Update on Surface Backgrounds

R.Svoboda, 27 June, 2012

Update

- Muon calculation by Cosmic Ray and Cosmogenics Working Group members V.Kudryavtsev, M.Richardson, M.Robinson (Sheffield)
- Analysis from a series of meetings organized by group conveners D.Mei and V.Kudryavtsev
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Assumptions for Muon Calculation

- 1.6 ms drift time
- 30m (length along beam) x 15m (width) x 16m (height) under 3m of rock (or enough to reduce primary hadrons and EM showers to insignificance)
- muon flux at that depth is ~100 /m^2/sec through a sphere, giving 75 muons/spill
- At these rates, data acquisition is unlikely to be a problem – likely only beam physics is possible due to spallation backgrounds and high energy neutrons
- "Confusion" less likely to be a problem, but cannot study without full automated reconstruction
- Backgrounds likely to be the most serious problem

Backgrounds

- Since we need to detect ~few hundred ν_e events/year, backgrounds need to be significantly smaller than this.
- Electron tracks from muons likely not a problem, since such events can be cut by excluding a cylinder of a few cm around a muon track and tracks originating within potential dead volumes. Estimated loss perhaps 1% but likely <10% of fiducial volume. Bremsstrahlung from such electrons could be a potential problem. Rock muons drive the 10% number.

Backgrounds (cont.)

- Muon Bremmstrahlung could be a potential problem, but for vertical muons the chances to emit a photon in the rough direction of the beam and >0.5 GeV is quite small. More horizontal muons may present a problem
- Neutral hadrons could be problematic in that pizero's can mimic an electron shower. Fast neutrons and K^0 can also produce pizero's. These can be suppressed by the ability to separate e/gamma showers.

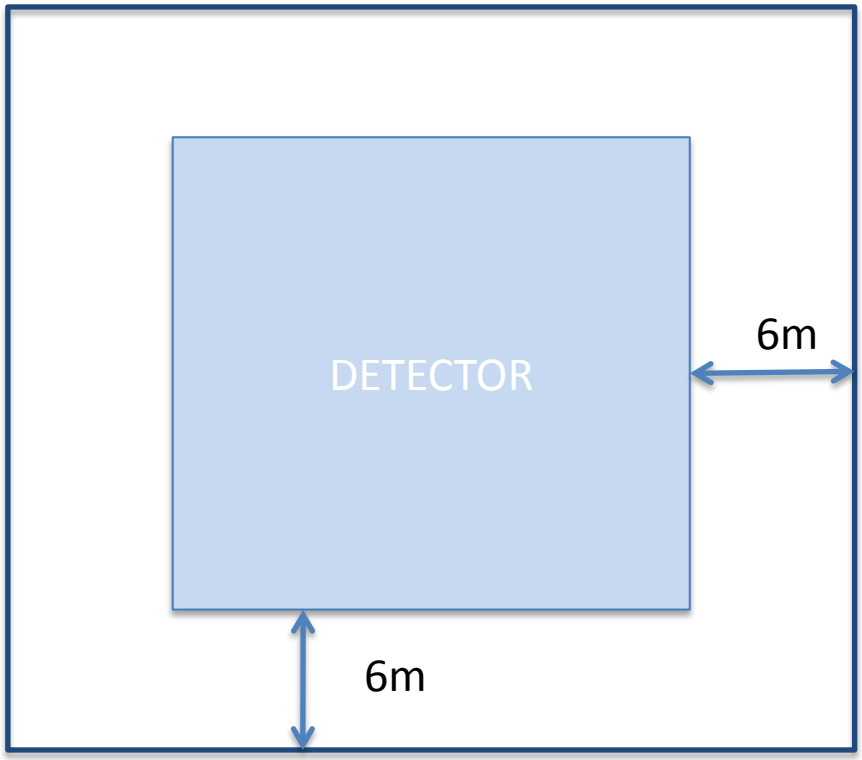
Preliminary Simulation Results

- Consider muons >70^{o} zenith angle and within an azimuth angle of +/- 20^{o} w.r.t. beam direction. Note: beam is rising at angle of 6^{o}. While it is thought these are the most dangerous, we still need to assess the uncertainty due to this cut.
- Muon spectrum and zenith angle distribution from modified Gaisser parameterization (see PDG). Note: roughly consistent with independent calculations from J. De Jong.
- Consider 10^{7} passing through a surface extending out six meters from the detector boundaries. About 2 years continuous running.
- Note: this study done for 1.6 ms rather than 1.4ms

Simulation Geometry

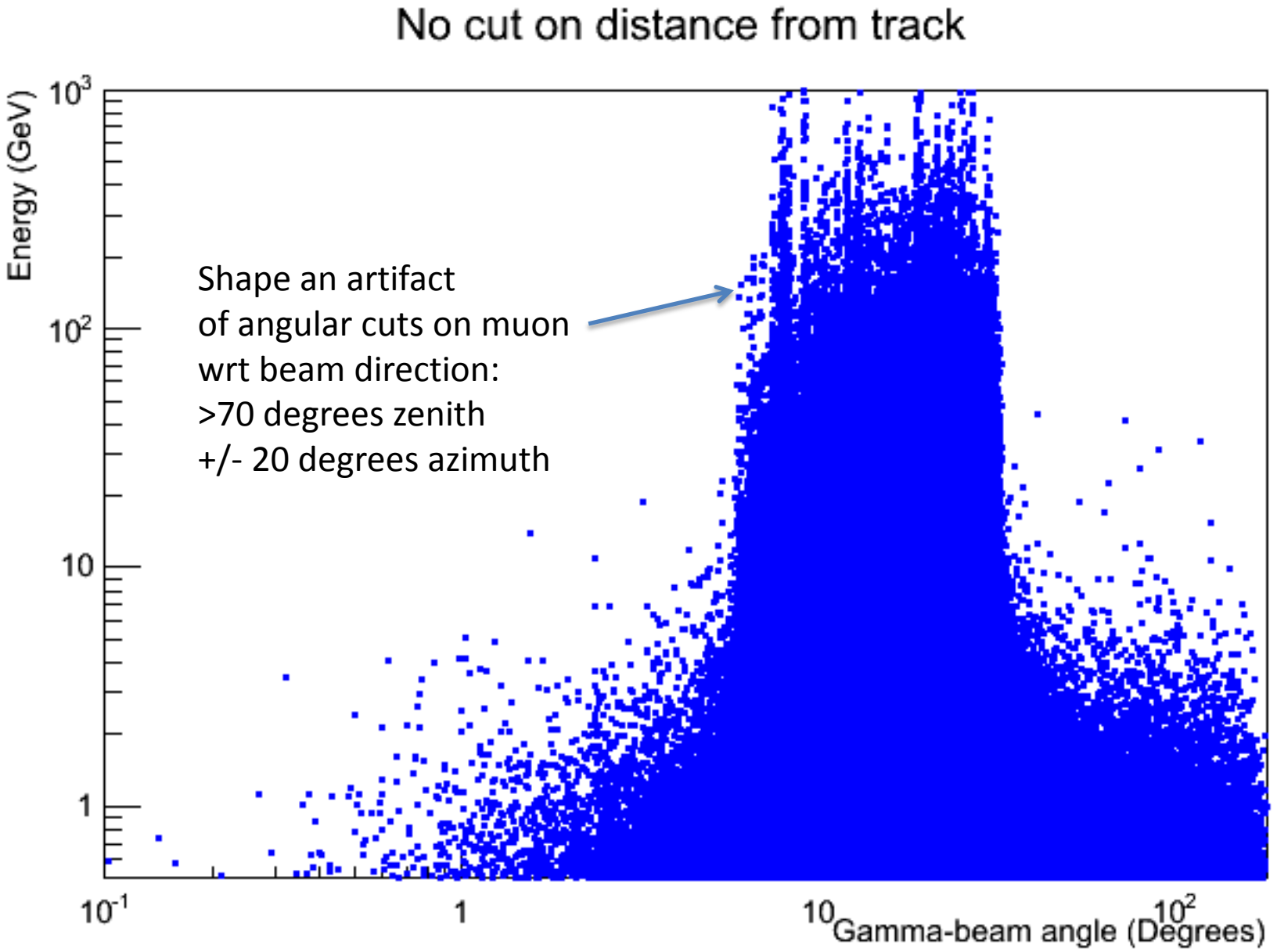
(15+6)(16+6) =

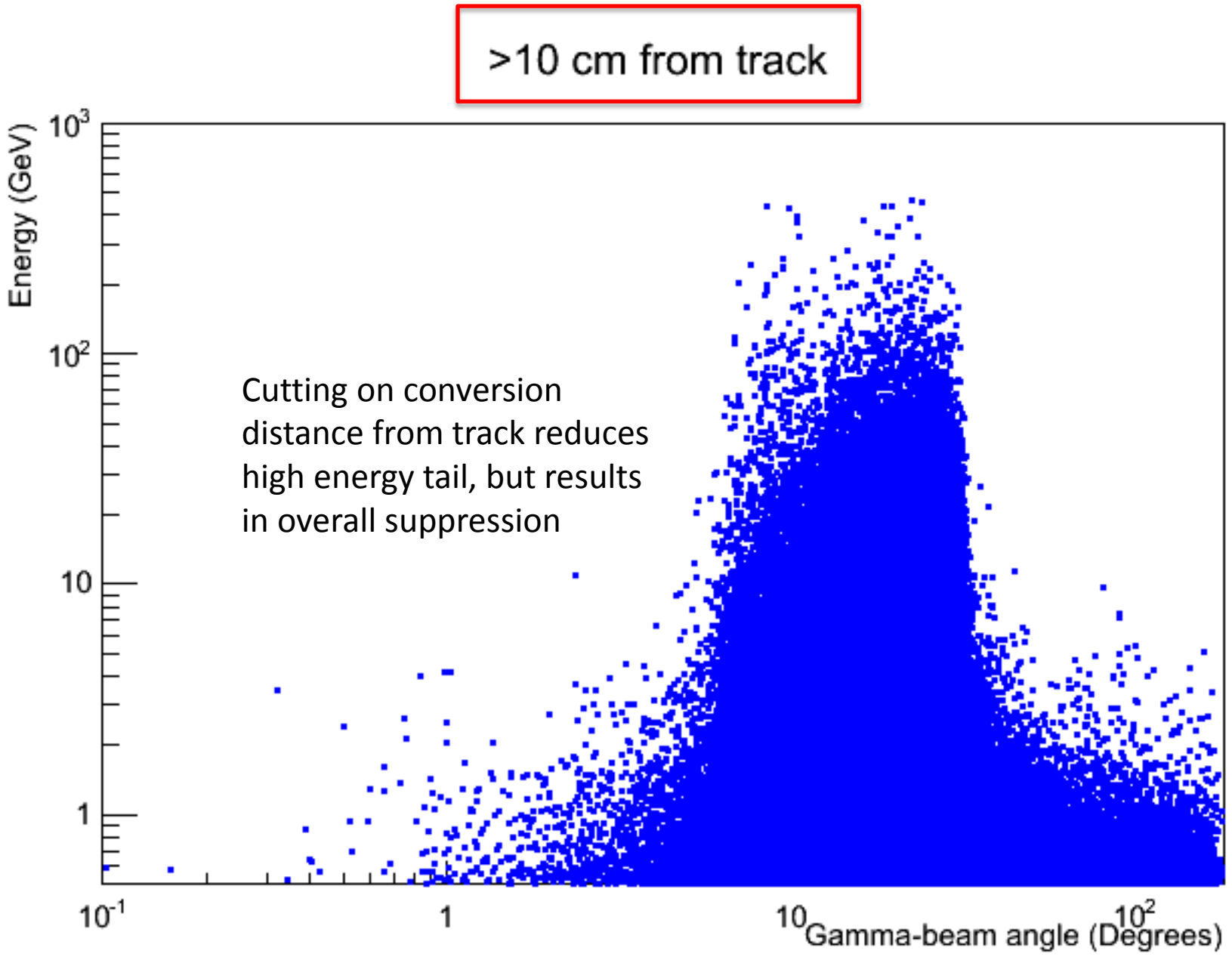
462 m^2

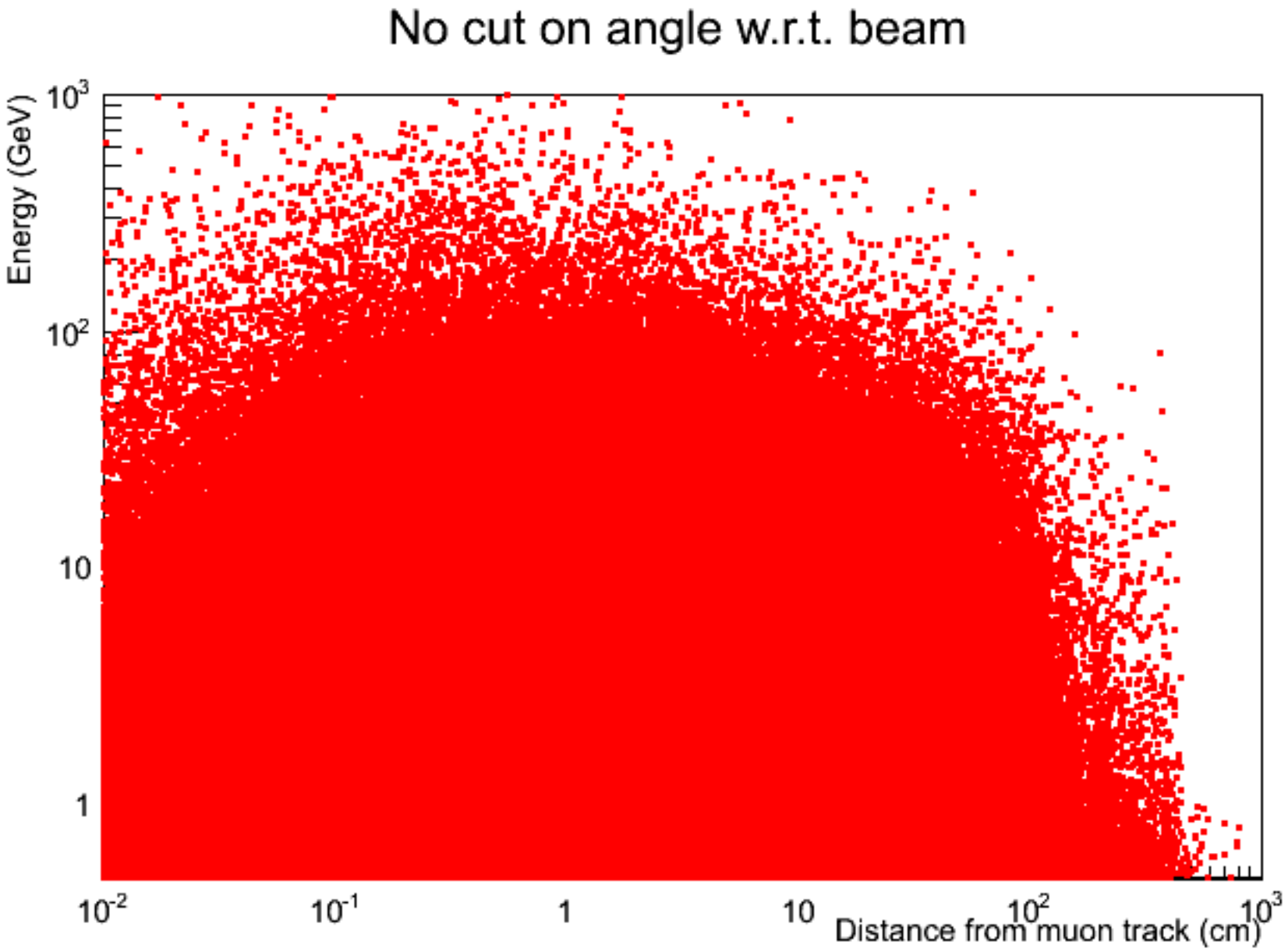


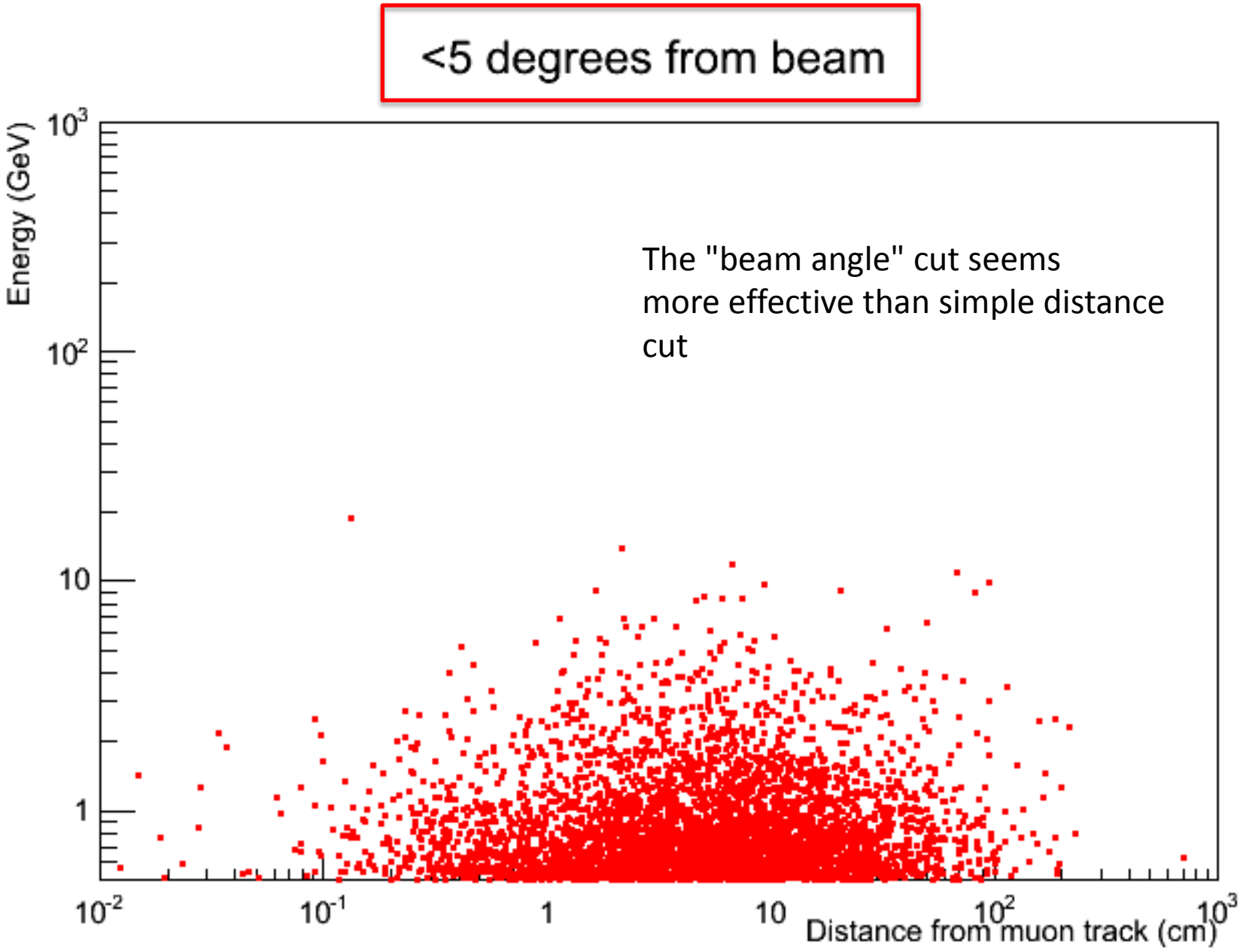
Beam going into paper at angle 6 degrees from the normal

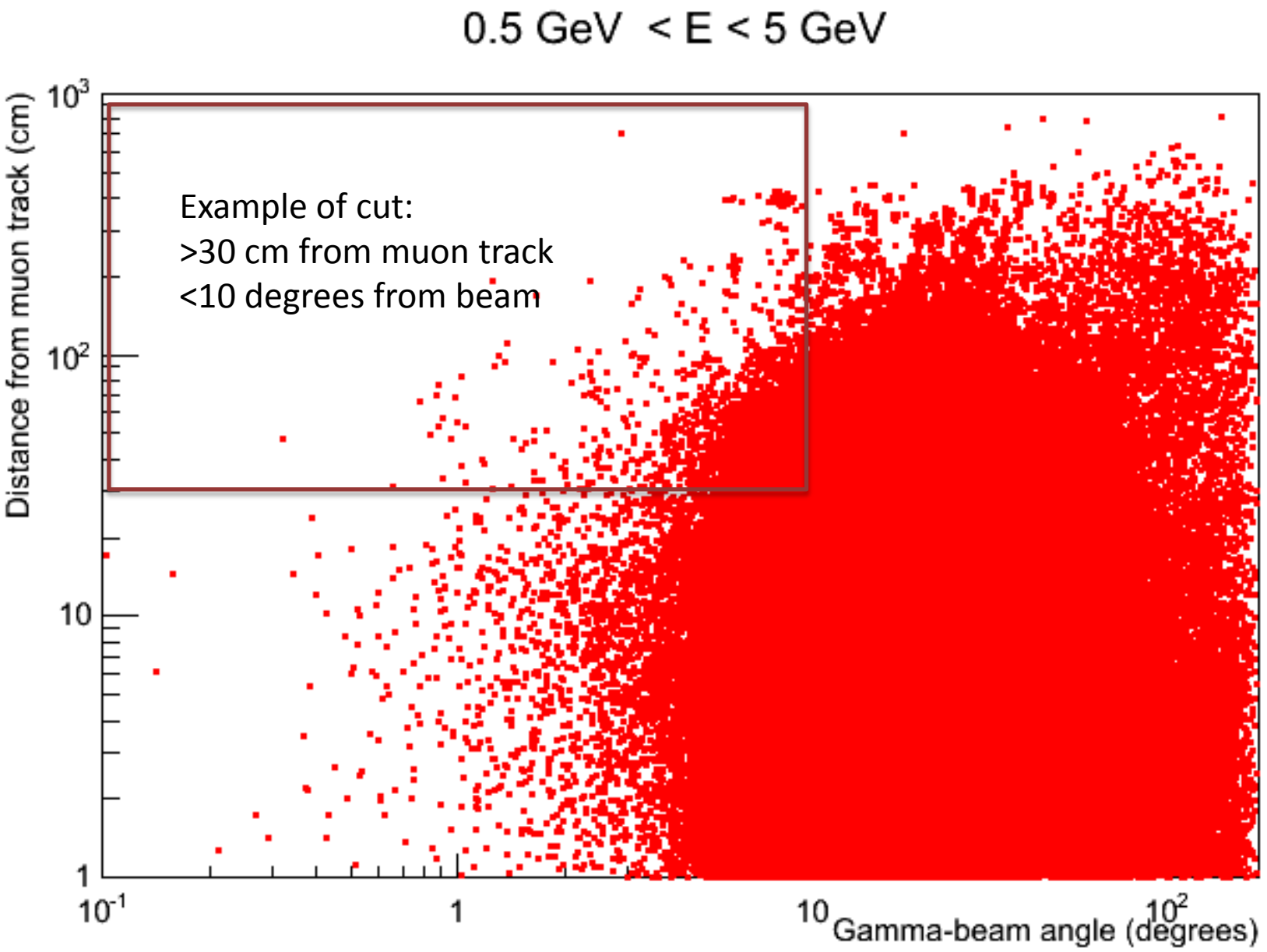
- 0.499% of muons fall within the horizontal cone. If one requires E>10 GeV (more chance for to produce a neutral daughter above 0.5 GeV) this reduces to 0.277%
- Require photons to have energy >0.5 GeV in order to mimic electron showers in the energy range of interest.
- Note: photons from pizeros were essentially "double counted", leading to ~20% overestimate.


No cut on distance from track
Energy (GeV)
10^3
10^2
10
1
10^{-1}
1
10
10^2
Gamma-beam angle (Degrees)
Shape an artifact
of angular cuts on muon
wrt beam direction:
>70 degrees zenith
+/- 20 degrees azimuth


>10 cm from track
Energy (GeV)
10^3
10^2
10
1
10^{-1}
1
10
10^2
Gamma-beam angle (Degrees)
Cutting on conversion distance from track reduces high energy tail, but results in overall suppression


No cut on angle w.r.t. beam
Energy (GeV)
10^3
10^2
10
1
10^{-2}
10^{-1}
1
10
10^2
10^3
Distance from muon track (cm)


<5 degrees from beam
Energy (GeV)
10^3
10^2
10
1
10^{-2}
10^{-1}
1
10
10^2
10^3
Distance from muon track (cm)
The "beam angle" cut seems more effective than simple distance cut


0.5 GeV < E < 5 GeV
Example of cut:
>30 cm from muon track
<10 degrees from beam
Distance from muon track (cm)
10^3
10^2
10
1
10^{-1}
1
10
10^2
Gamma-beam angle (degrees)

Potential Cuts

Selected events	> 5 cm	> 10 cm	> 20 cm	> 30 cm
$< 5°$	2337	1348	582	340
$< 10°$	83006	39732	14532	7286

This is for two years of continuous operation and 1.6ms drift

Assuming 2% mis-ID of photon versus electron events,
then a "loose" cut would give:

(83006/2)(0.02) = 830 events/year

While for a "tight" cut it would be:

(340/2)(0.02) = 3.4 events/year

Also done for flat overburden. The actual location could be better.

Conclusions and further work

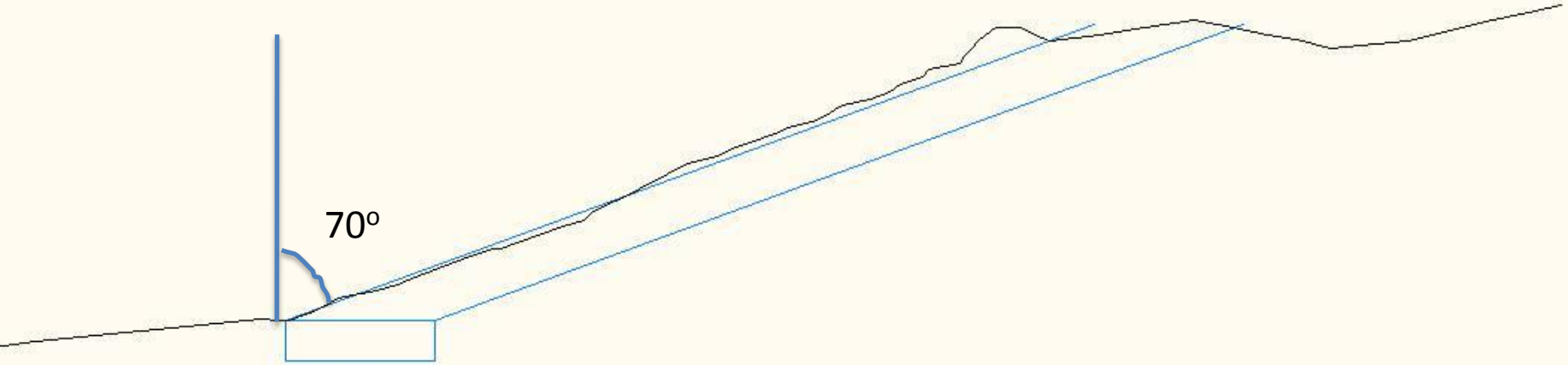
- **An initial estimate shows that the backgrounds from high-angle muons is significant, but not overwhelming.**
- Ability to separate e/gamma very important
- This estimate does not use the addition information that could be provided by an active veto system and/or internal photon system
- Slight change in depth could have significant benefits also

Depth, m w. e.	0	10.2	20	50	100	150	200
Depth, m	0	3.764	7.380	18.45	36.90	55.35	73.80
Muon flux, $cm^{-2}\ s^{-1}$	2.07×10^{-2}	1.14×10^{-2}	6.50×10^{-3}	1.99×10^{-3}	6.02×10^{-4}	2.71×10^{-4}	1.47×10^{-4}
Attenuation factor	1	1.82	3.18	10.4	34.4	76.7	141
Muon flux at $\theta > 70°$ $\phi < 20°$, $cm^{-2}\ s^{-1}$	1.02×10^{-4}	5.88×10^{-5}	3.39×10^{-5}	1.02×10^{-5}	2.92×10^{-6}	1.23×10^{-6}	6.21×10^{-7}
Attenuation factor for selected muons	1	1.74	3.02	10.0	35.0	83	164

Going underground even 50 mwe (~18 meters) could provide up to an order of magnitude suppression of this background

Candidate Surface Detector Site at

Location in back of this hill between the detector and Fermilab would Add 100m of effective overburden



Topographic section from SURF

To Do List:

- What fraction of ν_e events are lost by these cuts? What are optimal cuts? This study was done for 1.6 vrs 1.4 ms (planned drift time)
- Improved cosmic ray model using actual local topography
- Assess potential benefits of veto and photon trigger system.
- Explore other possible cuts – e.g. CPA to muon track from fitted shower?

Even More to Do

- Check the simulations with independent calculations
- Check contribution from muons outside the angular cuts
- Study muons in the rock outside the detector to determine appropriate FV cut
- Use proper detector geometry, included dead zones.
- Keeping thinking about backgrounds – did we miss anything?