

# Accelerator Design meeting

Monday 25/09/2023, 16:00 – 17:30

(<https://indico.cern.ch/event/1323076/>)

*Chair:* Daniel Schulte

*Speakers:* Daniel Schulte, Anton Lechner, Antoine Chancé, Christian Carli

*Participants  
(zoom): 39*

*Akira Yamamoto, Alexej Grudiev, Antoine Chancé, Anton Lechner, Bernd Stechauner, Chris Rogers, Christian Carli, Claude Marchand, Claudia Ahdida, Daniel Schulte, Daniel Novelli, Daniele Calzolari, Daniele Sertore, David Amorim, David Kelliher, David Neuffer, Donatella Lucchesi, Erik Kvikne, Elias Métral, Fabian Batsch, Gianluca Vernassa, Isabella Vojskovic, John Hauptman, Jose Antonio Ferreira Somoza, Jurj Paul Bogdan, Kyriacos Skoufaris, Leonard Thiele, Mark Palmer, Massimo Casarsa, Nadia Pastrone, Natalia Milas, Patricia Tavares Coutinho Borges De Sousa, Rob Van Weelderen, Roberto Losito, Roger Barlow, Scott Berg, Siara Fabbri, Toms Torims, Vladimir Shiltsev.*

## **MEETING ACTIONS: NO PARTICULAR ACTION (TO BE CONTINUED)**

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### **1. NEWS (DANIEL SCHULTE)**

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- 2nd round on parameters today
- News: another iteration made for the PSC. So far we got only comments from NadiaP => To be continued and finalised soon.
- Next:
  - o We need to go through all the process before having the list of all people

- o In the parameters' document (overleaf), it would be great to have all the people in, so we need to try and define the list of all the people asap
- o The next big report (i.e. the Interim Report) will need to have all the people in
- Daniel announced the workshop for the young people on Wednesday 27/09/23 (Future Colliders for Early-Career Researchers) => See: <https://indico.cern.ch/event/1293507/> and in particular the talk from TatianaP and Daniel: [https://indico.cern.ch/event/1293507/contributions/5436397/attachments/2722590/4730493/ECR\\_2023\\_Pieloni\\_Schulte.pdf](https://indico.cern.ch/event/1293507/contributions/5436397/attachments/2722590/4730493/ECR_2023_Pieloni_Schulte.pdf).

## 2. PARAMETERS: MDI AND RADIATION (COLLIDER), INCLUDING THE RADIAL BUILD (ANTON LECHNER)

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- Anton reminded us that these parameters are discussed in different chapters in the Overleaf parameters document
  - o Chapter 10 (front-end) => Discussed by ChrisR last week and not repeated here
  - o Chapter 17 (radiation) => Radial build in Chapter 6 (collider)
  - o Chapter 24 (MDI)
  - o Note1: some of the presented results are rather reference values than parameters
  - o Note2: focus is on 10 TeV collider, although some results for 3 TeV are also given
- All this can be found in the Overleaf document
- The basic assumptions concerning muon decays in the collider are given on slide 3 => Should be used consistently for all radiation studies
  - o Note: with an instantaneous lumi of  $1.7E35 \text{ cm}^{-2}\text{s}^{-1}$  at 10 TeV (from Chapter 6) one gets  $10 \text{ ab}^{-1}$  after 5 years (for  $1.2E7 \text{ s/year}$ )
- Discussion about the 5 years of slide 3: it is based only on lumi we want to achieve and it is the minimum. If we are not limited by radiation, we can run for longer time
- Radiation load to magnets (chapter 17) => radial build of arc magnets
- RobertoL mentioned that he sees Tungsten everywhere and therefore we should do a cost estimate. Daniel started already and it seems expensive but not prohibitive. The total length to be considered should be almost the 10 km of the circumference
- Neutrino cross section and dose kernels (chapter 17) => Dose kernels (peak, width) per decay to be folded with beam phase space distribution
  - o Note: we do NOT report absolute dose values in the parameter document (Sv/year). Would depend on lattice as well as periodic movement of magnets
- MDI - nozzle geometry (MAP) (chapter 24)

- o Note: we still use the MAP nozzle (1.5 TeV) , but the optimisation for the 3 TeV and 10 TeV will be an important task in the coming months
- MDI - background particles entering detector (chapter 24)
  - o Note: the calculations were done for a MAP-like nozzle
- MDI - radiation damage in detector (chapter 24)
  - o Note: the calculations were done for a CLIC-like detector, assuming a MAP-like nozzle
- Questions / open points
  - o Not included in the document: Radiation estimates for accelerator (studies did not yet start)
  - o Anything else missing, which should be included?
  - o We still need to polish Chapter 17 and 24 (author list, references, ...)
- Comment from Daniel
  - o You gave tools for design which is great and we need to do the same for magnets and RF now => Daniel suggested to write somewhere that these results are to guide the design.
  - o Anton stressed that the considered only the muon decay for the moment and not the pair production => To be done in the future
- I showed the Overleaf document and the summary of chapter 24 remains to be done. The summary for chapter 17 is fine.

### **3. PARAMETERS: HIGH-ENERGY (ANTOINE CHANCÉ)**

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- All this can be found in the Overleaf document as well
- Cryogenics should be around then entire RCS2/3/4 (which are hybrid, i.e. using both NC and SC magnets)
- General parameters
  - o RF dictated through the muon decay
  - o The survival rate and energy swing define the acceleration time and average RF gradient and number of required RF cavities
- Currently the ramp is assumed to be quasi-linear => Ramp parameters need to be refined
  - o RF considerations
  - o Powering considerations
  - o Cost considerations

- Machine and lattice parameters
  - o Most RCS are hybrid
  - o Total dipole length determined by injection/ejection energies and maximum dipole field
  - o Path length and orbit differences depend on the number of cells
- RF parameters
  - o Consequences are unique longitudinal dynamics due to fast acceleration and high intensities ( $>2.2 \times 10^{12}$ )
  - o Large synchrotron tune requires a distributed SRF system => Up to 30 RF stations
  - o Synchronous phase defines number of cavities, RF voltage and bucket area, i.e. beam dynamics
- Summary
  - o A first parameter table is proposed for the high-energy acceleration
    - ⇒ The RCS4 is the most preliminary and needs more studies to be consolidated
    - ⇒ The needed total dipole length and RF voltage are evaluated and can be a first step for costing considerations
    - ⇒ The optics is based on FODO cells and should be reviewed
    - ⇒ The acceleration ramp is quasi-linear and may evolve
  - o Future versions of the parameter table should include also an FFA alternative
  - o We need to continue the discussions to see how to marry RF, magnet, powering, costing, vacuum, collective effects, and optics considerations.
- Discussion
  - o Question/comment1 from VladimirS: typo on RCS4 with 2.22 > 2.2 in RCS3; they should all lose 10%; etc. => Indeed, due to rounding of the numbers, to be corrected. The day after the meeting, AntoineC checked and sent us this information: *"I had a look at the excel sheet and the bunch population was not calculated but directly written, which explains the typo. I have updated the table in overleaf with calculated values (and we find again the bunch population used by Christian for the luminosity calculation). I have to check again other values to make sure that we do not meet the same kind of issues (but I am confident). Concerning the text, I may change it a bit to include the remarks of yesterday and insist that the table is preliminary and needs to include some costing considerations in the future (or RF budget minimisation for instance). Currently, the circumference was an input (based on MAP study) but with a green-field approach, we may explore other circumference sets."*
  - o Question/comment2 from VladimirS: can we reduce the number of rings by 1? Furthermore, VladimirS mentioned that we should put all the rings in SPS and LHC

and build only 1 ring. This is indeed an excellent option for a CERN-based version but Daniel mentioned that the project should remain lab-free for the moment and therefore it is not the proper moment to do such investigations (MarkP made the same comment). ScottB added that doing this, you over constraint the system. Daniel added that the RCS4 is based on LHC so we should separate it as it would not work in the USA. This should just be an example

- o RobertoL: we need  $\sim 30$  RF stations, does this mean that everything linked to this should be also distributed? => Seems yes.
- o ScottB: With 2 T for NC dipoles, we force ourselves to use Cobalt. So it means that doing so we need to make a decision if we can work with Cobalt poles or not...
- o Daniel said that now we need to review the whole energy sequence
  - ⇒ Indeed, now that we have all the machinery etc., the next important question is: what are the energy swings that we can afford and make an optimum (starting from a green field)
  - ⇒ The gradient should be a constant up to  $\sim 1$  and it should be 2.4 MV on average. The same total RF peak power should be used in all the rings; etc.
  - ⇒ Reminder from Daniel: we need to put all this inside the document but we need to state clearly in the document that we needed this step first to now review in detail the energy acceleration
- o NadiaP: Can we think we could use the same tunnel for RCS3 and the collider? Same answer as before
- o FabianB: for the longitudinal matching, the 90% is not exactly constant and needs to be optimised.
- o ChristianC: we need to be sure that at the end the bunch is short enough such that it can enter the collider => What about adding this target value already in this section?
- o Daniel showed his table with some parameters which he thinks are reasonable
- o Daniel mentioned that we don't need to have consistency everywhere but we need to be aware of all the inconsistencies

## 4. PARAMETERS: COLLIDER RING (CHRISTIAN CARLI)

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- All this can be found in the Overleaf document as well
- Slides 2 and 3 are reminders about the luminosity formula and the different contributions. Daniel gave a comment about the luminosity which is slightly higher than the geometric one due to the fact that the 2 beams attract each other and he made some estimates. Following a question from VladimirS, Daniel answered that the values he showed are averaged values over operation time => It was just to show that there is an  $\sim 10\%$  effect
- The collider ring parameters at 10 TeV are shown on slide 4

- What is not in the list or is covered in other presentations
  - o Details on optics as Twiss functions, (maximum) chromatic aberrations, working point...
  - o Radial built in presentation on MDI
  - o Assumptions on maximum magnetic fields and gradients
    - ⇒ A formula was given for region close to IP (< 20 T) or other regions (arc, < 16 T)
    - ⇒ Similar relation for sextupoles
    - ⇒ To be discussed and coordinated further (aperture in arc, maximum fields, mechanical stress management)
  - o Parameters relevant for neutrino radiation
    - ⇒ Maximum equivalent dose at Earth's surface (10  $\mu$ Sv/year for site in Europe)
    - ⇒ Computations (FLUKA results, analytical estimates and folding integrals ...)
    - ⇒ Longitudinal magnetic field profile around interconnects (now hard edge model with 30 cm between magnets) – input from magnets working group required
    - ⇒ Parameters for machine wobbling: 1 mrad amplitude ..... (feasibility?)
    - ⇒ Depth of tunnel
  - o Impedances
  - o Cryogenic system
  - o Vacuum system and needs
- AkiraY raised the important point of the many issues linked to 16T magnets and stressed that it would be good to specify the aperture. It is true but ChrisR stressed that this a parameter which is not critical for the design as it is only to gain a factor 2 in lumi BUT even in this case a muon collider is still valid. Furthermore, Daniel mentioned the possible use of HTS (but Akira said the same in this case also)
  - o VladimirS asked to mention the range, say between 12 and 16 T and not only 16 as then some people can easily criticise
  - o MarkP: a muon collider is not at the level of maturity of p-p etc. => We are establishing a baseline design and we should not discuss this at the moment
  - o DanielS said that 16T is something to explore but this does not mean indeed that if this does not work, the project collapses as this is wrong
  - o ChristianC mentioned that it is written on the slide 5 (to be discussed...)

- o Daniel said that we should try to avoid putting doses in Sievert here as it might have the same impact as black holes with the LHC... Daniel said that it is negligible, it is 10 microS but then the people do not understand what it means. The first thing we need to say is how far it is from the limit.
- o Daniel asked if some people think that we should add some other parameters there. If yes, please contact ChristianC.

## 5. AOB (EVERYBODY)

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- Next meeting will take place next Monday 02/10/23 to finish the 1st round of the parameters review (see <https://indico.cern.ch/event/1329307/>)

*Reported by E. Métral and D. Schulte*