The International Linear Collider

Muons from the muon spoilers in the SiD detector -

FIRST RESULTS

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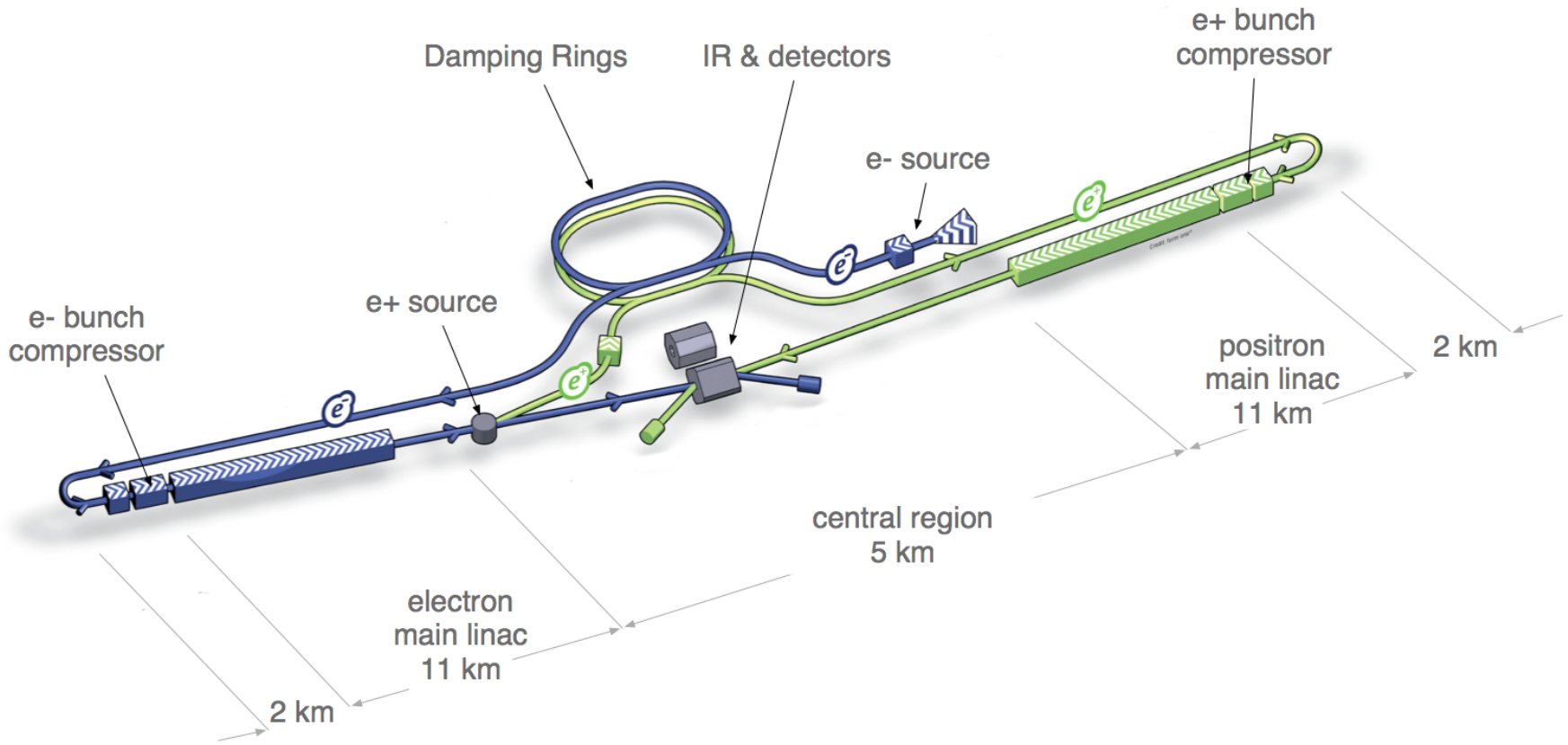
DESY

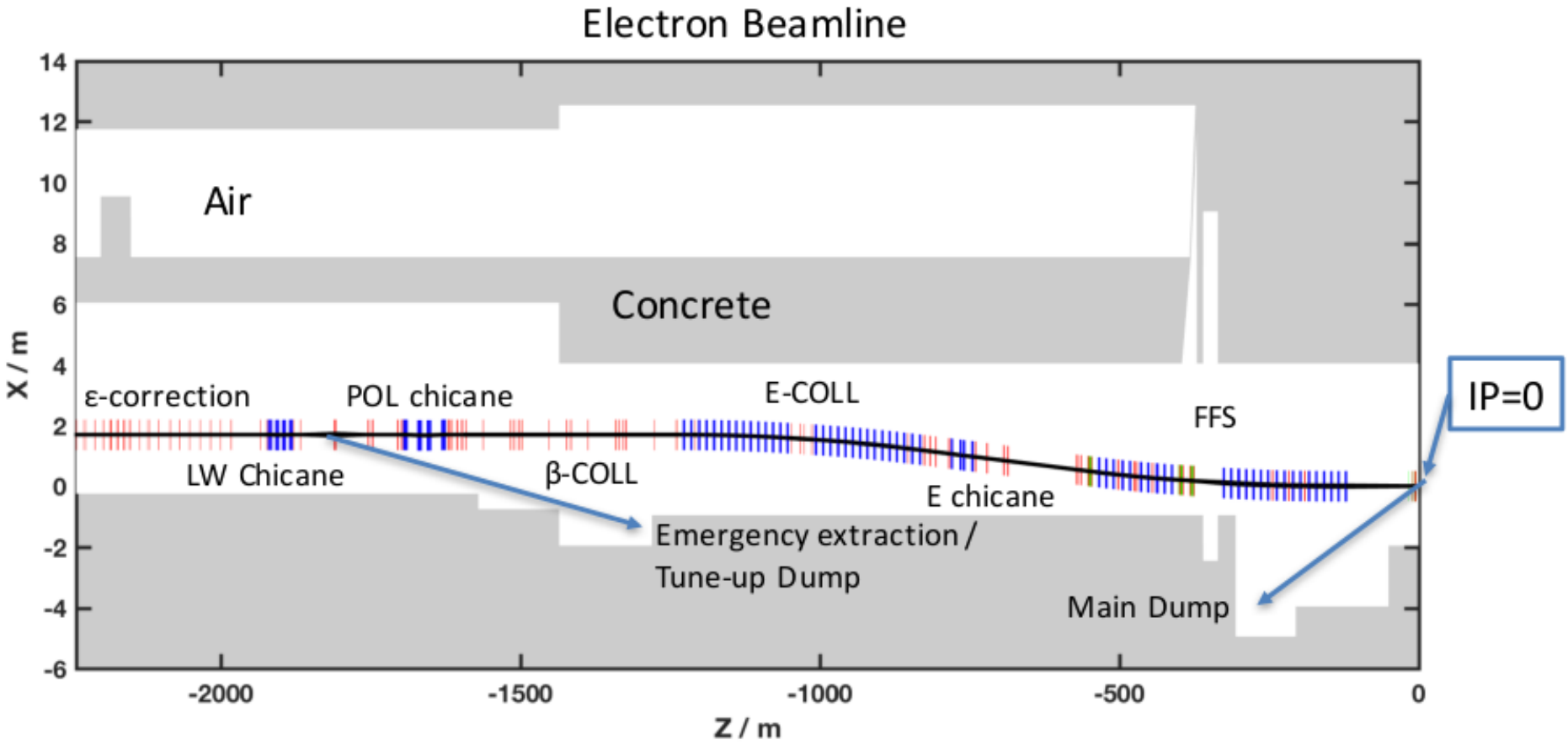
23rd September 2016

The layout of the ILC



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

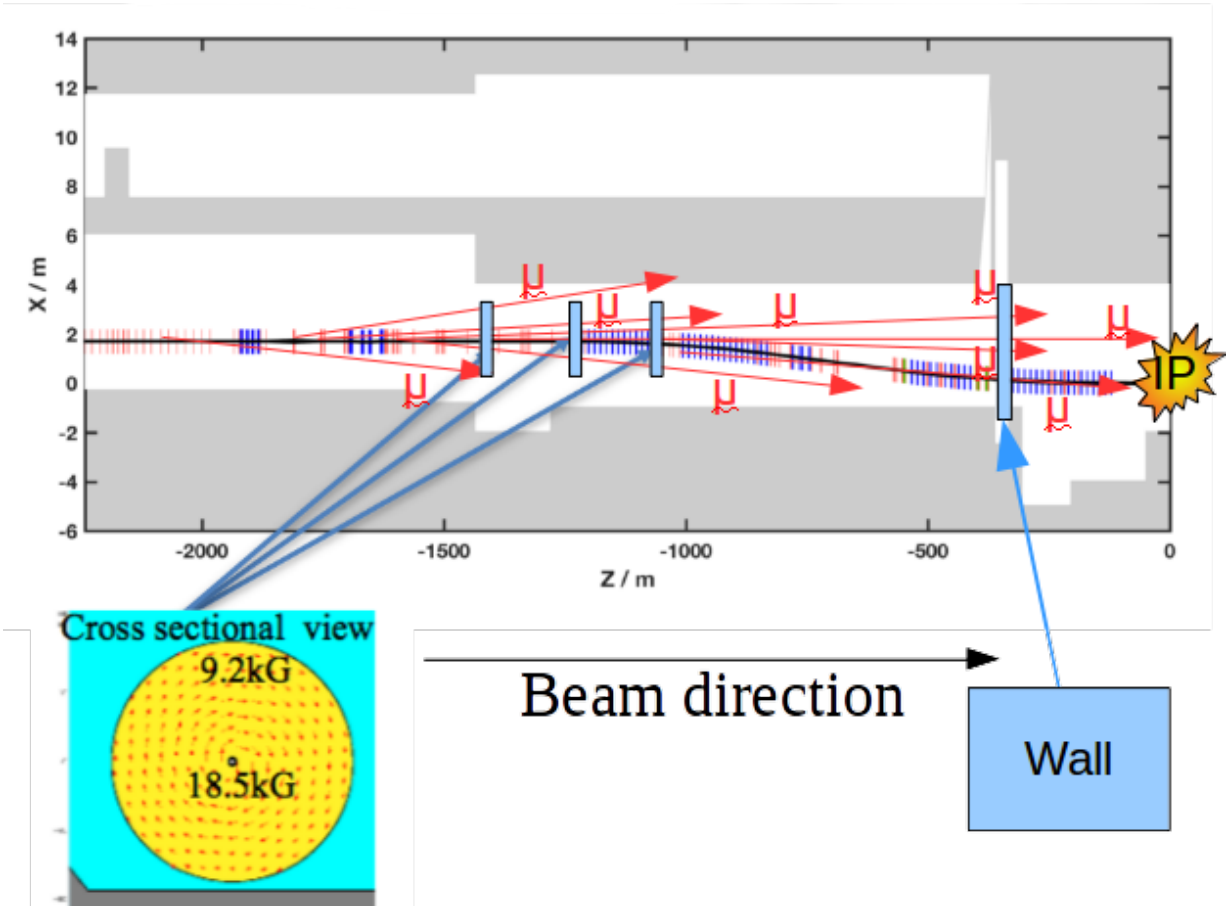
BDS tunnel layout



Muon spoiler scenarios

There are two spoiler scenarios under discussion:

- 3 donut spoilers
- 3 donut spoilers + wall



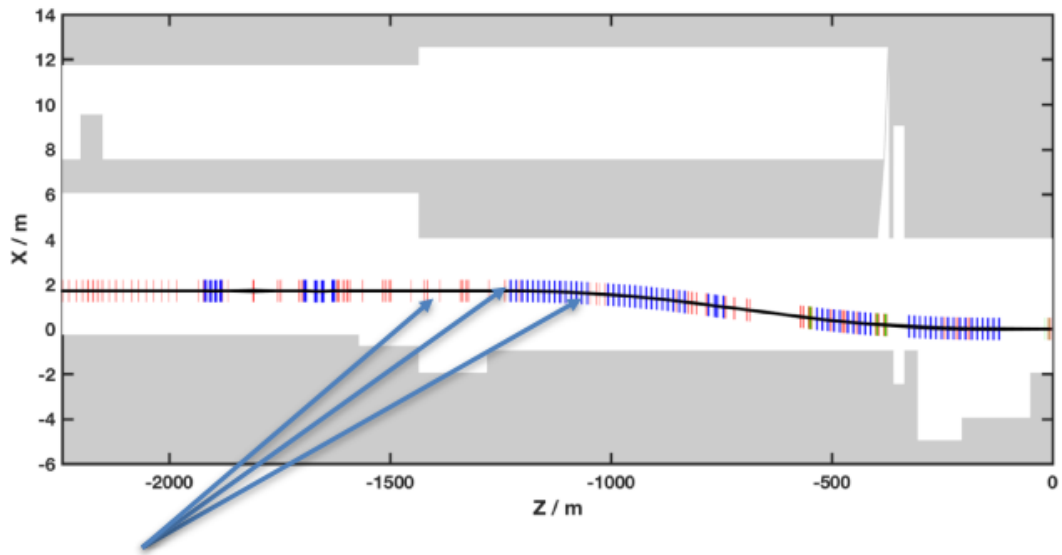
3 donut spoilers

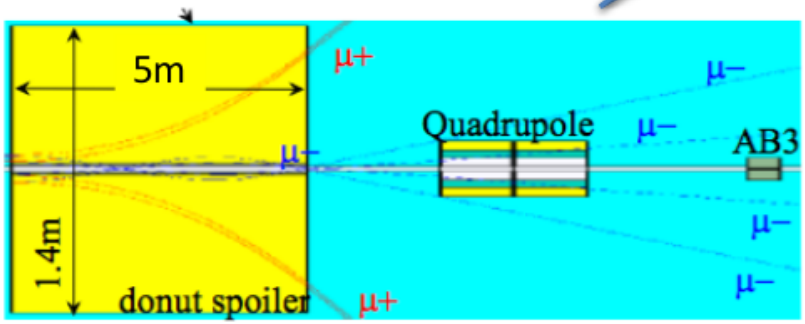
The donut spoilers are designed as follows:

- 70 cm radius
- 5 m long
- Magnetized iron with a field of ∼10-19 kG

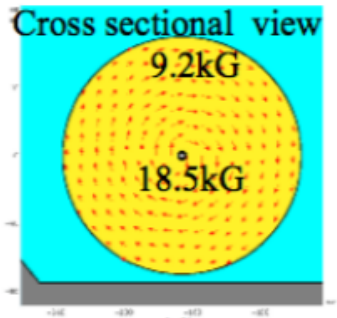
3 muon spoilers at z locations from IP:

- 1143m
- 1227m
- 1408m





(c)

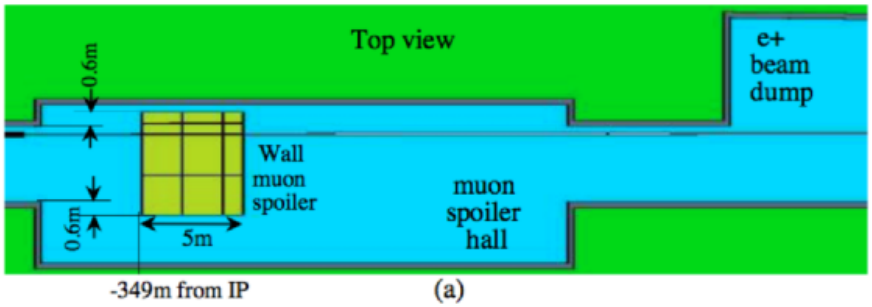


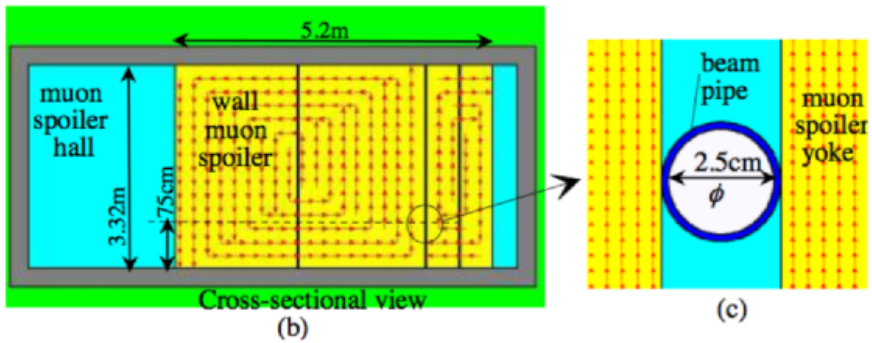
(d)

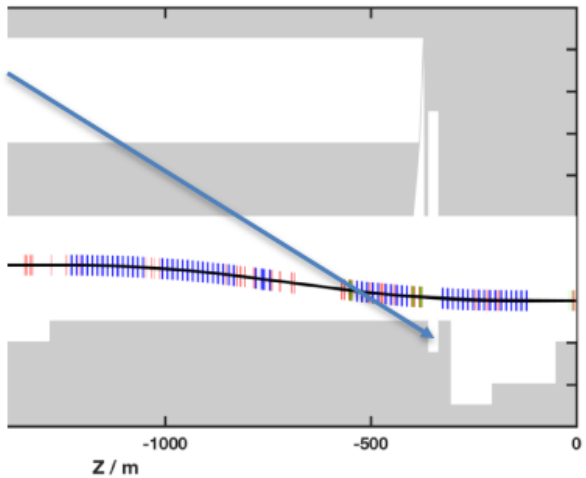
3 donut spoilers + wall

The iron wall would completely fill up the tunnel:

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





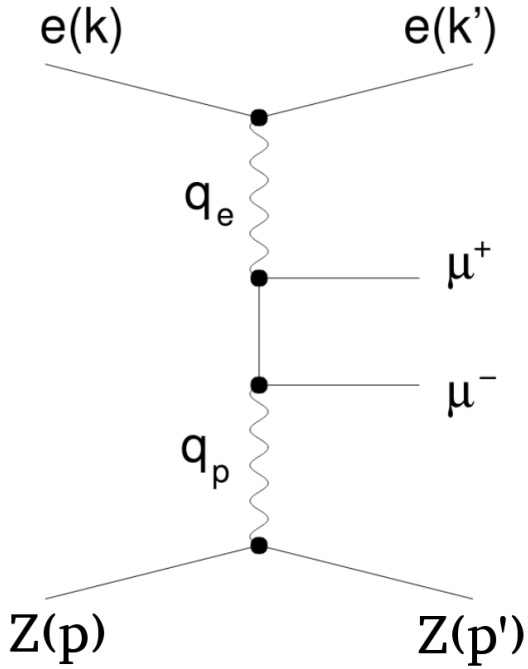


FERMILAB-CONF-07-276-AD

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

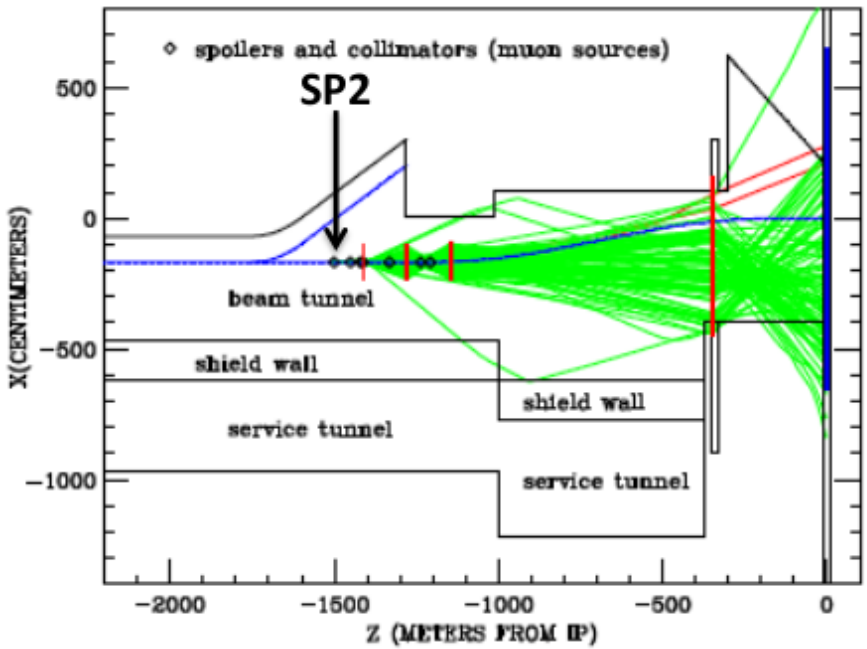
MUCARLO simulation overview

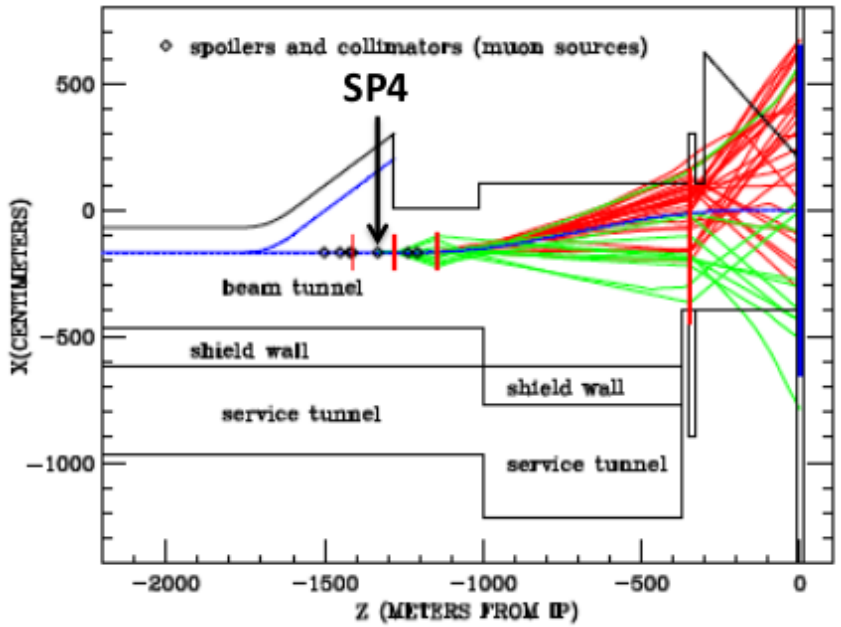
- BDS backgrounds with muon collimation system modelled with MUCARLO [Lewis Keller, SLAC] and Geant4 [Glen White, SLAC]
- Using TDR baseline machine parameters for the ILC500
- Muon production processes:
  - Predominantly: Bethe-Heitler process: $\gamma + Z \rightarrow Z' + \mu^+\mu^-$
  - Few % level: 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

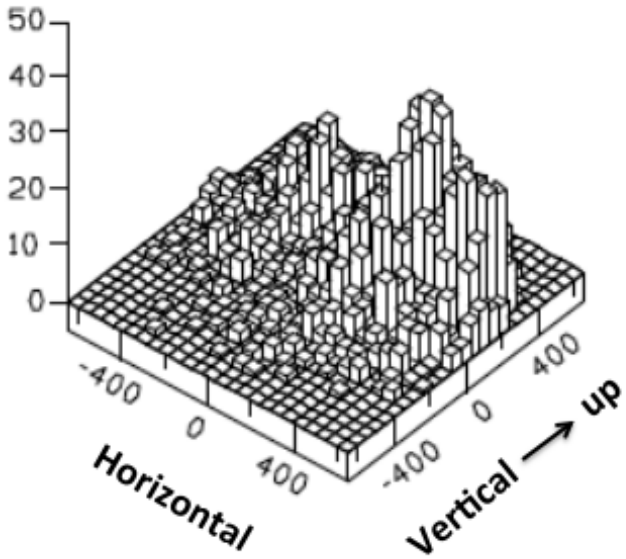
Muon tracks of positively (μ^+) and negatively (μ^-) charged muons, originating at two different primary betatron collimators: SP2 and SP4.

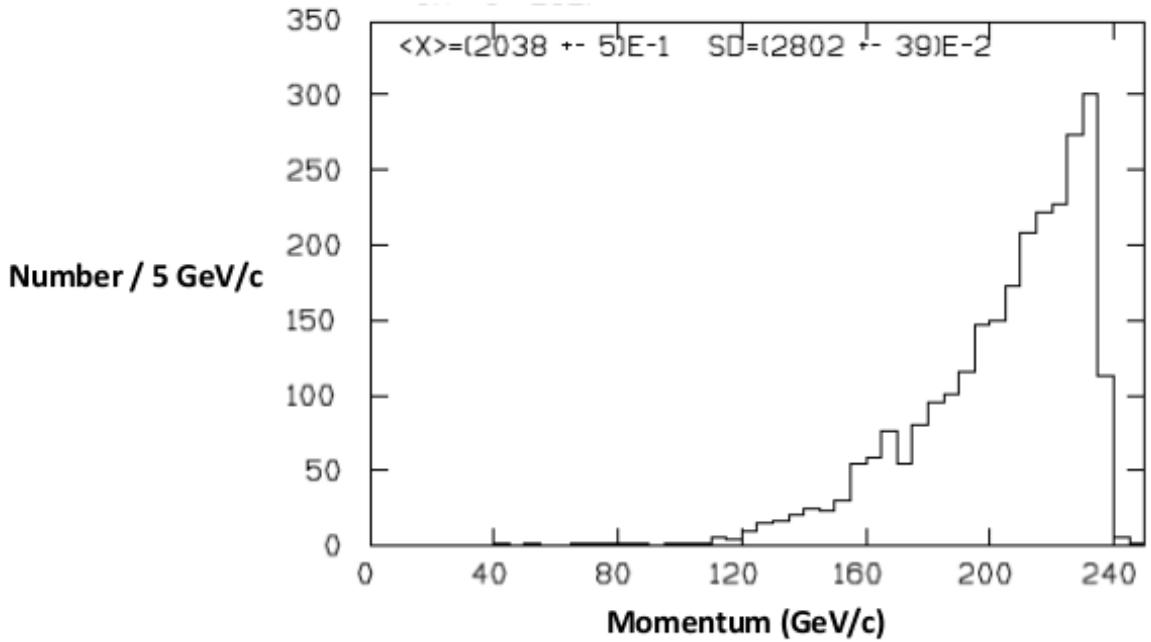




The tracks that are drawn are only the ones that reach the detector. Because the SP2 is further away and the negative muons are deflected by the magnetized spoilers, the negative muons are not drawn because they don't reach the detector.

Muon 4-vectors





Spatial and momentum distribution of muons in a detector (of 6.5m radius). 4-vectors provided to SiD and ILD.

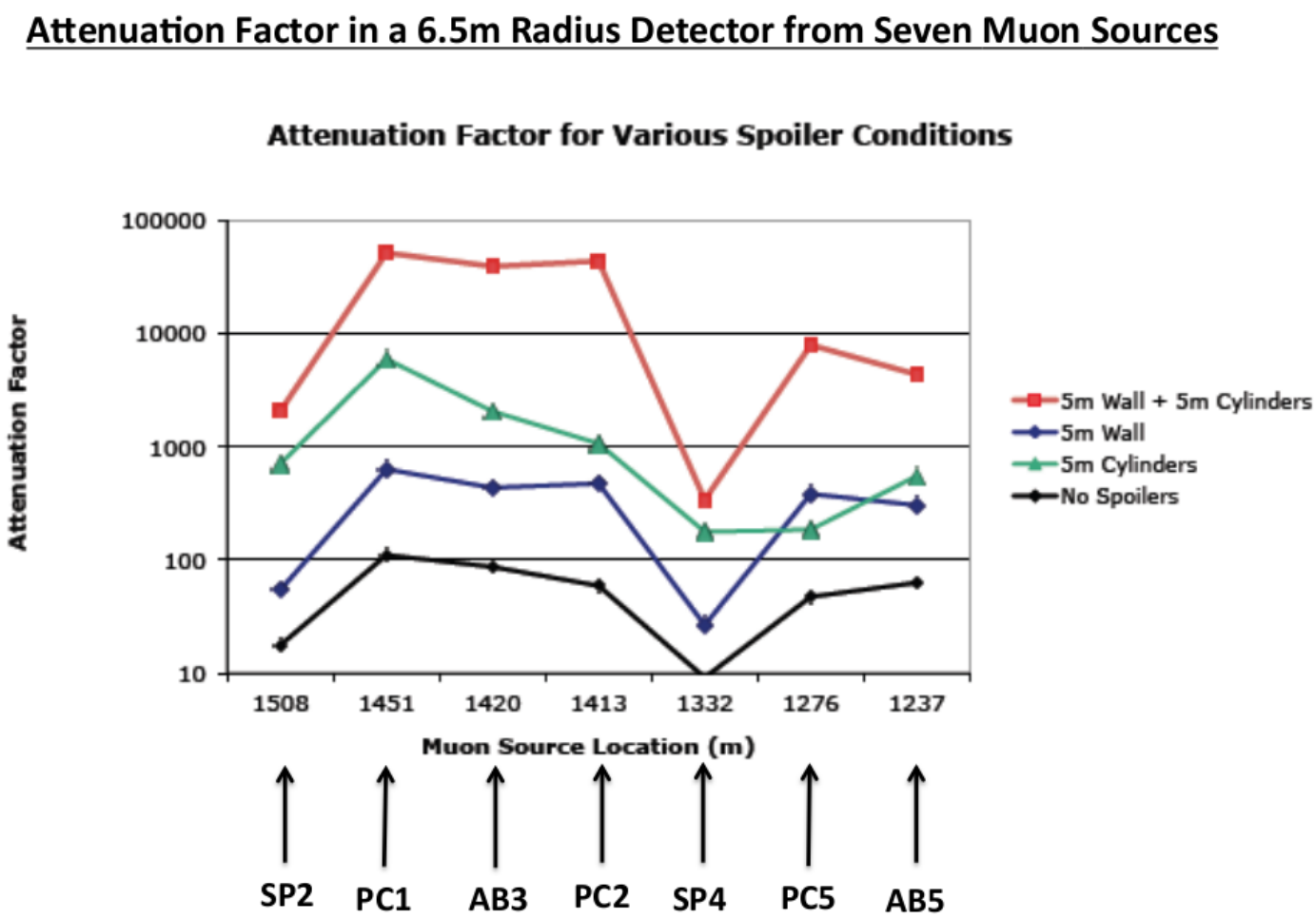
Muons in the detector

Tunnel Condition	#/bunch in 6.5m radius detector	#/200 bunches in 2.5m radius TPC
1. No spoilers	138	9648
2. Two 5m magnetized spoilers (z = 344-349m) fill tunnel	25	1008
3. Three 5m toroid spoilers	3.3	273
4. Three 5m toroid spoilers and two 5m spoilers (z = 344-349m) fill tunnel	0.5	17

- *(1) GEANT4 Preliminary: ~156 / bunch in 6.5m radius detector*

First column: muon numbers per bunch in a detector with 6.5m radius.
The number can be reduced to below 1!

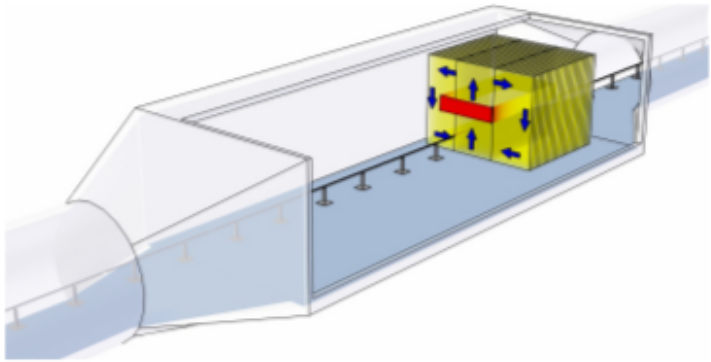
Attenuation Factor



The ratio of muons produced over muons which reach the detector, for different spoiler conditions and different source locations.

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.

Muon Wall Required?



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

Summer student project

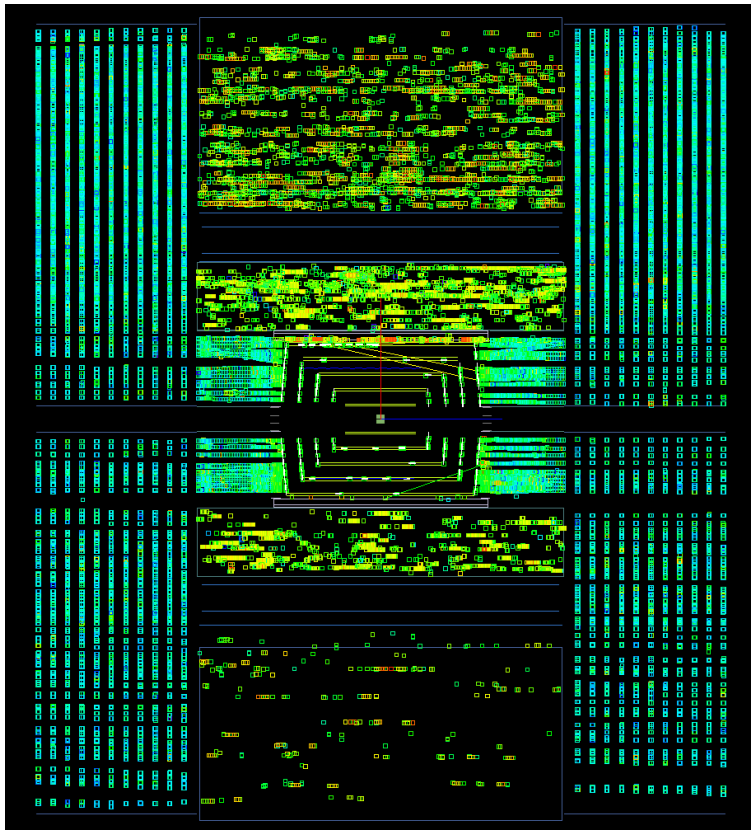
The first analysis of the muon hits and the detector occupancy in the SiD detector was done by Jonas Glombitza, Marcel's and my summer student this summer 2016.

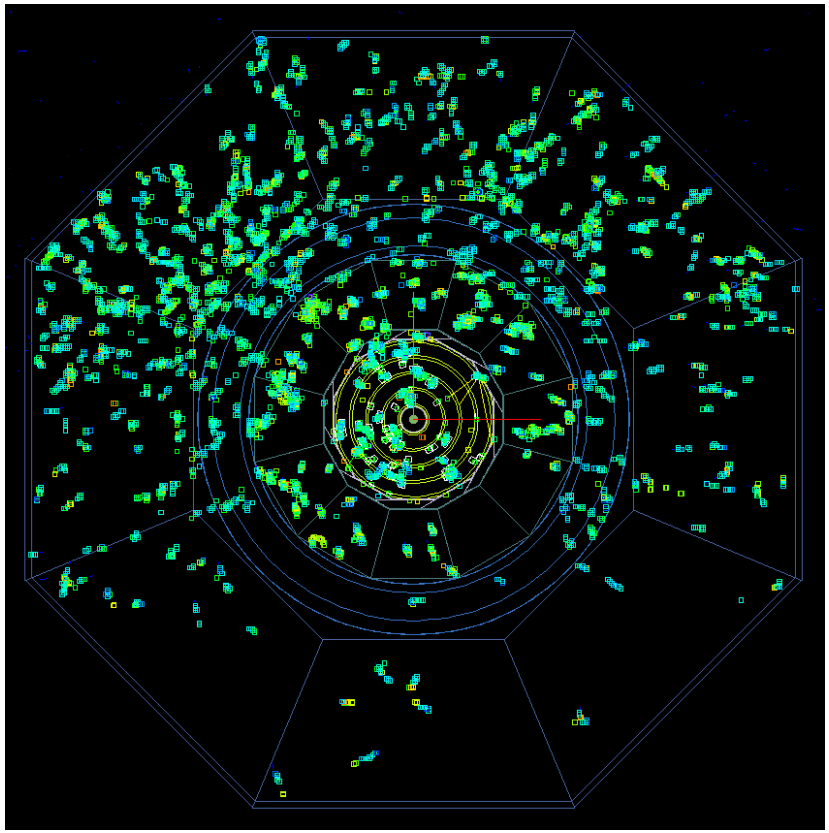
Preparations:

- 4-vector files from Lewis Keller:
  - Spoilers + wall: from electron line: ∼1500 muons
  - Spoilers + wall: from positron line: ∼2100 muons
  - Spoilers: from electron line: ∼1080 muons
  - Spoilers: from positron line: ∼2280 muons
- Conversion of the text files with the 4-vector values to STDHEP files of 1 train worth of muons.
- The STDHEP files were used as input to a full SiD detector simulation with SLIC.
- Nice event displays from the simulations with WIRED4 in JAS3.

WIRED4 event display

1 train's worth of muons ($\sim$ 650 muons):

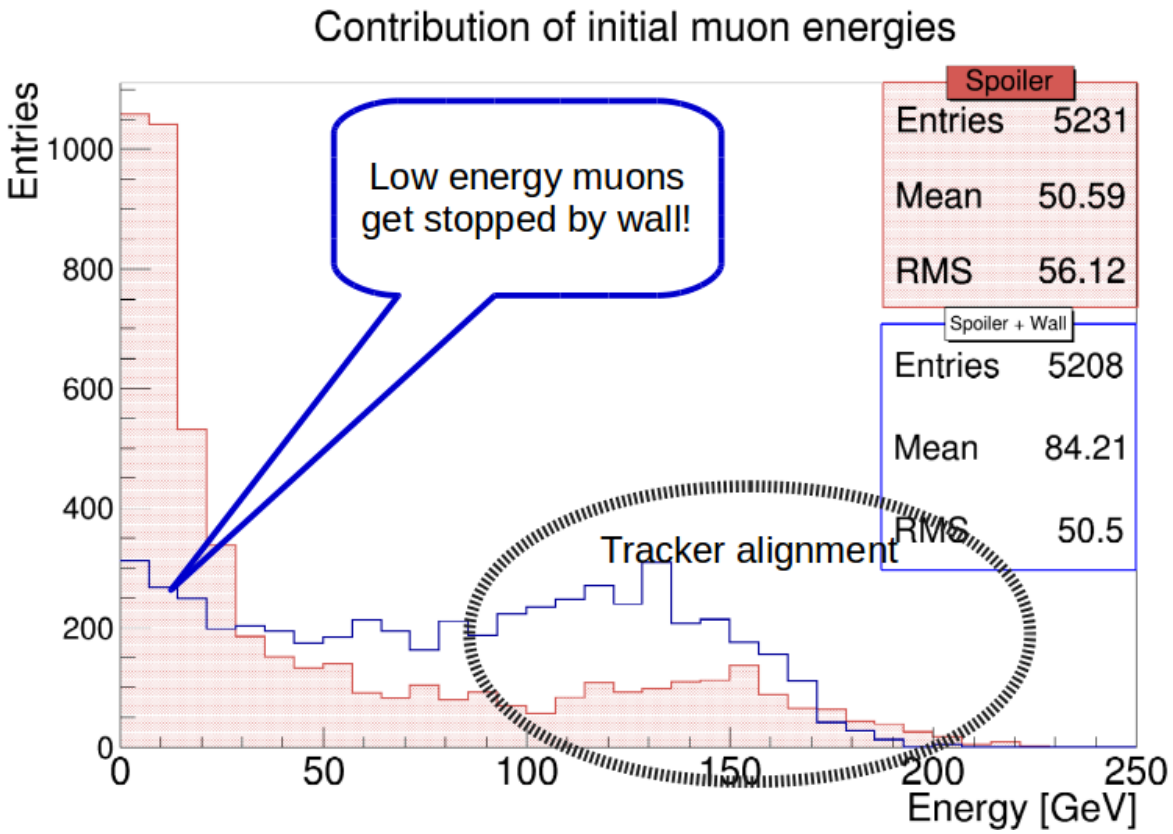




The asymmetry in the xy plane is predicted by the MUCARLO simulation output (see a few slides before), and clearly visible also in the SLIC simulation.

Energy distribution of muons -

Spoiler and Spoiler+Wall scenarios

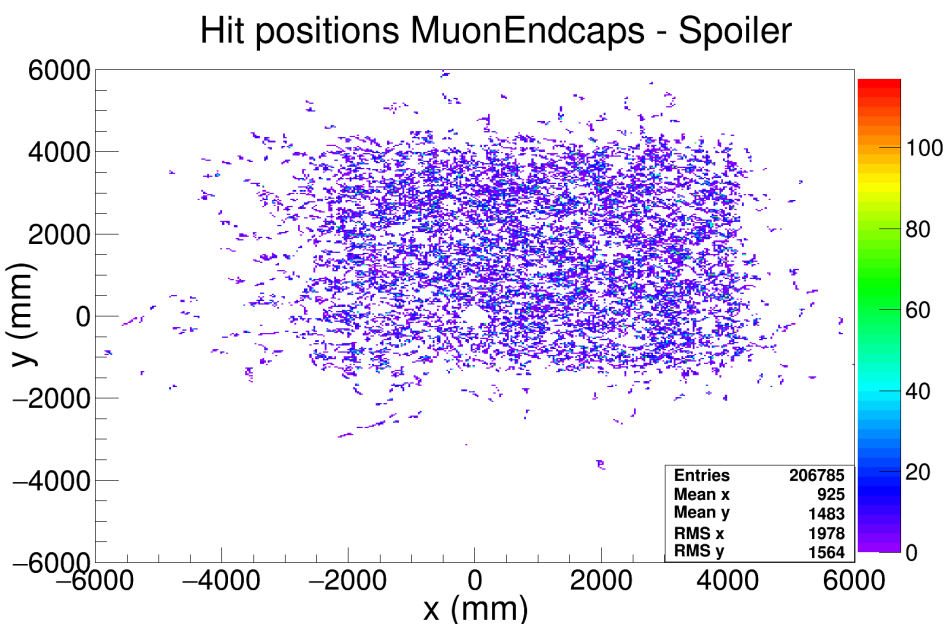


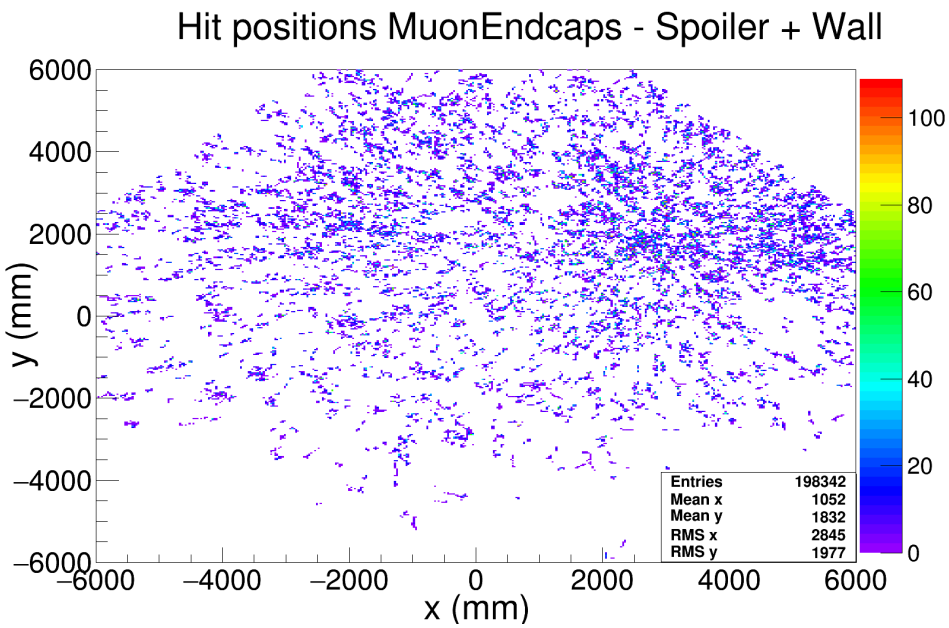
This is showing equal number of events. The real absolute number of muons cannot be analyzed yet because more simulation files from Lewis Keller are missing. There would be a lot more events for the Spoiler-only scenario.

Spatial distribution in the MuonEndcaps -

Spoiler and Spoiler+Wall scenarios

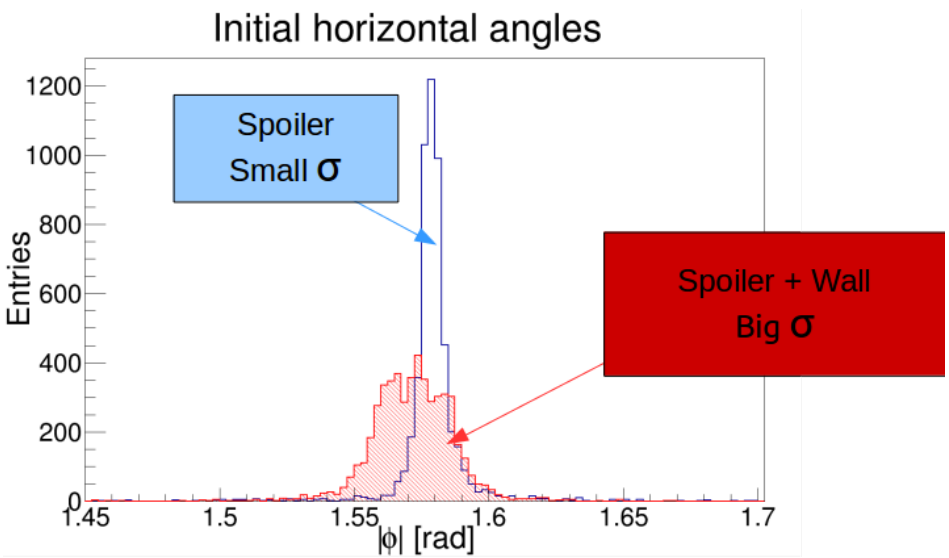
Hits from muons from 5 trains for both MuonEndcaps and all their layers:

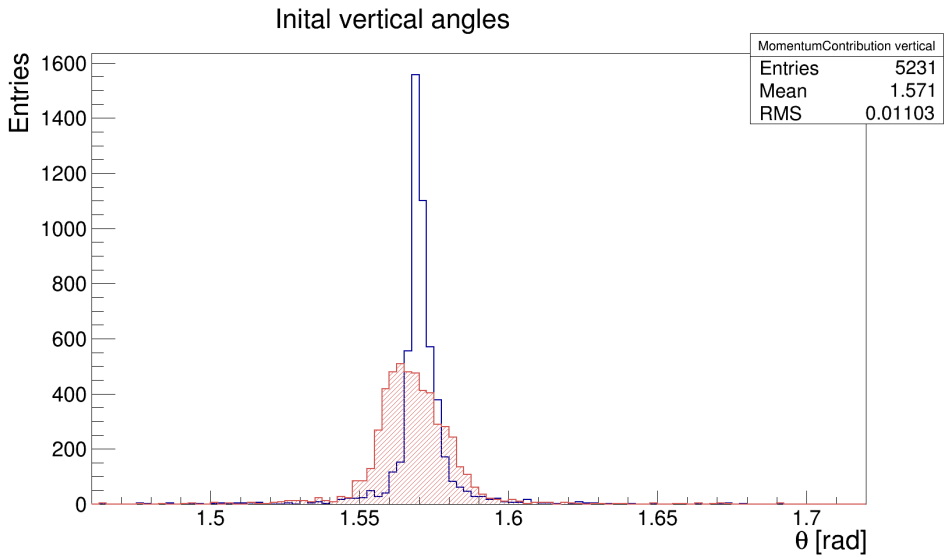




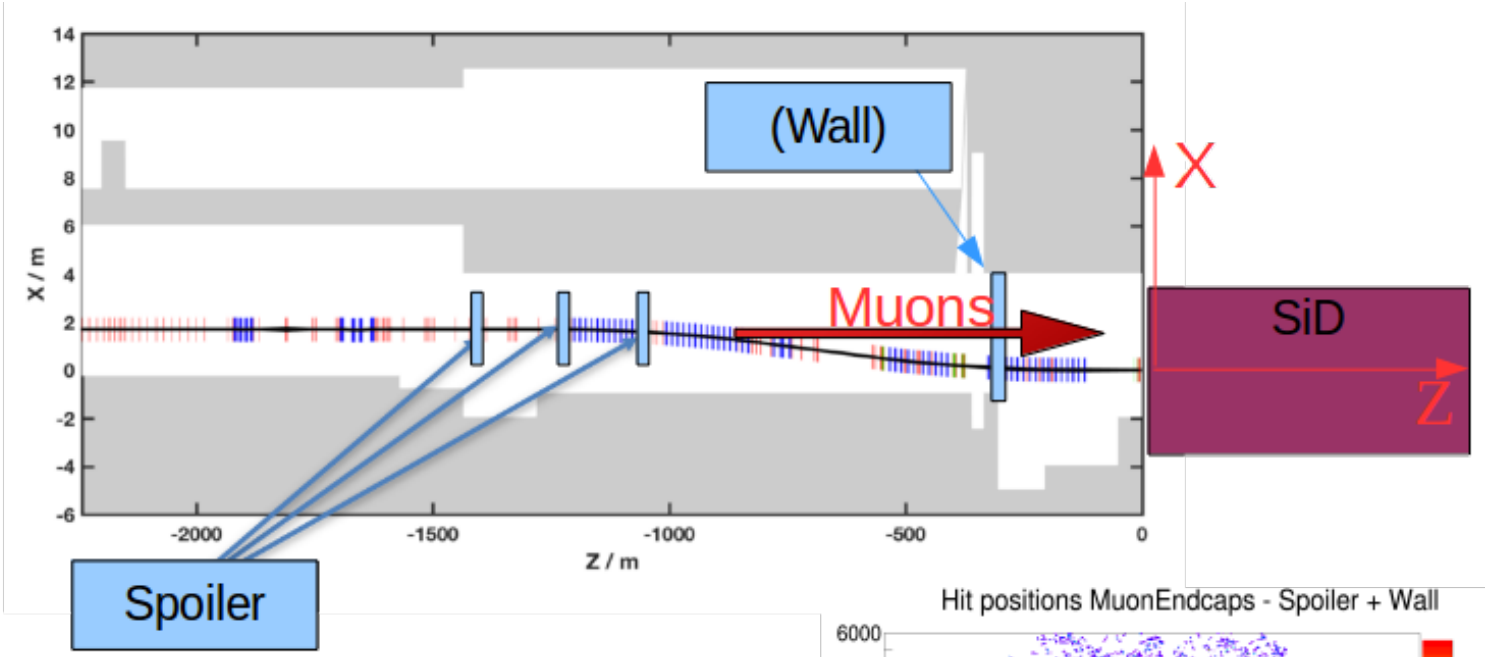
Angular distributions of muons before hitting the SiD

Muons from 5 trains:

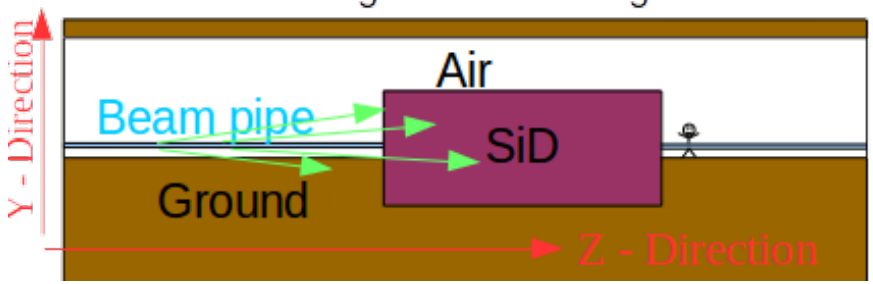


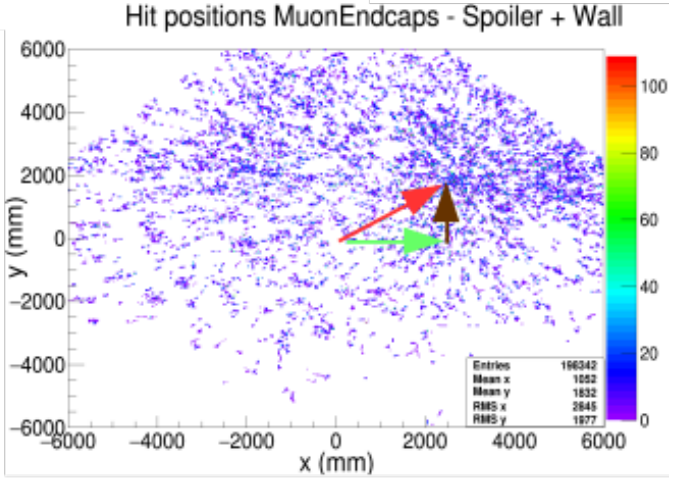


Explanation of spatial distributions in the MuonEndcaps

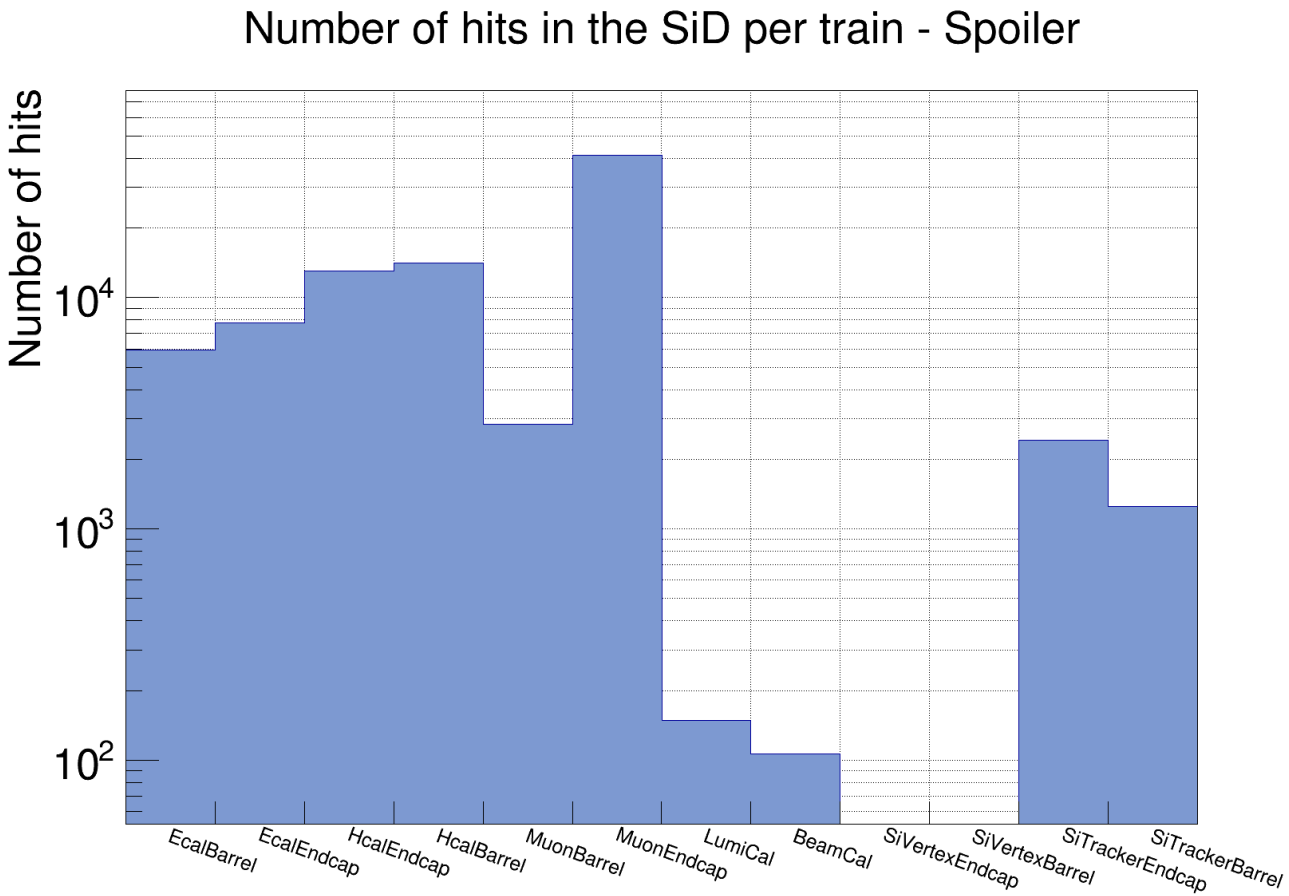


- Beam pipe is curved
- Beam pipe close to floor
  - High tunnel ceiling





Total number of hits - Spoiler scenario

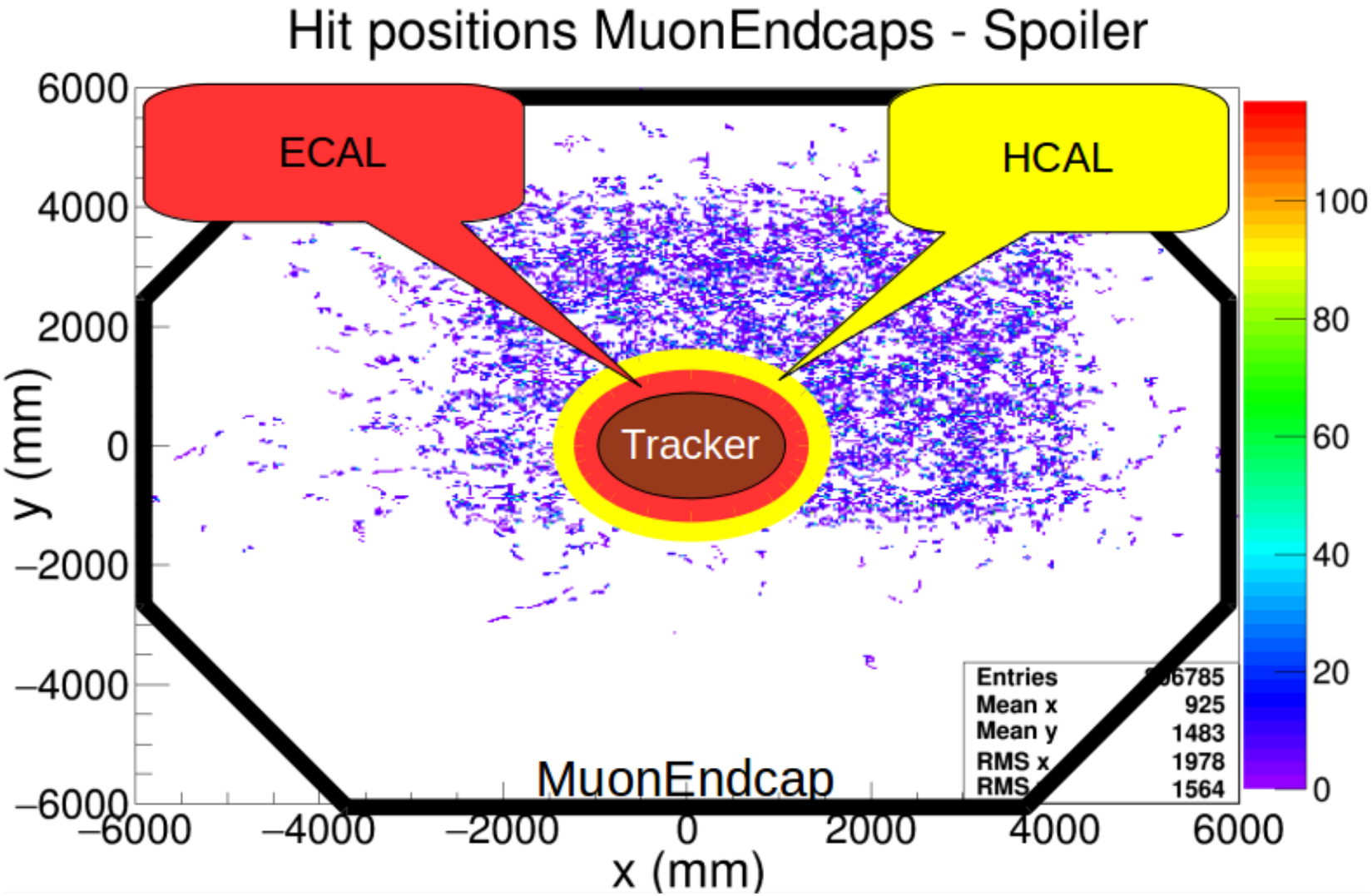


Vertex detectors $<$ ECAL, HCAL $<$ MuonEndcaps

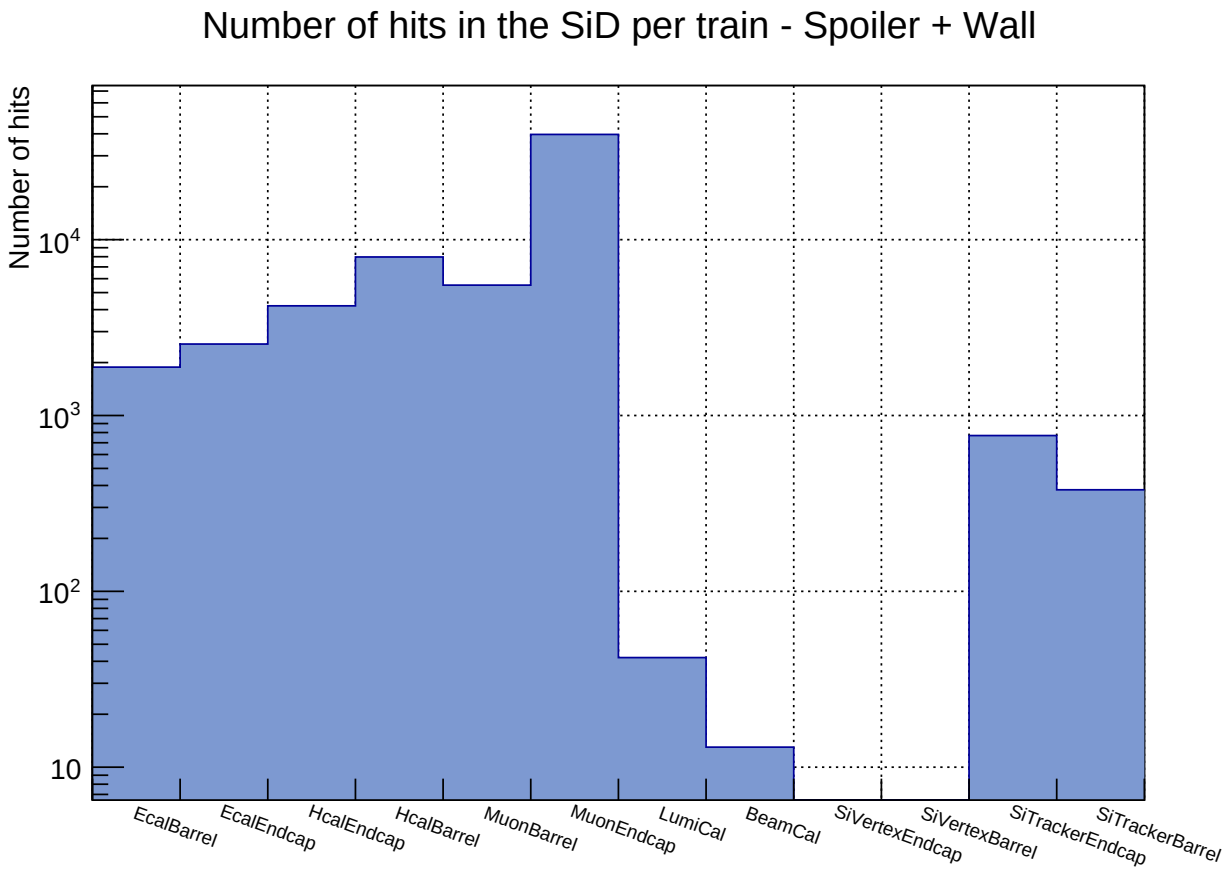
Smallest effective detector area | Particle showers | Biggest effective detector area

Explanation of hit number distribution -

Spatial distribution in the MuonEndcaps



Total number of hits - Spoiler+Wall scenario

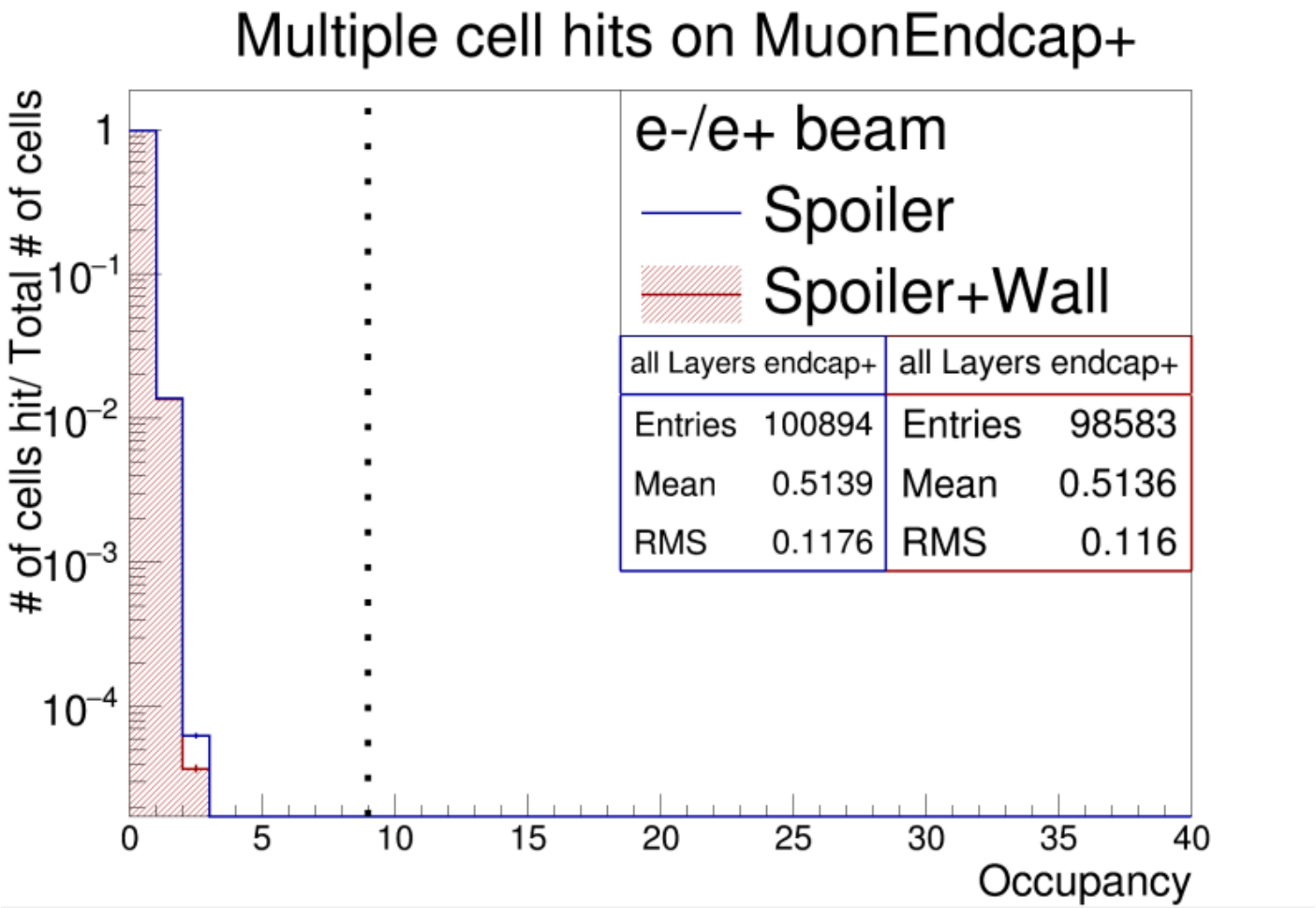


Number of hits more equally distributed, but still:

Vertex detectors $<$ ECAL, HCAL $<$ MuonEndcaps

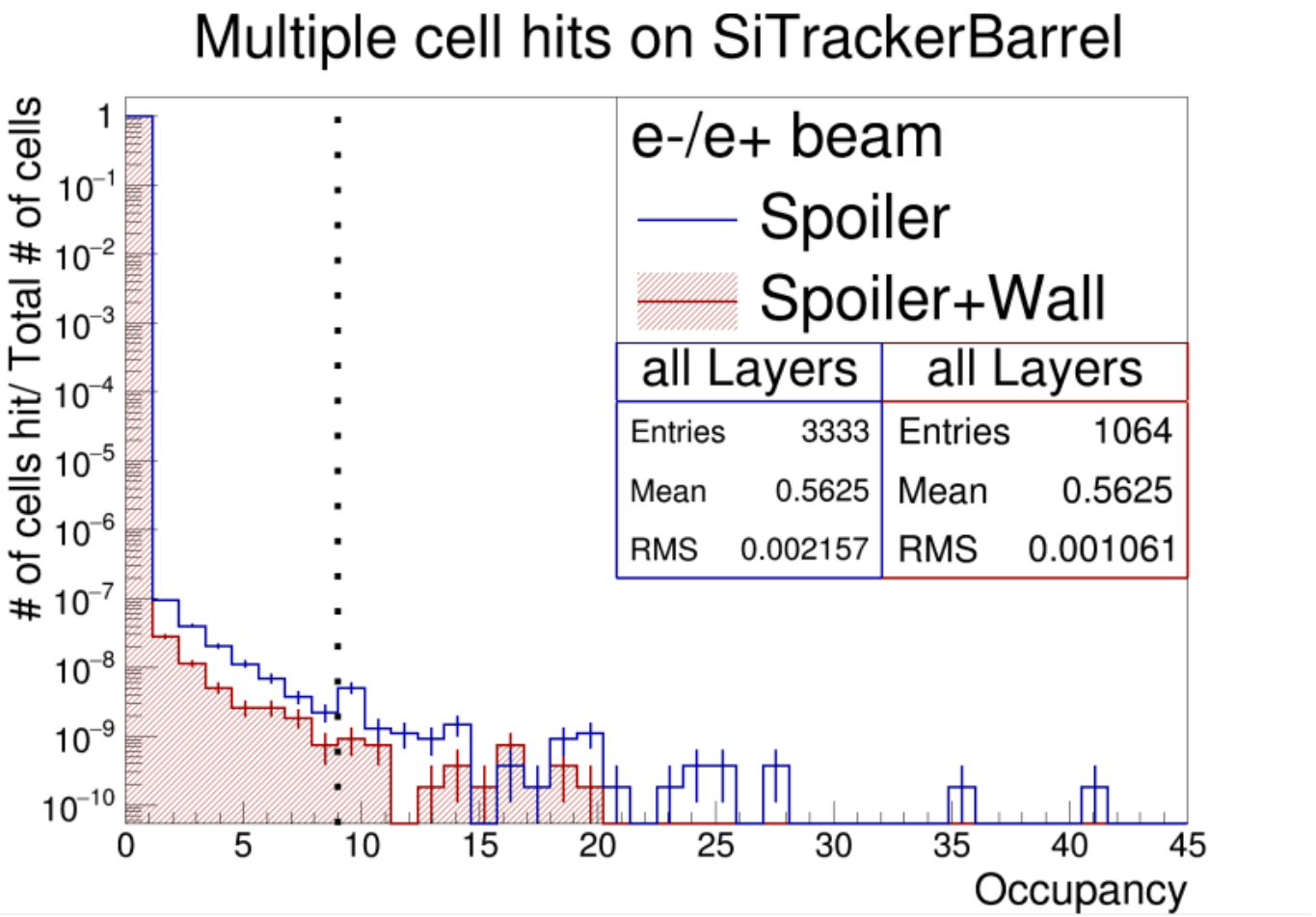
Smallest effective detector area | Particle showers | Biggest effective detector area

Occupancy plots - MuonEndcap



The muon background has a small impact on the MuonEndcaps.

Occupancy plots - SiTrackerBarrel

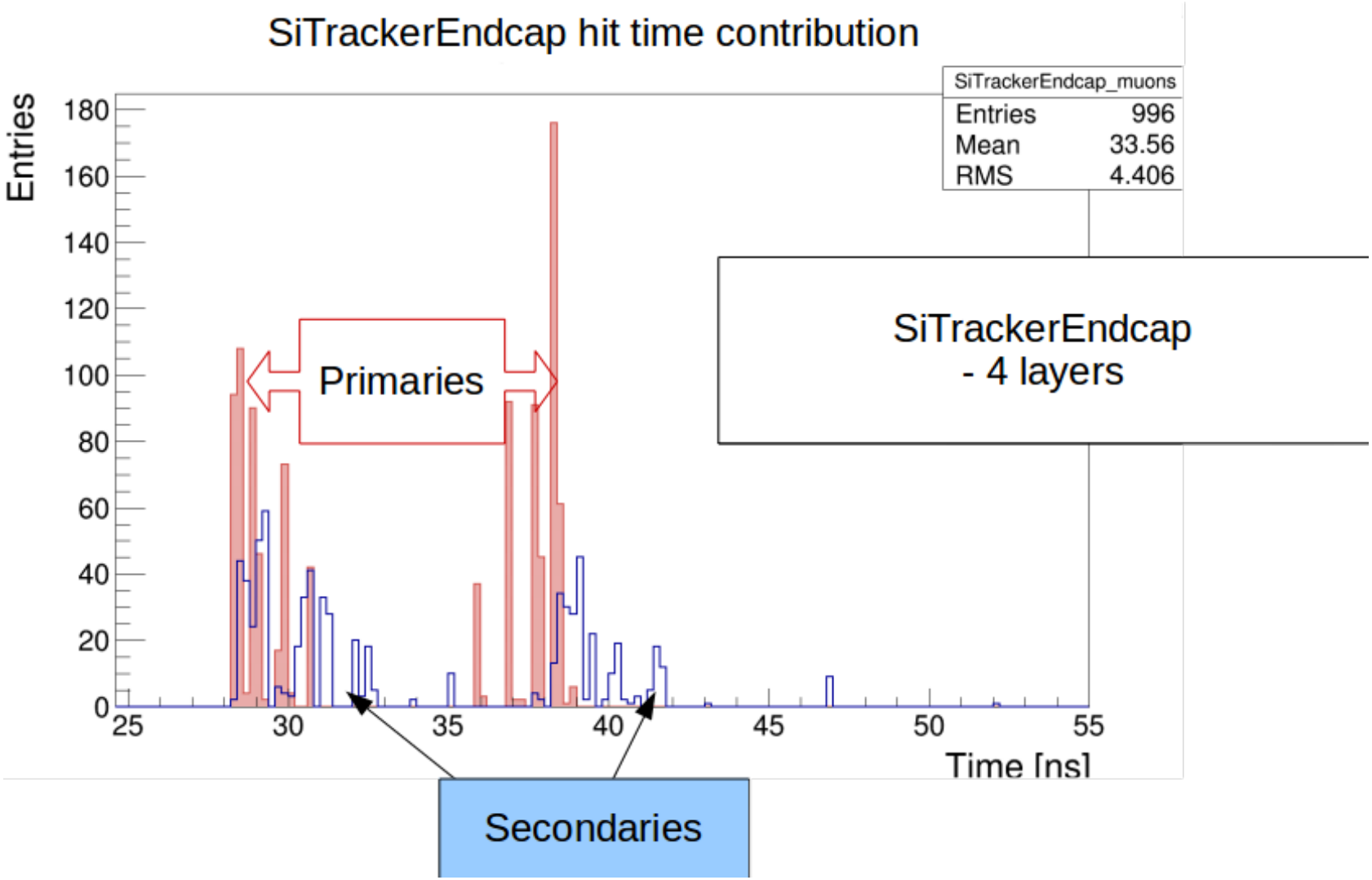


10^{-9} - 10^{-8} of all cells that get hit, have 9 hits.

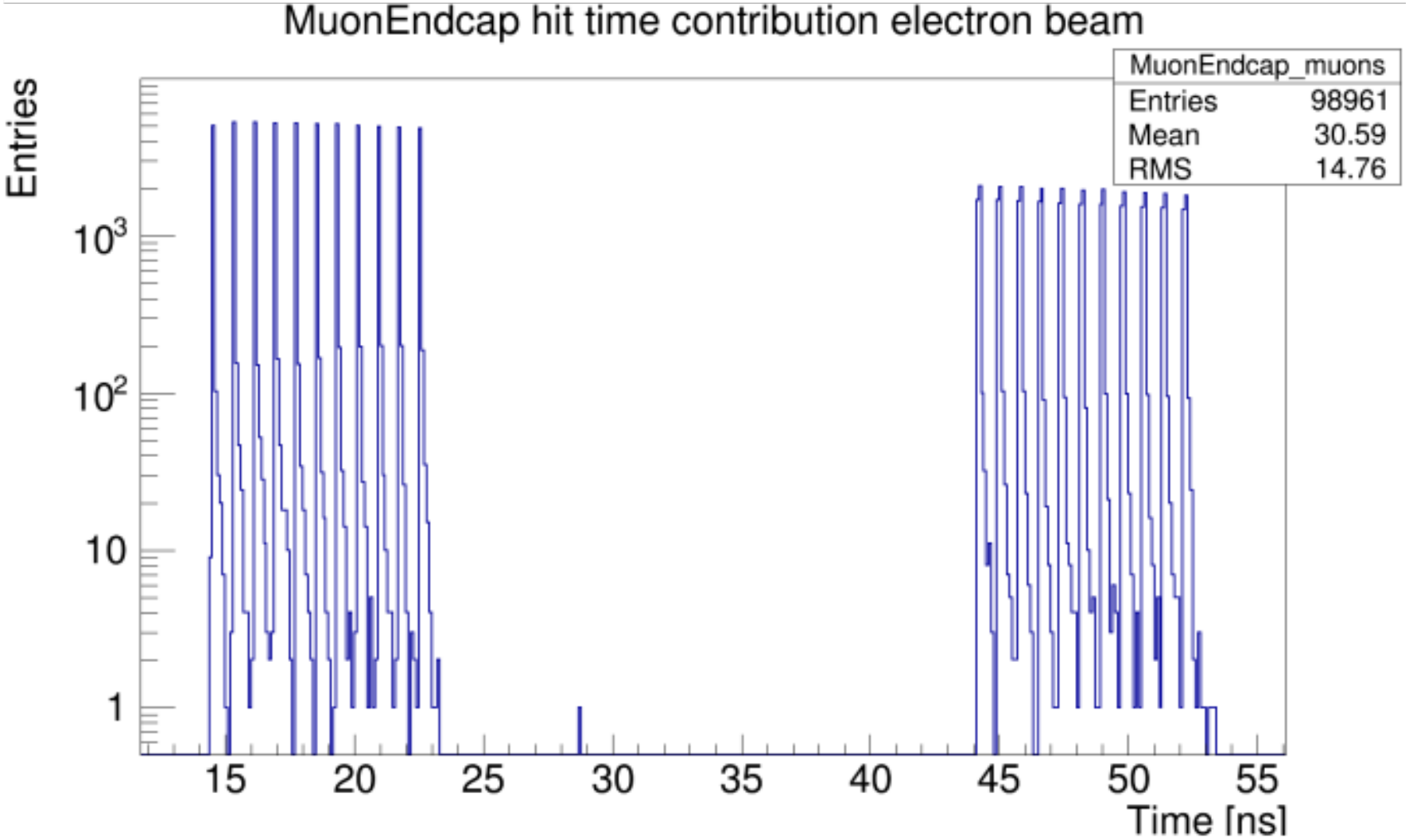
Spoiler+Wall seems to do better by a factor of 3-5, with the same initial number of events. BUT final statement cannot be made yet!

Time distribution - SiTrackerEndcaps

Note that the timing of the muons is not 100% accurate yet! Lewis Keller will send the accurate numbers soon.



Time distribution - MuonEndcaps



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 Spoiler and Spoiler+Wall scenarios.
- Number of hits in subdetectors are explained by geometries.
- Occupancy is small, but final statement cannot be made yet.
- Muons are instantaneous in comparison to pair background.

Outlook:

- Need to wait for more files from Lewis. He is cross-checking his results with Glen White at the moment.
- The timing information need to be updated.
- Finalizing statement about absolute numbers of muons in both scenarios (spoilers, spoilers + wall), and about detector occupancies

Maybe a final conclusion about whether a muon wall is needed will have to wait till then...

→*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

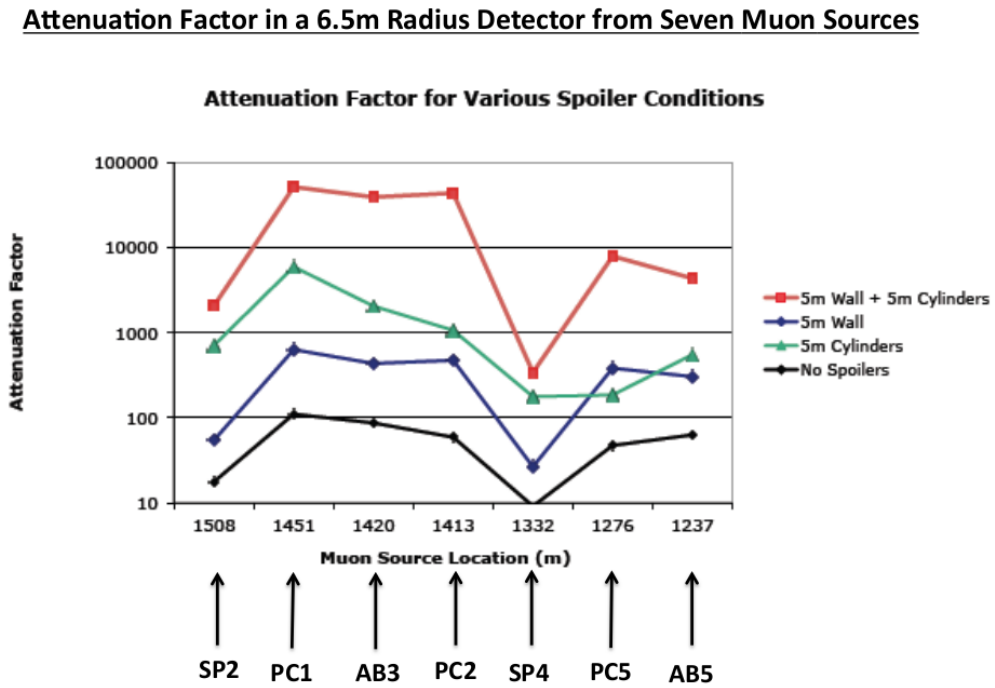
[3] *FERMILAB-CONF-07-276-AD: "Suppression of Muon Backgrounds generated in the ILC Beam Delivery System", Drozhdin et.al, 2007.* https://inspirehep.net/record/771808/files/fermilab-conf-07-276.pdf

[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

Attenuation Factor



Spoilers (SP) have a much smaller gap than the absorbers (PC and AB), and they intercept the primary beam halo.
Muons originating at the SPs:

- smaller radius → "see" more of the detector
- smaller angular spread (SPs are at max-beta points = min-divergence)