A calibration study of local ice and optical sensor properties in IceCube

IceCube Collaboration (Dmitry Chirkin), ICRC 2021

What is this contribution about?

- Calibration of ice optical properties is fundamental to simulation & reconstruction of Cherenkov signals from muons and neutrinos as recorded by the IceCube Neutrino Observatory.

- Optical sensors are placed on strings in holes created by the hot water drill. After the ice in these holes re-freezes, a central column of milky bubbly ice is created in the center, surrounded by much clearer ice inside the re-frozen hole.

- Precise sensor position within the hole in relationship to the central column, azimuthal orientation, position of the cable, a possible sensor tilt and in-situ optical sensitivity all need to be characterized.

- We fitted the local ice and optical sensor properties to the so-called *flasher* calibration sets in which built-in LEDs were operated individually or in unison, and surrounding sensors collected the photon data.

Why is it relevant / interesting?

- Details of ice and sensor position and orientation in the re-frozen holes are important as they can significantly affect *the last few ns* in photon propagation before photons reach the IceCube optical sensors.

- These can also significantly affect the photons during *the first few ns* after they have been emitted by our calibration LEDs. Full calibration of these effects is needed for improved precision of the inter-string ice calibration.

What has been done?

- Azimuthal orientation of all DOMs in IceCube was determined with (on average) better than 1 degree resolution.

- Hole ice properties have been characterized and DOM positions within the re-frozen holes were reconstructed.

- We also studied cable shadow, DOM tilt, and in-ice relative optical sensitivities of DOMs.

What is the result?

- Recent ice models rely on *single-LED* calibration data sets, and azimuthal calibration of DOM orientations presented here is required.

- Significant improvement in the quality of description of our calibration data sets is achieved when the hole ice effects described here are included.

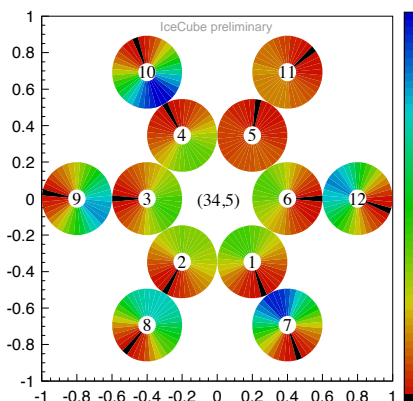- Improvement in real-life data events of IceCube has also been demonstrated when these effects are included.

Figure 1: Reconstructed beams shown in black for all 12 LEDs after azimuthal orientation calibration.
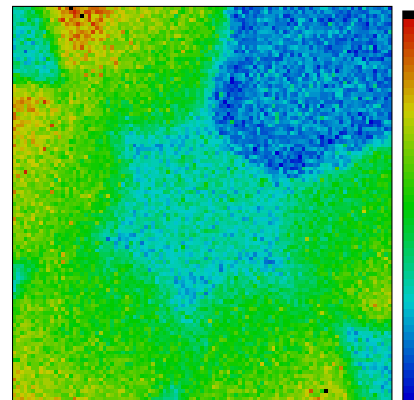

Figure 2: *llh* landscape for hole ice column positions (same DOM). Position in front of LEDs 5 and 11 is preferred.