The International Linear Collider

The Coming Revolution in Particle Physics
Report of the Fermilab Long Range Planning Committee
May 2004

Shekhar Mishra

Linear Collider Accelerator R&D

Technical Division

6/02/04

- Fermilab Linear Collider R&D
- Illinois, US and International collaboration efforts
- ITRP and GDI
- Technology Selection and Fermilab
- Join to shape the future of HEP and yours

Introduction

- Fermilab is the only laboratory in the US that is collaborating on both Warm (NLC) and Super-conducting (TESLA) Linear Collider accelerator technology R&D.
- Accelerator Physicists and Engineering staff from Technical Division and Accelerator Division have contributed significantly to both the Linear Collider designs, including the US Option and site studies.
- Fermilab Particle Physicists are working on four major detector components R&D and coordinating LC detector simulation efforts.
- Fermilab Director has charged a group to take a leading role in the Linear Collider Accelerator R&D.

The Charge

March 18, 2004

To: Shekhar Mishra

From: Michael Witherell

Subject: Linear Collider at Fermilab

I would like you to expand and lead the Fermilab Linear Collider effort in the directions recommended by the Fermilab Long Range Planning Committee. The Office of Science 20-year facilities plan has identified the Linear Collider as their highest priority mid-range project, and I have indicated publicly Fermilab's desire to serve as the host laboratory for such a machine. Your team will strengthen Fermilab's position to achieve this goal.

I would like Fermilab to act swiftly to develop its capability to provide technical leadership on the LC construction by engaging in the critical accelerator physics and technology issues. I would like you to concentrate on a few accelerator areas that are central to the LC and well-matched to the lab's interest and expertise. Suitable possibilities might be the damping rings and the main linac. This involvement should begin now, covering both technologies, without waiting for the technology decision. However, it is also important that we prepare a plan that builds Fermilab momentum no matter which technology is selected.

The FLRPC also recommended that Fermilab should assume leadership of the effort to define the scope of an Engineering Test Facility (ETF) for the chosen Linear Collider technology. Your group should develop a Fermilab viewpoint on the ETF design goals and work with international partners to establish a design for such a facility. This should be done within the context of Fermilab aspirations to host such a facility.

Fermilab should also develop a LC site plan appropriate for a host lab. Your group should work to identify one or more sites in Illinois and carry out the appropriate geological studies to establish their suitability for construction and operation of the LC. Your group should work with the Office of Public Affairs to establish collaborations with local institutions and state and local governments and participate in community outreach efforts.

In organizing and undertaking this assignment I would like you to collaborate closely with all our divisions and sections. I would further ask you to involve institutions outside of Fermilab who have potential interests in collaboration on development, construction, and operations of the Linear Collider itself or in the scientific research programs enabled by the facility. I would like you to work with Steve Holmes to ensure that Fermilab is well represented at the national and international level in the Linear Collider.

As with any such responsibility you may be asked from time to time to report on Linear Collider progress to various review committees, help with the lab's long range financial planning for such a project, and help inform the Fermilab User Community about the exciting physics prospects of such a facility.

Action to implement the vision for the future outlined by the Fermilab Long Range Planning Committee is important to securing a healthy and productive future for both Fermilab and for the U.S. Steve Holmes will serve as the Directorate point of contact on this activity, and both Steve and I look forward to working closely with you, and the participating divisions, sections, and outside institutions on this. Thank you.

Cc
Associate Directors
Division/Section Heads
J. Jackson

Fermilab LC Efforts

The charge is aimed to increase the Linear Collider Accelerator R&D at Fermilab with a goal to host it near Fermilab and is in line with FLRPC report.

- Provide technical leadership on the LC construction by engaging in the critical accelerator physics and technology issues.

- Fermilab viewpoint on the Engineering Test Facility design goals and work with international partners to establish a design for such a facility.

- Identify one or more sites in Illinois and carry out the appropriate geological studies to establish their suitability for construction and operation of the LC.

Fermilab and LC Effort..

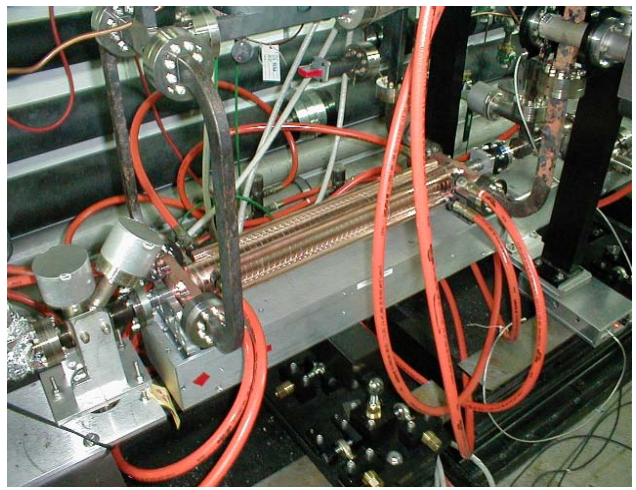
- Work with the Office of Public Affairs to establish collaborations with local institutions, state and local governments and participate in community outreach efforts.
- Work with Steve Holmes to ensure that Fermilab is well represented at the national and international level in the Linear Collider.
- Report on Linear Collider progress to various review committees, help with the lab's long range financial planning for such a project, and help inform the Fermilab User Community about the exciting physics prospects of such a facility.

Status of Current (X-Band and SCRF) R&D

- X-Band
  - RF Structure Design and Fabrications
  - New design of Wave guide Coupler and HOM Extraction
  - Girder motion controller, Vibration and Ground Motion
- SCRF
  - FNPL: Injector for TESLA, Technology Development, Accelerator Physics
  - Developing SCRF Technology and local expertise
    - Material development
    - Production and testing of CKM and 3.9 GHz TESLA cavity
- Civil design of the LC Facility and Geological Studies

FX-band Structures at NLCTA

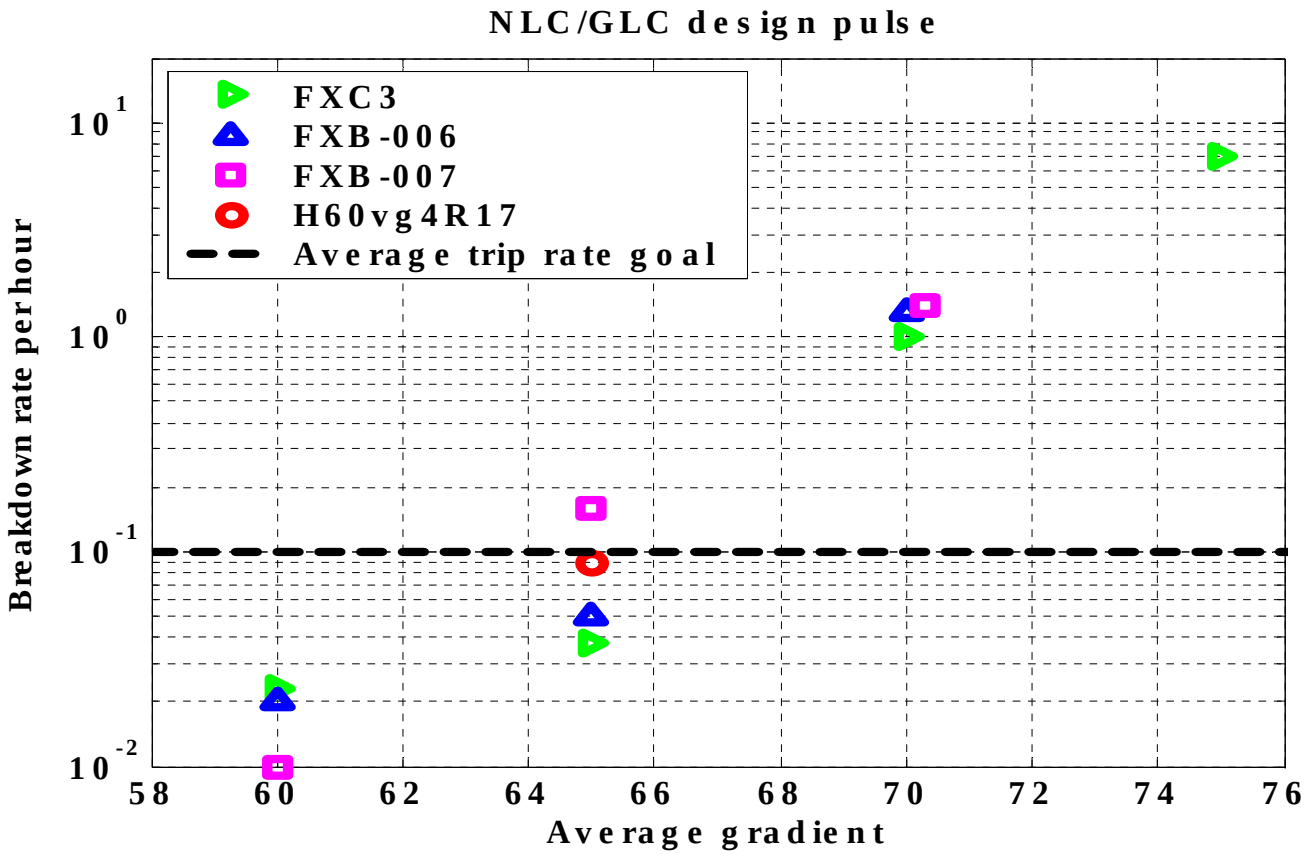
- Five structures currently operating at the SLAC NLCTA were fabricated by Fermilab.
- Fermilab build structure: FXB-006 is the first structure built by anyone to achieve TRC R1 requirement for gradient and breakdown rate (<0.1 breakdown/hour @ 60 Hz, 400 nsec pulse width, 65MV/m)
- FXC003 was the first damped and detuned structure to meet the TRC R1 requirement.
- FXD001 is installed in NLCTA. It is a tapered design to reduce Wake Field Effect.



FXC-001

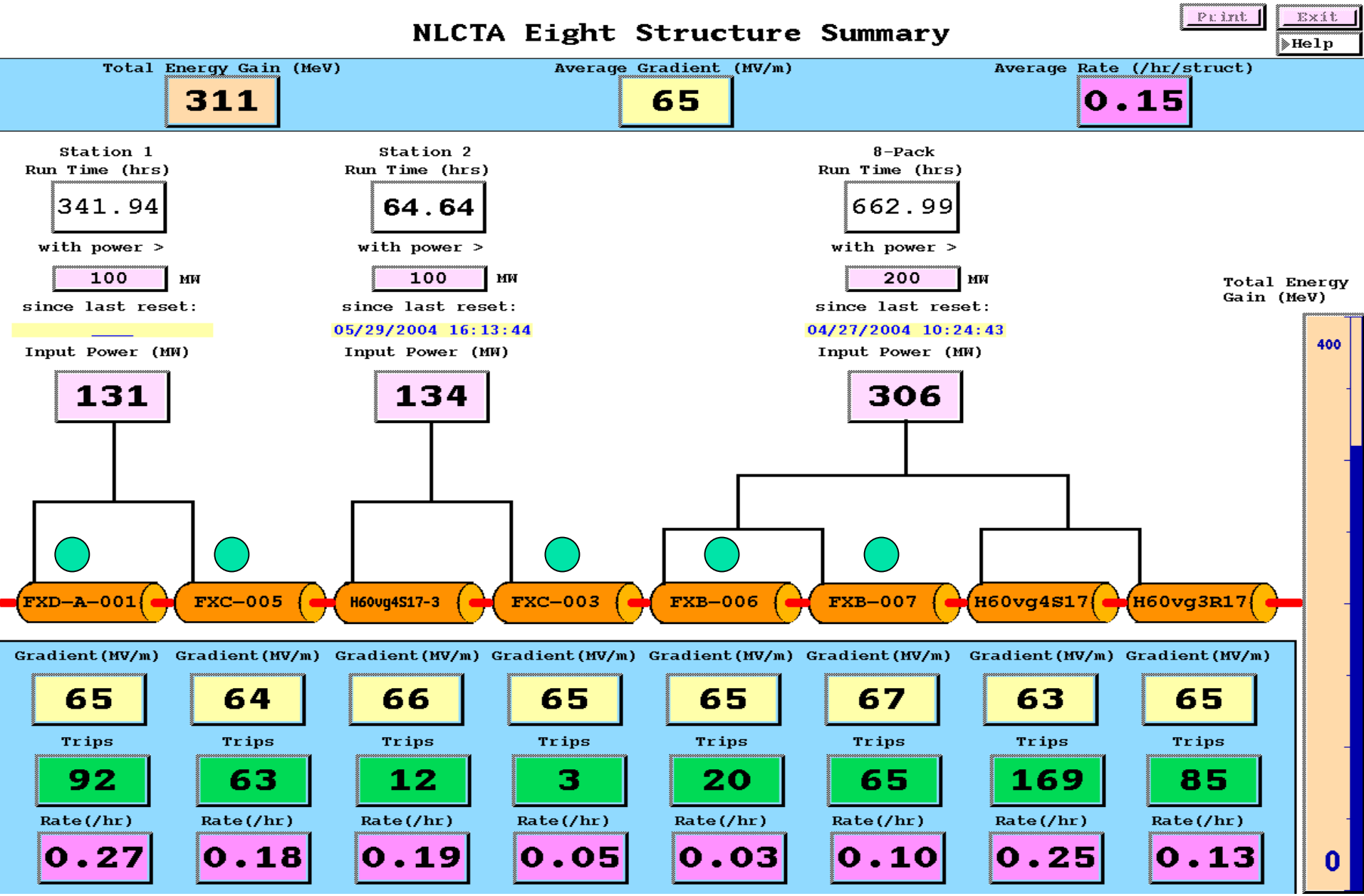
Processing results from the 4 latest NLC/GLC prototype structures

3 out of 4 exceed breakdown rate requirements at 65 MV/m



- Out of 3 Fermilab Structures in NLCTA to date 2 meets the R1 requirement in contrast to several structures produced by other labs. (4/8/04)

NLCTA Running



Overview of SCRF activities

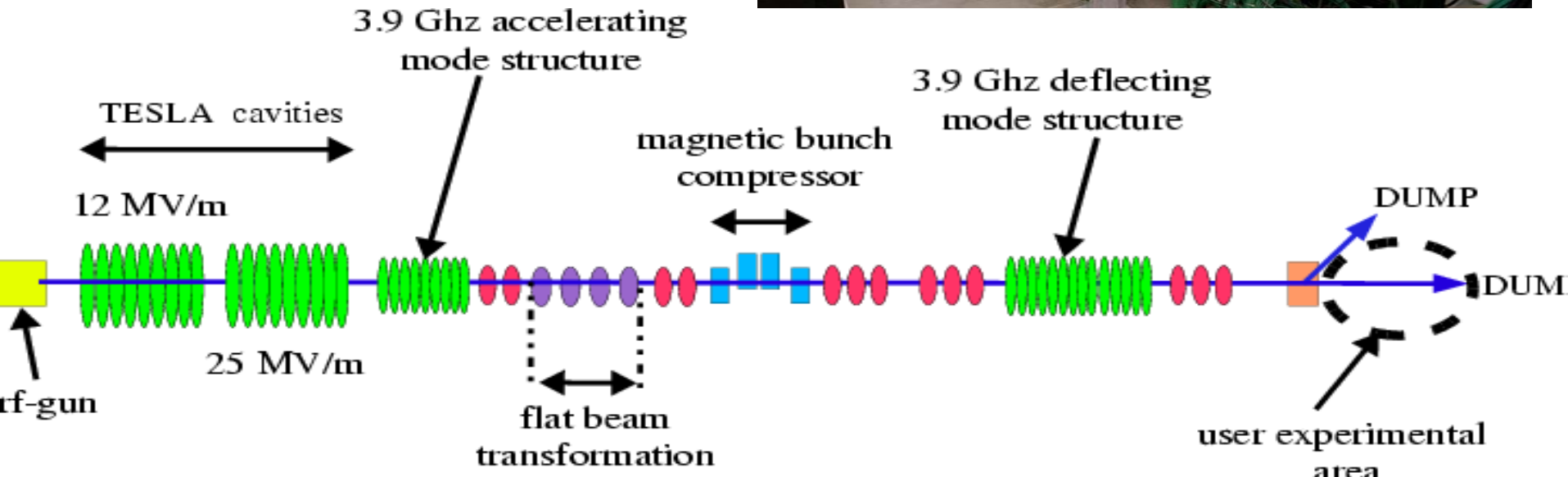
- Linear Collider R&D
  - We built modulators and electron guns for TESLA TTF at DESY (AD) and designed vertical test dowers and cryostats.
  - The A0 photo-injector at FNAL is similar to TTF and uses TESLA acceleration cavities
  - We are designing and building a 3.9 GHz 3rd harmonic cavity. The purpose is to reduce the beam energy spread that will shorten the electron bunch pulse length.
- CKM
  - FNAL has been doing R&D to build 3.9 GHz transverse kick cavities for a K beam Experiment.
- Proton Driver

Fermilab NICADD Photo Injector Laboratory

A facility to develop injector beam for TESLA, SRF technology at Fermilab and beam studies.

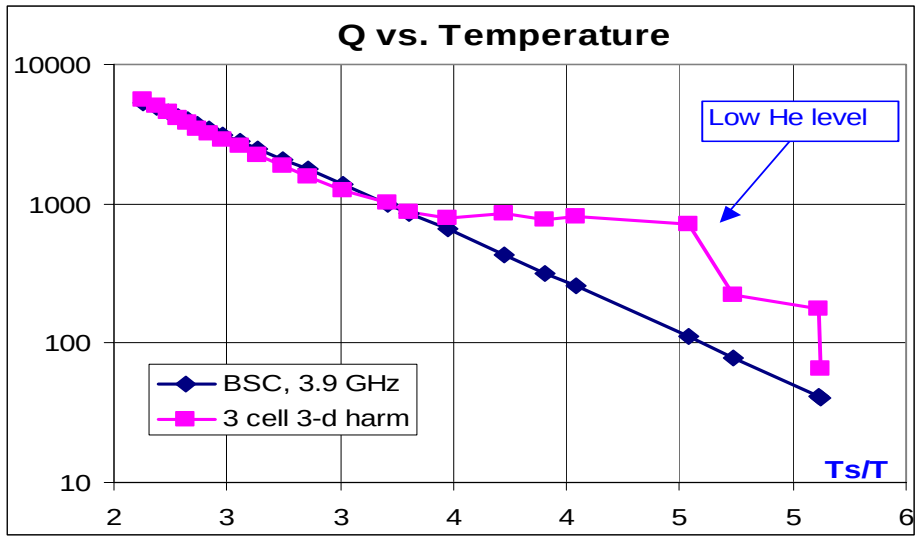
Plan exist to upgrade this facility further.

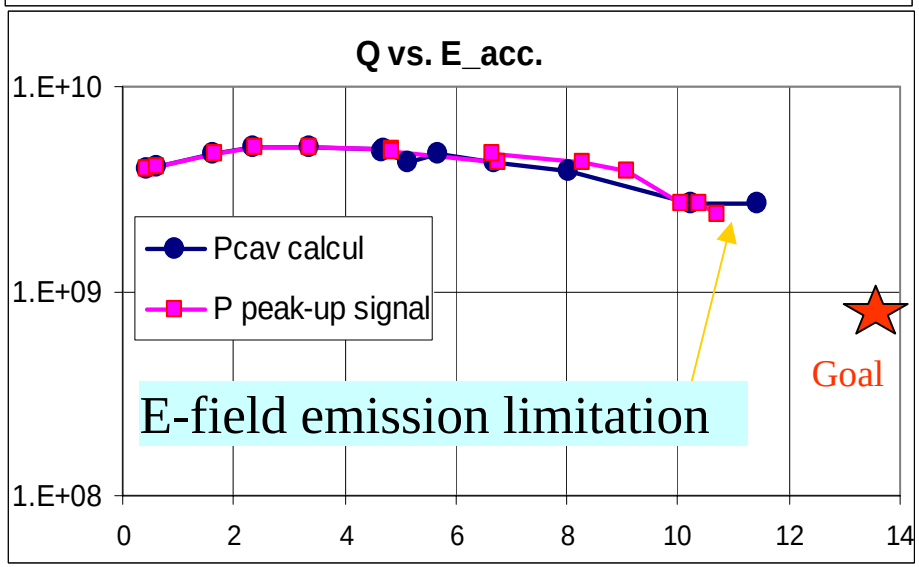
If technology choice is cold, FNPL can be upgraded to ETF.



Cold Test of the 3.9GHz 3-cell cavity in the Vertical Cryostat

Tested after 140 μm BCP, heat treatment and HPR





Linear Collider @ Fermilab

- Fermilab/Northern Illinios/U.S. is a natural host
  - Fermilab
    - Scientific and engineering expertise in forefront accelerator and detector technologies
    - Significant experience in construction and operations of large accelerator based projects.
    - The flagship laboratory of U.S. high energy physics
  - Northern Illinois
    - Strong scientific base, including two national laboratories and five major research universities.
    - Geology ideally suited to a Linear Collider
    - Transportation and utilities infrastructure system that could support LC construction and operations.

Linear Collider Site Studies

Pictures Removed

- **Four Complete Design Solutions Have Been Developed.**

IL and CA X Band Linear collider

IL and CA Superconducting LC

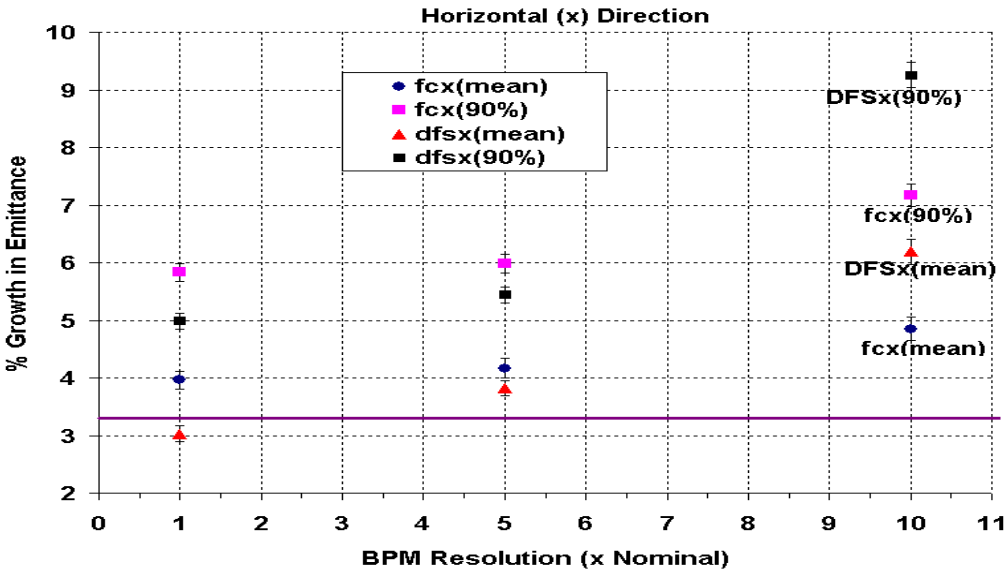
- **Design Solutions include Design Summaries, Cost Estimates, Drawing Sets and Project Schedule Information**

- **This work is done in collaboration with NIU Geology and NICADD.**

Accelerator Physics Studies

- The key to the success of the Linear Collider is production and transport of low emittance beam to IR.
- We have decided to study the Linac and Damping Ring as our accelerator physics efforts at Fermilab.
  - Emittance preservation in LINAC and alignment requirements.
  - Damping Rings for TESLA and Pre-Damping Ring for NLC.
  - Development of Wiggler Field Map, Study of Electron Cloud Effects etc.
  - Electron Beam Physics modeling tools

BPM Resolution



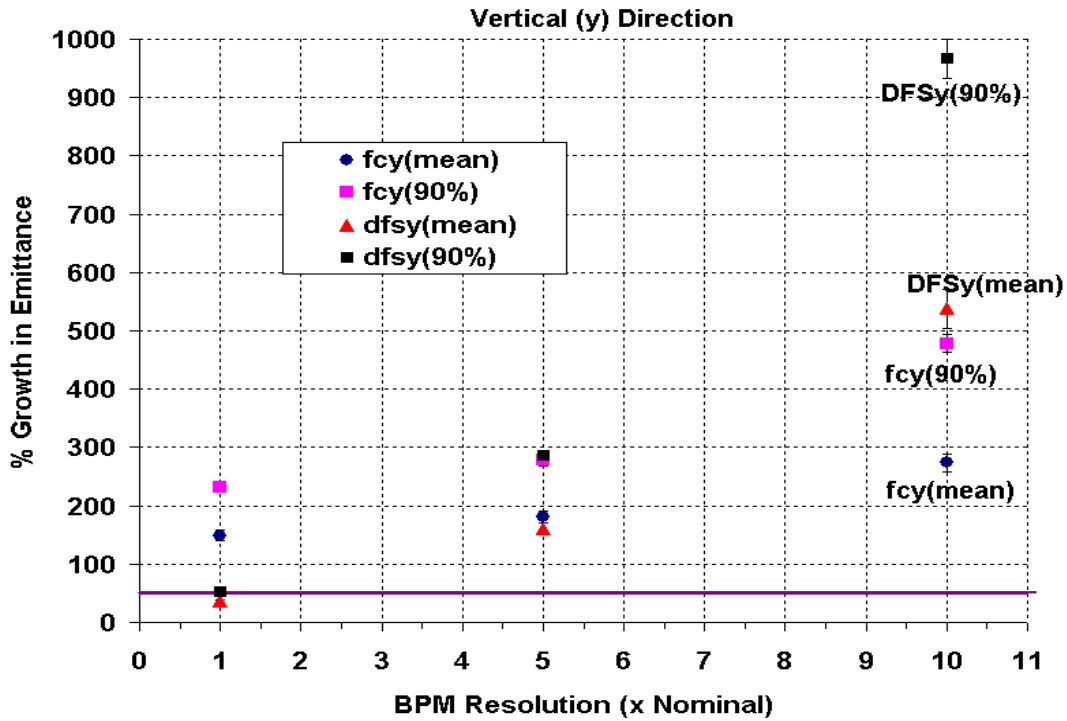
- $\gamma\varepsilon_y$ & $\gamma\varepsilon_x$ growth in FC:
  - lesser dependence, but,
  - much above tolerance.

Nominal Values

Rms offset in x-direction : 0.4 µm

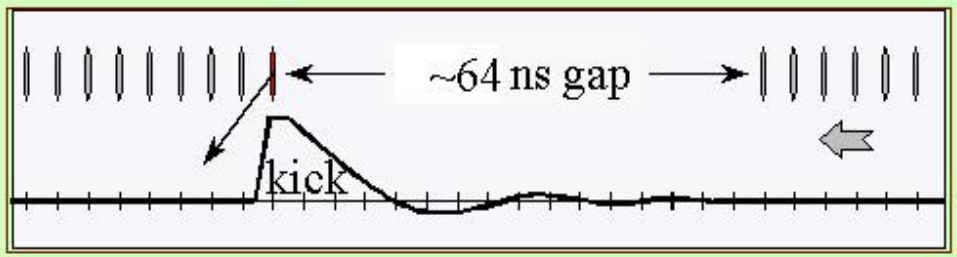
Rms offset in y-direction : 0.4 µm

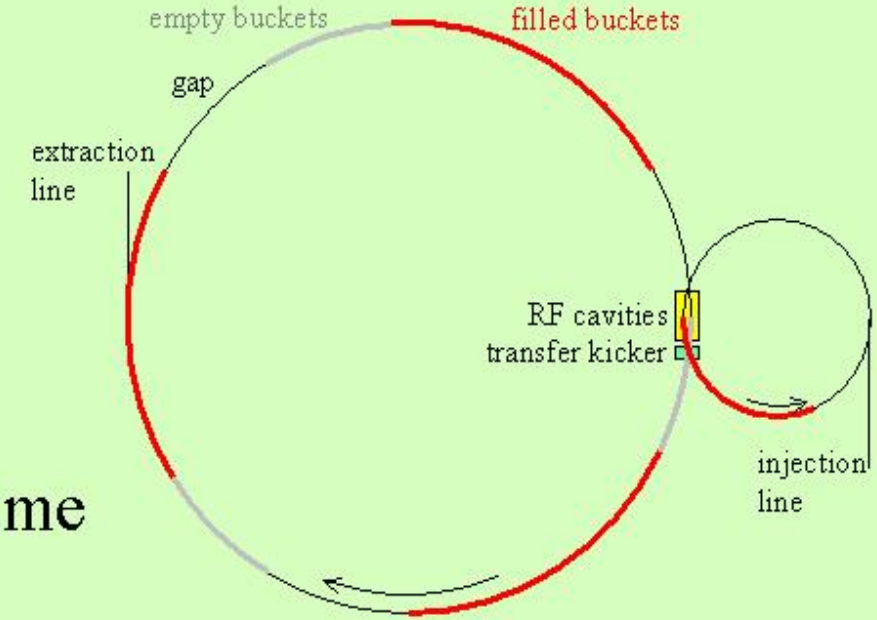
- $\gamma\varepsilon_y$ & $\gamma\varepsilon_x$ growth in DFS:
  - depends heavily on BPM resolution.
  - should remain within Nominal values.



Damping Ring Studies

Multi-Bunch Trains with inter-train gaps





- always inject and eject the last bunch in a train
- kicker rise time < 6 ns, but fall time can be ~gap length
- beam loading maintained by ~100 m ring with shared RF system
- ~6 km ring filled by transfers of undamped trains from the ~100 m ring

J. Rogers

Comparison of two designs

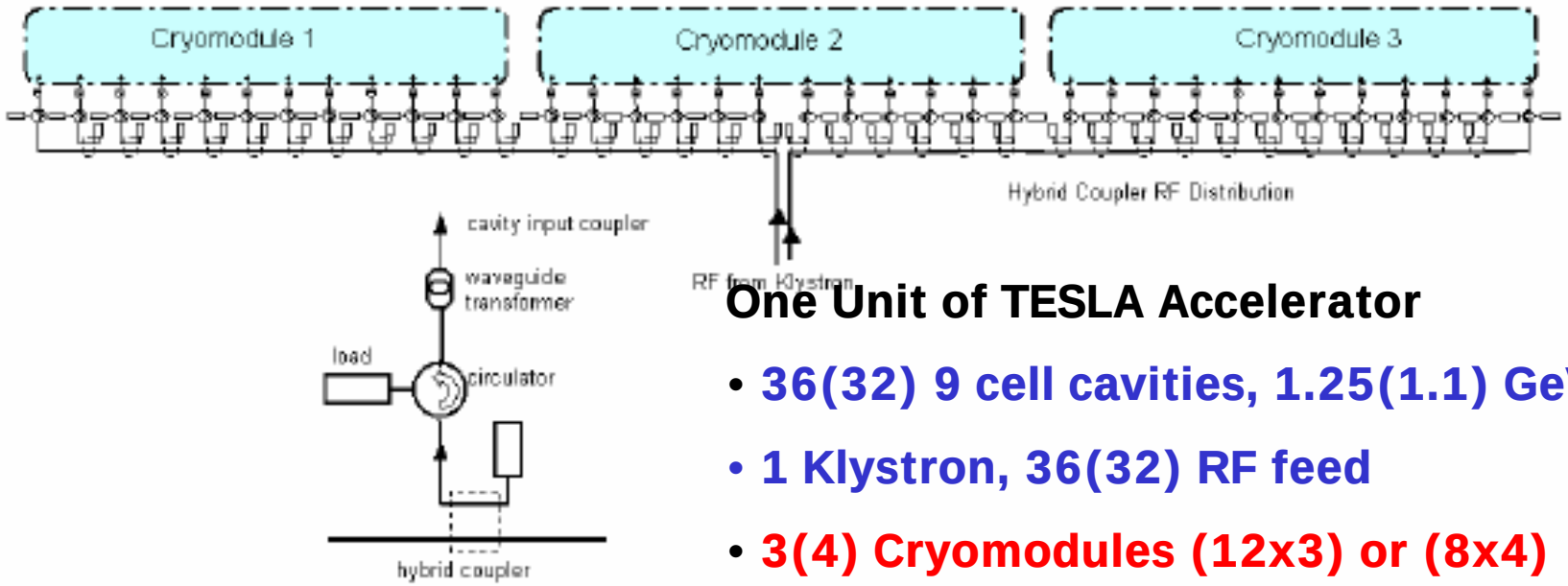
Parameter	Small ring (e^+/e^-)	Dogbone (e^+/e^-)
Energy	5 GeV	5 GeV
Circumference	6.12 km	17 km
Horizontal emittance $\gamma\varepsilon_x$	2.5×10^{-6} m	8×10^{-6} m
Vertical emittance $\gamma\varepsilon_y$	0.02×10^{-6} m	0.02×10^{-6} m
Transverse damping time τ_d	28 ms / 44 ms	28 ms / 50 ms
Current	444 mA	160 mA
Energy loss/turn	7.3 MeV / 4.7 MeV	21 MeV / 12 MeV
Radiated power	3.25 MW / 2.1 MW	3.2 MW / 1.8 MW
Tunes Q_x, Q_y	62.18, 28.38	72.28, 44.18
Chromaticities ξ_x, ξ_y	-112, -64	-125, -68

- We are working on further developing these Kicker ideas with EE Support in Accelerator Division.
- Working with ANL/LBNL on Damping Ring Simulation

Engineering Test Facility for LC

- At present there are Test Facilities at SLAC, KEK and DESY that are designed to do LC R&D.
- We believe that next generation of LC Engineering Test Facility is needed for a complete system test of the Linear Collider and Accelerator Physics.
- Main Goal: Establish confidence that an LC, as designed, can be constructed for the cost specified, on the schedule specified, and it will meet the performance specification. The scope of such a facility needs to be defined.
- This proposal should be developed by the International Linear Collider collaboration. We assume that the emerging design would go to the Global Design Organization as a proposal.

Thoughts on SRF ETF



One Unit of TESLA Accelerator

- **36(32) 9 cell cavities, 1.25(1.1) GeV**
- **1 Klystron, 36(32) RF feed**
- **3(4) Cryomodules (12x3) or (8x4)**
- **Total of 400(450) units**

Figure 3.3.5: *RF waveguide distribution of one RF station.*

- A 300 meter facility with 4(5) of these TESLA units is needed to achieve 5 GeV or 1% of final Linac.
- Fermilab LC and PD together should initiate a plan to test one unit ASAP

Thoughts on X Band ETF

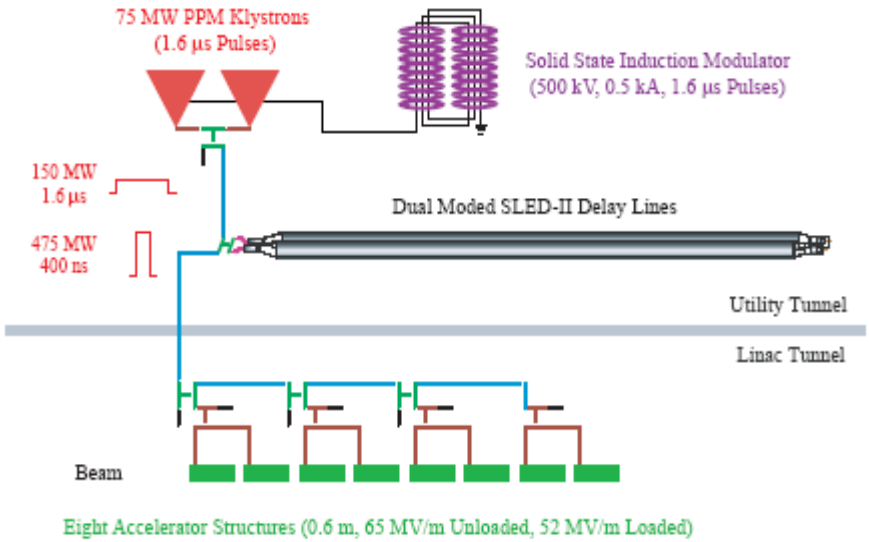


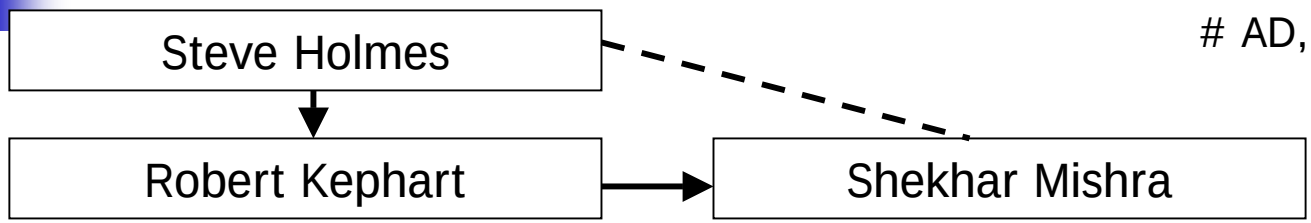
Figure 3.4.5.2: Schematic of an X-band linac RF unit.

One Unit of NLC Accelerator

- 8 RF structures, 0.25 GeV
- 2x75 MW Klystrons, 2x500 kV modulators, 1 SLED-II
- Total of 2000 units for 500 GeV

- A 300 meter facility with 20 of these NLC units is needed to achieve 5 GeV or 1% of final Linac.
- Both warm and cold ETF should be done in two tunnel final configuration of the machine.
- Fermilab FESS is developing a site plan for these tunnels.

Fermilab LC Accelerator R&D Organization



AD, ^PPD

Accelerator Physics
N. Solyak
G. Gollin
K. Ranjan
P. Bauer
H. Edwards#
P. Piot#
M. Huening#
K. Desler#
L. Bellantoni^
F. Ostiguy#
B. Ng#

FESS LC
V. Kuchler
J. Sims
M. Magnuson
T. Lackowski

Power Development

Machine Detector Interface
N. Mokhov#
A. Drozdin#

Kicker Development
G. Krafczyk#
C. Jensen#

Instrumentation & Controls

Computing

ANL/Univ Collboration

RF Technology Dev.
H. Carter
T. Arkan
C. Baffo
E. Barissov
T. Khabiboulline
G. Romanov
N. Chester
D. Mitchell
I Terechkine
S. Bhashyam
T. Peterson
M. Foley#
A Rowe#
T. Berenc#

Collaboration Efforts

- Fermilab is developing collaborative working relation with ANL on Linear Collider Accelerator Physics and SRF Technology Development.
- ANL with RIA project and Fermilab with LC and PD projects see many areas of collaborative effort.
- ANL is developing a compact and dedicated wake field measurement facility for the NLC RF structure measurements.
- Fermilab and ANL are collaborating on building a Buffer Chemical Treatment Facility at ANL.
- ANL and Fermilab accelerator physicists are working together on TESLA damping ring design. (IAAP at ANL)

Collaboration…

- Illinois Consortium for Accelerator Research(ICAR) university faculties funded by State of Illinois are diversifying their research interest to include Linear Collider.

- Northern Illinois Center for Accelerator and Detector Development (NICADD) funded by DOE is contributing to the FNPL, LC Accelerator and LC Detector research programs.

- Fermilab, ANL, Jlab, Cornell, LANL and SNS are taking a lead in establishing a Super-conducting RF Cavity production and Testing Facility in the US. (SMTF Collaboration)

- There are several projects across US DOE and NSF that has brought these laboratories and universities together to work on SCRF development.

Collaboration... & Outreach

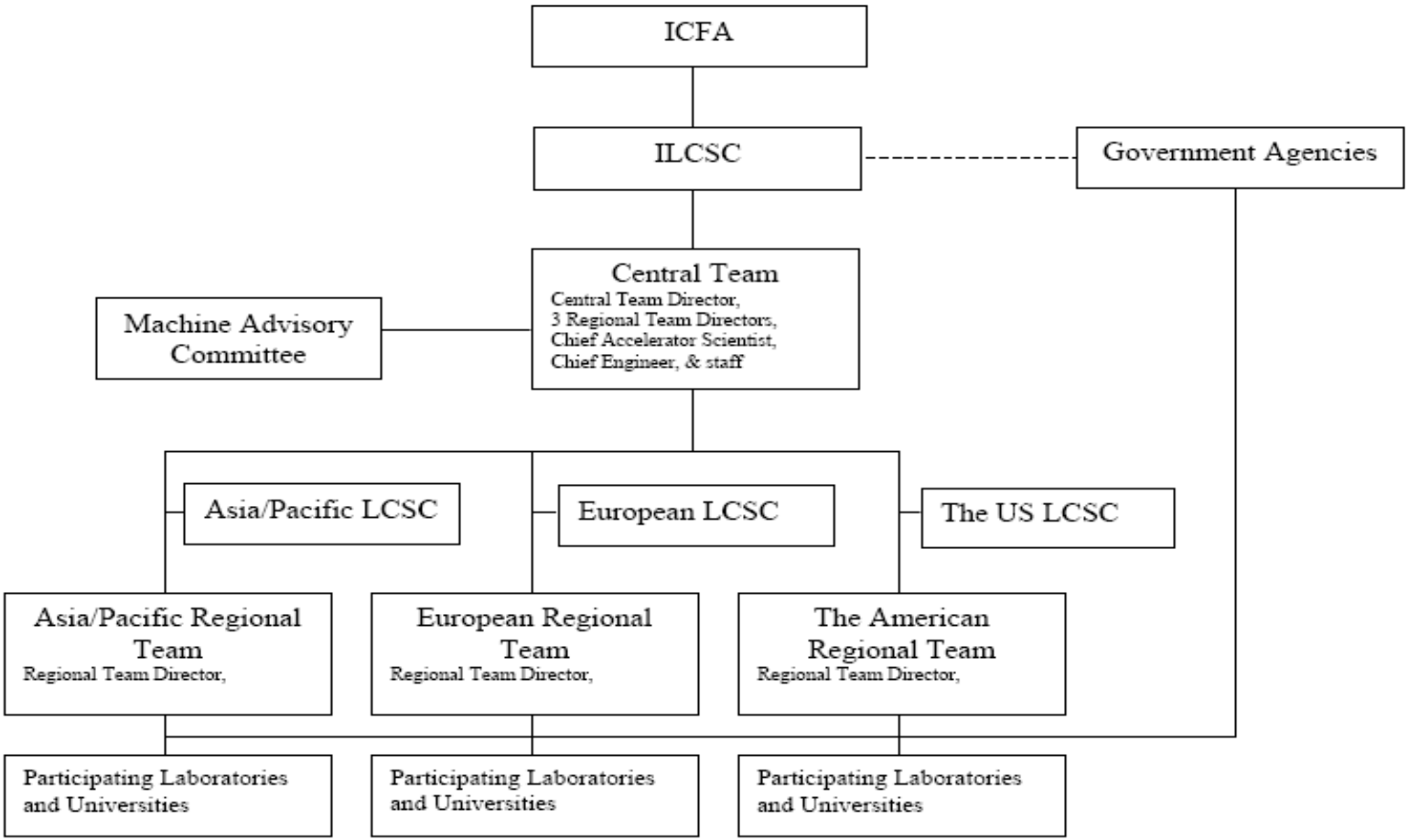
- Fermilab has formed an Outreach Committee made up of senior professors from major Illinois universities, spokesperson of two major experiments at Fermilab, public affairs office persons from FNAL and ANL.

- **The Federal government, including both the congress and the Executive Branch**
- **The Illinois State government**
- **The High Energy Physics and scientific community beyond HEP**
- **Local universities, businesses and laboratories**
- **The communities nearby the Linear collider site and Fermilab**
- **The broad public, especially yong people**

ITRP and GDI

- An International committee ITRP, chaired by Prof. Barry Barish has been formed by ILCSC chaired by Prof. Maury Tigner to select the Technology for the Linear Collider.
- Fermilab is actively participating in this process.
- There are a lot of discussion on how to manage such a larger international projects with major players in US, Germany and Japan.
- A request for proposal to host Global Design Initiative has been send by ILCSC.
- It is the intension of Fermilab to submit a proposal to host GDI at Fermilab.

GDI (1st Phase)



Technology Selection and Fermilab

- Engineering Test Facility and site studies
- Accelerator Physics, Instrumentation, controls and feedback system
- **If warm**
  - We will push ahead with warm RF structure production and industrialization
  - We will start RF power (Klystron, Modulator, SLED-II, etc.)
- **If Cold**
  - We will increase the SCRF cavity R&D and propose to lead this activity in US
  - A short term goal is to build and test one unit of TESLA cryo module with 8 x 9 cell cavity with a mid term goal of testing with beam a TESLA unit.
- Develop International Collaboration

Summary

- Fermilab has made significant contributions to both the NLC and TESLA R&D. Fermilab is aligning itself to be a significant player in the Linear Collider with a goal to host it at or near Fermilab.
- We will continue and expand our efforts in the accelerator, detector and IL site studies.
- We view that there are a lot of common R&D between LC, RIA and Proton Driver.
- We will focus our Accelerator Technology Efforts after ITRP.
- We have proposed that a LC Engineering Test Facility (warm or cold to be in line with technology decision) is needed. A detailed scope this facility needs to be defined.
- Please join us in shaping the future of HEP.