2x2 Chicago Meeting

March 5, 2024

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Agenda

1. Paper Update
2. NEUTRINO 2024 Poster Abstract Submissions from UChicago
3. Update on impact of dead space between modules
4. Update on physics advantages of 3D reconstruction

2x2 Paper Update

Link to Overleaf Draft: https://www.overleaf.com/8458358216drvhjgctvqpr#7b24bd

Status:

- General Structure Forming
- The detailed technical paper proposed by Callum and James was not approved by consortium leadership
  - May be others preparing a first (longer) physics paper instead?

To Do:

- Make plan for plots to include in this “first events” paper
  - We will have to go through a full collaboration review, so including anything potentially controversial may delay paper
  - Is there anything “non-controversial” enough to include other than event displays?
  - What needs to be done to prepare an event display which can be used in the paper?

UChicago 2x2 Posters at NEUTRINO 2024

We're submitting poster abstracts to NEUTRINO 2024! General topics are:

Angela: Full Light Readout System

Elise: 2x2 Overview + Initial Physics Goals (Focus on CC0pi + track mult.)

Dead Space Between Modules

Last week: initial studies show that we can restrict fiducial volume to reduce potential impact of dead space on analyses

- Impact of dead material is mentioned in ND CDR
  - Field shaping structure chosen to minimize dead material between modules
  - Modular structure support mostly made of G10 panels
  - Plan to use 2x2 cosmics data to evaluate impact of dead material (unclear if this is still happening)
  - Posits benefit to O(10 mm) gap in energy deposits vs. dead wires creating bigger gaps in charge readout

arXiv:2103.13910

Dead Space Between Modules

In LAr, we have:

- **Radiation length:** 14.00 cm
- **Nuclear collision / interaction lengths:** 54.25 / 85.77 cm
- **Pion collision / interaction lengths:** 72.58 / 106.7 cm
- **Molière radius:** 9.043 cm

2x2 Modules: 70 cm x 70 cm x 140 cm (l x w x h, not all active volume)

Even with 4 modules and ignoring dead space, 2x2 is not expected to fully contain hadrons

J. Ho UChicago Thesis / PDG Table

arXiv:2103.13910

Advantages of pixel-based readout: High Pileup

Looked extensively for information on NuMI beam structure

- Beam spill = 10 microseconds
- 11 Booster batches (=5 double intensity bunches and one single intensity bunch) where each batch ~67 ms
  - 52.8 MHz extraction frequency
- Each spill cycle (injection, acceleration, magnet ramp down) is 2.2 s (roughly 0.8 s / 0.7 s / 0.7 s breakdown)

LBNF beam spill expected to also be 10 microseconds and consist of six batches each with 84 53.1 MHz bunches (?? may just have harmonic number of 84, which is the same as NuMI)

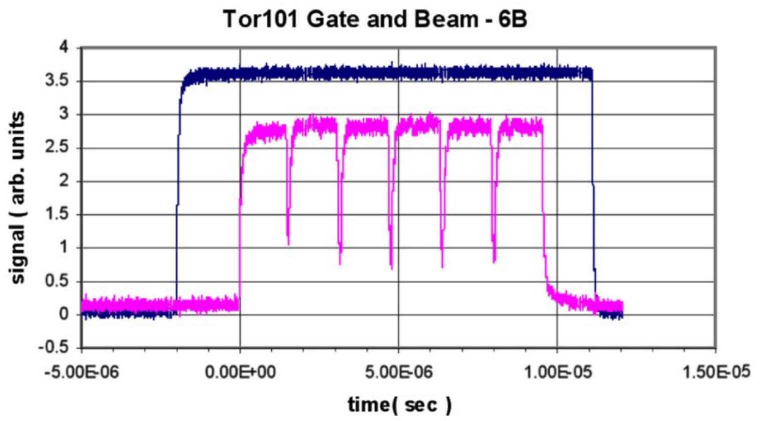
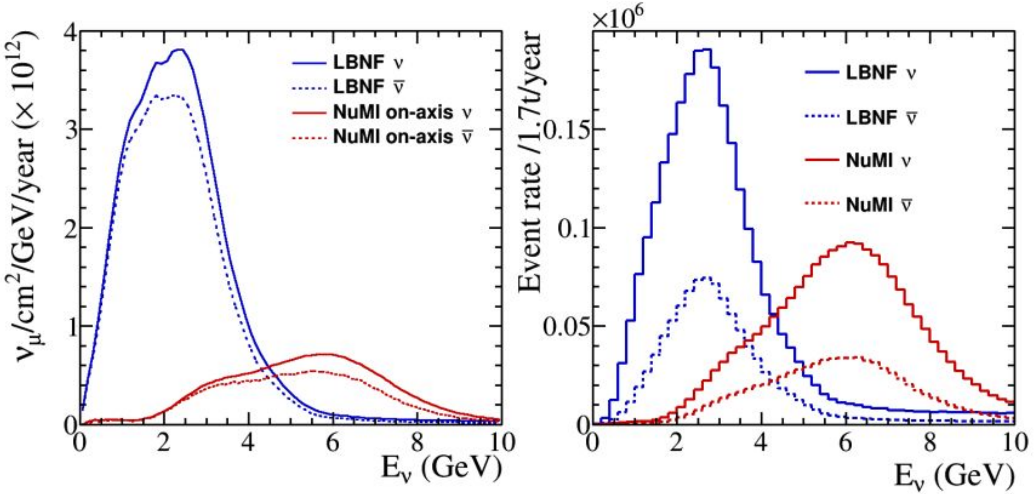


Fig. 32. An Oscilloscope trace of the proton current as seen by the NuMI Toroid in NuMI-Only mode. This is shown as a pink line, and the Booster batch structure is clearly visible. The dark blue line corresponds to the beam trigger window. The first batch is usually sent to the anti-proton source and is then lost to the NuMI beam. The remaining 5 batches are extracted and sent to NuMI. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

arXiv:2103.13910

https://doi.org/10.1016/j.nima.2015.08.063

Advantages of pixel-based readout: High Pileup



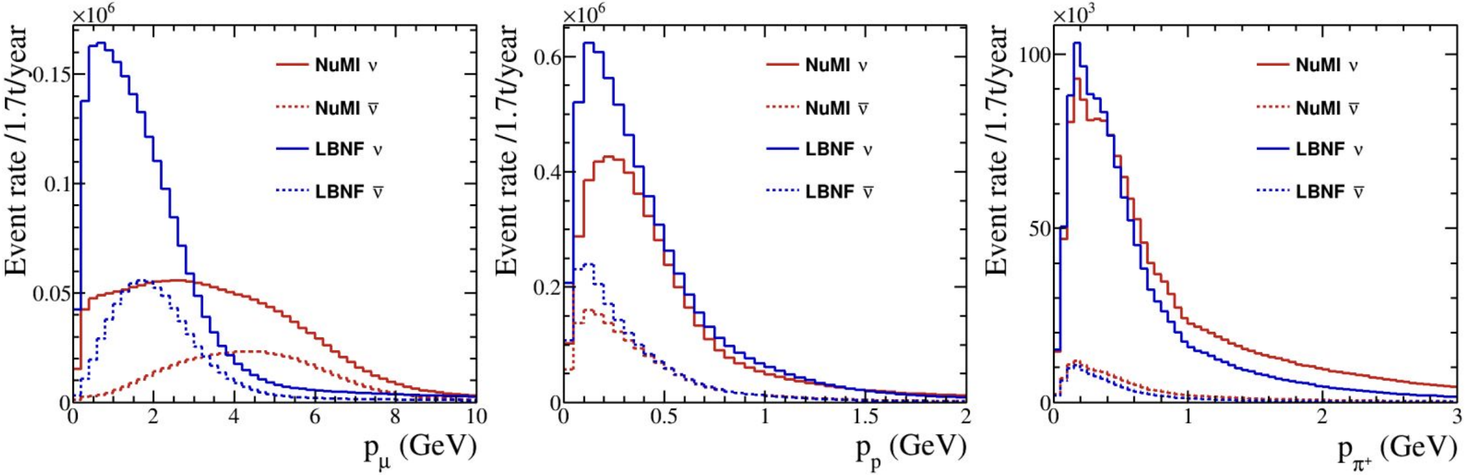
(a) Flux

(b) Rate

Figure 2.15: Comparison of the absolutely normalized fluxes for different neutrino beamlines at Fermilab, and the expected yearly rates in the ArgonCube demonstrator's 1.7 t active LAr mass as a function of E_ν, produced using GENIE v2.12.10 [72].

arXiv:2103.13910

Pixel-based Readout/Physics at ProtoDUNE-ND



(a) $\mu^{\pm}$

(b) Protons

(c) π^{+}

Figure 2.18: The yearly rates of various particles produced at the primary vertex, as a function of their momentum, as expected in the the demonstrator's 1.7 t LAr mass for the NuMI ME and LBNF fluxes, produced using GENIE v2.12.10 [72]. Note that every relevant particle from each event is included.

arXiv:2103.13910

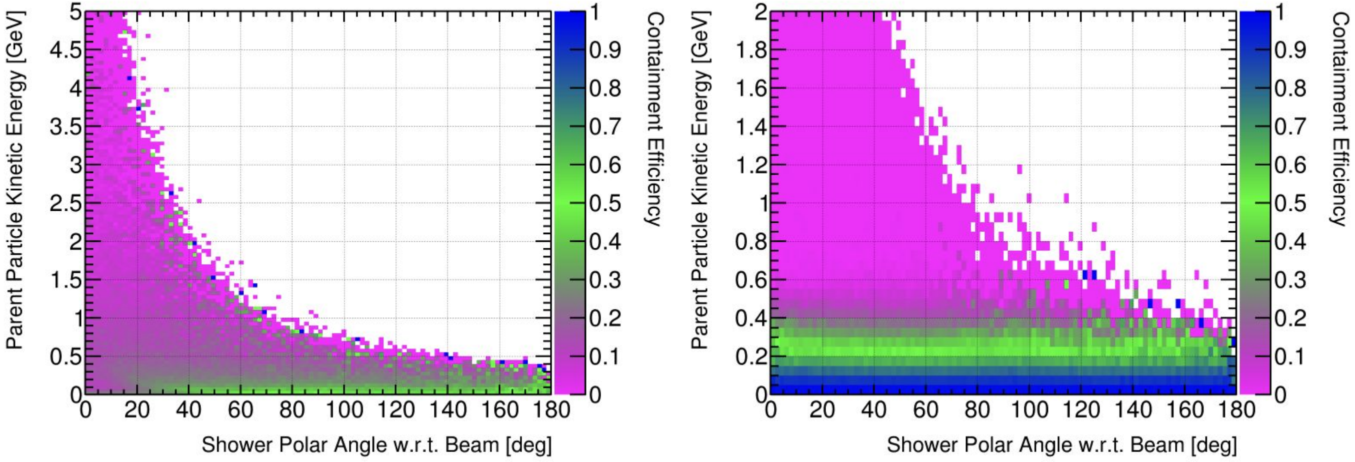
Pixel-based Readout/Physics at ProtoDUNE-ND

Physics studies specified in ND CDR:

- Fast neutron-tagging with prompt scintillation light (makes use of O(ns) light timing)
    - Pixel readout can resolve ~30% of recoiling protons
    - Most neutron recoils show up as single pixel hits
- Concern with shower reconstruction due to modularity
    - Suggestion to use neutral pion reconstruction to evaluate shower reconstruction (only low energy neutral pions contained)

arXiv:2103.13910

Pixel-based Readout/Physics at ProtoDUNE-ND



(a) EM shower

(b) Proton tracks

Figure 2.25: Containment efficiency for EM showers and proton tracks produced by an interaction within the ArgonCube 2×2 active volume, as a function of initiator particle energy and angle w.r.t the incoming beam direction. Note that if $\geq 90\%$ of energy is deposited within the 2×2 active volume, it is classed as contained.

arXiv:2103.13910

Follow-Up: Current Detector Effects + 3D Reco

Known pathologies with current pixel-based readout

- data/MC comparisons (single module data from Bern for now) targeted for learning more about these potential issues
- Close to full (charge + light) processing of **Module 1 data**
- **Module 1 simulation** (run by Elise) is getting closer to full deployment
  - Still pulling together relevant simulation parameters
- Ideally, want to also look at data/MC comparisons using the **full reconstruction chain** (e.g. ML Reco)
  - Supported based on 2x2 goals laid out at January CM

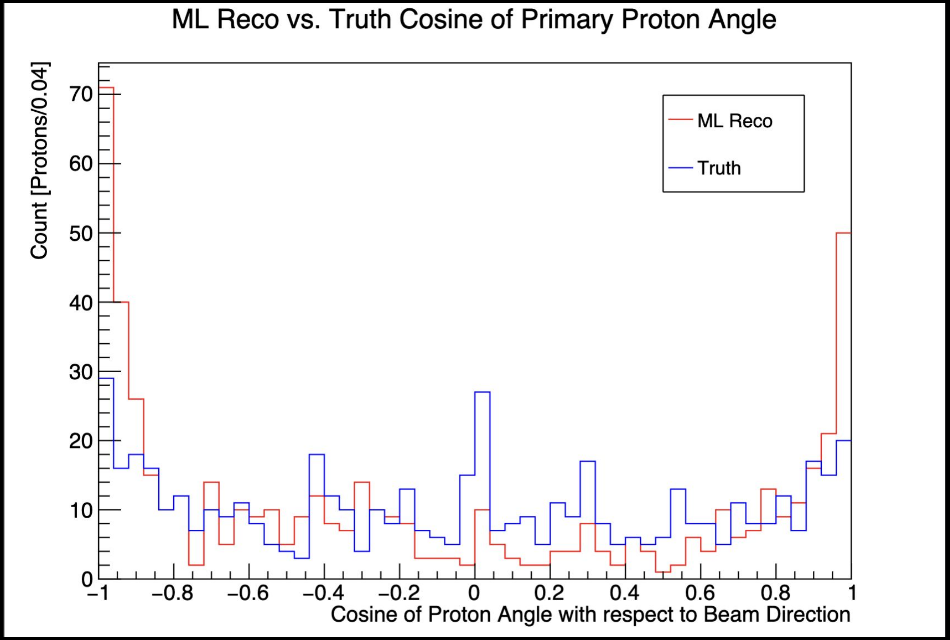
Follow-Up: Current Detector Effects + 3D Reco

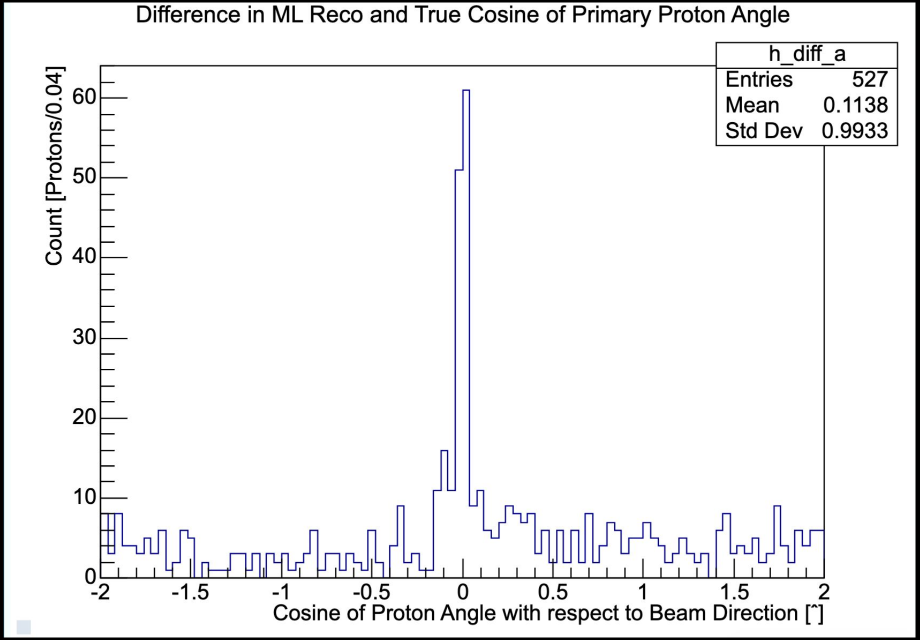
Reconstruction evaluation updates:

- **ML Reco** = only widely available reconstruction
  - **Known issues:** PID (trained on ND-LAr volume)
  - **Goal:** develop scripts to compare reconstructed quantities (currently using 2x2 Simulation) to provide real-time feedback to ML Reco group on reco abilities
  - Have started doing this using ML Reco PID–selected protons; in future will look at **track-like particles vs. shower-like** (as we know ML Reco PID is bad)

Follow-Up: Current Detector Effects + 3D Reco

Reconstruction evaluation example (very preliminary) plots:





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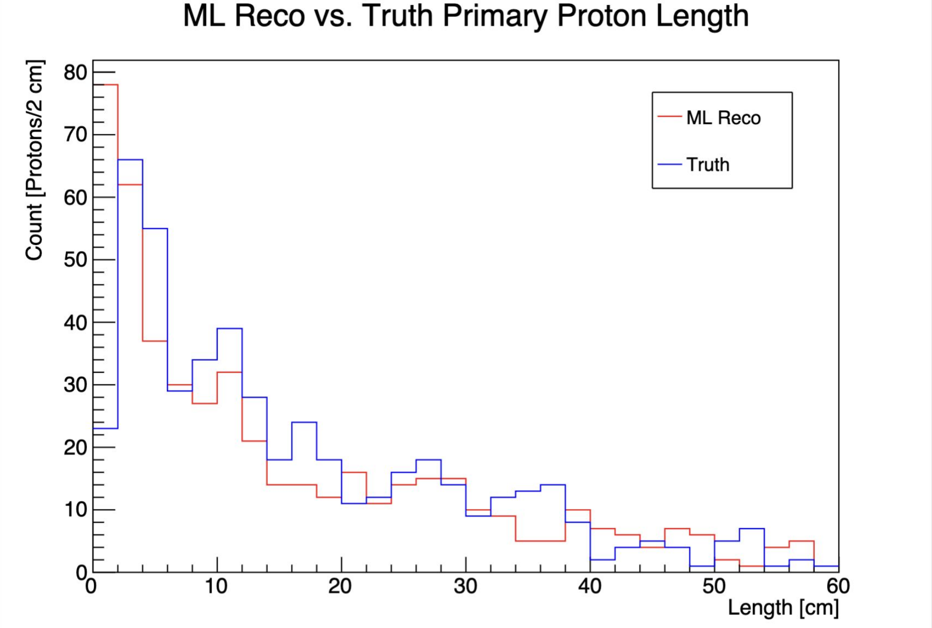

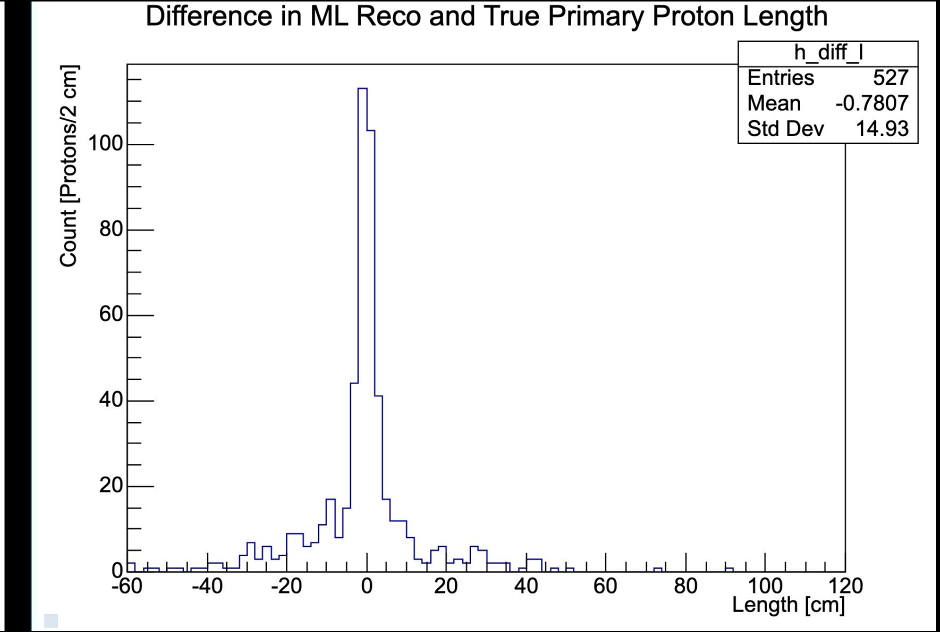

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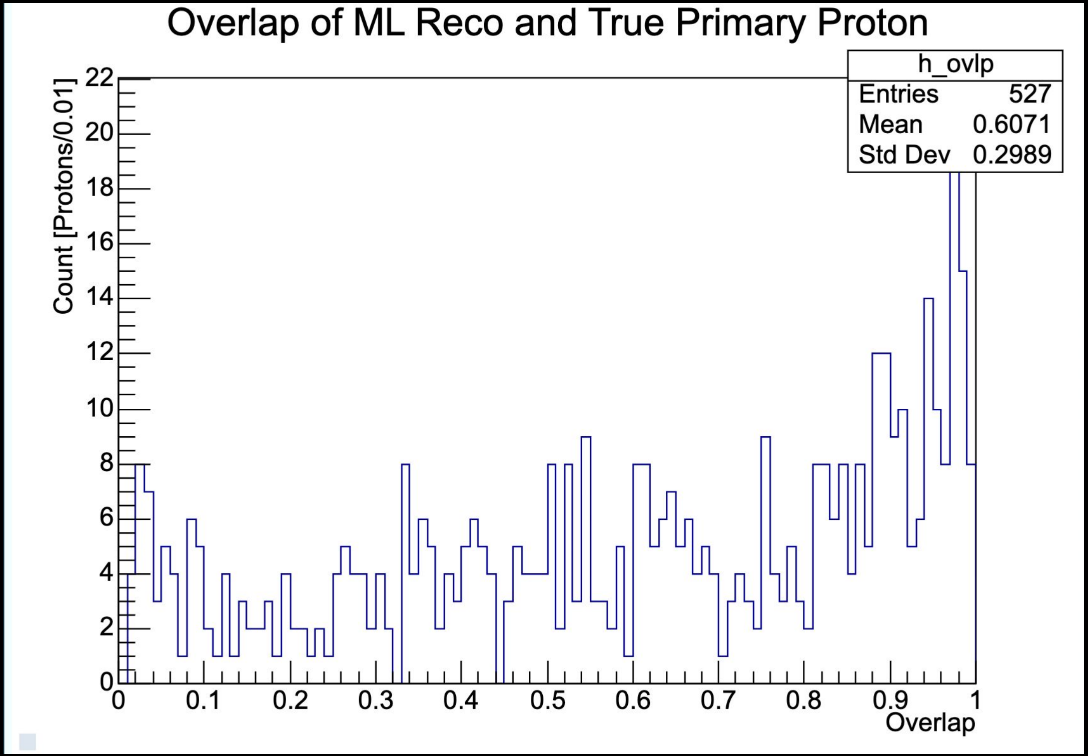
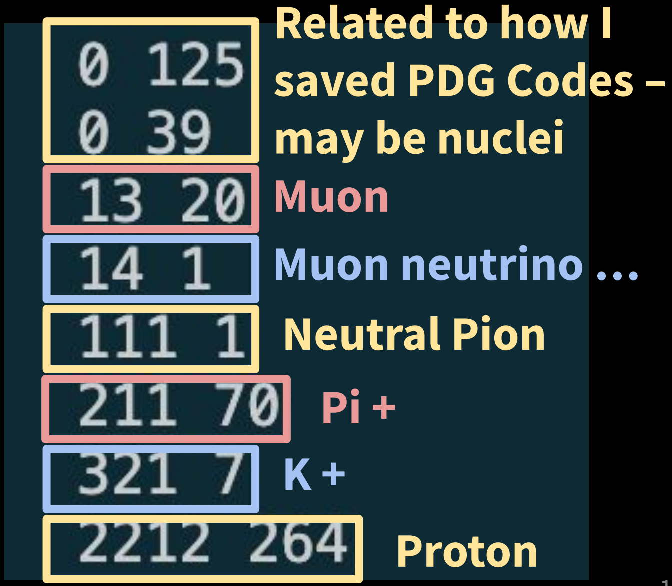


True PDG codes of Reco Protons



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0 125
0 39
13 20
14 1
111 1
211 70
321 7
2212 264
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Related to how I saved PDG Codes – may be nuclei

Muon

Muon neutrino …

Neutral Pion

Pi +

K +

Proton