# CDR for LHeC

preliminary studies

Friedrich Haug

# Scope: Preliminary Study of External Cryogenics for a CDR

Definition: The External Cryogenics comprises the refrigeration and distribution systems for the accelerators and detectors.

Accelerator (New „Add-ons“ to LHC) :

**Linac-Ring** version: **ERL** P-140

**Ring-Ring** version: **Ring acc.** **Injector** („mini-ELFE“)

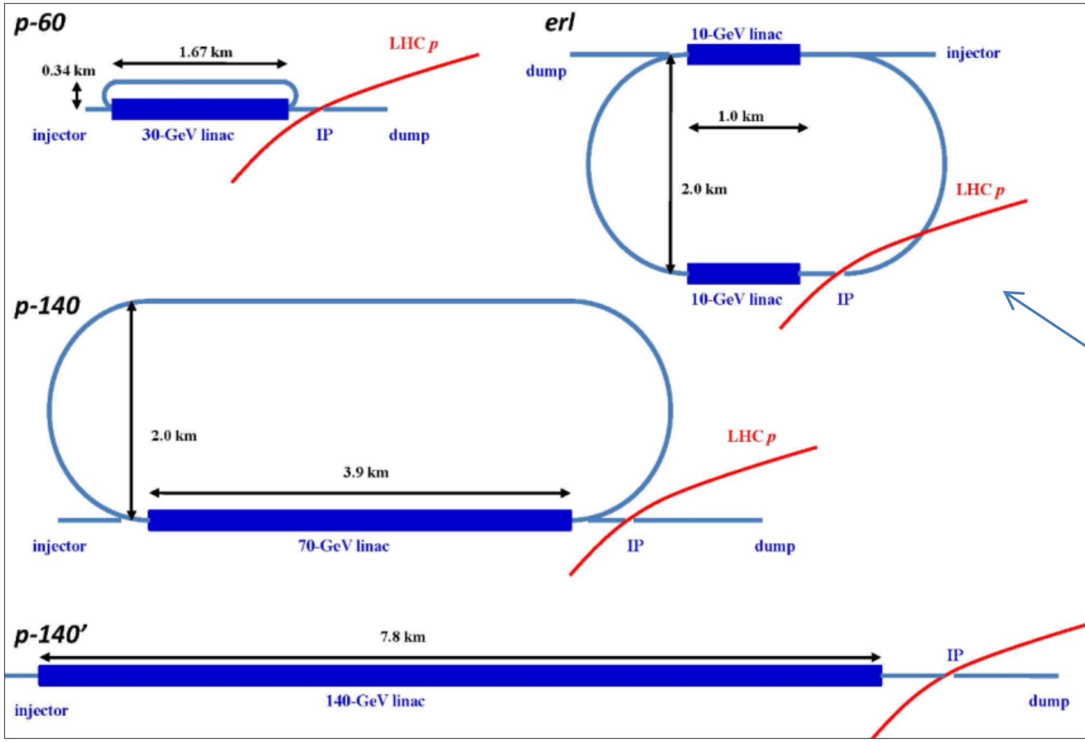
LHC adaptation (inner triplets)

New Detector:

Solenoid(s), Dipoles, insertion magnets (like H1?)

(LAr calorimeter?)

# Linear collider studies




From the 4 originally proposed and studied version two are retained, P-140 and ERL

**ERL** is a recirculating (recovery) machine and is the **FAVORITE**


With 7.8 km, 31.5 MV/m, 140 GeV, pulsed:

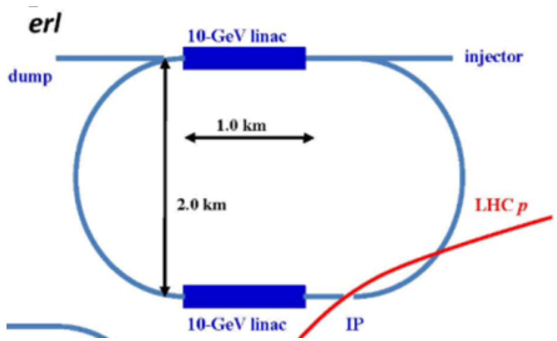
2 K total load (stat. + dyn.) = 17 W/m

**Refrigeration power 75 kW @ 2 K** (per 7.8 km)

With COP = 700 700 x 75 kW = 52 MW el. power)

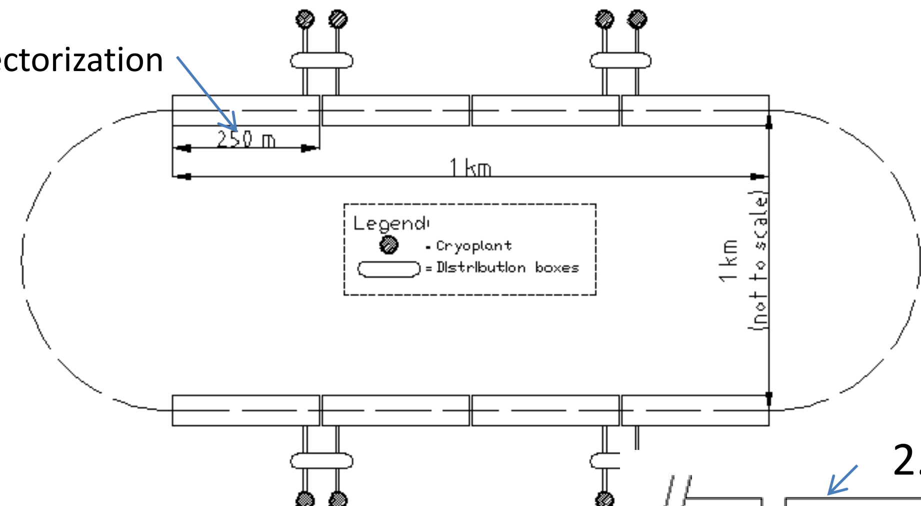
This goes in the direction of ILC. see publication Juan, Serge, Laurent 2005

# ERL




Recirculating Energy Recovery Linac.
60 GeV.
Cryomodules **CW operation**. Large heat load at 2 K requiring cooling capacity of approx. **42 kW @ 2 K**

sectorization



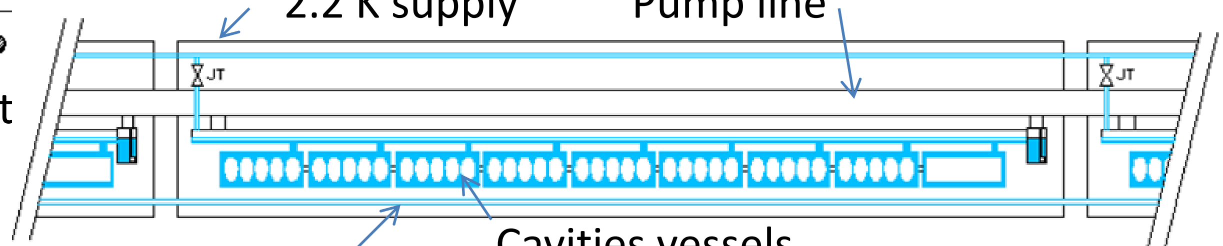

8 x 5 kW @ 2 K cryoplant

Studies are ongoing (Ed Ciapala) which typ of cavities suited

Proposal cryomodule cooling (all lines internal)

2.2 K supply

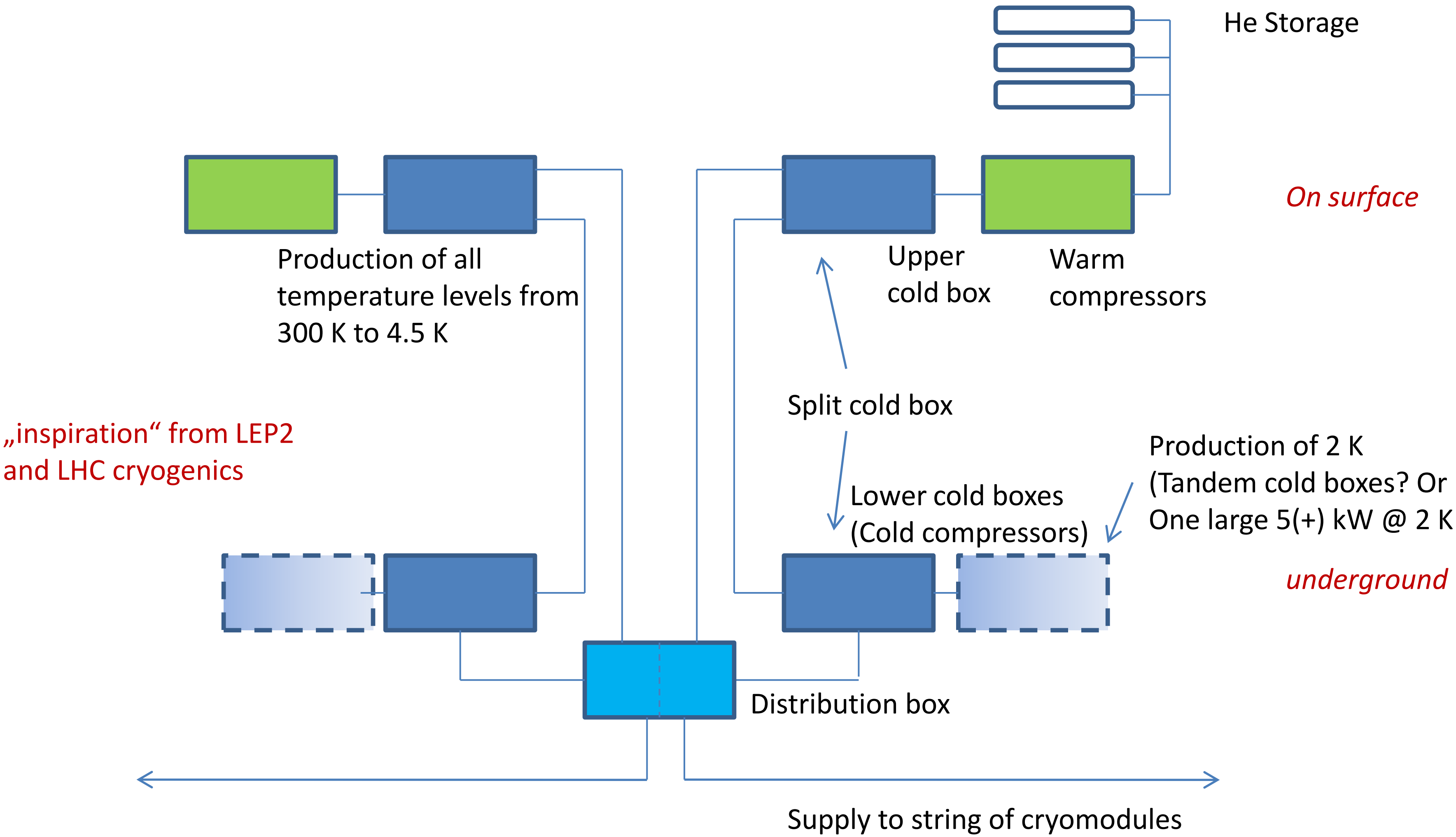
Pump line




Cavities vessels

40-80 K

# Basic refrigerator lay-out (simplified)



# Ring-Ring Cryogenics (basics)

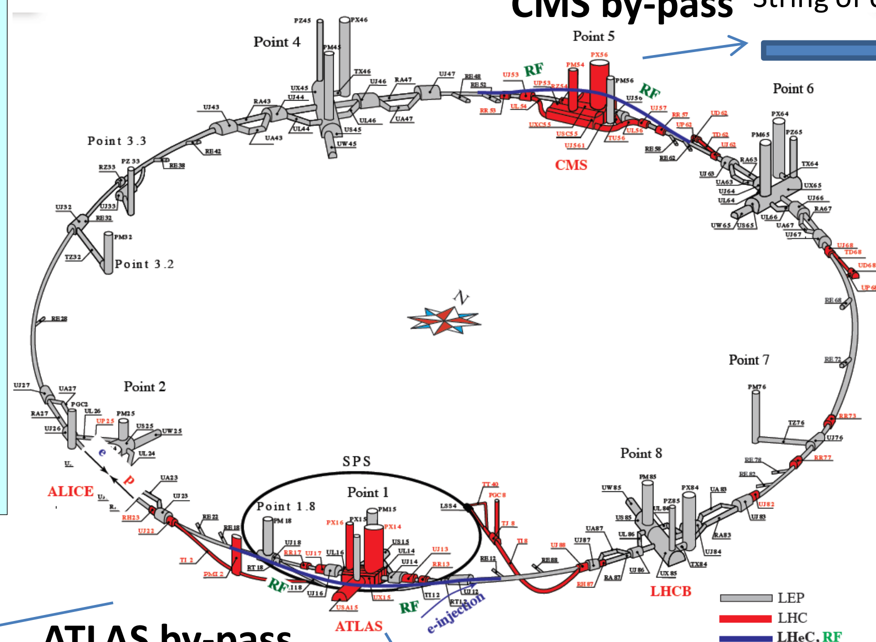
For the CMS and ATLAS bypasses are considered:

1. LHC type cryomodules (400 MHZ)
2. SPL type cryomodules (704 MHz)

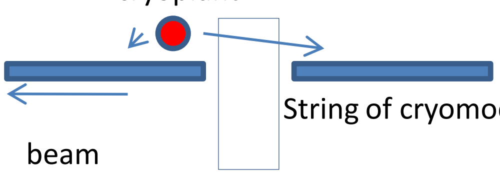
Cryogenics requirements

1. 4.5 K operation. Two cryoplants of approx. 10 kW @ 4.5 K each. El. power approx. 5 MW total.
2. 2 K operation. The installed power of the cryoplants is a function of acc. field (to be determined). (El. power comparable to 1.)

**CMS by-pass** String of cryomodules cryoplant




cryoplant



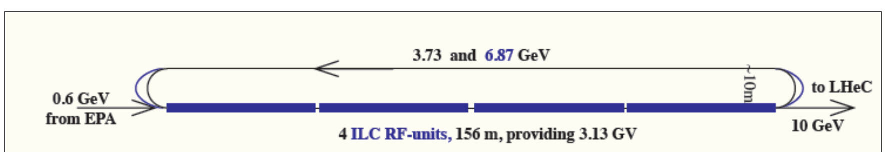
String of cryomodules

beam

ATLAS area

**ATLAS by-pass**

**Injector**



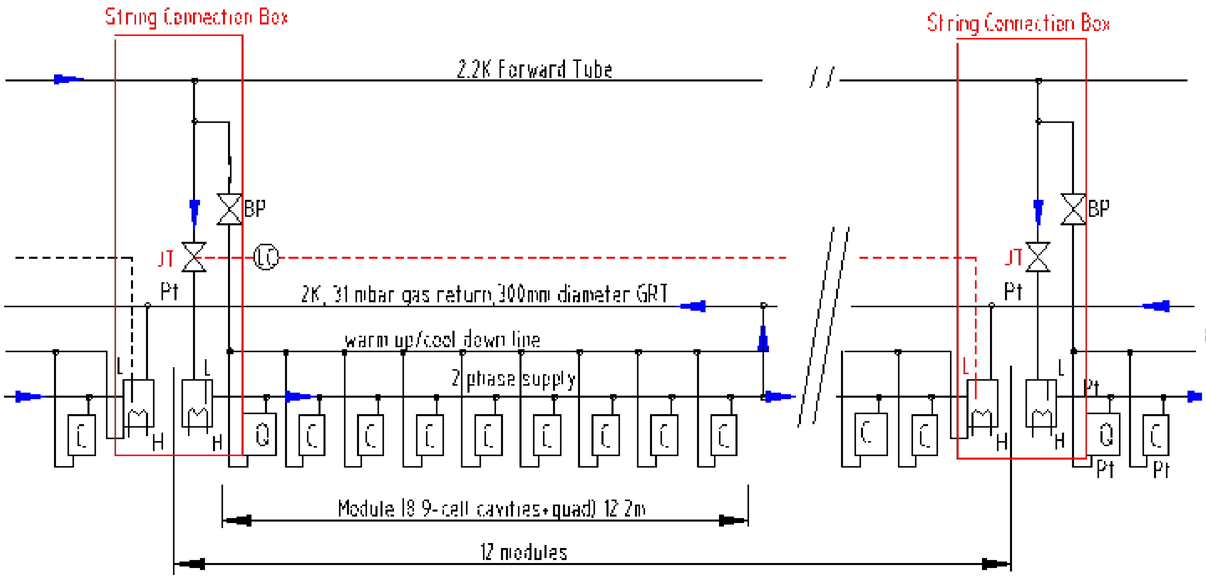

**Injector**:
12 ILC (XFEL) cryomodules.
Intermittend operation.
Operation temp. 2K.
Cryoplant of modest size (0.2 kW @ 2 K)

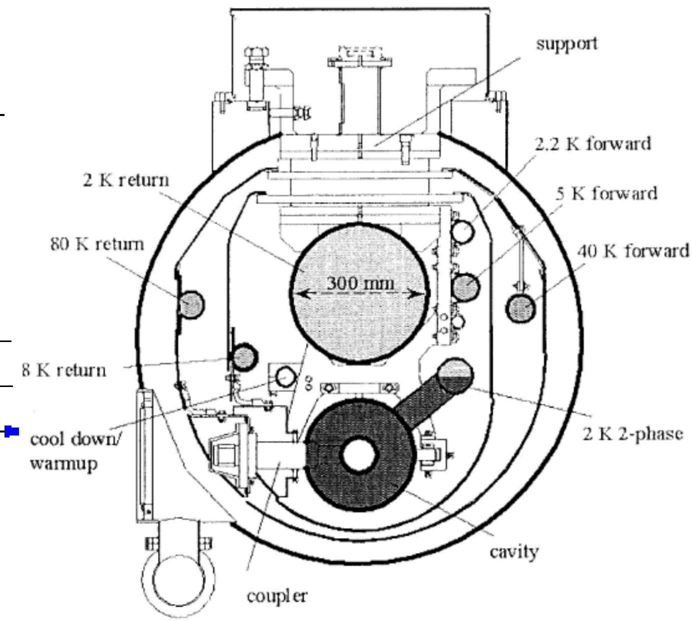
# XFEL type 2K cryomodules

XFEL type cryomodules can be readily used for injector !! No modification.

Three temperature levels:

1. 2 K bath cooling of sc devices
2. 5-8 K thermal screen and intercept (not shown)
3. 40-80 K thermal shielding (not shown)




„**Sectorisation**“: 12 cryomodules corresponding to appr. **144 m** supplied with 2 phase 2 K helium

Courtesy Bernd Petersen, DESY

# ILC type cryo-string (12 modules)

Table: distributed heat load of one cryomodule 12.2 m, (24 MV/m)

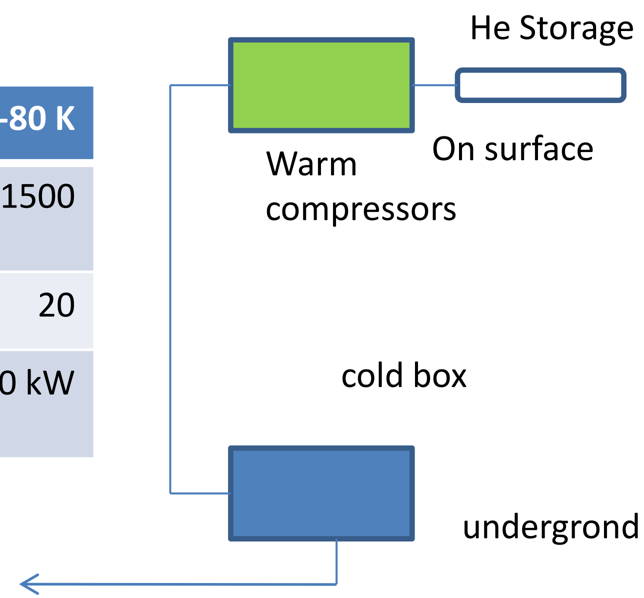
| Temp. level | 2 K | 5-8 K | 40-80 K |
|---|---|---|---|
| Static heat loads | 5 | 14 | 85 |
| Dynamic load (duty cycle 10 Hz) | 9 | 3 | 40 |
| Total (no contingency) | 14 | 17 | 125 |

...largest (rough) values of recent publications

These data may not fully apply to mini-ELFE injector. Detailed info is welcome.

Table: power cryo-string (12 modules)

| Temp. level | 2 K | 5-8 K | 40-80 K |
|---|---|---|---|
| Total 12 cryomodules | 170 W (8 g/s) | 200 | 1500 |
| COP (estimates) | 1200 | 300 | 20 |
| Total installed electric power (no contingency) | 200 kW | 60 kW | 30 kW |

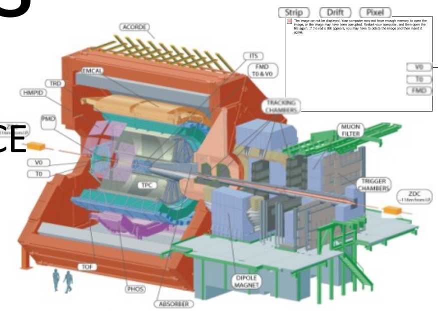


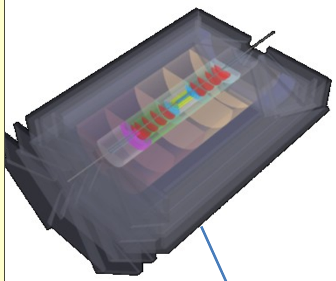
# Detector Cryogenics

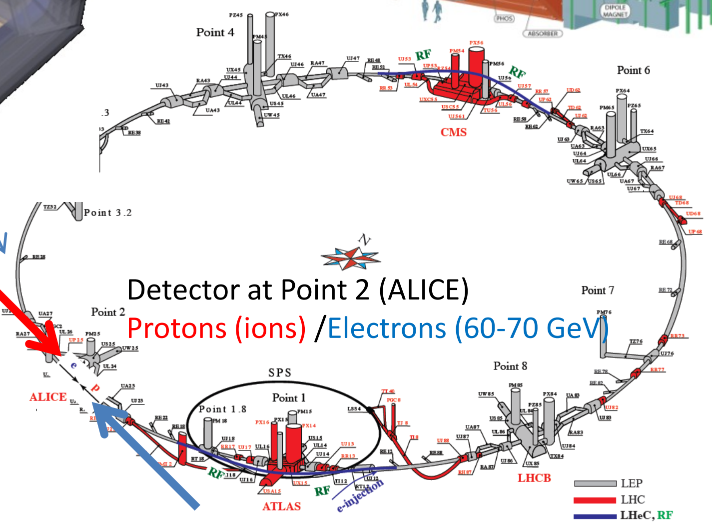
**Detector „cryo“ scenarios:**
- 1-2 CMS type solenoids or smaller diameter solenoids
- Integrated dipoles
- Small toroid
- Detector Insertion magnets (magnet design and choice depends on RR or LR version)

- LAr calorimer ?

New LHeC detector replacing ALICE

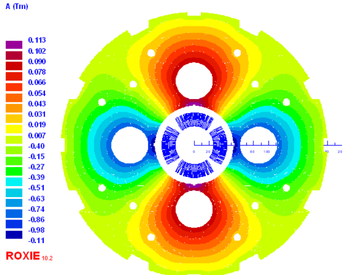


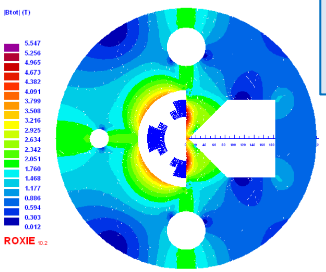





Detector at Point 2 (ALICE)
Protons (ions) /Electrons (60-70 GeV)

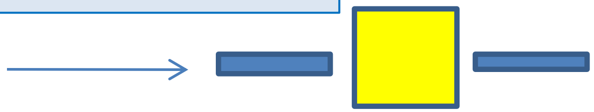
New LHC insertion magnets. Type depends on the version LR, RR. NbTi and Nb3Sn studies (Russenschuck). Cryostats = LHC dipole ones!!



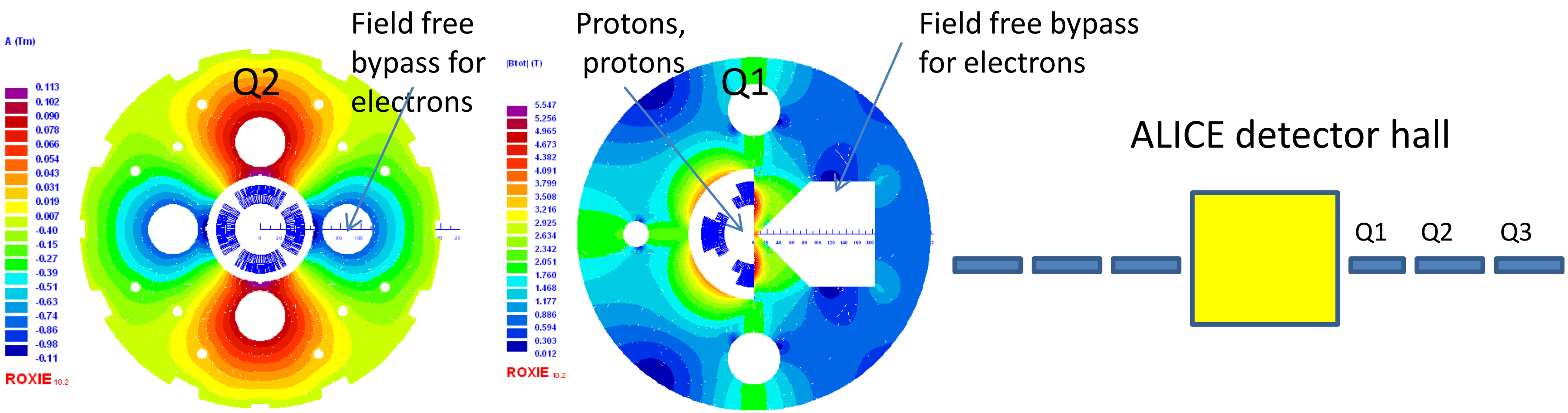

LHC insertion magnets (in Diploe cryostats, 1.8 K „typical“ bath cooling)

„ALICE“ detector hall



F.Haug, CRG, 1.12.2010

# LHC inner triplets: Q1 and Q2 (Russenschuck)

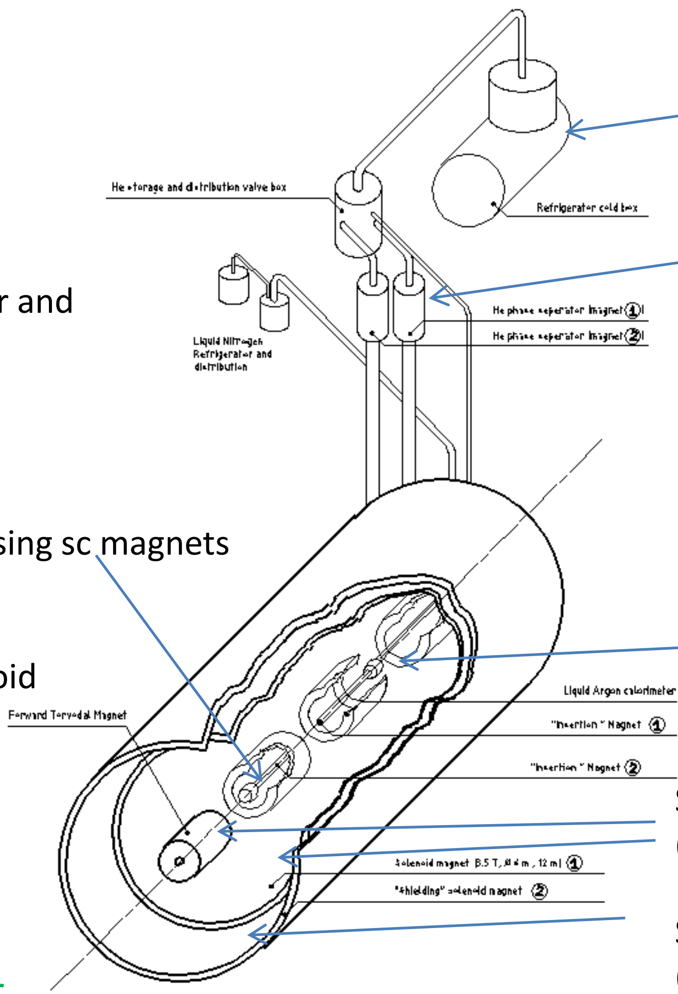



| | |
|---|---|
| NbTi: 6700 A, 248 T/m at 88% LL<br><br>Nb3Sn: 8600 A, 311 T/m, at 83% LL | NbTi: 4500 A, 145 T/m, 3.6 T at 87%<br><br>Nb3Sn: 5700 A, 175 T/m, 4.7 T at 82% on LL |
| 23 mm aperture, 87 mm septum | 46 mm (half) aperture, 63 mm septum (space for p and e-beams) |
| 0.03 T, 3.5 T/m in e-beam pipe<br><br>0.09 T, 9 T/m in e-beam pipe | 0.37 T, 18 T/m<br><br>0.5 T, 25 T/m |

New triplet magnets.
Depending on version R-R or L-R the magnets are different in design. Nb-Ti, 1.8 K for ring-ring and Nb3Sn, 4.2 K for linac-ring
However for cryo adaptation within range as comparable to triplet upgrade (studies Rob, Bruno...).

Cryostat can be identical to LHC dipoles.
Cooling 1.8 K static bath cooling with internal heat exchanger. Static heat load knons, thermal loads from beams not known yet.

# Detector Cryo lay-out




> 3 kW @ 4.5 K He refrigerator

He phase seperators

LN2 refrigerator and distribition

Studies on cooling principles for various systems required (thermosyphon, forced flow, superfluid?). Basic ideas ready.

„insertion" focusing sc magnets

3 LAr calorimeters

„forward" Toroid magnet

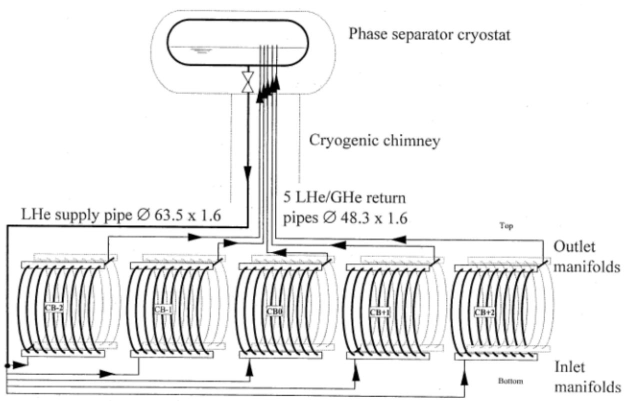
Sc solenoid ,Ø 6 m dia, 3.5 T (magnet 1)

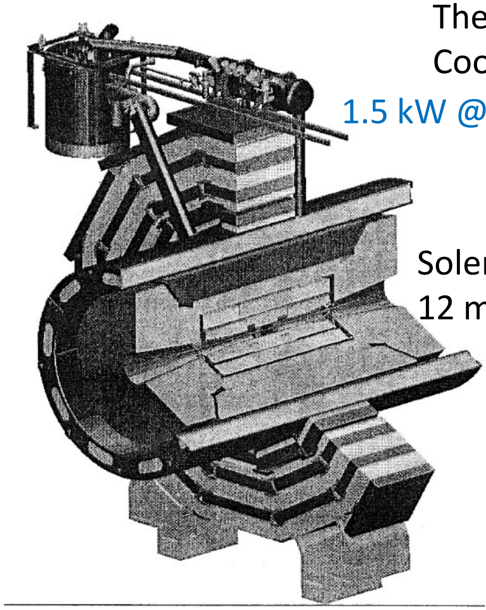
Sc Compensation solenoid, Ø 8 m?, 1.5 T (magnet 2)

*Great thanks to Sydney Bussard for drawings !*

# Challenge: mixture of CMS and ATLAS Cryo

## (however, on smaller scale than ATLAS, but larger than CMS)

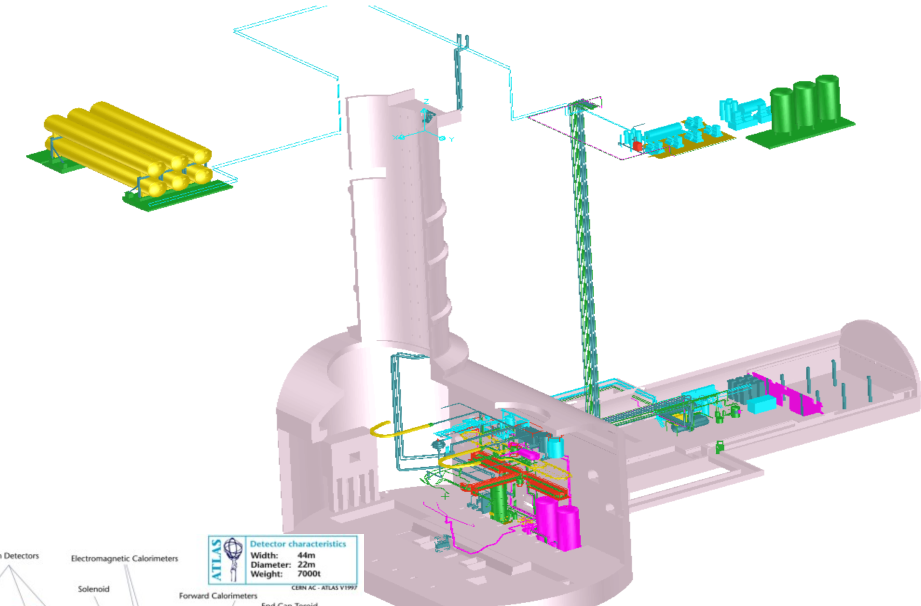


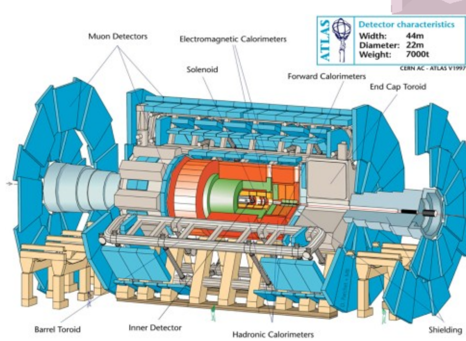



Thermosyphon
Cooling Principle

1.5 kW @ 4.5 K refrigerator

Solenoid 6 m diam.,
12 m length






Forced flow cooling !

<u>Refrigerators</u>

1. 6 kW @ 4.5 K main rerfrigerator
2. 20 kW @ 40-80 K shield refrigerator
3. 20 kW @ 80 K Nitrogen refrigerator

# Summary

- Linac-Ring (ERL) = extremely demanding on Cryo.
- Ring-Ring = integration problems in existing tunnel (space, radiation), but logic!

  Advantage for Cryo: Technically feasible and logic.
- Detector: Complex, but technically feasible.

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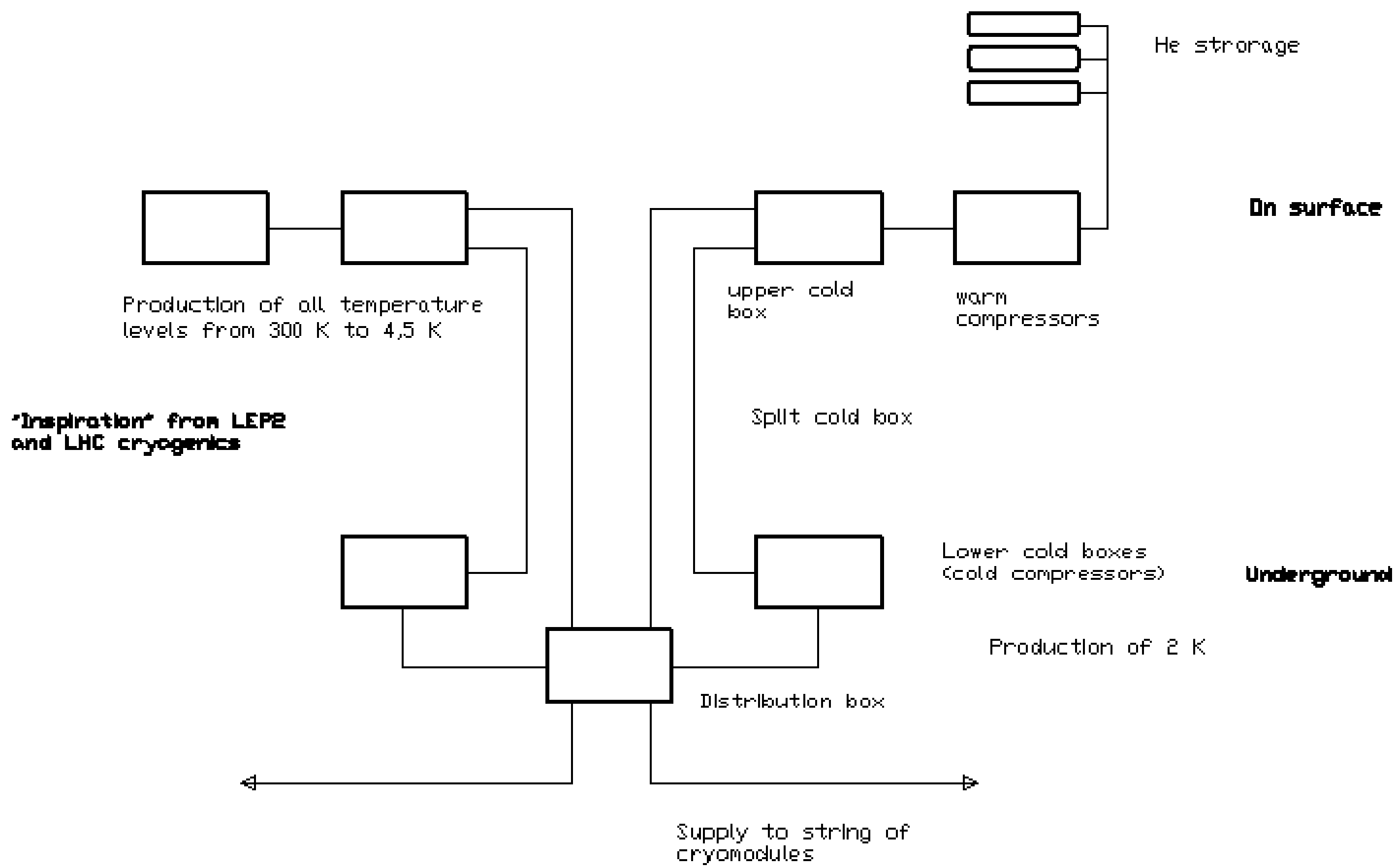
*Needs: information, technology (DESY, BNL, ...)*

*Follow-up: SPL cryomodules*

*Maybe later small R&D on the one or other subject depending on the outcome of next years „review“ of the CDR*

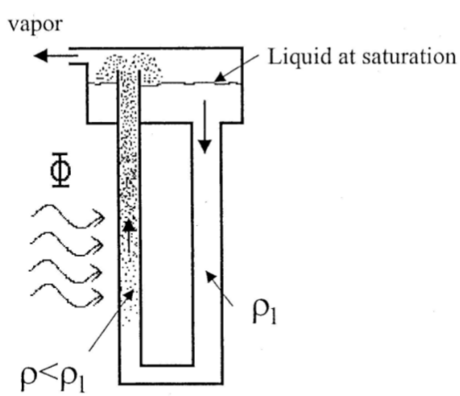
# Basic refrigerator lay-out



# CERN large sc Magnets Cooling principles

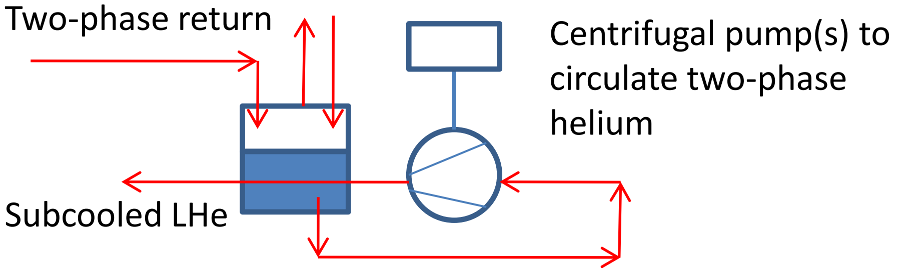
**Thermosyhon principle**

- Aleph Solenoid
- **CMS Solenoid**
- **ATLAS Solenoid**

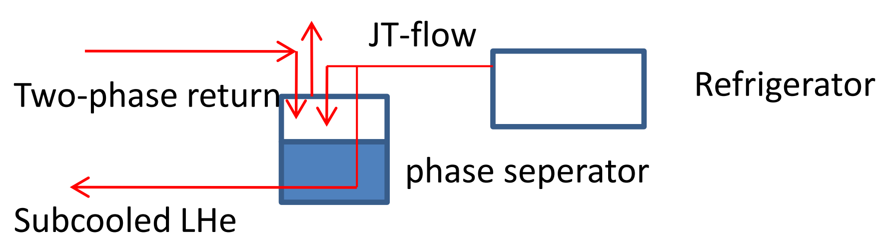



**Forced flow principle**

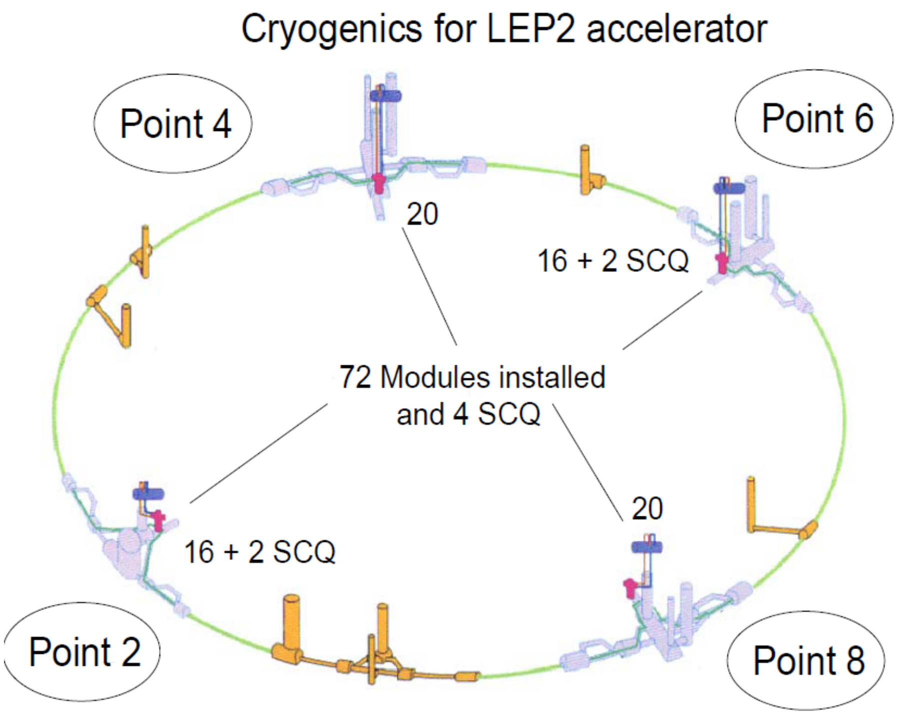
- **ATLAS Toroids (Barrel and two End Cap magnets)**




- **ATLAS Solenoid**



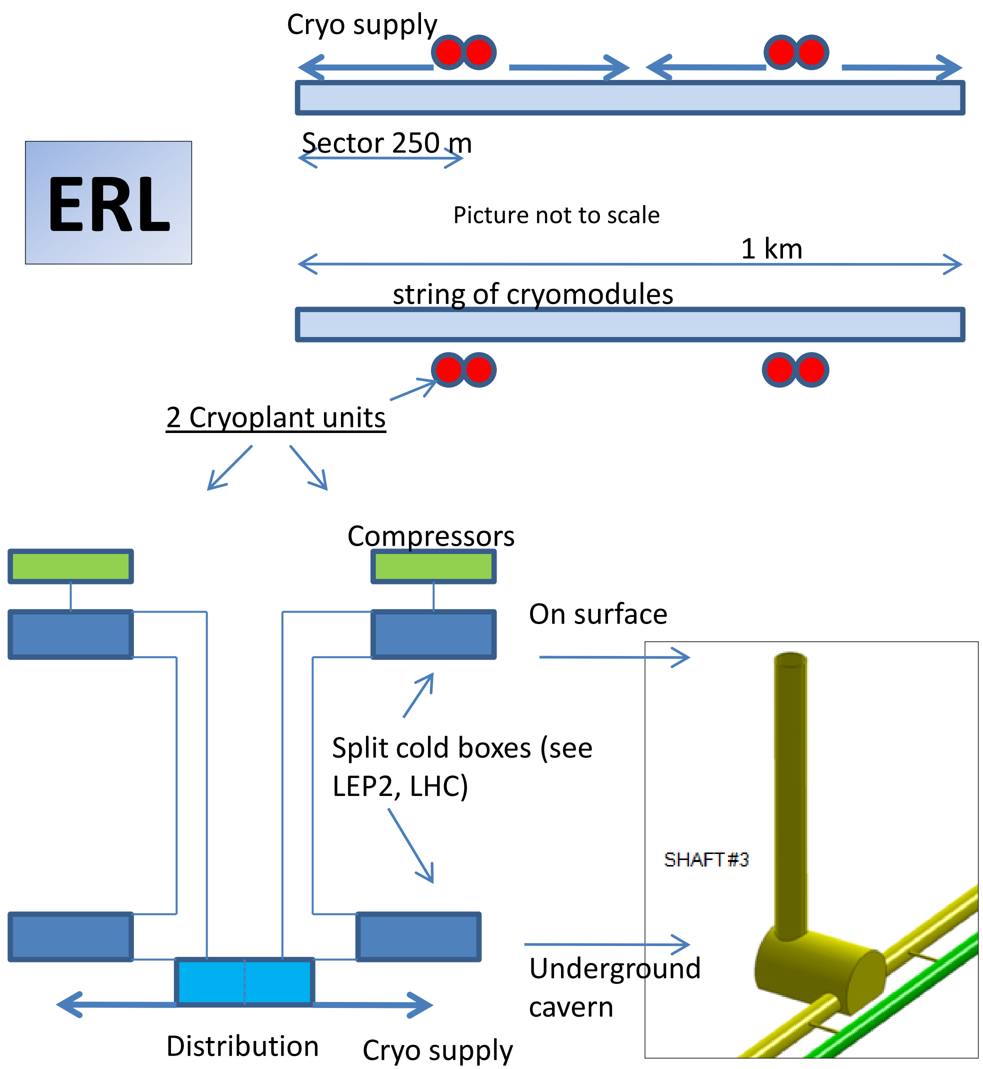
# LHeC R-R version / LEP2

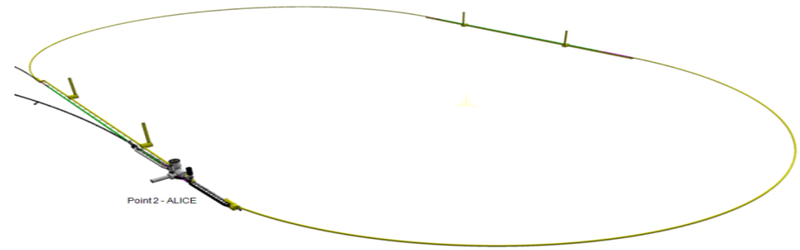



**LEP2**:
**4 x 12 kW @ 4.5 K**

**LHeC R-R** version:
**2 x 3 kW @ 4.5 K**
**Or 2 K version with SPL type cavities**
Challenge for LHeC is considerably smaller in terms of istalled power

# Linac-Ring Cryogenics (basics)




CW operation, 18 MV/m
2 K thermal load: 37 W/m (for active length)
2 K total thermal load: 42 kW @ 2 K
Electric power: 30 MW
(with a COP of 700)

Cooling requirements dominated by dynamic losses at 2 K (other loads neglected here for simplicity)

Lay-out is based on LHC cryogenic principles with split cold boxes (surface cold box and underground cold box with cold compressors).

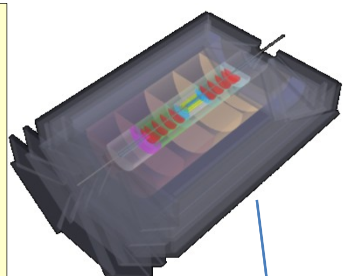
Refrigerator units of approx. 5 kW @ 2 K assumed. To be designed. Technology and experience: LHC, CEBAF (JLAB).

# CDR for LHeC

Objective: New Physics at LHC beyond 2025 with Collission of Electrons on Protons and Heavy Ions

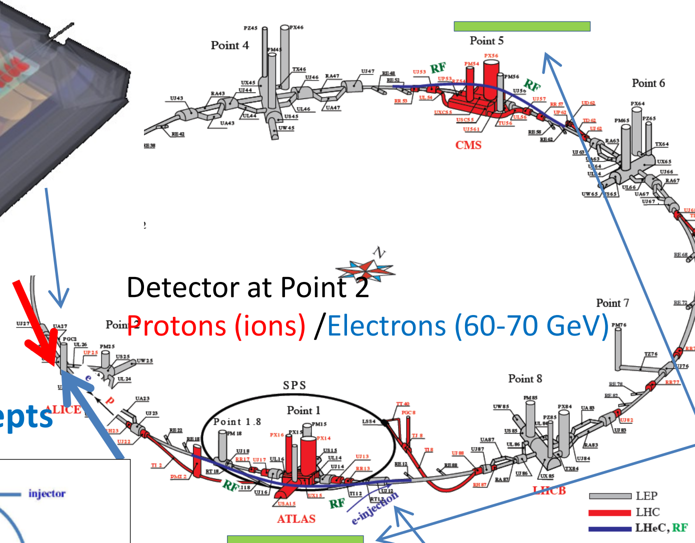
***CDR design studies: varios accelerator scenarios, one detector***

**Detector „cryo" scenarios:**
•1-2 CMS type solenoids or smaller diameter solenoids
•Integrated dipoles
•Small toroid
•Insertion magnets
•LAr calorimeter?



**Accelerator scenarios:** For the electron accelerator two main versions are studied

1. **Linac-Ring version (L-R)**
2. **Ring-Ring version (R-R)**



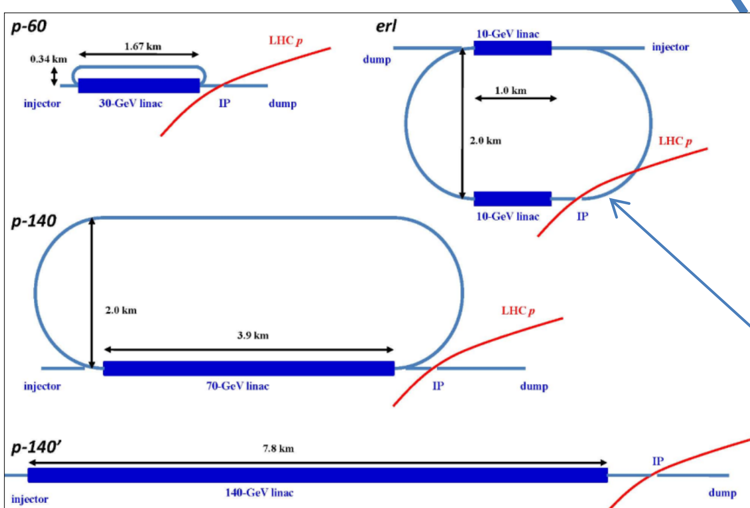

Detector at Point 2
Protons (ions) /Electrons (60-70 GeV)

For the Ring-Ring version the LHC tunnel is used. Normal conducting magnets „on top" of LHC magnets.

2 sc accelerating areas (ATLAS, CMS) in by-passes.
Cryomodules scenarios
1. LHC type at 4 K
2. „SPL" type at 2 K

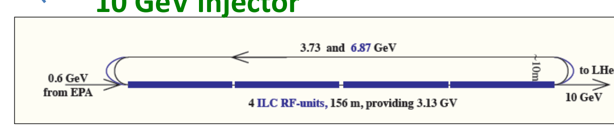
10 GeV recirculating injector
ILC (XFEL) type cryomoduls at 2 K

**1. Linac-Ring: Varios Linear collider concepts**




Favorite ERL. Recirculating Energy Recovery Linac. 60 GeV. Cryomodules CW operation. Large heat load at 2 K requiring cooling capacity of approx. 42 kW @ 2 K

**10 GeV injector**

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