



Trasgos

Towards a new standard of measuring cosmic rays

Juan A. Garzón (LabCAF - IGFAE, Univ. Santiago de Compostela)

(on behalf of TRAGALDABAS, MuTT, TRISTAN and Stratos Collaborations)

Cosmic rays

$E \sim \text{Joule}$
 $1 / (\text{km}^2 \cdot \text{century})$

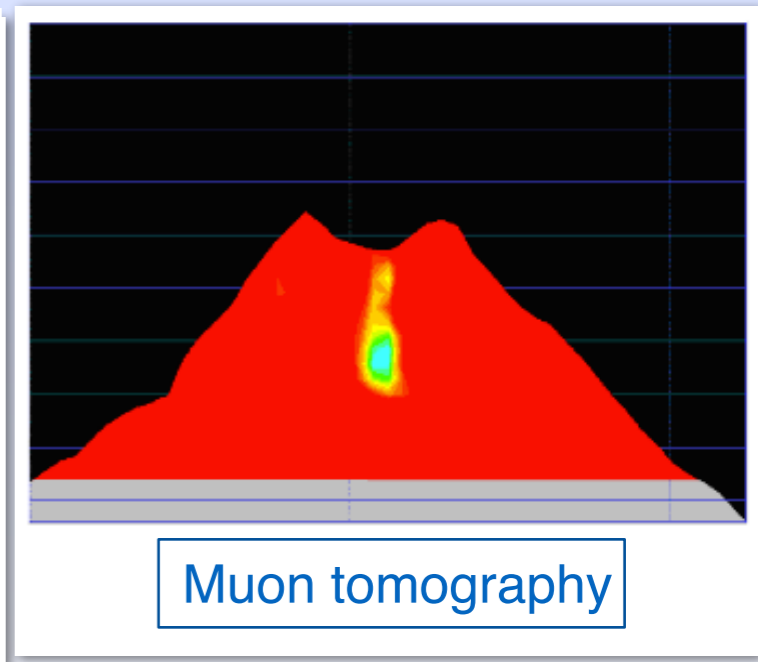
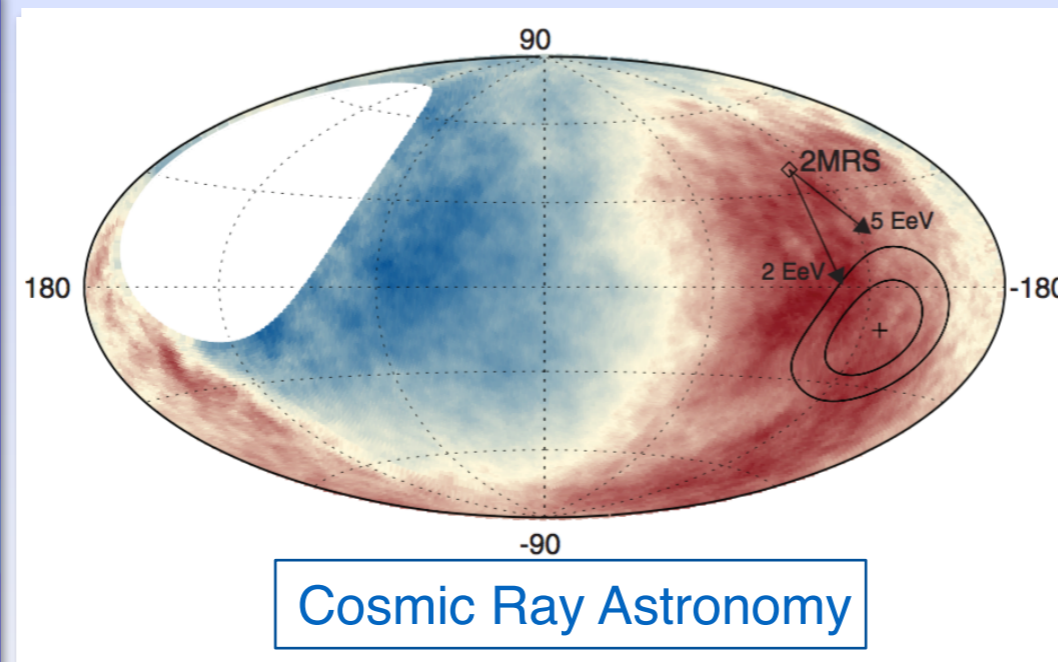
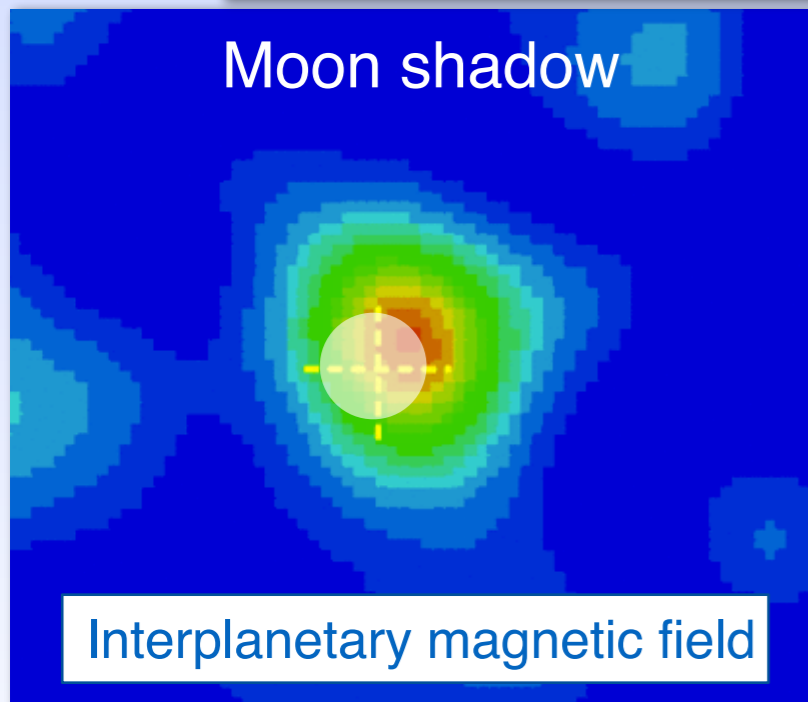
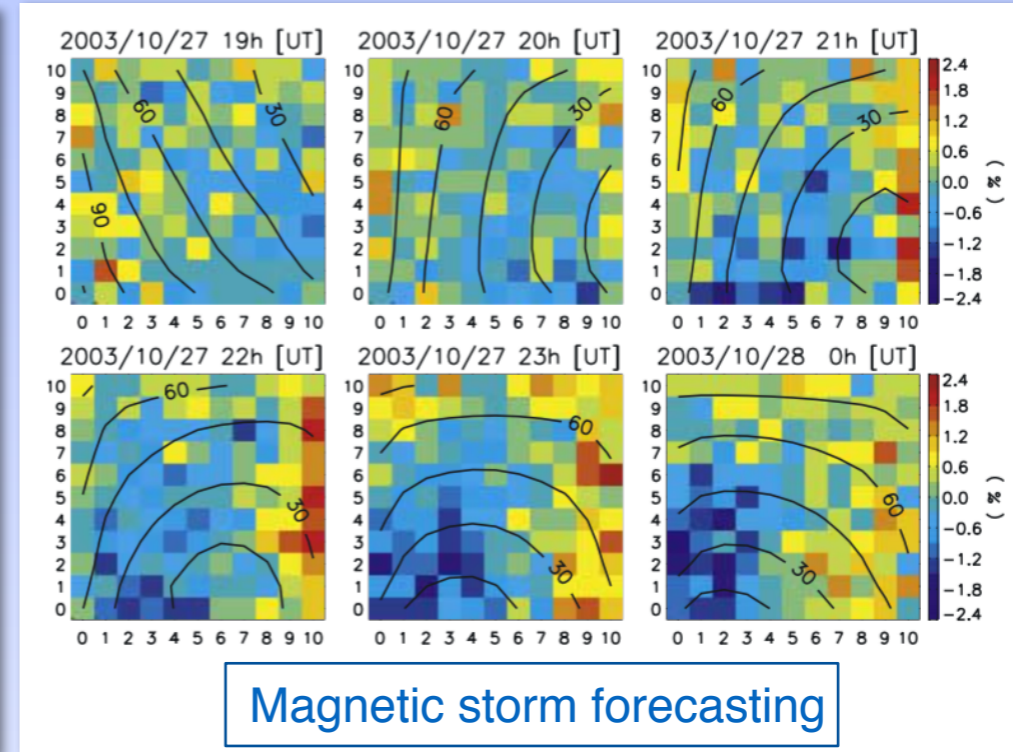
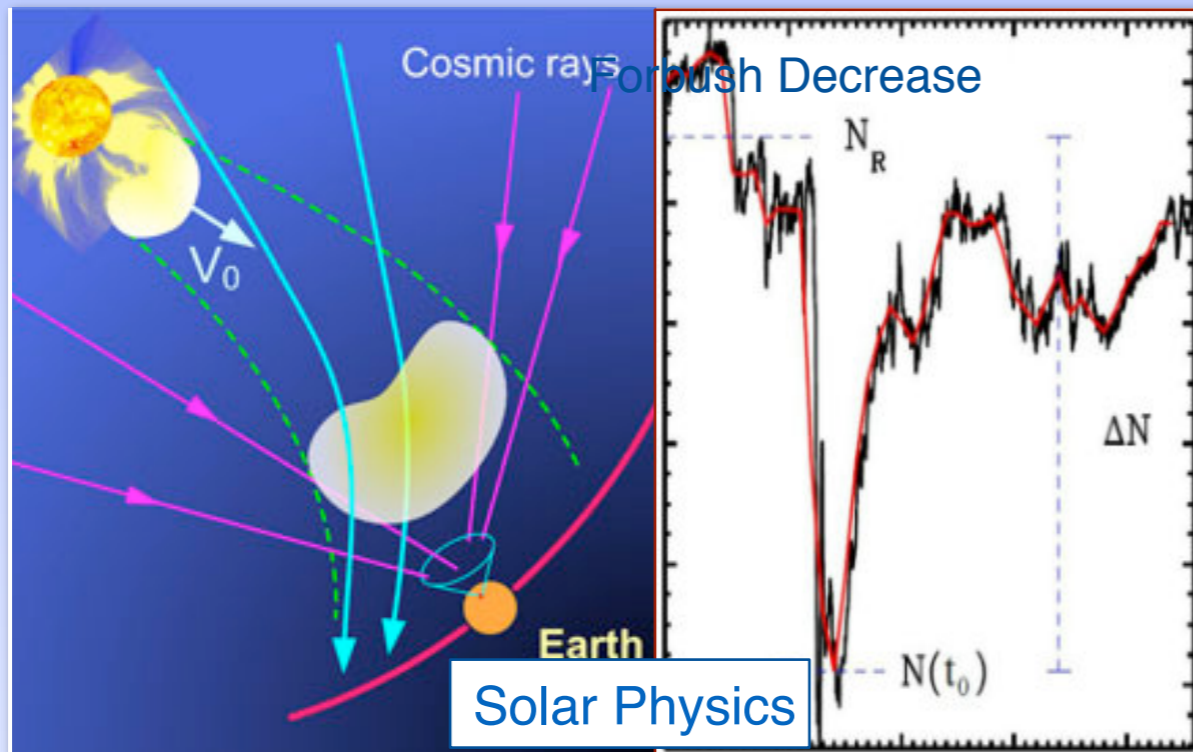
Primary cosmic rays

Secondary cosmic rays

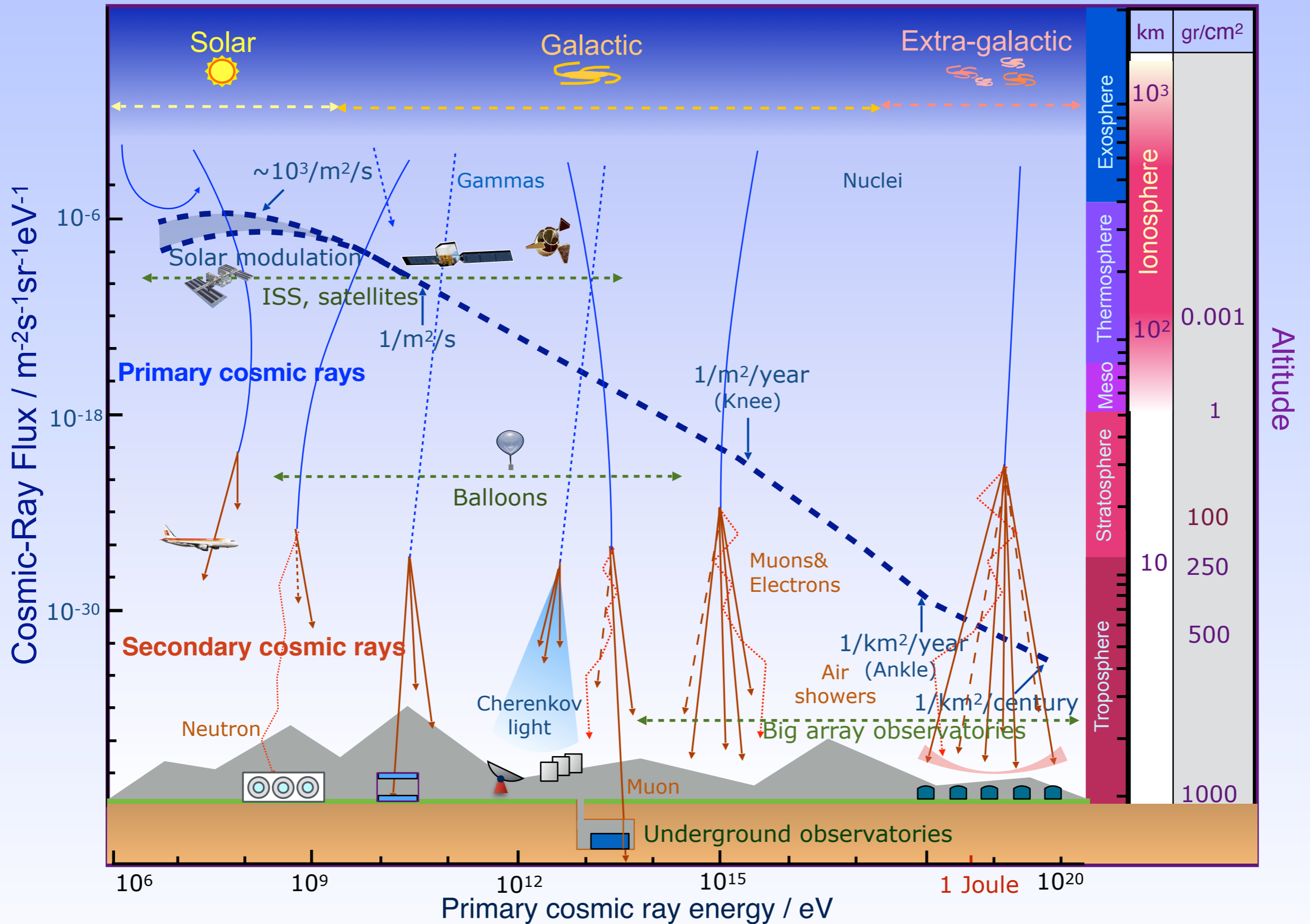
$E \sim 1 \text{ erg}$
 $1 / (\text{m}^2 \cdot \text{year})$

COSMIC RAYS

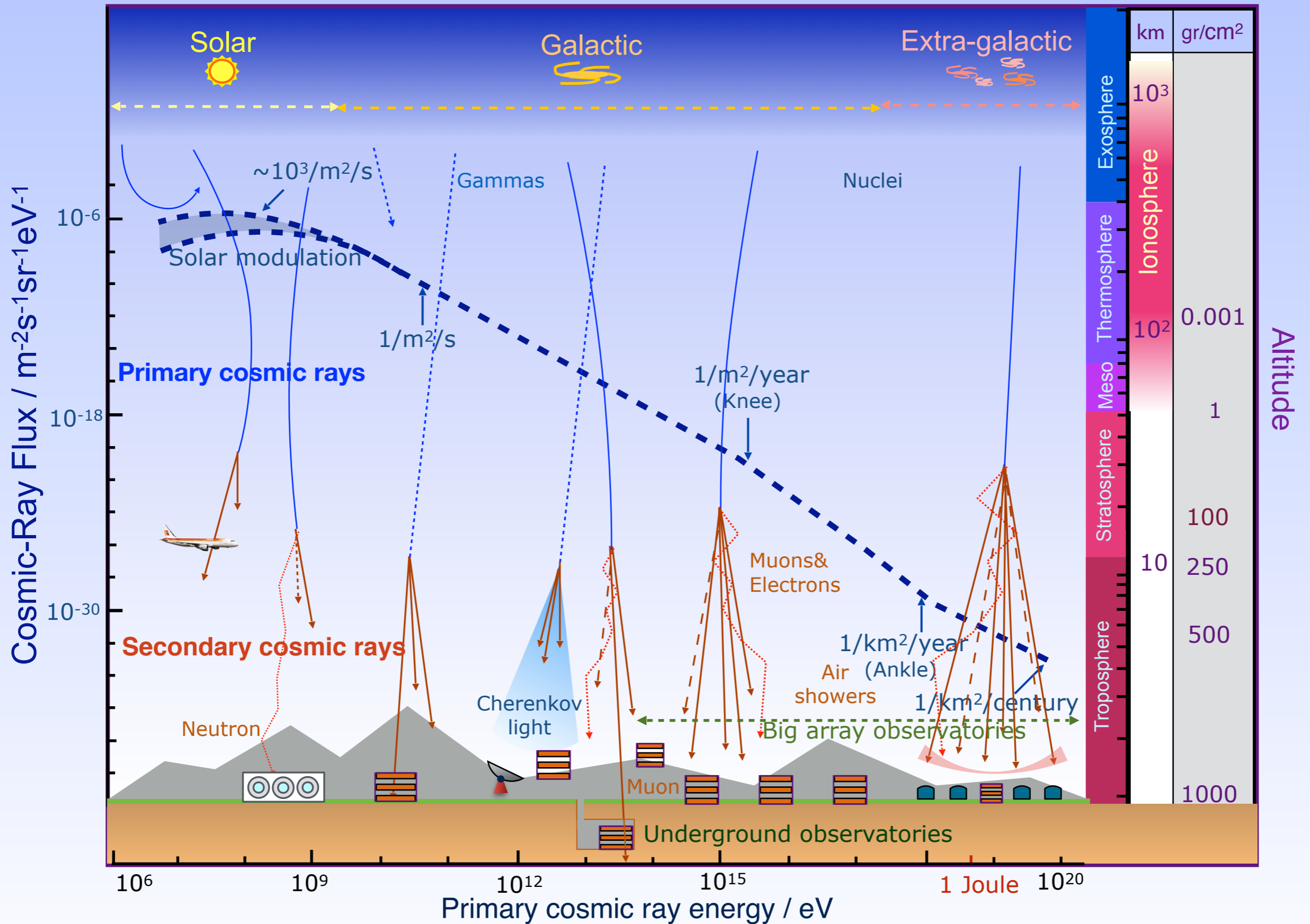
A few research fields



THE COSMIC RAYS: Typical detectors



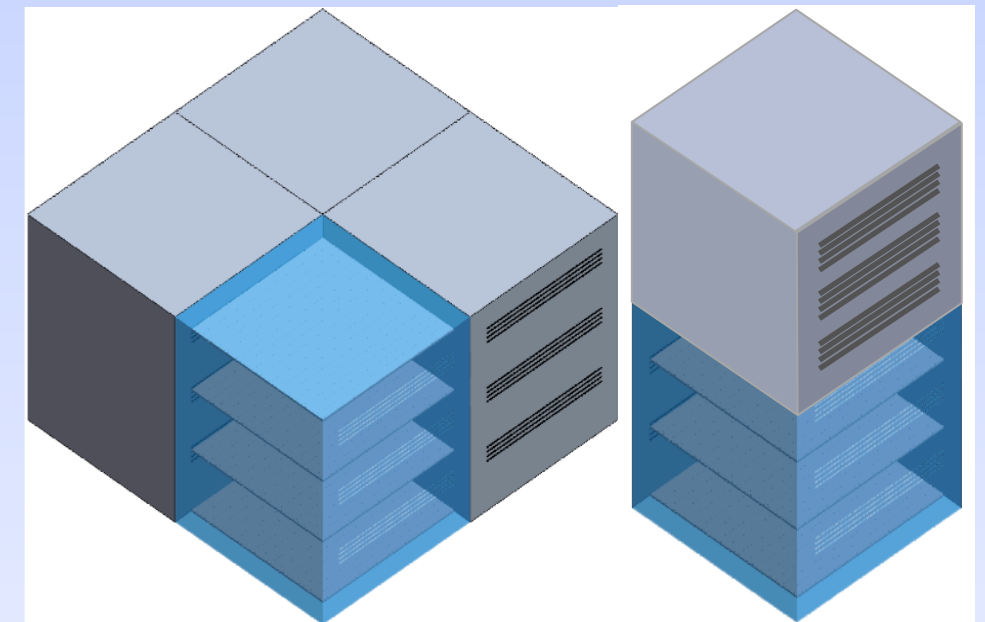
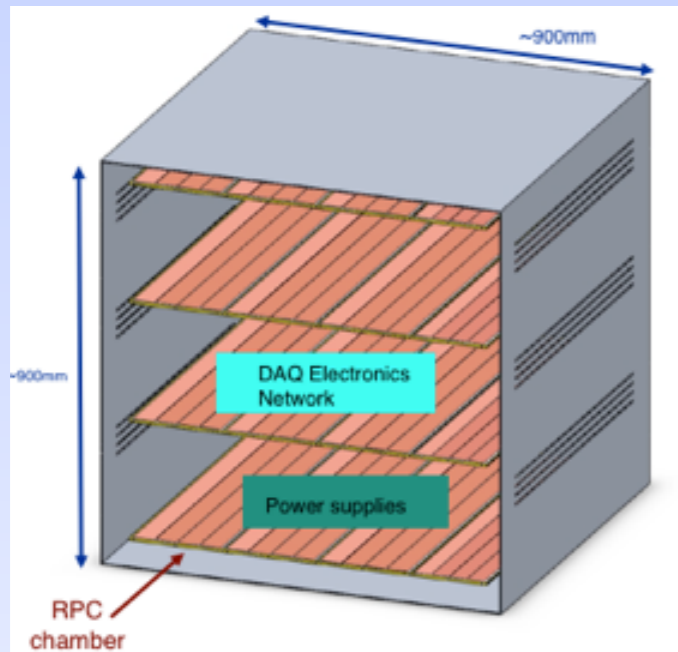
THE COSMIC RAYS: TRASGOS, a versatile complement



Juan A. Garzon, LabCAF-IGFAE / Univ. Santiago de Compostela
 2nd. Joint IGFAE-LIP Workshop, S. Compostela April, 26th. 2019

THE TRASGO CONCEPT (A PHILOSOPHY)

TRASGO: TRAck reconStructinG bOx (Fradinho de mão furada)

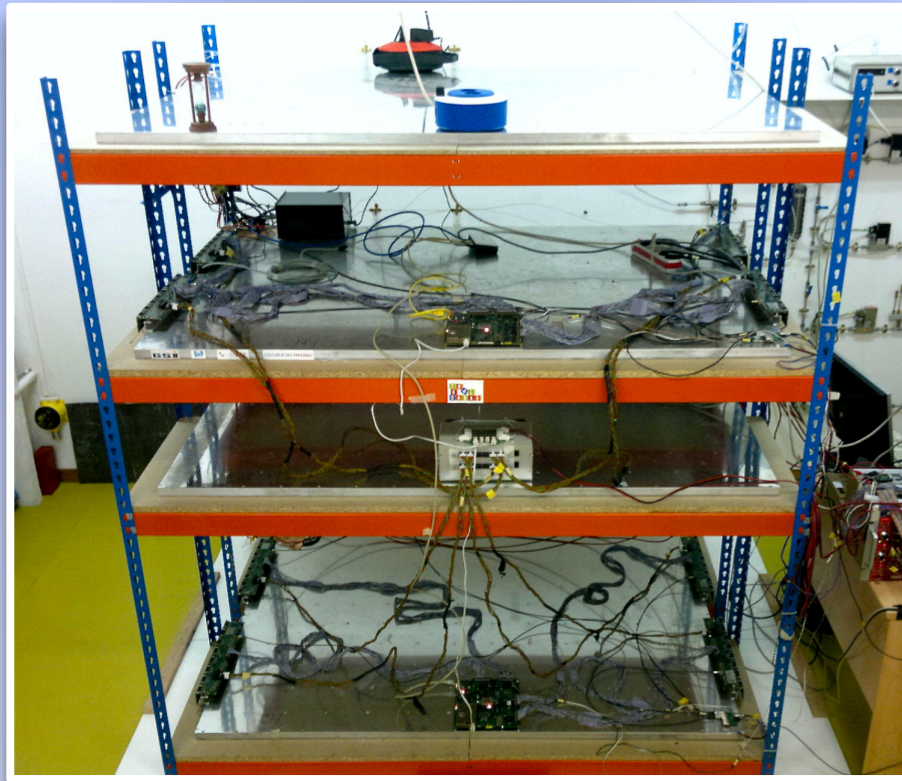


Main features:

- High granularity tracking detector
- Electron-Muon PID
- Affordable RPC-based detectors
- High modularity

with a complete set of tools (monitoring, reconstruction, analysis, visualization...)

THE PRESENT FLEET OF TRASGOS



TRAGALDABAS

(Univ. S. Compostela)
Multipurpose detector



MuTT

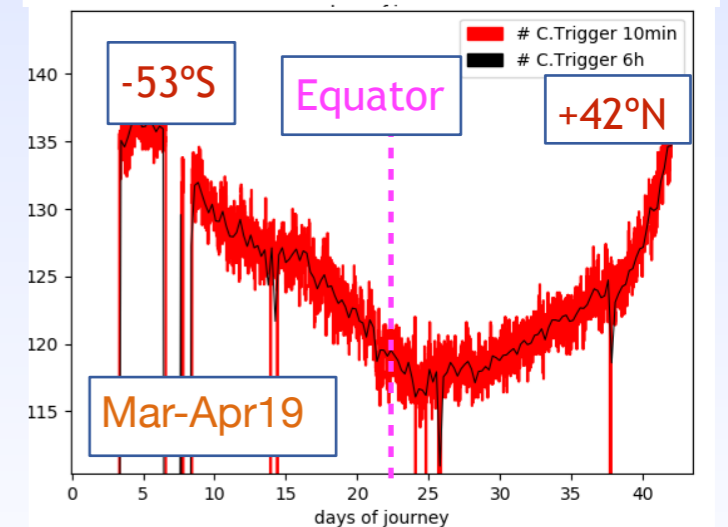
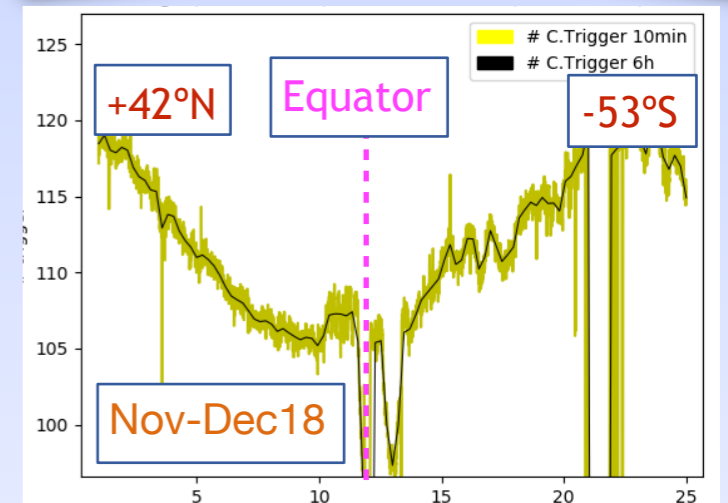
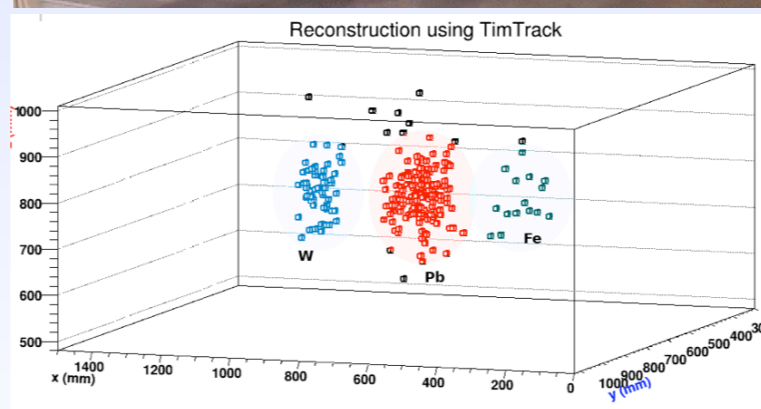
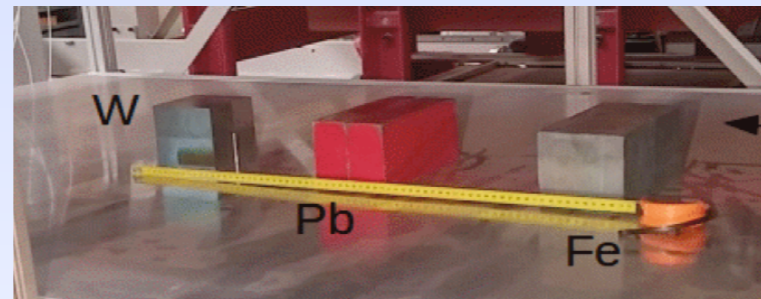
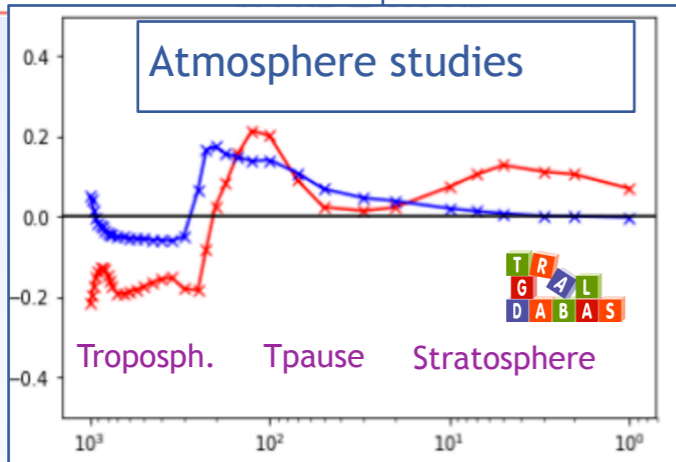
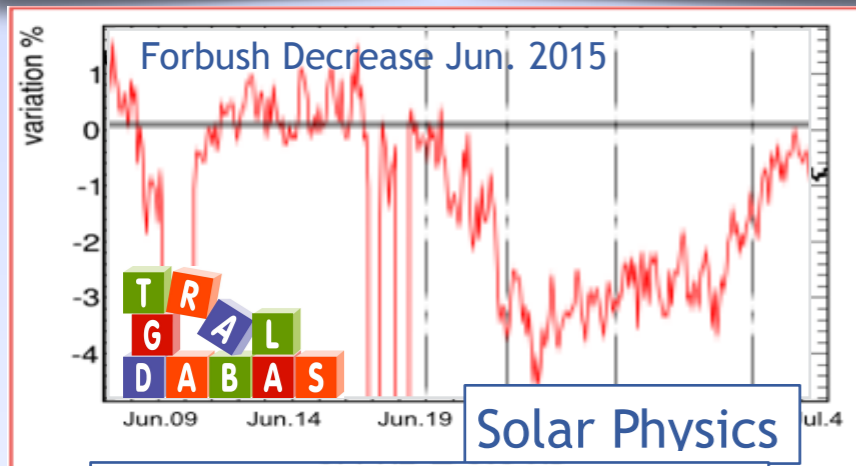
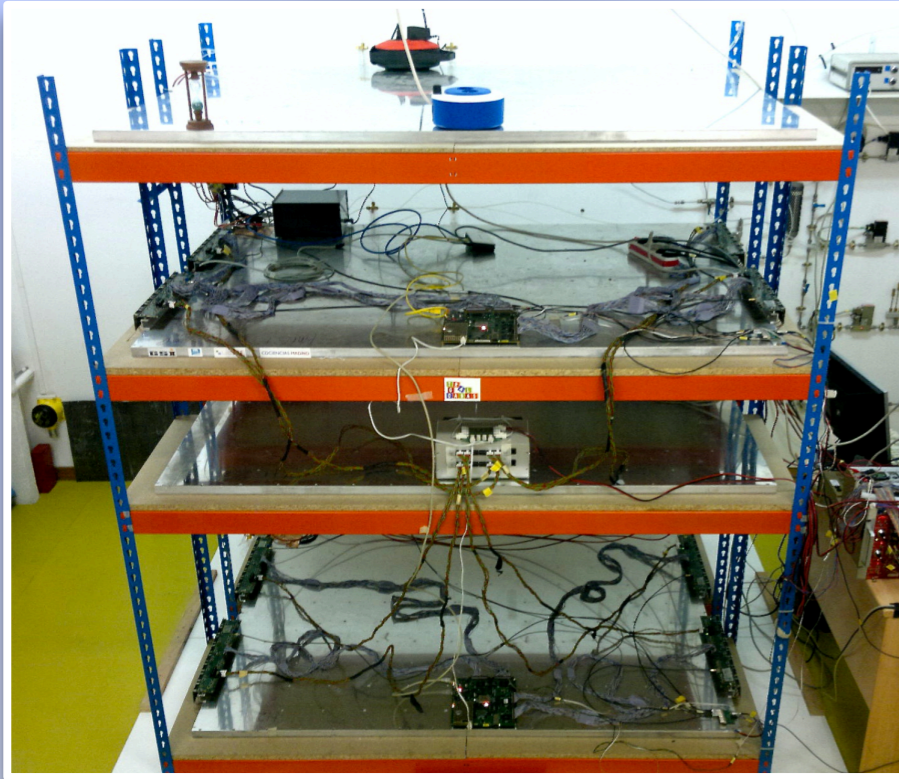
(Porriño, Vigo)
Tomography studies
HIDRONAV Initiative



TRISTAN

(Antarctica, End 2019)
Multipurpose detector

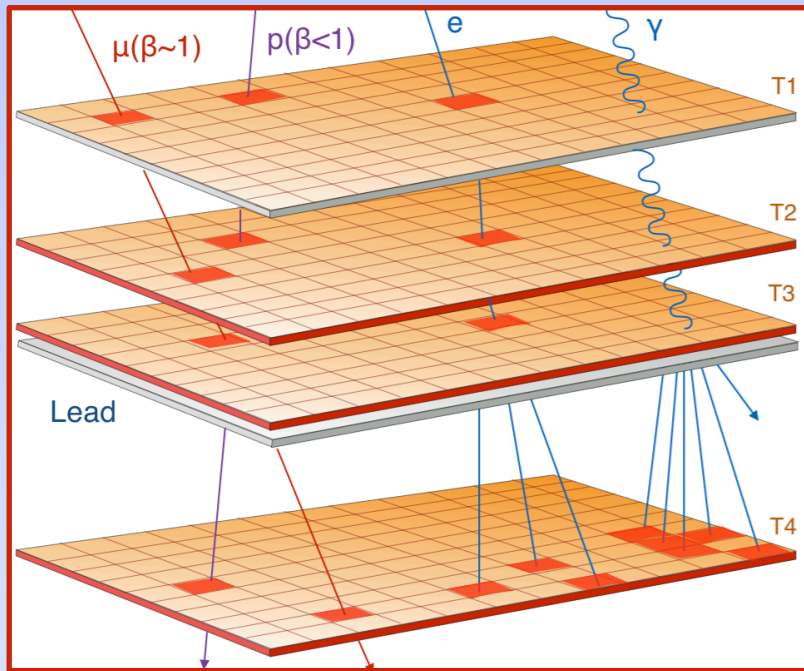
THE PRESENT FLEET OF TRASGOS



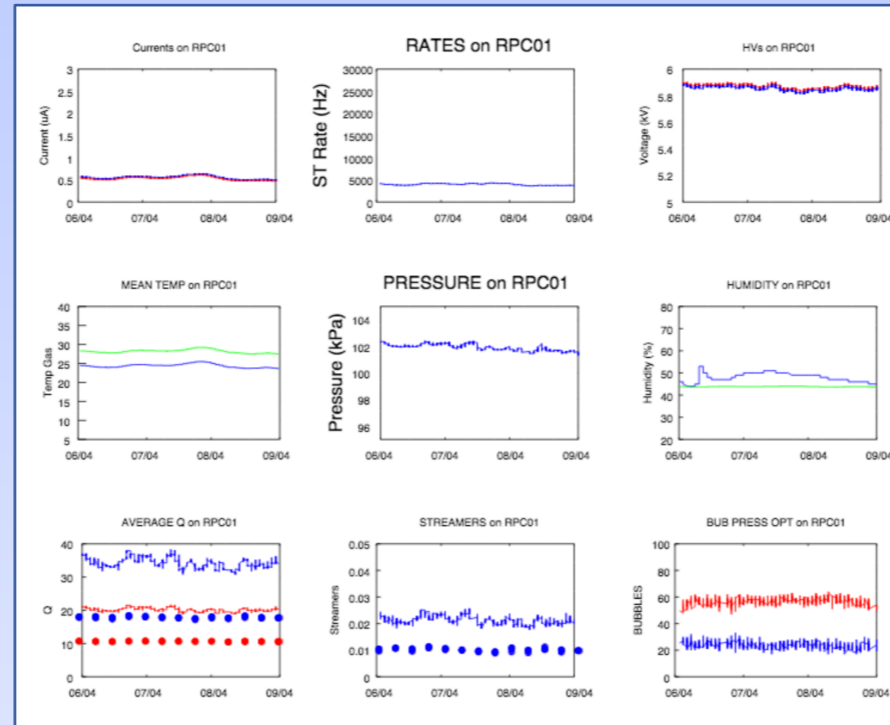
THE PRESENT FLEET OF TRASGOS

Some tools

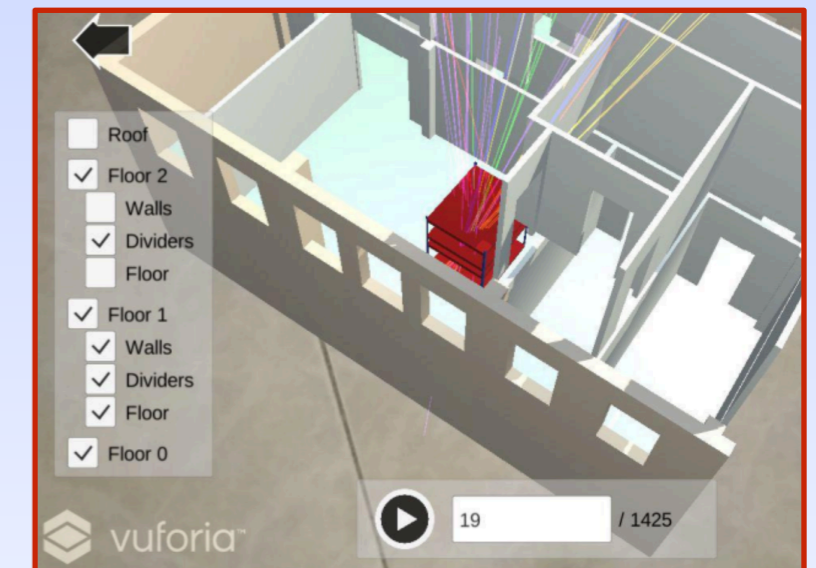
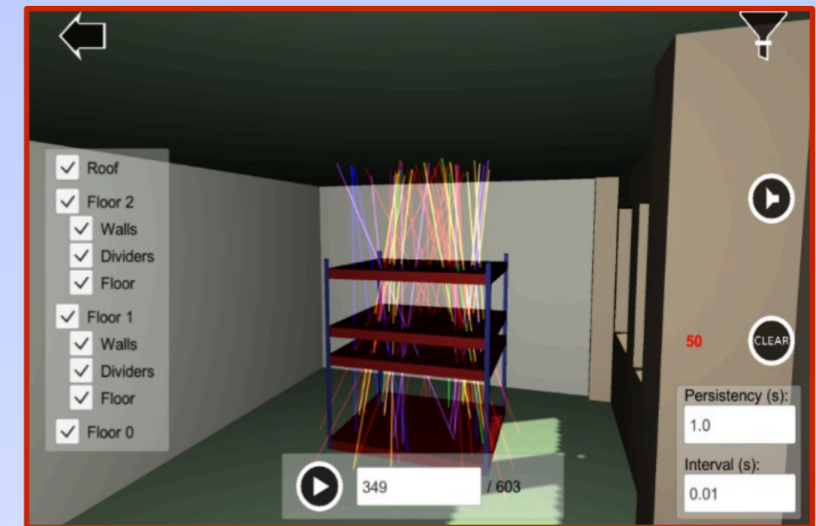
Particle identification



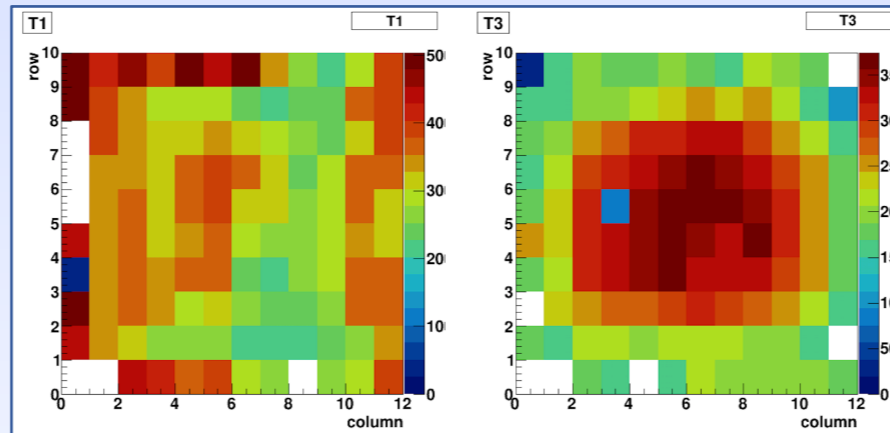
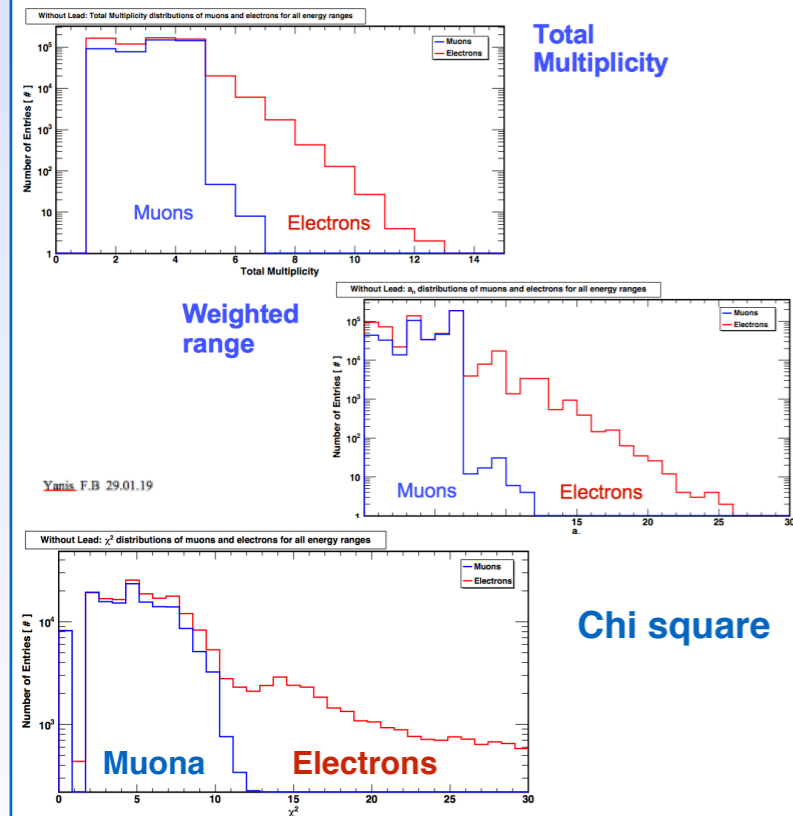
Monitoring



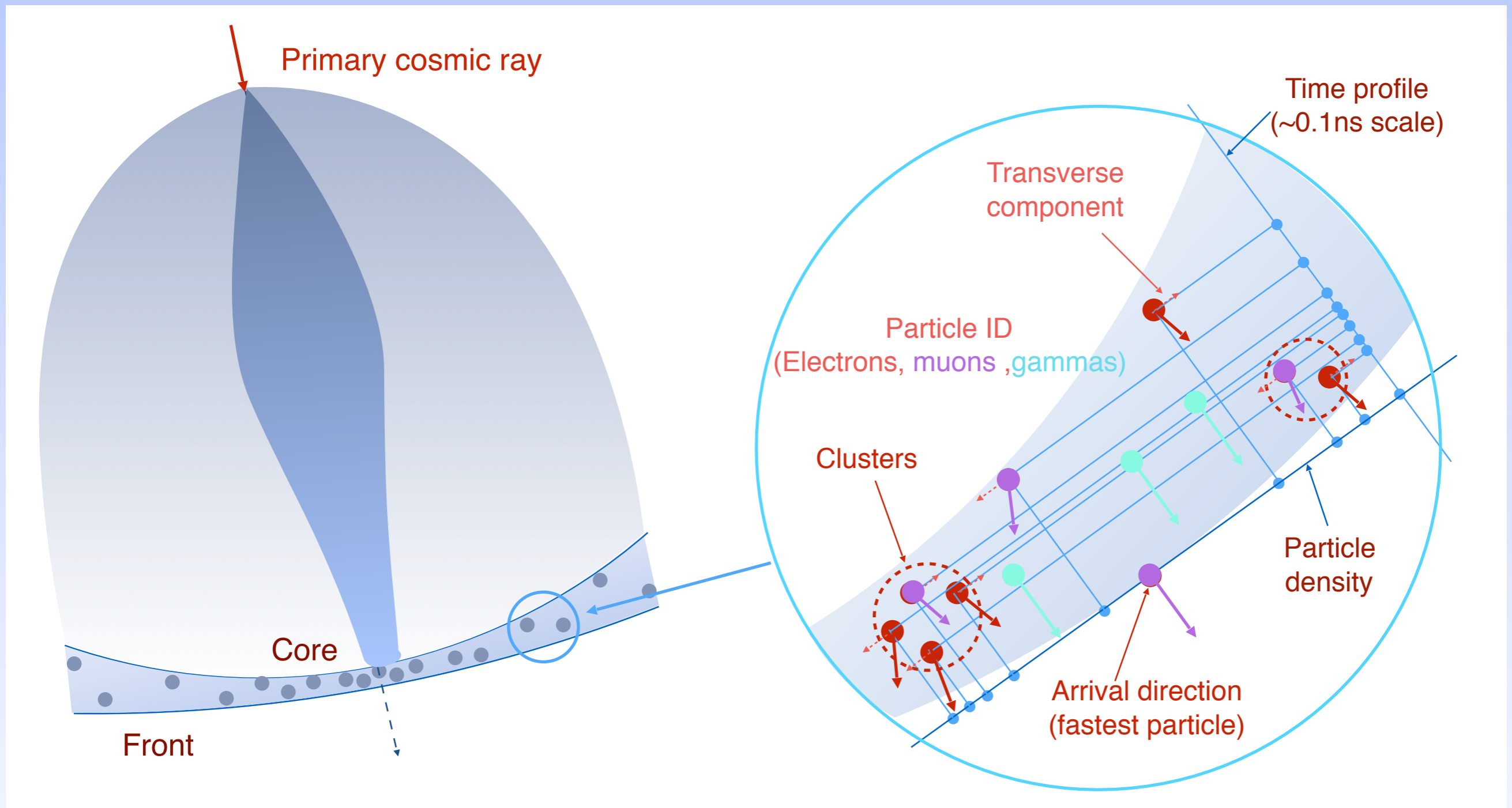
3D-Visualization



Simulation of 100k electrons and muons



1. Analysis of the microstructure of cosmic ray air showers




👁 Correlations between primary cosmic ray parameters and air shower properties

THE TRASGO PROJECT: Other initiatives

2. Systematic analysis of the properties of low energy cosmic ray extensive air showers (in S. Compostela- Spain, Sierra Negra- Mexico, Livingston I.-Antarctica)

1. Lateral distribution analysis [+ O. Martinez, A. Parra (Puebla, Mexico)]



Studies of Multiplicity and Response Function to Low Energy Simulations for Cosmic Rays

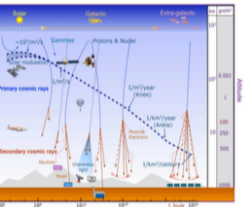
Alejandra Parra¹, Oscar Martínez¹, Juan A. Garzón², Yanis Fontela², Humberto Salazar¹
¹-Facultad de Ciencias Físico - Matemáticas (BUAP); ²-LabCAF, IGFAE-Univ. Santiago de Compostela, España.

Resumen

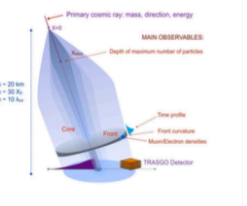
One of the most important question to answer in the cosmic rays field is to know their possible astrophysical scenarios. An approach to achieve this, is through the study of their primary radiation mass composition. The main objective of this work is to study low energy simulations for atmospheric extended showers (EAS) in order to parameterize their behavior and extrapolate it to higher energies. Our simulations will allow us to analyze the arrival of the secondary particles, considering the lateral distribution of particles near to the core of the EAS, where the electromagnetic to muonic ratio depends more strongly of the effective cross section, i.e. the mass of the primary particle. Here we present some preliminary results of the multiplicity and response function, with the objective to explore the lateral distribution function for the different components of the EAS. In a next future we pretend to validate or improving the results making direct measurements with a high resolution tracking detector of the TRASGO family.

Extended Air Showers (EAS)

- The Cosmic Rays covers an energy range that goes from 10^9 eV to 10^{20} eV.
- Therefore different detection techniques are employed for their study.

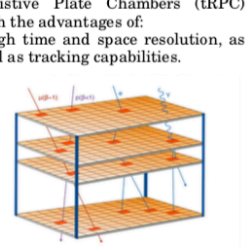


We will focus in the lateral distribution of the secondary particles arriving near to the core of the EAS.



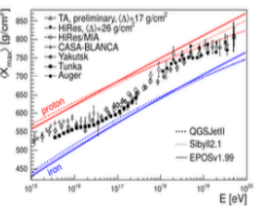
TRASGO (TRAck and time reconStructinG bOx)

- There consist on a stack of timing Resistive Plate Chambers (RPC) with the advantages of:
- High time and space resolution, as well as tracking capabilities.



Motivation: The Composition Problem

- An approach to solve this problem is through the study of the primary radiation mass composition.
- One of the observables which give more information about the primary mass is the X_{max} , this corresponds to the high at which the shower reach its maximum development.



Work Proposal

- Considered an hybrid detector, i.e. combine the advantages of the TRASGOS with a traditional water Cerenkov Detector array for high energies.
- This will allow us to perform a high precision study of the cosmic rays.

Multiplicity Function and Response Function

- Study low energy simulations for EAS.
- Using different libraries considering proton, carbon, helio and iron as primary particles.
- Analyzing their multiplicity function, i.e. the number of secondary particles of a specific kind from one primary particle of a given energy [2,3]:

$$M(E, \theta) = \int_{R_{th}}^E m^{GL}(E_p, E, \theta) dE_p$$

- And the response function, which represents a distribution of detector counting rate at given direction of the primary energy particle [2].

$$G(E, \theta, \phi) = P(E, \theta, \phi) \cdot J_p(E)$$

- Where $P(E, \theta, \phi)$ corresponds to the yield function and $J_p(E)$ will be the cosmic ray flux [2].

Preliminary Results

- In the following plots are shown the multiplicity function and the response function respectively, for simulated events.

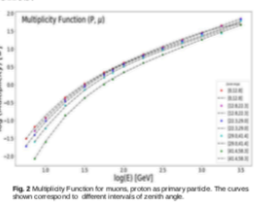


Fig. 2 Multiplicity Function for muons, protons as primary particle. The curves shown correspond to different intervals of zenith angle.

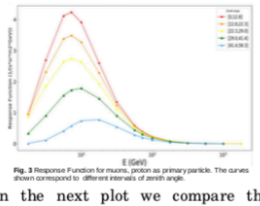


Fig. 3 Response Function for muons, protons as primary particle. The curves shown correspond to different intervals of zenith angle.

- In the next plot we compare the response function for simulated events considering different primary particles (p, C, He).

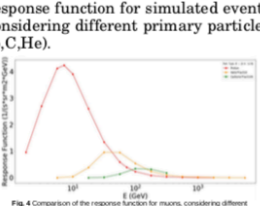
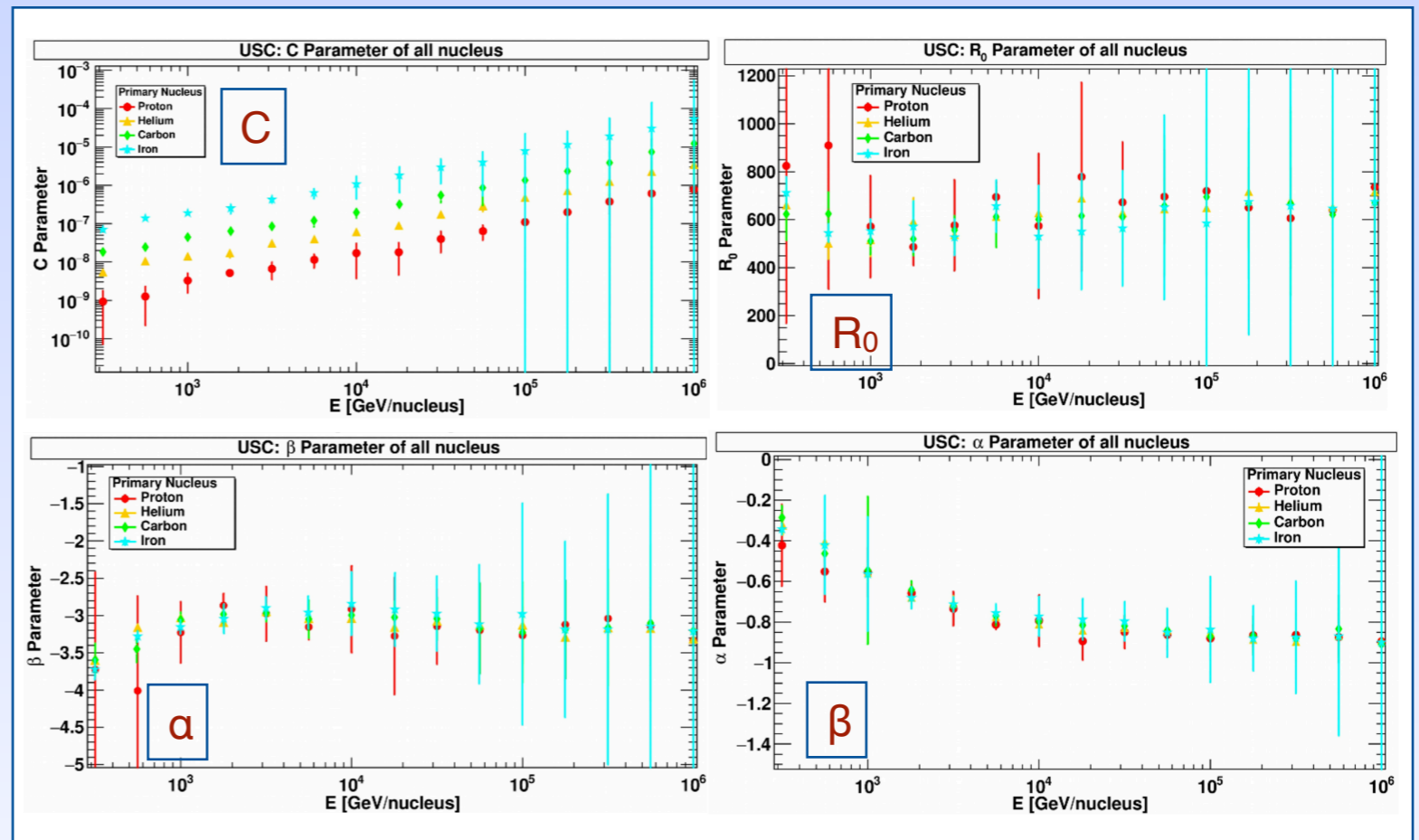


Fig. 4 Comparison of the response function for muons, considering different primary particles for the simulated showers.

Bibliography

- (1) Kampert, Karl-Heinz et al. *Astropart.Phys.* 35(2012) 666-678 arXiv:1201.0018 [astro-ph.HE]
- (2) D. Balcer et al., "TRASGO: A proposal for a timing RPC based detector for analysing cosmic ray air showers", *Nuc.Inst.&Meth.* A661 (2012), 5163-5167.
- (3) Bogdanov, Aleksey et al., "Coupling functions for primary cosmic rays and ground-level muons at various zenith angles", *Bulletin of the Russian Academy of Sciences: Physics*, 2009, Vol. 73, No. 3, pp 357-360.
- (4) Yakovleva, E. I. et al., "Coupling Functions for Muon Hodoscopes", *Bulletin of the Russian Academy of Sciences: Physics*, 2009, Vol. 73, No. 3, pp 357-360.

$$\rho(R) = C (R/R_0)^\alpha (1 + R/R_0)^\beta$$



2018: Mexican meeting on particles&fields

Lateral distribution analysis for P, He, C & Fe, under the knee at SCQ

THE TRASGO PROJECT: Other initiatives

2. Systematic analysis of the properties of low energy cosmic ray extensive air showers (in S. Compostela- Spain, Sierra Negra- Mexico, Livingston I.-Antarctica)

2. Muon cluster analysis analysis [+ A. Diaz]

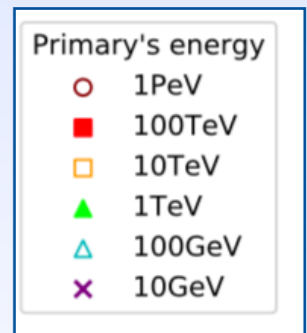
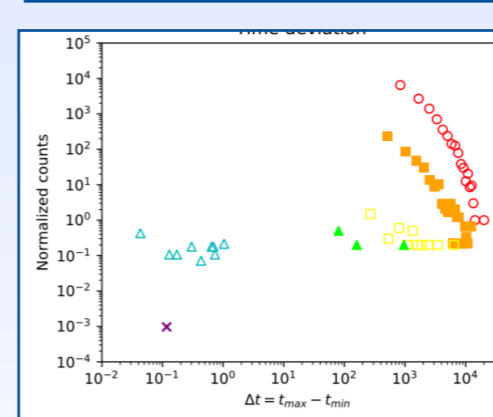
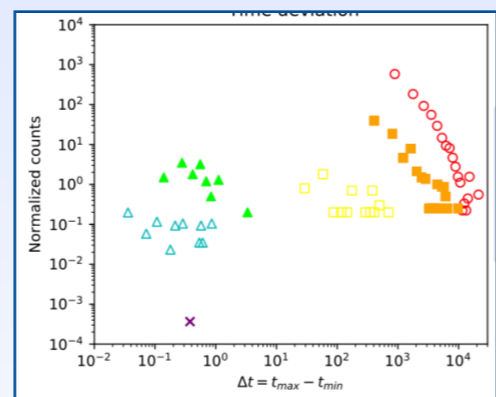
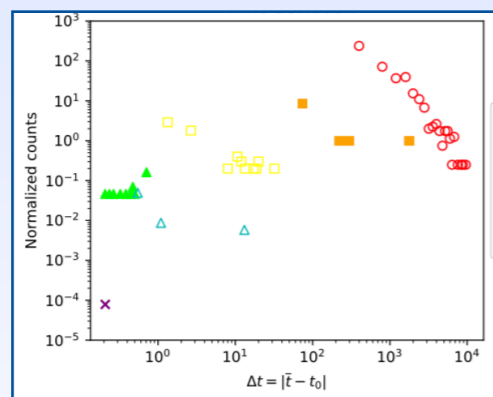
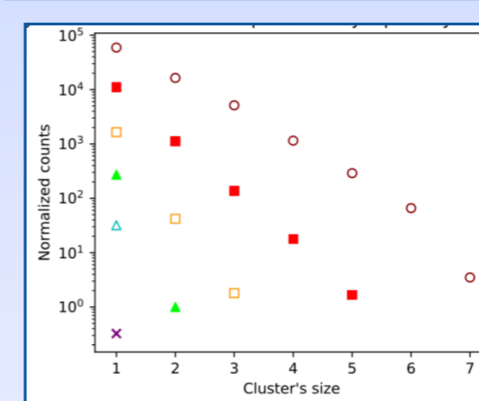
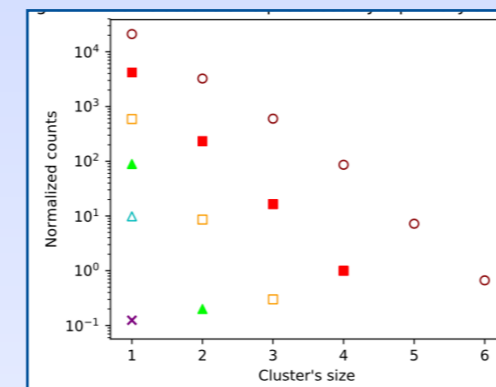
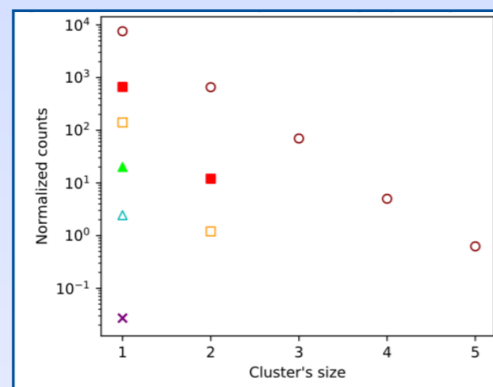
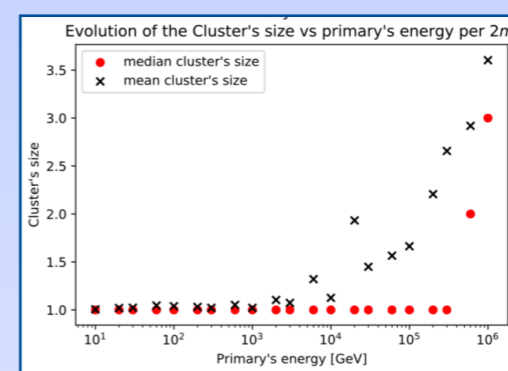
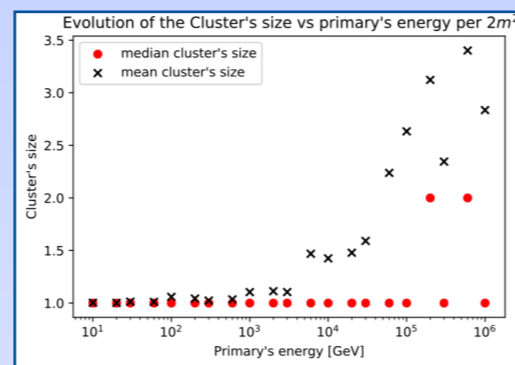
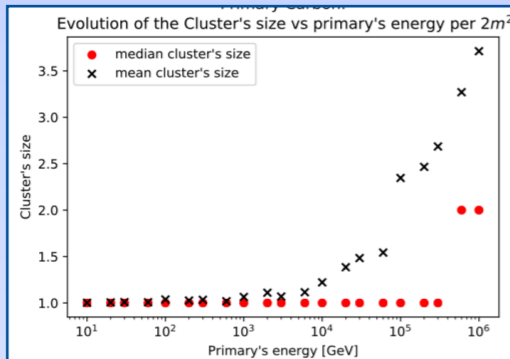
P

He

C

Fe

cluster size vs. energy



μ clusters

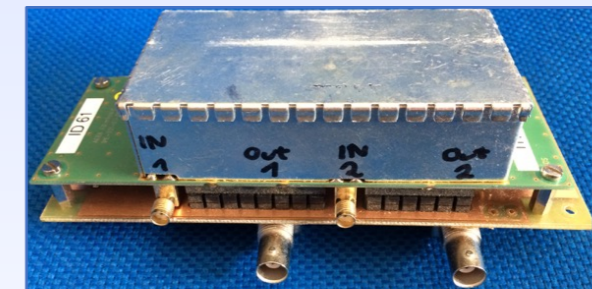
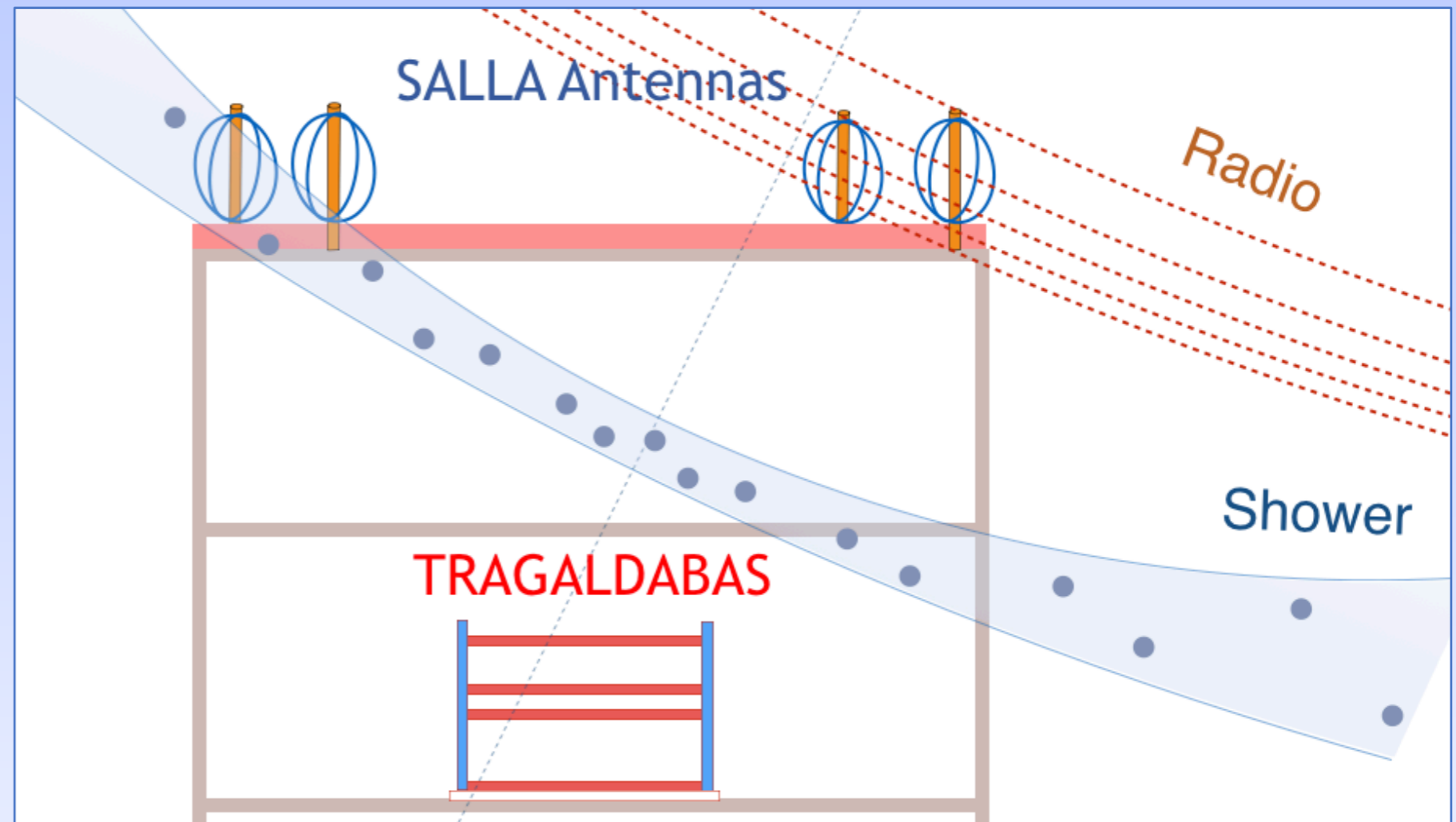
cluster time width

👁 Correlations between primary cosmic ray parameters and cluster of particles properties

THE TRASGO PROJECT: Other initiatives

3. MICROSCOPE: MIni Cosmic Ray Observatory of Santiago de COMpostela

Four SALLA antennas have been installed at the roof on top of the TRAGALDABAS detector



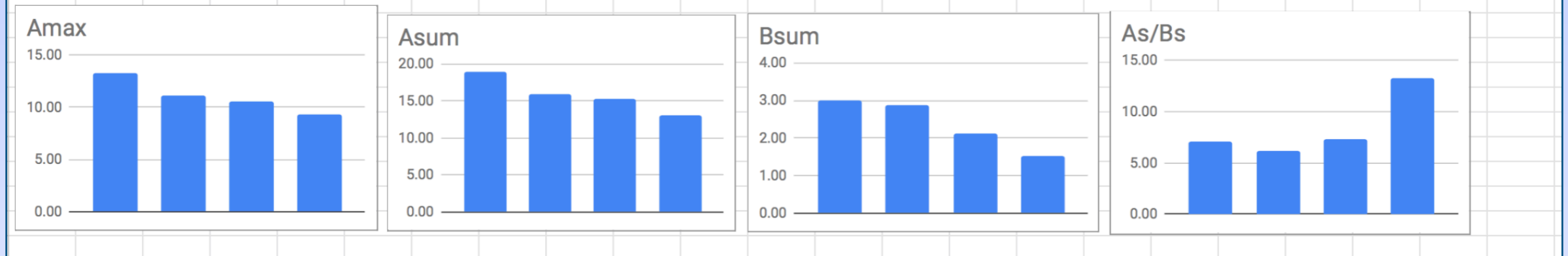
👁 Correlation between Tragaldabas measurements with an external energy estimation

THE TRASGO PROJECT: Other initiatives

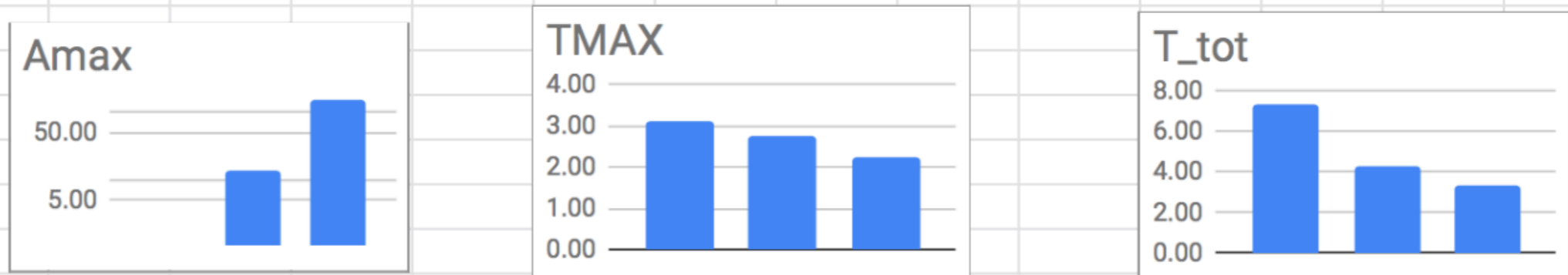
3. MICROSCOPE: MIni Cosmic Ray Observatory of Santiago de COMpostEla

Four SALLA antennas have been installed at the roof on top of the TRAGALDABAS detector

Z	A	Xa	Ya	Seed	1stH	MxPH	NMxP	Amax	AL	AR	BL	BR	BLL	BRR	tMax	tAL	tAR	tBL	tBR	tBLL	tBRR	Asum
1	1						mean	13.29	2.86	2.84	0.55	0.87	0.30	1.30	2.75	-26.00	30.88	-17.50	22.75	-37.28	39.25	18.99
2	4						mean	11.09	2.41	2.37	0.50	0.92	0.27	1.18	2.88	-25.63	31.13	-17.13	23.00	-37.13	39.38	15.87
6	12						mean	10.58	2.27	2.49	0.51	0.92	0.28	0.43	3.00	-25.63	31.38	-17.00	22.75	-36.88	43.25	15.34
26	56						mean	9.28	1.97	1.85	0.46	0.78	0.24	0.05	3.25	-25.63	31.75	-16.88	24.00	-36.75	32.44	13.09



Energy	Xa	Ya	Seed	1stH	MxPH	NMxP	Amax	AL	AR	BL	BR	BLL	BRR	tMax
1.0E+05						mean	1.12	0.24	0.25	0.05	0.09	0.03	-0.22	3.13
1.0E+06						mean	13.29	2.86	2.84	0.55	0.87	0.30	0.21	2.75
1.0E+07						mean	153.93	33.48	33.70	7.27	10.90	3.96	4.47	2.25



- A big simulation program (energy, angle, position, etc.) is going on

THE TRASGO PROJECT: Other initiatives

3. MICROSCOPE: MIni Cosmic Ray Observatory of Santiago de COMPostEla

Four SALLA antennas have been installed at the roof on top of the TRAGALDABAS detector

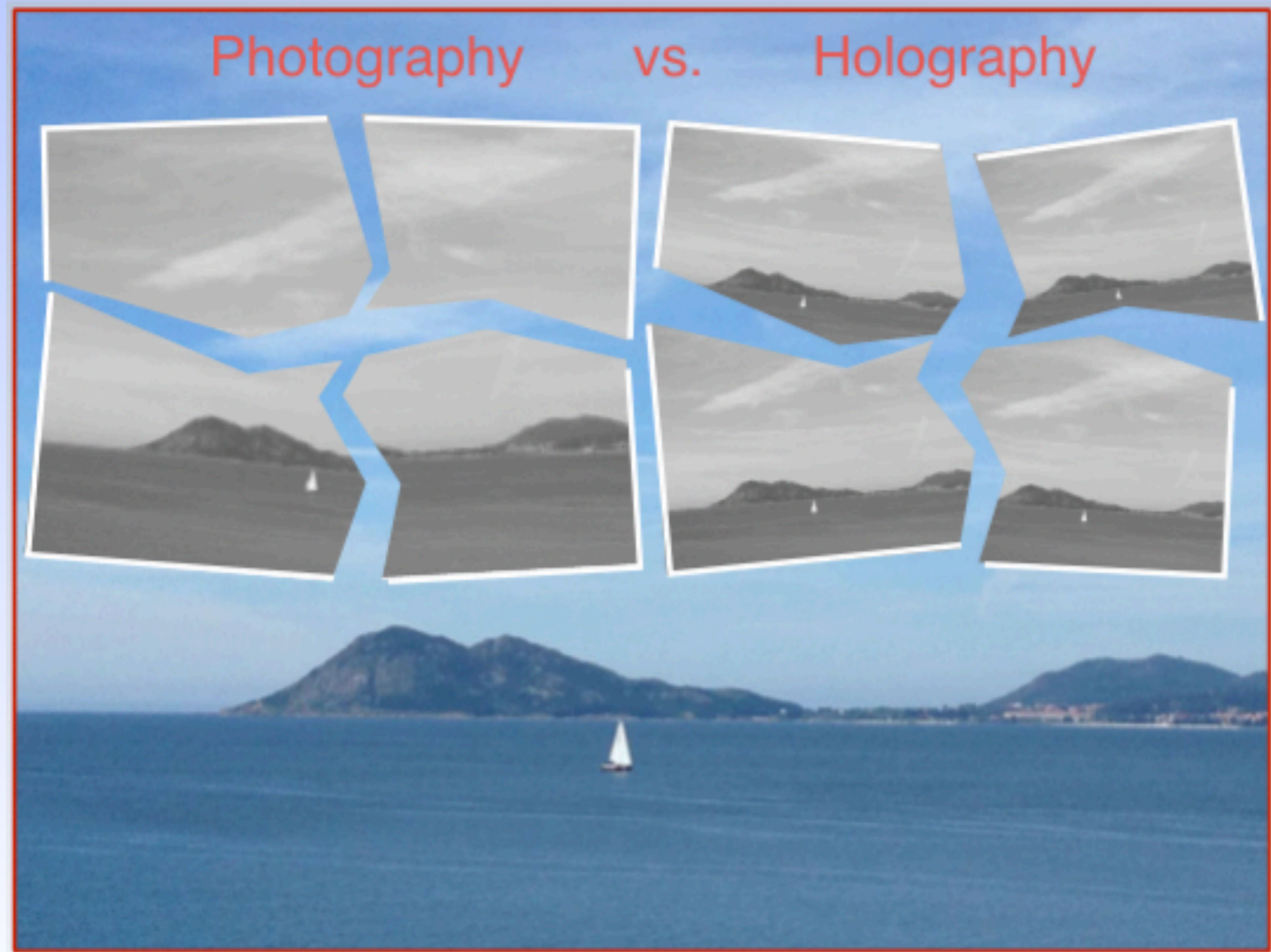
Daily rate of clusters of secondaries at sea level for different primary energies (NKG parametrization)											
Energy		Flux of primary cosmic rays			Daily rate of clusters/m ² .sr, for different multiplicities M						Energy
E/GeV	F/GeV.m ² .sr.s	IF/m ² .sr.s	IF/m ² .sr.day	M=3-5	M=5-10	M=10-20	M=20-30	M=30-40	M > 40	E/eV	
1.00E+06	1.1E-12	6.8E-07	5.9E-02	296	166	60	15			1.00E+15	
1.78E+06	2.4E-13	2.6E-07	2.2E-02	222	130	54	17			1.76E+15	
3.16E+06	5.1E-14	9.0E-08	7.8E-03	156	95	46	18			3.16E+15	
5.62E+06	3.5E-14	5.6E-08	4.8E-03	193	122	69	32			5.62E+15	
1.00E+07	6.3E-15	3.8E-08	3.3E-03	264	174	114	66	51	31	1.00E+16	
1.78E+07	1.1E-15	1.2E-08	1.0E-03	127	86	59	34	27	17	1.76E+16	
3.16E+07	2.0E-16	3.8E-09	3.3E-04	61	43	30	17	14	10	3.16E+16	
5.62E+07	3.5E-17	1.2E-09	1.0E-04	29	21	16	9	8	5	5.62E+16	
1.00E+08	6.3E-18	3.8E-10	3.3E-05	14	11	8	5	4	3	1.00E+17	
1.78E+08	1.1E-18	1.2E-10	1.0E-05	6	5	4	2	2	1	1.78E+17	
3.16E+08	2.0E-19	3.8E-11	3.3E-06	3	2	2	1	1	1	3.16E+17	
5.62E+08	3.5E-20	1.2E-11	1.0E-06	1	1	1	0	0	0	5.62E+17	
1.00E+09	6.3E-21	3.8E-12	3.3E-07	1	0	0	0	0	0	1.00E+18	
1.78E+09	1.1E-21	1.2E-12	1.0E-07	0	0	0	0	0	0	1.78E+18	
3.16E+09	2.0E-22	4.6E-13	3.9E-08	0	0	0	0	0	0	3.16E+18	
TOTAL		1.1E-07	9.8E-02	1,373	858	462	216	107	69	TOTAL	
E/A.GeV	Flux	FluxIAS	IF/m ² .s	M=3-5	M=5-10	M=10-20	M=20-30	M=30-40	M > 40	E/A.GeV	

Expected rates of showers of different multiplicities and at different energies.

Around 500 daily triggers of showers with $E > 10^{16}$ eV!!

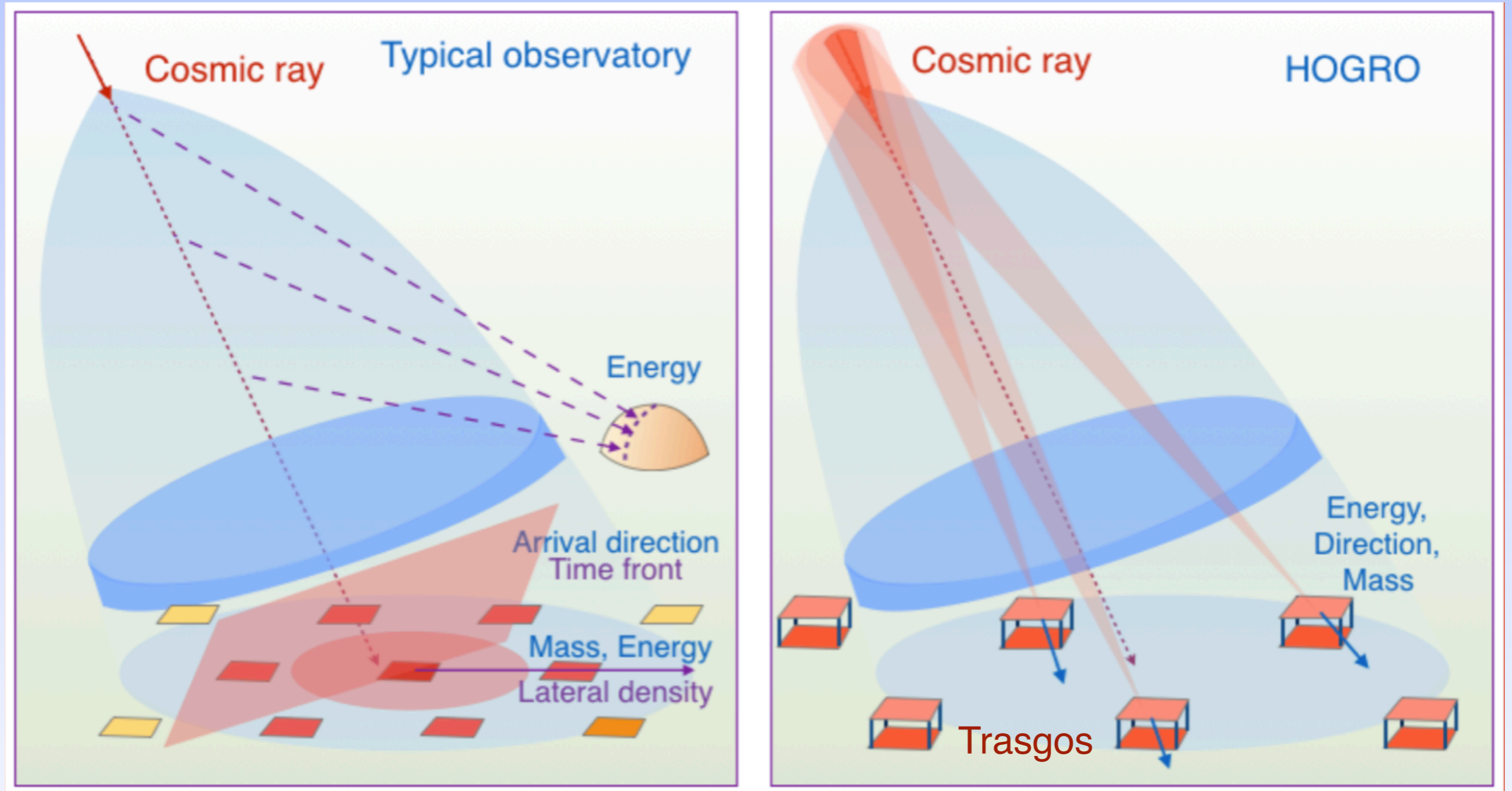
THE TRASGO PROJECT: Other initiatives

4. Main. HOGRO: HOloGRaphic Observatories?

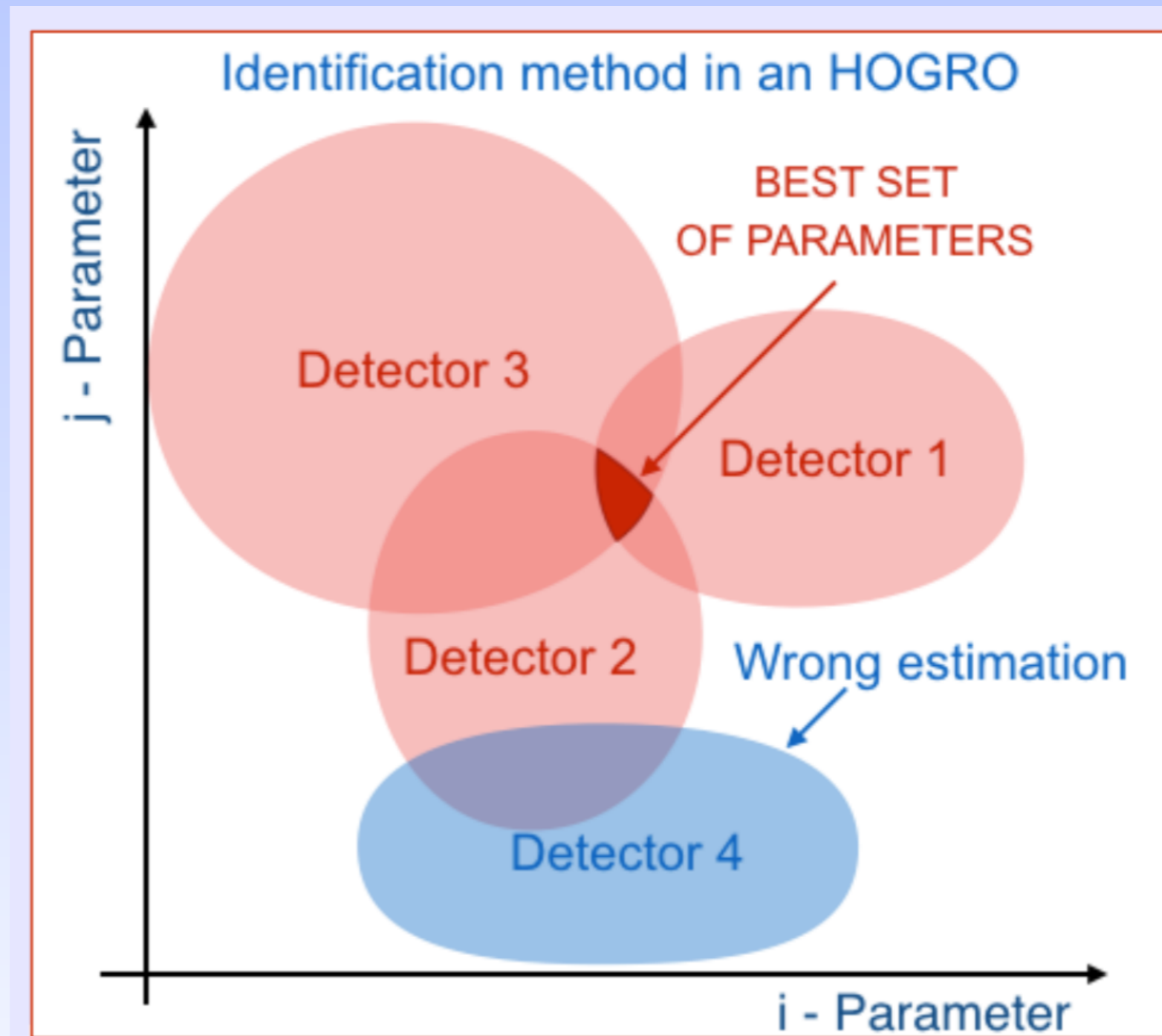


THE TRASGO PROJECT: Other initiatives

4. Final goal. HOGRO: HOloGRaphic Observatories?



4. Final goal. HOGRO: HOloGRaphic Observatories?



- The best set of parameters is obtained from the independent estimations done by all the TRASGO stations

SUMMARY and CONCLUSIONS

- A new family of detectors, **Trasgos**, for the regular study of cosmic rays has been proposed by the LIP-Coimbra & LabCAF-IGFAE teams.
- **3 Trasgos** are now operative and soon other two detectors will be built for atmospheric studies in Galicia.
- **Trasgos** may become a **NEW STANDARD** for the study of cosmic rays all around the world: they are small and affordable and do offer high performances. All the main tools (acquisition, monitoring, reconstruction, analysis, display, etc. are under development) and the main standard levels are being defined.
- The main goal is to offer **Plug&Play detectors + their main operative tools**, that can be easily adapted to many research areas either to substitute or to complement the existing devices.

The TRAGALDABAS Collaboration

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Laboratory / Task

1. Univ. Alcalá de Henares, Spain / **Solar Physics**
2. CEN - Bordeaux, France / **Nuclear and Solar Physics**
3. CITEUC - U. Coimbra, Portugal / **Geomagnetic field and Space Weather**
4. LIP- Coimbra, Portugal / **RPC detectors and instrumentation**
5. Technische Univ. Darmstadt, Germany / **Software development**
6. IGN - Madrid, Spain / **Geomagnetic field**
7. CESGA Super-computation Center - Santiago de Compostela, Spain / **Data storage and distribution**
8. GENP - Univ. Santiago de Compostela, Spain / **Software development and simulation**
9. IGFAE - Univ. Santiago de Compostela, Spain / **Monitoring and Slow control**
10. LabCAF - Univ. Santiago de Compostela, Spain / **Cosmic rays physics, software and tracking**
11. GFNL - Univ. Santiago de Compostela, Spain / **Atmosphere Physics and Climate**

Other partners:

ATI Sistemas. La Coruña, Spain
Club Desarrollo de las Ciencias, Madrid, Spain
HIDRONAV. Vigo, Spain

+ C. Alemparte (Hidronav), A. Iglesias (Hidronav), J. Saraiva (LIP-Coimbra), M. Valladares (Hidronav)
+ a few others :(:(:(

*TRAsGo for the AnaLysis of the nuclear matter Decay, the Atmosphere, the earth B-field And the Solar activity

The end
Thanks!