Linear Collider R&D Program

David Finley

Accelerator Advisory Committee
Fermilab
May 14, 2002

Outline

- Goals
- Linear Collider R&D Program Elements
- LC R&D Activities
  - US LC R&D
  - LC R&D At Fermilab
    - NLC Activities
    - TESLA/SCRF Activities
- Site Studies
- Summary

Goals

(Steve Holmes to Chicago Linear Collider Workshop January 9, 2002)

- Context

  The directors of the U.S. laboratories have publicly stated their support for construction of a linear collider as an international endeavor based on the optimum technology. This vision has been further supported by the HEPAP Subpanel and its European and Asian counterparts.

- Goals

  The goal of the U.S. Linear Collider R&D program is to develop the technology that would support construction of a linear collider, operating at an initial energy of 500 GeV and luminosity of at least 10^{34} cm^{-2} sec^{-1}, and upgradeable to an energy in excess of 1 TeV.

  - Bulk of the U.S. effort is currently being directed into x-band (11 GHz) based implementation.
  - Aiming for technology demonstration/decision on the timescale of 2003-04. (As is superconducting effort.)

Personal Perspective
General comments
(Kephart to HEPAP April 26, 2002)

- To participate in an informed LC technology choice our field as a whole must:
  - Become better informed about the technical issues
  - Participate vigorously in BOTH NLC & TESLA R&D programs
  - Not allow technical choices to be made for political reasons
- Our field needs a forum in which the benefits and problems of these machines can be openly discussed and compared !
- This are activities that ALL of us should and MUST participate in !
  - April 5,2002 “grassroots” meeting on University participation in LC R&D is a good start in this direction!

Goals
Performance Parameters

	NLC/JLC	JLC(C)	TESLA	
Energy (CM)	**500**	**500**	**500**	**GeV**
Repetition Rate	**120**	**100**	**5**	**Hz**
Bunches/pulse	**190**	**72**	**2820**	
Bunch separation	**1.4**	**2.8**	**337**	nsec
Particles/bunch	7.5×10^{9}	1.1×10^{10}	2×10^{10}	
Beam sigma at IP (H)	**245**	**318**	**553**	**nm**
Beam sigma at IP (V)	**2.7**	**4.3**	**5.0**	**nm**
δ_B	4.7	3.4	3.2	%
Luminosity Enhancement	1.4	1.7	2.1	
Luminosity	**20×10^{33}**	**8.6×10^{33}**	**34×10^{33}**	**$cm^{-2}sec^{-2}$**
Beam power	**13**	**6**	**23**	**MW**

LC R&D Program Elements

- Energy Performance
  - RF Structures
    - An accelerating structure must be developed that can support the desired gradient in an operational setting and there must be a cost effective means to fabricate this structure.
  - RF power generation and delivery
    - The rf generation and distribution system must be capable of delivering the power required to sustain the design gradient.

  ⇒ Demonstration projects: NLC 8-pack test, TTF-II
- Luminosity Performance

  The specified beam densities must be produced within the injector system, preserved through the linac, and maintained in collision at the interaction region … reliably.
  - Damping ring performance
  - Vibration specification and site characterizations.
  - Wakefield suppression/compensation and IR feedback schemes.

  ⇒ R&D Facilities: ATF, ASSET, NLCTA, TTF, and LINX(?)

LC R&D Program Elements

- Energy Upgrades

  There need to be plausible visions of how to upgrade the energy (to and beyond 1 TeV) somewhere down the road.

  ⇒ Gradient R&D to establish the limits of x-band and SC structures.

- Site(s)

  At least one viable site has to be identified and understood. This includes both technical feasibility and public acceptance/support.

  ⇒ Site studies

- Cost

  The cost of facility construction and operation has to be understood.

US Linear Collider R&D Program

- The current U.S. LC R&D effort is largely focused on XBand technology for NLC.
  - –SLAC, FNAL, LBNL, LLNL, (and KEK) are participating in this part
- The TESLA collaboration submitted a TDR to the German government in March 2001 for a linear collider based on superconducting RF technology.
  - –TESLA is an international collaboration
  - –US institutions including FNAL contributed to the TESLA TDR
  - –There is an active international program of R&D in support of TESLA
  - –US participation in this program is limited compared to XBand effort
- Both efforts are aiming for technology demonstrations and/or decisions on the timescale of 2003-04.
- Both efforts face many similar challenges for delivering integrated luminosity
  - – e.g. creating very small emittance beams, preserving their quality through the main linacs, and colliding nanometer sized beams … and reliability.

Linear Collider at Fermilab !

- FNAL Director, Mike Witherell, stated in his June 12, 2001 presentation to the DOE/NSF HEPAP subpanel:

  "We propose to the U.S. and to the international HEP community that we work together to build a linear collider at or near the Fermilab site."

- Fermilab activity in the U.S. LC R&D program is increasing.
- Goals : Develop the technology to support construction of a linear collider.
  - initial CM energy of 500 GeV
  - luminosity of at least 10^{34} cm^{-2} sec^{-1}
  - upgradeable to an energy in excess of 1 TeV.

LC R&D at Fermilab

- Fermilab is the only US institution that is both an NLC and TESLA collaborator
- On NLC Fermilab is:
  - –Making RF structures for the 8 pack test at SLAC
  - –Working on industrialization of RF structures
  - –Working on support girder design for the main linac
  - –Investigating adjustable permanent magnet quadrupoles
- On TESLA/SCRF
  - –FNPL (Fermilab NICADD Photo-injector Lab)
  - –EOI for High Brightness Photo-injector (HBPI), with many universities and labs
  - –CKM cavities (SC cavities for separated K beam experiment at FNAL ~TESLA)
  - –Design of 3rd harmonic cavities appropriate for both TTFII and HBPI
  - –Study of the TESLA TDR:Goal = understand costs in US terms and to familiarize FNAL staff with the engineering aspects of the proposal
- For Both : Studies of possible US sites (including Fermilab) for a Linear Collider

LC R&D at Fermilab
Organization

- David Finley is responsible for LC R&D at Fermilab
  - As of February 1, 2002
  - Reports to Steve Holmes
  - XBand, SCRF, Conventional RF, Magnets
    - Helen Edwards is in charge of SCRF
    - David Finley is in charge of room temperature RF
- Bob Kephart is head of the Technical Division
  - David Finley is in charge of the RF Tech Development Group
    - XBand, SCRF … and Physics, RF Engineering
    - Reports to Bob Kephart
- Helen Edwards is in the Beams Division
  - All resources go to CKM and FNPL in FY02
    - CKM = Fixed Target Experiment, FNPL = Fermilab NICADD Photoinjector Lab

LC R&D at Fermilab
Organization

- David Finley is responsible for LC R&D at Fermilab
  - As of February 1, 2002
  - Reports to Steve Holmes
  - XBand, SCRF, Conventional RF, Ma
    - Helen Edwards is in charge of SCR
    - David Finley is in charge of room t
- Bob Kephart is head of the Technical D
  - David Finley is in charge of the RF
    - XBand, SCRF … and Physics, RF Eng
    - Reports to Bob Kephart
- Helen Edwards is in the Beams Division
  - All resources go to CKM and FNPL
    - CKM = Fixed Target Experiment, F

All four of the people named here have some responsibilities associated with Run II …

Holmes: Big

Kephart: Medium

Finley: Medium

Edwards: Small

LC R&D at Fermilab
FY02 Resources

Obligations through
March 31, 2002

$4.7M Total Fermilab

$2.5M NLC capped

$2.2M SRF

~24.5 FTEs

$2.26M M&S

Fermilab LC R&D

Cost Cat	Obligation Budget	Obligation Cost + Chg in Comm (K$ Obligated)	Obligation Cost + Chg in Comm (% Obligated)
BD + TD LC Capped			
1YA Personnel Costs	1,367.0	628.2	46%
1YB Materials & Services	1,133.0	413.2	36%
Total LC:	2,500.0	1,041.4	42%
BD + TD SRF			
1YA Personnel Costs	1,087.0	399.2	37%
1YB Materials & Services	1,130.0	310.2	27%
Total SRF:	2,217.0	709.4	32%
Total LC Capped + SRF			
1YA Personnel Costs	2,454.0	1,027.4	42%
1YB Materials & Services	2,263.0	723.4	32%
Total LC + SRF:	4,717.0	1,750.9	37%

LC R&D at Fermilab
FY02 Resources

Obligations through March 31, 2002

BD LC R&D

Code	Cost Cat	Obligation Budget	Obligation Cost + Chg in Comm (K$ Obligated)	Obligation Cost + Chg in Comm (% Obligated)
BD-LC Total Capped				
1YA	Personnel Costs	150.0	25.0	17%
1YB	Materials & Services	400.0	55.0	14%
Total BD LC:		550.0	80.0	15%
BD-SRF Total				
1YA	Personnel Costs	450.0	291.3	65%
1YB	Materials & Services	600.0	300.1	50%
Total BD SRF:		1,050.0	591.4	56%

TD LC R&D

Code	Cost Cat	Obligation Budget	Obligation Cost + Chg in Comm (K$ Obligated)	Obligation Cost + Chg in Comm (% Obligated)
TD - LC Total Capped				
1YA	Personnel Costs	1,217.0	603.2	50%
1YB	Materials & Services	733.0	358.2	49%
Total TD LC:		1,950.0	961.4	49%
TD-SRF Total				
1YA	Personnel Costs	637.0	107.9	17%
1YB	Materials & Services	530.0	10.1	2%
Total TD SRF:		1,167.0	118.0	10%

Note: BD SRF is: $0.9M for support of operation of FNPL Photoinjector at A0 plus $0.15M for CKM cavities

RF Technology Development Group

These support these

- D. Finley / Group Leader
- N. Solyak / Physics
- G. Romanov / RF Engineering
  - T. Khabiboulline
  - I. Gonin

- H. Carter / XBand
  - T. Arkan
  - C. Boffo
  - E. Borrisov
  - B. Smith
  - M. Battistoni
- I. Terechkine / SRF
  - Connections to others

(1) SRF "connections" include some XBand team members, Helen Edwards' team in the Beams Division, Cornell, JLab, DESY …

(2) LC / NLC "connections" include SLAC, LBNL, KEK in areas of physics, engineering, production development

RF Technology Development Group

These support these

- H. Carter / XBand
  - T. Arkan
- D. Finley / Group L
- N. Solyak / Physics
- G. Romanov / RF En
  - T. Khabiboulli
  - I. Gonin

oni

/ SRF

ns to others

Solyak also has a small responsibility associated with Run II.

And the Physics effort associated with LC is suspended until Run II works. (The other two physicists are working on Run II also.)

(1) SRF "connection
team in the Beams

n Edwards'

(2) LC / NLC "connections" include SLAC, LBNL, KEK in areas of physics, engineering, production development

The Top Priority of the NLC R&D Program is …
The 8-pack Test

"8-pack" test: Proof of principle demonstration of the NLC rf generation and distribution system

Goals:

"Single feed" demonstration in 2002 >>> 2003

- Deliver rf power suitable to support 70 MV/m (unloaded) for one girder (5.4 m) of structures.
- Test facility for rf power system to run independently of the high-gradient structure testing.

Complete 8-pack in late 2003 >>> mid 2004

- Demonstrate full power source with one DLDS arm.
- Demonstrate full power operation of two girders (10.4 m) worth of accelerating structures, including at least one of the final RDDS design.

The NLC R&D 8-pack Test

NLC Linac RF Unit

Full "8-Pack"
NLCTA Fall 2003

Low Level RF System

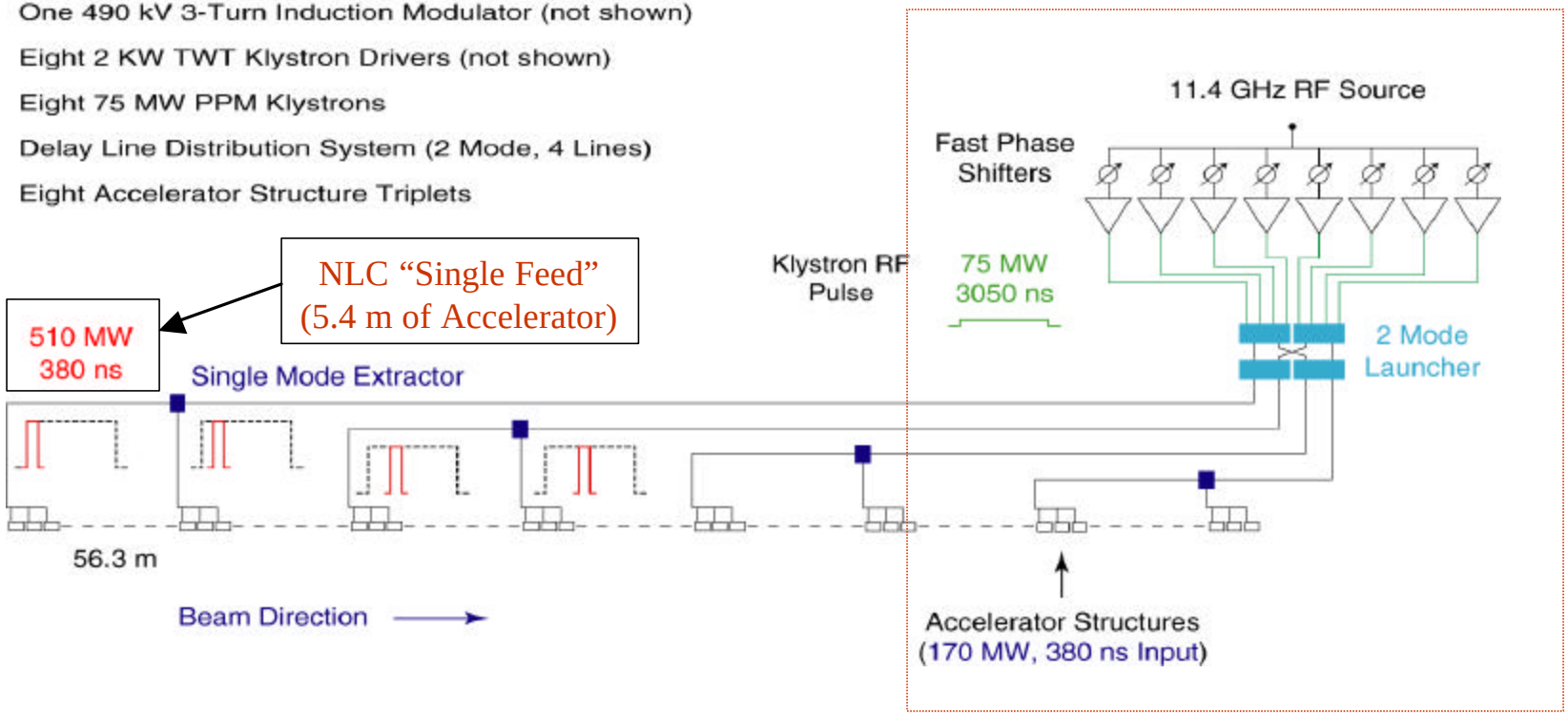
One 490 kV 3-Turn Induction Modulator (not shown)

Eight 2 KW TWT Klystron Drivers (not shown)

Eight 75 MW PPM Klystrons

Delay Line Distribution System (2 Mode, 4 Lines)

Eight Accelerator Structure Triplets



The NLC R&D 8-pack Test

NLC Linac RF Unit

Full "8-Pack"
NLCTA Fall 2003

Low Level RF System

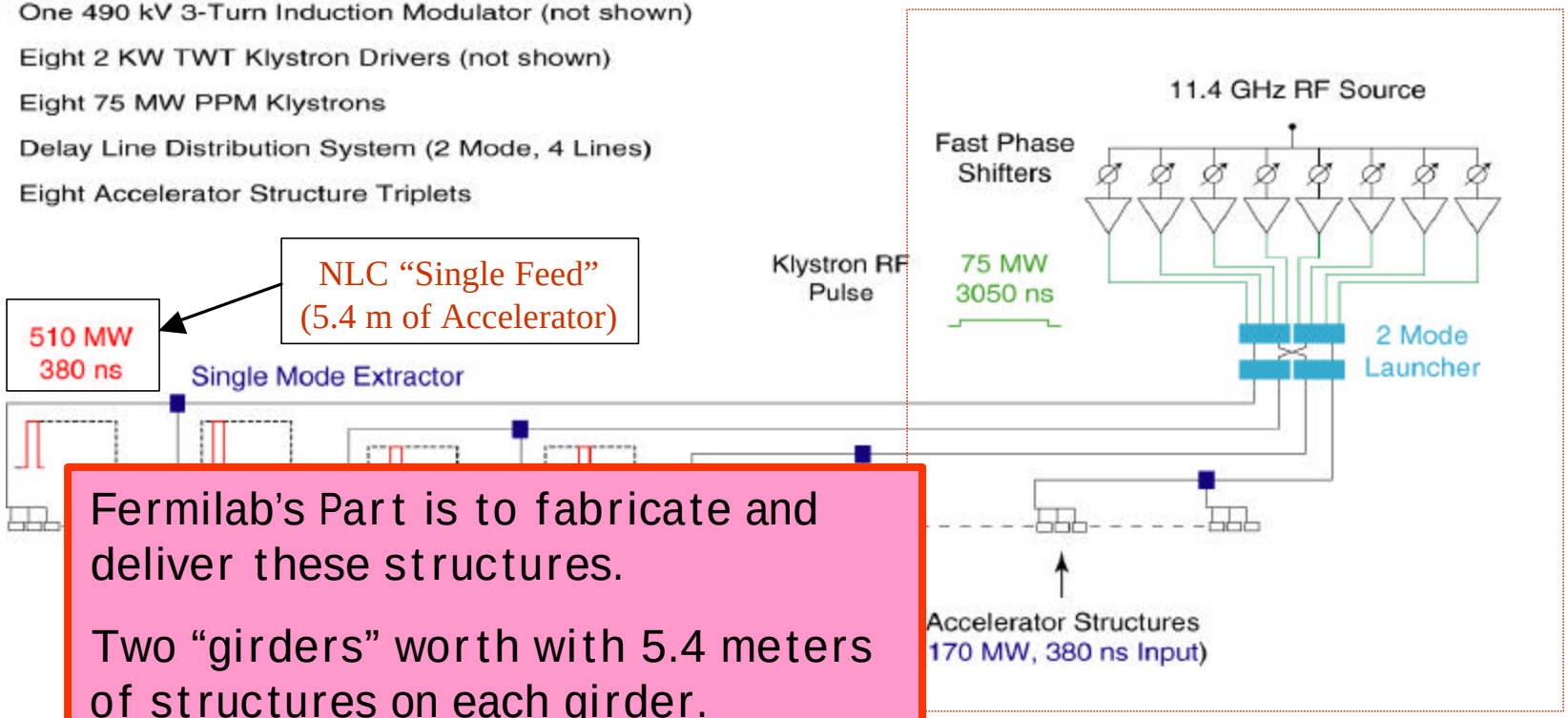
One 490 kV 3-Turn Induction Modulator (not shown)

Eight 2 KW TWT Klystron Drivers (not shown)

Eight 75 MW PPM Klystrons

Delay Line Distribution System (2 Mode, 4 Lines)

Eight Accelerator Structure Triplets



Fermilab's Part is to fabricate and deliver these structures.

Two "girders" worth with 5.4 meters of structures on each girder.

The NLC R&D Program
Structures/Industrialization

The NLC requires ~11,000, 0.9 meter, accelerating structures to reach 500 GeV. Fermilab has undertaken the task of developing an industrialization process for x-band structures fabrication

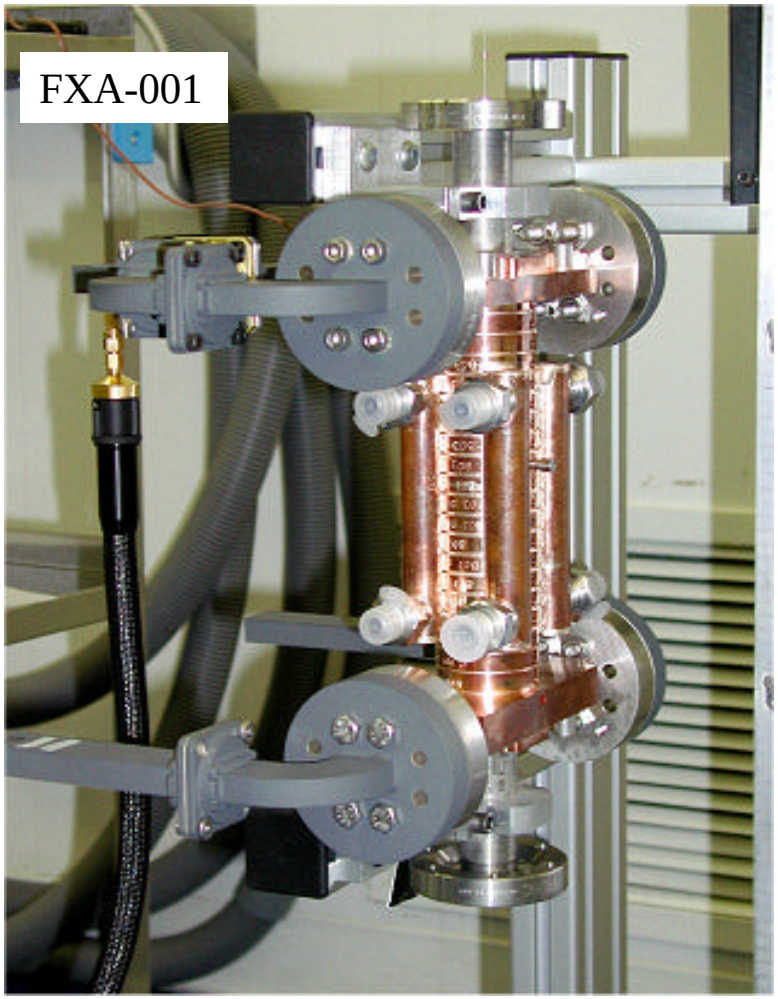
- Short term Goals
  - Driven by desire to initiate 8-pack test at SLAC in late 2003/mid 2004
  - Structures fabrication facility
    - Assembly of eighteen 0.9 (or twenty four 0.6) meter structures
    - Includes twelve (or 18) destined for 8-pack test at SLAC
    - Capability of >1 structure/month by December 2002
  - Tolerances/acceptance criteria
    - Develop complete understanding of tolerances and develop QC criteria and specifications
  - Girders
    - Develop girder design and prototype
    - Delivery of two complete girders to SLAC for 8-pack test

The NLC R&D Program
Structures/Industrialization

- Status
  - IB-4 conversion to structures fabrication facility nearly complete (w/NICADD support)
  - Two 20 cell Fermilab structures complete (FXA series)
  - Parts for a third 20 cell structure, and three 60 cm structures are in hand (FXB series)
  - Waiting for delivery of the large furnace.

"Small" furnace and the structures fabrication facility at Fermilab

Status of X-Band Structures Production

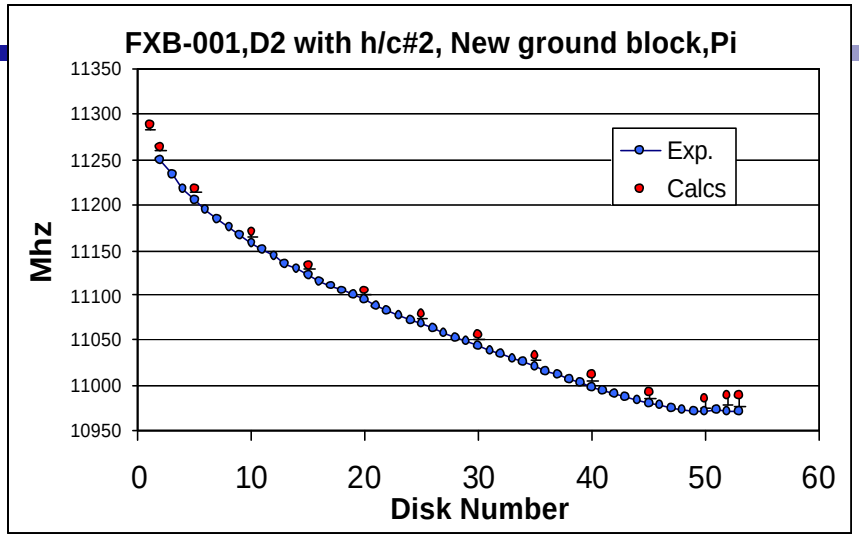


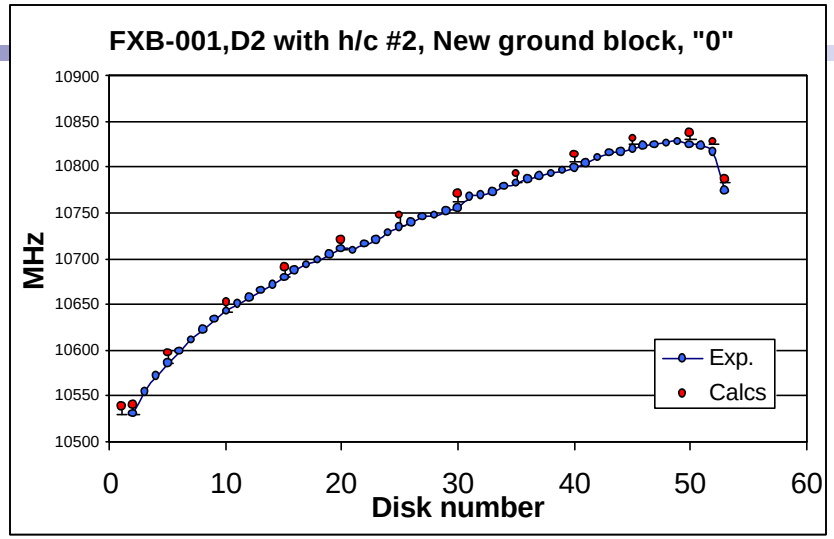
Two FXA-001/2 structures are built, measured and tuned at Fermilab. First structure took a little more than 9 months, second – 2.5months. Target is one structure per month.

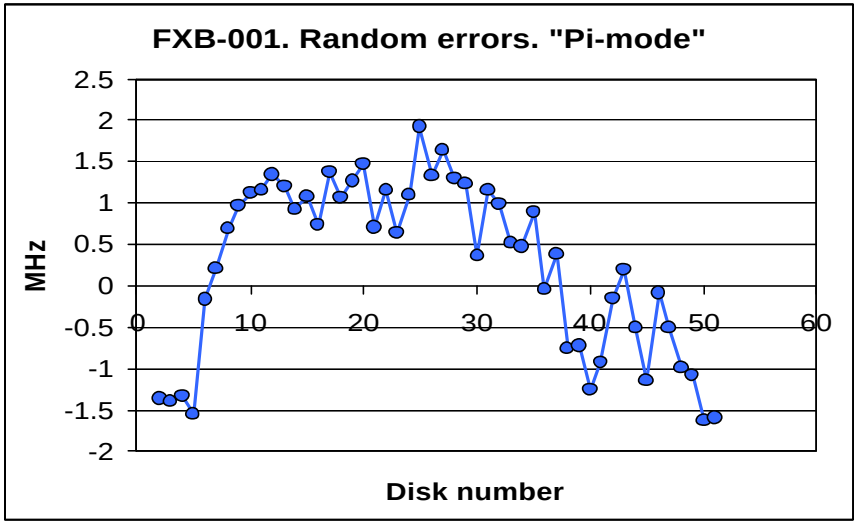
We are in the process of producing FXA-003 and FXB-001(thru 003). Both currently delayed due to lack of receipt of Large Vacuum Furnace from AVS.

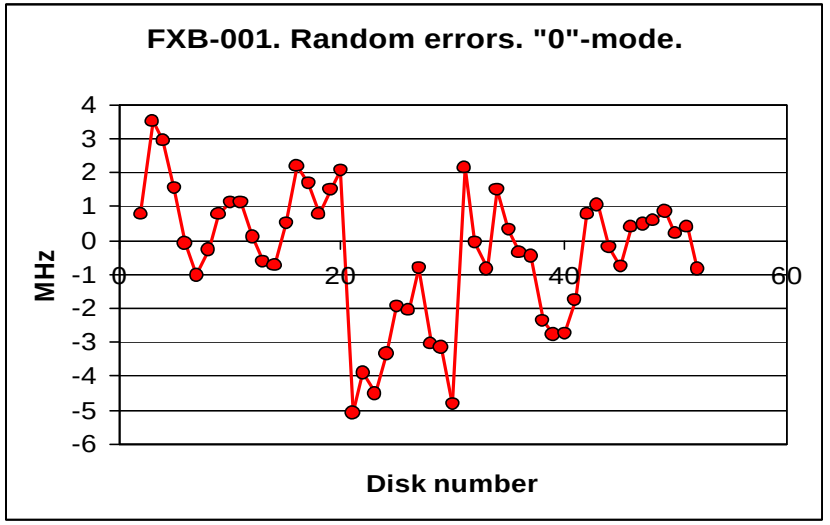
- **FXA** is 20 cm long, 3π/2 structure, made according to SLAC's design of T20VG5 (5% group velocity).
- **FXB** is 60 cm long, 5π/6 structure with 3% group velocity, made for NLC High Gradient Testing.

RF QC of FXB-001 structure









TESLA R&D in the U.S.

The U.S. is in a unique position as the only region in the world in which the technology choice for a linear collider does not appear to be “locked in”. However the character of the U.S. effort on TESLA is fundamentally different from the NLC program because leadership comes from abroad (DESY).

- US members of the TESLA collaboration
  - Argonne National Laboratory
  - Cornell
  - Fermilab
  - Jefferson Lab
  - UCLA
- Elements of the U.S. Program
  - Collaboration on construction and operation of the TESLA Test Facility (TTF)
  - Collaboration on preparation of the TESLA proposal
  - Superconducting materials/processing/fabrication R&D
  - Injector development and R&D
  - Engineering/cost study of the TESLA proposal (w/SLAC participation)
  - SCRF operational experience at Cornell and JLab

TESLA R&D in the U.S.
Highlights

- Superconducting structure R&D
  - Fundamental investigations into breakdown phenomena, surface conditions and processing at Cornell
- Flat beam studies at Fermilab/NICADD Photoinjector Laboratory (FNPL)
  - Goal
    - Generate a flat beam with an emittance ratio tailored to future linear collider requirements ($e_H/\varepsilon_V \approx 100$)
  - Typical emittance ratio achieved thus far is ~40 (@17 MeV and 1 nC)
  - Next step is to increase emittance ratio by decreasing space charge.

TESLA R&D in the U.S.
Highlights

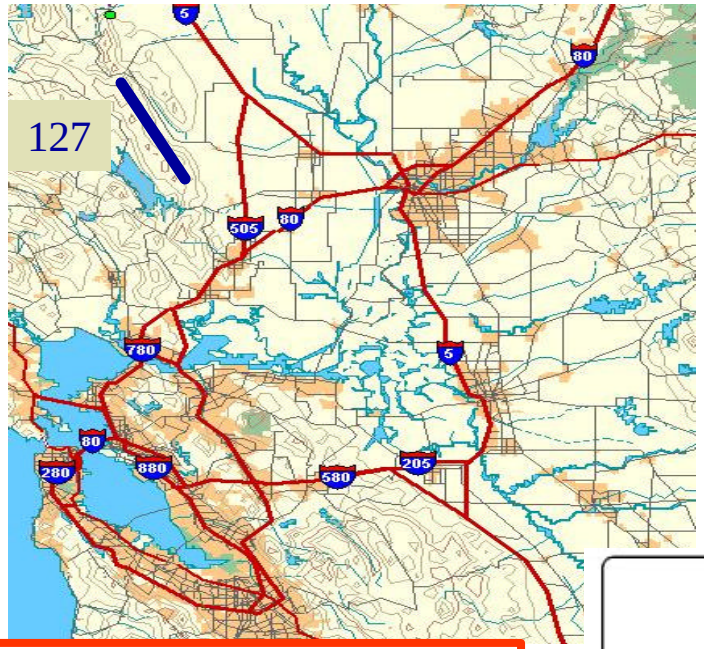
- Engineering/Cost Study
  - Develop an understanding of:
    - Scope included in the TESLA estimate
    - Basis and estimating methodology
    - Supporting studies (industrialization, schedules, etc.)
    - Implicit (or explicit) implementation choices
    - Mapping onto a U.S. style estimate
  - Report will be arrive for Director's review in May 2002

Peter Garbincius' Talk Yesterday

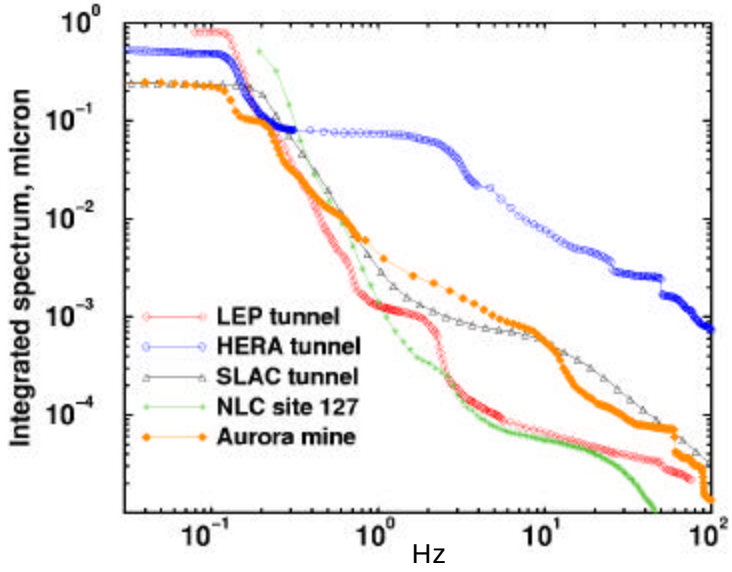
- Opportunities
  - Activities centered at FNPL (many also applicable to NLC):
    - Flat beam experiments
    - Remote operations demonstration
    - 3.9 GHz (3rd harmonic) cavity to support longer bunches
    - Polarized rf guns?
  - Engineering study of TESLA in a deep site
  - Pursue other opportunities with U.S. collaborators

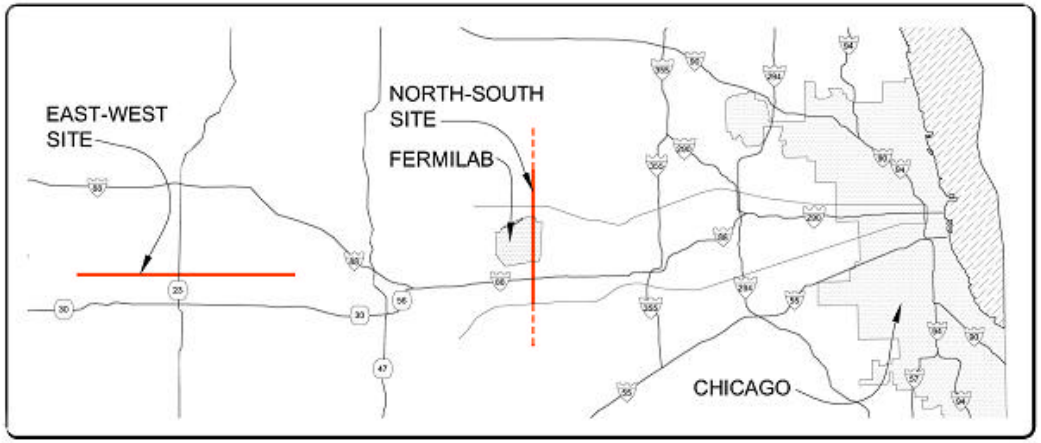
Court Bohn's Talk Next

LC Site Investigations
California and Illinois Sites



San Francisco Area





David Finley / AAC @ Fermilab

http://tdserver1.fnal.gov/Finley/020514AAC.pdf

Other RF and LC R&D at Fermilab

- RF R&D
  - "Minimal funding" status
  - A single 805 MHz cavity in a solenoid at Lab G
    - Steve Geer gave talk at NLC Collaboration meeting last Tuesday
  - Initiated by need for ionization cooling for muon beams
- LC R&D
  - Adjustable Permanent magnets
  - Beam Physics … on hold until Run II works
  - XBand Powerstation, 3.9 GHz Powerstation
- Connecting Universities and LC R&D
  - "We want an e^+e^- linear collider, how can we help?" … or …
  - The linear collider "is too important to be left in the hands of the experts"
  - April 5, 2002 Meeting at Fermilab: Midwest consortium
  - April 19, 2002 Meeting at Cornell: NSF proposal
  - "The List" (Himel / Finley / Rogers) http://www-project.slac.stanford.edu/lc/Project_List/intro.htm
  - May 10, 2002 (Friday)
    - Cornell, Fermilab, SLAC … Checking signals

Summary

Linear Collider R&D is being pursued in the U.S. and abroad with a goal of establishing underlying technologies in late 2003/early 2004 timeframe.

Both NLC and TESLA are currently on paths that are expected to lead to credible technology demonstrations on this timescale.

- Current support levels in the U.S. (and perhaps also abroad) could imperil this timescale.

We need more resources (=people +$) on this.

- The experimental community can help by getting directly involved in the machine R&D and technology discussion.

If we are successful on the R&D (and establishing public support and forming an international collaboration) the world could construct such a facility over the ~2006-2012 time period