International Muon Collider Design Study

Beam Dynamics meeting

Wednesday 22/09/2021, 16:00 – 17:30

(https://indico.cern.ch/event/1075779/)

Chair:	Elias Métral
Speakers:	Elias Métral and Jean-Baptiste Lagrange
Participants (zoom): 10	*Bernd Stechauner, Elena Fol, Elias Métral, Heiko Damerau, Ivan Karpov, J. Scott Berg, Jean-Baptiste Lagrange, Kyriacos Skoufaris, Rob Ryne, Xavier Buffat.*

MEETING ACTIONS

1: Everybody	**Send any comment about the proposed BD workplan (see updated version here: https://indico.cern.ch/event/1075779/contributions/4524081/attachments/2313407/3940122/TemplateFromDanielS_BD-WG_Filled-21-09-21_EM.pdf).**

1. NEWS (ELIAS METRAL)

- Elias showed the proposed BD workplan as concerns the objectives, deliverables and resources (with currently CERN staff + 2 fellows to come + 4 PHD students who still need to be determined).
    - Heiko confirmed that an RF fellow has been hired for 2 years (supervised by Ivan), who will start in October. He will work on the RF design of the RCS chain. Furthermore, Heiko and Ivan will both contribute as staff (0.1 from Heiko + 0.1 from Ivan).

    - Jean-Baptiste mentioned that UK wants to join and it will be discussed on Monday. From UK, there is already a PHD student focusing more and more on muons and BD for FFAs, supervised by Shinji and Jean-Baptiste.

- As I mentioned, I am now looking for potential university supervisors for the 4 PHD students. Following some first discussions (which need to be continued):
    - MauroM and AndreaM from INFN / La Sapienza would be happy to join.
    - OliverBF from TUD/GSI would be happy to join.
    - TatianaP and MikeS from EPFL would be happy to join.
    - NicolasD from LAL Orsay would be happy to join.
    - GiulianoF will discuss with the head of the university institute => Answer should come on Monday.
    - Others?
- Rob asked about the code for beam-matter interaction and we clarified that the point here is to **have it self-consistent, i.e. to take into account the intensity-dependent effects. This is currently not the case in the beam-matter interaction codes (whose results are single-particle results)**.
- Scott clarified the 3 following points:
    - **1st class of effects**: Standard collective effects as space charge => Those, we know how to do and have codes to do this and maybe we have to do some modifications. Trick is only the integration of the ionisation effects.
    - **2nd class**: interaction with gas (as for instance the gas-filled RF cavities) => Some codes can handle this (as used for instance for plasmas).
    - **3rd class:** interaction in a solid. There is no well-developed code for this and this is what we are looking for => Need indeed to emphasis that it has to be "self-consistent", i.e. handling the current-dependent effects self-consistently.

2. Current Status of the vFFA Studies (Jean-Baptiste Lagrange)

- **Reminder about the vertical excursion FFA (vFFA)**
    - Invented in 1955, rediscovered in 2013
    - Orbit moves vertically when the beam is accelerated
    - Constant path length over whole momentum range (zero momentum compaction factor for all orders)
    - Isochronism for ultra-relativistic energies (slippage factor only dependent of Lorentz gamma, like a Linac)
- **Advantages of FFAs**

    - Flexibility: Beam pulse only controlled by RF, allowing fast and sophisticated patterns
    - Sustainability: energy efficient operation, enhanced with SC or permanent magnets, reduced operating cost
    - Reliability: DC power supply simple and cheap, low failure rate and higher redundancy
    - **Particular case of vFFA**
        - ⇨ Fixed RF frequency scheme for any momentum range at relativistic energies
        - ⇨ Rectangular magnet considered, potentially easier to manufacture than spiral HFFA
        - ⇨ Tall magnet, but smaller footprint than HFFA
- **Disadvantages of FFAs**
    - Reverse bend
        - ⇨ Pros: Orbit oscillations could reduce problem of neutrino radiation
        - ⇨ Cons: Big circumference of the machine
        - ⇨ Mitigation
            - SC magnets
            - Minimisation of reverse bend, addition of edge focusing
    - Orbit excursion too large for high gradient cavities
        - ⇨ Mitigation
            - Maximisation of field gradient
            - Insertion of dispersion suppressor
            - Reduction of momentum range
- Magnetic field in vFFA => Strongly coupled optics
- Shinji proposed a vFFA lattice for muon acceleration using the LHC circumference, a FODO design, and going from 50 GeV to 1.5 TeV
    - Bigger machine compared to what a RCS can do
    - Could have different stages of FFAs as for the RCS
    - Maximum B field reaches 9 T
    - It is not compatible with high-gradient cavities => There PHD is looking at this.

- **They are working on a vFFA test ring, which will be a Proof-Of-Principle ring (3-12 MeV proton) to be built by 2027**. Main concern they have to build this machine is to build the magnets which will be SC so it will be a coil design.
- Jean-Baptiste then showed their R&D plan for the VFFA magnet
    - They are currently working on a 1st NC prototype
    - Then by 2027 the will build the 12 MeV proton ring (discussed above)
    - Then 1.2 GeV proton
    - Then 1.5 TeV muon
- Reminder: advantage of FFA is that we decorrolate the magnets and the RF, so we can do want we want with the RF.
- Jean-Baptiste looked at the maximum transverse space charge tune shifts (using the classical formulae) with the muon beam parameters from our webpage at 50 GeV and found quite some high values
    - ~ -0.5 in the U-plane
    - ~ -1.1 in the V-plane

=> They look quite big and certainly need to follow-up: can we use the usual formulae in this coupled optics? Are they the correct things to look at as the particles do not stay long: shouldn't we look at the effect per cell in this case as Scott stressed? Etc.

- Summary
    - Development at RAL of vFFA as a proton driver for spallation neutron source
    - Proof-Of-Principle ring (3-12 MeV proton) planned by 2027
    - Coil-based prototype magnet designed
    - Strong synergy with muon collider study, preliminary design for muon acceleration from 50 GeV to 1.5 TeV
    - Concern over space charge in current lattice for muon acceleration
- Question from Rob about injection and extraction areas as there are a lot of fringe fields => Indeed, this requires some optimisation with the placement of the septum etc.
- Scott stressed that there are many other issues such as the shielding of the RF cavities for instance as it is difficult to have a very low magnetic field.
- Heiko asked about the RF requirements and Scott mentioned that as for the RCS it is better to distribute the RF cavities along the ring.

3. Preparation for the 3rd Muon Community Meeting on 06-08/10/21 (Everybody)

- This will take place in ~ 2 weeks and there will be certainly no other BD meeting before.
- Nothing else particular to mention.

4. Round Table and AOB (Everybody)

- Rob mentioned that he is currently updating a contribution for the handbook on codes and he wanted to check the correct entry point at CERN: we confirmed that he should contact Giovanni Iadarola (giovanni.iadarola@cern.ch) who is currently leading the ABP computing @ CERN working group (http://abpcomputing.web.cern.ch/).

Reported by E. Métral