Measurement of PeVatrons with the future Southern Wide-field Gamma-ray Observatory

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LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS

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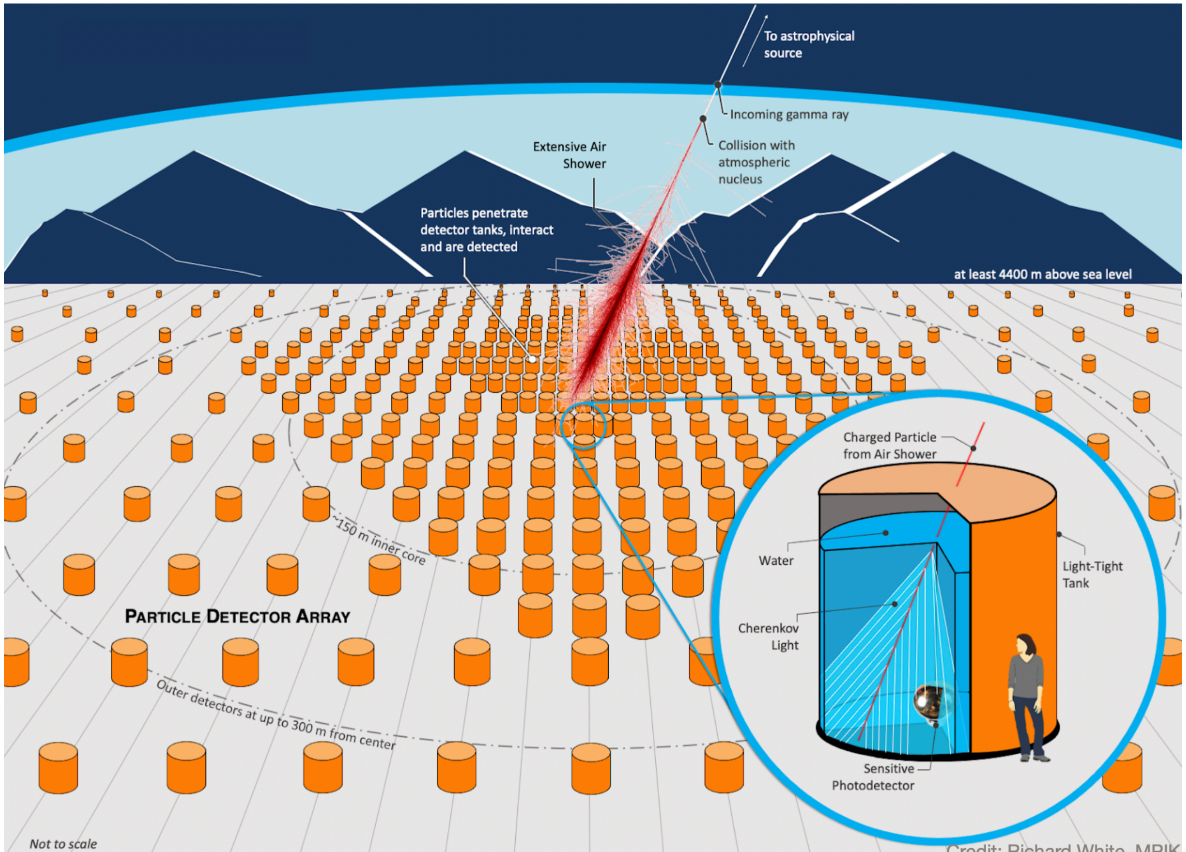
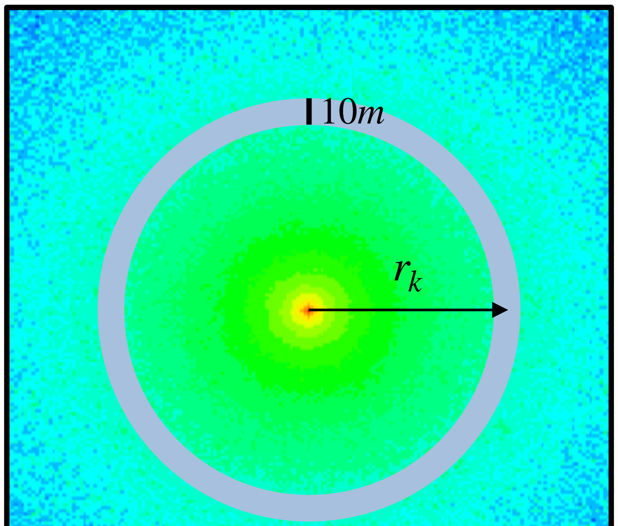
The challenge



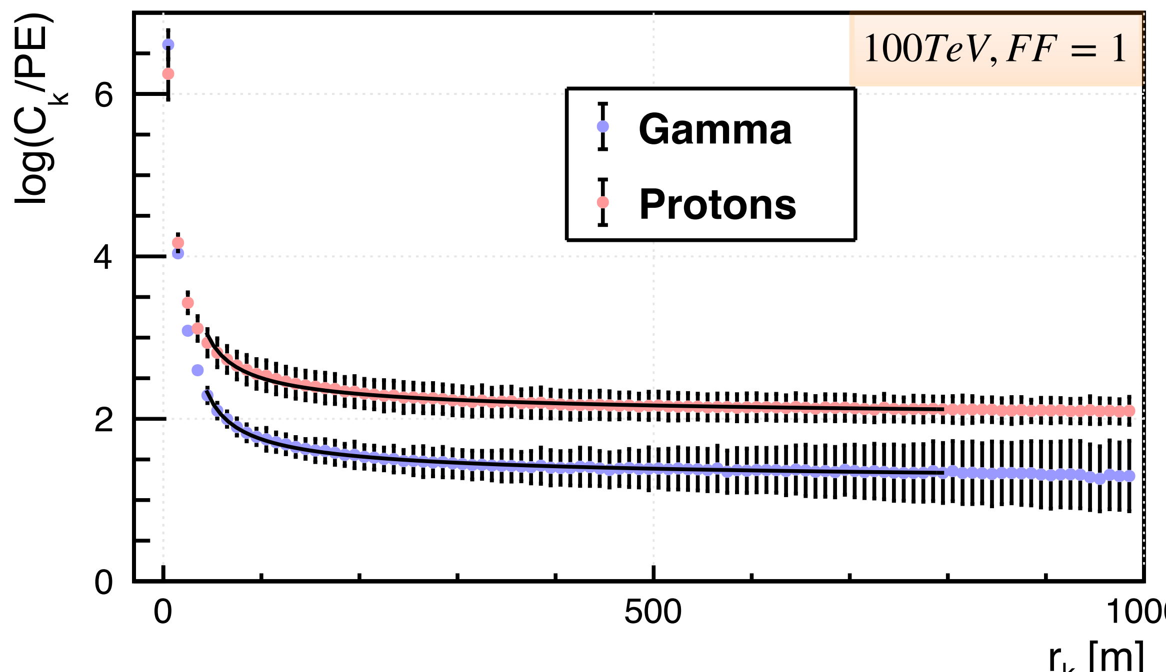
- Goal: identifying PeVatrons → sources capable of accelerating protons at energies $\geq 1 PeV$.
- High energy = small flux → necessary to cover a large surface.
- Only neutral particles point directly to the sources → gamma rays.
- Gamma rays are a tiny fraction of the all-particle flux (~1%) → excellent gamma/hadron discrimination capabilities are needed.
- Counting muons is too expensive → alternative solutions should be preferred.

The C_k variable

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



Ring with n_k stations and mean signal $\langle S_k \rangle$



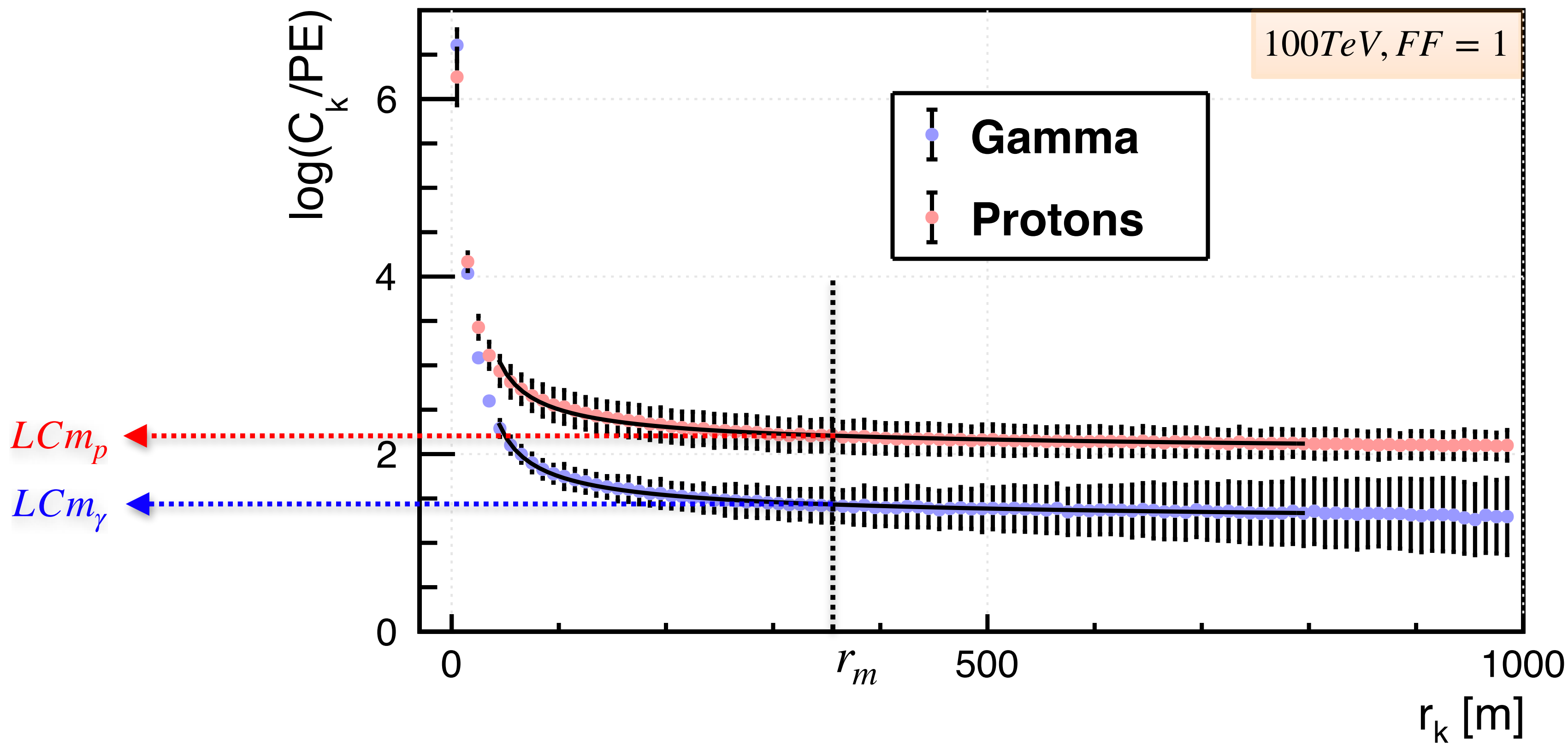
- C_k is sensitive to the azimuthal fluctuations of the shower footprint at the ground!

The LCm variable

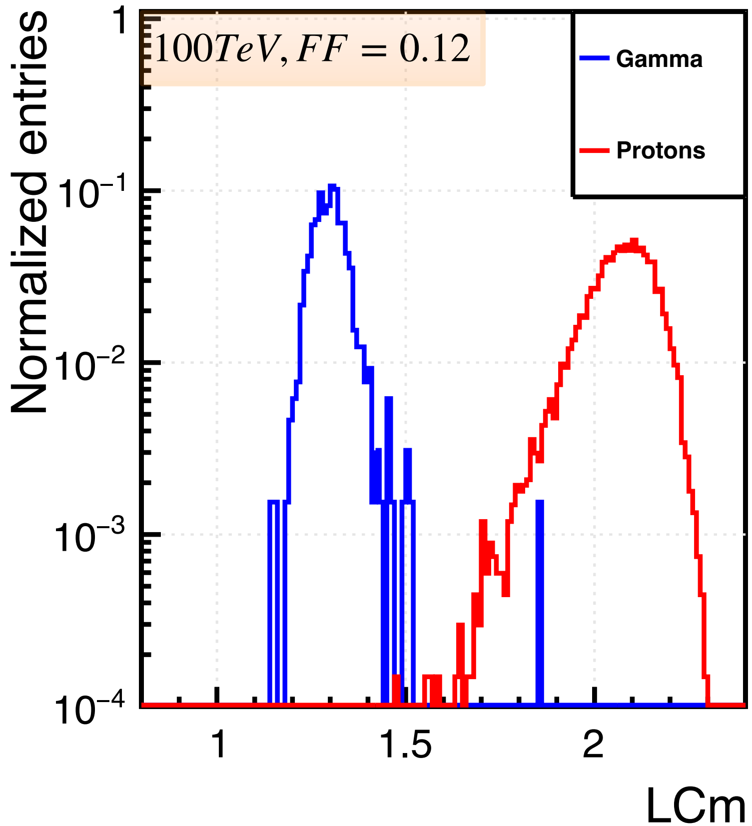
$$\log(C_k) = a + \frac{b}{\log\left(\frac{r_k}{40\,\mathrm{m}}\right) + 1}$$

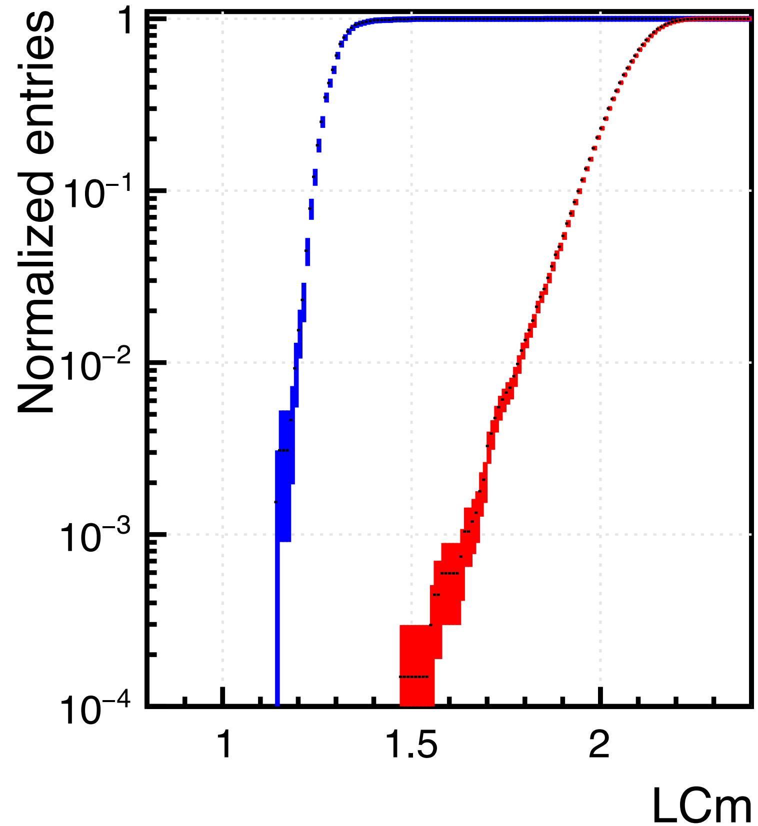
$$LCm \equiv \log\left(C_k\right)\Big|_{r_k = r_m}$$

$$r_m = 360m$$

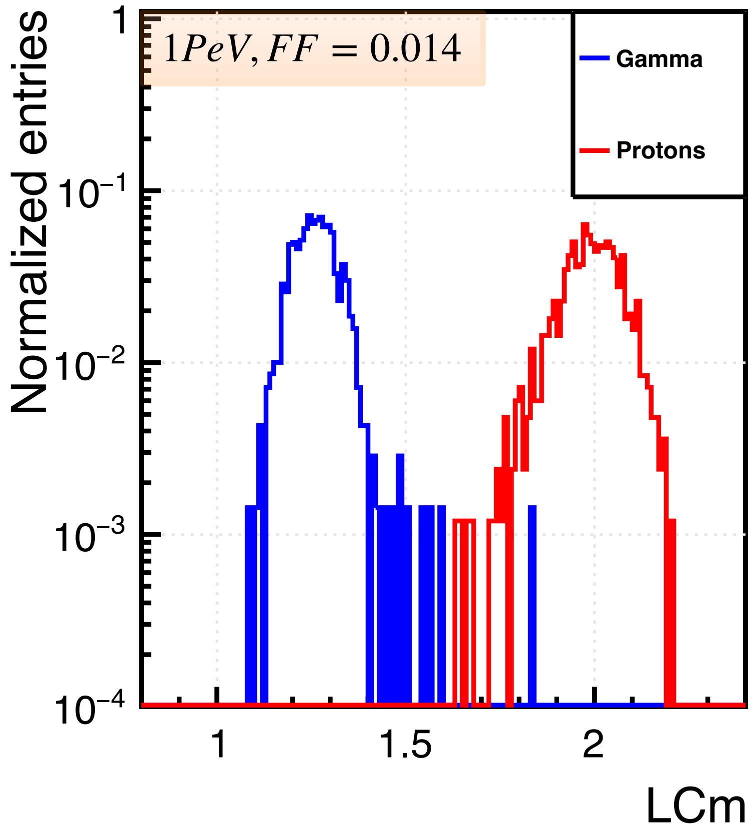


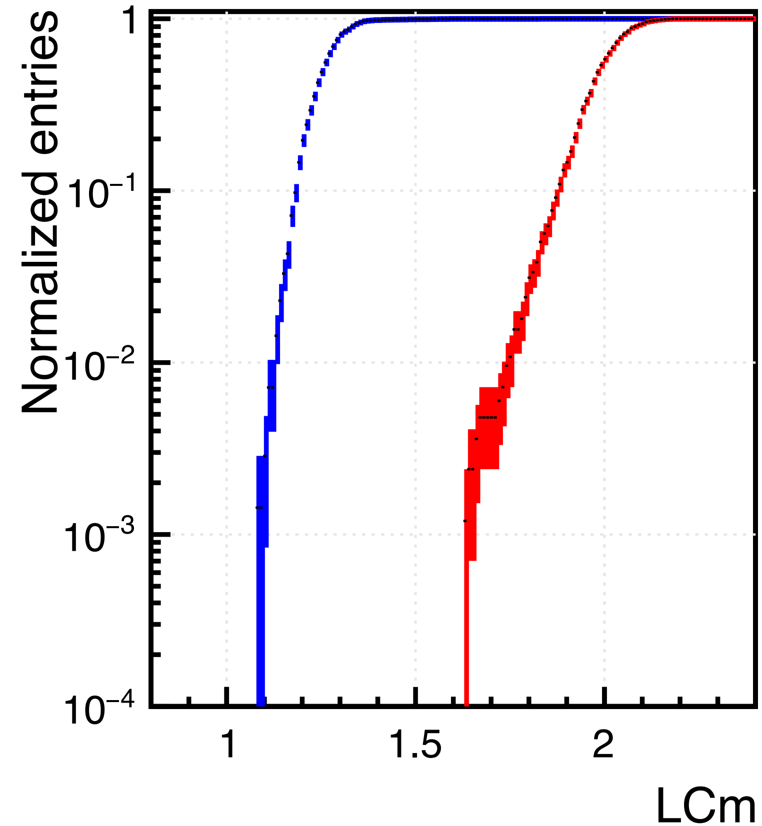
The LCm variable



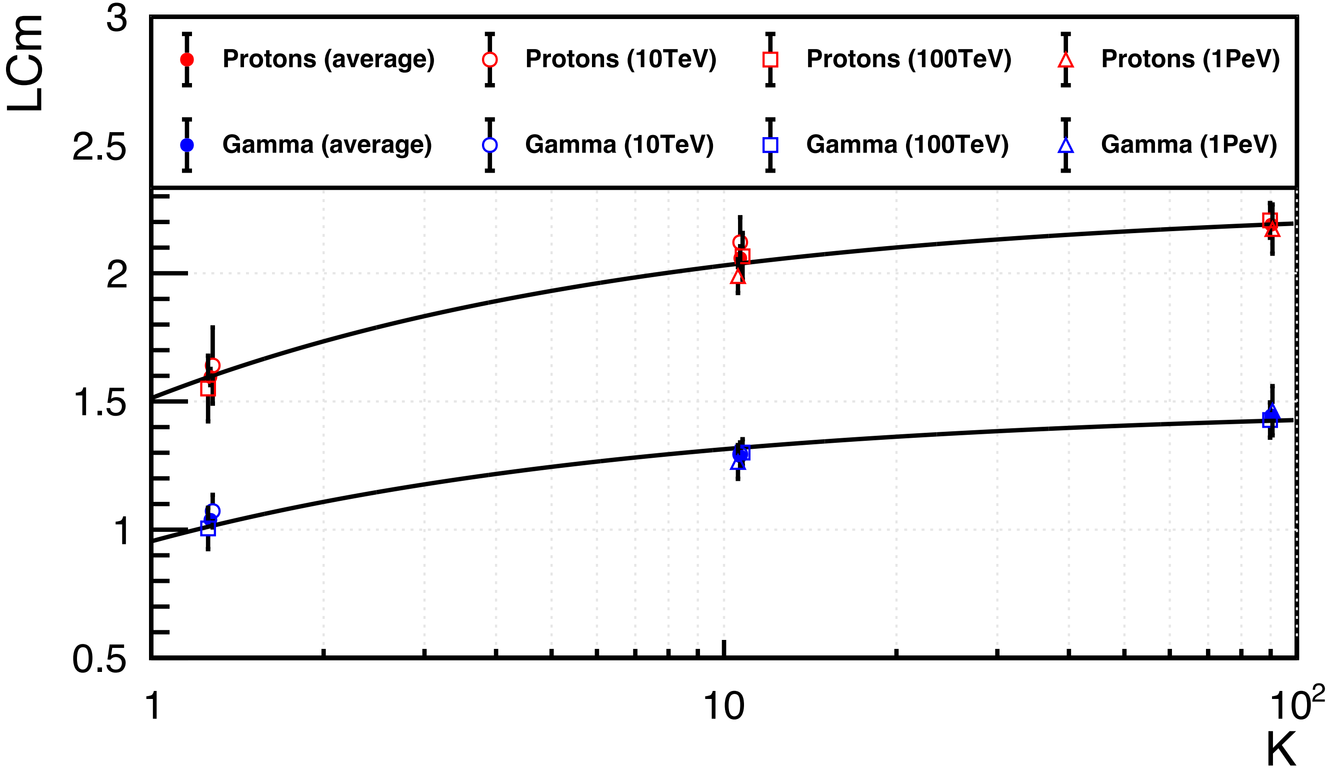


The LCm variable





LCm scaling with the K factor

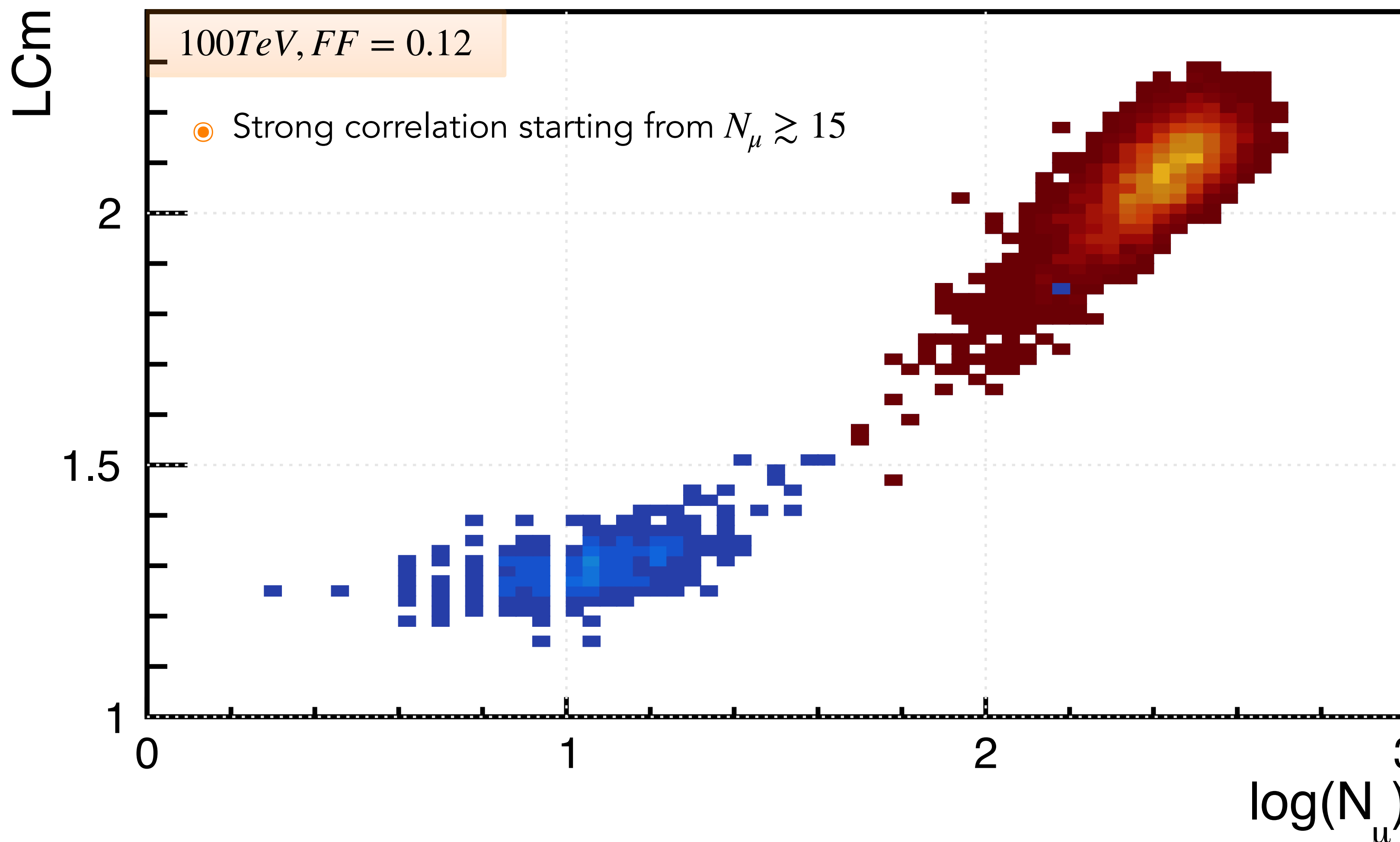


$$K = E^{\beta} \times FF$$

- E: simulated energy of the gamma showers $[TeV]$
- $\beta = 0.925$ - index of power dependence of mean number of muons at the ground
- FF: fill factor $\in \,]0,1]$

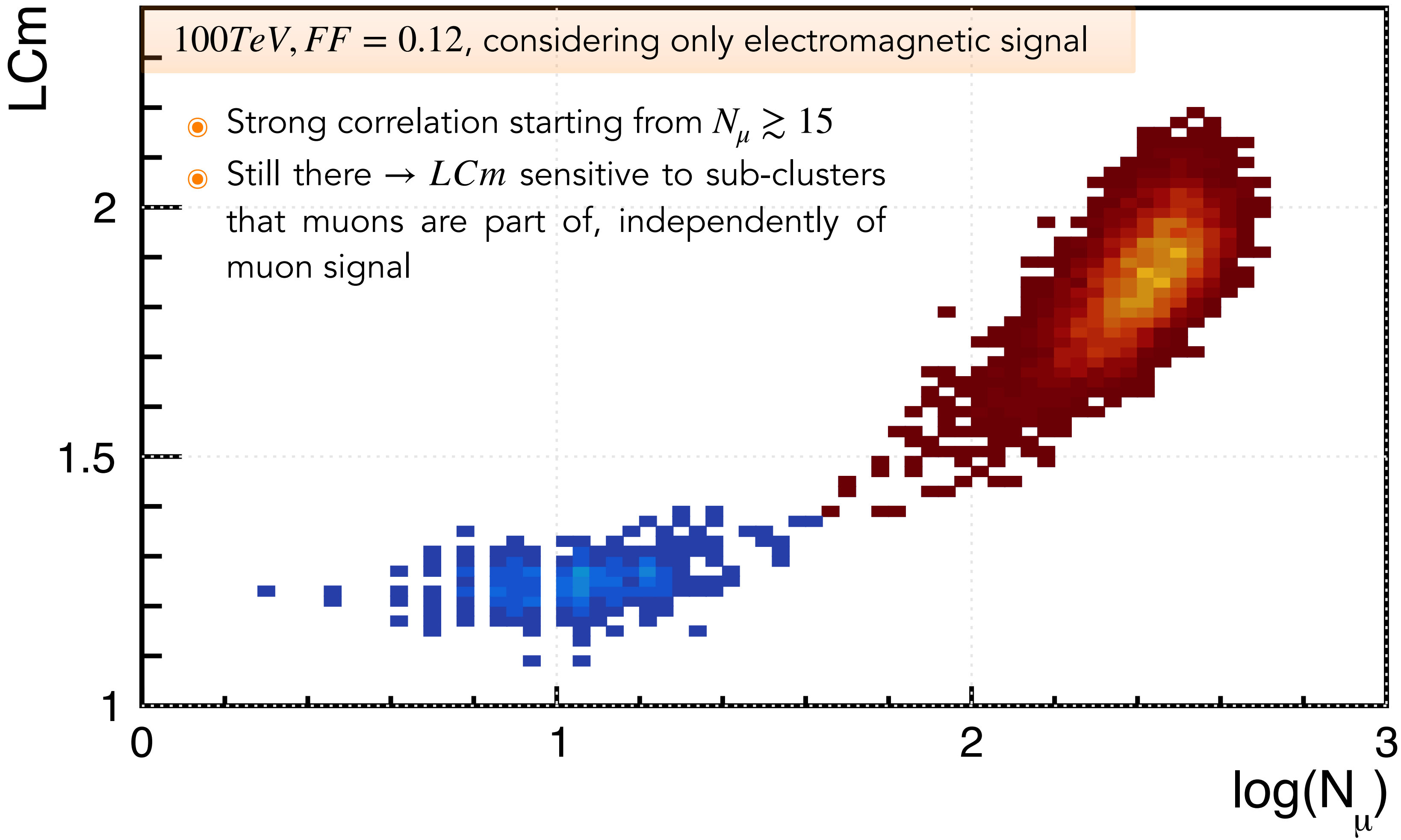
$$LCm_i(K) \sim A_i + \frac{B_i}{\sqrt{K}}$$

LCm vs N_μ



$100 TeV, FF = 0.12$
Strong correlation starting from $N_\mu \gtrsim 15$
LCm
1
1.5
2
0
1
2
3
log(N_μ)

LCm vs N_μ - E.M. signal only

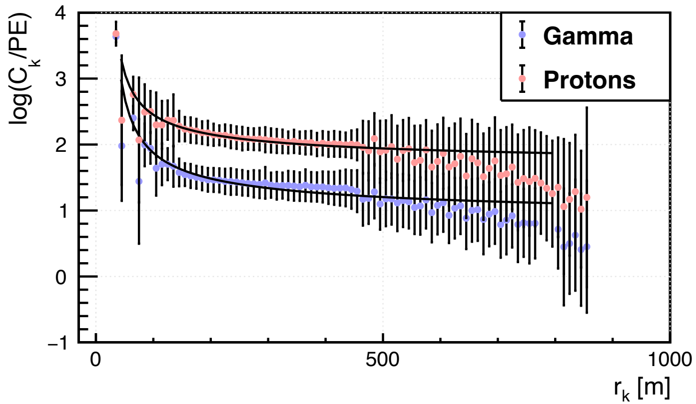


$100TeV, FF = 0.12$, considering only electromagnetic signal

- Strong correlation starting from $N_\mu \gtrsim 15$
- Still there $\rightarrow$ LCm sensitive to sub-clusters that muons are part of, independently of muon signal

Future developments

Sparse + compact array, centered far from the core



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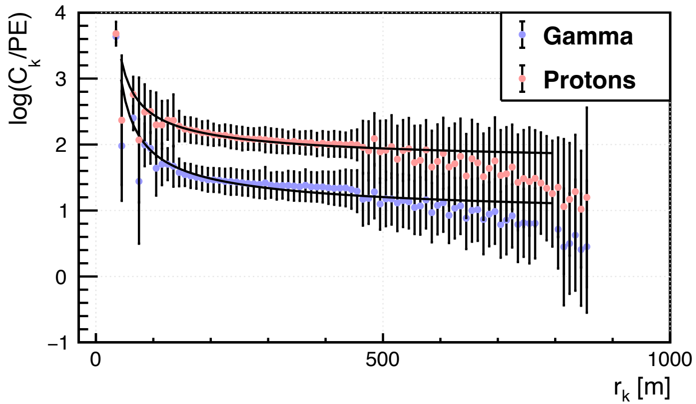
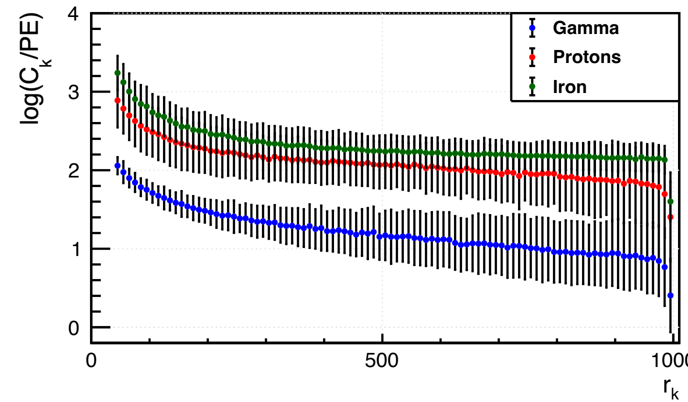


Iron showers



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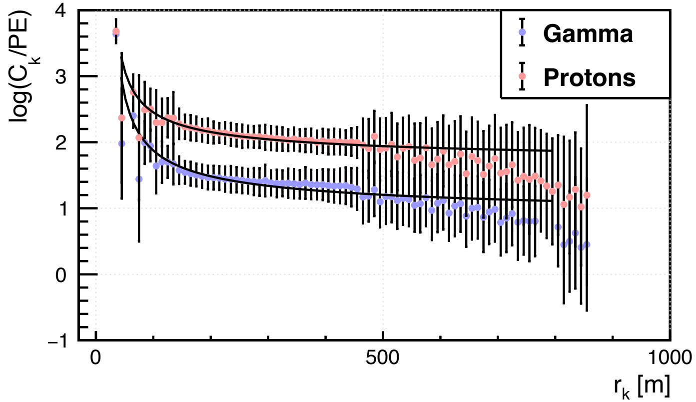

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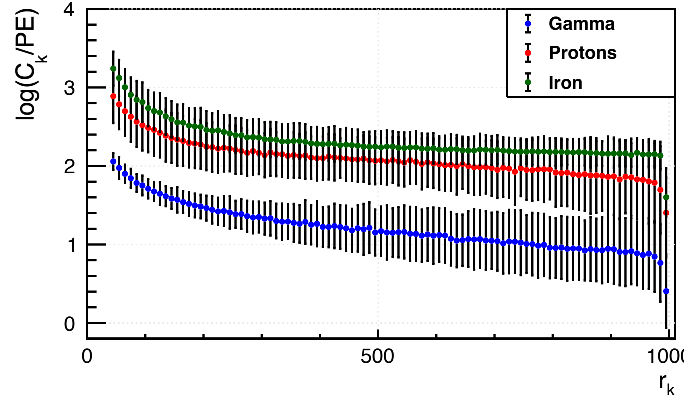
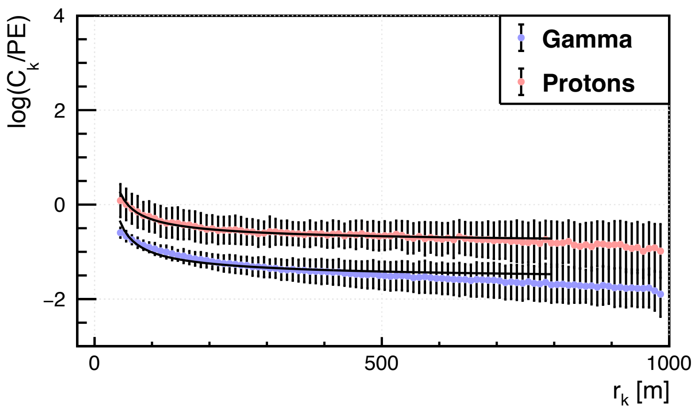


1 PMT stations, normalized to VEM



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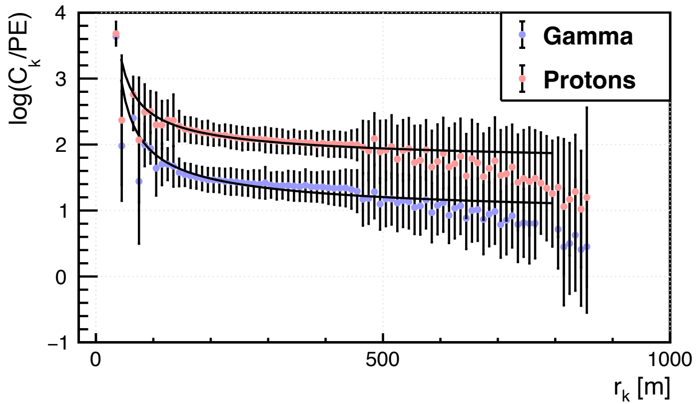

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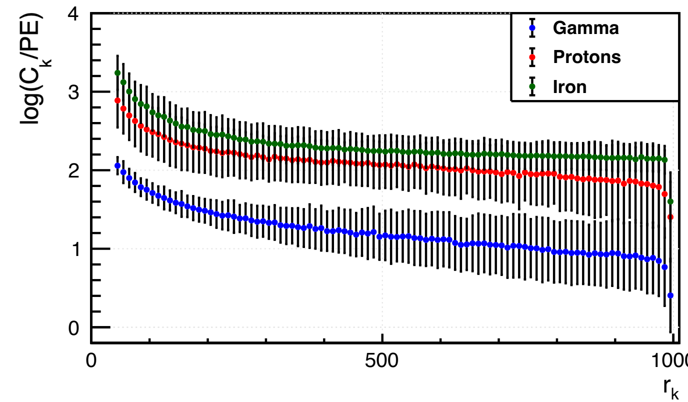

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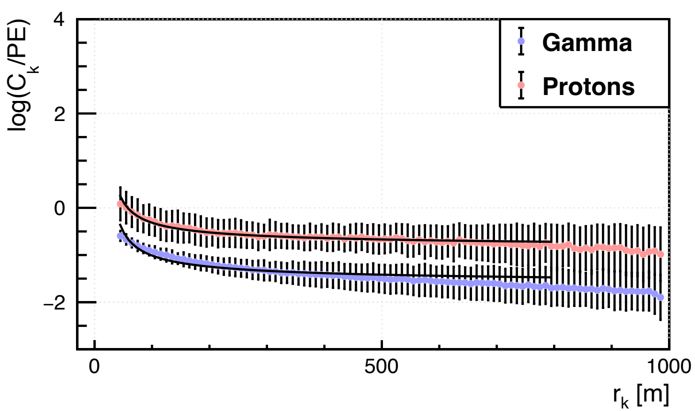
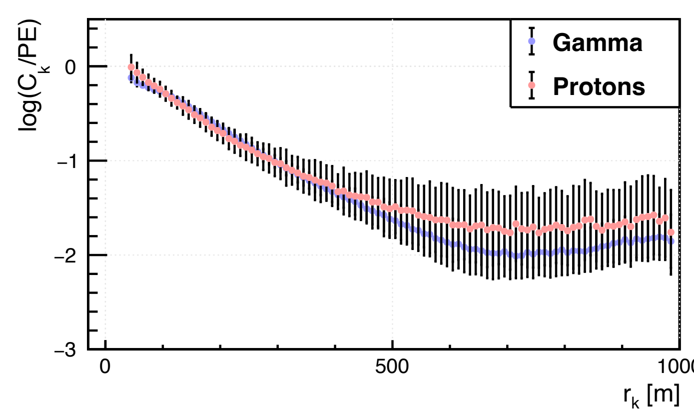


1 PMT stations, computed with the number of particles



Conclusions

- The LCm variable, which quantifies the azimuthal asymmetry of the shower footprint at the ground, has been introduced.
- LCm correlated with N_μ.
- Paper introducing LCm submitted for publication to JCAP: arXiv:2204.12337.
- SWGO internal note produced to describe the functioning of LCm in multi-fill-factor arrays centered far from the shower core.
- Multiple work lanes open: testing of LCm with different kinds of WCDs and scintillators, combination with other gamma/hadron discriminating variables, studies on composition, testing with real data from LHAASO…

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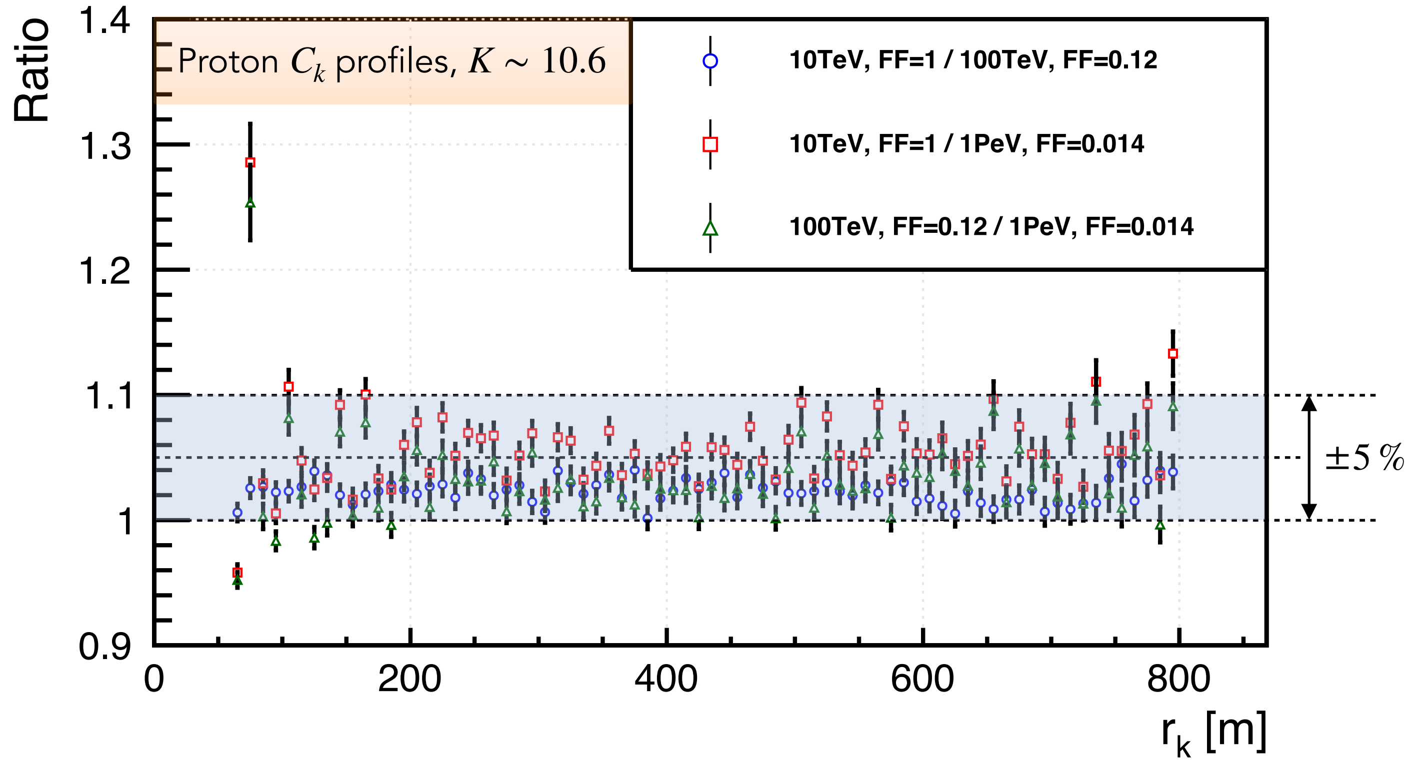
Thank you for your attention!

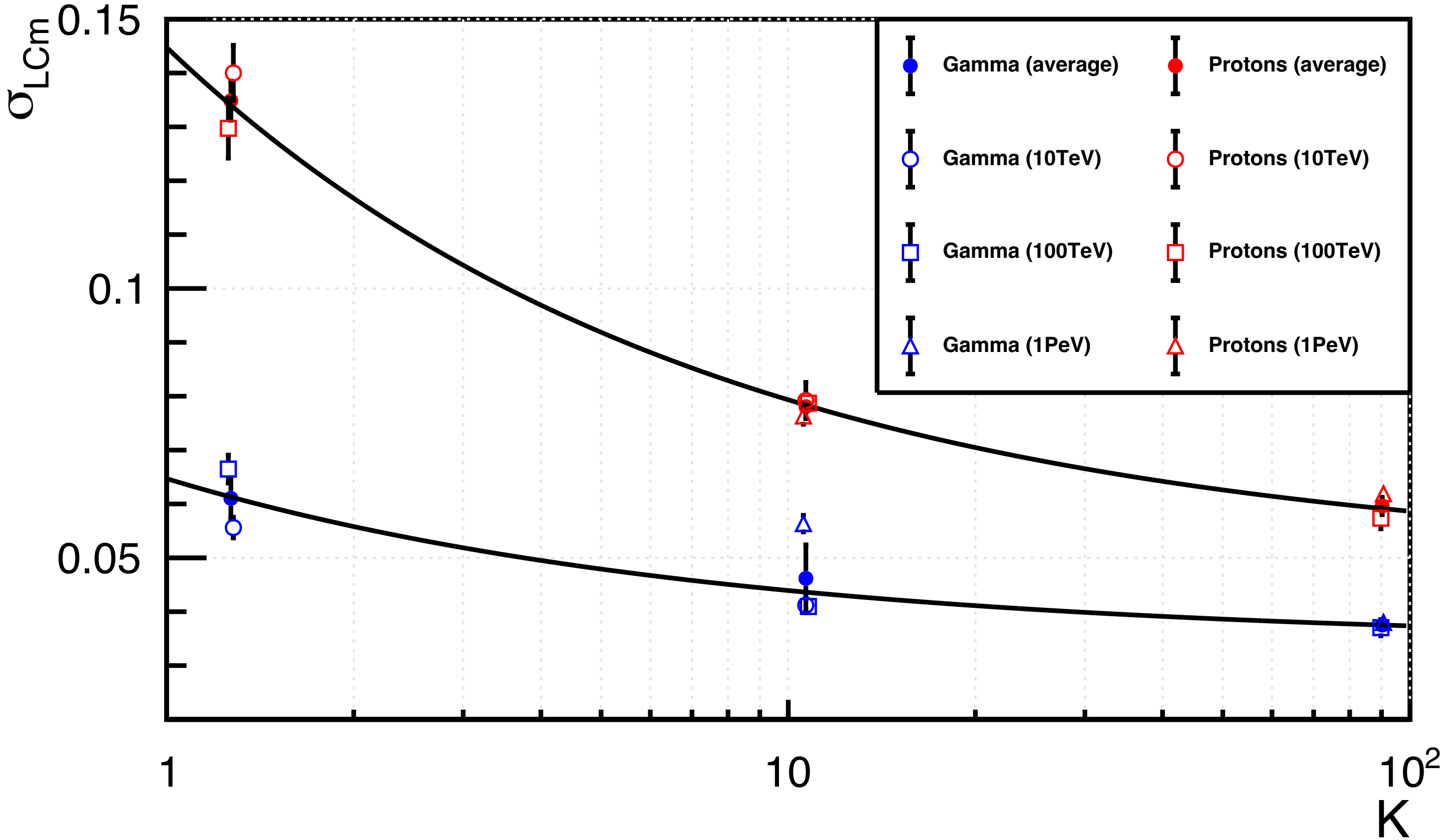
Backup

C_k ratios at fixed K



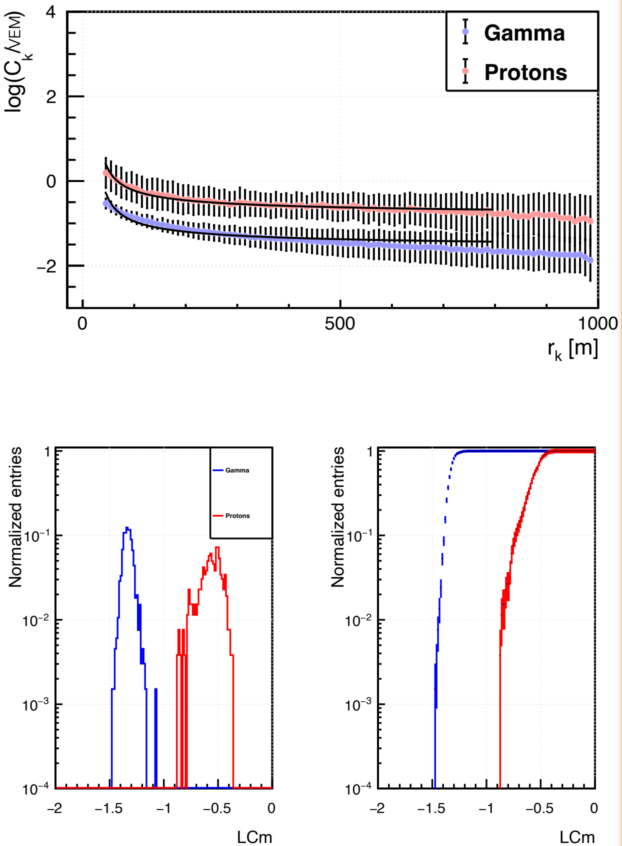
LCm's width's scaling with K

$$\sigma_{LCm_i}(K) \sim \Delta_i + \frac{C_i}{\sqrt{K}}$$

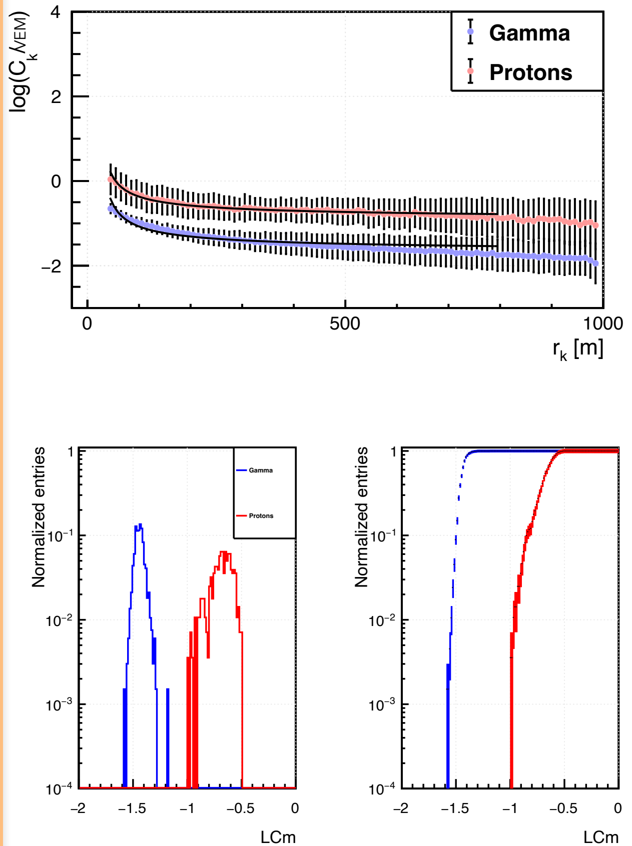


Different types of stations

4 PMTs



Mercedes (3 PMTs)



1 PMT