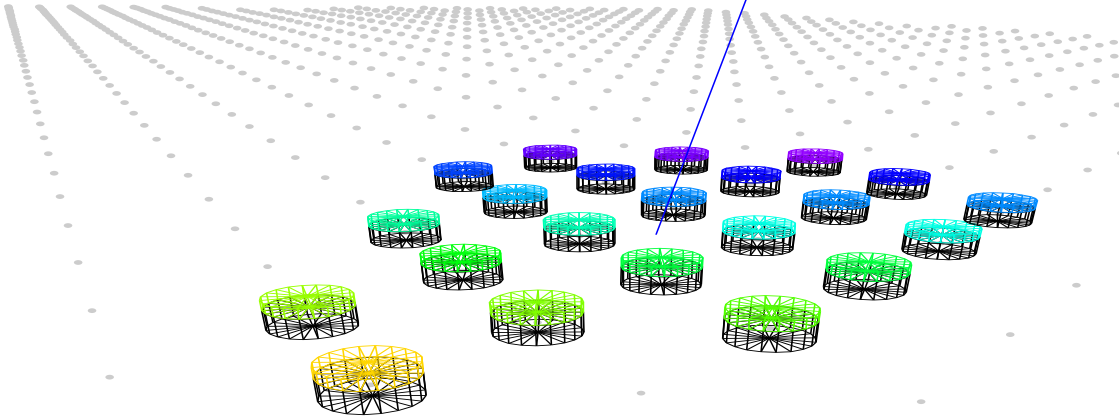
Layered Surface Detector for $\mu^{\pm}$ - $(\gamma, e^{\pm})$ separation at GCOS



Ioana C. Mariș (Université Libre de Bruxelles)

(A. Letessier-Selvon, P. Billoir, M. Blanco, I. C. Maris, M. Settimo, NIM A767 (2014), arxiv:1405.5699)

Global Cosmic Rays Observatory

How to reach the physics case with a surface detector?

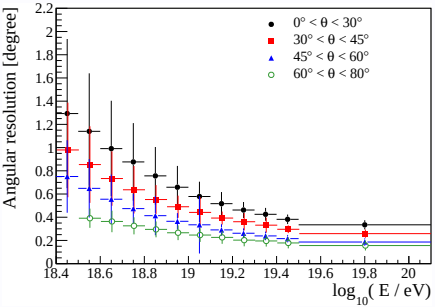
A. Energy resolution: 10% at 100 EeV
   → Driven by spacing between detectors and number of particles measured in the detectors

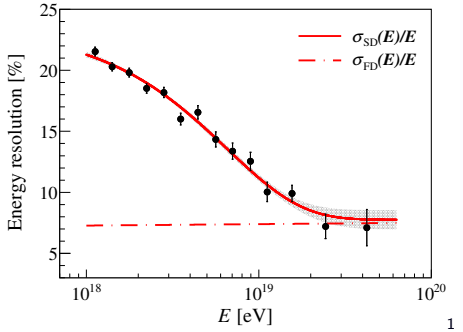
B. Angular resolution: 0.5 degrees at 100 EeV
   → Driven by spacing between detectors and the time resolution

C. Excellent mass composition determination
   → Determined by the quality of the separation between the em and muonic components of air-showers and hadronic interactions modeling

D. Huge exposure
   → Driven by the effective cost of a detector (including deployment) and constrained by resolutions

Can Water Cherenkov Detectors do it?

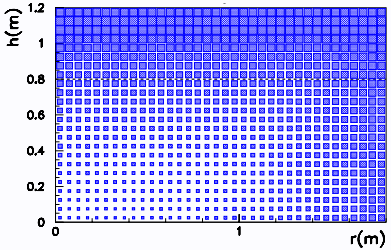




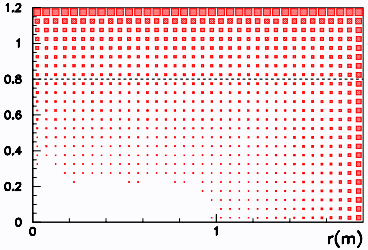
The idea: optical separation of a Water Cherenkov Tank

A water volume responds different to photons, $e^{\pm}$ and $\mu^{\pm}$

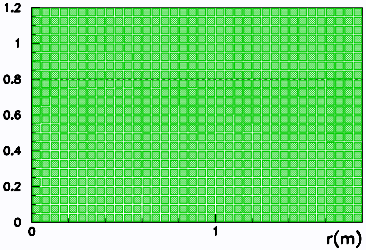
photons



electrons



muons



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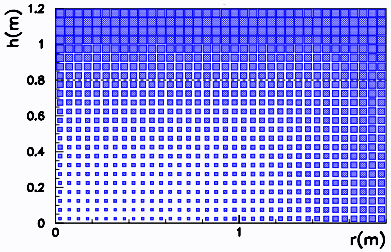
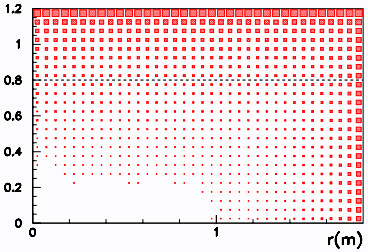
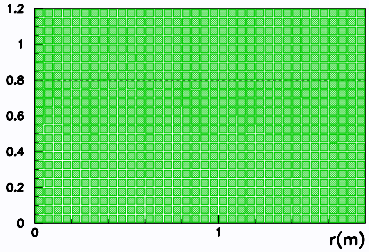
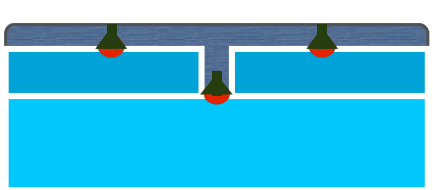


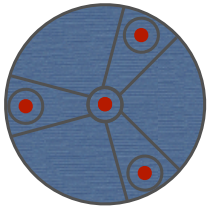
electrons

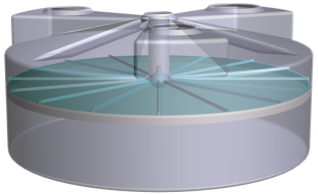


muons









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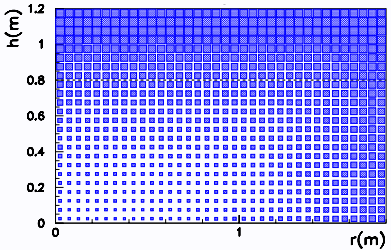
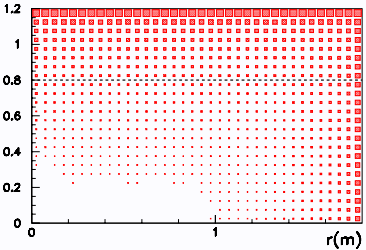
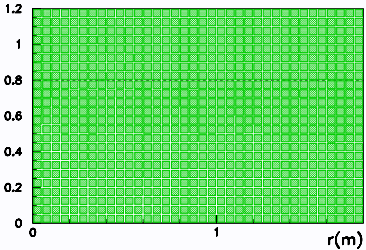
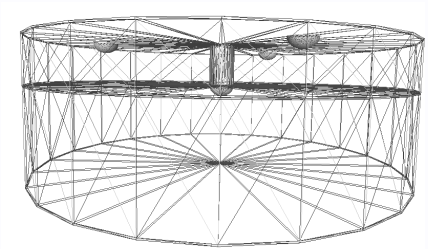


electrons



muons



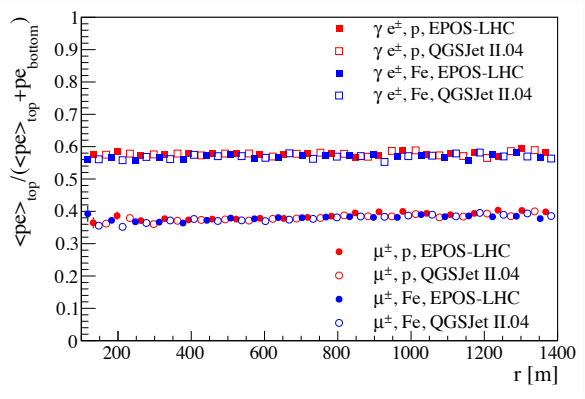


$$\begin{pmatrix} S_{\text{top}} \\ S_{\text{bot}} \end{pmatrix} = \mathcal{M} \begin{pmatrix} S_{\text{EM}} \\ S_{\mu} \end{pmatrix} = \begin{pmatrix} a & b \\ 1-a & 1-b \end{pmatrix} \begin{pmatrix} S_{\text{EM}} \\ S_{\mu} \end{pmatrix}$$

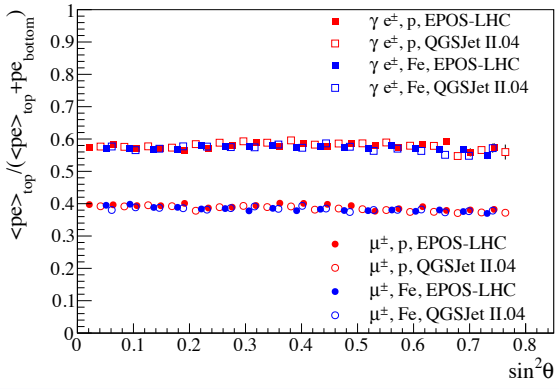
$$\begin{pmatrix} S_{\text{EM}} \\ S_{\mu} \end{pmatrix} = \mathcal{M}^{-1} \begin{pmatrix} S_{\text{top}} \\ S_{\text{bot}} \end{pmatrix}$$

Universality of a and b

independent of distance to axis

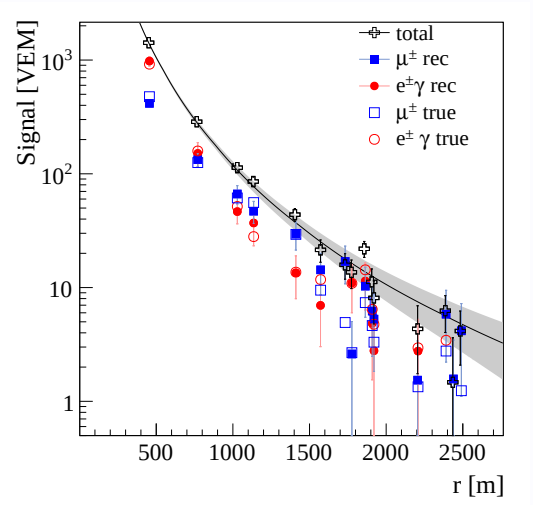


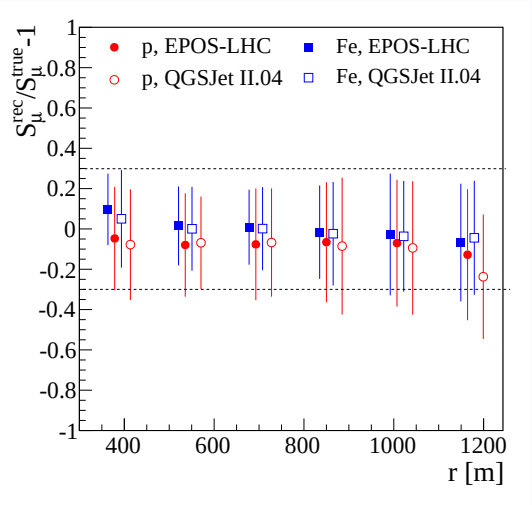
indepedendent of zenith angle



independent of hadronic models/primary

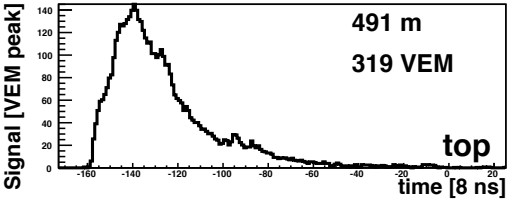
Good resolution for muonic and electromagnetic signals at station level

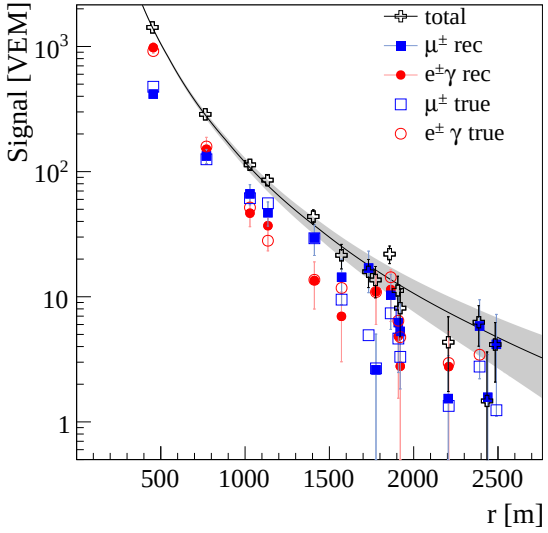




bias smaller than 5% and resolution of about 20-25% on station signal
leads to a event muonic signal resolution of better than 18%

Not only total signal, but also time distributions





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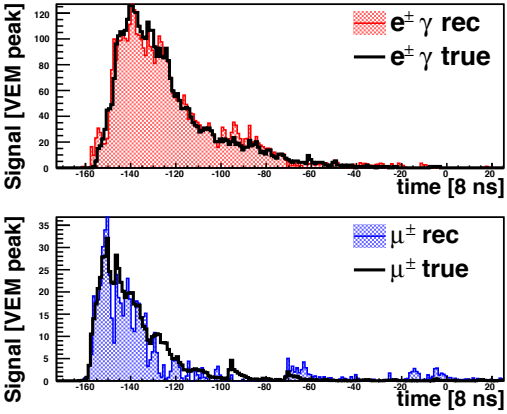
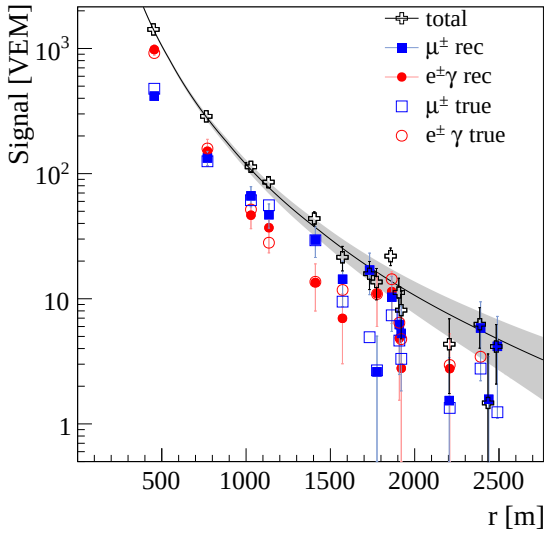
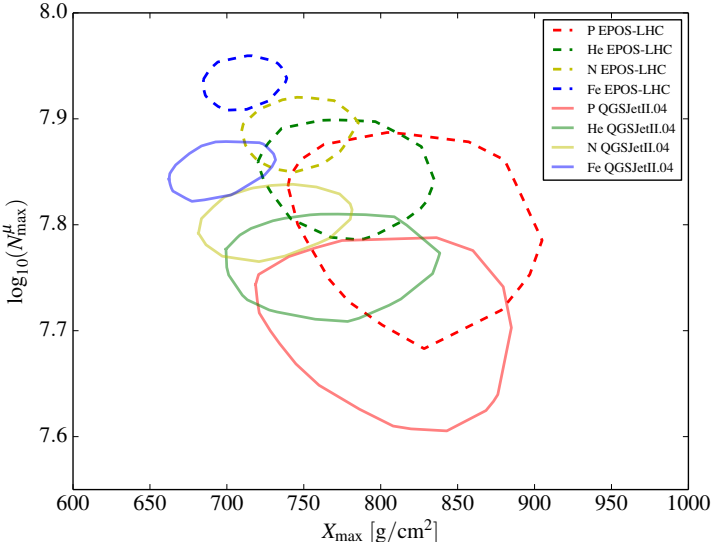


Based on Universality or DNN we can get $X_{\max}$



Mass composition separation

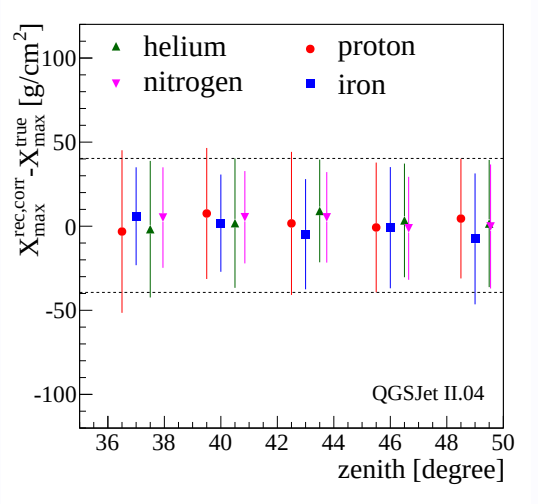
10 EeV, 38 degrees

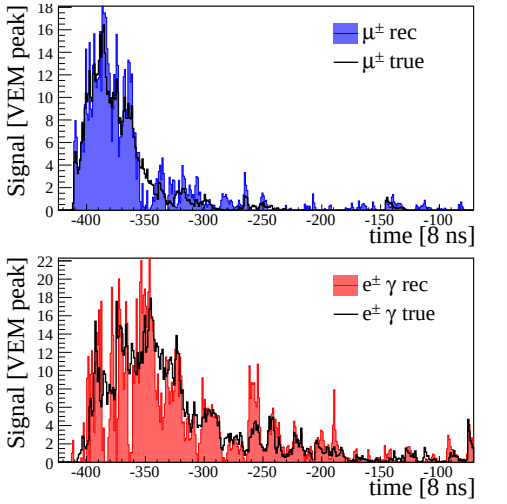


If we can obtain N_μ and $X_{\max}$ we win :)

(i.e. separate the electromagnetic and the muonic components)

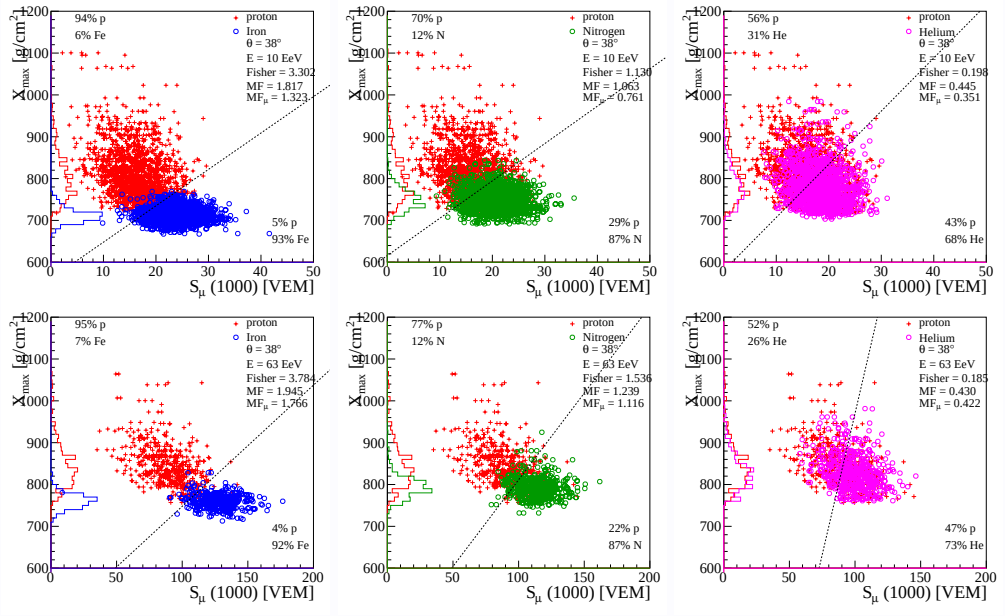
Example of $X_{\max}$ reconstruction from Universality



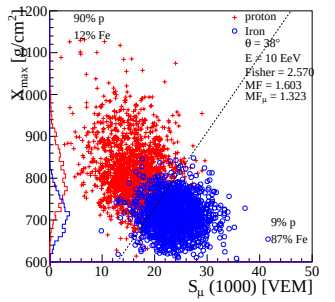


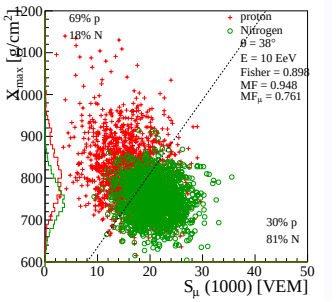
10 EeV primaries

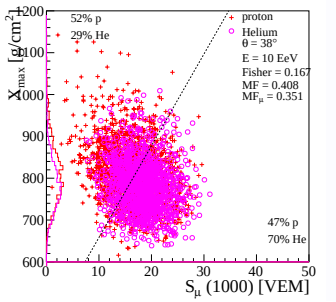
Example of merit factors at 10 EeV and 63 EeV

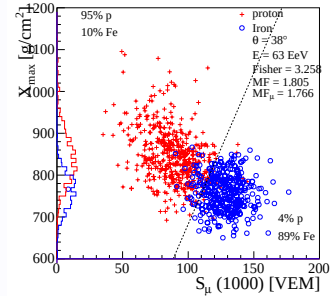


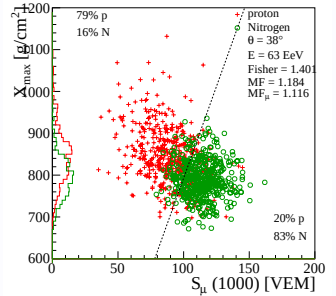
Example of merit factors at 10 EeV and 63 EeV(extra randomisation)

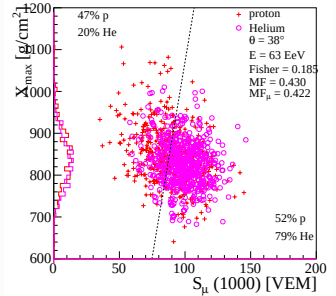






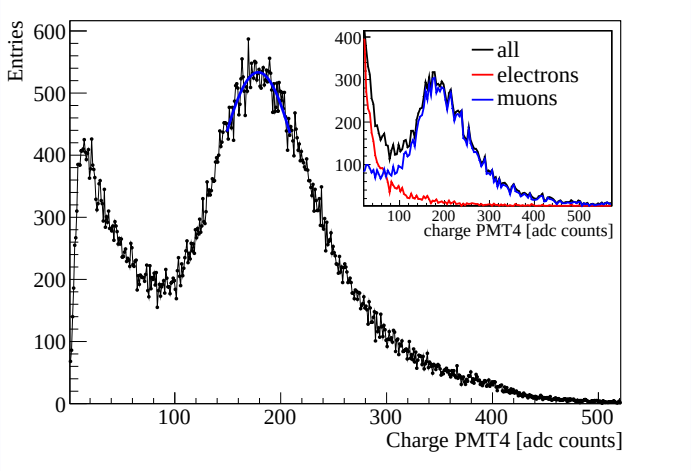


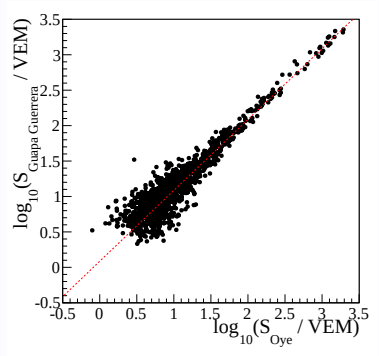




Guapa Guerrera, born on 26th of February 2014

Simple and standard calibration with atmospheric muons

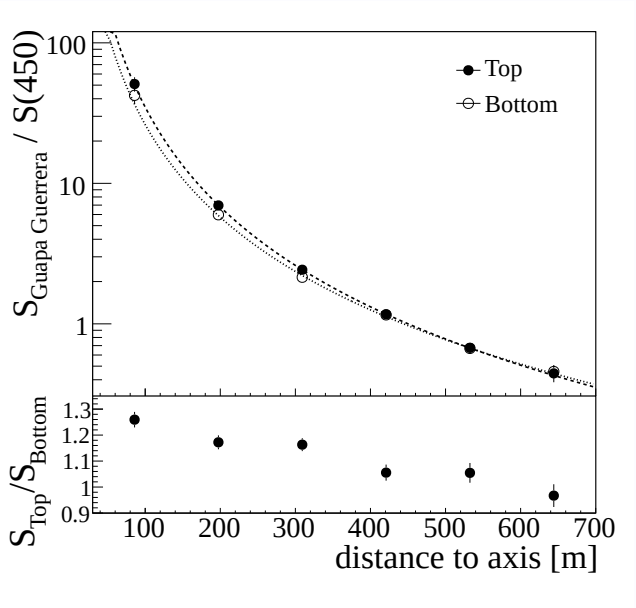




At least as good as Auger on total signal resolution (measure all the components, including photons)

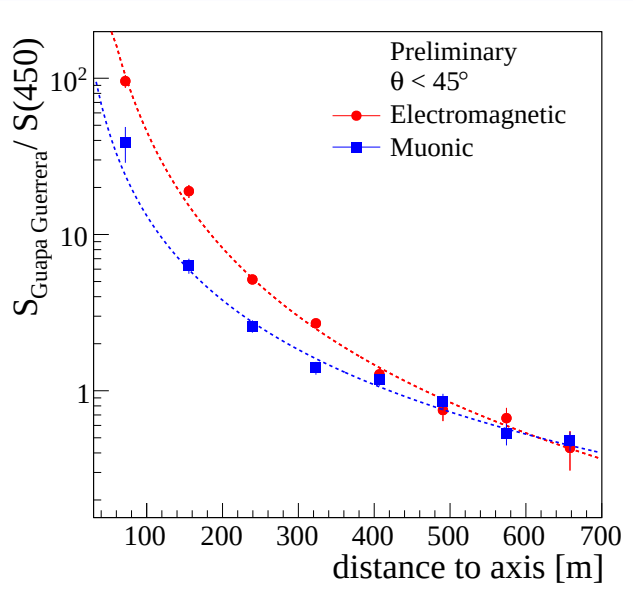
Mean lateral distributions: the detector performed as expected

900 events ($E > 0.03\,\mathrm{EeV}$, $\theta < 45°$)



Mean LDFs for the electromagnetic and muonic components

900 events ($E > 0.03\,\mathrm{EeV}$, $\theta < 45°$)



Using the LSD for GCOS? Could be a good option

A layered surface detectors can provide a very good separation of the electromagnetic (including photons) and muonic components of air-showers

Proof of concept achieved at Auger site (design can be easily tuned, playing with the Tyvek reflectivity, new photosensors etc..)

A few more pluses

- Very robust detectors (not too much mantainance, especially is other photosensors are used) with 100% duty cycle
- In principle can be deployed in the middle of the cities (with some nice mountains in the surroundings for neutrinos)
- Photons and neutrinos: trivial to separate