

# Simulation of Beam Induced Background at Muon Collider and Study of its properties

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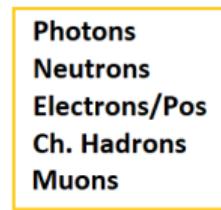
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Huge amount of interesting physics at Muon Colliders but careful analysis of background needed to preserve detector performances

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

- Main issues for the detector



Most of them reaching the detector produced by muons decaying within few tens m from IP  
Secondary muons production quite constant by muons decaying up to 200 m from IP

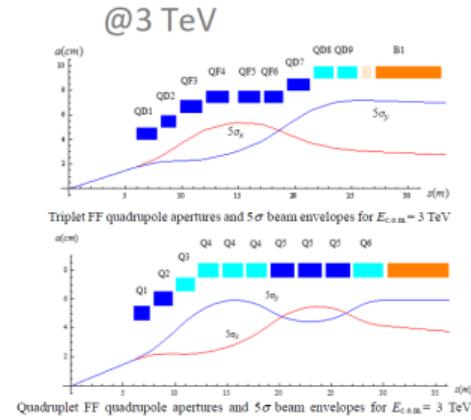
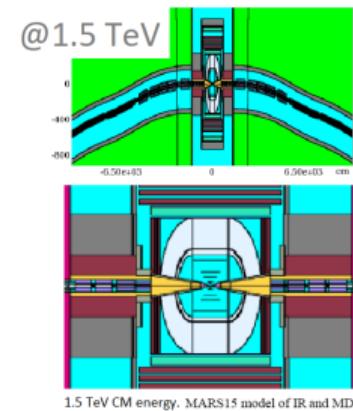
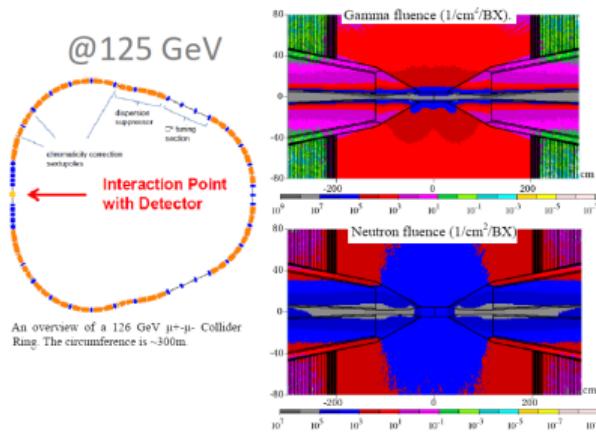
- BIB strongly depends on Center of Mass (CM) energy and machine design
- Realistic BIB simulation of paramount importance
- Challenging physics measurements are possible if BIB effects in the detector are known

63 See talks by N. Bartosik, L. Sestini, L. Buonincontri, M. Casarsa, S. Pagan Griso, H. Weber, C. Aime', K. Krizka

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

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

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



## 6) The Muon Accelerator Program

6) "A muon collider as a Higgs factory" D. Neuffer (2015)

6) "Reducing backgrounds in the higgs factory muon collider detector" N. V. Mokhov (2014)

6) "Detector background at muon colliders" N. V. Mokhov (2011)

6) "Muon Collider Lattice Concepts" Y. I. Alexahin (2018)

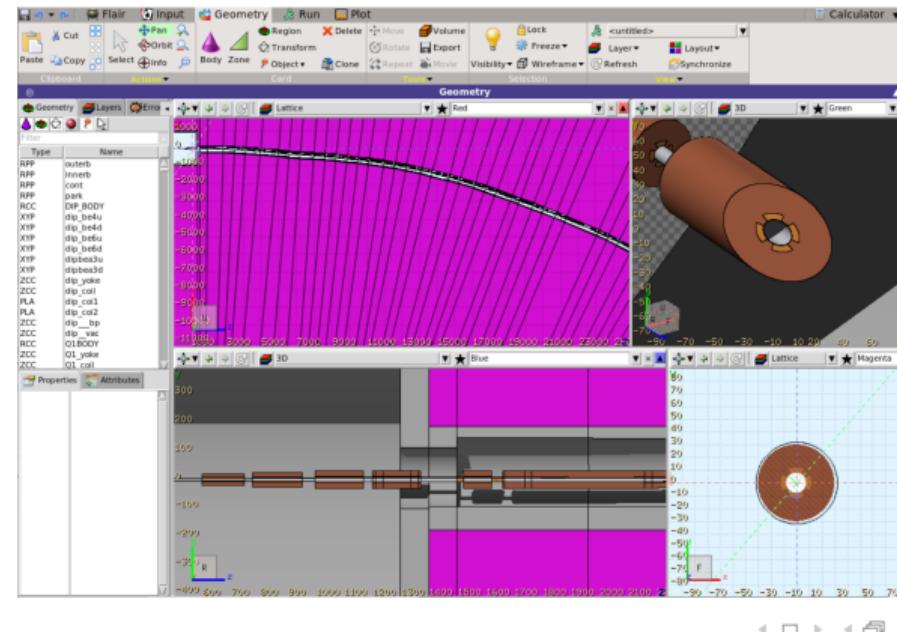
# NEW FLUKA-BASED SIMULATION SETUP

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

Choice: **LineBuilder + FLUKA**

↳ LineBuilder 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

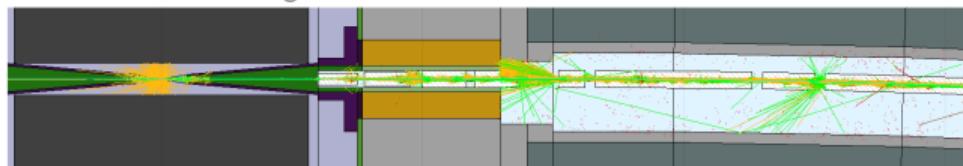
↳ FLUKA: A Multi-Particle Transport Code supporting very complicated and detailed geometries



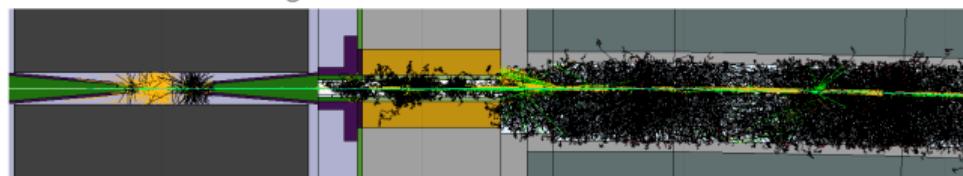
Analysis of BIB obtained by realistic  $\mu^-$  beam of  $2 \times 10^{12}$  particles: MARS15 vs FLUKA @ 1.5 TeV CM energy

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

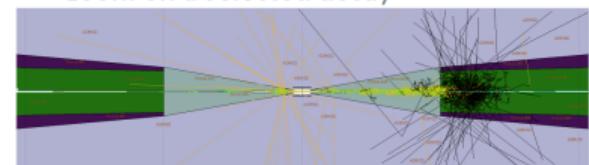
FLUKA tracking without neutrons



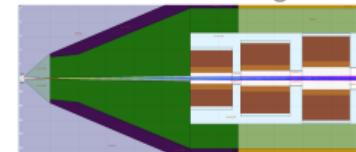
FLUKA tracking with neutrons



zoom on a selected decay



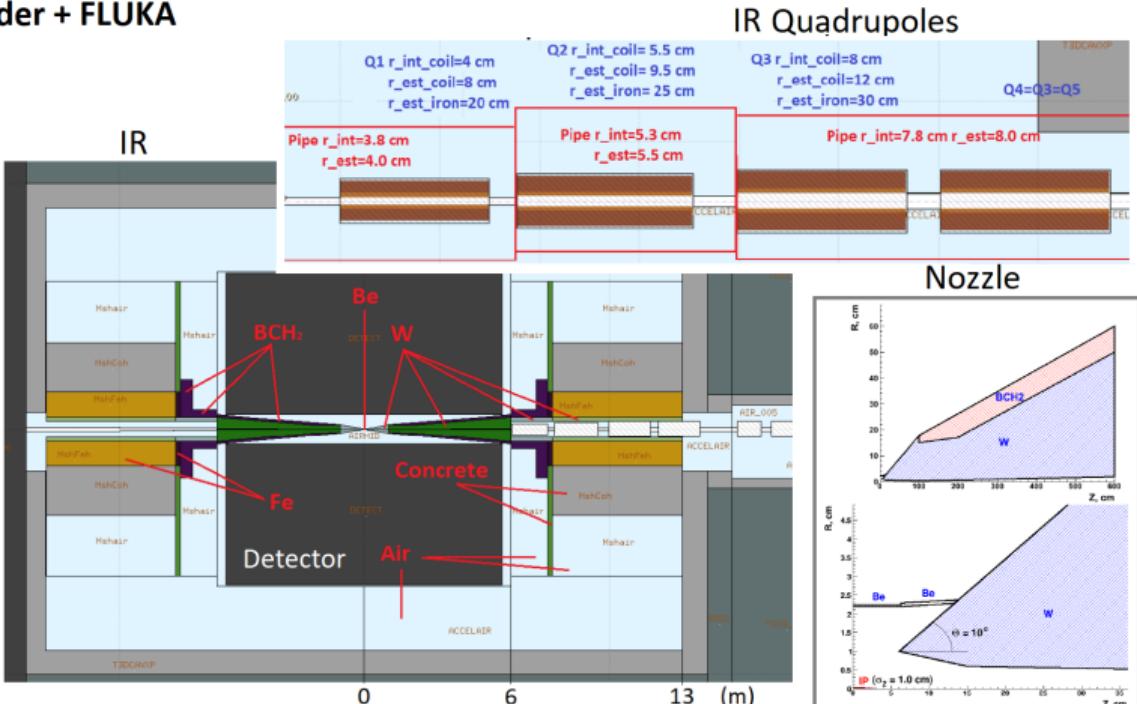
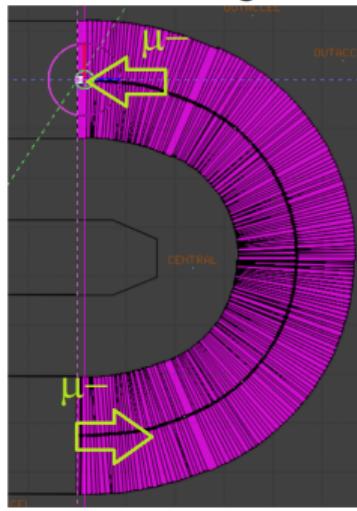
muon beam focusing at IP



# MACHINE DETECTOR INTERFACE (MDI) LAYOUT DESCRIPTION

Simulation tool: LineBuilder + FLUKA  
Data analysis: Python

750 GeV muon beam  
travels half ring to IP

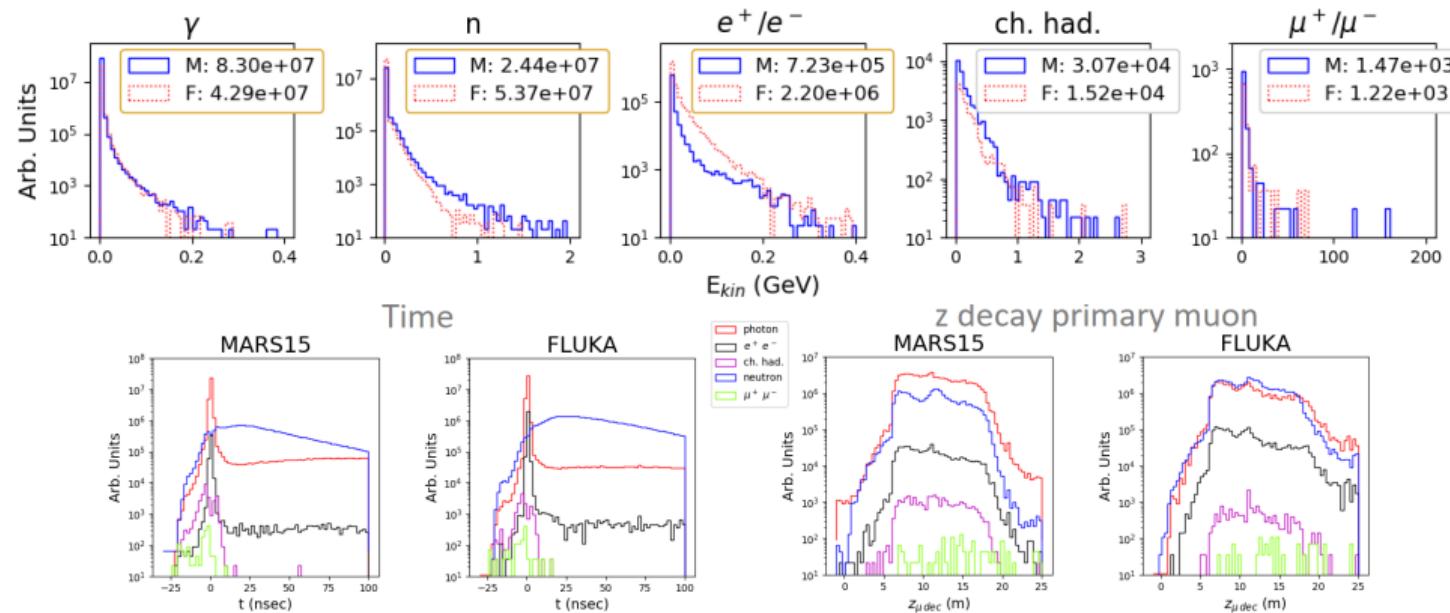


63 "Muon collider interaction region design" Y. I. Alexahin (2011)

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

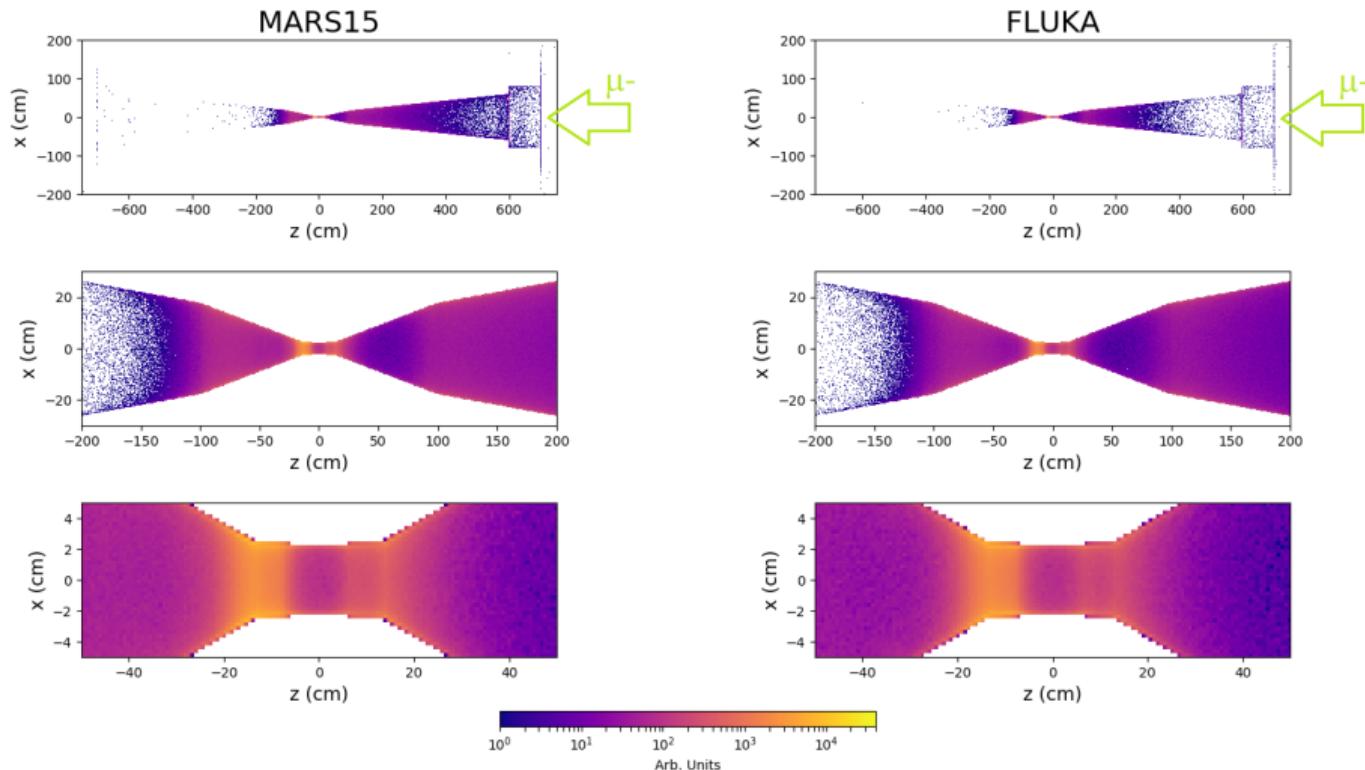
Quite good agreement between MARS15 and FLUKA, reasons for discrepancies:

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

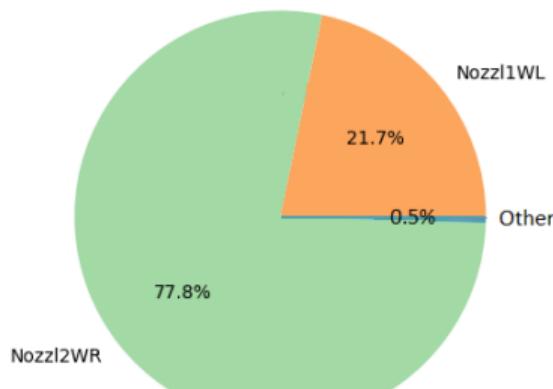


63 "Detector Backgrounds at the Higgs Factory Muon Collider: MARS vs FLUKA" N. V. Mokhov (2018)

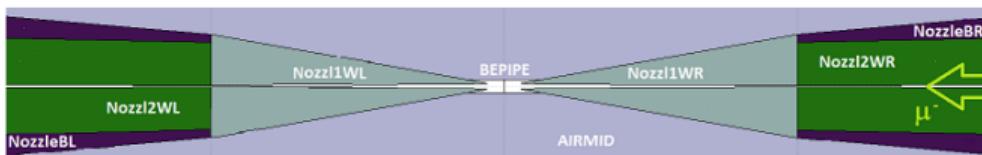
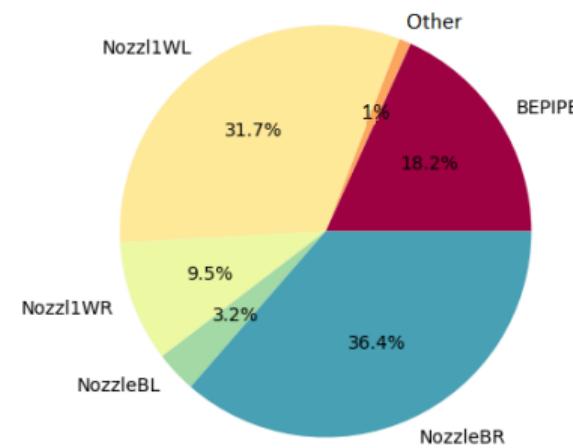
# MARS15 vs FLUKA @ 1.5 TeV: (z,x) BIB EXIT



where first interactions occur after muons decay

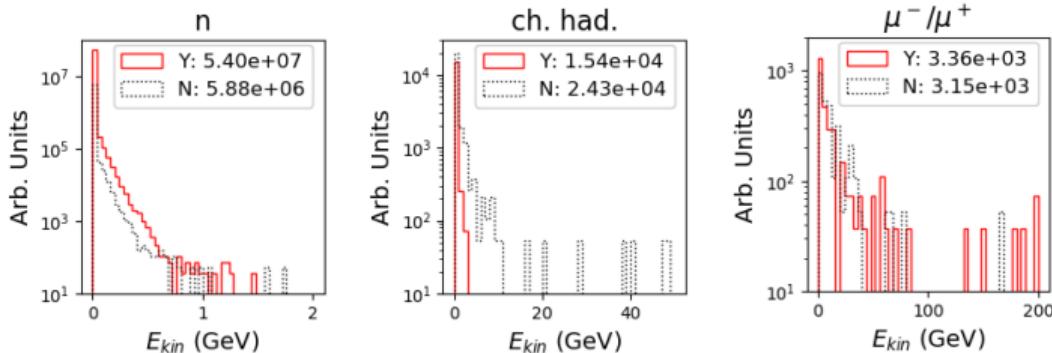
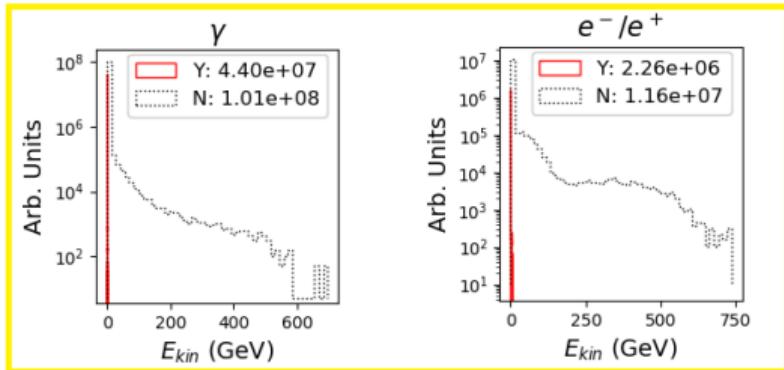


where particles exit the ring



NB: here muons' decay considered up to 100 m from IP

# MORE ON FLUKA RESULTS: NOZZLE YES OR NO?



NB: here muons' decay considered up to 100 m from IP

## 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  $\gamma$  and  $e^+/e^-$  contributions
- 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