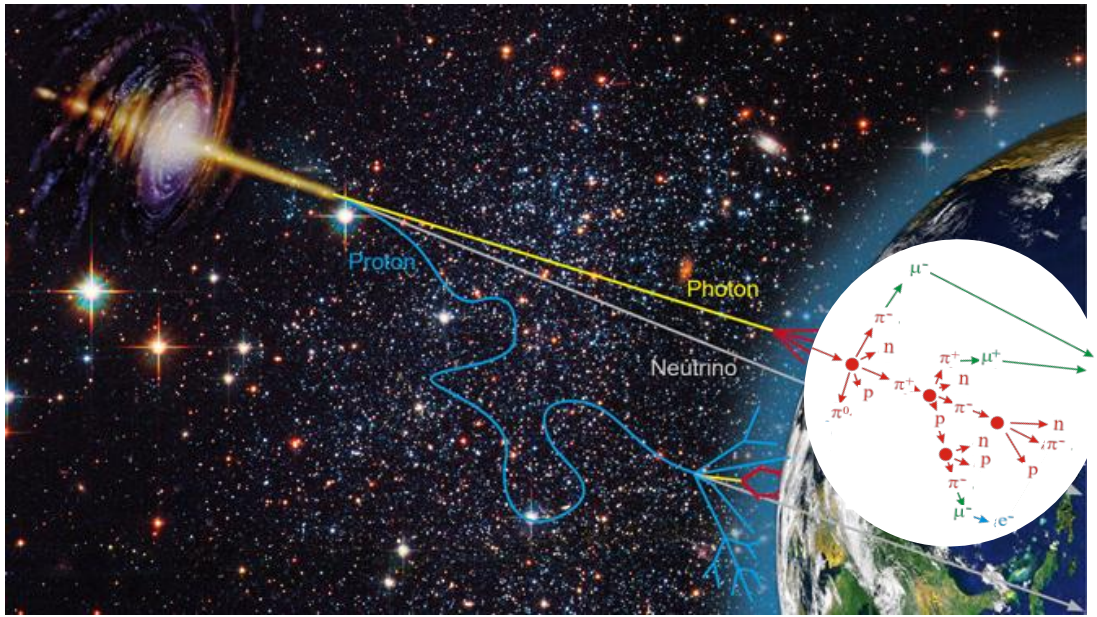
Particle Detection with portable scintillation-based devices

Joaquin Masias
HEP - PUCP

Contents

Cosmic Rays and the Desktop Muon Detector and Simulations on Geant4

Cosmic Rays



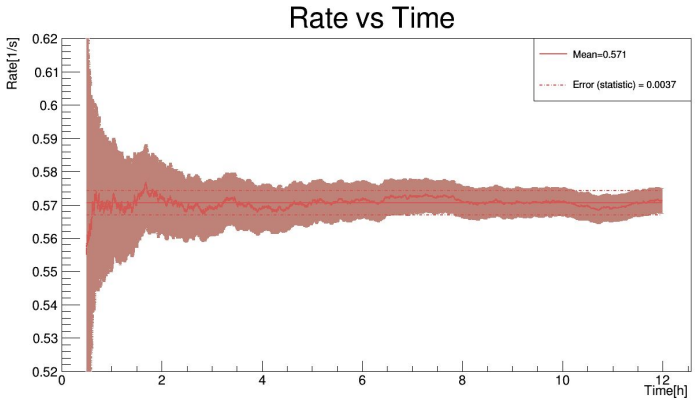
Cosmic rays, mainly protons and ionized nuclei interact with Earth's atmosphere producing primarily pions and kaons which then decay forming showers of particles.

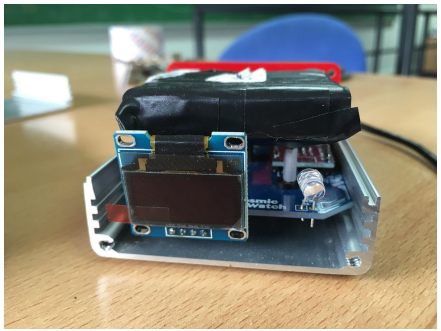
Muons are part of the decay products reaching sea level.

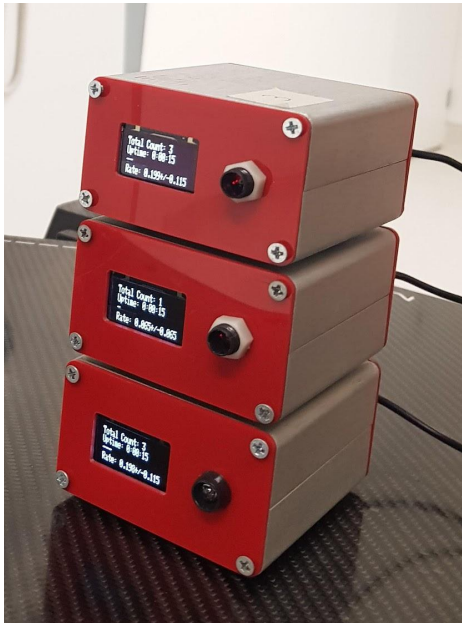
$$p + N \rightarrow p + N + \pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

The Desktop Muon Detector

We use a MIT designed model for a portable, self-contained, Muon Detector[1].







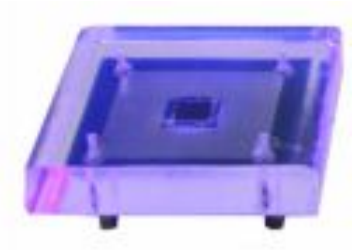
[1] The Desktop Muon Detector: A simple, physics-motivated machine- and electronics-shop project for university students (S. Axani, J. Conrad, C. Kirby) arXiv:1606.01196

The Desktop Muon Detector

We have built 3 of these detectors consisting primarily of:

A Plastic Scintillator:

-Peak Emission ~ 420 nm

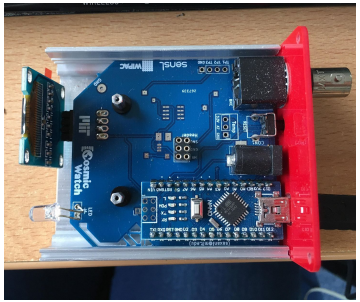


A SiPM:

-SensL C-Series

Circuitry:

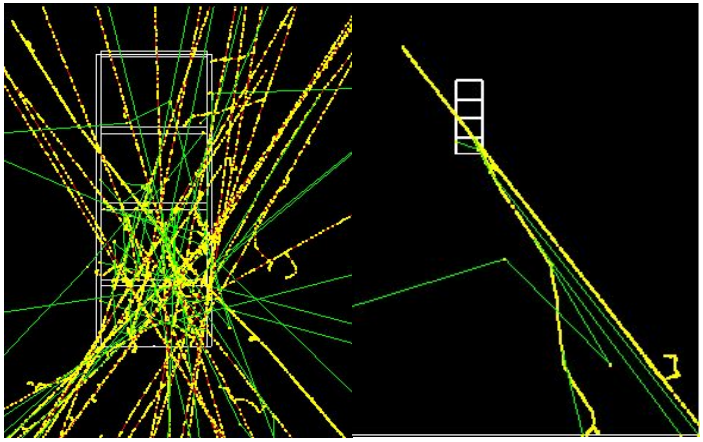
-Double PCB



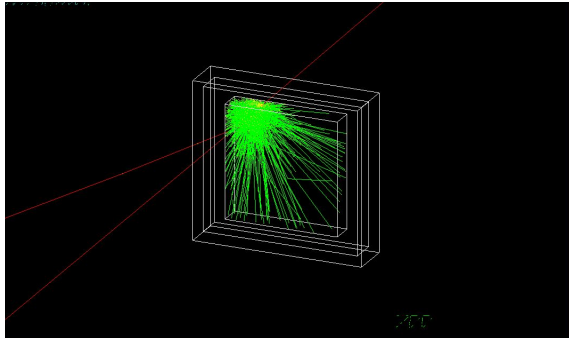
Geant4

Cern Developed Toolkit for the simulation of the passage of particles through matter.

- Geometry of the detector
- Tracking particles(type, energy, source, decay, etc)
- Atmospheric muon angular and energy distribution



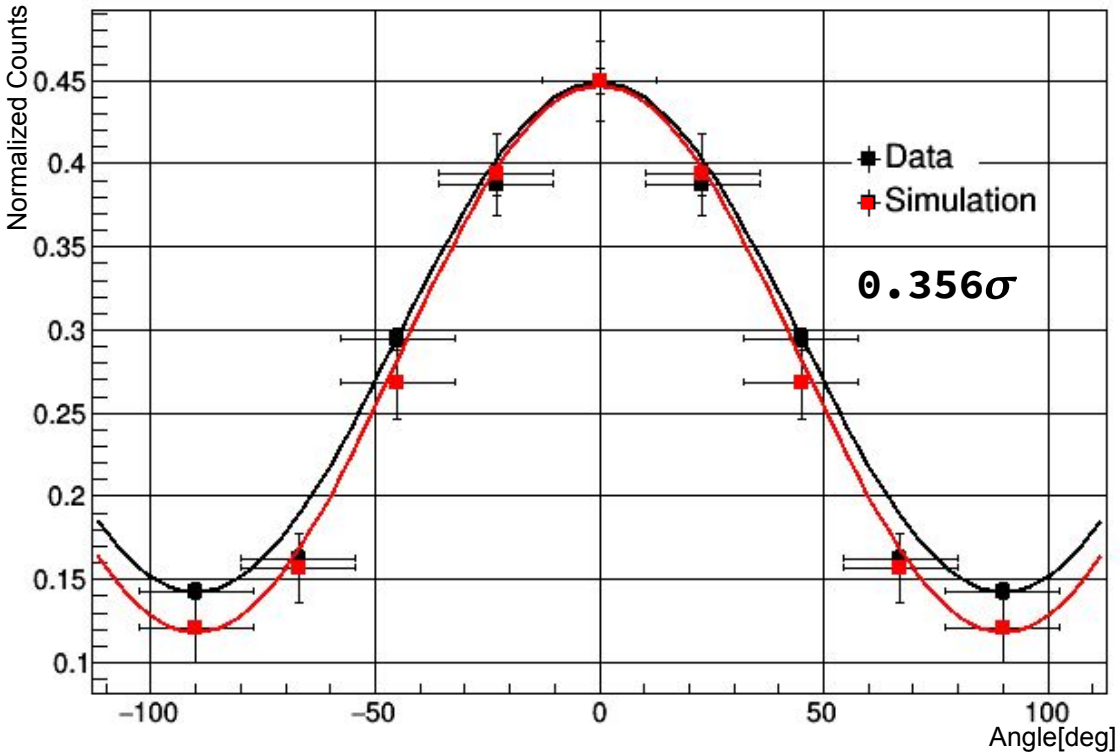
4 storey building simulation

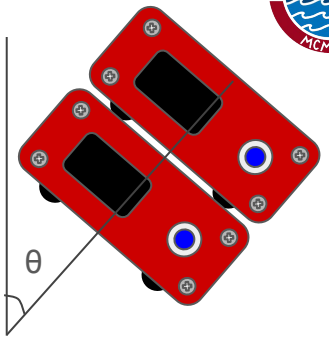


Particle passing through detector

Angular Measurements and Coincidences

2 Detector Coincidence





Fit: A + Bcos²(θ)

Data:

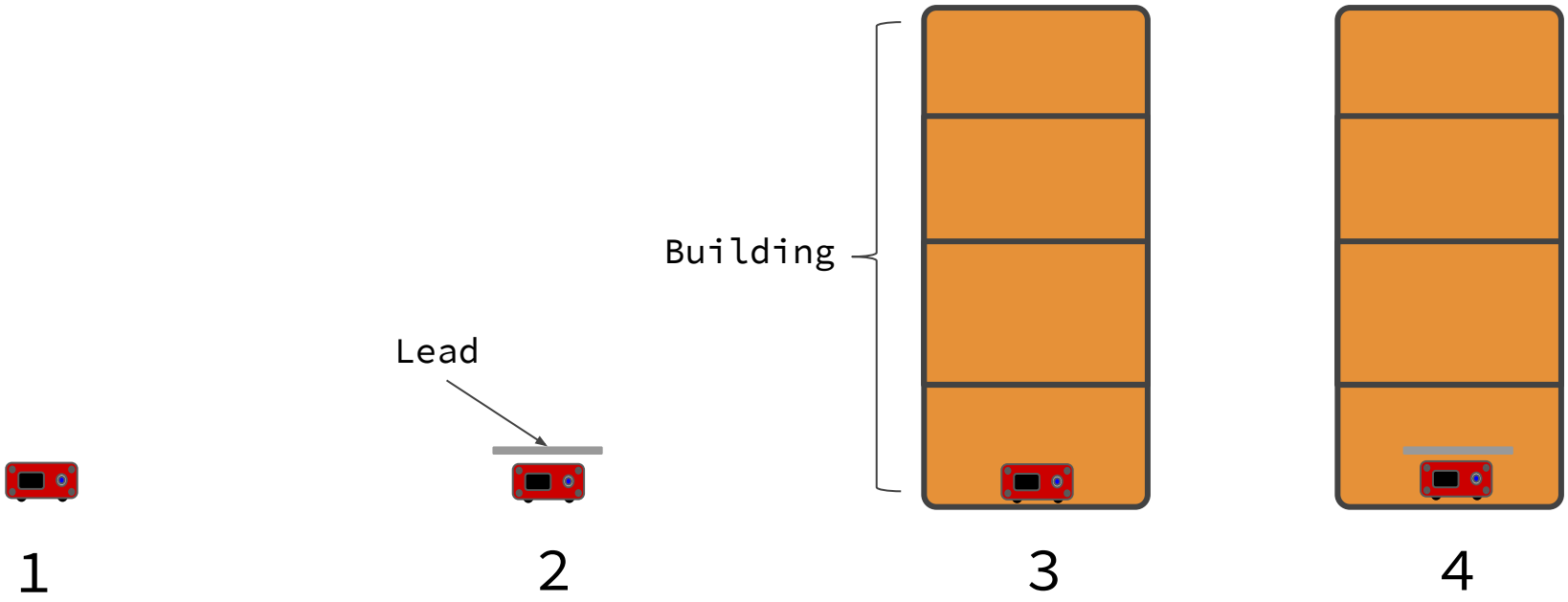
A= 0.143 ± 0.004
B= 0.307 ± 0.008
(χ2)/NDF= 0.111

Simulation:

A= 0.118 ± 0.013
B= 0.329 ± 0.026
(χ2)/NDF= 0.028

Effects of large structures on Muon Detection

Schematics



Attenuation Comparison

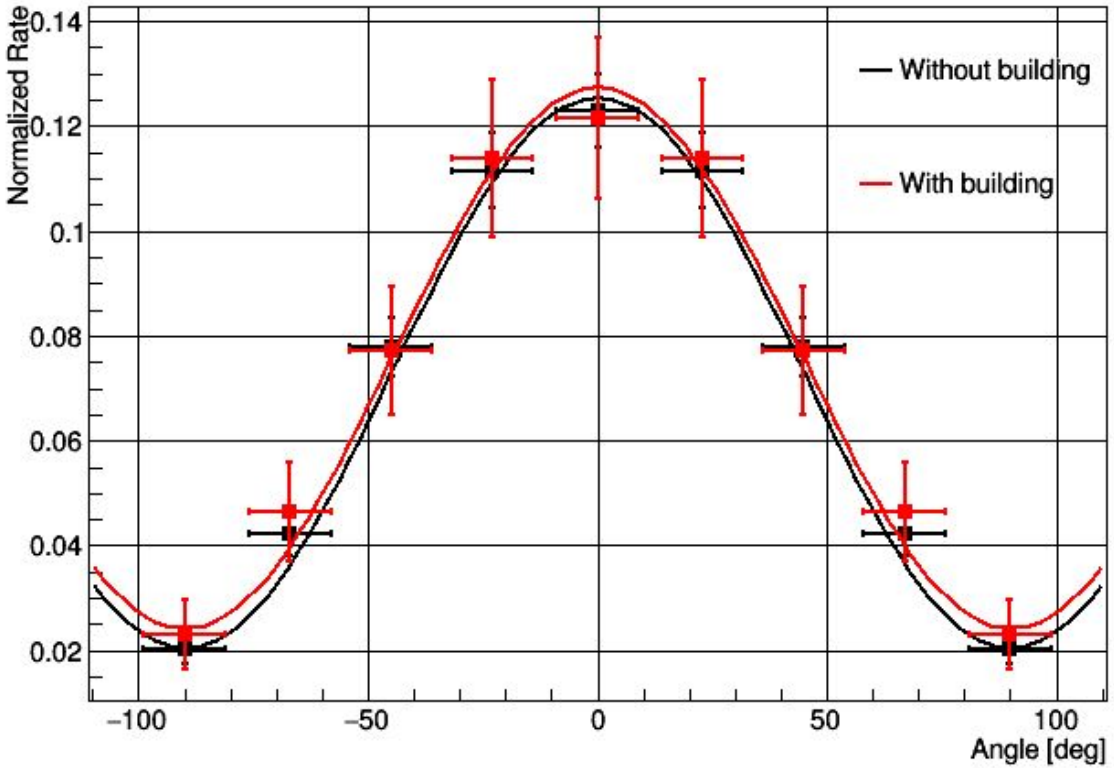
Ratio: $\frac{\text{1.5cm thick lead plate}}{\text{open field}}$

Ratio(Measurement)	0.99 ± 0.01
Ratio(Simulation)	1.011 ± 0.06

$\frac{\text{4 storey building}}{\text{open field}}$

Ratio(Measurement)	0.99 ± 0.01
Ratio(Simulation)	1.005 ± 0.06

Building Attenuation Simulation



Fit: A + Bcos²(θ)

Without building:

A = 0.021 +/- 0.002

B = 0.105 +/- 0.006

(χ2)/NDF = 0.11

With building:

A = 0.024 +/- 0.005

B = 0.103 +/- 0.012

(χ2)/NDF = 0.09

Combined Attenuation Simulation

Open field

Total events:	525
Events without muons:	52
Electrons per event:	0.27

4 storey building + 1.5 cm lead plate

Total events:	490
Events without muons:	74
Electrons per event:	0.397

Combined Attenuation Simulation

Open field

Total events:	525
Events without muons:	52
Electrons per event:	0.27

4 storey building + 1.5 cm lead plate

Total events:	490
Events without muons:	74
Electrons per event:	0.397

Ratio(Measurement)	0.87 ± 0.02
Ratio(Simulation)	0.933 ± 0.06

Estimated error = 0.997σ

Radioactive Source Measurements

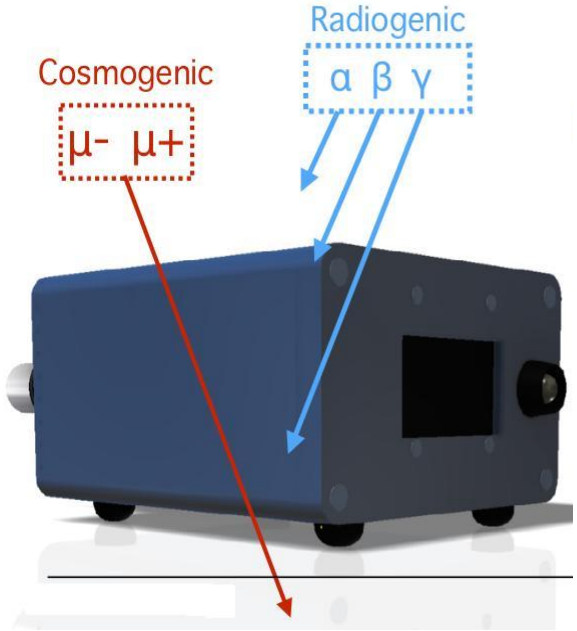
Particle Sources

Atmospheric Muons

Alpha Particles

Beta Particles

Gamma Particles



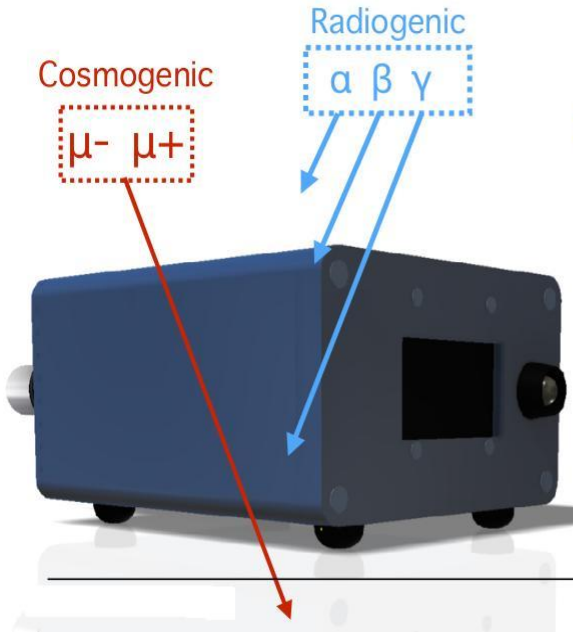
Particle Sources

Atmospheric Muons

Alpha Particles

Beta Particles

Gamma Particles



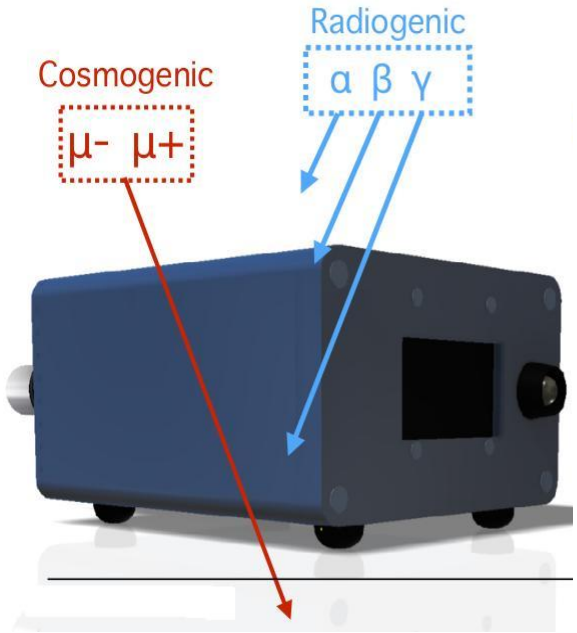
Particle Sources

Atmospheric Muons

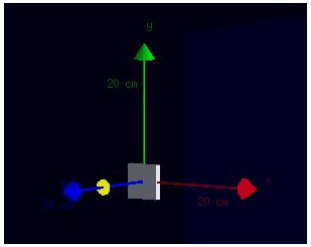
Alpha Particles

Beta Particles

Gamma Particles



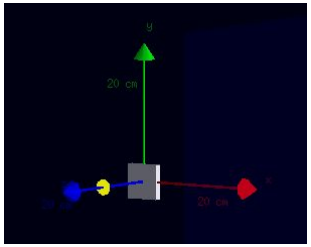
Activity Measurements



2 Sr90 sources dated 2015 and 2000 with initial activity 0.1μCi

	Rate(events/s)
Sr90-1	5.79 ± 0.05
Sr90-2	8.73 ± 0.05

Activity Measurements



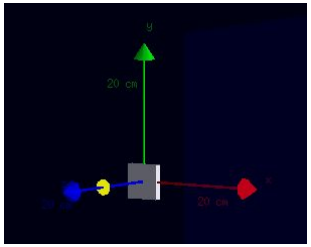
2 Sr90 sources dated 2015 and 2000 with initial activity 0.1μCi

	Rate(events/s)
Sr90-1	5.79 ± 0.05
Sr90-2	8.73 ± 0.05

Sr90-1/Sr90-2	Ratio of rates
Theoretical	0.695 ± 0.02
Measured	0.673 ± 0.05

Estimated error = 0.409σ

Activity Measurements



2 Sr90 sources dated 2015 and 2000 with initial activity 0.1μCi

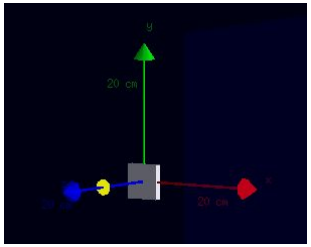
	Rate(events/s)
Sr90-1	5.79 ± 0.05
Sr90-2	8.73 ± 0.05

Sr90-1/Sr90-2	Ratio of rates
Theoretical	0.695 ± 0.02
Measured	0.673 ± 0.05

Estimated error = 0.409σ

Factor (μCi*s/event)
0.0097 ± 0.0001

Activity Measurements



2 Sr90 sources dated 2015 and 2000 with initial activity 0.1μCi

	Rate(events/s)
Sr90-1	5.79 ± 0.05
Sr90-2	8.73 ± 0.05

Sr90-1/Sr90-2	Ratio of rates
Theoretical	0.695 ± 0.02
Measured	0.673 ± 0.05

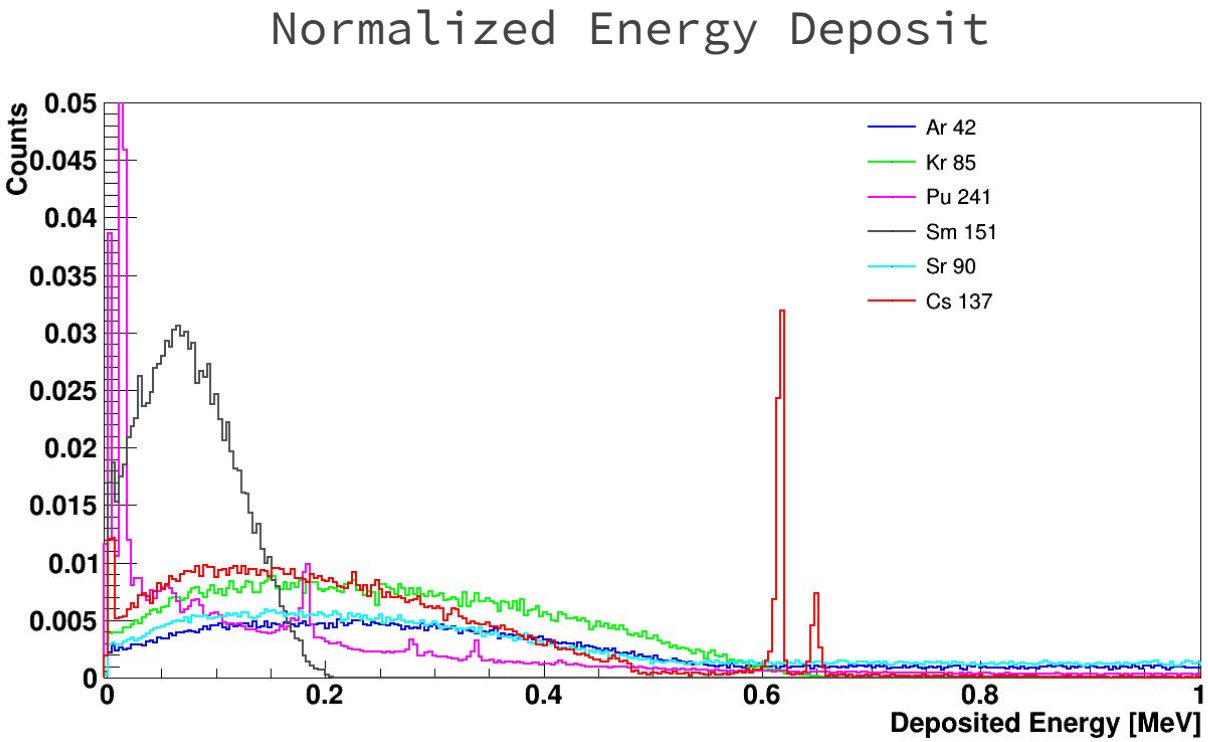
Estimated error = 0.409σ

Factor (μCi*s/event)
0.0097 ± 0.0001

	Activity(μCi)
Sr90-2(known)	0.0926 ± 0.001
Sr90-1(known)	0.0644 ± 0.002
Sr90-1(estimated)	0.0623 ± 0.005

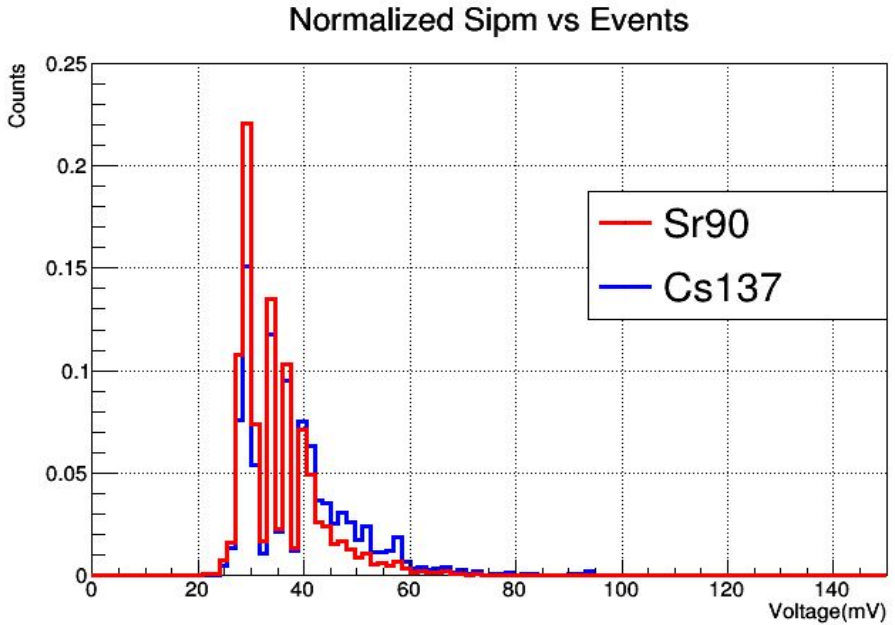
Estimated error = 0.402σ

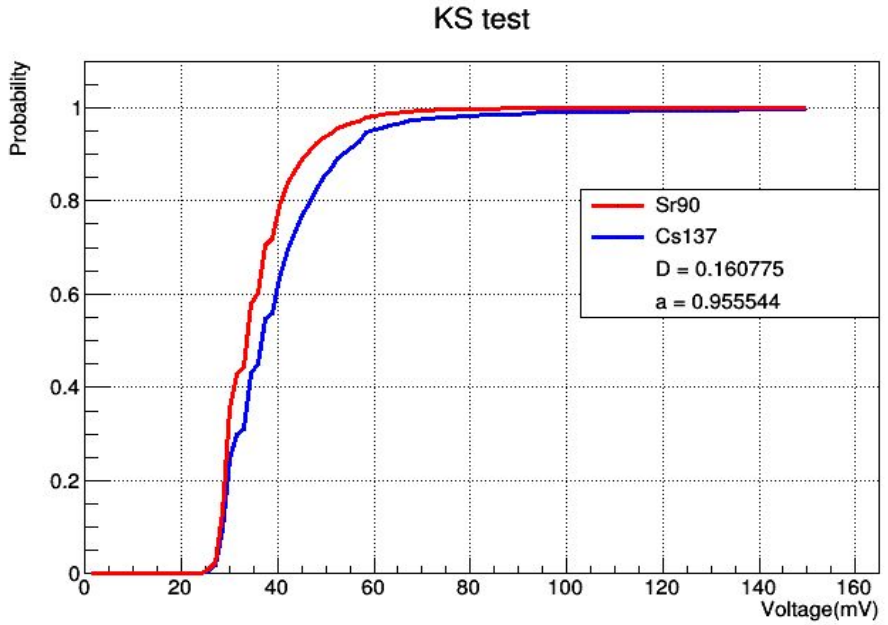
Source Simulation



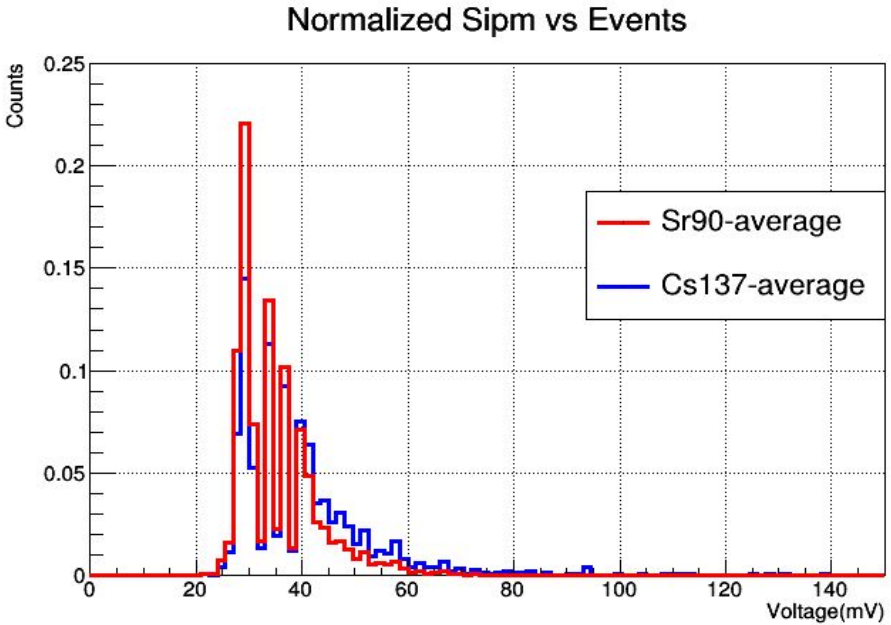
Source Recognition

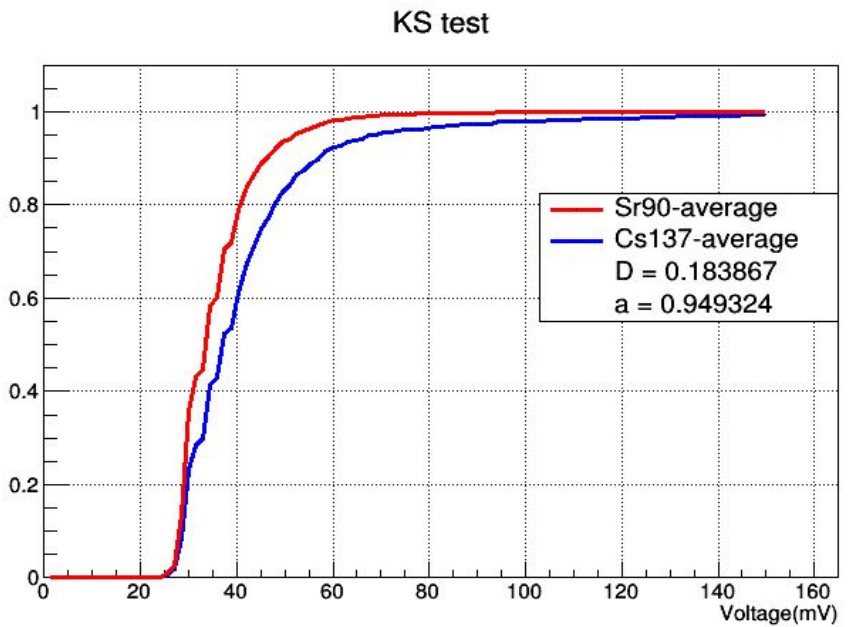
Two types of beta sources 2 Sr90(0.1µCi) and 2 Cs137(0.25µCi and 10µCi).





Averaged Voltage Spectra





KS Tests

D parameter and significance level

D/alpha	Muon background	Sr-1	Sr-2	Cs-1	Cs-2
Muon background	0/1	0.22/0.939	0.22/0.939	0.08/0.977	0.11/0.97
Sr-1		0/1	0.006/0.998	0.21/0.943	0.16/955
Sr-2			0/1	0.21/0.943	0.16/0.95
Cs-1				0/1	0.03/0.991
Cs-2					0/1

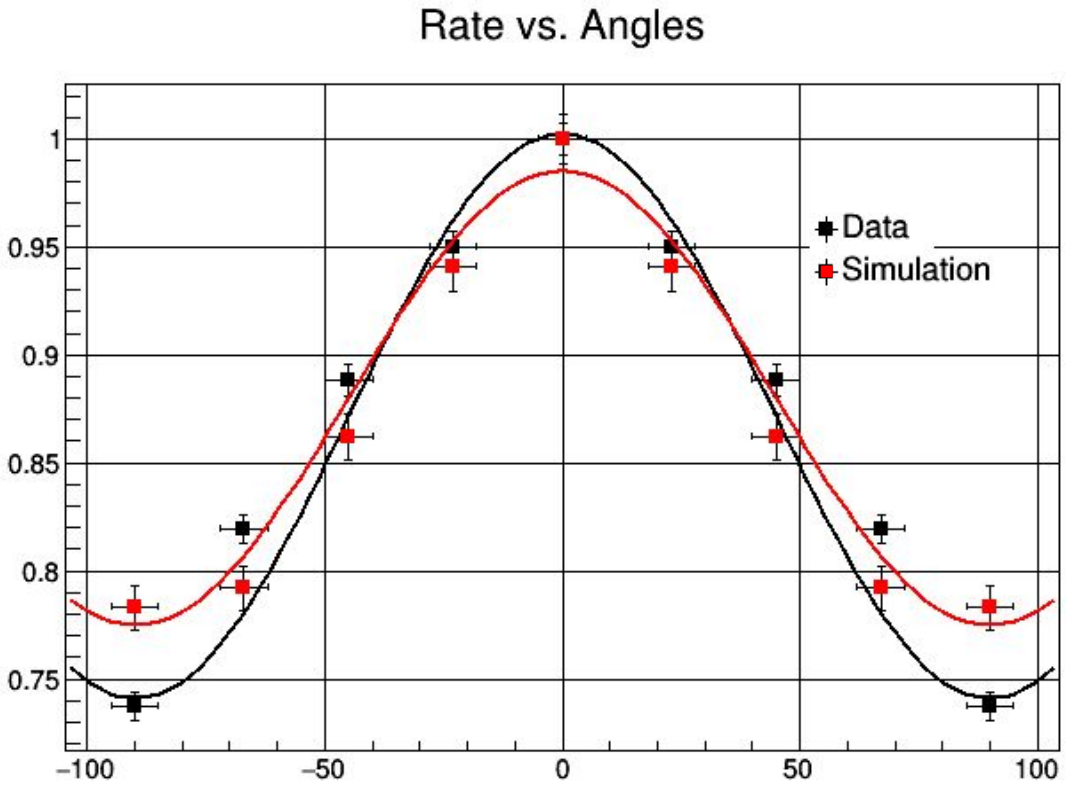
Summary and Conclusions

- The atmospheric Muon distribution follows a $\mathrm{Cos}(\theta)^2$ law.
- Electron are produced inside building due to atmospheric muons.
- Desktop Muons Detectors can be repurposed to measure and identify beta sources.

Thanks and Credits

Dr. Alberto Gago
Dr. José Luis Bazo
Lucía Coll
Franco Delgado
Alicia Pérez

Total Rates



Fit: A + Bcos²(π*x/180)

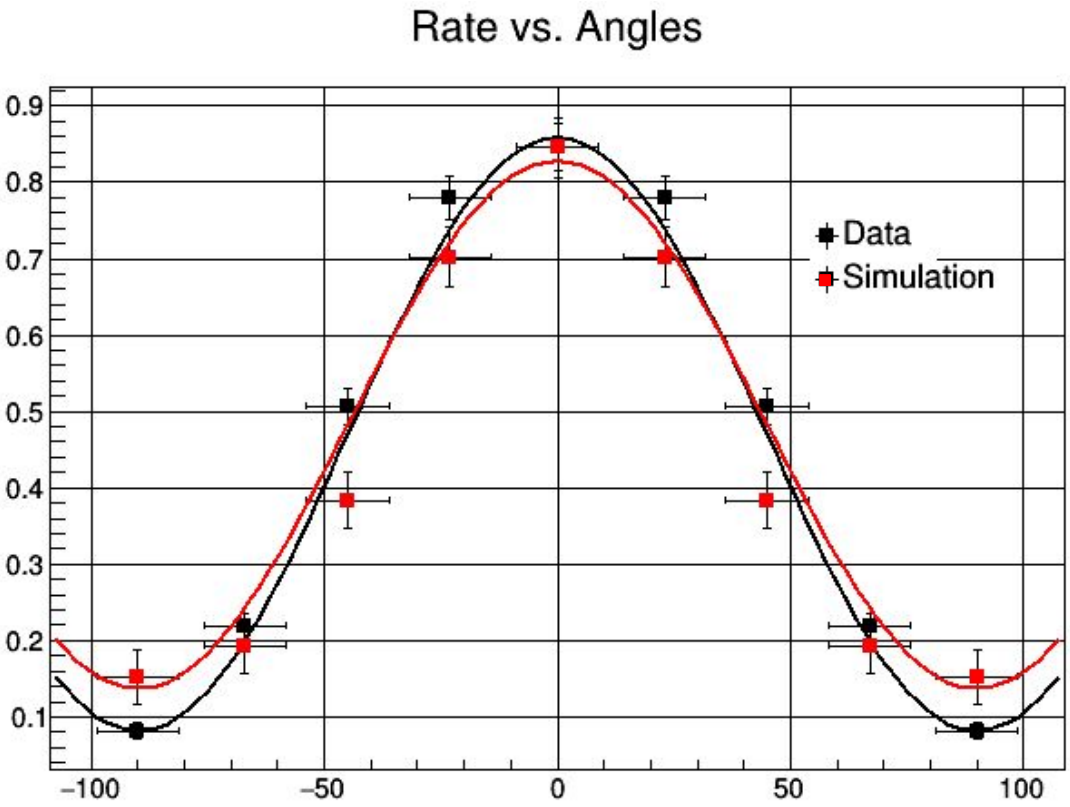
DMD2:

A= 0.741033 ± 0.0050075
B= 0.261226 ± 0.00837512
(χ2)/NDF= 1.72802

Simulation:

A= 0.774960 ± 0.00614009
B= 0.210009 ± 0.0118004
(χ2)/NDF= 0.97887

3 Detector Coincidence



Fit: A + Bcos²(π*x/180)

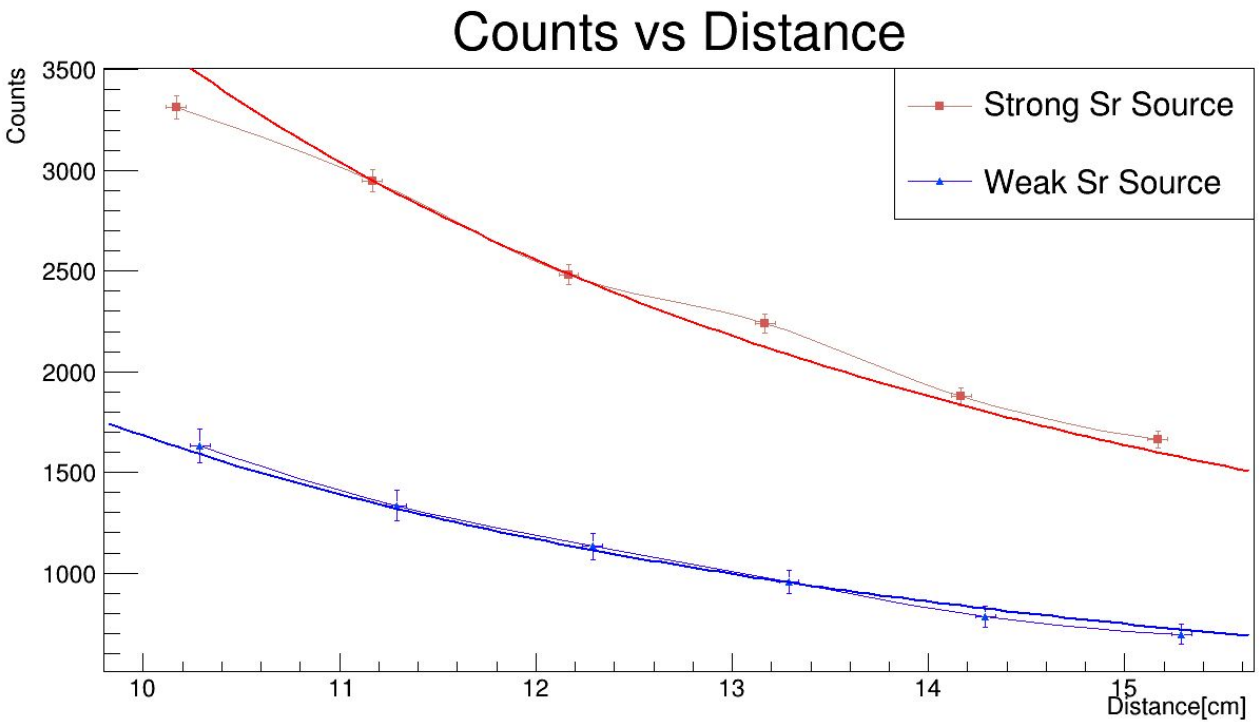
Data:

A= 0.0819934 ± 0.0076649
B= 0.775361 ± 0.0287548
(χ2)/NDF= 0.11581

Simulation:

A= 0.137781 ± 0.0224595
B= 0.689859 ± 0.0426924
(χ2)/NDF= 0.42655

Counts vs Distance



Fit: A/x^2

Strong source:

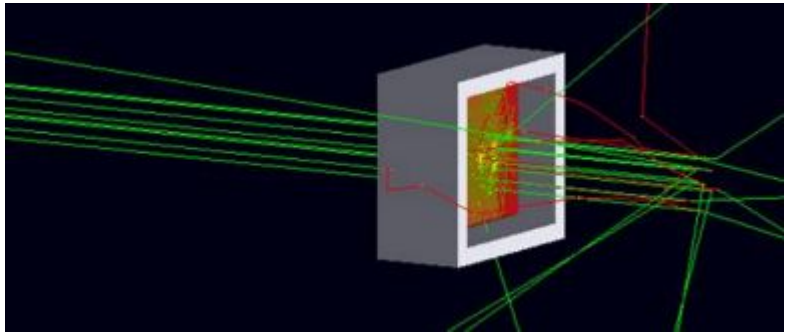
$A=3.681 \times 10^5 +/- 3.352 \times 10^3$

$\chi^2 = 4.434$

Weak Source:

$A=1.683 \times 10^5 +/- 4.137 \times 10^3$

$\chi^2 = 0.236$



Coincidences vs Distance

$$g(y) = c_1 + \frac{c_2}{y} + atan(\frac{c_3}{y})$$