

# International Muon Collider Design Study

## Beam Dynamics meeting Wednesday 12/05/2021, 14:00 – 16:00 (<https://indico.cern.ch/event/1037618/>)

*Chair:* Elias Métral  
*Speakers:* Elias Métral and everybody (round table)

*Participants (zoom):* Alexej Grudiev, Bernd Stechauner, Elias Métral, Elena Fol, Heiko Damerau, Ivan Karpov, J. Scott Berg, Kyriacos Skoufaris, Tor Raubenheimer.

### AGENDA

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### MEETING ACTIONS

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- 1: Everybody** Continue to prepare the 1<sup>st</sup> Community Meeting:
- 1) Try and look, all of us, at what has been done already and collect the info to document our Beam Dynamics webpage.
  - 2) Identify possible bottlenecks in the different stages of the Muon Collider Complex, which should be studied in more detail in the future.
  - 3) Perform first estimates on some (classical) mechanisms we know (BBU, beambeam, acceleration and RF power, etc..), limiting ourselves (for the moment) at the acceleration (after the cooling) and the collider ring
  - 4) Think about the main info which we could/should pass to the other WGs and which questions we would like to ask to the other WGs.

# 1 NEWS (ELIAS METRAL)

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- I reviewed the last actions (see last minutes at <https://indico.cern.ch/event/1035919/>) and we confirmed the joined sessions which were proposed the last time (to check with the experts who worked on this subject in the past what we know and what remains challenging) => See updated timetable of the 1<sup>st</sup> Community Meeting: <https://indico.cern.ch/event/1030726/timetable/#all.detailed>.
- Shinji informed me that he will summarise issues on FFA in the HE-Complex WG. Would be good if this would be discussed during the joined session with us.
- For the moment we did not foresee anything with the magnets yet.
- News on the list of parameters to be used along the chain: Mark informed me yesterday that Jean-Pierre and him have had 2 meetings to review the parameter tables and have attempted to clear up several potential points of confusion. They plan to meet again this Thursday to finalize the table. The table along with the reference document package that he has been assembling will be available for everyone to access by the end of this week.
- There will be an Accelerator Design meeting on Monday 31/05/2021 where all the WGs will present an updated version of their preliminary summaries of the 1st Community Meeting (see evolving agenda here: <https://indico.cern.ch/event/1038303/>).
- I added also Christian Carli and Kyriacos Skoufaris to the list of BD colleagues (many thanks to you!): they have a slightly updated version the MAP 3TeV original madx file (see last minutes) => See <https://muoncollider.web.cern.ch/design/lattices>.

## 2 FOLLOW-UP OF LAST MEETING AND PREPARATION OF THE 1ST COMMUNITY MEETING ON 20-21/05/21 (EVERYBODY)

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- Heiko mentioned that, following last week's discussion, he updated his version of the RCS parameter table, which has been uploaded here: <https://indico.cern.ch/event/1035919/contributions/4350468/attachments/2239829/>. See also attachment. It can be seen in particular that we are in the regime of  $\sim 20\text{-}25$  MV / m as we need more RF voltage than the minimum possible one ( $\sim 2$  times), as we don't want to accelerate on crest and we cannot use all the straight sections.
  - o They also started to look into the mechanism (and bucket deformation) with a large synchrotron tune. They confirmed that for (very) strong RF focusing they need more than 1 RF station.
  - o Next steps are to compute the over-voltage requirement for the bucket, synchrotron tune, etc., and to set up a small tracking model for one of the RCS.
  - o Scott commented that another reason for having more than 1 RF system is the difference between energy defined by magnets and energy from RF as this is in fact what governs the number of RF station we need. The problem for us for the muon collider is that we have 2 counter-rotating bunches in our RCS and therefore we lose some freedom to have some uniformity along the ring.
  - o For the acceleration, Scott had in mind a hybrid pulsed synchrotron as discussed in the past (see

<https://indico.cern.ch/event/1016248/contributions/4282413/attachments/2215263/3751017/JSBerg-210325-01.pdf>) and it needs to be 98% efficient otherwise, with a RepRate of 15 Hz.

- Tor mentioned that he is trying to get a feeling (working with Scott) of what happens in the first stages of the acceleration with the 2 bunches, i.e. between  $\sim 200$  MeV/c and 63 GeV, i.e. before the RCS.
  - o Tor mentioned also that we could start by using as HOMs the HOM spectrum from the 1.3 GHz Tesla cavities but Scott mentioned also that we would need some new cavities better optimized for our purpose. At the moment, Scott worries less on HOM than on the short-range wake and mainly for the longitudinal plane than the transverse one.
  - o Tor discussed the BNS damping (to stabilize the BBU instability) and reminded us that when the spread is too much (several %) it is difficult to operate (from past experience at SLAC). It is foreseen to be less than 1% for ILC and here we have something like 1.5%, so it will need to be studied in detail by detailed simulations.
  - o Tor mentioned that in the past they used a lot 3D IMPACT and Bmad.
- Ivan mentioned that they started to write a script for the BLOND code and he asked about the momentum compaction factor to be used. Scott gave the number  $2.4 \cdot 10^{-3}$ , which means a gamma transition of 20.4, i.e. it is close to the SPS case. Scott mentioned that we don't have much flexibility here to modify the optics to be able to modify this value. Ivan will perform first some studies without intensity effects and then he will include the impedance.
- Kyriacos mentioned that he is working with Christian Carli on the arcs of the collider to develop an FMC lattice, to be able to go from a momentum compaction factor of  $\sim 1E-3$  to very small values. They will have to discuss with the magnets people. Scott reminded that from past MAP studies with very the large momentum spread (at the % level),  $\alpha_3$  was dominating so even if  $\alpha_1$  is very small ( $10^{-6}$  or less) then we need to care about the higher orders indeed. Kyriacos reminded that here we discuss  $\sim 0.1\%$  of energy spread from the parameters list for the collider. Scott mentioned also that in some past studies  $\alpha_2$  was about 0 but he is still wondering if this was intentional or not. To be checked in the future.
- Elena mentioned that she is the new fellow of Daniel and she is working to develop an analytical model of the evolution of the beam losses and transverse emittance from after the cooling up to the collisions in the collider ring. Her 1<sup>st</sup> task is to work with Bernd to develop a model for cooling. She also would like to develop a little python tool (with the known formulas) to be able to make quick scans of some relevant parameters.
- Bernd mentioned that he is dealing with the final cooling and he is trying to reduce the transverse emittances with the ICOOL code. He had a question to Scott as only one person seems to have worked on this in the past and he was wondering if someone (Scott for instance) would have the corresponding lattices. Scott mentioned not and that he has also no contact with this person. Bernd should try and contact this person directly. I mentioned that following the past discussion with Rob (see last minutes), there is a parallelized version of ICOOL which could be of great help for Bernd.
- I showed some updated results from Mauro Migliorati for the BBU instability in the muon collider rings using his new code called MILES (for Modeling Instabilities in Linacs with Ellipsoidal Space charge)
  - o Paper to be presented at IPAC2021 in 2 weeks.

- This is a code for Linacs that they are adapting for a circular machine as far as synchrotron motion can be ignored
- Next
  - ⇒ Resistive-wall => Results should be presented next week.
  - ⇒ Transverse damper => Should be possible to add it => To be looked at in the future.
  - ⇒ Space charge (for the low-energy machines) => It can be included with a simple model (a uniformly charged ellipsoid having a linear field, also in z) => It is very fast.
- The next BD meeting will take place next Wednesday 19/05 between 14:00 and 16:00 (see <https://indico.cern.ch/event/1039182/>). The Outlook invitation was already sent.

*Reported by E. Métral*