Elements of a Bid to host the ILC in the U.S.

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(+ H Padamsee)

Introduction

- A letter from Robin Staffin (DOE) and Joe Dehmer (NSF) to Maury Tigner, Chair of Linear Collider Steering Group of Americas requested that a subcommittee be formed to recommend a plan for U.S. bid-to-host including the "scope and time scale for these activities and provide an estimate of the expected cost profile of funds needed."
- Chair = S. Ozaki, BNL
- "A crucial aspect of your panel's advice is articulation of the priority of these US bid-to-host activities, relative to the R&D and technical design work being coordinated by the GDE."
- "The relative priority of these two aspects of ILC R&D is important since the DOE ILC budget for FY07 and in the out-years will include both categories of expense",
- "we ask that your report be completed by August 1, 2006."
- Disclaimer: Hasan and I are both on this subcommittee but this talk contains only our initial thoughts which have not yet been discussed by or approved by the subcommittee…

Introduction (cont)

- In this talk I will first describe what I think the global HEP community must do to make the ILC happen somewhere in the world
- However most of the talk is focused on what I think the United States must do in order to host the ILC on U.S. soil.
- The talk will necessarily be U.S. centric
- This should not be construed as diminishing the importance of our international partners nor the need for strong international collaboration to make this project happen

For a Region to Host the ILC

- **Minimum information required:**
  - **Technical viability:**
    - **There must exist machine and detector designs that have a high likelihood of achieving the desired physics performance**
    - **The technical risk of the project is acceptable**
    - **There must be a credible plan & schedule for building the machine.**
  - **Financial viability**
    - **A credible international cost estimate for the RDR machine**
    - **Clear explanations of how the costing was done & what is in or out of the resulting cost estimate**
    - **A credible scheme for how such a machine could be realized using global resources (so that host region costs known)**
    - **Long term commitments by the international partners**
  - **An international management plan**
- **All of this is the responsibility of the GDE during the ongoing Reference Design Report (RDR) phase**

For the U.S. to host the ILC

- **Information required:**
  - A U.S. site specific machine design (e.g. @ FNAL)
  - A U.S. site specific civil design
  - Demonstration to the U.S. HEP funding agencies that the ILC technology is ready for a multi-billion dollar project
  - Evidence that U.S. Industry can provide the required U.S. technical components
  - A credible plan & schedule using plausible U.S. resources and “in kind contributions” from outside the U.S.
  - A cost for the U.S. share of the ILC machine and detector in sufficient detail to convince the DOE Office of Science, OSTP, and OMB that the U.S. costs are known
  - An international management plan acceptable to DOE and the international community
- **Producing the information listed above is an important part of the Technical Design Report (TDR) phase of ILC**
- **The site specific parts of the TDR will necessarily be the responsibility of the regions that wish to bid-to-host the ILC**

The GDE in the TDR era

- My view only… not approved by anyone…
- The Global Design Effort (GDE) will continue to develop common elements of the ILC:
  - Global communication and review of the machine designs
  - Cavity & Cryomodule design and R&D
  - Radio Frequency (RF) power sources & distribution
  - Low Level RF and controls, electron & positron sources
  - Beam Delivery, Physics, detector design and R&D
- Regional efforts will emerge on:
  - Site specific machine design
  - Site specific civil design
  - Regional Industrialization
  - Technology demonstrations to minimize risk
  - Regional cost estimates based upon regional industrial costs
  - Building political and public support
  - Whatever else it takes to convince regional funding agencies to bid-to-host the project

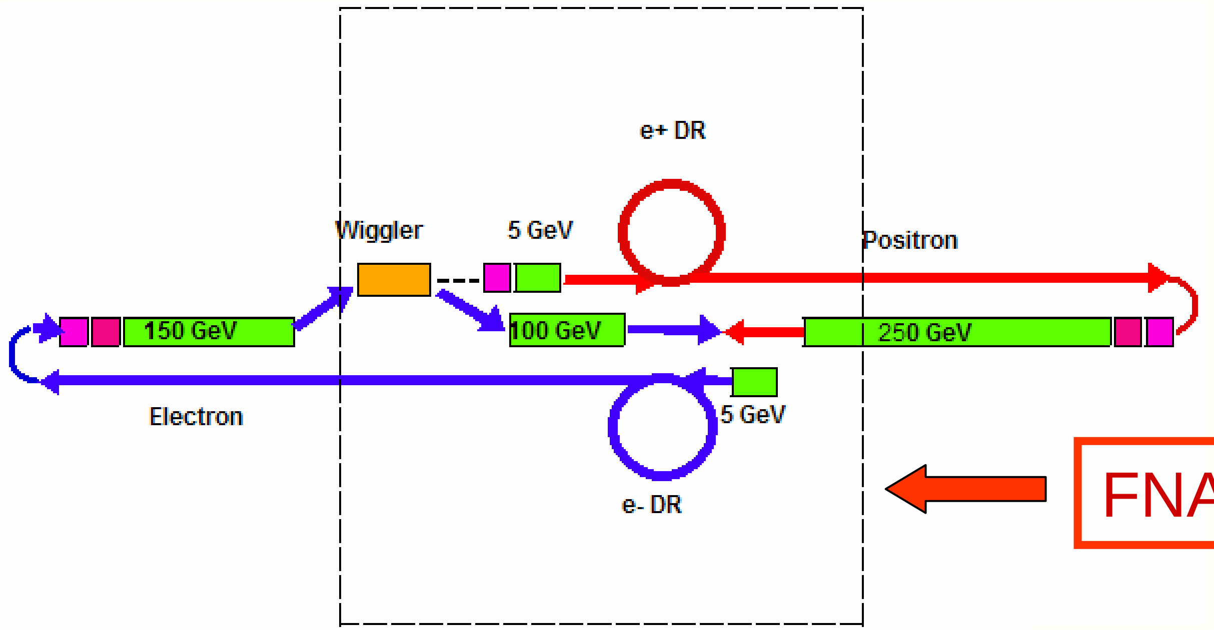
U.S. Site Specific Design

- **Will vary significantly from the RDR Design**
  - **Assume that the U.S. site is on or near the FNAL site as stated by DOE Office of Science**
  - **Develop a machine layout that uses the FNAL site or a site west of the lab (pick one) & minimize overall project cost including land acquisition and geology effects.**
  - **Develop a plan that is accepted by the surrounding community**
  - **Example:**
    - **Optimize the ILC design for the FNAL site**
    - **Layout the machine with the Interaction Point on FNAL site**
    - **Move the damping rings to a central location**
    - **Centralized He storage, compressors and related infrastructure to minimize impact on the surrounding community**
    - **Plan for the eventual 1 TeV upgrade of the machine**

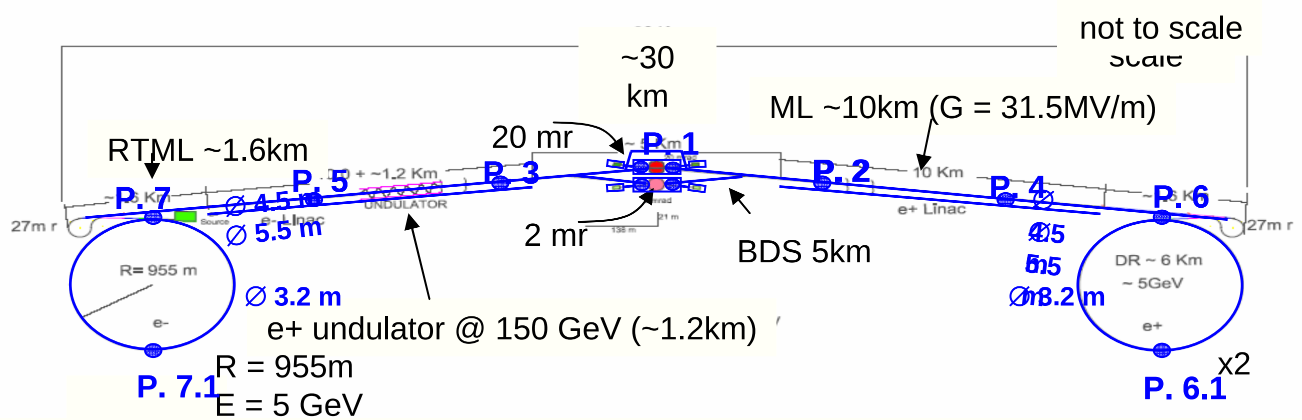
ILC
Americas

FNAL Specific ILC layout

Fermilab



FNAL site

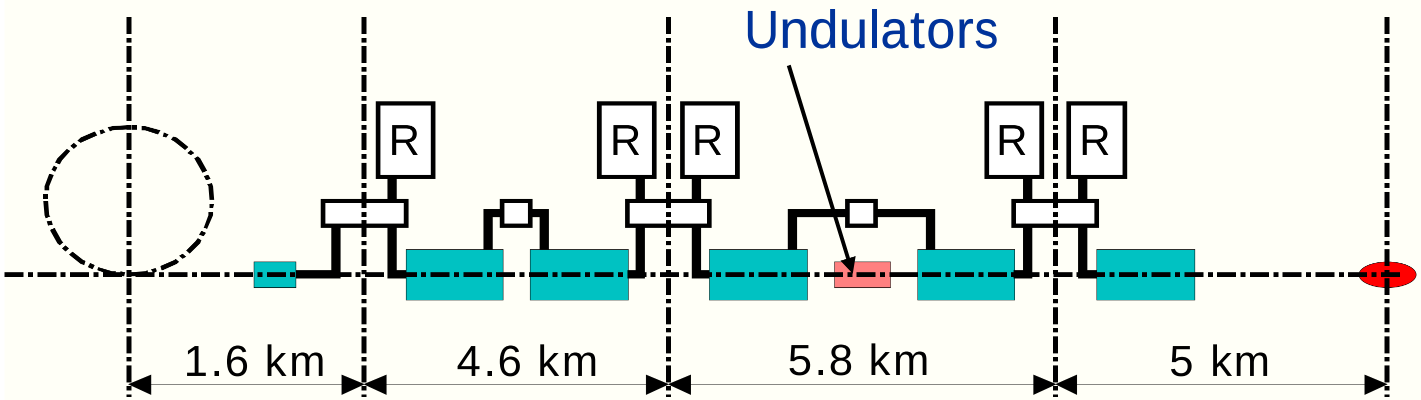


RDR Baseline

Site Specific Civil Design

- For the Fermilab site:
  - Damping rings on site
  - Longer beam transport enclosures
  - Variations in surface presence vs RDR
  - Site specific tunnel construction methods
  - Tunnel access and shafts may be different
  - Minimize spoil removal or other surface activity offsite
  - Maximize He compressors and storage on site
  - Cooling water design optimized for Northern Illinois site
  - Optimize design for existing electrical infrastructure
  - Design around existing roads, ponds, sewers, etc
  - Land acquisition, permits, community issues, etc.
- DeKalb site
  - Different set of issues

ILC Surface Presence



RDR Plan
5
Cryo Plants
/linac

LHC plant = 18 KW at 4.5 K

ILC plants are similar

LHC Helium Compressor Station

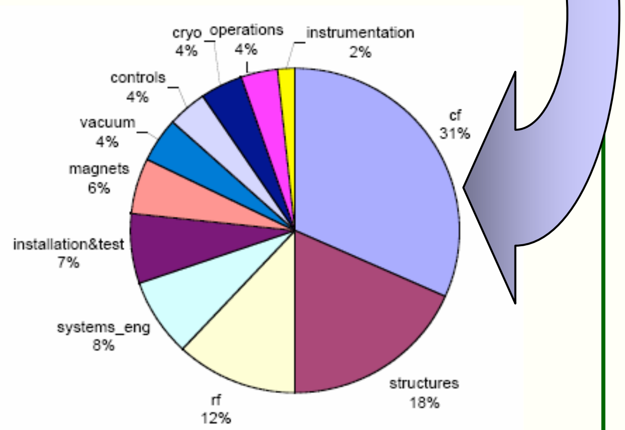
Impressive but would you like one of these in your suburban neighborhood ?

LHC He Gas Storage Vessels

He storage associated with one LHC refrigerator. Also cooling towers, noise, etc

What is the cost to host ?

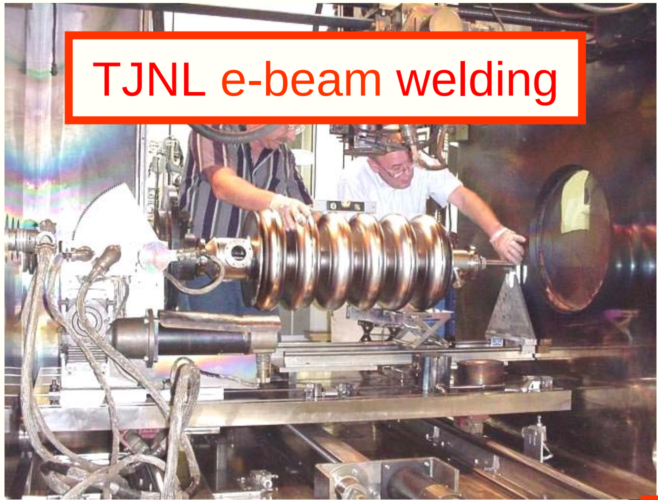
- Although we still do not know the cost of the machine, we can guess about what fraction of the machine the U.S. would have to fund if we wish to host the machine
- Civil cost is likely to be the responsibility of the host (31 % in US options study)
- If the U.S. provided 1/3 of the technical components ➔ another 20%
- So 50% is a reasonable guess
- …but…it could be more
- No examples of inter-regional contributions for a HEP machine at this scale
- Ex: 30% cf, 6-10% =CM/3, 4% RF/3, few% misc ?



SCRF Infrastructure

- The ILC requires extensive infrastructure for:
- Bare cavity production
  - Fabrication facilities (e.g. Electron beam welders)
  - Buffered Chemical Polish facilities (BCP)
  - Electro-polish facilities (EP)
  - Ultra clean H_20 & High Pressure Rinse systems
  - Vertical Test facilities (Cryogenics + low power RF)
- Cavity Dressing Facilities (cryostat, tuner, coupler)
  - Class-100 clean room
  - Horizontal cavity & Coupler test facility (RF pulsed power)
- String Assembly Facilities
  - Large class-100 clean rooms, Large fixtures
  - Class-10 enclosures for cavity inner connects
- Cryo-module test facilities
  - Cryogenics, pulsed RF power, LLRF, controls, shielding, etc.
  - Beam tests ➔ electron source (e.g. FNPL Photo-injector)
- Host country <u>must</u> have these facilities (expensive)

Examples: SCRF infrastructure


TJNL e-beam welding


Chemistry


Horizontal Test of Dressed Cavity @ DESY


TJNL Electro polish


Cryomodule Test at DESY TTF

ILC
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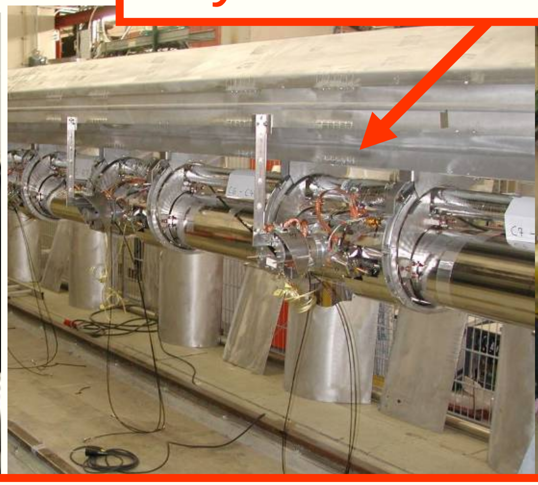
Examples: Cryomodule Assembly

Fermilab

Assembly of a cavity string in a Class-100 clean room at DESY

The inter-cavity connection is done in class-10 cleanroom

Cryomodule Assemby at DESY



Lots of new specialized SCRF infrastructure needed for ILC!

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MP9 Clean Room

Fermilab

ILC Cryomodule Production will require ~10 of these, or perhaps a bit less with multi-shift operations

- **Sized to assemble ~2 cryomodules/month**

SCRF Infrastructure (issues)

- **DESY infrastructure has built a total of 6 cryomodules for TTF. The rate was ~ 1-2 cryomodules/yr**
- **TJNL successfully built 2 cryomodules/month for SNS**
- **DESY XFEL will produce 116 cryomodules in 5 yrs → average of ~20 cryomodules/yr (peak = 50) in industry**
- **If U.S. builds 1/3 of the ILC cryomodules on the RDR timeline → average of 133 cryomodules/yr (peak =200)**
- **Industry will not buy this infrastructure prior to project approval, nor will they "mothball" for 5-10 yrs waiting for the ILC upgrade → Probably must assemble much of this at labs and allow industry to bid to use it.**
- **Building this infrastructure is a regional issue**
- **It is unlikely that a region could "bid-to-host" the ILC without a plan to put significant infrastructure in place**

U.S. Industrialization

- The principle goal of ILC industrialization is to establish in US industry the capability to mass produce the components to build the ILC
- Another important goal is cost reduction

- Cryomodules (2000 required for 500 GeV of linac)
- SCRF Cavities: (16,000)
  - Reliably achieve $\geq$ 35 MV/m and Q ~1×10^{10}
- RF couplers and Cavity Tuners (16,000 each)
- RF Components
  - ~ 650 klystrons (1.3 GHz, 10 MW, 1.5 ms, 5 Hz)
  - ~ 650 modulators
  - waveguides, circulators, other RF and vacuum components that help drive the cost of ILC…

Industrialization

- **Large Cryogenic systems (~ 40 KW at 1.8 K)**
- **Detectors, instrumentation, etc…**
- **Civil construction**
  - **A huge job (currently estimated @ 30% of the ILC cost)**
- **In FY06 the GDE plans Industrial Cost Studies**
  - **Great…but… limited in scope (available funding is small)**
  - **Need to do much more…**
- **If we want U.S. industry to develop the required capabilities and if we want verified U.S. cost estimates then we need U.S. industry to build things !**
- **Our ability to engage U.S. industry is currently limited by incomplete designs and the available funding in the near-term.**

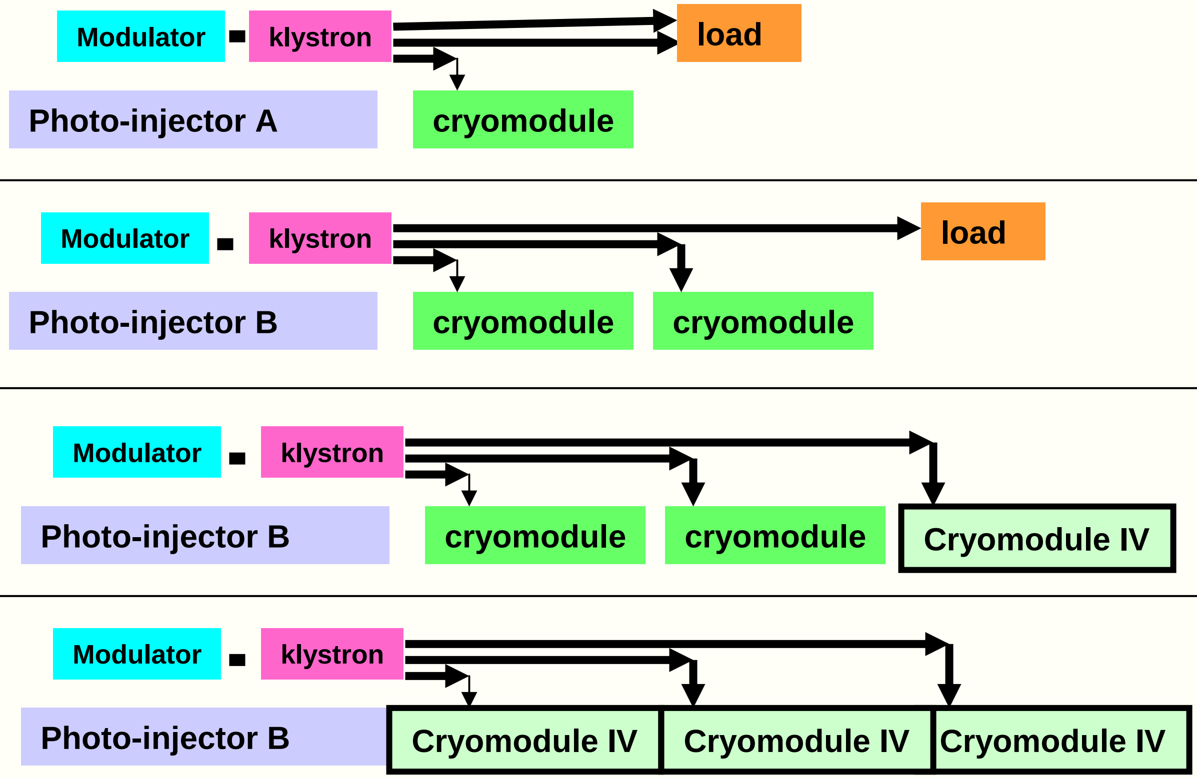
ILC Schedule

- We first need a “bid-to-host” (BTH) plan and schedule that:
  - Charts the course from current R&D & design phase through industrial and technical demonstrations
  - Includes development of site specific machine & civil designs
  - Includes plans for U.S. cost and project schedule estimates that can form the basis of a U.S. hosted international project
- Cavity, cryo-module, civil, and RF power systems should all be focal points because:
  - They are cost drivers
  - Extensive industrialization and infrastructure will be required
  - Large scale system tests are likely to be required
  - Verification of U.S. industrial capability & cost will be required
  - Cost & Risk mitigation are crucial elements for project approval
- Damping rings and sources are other possible focal points

ILC Schedule

- We also must develop an ILC construction schedule
  - It should include site specific machine design and engineering efforts
  - It should incorporate technology demonstration to verify industrial capability and validate costs
  - It should include a plan to stage the required cryo-module fabrication and test infrastructure
  - It should include a plan to develop and demonstrate the performance and reliability of RF power source
  - It should have realistic timescales for civil design, environmental permits, public hearings, etc.
  - It should have achievable milestones to track progress and build the credibility of the project
- A credible long range construction schedule is crucial for both project approval and for long term strategic planning in our field

Current ILCTA_NM R&D Plan



Year	Cryomodule Number
07	1
08	2
09	3
10	4-5

By FY10, One RF unit= basic building block of ILC ML

By FY11, Two RF units

ILC RF unit = three ILC Type IV cryomodules, modulator, 10 MW klystron

Type IV design will not exist until FY07

~ 2 years before a module is delivered

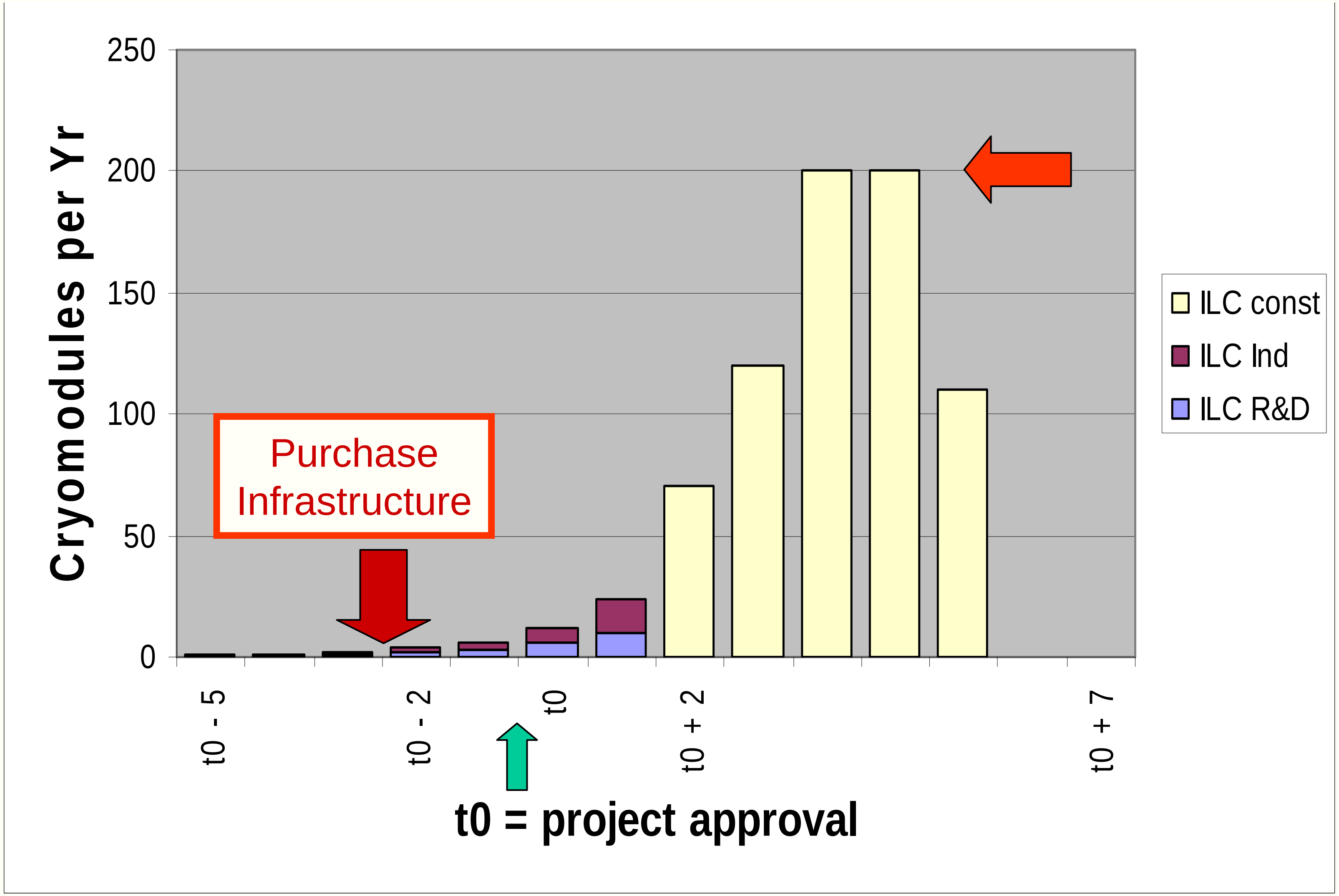
CM Infrastructure vs ILC Schedule

- We do not yet know the final process steps for ILC cavities ➔ infrastructure must wait for critical R&D to be finished (e.g. EP vs BCP & large grain Nb)
- There is a big delay from the time infrastructure is ordered until it can be used to assemble cryomodules
- A fast start on ILC requires that at least PART of the infrastructure be in place before project approval (~10%?)
- Since in the U.S. industrial contracts cannot be bid prior to project approval ➔ a fast ILC start means that the initial infrastructure to build cryomodules must be at labs.
- Is it is likely that cavity and cryomodule test areas will never be in U.S. industry ?
  - Europe, despite experienced industry will not try this for XFEL
  - Tests➔ Big cryo & RF systems, rad safety issues, $$$, etc
  - Facilities must be in place well in advance of project approval

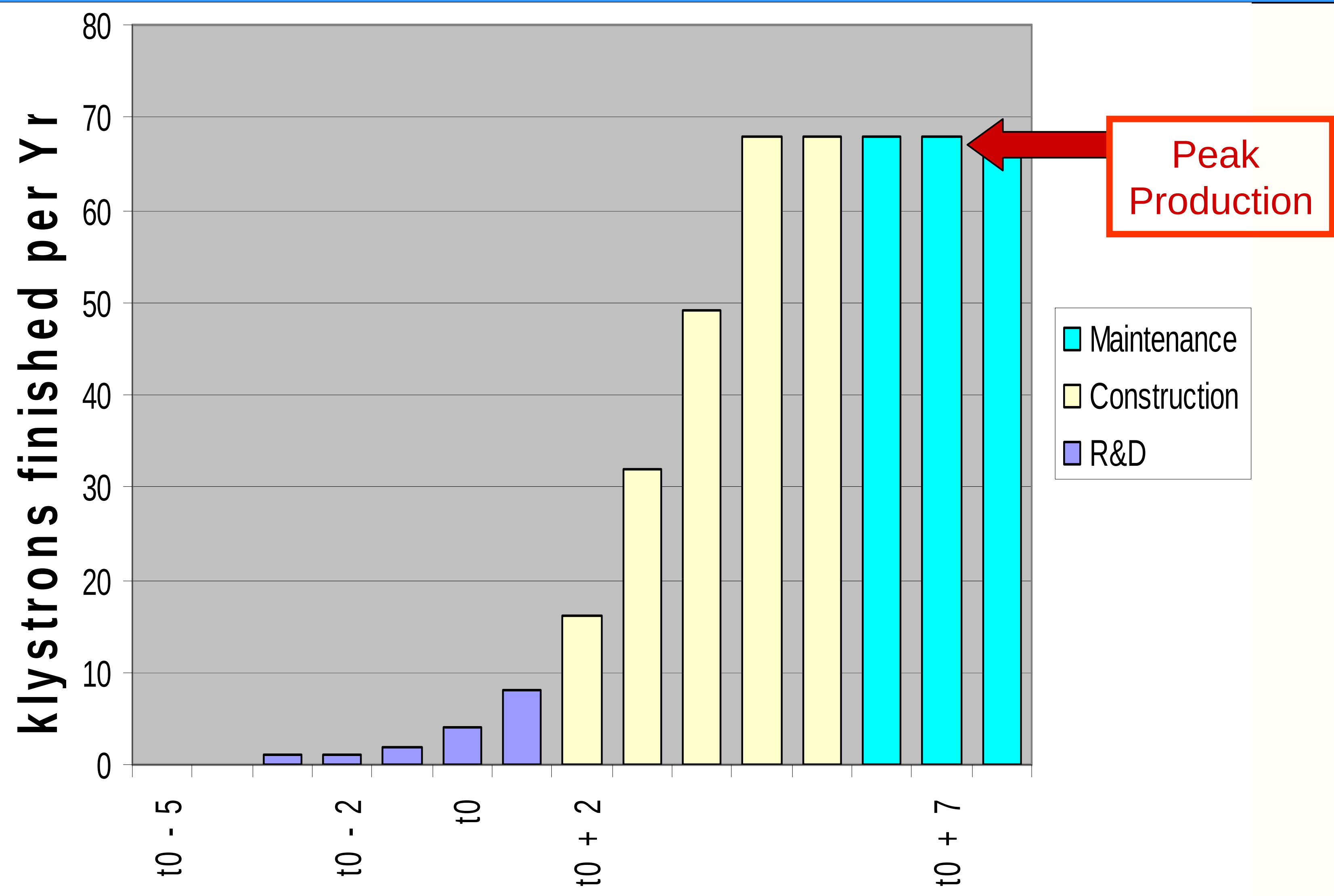
Infrastructure time delays

- **Schedule: Purchase Order to operational item**
  - **Electron Beam welder: ~2 yrs**
  - **Large wire EDM machine: ~ 1.5 yrs**
  - **Large Class 100 clean room: ~ 1.5 yrs**
  - **Assembly tooling: ~ .75 yr**
  - **Large BCP or EP facility: ~ 2 yrs**
  - **Large Cryogenic plant: ~ 2 yrs**
  - **Vertical test facility: ~ 1.5 yrs**
  - **Horizontal test facility: ~ 1.5 yrs**
  - **Klystron + modulator: ~ 1.5-2 yrs**
  - **Build an industrial building: ~ 2 yrs**
- **Plus the time required to train the technical staff**

U.S. Cryomodules



U.S. Klystrons



Large Scale System Demonstration

- **The current plan to build 2 RF units at ILCTA_NM is a useful first step (eg R1, R2 demonstration) but is not a sufficient technology demonstration to launch a multi-billion dollar project**
  - XFEL plans 16 preproduction cryomodules in 3 batches (>10%) before series production
  - e.g. CERN LHC pre-series was 10% of full set of 1200 cryo-magnets (over 2.5 years)
  - U.S. needs a plan to develop its industrial capability (working with labs)
- **Proposal: Make 8 more ILC RF units, 24 modules, 240 cavities (80% yield)**
- **Approximate Cost :**
  - 2 M$ per module ~ 48 M$
  - Infrastructure to produce & test ~ 21 CM/year ~42 M$

  Total ~90 M$
- **Install 7 units in a twin tunnel and build a 5 GeV linac (1.0% system test)**
- **Approximate Cost :**
  - 14 klystrons + 14 modulators (via SLAC) ~ 28 M$
  - Cryogenics (use FNAL CHL) ~10 M$
  - Civil 300 m of ILC twin tunnel (near surface) + infrastructure 31 M$

  Total ~69 M$
- **~160 M$ total: These numbers are just rough estimates right now**

Large Scale System Demonstration

- How long will it take to execute this plan ?
  - First priority is to build and install cryomodule infrastructure at U.S. labs and contract fabrication work out to industry
  - Industry and labs should work closely together
  - Build CM in groups paying careful attention to cost. Review cost after each ~5 CM and then adjust the fabrication and assembly procedures, to get a new cost point for the next 5
  - By the time you are finished (3-5 yrs) the cost curve from U.S. industry and extrapolation will be believable.
  - Possible LSSD Funding profile: 10 M$ in 2007, 20 M$ in 2008, 50 M$ in 2009, 80 M$ in 2010 ?
  - Lots of overlap with current plans to build infrastructure
  - Cavity and cryomodule test facility for 2 modules per month can be in new 35 M$ State of Illinois (IARC) building at FNAL

Infrastructure to build ~21 CM/yr

- Size infrastructure at 10% (scale x 10 to build ILC)

• 2 e-beam welders	$ 4 M
• Processing (Chemistry,HPR)	$ 4 M
• EP systems (2 ?)	$ 3 M
• VTS (1 cavity/wk/system => 4 systems)	$ 3 M
• HTS (1 cavity/2 wks → 8 systems)	$ 12 M
• Module assembly (MP9 Clean room + fixtures)	$ 1 M
• Module test (1/month→ 2 + 1 stands)	$ 9 M
• Klystron test stations at SLAC (6)	$ 6M
Total	$ 42 M

Processing: 3 total: Fermilab/Argonne, Jlab and one at Los Alamos/MSU/Cornell
- A lot of infrastructure already exists at these places

Install EP facility at Fermilab/Argonne, Cornell/MSU, : total $ 2 M
- Basic chemistry facilities exist, need to add EP

VTS systems = Cornell, TJNL, MSU, FNAL ILCTA_IB1, IARC (1→4)
HTS systems = ILCTA_MDB, ILCTA_IB1(2), TJNL, IARC(4-6)
Module test = IARC (3 stands)

What will a bid-to-host cost ?

- Site specific TDR Machine Design: > current U.S. RDR effort for about 2-3 years
- Civil: $3-4 M /yr for 3yrs
- U.S. Industrialization: $10, 20 M in FY07 & FY08
- 1% technology demonstration machine ?
  - $ 160 M ?
  - Develops/verifies industrial technical components
- Physics, Detectors→ collaborations
- Community outreach, politics, etc… require human resources
- Answer is: We don’t yet know, but we need to find out soon!

Conclusions: Next steps

- We need to develop a U.S. ILC R&D plan with an achievable milestones and realistic cost estimates.
- We need to work with our international partners to develop the ILC design AND at the same time prepare an ILC design optimized for U.S. site near Fermilab
- We need to agree on what large scale technology demonstrations are needed to show that we are ready to build this large project in the U.S. and how this might fit into the project timeline
- We need to make a U.S. ILC construction schedule with realistic times, achievable milestones, and which includes resources and time to create the required infrastructure and to industrialize the high volume components
- Industry participation will be crucial in this entire process
- This is all preliminary. Our thinking continues to evolve, so your comments and suggestions are most welcome

Extra slides

- follow

Cryomodule Cost estimate from Fermilab

Item	Detail	Source	Pre-production Cost (1 unit)
Vacuum Vessel & Pipes		RFQ	418
Cavities (ACCEL)	Nb	RFQ	153
	Bare Cavity	RFQ	459
	Processing to 25 MV/M	RFQ	184
Helium Vessel		RFQ	210
Quads		WAG	18
Supports		WAG	92
Magnetic Shields		WAG	27
Couplers (AMAC)		WAG	332
Tuners		WAG	121
Instrumentation		WAG	1
Interconn. Parts		WAG	19
			2034

XFEL Next Modules 2005-2008

Order at Zanon
Sep-05

M8

M9

Goal:
Modify for Type3+
Must:compatible with
Type3(spare TTF)
Learn specification

Order at A, B, C
3x2 cryostats
Sep-06

M A1

M B1

M C1

Goal:
3 producers
improved design
Type 3++

2007

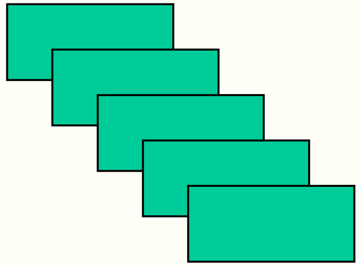
M A2

M B2

M C3

Goal:
3 producers for
XFEL prototype
best solution

Order at ?
5 cryostats
2008



Goal:
Production and
Test of 5 XFEL
preseries
modules

U.S. Assumptions

- Construction period 5 yrs
- Cryomodules/linac 960
- Total ML cryomodules 1920
- RTML cryomodules 120
- 1/3 = U.S. share 680
- Initial spares = 3% 20
- Total U.S. Plan 700
- Klystrons=cryomodules/3 233

- U.S. klystron hrs 39144 /ILC wk
- Assumed lifetime 30000 hrs
- Maintenance production 68 /yr

- Note: Assumed peak cryomodule or klystron production rates set the cost of the required industrial infrastructure

LCSGA BTH subcommittee

- Chair = S. Ozaki, BNL
- Hasan Padamsee, Cornell
- Johnathan Dorfan, SLAC
- Swapan Chattothadya, TJNL
- Richard York, MSU
- George Gollin, Illinois
- Pier Oddone, FNAL
- Bob Kephart, FNAL
- Steve Gourlay, LBNL