1. **Introduction**

- Precise determination of muon number in extensive air showers crucial to separate mass groups of primary cosmic rays at ultra-high energies.
- Study of expectations on separability of primaries essential to optimize performance of future muon detectors.

2. **Simulations**

- Simulation of ideal muon detector by calculation of expected muon number for $A_{det} = 10 \text{m}^2$ in ring in shower plane.

3. **P-Fe Separability**

- Figure of Merit $F_{\text{FoM}} = \frac{N_{\text{Fe}} - N_{\text{p}}}{\sqrt{\sigma_{\text{Fe}}^2 + \sigma_{\text{p}}^2 + \sigma_{\text{p}}^2 + \sigma_{\text{Fe}}^2}}$ quantifies separability of p & Fe showers.

4. **Photonuclear Reactions**

- Photon + air $\rightarrow \mu^+ \mu^-$
- $\rightarrow$ Hadron + X
- $\rightarrow \{\rho^0 \text{ or } \omega^0\}$
- $\rightarrow$ recoil nucleus

- Influence of muons from EM shower part on the figure of merit $F_{\text{FoM}}$.
- Tag muons from photonuclear reactions with EHISTORY [3] option in CORSIKA.

5. **Energy Threshold Dependence of $F_{\text{FoM}}$**

- Separate analysis of $F_{\text{FoM}}$ components by calculation of $F_{\text{FoM}} = \frac{\int dN}{\int d\sigma}$.
- Muons from photonuclear origin suppressed w.r.t. muons from other hadronic processes.
- Distributions approach each other at low muon energies for $i = \Sigma$ and $i = \Sigma - \gamma$.

6. **Conclusion:** $E_{th} \geq 1 \text{ GeV}$ favored.

- Muons of photonuclear origin reduce $F_{\text{FoM}}$ up to radius dependent muon energy.
- Better separability with increasing energy detector threshold for both $F_{\text{FoM}}^{\Sigma}$ and $F_{\text{FoM}}^{\Sigma - \gamma}$.
- 95% region $E_{th} : F_{\text{FoM}} \geq 0.95 \cdot F_{\text{FoM max}}$ large for small $r$, displayed by error bars.
- Optimal energy threshold $E_{th} \sim 1 \text{ GeV}$ up to 800 m, $E_{th} \sim 2 \text{ GeV}$ for $r \leq 550 \text{ m}$.

References: