Can we detect a marble tomb with cosmic muons ?

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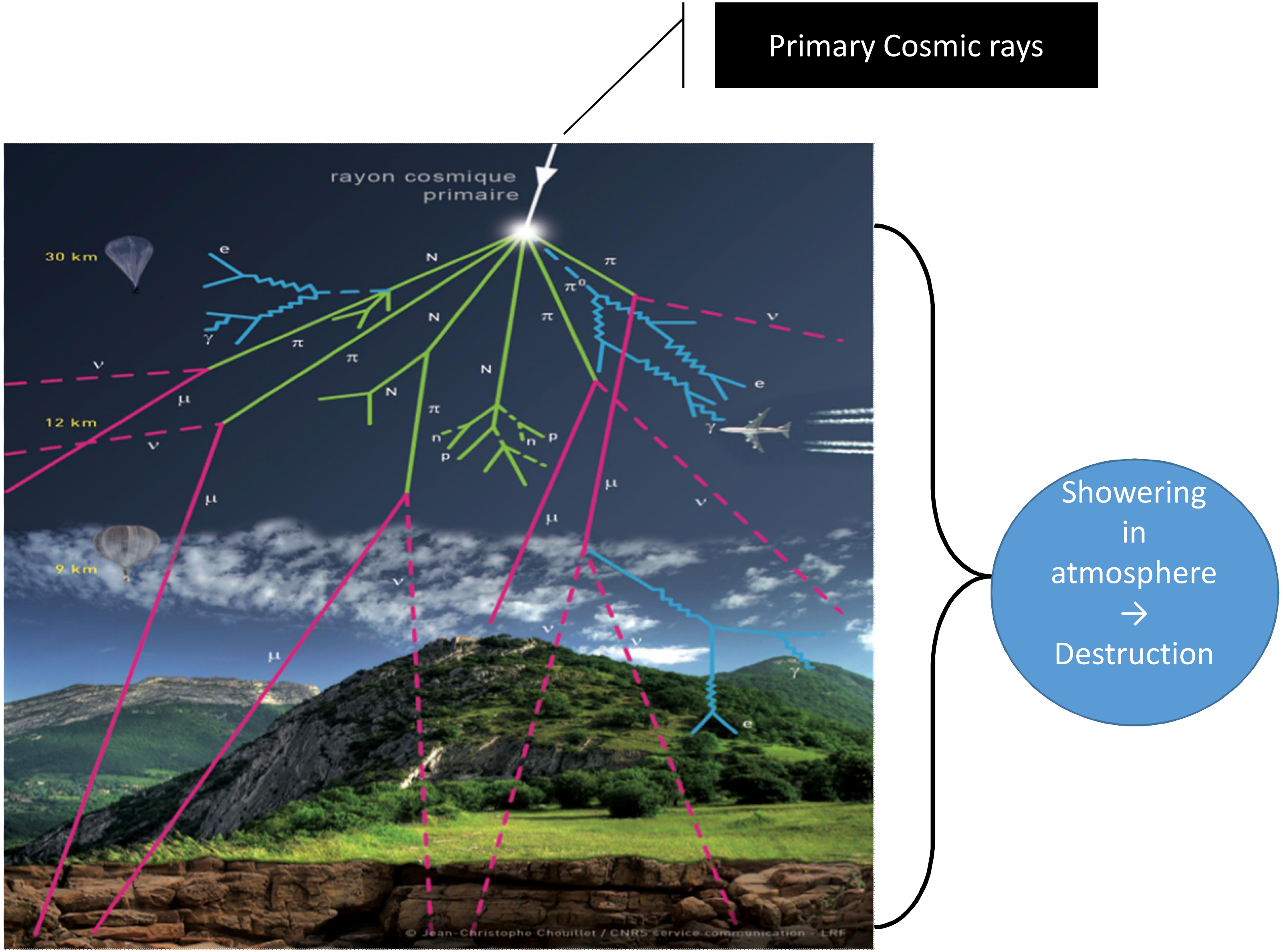
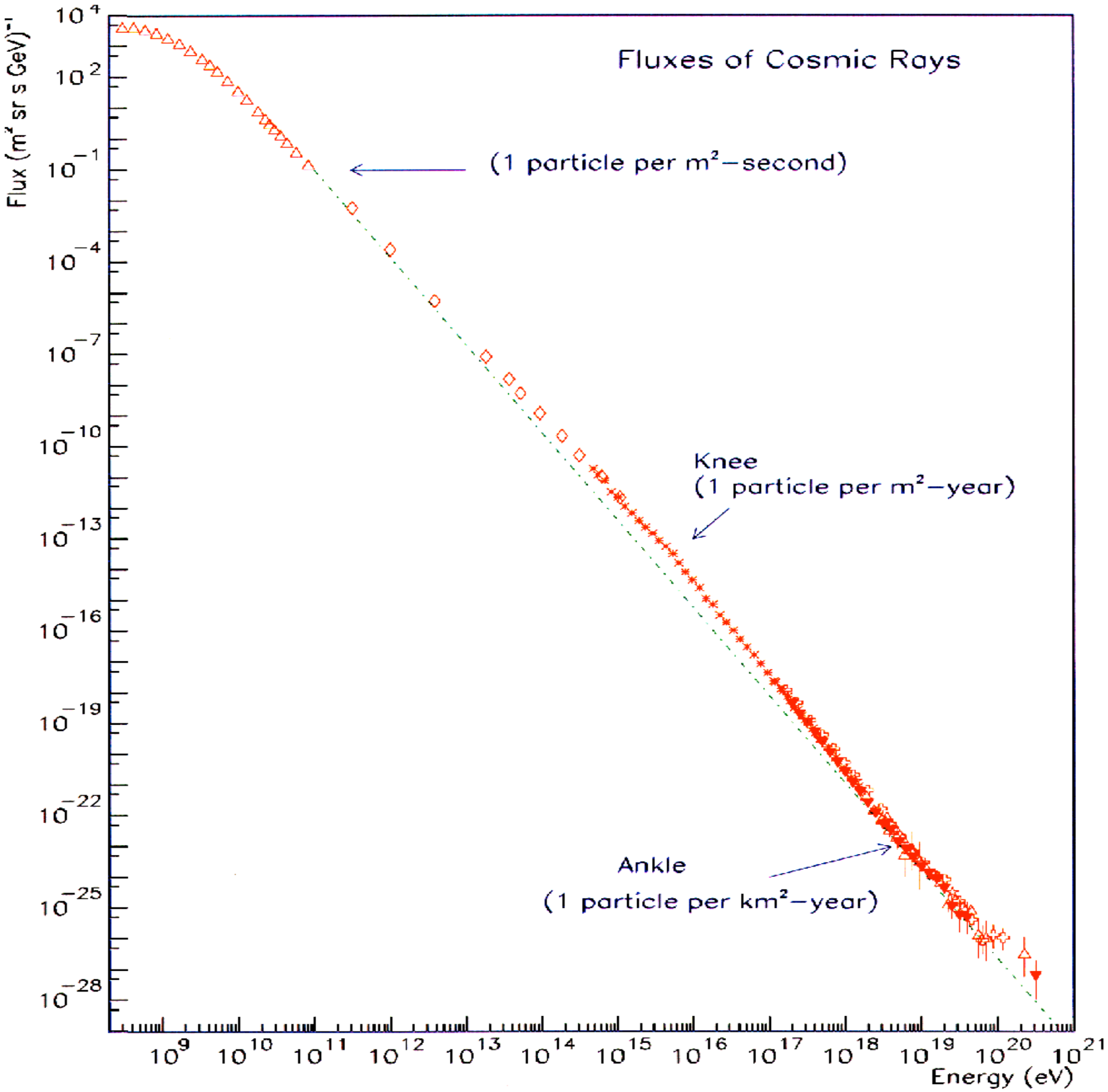
21 December 2015



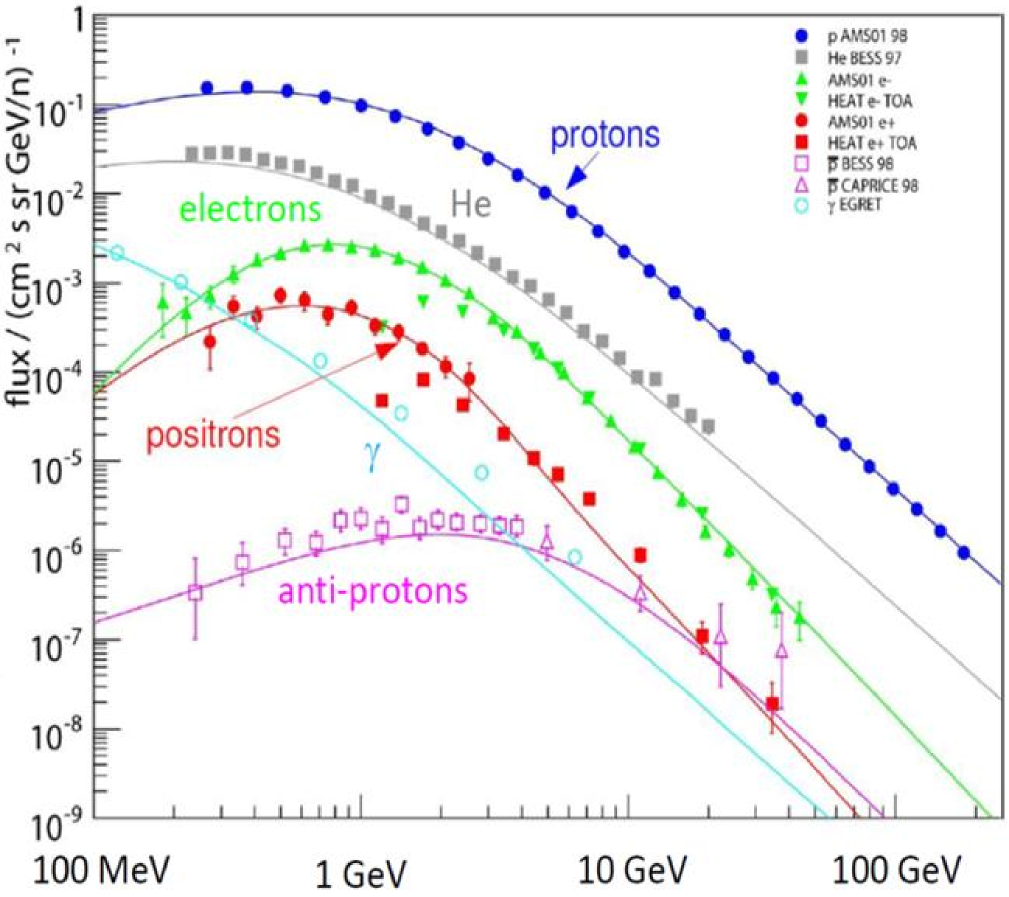
Primary Cosmic rays
rayon cosmique
primaire
30 km
12 km
9 km
Showering
in
atmosphere
→
Destruction

Flux (m^2.sr.s.GeV)$^{-1}$



$1\ \text{GeV} = 10^{9}\ \text{eV}$

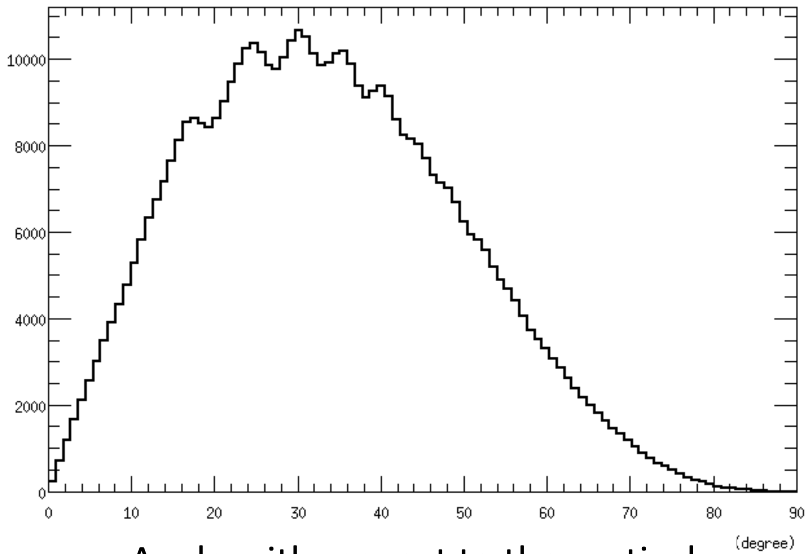
Composition of primary cosmic rays



90 % protons
10 % Helium
1 % electrons
0.1 % positrons

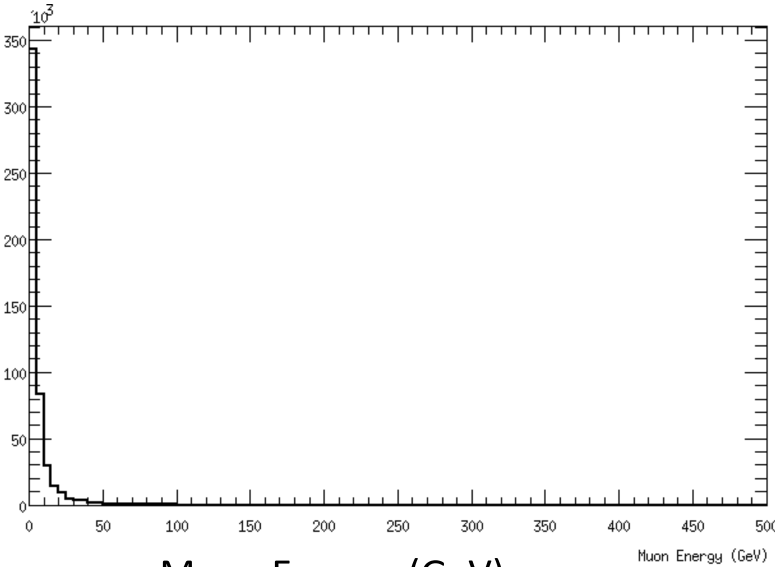
Sea – level : remnants of primary CRs – essentially muons (and neutrinos)

Few Horizontal muon



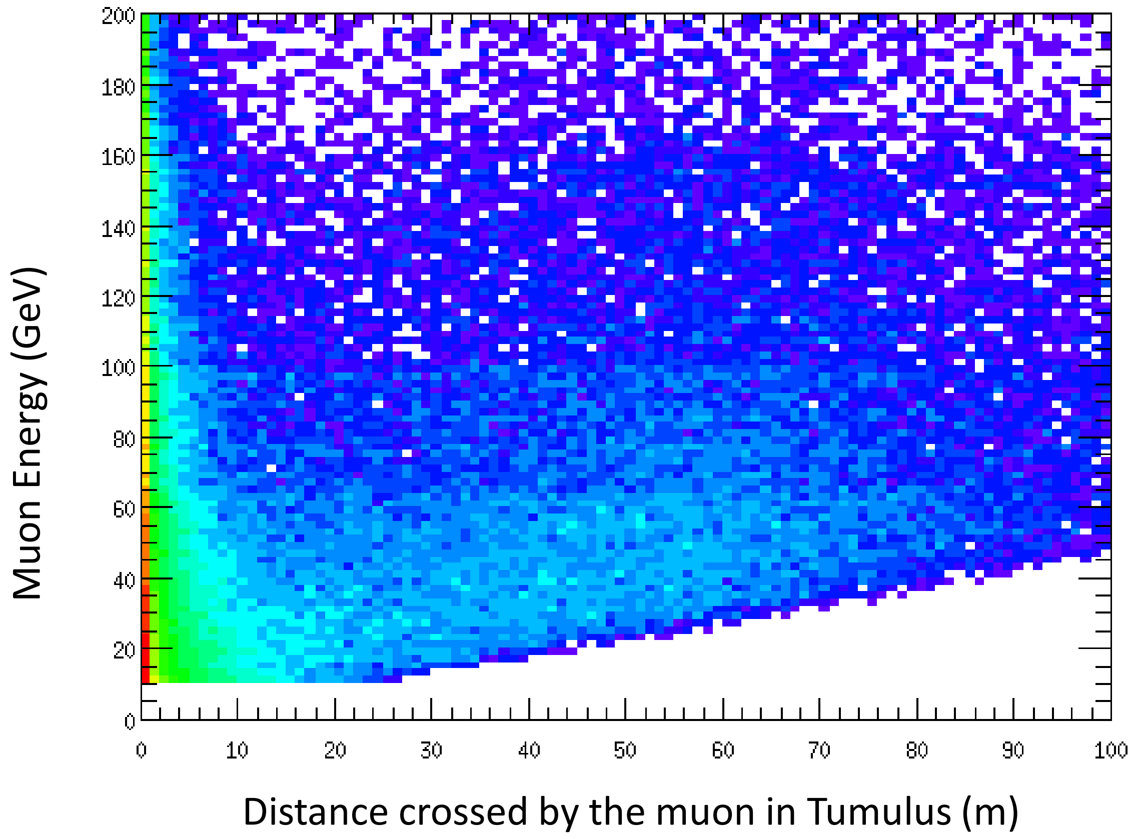
Angle with respect to the vertical

Low energy



Muon Energy (GeV)

We are interested in rather high energy muons , otherwise they are absorbed in the tumulus before reaching the detector



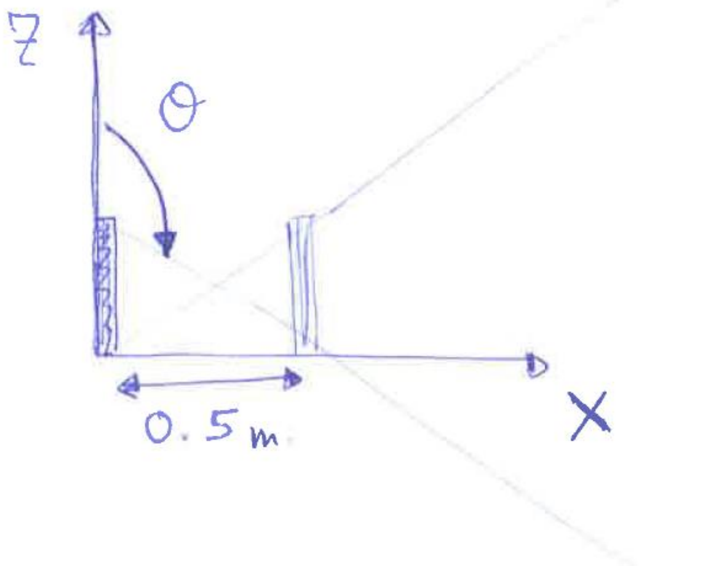
Acceptance Studies

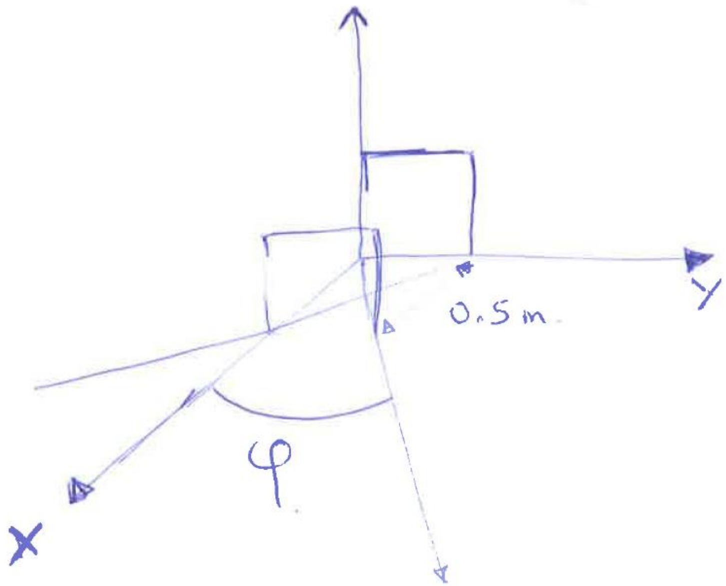
Methods and prelim. Results

Toy MC

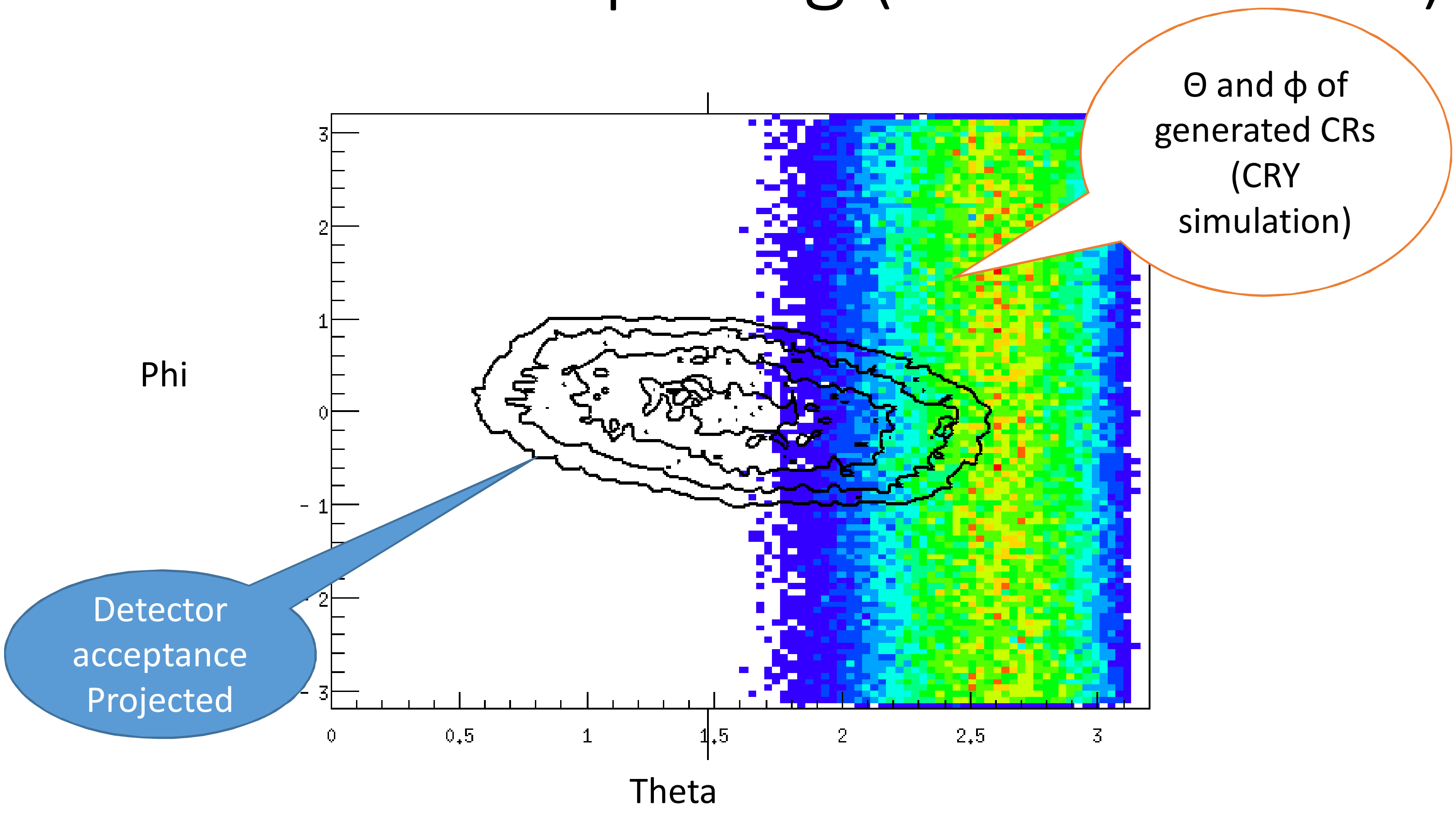
- Generate random Y & Z on a 1 square meter. (~= 1 chamber) at X = 0.
- Generate ϕ in [-π;+π]
- Generate θ in [0;π]
- Extrapolate track to X = 0.5 m (resp 2 m)

- Retain tracks that crosses the second chamber ie
  - 0 < Z < 1m
  - 0 < Y < 1m @ X =0.5 m (resp 2m)



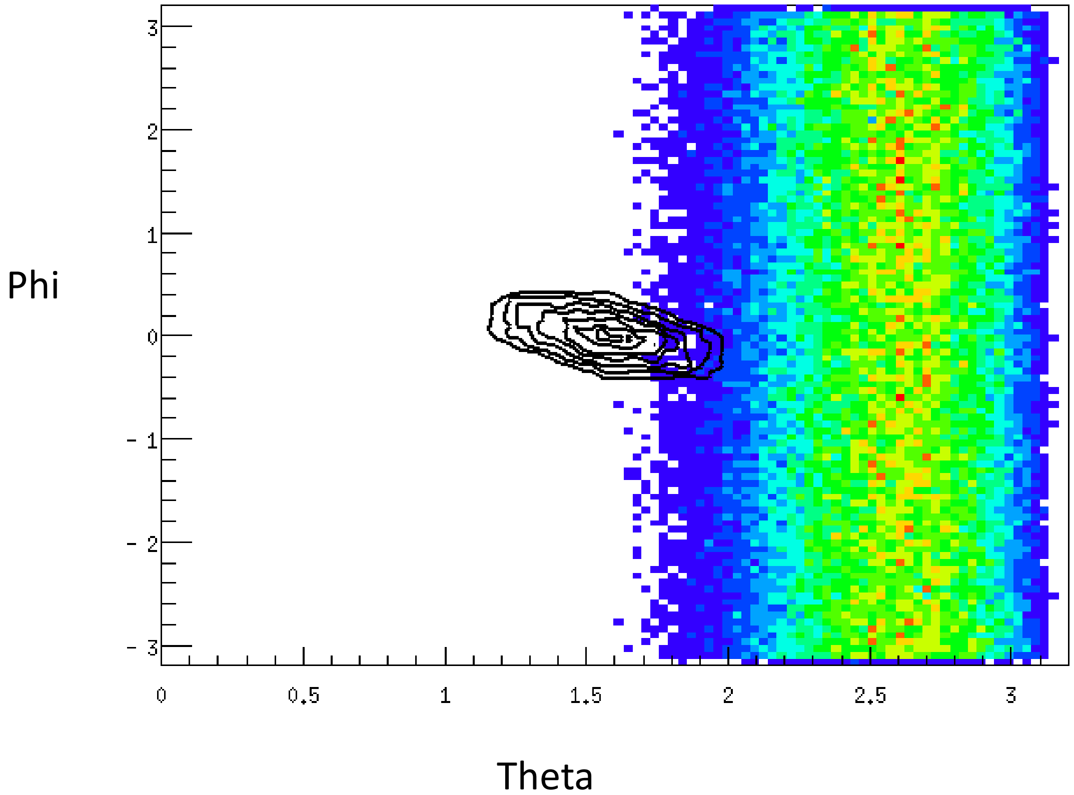


2 det. with 50 cm spacing (for illustration)

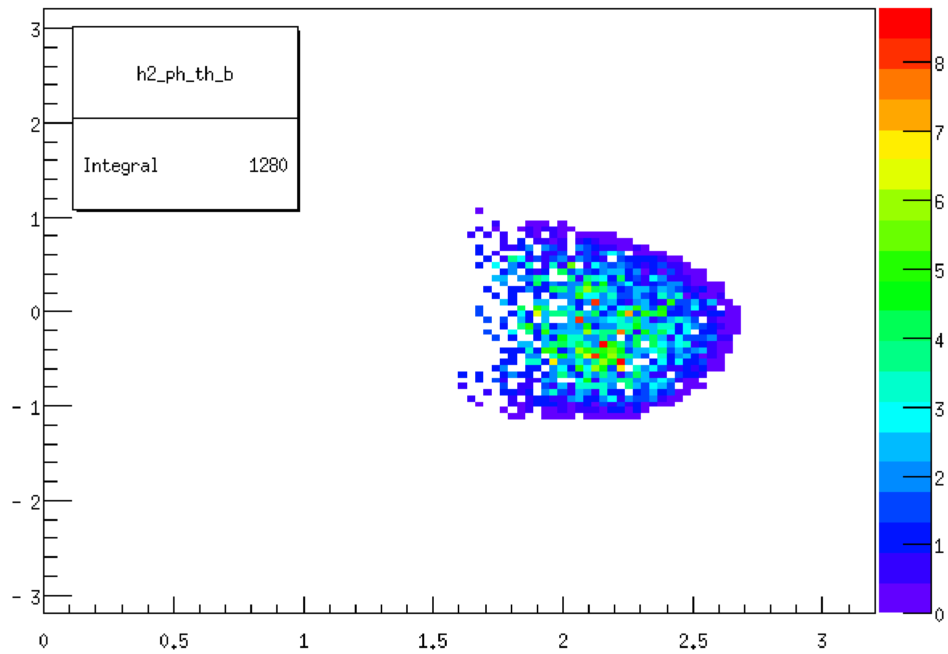


Inclined detector will move the pattern to the right

2 det. with 2m spacing (for illustration)



Number of muons per (θ,ϕ) bin = Number of generated * efficiency of the detector
normalized by the time (gen.SimulatedTime /CRY)



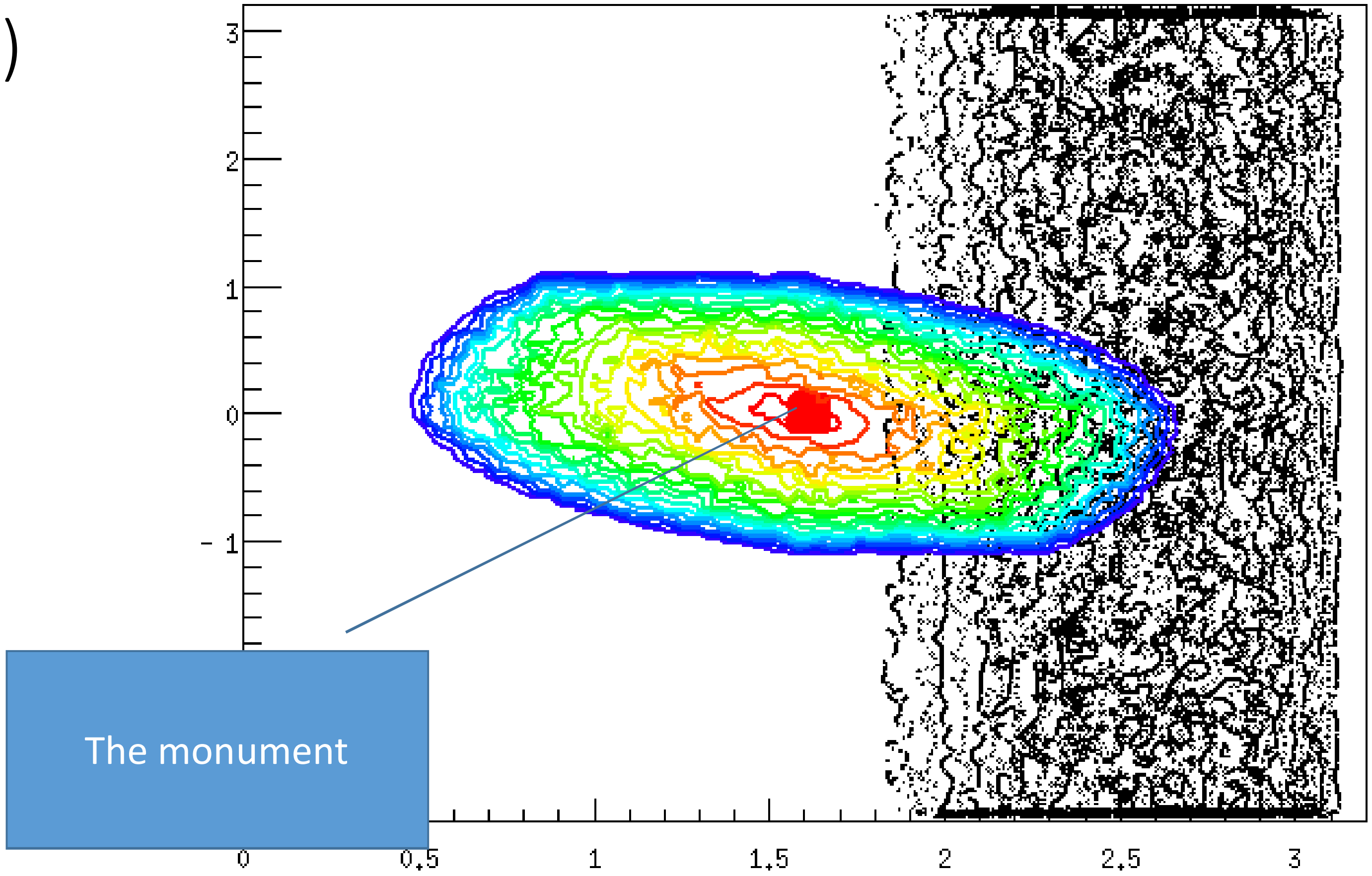
- Muons (E>20 GeV) per hour in the “toy” detector
- Detector horizontal

Exp Muons per hour in the det acceptance (w/o tumulus)

Emin (GeV)	Lbox = 300 m Horizontal	Lbox =10m Horizontal	Lbox = 300 m Det @ 20deg
8	3830	4920	9107
10	2980	3910	6920
15	1830	2470	4095
20	1280	1740	2785
25	900	1220	1907
50	300	430	600
100	70	110	135

ÅDet @ y = 31.5 m
x = 49.0 m
z = -0.5 m

Solid Angle of the monument (seen from the detector)



Full simulation

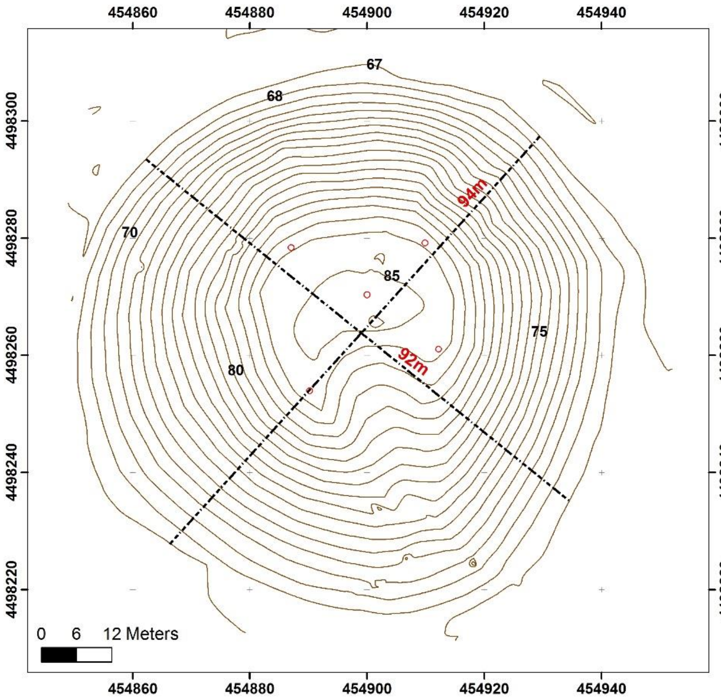
ÅDefine geometry : Tumulus, monument, detectors

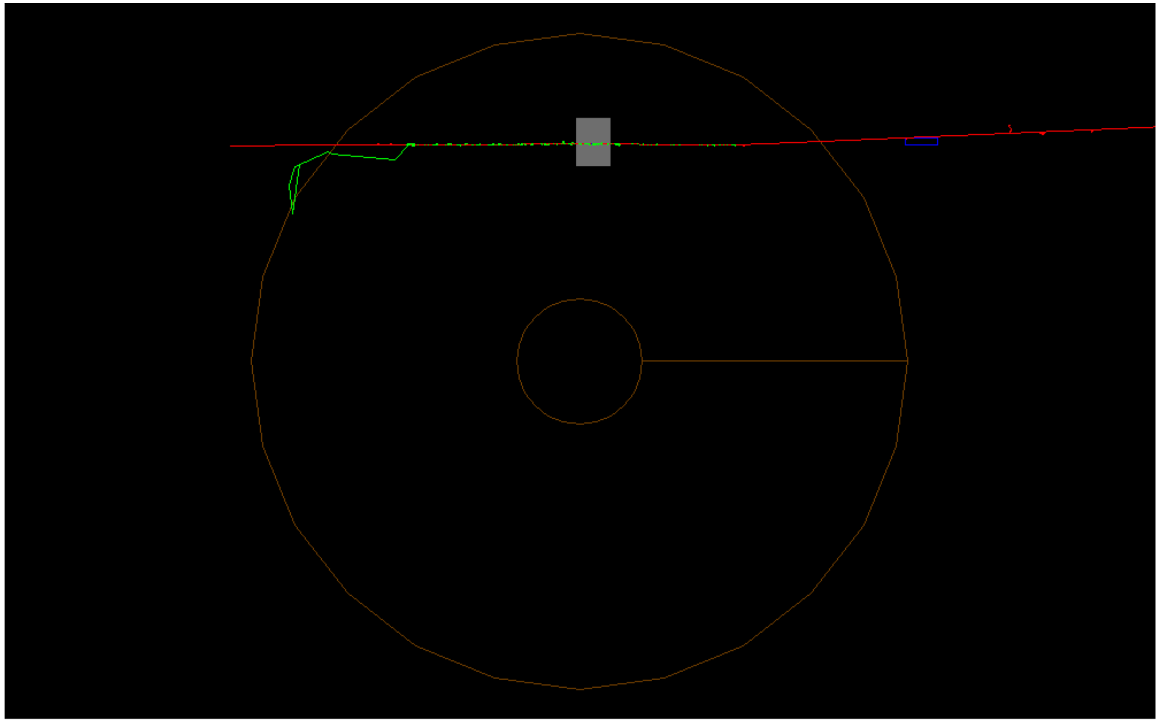
ÅGenerate muons using an energy parametrization from CRY, and limited θ and ϕ range

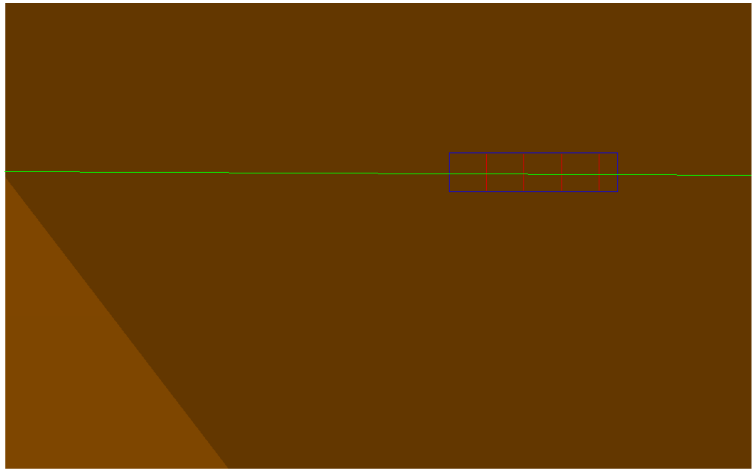
ÅTrack each muon through matter, tumulus soil, marble air, detector material etc and record hits on the detectors if any.

ÅReconstruct the muon track if detected inside the detector layers

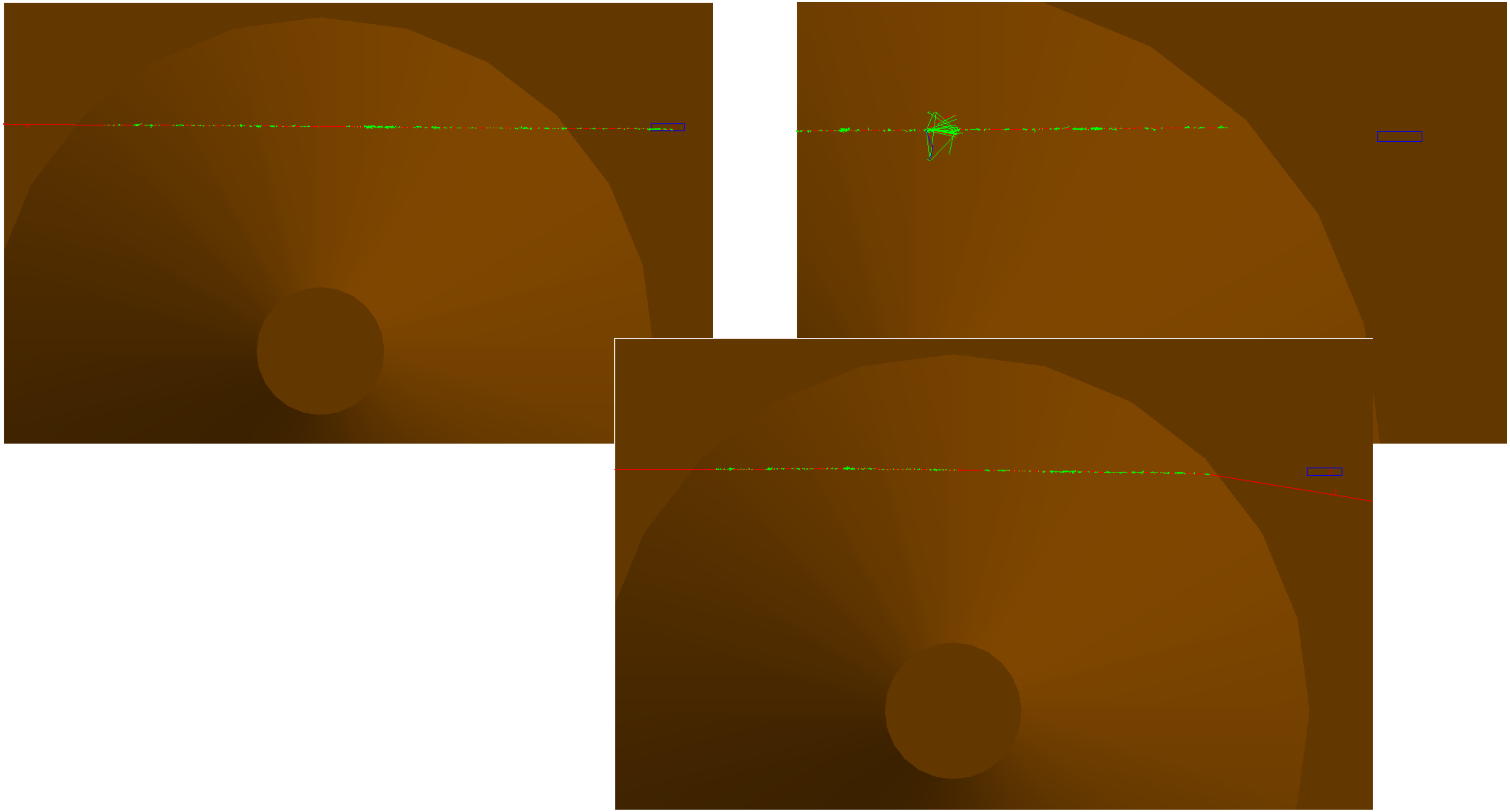
Simulation layout







Tumulus : Cone R_bottom =47m R_top = 9m Dirt with d=2.3gr/cm3
Tomb: Size5x5x7 m, walls 1m thick (CaCO3 or Pb!) placed inside tumulus at R=31.5m and 2.5m below the ground. Air inside tomb
Detector : 4 1x1 m2 layers placed at R=49m in front of the tomb



Two tombs were simulated :

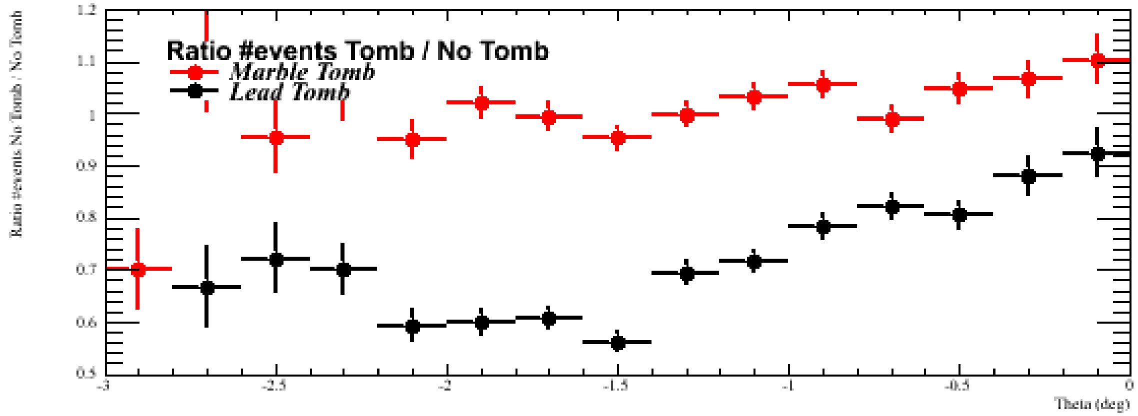
Å A marble tomb

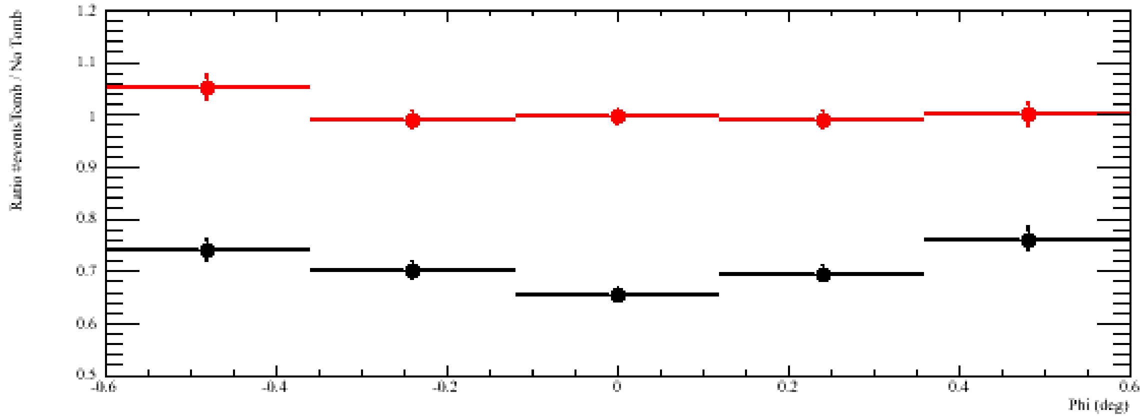
Å A lead Tomb !

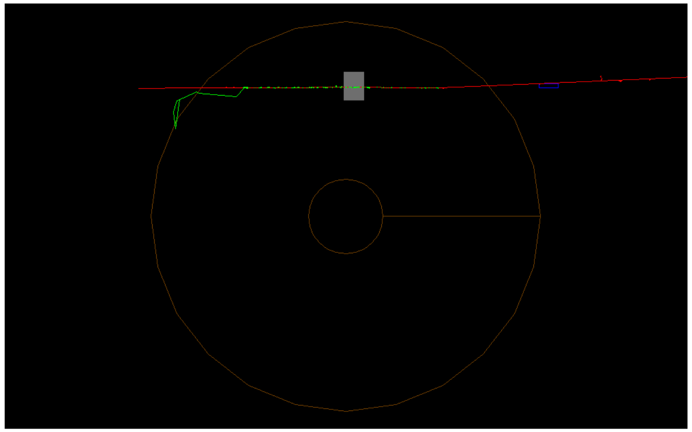
Å 1.2 M events generated to cross the monument if it is there

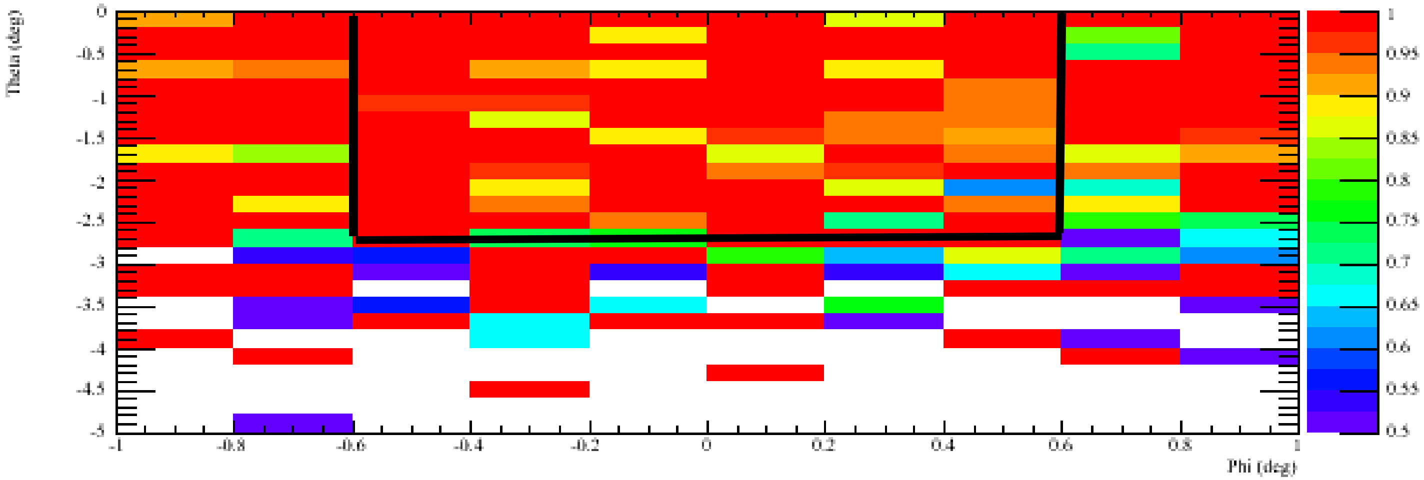
  Å 87 ° < θ < 90° and -0.6 ° < ϕ < 0.6 °

  Å 3 runs : 2 with tombs and 1 without any monument

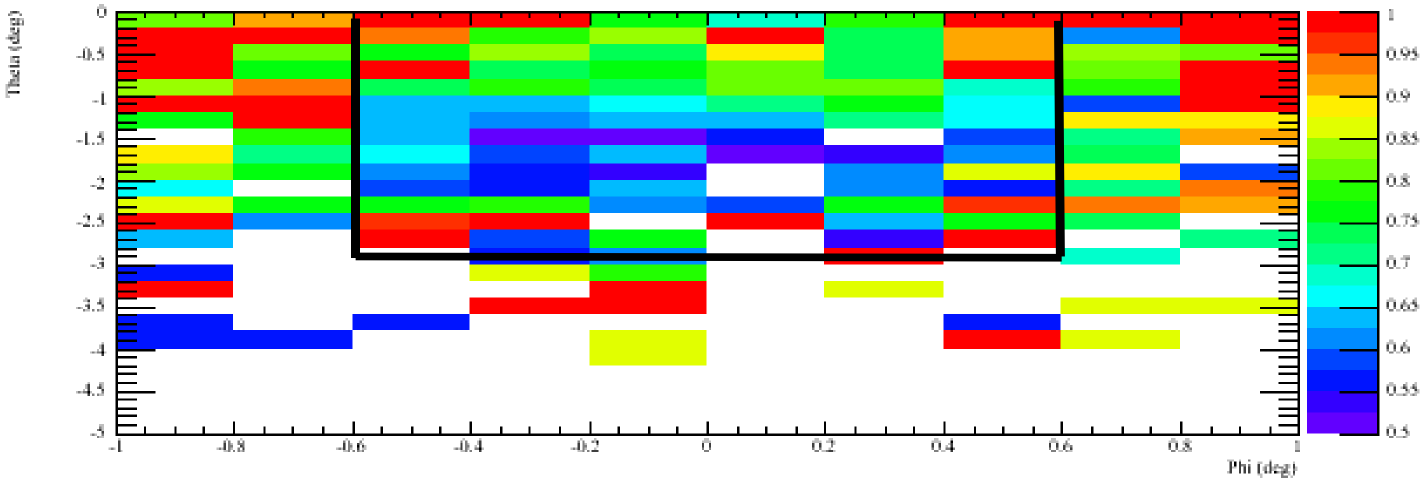






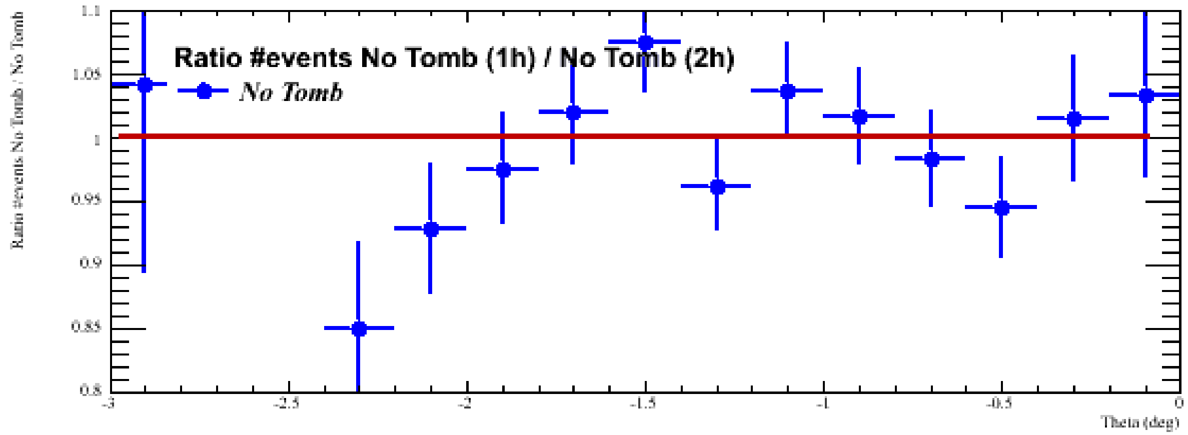


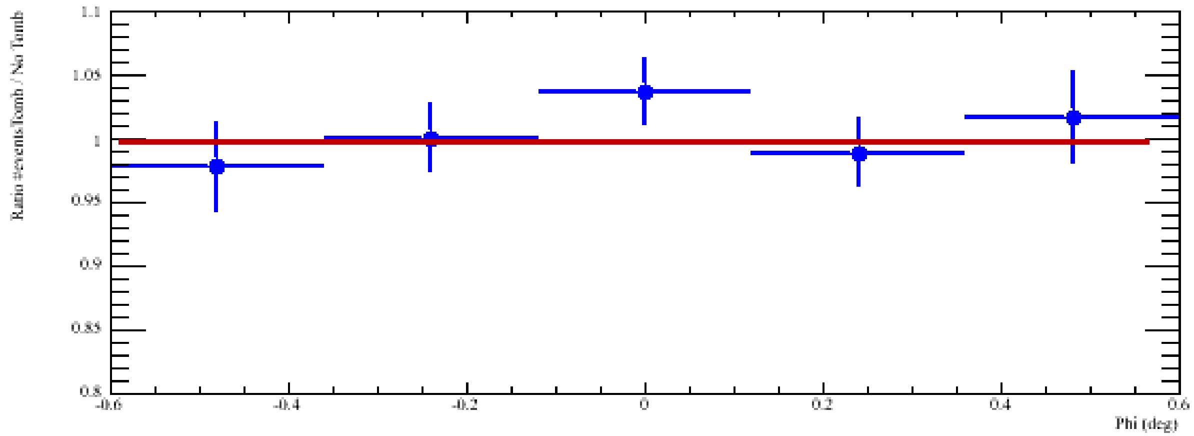
Theta (deg)
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Phi (deg)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5

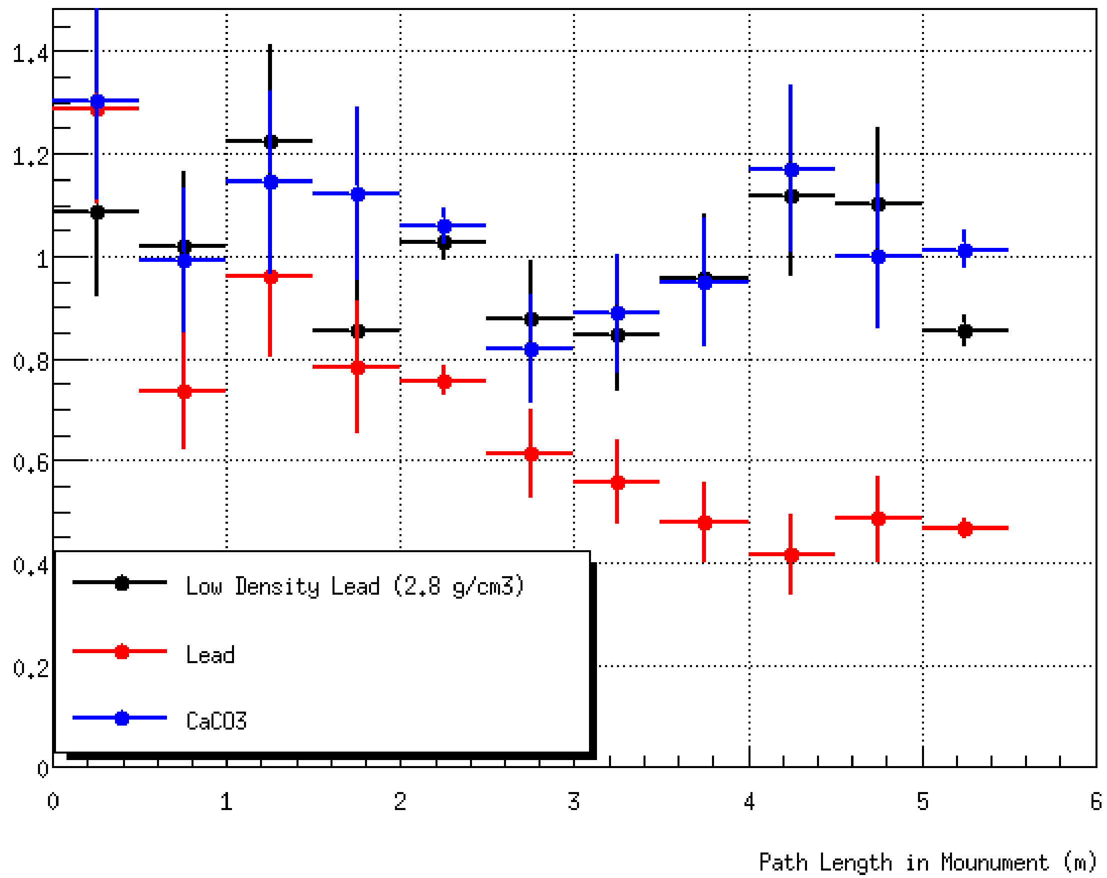


Theta (deg)
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Phi (deg)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5

We have 1.2 M events without any monument.
Using 1st half (1h) of them to compare with second half (2h)







1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
Path Length in Mounument (m)
Low Density Lead (2.8 g/cm3)
Lead
CaCO3

Conclusion

- Detecting a monument inside a tumulus will not be an easy task
  - Low statistics
  - Standard dirt and marble not very different
- Impove simulation
  - Use a different model (Fluka) for cross check
  - Input real soil composition. Need some chemical analysis.
  - Compare with data
- My proposal :
  - We have already one or two set of detectors. It is worthwhile to deploy them after March and make an exploratory run until summer.
  - Depending on findings, improve simulation and decide on a longer campaign