Beamline Background Muons in ILC Detectors

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ILC Physics and Detector Workshop and
Second ILC Accelerator Workshop
Snowmass, Colorado
August 14-27, 2005

OUTLINE

- IP Backgrounds.
- Collimation in Beam Delivery System and Related Backgrounds.
- Dealing with Muon Spray from Collimators: Earlier Results for NLC.
- Beamline Muons and Their Suppression for ILC Detectors: Recent MARS15 Results.
- MARS+GEANT4 Integration.
- Conclusions.

IP BACKGROUNDS

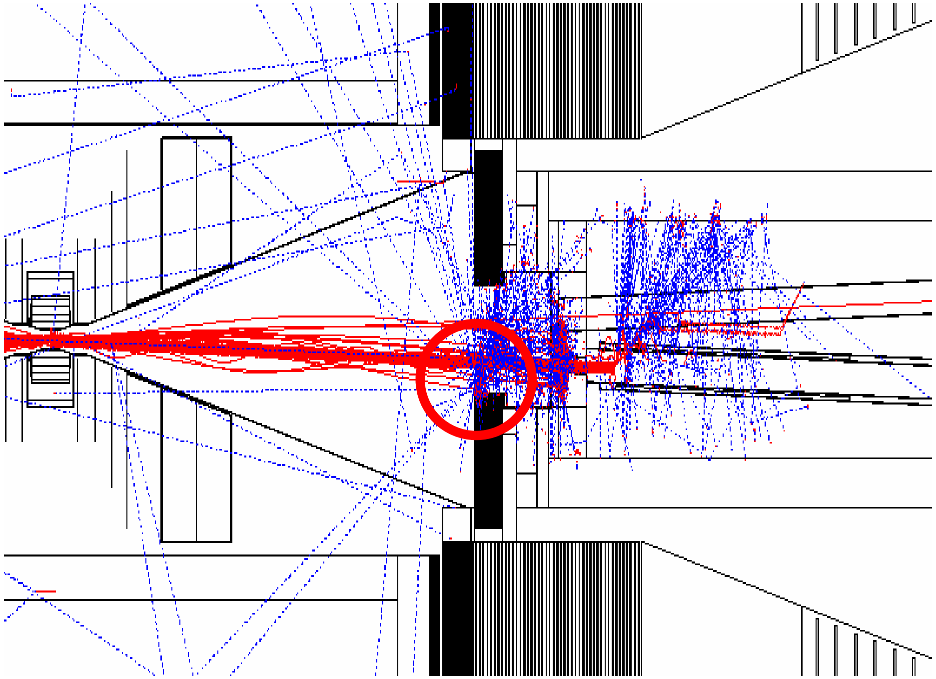
Source: Beam-beam interactions (e^+e^- pairs, disrupted primary beam and beamstrahlung photons), hadrons from $\gamma\gamma$ interactions and radiative Bhabhas.

From the standpoint of integrated background, e^+e^- linear colliders are relatively 'clean' machines. Average integrated hadronic fluxes produced at the IP are about six orders of magnitude lower compared to LHC.

However, the instantaneous rates are not so drastically different. Say, for the $\gamma\gamma$ option, a peak radiation field is about 10% of that at LHC. The e^+e^- option is 10 times better.

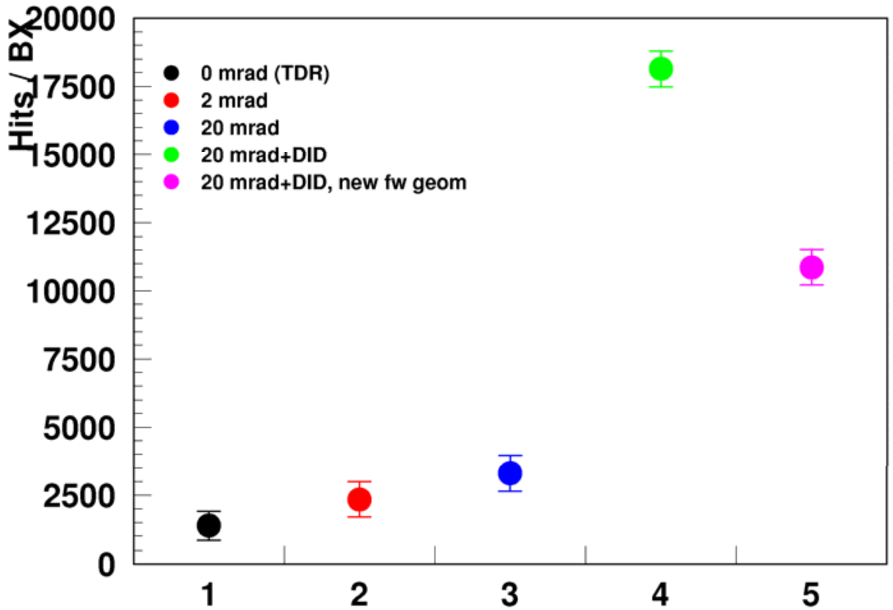
In general, this source is well understood and under control.

Hits in the TPC with Solenoid+DID



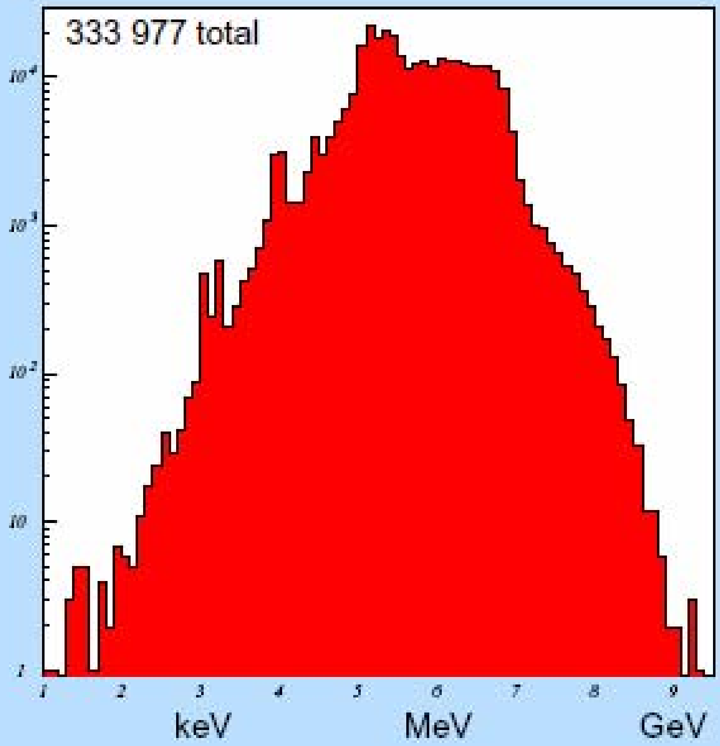
Karsten Büßer

Comparing configurations:

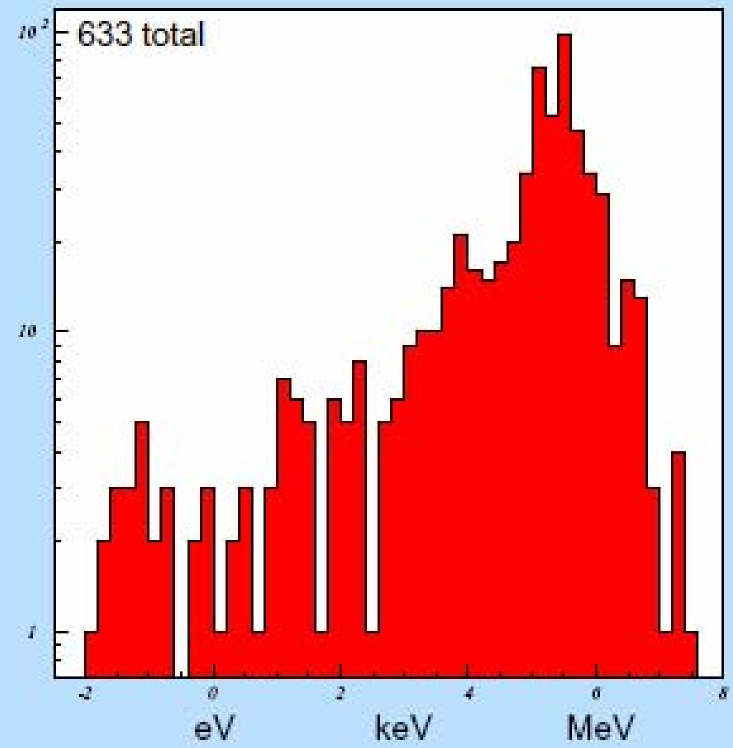


Origin of TPC photons:
pairs hit edge of LumiCal

Neutron Production – Energies



Energies of neutrons. . .



. . . when entering the TPC
(some more than once)

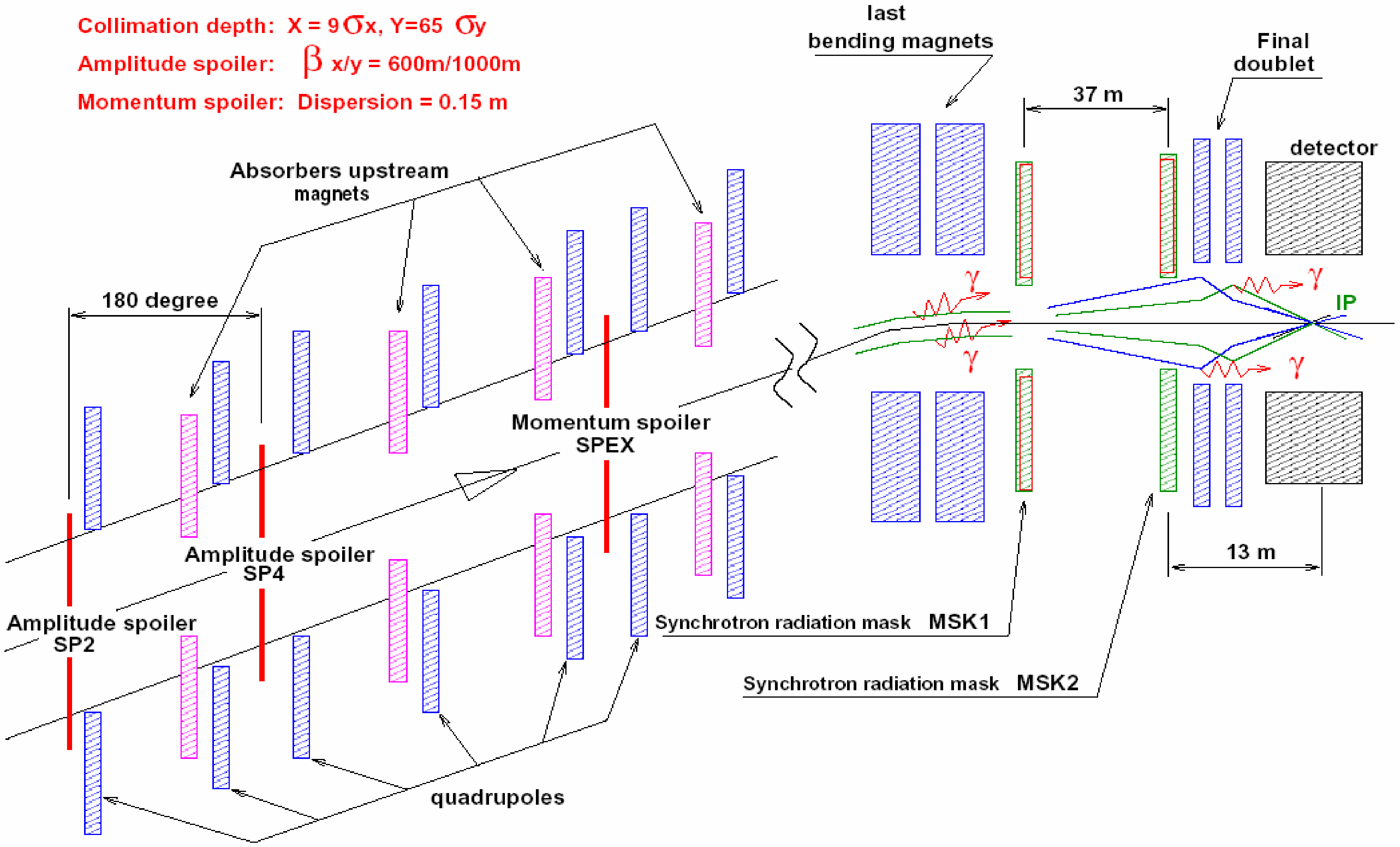
MACHINE-RELATED BACKGROUNDS

Synchrotron radiation, spray from the dumps and extraction lines, beam-gas and beam halo interactions with collimators and other components in BDIR create fluxes of muons and other secondaries which can exceed the tolerable levels at a detector by a few orders of magnitude.

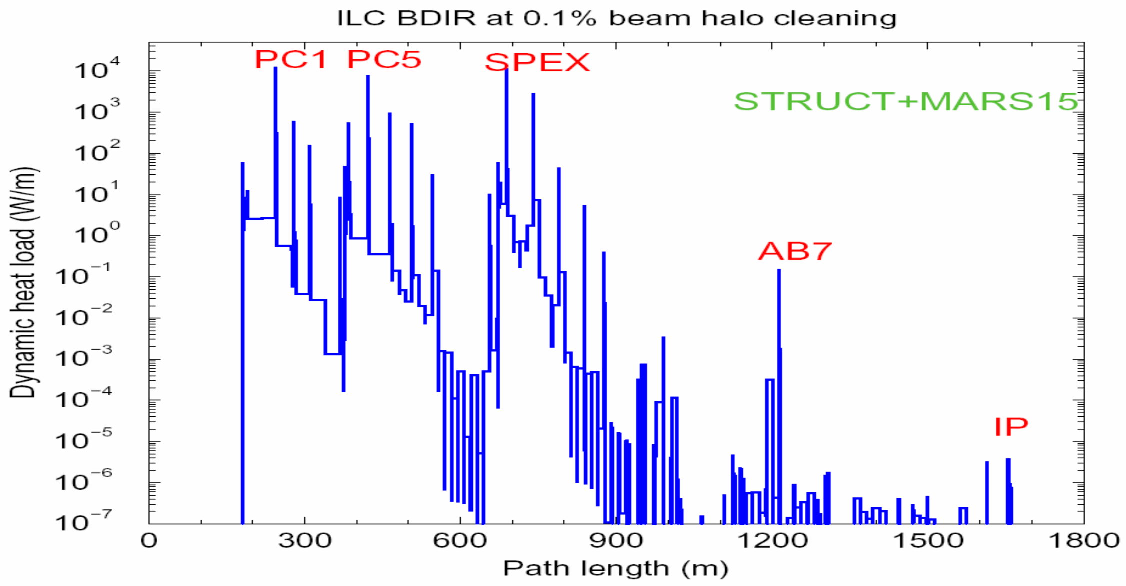
With a multi-stage collimation set and a system of magnetic iron spoilers (which fill the tunnel), one can hopefully meet the design goal of allowing a continuous 0.1% beam scraping rate, resulting in a tolerable muon flux at the detector.

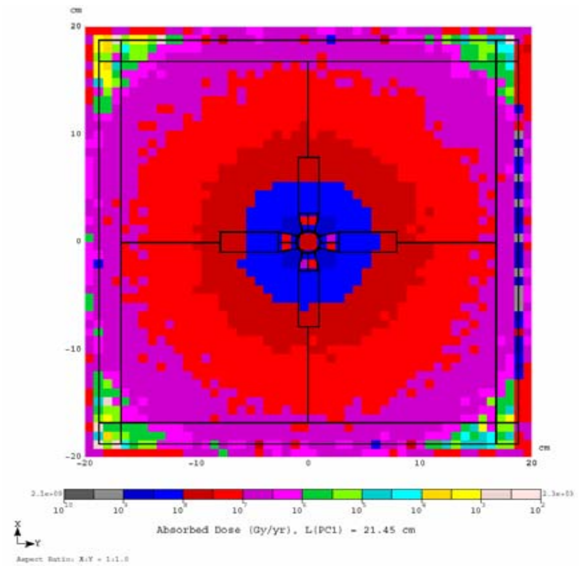
Studies are towards detector tolerance levels, muon suppression, contribution of photons, hadrons and low-energy neutrons in all the beam loss mechanisms.

ILC COLLIMATION SYSTEM



DYNAMIC HEAT AND RADIATION LOADS IN BDIR AS STUDIED AT FERMILAB



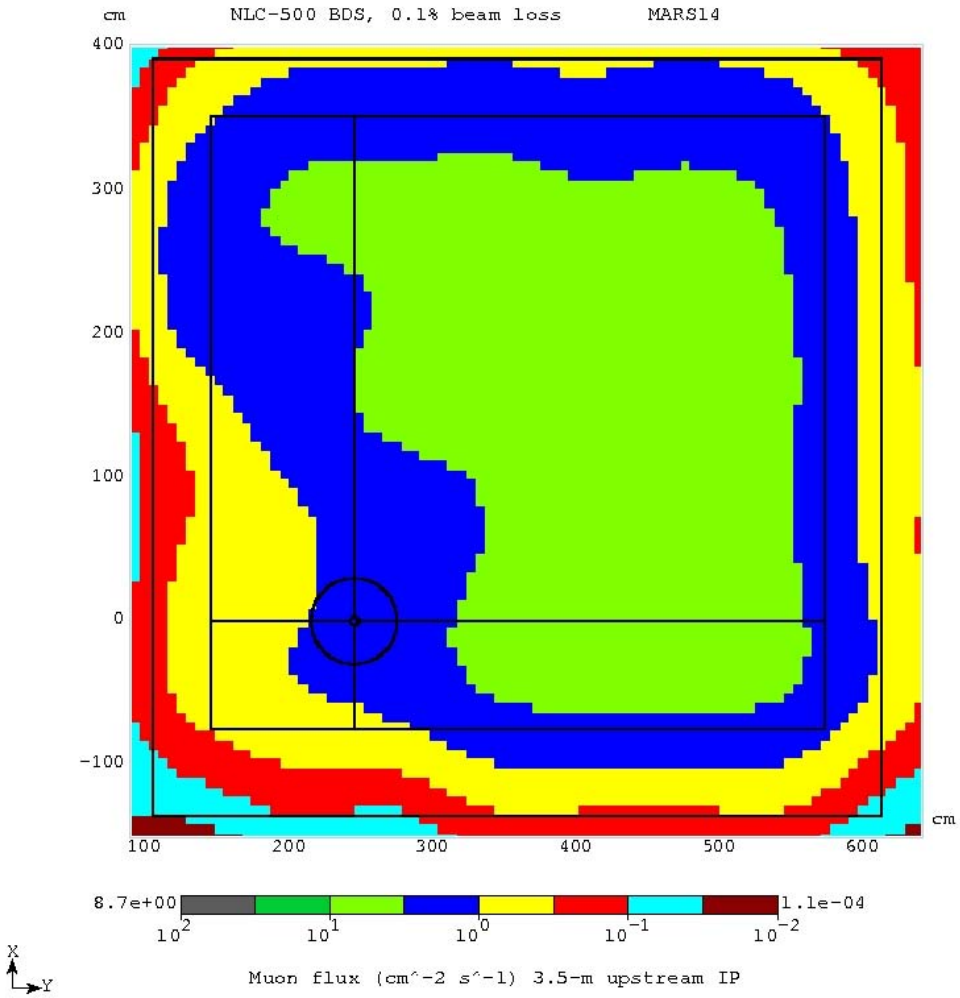


50 W/m for SP2, SP4 and SPEX, and 10 kW/m for PC1, PC5, PC8 and PC9

First quad downstream of protection collimator PC1: peak absorbed dose in coils ~300 MGy/yr (a few days of lifetime for epoxy), residual dose on the upstream face is 7.7 mSv/hr (should be below 1 mSv/hr). It is shown that increasing PC1 length from 21 cm to 60 cm of copper, reduces peak absorbed dose in the hottest coil by a factor of ~300, providing at least a few years of lifetime.

It is shown that temperature rise and stress should not be a problem except accidental conditions. Peak heating per train: 1.4 J/g and 2 K in SP2, and 4.7 J/g and 6.6 K in PC1.

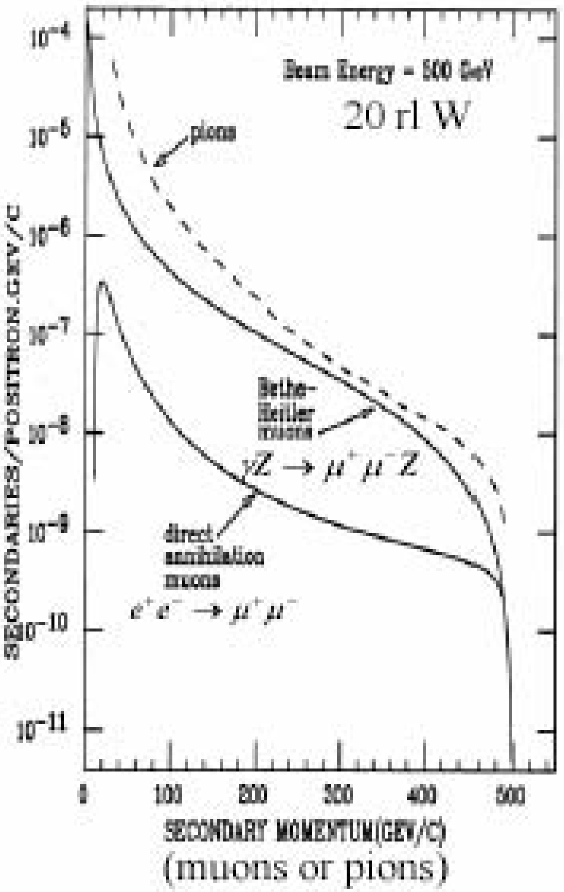
MUON SPRAY FROM COLLIMATORS



Earlier MARS14 results for 0.1% beam cleaning of NLC 250-GeV beam: 5 $\mu/cm^2/s$ or about 10^4 muons per pulse train total in detector.

A factor of 1,000 to 10,000 above the limit!

MUCARLO Muon Transport Program



- Written by G. Feldman for MarkII & extensively used/modified by Lew Keller
- Step-by-step transport with MCS & dE/dx, $\mu Z \to \mu Z \gamma$, $\mu Z \to \mu Z e^+ e^-$, & $\mu N \to \underline{\mu} X$
- Geometry extensively modeled
  - magnets w/poles, coils & flux return
  - Tunnels with concrete, dirt, Pb, air, steel…
- Basic production mechanism: Bethe-Heitler in "Thick-Target Approx"
  - Thin targets, direct annihilation require separate EGS runs
  - Pions not included
    - Long decay lengths
    - Assumed will interact in a filled tunnel
- Benchmarked against Muon89 (Ralph Nelson/SLAC ES&H) & Mark II data
  - Await comparison with MARS & GEANT4

Conditions for NLC MUCARLO Runs

1. E_{beam} = 250 GeV, pulse train = 1.4E12, (1.4E09 lost on collimators and thin spoilers)

2. Square tunnel, 4.27 x 4.27 m, beam axis 100 cm from wall, 75 cm above floor

3. Any muon with enough energy to pass through 1 m of iron within a radius of 6.5 m at the IP is counted as a hit.

4. NLC conventional dipole and quadrupole design

5. $\pi \rightarrow \mu$ decays are not included

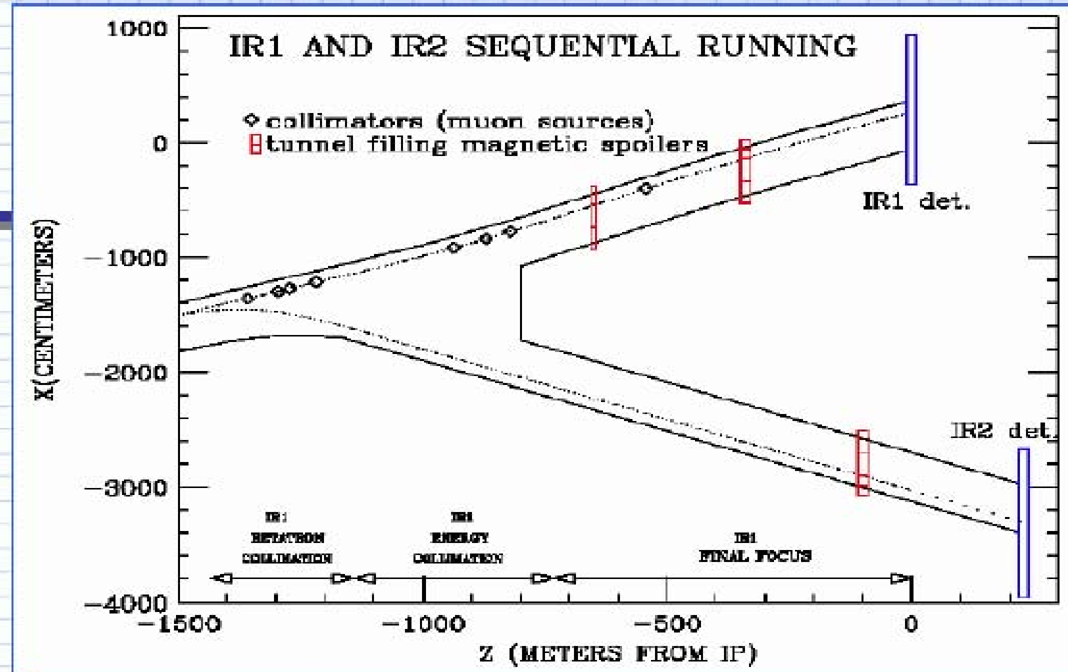
6. Since there are a relatively large number of muon sources in the collimation section, space is provided for rectangular, magnetized iron spoilers which fill the tunnel in two axial locations, inboard from the collimation section. At each location there is a rectangular spoiler on either side of the 2 cm diameter beampipe with the field polarity set to minimize the stray field in the beampipe. Space is provided in the tunnel for each of these spoilers to extend 60 cm beyond the nominal tunnel wall. Spoilers similar to this were built for SLC, but did not fill the tunnel.

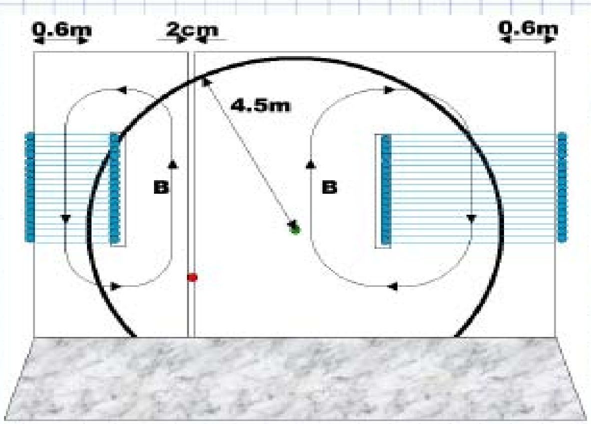
DEALING WITH BEAMLINE MUONS

Dealing with muons

Lew Keller

Assuming 0.001 of the beam is collimated, two tunnel-filling spoilers are needed to keep the number of muon/pulse train hitting detector below 10





Tunnel filler

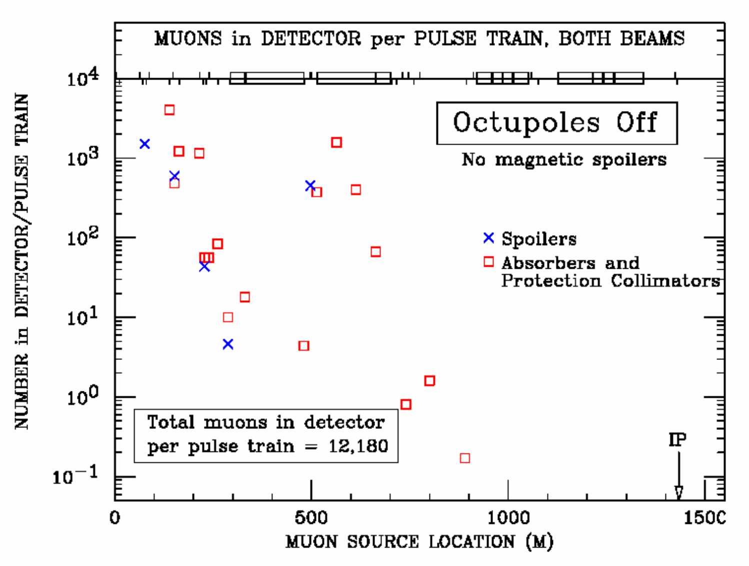
Good performance achieved for both Octupoles OFF and ON

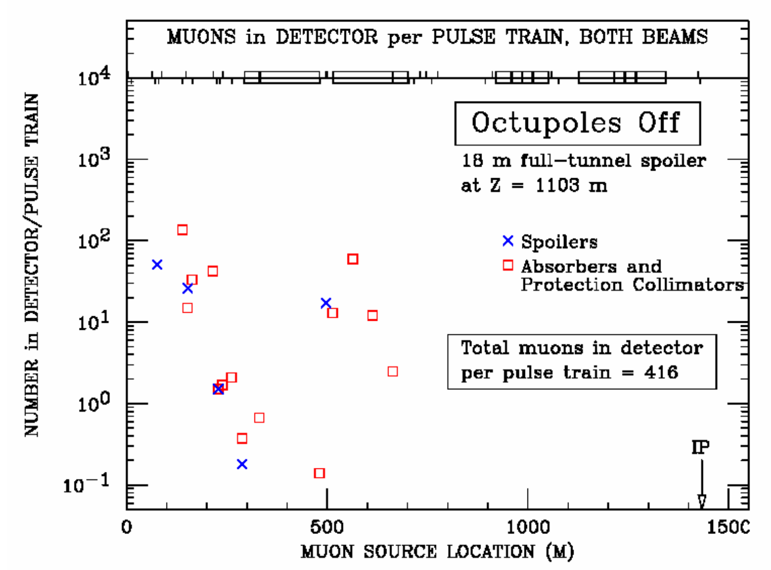
Would like to confirm these MUCARLO simulations with MARS

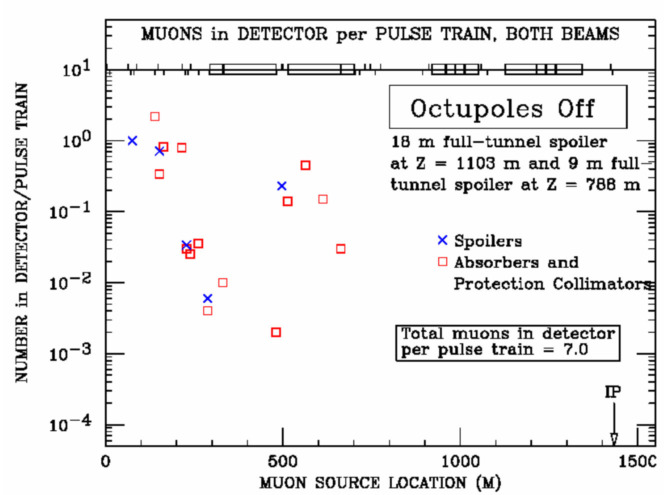
Studies at FNAL with MARS are ongoing. N.Mokhov

32 A. Seryi, 07/14/03, ALCW03

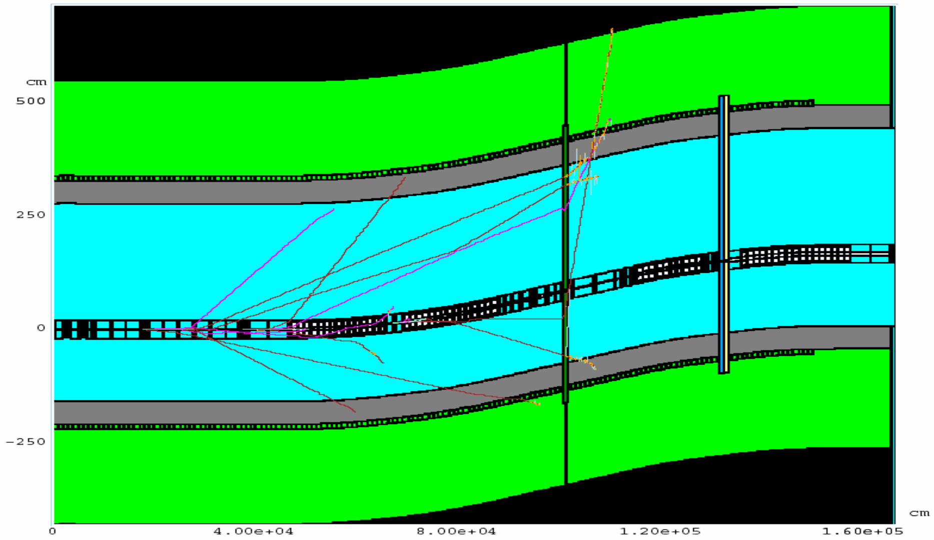
TUNNEL FILLERS DO THE JOB

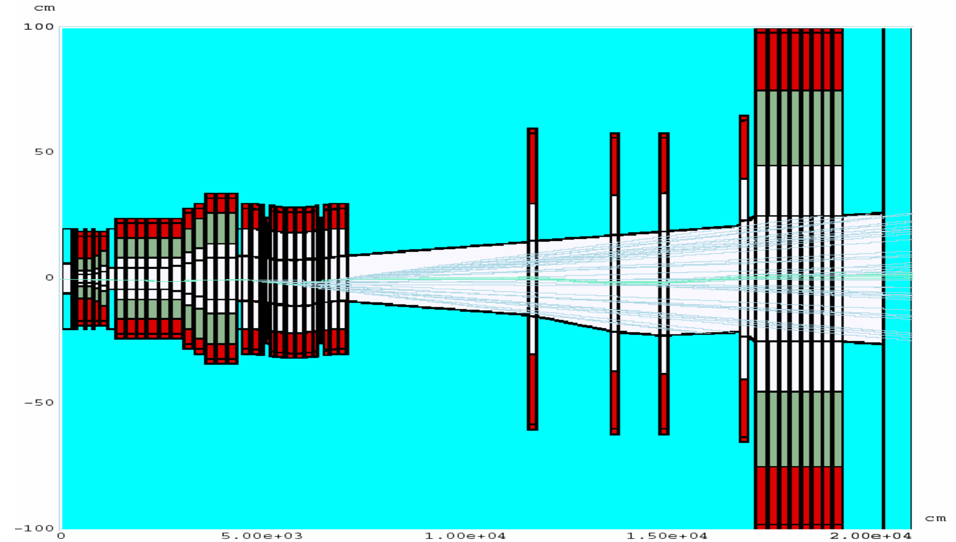




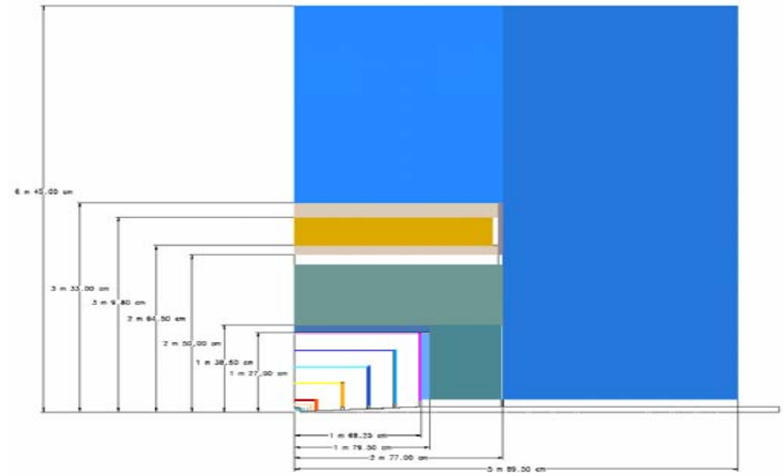


BDIR MARS MODEL: 1700 m BDS, SiD (GEANT4) at IP, followed by 200-m extraction line (20 mrad X)



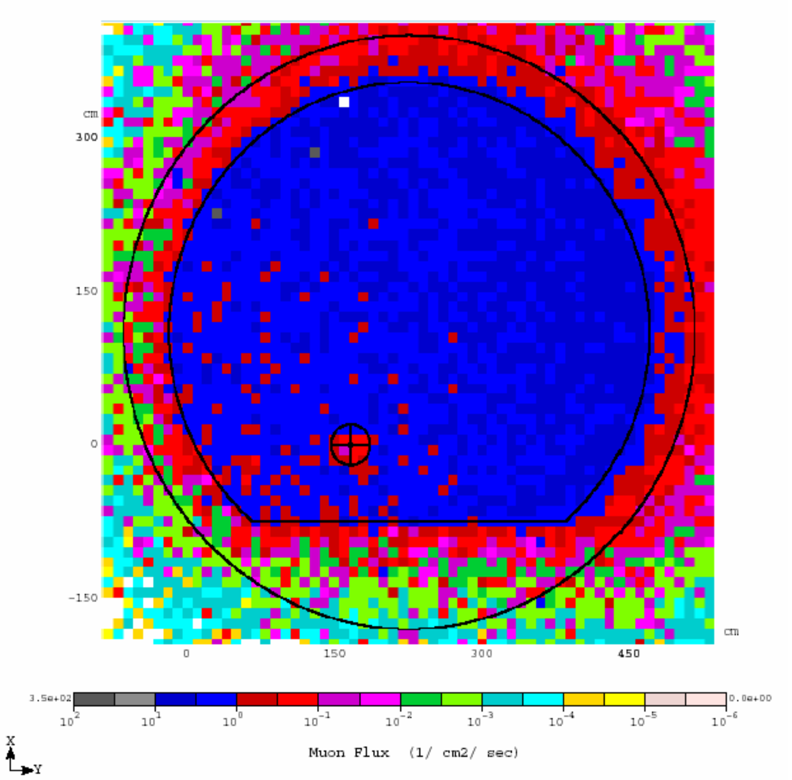


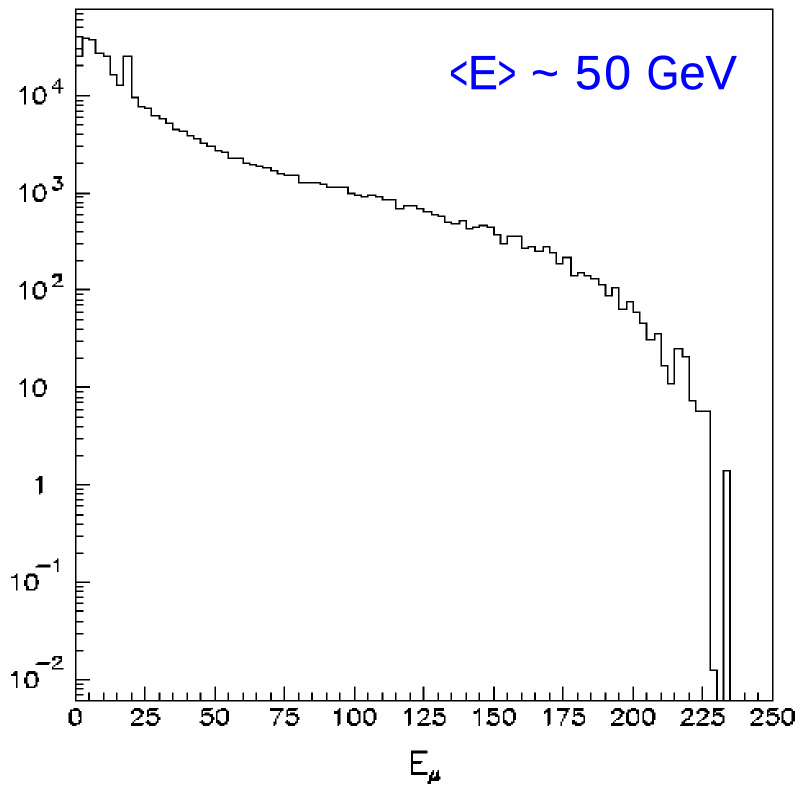
Model includes all magnets, tunnel (R=2.44 m, 0.46-m concrete walls, dirt), multi-stage collimation system (spoilers, absorbers, protection collimators, and photon masks), muon tunnel fillers, SiD, and extraction line (0 and 120-nm vertical displacement for high-lum 250-GeV beams, so far).



MUON AND OTHER PARTICLE FLUXES ON COLLIDER DETECTOR

MARS15



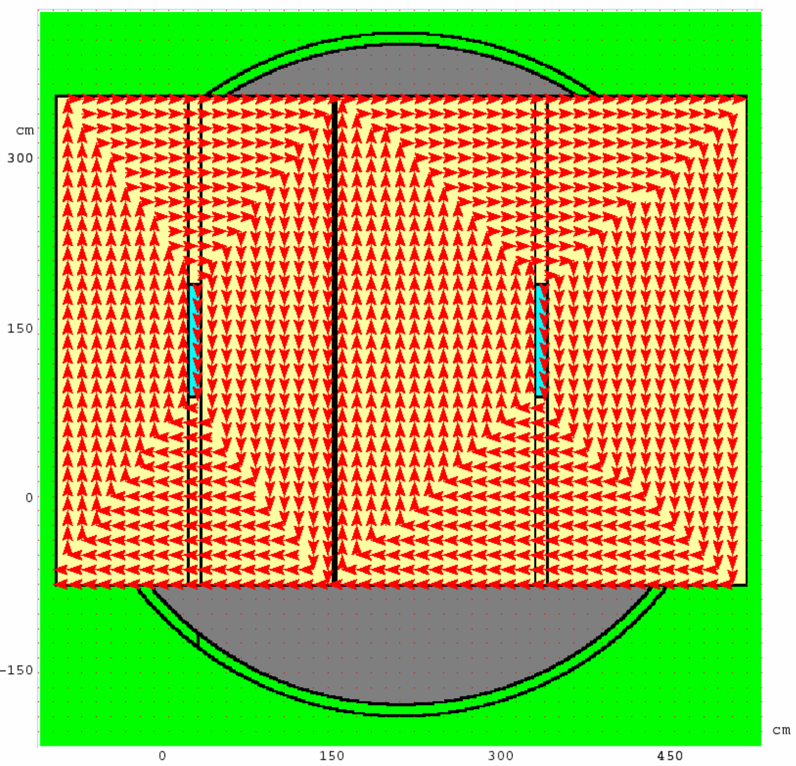


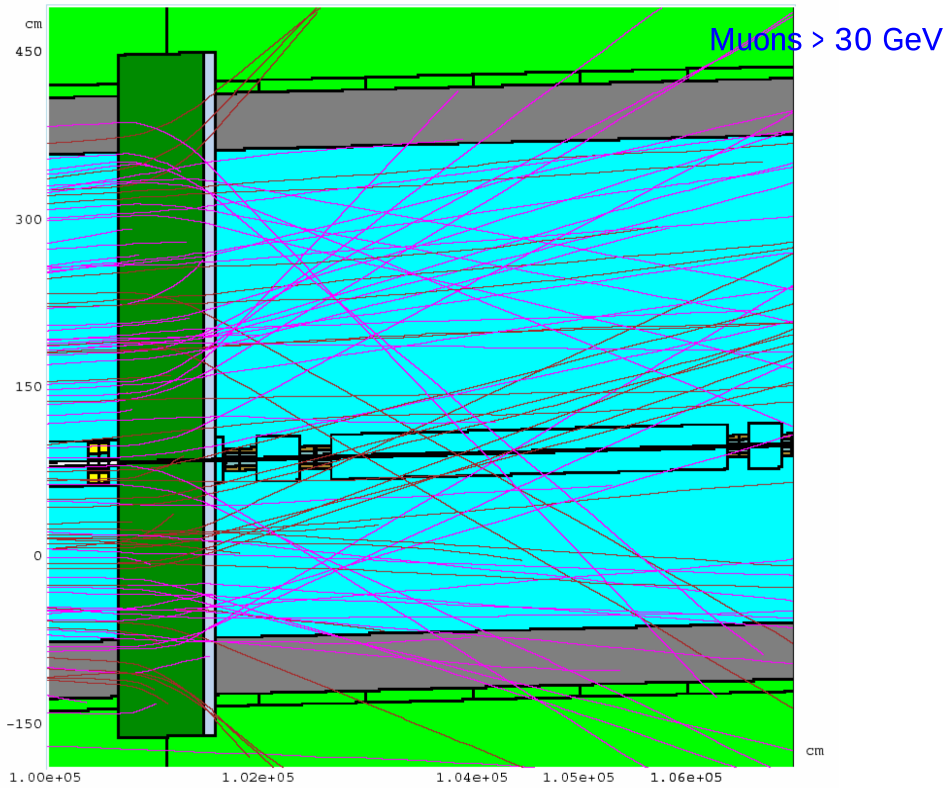
7600 muons, 7×10^5 photons, 2×10^5 electrons per 150 bunches

Limit: less than a few muons!

MUON SPOILERS IN BDS TUNNEL

MARS15





Two iron 9 and 18-m thick spoilers at 1.5 T sealing tunnel at 660 and 350 m from IP. Opposite field polarity in two parts. Extended 0.6 m into the tunnel walls. Central gaps are 10-cm wide and 1-m high with 0.8 T field. The gap between the parts is as beam pipe.

MUON FLUX SUPPRESSION ON DETECTOR

MARS15

Spoiler configuration	# muons in tunnel x-section per 150 bunches	Muon flux $cm^{-2}\ s^{-1}$
No spoilers	7587	4.1
Realistic	2.2	1.2×10^{-3}
Solid	0.8	4.3×10^{-4}

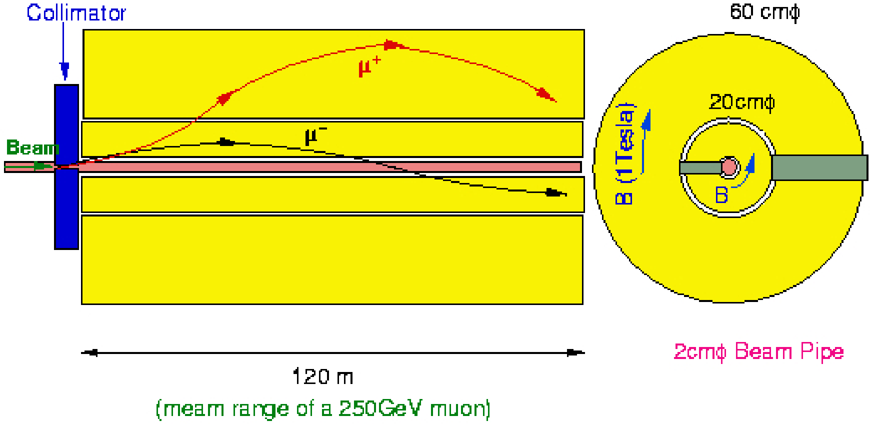
Consistent with Lew Keller predictions.

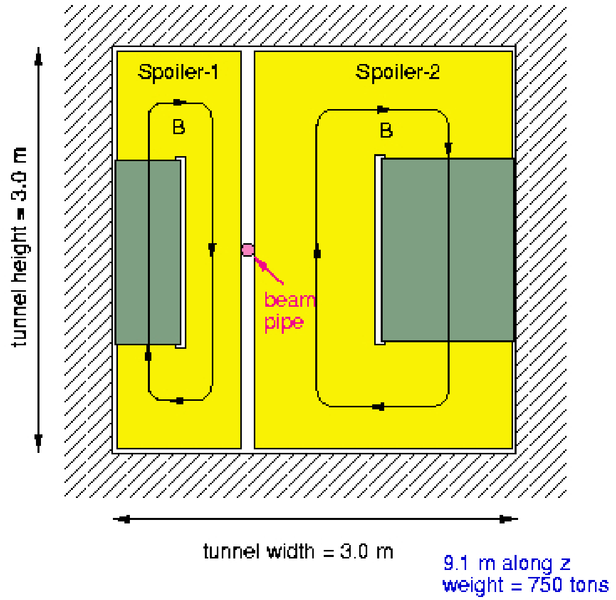
Other particle fluxes on detector for solid spoilers:
0.1 n, 400 γ, 94 e $cm^{-2}\ s^{-1}$

Exploring two alternative methods to suppress muons to mitigate engineering problems (bypass tunnels etc):

- **Muon attenuator** (colar at 1 T, 0.6-m OD, 120-m long).
- **Wide aperture magnets** (first results are quite encouraging: three to five 5-m long dipoles at 1 T give better performance than tunnel spoilers).

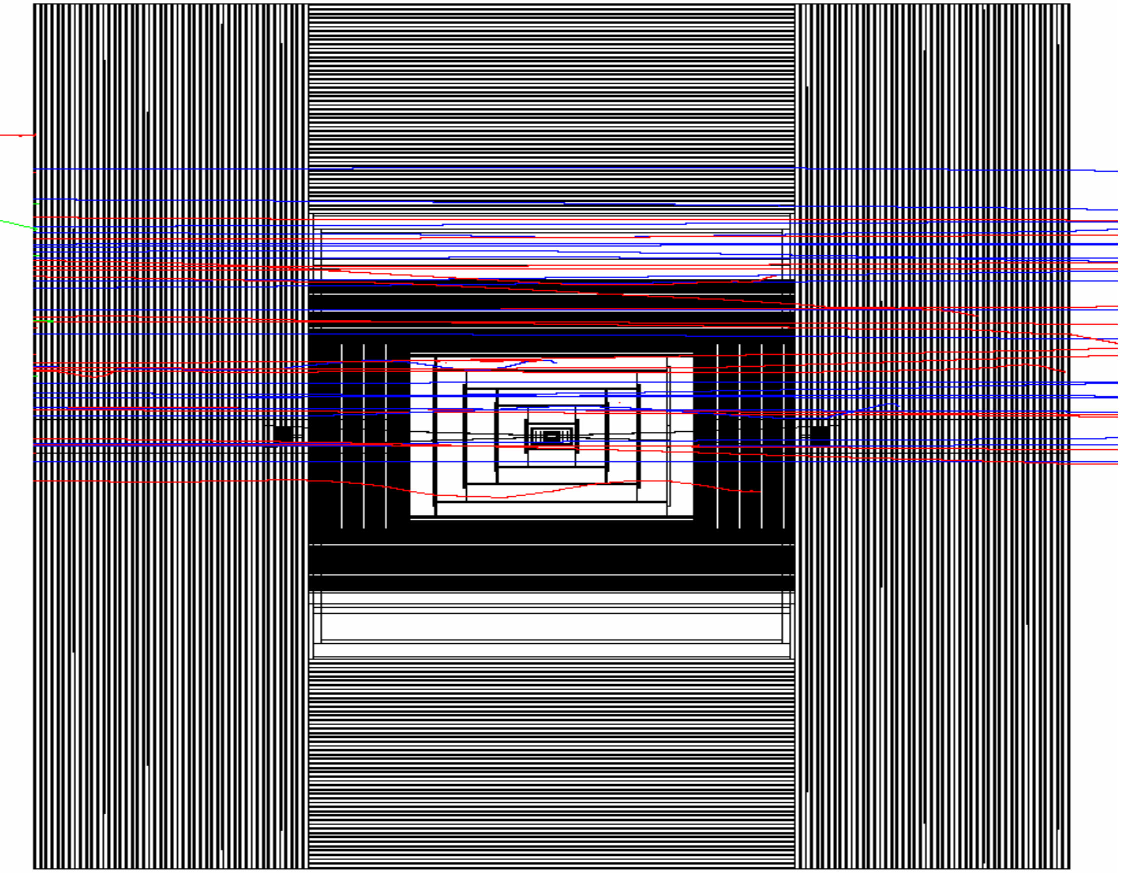
MUON ATTENUATOR AND SPOILER





MARS15+GEANT4/SLIC INTEGRATION

Beamline muons on SiD: side view



I. Tropin

SLIC and related software installed on ILCSIM farm at Fermilab. Tested with IP and MARS's event generators (sources). Work is underway on G4 physics evaluation and adding new hit collectors. **Problem: statistical weight use and propagation in GEANT4.**

Aiming at full detailed description of beamline and detector components for two-way info flow between MARS and GEANT to calculate hit rates (occupancy, with timing) and flux/dose (radiation damage and heat loads) in each sub-detector and final focus components.

CONCLUSIONS

Results on beamline-induced backgrounds are encouraging – with considered protection and mitigation measures; there is no show stopper so far.

Work to do:

1. **Build consistent, realistic BDS+detector integrated models, with detailed magnetic field maps, tunnel and experimental halls. Add engineering realism wherever possible.**
2. **Generate/refine sub-detector tolerance tables: three levels**
   - **Pile-up**
   - **Pattern recognition**
   - **Radiation damage (flux/dose)**
3. **Study backgrounds for 3 detector concepts x 2 crossing angles**
   - **Sensitivity windows wrt tagged origin and crossing**
   - **Tag origins of backgrounds for μ, synchrotron γ, neutrons, pairs**
   - **Mitigation methods: collimation system performance, muon tunnel spoilers or muon attenuator or wide-aperture magnets.**
4. **Code/model benchmarking, interfacing, BDIR code/model/map repository.**