

# International Muon Collider Design Study



## Beam Dynamics meeting

Wednesday 25/08/2021, 16:00 – 17:30  
(<https://indico.cern.ch/event/1067302/>)

*Chair:* Elias Métral  
*Speakers:* Elias Métral and Xavier Buffat

*Participants (zoom):* Bernd Stechauner, David Neuffer, Elias Métral, Ivan Karpov, J. Scott Berg, Jean-Baptiste Lagrange, Kyriacos Skoufaris, Rob Ryne, Shinji Machida, Xavier Buffat.

### AGENDA

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### MEETING ACTIONS

**1: Elias and Jean-Baptiste**      **Plan a talk from Jean-Baptiste on the current status of the vFFA studies.**

### 1 NEWS (ELIAS METRAL)

- Last but one BD meeting (#8) was on 30/06/21 and Rob raised some questions:
  - o (1) Regarding this: Discuss with RF and the computing working group to see how to attack the necessary modifications in our simulation codes to properly simulate our cases for the muon collider: Does "RF and computing" refer to the CERN group that you have

mentioned before, or do you mean the RF group in the Muon Collider collaboration?" Also, is there a detailed description of the required modifications for the various codes, or at this time is it just high-level thoughts?

- ⇒ Being followed up by Xavier who is in contact with the ABP computing working group (see maybe more news today).
- (2) Regarding BLoND and the discussion of longitudinal and transverse dynamics: There are many codes that do fully 3D beam dynamics modeling. Collective effects are usually added using some technique, for example a splitting method, correct? So, shouldn't the fully 3D model be the starting point of any future code development?
  - ⇒ Being followed up by Xavier who is in contact with the ABP computing working group (see maybe more news today).
- (3) Regarding this: Scott reminded us that cooling longitudinally is much easier than cooling transversally. Scott explained this on our Zoom call but I still do not understand. To my mind transverse ionization cooling is straightforward, it involves something like what was done in the MICE experiment. Longitudinal cooling involves schemes where magnets are tilted in complicated schemes sometimes involving very tiny tilts of the magnets. So, could Scott explain again why it is that longitudinal cooling is easier than transverse?

⇒ Answer from Scott:

- As to longitudinal cooling being easier than transverse: This is mostly an observation without much theory behind it. More specifically, if you look at various designs for isolated cooling stages that have been optimized to some 6-D cooling standard, in most cases the amount of longitudinal cooling is greater, usually significantly, than the cube root of the reduction in the 6-D emittance.
- My speculation (and it is no more than that) as to why is related to the equilibrium emittance: for transverse, this requires making a small beta function at the absorber, which is hard. For longitudinal, this is related to the energy spread, which a) is maybe not as difficult to make, and b) needs to be large enough anyway to reduce spillage from energy straggling tails, and therefore the Gaussian part of the straggling is well inside the distribution. We're getting the non-stochastic damping of the longitudinal from the transverse-longitudinal coupling, but in practice we have not had significant difficulty in creating that (outside of making wedges with steep angles).
- This is a lot of hand-waving, I know. But I think it points a direction to go in optimization, which is more heavily weighting transmission and transverse emittance reduction relative to the longitudinal emittance reduction, rather than something more democratic (like using 6-D emittance) which tends to favor reducing longitudinal emittance. I think this is in accord with the observation of the emittance evolution diagram where we appear to be reducing longitudinal emittance only to blow it back up again later. One could even try something extreme like  $N^2 / \epsilon_t$  as your merit function, ignoring longitudinal emittance. Taken over a series of stages, longitudinal emittance would need to decrease to maintain transmission and continued emittance reduction (you would likely need to look at multiple stages to ensure that).

⇒ Comments from ChrisR

- The fact that the tilt is only small is a good thing. It shows us that we need only a weak dipole field to get enough dispersion to cool longitudinally. In practice, I am sure we will use trim coils not tilted solenoids (for example in order to prevent asymmetric forces on the magnets, so that the dipole field can be tuned independent of the main magnet, etc). I guess that, considering longitudinal cooling to be mixing of partition functions, we can get essentially any mix of partition functions we want (any mix of transverse and longitudinal cooling) by trimming the dipoles and choosing an appropriate the wedge angle.
  - The schemes with small tilts were designs by YuriA, done in G4BL, and by Diktys, done in ICOOL. Probably some others. I have some of the lattices on my hard drive – I can pass them to Elias or others => **ChrisR sent them to me this morning and I put them on our webpage (see <https://muoncollider.web.cern.ch/design/lattices>), while waiting from the promised framework from the CERN optics team.**
- Last BD meeting (#9) was on 06/07/21 and chaired by Tor in preparation of the 2<sup>nd</sup> Muon Community meeting which took place on 12-14/07/21:
    - o Tor shared a google doc with the possible milestones etc. and associated resources: <https://drive.google.com/file/d/1-LcHoda0EmTKQmGk4IzkkgyMQcBzBWoc/view>.
    - o Tor then summarised all this during the 2<sup>nd</sup> Muon Community meeting => See <https://indico.cern.ch/event/1043242/contributions/4443505/attachments/2281072/3875889/210713%20MC%20BD%20WG%20summary.pdf>.
      - ⇒ Please don't hesitate for any comment from the 2<sup>nd</sup> Muon Community meeting, while preparing for the 3<sup>rd</sup> and last one of the year (see below).
  - As foreseen, the interim report has already been sent to the LDG: seems we need to reduce it a bit from 14 pages down to 10 pages => Should be done for next week.
  - I gave the talk “Towards a Muon Collider” at the SUSY 2021 conference: [https://indico.cern.ch/event/1067302/contributions/4488185/attachments/2297285/3907127/TowardsAMuonCollider\\_SUSY2021\\_EM\\_23-08-21.pdf](https://indico.cern.ch/event/1067302/contributions/4488185/attachments/2297285/3907127/TowardsAMuonCollider_SUSY2021_EM_23-08-21.pdf).
  - Final cooling studies by Bernd and Elena presented at the Muon Capture and Cooling Working Group on 12/08/21 => See <https://indico.cern.ch/event/1061277/>.
    - o Following a question from Rob, Scott reminded us that space charge is expected (and mainly longitudinal) to have some effects only before the final cooling, which justifies why space charge was not taken into account in the previous studies.
  - News from CERN optics team to store all the lattices etc. (Ghislain Roy): it is taking a bit more time and should have more news at the beginning of September.

## 2 MODELING OF BEAM-BEAM AND WAKEFIELDS IN THE RLAS (XAVIER BUFFAT)

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- Xavier presented a 3-step approach:
  - o He first reviewed the requirements in our RLas with 2 bunches counter-rotating in the arcs.
  - o He then discussed the available codes, making a detailed comparison between PLACET2 (reminder: PLACET was developed for linacs and written by DanielS. PLACET2 was later developed by a student of DanielS for recirculating linacs and AndreaL is now

taking care of it) and xsuite/PyHEADTAIL in development. PLACET2 has been designed for RLAs so it is quite well suited for our studies. Xavier also discussed other codes such as MAD, ELEGANT, BMAD, IMPACT, COMBI and BeamBeam3D. Scott mentioned that BMAD (from David Sagan) does recirculating very nicely, so it is really an alternative to PLACET2. As concerns IMPACT, Rob will discuss with Ji Qiang to check what can be done for recirculating linacs. Xavier mentioned that the main issue for the codes is bookkeeping and Scott said that the alternative is to make a long line with duplication but BMAD has this possibility, which simplifies it a lot.

- Finally, Xavier tried to build something with xsuite, using a simplified tracking model to assess the potential impact of beam-beam interactions. He used linear transfer matrices between BB interactions (using the Bassetti-Erskine formula, which assumes that the beam remains Gaussian but it is a first good assumption) to see if beam-beam could be a killer. Xavier mentioned that a re-matching of the optics functions is done at each step (otherwise the values would be even larger). The worst case is with 0 phase advance between the BB interactions and without dispersion. Mitigations can be obtained by optimizing the phase advances between IPs and/or increasing the beam size at the IP using dispersion, as the cost of synchrotron coupling.
- Summary
  - It seems possible to fully mitigate the emittance growth from beam-beam interactions in the RLA1 by adjusting the phases between the interaction points
    - ⇒ The dispersion at the IPs seems necessary to reduce the strength of the beam-beam interactions.
- Next steps
  - Confirm the results with tracking through a real lattice (→ PLACET2) and adjust the optics if needed.
  - Xavier asked if there are some constraints on the delay between the two bunches but Scott mentioned that there is no really hard constraint => We have the flexibility to decide what we need and we will see in the future if we have other constraints.
  - Wake fields.
- Xavier will start with PLACET2 and then we could see with BMAD and maybe also with IMPACT following the coming discussion between Rob and JiQ.
- Scott mentioned that in RLAs we use passive injection and extraction kicker magnets. In the FFA or RCS, these magnets will be active.
- Scott mentioned that he tried to suppress the synchrotron coupling with dispersion suppressors in the RF (in the straights of the RCS) but now it raises the question to do this or not..
- Comment from Kyriacos about the possible compensation with an octupole. Xavier said that this could indeed be tried and even with an electron/positron lens as discussed in the past with Daniels.
- Finally, Xavier asked Ivan about the longitudinal part: should we use BLOND which is 1D or should we use another 3D code directly? It might be good to do both but the 3D studies will have to be done at some point so Xavier and Ivan need to discuss together to see what the best approach would be.

### 3 PREPARATION FOR THE 3RD MUON COMMUNITY MEETING ON 06-08/10/21 (EVERYBODY)

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- It is overlapping with the second part of the HB2021 workshop (<https://conferences.fnal.gov/hb2021/>).
- Rob Ryne will chair it for the BD WG.
- See webpage and goals: <https://indico.cern.ch/event/1062146/>.
- There will be a conveners' meeting next Wednesday 01/09/21 (<https://indico.cern.ch/event/1066941/>).

### 4 ROUND TABLE AND AOB (EVERYBODY)

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- Jean-Baptiste: **See Action 1** => Next (11<sup>th</sup>) BD meeting will be announced in due time.
- Short round table but no other relevant news to mention.

*Reported by E. Métral*