Flux normalization with D_2O detector and CC on Oxygen

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COHERENT Analysis Meeting

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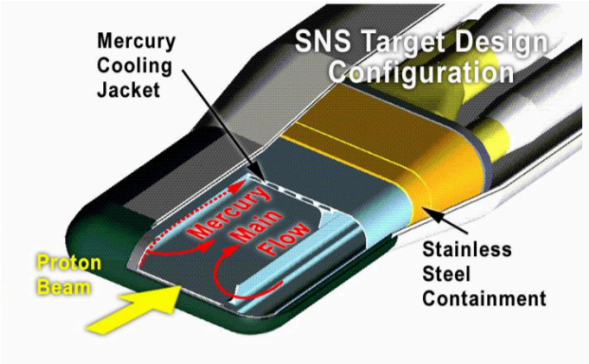
Precision Neutrino Program

- CEvNS potential as multi-physics probe fully realized with precision measurements
- SNS neutrino flux currently known to ~10%.
- Largest uncertainty is pion production from p+Hg
- Options
  - Measure pion production
    - Cons: proton energy loss in target requires measurement over broad energy range, at all outgoing angles, and measurement of pion interaction in target
  - Direct measurement of neutrinos with well calibrated process
    - Con: neutrino cross sections are low



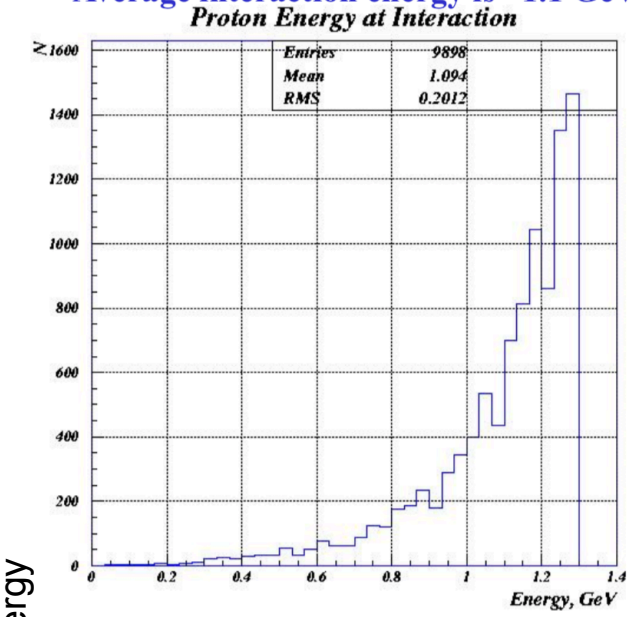
Source Parameters

- Proton Energy ~1 GeV
- Compact source
- Estimate 0.08 ±10% pions/proton

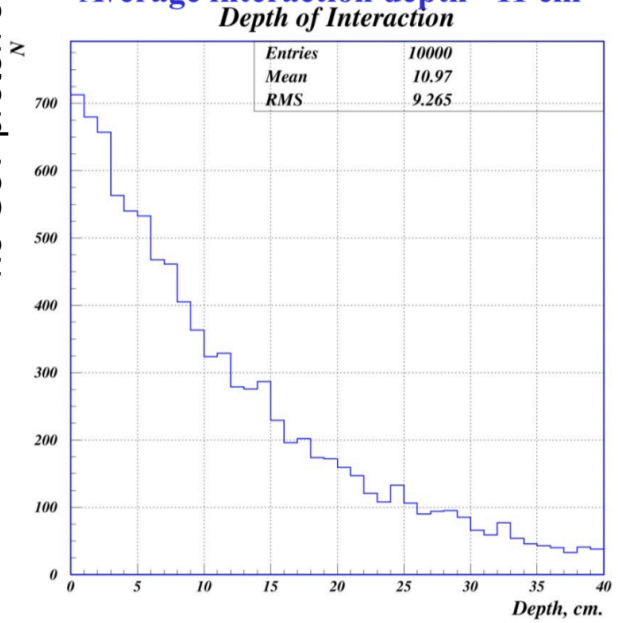
Proton Energy	G4 π/p
939.5	0.082
957	0.084
972	0.086
990	0.088
1010	0.09

1.3 GeV proton energy

Average interaction energy is ~1.1 GeV



Average interaction depth ~11 cm



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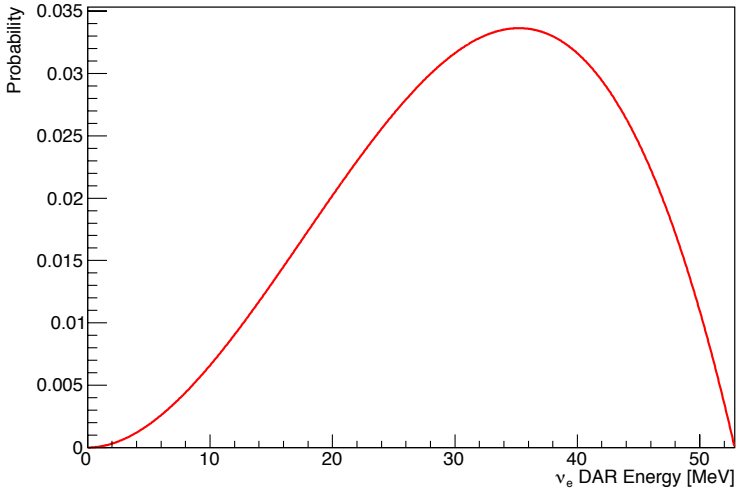
Direct Measurement of Neutrino Flux with Heavy Water

- Charged current ν_e-d cross section known to about 2-3%.

S.Nakamura et. al. Nucl.Phys. A721(2003) 549

$$\nu_e + d \rightarrow p + p + e^-$$ 5.5×10^{-41} cm^2



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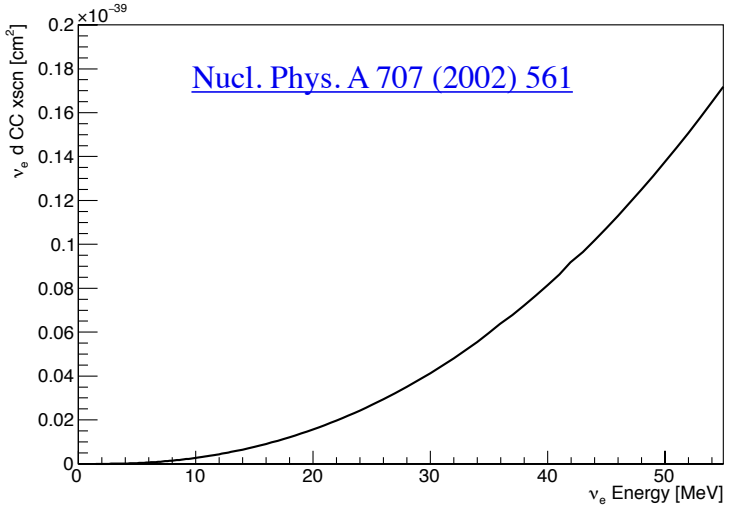

930 CC interactions per ton per SNS-year

5000 hrs/yr @ 1.4 MW
0.09 ν_e per proton

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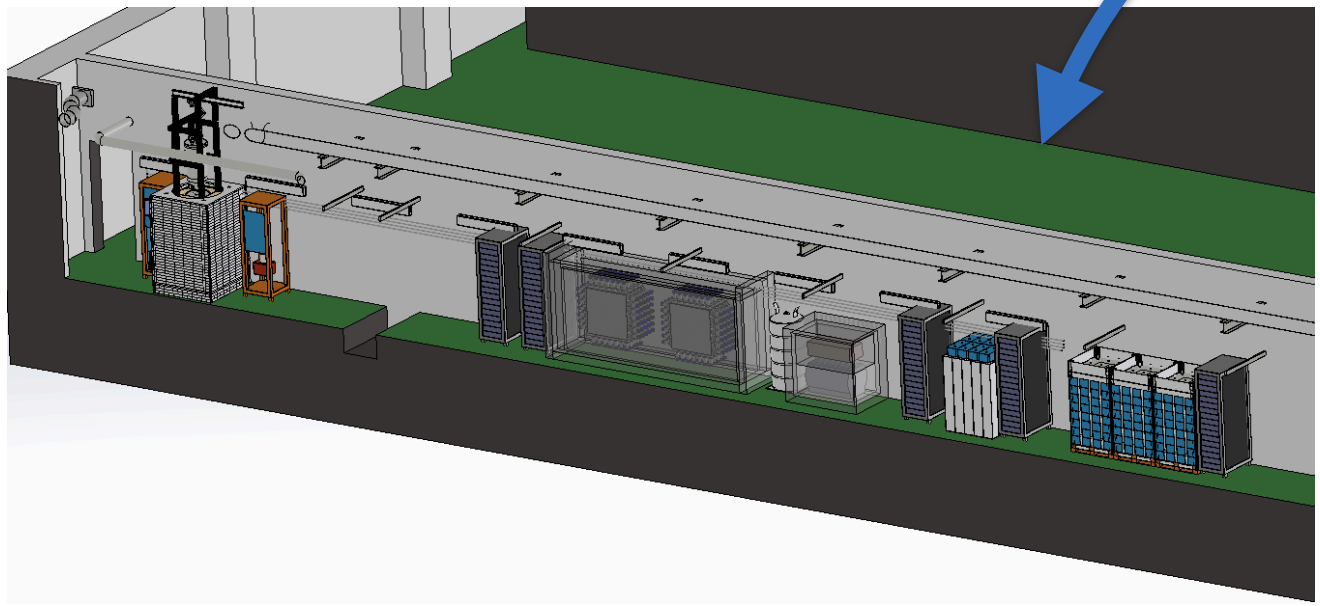
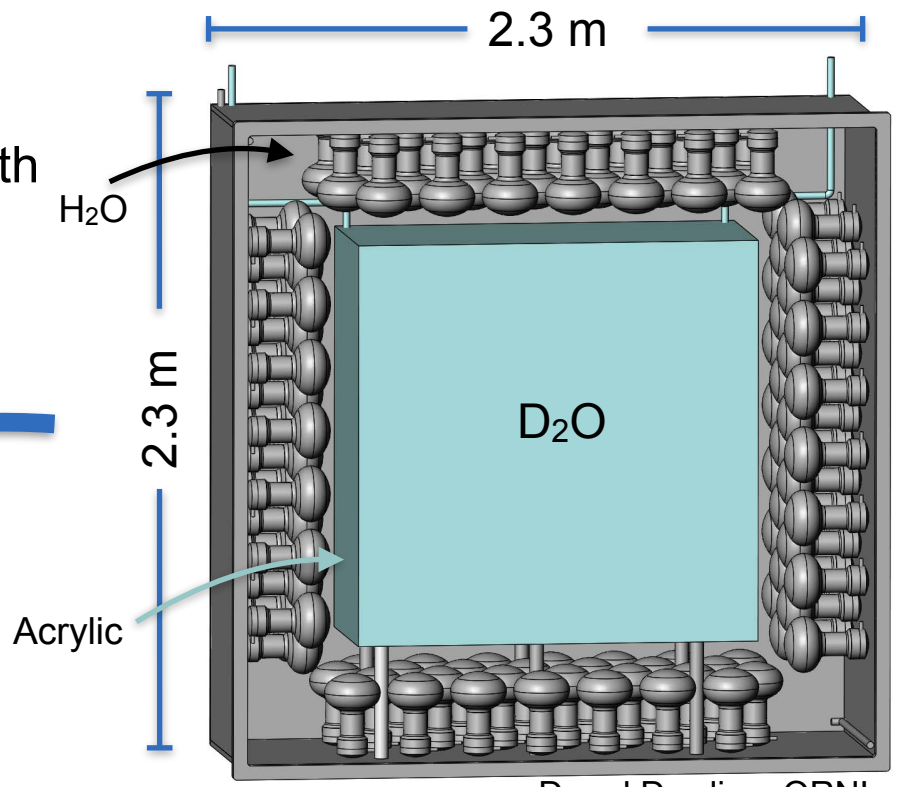
1-ton Heavy Water Detector at the SNS

- Neutrino Alley space constraints: 1m depth x 3m height x 3m width
- Locations 20-29 meters from target
- Required facility services, safety and accountability controls in place

Neutrino Alley





Darryl Dowling, ORNL

- 1.3 tons D_2O within acrylic inner vessel
- H_2O “tail catcher” for high energy e^-
- Outer light water vessel contains PMTs, PMT support structure, and optical reflector.
- Outer steel vessel to support shielding and veto

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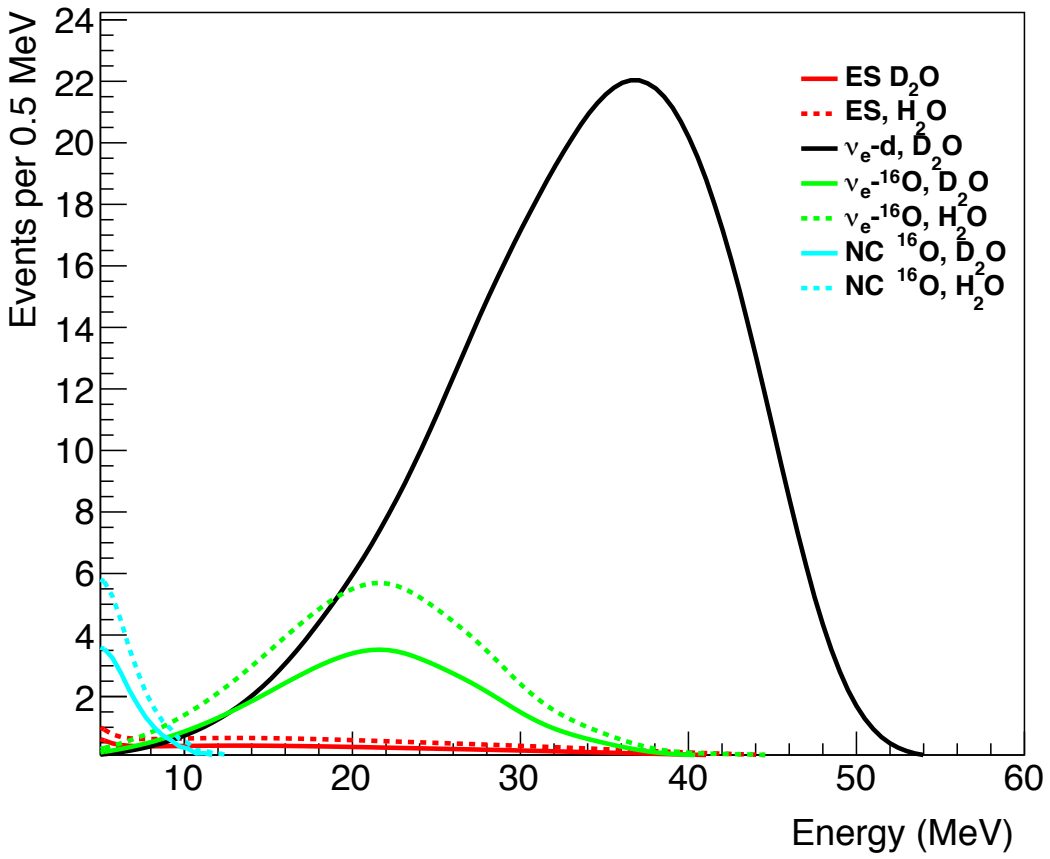
Dominant Beam Related Backgrounds?

- Updated SnowGlobes tool indicates largest beam related background is charged current on oxygen
- With a nominal 10cm tail catcher, 1.3 tons of D_2O requires 1.8 tons of H_2O. The latter produces Cherenkov too.
- Full detector response model needed for accurate optimization.



SnowGlobes

SNS flux weighted ν_e-d CC xscn by Jes Koros
SNS flux weighted ν_e-O CC xscn by Kate S.

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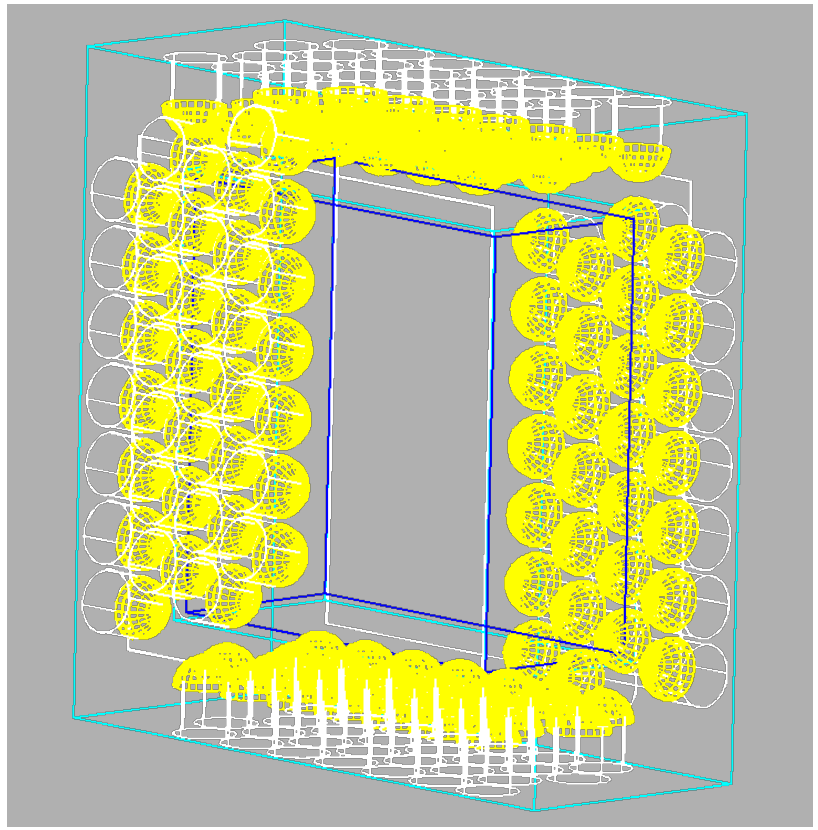
How much light water is optimal?

- G4 Simulation
  - 1.3 tons of D_2O (60×140×140 cm)
  - 1 inch acrylic tank
  - Light water gap to reflector/PMT {5,10,15,20} cm
  - 8 Inch Bialkali PMT on four sides
  - 0.25 Inch Teflon reflector on 2 sides
  - No reflector between PMTs



Geant4 Model
Matthew Blackston

- 160 PMTs for TC=15,20 cm
- 112 PMTs for TC=5,10 cm

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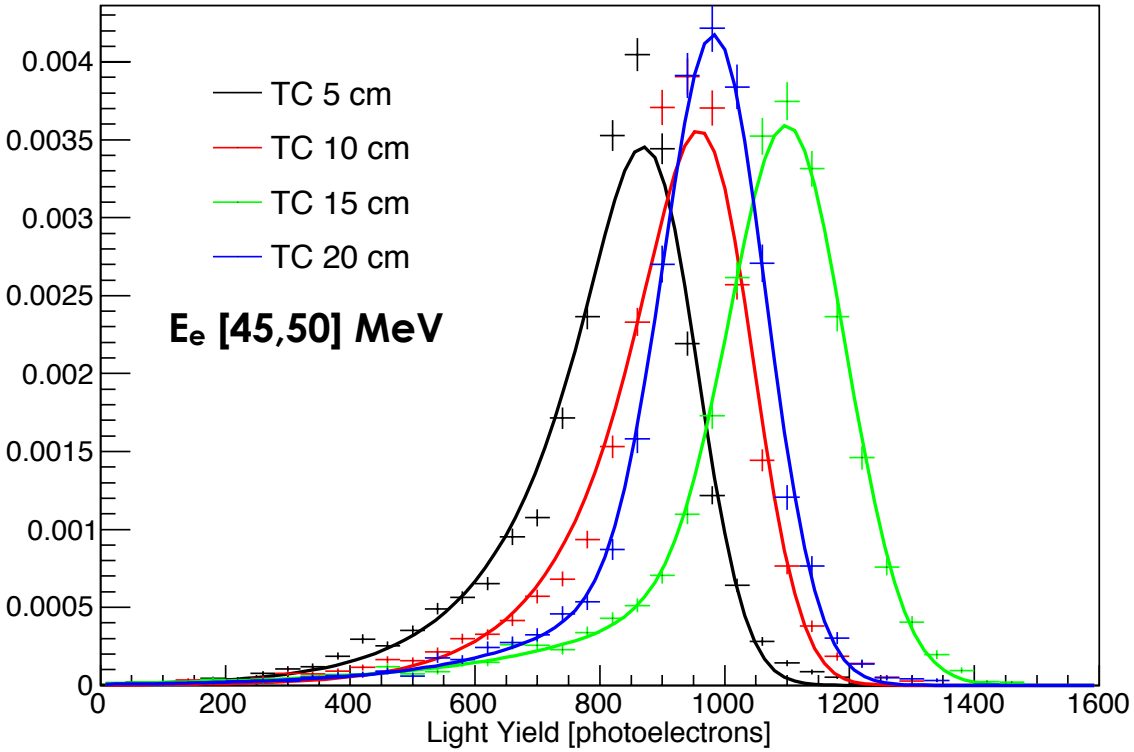
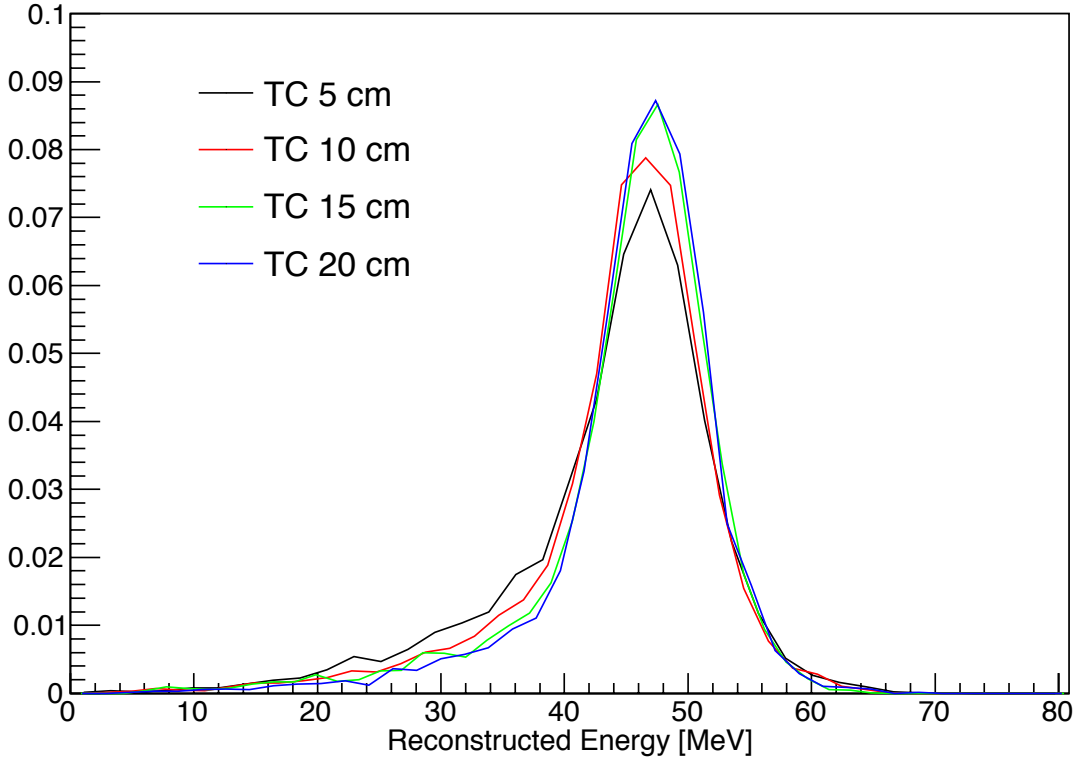
Energy Resolution Degrades slightly with less H_2O





- 200k electron recoils thrown for each TC
- E_e 0-55 MeV
- E dependent QE applied at PMT

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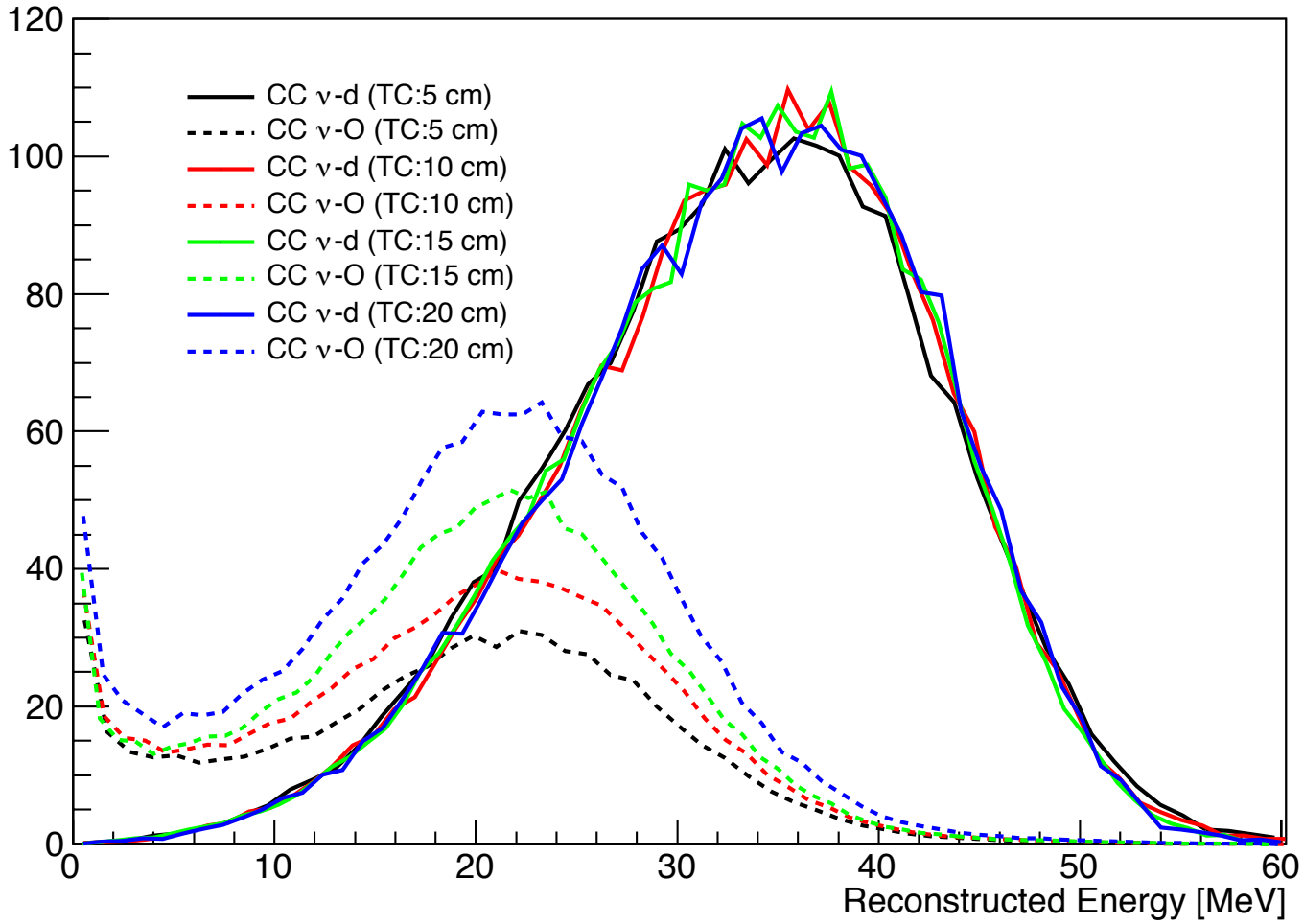
Flux Weighted Distributions for 2 SNS Years @ 1.4 MW



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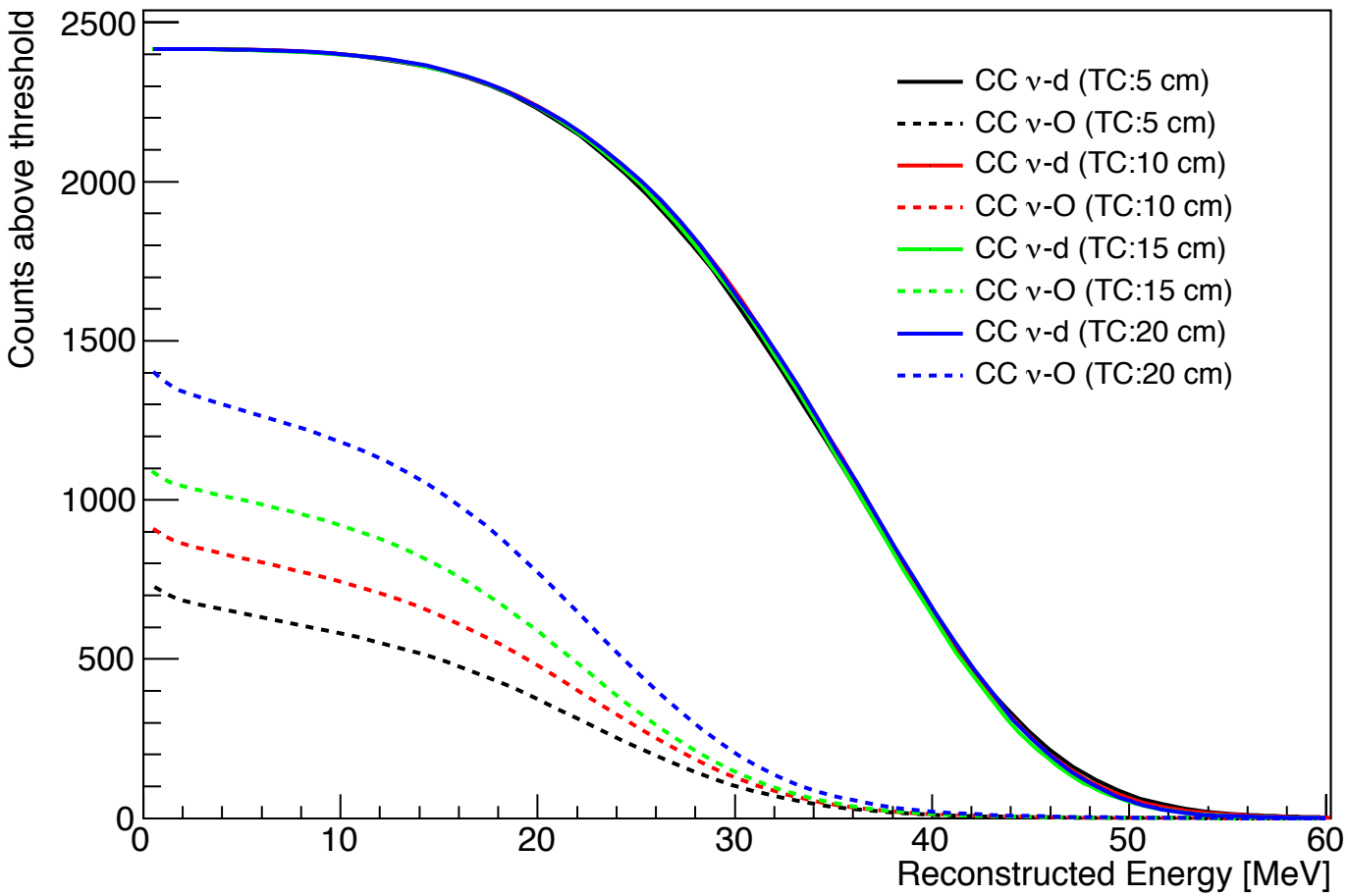
Integrated Counts above threshold



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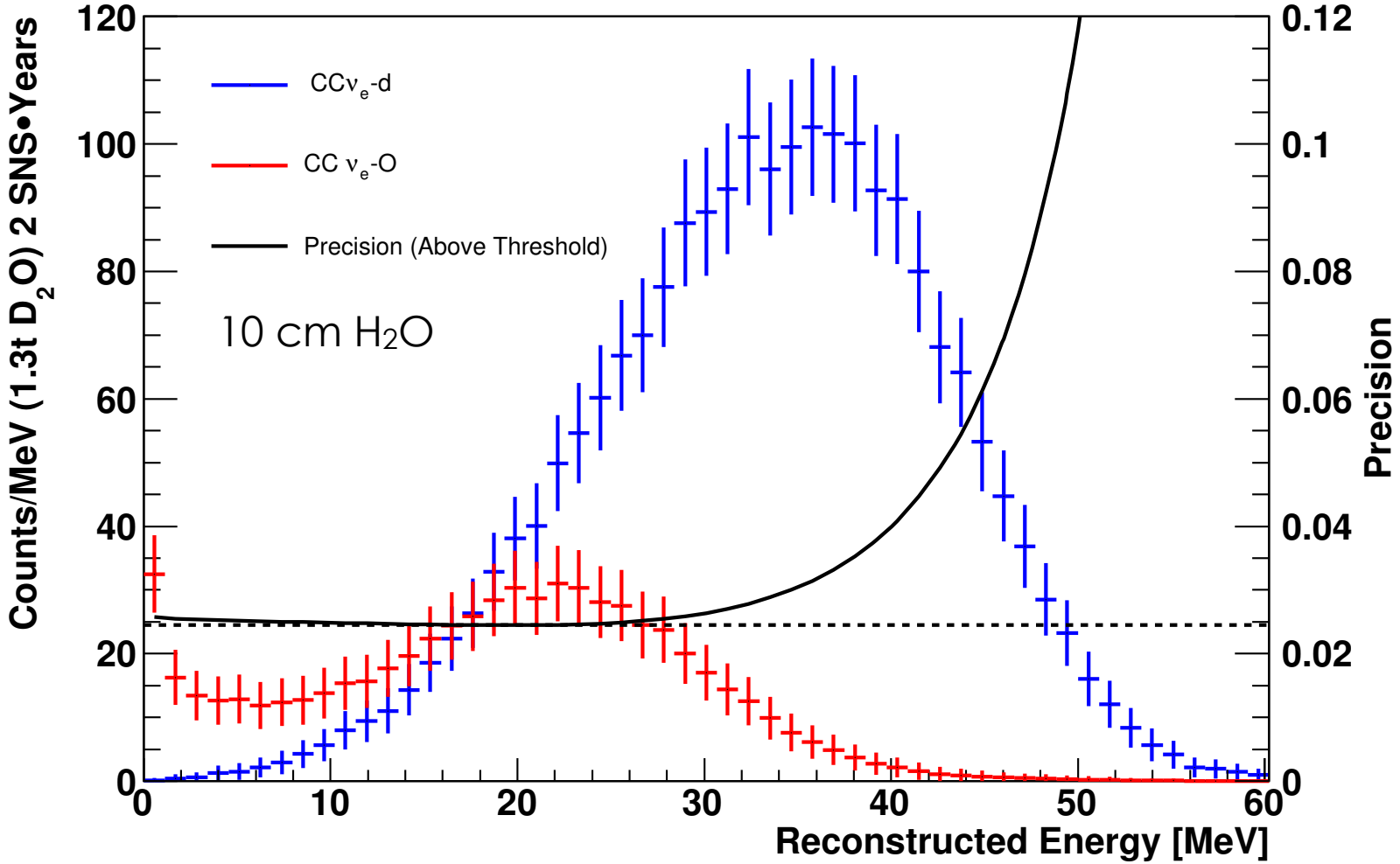
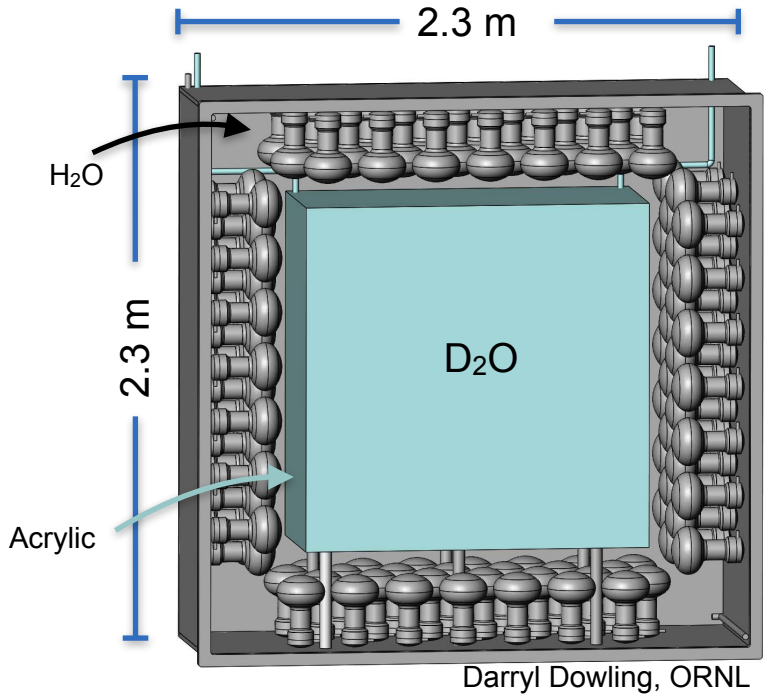
Measurement Precision with 2 SNS years at 1.4 MW





- 1.3 tons D_2O within acrylic inner vessel
- 10 cm H_2O “tail catcher” for high energy e^-
- 112 8” bialkali photomultipliers

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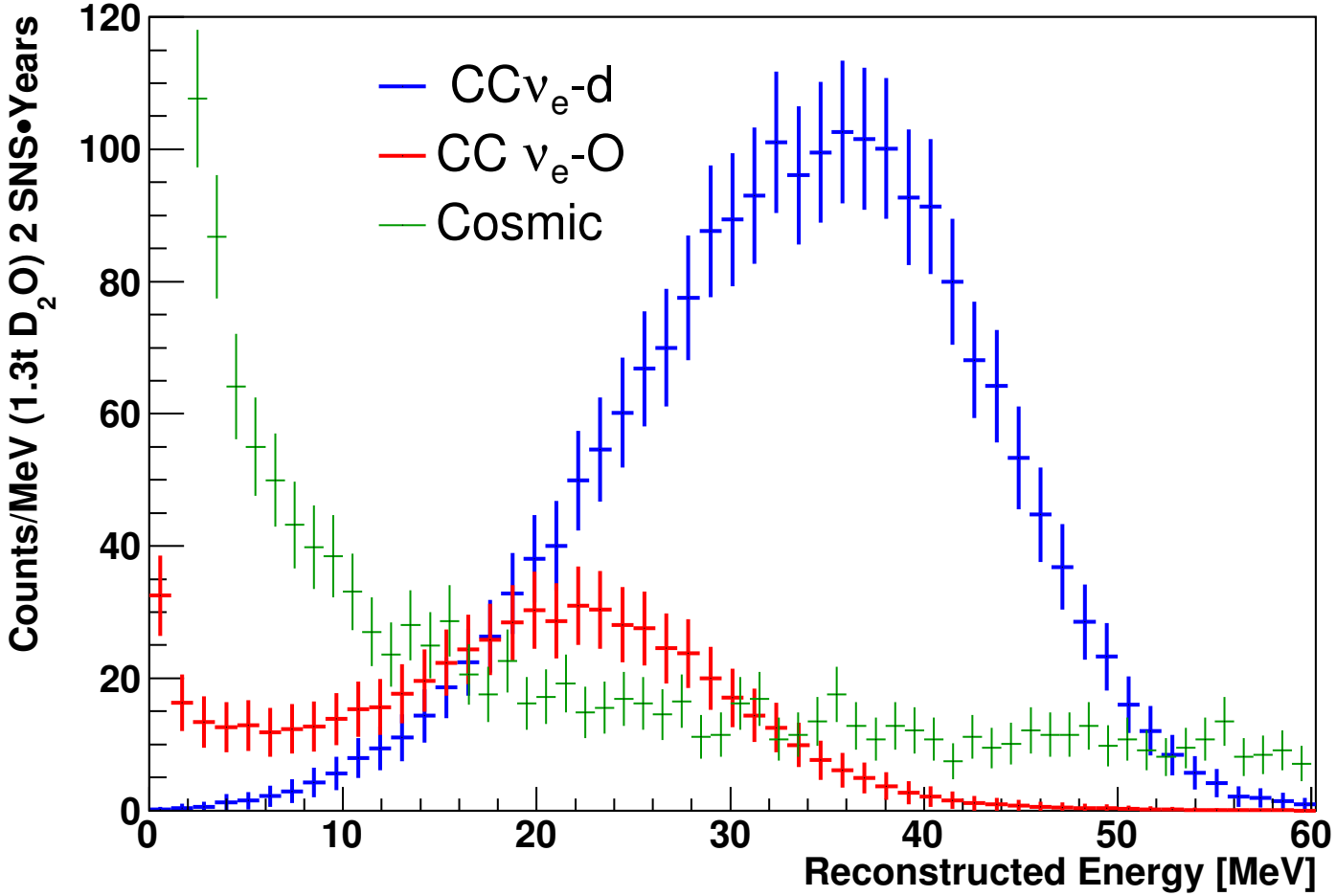
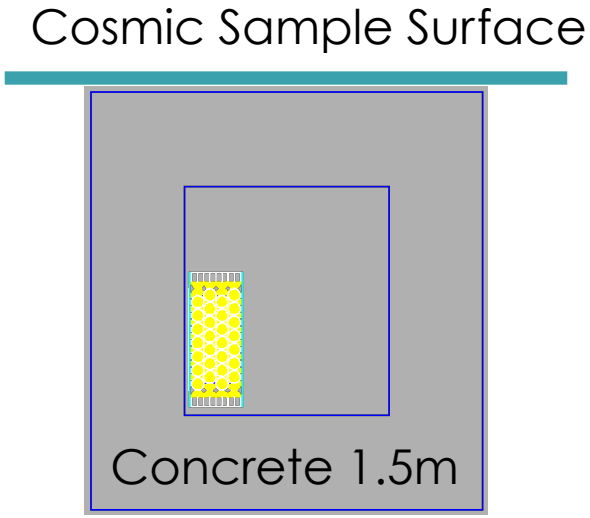
Cosmic Backgrounds



- Geant4 simulation using LLNL CRY package
- Neutrino Alley simulated as 1.5 m concrete ceiling, wall, and floor.
- 10×10 m surface sampled for 35 seconds scaled to 2 SNS years with 5μs beam coincidence window.
- Assuming 99.9% cosmic veto efficiency



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Design Considerations

- Photocathode area: PMT size vs space vs cost, Energy Resolution
- Side Teflon optical reflectors
- Muon veto system
- Gamma shielding
- Water Purification
- Position Dependent Calibrations diffuse laser, γ-sources, n-sources

Component Costs

- 1.3 tons D2O from isotopes.gov $430k
- 160 8 Inch Bialkali R5912 $146k
- PMT Packaging $64k
- 176 Channels of 250MS/s 14-bit Digitizers (SIS3316) $120k
- Shielding $40k

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Summary

- Direct SNS neutrino flux measurement feasible with ton-scale heavy water detector in Neutrino Alley.
- Simulations indicate light collection on 4 sides is sufficient for uniform response over fiducial volume.
- Background simulations needed to address shielding and cosmic veto requirements.
- Initial mechanical design underway for accurate costing.
- Replacement of D_2O with H_2O for CC neutrino interactions for SN neutrinos with Oxygen.

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