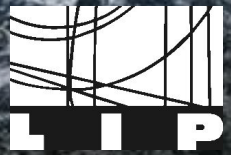
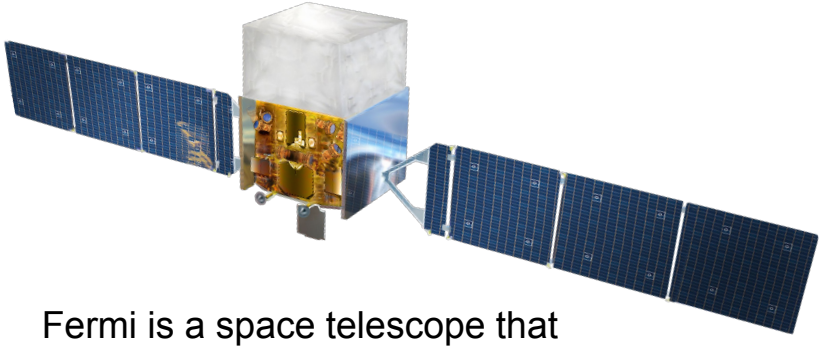
Development of Novel Reconstruction Techniques for Low-energy Gamma-ray Showers

Luís Lourenço & Hugo Lóio

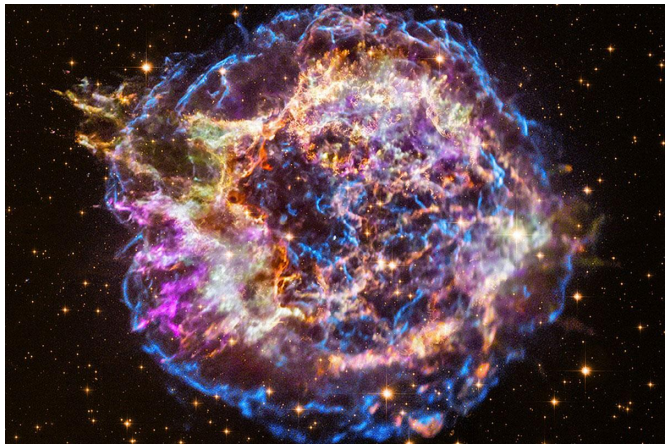
Supervisors:
Bernardo Tomé
Ruben Conceição



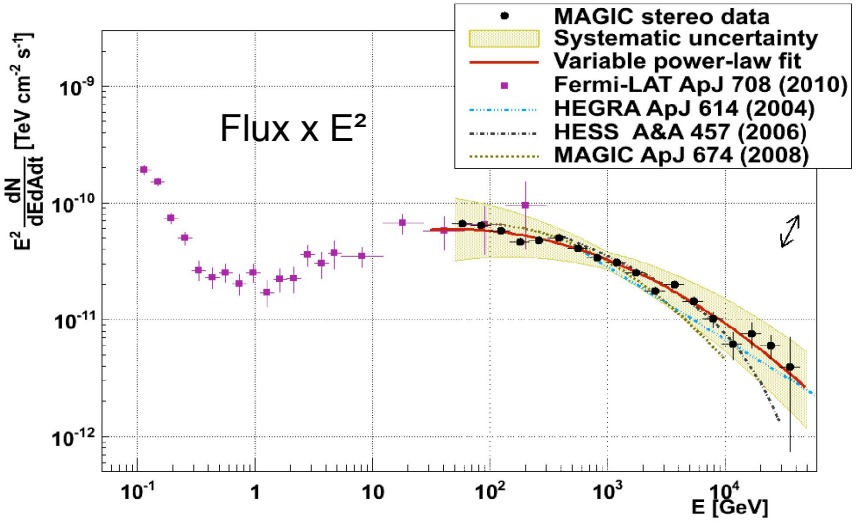
Cosmic gamma-rays



Fermi is a space telescope that detects cosmic gamma-rays

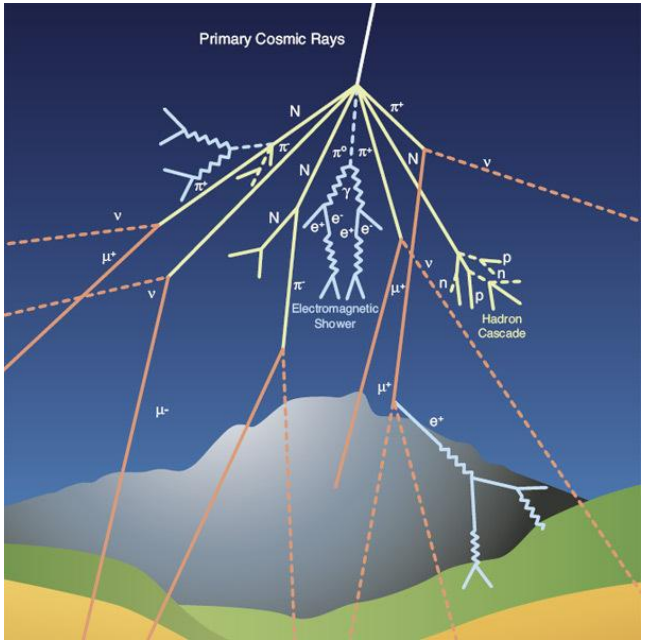


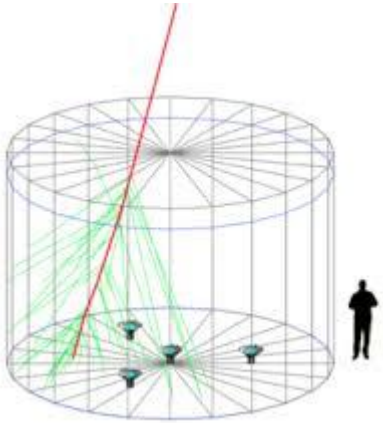
Main source of cosmic gamma-rays in our galaxy are supernova remnants



Cosmic gamma-ray flux decreases with particle energy (Crab Nebula)

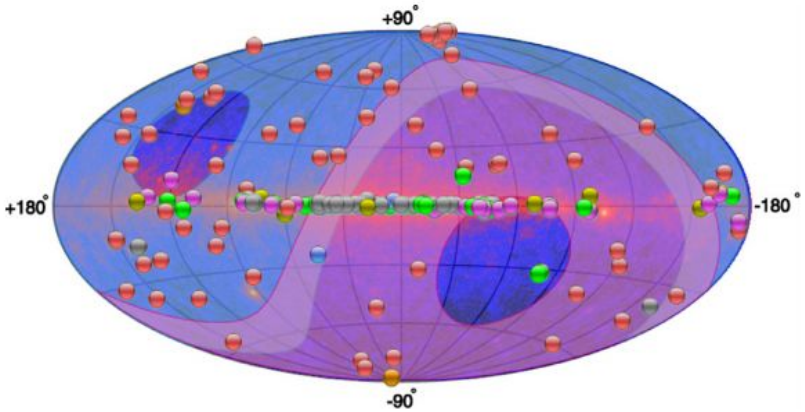
Particle showers and ground detectors



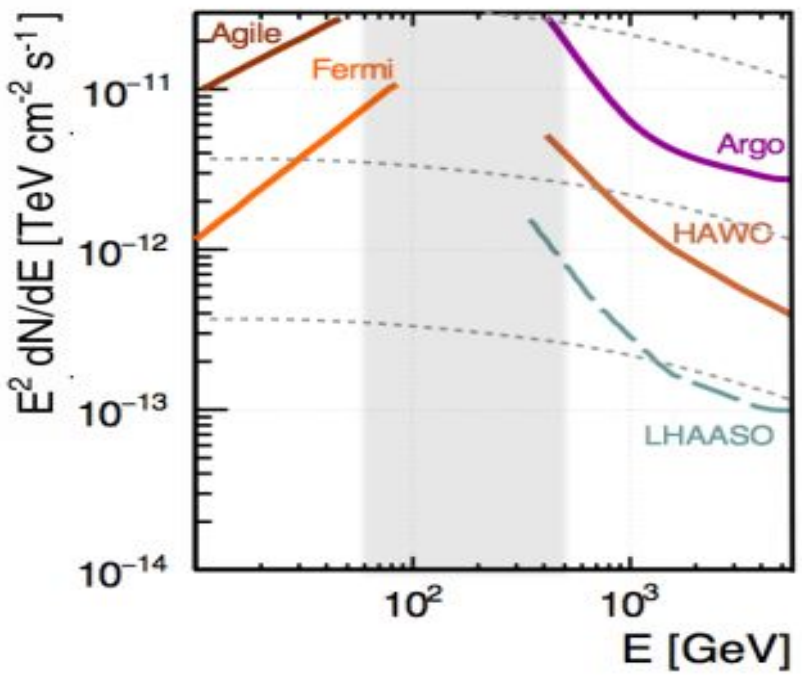


Ground detectors form arrays with very large areas (example of HAWC experiment). These detectors can't detect cosmic rays directly, only the resulting shower of their interaction with the atmosphere.

The need for a new detector

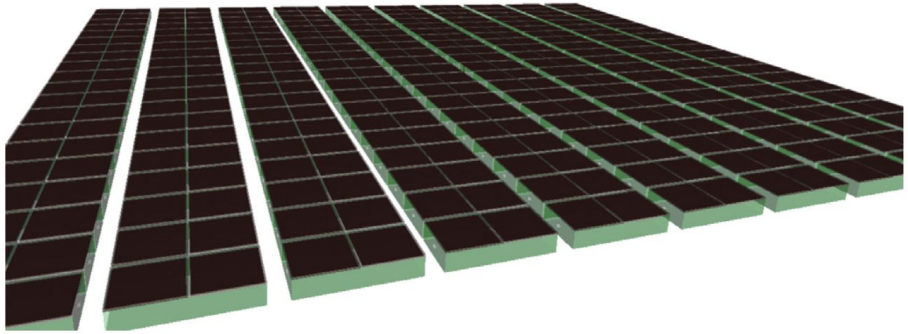


Very High Energy Emissions in Galactic Coordinates



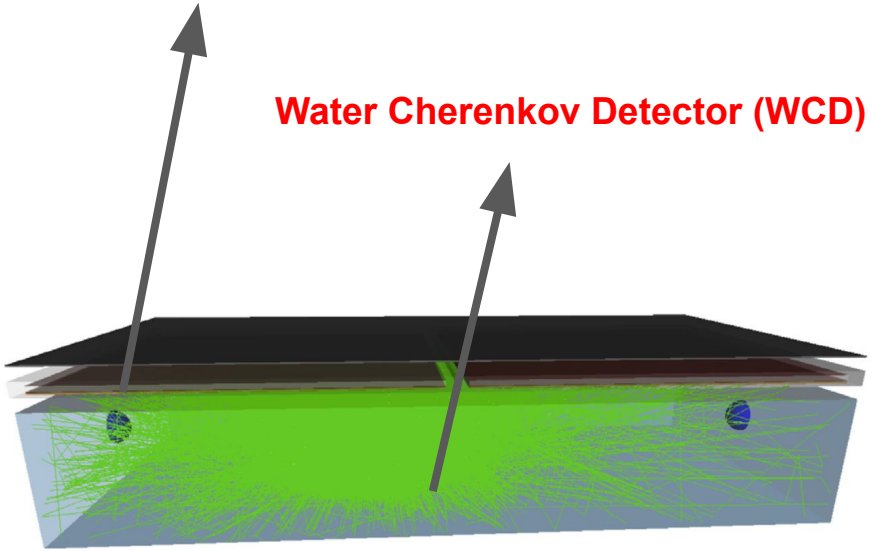
Energy gap filled by the new detector

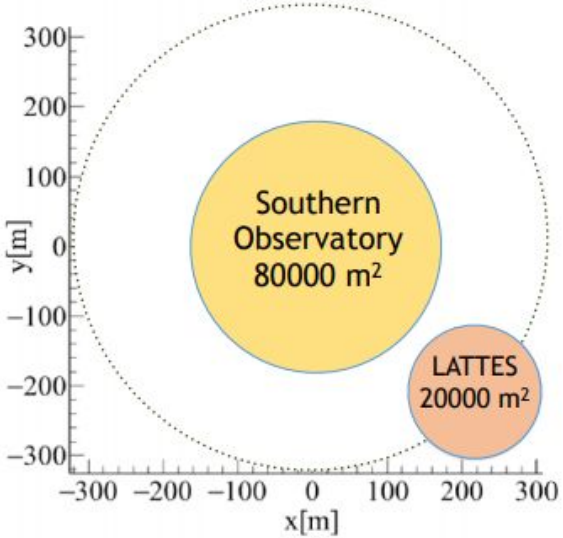
LATTES - hybrid concept



Resistive Plate Chamber (RPC) -> Hit Time

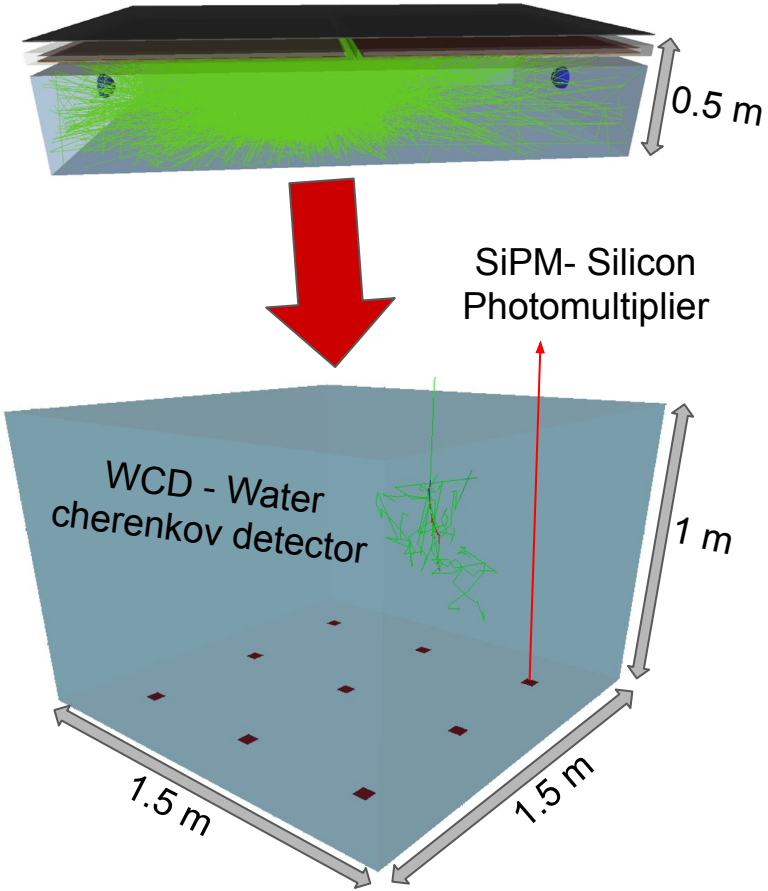
Water Cherenkov Detector (WCD) -> Total Signal



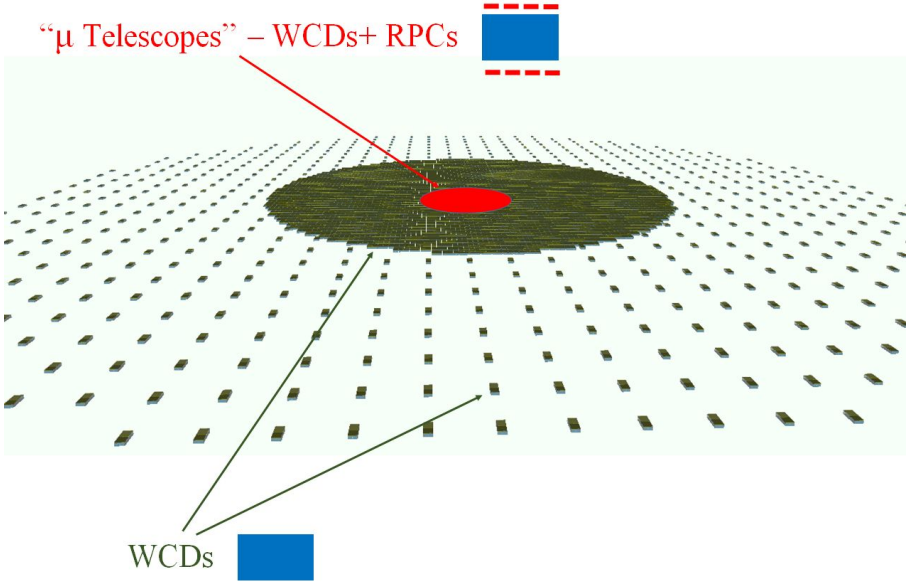


Size Matters!

SWGO - new concept



With a bigger array, less sophisticated detectors must be used in order to reduce costs and maintenance work.



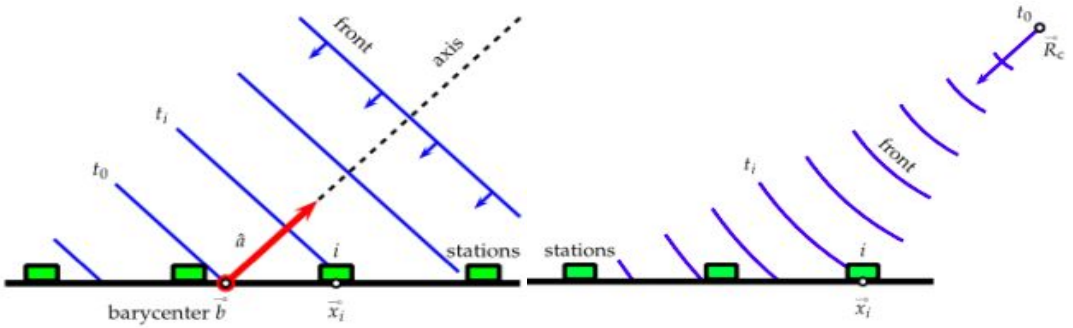
The new challenge is to have measurements with the same precision as before with these simpler detectors.

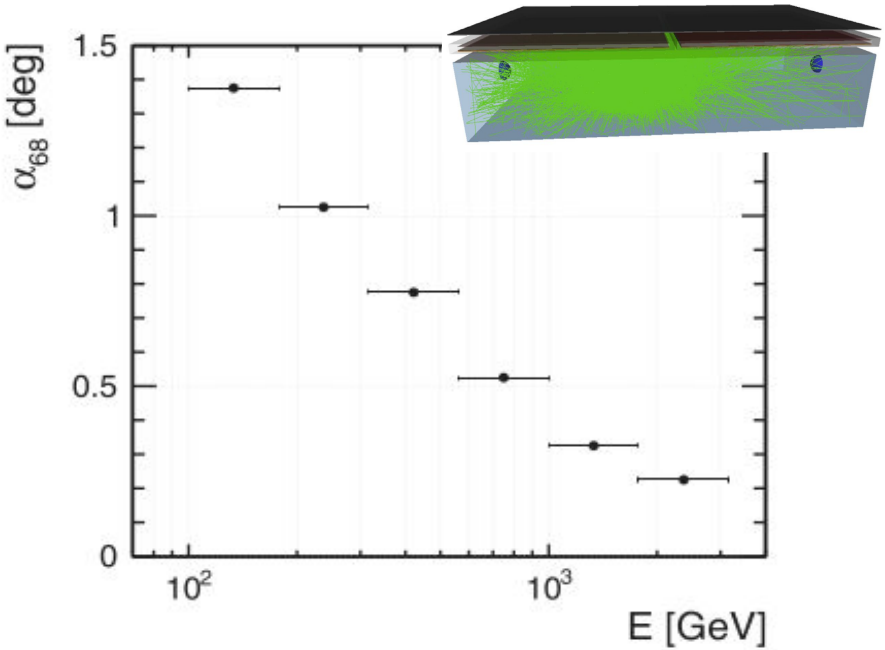
Reconstruction of Shower Geometry

hit time (RPC) + Shower Core
(1ns time resolution)

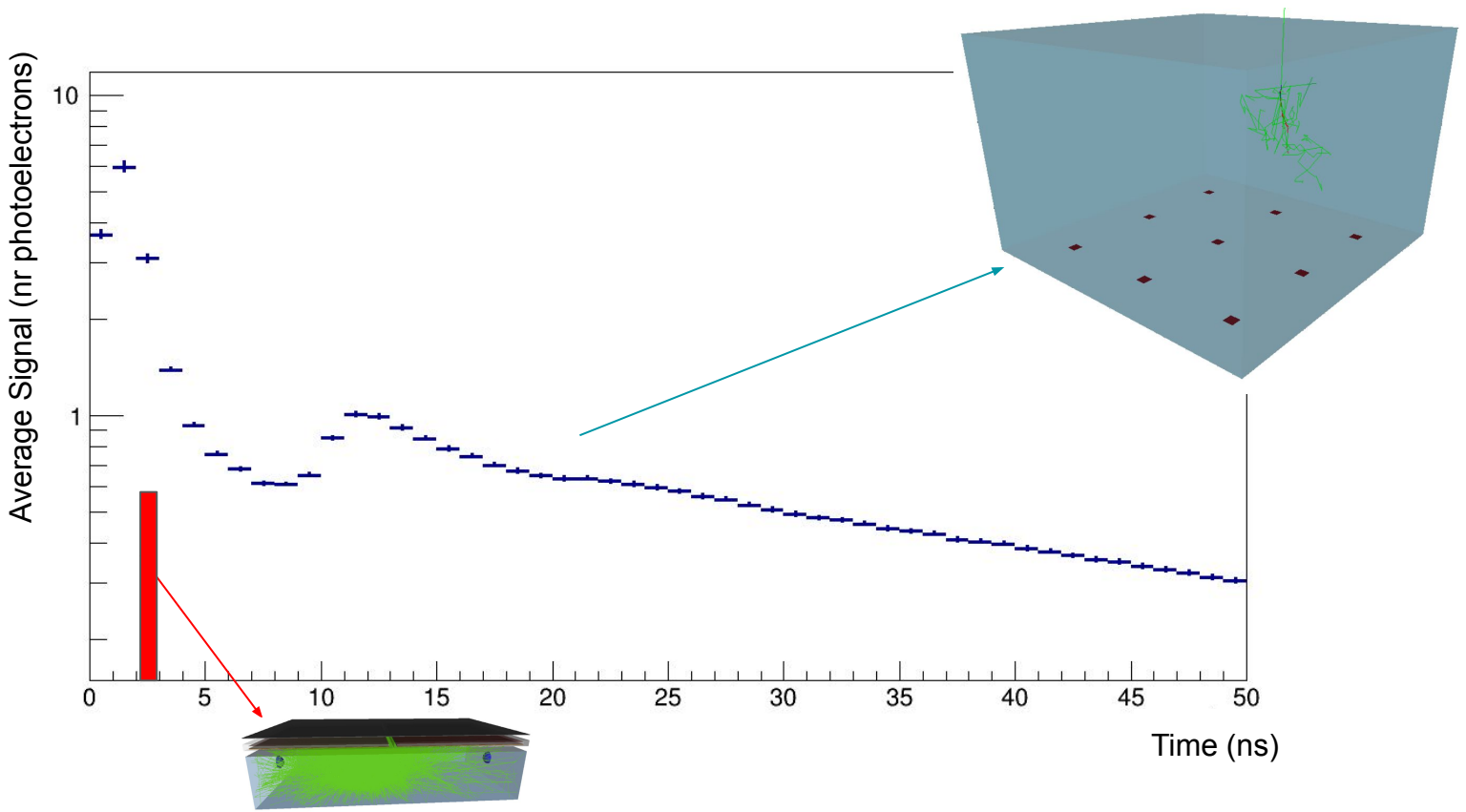
- Apply quality cuts - Only consider triggered WCD stations;
- Shower plane front fit and remove late arrivals (mainly low energy electrons);
- Shower conic front fit.

Shower Direction

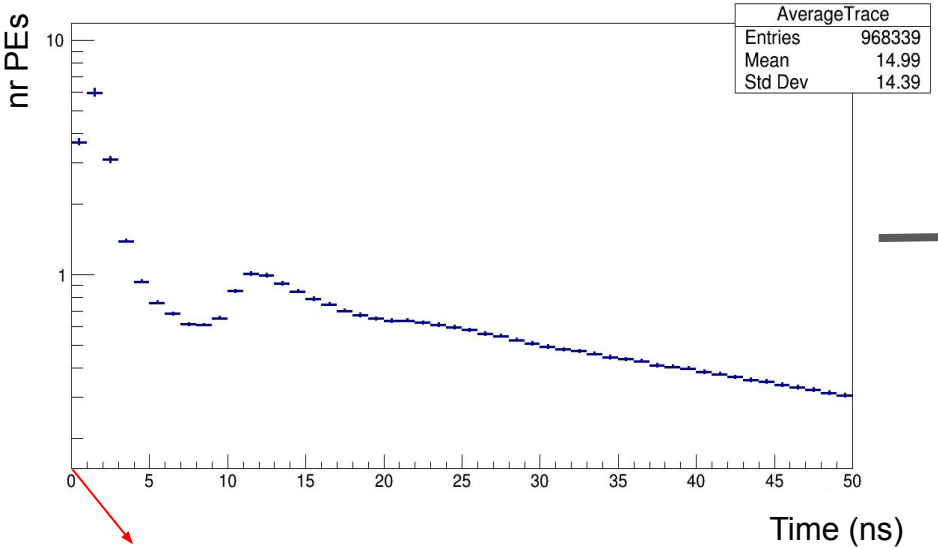




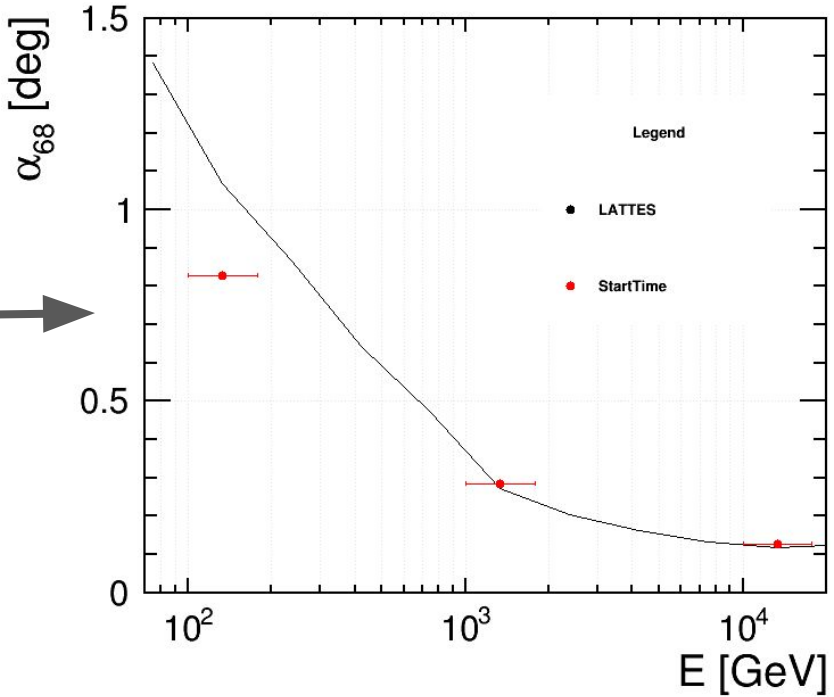
Time measurements - A new challenge



A simple starting point

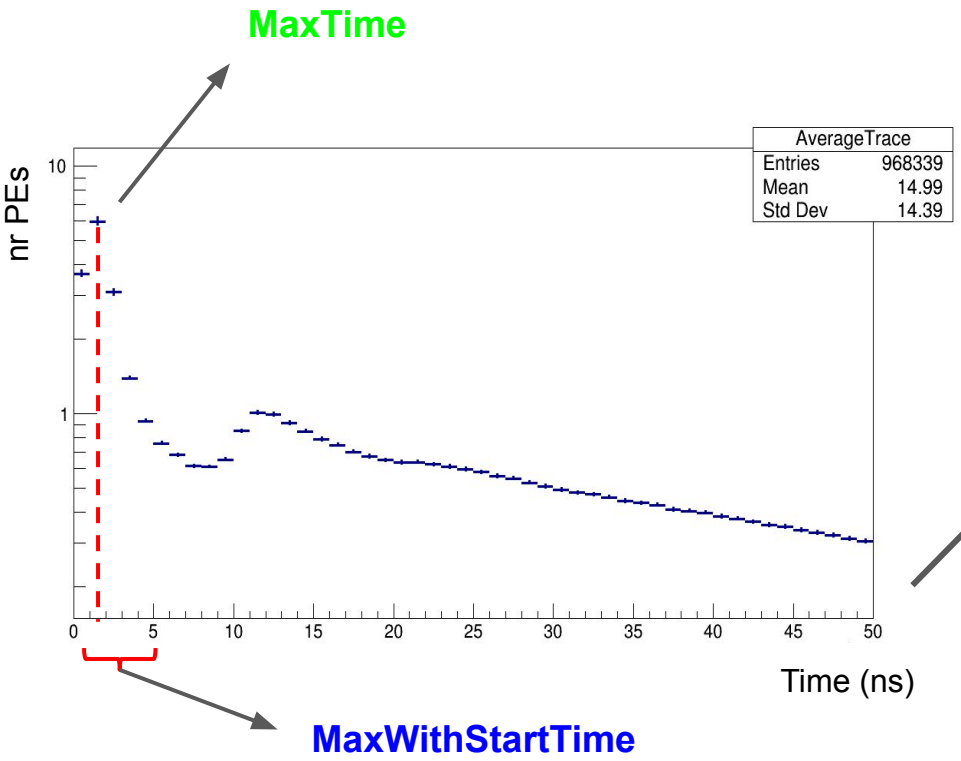


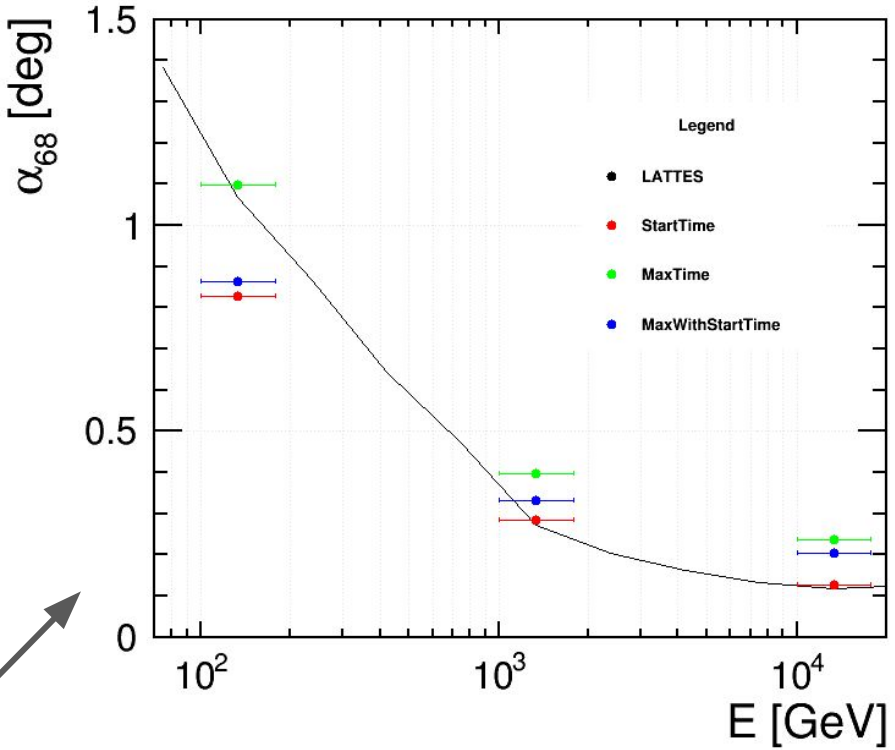
StartTime given by simulation



Best case scenario:
Geant4 ⟶ StartTime

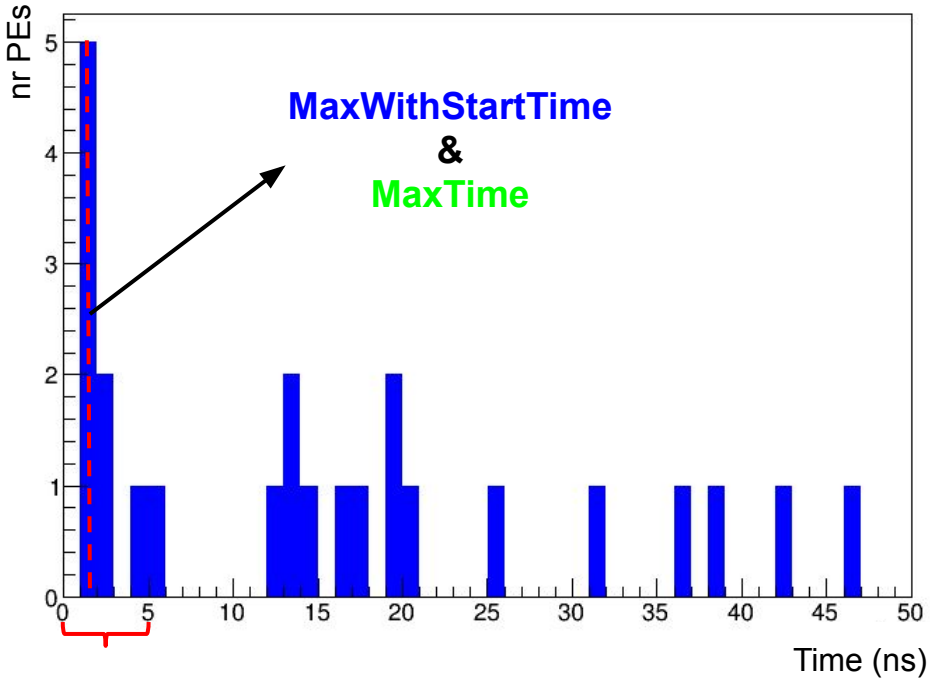
Time estimators





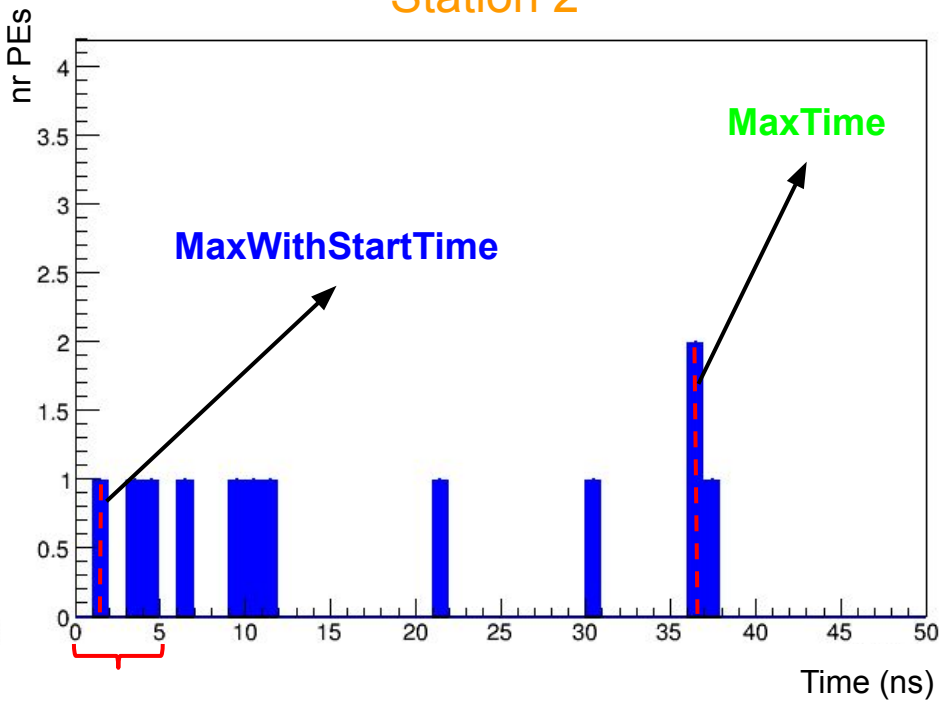
Why MaxTime and MaxWithStartTime differ

Station 1



MaxWithStartTime = MaxTime

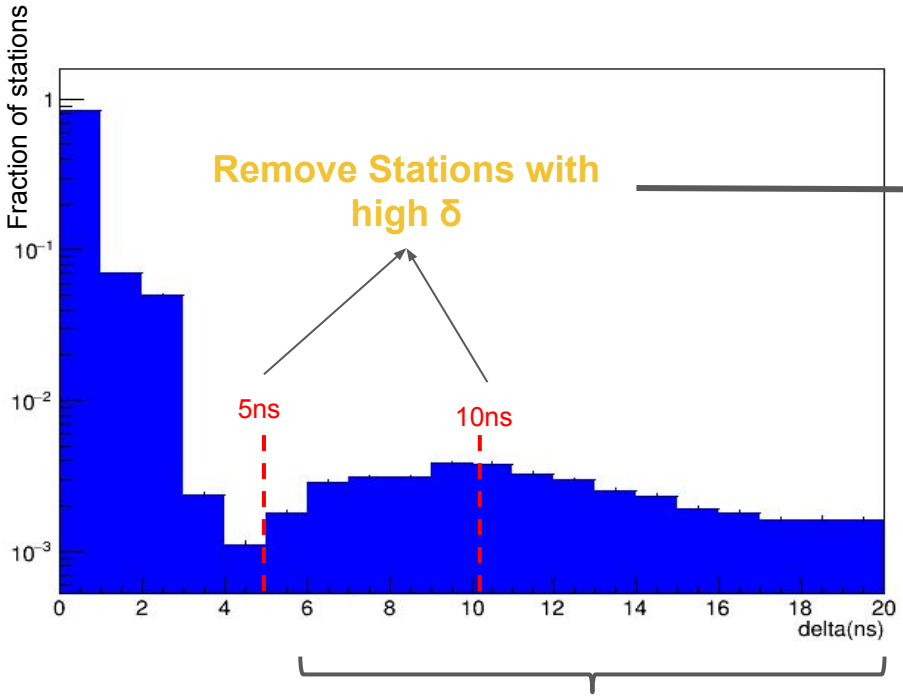
Station 2



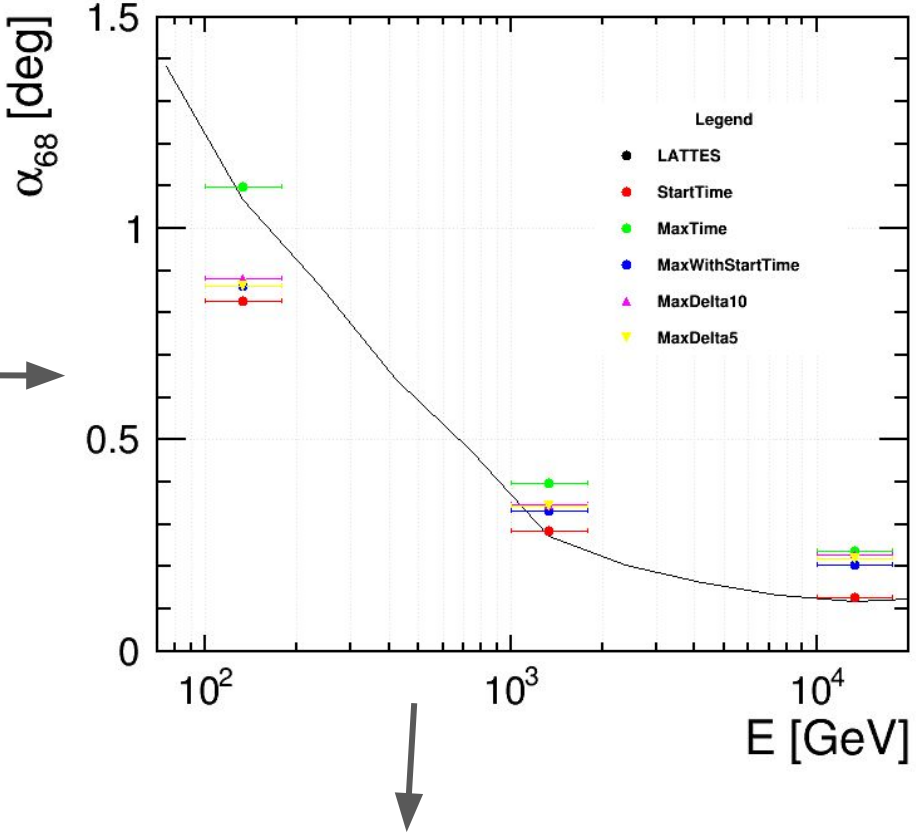
MaxWithStartTime ≠ MaxTime

δ = MaxTime - MaxWithStartTime

Using δ to select stations



Stations with high **δ**

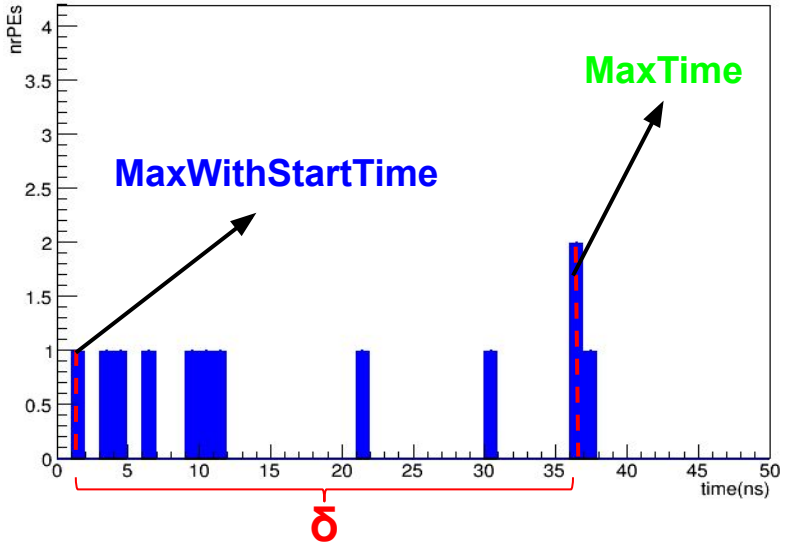


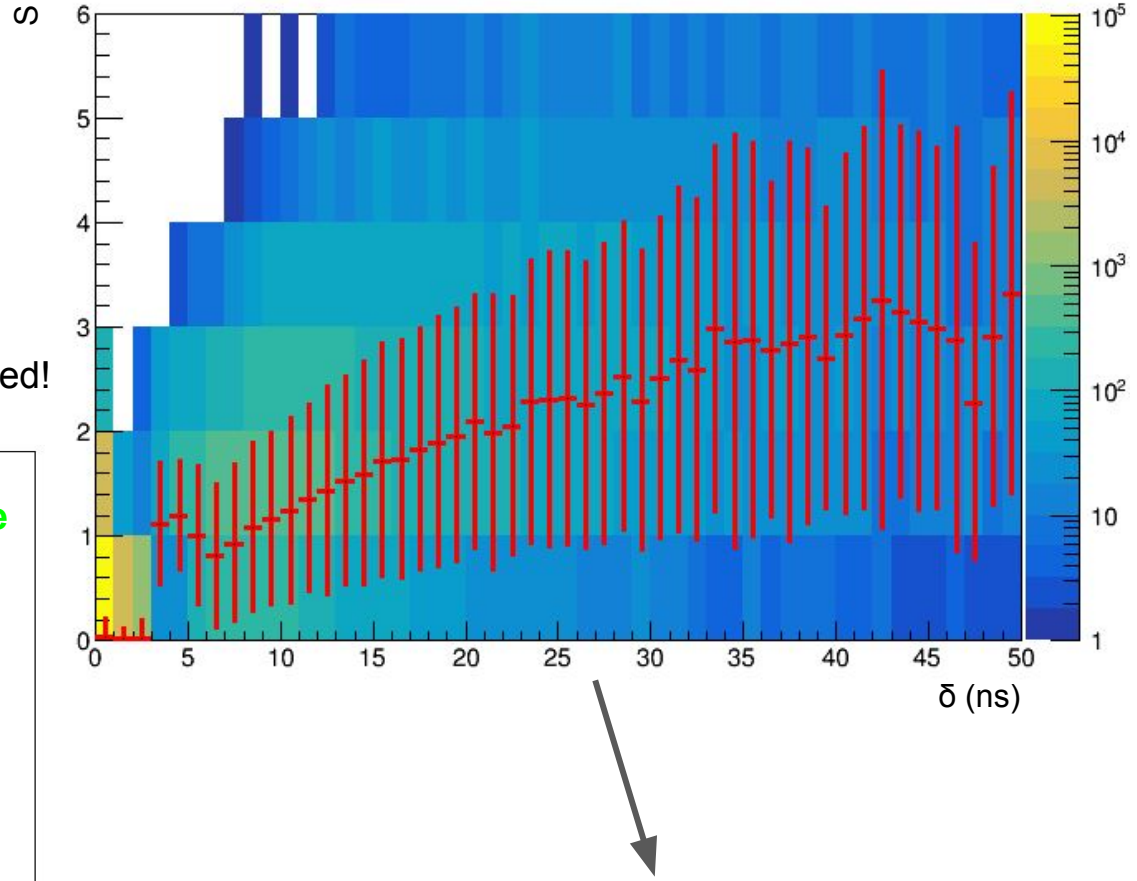
Using δ_{max} as trigger improves reconstruction

How to find δ?

$$S = \frac{\sum_{\mathrm{StartTime}}^{\mathrm{MaxTime}} \mathrm{Signal}}{\mathrm{Signal(MaxTime)}}$$

S will still work when background signal is added!

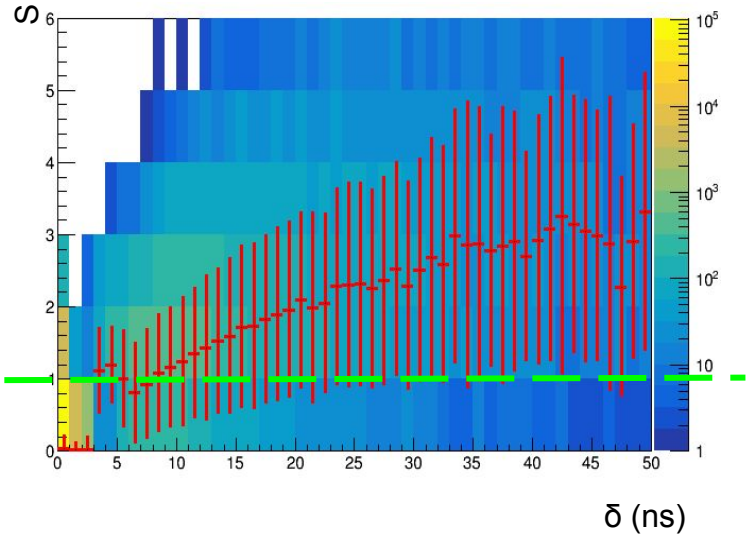


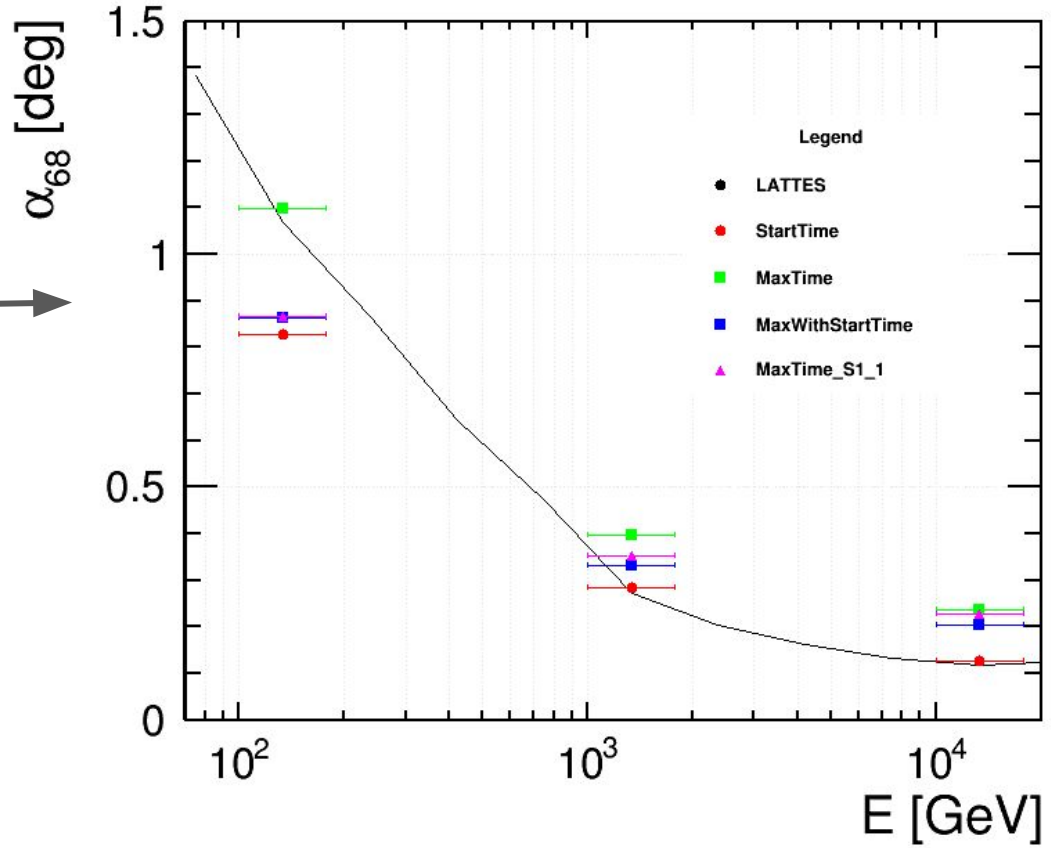


S increases with δ

Applying cuts with S

Disregarding stations with S larger than 1...





Our estimator approaches MaxWithStartTime!

Summary:

- It was shown that the new detector concept can be used to accurately reconstruct the shower geometry;
- Additional improvements at lower energies.

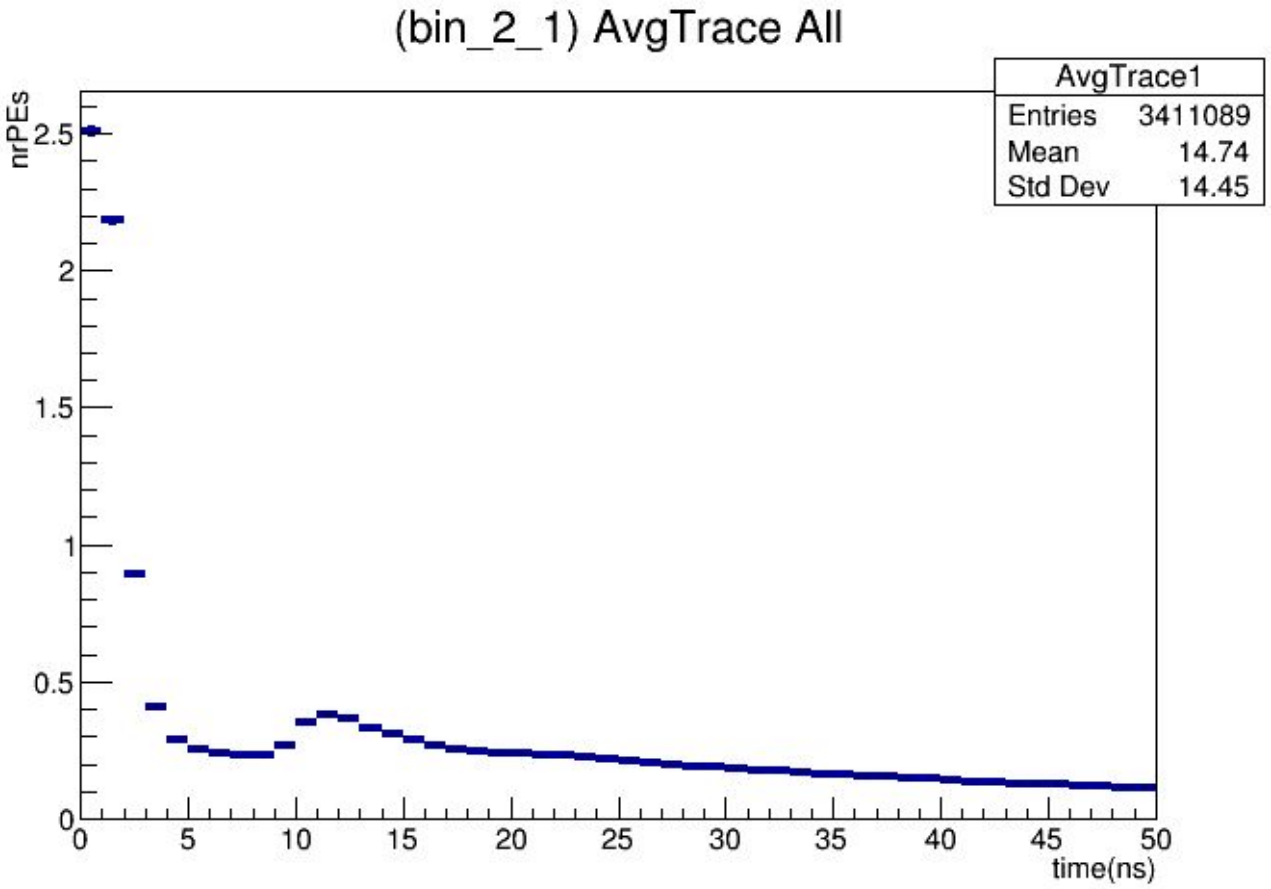
What next:

- Combined analysis with the core reconstruction;
- Optimization of late arrivals cuts;
- Optimization of the shower curvature model.

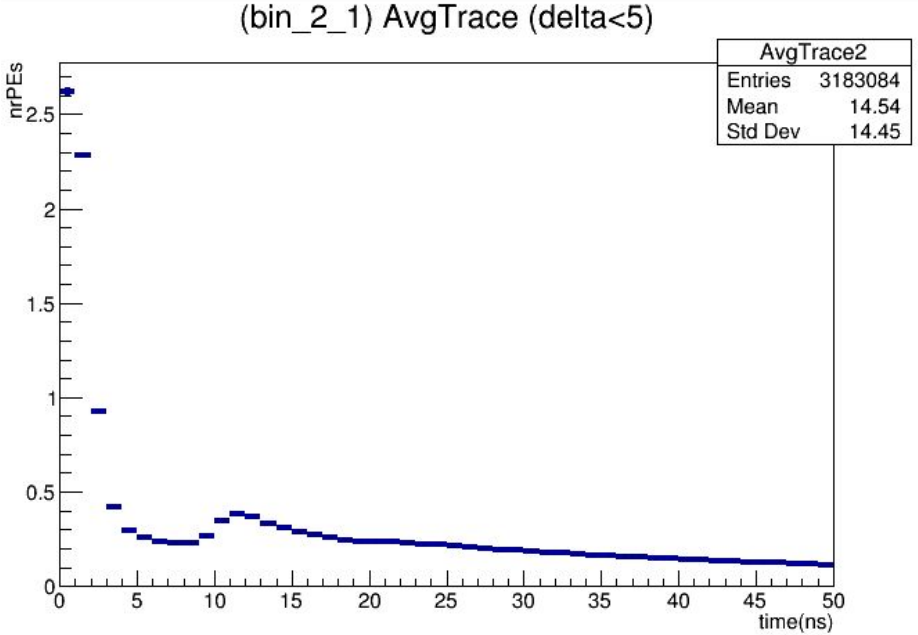
Thank you!
Questions?

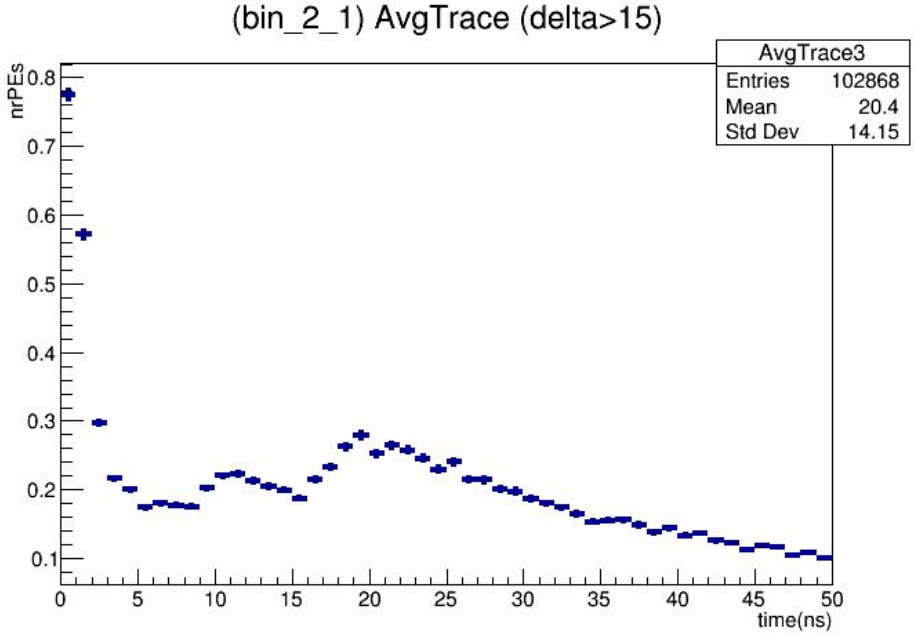
Backup

Average Trace



Average traces filtered by δ





How we chose our S cut