

PINGU, MicroBooNE & LAr1-ND













The MSW effect

Atmospheric neutrinos pass through the Earth

> Feel an interaction with the Earth's matter

Electron neutrinos feel an additional interaction

- > Acts like a refractive index
- > This effectively changes the mixing angles







All flavours

Electron flavour





Neutrino oscillations in matter





Neutrino oscillations in matter

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PINGU

- 40 new strings in the central region of IceCube & DeepCore
 - > 20 m between strings
 - 5 m vertically between DOMs
- Energy threshold down to a few GeV





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DeepCore



DeepCore released impressive new oscillation measurements this summer



The University of Manchester Hierarchy sensitivity

arXiv:1401.2046



At least 3σ sensitivity after four years of running

 \succ Can be even easier to determine, depending on the value of θ_{23}

The University of Manchester The global situation after Blennow et al., arXiv:1311.1822

; LBNE 34 kt LBNE 10 kt Preliminary Sensitivity [σ] = $\sqrt{\Delta\chi^2}$ Hyper-K PINGU JUNO TNO 2 NOvA 0 2015 2020 2025 2030 Date

PINGU is the most competitive medium-term experiment

Supported in the recent P5 report

A very affordable option

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- <10% the price of LBNE</p>
- > A small contribution can make the UK a major player



UK groups

Manchester

- Convener of mass hierarchy group
- Working on DeepCore oscillation analysis

Queen Mary

Expertise in neutrino interactions and cross sections

Oxford

- Theory group
- Significant European involvement
 - Germany, Belgium, Sweden, Denmark

This effort is currently unfunded by STFC

> Since it came along after the programmatic review

Risk of losing a major opportunity for UK particle physics

> To determine the mass hierarchy within the decade



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Queen Mary University of London





Sterile neutrinos



LSND and MiniBooNE see v_e appearance signals consistent with short-baseline oscillations

But is this a non-neutrino background? Or an inherent v_e component of the beam?
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MicroBooNE



Repeat MiniBooNE

- > But with a superior detector: liquid argon TPC
- > Greater ability to reject NC electromagnetic activity



MicroBooNE

87 ton active mass 2.5x2.4x10.4 m³ TPC

- Recently moved into its final location in the Booster Neutrino beam
- Commissioning will occur this autumn
- First neutrino events by the end of the year





UK involvement

Oxford

- > Level-2 project manager for the TPC
- Cosmic muon detector system for commissioning
- Development of run control software
- Event reconstruction

Cambridge

> Development of PANDORA event reconstruction chain

Manchester

- > Not yet MicroBooNE members, but a new academic (Georgia Karagiorgi) will join in January
- Convener of MicroBooNE oscillation group
- > Commissioning MicroBooNE readout
- > $n-\overline{n}$ and proton-decay analyses



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MANCHESTER The University of Manchester The need for a Near Detector

MicroBooNE alone may not answer the sterile neutrino question

- \succ It can tell us if the excess is really electron neutrinos
- It can't tell us if those electron neutrinos are intrinsically in the beam or arise via oscillation

MicroBooNE @ 470 m





LAr1-ND



A liquid argon near detector for MicroBooNE

- > Characterize the beam composition
- A near-far comparison cancels many systematic uncertainties (e.g. cross sections)



LAr1-ND





The benefits of a Near Detector





UK hardware contribution

UK will build much of the TPC

- Sheffield: anode frame
- Manchester: anode wiring
- Liverpool: cathode plane
- Lancaster: cold testing
- VCL: high voltage feedthrough

Vital part of our LBNE proposal

- > Sets us up to make a significant construction contribution to the LBNE FD
- LAr1-ND builds IL experience and demonstrates that the UK can build a working TPC

Oxford and Cambridge are also collaborators









PINGU

 \geq

neutrinos



MicroBooNE

Investigating the MiniBooNE lowenergy excess with a liquid argon TPC

LAr1-ND

Forming a highly sensitive twodetector search for sterile neutrinos