Assessment of the extent to which studies of neutrino properties with solar neutrinos are complementary to those with accelerator beams and the extent to which they duplicate them

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Measurements of neutrino mixing and masses will require investigations using both solar and Earth-based neutrino beams (reactors or accelerators). The early goals will be to test our understanding of the phenomena, restrict the oscillation parameters and see if further investigations have access to CP violation effects in the neutrino sector.

At present we have three pieces of evidence for neutrino flavour conversion: the solar neutrino deficit, the atmospheric neutrino anomaly, and the LSND result. While atmospheric and LSND data are difficult to accomodate within scenarios other than neutrino oscillations, solar neutrinos may still be well explained in the context of alternative mechanisms. Thus, first it will be imperative to show that the deficit in solar neutrinos are due to neutrino oscillations. This will be solved by KamLAND reactor experiment and/or future solar neutrino experiments. Long baseline (LBL) accelerator experiments have no role in this.

If the three pieces of evidence are due to oscillations they point out towards oscillations with hierarchical mass square differences. For solar neutrinos, there are several ranges of $\Delta m^2_{\rm solar}$ still allowed within the present data analysis: Large Mixing Angle (LMA) (with $2\times 10^{-5}{\rm eV}^2 < \Delta m^2_{\rm solar} < 2\times 10^{-4}$ eV^2), LOW (with $\Delta m^2_{\rm solar} < 10^{-7}$ eV^2) or Vacuum solutions (with $\Delta m^2_{\rm solar} < 10^{-9}$ eV^2). Present global analyses prefer the LMA solution at greater than 99% C.L. For any of these solutions $\Delta m^2_{\rm solar}$ is much smaller than any of the other relevant mass differences.

It is this hierarchy between the mass differences relevant to solar and to atmospheric (and/or LSND) oscillations which makes the solar neutrino and accelerator based experiments target different pieces of the puzzle. After putting together all the existing data, one finds out that solar neutrinos are not quantitatively affected by oscillations with the mass differences and mixing angles relevant to atmospheric (and LSND) oscillations. These, on the other hand, can be precisely tested at LBL accelerator experiments studying $\nu_\mu \to \nu_\mu$ oscillations. Accelerator experiments may also probe the sign of $\Delta m^2_{\rm ATM}$, which, again, does not affect solar neutrino oscillations. (See the Executive Committee summary on neutrino oscillations.)

Conversely LBL accelerator experiments cannot provide any precise measurements of $\Delta m^2_{\rm solar}$ and $\theta_{\rm solar}$:

(i) For LOW and Vacuum solutions , the $\Delta m^2_{\rm solar}$ oscillations are totally inaccessible to Earth-based beam experiments even at the subdominant level.

(ii) For LMA (presently the favoured solution by the solar neutrino analysis) the KamLAND reactor experiment in Japan will provide Earth-beam based precise measurements of $\Delta m^2_{\rm solar}$ and $\theta_{\rm solar}$. Further precision on the determination of $\theta_{\rm solar}$ can be obtained with future solar neutrino experiments. (See the Executive Committee summary on solar neutrinos). In this case there will be a subdominant effect of $\Delta m^2_{\rm solar}$ oscillations at LBL accelerator experiments but no precision on the determination of $\Delta m^2_{\rm solar}$ and $\theta_{\rm solar}$ will be attainable. However in this case LBL accelerator experiments will be able to test the possibility of CP because they will be able to measure the product $\Delta m^2_{\rm solar}\sin^2 2\theta_{\rm solar}$, the mixing angle $\theta_{\rm CHOOZ}$, and the CP phase (provided that $\theta_{\rm CHOOZ}$ that governs $\nu_\mu \to \nu_e$ oscillations is not too small).

Summarizing, $\Delta m^2_{\rm solar}$ and $\theta_{\rm solar}$ can only be precisely measured at KamLAND and/or future solar neutrino experiments. $\Delta m^2_{\rm ATM}$ and $\theta_{\rm ATM}$ can only be precisely measured at LBL accelerator experiements. With these parameterers well determined, $\theta_{\rm CHOOZ}$ and the CP phase can be measured in LBL accelerator experiments.

We conclude that solar and accelerator studies of neutrino properties are highly complementary and that in none of the possible scenarios there is any duplication.