Detector Tolerances to Background and Reduced Muon Shielding

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BACKGROUNDS AND DETECTOR PERFORMANCE

Two sources

1. **IP backgrounds:** Particles originated from the interaction point (IP) – beam-beam interaction products and collision remnants.
2. **Machine backgrounds:** Unavoidable bilateral irradiation by particle fluxes from the beamline components and accelerator tunnel.

Backgrounds affect ILC detector performance in three major ways:

- Detector component radiation aging and damage.
- Reconstruction of background objects (e.g., tracks) not related to products of e^+e^- collisions !!!
- Deterioration of detector resolution (e.g., jets energy resolution due to extra energy from background hits).

DETECTOR TOLERANCES

Subdetector	Tolerance criterion
Vertex detector and/or Silicon Tracker	Rad. damage (worst-case: CCD's) : $\int$ < 3-10 x 10^9 n cm^{-2} Occupancy (pattern recognition): < 1% (2-d hit density) Occupancy (pile-up): ≤ 1 hit / channel ("buffered")
Time Projection Chamber	Occupancy (pattern recognition): < 1% (3-d density) ? *Experts disagree on impact on reconstruction + space charge*

Subdetector	Granularity	Sensitivity window	Fract'l sensitivity
Vertex detector (Layer 1)	20 μ x 20 μ pixels = 2500 pixels/mm^2	50 μs (~ 150 bunches)	Chgd trks: ε = 1.0 (4 pixls) γ: ε = 0.02 (4 pixels)
TPC	1.5 10^6 pads x 10^3 time buckets = 1.5 10^9 voxels		Chgd trks: ε = 1.0 γ: ε = 0.02 n: ε = 0.01 μ: ε = 1.0

By Witold Kozanecki

1% generic occupancy limit (per train or per SW) implying x10 safety factor

Background tolerance levels

(*) As per R. Settles et. al., TESLA St Malo workshop
Detector-specific data from T. Maruyama + detector response to MDI questions, Aug 05.

Limits are expressed in # particles either per sensitivity window [SW] (typically 50 μs ≈ 150 bunches in VXD/TPC), or per bunch train [tr]

Subdetector	Charged hits	γ	n (~ 1 MeV)	Model
Vtx detector (L1)	6 mm^{-2} / SW 100 mm^{-2} tr^{-1}	300 mm^{-2} /SW	3 x 10^7 mm^{-2} 10^8 mm^{-2}	1 % generic GLD
Si tracker	Pile-up: 0.2 / 1.0 mm^{-2} tr^{-1}	Pile-up: 10/50 mm^{-2} tr^{-1}		SiD: analog/digital
TPC (/SW)	1.5 x 10^7 voxels ≈ 2.5 - 5 10^3 tracks	1.25 x 10^6 γ	2.5 x 10^7 n	1 % generic

Notes

By Witold Kozanecki

1. No generic answers – depend strongly on subdetector technology
2. Need to clarify impact of TPC occupancy on track reco efficiency & space charge
3. Only rough estimates so far. Real answer needs detailed simulations, pattern recognition studies, space charge, understanding of background distribution....
4. 1% may sound overconservative...but we need ~ x 10 safety factor!

BACKGROUND TOLERABLE LIMITS SUMMARY

Denisov, Mokhov, Striganov, Kostin, Tropin (2006, JINST-1-P12003)

Calorimeter, tracker and vertex detectors: in smallest element, ***occupancy*** ≤ 1%.

To avoid ***pattern recognition*** problem in tracker, hit density from charged particles should be ≤ 0.2 hit/cm^2/bunch.

To avoid ***pile-up*** problem (from previous BX !) in tracker, hit density from charged particles should be ≤ 0.2 hit/mm^2/train.

Muon system: the RPCs (sensitive media) need 1 ms to re-charge a 1 cm^2 area around the avalanche, therefore, the hit rate in excess of 100 Hz/cm^2 would result in an unmanageable dead time. With typical 80 sensitive layers in a Muon Endcap, it corresponds to a muon flux at its entrance of about 1 μ/cm^2/s.

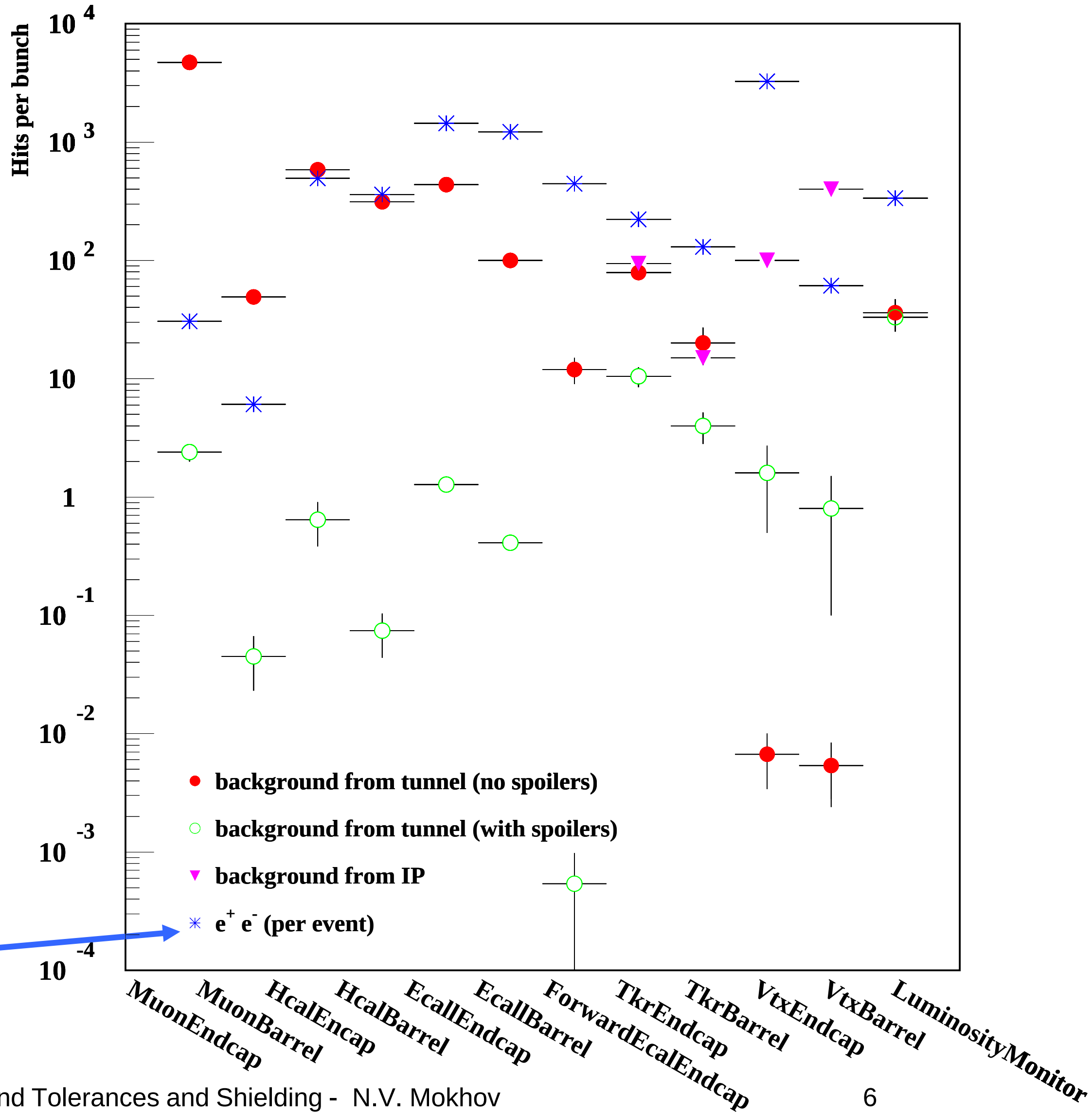
Hit Rates in Detector Subsystems

1. Machine-related background with and without spoilers – STRUCT+MARS15 + SLIC.
   Here – only from e^+ beam.

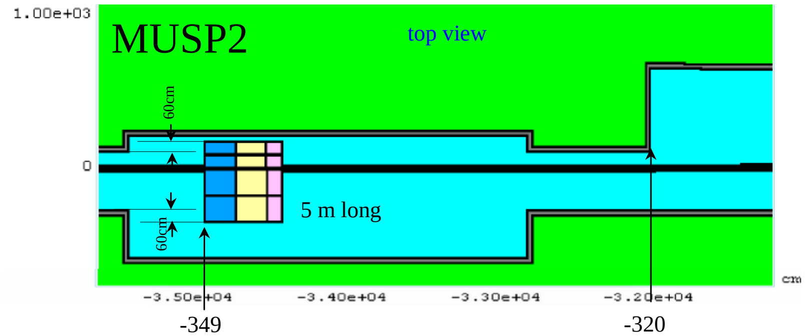
2. IP-related background – radiative Bhabas from beam-beam interaction and synchrotron radiation from beam. Guineapig + GEANT3

3. $e+e-$ events at 500 GeV- PYTHIA + SLIC

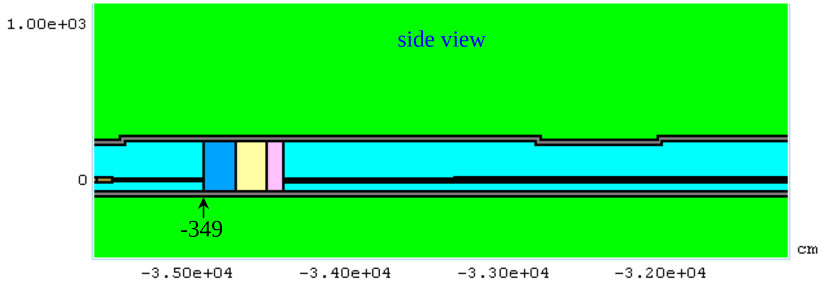
Per e^+e^- event

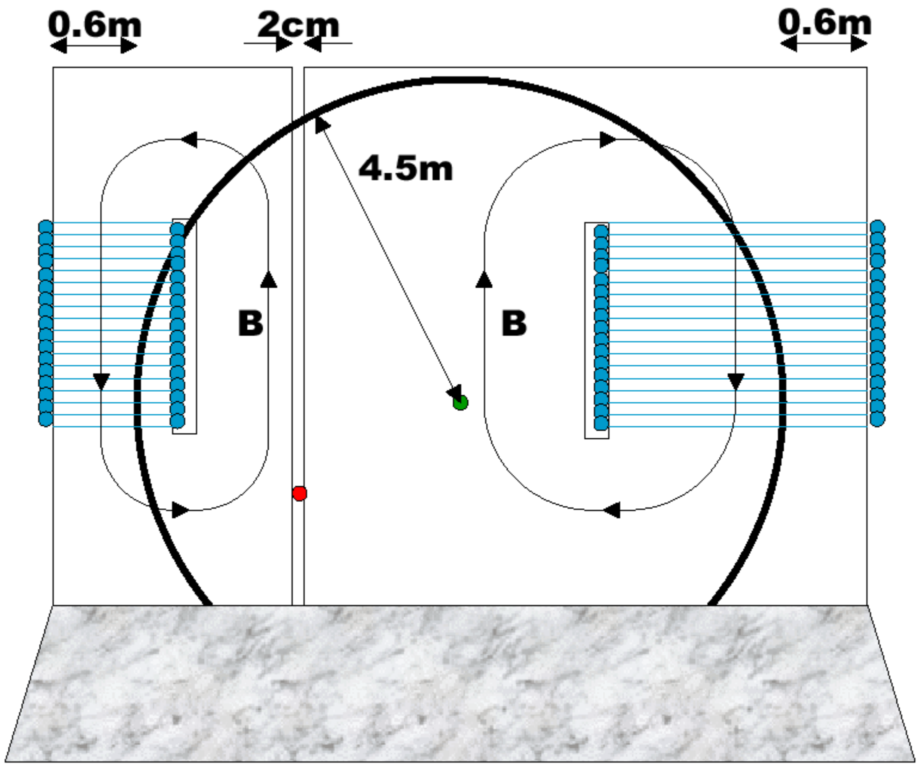


TUNNEL MUON SPOILERS: 9+18 m or 5 m Walls

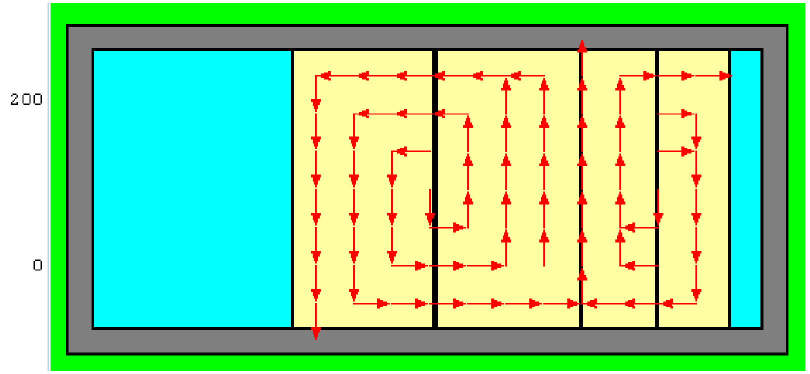


Thick steel 1.5-T magnetic wall sealing tunnel x-section, to spray the muons out of the tunnel

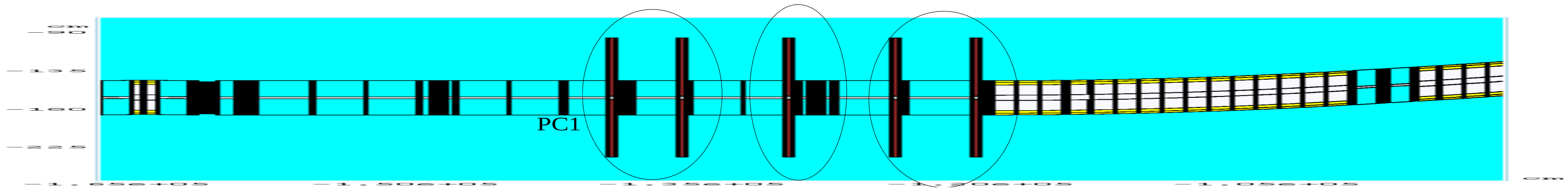


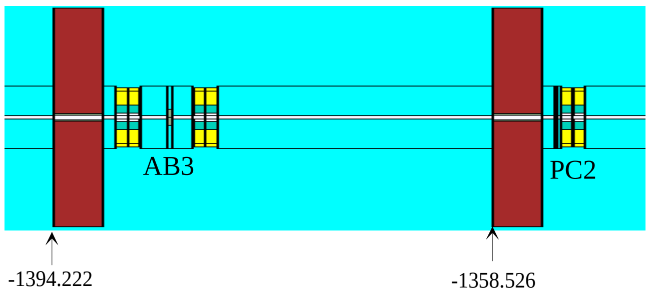


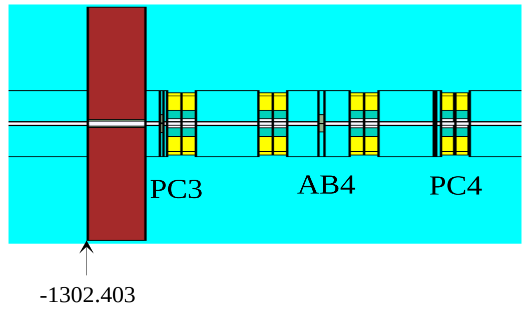
Cross sectional view (looking toward downstream)

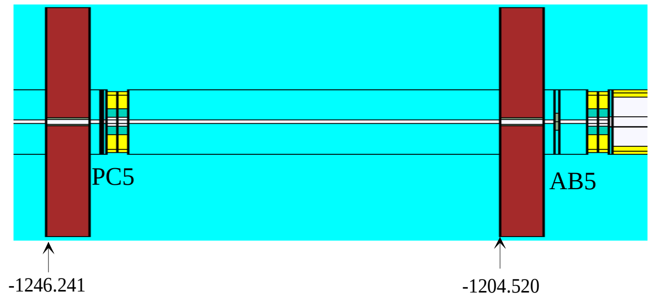


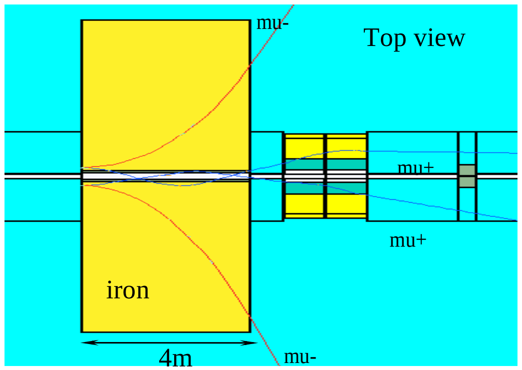
Five 4-m Thick Doughnut Scheme

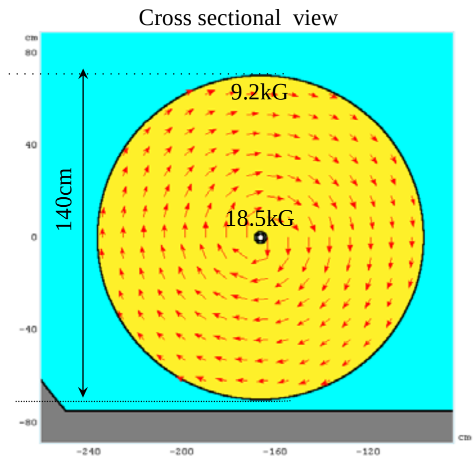


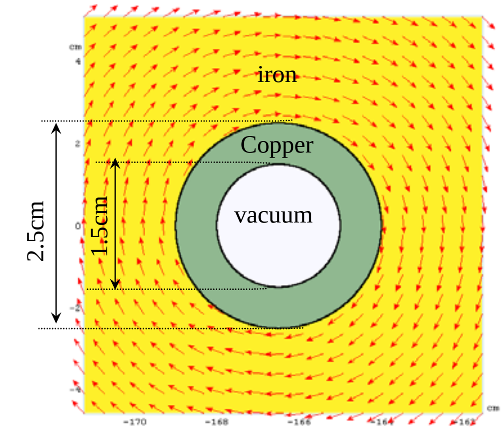




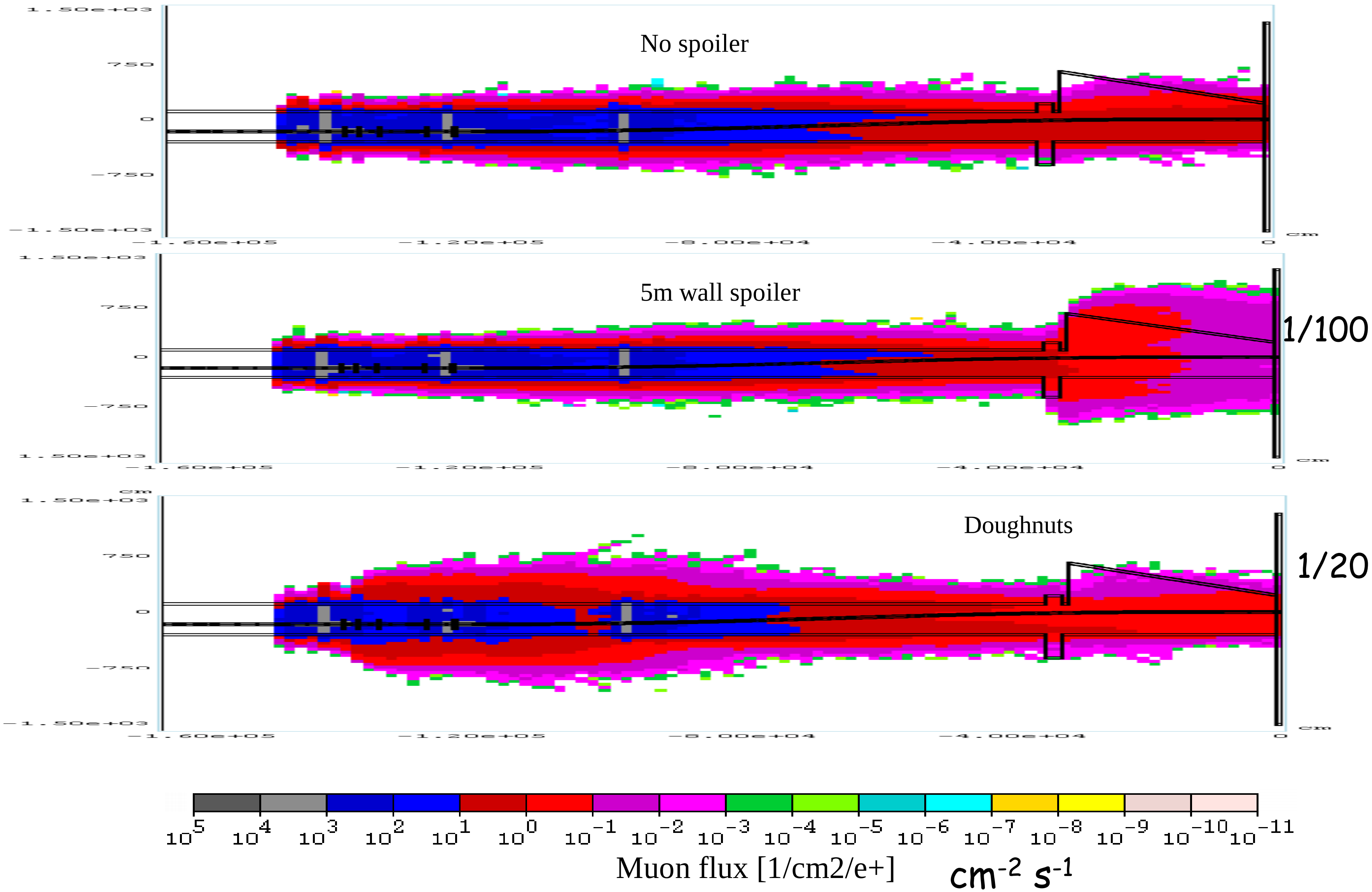






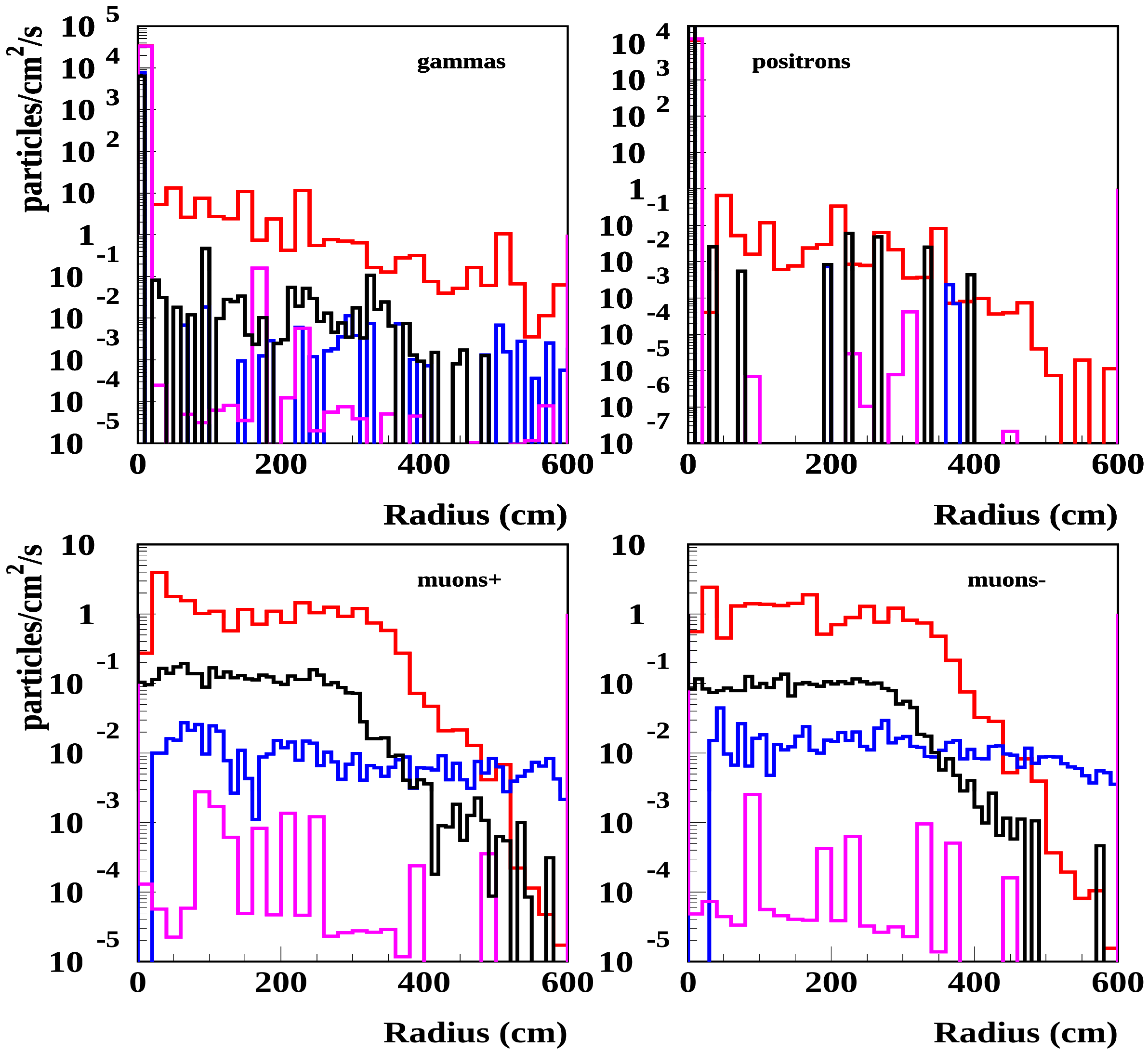


Muon Flux Isocontours



Particle Fluxes ($cm^{-2}s^{-1}$) at SiD from e^+ BDS

Red lines: no shielding
Magenta: 9m + 18m walls
Blue: 5m wall
Black: Five 4-m doughnuts



OK with a safety margin

Particle Energy Spectra (per bunch) at SiD from e⁺ BDS

Red lines: no shielding
Magenta: 9m + 18m walls
Blue: 5m wall
Black: Five 4-m doughnuts