UMD: Simulating the calibration of the integrator

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Counter vs Integrator

Counter mode:

- Independently handles the 64 SiMP signals through a discriminator
- "1-bit" is output if the signal is above the discriminator threshold, and "0-bit" otherwise
- Muons can be identified as sequences of "1" s in the binary traces

Integrator mode:

- The 64 SiPM are summed, the output signal is based on the total signal charge
- The number of muons can be estimated by dividing the signal charge by the mean charge of a single muon

Motivation

Calibrate the integrator with the new Simulation on Offline:

- StandardApplications/MdSdSSdSimulation
- StandardApplications/MdSdSSdReconstruction

Inject one muon on the UMD → **Get Charge with the integrator**

Simulate many muons (changing energy, angle) → **Charge Histogram** → **Mean Charge of the muon**

To do this, modify the applications:

- Particle Injector (in the Module Sequence of simulation)
- "Only Muons" on G4StationSimulator (bootstrap): Only Muons are injected in scintillators (no e+/e- from ionization)

Simulation

```
<moduleControl>
  <module> EventFileReaderOG </module>
  <module> EventGeneratorOG </module>
  <loop numTimes="1" pushEventToStack="yes">
  <loop numTimes="1" pushEventToStack="no">
      <module> ParticleInjectorNEU </module>
      <module> G4StationSimulatorOG </module>
   </loop>
  <module> MdOptoElectronicSimulator </module>
  <module> ClearParticleLists  </module>
  <module> EventFileExporterOG </module>
  </loop>
</moduleControl>
```

Module Sequence

- The type of particle
- How many?
- Where to inject?
- The energy

Simulation of the Sd, SSd and Md scintillators

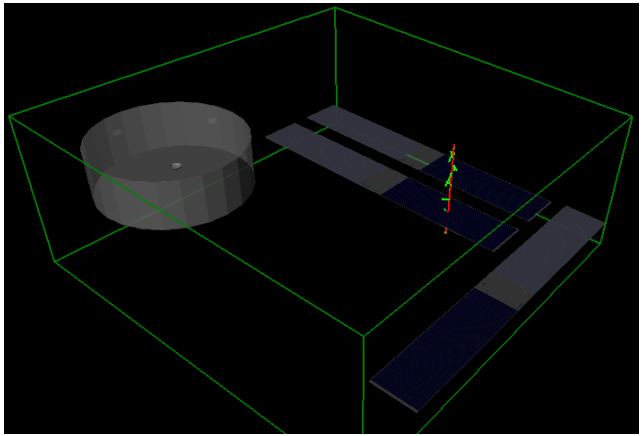
SiPM/PMT and electronics simulation

force the Sd to trigger

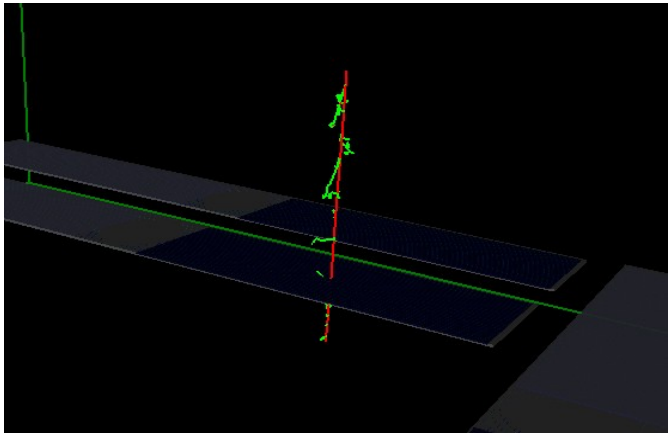
```
<configLink id="MdOptoElectronicSimulator">
  <MdOptoElectronicSimulator>
      <forcedSDTrigger> 1 </forcedSDTrigger>
  </MdOptoElectronicSimulator>
</configLink>
```

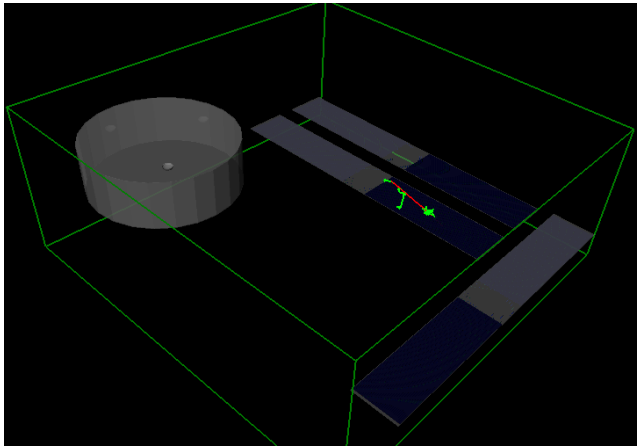
Bootstrap

Visualization with view3dscene

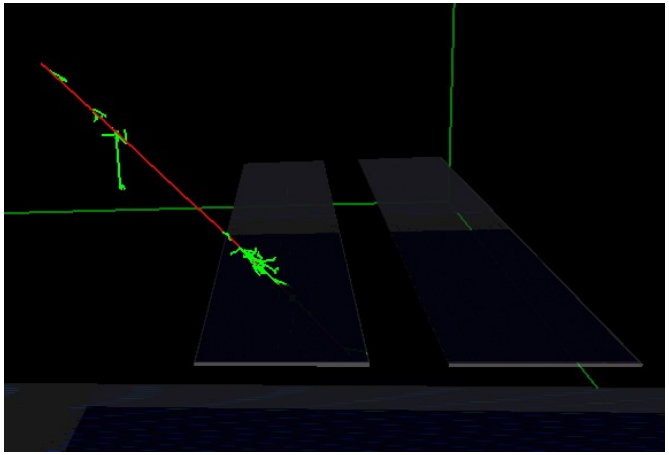


Vertical Muon

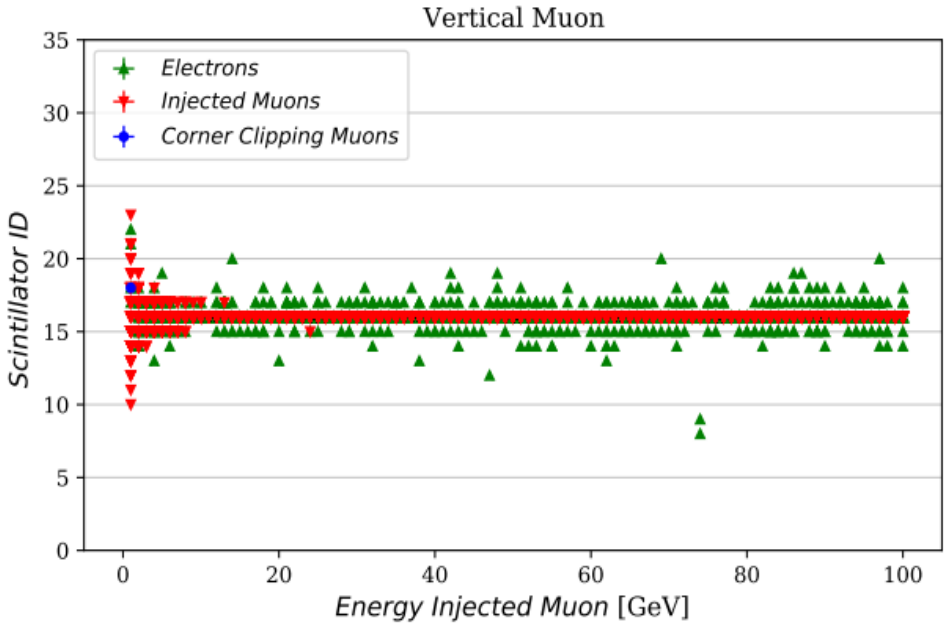


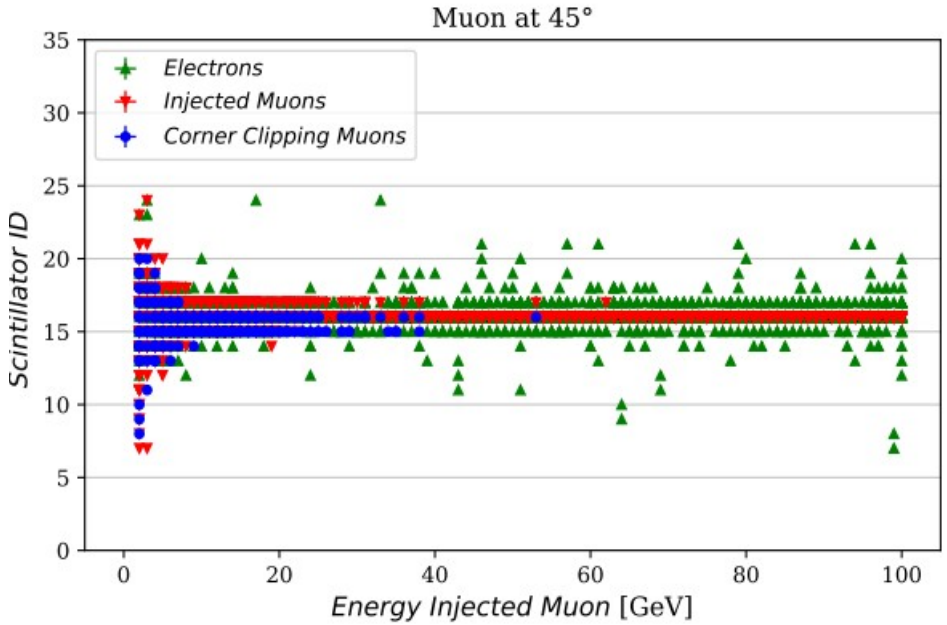


Muon at 45°

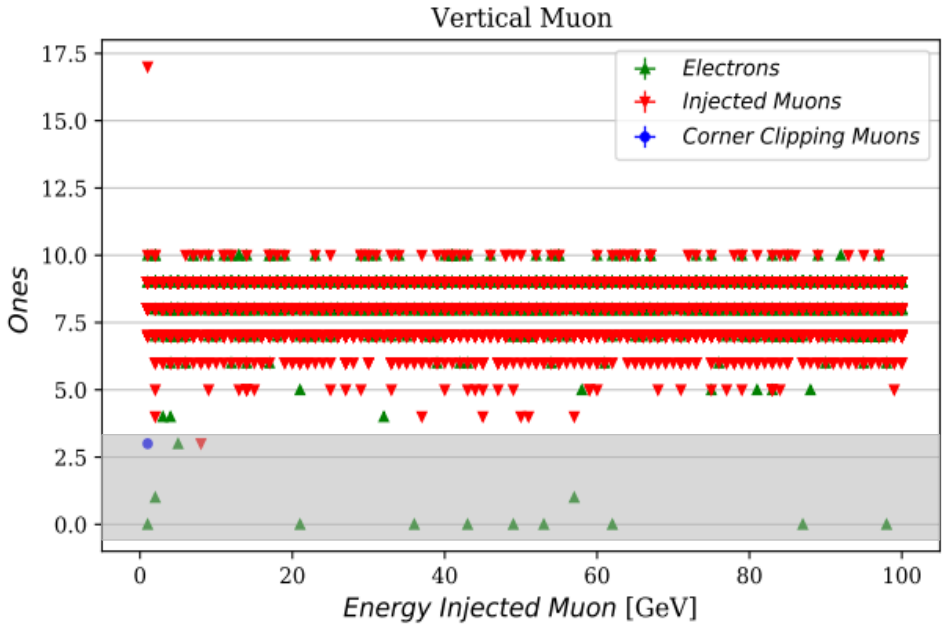


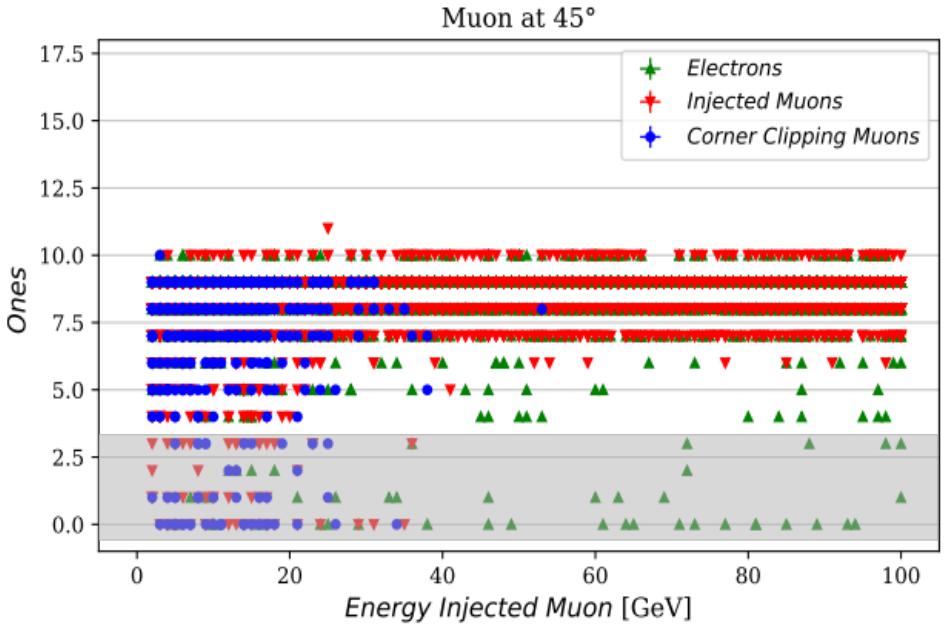
Scintillator Id for particle type





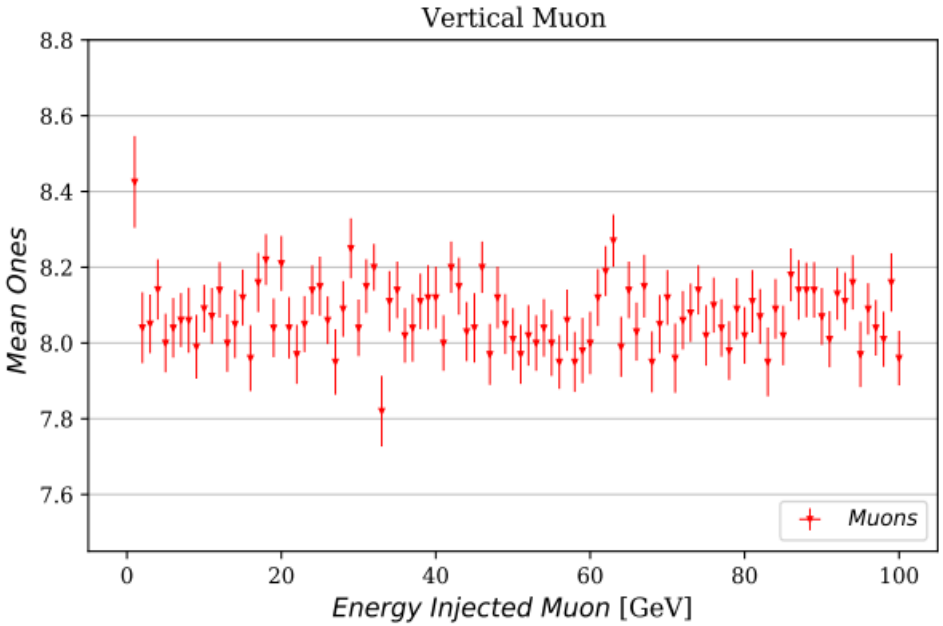
Binary traces for particle type

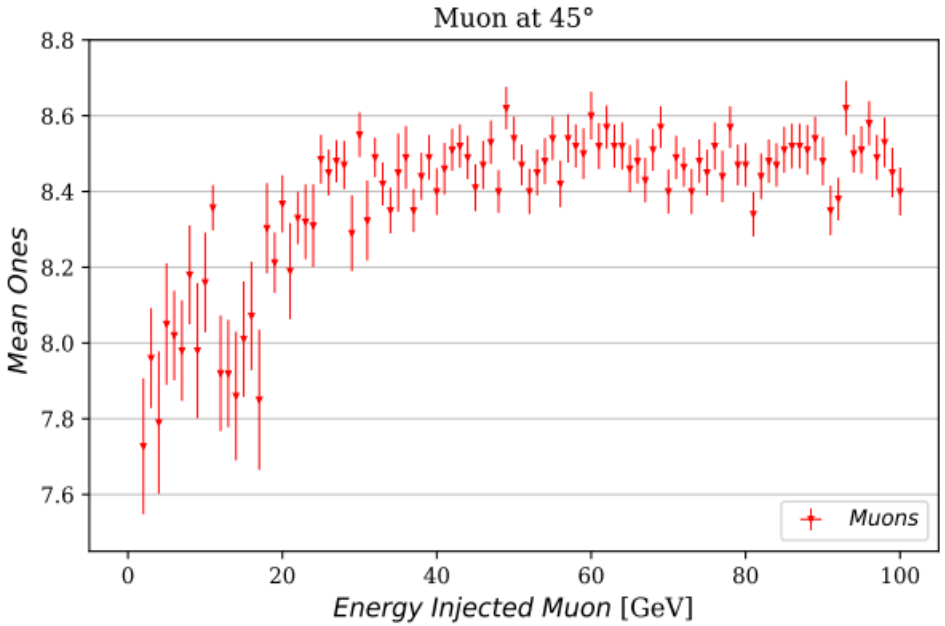




First condition to store calibration in the field is having from 4 to 12 Ones, most muons pass the counting strategy "1111x" for SiPM

Mean ones on binary for muons





Zenith angle dependence

Distribution of atmospheric muons

↓

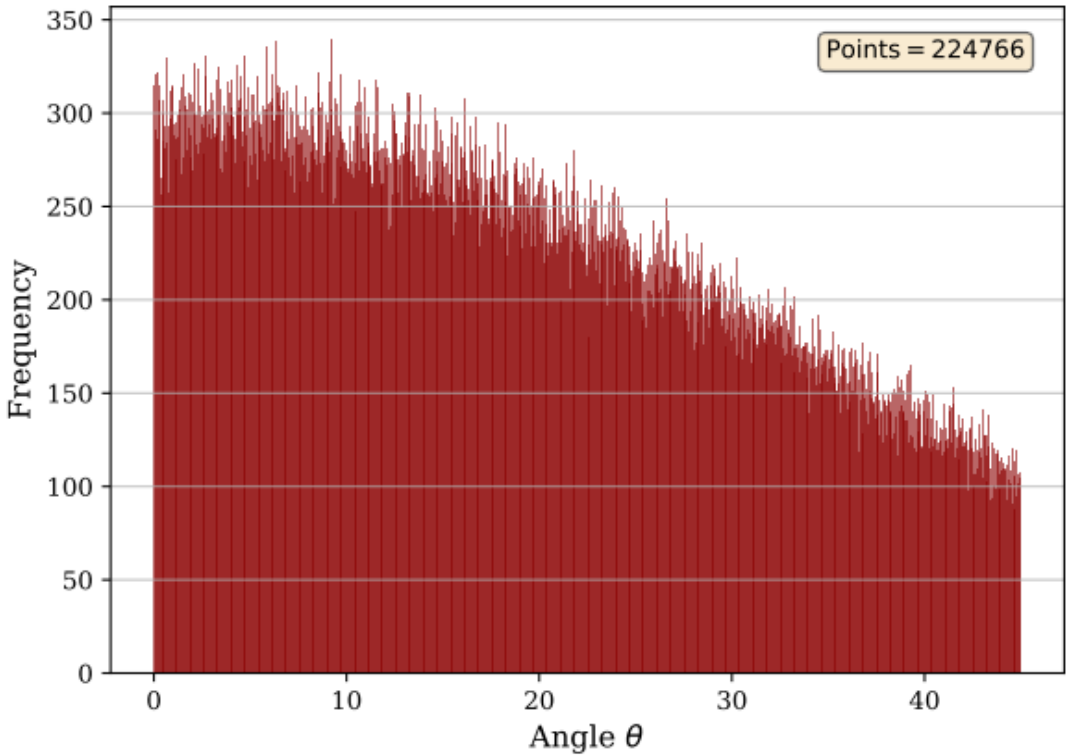
follows a $\cos^2(\theta)$

↓

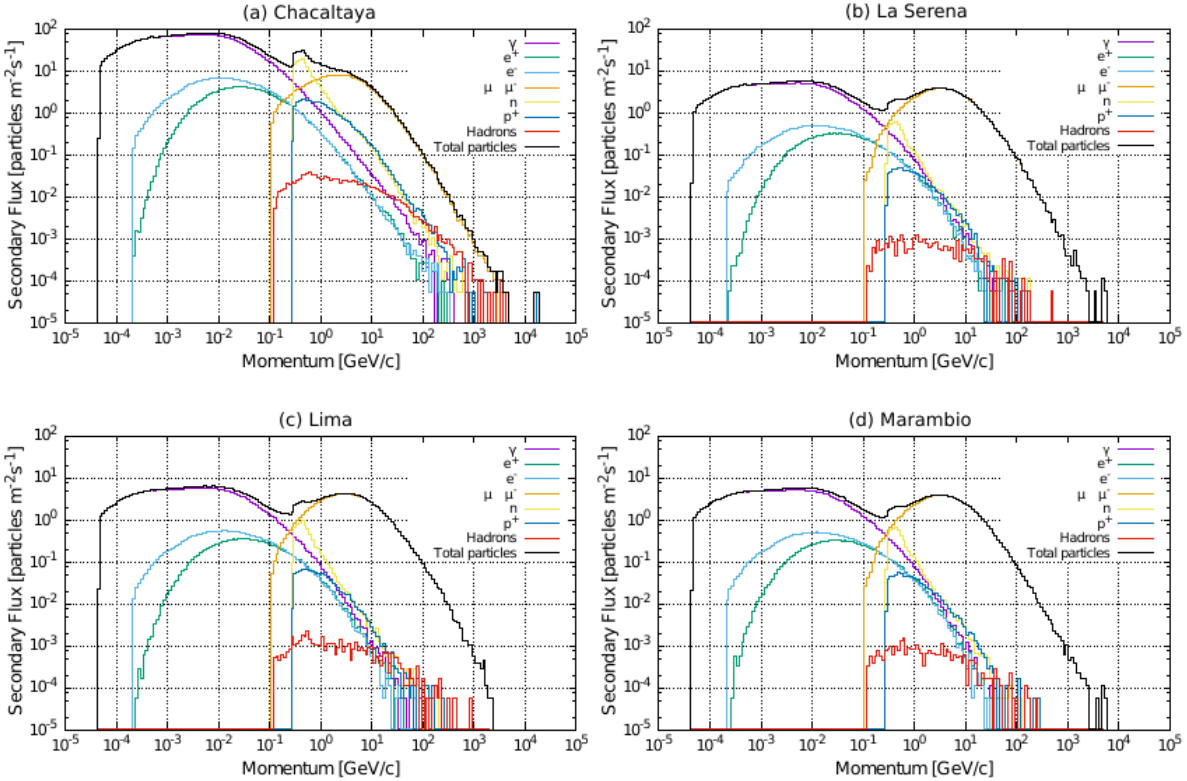
Projecting this intensity on a finite area flat detector at ground level

↓

The distribution of muons follows a $\cos^3(\theta)$

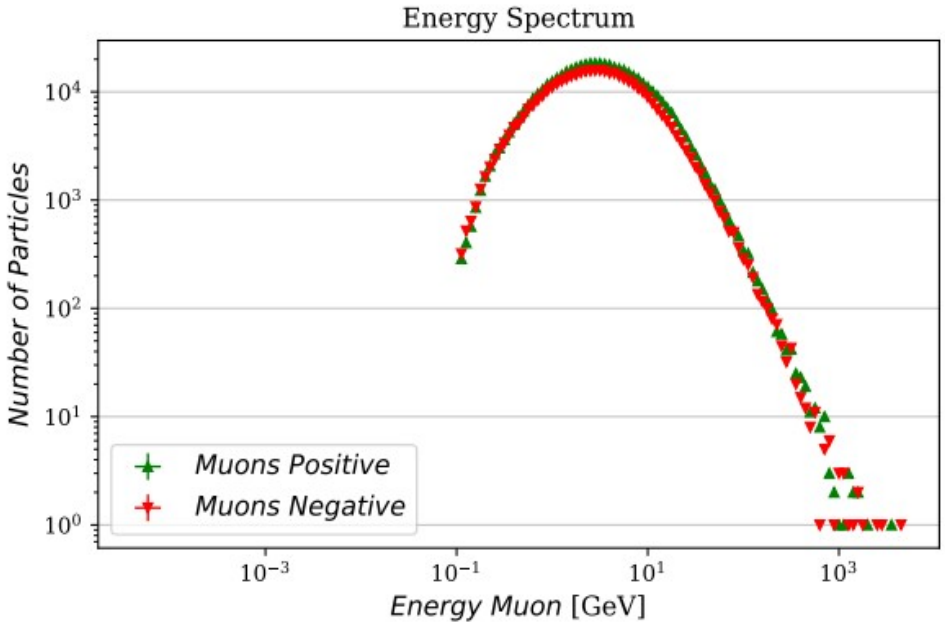


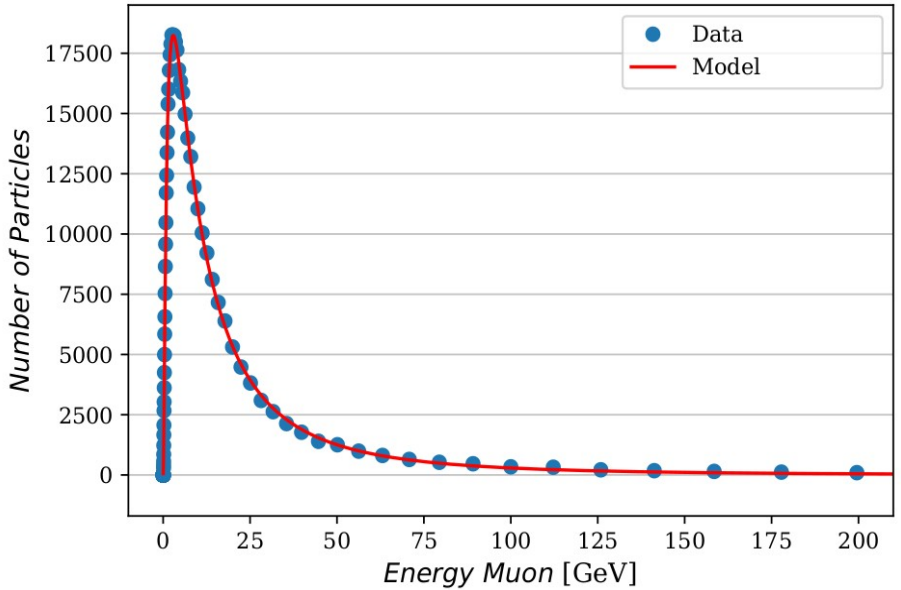
Spectrum secondary particles



** Performance of the LAGO water Cherenkov detectors to cosmic ray flux
https://pc.auger.unam.mx/sites/default/files/papers_file/jcap_lago_14Aug2020.pdf

Energy dependence

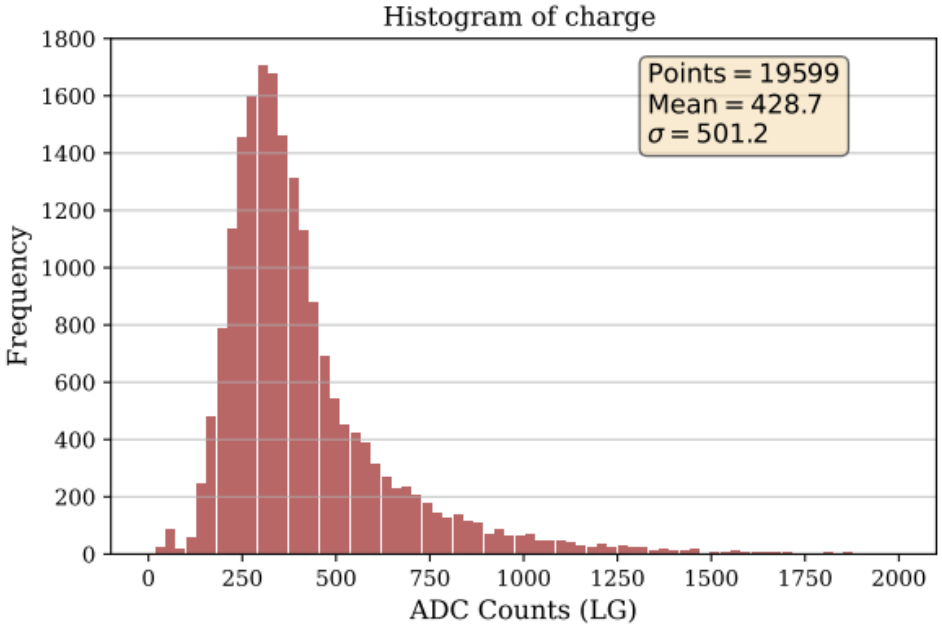


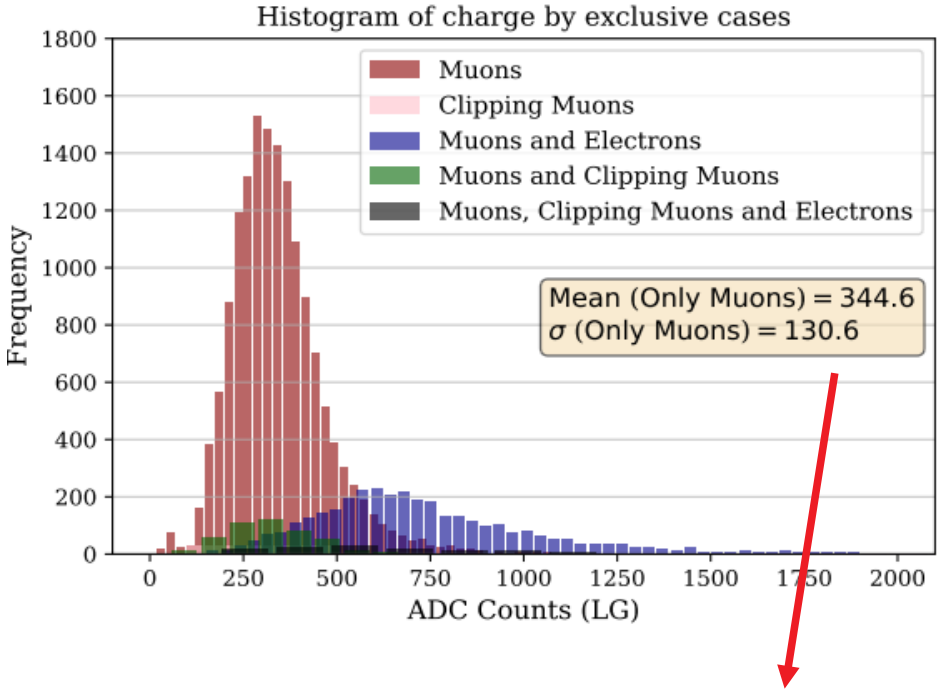


Energy spectrum of muons → **Fit with a Log-normal distribution**

$$\frac{1}{x\sigma\sqrt{2\pi}}\exp\left(-\frac{(\ln x-\mu)^2}{2\sigma^2}\right)$$

Random simulations*



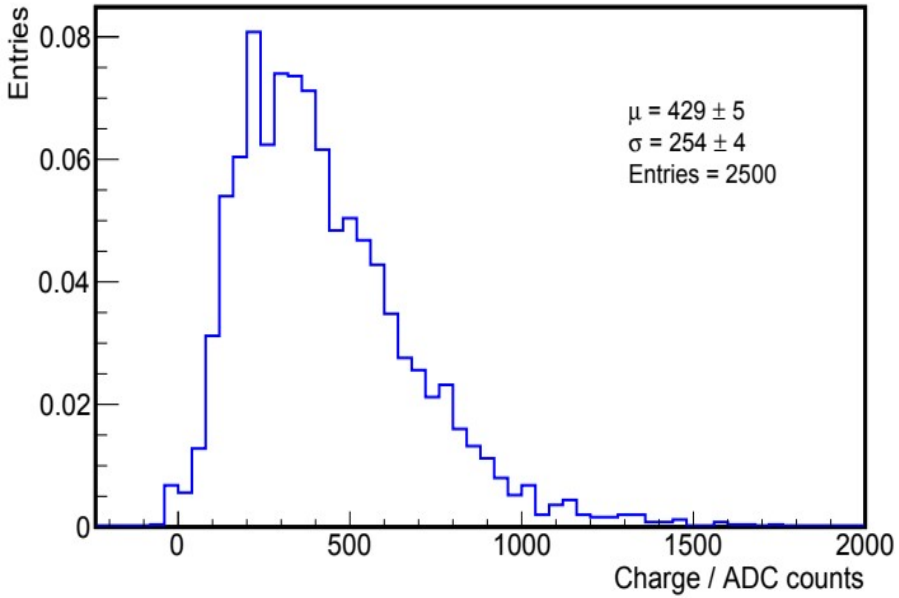


*(φ fixed, perpendicular to the module)

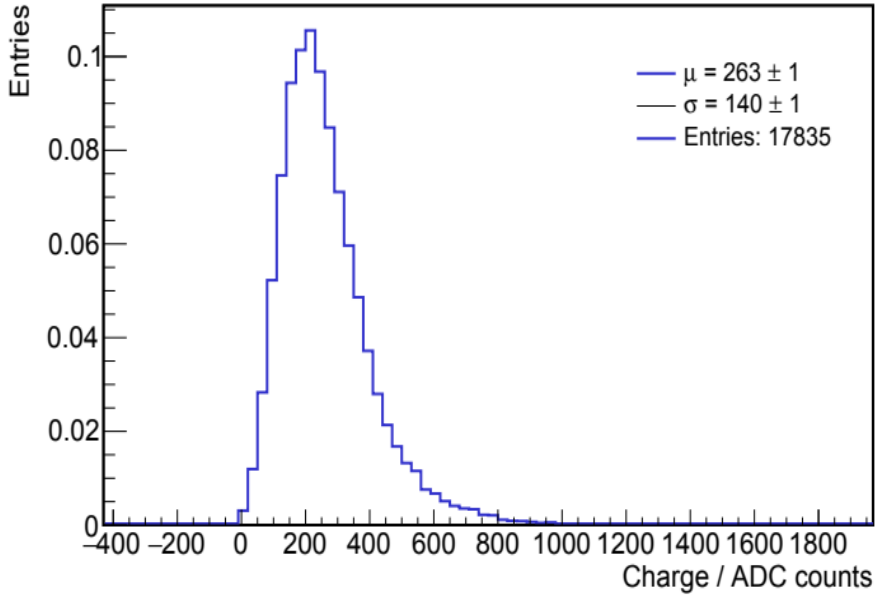
For Only Muons ~ 20% less mean charge

Mean charge on data

Mean Charge on Field:



Mean Charge on Lab:



**Ana Martina Botti

Summary and future work

- We study the charge contributions to the integrator, building the histograms of charge weighted by zenith angle and energy. Simulations are in agreement with UMD field data.

- We can have a more realistic study including simulations with random values in φ angle (with a uniform distribution).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