Injector magnet considerations

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Foreword

Injector magnet considerations

magnet = bending magnet

(*combined function* might be interesting too)

injector = High Energy Booster (HEB), taking proton beams at 450 GeV (or lower) from existing LHC injector chain up to injection energy of collider ring

(only injector for collider ring, or also parallel physics?)

assumption: no dedicated new tunnel for HEB

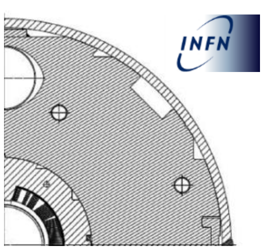
HEB magnets in the SPS tunnel

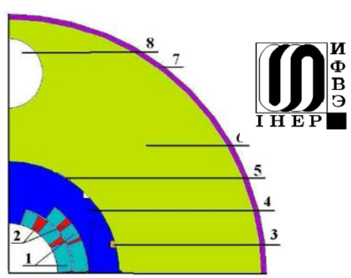
top field HEB [T]	4.5	6.0	8.0	11.0
technology	Nb-Ti, 4.2 K	Nb-Ti, 4.2 K	Nb-Ti, 1.9 K	Nb_3Sn, 1.9 / 4.2 K
top energy HEB [TeV]	1.0	1.3	1.8	2.4
injection energy HEB [TeV]	0.450	0.450	0.450	0.450
injection field 100 km collider [T]	0.3	0.4	0.5	0.8
ramp time [s]	5-10	5-10	30-60	300-600
applicable for parallel physics	yes	yes	yes	?

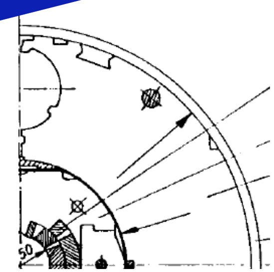
FAIR SIS-300 prototypes

LHC-like, design optimized for faster ramp, one aperture

2-layers cos-θ [MSUT @ UniTwente, HFD @ FNAL, 11 T @ CERN / FNAL]



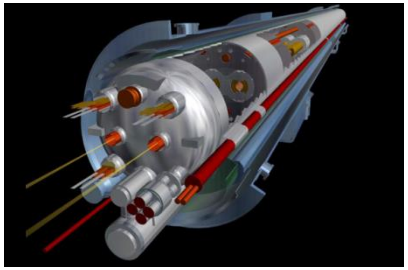




HEB magnets in the LEP/LHC tunnel

top field HEB [T]	1.8	1.8	5.0
technology	resistive	superferric	LHC magnets (faster)
top energy HEB [TeV]	1.5	1.5	4.2
injection energy HEB [TeV]	0.450	0.450	0.450
injection field 100 km collider [T]	0.5	0.5	1.3
ramp time [s]	2-5	2-5	140-200
applicable for parallel physics	? (consumption?)	yes	?

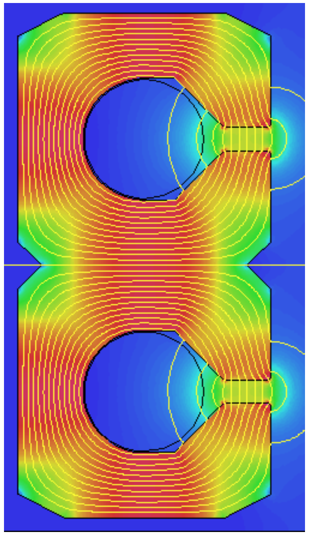
To ramp in 2.5 minutes (50 A/s instead of 10 A/s):



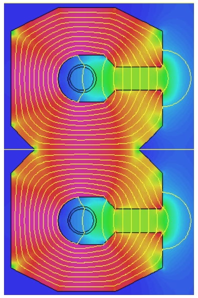
- *diode*: ok, limit at 60 A/s
- *cryogenic load*: to be fully checked
- *premature quench*: not an issue
- *quench protection*: not an issue (for main circuits)
- *impact on (faster) correctors*: to be checked, also for quench protection
- *powering*: splitting each circuit in 2 likely, power converters to be changed anyway
- *field quality*: dynamic effects at injection can be handled with same scheme used now (if correctors follow)
- *machine modification / decommissioning*: to be evaluated in detail

HEB magnets in a 100 km tunnel

top field HEB [T]	1.1	1.1
technology	resistive	superferric
top energy HEB [TeV]	3.4	3.4
injection energy HEB [TeV]	0.450	0.450
injection field 100 km collider [T]	1.1	1.1
ramp time [s]	2-5	2-5
applicable for parallel physics	? (consumption)	yes

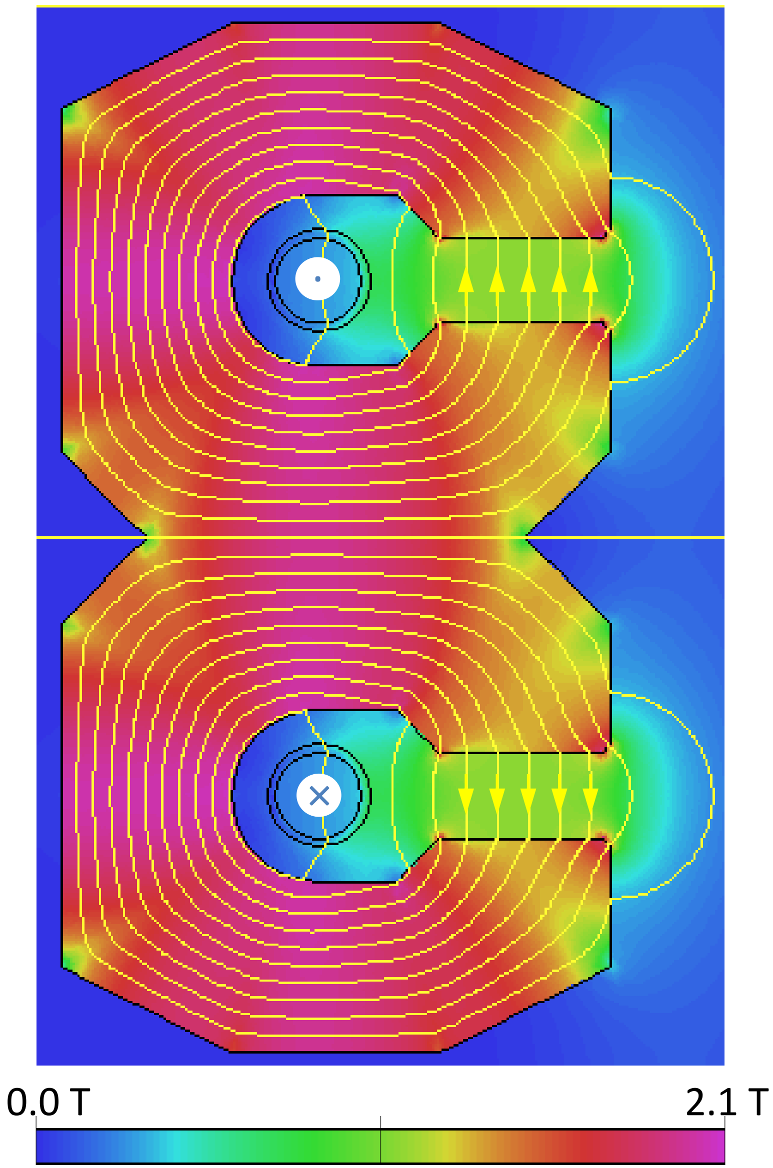


- peak power (in magnets only) of 100 MW with coil operating at low current density (1 A/mm^2)
- overall size 54 x 108 cm
- 45 kA for 1.1 T in bore



- overall size 32 x 60 cm
- 50 kA for 1.1 T in bore
- cryogenic power to be evaluated, function of cycle (ramp rate and frequency), superconducting material and operating temperature

HEB magnets in a 100 km tunnel



- "transmission line", iron dominated, superferric, 2-in-1 dipole
- tentative parameters:
  - vertical full gap 50 mm
  - good field region of the order of ±20 mm
  - overall diameter of "super-cable", including cryostat, 100 mm
  - type and amount of superconductor to be defined
- 50 kA for 1.1 T (3.4 TeV), at injection could be filled by the SPS at 0.45 TeV (0.14 T)
- the field in the second aperture comes for free with the return cable
- 1-turn design: bus-bar coils (*à la* LEP, but superconducting), with minimum inductive voltage for given dB/dt and volume
- at much lower current (resistive? different cable?), the apertures could be used in bipolar operation as a lepton booster

conceptual sketch, for discussion only

A tentative rating

tunnel circumference	7 km SPS	27 km LEP/LHC	100 km
resistive	n. a.	●●	●●
superferric	n. a.	●●	●●●
Nb-Ti, low field	●●	●	●
Nb-Ti, high field	●●●	●●●	●
Nb_3Sn	●●	●	●

● don't even think about it ●●● looks more attractive

The rating depends highly on the relative weights that are given to the various arguments, also not directly magnet related.

discussion time

Thanks in particular to

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L. Rossi, D. Tommasini, A. Verweij.

Thank you.