Cryomodule Design and R&D during the EDR phase

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EDR Cryomodule Plan

- **A plan for the development of ILC cryomodules during the EDR phase would have three main elements**
  - **Cryomodule Design Effort**
    - **Goal: Meet ILC technical objectives**
    - **Goal: Cost Reduction via design improvements**
  - **Cryomodule R&D and Testing Program**
    - **Develop improvements for CM prototypes**
    - **Development of regional CM test facilities**
    - **Carry out tests of CM to VALIDATE performance & reliability**
  - **An industrialization plan**
    - **Laboratory-built prototypes → industrial production**
    - **Educate industry, then learn from them about mass production**
    - **Programs needed in all 3 regions (different… eg XFEL)**

From Beijing meeting

EDR Cryomodule Plan

- The EDR phase of ILC will require a detailed plan that divides up all this work into work packages and provides for coordination across regions
- Many of the elements of that plan exist as efforts started during the RDR phase
  - Some as regional efforts or plans
  - Some as collaborations started during the RDR phase
- Example: There already exists an international collaborative CM design effort with work packages and assignments
- However, for the EDR phase to succeed we must address some key questions VERY SOON!

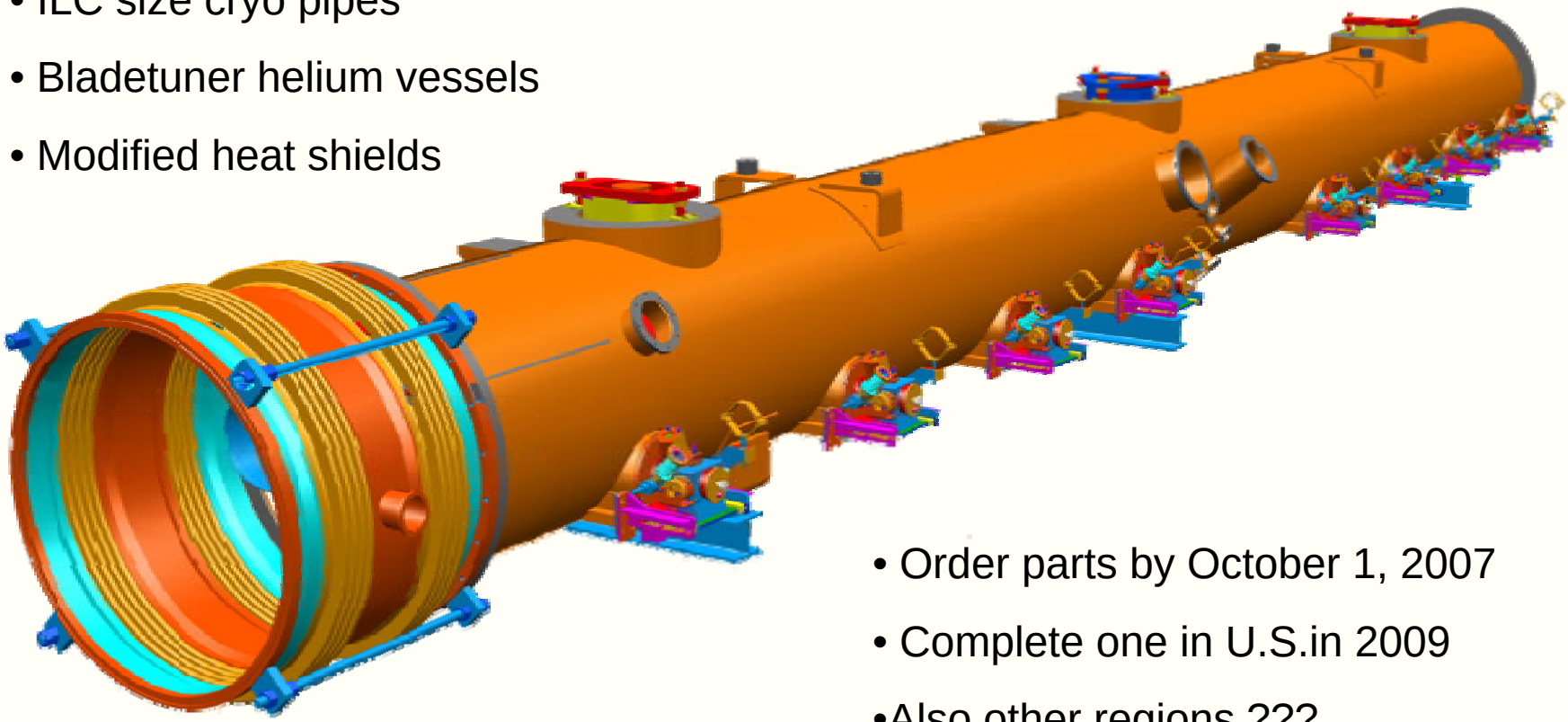
T4CM Collaboration

- FNAL, DESY, INFN (Pisa, Milan), India, TJNL,Triumf, etc.
- Already have working international collaboration with work package assignments and coordination
- Cryomodule development as a team
  - Compatible CAD design tools
  - Recent CAD training at FNAL
- Communication is essential! (Need good Tools)
- Shared common data base
  - DESY has provided their Team Center Enterprise (EDMS) as well as their IT services to the collaboration effort.
- Real time 3-D visualization in meetings
  - Online meetings
  - Collaboration meetings at CERN, FNAL, Milan

From Beijing meeting

Type 4 Cryomodule (T4CM)

- 8 standard cavities, 1 quad magnet pkg
- Magnet under center post
- ILC size cryo pipes
- Bladetuner helium vessels
- Modified heat shields



- Order parts by October 1, 2007
- Complete one in U.S.in 2009
- Also other regions ???

Key CM questions for EDR phase

- Is the goal to build IDENTICAL CM all regions ?
  - All parts built to the identical spec ?
  - Global parts vendors (e.g. couplers, feed thrus, etc ?)
  - Can this fly politically ?
- Are CM that are “plug compatible” good enough ?
  - What does that even mean for an object this complex ?
  - Dramatically increases the testing and validation effort.
- Should we consider RF units, or even whole sections of the linac as deliverables from a region?
  - What does this do to the “risk” of the machine
  - Will we require “global review and approval” of designs ?
  - Who has to approve the design? (in-kind contributions)

Key CM questions for EDR phase

- **Do we agree on what must be done to the current CM design ?**
  - **Are we on track for Type IV by Oct 1 ?**
  - **Is it good enough ?**
- **How important is it to lower the cost?**
  - **Cheaper helium vessels, possible stainless steel?**
  - **Do we pursue single crystal Nb?**
  - **Seamless cavities hydroform/spinning?**
  - **Simplified couplers ?**
  - **Simplify cavity end-groups and TIG weld ?**
  - **New cavity-to-cavity bellows, flanges, and seals?**
  - **Simplify insulation scheme, e.g. lose 5 K shield ?**
  - **Simplify magnetic shield design?**
  - **When/how do we start value engineering ?**

Key CM questions for EDR phase

- What is the criterion for a “better CM design”
  - Higher performance?
  - Cheaper?
  - Less Technical Risk?
  - Who will decide ?
- For CM contributed as “in kind” gifts
  - How do we make decisions stick ?
  - How do we avoid the “not invented here” syndrome
  - Can you “force” an idea or design on a region, and then expect them to take full responsibility for the CM performance?

Key CM questions for EDR phase

- **What is the "time scale" for changes?**
  - **Does the "final" design have to validated in test areas AND produced in industry before the start of the project ?**
  - **If no, then what must be done ?**
  - **When must a cavity shape decision be made?**
  - **When do we pick the coupler, the tuner, etc.**
  - **How will XFEL experience feed into the design ?**
  - **Do we have time for a "clean piece of paper" approach to cryomodule design aimed at cost reduction ?**
  - **What is the date of the "latest major change" relative to project start (t=0)?**

Key CM questions for EDR phase

- **How do we manage industrialization ?**
  - **Do we ask industry to guarantee "performance" or just build to "print and process"**
  - **If vertical test and CM test is done at labs, how to we handle the "hand offs" with industry**
  - **How do we encourage industry to improve CM AND at the same time manage intellectual property rights?**
  - **How does region A interact with industry in region B ?**
  - **What is the shipping criterion for a CM**
    - **Eg Ship in parts, assemble at site ? Or ship full CM…**
    - **Horizontal installation vs tipping on end (ILC shaft size)**
- **We must address many of these questions before we can make an EDR plan !**

Other misc questions

- For EDR: Resources are ~ fixed, so is time scale… can we accomplish the scope of work required in the 3 yrs available ?
- To insure that we use the same techniques, should we have a plan to cross train people (send KEK techs to FNAL or DESY and vice versa)?
  - What are the limitations rules that would get in the way?
- How do we coordinate the cryomodule effort across the regions, and with related activities ?
  - BPM design
  - SC quad and corrector package
- How do we coordinate mainstream Cavity and CM effort with the “special” items requiring CM’s ?
  - E.g. 650 MHz cavities
  - Crab cavities
- How does all of this translate into work packages, deliverables, and milestones ?

EDR CM work packages & milestones

#	EDR goal/task description	milestone	date
CAVITY and CM			
	S0: Demonstrate yield > 85% at 35 MV/M on 1st processing	Reproducible process defined and operational in all 3 regions	
	S1:Cryomodule performance goal	one single cryomodule operating at 31.5 MV/M average gradient	
	Design, build, test a cryomodule suitable for ILC (type IV)	1 CM that meets ILC spec's, tested with beam	
	Regional CM difference	Decide if CM are identical, plug compatible, or different	
	Cryomodule timeline	Agree on working assumptions for timeline, understand consequences	
	ACD down select	Agree on which ACD should not continue(late or negiligible savings)	
	Cavity shape downselect	chose cavity shape for ILC cryomodules	
	Coupler, tuner, etc downselect	chose among CM options	
	Design and build low cost CM	demonstrate 1 CM that meets ILC spec's and can cost 50% less	
	Cavity cost reduction	hydroformed cavity with TIG welded endgroup, SS He vessel	
	Value engineer ILC cryomodules, and build in industry	3 CM produced by industry operating in ILC RF unit at 31.5 MV/M	
	Selection final CM design (or designs)		
	S2: ILC RF unit test	3 CM,klystron, modulator, operating in ILC RF unit at 31.5 MV/M	
	Build and operate STF		
	Build and operate ILCTA_NM		
	Flash operations for ILC at DESY		
	CM redesign based on S2 test results		
	CM preproduction series	industrial preproduction of ~ 30 modules (10/region)	
	CM design (s) validated for preseries production		
	Pre-series CM production release		
	Pre-series CM validation	Validate pre-series CM in RF unit test facilities	
	Ready for mass production of CM in industry		

My attempt at work packages and milestones

R&D and Test Facilities

- **The core of a R&D and test plan exists as a result of the efforts of the S2 task force**
  - **Table of required tests**
  - **Some understanding of what can and cannot be tested**
- **The overall plan involves test facilities in all 3 regions with either one or two RF units (3 CM, klystron, modulator) and at least one test facility with ILC-like beam capabilities**
- **The S2 task force indicated that larger test facility may eventually be required. This requires further study but just due to resource arguments alone is likely to be beyond the EDR era.**

CM R&D and Test Facilities

- **Elements:**
  - Americas plan (FNAL): ILCTA_NM
  - European plan (DESY): FLASH, XFEL
  - Asia (KEK) : STF

Example: Americas Plan

- **CM #1**
  - TTF Type III+ complete kit from DESY, Assembly at FNAL
  - NO quadrupole magnet, probably no HOM absorber
  - Assembly begins Summer, 2007 (~4 months)
  - Test in FNAL New Muon Lab (ILCTA_NM)
- **CM # 2**
  - Modified TTF III+ but U.S. Processed cavities
  - Blade tuners and new magnetic shielding
  - NO Quadrupole magnet, FNAL style BPM, etc.
  - Assembly Summer, 2008 , test in ILCTA_NM
- **CM # 3 →**
  - First ILC type Cryomodule
  - Quad in center, Smaller cavity interconnects, etc
  - Fab in 2008, test in 2009

S2 Goals

- Demonstrate an RF unit operating at ILC specifications
- Measure cavity quench and coupler breakdown rates
- Determine component MTBF and other CM weaknesses before large scale production
- Understand RF control issues in a system with many RF cavities over a large physical space
- Measure RF phase and beam energy control and stability
- Measure cavity gradient spread can be handled by LLRF
- Develop RF fault recognition and recovery software
- Test Beam based feedback schemes (steering, energy, and intra-train feedback)
- Test and evaluate CM instrumentation

From S2 task force report

S2 Goals

- Measure CM static and dynamic heat loads
- Evaluate cryo control issues (liquid levels, response times)
- Measure cavity dark current, radiation, cryo loads from this
- Check heating in HOM's
- Measure cryomodule quad vibration
- Determine consequence of dirty vent, test effectiveness of fast action vacuum valves
- Mock up tunnel to study installation, maintenance, repair
- Test transport of cryomodules across regions
- Test interoperability of cryomodules from different regions of the world
- Provide a test bed for evolving industrially produced cryomodules

These need to be turned into specific WP's and milestones

EDR Workforce

- **Cryomodule Design Effort**
  - Current Effort 23 people (~16 FTE)
  - EDR Phase 33 people (~25 FTE) + Industrial Participation
- **A Cryomodule R&D and test plan**
  - Current Effort: Cavity/EP/VTS/HTS(17.5 FTE) +CM+ FLASH(??)
    Cavity/EP/VTS/HTS(??) + CM+ STF(??)
    Cavity/EP/VTS/HTS(29)+CM(8) + ILCTA (19 FTE)
  - EDR Phase: factor two ?
    (const→operations, higher throughput)
- **An industrialization plan for all participating regions**
  - Liaison people to work with industry
  - Q/A people
  - ~5 FTE from each region ?
  - Coordination across regions … complicated !

From Beijing meeting

Conclusions

- A significant workforce is already engaged
  - Most of this effort continues to the EDR phase
  - Many of the elements of a plan are there
  - The design effort is well advanced
- However, we must answer a set of key questions before we can really plan the EDR effort
- Estimates of the labor and M&S funding for the R&D program are just crude guesses
- The plans for industrialization are least complete
- The scope of the test facility activities in all three regions needs to be understood, and a plan created to insure these efforts are coordinated.