Design Study and R&D plan for IR Cryogenics and ILD Superconducting Solenoid

KEK/IPNS

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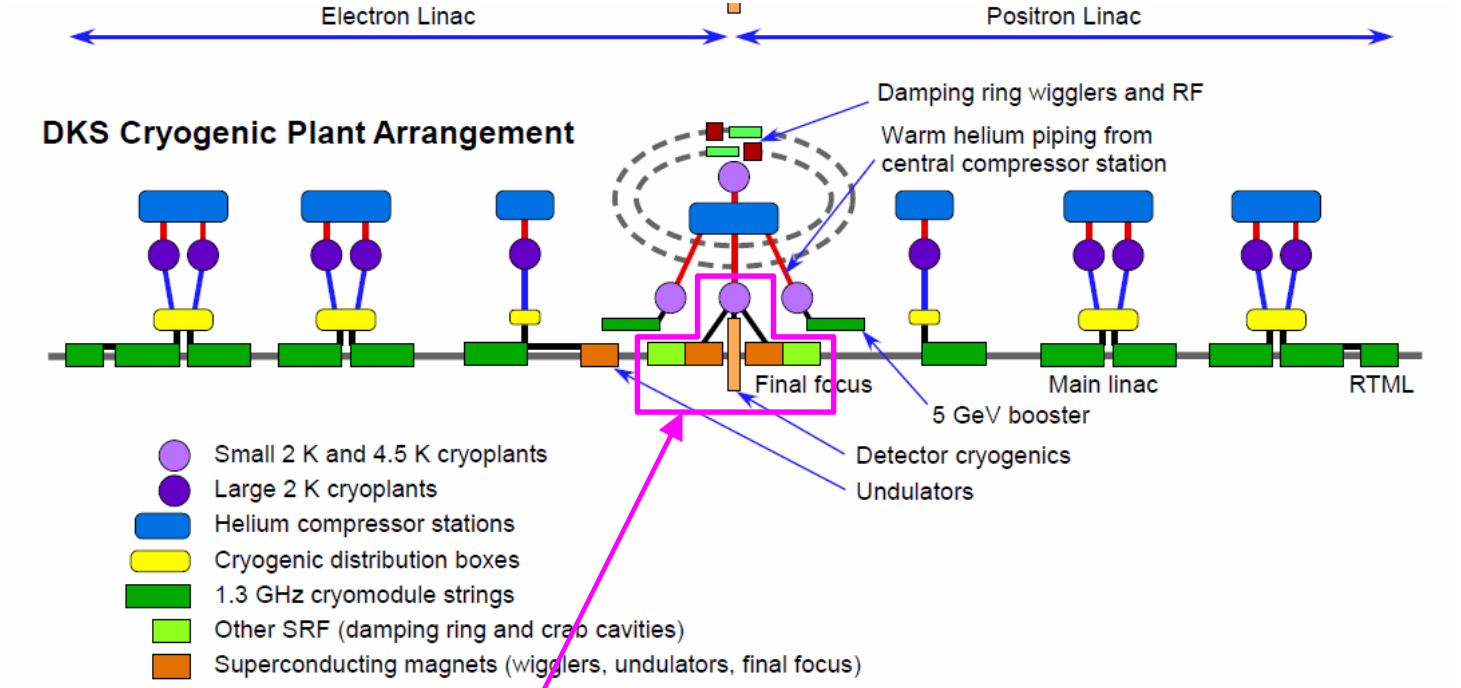
  - Field design including Anti-DiD optimization.
  - Structural analysis and design of the solenoid including the conductor development.
  - Conductor R&D and fabrication technique.
  - Winding and fabrication technique study.

1. Cryogenic System for IR including CC and QF1

Configuration of Cryogenic System for ILC

Brief Decision of ILC cryogenics in mountain site

- Four small cryo-plants for detector, final focus, crab cavity, damping ring.
- 10 large cryo-plants for electron positron Linac



Today's talk is about cryogenics at IP (detector + Final focus + Crab cavity)

Cooling condition

QF1
- Coolant = Pressurized He II (1.8 K ∽ 2.0 K)
- Heat Load = 15 W@1.8 K
- Inventory = ?

Crab Cavity
- Coolant = Saturated He II (1.8 K ∽ 2.0 K)
- Heat Load = 10 W@ 1.8 K
- Inventory = ?

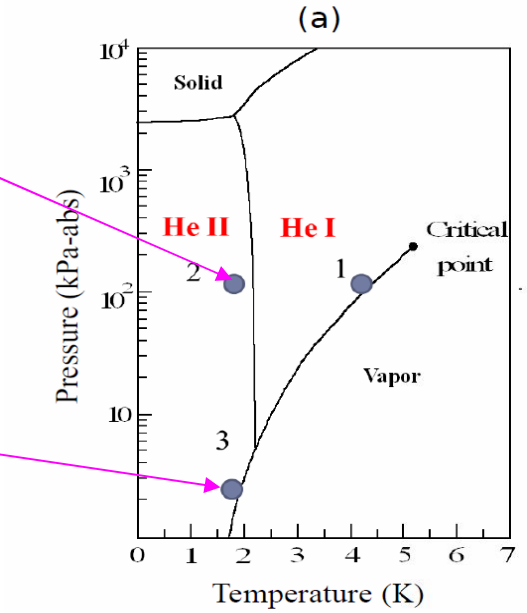
• Non nucleate boiling in the case of He II

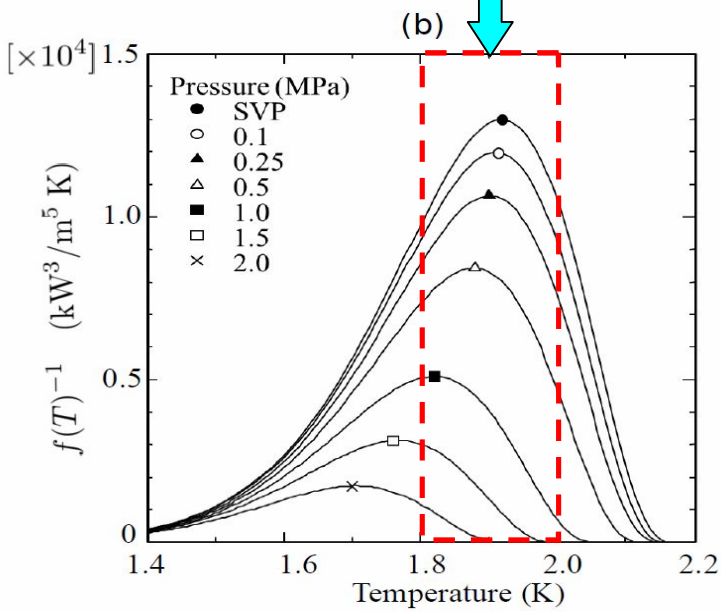
• It is suitable to reduce vibration of final focus magnet

Large heat transfer function Around 1.8K

Pressurized He II

Saturated He II





Cooling Strategy of IP cryo system

Definition : IP cryo system → cryo system for “Detector”, “QD0”, “QF1”, “CC”

- Three cold boxes are installed in the experimental hall (Utility Space).
- Two kinds of 2K refrigerator should be prepared.
  - One for QD0, the other for QF1 and CC

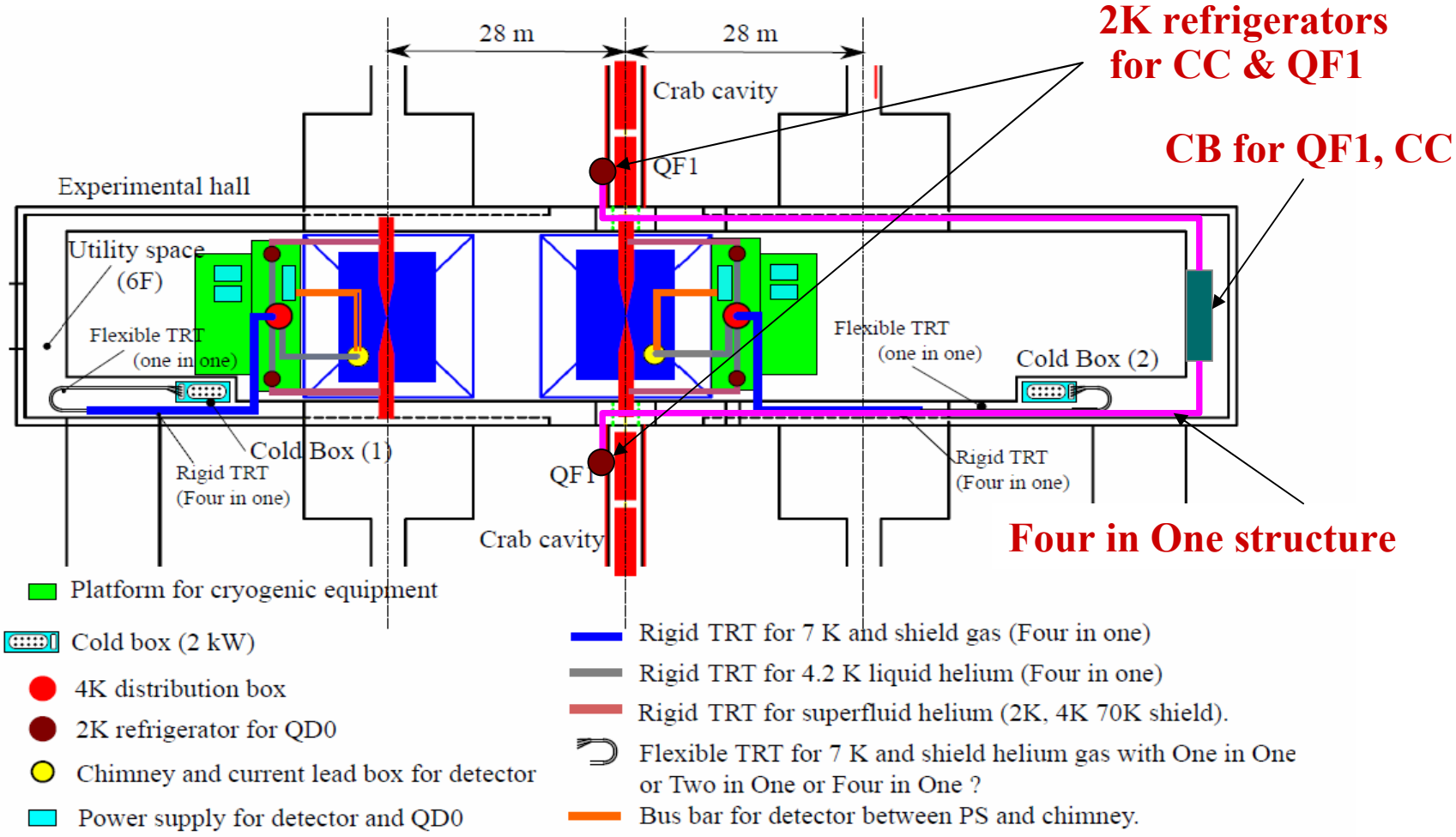
Table1 : Summary of cryogenic system for each superconducting equipment of IR

	Total num	ILD + QD0 (pushpull)	SiD + QD0 (pushpull)	CCs + QF1s (fix)
4K Cold BOX (W, location)	3	2.0 kW platform or hall space	2.0 kW platform or hall space	~1.0 kW hall space
2 K refrigerator (location)	6	P-He II Platform	P-He II Platform	S-He II & P-He II Accelerator tunnel
TRT from CB (length)		rigid or flexible (5m or 30m)	rigid or flexible (5m or 30m)	Rigid (40m)
Compressor	3	700 kW	700 kW	350 kW

* 1.8 K refrigerator : 850 W / W, 4.5 K refrigerator : 350 W / W

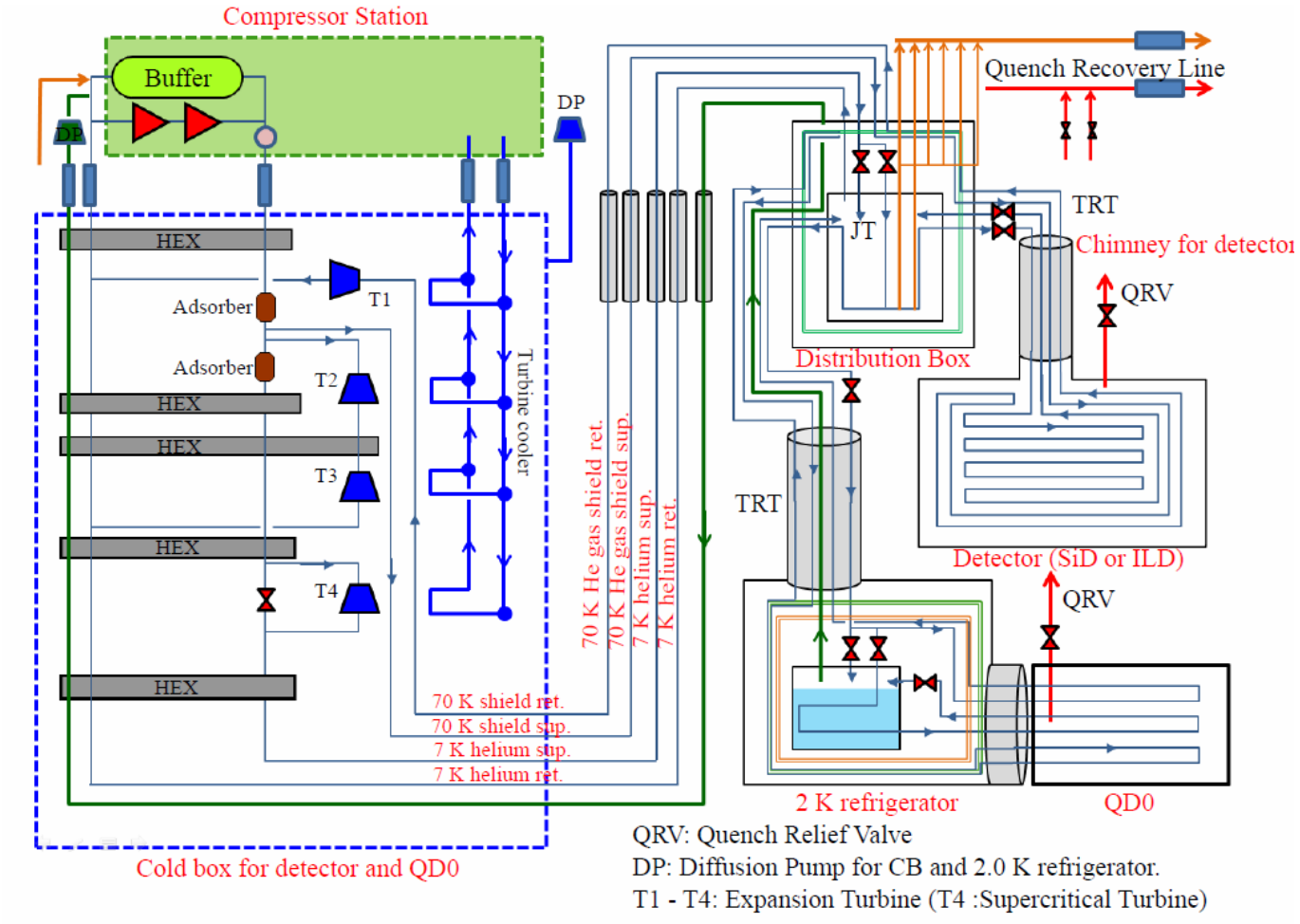
Installation Location

- A cold box for CC and QF1 will be installed in the IR hall (utility space)
- Two 2K refrigerators are installed adjacent to the both side of the QF1 (in the accelerator tunnel)



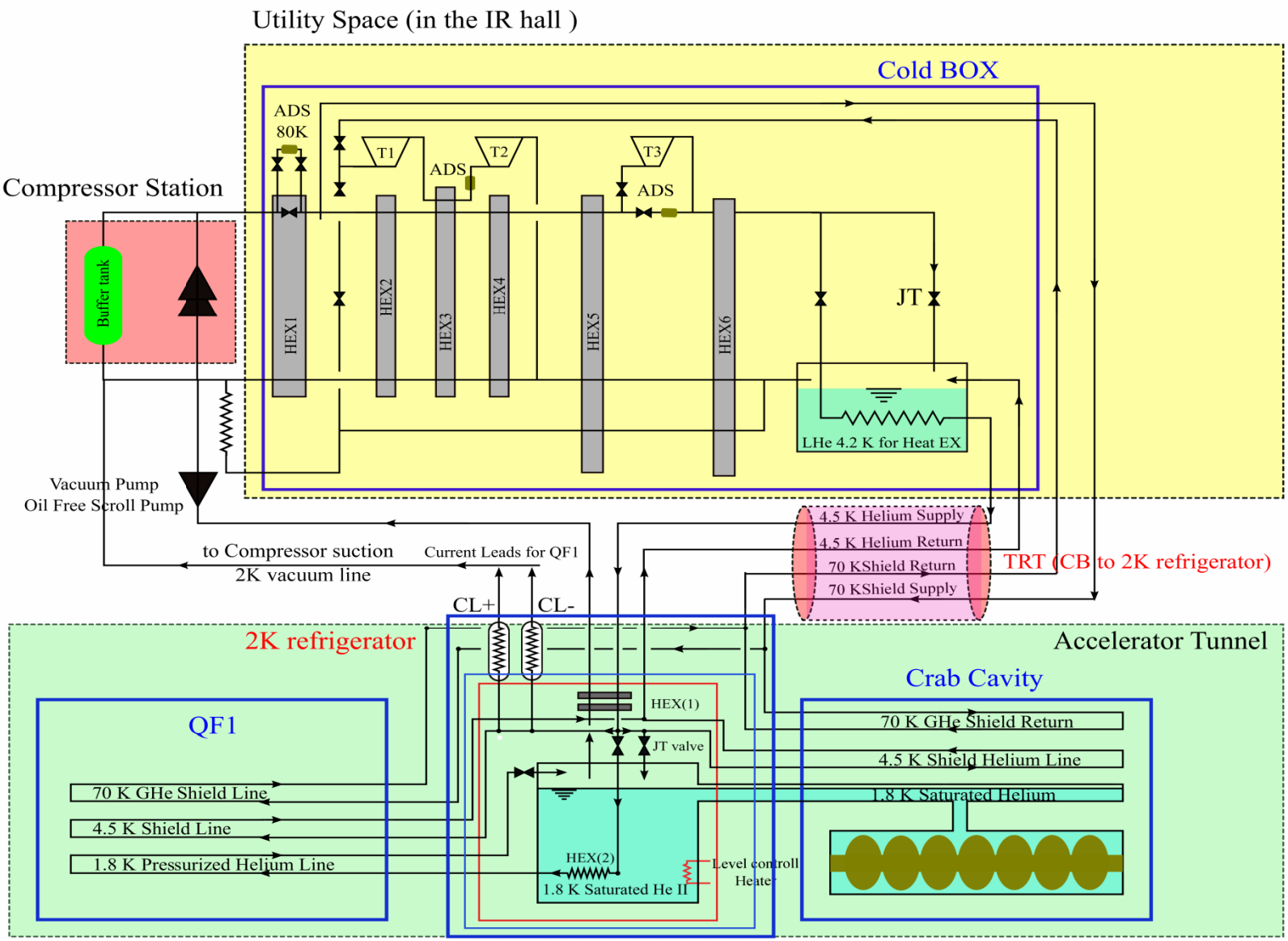
Cryogenic Configuration for ILD (SiD)

- The configuration for detector parts was already introduced in the previous workshop.
- Installation location of CB is quite important from the viewpoint of vibration of QD0.
- In the future, CB location will be determined by discussing SLAC and by performing fundamental studies (dynamic simulation and vibration measurement).



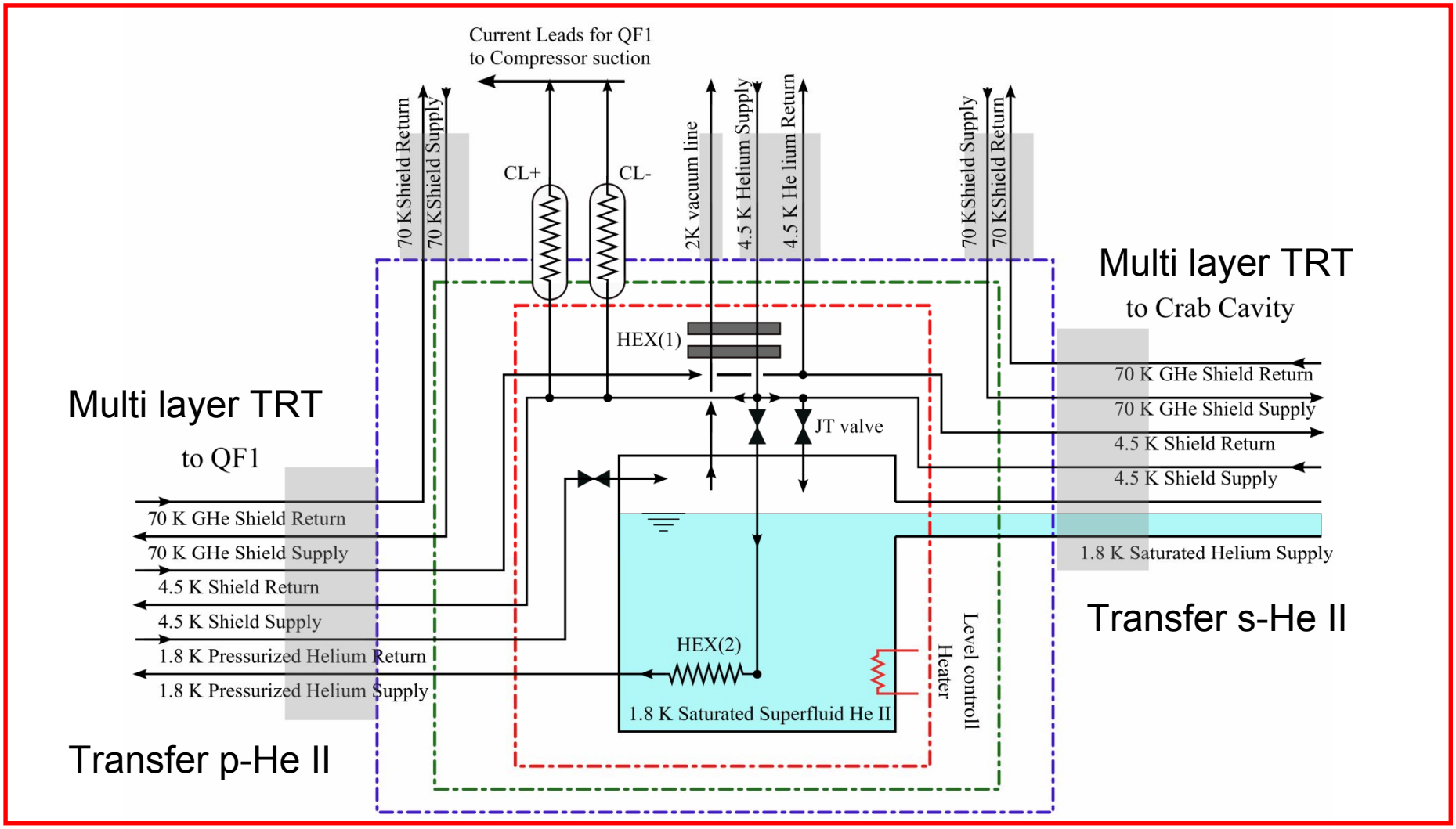
Cryogenic System for QF1 and CC

- Saturated and Pressurized He II are generated by a 2K refrigerator.
- Kernel of this system is clearly structure of 2K refrigerator.



Flow diagram of 2K refrigerator for CC &QF1

- Two Heat exchangers, HEX1 and HEX2
- JT valve to obtain s-HeII, flow control valves
- Current leads for QF1 are equipped (but the other solution is to install CL at Cryostat of QF1)



2. R&D Plan of Superconducting Solenoid for ILD

Background & Purpose

- Present Status
  - Required specifications of the solenoid and the cryogenic system have been almost confirmed.
  - Conceptual design of the solenoid and the cryogenics according to the requirements has been completed.

- Starting Now
  - Engineering study and design of solenoid.
    - Field design including Anti-DiD optimization.
    - Structural analysis and design of the solenoid including Anti-DiD
    - Conductor R&D and fabrication technique.
    - Winding and fabrication technique study.

R&D of superconducting solenoid

Solenoid Design
- FEM calculation
- Magnetic field calculation
- Structure analysis
- Winding machine R&D

Superconductor R&D
- FEM calculation
- Conductor Design
- Sample fabrication

Cryo equipment preparation
Cold box ,cryostat
Field measurement equipment
DAQ system ,Power supply

Test Coil Fabrication
Test coil is fabricated by using developed sample conductor and winding machine.

Cooling test, excitation test, field measurement

- **Cool down test**
  → check thermal cycle and validity of design
- **Excitation and Quench test**
  → check superconductor and dynamics of conductor during quench
- **Accuracy of magnetic field measurement**
  → check validity of design of solenoid and winding machine.

The information obtained by cooling test will be fed back to a engineering design.

Present approach of Conductor (CMS Type)

Electron beam welding technique has to be applied to joint pure Al and Al alloy layer.

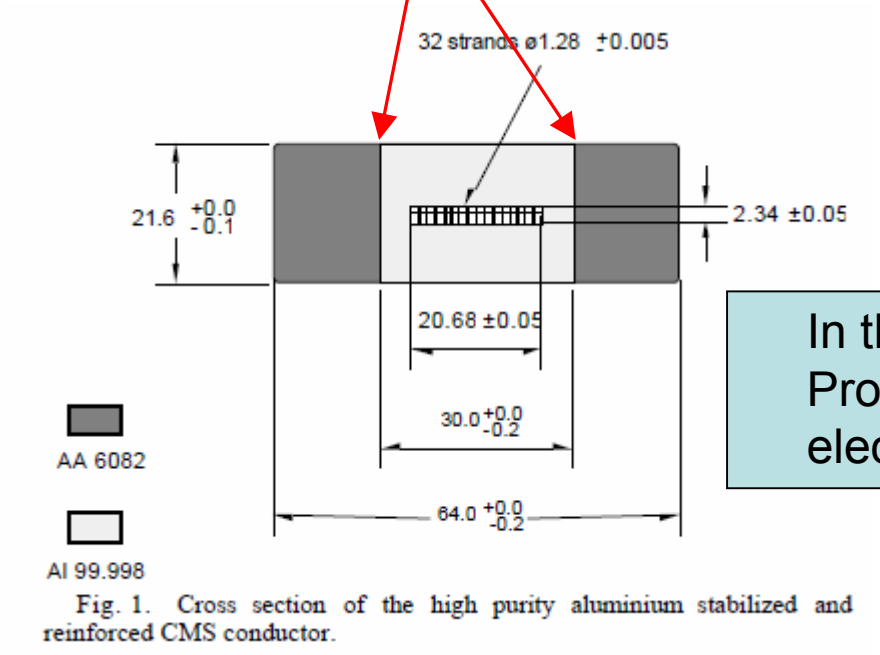


Fig. 1. Cross section of the high purity aluminium stabilized and reinforced CMS conductor.

The size of ILD is very huge, therefore it is necessary to fabricate superconductor with the length of around 30 km

In the case of the CMS type conductor, Production cost increase, because of the electron welding process

Rutherford Cable clad with Aluminum alloy without pure Al is developed in this study (See next page) to aim the production cost down of the superconductor

Background of this proposal

Current redistribution into low resistive aluminum stabilizer takes the time for second order.

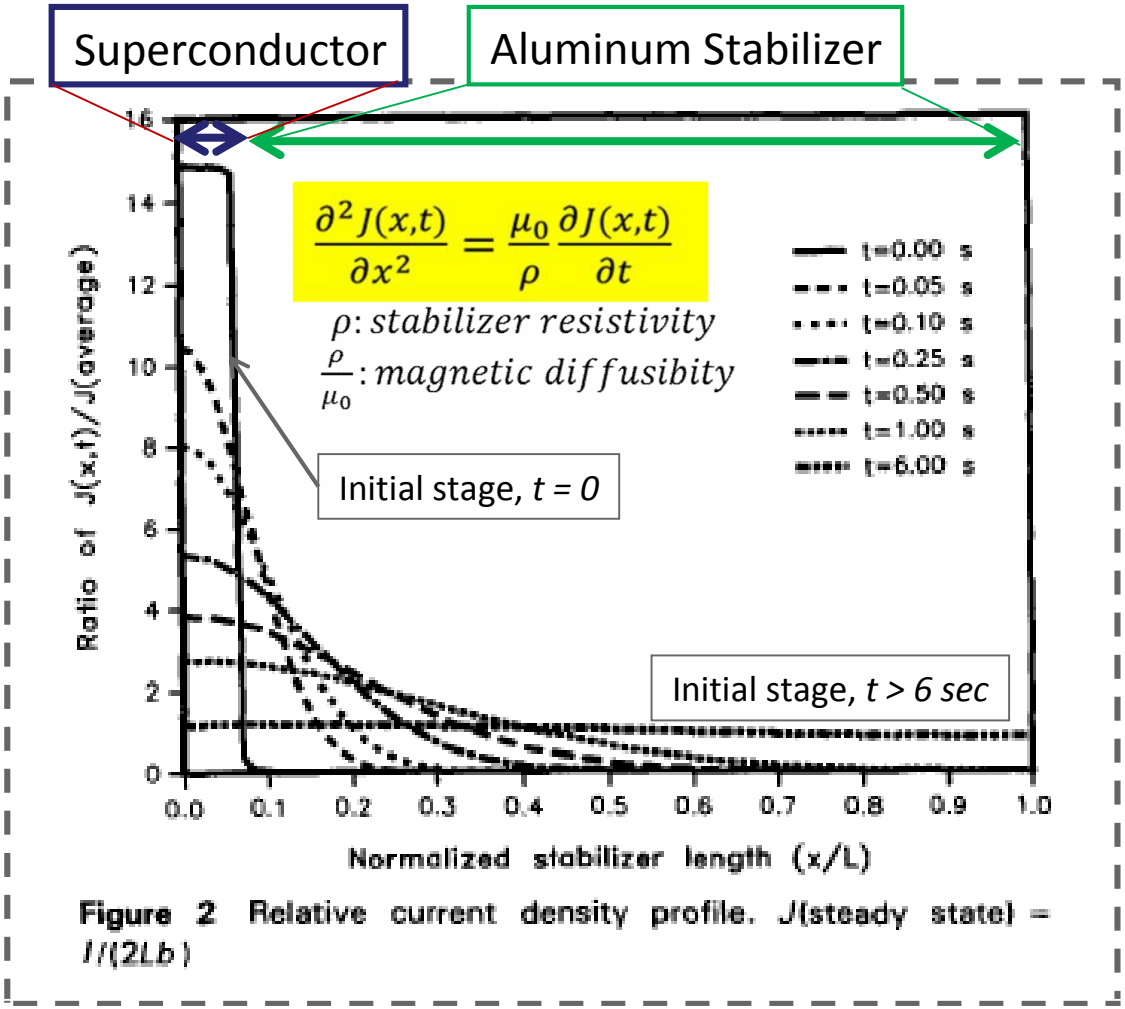


Figure 2 Relative current density profile. *J*(steady state) = *I*/(2*Lb*)

From A. Lee, R.H. Wands and R.W. Fast, "Study of current redistribution in an aluminum stabilized superconductor", Cryogenics 1992 Vol 32, No.10, p.865

From view point of **Superconducting Stability** :

Larger area ratio of cupper matrix in close proximity to NbTi multi filaments is more effective.

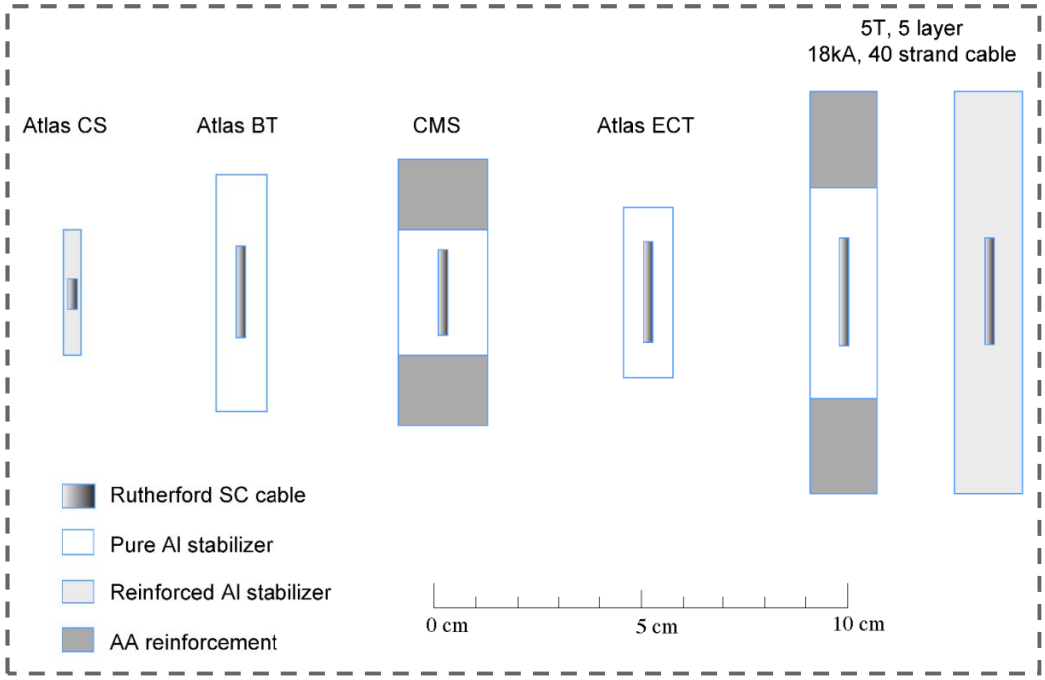
Accelerator magnets are wound with NbTi/Cu cables.

From view point of **Quench Safety** :

Large area of Al or Al Alloy give large thermal capacity which prevent the conductor from being burnt out after quench.

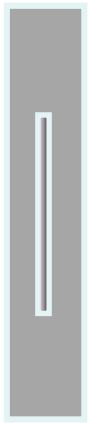
First, we'd like to make simulation study to confirm this proposal.

Cross Sections of Al Stabilized Superconductor in LHC detectors and R&D

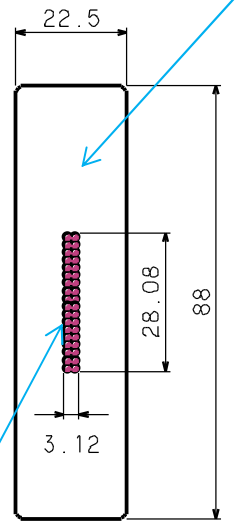


Cu/NbTi Ratio : 1~1.3

New Proposal



Aluminum Alloy Clad
A6061
$\sigma_{0.2}$ > 250 MPa



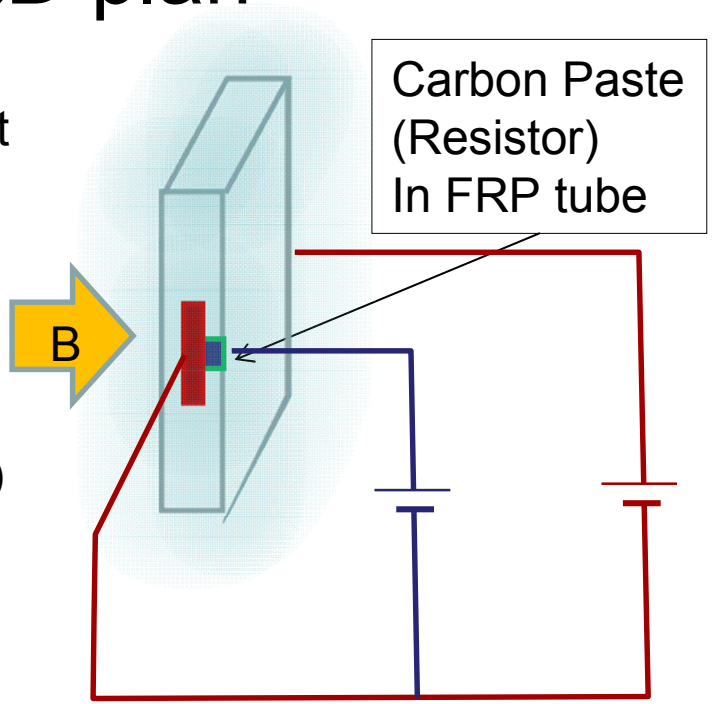
Strands
ϕ1.6 Nb –Ti
Cu to SC ratio > 4
Ic > 650 A at 5 T
RRR of Cu > 180
$\sigma_{0.2}$ > 200 MPa

Cable
36 strands
Cu to SC ratio > 4
Ic > 23000 A at 5 T

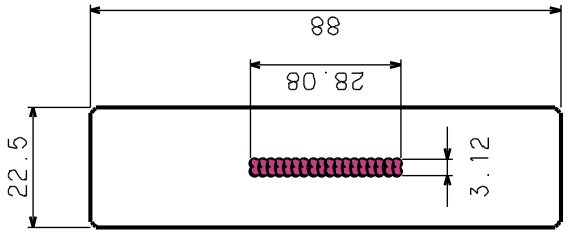
From presentation material by Andrea Gaddi & Benoit Curé about "LCD Solenoid Design Reinforced Conductor R&D Magnet Services" at ILD Workshop, LAL/Paris, May 22-25, 2011

Conductor R&D plan

- Simulation and Experimental Confirmation about Superconducting Stability in Aluminum Alloy Clad Conductor.
  - Core cable is heated by carbon paste directly.
  - Normal zone recover to Superconductor or propagate to quench (MQE measurement)
  - Compare MQE in Pure Al clad cond. and that in Aluminum Alloy clad cond..



- Trial Co-extrusion of NbTi/Cu cable clad with Aluminum Alloy (A6061 or others)
  - Metallurgical check on cladding process with aluminum alloy.
  - Mechanical and electrical contact b/w Cu and aluminum alloy.



Summary and Future Plan

- Conceptual flow diagrams for all superconducting equipment (detector, final focus, crab cavities) are proposed.
- Dynamic simulations will be performed for flow diagrams as to various situations and more accurate and practical flow diagram will be proposed.
- Engineering study and design of ILD solenoid are such as FEM field calculation and R&D of conductor are starting now by KEK cryo-groups.
- We would like to collaborate as to engineering study of superconducting solenoid.