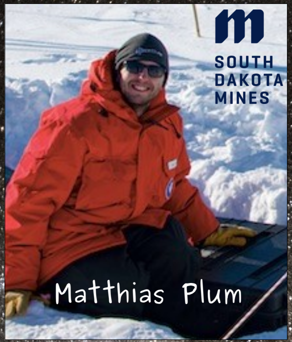
Cosmic Ray Working Group

IceCube
South Pole Neutrino Observatory

University of Delaware
Bartol Research Institute

Credit: Johannes Werthebach/NSF



Reach out to us, we are happy to help!

slack

Credit: Johannes Werthebach/NSF

CR-WG resources

Wiki page

https://wiki.icecube.wisc.edu/index.php/Cosmic_Ray

- Completed & ongoing studies
- MC/data information
- Collection of theses
- Useful links, notes ...

GitHub

https://github.com/icecube/wg-cosmic-rays

Analysis in the Cosmic-Ray WG

https://drive.google.com/file/d/154BDgi_UAYimsygurSMUVWgXHU55tr18/view

Analysis in the Cosmic-Ray Working Group (CR-WG)

If you want to perform an analysis on IceCube data related to cosmic ray physics, there are certain requirements to prevent bias and/or to allow the WG and collaborators to review your analysis and comment. This document summarizes the CR-WG specific steps to perform an analysis. A documentation of the generally valid IceCube analysis procedures can be found at: https://wiki.icecube.wisc.edu/images/0/0f/Analysis_in_the_IceCube_collaboration_-_2021-05-10.pdf

General guidelines:

Phone calls on Fridays at 9 am CDT

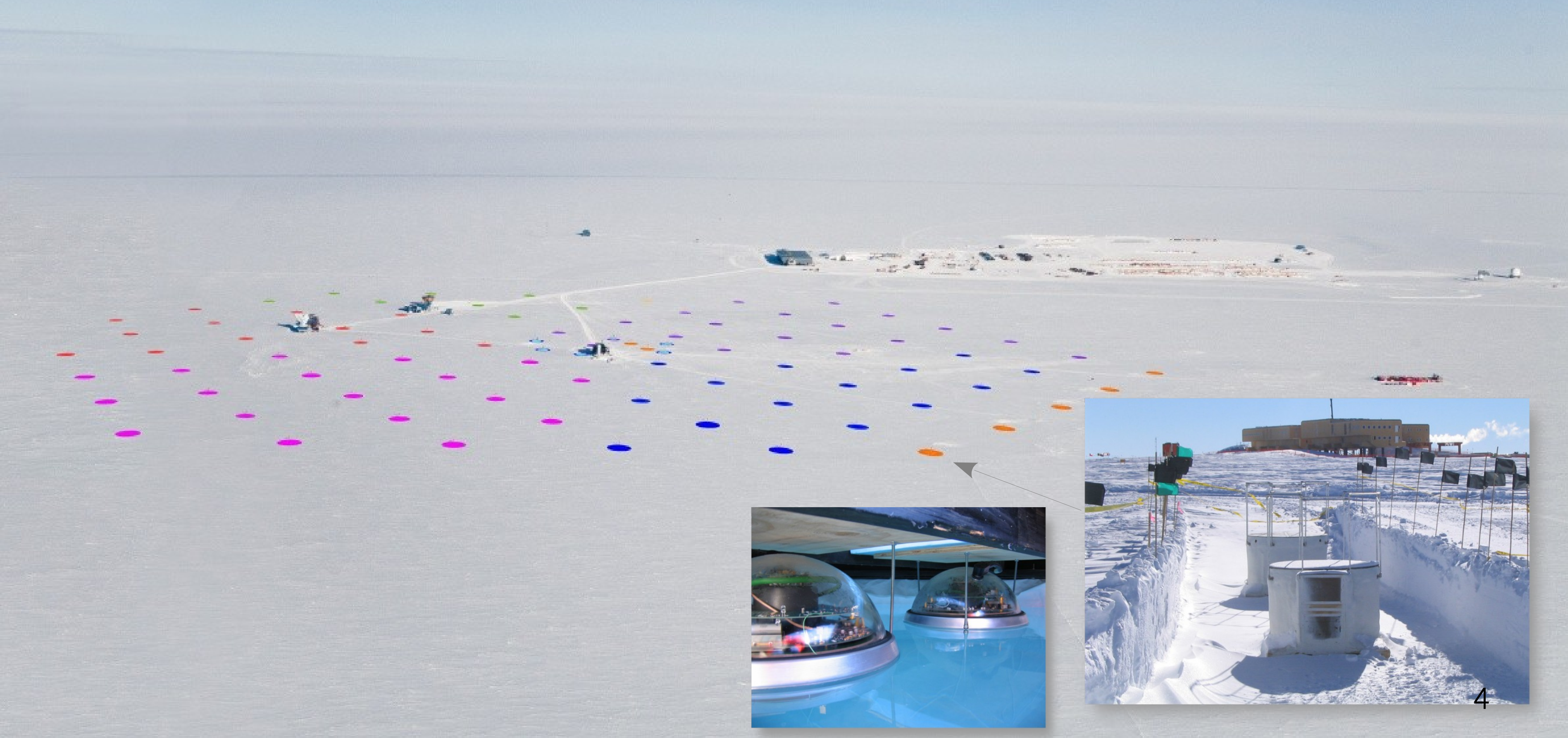
https://wiki.icecube.wisc.edu/index.php/CR_PhoneCall_Index

Contact

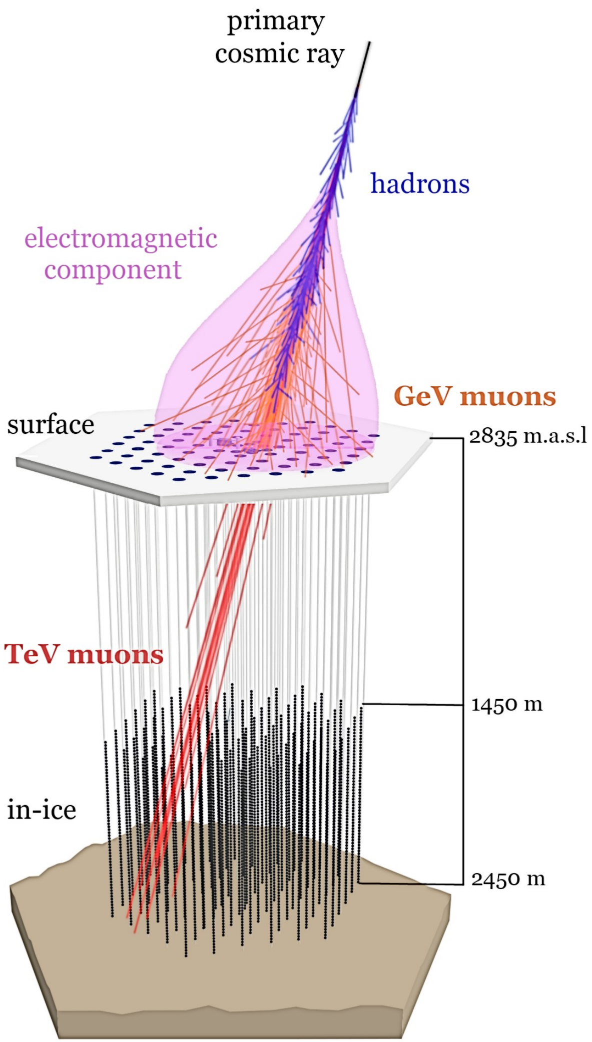
cr-wg@icecube.wisc.edu

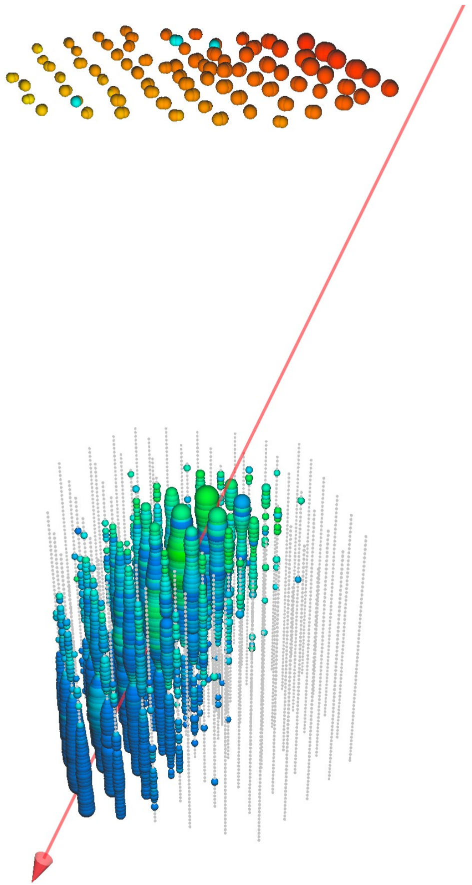
https://icecube-spno.slack.com/messages/icetop

IceTop



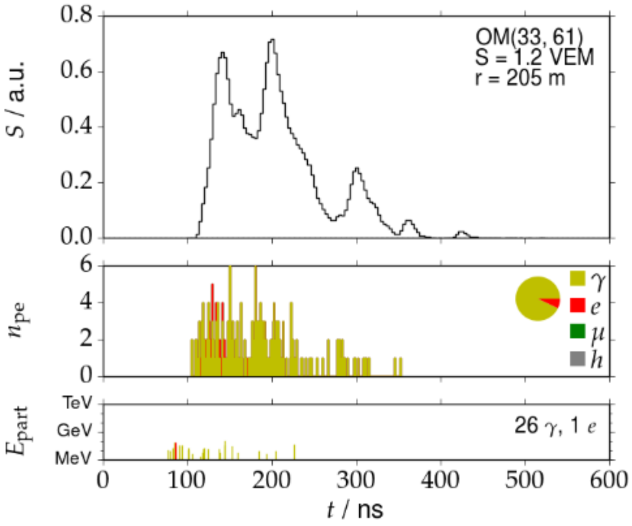
Extensive air-shower event



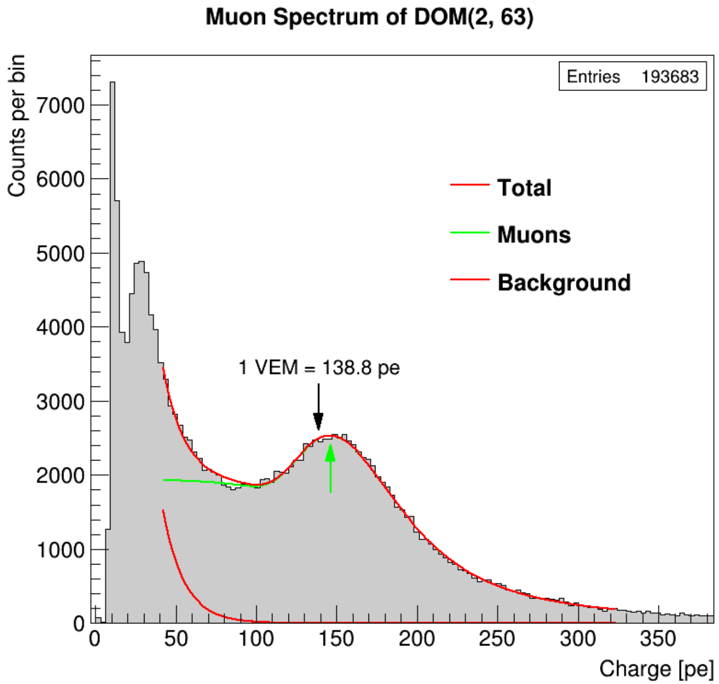


IceTop: The surface component of IceCube:
https://arxiv.org/abs/1207.6326

Signals & Unit



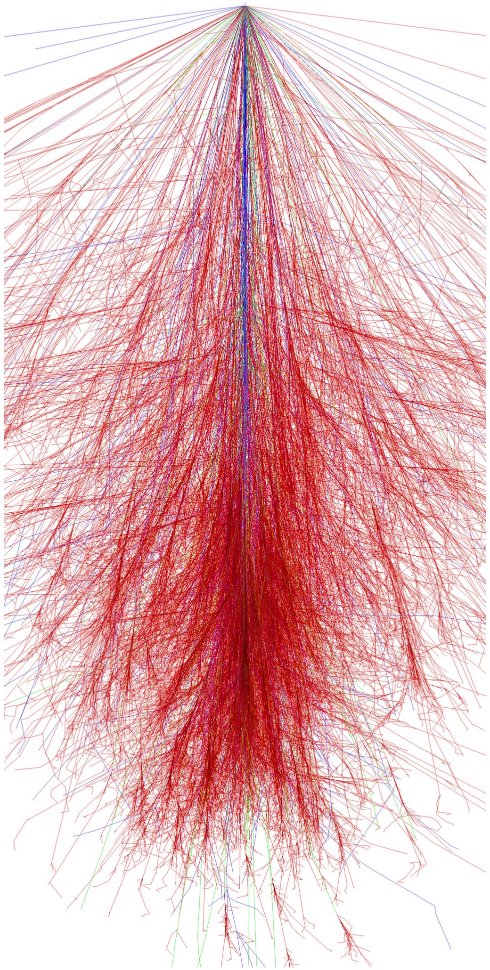
- Each tank has 2 DOMs, with high and low gain PMT
- Charge and timestamp for each DOM is measured
- Processing provides signal per tank
- SLC → single tank triggers
- HLC → two tanks in a station trigger



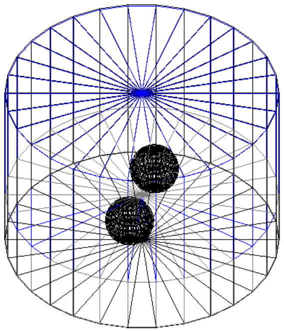
- Each detector is different → detector calibration with atmospheric muons
- Unit of 1 VEM (vertical equivalent muon) → 95% of the peak value from tank charge distribution

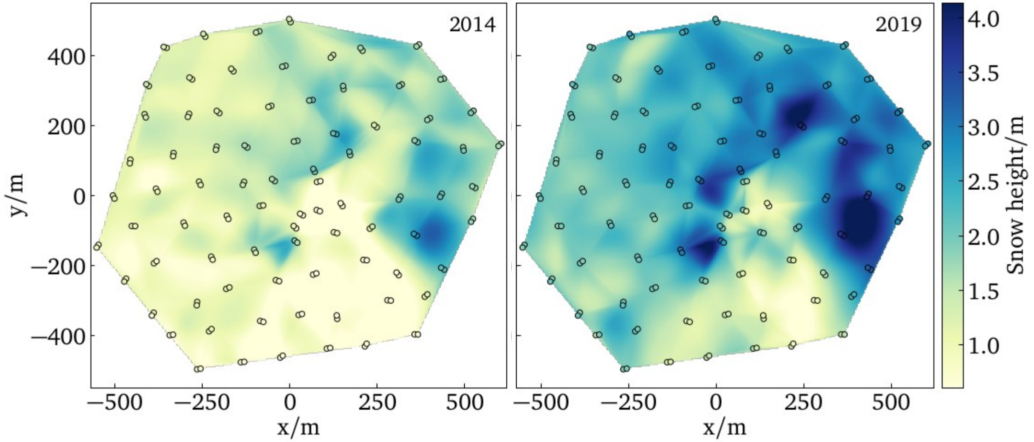
IceTop and how we simulate its response?

CORSIKA



GEANT4 A SIMULATION TOOLKIT embedded in topsimulator project



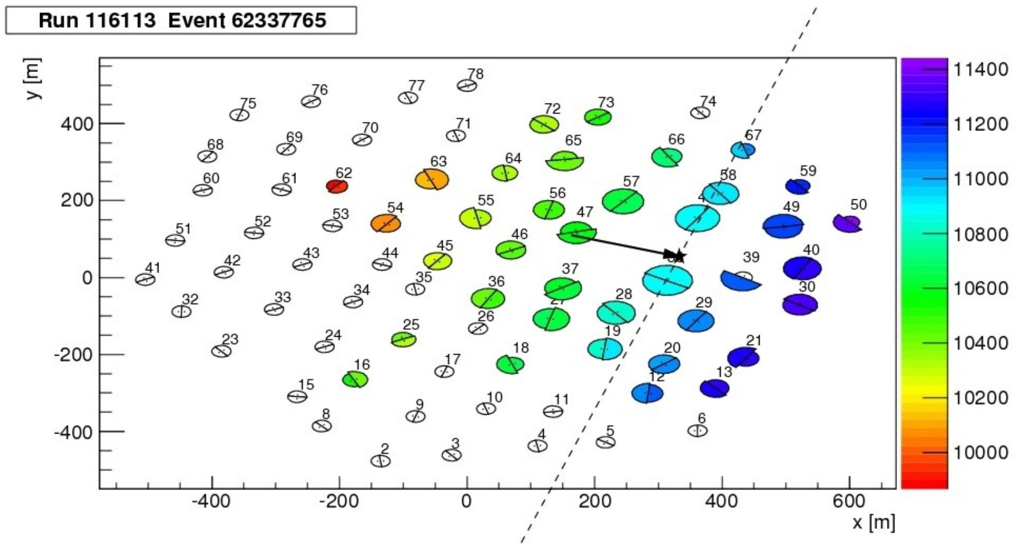


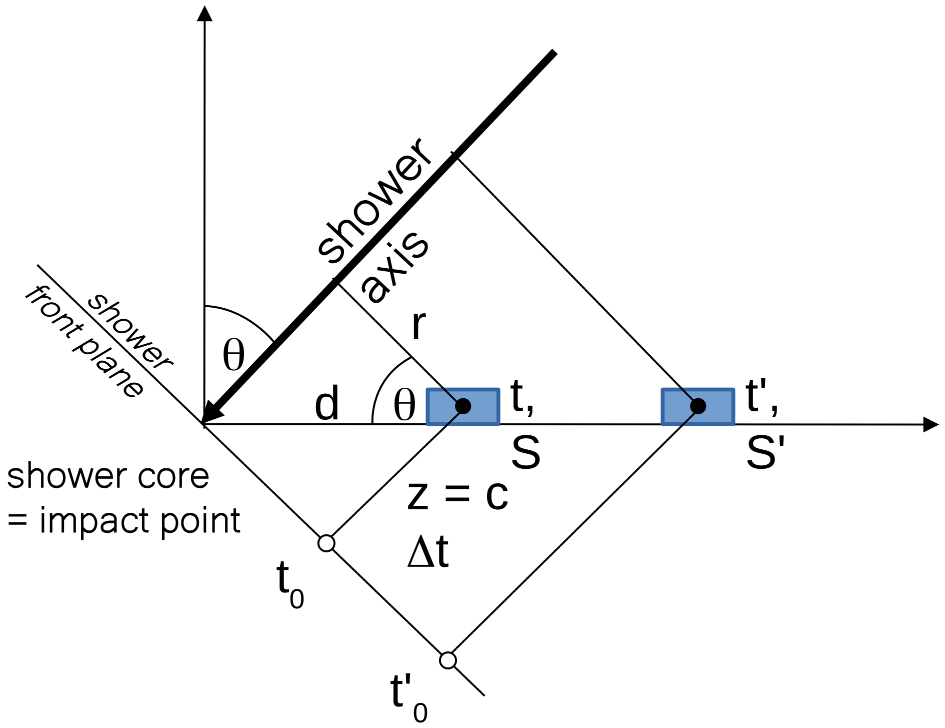
- Secondary particles from simulated air shower are injected onto the array
- Geant4 calculated energy deposits in each tank → PE → VEM
- IceTop array is burried under snow → triangulation of the snow layer with snow heights taken from the South Pole measurements twice a year

Air-shower reconstruction

Laputop

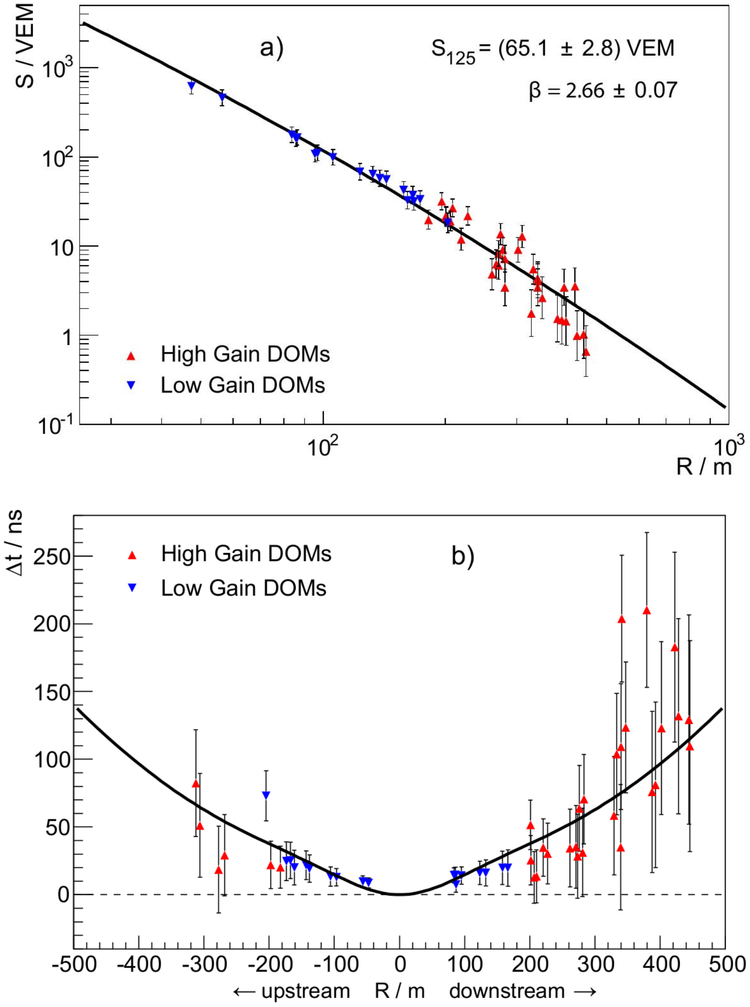
Particles from extensive air showers leave signals at the ground → these can be used to reconstruct properties of an initial cosmic ray: impact point/direction, energy, mass

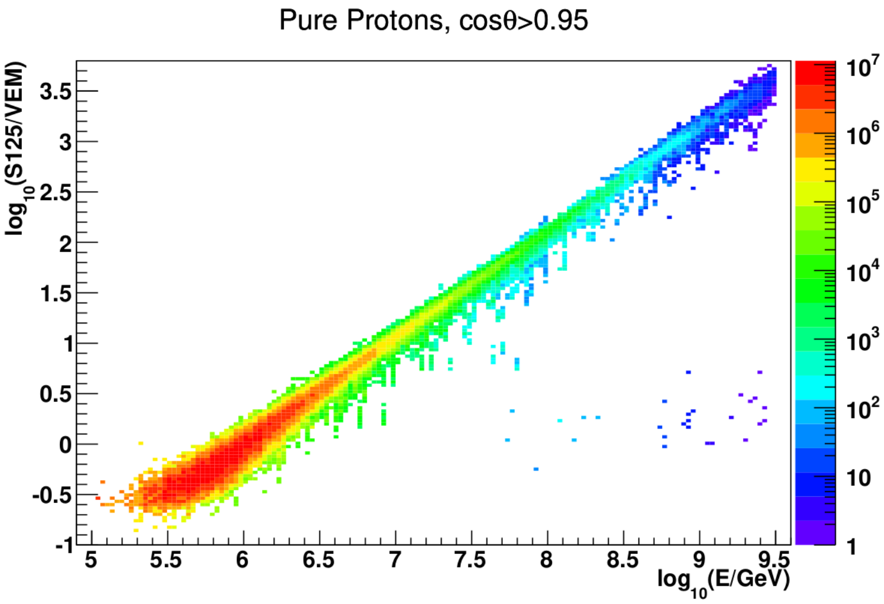




Air-shower reconstruction

Laputop



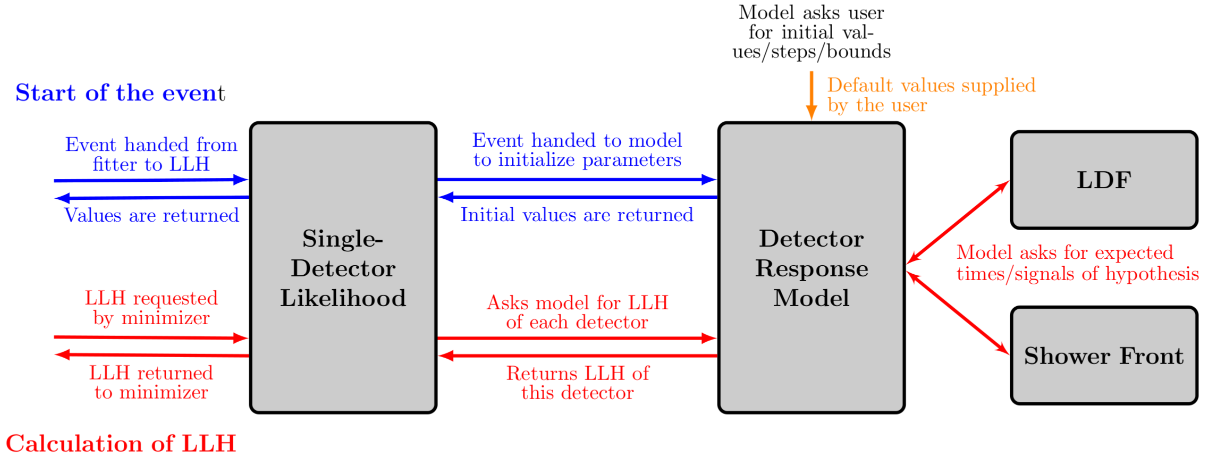


- CR energy reconstructed from lateral signal distributions based on MC
- Lateral shape slightly sensitive to mass

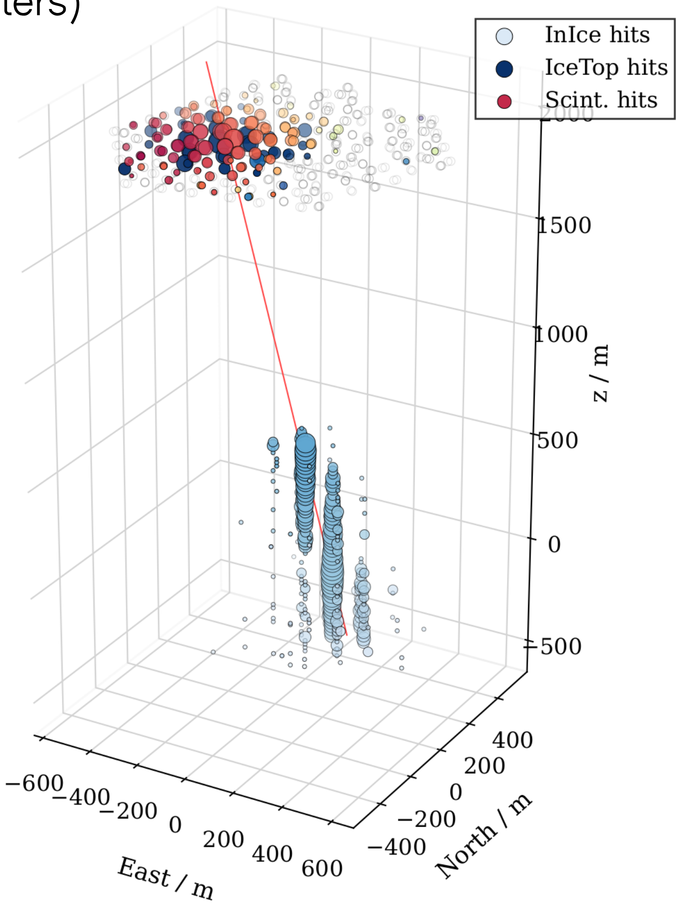
RockBottom

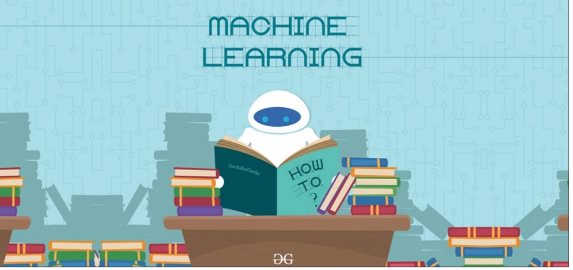
Air-shower reconstruction

- framework to **reconstruct air showers** (core, direction, LDF parameters) for a given detector model or combination of detector models.



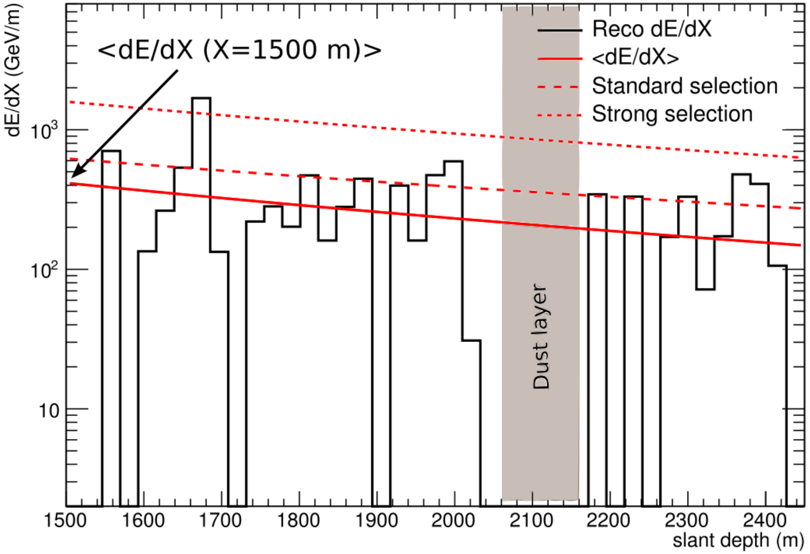
+ I3RecoLLH (with any PE probability)

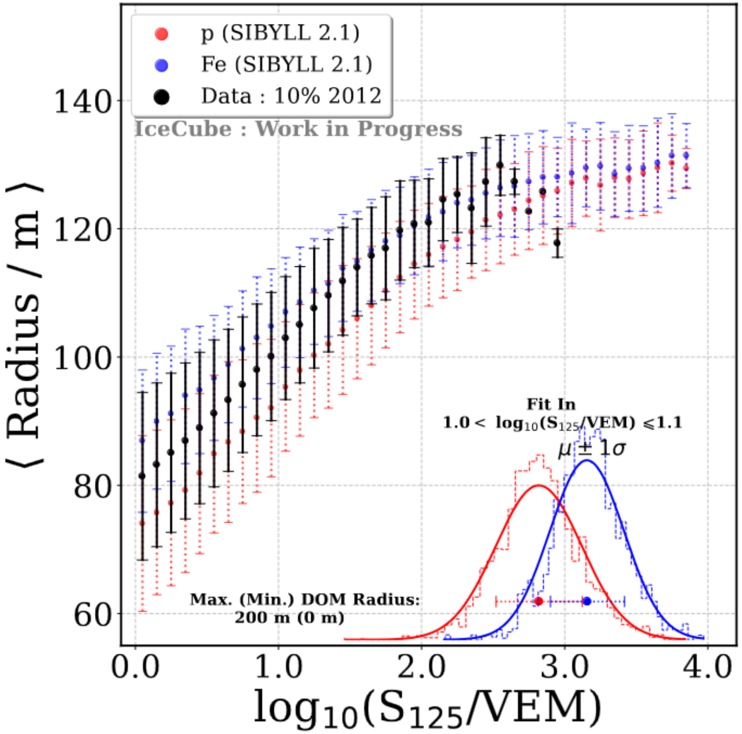




Cosmic ray composition

Ongoing studies





In-ice distribution sensitive to CR mass:

- heavier CR → more muons → more in-ice deposition
- lighter CR → higher-energy muons → local large deposition
- heavier CR → interact earlier → muons more spread

Ongoing studies

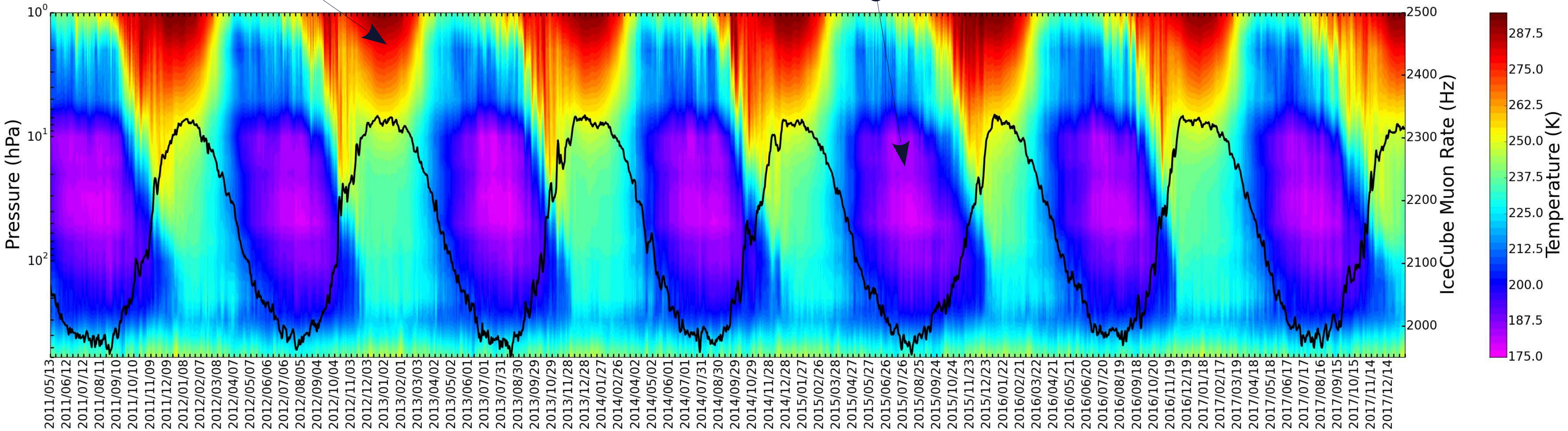
atmospheric muons

Seasonal variations

- Atmospheric muon rate depends on atmospheric density
- Rates are sensitive to the kaon/pion ratio

Summer → warm → less dense → pions decay

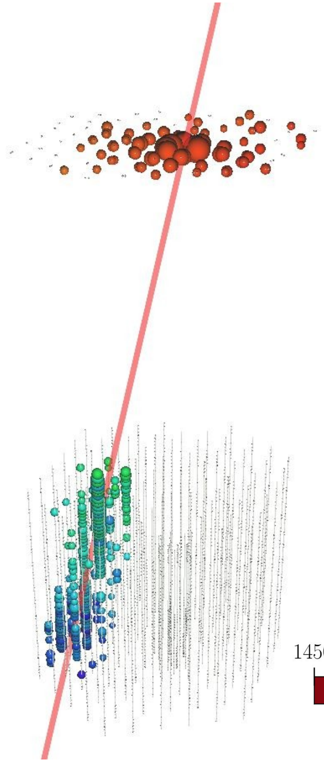
Winter → colder → more dense → pions interact



S. Tilav, T. K. Gaisser, D. Soldin, P. Desiati, PoS ICRC2019 (2020) 894

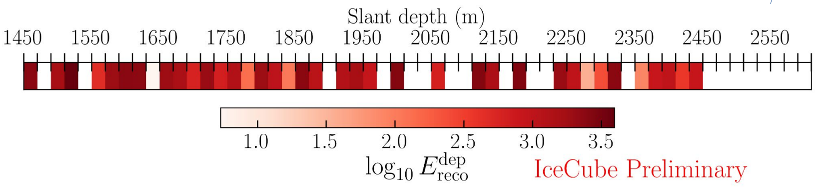
Ongoing studies

TeV muons@IceCube



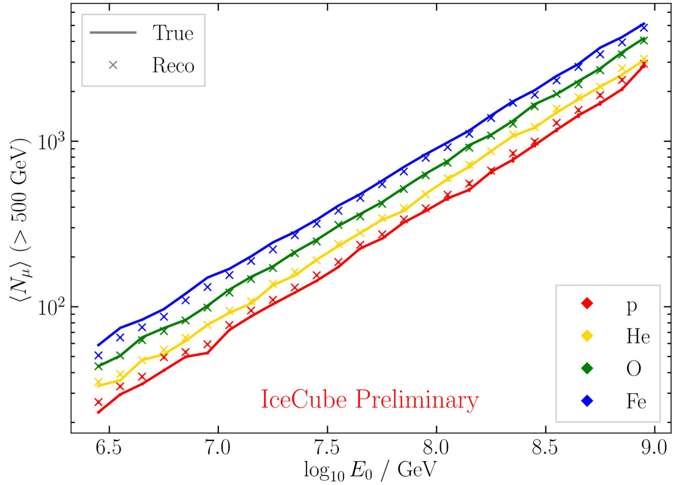
IceTop EAS reconstruction:
CR energy and EAS geometry
(direction, impact point at the ground)

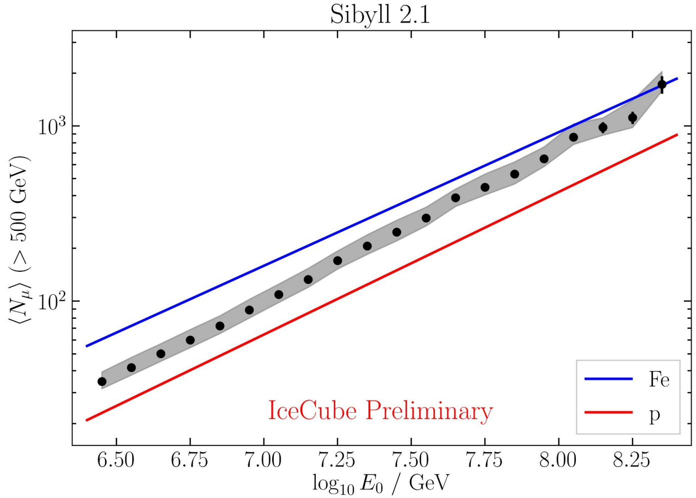
InIce energy losses along the track



Neural network reconstruction

Number of muons with E > 500 GeV

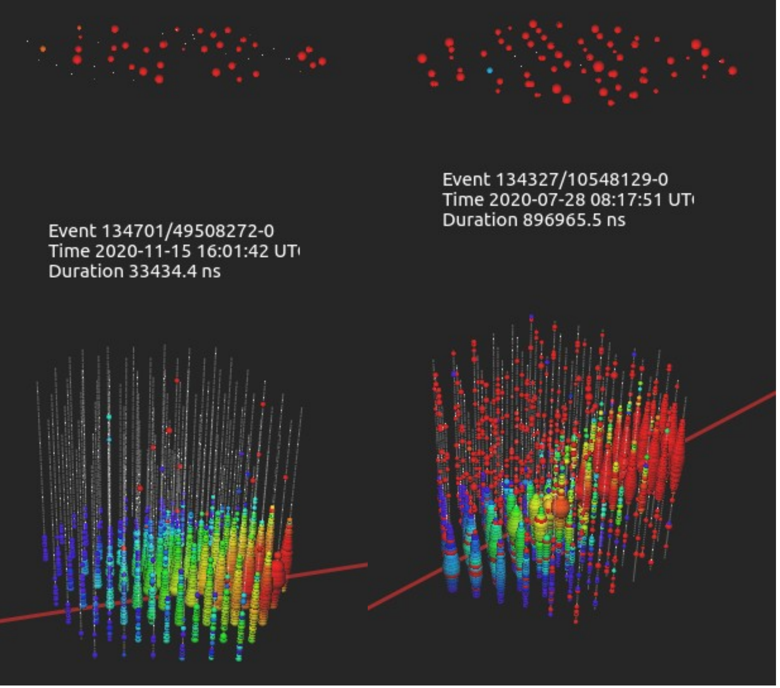


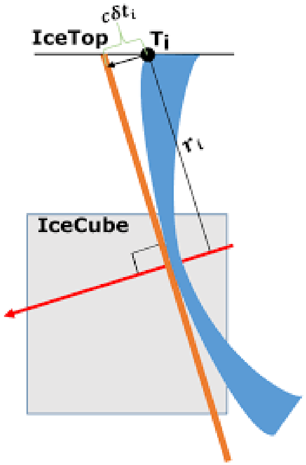


Stef Verpoest, ECRS 2022

Ongoing studies

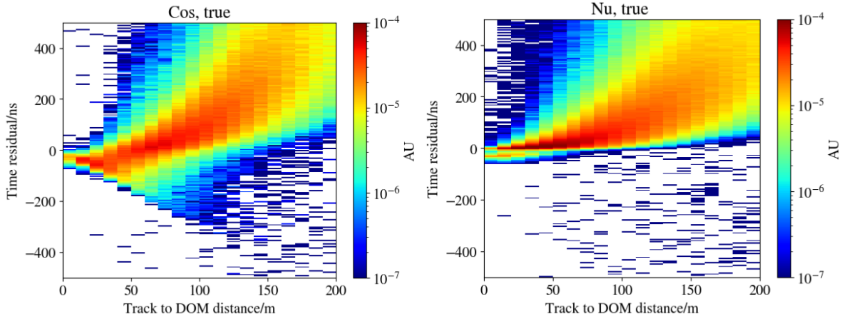
IceTop as veto



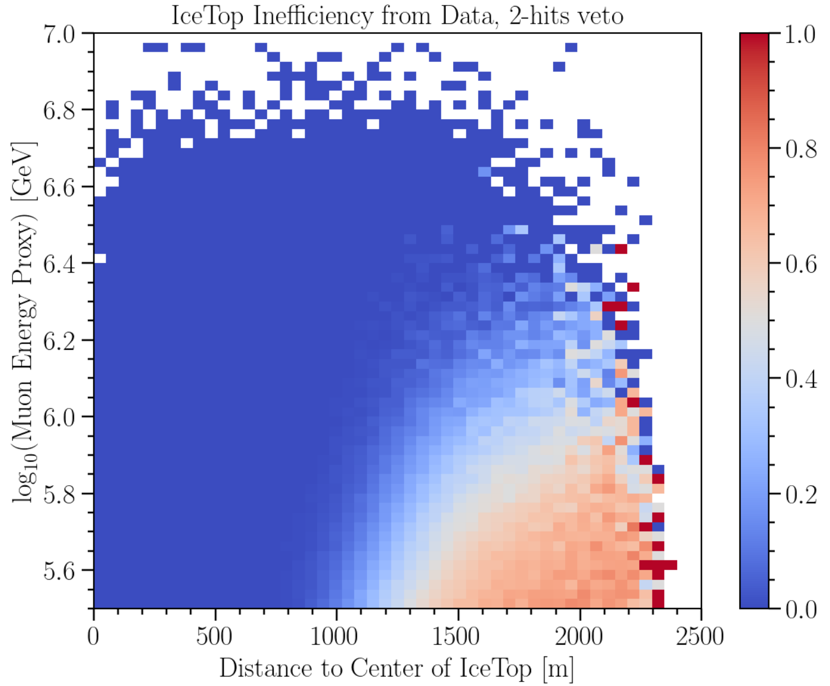


In '20: 32 alert events and 3 were vetoed by IceTop

→ muon bundle characteristics under investigation



Y. Lyu, PoS-ICRC2021-1137



Veto inefficiency for down-going PeV tracks

Reach out to us if you are interested in joining CR-WG!

slack