ECal-based particle ID for neutrino-nucleus interaction measurements in ND280

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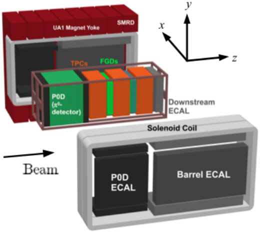
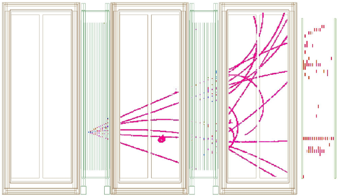
T2K

19/12/2019

ECal PID for neutrino-nucleus interactions in ND280

The ND280 detector





ND280: off-axis near detector for T2K. Designed to measure charged- and neutral-current neutrino interaction rates and kinematics.

- Fine-grained detectors (FGDs): active targets
- Time projection chambers (TPCs): charged particle tracking and ID
- Electromagnetic calorimeter (ECal): neutral particle reconstruction, charged particle ID

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Charged-current ν_μ interactions in ND280

Muon-(anti)neutrino interacts with nucleus via CC weak interaction. FSIs mean we can only see the particles that leave the nucleus (topology): an (anti)muon and some combination of other particles: pions, protons, neutrons, etc.

Categorise based on number of pions in final state:

- CC0pi: no pions in the final state (includes CCQE)
- CC1pi: one charged pion (π^+ for ν_μ, π^- for $\bar{\nu}_\mu$)
- CC-other: any other configuration of pions

Measuring the cross-sections of these interactions improves our understanding of neutrino interactions and helps reduce systematic error in T2K oscillation measurements. My focus is on CC1pi – new channel for oscillation analysis.

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TPC PID

PID in ND280 is done mainly using the TPCs: dE/dx curves.
Shortcomings:

- dE/dx curves overlap at some energies
- TPC information not always available – high-angle tracks
- In particular, bad at distinguishing muons from pions

Using only TPC PID, CC1pi muon candidates suffer from pion contamination: 7% (ν_μ) and 22% ($\bar{\nu}_\mu$).

ECal is an excellent alternative source of PID information.

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ECal PID

Shape and distribution of ECal charge cluster provide useful PID information. I am working to develop PID cuts using this information, to improve the quality of ND280's event selections.

I am focusing on muon/pion discrimination: muon candidate is central to all ν_μ and $\bar{\nu}_\mu$ CC selections, and TPC cannot remove pion background.

Muons are MIPs: pass through ECal leaving a straight track. Pions may either pass through as MIPs or shower (roughly 50:50). If my PID cuts can separate tracks from pion showers, we can expect to remove as much as $\sim$50% of the pion background.

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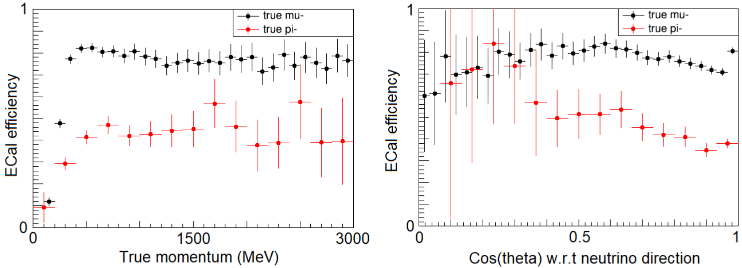
ECal segment efficiency



MC study of ECal efficiency for ν_μ CC selection muon candidate:

- Muons have higher ECal efficiency than pions
- Efficiency increases with momentum, then plateaus
- Pion efficiency increases with angle

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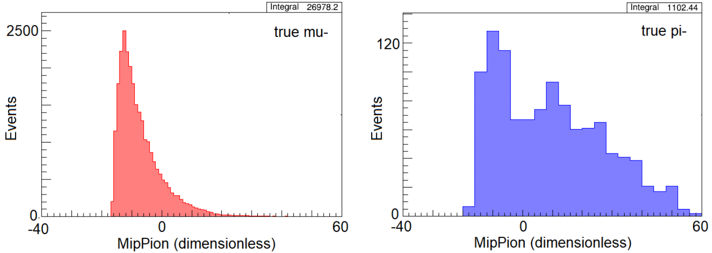
ECal variables for μ/π discrimination



Two main candidate variables so far:

- MipPion: calculated via neural network; designed to distinguish MIPs from pion showers using charge shape and distribution
- Energy (or charge) deposit/track length: expect a constant value for MIPs, varying for non-MIPs

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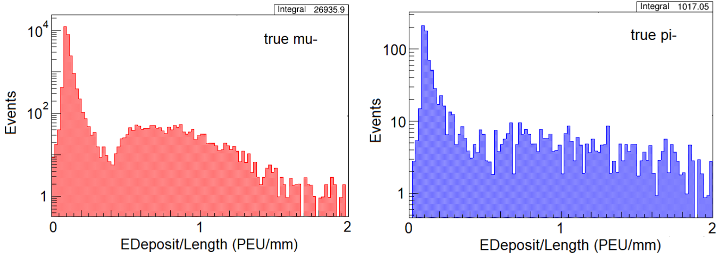
ECal variables for μ/π discrimination (contd.)



MC predicted distributions of ‘EDeposit’ (charge deposit) divided by ‘Length’ (ECal track length).

Anomaly can be seen in the relationship between these variables for true muons: some appear to be deviating from expected MIP behaviour.

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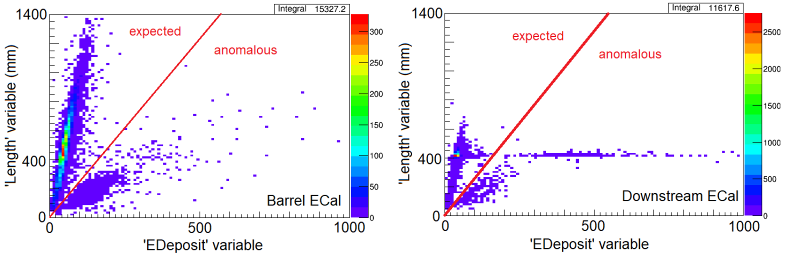
ECal charge-length anomaly



- 5% of true muons deviate from expected constant EDeposit/Length
- Anomalous muons correspond exactly to those tagged as showers by reconstruction
- Investigation revealed that EDeposit variable is actually getting filled with two different quantities: charge deposit for tracks, fitted EM energy for showers (different units!)

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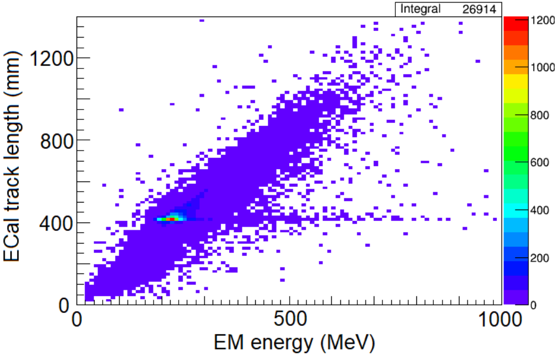
EM energy vs Length



- Use EM energy instead – muon distribution looks as expected.

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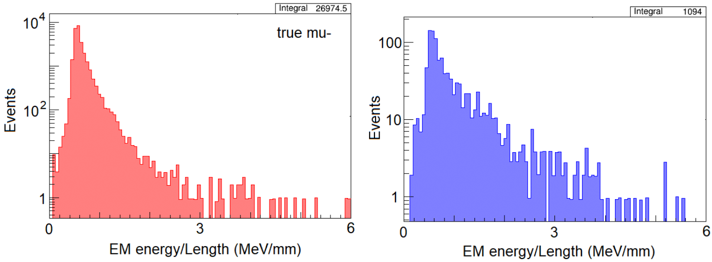
EM energy/length for muon/pion discrimination



MC predicted distributions of fitted EM energy divided by ECal track length.

Distributions look as expected and show sufficient separation for PID cut.

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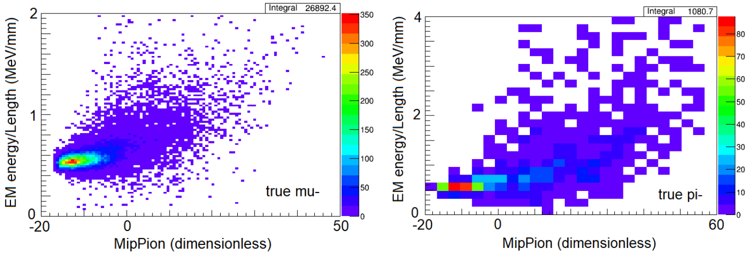
EM energy/length and MipPion: correlation



MipPion and energy/length both show promise as muon/pion discriminators, and weak correlation so both can be cut on effectively.

Next steps and further work

- Develop PID cuts for μ/π discrimination using these ECal variables
- Develop a standard pion PID using ECal and TPC information
- Possibility of a 'global' PID, combining information from TPCs, ECal and FGDs
- Use PID tools to develop an improved $\bar{\nu}_\mu$ CC1pi- selection and measure cross-section

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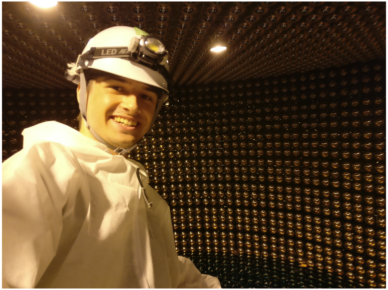
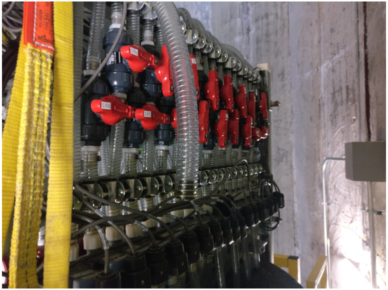
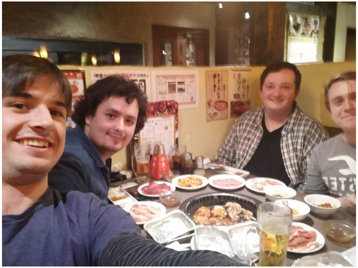
Other activities





- Responsible for ECal scintillator bar equalisation calibration
- Currently on LTA at J-PARC as TTD (ECal) detector expert
- Worked two weeks of maintenance shifts in Super-Kamiokande



Thank you for your attention!