ILC Cryogenic Systems Status and EDR Plans

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25 October 2007

ILC Cryogenics -- outline

- A few slides to review cryogenic systems concept and status
- KOM notes
  - **Cryomodules/Cryogenics Kickoff Meeting was held at KEK, 12 - 14 Sep 2007**
  - **http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=1854**
- System and interface design parameters
  - **A start at creating a concise set of system and interface requirements/parameters in one table**
- Work package summary
- Notes from discussions this week

Acknowledgements

- Primary RDR cryogenic system co-authors
  - **Arkadiy Klebaner, Jay Theilacker (Fermilab)**
  - **Vittorio Parma, Laurent Tavian (CERN)**
- TESLA collaboration
  - **Especially DESY and INFN**
- Recently for parameters list and work package planning
  - **Arkadiy Klebaner and Jay Theilacker**

ILC cryogenic system definition

- The cryogenic system is taken to include cryogen distribution as well as production
  - **Cryogenic plants and compressors**
    - Including evaporative cooling towers
  - **Distribution and interface boxes**
    - Including non-magnetic, non-RF cold tunnel components
  - **Transfer lines**
  - **Cryo instrumentation and cryo plant controls**
- Cryogenic system design is closely integrated with cryogenic SRF module and magnet design
- R&D systems and production test systems will also include significant cryogenics

Cryogenic system design status

- Fairly complete accounting of cold devices with heat load estimates and locations
  - **Focus has been on main linac cryomodules**
  - **Some other cold devices still not well defined**
  - **Some heat loads are very rough estimates**
- Cryogenic plant capacities have been estimated
  - **Overall margin about 1.54**
  - **Main linac plants dominate, each at 20 kW @ 4.5 K equivalent total capacity**
- Component conceptual designs (distribution boxes, end boxes, transfer lines) are still sketchy
  - **Need these to define space requirements and make cost estimates**
  - **Used area system lattice designs to develop transfer line lengths and conceptual cryosystem layouts**

Main Linac Cryogenic Unit

modules

RF unit (lengths in meters)	without quad	with quad	without quad
	12.652	12.652	12.652

three modules

string (vacuum length)	RF unit	RF unit	RF unit	RF unit	end box
	37.956	37.956	37.956	37.956	2.500

twelve modules plus string end box

possible segmentation unit	string	string	string	string
	154.324	154.324	154.324	154.324

48 modules
(segmentation box is the same as string end box (2.5 m) and all contain vacuum breaks)

Cryogenic Unit **(16 strings)**	service box end	segment	segment	segment	segment	service box end
	2.500	617.296	617.296	617.296	614.796	2.500

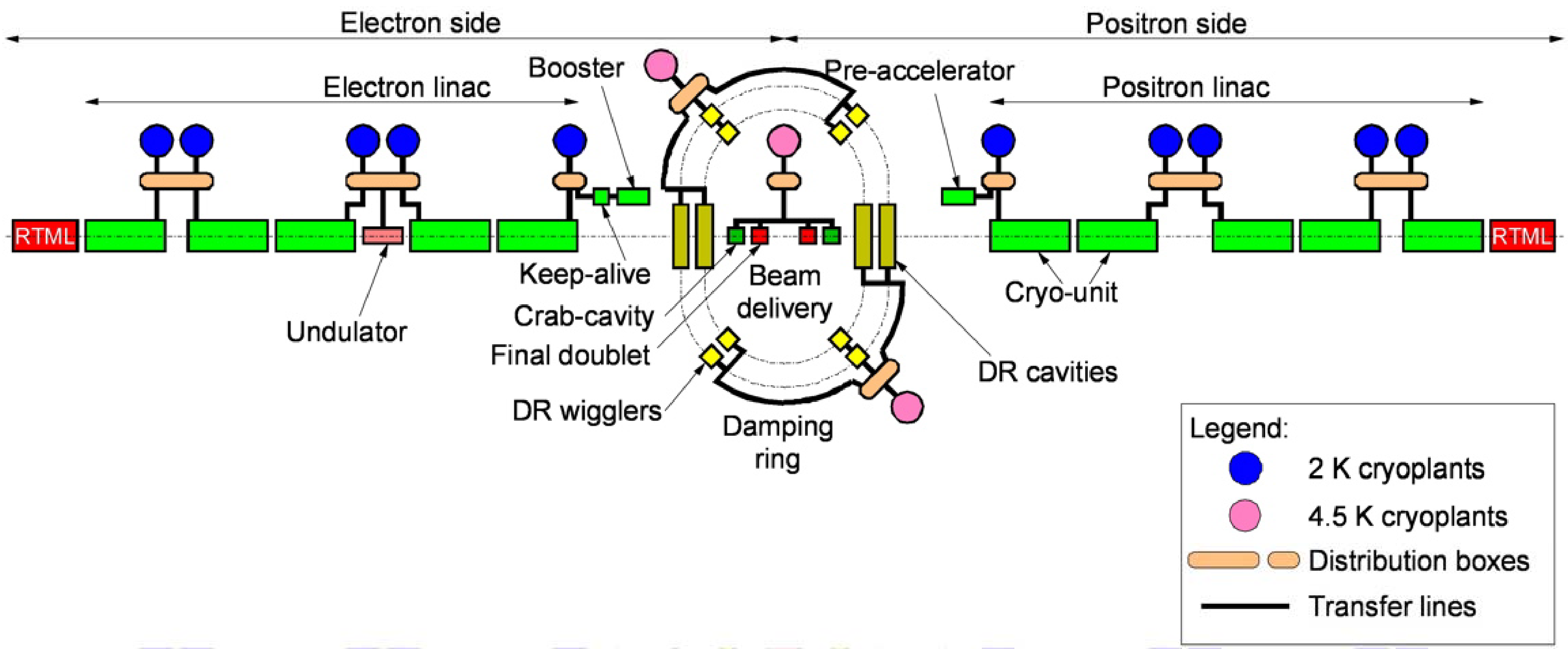
(1 cryogenic unit = 192 modules = 4 segments*48 CM with string end boxes plus service boxes.)

2471.7 meters

Cryogenic unit length limitations

- **25 KW total equivalent 4.5 K capacity**
  - **Heat exchanger sizes**
  - **Over-the-road sizes**
  - **Experience**
- **Cryomodule piping pressure drops with 2+ km distances**
- **Cold compressor capacities**
- **With 192 modules, we reach our plant size limits, cold compressor limits, and pressure drop limits**
- **192 modules results in 2.47 km long cryogenic unit**
- **5 units (not all same length) per 250 GeV linac**
  - **Divides linac nicely for undulators at 150 GeV**

Cryogenic plant arrangement



10 large, 2 Kelvin cryogenic plants

3 or more, smaller, mostly 4.5 Kelvin cryogenic plants

Significant distribution systems

Major cryogenic distribution components

- 6 large (2 K system) tunnel service or “distribution” boxes
  - **Connect refrigerators to tunnel components and allow for sharing load between paired refrigerators**
- 20 large (2 K) tunnel cryogenic unit “feed” boxes
  - **Terminate and/or cross-connect the 10 cryogenic units**
- ~132 large (2 K) string “connecting” or string “end” boxes of several types
  - **Contain valves, heaters, liquid collection vessels, instrumentation, vacuum breaks**
  - **Note that these have many features of modules!**
- ~3 km of large transfer lines (including 2 Kelvin lines)
- ~100 “U-tubes” (removable transfer lines)
- Damping rings are two 4.5 K systems
  - **Various distribution boxes and ~7 km of small transfer lines**
- BDS and sources include transfer lines to isolated components
- Various special end boxes for isolated SC devices

KOM notes -- September 2007

- Reviewed RDR cryogenic system status
- Discussed LHC cryogenic system experience
  - **See very informative talks by Vittorio Parma and Laurent Tavian (CERN) about LHC cryostats and cryogenics, linked to the KEK meeting website**
- Reviewed work package table
- Discussed focus and objectives of EDR phase

Two key points from KOM

- We need a unified parameters table for the cryogenic system
  - **Performance parameters, functional requirements, and interface parameters are in various spreadsheets**
  - **Not all of this information is in the RDR**
  - **Will serve as a guide and a reference for EDR**
  - **Becomes the basis for functional and interface specification documents**
- We want to retain the flexibility of a "plug compatibility" strategy in order to retain parallel lines of cryomodule and cryogenic component development work
  - **Parameters table will help define interfaces**

Parameters table (a start)

Cryogenic system parameters and cryomodule thermal parameters

Cryomodule

	Line	MAWP	Pressure Nominal Range Minimum	Pressure Nominal Range Maximum	Tolerance/Stability	Temperature Nominal Range Minimum	Temperature Nominal Range Maximum
		Pa	Pa	Pa		K	K
1.3 GHz RF cavity helium circuit	B, G	200,000	2,700	3,600		1.95	2.05
Subcooled helium supply	A	2,200,000	130,000			2.20	
Cold thermal intercept/shield	C, D	2,200,000	500,000	550,000		5.00	8.00
Warmer thermal intercept/shield	E, F	2,200,000	1,800,000	2,000,000		40.00	80.00
Warmup/Cooldown	H	200,000				2.20	300.00

Cryogenic Plant

	Min. Plant % Carnot	Uncertainty Factors Static	Uncertainty Factors Dynamic	Plant Overcapacity Factor
Nominal cryoplant efficiency				
2 K level	22%	1.10	1.10	1.40
5 - 8 K level	24%	1.10	1.10	1.40
40 - 80 K level	28%	1.10	1.10	1.40

Could include much more and will add more, but want to restrict table to primary parameters

Cryo System Work Packages

- Work packages are derived largely from a work list drafted during the RDR
- Precise EDR scope not yet defined and will depend on resources (funding and people)
  - **Will do what we can afford to do, starting with highest priorities**
- Work will be internationally distributed
- Solicited expressions of interest in cryogenic systems and vacuum work
  - **Via e-mail on 10 October 2007 to cryogenics experts at various institutions world-wide and RDR leaders**

Cryogenics work packages

- Heat loads
  - **Static, dynamic, non-module, distribution, uncertainty**
- Cryogenic plant design
  - **Contract with industry, overall system “cycle” design**
- Reliability, repair
  - **Segmentation, load-sharing, maintenance**
- Venting, pressure limits
  - **Peak pressures, loss-of-vacuum, distribution of reliefs, vessels and pipes**
- Surface impact
  - **Grouping compressors, plants, trade-offs with dist'n**
- ODH
  - **Oxygen deficiency, surface buildings and tunnel**

Cryo work packages (continued)

- Cryobox design
  - Distribution and tunnel end and bypass boxes
- Liquid control
  - 2-phase flow control, dynamic load changes, heaters
- Optimization
  - Trade cryomodule complexity and cost for cryosystem heat load
- 2K heat exchanger
  - 4 K to 2 K heat transfer to pumped vapor, pre-cool liquid supply, very large heat exchanger
- Standards
  - Regional, code compliance, hardware transfer
- Source cryogenics
  - e- and e+ source linacs, undulators

Cryo work packages (continued)

- Damping rings cryogenics
  - **System unique and separate from Main Linac**
- BDS cryogenics
  - **System unique and separate from Main Linac**
- Main Linac Vacuum
  - **Beam vacuum and insulating vacuum for ML**
- RTML vacuum
  - **RTML tranport line vacuum**
- RTML
  - **RTML cryo, distribution and special objects**
- Cryogenic systems EDR management

Institutions responding (so far)

- US and Canada
  - **Fermilab**
  - **SLAC**
  - **TJNL**
  - **BNL**
  - **Triumf**
  - **ANL**
- Europe
  - **CERN**
  - **DESY**
  - **INFN**
- Asia
  - **KEK**
  - **India-IUAC**

Work package conclusions

- Work package list is certainly not comprehensive; other topics may be added.
- ~10 man-years (5 FTE's for two years) of engineering and design labor are identified for EDR cryogenics.
  - **For comparison, the RDR cryogenic system effort had less than 1 FTE of effort.**
- Would like close to an FTE in each region through the EDR phase (~2 - 3 FTE minimum total).
- Since cryogenic experts around the world continue to have other, local commitments in addition to ILC, this work will require part-time (but significant fraction) efforts from at least 2-3 people in each region.
  - **We do have this level of interest**
  - **Still need to verify institutional support**

System integration

- System integration issues are identified for each work package
- Cryogenic system design involves collaboration with all areas
  - **Sources, RTML, Main linac, DR, BDS**
- Cryogenic systems include integration with many other technical systems
  - **Cryomodules of all species, magnets, vacuum, CF&S, life safety (ODH)**
- Cryogenic systems may be the most visible part of ILC in terms of surface impact
  - **Buildings, compressors (noise), cooling towers (clouds)**
  - **Public perception of ILC**
  - **Close collaboration with CFS group**

Next steps

- Will continue to discuss next steps during the remainder of this week, but my view is . . .
- Organization of EDR work
  - **Refine work package definitions**
  - **Begin to determine work package allocation**
    - Need resource availability from participating institutions
- Continue to add to parameters table
  - **Distribute to and discuss with interface groups**
- Start (in some cases continue) some of the high-priority technical work
  - **For example, helium vessel pressure limits**