Presentation of Charge and Overview of Steering Committee Report

Steve Holmes

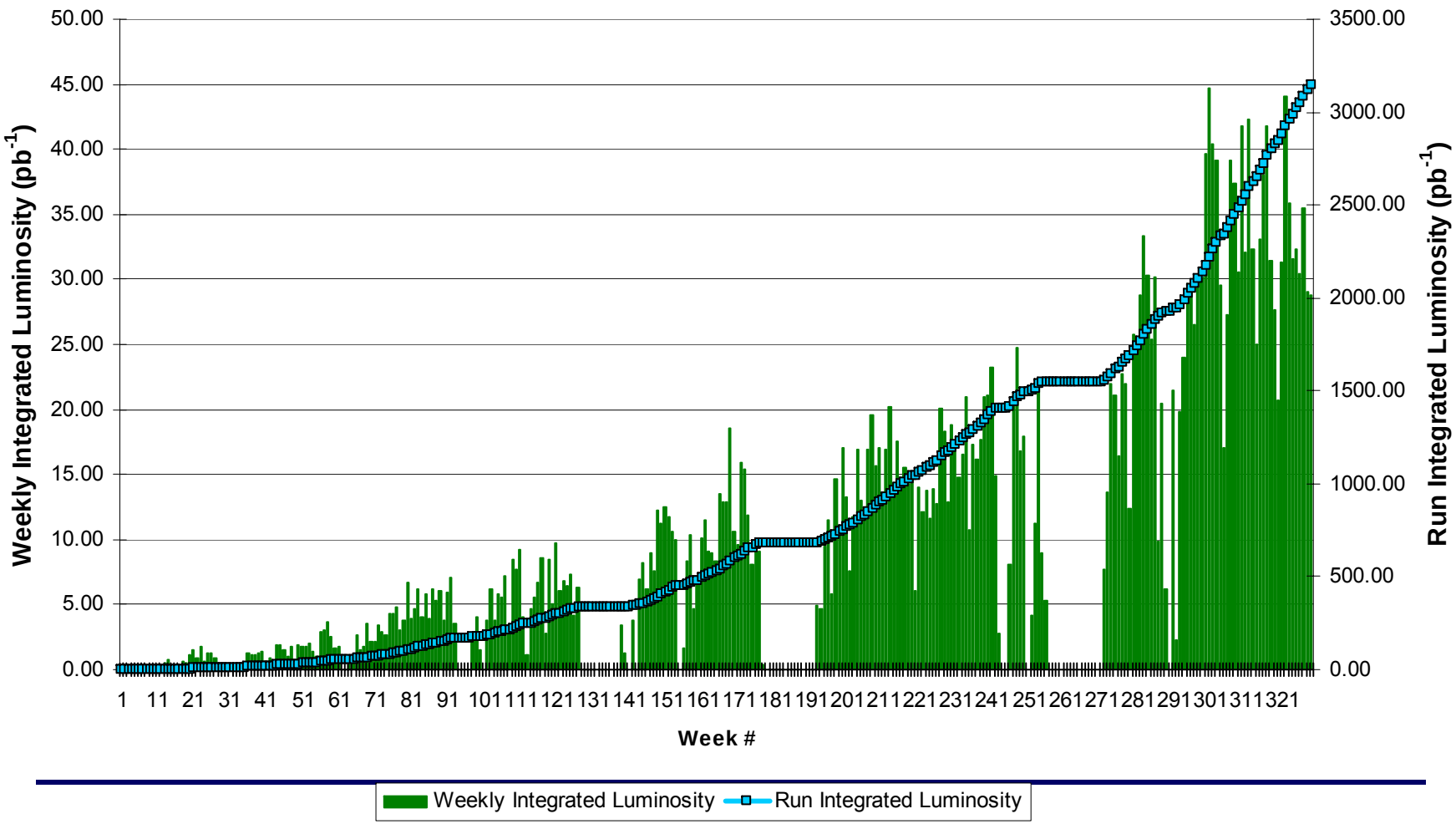
Accelerator Advisory Committee Meeting
(http://www.fnal.gov/directorate/Fermilab_AAC_mtgs.htm)

August 8-10, 2007

Update Since December Meeting
Run II

- 1.3 fb^{-1} delivered to CDF and D0 in FY07
  - >2x FY06 total
  - 3.2 fb^{-1} delivered Run II to date
  - FY07 shutdown started on August 6
- Antiproton stacking rate over 23 $\times 10^{10}$/hour
- Recycler stash up to ~475x10^{10}
- Most likely integrated luminosity through FY2009: 6.3 – 7.3 fb^{-1}
  - Design goal (8 fb^{-1}) requires >30 $\times 10^{10}$/hour stack rate and 500x10^{10} Recycler stash
- **Cessation of operations still planned for 9/30/09**
  - P5 meeting in September to identify conditions that would warrant operations in FY2010

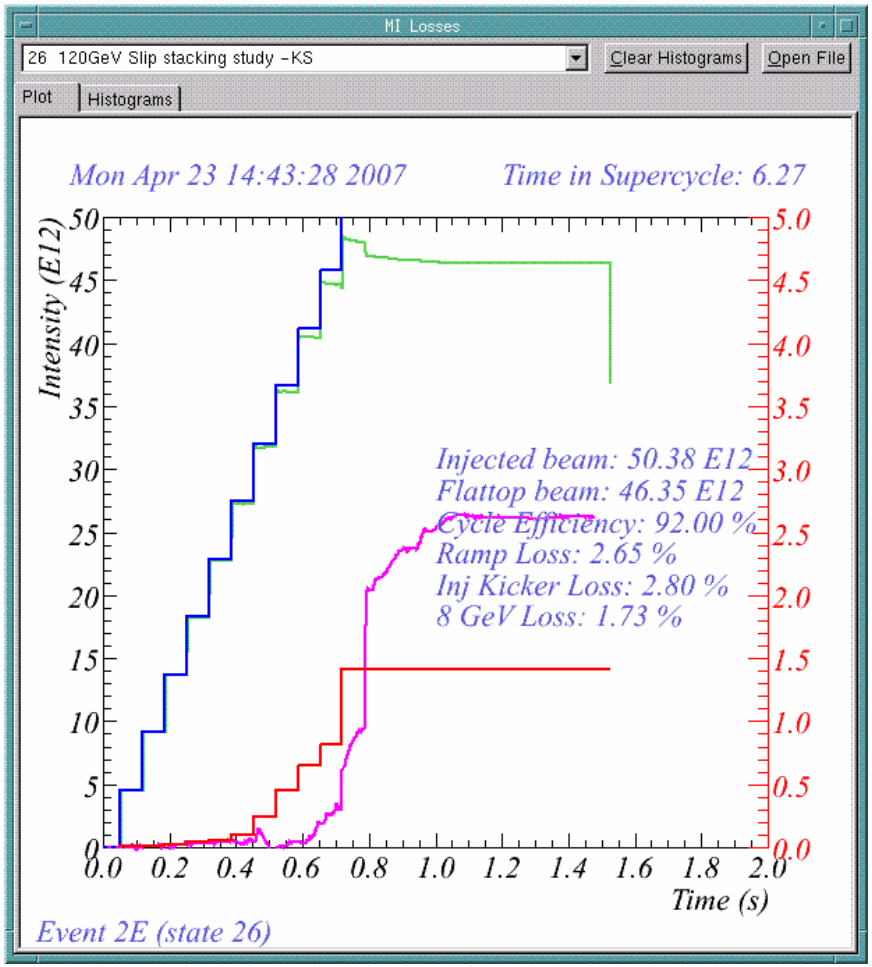
Update Since December Meeting
Integrated Luminosity (through 7/22/07)



Update Since December Meeting
Neutrinos

- 1.9×10^{20} protons to NuMI in FY07
  - ~2x FY06 total
  - Typically 200 kW simultaneous with antiproton production
    - (>300 kW in dedicated mode)
  - Multi-batch slip-stacking demonstrated
    - Will support 320 kW on target simultaneous with antiproton production
- 1.4×10^{20} protons to MiniBoone in FY07

⇒**Total Booster throughput at record levels**



Update Since May Meeting
Future Accelerators

- Accelerator Physics Center established on June 1, 2007
  - Vladimir Shiltsev is inaugural director
- ILC RDR released in February 2007
  - Complete design concept, schedule, and associate value estimate
  - Orbach response:
    - Reiterates commitment to ILC R&D program and to US aspirations to host;
    - Requests the HEP community to explore plans for a viable US program in the event that ILC is delayed relative to GDE timeline
- Fermilab strategic planning "Steering Group" established by the Director
  - In response to the Orbach request
  - Focus on accelerator based elementary particle physics
  - Report due in August (initial draft at this meeting)

Steering Group Charge

In his remarks to HEPAP, Undersecretary Orbach requested a dialog with the HEP community:

"In making our plans for the future, it is important to be conservative and to learn from our experiences. Even assuming a positive decision to build an ILC, the schedules will almost certainly be lengthier than the optimistic projections. Completing the R&D and engineering design, negotiating an international structure, selecting a site, obtaining firm financial commitments, and building the machine could take us well into the mid-2020s, if not later. Within this context, I would like to re-engage HEPAP in discussion of the future of particle physics. If the ILC were not to turn on until the middle or end of the 2020s, what are the right investment choices to ensure the vitality and continuity of the field during the next two to three decades and to maximize the potential for major discovery during that period?"

Steering Group Charge (cont.)

With the encouragement of the Office of Science and the support of Professor Mel Shochet, the chair of HEPAP, Fermilab will **develop 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. **This roadmap should keep the construction of the ILC as a goal of paramount importance**. To guide this proposal, the Fermilab Director has appointed a Steering Group consisting of members from Fermilab and the national particle and accelerator physics community to insure that the plan serves national needs. The Steering Group will also engage additional constituents in the analysis of the various physics opportunities.

Steering Group Charge (cont.)

The Steering Group will **build** the roadmap based **on the recommendations of the EPP2010 National Academy report and the recommendations of the P5** subpanel of HEPAP. The Steering Group should consider the **Fermilab based facilities in the context of the global particle physics program**. Specifically the group should develop a strategic roadmap that:

1. supports the international R&D and engineering design for as early a start of the ILC as possible and supports the development of Fermilab as a potential host site for the ILC;
2. develops options for an accelerator-based high energy physics program in the event the start of the ILC construction is slower than the technically-limited schedule; and
3. includes the steps necessary to explore higher energy colliders that might follow the ILC or be needed should the results from LHC point toward a higher energy than that planned for the ILC.

Steering Group Charge (cont.)

I am asking Deputy Director Kim to chair the Steering Group.

Any recommendations that might be relevant to the FY09 budget should be transmitted as early as possible.

The Steering Group's final report should be finished and delivered to the Fermilab Director by **August 1, 2007**. This deadline would allow for **presentations to the DOE and its advisory bodies before the structuring of the FY2010 budget.**

Website: http://www.fnal.gov/directorate/Longrange/Steering_Public/

Steering Group Membership

Eugene Beier	U. Penn
Joel Butler	Fermilab
Sally Dawson	BNL
Helen Edwards	Fermilab
Thomas Himel	SLAC
Steve Holmes	Fermilab
Young-Kee Kim (chair)	Fermilab / U.Chicago
Andrew Lankford	UC Irvine
David McGinnis	Fermilab
Sergei Nagaitsev	Fermilab
Tor Raubenheimer	SLAC
Vladimir Shiltsev	Fermilab
Maury Tigner	Cornell
Hendrick Weerts	ANL

Subgroups

- Advice/Oversight
  - Assure roadmaps are consistent with EPP2010 and P5 recommendations
- Neutrino Physics
  - Develop roadmap for neutrino physics based on NuSAG studies
- Flavor Physics: quarks, charged leptons
  - Develop 10-year plan based on reconfiguring existing accelerator complex
- Accelerator Facilities (based on technical and resources feasibilities)
  - Develop options that support ILC R&D for early start, Fermilab as a potential host site, and provide an accelerator-based HEP program in case of delay – H. Edward, T. Himel, S. Holmes (chair), D. McGinnis, S. Nagaitsev, T. Raubenheimer, V. Shiltsev, M. Tigner, (YKK)
- High Energy Colliders beyond the ILC
  - Develop steps necessary to explore higher energy colliders that might follow ILC or be needed should results from LHC point toward >800 GeV for ILC – H. Edward, V. Shiltsev, M. Tigner (chair), (YKK)

Letters and Proposals from the Community

- Six Letters from the Community received
- One Page Proposals from the community
  - 6GeV ILC Test Linac – G. Apollinari and R. Webber
  - LAr TPC in FNAL's Neutrino Beams – D. Finley
  - Precision Neutrino Scattering at Tevatron – J. Conrad and P. Fisher
  - Very Large Cherenkov Detector – M. Diwan et al
  - From Tevatron to Muon Storage Ring – T. Goldman
  - Antimatter Gravity Experiment – T. Phillips
  - Neutrino Oscillation with high energy/intensity beam – H. Piekarz
  - Space-Time Ripples Study – N. Andreev
  - Fixed Targer Charm Expt – J. Appel and A. Schwartz
  - Stopped Pion Neutrino Source – K. Scholberg
  - UNO Experiment – C. Jung
  - n-nbar Transition Search at DUSEL – Y. Kamyshkov
  - 8GeV cw Superconducting Linac – C. Ankenbrandt et al
  - Neutrino Expt with 5kton LAr TPC – B. Fleming and G. Rameika
  - MicroBooNE – B. Fleming and W. Willis
  - delta_s – R. Tayloe

Letters and Proposals from the Community

- Expression of Interest (EOI)
  - μ to e conversion – W. Molzon
  - μ to e conversion - E.J. Prebys, J.P. Miller et al
  - – $K^0_L \to \pi^0 \nu \bar{\nu}$ - D. Bryman et al
- Letter of Intent (LOI)
  - – Low- and Medium-Energy Anti-Proton Physics - D. Kaplan et al

Facilities Considered

- Criteria for consideration:
  - Alignment with the ILC R&D program
  - Effective utilization of accelerator assets freed after the end of Run II
  - Alignment with the goals of the physics WGs
  - Realizable over the next 5-10 years
  - Colliders with capabilities beyond ILC
- Information associated with each potential facility
  - Brief description/basics of operation
  - Anticipated performance parameters
  - Anticipated cost range (<$100M, $100M – $0.5B, >$0.5B)
  - Critical R&D issues that need to be resolved before construction
  - Estimated construction duration
  - Potential synergies and/or conflicts with ILC and other programs
- 17 Facilities considered

Facilities Considered

- LHC Luminosity Upgrade
- ILC R&D and construction
- 6 GeV ILC Linac
- ILC Damping Ring Test Facility
- High Intensity Proton Source
  - SC linac based (Project X)
  - Based on modifications to existing complex (SNuMI)
  - Based on new 8 GeV synchrotron
- Super B Factory
- Giga-Z
- 800 GeV Tevatron Fixed Target
- Double, 480 GeV, Fast Cycling Proton Accelerator
- Antiproton Facility
- Beta-beams
- Muon Cooling Facility
- Colliders beyond ILC/LHC
  - Muon Collider
  - Neutrino Factory
  - VLHC

ILC Scenarios

- Scenarios 1-3: ILC built in the US
  - Scenario 1: GDE baseline – Decision in 2010, 2012 construction start
  - Scenario 2: GDE baseline + 2 years
  - Scenario 3: GDE baseline + 5 years
- Scenario 4: ILC built outside US or LHC says > 800 GeV is required

We will know in ~2010 if we are in Scenario 1.

Challenge will be in identifying which scenario we are in if not Scenario 1.

ILC Activities at Fermilab
(Accelerator, all scenarios)

- Technology R&D
  - NML test facility leading to single rf unit test (3 cryomodules)
    - 2010: Technology demonstration
  - US industrialization
    - 2012-2013: Capability of 25 cryomodules/year
    - Potential synergy with Project X
  - Beam dynamics investigation using a 6 GeV linac and damping ring
    - 2013-2015?: B-Factory synergy?
- Site development
  - Site characterizations
  - Site specific designs
  - Public outreach & involvement
- Engineering Design Report
  - US leadership with significant engineering investment

LHC Activities at Fermilab
(Accelerator, all scenarios)

- LHC Accelerator Research Program (LARP)
  - Development/demonstration of magnet technology (Nb_3Sn) that could be used for an LHC luminosity upgrade
  - Participation/assistance in LHC commissioning
- LHC Upgrades
  - Potential opportunities:
    - Fabrication of high performance (Nb_3Sn) IR quadrupoles
    - Collimators
    - Crab Cavities
    - Beam-beam compensation (TEL or wires)
  - Possible synergies between SPL and Project X
    - SC linac: 4 GeV x 20 mA x 2 Hz
    - 700 MHz rf system

Facilities for Neutrino and Flavor Physics

Four facilities identified for further consideration:

- SNuMI (Scenario 1 and 2)
  - Upgrade to 1.2 MW of proton beam power at 120 GeV based on utilization of the Accumulator for proton momentum stacking.
- Project X (Scenario 3, and 4?)
  - Construction of a 8 GeV superconducting H- linac supporting simultaneous delivery of 2.3 MW at 120 GeV and 200 kW at 8 GeV
- Tevatron Facilities for Post-Run II Era (All scenarios?)
  - Tevatron based 120 GeV stretcher ring
  - Tevatron based 800 GeV high intensity beam

Facilities for Neutrino and Flavor Physics: Proton Evolution

	Now	Proton Plan	Nova*	SNuMI	Proj X		
Batch Intensity (8 GeV)	4.40E+12	4.30E+12	4.10E+12	4.50E+12	5.63E+13		protons/pulse
Rep Rate	7	9	12	13.5	5		Hz
Protons/hour	1.11E+17	1.39E+17	1.77E+17	2.19E+17	1.01E+18		
Main Injector batches	7	11	12	18	3		
MI batches to pbar target	2	2	0	0	0		
MI Cycle Time	2.4	2.2	1.33	1.33	1.4		sec
MI Beam Power (120 GeV)	**176**	**338**	**710**	**1169**	**2314**		kW
8 GeV Beam Power (available)	**18**	**17**	**16**	**0**	**206**		kW
Injection energy (1st synch)	400	400	400	400	8000		MeV
$\beta\gamma^2$	1.45	1.45	1.45	1.45	90.30		
Injection emittance	10	10	10	10	20		πmm-mr
Injection space charge tune shift	0.23	0.22	0.21	0.23	0.07		
*Nova column includes a potential upgrade of the Booster repetition rate to support simultaneous							
delivery of ~2E20 protons/year at 8 GeV. Nova itself requires Booster operations at 9 Hz.							

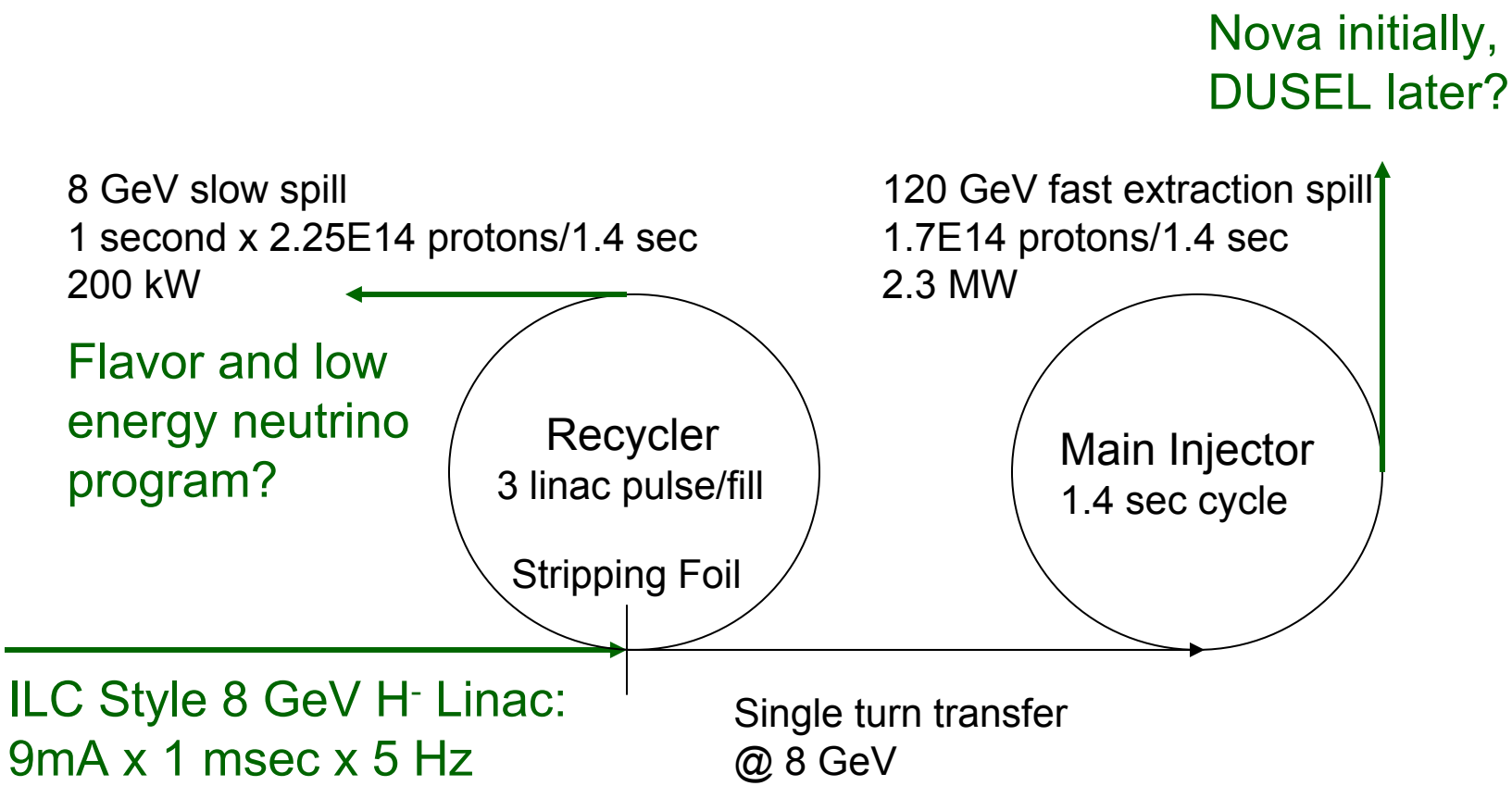
Facilities for Neutrino and Flavor Physics: SNuMI

- 1.2 MW beam power at 120 GeV, modest beam power at 8 GeV.
  - Accumulator serves as a momentum stacker, Recycler as a box car stacker
  - Modest beam power available at 8 GeV at expense of the 120 GeV program ; Debuncher as an 8 GeV slow spiller
  - 18 Booster batches per load $\Rightarrow$ 8E13 ppp, 1.33 second cycle time.
- Cost range: Medium $100-200M
- R&D needed: a) resonant extraction from the Debuncher; b) space charge, electron cloud, instabilities, transition loss limitations; c) loss control/collimation in all machines
- Estimated construction duration : 2-3 years
- Potential synergies : Tevatron 120 GeV and 800 GeV fixed target

Facilities for Neutrino and Flavor Physics: Project X

- >2 MW beam power at 120 GeV, with 200 kW available simultaneously at 8 GeV.
  - Based on superconducting 8 GeV H^- linac with ILC beam structure
  - Recycler serves as a stripper/accumulator ring
    - Distributes beam to MI or to 8 GeV areas
  - 7 linac pulses/MI cycle $\Rightarrow$ 1.4 second cycle time.
- Cost range: Large $500-1000M
- R&D needed: a)linac RF distribution; b)stripping; c)space charge, electron cloud, instabilities; d)loss control/collimation in all machines; e)RR and MI RF manipulations; f)β<1 R&D plan.
- Estimated construction duration : 4-5 years
- Potential synergies : ILC linac, Tevatron 120 GeV and 800 GeV fixed target

Facilities for Neutrino and Flavor Physics: Project X



Facilities for Neutrino and Flavor Physics: 120 GeV Stretcher

- High duty factor 120 GeV slow spill (~4E19 protons/year)
  - Tevatron configured for 120 GeV slow spill/stretcher ring 7.5E13 protons per spill, every 60 seconds
  - 95% duty factor
  - Competes (at 5% level) for protons from the SNuMI program
- Cost range: small <$100M
- Critical R&D needed: a)new Tevatron resonant extraction; b)beam stability; c)loss control and collimation
- Estimated construction duration : 1-2 years
- Potential synergies : SNuMI, Project X

Facilities for Neutrino and Flavor Physics: 800 GeV Fixed Target

- High intensity 800 GeV Fixed Target (~4E19 protons/year)
  - Tevatron configured for 7.5E13 protons per spill
  - Cycle time ~40 seconds with < 1 second spill
  - Competes (modestly) for protons from the neutrino program
- Cost range: small <$100M?
- Critical R&D needed: a)Tevatron fast extraction scheme; b)beam stability; c)loss control and collimation; d)recommissioning plan for C0 abort; e)reliability analysis, in particular the magnets (experience is ~1 magnet failure/250K ramps)
- Estimated construction duration : 1-2 years
- Potential synergies : SNuMI, Project X

Project X: Role in the Roadmap

- "Medium size' ($0.5B – $1B) project
  - Accelerator project is of the same scale as the Main Injector
    - R&D, Engineering, Construction: required resources being analyzed
  - Operations: expect to be simpler than the current 30+ year old complex
- Physics Opportunities and Connection to Future
  - Initially extends reach of NOvA
  - Enables new initiatives in flavor physics
  - Future possibility: optimized beam to DUSEL
    - ν oscillation / CP violation, Proton decay, ..
  - Stepping stone for longer-term programs
    - neutrino factory
    - higher energy colliders (e.g. muon collider, VLHC)

Project X: Relationship to ILC

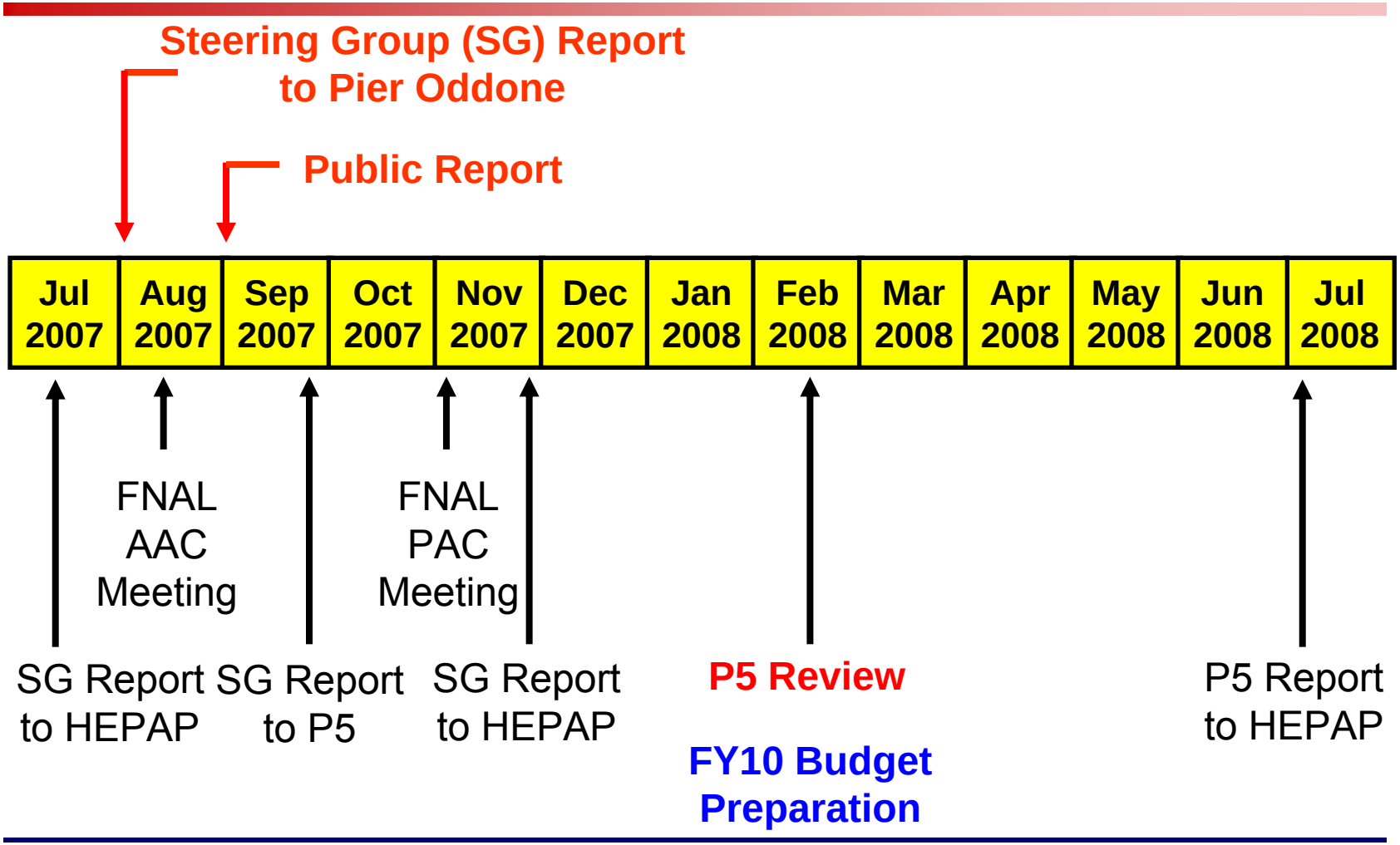
- Intention: Does not delay but helps timely realization of ILC
- Project X is unique among the neutrino facilities considered in providing support to ILC development at Fermilab.
  - It could play an important role in driving the initial stage of industrialization of cryomodules and providing experience with operating the linac as a complete system;
  - Such roles could advance the ILC if a delay in a decision to construct were accompanied by a lack of support for industrialization
- Industrialization
  - Project X requires ~36 β=1, ILC style cryomodules (2 – 8 GeV)
  - Production over a two-to-three-year period represents a significant advance over capabilities anticipated in ~2010; however, production rate is below that required by ILC

  $\Rightarrow$ This activity would represent the initial phase of an industrialization buildup for ILC.

Project X: Relationship to ILC

- Operational Experience and Systems Testing
  - Project X linac configured to the same beam parameters as the ILC (9 mA $\times$ 1 msec $\times$ 5 Hz)
  - RF generation and distribution system is the same as ILC
  - Focusing requirements not completely aligned with ILC, but this is not critical for technology demonstration
    - Currently under study
  - Linac can be operated a gradients <31.5 MV/m
  - Operation of the linac with electrons should be possible and is under study.
    - Operation at the full ILC specification could provide important understanding of higher order modes and associated loads on the cryogenic system, performance of the rf systems, etc.

Next Steps: Timeline



Conclusions and Recommendations

- Planning guidelines:
  - LHC is the most important near term program element.
    - It is essential to support the accelerator and detector upgrades.
  - The particle physics community's highest priority for investment in the future is the ILC.
    - Fermilab will continue to participate vigorously and provide leadership within the international R&D effort;
    - We will strive to make the ILC at Fermilab a reality
  - There must be an intermediate science program in case ILC construction is delayed beyond the GDE timeline. The program needs to provide:
    - Great discovery potential,
    - Support for the timely realization of the ILC,
    - R&D on future accelerators beyond the ILC and LHC,
    - Strengthen Fermilab ties with the university community and with other laboratories, and
    - The plan must be robust and flexible.

Conclusions and Recommendations

- Roadmap
  - Fermilab's highest priority is discovering the physics of the Terascale by participating in LHC, being one of the leaders in the global ILC effort, and striving to make the ILC at Fermilab a reality.
  - Fermilab will continue its neutrino program with NOvA as the flagship experiment through the middle of the next decade.
  - Scenario 1 (ILC construction near the GDE proposed timeline)
    - Fermilab will focus on the above programs.
  - Scenarios 2 & 3 (ILC delayed)
    - Fermilab should extend our neutrino and flavor physics opportunities by upgrading the proton accelerator complex.
    - Modest delay ⇒ SNuMI
    - If ILC delay would accommodate an interim major project ⇒ Project X

Conclusions and Recommendations
Excerpts from the Report

- Scenario 4 (ILC constructed off-shore or energy deemed insufficient)
  - Do SNuMI at a minimum.
  - Do Project X if resources are available and ILC timing permits.
- In all scenarios,
  - Provide support of Project X R&D starting now with emphasis on:
    - expediting R&D and industrialization of ILC cavities and cryomodules
    - overall design of Project X
  - increase R&D for future accelerator options concentrating on neutrino factory and muon collider.
  - support detector R&D for effective use of future facilities

Charge to the Committee:

- Review and comment on the draft Steering Committee report.
  - Input for the AAC will be considered in preparation of the final (public) report.
- Review and comment on the major accelerator facility elements of the plan:
  - Project X
  - Utilization of the Tevatron for fixed target programs at either 120 GeV or 800 GeV
  - Muon Collider R&D
- Assist us in evaluating the request for study time for crystal collimation studies in the Tevatron
  - Aimed at LHC

Charge to the Committee
(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:

Charge to the Committee
(cont.)

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.

Charge to the Committee
(cont.)

Project X

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.

Charge to the Committee
(cont.)

Muon Collider R&D 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.

Charge to the Committee
(cont.)

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?

Fine Print

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.