HE-LHC'10

Using LHC as Injector and Possible Uses of HERA Magnets/Coils,

or the Accelerator Flee-market

Outline

- List of important parameters for both machines/dipoles
- Use of the LHC magnets
- Use of the HERA magnets
- Summary and conclusions

List of parameters

Machine	LHC [1]	HERA [2]
Circumference	26.7 km	6.4 km
# of main bends	1232	422
Magnet length	14.3 m	8.9 m
Field	0.535...8.33 T	0.227...4.649 (5.216) T
Current	763...11850 A	245...5027 (5640) A
Beam energy	450...7000 GeV	40...820 (920) GeV
Bending radius	2804 m	588 m
Sagitta	9.14 mm	14.4 mm
Inner coil diameter	56 mm	75 mm
Cold tube diameter	50 mm	55.3 mm
Nom. dI/dt	10 A/s	10 A/s
Tunnel diameter	3.76 m	5.20 m

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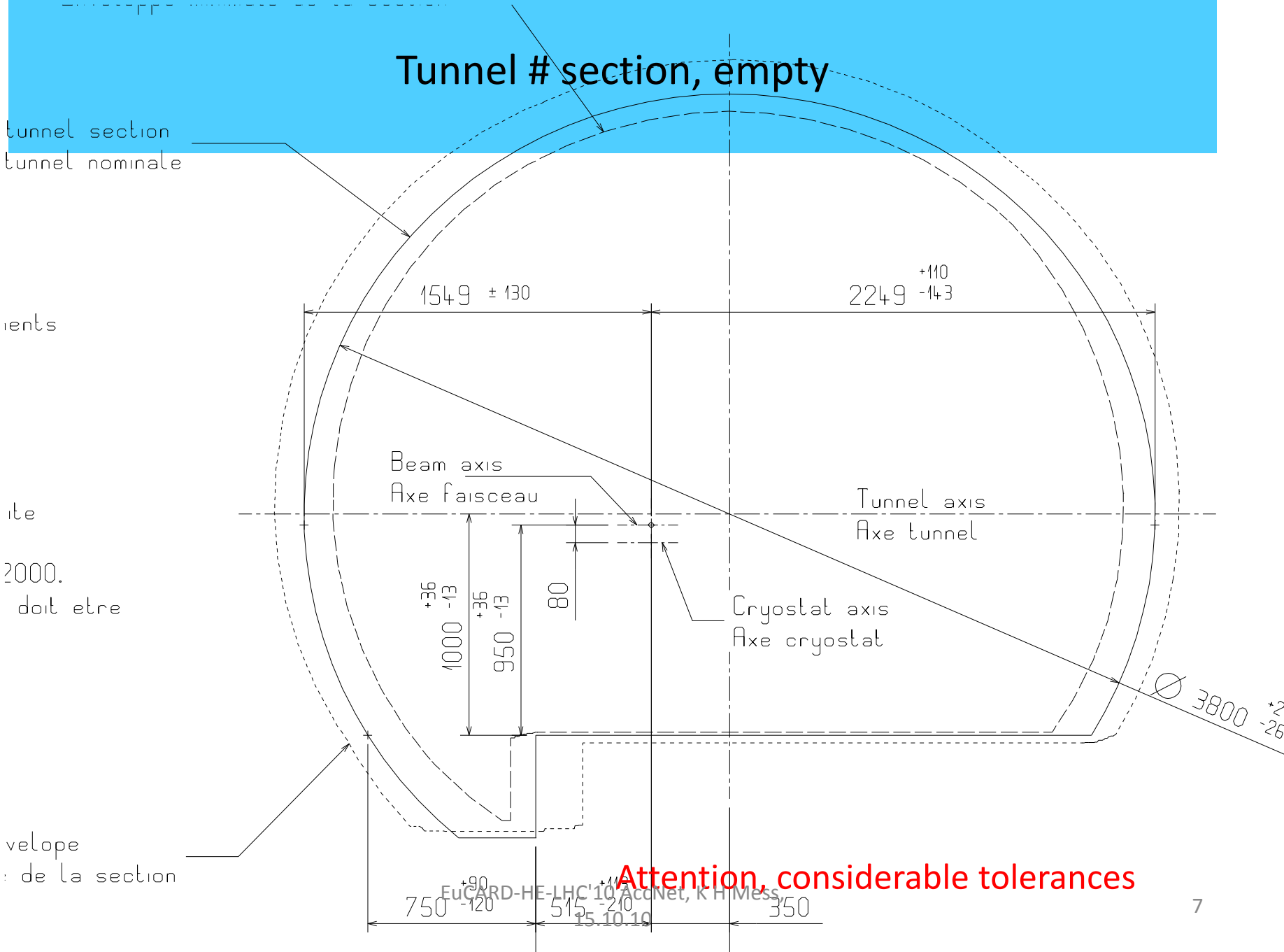
$$|B\,[T]| = \frac{\beta \cdot E\,[GeV]}{0.2998 \cdot \rho\,[m]}$$

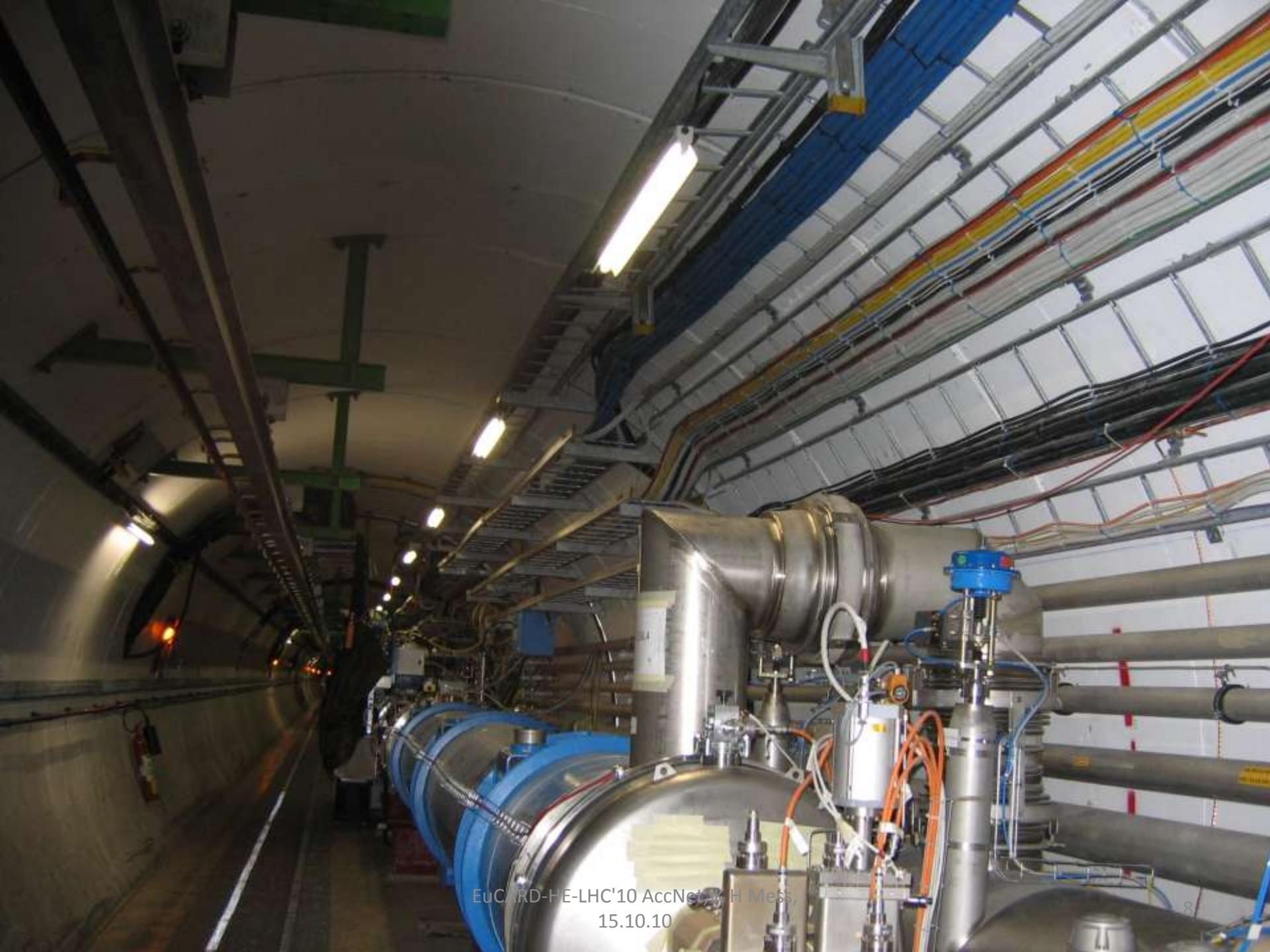
LHC

- The radius of curvature is so large that the magnets fit only into a LEP-size tunnel i.e. the LHC.
- Does the “old” LHC and the HE-LHC fit both in the tunnel?

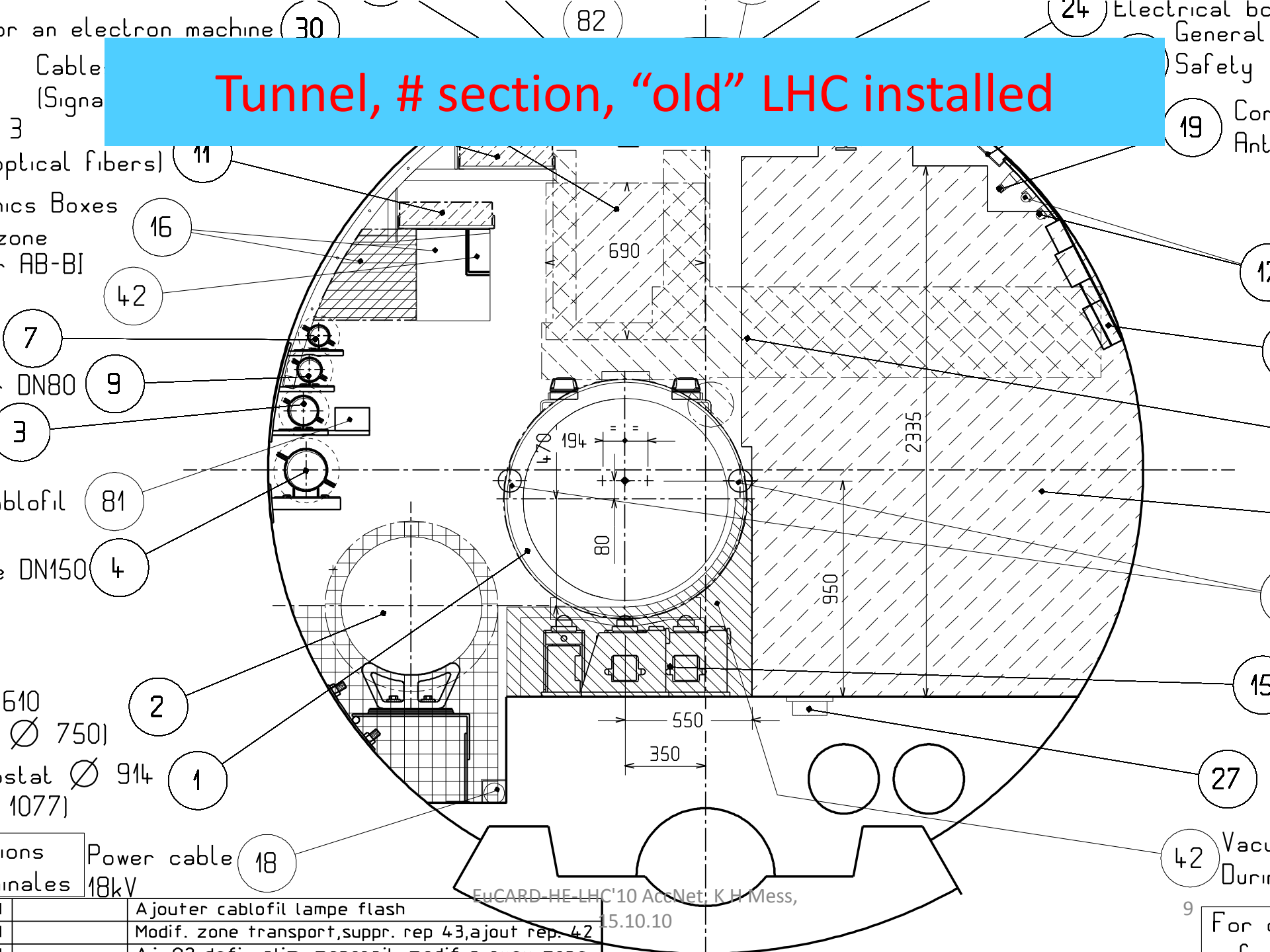
Tunnel # section, empty



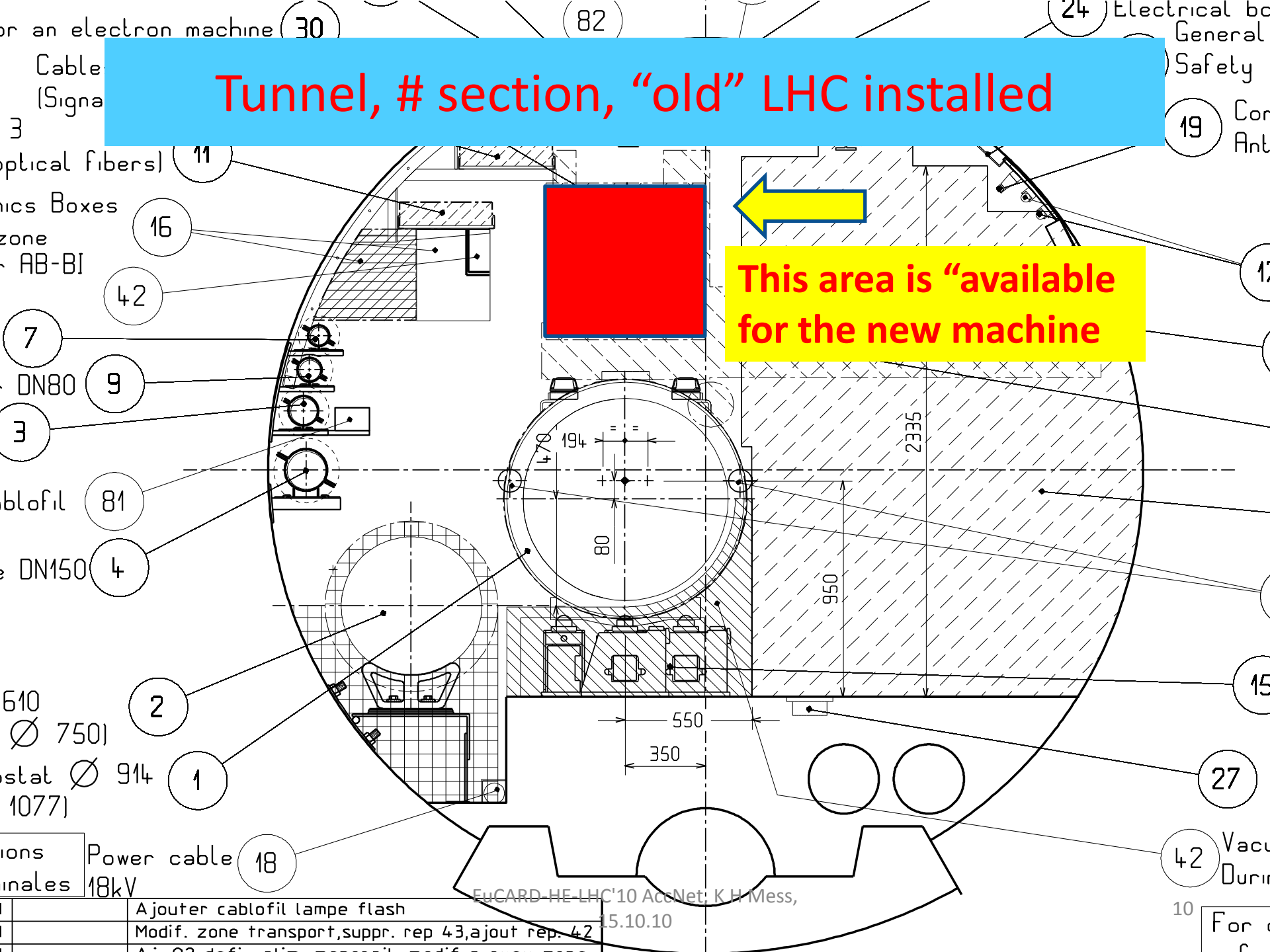
Attention, considerable tolerances



Tunnel, # section, “old” LHC installed



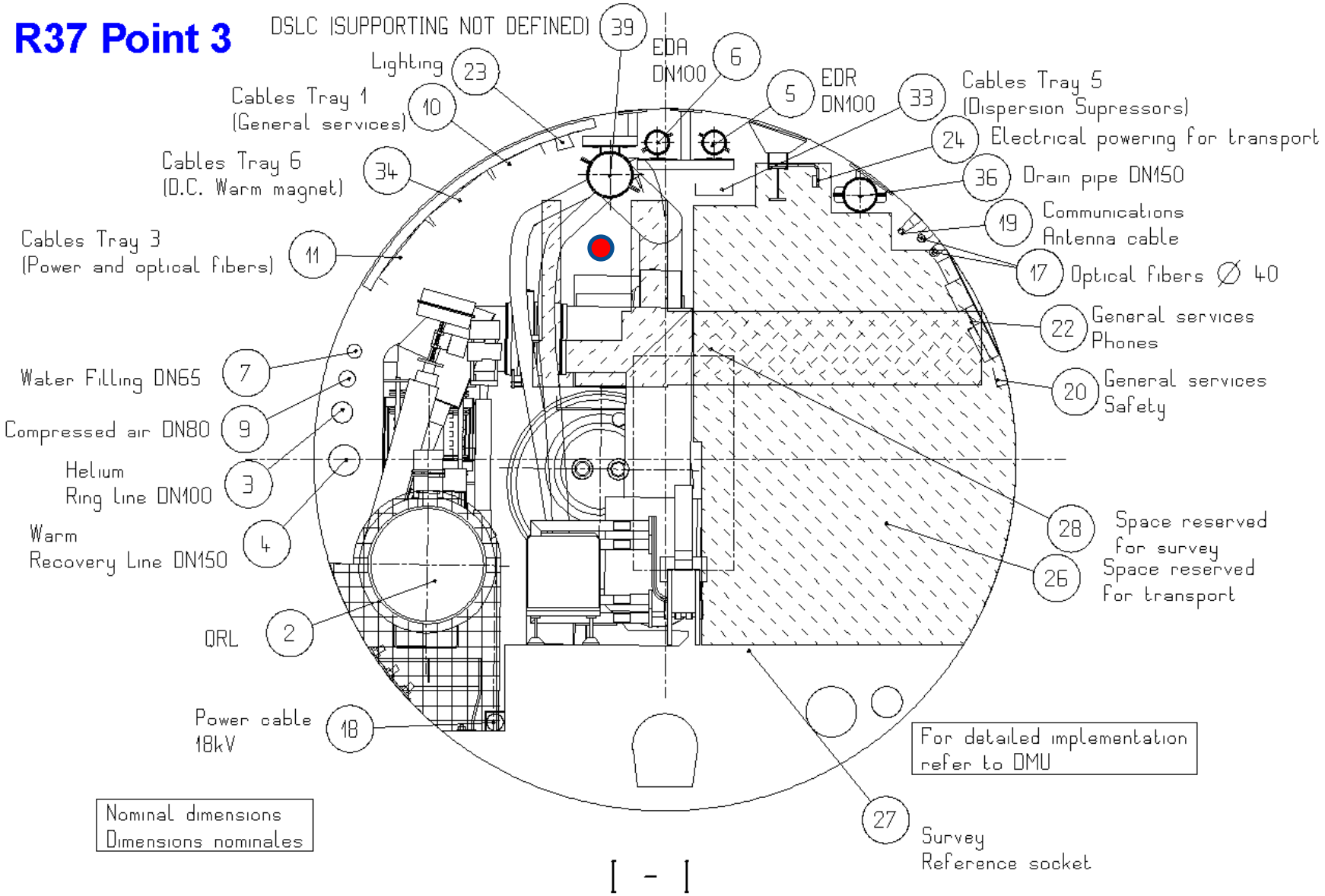
Tunnel, # section, “old” LHC installed

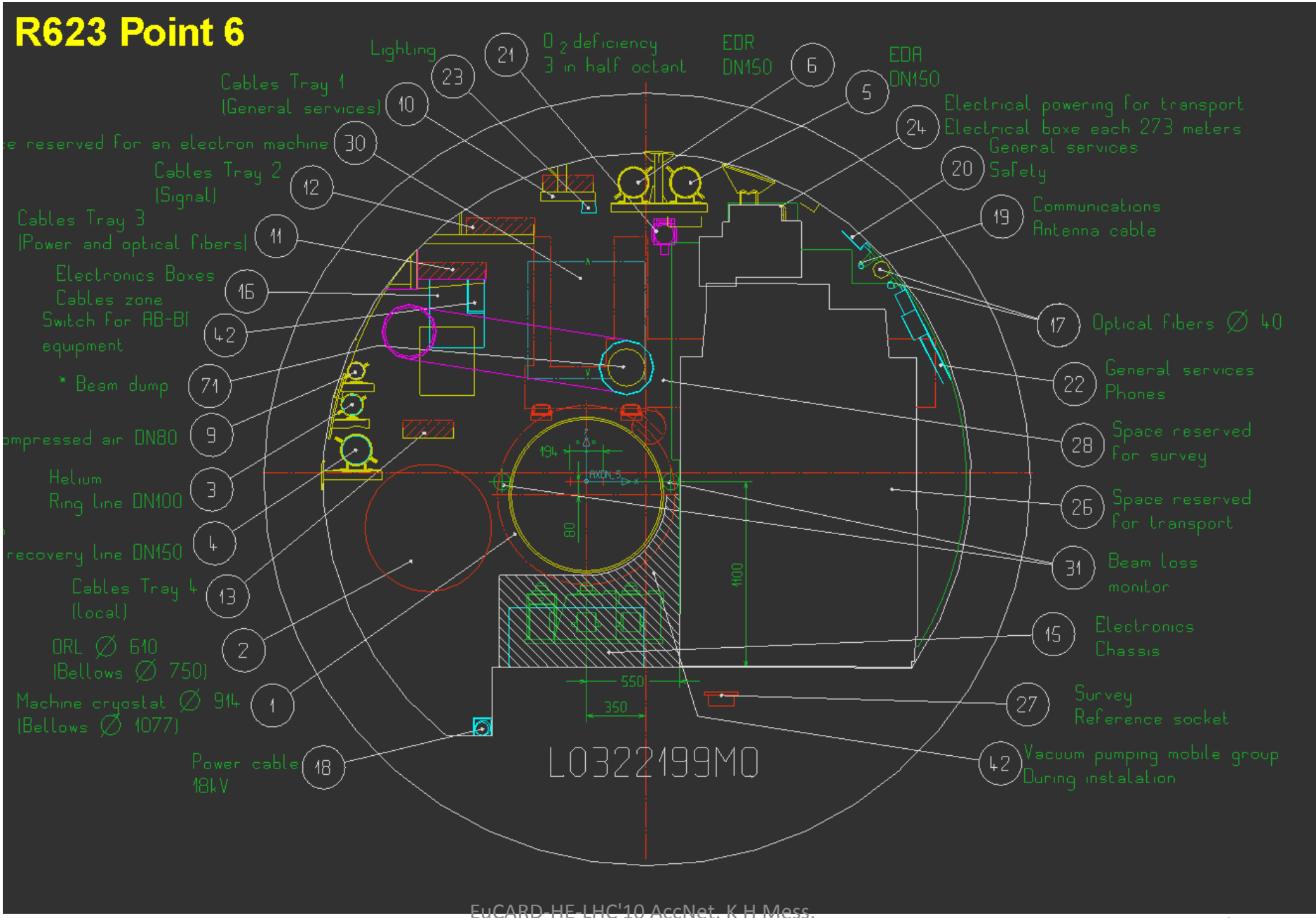


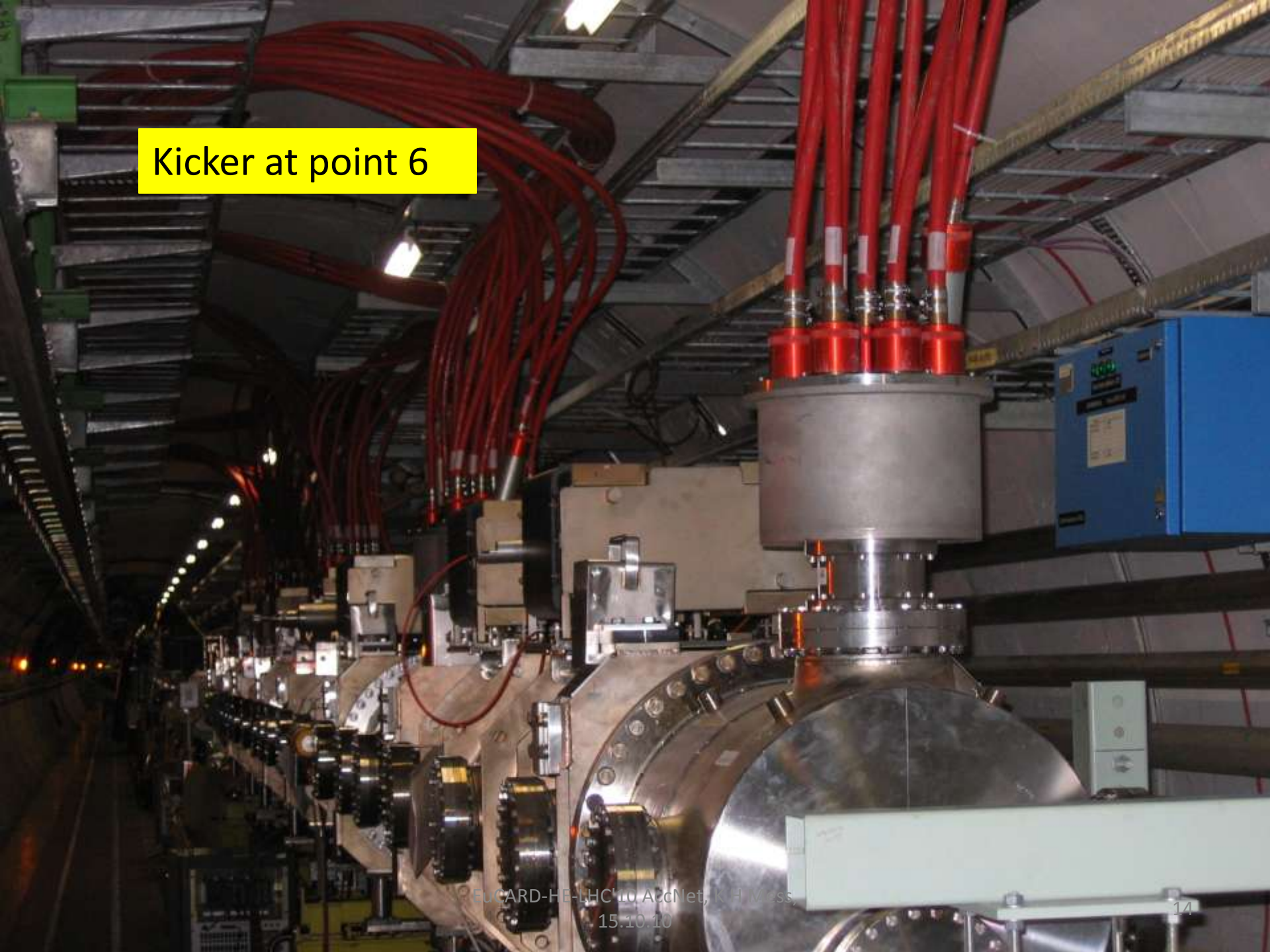
LHC

- The radius of curvature is so large that the magnets fit only into a LEP-size tunnel i.e. the LHC.
- Does the “old” LHC and the HE-LHC fit both in the tunnel?
  - Two machines of the LHC size do not fit. Note that even a slim e-machine barely fits [3], [4]
  - As the HE-LHC is likely to be bigger => the LHC magnets have to become slimmer or integrated into the new cryostat.
    - A restriction to say 3 TeV would allow to cut away some flux steel.
    - With a common cryostat and a common cryogenics it may fit.
- But what about the QRL for two machines?
- What about other size restrictions?

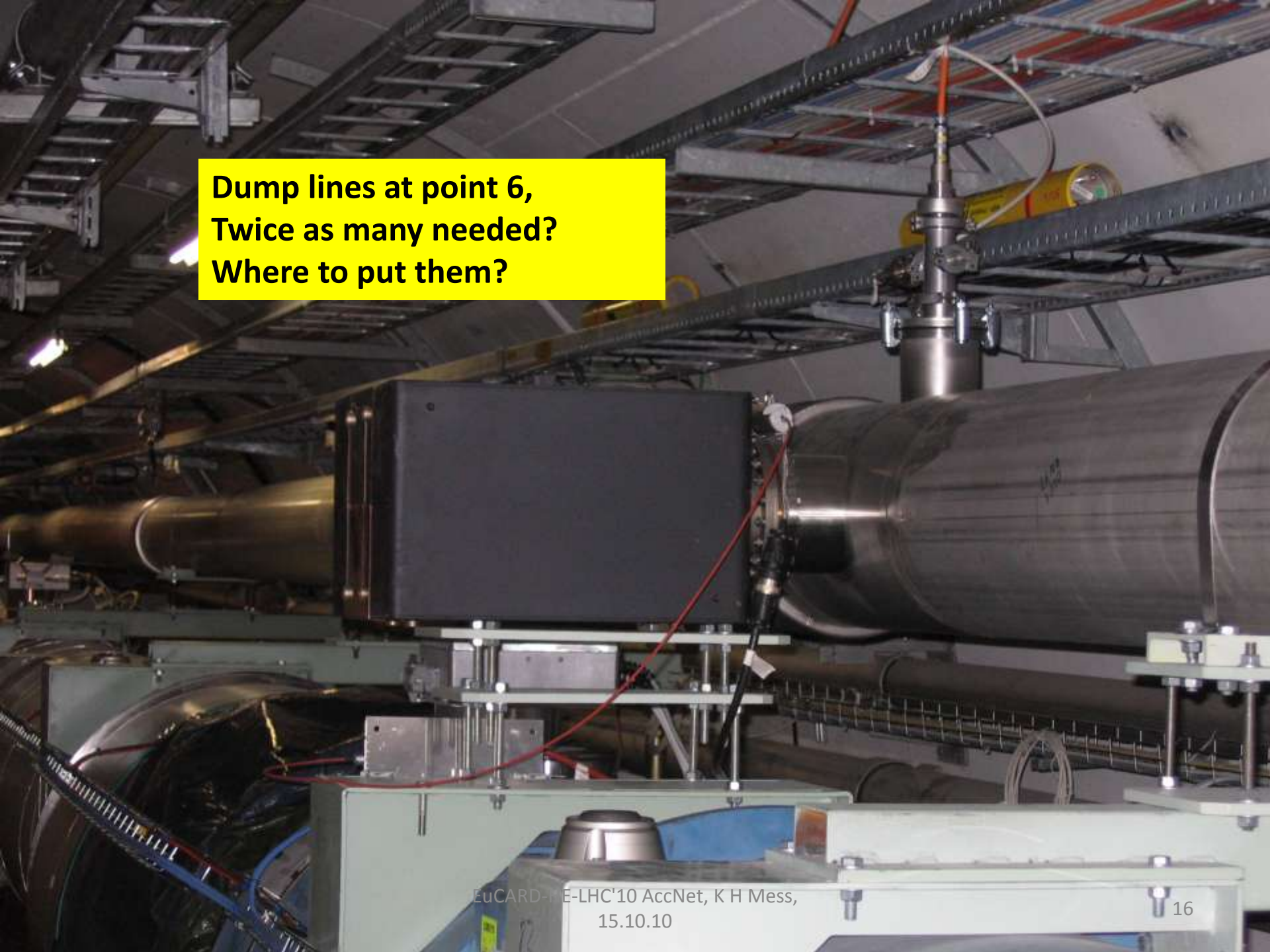
R37 Point 3

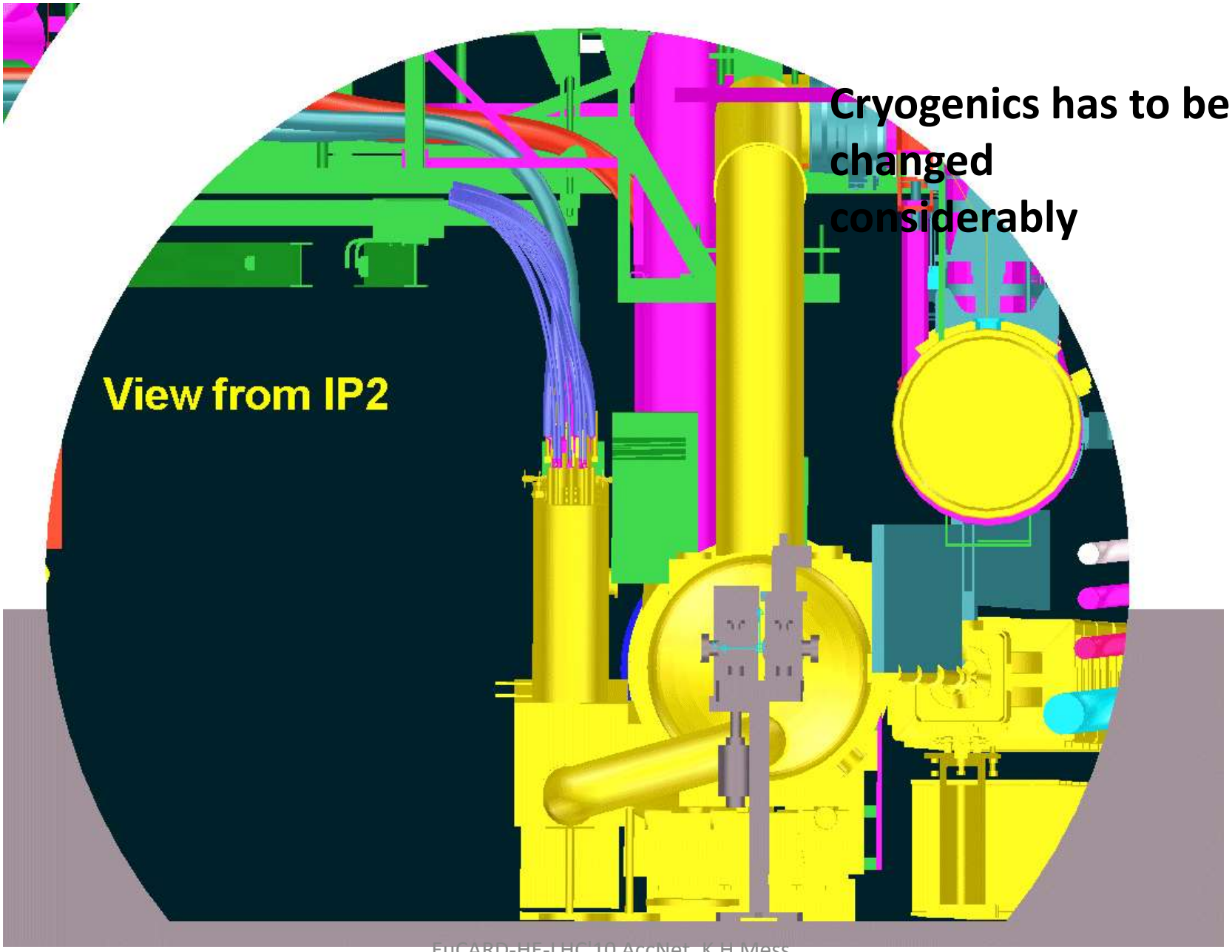

DSLC (SUPPORTING NOT DEFINED) 39
EDA DN100 6
EDR DN100 5
Lighting 23
Cables Tray 1 (General services) 10
Cables Tray 6 (D.C. Warm magnet) 34
Cables Tray 3 (Power and optical fibers) 11
Cables Tray 5 (Dispersion Supressors) 33
Electrical powering for transport 24
Drain pipe DN150 36
Communications Antenna cable 19
Optical fibers ∅ 40 17
General services Phones 22
General services Safety 20
Water Filling DN65 7
Compressed air DN80 9
Helium Ring line DN100 3
Warm Recovery Line DN150 4
QRL 2
Power cable 18kV 18
Space reserved for survey 28
Space reserved For transport 26
Survey Reference socket 27
For detailed implementation refer to DMU
Nominal dimensions
Dimensions nominales


R623 Point 6
Lighting
23
21
O 2 deficiency
3 in half octant
EDR
DN150
6
EDA
DN150
5
Cables Tray 1
(General services)
10
Electrical powering for transport
24
Electrical boxe each 273 meters
General services
20
Safety
e reserved for an electron machine
30
Cables Tray 2
(Signal)
12
Cables Tray 3
(Power and optical fibers)
11
19
Communications
Antenna cable
Electronics Boxes
Cables zone
16
Switch for AB-BI
equipment
42
17
Optical fibers ∅ 40
* Beam dump
71
22
General services
Phones
ompressed air DN80
9
28
Space reserved
for survey
Helium
Ring line DN100
3
26
Space reserved
for transport
recovery line DN150
4
31
Beam loss
monitor
Cables Tray 4
(local)
13
ORL ∅ 610
(Bellows ∅ 750)
2
15
Electronics
Chassis
Machine cryostat ∅ 914
(Bellows ∅ 1077)
1
27
Survey
Reference socket
Power cable
18kV
18
42
Vacuum pumping mobile group
During instalation
194
AXIS
80
1100
550
350
LO322199MO

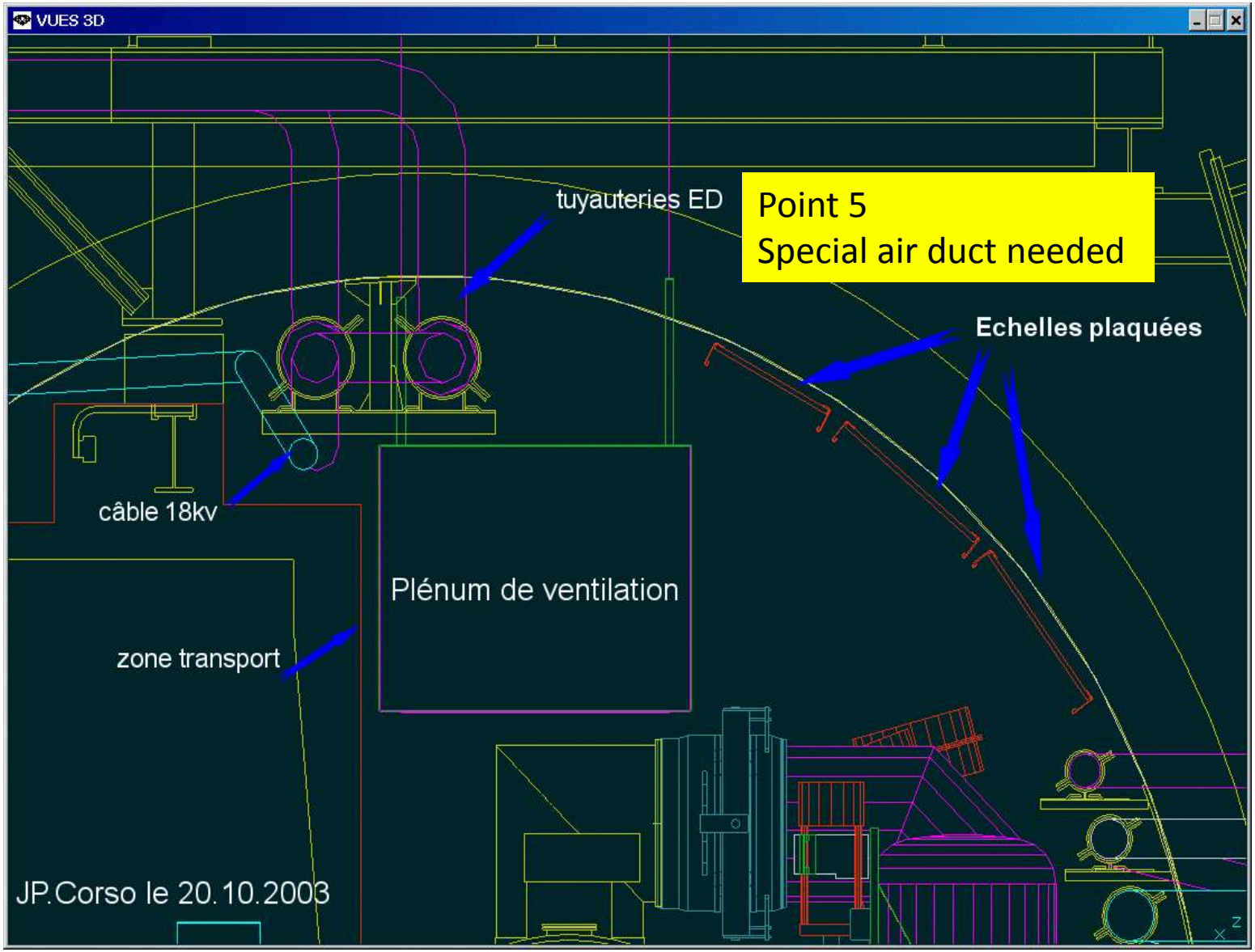

Kicker at point 6


Dump lines at point 6


Dump lines at point 6,
Twice as many needed?
Where to put them?



Cryogenics has to be changed considerably


VUES 3D
tuyauteries ED
Point 5
Special air duct needed
Echelles plaquées
câble 18kv
Plénum de ventilation
zone transport
JP.Corso le 20.10.2003


Where does the HE-LHC RF go?

LHC

- The radius of curvature is so large that the magnets fit only into a LEP-size tunnel i.e. the LHC.
- Does the “old” LHC and the HE-LHC fit both in the tunnel?
  - Two machines of the LHC size do not fit.
  - As the HE-LHC is likely to be bigger => the LHC magnets have to become slimmer or integrated into the new cryostat.
  - A restriction to say 3 TeV would allow to cut away some flux steel.
  - But what about the QRL for two machines?
  - What about other size restrictions?

  - **Size of the energy extraction of HE-LHC requires serious rework [5], probably additional switches in the middle of the arc.**
- **It will be almost impossible to fit . Considerable rework on the “old” LHC and heavy constrains on the HE-LHC.**

LHC

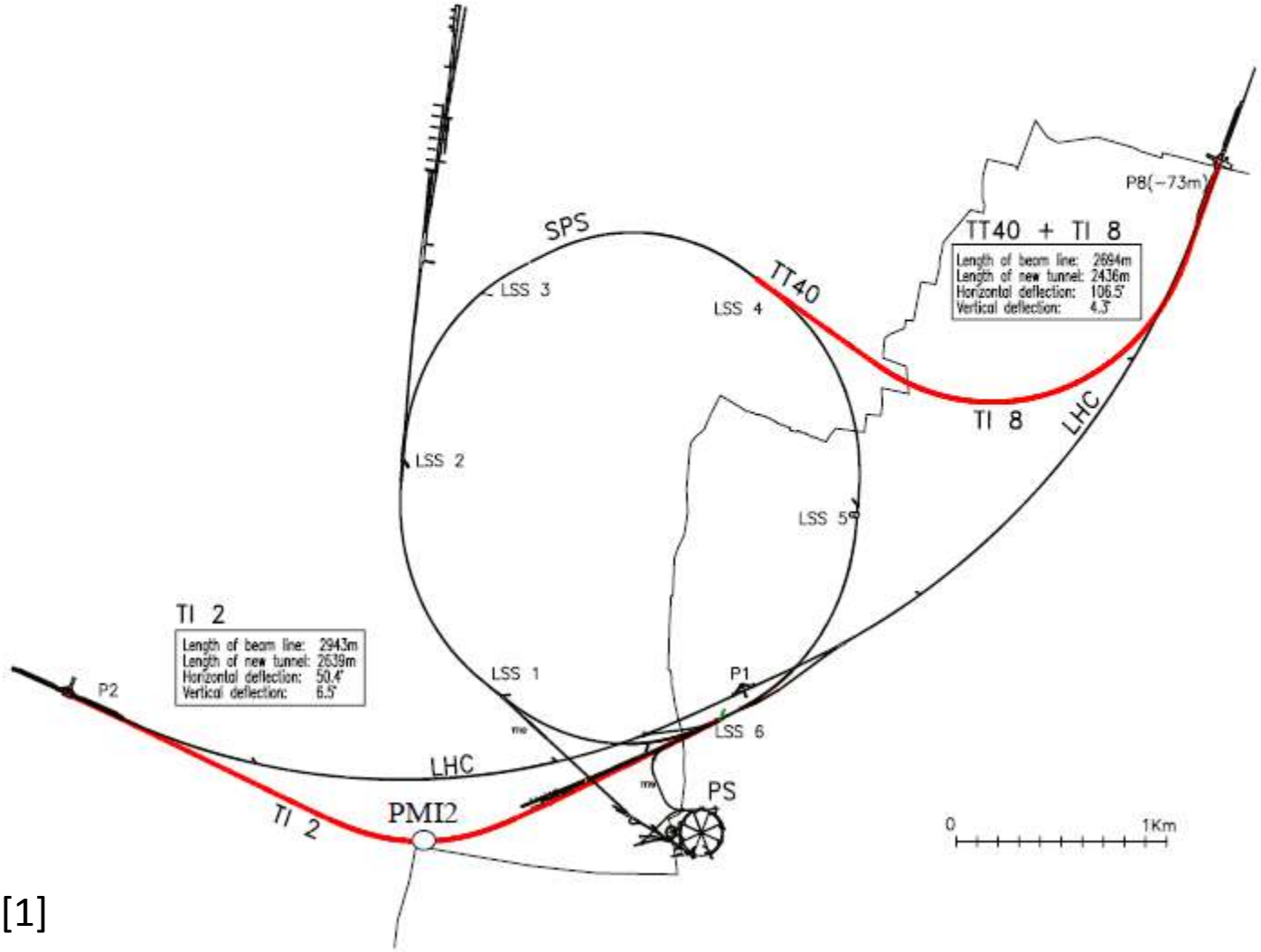
- What could the “old” LHC be good for?
  - We could ramp from 450 GeV to above 1.3 TeV
  - That is in principle very slow, however it could be in the shadow, while HE-LHC is still filled and running.
  - It can be done, while the HE machine is up, if 3 TeV bypasses are created.
    - This requires beamlines through the galleries and consequently a shift towards the transport space everywhere else
  - This makes sense only, in case we have to keep the injection lines at 450 GeV (no upgraded SPS).
  - Conclusion?

Recycling in a most drastic fashion ?

HERA Magnets [6]

21.1 SITUATION

Two new transfer lines, TI 2 and TI 8, with a combined length of 5.6 km are being built to transport protons at 450 GeV/c and ions from the SPS to the LHC. The geographical layout of these lines is shown in Fig. 21.1. Also shown are some of the main geometrical parameters. An overview of these lines including the LHC injection systems has been given in [1,2].



Ref [1]

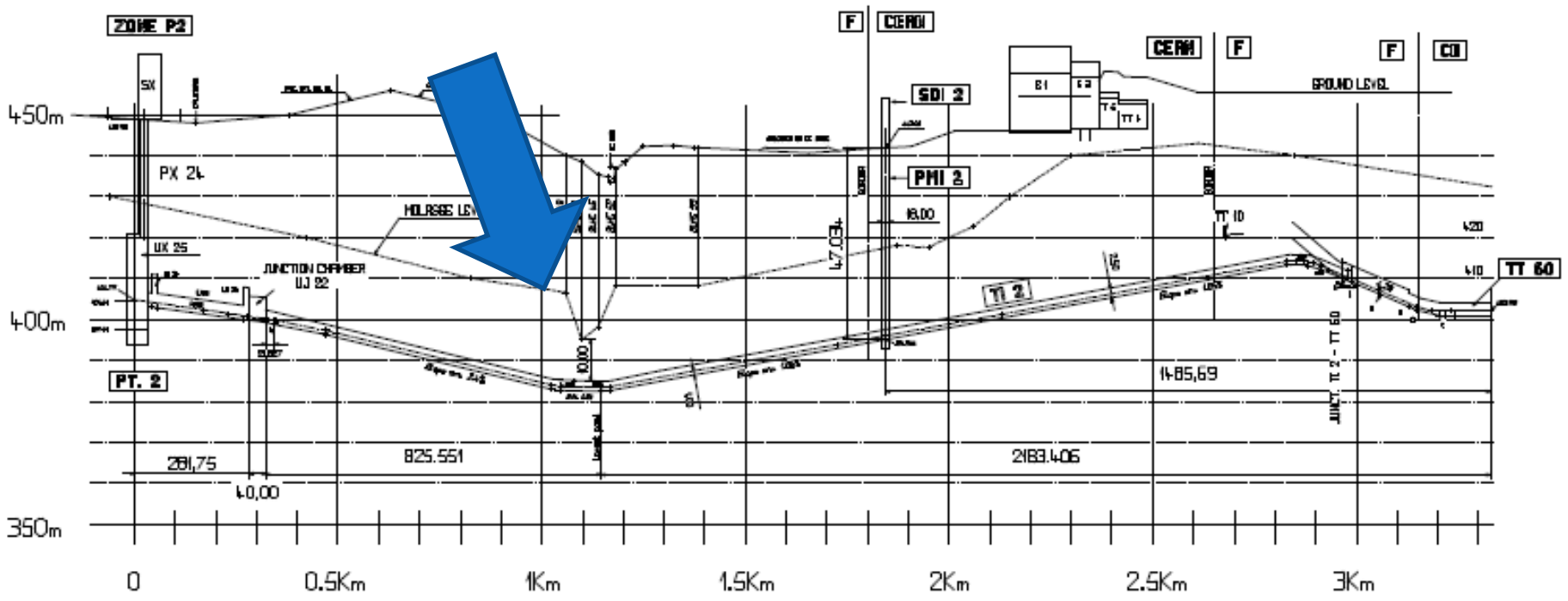
Figure 21.1: Overall layout of TI 2 and TI 8

HERA Magnets [6]

- The injection lines TI2 and TI8 have almost the bending radius as HERA.
- The SPS has a larger radius and a wide tunnel, the HERA magnets would fit.
  - However HERA is slow and useless as a SPS upgrade.

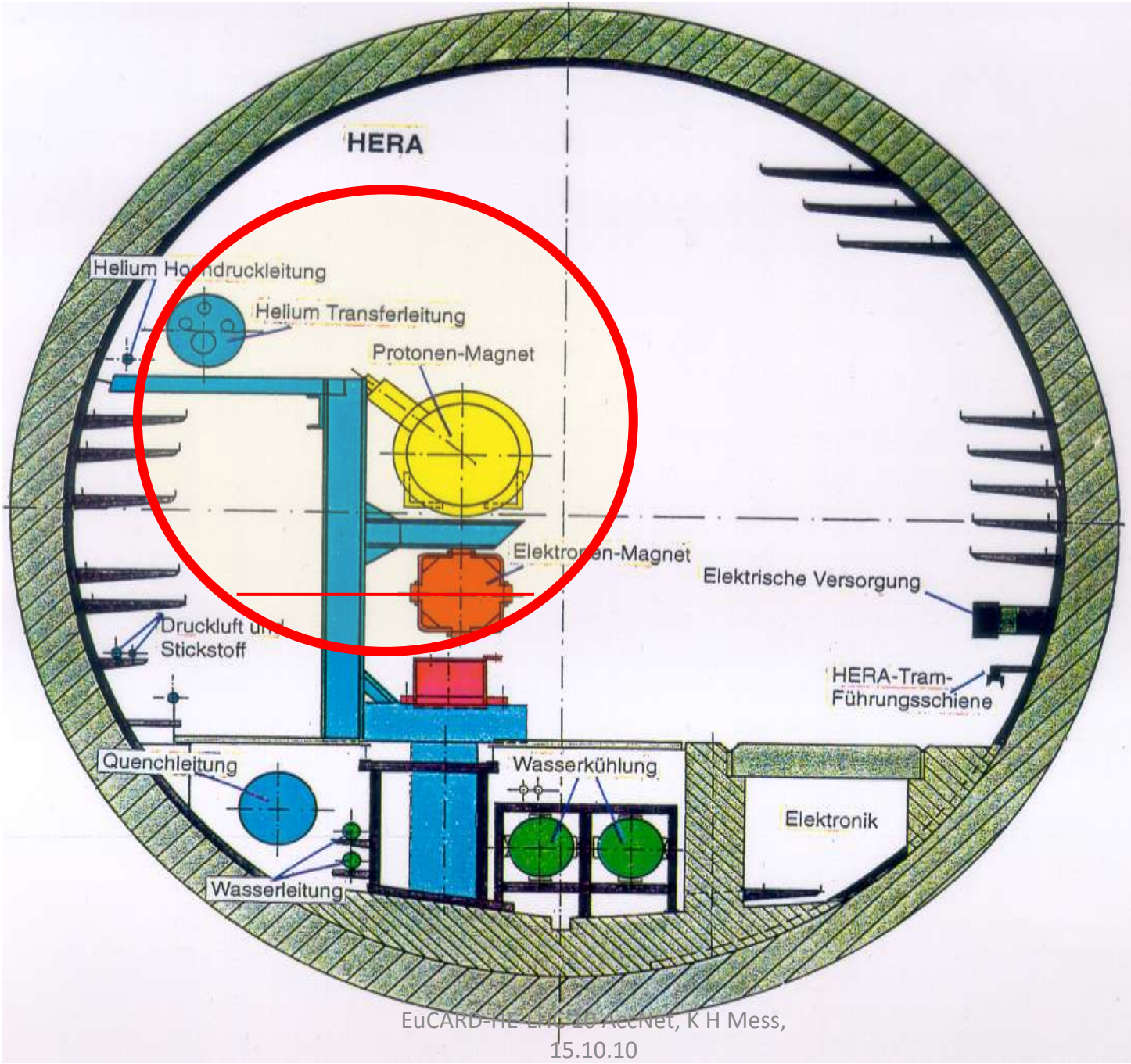
HERA Magnets for TI2/8

- The injection lines TI2 and TI8 have almost the bending radius as HERA.
- TI2 has however a nasty vertical bend due to the underground river below the creek Lion.

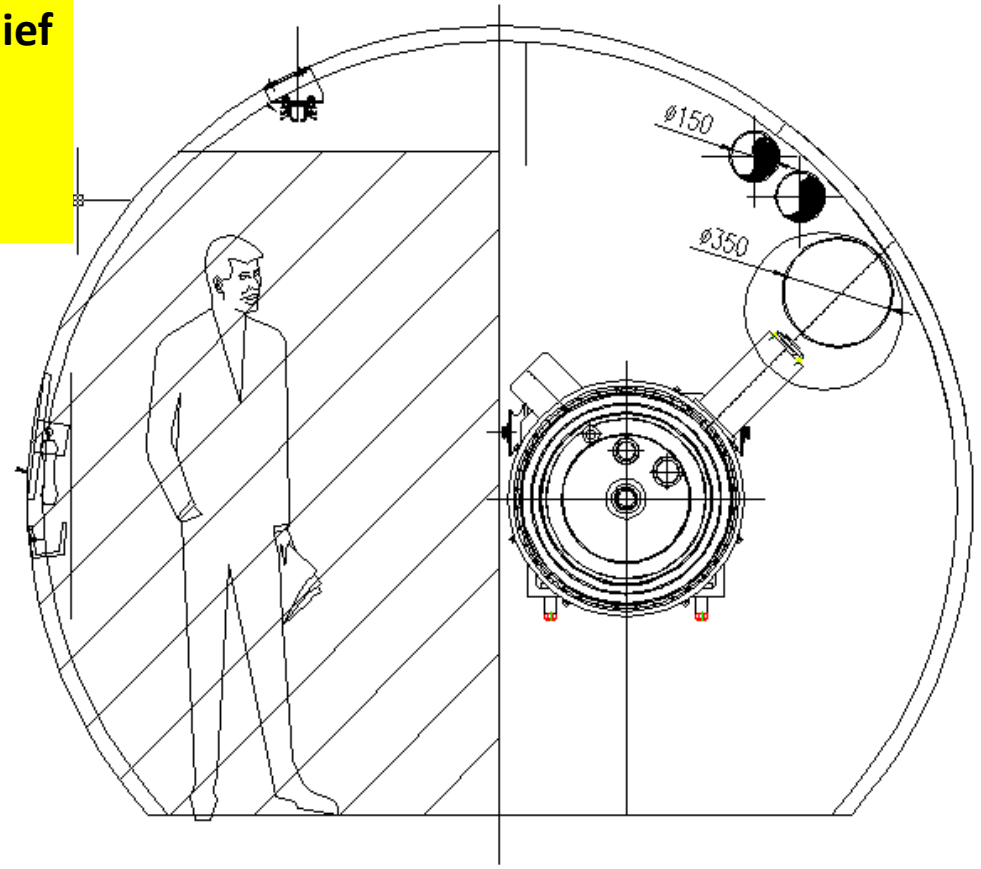

ZONE P2
F
CERDI
CERN
F
F
CDI
SDI 2
PMI 2
GROUND LEVEL
PX 24
UX 25
JUNCTION CHAMBER
UJ 22
TT 2
TT 10
TT 60
PT. 2
450m
400m
350m
281,75
40,00
825.551
2183.406
1485,69
0
0.5Km
1Km
1.5Km
2Km
2.5Km
3Km

HERA Magnets

- The injection lines TI2 and TI8 have almost the bending radius as HERA.
- TI2 has however a nasty vertical bend due to the underground river below the Lion.
- The injection tunnels are small.


HERA
Helium Hochdruckleitung
Helium Transferleitung
Protonen-Magnet
Elektronen-Magnet
Elektrische Versorgung
Druckluft und
Stickstoff
HERA-Tram-
Führungsschiene
Quenchleitung
Wasserkühlung
Elektronik
Wasserleitung

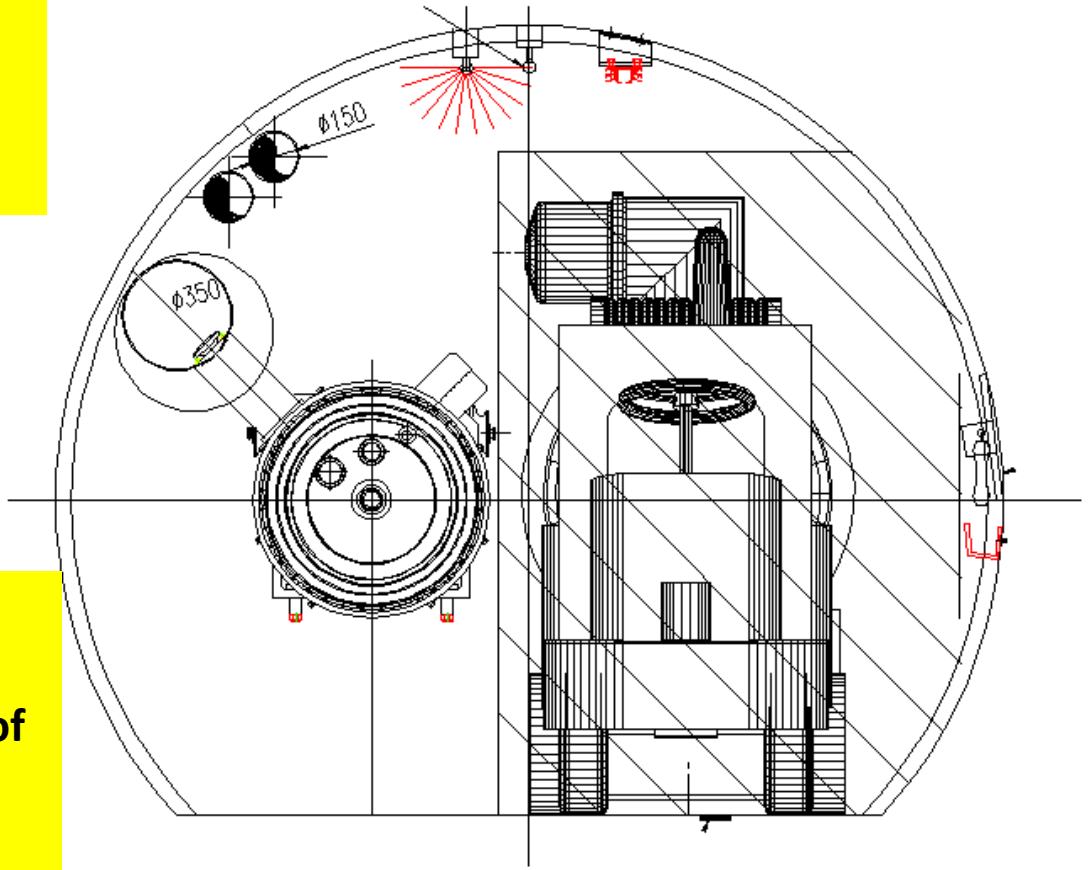
The original quench relief pipe does not fit, Cable trays have been removed in the plot.



TI8 Cross-Section
(Magnet on the tunnel outer curvature)

Ref [7]

Reversed polarity of the magnets, diode reversal. The quench line is too small and the cable trays are missing.



TYPICAL TI 2 CROSS SECTION
between PMI2 and UJ22

Note, also HE-LHC components have to pass through this eye of a needle.
In particular the PMI2 ends right on top of the magnets!

HERA Magnets in TI2/TI8

- Out of the 196 dipoles needed, 11 need to be turned axially and 6 need to be tilted. Cold mass needs to be reworked. [8] [9]
- In general the slope is much steeper than in HERA: cryostats to be improved. (That is possible thanks to the long. tierods)
- Quadrupoles do not fit optically. New quads (MQTL type) are needed.
- The steering magnets could be used in principle (by scrapping the HERA quad-corrector packs), however the current is very high. [10] [11]
- The HERA cooling scheme [12] [13] is incompatible with the preferred cooling scheme [12]. The heat exchangers have to be redone. The steep up-hill – down-hill slope presents a serious problem.
- The energy extraction seems possible.

Conclusion and Summary, TI2/8

- The reuse of the HERA magnets presents many problems.
  - The geometry of the transfer lines is difficult, the tunnels very narrow.
  - The cryostats and coldmasses have to reworked.
  - Half the diodes have to be reversed.
  - Space for the energy extraction is an issue (also for alternatives)
  - New quads and correctors are needed.
  - The magnets will be very old.
- A new solution (combined function ?) seems more appropriate to me.

Conclusion and Summary

- Any machine bigger than the LHeC (to be proposed) does not fit in the LEP tunnel along with the LHC (let alone the HE-LHC).
- There is no clear advantage for a pre-accelerator in the LEP tunnel.

- The reuse of the HERA magnets presents many problems.
- A new solution seems more appropriate.

When you get something for a bargain price,
make sure it is useful,
otherwise you have to get rid of it again.

References

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3. **LHC-LHeC Interference,** Mess, K H, LHeC design meeting, Tuesday 02 February 2010, http://indico.cern.ch/conferenceDisplay.py?confId=83244
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6. **Cold yoke dipole magnets for HERA** /, Balewski et al,1987
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11. **private communication,** P. Schmüser (University Hamburg), S. Wolff (DESY),
12. **private communication**. H Lierl, (DESY),
13. **Computer Calculation on Steady-State Operation and Different Modes of Cool Down and Warm Up of the HERA Superconducting Proton Ring**, G. Horlitz et al., Advances in Cryogenic Engi-neering, Vol 31, 1985, p 723 ff
14. **Design criteria of the cryogenic system for the CERN LHC injection lines**, Delruelle N ; Kouba G; Passardi G; Tischhauser J, CERN-AT-93-24-CR; LHC-NOTE-240

LHC Key Parameters

Circumference	**26.7 km**
Top Proton Energy	**7 TeV**
Number of Protons	**2808 x 1.15 x 1011**
Circulating current	**0.584 A**
Stored Energy/Beam	**362 MJ**
Number of Bending Magnets	**1232**
Maximum Field	**8.33 T**
Number of Lattice Quads	**392**
Number of SC Correctors	**7292**
Other SC Quads	**142**
Number of NC Magnets (LHC)	**156**
Number of Injection Line Magnets	**709**

It's a pp or ion-ion collider