Muon background from the BDS in SiD

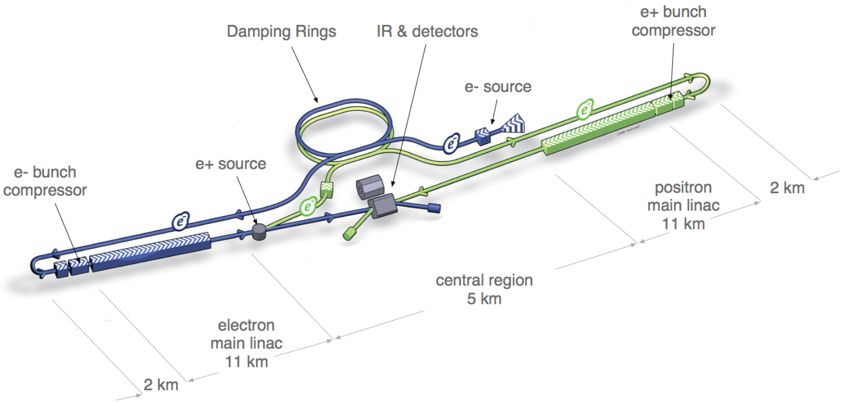
LCWS Morioka

Anne Schütz
Lewis Keller (SLAC), Glen White (SLAC)

DESY

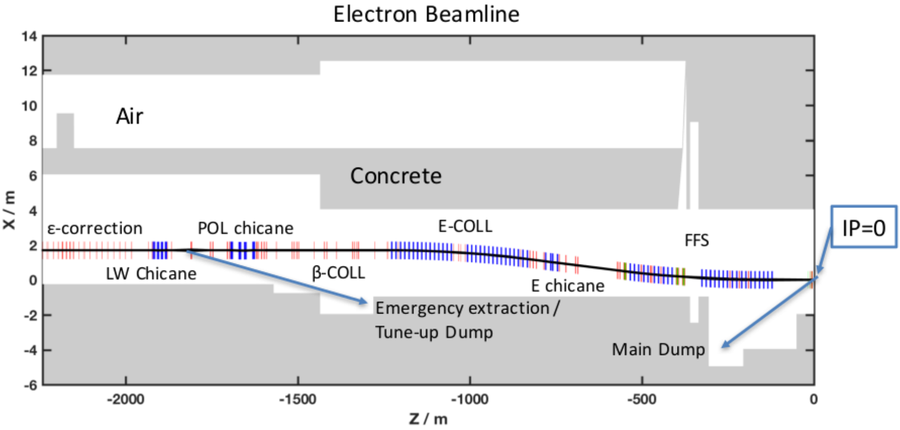
8th December 2016

The layout of the ILC



The muon spoilers will be installed in the Beam Delivery System (BDS) in the central region.

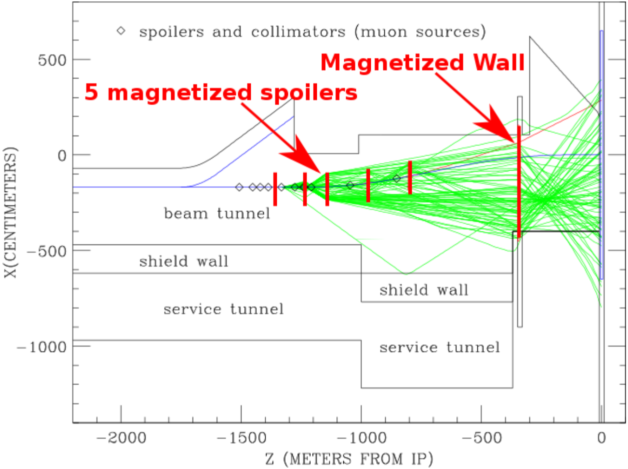
BDS tunnel layout



Muon spoiler scenarios

There are two spoiler scenarios under discussion:

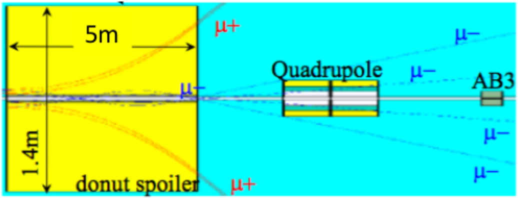
- 5 donut spoilers
- 5 donut spoilers + wall

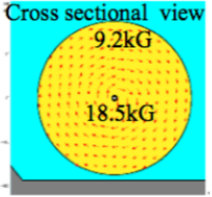


5 donut spoilers

The donut spoilers are designed as follows:

- 70 cm radius
- 5 m long
- Magnetized iron with a field of ∼10-19 kG
- 5 locations (before IP):
  - 802.5m
  - 975.5m
  - 1145.5m
  - 1234.5m
  - 1358.5m

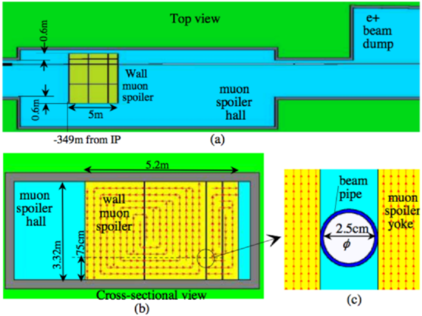


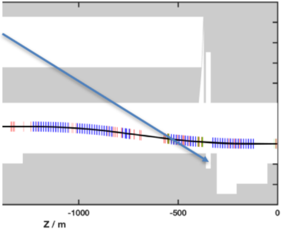


5 donut spoilers + wall

The iron wall would completely fill up the tunnel:

- 5 m x 5 m, 5 m long
- Magnetized with a field of ∼16 kG
- Located ∼400 m away from the IP
- Would cost ∼ $3 million



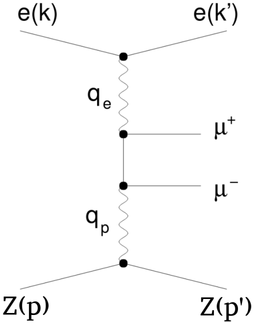


FERMILAB-CONF-07-276-AD

SUPPRESSION OF MUON BACKGROUNDS GENERATED IN THE ILC BEAM DELIVERY SYSTEM *

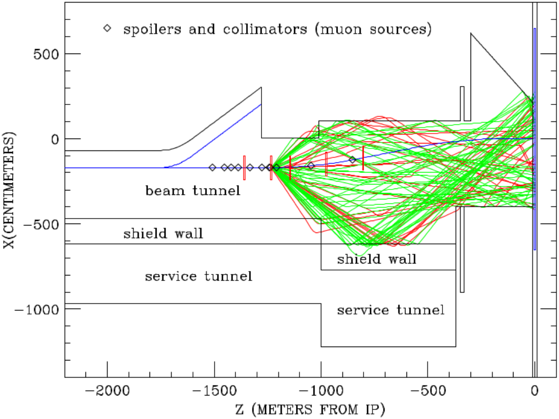
MUCARLO simulation overview

- BDS backgrounds with muon collimation system modelled with MUCARLO [Lewis Keller, SLAC] and Geant4 [Glen White, SLAC]
- Using TDR baseline machine parameters for the ILC500
- Muon production processes:
  - Predominantly: Bethe-Heitler process: $\gamma + Z \rightarrow Z' + \mu^+\mu^-$
  - Few % level: direct annihilation of positrons with atomic electrons: $e^+e^- \rightarrow \mu^+\mu^-$
- Halo particle tracking:
  - Turtle with MUCARLO
  - Lucretia with a built-in Geant4 model interface



Muon tracks in the BDS tunnel

Muon tracks of positively (μ^+) and negatively (μ^-) charged muons, originating at a specific source location:



The tracks that are drawn are only the ones that reach the detector.

The spoiler polarities are set to defocus muons with the same charge as the beam charge. → More μ^+ from the e^- beam than from the e^+ beam, and vice versa.

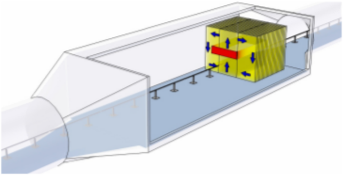
Muons in the detector

4-vectors of the muons are given to SiD and ILD for studying the effect of the muons on the detector performance.

Scenario	Number of muons in a detector with 6.5m radius
5 spoilers	4.3 muons/bunch crossing
5 spoilers + wall	0.6 muons/bunch crossing

Question to SiD and ILD: Do we need the muon wall at all?! MID people would be happy to get rid of it because of safety issues, and the costs for such a iron wall.

Muon Wall Required?



- If flux with toroid spoilers acceptable running condition from detector groups:
  - **Can we remove 5m magnetized iron muon wall?**

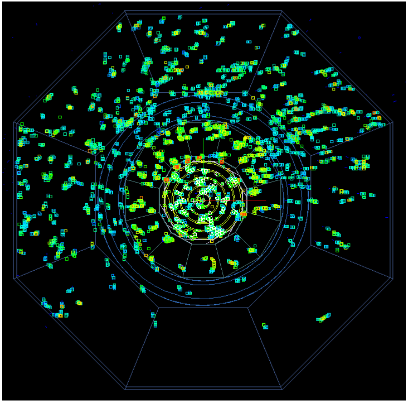
Analysis Method

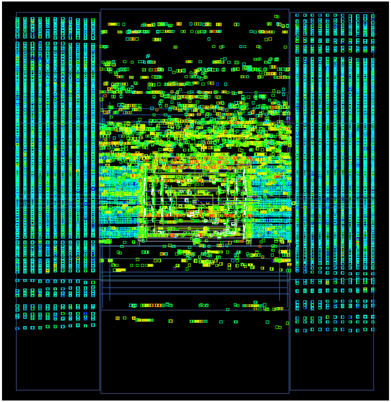
Analysis method:

- 4-vector files provided by Lewis Keller:
  - 5 Spoilers + wall: from electron line: ~4321 muons
  - 5 Spoilers + wall: from positron line: ~5834 muons
  - 5 Spoilers: from electron line: ~30292 muons
  - 5 Spoilers: from positron line: ~33482 muons
- Conversion of the text files with the 4-vector values to STDHEP files.
- The STDHEP files were used as input to a full SiD detector simulation with Genat4.
- Nice event displays from the simulations with WIRED4 in JAS3.
- Studies of the spatial distributions, the muon energy, and the detector occupancies.

WIRED4 event display - 5 spoilers + wall

1 train's worth of muons ($\sim$ 515 muons) from the positron line:

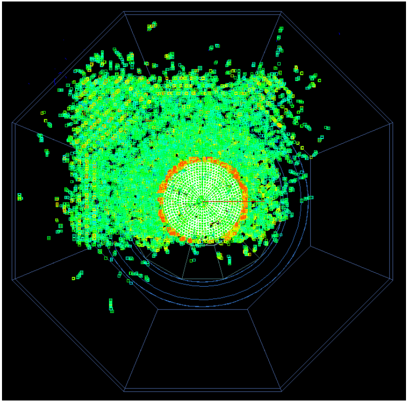


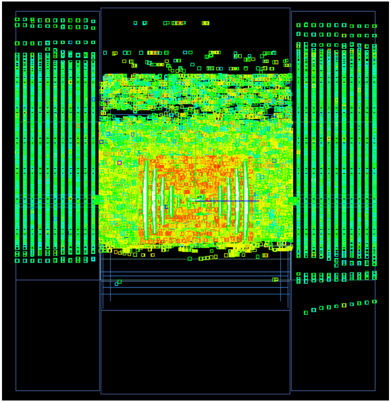


The asymmetry in the xy plane is predicted by the MUCARLO simulation output (see a few slides before), and clearly visible also in the SLIC simulation.

WIRED4 event display - 5 spoilers

1 train's worth of muons ($\sim$ 2961 muons) from the positron line:



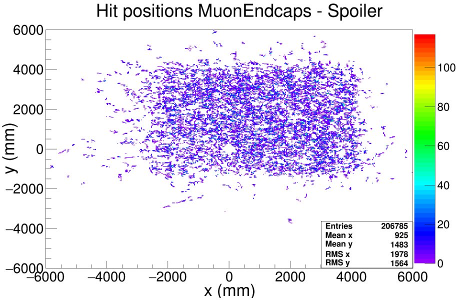


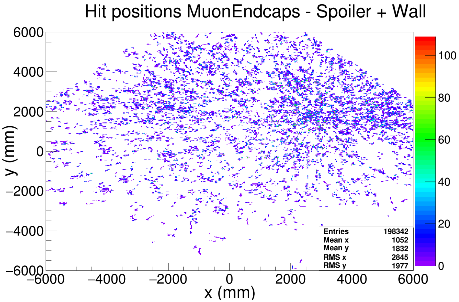
The spatial distribution is due to the tunnel shape and its shielding effects.

Spatial distribution in the MuonEndcaps -

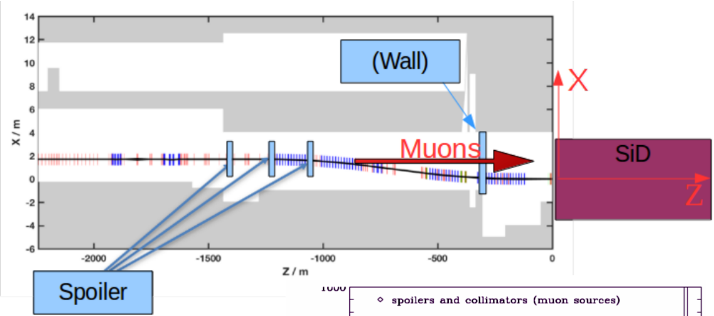
Spoiler and Spoiler+Wall scenarios

Hits from muons from 5 trains for both MuonEndcaps and all their layers:

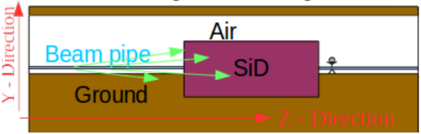


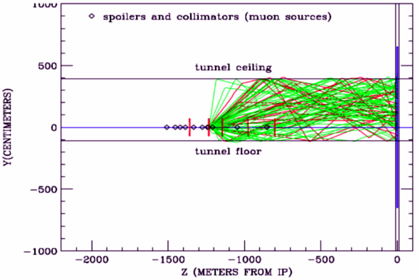


Explanation of spatial distributions in the MuonEndcaps

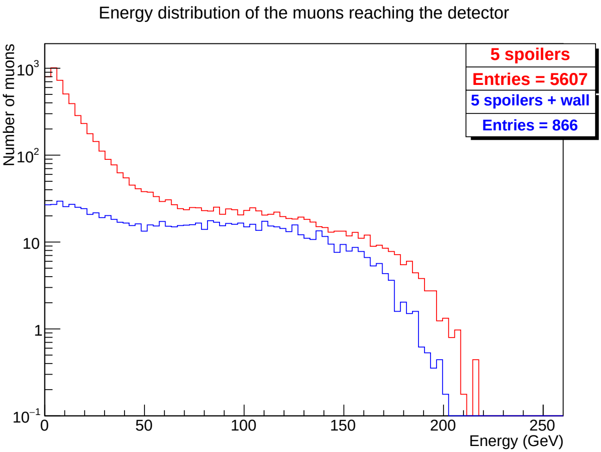


- Beam pipe is curved
- Beam pipe close to floor
  - High tunnel ceiling



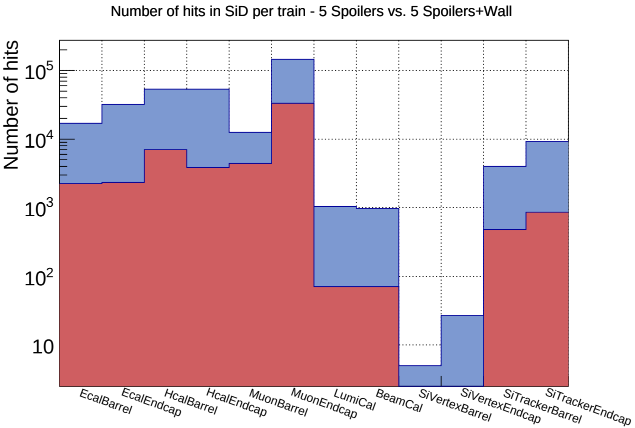


Energy distribution of muons



In the 'Spoiler + Wall' case, the lower energy muons are either stopped or deflected by the magnetized wall.

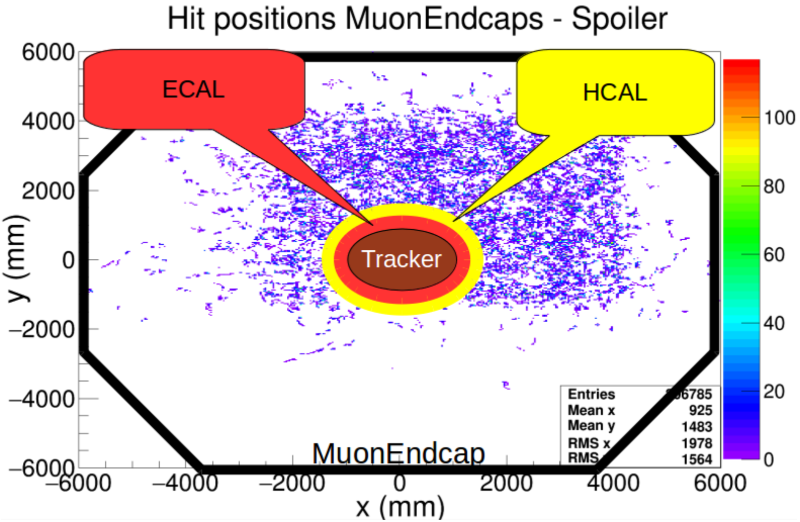
Total number of hits



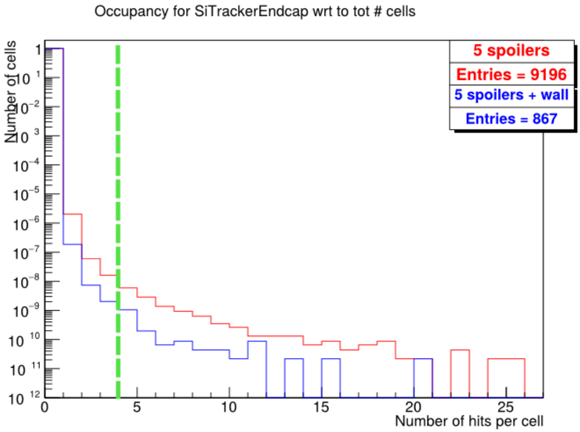
Vertex detectors	<	ECAL, HCAL	<	MuonEndcaps
Smallest effective detector area		Particle showers		Biggest effective detector area

Explanation of hit number distribution -

Spatial distribution in the MuonEndcaps

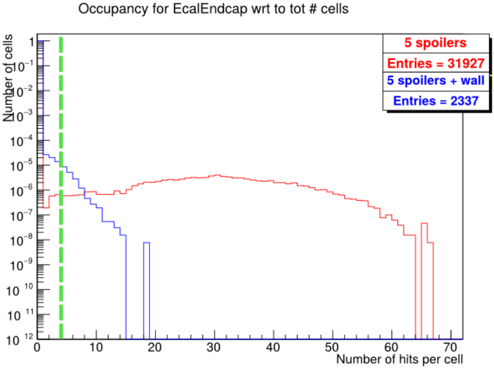


Occupancy plots - SiTrackerEndcap



For both scenarios, 5 Spoilers w/ and w/o Wall, 10^{-9} - 10^{-8} of all cells that get hit have 4 hits.

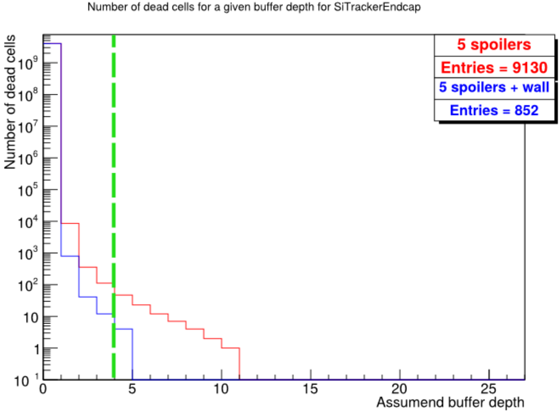
Occupancy plots - EcalEndcap



'5 Spoilers + Wall' seems to do better by an order of magnitude, when looking at a buffer depth of 4. The occupancy is still at a level of only 10^{-5}.

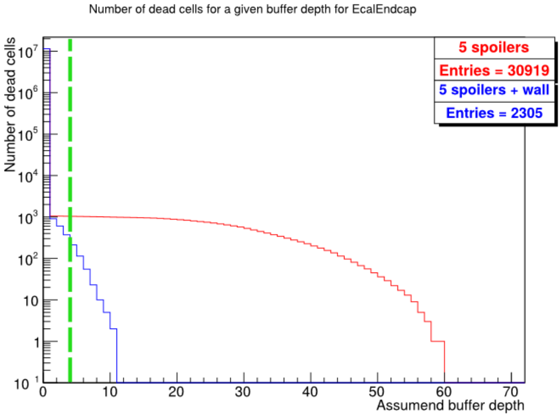
The '5 Spoiler' case shows up to 70 hits per cell. → Constant occupancy for all buffer depths.

Dead cells - SiTrackerEndcap



For a assumed buffer depth of 4, the total number of dead cells is different by an order of magnitude. → In the '5 Spoiler' case, 100 cells would have reached the buffer limit.

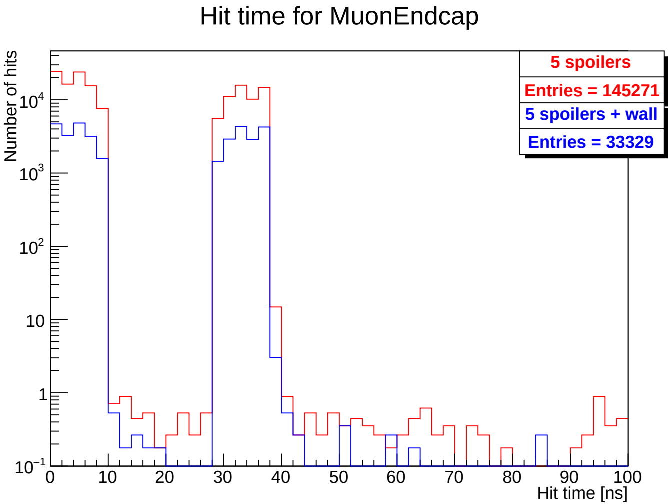
Dead cells - EcalEndcap



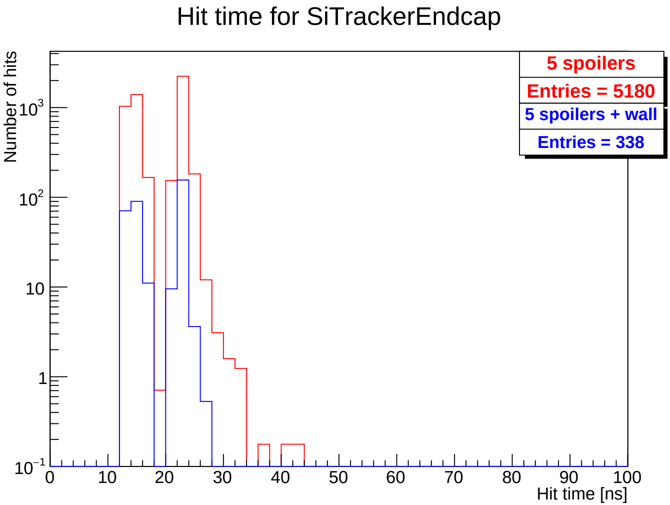
For a assumed buffer depth of 4, the total number of dead cells is different by a factor of about 5. → In the '5 Spoiler' case, 1000 cells would have reached the buffer limit.

Time distribution - MuonEndcaps

All of the muons are created up to 0.5 ns after the bunch passing.



Time distribution - SiTrackerEndcaps



Conclusion:

- Low energy muons are stopped by the muon wall.
- High energy muons could be used for tracker alignment.
- Spatial distributions quite different in the '5 Spoiler' and '5 Spoiler+Wall' scenarios.
- Number of hits in subdetectors are explained by geometries.
- Occupancy is small, but
- Muons are instantaneous in comparison to pair background.

Outlook:

- PACMAN should be included in the SiD geometry. This will have a big effect on the backgrounds, not only the muon spoiler background $\rightarrow$ PACMAN will stop muons with energies below 3-4 GeV.

$\rightarrow$ *Stay tuned!*

References

[1] *ECFA 2016: Talk by Glen White about the MUCARLO simulation of the muons from the muon spoilers.* https://agenda.linearcollider.org/event/7014/contributions/34689/attachments/30076/44961/ILC_muons.pptx

[2] *DESY summer student program: Talk by Jonas Glomitza (RWTH Aachen) about "The Impacts of the Muon Spoiler Background on the ILC Detector Performance", 08. September 2016.* https://indico.desy.de/getFile.py/access?contribId=9&resId=0&materialId=slides&confId=15972

[3] *FERMILAB-CONF-07-276-AD: "Suppression of Muon Backgrounds generated in the ILC Beam Delivery System", Drozhdin et.al, 2007.* https://inspirehep.net/record/771808/files/fermilab-conf-07-276.pdf

[4] *"Calculation of Muon Background in Electron Accelerators using the Monte Carlo Computer Program MUCARLO", Rokni et.al.* http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-7054.pdf

[5] *SLAC-PUB-6385: "Muon Background in a 1.0-TeV Linear Collider", L.P. Keller, 1993.* http://www.slac.stanford.edu/pubs/slacpubs/6250/slac-pub-6385.pdf

[6] *SLAC-PUB-5533: "Calculation of Muon Background in a 0.5 TeV Linear Collider", L.P. Keller, 1991.* http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-5533.pdf