Possibility of Pipetron magnets in the LHC tunnel

- Collaborators
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- Pre-accelerator LHCI
- Pipetron - VLHC magnets FNAL
- Feasibility study - tunnel space
- Experiment bypass options
- Issues to be studied
- Cost estimate
- Some schedule ideas

Collaborators

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Many discussions with:

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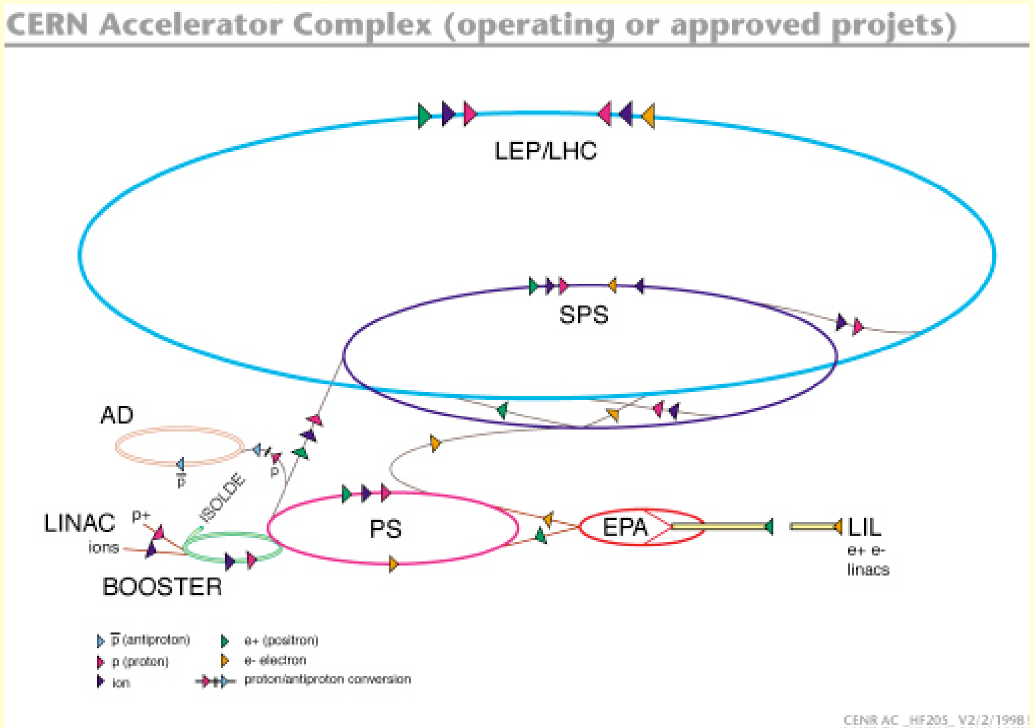
LHC Limits

- LHC will be limited in bunch intensity and emitance due to the multipoles at the injection plateau.
- The large 'swing' of the machine 0.45 TeV => 7 TeV

  0.53 T => 8.34 T is the cause of sizable persistent currents in the cables.
- Persistent currents in cables give rise to the multipoles. These currents are not stable and a 'snapback' occurs of e.g. the b_3 during the beginning of the ramp
- These effects should be smaller at a higher injection energy (e.g 1.5 TeV instead of 0.45 TeV) and a shorter injection plateau (e.g. few ms instead of 20 min)

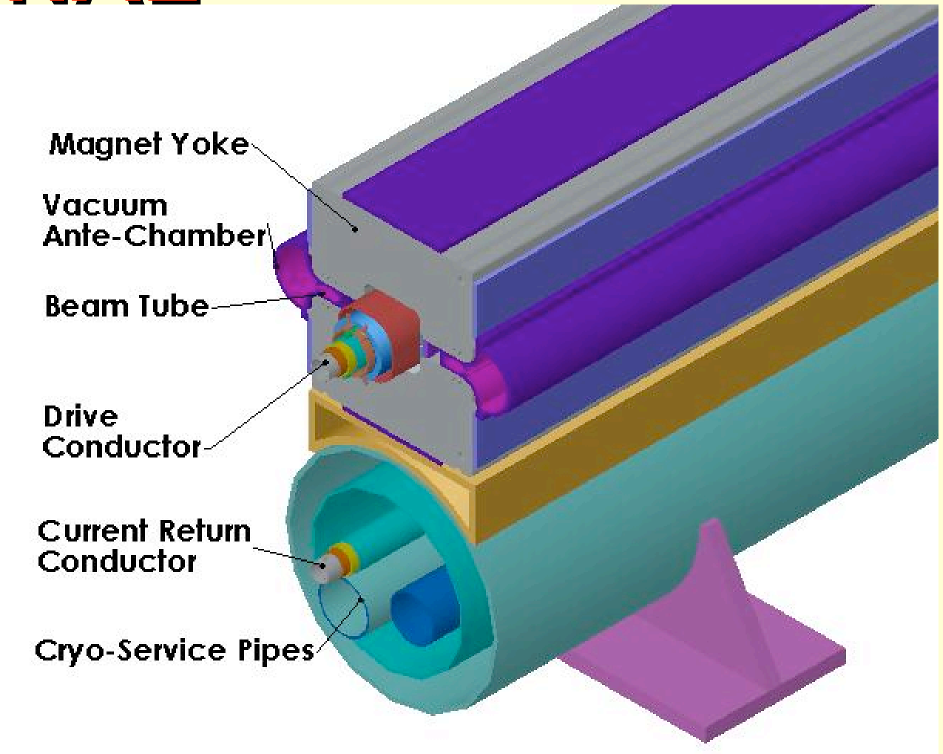
Pre-accelerator LHCI

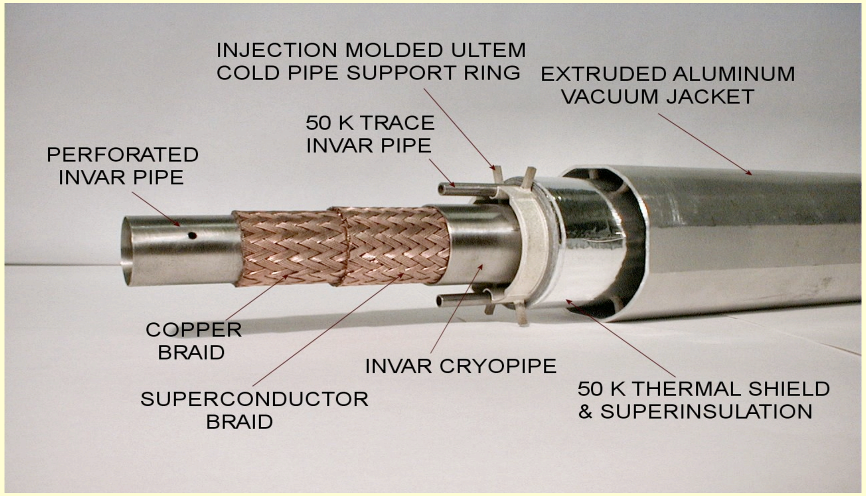
- **Put a pre-accelerator of 0.45 TeV => 1.5 TeV in the LHC tunnel.**
- **This machine should be of small transverse dimensions**
- **This machine should be cheap (CHF/Tm) : Try to use the VLHC 'pipetron' magnets.**
- **Inject all bunches into the LHCI, accelerate and thentransfer to the LHC in one go**



Pipetron - VLHC magnets FNAL

- 0.45 TeV injection at 0.055 T
- 1.5 Tev top at 1.84 T
- Gradient ~ 4%
- 20 mm pole gap





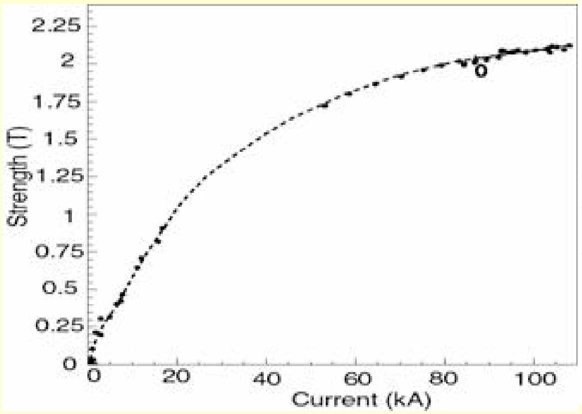
- VLHC phase I :233 km ring
- Combined function magnets 2 in 1

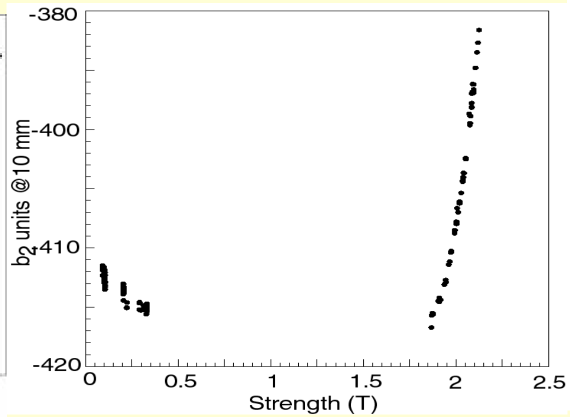
Pipetron - VLHC magnets- FNAL

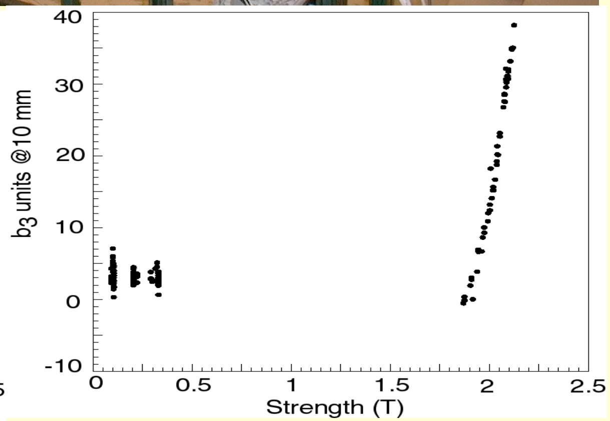
- **Design exists for VLHC**
- **Short model successfully tested at FNAL**
- **Saturates strongly above 1.9 T**

See:

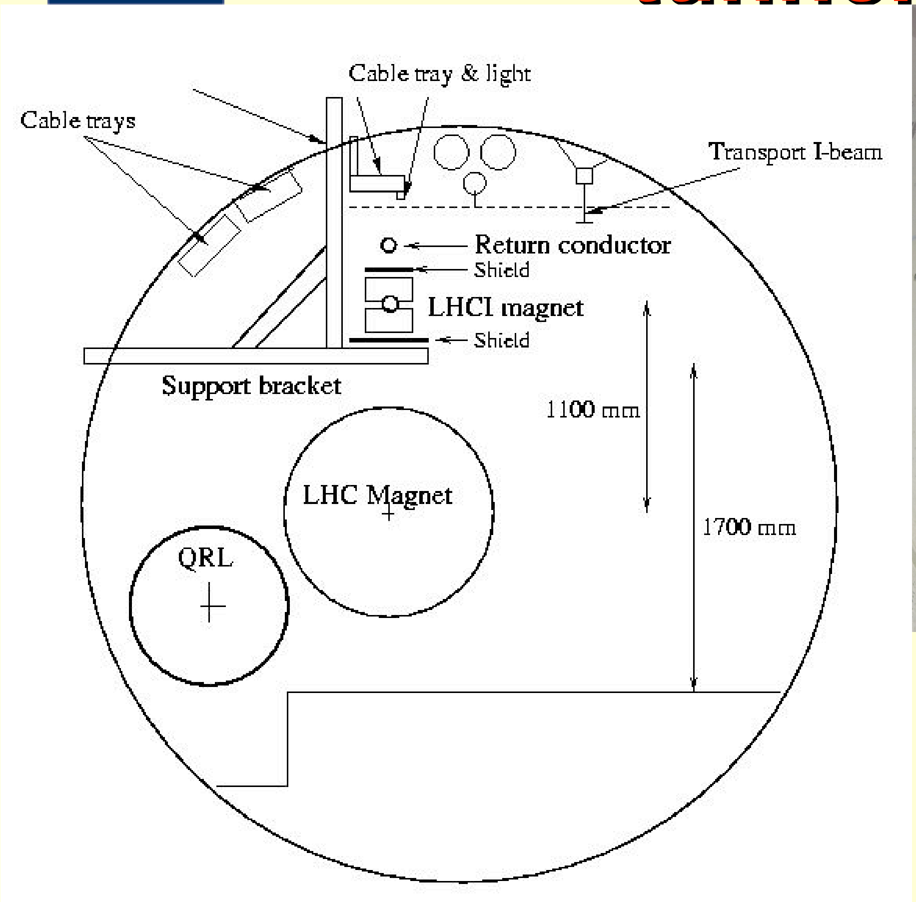
H.Piekarz et al, Test of 2 Tesla Superconducting Transmission Line Magnet System, MT19, Genoa, 2005

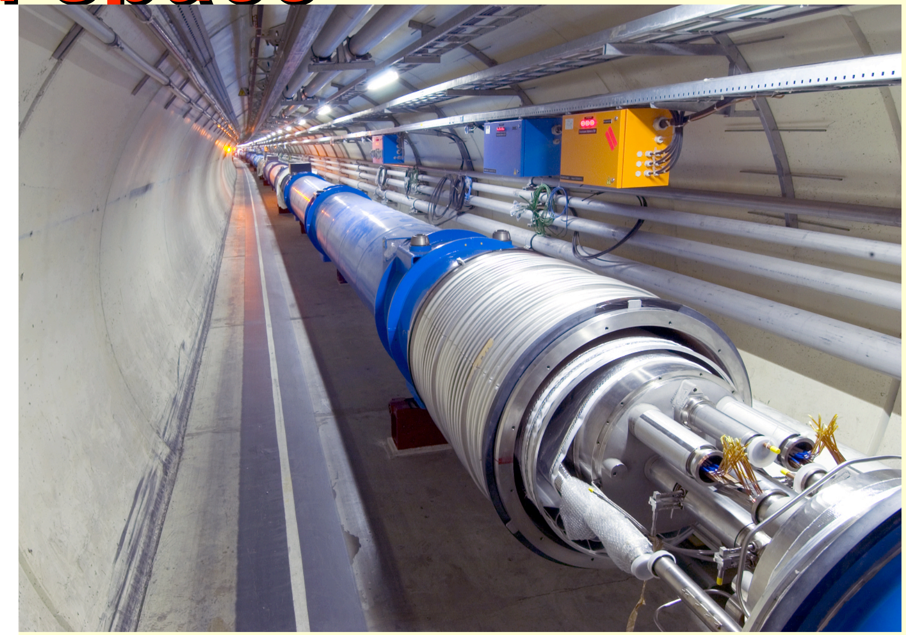






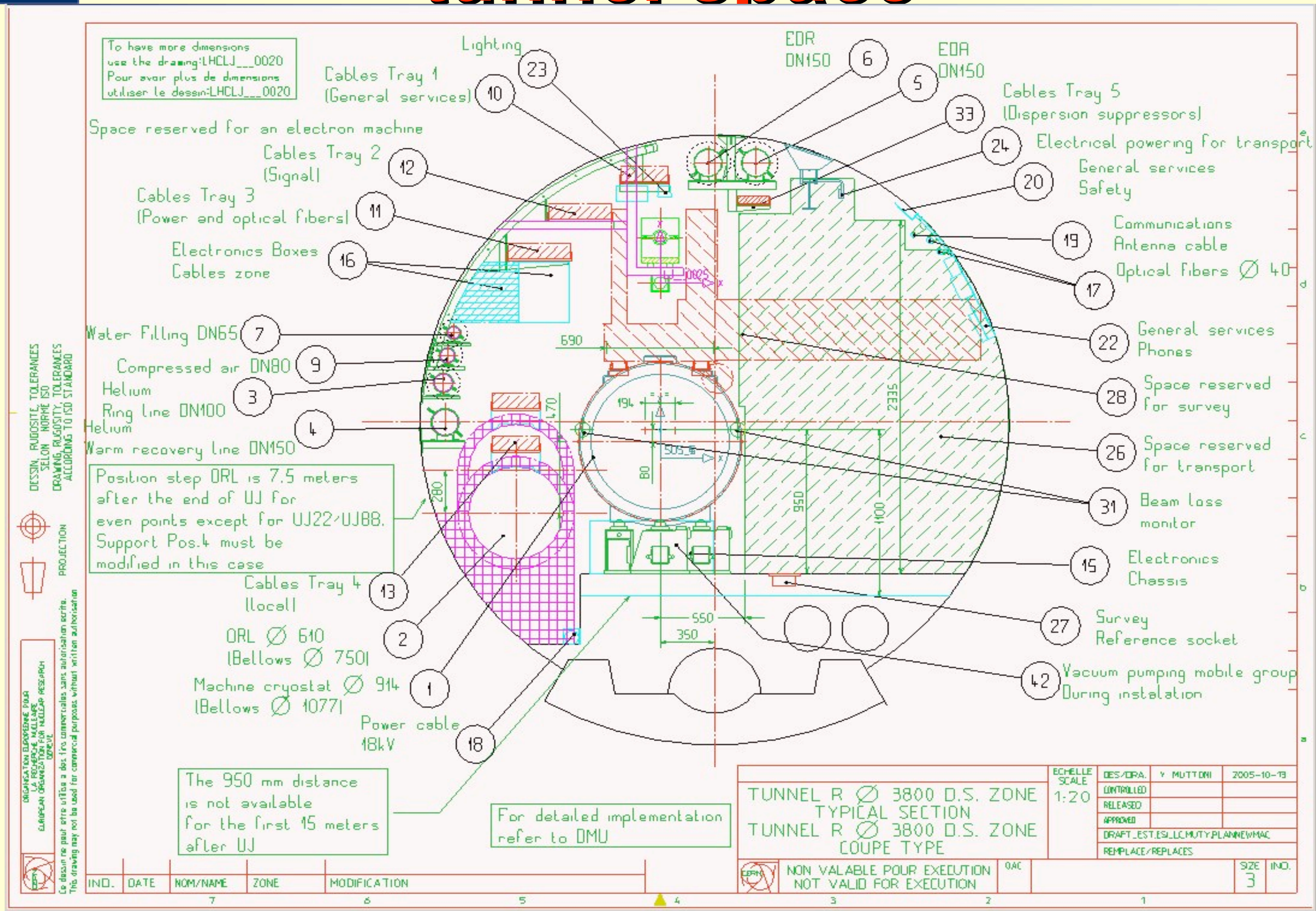
Feasibility study - tunnel space



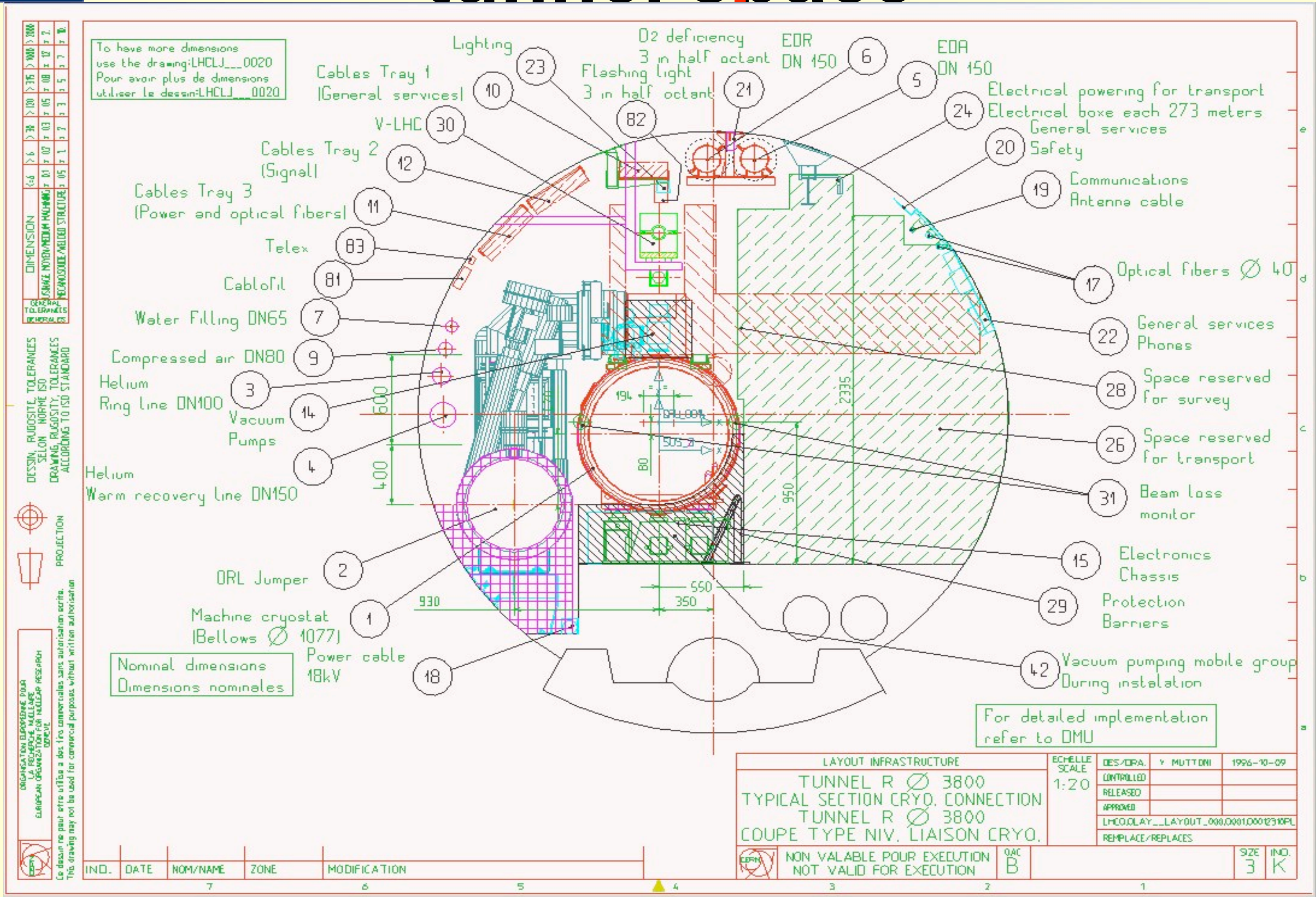


- QRL has the capacity to cool the current line
- LHC tunnel has some limited space above the LHC machine
- LHCI magnets: 24 cm x20 cm + return line

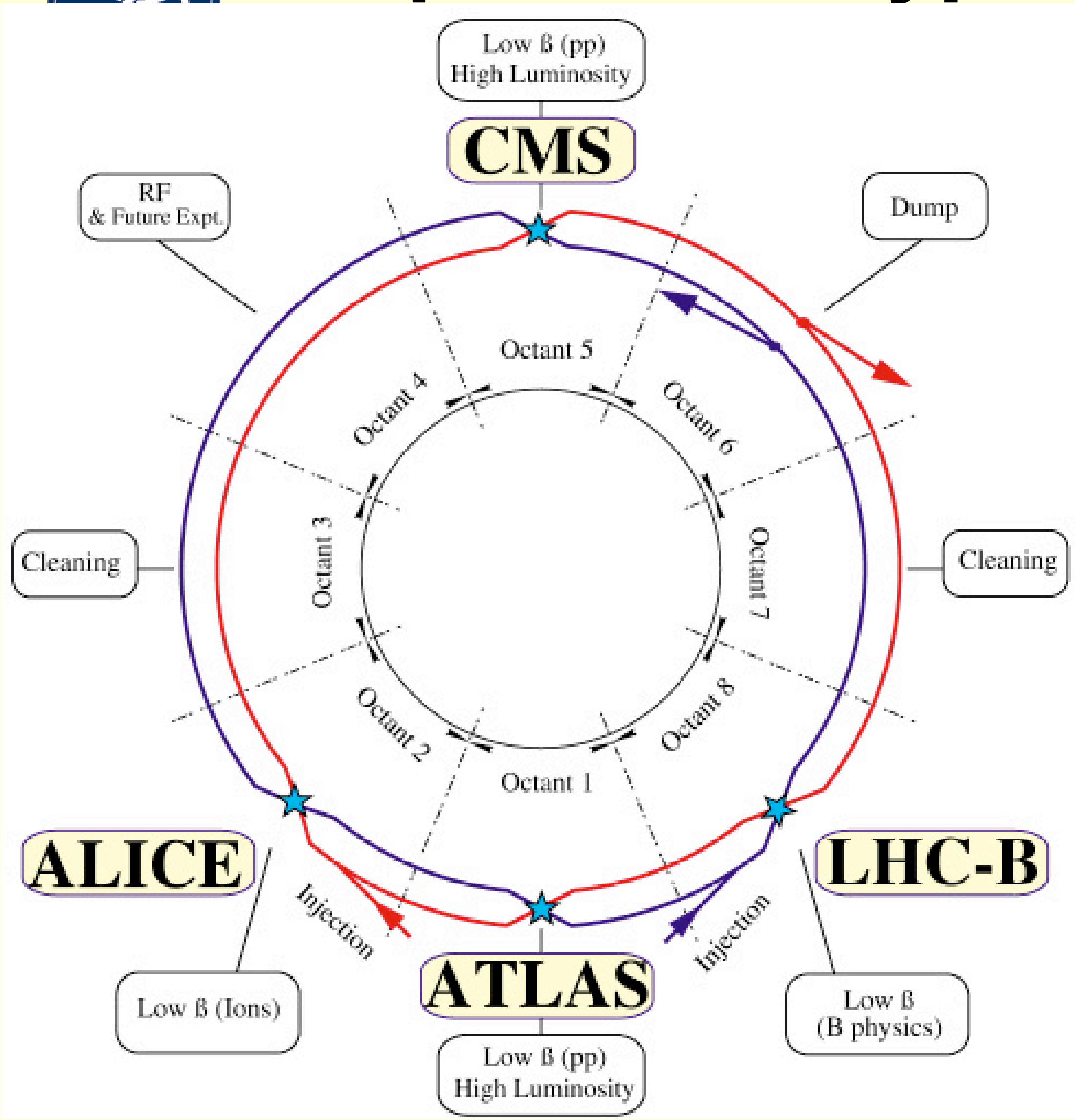
Feasibility study - tunnel space



Feasibility study - tunnel space

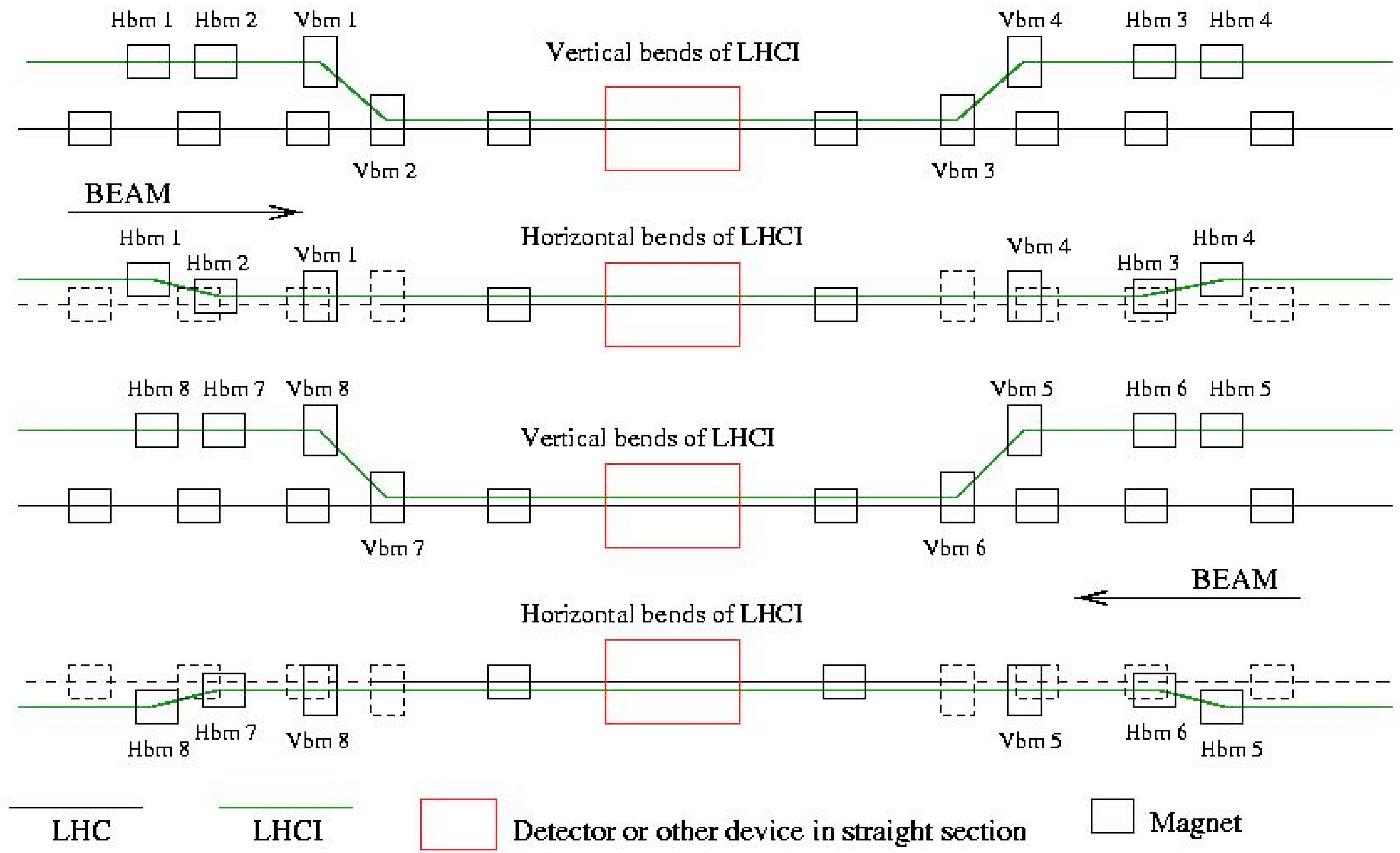


Experiment bypass options



- 4 (or 2) exp to (by) pass
- Either dig tunnels (20MCHF each)
- Or pass through LHC beam pipe
- If problem of transfer to LHC beam pipe solved: use all 8 LSS with RF, cleaning, dump, etc.

(by)pass options



(by)pass options

- **The beam**
  - **Transfer the beam 1.10 m down (and up): 0.29° bend (125 m).**
  - **Rev. freqeuncy 89μs with a dump hole of 3 μs**
- **Transfer the 2 beams by switching the vertical transfer magnets off in the 3 μs hole**
- **Only the magnets nearest to the LHC need to be switched**
- **Either use kicker type magnets (0.17 T - 0.25 T): FNAL model exists (Ferrite core single turn)**
  - J.R. Lackey et al., New Pulsed Orbit Bump Magnets for the Fermilab Booster Synchrotron, Superconductivity Conf., 2004
- **Or a single turn SC 2 T magnet with fast quench at fast switch off : to be developed (MgB_2 technology ?)**

Issues to be studied

- **Optics**
  - Combined function lattice with same cell length as LHC
  - Beam size => determine required aperture
  - Vertical dispersion compensation and Matching of LHCI to LHC straight sections
- **Impedance**
- **Beam transfer LHCI => LHC**
  - Possible transfer positions in LHC (differences around each IP)
  - DC Magnets
    - Fast switched vertical bending magnets (~3 μs)
    - Vertical septum magnets (resistive or SC)
    - Vertical bends (resistive or SC)
  - Fast switched magnets
    - Kicker type
    - SC fast switch off type

Cost estimate

The cost in 2001 $ includes 20% contingency, and it was estimated by scaling down by a factor of 10 from the VLHC proposal [1]. The cost of the power supply systems, cooling water, etc. is included in the cost of the components.

Main arc magnets	80	[$M]
Correctors and special magnets	12	
Transfer line magnets	6	
Installation (120 people @ 100K$/y)	24	
Beam pipe vacuum system	15	
Main arc magnet cryogenic support	3	
Grand Total	$M 140	

[1] Design Study for a Staged VLHC, Fermilab-TM-2149, 2001

Some schedule ideas

	Time[y]	Total[y]
▪ LHCI accelerator design, including transfer lines	1	1
▪ Prototyping and testing transfer line magnets		
▪ (and main arc dipole magnet, if needed)	2	2
▪ Preparation of main arc magnet industrial production	1	2
▪ Magnet production	3	5
▪ Magnet installation in the tunnel	2	5
▪ LHCI commissioning	1	6

Items 1–3 and the items 4-5 can proceed simultaneously,

The overall lapsed time for the LHCI completion work will be determined, however, by the number of months per year allowed for the LHCI installation,

We assumed that 20 crews of 6 people should be able to install 40 magnets per week, or 1200 magnets in 30 weeks (~8 month).

In summary, the LHC operation with the LHCI as injector could be ready in 6 years from the time “zero”.

Conclusions

- An effort was recently started to look into the possibility of a pre-accelerator in the LHC tunnel.
- In the arcs there are no unmanageable problems to fit such a machine (some relocation around some connection boxes).
- The challenge is to pass the experiments either with a bypass tunnel or through the LHC beam pipe
- Passing the beam 1.1 mm vertically into the LHC should be possible but development of fast switched magnets is needed.
- A solid optics / aperture / impedance study is needed
- The LHCI is to be a high intensity machine !