
Accelerator Division Proton Driver Kickoff - Motivation, Information and Work Assignment

W. Chou

March 10, 2004, Huddle

<http://www-bd.fnal.gov/pdriver/>

Proton Driver Study I (PD1) Kick-off

On the field: VLHC, muon collider, neutrino factory, linear collider, proton driver, ...

October 29, 1998

To: C. Schmidt, M. Popovic, A. Moretti, J. Lackey, F. Ostiguy, B. Ng, C. Ankenbrandt, W. Wan, A. Drozhdin, N. Mokhov, O. Krivosheev, J. Johnstone, C. Johnstone, I. Kourbanis, D. Johnson, C. Bhat, D. McGinnis, J. Steimel, V. Wu, L. Spentzouris, D. Wildman, Z. Qian, J. Leibfritz, H. Pfeffer, D. Wolff, S. Fang, D. Ritson, J. Griffin, F. Mills

Cc: S. Holmes, D. Neuffer, A. Tollstrup

From: Bob Noble and Weiren Chou

Dear Colleagues,

*With the completion of Main Injector construction, the Beams Division can begin to redirect some resources into exploring options for future machines at Fermilab. As part of the Muon Collider design studies in progress, **Steve Holmes has endorsed the idea of preparing a Conceptual Design Report for a so-called "Proton Driver" at Fermilab.** This proposed machine would be a new high-intensity linac and synchrotron to replace our present Linac and 8 GeV Booster.....*

Proton Driver Study II (PD2) Kick-off

January 24, 2002

On the field: Linear Collider, Proton Driver

To: ralber@fnal.gov, allen@fnal.gov, tander@fnal.gov, ankenbrandt@fnal.gov, reese@fnal.gov, cbhat@fnal.gov, bogert@fnal.gov, capista@fnal.gov, carson@fnal.gov, cossairt@fnal.gov, crisp@fnal.gov, dimarco@fnal.gov, drozhdin@fnal.gov, dudnikov@fnal.gov, mferg@fnal.gov, glass@fnal.gov, gelfand@fnal.gov, jgriffin@cns55.fnal.gov, jgriffin@enteract.com, grossman@fnal.gov To: harding@fnal.gov, dharris@fnal.gov, jach@fnal.gov, ccjensen@fnal.gov, dej@fnal.gov, cjj@fnal.gov, kash@fnal.gov, kiyomi@fnal.gov, ioanis@fnal.gov, lackey@fnal.gov, tomski@fnal.gov, leibfritz@fnal.gov, maclachlan@fnal.gov, amakarov@fnal.gov, malamud@fnal.gov, pmartin@fnal.gov, mccrory@fnal.gov, michelotti@fnal.gov, fredmills@aol.com, moehs@fnal.gov To: mokhov@fnal.gov, moretti@fnal.gov, cmoore@fnal.gov, ng@fnal.gov, ohnuma@phys.hawaii.edu, ostiguy@fnal.gov

Cc: witherell@fnal.gov, holmes@fnal.gov, gwf@fnal.gov, marriner@fnal.gov, pjlimon@fnal.gov

Dear Colleagues,

The Director's office has decided to pursue Proton Driver Study II. The charge can be found on the web: <http://www-bd.fnal.gov/pdriver/8GEV/> There will be a "kickoff" meeting on Thursday, Jan. 24 at 3:00 pm in the Comitium. Mike (W.) and Steve (H.) will talk about what we want to achieve from the study and answer questions. You are invited to attend this meeting. Thank you.

Peace,

Bill and Weiren

This Kick-off

On the field: Proton Driver, LC

March 10, 2004

To: "Ankenbrandt, Chuck" <ankenbrandt@fnal.gov>, "Bogert, Dixon" <bogert@fnal.gov>, "DiMarco, Joe" <dimarco@fnal.gov>, "Drozhdin, Sasha" <drozhdin@fnal.gov>, "Griffin, Jim" <jgriffin.enteract@rcn.com>, "Harding, Dave" <harding@fnal.gov>, "Kashikhin, Vladimir" <kash@fnal.gov>, "McCrary, Elliott" <mccrary@fnal.gov>, "Johnstone, Carol" <cjj@fnal.gov>, "Lackey, Jim" <lackey@fnal.gov>, "MacLachlan, Jim" <maclachlan@fnal.gov>, "Moehs, Doug" <moehs@fnal.gov>, "Mokhov, Nikolai" <mokhov@fnal.gov>, "Moretti, Al" <moretti@fnal.gov>, "Ng, Bill" <ng@fnal.gov>, "Ostiguy, Francois" <ostiguy@fnal.gov>, "Reid, John" <jsreid@fnal.gov>, "Schlabach, Phil" <schlabach@fnal.gov>, "Tomlin, Ray" <tomlin@fnal.gov>, "Wildman, Dave" <wildman@fnal.gov> To: "Wolff, Dan" <wolff@fnal.gov>, "Chou, Weiren (pc)" <chou@imapserver2.fnal.gov>, "Chou, Weiren" <chou@fnal.gov>, "Chen, Alex" <alexchen@fnal.gov>, "Marchionni, Alberto" <alberto@fnal.gov>, "Lucas, Peter" <lucas@fnal.gov>, "Johnson, Dave E." <dej@fnal.gov>, "Pasquinelli, Ralph" <pasquin@fnal.gov>, ding@fnal.gov, "Chase, Brian" <chase@fnal.gov>, "Hays, Steve" <slh@fnal.gov>, "Pfeffer, Howie" <pfeffer@fnal.gov>, "Theilacker, Jay" <theilacker@fnal.gov>, "Klebaner, Arkadily" <klebaner@fnal.gov>, "Soyars, William" <soyars@fnal.gov>, "Huening, Markus" <mhuening@fnal.gov>, "Piot, Philippe" <piot@fnal.gov>, "Tang, Zhijing" <ztang@fnal.gov>

Cc: "Dixon, Roger" <roger@fnal.gov>, "Holmes, Steve" <holmes@fnal.gov>, "Foster, Bill" <gwf@fnal.gov>, "Geer, Steve" <sgeer@fnal.gov>, "Kephart, Bob" <kephart@fnal.gov>, "Mishra, Shekhar" <mishra@fnal.gov>

Dear Colleagues,

The Accelerator Division (AD) has formed a Proton Driver Study Group. You are invited to join this group. There will be a kickoff meeting on Monday, March 10, 2004 at 3:00 pm in the Huddle.....

AD Proton Driver Study Group Kickoff Meeting, Mar 10, 2004

What's New

Proton Driver – One of 28 new facilities on DOE's 20-year Plan

Priority: Tie for 21 Super Neutrino Beam

The Facility: The Super Neutrino Beam will allow more comprehensive studies of neutrino properties by producing a neutrino beam 10 times more intense than those available with current accelerators.

Background: Neutrinos are the most poorly understood of the elementary particles but may be the most important for answering fundamental questions ranging from why there is any matter in the universe at all, to how all particles and forces in the universe “unify” into a simple picture. Because neutrinos rarely interact with matter (many billions pass through each of us every second), the ability to generate controlled beams containing large numbers of neutrinos greatly increases the ability to study them.

What's New: The Super Neutrino Beam will be powered by a new, megawatt class “proton driver” which will be able to provide an intense, well-controlled neutrino beam—with 10 times more neutrinos per second than are available from any existing facility—to detectors hundreds or thousands of miles distant.

Applications: The 2002 Nobel Prize in physics was shared by two scientists—one American and one Japanese—for their path-breaking measurements of solar and atmospheric neutrinos. Their research strongly suggested that neutrinos have mass and oscillate among three types as they travel through space. These oscillations have recently been confirmed, and the properties and behavior of neutrinos are now ripe for measurement. The results will have profound implications for our understanding of the fundamental properties of matter and the evolution of the early universe.

What's New (cont...)

- ◆ Fermilab Long Range Planning Committee has recommended the **Proton Driver as a future construction project at Fermilab.**
- ◆ Fermilab Director issued a new charge regarding the Proton Driver project, which is defined as:
"a complete replacement of our current 400 MeV linac and 8 GeV Booster, accompanied by Main Injector upgrades."
- ◆ Bill Foster (TD) and ? (PPD) have been appointed to be the project leaders.
- ◆ Accelerator Division has formed a study group to work on this project.
- ◆ Weekly steering meeting in Steve's office.
- ◆ Lab line item budget for Proton Driver R&D.
- ◆ The near term goal is to complete the documentation required by DOE's CD-0 process by the end of 2004.

What's New (cont...)

To build a strong physics case for this project, we need to expand our horizon.
Example – a message from *Chen Hesheng*, Director of IHEP, China.

Dear Weiren,

Nice to hear from you. We are interested in the very LBL neutrino oscillation experiment from FNAL to Beijing.

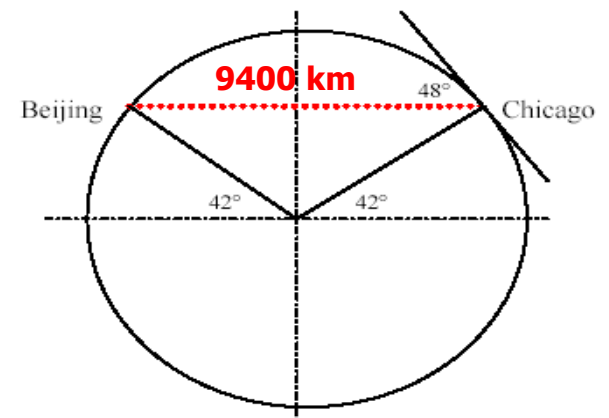
Many interesting physics could be done with such long base line. However, I will not attend the APAC meeting at Korea.

Chuang and some machine people will attend APAC. I think the major challenge to the idea is the beam line + near detector with large dip angle. Can you bypass Beijing after APAC to discuss in detail? Otherwise, we could find some other chance.

best regards,

Hesheng

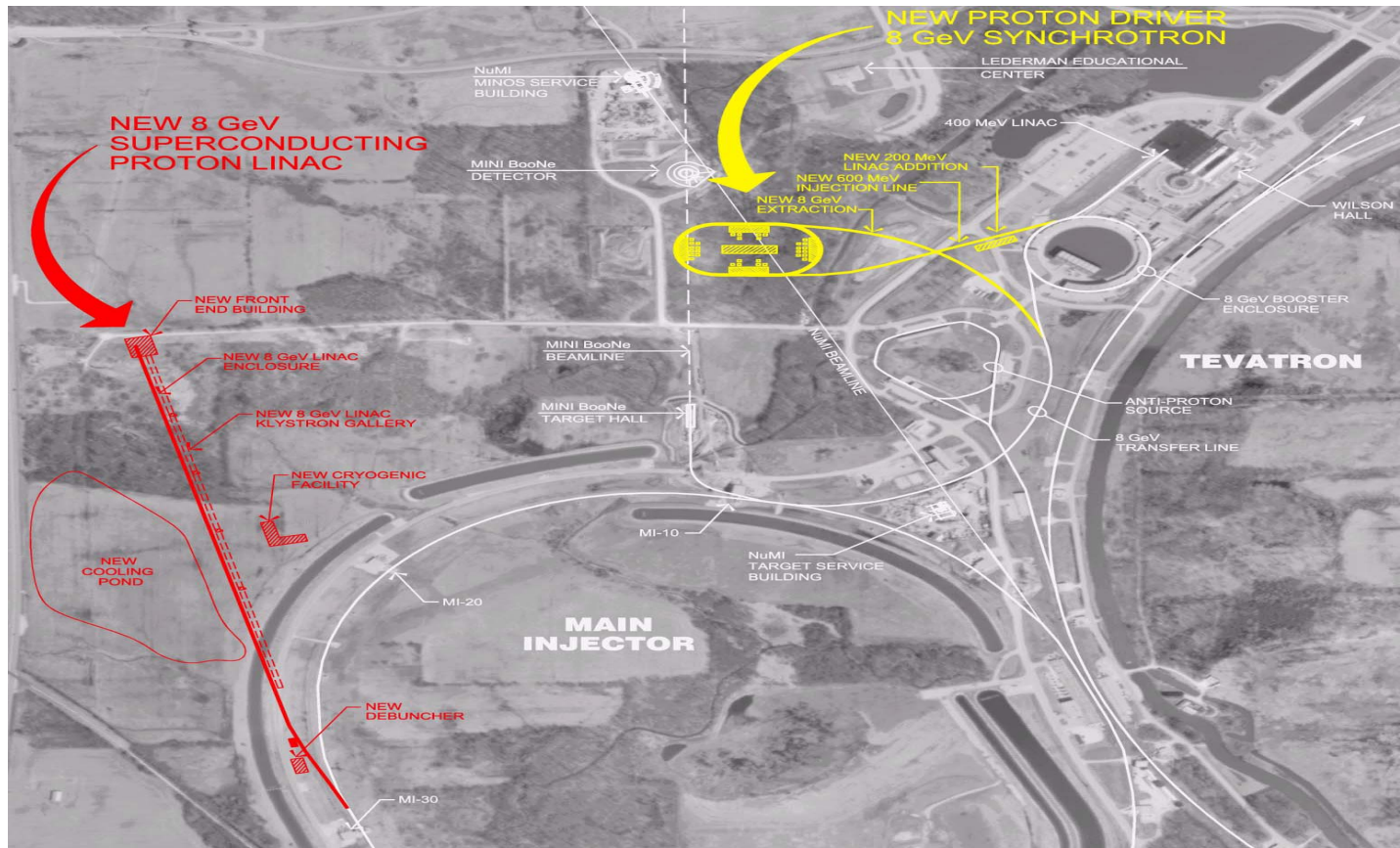
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Chicago	41:50:13 N	87:41:06 W
Beijing	39:55:00 N	116:23:00 E
Tokyo	35:41:00 N	139:44:00 E



What's New (cont...)

- ◆ Beam power specification:
 - 8 GeV Proton Driver: ≥ 0.5 MW
 - Upgraded Main Injector: 2 MW
 - **Total beam power: ≥ 2.5 MW**
- ◆ Two options:
 - 8 GeV sc linac
 - 8 GeV synchrotron
- ◆ **The linac option is the preferred one.**
- ◆ But technology decision won't be made until 2005. (CD-0 does not require technology specification)
- ◆ An important part of this study is to have a better understanding of the cost differential between the two options.

Proton Driver Study II (Fermilab-TM-2169, Revised)

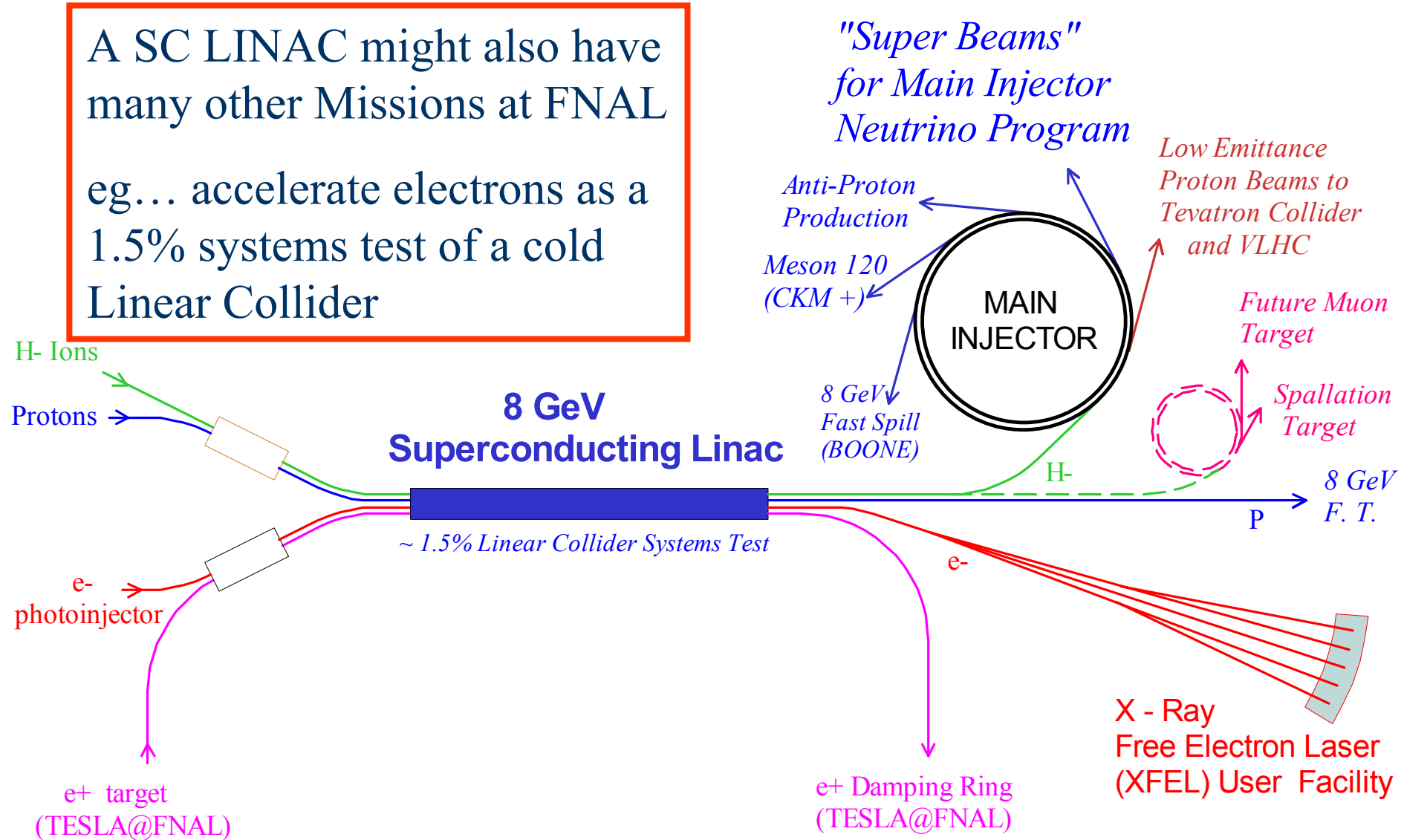


(1) 8 GeV Linac Parameters

Energy	GeV	8
Particle Type	H- Ions, Protons , or Electrons	
Rep. Rate	Hz	10
Active Length	m	671
Beam Current	mA	25
Pulse Length	msec	1
Beam Intensity	P / pulse	1.5E+14
	P/hour	5.4E+18
Linac Beam Power	MW avg.	2 (0.5)
	MW peak	200

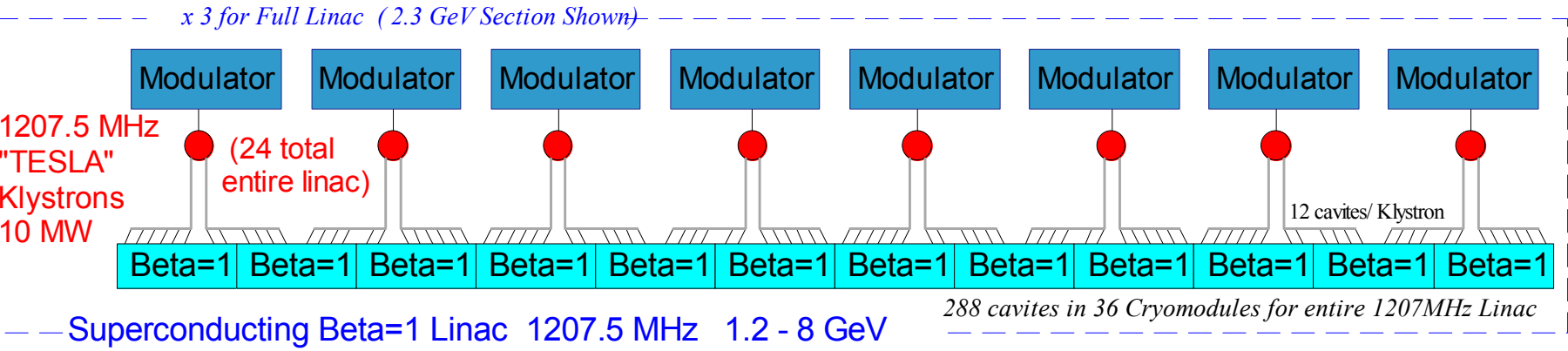
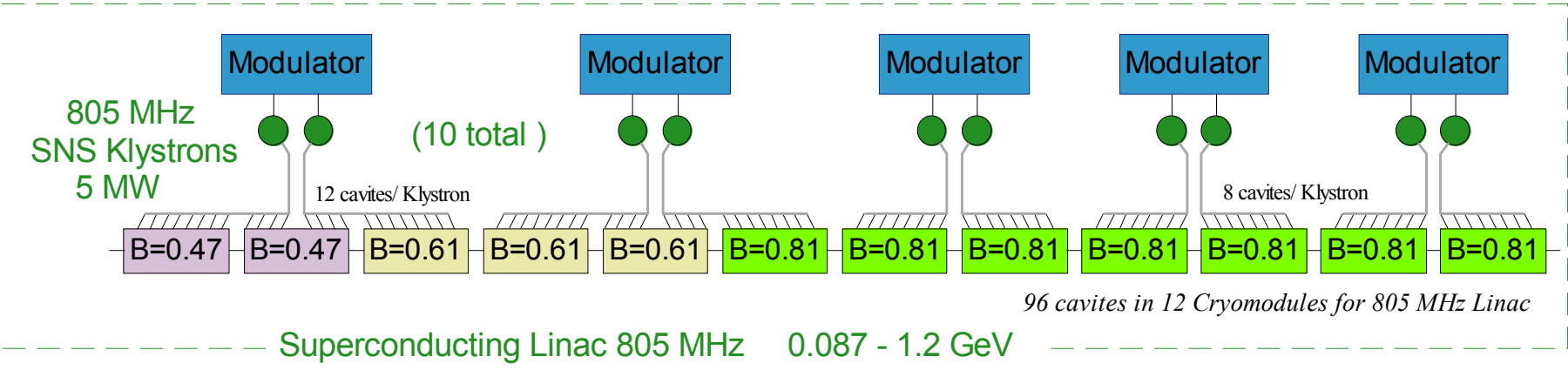
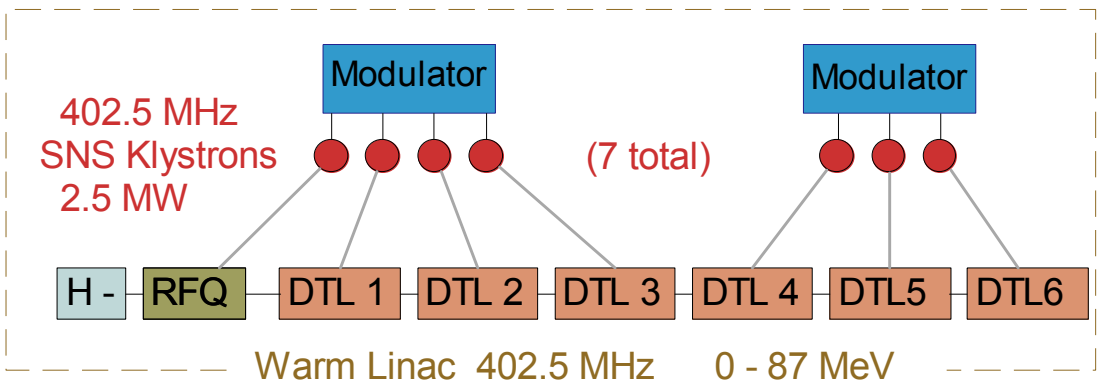
Multi-Mission 8 GeV Injector Linac

A SC LINAC might also have many other Missions at FNAL
 eg... accelerate electrons as a 1.5% systems test of a cold Linear Collider



8 GeV RF LAYOUT

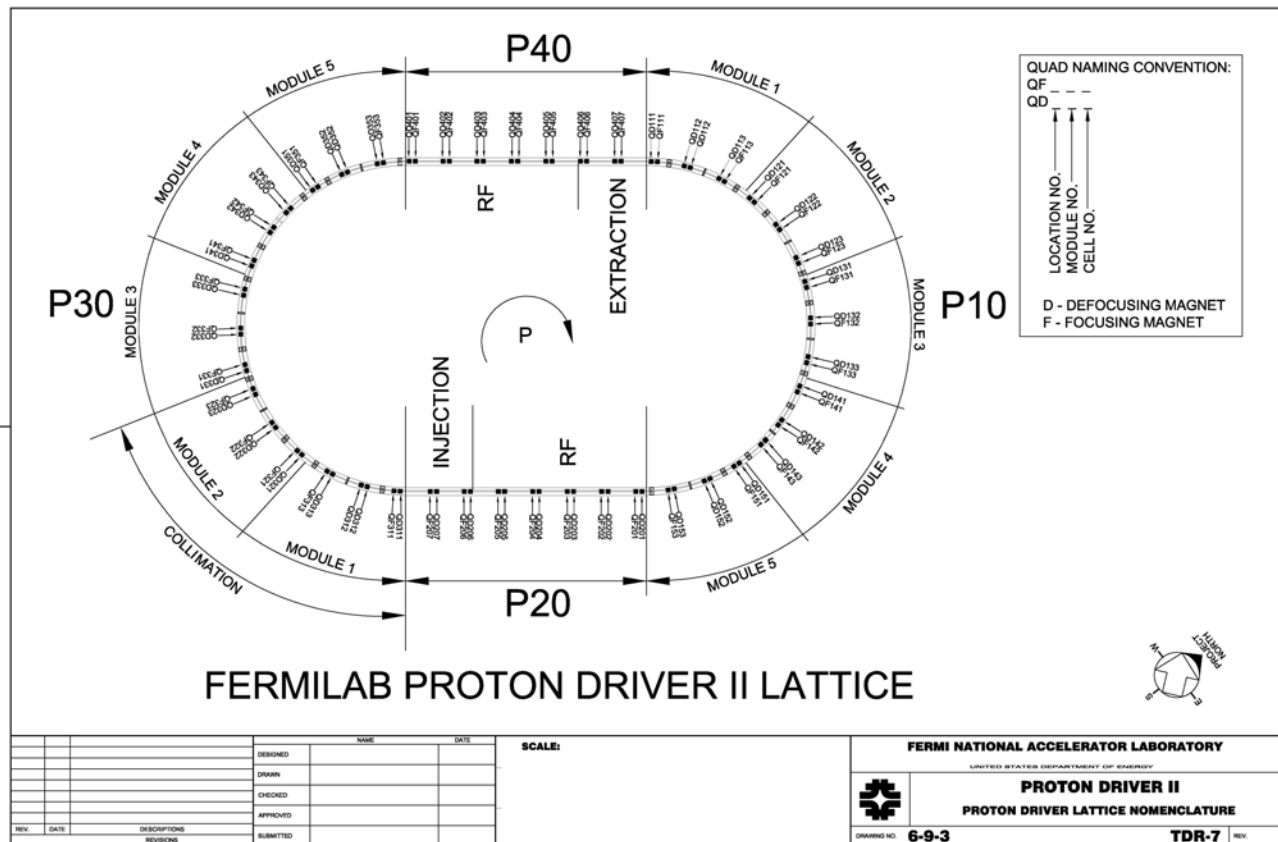
- 41 Klystrons (3 types)
- 31 Modulators 20 MW ea.
- 7 Warm Linac Loads
- 384 Superconducting Cavities
- 48 Cryomodules



(2) 8 GeV Synchrotron Parameters

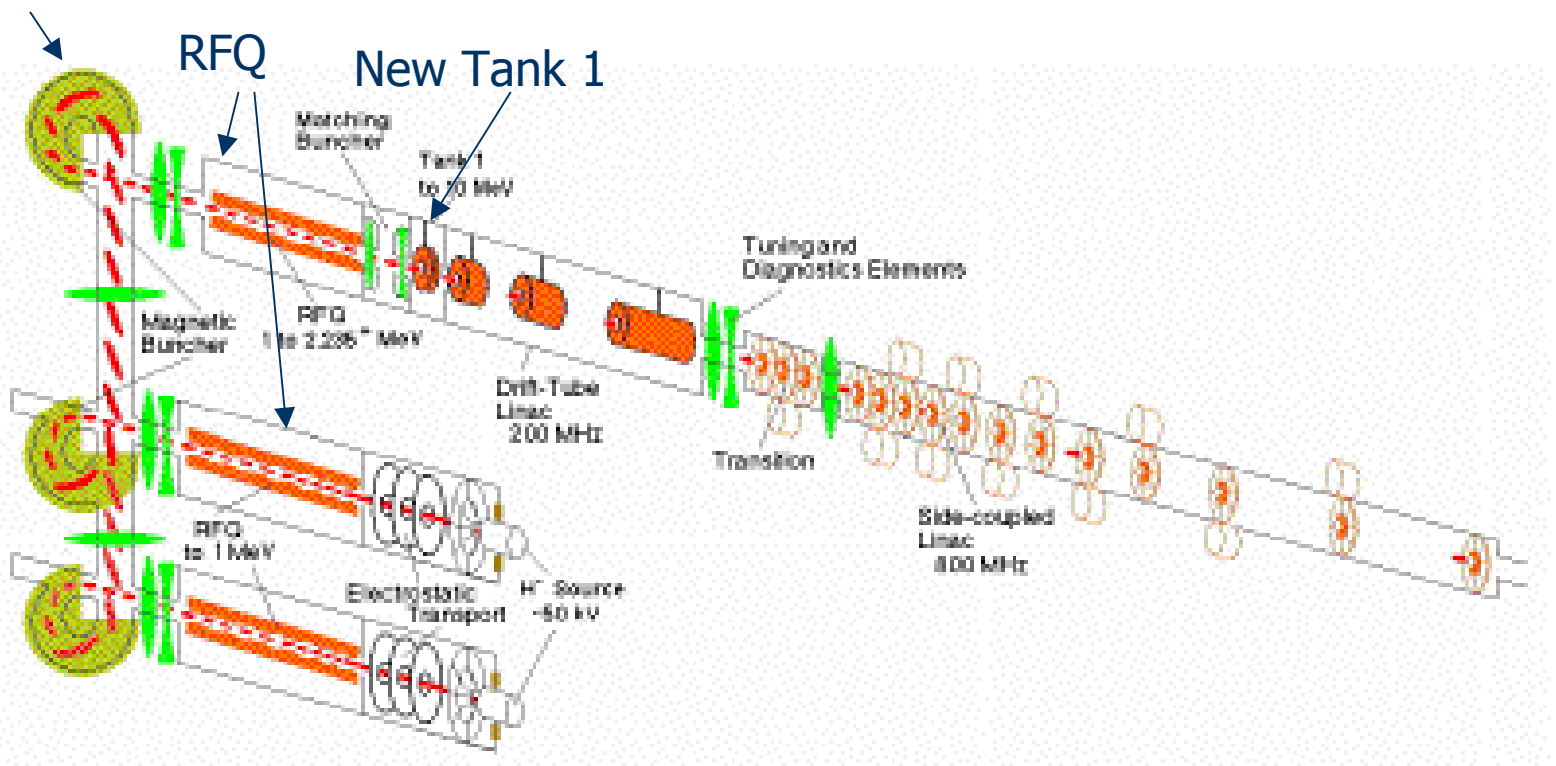
Parameters	Present Proton Source	Proton Driver (PD2)
Linac (operating at 15 Hz)		
Kinetic energy (MeV)	400	600
Peak current (mA)	40	50
Pulse length (μs)	25	90
H ⁺ per pulse	6.3×10^{12}	2.8×10^{13}
Average beam current (μA)	15	67
Beam power (kW)	6	40
Booster (operating at 15 Hz)		
Extraction kinetic energy (GeV)	8	8
Protons per bunch	6×10^{10}	3×10^{11}
Number of bunches	84	84
Protons per cycle	5×10^{12}	2.5×10^{13}
Protons per hour	9×10^{16} (@ 5 Hz)	1.35×10^{18}
Normalized transverse emittance (mm-mrad)	15π	40π
Longitudinal emittance (eV-s)	0.1	0.2
RF frequency (MHz)	53	53
Average beam current (μA)	12	60
Beam power (MW)	0.033 (@ 5 Hz)	0.5

8 GeV Synchrotron Lattice Layout



(3) New Linac Front End (common to both options)

Alpha magnet



(4) 2-MW Main Injector Upgrade

- Increase beam intensity by a factor of 5
- Reduce cycle time by 20%
- Increase beam power by a factor of 6

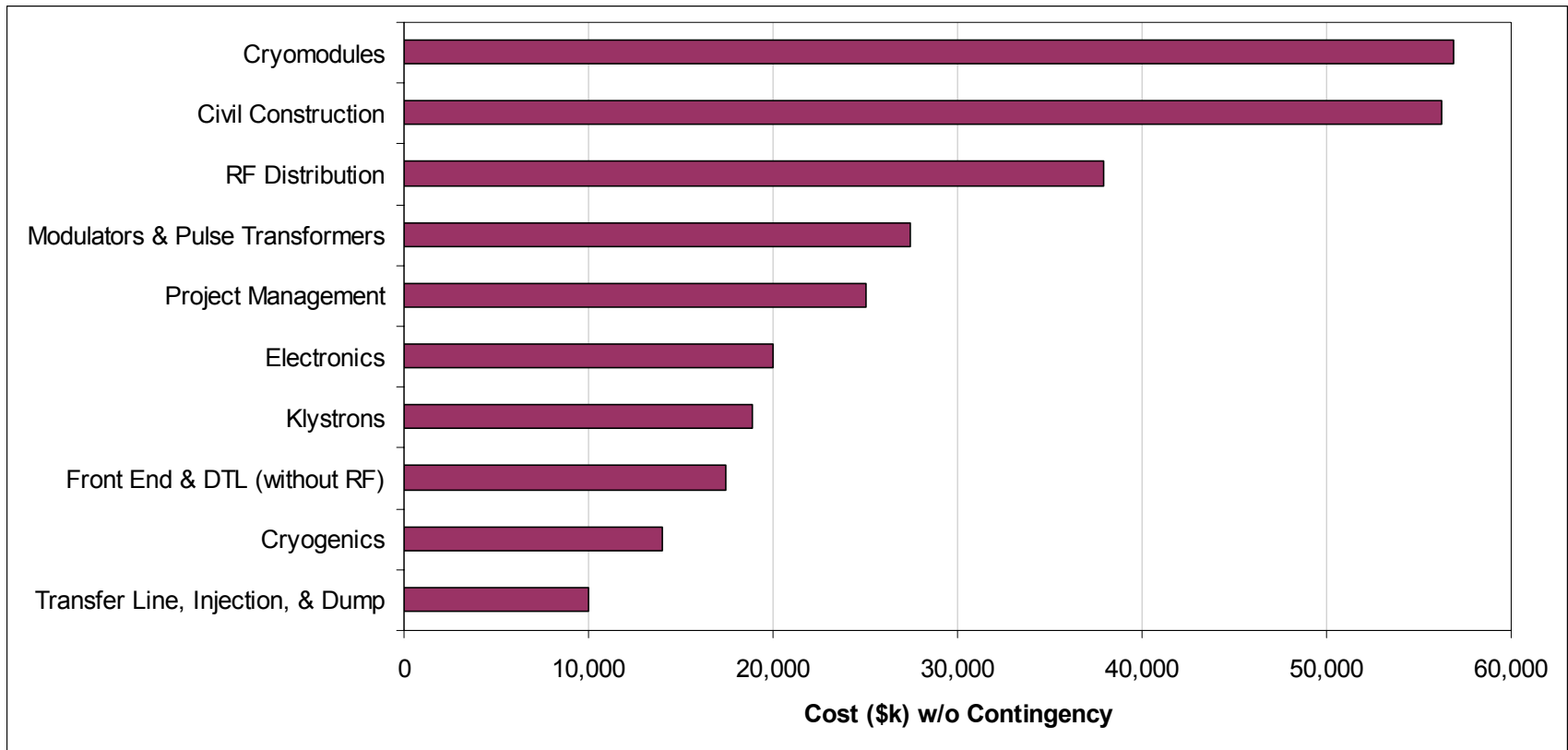
	Present MI	Upgraded MI
Injection kinetic energy (GeV)	8	8
Extraction kinetic energy (GeV)	120	8 - 120
Protons per MI cycle	3×10^{13}	1.5×10^{14}
Cycle time at 120 GeV (s)	1.867	1.533
Beam power (MW)	0.3	1.9

Main Injector Technical System Upgrades

- ◆ One major upgrade:
 - RF system
- ◆ Several moderate upgrades:
 - Magnet power supply
 - Kickers
 - Feedback and damper
 - Beam dump
 - Cooling
 - NuMI and MiniBooNE beam lines
- ◆ Three new systems:
 - Gamma-t jump
 - Large aperture quadrupole (WQB)
 - Collimators
- ◆ No need for upgrade:
 - Magnet (But the recycled Main Ring quads may need to be replaced for reliability reason)
 - Shielding
- ◆ Two additional upgrades for sc linac option:
 - 8 GeV H⁻ injection
 - MiniBooNE beam line

8 GeV Linac Cost Estimate

\$283M (x 1.3 Contingency) = \$369M



...so this is a Fermilab Main Injector sized project.

8 GeV Synchrotron Cost Estimate

1	Technical Systems			98,986
1.1	8 GeV Synchrotron		78,997	
1.2	Linac Improvements and Upgrade		17,500	
1.3	600 MeV Transport Line		900	
1.4	8 GeV Transport Line		1,589	
2	Civil Construction			37,152
2.1	8 GeV Synchrotron		17,500	
2.2	Linac extension		2,500	
2.3	600 MeV Transport Line		1,800	
2.4	8 GeV Transport Line		2,200	
2.5	Site work		4,800	
2.6	Subcontractors OH&P		5,760	
2.7	Environmental controls and permits		2,592	
	Total Direct Cost			136,138
	EDIA (15%)			20,421
	Lab Project Overhead (13%)			20,353
	Contingency (30%)			53,073
	Total Estimated Cost (TEC) (\$k) (in FY02 dollars)			229,985

2 MW Main Injector Upgrade Cost Estimate

1	Main Injector Upgrade		23,502
1.1	RF system	14,238	
1.2	Main power supplies	430	
1.3	Gamma-t jump system	490	
1.4	Large aperture quadrupole	710	
1.5	Kickers	1,060	
1.6	Longitudinal feedback	625	
1.7	Collimators	325	
1.8	Beam dump	500	
1.9	Controls	303	
1.10	Utilities	1,406	
1.11	ED&I	3,415	
2	NuMI Beamline Upgrade		8,920
3	MiniBooNE Beamline Upgrade		250
4	Project Management		3,000
	TOTAL (\$k)		35,672

Correlation to Other Lab Project

- E. Prebys is leading a *Proton Source Improvement Plan*, which has a total budget of **\$18M** in five years. It can partly offset the Proton Driver project cost, e.g.,
 - It will cover:
 - Booster RF upgrade (multi-million, beneficial to the synchrotron option)
 - Dual harmonic power supply R&D (beneficial to the synchrotron option)
 - Laser chopping R&D (beneficial to both options)
 - It may also cover several MI upgrade projects: (under negotiation)
 - Large aperture quads (WQB)
 - Collimation system
 - Gamma-t jump system
 - Kicker upgrade
 - But it will not cover:
 - New Linac front end, or any significant 200 MHz upgrade.
 - Faster Main Injector ramp

Prebys' Large Projects

- ◆ Booster RF system:
 - Commission a design for a new booster RF system
 - Larger aperture, higher gradient cavities
 - Solid state distributed amplifiers
 - Goal to have design by January 2005.
 - Two year timescale to build and install (perhaps solid-state DA's can come sooner).
 - Cost ~all of it.
- ◆ Two additional booster RF cavities
 - Can use large aperture prototypes, and mostly spare parts.
 - Would increase efficiency and reliability (can't run well with one station down, at the moment).
 - Cost ~500K.
 - Might happen in the summer shutdown.
- ◆ 30 Hz harmonic to booster ramp.
 - Effectively increases RF power
 - Cost of order \$1-2M
- ◆ New LEL quad power supplies.
 - A reliability concern.
 - Cost of order \$1M.

Accelerator Division Proton Driver Study Group

March 10, 2004

To: Weiren Chou
From: Roger Dixon
Subject: Charge for Accelerator Division Proton Driver Study Group

I would like you to organize and coordinate a group of people from the Accelerator Division to work closely with the Technical Division to begin the effort to understand and design a Proton Driver for Fermilab. Mike Witherell has given Bill Foster a charge to lead an effort that will begin taking the first steps toward a Proton Driver. Your efforts shall be directed toward fulfillment of the charge given to Bill.

I expect you to assemble a group of individuals who are interested in contributing to the Proton Driver effort and who are willing to spend 10% to 30% of their time on this activity depending on their other Accelerator Division activities. You will work closely with the Technical Division team to plan the Proton Driver effort and to determine which tasks should be assigned to individuals in the Accelerator Division Proton Driver Study Group.

Before the effort begins I want to approve a list of people who are expected to contribute to the study along with an estimate of the amount time they have agreed to spend on it. Note that people who agree to spend more time will be approved for this once I am convinced that this is a reasonable way for them to spend their time. I would also like to have a list of the tasks and goals for the Accelerator Division Study Group once these matters have been negotiated. I expect the department heads will help you to secure the support that you will need in this task.

During the course of this study, I ask that you meet with me once a month to report progress and problems, and to update the task list and the goals. In addition, I would like you to write a brief report once every 3 months detailing the amount of effort and accomplishments of the Study.

AD Proton Driver Study Group (cont...)

- About 30 people, 6 FTEs.
- Work list:
 - Design of the low energy section (warm part) of a new linac
 - Design of an 8 GeV H⁻ injection line
 - Main Injector upgrades
 - Target and beamline upgrades
 - Collaboration with TD on the cryo and RF design of an 8 GeV sc linac
 - Further improvement of the 8 GeV synchrotron option
 - Cost and schedule estimate of the above
 - Documentation of the above
- Things yet to be decided:
 - RF frequency of the sc linac: 1.2 GHz or 1.3 GHz (TESLA design)?
 - Energy range of the warm linac. (Shall sc spoke cavity be adopted?)

AD Proton Driver Study Group (cont...)

- Warm linac
 - Ion source and LEBT
 - Laser chopping
 - 8 GeV H⁻ transport line
 - 8 GeV H⁻ injection
 - MI upgrades
 - Target/beamline upgrades
 - Space charge
 - Beam dynamics
 - Warm RF
 - Power supplies
 - Collimators
 - Beam loss, shielding
 - Magnets
 - Beam pipe, mechanics
 - Cold RF (incl. electron)
 - Cryogenics
- E. McCrory, D. Sun, A. Moretti
D. Moehs
R. Tomlin
C. Johnstone, A. Drozhdin, W. Chou, D. Raparia (BNL)
J. Lackey, D. Johnson, A. Drozhdin
A. Marchionni, W. Chou
D. Bogert
P. Lucas, F. Ostiguy, W. Chou
K-Y. Ng, J. MacLachlan, C. Ankenbrandt
D. Wildman, R. Pasquinelli, J. Reid
D. Wolff
A. Drozhdin, N. Mokhov
N. Mokhov
F. Ostiguy, D. Harding, V. Kashikhin, J. DiMarco, P. Schlabach,
R. Yamada
A. Chen, Z. Tang
R. Pasquinelli, A. Moretti, D. Sun, J. Reid, M. Huening, P. Piot,
B. Chase, D. Wildman, S. Hays, H. Pfeiffer
J. Theilacker, A. Klebaner, W. Soyars

AD Proton Driver Study Group (cont...)

- R&D projects:
 - (Fast RF tuner and other sc RF R&D) B. Foster
 - Dual harmonic power supply test at E4R D. Wolff
 - Laser chopping R. Tomlin
 - Beam pipe prototyping A. Chen
- Related Run2 projects in Booster and MI:
 - Large aperture Booster RF J. Reid
 - MI WQB (large aperture quads) D. Harding
 - MI Collimation (to start soon) A. Drozhdin, N. Mokhov

AD Proton Driver Study Group (cont...)

- Milestones:

- May: AAC Review
- Summer: Proton Driver Workshop at Fermilab
- October: ICFA HB2004 Workshop in Germany
- December: CD-0 Documentation

- Weekly meetings:

- **AD study group:** **Wednesday, 3:00 pm, Huddle**
 - Alternate topics on linac and MI (including target and beamlines)
 - Early focus on 8 GeV H⁻ injection
- **Cold RF:** **Tuesday, 3:00 pm, Penthouse**
 - Early focus on ferrite tuner
- **Cryogenics:** (TBA)
- **Footprint:** (TBA)
- **General:** **Friday, 2:00 pm, ICB 2E**