Energy Deposition in MICE Absorbers and Coils

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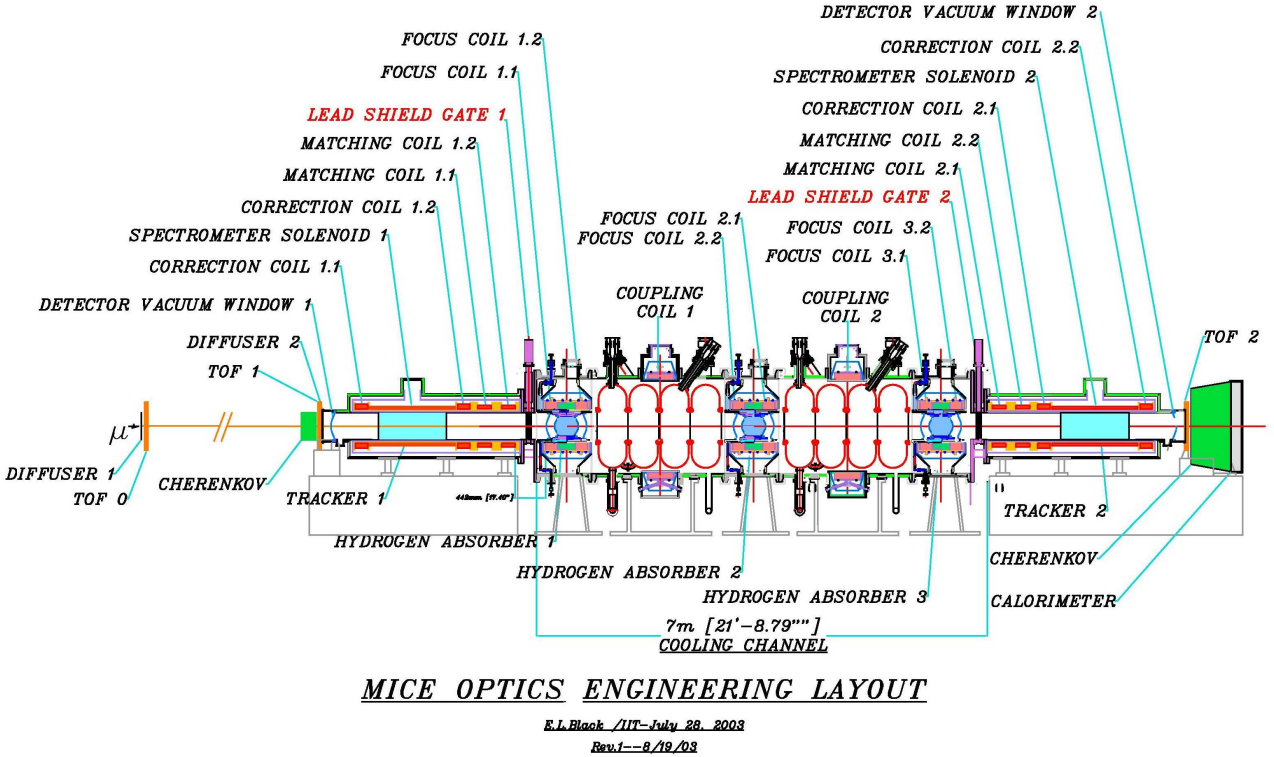
Energy Deposition – An Application for G4Mice

- We would like to estimate how much energy is deposited in magnet coils and the hydrogen absorber.
- Most of the energy deposited will come from the part of the beam that is not interesting to us:
  - Pions and protons in the beam since they dominate.
  - Electrons and photons from RF.
  - The halo of the beam is particularly interesting since it is likely to be in the vicinity of the coils.
- In order for this study to be meaningful we need to normalize to something so that we can calculate something like *joules per pulse.*

G4Mice Glossary of Terms

- VirtualDetector:
  - This is a detector volume that is place for the purpose of making histograms of track variables that pass through it.
    - This is (will be) used for calculating emittances at various planes along the MICE channel. (This is not the subject of today's talk)
- SpecialVirtualDetector:
  - Special case of a virtual detector that descends (*hangs off*) the coil and absorber volumes to histogram the energy deposited in those volumes.
    - These SpecialVirtualDetector volumes can be subdivided so as to force the step size to be small enough that the hits are deposited locally.

MICE Engineering Layout



Beam and Normalization

•We will approximate our input beam to be the output beam of the beamline described by Tom Roberts (Sept 24, '03)

•We will start the beam at Diffuser 1. The number of π and μ per second are given in table below.

•The beam description at Diffuser 1:

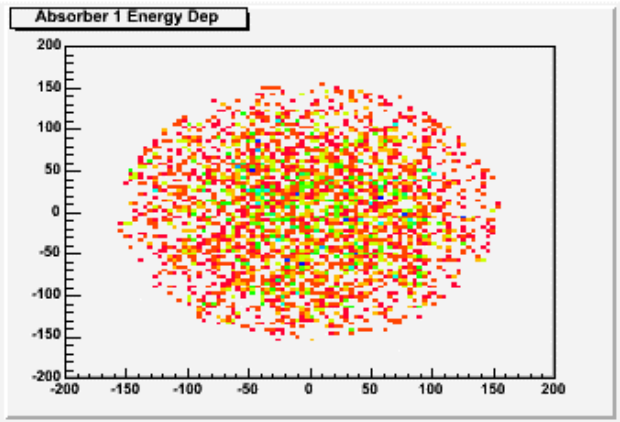
•$\sigma_X=\sigma_Y=200$ mm; $\sigma_{X'}=\sigma_{Y'}=0.15$ radians; no correlations

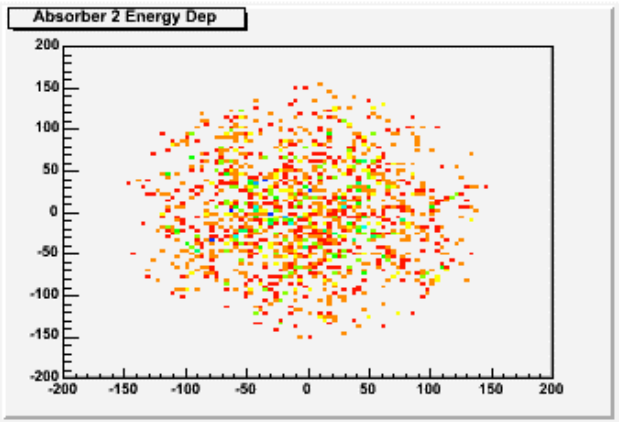
•$\langle E_\pi^{kin}\rangle=178$ MeV; $\Delta E/E|_\pi \approx 0.05$; $\langle E_\mu^{kin}\rangle=121$ MeV; $\Delta E/E|_\mu \approx 0.1$

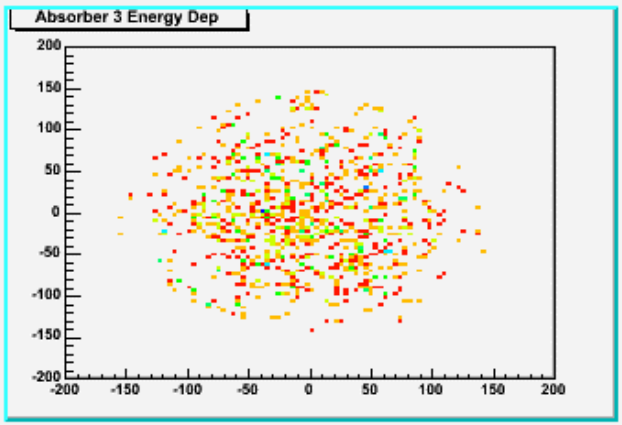
Quantity	*Value*
Protons/sec in accelerator	3.7×10^{16}
Protons/sec on target	1.7×10^{12}
Pions/sec in Beamline Acceptance	3.0×10^{6}
Pions at Diffuser 1	11100
Muons at Diffuser 1	25400
Muons Through Detector	215

•Note that this beam is very inefficient since most of the particles will not get into the detector channel. We are interested in getting a reasonable approximation to the halo

Distribution of Deposited Energy in the Three Absorbers

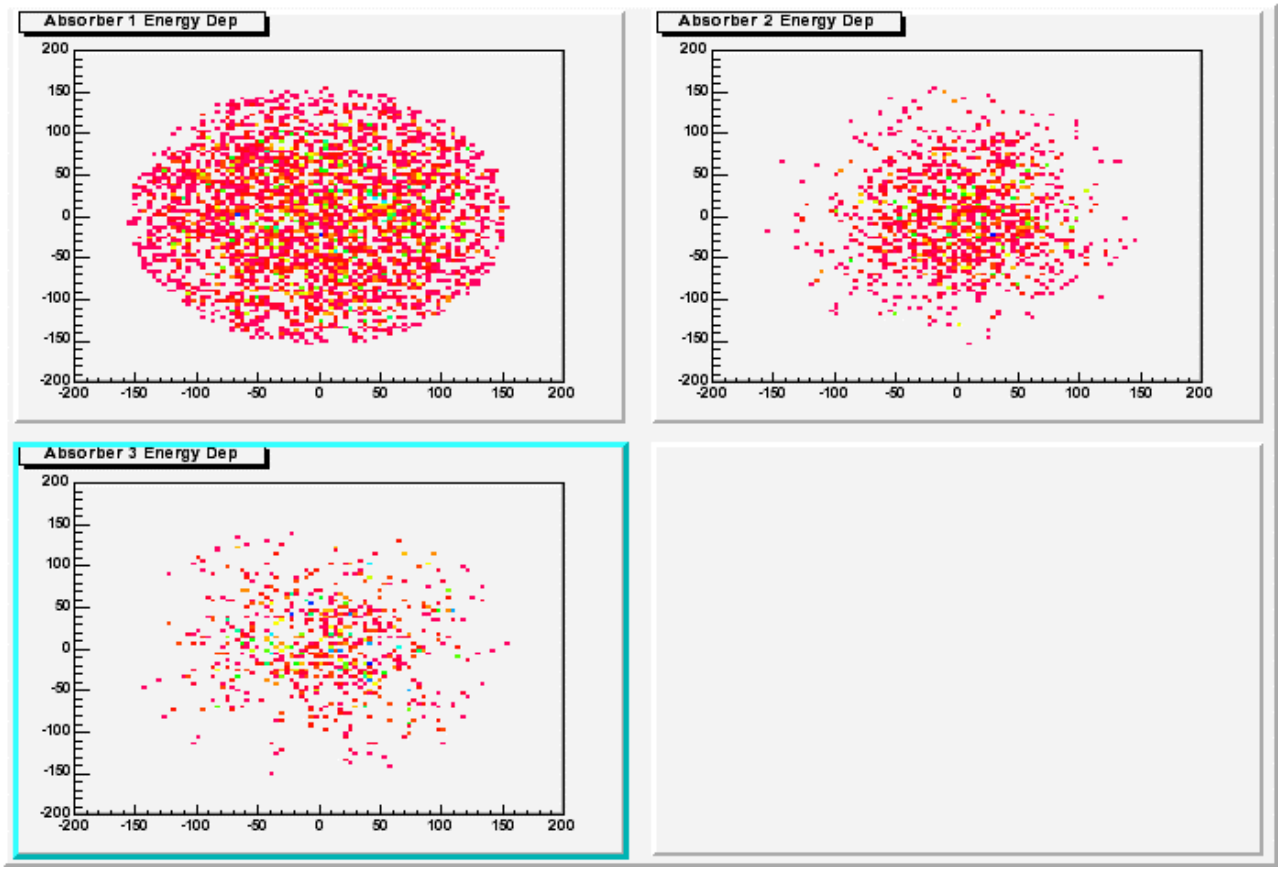




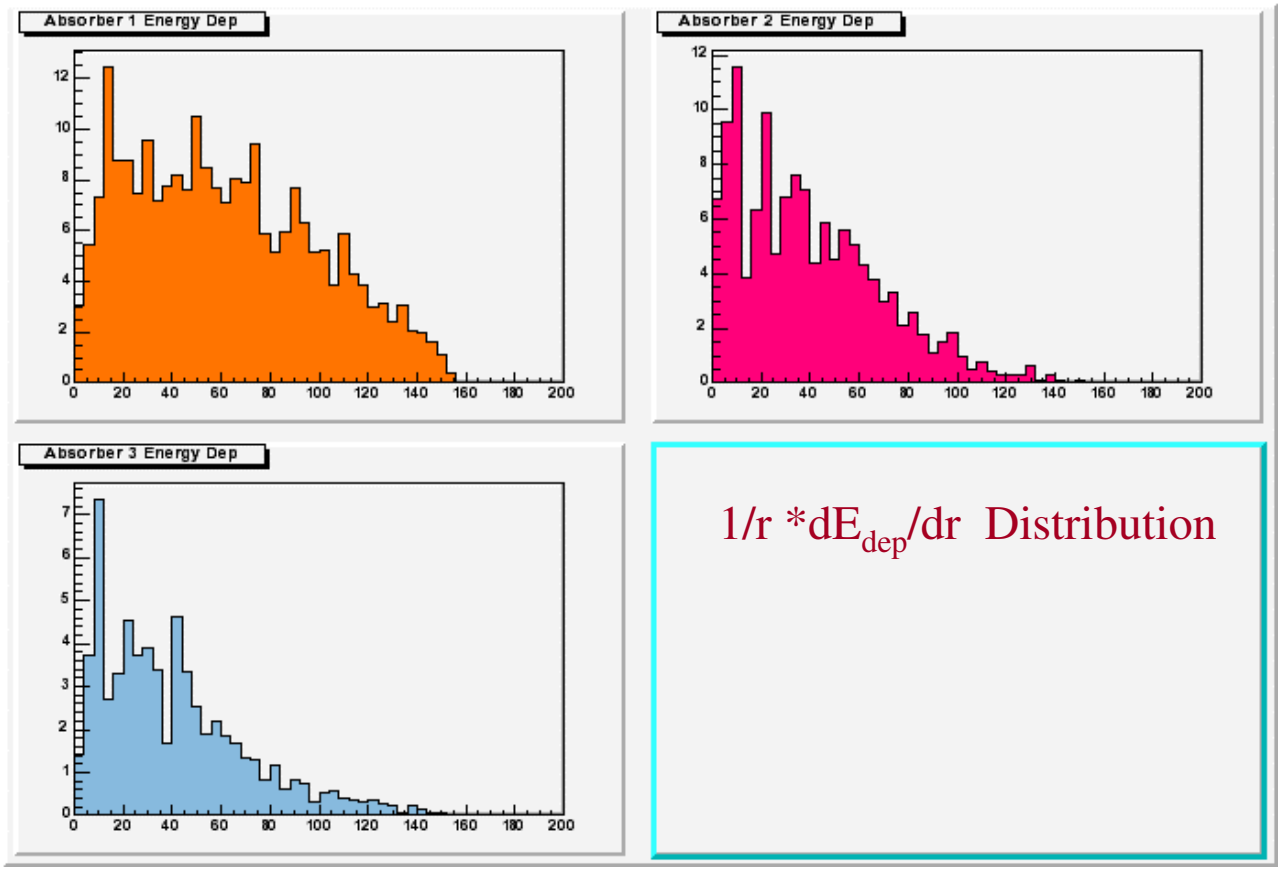


- Energy is integrated over Z
- We will discuss normalization elsewhere.
- This plot shows energy deposited by pions

Absorber Energy Deposit Distribution for Muons



Radial Distribution of E_{dep} Density for Muons



Total Energy Deposited in the Absorbers

- Below are the results for energy deposited in the absorbers from a sample of tracks passed through G4Mice:
  - Sample of 250000 pions at Diffuser 1.
  - Sample of 450000 muons at Diffuser 1.
- The power is the energy deposited in the absorber in pico-joules/sec normalized to Tom Roberts' beam.

Absorber	Pions			Muons		
Number	Hits	E_{Dep} (MeV)	Power (picoWatts)	Hits	E_{Dep} (MeV)	Power (picoWatts)
1	11244	32522	231	18112	54067	488
2	4694	13545	96	6662	20112	182
3	3358	9944	71	3332	10079	91

Energy Deposited in Magnet Coils

- Below are the particle hits and associated energy deposit in the magnet coils. The coils listed below are those with the most significant energy depositions.
- These are very small numbers. If we imagined that all of this energy were deposited at one location in the coil we would not quench a magnet:
  - Quenching requires *millijoules* deposited in ~1/100 sec with coils at approximately 90% of *short sample* current.
    - We aren't anywhere near that.

Coil	Pions			Muons		
Number	Hits	E_{Dep} (MeV)	Power (picoWatts)	Hits	E_{Dep} (MeV)	Power (picoWatts)
Focus 1.1	751	9065	64	873	8007	72
Match 1.1	2802	32146	228	2468	23118	209
Solenoid 1	442	2620	19	282	2172	20
EndCoil 1.1	?	?	?	?	?	?

Concluding Caveats

- These results are *extremely preliminary* at this point.
  - There are likely to be errors both in the program and my understanding.
- These calculations are without RF.
  - It ignores X-rays and electrons produced.
  - It ignores disruption of beam from the RF.
- It ignores protons and neutrons from the upstream beam.
  - There are 10× as many protons produced at the target than π. Some could get through.
  - Neutrons go everywhere.