Type 4 Cryomodule Technical Discussion

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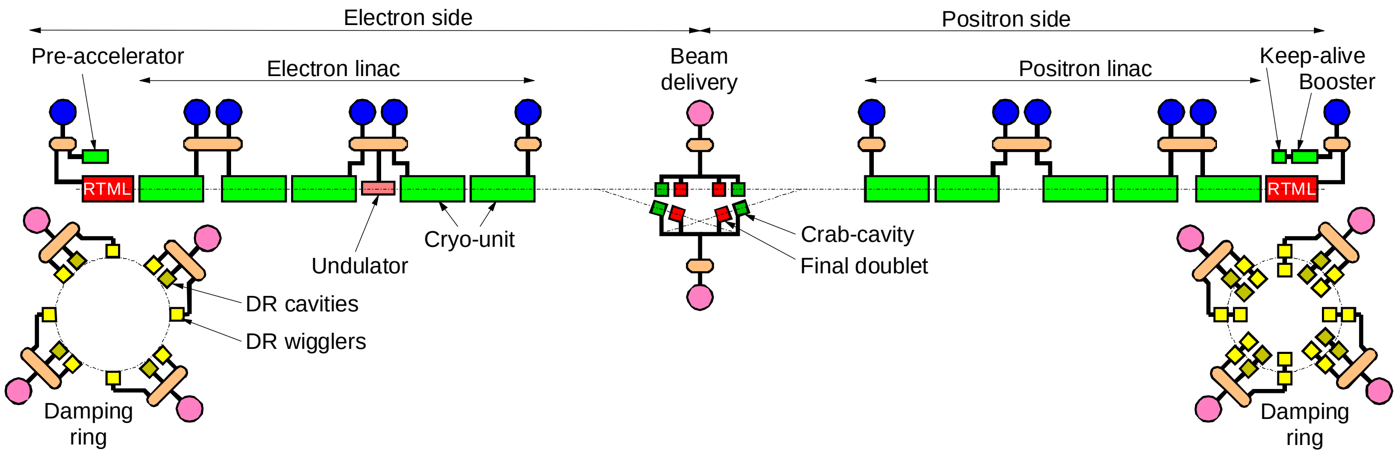
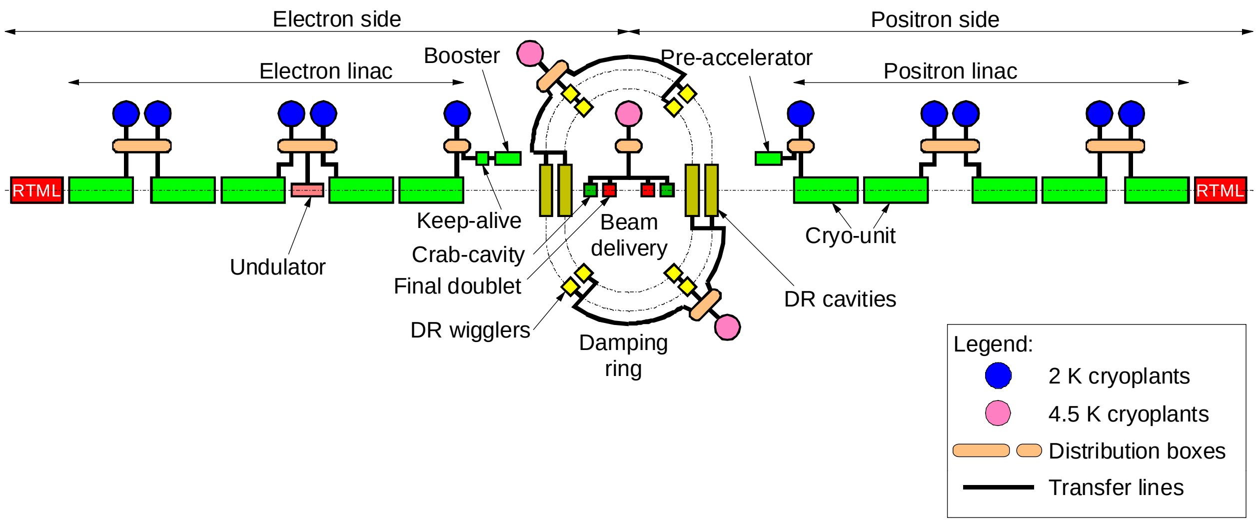
Compiled from various previous meeting notes and many sources

30 May 2007

Baseline Configuration Layout



Reference Design Layout



Main Linac Layout

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)

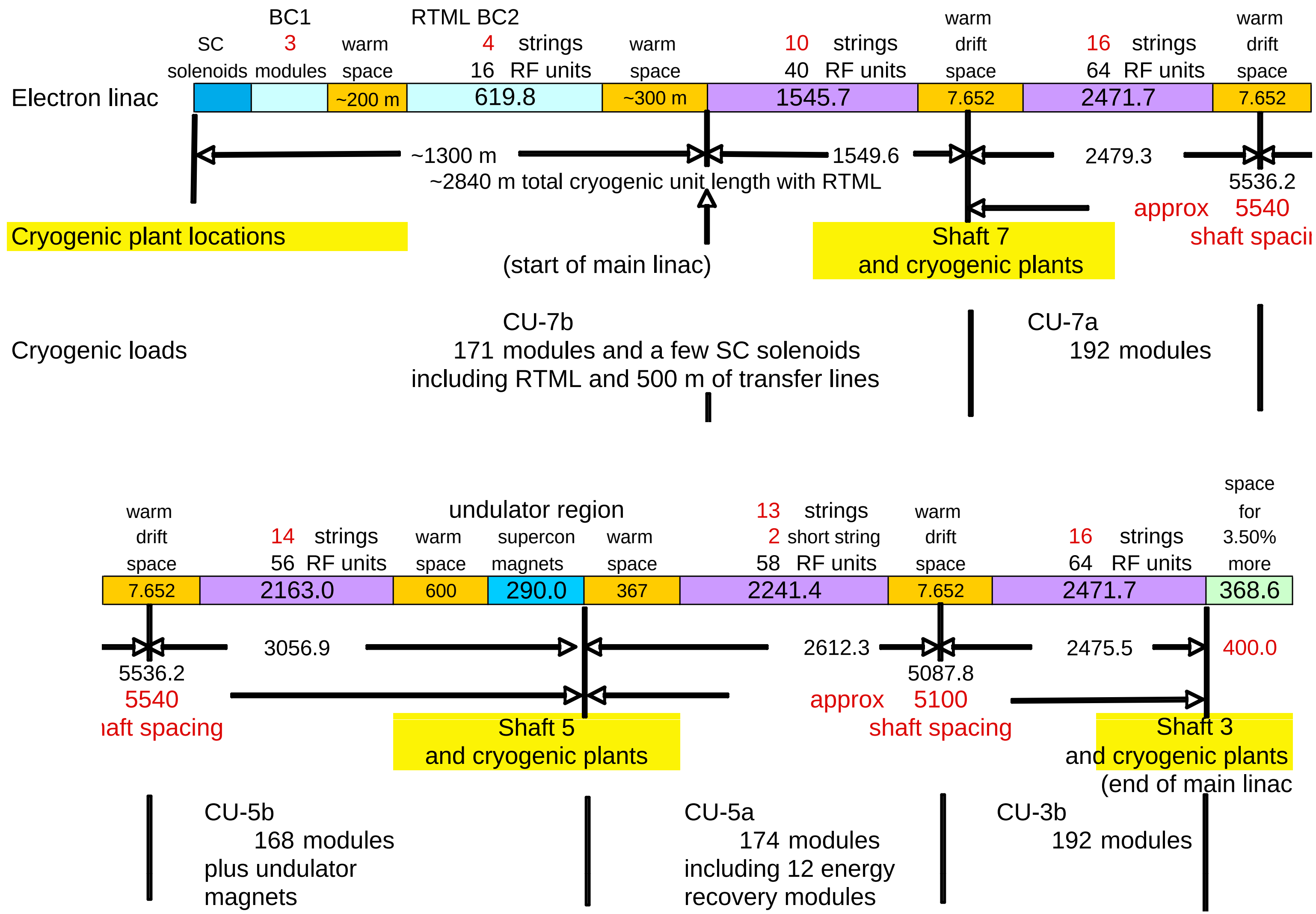
Cryogenic Unit
(16 strings)

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

Main Linac Layout - 2



Module numbers for ILC

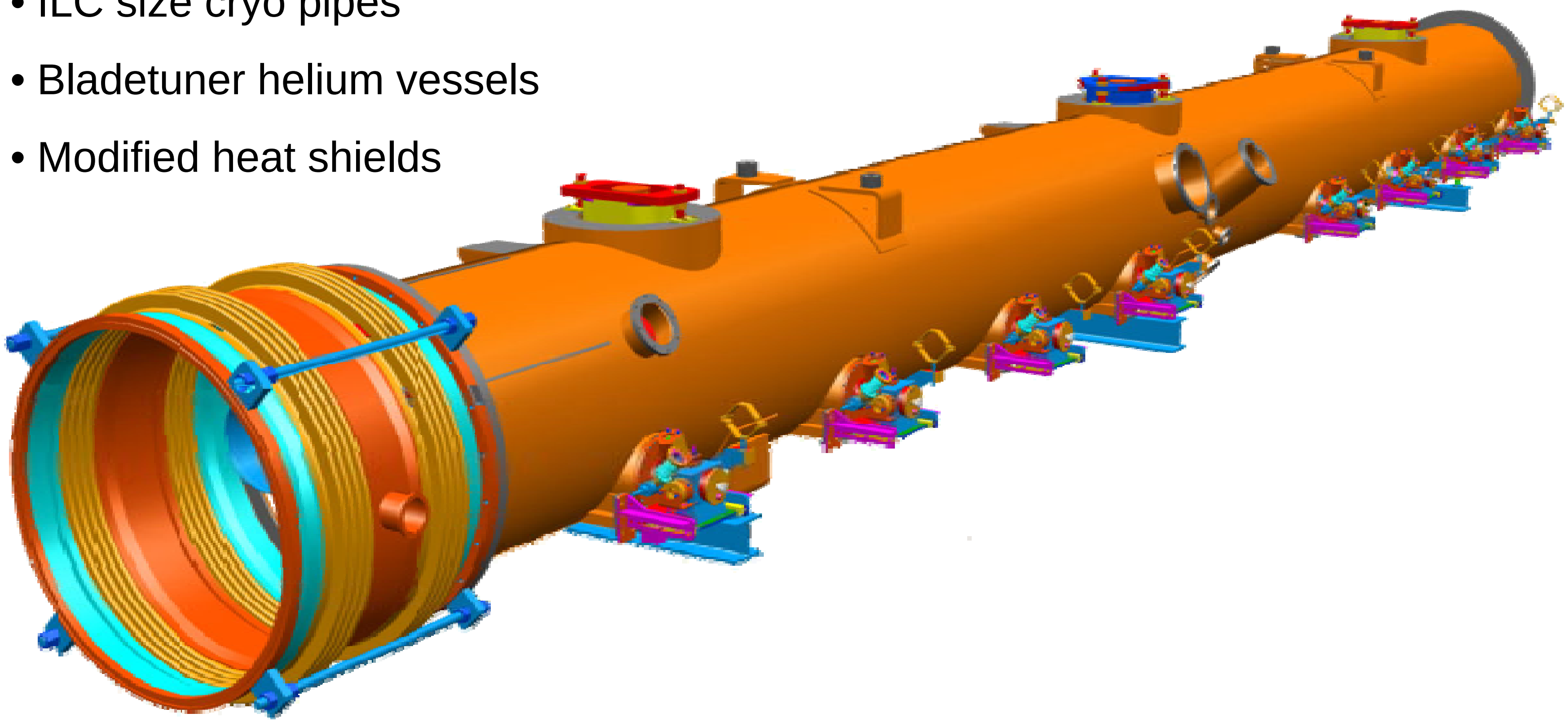
- 634 standard cryomodules with magnet package
- 1180 standard cryomodules with no magnet package

Cryomodules	8-cavity 1 quad	9-cavity no quad	8-cavity 2-quad	6-cavity 6-quad*	1300 MHZ	1-cavity 650 MHZ	2-cavity 3900 MHZ
Main Linac e-	282	564			846		
Main Linac e+	278	556			834		
RTML e-	18	30			48		
RTML e+	18	30			48		
e- source	24				24		
e+ booster	12		6	4	22		
e+ Keep Alive	2				2		
e- damping ring						18	
e+ damping ring						18	
beam delivery system							2
TOTAL	634	1180	6	4	1824	36	2

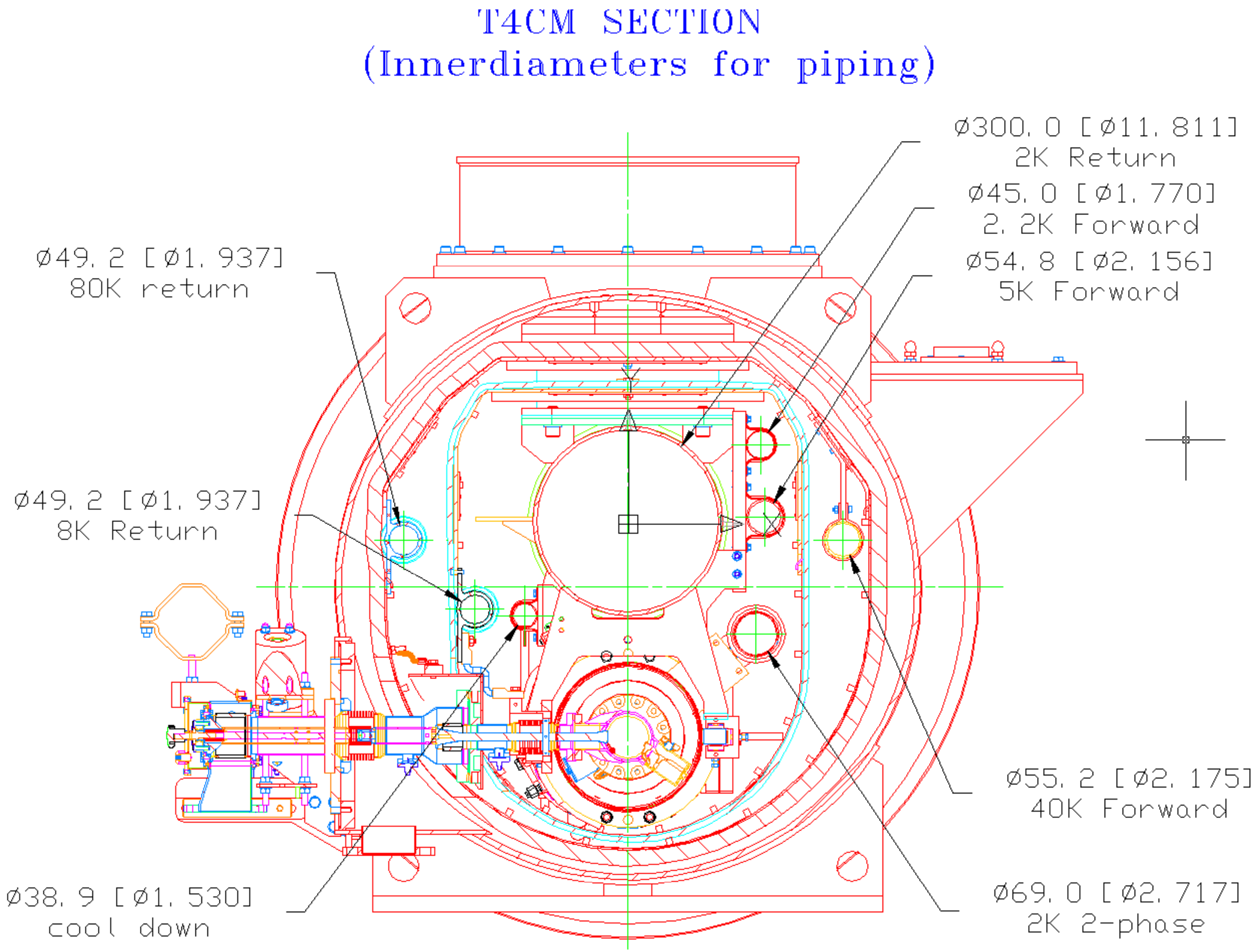
* I would make these 3 cavities and 3 quads per module and double the number of modules

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



T4CM PIPING based on Type 3+



Pipe size summary now (May 07)

Pipe function	BCD name	TTF inner diameter (mm)	XFEL plan inner diameter (mm)	**ILC and T4CM proposed inner dia (mm)**	ILC allowed pressure drop
2.2 K subcooled supply	A	45.2	45.2	**60.2**	0.10 bar
Major return header, structural supp't	B	300	300	**300**	3.0 mbar
5 K shield and intercept supply	C	54	54	**56.1**	
8 K shield and intercept return	D	50	65	**69.9**	0.20 bar (C+D)
40 – 80 K shield and intercept supply	E	54	65	**72.0**	
40 - 80 K shield and intercept return	F	50	65	**79.4**	1.0 bar (E+F)
2-phase pipe		72.1	>72.1	**69.0**	
Helium vessel to 2-phase pipe cross-connect		54.9	54.9	**54.9**	

Pipe size summary

(300 mm ID is OK and effectively fixed)

(50 mm --> 79.4 mm)

(50 mm --> 69.9 mm)

(45 mm --> 60 mm)

(54 mm --> 72 mm)

(54 mm --> 56.1 mm)

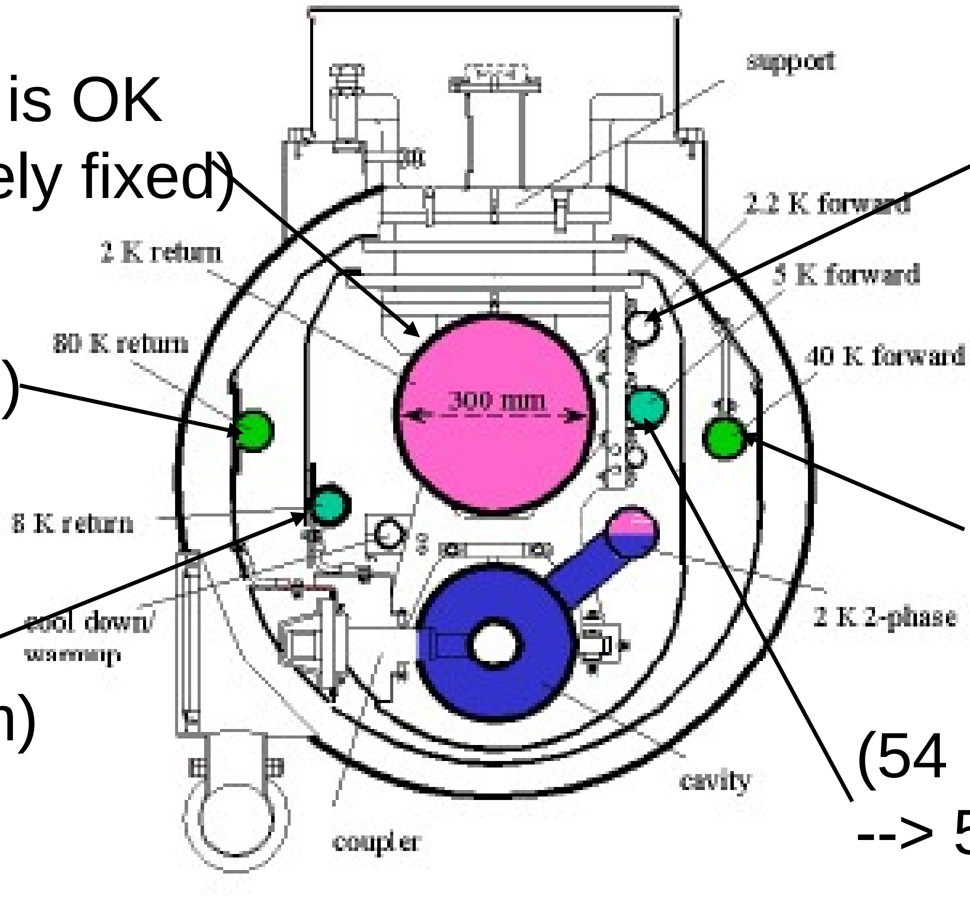
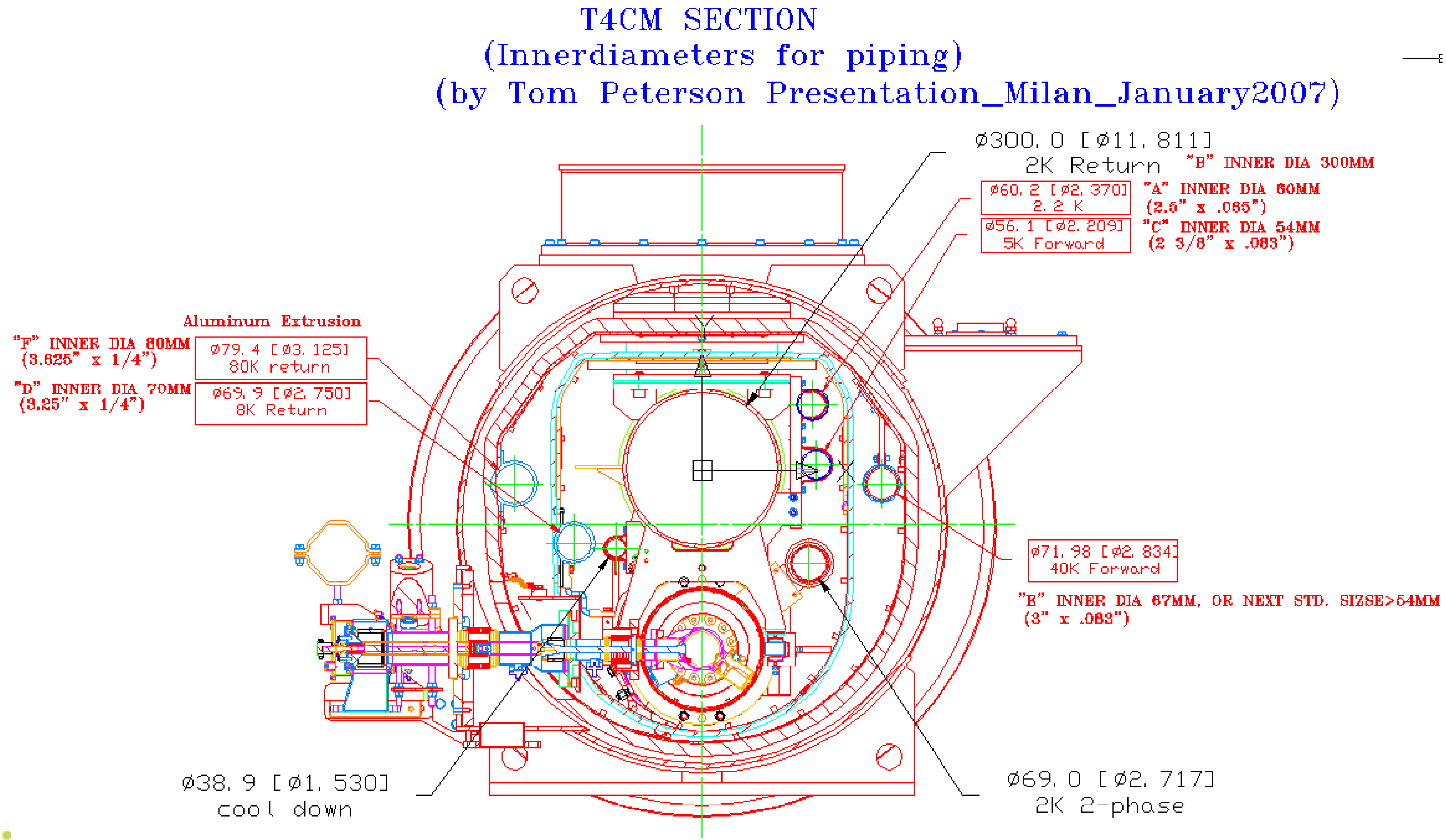


Figure 3.2.11: *Cross section of cryomodule.*

T4CM PIPING proposal



Maximum allowable pressures

- Helium vessel, 2 phase pipe, 300 mm header
  - **2 bar warm**
    - Limited by cavity detuning
    - Issue for pushing warm-up and cool-down flows
  - **4 bar cold**
    - Limited by cavity detuning
    - Issue for emergency venting
- Shield pipes
  - **20 bar**
    - Need high pressure for density to reduce flow velocities and pressure drops

Earlier discussions - 1

- SMTF collaboration meeting at Fermilab, 5 – 7 October 2005. Working group 2 (modules) notes and comments
- Cyromodule meeting at CERN, 16 - 17 January 2006, from my notes
- Cryomodule meeting at Milan, 22 - 24 January 2007, from my notes
- Various other meetings and discussions

Earlier discussions - 2

- General issues (2005)
  - **Need to gain assembly and test experience within the collaborating labs (still true)**
  - **Also need to start work toward ILC module design; assembly work competes for resources but feeds into design.**
  - **Need specifications for type 4**
  - **Particularly need design specifications for quad-steerer package with respect to centering, hysteresis, etc. (ILC magnet technical group has these)**

Earlier discussions - 3

- Revise the intercavity connecting flange and bolting (or welding) arrangement, detail the new spacing (Ideas have been sketched, some work is being done)
- Alignment and positional stability
  - **Need requirements (have these)**
  - **Measurement and verification of positions**
  - **Position of quadrupole (center, end, separate). Center is preferred basis for Type 4. (See 2005 notes.)**
  - **Integration of BPM with quad**
  - **Stability with shipping**
  - **Stability with thermal cycles**
  - **Vibrations**

Type 4 magnet position

- The largest change "on the board" right now in going from Type 3+ to Type 4 cryomodule is to move the magnet package to the center.
  - **Goal is positional stability with respect to interconnect forces**
  - **Central location has some disadvantages. Magnet people are among the strongest proponents of retaining better access to the magnet package for in situ measurements and alignment checks.**
  - **If center position has no mechanical advantage, magnet should go back to end like type 3+ (our second choice) or to separate cryostat**
    - See Module Working Group Report 7 Oct 2005
  - **Need to assess the central position for the magnet package with data from Type 4 modules compared to Type 3**

Type 4 magnet package

- Magnet package status
  - **Vladimir Kashikhin has designed a nested quad/corrector.**
  - **The first coil is being wound and a test is planned this summer in Fermilab's vertical test dewar.**

Earlier discussions - 4

- In any solution need quad-BPM-steerer package integration, including clean-room compatibility, an important engineering effort. Would like to see real BPM in type 3+.
- Active remote “movers” for quad alignment (not presently planned)
- Reliability
  - **Vacuum feedthroughs**
  - **Tuner (fast and slow)**
- Assembly
  - **Industrialization**
  - **Cost reduction**
    - Labor (60 – 80 man-days now per module at DESY)
    - Materials
    - Designs, e.g., flanges

Module-to-module interconnect

- Need layout for automatic end pipe welding
- Minimize space (850 mm vacuum flange to vacuum flange in TTF)
- Two beam vacuum isolation valves (each end of modules)
- HOM absorber in interconnect space
- 2-phase pipe to 300 mm header cross-connect in interconnect space
- CERN is interested in providing help in this aspect of the design but has not been able to provide the manpower due to LHC effort
- A mock-up is planned

Earlier discussions - 5

- Decide on pressure drop criteria and pipe sizes for the modules
  - **Done**
- Design a “segmentation” spool piece
  - **Segmentation for warm-up and cool-down has been dropped**
- Modify the slow tuner design to allow closer cavity-to-cavity spacing
  - **Blade tuner! (Done)**
- Modify the fast tuner design for proper piezo function
  - **Designed (status?)**

Earlier discussions - 6

- Design the support details for locating quad/corrector/BPM package under center post, but still hung from 300 mm tube
  - **Done**
- Select some possible quadrupole current leads and work out configurations for integration into module
  - **Need this!** **(Idea is to follow XFEL plan to use modified CERN current leads, but no details yet)**
- Design module end to accommodate the input coupler at the far end of the cryostat
  - **Done**

Earlier discussions - 7

- Vibrational analysis of the quad and cavity support structure
  - **In progress, much has been done (see Vibration Stability measurements talk earlier today)**
- Design for stability with shipping, analysis of shipping restraints and loads
  - **Some preliminary work in progress, initially motivated by 3.9 GHz module**
- Develop module test plans and module component test plans
  - **Have concepts and DESY's test examples**
- Design of instrumentation for installation into the module
  - **Some work but needs more**
  - **R&D module instrumentation versus production model**

Earlier discussions - 8

- Conceptual design of separate quad cryostat
  - **An alternate, not receiving attention**
- Determine module slot lengths
  - **Set equal for 8 cavity/magnet and 9 cavity**
  - **Our present slot lengths are a good "working assumption", but**
  - **Ongoing, still may change with magnet and interconnect details**

Regional differences

- Cryomodules will not be identical in all regions
  - **Regions should pursue different design concepts in parallel**
  - **However, it would be nice if they are compatible in having (almost) the same interconnect piping positions and dimensions, with those similar to XFEL.**
  - **We should agree on an interface spec**
  - **The most fundamental requirement for interconnect compatibility is that the beam tube position and 300 mm pumping line position relative to the vacuum shell be held the same; we should be happy if we have that!**

Design evolution

- Allow the ILC design to continue to evolve
  - Do not "fix" a design too early for fear of interfering with project start.
  - But Type 4 will have to be fixed this summer to allow procurement
- A "clean piece of paper" approach would require a major separate parallel build and test effort for validation, probably more than we can afford.
- Design should be validated with system testing as close to ILC conditions as possible before project start (lessons learned from LHC experience)
- Pre-production should have involved significant industrial participation.
  - But pre-project assemblies would not include full industrial production since the large-scale infrastructure probably cannot be completed so early.

Possibility for Cost Optimization

- Cryomodule / cryogenic system cost trade-off studies
  - **Additional 1 W at 2 K per module ==> additional capital cost to the cryogenic system of $4300 to $8500 per module (depending on whether we scale plant costs or scale the whole cryogenic system). (5 K heat and 80 K heat are much cheaper to remove than 2 K.)**
  - **Additional 1 W at 2 K per module ==> additional installed power of 3.2 MW for ILC or $1100 per year per module operating costs.**
  - **Low cryo costs relative to module costs suggest that an optimum ILC system cost might involve relaxing some module features for ease of fabrication, even at the expense of a few extra watts of static heat load per module.**
    - For example, significant simplification of thermal shields, MLI systems, and thermal strapping systems
    - In Milan (January, 2007) we agreed that the 5 K thermal shield bridge at interconnects can be left out

ILC Cryomodule

- T5CM?
- Industrial involvement for design for manufacturability
- The final ILC cryomodule will implement cost reduction designs:
  - **New cavity end-groups**
  - **New cavity-to-cavity bellows, flanges, and seals**
  - **New helium vessels, possible stainless steel**
  - **Optimized cryogenic pipe sizes**
  - **Pipe locations may change.**
  - **New insulation scheme**
  - **Possible magnetic shield design change**
  - **Design modifications to resolve shipping concerns**

Other cryomodules

- 1300 MHz with multiple magnet packages
  - **Only about 10 of these**
  - **All in the positron source**
  - **Consider dividing them to avoid longer than the standard cryomodule and simpler assembly**
- Other frequencies
  - **650 MHz cavity cryostats and crab cavity cryostats are so totally different from the main 1300 MHz cryomodules that they make very nicely separable work packages.**