Report of EUROν International Advisory Panel

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Executive Summary

This report summarizes the IAP findings from the EUROν meeting held at CERN from March 23–27, 2009. The Executive Summary, which comprises material from the closeout presentation to the Governing Board augmented with material generated in the preparation of this report, includes both "comments" from the Panel and some specific "recommendations." In the summary below, the particular Work Packages (WPs) for whom the comment or recommendation is meant are indicated in square brackets.

We heard many interesting presentations and we thank the EUROν group for their efforts in describing the many activities now being launched. It is clear that the EUROν community brings a lot of talent and enthusiasm to its task. We are looking forward to future meetings to hear of the continued progress.

Comments

- We would like to see a few more "intermediate" milestones to be sure work gets started in a focused and timely manner. [WP1]

- How WP6 obtains and provides input from/to other Work Packages (WPs) is unclear. A mechanism for WP6 members to interact frequently with the other WPs should be implemented. [WP6]

- Commonality between groups, e.g., proton driver and target station for WPs 2 and 3, and detector for WPs 2 and 4, means that some joint meetings should be encouraged. These should be held more often than the annual plenary meetings. [WP1]

- Proton driver parameters seemed to be coming from the linac group rather than driven by user needs. WPs 2, 3, and 4 should each provide optimized requirements for the proton driver. WP1 has the task of reconciling the various demands. [WP1–4]

- Design choices for each WP should be reviewed independently before they are finalized. Such reviews should be aimed at *validating* choices, not making them for the collaboration. [WP1]

- The baseline configuration for WP4 should not be changed unless and until a superior alternative is validated. [WP4]

- Up-to-date parameter lists should be maintained on the web for each WP. This will aid physics evaluations and comparisons as well as being invaluable for the cost estimating effort. WP1 should consider some form of configuration control even at this early stage. [WP1]

- There is an optimum time to engage engineers in the study. Having an experienced mechanical and an experienced electrical engineer available as "consultants" from the outset is wise. [WP1]

- It was unclear whether the intention is to have a single cost group or four independent cost groups. A single group—or exchange of estimates among groups—will help ensure uniformity of approach. [WP1]

- Having an estimate of cost derivatives with respect to key performance parameters will be of value even in the early stages of the study. These will guide the design choices toward a roughly cost-optimized configuration. [WP1]

- Criteria by which the WPs will be evaluated should be developed and conveyed to the groups as soon as possible. Creating a common metric is worth considering. [WP1]

- While the Superbeam concept is the most technically advanced, an integrated approach to its design was not evident. The various subsystems should be considered together, and environmental protection should be an important design consideration from the outset. [WP2]

- It was not clear from what was presented that 130 km is an optimal Superbeam baseline. Having options for other baselines, to be identified in discussions with WP6, would be prudent. [WP2]

- Implications of the proposed "4-horn" system should be evaluated in detail before adopting this as the baseline configuration. [WP2]

- For both WP2 and WP3, the choice of a 4 MW proton driver needs firmer justification. [WP2 & 3]

- Physics performance optimizations should also include the near detector(s) and their associated systematics issues. [WP5 & 6]

- Interaction between the WP5 group and existing detector groups such as Super-Kamiokande and MINOS should be encouraged. [WP5]

- A decision tree that reflects possible outcomes of ongoing experiments should be developed. This will show how the program might be affected by changes in the physics landscape, for example an actual measurement of $\sin^2\theta_{13}$. [WP1]

- "Team building" should be a vital part of the EUROν activity, and should lead to a set of agreed-upon findings and recommendations. These will provide an opportunity for the neutrino community to inform the rest of the worldwide scientific community about the importance of neutrino science goals. [WP1]

- Recognizing that not all WPs are at the same level of technical maturity, it is wise for each group to consider the balance between facility design effort and that for enabling R&D. [WP1]

Recommendations

1. A parameter list should be prepared for each WP. [WP1]

2. Evaluation criteria for all groups should be developed and disseminated as soon as possible. [WP1]

3. A decision tree reflecting possible outcomes of ongoing experiments should be prepared for WPs 2–5. [WP1]

4. WP2, WP3, and WP4 should each develop optimized requirements for the proton driver. WP1 should reconcile these requirements and provide performance specifications for the driver to the SPL group. [WP1, 2, 3 & 4]

5. Implications of the 4-horn approach should be evaluated in detail before adopting this as the baseline configuration. In the meantime, continue pursuit of backup designs. [WP2]

6. Develop a parameter list for the baseline (EURISOL version) WP4 configuration and maintain it via a configuration control process. [WP1 & 4]

7. Identify potential collaborative partners to enhance and speed up work on WP4. [WP4]

8. WP6 should be integrated with the other WPs to aid in establishing performance goals. [WP1 & 6]

9. Develop a "comparative metric of physics performance" for different facilities, taking into account systematic uncertainties between experimental set-ups (WP5) and theory (WP6), and facility/accelerator constraints (WP 2, 3 and 4) with regard to distance of the detector and neutrino beam energies as well as synergies between multiple set-ups. [WP1 & 6]

Work Package 1: Management and Knowledge Dissemination

Findings

The EUROν design study was set up under the EU Framework 7 program. It will examine three possible projects, a CERN-to-Fréjus Superbeam, a Neutrino Factory, and a Beta Beam facility. The study was ranked first among the 51 proposals submitted and was awarded €4M. The duration of the study is from September 1, 2008 through August 31, 2012. There are many associated institutions in the U.S., EU, and Canada. There is a Governing Board (GB), chaired by Steve Myers (CERN). The IAP reports to the GB. WP1 covers the management task, and is led by Rob Edgecock (RAL). WP1 is responsible for producing annual reports on the study progress and making sure that the comparisons among the facilities are complete and fair.

Comments

The panel notes that most of the study milestones come rather late, and that there are few, if any, "intermediate" milestones. We would like to see more internally held intermediate milestones to ensure that the work proceeds in a focused and timely manner. Because of the commonality of certain systems, e.g., the proton driver for WPs 2 and 3, or the detector for WPs 2 and 4, we suggest that some joint WP meetings be initiated. These will likely need to be more frequent than the annual plenary meetings, at least at the beginning.

In the various presentations we heard, there was a sense that the proton driver parameters were being dictated by the linac group and not by the requests of the WP 2, 3, and 4 users. We suggest that the WP 2, 3, and 4 managers each be asked to provide a set of optimized specifications for the proton driver. WP1 must handle the task of reconciling the various demands.

It is prudent to have the design choices of each of the technical WPs (2–5) independently reviewed before finalizing them. Arranging this should fall to WP1. Such reviews should not be *making* choices for the WPs, but simply *validating* them (or declining to do so). We recognize that not all WPs are at the same level of technical maturity. For this reason, WP1 should urge each group to find the proper balance between facility design effort and that for enabling R&D.

In order to maintain some coherence, WP1 should require an up-to-date parameter list from WPs 2–5. These should be kept on the web and—even at this early stage of the design process—some form of configuration control should be maintained by WP1, possibly with ratification by some technical advisory group, such as the Coordination Board.

It is valuable to have access to a few experienced engineers, say a mechanical engineer, an electrical engineer, and possibly a plant engineer, to guide the initial technical choices. These people are not needed full-time, but could function, in effect, as consultants.

CERN would be a good source of such people if they could be made available. At a later stage, when the cost estimate for each system must be prepared, considerably more engineering effort will be needed. There is an optimum time to ramp up the engineering, and WP1 management should make sure the engineers are brought on at the proper time—not too early and not too late. It was unclear to the panel whether the plan is to have a single cost group or four separate groups. If multiple cost groups are utilized, there must be a means of exchanging cost estimates among the groups to ensure uniformity of approach. Having an estimate of cost derivatives with respect to key performance parameters is another way to guide the design decisions toward a cost-optimized facility, and the Panel suggests that this be part of the costing methodology.

The Panel presumes that the final recommendations from EUROν will be based on some agreed-upon set of criteria. These should be developed by WP1 and conveyed to all the other groups to get buy-in. On the assumption that it is possible to define a common metric for all WPs, we suggest that this be considered.

Because the decision process is likely to be heavily dominated by the actual value of $\sin^2 2\theta_{13}$, it is worthwhile for WP1 to develop a decision tree that reflects possible outcomes of the ongoing experiments and shows how the program would be affected by such changes in the physics landscape. The Panel was concerned by indications that the WP1 group may be backing away from the goal of arriving at an agreed-upon set of findings and recommendations. We believe that such recommendations will provide an opportunity for the neutrino community to inform the broad scientific community about the merits of its goals, and that they also serve a team-building purpose to allow the European neutrino community to converge on a proposed direction.

Recommendations

1. A parameter list should be prepared for each WP.

2. Evaluation criteria for all groups should be developed and disseminated as soon as possible.

3. A decision tree reflecting possible outcomes of ongoing experiments should be prepared for WPs 2–5.

Work Package 2: Superbeam

Findings

The goal of Work Package 2 is a conceptual design of a long baseline neutrino beam facility based on the Superconducting Proton Linac (SPL) and a newly constructed target facility and neutrino beam line (referred to as a “Neutrino Superbeam”). The primary design criterion is to provide competitive (in a world context) sensitivity to CP violation in the neutrino sector for values of the mixing parameter $\sin^2 2\theta_{13}$ down to $\sim 1\times10^{-3}$. It is assumed that the detector would be located at Fréjus, approximately 130 km distant. Performance specifications based on this sensitivity goal and the Fréjus facility are: 4 MW beam power over an operational energy range of 2–5 GeV.

The SPL will be constructed initially as a lower beam power facility capable for supporting LHC performance upgrades. A subsequent upgrade is required to support multi-MW beam power. The schedule presented by the SPL group indicates that an earliest startup date for multi-MW beams is 2020. This is believed to be a competitive schedule based on developments elsewhere in the world.

The development of the SPL design is not a major component of this work package—it, including an accompanying accumulator ring, is being developed independently. The primary emphasis in WP2 is on design of the neutrino beam facility: target, horn, decay pipe, and dump, and characterization of the resulting neutrino beam. These elements, and accompanying cost estimate, are to be included in a Conceptual Design Report which should be issued in September 2012. The primary focus of the work to date has been on a solid graphite target inserted into a classical horn and reflector, using the T2K target design as its starting point. Because of the high beam powers involved, the baseline design assumes four horn-plus-target systems. Consideration of maintenance strategies was being integrated into the planning for individual components.

Comments

While the Superbeam concept is the most technically mature of the three options, an integrated approach to its design was not evident to the Panel. We suggest an integrated approach to the design of the accumulator, horn and target facility, decay pipe, and absorber. Environmental protection measures need to be incorporated into these designs. An accumulator design optimized for the Superbeam facility needs to be developed.

It was not clear from the WP6 presentation that 130 km is the optimum baseline for a neutrino experiment. We suggest that the Superbeam design team leave options for other baselines open, as identified in discussions with WP6.

As already noted, criteria that will be utilized for evaluation of the Superbeam CDR have not been conveyed to the WP2 members[1]. Evaluation criteria will affect development of

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[1] This is also true for the Neutrino Factory, Beta Beam, and Detector groups.

the design concept and should be provided by WP1 to this group (and the other groups) as soon as possible.

Proton parameters seemed to be coming from the SPL group rather than being responsive to the needs of the Superbeam facility. For example the proton accumulator ring is being designed to provide a spill length to the neutrino target that is a factor of three shorter than the Superbeam team would prefer. It appears that the spill length has been optimized to Neutrino Factory requirements.

The horns and target are correctly identified as a major technical uncertainty. The group has dropped exploration of a liquid mercury jet target in favor of pursuit of a graphite target. The reasons for pursuing this course appear sound to the committee (based on consideration of energy deposition, neutron production, and configuration within the field null of the horn). Four parallel target/horn systems are established as the baseline. This choice is made to reduce energy deposition to levels being contemplated for the T2K upgrades. The configuration looks problematic to the committee (mounting the targets/horns on a 2.5 m diameter circle going into a 3 m decay pipe). Details of how the system would operate and the neutrino spectrum that would be generated have not been worked out. Finite element modeling of the target and horn have just begun. Powder jet and pebble bed designs are being explored as backups.

The development of the Superbeams target is being done largely independently of the development of the target station for a Neutrino Factory. However, development of the horn design is aiming for dual utilization.

Recommendations

4. WP2, WP3, and WP4 should each develop optimized requirements for the proton driver. WP1 should reconcile these requirements and provide performance specifications for the driver to the SPL group.

5. Implications of the 4-horn approach should be evaluated in detail before adopting this as the baseline configuration. In the meantime, continue pursuit of backup designs.

Work Package 3: Neutrino Factory

Findings

The Neutrino Factory Work Package is coordinated with the work of the International Design Study for a Neutrino Factory (IDS-NF). The effectiveness of the coordination was evident from the presentations, many of which were given by IDS-NF members who are not formally part of EUROν. The accelerator design for the Neutrino Factory is presently well ahead of that of the Beta Beam facility, owing to the international effort on Neutrino Factory design carried out over the past several years. A complete baseline design now exists, and is being optimized and refined by the combined forces of EUROν and IDS-NF.

Tasks for the WP3 group include end-to-end tracking studies, proton beam handling and safety issues, and contributing to an interim design report in 2010 followed by a Reference Design Report in 2012.

Comments

Given that there is already a fairly detailed design for most of the Neutrino Factory subsystems, the Panel was surprised that the initial evaluations of the front-end and accelerator systems were scheduled to take as long as 18 and 24 months, respectively. We would expect more rapid progress in evaluating existing designs. Similarly, developing alternative—presumably improved—designs for the ionization cooling channel and acceleration system would benefit from earlier completion dates, as would the safety evaluation of the proton beam system. If some or all of the improved designs require changes elsewhere in the facility, it would be good to know this early rather than late. The Panel thinks that emphasis on developing alternatives may be a more valuable contribution to Neutrino Factory progress than spending nearly two years evaluating existing designs.

Although the EUROν WP3 is supposed to be a coordinated but independent activity, it was hard from the presentations to tell who was doing what. It is proper and informative to place the work in the broader IDS-NF context, but we would like to see a bit more focus on specific EUROν activities, progress, and plans at future meetings.

There still appears to be “tension” between the proponents of the baseline liquid-Hg jet target and alternative solid and powder targets. It would be good to define some means for reaching a decision on this topic as early as possible in the design process. We are also puzzled about the proton driver and target design being studied exclusively in WP2. The WP3 group will not necessarily have the same specifications and priorities, and we do not clearly see how their requirements will be incorporated into a European proton driver design. In particular, the implications of using horns (which sign select) rather than solenoids should be evaluated.

Recommendations

None.

Work Package 4: Beta Beam

Findings

The aim of beta-beam facilities is production of a pure beam of electron neutrinos (or antineutrinos) through the beta decay of radioactive ions circulating in a high-energy storage ring. All studies attempted to date make maximum use of existing infrastructure (e.g., at CERN or DESY in Europe) or of future planned facilities (e.g., EURISOL).

Beta Beam studies to date have included various scenarios: (*i*) low-energy Beta Beams with relativistic gamma factors <20; (*ii*) medium-energy Beta Beams with gamma factors ≤100; (*iii*) high-energy Beta Beams with gamma factors ≥350; (*iv*) monochromatic neutrino beams (taking advantage of the electron-capture process); (*v*) high *Q*-value Beta Beams with a gamma factor of about 100. Today, by consensus between accelerator and neutrino physicists, the only detailed study of a Beta Beam accelerator complex has been performed in the context of the EURISOL Design Study.

The baseline Beta Beam design that resulted from the EURISOL study permits a ^{6}He beam with $\gamma = 100$ and a ^{18}Ne beam with $\gamma = 250$, limited by the SPS. The Beta Beam physics scenario studied had both beams with $\gamma = 100$. An ISOL production target is employed to produce the two isotopes, after which a pulsed ECR source provides ions for acceleration. A linac and then an RCS accelerate the beam, after which it is injected into the existing CERN PS and SPS, followed finally by a decay ring with a circumference of 6900 m and a 2500 m long straight section aimed at Fréjus. Ion production rates for the required species have been estimated. The ^{6}He can be produced with the ISOL method at an intensity about half that desired for the physics program. The ^{18}Ne production with an ISOL is low by a factor of 25, but direct production boosts the rate to within a factor of two of the desired value.

In the EUROν study, a new concept for ion production will be explored. The desired isotopes are ^{8}Li and ^{8}B, produced from ^{7}Li (d,p) and ^{6}Li(^{3}He,n) using "reverse kinematics" and a production ring that employs ionization cooling of the circulating ions.[2] While ^{8}Li appears straightforward to produce, ^{8}B does not. Cross sections for both reactions are available, with ^{8}Li production of several hundred mb and ^{8}B about 10 mb. Ion source technology is also under study. The suggested concept is exploratory in nature and will require significant development time.

Comments

The Beta Beam team is focusing mainly on the Decay Ring design and on ion production techniques. The Panel believes that the latter topic represents the technical performance limit and, given limited resources, should receive the bulk of the effort. While the presumed goal is a design of an updated facility, the Panel is concerned that the resources to do this are not sufficient. We encourage the WP4 group to focus on the ion production

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[2] C. Rubbia, A Ferrari, Y. Kadi, and V. Vlachoudis, "Beam cooling with ionization losses," NIM A 568 (2006) 475.

and production ring aspects mentioned above, i.e., the technique using ionization cooling in a ring. It seems premature to update the baseline design until there is a demonstrated replacement version, and we caution against doing this. A realistic assessment of the overall production rates of the two high-*Q* isotopes should be a goal of this study.

Recommendations

6. Develop a parameter list for the baseline (EURISOL version) WP4 configuration and maintain it via a configuration control process.

7. Identify potential collaborative partners to enhance and speed up work on WP4.

Work Package 5: Detectors

Findings

The goal of the detector work package is to evaluate and optimize the baseline detector options for the three facilities (Superbeam, Neutrino Factory and Beta Beam) and to provide information for relative cost and performance comparisons.

Three detector options have been selected as baseline scenarios for study:

1. Magnetized ion neutrino detector (MIND) for the Neutrino Factory.
2. Water Cherenkov detector for the Superbeam and Beta Beam
3. Near detectors for each facility for absolute flux normalization, backgrounds and systematics.

Considerable work has already been carried out during the International Scoping Study (ISS) to identify designs for these detectors, as well as for other competing options. There are existing detectors such as MINOS and Super-K that can be used for extrapolation of the technologies and for costing purposes. The ISS identified some R&D areas that need to be pursued to establish the viability of the baseline scenarios. Some of this detector R&D and prototyping is being carried out by other groups for planned neutrino detectors. The WP5 participants are well aware of this effort and plan to take advantage of it.

The deliverables for WP5 are a report on the detector performance for the baseline scenarios by January 2010 and a report on the detector optimization for the near and far detectors by January 2012.

Comments

The WP5 subgroups are encouraged to interact with existing detector groups to optimize their designs. As there are a lot of developments going on around the world, some organizational effort will be required for the working groups to focus on the areas that are most important for this study. We suggest that the groups should concentrate first on establishing the baseline parameters for the detectors and then the technological and cost drivers in extrapolating the existing detector designs to the much larger detectors envisaged for EUROν, e.g., the magnet coils for the 40 m long MIND detector or the large caverns and containment vessels required for the water Cherenkov detectors.

The near detectors are a topic that has not received as much attention as have the larger far detectors. The physics performance optimizations should include the near detectors and the requirements for understanding all of the flux, systematic and background issues. The near detector optimization is reasonably well understood for the Superbeam option, e.g., the T2K near detector, but may not be so well understood for the distributed neutrino sources from the Neutrino Factory and Beta Beam.

The detector optimization could be significantly influenced by the outcomes of present experiments, in particular a measurement or improved limit on $\sin^2 2\theta_{13}$.

Recommendations

None.

Work Package 6: Physics

Findings

The physics work package provides the tools and expertise to quantify the physics performance of the facilities being developed under WPs 2, 3, and 4. The methodology used in the studies will be common to all three facilities to permit direct performance comparisons. The WP6 group will incorporate results from ongoing experiments, e.g., T2K and NOνA, to ensure that the neutrino parameters are as up-to-date as possible.

Specific tasks include evaluating the physics performance of the facilities, providing optimized parameters, such as detector baseline distance, evaluating synergies among the facilities, if any, and evaluating the effects of systematic uncertainties in both the experiment and the theoretical models.

Theoretical explorations will include attempts to identify opportunities for discovering new physics via the neutrino sector. Guidance in what to look for in terms of non-standard interactions is also being provided.

Comments

Good progress has been made in developing performance criteria for the three facilities, spurred on to some extent by the IDS-NF and the ISS that preceded it. However, it was not clear to the Panel how WP6 members coordinate with the other working groups. We did not hear about any joint meetings, aside from the infrequent plenary meetings, and it did not seem convincing that the plenary meetings would suffice for coordination. Arranging more joint meetings with the accelerator design groups is called for.

We heard some information about the near detector performance requirements. We believe this aspect will be important in the performance evaluations and that WP6 should continue to be involved in developing specifications for such devices. We also believe that WP6 ought to be integrally involved in defining the performance criteria against which the three facilities will be judged. If possible, an agreed-upon set of criteria should be defined and accepted by the other WPs as soon as possible. WP6 also has a role to play in guiding the scientific program under various assumptions on the size of θ_{13}. It is possible that this parameter will actually be measured in the next few years, and scenarios for this outcome must be developed in WP6.

Recommendations

8. WP6 should be integrated with the other WPs to aid in establishing performance goals.

9. Develop a "comparative metric of physics performance" for different facilities, taking into account systematic uncertainties between experimental set-ups (WP5) and theory (WP6), and facility/accelerator constraints (WP 2, 3 and 4) with regard

to distance of the detector and neutrino beam energies as well as synergies between multiple set-ups.