# Notes on PPAP Neutrinos + non-accelerator-based physics Day: 15th July 2009

## (1) Draft PPAP findings

*NB: These notes do not represent a verbatim transcript of everything said on the day, but rather provide a brief summary of the main points which came up in the discussions. For details of the presentations please see the slides on the agenda page at*

http://conference.ippp.dur.ac.uk/conferenceDisplay.py?confId=275 .

Neutrinos

- Neutrino physics is an exciting area. There have been notable advances over the past decade, namely the observations of mixing between neutrinos in different generations, and the subsequent explanation of the atmospheric and solar neutrino data in terms of mixing among neutrino species with non-zero mass. Several recent Nobel Prizes have been awarded in this area.
- Key measurements in the neutrino sector include: the size of the mixing angle theta-13, and, if the angle is large enough, search for direct CP violation in the neutrino sector; determination of the neutrino mass scale, the sign of the mass ordering of the species, and the Majorana vs. Dirac nature of the neutrino.
- Existing long-baseline experiments (MINOS, miniBoone) are due to complete data-taking in the next couple of years. For measurements of theta-13 next generation long-baseline experiments (T2K, Nova), as well as reactor-source experiments (DoubleCHOOZ, RENO, Daya Bay) are under construction/ being commissioned. In addition, the possibility of a wideband beam from Fermilab to DUSEL as part of Project X is being actively discussed in the US. By around 2015 it should be known if theta-13 is 'large' or likely to be 'small', i.e. sin**2(2 theta-13) < 0.01. If the angle is 'large' conventional-beam long-baseline experiments, with very large detectors, would be able to search for CP-violation; if the angle is 'small' a beta-beam facility, or neutrino factory, would be required to extend the search range down to very small angles sin**2(2 theta-13) ~ 0.0001. Precise measurement of sin**2(2 theta-13) is hence crucial for determining the nature of future long-baseline neutrino facilities and experiments. A major decision point will arise c. 2014/2015 when the sensitivity to sin**2(theta-13) is likely to have reached around 0.01.
- The UK has made significant investments in MINOS and T2K. There has been a small involvement (Sussex) in DoubleCHOOZ.
- There is worldwide R&D activity in developing technologies for future large-scale neutrino detectors based on e.g. water Cerenkov detectors, scintillator based tracking calorimeters, emulsions, and liquid argon TPCs. There is European coordination and funding via FP6/7 activities such as Euronu and LAGUNA. The UK is pursuing currently small-scale R&D on liquid argon (Sheffield, Warwick) and scintillators (Brunel). A SoI on liquid argon has been submitted to STFC. In order to pursue the R&D over the next few years several £M may be required; a large-scale detector might cost O(£100M), with a possible UK aspiration to contribute at the 10% level. There was some feeling that the UK should focus its efforts on a small number of promising R&D avenues.
- The UK is active in R&D for a possible future neutrino factory; this is the only currently conceived large-scale particle physics facility which might stand any chance of being built in the UK. The cost is not known, but likely to be at the several billion £ level. The UK hosts the MICE (muon cooling) experiment at RAL and leads the international neutrino factory design study. There was some feeling that a very significant ramp-up in resources would be needed in order to mount any credible UK bid to host a neutrino factory, well beyond what could be accommodated within the UK particle physics programme as it stands. The Boulby Mine is a possible site for a future large neutrino detector in the UK if the beam were provided by a neutrino factory or a beta-beam located at CERN.
- There was some feeling that strategic investment in R&D for future neutrino detectors/facilities needs to be carefully balanced against physics exploitation of the current and soon-to-be running experiments.
- There are two 'single' beta-decay experiments which aim to address primarily the (electron) neutrino mass scale; the UK has some involvement (Swansea, DL, UCL) in participating in the main experiment, KATRIN; a possible investment at the level of £100k/an might be required.
- There are numerous ideas worldwide for detectors to search for neutrinoless double-beta decay, which would demonstrate the Majorana nature of the neutrino. The next generation of experiments

are starting to reach the theoretically interesting level of sensitivity for inverted hierarchy and will be able to test the Klapdor claim. The UK has expressed strong interest in SuperNEMO (UCL, MSSL, Manchester, IC) and SNO+ (Oxford, Sussex, Leeds, QMUL). In both cases data-taking could start around 2012 and would go on for several years. Likely UK investment in the development phase of SuperNEMO is c. £1.8M/an from 2009-12. The construction phase (2012-19) could involve a further £10-15M-scale contribution. A proposal is being developed for a smaller-scale investment in SNO+ at the level of £400k/an. SuperNEMO is seen as essential to firmly establish any claimed signal from other experiments.

Dark Matter

- The search for dark matter is an active area worldwide. The field has pushed down the limits on the DM coupling by roughly an order of magnitude every 3-4 years. Numerous groups have pursued particular detection technologies. Recently there has been coalescence into larger consortia which aim at eventual detectors in the ton mass range, based on multiple event signatures (scintillation, ionization, phonons).
- The UK plays a leading role in dark-matter search experiments. It leads two international consortia: EURECA (Oxford, Sheffield) and LUX-ZEPLIN (IC, RAL, Edinburgh) for development of large-scale detectors based on phonons and scintillation, and scintillation and ionization, respectively. There is additional interest in R&D on directionally-sensitive detectors (CYGNUS/DRIFT – Edinburgh, Sheffield) and liquid argon detectors (ArDM - Sheffield). The directional detectors would be designed with capability to measure the 'WIMP wind' as a function of diurnal position. Future ton-scale detectors will probably cost O(£100M); at current pro rata this might imply UK investment at the £15-20M level.
- There is scope for expansion at the Boulby Science Facility to accommodate low-background underground R&D facilities and detectors; the mining company is expanding into hard rock, which could provide a capability (unique in the UK) for (a) large underground detector(s) in a low-background environment.

Dipole moments

- The search for neutron and electron electric dipole moments provides a complementary window on possible new physics effects via loop contributions; Standard Model effects typically enter via 3-loops and are order 10^6 times smaller than possible beyond-SM contributions from, for example, SUSY, which enter at 1-loop order.
- The UK leads forefront experiments on both neutron and electron EDMs. CryoEDM (Sussex, Oxford, RAL) is being commissioned; results are expected in 2011-12 at the sensitivity level 3 .10**-27 ecm; a proposal is in preparation for a possible future phase, leading to a limit of 3.10**-28 ecm by 2016. The eEDM experiment (IC) has the capability to improve its current limit from 10**-26 ecm to 10**-29 ecm within about 5 years.