Fermilab Accelerator Advisory Committee

Report of the August 8-10, 2007 Meeting

September 13, 2007

Committee

S. Chattopadhyay (Cockroft Institute), J. Corlett (LBNL, Chair), G. Geschonke (CERN), G. Hoffstaetter (Cornell University), K-J Kim (ANL), S-I Kurokawa (KEK), S. Peggs (BNL), T. Raubenheimer (SLAC), H. Weise (DESY). Apologies for absence from M. Minty (BNL), and H. Padamsee (Cornell University).

Introductory remarks

The committee recognizes the hard work of the many Fermilab staff involved in preparing for this meeting. We would like to thank the presenters for well-prepared materials and for informative and interesting discussions, and the administrative staff for assisting the committee with travel arrangements and hospitality.

Executive Summary and General Comments

The committee was charged to review a variety of activities being conducted and/or planned under the auspices of the newly established Accelerator Physics Center, and within the context of the recently prepared Fermilab Strategic Plan.

The committee welcomes the initial draft report from the Fermilab Steering Group, and supports the plan outlined therein. The plan supports accelerator design and R&D at Fermilab, to provide a physics program both at the Terascale in LHC and ILC energy frontier machines, and in the complementary intensity frontier physics based on high intensity proton sources. Major aspects of the plan are strong support for a timely start to ILC and hosting of the facility at Fermilab, development of the intensity frontier using new and existing infrastructure, and a route toward the energy frontier beyond LHC and ILC.

The committee supports the Fermilab priorities; in the immediate term to provide full support to Tevatron Run-II operations until completion of the program, and continuation of the neutrino program. In the near term, support for Terascale physics at the LHC, including accelerator and detector upgrades, and leadership in the global ILC effort including hosting of the facility at Fermilab, are priorities, and Fermilab will also develop it's existing infrastructure to enhance the neutrino program, with NOvA as a flagship experiment. In addition, support for accelerator R&D will be enhanced through the development of Project X, an 8 GeV linac based to a great extent on ILC technology, and also with R&D toward a future TeV-scale muon collider. The committee encourages production of resource-loaded schedules for these activities that will establish a credible overall plan, with realistic manpower needs, to address tasks in order of priority.

Project X is strongly supported by the committee and we congratulate the team on an innovative design that is supportive of ILC, the neutrino sector, and ultimately a muon collider. Fermilab leadership is encouraged to drive Project X forward at a rate commensurate with a project aimed at construction start in the early years of the next decade. In addition to a new, high-power, superconducting linac injector, the project requires operation of the Main Injector (MI) and Recycler Ring (RR) under conditions not yet demonstrated. Dedicated beam time to establish the viability of the MI and RR in supporting the proposed beam conditions is recommended.

Fermilab must be concerned with, and must directly address, the potential for mis-interpretation of the priority of ILC with respect to Project X by the broader community.

Long-range R&D toward a future energy frontier muon collider is important to pursue, and for Fermilab to maintain a secure leadership role in the program. CERN is pursuing CLIC as a potential future energy frontier machine. It is important that multiple options be available to the community. The R&D required for a muon collider is significant, and the program will extend over decades. The committee recommends that Fermilab takes a leading position in the global context of this long-range R&D. While the importance of the muon collider R&D program is recognized, the committee feels that this does not have the same priority as other, nearer-term, projects in ILC, LHC, and development of the neutrino sector with Project X and existing infrastructure.

The role and activities of the Accelerator Physics Center (APC) are becoming more clearly defined. The committee is pleased to see the APC in action, and recommends continued attention to planning of its activities and coordination of the necessarily diverse plans, to provide a coherent long-range R&D program.

Collaborations with other institutions are important to the success of the Fermilab strategic plan. The highly productive work in development of muon cooling techniques and technologies in collaboration with Muons Inc. is a shining example of successful collaboration.The committee supports continued development of collaborations, and strategic actions on Fermilab's part to build collaborations, for example through dialog with DOE to raise awareness of the importance of Fermilab projects in the national context.

Fermilab Strategic Plan

Findings

The Fermilab Director formed a Steering Group on March 22, 2007, to build a strategic roadmap for the evolution of the accelerator-based HEP program, focusing on facilities at Fermilab that will provide discovery opportunities in the next two to three decades, and with construction of the ILC as a goal of paramount importance. The Steering Group membership consisted of staff from Fermilab and other institutions, with a strong component of accelerator physics and technology expertise, and with deputy director Young-Kee Kim as chair. A number of subgroups was formed to assure consistency of the roadmap with EPP2010 and P5 recommendations, and were tasked to develop the following:

- neutrino physics plans based on the Neutrino Scientific Assessment Group (NuSAG) studies
- flavor physics plans using the reconfiguration of the present collider complex
- options based on technical and resource feasibilities that support ILC R&D for a timely start and with Fermilab as a potential host site
- a potential physics program in case of delay in the ILC program

- options for energy frontier colliders that might follow ILC or be needed should the reach of ILC be insufficient

The Steering Group received six letters from the community, sixteen one-page proposals, three expressions of interest, and one letter of intent. A total of seventeen facilities were considered, in alignment with the charges to the subgroups. Brief descriptions of each potential facility were developed, with anticipated performance parameters and cost range, critical R&D requirements, estimated construction duration, and potential synergies with ILC and other programs.

In framing their plans, four scenarios were identified by the Steering Group. In scenarios 1-3 – ILC is built in U.S.:

Scenario 1: GDE baseline, decision in 2010, 2012 construction start
Scenario 2: GDE baseline + 2 years
Scenario 3: GDE baseline + 5 years

In scenario 4, the ILC is built outside U.S. or LHC shows that a larger energy is required.

Under all scenarios Fermilab proposes strong support for LHC and ILC, and for the continuation of the Fermilab neutrino program with NOvA as the flagship experiment. ILC activities are in technology R&D, site development, and leadership and engineering investment in the Engineering Design Report. LHC activities support the LHC Accelerator Research Program (LARP), and LHC upgrades.

The report also proposes that in all scenarios Fermilab provide support for accelerator R&D toward future facilities to develop the neutrino program, and to provide future options for a neutrino factory or muon collider. A major component is the R&D required for a new 8 GeV superconducting H^- linac (Project X) supporting simultaneous delivery of 2.3 MW at 120 GeV and 200 kW at 8 GeV. R&D for Project X would begin immediately with emphasis on expediting the R&D and industrialization of ILC cavities and cryomodules, and overall design of the project. R&D for future accelerator options concentrating on a muon collider would increase.

Modifications to the existing Tevatron facilities may also provide for fixed-target programs and test beams with the Tevatron operated as a 120 GeV stretcher ring, or even as an 800 GeV high intensity proton source.

The 8 GeV superconducting H^- linac is tentatively known as Project X. The linac would be highly synergistic with ILC, in using many similar and a number of identical cryomodules at higher energies, and in accelerating beam with the ILC time structure and intensity, thereby requiring the same RF source, distribution, and controls as ILC. Project X provides support for ILC development, in industrialization of cryomodules based on or identical to ILC designs, and potentially in operational experience. The cost range for Project X is estimated as $0.5-1.0B, with an estimated construction duration of 4-5 years.

In Scenario 1, Fermilab will pursue the above programs in LHC, ILC, neutrino program based on NOvA, R&D toward Project X, and increased R&D toward a muon colldier.

In Scenarios 2 and 3, the neutrino program would be enhanced for SNuMI by an upgrade of the existing facilities to provide 1.2 MW of beam power at 120 GeV, in addition to supporting LHC physics and leadership in the global ILC effort. In this scenario the accumulator serves as a momentum stacker for protons, and the recycler as a box car stacker. Modest beam power would also be available at 8 GeV, using the debuncher as a slow spiller (at the expense of the 120 GeV program). With a modest delay in ILC, Fermilab would pursue construction of Project X, as a medium-sized project with an estimated construction duration of 4-5 years. Use of a new linac would simplify operations compared to the existing 30+ year-old complex. This would provide physics opportunities in extending the reach of NOvA, enabling new initiatives on flavor physics, optimizing the use of the Deep Underground Science and Engineering Laboratory (DUSEL), and stepping toward longer-term programs such as the neutrino factory and an energy frontier with VLHC or a muon collider.

In Scenario 4, the plan calls for development of the SNuMI program as a minimum, plus implementation of Project X should resources be available and ILC timing permit.

Comments

The committee strongly supports the plan presented, and recognizes the strength of Fermilab leadership in generating a plan which is of critical importance to high energy physics in the U.S. The plan provides options for the future of accelerator based high-energy physics at Fermilab, with broad scope allowing for exploration and discovery in energy frontier, neutrino, and flavor physics. The plan addresses near and far-term needs, and allows flexible choices as the community pursues ILC as the next energy frontier facility. Uncertainties in the ILC project timeline call for prudent alternate programs in the event of delays to the technically-driven schedule of approval and construction start early in the next decade.

Project X is strongly supported, and the committee congratulates the team on an innovative design that is supportive of ILC, the neutrino sector, and ultimately a muon collider. Fermilab leadership is encouraged to drive Project X forward at a rate commensurate with a project aimed at construction start in the early years of the next decade. The committee considers that the project needs to be ready with an engineering design in the 2010 timeframe, and a strong start is needed. The committee supports Fermilab management in its goal to develop the project to the level of CD0 in 2008. Fermilab leadership must choose whether to pursue the critical decision route or alternate approaches, and the committee suggests that consideration to the CD process be considered in the light of potential strategic benefits for collaborators.

Fermilab must be concerned with, and must directly address, the potential for mis-interpretation of the priority of ILC with respect to Project X by the broader community.

Ongoing projects are the completion of Run-II, development of the NOvA program, support for LHC, support for ILC, and R&D toward Project X. These projects are therefore considered by the committee to be core commitments for Fermilab. R&D toward a muon collider is considered a role in which Fermilab should provide leadership in collaboration with the NFMCC and others, in order to maintain long-term capabilities for accelerator based high-energy physics. However this does not require the same commitment and priority as for the core activities.

Development of the existing infrastructure to enhance proton production in support of neutrino programs, and using of the Tevatron as a source for fixed target and test beam experimentation, would make good use of the resources and investments made at Fermilab. The extent to which the options explored by the Steering Group need to be implemented will be determined by the developments over the next few to several years, and options should be kept alive by maintaining infrastructure where possible.

The committee recognizes the early stage of current planning, and encourages development of resource-loaded schedules to allow planning to proceed in more detail. Where possible, plans should be developed that accommodate the impact of cessation of Tevatron operations at the end of FY09, with an integrated and realistic budget and schedule for each of the major programs, under different scenarios.

The Fermilab strategic plan represents an ambitious pursuit of accelerator R&D, engineering, and design. Resources to achieve the proposed goals will be limited, and Fermilab management is encouraged to look for collaborations and for means to engage other institutions. Examples include re-engaging HINS collaborators in Project X at a more significant level, expansion of collaborations to other institutions, pursuit of DOE support for Project X, and stronger engagement with the international community in muon collider R&D.

While the Fermilab strategic plan is by nature focused on the needs of FNAL, integration into the national plan needs to be developed and some points clarified. There are areas such as Advanced Accelerator R&D (AARD), and high gradient research, that are important in the national HEP planning, but which are not major constituents of the Fermilab plan. The committee also notes that CLIC is not part of the Fermilab plan. Although this is understandable given the resources available and current direction of interest and expertise at Fermilab, this should not be interpreted as neglect of CLIC in the national program.

With many challenges and uncertainties in the road ahead, FNAL leadership must support a diverse range of R&D activities to retain options for accelerator based HEP in the future, while ensuring timely progress in projects of the highest priority in the physics community. The committee considers the strategic plan produced by the Steering Group to be a strong base for the future of Fermilab.

Project X

Findings

Project X has evolved from the proton driver effort, which was to produce a 2 MW beam at 120 GeV by providing strip injection into the Main Injector using an 8 GeV superconducting H^- linac. It has recently been recognized that stacking in the Recycler allows a reduction of the pulse current in the H^- linac to the 9 mA planned for the ILC, and that also the ILC repetition rate of 5 Hz can be used. Stacking in the Recycler rather than in the Main Injector has two advantages: (a) the Main Injector repetition rate is increased since time spent at injection energy is avoided, and (b) proton beam is available from the Recycler at 8 GeV for other experiments while the Main Injector is ramping to higher energy. The location of the proton linac remains that of the proton driver, and the proton target has been oriented to be toward the newly chosen DUSEL site at the Homestake mine in Minnesota. Project X would dramatically increase the high-energy proton power for neutrino experiments from 0.36 MW today to 2 or even up to 2.5 MW, and it would additionally provide an unprecedented intensity of 8 GeV proton beam for other studies.

For the proton driver, an analysis found that a booster synchrotron is more efficient than a normal conducting linac, but that an 8 GeV superconducting linac can be at least as efficient as a synchrotron. This analysis still holds for the SRF linac parameters of Project X.

While the proton driver had ß<1 cavities up to 1.2 GeV, the linac sections of Project-X are proposed to be constructed as close to the ILC design as possible, and the proposed cavities are basically the ILC design for betas above 0.6. For efficiency with the lower beta beam, the ILC-type cavities would be stretched such that they are operated in the $8\pi/9$ mode at 1300 MHz. There are some differences from the ILC cryomodules, arising from different focusing requirements for proton beams, where a larger number of quadrupoles is required. Above 2.4 GeV, however, the cryomodules are identical to those for the ILC, and above 5.2 GeV the configuration of modules into RF units is also identical to that of the ILC.

The H^- source and front-end of Project X are similar to the design already developed for the High Intensity Neutrino Source (HINS). The HINS R&D program is making progress, albeit slower than anticipated primarily due to lack of resource assignments. The HINS R&D program has strong synergies with ILC in the development of RF distribution and control systems from a single klystron to multiple cavities.

The power of the high-energy proton beam remains at 2 to 2.5 MW. It is expected that the space-charge dynamics with very large energy spread and chromaticity, the transition jump in the Main Injector, the power load in the proton transport to the target, and power dissipation in the target itself, can limit this beam power. A preliminary target design was presented that should be able to operate with the approximately 2% energy deposition from a 2.3 MW beam, and a new proton transport line with sufficiently low beam loss has been designed.

The proton energy of the 2 MW beam from the MI is very flexible and can be chosen between about 40 GeV and 120 GeV. When changing the energy, the proton current and the Main Injector ramping speed remain constant, so that the beam power on target remains invariant. However, the number of protons available for other experiments at 8 GeV increases with higher energy in the MI, as a result of the correspondingly lower Main Injector repetition rate.

Comments

As described above, Fermilab has developed a strategic plan recognizing that the ILC might not begin construction as fast as technically possible, and therefore a physics program has been developed that could be pursued if the ILC is delayed. It is important to prepare for such a program now, so that it is ready to be launched quickly in case it becomes clear early in the next decade that ILC construction is delayed. We therefore welcome the effort to have an engineering design of Project X on the timescale of 2010, while remaining clearly committed to construct ILC based on a technically driven schedule. Project X is especially suitable for Fermilab in the current scenario of a not well-defined schedule of ILC construction, because its engineering design includes many critical components of the ILC. Additionally, there is synergy with neutrino-factory and muon-collider R&D work. The committee therefore very strongly supports the work that is planned for Project X.

The front end of the H^- linac has so far been developed within the HINS effort, and has made significant progress during the last year even though it has suffered under reduced budget allocation and personnel shortages. The committee supports the plan to henceforth manage the HINS effort as part of Project X, and to allocate resources to it according to prioritization within this project. Generally speaking, projects with the longest lead time, and those synergistic with the ILC, should be emphasized. For the front-end linac it is especially recommended make progress with strengthened collaborations, for example for testing of low level RF control of the Lorenz force detuning in pulsed spoke resonators.

Collaborations in the HINS R&D program already exist with ANL, BNL, and LBNL, although funding for these partners has been reduced significantly in FY07. ANL involvement profits from similarities of the front ends of RIA and of the 8 GeV linac. BNL are developing H^- strip injection and ring dynamics, and LBNL are studying electron cloud, LLRF controls, and design of buncher cavities. It is recommended to revitalize and strengthen these collaborations. Significant deviations between design and performance have been experienced in collimation and injection processes at the SNS. We therefore recommend that Project X designers pay close attention to the experience obtained, and the calculation tools used, at the SNS. This includes the multi-turn simulations of the process of beam accumulation. Active collaboration with scientists from SNS could be fruitful. Also, strengthening of collaborations on electron cloud effects is recommended, because the electron cloud has been identified as the potential problem that could be hardest to deal with. The Recycler and Main Injector have parameters that make electron cloud parameters comparable to those in RHIC and KEK-B, and collaborations with these projects could be fruitful.

Design and production of Project X cryomodules prepares and contributes to ILC industrialization and/or, depending on the status of the ILC preparation work, the pre-series production. The ILC industrialization program calls for each region to develop the capacity to produce 25 ILC cryomodules per year, to be compared with the approximately 40 ILC-like cryomodules required for Project X. The committee sees this synergy, together with operation experience gained from Project X, as supportive of the ILC.

For betas from 0.6 to 0.9, the cavities are proposed to operate in the 8pi/9 mode. Potential disadvantages of the 8pi/9 mode need to be carefully studied, including the effect of weakly damped modes around 1.3 GHz, and the modified mode spectrum due to the required cavity length increase of about 2-3mm to increase the 8pi/9 mode frequency by about 800 kHz to 1.3 GHz.

While the synergy between Project X and the ILC is extremely welcome, the physics potential of Project X should not be sacrificed. The technical choices that were presented did not seem to make such sacrifices, assuming the accumulation in the Recycler and high intensity in the MI can be made to work. Also, unnecessary costs should be avoided that could occur by insisting on similarities to the ILC that are not needed. A two tunnel design, for example, does not seem to be needed for Project X.

One limit to the performance of Project X could be the space-charge dynamics for the 2/3 filled Recycler that is waiting to stack the third pulse train before transfer to the Main Injector. The space-charge tune spread is planned to be reduced by approximating a transverse KV distribution, and by utilizing a harmonic RF system, and damping is to be provided by a relatively large negative chromaticity that produces a tune spread of about 0.04. While comparisons to other rings seem to indicate that the Recycler could cope with such a beam, more detailed studies, including a strong component of experimental physics studies, are planned and encouraged. The committee recommends the allocation of sufficient beam-study time in the Recycler and the Main Injector to investigate potential problems in anticipation of Project X conditions. These studies should include further analysis of resonance extraction from the Recycler. Also, the installation and commissioning of a 2nd harmonic cavity and of fast, 10 turn dampers would need significant study time.

It was indicated that a one turn injection into the Recycler or directly into the Main Injector could be envisioned as an upgrade, where up to 3 times larger pulse currents, and/or up to 3 times longer pulse trains could be accelerated in the SRF linac, with up to 2 times the repetition rate. If such upgrades are desired, the accelerator module design has to be adjusted accordingly before construction. The committee recommends careful consideration be given to the pros and cons of such an approach, and that pursuing operating scenarios without clearly defined benefit do not increase the cost or technical risk to Project X.

The committee discussed the best timing for CD0. Considering that it will take until early in the next decade to determine whether the ILC is being delayed, 2008 may appear to be early for CD0. However, this date might help other DOE laboratories to collaborate with FNAL on Project X. Fermilab management may, in due course, determine that a different schedule or approach to funding Project X is more productive. The committee supports the proposed target of being technically prepared at the level required for CD0 in 2008 in all scenarios.

Muon Collider R&D Initiative

Findings

The development of technologies leading to a viable muon collider design was presented as an important part of the FNAL Steering Group plan, in providing a route to higher energy colliders that might follow ILC or be needed should results from LHC point toward a higher energy than that planned for ILC. New parameters and new ideas about muon cooling make studies of such a collider particularly interesting. Many steps are required to demonstrate the viability of a muon collider, including development of: design of a proton driver; target, capture, and phase space rotation schemes; 6-D cooling schemes; acceleration; collider design; detector configurations; exploration of possible overall schemes. A program of about 10 years duration, with an annual funding of $20M and manpower resources of 100 FTE, was estimated to be necessary on a national level, in order to provide significant evaluation of these major items, and allow for a statement on feasibility of a muon collider and a preliminary cost estimate by 2017. R&D plans reach as far as 2024. Precise planning is not possible at this stage, however, and a rough estimate points to a possibility to begin construction in the middle of the decade 2020. While progress needs to be made in all areas, the pursuit of 6-D cooling was presented as the pacing item, given a technically limited schedule.

The Muon Collider Task Force (MCTF) was formed in July 2006 by the FNAL Director, to develop a plan for an advanced R&D program aimed at the technologies required to support the long-term prospects of a Muon Collider. The Task Force is led by S. Geer and V. Shiltsev, and includes staff from FNAL, BNL, Jlab, Muons Inc., LBNL, and ANL. All muon collider and neutrino factory R&D activities at Fermilab are being coordinated through the APC Muon Accelerator R&D Department.

The MCTF has a focus on revisiting the overall Muon Collider design, and on developing and testing the cooling channel components that are needed, with requirements significantly beyond those needed for a Neutrino Factory. Activities are in muon collider design and simulations, development of helical magnets for cooling channels, development of high-field solenoids, testing of pressurized RF cavities and materials, and beam tests with high intensity proton beams soon to be available in the Muon Test Area (MTA).

Simulations have been used to verify 6-D cooling using the Helical Cooling Channel (HCC), which consists of a series of transversely offset solenoidal windings. A proposal for the muon collider and neutrino factory experiment (MANX), to build and test a helical cooling channel with beam, is expected in the spring of 2008. MANX is expected to reduce the horizontal, vertical, and longitudinal phase space of a muon beam by 50%. The initial stage will be building and testing of a section of offset superconducting solenoids forming part of the helical channel, leading to construction and installation of the MANX experiment in FY09-10.

The MCTF plan includes RF cavity and power source development, cooling experiments, high-temperature superconductor (HTS) development, and feasibility, cost, and performance studies, leading to readiness for construction of a muon collider in the 2025-2030 timeframe.

The MCTF takes advantage of developments aimed at the neutrino factory (the MERIT and MICE experiments, both supported by the NFMCC), as well as work done for MUCOOL (cavity, solenoid, and absorber design, and testing at the MTA). A coordination committee has been established to ensure that the combined R&D activities are coherent and effective. A protocol has been formulated to guide relations between MCTF and NFMCC, with MCTF to manage those activities that require Fermilab to play a significant role as a host laboratory, and the NFMCC manage those activities with an international character.

Comments

The MCTF has been instrumental in revitalizing muon collider studies, and collaborations with Muons Inc. have been particularly productive. We congratulate the team on their enthusiasm and creativity. Areas where R&D is required have been identified and a comprehensive work plan is being established.

The committee supports the muon collider R&D program as an important step towards future lepton colliders in the TeV range. We specifically endorse the statement in the report of the Fermilab Steering Group that "In all scenarios R&D for future accelerator options concentrating on the neutrino factory and muon collider should be increased." In spite of the long time scales involved, it is important to maintain a "critical mass" level of funding in order to advance with the most important technological issues.

While the committee acknowledges the decision of Fermilab to increase the funding towards this R&D program, resources and priorities at Fermilab will not likely match the technically limited R&D plan. The committee strongly recommends pursuit of national and international collaborations. Coordination with the NFMCC has begun, but there is room for a broader collaboration.

New concepts have emerged in recent years for self-consistent 6-D cooling schemes, and the MCTF has plans to develop the most critical technologies, which might be the key towards the muon collider. Simulations have been used to verify the 6-D cooling using the Helical Cooling Channel (HCC), which consists of a series of transversely offset solenoidal windings. This is a very promising result, which is critical to the feasibility of the Muon Collider. No baseline design exists for the cooling channel yet. The committee recommends to closely observe developments elsewhere in this area and to coordinate R&D plans with other laboratories. An example is the alternate "Guggenheim" cooling channel being studied at BNL.

It is planned to complete an engineering design of MANX in early 2008, which is a challenging task. This experiment will be an important test of the HCC concept, and the preparatory work to date is impressive. The committee strongly recommends that tolerance and sensitivity studies be performed as part of the engineering design. This includes assessing requirements on magnetic field quality, sensitivity to alignment errors, etc. In addition, the parameter space for the Muon Collider HCC should be fully explored. Since it is likely that MANX will be the experimental basis for a Muon Collider reference design, the experiment should be designed to be as representative as possible of a final design. Extensive thought should be given to understanding the experimental procedures and necessary diagnostics to ensure unambiguous results. Several systems to experimentally observe the change in emittance were presented to the committee, and the committee recommends that other possibilities also be considered, for example single particle diagnostics, which might lead to results which are easier to interpret. A collaboration with particle physicists in this domain will be very helpful.

The committee applauds the work on RF cavities providing high gradients up to 65 MV/m, under high pressure hydrogen gas and immersed in a 5 T solenoidal magnetic field. We strongly recommend continued pursuit of the R&D program in this direction. The development of windows and other cavities for cooling channels is also advancing well (under the auspices of the NFMCC).

R&D priorities should be on the helical cooling channel (MANX experiment), and development of high-gradient RF cavities for operation in strong magnetic fields. The committee does not support the development of high field (>30 T) superconducting solenoids as a priority. However, we strongly encourage Fermilab to support the enhancement of HTS conductor development aimed at high field magnets. Such a program should be encouraged in collaboration amongst interested national laboratories, universities and HTS vendors.

Work on the beam line to provide beam to the MTA is advancing well. The MTA will allow an important test program with muons. The committee encourages the development of more detailed plans to fully exploit the possibilities this facility offers.

Crystal Collimation Experiment at the Tevatron

Findings

The committee thanks Nikolai Mokhov for his clear and comprehensive presentation of recent advances in crystal collimation experiments, in both 1) crystal channeling, and 2) volume reflection modes of operation. The volume reflection mode in particular shows significant promise for use in advanced collimation schemes in the LHC, and in other potential future colliders, with the confirmation of 97% efficiency during the SPS H8 experiments.

Comments

The committee supports the exploitation of the unique opportunity that Fermilab has, to perform dedicated end-of-store beam studies in the Tevatron in order to confirm the accelerator science, and to build a case for an LHC implementation of a collimation scheme that incorporates crystals as a key component.

LARP is an appropriate vehicle through which such a "high risk, high gain" activity could be coordinated. If Fermilab management agrees to LARP coordination, FY08 and 09 planning should immediately become a high priority for LARP Accelerator Systems management.

There is a need to establish better relations with the well-established Italian-Russian collaboration, which has recently used SPS beam time so effectively, and which has plans for further beam studies there. Fermilab management may consider the possibility of hosting graduate students or post-doctoral fellows from the Italian-Russian collaboration at Fermilab. There is also a need for stronger communication with CERN management, for example in defining what constitutes a demonstration of viability for LHC, in order for preliminary design studies to begin.

A carefully thought out experimental plan is required, including theoretical predictions that can and will be tested against experimental observations. We commend Dr. Mokhov for his openness in discussing current shortfalls, illustrating the need to enhance and clarify the proposed experiment:

1. Enhanced beam diagnostics are required, perhaps even including single particle tracking capabilities.
2. We recommend inviting particle physicists to join this experiment, as in MICE, MANX and the SPS H8 experiments.
3. Estimates of required beam time need to be refined. Beam time in (e.g.) 2009 should depend on reasonable demonstrations of success in 2008.

In summary, we believe that this is an experiment with great potential. It could definitively establish the multi-turn physical model, building on the recent single pass success in the H8 beam line at the SPS. Further, it could revolutionize collimation systems in the LHC and other future accelerators. However, to be effective the experiment needs to unambiguously demonstrate the physics and viability of crystal collimation. The committee recommends that planning and external coordination be enhanced, and we urge the principal investigators to work with Fermilab management to assign adequate beam time to assure a high chance of success.

APPENDICES

i) Charge
ii) Committee assignments
iii) Agenda

Fermilab Accelerator Advisory Committee

August 8-10, 2007

Charge (Draft Rev. 4)

At its August 2007 meeting the Fermilab Accelerator Advisory Committee is asked to look at a variety of activities being conducted and/or planned under the auspices of the newly established Accelerator Physics Center, and within the context of the recently prepared Fermilab Strategic Plan. The primary topics for review and discussion are:

1. Fermilab Strategic Plan

Fermilab has recently completed a new strategic plan aimed at future facilities in support of accelerator based elementary particle physics at Fermilab following the end of Collider operations. The plan retains the ILC as the primary goal, but develops concrete options under a number of scenarios for the ILC. The strategic plan will be outlined for the committee, with accompanying discussion and comments welcomed. The plan will also provide the context for the discussions of the other R&D activities presented within this review.

2. 8 GeV Linac coupled with the Recycler

A concept emerging from the strategic planning exercise is the 8 GeV superconducting linac that has been discussed previously, but with modifications that would align the operational beam parameters more closely with those of the ILC (9 mA x 1 msec). This alignment is enabled by the utilization of the Recycler as a stripper/accumulator ring. In parallel, development of the 60 MeV front end test is proceeding in the Meson Lab.

The committee is asked to review and offer comments and recommendations relative to the overall strategy, including alignment with the ILC program, the plan for integration into the accelerator complex, and the R&D program including both the ongoing effort on the 60 MeV front end and further efforts required to support the newly conceived accelerator configuration.

3. The Muon Collider initiative

The Muon Collider initiative is centered within the Muon Collider Task Force in APC. The scope of activities coordinated by the Task Force involve the APC, the Accelerator and Technical Divisions, and collaborations with the (national) Neutrino Factory and Muon Collider Collaboration (NFMCC), and Muons Inc. These activities are intended to be complementary to work coordinated by the NFMCC which involve collaborations within the international community on a first generation ionization cooling experiment (MICE).

The committee is asked to review the activities of the MCTF and offer comments on the strategic approach, including alignment with the strategic plan, and the scope of the planned activities. Included in the scope of the meeting will be a description of preliminary plans for a second generation muon cooling experiment. In formulating its comments and recommendations the committee should consider, and offer advice as appropriate, on the interaction between these activities and the NFMCC program.

4. Crystal Collimation

Fermilab has received a proposal for an R&D program on crystal collimation targeted towards the LHC. The committee is asked to review this proposal and offer comments and advice relative to:

- Are goals well established and are they well aligned with needs of the LHC?
- Is the proposed program structured to provide confidence that these goals can be met?
- Are the impacts on Tevatron operations well understood?

As usual the committee is invited to issue comments or suggestions on any aspect of the programs discussed beyond those specifically included in this charge. It is requested that a concise report responsive to this charge be forwarded to the Fermilab Director by October 1, 2007. Thank you.

Committee assignments to address points of the charge:

1. Fermilab Strategic Plan:
   - John Corlett
   - Swapan Chattopadhyay
   - Tor Raubenheimer

2. Project X:
   - Georg Hoffstaetter
   - Swapan Chattopadhyay
   - Steve Peggs
   - Hans Weise

3. Muon Collider Initiative:
   - Gunther Geshonke
   - John Corlett
   - Kwang-Je Kim
   - Shin-Ichi Kurokawa
   - Tor Raubenheimer

4. Crystal Collimation:
   - Steve Peggs
   - Shin-Ichi Kurokawa

Fermilab Accelerator Advisory Committee
Agenda
August 8-10, 2007
Comitium, Wilson Hall 2SE

Wedensday, August 8

8:30-9:00	Committee Executive Session	J. Corlett
9:00-9:15	Welcome and Presentation of Charge	S. Holmes

Strategic Planning Report (Organized by Steve Holmes)

9:15-9:45	Overview of the Steering Committee Report	S. Holmes
9:45-10:15	Tevatron based facilities beyond Run II	M. Syphers
10:15-10:30	Discussion	
10:30-10:50	Break	

Project X (Organized by Dave McGinnis and Giorgio Apollinari)

10:50-11:10	Project X Overview	D. McGinnis
11:10-11:30	Project X Linac	G. Apollinari
11:30-11:45	8 GeV injection	D. Johnson
11:45-12:00	Discussion	
12:00-1:00	Lunch	
1:00-1:20	Recycler	S. Valishev
1:20-1:40	Main Injector	V. Lebedev
1:40-1:55	8 GeV extraction	D. Johnson
1:55-2:10	120 GeV targeting	J. Hylen
2:10-2:30	HINS R&D program	R. Webber
2:30-2:50	Discussion	
2:50-3:10	Break	

Muon Collider Task Force (Organized by Vladimir Shiltsev and Steve Geer)

3:10-3:30	MCTF Overview	V. Shiltsev
3:30-3:50	6DMANX Overview	R. Johnson
3:50-4:10	Cooling simulations for Muon Collider and 6DMANX	K. Yonehara
4:10-4:30	Hardware development plans	M. Lamm
4:30-4:50	6DMANX implementation plan at Fermilab	A. Jansson
4:50-5:00	Discussion	
5:00-6:30	Committee Executive Session. Requests for supplementary or breakout presentations on Wednesday	
7:00	Dinner	

Thursday, August 9

Muon Collider Task Force (cont.)

8:30-8:45	MTA Beamline status	F. Garcia
8:45-9:00	Pressurize gas cavities	M. BastaniNejad
9:00-9:20	NFMCC experimental program and plans	Y. Torun
9:20-9:35	Muon Collider large $\Delta p/p$ IR	E. Wendt
9:35-9:50	Discussion	
9:50-10:10	Break	

Crystal Collimation Experiment (Organized by V. Shiltsev)

10:10-10:55	Status of Tevatron Experiments and Proposal for Crystal Collimation experiment	N. Mokhov
10:55-12:00	Discussion	
12:30-1:30	Lunch	
1:30-5:00	Supplementary presentations and/or breakout discussions as requested by the committee. Committee Executive Session	

Friday, August 8

8:30-11:00	Committee Executive Session
11:00-12:00	Closeout
12:00	Adjourn