Observation of the Forbush decrease of 22\textsuperscript{th} June 2015 with the LAGO detector in Brazil

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\textsuperscript{2}full list of members and institutions at lagoproject.org/collab.html
What is LAGO?

• The Latin American Giant Observatory (LAGO) is an extended cosmic ray observatory composed of water-Cherenkov detectors (WCDs) placed throughout Latin America
• The study of the space weather through the solar modulation of galactic cosmic rays
• A collaborative and non-centralized network of institutions from ten countries (Argentina, Bolivia, Brazil, Colombia, Ecuador, Guatemala, Mexico, Peru, Venezuela and Spain)
• 28 institutions, 113 members
• Developments, expertise and data are shared across the LAGO network
The LAGO sites

The LAGO collaboration uses single or small arrays of detectors located at different altitude sites and covering a large range of geomagnetic rigidity cut-offs.
Some LAGO detectors

- Sierra Negra, Mexico
- Chacaltaya, Bolivia
- Merida, Venezuela
- Guatemala
- Bariloche, Argentina
- Antarctica, by Argentina
- Campina Grande, Brazil
What is TANCA?

TANCA is a nickname for the TANk detector of CAmpinas, the LAGO water-Cherenkov detector at University of Campinas, Brazil.

University of Campinas

Campinas, SP, Brazil
22º 54’ S, 47º 03 N
650 meters a.s.l.

South Atlantic Anomaly
The TANCA detector

- 3 PMT 9” Photonis XP1805
- Liner Tyvek
- 11400 liters of pure water
- $A_{\text{vertical}} = 10 \text{ m}^2$

Water level height 1.14 m

Muon pulse

Photonis XP1805

Voltage-divider, HV power supply

50ns; 10mV
The TANCA DAq

CAMAC/NIM modules: LeCroy Scaler 2551 (100 MHz); Logic Unit CAEN; Discriminator CAEN; Dual Gate Generator LeCroy 2323A; DAC CAEN

Precise (0.02sec) gate for the 1 sec time interval of the counts, future GLE detection?

Atmospheric date every 10 minutes

HV1=1075V  HV2=1125V; HV3=1250V; Lminima: L=-22mV; TC=300ns

Precise (0.02sec) gate for the 1 sec time interval of the counts, future GLE detection?
TANCA muon count efficiency

Two small, 40x38cm$^2$, plastic scintillators used to select vertical muons

Vertical muon (VM)

$$\epsilon = \frac{VM + \text{tank}}{VM}$$

(95.7 ± 0.8) %

Pulse amplitude histogram

The three PMTs calibrated to have the same gain

Trigger: an other PMT with a threshold of 15mV
Barometric coefficient

The flux of muons depends on the barometric pressure and this correlation can be approximated with an exponential behavior

\[ I = I_0 e^{-\beta (P - P_0)} \]

\[ \frac{dN}{N} = -\beta \, dP \]

\[ \ln \left( \frac{N}{N_0} \right) = -\beta (P - P_0) \]

\[ \beta = (0.108 \pm 0.06)\%/mbar \]

The Forbush analyses are done with data corrected by the barometric coefficient.
June 2015 Coronal Mass Ejections

Five CMEs detected by SOHO/LASCO.

WSA-Enlil simulation of the three first CMEs.

TANCA registered a Forbush decrease

CME score board: NASA GSFC Community Coordinated Modeling Center (CCMC), https://kauai.ccmc.gsfc.nasa.gov/CMEscoreboard/

The CMs and its magnetic interactions generated a strong geomagnetic storm.

The dashed vertical lines shows the CMEs arrival time on Earth.

Dst\(=\)\(-204\)nT

The Dst index correlates well with the TANCA variations in muon counts.
Forbush detection by TANCA, McMurdo and Auger Scaler Mode

The McMurdo neutron monitor is located at the South Pole and has a very low geomagnetic cut-off.

The Auger Scaler Mode (single particle technique) is 15 minutes time averaged data from the Pierre Auger Observatory surface detectors. It is placed at Malargue, Argentina.

McMurdo and Auger Scaler Mode correlate well with the TANCA result.
Summary

• The TANCA detector is installed, calibrated and now is taking data continuously.
• The TANCA is detecting Forbush decreases and a new step will be analyzing these events together with others LAGO detectors.
• The TANCA detector is ready to detect a future muon short-term GLE.
• LAGO collaboration is helping a regional integration in Latin America.
• Using this WCD Brazilian students are learning about muon decay, detector physics and interaction of radiation with matter.
Thank you for your attention

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Extra slides
## LAGO sites

<table>
<thead>
<tr>
<th>Country</th>
<th>Site</th>
<th>Number of WCD</th>
<th>Altitude [m a.s.l.]</th>
<th>Rigidity cut off [GV]</th>
<th>Latitude [deg]</th>
<th>Longitude [deg]</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>Bariloche</td>
<td>3</td>
<td>850</td>
<td>8.10</td>
<td>41.15 S</td>
<td>71.30 W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Buenos Aires</td>
<td>1</td>
<td>10</td>
<td>8.41</td>
<td>34.54 S</td>
<td>58.44 W</td>
<td></td>
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<tr>
<td></td>
<td>Marambio[13]</td>
<td>1</td>
<td>200</td>
<td>2.31</td>
<td>64.24 S</td>
<td>56.62 W</td>
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</tr>
<tr>
<td>Bolivia</td>
<td>Chacaltaya</td>
<td>3</td>
<td>5240</td>
<td>11.87</td>
<td>16.35 S</td>
<td>68.13 W</td>
<td>RC lowest value (south)</td>
</tr>
<tr>
<td></td>
<td>Cota Cota</td>
<td>1</td>
<td>3917</td>
<td>11.88</td>
<td>16.41 S</td>
<td>68.5 W</td>
<td>Highest place</td>
</tr>
<tr>
<td>Brazil</td>
<td>Campinas</td>
<td>1</td>
<td>685</td>
<td>9.93</td>
<td>22.9 S</td>
<td>47.06 W</td>
<td>Eastern place</td>
</tr>
<tr>
<td></td>
<td>Campina Grande</td>
<td>1</td>
<td>550</td>
<td>12.17</td>
<td>34.54 S</td>
<td>58.44 W</td>
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<tr>
<td>Colombia</td>
<td>Bucaramanga</td>
<td>1</td>
<td>956</td>
<td>12.52</td>
<td>7.14 S</td>
<td>73.12 W</td>
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<tr>
<td>Ecuador [14]</td>
<td>Riobamba</td>
<td>1</td>
<td>2750</td>
<td>12.55</td>
<td>1.81 S</td>
<td>78.74 W</td>
<td>RC highest value</td>
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<tr>
<td></td>
<td>Quito-SF</td>
<td>1</td>
<td>2800</td>
<td>12.49</td>
<td>0.2 S</td>
<td>78.5 W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quito-PO</td>
<td>1</td>
<td>2800</td>
<td>12.49</td>
<td>0.2 S</td>
<td>78.5 W</td>
<td></td>
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<tr>
<td>Guatemala</td>
<td>Guatemala</td>
<td>1</td>
<td>1490</td>
<td>10.32</td>
<td>14.63 N</td>
<td>90.59 W</td>
<td></td>
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<tr>
<td>México [7]</td>
<td>Sierra Negra</td>
<td>4</td>
<td>4550</td>
<td>8.26</td>
<td>18.16 N</td>
<td>97.95 W</td>
<td>RC lowest value (north) and western</td>
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<tr>
<td>Perú [8]</td>
<td>Lima</td>
<td>2</td>
<td>150</td>
<td>12.37</td>
<td>12.10 S</td>
<td>77.02 W</td>
<td>Large difference in altitude at same RC</td>
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<tr>
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<td>Cusco</td>
<td>1</td>
<td>3400</td>
<td>12.19</td>
<td>13.52 S</td>
<td>71.96 W</td>
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<td>Huancayo</td>
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<td>3370</td>
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<td>12.04 S</td>
<td>75.30 W</td>
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<tr>
<td>Venezuela</td>
<td>Caracas-UCV</td>
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<td>900</td>
<td>12.01</td>
<td>10.49 N</td>
<td>66.89 W</td>
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</tr>
<tr>
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<td>Caracas-USB</td>
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<td>1200</td>
<td>12.02</td>
<td>10.41 N</td>
<td>66.88 W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mérida-ULA</td>
<td>1</td>
<td>1893</td>
<td>11.99</td>
<td>8.63 N</td>
<td>71.15 W</td>
<td></td>
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