

Cosmic-Ray Extremely Distributed Observatory*: the new beginning



Piotr Homola[□]

[□]) Institute of Nuclear Physics
Polish Academy of Sciences, Kraków, Poland

^{*)} <http://credo.science>

CREDO Visegrad Workshop, Opava, 21-23.11.2019

take home physics:
N_{ATM} >= 1!

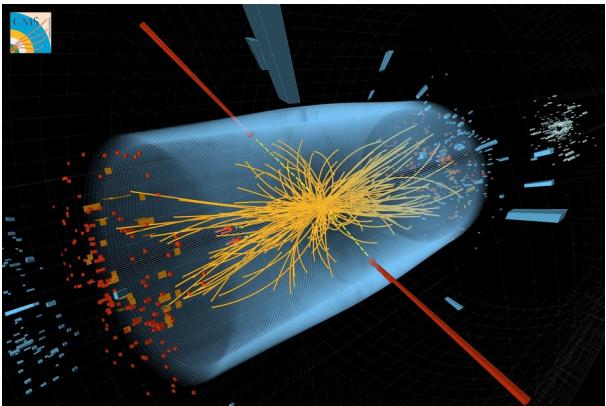
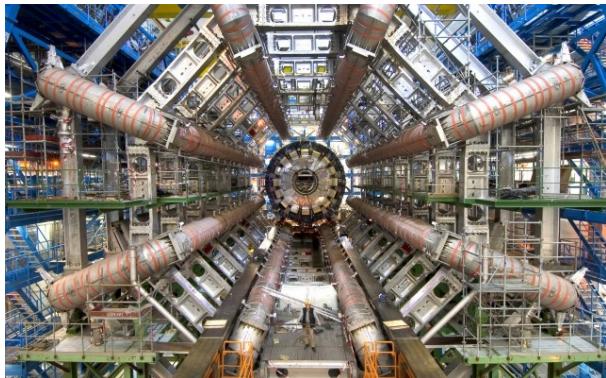


Where to find new data? A biased view

production → (acceleration) → interactions → particle ensemble → conclusions

Laboratories (experiments)

accelerators & colliders



Investment:

~100 mld \$ ~0 \$

Energies

< 10^{12} eV < 10^{20} eV+

Availability:

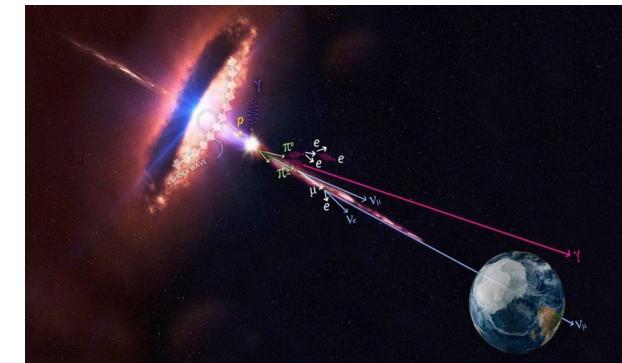
Rich Everybody
countries

Data flux:

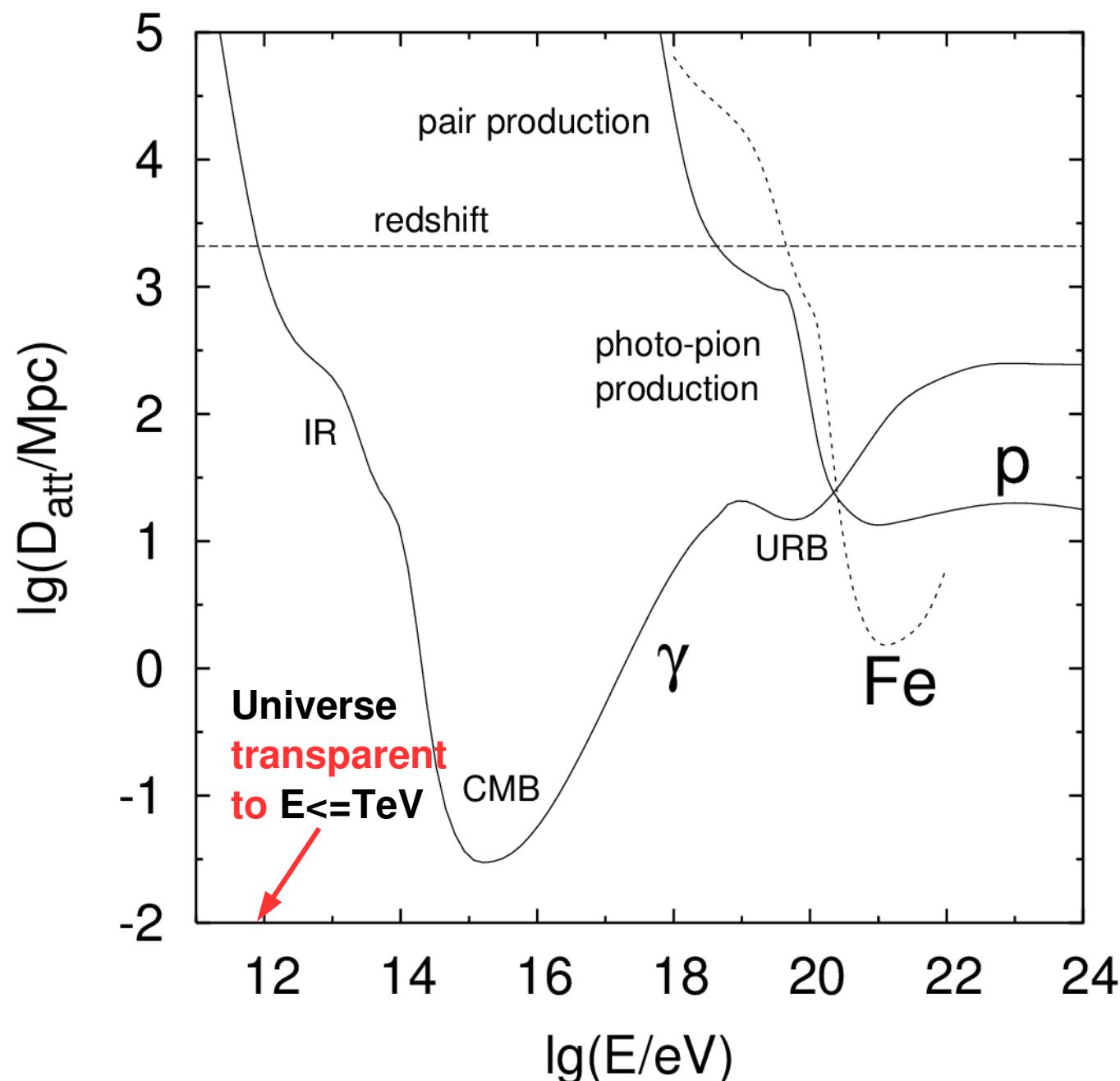
huge small

Cosmos (observations)

accelerator & collider



free propagation → interactions → products!



CR: under-explored field! Global search not yet tried!

Ranges:

energy: > 10 orders of magnitude

flux: > 30 orders of magnitude

→ diverse physics (sources)

→ diverse detection techniques

Flux rapidly decreases with energy ($\sim 10^{-3}$),

Highest energies → the most demanding challenges:

→ technical:

extremely low flux (at $E=10^{20}$ eV

1 particle / km² millenium), but now:

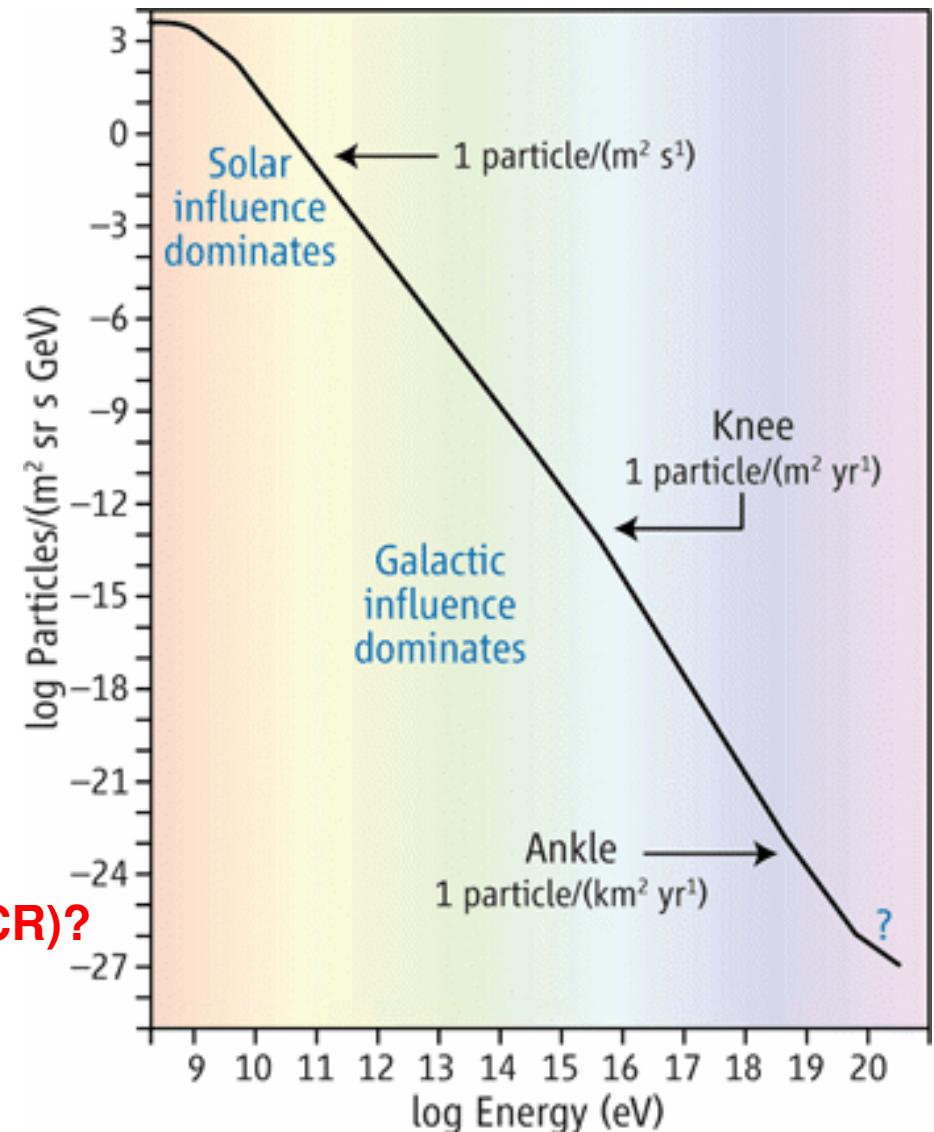
the Pierre Auger Observatory (~ 3000 km²)

→ scientific:

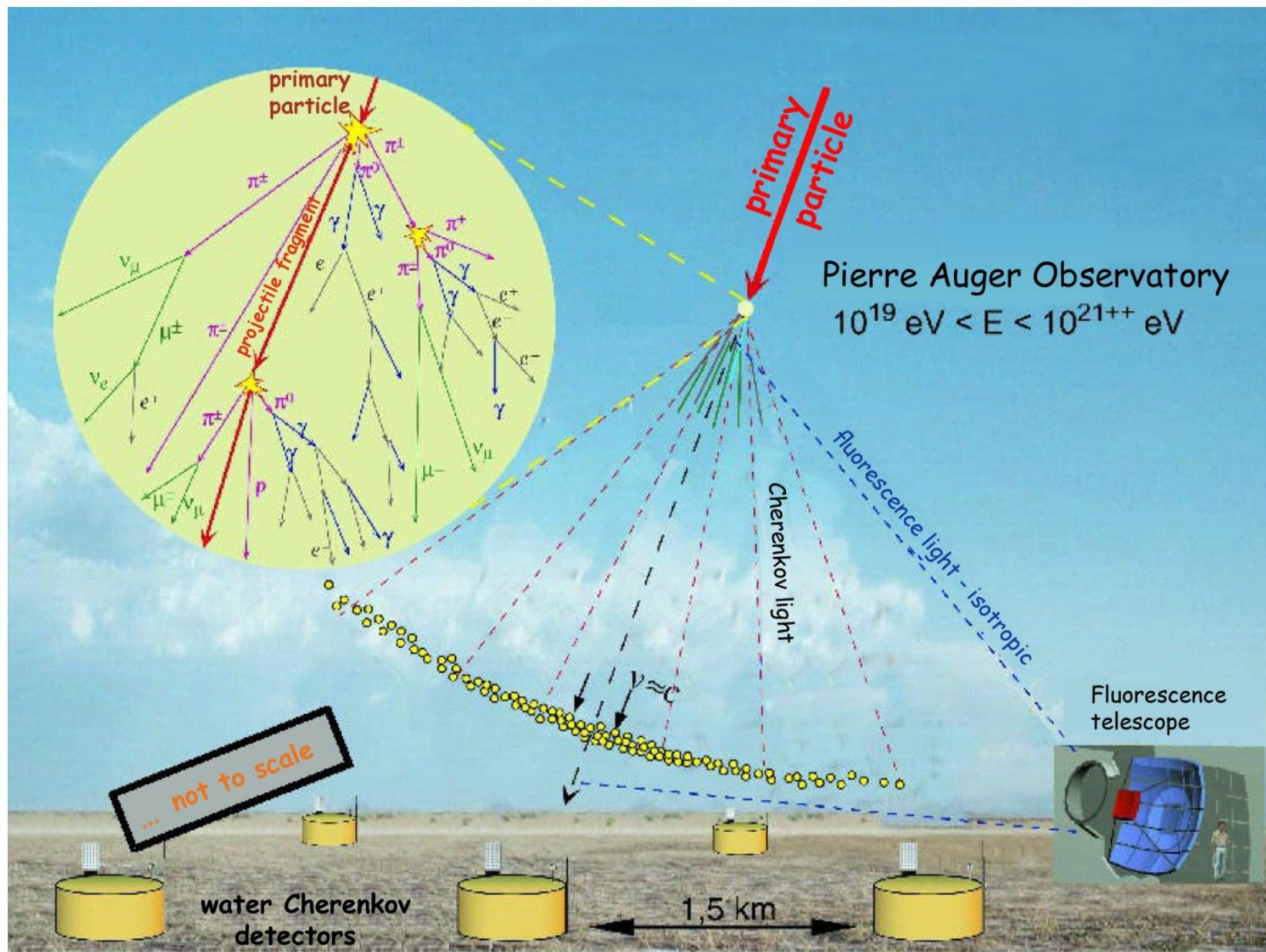
What are Ultra-High Energy Cosmic Rays (UHECR)?

Where they come from?

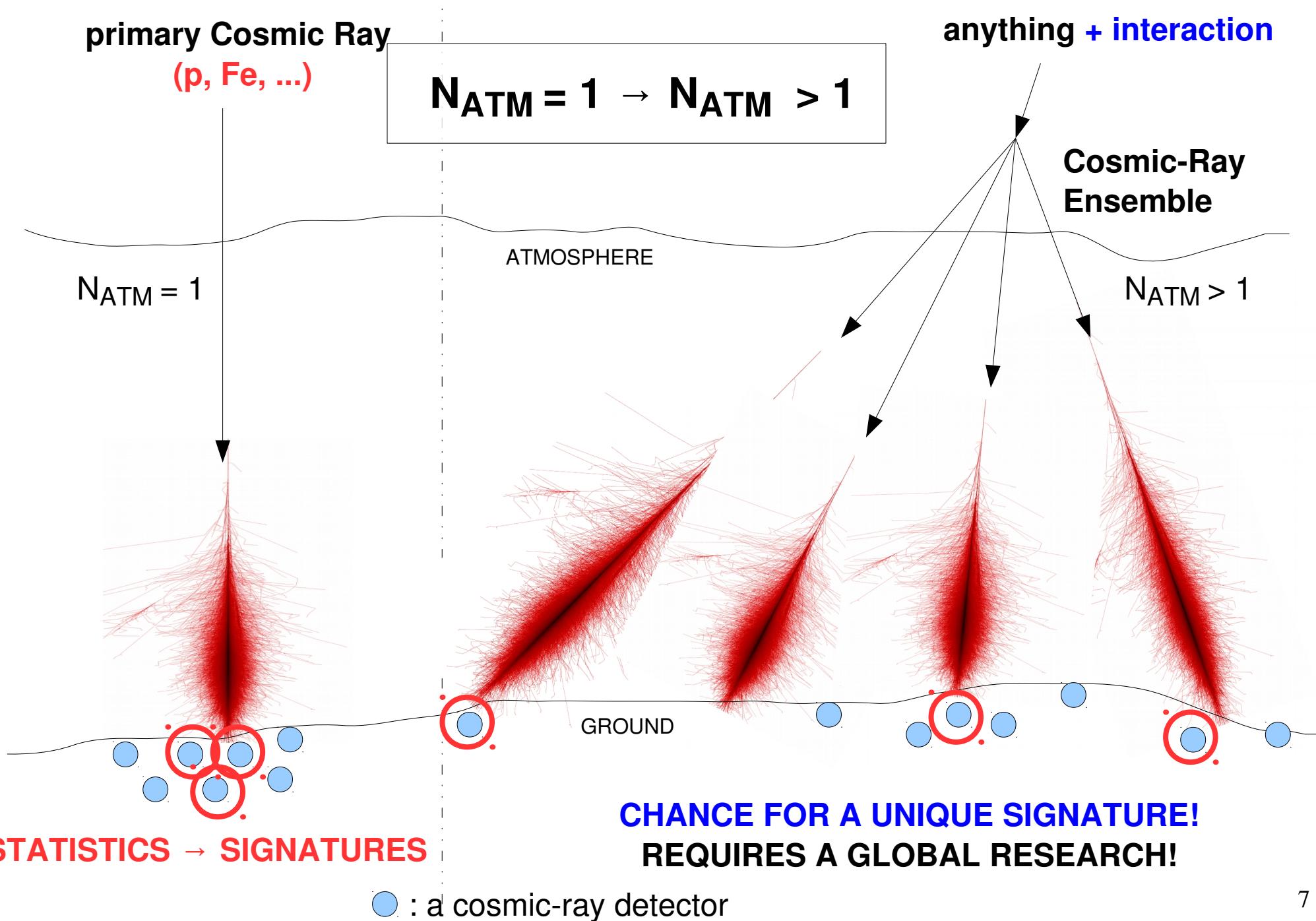
How do they propagate?



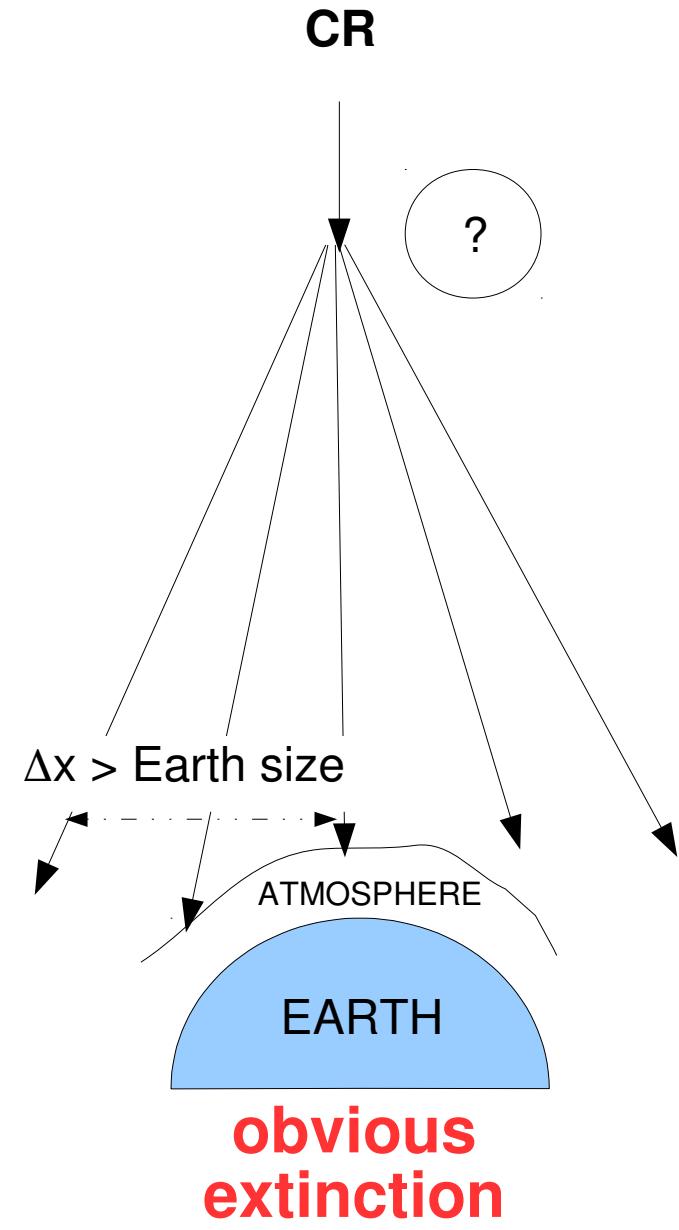
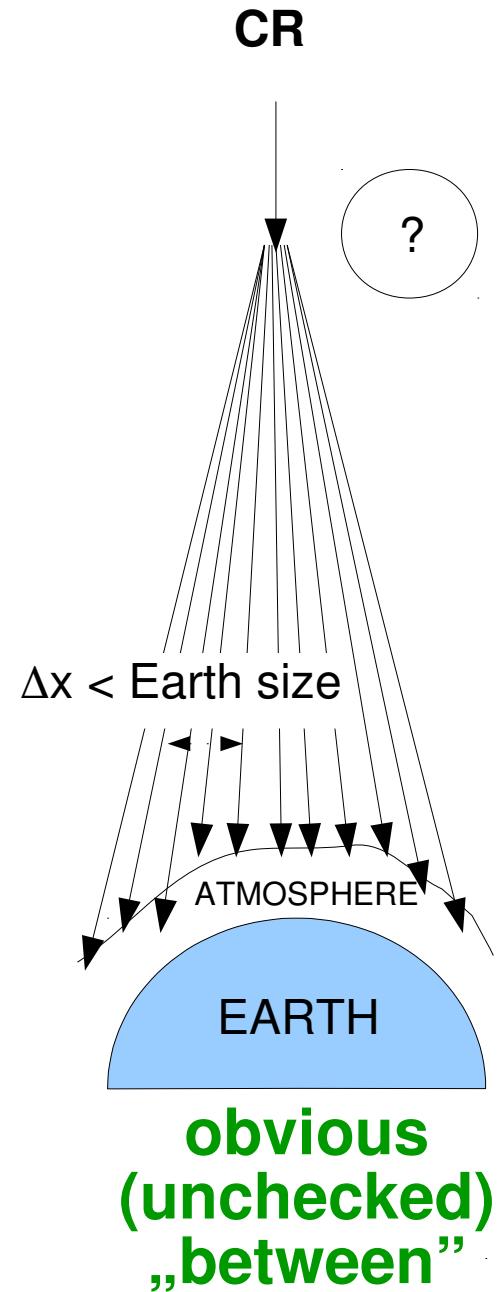
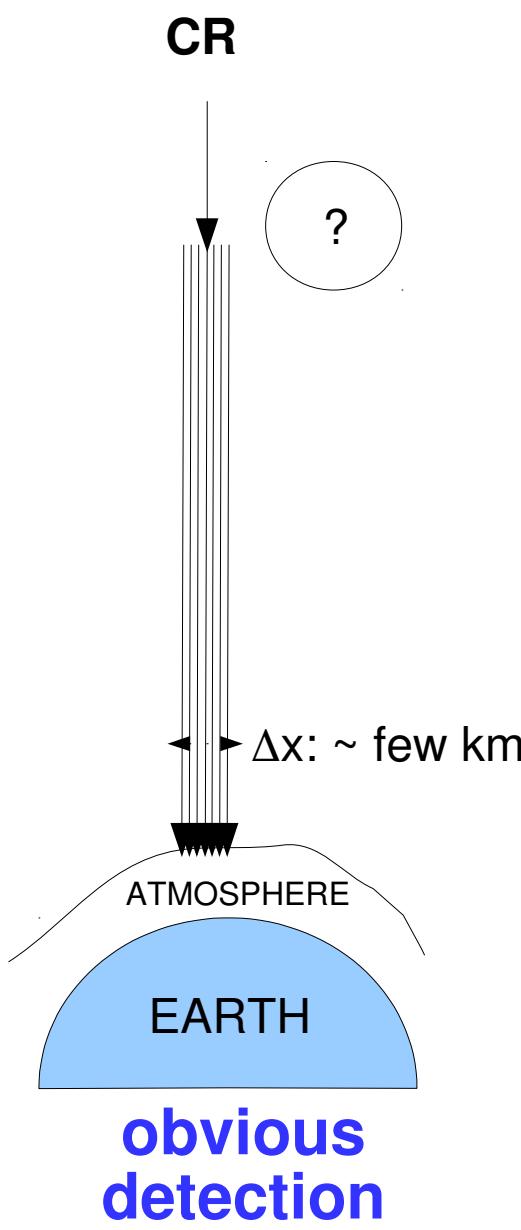
State-of-the-art detection of cosmic rays: $N_{\text{ATM}} = 1$



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



$N_{ATM} \geq 1$: obvious, untouched ground



$N_{ATM} > 1$ motivated by data! (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. Ogmén, E. Buller, and S. Standil

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

(Received 7 April 1983)

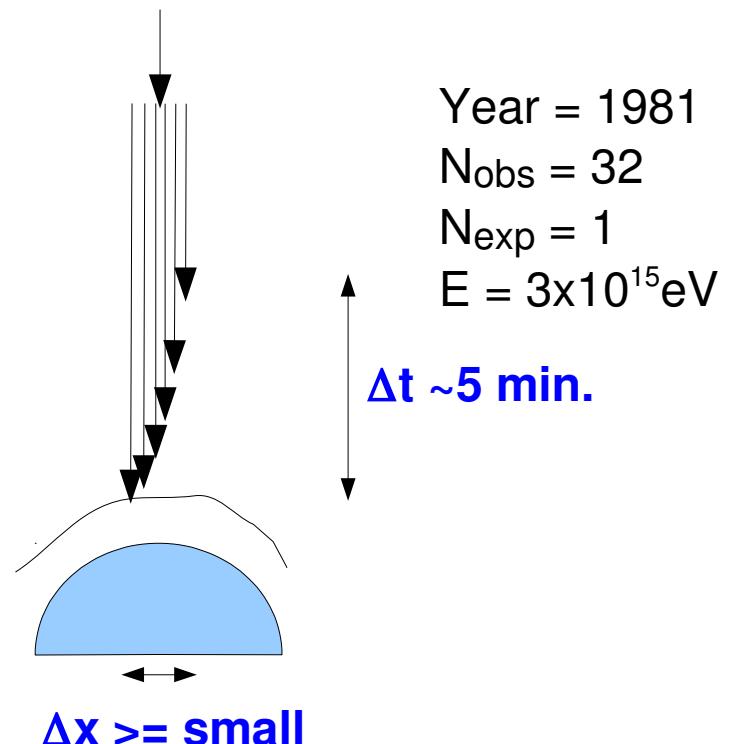
A series or burst of 32 extensive air showers of estimated mean energy 3×10^{15} eV was observed within a 5-min time interval beginning at 9:55 A.M. (CST) on 20 January 1981 in Winnipeg, Canada. This observation was the only one of its kind during an experiment which recorded 150 000 such showers in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

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

Forgotten (!) treasure (?) no. 1

PH: Correlated cosmic rays?

$N_{ATM} > 1?$



$N_{ATM} > 1$ motivated by data! (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

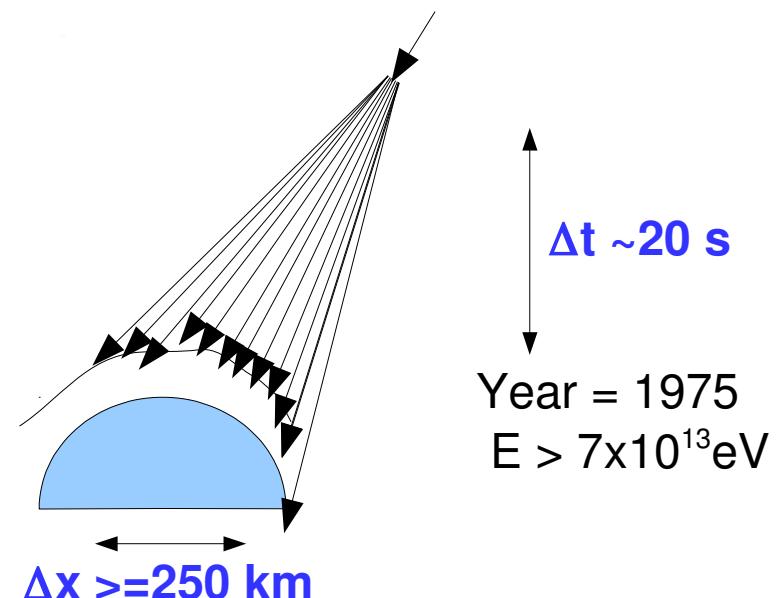
(Received 14 September 1983)

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 nature 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

PH: Correlated cosmic rays?

$N_{ATM} > 1?$



$N_{\text{ATM}} > 1$: new channel in multi-messenger astrophysics!

Please help to name the object of investigation:

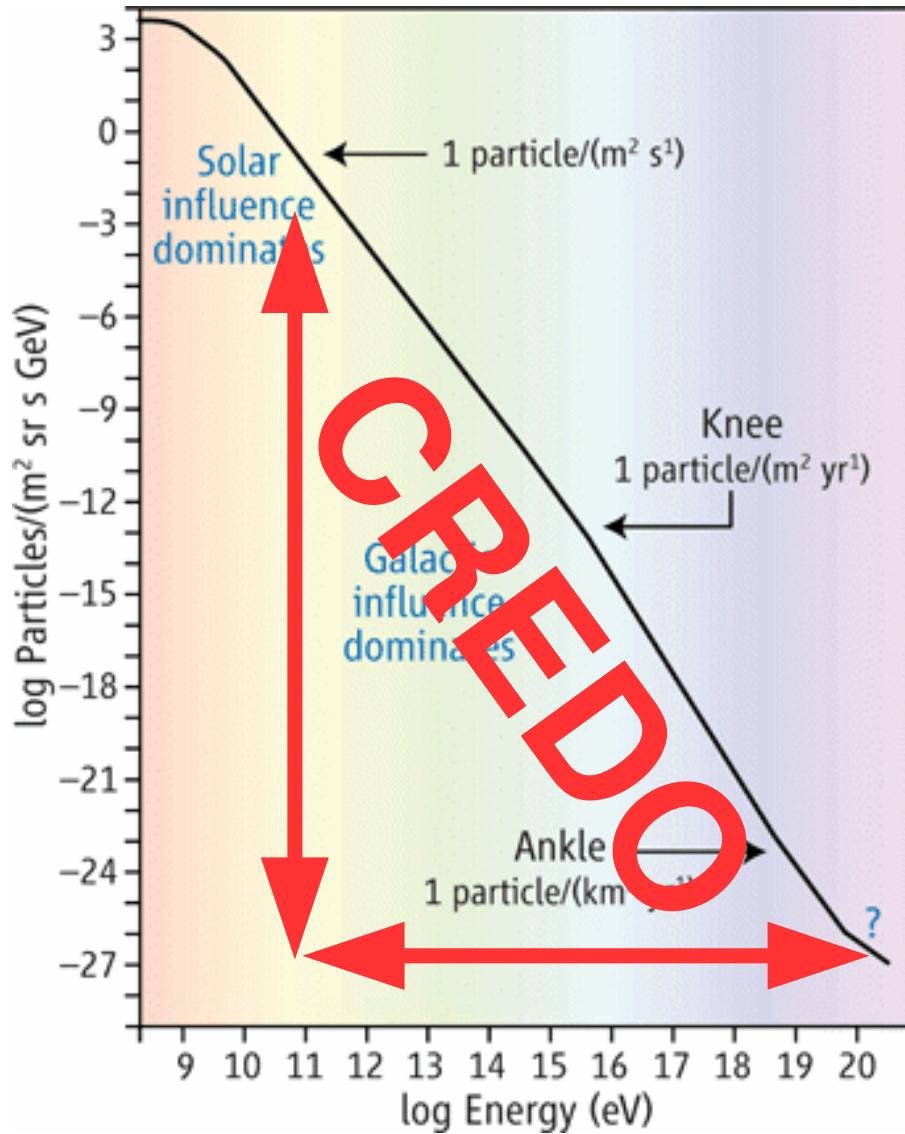
Cosmic Ray Ensembles (CRE)"?

„Cosmic-Ray Cascades (CRC)"?

„Extraatmospheric Showers (ES)"?

„Super-Pre-Showers (SPS)"?

CRE? Full energy spectrum!



CREDO: the first $N_{\text{ATM}} \geq 1$ observatory

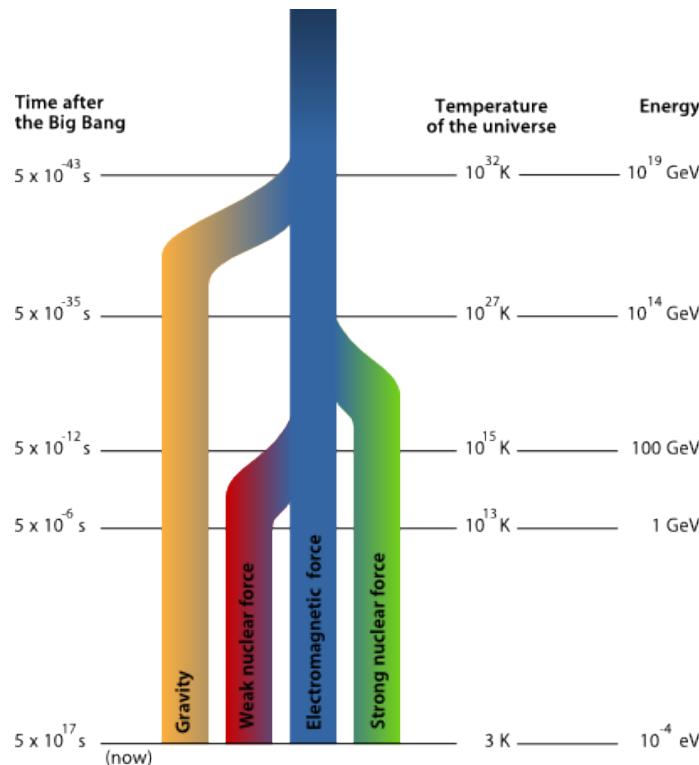
Cosmic-Ray Extremely Distributed Observatory



Central database/interface: access to everything for everybody

$N_{ATM} \geq 1$ mission (briefly)

Scenarios AND Fishing



Foundation of foundations: The spacetime



Smooth?

Foundation of foundations: The spacetime



Astro-tests of the space-time structure



- maximum photon energies $< 10^{12}$ eV
- testable scale of the space-time „grain” $< 10^{-18}$ m



- maximum photon energies in CRE (ensembles) $< 10^{20}$ eV +
- Potential sensitivity to the space-time „grain” $< 10^{-26}$ m

CRE and Experimental Quantum Gravity

T. Jacobson, S. Liberati, and D. Mattingly, Annals Phys. 321 (2006) 150

Lorentz violation at high energy: concepts, phenomena and astrophysical constraints

Ted Jacobson^a, Stefano Liberati^b, David Mattingly^c

^a*Department of Physics, University of Maryland, USA*

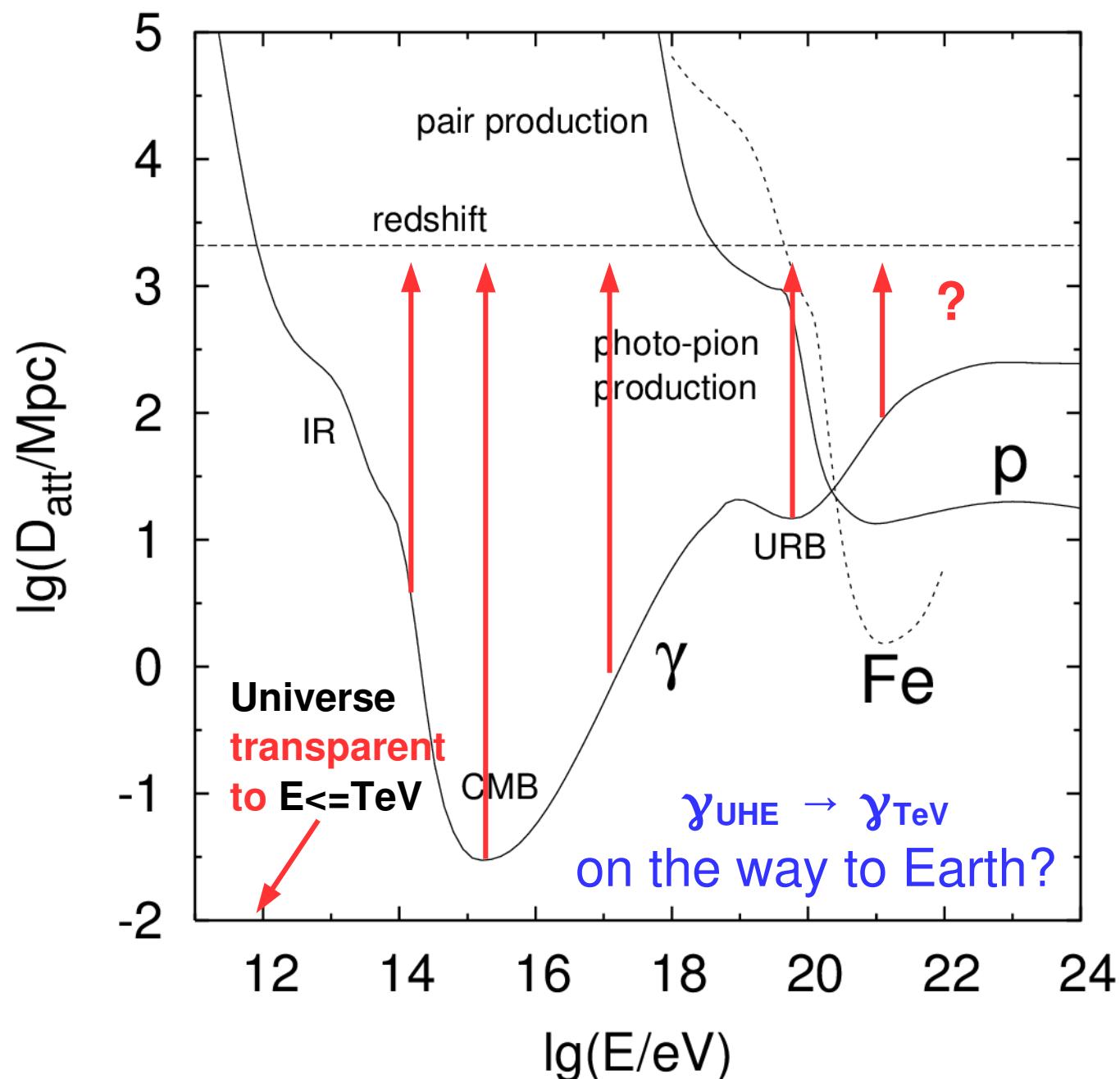
^b*International School for Advanced Studies and INFN, Trieste, Italy*

^c*Department of Physics, University of California at Davis, USA*

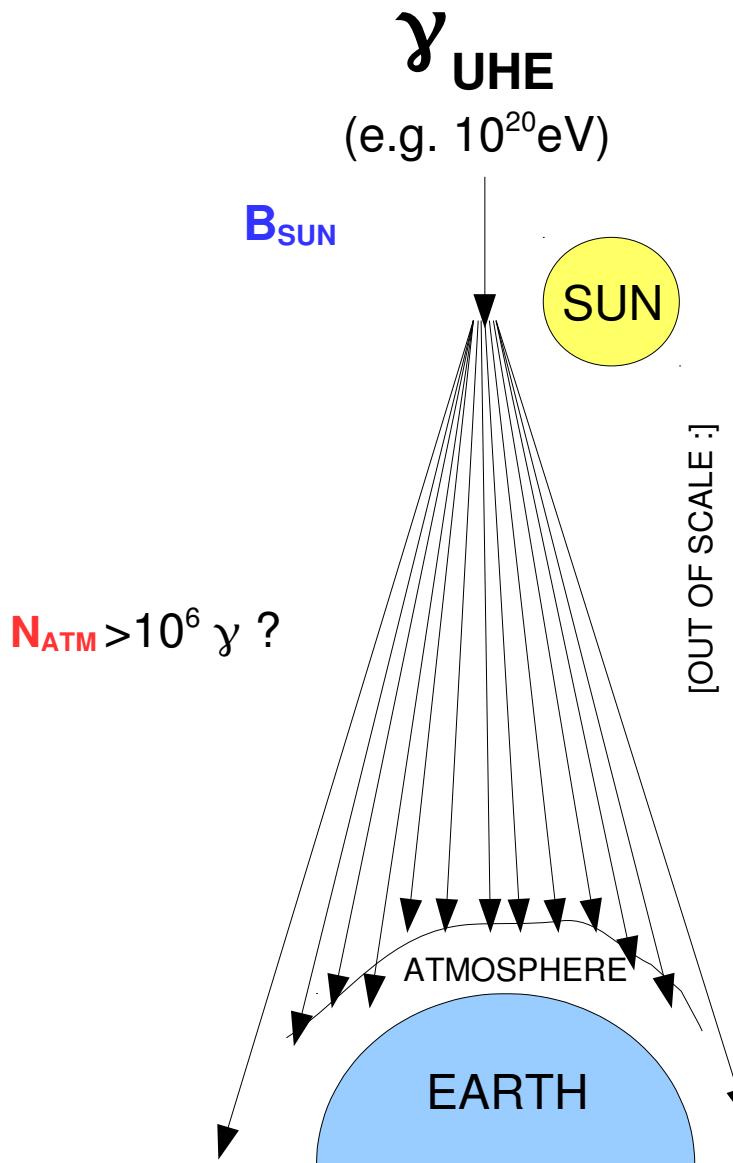
extensive review). A partial list of such “windows on quantum gravity” is

- sidereal variation of LV couplings as the lab moves with respect to a preferred frame or directions
- cosmological variation of couplings
- cumulative effects: long baseline dispersion and vacuum birefringence (e.g. of signals from gamma ray bursts, active galactic nuclei, pulsars, galaxies)
- new threshold reactions (e.g. photon decay, vacuum Čerenkov effect)
- shifted existing threshold reactions (e.g. photon annihilation from blazars, GZK reaction)
- LV induced decays not characterized by a threshold (e.g. decay of a particle from one helicity to the other or photon splitting)
- maximum velocity (e.g. synchrotron peak from supernova remnants)
- dynamical effects of LV background fields (e.g. gravitational coupling and additional wave modes)

γ_{HE} travelling through the Universe: photon decay?

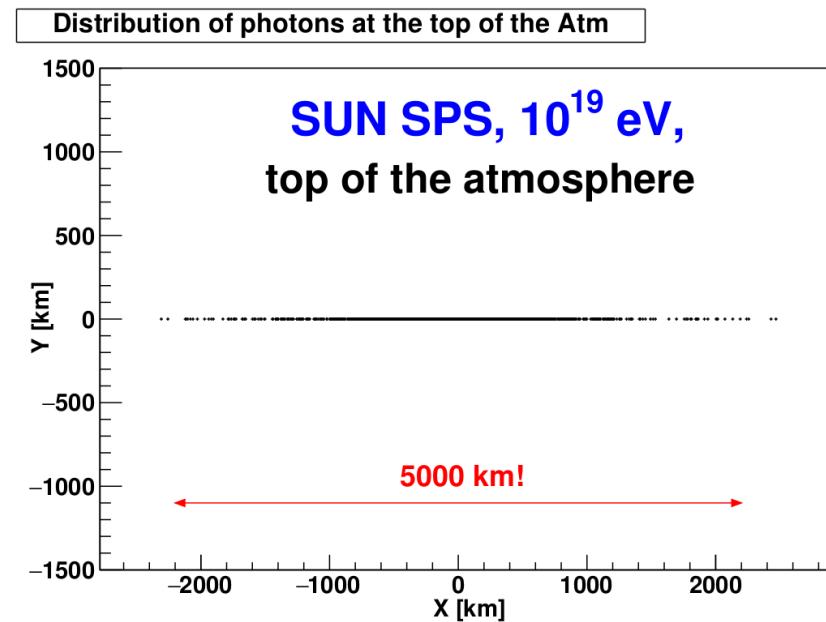


Super-preshowers (SPS) from the vicinity of a star



→ First calculations: W. Bednarek 1999
low energies not treated: extent \sim tens of km

→ N. Dhalal, arXiv:1908.04600
wide energy spectrum: extent
 \sim thousands of km

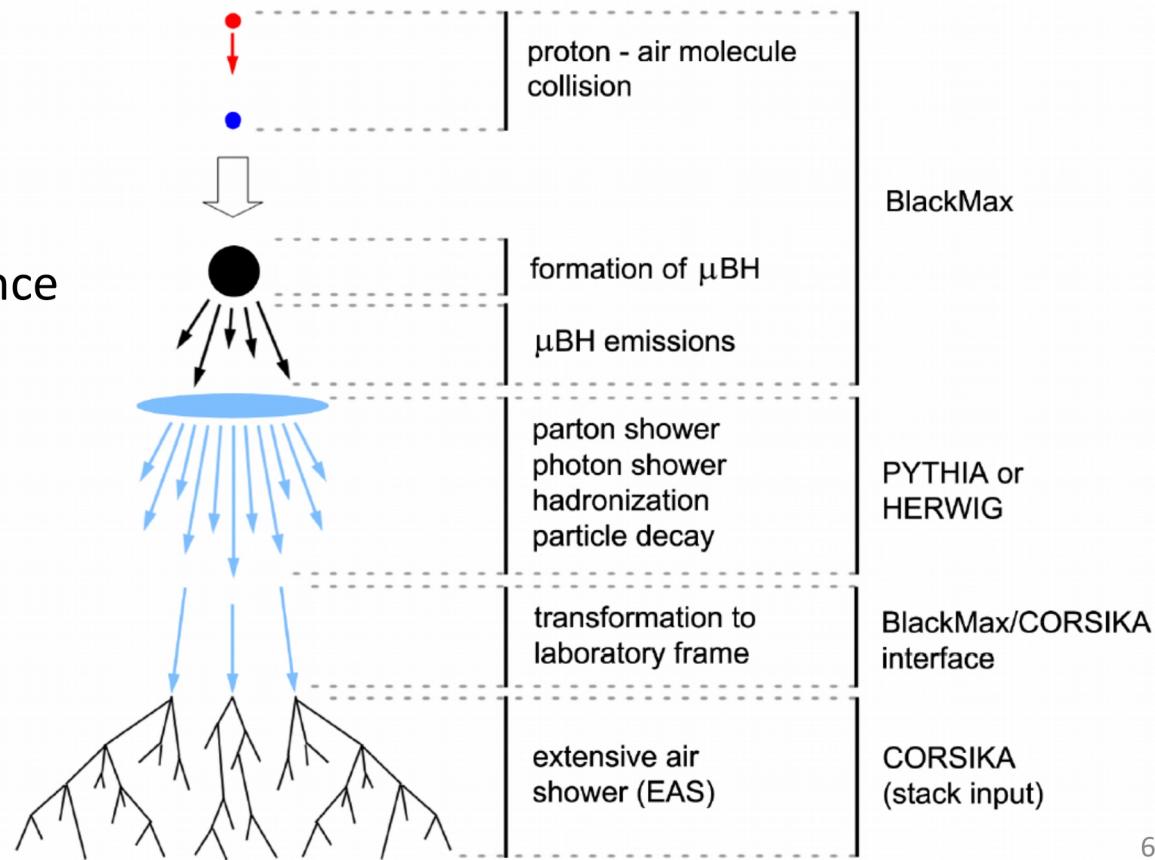


Distribution of photons ($E > 10^{13}$ eV) at the top of the atmosphere.
 $E_{\gamma} = 10$ EeV, Impact parameter = $2.5R_S$.

$N_{\text{ATM}} > 1 \rightarrow$ observable (line even 10000 km wide), not yet tried

Detection of μ BHs at the PAO

- Main research idea: Prepare an interface between two Monte Carlo simulators and check, if μ BH induced extensive air showers (EAS) can be separated from normal cosmic ray EAS
- Simulators used: BlackMax (μ BH evaporation) and CORSIKA (development of EAS)
- Formation of μ BHs assumes existence of extra dimensions
- Use longitudinal development of an EAS and X_{max}^μ as a separation indicator



Credit: Gasper Kukec, University Nova Gorica, Slovenia

CREDO



THE QUEST FOR THE UNEXPECTED



**CREDO the 2nd Anniversary Symposium
IFJ PAN, Kraków, 4 October 2018**

International scientific collaboration: Cosmic Ray Extremely Distributed Observatory (CREDO)

11.09.2019

Miembros oficiales de CREDO



credit: Matias Rosas, Uruguay

Cosmic Ray Extremely Distributed Observatory (CREDO)



This multi-beneficiary Memorandum of Understanding (MoU) is made

BETWEEN:

the Institutions named in Section 8: Signatories, henceforth referred to as "Parties", with the Effective Date being the date of signing by each of the Parties,

in relation to the Project entitled

COSMIC RAY EXTREMELY DISTRIBUTED OBSERVATORY (CREDO), henceforth referred to as "Project".

THEREFORE, IT IS AGREED THAT:

Section 1: Background

The Parties agree to cooperate in exploring the multidisciplinary potential of a widely distributed network of cosmic ray detectors, under the name of the Cosmic Ray Extremely Distributed Observatory (CREDO). As an initiative of the Henryk Niewodniczański Institute of Nuclear Physics Polish Academy of Sciences the CREDO concept has been under development since 30th August 2016.

Section 2: Purpose

The purpose of this MoU is to stipulate, in the context of the Project, the relationship between the Parties. In particular, this concerns the distribution of work between the Parties, the management of the Project and the rights and obligations of the Parties.

CREDO institutional members 1.03.2019

- Australia (2)
- Czech Republic (2)
- Georgia (1)
- Hungary (1)
- Mexico (1)
- Nepal (1)
- Poland (12)
- Russia (1)
- Slovakia (1)
- Ukraine (2)
- Uruguay (1)
- USA (3)

The CREDO Detector

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 [Google Play](#) or scan QR





mobile application

<https://play.google.com/store/apps/details?id=science.credo.mobiledetector>



The screenshot shows the app's landing page. It includes a large globe icon with red dots, the project name "CREDO Detector", and logos for IFJ PAN and Nadzór rodzicielski. Buttons for "Dodaj do listy życzeń" (Add to wishlist) and "Zainstaluj" (Install) are visible. Below this are three smaller screenshots of the app's interface: one showing the project description, another showing detector status, and a third showing a list of detections with detailed data.



data acquisition!

CREDO Detector: examples

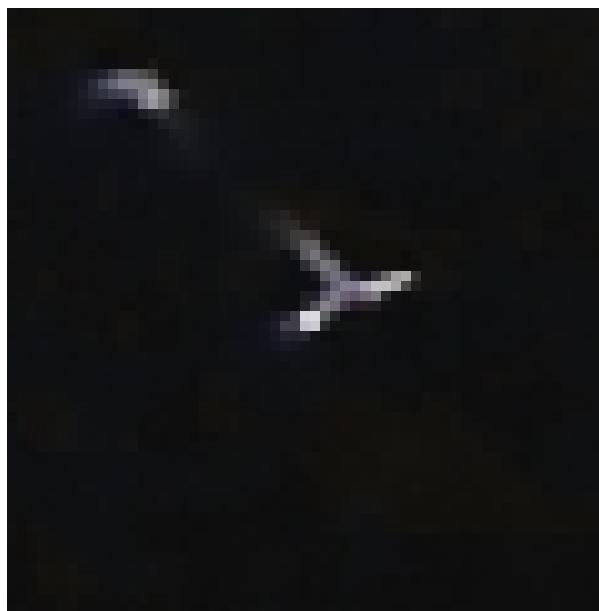
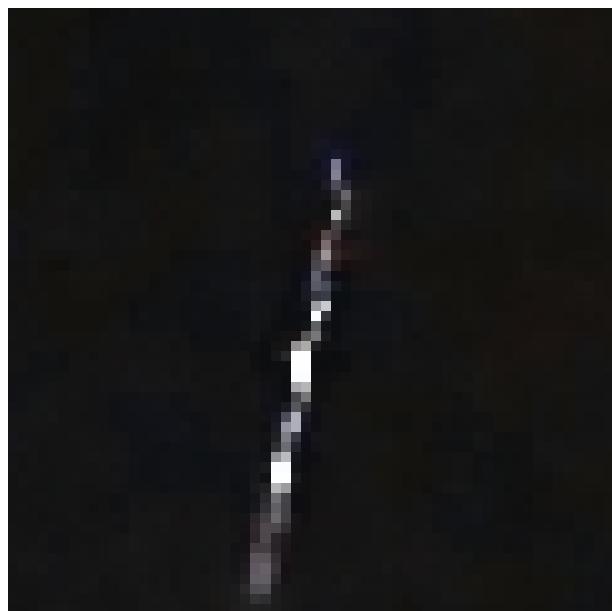
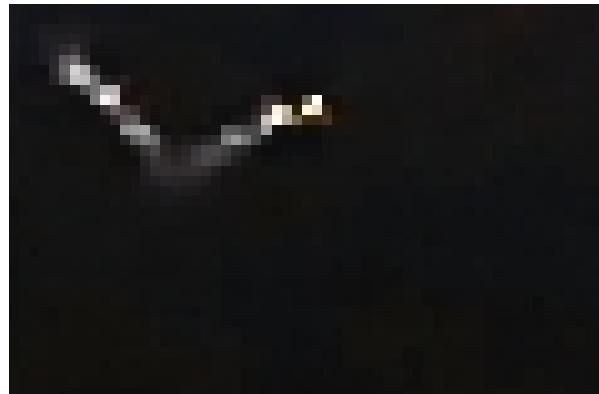
User: „smph-kitkat”, <https://api.credo.science/web/user/smph-kitkat/>

Device: Smasung SM-G357FZ, Android 4.4.4 (KitKat)

Average detection rate: ~10/hr

(flight to Kyiv on 29.05: 60/hr :)

Example images:



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

Slide 16

4 October 2018: CREDO's first light!

https://www.eurekalert.org/pub_releases/2018-10/thni-cfl100418.php

EurekAlert! | AAAS

SEARCH ARCHIVE ADVANCED SEARCH

HOME NEWS MULTIMEDIA MEETINGS PORTALS ABOUT LOGIN REGISTER

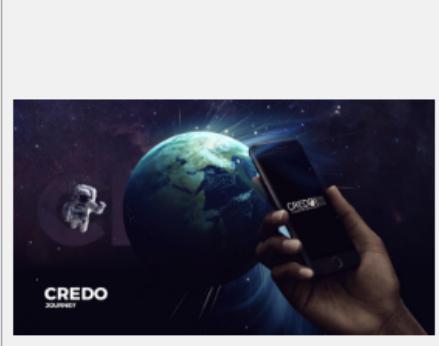
PUBLIC RELEASE: 4-OCT-2018

CREDO's first light: The global particle detector begins its collection of scientific data

THE HENRYK NIEWODNICZANSKI INSTITUTE OF NUCLEAR PHYSICS POLISH ACADEMY OF SCIENCES

[SHARE](#) PRINT E-MAIL

Now everyone can become co-creator and co-user of the largest detector of cosmic ray particles in history - as well as a potential co-discoverer. All you need is a smartphone and the CREDO Detector application turned on overnight. Under development for over two years, the CREDO project is entering the era of its maturity. Today, at the Institute of Nuclear Physics of the Polish Academy of Sciences in Cracow, the "first light" of the



Media Contact
Dr. Piotr Homola
piotr.homola@ifj.edu.pl
48-126-628-341
<http://www.ifj.edu.pl/?lang=en>

More on this News Release

CREDO's first light: The global particle detector begins its collection of scientific data
THE HENRYK NIEWODNICZANSKI INSTITUTE OF NUCLEAR PHYSICS POLISH ACADEMY OF SCIENCES

FUNDER
International Visegrad Fund (IVF)

MEETING
The Cosmic-Ray Extremely Distributed Observatory (CREDO) Week

ŁOWCY CZĄSTEK

Weź udział w wyjątkowym projekcie naukowym!

Jak dołączyć do konkursu?

- zbierz drużynę i zgłoś ją na stronie credo.science/rejestracja-druzyny
- 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)
- łapcie cząstki promieniowania kosmicznego!

Konkurs organizowany jest przez Instytut Fizyki Jądrowej PAN oraz CREDO Collaboration.

Biorąc udział w konkursie współtworzycie największy na świecie detektor promieniowania kosmicznego.

Zajrzyj na stronę credo.science.

Regulamin
credo.science/lowcyczastek.



[CREDO.SCIENCE/LOWCYCZASTEK/](http://credo.science/lowcyczastek/)



Instytut Fizyki Jądrowej
Panstywowego Uniwersytetu
Technologiczno-Przyrodniczego
w Szczecinie



Visegrad Fund
Fundacja na rzecz Rozwoju
Sztuki, Nauki i Kultury



Institute
of Cybernetics
and Informatics
Cybernetics



Wigner
Research Center
for Physics
Hungarian Academy
of Sciences

CREDO
THE QUEST FOR THE UNEXPECTED

... Particle Hunters
League and Marathon!
Not only for schools!



... Particle Hunters
League and Marathon!
Not only for schools!

https://credo.science/ranking-druzy-maraton/

The screenshot shows a web browser displaying the CREDO ranking page. The URL https://credo.science/ranking-druzy-maraton/ is visible in the address bar. The page features the CREDO logo at the top left and social media links (Facebook, YouTube, Instagram, Camera, Test Tube) at the top center. A quote from Mikhail V. Medvedev is displayed on the right: "I think CREDO has a unique capability of entering in and exploring a completely uncharted realm of science." Below the quote is a table listing the top 15 teams and their scores. The table has two columns: "NAZWA ZESPOŁU" (Team Name) and "LICZBA PUNKTÓW" (Score). The scores are listed in descending order. A green arrow icon is on the left side of the table, and a grey arrow icon is on the right side.

| NAZWA ZESPOŁU | LICZBA PUNKTÓW ▲ |
|-------------------|------------------|
| XI LO Kraków | 6486 |
| ananasy z sp26krk | 6249 |
| CREDO ASP OXFORD | 5093 |
| Kwiatek | 4784 |
| sidzina | 3799 |
| CREDO 4LO KEN BB | 3753 |
| zseo tarnów | 3590 |
| 12SPJasło | 3448 |
| 13LO Kraków | 2867 |
| LazyGalactic | 2857 |
| credogosia | 2773 |
| FASOLKI | 2556 |
| Nakielanie | 2506 |
| lonisko | 2385 |

June 2019: ~ 1200 participants from ~ 60 schools!



novelty



CREDO type

