Contribución española a la red global de monitores de neutrones

3rd. Workshop on Trasgo detectors. The New Generation

Juan José Blanco, Space Research Group, Universidad de Alcalá

27/06/2023

Proyecto: PID2019-107806GB-100

Space Research Group

≈ 30 investigadores (Ingenieros, Físicos y Estudiantes) 6 en CaLMa
Lineas de investigación del Grupo

- Arquitectura y modelado de procesadores optimizados para aplicaciones espaciales
- Control óptimo
- Desarrollo de instrumentación científica embarcable en misiones espaciales
- Diseño de software basado en componentes
- Hardware en Ingeniería Espacial
- Ingeniería de software dirigida por modelos
- Modelado orbital y de radiocomunicaciones
- Software de Control en tiempo real para Sistemas Espaciales
- Sistemas de adquisición de datos para instrumentación nuclear
- Física del Sol y de la Heliosfera
- Interacción Sol-Tierra
- Rayos cósmicos

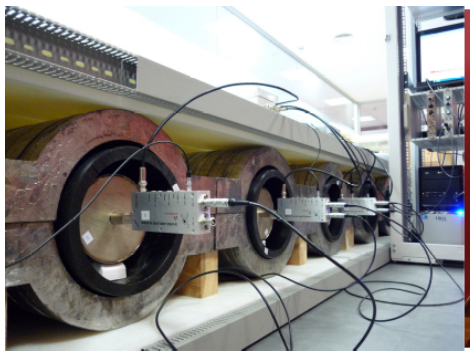
`https://www.uah.es/es/investigacion/unidades-de-investigacion/grupos-de-investigacion/`

`Grupo-de-Investigacion-Espacial-Space-Research-Group./`

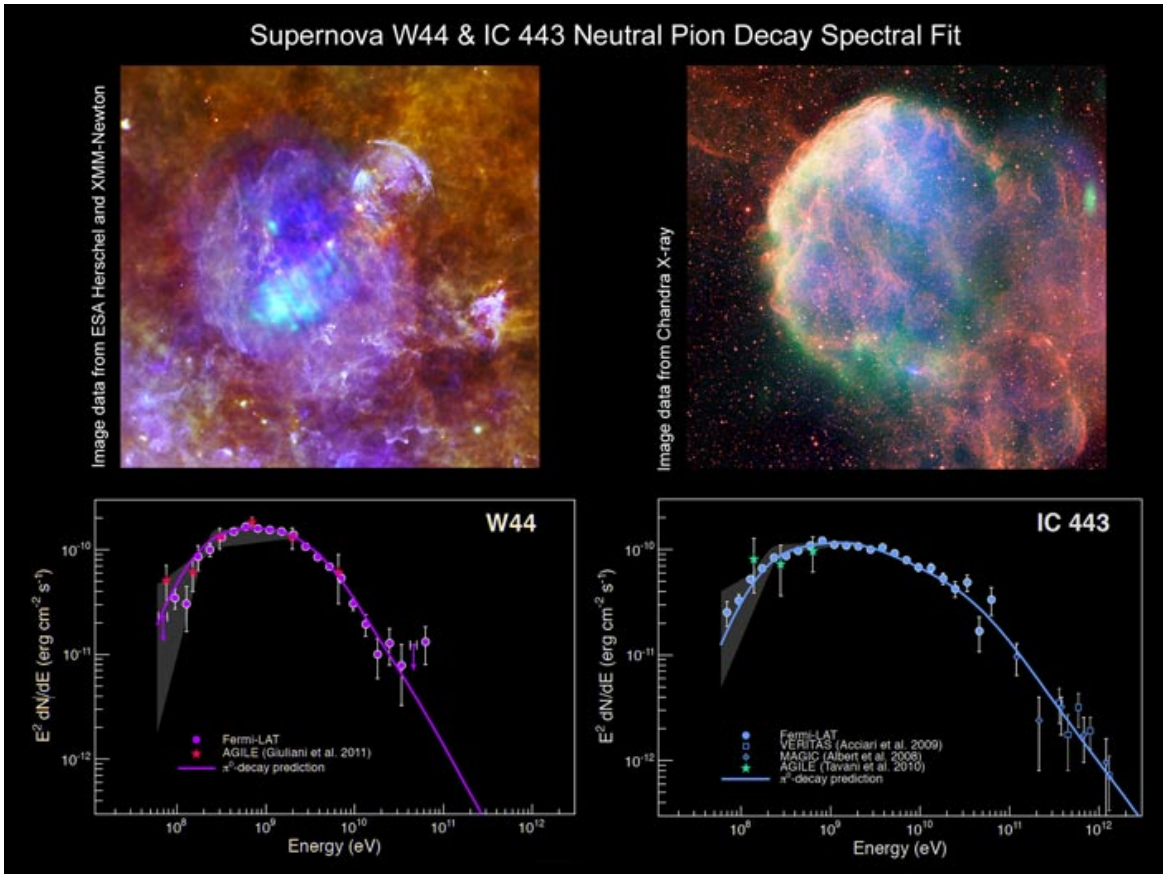
CaLMa

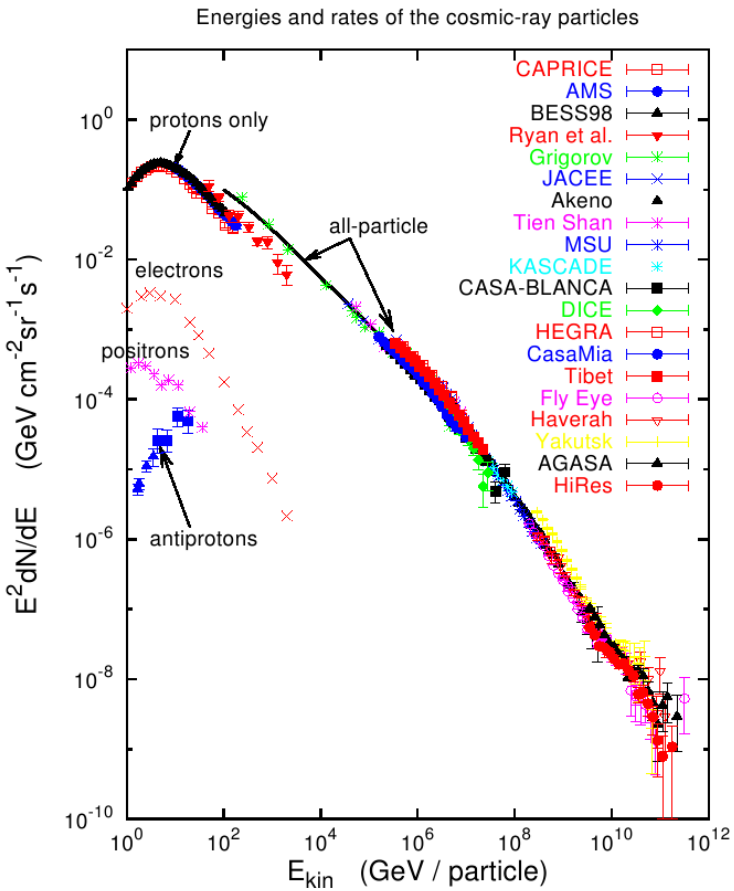
CaLMa hace referencia a un conjunto de detectores distribuidos en diferentes localizaciones geomagnéticas cuyo objetivo principal es la observación de la actividad solar a través de la medida de rayos cósmicos de energías por debajo de 100 GeV/nucleon.
web: https://neutronmonitors-srg-uah.web.uah.es/

- CaLMa: Castilla-La Mancha Neutron Monitor
- ORCA: Observatorio de Rayos Cósmicos Antártico
- MiniCaLMa
- ICaRO: Izaña Cosmic Ray Observatory

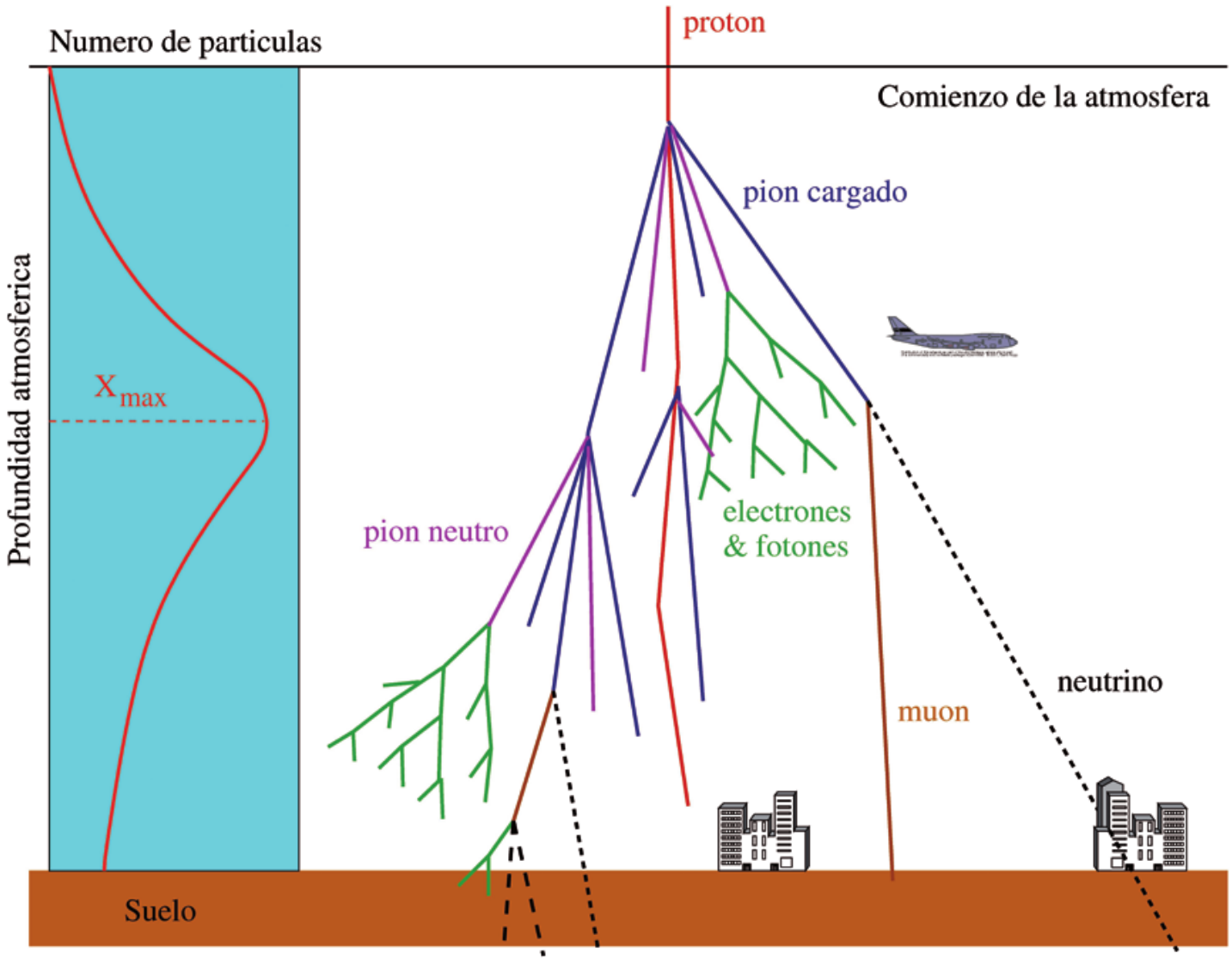


Rayos cósmicos galácticos

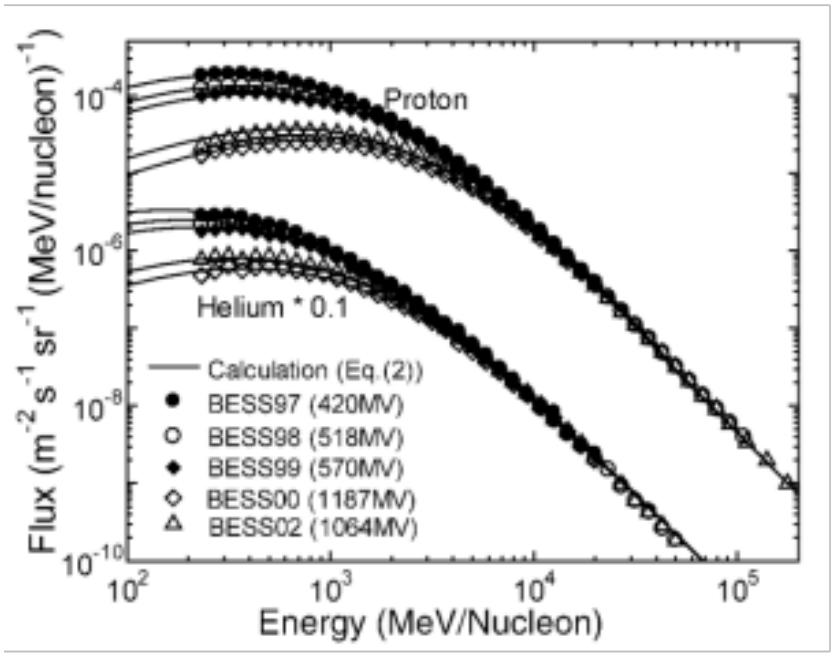




Rayos cósmicos galácticos



Rayos cósmicos galácticos



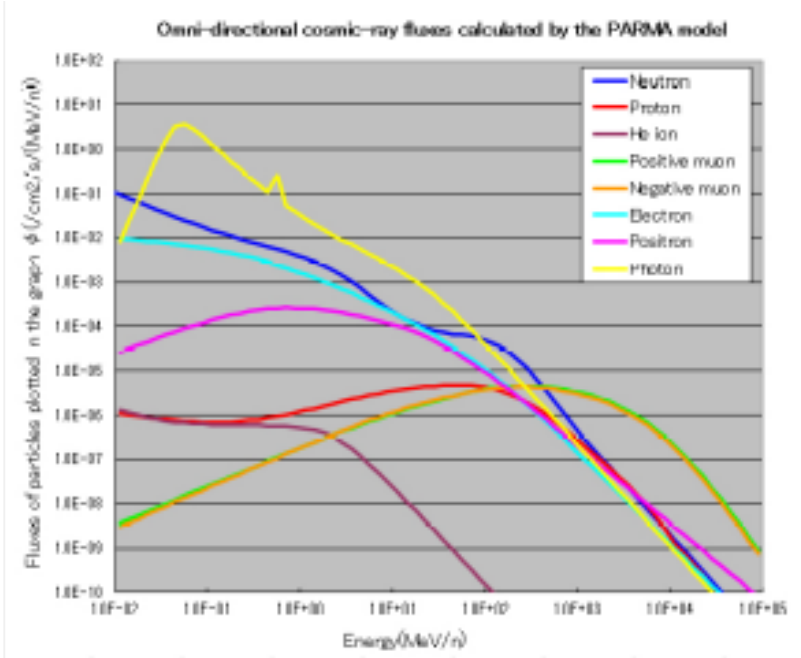


Figure: Sato et al., 2008

Rayos cósmicos galácticos

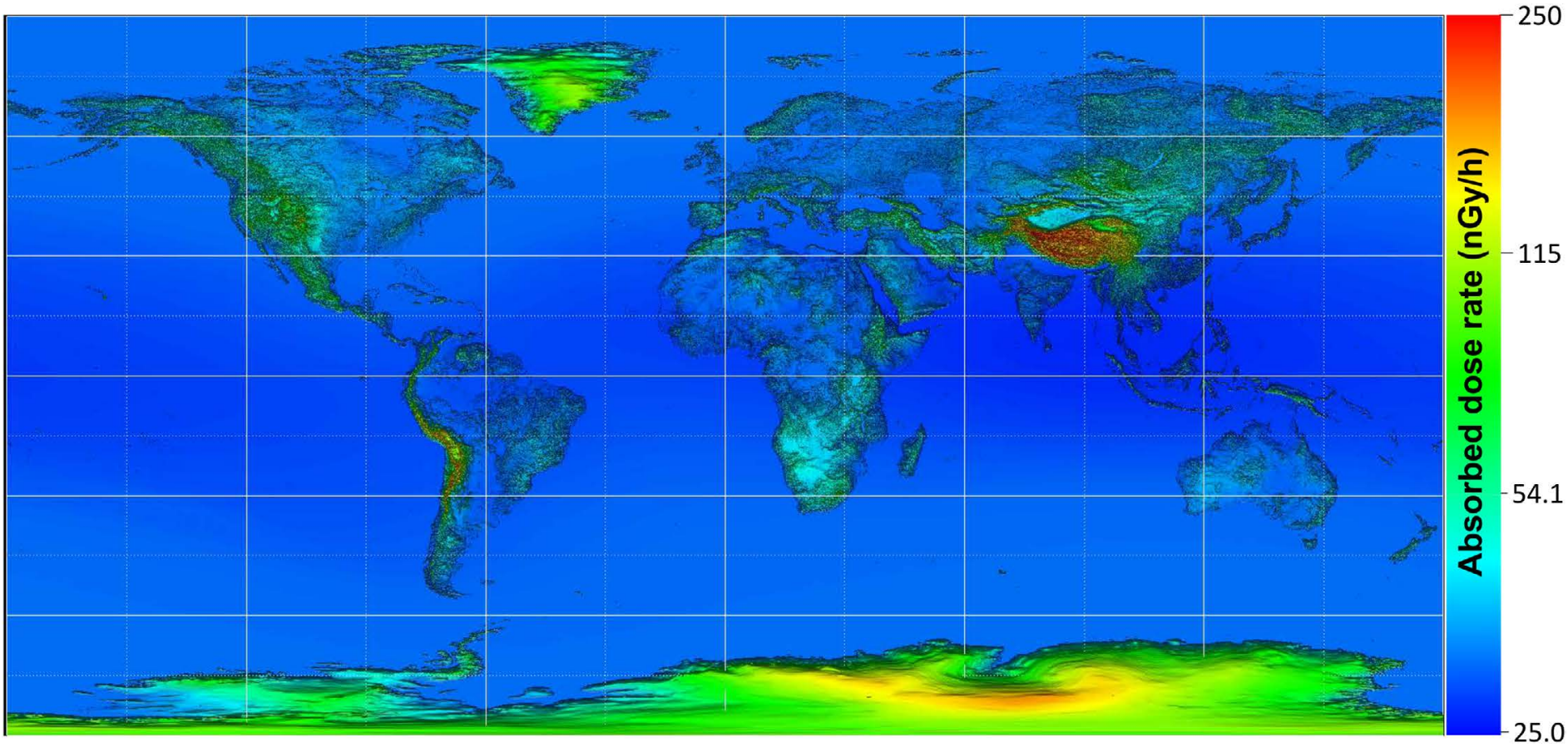


Figure: Sato et al., 2016

Neutron Monitor Data Base

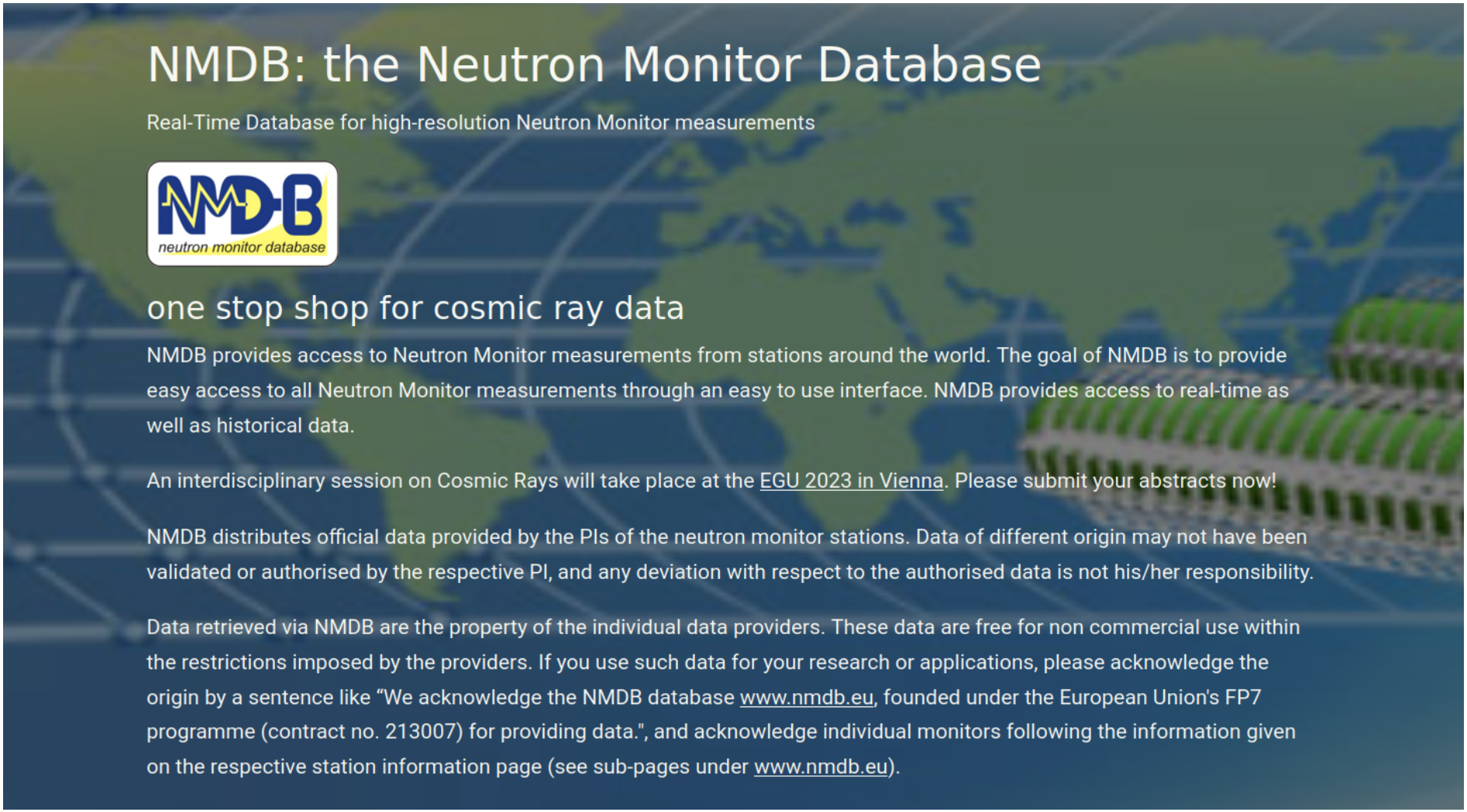


Figure: `https://www.nmdb.eu/`

Neutron Monitor Data Base

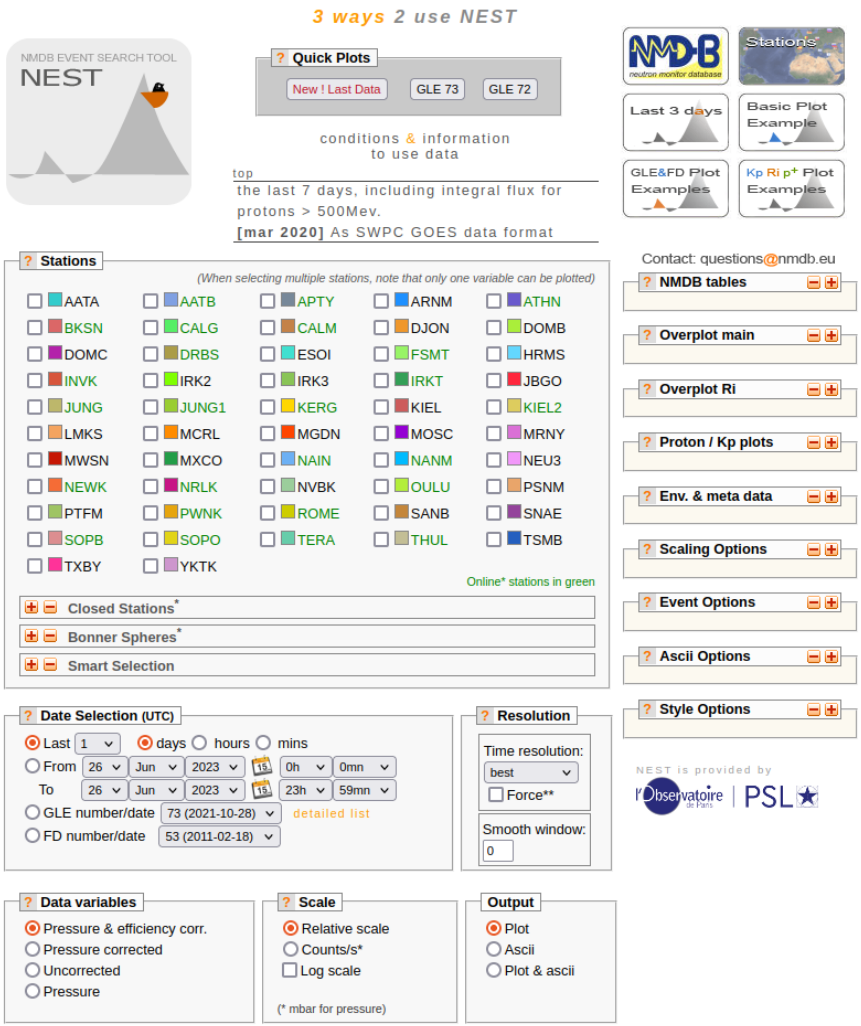
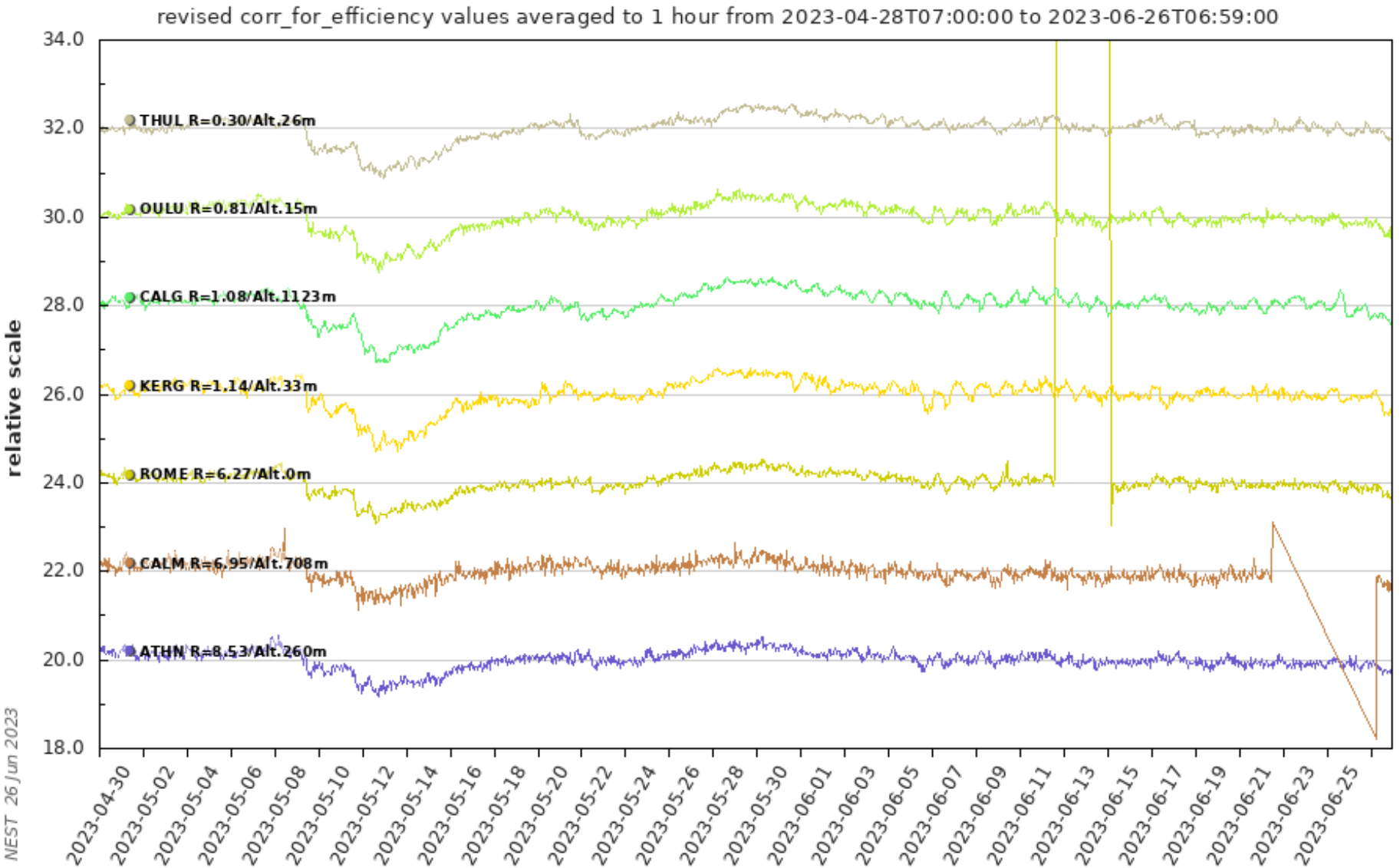
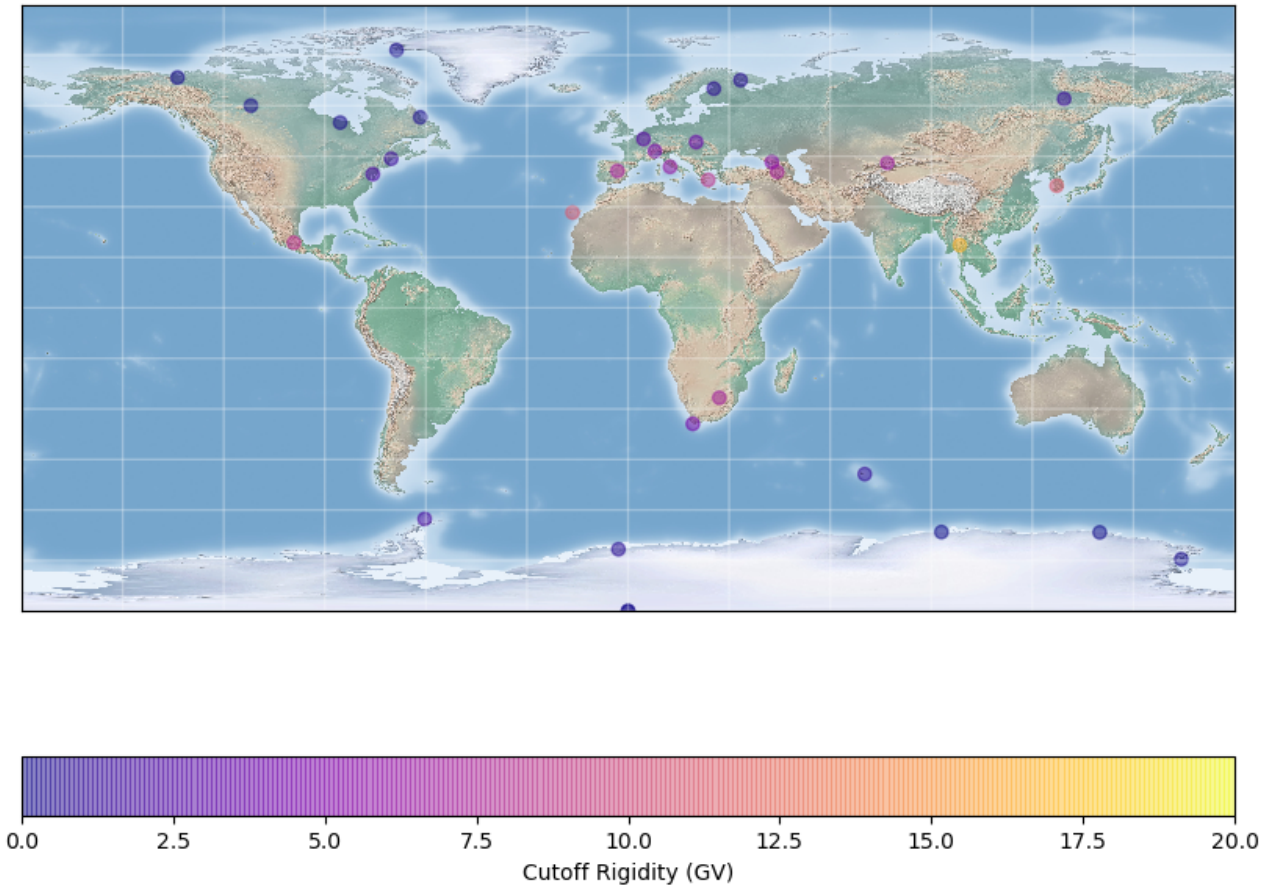


Figure: `http://www01.nmdb.eu/nest/`

Neutron Monitor Data Base



The Earth as a global detector



The Earth as a global detector

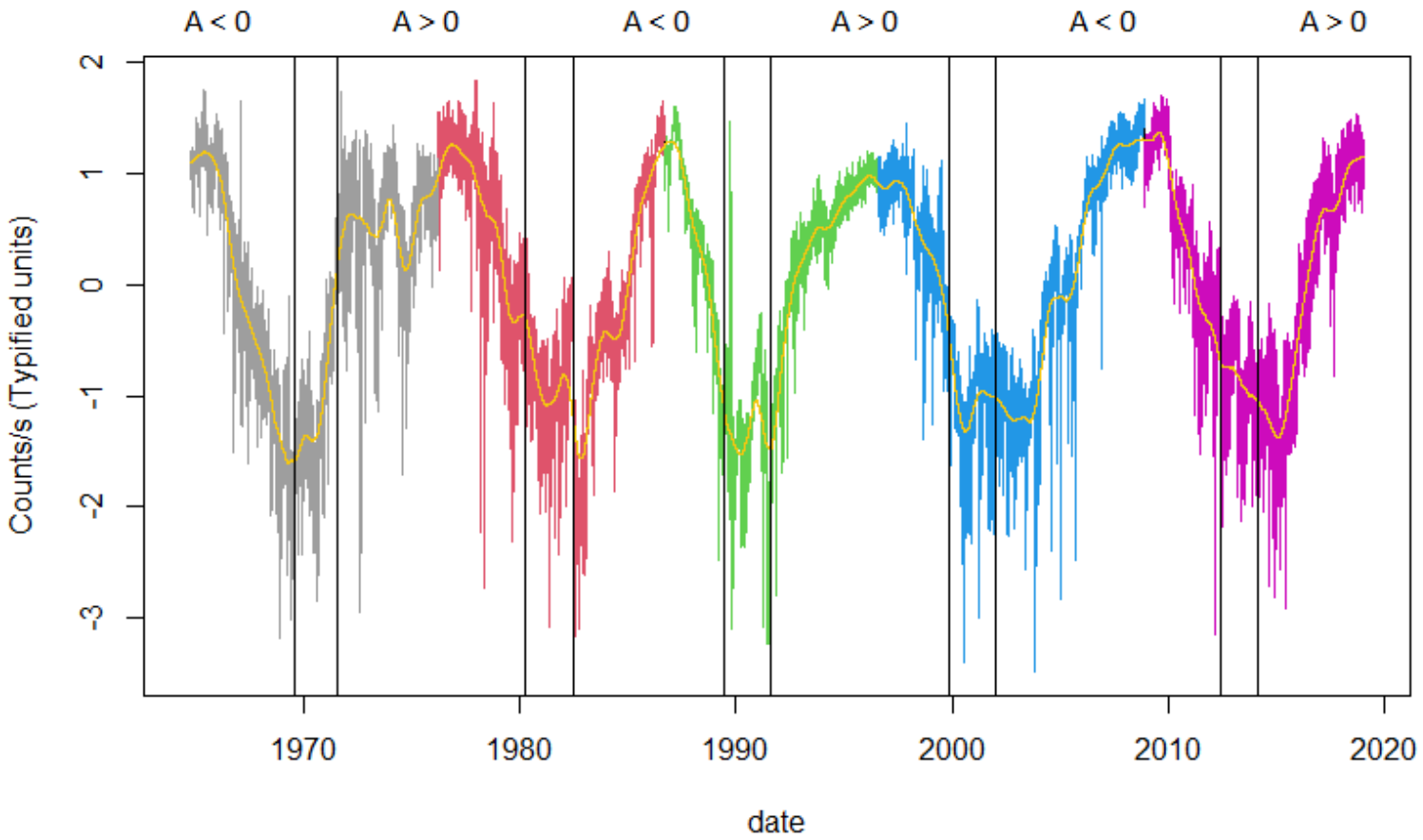
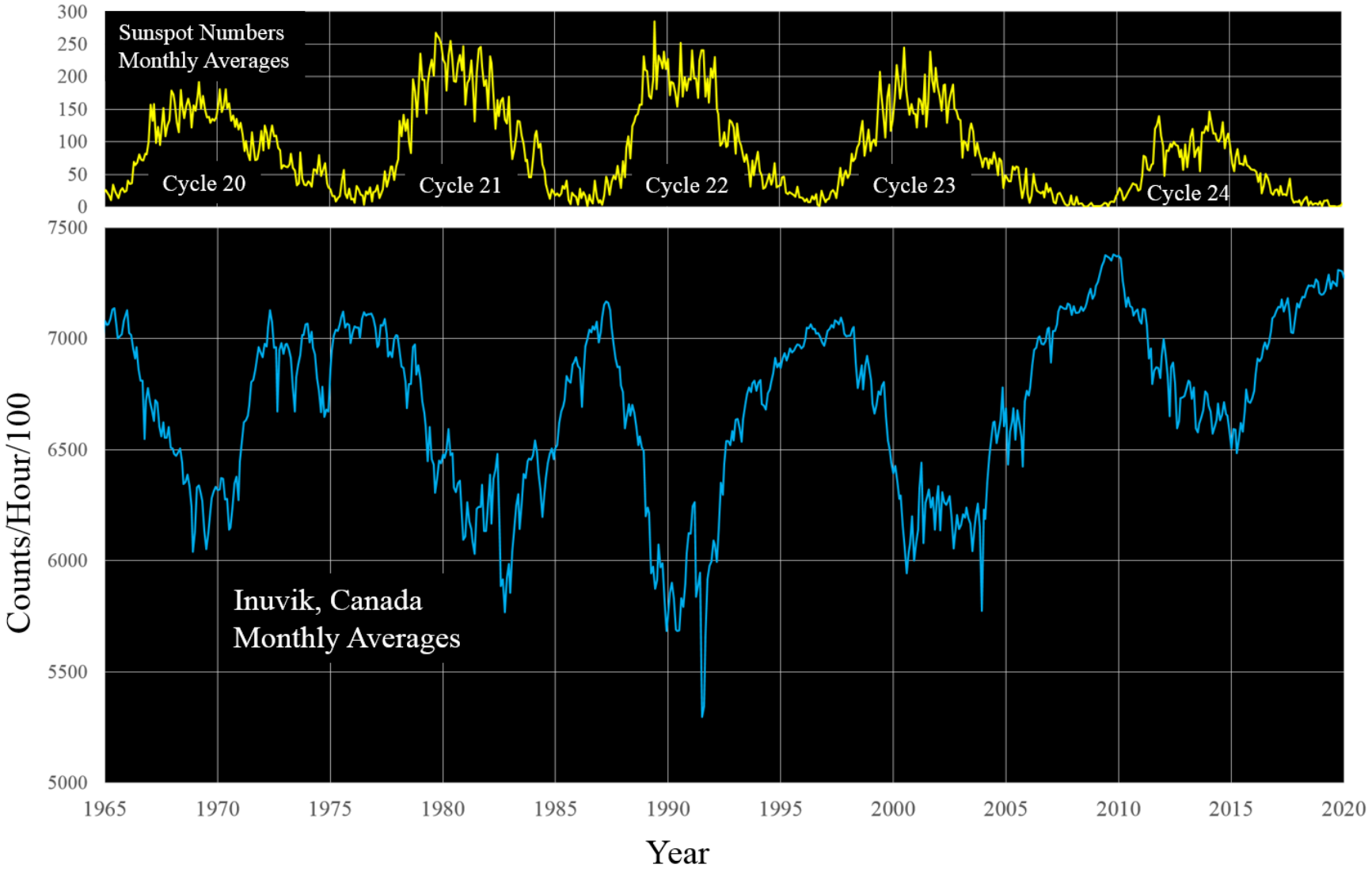
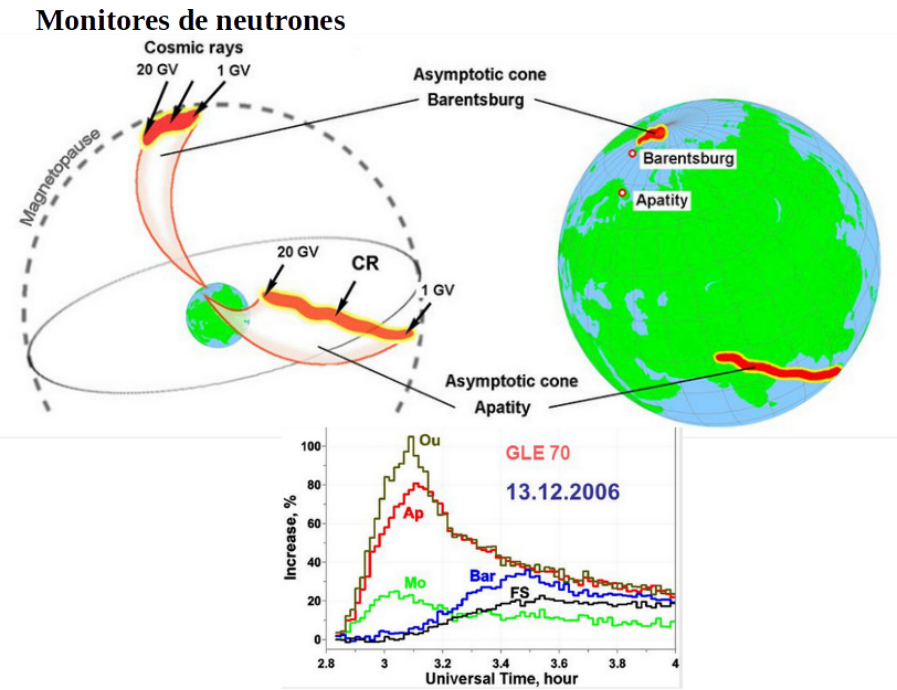


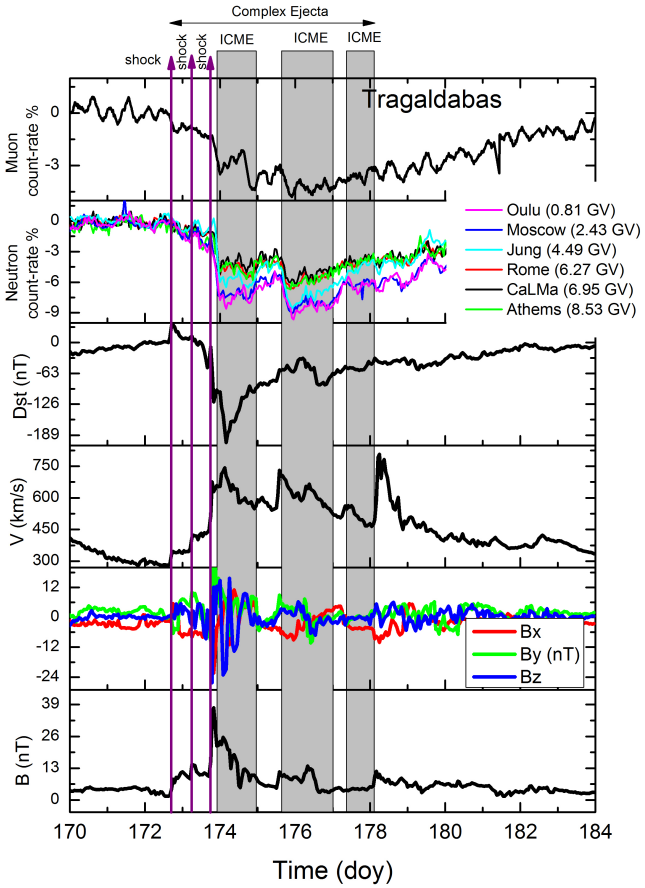
Figure: López-Comazzi and Blanco, ApJ 2022

The Earth as a global detector



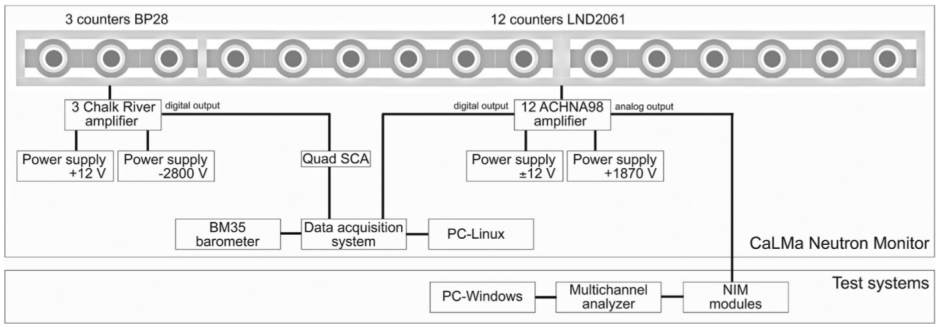
The Earth as a global detector





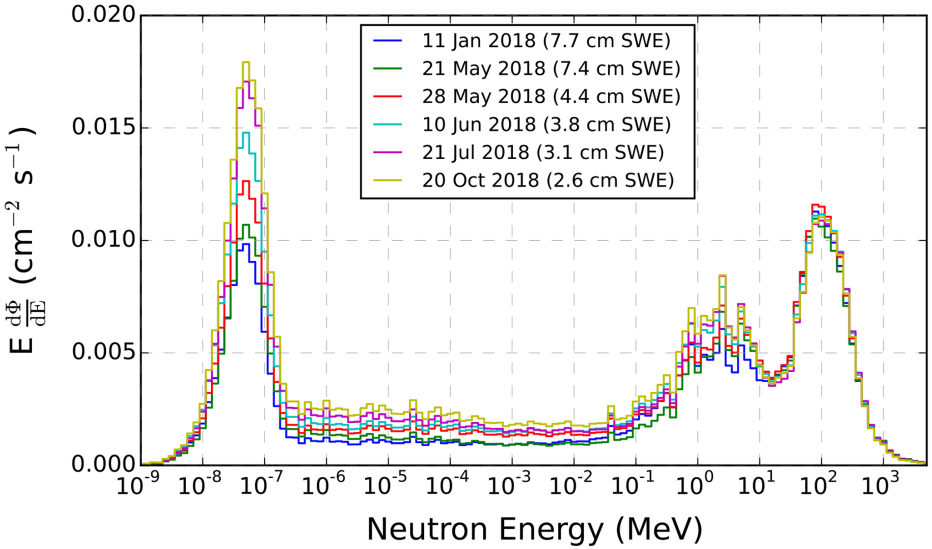
CaLMa ($R_{eff} = 6.95 GV$)

Flujos de neutrones (5.3 /s /counter)



12 NM64
Guadalajara, Spain
($40°38'N, 3°19'W$ at 708 m above sea level)

	CaLMa
Counter Type	LND2061
Effective diameter (mm)	149.1
Effective length (mm)	1956.3
Cathode material	Stainless steel
Gas filling	$BF_3(96\%\ ^{10}B)$
Gas pressure (mmHg)	200
Operational voltage (V)	1800
Number of counters	12
Moderator (g/cm^2)	Polyethylene (1.84)
Producer (g/cm^2)	Lead (156)
Reflector (g/cm^2)	Polyethylene (7.0)



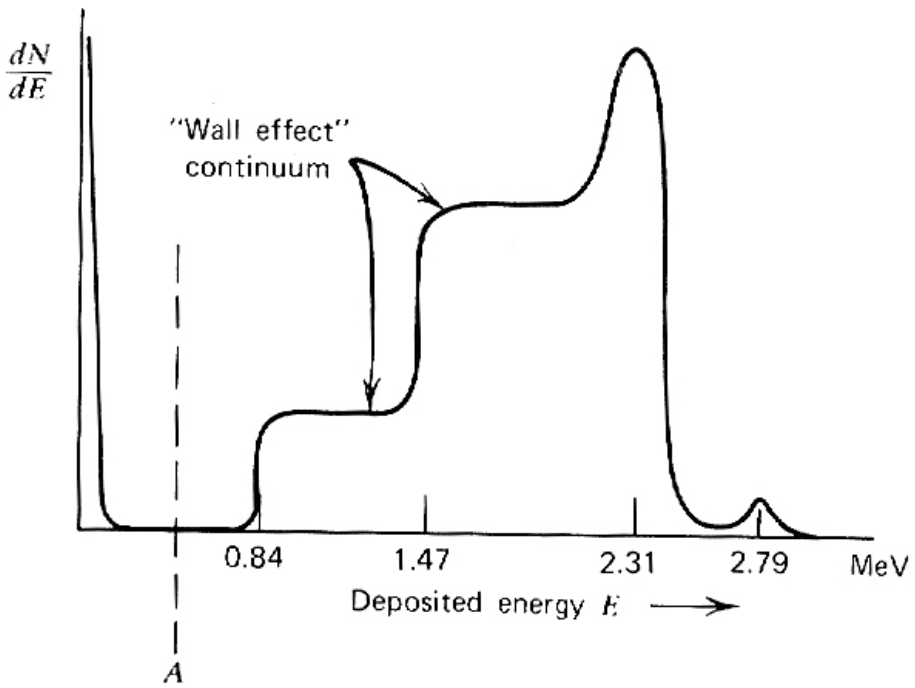


Figure: Brall et al, The Cryosphere, 15, 4769–4780, 2021.

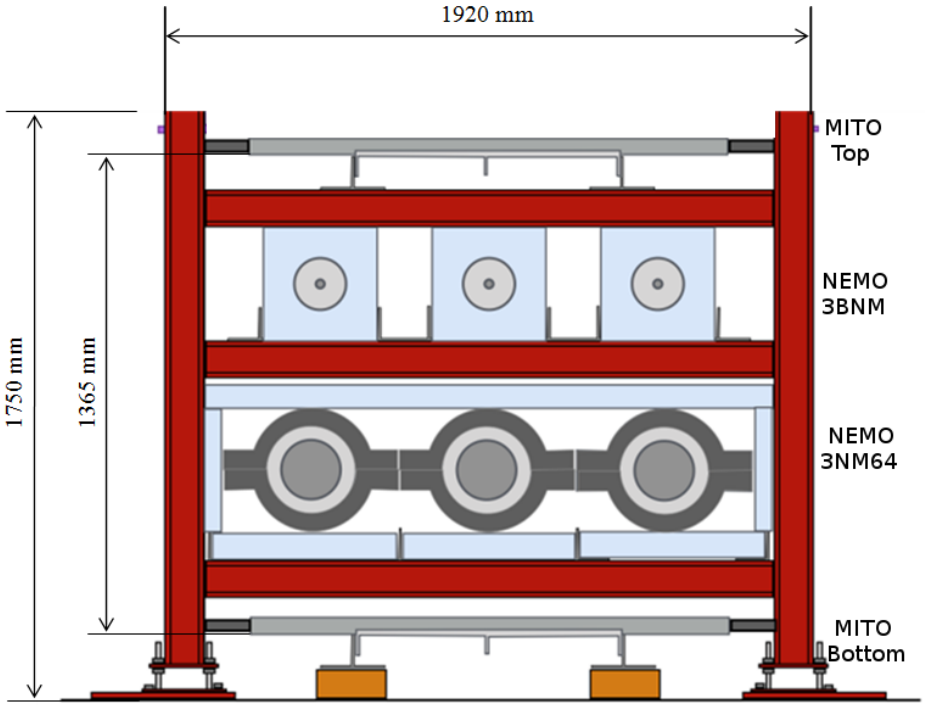
$$^{10}B + n \rightarrow^{7} Li + \alpha + 2.792MeV$$

$$^{10}B + n \rightarrow^{7} Li^{*} + \alpha + 2.310MeV$$

ORCA ($R_{eff} = 2.487 GV$)

Penumbra for the Juan Carlos I Spanish Antarctic Base at ($S62.65^{\circ}$, $W60.38^{\circ}$), 12m asl at a date 2019-01-02 12:00:00 UT according to the results of the calculator at `http://crsv.izmiran.ru/cutoff` using the IGRF model. $R_d = 2,221 GV$ and $R_u = 2,673 GV$

ORCA & ICaRO



ORCA: 12 /s /c, ORCB: 2 /s /c
Top: 190 /s , Bottom: 130 /s and Coin8: 30 /s

$135W$

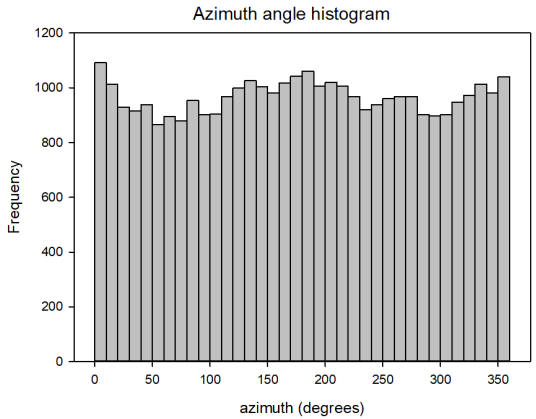
	NEMO 3NM64(ORCA)	NEMO 3BNM(ORCB)
Counter Type	BP28	LND2061
Effective diameter (mm)	148.5	149.1
Effective length (mm)	1908.0	1956.3
Cathode material	Stainless steel	Stainless steel
Gas filling	$BF_3(96\%\,^{10}B)$	$BF_3(96\%\,^{10}B)$
Gas pressure (mmHg)	200	200
Operational voltage (V)	-2700	1800
	MITO Top	MITO Bottom
Scintillator	BC400	BC400
Dimension (cm)	100x100x5	100x100x5
Operational voltage (V)	1000	1000
PMT	4 R2154	4 R2154
	Vaisala Meteorologic station	
PTU 301	500-1100 hPa	$\pm 0.05 hPa$
Pt100	-40 to 60°C	$\pm 0.2°C$
HUMICAP 180C	0-100%	$\pm 1\%$

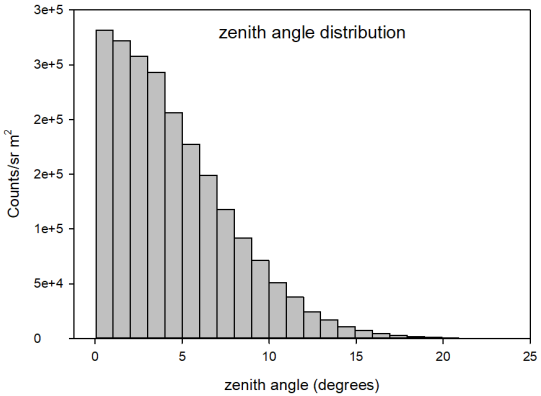
ORCB: neutrones $< 10eV$

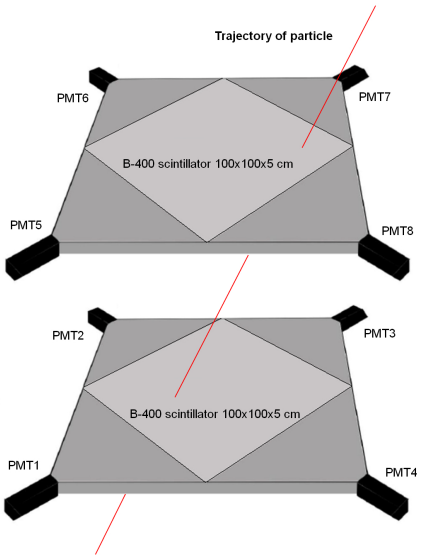
ORCA: neutrones $> 100MeV$

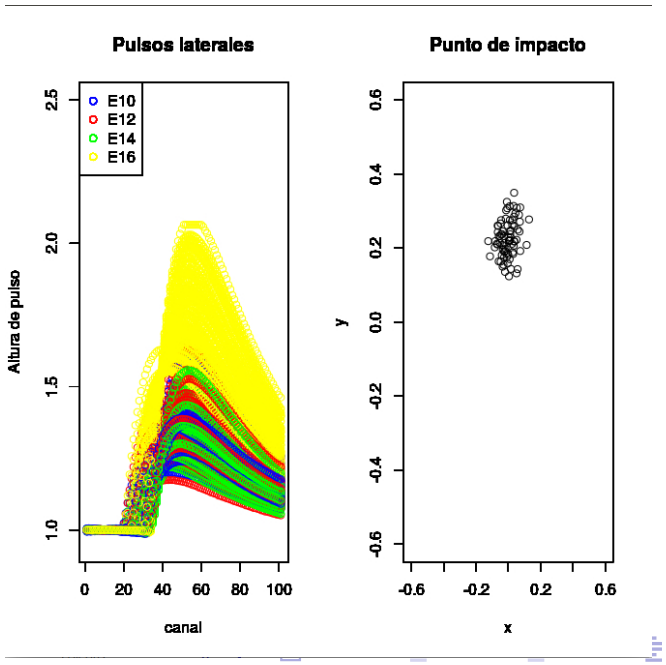
Coin8: muones $> 350MeV$, protones $> 290MeV$, electrones No

MITO

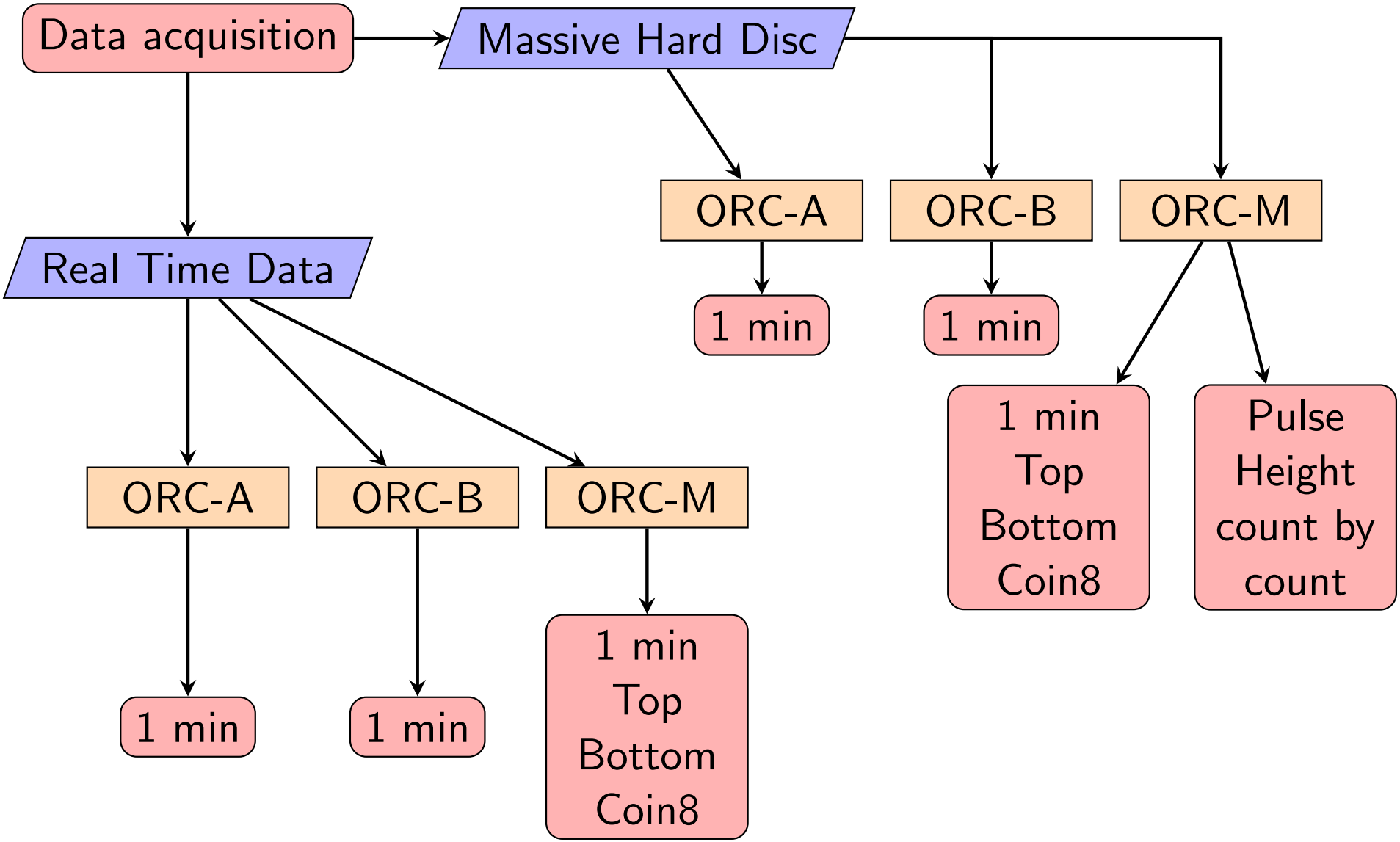

Azimuth angle histogram
Frequency
azimuth (degrees)
0
200
400
600
800
1000
1200
0
50
100
150
200
250
300
350


zenith angle distribution
Counts/sr m^2
zenith angle (degrees)
0
5e+4
1e+5
2e+5
2e+5
3e+5
3e+5
0
5
10
15
20
25


Trajectory of particle
PMT6
PMT7
B-400 scintillator 100x100x5 cm
PMT5
PMT8
PMT2
PMT3
B-400 scintillator 100x100x5 cm
PMT1
PMT4


Pulsos laterales
Punto de impacto
E10
E12
E14
E16
Altura de pulso
canal
y
x
1.0
1.5
2.0
2.5
0
20
40
60
80
100
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
-0.6
-0.2
0.2
0.6

ORCA/ICaRO data



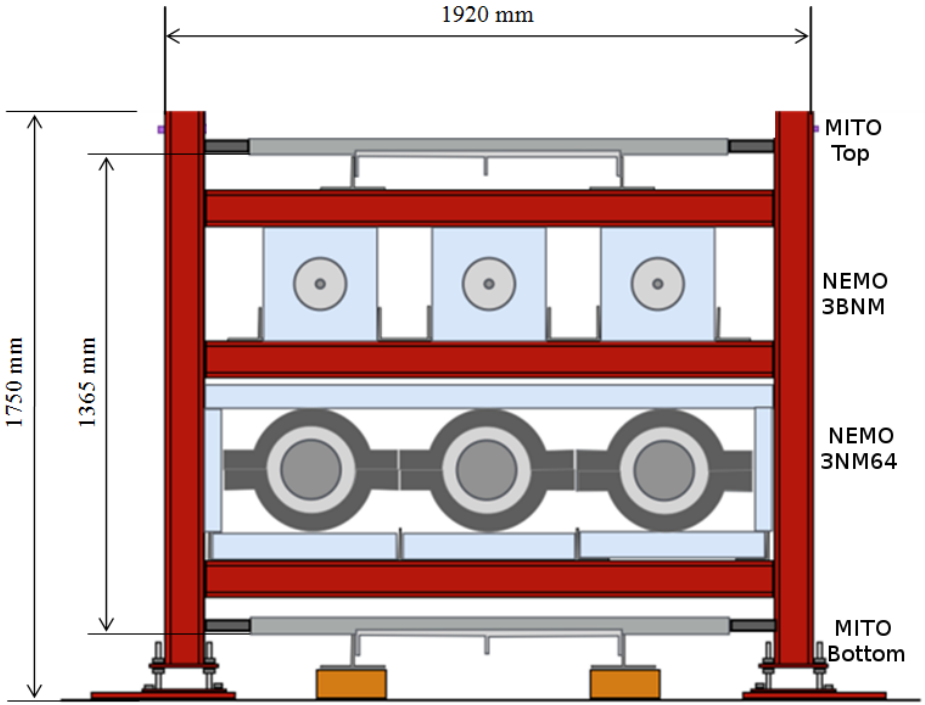
ICaRO 11.5 GV

- Hermano gemelo de ORCA
- $28°18'N$, $16°29'W$, 2373 m a.s.l., R = 11.5 GV.
- Cubre un hueco en la NMDB [Artamonov et al.,2016.]
- Su altura y corte en rigidez magnética podría permitir la observación de neutrones solares
- Izaña Atmospheric Research Center (IARC)
- Güimar Geomagnetic Observatory (GGO)
- Observación de RC, condiciones atmosféricas y estado de la magnetosfera

Proyecto

PID2019-107806GB-100, financiado por Ministerio de Ciencia e Innovación.

ORCA & ICaRO



ICRO: 13 /s /c, ICRB: 3 /s /c
Top: 300 /s , Bottom: 180 /s and Coin8: 30 /s

$135W$

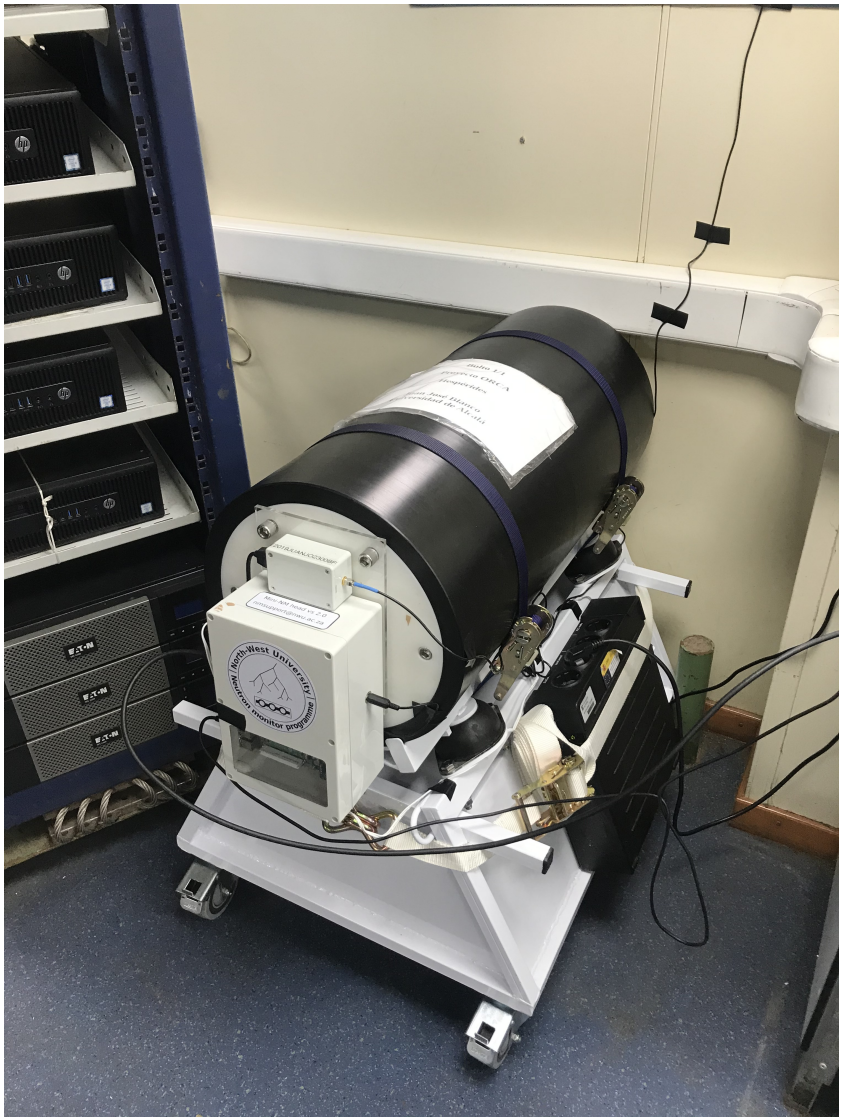
	NEMO 3NM64(ICRO)	NEMO 3BNM(ICRB)
Counter Type	BP28	LND2061
Effective diameter (mm)	148.5	149.1
Effective length (mm)	1908.0	1956.3
Cathode material	Stainless steel	Stainless steel
Gas filling	$BF_3(96\%\,^{10}B)$	$BF_3(96\%\,^{10}B)$
Gas pressure (mmHg)	200	200
Operational voltage (V)	-2700	1800
	MITO Top	MITO Bottom
Scintillator	BC400	BC400
Dimension (cm)	100x100x5	100x100x5
Operational voltage (V)	1000	1000
PMT	4 R2154	4 R2154
	Vaisala Meteorologic station	
PTU 301	500-1100 hPa	$\pm 0.05 hPa$
Pt100	-40 to 60°C	$\pm 0.2°C$
HUMICAP 180C	0-100%	$\pm 1\%$

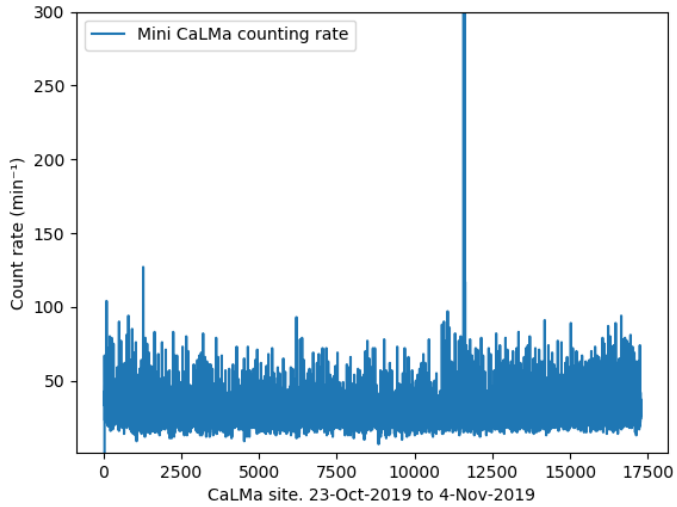
ICRB: neutrones $< 10eV$

ICRO: neutrones $> 100MeV$

Coin8: muones $> 350MeV$, protones $> 290MeV$, electrones No

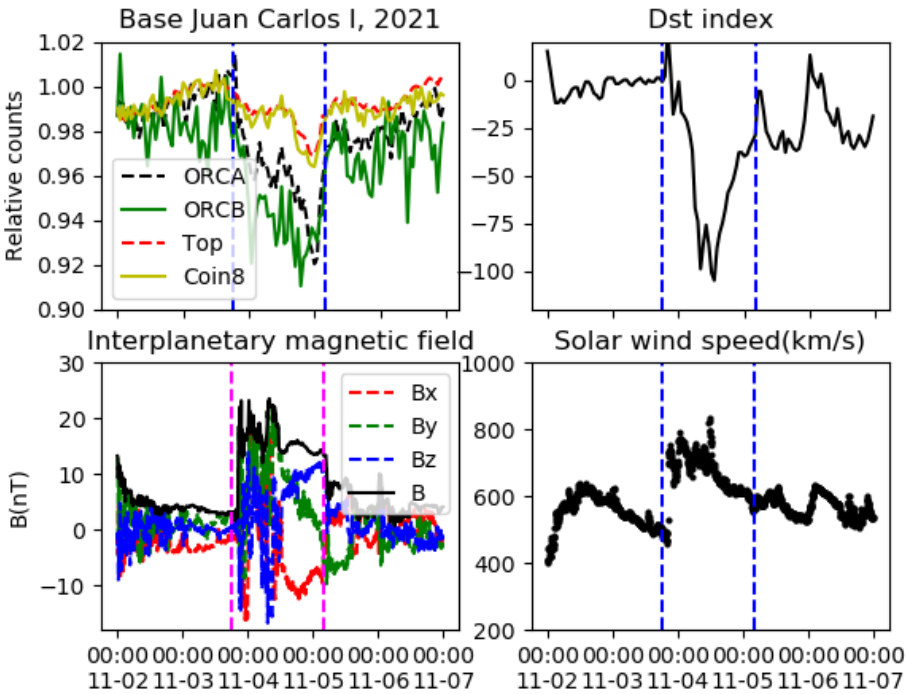
miniCaLMa

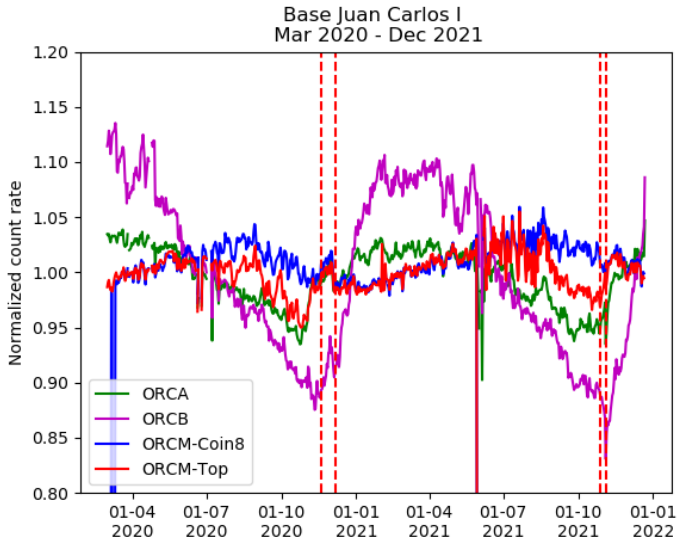


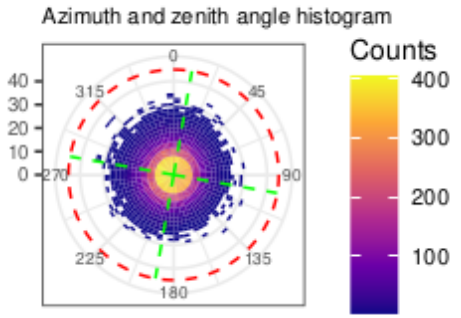


	MiniCaLMa
Counter Type	LND2043
Effective diameter (mm)	89
Effective length (mm)	697
Cathode material	Stainless steel
Gas filling	$BF_3(96\%\,^{10}B)$
Gas pressure (mmHg)	700
Operational voltage (V)	2120–2370

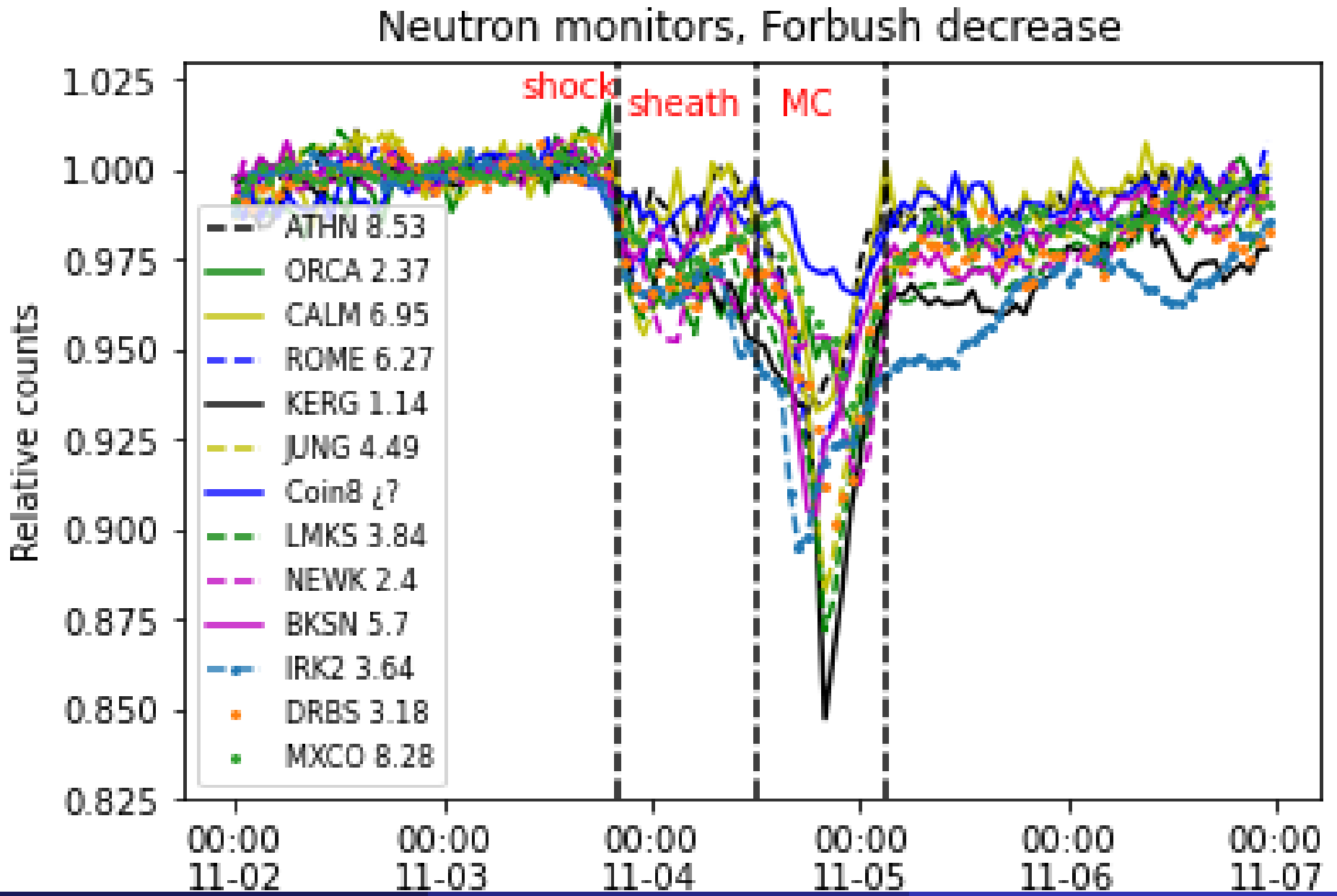
Ejemplos de medidas



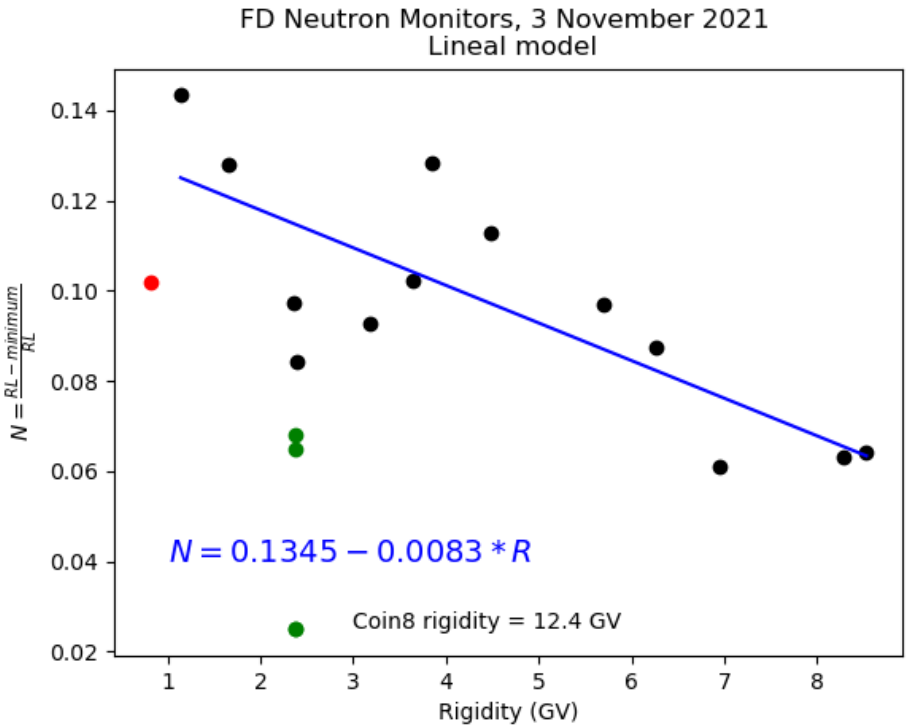




Solar events: November 2021 FD



Solar events

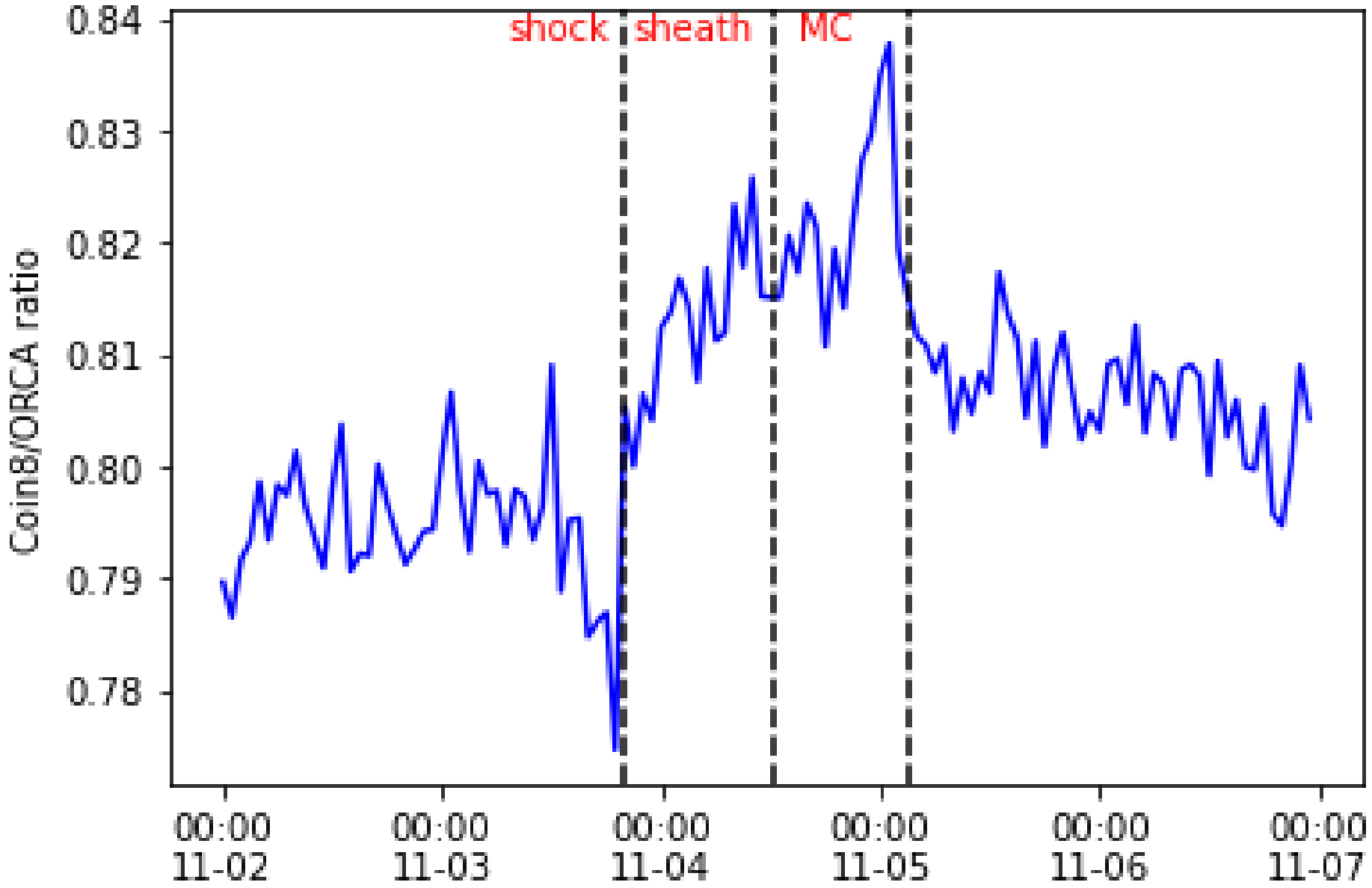


Coin8: Rigidity threshold estimation $\rightarrow 12.4 GV$

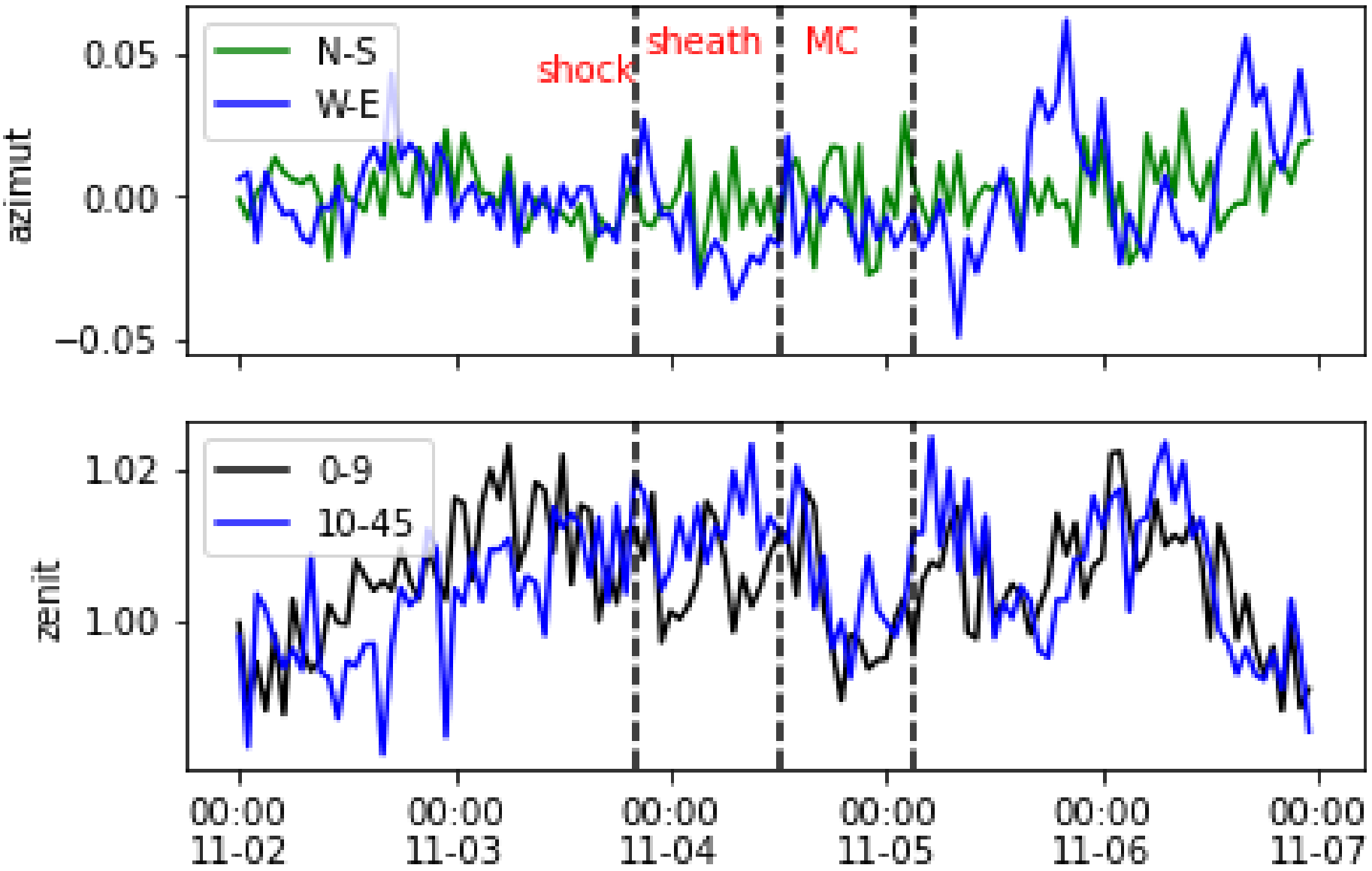
Neutron monitors

Name	Rigidity (GV)	$N = \frac{RL-minimum}{RL}$
ATHN	8.53	0.0640
MXCO	8.28	0.0631
CALM	6.95	0.0610
ROME	6.27	0.0874
BKSN	5.7	0.0968
JUNG	4.49	0.1128
LMKS	3.84	0.1284
IRK2	3.64	0.1023
DRBS	3.18	0.0927
NEWK	2.4	0.0843
KIEL2	2.36	0.0972
IKTK	1.65	0.1281
KERG	1.14	0.1433
OULU	0.81	0.1020
ORCA	2.37	0.0680
Top	¿?	0.0249
coin8	¿?	0.0251
ORCB	2.37	0.0649

Solar events: November 2021 FD



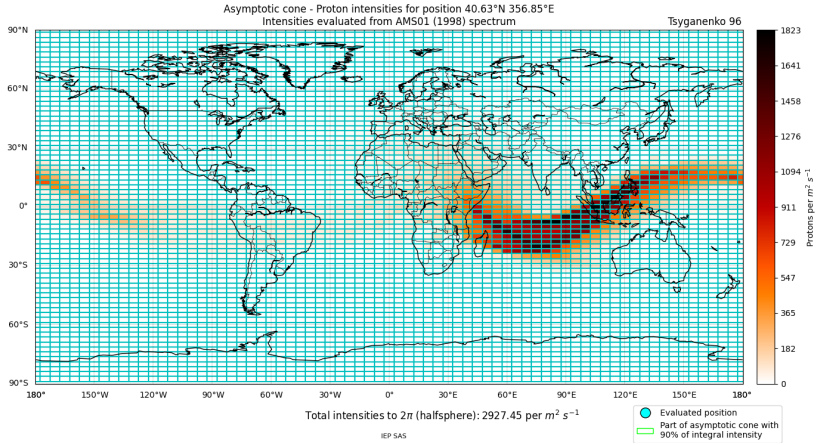
Solar events: November 2021 FD

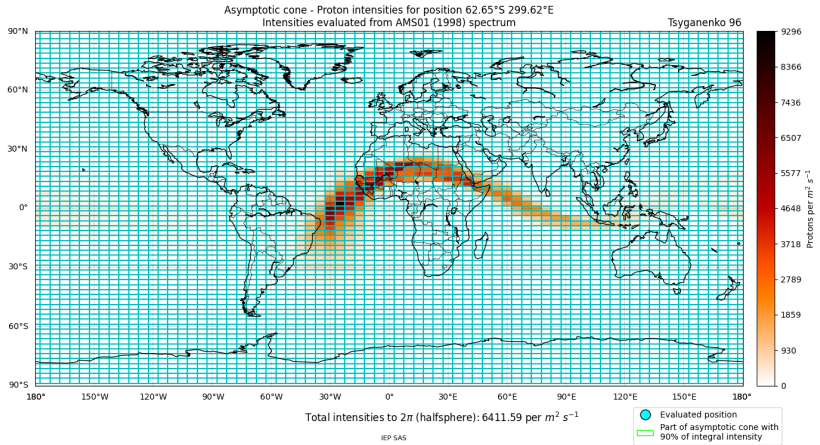


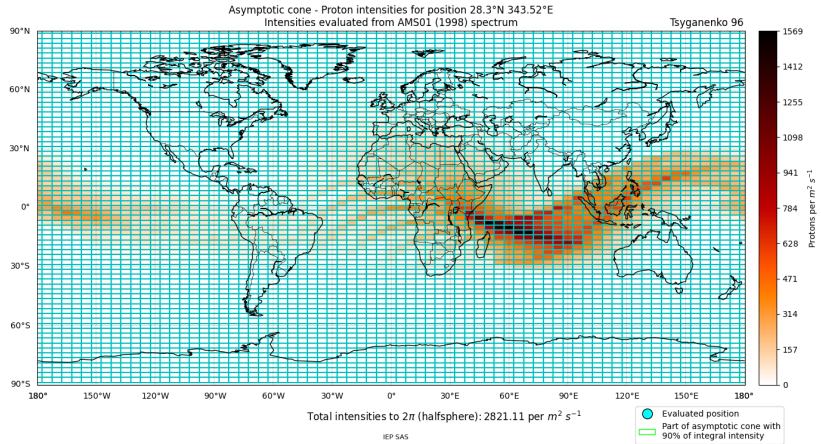
Más información

- Castilla-La Mancha neutron monitor, Medina et al., Nuclear Instruments and Methods in Physics Research A 727 (2013) 97–103
- The mini-neutron monitor: a new approach in neutron monitor design, Du Toit et al., J. Space Weather Space Clim. 2020, 10, 39.
- MITO: a new directional muon telescope, Ayuso et al., J. Space Weather Space Clim. 2021, 11, 13S.
- Cosmic ray observations from Livingston Island, Blanco et al., Advances in Space Research 69 (2022) 3514–3524

Conclusions







https://cor.crmodels.org/