NuFact11 WG1 summary

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Questions from NuFact10

1. Sensitivity and optimization studies.
Please compile from FEASIBLE projects (i.e. eliminate high gamma beta beams from the plots)

1'. Express sensitivities in term of error on parameters

2. Write down a consistent model that gives observable non-standard neutrino interactions.

3. Provide physics motivation of LBL oscillations within wider context of particle physics, beyond a relatively small (compared to the scale of the facility) neutrino aficionados circle.

4. Provide statement on precision that is interesting for measurements of nu_mu->nu_tau and nu_e->nu_tau oscillation measurements. Report on studies of such measurements for superbeam and neutrino factory.

5. More generally explicit what testing universality of 3x3 mixing matri^x means, limits on 4th family neutrino or sterile neutrino

6. Can liquid Argon TPC be used as detector for beta-beam? (mu/pi separation for both signs)

7. Is any LHC physics search or discovery able to shed light on the neutrino paradigm?

Sensitivity and optimization studies

- Compile from feasible projects
- Express sensitivities in terms of error on parameters
- Provide statement on precision that is interesting for measurements of $\nu_\mu \rightarrow \nu_T$ / $\nu_e \rightarrow \nu_T$ measurements

Discussion session on facility comparison

lead by W. Winter

Short presentations on facilities + lively discussions

- Super Beam (LBNE) J. Strait
- Beta-Beam E. Wildner
- NuFact K. Long

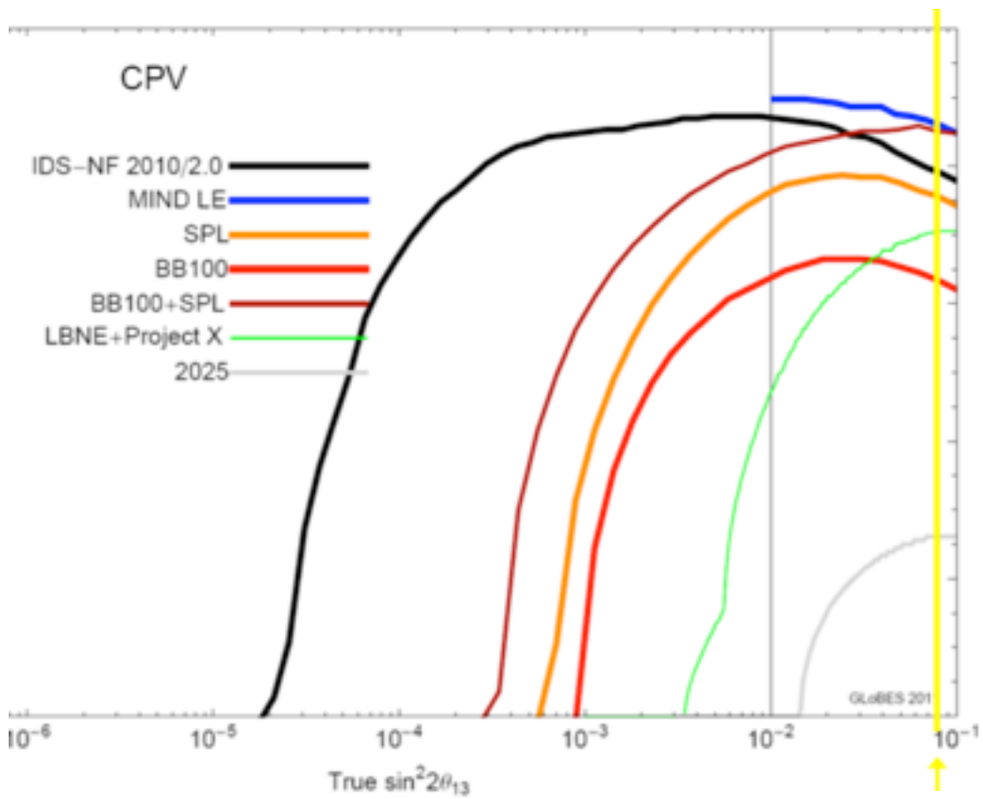
summary-doc by W. Winter available at indico

talks by S. Agrawalla, P. Ballett, D. Meloni, S. Prakash, S. Parke, H. Minakata, P. Coloma,

- Systematics especially important for large θ_{13}, not transparent (need better documentation). How to compare systematics for different facilities / detectors?

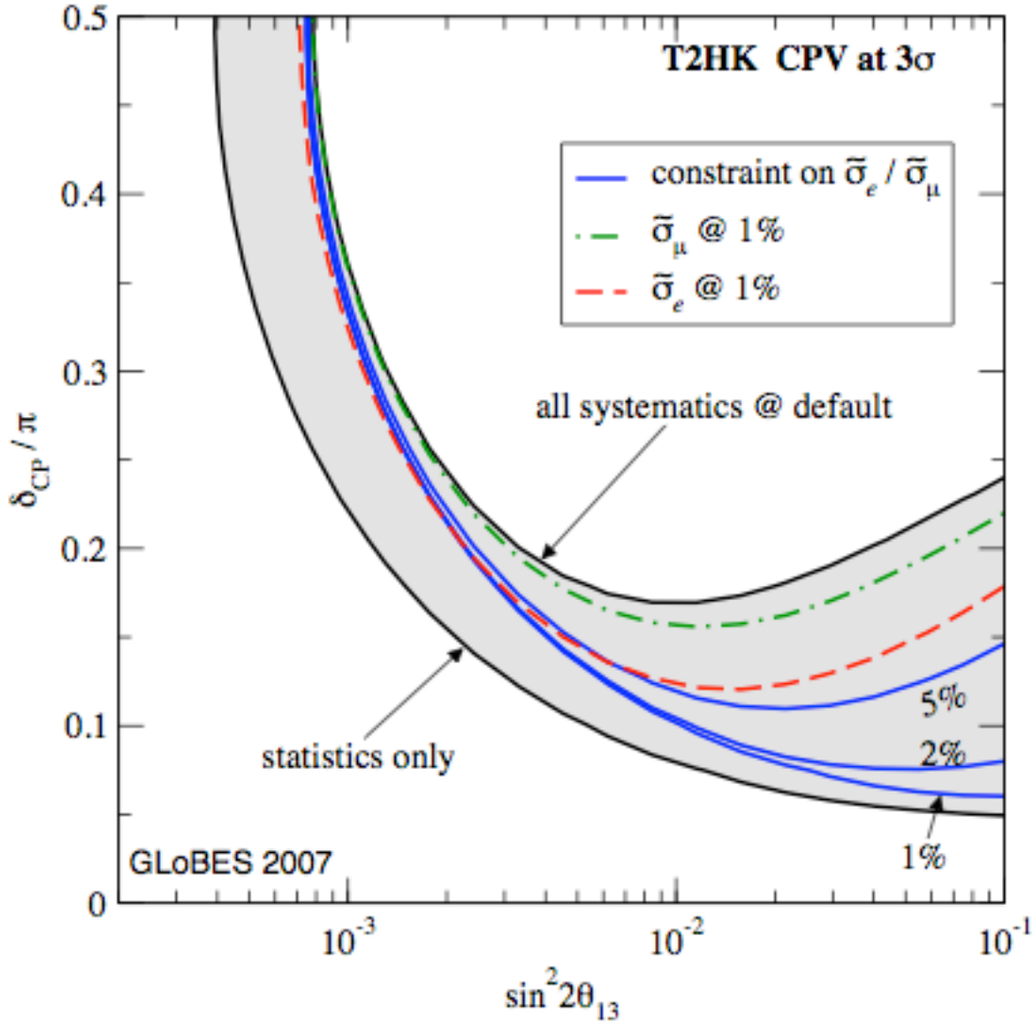
- If θ_{13} is large, do we need to measure CPV and hierarchy in a LBL experiment, or can we get the hierarchy from other data e. g. , atmospheric neutrinos (Minakata), IceCube (Halzen, Smirnov) PINGU (20 M$)?

- sensitivities if θ_{13} / hierarchy is known
- accuracy on θ_{13} / δ
- does the optimization change in case of large θ_{13}?

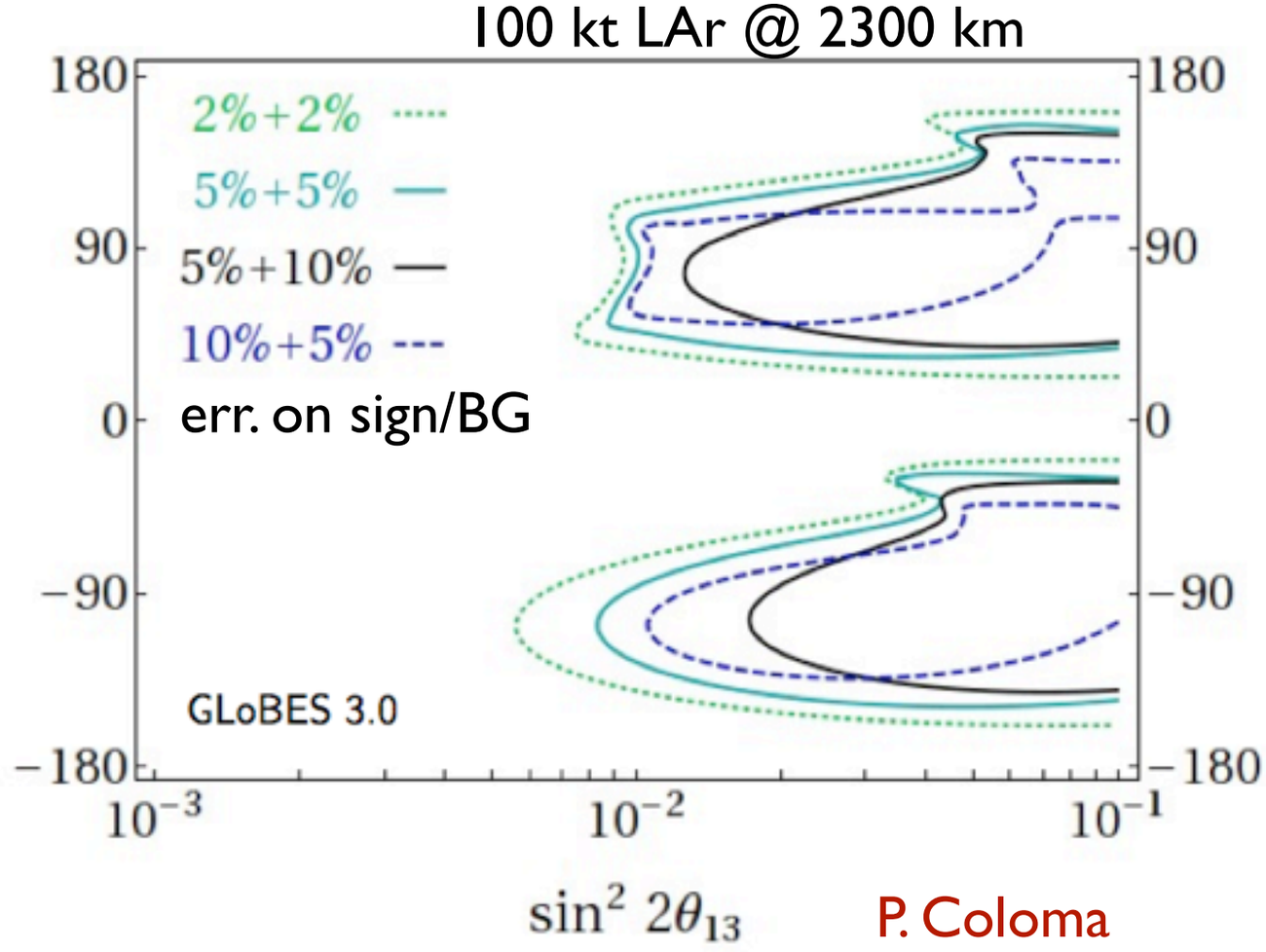


P. Huber @ ECFA Panel review, May 2011

Systematics in Superbeams



Huber, Mezzetto, TS, 07



P. Coloma

Large θ_{13}: Superbeam systematics critical!
What is the situation for NuFact / Beta Beam?
Can we use this to decide on technology?

ν_τ detection

David vs. Goliath

4-10 kt (M)ECC 17% eff.	100 kt MIND 80% eff.

W. Winter

Factor 50-100 more statistics in golden (disappearance) versus silver (discovery) channels

- tau detection does not add much information for standard three-flavor oscillations
- can be useful in search for non-standard physics: NSI (near detector), CPV due to sterile neutrinos

T. Ota

Find a consistent model that gives observable non-standard neutrino interactions

- "observable": $\varepsilon \sim 10^{-3} - 10^{-2}$

- $O(10^{-3})$ bounds on neutrino NSI when trying to avoid similar charged lepton operators at d=6: Non-Unitarity, Asymmetric Operator

  - "Chiral enhancement" in ν production from π decay could bring them to $O(10^{-2})$ level. Specific models?

  - Loop level or d=8 do not seem to improve the situation. Other ways out?

- Are these NSI observable? What would it take?

- If we don't try to avoid charged lepton ops. Flavour diagonal NSI can be $O(10^{-2})$- O(1). Observable? Effects?

E. Fernandez, S. Davidson, H. Lee

Explicit what testing universality of the 3x3 mixing matrix means, limits on 4th family neutrino, or sterile neutrino

- 4th family: critical limits from LHC J. Herrero

Just extra SM-like families with the minimal Higgs content of the SM seem to be sick... (but not yet dead).

Sterile neutrinos

- Status of E/L ~ eV^2 indications

  MiniBooNE results (Djurcic), Reactor neutrino anomaly (Mention), MINOS NC (Sousa)

- Possibilities to test

  MicroBooNE (Jones), Very Low E NuFact (Bross), CERN PS exper (Pieropaolo), FNAL (Louis), MINOS+ (Sousa), IceCube (Halzen)

- Possible explanations

  sterile ν osc (Giunti), sterile ν decay (Gninenko)

- Sterile neutrino models Hernandez, He

eV-scale sterile neutrinos

- Hints for eV sterile neutrinos are intriguing but not yet convincing. Establishing sterile neutrinos would be a major discovery.
- Want to solve this problem with high significance (not produce another 2-3σ anomaly). What's the best experiment?
- Quantify the impact of hypothetical eV-scale sterile neutrinos for the three-flavor long-baseline program.

WG1 – Monday Afternoon Discussion

QUESTION from the WG organizers: "Provide physics motivation of LBL oscillations within wider context of particle physics, beyond a relatively small (compared to the scale of the facility) circle of neutrino aficionados"

Presentations: H. Minakata and R. Mohapatra, and A. Ibarra, see also G. Senjanovic.

also WG talks by P. Machado, M. Nemevsek

Main Point:

Neutrino physics provides a unique window on new physics and on the problem of flavour.

- Origin of Neutrino Masses?
- Origin of Flavor?
- How Are They Related?
- How About Sterile Neutrinos, Different (Apparent) Masses for ν and $\bar{\nu}$?
  - How are these questions addressed by neutrino experiments?
  - How are these questions addressed by nonneutrino experiments?

– Can we probe the origin of neutrino masses at the LHC? [Nemevsek]

Yes, we might. [Senjanovic, Ibarra]. Need more than the simplest model (SM + right-handed neutrinos). E.g. Inverse seesaw, left-right models...

– If θ_{13} is as large as hinted by T2K, what do we learn about flavor? Is the tri-bi-maximal (TBM) paradigm still useful?

"Large" θ_{13} good fit to some sophisticated top-down approaches to flavor (e.g., SUSY GUTs [Mohapatra]). Large θ_{13} is also consistent with the most naive guess, anarchy [Minakata]. TBM still useful benchmark, but, if it is a fundamental consequence of a symmetry the latter seems to be strongly broken.

– What do we learn from measuring all oscillation parameters? How well do we need to measure them?

From the point of view of top-down scenarios, different measurements point in different directions (NH versus, IH, $\sin^2\theta_{23}$ deviation from maximum, ... [Mohapatra]). Correlations are very important ($\theta_{13} \propto \cos 2\theta_{23}$, etc), provide some guidance for precision. Need to address the second question better!

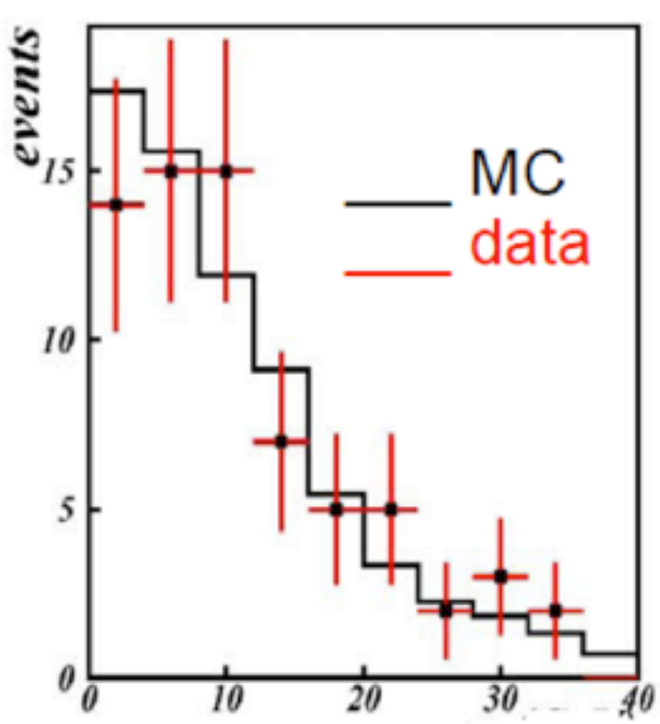
– What if sterile neutrinos are discovered?

A: This would be a "paradigm shifting" discovery. Might indicate that the origin of neutrino masses is very low. "Revolution in particle physics" [Minakata].

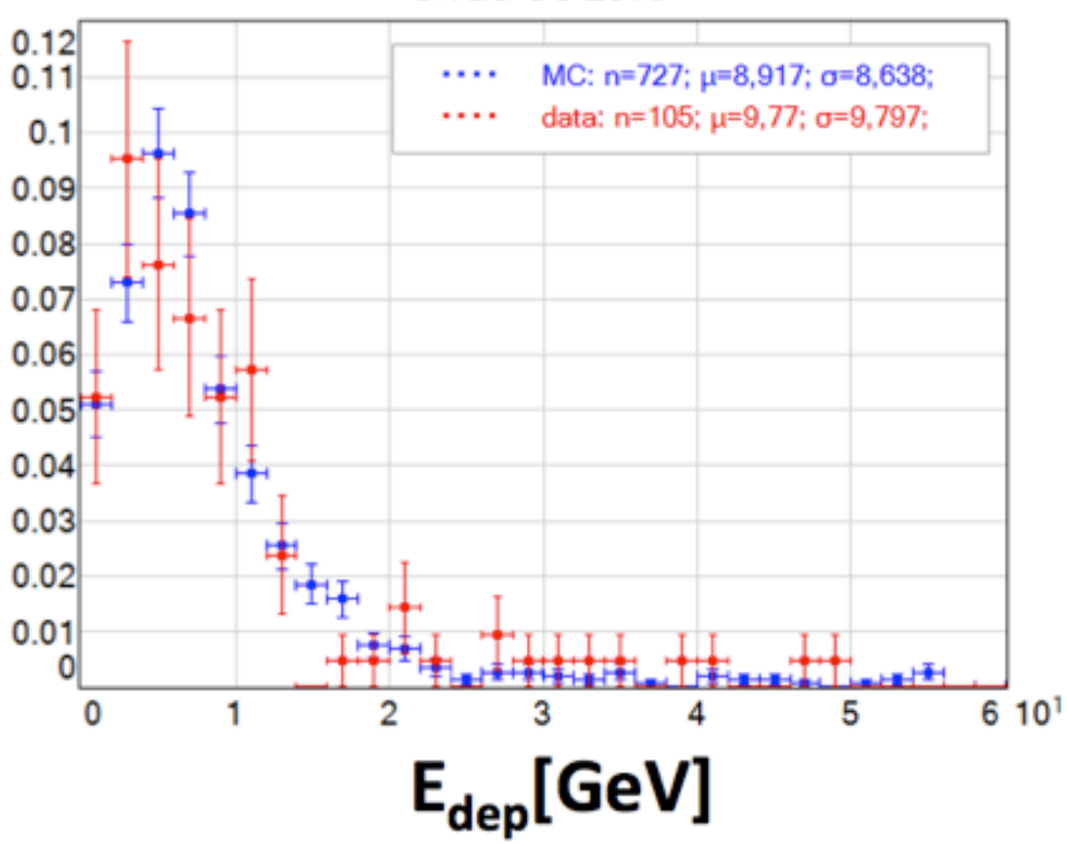
Can liquid Argon TPC be used as detector for beta-beam? (mu/pi separation for both signs)

We don't have the answer at this point, but we did see good progress on the reconstruction of events in the Icarus talk, which indicates that an answer could be available at the next NuFact.

Measurement of muon momentum from multiple scattering



Calorimetric measurement of the deposited energy



D. Stefan

Questions from panel to NuFact

WG1 answers

Sergio Bertolucci: I hear that international collaboration on coordinated R&D is lacking. Could the community propose a realistic plan for common and staged neutrino R&D**?**

- There is some coordinated collaboration within the EUROnu and IDS-NF framework.

Steve Myers: As an accelerator physicist, there are too many options – we need to kill some to make progress. Need to make a choice, define the next steps, define critical R&D and move on. What is it that the community really wants to build?

- WG1 not in the position to answer yet.

Tatsuya Nakada: In the incremental approach, where does a Betabeam fit? This question is in regard both to the physics case and the R&D needs.

- There is no general consensus in WG1 on this question. Need input from other WGs. We pose this question for the next NuFact meeting.

Sachio Komamiya: Physics question: θ13 & δ are similar to Vub and CP phase in the quark sector. In heavy flavors, angles are not really the interesting thing – CP violation there is found to be insufficient to generate Baryogenesis. How about neutrinos? We know about Leptogenesis, is there further fundamental physics in neutrinos beyond the numerical values of the angle and phase?

- Data from the quark sector did provide much more information than V_{ub} and CP phase: constraining heavy beyond Standard Model (BSM) physics through loop processes. Neutrino physics gives information about BSM in a complementary way and at different energy scales (for example sterile neutrinos).

- Leptogenesis does provide a valid explanation of Baryogenesis. We need support for this hypothesis (establishing low-energy CP violation and Majorana nature of neutrinos).

- Neutrino mass is physics BSM. Measurements in the Lepton sector provide important information, establishing the mechanism of neutrino mass generation: TeV scale ↔ LHC (Senjanovic) or seesaw ↔ GUT scale(Mohapatra),

  testing the hypothesis of flavor symmetries by precision measurements.

- Neutrinos have implications for cosmology and can be used as tools to learn about the sun, the earth, astrophysics, dark matter, if neutrino properties are known precisely.

Koichiro Nishikawa: In the near term, the international framework should be bottom up and not top down? At what point should an international framework be forced from the top?

- WG1 not in the position to answer.

Jim Strait: If you didn't have a neutrino factory, how precise a measurement of parameters can be done with superbeams before reaching their limitations? What "external" measurements, e.g. particle production, neutrino cross sections, etc., can be done to improve the current systematic error limits on superbeam experiments, and what are the ultimately limiting systematic errors?

- Important question. WG1 is not yet in the position to answer. Need input from other WGs as well as results from current oscillation experiments. Pose this question for next NuFact.

John Womersley:

- Do I need to worry whether neutrino and antineutrino oscillation parameters are the same, or worry about the LSND anomaly?

- LSND anomaly and other hints for E/L ~ eV^2 are intriguing but not conclusive yet. It is desirable to solve this question with high significance (many ideas discussed at this NuFact). Establishing eV sterile neutrinos would be a major discovery.

- The LSND anomaly has probably only a small impact on the three-flavor program. This statement should be quantified till next NuFact.

- Ideally we would like to have a future high precision facility which can address three-flavor physics as well as testing anomalies and deviations from the three-flavor scenario.

John Womersley:

- Do neutrinos play a role in dark matter, especially if there is no light neutralino?

- We know that neutrinos are a small part of the DM (hot DM).
- keV sterile neutrinos can provide all of the dark matter (warm DM). This possibility is maybe even slightly favored over cold DM by structure formation arguments.
- If DM is a WIMP neutrinos do play a role in the search for it: DM annihilations into neutrinos, solar neutrino background in DM direct detection experiments, NC neutrino scattering experiments to get information on DM-nucleus interactions, experimental similarities between neutrino and DM detector requirements.

John Womersley:

- Since STFC and funding agencies from other countries in Europe, the US, and Japan are investing substantially in MICE, please consider, given the new indications that θ13 may be large, the importance of continuing to support R&D for the Neutrino Factory (and ionization cooling in particular).

- We need a Neutrino Factory to probe the three-flavor neutrino paradigm with high precision (comparable to the quark sector), irrespective of the value of θ_{13}.

- We do not know yet definitely whether θ_{13} is large.

- We should support R&D now to have the option for a Neutrino Factory later, also in view of a muon collider.

WG1 Questions for NuFact12

Questions for NuFact12

Working hypothesis: θ_{13} is large

- **Impact of systematical uncertainties on sensitivities.** Identify crucial uncertainty for each facility. Impact on detector design. Can we use systematics to argue in favor or against certain facilities?

- **What is the accuracy on parameters needed to constrain models?** Is Tri-Bimaximal mixing (or similar hypotheses) still appealing, or can it never be excluded? How accurately do we want to know the CP phase?

- **For large θ_{13}, is a SB + hierarchy from atmospheric neutrinos an option?**

- **Is the NuFact the only facility able to achieve the required accuracy?**

Questions for NuFact12 (cont)

- **In which sense do we need to over-constrain the 3-flavor system?** Which kind of new physics can we constrain? Which facility(ies) are needed to achieve this?

- **What is the impact of eV-scale sterile neutrinos on the 3-flavor physics?** Can we (or should we aim for to) design a next stage facility which is able to address both, eV-scale and standard oscillations?

- **Identify the physics role of a Beta Beam?** What are the measurements unique to a BB? What cannot be done with a BB? Is a BB only useful combined with a SB?

- **Can liquid Argon TPC be used as detector for beta-beam?** (mu/pi separation for both signs)

Thanks to all WG1 participants for lively and productive discussions