Machine-detector interface studies for a multi-TeV muon collider

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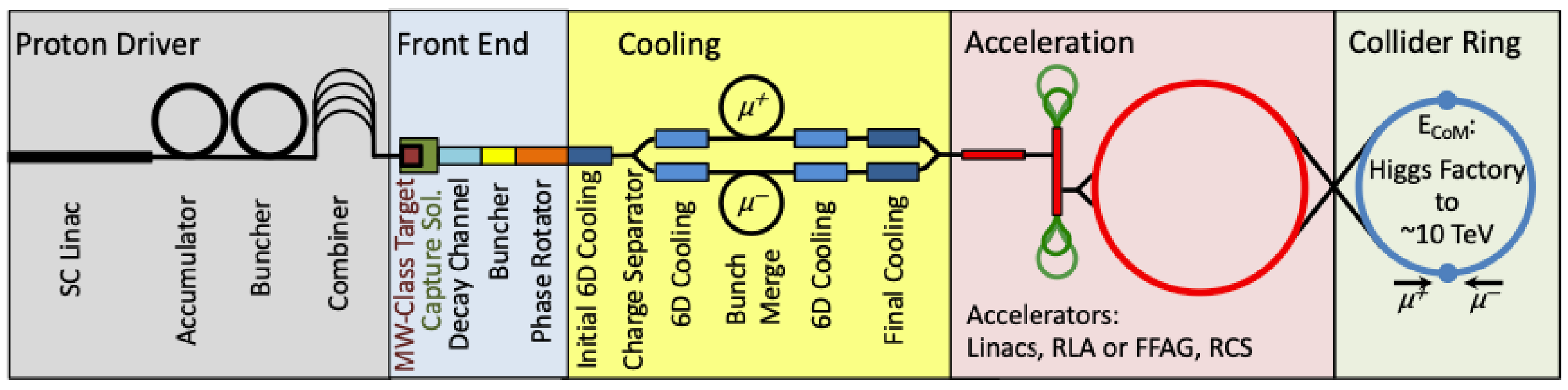
Abstract



The muon colliders are an extremely promising class of accelerator. Employing high energy muon as colliding particle, they allow the the investigation of the Higgs properties with an unprecedented precision. With center of mass energies of the order of ~10 TeV, we can explore physics beyond the standard model at high energies.

Due to the muon's nature, the Machine-detector interface (MDI) is a complex challenge. Decaying spontaneously with a rest lifetime of 2.197 μs, they arise a strong secondary radiation field.
Therefore, many are the radiation challenges to be addressed, as the heat deposition and radiation damage in the superconducting coils, the neutrino hazard for the dose delivered to the environment, and the background to the experiment.
In the context of the MDI simulations studies, our efforts will be aimed toward an assessment of the beam induced background (BIB), to achieve a clear picure of the phenomena involved, and to devise an interaction region design compatible with the experiments.
The work done is in the context of the International Muon Collider Collaboration (IMCC).

Simulation framework and parameters

All the simulation are done with FLUKA Monte Carlo code. For the scoring of the beam induced background (BIB), the energy cutoffs have been chosen to collect most of the background. The muon decay is sampled considering the matched phase space distribution.

Particle species	Photons	Neutrons	e+/e-	Charged hadrons	Muons
Cutoff energy [GeV]	1E-4	1E-14	1E-4	1E-4	1E-4

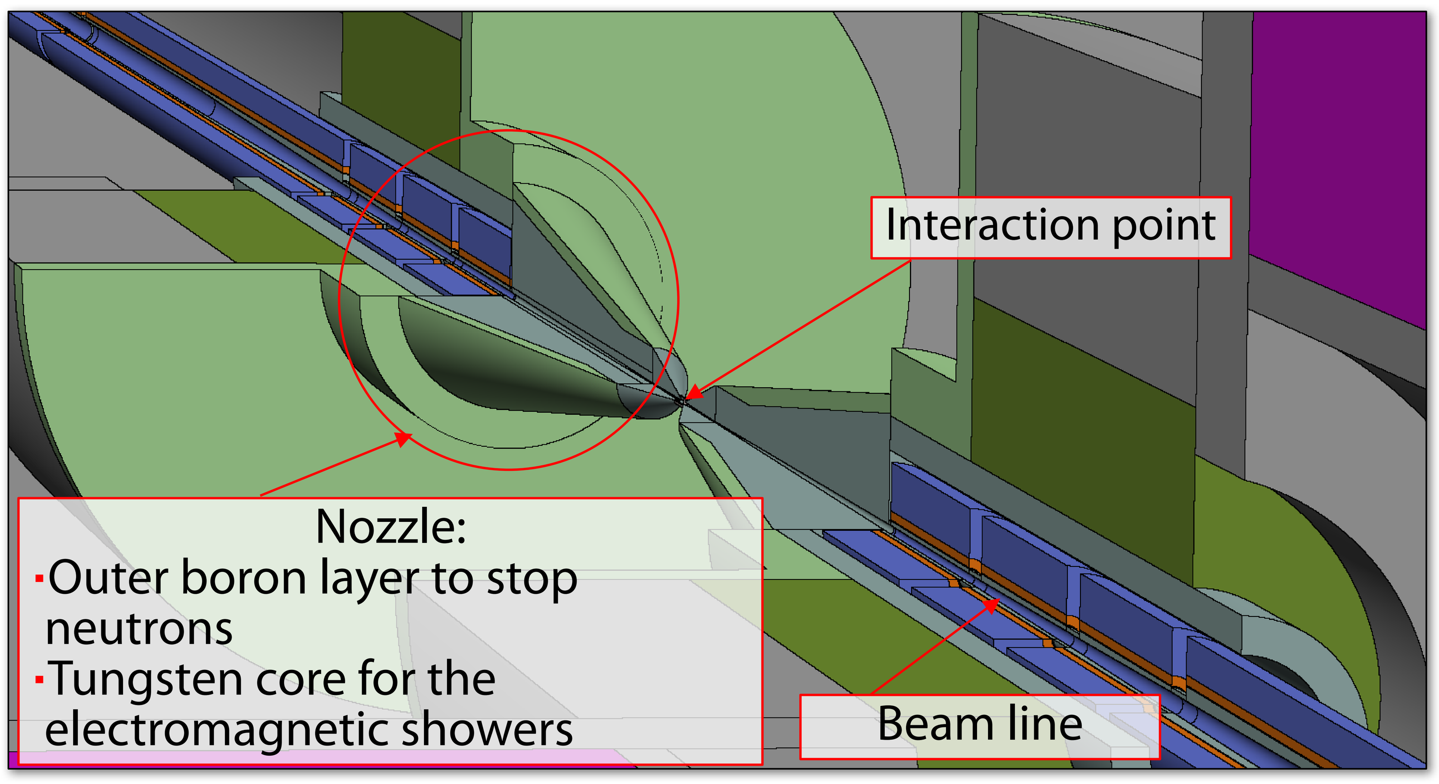
Total number of particles MDI

Considering the BIB arising from the muon decay, the total number of particles going into the detector area is scored. With different collider energies, the overall number of particles is not significantly greater in the high energy cases.

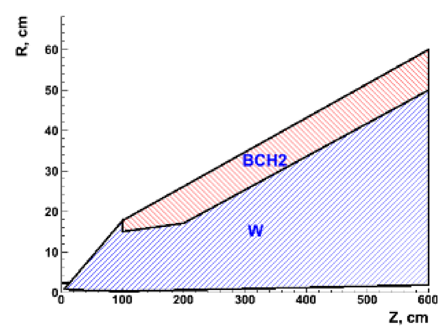
Non optimized

Collider energy	1.5 TeV	3 TeV	10 TeV
Photons	5.1E+7	7E+7	1.16E+8
Neutron	1.1E+8	9.1E+7	8.88E+7
e+/e-	8.6E+5	1.1E+6	9.49E+5
Ch. hadrons	1.7E+4	2.0E+4	3.37E+4
Muons	3.1E+3	3.3E+3	2.99E+3

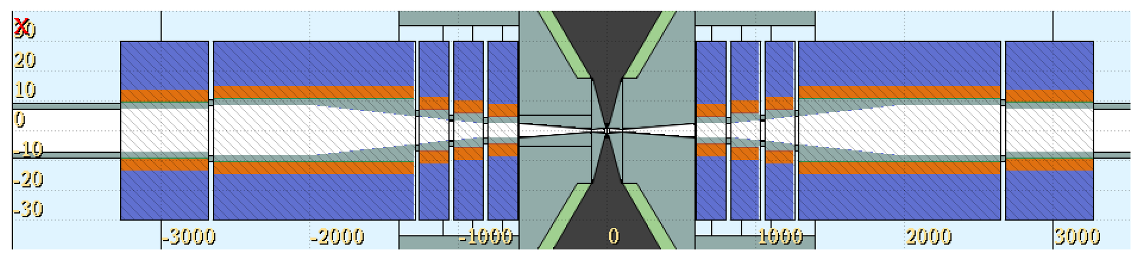
MDI Geometry



Original nozzle tip design from [arXiv:1807.00074]

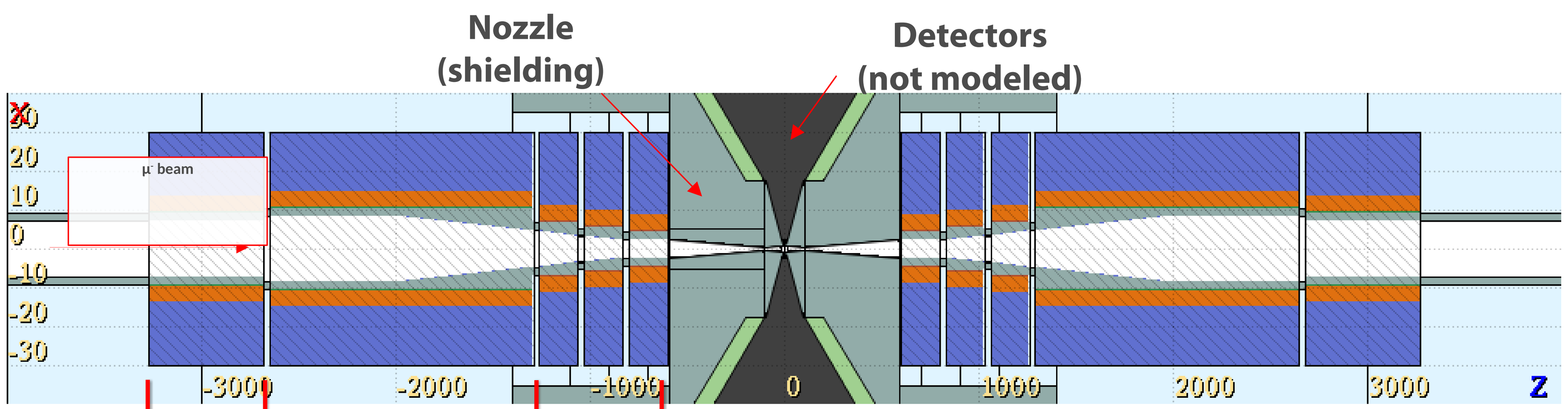


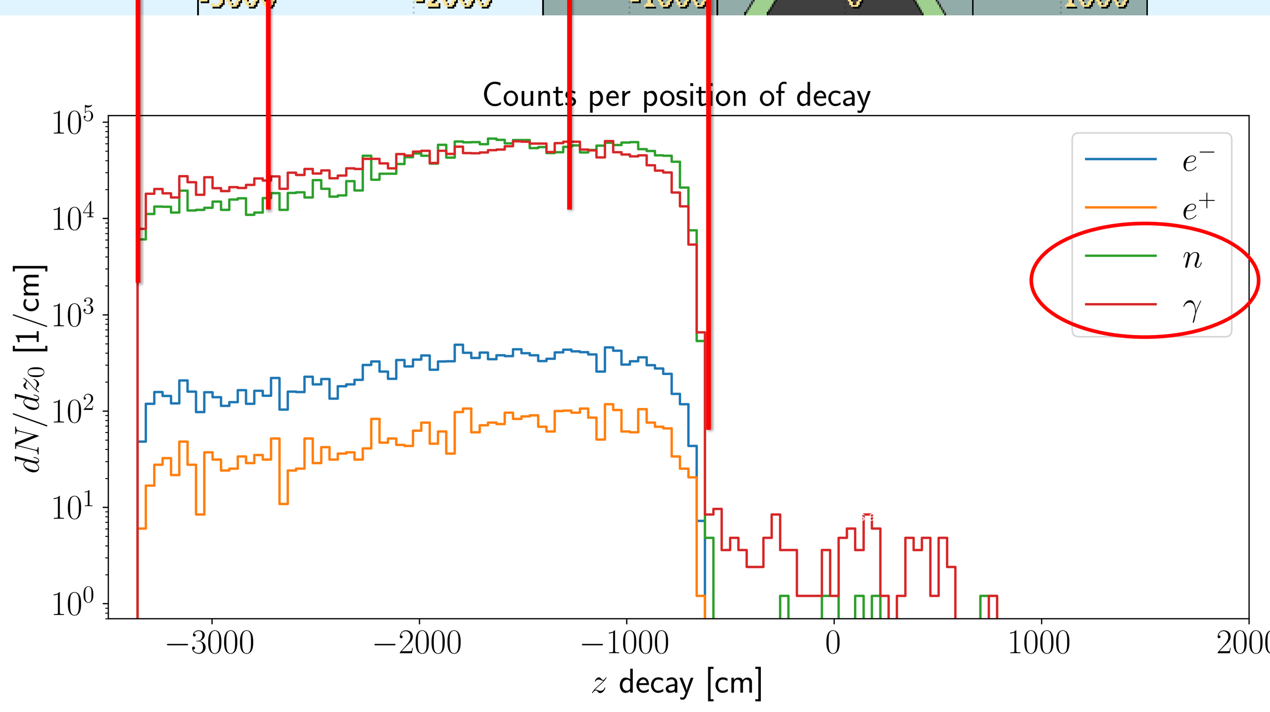
View of the interaction region lattice and nozzle from the top.



10 TeV muon collider: muon decay

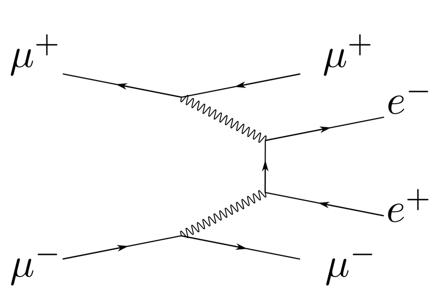
Scoring the total number of counts per particle species in function of the muon decay longitudinal position, most of the contribution arises primarily in the close proximity of the beginning of L*.
To achieve a more detailed view, longer lattices will be needed.



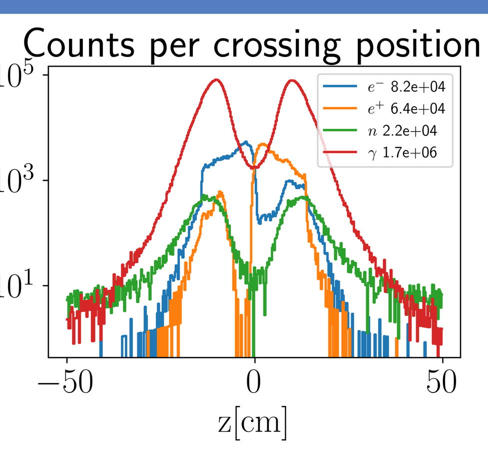


Neutron and photons are the prevalent component going into the detector area.
Muon decaying as far as 30 m from the interaction point are a non negligible source of BIB.

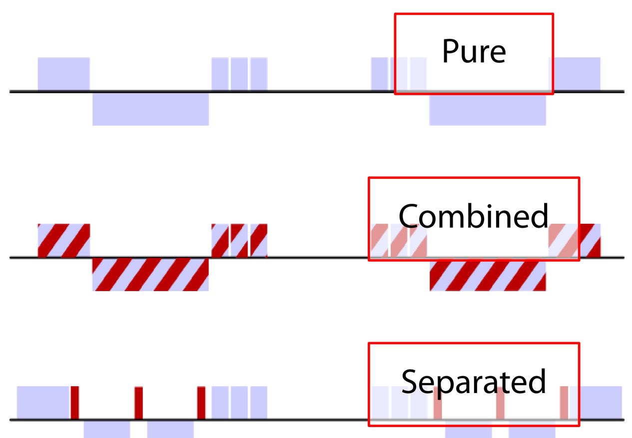
10 TeV muon collider: incoherent pair production



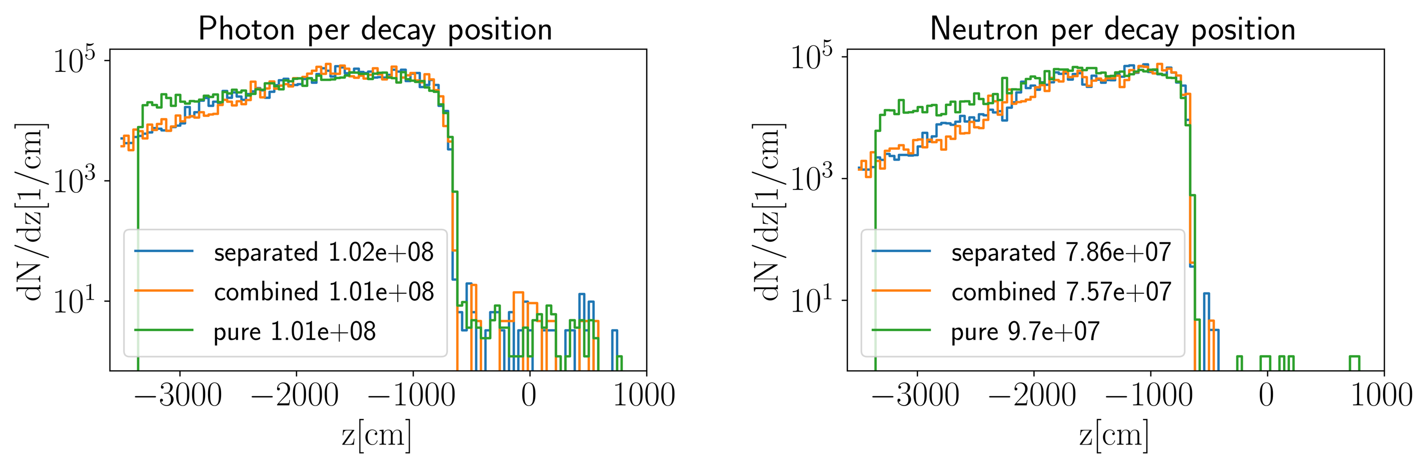
During the bunch crossing, electron and positrons pairs are generated. With low energy collider, they can be shielded with a solenoidal field, which forces the particle to follow the beam line. However, with a 10 TeV collider, this contribution should not be ignored, since the secondary field is generated directly in the interaction point.



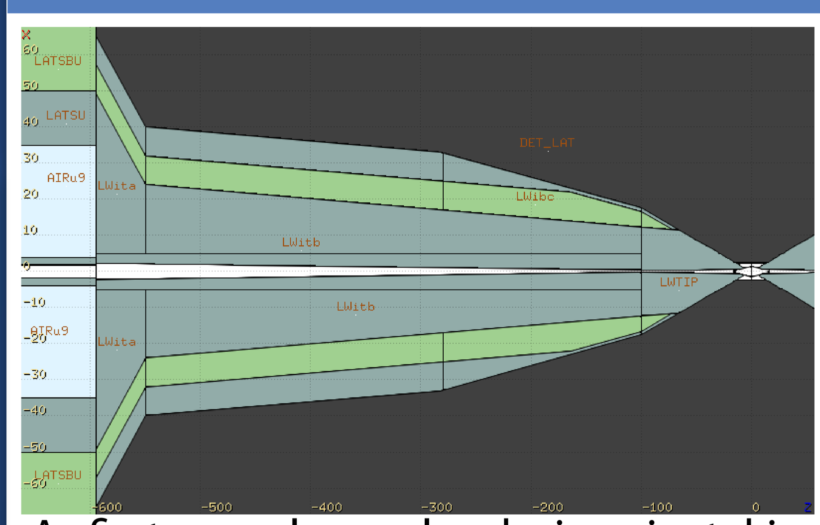
10 TeV collider: optics under consideration



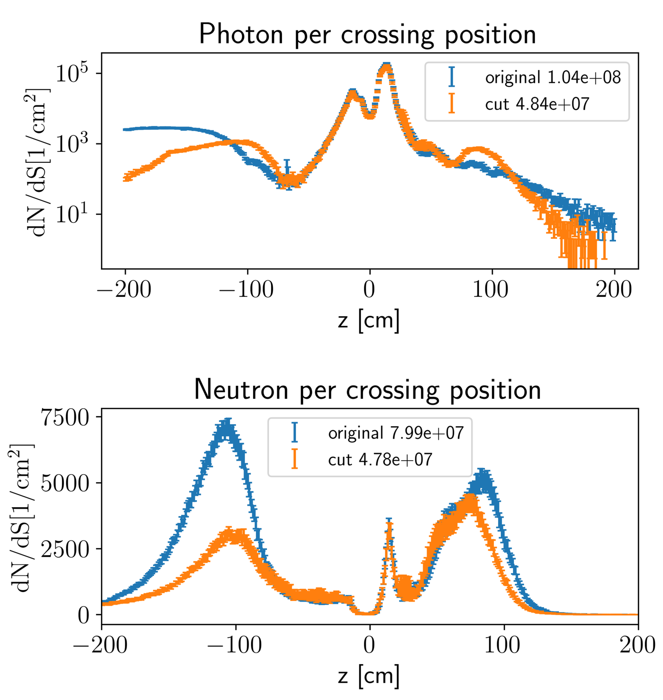
In principle, a dipolar magnetic field component might be beneficial to suppress BIB. Testing different configurations, however, proved that the effective reduction takes place only far away from the interaction point.
Three different possibilities are considered: using only quadrupoles in the final focusing (pure), adopting combined function magnets (combined) or to separate the dipolar component into 10 T dipole magnets (separated).



10 TeV collider: nozzle reshaping



A first novel nozzle design is taking place. The aim is to reduce the BIB peaks modifying the shape and the composition of the nozzle profile.



Conclusions

In the context of the IMCC, we simulated the BIB for a possible 10 TeV muon collider. Comparing the results with present and past studies, background is comparable for different colliders with different energies. Different lattices do not significantly alter the BIB from muon decay in close proximity with the final focusing, while changing the nozzle shape alter the background profile in a more substantial way. The detectors damage and response has yet to be fully addressed.