1. Physics and phenomenology

1.1 Context

Themes in today's particle physics:

- Origin of mass: Higgs & Tevatron, LHC, ILC
- Origin of flavour:
  - In quark sector: Babar, Belle, Tevatron, LHC, ILC, …
  - In lepton sector: <list of neutrino and muon experiments>, future experiments …
- Search for new physics, SUSY etc: Tevatron, LHC, ILC, CLIC, rare decays (muon, kaon, etc.)

Goal is to show importance of developing future neutrino programme in terms of an overall vision of the field.

1.2 Review and overview

1.2.1 The standard scenario

- 3-flavour mixing: issue is to define terminology. Need to include absolute mass scale, and Majorana/Dirac nature.
- Need to note absence of charged lepton mixing in the standard scenario. Reason is to carry through muon case.

1.2.2 Alternative hypotheses

Neutrinos:

- Non-standard phenomenology: e.g. more than three neutrino species. Note that it is expected that LSND will have produced a result by the end of the study.
- Models: SUSY etc. Reason is to show that there are underlying mechanisms that precision measurements of neutrino oscillation can probe. Need to lay the foundations for consideration of the precision that is required to probe the various models and the analysis of the precision which can be achieved in the various facilities.

Muons:

- Non-standard phenomenology: physics of searches for lepton flavour violation (LFV) and a permanent electric dipole moment (EDM).

1.2.3 Impact

Study of properties of neutrinos, and muon properties and decays beyond the standard model, impacts many fields beyond 'just' neutrino physics. So, review impact of these measurements on:

- Cosmology: e.g. leptogenesis. Complementarity with cosmological constraints on absolute neutrino mass scale.
- Astrophysics: e.g. large-scale structure
- Dark matter constraints from the muon sector.

1.2.4 Definition of context

Neutrinos:

- Present knowledge;
- Likely development over next 5, 7, 10 years, i.e. set context in which next generation facility will operate;

- Define remit: i.e. review the measurements that are required beyond planned experiments, i.e. in the 'precision era'. This means δ, θ_{13} of course, but indicate need for unitarity tests flexibility etc.

Muons:

- Present knowledge
- Likely developments in dipole moments and lepton LFV in near term: muon (g-2), MEG (the $\mu \rightarrow e\gamma$ experiment at PSI).
- Review the physics of the measurements which can only be done at a very intense muon source (HIMS), such as a search for a muon EDM, and detailed LFV studies if it's found at PSI, or more sensitive $\mu \rightarrow e$ conversion experiments and muonium to antimuonium conversion at the HIMS if LFV is not found at PSI.

1.3 Specification

Neutrinos:

For the moment, take the goal to be to get an understanding of the neutrino at least as good as that which we presently have of quarks. Would like to review the precision required, in the precision era not only on δ and θ_{13} but also on the unitarity constraints.

In particular, need to define:

- Assumptions on accelerator performance – for super-beam, beta-beam and NF;
- Assumptions on detector performance – for the options considered by detector group;
- Definition of baseline tools used for analyses: e.g. Nuance/Globes. Need to discuss early if propose to standardise.
- Neutrino cross sections: status and what will be assumed. Through systematic error analysis in section 1.4 will feedback into the needer R&D programme.

This means an initial request for a set of working assumptions and a 'review loop' by which the final set of assumptions is defined.

Muons:

- Take the sensitivity goal for LFV to equal or exceed the PRIME LOI (at J-PARC) single event sensitivity of 10^{-18}.
- Take the sensitivity goal for a search for a permanent muon EDM to be at least 10^{-24} e cm, with a clear path for upgrading this sensitivity by one to two orders of magnitude.

1.4 Performance

Neutrinos:

Need to present results in a 'coherent' way, i.e. building on the definitions from 1.1.1 need to assess performance in terms of the same variables for each option, of course using the assumptions from 1.2. For now I have separated the assessment of performance from the comparison. The performance would have to be presented for each of super-beam, beta-beam and Neutrino Factory so would end up with a series of sub-sections. Would need to consider sensitivity to δ, θ_{13}, precision on standard parameter sets (for unitarity tests for example) as well as measurements that would have sensitivity to the various non-standard scenarios.

Need to include analysis of how to remove degeneracies and ambiguities. Would also need to compress information into a sensitivity chart to allow an accessible summary to be made.

1.4.1 Super-beam

1.4.2 Beta-beam

1.4.3 Neutrino Factory

Muons:

- Need to assess physics performance of muon facility. Perhaps as a function of assumptions from 1.2.
- Study of sensitivity to systematic errors, including backgrounds for the LFV experiments and other systematic errors for the EDM experiment.

1.5 Comparisons & combinations

Crucial contribution: based on specifications for measurements and performance assumptions from 1.2 need to make a critical comparison of the various facilities.

- Physics performance as a function of energy, here or in 1.4?;
- Physics gain at NF from more than one far detector;
- Role of NF if θ_{13} is large;
- Is NF 'better' than combination of other facilities, in principle – and could NF come earlier than the set of facilities that are required to do as well or better;
- Impact of lack of knowledge on neutrino cross sections on measurements from the various facilities.
- Phyiscs gain and symbiosis of a muon facility and muon program at the NF.

Need to present the method by which the facilities were combined, and the assumptions made. Again, need to compress the combined results into a sensitivity chart to allow succinct presentation of the results. Analysis must include removal of degeneracies.

1.6 Conclusions and plans

Conclusions and recommendations, plus the list of future work.