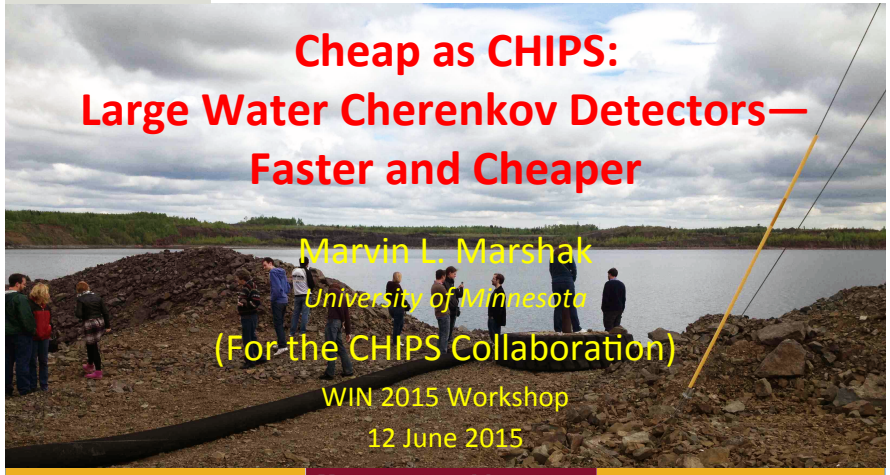
25th International Workshop on Weak Interactions and Neutrinos (WIN2015)

June 8–13, 2015, MPIK Heidelberg, Germany



Cheap as CHIPS: Large Water Cherenkov Detectors—Faster and Cheaper

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University of Minnesota

(For the CHIPS Collaboration)

WIN 2015 Workshop

12 June 2015

Long-Baseline Neutrino Physics

- For at least the next decade, Long Baseline Neutrino Physics (LBNP) has a clear plan:
  - Determine the mass hierarchy
  - Measure δ_{CP} as well as possible
- For the next decade or so, LBNP also has significant assets:
  - NuMI Beam, with NOvA and MINOS+ Near and Far Detectors
  - T2K Beam, with Super Kamiokande Detector
- Data collection with new, large underground experiments is unlikely to start much before 2025
  - Technically-driven schedules include complex construction requirements.
  - Funding levels are uncertain.
  - The multiple planned short baseline experiments will likely contribute to the development of LAr techniques, but not to LBNP physics.
  -

Long Baseline Neutrino Physics

What to do? **CH**erenkov detectors **I**n mine **P**it**S** (CHIPS)

Utilize existing infrastructure as much as possible

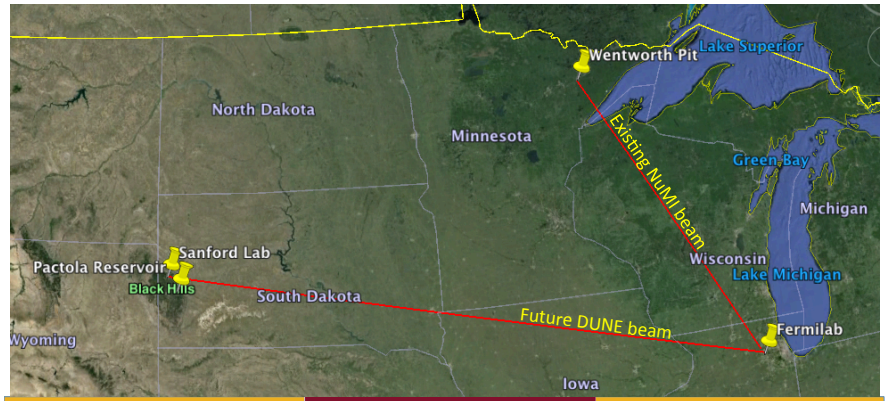
- Phase 1: Existing Infrastructure
  - NuMI Beam
  - Wentworth Pit
    - 1250 m x 750 m x 70 m
    - ~50 MT of water
- Phase 2: Planned Infrastructure
  - DUNE Beam
  - Pactola Reservoir
    - 2nd oscillation maximum of 20 mr
- Much of Phase 1 instrumentation can be utilized for Phase 2

NuMI Beam

- Running since 2005
- 3.5 x 10^{13} protons/pulse
- ~380 kW, 120 GeV beam
- 2.2 sec cycle time
- Two magnetic horns
- Movable target & horns to adjust energy spectrum
- Proton Improvement Plan (PIP) underway
  - 700 kW
  - 1.7 sec, then 1.33 sec cycle time

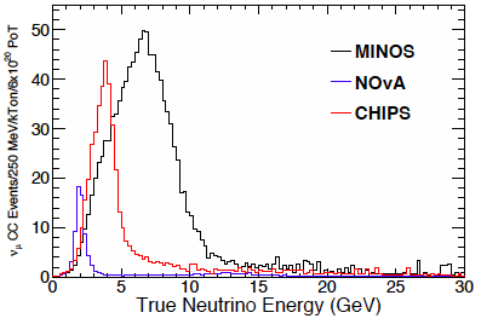
CHIPS Collaboration

Caltech, Cincinnati, Iowa State, Fermilab, Univ. College London, Minnesota, Minnesota Duluth, Pittsburgh, Stanford, Tufts, Texas, William and Mary, Wisconsin



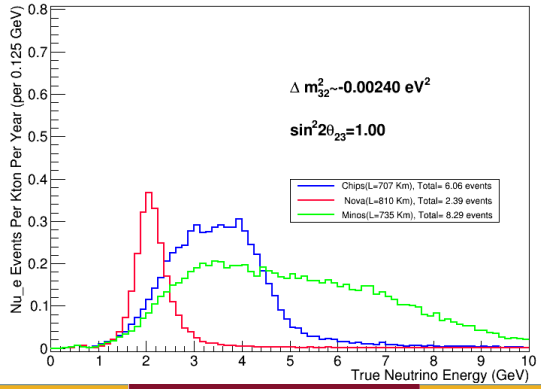
NuMI nu mu ccBeam Energy Spectra

- Wentworth Pit is 7 mr off-axis in the NuMI Beam (red).
  - Optimized for flux and background rejection.
- MINOS+ (Soudan) is on-axis (black).
- NOvA (Ash River) is 14 mr off-axis (blue).



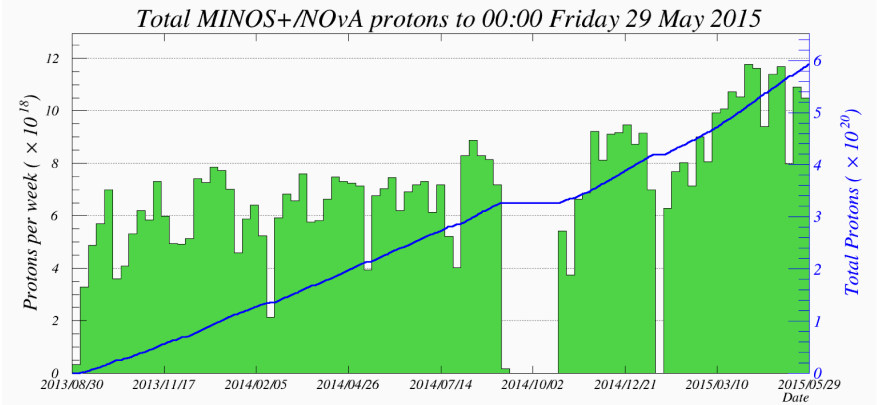
NuMI nu e cc Beam Event Rates

- This plot compares the per kiloton event rates for NuMI Beam experiments.



NuMI Beam Improvements

- Fermilab has developed a program in progress to increase the NuMI power, currently at about 400 kW, to 700 kW.

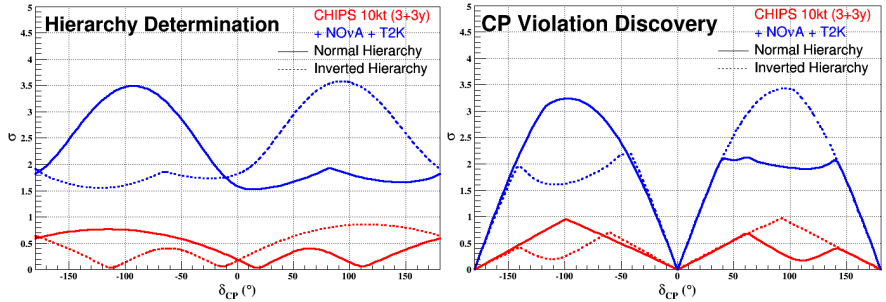


CHIPS Phase 1 Strategy

- CHIPS-M
  - 33 ton prototype, 4 ICECUBE Digital Optical Modules (DOMs), aluminum frame, fabric liner, continuous water filtration
  - Installed under 60 m water August 2014
  - Operated August 2014 to June 2015
  - Removed for modification 9 June 2015
  - Scheduled for 2nd run beginning August 2015
- CHIPS-10
  - 10 kT detector currently under development
  - Install in Wentworth Pit in 2017
- CHIPS-100
  - Eventual detector for NuMI Beam

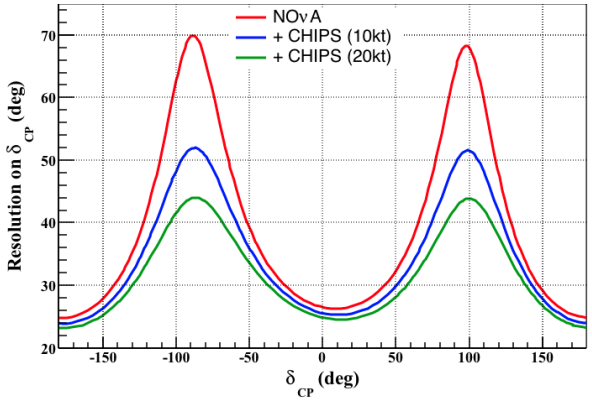
Physics Potential of CHIPS-10

- CHIPS-10 adds to the sensitivity of NOνA and T2K. Combined data from the three experiments likely makes interesting measurements of both the mass hierarchy and δ_{CP} in the pre-DUNE/HyperK era.
- These GLoBES plots assume three years of neutrino and three years of antineutrino data collection.



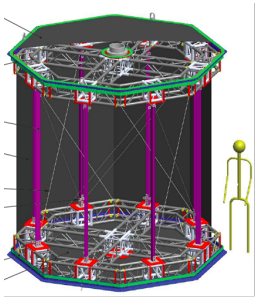
Physics Potential of CHIPS 10

- Assuming mass hierarchy is known, CHIPS 10 would reduce uncertainties in NOνA's measurement of δ_{CP}.



Experience with CHIPS-M

- Constructed summer 2014
- Deployed in Wentworth Pit August 2014



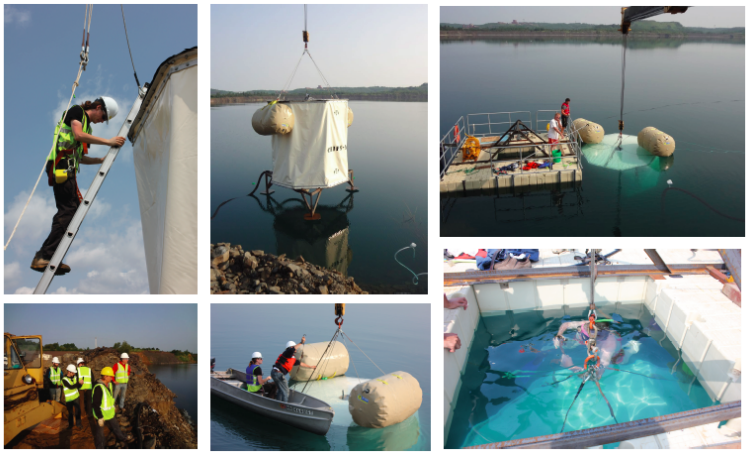
Spring 2014

June-July 2014

August 8, 2014

Construction accomplished mostly by students and postdocs!

Deployment of CHIPS-M



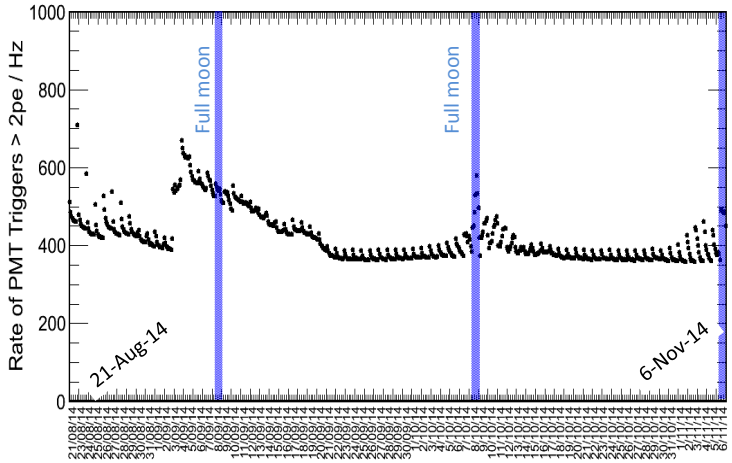
Water Characteristics

- CHIPS is under ~6 bar of pressure, which reduces bubbles.
- CHIPS ambient temperature is 4° C, which reduces probability of bacterial blooms.
- Water system treats water during both initial fill and recirculation.
  - Filters remove particulates down to 0.2 µ.
  - Activated carbon removes organics and life forms.
  - UV sterilization also reduces life forms.
- Offline water studies use 8 m long vertical column.

Measurements with CHIPS-M

- Detector can be operated over the winter despite outdoor temperatures as low as -40° C.
  - Propane used for heat of control room and for providing electrical power for electronics.
  - 24/7 reliable mobile phone network to permit remote control and data access.
  - Umbilical cable enters the pit underground, beneath the surface ice layer.
- Detector has a light leak and sunlight penetrates to bottom of the pit.
  - Operated only during hours of darkness.
  - Full moon causes substantial jump in the counting rate.
- Water may attack aluminum and galvanized iron in detector and precipitate black sulfates.

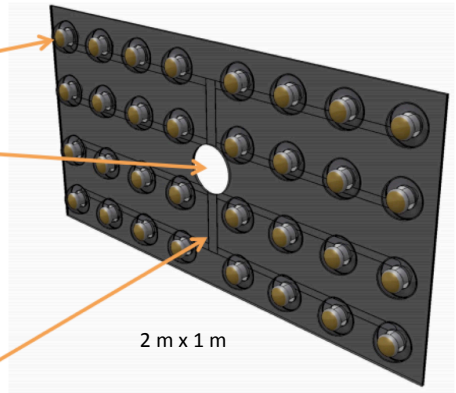
Rate of PMT Triggers > 2 pe



Summer 2015: NIKHEF KM3NeT Plane)

Plane design

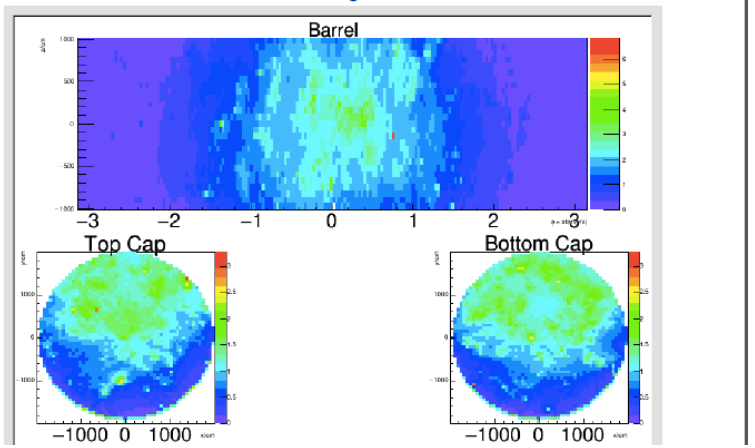
- 31 PMTs on an acrylic plane
  - Encased in acrylic hemispheres on both sides
- Readout electronics in a central aluminium container
  - Currently in design
  - Two copper wires provide power, one fibre for communication with shore
- Two sheets sandwiched together with cables routed in grooves on the inside



CHIPS Design Strategy

- The design strategy for CHIPS includes:
  - Reduced instrumentation of the backward direction (backward light is used as a veto)
  - Small tubes with 2 ns timing resolution
  - Combine long distance, tight position resolution and good timing to facilitate reconstruction
  - NIKHEF plane coverage is currently 7%; 5% is longer term goal. (NIKHEF plane are 1.5 m by 2 m; cost is 7200 euro
  - Overall photocathode density is 3% is 3% 1.5 x 2 m for 7200 euro; 250 planes for CHIPS 10; 250 NIKHEF-style planes are needed for CHIPS 10.

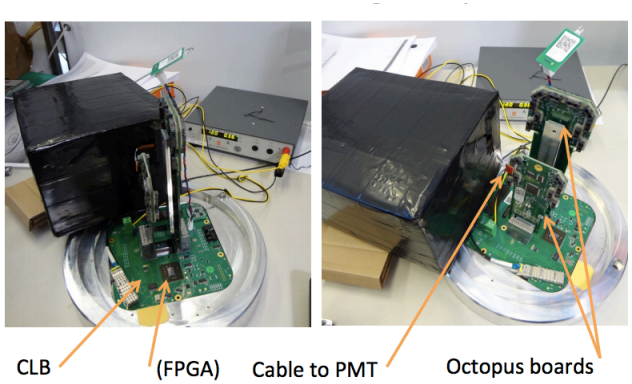
Hit Map 2000 ν_eCC Events



Signal events don't need to instrument the whole detector

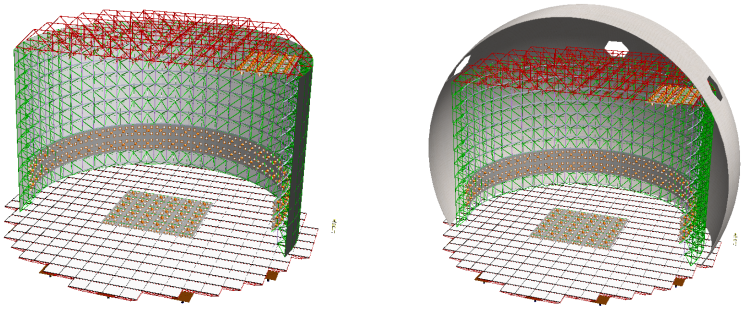
KM3NeT Electronics from NIKHEF

Complete package FPGA PMTs Control Boards Fiber Ethernet



Concepts for CHIPS-10

- 10 kT Detector to be constructed in 2016-2017
- Use large numbers of smaller phototubes for better pattern recognition and lower cost. Some recycled tubes are available.
- Several designs under consideration, using fabric or fiberglass skins.



Summary

- The CHIPS concept enables data collection from a new, large long baseline neutrino detector in less time than any other currently discussed projects.
- CHIPS-10 combined with NOνA and T2K has significant physics potential in the pre-DUNE/HyperK era. These results may help optimize the DUNE/HyperK designs in a way that is not accessible to the plans for multiple LAr short baseline experiments.
- One winter's experience with CHIPS-M has validated some ideas, pointed out problems, and provided a basis for a retrofit this summer (2015).