Tau Neutrino Beam Optimization

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Beam Optimization Review

- Original reference DUNE beam was NuMI beam!

- Laura Fields optimized using genetic algorithm powered by beam simulation. Suggested novel 3-horn design!

- Optimizes for CP sensitivity which was established to be mainly a function of energy

- Goal: **re-optimize for tau production**

  - Maximize number of nu_tau CC interactions

  - Today: use existing horns

  - This has been done before… with NuMI geometry. Will compare

Why Tau Neutrinos?

- Tau neutrinos and taus have rarely been studied since discovery

    - Hard to produce in large quantities

    - Hadronic decays make them hard to reconstruct

- DUNE will have extremely intense beam. Could it be tuned to produce world-leading tau sample?
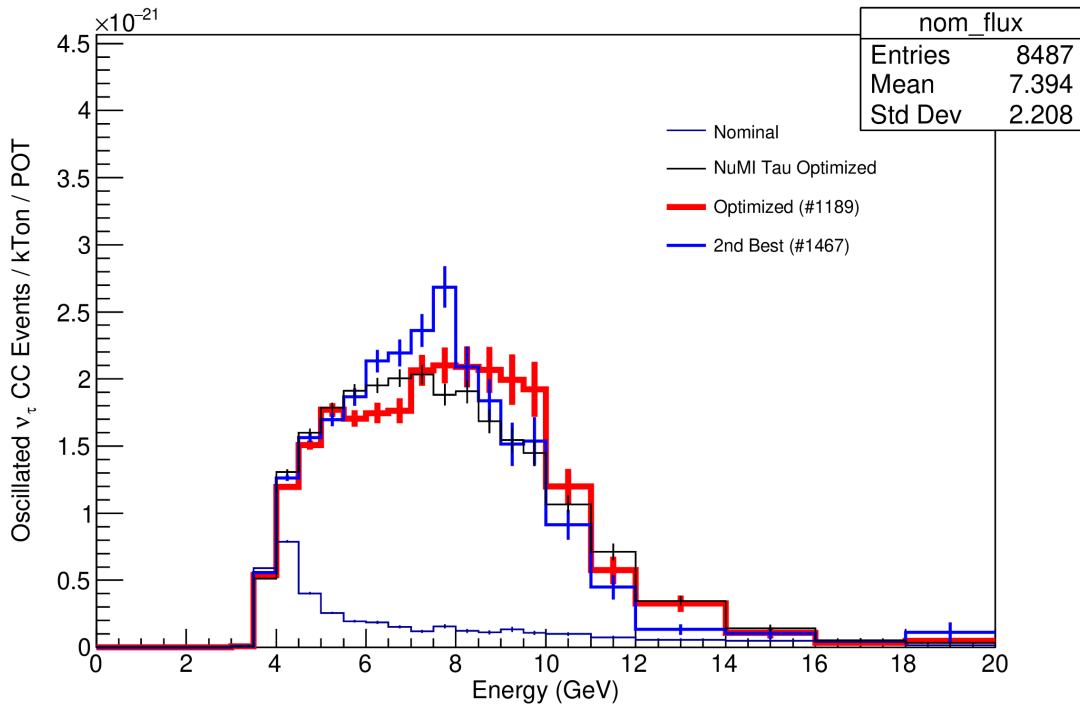
Tau Neutrino Optimization
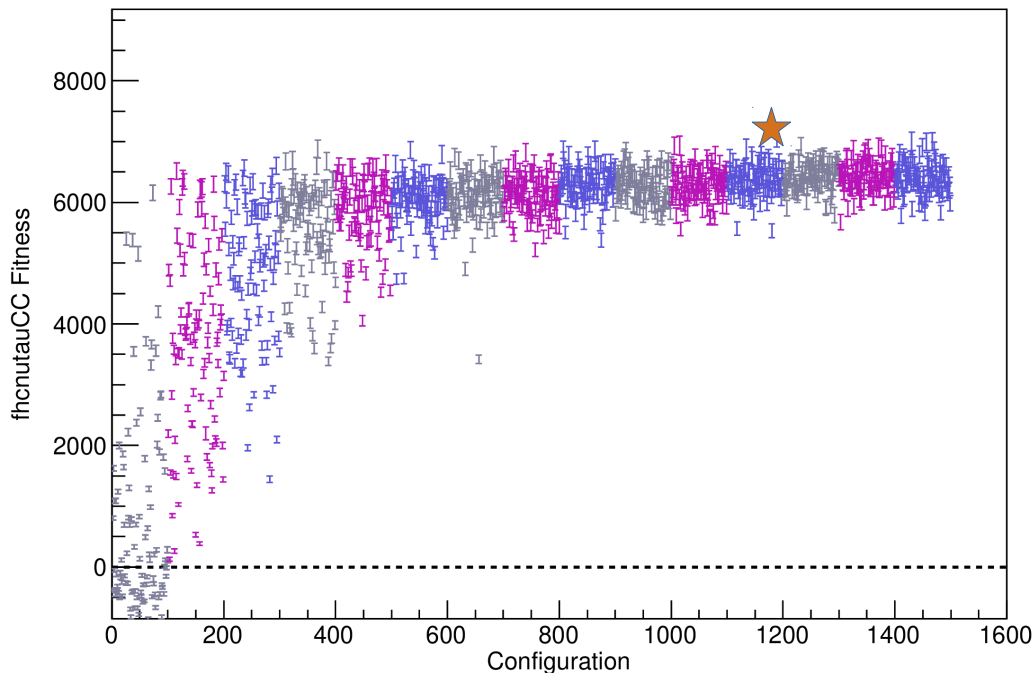
- Parameters Optimized:
    - Horn positions along beam
    - Target fin width
    - Beam spot size
    - Horn current
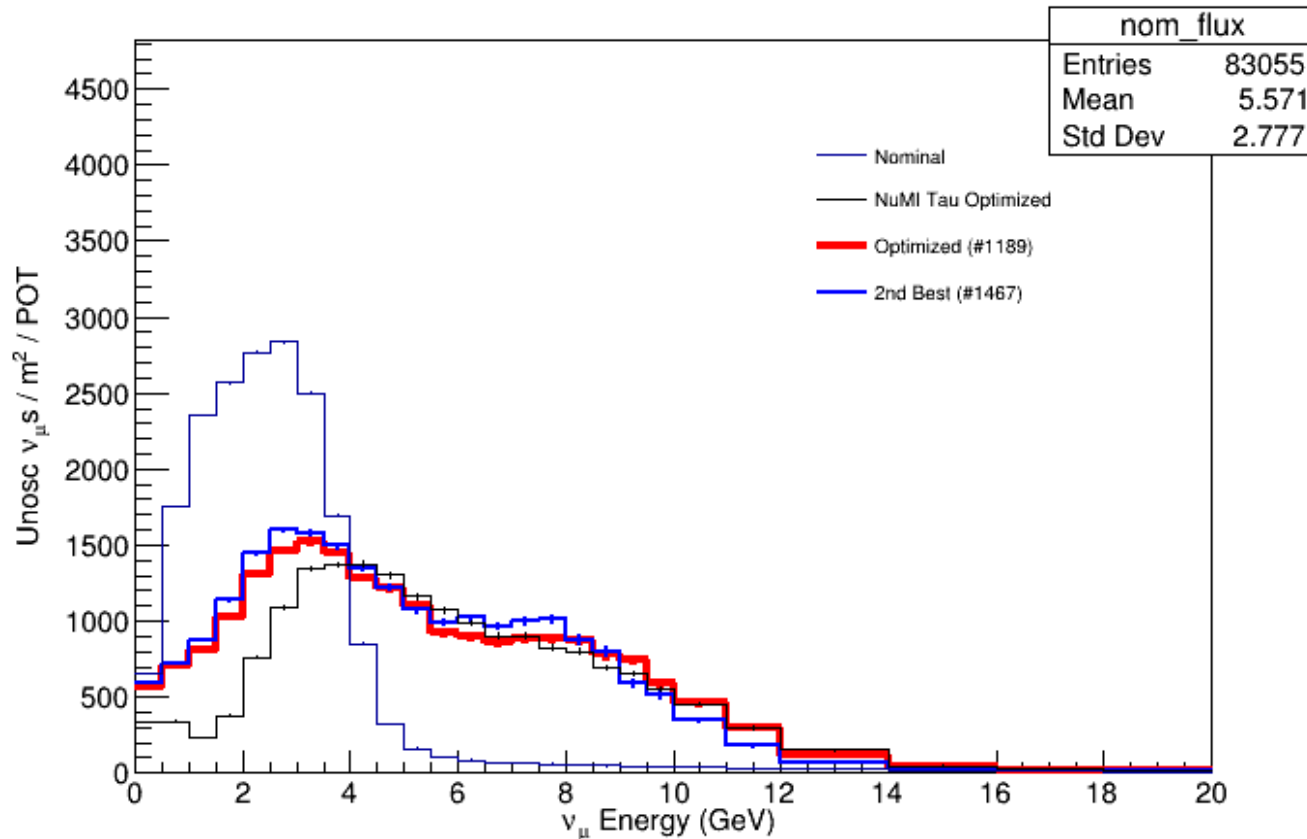   - Incoming proton energy

- Beam optimization is working
- ⭐ = best configuration so far

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Optimized Tau Neutrino Flux

- Red: best configuration
- Dark blue at bottom: CP-optimized (ideal) beam
- Close to estimate based on NuMI horns
- Room for flexibility: other configurations do well too

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What does this do to nu_mus?

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- Optimizing for nutaus deflates numu distribution

- Remember: these are pre-oscillation numus. Many oscillate into taus.

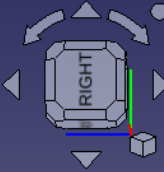- Optimized horns still have more low energy tail than NuMI design

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Which Parameter Most Important?
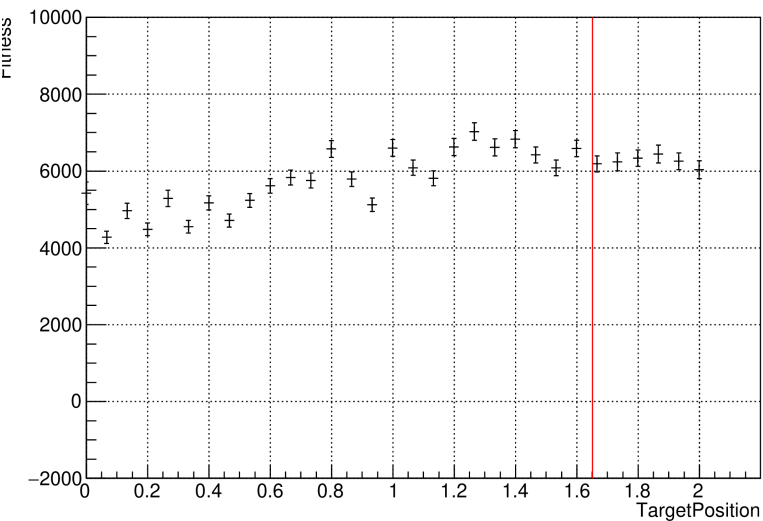
- Algorithm: Scan 1 parameter at a time given optimized configuration
- "fitness" = integral of nutau CC event rate
- Horn 2 position is biggest improvement
- Target position effectively moves horn 1
- Other parameters even flatter in "fitness"

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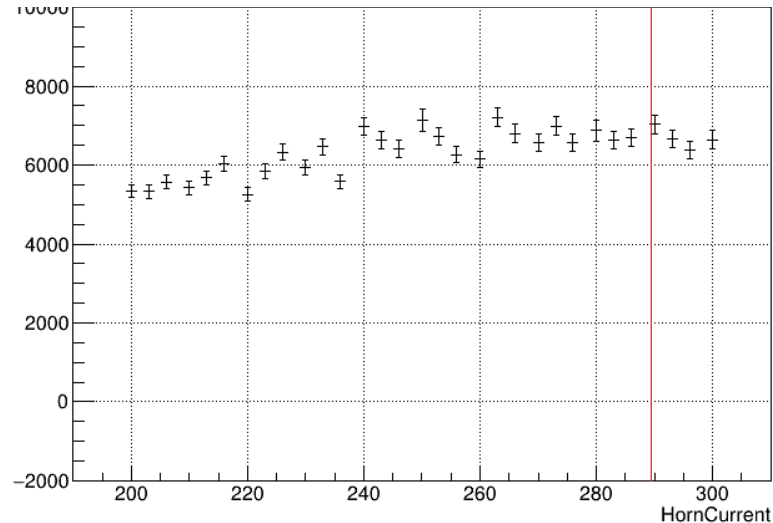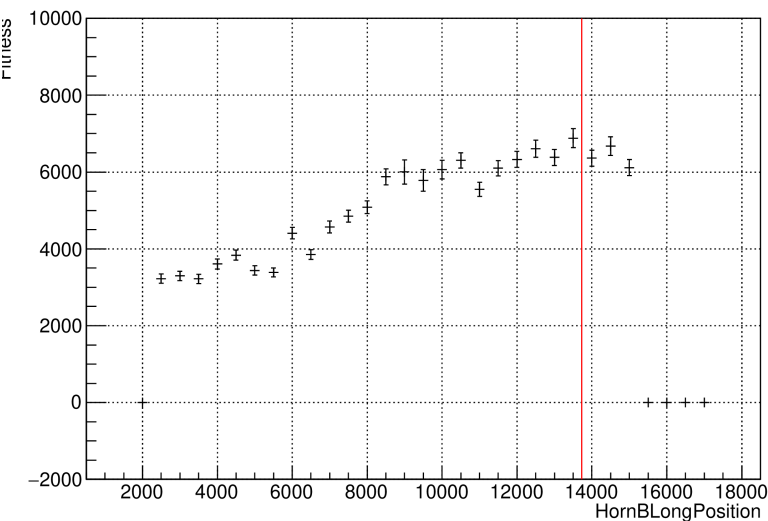
What does Tau Beam Look Like?

- Red: OptimizedIdealJan2017: close to horns we'll build
- Teal/green: same horns with <u>positions</u> optimized for taus!

What I learned: Tools

- Beam optimization working

  - Changed some usernames and fixed bugs on branch TODO

  - Seamless migration to CephFS so far

  - Used DoOptimization.py and submitScan.py

  - Cron jobs not working well. Authentication frequently needs manual intervention.

- FreeCAD can also read GDML files

  - Paraview converter works for CP-optimized geometry but not for my optimization. Not sure why.

  - JPL(?) recently added a plugin to let FreeCAD read GDML files

  - Conversion takes a while, but FreeCAD may make overlaying geometries easier

Next Steps

- Optimize horn shape for tau physics
- Update target design in optimization

Thank you

What I Changed

- On branch feature/aolivier_reviveBeamOptimization until I have more time to double-check changes

- Changed username for input files

- 1024MB of memory instead of 512MB needed for about 1/3 of simulation jobs

- Added more self-debugging

  - Rerun entire stage if more than 10 files missing

  - Keep trying if grid jobs are still running

- Commit hash for posterity: 1afd9868671588b97254b7536c9566f23145c3e4

How to Run

- Work through README file in g4lbne to test interactively first
- Laura's instructions work great for getting started: https://cdcvs.fnal.gov/redmine/projects/lbne-beamsim/wiki/Beam_Optimization
- Places I got stuck initially:
    - You have to create your own cron job that uses kcron
    - Change username from aolivier to yours
    - Leave lfields: uses CP sensitivity studies from original work

Manual Debugging Tips

- "Not enough runs for next iteration"

  - Will try to fix itself by deleting last round of optimization and rerunning

  - Will keep trying if grid jobs still running

  - Gets stuck if jobsub_q also stops working in cron jobs

    - Interactively make sure no grid jobs running

    - Delete directories listed in log file

    - Run DoOptimization.py interactively once to restart

    - May need to rerun kcroninit

- "TObject has no method Rebin": Delete the one directory mentioned in log and rerun

- "condor_submit exited with status 1": Run DoOptimization manually once to restart and be prompted to solve any authentication problems