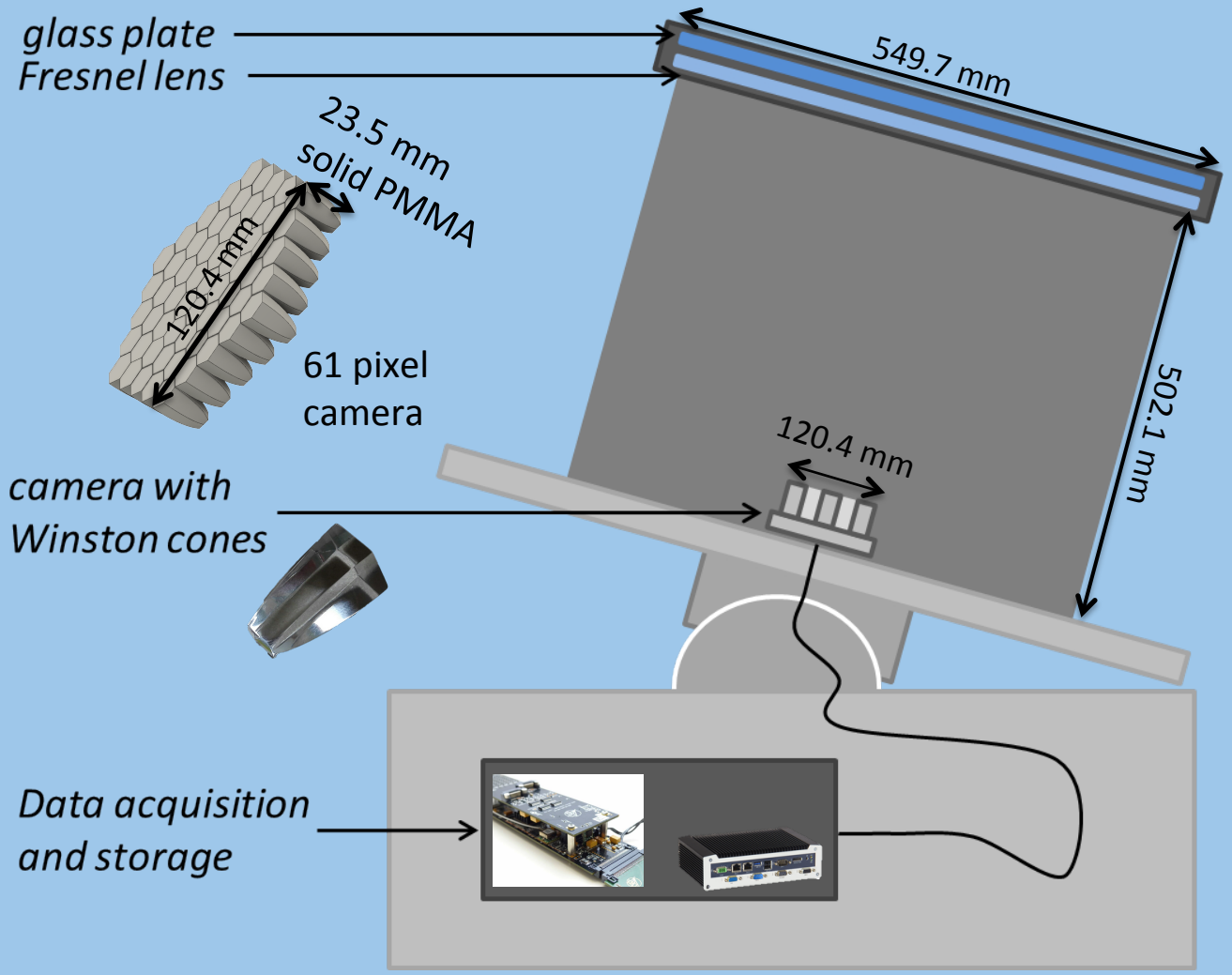
Compact imaging air Cherenkov telescopes as an additional component for large astroparticle detectors like IceCube and HAWC

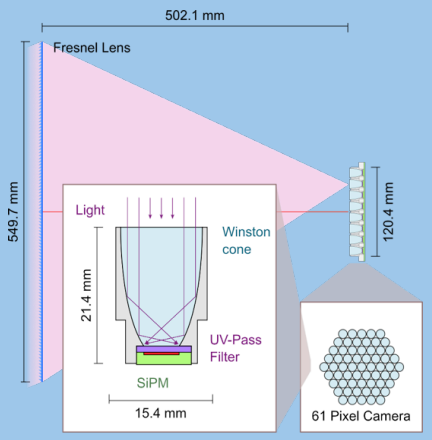
by
Jan Auffenberg

DFG Deutsche Forschungsgemeinschaft

Bundesministerium für Bildung und Forschung

IceAct/FAMOUS Mechanical Concept





0.034sr solid angle
12° Field of view
(~1.5° per pixel)

Famous/IceAct

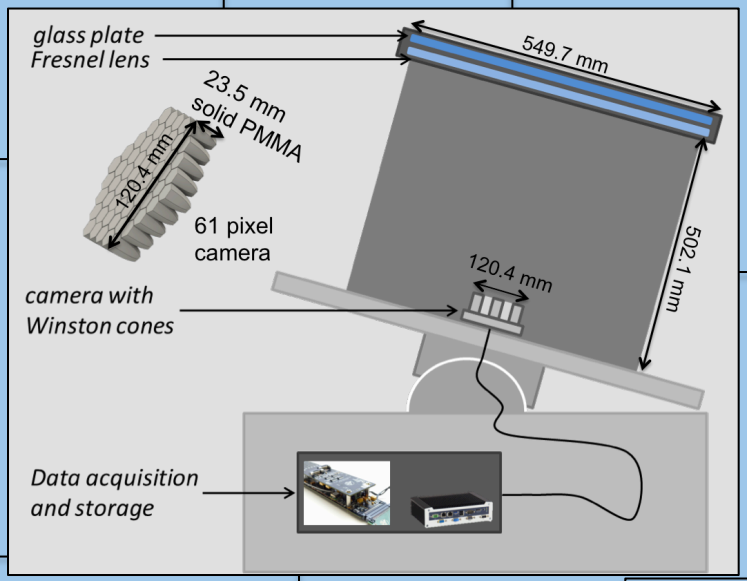
Small Imaging Air Cherenkov Telescopes with wide field of view

Florescence Air-Shower Detection for the **Pierre Auger Observatory**

- Hybrid EAS detection
  - Composition measurements

Cherenkov light Telescope for **IceCube**

- Air shower veto for astrophysical neutrino detection
- Hybrid detector component for composition studies



Cherenkov light Telescopes for **HAWC**

- improving gamma ray detection
  - energy resolution
  - background separation

Small telescope for **education**

- air shower physics
- air-Cherenkov detectors

Famous/IceAct

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ICECUBE

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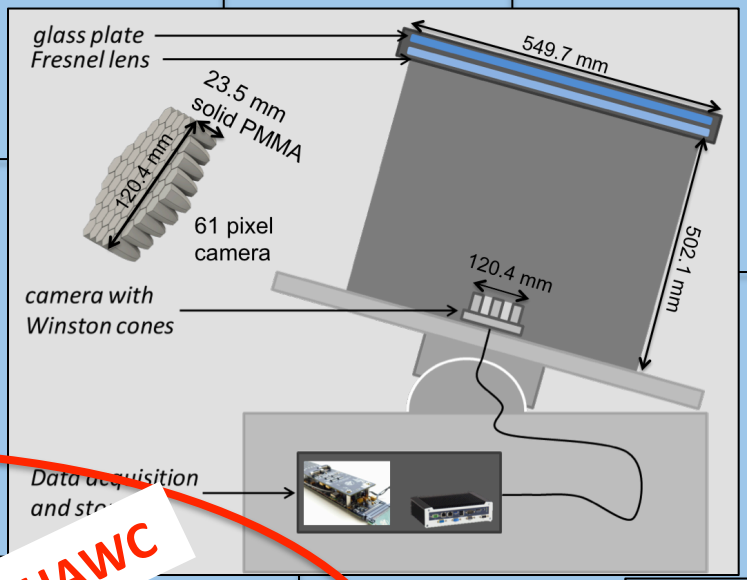

Cherenkov light Tele… …r **HAWC**

- impro… …ma ray detection
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More on applications for HAWC

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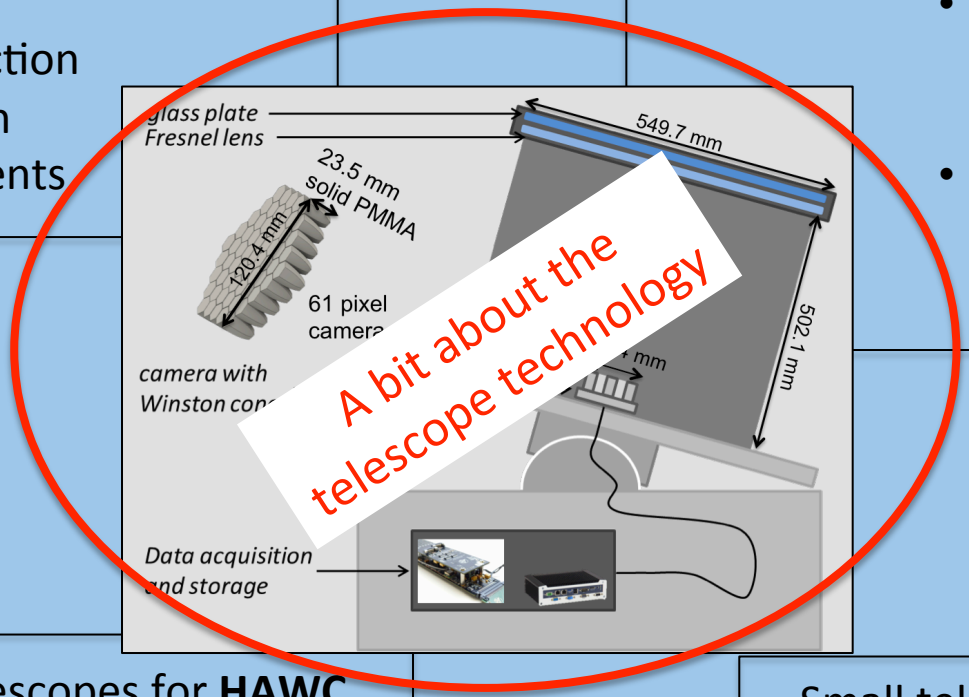

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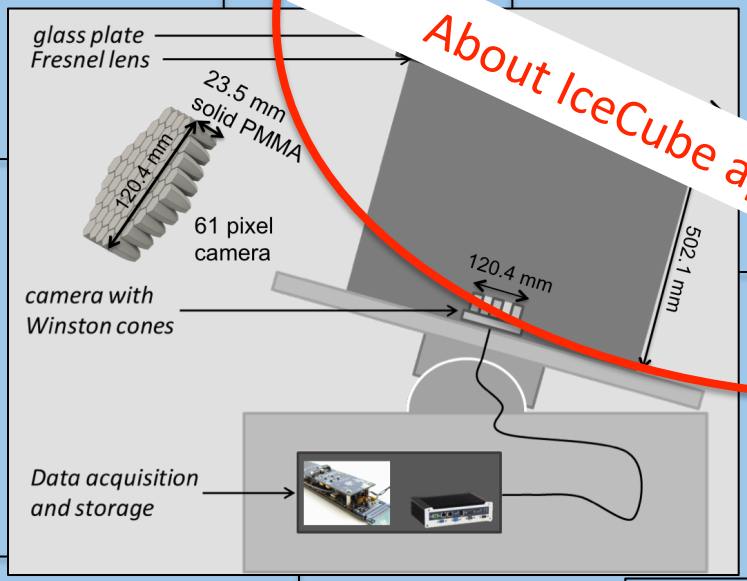
About IceCube applications



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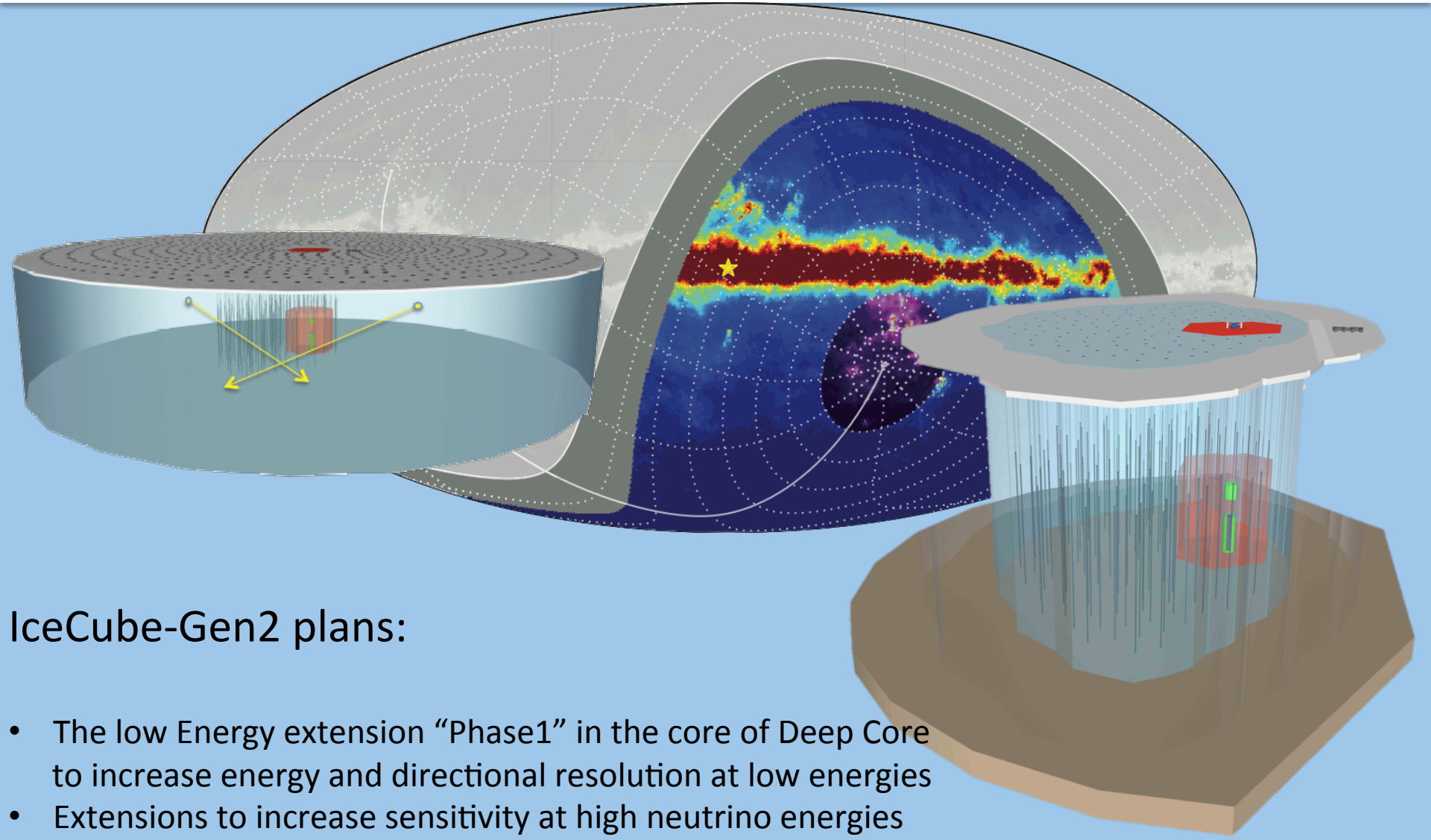
IceCube-Extension



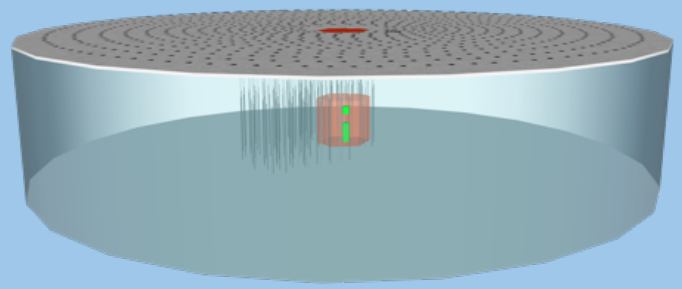
IceCube-Gen2 plans:

- The low Energy extension “Phase1” in the core of Deep Core to increase energy and directional resolution at low energies
- Extensions to increase sensitivity at high neutrino energies

Veto CRs to measure astrophysical neutrinos

Requirements for a surface veto:

- extremely good detection efficiency for CR
  - -high duty cycle
  - -low energy threshold



One solution: many surface stations to detect particles on the surface.

- requires a high instrumentation density to reach sufficient detection efficiency at high energies

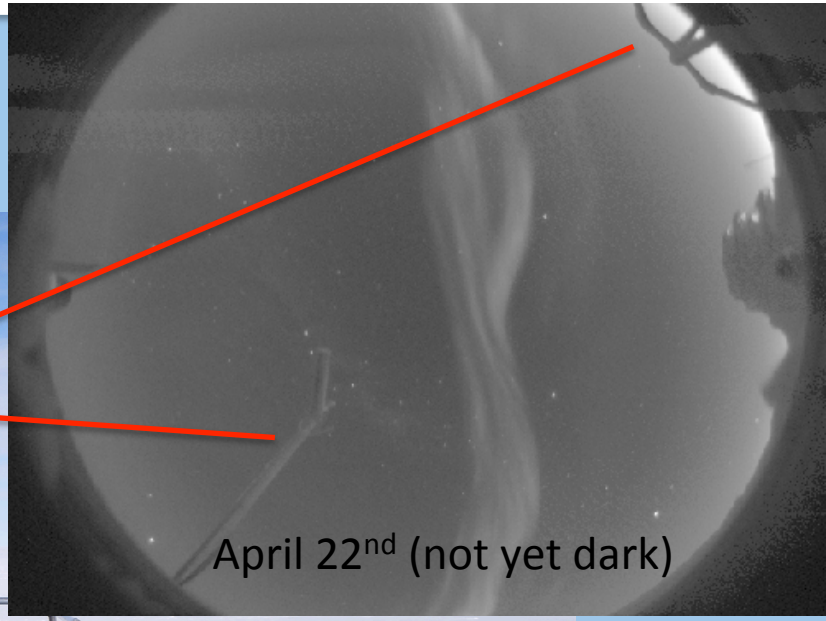
This idea: take atmosphere as active volume and measure the air-Cherenkov light of the air shower.

- Lower duty cycle but low energy threshold.

(see ICRC2015 PoS(ICRC2015)1156, PoS(ICRC2015)568, PoS(ICRC2015)649, PoS(ICRC2015)605, and PoS(ICRC2015)1047)

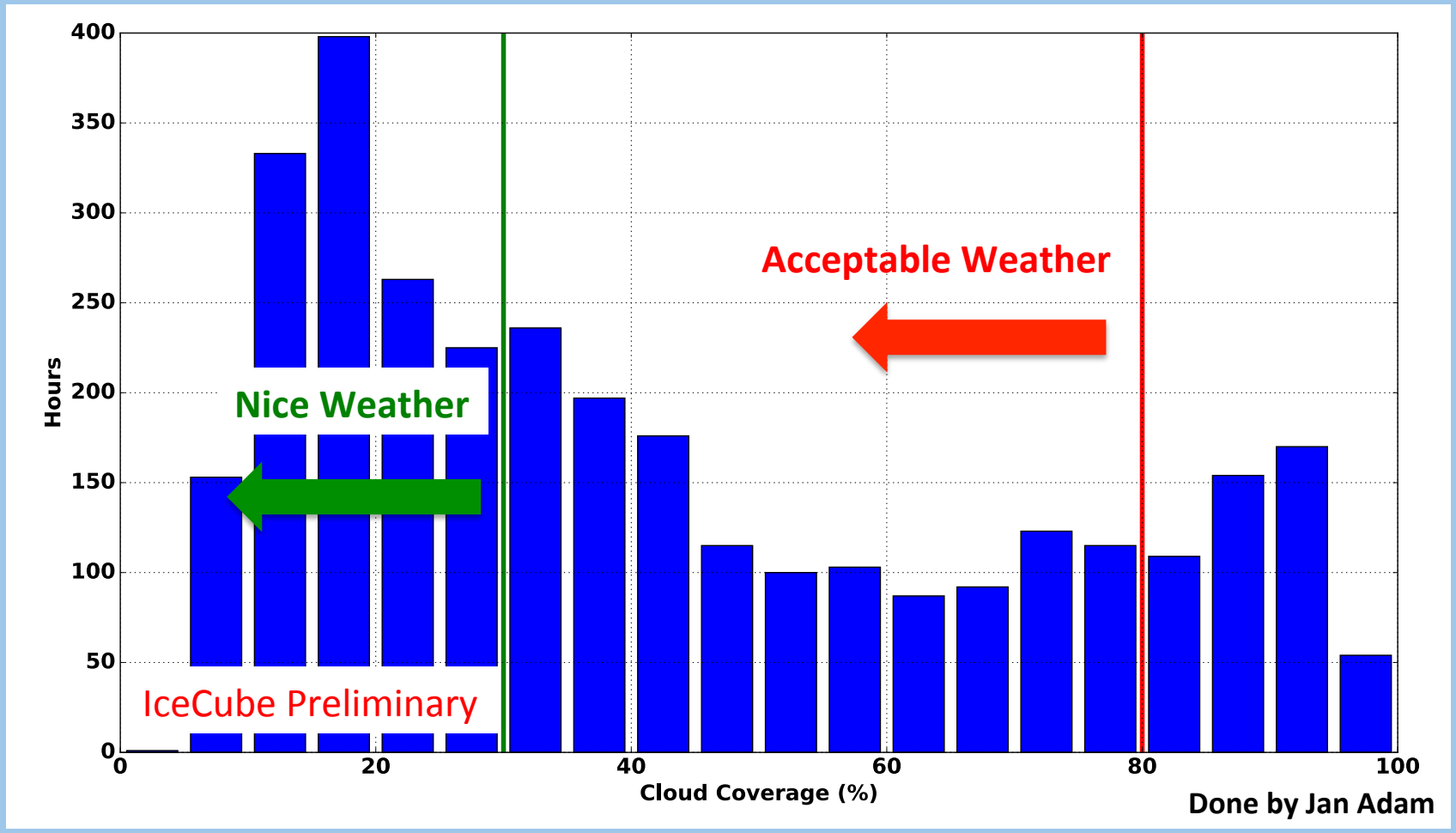
Of course the systems can be combined!

Cloud monitoring is about to improve



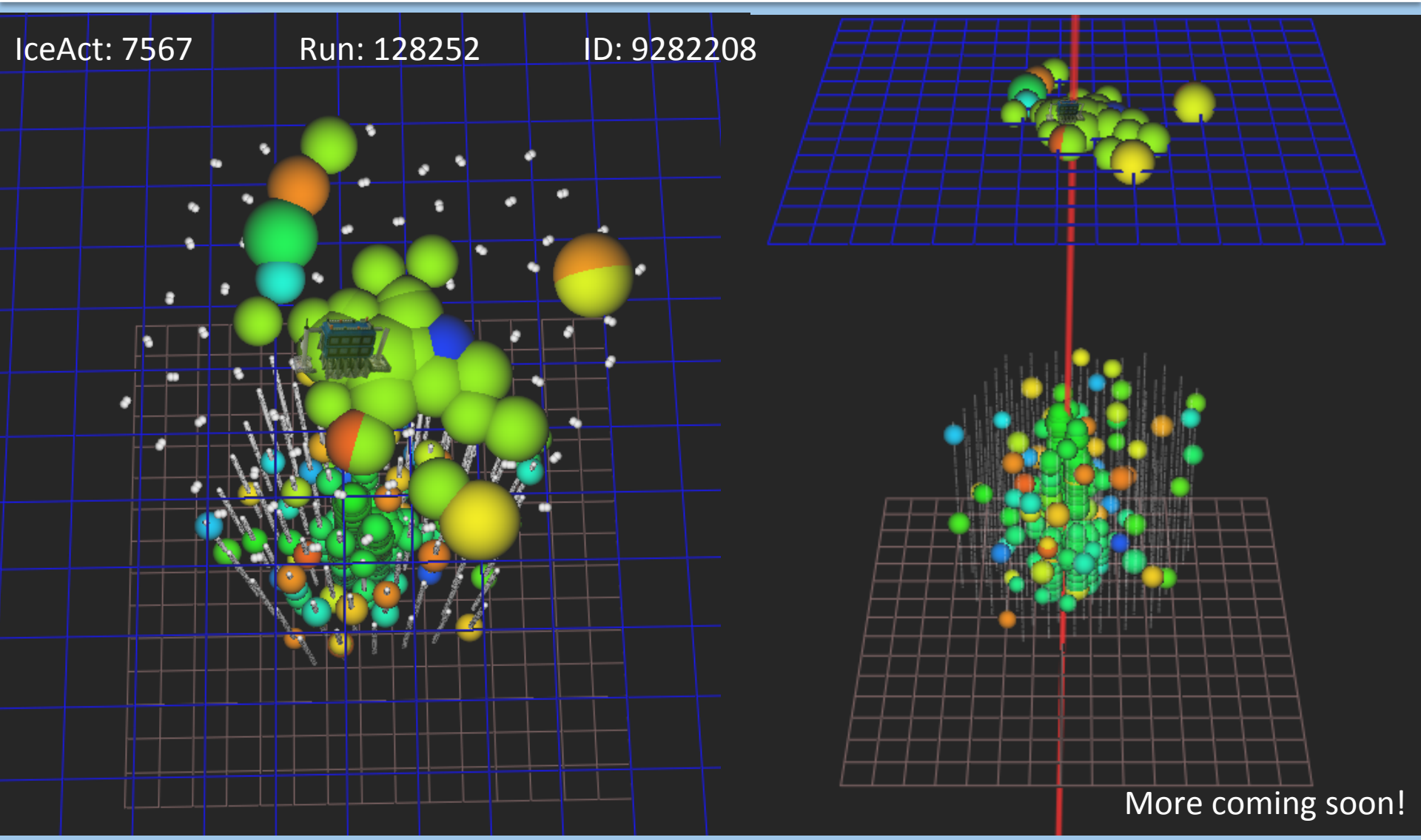
IceAct demonstrator

IACT at South Pole Duty Cycle



Overall annual duty cycle at the South Pole is indeed in the order of ~25% or better!
TU Dortmund will keep working on this building on experience from FACT

A first glance in coincident data



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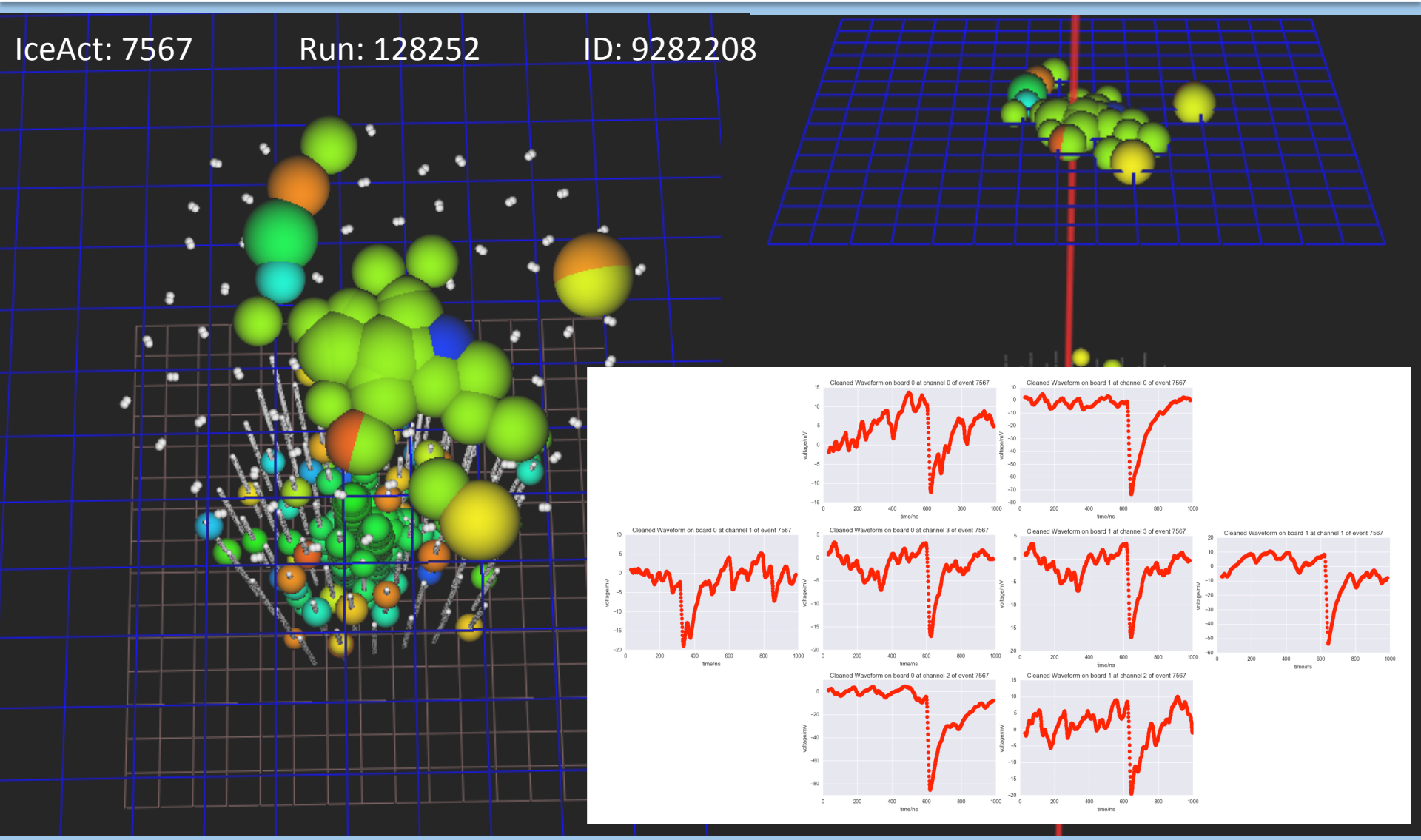
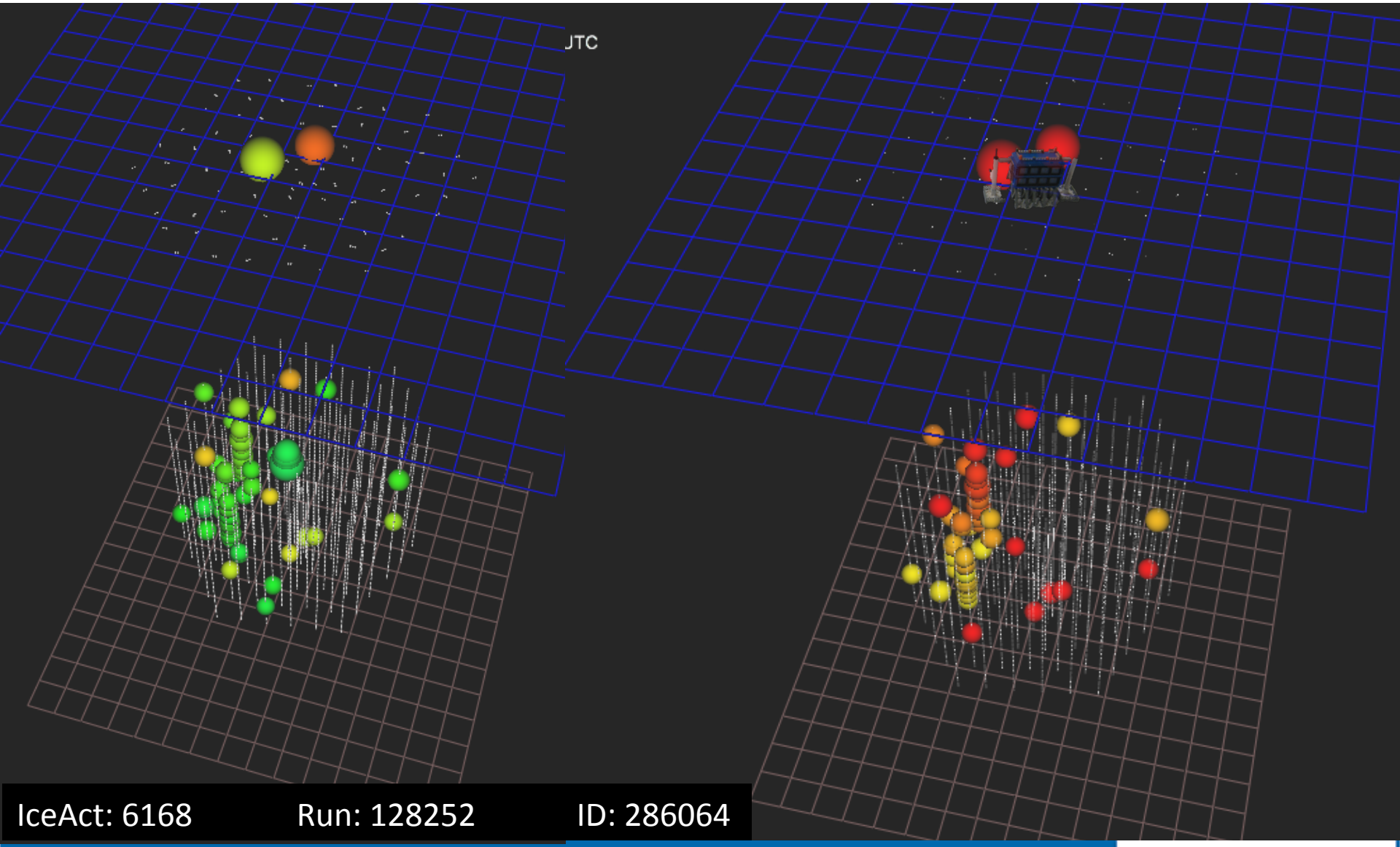
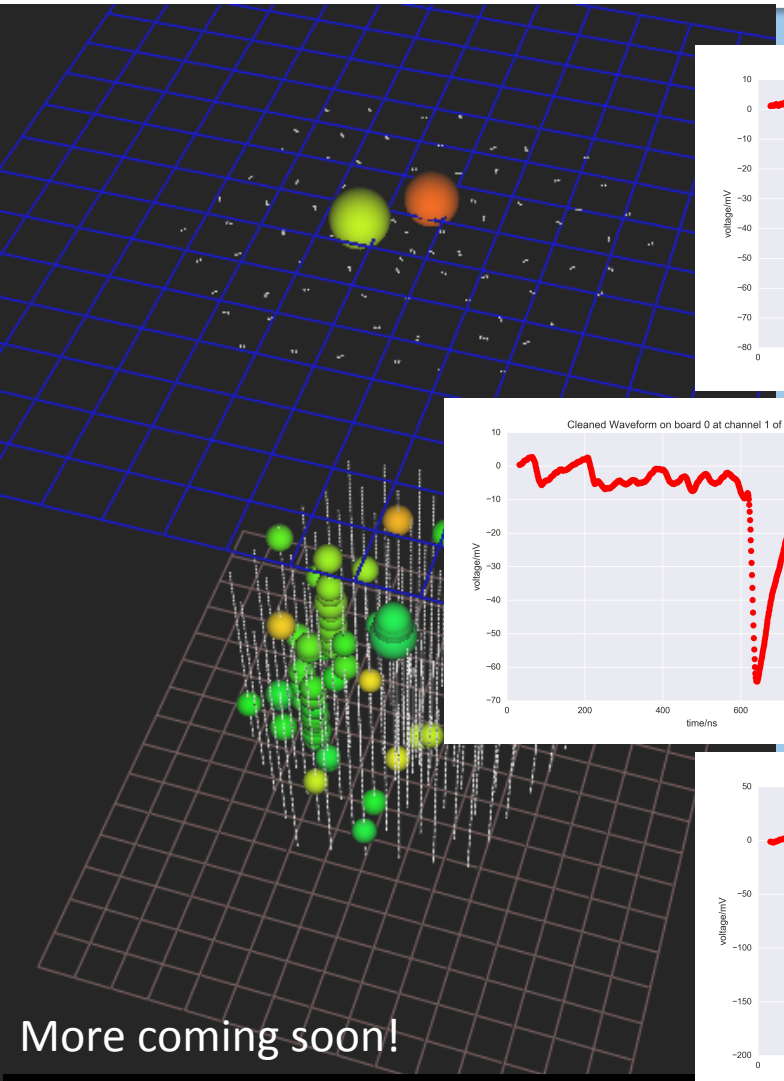


Another Event

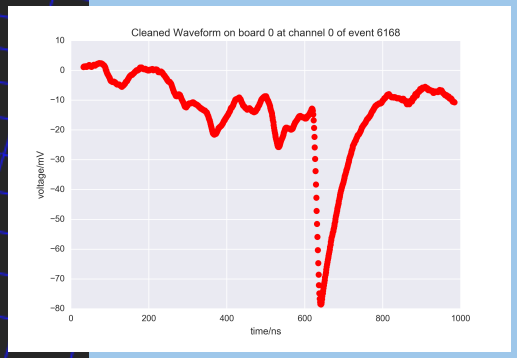


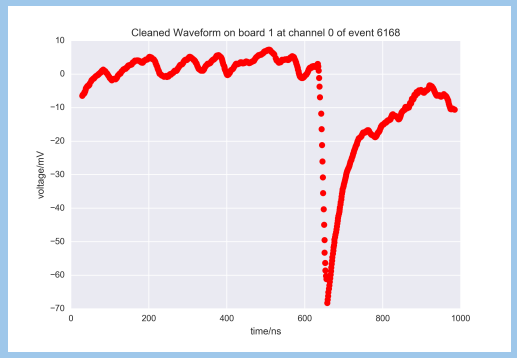
Another Event

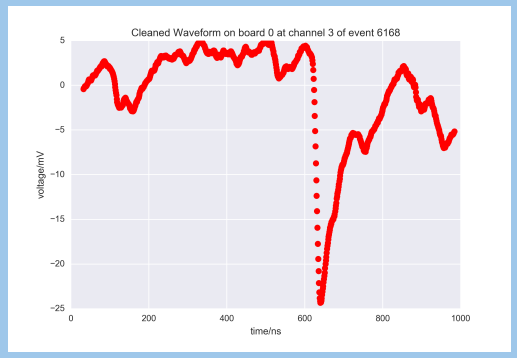


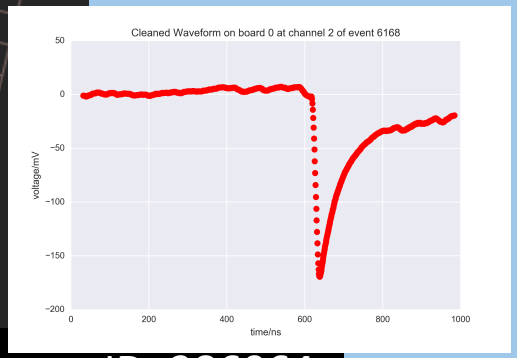
More coming soon!

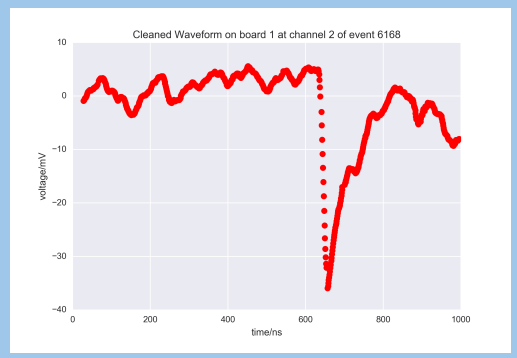
IceAct: 6168 Run: 128252 ID: 286064







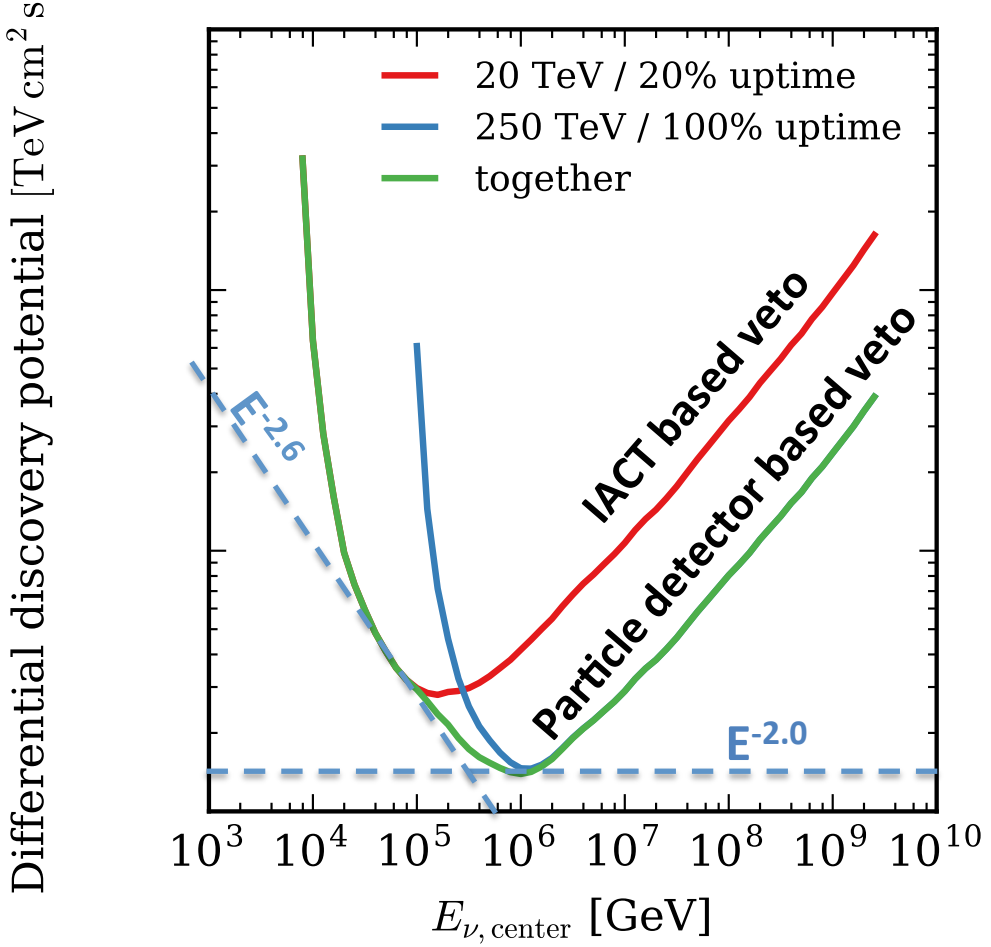




Motivation for IceAct Veto

- Uptime is pessimistic
- Energy threshold 20 TeV not unrealistic
- Could act as a low energy in-fill for the surface Veto
- Needs more careful investigation!

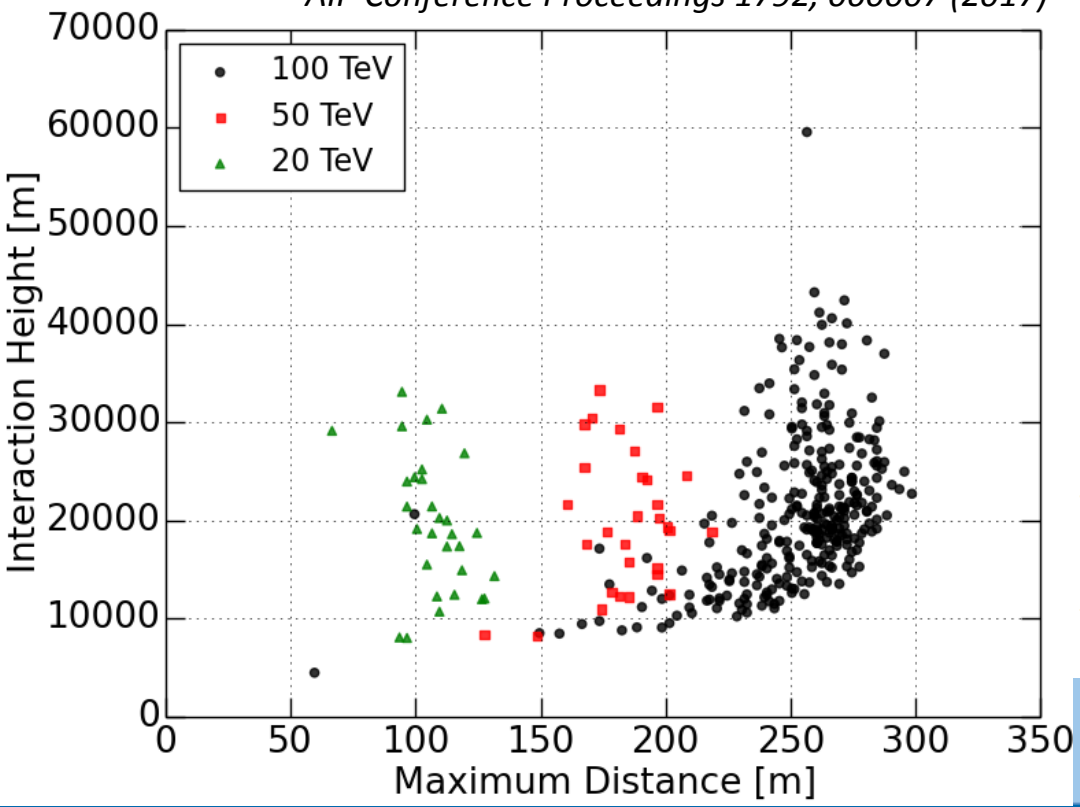
Hypothetical surface veto detector @ 60° declination (Galactic Center) @ South Pole

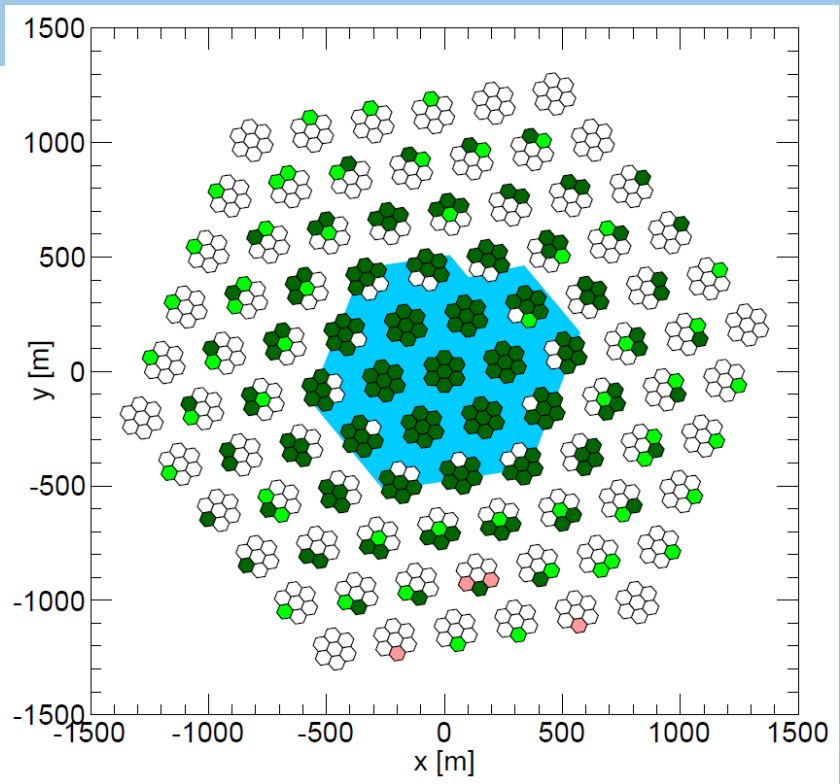


First simulation studies

- threshold @ 50 TeV CR energy (about 20 TeV neutrino primary energy) for telescopes @ 150m distance
- to cover IceTop (20° inclination) about 250 telescopes might be needed

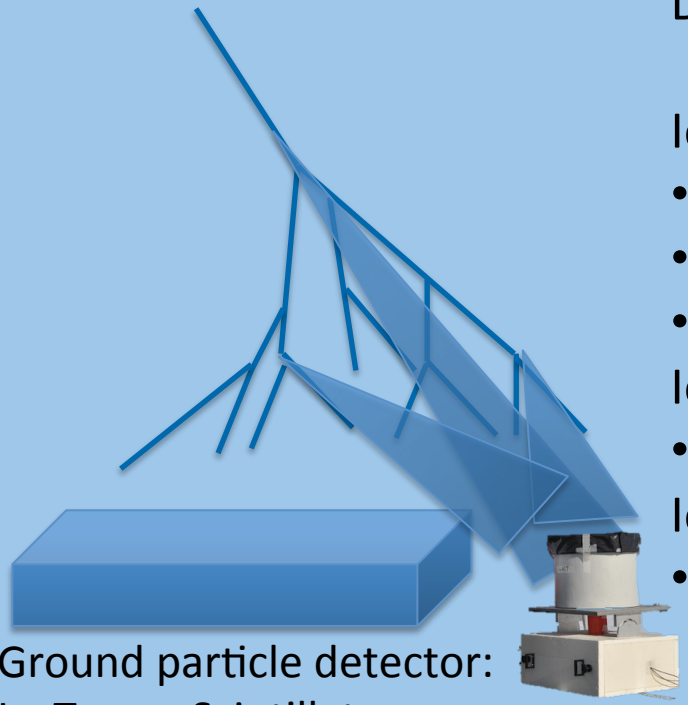
AIP Conference Proceedings 1792, 060007 (2017)





- **See the talk by Ty DeYoung for more details!**

CR Physics with IceAct and IceTop



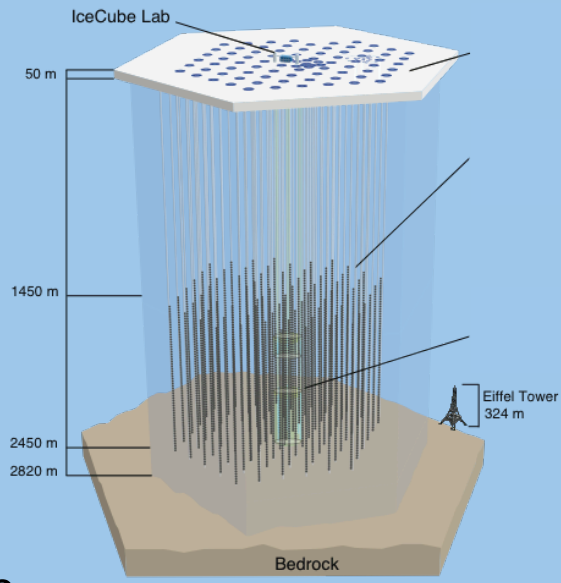
Ground particle detector:
IceTop or Scintillators

Detector Strength:

IceTop:
- Energy
- Direction
- Particle density on ground

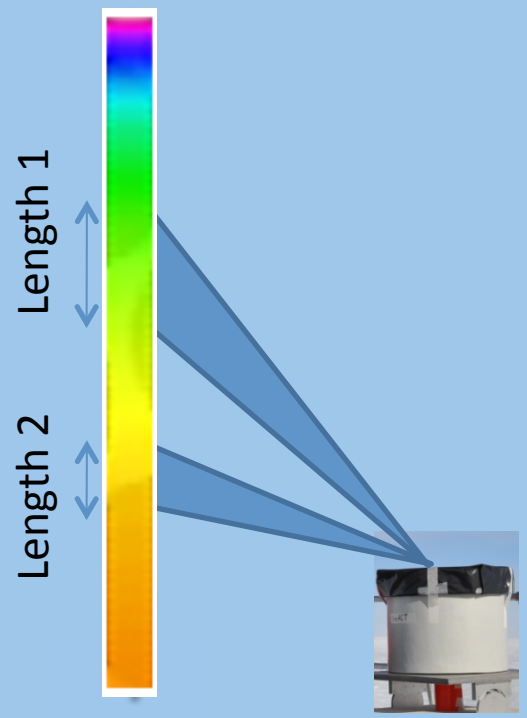
IceCube:
- high energy muon density

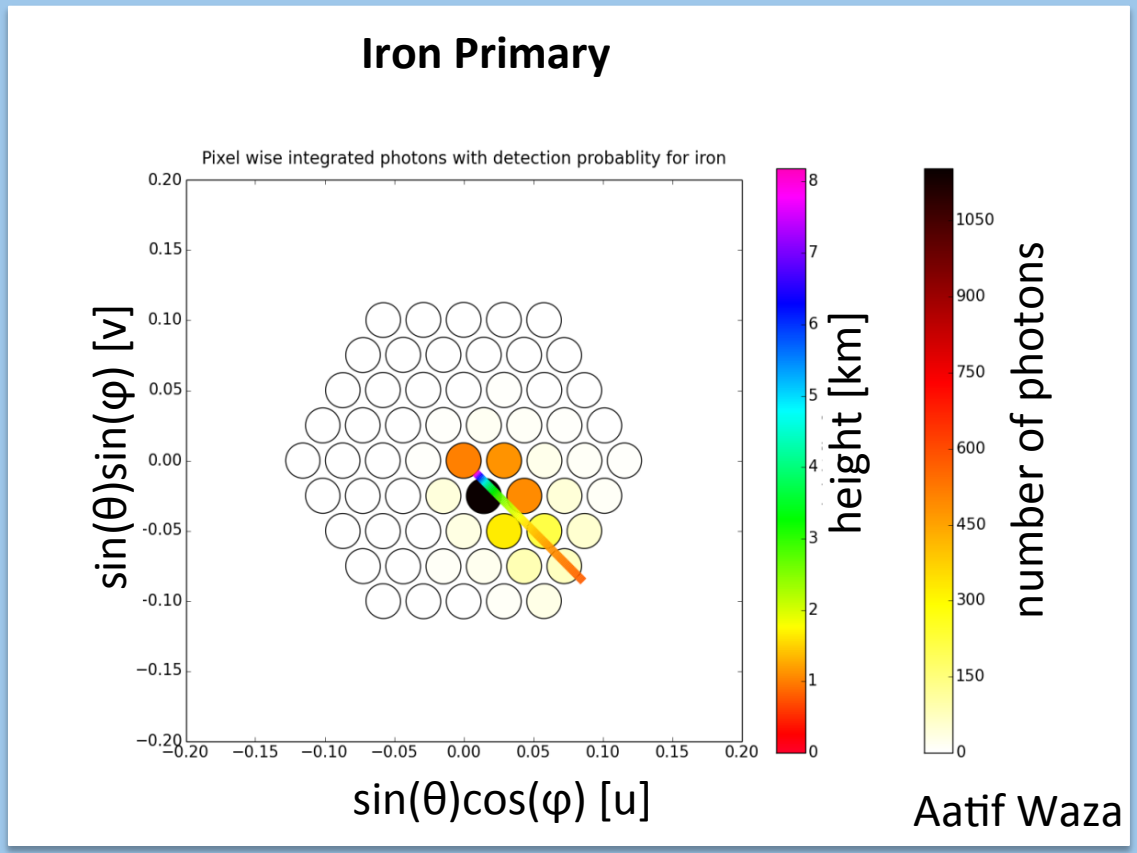
IceAct:
- shower evolution along the shower axis



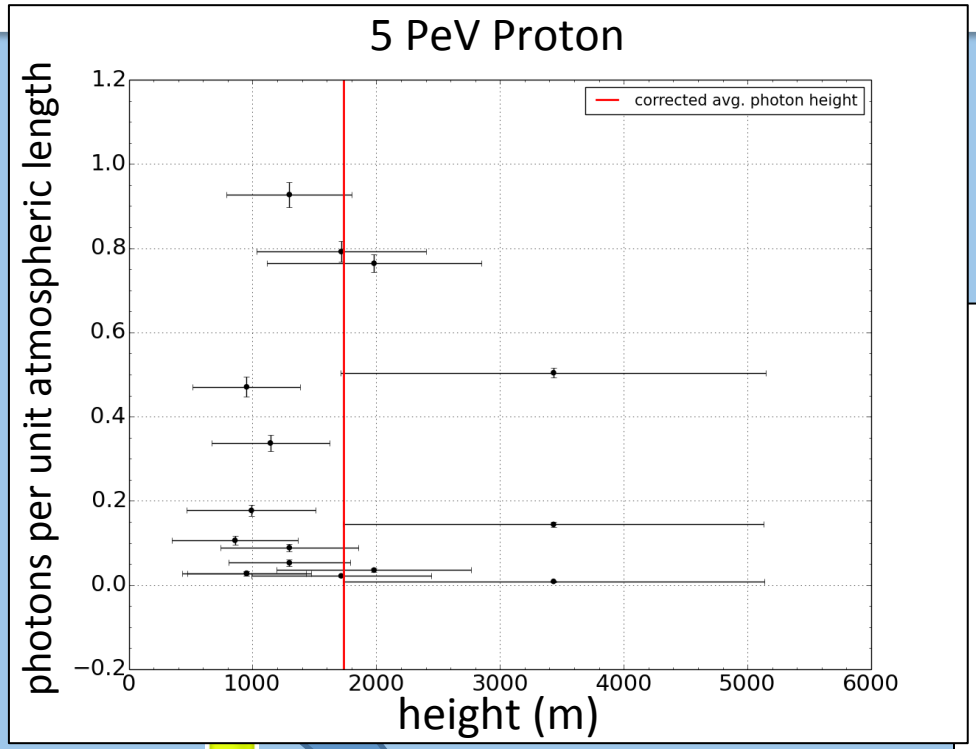
Might enable us to very precisely measure the particle ID!

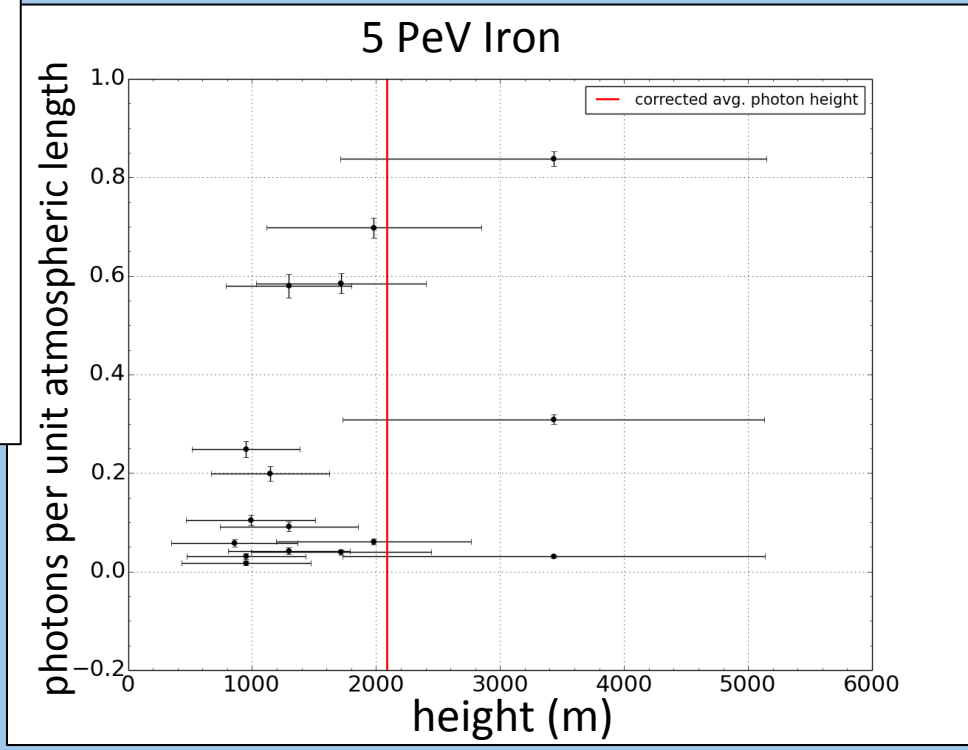
Projection relative to the average Photon Height

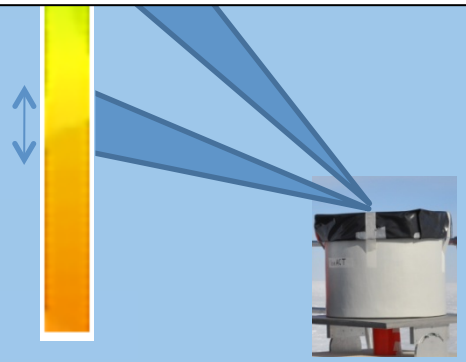




Photon projection on Shower Axis



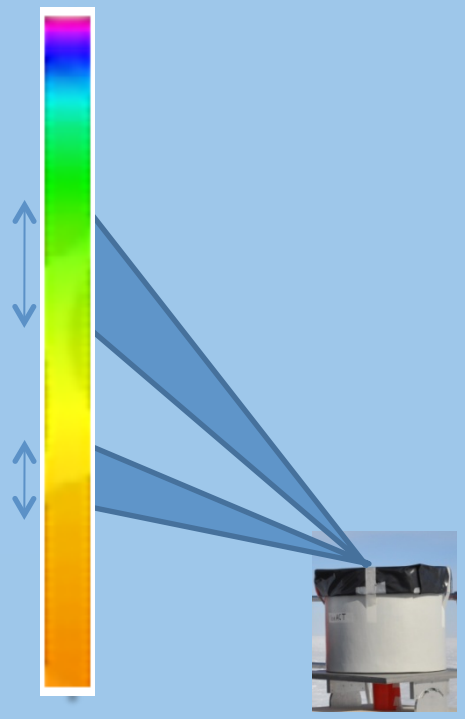




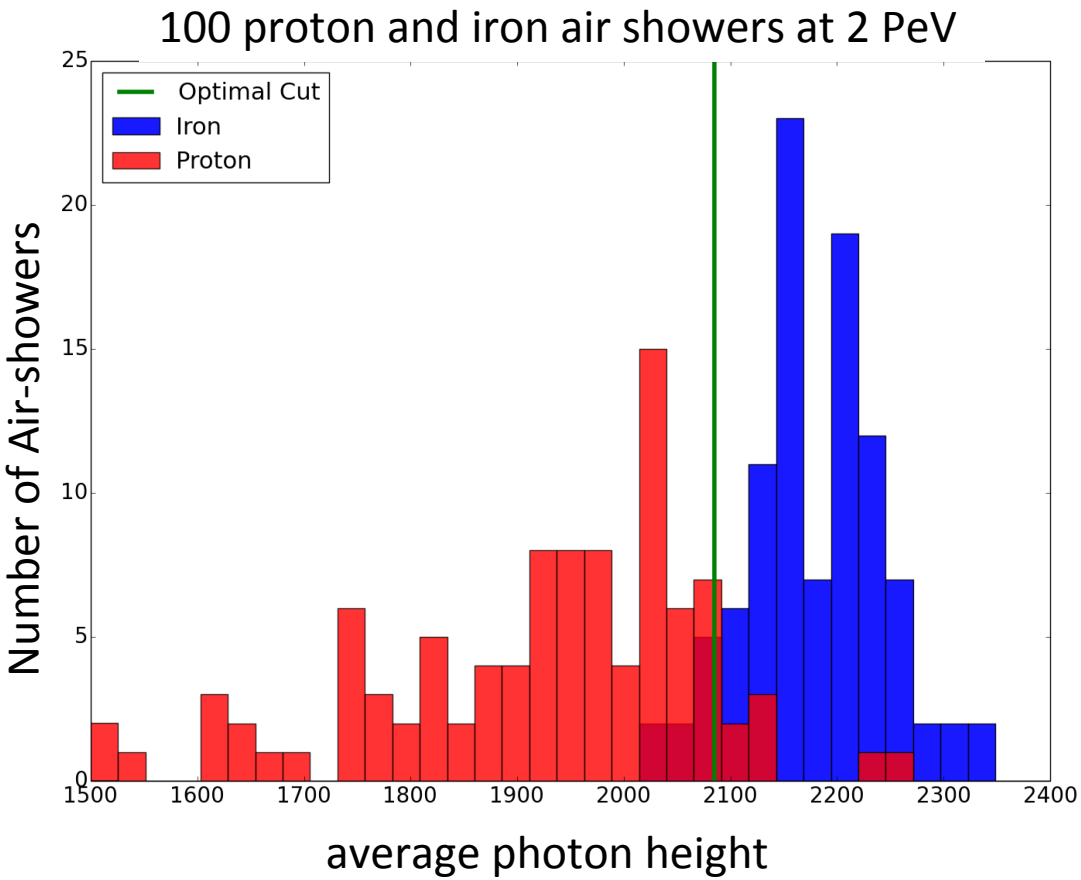
Shower Axis

Length = Height Acceptance Range of Pixel (Central 68%)

Proton/Iron 2 PeV primary energy

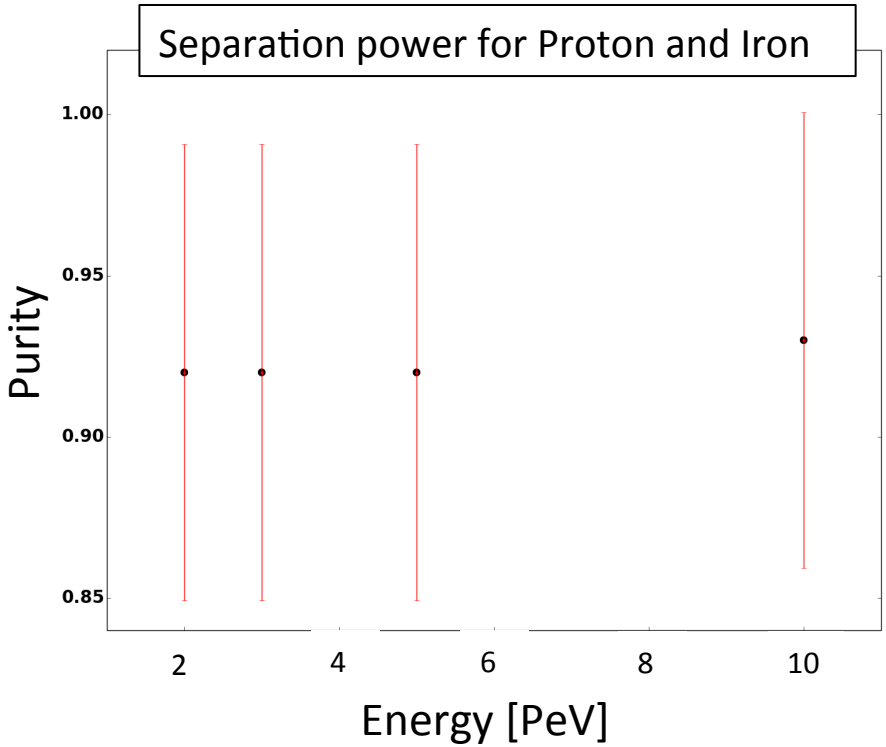


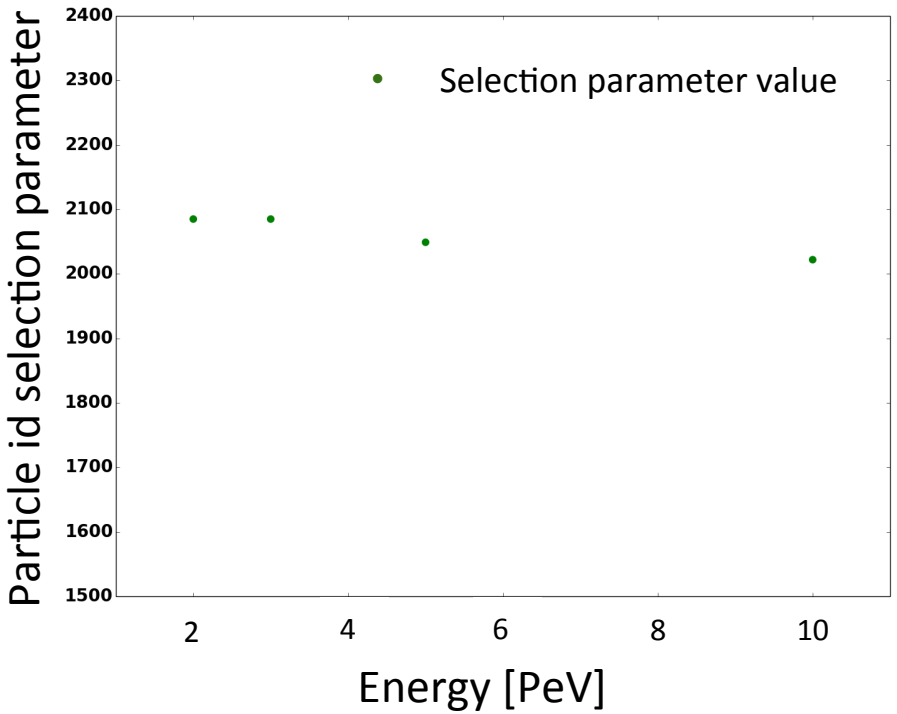
Shower Axis



Particle separation Power

Aatif Waza

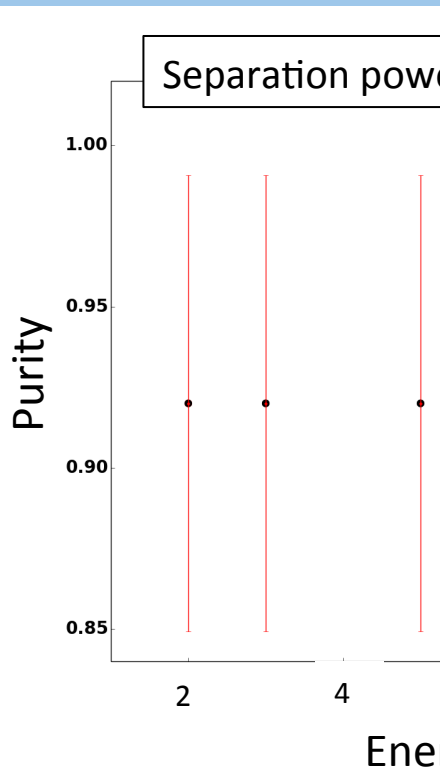


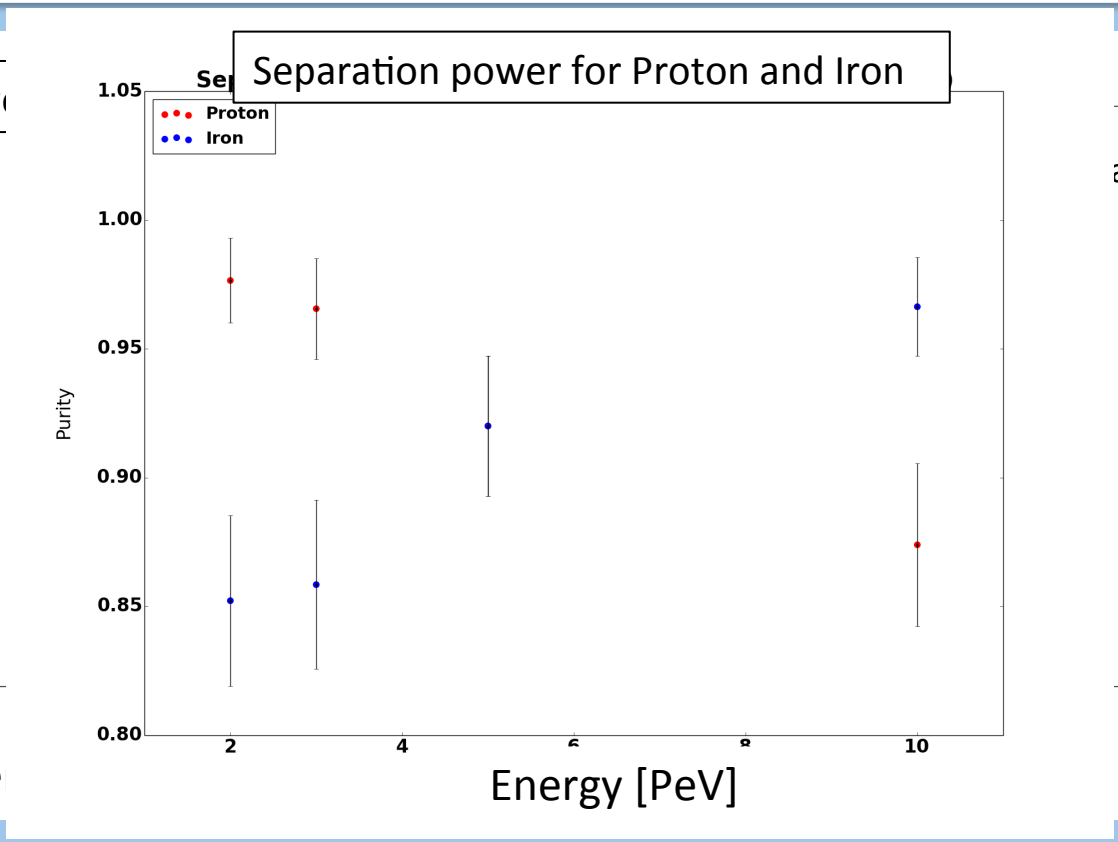


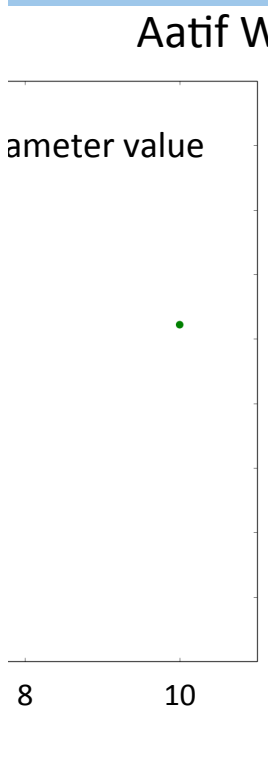
Purity and selection parameter are marginally changing with energy
The particle identification has low energy dependence!

Needs further investigation...

Particle separation Power







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Applications for HAWC

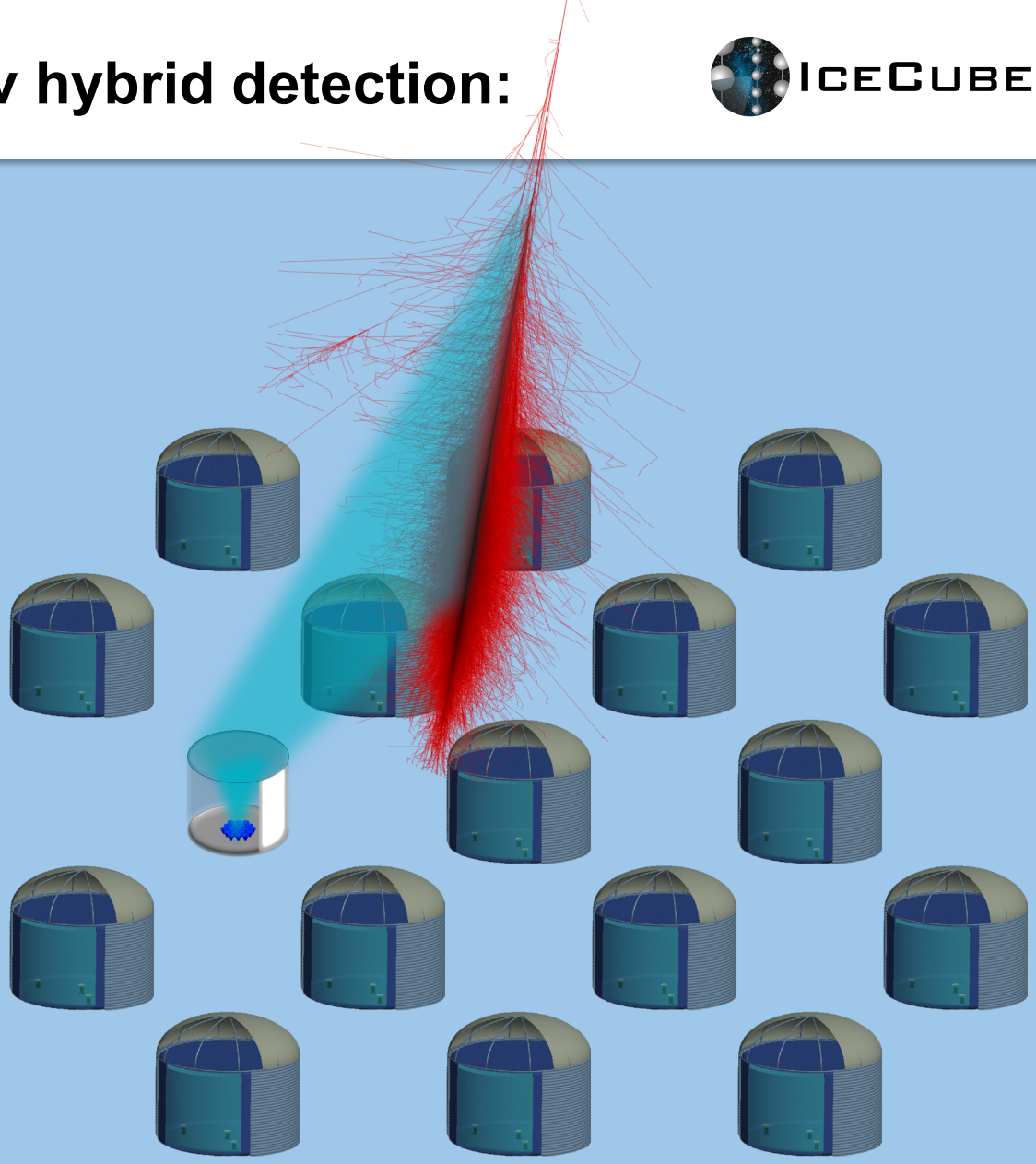
Array and air-Cherenkov hybrid detection:

Array (HAWC):

- Ionizing particles:
  - Inclination angle
  - Shower core
  - (γ/Hadr. sep.)

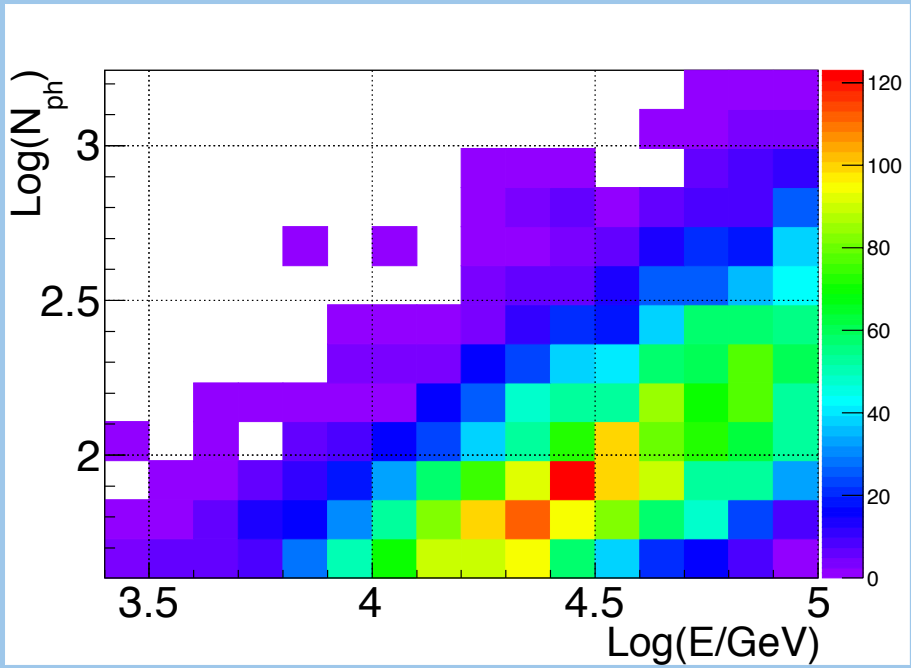
IceAct/FAMOUS:

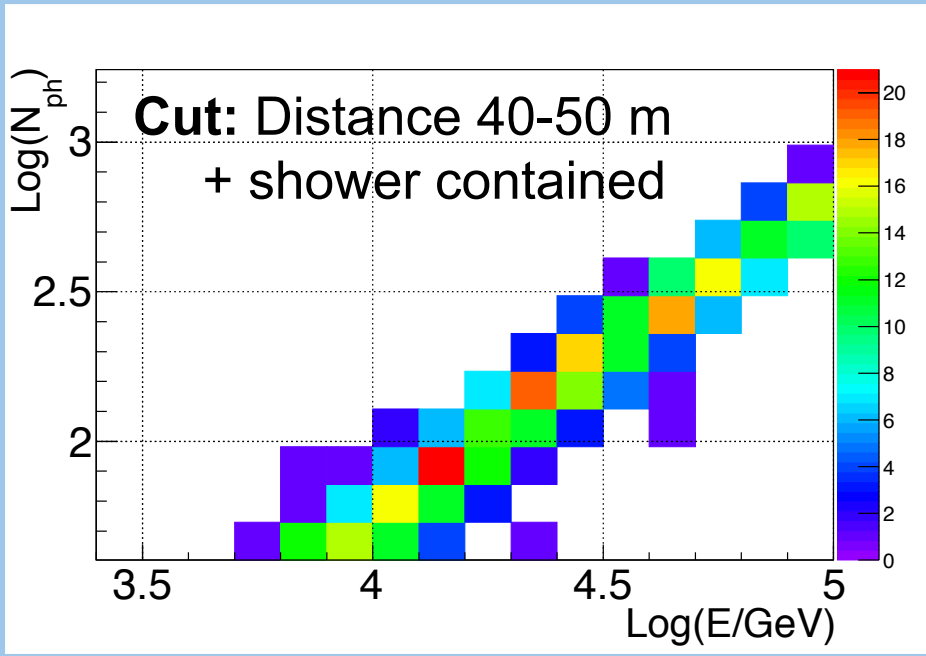
- Cherenkov light:
  - Primary Energy
  - (γ/Hadr. sep.)

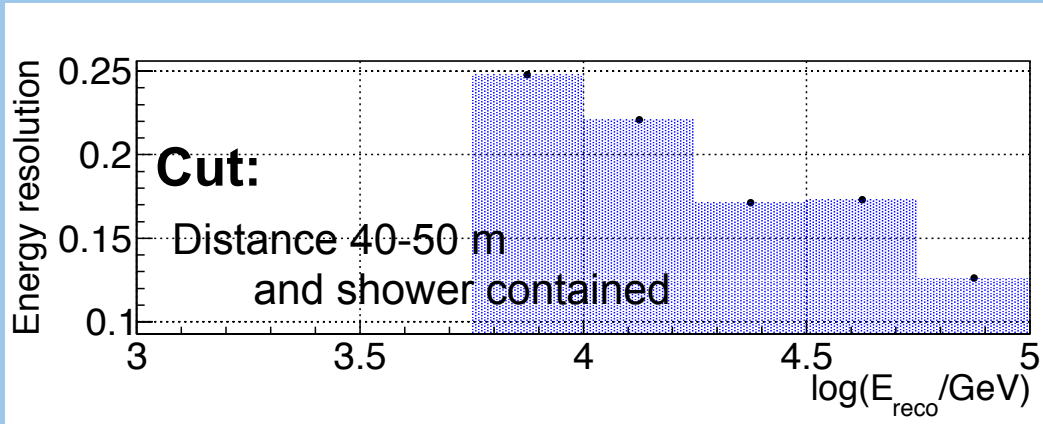


Applications for HAWC

Possible Applications for HAWC







Shower contained:
Less than 30 photons in the outer pixel ring.

Done by Merlin Schaufel

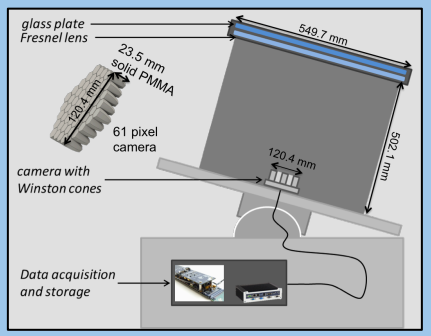
IceAct/FAMOUS summary

IceAct/Famous is a candidate component for IceCube extensions.

- As a surface veto component
- For CR composition measurements

Prototype continuously running at South Pole.

- First coincident data with IceCube was shown



This year a fully equipped 61 pixel telescope will be deployed at the South Pole!

- can be used for IceTop calibration studies

IceAct/FAMOUS has the potential to improve the energy resolution of HAWC.

- Will be tested soon!
- Other applications like background separation might also be possible.

Bundesministerium für Bildung und Forschung

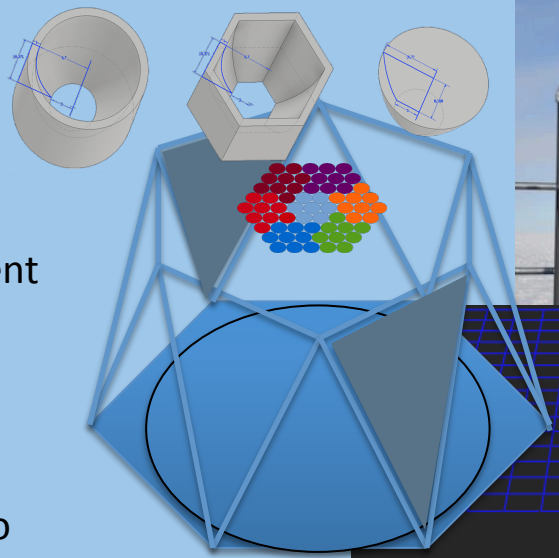
DFG Deutsche Forschungsgemeinschaft

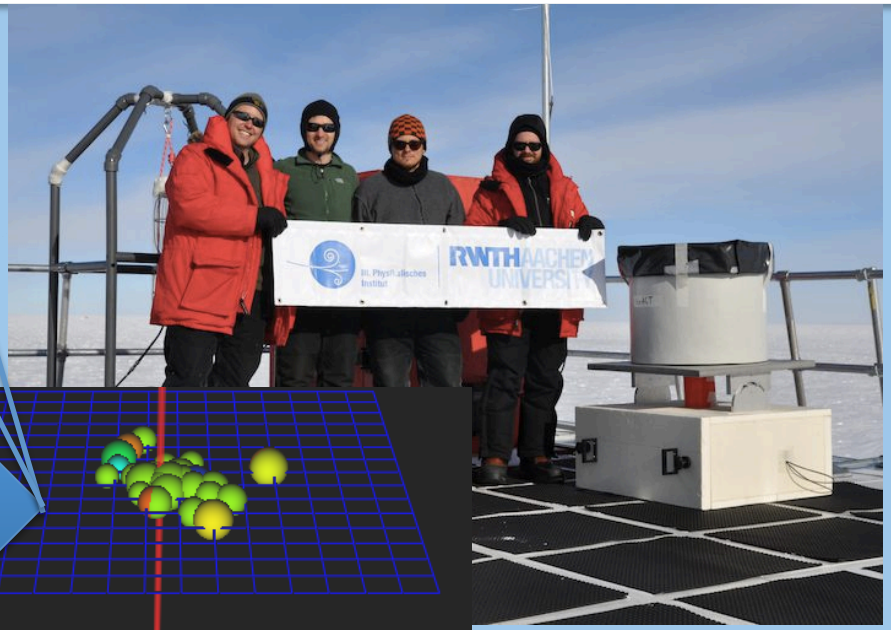
Thank you!

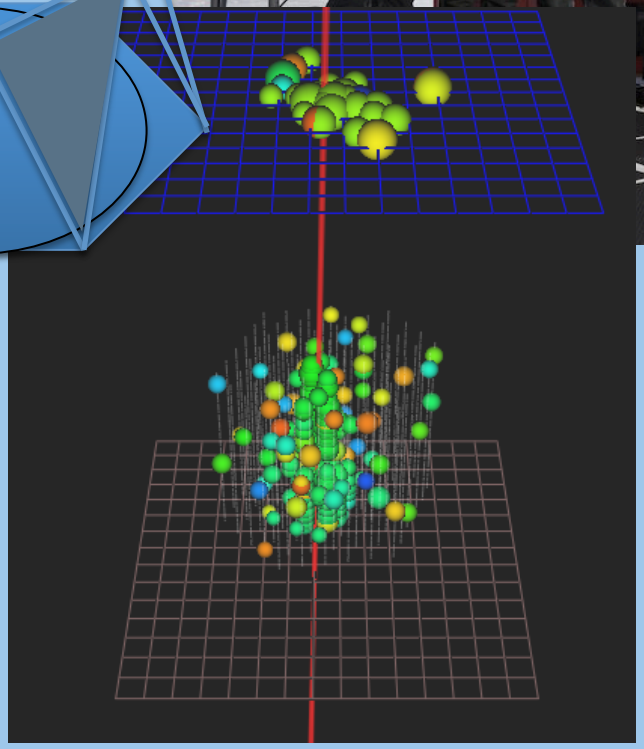
Let us know if you are interested

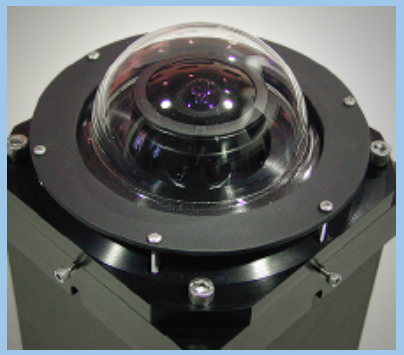
Let us know if you want to contribute to

- Hardware R&D
  - mechanics
  - optics
  - electronics
- software development
  - slow control
  - daq
  - monitoring
- Simulation
  - corsika for veto
  - optical components
  - array configuration for CR study
- Data analysis
  - IceAct as veto
  - IceAct for composition studies
  - IceAct energy reconstruction
  - IceAct uptime study
  - Skcam data analysis
  - Lidar data analysis
- …





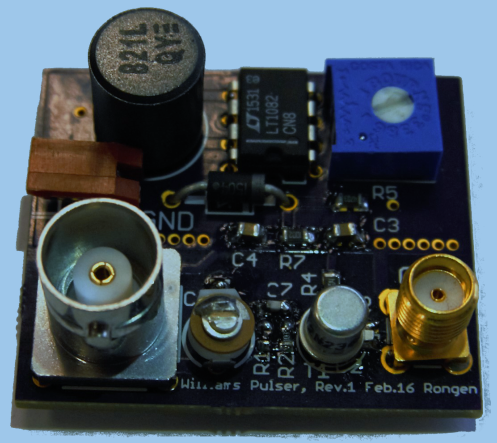


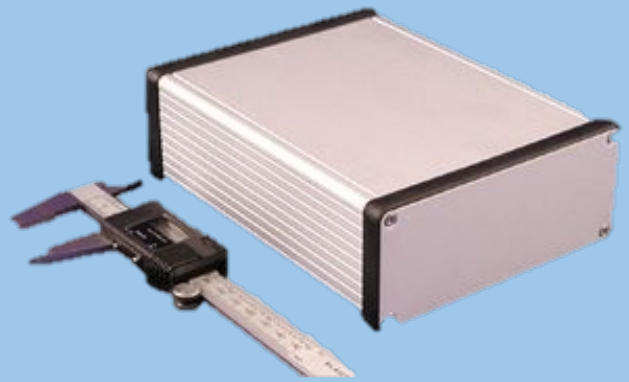


IceAct 16/17 (hardware)

New DAQ

- Pixel wise calibration of 7 pixel camera
- removing the UG11 filter
- New DAQ
- adding a flasher LED
- adding another heating system

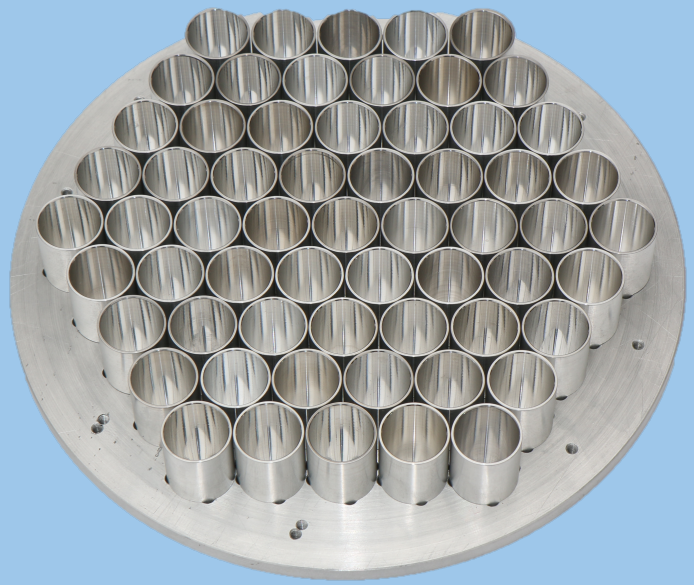


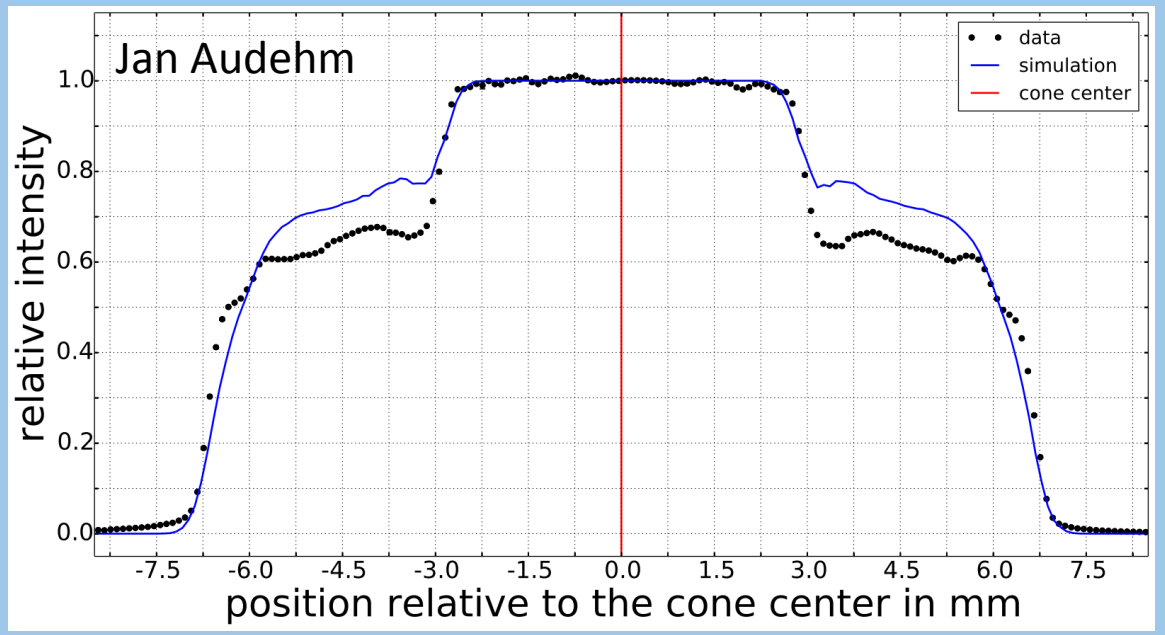


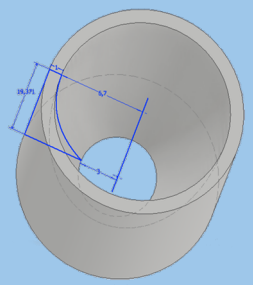
Martin Rongen

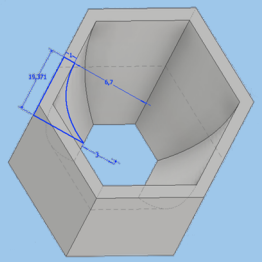
IceAct 17/18 (hardware)

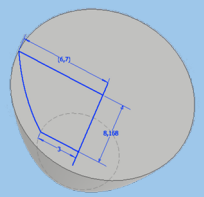
61 pixel camera + DAQ

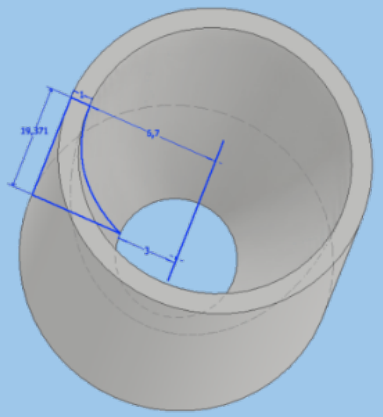


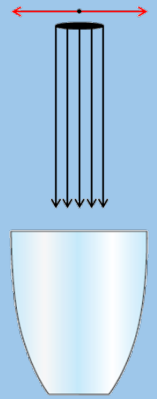












Summary

- IceAct is a candidate technology for surface veto arrays
- IceAct might be used for composition studies in the knee region already with about 4-6 telescopes.
- The annual duty cycle seems to be ~20-25% to Veto CR with a threshold of ~20 TeV neutrino energy. A new skycam will measure this value to higher accuracy.
- So far we did not evaluate the potential for gamma-ray detection
- A first IceAct prototype was successfully taking data throughout the Polar winter.
- We are interested in more people to join the IceAct effort!

DFG Deutsche Forschungsgemeinschaft

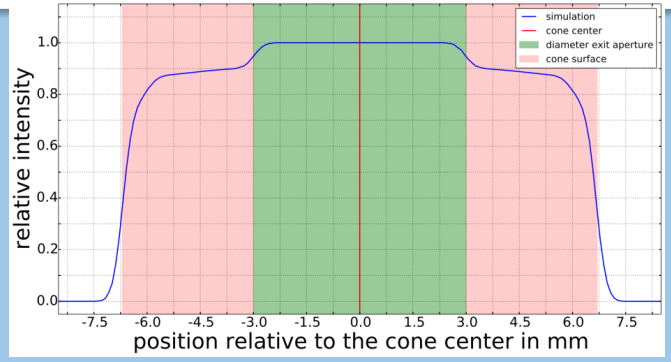
Bundesministerium für Bildung und Forschung

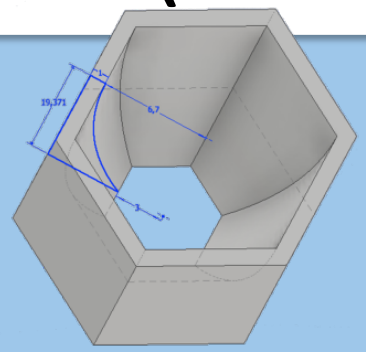
- Backup

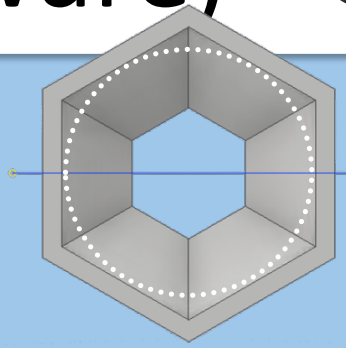
iACT at South Pole Duty Cycle

- The South Pole skycam data analyses summary:
  - Observation between 16th-March-2015 and 27th-August-2015 (133 days)
  - on average 40 stars (mag >2.7) where continuously monitored to estimate the cloudiness (limited by the quality of the camera)
  - ~60% of the sky (57.4%) was clear. This corresponds to an annual duty cycle of 20-25%
    (This will increase with a better sky cam)
  - Very good weather is in 43% of the dark period
    (less than 30% clouds)
  - And acceptable weather (less than 60% clouds) is found in 73% of the time.

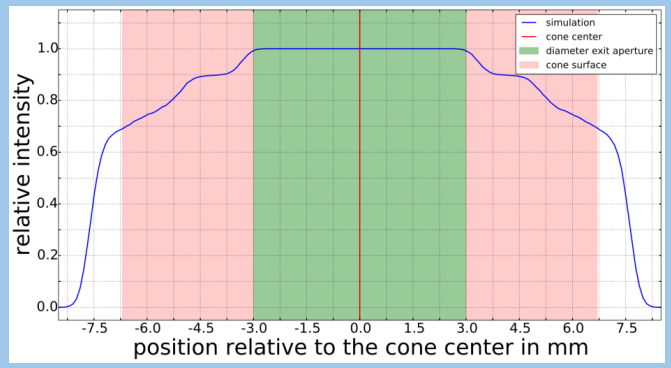
IceAct 17/18 (hardware)

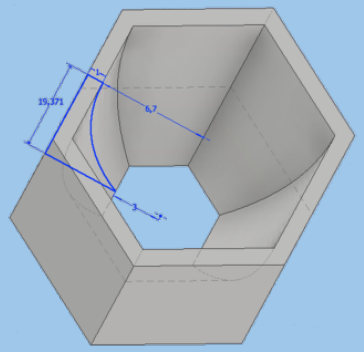


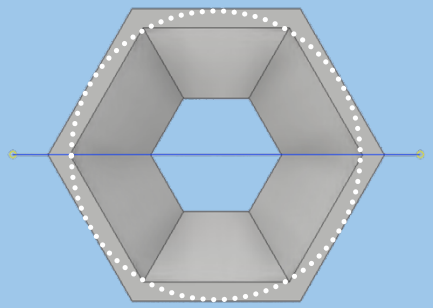




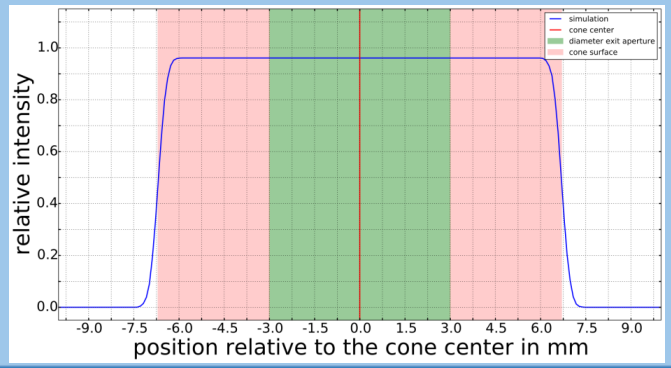
Eff: 0.779

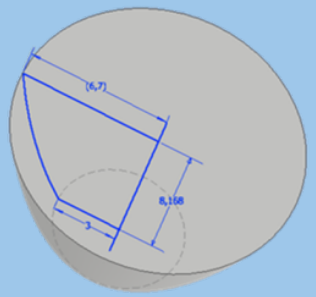






Eff: 0.918

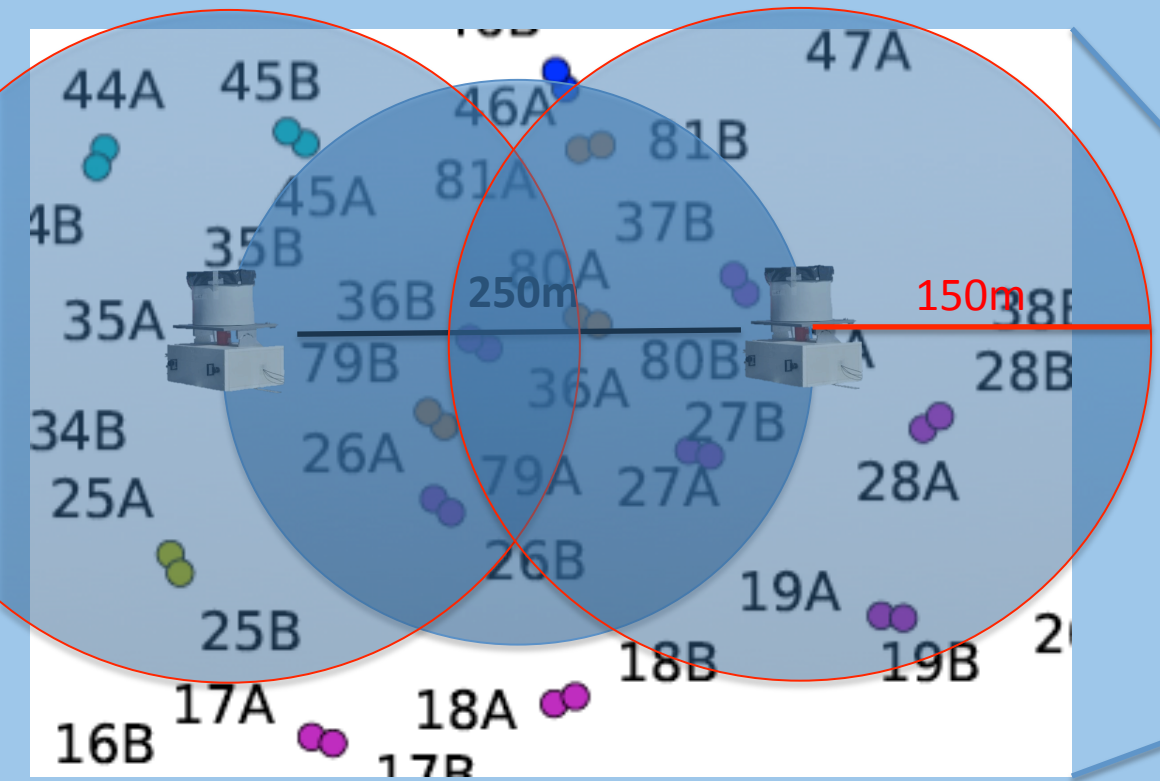


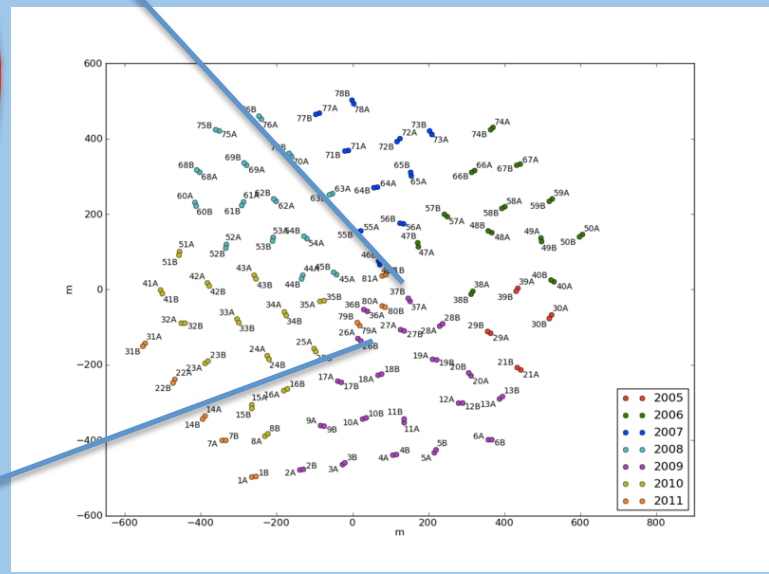


Eff: 0.845

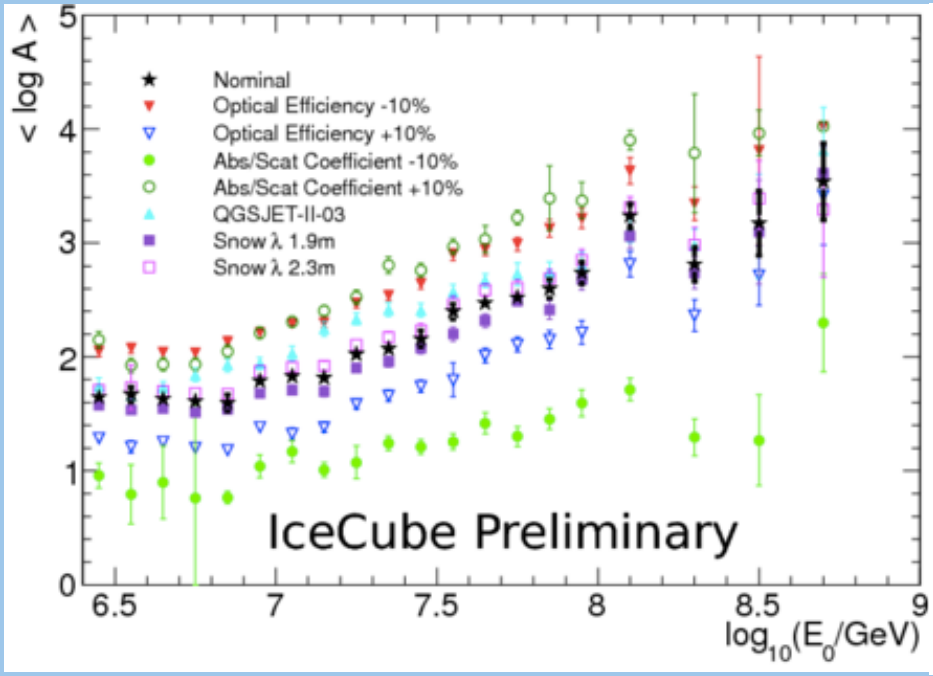
Statistics @ 1PeV

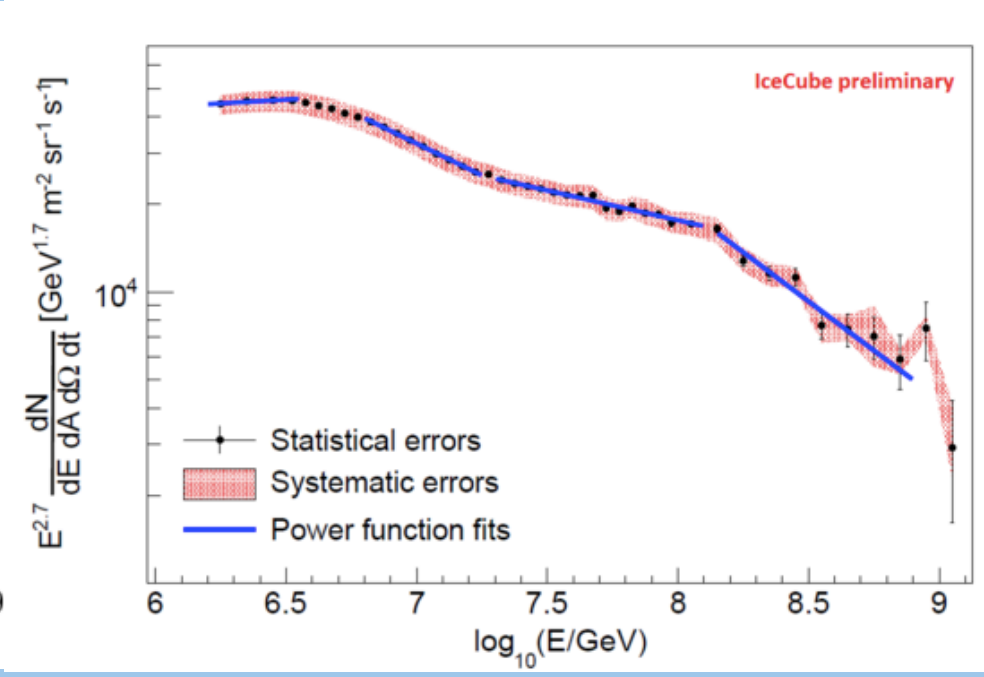
125*125*pi m^2 and 0.03 sr * 0.3 duty cycle * 1 CR/m2/year/sr (at PeV) * 3 (6 Telescopes in one direction each) = 1350 events.
Without stereo requirement up to ~3800.



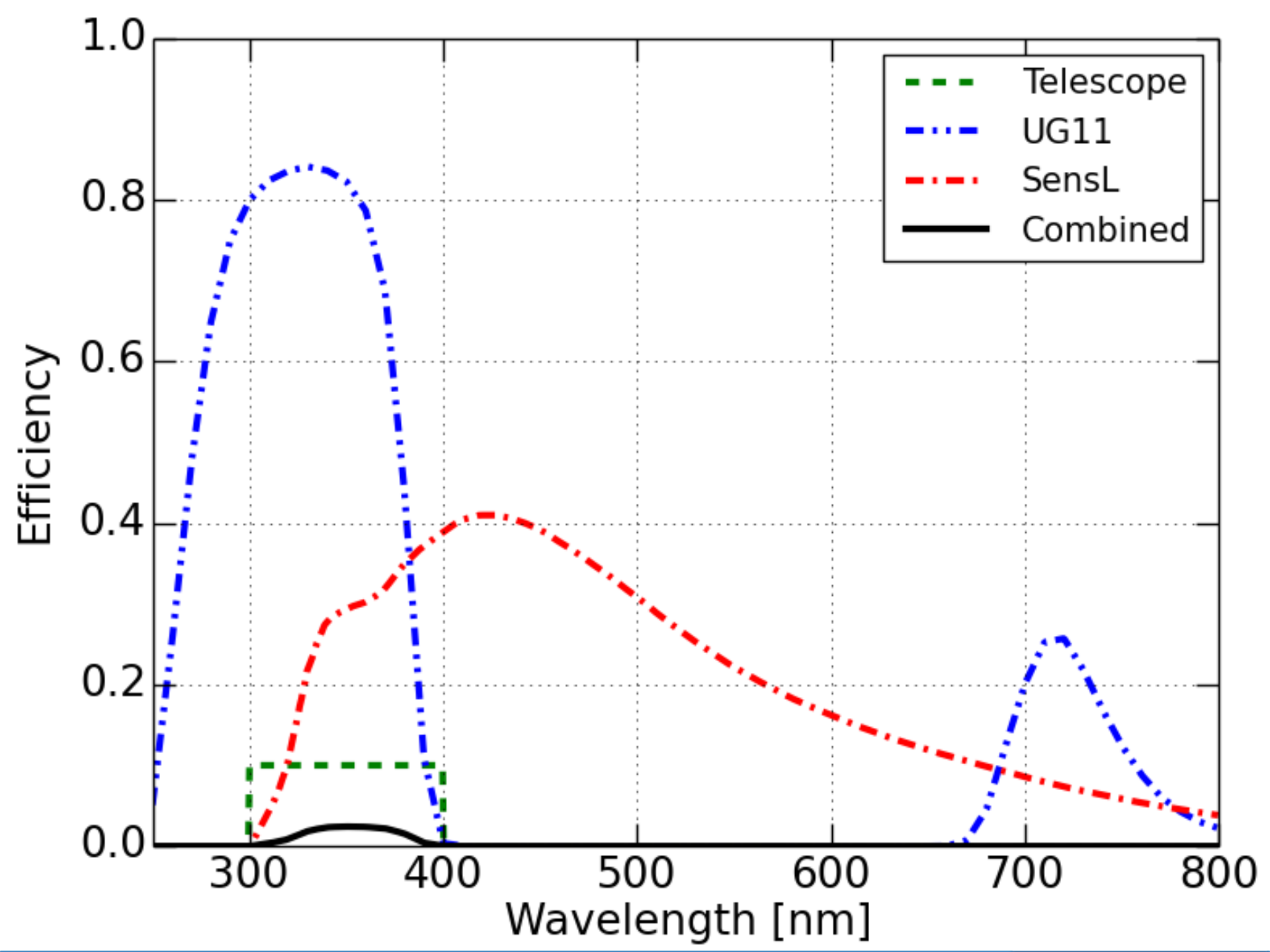


Precise CR Composition measurements in the knee region with IceTop and IceAct

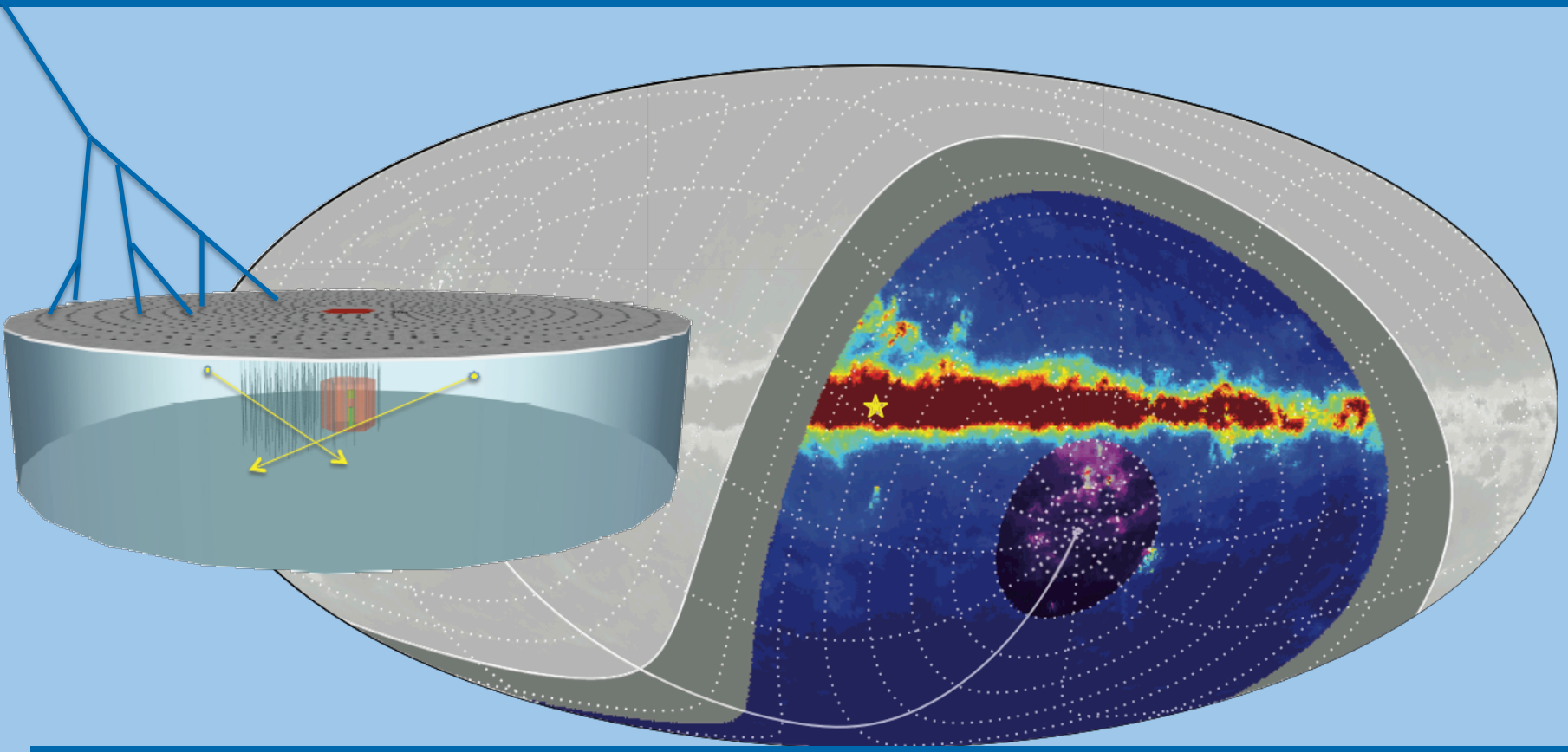




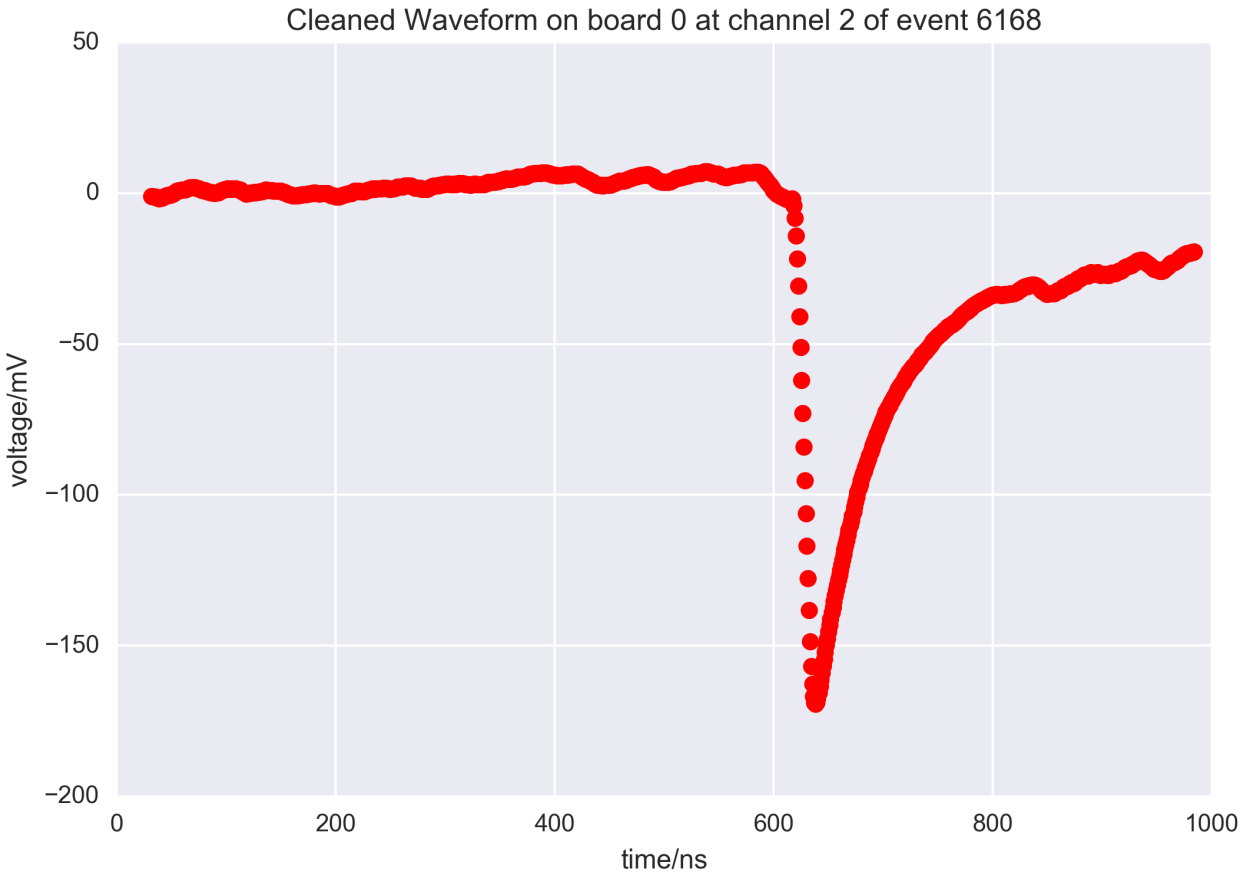
- Energy reconstruction comes mainly from IceTop
- Directional reconstruction comes from IceTop
- high of x-Max comes from IceAct telescope array

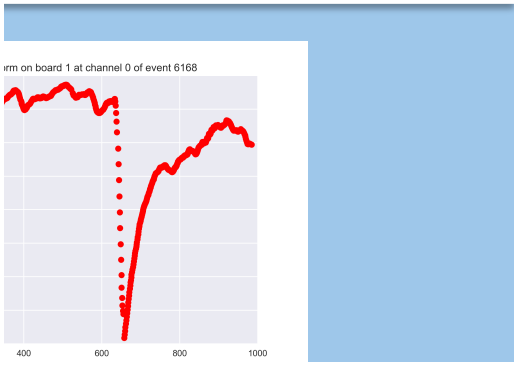

Telescope
UG11
SensL
Combined
Efficiency
Wavelength [nm]
1.0
0.8
0.6
0.4
0.2
0.0
300
400
500
600
700
800

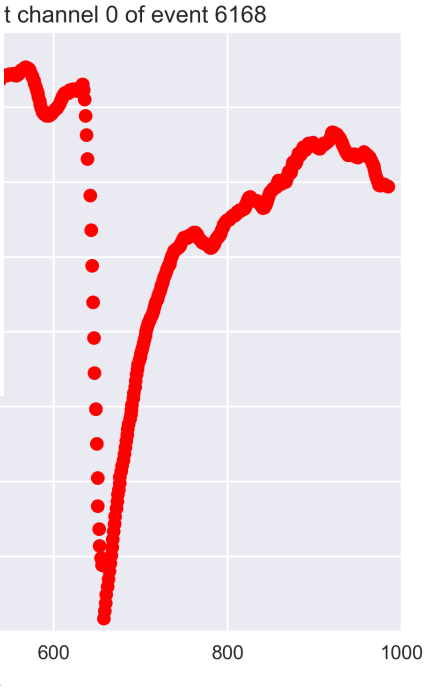
We need more high energy tracks e.g. from the southern sky!

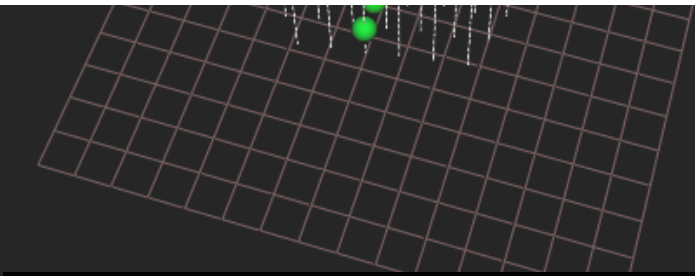


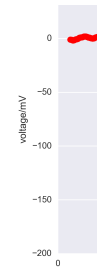
Open the southern sky for E < 100 TeV Neutrino induced muon tracks by vetoing signals with coincident air showers

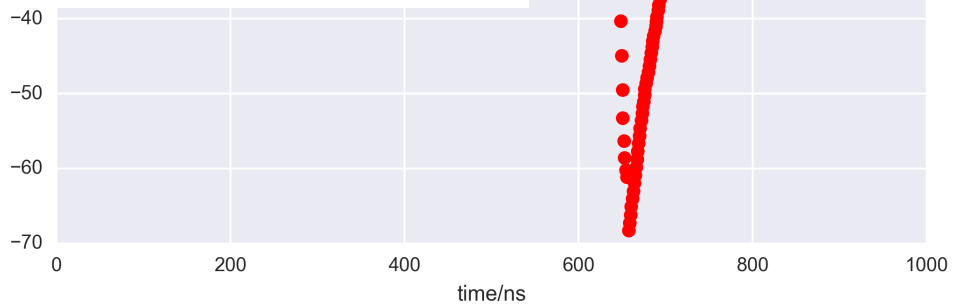






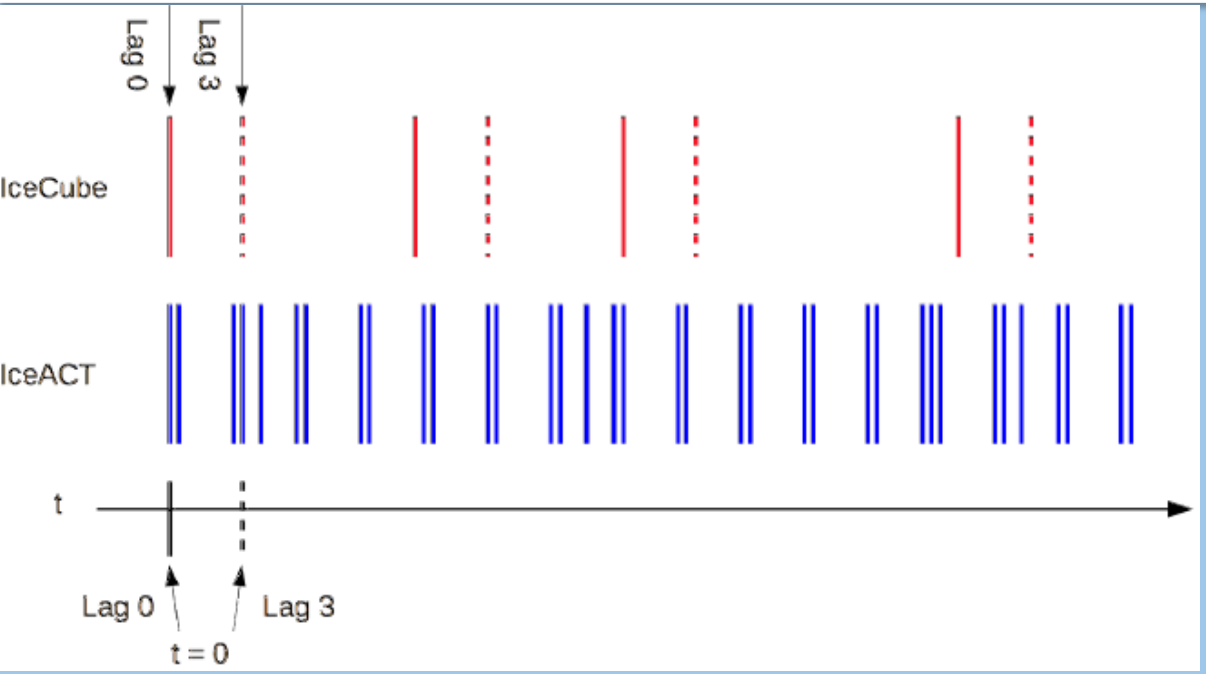






IceAct: 6168 Run: 128252

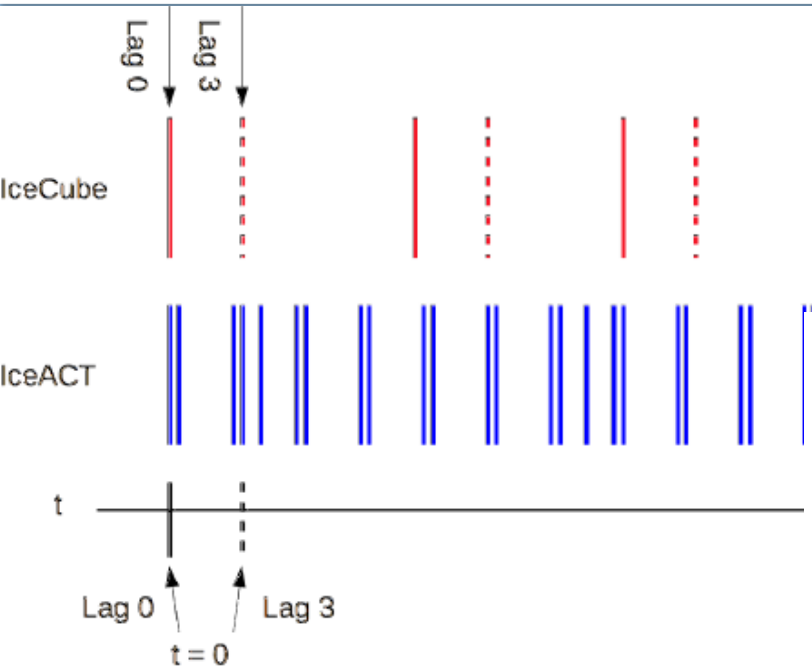
Time calibration IceAct/IceTop

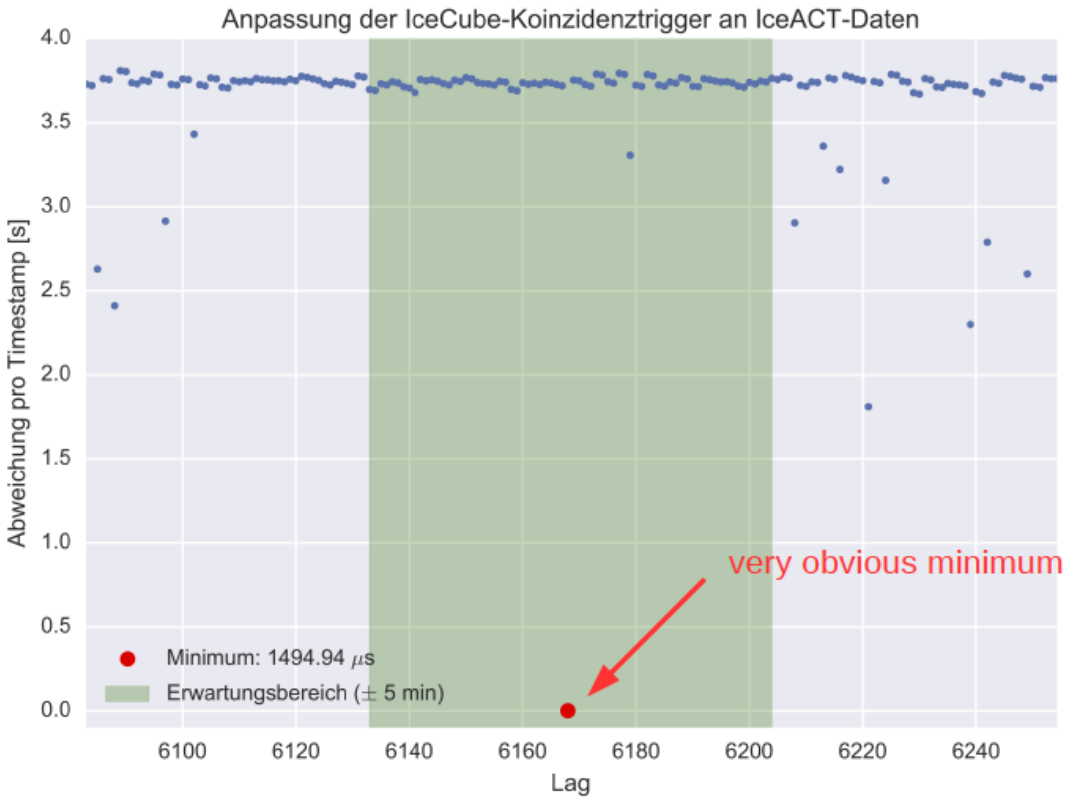


- The pattern of the two fixed rate DRS4 boards has to be found in the random coincidence data with IceCube

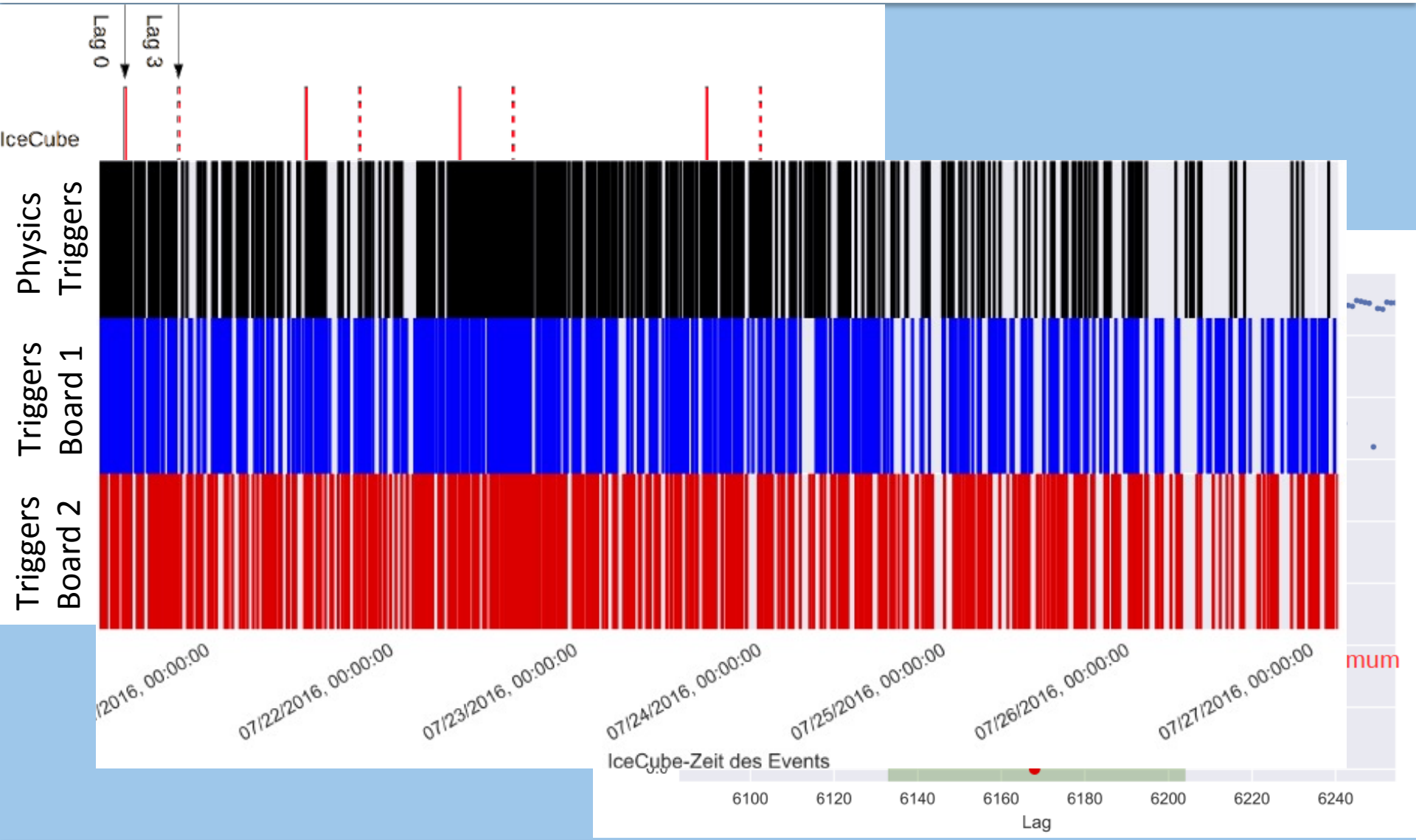
For more information see talk by Maurice Günder

Time calibration IceAct/IceTop

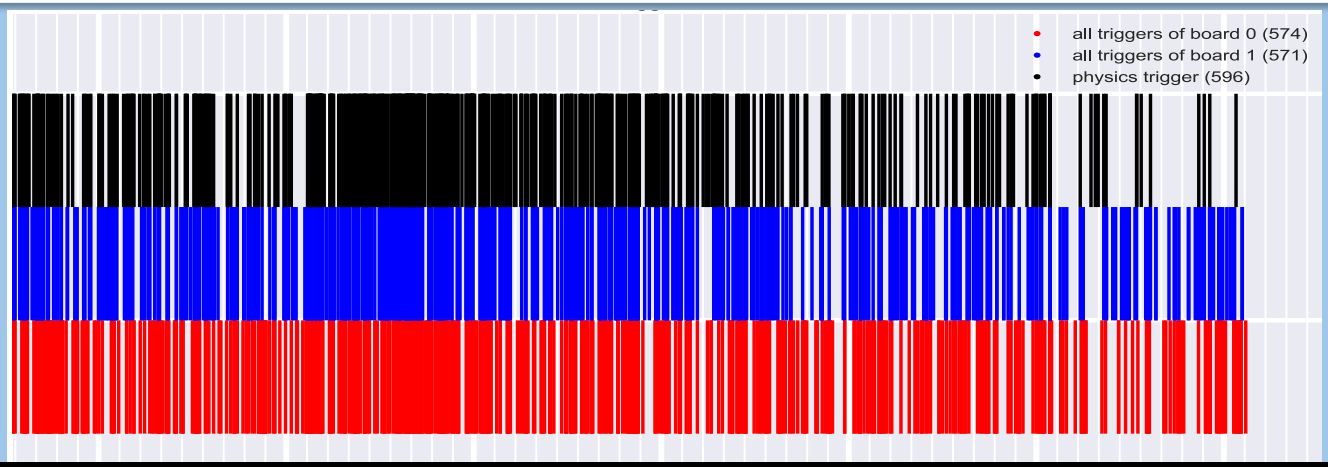


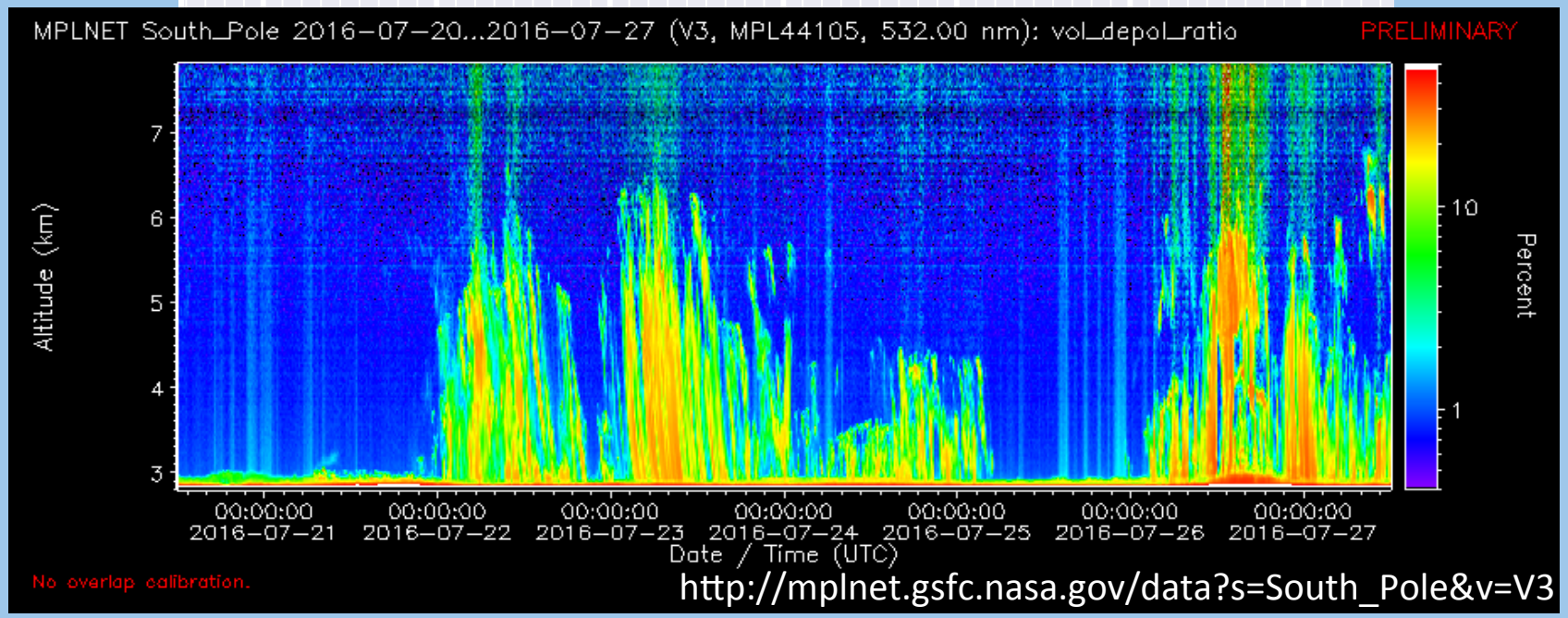


Time calibration IceAct/IceTop

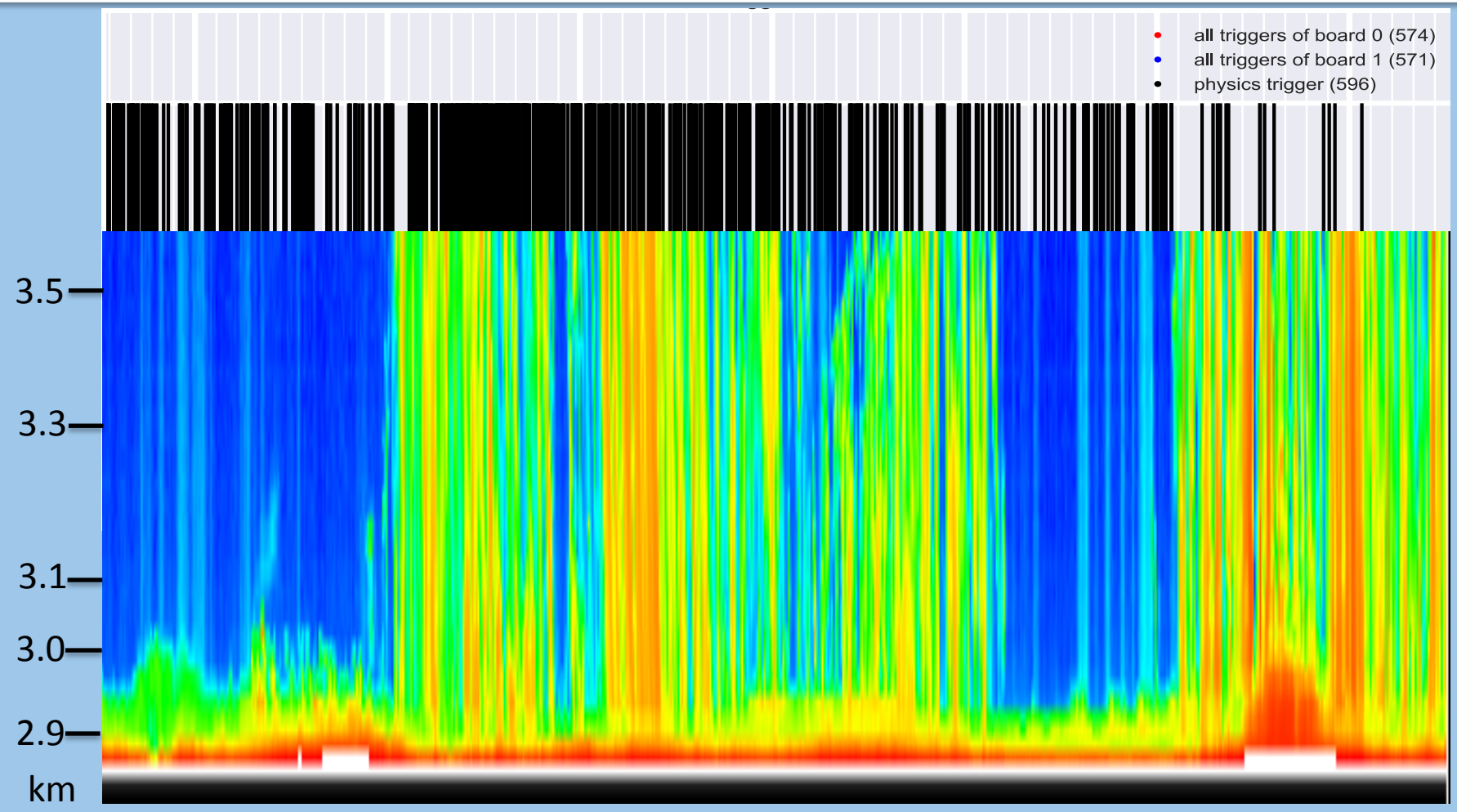


Weather conditions for the ACT





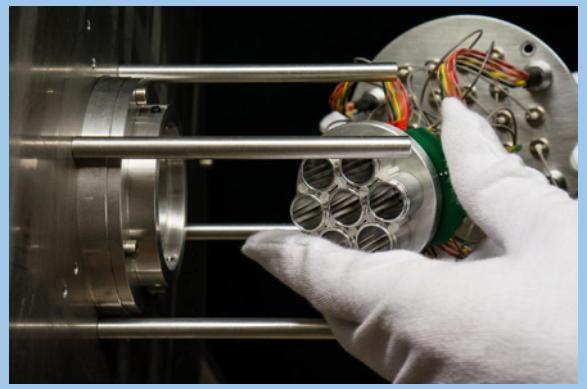
Weather conditions for the ACT



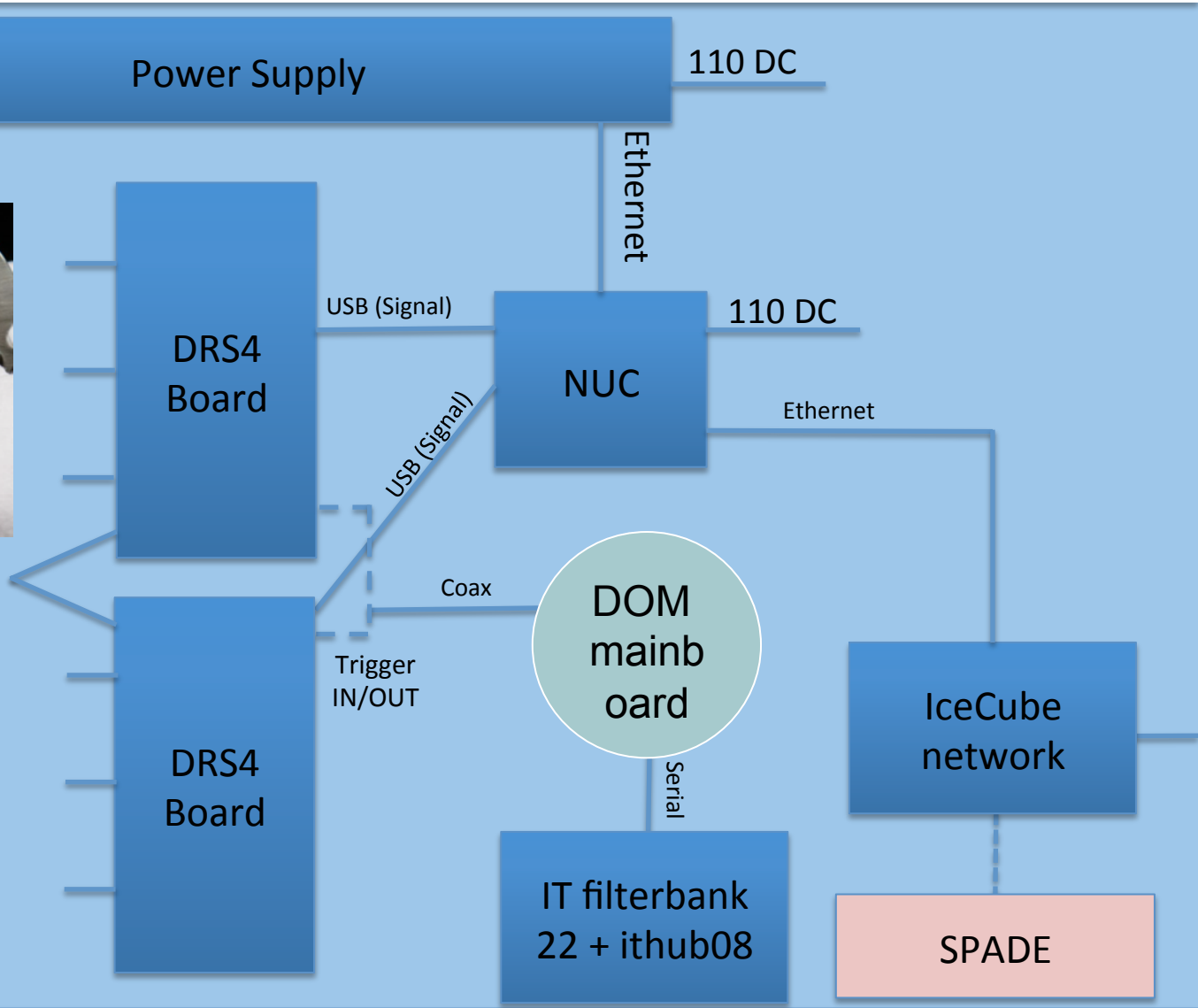
It is going to be interesting!

Prototype at the South Pole

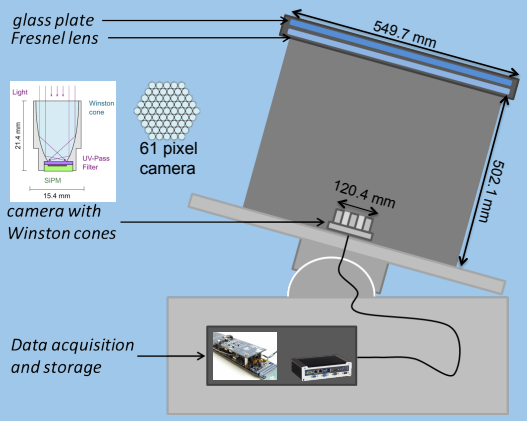
7 Pixel Camera



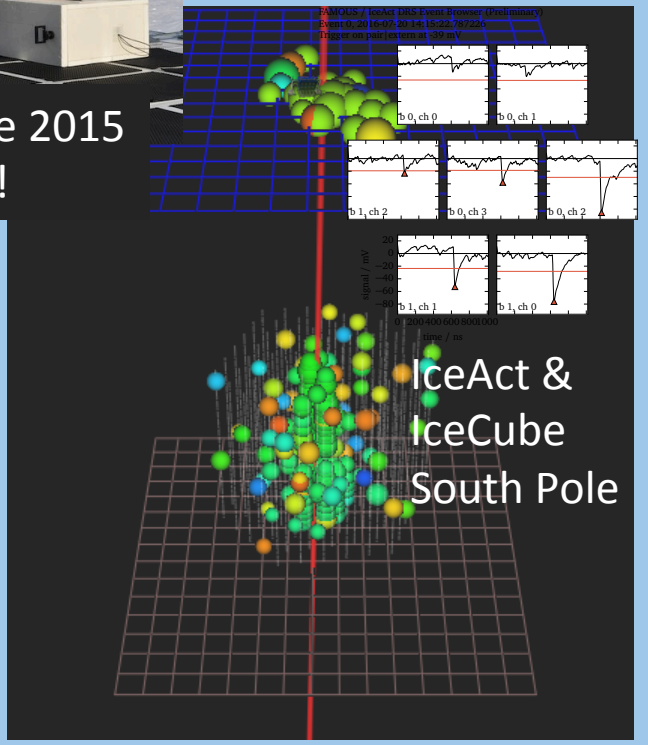
SensL
SiPMs



Small ACT for harsh environments



At South Pole since 2015
One more in 2017!



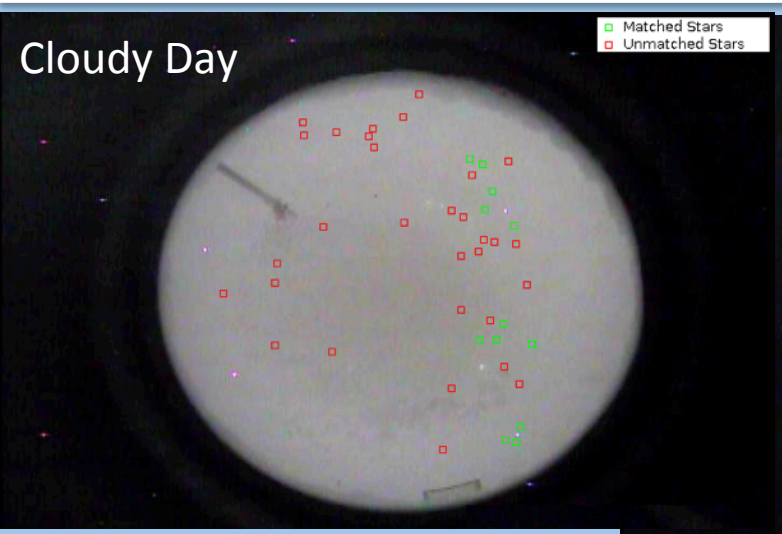
IceAct & IceCube South Pole

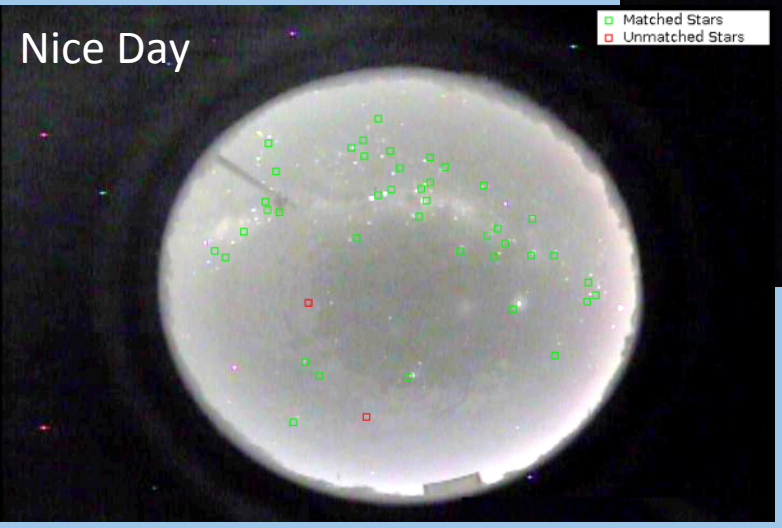
Learning from IceCube, FACT and CTA:

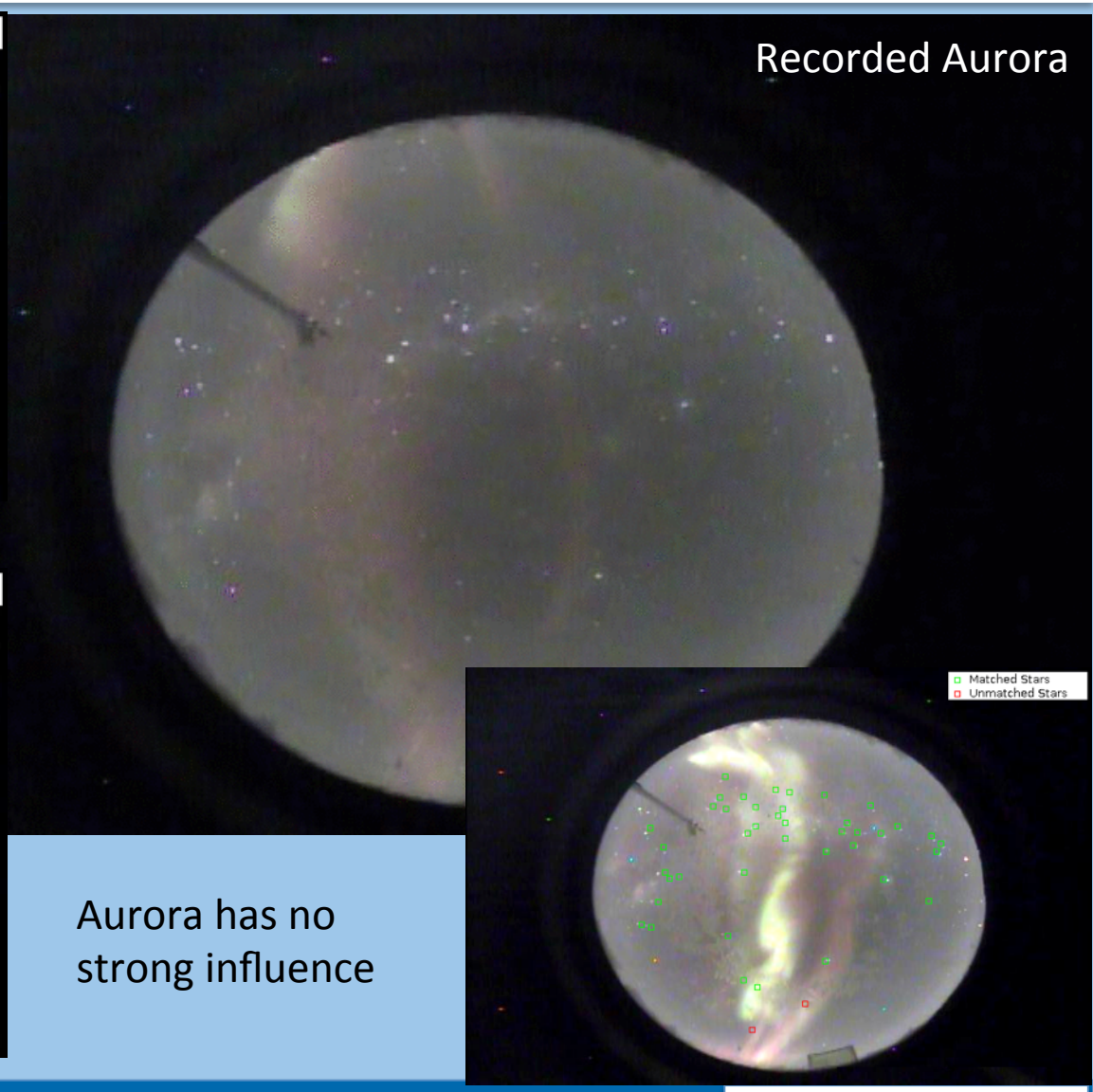
- Very efficient CR detection (veto) to open the southern sky for high energy neutrino detection with IceCube.
- Third detector component for IceCube and IceTop to precisely measure the composition of CR above 2 PeV.
- Possible second component for HAWC improving the Energy reconstruction (1 will tested in Mexico in May).
- Applications for CTA are under investigation.

First time that SiPMs are taking stable data at the South Pole!
Trailblazer in Germany: Aachen, Bochum, Dortmund, Essen

IACT at South Pole Duty Cycle

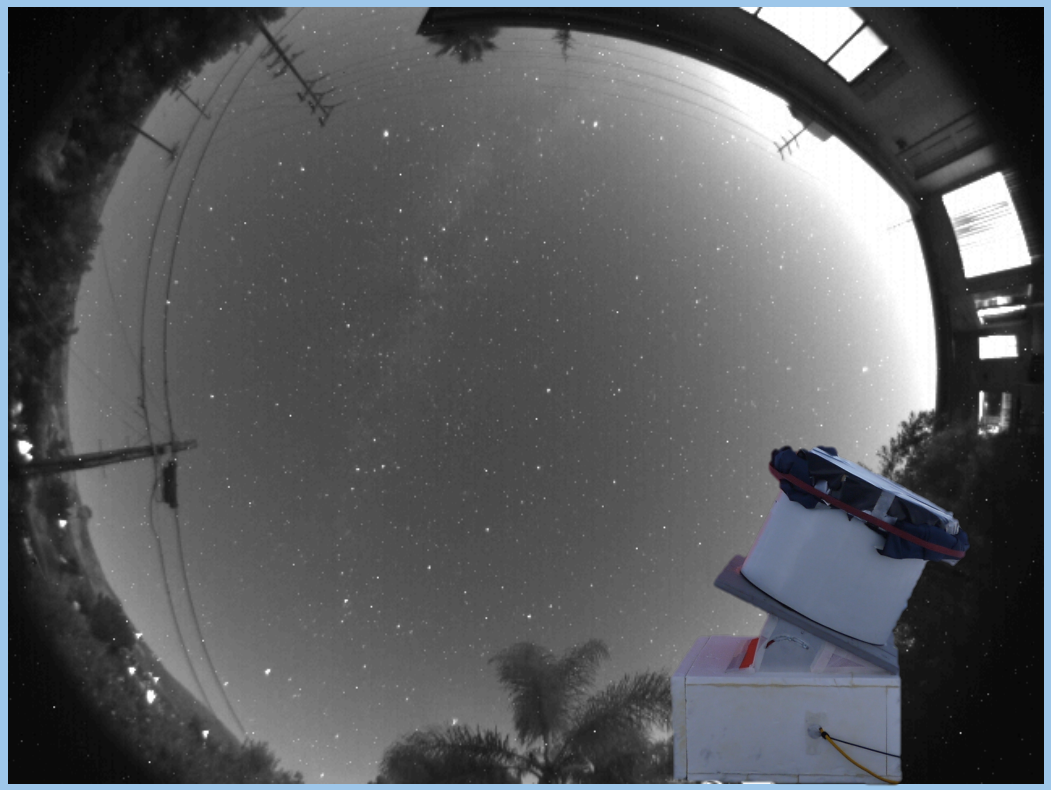




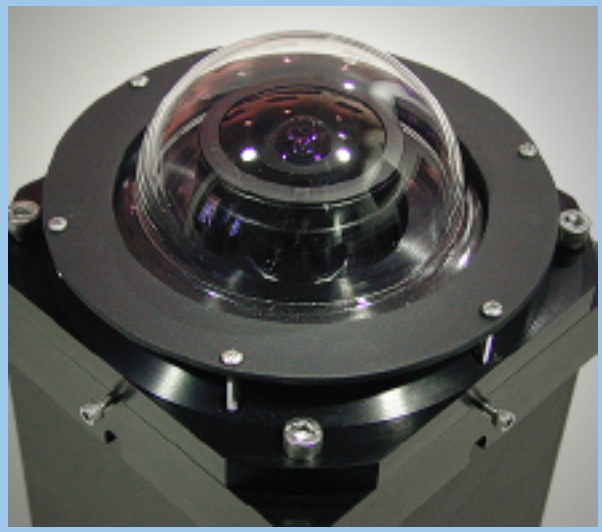


Aurora has no strong influence

Cloud monitoring is about to improve



sensor:
Kodak KAI-340 CCD
(640 x 480 pixels)
Lens:
Fujinon's FE185C046HA-1,
1.4 mm focal length, F/1.4



https://www.sbig.com/products/cameras/specialty/the-allsky-340-camera/

Installed this Season!