THE TRISTAN DETECTOR
2018-2019 LATITUDE SURVEY OF COSMIC RAYS

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& Experimental Particle Physics

LIP – RPC Group

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Authors and Institutes

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Overview

1. TRISTAN Detector

2. DAQ System

3. Detector Installation & Latitude Survey

4. Vertical Cutoff Rigidity of Primary Cosmic Rays

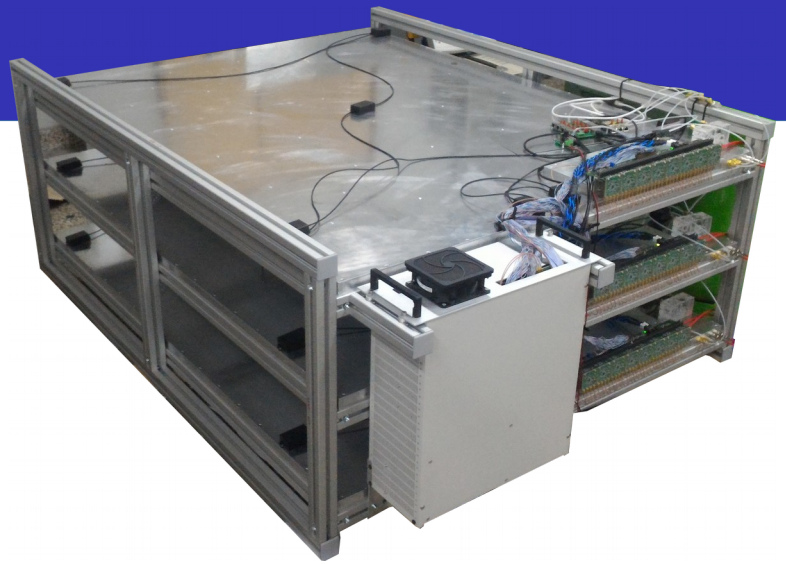
5. Results

- 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

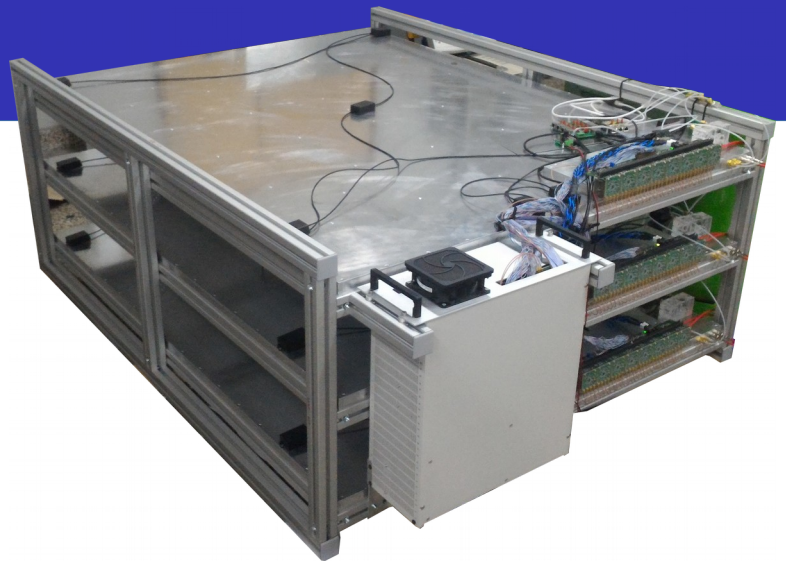
6. Conclusions

TRISTAN Detector

3 RPC planes to study Secondary Cosmic Rays

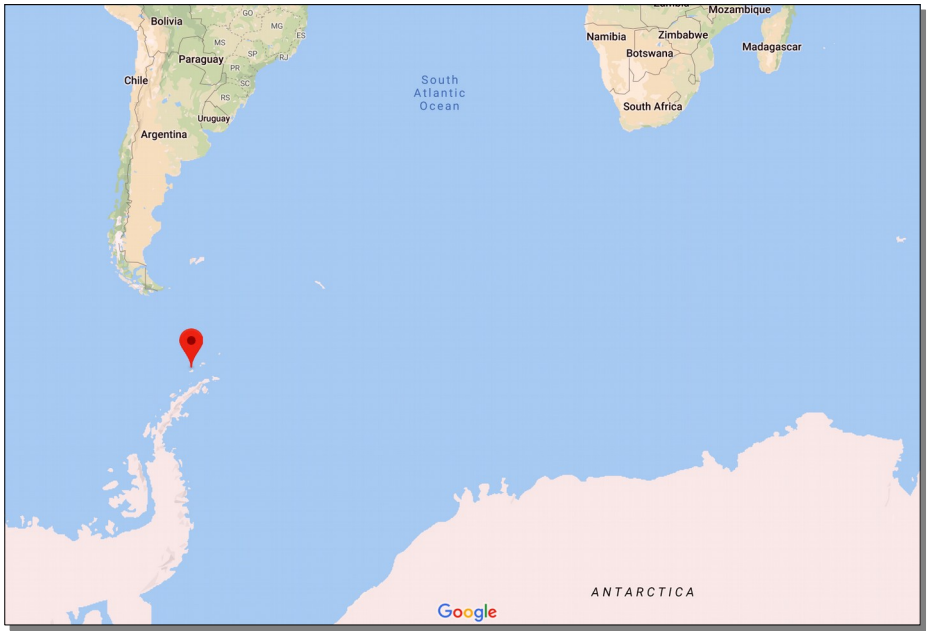


TRISTAN Detector



3 RPC planes to study Secondary Cosmic Rays

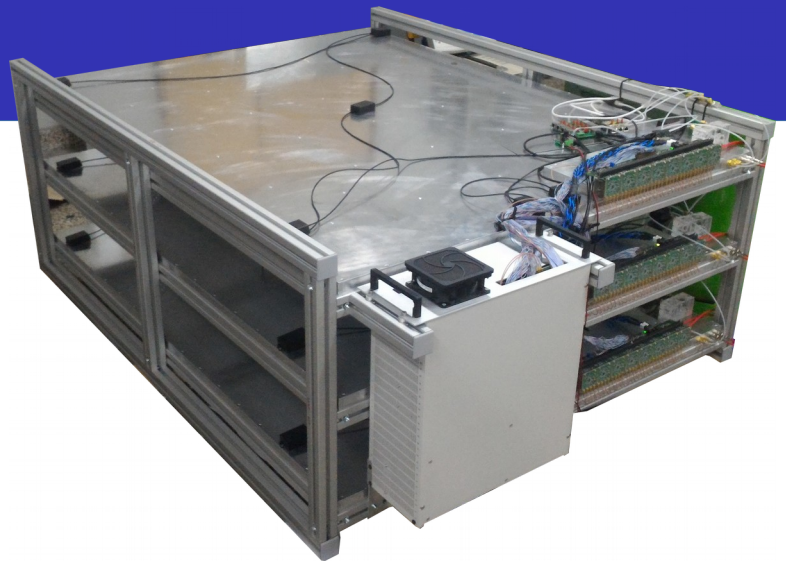
Designed to be part of the **ORCA Observatory**[1] in the Livingston Island[2]



[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

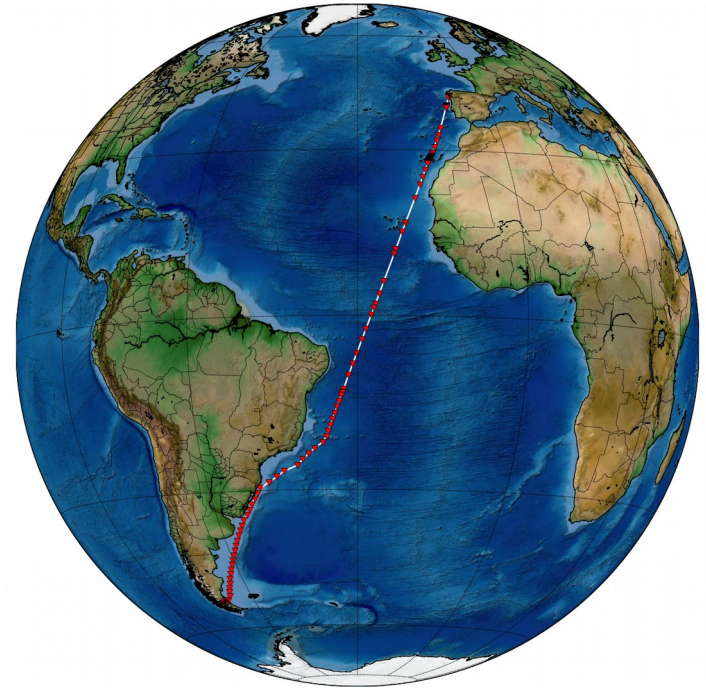
TRISTAN Detector

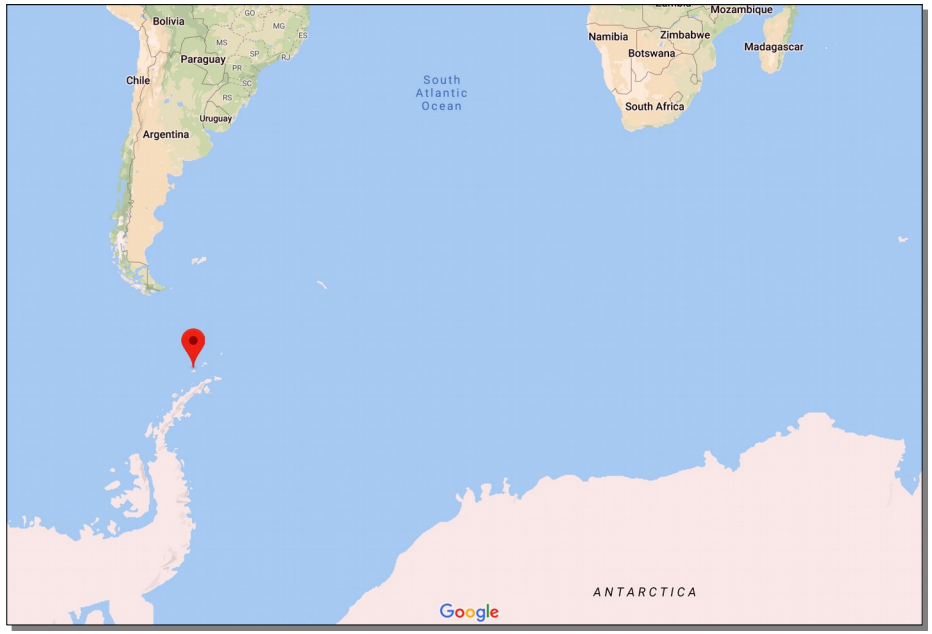


3 RPC planes to study Secondary Cosmic Rays

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

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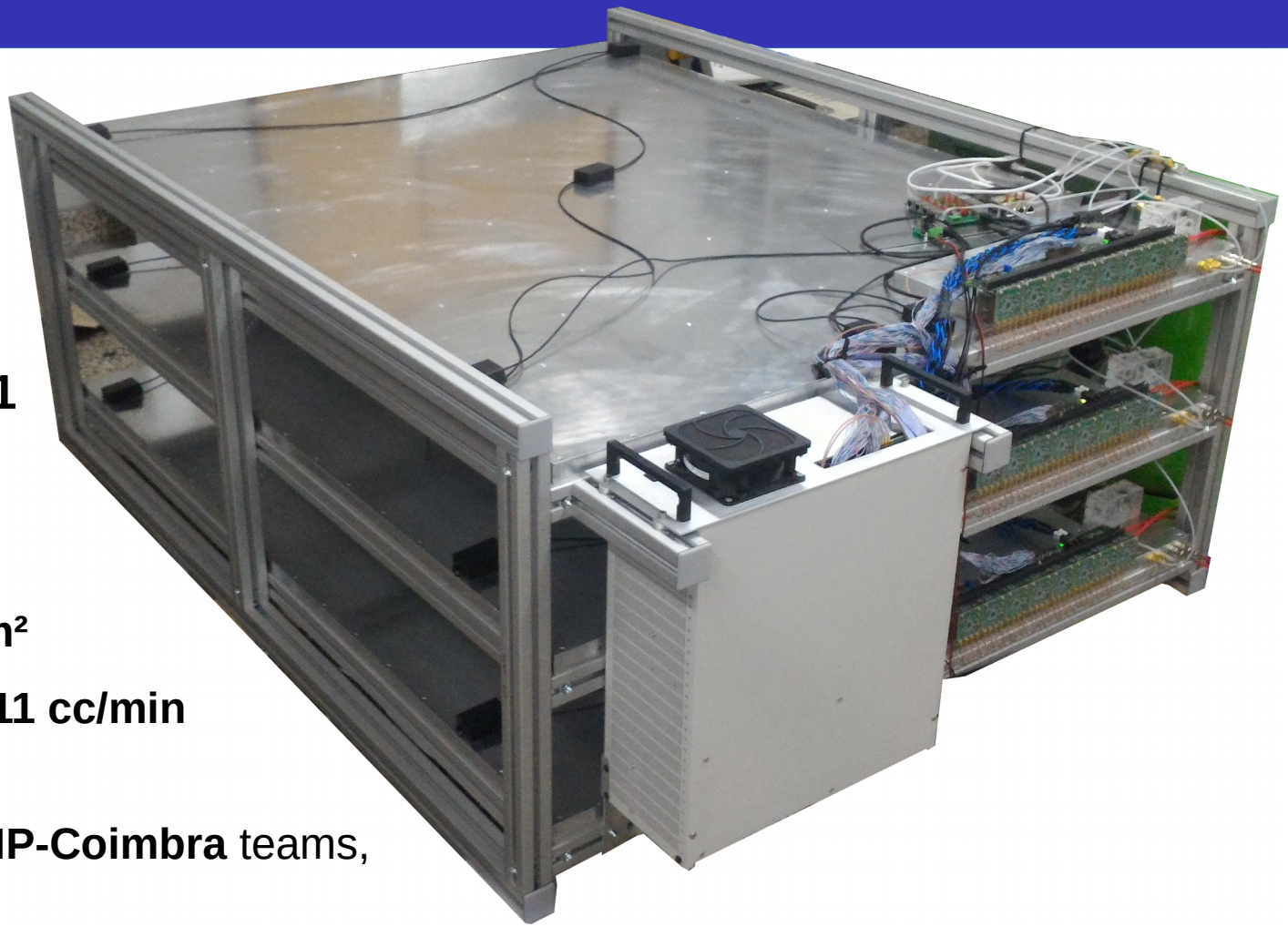
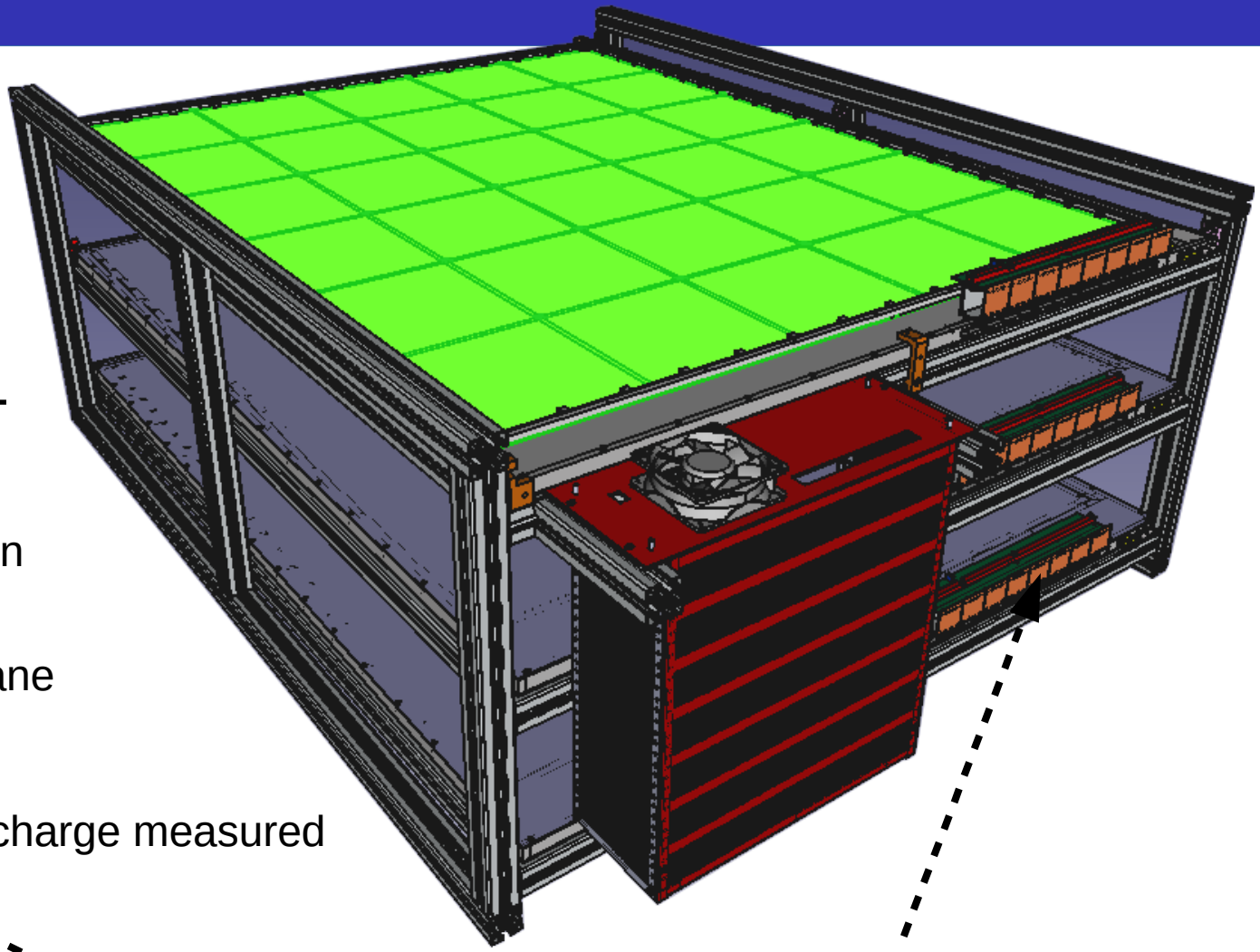
TRISTAN Detector

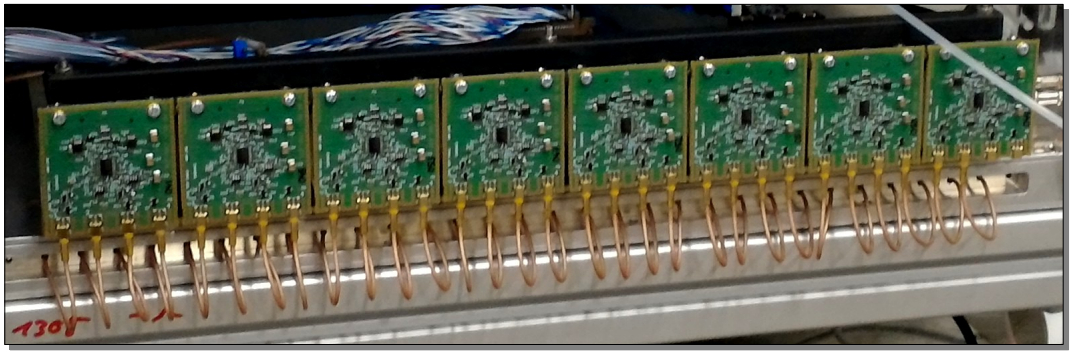


- 3 planes of RPCs
- Active areas of **120x150 cm²**
- Operated in pure **$C_2H_2F_4$, ~11 cc/min** (open gas loop)
- **Built & designed by the LIP-Coimbra** teams, including:
  - HV power supplies
  - gas system w/ monitoring capability

TRISTAN Detector

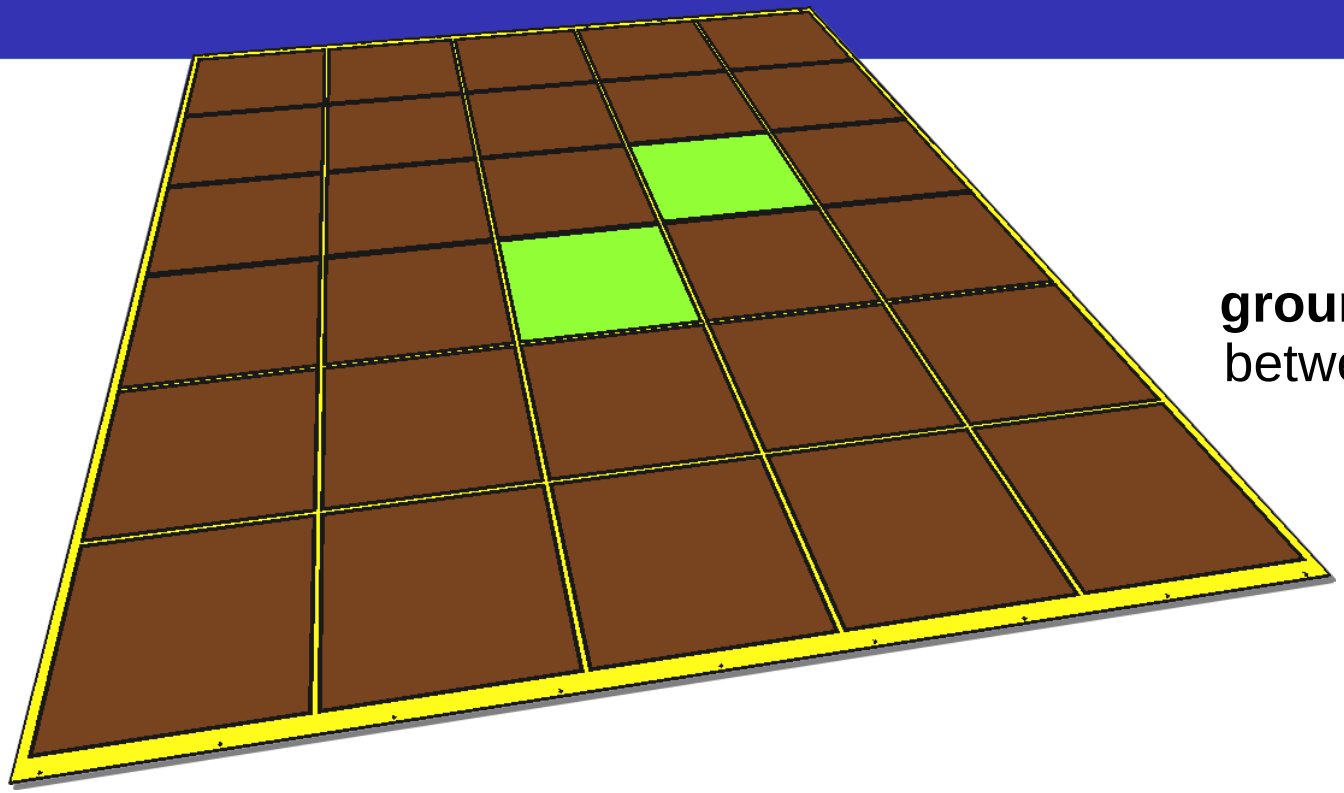


- Multitrack detector working in avalanche mode
- **6x5** 24x25 cm^2 **pads** per plane
- 90 channels in total
- **FEE**[3], time (σt ~35 ps) and charge measured in each single channel



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

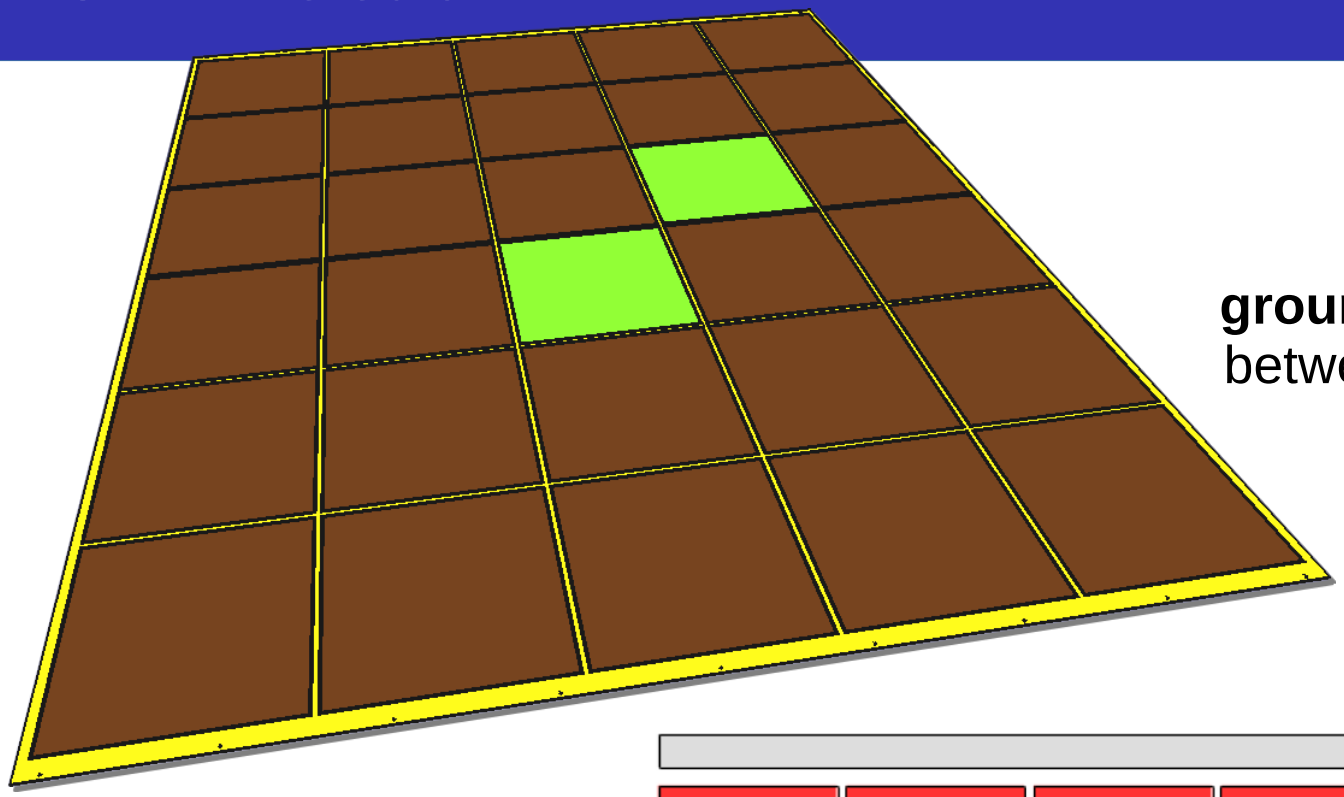
TRISTAN Detector



6 mm wide
grounded guard rings
between pads[4] to avoid
crosstalk

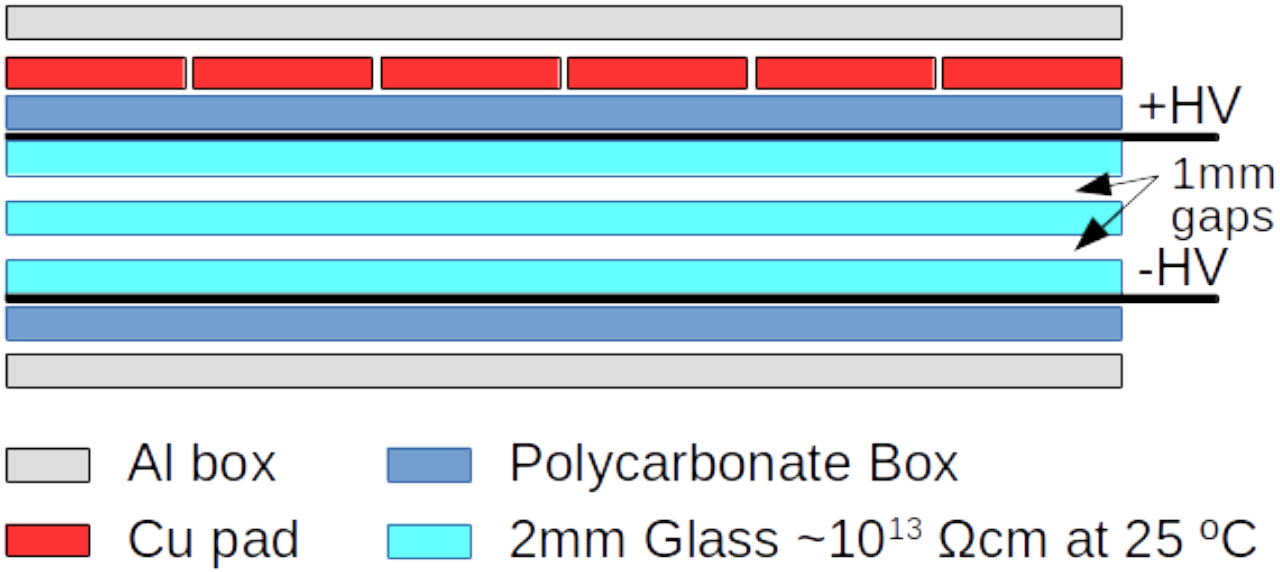
[4] R&D done in the Auger framework (DOI: 10.1088/1748-0221/9/10/C10023)

TRISTAN Detector



6 mm wide
grounded guard rings
between pads[4] to avoid
crosstalk

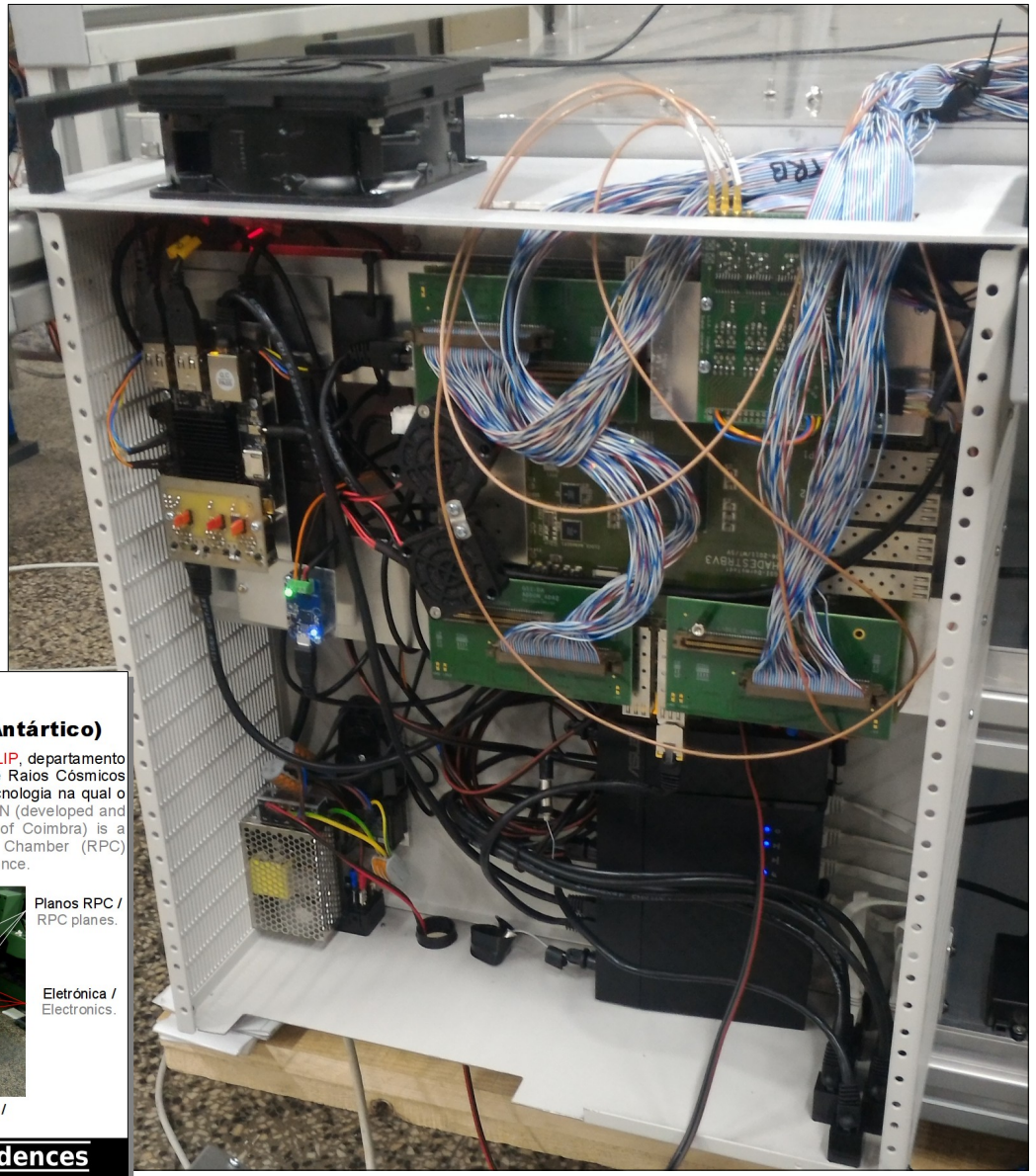
2mm glass with
2 gaps of 1mm



[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



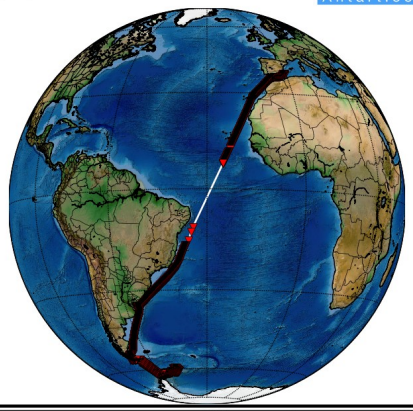
LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS

ORCA Observatorio de Rayos Cósmicos Antártico

TRISTAN e ORCA

(Observatório de Raios Cósmicos Antártico)

TRISTAN (desenvolvido e construido integralmente no LIP, departamento de Física, 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.



TRISTAN no Laboratório de Detetores no LIP / TRISTAN at Detector Laboratory at LIP.

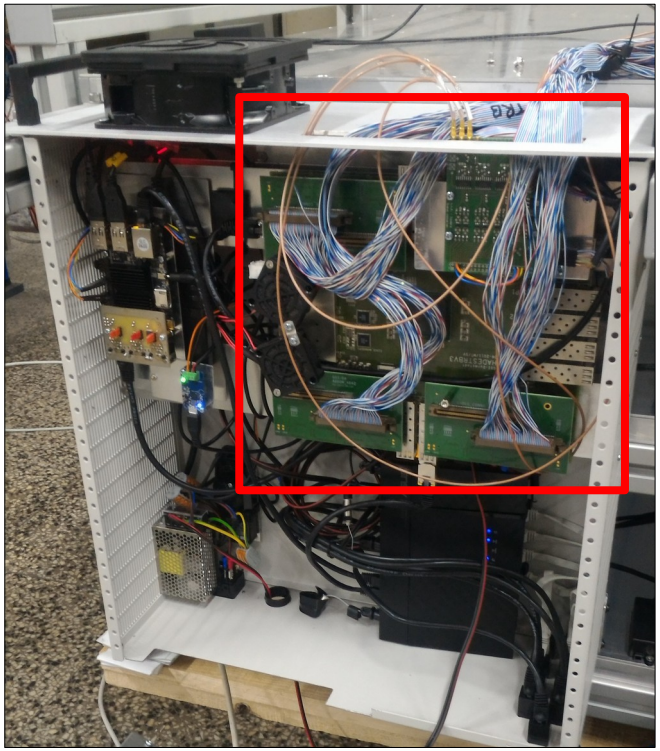
Date	Plane 1	Plane 2	Plane 3	Coincidences
2020-01-23	1962.8	3187.9	3472.0	161.5
2020-01-24 10:00	2027.7	3455.6	3682.7	161.3

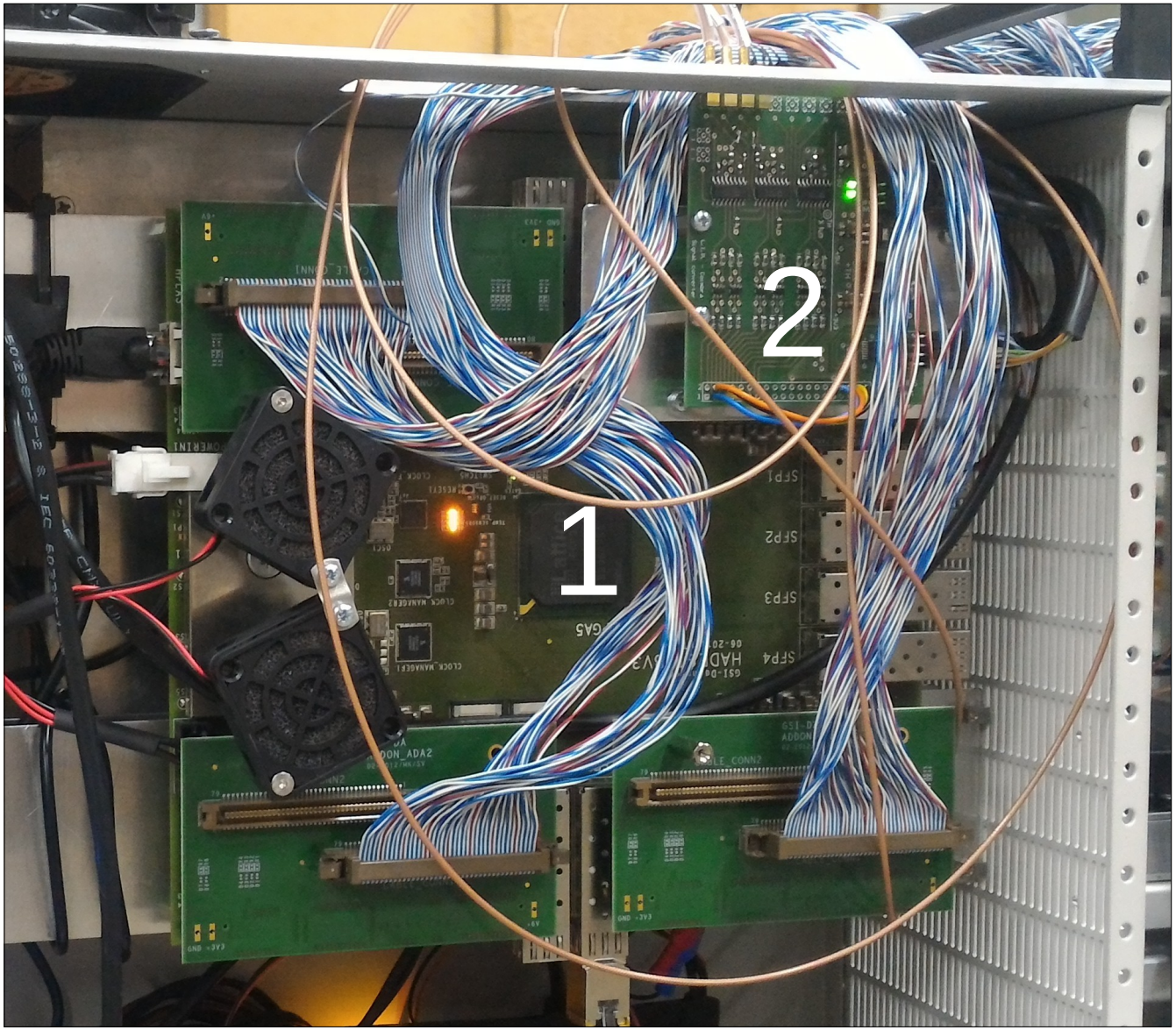
(RPC rates per plane and respective coincidences)

DAQ System – readout board

1 – **TRB3 Readout board**[5] with four FPGA-based **TDCs**, σt ~20 ps

2 – Trigger & LVDS converter board





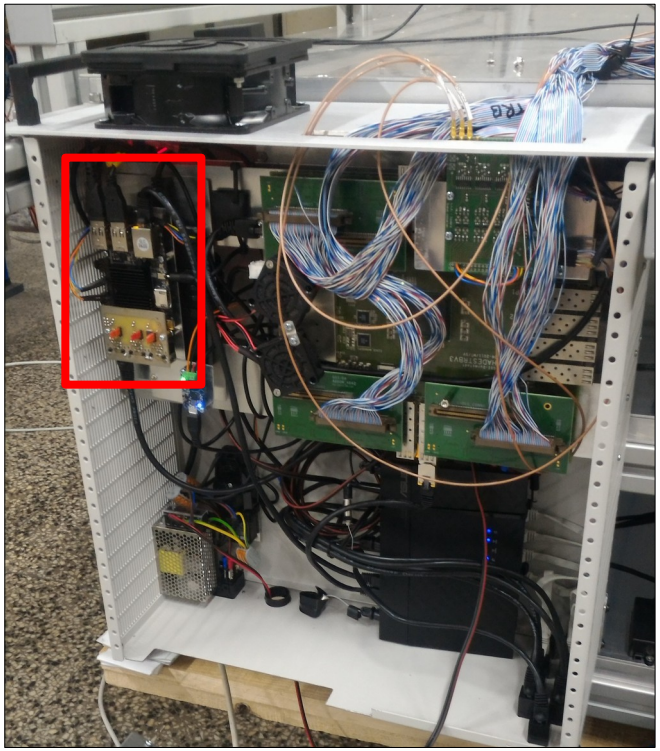
[5] DOI: 10.1088/1748-0221/8/12/C12043

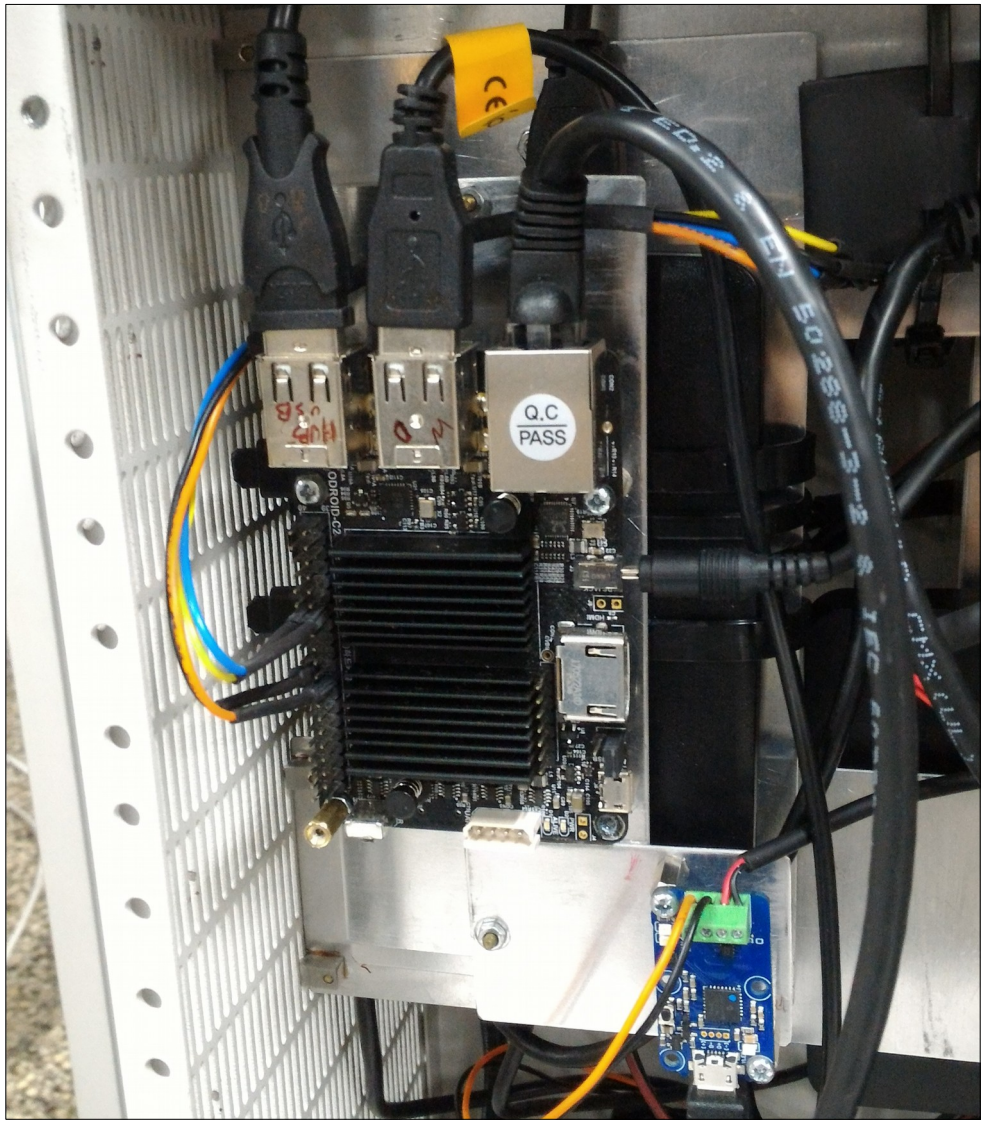
DAQ System – computer

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

with,

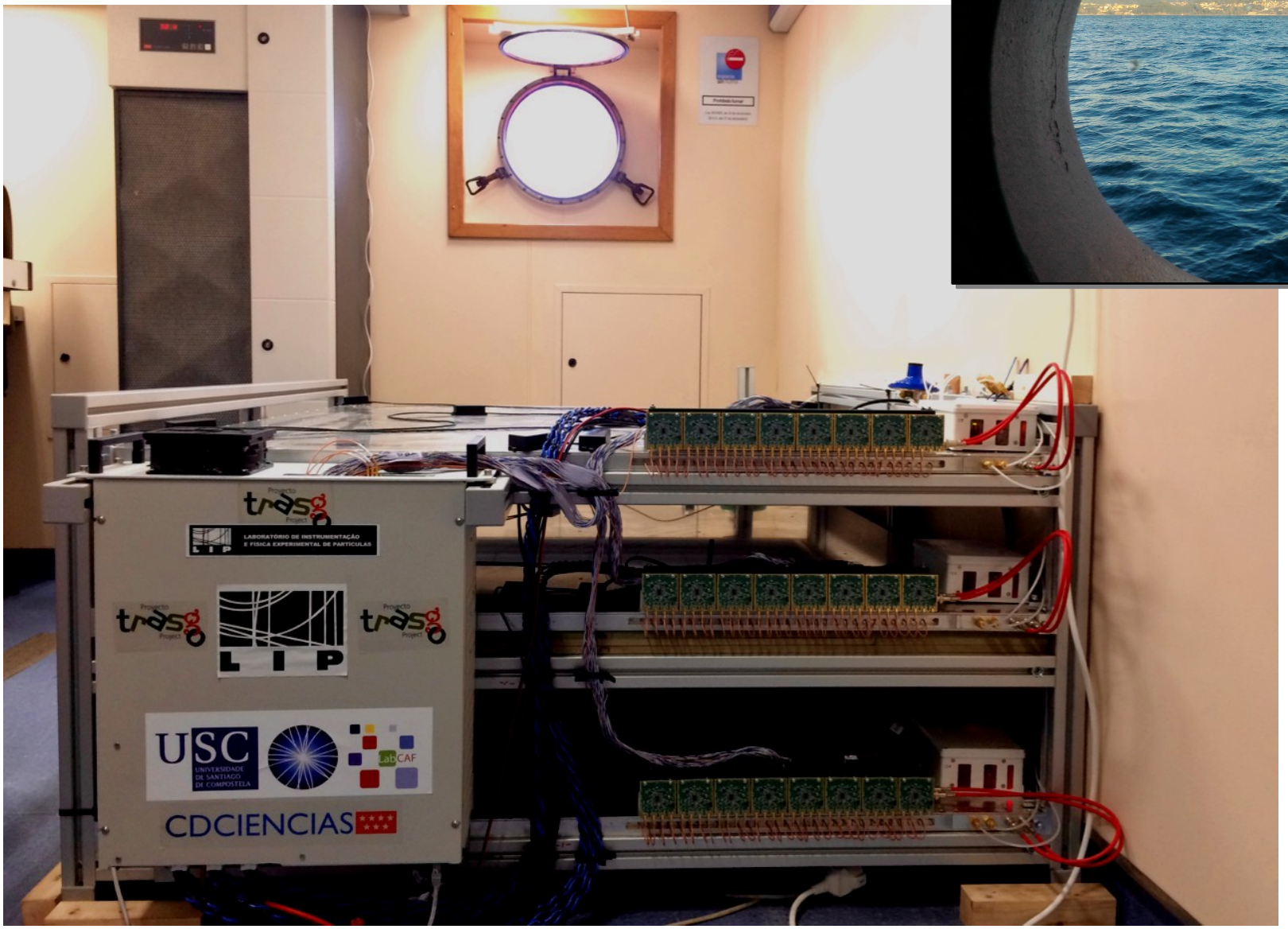
- **watchdog** (power-cycle after 15 min in case of computer crash)
- **i2c** communication w/ environmental sensors...
- RTC clock (if NTP server unavailable)





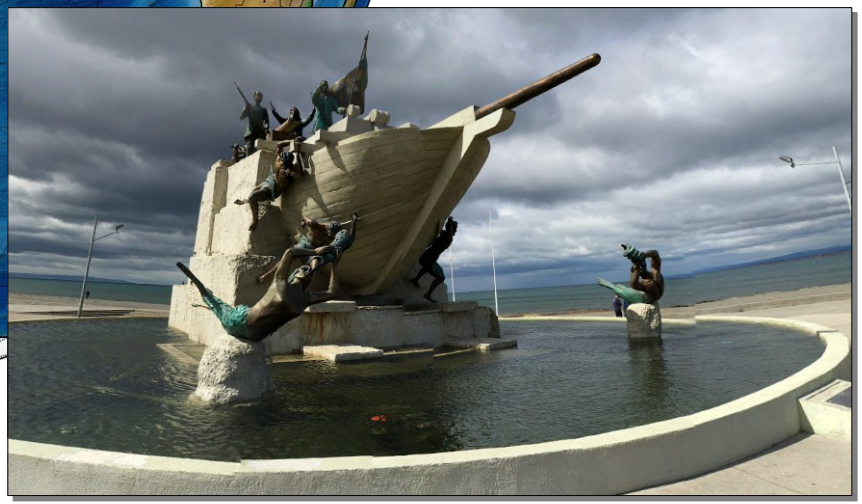
Detector Installation – Boat Sarmiento de Gamboa

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



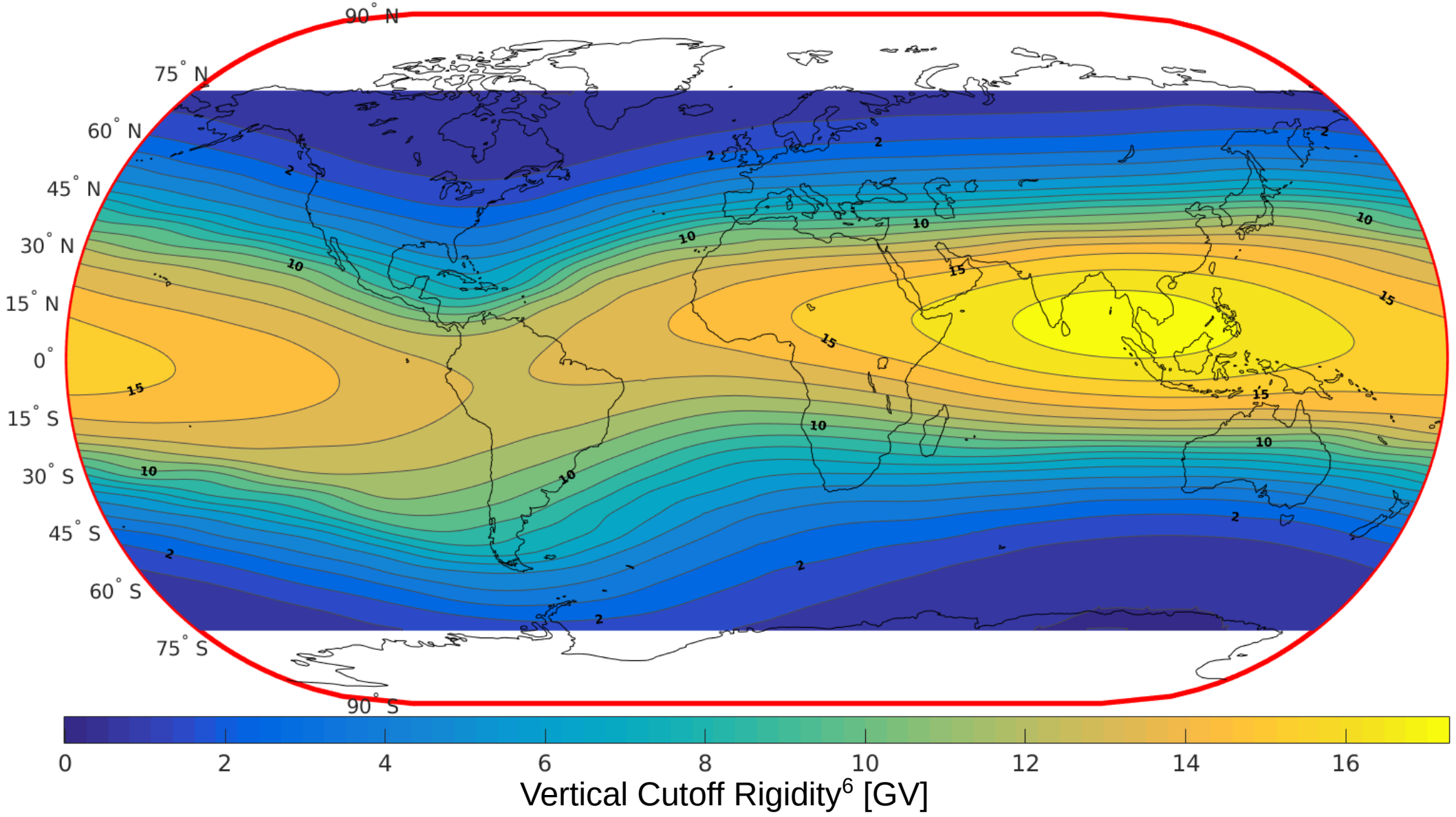
Latitude Survey – Secondary Cosmic Rays

Sarmiento de Gamboa



Nov 2018 -> April 2019
Two way scan:
Vigo (Spain) <-> Punta Arenas (Chile)
Results -> first journey

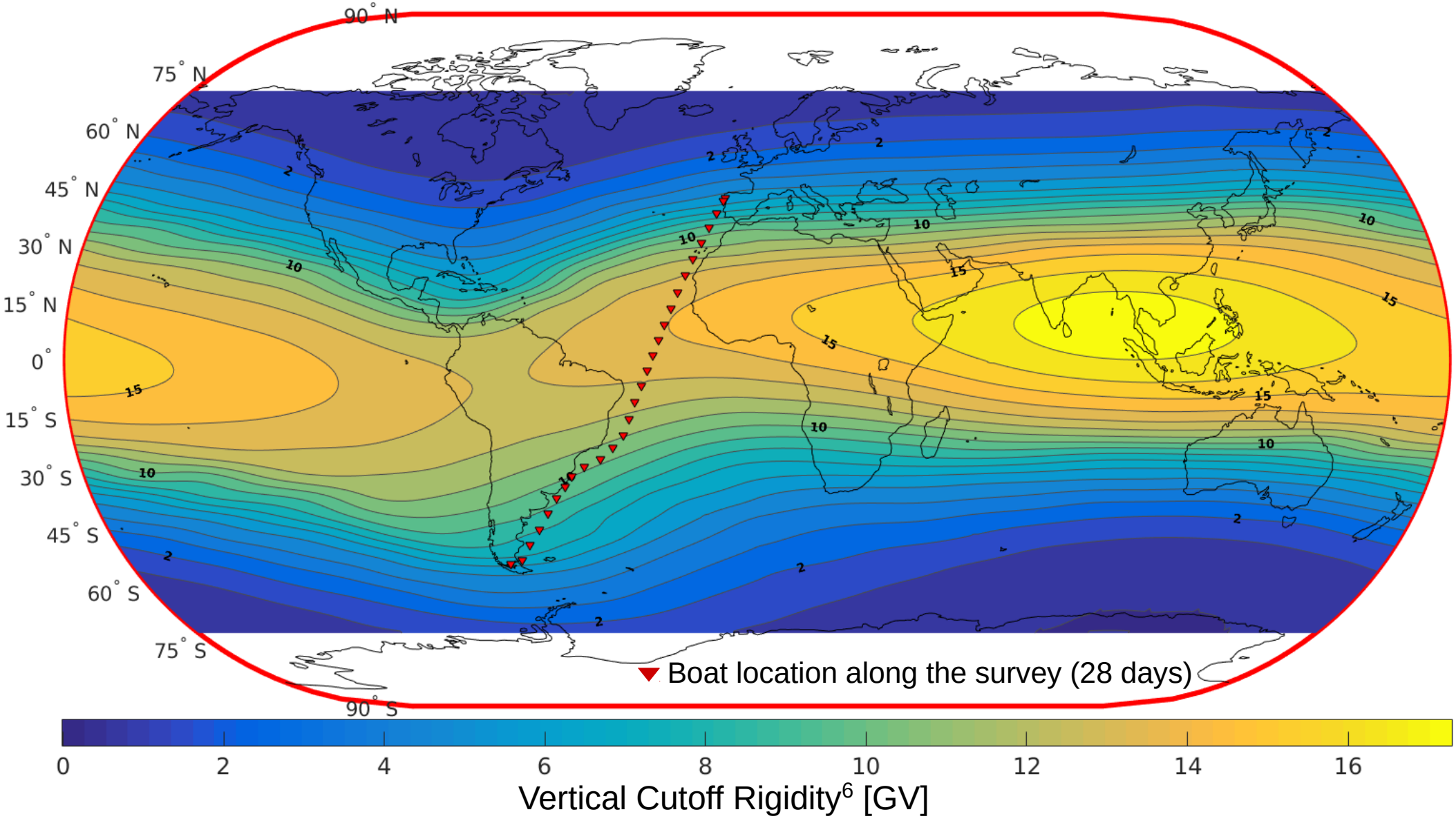
Vertical Cutoff Rigidity of Primary Cosmic Rays



Minimum Rigidity (pc/Ze)
to cross the Geomagnetic Field

[6] Shea and Smart [1983]

Vertical Cutoff Rigidity of Primary Cosmic Rays – Daily Boat Location



Minimum Rigidity (pc/Ze)
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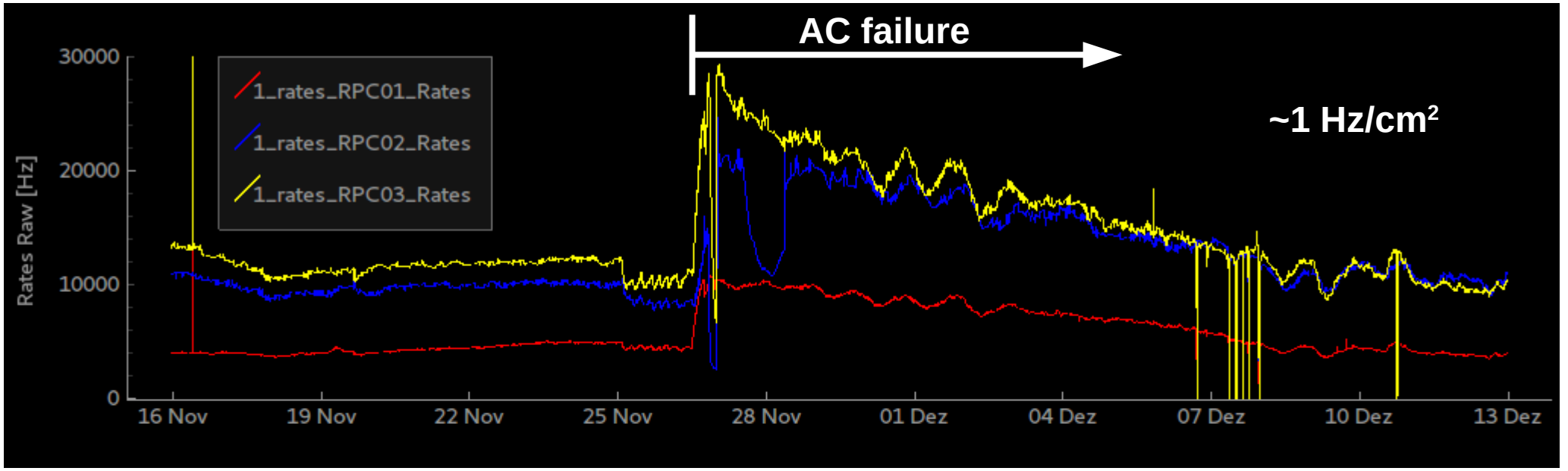
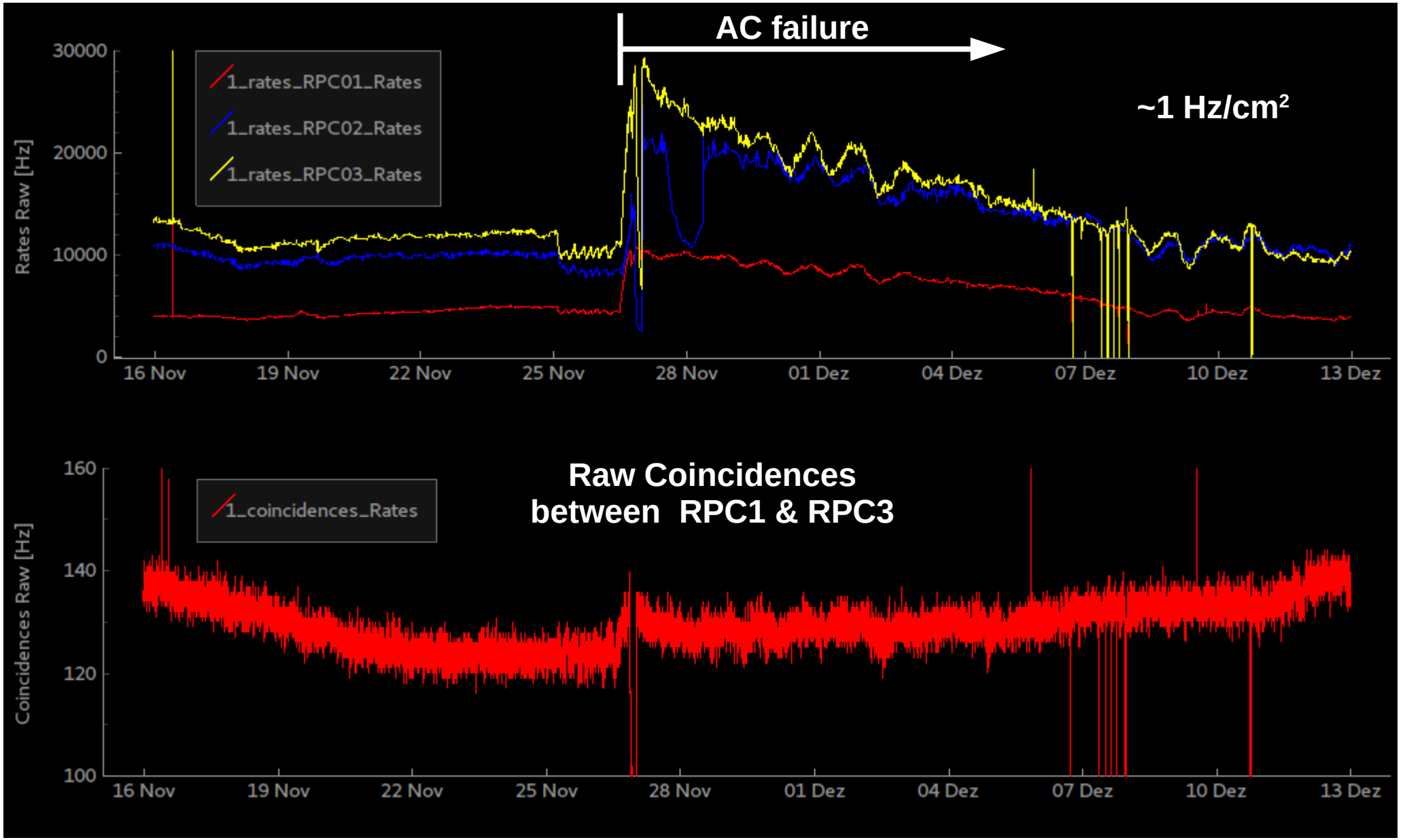
[6] Shea and Smart [1983]

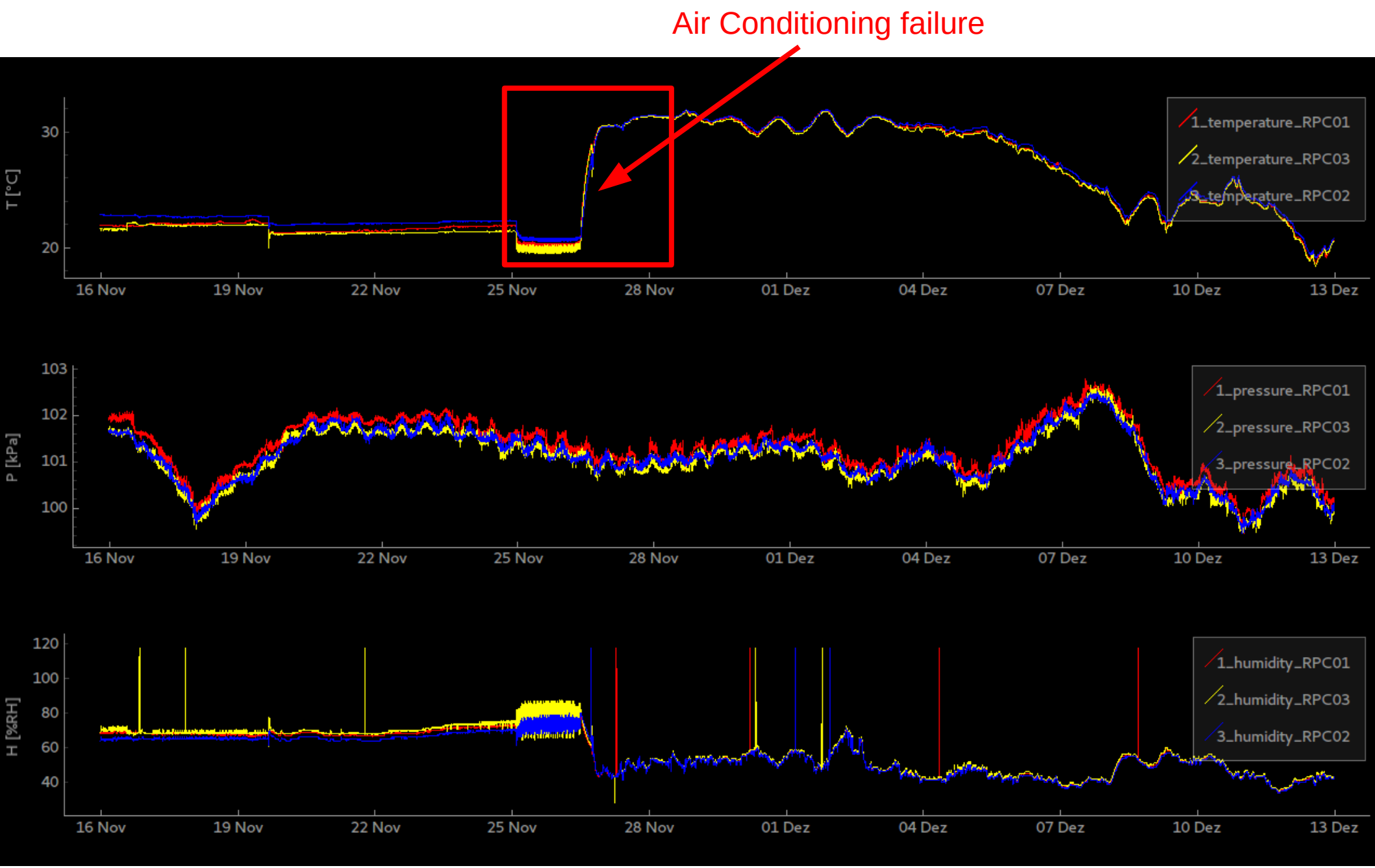
Background Rates & Raw Coincidences



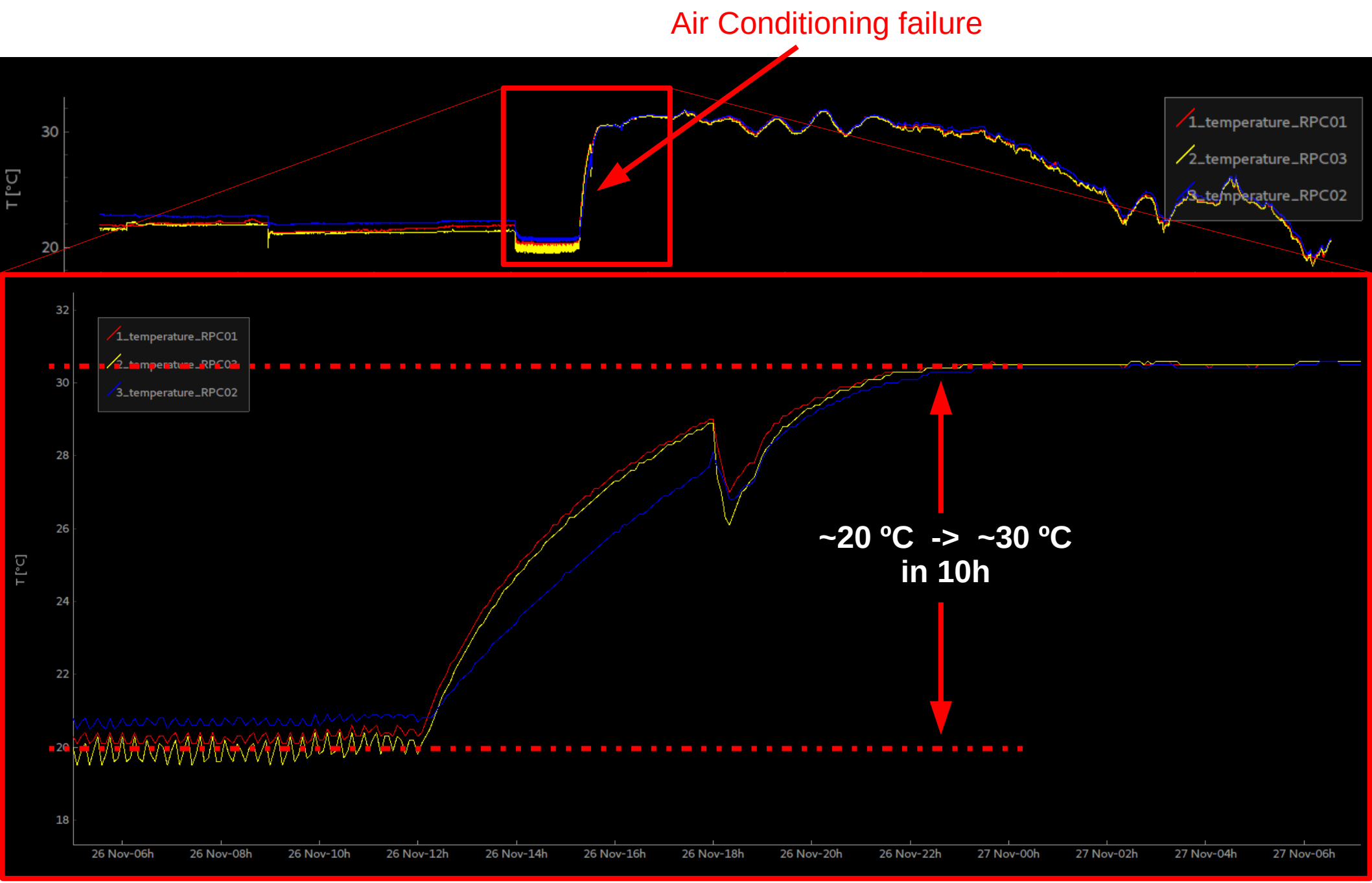
Background Rates & Raw Coincidences



Environmental Sensors – Temperature, Pressure, Humidity



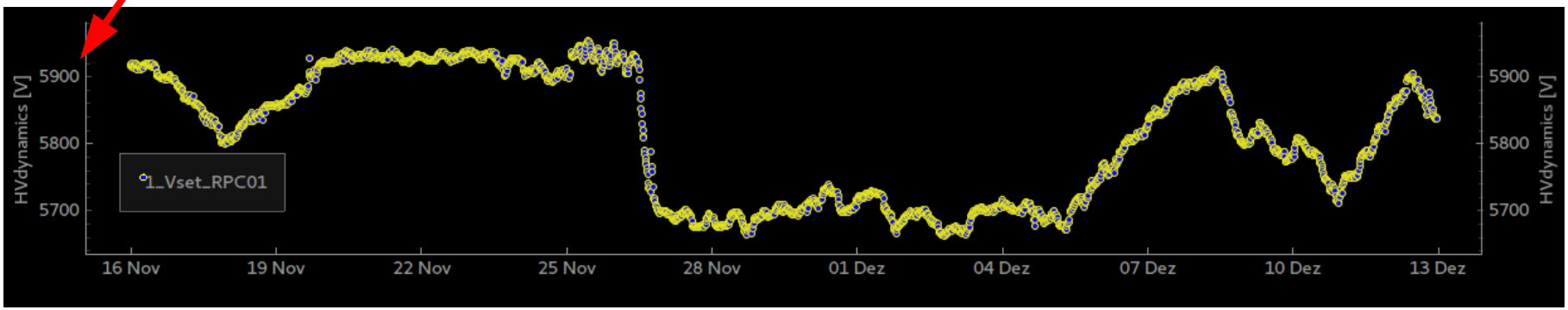
Environmental Sensors – AC failure (Δ ~10 ºC)



HV – function of Pressure & Temperature

$$HV\,[V] = \frac{E/N[Td] * d_{gap}[cm] * P[mbar]}{0.0138068748 * T[K]}$$

HV automatically adjusted[7] as a function of Pressure & Temperature



[7] DOI: 10.1088/1748-0221/9/10/C10023

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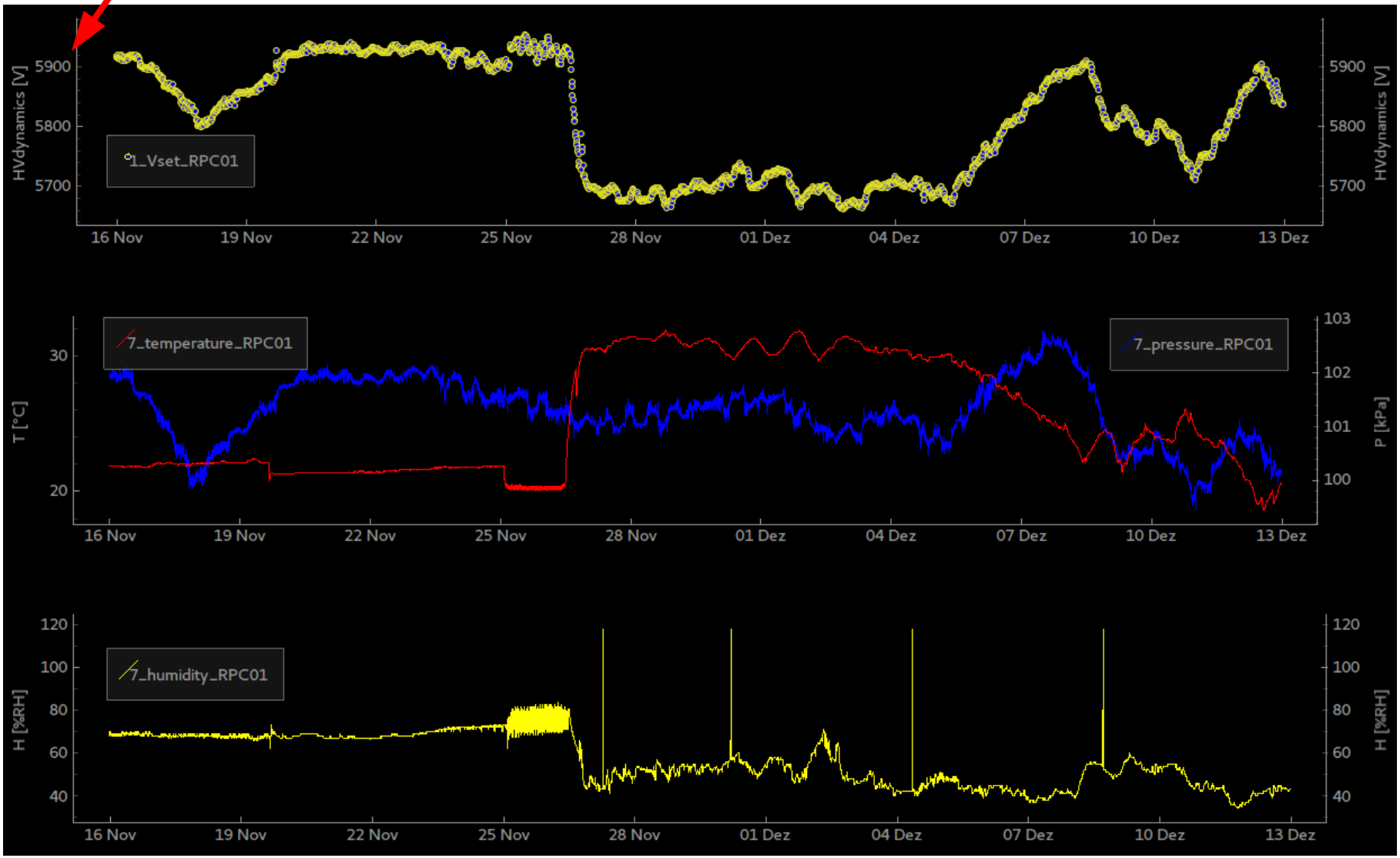
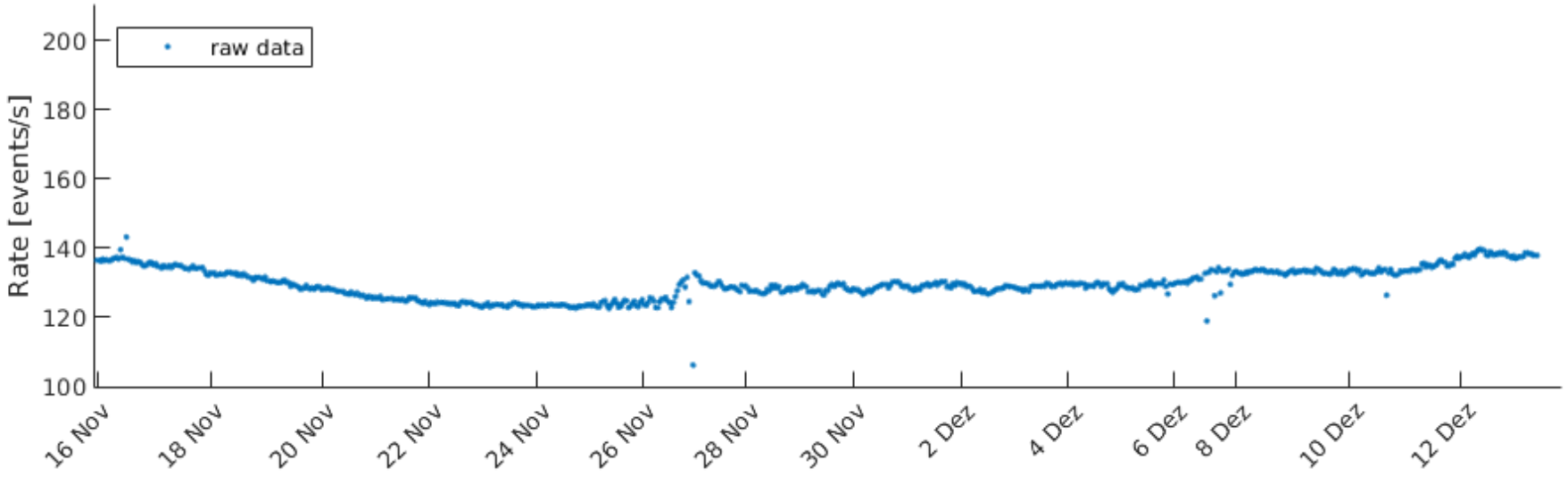


[7] DOI: 10.1088/1748-0221/9/10/C10023

Raw Coincidences & Randoms



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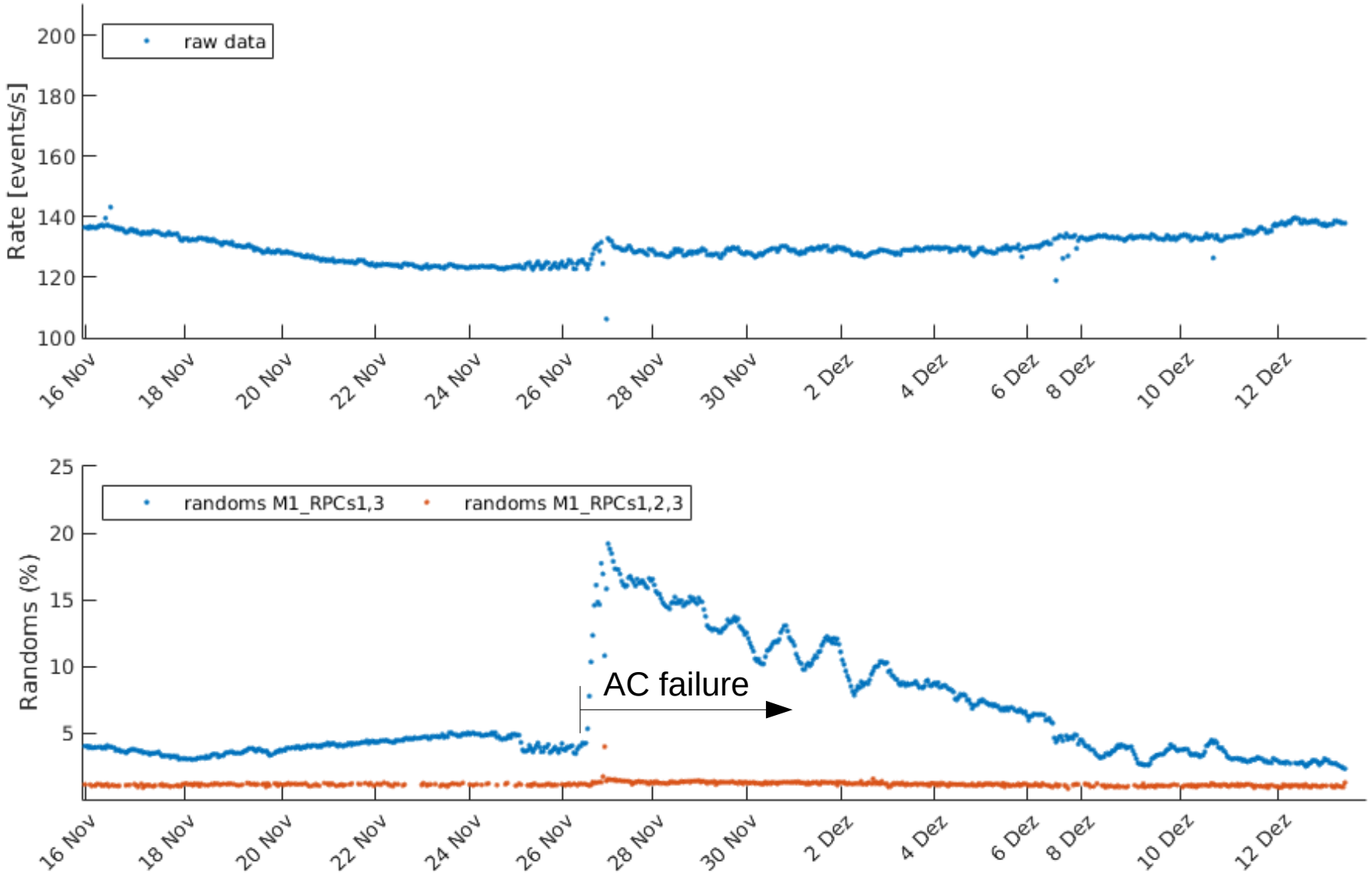

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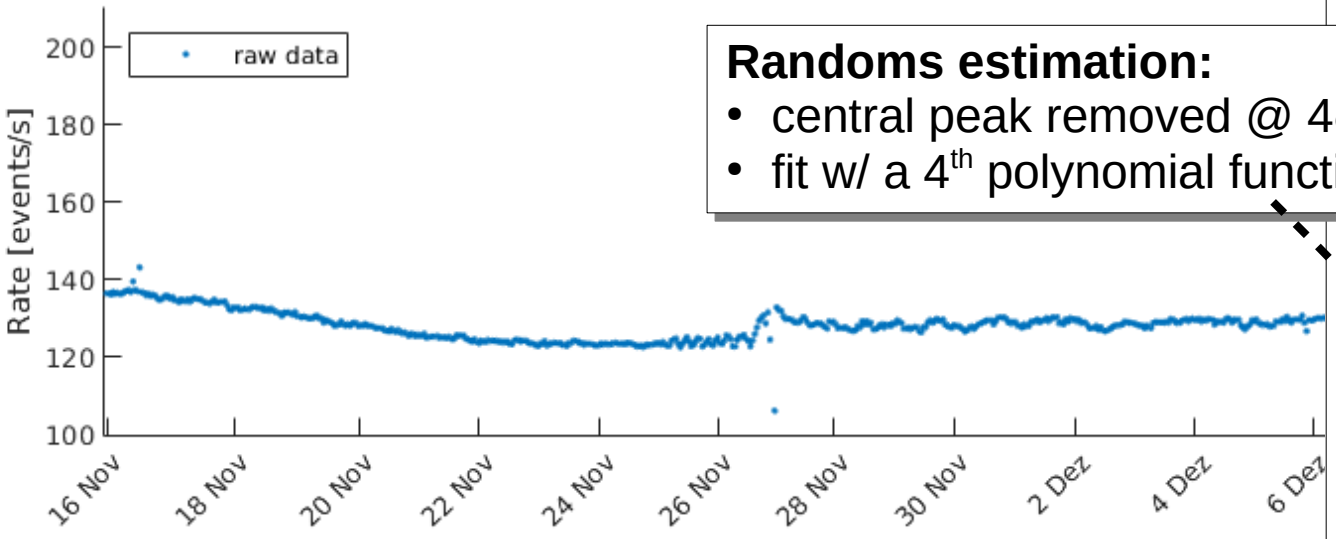
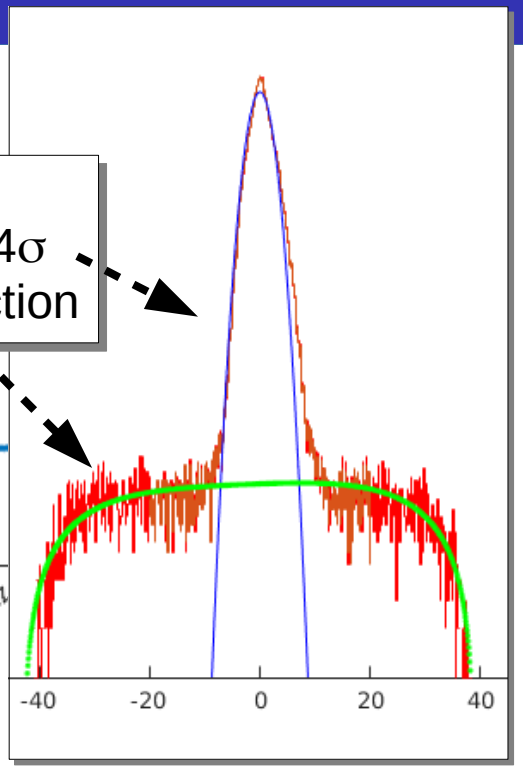
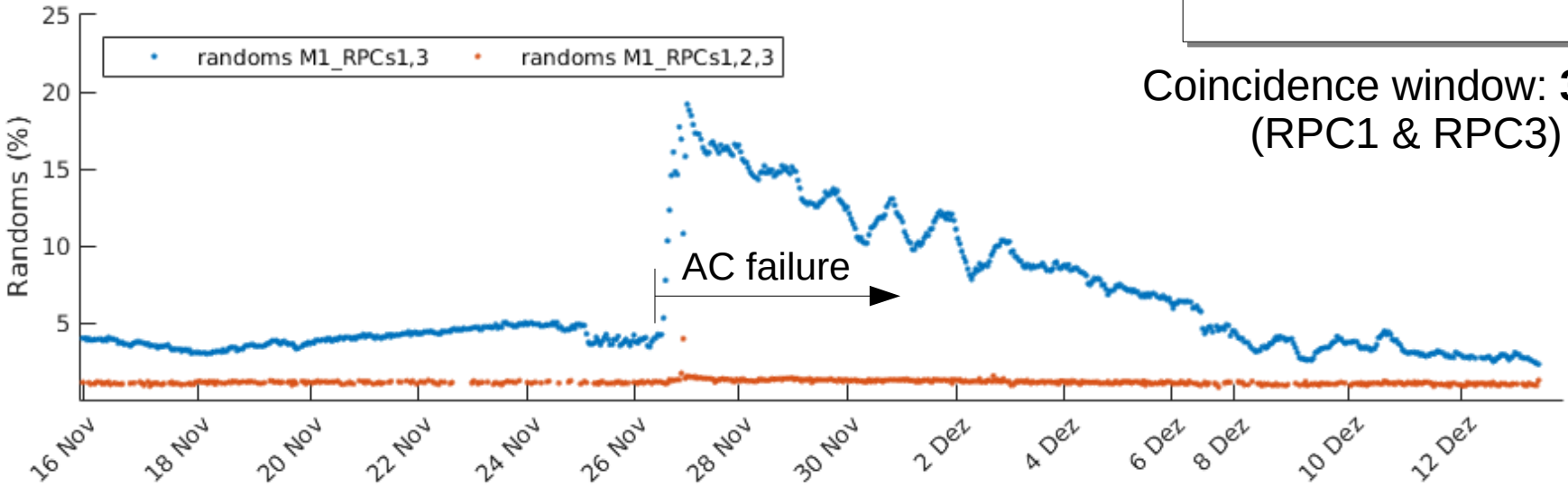


Randoms estimation:

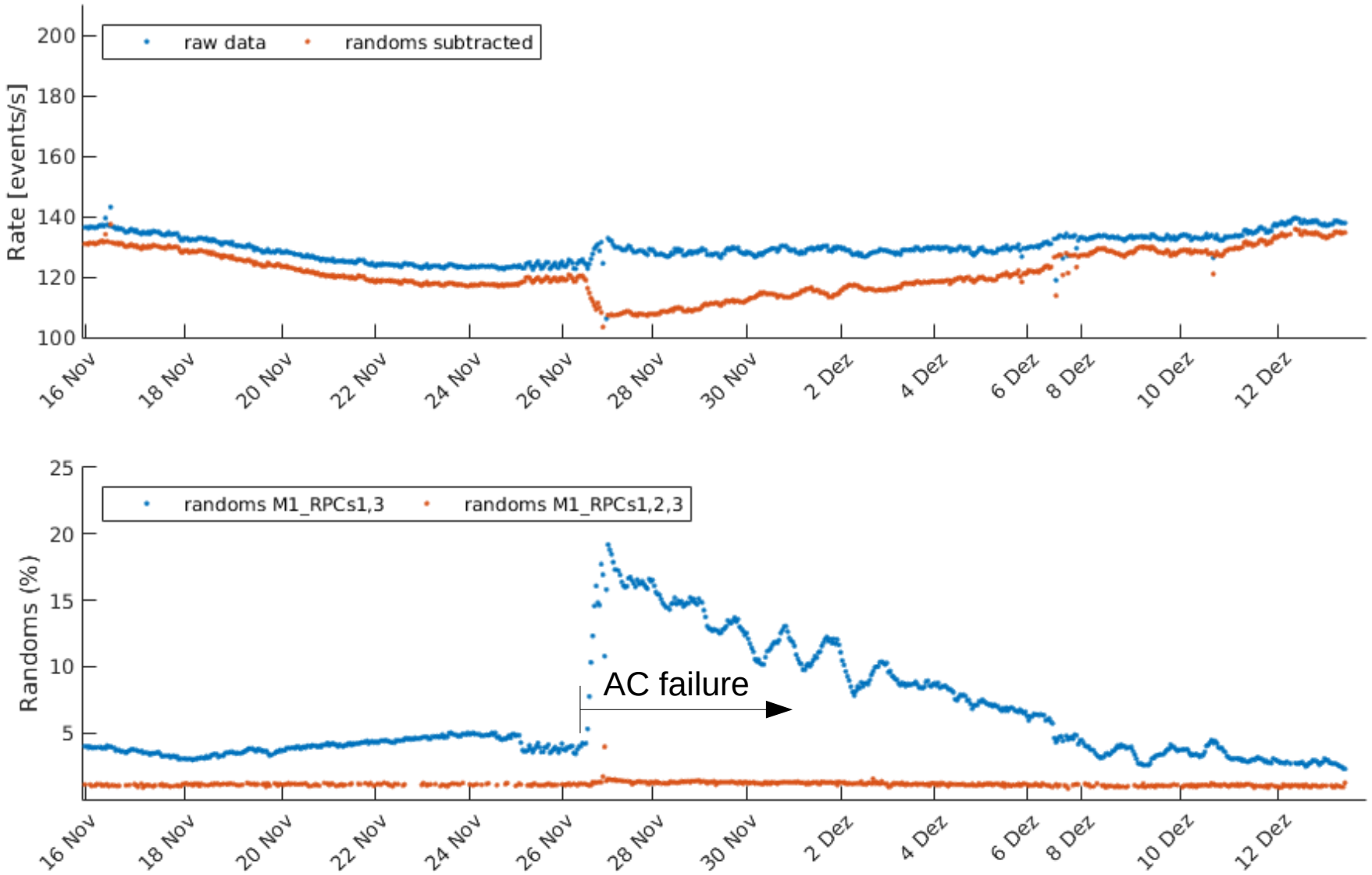
- central peak removed @ 4σ
- fit w/ a 4th polynomial function



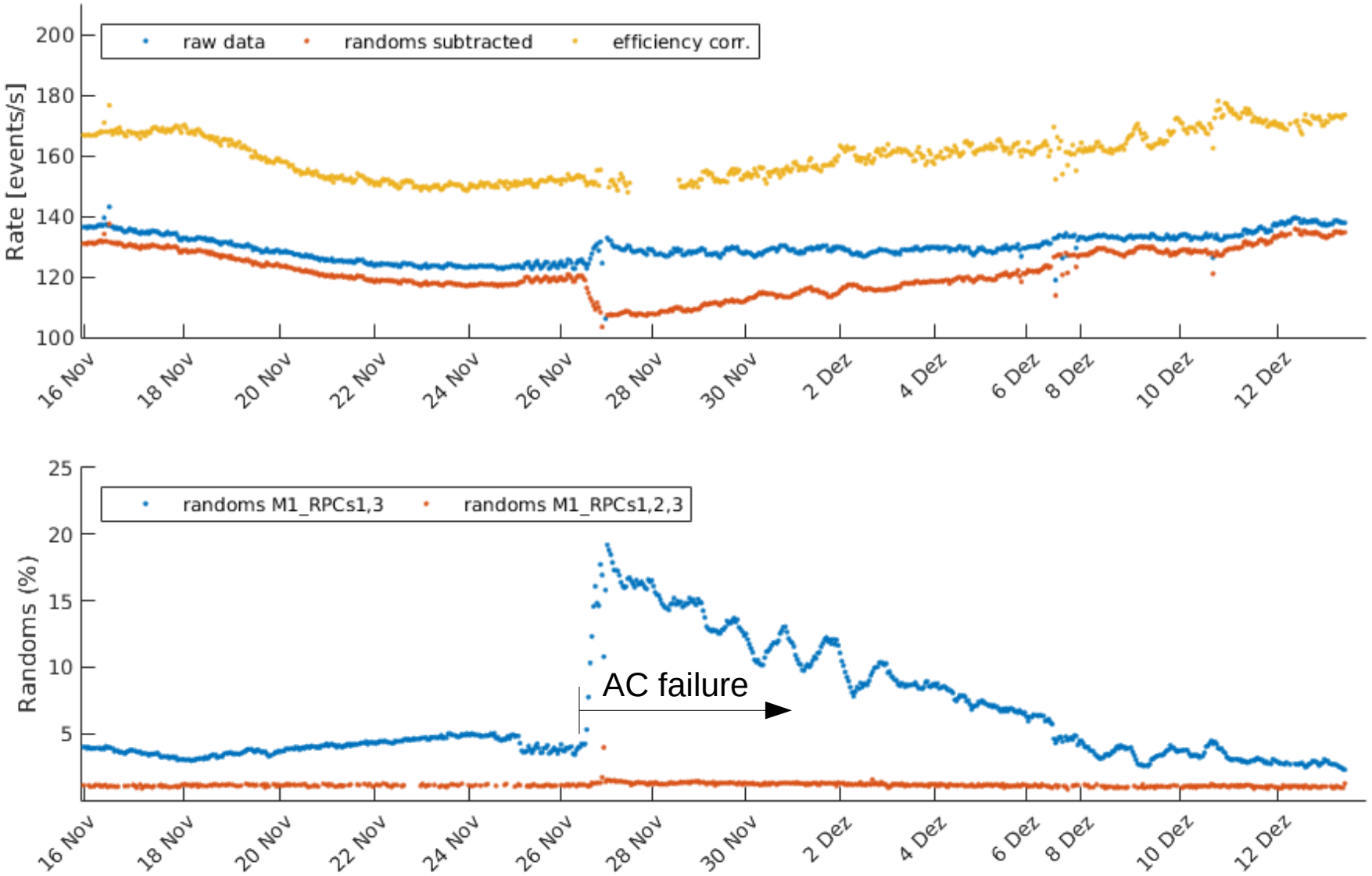
Coincidence window: **30 ns**
(RPC1 & RPC3)



Raw & Corrected Coincidences – Randoms



Raw & Corrected Coincidences – Randoms & Efficiency



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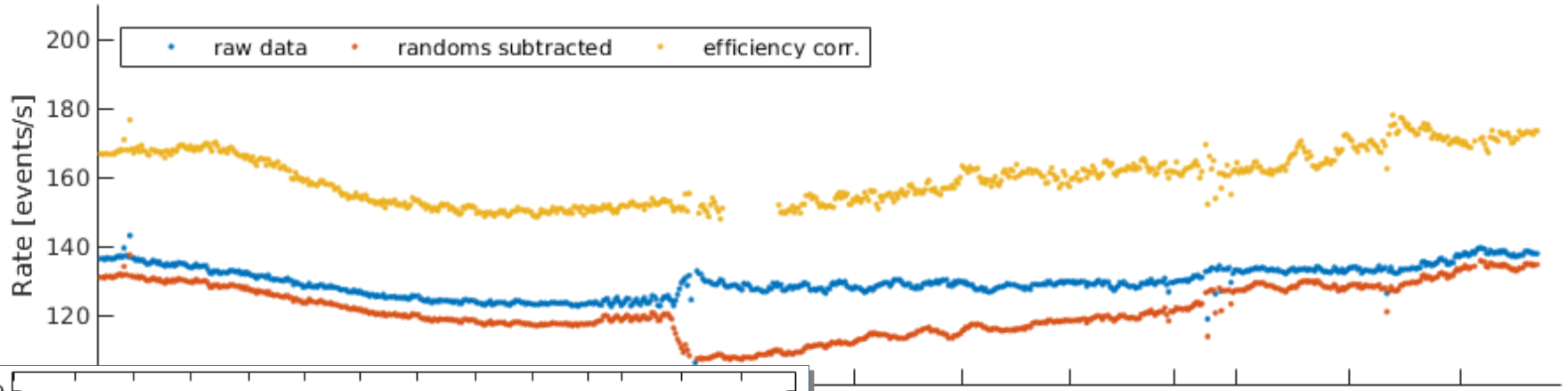
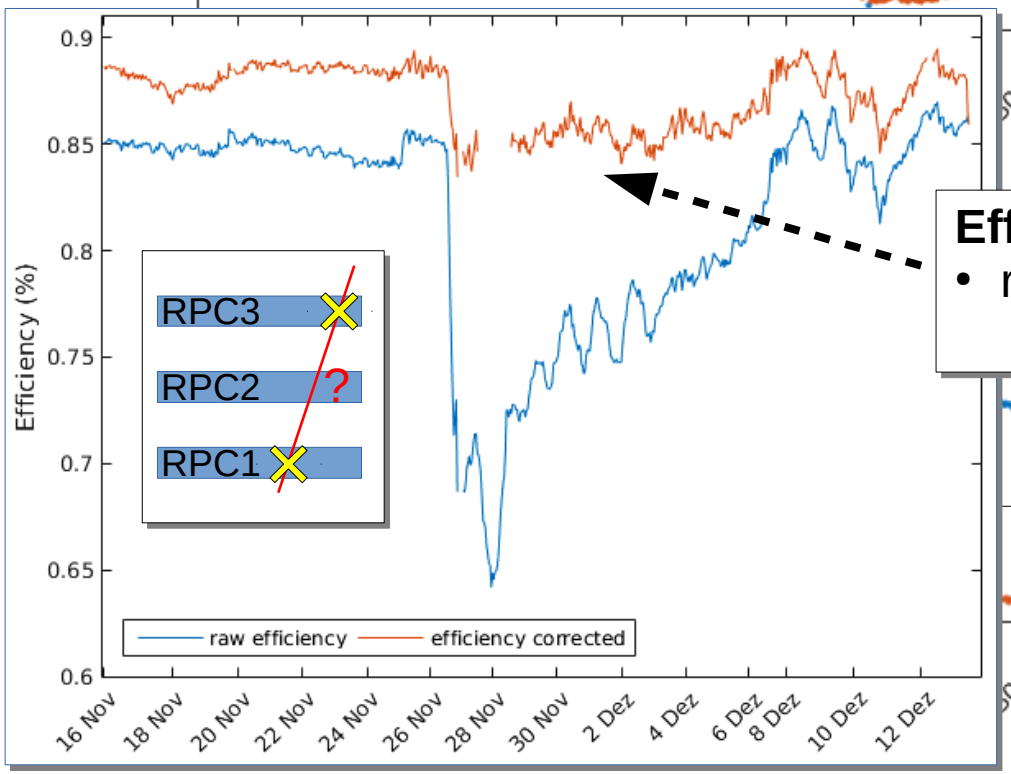
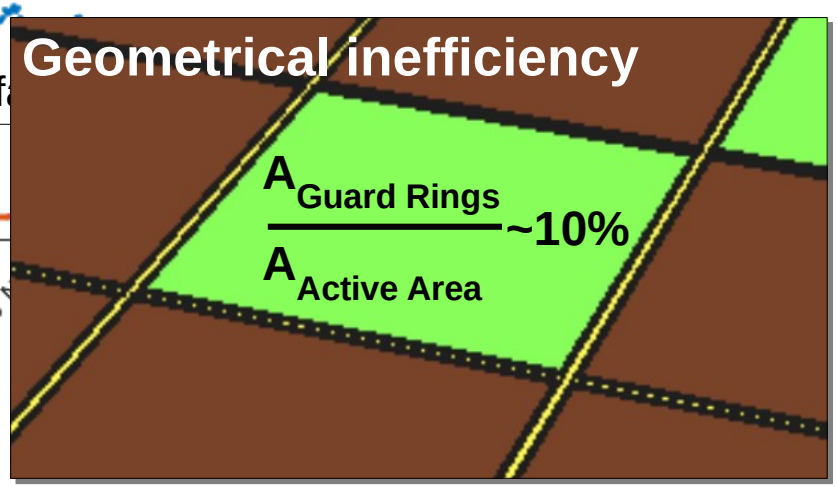
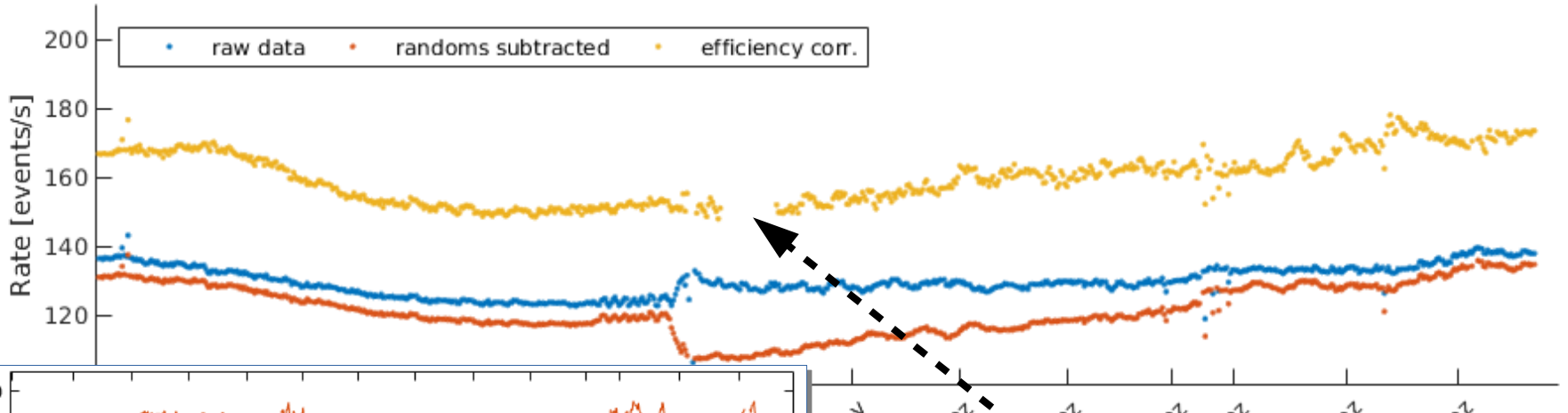


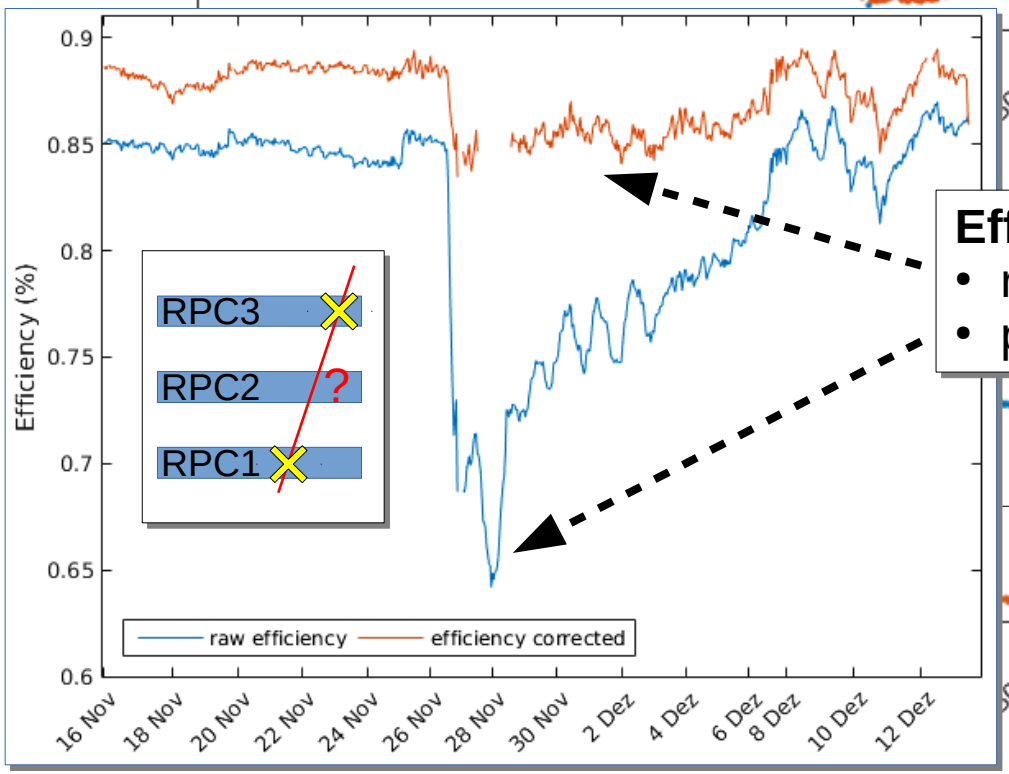


Efficiency of RPC2:
- randoms removed



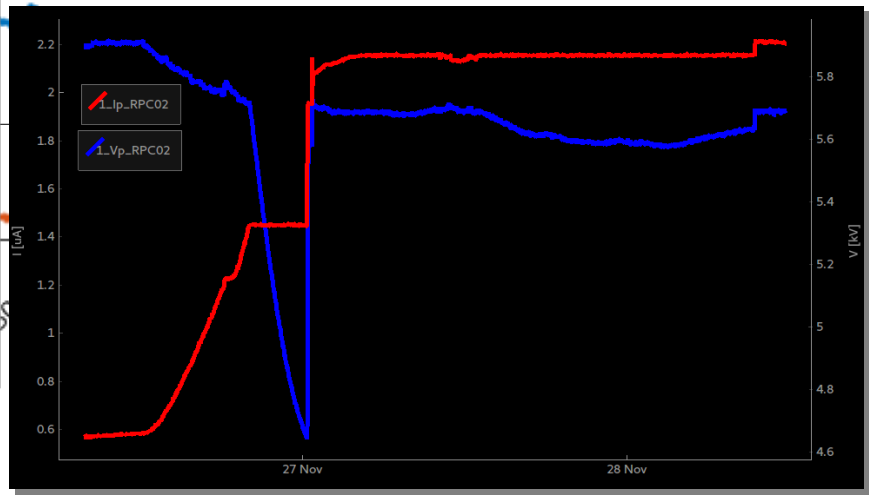
Raw & Corrected Coincidences – Randoms & Efficiency



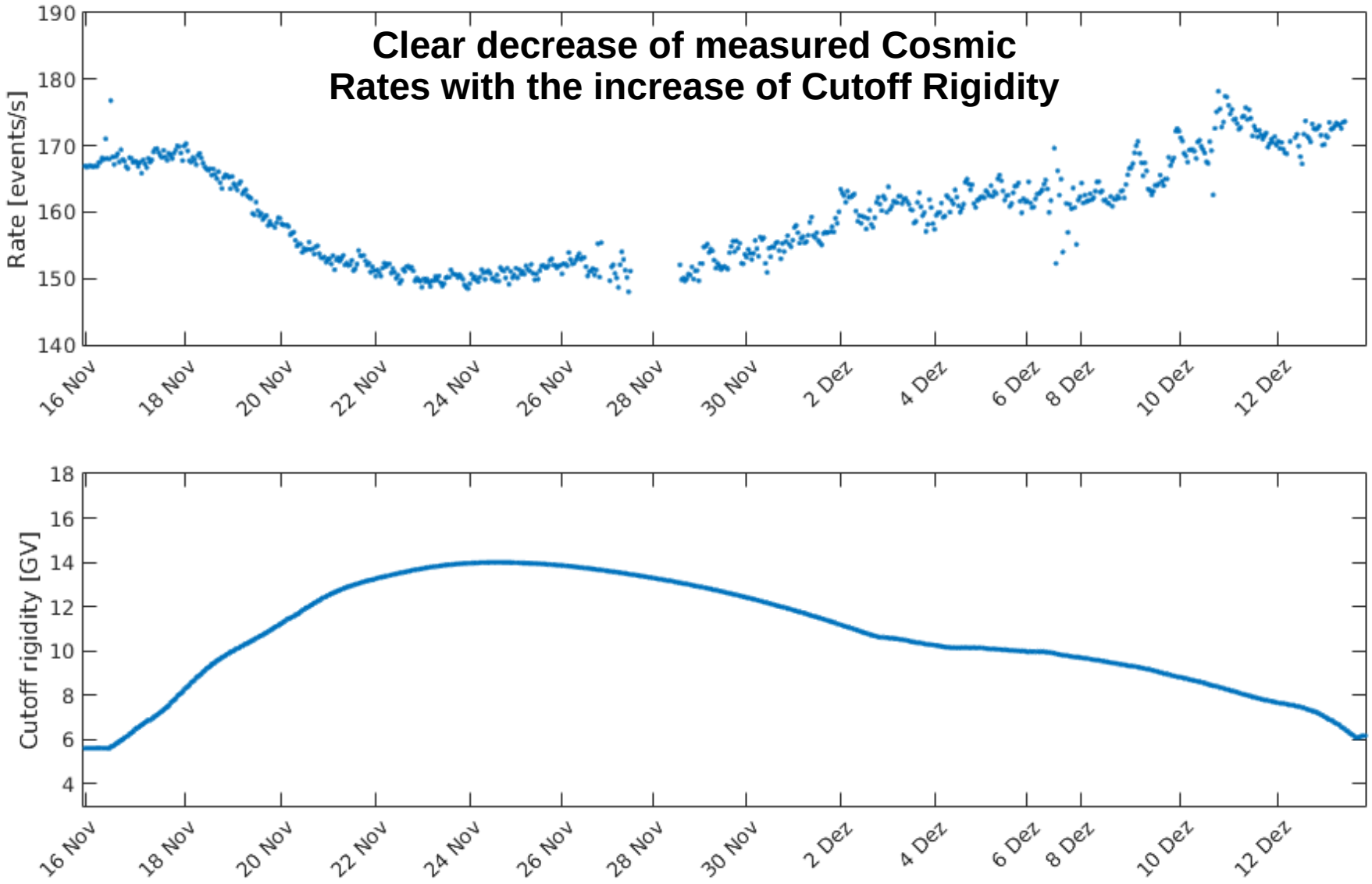


Efficiency of RPC2:

- randoms removed
- peak due to current saturation



Corrected Coincidences & Cutoff Rigidities along the Survey



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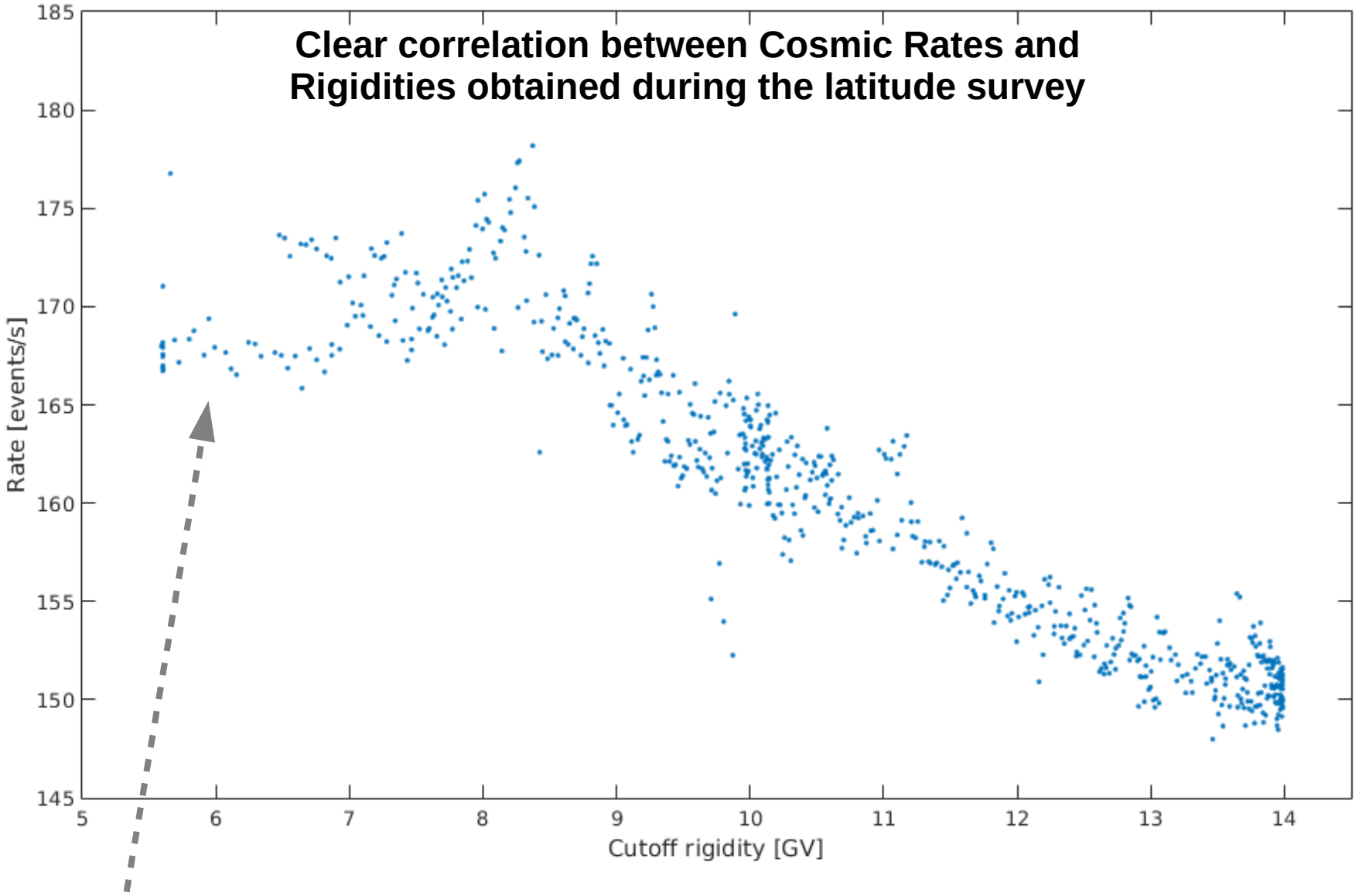
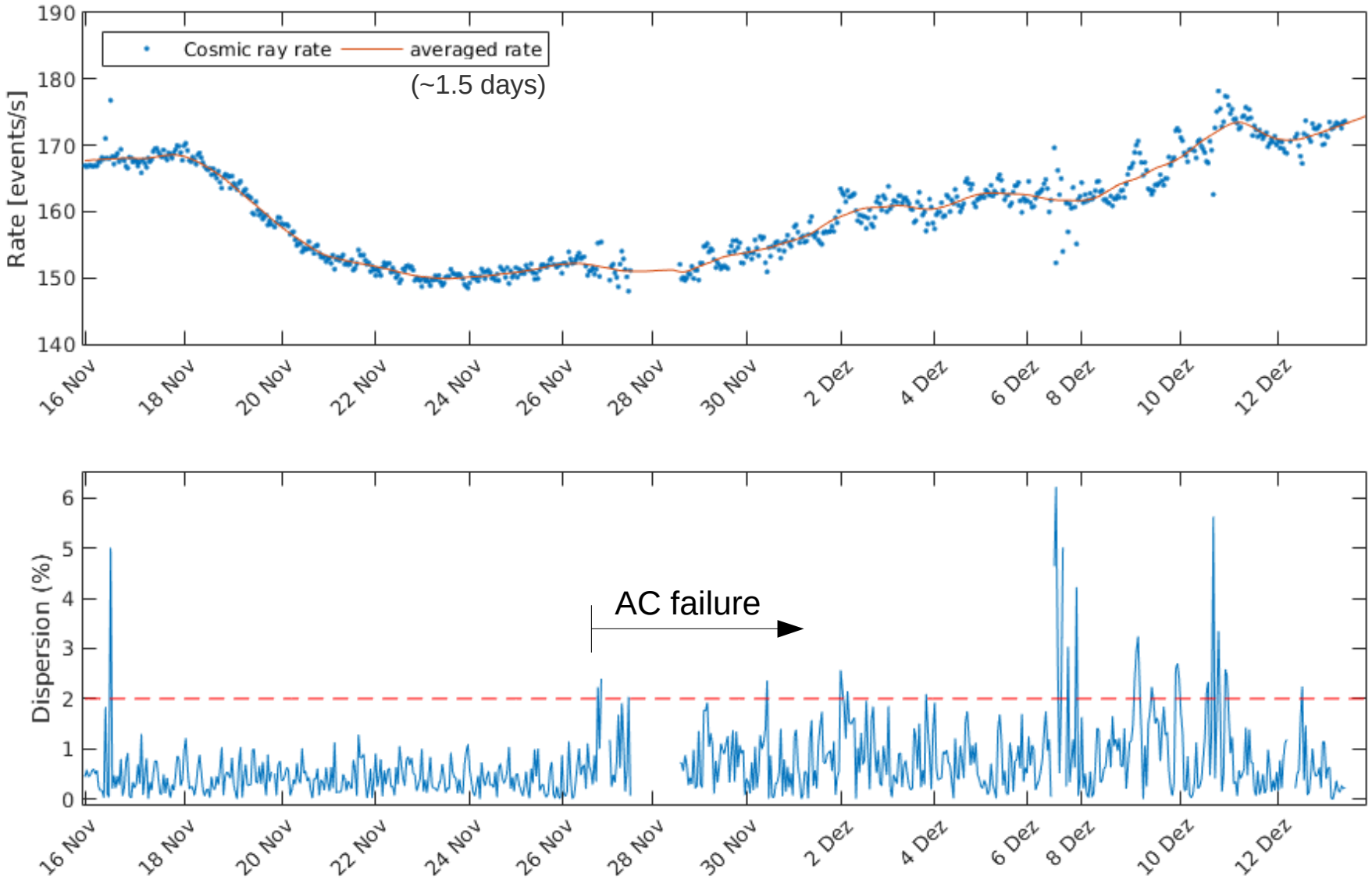


-> points outside the correlation region being investigated

Coincidence Dispersion below 2%

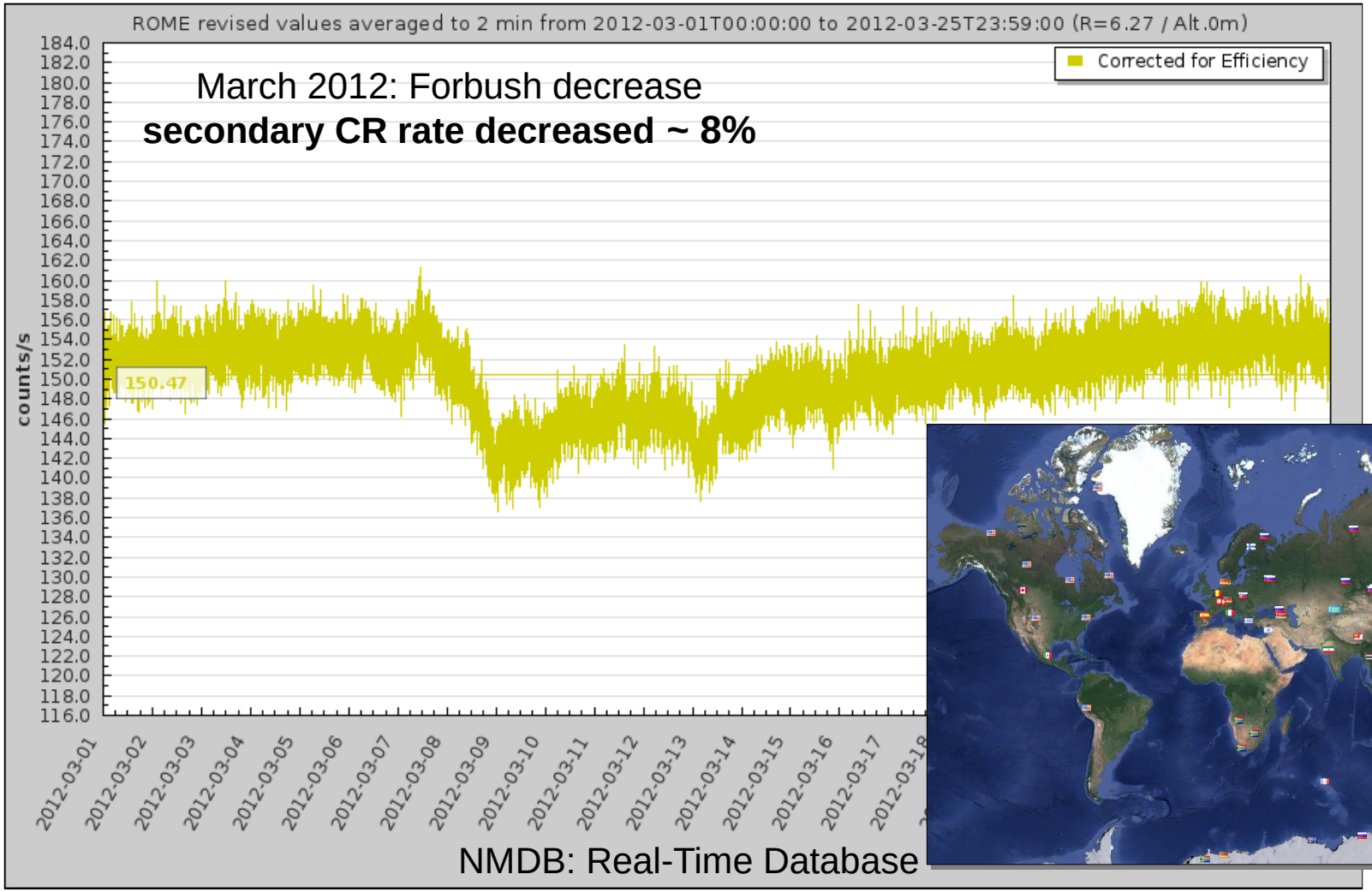


More than 99% of measurements are below a 2% dispersion

-> can be even better with controlled temperature

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

Conclusions

- **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

Conclusions

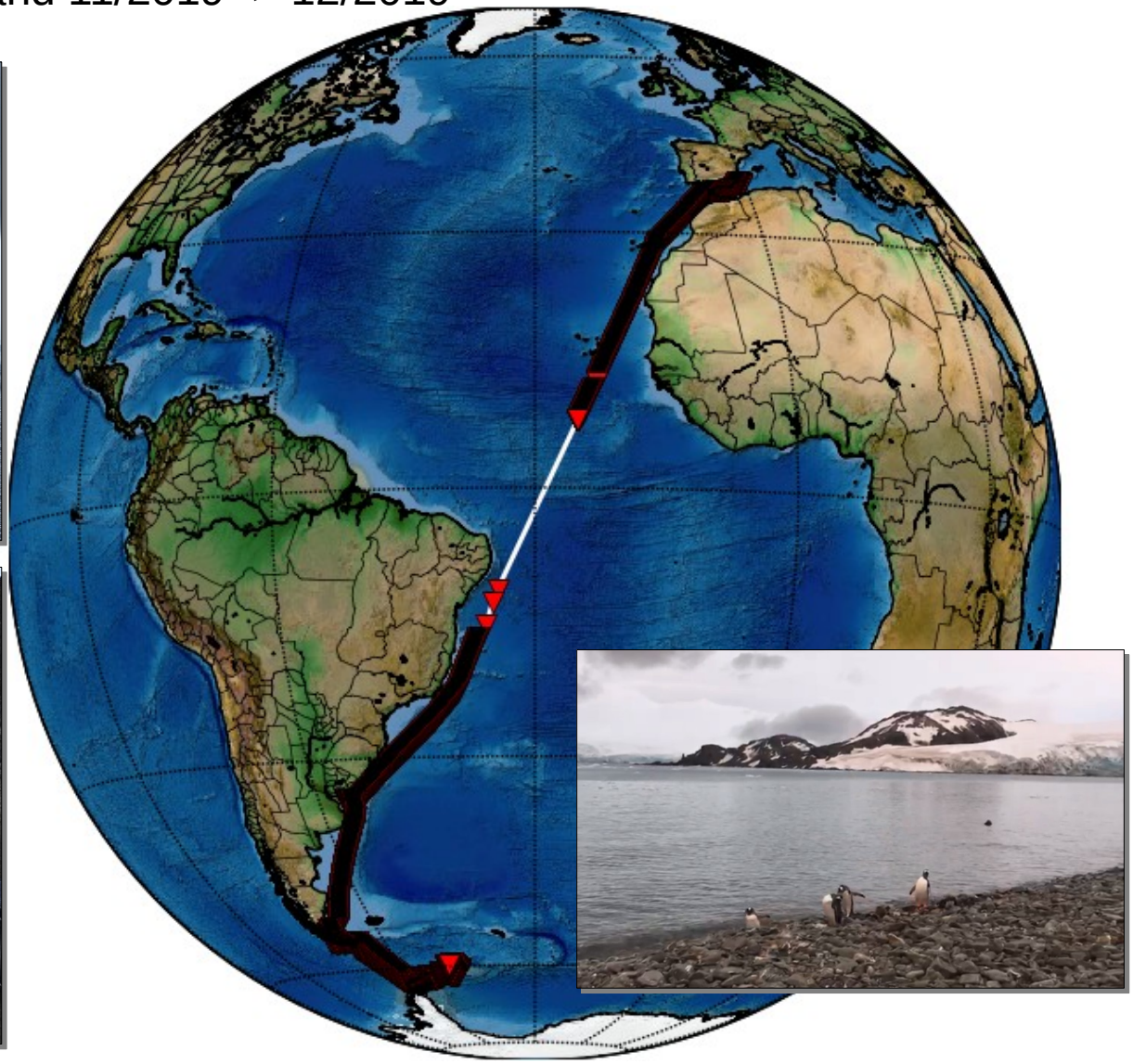
- **RPC detectors measured successfully Secondary Cosmic-Ray flux** during a **Latitude Survey along the Atlantic Ocean**
- **Fully Autonomous DAQ System** used with success
- Clear correlation between **Cosmic-Ray Rate and Cutoff Rigidity** obtained during the survey
- **Efficiency decreased few %** with air conditioning failure (**Δ ~10 ºC**), 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)

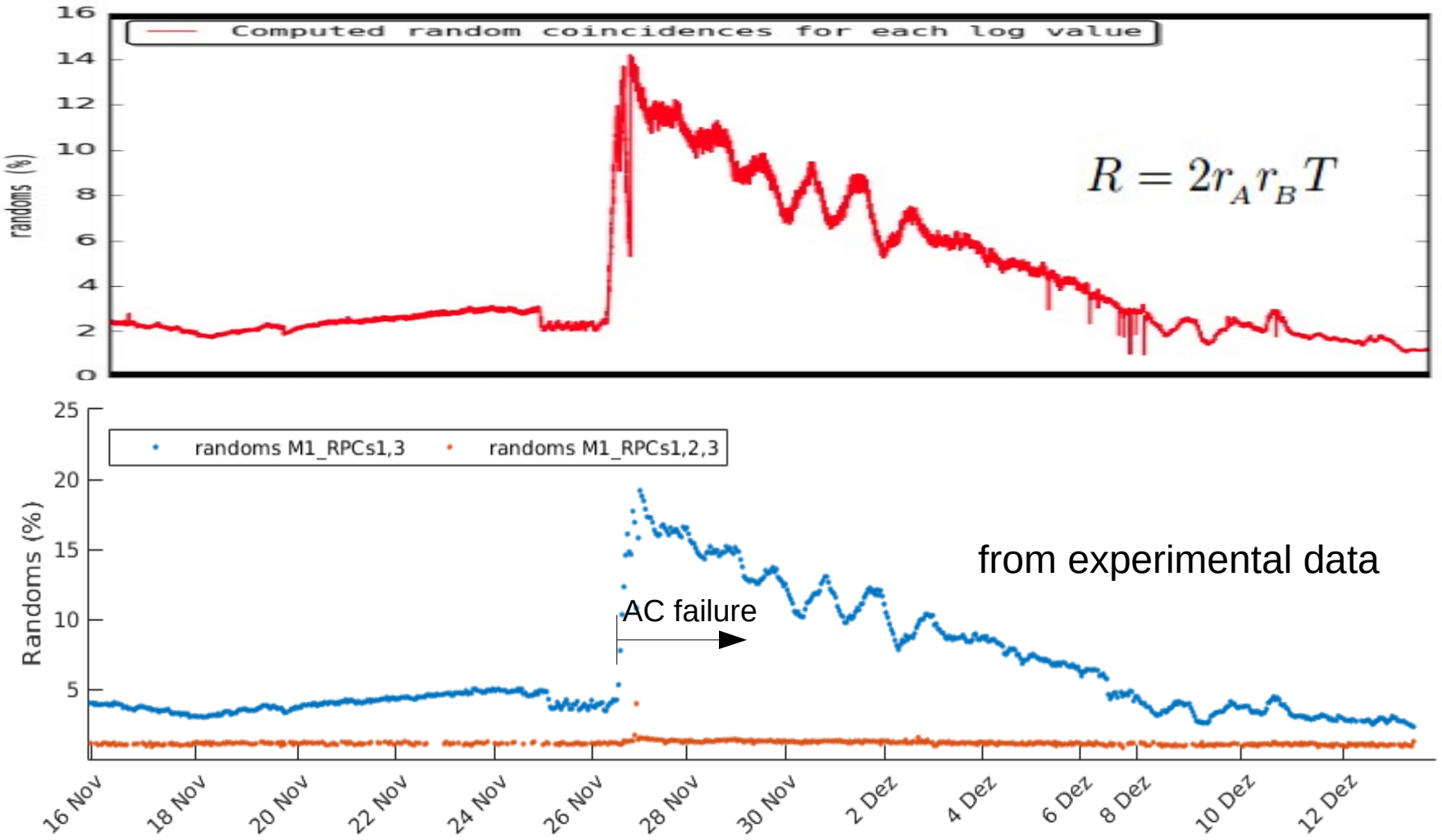
1st survey: Vigo - P. Arenas 11/2018 -> 12/2018; P. Arenas - Vigo 02/2019 -> 04/2019

2nd survey: Cartagena - Livingston Island 11/2019 -> 12/2019

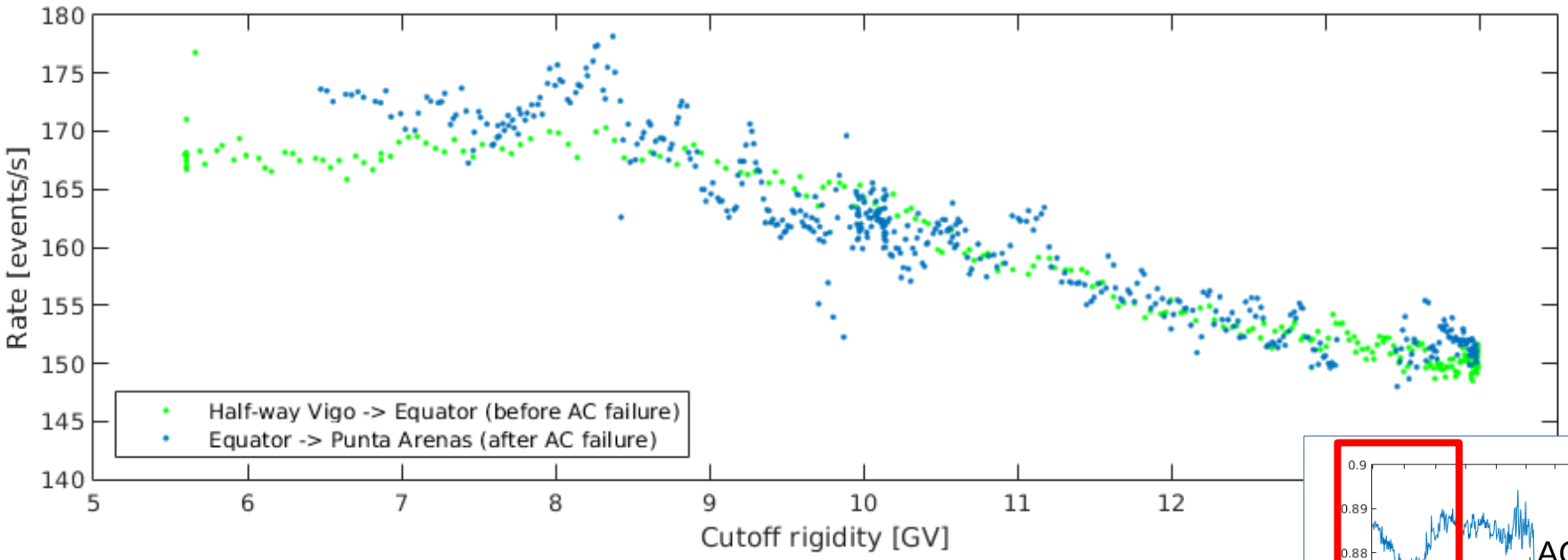


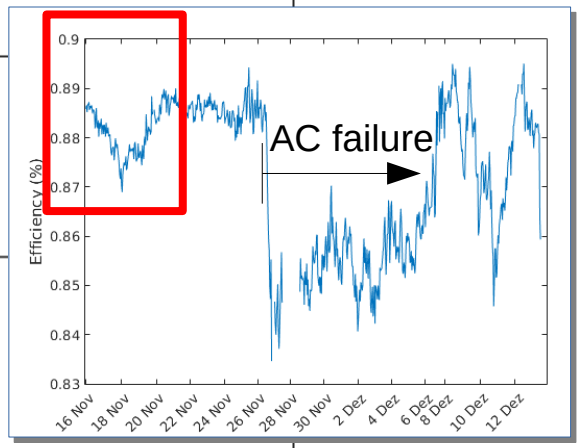
Backup

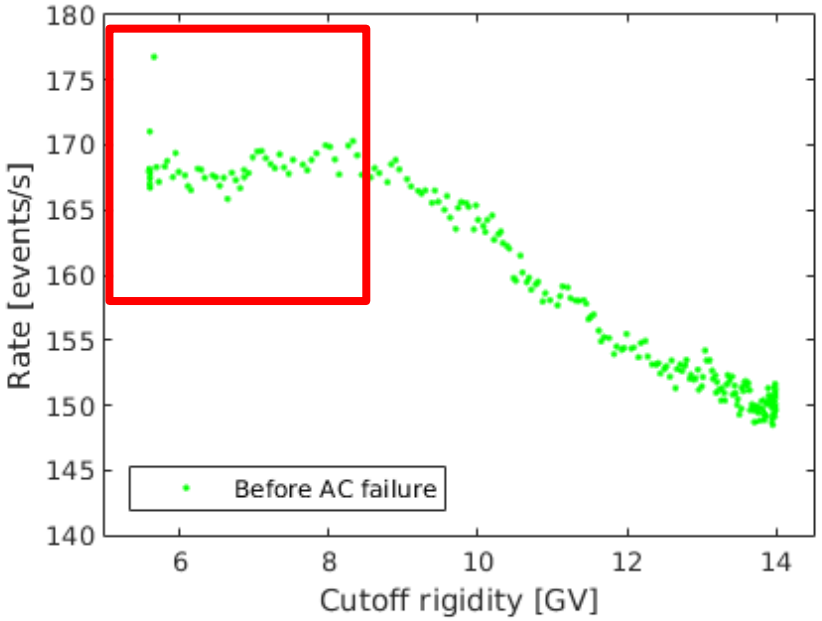
Computed vs. Estimated Randoms

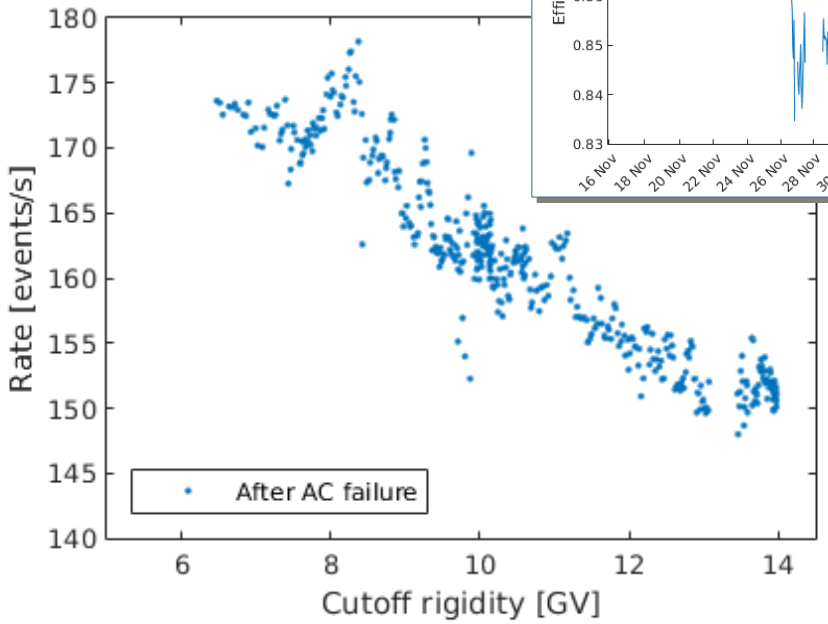


Cosmic Rate/Cutoff Rigidity correlation – Efficiency

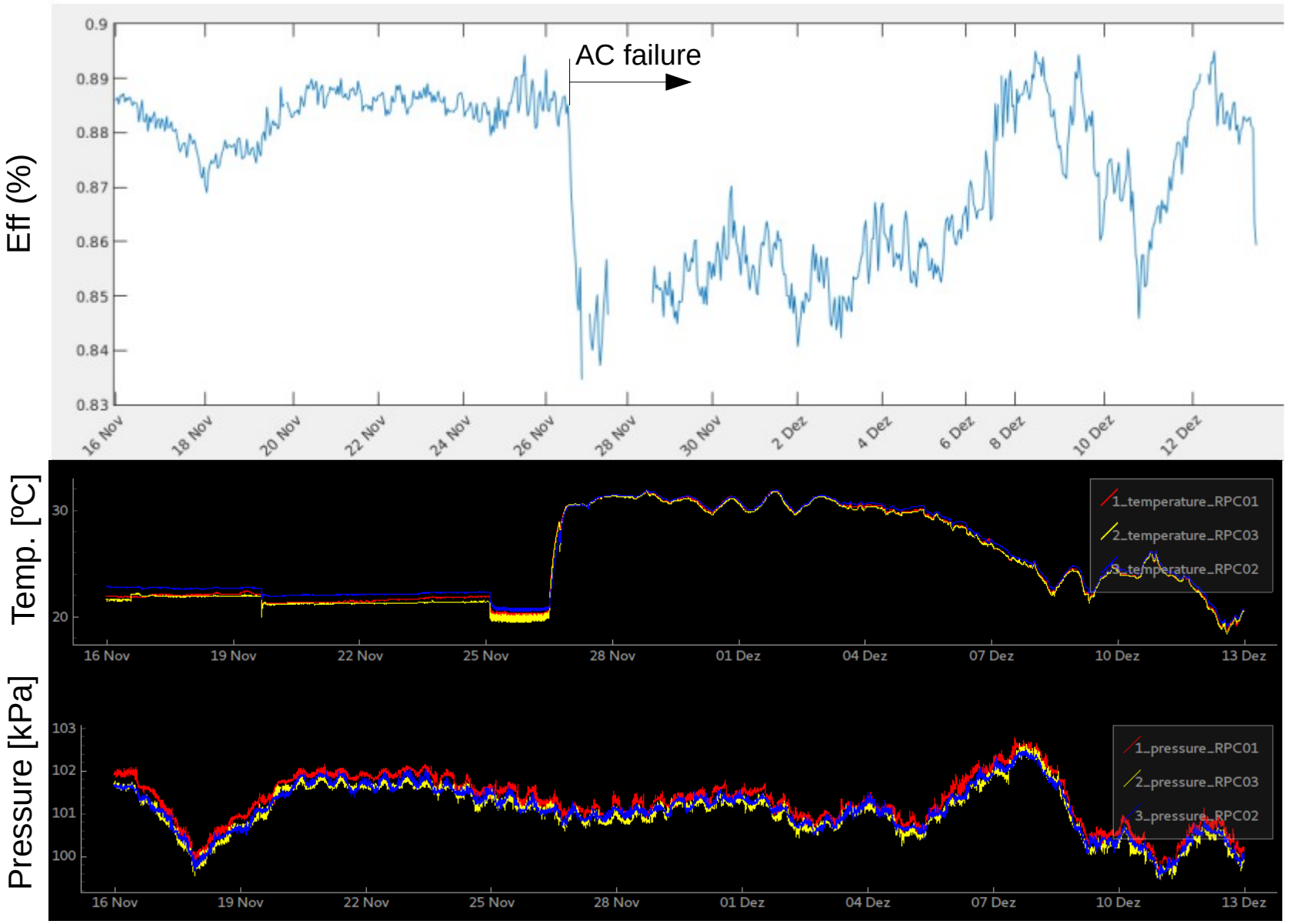




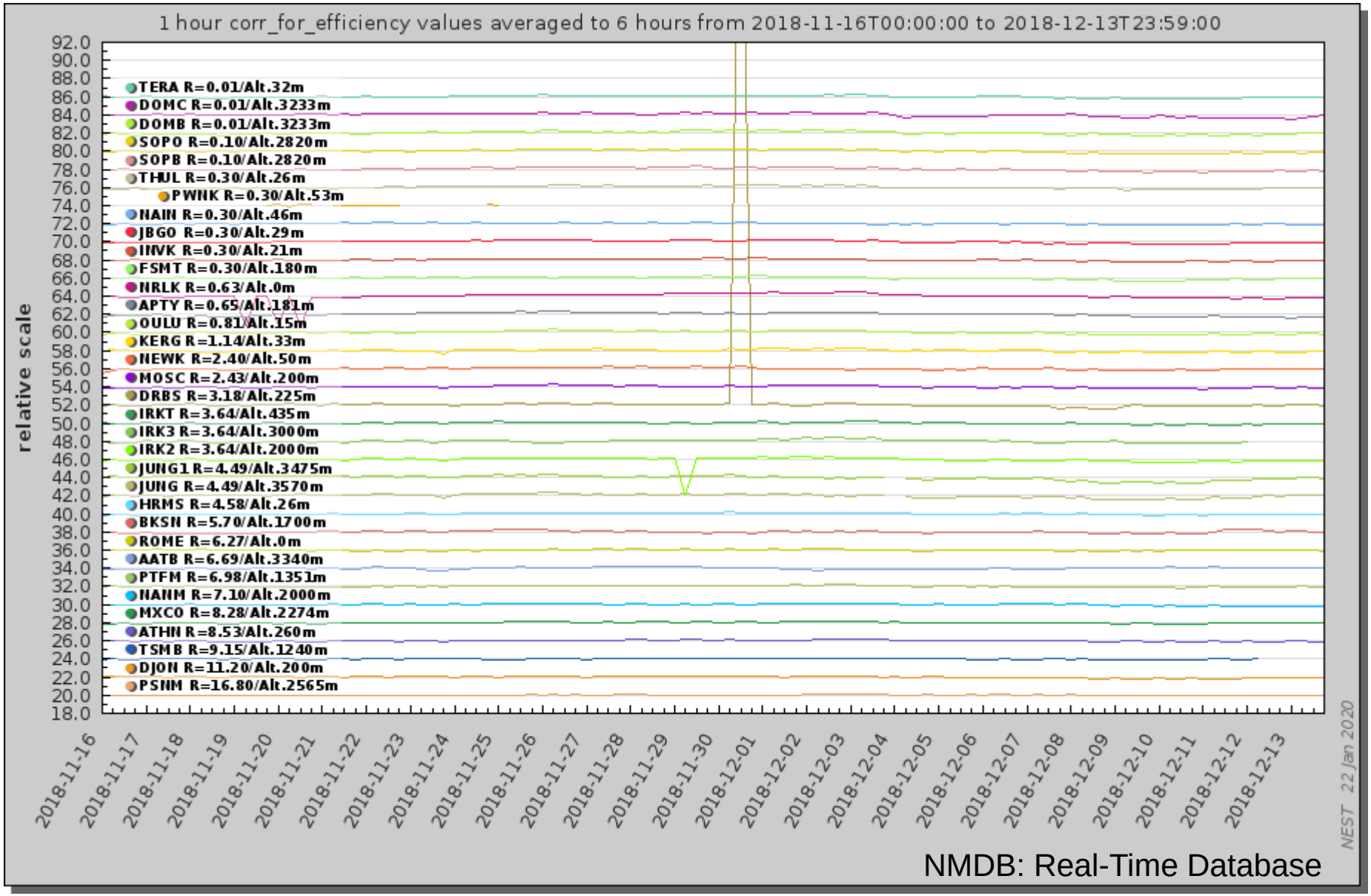




Efficiency – Temperature & Pressure



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



Forbush Decrease – Rate Uncorrected vs. Corrected for Pressure

NMDB: Real-Time Database