Muon cleaning in the CLIC beam delivery system

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Overview

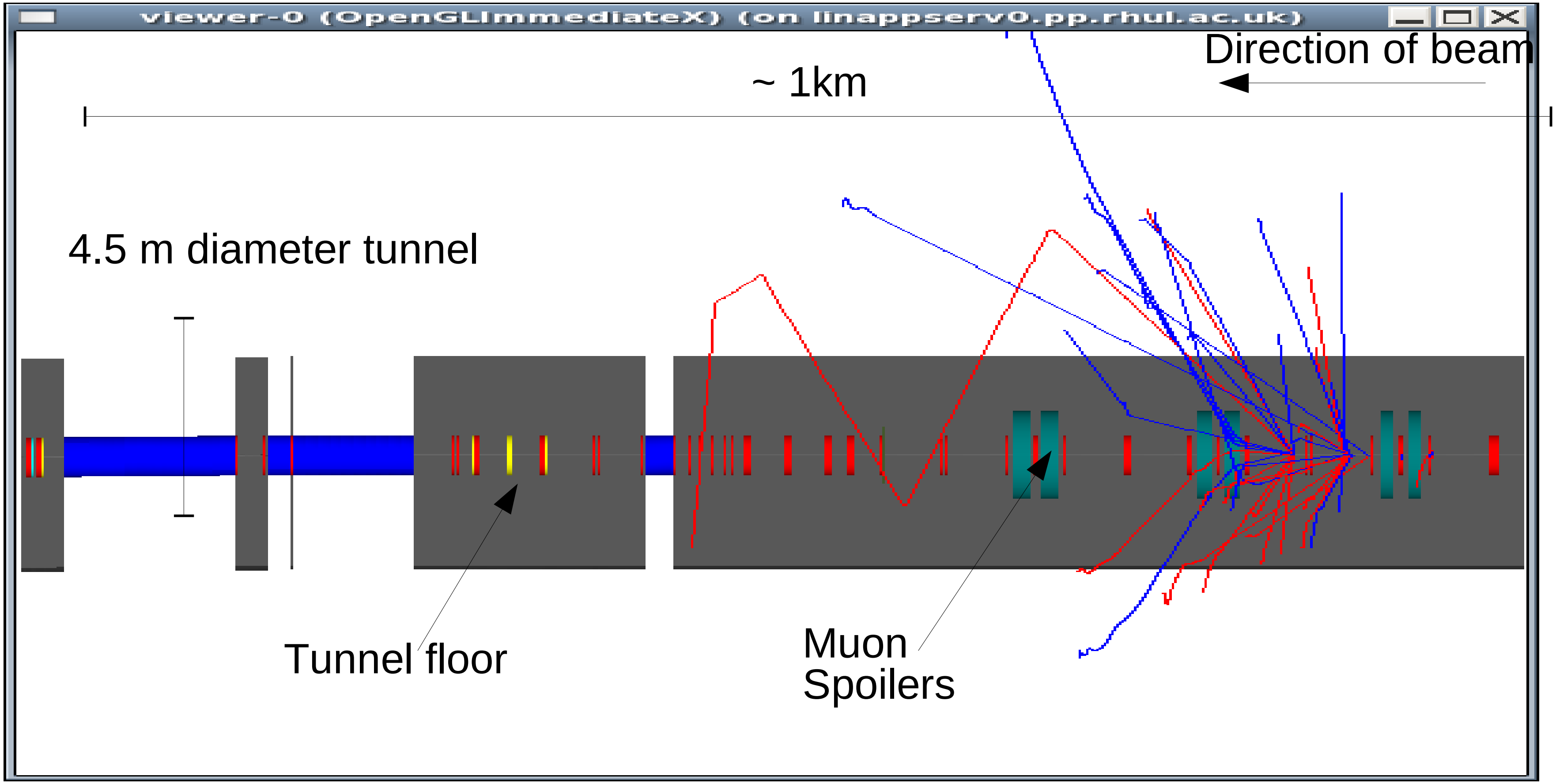
- Simulation procedure
- Effect of swapping energy and betatron collimation sections
- Effect of placing magnetized muon spoilers
- Optimisation
- Summary

Simulation procedure

- Halo particles were generated using HTGEN
- Interactions and tracking of secondaries from the first spoiler to the detector using BDSIM (Nucl.Instrum.Meth.A606:708-712,2009)
- The beam line used was the v10_01_10 MAD deck
- The optics were verified using a Gaussian input beam
- Muon production processes were cross section biased
- Muons were recorded at a sampling plane a few metres upstream of the detector, at the exit of QF1.

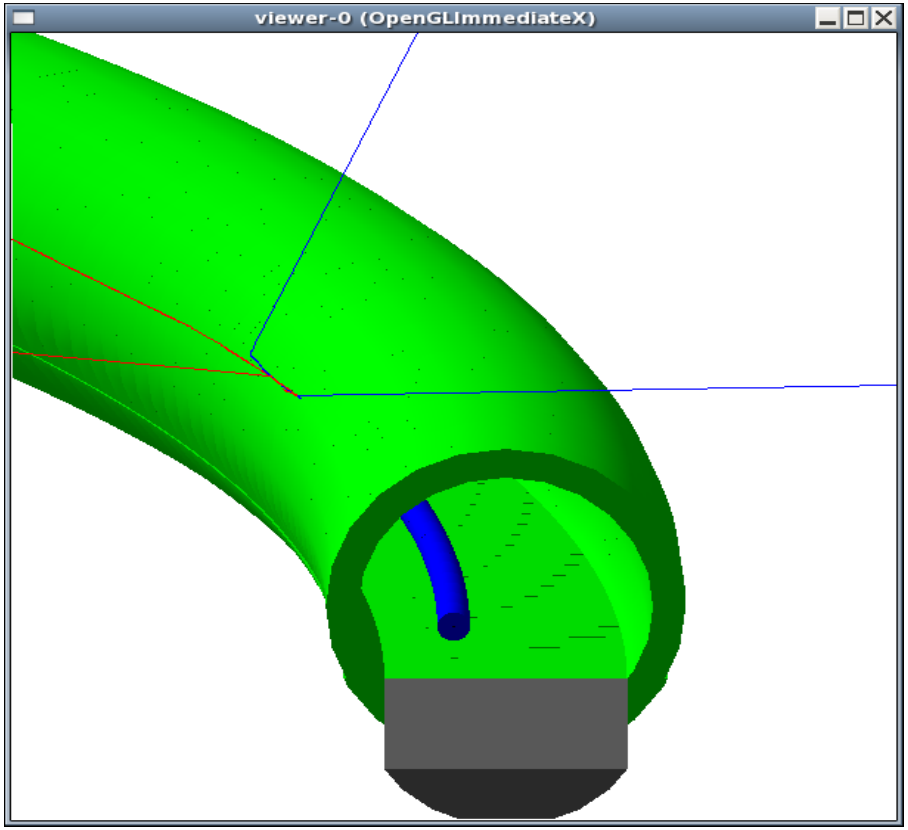
Simulation procedure - geometries

- Cylindrical beam pipe – default aperture 8 mm radius -varying along beam line – 2mm thickness
- Cylindrical magnets – 25cm radius
- Below – CLIC BDS from from YSP1 with some magnetised muon spoilers.
- Tunnel including floor and beam line offset, 0.5m thick concrete surrounded by soil.



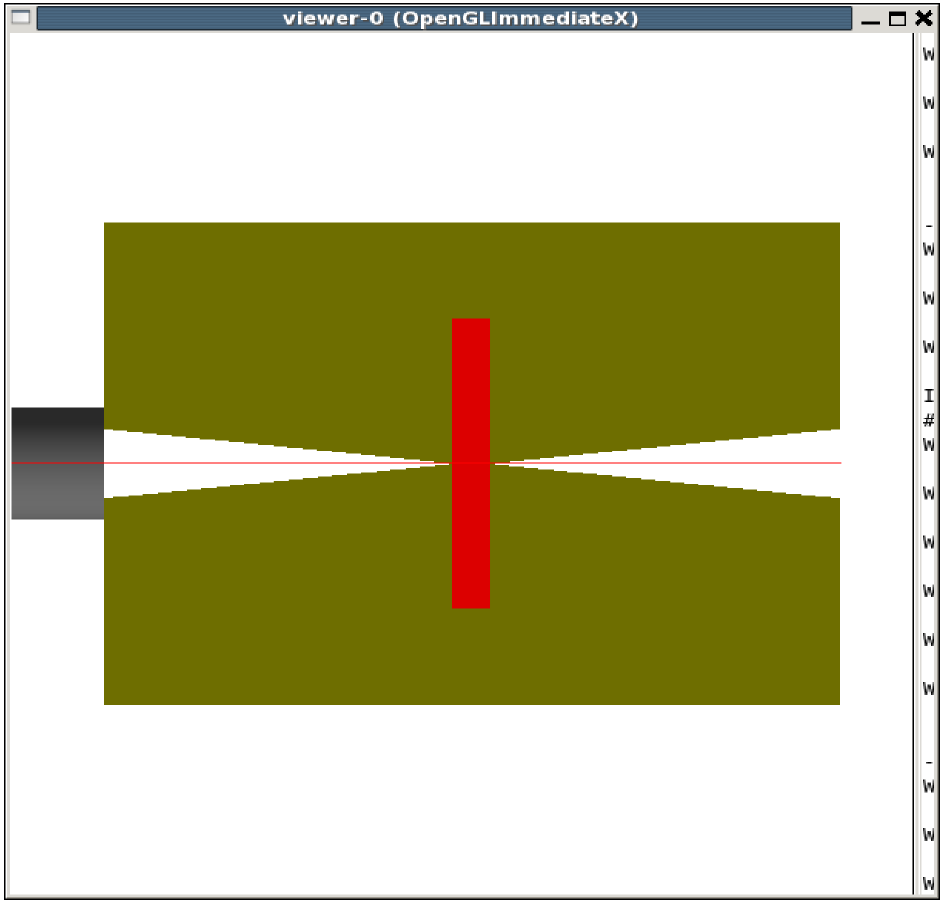
Tunnel geometry

- Based on typical cross section, J. Osborne/ A. Kosmicki, CLIC-ILC conference October 12th 2009
- Tunnel follows bends in beam lines



Spoiler geometry

- Based on option 1 in "spoiler designs and damage tests", Nigel Watson, CLIC collimation meeting, 15th Jan 2009.
- Tapered Beryllium (green): 10mm -> 0mm (when fully closed) over 190mm (i.e. +/- 26.3 mrad opening angle)
- Titanium block (red): 20mm long
- Total length: 400mm
- Absorber geometry: titanium block with aperture, 70cm long, elliptical apertures.



Collimator apertures

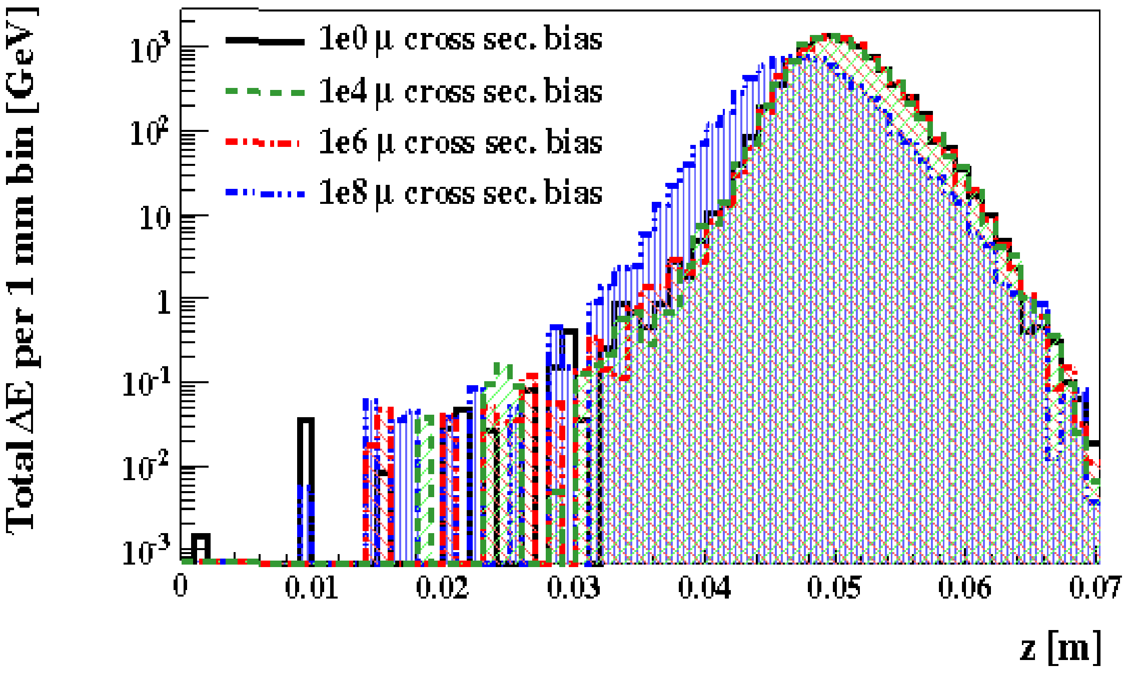
- From Rogelio Tomas et. al., “BDS collimation system and muon spoilers”, CLIC workpackages for STI, March 2010
- Y Spoilers: 10 X 0.12 mm
- X Spoilers: 0.12 X 10 mm
- Absorbers: 1 X 1 mm elliptical aperture
- Energy spoiler: 3.51 X 25.4 mm, Beryllium
- Energy absorber: 5.41 X 25.4mm, Titanium

Muon Production

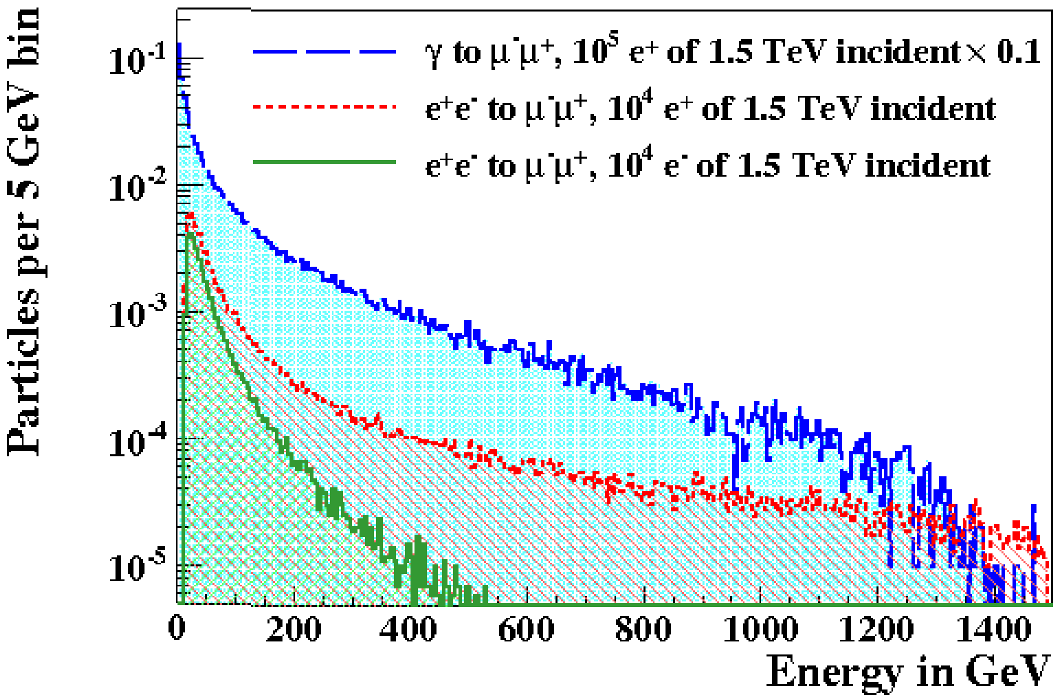
- The following muon production processes are simulated:
- $\gamma \rightarrow \mu^+ \mu^-$
- $e^+ e^- \rightarrow \mu^+ \mu^-$
- $e^+ e^- \rightarrow \pi^+ \pi^-$ followed by decay to muons
- To reduce required computing time, cross sections biased by some enhancement factor Fe
- Secondary particles assigned weights – W = W'/Fe where W is the new weight and W' is the original weight

Muon Production

- Profile of energy loss through material not affected by biasing up to Fe = 1e6



Muon Production

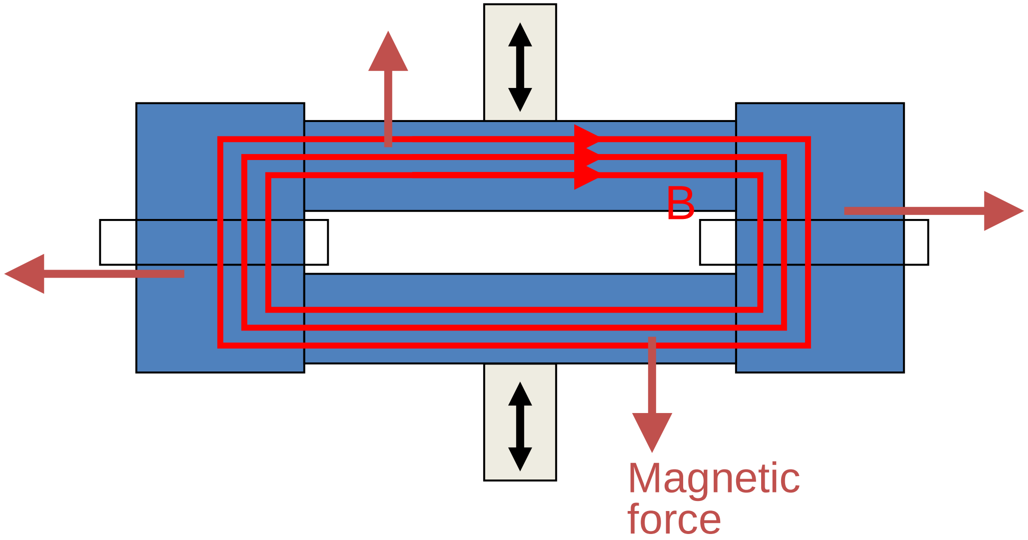


Results

- After first Y spoiler YSP1: 2.1E3 muons/train
- After XSP1: 6.6E3 muons/train
- After first X absorber XAB1: 2.6E5 muons/train
- After YAB1: 1.5E5 muons/train
- 3.2E4 muons/train at end of collimation section
- 1.2E4 muons / train at exit of QF1, 10m upstream of IP, and within a 6m radius of the beam line (assuming 10^{-4} of beam hitting spoilers, based on ideal machine, so should be taken as a minimum value).
- "Swapped" layout (Rogelio Tomas) – betatron before energy collimation – muon flux is decreased by a factor of 0.4 to 4.8E3 muons/train (presented at IPAC 2010).
- Modest reduction

Options to reduce muon backgrounds

- Tunnel fillers
- Toroidal fields in iron (*left*) - as used at COMPASS - and suggested for use at CLIC (Lau Gatignon, 10th MDI Meeting, 19/2/2010, “Muon sweeping: example from M2 beam for COMPASS)
- Magnetised scrapers (*right*)– adjustable gap, vacuum more difficult, less coverage.



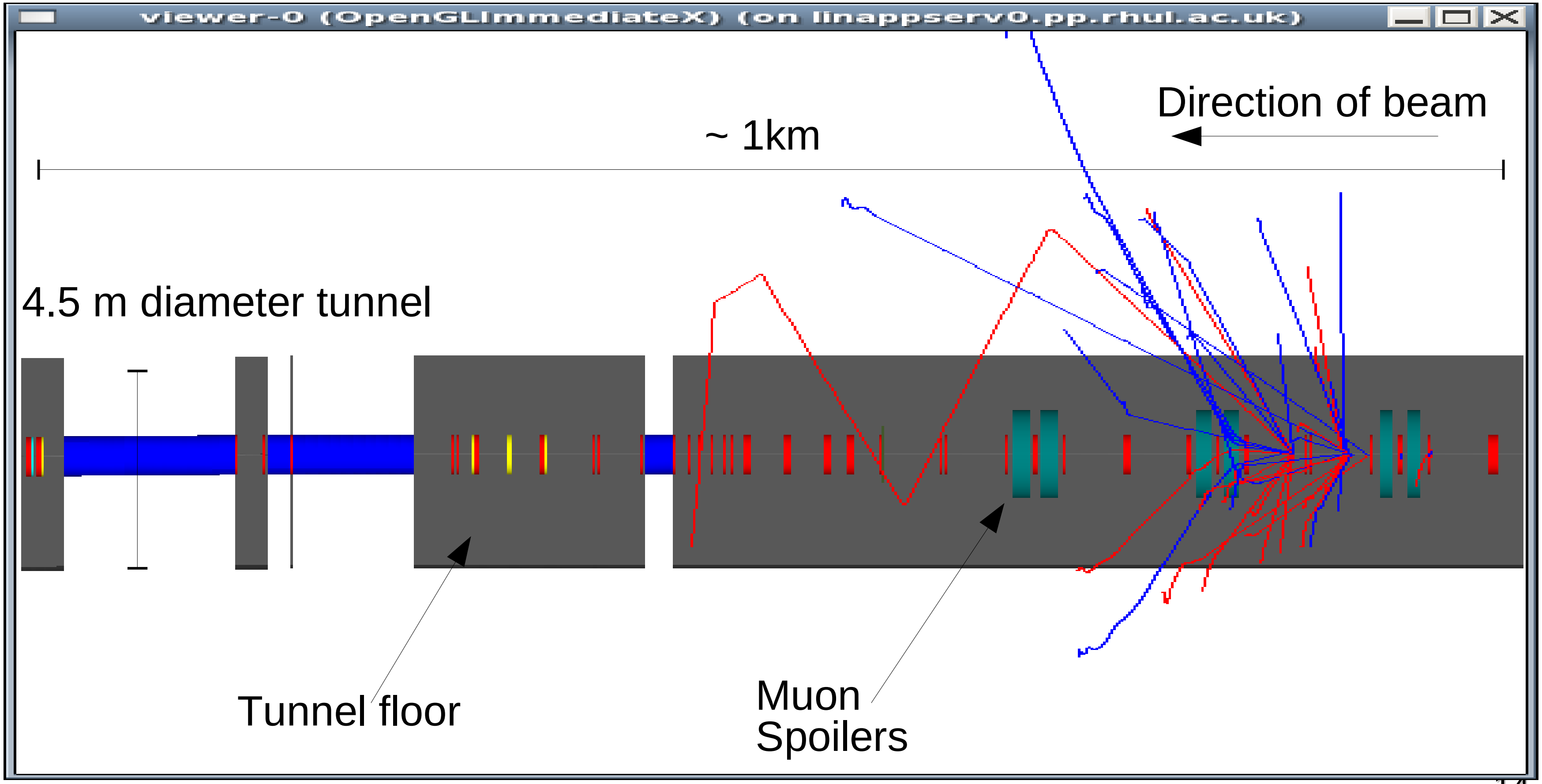
Images: Lau Gatignon

Initial muon spoiler layout and design

- We simulated the toroidal fields in iron (“muon spoilers”)
- In simulation we use cylindrical shape
- Outer radius = 55 cm
- Inner radius = 1cm
- Magnetic field = 1.5 T
- Length determined by: distance to detector, energy of muons
- Assuming 1.5 TeV beam, most muons having less than 1 TeV energy and:
- Spoilers placed ~100m upstream (where muons that reach detector leave the beam pipe) of four main muon sources (clusters of collimators) ->
- Four spoilers, lengths of between 16 and 27m (will fit into existing drift spaces)
- Sum of spoiler lengths = 83m = 79 m^3 = 620 metric tons of iron

Results

- The addition of these muon spoilers results in a factor ~0.1 reduction in muon flux to detector

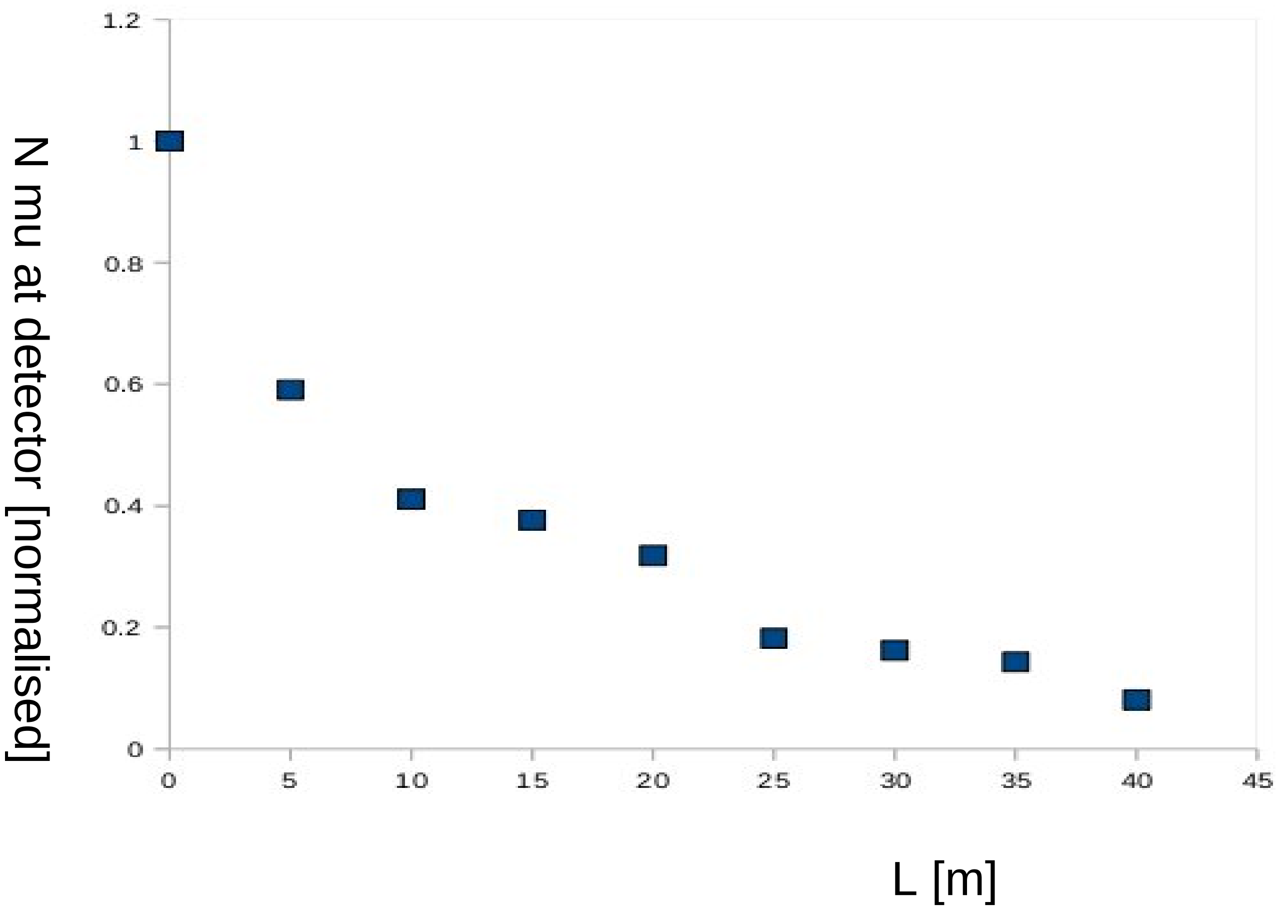


Iterative muon spoiler layout and design

- To improve the muon spoiler placement, an iterative process was followed
- The beam line was simulated
- A 5m long magnetized muon shield was placed at the location of the maximum number of the muons reaching the detector would hit the shield
- The process was repeated

Iterative muon spoiler layout and design

- With L = 40 m, 8% of muons reach detector



Genetic algorithm

- Design of shielding depends on many variables, e.g. polarity (muons focus, antimuons defocus), inner radius, outer radius, field.
- Trying to optimise further using genetic algorithm
- Initially, attempted to optimise positions of 100 X 1m long spoilers
- After 560 iterations, the number of muons reaching the detector reduced from 35% (random layout) to 2.5%, and still decreasing
- Still in development, not sure yet if this will help

Summary

- First attempt at simulating muon spoilers -> ~0.1 reduction in muon flux to detector
- Second attempt using a simple iterative process does the same with half the length of spoilers
- Attempting to optimise further (genetic algorithm?)
- Distribution files available on web - new files to be added soon
  https://www.pp.rhul.ac.uk/twiki/bin/view/JAI/ClicMuon
  Based on certain assumptions, the simulations predict flux of 1.2e4 muons per train hitting the detector – figure not final – halo difficult to predict
- What would be the effect of these muon trajectories on the detector backgrounds?
- Should reserve space for muon shielding in existing drift spaces, so that it can be added later in stages if required