MDI Summary

The physics goals of a Muon Collider can only be achieved with a self-consistent design of the collider ring, interaction region (IR), high-field SC magnets, Machine Detector Interface (MDI) and detector. At a muon collider the role of MDI is unique, due to muon beams decay products interacting with the machine components tens of meters from the Interaction Point (IP), generating high fluxes of beam induced background (BIB) on the detector.

BIB composition, distribution, rates and arrival time may vary at different beam energies and are strongly related to IR design optimization. The ultimate goal of MDI design is to suppress by several orders of magnitude the BIB rates reaching the detector volume. At the moment, this is achieved by adding absorber shielding around the beampipe region impacting on the detector acceptance and performance.

The most recent studies are based on MAP IR design and optimized MDI at 1.5 TeV [1], as benchmark, and they are summarized in [2] and references therein.
The present absorber solution, proposed by MAP is a twofold cone shaped tungsten “nozzle” with the vertex close to the IP.

To face the need to prepare for specific MDI designs and study the detector constraints, tuned at different energies in the center of mass, the main recent achievement was the implementation of a flexible framework able to read the lattice and optics code optimized at each energy with traditional code like MAD-X, importing the beam line geometry in FLUKA [3]. Over the past ten years, the simulation tools have been extensively used and benchmarked for beam loss studies in the LHC [4], which indicates the predictive ability of radiation field studies for a high-energy collider environment. This FLUKA implementation also allows comparison of results with the pioneering MARS15 studies [5], thus building further confidence in the background rates. With the new tool it is possible to identify the origin and the sources of the BIB and therefore one can act on the IR active and passive elements to minimize the particles’ fluxes on the detector and go toward a second order MDI optimization. Ambitious IR focusing magnet design defines IP parameters and detector size.

To demonstrate the full physics potential required to scientifically justify the investment into a full CDR for a facility with centre of mass energy up to 10+ TeV demands dedicated efforts to optimize the MDI and detector design simultaneously to the IR configuration while aiming at the highest instantaneous luminosity.
Dedicated studies and optimization are needed for the forward region, covered at 1.5 TeV by the tungsten polyethylene-borated nozzle, to evaluate if it could be instrumented to extend detector acceptance.

For the 10+ TeV, we need to study the BIB in detail only when we will have a
1 possible viable IR design. Extrapolating from the current IR and the current BIB is highly challenging, since the processes we have to deal with are not only non-linear, but also hard to predict.

In the following the current work plan is described including the MDI activities shared with other working groups.

MDI Studies done - ongoing

- first proof of BIB mitigation by several order of magnitude at detector volume and IR optimization by MARS15 [1]
- framework to import lattice and optics in FLUKA ready to study any energy

MDI next steps

2
- shielding absorber optimization including IR design for BIB mitigation at 3 TeV

3
- identify a strategy to attempt a first absorber design at 10+ TeV, identifying challenges and potential solutions to address these challenges

MDI plans – next 4-5 years

- define and optimize BIB generation tools at each different energy

4
- explore new ideas for detector shielding to optimize acceptance and efficiency at 3 TeV and then at 10+ TeV
- study of detector magnet at 10 TeV to investigate possible interferences with optics in the IR

Activities shared with other working groups

Accelerator, Magnets and RF design

Activities in progress

- dedicated efforts on the lattice and IR design starting from MAP 3 TeV lattice

FIRST BASELINE
- tune a well consistent collider lattice at 3 TeV

Planned activities

- optimize lattice and IR design at 3 TeV up to several tens of meters from IP
- start to design a feasible lattice and IR optimized design at 10+ TeV

  ⇒ The requirement to reduce β* for higher energies poses strong challenges

Physics and Detector

Major progress has been made recently in understanding physics reach and detector specifications for a Muon Collider detector. More details can be found in [6].

Activities in progress

- full detector with improved tracker and calorimeter capabilities studies at 1.5 TeV with FLUKA/ILCsoft/Geant4 full simulation under final optimization
- optimize detector design and performances with defined physics benchmarks, also exploiting new detector technologies
- detector and on detector read-out technologies and reconstruction tools are key items to improve detector and physics performances in presence of BIB (on-detector logic, timing, granularity, DAQ and back-end data processing)

  ⇒ strong links with the on-going work by Physics&Detector Group and the ECFA Detector R&D Roadmap

Planned activities

- optimize detector/reconstruction performances at 3 TeV
- first experiment design and plan R&D for new technologies for 10 TeV

Neutrino induced dose

The maximum radiation dose due to neutrinos generated in the straight section between the focusing structures around the IP are reduced by the divergence of the beam, widening the opening of the effective neutrino radiation cone. Several mitigation strategies were proposed in [7] and we do not therefore consider it as an insurmountable challenge. However, further studies are needed to finalize the mitigation strategy and the projected doses.

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