Collimation chapter in FCC-hh conceptual design report

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Scope

- Long CDR to be prepared
- Describe design and performance of collimation system. List any open points
- Timescale:
  - To be sent to editors beginning of September 2018
  - We should aim at having a draft before summer holidays - end of June
  - The sooner the better… If we could have some part done by the FCC week, it would be helpful for the others
- No particular page limit or recommendation on number of pages
- Overleaf document started – read link is https://www.overleaf.com/read/jbqtqwxgrvdg
  - For people contributing to the writeup: Ask me for edit link

Overall structure from D. Schulte

1. Parameters and Performance
2. Experimental insertion region concept
3. RF insertion
4. Collimation concept (merge with collimation system performance?)
    1. Overview
    2. System layout and optics
    3. Key issues
    4. Hardware specifications
    5. Alternatives
5. Injection and extraction concept
6. Arc concept
7. Integrated optics design
8. Single beam current limitations
9. Beam-beam effects
10. Collimation system performance
    1. Overview
    2. Key issues
    3. Aperture
    4. Critical components
    5. Alternatives and key R&D
11. Operation cycle
12. Losses
13. Ion considerations
14. Hadron-lepton option
15. Magnets
16. Beamscreen
17. Instrumentation

From FCC design meeting 14/12/2017

Merge the two collimation chapters?

- To be discussed:
  - We could consider merging the two collimation chapters, including concept and performance in the same chapter
    - Some common points listed in both chapters
    - Gives possibly a better understanding if all results on collimation are presented in one place
  - Should possibly come after the optics design in chapter 7 (we might rely on the optics), but before single beam current limitations in chapter 8 (which will discuss the impedance effects, so system design should be known)

Structure with one collimation chapter

1. Parameters and Performance
2. Experimental insertion region concept
3. RF insertion
4. Injection and extraction concept
5. Arc concept
6. Integrated optics design
7. Collimation: system design and performance
8. Single beam current limitations
9. Beam-beam effects
11. Operation cycle
12. Losses
13. Ion considerations
14. Hadron-lepton option
15. Magnets
16. Beamscreen
17. Instrumentation

Outline of collimation chapter

1. Introduction: roles of collimation, loss specification
2. Baseline collimation concept and settings

If two chapters are required, this could be the first chapter

3. Machine aperture
4. Betatron collimation performance: tracking and protection of cold magnets
5. Energy deposition in warm betatron section
6. Collimator robustness
7. Off-momentum collimation performance
8. IR collimation
9. Passive protection during failures
10. Advanced concepts and key R&D
11. FCC collimation with heavy ions ← Goes in ion chapter?
12. Conclusions and outlook

Overview of sections

- Next slides: look section by section.
  - What work is still needed (red)
- These points are tentative and open for discussion
- I didn't manage to discuss with everyone beforehand – apologies…

1. Introduction

- Motivation for collimation system. What should it be able to handle? Design loss scenarios
  - Betatron halo cleaning – prevent quenches. 12 minute lifetime for ~10 s. Mention estimated quench limit
  - Off-momentum cleaning: 1% beam loss over 10 s at start of ramp. (mention top energy cases?)
  - (Clean physics debris: sustain design luminosity without quenches)
  - Localize losses to controlled areas and reduction of total dose
  - Passive protection during failures: asynchronous beam dump (injection failure?)
  - Keep experimental background at acceptable level
  - … All while not violating impedance constraints
  - Maybe brief recap of LHC experience for each point and LHC references

2. Baseline collimation concept

- Basic principles: scaled LHC system, multi-stage system with double-jaw collimators
- Collimator layouts in betatron and momentum cleaning insertions.
- Brief recap of optics
  - To be discussed: do we make a separate section on collimation optics?
- Collimation hierarchy, list of all collimators (material, length, orientation, s-position)
- Collimator design inherited from LHC / HL-LHC
- Collimator settings through the cycle
- Impedance – mentioned in other chapter?

3. Machine aperture

- Assumed parameters to use in MADX aperture calculations
  - Tolerances for orbit, beta-beat etc that must be met to have acceptable aperture
- Calculations with MADX and comparison to aperture protected by collimation system
  - Injection
  - Top energy: triplets, validation of beta*
  - Work to be done: overview of outstanding bottlenecks with latest optics and aperture model
  - Follow-up in case of problems

4. Betatron collimation performance

- Betatron loss maps at injection and top energy
  - Compare with criterion on cleaning inefficiency for 12 minute lifetime
- Influence of removed skew primary: what happens to skew losses?
  - Study to be done
- Influence of imperfections
  - Study to be done
- Recap work done on power deposition in cold section: check that we don't quench
  - Need iteration with latest design?
- Losses in experimental Irs, other loss spikes around the ring if applicable

5. Energy deposition in warm betatron section

- Assumptions on element design and layout, FLUKA model
- Energy deposition in warm section based on tracking from previous section
  - Overview of where the power goes
  - Discuss critical elements and what can be done.
    - Iterations with shorter TCP, thicker TCSG, no skew TCP
  - Any outstanding point? (Collimator robustness in next section)
- Outstanding work – to be discussed:
  - Systematic summary of remaining elements with high loads. Any worries? Warm magnets, passive absorbers, tunnel wall, beam pipe,
  - another iteration with final collimation system design?
  - Comparison of 50 TeV energy deposition between FLUKA and MARS?

6. Collimator robustness

- Thermo-mechanical studies of most loaded collimators during design loss scenario
  - Done: TCSG with thicker jaws
  - Outstanding (to be discussed)
    - Look also at the TCPs?
    - Another iteration with final system design?
- Statement on severity of consequences

7. Off-momentum collimation performance

- Tracking studies for design loss scenario (start of ramp). Compare to quench limit at injection
  - To be done
- Possibly tracking studies of off-momentum cleaning at top energy
  - To be done
- Optics and design alternatives
- Energy deposition studies?

8. Passive protection during failures

- Asynchronous beam dump: tracking studies to see losses on collimators and aperture around the ring
  - Focus on top energy
  - Summary of most loaded elements – any risk of damage?
  - How many extraction kickers can be tolerated to fail, in view of protection of collimators and aperture?
  - Extraction concept discussed in previous chapter, so no need to repeat
  - Work ongoing
- Local effects at extraction and design of extraction system in other chapter
- Injection failure – in other chapter?

9. IR collimation

- Possible issues, with experience from LHC and HL-LHC design in mind.
- Collimator layout in experimental IRs.
  - To be fixed in present layout: TCT should be further away than TAN from the IP
- Losses in experimental Irs during different loss scenarios
- Energy deposition studies for DS collimators?

10. Advanced concepts and key R&D

- Hollow electron lens
- Crystal collimation with heavy ions
- Probably a short section with no new FCC results presented, rather overview of topics and possible future developments

11. FCC collimation with heavy ions

- Reminder of challenges of heavy-ion collimation compared to proton collimation
- We need the beam parameters for ions – should this section be a part of the ion chapter instead, after that has been presented?
- Cleaning simulations for the design betatron loss scenario, comparison of inefficiency with proton results and estimated quench limit
  - Work ongoing
- Energy deposition study in DS?
- This section might go into the heavy-ion chapter
  - Need probably beam paramters etc. before discussing collimation

Summary of outstanding studies

- Aperture calculations with latest lattice and aperture model:
- Tracking studies
  - Repeat tracking with latest lattice and collimation system design for 12 minute lifetime (betatron losses)
  - Finalize asynchronous dump tracking studies
  - Effect of skew losses without skew primary
  - Tracking of off-momentum losses at start of ramp, and possibly at top energy
  - Cleaning studies with imperfections
  - Betatron loss maps with heavy ions
- Energy deposition
  - Check loads on remaining elements: tunnel wall, beam pipe, passive absorbers etc. Any problems?
  - If needed, repeat energy deposition with latest collimation system design for 12 minute lifetime (betatron losses)
  - Iteration of cold section?
  - Study of cold section with ions?
  - FLUKA/MARS energy deposition at 50 TeV
- Robustness
  - Quantify effect on TCPs during betatron loss
  - If needed, repeat thermo-mechanical studies with latest collimation design

Ideally, it would be good to finalize these studies for the CDR.
But clearly it's quite some work - cannot count on having all done!

Conclusions

- Suggestions, comments and questions? Anything forgotten?