SOME CONSIDERATIONS ON INJECTION ENERGY IN FCC-hh

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Thanks to S. Izquierdo Bermudez

BASICS

- Main option for FCC-hh injection: 3.3 TeV using the LHC
- Alternative: 1.3 TeV using a superconducting machine in the SPS tunnel

ENERGY SWING

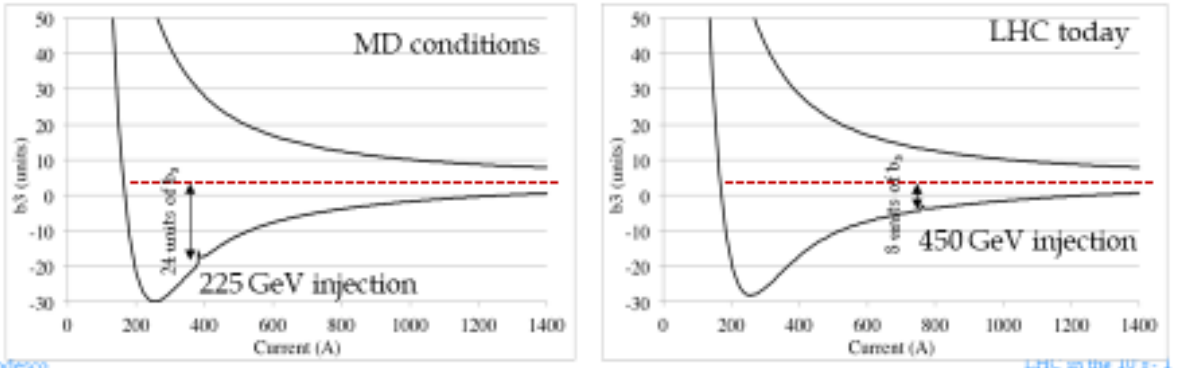
- For the baseline, energy swing in FCC-hh is 50/3.3=15, that is not far from the LHC value
  - Tevatron had 6
  - HERA had 26, with numerous issues
- Going to 1.3 TeV, we would have a factor 38 – extremely challenging with respect to what done in the past in superconducting machines

ENERGY SWING

- An MD proposed in 2018 to inject in the LHC at 225 GeV

225 GeV INJECTION

- In the LHC swing of chroma during ramp is 360 units (8 units change of b_3 × 45 chroma units/b_3)
  - Today this is mastered in two step: FiDeL setting (giving a 5-10% residual error) then and feed forward based on chromaticity measurements
- In FCC with 3 TeV injection we aim at 1000 units swing of chroma during ramp (~10 units of change of b_3 × 90 chroma units/b_3)
  - Note that the sensitivity on b_5 doubles due to longer cell
- With this MD we explore the same chroma swing thanks to a 3 times larger b_3 in the LHC
  - Plus a check of all systems proving the possiblity of a 31 fold energy increase in a proton collider (Tevatron did 6 fold, HERA 25 fold – this would be a world record)



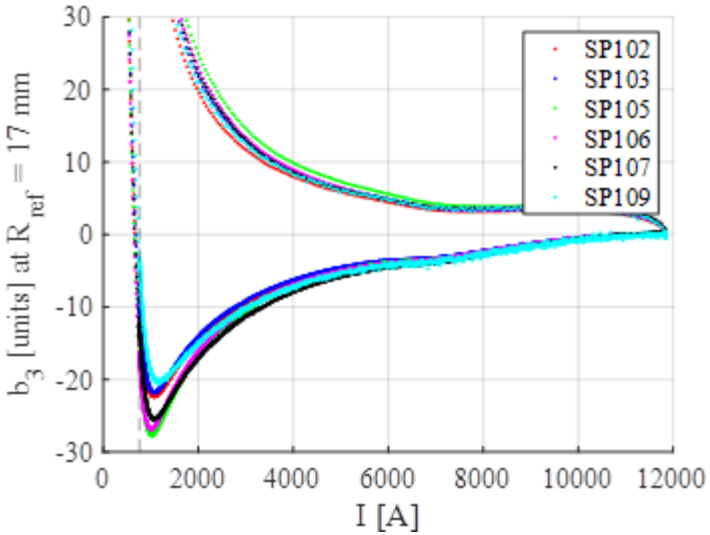
Measurements on dipole 4001 simulating 225 GeV injection [L. Fiscarelli]

APERTURE

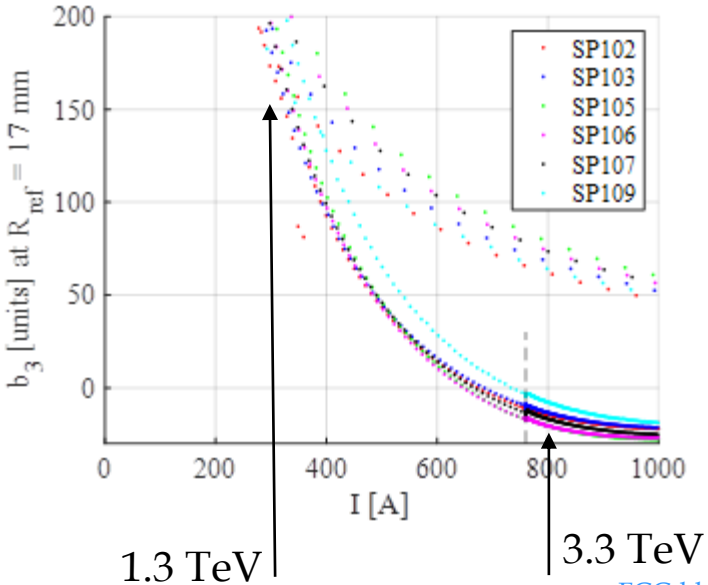
- Aperture of the FCC-hh magnets is 50 mm
  - Reducing the injection energy by a factor 3 gives a 60% larger beam
  - Probably (to be confirmed) 50 mm is still perfectly adequate for an injection at 1.3 TeV
  - Aperture of LHC (56 mm) is fine for 0.45 TeV injection, so there is a wide margin
- On the other hand the large margin that we have today in aperture could be used for
  - Getting rid of all the issues related to high order nonlinearities
  - Use a much longer cell to increase the filling factor and reduce quadrupole number and strength

B3 AND CHROMATICITY

- The main issue is the fact that with a Nb3Sn magnet, not having filaments so small (6-7 mm) as Nb-Ti, we will inject well below the penetration field
  - Injection current with 3.3 TeV: 800 A
  - Injection current with 1.3 TeV: 300 A
  - Issue is not only the swing during ramp, but also reproducibility



b_3 swing for the 11 T short models (S. Izquierdo Bermudez)



B3 AND CHROMATICITY

- A study dedicated to this problem (1.3/3.3 TeV injections, and issues related to b3 and chromaticity swing), using the designs considered for FCC-hh was presented in 2018, see EDMS 2036614 (S. Izquierdo Bermudez)
  - Not to be presented here, but may be by Susana in one of the next meetings
- Another way to work on the issue of chromaticity swing is to reduce the sensitivity (how much 1 unit of by gives as chromaticity) acting on the lattice

THANKS

- In conclusion, we do not have elements today to prove that a 1.3 TeV injection is viable
  - Some bottlenecks should be addressed

- On the top of this, with the recent reduction of FCC size, a revision of the FCC-hh energy is needed
  - The 17 T, 100 TeV option that is being presented is not sound
  - A branching between a 80 TeV all Nb_3Sn machine at 14+ T, and a 120 TeV, 20+ T machine with Nb_3Sn + HTS would be the most sound proposal