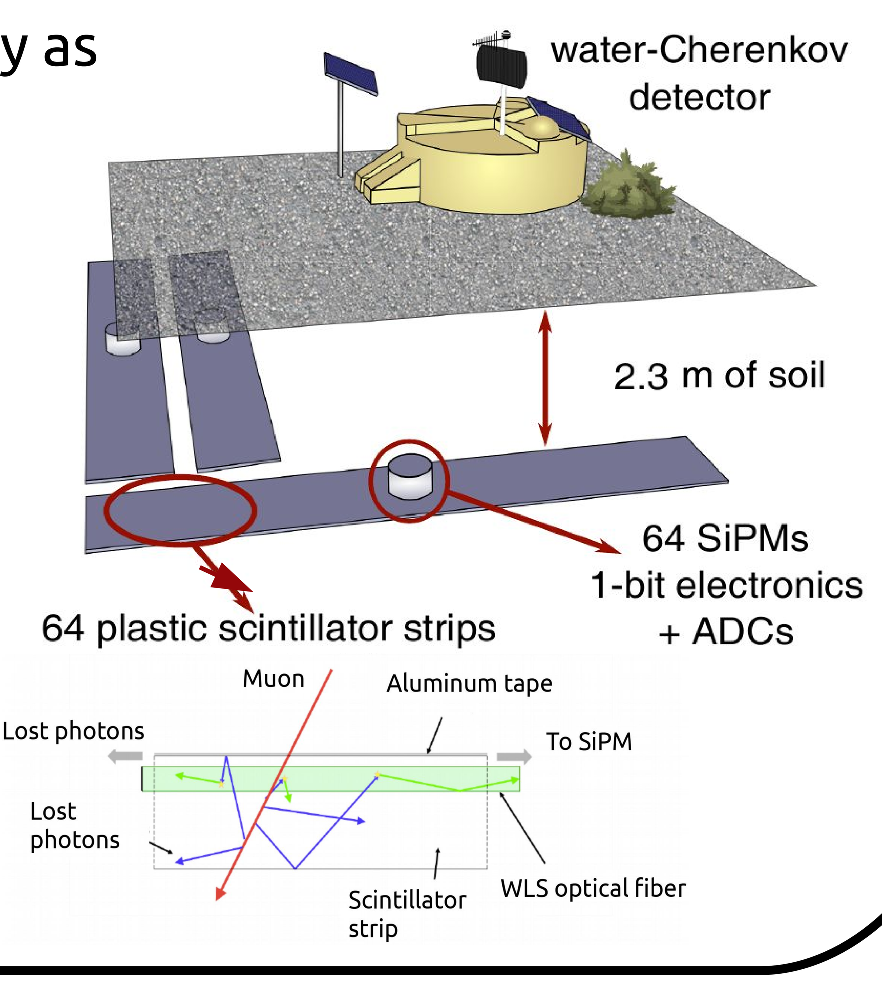
Data-driven method to quantify and correct the corner-clipping effect in segmented muon counters

J. de Jesús[a,b], J.M. Figueira[a], F. Sanchez[a], D. Veberič[b]

a) Instituto de Tecnología en Detección y Astropartículas (CNEA, CONICET, UNSAM), Buenos Aires, Argentina
b) Karlsruhe Institute of Technology (KIT). Institute for Astroparticle Physics (IAP), Karlsruhe, Germany

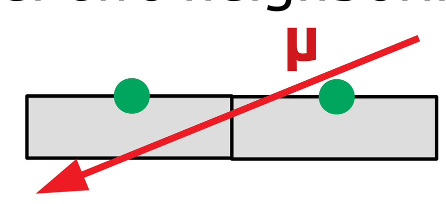
Underground Muon Detector (UMD) [1]

- Use UMD of the Pierre Auger Observatory as an example
- Array of muon detectors buried in the vicinity of water-Cherenkov detectors
- Each detector comprises 3 modules of 10 m² of plastic scintillator
- Each module is segmented into **64 independent strips**
- Muon signal → a bar is triggered if signal is above threshold for ≥ 12.5 ns

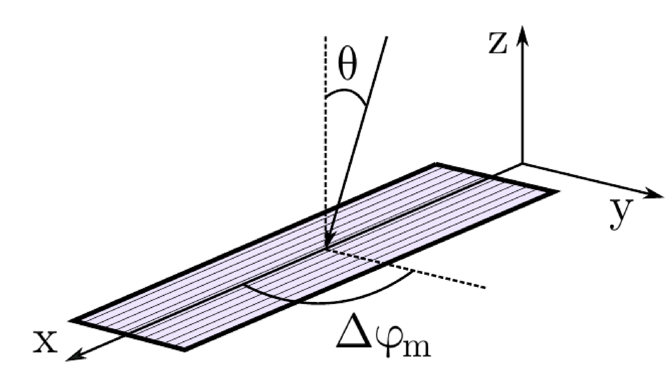


Corner-clipping muons

- An inclined μ may trigger two neighboring strips



- Effect dependent on the zenith and the azimuth of the muon w.r.t. the module



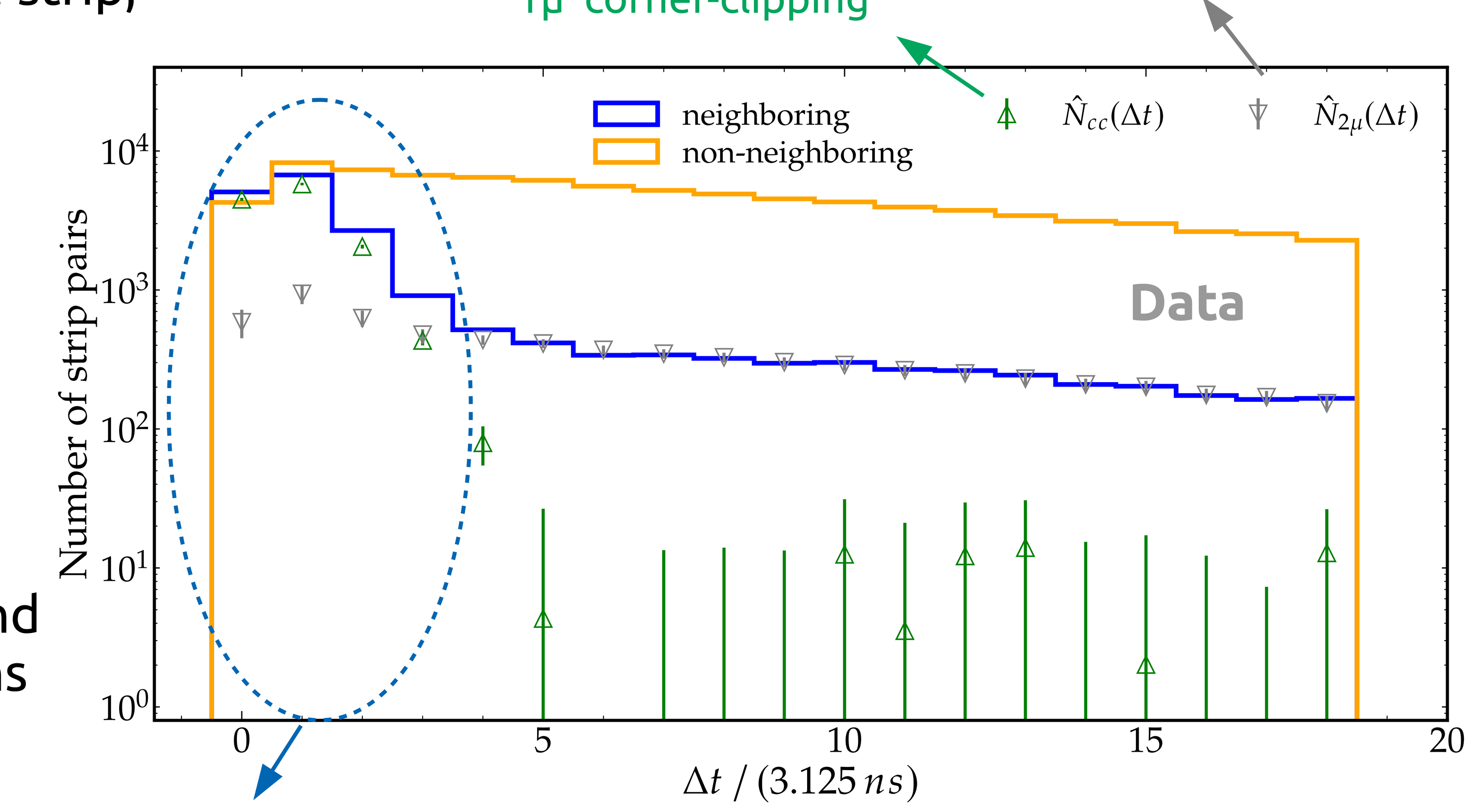
- Source of **bias**, leading to overcounting
- Previously accounted for with simulations

Single-muon corner-clipping probability

- When a single muon is injected into a module it can activate one strip, $N_{1\text{strip}}$, or two neighboring strips, N_{cc} (corner-clipping)
- Single-muon corner-clipping probability:

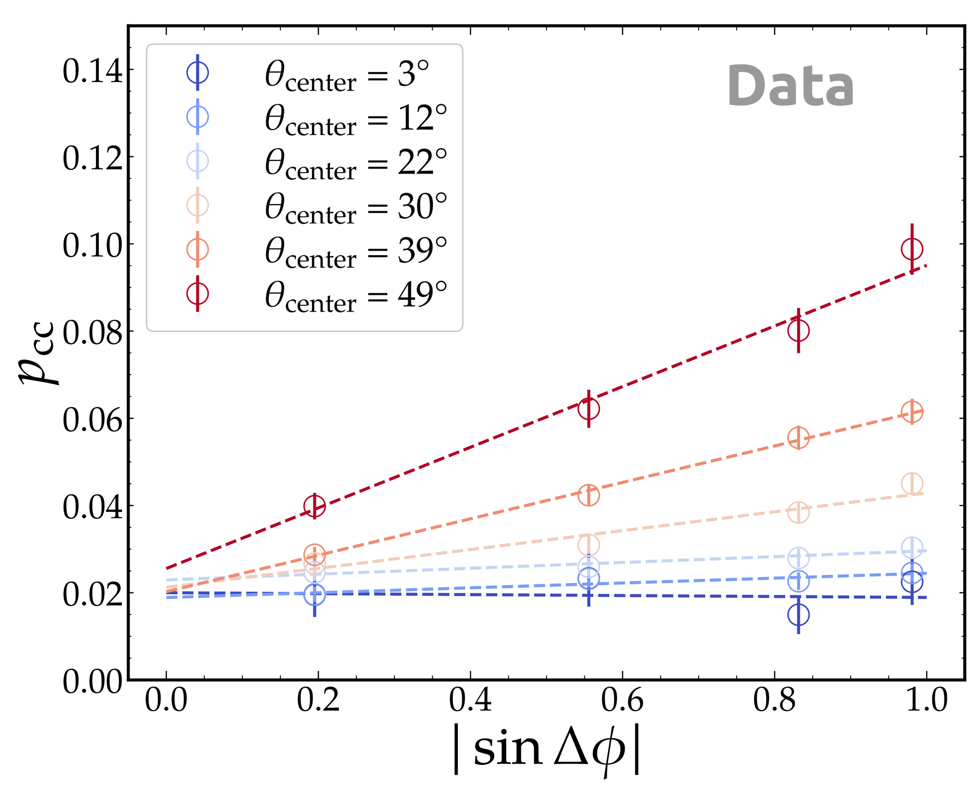
$$p_{cc}(\theta,\Delta\phi) = \frac{N_{cc}(\theta,\Delta\phi)}{N_{1\mu}(\theta,\Delta\phi)} \cong \frac{N_{cc}(\theta,\Delta\phi)}{N_{cc}(\theta,\Delta\phi)+N_{1\text{strip}}(\theta,\Delta\phi)}$$

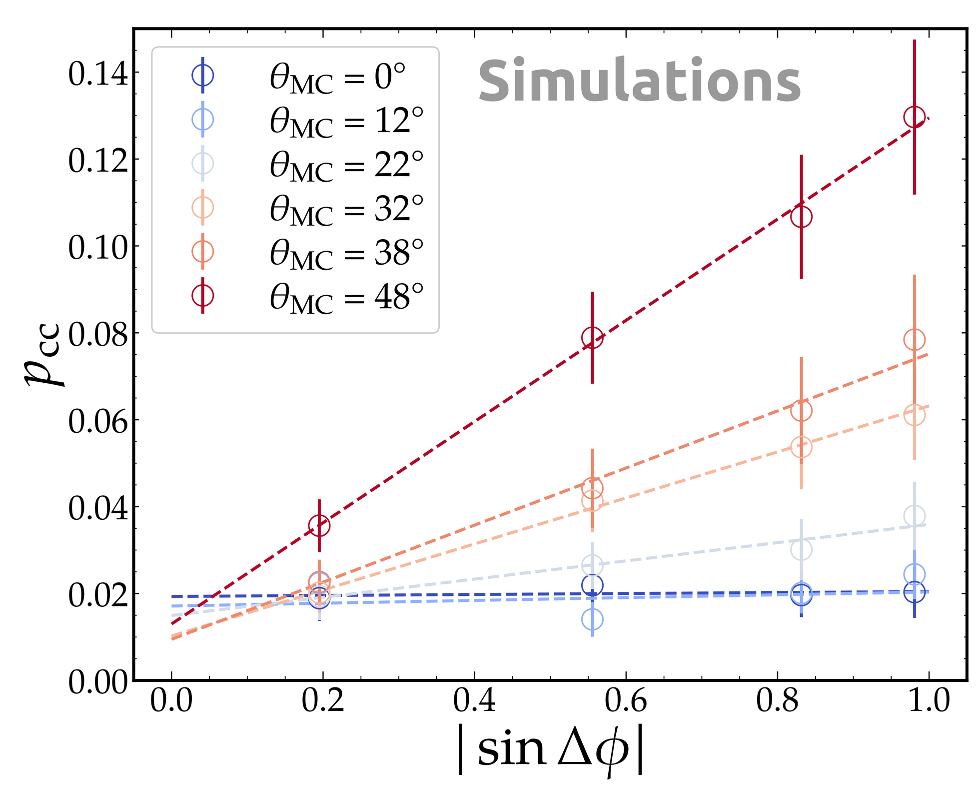
- Use **timing with modules with only 2 strips activated** → Δt = difference between start times of the 2 strips
- N_{cc} obtained by quantifying **excess of events with Δt < 5** in the neighboring histogram → difference between the neighboring and non-neighboring distributions attributed to corner-clipping muons
- $p_{CC}(\theta, \Delta\varphi)$ can be **obtained from data and be used to correct for overcounting**

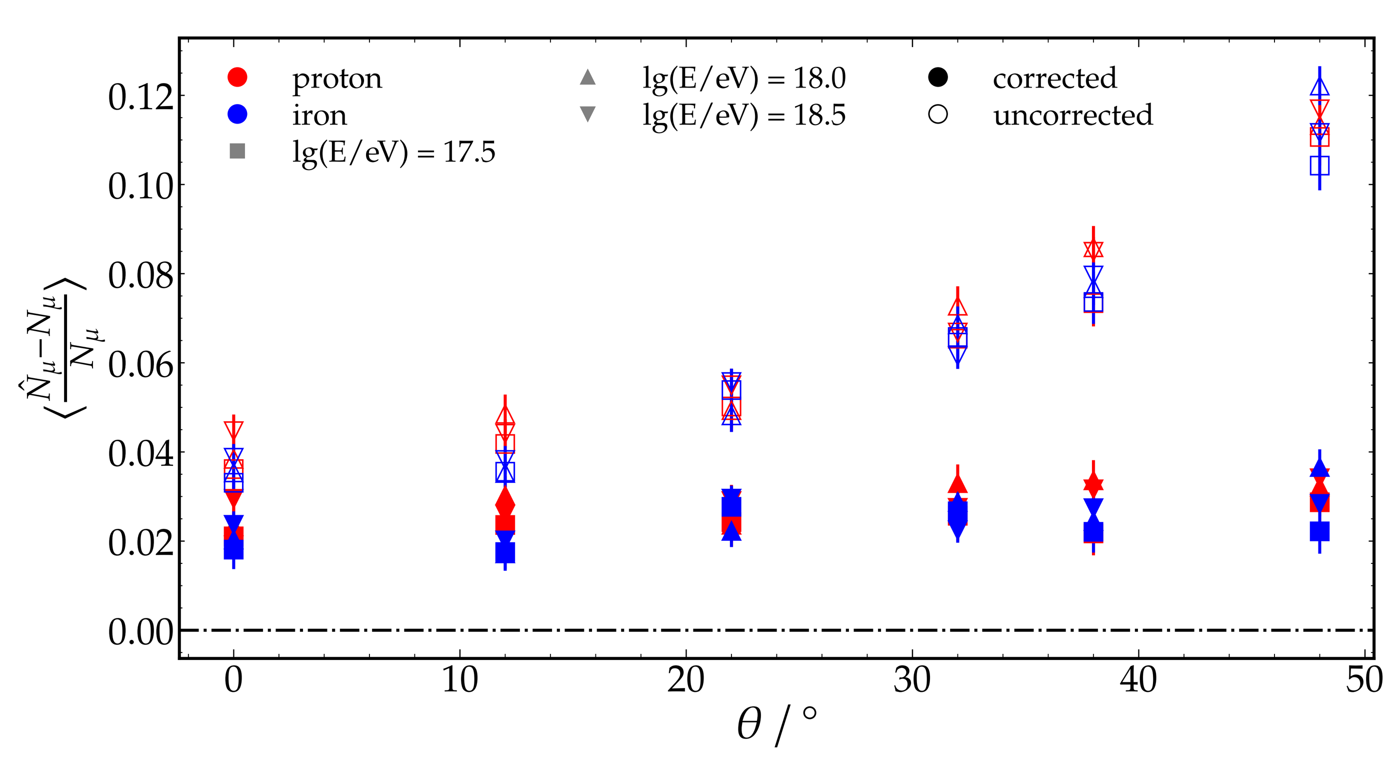


N_{cc} = excess of neighboring events

Application of the method to data and simulations







✔ Data and simulations show similar behavior

- Corrected muon estimator:

$$\hat{N}_\mu = \frac{-64\ln(1-k/64)}{1+p_{cc}(\theta,\Delta\phi)}$$

(k: number of triggered bars)

✔ After correction, bias is flat with θ and below 3%

Summary

✔ Developed a **data-driven method to correct for corner-clipping effect** using the UMD of the Pierre Auger Observatory

- Generally applicable to any kind of segmented detector with time resolution

Outlook

- Extend the method to modules with more than 2 activated strips

References

[1] The Pierre Auger Collaboration. JINST 16 P04003 (2021)

joaquin.dejesus@iteda.cnea.gov.ar