



**TLEP cryogenics  
first presentation:  
Review of Cryogenics for the Large Hadron  
Collider Electron Collider (LHeC)**

**Friedrich Haug**

**CERN**

**TE-CRG**



# Motivation for LHeC review

Frank:

„TLEP RF systems parameters similar to LHeC Linac-Ring (ERL) version“

i.e.

- Similar total integrated Voltage
- Similar (same) gradient
- Similar (same)  $Q_o$



# Two e-accelerator versions: Ring-Ring, Linac-Ring



LHeC = ADD-ON new facility.  
Maintain existing LHC functionality.

LHC collider

CMS

LHCb

Linac-Ring  
(ERL)

Ring-Ring

LHeC  
Detector

ATLAS

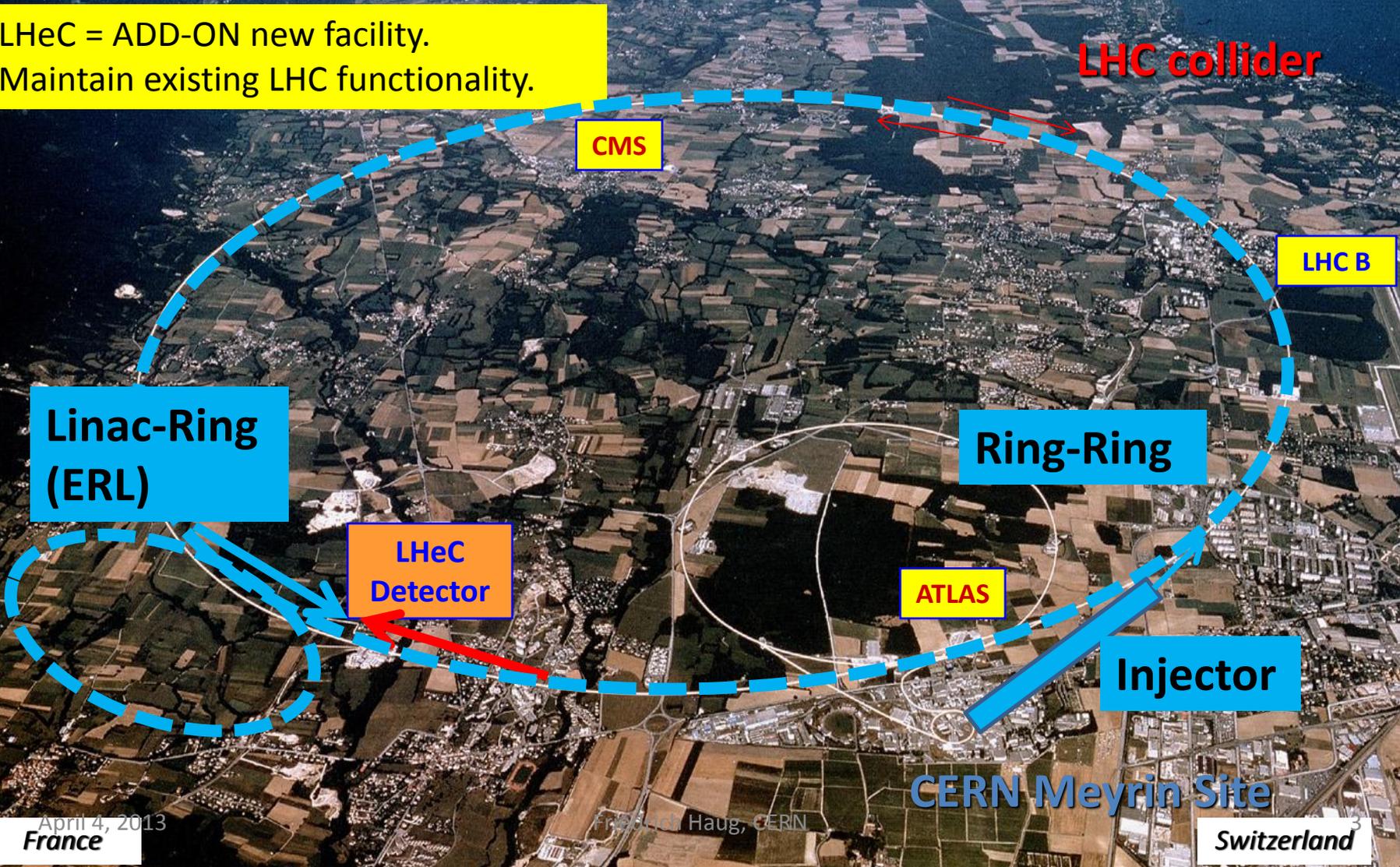
Injector

CERN Meyrin Site

Fredrick Haug, CERN

Switzerland

April 4, 2013  
France





# Ring-Ring Cryogenics

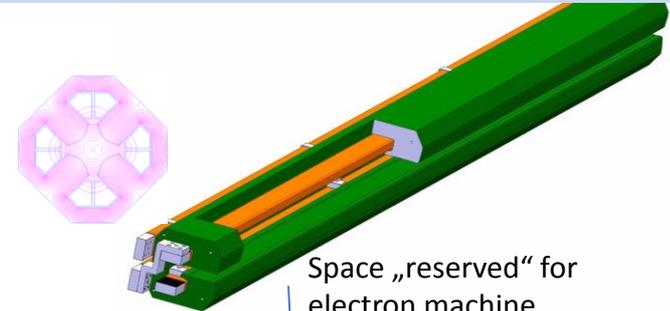
Principle: use LHC tunnel for additional new electron Ring accelerator

Superconducting cavities for acceleration

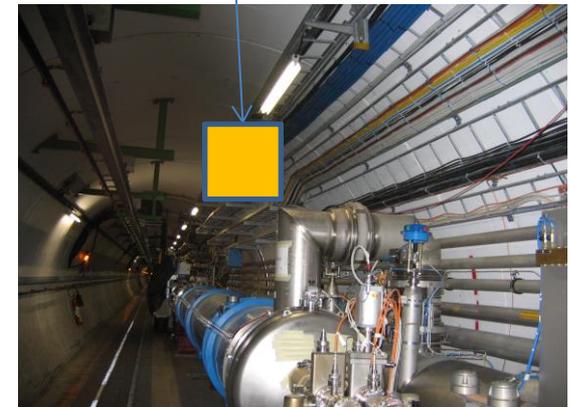
Normal conducting low-field magnets to guide electrons of 60 GeV

CMS by-pass String of cryomodules

cryoplant



Space „reserved“ for electron machine...

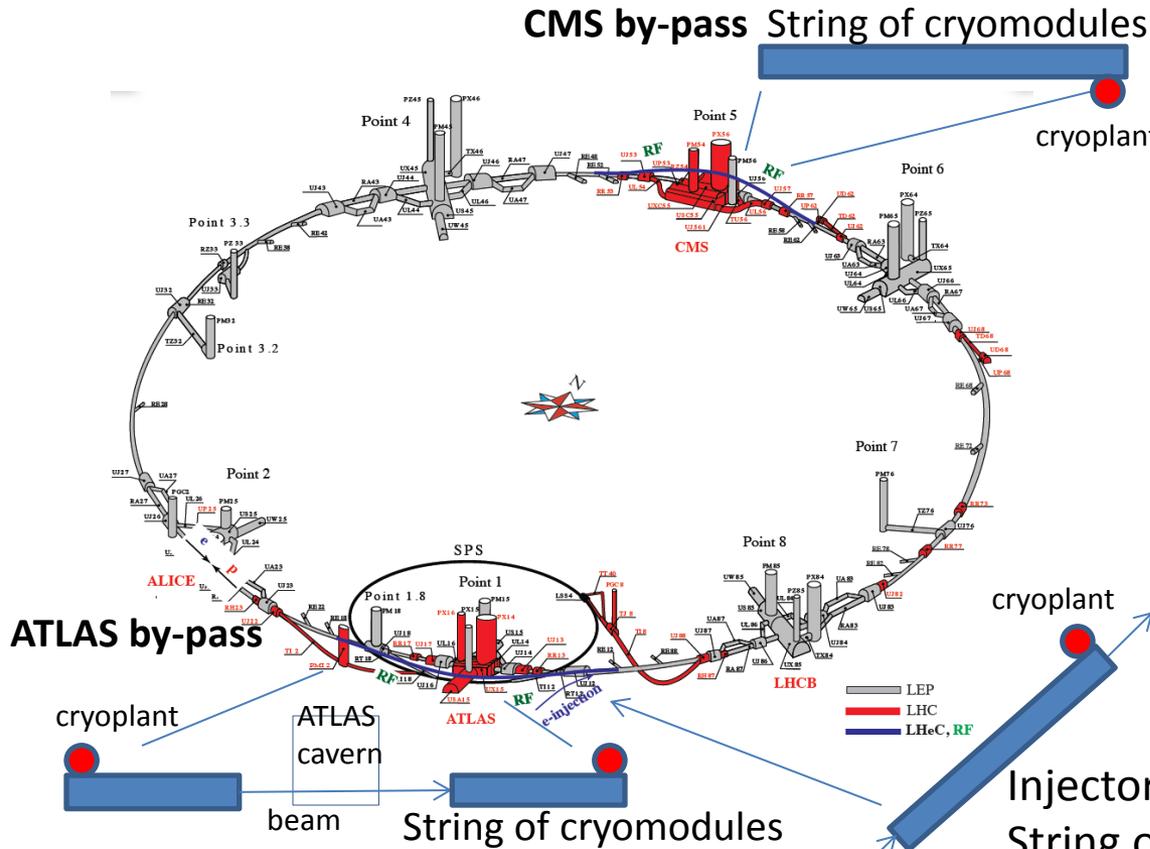


LHC 27 km tunnel

cryoplant

Injector;  
String of cryomodules

Friedrich Haug, CERN



April 4, 2013



# Ring-Ring Cryogenics



## SC Cavities for the bypasses

2-cell	721 MHz
Length	0.42 m
Acc. Field	12 MV/m
Operation	CW mode
Operation temp.	2 K
Dissip.	4 W

## Cryomodules

nr. of cavities	8
Length	10 m

## Location and number of cryomodules

CMS side	8
ATLAS left	3
ATLAS right	3

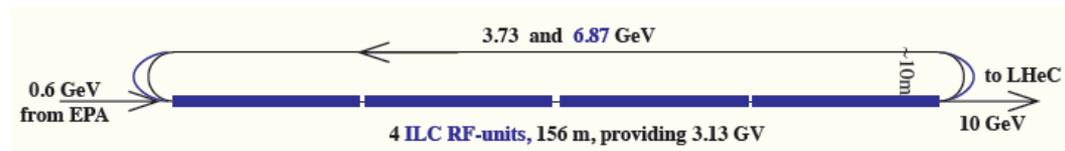
## SC Cavities for the Injector

9-cell	1.3 GHz
(ILC/XFEL type)	
Length	1 m
Acc. Field	23 MV/m
Operation	pulsed mode

## Cryomodules

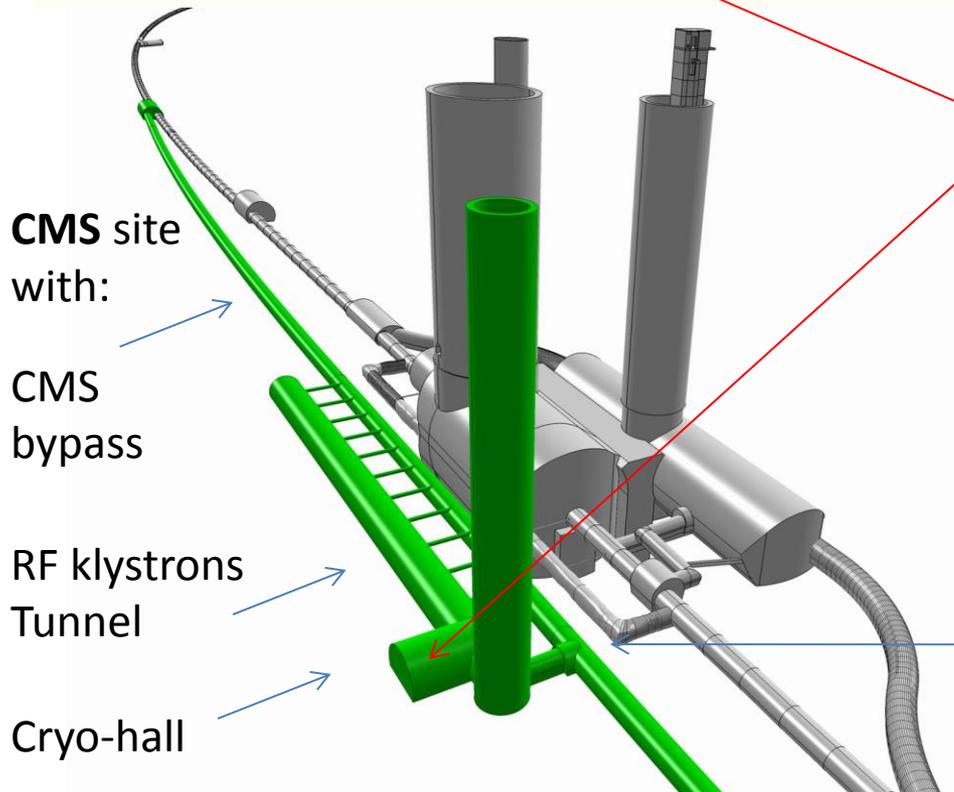
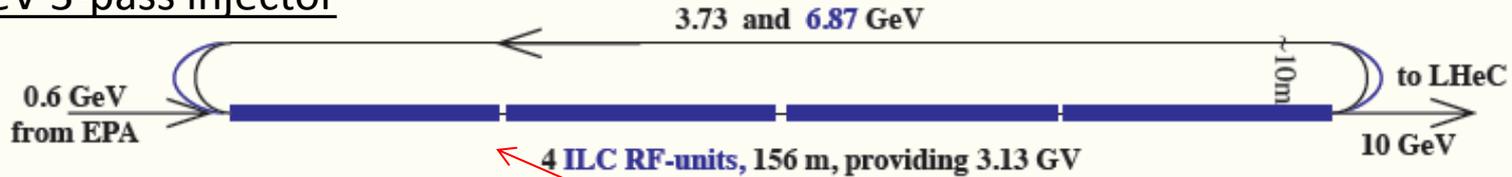
nr. of cavities	8
Length	12.2 m
Nr. of modules	12

*(exact copy of XFEL)*



# Ring-Ring Cryogenics

10 GeV 3-pass injector

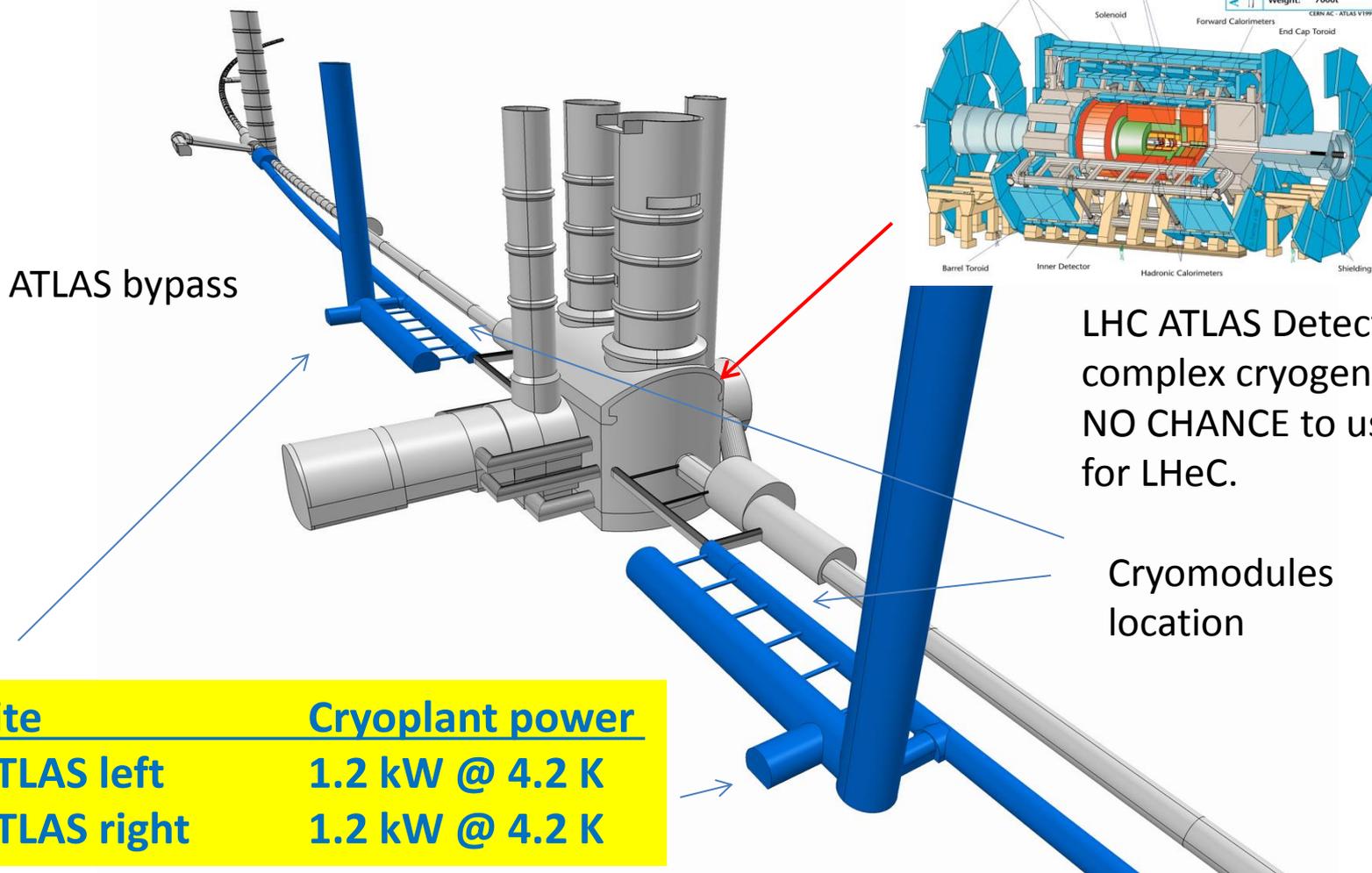


Site	Cryoplant power
Injector	2.0 kW @ 4.2 K
CMS	3.0 kW @ 4.2 K
ATLAS left	1.2 kW @ 4.2 K
ATLAS right	1.2 kW @ 4.2 K
<b>2 K operation of cryomodules</b>	

Acc. String with 8 cryomodules



# Ring-Ring Cryogenics





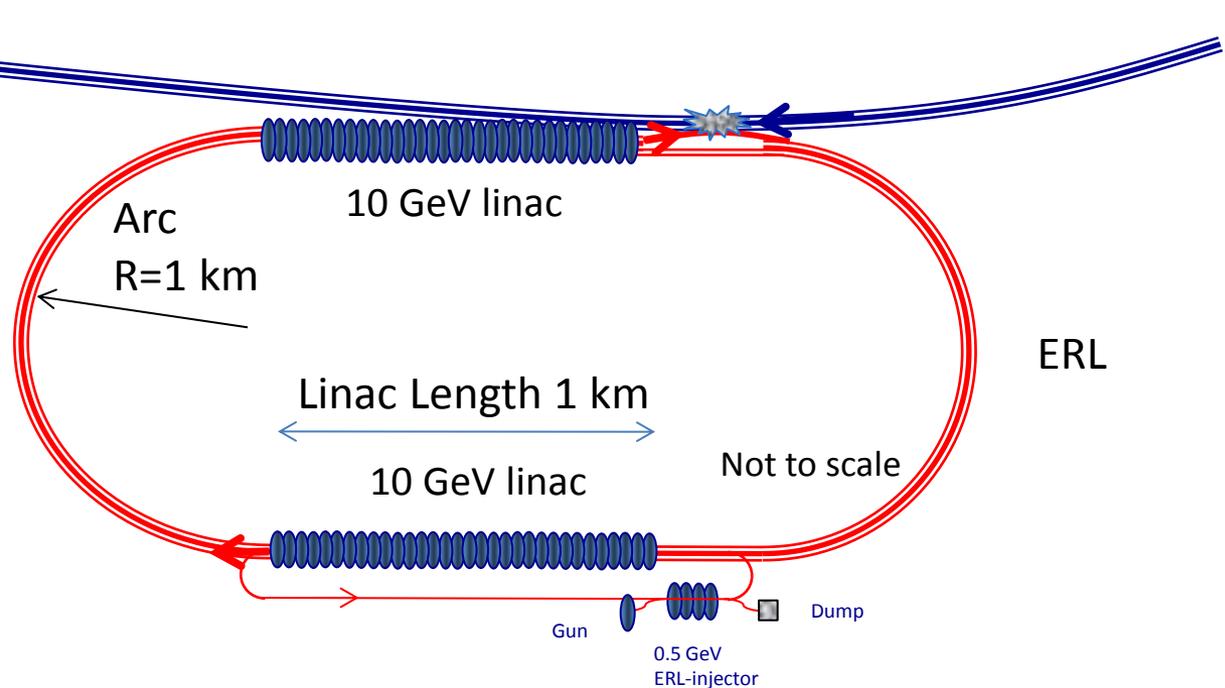
# Linac-Ring Cryogenics (ERL)

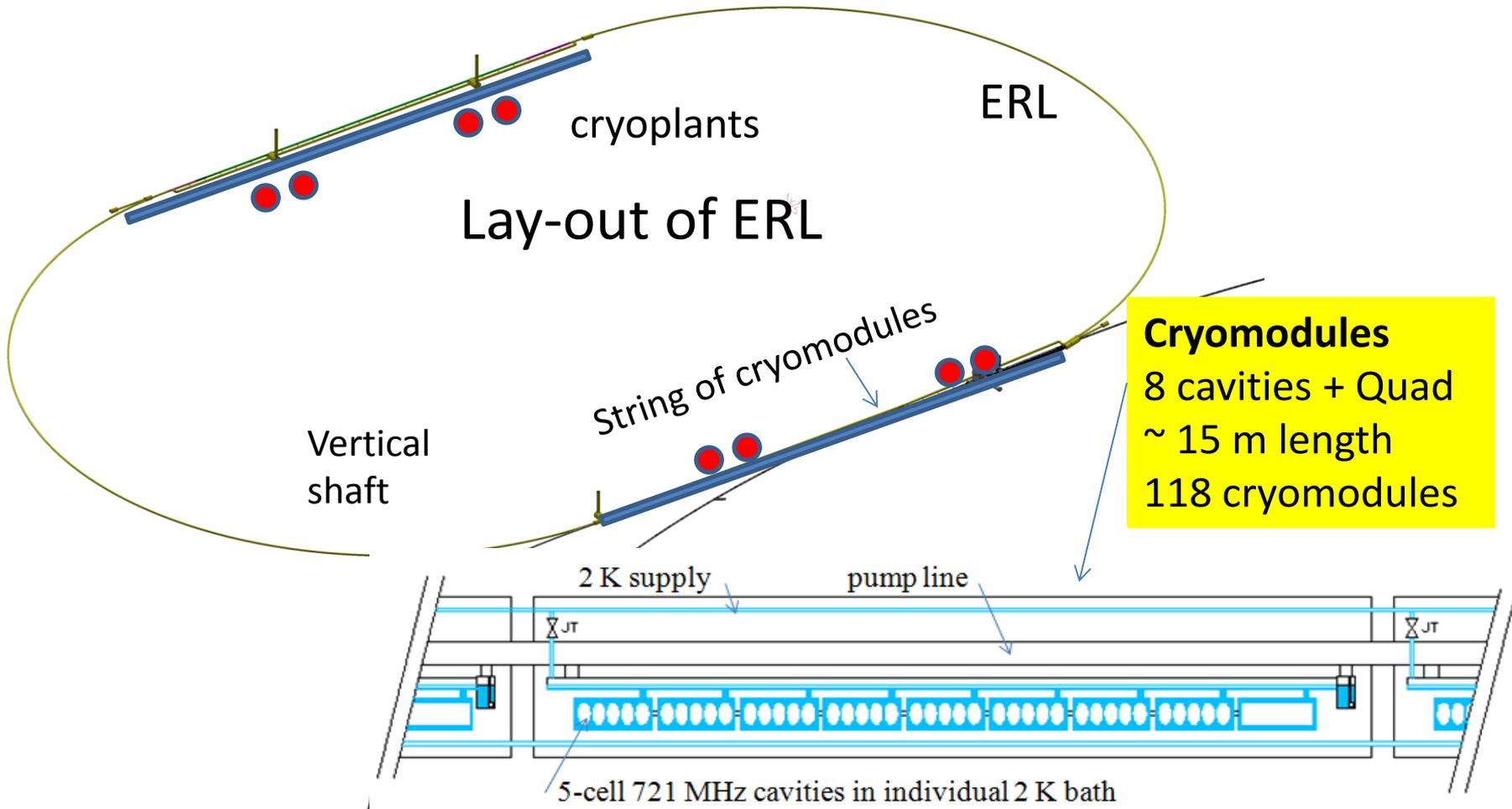
## Racetrack

Energy Recovery Linac  
2 linacs 1 km length  
6-pass, 60 GeV, 8 mA

## Cavities

5-cell 1.04m length  
721 MHz, CW operated  
Power diss. 32 W @ 2K  
for 21.2 MV/m





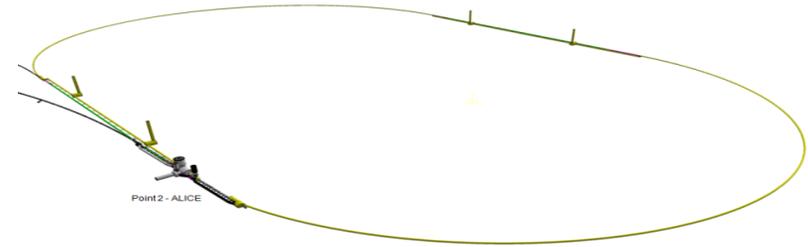
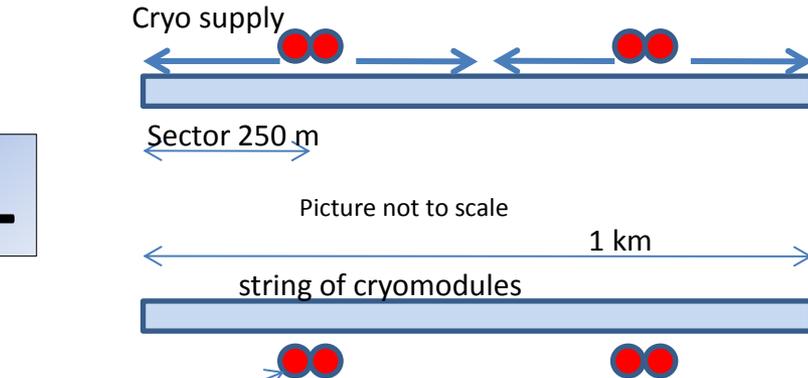
Proposed cryomodule configuration (cryostat similar to XFEL)



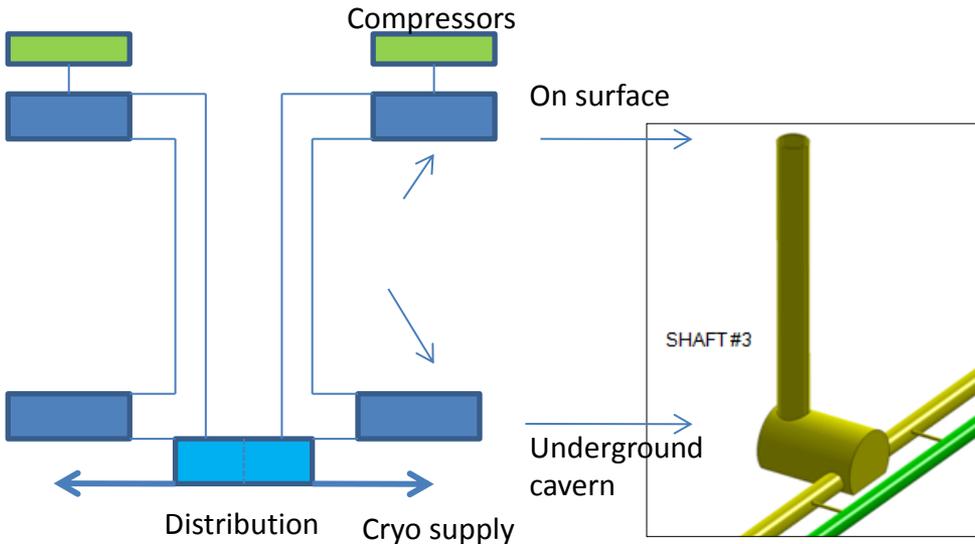
# Linac-Ring Cryogenics



**ERL**



2 Cryoplant units



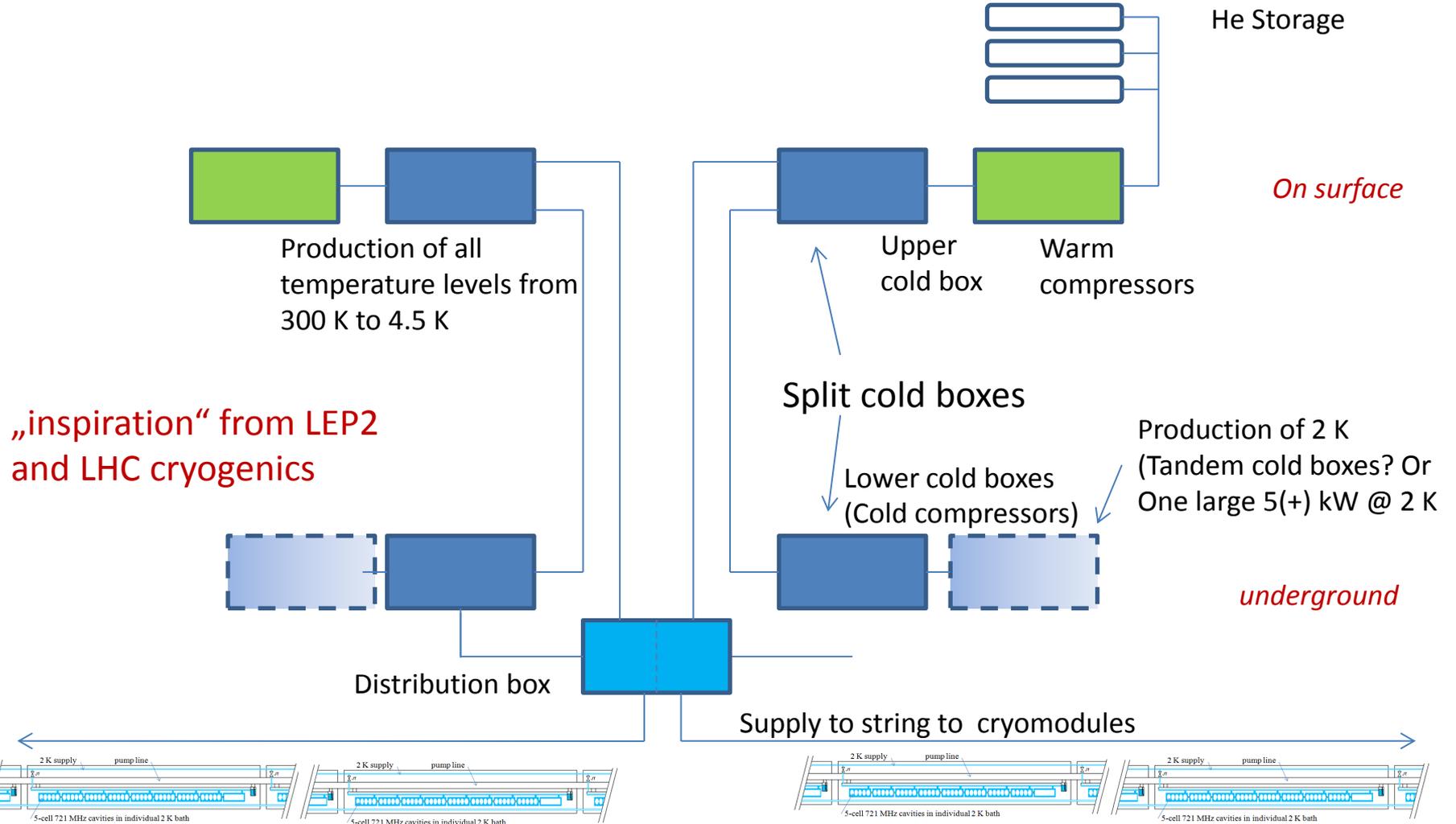
Cooling requirements dominated by dynamic losses at 2 K (other loads neglected here for simplicity)

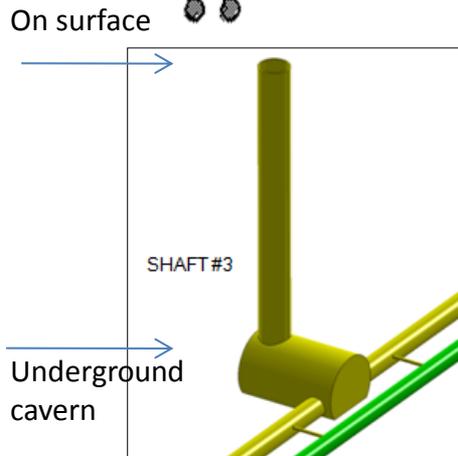
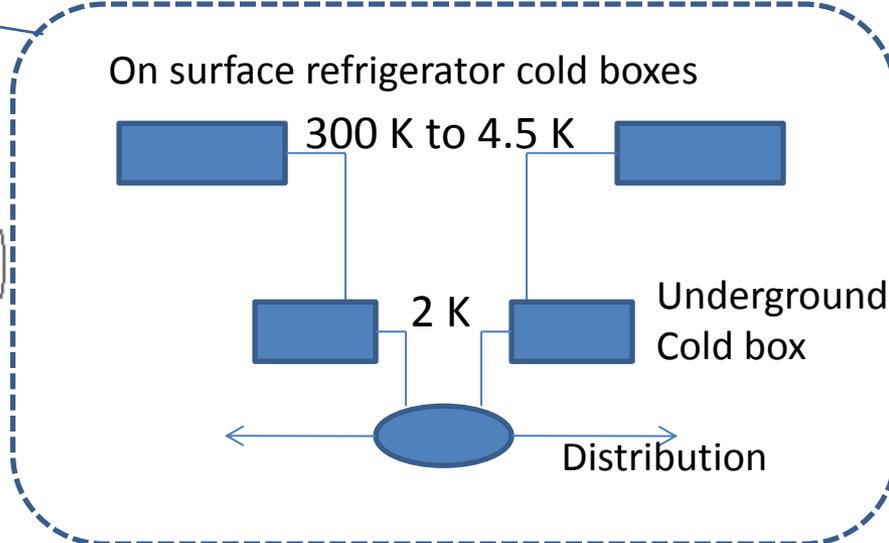
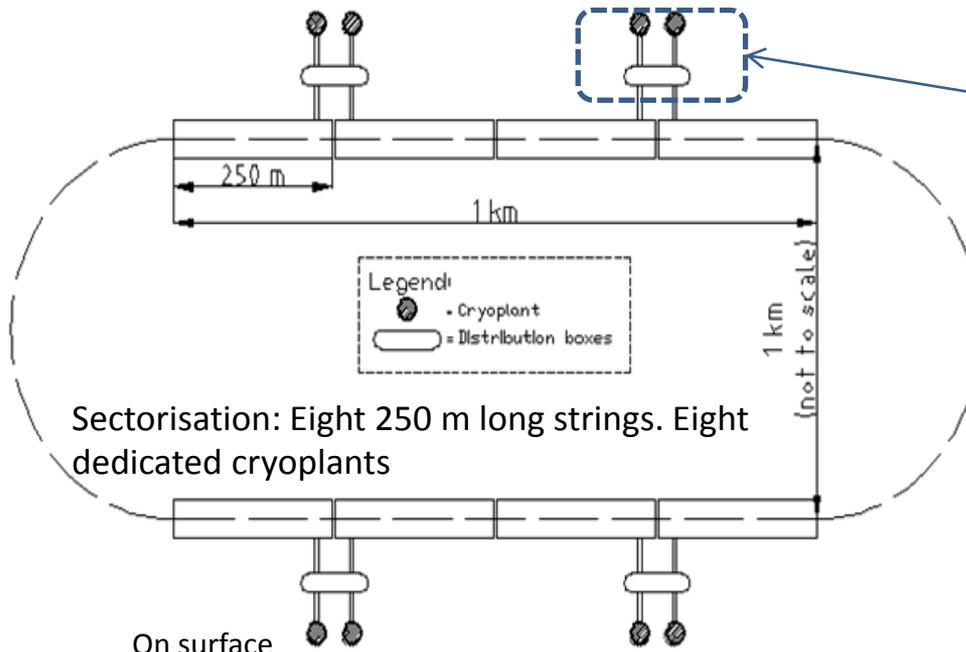
Lay-out is based on LHC cryogenic principles with split cold boxes (surface cold box and underground cold box with cold compressors).

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



# Basic refrigerator lay-out





Split cold boxes (see LEP2, LHC (4.2K on surface, 2K in tunnel)

Total (minimum) cooling power;  
**84 kW @ 4.2 K** (no contingency)  
**Cryoplants proposed**  
**8 x 10.5 kW @ 4.2 K**  
 R&D cavities ongoing.  
 Expectance improved Q values....



# Summary Parameters (CDR)



Parameter	Value
Two linacs	length 1 km
5-cell cavities	length 1.04 m
Number	944
Cavities/ cryomodule	8
Number cryomodules	118
Length cryomodule	14 m
Voltage per cavity	21.2 MV
R/Q	285 $\Omega$
Cavity $Q_0$	$2.5 \cdot 10^{10}$
Operation	CW
Bath cooling	2 K
Cooling power/cav.	32 W @ 2 K
Total cooling power (2 linacs)	30 kW @ 2 K



# Summary Parameters (CDR)



Parameter	Value
Number of Refrigerators	8
1/COP @ 2 K	700
Minimum cooling capacity/refrigerator	10 kW @ 4.5 K
Contingency	none
Minimum total cooling power	80 kW @ 4.5 K
Grid power consumption	21 MW

# Comparison

## LEP2

4 Acc points. 4 Cryoplants 12 kW @ 4.5 K.

4.5 K bath cooling (already split principle). Upgraded later for use at LHC...

## LHC

8 Cryoplants 18 kW @ 4.5 K + 8 cold boxes 1.8 K. Largely for LHC sc magnet cooling at 1.9 K. Grid power consumption appr. 40 MW (with ATLAS and CMS detector cryoplants)

## LHeC

**Ring-Ring version:** 2 acceleration points (IP 1, 5), 4 cryoplants,

2 K bath cooling, total < 8 kW @ 4.5 K

**Linac (ERL)-Ring version:** 2 accel. strings 1 km each. 8 cryoplants

2 K bath cooling, 8 x 10 kW @ 4.5 K. Grid power consumption appr. >21 MW

## TLEP

....homework....

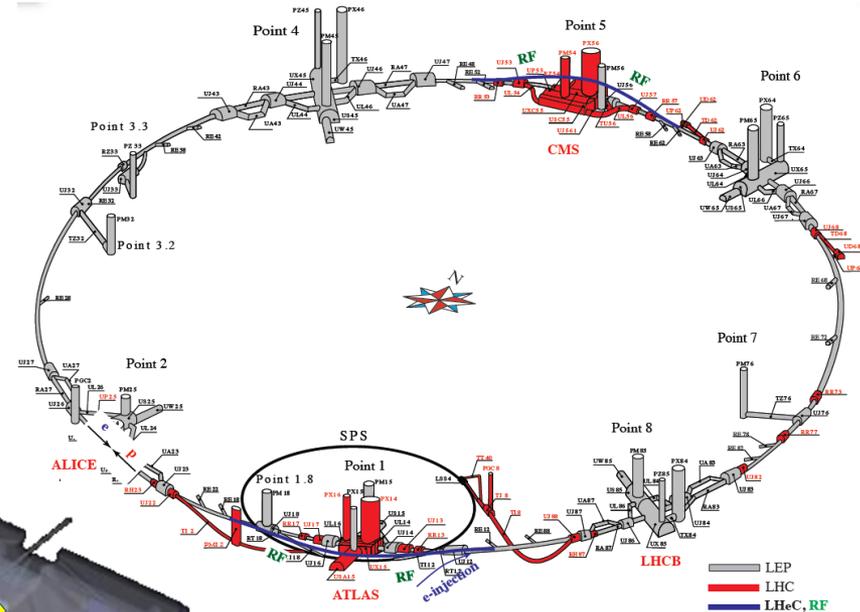
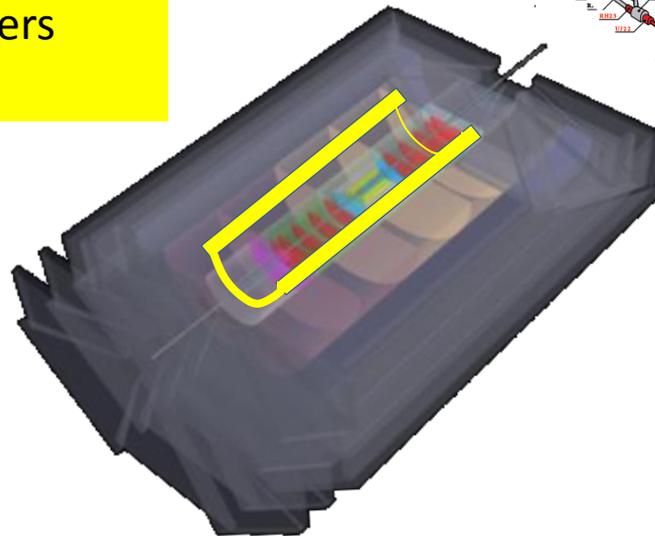


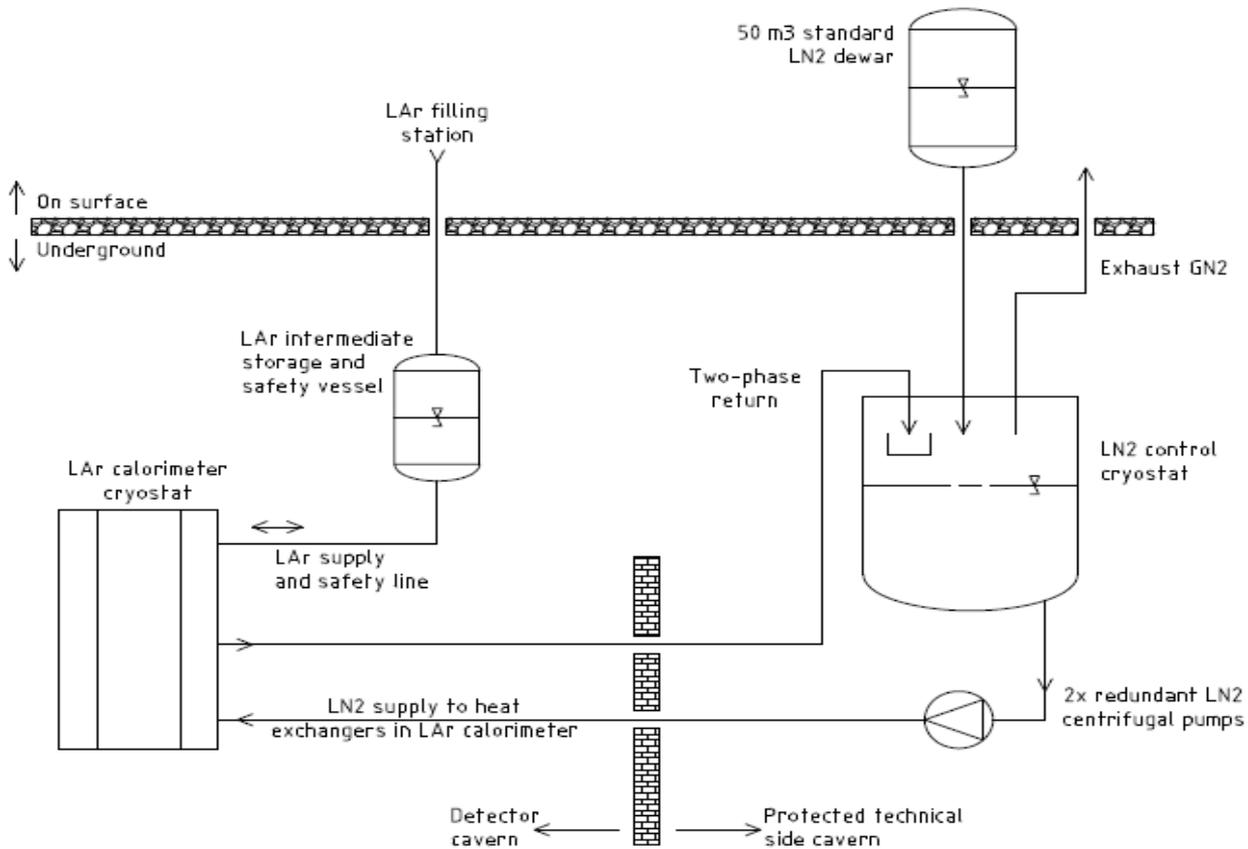
# Detector Cryogenics



SC solenoid (3.5 T) and two  
dipoles on one support  
cylinder  
diam. 2 m, 9.5 m length  
Cryoplant: 300 W @ 4.5 K

Liquid Argon calorimeter  
12 m<sup>3</sup>  
1/8 of Atlas Calorimeters  
Volume (all 3)





## Liquid Argon Calorimeter

### Principle flow-scheme of the LN2 (87 K) cooling system

LN2 Cryostat and phase separator

Redundant centrifugal pumps

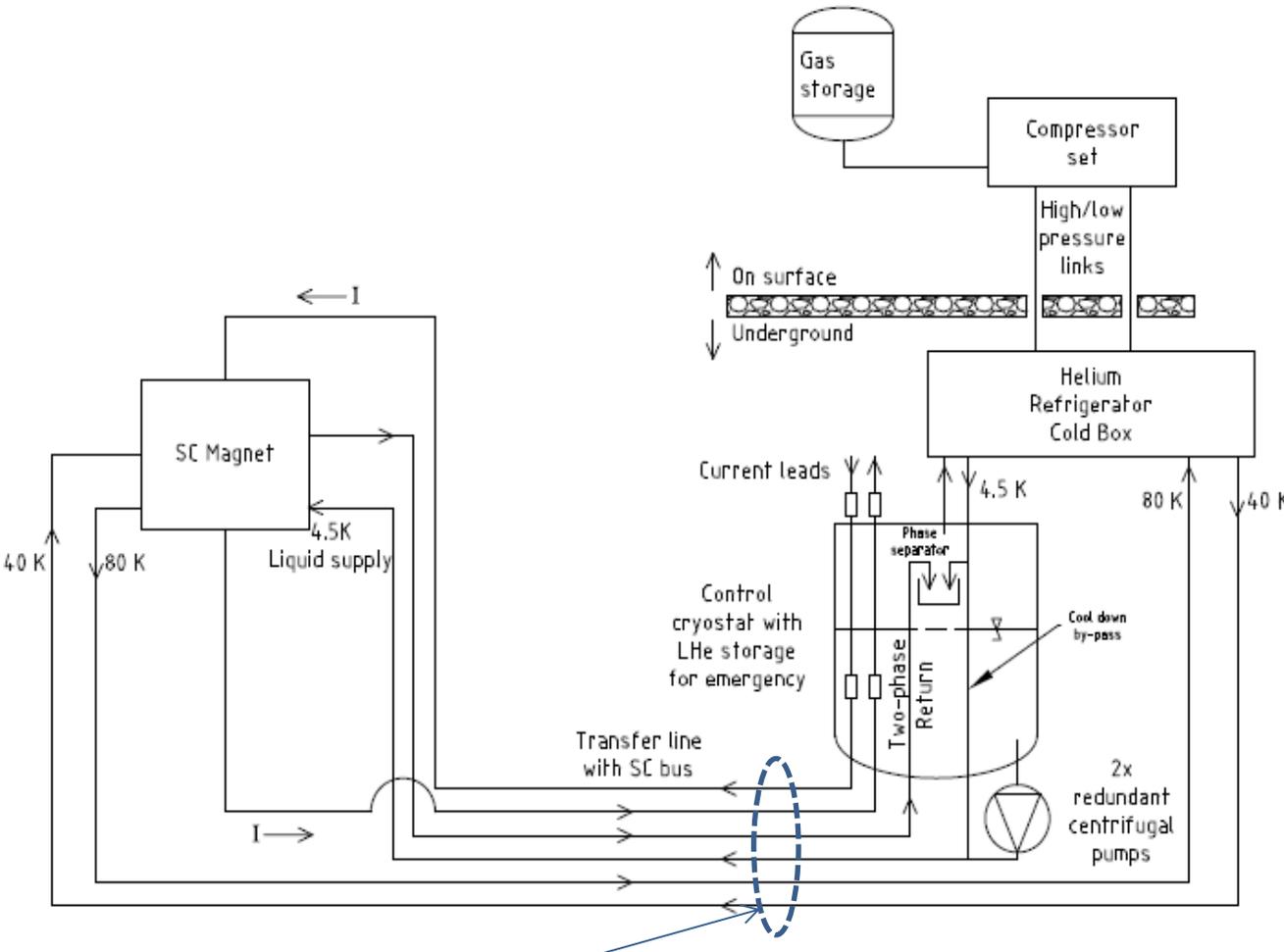
## SC Solenoid and dipoles

### Principle flow-scheme

He Cryostat and phase separator

Redundant centrifugal pumps

Similar to Atlas Test Facility H180



SC bus integrated in transfer line