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miniTRASGO: Toward a Global Network of Compact RPC Telescopes for Cosmic Ray and Space Weather Monitoring

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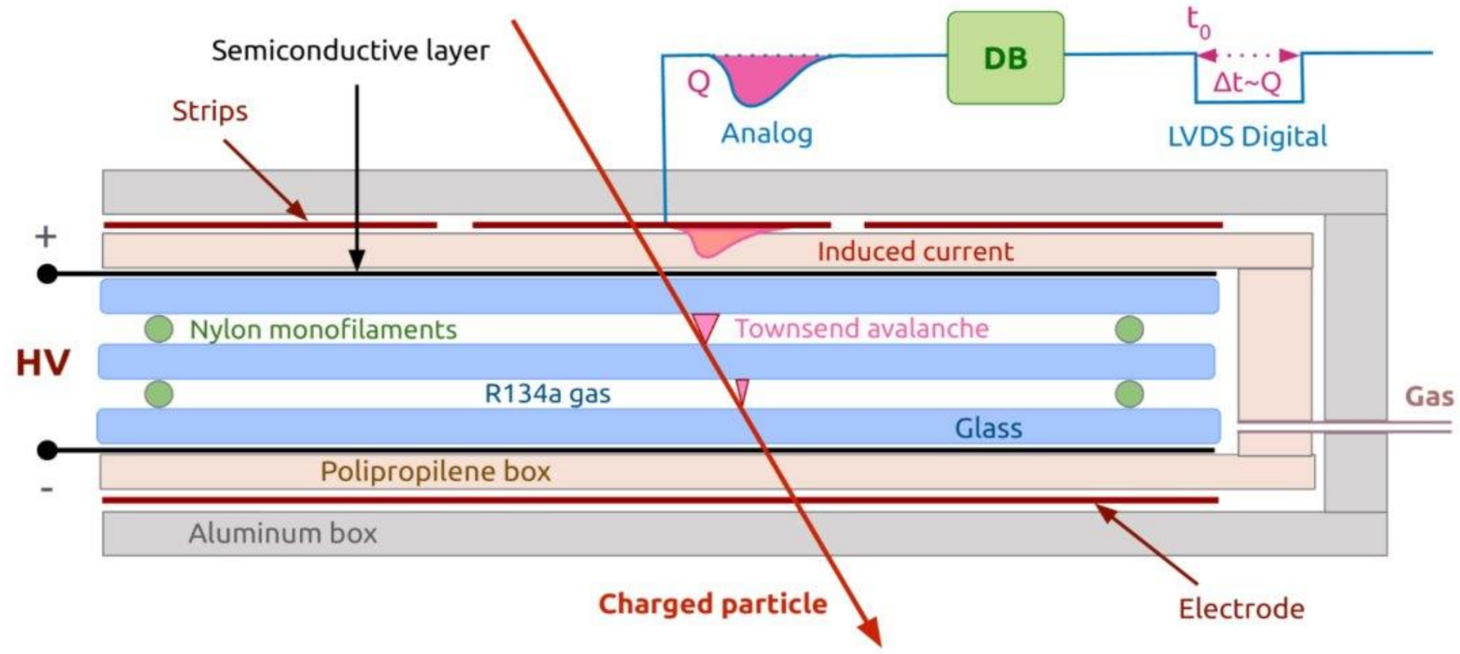
1. Introduction

- **Cosmic Rays and Motivation**
  - Cosmic rays are high-energy particles (mostly protons and atomic nuclei) arriving from outside the Solar System, producing secondary particles when interacting with Earth's atmosphere (Blasi, 2013; Grieder, 2001).
  - Their flux depends on geomagnetic cutoff rigidity, atmospheric absorption, and solar modulation (Dorman, 2004).
  - Ground-based detectors monitor cosmic rays to study their temporal and spatial variations, especially important during solar-driven events (Forbush, 1937, 1938).
- **miniTRASGO Project Overview**
  - miniTRASGO is a portable, cost-effective cosmic ray detector based on Resistive Plate Chambers (RPCs) (Soneira et al., 2025; in review for publication).
  - It aims to complement existing networks by providing directional measurements of charged secondary cosmic rays.
  - First stations deployed in Madrid (Spain), Warsaw (Poland), and Mexico, enabling multi-site observations.

2. Materials & Methods (I)

- **Detector Structure**
  - Four RPC planes arranged vertically within a ~50 cm cubic frame.
  - Each plane: 30 × 30 cm^2 active area, two-gap configuration enclosed in plastic with high-voltage and gas feedthroughs.
  - Operates with pure R134a gas at around 5.5 kV per gap, adjusted for local pressure and temperature (Soneira et al., 2025; in review for publication).
- **Readout System**
  - Each RPC plane has four copper readout strips (one wide, three narrow) on top plus a reference electrode below.
  - Signals from both ends of each strip provide position and timing (Belver et al., 2010).
  - Time-to-Digital Converter (TRB3sc) records leading and trailing edges for precise timing and charge measurement.



2. Materials & Methods (II)

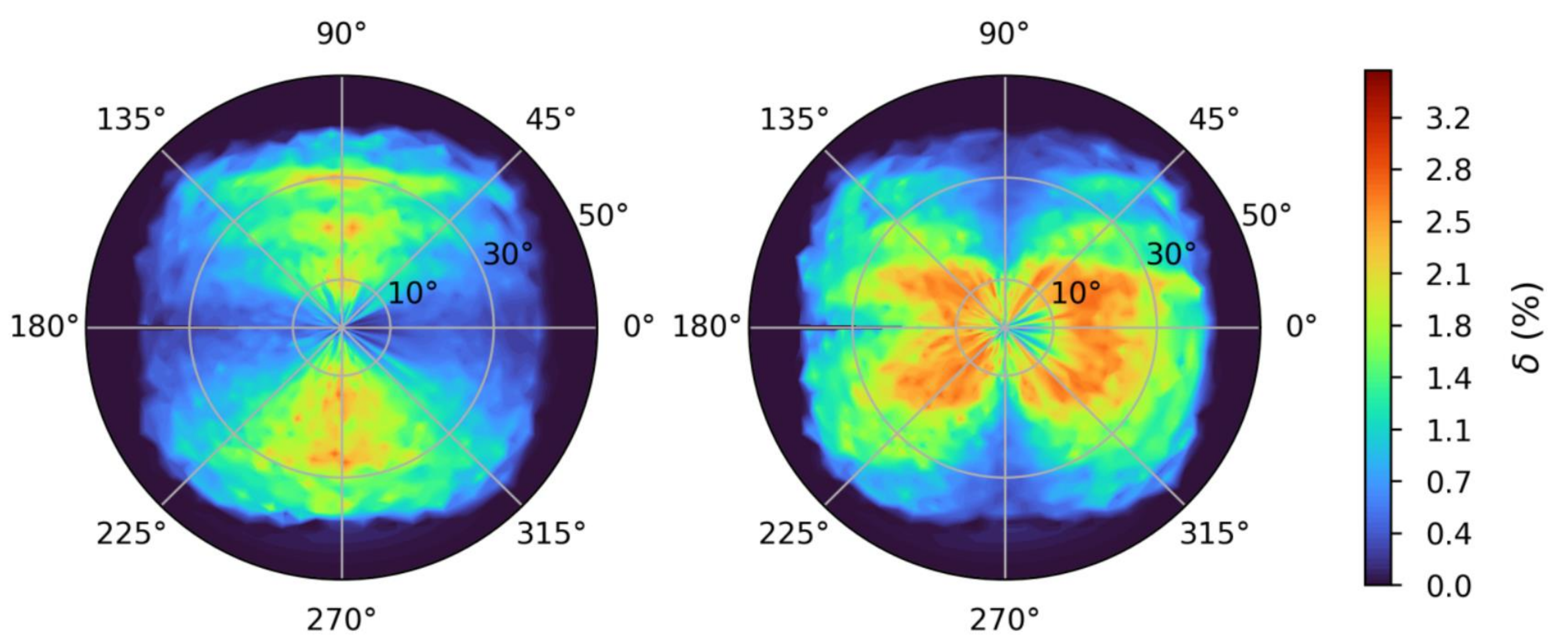
- **Signal Processing**
  - Front-End Electronics digitize signals above the discriminator threshold, converting them into Low Voltage Differential Signals.
  - Charge is inferred via Time-over-Threshold, and positional information comes from the time difference between strip ends.

- **Calibration**
  - **Time Offsets**: A custom-made software tool aligns reference times among strips and planes to the few-hundred-ps level.
  - **Position**:
    - **Y-coordinate** (perpendicular to strips) determined by which strip(s) fired.
    - **X-coordinate** (along strips) from time difference between front/back ends.
  - **Efficiency**: Calculated by checking whether a plane fired when its three companion planes detected a crossing particle, yielding ~95% efficiency (Soneira et al., 2025; in review for publication).

3. Results (I)

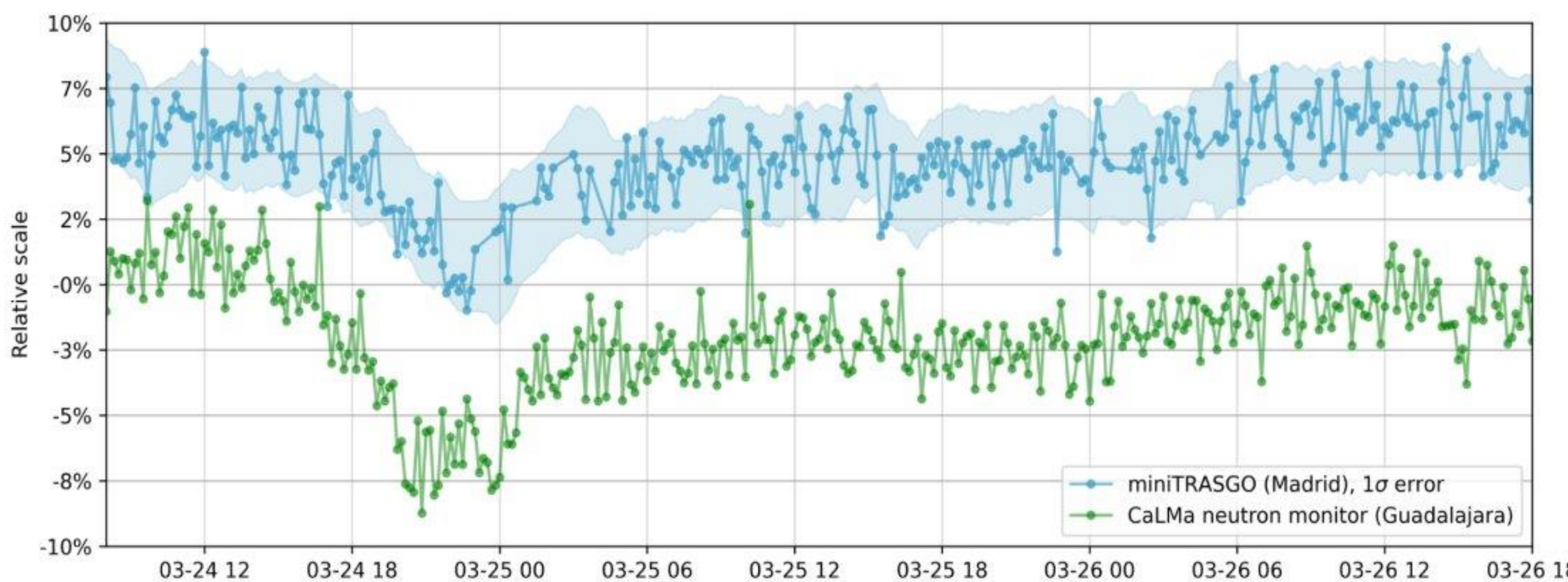
- **Angular and Charge Measurements**
  - Angular resolution better than 3% for muons above ~1 GeV, where multiple scattering is minimal.
  - Charge distributions show single-strip signals dominate (~90%), with multi-strip "clusters" mainly due to adjacent strip sharing or crosstalk.

- **Atmospheric Corrections**
  - Pressure changes significantly affect rates. A barometric coefficient of about -0.215%/mbar (Madrid station) is applied to correct raw count rates.



3. Results (II)

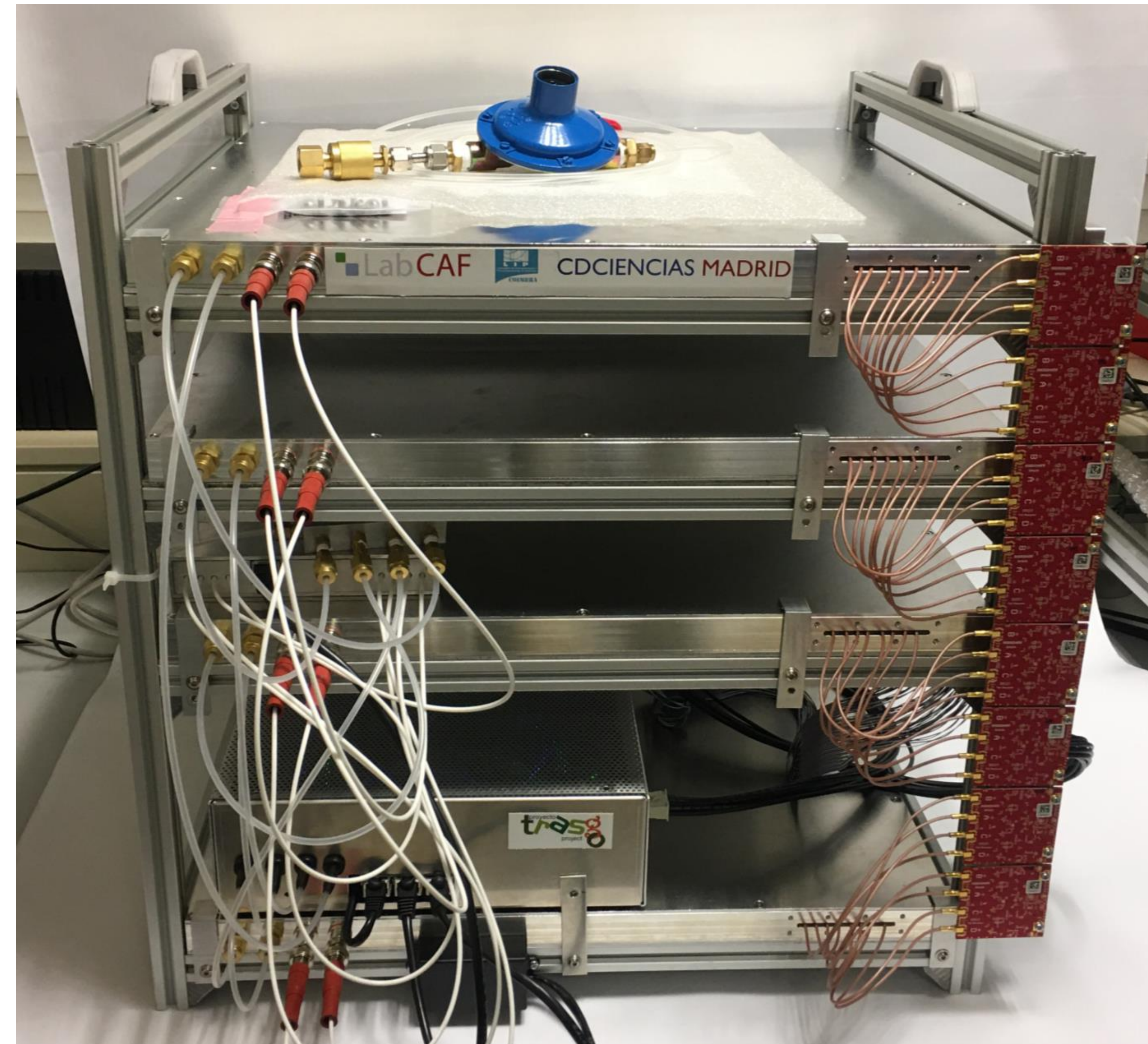
- **Forbush Decrease Detection**
  - miniTRASGO observed a ~5% drop in cosmic ray intensity during the March 2024 Forbush Decrease, consistent with CaLMa neutron monitor data in Spain (Steigies et al., 2008).
  - Demonstrates miniTRASGO capability to track transient cosmic ray events for space weather studies.



4. Conclusions

- **Performance**
  - Compact and easily deployable system with good angular (<3%) and time resolution (~300 ps).
  - Consistent efficiency (~95%) under varying environmental conditions.

- **Implications for Global Monitoring**
  - Complements existing neutron monitor and muon detector networks by adding directional sensitivity and broader geographic coverage.
  - Ongoing and future deployments will enable multi-site comparative data on cosmic ray flux variations and solar-terrestrial interactions (Soneira et al., 2025; in review for publication).



5. References

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