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

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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

| Photons
Neutrons
Electrons/Pos
Ch. Hadrons
Muons | ⟹ | **Most of them reaching the detector produced by muons dacaying within few tens m from IP. Secondary muons production quite constant by muons dacaying 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

🔖 The Muon Accelerator Program
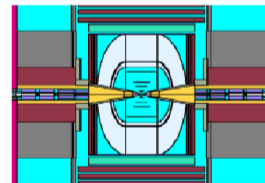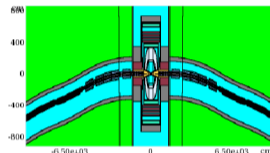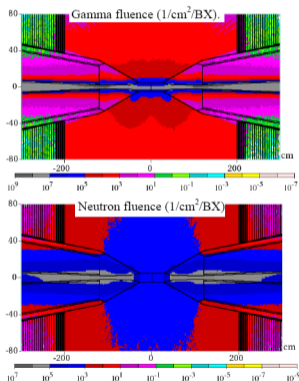🔖 "Detector Background at Muon Colliders" N.V. Mokhov (2012)
🔖 "Detector and Physics Performance at a Muon Collider" N. Bartosik (2020)

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
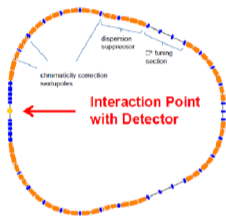
An overview of a 126 GeV μ^+-μ- Collider Ring. The circumference is ~300m.

Gamma fluence (1/cm²/BX).

Neutron fluence (1/cm²/BX).

1.5 TeV CM energy. MARS15 model of IR and MDI

📖 "A muon collider as a Higgs factory" D. Neuffer (2015)
📖 "Reducing backgrounds in the higgs factory muon collider detector" N. V. Mokhov (2014)
📖 "Detector background at muon colliders" N. V. Mokhov (2011)

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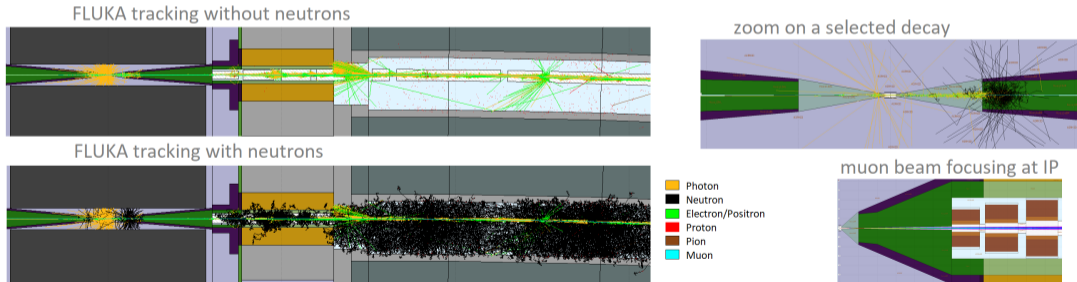
Choice: **LineBuilder + FLUKA**

👓 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

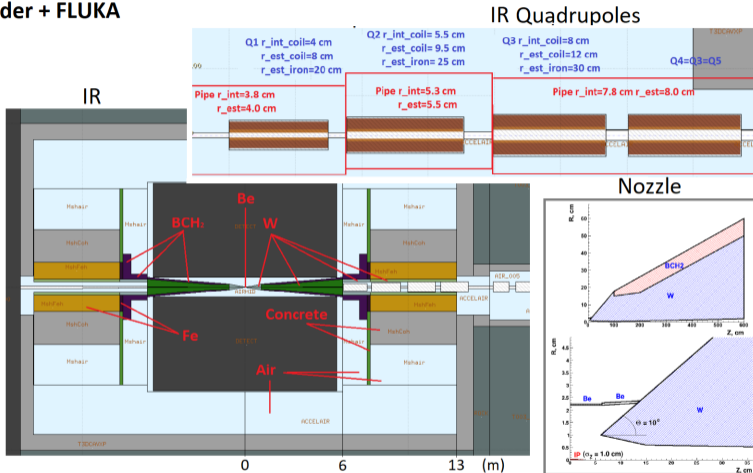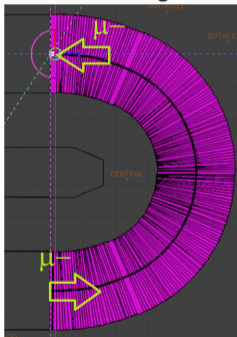👓 FLUKA: A Multi-Particle Transport Code supporting very complicated and detailed geometries

CAMILLA CURATOLO UNIVERSITÀ & INFN PADOVA, ITALY   BEAM INDUCED BACKGROUND AT MUON COLLIDER
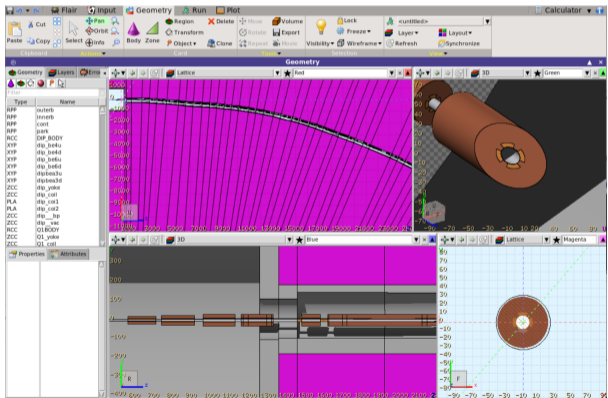
Analysis of BIB obtained by realistic μ^- beam of 2×10^{12} particles: MARS15 vs FLUKA @ 1.5 TeV CM energy

- Lattice, optics and MARS15 simulated files provided by MAP
- Some MDI passive elements retrieved by MAP publications
- Energy threshold cuts: 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

FLUKA tracking without neutrons

zoom on a selected decay

FLUKA tracking with neutrons

muon beam focusing at IP

Photon
Neutron
Electron/Positron
Proton
Pion
Muon

Simulation tool: **LineBuilder + FLUKA**
Data analysis: **Python**

750 GeV muon beam travels half ring to IP

IR Quadrupoles

**IR**

Q1 r_int_coil=4 cm
r_est_coil=8 cm
r_est_iron=20 cm

Q2 r_int_coil 5.5 cm
r_est_coil = 9.5 cm
r_est iron = 25 cm

Q3 r_int_coil=8 cm
r_est_coil=12 cm
r_est_iron=30 cm

Q4=Q3=Q5

Pipe r_int=3.8 cm
r_est=4.0 cm

Pipe r_int=5.3 cm
r_est=5.5 cm

Pipe r_int=7.8 cm r_est=8.0 cm

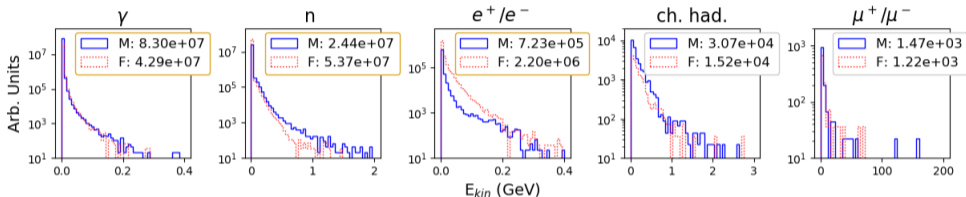**Nozzle**

Be
BCH₂
W

Fe

Concrete

Air

0   6   13   (m)

🔎 "Muon collider interaction region design" Y. I. Alexahin (2011)
🔎 "A study of muon collider background rejection criteria in silicon vertex and tracker detectors" V. Di Benedetto (2018)

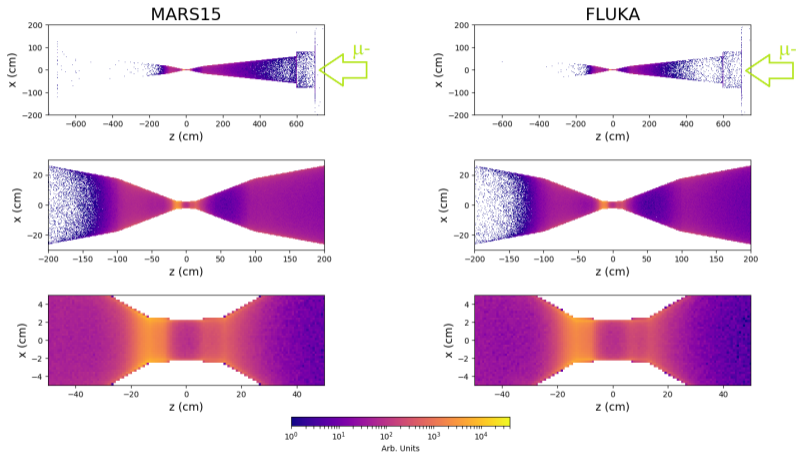◁ □ ▷ ◁ 🖙 ▷ ◁ 🗏 ▷ ◁ 🗏 ▷ 🗏 ⟲ ९ ९ ⟲   6/11

Quite good agreement between MARS15 and FLUKA, reasons for discrepancies:
- Possible layout differences, missing infos about passive elements and absorbers
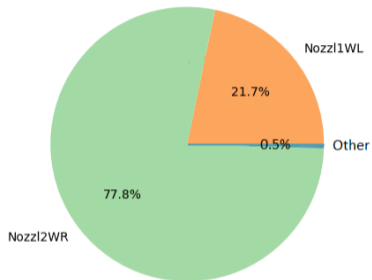- Intrinsic difference between simulation tools
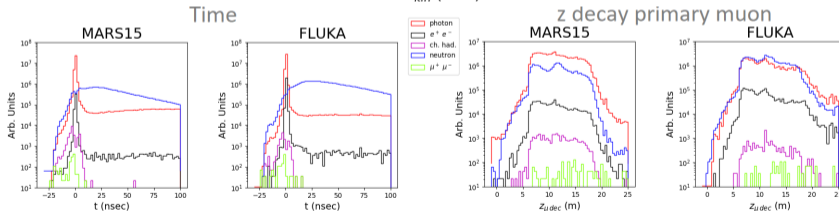
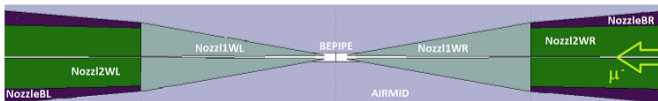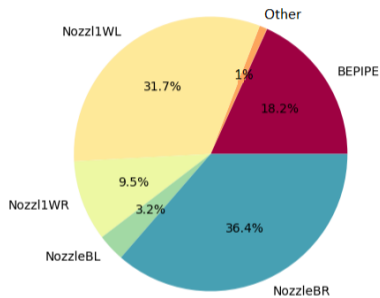"Detector Backgrounds at the Higgs Factory Muon Collider: MARS vs FLUKA" N. V. Mokhov (2018)

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where first interactions occur after muons decay

where particles exit the ring

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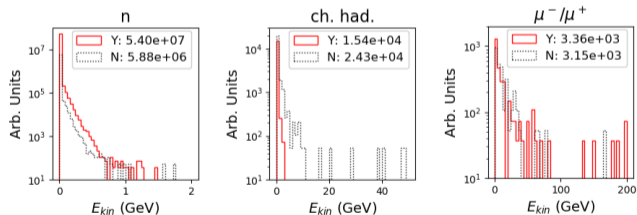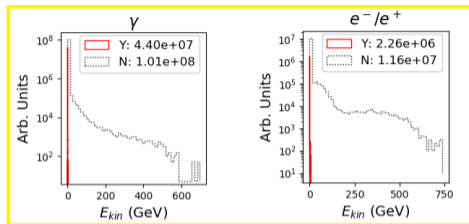
Here muons decay considered up to 100 m from IP

Work done:
- New simulation tool set up - LineBuilder + FLUKA
- Reproduction of MAP configuration at 1.5 TeV
- FLUKA benchmarked against MARS15 results at 1.5 TeV

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