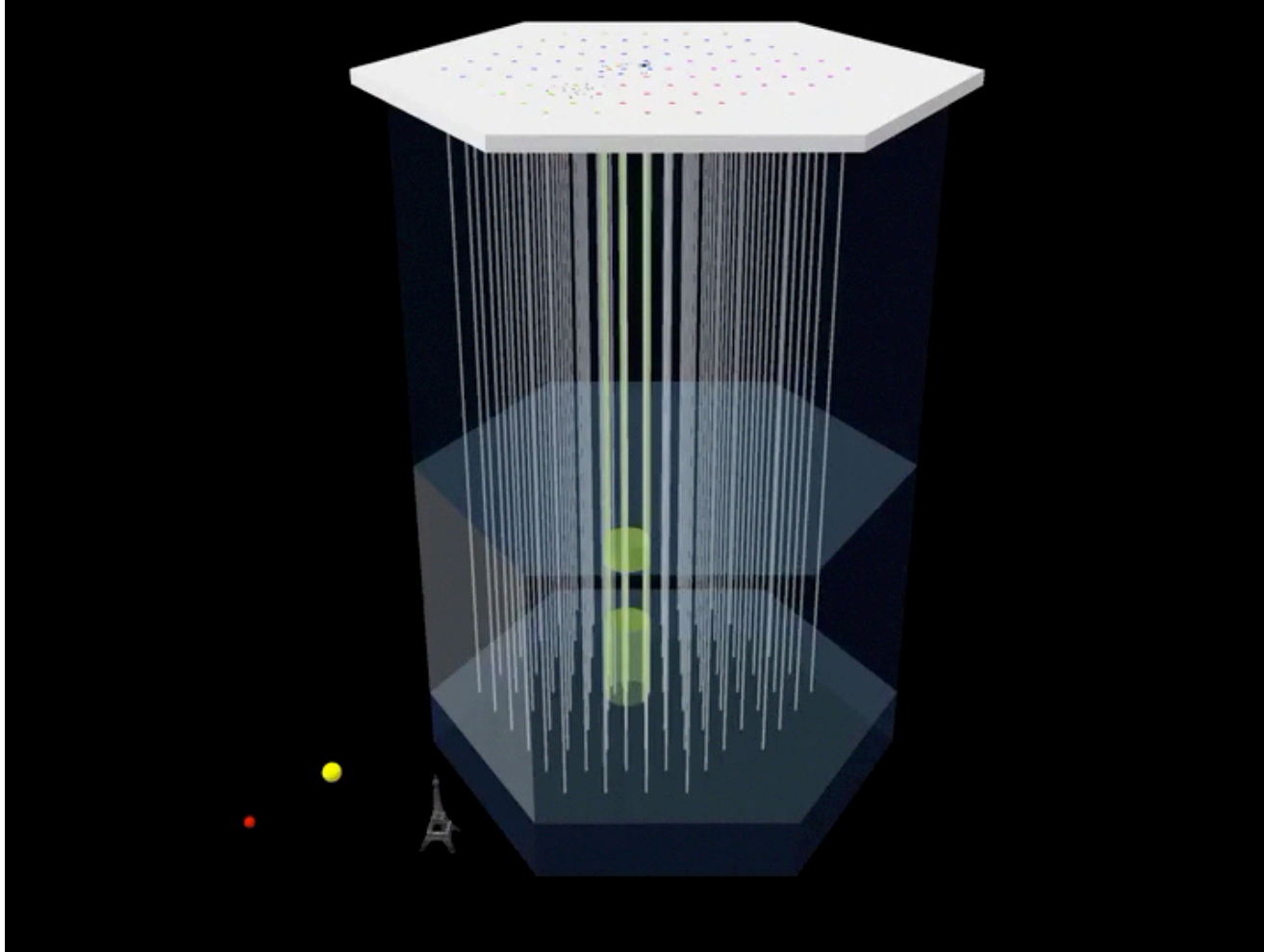# Design of a Robust Fiber Optic Communications System for Future IceCube Detectors

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IceCube South Pole Neutrino Observatory

- Uses >5k 10" PMTs frozen into the Antarctic Glacier to detect muons and neutrinos from ~4Gev to ~10PeV

- Signals are time-tagged and digitized in the optical modules and sent to surface over long run copper

- To achieve timing requirements, cables must be designed with stringent cross talk suppression

- Communications is done with a custom protocol to mitigate signaling challenges

arXiv:1612.05093
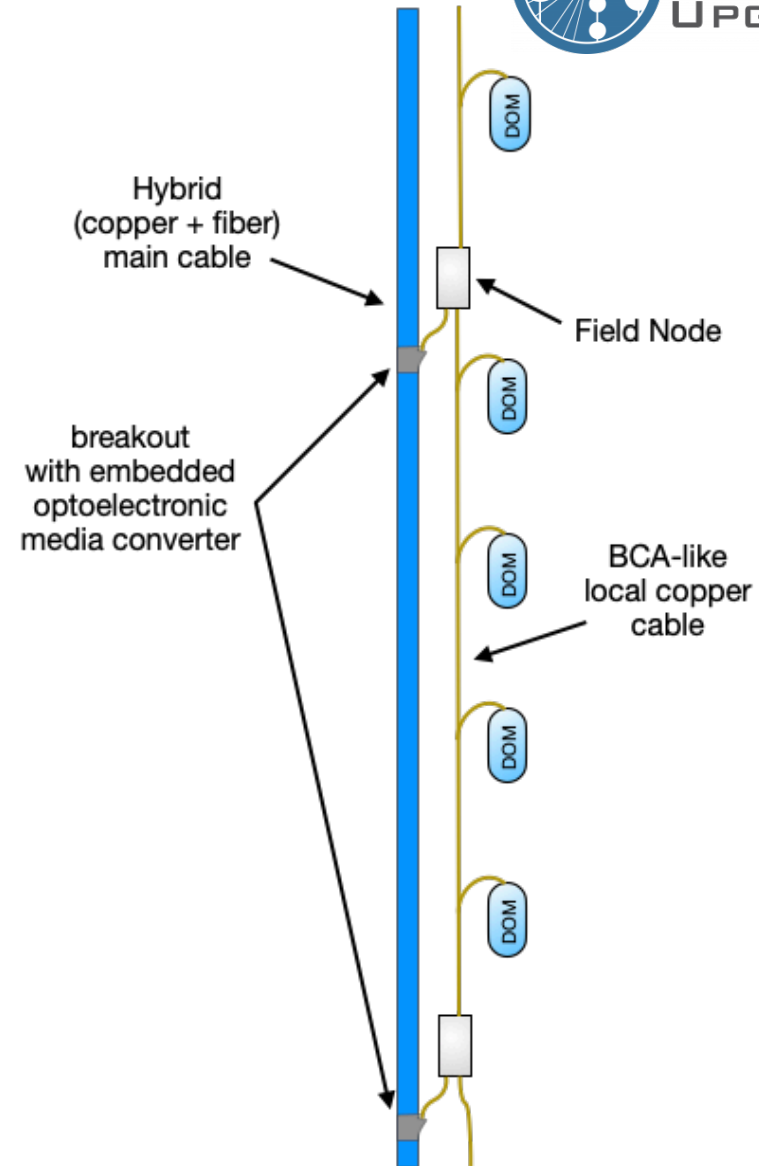
Future Detectors
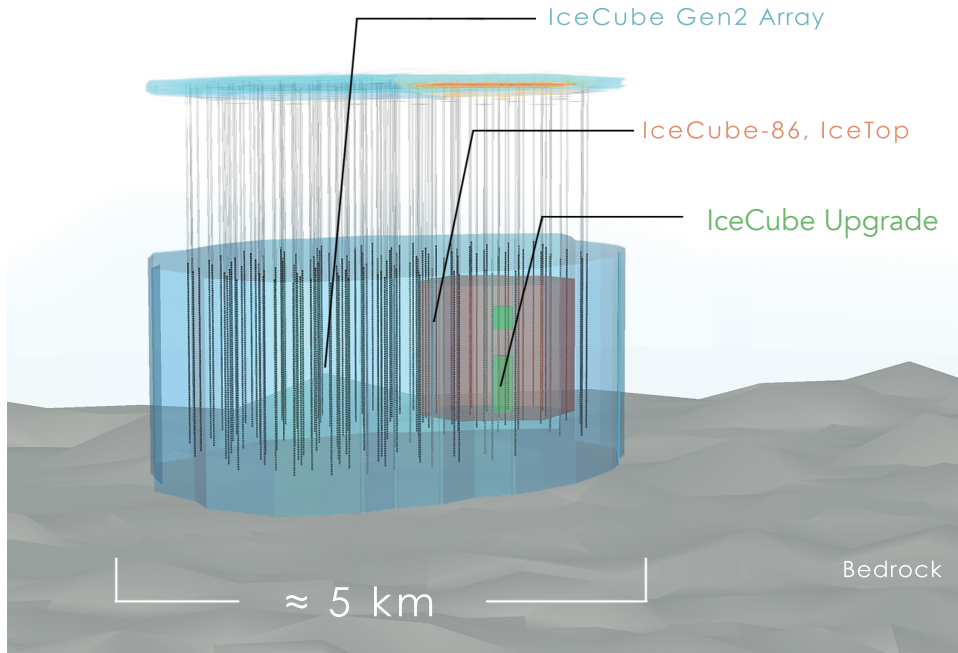
- IceCube Upgrade infill for science at lower energies + testbed for Gen2 devices + ice calibration

- IceCube-Gen2 will expand detection volume to 8km^3 for high energy astrophysics

- Current protocols and timing will be strained to communicate over these distances
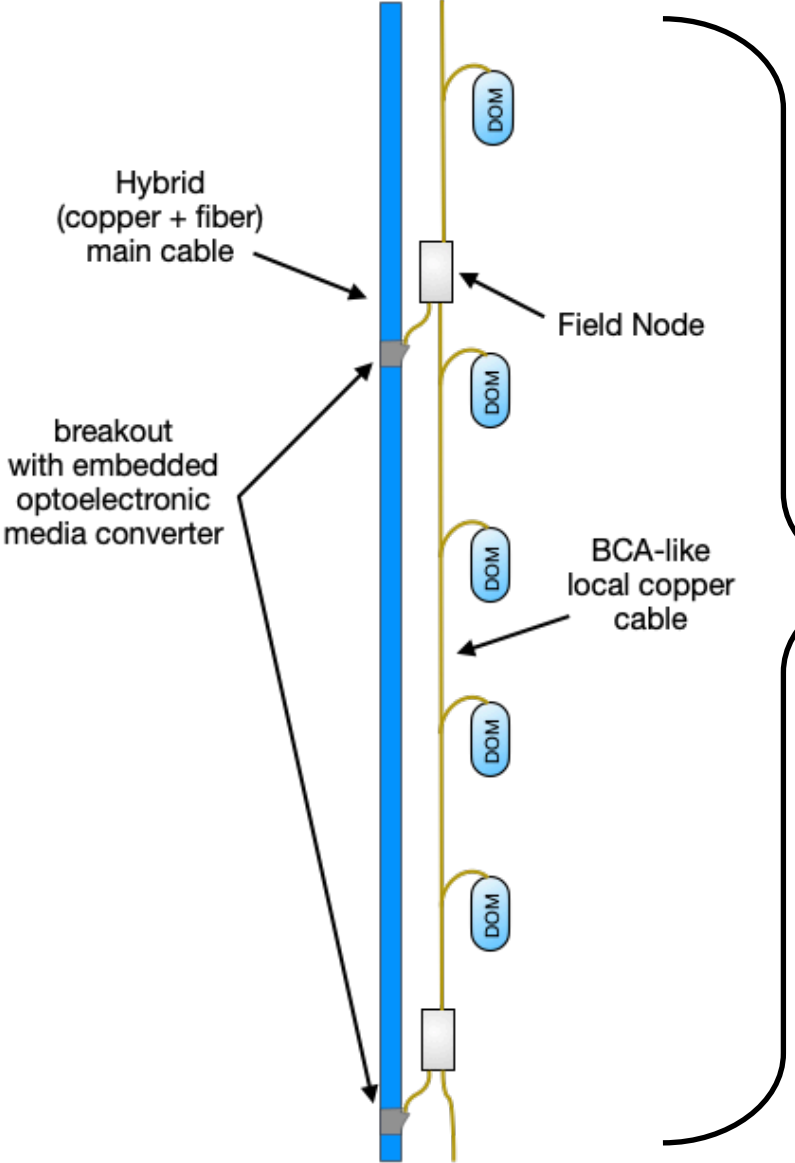 - cables also become quite expensive
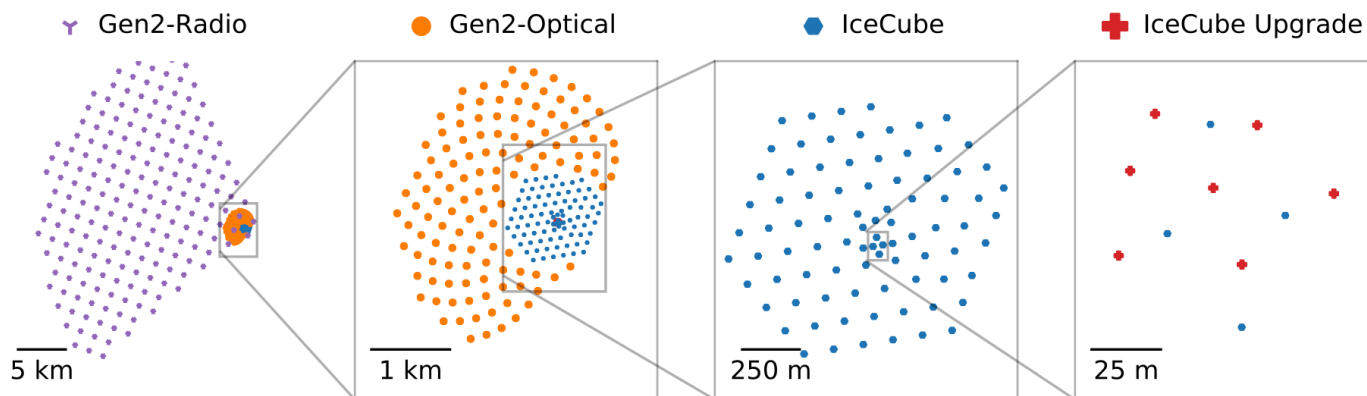
> Fiber is a natural solution to get past these constraints
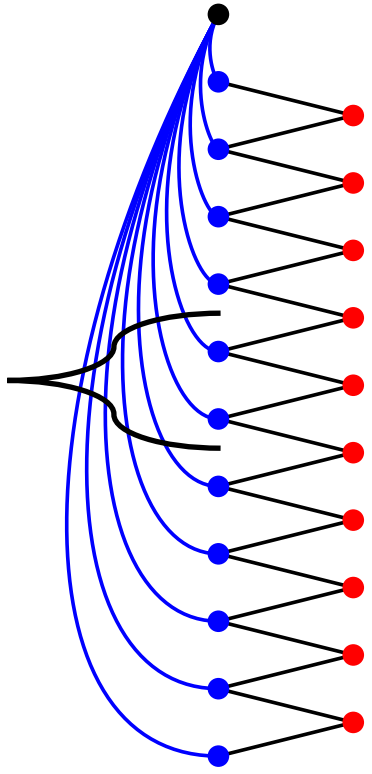
Gen2 Fiber Option

- Hybrid main cable with fiber data path and copper power delivery

- Main cable feeds fiber data to Field Nodes

- Field Nodes distribute power and timing and communicate with DOMs over local copper
  - White Rabbit timing and Ethernet
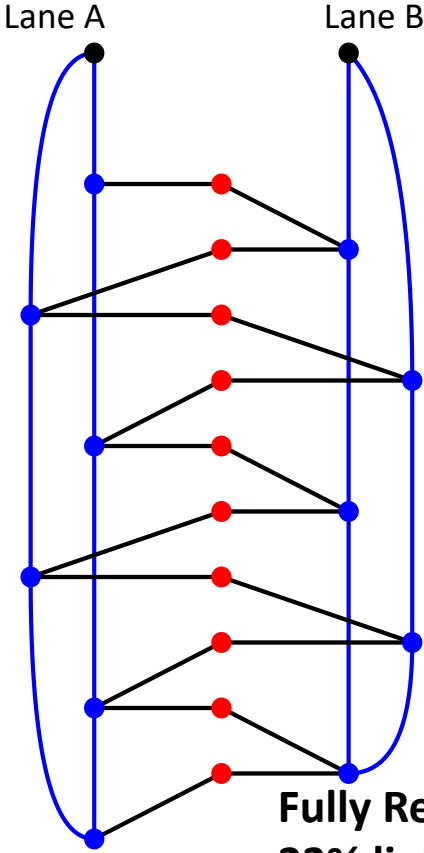 - Redundant up and downgoing copper connections

Hybrid (copper + fiber) main cable

Field Node

breakout with embedded optoelectronic media converter

BCA-like local copper cable

Fiber Redundancy/Network Topology

Hybrid (copper + fiber) main cable

Field Node

breakout with embedded optoelectronic media converter

BCA-like local copper cable

Classic Connections

Cascading Connections

Lane A   Lane B

OR

Redundant to 1 link breakage (7.6% of links)

Fully Redundant to 23% link breakage and uses less fiber

- ● Endpoint Node (Surface)
- ● Prototype Fiber Node
- ● Copper Substring (DOMs) ~8 each
- ── Fiber Connection
- ── Copper Connection

5

Demonstrating the Building Blocks – the Fiber Test System

- Deploying the Fiber Test System in the IceCube Upgrade

- 6 Prototype Field Nodes communicate via White Rabbit and with the surface via standard comms

- System connectorized drop in for standard IC-Upgrade breakout cable
  - 4 DOM equivalent

Prototype Field Node - timing and data hub

Penetrator Carrying High Speed White Rabbit signals

3m separation (devices not to scale)

Fiber Test Cable – connects as BCA, contains standard copper quad as well as fibers

Standard Upgrade Main Cable

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