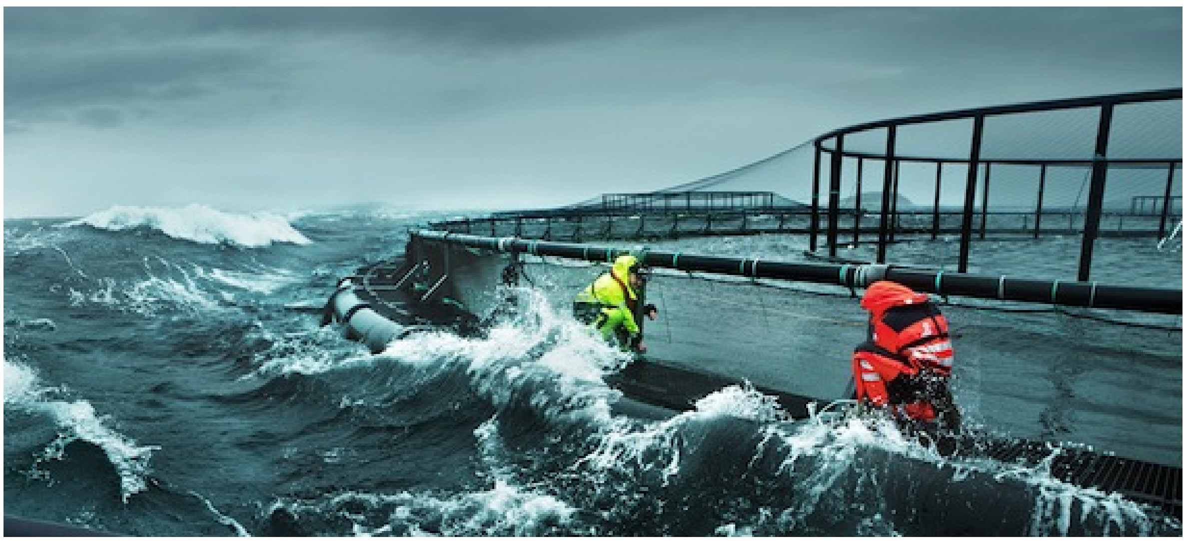
CHerenkov detectors In mine PitS (CHIPS)
A White Paper

J.Thomas, C. Wendt, A. Habig, K. Lang, J.K.Nelson

- Primary Goal: Measurement of δ_{CP} to $\approx$15-25^o for all values of δ_{CP} by 2022
- Primary Goal: 1% measurement of $\sin^2(2\theta_{23})$
- Secondary Goal: Factor 2 improvement in the MH coverage above 90% C.L. in combination with NOνA



A floating platform used in the fisheries industry

Figure 1: Left: A typical mine pit in Minnesota on a lovely day. Right: Satellite map of a small region populated with mine pits at off-axis angles between 12 and 20mr (also on a nice day).

CHIPS Physics Goals

- Primary Goal: Measurement of δ_{CP} to ≈15-25^o for all values of δ_{CP}
- Primary Goal: 1% measurement of $\sin^2(2\theta_{23})$
- Secondary Goal: Factor 2 improvement in the MH coverage above 90% C.L. in combination with NOνA

CHIPS: 100kt Water Cherenkov Detector (WCD).

CHIPS would deliver complementary information to NOνA to enable the best reach from the NuMI beam in terms of δ_{CP}, and MH via a 1% measurement of $\sin^2(2\theta_{23})$. Preliminary simulations show that 100kt of WCD has an equivalent reach to 20 kt of LAr. The most efficient unit is 50 kt, from considerations of light attenuation and cosmic ray background. There are a number of mine pits in the vicinity of the Soudan mine, which could be used to deploy such a detector. The concept uses design elements from the WCD option at LBNE, with adaptations for deployment from a floating platform. University groups could play a leading role in construction and testing of the detector.

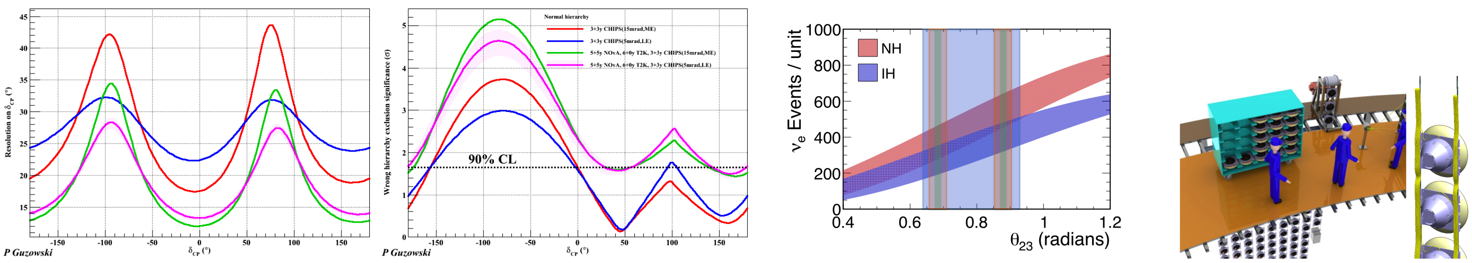


Figure 2: 1st panel: accuracy of δ_{CP} measurement for 100kt CHIPS with 6 years of running with 0.5% NC contamination at 5mr off-axis (LE), 15mr off axis (ME) at 700 km baseline and both combined with NOνA and T2K. 2nd panel: MH reach for same, pink shaded region indicates example uncertainty on mixing parameters. 3rd panel: number of predicted ν_e events together with the error band from $\sin^2(2\theta_{23})$(4%(SuperK, blue transparent band), 2.5%(NOνA predicted, orange bands) and 1%(CHIPS, green bands)). 4th panel: conceptual design envisaged for the CHIPS deployment.

A GLOBES calculation of the combined reach of NOνA, T2K and CHIPS is shown in Figure 2 1st panel. Placing the detector off axis can aid precision in the ME beam but a 5mr off axis angle in the LE beam shows better precision in δ_{CP}, at complementary regions of δ_{CP} to far off axis or NOνA. The 2nd panel shows the reach for MH. The main uncertainty is the level of NC background rejection which can be offset by choice of off-axis angle. A complete optimization of reconstruction efficiency, background rejection and detector position has not yet been completed. WCD QE reconstruction has been proved to be efficient at and below 1.6 GeV, the oscillation maximum for CHIPS, and therefore a 1% precision measurement of $\sin^2(2\theta_{23})$ could be delivered (CHIPS would have a factor 60 higher statistics than the full MINOS dataset) using a Near Detector measuring low intensity sample runs. This precision measurement is essential to reduce the error on the predicted number of ν_e events, presently one of the limiting factors in MH reach for all the LB experiments shown in 3rd panel of figure.

The map (cover), shows several of the flooded mine pits at off axis angles of between 12 and 15 mr. A study of the water clarity for the Wentworth pit (off-axis at 6mr) is underway along with a full survey of depths and positions of other pits in the area. CHIPS would be suspended from a floating dock and assembled with underwater cage components using commercially available technology from the fisheries industry, to the maximum depth available for the pit. The detector volume would be enclosed by an opaque polymer membrane, like ones used in the roofing industry, and filled with purified water. Photomultiplier tubes would be deployed in water tight housings lowered along strings and frames attached to the underwater cage (4th panel). The conceptual design combines features from the LBNE WCD and IceCube. Digitized signals would be sent to links at the surface. Common marina technology would be used to keep floating structures free of winter ice.

Preliminary estimates put the total procurement cost at about \$80-100 M for 100 kt of water with 10% PMT coverage manpower brings this to ≈\$120M. Cost optimizations would be considered including the PMT coverage and choice of electronics for HV and readout.

Summary

CHIPS could provide a ≈12-25^o accuracy on δ_{CP} depending on exact position and beam energy, and an increase in the mass hierarchy reach of a factor 2, in combination with NOνA. An essential, very high precision measurement of $\sin^2(2\theta_{23})$ at the level of 1% could be made making use of a Near Detector. This experiment could potentially be redeployed to study the LBNE neutrinos when they are produced.