Cross-section Detectors @ a νSTORM Facility

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Introduction

- Restating the problem.
- νSTORM cross-sections: detector or facility?
- List of targets.
- Potential detector technologies.
- Evaluation in the software framework.

The Problem

- Stealing liberally from Steve Boyd's talk:
  - A better understanding of cross-sections, especially σ_{ν_e} will have a massive effect on long baseline oscillation experiments.
  - Not even ν_μ CCQE is actually that well understood.
  - The rest are worse.
- What is the solution?
  - Detectors capable of excellent PID and imaging of the interaction vertex.
  - Multiple target measurements.
    - C, O, Ar
    - Al, Fe, Cu, Pb
    - H or D
  - A damn good beam!

Measurement Style

- Be clear on what is being measured:
  - $1\mu + 1$p
  - $1\mu + 1$p$+0\pi$
  - $1\mu +$?p$+0\pi$
  - $1\mu +$ nothing visible.
- Where there is uncertainty, document the uncertainty; provide information on detection rates, e.g. energy threshold for protons.
- Measure useful parameters: particle energy, direction, multiplicity, neutrino energy, target nucleus.

Example from a past life: T2K's π^0 Detector

- Should soon publish a cross-section result called something like:
  - "Neutral Current π^0 Production on a H_2O Target".
- For the same result, I would want us to provide details on:
  - The energy and angle of the reconstructed π^0 particle.
  - The purity of the selected sample; μ or $\pi^{\pm}$ at 90° to the ν beam are very hard to detect given the P0D's design.
  - The uncertainty on the H_2O target; they use a subtraction method from a detector with C, Cu & Pb.
  - (I have no reason to believe T2K won't fulfill these requirements!)

Detector vs Facility

- We can't reasonably expect one detector to make all of the measurements we would like.
  - Even ignoring the desire for multiple targets, we would have issues with:
  - Containment vs energy resolution. (Size, density, detector technology).
  - Good understanding of vertex activity vs inactive target material.
  - CCQE vs NCπ^0. e.g. Gas TPC, great for $e^{\pm}/\mu^{\pm}/\pi^{\pm}$ ID and energy resolution, poor for π^0 detection.
- We probably all agree we should aim to offer a facility.

What is a Facility?

- A big hall with a ν beam going through it?
- A communal Muon Range Detector downstream of detector space?
- A generic magnet; large enough to provide a magnetized target region?
  - Aside: How useful is a magnet for cross-section measurement?
  - Gives you momentum and charge determination.
  - Helps with some μ/π separation, depending on charge.
- Software tools, control systems, a vetting process to guarantee complementary detectors?

Detector Considerations

- Should be targeted; don't compromise the primary measurement unnecessarily in an attempt at secondary measurements.
- Might not run for the whole run period.
  - Systematic errors vs statistical limits.
- Target material should match the global goals.
- But we probably don't get to decide all of this as a facility.

Potential Detectors

- Ar TPC
  - Event rate / pile up needs to be studied (gas vs liquid), but good fiducial cuts possible.
  - Clean event reconstruction.
- LBNE Near Detector, HIRESMNU
  - Straw-tube tracker, (S. Mishra & R. Petti).
  - Builds on experience to date; good vtx activity detection.
  - Foil layers for some nuclear targets.
- LBNO / LAGUNE Near Detector
  - Mentioned by A. Blondel in phone meeting.
  - Installed @ νSTORM prior to service in LBNO.
  - GAr TPC, with fully active calorimeter. Potential of H_2 target.
- Either would save money, while providing useful commissioning of detector before LBN(E/O) start.

Bubble Chamber 2017?

- Used to be a very favourable detector technology:
  - Low cost detector medium
  - Clear event readout, with 'easy' reconstruction.
- Major issue was timing; couldn't keep up with modern experiments.
- 'Rapid Cycling' bubble chambers from 70's & 80's had a rate of 30 Hz for the piston; i.e. one pump per beam pulse.
- CCD cameras could provide readout (200 ps time-scale with a 'gated intensified CCD'), with repeated shots during beam pulse allowing identification of first interaction.
- Would need to investigate event rates.

Software Framework for Detector Evaluation

- Very much a work in progress!
  - By myself, Ed Santos, Steve Boyd and Ken Long.
- Goal is to evaluate the potential physics reach of combinations of detectors.
- Relies on GENIE, GEANT4 and a fake reconstruction.
  - Track / shower reconstruction is completely fake.
  - Charge ID is real.
  - PID is fake, work in progress.
- Attempt to answer some of the questions raised earlier.

Confusion Matrix

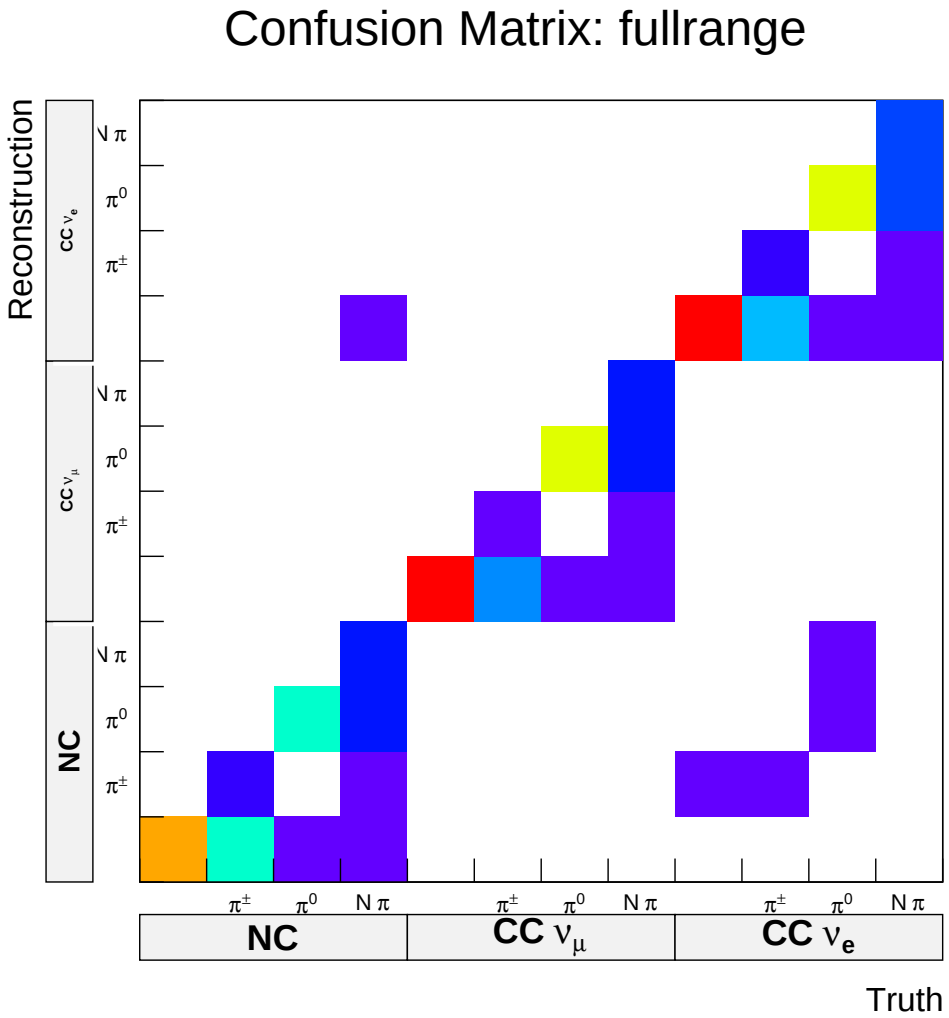

Figure: Confusion matrix for a selection of $\overline{\nu}_\mu$ and ν_e events, in an Ar TPC with a 0.4 T field.

Detection and Charge for Protons

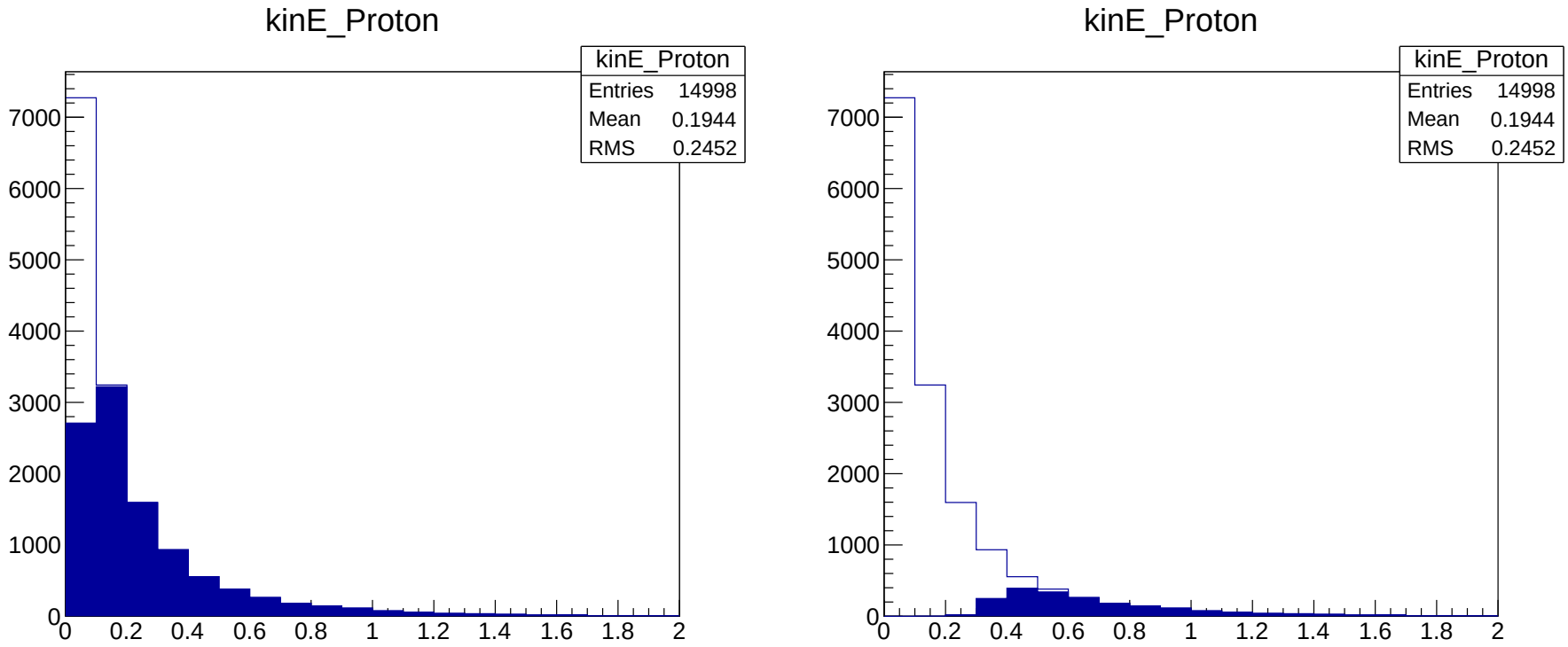

Figure: Detection efficiency (left) and charge identification (right) for primary protons from 10,000 $\overline{\nu}_\mu$ and 10,000 ν_e events.

Summary

- There are plenty of ideas for a suite of cross-section detectors.
- There are plenty of goals too.
- The tools to evaluate detector designs are at an early stage, but progressing.
- We probably need to tighten up the 'facility' concept.