Considerations for Magnets for a Muon Collider

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Magnet types: field

- 1.5 - 2T resistive (Cu or Al coils, steel yoke, all warm), ramp rates 10 th T/s, ~40kCHF/m
- 2 - 3 T Superferric (Superconducting, Nb-Ti coil, warm or cold steel yoke) ramp rates 10 th T/s
  - Multi turn coil in cryostat, H or C warm yoke, 2T, few T/s (FCM CERN)
  - Window frame, internally cooled cables, 2-3 T, ~4T/s, (JINR Nuclotron)
  - Transmission line: pipetron type, 2T, few T/s, <10 kCHF/m
- 3 - 8.5 T Superconducting, Nb-Ti , ramp rates from 0.1 to 4 T/s, ~65kCHF/m
- 9 - 12 T Superconducting, Nb_3Sn , ramp rates from < 0.1 T/s, ~85kCHF/m
- 12 - 16 T Superconducting, Nb_3Sn , ramp rates from < 0.1 T/s, ~100kCHF/m
- > 16 T Superconducting, HTS

■ = existing type used in accelerators

■ = prototypes exists

■ = under development, models in 5 years

■ = developed just started, at least 5 years before basic demonstration

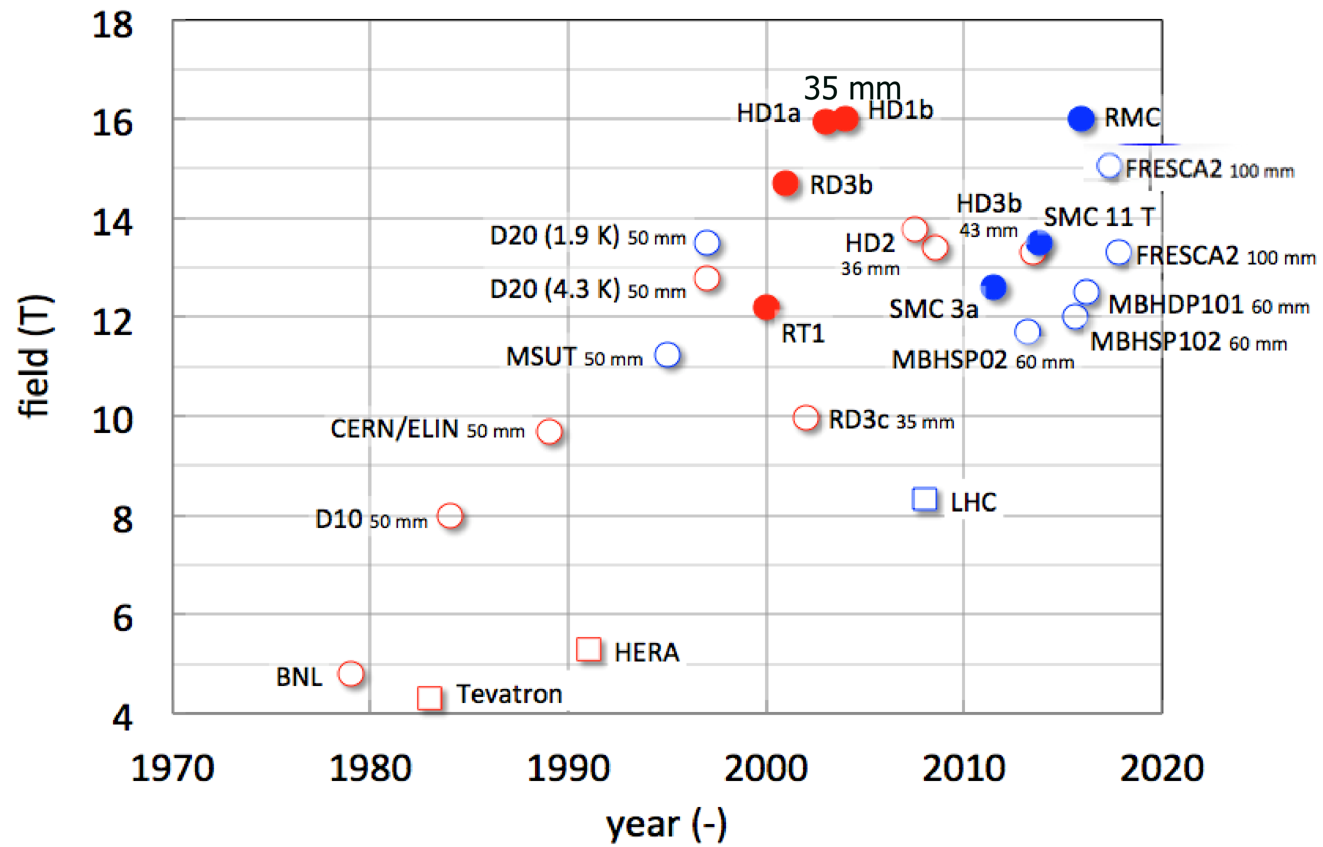
solenoids

- up to 1.5T resistive (Cu or Al coils, steel yoke, all warm) (MRI)
- 1.5 T-10 T , superconducting Nb-Ti (MRI)
- 10 T - 20 T, superconducting Nb_3Sn (MRI)
- > 20T superconducting HTS

- Issue: Rad hardness ! not the same game as MRI

Superconducting accelerators magnets; the state of the art

- Maximum attainable field slowly approaches 16 T
  - 20% margin needed (80% on the load line): for a 16 T nominal field we need to design for 20 T



Muon collider magnets, 10 Apr 2019, GdR

Magnet types: rad hardness

- Up to few MGy

  All HEP machine magnets are at least this standard

- Up to 30 MGy

  HL-LHC triplet magnets, Nb_3Sn and epoxy were rad tested

- > 50 MGy

  - Fusion: ITER both Nb_3Sn, Nb-Ti and special impregnation were rad tested (Cyanite ester-epoxy mix)
  - magnets in target areas: SPS north area (concrete insulation), spallation sources (mineral insulation)

Magnet stored energy

- Stored Energy and Power

$$E = \frac{1}{2\mu_0}\int B^2\,dV. \qquad P = \frac{dE}{dt}$$

  - Example 1 :

    A volume of 1 m^3 with a 2 T field has a stored energy of 1.6 MJ

    ramped in 30 ms requires a power of 53 MW purely to “feed the field”

  - Example 2 :

    Ring : C= 22 km, dipole filling factor 80%, fast pulsed dipole 89%,

    Fast pulsed dipole field B = ±2 T,

    ramp -2 T to +2 T in 3.8 ms., (I take 0-2 T in 3.8 ms)

    magnet aperture H x V = 100 x 50 mm^2 ➔

    V_{field}= 78 m^3.

    E_{stored}(2T) = 125 MJ

    P_{mag}= 33 GW

  - Comparison SPS

    E_{stored}(2T) = 36 MJ, ramp in 3 s, P_{mag}= 12 MW.

    (with a power convertor P_{peak}= 120 MW)

some remarks

- Magnet system conceptual design
  - to make a realistic cost and feasibility estimate we need a parameter table:
    - B, L_{mag} , aperture HxV, ramp rate
  - In general we always iterate over the parameter table to get to something feasible

- Development cycles for magnets are long (e.g. ~8 years for 1 new type model)
  - typically per new magnet type: 6 FTE and 2 MCHF per year

    "het is een dure tak van sport"

- Pulsed magnets are an effort of magnet and powering groups together

- Radiation flux on components need to be looked at early on: Radiation damage and heat load www.cern.ch