G4BEAMLINE AND MARS COMPARISON FOR MUON COLLIDER BACKGROUNDS*

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Abstract

Technological innovations in recent years have revived interest in muon colliders as the next generation energy frontier machine. The biggest challenge for muon colliders is that muons decay. Advances in muon cooling technology will make the focussing and acceleration of muons to TeV energies possible. The challenge for the detectors in such machines is overcoming the large backgrounds from muon decays in the colliding ring lattice that will inundate the interaction region (IR) and will make triggering and data reconstruction a challenge. Developing simulation tools that can reliably model the environment of the muon collider IR will be critical to physics analyses. We will need to expand the capabilities of current programs and use them to benchmark and verify results against each other. Here we are comparing an emerging capability of G4beamline, an interface for physicists to GEANT4 code, with MARS, a mature program for particle fluences, in developing code for muon collider background studies

INTRODUCTION

In 1996, a first comprehensive study [1] of muon colliders was done, including an extensive study of the backgrounds from muon decays in the IP region. Because of necessary shielding, particularly 20^{o} cones in the forward regions, to reduce decay backgrounds, the physics capabilities at a muon collider suffer some limitations. In recent years, however, muon collider designs have been revised, with new ideas to enhance performance. The low emittance approach yields the same luminosity with few muons. New types of detectors, such as solid state photon sensors that are fine-grained, insensitive to magnetic fields, radiation-resistant, fast, and inexpensive have become available. This makes it possible to consider smaller cone sizes or possible instrumentation of the cone shielding material. Also, large-scale picosecond timing detectors [2] are being developed and will enhance the capability for triggering and event reconstruction. A complete re-evaluation and re-design of the muon collider detectors and final focus region is underway, and understanding of muon decay backgrounds is critical to this endeavour.

BACKGROUNDS

In contrast to hadron colliders, almost all backgrounds that arise in the lattice are associated with the products of the decaying muons that get into the detector region. The size of the beam related backgrounds are proportional to the number of muons per bunch. Recent efforts have been made to realistically evaluate backgrounds from muon decays inside the lattice of a collider ring. The decay length for 0.75 TeV muons is $\lambda_D = 4\times10^6$ m. With 2×10^{12} muons in a bunch, one has 4.3×10^5 decays per meter of the lattice in a single pass, and $1.3X10^{10}$ decays per meter per second for two beams. The mean energy of electrons from muon decays is about a third that of the muons. 750 GeV muons will produce electrons with a mean energy of ~250 GeV, that travel to the inside of the ring magnets and radiate energetic synchrotron photons towards the outside of the ring. Electromagnetic showers induced by these electrons and photons inside the collider ring components generate intense fluences of muons, hadrons and daughter electrons and photons. This creates high background and radiation levels both into the ring and detector. Figure 1 shows recent calculations using a MARS15 model of a recent muon collider detector scheme [3] that illustrates the challenge. Here a smaller shielding cone angle is considered (~ 10 degrees).

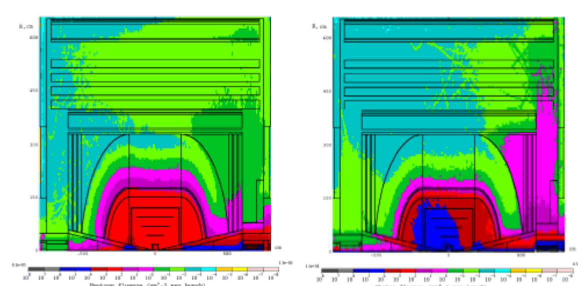

Figure 1: MARS output for an MC IR neutron (left) and photon (right) particle fluences in a 4th Concept Detector.

BACKGROUND SIMULATION TOOLS

Current work is underway to develop a computer program package that can calculate accelerator-based backgrounds for a muon collider. The program is built on Muons, Inc.'s G4beamline [4], an interface to the Geant4 toolkit for the simulation of elementary particles passing through matter. This package should be able to accept a MAD lattice description and provide particle fluences and an output file of background events for use with the physics analysis. The fluences from G4beamline will be compared to fluences calculated with identical lattices at the same detector locations using the "MARS15" program [3]. The MARS code system is a set of Monte Carlo programs which simulate the passage of particles through matter, and has been used widely in particle physics for radiation

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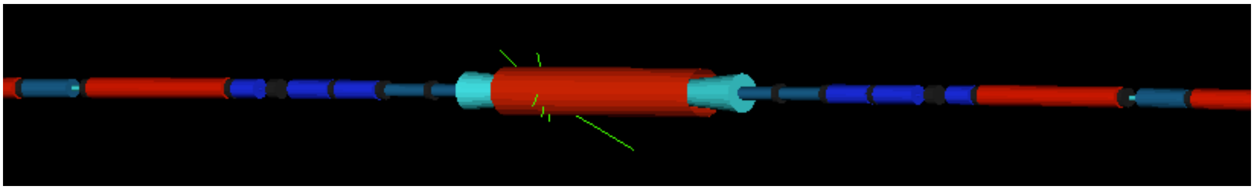

Figure 2: An extended view of the muon collider IR with forward shielding as modelled by G4beamline.

studies, beamline development and experiment simulation. The approaches of MARS and Geant4 are very different, with different weighting and physics propagation techniques. Agreement of simulation results would be a strong verification marker. The disparate approaches of MARS and Geant4 codes makes it less likely that any important physics gets overlooked. This is considered by the MAP collaboration as being a necessary and desirable procedure toward a robust Muon Collider design. Figure 2 shows a G4beamline simulation of a muon collider IR.

We have developed auxiliary programs that facilitate these comparison studies. *BruitDeFond* [5] can produce an ASCII file of G4beamline commands or the equivalent MARS.INP, GEOM.INP and FIELD.INP files that describe the ±75 m of muon collider interface region. *BeamMaker* produces a *BLTrackFile* that can be read by the G4beamline input card This same file is read by our version of Mars user subroutines for the beam description. The *BLTrackFile* contains e^+ and e^- thrown with the Michel decay distribution and boosted to the laboratory frame. This helps to ensure that comparisons are done on equivalent output. Figure 3 shows the geometry description for a MARS muon collider IR generated by the *BruitDeFond* package.

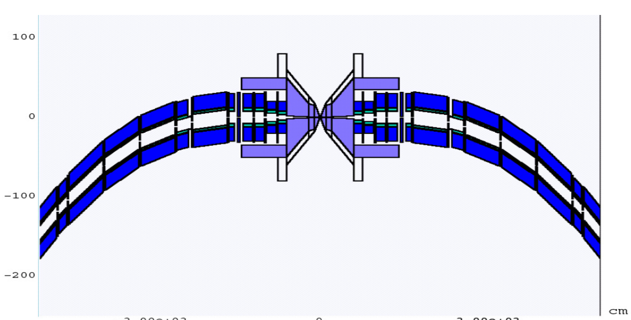

Figure 3: Layout of Mars Geometry Generated by *BruitDeFond* Package.

PRELIMARY RESULTS.

We have made some initial studies on the performance of Geant4 and MARS in backgrounds produces in the interaction region. The final focus region used was designed by E. Gianfelice-Wendt, shown in Figure 4. There are significant differences in set up and generation between MARS and G4beamline, and there are some outstanding issues, such as the generation of neutrons and energy cut-offs. .

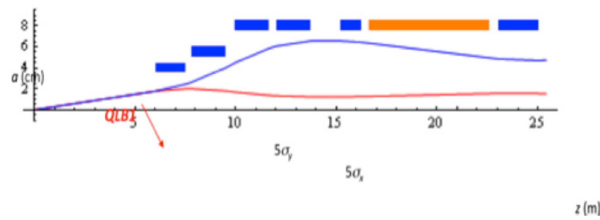

Figure 4: Layout of muon collider final focus region.

Below are a series of particle fluences generated from MARS and G4beamline. The event samples and weighting are significantly different. Table 1 summarizes the running conditions.

Table 1 Running Conditions

	G4beamline	MARS
Beam	BeamMaker File -30 m -> 10 m	BeamMaker File - 30 m -> 30 m
Physics List	QGSP_BERT, No _HP	Standard, No MCNP
Event Sample	10,000 events	400,000 weighted events
Min. Energy	200 keV for all particles	200 keV imposed by cut.

For the following graphs below, the muon collider configuration is as described above. In this particular study we used the 10° shielding cone. This requires three days on Northern Illinois NICADD cluster [6] running G4beamline, given the individual particle tracking, which is why there were fewer events generated than for MARS. In both cases, events carried a constant weight to normalize to 2×10^{12} muons/bunch, expected at a real muon collider. Detector planes positioned at SiD locations. Both vertex and tracker detector planes have equivalent SiD material description. Particles are scored as they pass through planes, and the plots in Figure 5 show particle fluences (particles/cm^2 vs. radial distance from the beam in cm) for gammas, electrons, neutrons and charged hadrons. Calorimeter material is present, but there is no particle scoring in the calorimeter region.

There is generally good agreement for the electrons and gamma backgrounds between MARS and G4beamline. More problematic are hadronic backgrounds, G4beamline neutron data should fall off as 1/r as the Mars data does.

This inconsistency and the lower energy neutron production will be studied more extensively.

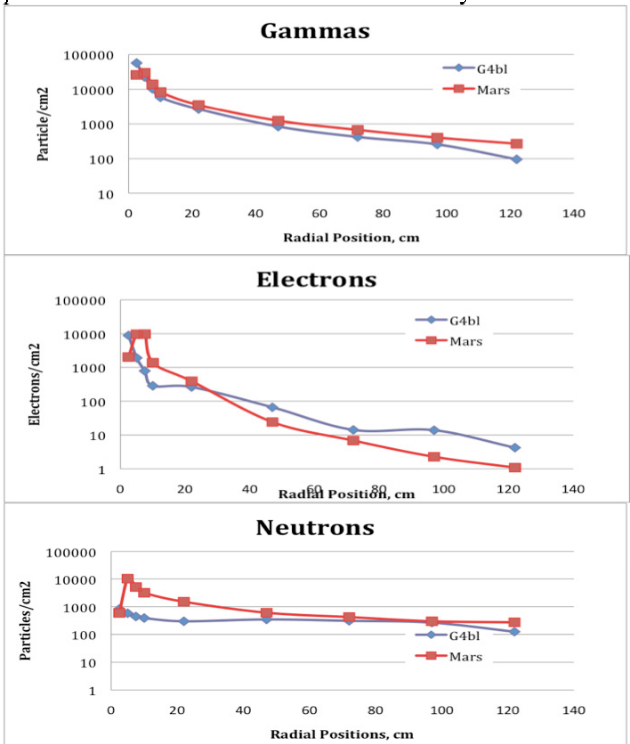

Figure 5: Particle fluences, gammas, electrons, and neutrons for G4beamline/ MARS comparison.

SCALING FOR CONE STUDIES

With advances in particle detection and read-out technology in the years since the 1996 Muon Collider Feasibility Study, it may be possible to extend the detector coverage into the forward region that was previously considered unsuitable for particle detection. This may allow for the recovery of particle ID and some information on energy deposition and timing.

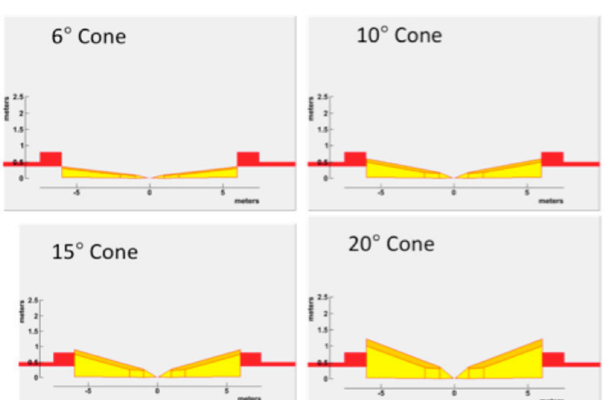

Figure 6: Conical Shielding configurations at angles ranging from 6 to 20 degrees.

The design of the interaction region shielding cone by optimizing the angle will be the starting point for cone instrumentation study .Figure 6 shows several cone sizes under consideration, and Figure 7 shows preliminary particle fluences for MARS and G4beamline simulations with a 10° cone.

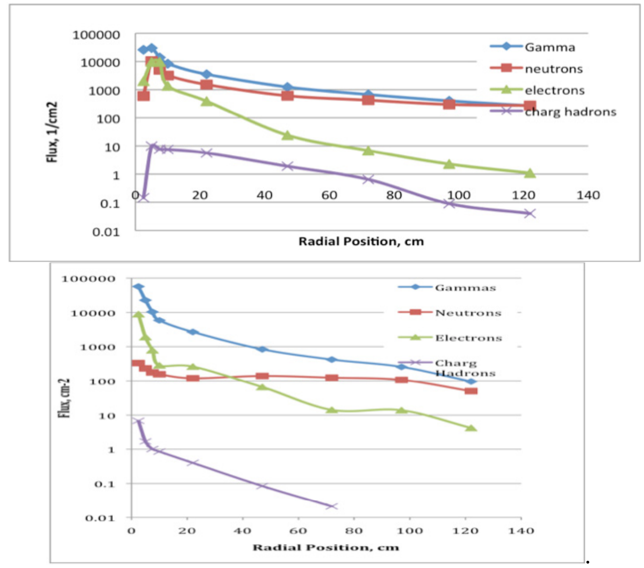

Figure 7: Particle fluences, gammas, electrons, neutrons, charged hadrons for radial positions for a 10° cone for MARS (top) and G4beamline (bottom).

FUTURE PLANS FOR BACKGROUND STUDIES.

We are undertaking improvements to G4beamline to enhance its capabilities for analysis of muon collider physics and detector design. We believe this will become a valuable development tool for the particle physics community and will facilitate more widespread participation of the particle physics community in muon collider physics studies. Understanding the environment of a muon collider IR will challenge all current physics modelling tools, and the comparison of detailed studies between two powerful programs such as MARS15 and GEANT4 will be necessary to understand the triggering and reconstruction issues that will be particular to this new kind of particle accelerator.

REFERENCES

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