Magnets Working Group Meeting Notes

Magnet Working Group

16 March 2023

News

- 28 March zoom meeting on
  - Task leaders will interact in the next days regarding design plan, to create consolidated picture of workplan
- Preparing a list of topics for upcoming meetings
- Daniel Schulte – summary from last couple days in Santa Barbara meeting – funding from USA to match…

Presentations

Cooling for a Muon Collider – Diktys Stratakis

Some key notes

a) Produce 21 well-aligned muon bunches using RF cavities after creation
b) Two sets of 6D cooling schemes
    a. One before recombination (transverse emittiance ~1.5um)
    b. One after recombination (....)
c) Final cooling – cools only transversely (transverse emittance ~ 25 um)
d) Constraints during the MAP studies
    a. Last stage can be done with Niobium Tin (Nb_3Sn) since the field at the coils is just below critical limit
        i. For new design this shouldn't be a limit
    b. Fringe magnetic field in the RF cavities – assumed that RF cavity could achieve 50% of achievable gradient.
        i. First data from a test with 3T field at Fermilab showed cavity could still operate at maximal field gradient without breaking down
e) Don summers from University of Mississippi – investigated magnets using HTS (without Nb3Sn constraints)
    a. Added 4 extra stages (B9 to B12)
    b. Cool the beam further transversely and longitudinally
f) Toward end of study – preliminary magnet study on the final stage B8
    a. 6 coils total: inner coil Nb3Sn, middle and outer: Nb-Ti
    b. Conclusion: Nb-Ti at 1.9K would be the best option
    c. Mechanical model: 187 MPa on Nb-Ti (azimuthal..?)
g) Lessons learned
    a. RF Cavity Design:
        i. A separation of 5.0 cm needs to be added between cavities for tuners/flanges
        ii. Can use curved waveguides to relax constraints in outer geometry/magnets
    b. Magnets

i. Extra space required
ii. Need to do analysis of other stages besides B8

c. Modifications to consider
    i. Could add gaps between a few sets of cells (ex. Every 6 cells a little gap)
    ii. Gap between coils for RF waveguides (break one solenoid into 2)
    iii. Tilted coils may not be realistic, instead add a flexible separate dipole magnet (see paper H. Witte)
d. Final Cooling concept
    i. Design in place
    ii. Final emittance is a factor of 2 above baseline goal
e. Additional remarks
    i. Tilted coils may not be realistic
    ii. Never investigated sensitivity to misalignment
    iii. Transmission is an issue, especially at 2nd half of channel
    iv. Beam is getting really long ~ 2-3 m range
    v. What should the B-field be to reach emittance ?

h) Some questions

a) From Sayed's paper: a final emittance of 25 micron is achievable, …
b) The field quality? Late stage channels are more sensitive – Juan
    a. Back of the envelope calc looking at harmonic content
c) Acceptance window (BL) should be fine
d) 1 comment – not much room for RF (JSB)
e) 2nd comment JSB – B1 has big radius
f) 2 canted cosine theta dipoles powered differentially to create tunable diple field
    a. LB – CCT , it can be tried, but high field solenoids gets extra problems – need to look from practical point of view
g) Never considered the end parts on the beam
h) [LB] comment – the magnets in stage B8, it would be difficult to put them so close to the cavity while including cryogenics, etc. …
i) [LB] – would a higher field 50T help (J Scott Berg -> it will help, the lower the field, the lower you have to bring the energy to get equilibrium emittance, lowering the energy is very complicated/difficult in terms of RF, non-linearities, etc., the transmission is most likely being hurt because of longitudinal matching -> the larger the emittance/blow up becomes the worse it is… higher field solenoids will help with all this
j) J Scott berg – transmission losses same scale as decay losses (if they are on order of W/m, this is a lot)
k) Final cooling channel (JSB) – everything is lower energy, so higher chance to stop and dump energy into magnets

Benchmark on MUC magnetic field calculation

a. 41 chicane coils – inner radius 430 mm, outer radius 530 mm
b. Ansys – done by Pietro
c. Numerical Codes: current-loop approximation
    a. Code by Jose - Based on well-known solution of field produced by single current loop with infinitely small cross section
    b. Code by Daniele – C++ code, provides a numerical integration of the Biot Savart law (consider infinitely this cylinders)
        i. Implements field in FLUKA
        ii. Uses magnetic cards approach in FLUKA
d. Data sets:

Points taken…	Region	Tapering magnets ON/OFF	Chicane magnets ON/OFF
In-axis	Tapering	ON	ON
In-axis	Chicane	Off	ON
Off-axis	Tapering	ON	ON
Off-axis	Chicane	ON	ON

e. Conclusions:
    a. Benchmark exercise has been implemented to validate different numerical codes used for design of MUC
    b. Magnetic field components compared along 4 different paths
    c. Results are in good agreement

Questions/comments

a. CR – check divergence and curl of B
b. LB – what did you learn based on varying accuracy of computations etc.? magnetic field can be independent of (conclusion to add to this: how fine does mesh/refinement need to be for these calculations)
    a. Daniele – depending on how fine I discretize the coil, if it isn't done enough or precisely the field is not what expected…
c. Alfredo Portone – in chicane picture, they are tilted but aspect ratio in plot makes them look not tilted
d. https://journals.aps.org/prab/pdf/10.1103/PhysRevSTAB.17.070102 Figure 6, if you keep going in taper length, it will go down; Also eq. 2, this is essentially what is being used in calculations.

AOB

- Note being uploaded for each meeting
- Future meeting ideas:
    - 27th April – conductor materials, cables, options
    - Other topics
        - Radiation – what will become activated
        - Assess all possible magnet design options