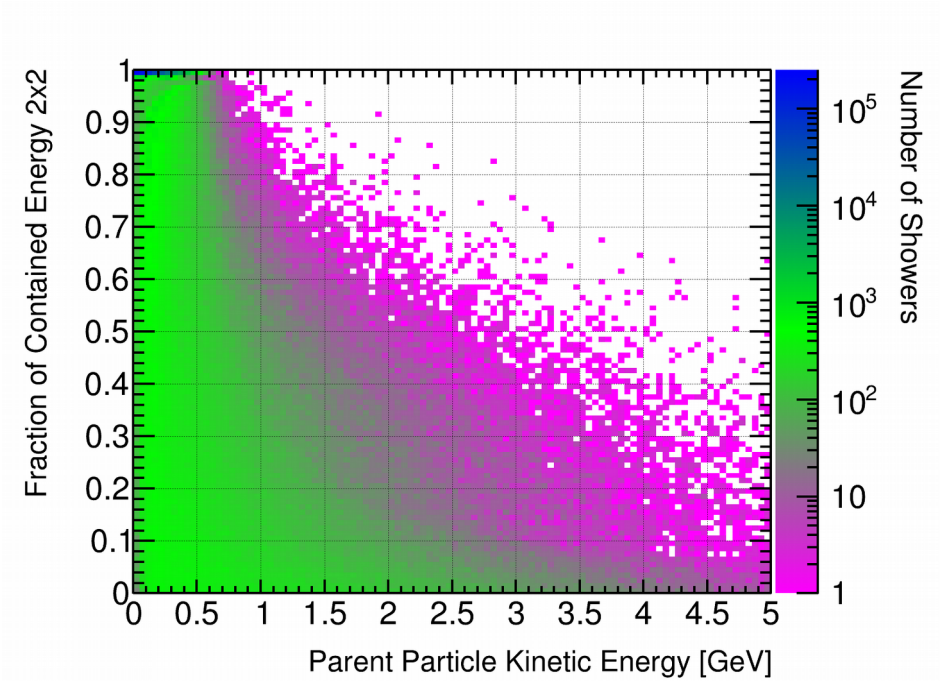
# Track Matching Efficiencies Across Modules

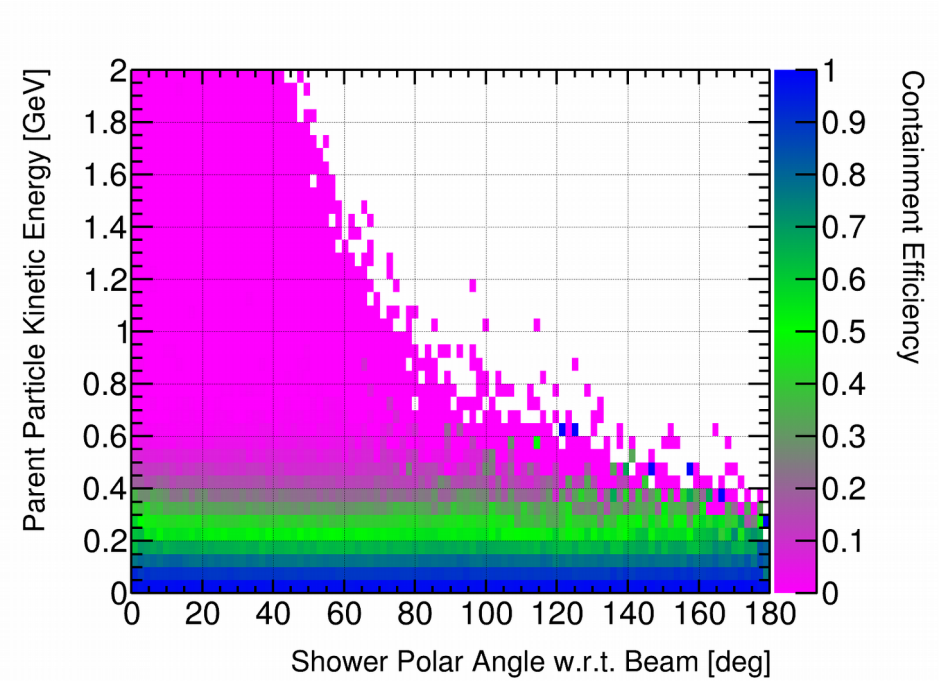
- Reconstruction performance given the module walls will need to be carried out
- More complicated for EM or hadronic showers which cross modules
- Contained samples provide the opportunity to look at the energy response of ArgonCube 2x2 Demonstrator

→ $\pi^0 \rightarrow \gamma\gamma$: if both photons are contained, this provides a measure of EM shower containment

# Shower Containment Study: Protons

Proton-induced tracks/showers:

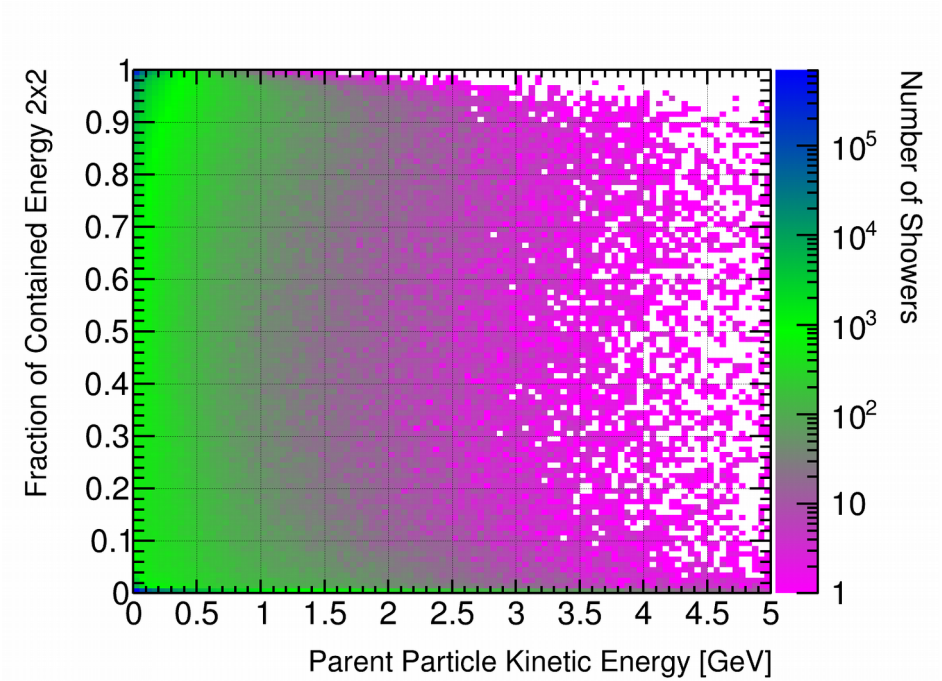


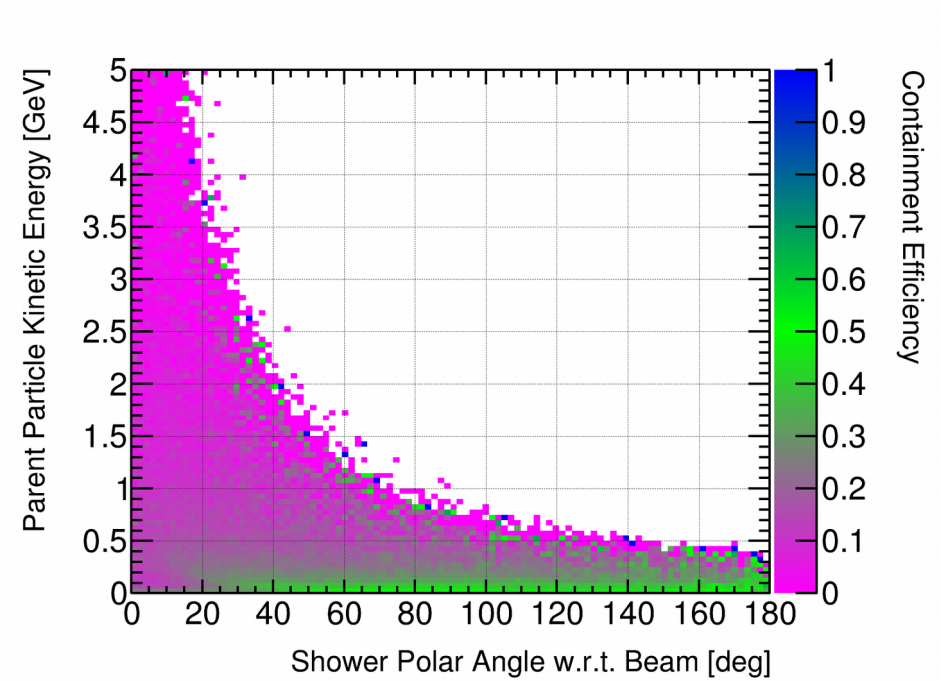




If more than 90% of energy is deposited within the 2x2 active volume, it is classed as contained.

# Shower Containment Study: EM Showers

EM showers:

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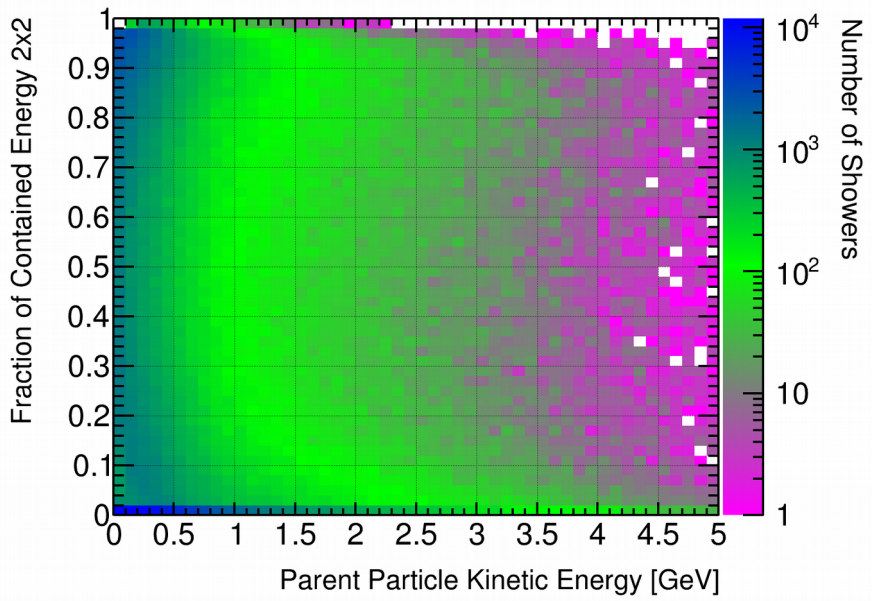
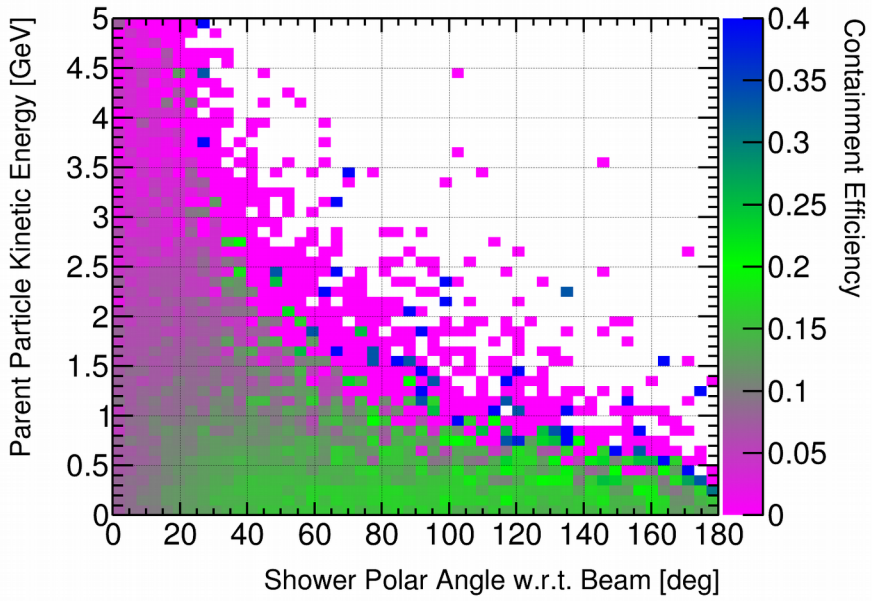
# Shower Containment Study: $\pi^0$ Showers

Attempt to reconstruct the invariant mass peak of the $\pi^0$ from $\pi^0 \rightarrow \gamma\gamma$ provides a measurement of the EM shower resolution:

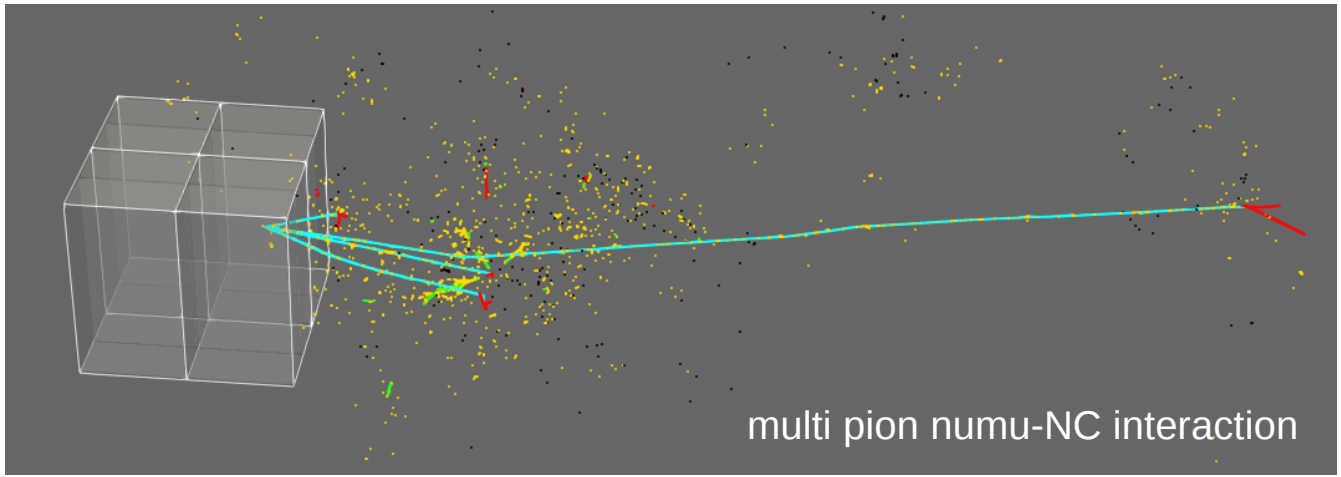



If more than 90% of energy is deposited within the 2x2 active volume, it is classed as contained.

# Incorporating other Detector Prototypes

- Many events will not be contained in the stand-alone 2x2 Demonstrator:




$\pi^{\pm}$ : blue
$\mu^{\pm}$ : purple
$e^{+}$ : green
e- : yellow
Proton : red
Recoiling nuclei : black

- In CC-interactions, the muon will be uncontained in most of the events
- Additional and extended detector physics studies would be possible, if additional subdetector prototypes are introduced in ProtoDUNE-ND (e.g. 3DST, HPgTPC)