Muon Collider Demonstrator: synergies with ENUBET and nuSTORM

Possible layouts at CERN

NuFact 2021

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Rui Franqueira Ximenes SY-STI-TCD
(on behalf of many other)

rui.franqueira.ximenes@cern.ch
Outline

1. Muon Collider possible locations
2. First conceptual layout
3. Synergies and conclusions
Muon Collider possible locations
TT10 line option

- **First ideas** proposed by Marco C. in the 1st Community meeting. **TT10 line option seen as most attractive (Roberto L. presentation).**
  - Beam from PS ($10^{13}$ p+ @26 GeV in 7ns)
  - O(80kW) should be easily feasible by going sufficiently underground (~40m, in the molasse).
  - 4 MW does not appear to be a showstopper for radiation protection in this layout, but detailed studies will have to be performed.
  - Future upgrades towards a collider and HP-SPL should be compatible with this layout.
- **Experience** with other facilities available
- Important to collect all requirements at this stage in order to be able to provide a first cost estimate by end of 2021 as requested by the study
ISR8 option

- **Alternative option inside the ISR complex**
  - Cost reduction. Would substantially reduce CE costs
  - Could reuse some of the surrounding infrastructure (e.g. TT7 line for the extraction)
  - Limited in terms of available space and beam power
  - Location on the surface imposes limitations from Radio Protection.
  - Likely compatible with a first stage demonstrator but not with a final facility.
First conceptual layout
Layout components of the Muon Collider Demonstrator:

- Target & Horn (first stage) and potentially superconducting solenoid at a later stage
- Momentum selection chicane
- Collimation & diagnostics area
- Muon Cooling area
- Downstream diagnostics area

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- Service areas (Cooling & ventilation, cryogenics, power, transport, etc…)
- Radioactive storage
- Branch to other experiments?
- … other??

*Indicative dimensions by C. Rogers
Layout ideas

Target + Horn (and/or superconducting solenoid)

- Target + Horn length (O) 5 m
- Cooling (Target + Horn) and power (Horn) supplies required
- High activation / radiation levels (specially for 4 MW case):
  - Service rooms for power & Cooling Ventilation
  - Shielding (& space for it)
  - Vessel
  - Handling solutions.
  - Radioactive storage in the surrounding area
  - Access from surface

All of these set requirements for the layout
Layout ideas

Target + Horn (and/or superconducting solenoid)

NuMI @ FNAL
T2K @ J-PARC
CN2PY
CENF

I. Efthymiopoulos, Design Study For A Future Laguna-LBNO Long-baseline Neutrino Facility At Cern, THPFI056, IPAC2013
R. Steerenberg, Design Study for a CERN Short Base-Line Neutrino Facility, TUPEA052, IPAC2013

Yun He, NuMI Neutrino Beam Operations and Megawatt Upgrade, NUFACT2019

https://t2k.org/docs/photos/beamline
https://doi.org/10.1016/j.nima.2011.06.067

M. Calviani, Design, maintenance and operational aspects of the CNGS target, 4th HPTW,

https://doi.org/10.23731/CYRM-2020-002

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Momentum selection chicane
- Chicane (“dogleg”) for momentum selection
- Can also serve as extraction to other experiments (nuSTORM / ENUBET)
- Set of Collimator, bending magnets, quadrupole magnets and a dump.
- Highly radioactive

Muon Cooling Area
- Collimation & upstream diagnostics + Muon Cooling area + Downstream diagnostics area
- Collimation w/ ~5 x cryostats (Ø 2x4 m)
- Cooling w/ ~10 x cryostats (Ø 2x4 m)
- Needs a klystron area & other utilities

AD-Target Area @CERN

FCC e⁺e⁻ Cryomodules tunnel & klystrons gallery
Muon Collider Demonstrator (VERY) Conceptual layout

- Target + horn (1st phase) / superconducting solenoid (2nd phase)
- Collimation and upstream diagnostics area: 10x4 m
- Downstream diagnostics area: 5x4 m
- Injection from TT10
- Momentum selection chicane 10x4 m
- Cooling area: 50x4 m

CERN TT10 branch

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Muon Collider Demonstrator (VERY) Conceptual layout

Indicative dimensions. Model is very flexible at this stage
Muon Collider Demonstrator (VERY) Conceptual layout
Conceptual layout

Muon Collider Demonstrator (VERY) Conceptual layout

Indicative dimensions. Model is very flexible at this stage.
Muon Collider Demonstrator (VERY) Conceptual layout

Target + Horn + chicane hall

Cooling tunnel

Services Gallery

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Conceptual layout

Muon Collider Demonstrator (VERY) Conceptual layout

Target + Horn + chicane hall

Indicative dimensions. Model is very flexible at this stage

Cooling tunnel

Services Gallery

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Muon Collider Demonstrator (VERY) Conceptual layout

- Muon Cooling section can be extended if needed (likely longer than in the current model)
- Experimental cavern (e.g. for low energy muons) can be foreseen downstream muon cooling tunnel
Muon Collider Demonstrator (VERY) Conceptual layout

- Target trench like system with beam line below tunnel floor level → robust solution for radio protection
- Vertical handling with beam equipment in modules, placed in a vessel (N2) container
- Close-by radioactive storage
- Utilities in parallel gallery
- Clear separation from downstream cooling area
- Possibility to branch to other experiments
- Flexible facility with space accounted for future upgrades. At an early stage (80 kW), shielding may be reduced for cost optimization and could start with a simple target & horn. Flexibility to introduce more complex target systems depending on the progresses of the studies for the final Muon collider.
Synergies and conclusions
The Facility is flexible enough to accommodate other experiments.

nuSTORM and potentially ENUBET could be branched from the MUC Demonstrator Facility.

The same target complex would be used profiting from its shielding and general target systems infrastructure, utilities, and accesses.

The double deflection of the beamline could reduce radiation streaming towards the nuSTORM ring.

Synergies between experiments would reduce costs on both sides. (as mentioned by D. Schulte https://indico.cern.ch/event/855372/contributions/4456520/

Compatibility of the extracted beam and momentum selection chicane to be assessed.
Some of the ongoing studies:

- Currently trying to fit the facility (at least vertical shafts) within CERN domain
- Adding granularity to some of the elements & infrastructure in the layout (Target/Horn, Shielding, CE)
- Assessing particle distribution after the horn (T2K horns as inspiration)
- Working on the beam transfer line from TT10 to the demonstrator facility.
- Currently exploring ISR option for cost reduction purposes. (possible incompatibility with nuSTORM/ENUBET)
Conclusions

- Supported on existing facilities and previous studies, a first Muon Collider Demonstrator facility “concept” layout is shown.
- The MUC facility shall be flexible enough & compatible with future upgrades.
- 3D facility modelling, even if with limited degree of detail is key for costing. Important to collect all requirements at this stage in order to be able to provide a first cost estimate by end of 2021, as requested by the study.
- Further inputs are needed, and early discussions with Civil engineering, RP, Transport, Cooling & ventilation, power, etc are of major importance.
- Possible synergies with nuSTORM/ENUBET if Target complex is shared such as reduced costs, Radiation Protection, equipment, etc.
- Muon Collider facility and its integration/compatibility with nuSTORM/ENUBET should be explored.
- Other alternatives focused on muon collider demonstrator objectives could be investigated.
Thank you for your attention!