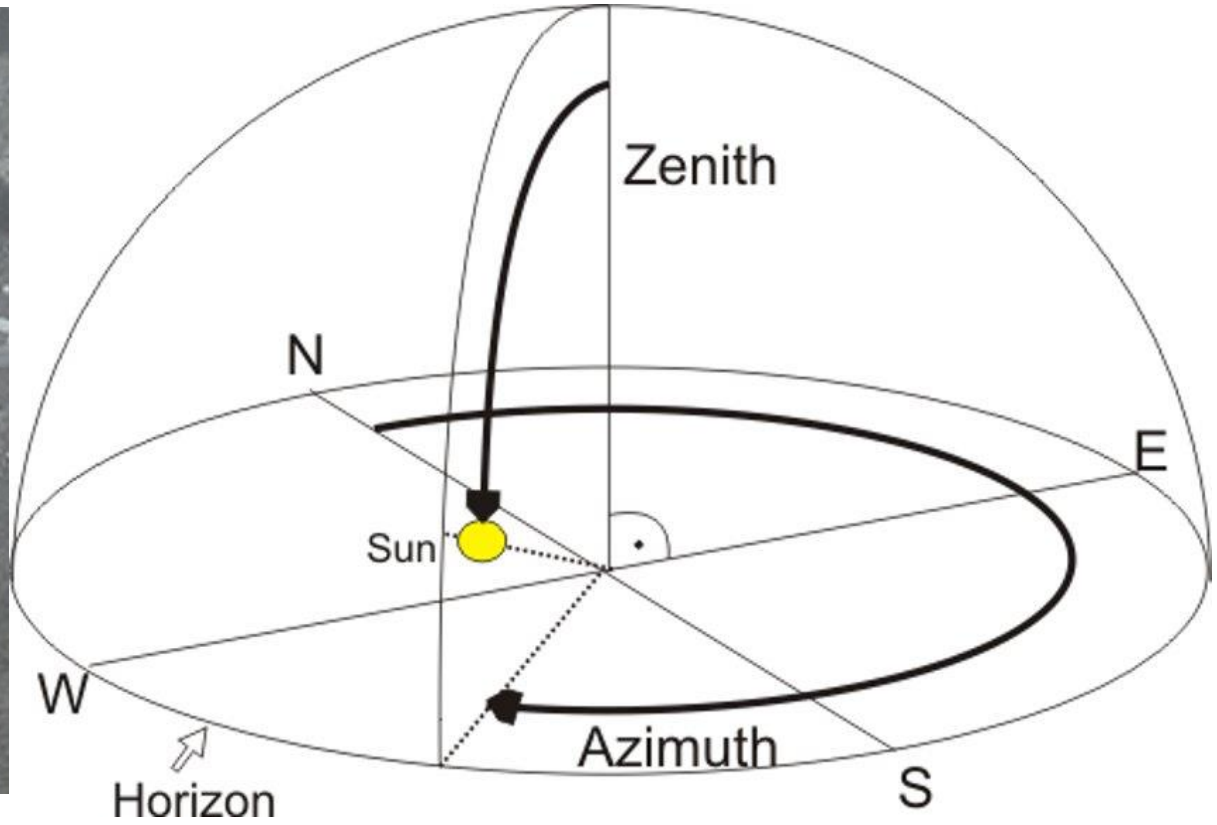
Does the Earth's magnetic field influence the arrival direction of particle showers?

(Fancy: Largescale Anisotropies and Potential Geomagnetic Effects)

or: The East-West Effect (maybe)

Detector Coordinates

Azimuth is measured counterclockwise from east on the array



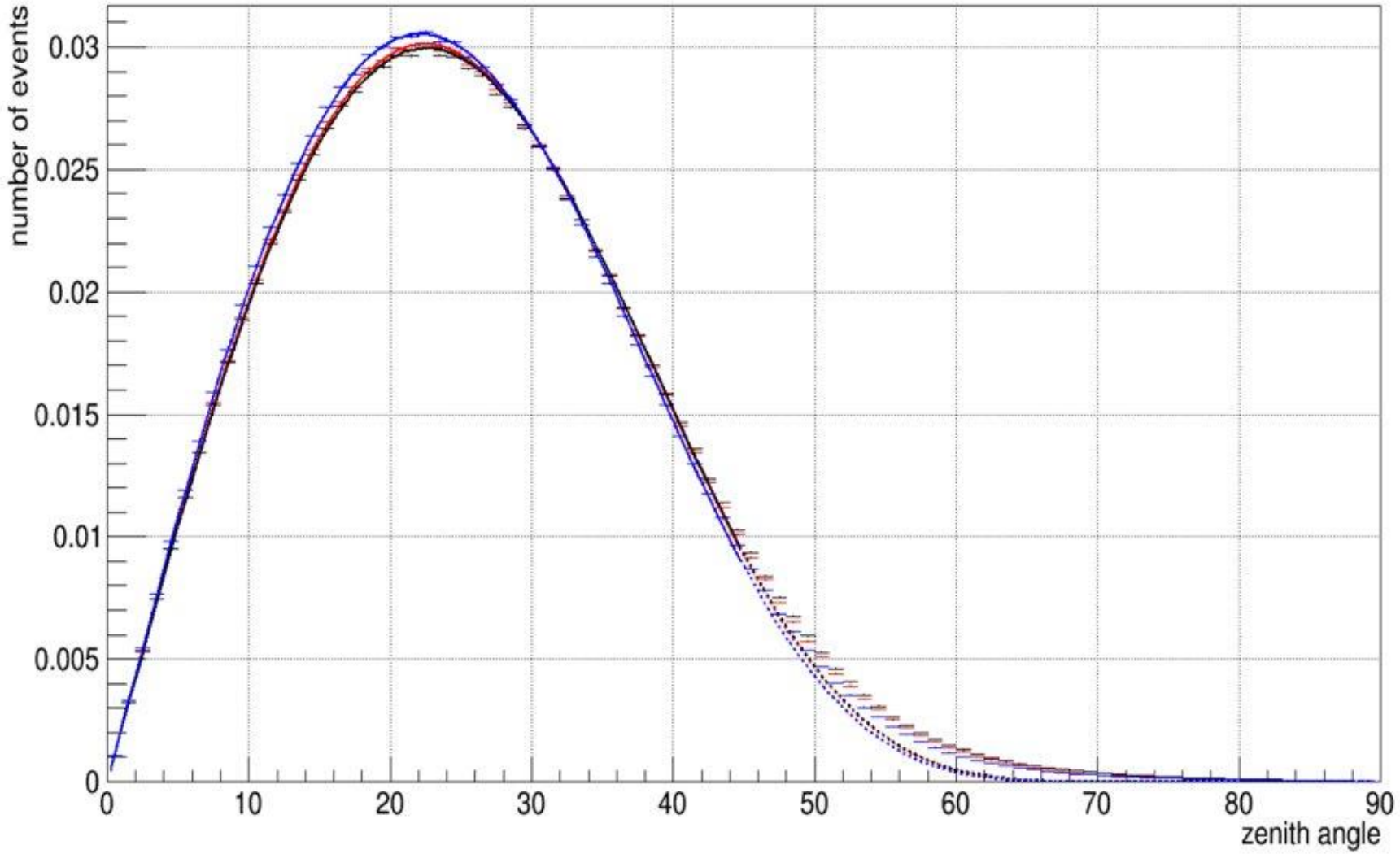
Aside: Data Collection

- Data is collected by the array in runs
- Runs are put through the Offline Reconstructor which does its best to determine arrival direction (among other things), quality assurance (we may determine some runs are bad)
- These runs are uploaded to be used for research

What do we expect?

- The azimuth distribution should be flat
- The zenith distribution should show few/no effects at 0 and 90 and be peaked somewhere in between

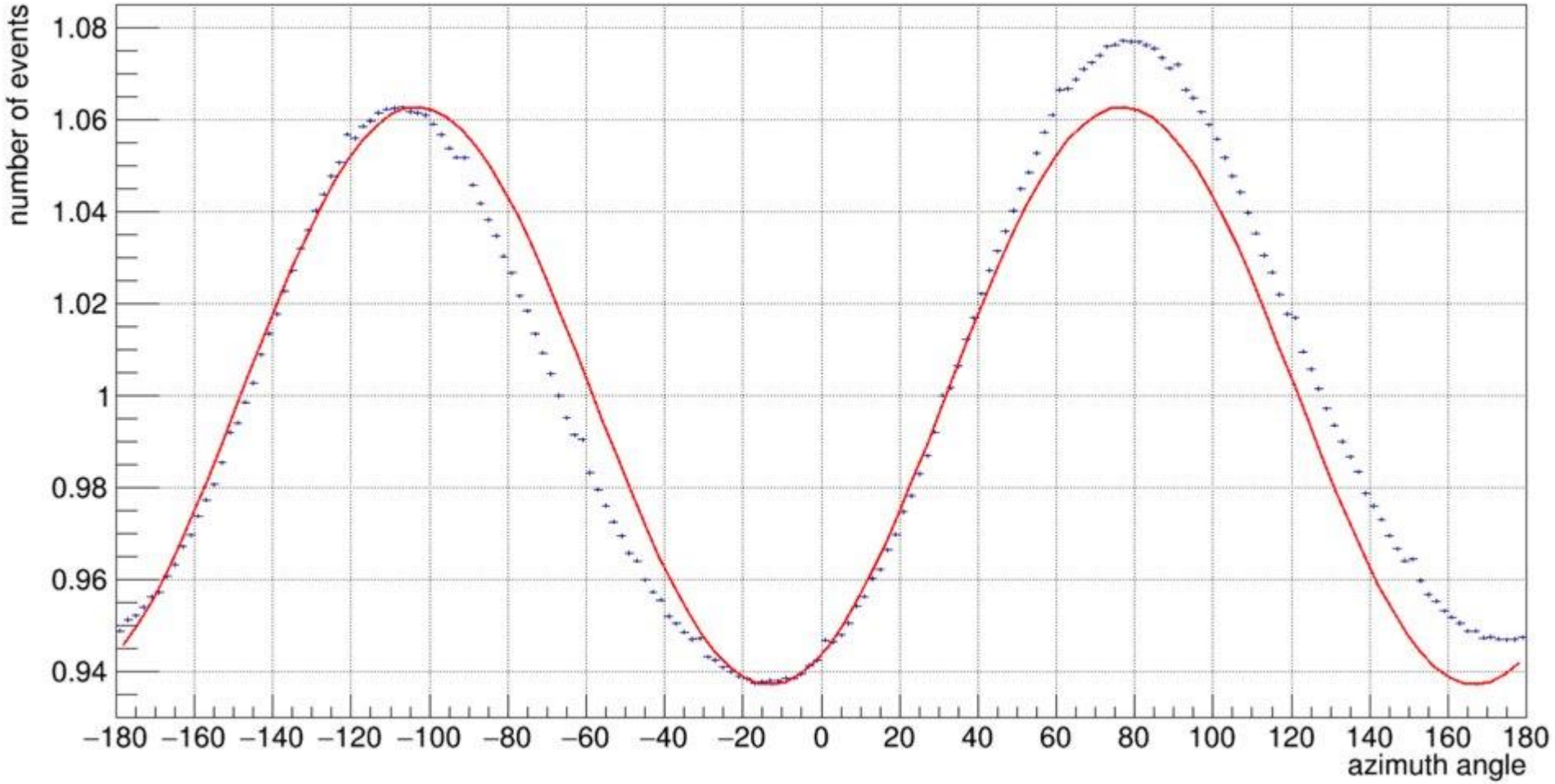
We do we actually get? - Zenith



[0]*TMath::Power(sin(pi*x/180.),[1])*exp(-[2]/cos(pi*x/180.))

$$C_1 \sin(\pi x/180)^{C_2} e^{-C_3/\cos(\pi x/180)}$$

We do we actually get? - Azimuth

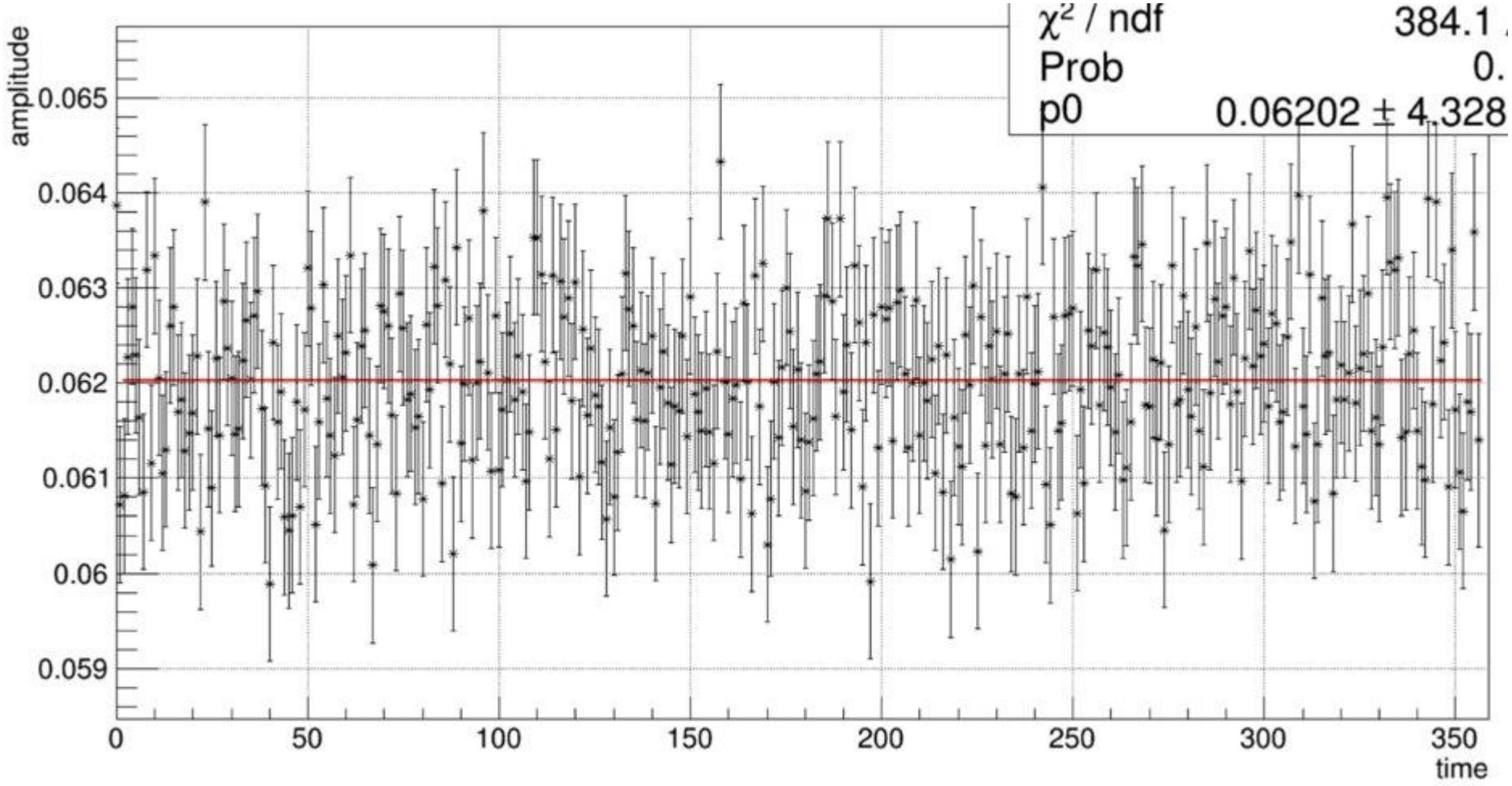


[0]*(1+[1]*sin(2*(x - [2])/57.3))

[0]-> Fixed to 1, [1]-> amplitude, [2]-> phase

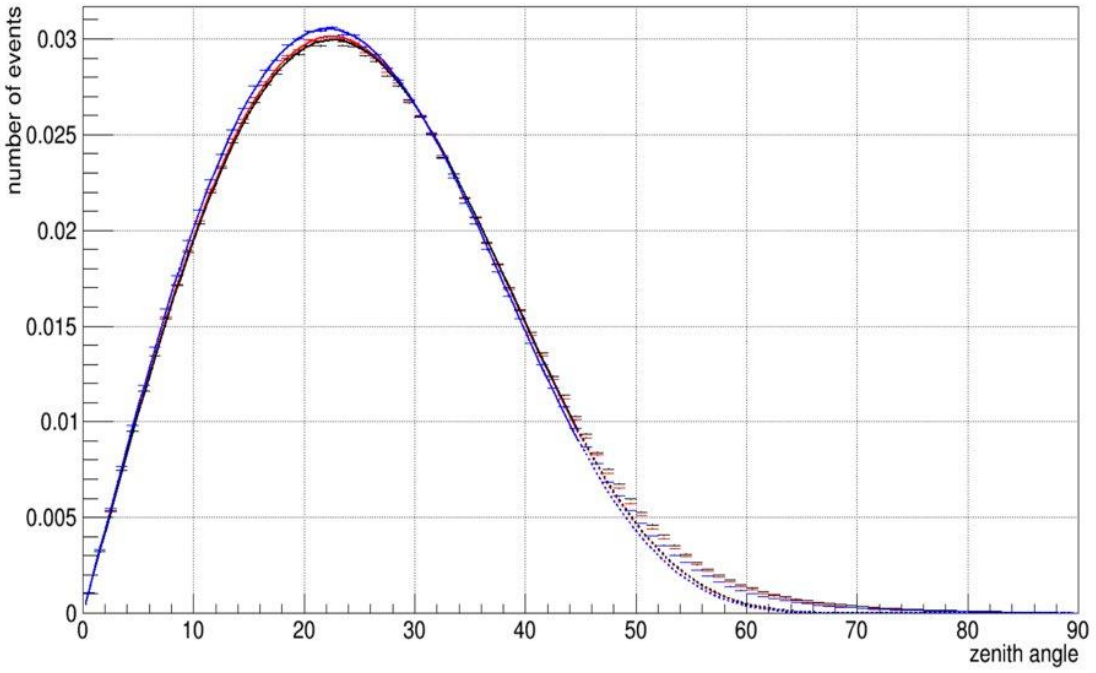
$$C_1\left(1 + C_2 \sin\left(2(x - C_3)/57.3\right)\right)$$

Is this an issue for data analysis?

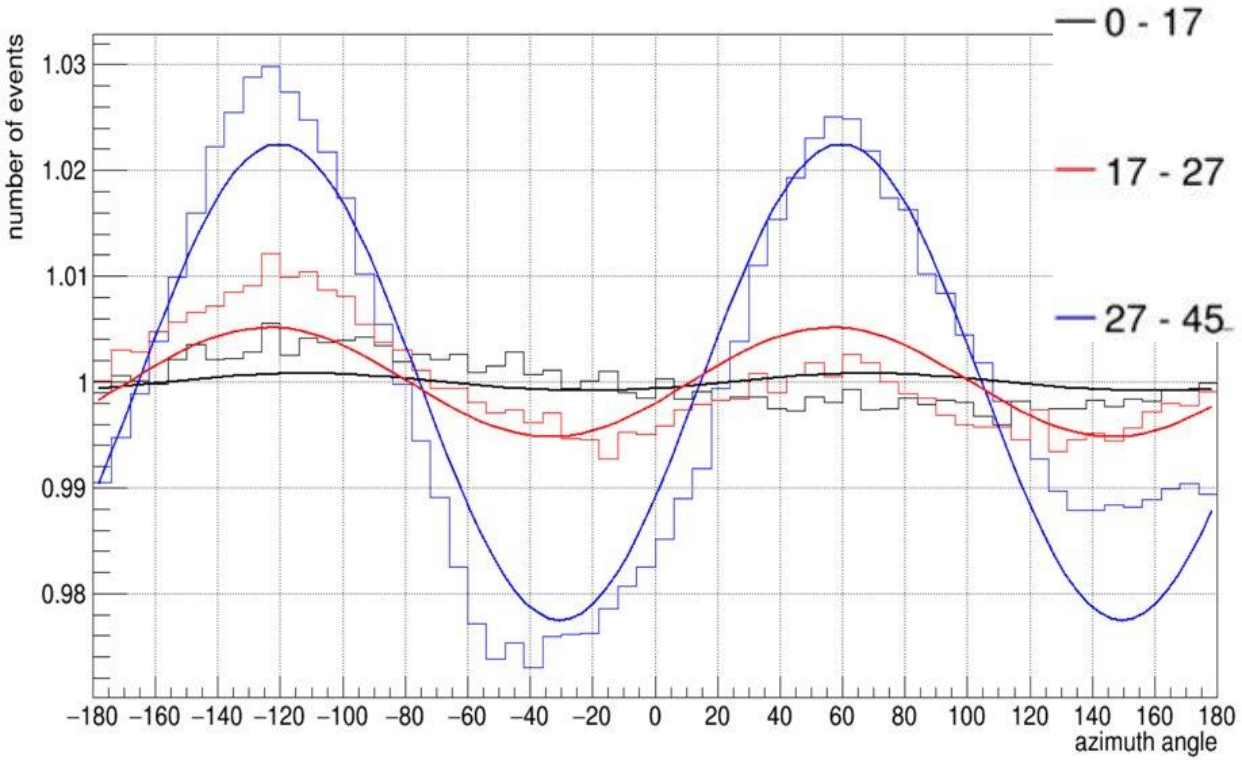


No – the amplitude is roughly constant in time

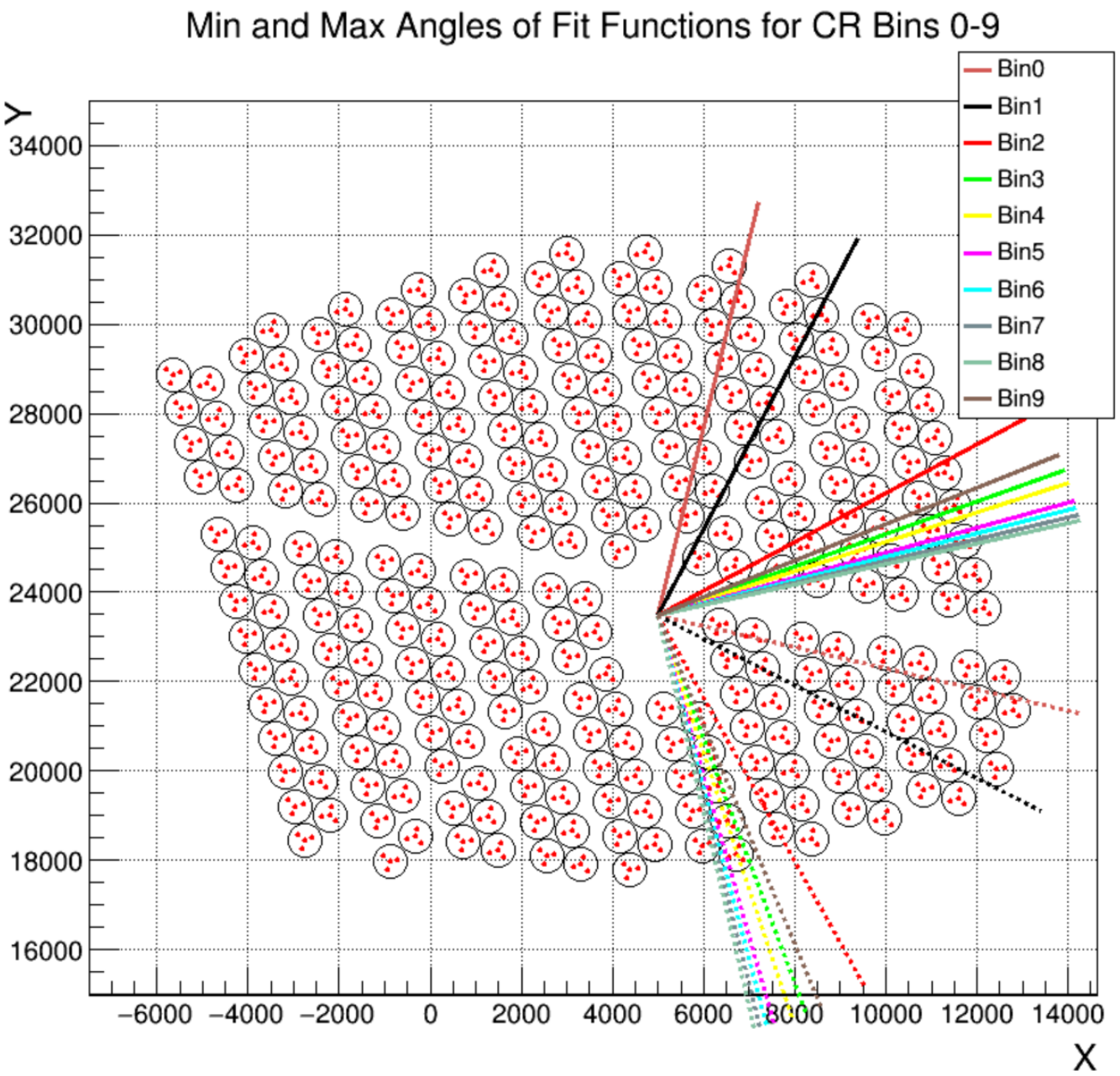
Understanding the effect



Zenith distribution does not change for different azimuth angles

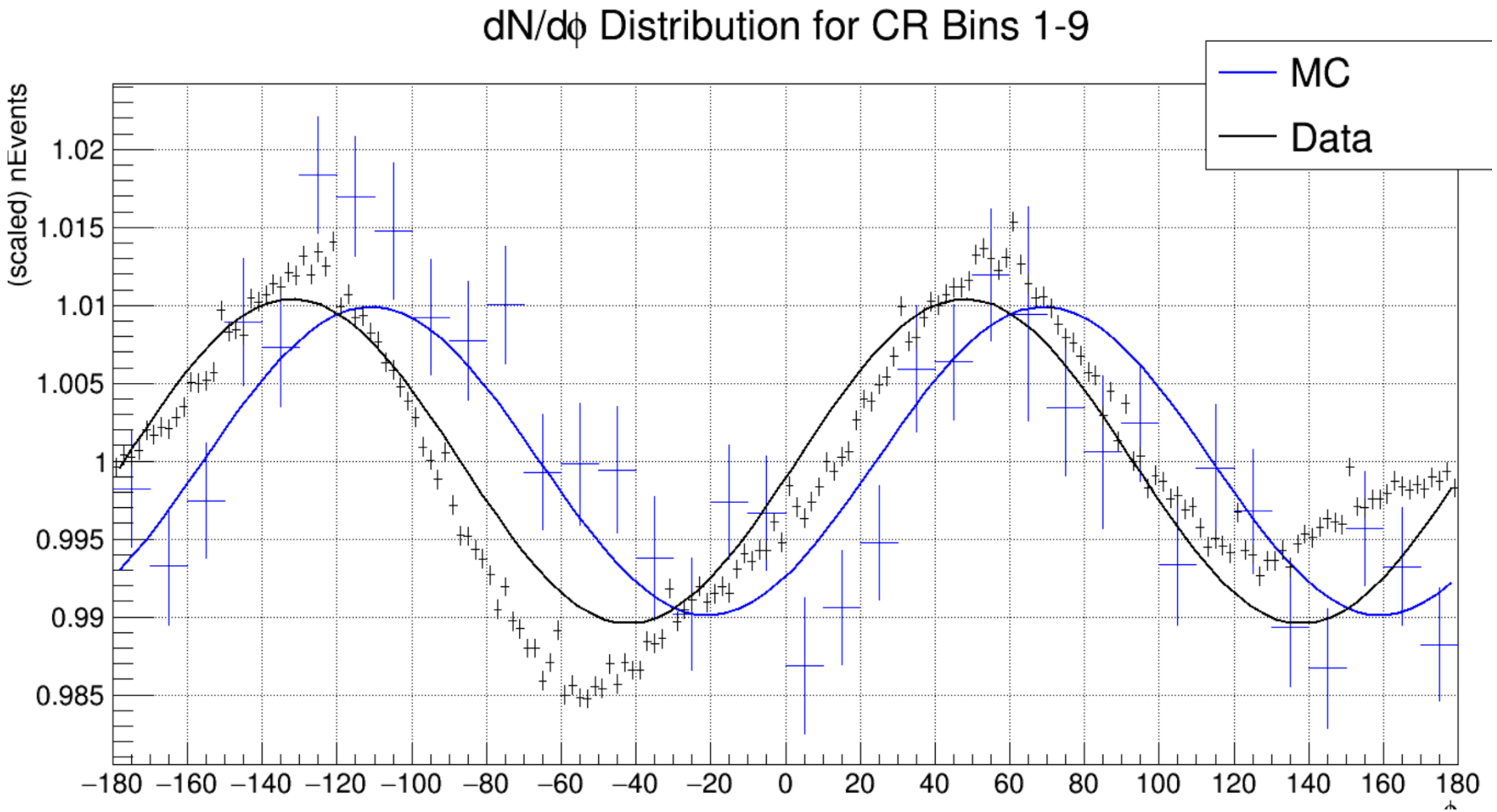


Azimuth distribution changes for different zenith angles, but only in amplitude



Event size increases from nHit bin 0 to 9 and event size is a proxy for energy

How does the data compare with Monte Carlo?



Monte Carlo is composed of simulated air showers that are thrown on the array and reconstructed

Other Stuff

- Core locations
- Different cuts
- Slices
- Proton simulations
- I looked at a lot of other stuff

Potential Explanations

- Bad luck – effect was there 4 years ago and is still here today, MC
- Array geometry
  - There is an alley through the middle of the array – peaks/valleys don’t line up with the alley
  - PMT trigger cascades – um no
- The mountains – it’s not the mountains
- Earth’s magnetic field - ?

Jump to today: modelling

- The goal is to simulate air showers that are detected by the array when there is no magnetic field present
- If we can compare this to current data then we'll know definitely if the Earth's magnetic field is responsible for the effect we see

Work Flow

Corsika

- Generates data files for air showers
- I can specify parameters for the showers

HAWCSIM

- Takes the air showers and runs them over the array
- Simulates what HAWC would detect for each shower

Offline Reconstructor

- Reconstructs what the detector saw
  - ie. azimuth and zenith angles

Other Stuff

- Macros for processing and plotting data

What gives?

- HAWCSIM is pretty new (at least for what I'm using it for)
  - There is little documentation and no one really knows how it works
  - Random bugs!
- First, I have to ensure that I can reconstruct similar to the data with the correct magnetic field
  - HAWCSIM is a huge pain with how it throws cores
  - There is a discrepancy between HAWCSIM and the OR when it comes to core locations and offsets
    - I can fix the HAWCSIM core locations but then the OR is upset