Measurement of large angle muon flux in GRAPES-3 experiment using triggerless DAQ system

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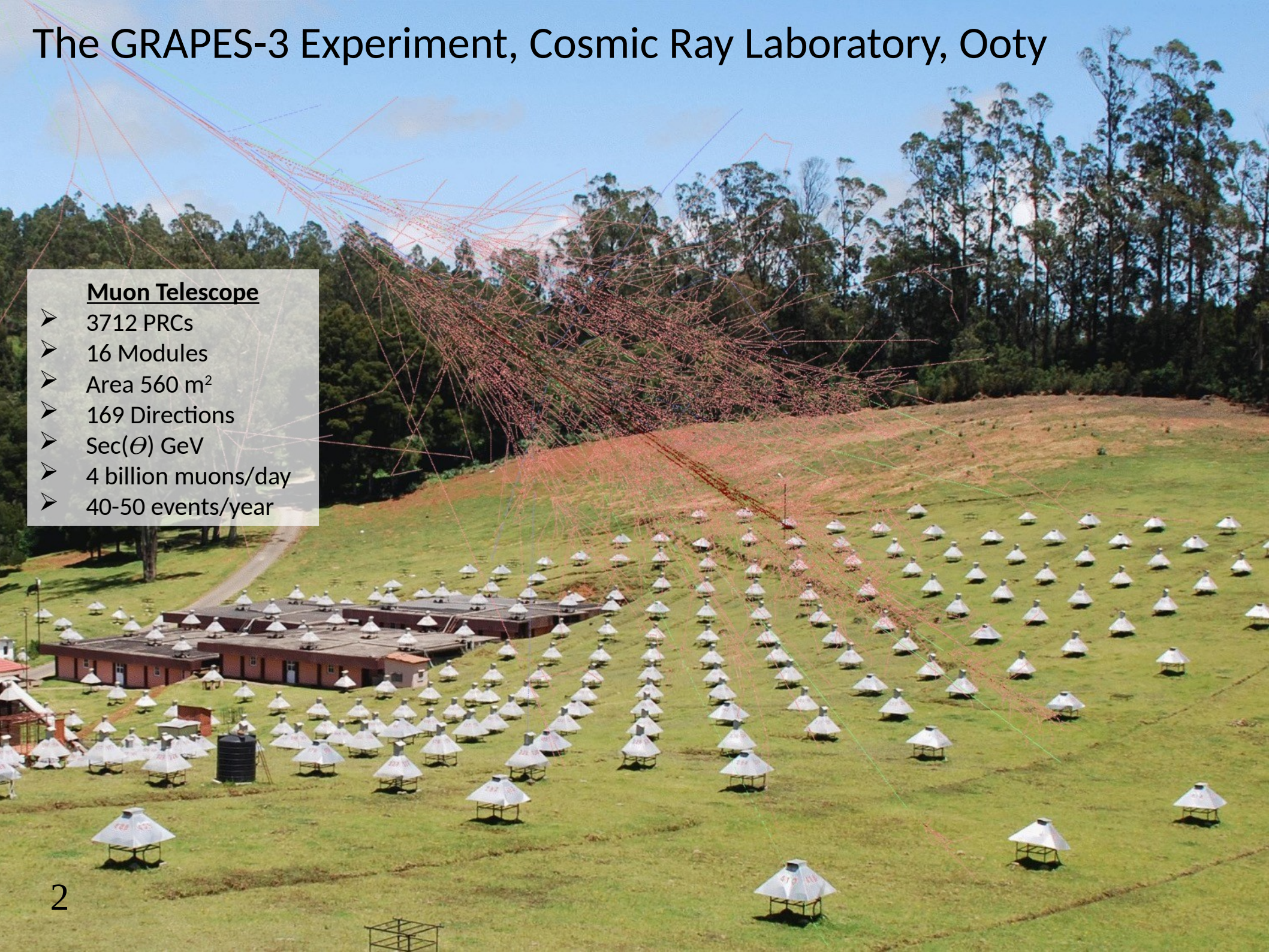
The GRAPES-3 Experiment, Cosmic Ray Laboratory, Ooty



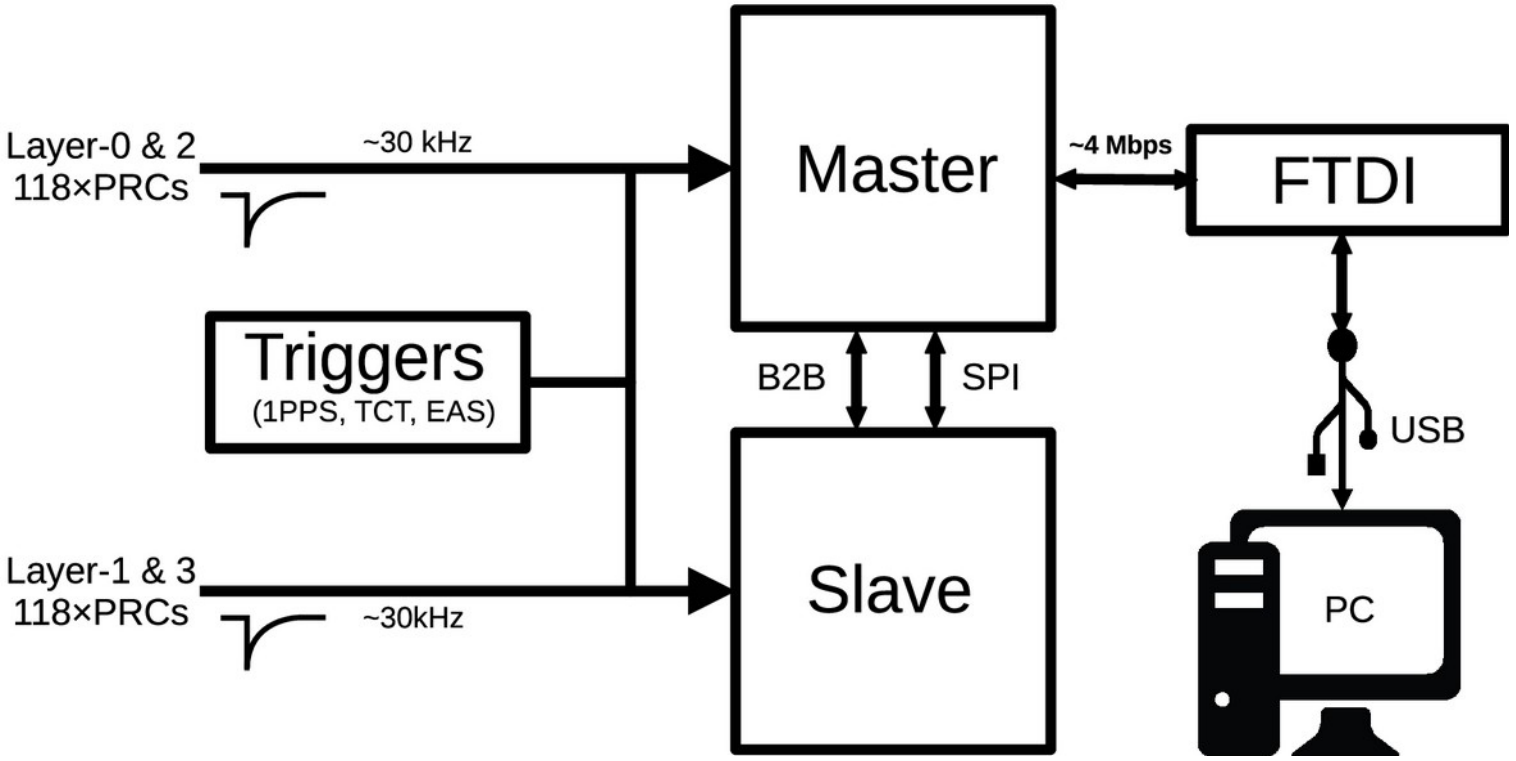
Muon Telescope

- 3712 PRCs
- 16 Modules
- Area 560 m^2
- 169 Directions
- Sec(θ) GeV
- 4 billion muons/day
- 40-50 events/year

Conventional DAQ

- Decades old electronics
- Independent DAQs
  - EAS muon component
  - Angular muon flux
- Limited information
- Angular coverage < 45°
- Dead time ~12%

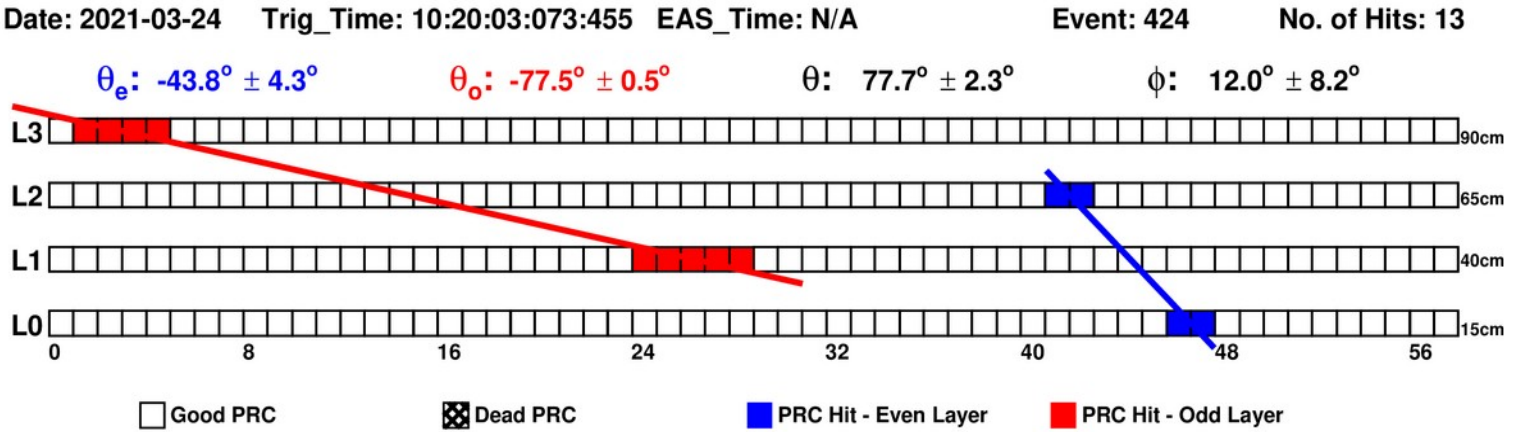
The new triggerless DAQ

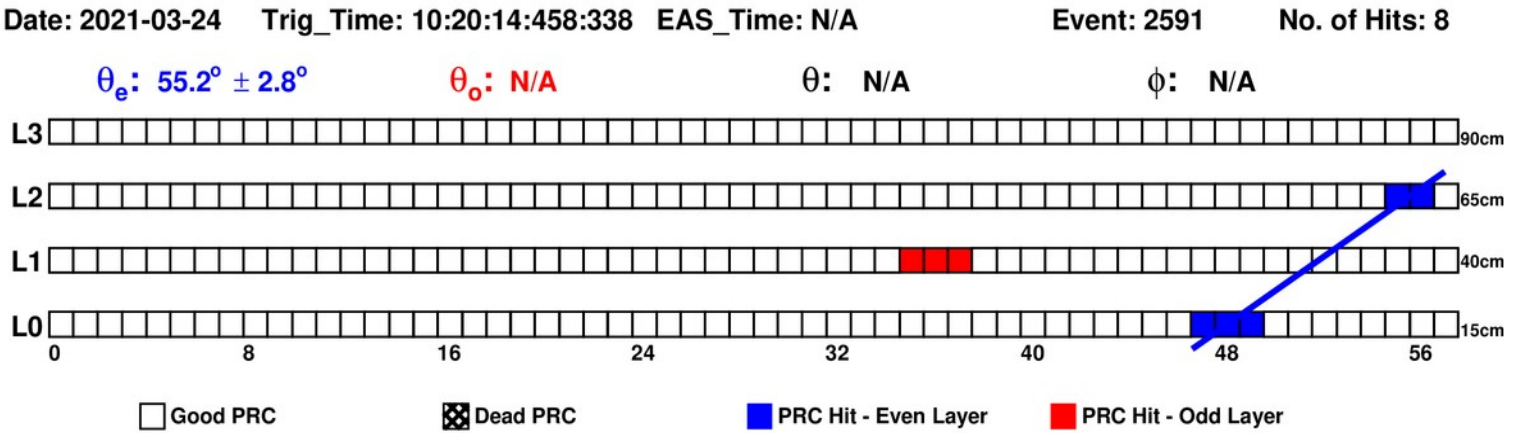


The new triggerless DAQ

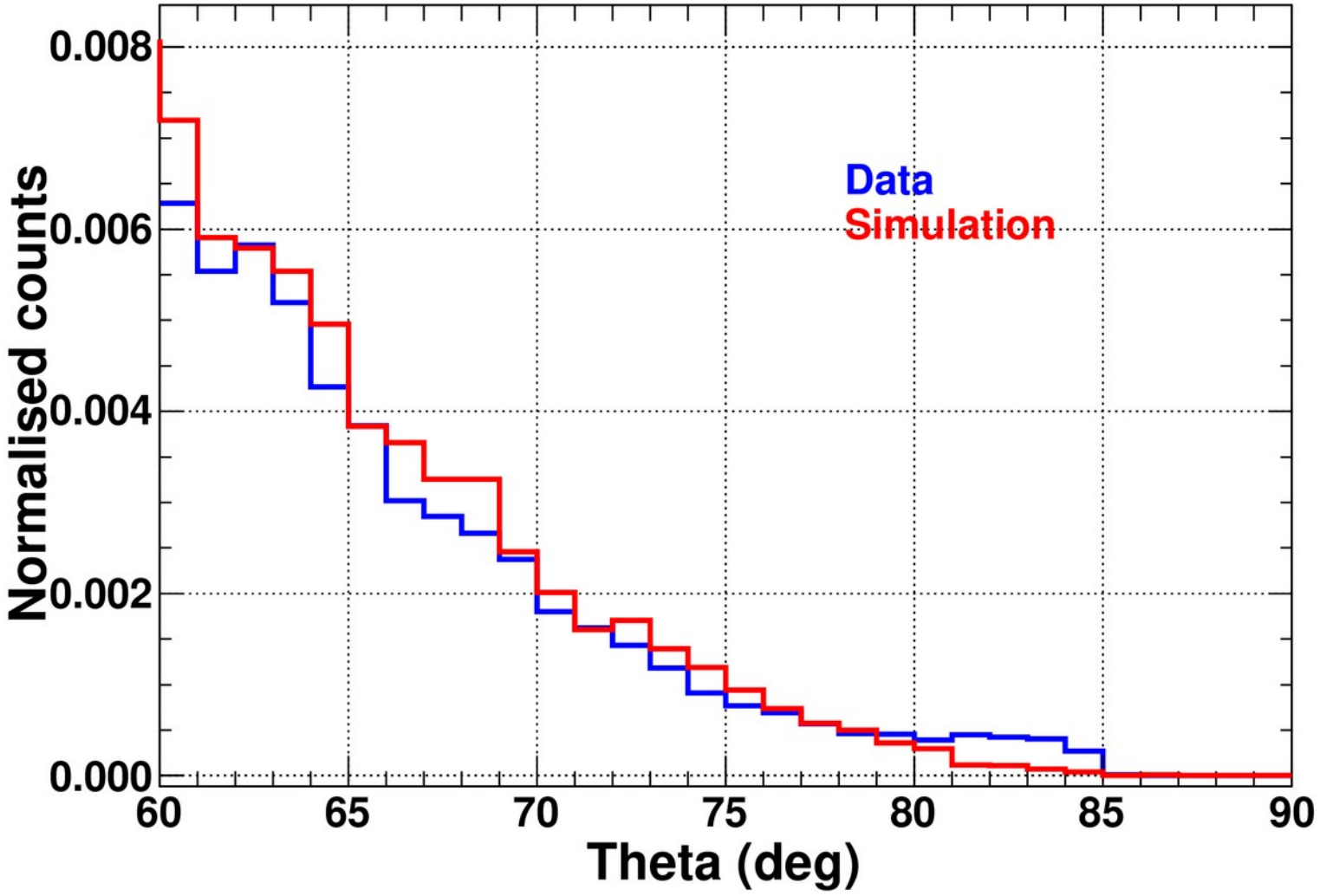
- ALICE FPGA card
- Onboard 100 MHz and 50 MHz clock
- Time resolution 10 ns
- Pulse width-time and count rate monitoring
- I/P signal rate ~60 kHz
- O/P data rate ~4 Mbps
- Dead time ~0.001%

Large angle muons





Zenith distribution

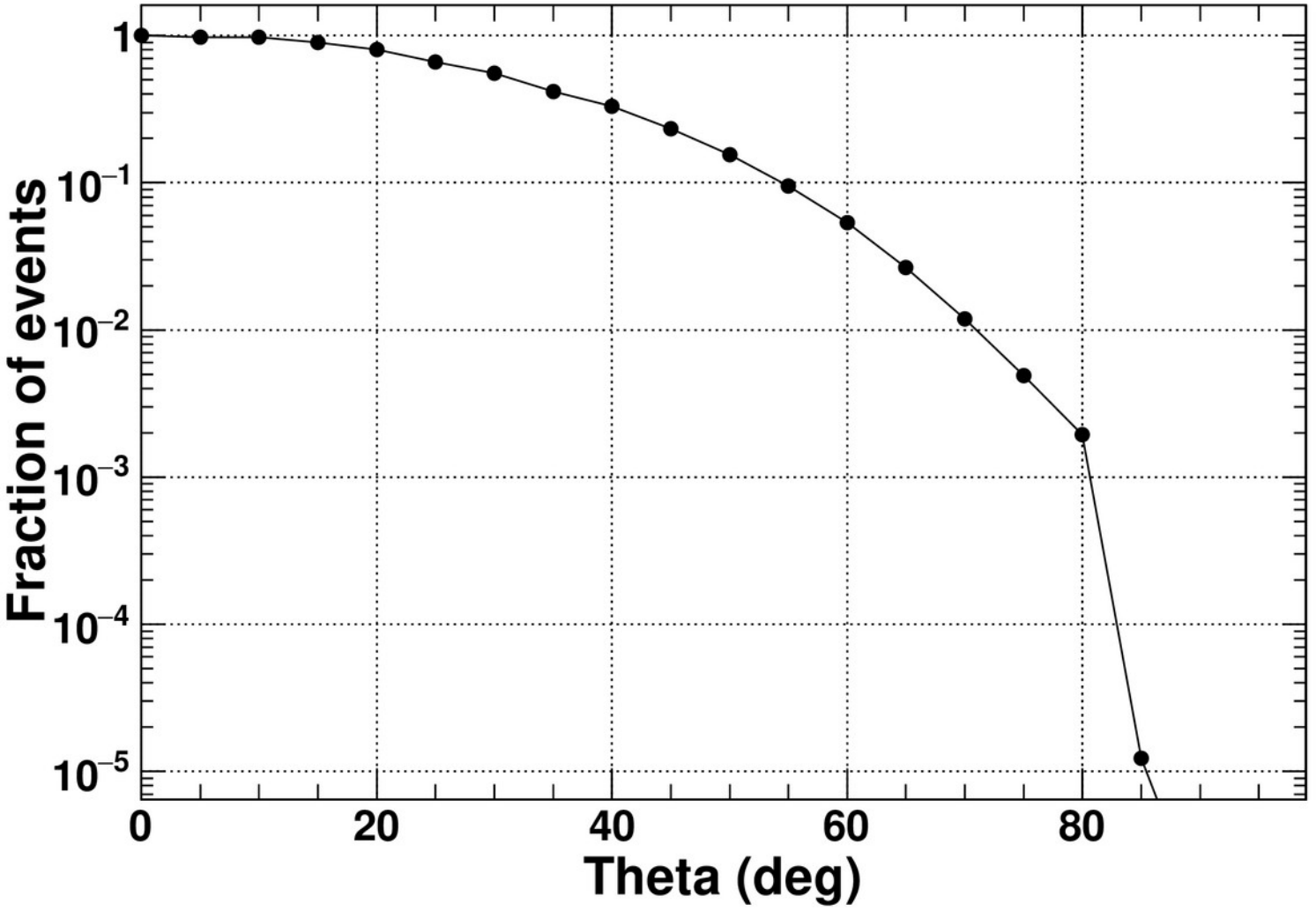


Data: 4-fold and θ > 60°

MC: CORSIKA v76900

Proton, 10^{10} – 10^{12} eV, 0 ≤ θ ≤ 85°

Zenith distribution



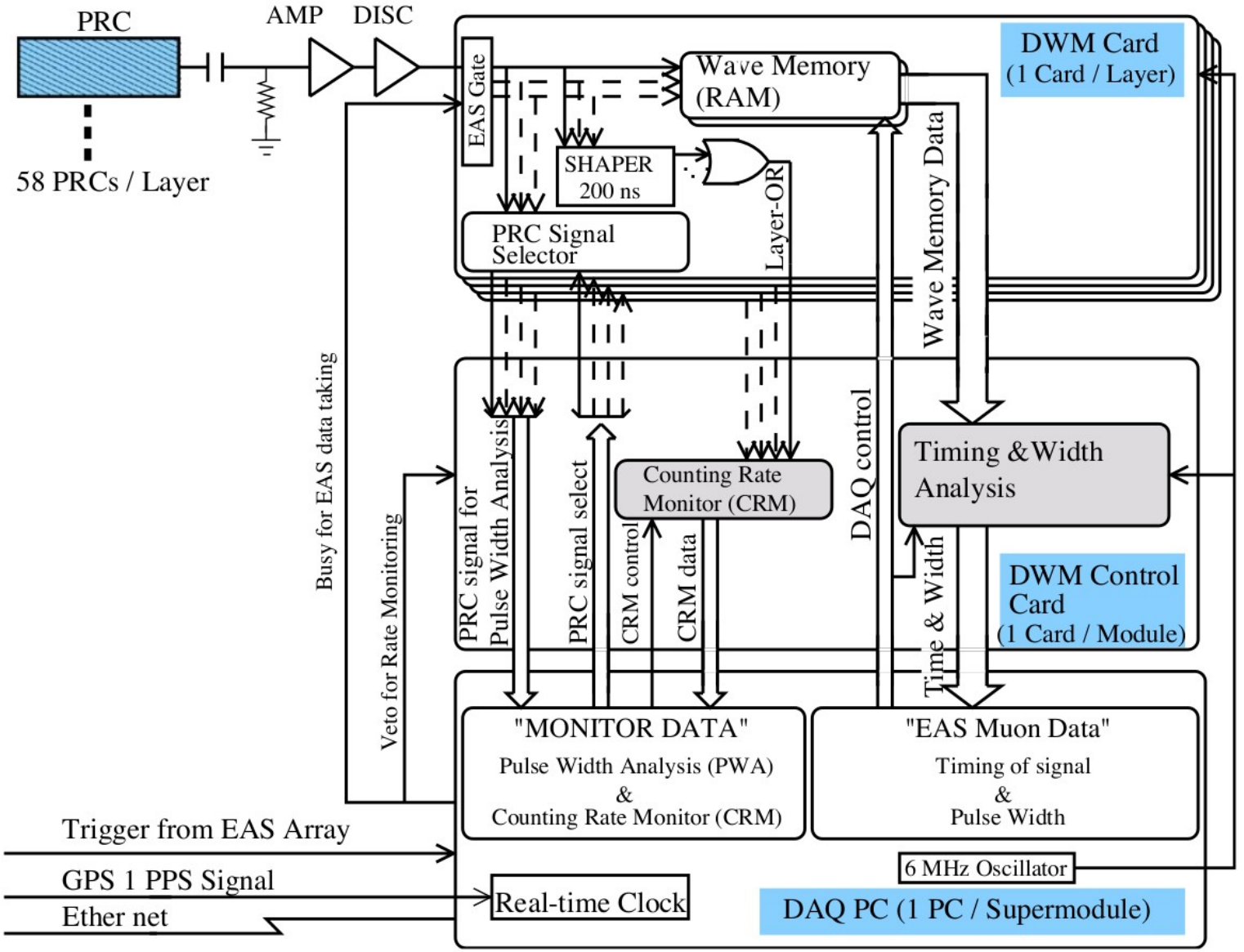
Data: 4-fold and θ > 60°

Conclusions

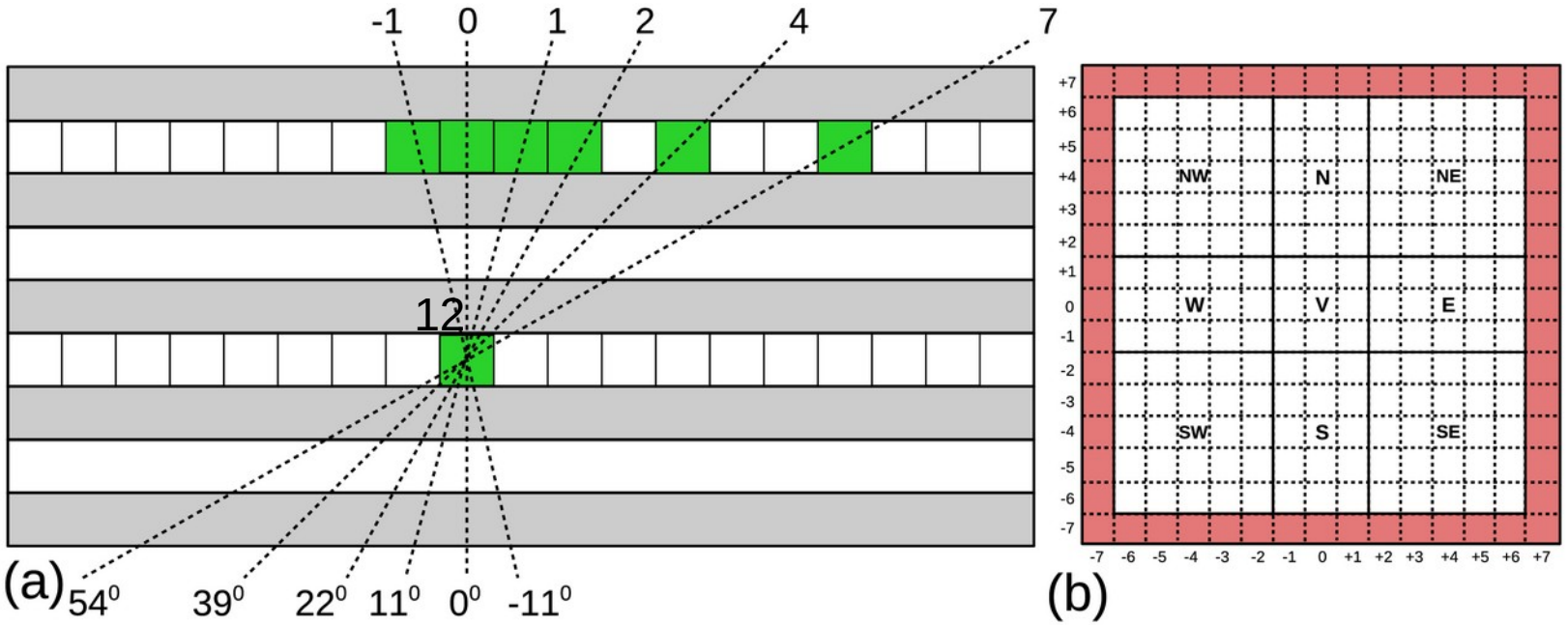
- DAQ designed to be triggerless
- Deployed for 25% of the telescopes
- Offline software trigger
- Ability to identify muons with timestamp (10 ns resolution)
- Large angle muons
- Extending the physics scope of the detector

Thank You

Conventional DAQ



Conventional way of direction reconstruction



Direction reconstruction

- Preparation
  - Formation of normalised time using 100 MHz clock count
  - Sorting the PRC hits based on normalised time
- Identification of clusters
  - Successive hits (N) delay < 1.1 μs
  - Minimum N = 2
  - Trigger time: T = last hit time if N <= 6
  - T = middle hit time if N > 6

Direction reconstruction

- Direction (θ, ϕ) determination
  - Identification of blocks in each layer
  - Blocks' coordinates are plotted and fitted for each projection (i.e. Even: L0 & L2, Odd: L1 & L3)
  - From the slopes (S) of least square fitting

$$\theta_{e,o} = \arctan\left(S_{e,o}\right)$$

$$\theta = \arctan\left(\sqrt{S_e^2 + S_o^2}\right) \qquad \phi = \arctan\left(S_o^2 / S_e^2\right)$$