HAWC Upgrade for Multi-TeV Gamma-Ray Detection

Roma International Conference on AstroParticle Physics 2016

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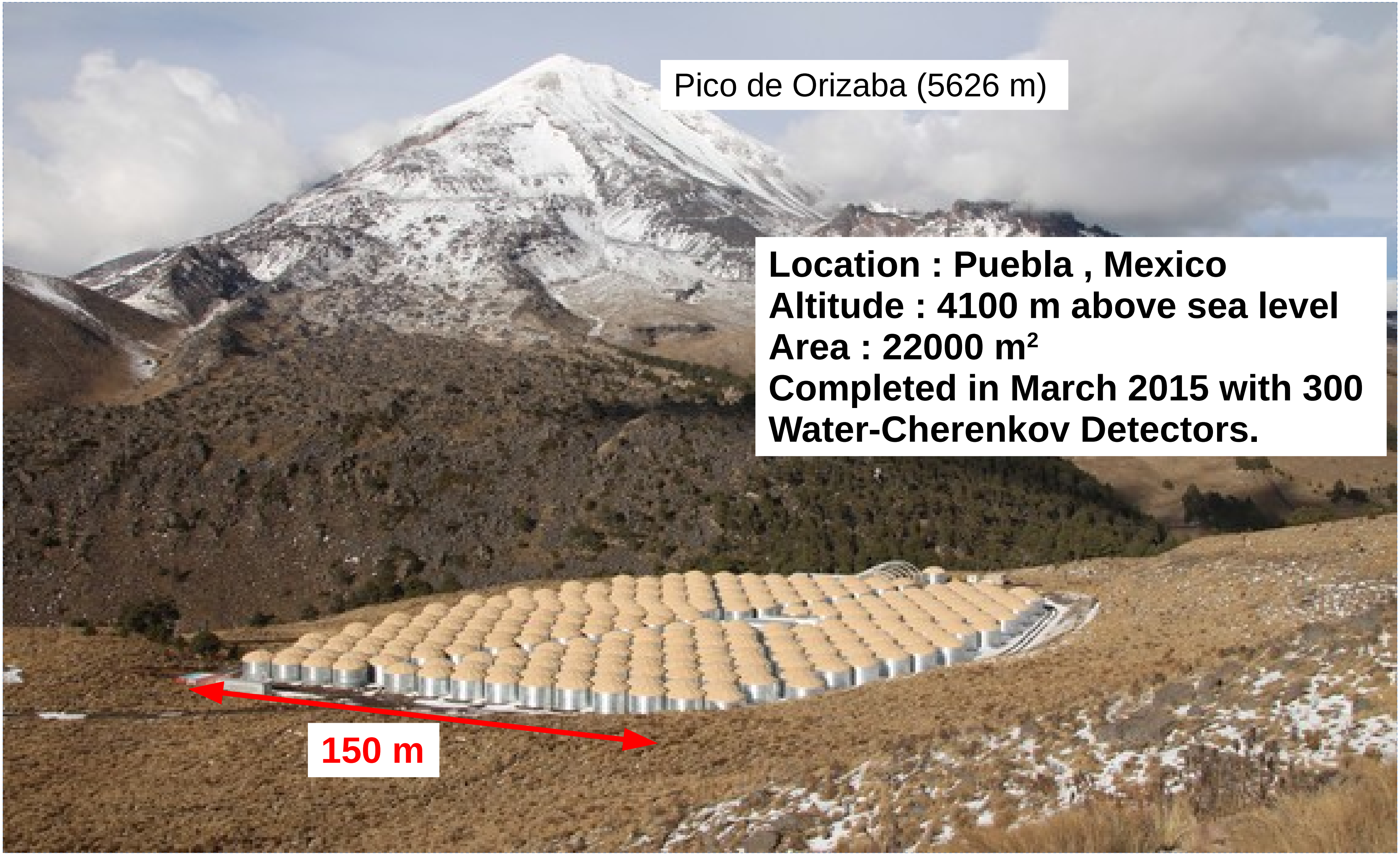
On Behalf of HAWC Collaboration

Outline

- General introduction to HAWC.
  (refer to: Talk by Sabrina Casanova on HAWC)
- Introduction to outrigger array concept.
- Readout and trigger electronics for outriggers.
- Results of outrigger simulations.
- Current status and time line of the outrigger installation.

The High-Altitude Water Cherenkov Observatory (HAWC)



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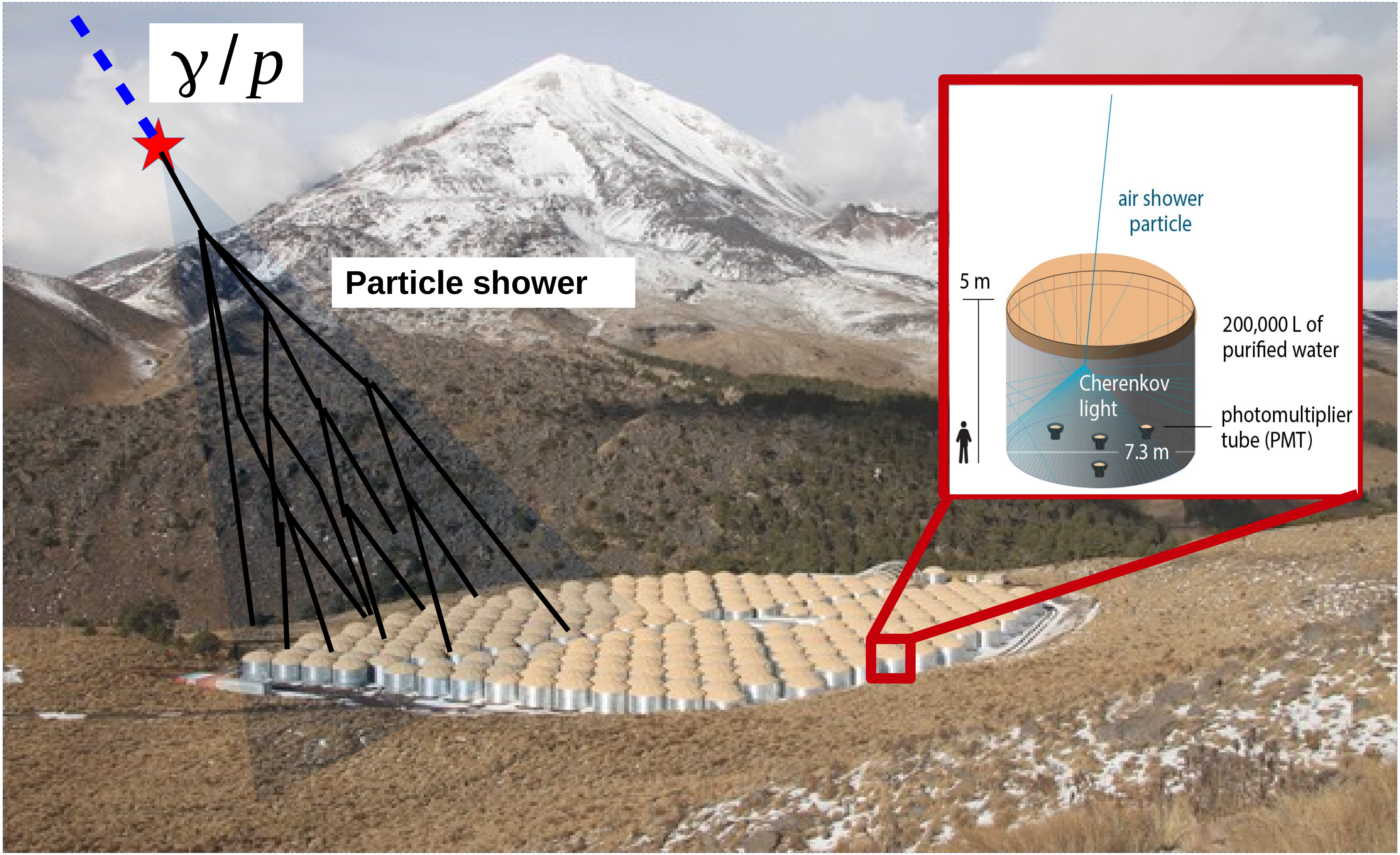

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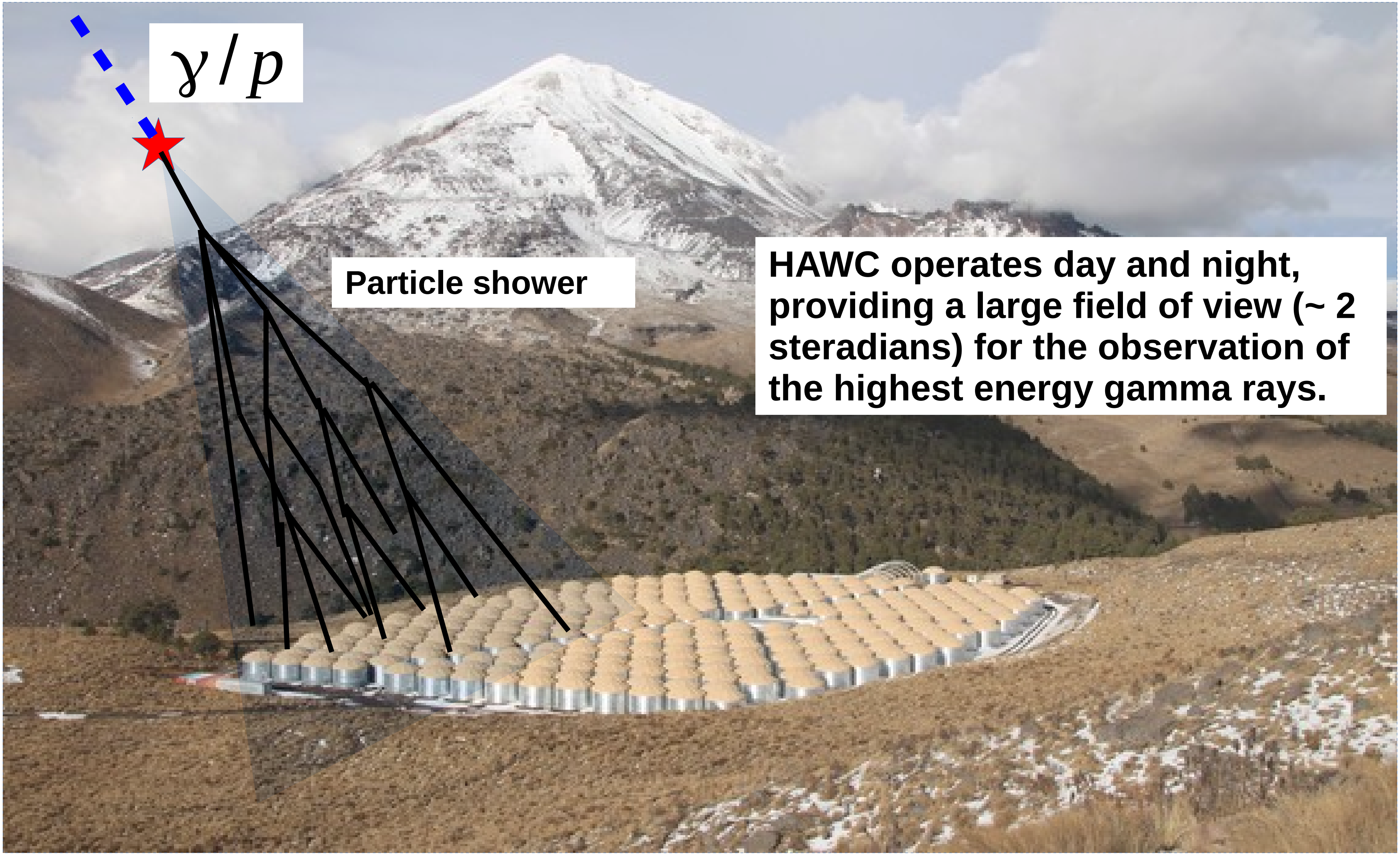
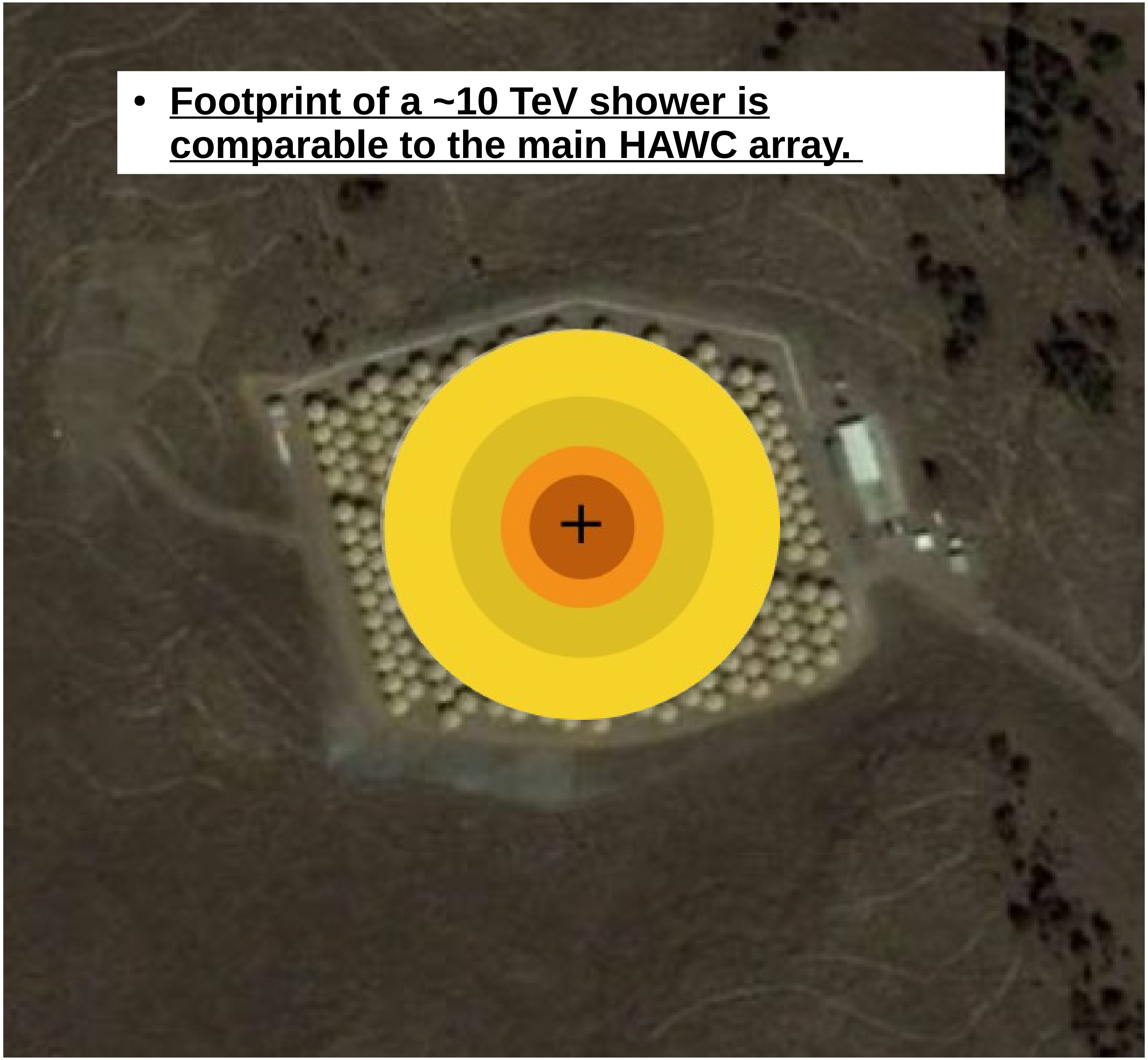


>10 TeV Showers at HAWC



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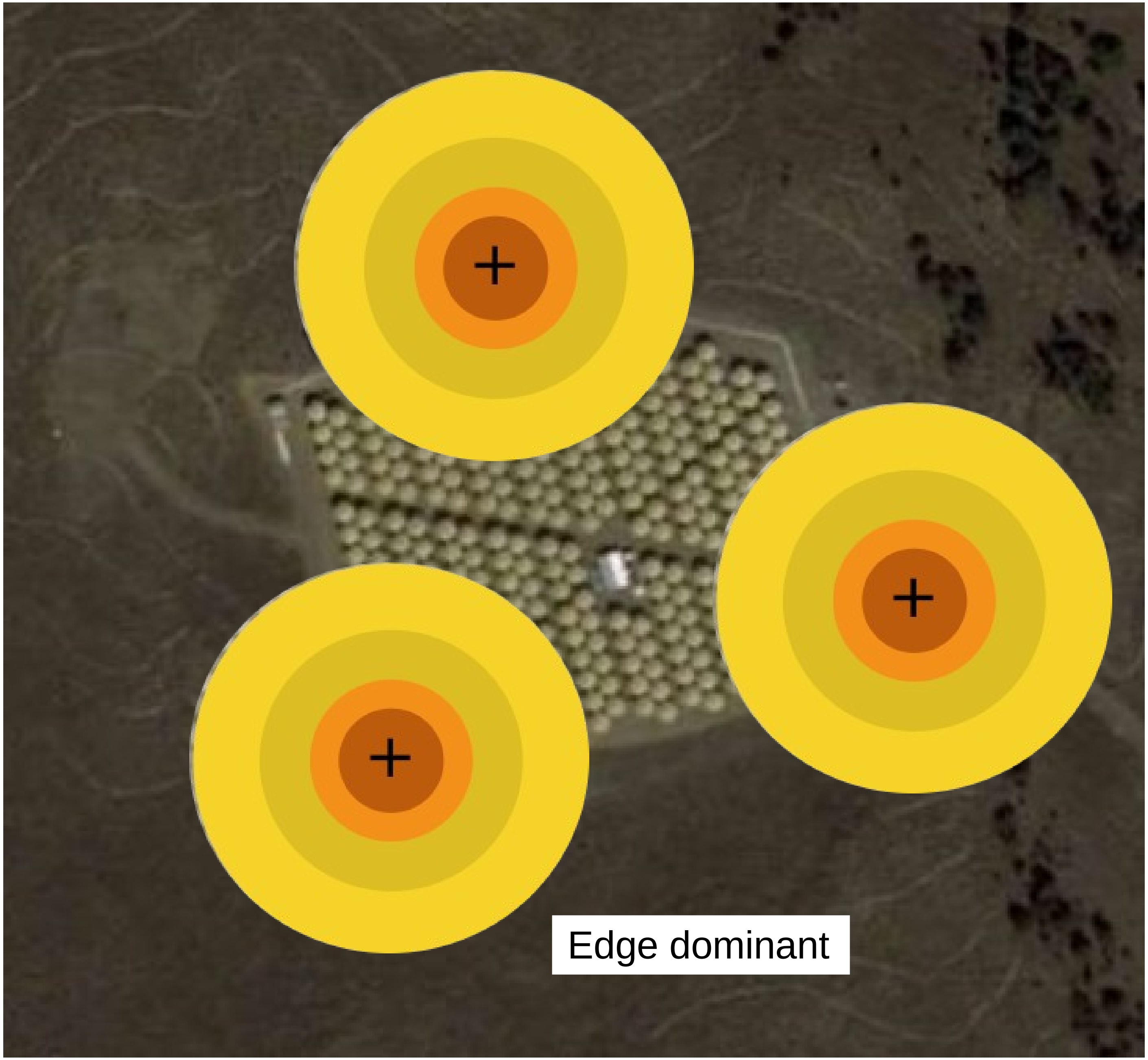
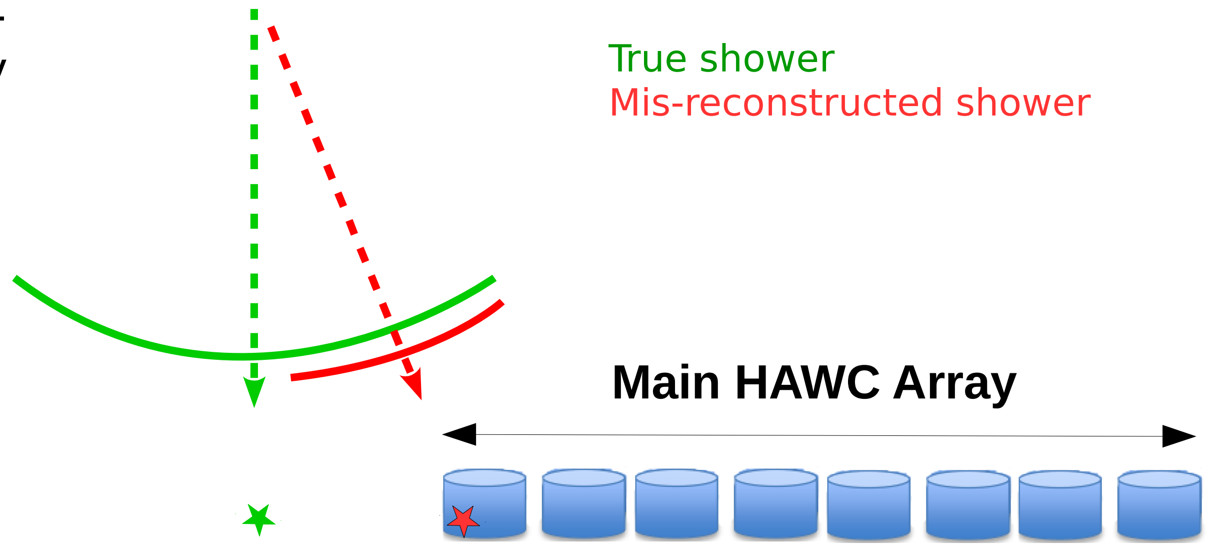


Motivation for Outriggers

- When shower core falls outside of the main array, it can be mis-reconstructed as a lower energy shower closer to the array.



So we have an uncertainty on the location of the shower.

- Which eventually affects :
  - Direction reconstruction.
  - Energy reconstruction.
  - Gamma hadron separation.

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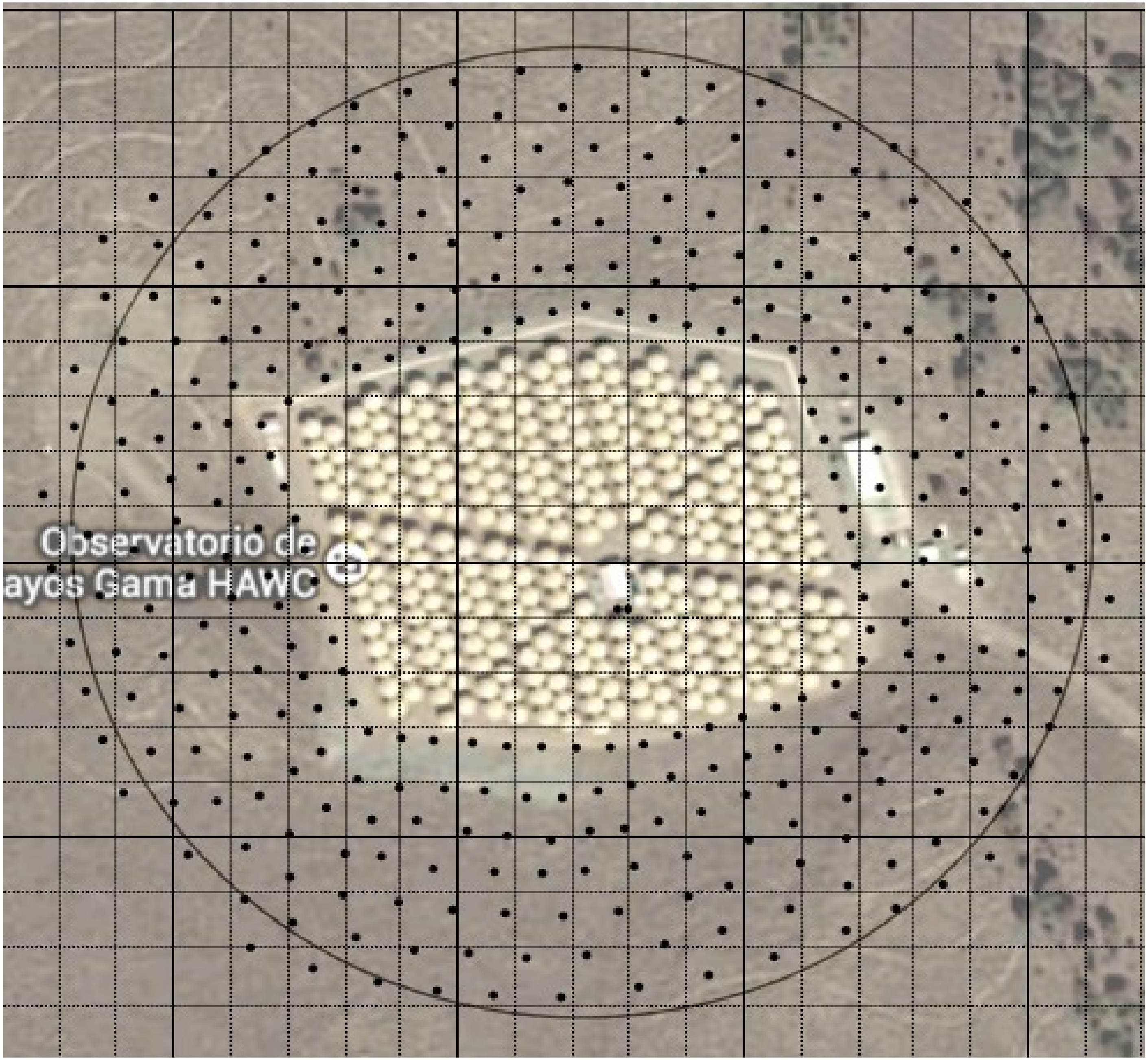

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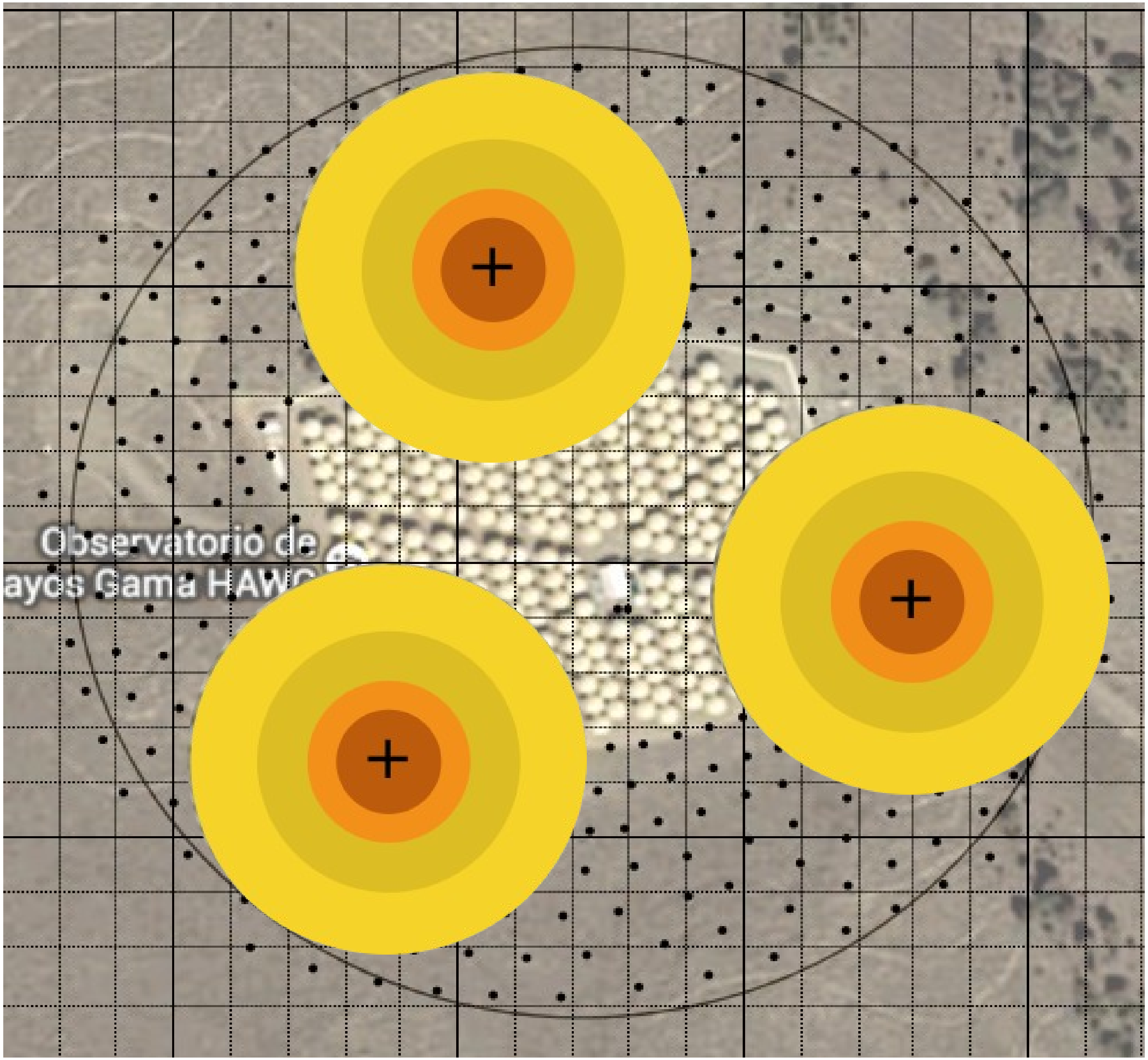
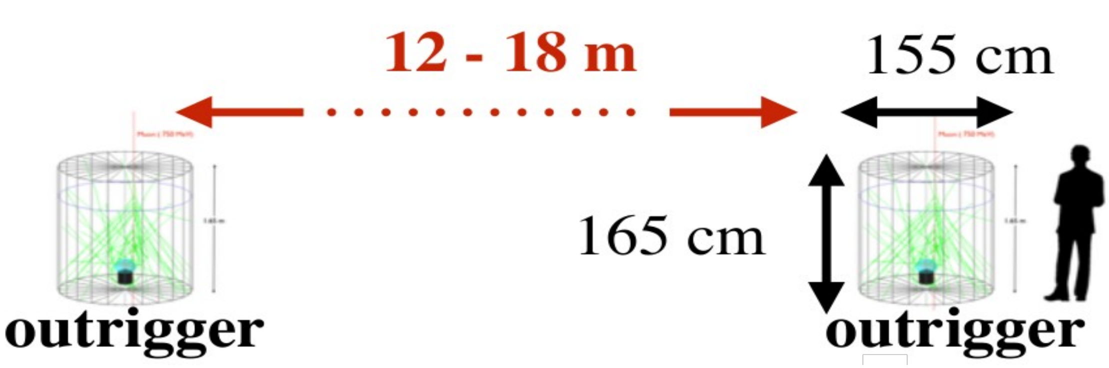
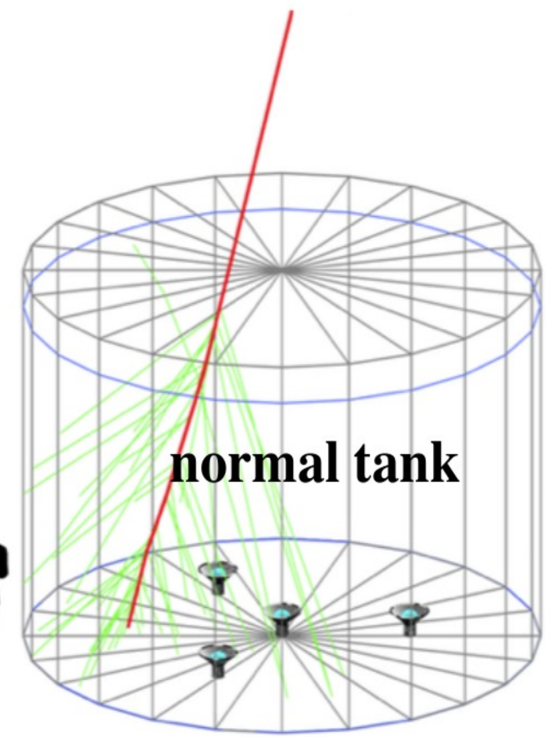


HAWC Outrigger Array Description

- A sparse outrigger array around the main HAWC array.
- It is mainly optimized for energies > 10 TeV.
- Increase in effective area for energies > 10 TeV, with a factor of 3-4.
- It will consist of 350 outrigger tanks, with one Hamamatsu R5912 8" PMT in each of them.

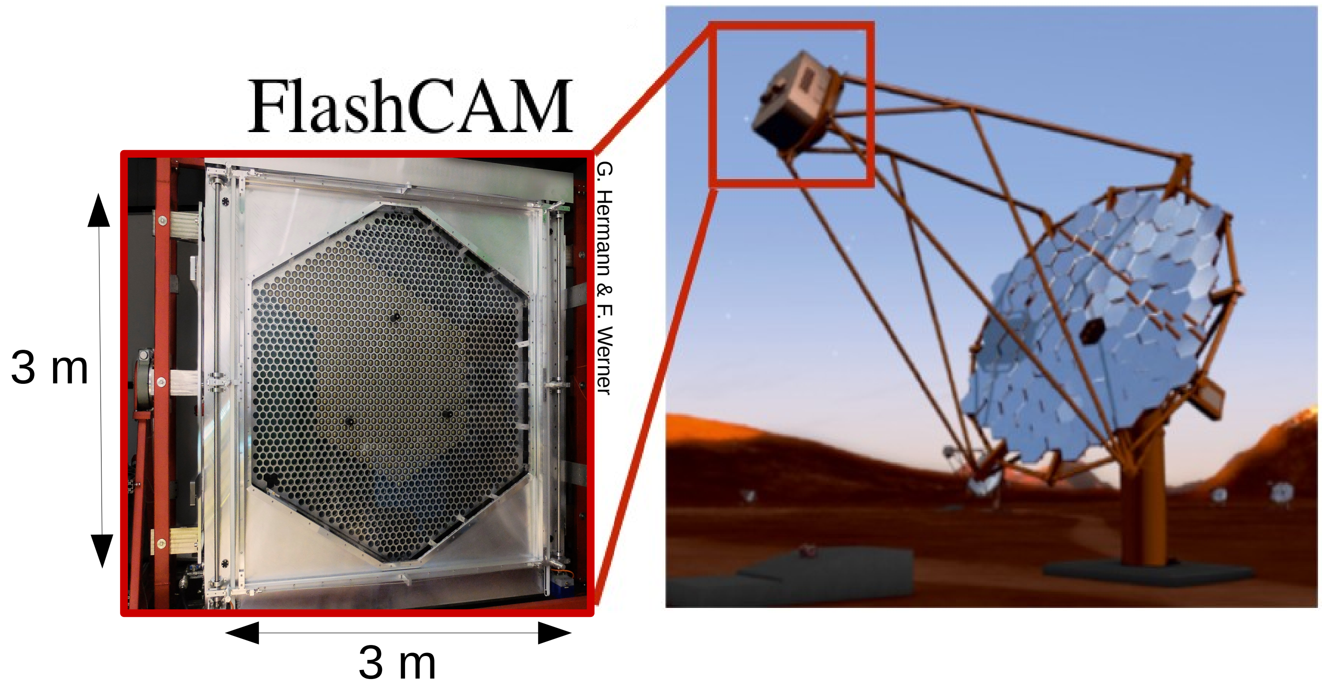




FADC Electronics for Outriggers

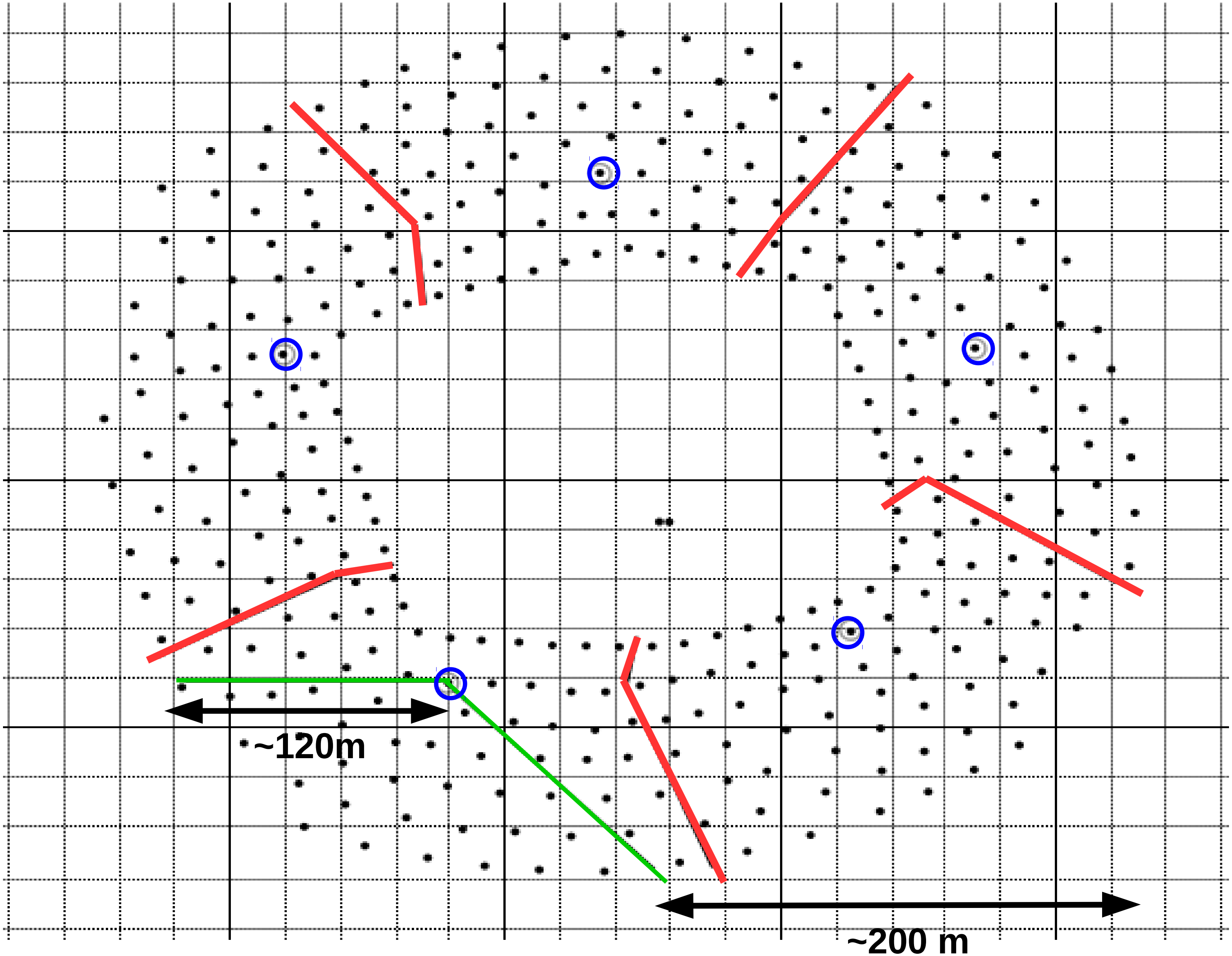
The idea is to use the prototype electronics originally developed for use on CTA medium sized telescopes.

Medium size telescope of CTA



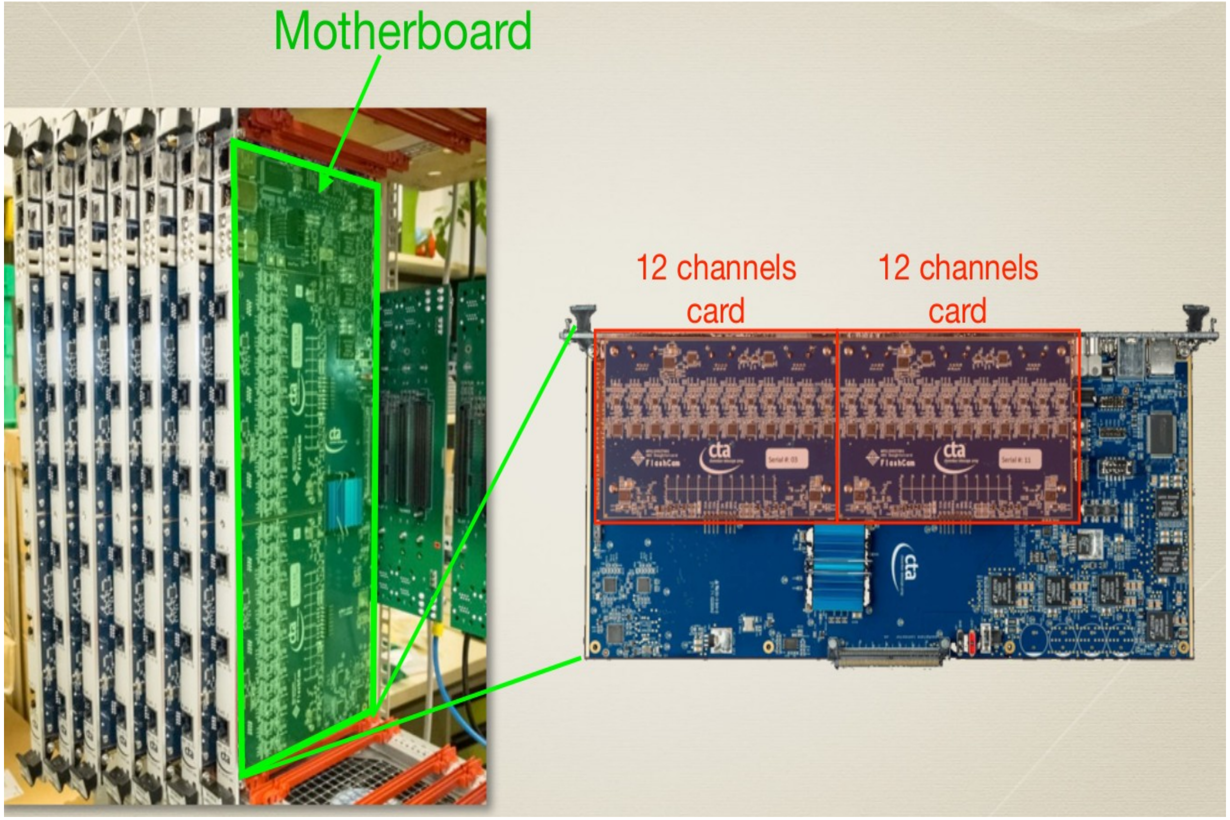
FALCON = **F**lash **A**dc e**L**ectronics for the **C**herenkov **O**utrigger **N**ode.

FADC Electronics for Outrigger Nodes



FADC Electronics Properties

- 24 channels per board.
- 12 bit FADC sampling at 250 MHz.
- Dynamic Range 0.8 V
- Flexible digital multiplicity trigger.
- Each of the HAWC outrigger PMT corresponds to one channel.



Outrigger Components and Simulations

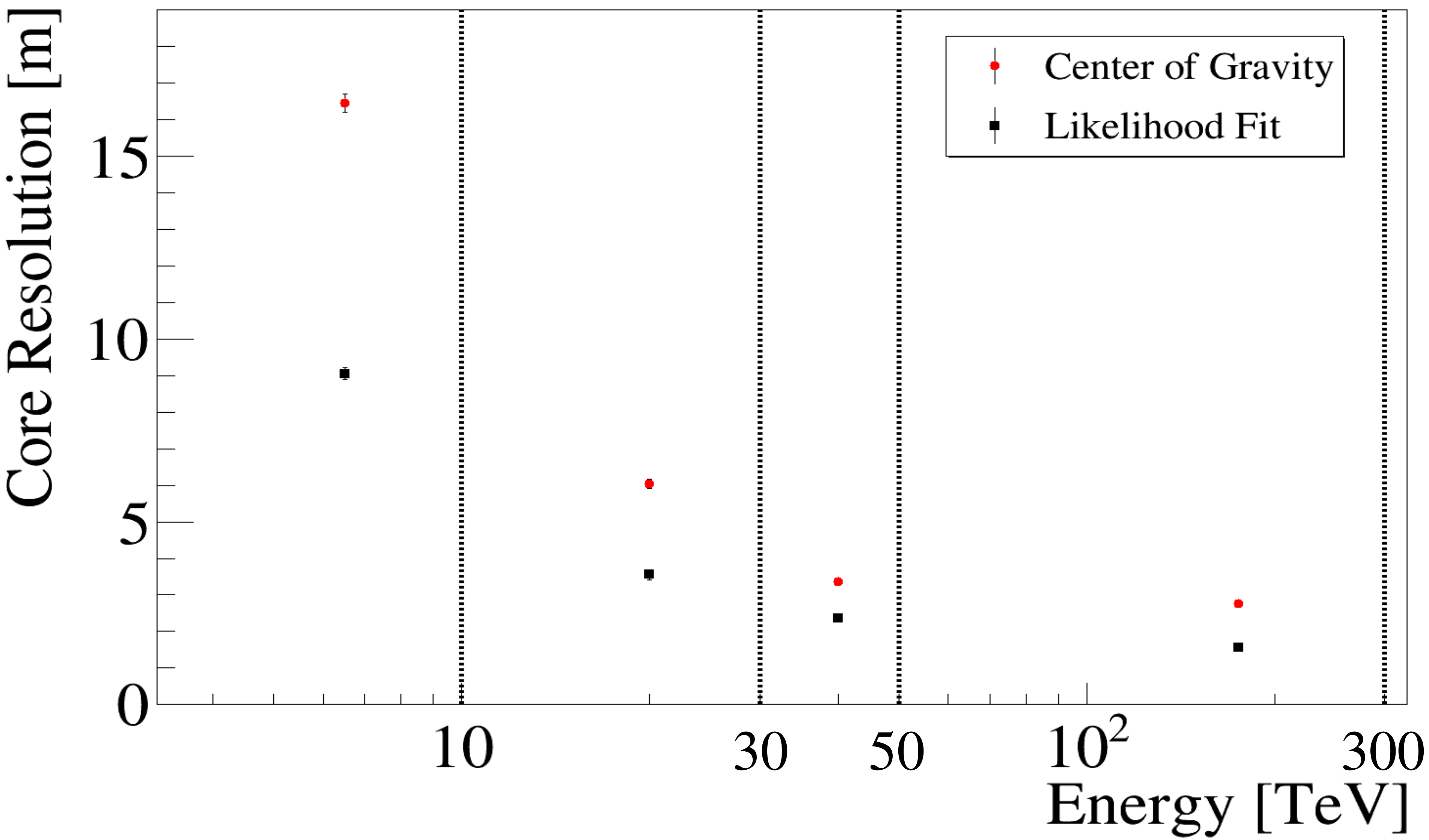
- Outrigger tanks have been bought and 1 prototype is already taking data at the site (10 others are about to be installed).

- Based on extensive MC simulations and prototype data the following decisions have been made:

  - Photo Multiplier Type/size : Hamamatsu R5912 8" PMT.
  - Tank wall color : Black (less diffusive, timing information is better).

Core location reconstructed by simple center of gravity method and maximum likelihood fit.

Core Reconstruction of Outriggers



- The data points are at the mid point of the concerned energy range.
- Core resolution is the 68% containment area value of (likelihood fit core – true core) histogram.
- **The seed value for the likelihood fit is the center of gravity location.**

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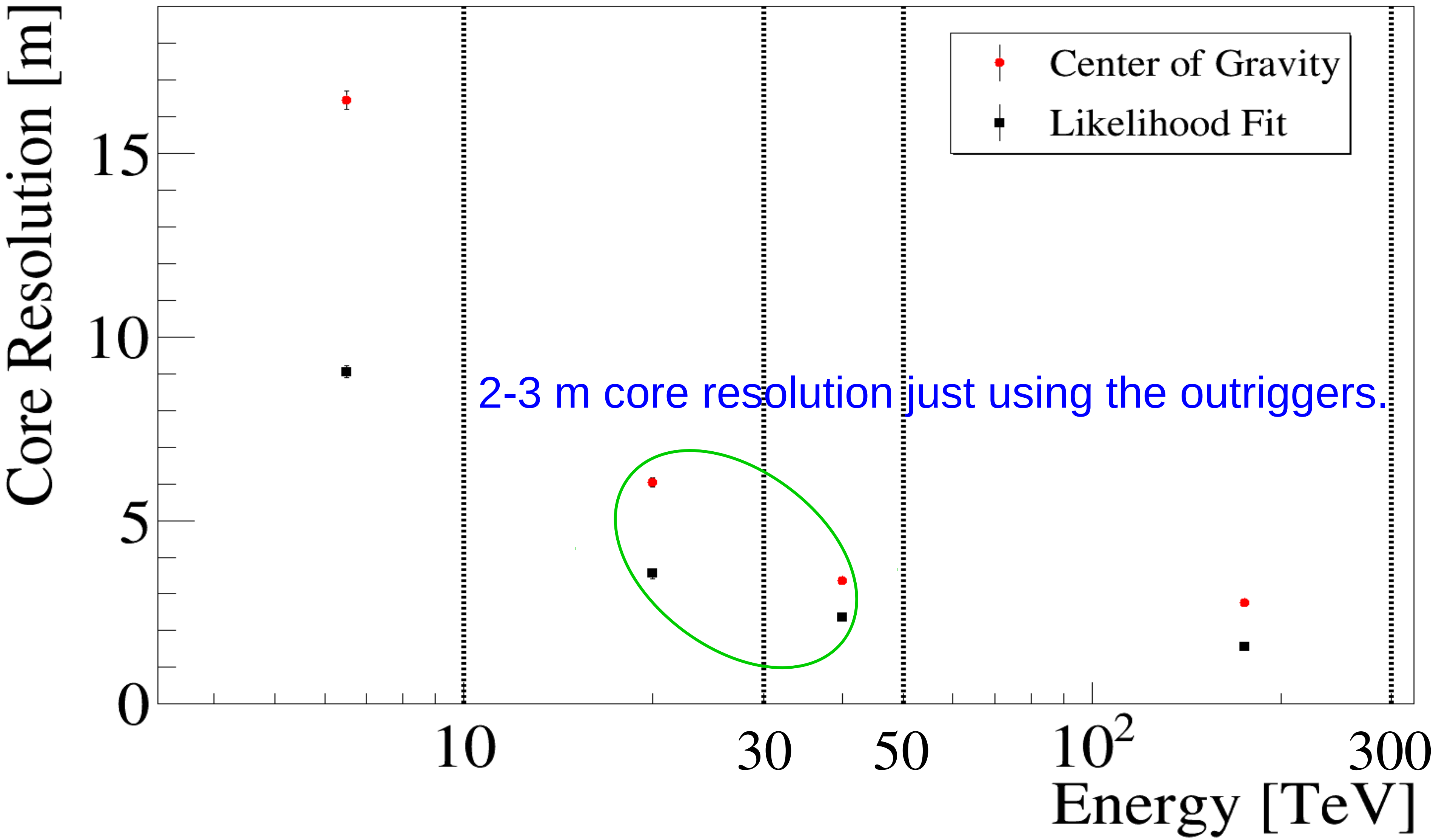

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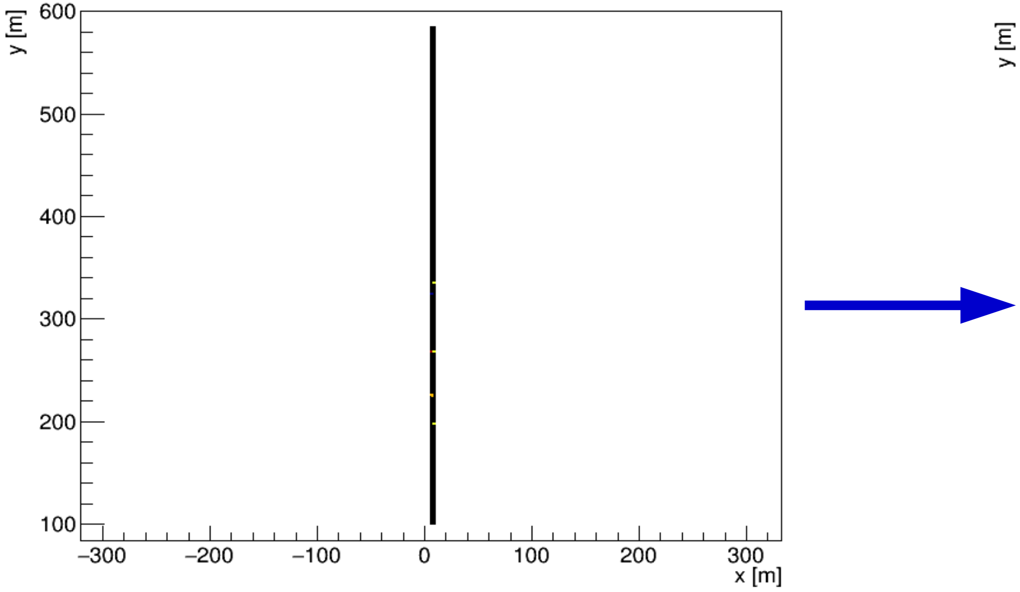
Summary and Future Plan

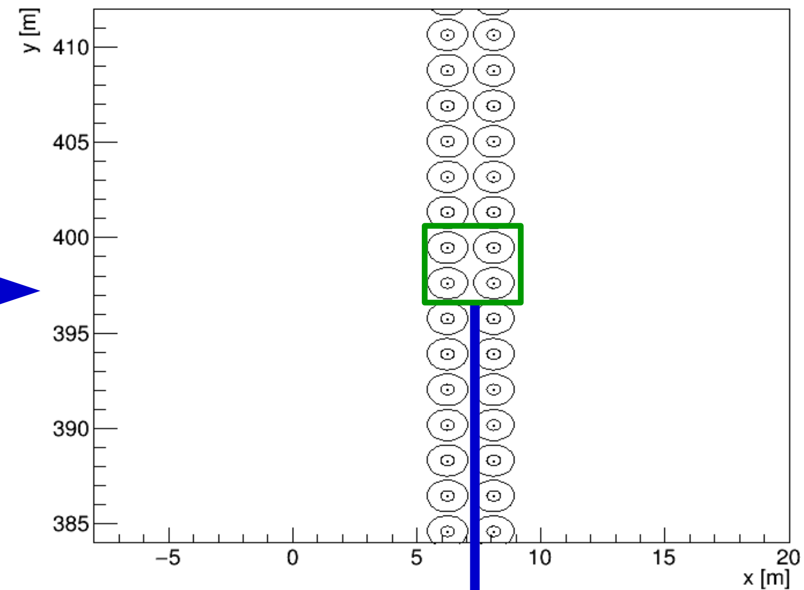
- **What we will achieve with outriggers?**
  - More accurate determination of the core position.
  - Increased effective area above 10 TeV by a factor of 3-4.
- **Current status:**
  - The installation of outriggers is currently taking place.
  - Software for combined analysis of outrigger + main array is being developed.
  - Testing of FALCON with outrigger tanks is being performed on site.
- **Future plan:**
  - Merging of the outrigger system with the central readout system (late summer).
  - Deployment of full outrigger array by the end of 2016.
  - It will start taking data from the beginning of 2017 with enhanced sensitivity above 10 TeV.

Thank You for Your Attention

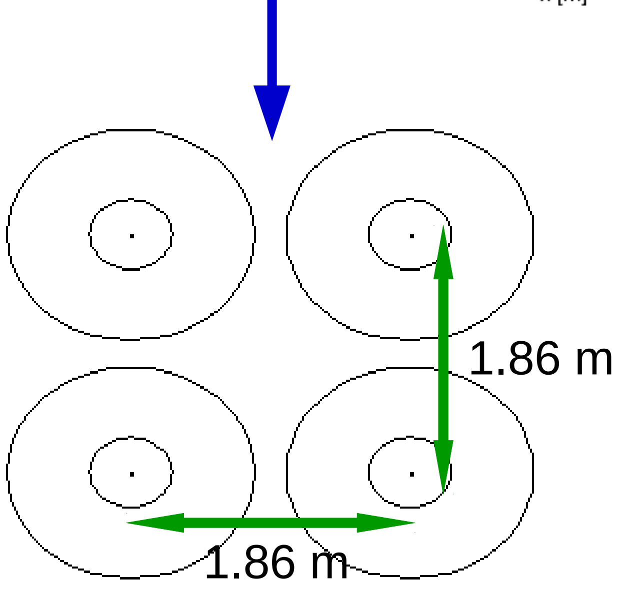
Backup Slides

Simulation Setup





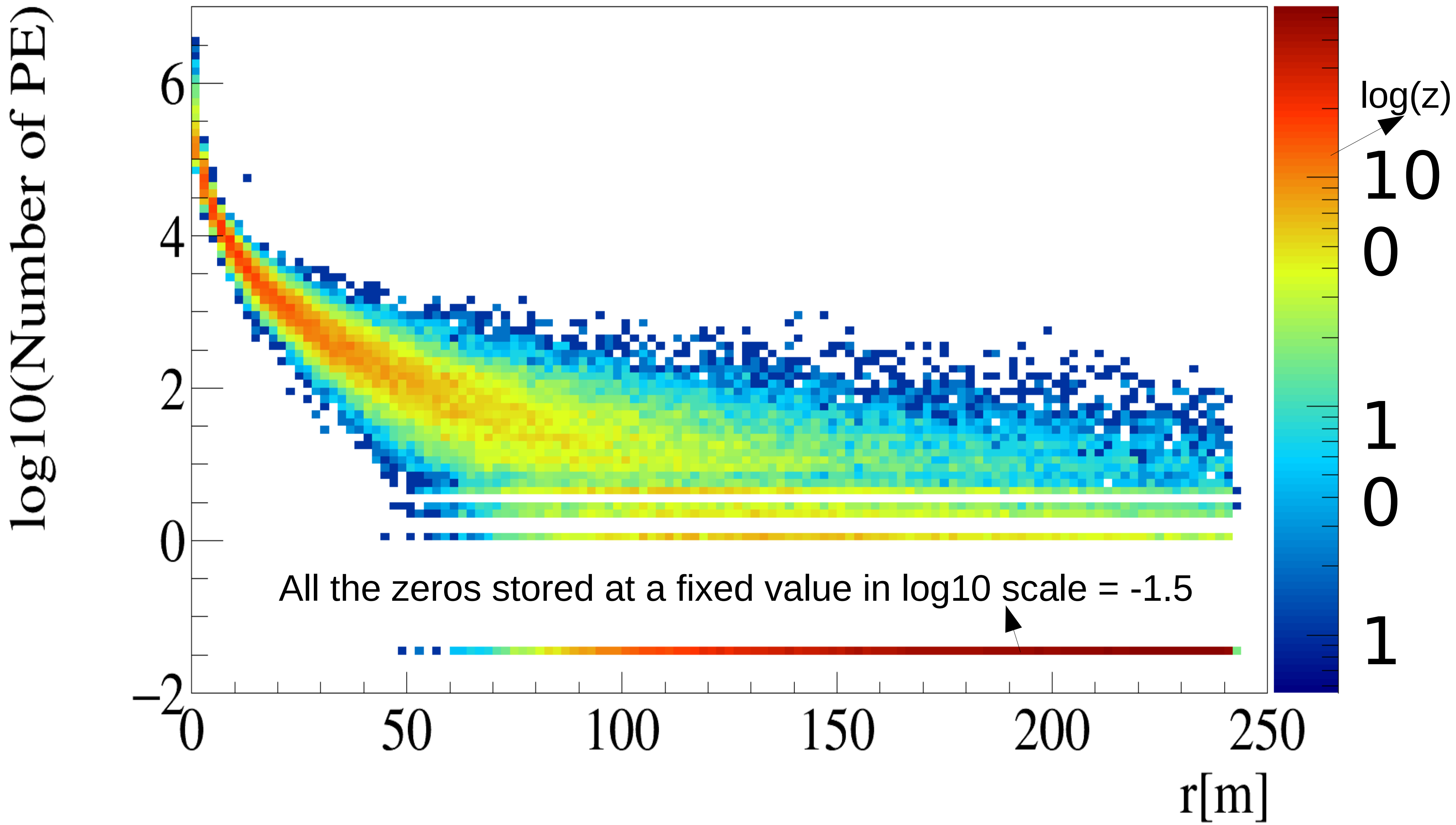
- Total number of tanks = 520.
- Aligned in two parallel columns of separation 1.86 m.
- Separation of two tanks in one column = 1.86 m.
- Showers are simulated with zenith angle = 0 deg, distributed uniformly in a square of 1.86 m x 1.86 m around the center of the array.



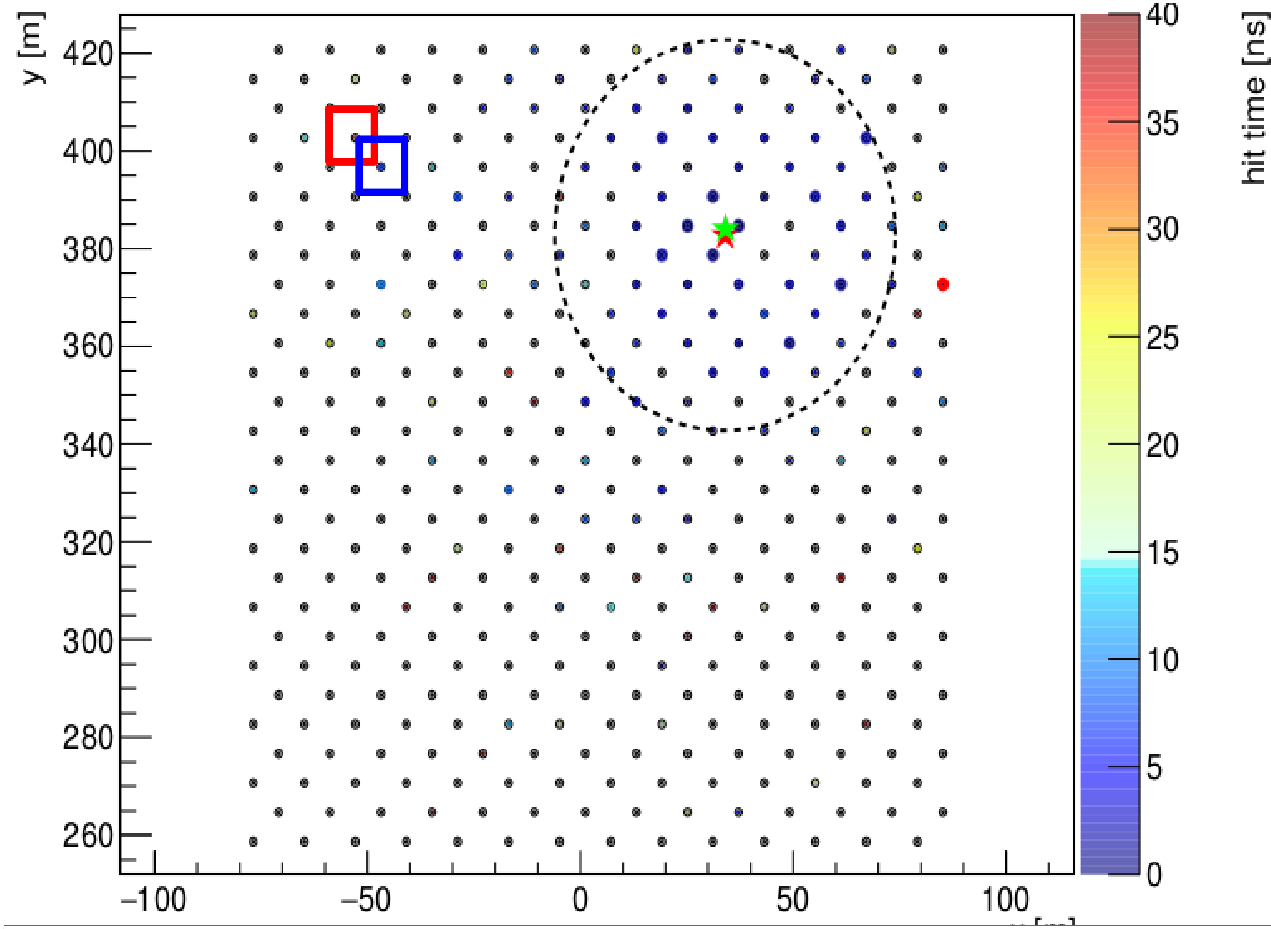
- Only gammas, 5 million showers.
- Energy: 300 GeV to 300 TeV; Spectrum slope = -2.
- Tank type: outrigger tank (Black),
- PMT size = 8 inch.

Typical Probability Distribution of Observed Number of PE with Distance from the Core

- Probability distributions have been binned in Xmax and Energy.
- e.g. the distribution below is with **Xmax:** 600 to 615 g/cm^2 and **Energy:** 75.356 TeV to 119.432 TeV.



Simulation Setup for study of Core location uncertainty



- Two overlapping square layouts.
- Each with 196 tanks.
- And with side length = 12m.
- Energy Simulated= 3,10,30 and 50 TeV.
- PMT Size = 3” ,5” and 9”
- Tank wall color = Black and white.

- **Method Used:**
- Core location uncertainty

$$\Delta r=\sqrt{\left(x_{centroid}-x_{simulated}\right)^2+\left(y_{centroid}-y_{simulated}\right)^2}$$

$$where,\quad x_{centroid}=\frac{\sum x_i\rho_i^2}{\sum \rho_i^2}\quad y_{centroid}=\frac{\sum y_i\rho_i^2}{\sum \rho_i^2}$$

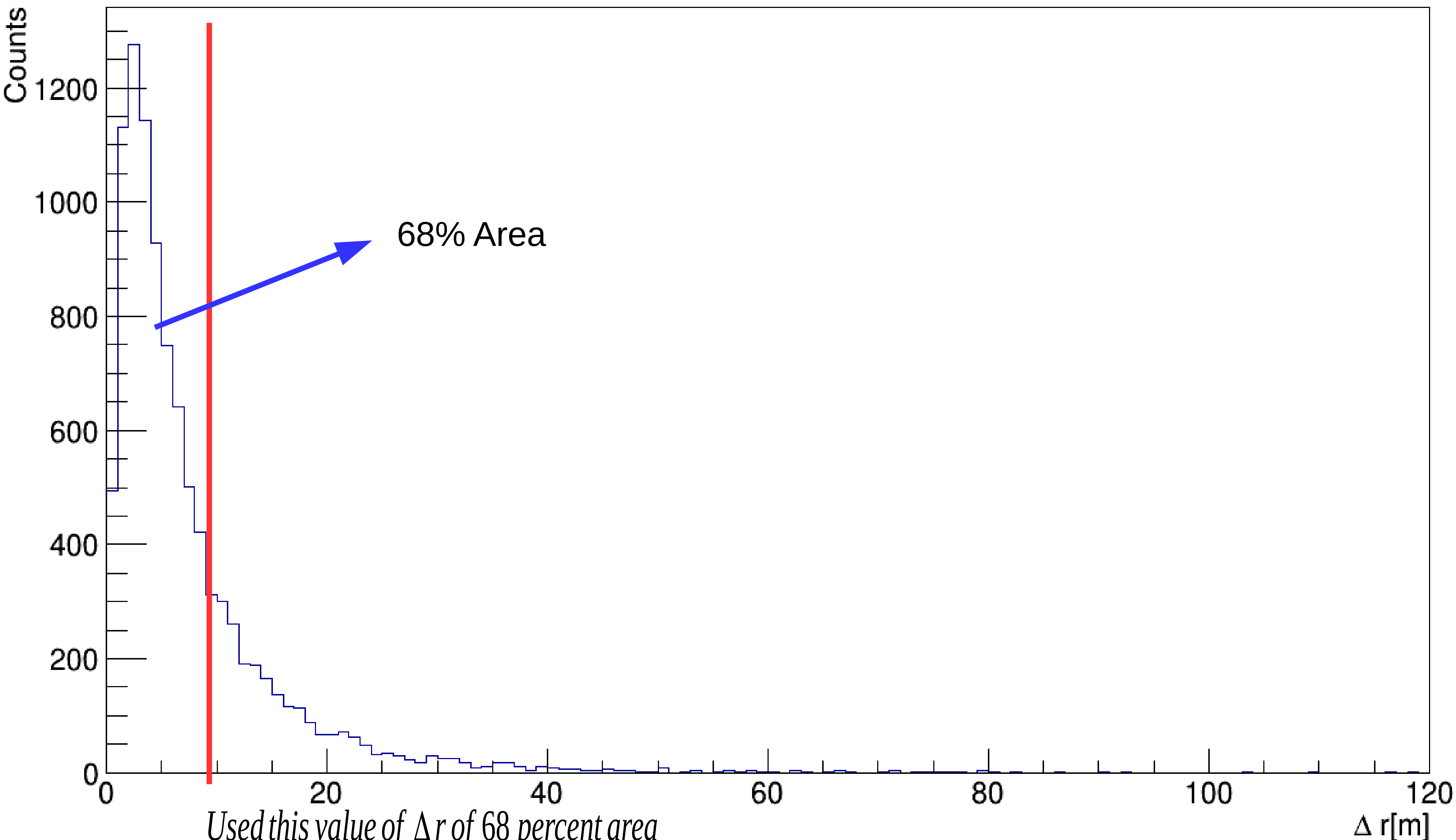
$$x_i = x\ coordinate\ of\ the\ PMT$$

$$y_i = y\ coordinate\ of\ the\ PMT$$

$$\rho_i = Number\ of\ PE\ observed\ at\ PMT$$

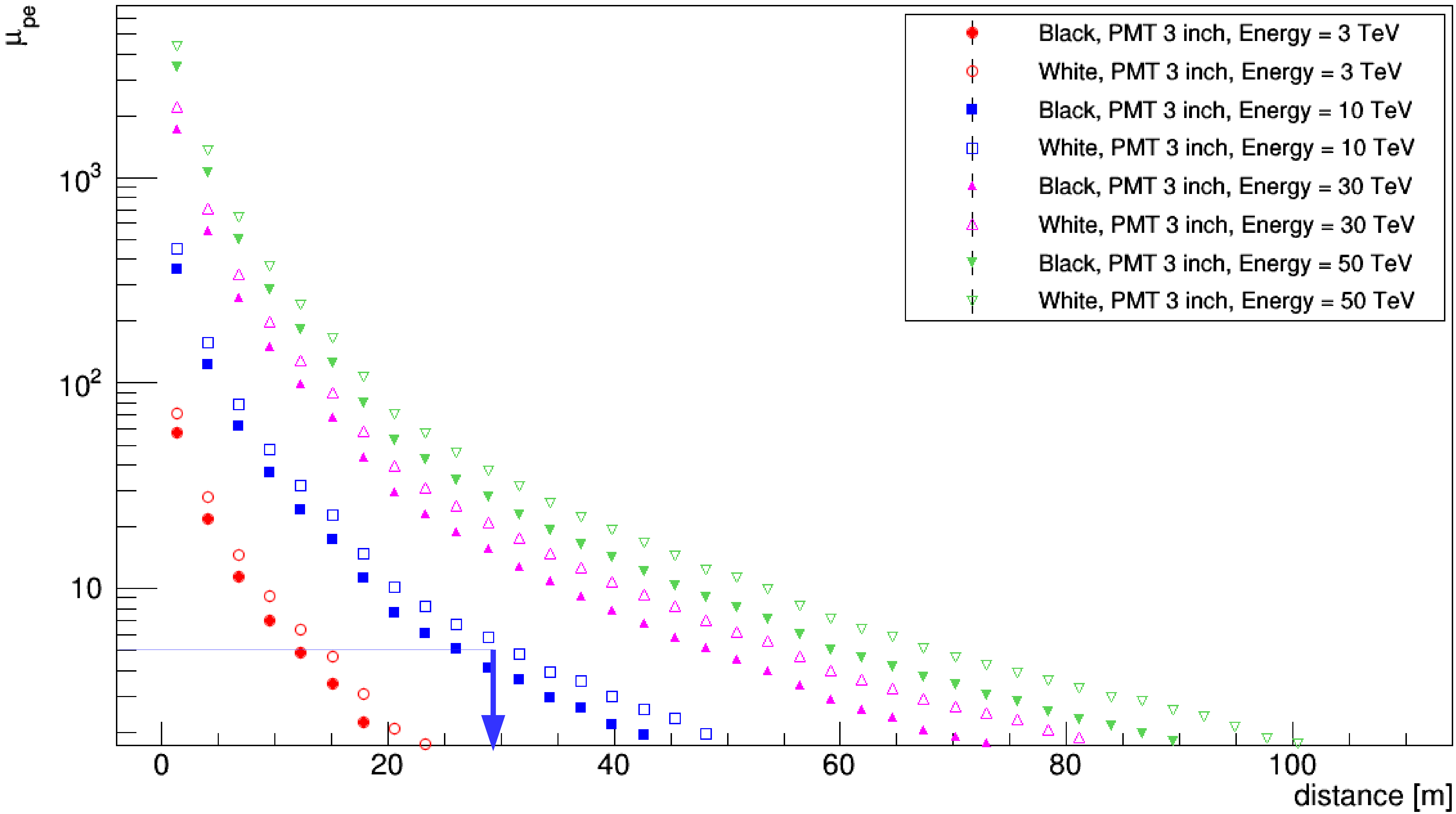
Spacing = 12m, comparable to real outrigger spacing (12-18m)

Histogram of delta_r for 5 inch PMT, Energy 10 TeV, tank color: Black and zenith angle: zero



Used this value of Δ r of 68 percent area

Average No. Of PE for 3” PMT with Black and White Tanks



Average No. Of PE for 8” PMT with Black and White Tanks