EU contract number RII3-CT-2003-506395 CARE-Report-2007-039-BENE

Beams for European Neutrino Experiments

NuFact'07
9th International Workshop on Neutrino Factories, Superbeams, Betabeams

Summary of Working Groups on Neutrino Oscillations,

P. Hernandez[1], C.W. Walter[2], O. Yasuda[3]

1) IFIC and Universidad de Valencia, Valencia, Spain
2) Duke University, Durham, NC, USA
3) Tokyo Metropolitan University, Minami-Osawa, Hachioji, Tokyo, Japan

Summary of Working Groups on Accelerator Physics, Machine Design and R&D

D. Li[4], C. Ohmori[5]

4) Lawrence Berkeley National Laboratory, Berkeley, California, USA
5) KEK, Tsukuba, Japan

Acknowledgements

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395)

Summary of Working Group One

Pilar Hernández*, Christopher W. Walter† and Osamu Yasuda**

*IFIC and Universidad de Valencia, Edif. Institutos Investigación Apt 2 2085, 46071 Valencia, Spain
†Department of Physics, Duke University, Durham, NC 27708 USA
**Department of Physics, Tokyo Metropolitan University, Minami-Osawa, Hachioji, Tokyo 192-0397, Japan

Abstract.
The theoretical and experimental issues discussed in working group one at Nufact07 are summarized.

Keywords: Neutrino Interactions, Neutrino Oscillations
PACS: 13.15.+g, 14.60.Pq

INTRODUCTION

The Ninth International Workshop on Neutrino Factories, Superbeams and Betabeams was held at Okayama University in Okayama, Japan in August of 2007. The neutrino oscillation working group met over three days and featured a comprehensive set of talks covering both experimental and theoretical developments in the field.

The talks had a particular emphasis on the physics to be found at possible new facilities and lessons that could be learned for the future from today's generations of experiments.

THEORETICAL SUMMARY

The main issues in the theoretical talks involved explanations for neutrino mass matrices, prospects of detecting deviation from the standard three-flavor neutrino oscillation framework, such as would result from the existence of sterile neutrinos, non-standard neutrino interactions or generic violations of unitarity of the mixing matrix.

Phenomenology with the CERN-INO experiment

Majumdar [1] reported some physics studies to measure deviation of the so-called tri-bimaximal mixing scenario. He considered a neutrino factory at CERN and a magnetized iron calorimeter at the India-based Neutrino Observatory (INO) with a baseline 7152 km. He concluded that one would need the muon energy $E_\mu \sim$ 105GeV to reach the sensitivity $\sin^2\theta_{13} \sim 10^{-3}$ in this CERN-INO scenario.

Theoretical Discussions on Neutrino Masses

Farzan [2] investigated whether there exists principles or symmetries to predict theoretically the values of the CP phases in the neutrino sector. She presented symmetries (such as the $\mu-\tau$ reflection symmetry or the generalized $\mu-\tau$ reflection symmetry) for three cases: (i) all the CP phases (one Dirac and two Majorana phases) vanish, (ii) the Dirac phase becomes maximal, and (iii) the Dirac phase and one of the Majorama phases satisfy a relationship.

Winter [3] proposed a way to generate a wide variety of neutrino mass matrices starting from the so-called extended quark-lepton complementarity. With this method he found 1981 examples which have textures, some of which have a symmetry. He also obtained the distribution of the models as a function of θ_{13}. He found that relatively large values of $\theta_{13} \gtrsim 10^{-2}$ are favored.

Sterile Neutrino Scenarios (ν_s)

To account for the solar and atmospheric neutrino data as well as the LSND result in terms of neutrino oscillations, one must have at least four neutrino mass eigenstates. It has been known [4], however, that the four-neutrino scenarios (the (2+2) and (3+1)-schemes) are disfavored by the global data. Furthermore, the four-neutrino scenarios predict the same oscillation probability for $P(\nu_\mu \to \nu_e)$ and $P(\bar{\nu}_\mu \to \bar{\nu}_e)$, so they are disfavored even more by the recent MiniBooNE result [5]. To give a better fit to the data, a scenario with two kinds of ν_s (the (3+2)-scheme) has been proposed [6], and it has been shown [7] that this scheme can have a difference between the neutrino and anti-neutrino channels due to the CP violating phase. Schwetz [8] and Karagiorgi [9] presented their analysis on the (3+2)-scheme taking the recent MiniBooNE data into account. They both concluded

CP981, 9th International Workshop on Neutrino Factories, Superbeams, and Betabeams -NuFact 07,
edited by O. Yasuda, C. Ohmori, and N. Mondal,

that the CP phase provides the possibility to reconcile the LSND and MiniBooNE data. It should be kept in mind however, that the negative results on $\bar{\nu}_e \to \bar{\nu}_e$ [10] and $\bar{\nu}_\mu \to \bar{\nu}_\mu$ [11] give strong constraints on this scheme in general, whether it consistently accounts for the LSND and MiniBooNE data or not.

New Physics

To probe physics beyond the Standard Model in long baseline experiments, it has been proposed to consider phenomenological consequences of the four Fermi interactions which do not necessarily conserve lepton flavors. In the presence of such a neutral current (NC) interaction, the matter potential in the flavor basis is modified, and in general it has off-diagonal small components $\varepsilon_{e\tau}$ which are normalized by the standard matter term $\sqrt{2}G_F N_e$. Agarwalla [12] discussed the phenomenology of the R-parity violating supersymmetric model at a beta beam experiment in which the beta beam is shot from CERN to the India-based Neutrino Observatory (INO). He concluded that it would be difficult to determine θ_{13} or the mass hierarchy unless the bounds on a coupling constant in the model are tightened, but that it could be possible to see a clean signal of new physics and put tighter constraints on the coupling.

Ohlsson [13] and Sugiyama [14] considered the implications of the modified matter potential to the MINOS experiment. Ohlsson concluded that the allowed region for θ_{23}, Δm^2_{31} is enlarged due to the existence of the extra parameters of the modified matter potential, and that the constraint on θ_{13} is given only for small value of $|\varepsilon_{e\tau}|$. Sugiyama showed, on the other hand, that there exists a small range within the allowed region of $(\varepsilon_{ee}, |\varepsilon_{e\tau}|)$ obtained by [15], such that MINOS can establish the existence of new physics in the affirmative case, and a small range in the allowed region of $(\varepsilon_{ee}, |\varepsilon_{e\tau}|)$ excluded by MINOS in the negative case.

In the presence of charged current (CC) non-standard interactions, the flavor basis at the production or at detection is modified. Ota [16] discussed how ignorance of the presence of CC or NC new interactions would lead to wrong conclusions. In the presence of the NC interaction, an extra matter effect appears, and, for instance, the best fit points for θ_{13} and the CP phase δ inferred from T2K and from a reactor experiment can be different. In the presence of CC interactions, the two best fit points would agree but they might be different from the true point.

Unitarity

Xing [17] discussed various aspects of leptonic unitary. From the analogy to the quark sector, he argued that it would be advantageous to measure CP violation if the unitarity triangle is close to a regular triangle, and he presented several results on the mixing matrix in matter. He showed the typical shape of unitarity triangles with terrestrial matter density for a realistic long-baseline neutrino oscillation experiment.

The standard three flavor framework predict that the two oscillation probabilities $P(\nu_\mu \to \nu_e) \equiv A_{\mu e}\cos\delta + B_{\mu e}\sin\delta + C_{\mu e}$ and $P(\nu_\mu \to \nu_\mu) \equiv A_{\mu\mu}\cos\delta + B_{\mu\mu}\sin\delta + C_{\mu\mu}$ satisfy $A_{\mu\mu} = -A_{\mu e}$. Kimura [18] proposed to test unitarity by checking this equality. Assuming the 4MW J-PARC beam and a 500 kton water Cherenkov detector at the baselines L=295 km and L=5000 km for 10 years running, he obtained the region for θ_{13} and δ in which this test is possible.

López-Pavón [19] discussed the possibility to measure the phase of the parameters which appear in the minimal non-unitarity model, where deviation from unitarity is at most $\mathcal{O}(10^{-2})$. Despite these strong constraints, assuming a neutrino factory experiment at the baseline L=130 km, where both $P(\nu_\mu \to \nu_\tau)$ and $P(\bar{\nu}_\mu \to \bar{\nu}_\tau)$ are measured, he showed that one can in general probe the phase of the $\mu\tau$ component of the deviation from unitarity.

EXPERIMENTAL SUMMARY

The experimental talks were roughly divided into sessions on experimental techniques and results, proposals for new experiments, a session on the current state of solar and reactor experiments, and a session on future experiments and facilities.

Experimental Results

In this session the latest results from the Super-Kamiokande experiment was reviewed [20], along with the final results from the K2K experiment [21]. These talks, along with the new results from MiniBooNE and MINOS presented in the plenary session set the stage for the discussion that was to come.

For future high statistics experiments the handling of systematic errors will be critical and there were two talks in the session which discussed in detail how the systematic errors were handled by the MiniBooNE and MINOS experiments [22, 23]. Finally, the plans for the future ν_e appearance search at the MINOS experiment were discussed [23].

Experimental Techniques

The experimental technique section focused on emulsion detectors. There were two talks presented. In the first the final results of the DONUT experiment were presented including the preliminary results of the first direct tau-neutrino CC cross-section measurement. This result is consistent with the standard model expectation of flavor independence, and will be published soon [24]. Next, there was an impressive demonstration of the emulsion scanning technique of the OPERA experiment which demonstrated that the experiment was now ready for the CNGS beam [25].

Proposals and R&D for new detectors

All of the talks in this session were focused on R&D for future detectors at different long baseline experiments. First, plans for the prototype detectors being built for the Nova experiment [26] were presented. There will be three successive prototypes built, culminating in the integration prototype near detector (IPND) which will be placed in the MINOS near detector surface building and should be operational in the fall of 2008.

The proposed 2KM detector complex for the T2K experiment is a suite of detectors located 2 km away from the neutrino production point where the neutrino energy spectrum is almost the same as that seen at SK, 295 km away. Design studies focusing on a water Cherenkov detector optimized to match SK resolution were shown [27].

Finally, one of the first quantitative analyses of $\nu_\mu \to \nu_e$ oscillations in a neutrino factory with the far detector flux constrained by a near detector was shown [28]. This was a very welcome development.

Solar and Reactor Experiments

After hearing about the expected updates to the Kamland solar parameter measurements, there was a presentation of the plans to purify the Kamland scintillator in attempt to measure solar neutrinos [29]. Then, there was a set of talks explaining the plans to measure θ_{13} with reactor neutrinos. There were contributions from the Double Chooz [30], Daya Bay [31],and Reno [32] experiments.

The Angra collaboration presented their plans to utilize the already existing Angra-I reactor facility [33]. They initially plan to build a one-ton prototype detector close to the reactor. In a sign of the growing maturity of our field, they will then use this prototype to monitor reactor activity and develop techniques for nuclear safeguards.

Future Experiments and Facilities

Finally, the working group considered future experiments and facilities. The next few years will see the start of both the T2K and NoVa programs. Both of these experiments utilize the off-axis neutrino technique [34] to make a narrow band beam of neutrinos. The also both aim to see the appearance of electron neutrinos in a almost pure muon neutrino beam, but use different energy beams and experimental techniques. The current status and design of both experiments were presented [35, 36].

Next, the plans for a 50-100 kt RPC based detector with charge identification capability (INO) was described [37]. The INO collaboration is taking a two phase approach, with the first phase concentrating on atmospheric neutrinos, and the second on acting as the far detector in a several thousand kilometer baseline neutrino factory experiment. One of the goals of the INO collaboration is to use matter effects in the earth to help determine the neutrino mass hierarchy. This was also the subject of a study of utilizing magnetized detectors, betabeams, and atmospheric neutrinos, optimized to measure the mass hierarchy [38].

One of the presentations which engendered the most discussion was a discussion of the joint FNAL/BNL neutrino study. This study attempted to determine the sensitivities for a few baselines and compared liquid argon and water Cherenkov detector technologies [39]. One of the most interesting conclusions of the study was that future long-baseline experiments may not be systematics limited. In this case, we should strive to build the largest detectors and most powerful beams that we possible can.

Thinking even further ahead to neutrino factories, a study was presented for a low energy neutrino factory option [40]. This work explored the use of a 4 GeV machine, along with a magnetized iron detector. Although costing approximately 40% less than a 25-50 GeV machine, it still gave excellent capability to explore the full neutrino mixing matrix even if the mixing angle θ_{13} was very small ($\sim 1^\circ$). An updated study of the performance of a Magnetized Iron Neutrino Detector (MIND) was presented in [41], where it was shown that the energy threshold for the wrong-sign muon signal could be lowered, resulting in a significant improvement of the physics reach of the Neutrino Factory.

CONCLUSION

As a field, we are currently preparing for new results from the next generation of long baseline and reactor experiments. However, at the same time we are planning for future facilities and exploring which models and theoretical frameworks we can test.

REFERENCES

1. D. Majumdar, A. Ghosal, S. Bhattacharya, and K. Kar, "Probing deviation of tribimaximal mixing and reach of θ_{13} using neutrino factory at CERN and ICAL detector at INO," in *these proceedings*, 2007, `arXiv:0710.3281[hep-ph]`.
2. Y. Farzan, "Leptonic CP violation: Zero, maximal or between the two extremes," in *these proceedings*, 2007.
3. W. Winter, "Systematic Model Building Based on Quark-Lepton Complementarity Assumptions," in *these proceedings*, 2007, `arXiv:0710.5660[hep-ph]`.
4. M. Maltoni, T. Schwetz, M. A. Tortola, and J. W. F. Valle, *New J. Phys.* **6**, 122 (2004), `hep-ph/0405172`.
5. A. A. Aguilar-Arevalo, et al., *Phys. Rev. Lett.* **98**, 231801 (2007), `arXiv:0704.1500[hep-ex]`.
6. M. Sorel, J. M. Conrad, and M. Shaevitz, *Phys. Rev.* **D70**, 073004 (2004), `hep-ph/0305255`.
7. G. Karagiorgi, et al., *Phys. Rev.* **D75**, 013011 (2007), `hep-ph/0609177`.
8. T. Schwetz, "Neutrino oscillations: present status and outlook," in *these proceedings*, 2007, `arXiv:0710.5027[hep-ph]`.
9. G. Karagiorgi, "Sterile Neutrino Oscillations and CP-Violation Implications for MiniBooNE," in *these proceedings*, 2007.
10. Y. Declais, et al., *Nucl. Phys.* **B434**, 503–534 (1995).
11. F. Dydak, et al., *Phys. Lett.* **B134**, 281 (1984).
12. S. Agarwalla, "New Physics searches with Beta Beams," in *these proceedings*, 2007.
13. T. Ohlsson, "Effects of non-standard interactions in the MINOS experiment," in *these proceedings*, 2007.
14. H. Sugiyama, "More on Non-Standard Interactions at MINOS," in *these proceedings*, 2007.
15. S. Davidson, C. Pena-Garay, N. Rius, and A. Santamaria, *JHEP* **03**, 011 (2003), `hep-ph/0302093`.
16. T. Ota, "Non-standard neutrino interactions in reactor and superbeam experiments," in *these proceedings*, 2007.
17. Z. z. Xing, and H. Zhang, "Leptonic unitarity triangle in matter," in *these proceedings*, 2007.
18. K. Kimura, "Measurement of Leptonic CP Phase in $\nu_\mu \to \nu_\mu$ Oscillation," in *these proceedings*, 2007.
19. J. Lopez-Pavon, "Non-unitary leptonic mixing and CP-violation," in *these proceedings*, 2007, `arXiv:0711.1049[hep-ph]`.
20. K. Okumura, "Super-Kamiokande," in *these proceedings*, 2007.
21. R. Terri, "K2K Oscillation Results," in *these proceedings*, 2007.
22. K. Mahn, "MiniBOONE Systematic Error Handling," in *these proceedings*, 2007.
23. S. Kopp, "MINOS Systematics," in *these proceedings*, 2007.
24. T. Furukawa, "Final Donut Results," in *these proceedings*, 2007, URL `http://aps.arxiv.org/abs/0711.0728v1`.
25. A. Ariga, "OPERA," in *these proceedings*, 2007.
26. J. Paley, "Nova Near Detector R&D," in *these proceedings*, 2007.
27. N. Tanimoto, "The T2K 2KM Detector," in *these proceedings*, 2007.
28. A. Laing, "Flux Measurement at a Neutrino Factory Near Detector for Neutrino Oscillation Measurements," in *these proceedings*, 2007.
29. C. Mauger, "KamLAND," in *these proceedings*, 2007.
30. T. Kawasaki, "Double Chooz," in *these proceedings*, 2007.
31. C. Mauger, "Daya Bay," in *these proceedings*, 2007.
32. S. Kim, "Reno," in *these proceedings*, 2007.
33. H. Nunokawa, "Angra," in *these proceedings*, 2007.
34. Long Baseline Neutrino Oscillation Experiment BNL E889 proposal (1995).
35. T. Nakaidara, "T2K," in *these proceedings*, 2007.
36. A. Norman, "NoVa," in *these proceedings*, 2007.
37. N. Mondal, "INO," in *these proceedings*, 2007.
38. F. Terranova, "Neutrino hierarchy from CP-blind observables with high density magnetized detectors," in *these proceedings*, 2007.
39. M. Dierckxsens, "Sensitivities of future long baseline experiments in the U.S.," in *these proceedings*, 2007.
40. M. Ellis, "The low-energy Neutrino Factory," in *these proceedings*, 2007.
41. A. Cervera, "MIND performance and prototyping," in *these proceedings*, 2007.

Summary of Working Group on Accelerator Physics and Machine Design and R&D

D. Li[1], C. Ohmori[2]

Accelerator & Fusion Research Division, Lawrence Berkeley National Laboratory
One Cyclotron Road, Berkeley, California 94720, USA[1]
KEK, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan[2]

Abstract. Working Group on Accelerator Physics and Machine Design R&D at Nufact-2007 focuses on topics on accelerator physics and technical issues of hardware components associated with a Neutrino Factory or its subsystems. There were 32 presentations given at the working group. A special session was held to discuss collaboration opportunities with the Muon Collider Task Force (MCTF) at Fermilab in consideration of many overlaps in the machine R&D between a Neutrino Factory and a Muon Collider. Two more sessions were held jointly with Working Group 2 on muon collection schemes and other related subjects.

Keywords: neutrino factory, accelerator, proton driver, target, collection scheme, muon acceleration, muon collider

INTRODUCTION

Significant progress has been made in R&D for a neutrino factory since Nufact-2006. Highlights of the progress this year include successful beam operation of NuMI, new experimental results from the HARP collaboration where precise measurements of pion productions were conducted and Target experiment at CERN. Moreover, there are advances on international MICE experiment, beta-beam schemes and T2K beam line components. Accelerator Physics and components R&D for a Neutrino Factory is the main focus of the Working Group. To summarize what had been presented at the Working Group, we categorized them in the following subjects:

- **Proton drivers**: Linac-based and RCS-based proton driver designs, hardware R&D and status of J-PARC Main Ring
- **Targets**: MERIT collaboration, a new idea on particle jet target , and T2K target
- **Muon cooling**: Progresses from the MICE collaboration including target, absorber and RF R&D, new idea on ionization cooling in circular machine (ERIT), 6D cooling experiments, and new schemes.
- **Muon accelerations**: progress to maximize number of passes in RLA, EMMA, non-scaling FFAG, RACCAM and required R&D issues

Two joint sessions were held for collection schemes of muon beams and we heard about PRISM R&Ds, MICE solenoid, FNAL mu-e experiments, J-PARC muon beam line, T2K horn and plasma lens schemes. We also heard about NuSNS. A special focus session to discuss collaboration between muon collider R&D was held.

CONVENTIONAL NEUTRINO FACILITIES AND SUPERBEAMS

An integrated number of $200\text{x}10^{18}$ protons were successfully delivered to the target for NuMI experiments in FY07 [1]. The main Injector provides $3.1\text{-}3.2\text{x}10^{13}$ protons per cycle. It is shared with a collider experiment. One batch is delivered for anti-proton production and 5 batches are for NuMI. After repair of the target cooling line, the transition to sustained operation was very smooth. Key issues were: comprehensive beam permit system, beam loss control, beam transport stability and auto-tune beam position control. The target has already taken 820-MWhr for over a year. The maximum beam power of 270-kW was achieved. Water leak problems occurred for both horns after sustained operation. The failure was in Kovar transition pieces of ceramic insulators. After practicing using a mock-up, the radioactive horn system repairs were accomplished. Both original horns is still used after reaching 16.7 million beam pulses.

CP981, 9th *International Workshop on Neutrino Factories, Superbeams, and Betabeams –NuFact 07,*
edited by O. Yasuda, C. Ohmori, and N. Mondal,

An upgrade scenario for NuMI to NOvA was presented [2]. NOvA requires $3.6\text{x}10^{21}$ protons for a 7 year run. Increase of booster repetition rate and slip stacking in Main Injector are currently ongoing as near term programs. The test of multi-batch slip stacking was successful. During two years operation for the collider experiment, beam loss by slip stacking was reduced to only a few percent. To stack 11 batches for NOvA, the beam loss level is still below 5 %. Furthermore, at the end of collider experiments, the Recycler will be reconfigured as a proton ring for multi-batch slip stacking for 700-kW. It is also planned for NOvA to modify the target hall to optimize the off axis neutrino beam and to increase the medium energy neutrino beam.

The status of the T2K beam line was reported [3]. It consists of Preparation, ARC and Final Focus sections. In the ARC section, 28 superconducting combined function magnets are used. These magnets will be installed in FY2008. Normal conducting magnets for the Preparation section were already installed. Those for the Final Focus section will be installed in FY2008. Four different types of beam monitors are prepared: Electro-static monitors to detect beam position, Segmented Secondary Emission Monitors for beam profile, Current transformers for beam intensity and ionization chambers as loss monitors. The decay volume for T2K is a 94 m-long iron helium vessel cooled by water to remove 150-kW heat deposited in the wall and concrete shield. The beam dump consists of 98 graphite blocks cooled by an aluminum module. The commissioning will start in FY2009.

Results of the HARP experiment were reported [4]. HARP covers a large angle distribution on pion production yields on different energy of 3 to 12-GeV/c and different target material. The results on a Tantalum target were compared with MARS simulation results. It shows that MARS seems rather optimistic for π- production and too pessimistic at low energy. More production cross-section measurements are basically finished and can be used to tune the hadron production model.

BETABEAM

Advantages of betabeam were reported [5]. For the precise measurements of θ_{13} and δ, neutrino energy determination is important. An idea of betabeam using an electron capture process is presented. If the neutrino energy at rest frame, Q, is very low and that at laboratory frame is very large, almost all neutrinos hit a detector.

The status of EURISOL betabeam with CERN PS upgrade was reported [6]. It is planned that some of the accelerators will be replaced to assure high reliability and to increase the performance of the injector chain for LHC operation. There is a preparation for a long-term upgrade to replace the existing PS by a higher energy PS2 to reduce the SPS energy swing. And, it is also considered to use a Superconducting Proton Linac and Rapid Cycling PSB as PS2 injector. It is pointed out that betabeam in PS2 requires to enlarge the tuning range of the 10-MHz RF system and to enlarge the physical ring aperture.

A collimation scheme of decayed particles in the storage ring was presented [7]. As 1-MW beam power will be lost in an accelerator cycle, the handling of beam loss and protection of components are crucial issues. A protocol between two computer codes, Fluka and ACCSIM has been developed and used to simulate the loss in the decay ring. The decay ring has a 7 km circumference and 2.5-km straight sections. For the local power deposition, loss from 6He betabeam is below the quench limits (~ 4-mW/cm^3) of super-conducting magnets. However, loss from 18F betabeam exceeds the limits. Alternative layouts of the superconducting dipole and absorbers are currently investigated.

The status of the EU design study was also reported [8]. The EU is supporting the study for a future neutrino facility including neutrino super-beam, betabeam and a neutrino factory.

PROTON DRIVERS

The design of accumulator and compressor for the SPL-based proton driver was presented [9]. The Superconducting Proton Linac will accelerate a proton beam up to 5-GeV. The accumulator stores the long beam pulse from the linac and forms 6 bunches with 120-ns bunch width. It will be an isochronous ring and no RF system is necessary to keep the bunch structure. The compressor will make the bunch shorter by phase rotation technique. The very short bunch of 2-ns bunch width will be delivered to the target. The ring will have a large slippage factor of 0.164 for rapid phase rotation. The required RF voltage is 4-MV per turn. Two constraints are pointed out: a long straight section of more than 40-m for the RF system and a small dispersion required reducing the beam size because of large momentum spread. The computer code, ORBIT, is used for a tracking simulation on bunch compression. The result shows that a very short bunch of 1.99-ns bunch width was formed.

Another candidate of a proton driver is a Rapid Cycling Synchrotron. The scenario of the ISIS upgrade was presented [10]. The ISIS is the world's most powerful pulsed neutron source and provides a beam power of 160-kW. Recently, the second harmonic RF systems were installed and it is planned to increase the beam intensity by 50 %. As the first step, replacing of the 70-MeV linac by a 180-MeV injector will halve the space charge tune depression and allow more beam to be accelerated. This modification will increase the beam power up to 500-kW. As second upgrade, a new 3-GeV RCS will accelerate the beam bunches from ISIS and provide 1-MW beam. The ring could also accelerate beam to 8-GeV at 16.7-Hz. The last upgrade scenario includes building a 1.2-GeV booster synchrotron and it will provide 2.5-MW.

Hardware development at RAL was also reported [10]. As Front End Test Stand, ion source, RFQ and beam chopper are under development. A new ion source is developed and aims to double the output current to 70-mA. A 0.5-m, 324-MHz, 4-vane RFQ cold model is almost completed. A high power Klystron for the RFQ has been delivered.

The status of the J-PARC Main Ring was reported [11]. All B, Q and S magnets have been installed. Installation of injection devices will be finished in February 2008. All magnetic cores for 5 RF cavities were tested and will be installed in this fall. Fast Extraction devices have been manufactured. To avoid serious discharge, each ferrite core is manufactured carefully and a slow rise time of 1.6-μs for the extraction kicker was also adopted. The number of bunches in the Main Ring will be 6 instead of 8 for day-one operation. The beam commissioning in the Main Ring will be started in May 2008. The fast extraction for the neutrino experiment will start in April 2009. It is required to deliver 100 kW beam for 1e8 seconds by 2010 summer shutdown.

TARGETRY

A neutrino factory requires a target that can handle MW beam power level. The solid targets typically work for less than 1-MW; liquid targets have potential to work beyond MW. A powder target was proposed and presented [17]. Progress and status on targets for current projects or R&D efforts were reported.

Target for MICE is progressing well. The design, construction and testing of the target are under way. The target mechanism can achieve 85g acceleration required to dip target into last 2 ms of ISIS spill. Good agreement between data, MARS and GEANT4 simulations are obtained.

T2K target uses Graphite with He-gas cooling; it is designed to beam power of 750-kW. The target is installed in a Ti-alloy container to reduce oxidization. Design of the target structure is almost finished, and He-gas cooling scenario has been verified by FEA simulation. He-gas circulation is confirmed with the test mock-up and actual compressor system. A prototype target is being fabricated and will be delivered by December 2007. T2K target is expected to be installed in the beam line in autumn of 2008. In addition, a powder jet target for a neutrino factory was also proposed.

MERIT target experiment at CERN has completed installation and was ready to take beam at Nufact-2007. Beam run was scheduled for the end October of 2007[18]. Good news on MERIT was heard when we are writing this paper (November 2007). The preliminary results of the MERIT experiment were very successful [19].

COOLING

There is a wide range of R&D activities for muon cooling. These activities include international MICE experiment, US MUCOOL program of hardware R&D for muon ionization cooling channels, MANX: 6-D Ionization Cooling Experiment, Dog-bone Cooler, a possible new open iris RF cavity experiment and ERIT.

MICE has made excellent progress towards Steps I & II in the past year [20]. The beam line magnet refurbishing and installation is partially completed. Detectors are completed and readied for installation. Production target has been tested at nominal parameters, but a dust issue still exists. The two SC spectrometer solenoids are in production. The first one will be available in December 2007. In collaboration between LBNL and ICST (Institute of Cryogenics and Superconductivity Technology) of HIT (Harbin Institute of Technology) in Harbin, the design of coupling coils is complete. A MOU between LBNL and HIT for fabrication was signed. SC wires have been ordered. A test coil will be winded in December of 2007. RF cavity design for MICE is being finalized. Cavity fabrication should start early next year. The absorber and focus coil module has been out for bid. Experimental Hall for MICE has been cleared and permits MICE equipment to be installed. D2 magnet has been installed in "out" position, and allow for shielding wall to be built up around the area.

Quadrupole magnets are being refurbished and will be installed later.

A 6D Muon Beam Cooling Experiment, MANX (**M**uon collider **A**nd **N**eutrino factory e**X**periment) was proposed by Muons, Inc. in collaborations with a few US national laboratories and universities [21]. The experiment proposes to use high-pressure hydrogen gas in helical cooling (magnet) channel (HCC) to cool muon beams both longitudinally and transversely. However, the experiment will not test with RF cavities. The HCC has potential for large cooling factors of ~ 10^{-5}, which is essential for a muon collider and beneficial for a neutrino factory. The R&D effort is currently funded by the US Phase II STTR for simulation studies and HCC prototype designs.

An idea for injection and extraction of a muon cooler ring was presented. Two methods were considered to reduce the strength of kicker magnets. One is generating a long straight section in the solenoid lattice. The other is distributing kickers in an alternating gradient insertion.

US MUCOOL programs focus on hardware R&D for muon ionization cooling channel [22]. The main challenge has been to run high gradient RF cavity in strong magnetic fields. Experimental studies have been carried in an 805-MHz pillbox-like cavity with conventional open beam irises terminated by thin beryllium windows. As has been reported before, the achievable accelerating gradients degrade with the increase of external magnetic field. Severe cavity surface damage, associated with high intensity x-rays and dark currents, was observed. The RF program now is focused on more fundamental understanding of RF breakdown with magnetic fields. The cavity was modified to accommodate a removable button with electric field enhancement on the button to study the RF breakdown problems. The button can be made from different materials or has different coatings so that we can explore what material and coatings can withstand high RF gradients in strong magnetic field. Buttons have been tested so far are copper, copper with Ti-N, Mo and W. Surface inspection of the buttons and data analysis are being carried out now. A 201-MHz prototype RF cavity has been designed, fabricated and tested recently. The cavity is also a baseline design for MICE. The main purpose was to explore engineering design and construction challenges, and learn how to condition and commission the cavity in a real cooling channel environment and more importantly to study RF cavity performance affected by strong magnetic field. Based on experience learned from the 805-MHz cavity, the 201-MHz cavity was designed with minimum surface field enhancement; that is the accelerating gradient is almost the same as the peak surface field. The cavity surface was treated with the same procedure as for superconducting cavity: high pressure water rinsing and electro-polish. Cavity component assembly has always been conducted in clean room to prevent cavity surface from possible contaminations. The cavity was first conditioned and tested with Ti-N coated flat copper windows and reached to design accelerating gradient of 16-MV/m very quickly and quietly without external magnetic fields. Two thin, large and curved beryllium windows (0.38-mm in thickness and 42-cm in diameter) were installed after initial run. The cavity surface was inspected before the installation. There was no surface damage was found. The cavity with curved beryllium windows, again reached to ~ 18-MV/m quickly and quietly. The next important test is to study external magnetic fields on the 201-MHz cavity performance. Together with MICE coupling coil magnet, a superconducting solenoid magnet for MUCOOL will be also fabricated by ICST of HIT and should be ready for tests at MTA by end of next year.

After the first successful test of KEK absorber at MTA, the second absorber test with upgrades of new electrical heater, temperature sensors and liquid hydrogen sensors have been assembled at Fermilab and ready for tests at MTA after safety approval [23].

To avoid RF cavity performance degradation due to external magnetic field, an alternative approach is to re-design the ionization cooling channel with RF cavity and magnets separated to reducing magnetic field in the cavity. An idea is to have a series of open iris cavities with magnets placed near “conventional” nose cone. Engineering details and assembly issues need to be further addressed. The idea could be tested with only one cell as well [24].

MUON ACCELERATION/FFAG

Orbit and optics distortion in a non-scaling FFAG for muon acceleration were investigated. In a non-scaling FFAG, the orbit shift can be small by tiny dispersion; however, tune excursion is large because of no chromaticity correction. In case of a 10-20 GeV muon ring, many integer and half integer resonances will be crossed in 17 turns. The tracking results show that small misalignment (0.1-mm) makes a large (10-15 mm) orbit distortion. And, a gradient error causes emittance growth. The amplification factor and growth factor are 110-143 and 250, respectively. In the tracking simulation, a resonance behavior was not observed since the tune changes quickly and such error affects a beam incoherently. A “random walk model” can explain the behavior of orbit and optics distortion. When the tune changes five times slower (85 turns), the resonance behavior appears.

An Electron Model with Many Applications, EMMA, aims to study a linear non-scaling FFAG with rapid acceleration, relativistic energies, and high frequency RF and muon acceleration. Important characteristics are rapid acceleration through many transverse resonances and serpentine acceleration.

Recent progress on the number of passes in a Recirculating Linear Accelerator (RLA) was presented. The Dogbone RLA aimed to accelerate a muon beam from 2.5-GeV to 10-GeV. It becomes possible to pass the linac for 7.5 times and accelerate up to 32.5-GeV by tracking simulation. The Dogbone RLA has an advantage on large orbit separation at the linac end compared with a Racetrack RLA. Although the final energy is 32.5-GeV, it still has a reasonable orbit separation in the "Droplet" arc sections, which have mirror symmetry to accelerate both μ+ and μ-, simultaneously. A possible muon collider RLA design is also presented. Adding droplet arc sections, a 103-GeV linac will accelerate muons up to 750-GeV by 7 passages.

Required R&D issues for muon acceleration are listed up. For an initial linac as the first accelerator, tracking simulation and studies on large amplitude beam are required. For an RLA as the second accelerator, a complete design including 6-D tracking, engineering design and cost estimation are needed. As a motivation to use FFAGs is cost, the number of passes in RLA and energy range should be optimized. For non-scaling FFAGs to accelerate to final energy, longitudinal coupling, injection and extraction should be studied. As general issues, system optimization including linac to RLA transition point, transfer between accelerators, R&D on high gradient RF and beam loading issues should be investigated.

FOCUS AND JOINT SESSIONS

A special session was held to discuss technical issues and collaboration with Muon Collider Task Force (MCTF) of Fermilab [25]. Discussions were focused on how can a neutrino factory be "upgraded" to a muon collider. In present baseline muon collider designs, the output from a neutrino factory cooling channel is the input to the muon collider cooling channel: a gift (it was not required to be that way). There is a large overlapping in R&D between a neutrino factory and muon collider. Collaborations should always be encouraged.

A joint session was held to discuss muon collection scheme. A Plasma Lens is examined as an alternative to a focusing horn for a neutrino facility. The concept is based on a combined lens/target configuration where the lens is a high-current plasma surrounding the target. The plasma can carry significantly larger currents than the traditional horn and can be shaped to give a desired neutrino flux distribution [26]. Progress and status on T2K horn was reported [27].

ACKNOWLEDGEMNTS

The Working Group had fruitful discussions and quality presentations. The authors thank everyone who had presented and attended the working group. A special thank goes to Dr. M. Meddahi from CERN for her efforts in helping organizing the working group.

REFERENCES

1. S. Childress, in this proceedings
2. S. Childress, in this proceedings
3. T. Sekiguchi, in this proceedings
4. G. Catanesi, in this proceedings
5. J. Sato, in this proceedings
6. S. Hancock, in this proceedings
7. A. Fabich, in this proceedings
8. M. Lindroos, in this proceedings
9. M. Aiba, in this proceedings
10. C. Prior, in this proceedings
11. T. Koseki, in this proceedings
12. J. Pasternak, in this proceedings
13. S. Machida, in this proceedings
14. S. Berg, in this proceedings,
15. A. Bogacz, in this proceedings
16. J. Berg, in this proceedings
17. T. Nakadaira, in this Proceedings
18. A. Fabich, in this Proceedings
19. K. Mcdonald, private communications
20. M. Zisman, in this Proceedings
21. D. Kaplan, in this Proceedings
22. D. Li, et al, in this Proceedings
23. S. Ishimoto, in this Proceedings
24. R. Palmer, in this Proceedings
25. S. Geer, in this Proceedings
26. M. Bishai, in this Proceedings
27. T. Sekiguchi, in this Proceedings