LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

High-energy gamma/hadron discrimination for SWGO

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The Southern Wide-field Gamma-ray Observatory

IDPASC
Fundação para a Ciência e a Tecnologia

IDPASC PhD grant PRT/BD/154192/2022

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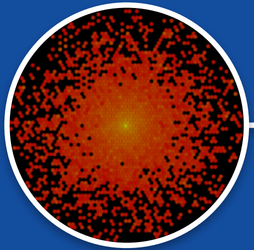
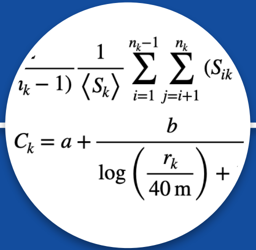
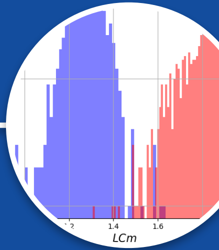
1.

LCm







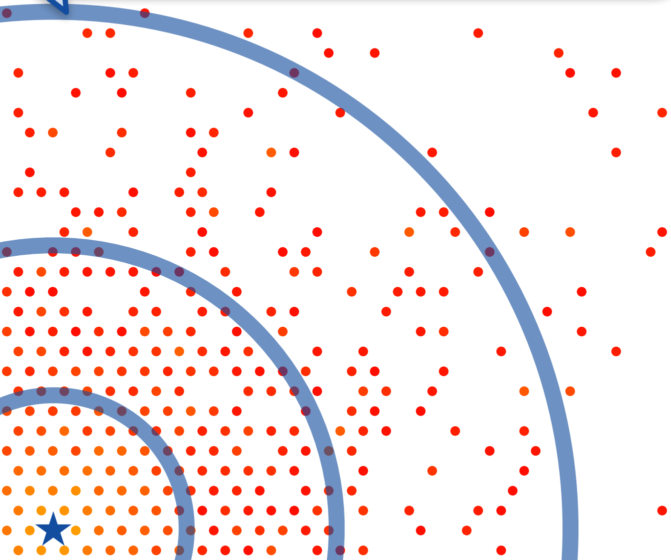
Quantifying azimuthal asymmetries in the shower footprint

LCm - Quantifying azimuthal asymmetries in the shower footprint

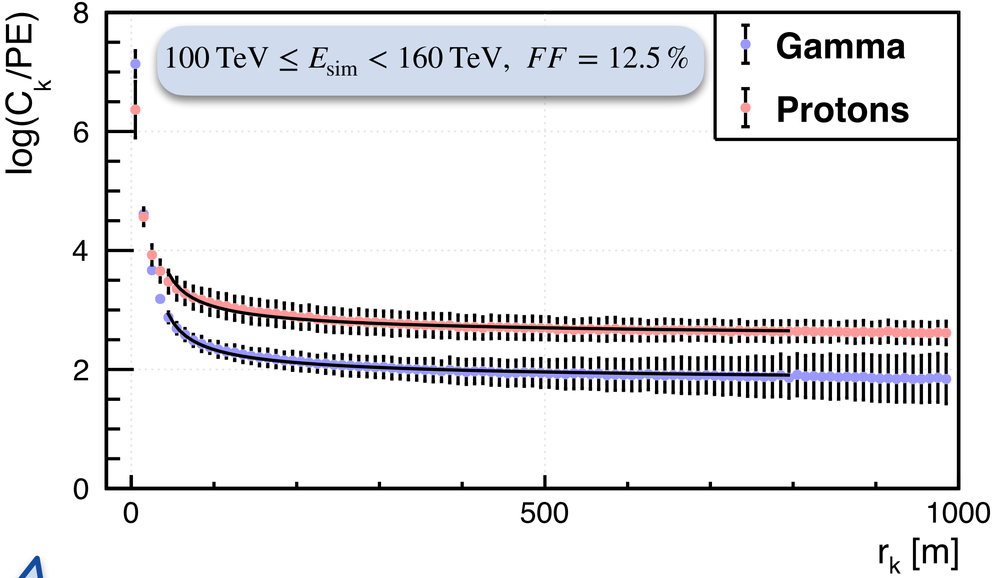
Conceição et al., JCAP10(2022)086

k

Rings centred in the shower axis.
Each ring is $10\ \mathrm{m}$ wide, contains n_k active stations with average signal $\langle S_k \rangle$ and is placed at a distance r_k from the shower axis.



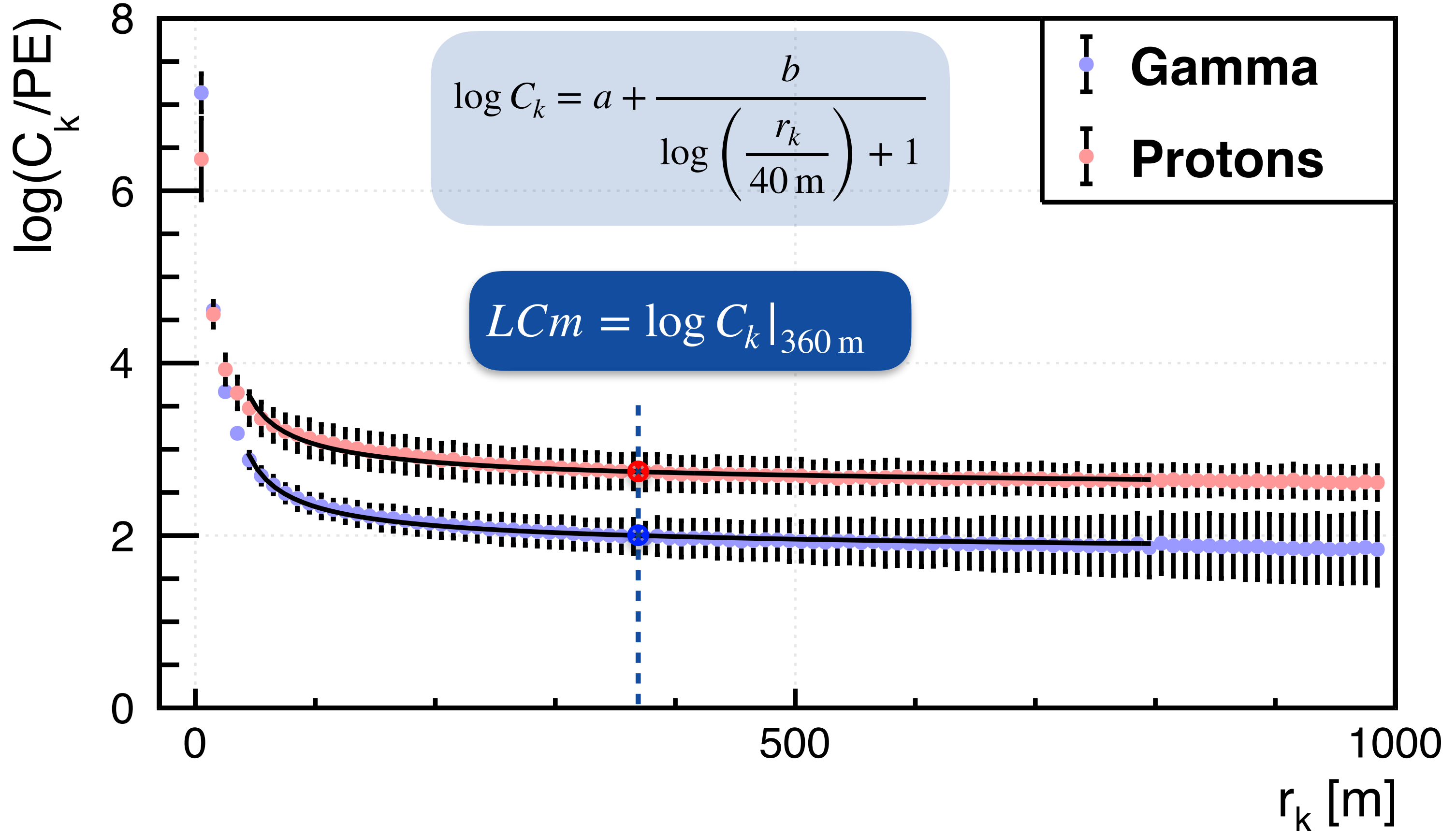
$$C_k = \frac{2}{n_k(n_k-1)} \frac{1}{\langle S_k \rangle} \sum_{i=1}^{n_k-1} \sum_{j=i+1}^{n_k} (S_{ik} - S_{jk})^2$$



C_k quantifies the azimuthal asymmetries of the shower footprint!

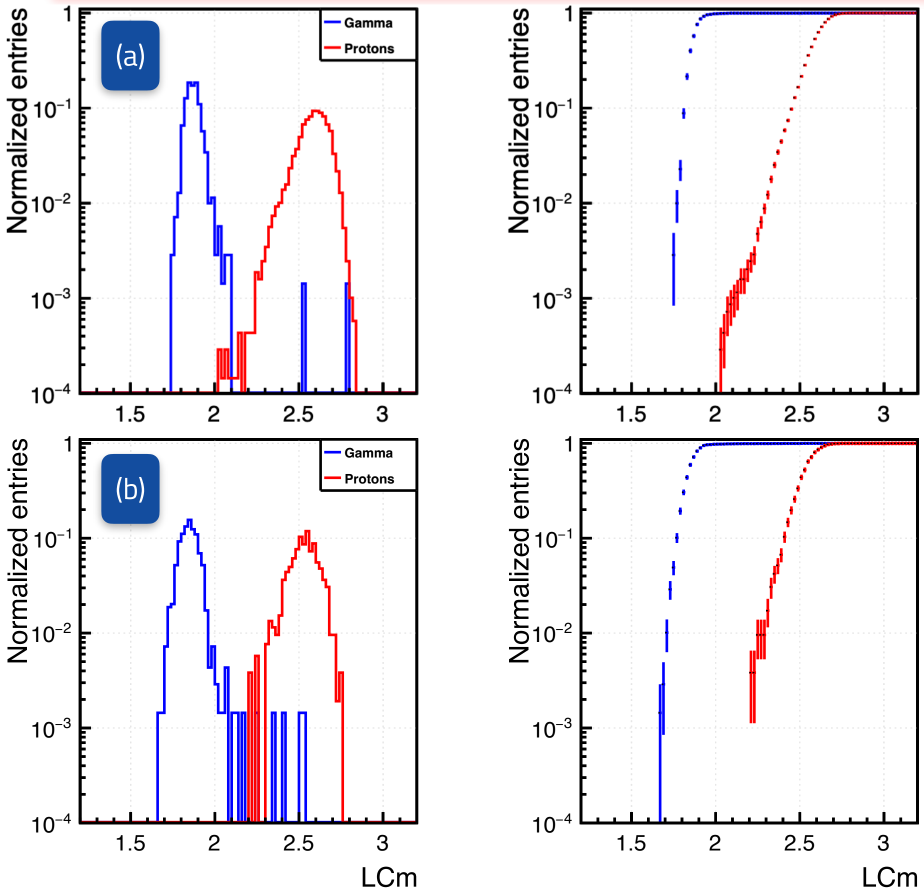
LCm - Quantifying azimuthal asymmetries in the shower footprint

Conceição et al., JCAP10(2022)086



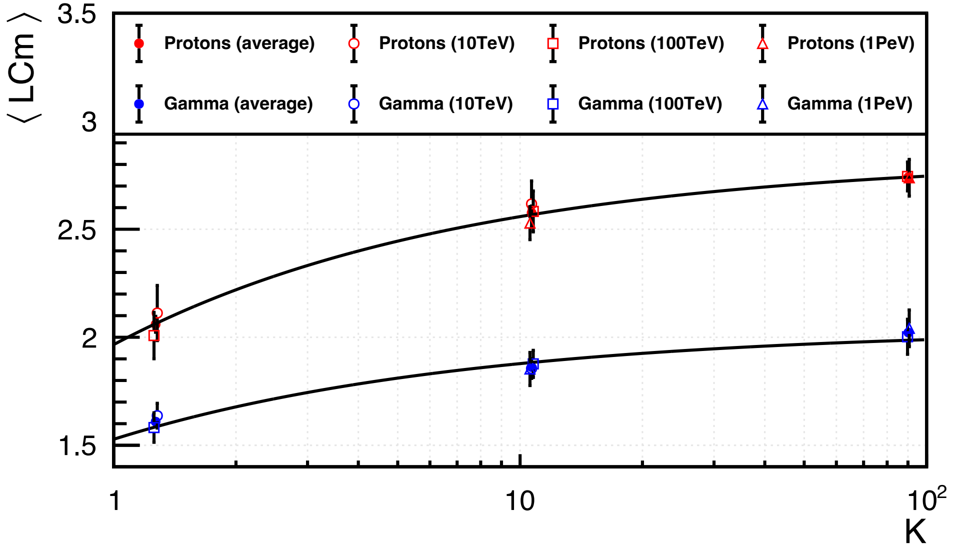
LCm - Quantifying azimuthal asymmetries in the shower footprint

Conceição et al., JCAP10(2022)086



(a) $100\,\mathrm{TeV} \leq E_{\mathrm{sim}} < 160\,\mathrm{TeV},\ FF = 12.5\,\%$

(b) $1\,\mathrm{PeV} \leq E_{\mathrm{sim}} < 1.6\,\mathrm{PeV},\ FF = 1\,\%$

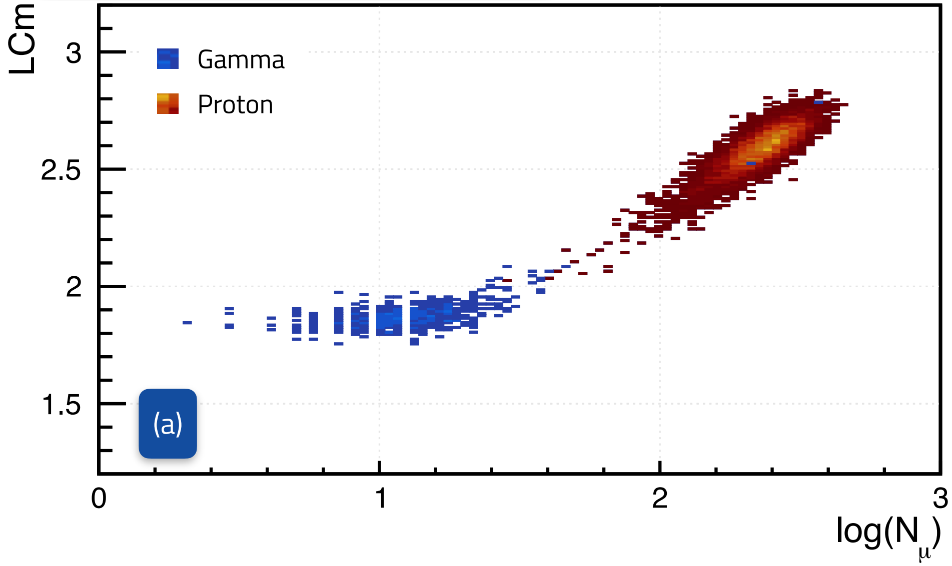


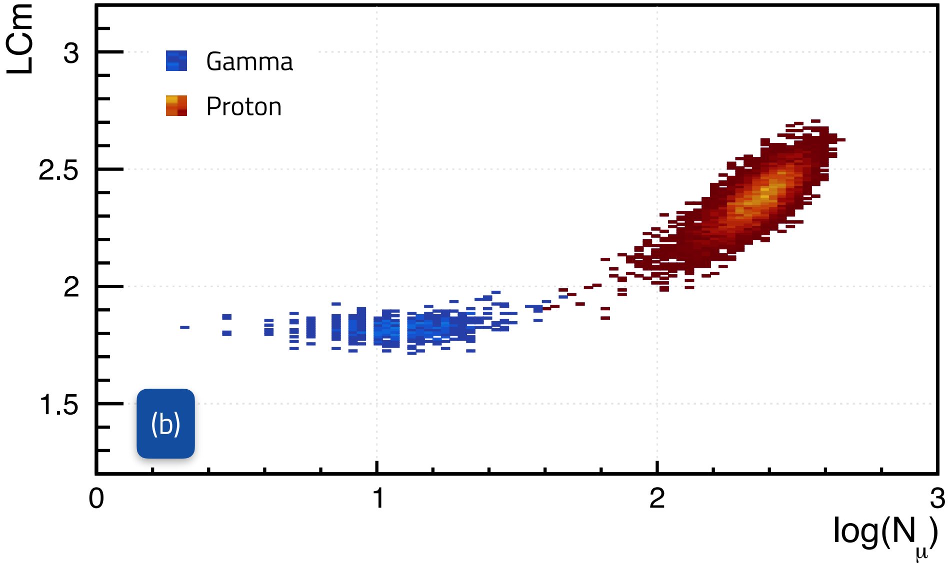
LCm scales with $K = E^{\beta} \cdot FF,\ \beta = 0.925$

LCm - Quantifying azimuthal asymmetries in the shower footprint

Conceição et al., JCAP10(2022)086

$100\ \text{TeV} \leq E_{\text{sim}} < 160\ \text{TeV},\ FF = 12.5\,\%$





(a) LCm computed using signal from all particles

(b) LCm computed excluding signal from muons

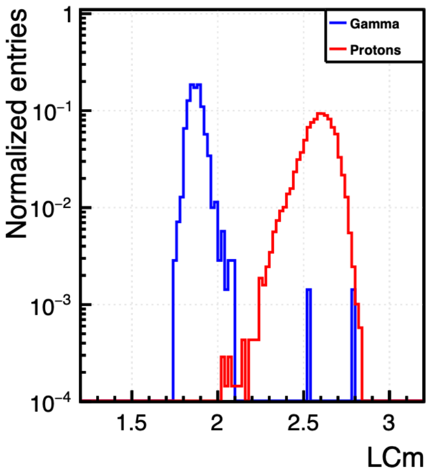
The correlation between LCm and the number of muons holds true when computing LCm without using the signal of muons!

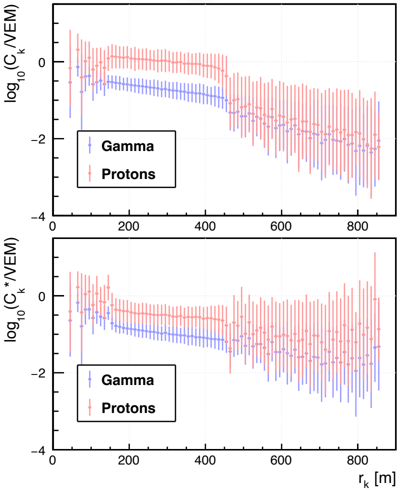
LCm - The output so far

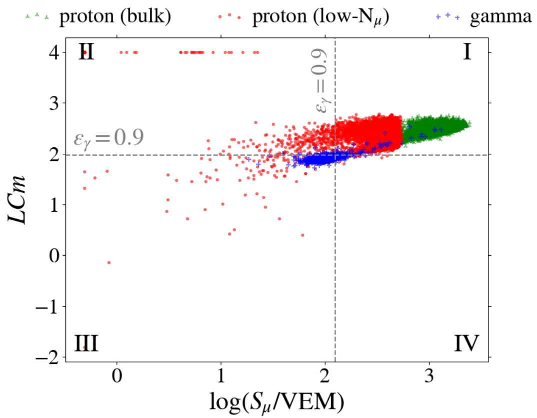
Conceição et al., *Gamma/hadron discrimination at high energies through the azimuthal fluctuations of air shower particle distributions at the ground*, JCAP10(2022)086

Conceição et al., *The gamma/hadron discriminator LCm in realistic air shower array experiments*, Eur.Phys.J.C.83,932(2023)

Bakalová et al., *Azimuthal fluctuations and number of muons in muon-depleted proton air showers at PeV energies*, PhysRevD.111.083036



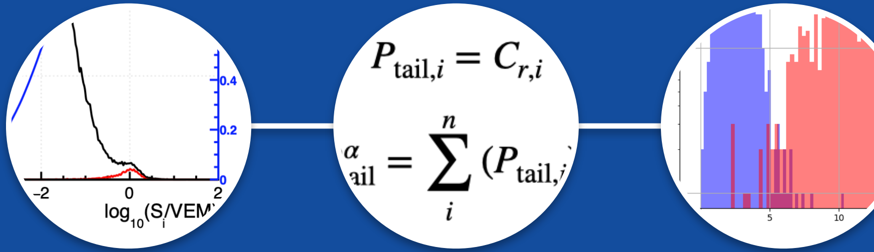




2.

P^{α}_{tail}

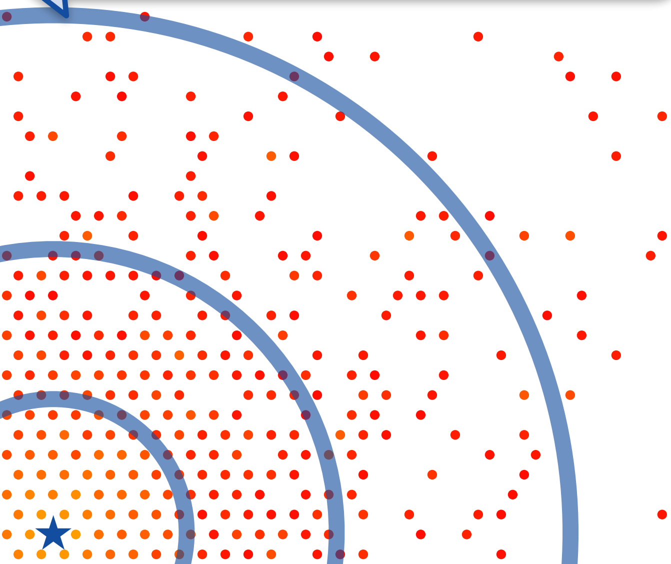
Counting signal outliers

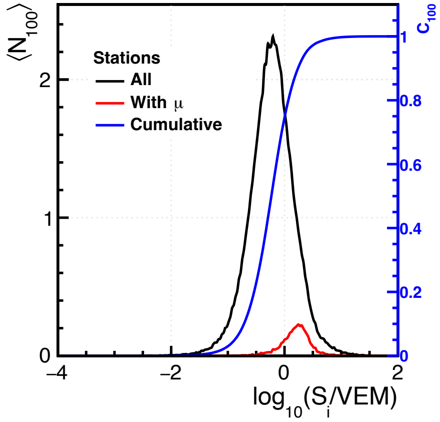


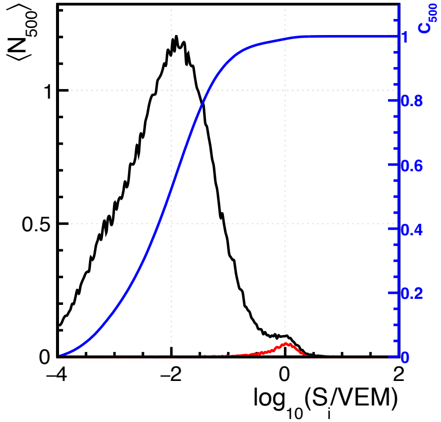
$P^{\alpha}_{\mathrm{tail}}$ - Counting signal outliers

Conceição et al., Phys. Rev. D 110, 023033

Rings centred in the shower axis. Each ring is $10\ \mathrm{m}$ wide and contains n active stations, each with signal S_i. Stations with muons are typically in the upper tail of the ring's signal distribution.







For each station, $P_{\mathrm{tail},i}$ is defined as:

$$P_{\mathrm{tail},i} = C_{r,i}$$

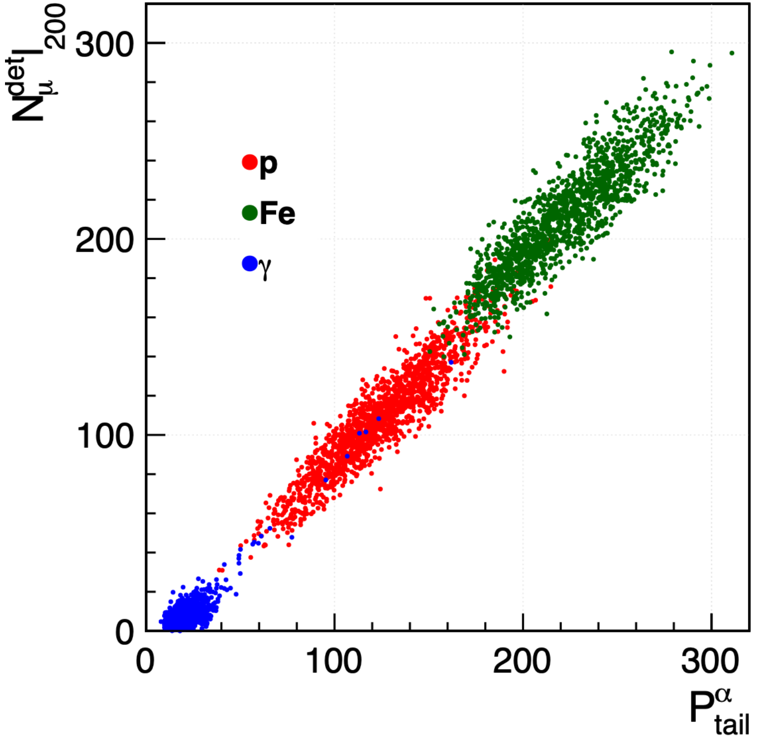
The sum of the $P_{\mathrm{tail},i}$ of all stations placed at a distance from the shower core larger than $200\ \mathrm{m}$ gives the event variable:

$$P^{\alpha}_{\mathrm{tail}} = \sum_{i}^{n} (P_{\mathrm{tail},i})^{\alpha}$$

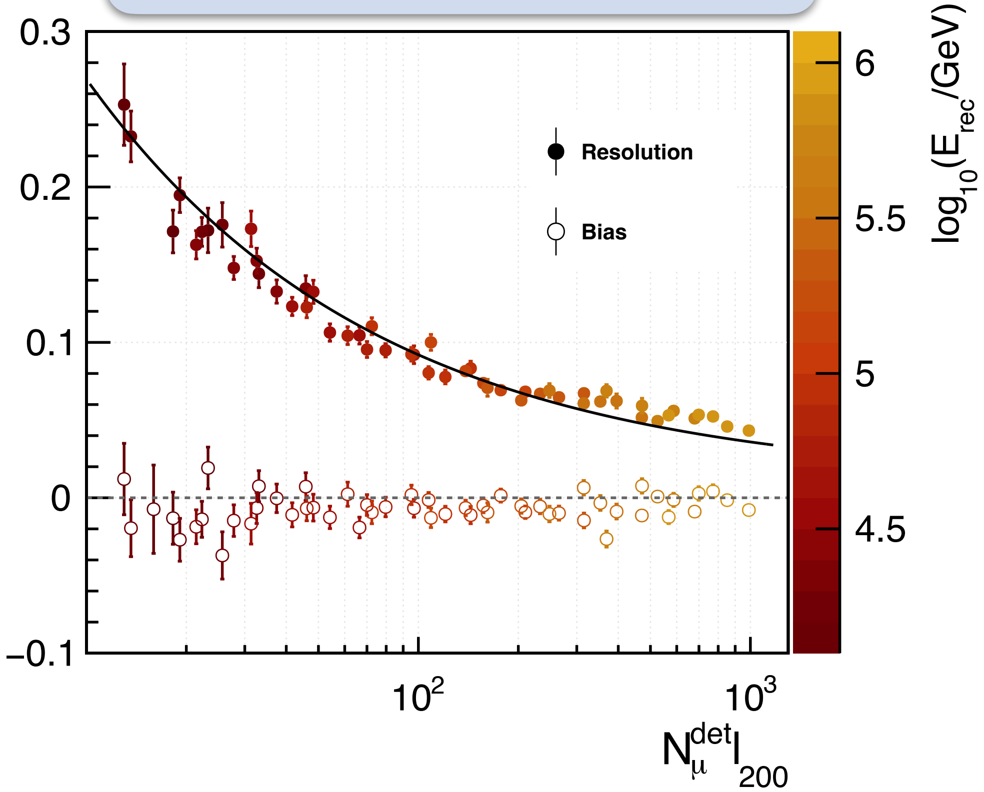
P^{α}_{tail} - Counting signal outliers

Conceição et al., Phys. Rev. D 110, 023033

Correlation of P^{α}_{tail} with the number of muons



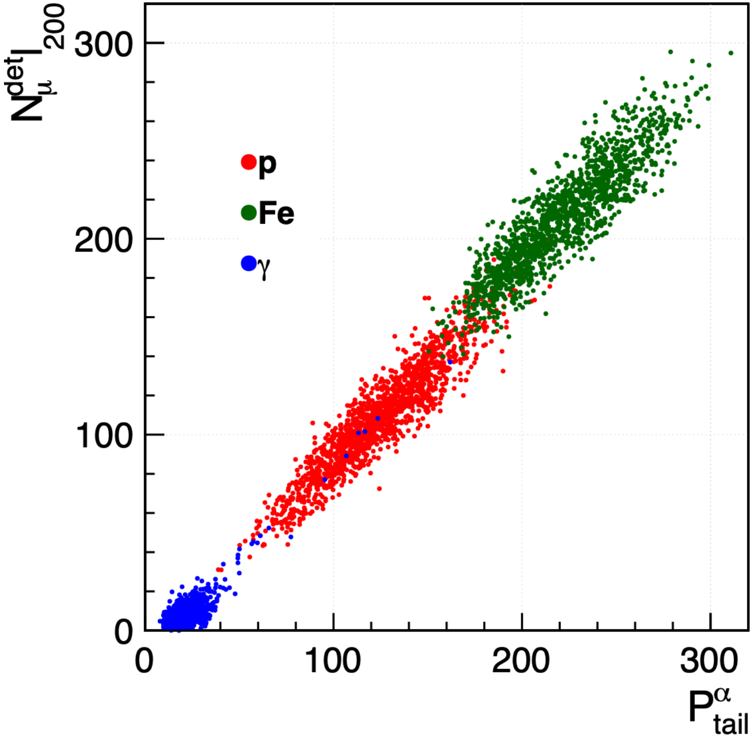
Reconstruction of the number of muons with P^{α}_{tail}



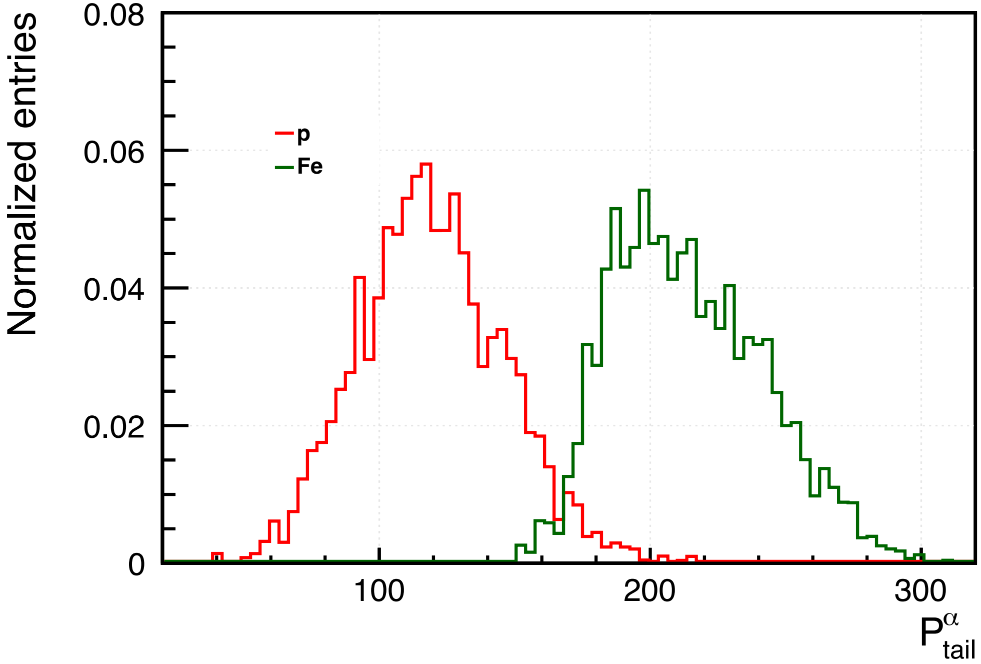
P^{α}_{tail} - Counting signal outliers

Conceição et al., Phys. Rev. D 110, 023033

Correlation of P^{α}_{tail} with the number of muons



The potential of P^{α}_{tail} as a mass composition variable

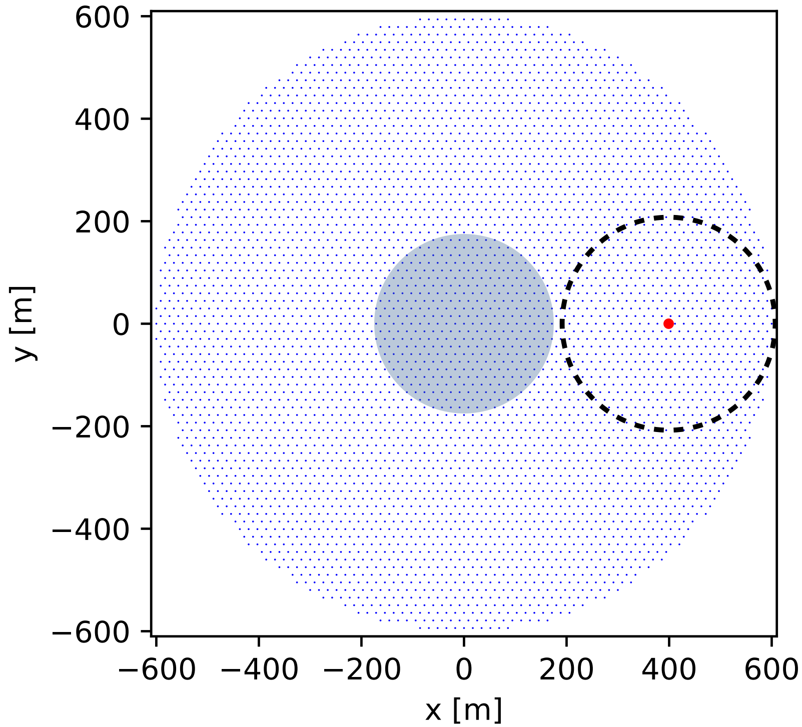


P^{α}_{tail} - Counting signal outliers

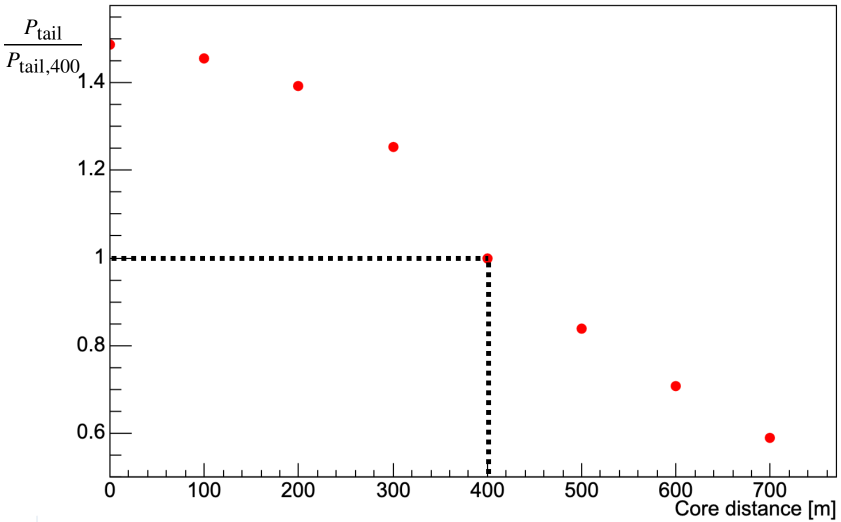
Conceição et al., [Phys. Rev. D 110, 023033]

$P_{\text{tail,D}}$

P^{α}_{tail} needs to be corrected for the shower core position. $P_{\text{tail,D}}$ is P^{α}_{tail} normalised to a reference value.



$$P_{\text{tail,D}} = P_{\text{tail}} \cdot \frac{\left\langle P^{\alpha}_{\text{tail,400}} \right\rangle}{\left\langle P^{\alpha}_{\text{tail}} \right\rangle}$$

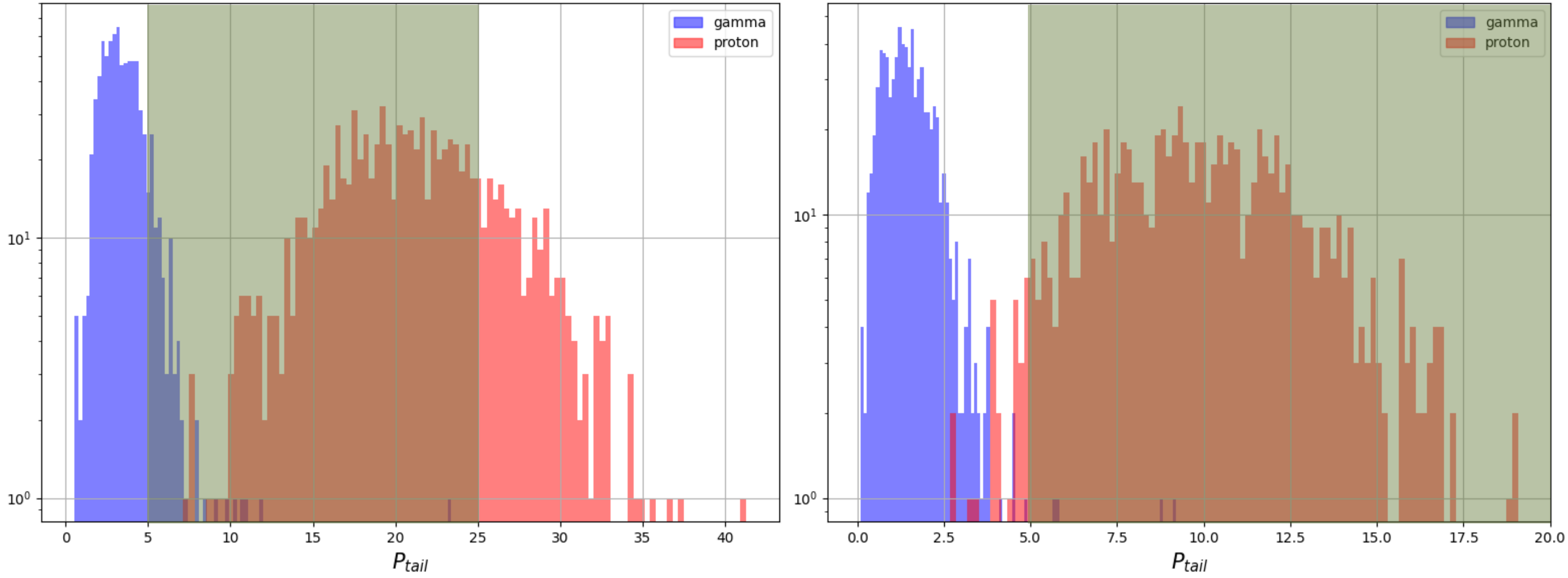


P_{tail}^{α} - Counting signal outliers

Conceição et al., Phys. Rev. D 110, 023033

Before the correction…

$D_{\text{core}} = 0\,\text{m}$ $D_{\text{core}} = 600\,\text{m}$

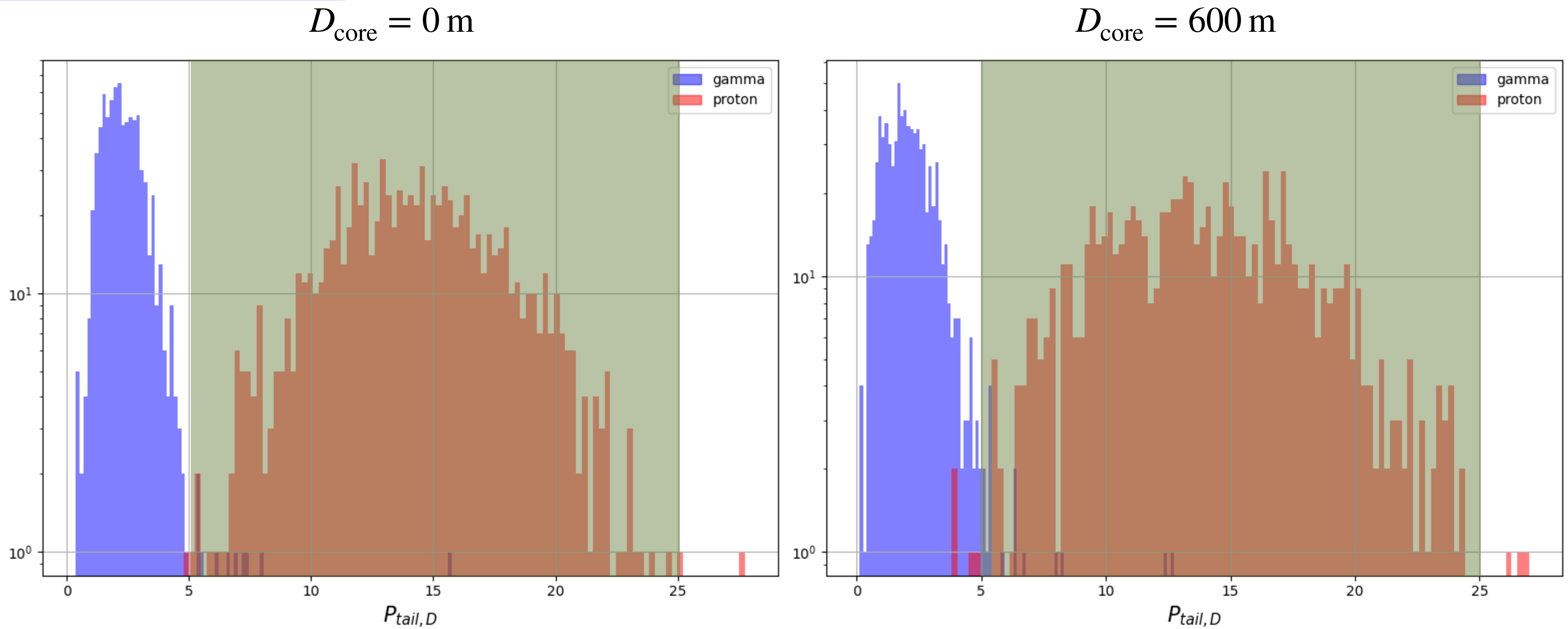


Range of P_{tail} distribution at the reference $D = 400\,\text{m}$

P^{α}_{tail} - Counting signal outliers

Conceição et al., Phys. Rev. D 110, 023033

... and after the correction

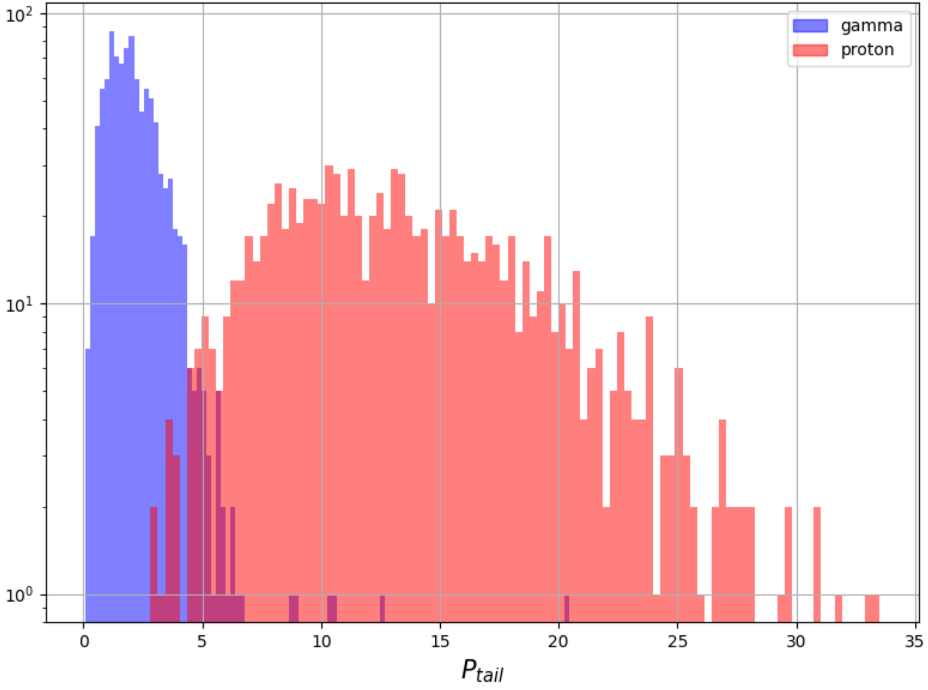


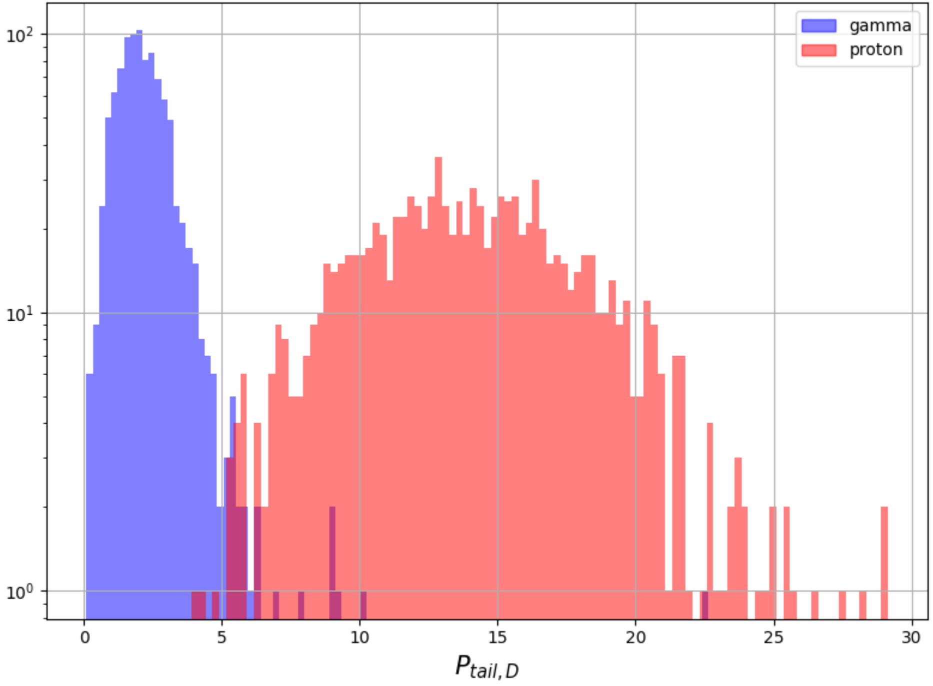
Range of P_{tail} distribution at the reference $D = 400\,\text{m}$

$P^{\alpha}_{\mathrm{tail}}$ - Counting signal outliers

Conceição et al., Phys. Rev. D 110, 023033

The effect of the $P_{\mathrm{tail,D}}$ correction - showers with $0\,\mathrm{m} < D_{\mathrm{core}} < 660\,\mathrm{m}$





Conclusions

LCm

- Gamma/hadron discrimination variable based on the quantification of the azimuthal fluctuations of the shower footprint
- Sensitive to the hadronic activity of the shower
- **Grants a discrimination power comparable to that of the number of muons at energies starting from $100\,\mathrm{TeV}$, without the need for muon detectors**
- Space left for optimisation

$P^{\alpha}_{\mathrm{tail}}$

- Gamma/hadron discrimination and mass composition variable based on the count of stations with unusually large signal
- **Able to reconstruct the number of muons with $<10\,\%$ resolution at energies starting from $100\,\mathrm{TeV}$**, granting a similar discrimination and composition power
- Space left for optimisation

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Thanks!

Any questions?

You can find me at gibilisc@lip.pt

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