Monte Carlo driven MDI optimization at a Muon Collider

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Huge amount of interesting physics at Muon Colliders but background mitigation through machine and Machine Detector Interface (MDI) design needed to preserve detector performances

Beam Induced Background (BIB): primary muons' decay produces many secondary and tertiary particles

• Main issues for the detector



- BIB strongly depends on Center of Mass (CM) energy, machine and MDI design
- Flexible tool for realistic BIB simulation of paramount importance to optimize the design
- Challenging physics measurements are possible if BIB effects in the detector are known

60 "Detector and Physics Performance at a Muon Collider" N. Bartosik (2020)

MUON ACCELERATOR PROGRAM (MAP) 2010-2018

MAP collaboration for 125 GeV, 1.5 TeV, 3 TeV and 6 TeV (preliminar) CM energy options worked on:

- Full machine design
- MDI design and optimization: crucial role of tungsten nozzle
- MARS15 code simulation and tracking of secondary and tertiary particles reaching the detector







60 The Muon Accelerator Program

- 60 "A muon collider as a Higgs factory" D. Neuffer (2015)
- 60 "Reducing backgrounds in the higgs factory muon collider detector" N. V. Mokhov (2014)
- 60 "Detector background at muon colliders" N. V. Mokhov (2011)
- 60 "Muon Collider Lattice Concepts" Y. I. Alexahin (2018)

NEW FLUKA-BASED SIMULATION SETUP

Goal: set up a flexible tool to simulate BIB at any desired CM energy and optimize machine lattice and MDI Choice: LineBuilder + FLUKA

6 <u>LineBuilder</u> is a Python program with a complete set of libraries, aimed at the generation of complex FLUKA geometries of accelerator beam lines, based on TWISS files and directives from the user

60 FLUKA: A Multi-Particle Transport Code supporting very complicated and detailed geometries



FLUKA BENCHMARK AGAINST MARS15 @ 1.5 TeV

Analysis of BIB obtained by realistic μ^- beam of 2 imes 10¹² particles: MARS15 vs FLUKA @ 1.5 TeV CM energy

- Lattice, optics and MARS15 simulated files provided by MAP
- Some MDI passive elements retrieved by MAP publications
- \bullet Energy threshold cuts: γ & e^+/e^- 200 keV, neutron 100 keV, proton & μ^+/μ^- 1 MeV
- Only muon decays within 25 m from IP considered for the comparison
- ullet Implicit symmetry for counterpropagating μ^+ beam



MDI OPTIMIZATION AT A MUON COLLIDER

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60 "Muon collider interaction region design" Y. I. Alexahin (2011)

Go "A study of muon collider background rejection criteria in silicon vertex and tracker detectors" V. Di Benedetto (2018)

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MARS15 vs FLUKA @ 1.5 TeV: NUMBER, ENERGY, TIME, Z MUON DECAY

Quite good agreement between MARS15 and FLUKA, reasons for minor discrepancies:

- Possible layout differences, missing infos about passive elements and absorbers
- Intrinsic difference between simulation tools



60 "Detector Backgrounds at the Higgs Factory Muon Collider: MARS vs FLUKA" N. V. Mokhov (2018)

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MARS15 vs FLUKA @ 1.5 TeV: (z,x) BIB exit



FLUKA RESULTS: BIB GENERATION AND EXIT



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Particles entering the detector hall: Y with nozzle, N without nozzle

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FLUKA RESULTS: WITHOUT NOZZLE



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Work done

- New simulation set up LineBuilder + FLUKA: flexible tool to simulate BIB at any desired CM energy and optimize machine lattice and MDI
- Reproduction of MAP configuration at 1.5 TeV: high sensitivity of BIB at machine and MDI design nozzle behaves like a funnel and filters higher energy γ and e^+/e^- contributions without nozzle high energy γ and e^+/e^- can reach the detector (in particular tracking system)
- FLUKA benchmarked against MARS15 results at 1.5 TeV: quite good agreement, small discrepancies given by some MDI layout slight differences

Work in progress

- Study of FLUKA-based BIB in the detector
- Simulation of 3 TeV configuration based on MAP lattice

Future work

• Extrapolation of BIB behavior at 10 TeV

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