Double Doctoral degree in Astrophysics

DDAp

Studies for cross-calibration between Sd-SSd and Md

02/11/2021

UNIVERSIDAD NACIONAL DE SAN MARTÍN

KIT Karlsruher Institut für Technologie

Lic. Carmina Pérez Bertolli
Supervisors: Prof. Dr. Brian Wundheiler, Prof. Dr. Ralph Engel

Work Plan

The main idea of my work plan is to study the correlation between the signals of Sd-SSd and Md to develop an unbiased estimator of the muon component

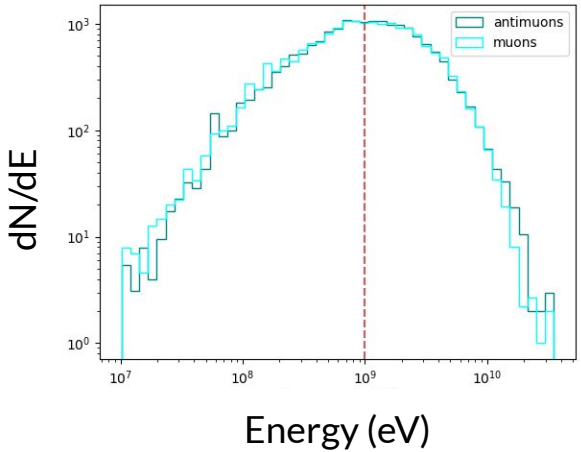
Outline

- **Muon Attenuation Studies**
- **Current Work: Detector simulation with Offline**
- **UMD Online Monitoring**

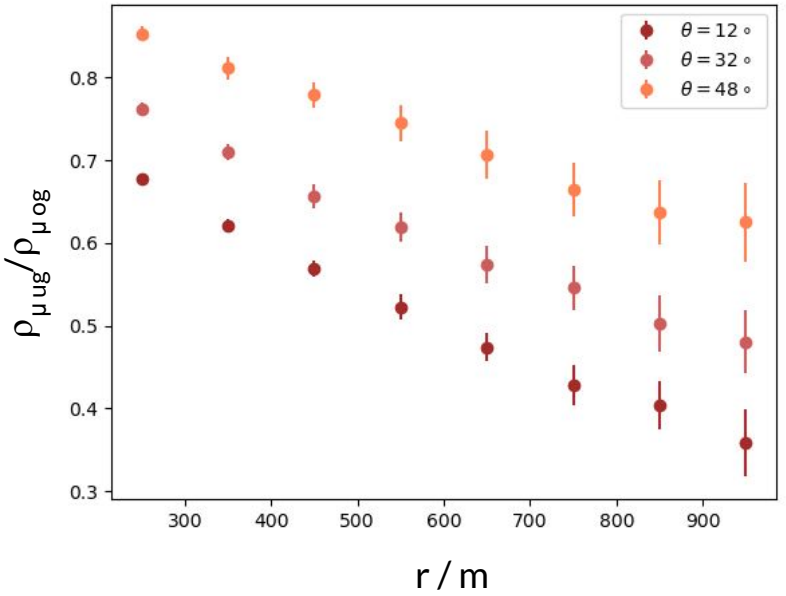
Muon attenuation: energy cut method

Studies on muon attenuation considering a sharp cut on their energy to reach the UMD depth

Energy threshold for muons at 2.25 m depth: **1GeV/cos(θ)**



Muon ratio



The Prague libraries

- Hadronic model: [EPOS_LHC, QGSJetII-04, Sibyll-2.3c]/
  - Primary: [photon[3], proton, helium, oxygen, iron]/
    - Energy bin: [16.5_17.0; 17.0_17.5; 17.5_18.0]/18.0_18.5
      - 1250 showers January atmosphere (Summer):
        DAT{010000..011249}.tar.gz,
        DAT{010000..011249}.small.tar.gz,
      - 1250 showers March atmosphere (Autumn):
        DAT{030000..031249}.tar.gz
        DAT{030000..031249}.small.tar.gz
      - 1250 showers August atmosphere (Winter):
        DAT{080000..081249}.tar.gz
        DAT{080000..081249}.small.tar.gz
      - 1250 showers September atmosphere (Spring):
        DAT{090000..091249}.tar.gz
        DAT{090000..091249}.small.tar.gz

θ = [0_15, 15_30, 30_45]

GAP 2018-043

Muon attenuation: Stopping power method

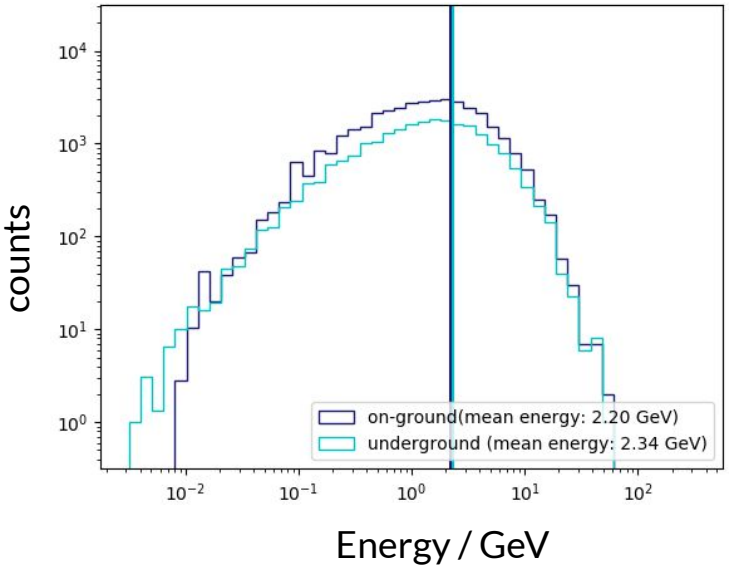
$$-\left\langle \frac{dE}{dx} \right\rangle = \frac{4\pi}{m_e c^2} \cdot \frac{nz^2}{\beta^2} \cdot \left(\frac{e^2}{4\pi\varepsilon_0} \right)^2 \cdot \left[\ln\left(\frac{2m_e c^2 \beta^2}{I \cdot (1-\beta^2)} \right) - \beta^2 \right]$$

```
Index =  245:  silicon dioxide (fused quartz) (SiO\sub{2})
     Absorber with <Z/A> =  0.49930, density = 2.200 (revised)
Sternheimer coef:  a      k=m_s   x_0    x_1    I[eV]   Cbar  delta0
                 0.0841  3.5064  0.1500  3.0140  139.2  4.0560 0.00
(Restricted energy loss for Tcut = 0.05 MeV
Table written with (1X, 1P9E10.3,0PF8.4,f8.5,1pE10.3)          post-Born included in pair prod
*** Results below 10 MeV are not dependable ***
     T          p      Ionization  brems      pair      photonuc   Radloss    dE/dx     CSDA Range  delta    beta    dE/dx_R
   [MeV]     [MeV/c]   ----------------------[MeV cm^2/g]-------------- ----------  [g/cm^2]                [MeV cm^2/g]
 1.000E+00 1.457E+01 2.660E+00 0.000E+00 0.000E+00 4.793E-05 4.793E-05 5.321E+00 2.327E-03  0.0000 0.13661 4.038E+01
 1.200E+00 1.597E+01 3.498E+01 0.000E+00 0.000E+00 4.802E-05 4.802E-05 3.498E+01 7.665E-03  0.0000 0.14944 3.498E+01
 1.400E+00 1.726E+01 3.096E+01 0.000E+00 0.000E+00 4.811E-05 4.811E-05 3.096E+01 1.376E-02  0.0000 0.16119 3.096E+01
 1.700E+00 1.903E+01 2.653E+01 0.000E+00 0.000E+00 4.824E-05 4.824E-05 2.653E+01 2.426E-02  0.0000 0.17725 2.653E+01
 2.000E+00 2.066E+01 2.331E+01 0.000E+00 0.000E+00 4.838E-05 4.838E-05 2.331E+01 3.635E-02  0.0000 0.19186 2.331E+01
 2.500E+00 2.312E+01 1.950E+01 0.000E+00 0.000E+00 4.860E-05 4.860E-05 1.950E+01 5.991E-02  0.0000 0.21376 1.950E+01
 3.000E+00 2.536E+01 1.686E+01 0.000E+00 0.000E+00 4.883E-05 4.883E-05 1.686E+01 8.758E-02  0.0000 0.23336 1.665E+01
 3.500E+00 2.742E+01 1.491E+01 0.000E+00 0.000E+00 4.905E-05 4.905E-05 1.491E+01 1.192E-01  0.0000 0.25120 1.455E+01
 4.000E+00 2.935E+01 1.341E+01 0.000E+00 0.000E+00 4.928E-05 4.928E-05 1.341E+01 1.546E-01  0.0000 0.26763 1.296E+01
```

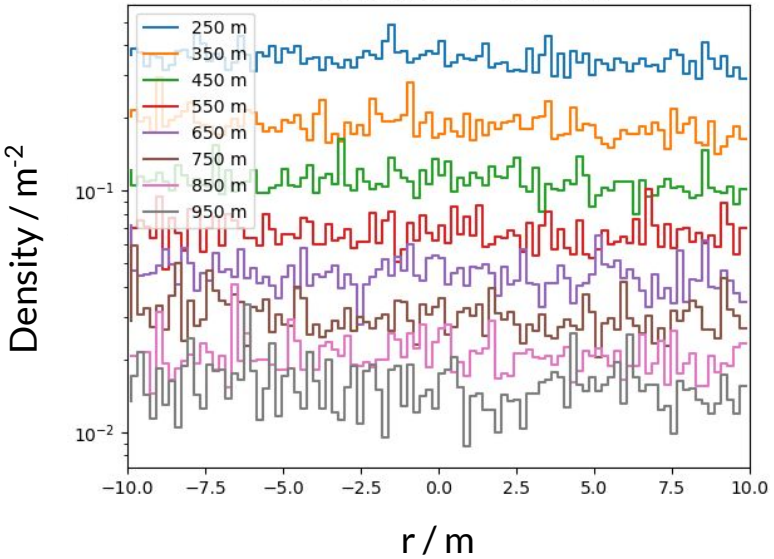
https://pdg.lbl.gov/2019/AtomicNuclearProperties/

Muon attenuation: Stopping power method

Proton, E= 3.1x10^{17}, θ = 5°



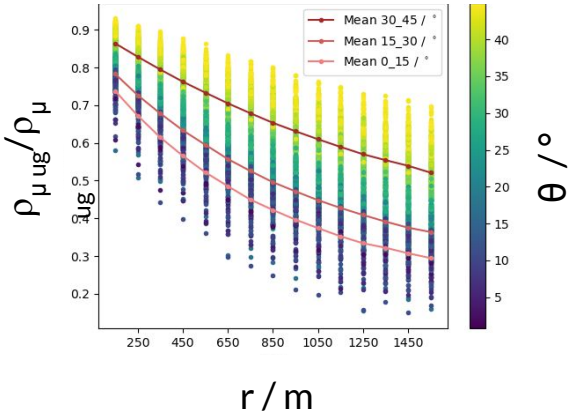
Density distributions on-ground



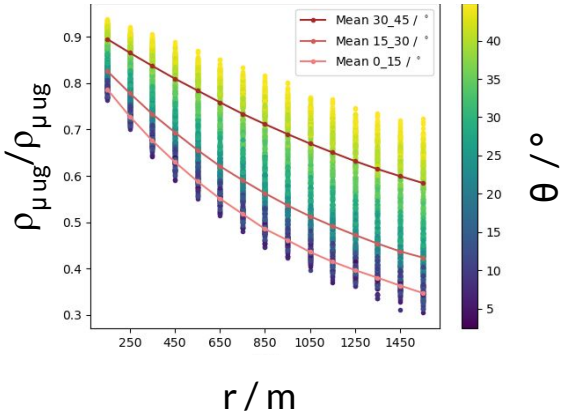
- **A displacement of the mean energy can be observed as well as more low energy muons for the underground histogram (lhs).**
- **At higher distances from the core lower muon densities are observed (rhs).**

Attenuation curves: dependency of the ratio

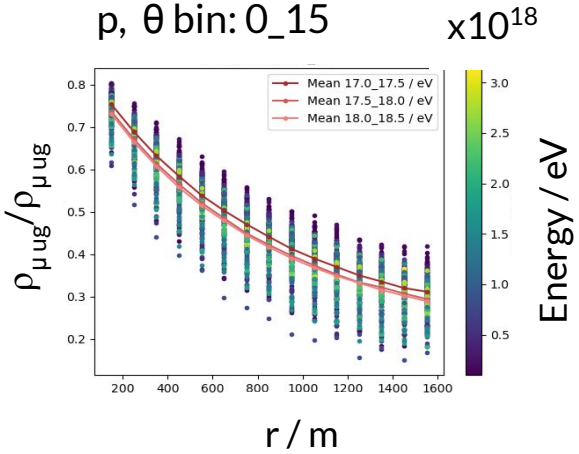
p, Energy bin: 17.5_18.0



Fe,Energy bin: 17.5_18.0



p, θ bin: 0_15

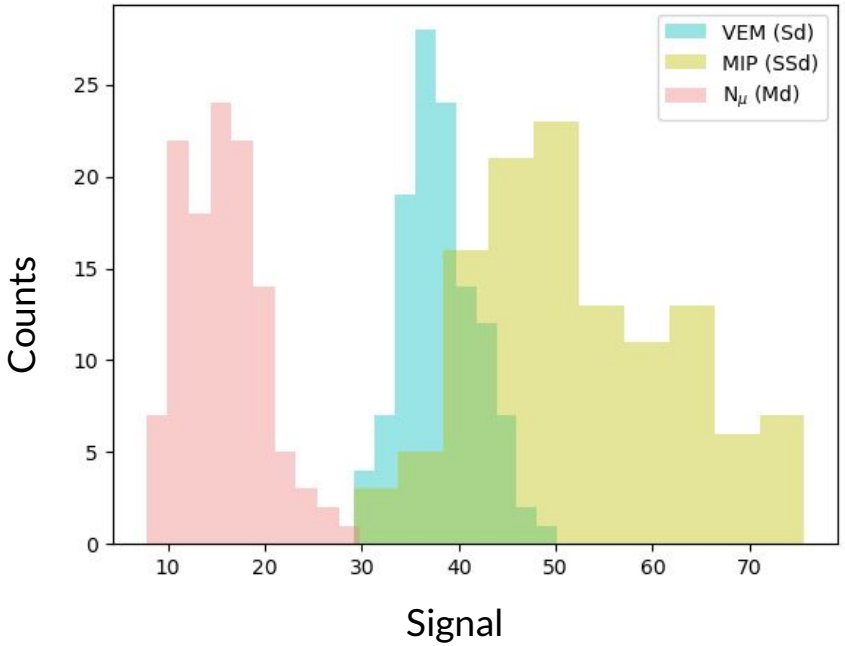


- The attenuation curves get steeper for lower zenith angles
- Ratio expected ϵ {0.57; 0.76} for p and ϵ {0.64; 0.83} for Fe at 450 m

- A dependence of the curves on the energy of the primary can not be observed

Hadronic Model: EPOS-LHC

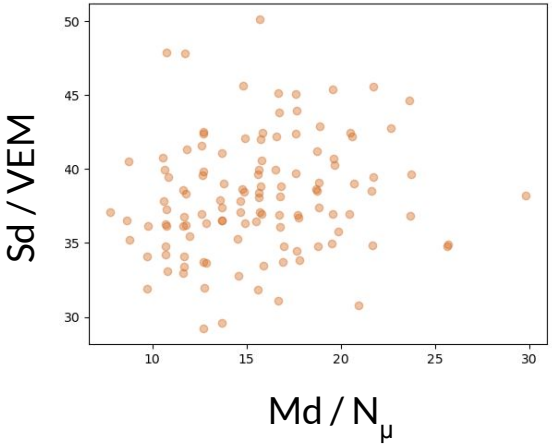
Current work: Detector simulation and reconstruction

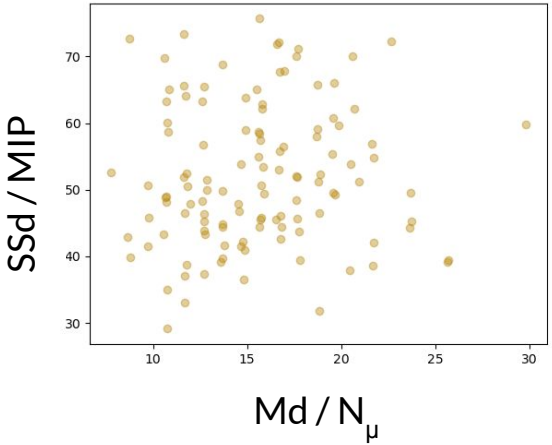


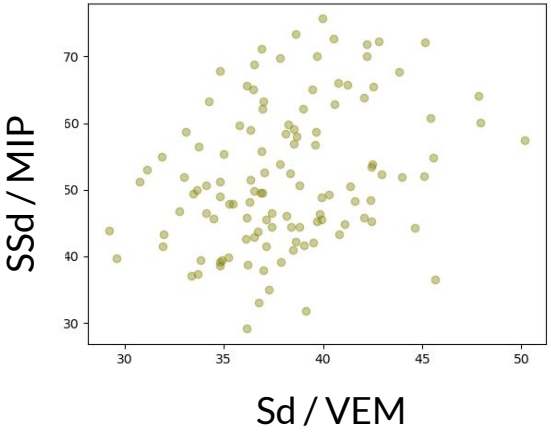
Signals at 450 m for 10 protons with $E=5.95 \times 10^{17}$ eV, $\Theta=27°$ and Model = EPOS-LHC

Goal: development of codes and scripts to produce and manage simulations and extract relevant information for analyses

Current work: Detector simulation and reconstruction



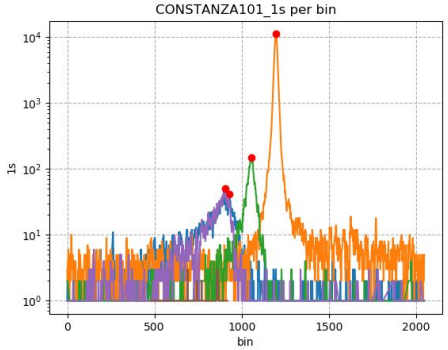




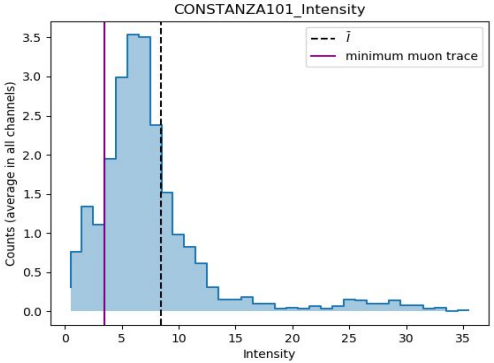
Very preliminary results. More statistics are needed.

UMD Online Monitoring

Latch bin

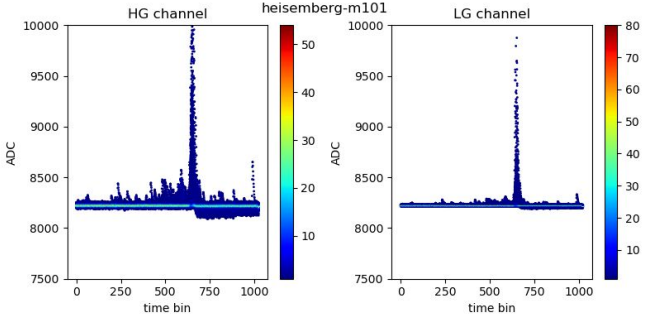


Intensity

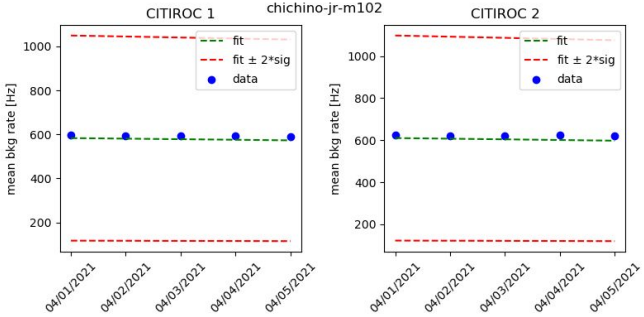


- **This tool was developed and is already available in the ITeDA server for shifters.**
- **A weekly report is produced based on the four monitoring observables.**
- **Already 9 shifters in the last 3 months.**

ADC Traces



Background level



Summary and Outlook of current work

Access to Lyon shower libraries

Use this showers to simulate the detectors response with Offline

Perform a station by station SD-SSD signal study with Matrix Formalism (or another...) outputs vs UMD signal

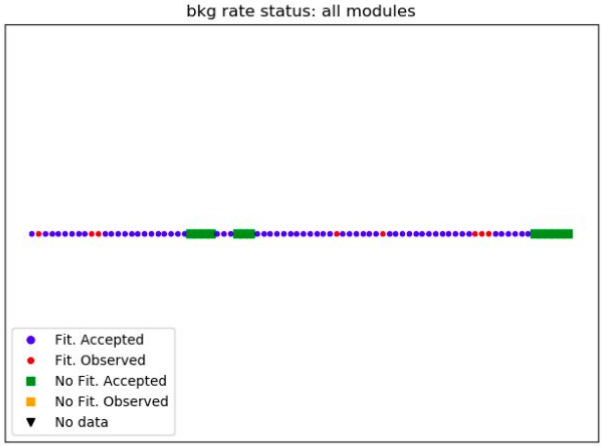
Find a correlation between muon ratio and muon density underground

Change the “energy cut method” for a stopping power (more realistic) method or using Offline simulations

Keep studying the muon attenuation with more showers

Backup

Md Shifts



Observed:
Data points outside the fit (8 modules): Catherina 102, Chichino Jr 101 and 102, Comenius 103, Correo Argentino 101, 102 and 103, Phil Collins 103.

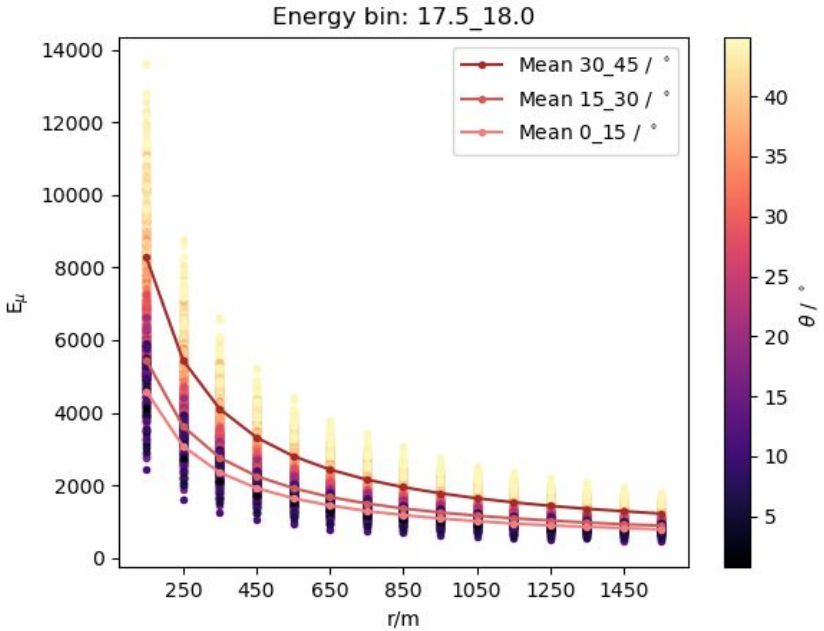
This tool is already available in the ITeDA server for shifters

Shifters write a weekly report about the performance of the detectors based on the four monitoring variables

Example of background monitoring from a report by Gabriel and Varada

Shifters: Marina, Joaquín, Gabriel, Varada, Flavia, Federico, Brian

Attenuation curves: dependency on the energy on-ground



Attenuation curves dependency of the energy underground