Improving Track Reco with Standard Arrows in IceCube

Will Thompson for the IceCube Collaboration

IPA 2026

October 14, 2026

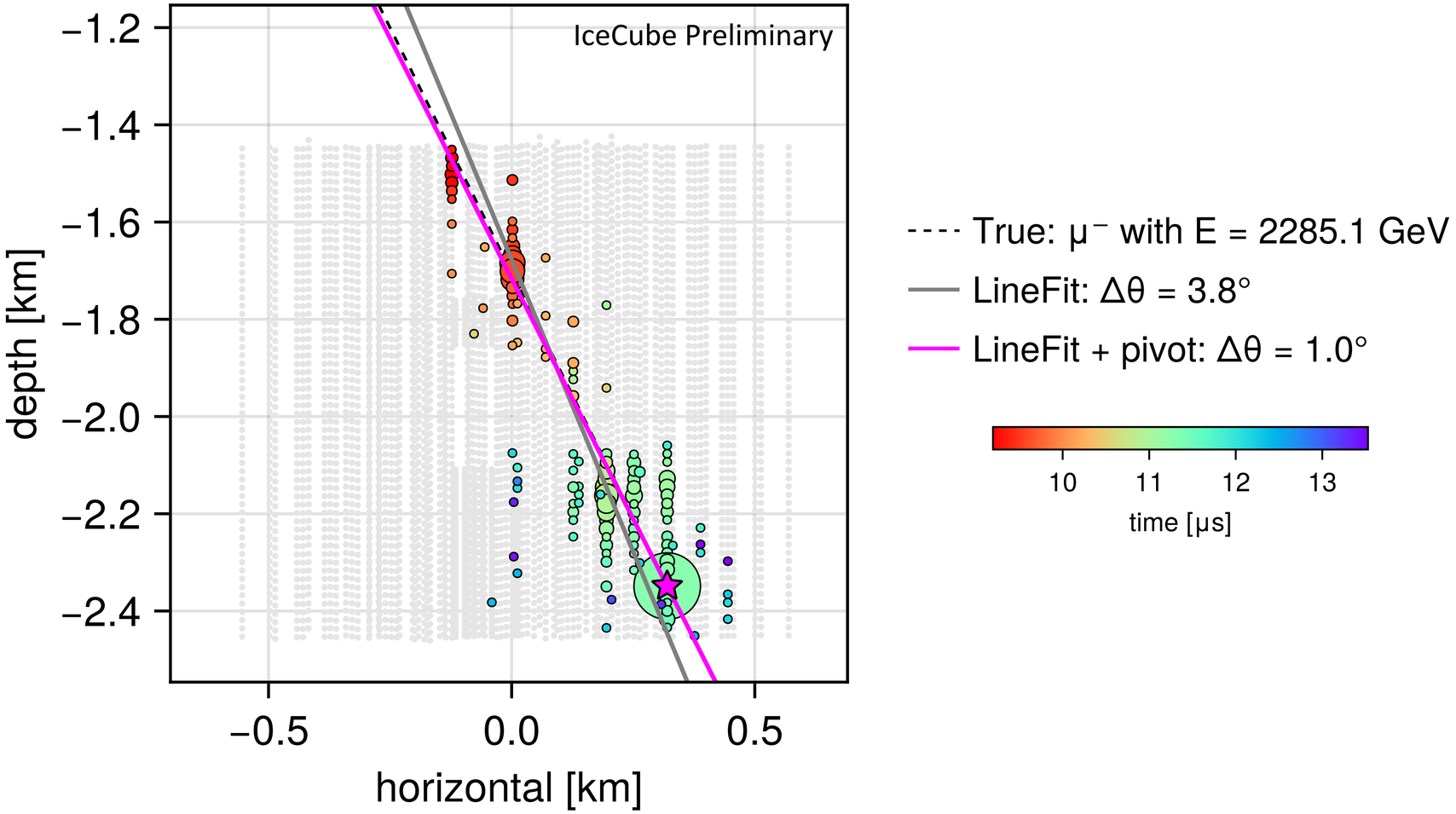


A “standard arrow” for neutrino telescopes

Typical track reco must fit (θ, ϕ) and position

Given “pivot point” only (θ, ϕ) unknown → higher precision reconstruction

“Standard arrow” = track reconstructed with pivot



Many new sensors deployed in the Upgrade

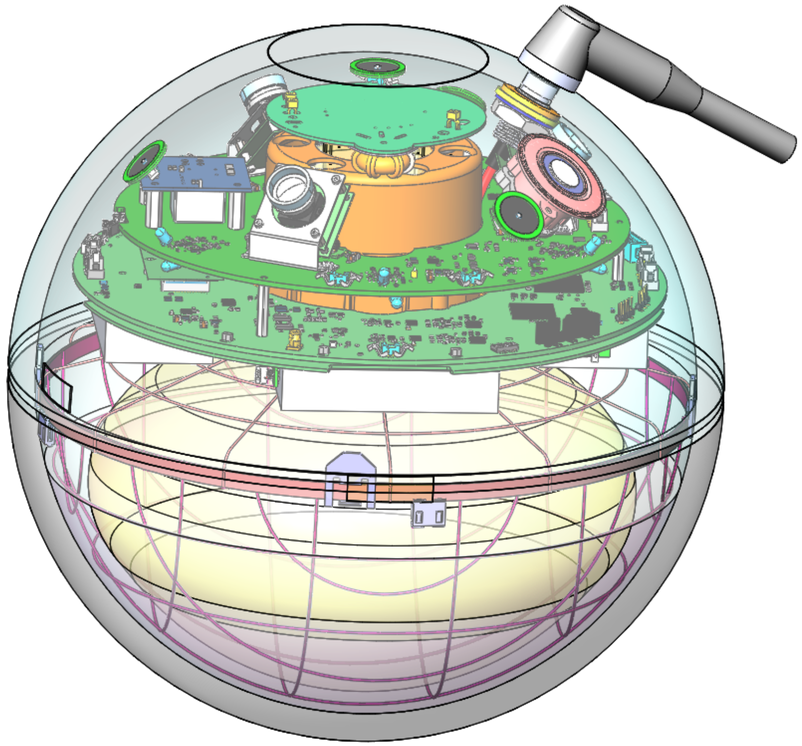


600+ new optical sensors and calibration sensors on 5 strings

Perfect opportunity to deploy a dedicated muon tagger!

Many new sensors deployed in the Upgrade





Plastic scintillator-based muon tagger deployed in 9 PDOMs and 3 FDOMs

MTA = Muon Tagger Assembly

Muon tagger science opportunities

With “standard arrows”

- Assess reconstruction algorithm performance
- Training set for ML recos using standard arrows as truth
- Use as *in situ* calibration source

Enhance studies of low-energy events by lowering trigger threshold

Proof of principle for MTA deployment in other neutrino telescopes

Looking to collaborate with other experiments; feel free to reach out!

MTA design goals

Reasonable Cost (~$400)

High muon efficiency & purity

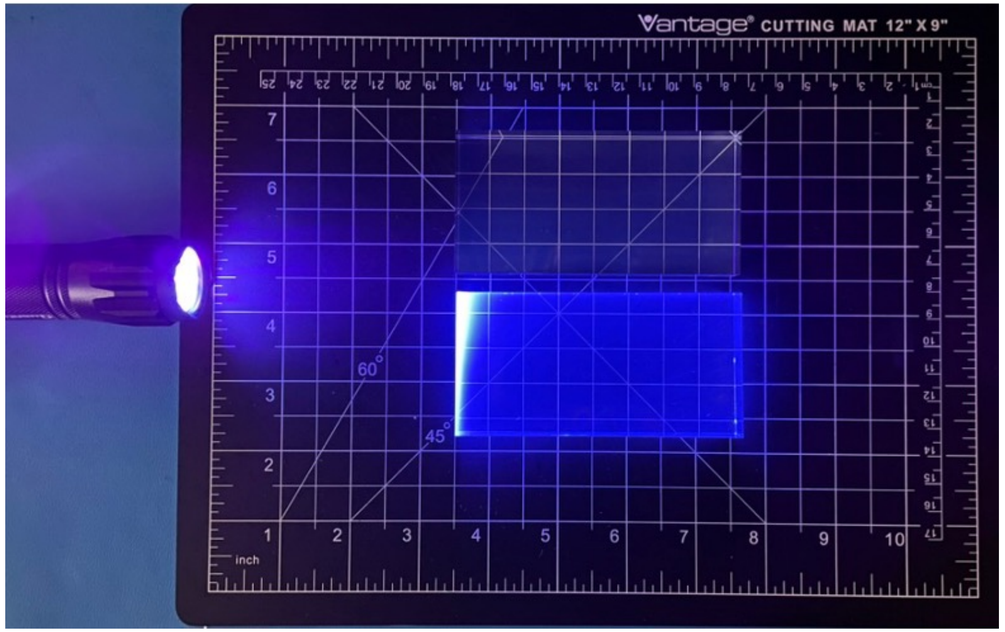
Maximize muon rate

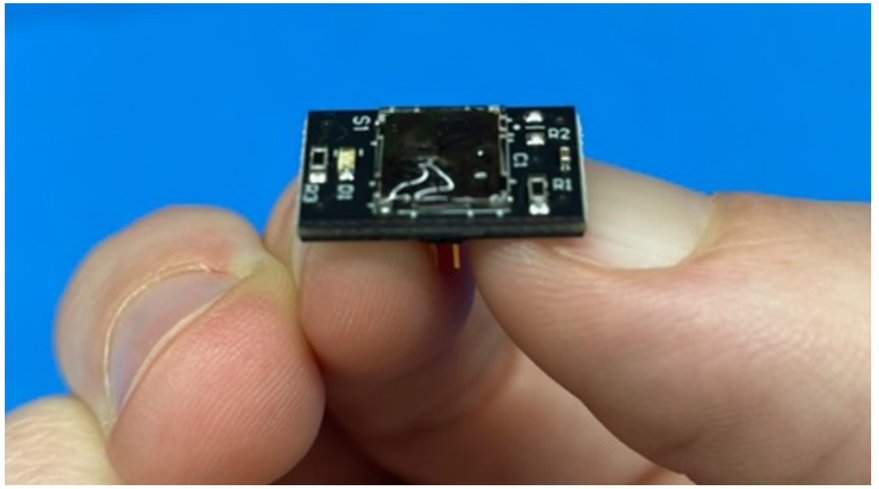
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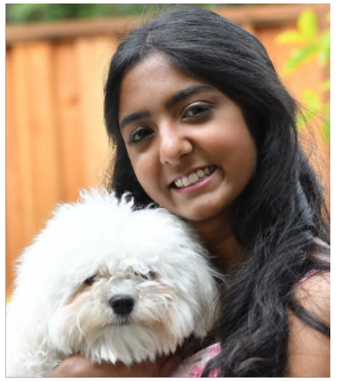
Maximize muon rate







Kiara Carloni



Tanvi Krishnan

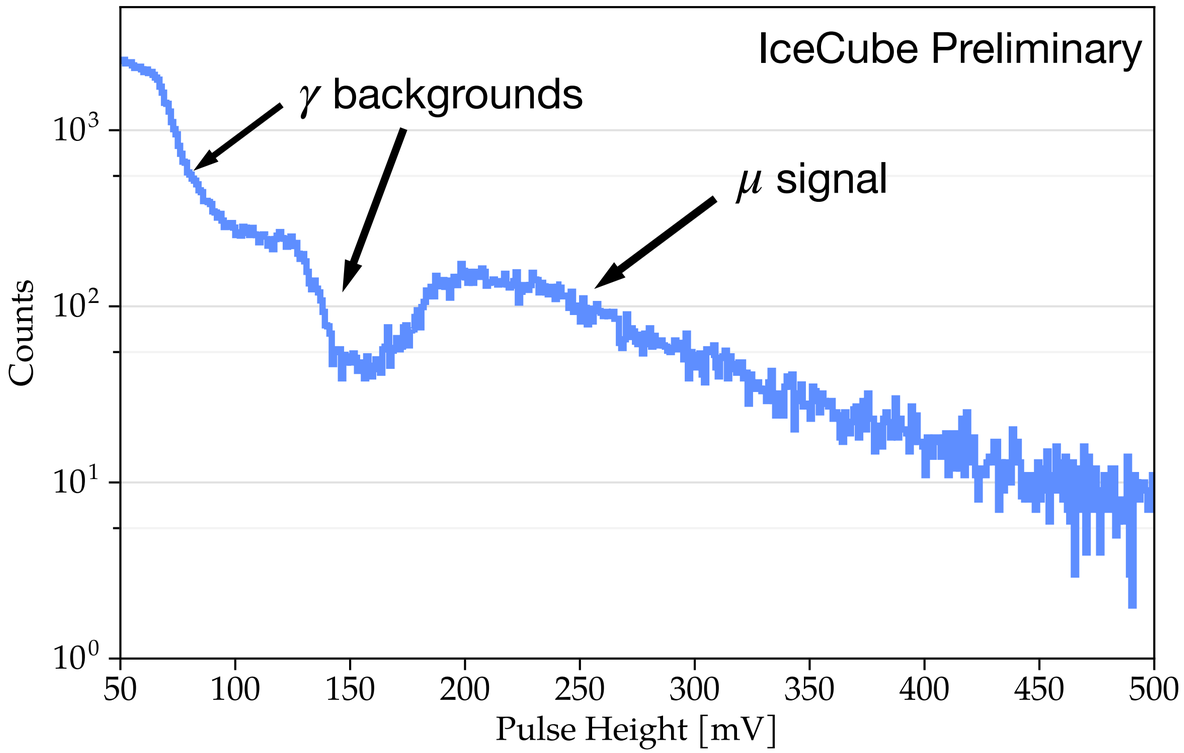
Affordable building materials: plastic scintillator, SiPMs, and grad students

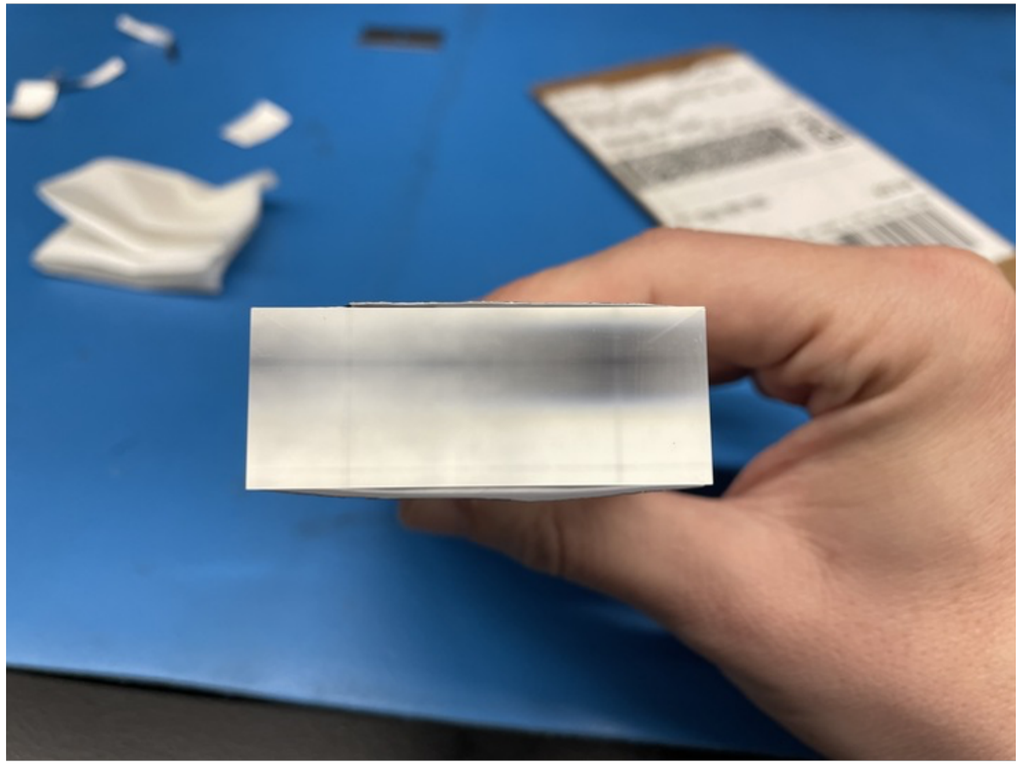
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Lab measurement: 2 cm thick scintillator separates muons from backgrounds

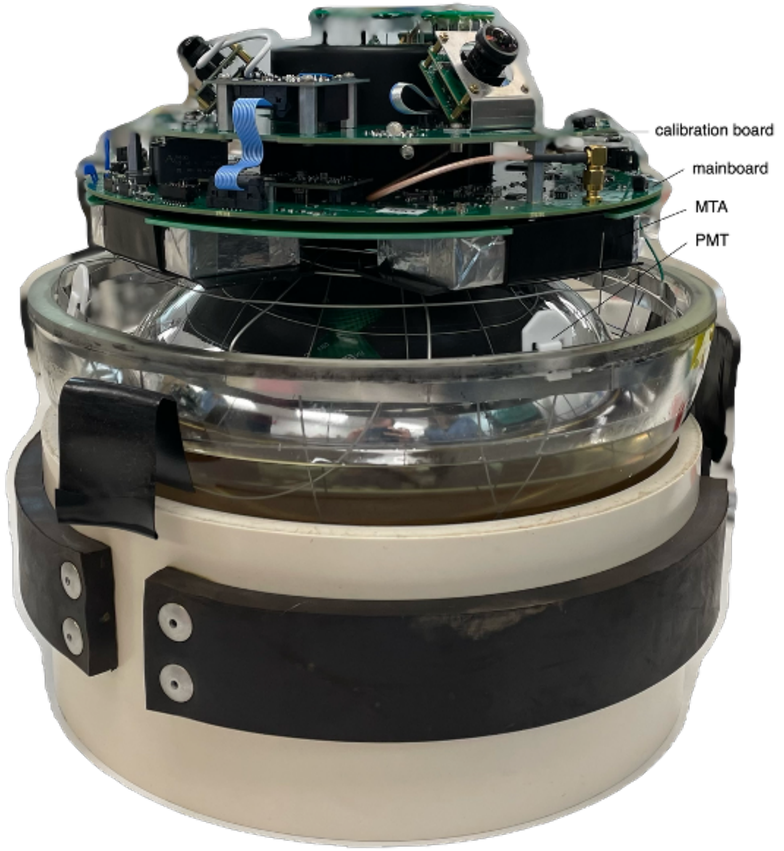
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MTA mounted under PDOM mainboard — 200 cm² active area

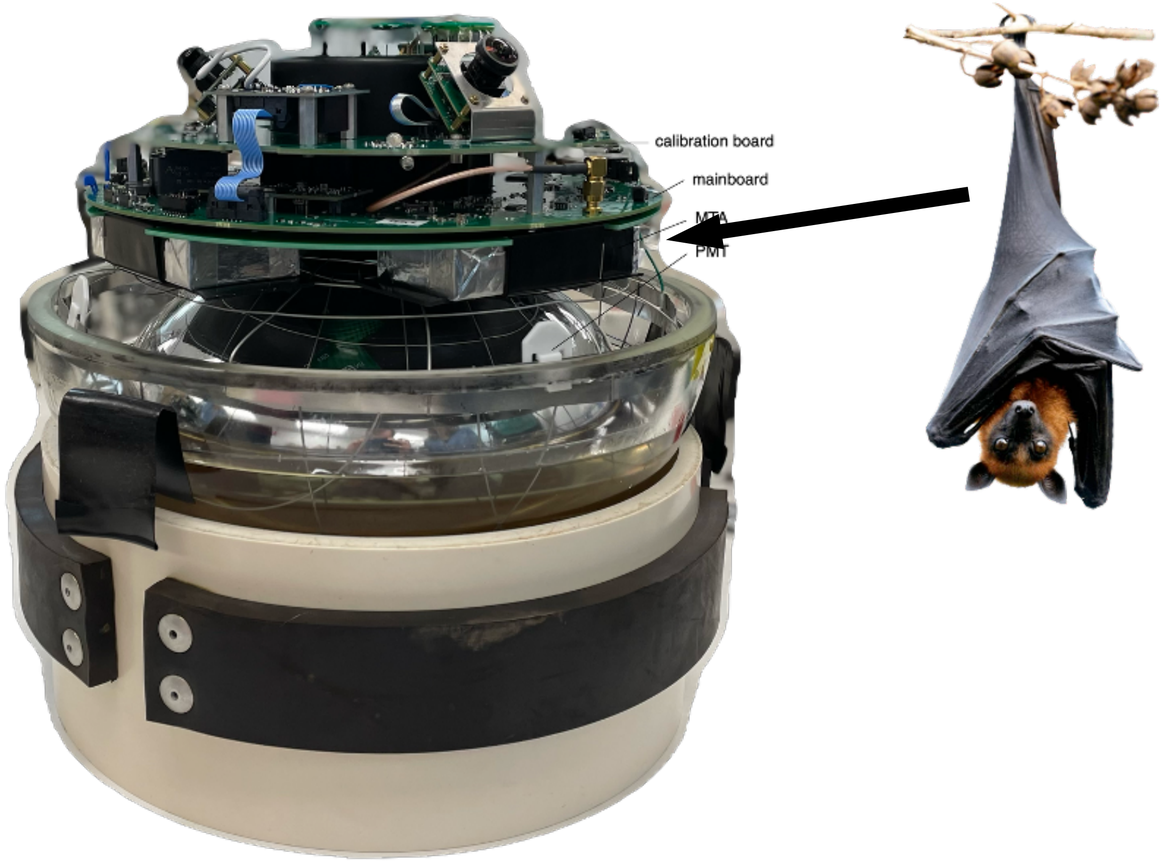
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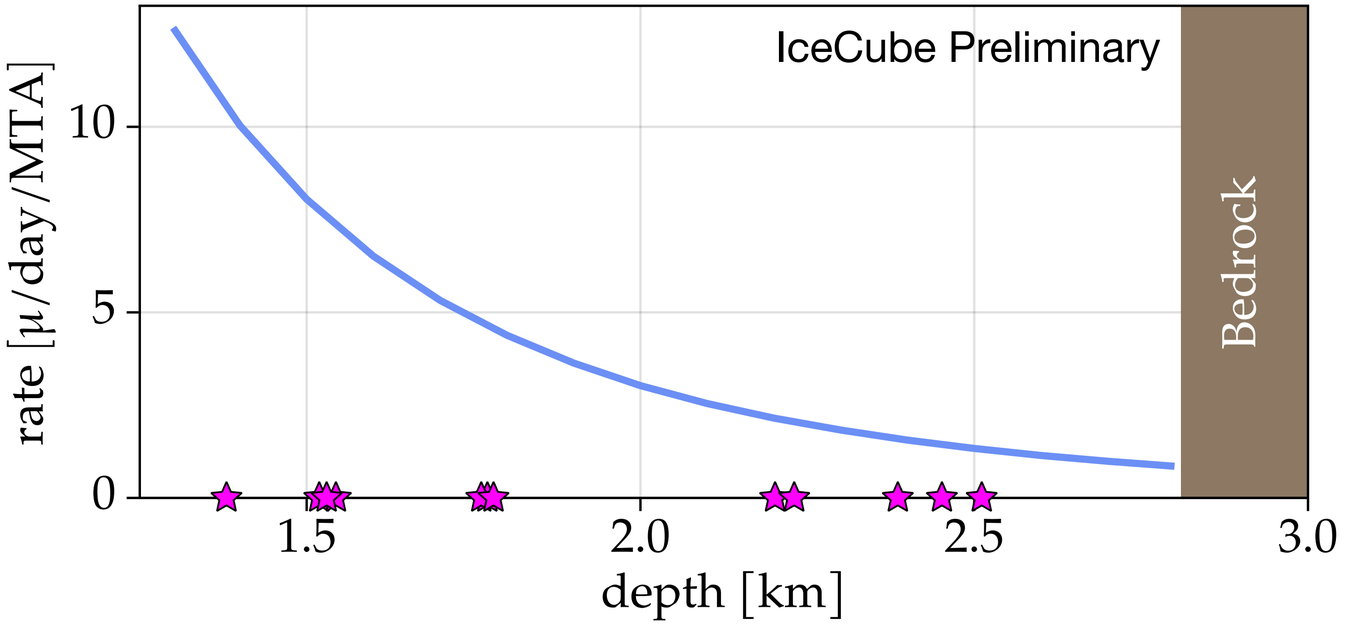
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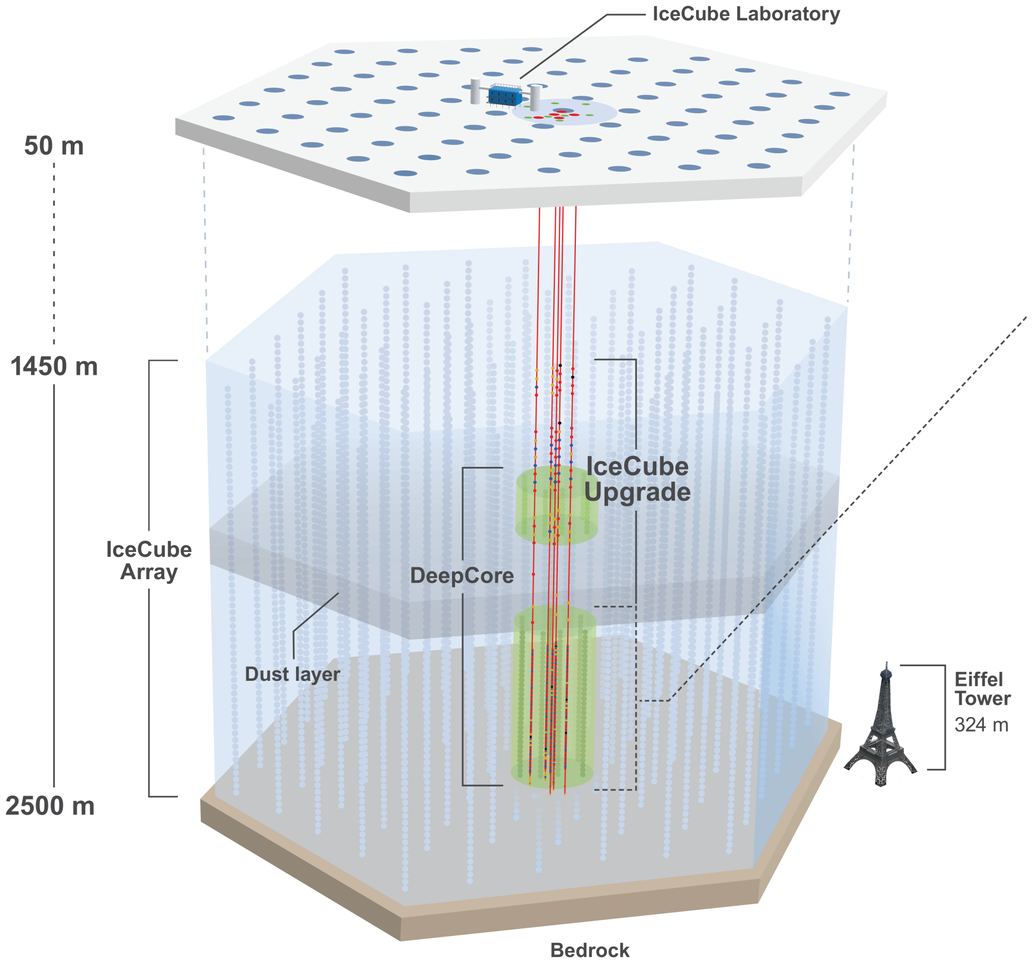




MTA mounted under PDOM mainboard — 200 cm² active area

How many muons will we tag?



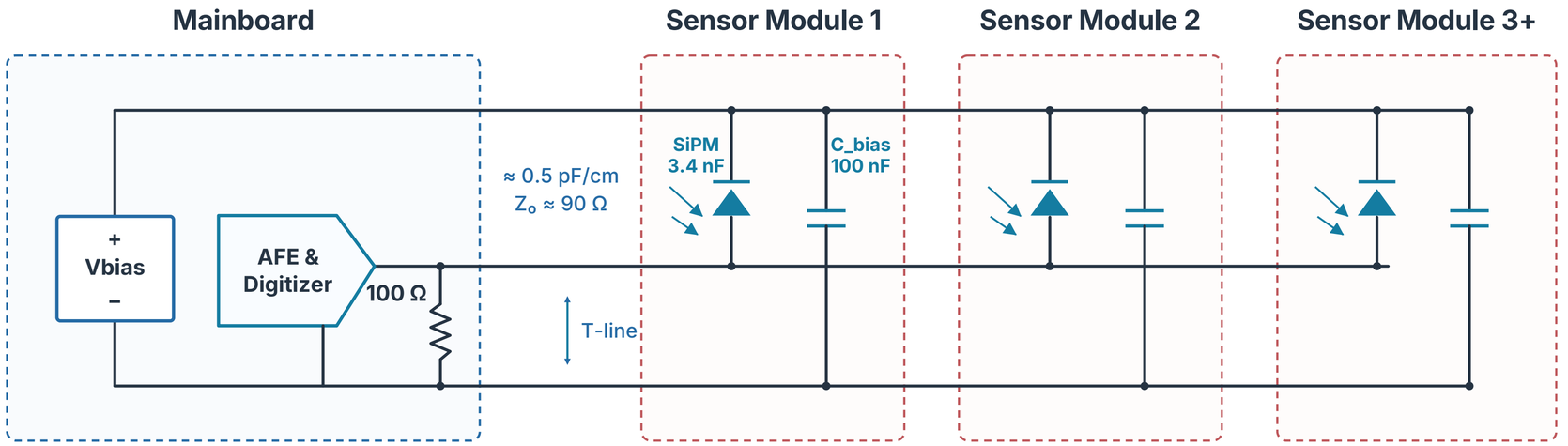


12 MTAs deployed at different depths

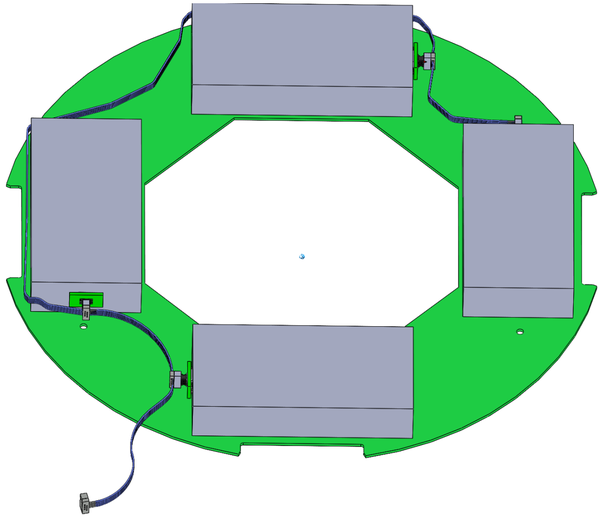
Expect ~20k μ/yr total

< 1 μ/yr expected to hit two MTAs

Passive summing of SiPM signals



=



Scintillators wired in parallel for single-channel digitizer

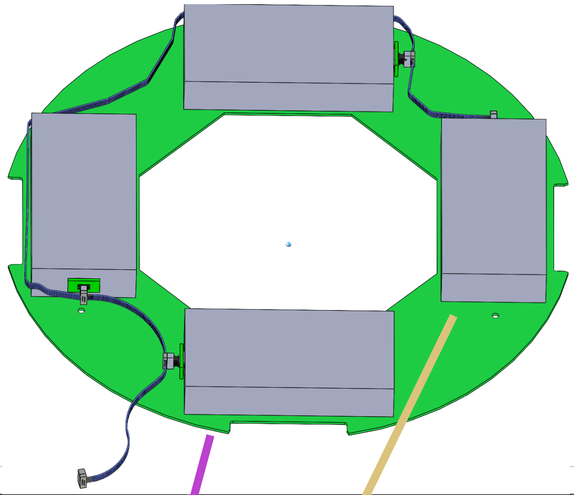
Not necessary to distinguish which block signal originates from

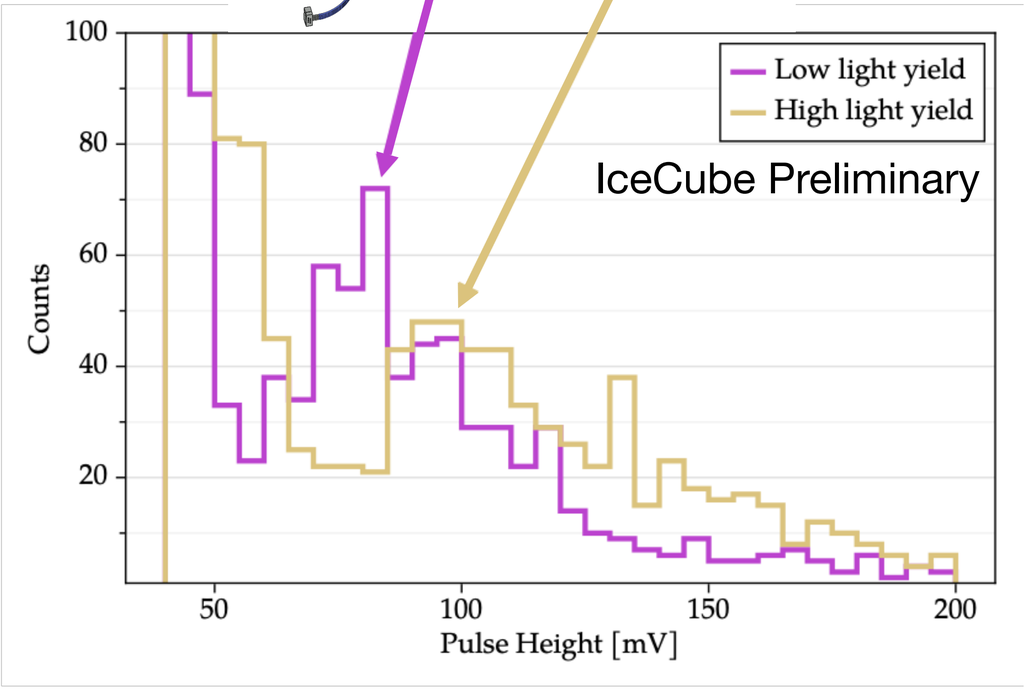
Response of 4 scintillators must be highly uniform to maximize muon purity!

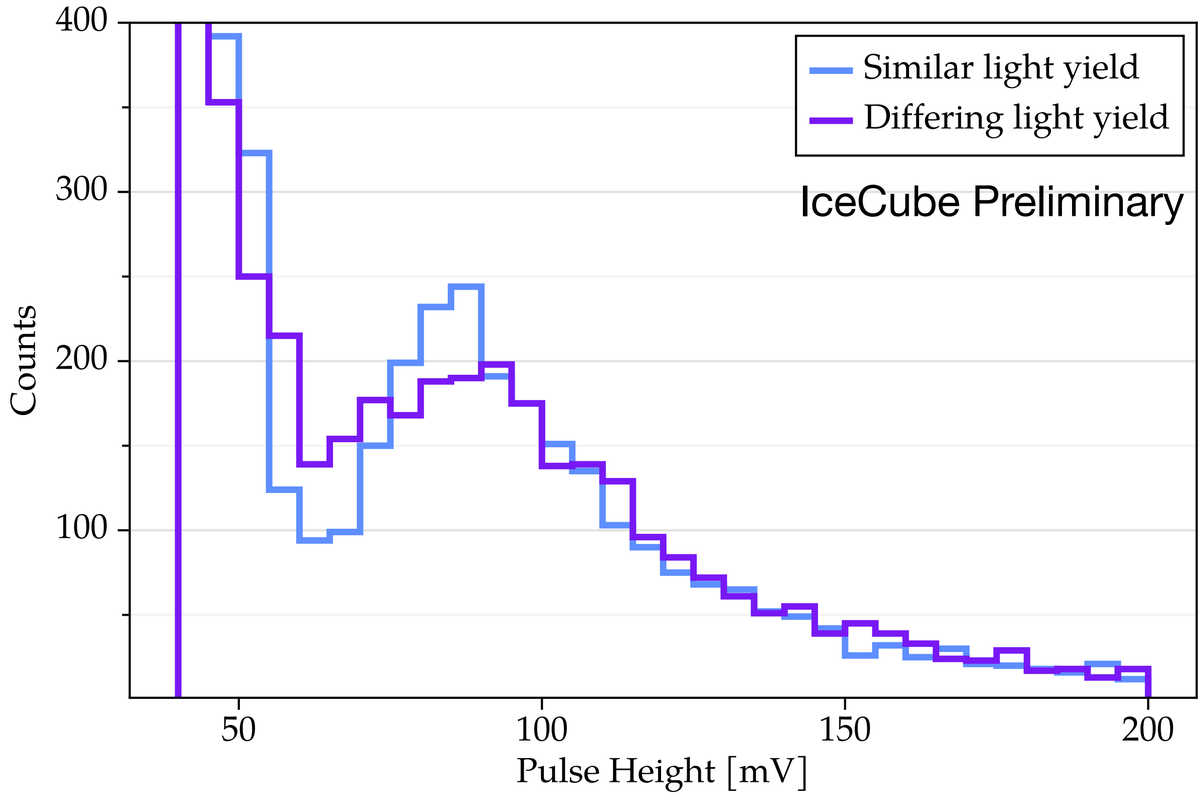


Perry Sandstrom

Scintillator light yields must be matched







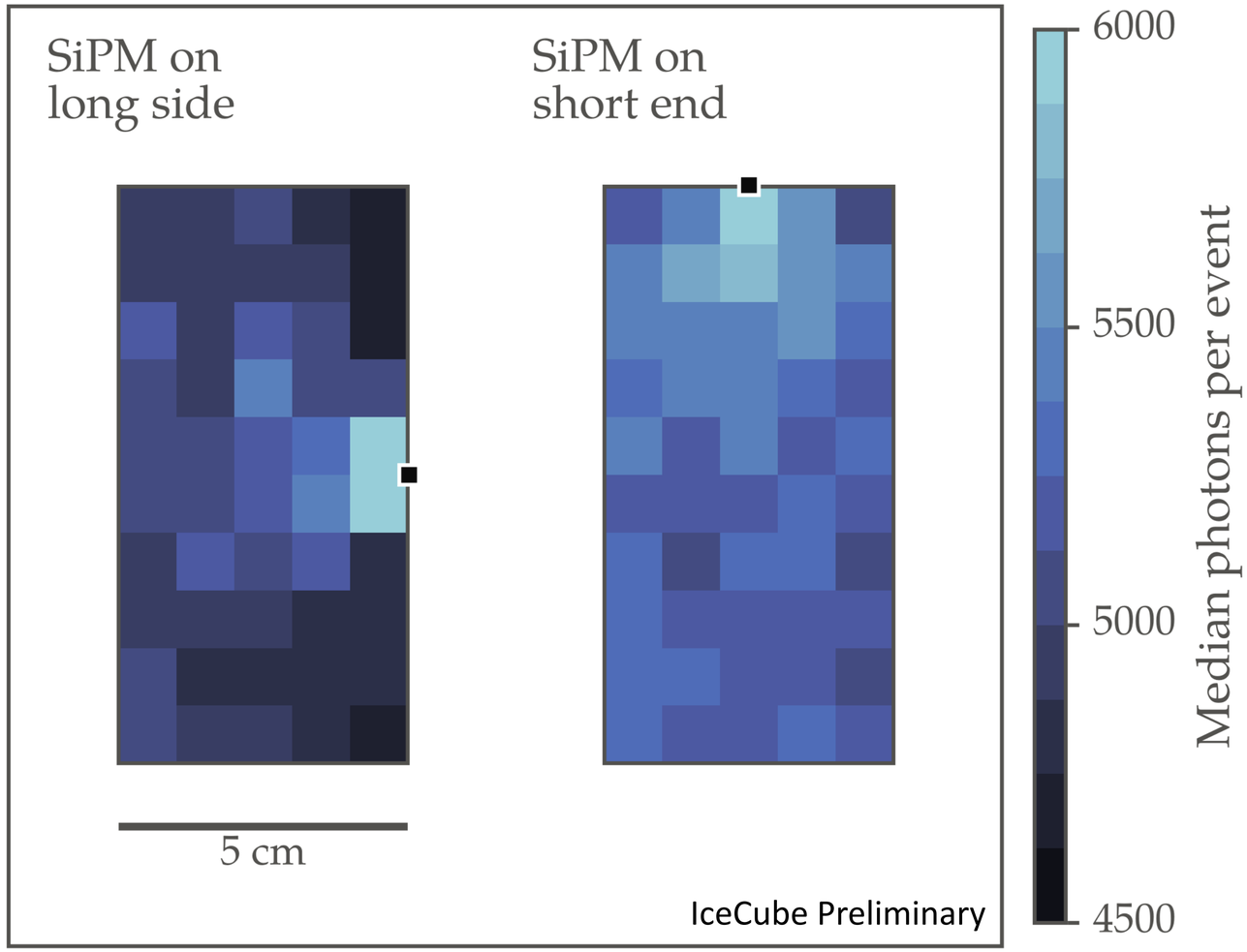
Light yield differs slightly for each scintillator

Match scintillators with similar light yield to maximize peak fidelity

Optimizing SiPM position



Felix Yu



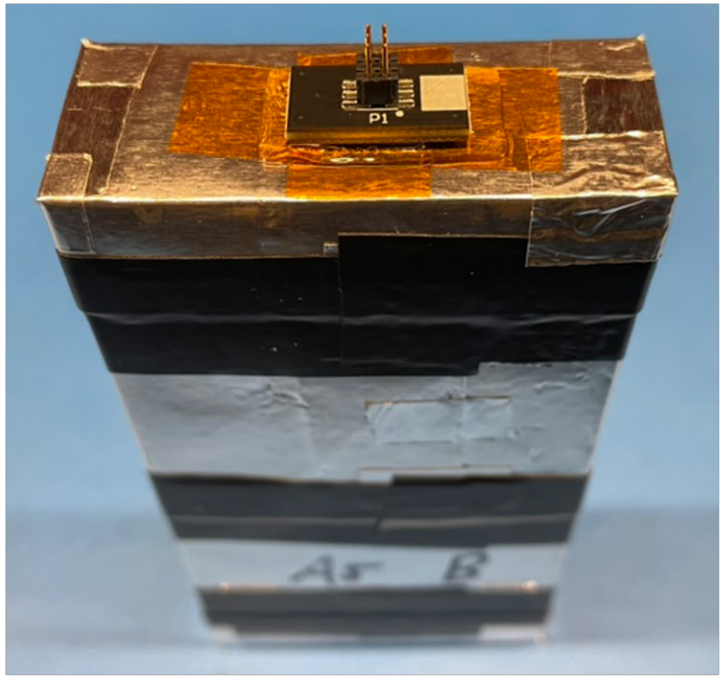
Light yield should be independent of muon interaction location

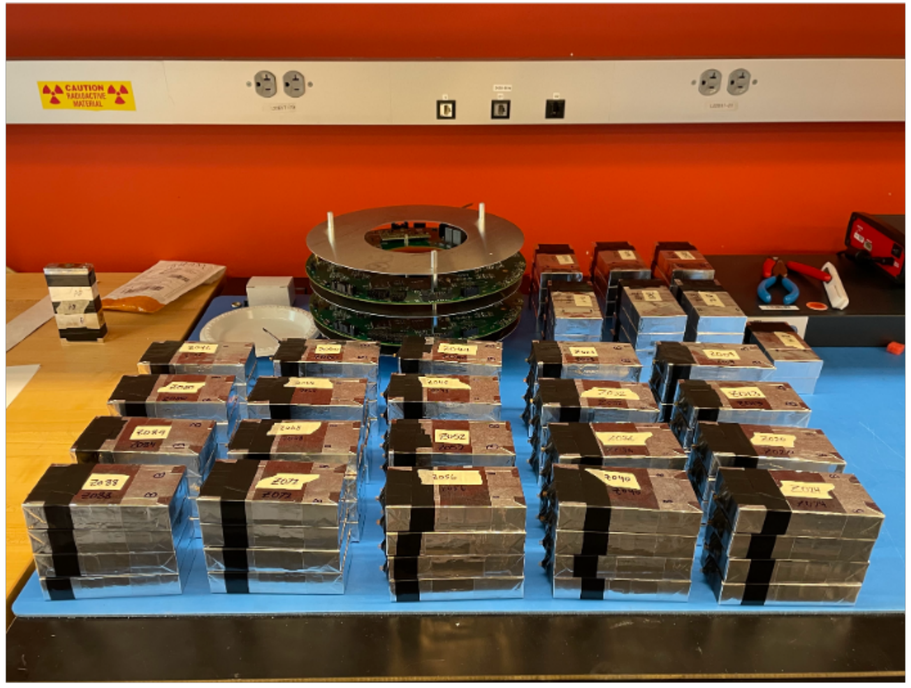
Assembly and testing

Tyvek/aluminum laminate used as diffuse reflector

SiPM mounted on short end of scintillator with gel pad

Prepared blocks tested and attached to support board



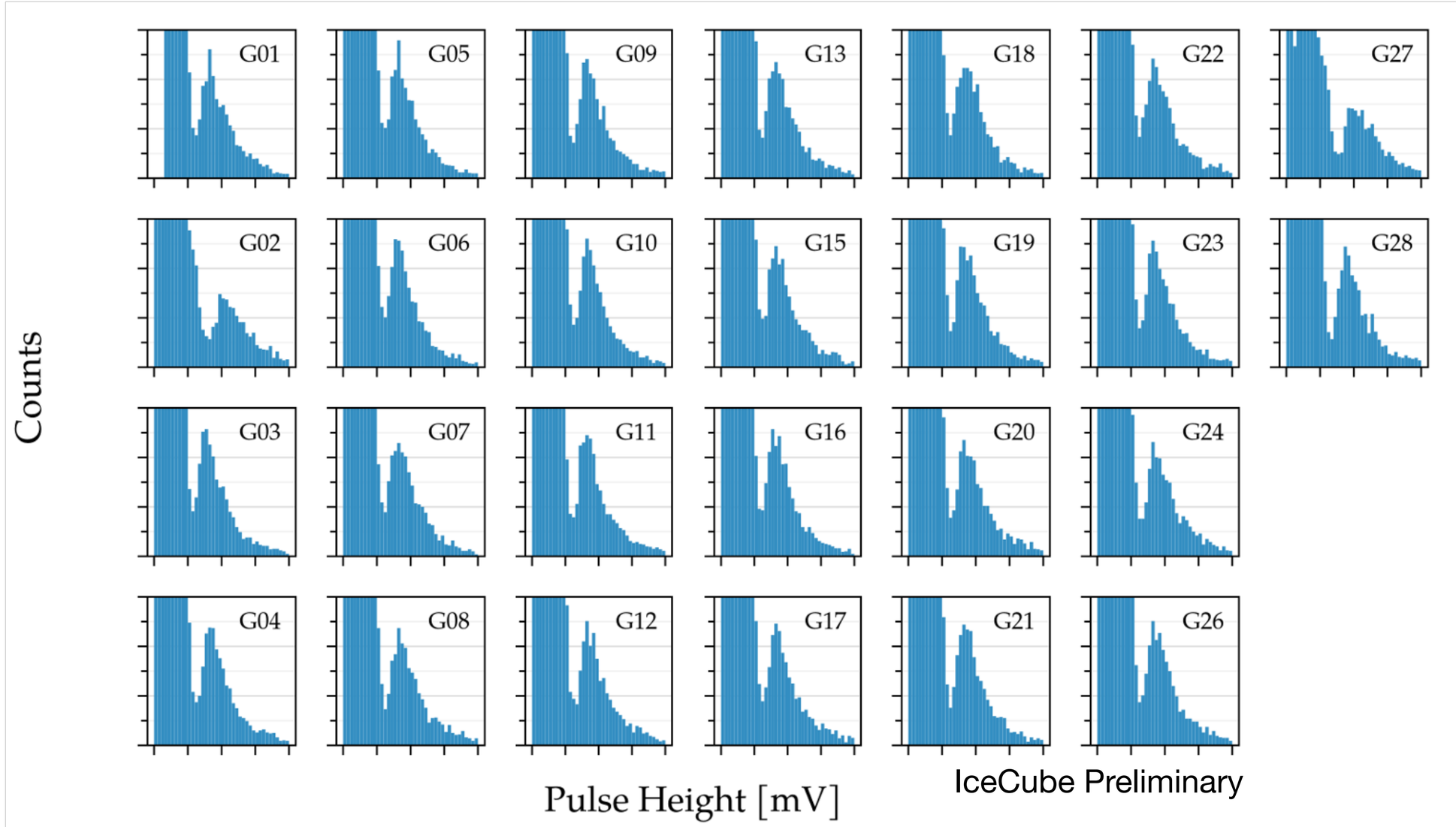




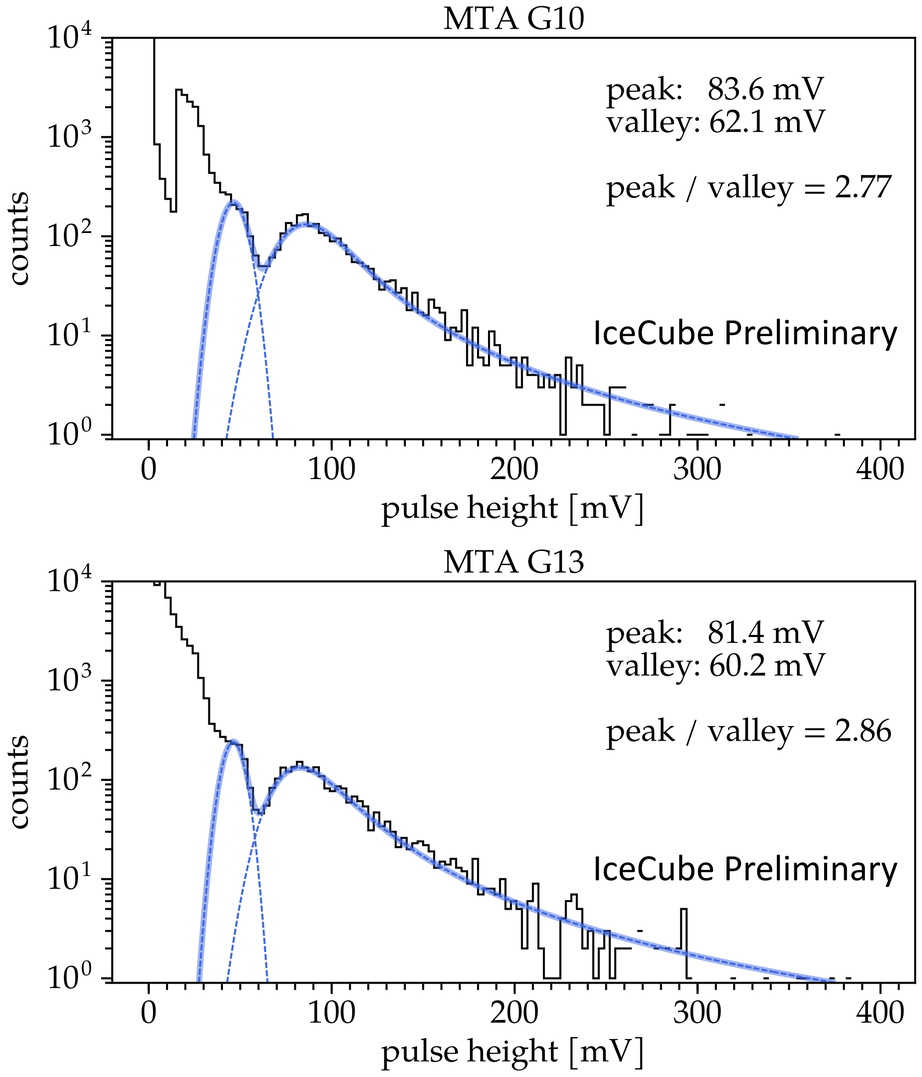
Clear muon/background separation seen in all scintillators

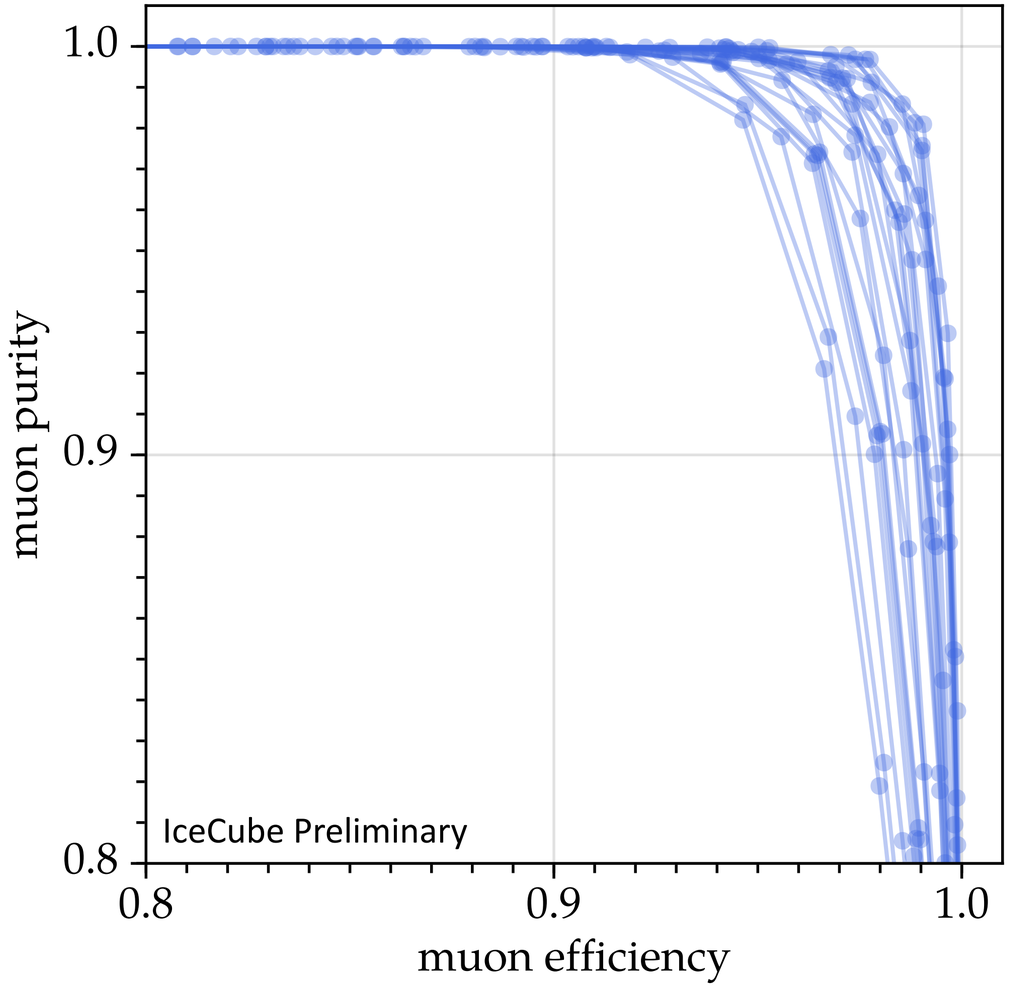


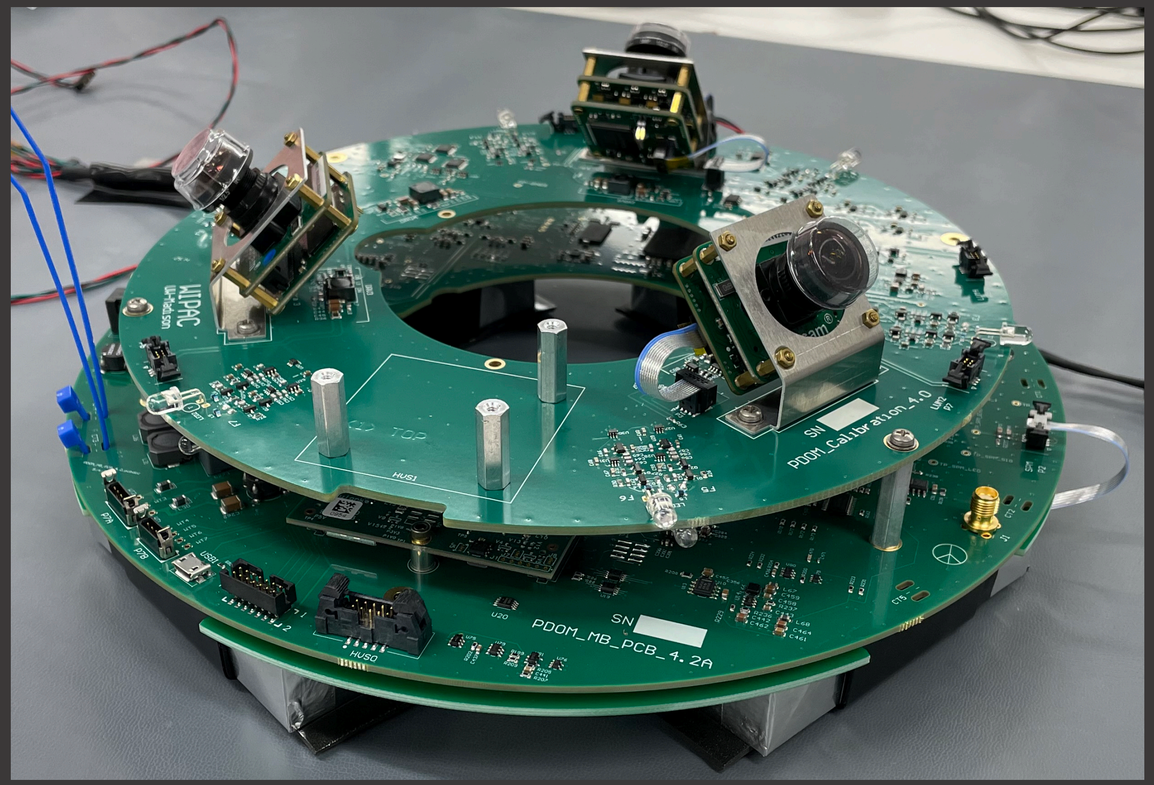
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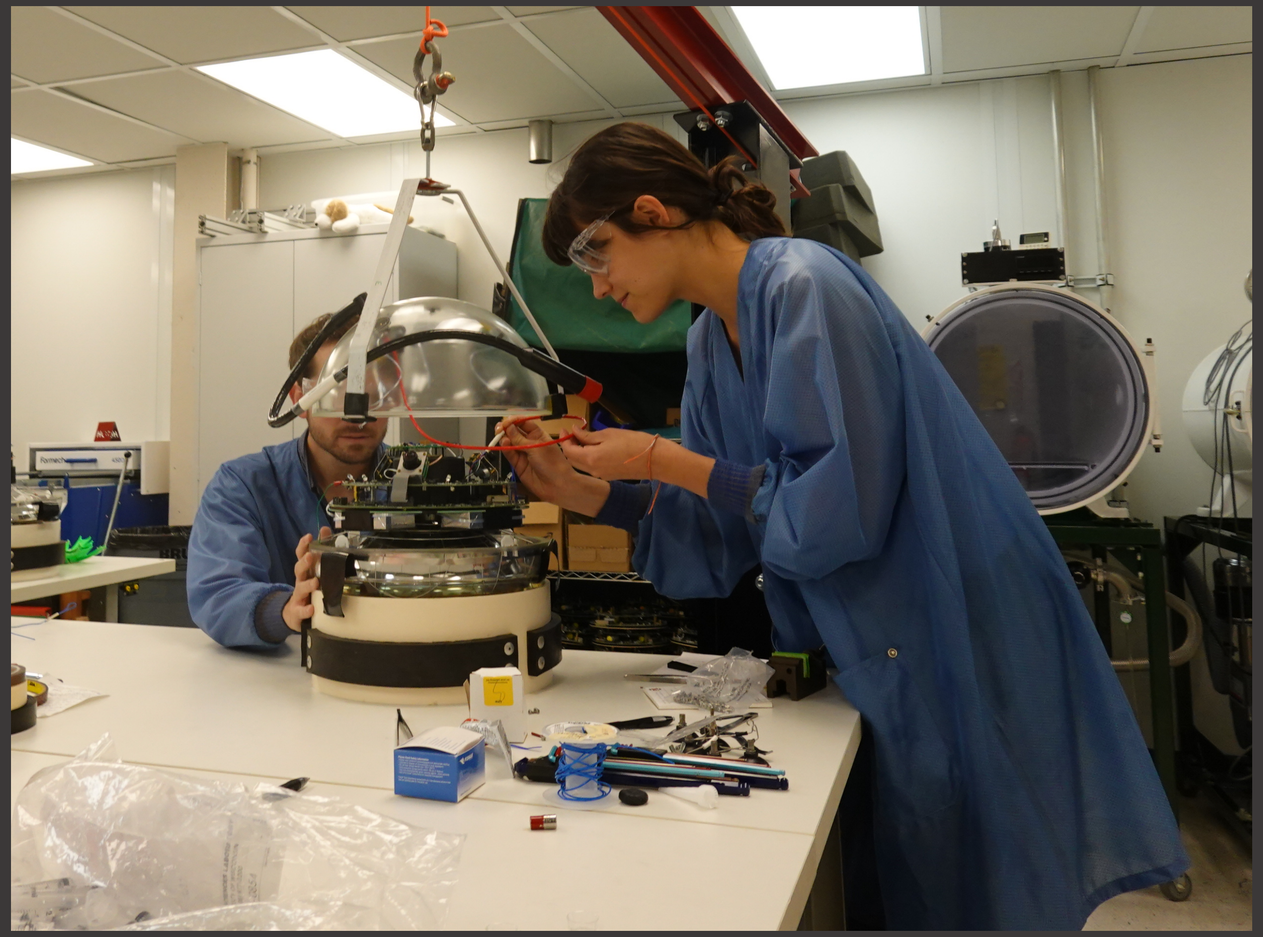


Large signal-to-background separation achieved in all modules






HUPAC
UH+Radison
TOP
SN
PDOM_Calibration_4.0
SN
PDOM_MB_PCB_4.2A

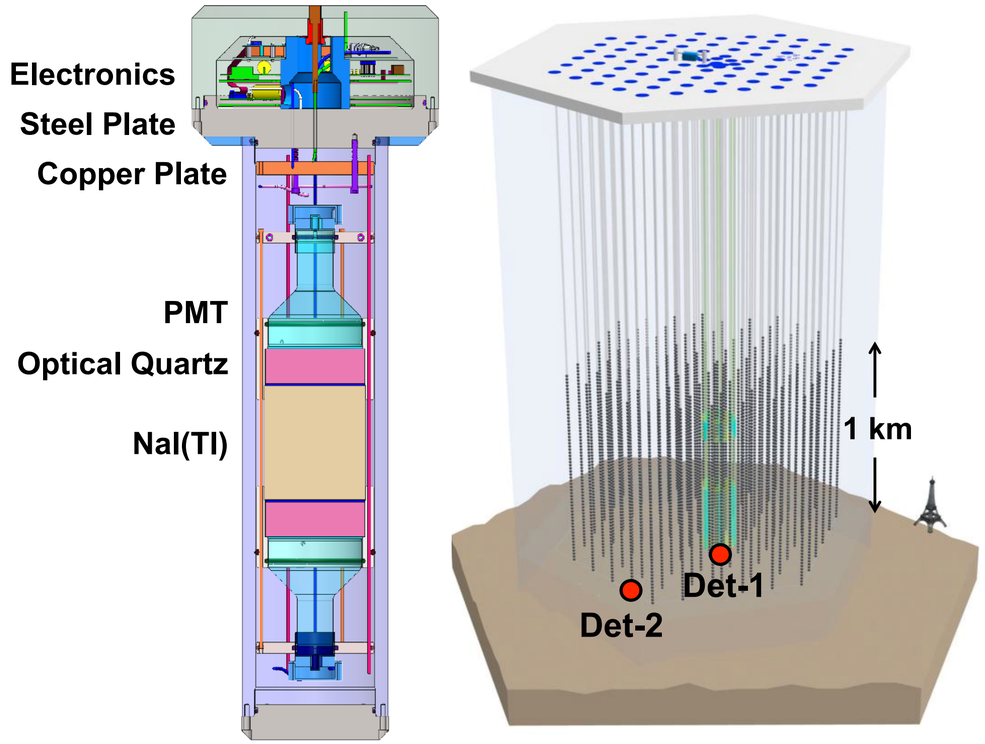


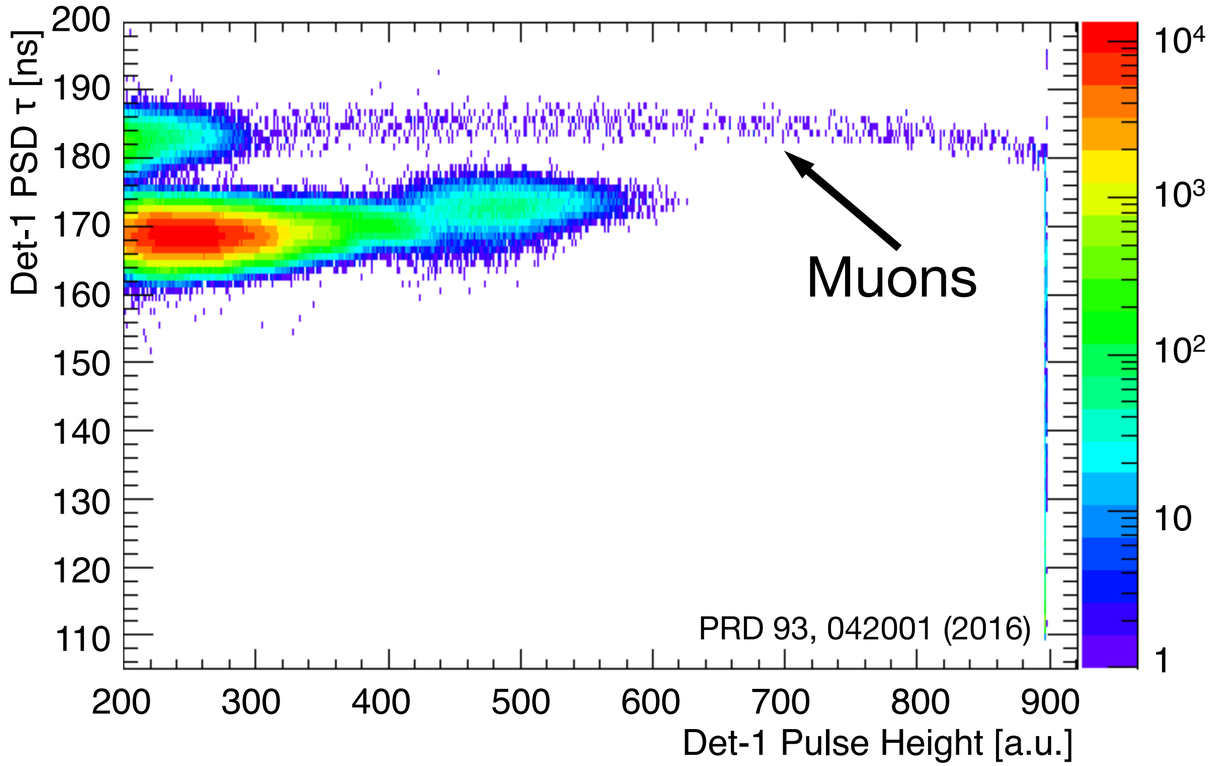

PDOM
ee9
PDOM
2d4
CONDENSATION
PDOM
ac5
BIOLOGIST TRAINTER
PDOM
Ød4
EDGE PROTECTORS
ULINE


PDOM
ac5
PDOM

Are there standard arrows hiding in data we've already taken?

Tagging muons with DM-Ice





DM-Ice: NaI(Tl) detectors deployed under IceCube for dark matter searches

… and a highly localized muon tagger

Following up on work by Teppei Katori and Rogan Clark

Summary

Standard arrows — muon tracks with high angular precision — enabled by tagging muons

Plastic scintillator muon tagger for IceCube Upgrade built and deployed in ice

Expect 20k tagged μ/yr from 12 muon taggers

Would like to explore possibilities in other neutrino telescopes; reach out if interested!