Cosmic-Ray Extremely Distributed Observatory: New research perspectives in astroparticle physics

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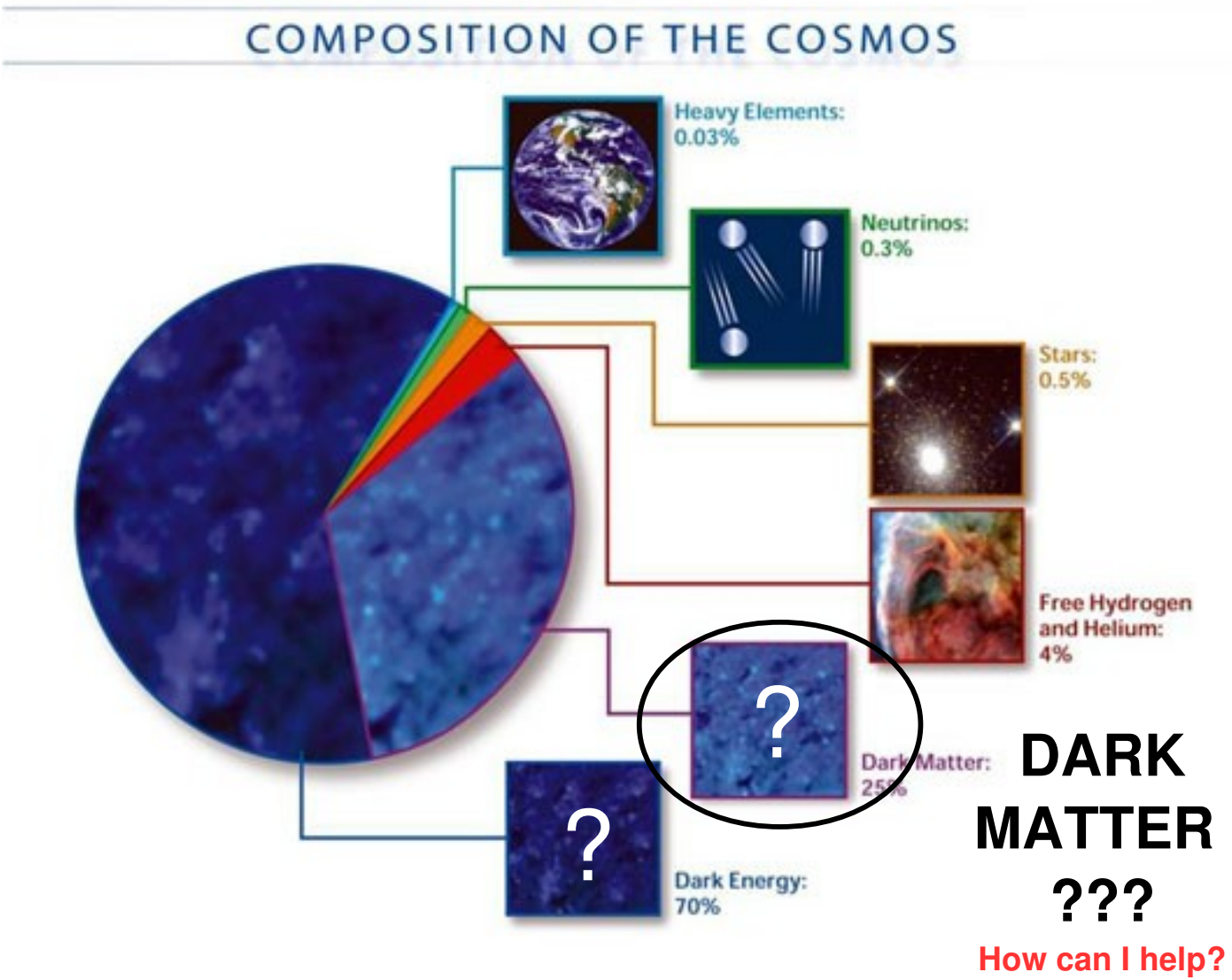
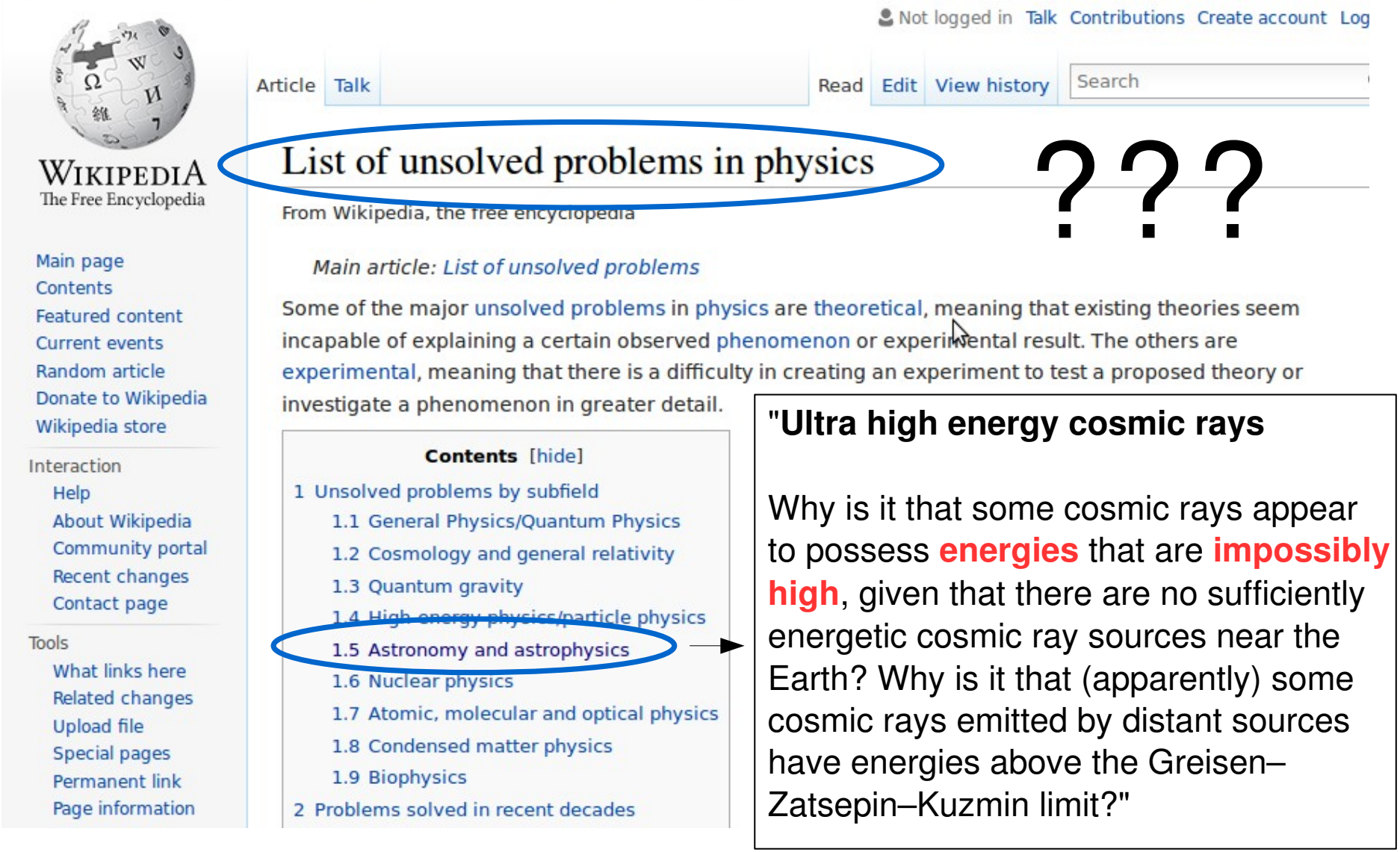
XXIV Cracow EPIPHANY Conference, January 12, 2018

Motivation: Fundamental Science



http://certificate.ulo.ucl.ac.uk/modules/year_one/NASA_cosmology/goals5.html

Motivation: Fundamental Science



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List of unsolved problems in physics

???

From Wikipedia, the free encyclopedia

Main article: List of unsolved problems

Some of the major unsolved problems in physics are theoretical, meaning that existing theories seem incapable of explaining a certain observed phenomenon or experimental result. The others are experimental, meaning that there is a difficulty in creating an experiment to test a proposed theory or investigate a phenomenon in greater detail.

Contents [hide]

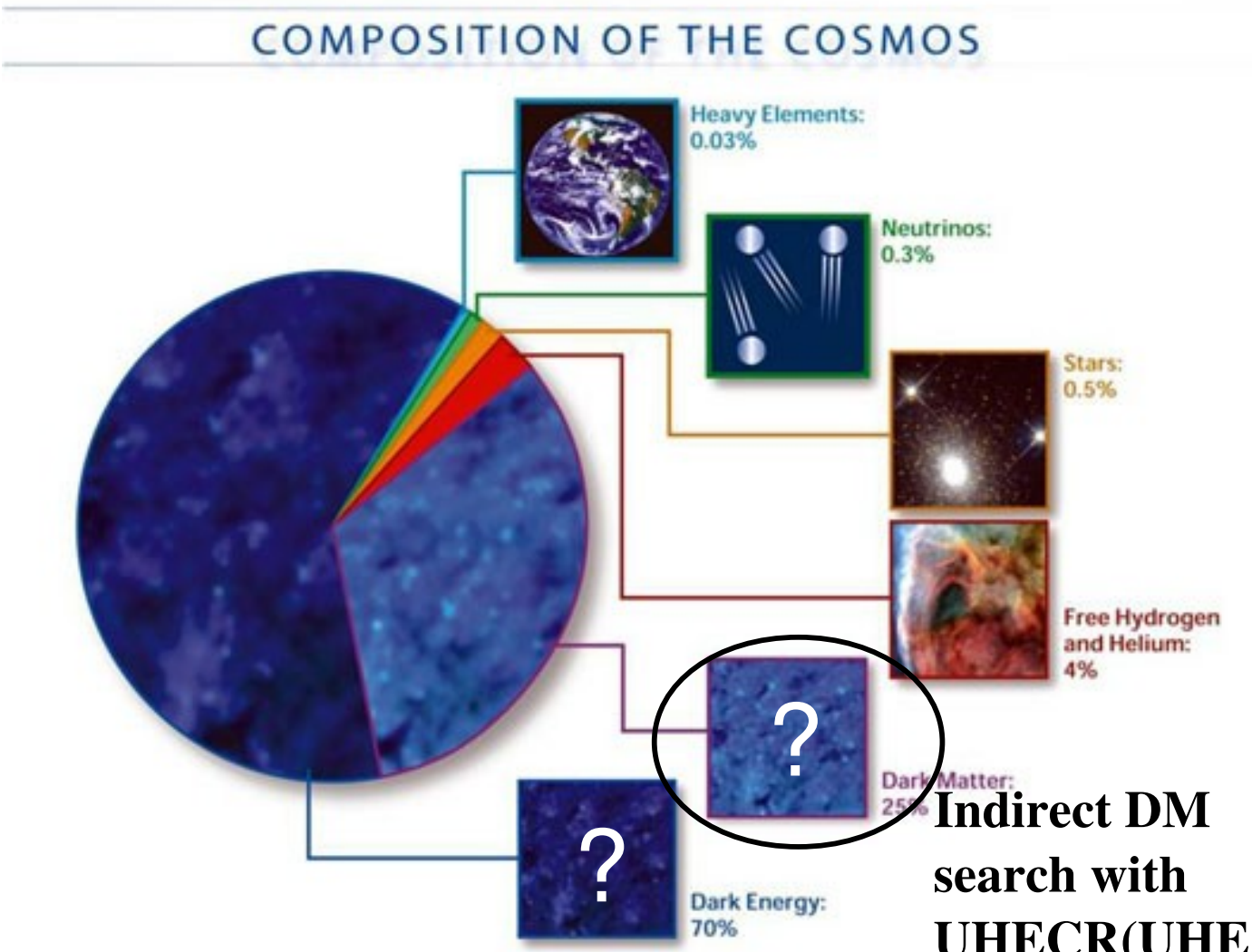
1 Unsolved problems by subfield
- 1.1 General Physics/Quantum Physics
- 1.2 Cosmology and general relativity
- 1.3 Quantum gravity
- 1.4 High-energy physics/particle physics
- 1.5 Astronomy and astrophysics
- 1.6 Nuclear physics
- 1.7 Atomic, molecular and optical physics
- 1.8 Condensed matter physics
- 1.9 Biophysics

2 Problems solved in recent decades

"Ultra high energy cosmic rays

Why is it that some cosmic rays appear to possess **energies** that are **impossibly high**, given that there are no sufficiently energetic cosmic ray sources near the Earth? Why is it that (apparently) some cosmic rays emitted by distant sources have energies above the Greisen–Zatsepin–Kuzmin limit?"

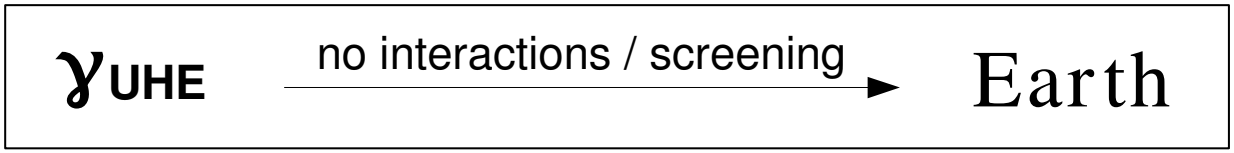
Motivation: Fundamental Science



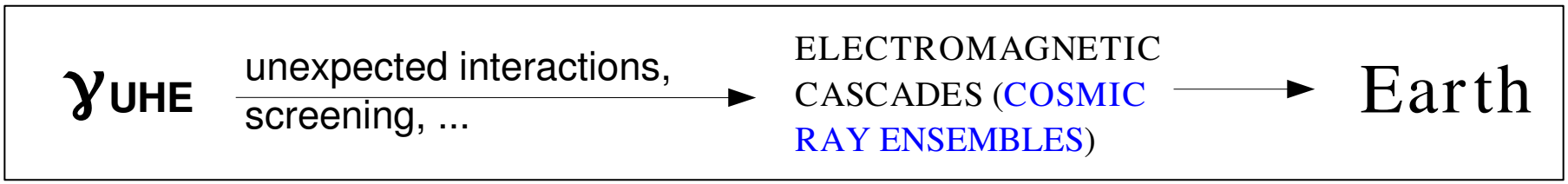
Indirect DM search with UHECR(UHE-γ)

http://certificate.ulo.ucl.ac.uk/modules/year_one/NASA_cosmology/goals5.html

Motivation: Fundamental Science



NOT OBSERVED



NOT TRIED SO FAR...

Cosmic-ray research phase transition:

$$\mathbf{N = 1 \longrightarrow \quad N > 1}$$

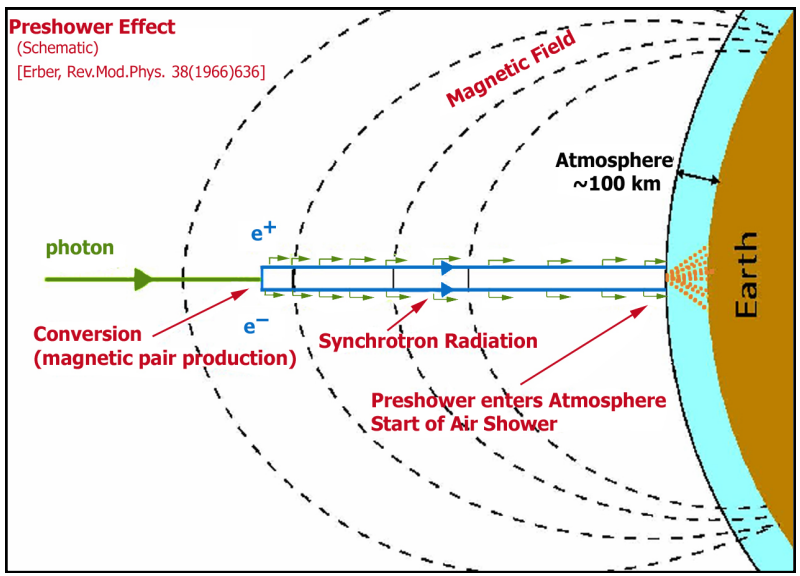
N: No. of CR particles correlated in time

Motivation: Fundamental Science

Example non-exotic scenarios: Preshower and super-preshower

Preshower:

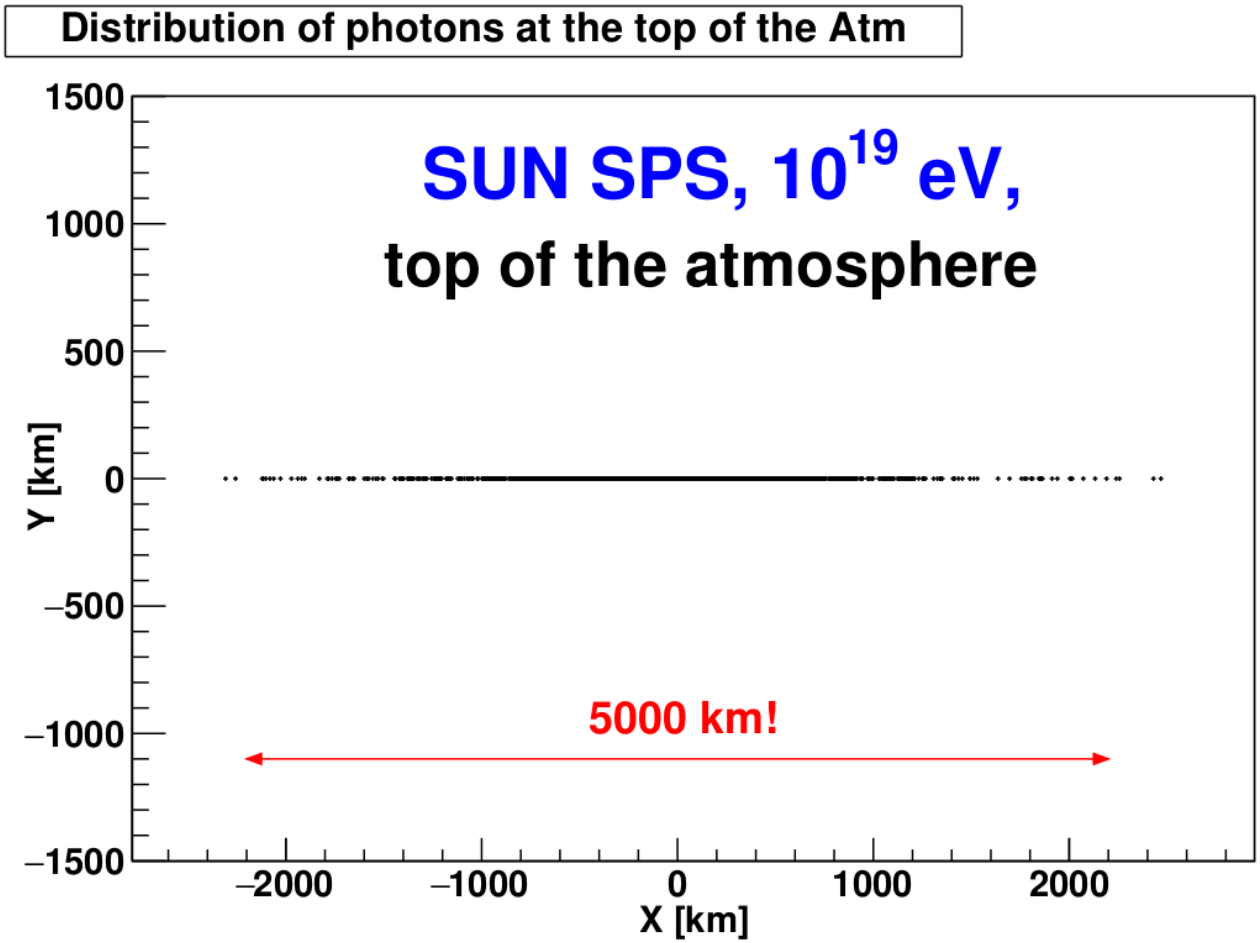
- Cascade of EM particles produced by interaction of UHE-γ with geomagnetic field.
- Typical altitude $\sim$ 1000 km a.s.l. $N \sim 100!$



Super-preshower (SPS):

- Cascade of particles produced due to exotic/non-exotic processes.
- Typical distance of cascade development is **very far**. $N \gg 100!$

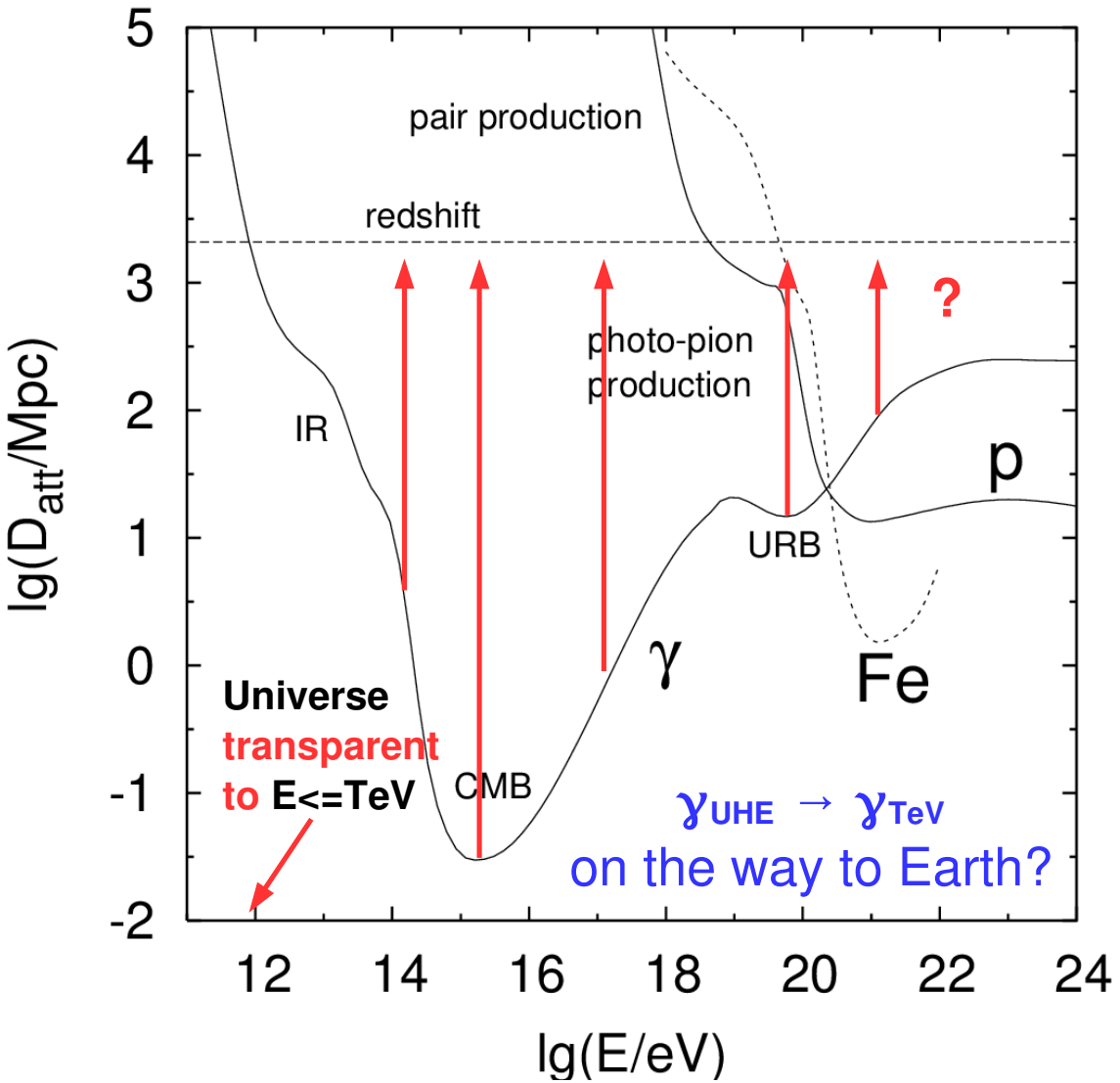
Motivation: Fundamental Science



Distribution of photons ($E > 10^{13}$ eV) at the top of the atmosphere.
$E_\gamma = 10$ EeV, Impact parameter $= 2.5 R_S$.

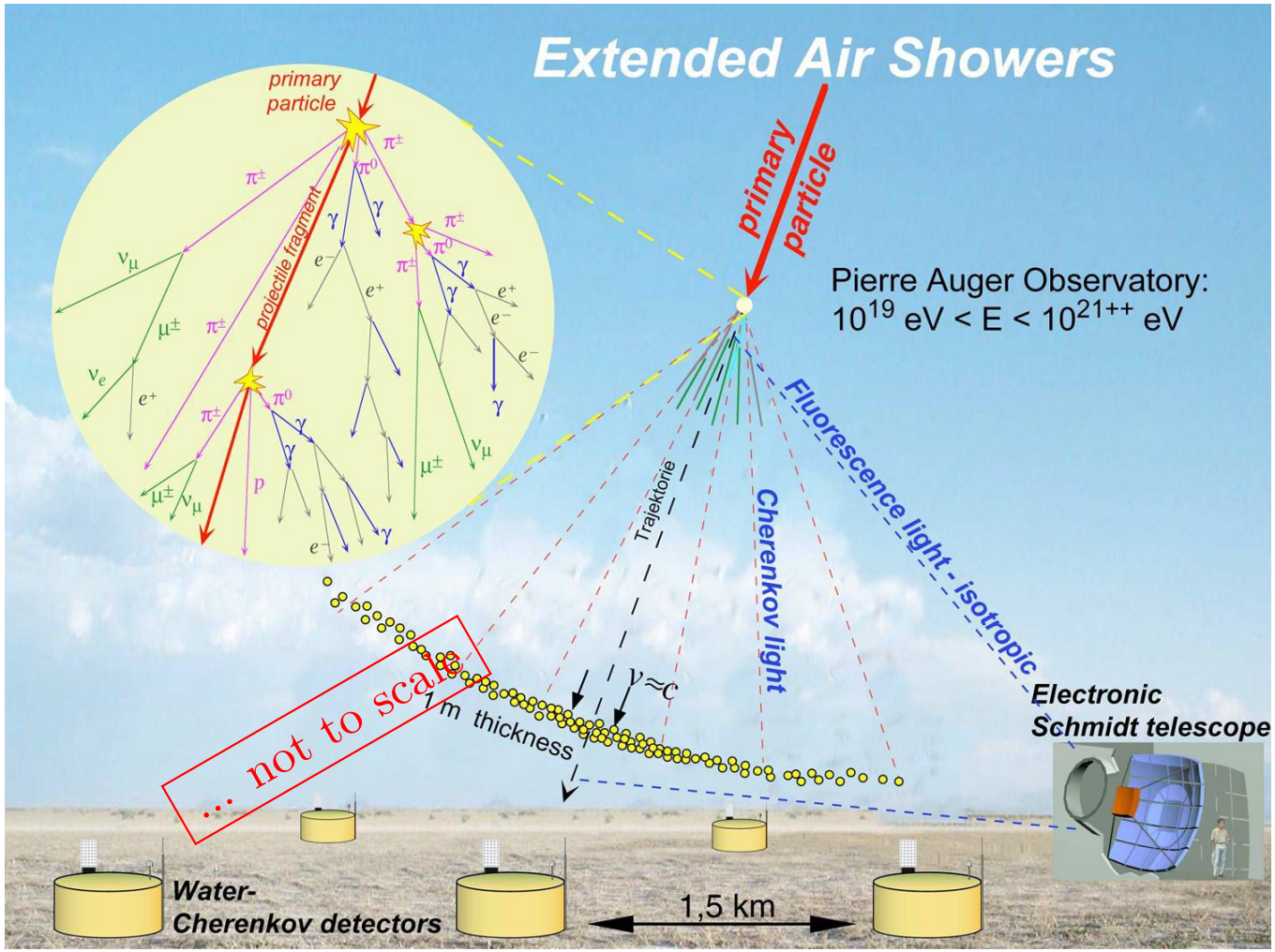
Motivation: Fundamental Science

Example exotic scenario



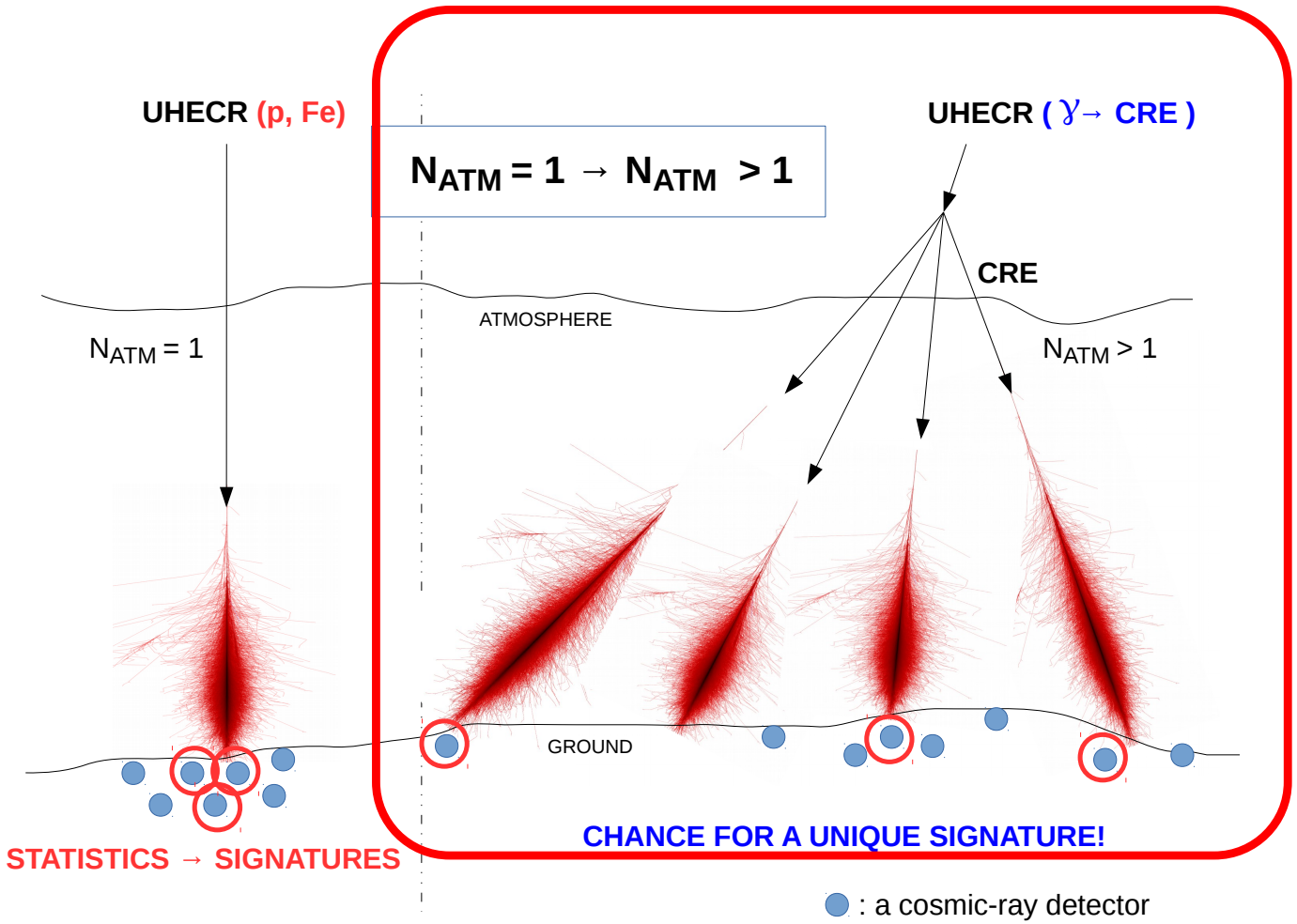
Single CR vs. CR Ensembles

State-of-the-art detection of cosmic rays: $N_{\mathrm{ATM}} = 1$



Single CR vs. CR Ensembles

Generalized detection of cosmic rays: $N_{\mathrm{ATM}} \geq 1$



Single CR vs. CR Ensembles

$N_{\mathrm{ATM}} > 1$ motivated by observation!

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)

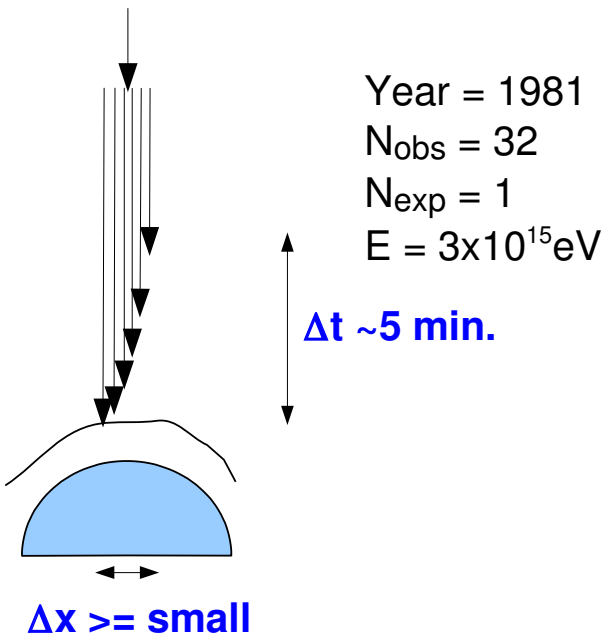
A series or burst of 32 extensive air showers of estimated energy 3×10^{15} eV was observed within a 5-min time interval beginning at 9:55 A.M. (CST) on 20 January 1981 in Winnipeg, Canada. This observation was the only one of its kind during an experiment which recorded 150 000 such showers in a period of 18 months between October 1980 and April 1982.

PACS numbers: 94.40.Pa, 96.40.Rc, 95.30.-k

Forgotten (!) treasure (?) no. 1

Correlated cosmic rays?

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



Single CR vs. CR Ensembles

$N_{ATM} > 1$ motivated by observation!

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)

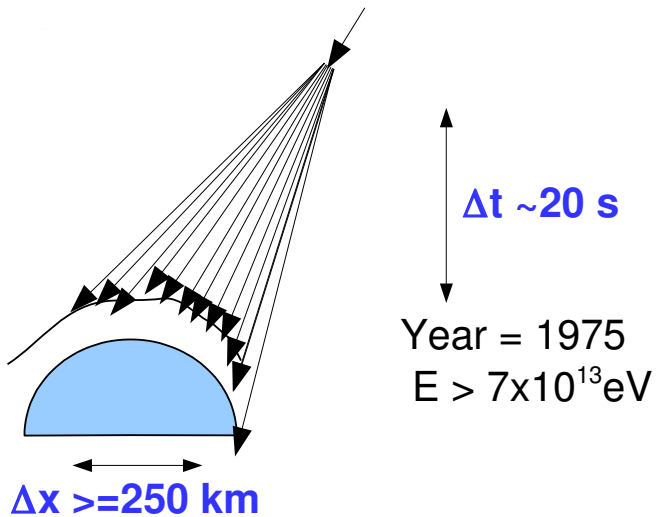
The authors report on an unusual simultaneous increase in the cosmic-ray shower rate at two recording stations separated by 250 km. The event lasted for 20 s. This event was the only one of its kind detected in three years of observation. The duration and structure of this event is different from a recently reported single-station cosmic-ray burst. The simultaneity of the 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

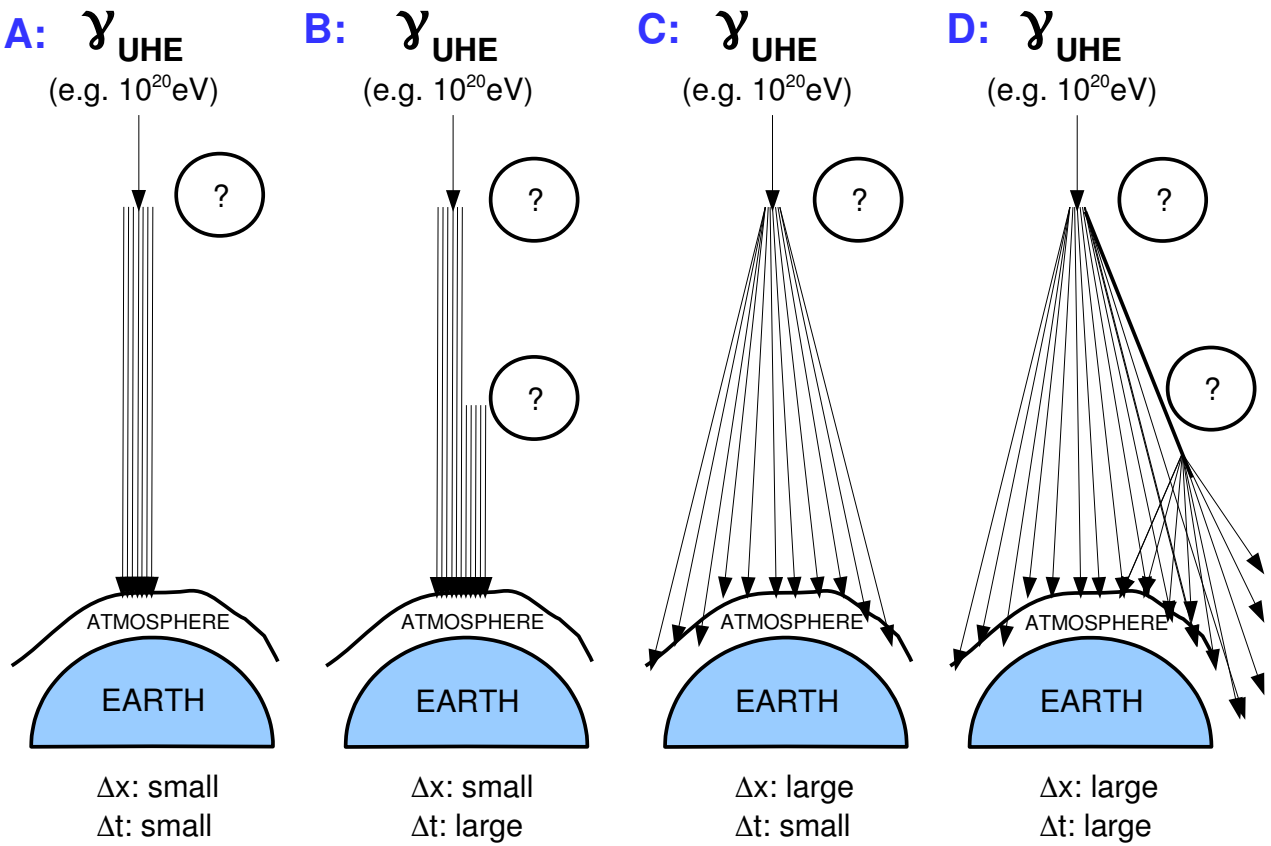
Forgotten (!) treasure (?) no. 2

Correlated cosmic rays?

$N_{ATM} > 1$?



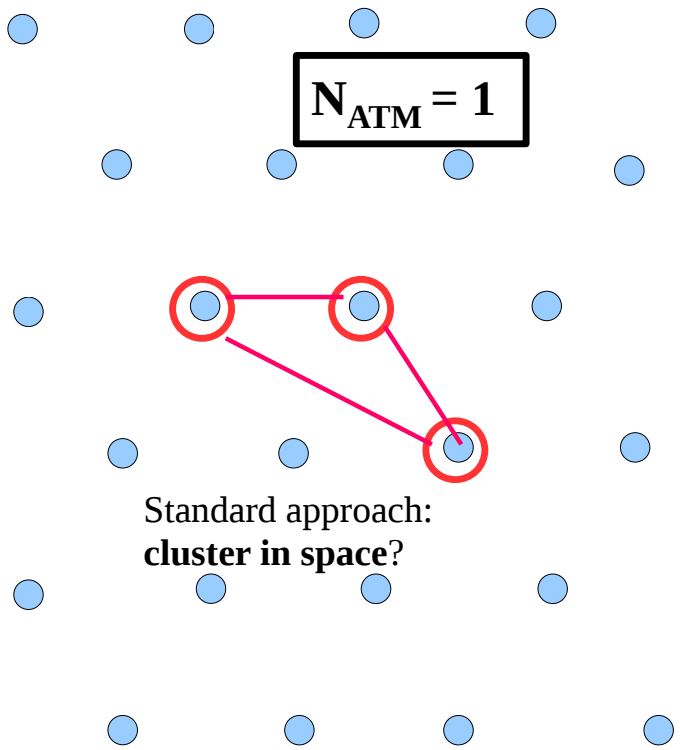
Single CR vs. CR Ensembles



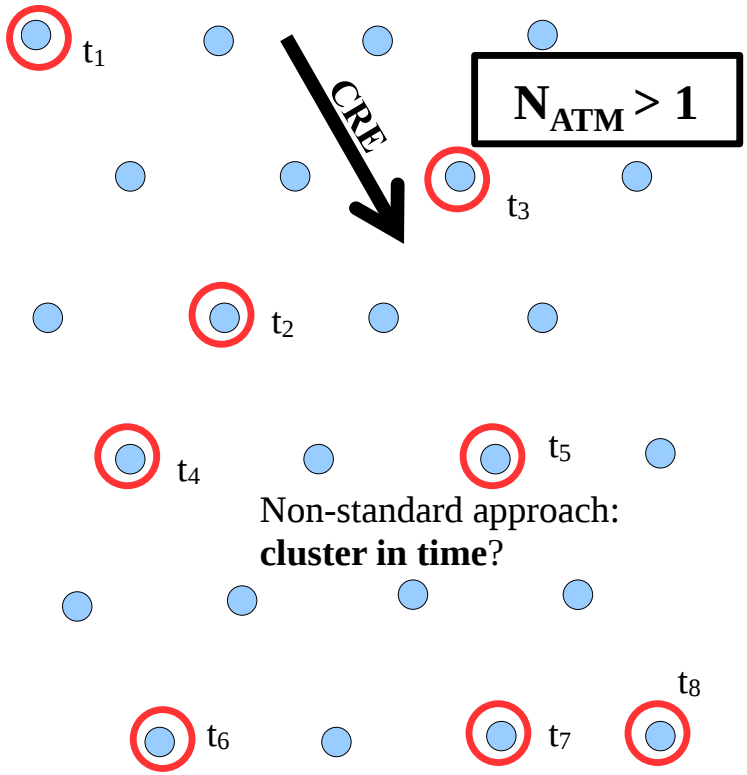
Various types of ensembles of cosmic rays arriving at the Earth.
Question marks represent unknown or uncertain physics processes at UHE.

Single CR vs. CR Ensembles

A chance for unique signature!



Standard approach:
cluster in space?



Non-standard approach:
cluster in time?

1) $t_n - t_1 <$ ~1 μs
2) $t_1 < \ldots < t_n$,

: a cosmic-ray detector

CREDO: What is it?

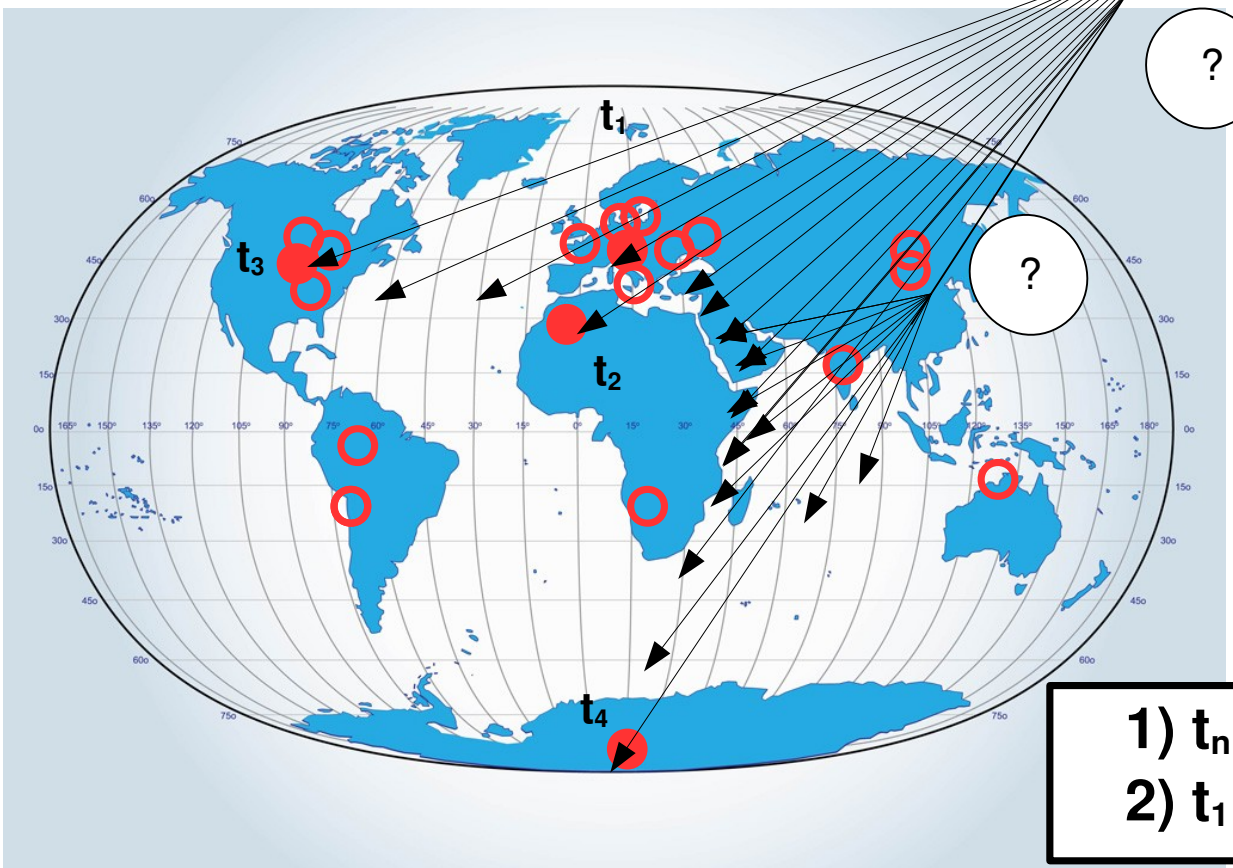
Cosmic Ray Extremely
Distributed Observatory

Central database/interface: access to everything for everybody

In short, **CREDO is a global scale cosmic-ray observatory which is accessible to all**
and comprises of **every type of cosmic-ray detectors possible**!
More details at: `http://credo.science`

CREDO: What is it?

Citizens strenghten trigger capabilities of the educational arrays with **smartphone networks**



Citizens browse the data looking for „improbable" **time space coincidences**

1) $t_n - t_1 < \sim 1\ \mu s$
2) $t_1 < \ldots < t_n$,

→ **indirect search for New Physics manifestations!**
→ **verification of „classic" QED predictions (preshower @ Sun)**

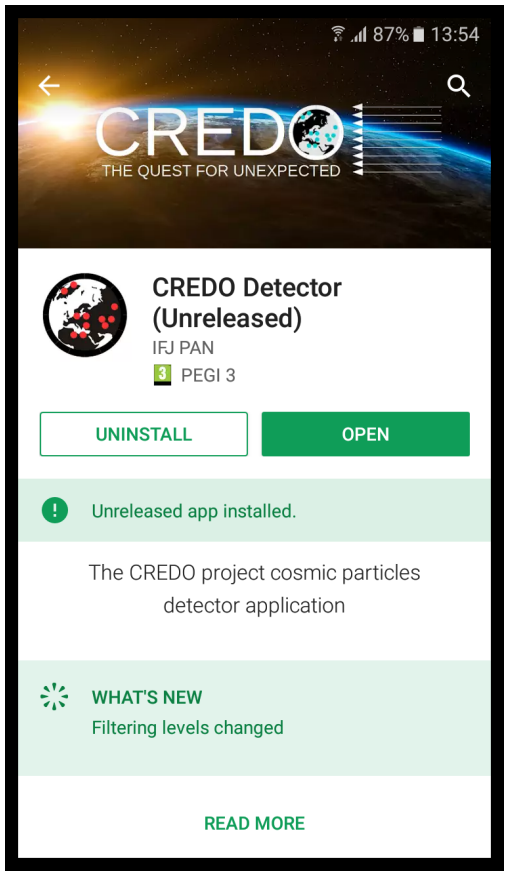
CREDO: Why?

- **Fundamental science:**
  - Nature of dark matter.
  - Better understanding of UHECRs.
  - Search for new physics.
- **Interdisciplinary studies:**
  - Geophysics, e.g., possibility of using cosmic rays as earthquake precursors.
  - Possibility of monitoring of spaceweather.
- **Education and outreach:**
  - Easy access to everyone for understanding fundamental science.
  - Invlovement of all interested for collaborative tasks.

CREDO Detector App

Smartphone App for cosmic ray detection developed in the Collaboration!

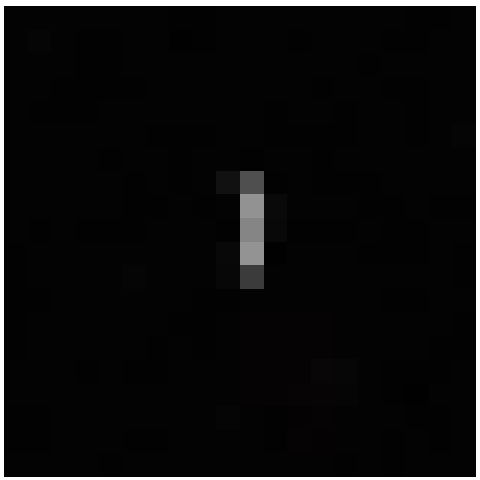
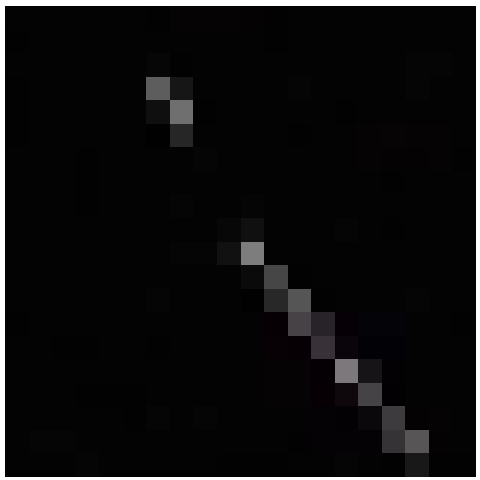
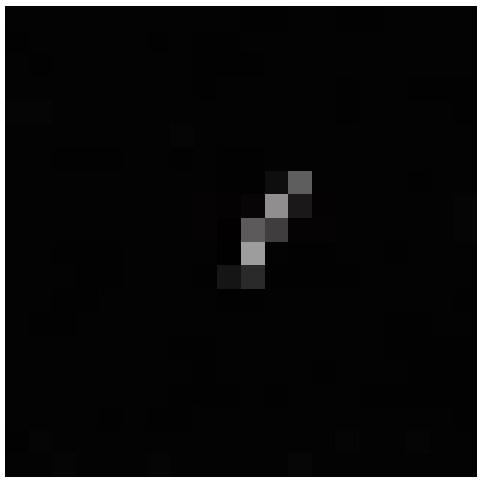
Open source project!



https://play.google.com/store/apps/details?id=science.credo.credomobiledetektor&hl=en

CREDO Detector App

Currently the app is available only for Android platform.
Will be available for iOS soon.

Some examples of cosmic ray hits detected by CMOS sensor of smartphones. In addition to the images of hits, other relevant information (e.g., timestamp, geogrpahic location etc.) are also recorded.

Please visit `https://api.credo.science` for some recent raw, unprocessed images of CR hits!

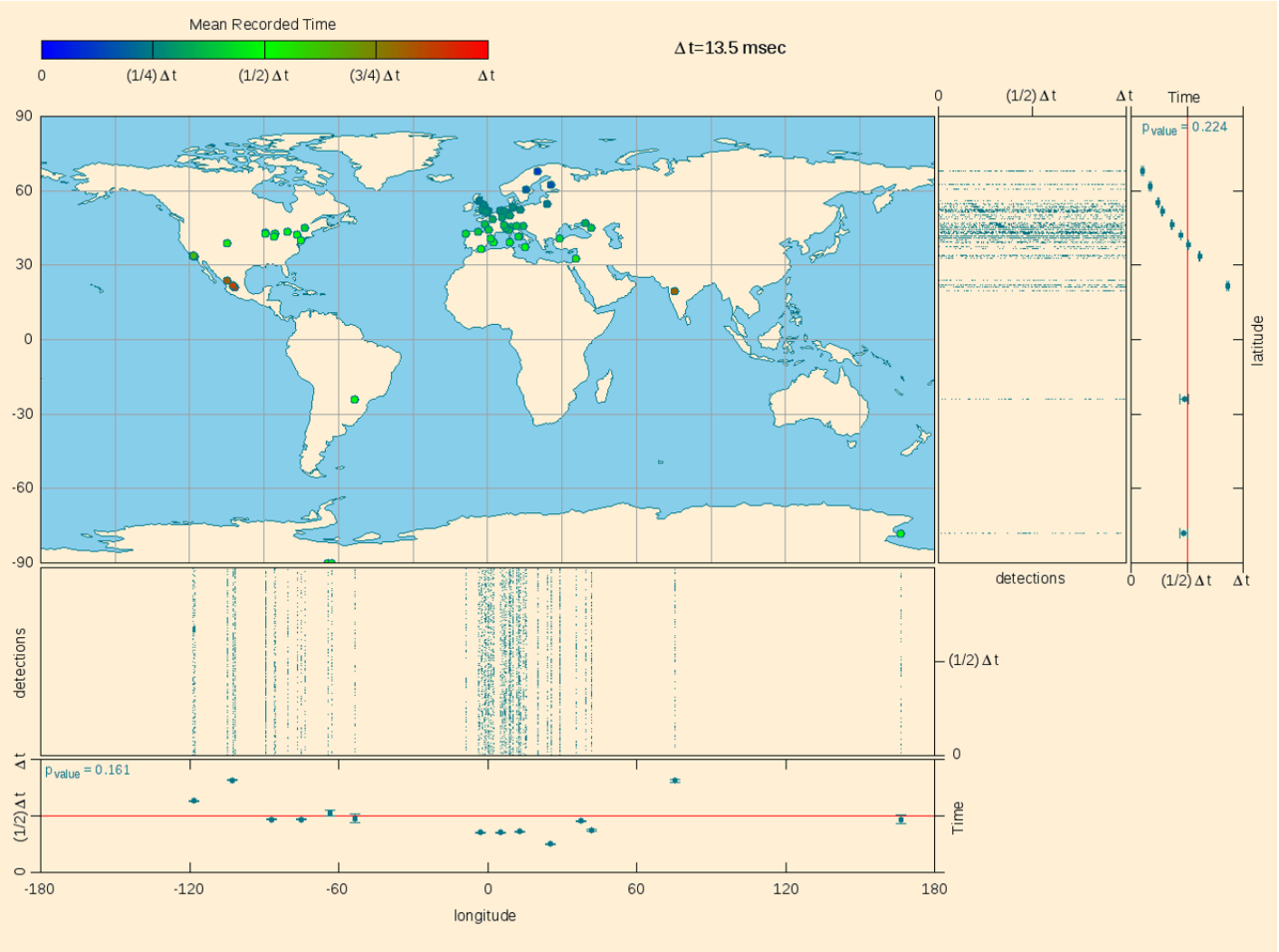
CREDO Monitor

CREDO monitor is a daily automated list of tasks whose ultimate objective is a search of Cosmic Ray Ensembles (CRE).

- **Data Acquisition/Migration:** Acquisition of data and transfer to the central server.
- **Data Conversion:** Conversion of data from different detectors/sources into a common format.
- **Data Preprocessing:** Data sorted in time and merged into the final form (daily sets).
- **Analysis:** A preliminary scanning done to look for possible CRE signatures.
- **Map Production:** Creation of maps for cosmic ray arrival time as a function of geographic locations.
- **Map Sharing:** Sharing the map for analysis/further classification.

The storage, monitoring and computing tasks of CREDO are hosted by ACC Cyfronet AGH-UST.

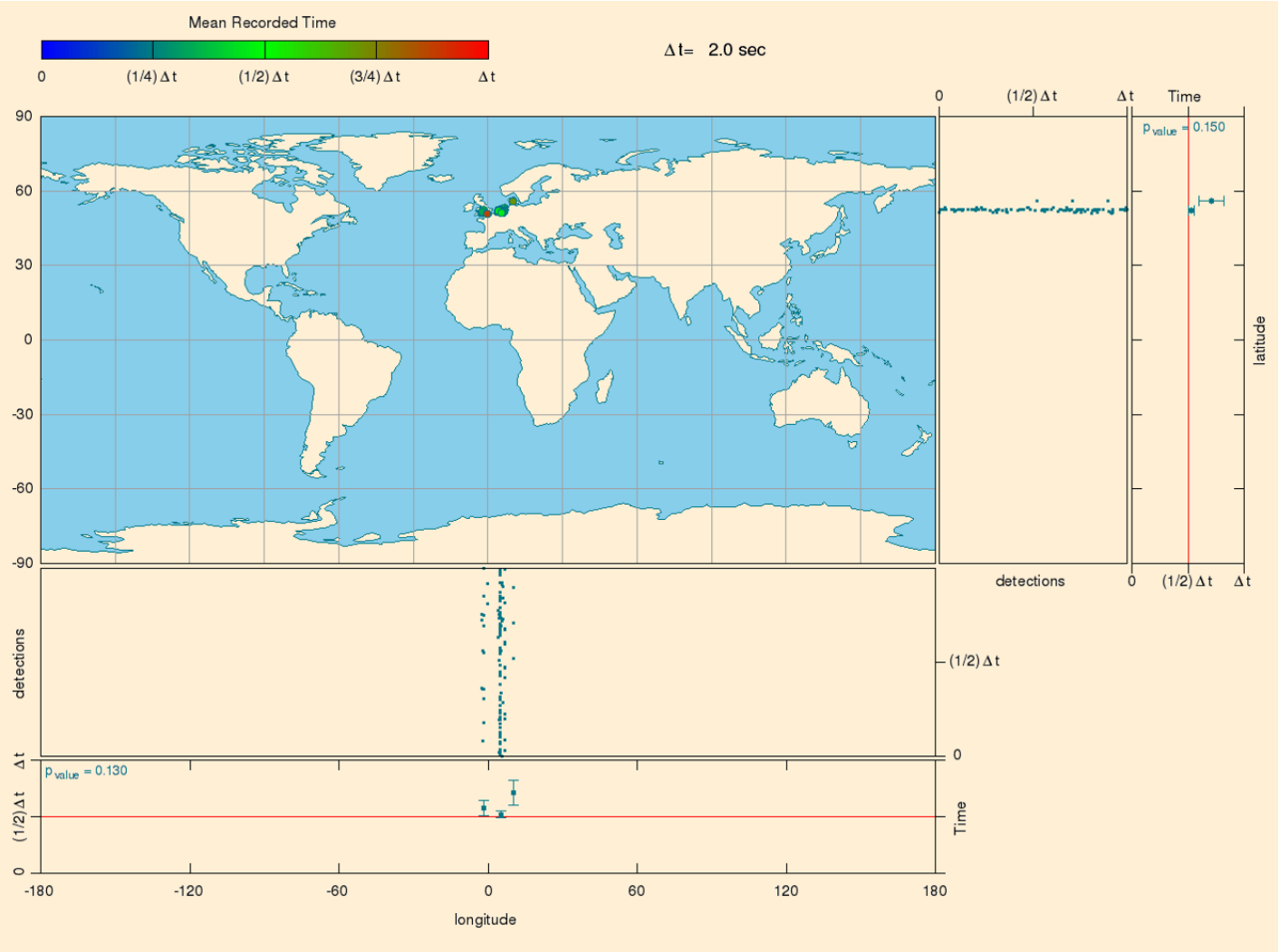
CREDO Monitor



How a CRE signature can look like

Simulation

CREDO Monitor



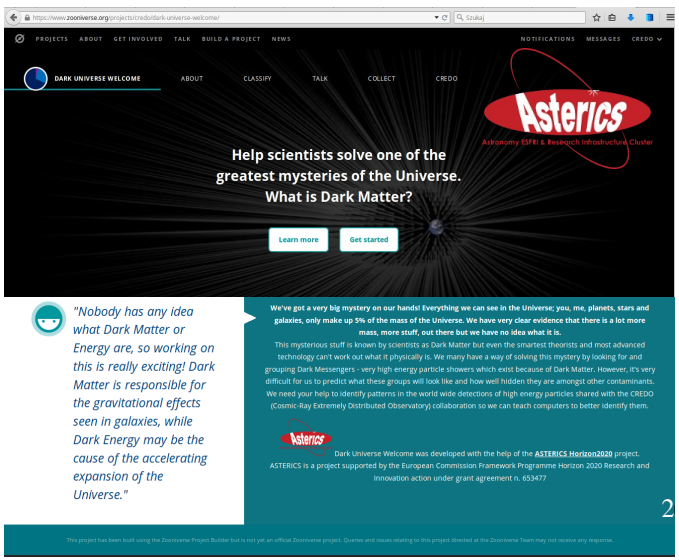
Real data analysis

DUW: Citizen Science Interface of CREDO

CREDO

THE QUEST FOR UNEXPECTED

Dark Universe Welcome



Citizen science motivation

Citizen science

From Wikipedia, the free encyclopedia

Citizen science (**CS**) (also known as **crowd science**, **crowd-sourced science**, **civic science**, **volunteer monitoring** or **networked science**) is scientific research conducted, in whole or in part, by amateur or nonprofessional scientists. Citizen science is sometimes described as "public participation in scientific research", participatory monitoring and participatory action research.[1]

Mutual benefit resulting from synergy!

Participants get opportunities:

- To educate themselves
- To do real science
- To feed their curiosity
- To become co-authors of a scientific paper

CREDO gets:

- Manpower
- Geographical expansion
- Popularization of its ideas and PR

Summary

- **CREDO** opens a new channel to explore the Universe (ensemble of cosmic-rays, super-preshowers) and has a wide range of potential fields it can serve (fundamental science, interdisciplinary studies, education).

- **Current status:**
  Already operational.
  Development and expansion is ongoing.

- **Outlook:**
  Implement more sophisticated analysis algorithms.
  Integrate data from mobile application.
  Expansion of DUW.

- **For more info:**
  Please visit `https://credo.science` and contribute to CREDO science

CREDO

THE QUEST FOR UNEXPECTED

Thank You!

CREDO The 1st Anniversary Symposium
IFJ PAN Kraków, 30th August 2017

fot. Jan Zych