THE TRISTAN DETECTOR 2018-2019 LATITUDE SURVEY OF COSMIC RAYS

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- **1. TRISTAN Detector**
- 2. DAQ System
- **3. Detector Installation & Latitude Survey**
- 4. Vertical Cutoff Rigidity of Primary Cosmic Rays

5. Results

- Background Rates & Raw Coincidences
- Environmental Sensors AC failure
- HV function of Pressure & Temperature
- Raw & Corrected Coincidences Randoms & Efficiency
- Corrected Coincidences vs. Cutoff Rigidities along the Survey
- Coincidence Dispersion below 2% Forbush Decreases

6. Conclusions

3 RPC planes to study Secondary Cosmic Rays



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Designed to be part of the ORCA Observatory 1 in the Livingston Island 2





¹ J. J. Blanco et al., ORCA (Antarctic Cosmic Ray Observatory): 2018 latitudinal survey, ICRC 2019

² Spanish Antarctic Station "Juan Carlos I" in the Livingston Island - Antarctica

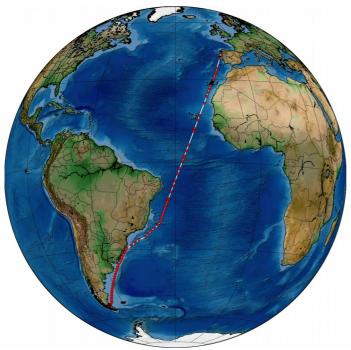
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3 RPC planes to study Secondary Cosmic Rays

Designed to be part of the ORCA Observatory 1 in the Livingston Island 2

Before installation in the Antarctic base, the detector made a **Latitude Survey** from Vigo (Spain) to Punta Arenas (Chile)







- ¹ J. J. Blanco et al., ORCA (Antarctic Cosmic Ray Observatory): 2018 latitudinal survey, ICRC 2019
- ² Spanish Antarctic Station "Juan Carlos I" in the Livingston Island Antarctica

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RPC 2

RPC 3

RPC 1

- 3 planes of RPCs
- Active areas of 120x150 cm²
- Operated in pure C₂H₂F₄, ~11 cc/min (open gas loop)
- Built & designed by the LIP-Coimbra teams, including:
 - HV power supplies
 - gas system w/ monitoring capability

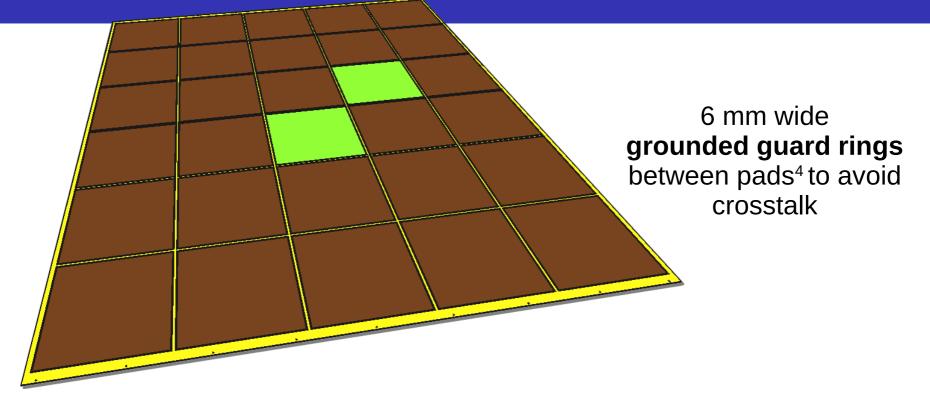
RPC 2

RPC 3

RPC 1

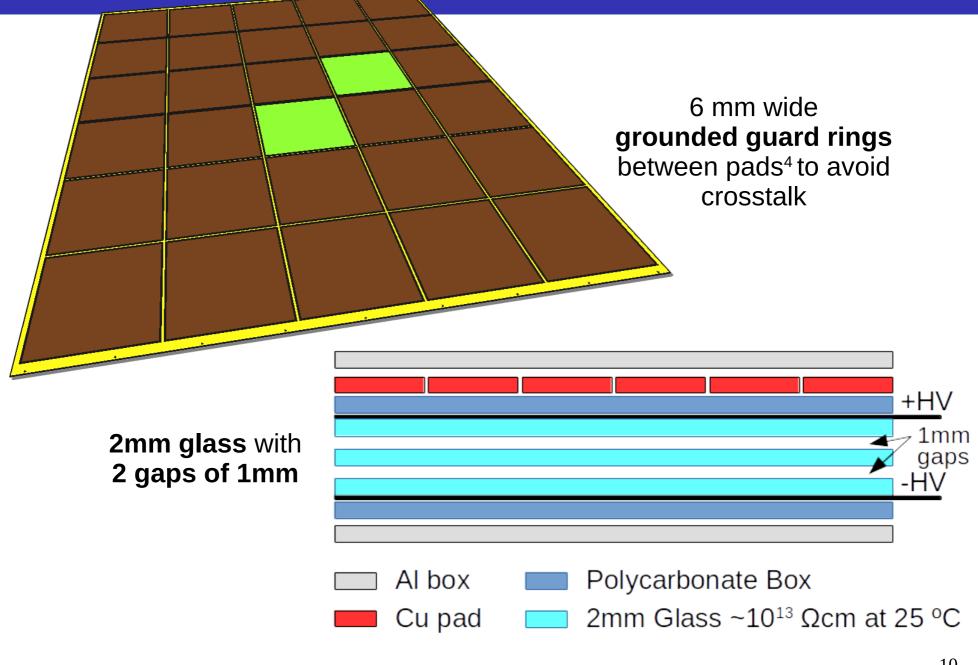
- Multitrack detector working in avalanche mode
- 6x5 24x25 cm² pads per plane
- 90 channels in total
- FEE³, time (ot ~35 ps) and charge measured in each single channel

³ 32-channel motherboards + 4-channel daughterboards with 2GHz amplifiers, IEEE TNS 57, 2848 (2010)



⁴ R&D done in the Auger framework (DOI: 10.1088/1748-0221/9/10/C10023)

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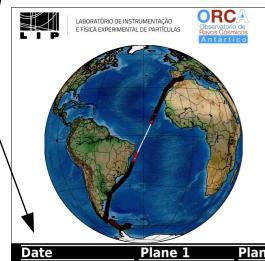
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⁴ R&D done in the Auger framework (DOI: 10.1088/1748-0221/9/10/C10023)

DAQ System – main features

System Fully Autonomous

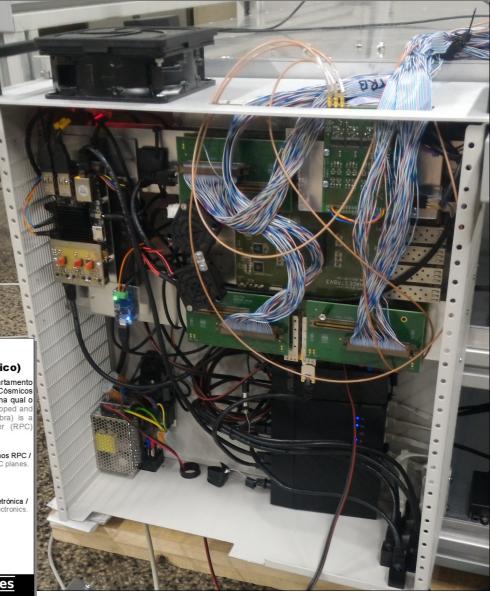
- Data acquisition starts automatically
- Hardware power-cycle in case of failure
- → Log analysis, search out of range values
- Alarms sent via email in case of issue
- Daily Reports sent via email
- Rates & Coincidences sent every 30
 minutes



TRISTAN e ORCA (Observatório de Raios Cósmicos Antártico) TRISTAN (desenvolvido e construido integralmente no LIP, departamento de Fisica, Universidade Coimbra) é um telescópio de Raios Cósmicos baseado em Câmara de Planos Resistivos (RPCs), tecnologia na qual o LIP tem uma longa experiência internacional. / TRISTAN (developed and built entirely at LIP, Physics Department, University of Coimbra) is a Cosmic Ray telescope based on Resistive Plate Chamber (RPC) technology, in which LIP has a long international experience.



Date	Plane 1	Plane 2	Plane 3	Coincidences
2020-01-23	1962.8	3187.9	3472.0	161.5
2020-01-24 10:00	2027.7	3455.6	3682.7	161.3
(RPC rates per plane and respective coincidences)				



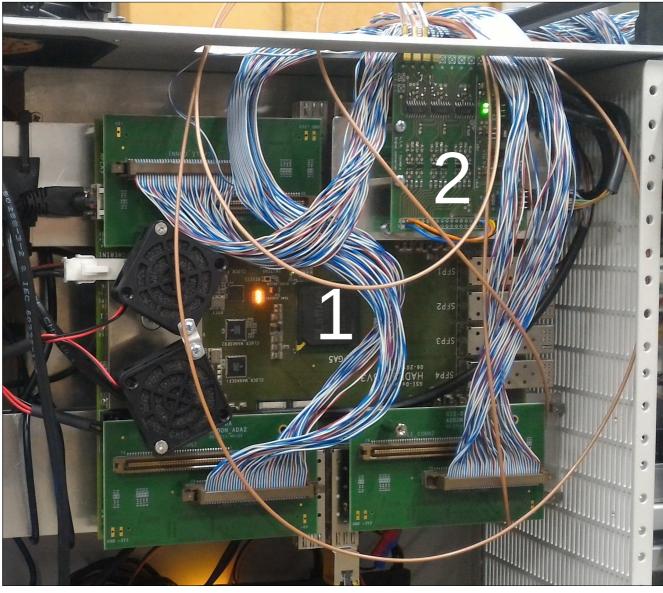
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DAQ System – readout board

1 – TRB3 Readout board⁵ with four FPGA-based TDCs, $\sigma t \sim 20 \text{ ps}$

2 – Trigger & LVDS converter board





⁵ DOI: 10.1088/1748-0221/8/12/C12043

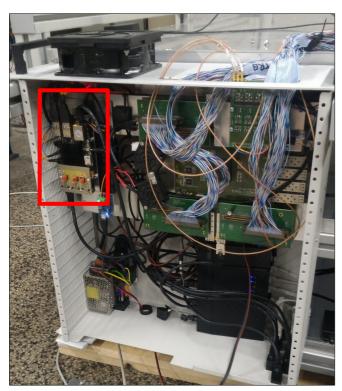
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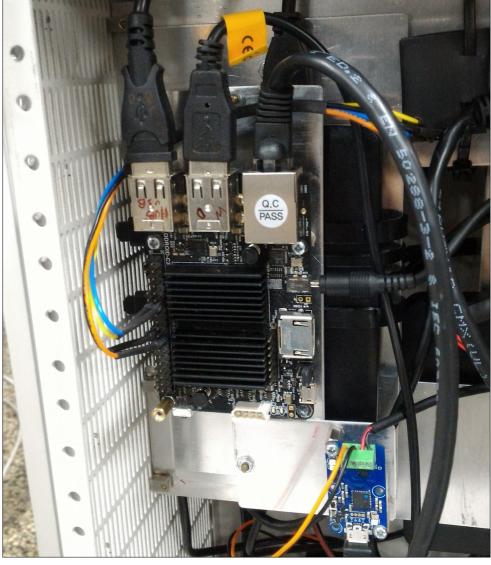
DAQ System – computer

ODROID-C2 quad-core single board computer (ARM Architecture, 2 GB RAM, GbE, Ubuntu 16.04)

with,

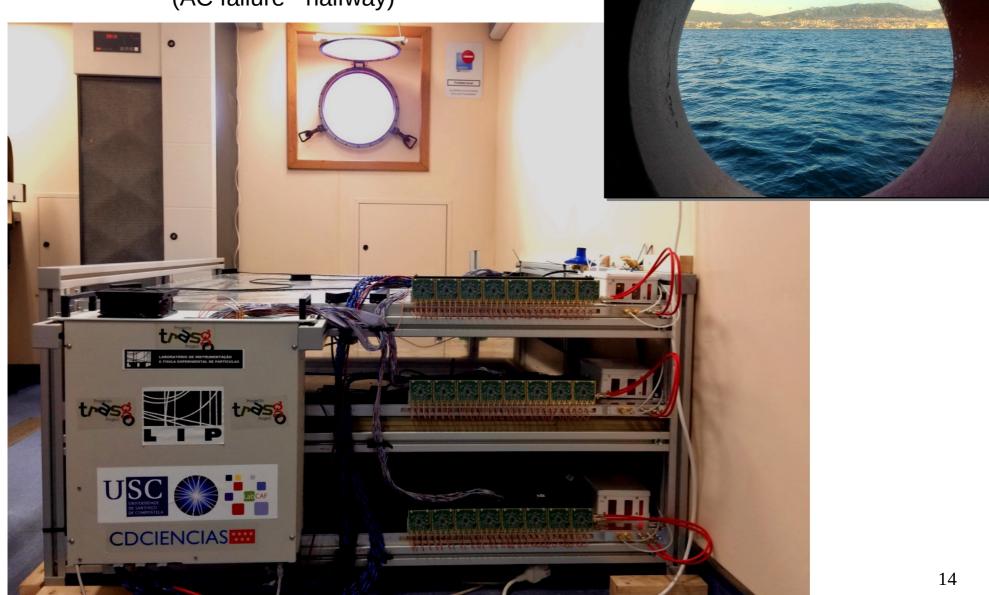
- **watchdog** (power-cycle after 15 min in case of computer crash)
- i2c communication w/ environmental sensors...
- RTC clock (if NTP server unavailable)





Detector Installation – Boat Sarmiento de Gamboa

TRISTAN installed in a controlled temperature room (AC failure ~halfway)



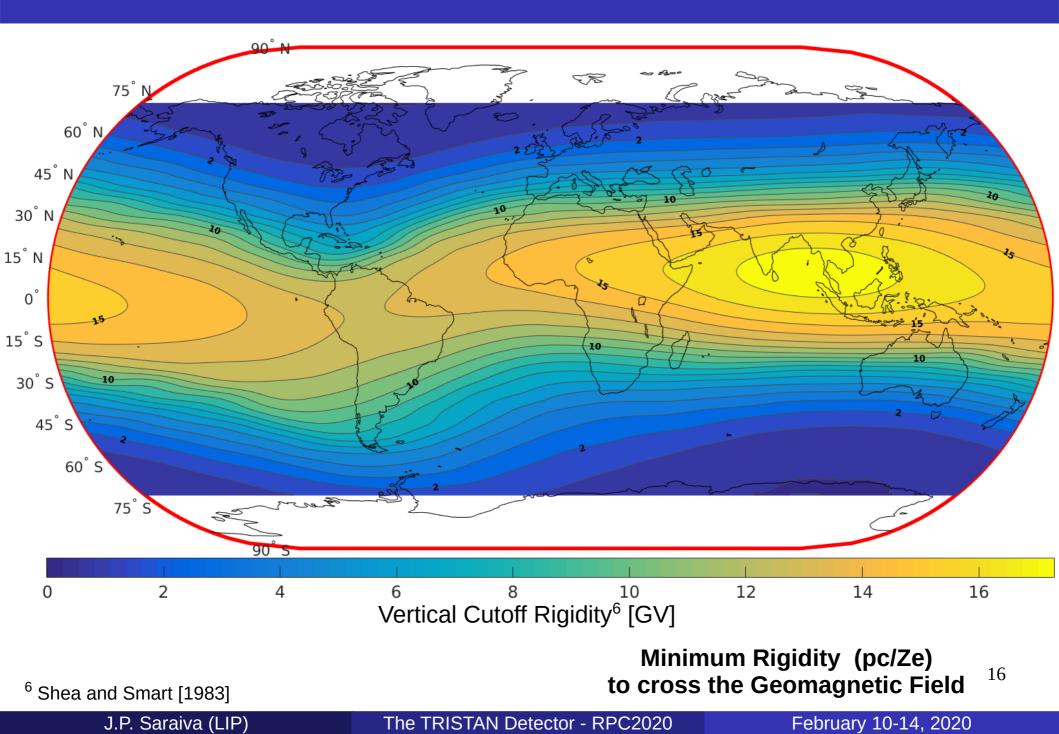
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Latitude Survey – Secondary Cosmic Rays

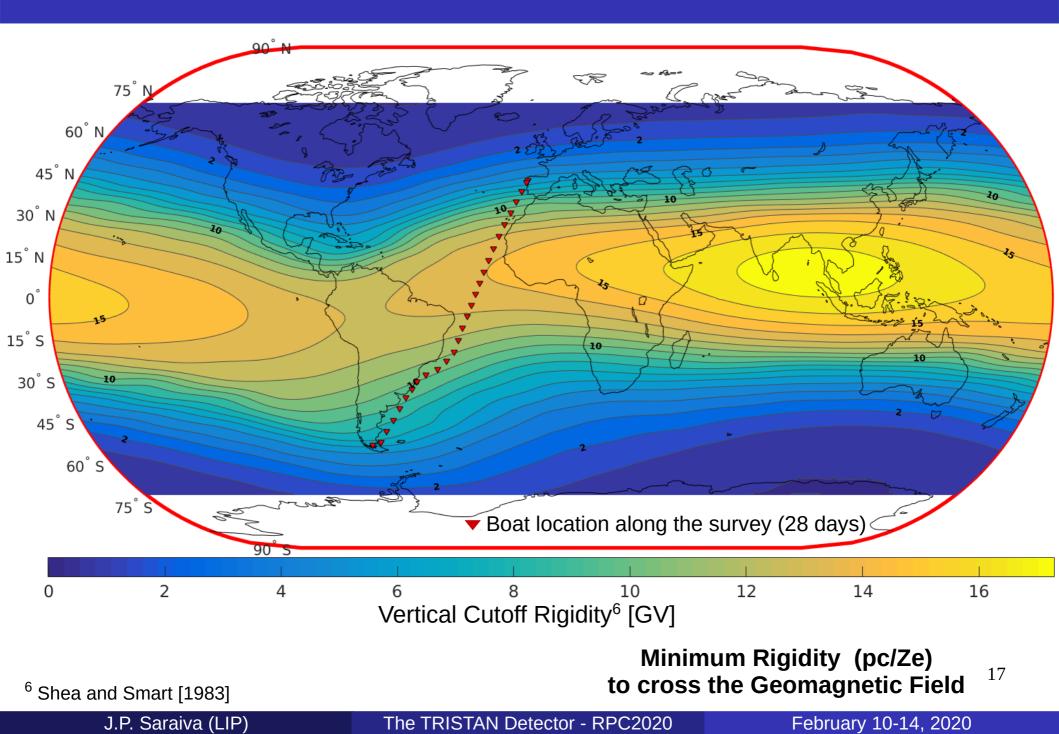


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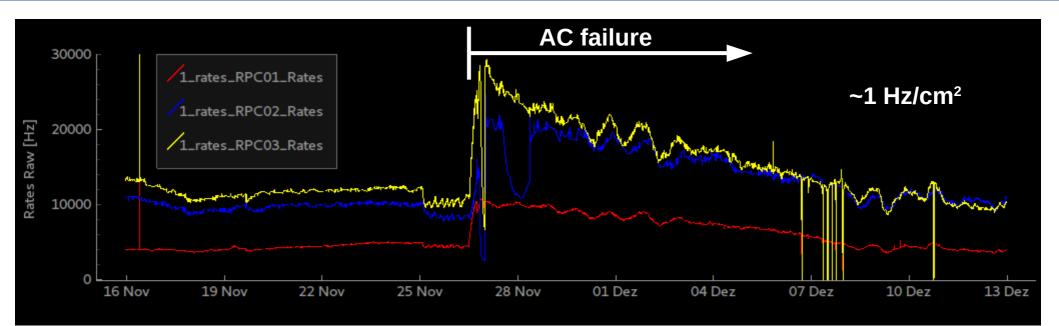
Vertical Cutoff Rigidity of Primary Cosmic Rays



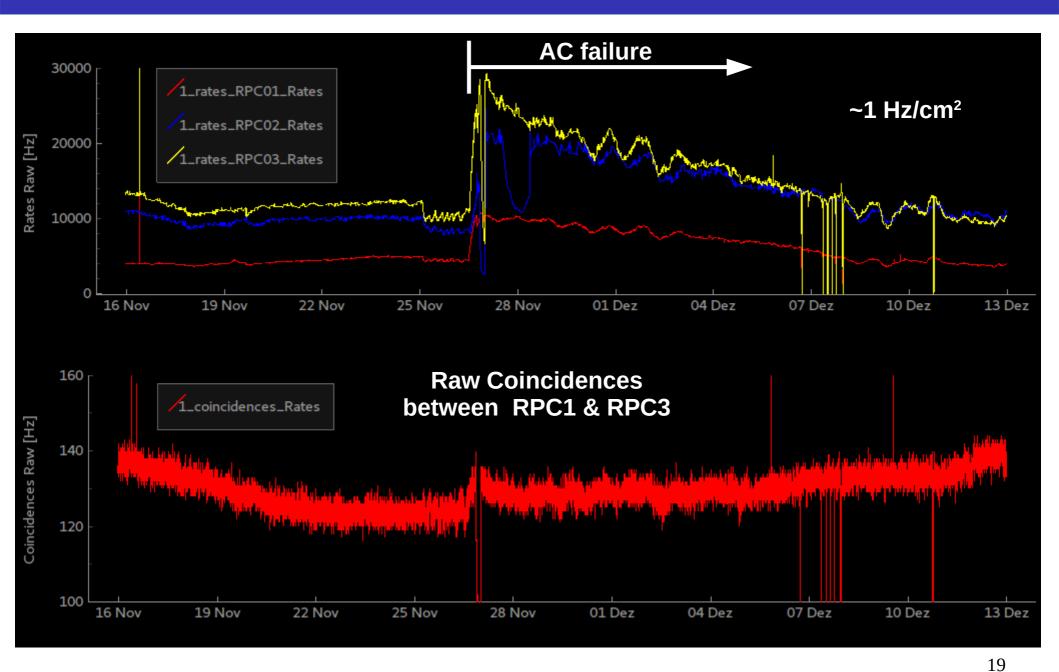
Vertical Cutoff Rigidity of Primary Cosmic Rays – Daily Boat Location



Background Rates & Raw Coincidences



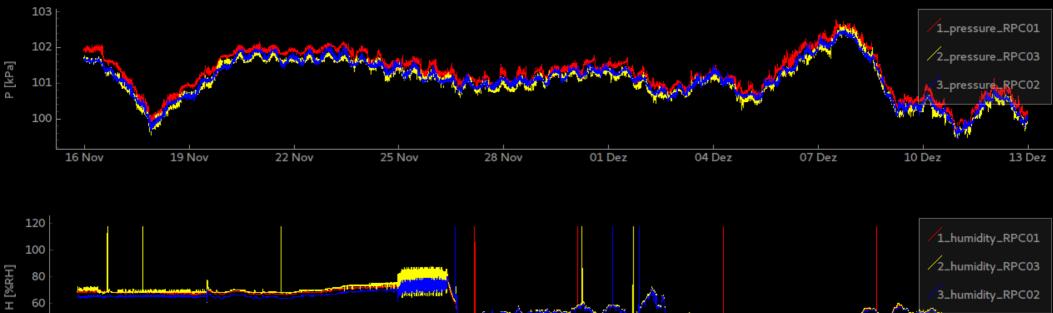
Background Rates & Raw Coincidences



Environmental Sensors – Temperature, Pressure, Humidity

30 30 20 16 Nov 19 Nov 22 Nov 25 Nov 28 Nov 01 Dez 04 Dez 07 Dez 10 Dez 13 Dez

Air Conditioning failure

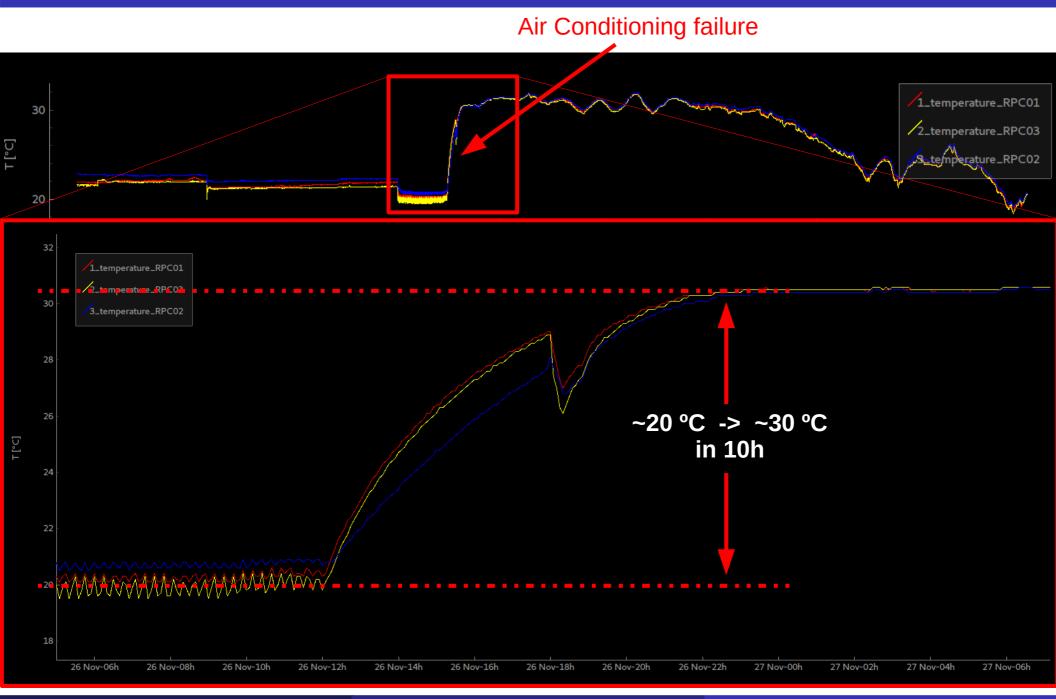


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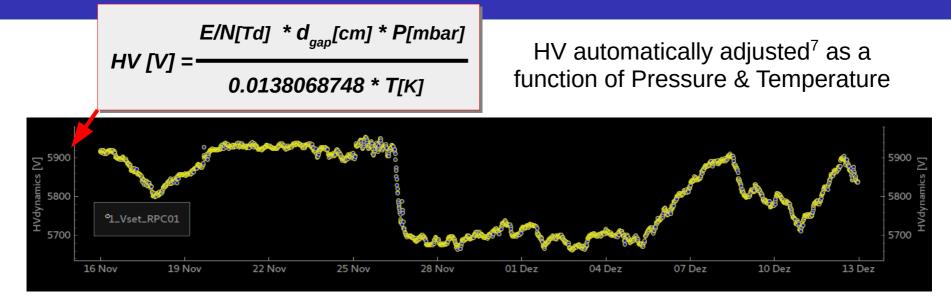
Environmental Sensors – AC failure ($\Delta \sim 10 \ ^{\circ}C$)



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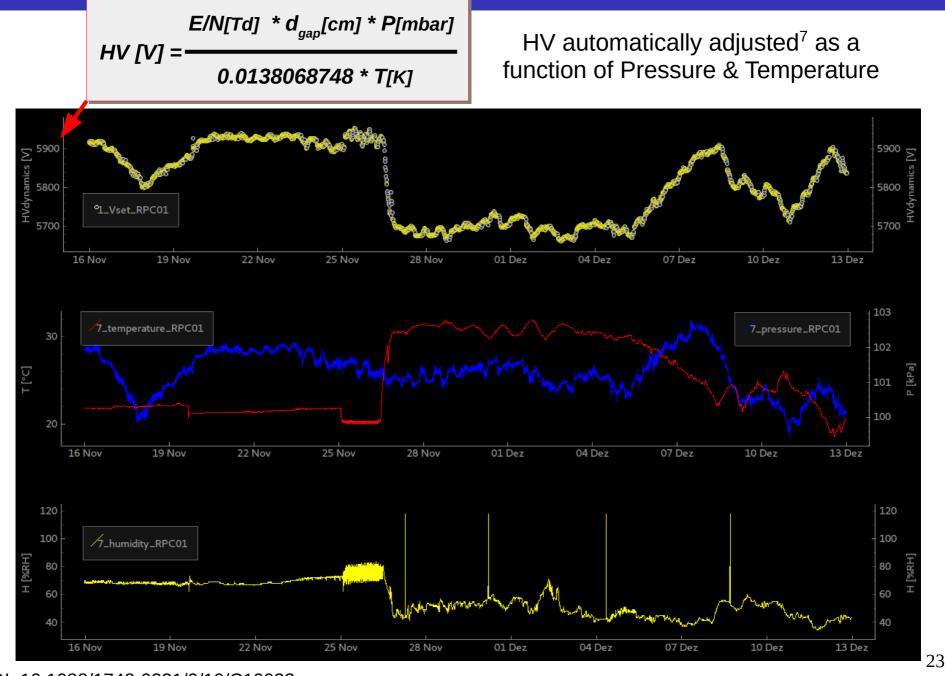
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HV – function of Pressure & Temperature



⁷ DOI: 10.1088/1748-0221/9/10/C10023

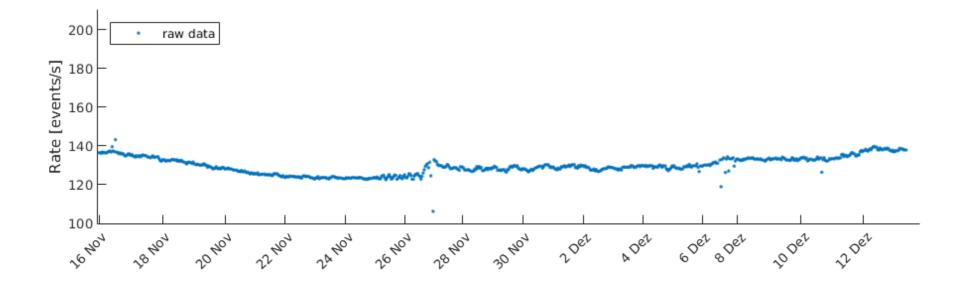
HV – function of Pressure & Temperature



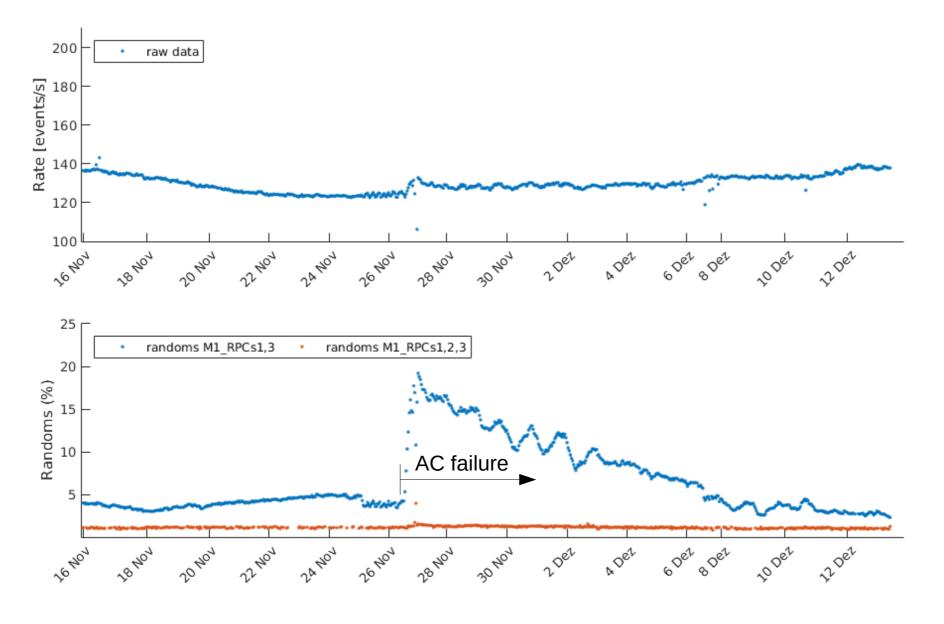
⁷ DOI: 10.1088/1748-0221/9/10/C10023

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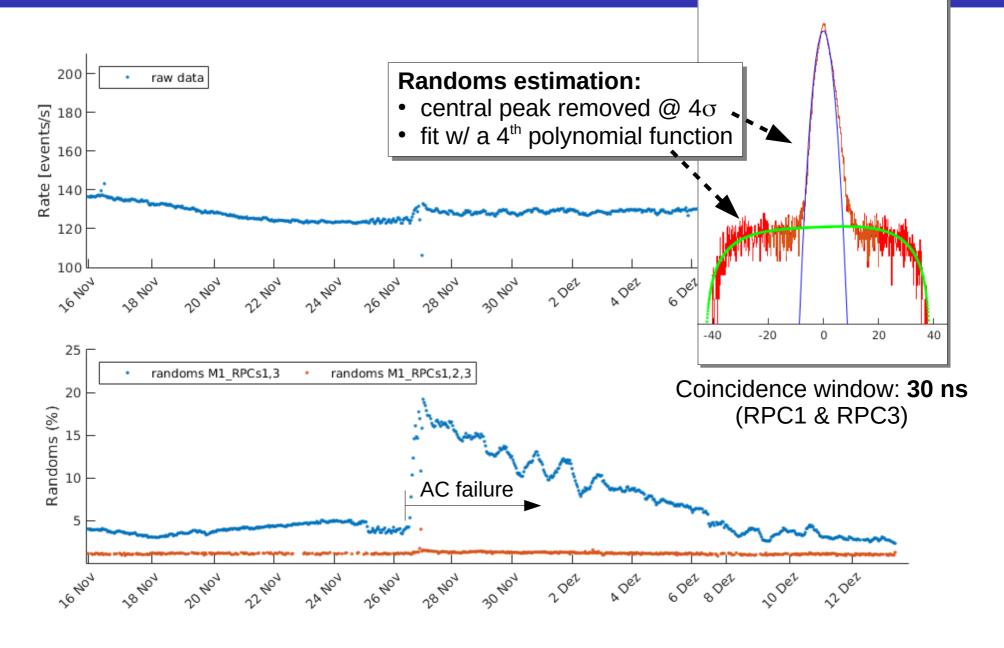
Raw Coincidences & Randoms



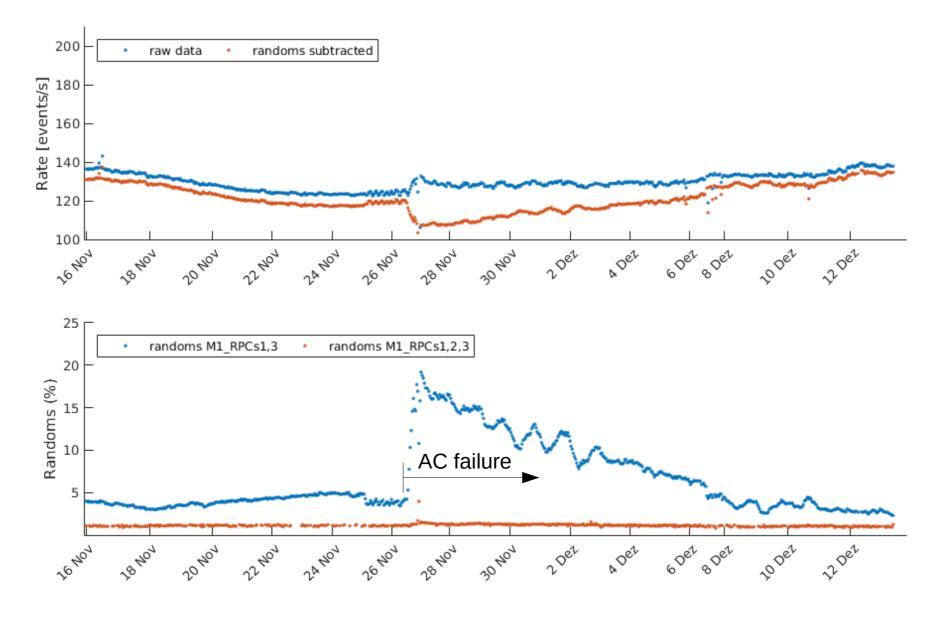
Raw Coincidences & Randoms



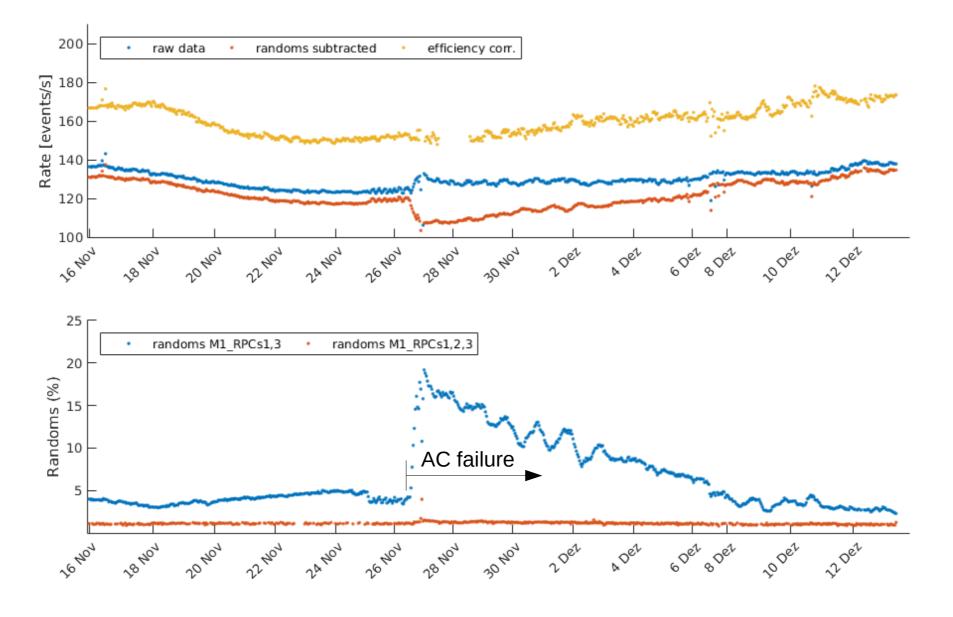
Raw Coincidences & Randoms

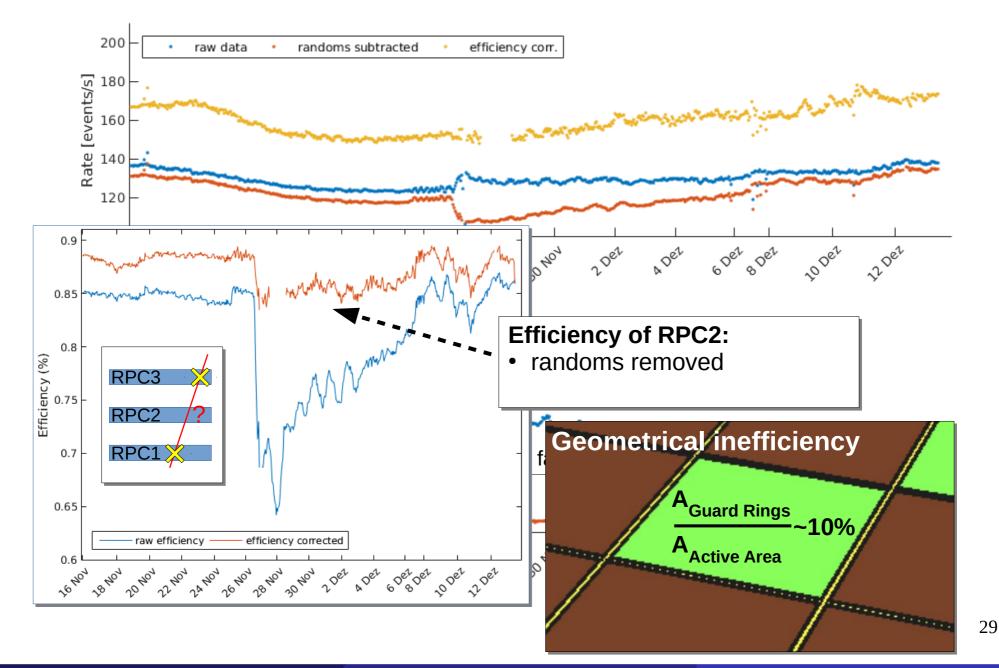


Raw & Corrected Coincidences – Randoms



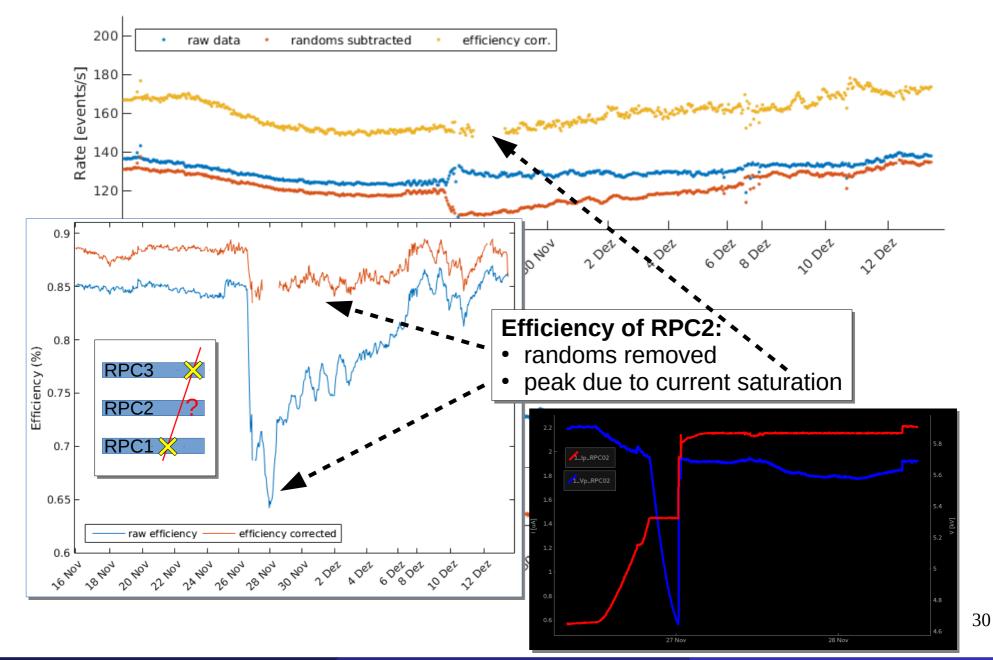
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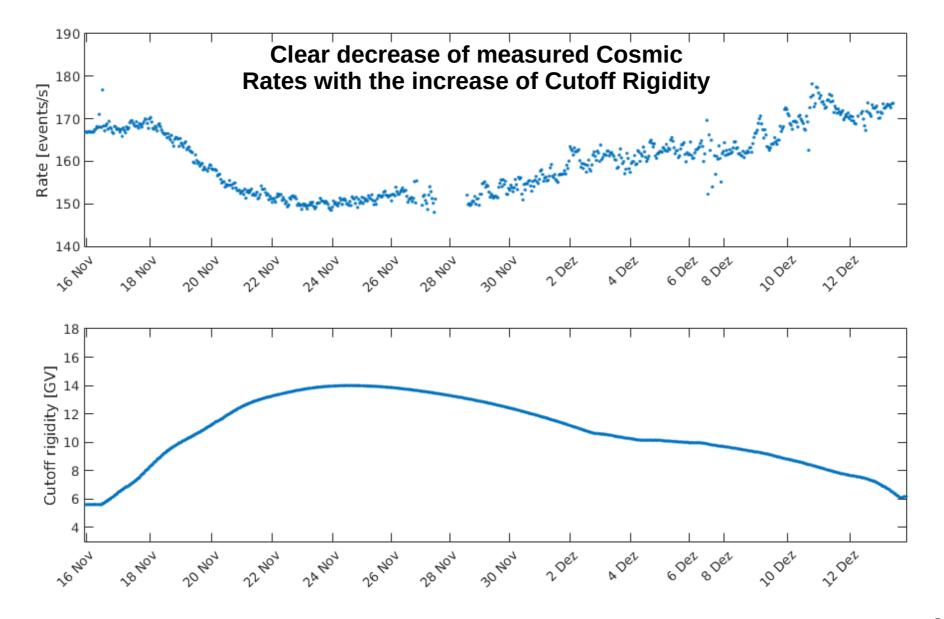
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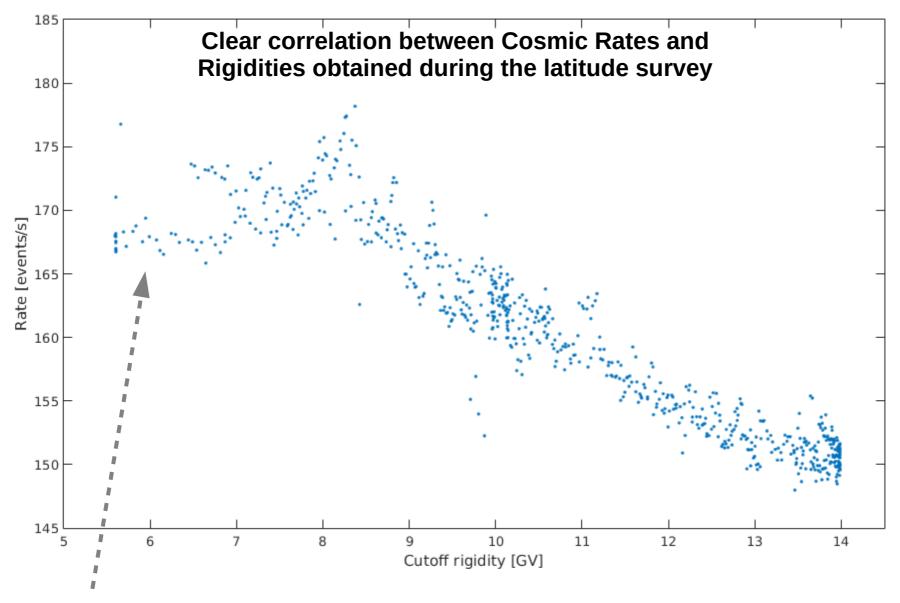


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Corrected Coincidences & Cutoff Rigidities along the Survey

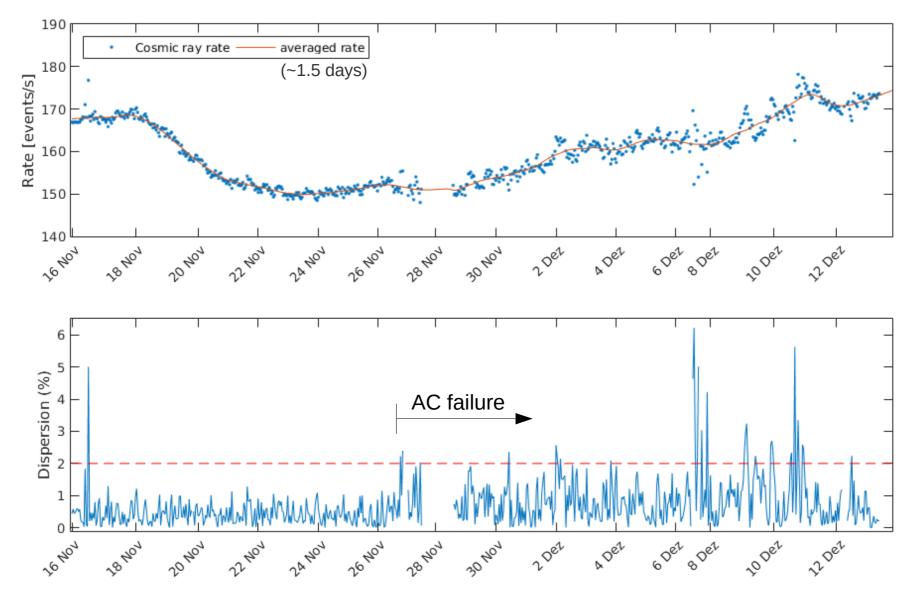


-> points outside the correlation region being investigated

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Coincidence Dispersion below 2%



More than 99% of measurements are below a 2% dispersion

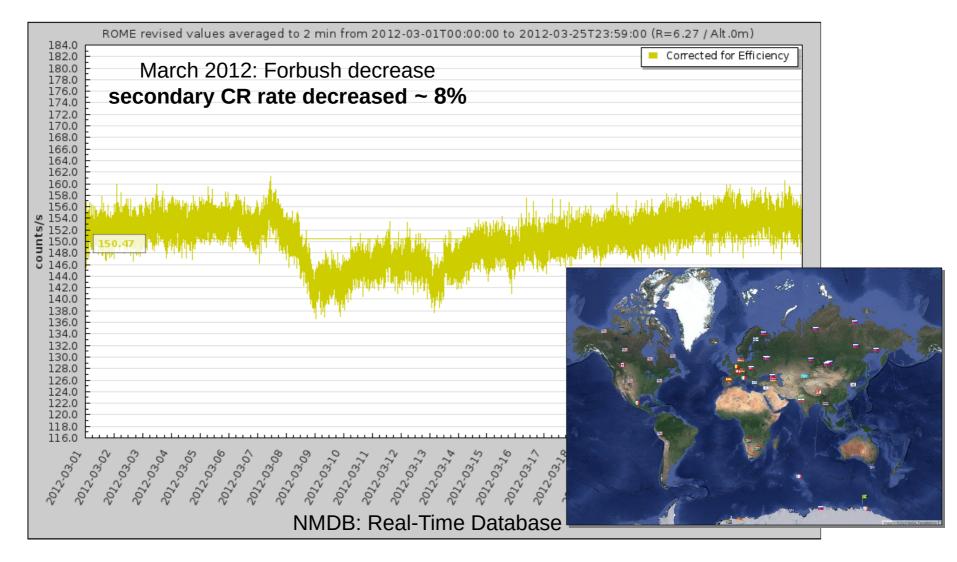
-> can be even better with controlled temperature ³³

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Coincidence Dispersion below 2% – Forbush Decreases

Forbush Decrease – decrease of galactic CR intensity with the increase of solar CR



TRISTAN could be used for Forbush Decrease measurements

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February 10-14, 2020

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- RPC detectors measured successfully Secondary Cosmic-Ray flux during a Latitude Survey along the Atlantic Ocean
- Fully Autonomous DAQ System used with success
- Clear correlation between Cosmic-Ray Rate and Cutoff Rigidity obtained during the survey

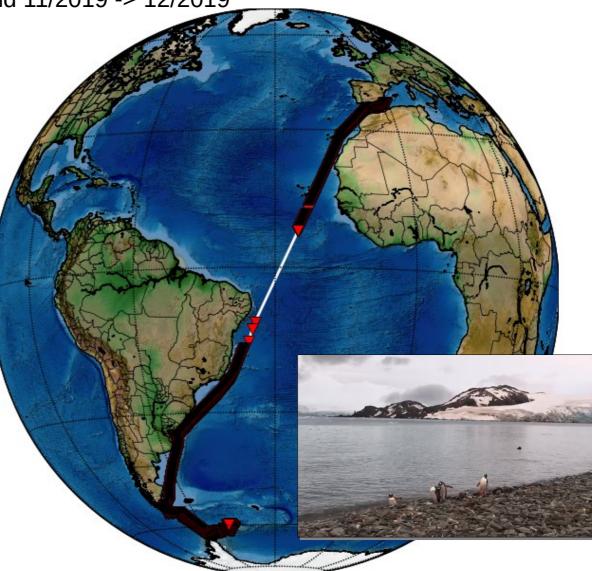
- RPC detectors measured successfully Secondary Cosmic-Ray flux during a Latitude Survey along the Atlantic Ocean
- Fully Autonomous DAQ System used with success
- Clear correlation between Cosmic-Ray Rate and Cutoff Rigidity obtained during the survey
- Efficiency decreased few % with air conditioning failure (Δ ~10 °C), despite the HV adjustment with Pressure & Temperature
- TRISTAN could be used for precise measurements of Cosmic-Ray flux and Forbush Decreases relevant for Solar Physics
- TRISTAN currently installed and being operated in the Antarctic base

TRISTAN Location – Feb. 2020

Spanish Antarctic Station Juan Carlos I (Livingston Island, Antarctic Peninsula)

1st survey: Vigo - P. Arenas 11/2018 -> 12/2018; P. Arenas - Vigo 02/2019 -> 04/2019 2nd survey: Cartagena - Livingston Island 11/2019 -> 12/2019



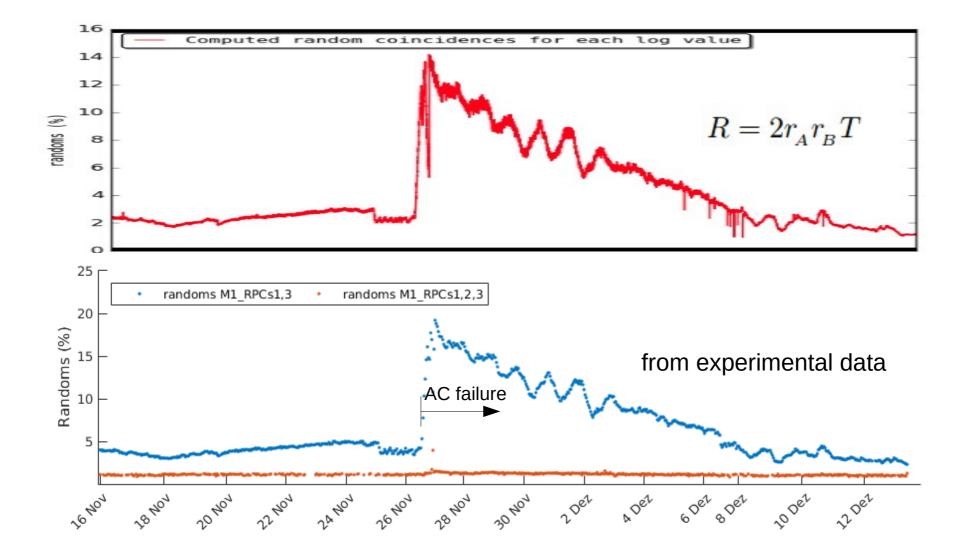


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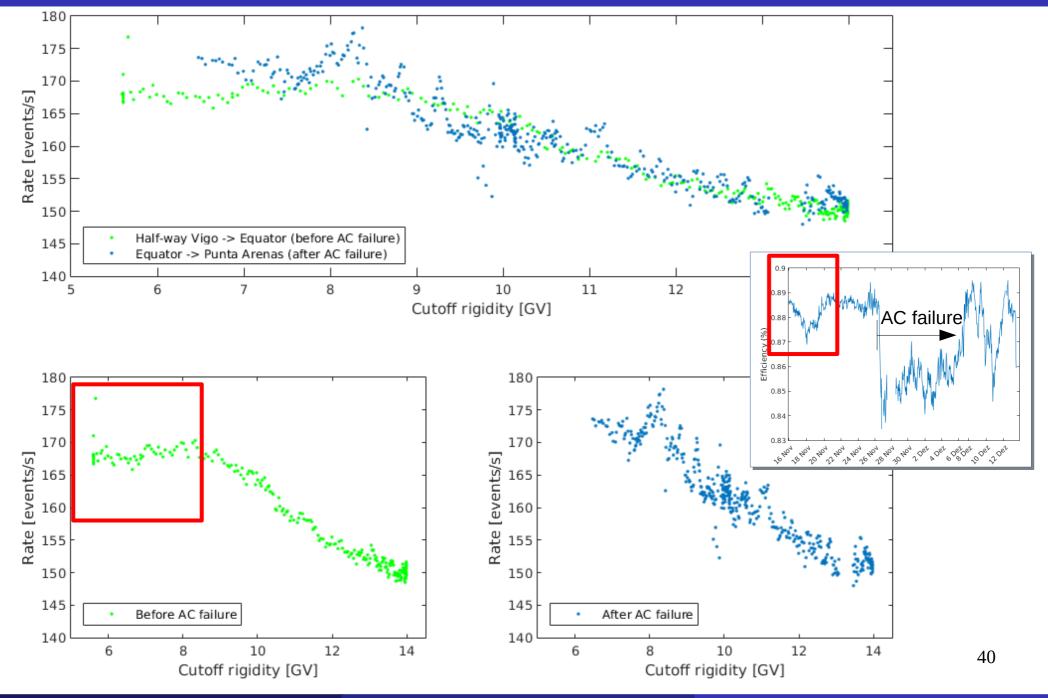
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Backup

Computed vs. Estimated Randoms

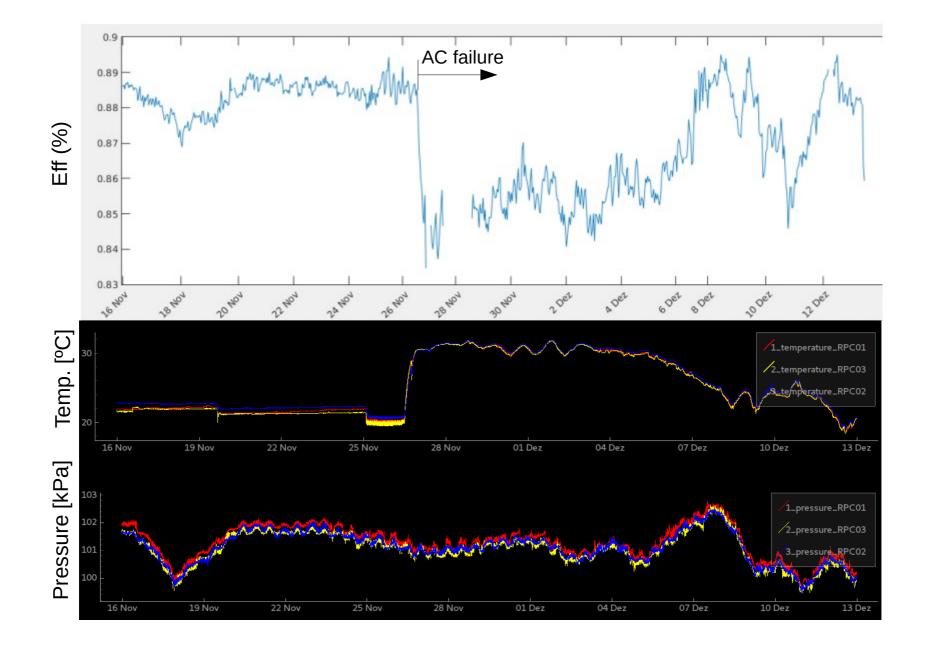


Cosmic Rate/Cutoff Rigidity correlation – Efficiency



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Neutron Detectors (NMDB) – 11/2018 -> 12/2018

900 ••••••••••••••••••••••••••••••••••••		1 hour corr_for_efficiency values averaged to 6 hours from 2018-11-16T00:00:00 to 2018-12-13T23:59:00
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000000000000000000000000000000000000	90.0	
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44.0 •JUHG R = 4.49/Alt.3570m • 42.0 •HRMS R = 4.58/Alt.26m • 9BKSH R = 5.70/Alt.1700 m • • 38.0 •ROME R = 6.69/Alt.330m • •AATB R = 6.69/Alt.330m • • •AATB R = 6.69/Alt.330m • • •ATB R = 6.69/Alt.320m • • •O • • • • OATH R R = 8.53/Alt.200m • • • OATH R R = 8.53/Alt.200m • • • OATH R R = 8.53/Alt.200m • • • ODION R = 11.20/Alt.200m • • • ODION R = 11.20/Alt.200m • • • O • • • • O • • • • O • • • • • O • • • • • • O • • • • •	46.0	● JUN G1 R= 4.49/Alt.3475m
40.0 • PIKH'S R 4-30 / Alt.200 m • PIKH'S R R = 5.70 / Alt.200 m • PIKH R = 6.27 / Alt.0 m • OAATB R = 6.59 / Alt.3340 m • PIFH R = 6.98 / Alt.3351 m • UANIM R = 7.10 / Alt.2000 m • OKCO R = 8.28 / Alt.2274 m • OKM R = 9.15 / Alt.22 / A m • OLO • OKM R = 9.15 / Alt.22 / A m • OLO • OKM R = 16.80 / Alt.2565 m • OKM R = 16.80 / Alt.2565 m / Alt.2565 m •	44.0	
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28.0 • ATHN R=8.53/Alt.260 m 26.0 • TSM B R=9.15/Alt.1240 m 0.10 • DJON R=11.20/Alt.200 m 0.20 • PSNM R=16.80/Alt.2565 m 18.0 • O O O O O O O O O O O O O O O O O O O	32.0	• NANM R=7.10/Alt.2000 m
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Forbush Decrease – Rate Uncorrected vs. Corrected for Pressure

