Possible Injection Scheme in the (80 km) TOE: Tunnel Of Everything

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Work of H. Piekarz (FNAL) widely used

HE-LHC cost: rough evalution based on LHC

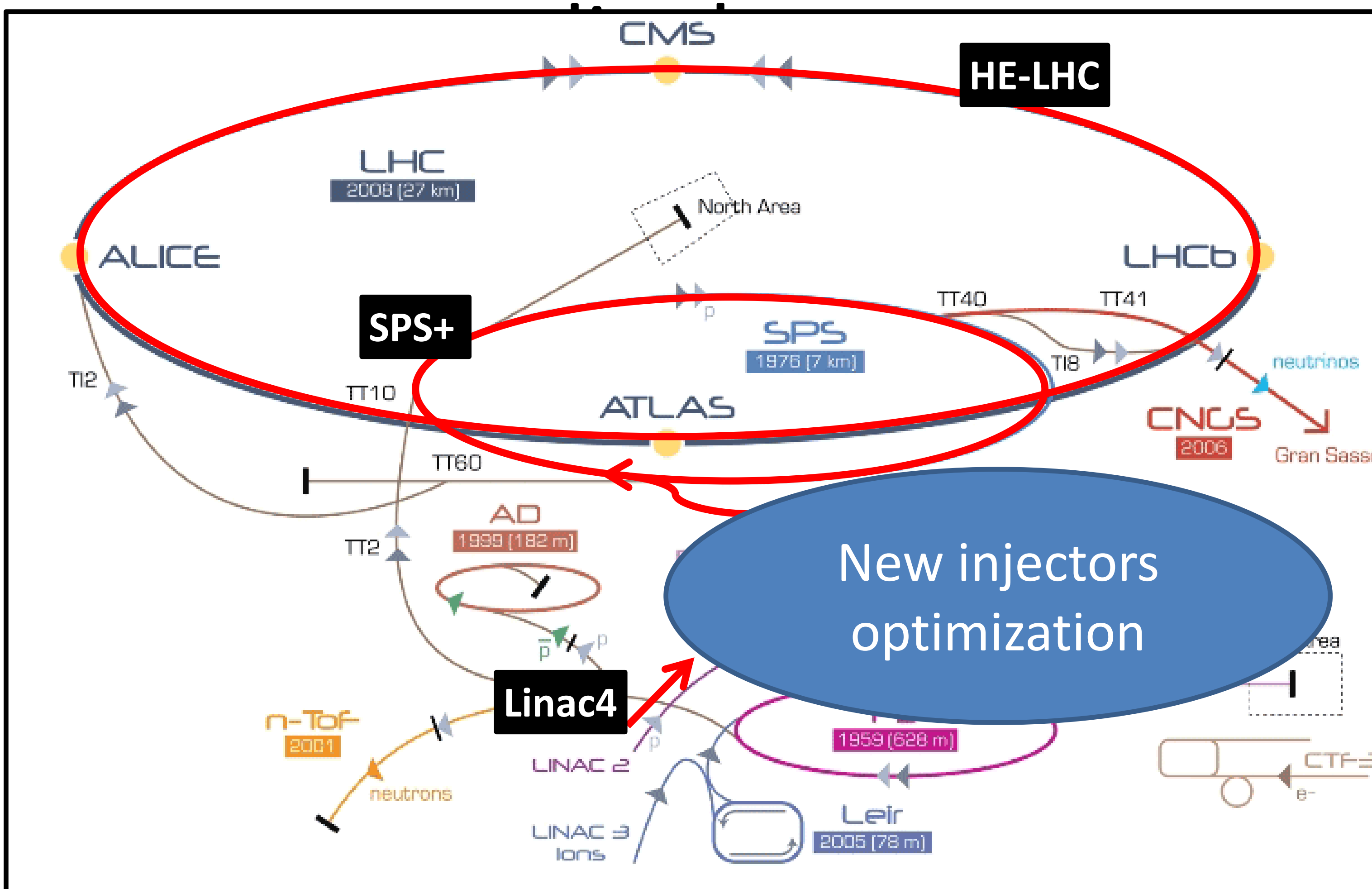
- LHC (machine): about 3 BCHF (material, 2008), **1.7 BCHF** for the magnet system,
- HE-LHC: The non-magnet is ~ same 1.5 BCHF
  - Magnet System Nb_3Sn (**26 TeV c.o.m.**) : ~ **3.5 BCHF** (for a total of **5 BCHF** for the whole machine)
  - Magnet System HTS (**33 TeV c.o.m**) : ~ **5 BCHF** (for a total of **6.5 BCHF** for the whole machine)
  - The above cost are for a new machine, like LHC. Economy could be made because Cryo and other systems need only renovation;
  - **however one should consider cost of LHC removal)**

Other important issues, among many

- **Synchrotron radiation**
- 15 to 30 times!
- The best is to use a window given by vacuum stability at around 50-60 K (gain a factor 15 in cryopower removal!)
- First study on beam impedance seems positive but to be verified carefully
- **Use of HTS coating at 50 K on beam screen to be explored**

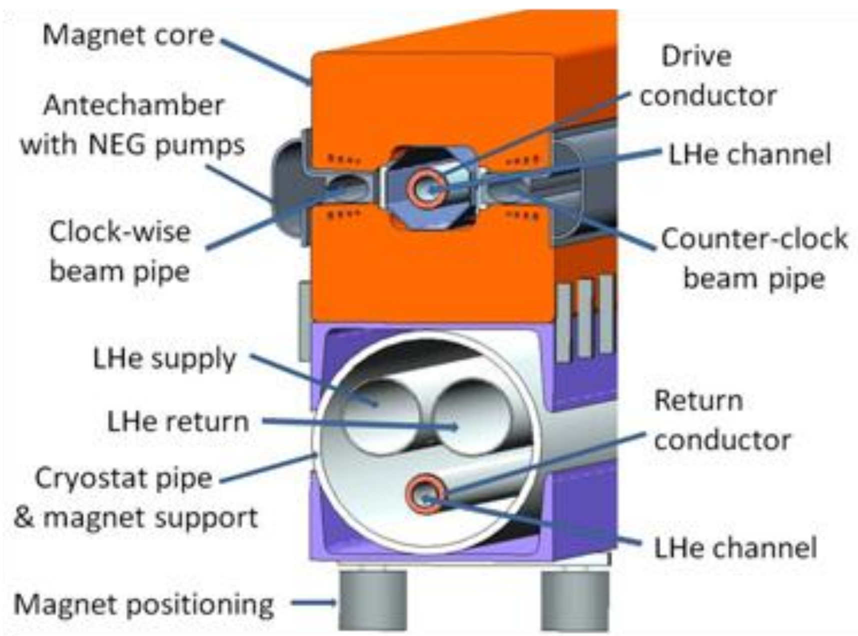
- **Beam in & out**
- Both injection and beam dump region are constraints.
- Ideally one would need twice stronger kickers
- Beam dumps seems feasable by increasing rise time from 3 to 5μs
- Injection would strongly benefit from stronger kickers otherwise a new lay-out is needed (different with or wihtout experiments)

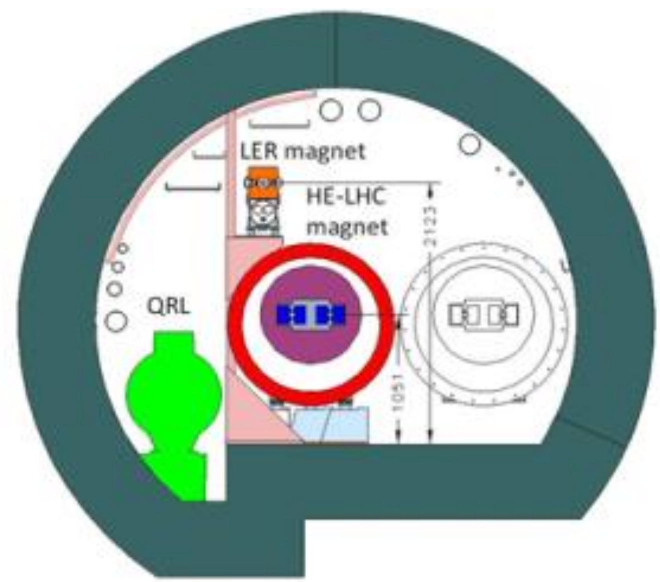
For HE-LHC :injection based on SPS+ Possible use of Tevatron and HERA



Alternate scenarios for Injectors

- Keeping SPS (and its transfer lines: 6 km!): Low Energy Ring in LHC tunnel with superferric Pipetron magnets (W. Foster).
- Work done by Fermilab (**H. Piekarz**), see Malta workshop proc.
  - **cost of LER is lower than SC-SPS option.**
  - Integration is difficult but no show-stoppers





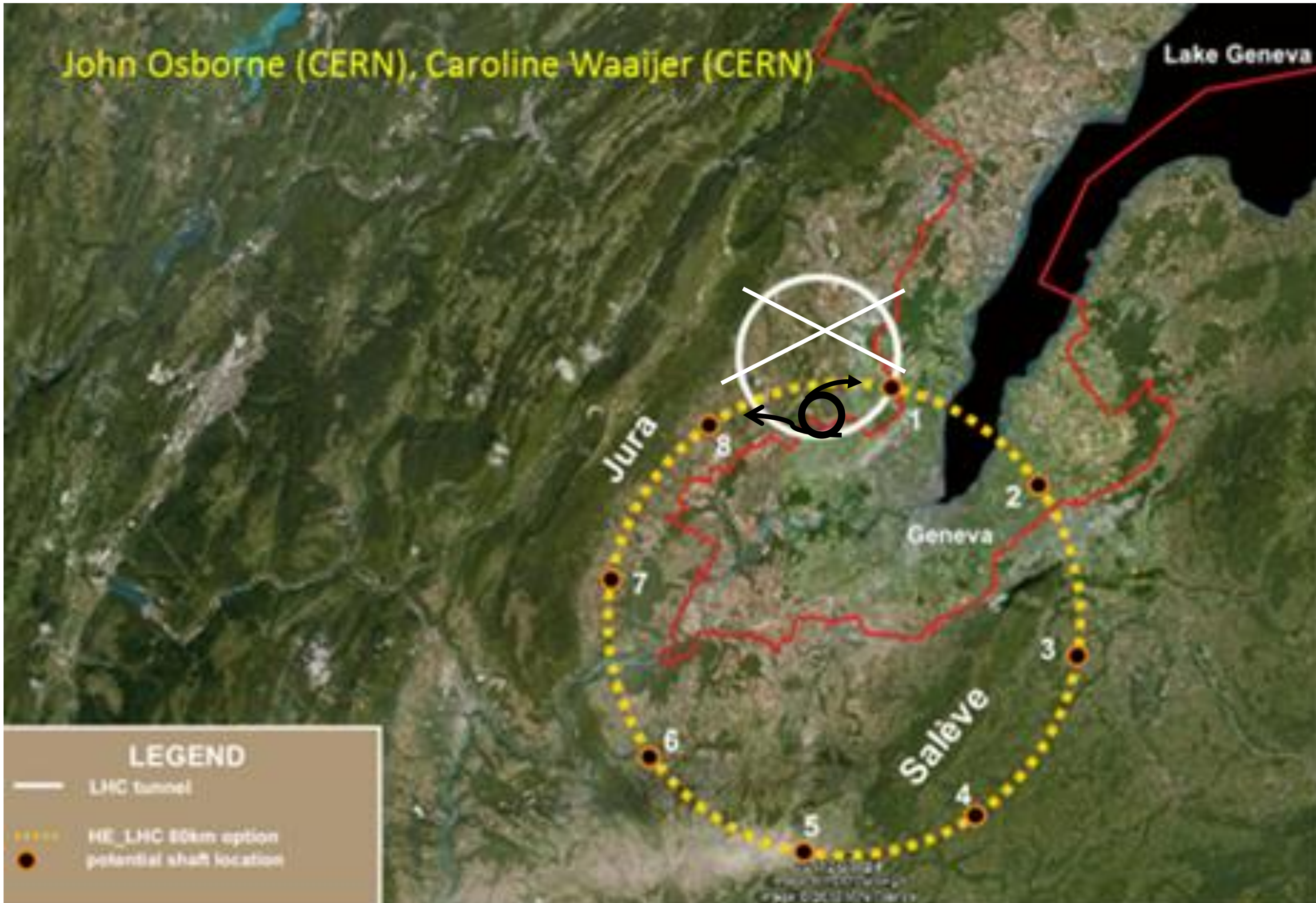
Specific issues of the VHE-LHC

- Beam Energy/Dipole Field optimization might be different
- Aperture can be larger
- Synchrotron radiation MUST be removed at the highest possible temperature: Photon stopper?
- A solution could be use of HTS coated on a beam screen at around 100 K. The wall resistance will be very low and the 2.5 MW/ring (about 30 W/m) can become 25(x2) MW of cryopower!
- Kicker problems will be strongly reduced.

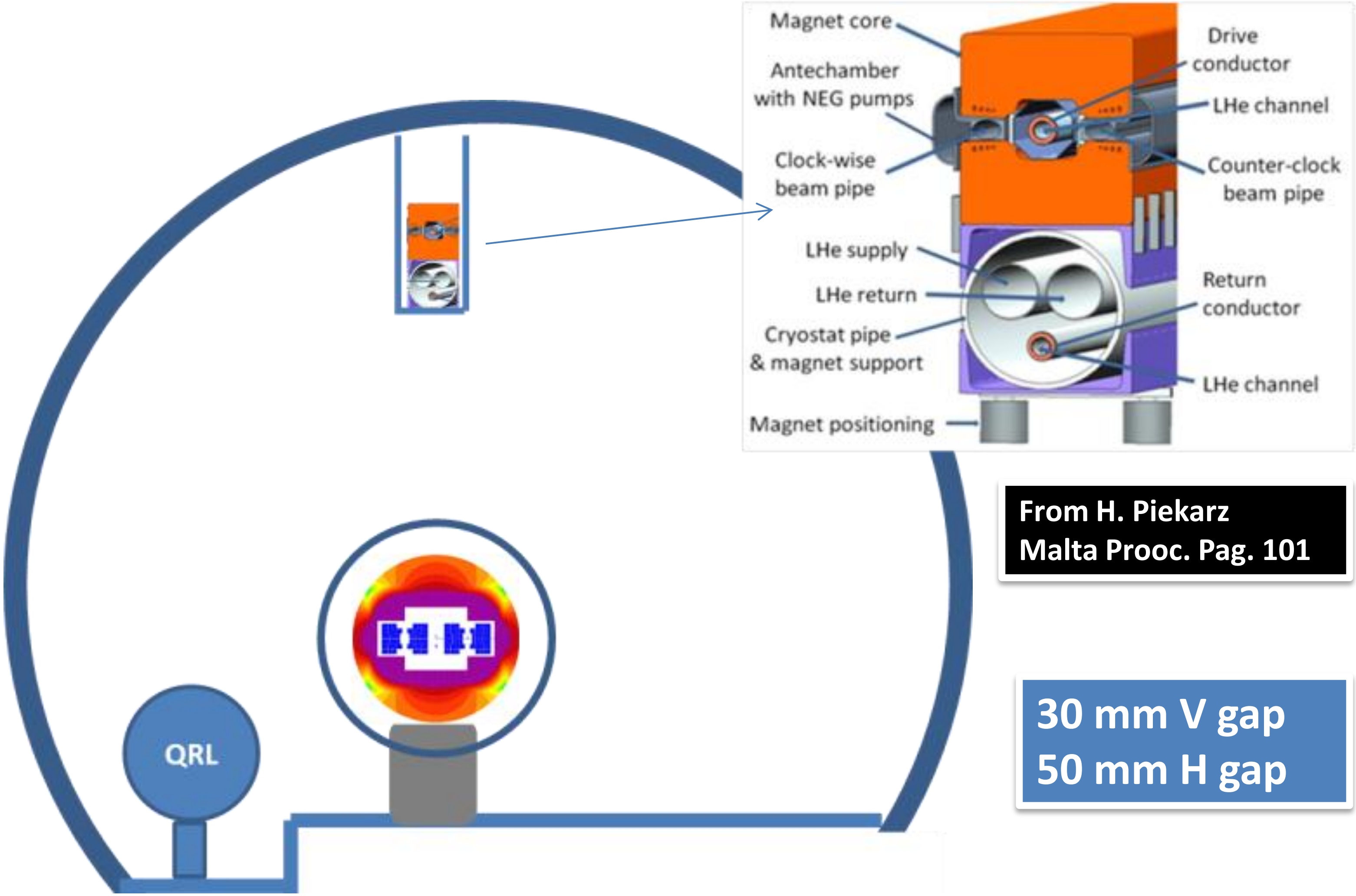
Injection Scheme

- The first baseline was to use LHC
- Either with a SPS+ or wiht a LER in LHC
- However if the LHC is used ONLY for injector it is not worth
  - About 40 MW continuous power at plug for Cryo only
  - Maintenance of a difficult 27 km tunnel and 7 km injection lines for 10% of use
- Proposal: remove LHC and inject from SPS into a 80km-LER

Injection scheme: SPS+ →LHC → VHE-LHC is to expensive (50 MW power for cryo)



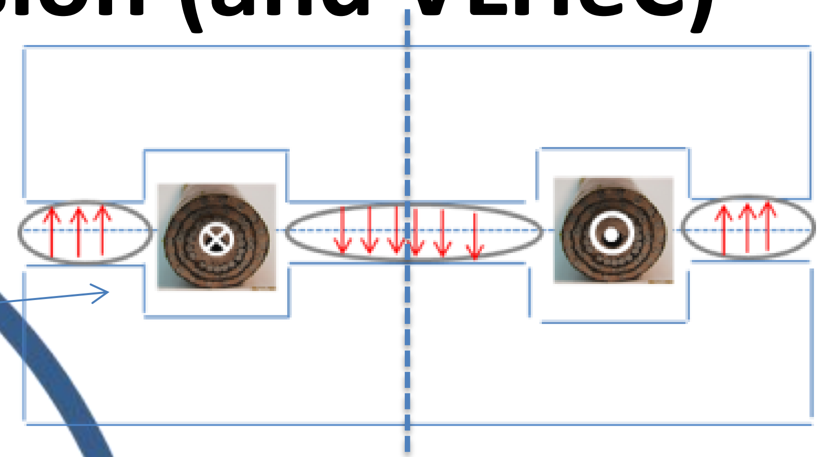
Possible arrangement in VHE-LHC tunnel

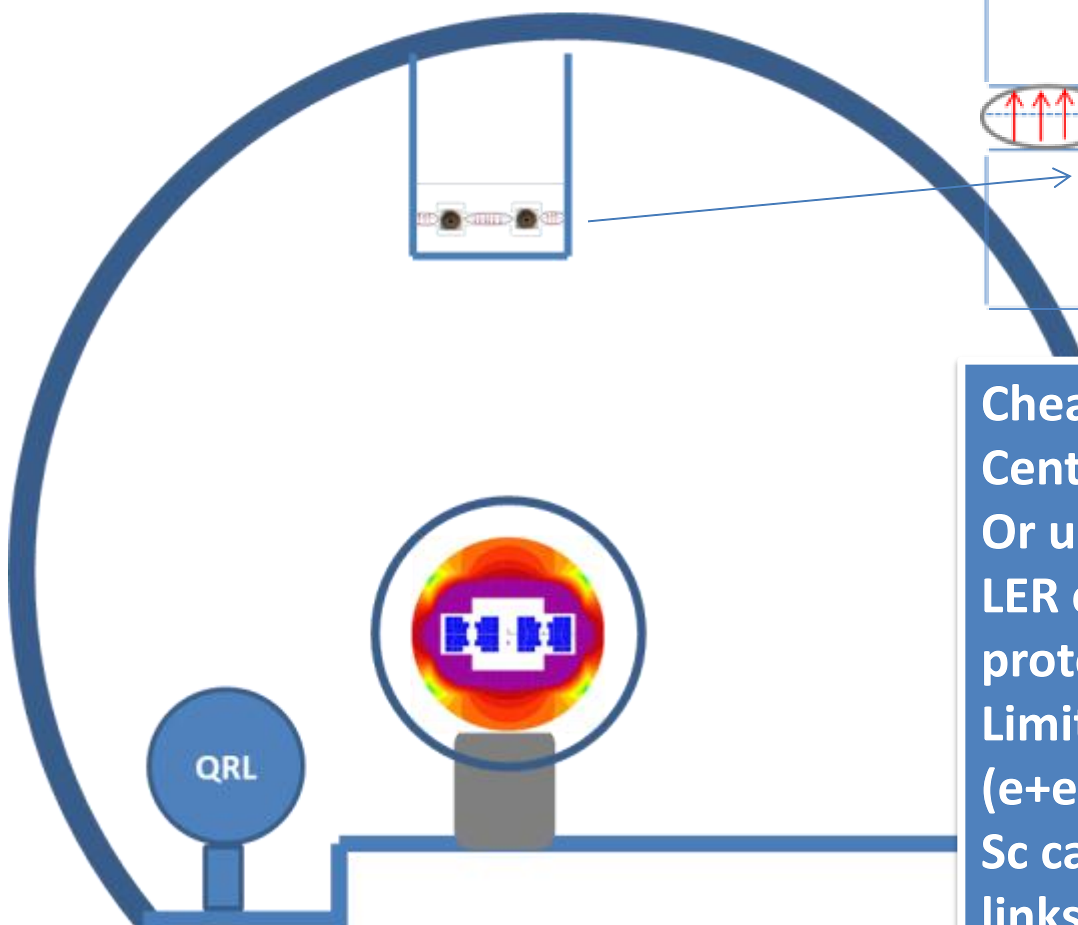


**From H. Piekarz
Malta Prooc. Pag. 101**

**30 mm V gap
50 mm H gap**

Possible VHE-LHC with a LER
suitable for e^+-e^- collision (and VLHeC)





Cheap like resistive magnets
Central gap could be shortcircuited
Or use of 4 beams to neutralize b-b
LER can bend electron 20-175 GeV
proton 0.45-4 or 5 TeV/beam
Limited power both for resisitive
(e+e-) and for p-p (HTS)
Sc cables developed already for SC
links (HiLumi).
SR by e- taken at 300 K

A few numbers for proton injector

	PROTONS		
	energy	field	
	[TeV]	[T]	
	0.026	0.117	
SPS	↓	↓	x 17.3
	0.450	2.03	
injector	0.450	0.167	
80 km tunnel	↓	↓	x 9.0
ρ = 9.0 km	4.1	1.5	75 kA

With I = 115-120 kA Bmax= **2 T**

A few numbers to use the same magnet for e+ - e-

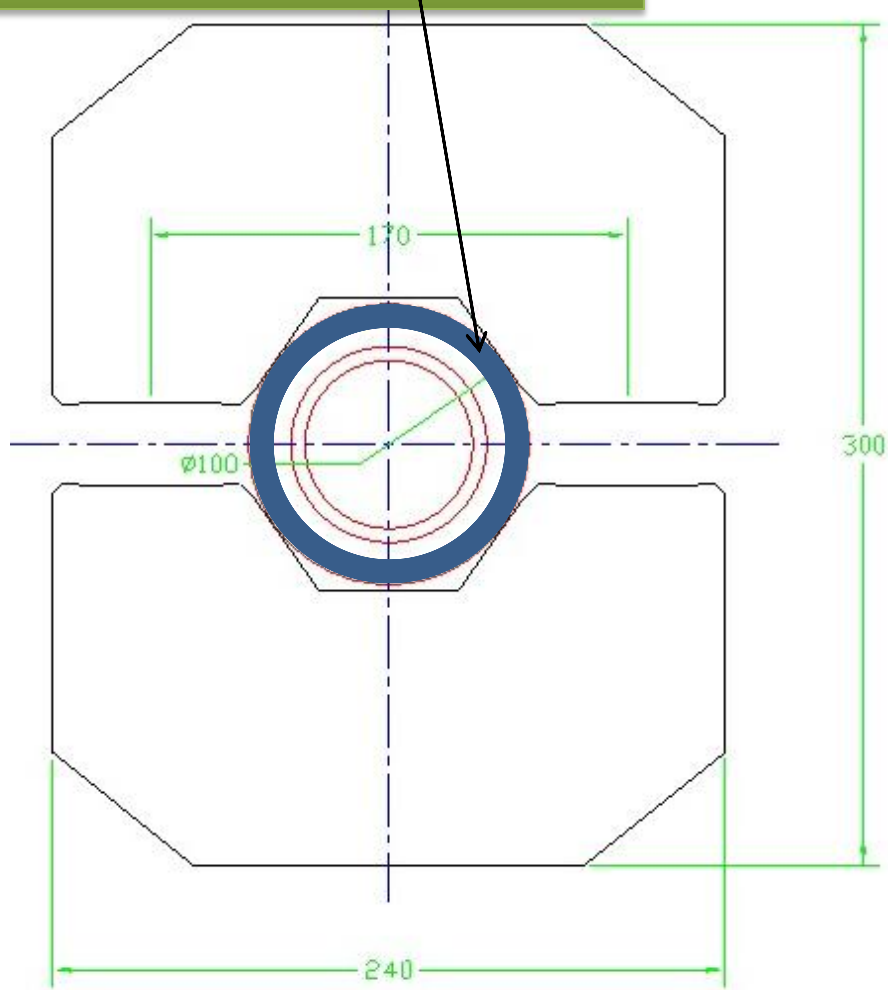
	ELECTRONS		
	energy	field	
	[GeV]	[T]	
	3.5	0.016	
SPS	↓	↓	x 5.7
	20	0.090	
e+ / e- machine	20	0.0074	
80 km tunnel	↓	↓	x 8.8
ρ = 9.0 km	175	0.0648	

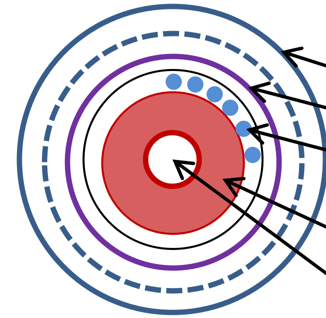
I =3 kA

The injection field is low, 74 Gauss (no diluition). Concern for field quaity.
We think is possîble with «noble» Fe grain oriented but probably also with normal Fe-Si.
Already tested at100 Gauss. Next magnet (for RCS) will be tested to 50 Gauss.
Diluition can also be a possibilty (not good for p-p injector)

A Super-Resistive cable

20 mm thick shield around cable
Gaps: 2 x V30xH60 mm



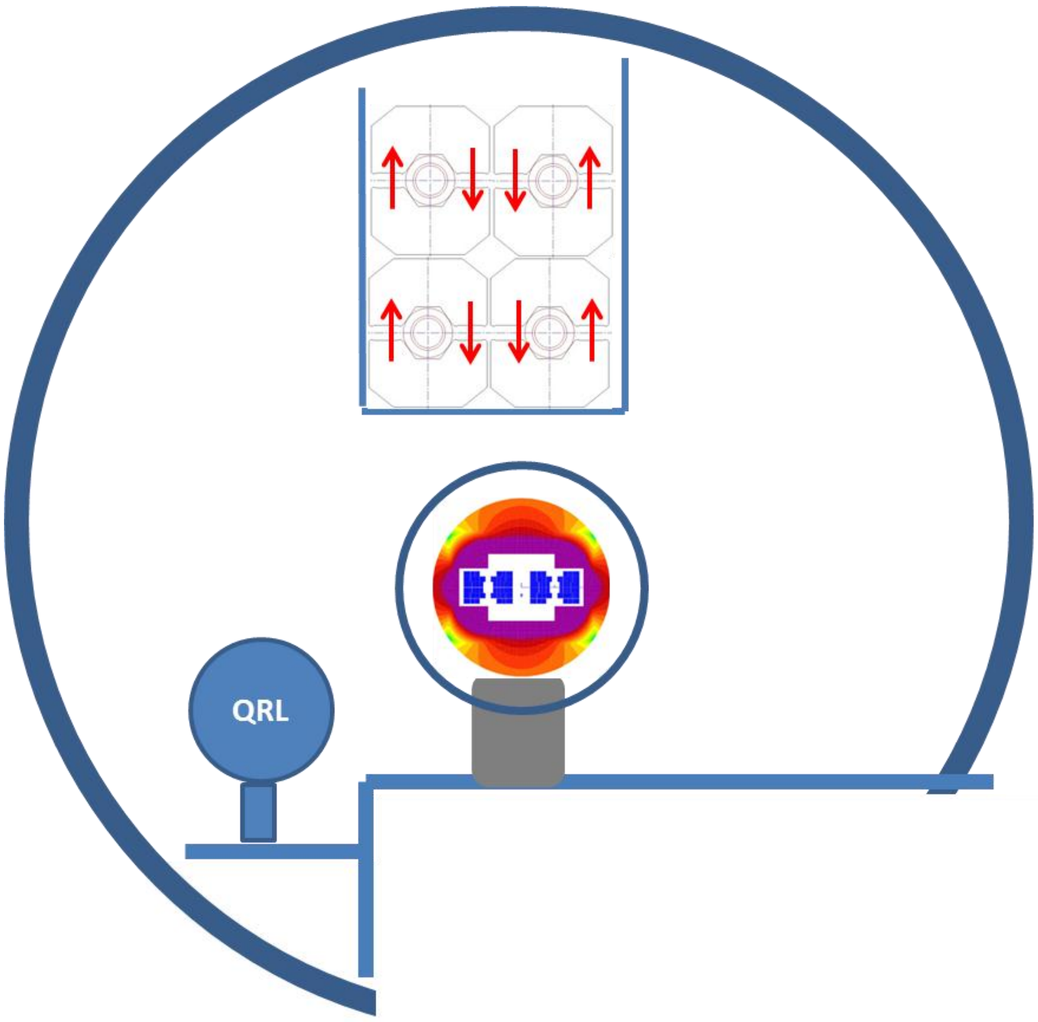


Cryostat : 60 mm
He envelope : 50 mm
SC part: 2 layers MgB_2 (Bi2212)150x∅1mm
Cu inner core 40 mm
Cooling hole: 10 mm

Cable:
inner core of 40 mm Cu (700 mm2)
+ outer core : 2 layers, 150 strands of MgB_2, 1 kA each; Outer size 45 mm.
120 kA =>120 k€/km !
For electrons: us Cu water cooled,
J_{ov} 2.5 A/mm2 (easy): P_{plug}=11 MW/80km

For protons: 800 A/strands
120 kA (for >2.1 T); the central copper is the stablizer
Power: 0.1-W/m at T_{op} = 10 K consumption/cable should be possible:
10 kW of cold power: P_{plug}= few MW
This is for each channel…

Possible arrangement



LER for e^+e^- 350 GeV
4 magnets, 8 channels
4 channel
P = 44 MW (say 50)

LER p-p injector
1 Magnet, 2 channels
T_{op} 10 K; $P_{cryostar}$ < 10 MW
If useful the second magnet is powered as return line
T_{BS}: 100 K ? ; P = 2x25 MW
Photon stoppers are a must

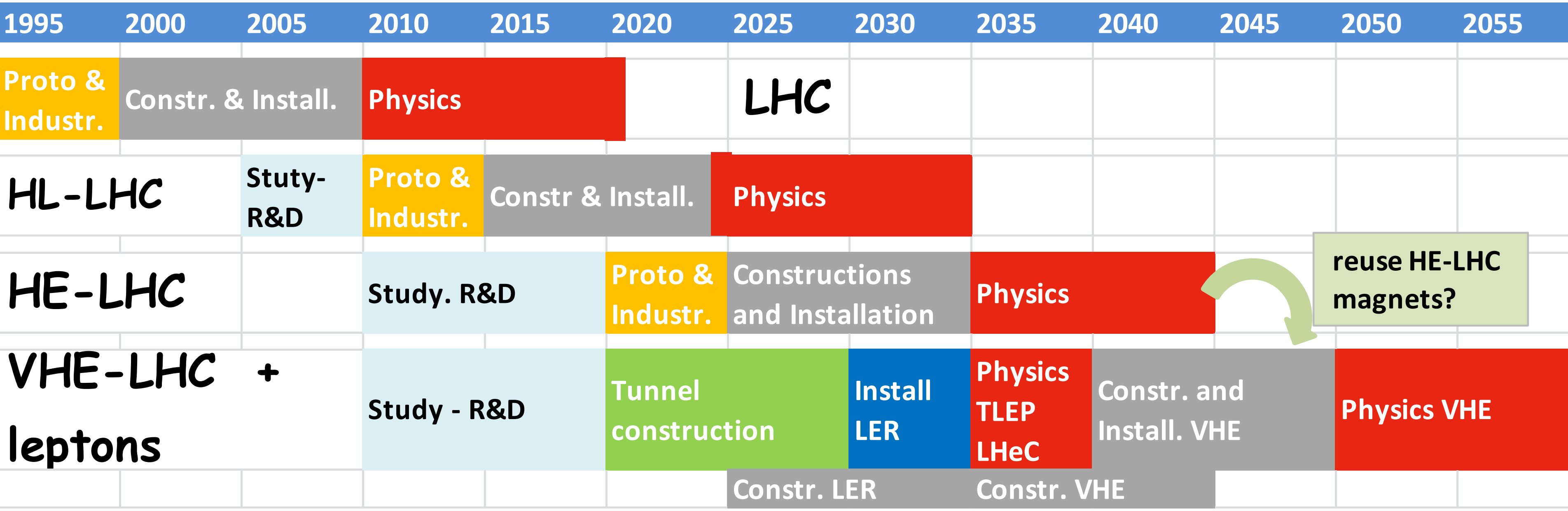
Use of 1 or 2 channels for e ring for a 150 GeV e^- vs. 7-50 TeV p

e^- vs. Ions is also possible

Few preliminary considerations

- Probably different optimization is possible for the channels used as collider at flat top and the ones used as synchrotrons for continuous injections
- Relatively fast cycle (Hz) seems possible
- Very rough cost of the LER magnets (no cryo): <500 MCHF for 2 magnets (4 channels)
- If the TLEP is to be pursued before VHE-LHC and if there is an interest for HE-LHC anyway in // one can install HE-LHC (27 TeV) meanwhile installing TLEP, and then re-use the HE-LHC magnets and cryo-system for VHE-LHC (saving 1/3).

In principle a plan for all is possible (for LHC exploitation): **2018-2020 is critical time**



- **According to Physics needs, the 80 km tunnel can:**
  - **Be alternative to HE-LHC**
  - **Or complementary to HE-LHC**
  - **Accomodating at moderate extra-cost TLEP and VLHeC**
  - **Skipping HE-LHC, TLEP/VLHeC may shorten 5-10years VHE-LHC**