How to Determine the Expected Performance of a Water Cherenkov Detector in a Future LBL Neutrino Experiment

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outline

introduction

- Water Cherenkov detectors are an appealing choice for a future LBL neutrino oscillation experiment.
- Well understood, affordable, scalable.
- But, the devil is in the details:
  - Can we reduce the NC background and keep the ν_e signal?
  - What minimum PMT coverage is required?
  - Can we make due with no veto detector?
  - How do single large volumes compare to multiple smaller ones?
  - How do our LBL directed designs affect the other important physics to be done in the detector?

We need a detailed simulation and realistic reconstruction efficiencies and systematics.

milind

- The result that started this game, showed what level of π^0 background rejection is required for an acceptable result.
- GEANT/custom simulation with some truth based reconstruction.
- No easy way to evaluate different detectors nor more subtle effects
- Expert only code.
- FORTRAN

Conclusion: useful for initial estimations, but not a good base to for continued work.

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chiaki

- Confirmed that the backgrounds are indeed manageable.
- Reweights detailed SK ν_{atm} simulation and reconstruction.
- Poor statistics at the higher energies typical of wide band beams.
- Not open (very proprietary to SK collaborators).
- Reconstruction tuned for lower energy atm-ν events.
- No avenue for evaluating different detectors or improving reconstruction.
- Underlying MC/reco code is FORTRAN/GEANT/CERNLIB and somewhat expert only.

Conclusion: provided an important confirmation but not applicable beyond its current use.

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our needs

- Open and accessible code, ideally with some expert assistance.
- Flexibility to simulate various designs.
- Enough commonality to avoid duplication of efforts.
- Need to build up the standard WC reconstruction:
  - vertex fitting based on PMT timing
  - single/multi ring discrimination
  - μ/e ring discrimination
  - rough π^0/e discrimination
  - rough multi-ring fitting
- Improved reconstruction using pattern based fitter (essentially fit event with MC lookup tables):
  - better π^0/e separation.
  - better multi-ring reconstruction to allow non-QE events to be used.
- Prefer C++/Geant4/ROOT to FORTRAN/GEANT/CERNLIB. (Excite the youngin's!)

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some choices

These are the few I know of:

1. UNO software
2. US Super-Kamiokande software
3. SNO's SNOMAN
4. Start from scratch
5. Others?

uno

- Originally written for UNO R&D, now somewhat adrift.
- Flexible support for different geometries & PMTs
- Needs some housekeeping and fixes to work with latest G4.
- Separates the Cherenkov simulation producing PEs & electronics.
- I/O, track/shower, minimization and other util classes defined.
- Modern development: C++, CMT, OO, ROOT, G4
- Has some working reconstruction, including initial pattern based π^0/e discriminator (student Jung Lee from Colorado State Uni)
- $<\sim$ 100Kloc

Conclusion: a good basis, ripe for the picking but some cleanup before rewards. Comes with a wanna-be expert (me).

ussk

- Written independently from current, official SK
- Used as cross check for first 400 days data (and my thesis).
- GEANT3 + ZEBRA + FORTRAN (MC only)
- Reconstruction is all in OO'ish C, ZEBRA mostly hidden.
- Lacks pattern based π^0 rejection code
- Some out of the box support for changing detector design
- Open but untouched for 5 years
- Multiple event displays

Conclusion: a fair basis for future work, low tech FORTRAN/C hybrid, probably needs substantial cleanup before rewards. Comes with a very forgetful expert (me).

snoman

- Simulation of SNO
- Mature, very well documented (Nick West!)
- Likely to be open, but need confirmation and details
- Somewhat flexible in terms of PMT placements though just input file tweaks (was “ported” to handle Braidwood).
- Would likely require Nick to officially get some fraction of his time to provide expert support.
- Large code base ($\sim$450Kloc)
- Unlikely that strong π^0 rejection software exists
- FORTRAN/GEANT/ZERBRA

Conclusion: some potential but would require more in depth expert evaluation.

from scratch

What if we start from scratch?

- Much harder than it sounds.
- Allows complete control on the outcome.
- Much harder than it sounds.
- Needs dedicated group with at least:
    1. 1/2 FTE dedicated to software management
    2. 1-2 FTE dedicated to development
    3. handfull of part timers
- Much harder than it sounds.

Conclusion: I just don't see it.

summary

- We have good indication from two independent studies that a Water Cherenkov detector will perform well for a LBL appearance experiment.
- Full simulation and reconstruction required for complete acceptance and to evaluate different designs.
- At this point I think our best bet is to base our future development on the existing UNO software.
  - Need to inform the other UNO developers of our intentions
  - Need volunteers to actually do some work.