Accelerator Design meeting
Monday 28/11/2022, 16:00 – 17:30
(https://indico.cern.ch/event/1219419/)

Chair: Daniel Schulte
Speakers: Daniel Schulte, Andrea Wulzer
Participants (zoom): 45

MEETING ACTIONS: NO PARTICULAR ACTION (TO BE CONTINUED)

1. NEWS (DANIEL SCHULTE)

- Daniel mentioned that some discussion will take place tomorrow during an Extended Coordination Committee meeting about the issue with the EU Design Study MuCol. However, he mentioned that overall we should feel confident and prepare ourselves to continue full steam on our different activities. Of course the kick-off meeting, initially foreseen in January 2023, will certainly be delayed by few months: more news soon.
2. Report from WG1: Physics (Andrea Wulzer)

- Reminder: WG1 is the current number, but as DanielS mentioned last week, it could change in the future and this is why Andrea called it WGx. Until further notice from Daniel, we will continue to use the current structure for convenience (using the same order as shown in some past slides from Daniel):
  - WG1: Physics (Andrea Wulzer)
  - WG2: Detector and MDI (Donatella Lucchesi)
  - WG3: Protons (Natalia Milas)
  - WG4: Muon production and cooling (Chris Rogers)
  - WG5: Muon acceleration (Antoine Chance)
  - WG6: Collider (Christian Carli)
  - WG7: Magnets (Luca Bottura)
  - WG8: RF (Alexej Grudiev + Claude Marchand for EU RF WP)
  - WG9: Beam-matter interaction / target systems (Anton Lechner)
  - WG10: Collective effects (Elias Metral)
  - WG11: Cooling cell (Lucio Rossi)
  - WG12: Demonstrator (Roberto Losito)

- Andrea started by quoting F. Maltoni from the IMCC Annual Meeting in October 2022: there is "a new interest on Muon Colliders (MuC), not a renewed one". See the blue component (from theoretical, Pheno, papers) which is a significant portion of all the papers recently published => It is really the physics driving/supporting this great interest.

- Then, Andrea mentioned the 4 reasons why this happened
  - 1) Before LHC, thinking to other future colliders was less urgent
  - 2) After LHC, need of perspective for ambitious jump ahead in energy exploration. Studies for F.C. like FCC and CLIC prepared the ground
  - 3) We sharply identified 10+TeV as the final goal. Shorter-term physics opportunities are intermediate steps towards 10+TeV realisation
  - 4) MuC is very new! Both from Facility and from Physics point of view. People like working on MuC, because there is interesting work to do!

- The MuC combines pp and ee advantages and its physics is composed of 4 pillars
  - 1) Direct searches => High available energy for new heavy particles production
  - 2) High-precision indirect probes = High available statistics for precise measurements (and no QCD bck)
3) High-energy probes \(\Rightarrow\) Can measure processes of very high energy

4) Muon-specific opportunities \(\Rightarrow\) Collides muons, for the first time

- 1st pillar: Direct searches
  - This is the bread and butter of a future MuC
  - mu mu annihilation: copious production of EW(Electro-Weak)-charged particles up to \(E_{cm}/2\)
  - Vector Boson Fusion: sensitive to EW-neutral Higgs-Portal particles
  - Our problem is not QCD
  - Sound comparison with FCC: not signature- but model-based
  - Much work is needed!

- 2nd pillar: High-precision indirect probes
  - Precision to-do list
    - Will per-mille class measurements for Higgs physics be possible?
    - And per-mille level predictions?
    - Furthermore, Higgs couplings is one over many ways to probe the SM EFT (Standard Model Effective Field Theory). Vector Boson Scattering defines a rich set of processes, much desired at LHC but challenging because of QCD. MuC will do much better and at higher energy

- 3rd pillar: High-energy probes
  - When \(10^{-6}\) can be reached at EW [FCC-ee] energies, \(10^{-2}\) can be reached at MuC energies
  - EW radiation poses a major challenge to theoretical predictions:
    - Order-one effects: need resummation
    - Unavoidable: no “safe” observables unlike QCD/QED
    - Helpful: real emission pattern brings information on new physics!
  - No systematic calculation strategy available
  - Challenge for phenomenology as well

- 4th pillar: muon-specific opportunities
  - Strong focus so far on B and g-2 anomalies
    - Both related with muons
    - MuC is (obviously) a superior device for assessing their origin
  - But the point here is anomaly-independent
⇒ New physics can hide in muons, because we never checked!
⇒ This is why B and g-2 anomalies can be explained by still untested models
  o To be re-considered when anomaly status settles
    ⇒ Lattice results and g-2 ongoing work
    ⇒ LHCb news coming soon
- More to-do list items
  o Muon beam “dump”? => Spent muons could be sent to target-magnet-detector searching for decaying Dark-Photon or similar signatures
  o The high-energy neutrinos physics case
    ⇒ Collimated precisely-known neutrino beam
    ⇒ Neutrino cross-section measurements and FASERv-like physics
  o A forward muon detector
  o Important question: intermediate steps towards the MuC?
    ⇒ Stages
    ⇒ Physics along the way
- How to make this happen?
  o The community at large must keep finding MuC physics interesting and work on it
  o ESPPU-2027 will be the next target => By then, MuC physics community must exist.
  o What we could also start doing => Factorise the WG activity in Tasks, to involve more people, reduce workload, enable a more fine monitoring and intervention on the to-do list
- Discussion
  o ScottB mentioned that from the US Snowmass-2022 discussion, an e+e- Higgs factory followed by an energy frontier machine is what is required by the physicists. How can this physics impacts the physics plan for a MuC?
    ⇒ Andrea answered that an e+e- Higgs factory will give some answers to the table shown on slide 22. Therefore, if the e+e- Higgs factory is done before the MuC, then this table would have less priority as many of its elements would be already known. Some other examples exist but a lot could still be done by the MuC.
    ⇒ The staging approach of the MuC will depend if the e+e- Higgs factory will be built before or not. At low energy (few hundreds GeV), we cannot compete with a MuC as the luminosity is too low. But, above ~ 3 TeV, there is a physics case also if the e+e- Higgs factory has been done before.
ScottB then asked about the W-mass anomaly and Andrea answered that this will be dealt with by slide 24.

Daniel asked if on slide 22 there is a statistical uncertainty and Andrea answered yes: If we double the luminosity, the uncertainty goes down by the factor $\sqrt{2}$.

Nadia asked how Andrea thinks to implement his proposal to “Factorise the WG activity in Tasks”, as she thinks it is a crucial point. To be followed up.

Elias asked 3 questions

- Isn’t good to have the ~ few hundreds GeV as a first stage? As already discussed before, the luminosity is very low. But this would be the first time we would collide muons... Otherwise, why not do LEP3 in the LHC tunnel before building the MuC? Indeed, see below the comment from VladimirS.

- Would 8 TeV instead of 10 TeV be fine (as with some recent analyses, still to be analysed in detail and checked/confirmed by Daniel, the larger acceleration ring would have the LHC circumference)? => VladimirS said that during the US Snowmass-2022 they compared some cases and in some cases/channels, 20% less luminosity give 40% less effect. Andrea mentioned that if we can do this, 8 TeV, and after build a 20 TeV collider, then he would be very pleased. Daniel said that we need to look in detail but of course if we could have a working scenario with the LHC tunnel and that it is much cheaper, it will certainly be well appreciated. To be continued.

- We said that we can do the physics programme in 5 years, what will we do then for the next decades? Elias reminded everybody that the LHC is currently planned to run for 32 years, from 2010 to 2042... Andrea mentioned that running for so long is maybe not so good for the community. On the other hand, it is a pity to run for only few years for such machines costing several tens of billions euros and taking decades to be built. To be followed up.

VladimirS mentioned that the US Snowmass-2022 finished its work and they asked ICFA now to look at the luminosity projections, costs and power consumptions, as the ITF could not, for instance, look at the luminosity risk. To be followed up.

Daniel said that neutrino physics could be done along the way of a MuC and emphasised that the fastest way to Higgs factory is to build the ILC in Japan, as all the other projects will be done after HL-LHC, i.e. after ~ 2045.

VladimirS mentioned that in ~ 2 years the discussion will start again for the next ESPPU and it might be that LEP3 (with a luminosity a factor ~ 4 lower, due to the factor ~ 4 smaller circumference, but so what? who cares? as it is much higher than ILC) will be favoured wrt FCC-ee.

VladimirS reminded that on 13/12/22, there will be a meeting from the NAS (National Academy of Sciences), which has a committee to look at colliders, and Daniel will give a talk there.
3. AOB (EVERYBODY)S

- The 2 next meetings (and last meetings of 2022) will take place on
  
  - Monday 05/12/2022 (see https://indico.cern.ch/event/1219421/): Report from WG3 (Protons) by Natalia Milas
  
  - Monday 12/12/2022 (see https://indico.cern.ch/event/1219424/): Report from WG7 (Magnets) by Luca Bottura

  Reported by E. Métal and D. Schulte