LEP3: infrastructure questions and options

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LEP3 day,

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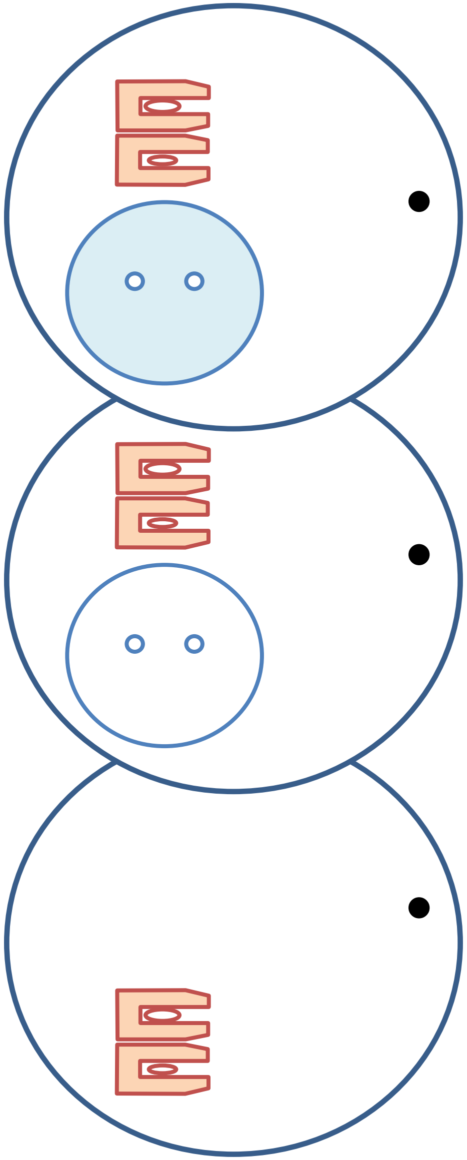
As an introduction

- LEP3 is (depending on what Nature has in store for us!) a serious contender as the high energy machine of choice of the twenties.
- It is a medium-cost machine, thanks to extensive re-utilization of existing infrastructure.
- BUT it is not a 'plain vanilla' machine. It is a very challenging machine in many ways.
- An R&D programme for its feasibility will be fun, challenging and gratifying. Machine physicists take note!

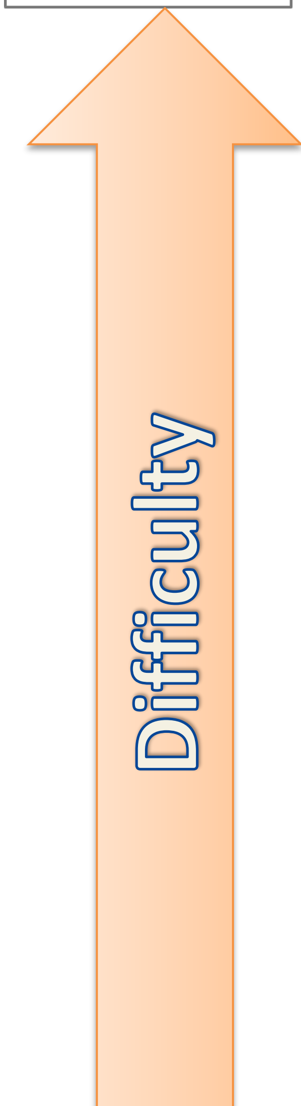
Concept stage

- We are at the concept stage of LEP3. At this stage, there are no stupid questions one can ask
- I will try to categorise some of the current ideas for the machine and invite you all to pose yourselves ‘crazy questions’

Cohabitation (with the LHC)



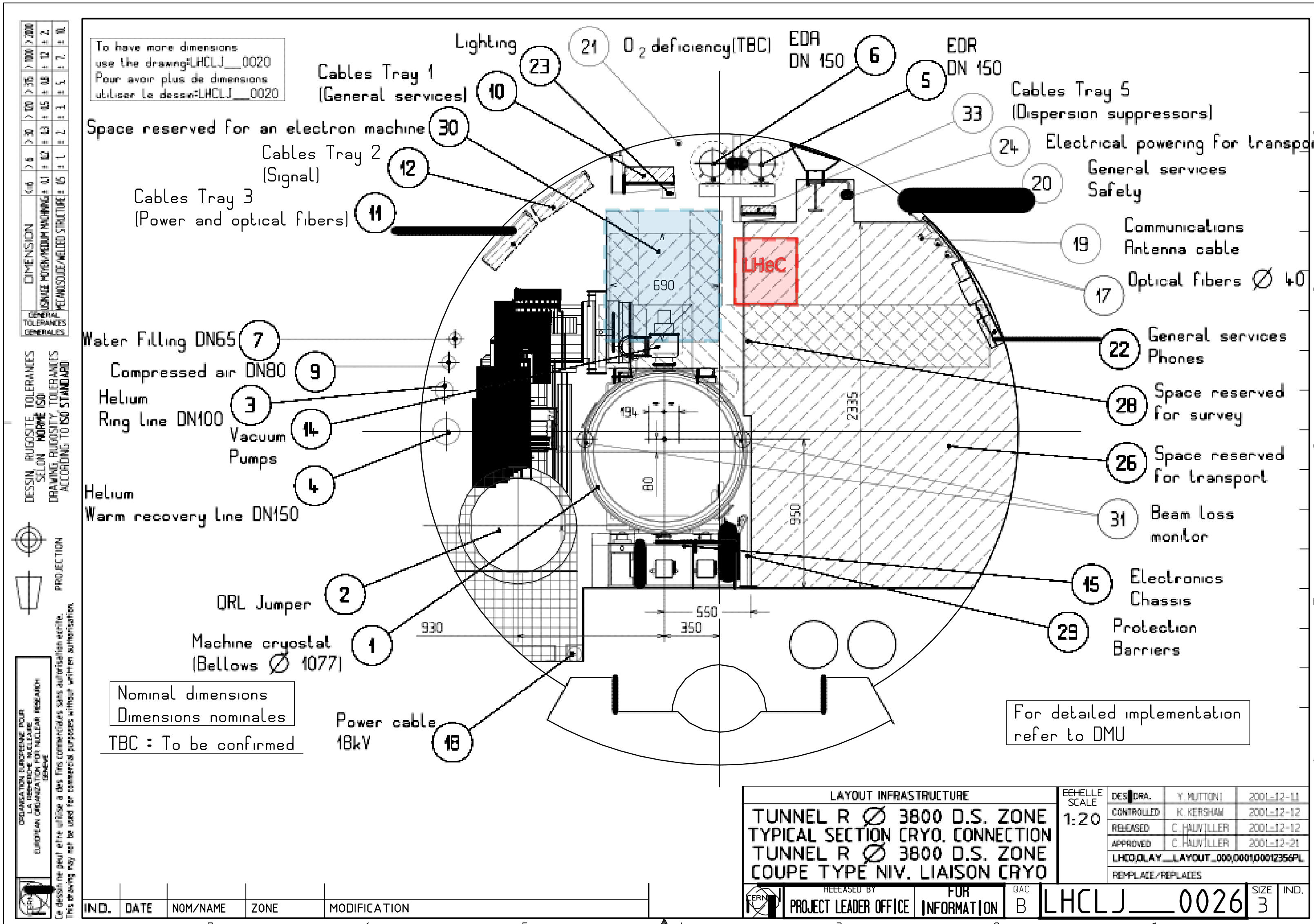
- Concurrent operation (LHeC style) Unnecessary
- Alternating operation (Y-to-Y or LS-to-LS) Currently the baseline
- Single operation – only one accelerator in tunnel



Cohabitation II

- Concurrent operation is very complex and unnecessary for the physics goals of LEP3
- Alternating operation has the advantage of being able to switch back to LHC, but many disadvantages:
  - Non-flat main ring
  - Expensive mechanical positioning
  - Possible constrains in the lattice
- Single operation has the advantage of being the less constrained approach (therefore offering the most optimized performance) but of course after LEP3 can only come HE-LHC.

Tunnel space considerations



: LHeC

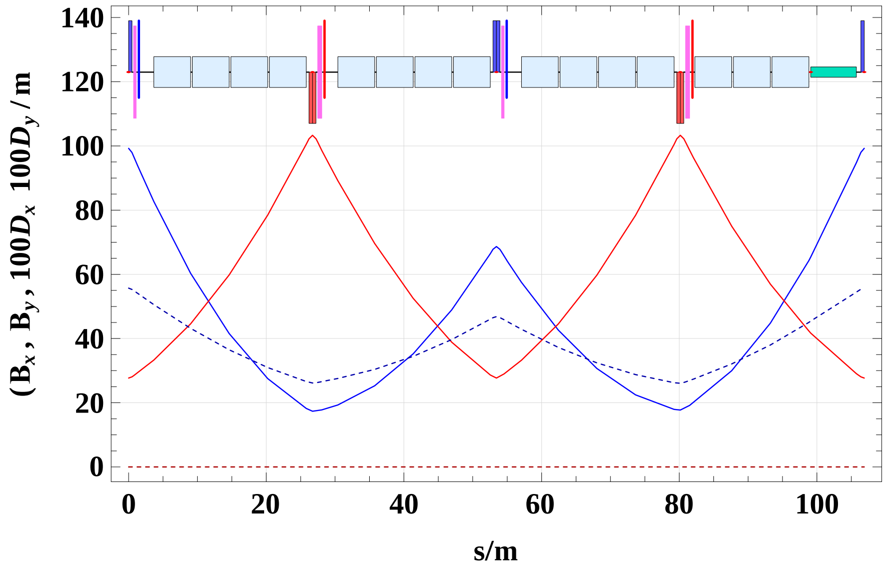
: Space reserved for future e⁺e⁻ machine

The LHeC ring is displaced due to the requirement of keeping the same circumference as the LHC ring. LEP3 has no such requirement

LEP3 (alternating operation) space considerations

- Is there enough space for a double ring LEP3 on top of the LHC?
  - The LHeC conseptual design report finds no showstopper for an one-ring electron machine
  - The space originally left for a future e^+e^- machine (690mmX690mm) appears sufficient for a double-decker dipole design
  - (Under single operation, there is no issue)

Dipole filling factor



Up to now the LHeC lattice has been used for LEP3.

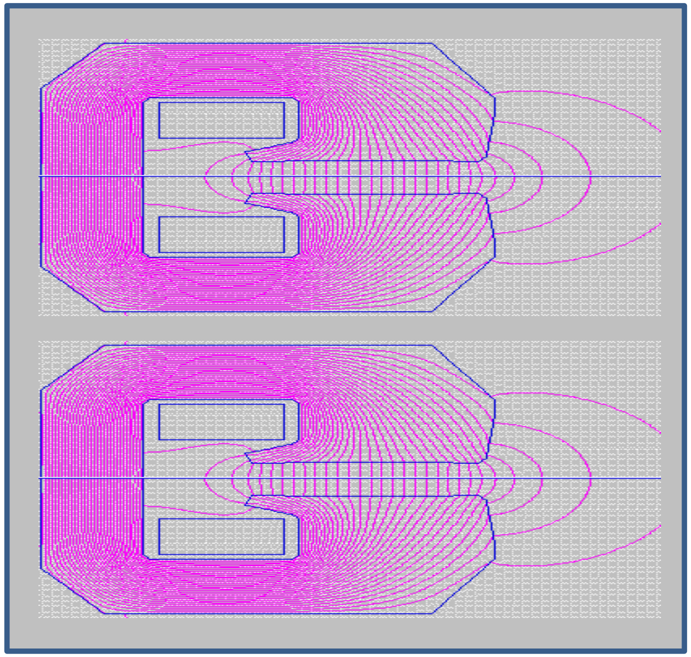
- LHeC has constraints that do not apply to LEP3: the length of the proton and electron rings should be the same
- LHeC has other constraints that might or might not apply to LEP3: concurrent operation means that no dipoles can be placed over QRL service modules or DFBs (space considerations)
- The dipole filling factor is not an issue for the LHeC.
- The LHeC dipole filling factor is a low 75%
- This comes from relatively short dipoles (5.35m long) and empty space left to pass obstacles

LEP3 lattice

- We need to work on (possibly two) LEP3 optics lattices
  - One for the baseline approach of alternating operation
  - One for single operation (ultimate)
- A 25% increase in the filling factor should be possible
- This has very beneficial effects:
  - Loss per turn: 7GeV→5.6GeV
  - RF power: 9000MV→7300MV (or 12000MV→9000MV)

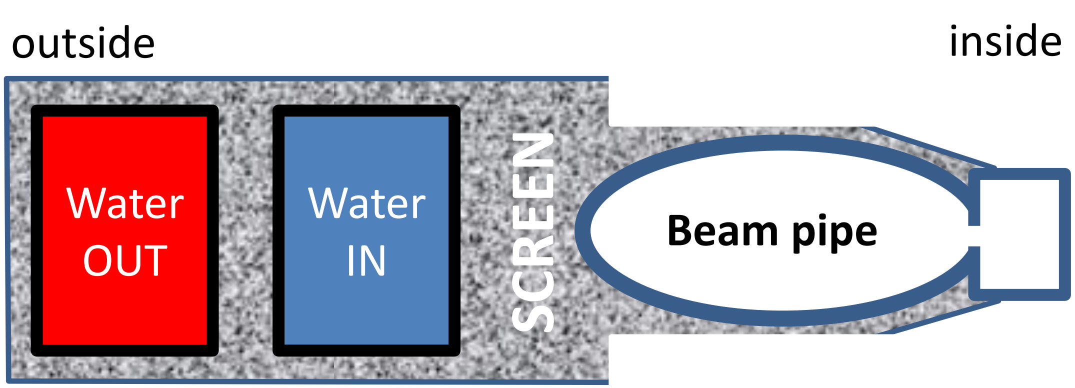
“double decker” dipoles

- The main ring and the accelerating ring should probably be on top of each other
- The magnets (one continuously ramping, the other at a steady field) should be separated sufficiently so as not to have cross talk.
- 1-2cm of air is sufficient – what about using a mu-metal screen?



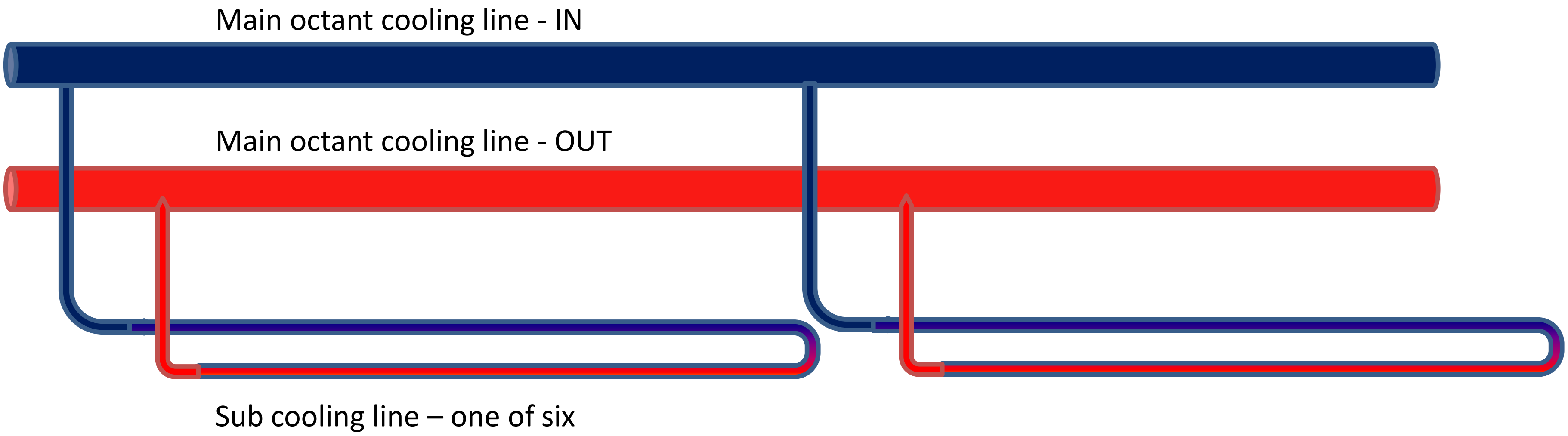
LEP3 beam pipe

- The LEP3 beam pipe should not be over-dimensioned, as the magnet (and mechanical fixing in position) costs scale with the size of the beam pipe
- Current best guess: 5cm sufficient, 4cm possible
- This makes a compact dipole design possibly 25cm in height, and the “double decker” design a bit more than 50cm. Is this optimistic?



Cooling

- 100MW of power will be dissipated in the arcs and need to be removed.
- Per octant, a total water flow of 60l/sec is needed (unpressurized, back of the envelope calculation). This can be split to 6 sub-units:



- Cooling power is important, but not unfeasibly large

Heat recovery

- LEP3 will generate 100MW in the form of heated water which we should try to recover
- Turbines can generate electricity with an efficiency of 85%
- Other hot water applications?

RF power

- The energy loss per turn in the current design is 7GeV (it can go down to 5.4GeV with a high dipole filling factor)
- The total RF power needed is therefore 7GV+margin for the main ring and 7GV+margin (a smaller margin) for the accelerator ring.
- In the IPAC paper we have quoted 12GV, needing 600meters of RF acceleration (at 20MV/m) and 900m of cryomodules (see A. Butterworth's talk)
- RF modules could be spread of the 4 even points (as in LEP2)
- It would be very beneficial if the cryomodules can be shared between the two rings (a saving of many×100MCHF)

Shared RF modules

- This looks like a crazy idea, as the aperture of the ILC RF modules is 23mm and ring separation in the arcs is 20cm
- Nevertheless, there is no a-priory reason that it cannot be done
- Temporal separation: the 1.3GHz wavelength is 23cm. The main and accelerator bunches could occupy different RF buckets
- The saving justifies some effort be put into this question

Vacuum and other SR problems

- The effect of synchrotron radiation (all 100MW of it) on vacuum should be looked at.
- Actually SR losses are similar to LHeC (a factor of 2 less)
- See J. M. Jimenez' talk
- LEP: Water leaking was a problem; stainless steel should be considered (a simpler design than LEP?) fast cooling down should be avoided (can be done with the cooling water)

Single vs double ring

- Of course the double ring design of LEP3 optimizes luminosity production
- A single ring is possible, at the expense of a factor of 2 to 5 integrated luminosity from the duty cycle and another factor from the (possible) higher emittance.
- A double ring has the extra complication of possible bypasses of the accelerator ring around the experiments. Going through the experiments should also be looked at.
- As this is an important question regarding overall costs, the exact loss of physics should be estimated if we used a single ring. Then the higher cost of the double ring can be justified
- The duty cycle loss is easily calculated if we could estimate the turnaround time of a single ring machine. At LEP we could ramp up in 10 minutes (total turnaround time of an hour or so). Could we think of a fast turnaround scheme to gain a factor 10 over LEP2?

Injector complex

- …does not exist! Need to be defined
- Nice to get 20GeV, 10GeV acceptable

Summary

- LEP3 is a challenging machine in many fronts
- Alternating operation with the LHC is possible but single operation will be more optimized
- An in-house optics lattice can improve a lot on the LHeC-borrowed one
- Sharing RF power between the main and accelerator rings should be investigated
- This is just a teaser of interesting problems waiting to be solved

End