Scintillator Detector Design & Integration

Will Thompson

TAMBO 101

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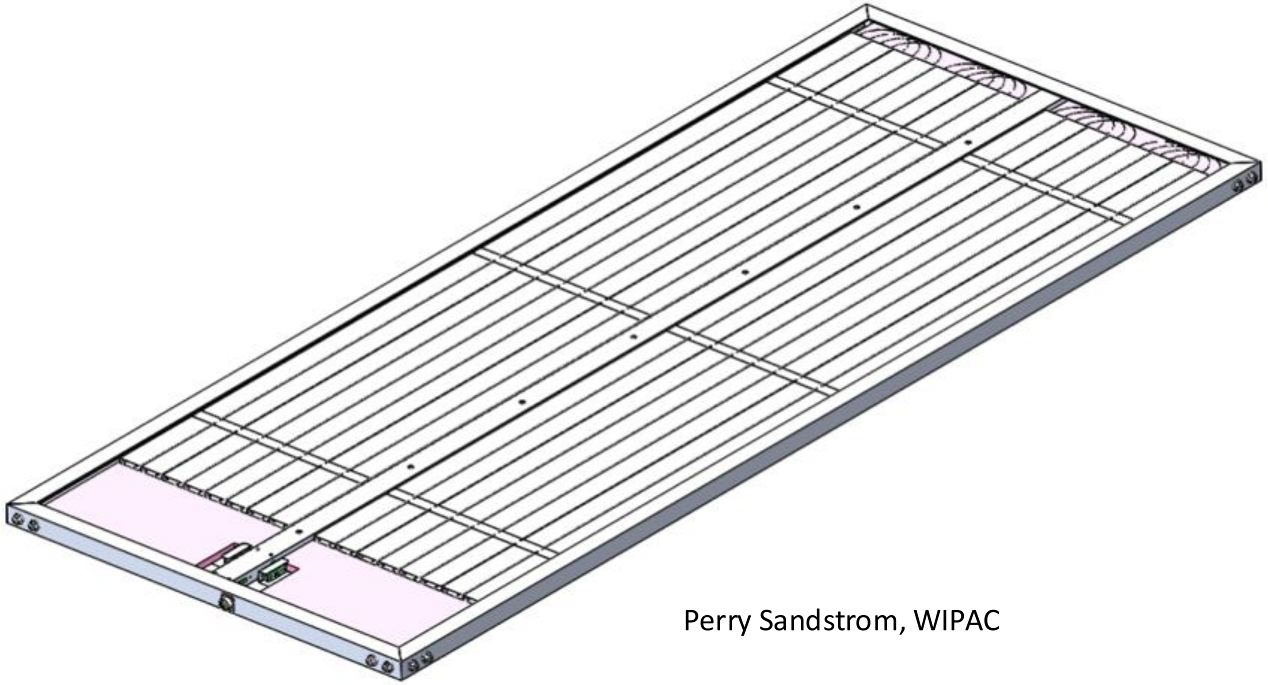
Scintillator Detector Background

- Scintillators commonly used in air-shower detectors, particularly to detect muons

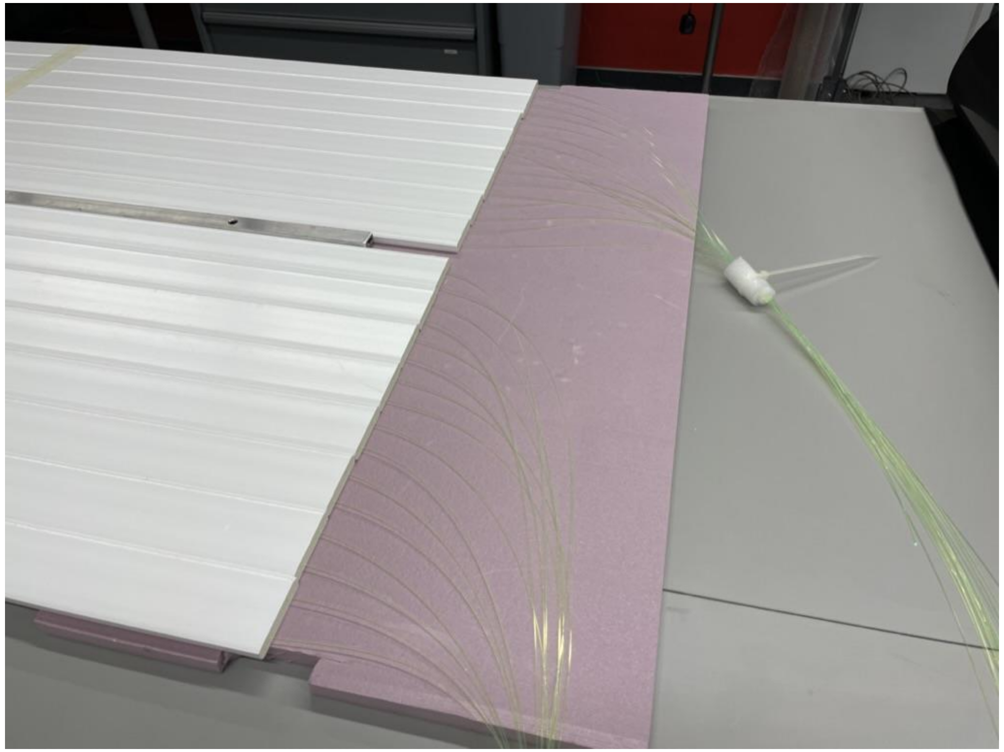
- Basic operating principle:
  - High-energy particle hits scintillator → scintillation light produced → routed to photodetector via fiber → SiPM produces electronic signal

- ”Baseline” design is essentially detectors used in IceCube
  - Design courtesy Perry Sandstrom (thanks!)
  - Lots of free materials from WIPAC (also thanks!)

Baseline Design Overview

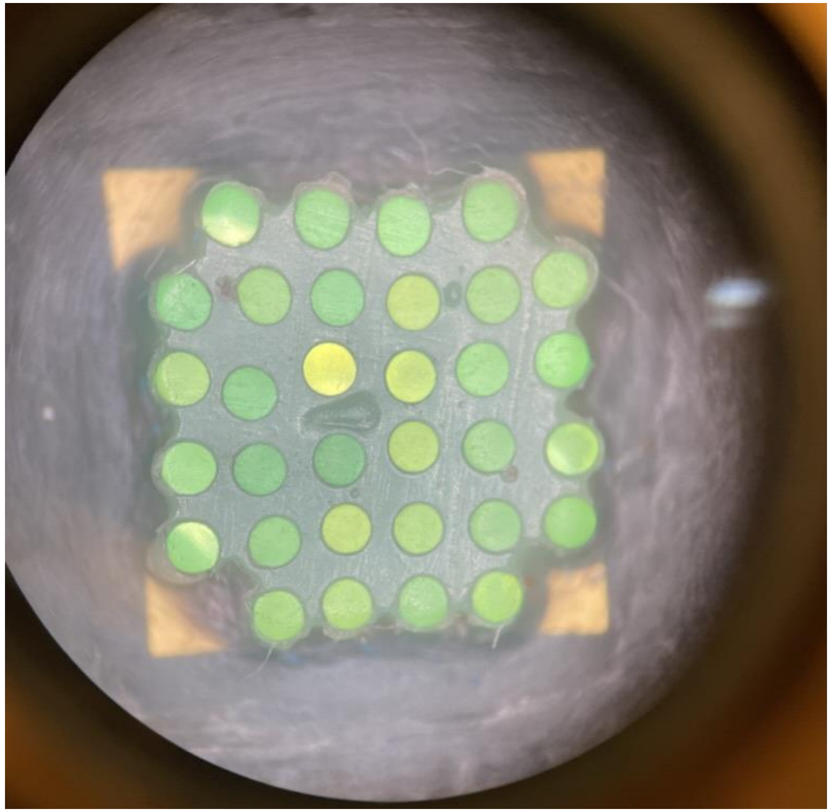


Perry Sandstrom, WIPAC



- 16, 1.875m x 5 cm scintillator bars
- Coated with TiO_2 for specular reflection
- Threaded with 0.7 mm diameter wavelength-shifting optical fiber
- Electronics inside module; external device (communications) can just plug in

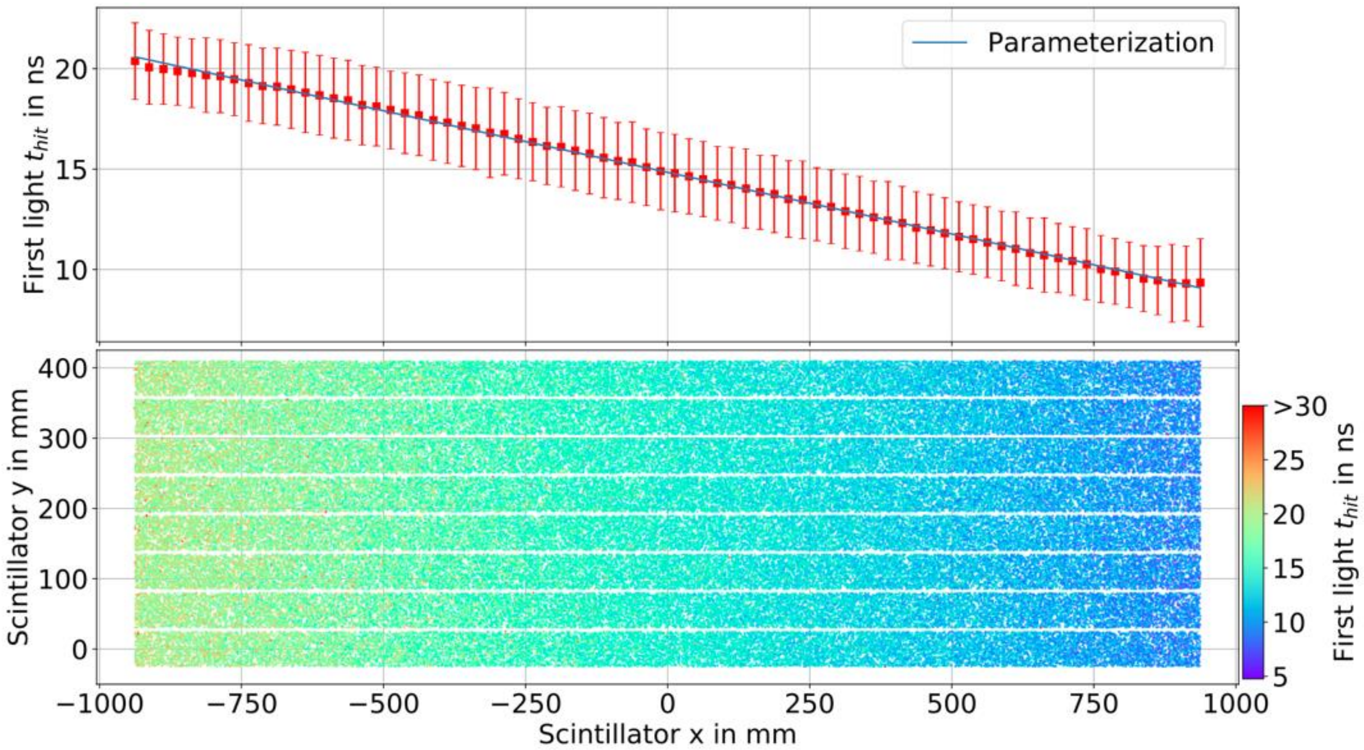
Fiber Coupling



- Probably the most tedious part of the process
- Some care needed when grinding/polishing fibers

Adapting for TAMBO: Timing Resolution

- Timing resolution of current design (~22 ns) insufficient for TAMBO pointing requirements
- Few optimization options:
  - Instrument both ends with SiPMs (improvement TBD)
  - Shorten scintillator length (time resolution ∝ length)
- Working on developing Geant4 simulation for prototyping

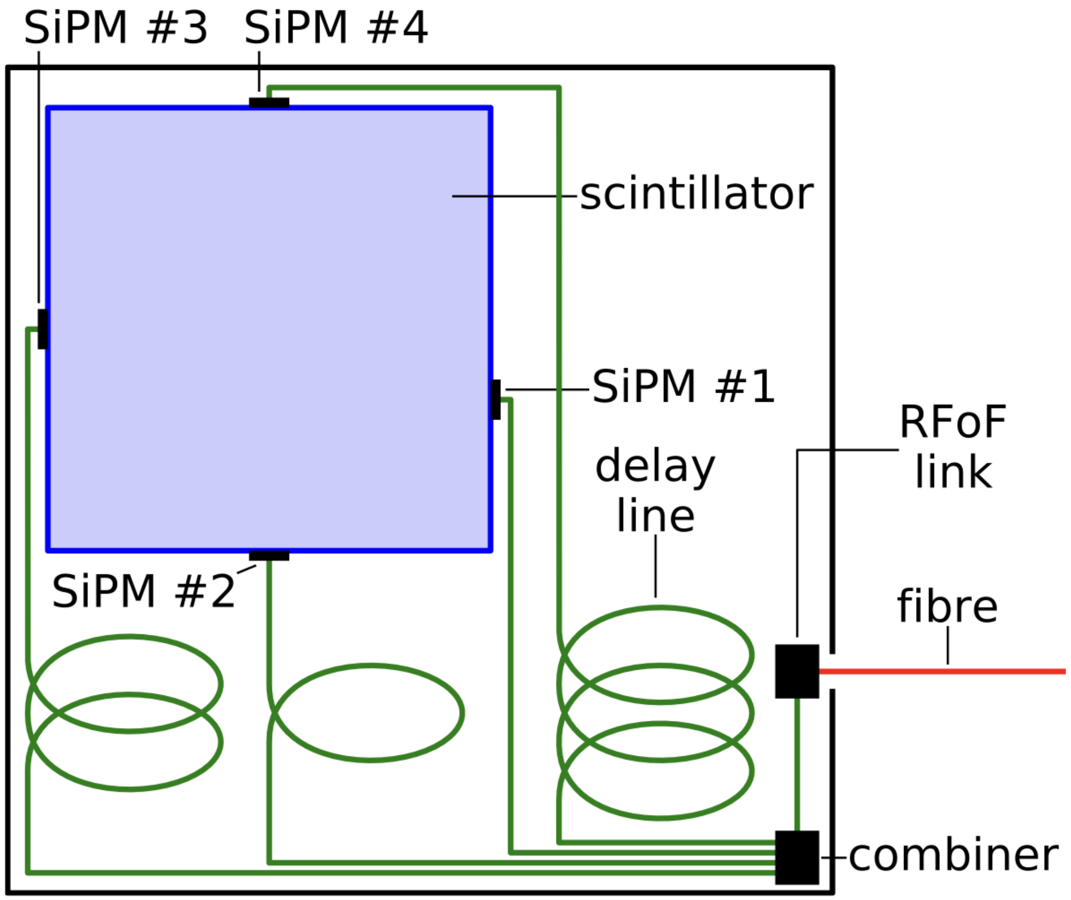


Thomas Huber PhD Thesis

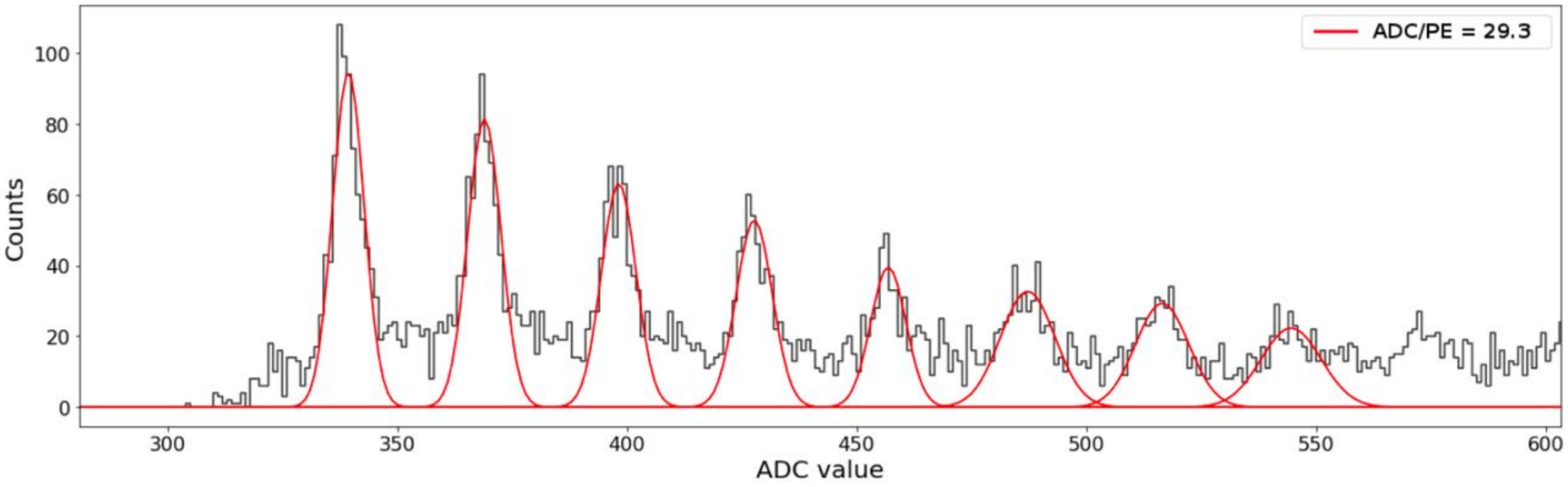
More Radical Changes Also Possible

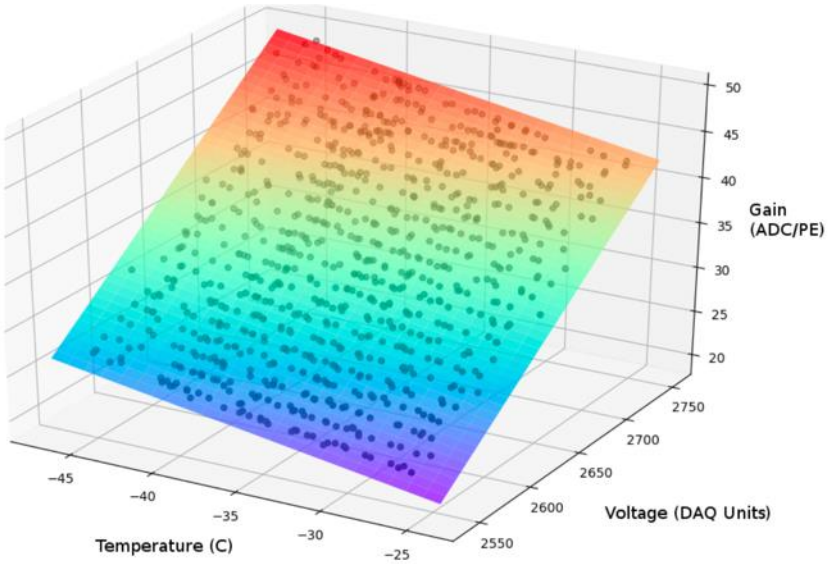
- Current panel design uses wavelength-shifting fibers to maximize light collection (~40 photons/MIP)
  - Fiber is biggest expense on each panel, $336 per panel with $1681 panel cost
  - ~64m of fiber per panel → almost enough to stretch from Boston to Chicago (20,000 panels)

- What about no fiber & more SiPMs?
  - [SKA (right) design:] 1 m^2, 4 SiPMs, no fiber
  - Claim ~65 photons/MIP for central crossing
  - Multi-scintillator module?



SiPM Temperature Compensation

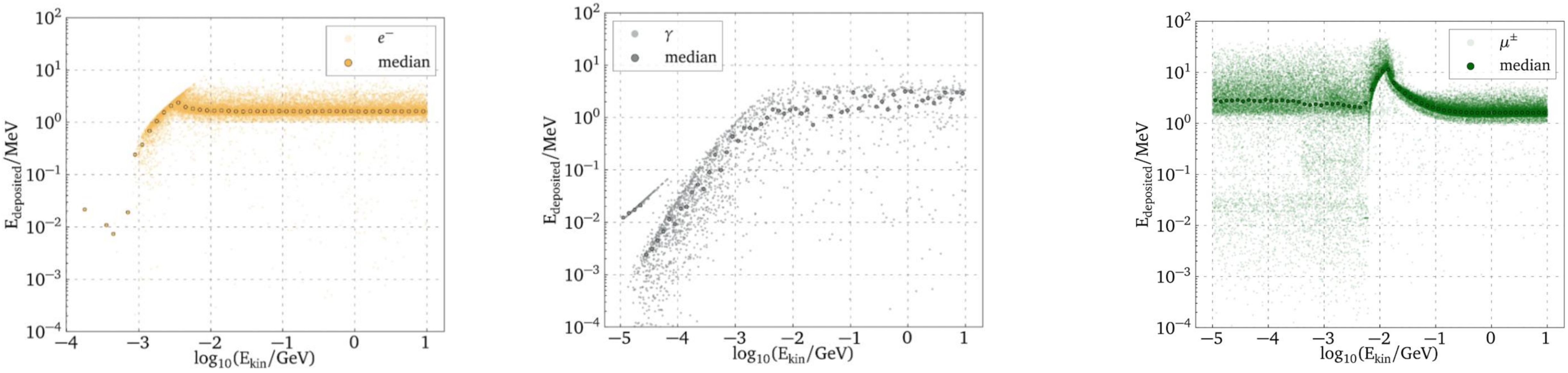




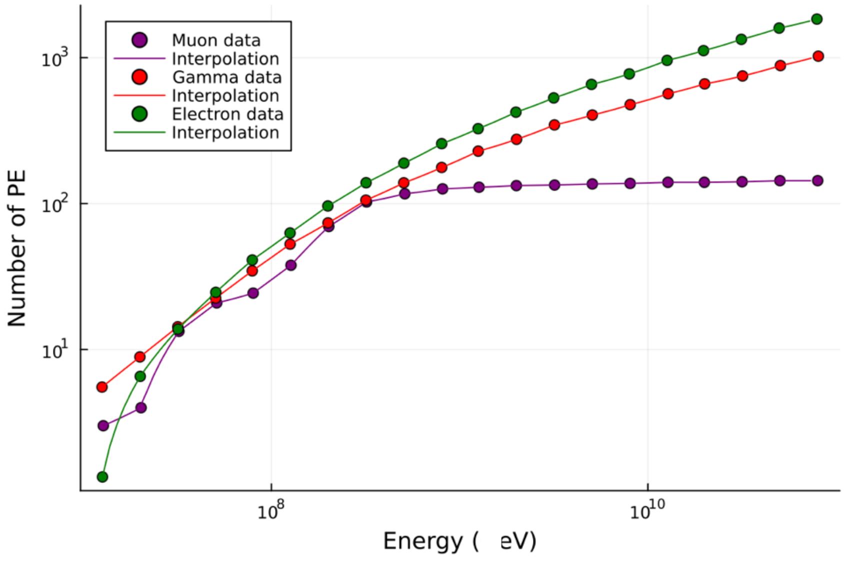
- SiPM gain fluctuates significantly with temperature changes
  - Mainboard can compensate by adjusting bias voltage if gain(temperature, voltage) known

- Need a laboratory measurement of SiPM to determine this function

Negatives of Scintillator: Poor Gamma Sensitivity



- Typical shower contains ~10x as many gammas as muons
  - They are also lower energy → less light produced in detector
  - Gamma energy losses also more stochastic than muons



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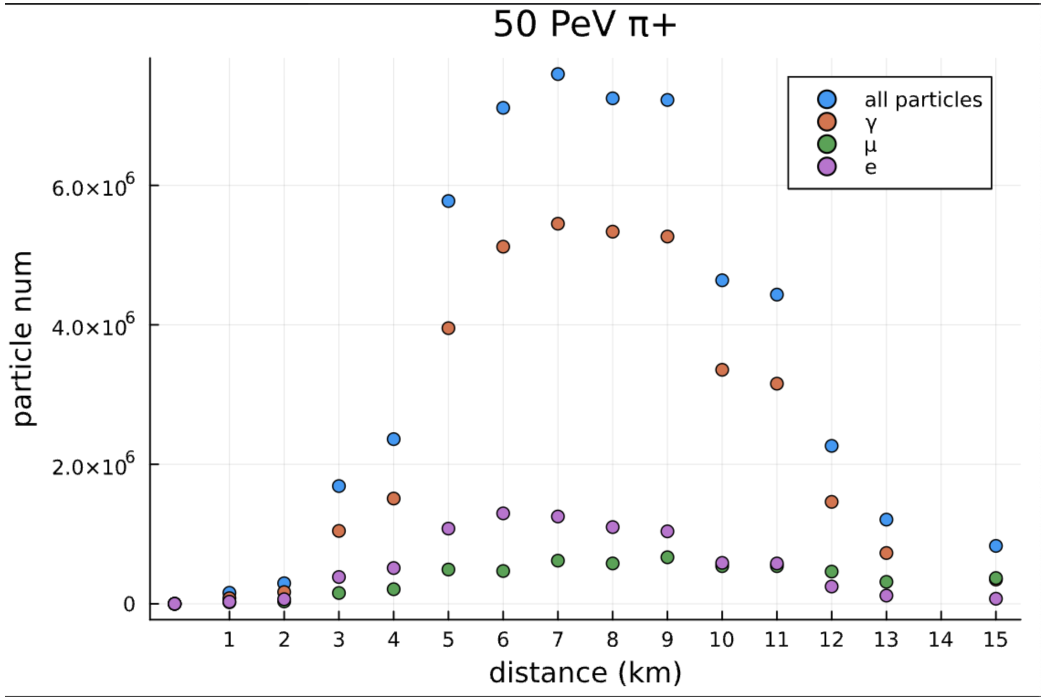
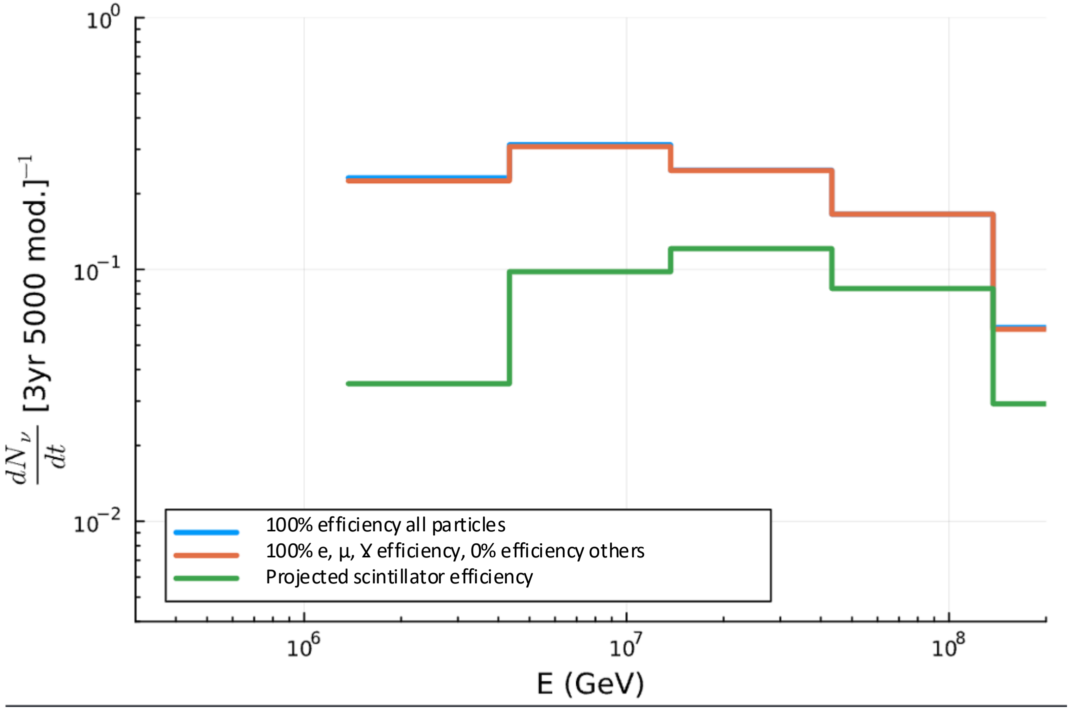
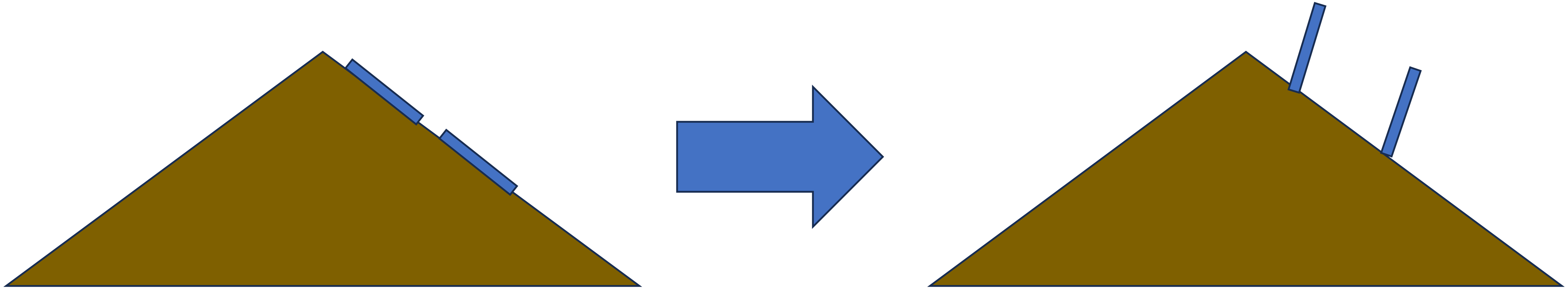




- Typical shower contains ~8x as many gammas as muons
  - They are also lower energy → less light produced in detector
  - Results in a large hit in detection efficiency

Caveat: Directionality of Scintillator Panels



- Scintillator panels are highly directional; should be angled off of valley face
- Simulation currently has them laying flat
  - This is probably the least optimal position, so rate should increase

Integration with Main DAQ Station

- Entirely undefined