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MUTAC Committee Report on the Muon Collaboration Review Oct. 18, 19, 2001

Mutac Advisory Committee Response to Charge of Meeting Oct 18,19, 2001

CHARGE TO MUTAC FOR THE OCTOBER 18/19 COMMITTEE MEETING

The Advisory Committee is to:

1) Review and comment on the progress achieved during the last year

2) Review and give advice on the R&D plans and corresponding budgets for fiscal year 2002

3) Analyze and comment on the results of the Neutrino Factory Feasibility Study – II

4) Assess and give advice on the long range R&D directions, including the plans for an international cooling demonstration

5) Give advice on the common R&D goals that are useful to the development of a neutrino factory as well as to the long range plan to develop a muon collider

RESPONSE

1. Review and comment on the progress achieved during the last year

The committee finds the progress since last year excellent.

There has been very good progress on studies. We note the completion of Feasibility Study II, further development of analytical theory (with extension of the linear theory to six dimensions) and computer simulations (enhancements to ICOOL and GEANT). A number of new and potentially important ideas such as "Bunching then Rotation" and "Ring Cooling" have emerged.

On the hardware side, a number of efforts are underway and first results have been presented. At Fermilab, Lab G has come into operation. Results from the RF processing of the NCRF 805MHz prototype cooling cavity in a ~3T solenoid field have already shown the importance of engineering tests. Hydrogen absorber engineering design has been validated in a successful test at room temperature of prototype windows. The development of important safety documentation related to the absorbers has begun. At BNL tests of carbon and mercury jet targets have been carried out. Results appear very promising. The carbon target behaved well, and the mercury jet did not show signs of rapid disintegration from the beam. This is very encouraging even though the bunch charge was limited. First tests at Grenoble of a jet entering a high solenoid field of 13T are in progress and are positive so far.

We congratulate the collaboration on its success of pulling in numerous small university groups. It was estimated that over 70 FTE's are working in the collaboration.

2. Review and give advice on the R&D plans and corresponding budgets for fiscal year 2002

The HEPAP Subpanel Draft Report outlines the level of effort it considers appropriate and realistic for Muon Collaboration work with a primary goal of neutrino source development.

With these guidelines in mind this committee believes that the collaboration needs to concentrate on the most critical R&D issues associated with the Neutrino Storage Ring. Ionization cooling employs new and as yet untested ideas. We believe that the target test study is not as high a priority as efforts toward showing a proof of principle for ionization cooling. The outlined plans and budgets presented for 2002 seem reasonably matched if activities in the target area are reduced. However we note that many hardware activities are just getting started and at the present rate of funding may take considerable time to complete. It is imperative that serious thought be given to the schedule ramifications of the expected limitations in funding levels before too many activities are initiated.

3. Analyze and comment on the results of the Neutrino Factory Feasibility Study – II

Feasibility Study II is a mature study that makes use of potential design optimizations, many of which were recognized but not implemented during Study I. Estimated cost has been reduced mainly by the reduction of the final energy, resulting in the elimination of one recirculating linac. The neutrino production rate has been improved by use of mercury jet target and three induction linac sections. The study is modeled on using the BNL site and an upgraded AGS as the proton source, but could as well be sited elsewhere.

The committee believes that the collaboration has accomplished the goal of specifying a complete system end to end, in some detail. This second iteration has made for a more cost-effective design.

We encourage continued work to improve areas which are still weak (e.g. emittance growth in the recirculating linac) and the incorporation of new ideas as they develop. But we feel that the time has come to focus more on critical areas of R&D.

4. Assess and give advice on the long range R&D directions, including the plans for an international cooling demonstration

The "cooling demonstration" is the key systems test for the Neutrino Factory.

The collaboration must develop a long term funding limited (flat funding) plan and establish priorities, so that the R&D efforts accomplish this test in a reasonable length of time.

However we note that the collaboration should not be too quick to define just what the demonstration experiment will be. There are new ideas emerging all the time; one of these new concepts may become the most attractive.

We note with pleasure progress on international cooperation and recommend that the US collaboration (which has a considerable depth in people resources) thoroughly understand the potential of the ideas from international groups (e.g. FFAG, and 44/88 MHz cooling). In particular we note that the FFAG group in Japan has limited resources and might benefit from US collaboration.

5. Give advice on the common R&D goals that are useful to the development of a neutrino factory as well as to the long range plan to develop a muon collider

Common R&D efforts, in particular on emittance exchange have generated new and interesting concepts. These new ideas (e.g. ring cooling) have considerable potential for benefiting both the neutrino factory and the muon collider. We certainly encourage further work on these ideas and the development of new common concepts.

However we believe that too much emphasis on the muon collider design is premature. The outlined staged approach to a muon collider is too dependent on future imponderables, both physics and accelerator, to be credible at this time.

6. Further remarks on funding support

Sufficient accelerator R&D funding in basic sciences and in particular HEP is critical for the future of fields which utilize accelerators as research tools. We believe that this support is insufficient at its present level to meet the demands necessary for the pursuit of future projects and new concepts. An overall increase in accelerator R&D funds is extremely important.

The HEPAP Subpannel has been charged with setting relative priorities in the HEP field and it is inappropriate for this committee to make comments related to these priorities.

We believe that the neutrino factory hardware developments could use more funding. But also note that new ideas are still being generated. Care must be taken that efforts started one year are not superfluous the next.

Realistic planning and the setting of priorities are required within the funding constraints and overall HEP plan.

General Comments
The following comments are a compilation of comments made by committee members. No attempt has been made to remove a certain amount of redundancy and change in style.

Progress over the last year

The collaboration is to be complemented on the very good progress that has been made in many areas over the last year. Specifically:

- The completion of Study II and its advancement of the precepts presented in Study I and it's new ideas and solutions as well as the resulting enhanced machine parameters show excellent progress.

- Completion of major phases of Targetry Experiment E951 at BNL on carbon and mercury targets to the point they appear to be viable alternatives up to at least 1.5 megawatt input beam from a proton driver.

- The excellent progress in the development of various simulation codes and their inter-comparison agreement. The tracking codes for the simulation of the machine front to back. And the further development of 6D analytical formalism.

- The presence and initial experimentation in Lab G at Fermilab of the 805MHz RF cavity and solenoid system is an important start understanding what gradients will be realizable.

- The starting development phases of the LH_2 absorption unit with window integrity studies and their encouraging results.

The collaboration is to be further complimented on its great diversification including national and international accelerator labs, university groups and consortiums, and the advancements made and documented by them.

The collaboration and Brookhaven National Laboratory are to be complemented upon the completion of Study II and the positive performance results obtained in the study.
They are also to be complemented on the mounting the E951 experimental apparatus and obtaining of critical results with the high speed camera for the mercury targets and the carbon target enhanced material variations. All this showed the ability to obtain applicable results in a very timely fashion.

Future Plans

The R&D plans and corresponding budgets need to be reconciled especially in light of HEPAP priorities and guidance.

The collaboration needs to set priorities that are consistent with the budget scenarios as presently envisioned. If the budget is as constrained relative to the request as it now appears, hard choices should be made within the collaboration to move forward on the most critical and fundamental issues i.e. ionization cooling. Main emphasis for hardware should be directed toward the cooling channel development (MUCOOL) and starting to develop a sound plan and schedule toward the "International Cooling Experiment". The International Cooling Experiment must be based on reasonable hardware development programs and should avoid an inadvertent freeze out of new ideas or scheme for cooling. The experiment should not be specialized to early before it rests on a firm technical basis.

Physics Program

The potential of the physics programs of the neutrino factory and Higgs factory- muon collider and their place in the overall national high energy plan have been addressed in the recent HEPAP Subpannel Report (Draft). We only put forward a few remarks here.

The neutrino factory sounds very interesting and appears to be a strong physics program.

The collaboration talked about a staged construction scenario, starting with a neutrino "superbeam", moving to a neutrino factory, and ending with a muon collider-Higgs factory. However, no clear plan was presented. This is probably understandable as the technical approach for a collider is still far from firm and the time scale is in decades.

Feasibility study II

The second feasibility study (FS-II) produced by the MC collaboration is a BNL site specific study. Building on the initial Fermilab study FS-II is an attempt to provide the ‘”best possible performance” at this time. Compared to the initial study a factor of six improvement in muon yield was achieved. Improvements included a non-distorting phase rotation section, a liquid mercury target, and a variable focusing ionization channel. Other design variations in FS-II compared to FS-I were the adoption of a lower final energy and the use of skew quadrupole focusing in the storage ring to accommodate the higher intensity beam decays. Both 1MW and 4MW designs were investigated.

MUTAC is very positive about the evident progress made in FS-II. We find that the MC Collaboration succeeded in demonstrating the main goals of the study: viability of the BNL site, improved performance, improved technical integration and increasing sophistication of the sub-system designs. Indeed the significant increase in muon yield (not just from the Hg target) over FS-I leads MUTAC to conclude that further gains should be expected with increasing maturation. In addition the Committee notes that new ideas not ready for inclusion into the design study such as emittance exchange cooling, FFAG’s, and bunch beam phase rotation could result in further design enhancements.

It must be emphasized that the Feasibility Study II has made significant effort to reduce the cost and improve the performance. The improvement of factor 6 in the mu/p ratio is remarkable. However, the estimated cost for the neutrino factory seems to be still high. It is comparable to a 500GeV e+e- linear collider, which is a general purpose machine.

MUTAC welcomes the attempt to provide a preliminary cost estimate but believes that at a relatively early stage in sub-system R&D cost estimates are primarily useful in identifying potential cost effective trade-offs rather than assessing the bottom line cost of a facility. We note that the Japanese neutrino factory concept utilizing cascading Fixed Field Alternating Gradient rings (FFAG's) and no beam cooling offers a very different approach to cost optimization to that adopted here. The studies of the (FFAG) recirculating accelerator are just starting, but may be promising and need to be understood.

The Japanese idea of using FFAG for phase rotation and acceleration and omitting the cooling is attractive from the view point of the cost, although obviously the performance would be somewhat lower. A quantitative comparison of figure of merits of the FSII and FFAG is desired. To do so, considering the primitive design stage of the Japanese project and their limited man power, it will benefit the neutrino factory society as a whole if the US group would work with them. MUTAC recommends this direction of collaboration.

Including cooling in the neutrino factory has an advantage that it can be a step to the muon collider. However, the staging from the neutrino factory to the muon collider is not clear at the present time. R&D of cooling for the neutrino factory will surely benefit that for the collider but the actual cooler and subsequent RLA may not be adequate as the first part of the muon collider.

The Committee believes that it is useful to continue to investigate the higher power 4 MW design even if this represents a "phase-2" scenario. The incorporation of remote handling and the recognition that the target station area will be classified as a nuclear facility is a welcome step in this regard.

We heard about Study II recirculating acceleration studies, both in a standard geometry and in a new dog-bone geometry. There is some emittance dilution in the arcs. This needs to be understood and placed in the context of an imperfect machine with the expected level of errors present. After working so hard to achieve low emittance, it should not be given away.

Finally MUTAC congratulates the MC Collaboration for the ability to organize the various disparate groups and entities to produce a well integrated, conceptually detailed report on the desired schedule and meeting the technical goals as outlined by the BNL Director. This bodes well for the future where increased international collaboration seems both desirable and inevitable.

Theory and Simulation

Feasibility Study II has shown remarkable progress on the simulation of targetry, phase rotation and cooling. A few highlights included theoretical developments on cooling, simulations and comparisons between codes, the Study II simulations, Target to end cooling simulations, and finally new ideas for ring cooling.

Also, the formalism of the cooling process extended to 6D gives clear physical insight to the problem. The 6D theoretical development will aid in understanding and developing new cooling ideas. The transition from a degenerate to a non degenerate case in the two transverse degrees of freedom was not obvious in the presentation and perhaps should be explored. The real system will probably lack the perfect symmetry to have the degeneracy. In this respect simulations that include errors are critical.

The proposed ring-type cooling system is very attractive although still premature. It is desirable to continue the study to find the best configuration and to investigate the difficulties of injection and extraction.

MUCOOL

The principal activities encompassed under MUCOOL are:

1. Cooling channel design and simulation (current designs are SFOFO and DFLIP)
2. RF development, including both 805 MHZ and 201 MHZ open and pillbox (windowed) cavities
3. 3-7 T solenoids
4. Hydrogen absorber
5. System integration
6. Cooling demonstration

Channel design has stabilized on the SFOFO and DFLIP design, both of which work on paper with similar performance. The hardware required for implementation is much different in each case and a rational choice must await further development.

At Lab G, more than two years of preparatory efforts are finally coming to fruition with the start of tests of high-gradient (53 MV/m peak surface field) open rf cavities in a solenoidal (5 T) field. Large dark currents appeared with initial operation but have been decreasing as the cavities process. Understanding the source of the dark current will be a key goal. The next major test will be 805 MHz windowed pillbox cavities, which have been completed and are scheduled for tests in the near future. Further in the future are the design (2002), construction (2003) and test (2004) of 201 MHz rf cavities.

Significant progress has also been made in the area of hydrogen absorbers. University collaborators have fabricated and successfully tested two thicknesses of Be windows for the absorber. Completely fabricated absorbers should be ready for filling in 2003 and beam tests (in a solenoidal field) in 2004.

Some work has also been done at Fermilab and local universities on instrumentation, although this activity has been resource limited.

The preparation of the test area at the end of the Fermilab linac has made good progress. When completed and outfitted in 2004, this area will be used to great advantage for filling and beam tests of hydrogen absorbers, and power and beam tests of 201 MHz RF and high field solenoids.

MUCOOL efforts will culminate with participation in the International Cooling Experiment, a crucially important demonstration of a complete technical system that establishes experimentally the validity of ionization cooling. MUCOOL anticipates providing the absorbers and possibly the RF cavities.

Ionization cooling remains the primary R&D issue for the collaboration. The most difficult part is the development and integration of the hardware, which is the goal of the MUCOOL efforts. This work is now beginning to show the first experimental results with real hardware. The next three years should provide considerably more information about component and subsystem feasibility, allowing the evolution of a realistic and optimized cooling channel design, which can be tested in the International Cooling Experiment

Normal Conducting RF

It is great to see the normal conducting RF development make progress with high field studies. It may be useful to make contact with other NCRF high gradient research. The issue of the large dark current should be taken very seriously. The desired gradient is far above the capture gradient at that frequency. The capture gradient for an electron at rest at the correct phase in a one dimensional model is about 16 MV/m at 3 GHz. It scales proportional to the frequency.

The collaboration needs to quantify the running scenario and determine how many breakdowns per cavity are allowed during a given running period. This will set more precise goals for the normal conducting work.

Understanding the NCRF for the cooling channel and its limitations is key to determining the effectiveness of the channel. However the field gradients and the environment of the strong solenoid field make this far from a standard cavity certification test. Initial results bear this out. Dark currents that have been encountered are way above any normal acceptable limit and structure damage of the cavity can not be ignored. As building and preparing test cavities is an expensive and time consuming process, real thought should be given to the focus of the future program.

Though 800 MHz is not the final desired frequency, it is easier to manage than 200MHz cavities. It would seem prudent to proceed to understand cavity limitations at the 800 MHz frequency before putting significant effort and expense into 200 MHz. However we note that both breakdown levels and darkcurrent effects will doubtless be different for the two frequencies.

These are not conventional cavities. Two different cavity shapes (or three if one counts the present test cavity) are under consideration. They will have different multipacting and darkcurrent behavior. Models should be carefully tested as soon as possible. Simulations of darkcurrent trajectories and their interaction with foils will help basic understanding and the differences between the two frequencies. Simulations of breakdown and plasma spots in the strong magnetic field will give further insight.

The subject of RF breakdown and Cu surface destruction is a major R&D issue today. The muon collaboration should avail itself of these and past efforts.

Surface breakdown tests can be carried out in simple dc setups (such at Cornell) before being applied to more difficult RF tests. Cleanliness during assembly and care during cavity processing must be carefully implemented. Cavity gradients should not be pushed far beyond the required operating gradient until extent of damage at operating gradient has been determined.

The HEPAP Subpannel Report speaks to the possible level of support it expects for the muon activity and consequently encourages focus on development of concepts and simulations which have minimum cost. We can not fully support this point of view. There must be connection to real problems with real hardware if fundamental technical limitations are to be realistically addressed.

MUTAC recommends that a well thought through prioritized plan be implemented to work toward addressing the NCRF structure issues without starting down too many parallel paths simultaneously.

SuperConducting RF R&D 200 MHz

MUTAC is impressed by the progress made by the Cornell-NSF sponsored Cornell 200 MHz Superconducting Cavity Program. Evident progress has been made both with infrastructure improvements and toward the fabrication of a cavity. Important collaborations have been established with CERN and INFN Legnaro. We look forward to hearing further details of design and plans for the power and HOM couplers, rf power sources, and future design choices of the cryoplant.

We do note however that there is considerable effort needed to produce a cavity and perform successful vertical dewar tests. As noted in the FSII report, near term R&D must focus on achieving gradient and Q in single cell cavities, studying mechanical and vibrational problems, exploring potential cooling schemes, and working toward economical structure costs. Stable and predictable funding will help in carrying out these goals.

LH2 Absorbers

The LH_2 absorber work, in particular the window development seems to be advancing very nicely. The use of optical means to monitor the window displacements is suggested in order to increase the temperature range of the measurement to low temperature work in particular. The overall effort seems to be in a position now to attack the problem of the heat exchange involved in the high instantaneous heat load presented by the beam and a cold high flow cooling scenario by using low temperature thermometry techniques.

The interaction of the aluminum window with the collapsing solenoid field during quench should be investigated both through calculations and experiments.

Low energy muon cooling

This is a novel approach to the problem of obtaining muon beams with high phase space density. It relies on "frictional cooling"-that is, energy loss at very low muon energies, where the dependence of energy loss on energy is such that both longitudinal cooling and transverse cooling take place as the muon beam slows down. Unfortunately, in order to realize this, muon beam energies must be in the keV range, and the muons are subject to muonium formation (for mu-plus) or atomic capture (for mu-minus). Using helium gas as the stopping medium can inhibit muonium formation. The mu-minus atomic capture cross sections are not known at these energies; measuring them is one of the goals of this work. An experiment has been proposed at PSI, using a 10-40 keV muon beam, to measure atomic capture cross-sections and to check energy loss and multiple Coulomb scattering.

In the current design of a cooling channel based on this scheme, the proton driver and target must be optimized to produce very low energy muons. The muons are collected in a 30-50 m long channel containing a solenoidal field, absorbers, and a transverse electric field. The cooled muons drift to the radial edges of the channel and form a distributed source along the outer radial boundary of the channel. A scheme for collecting the muons from this source for acceleration remains to be worked out.

This scheme is recognized to be a "long shot" but is nevertheless quite worthwhile to continue, as the potential payoff if successful would be very significant. "High-energy" ionization cooling, a dominant source of uncertainty and cost, could be rendered unnecessary. It would be very desirable for the proponents to show quantitatively how this scheme would satisfy the requirements on muon flux and emittance for a neutrino factory and a muon collider. This information may be available, but was not presented to the committee.

The work to date has been good, despite the limited availability of resources. It should be encouraged to continue especially since it is a proposal for muon cooling, which is a critical issue in the neutrino factory. This may be an area in which new small university efforts could be started, expanding the R&D base in accelerator physics at universities.

Targetry

The efforts on targetry over the past year have been significant, in particular the early success of E951 which has results for both the carbon option and initial results on a Hg jet. The HG jet is a basic component of Feasibility Study II (FS II) in that it has a x2 higher yield compared with carbon. The E951 experiment has provided impressive results, in particular the movie frames of the Hg jet-proton beam interaction.

The studies on the carbon target, a critical backup option for the collaboration, are particularly encouraging because of the agreement between finite element analysis simulations and experiment. The results indicate that the carbon-carbon composites are the choice for a back up design since they will tolerate even a 4 MW beam, neglecting lifetime issues associated with radiation damage. The carbon option avoids the issues associated with Hg jet injection into the 20 T solenoid, which is another attractive feature.

The Hg jet studies in E951 are an indicator that this technology too will be compatible with 4 MW proton beams. The experiments indicate at the present proton intensity that the jet survives intact more than long enough at the proposed jet velocity of 20 m/s to provide a 'new' target for each proton pulse.

There are several open questions for the Hg jet:

- Injection into the 20 T field
- Nonlinear effects in jet dynamics at the full proton intensity and pulse duration

The field injection question seems to be under study, with the concept of placing the nozzle into the high field region of the solenoid being an attractive solution. The collaboration is actively pursuing studies of these issues at the High Magnetic Field Laboratory in Grenoble, France.

As for the nonlinear effects, this is a more open-ended issue. K. McDonald pointed out after the open meeting that at the proposed high intensity for the E951 experiments the Hg temperature will exceed the boiling point and this certainly falls into a non-linear effect. The question is what is the boiling point at the effective pressure of the Hg that is heated by the proton beam and surrounded by cold Hg liquid. These issues may in fact be best addressed by further experiment. It is however not clear whether the priority for these studies is sufficient to justify the expense.

In summary the progress on targetry is indeed impressive and the carbon carbon composite constitutes a good day one solution with the x2 advantage of Hg being important enough that it should be considered as the target of choice at this stage.

Solenoids

The solenoid work appears to be well in hand for all of the magnets individually with the possible exception of the 20T (14T) Target Source Magnet, and are very similar to MRI or detector magnets that are presently produced commercially.

The more interesting and novel problems are related to the Mechanical Engineering involved in the integrated system's operational scenarios and electrical protocol to deal with them. A failure analysis at some early stage would be in order in that probably the failure will be the most critically stressful scenario for the integrated systems e.g. cavities, solenoids and structures associated with them, or solenoids quenching with the induction linacs surrounding them. Adjacent opposing field solenoids failure mode analysis will need to be carried out in detail in order to mitigate their foreseen effects.

Lastly, a few comments on the 20T target solenoid utilizing a superconducting outsert with a normal conduction insert. It appears that given the curves presented at the review, the case for changing to a 15T design is preferable in light of the comparison of costs, technical risks, and limitations versus performance gain.

Emittance Exchange /Ring Coolers

Longitudinal cooling through emittance exchange would benefit a neutrino factory and is essential for a muon collider. This is an area of very active R&D: in the development of analytic linear theories in six-dimensions, in the development of new ideas for implementation of emittance exchange (helical coolers, ring coolers, spiral coolers), and in the simulation of these schemes using GEANT, ICOOL and COSY.

The committee heard a report on the recent emittance exchange workshop, in which several ring cooler designs were studied, analytically and in simulation. The emittance exchange workshop sounds like it was very productive. There are lots of new ideas on the theme of ring cooling. Modeling and theory are moving towards being able to handle all the physics. Nonlinearities and end fields will be very important. We believe the collaboration should keep these creative juices running.

The designs looked at both solenoidal and quadrupole focusing, with rectangular and octagonal footprints, and with ring momenta ranging from 200 MeV/c to 1 GeV/c. End fields were not included in some of the simulations, and the difficult problems of injection and extraction need to be solved. Spiral “snake” coolers, helical dipole channels and bent solenoids also continue to be investigated. One or two ring coolers appear to be sufficient (on paper) to achieve the required longitudinal emittance for the muon collider, but the transverse emittance still falls short of the requirement.

These efforts are quite important because of the significant potential payoff for the neutrino factory (easing of the requirements on systems downstream of the cooling section, with potentially large cost ramifications) as well as for the muon collider. Ring coolers have a major advantage over spiral or linear systems because of the potential for significant hardware cost savings. Addressing the currently unsolved issue of injection and extraction should be the highest priority. Strong efforts should be made to define a technically feasible design.

International Cooling Demonstration Experiment

An international muon-cooling demonstration experiment is currently being organized by a steering committee with membership from the US, Europe and Japan. The collaboration would design and build a section of a cooling channel and test it in an existing muon beam. The members of the collaboration would provide components of the channel and instrumentation to measure its performance, after a single design was agreed upon. The cost of the demonstration, estimated at $30-40M, would be shared among the collaborators. The schedule for deciding on the design parameters seems unrealistically aggressive: the design would be settled in November of this year, although the experiment would not be run until 2004. This will be a very important experiment.

Work directed toward MUCOOL and this experiment should be the highest priority of the muon collaboration. The experiment is absolutely required to validate the concept of ionization cooling. However, the design should not be frozen prematurely, as many hardware issues must be proven and new ideas are still being generated. It is important to retain the flexibility to be able to incorporate potential changes in the ultimate experiment. The collaboration must define precisely the goals of the experiment and be sure that the proposal addresses the critical technical and theoretical issues.

MUTAC does not believe that the proposed schedule for making technical decisions regarding specifications of the cooling experiment to be credible. The Committee recommends that a more realistic schedule, consistent with reasonable expectations of resources, be adopted in the near future.

International Activities

The Committee heard a summary of the world-wide activities associated with neutrino-factories. It sounds like the collaboration for the International Cooling Experiment is developing well.

A significant effort exists at CERN based on a similar design concept to the U.S. one but using different technical choices for many of the elements. Lower frequency RF systems (44 MHz) and pulsed horns rather than solenoids at the target are some examples. The CERN group has not developed the simulation tools to the same level as the U.S. team and an effort has been started to simulate the CERN design using the U.S. software tools.

In addition to the CERN group a much smaller effort is underway in Japan but there a radically different approach based a series of FFAG rings without cooling is used. While this approach does not naturally lead to the eventual goal of validating the technical systems needed for a muon-collider, it does potentially result in a lower cost neutrino-factory. MUTAC suggests that a closer collaboration with the Japanese group is both desirable and feasible. Technical evaluation of different design concepts with common simulation software would seem to be appropriate goal.

The Committee also heard of the re-emergence of a U.K. group who are starting to work in this area. The initial stage of an international collaboration, primarily with the CERN group, has started. We are pleased to note the U.K. involvement and urges the MC Collaboration to ensure that the international committee is sufficiently broad based to represent the whole community.

MUTAC believes that world-wide financial pressures in HEP R&D will mean that no single national group will have the necessary resources to complete a full R&D program. International collaboration is therefore a necessity rather than a goal. In this context the Committee welcomes the formation of the international collaboration for the International Cooling Experiment and finds the technical goals (but not the schedule) reasonable at this time.

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