



THE QUEST FOR THE UNEXPECTED

Cosmic Ray Extremely Distributed Observatory:

Status and Perspectives of a Global Cosmic Ray Detection Framework

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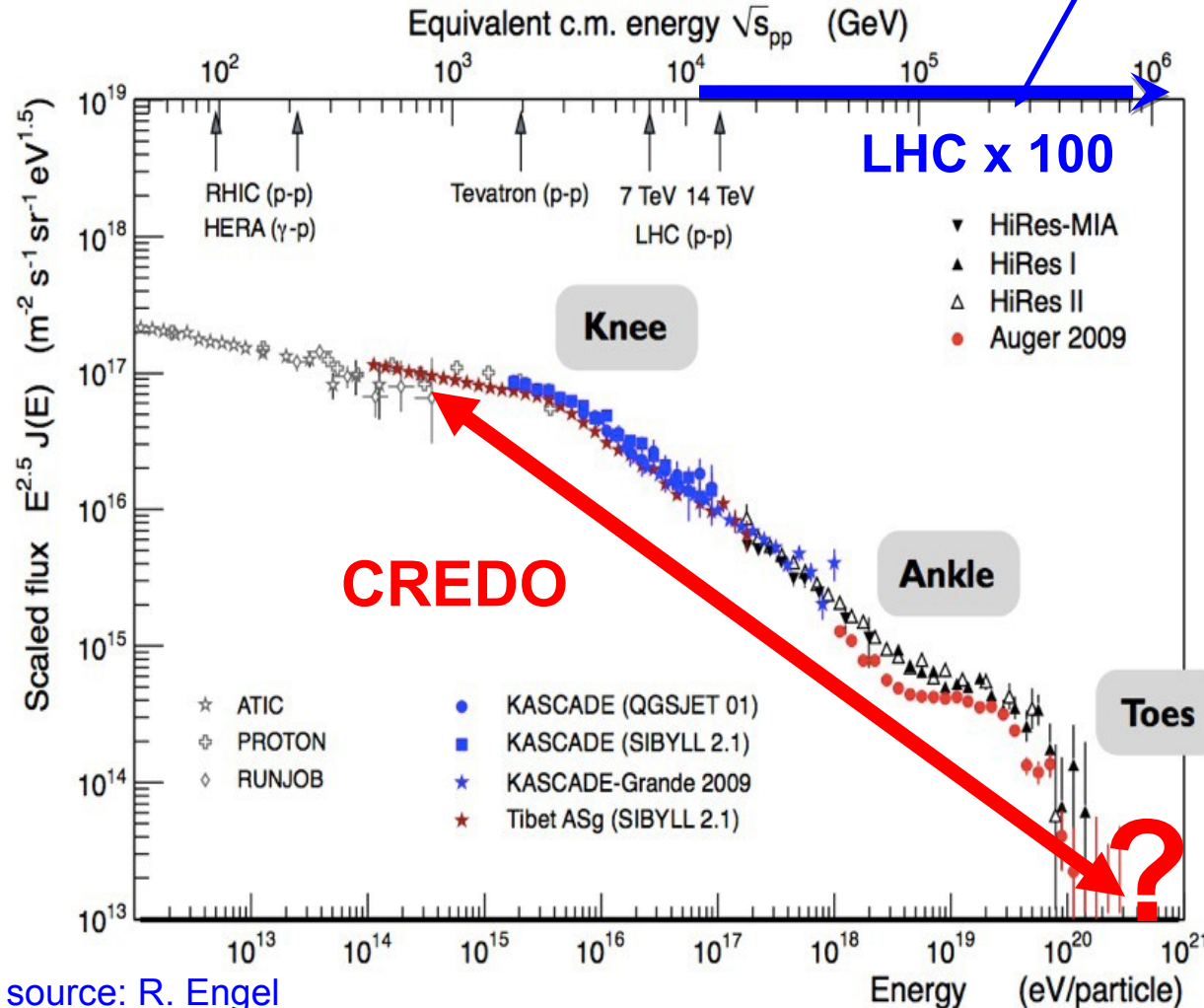
* <http://credo.science>

Outline :

- Introduction: Cosmic rays, preshower effect
- Mobile application and the first results
- Citizen science
- Summary

The Ultra-High-Energy Cosmic Ray mystery

Particle physics beyond
the reach of colliders



source: R. Engel

> What's their composition?

> Where do they come from?

→ *anisotropies weakly correlated to known possible sources: active galactic nuclei, gamma-ray burst, ...*

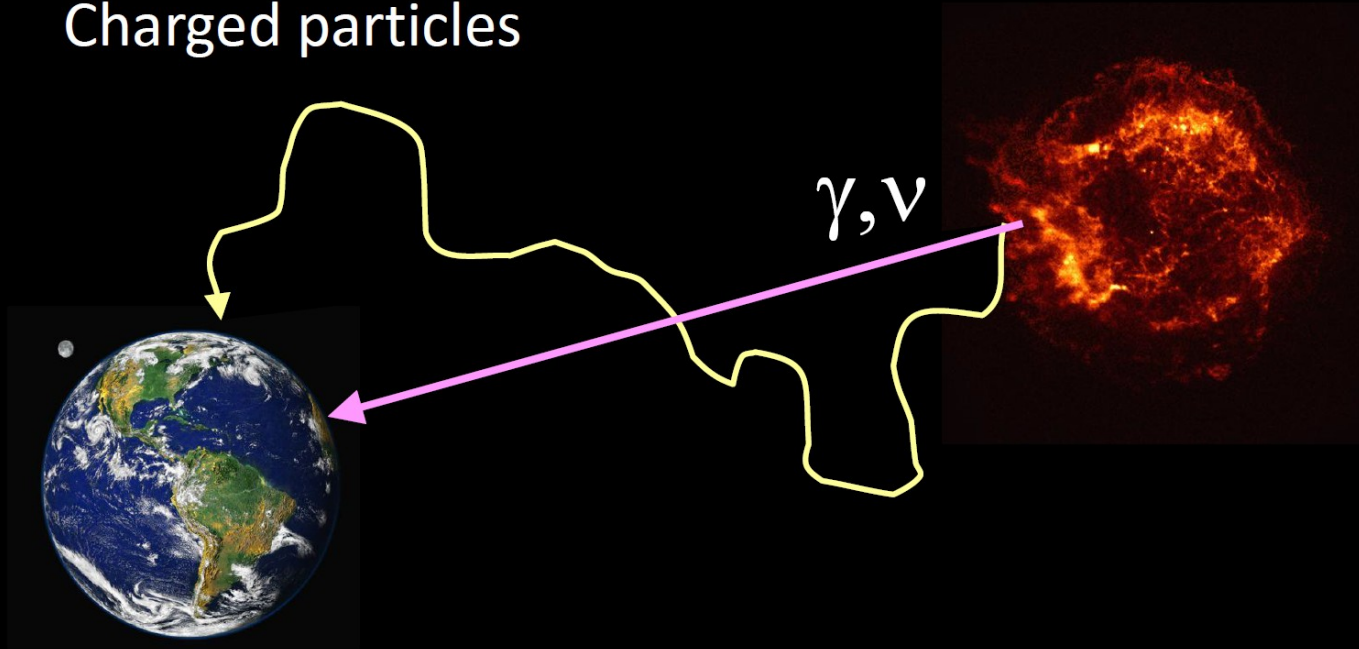
> How do they reach such tremendous energies?

Spectrum suppression:
in the past: *the GZK cut-off*

now: rather the efficiency limit of particle acceleration by sources

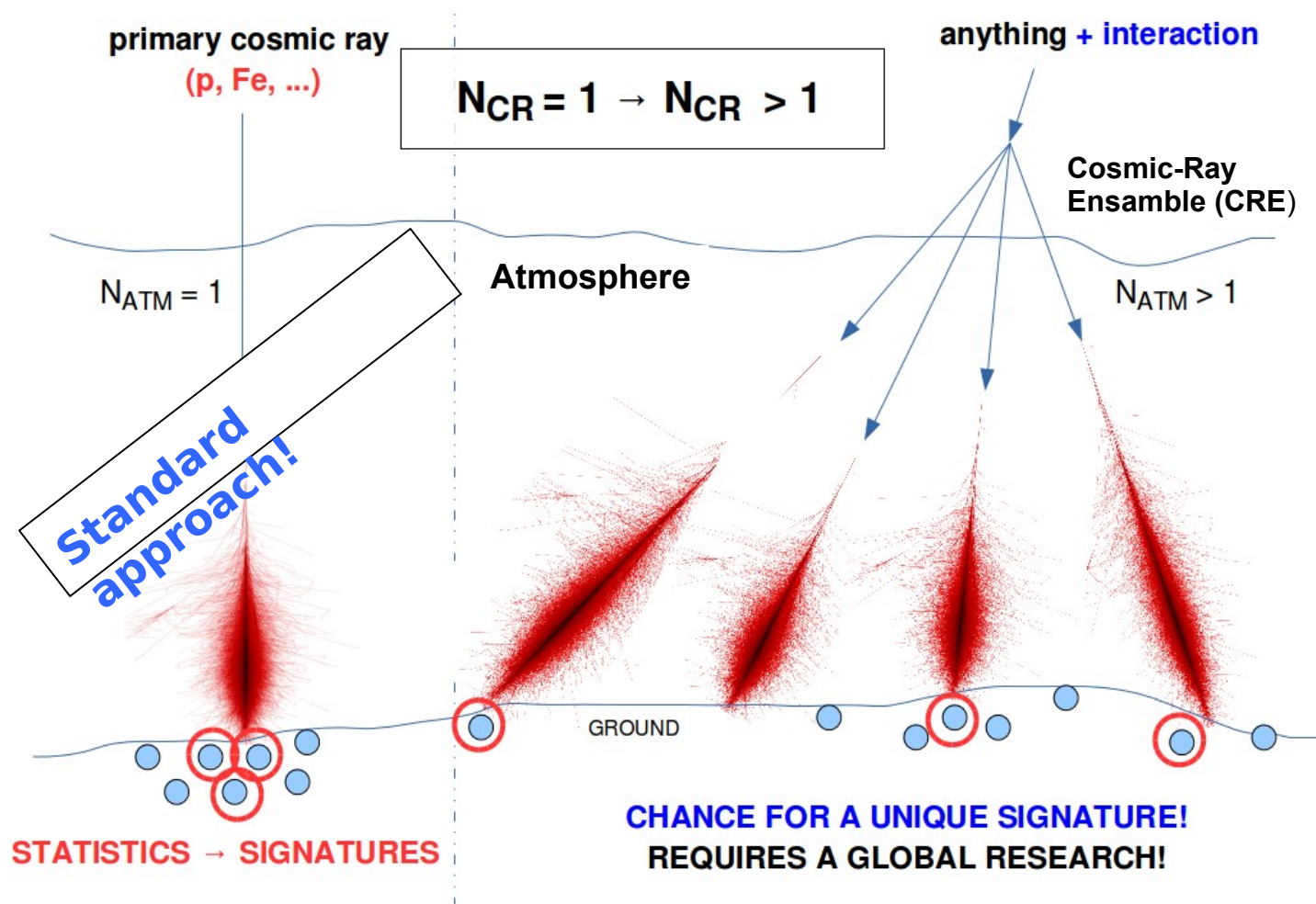
Charged cosmic rays vs. gamma rays

Charged particles



Motivation: looking for Cosmic Ray Ensembles (CRE)

... many air showers and individual particles arriving simultaneously to the Earth ($N_{CR} > 1$)

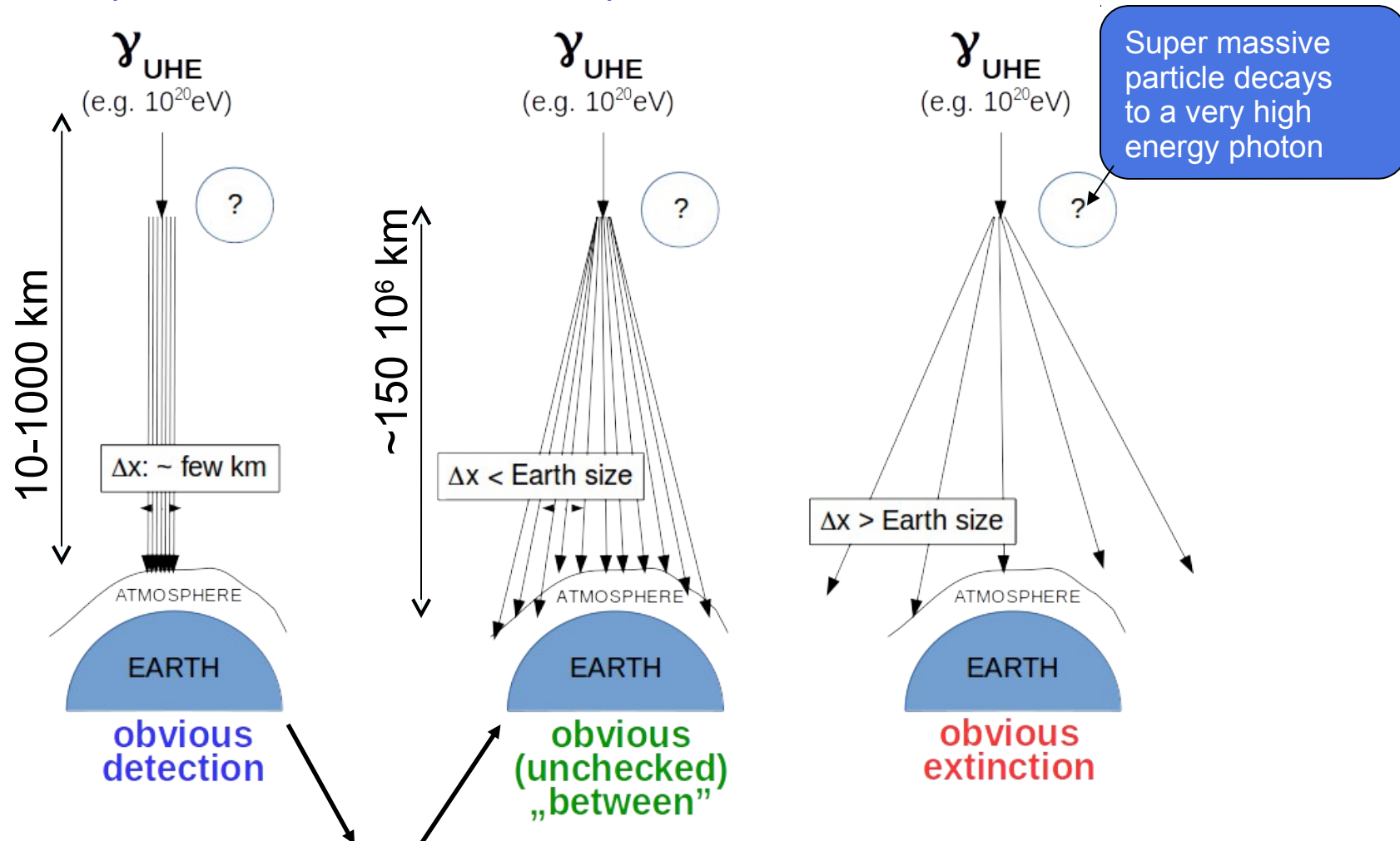


● : a cosmic-ray detector

CREDO strategy: Looking for multiple air showers correlated in time

Classes of CRE

Multiple scenarios: are possible based on the distance between the interaction point and the Earth's atmosphere, and the nature of the interaction.



$N_{\text{cr}} > 1$ scenario have been reported in the literature:

G.R. Smith et al., *Phys. Rev. Lett.* 50 (1983) 2110;177; D.J. Fegan and B. McBreen, *Phys. Rev. Lett.* 51 (1983) 2341

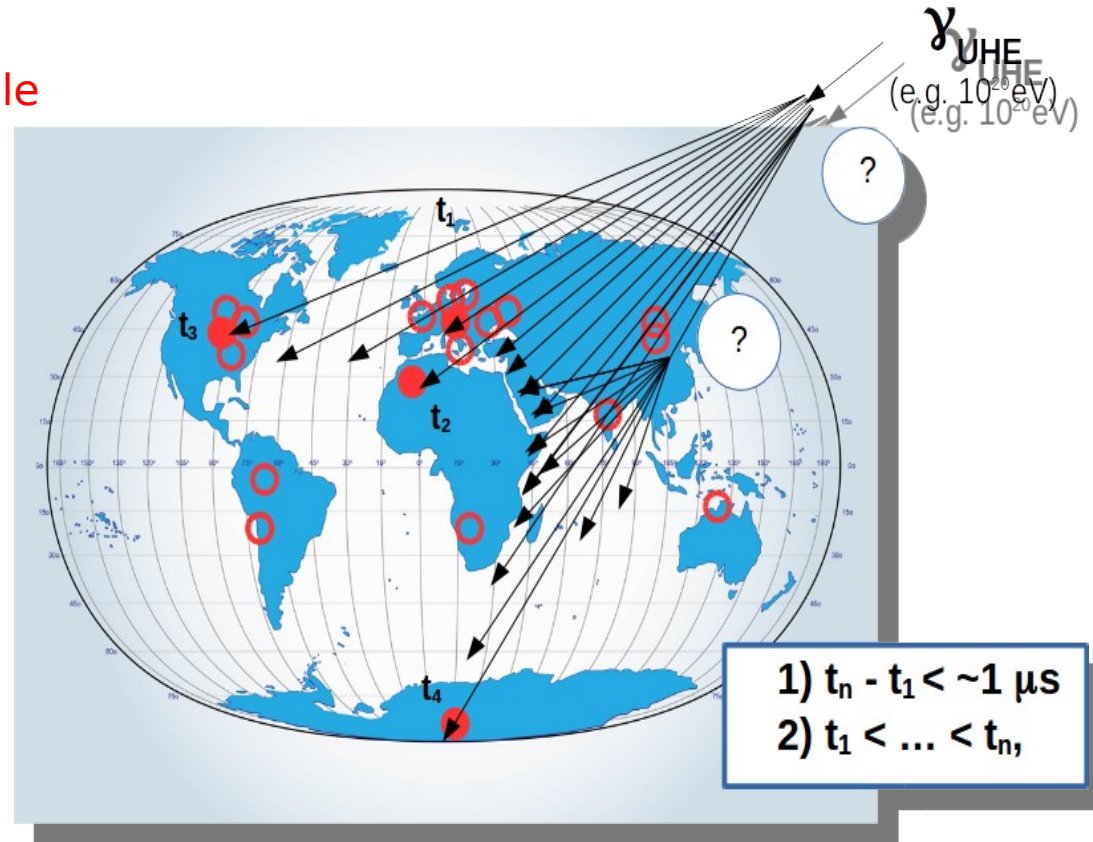
but they have not been observed repeatedly until now.

Cosmic-ray Extremaly Distributed Observatory

CREDO's main idea:

creating a global network of particle detectors!

How?...



Cosmic-ray Extremaly Distributed Observatory

CREDO's main idea:

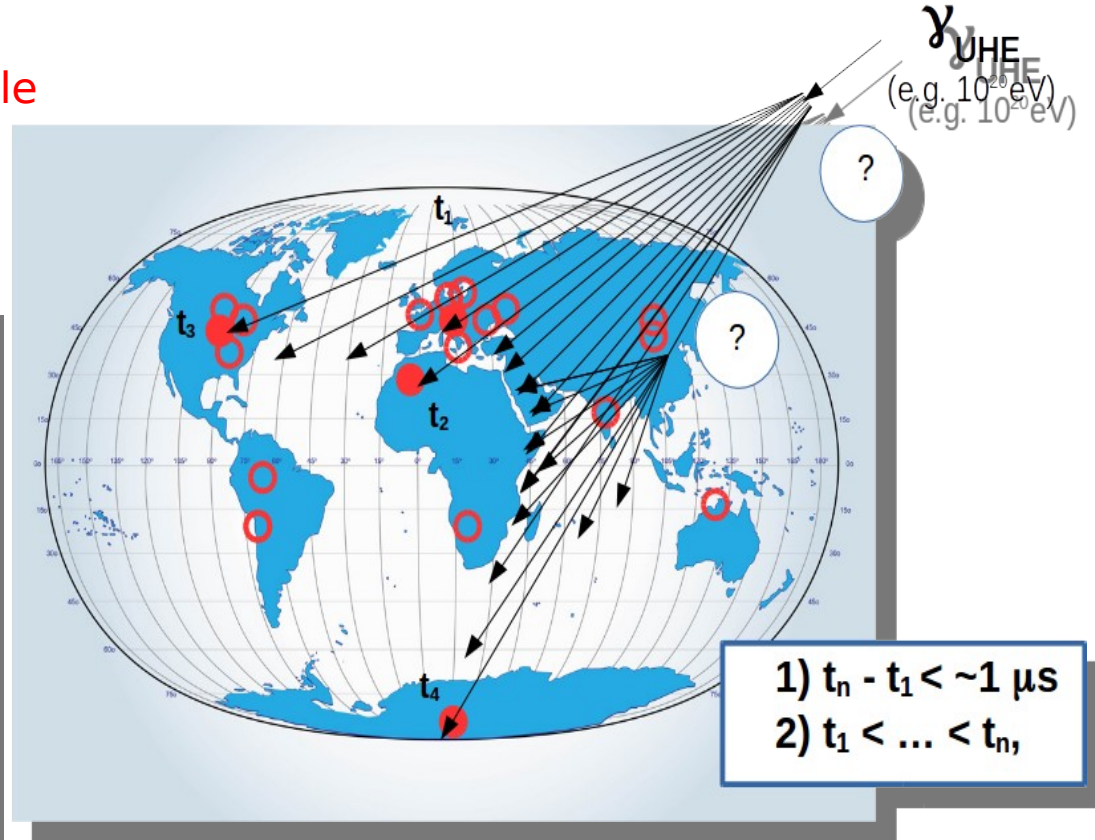
creating a global network of particle detectors!

How?...

**DID YOU KNOW THAT YOU HAVE
AN INTERGALACTIC
PARTICLE DETECTOR
RIGHT IN YOUR
POCKET?**

Install CREDO Detector app for Android
and hunt for the deeply hidden
treasures of the Universe.

Find CREDO Detector on  or scan QR 



Code of application is public on GitHub:

<https://github.com/credo-science>

Different version available:

CREDO-PC-Windows, CREDO-Desktop-Det., Raspberry-Pi,...

Cosmic-ray Extremaly Distributed Observatory

CREDO's main idea:

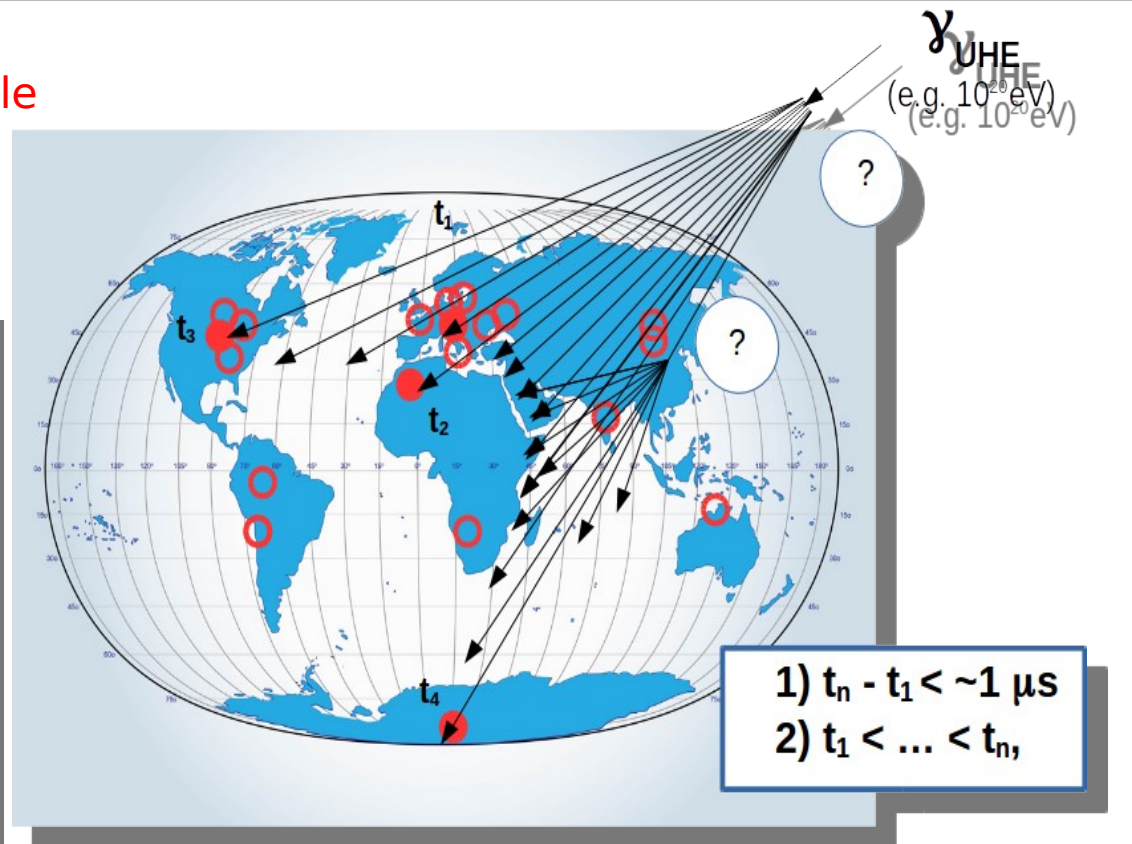
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+ small type of scintillator detectors,

PoS(ICRC2019)428

+ connecting **existing observatories** to the network

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Mobile application

> Smartphone application developed by CREDO collaboration, PoS(ICRC2019)367

Motivation: D. Groom, *Cosmic rays and other nonsense in astronomical CCD imagers*, Experimental Astronomy (2002) 14, 45



Principle:

particles hitting the camera sensors and triggering pixels by depositing energy*

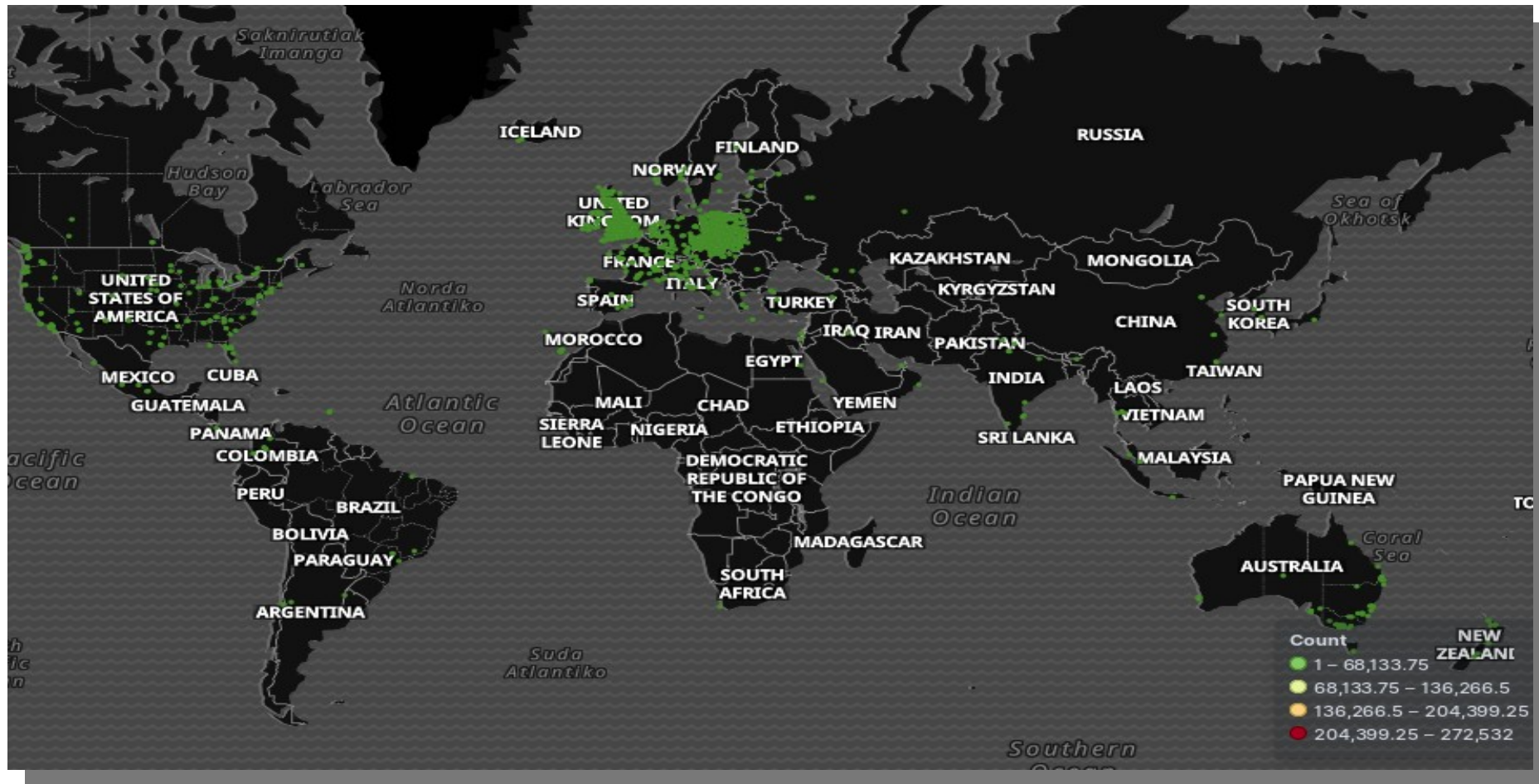
- > Detections are filtered to remove artifacts and stored in a central database (Cyfronet AGH-UST).
- > Analysis are run to search for peculiar signal signatures.
- > Users can access the data they collected and see the results from the analysis run on their data

STIMULATES CITIZEN SCIENCE !

*The **DECO/CRAFIS** project demonstrate discrimination between GeV cosmic-ray muon tracks and MeV electron, see Journal of Instrumentation 2016 11, P04019; M. Winter et al., Particle Identification In Camera Image Sensors Using Computer Vision, Astropart. Phys. (2019), 104, 92. However, large number of smartphones ($\sim 10^6$ M. Unger and G. Farrar, [arXiv:1505.04777] are needed to reach the sensitivity comparable to the largest cosmic-rays observatories.)

Mobile application: we already reach the global scale !

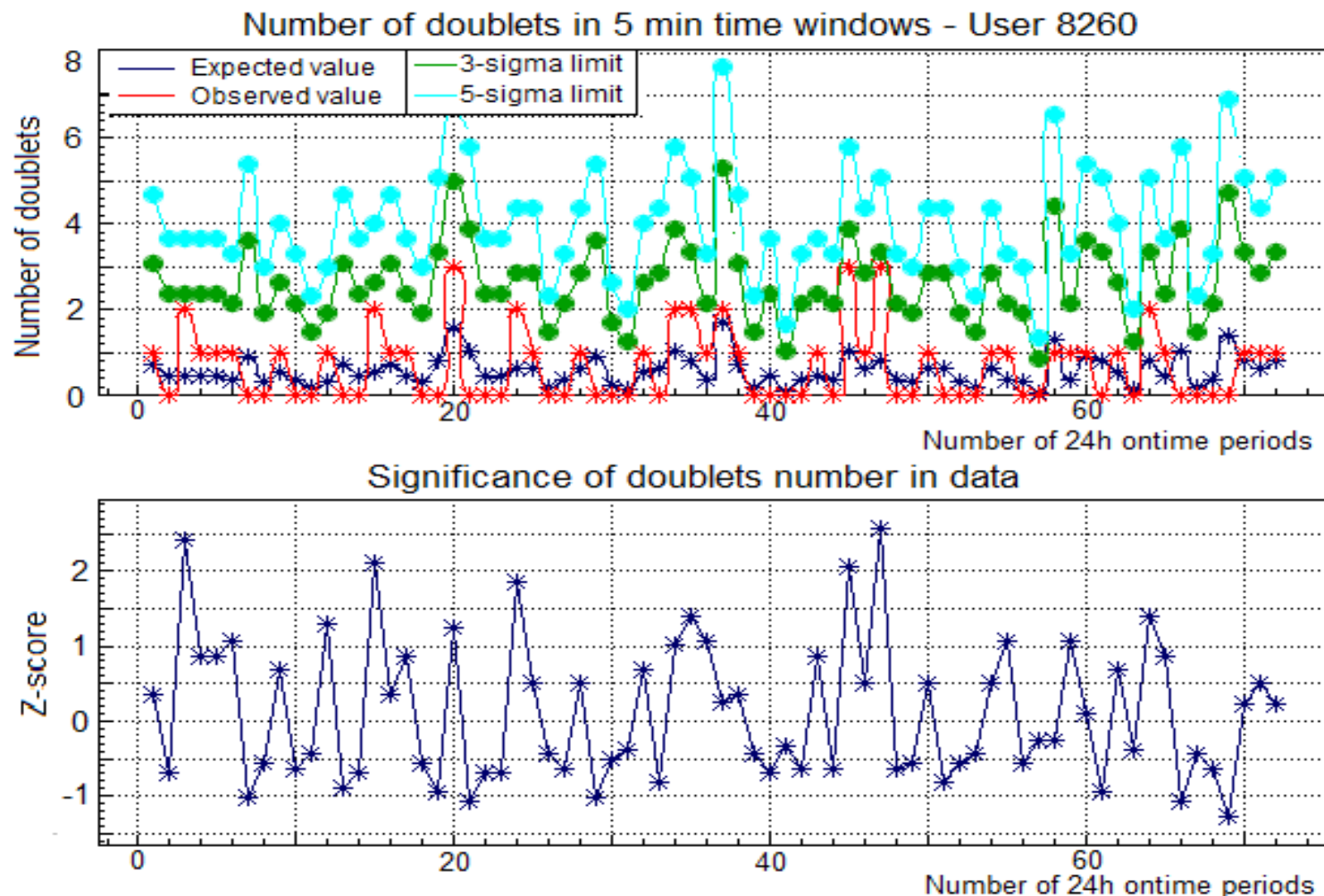
> Location of users since the launch based on data from:
<https://api.credo.science/web/>



Statistics from launch to July 25th 2019: > **7500 users** with at least 1 detections ~**3 200 000 detections** App running time sums up to **947 years**

Example of analysis on data from individual users

> **First achievement (4.10.2018):** the signal from the first automatized, mass participation scientific experiment on the CREDO infrastructure



A significance of given doublet is calculated using scrambled technique, as described in *D.G. et al., Universe, 4(11) (2018) 111.*

Mainframe (AGH Univ., Krakow)



2140 TFLOPS in CPUs + 256 TFLOPS in GPUs
2232 nodes, 53568 CPU cores, 279 TB RAM
10 PB usable disk space @ 180 GB/s

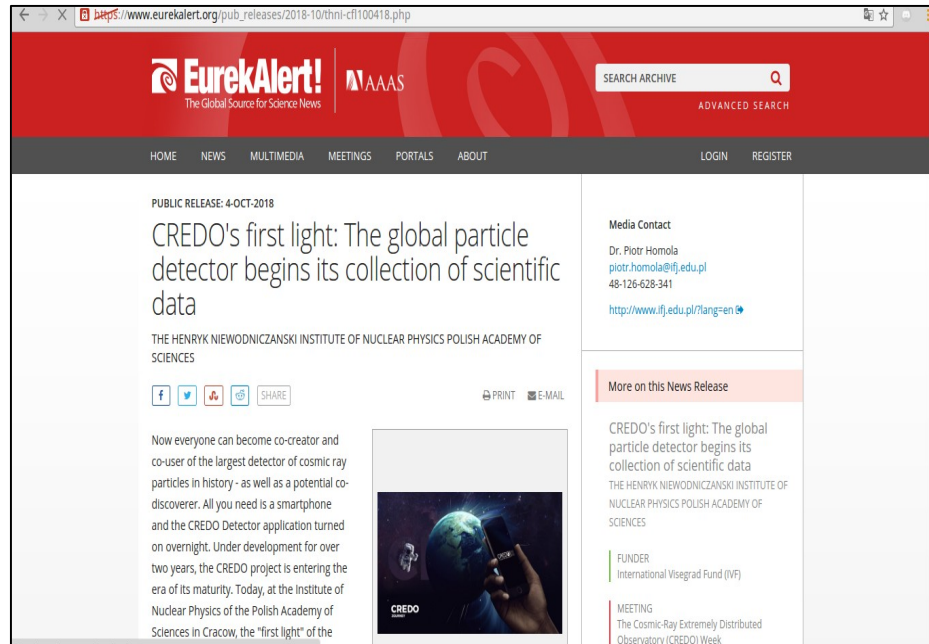


The CREDO heart :)

2.4 PFLOPS, #59 ON TOP500

Spreading the word...

> The second goal of CREDO involves a large number of participants (citizen science!)



Particle Hunters League and Marathon!
Not only for schools!

A Polish poster for the 'ŁOWCY CZĄSTEK' (Particle Hunters) project. The title is in large white letters on a dark background. Below the title is the text 'Weź udział w wyjątkowym projekcie naukowym!'. A section 'Jak dołączyć do konkursu?' lists three steps: 1. zbierz drużynę i zgłoś ją na stronie credo.science/rejestracja-druzyny, 2. zainstalujcie na waszych smartfonach aplikację CREDO Detektor wybierając nazwę waszej drużyny (nazwa drużyny zgłoszona do konkursu musi być taka sama, jak przy rejestracji w aplikacji), 3. łapcie cząstki promieniowania kosmicznego! Below this, it says 'Konkurs organizowany jest przez Instytut Fizyki Jądrowej PAN oraz CREDO Collaboration.' and 'Biorąc udział w konkursie współtworzycie największy na świecie detektor promieniowania kosmicznego. Zajrzyj na stronie credo.science.' The bottom section is titled 'Regulamin' and 'credo.science/lowcyczastek'. It includes a QR code and logos for CREDO, Vitegrad Fund, IFJ, and others.

<https://credo.science/lowcyczastek>

> Conferences: CREDO week,...
<https://indico.ifj.edu.pl/event/213/>

July 2019: ~ 1200 participants
from ~ 60 schools!

Conclusion

CREDO: a unifying, global cosmic-ray project: GeV – ZeV→ completing the closest accessible approach to GUT scale.

23 institutions representing **11 countries** [Australia (2), Czech Republic (2), Georgia (1), Hungary (1), Mexico (1), Nepal (1), Poland (8), Russia (1), Slovakia (1), Ukraine (2), USA (3)] are institutional members.

Many others ongoing projects:

- Ultra-high energy photon propagation simulations with CRPropa.
- Simulations of smartphone detectors' response to air showers.
- Calibration of smartphones for air showers and muons.
- Search for correlations between cosmic-rays and earthquakes on a global scale.
- “*Gamification*” for public outreach and development of low-price detectors



$N_{\text{ATM}} > 1$: data in literature ! (1)

VOLUME 50, NUMBER 26

PHYSICAL REVIEW LETTERS

27 JUNE 1983

Possible Observation of a Burst of Cosmic-Ray Events in the Form of Extensive Air Showers

Gary R. Smith, M. Ogmen, E. Buller, and S. Standil

Physics Department, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

(Received 7 April 1983)

A series or burst of 32 extensive air showers of estimated mean energy 3×10^{15} eV was observed within a 5-min time interval beginning at 9:55 A.M. (CST) on 20 January 1981 in Winnipeg, Canada. This observation was the only one of its kind during an experiment which recorded 1200 extensive showers in a period of 18 months between October 1980 and April 1982.

PACS numbers: 94.40.Pa, 94.40.Rc, 95.30.-k

Cosmic ray group?

$N_{\text{ATM}} > 1$?

Hidden treasure 1

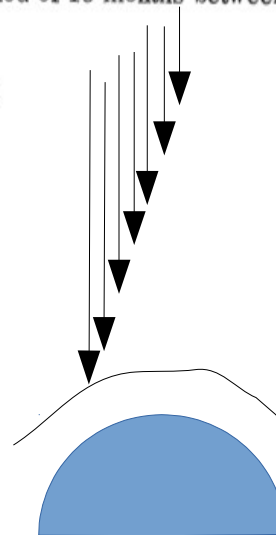
Year = 1981

$N_{\text{obs}} = 32$

$N_{\text{exp}} = 1$

$E = 3 \times 10^{15}$ eV

$\Delta x \geq \text{small}$



$N_{\text{ATM}} > 1$: Data in literature (2)

VOLUME 51, NUMBER 25

PHYSICAL REVIEW LETTERS

19 DECEMBER 1983

Observation of a Burst of Cosmic Rays at Energies above 7×10^{13} eV

D. J. Fegan and B. McBreen

Physics Department, University College Dublin, Dublin 4, Ireland

and

C. O'Sullivan

Physics Department, University College Cork, Cork, Ireland

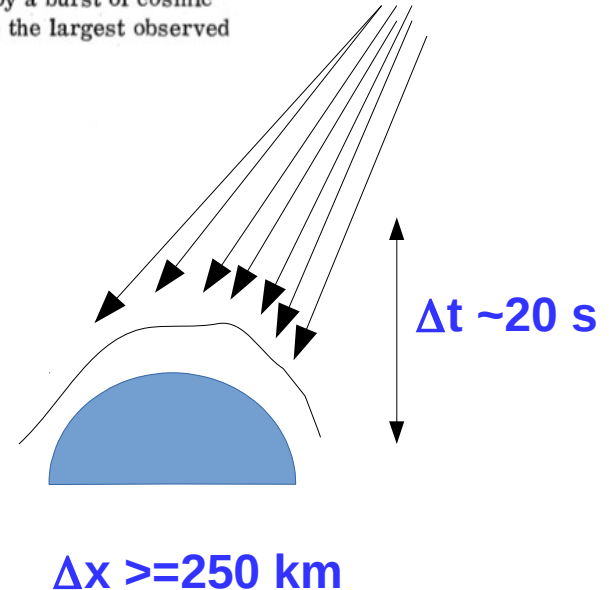
(Received 14 September 1983)

The authors report on an unusual simultaneous increase in the cosmic-ray shower rate at two recording stations separated by 250 km. The event lasted for 20 s. This event was the only one of its kind detected in three years of observation. The duration and structure of this event is different from a recently reported single-station cosmic-ray burst. The simultaneous and coincident event suggests that it was caused by a burst of cosmic gamma rays. There is a possibility that this event may be related to the largest observed glitch of the pulsar in the Crab Nebula.

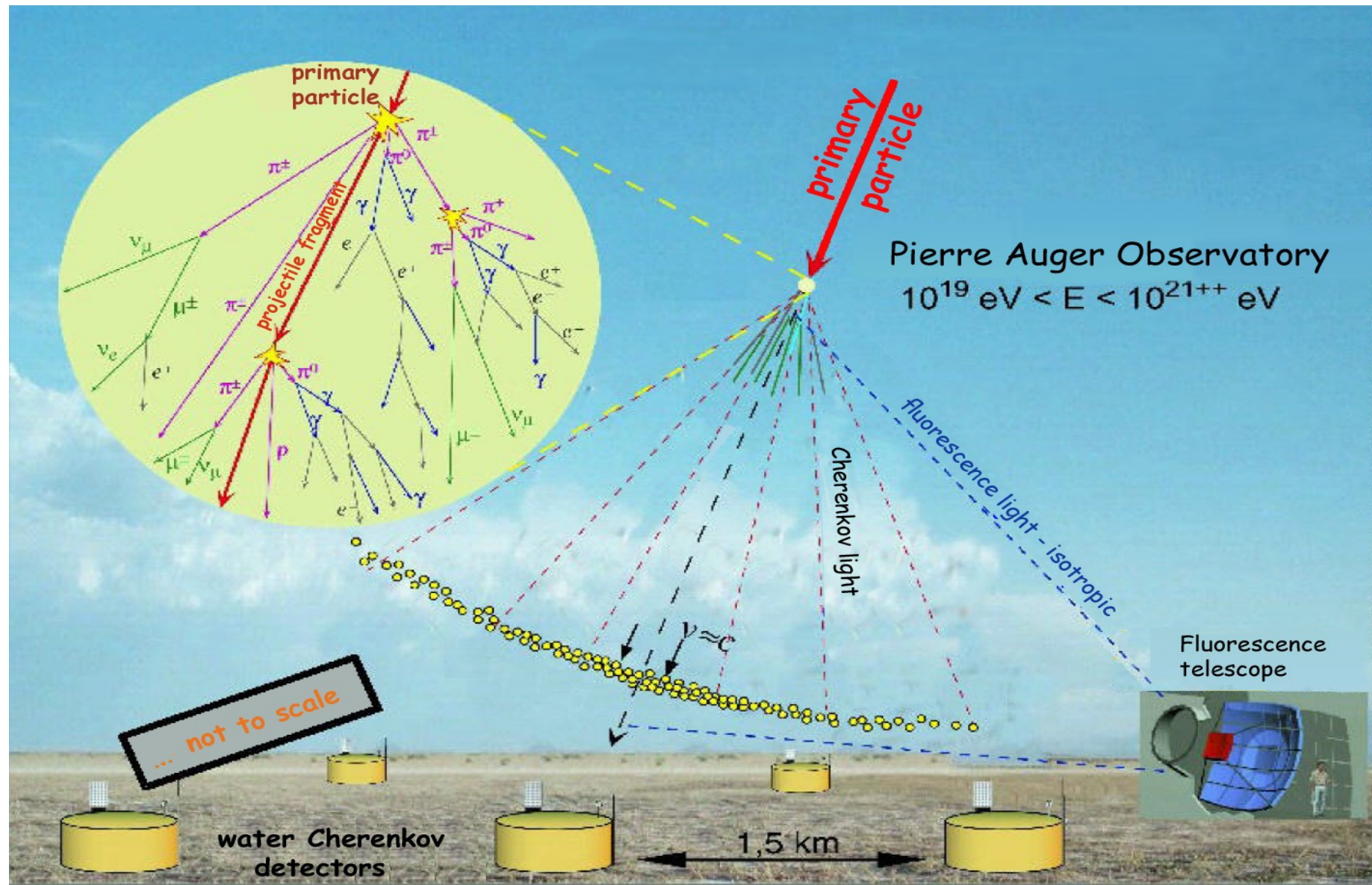
PACS numbers: 94.40.Pa, 95.85.Qx, 97.80.Jp

Cosmic ray group?

$N_{\text{ATM}} > 1$?



Big atmospheric showers: ($N_{\text{ATM}} = 1$)



Example of CRE : Preshower near the Earth

Monte Carlo simulation chain

PoS(ICRC2019)688

(1) Simulation of electromagnetic particle by interaction with geomagnetic field (Preshower effect)

(2) Simulation of shower in air at high zenith angles

(3) Simulation of CTA response

PRESHOWER

II

CORSIKA

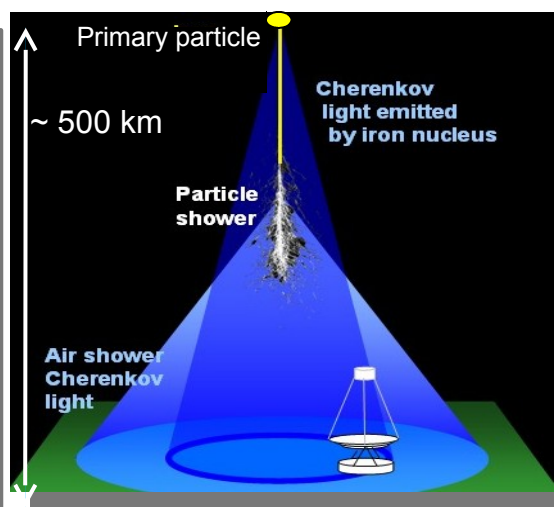
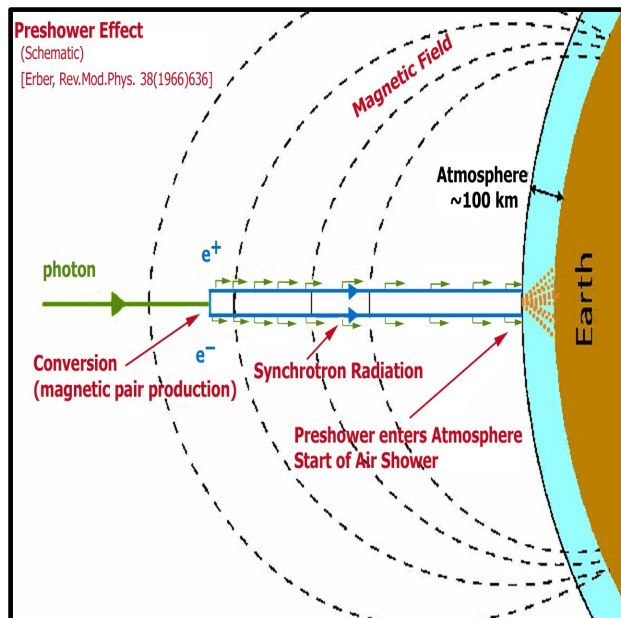
II

Sim_telarray

Homola et al.,
Computer Physics Commun.
184 (2005), 1468

D. Heck, et al.,
FZKA Report, 6019 (1998)

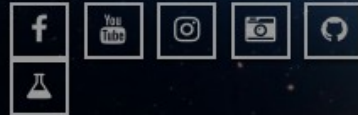
K. Bernlöhr,
Astropart. Phys. 30 (2008), 149



Compiled: with **CURVED-EARTH**,
CHERENKOV/IACT, THIN option

Mirror optics/camera electronics
simulations,
with public **Production-1** settings

For more information visit CREDO.science



"I think CREDO has a unique capability of entering in and exploring a completely uncharted realm of science."

Mikhail V. Medvedev

Cosmic-Ray Extremely Distributed Observatory

The Cosmic Ray Extremely Distributed Observatory (CREDO) collaboration is an ongoing research project involving scientists and the public from around the world. Our objective is to answer one of the most fundamental questions in the Universe – What is dark matter?

[Read More](#)



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CREDO PROJECT

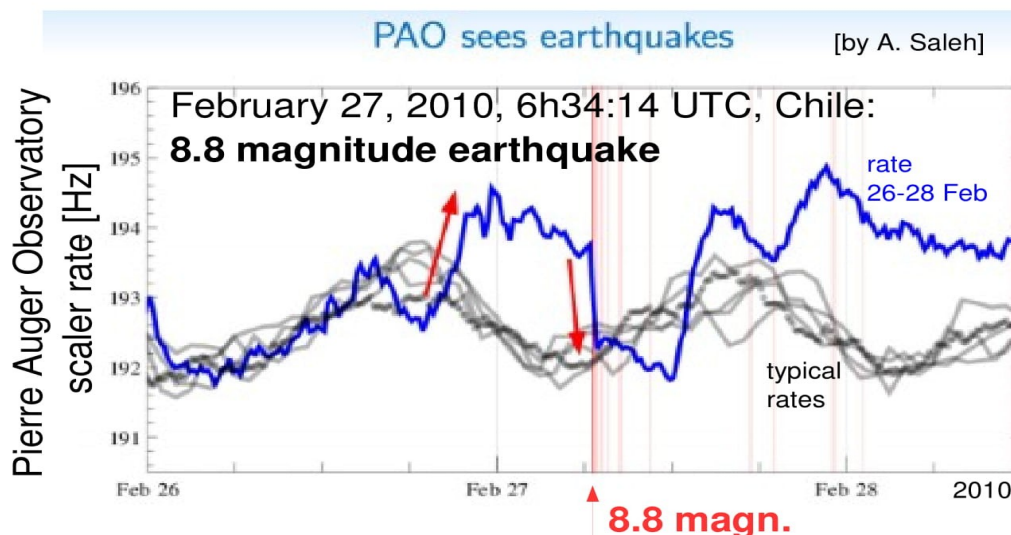
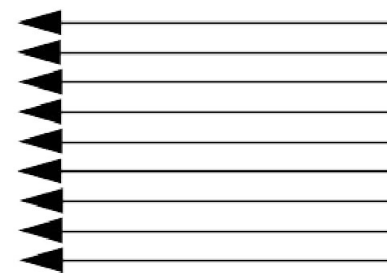
CREDO for Geo, cosmic rays vs earthquakes

CREDO



THE QUEST FOR UNEXPECTED

Scientific diversity: GEO



- Increase of CR before the earthquake
- Strong drop during the earthquake

→ **CREDO-earthquakes task** [already existing]

Inhabitants of territories
threatened by earthquakes
[= potential CREDO
public egagement target]:

2,7 billion people

**Science as a service to
the human community?**

Even the smallest chance to
save lives

= a must check!