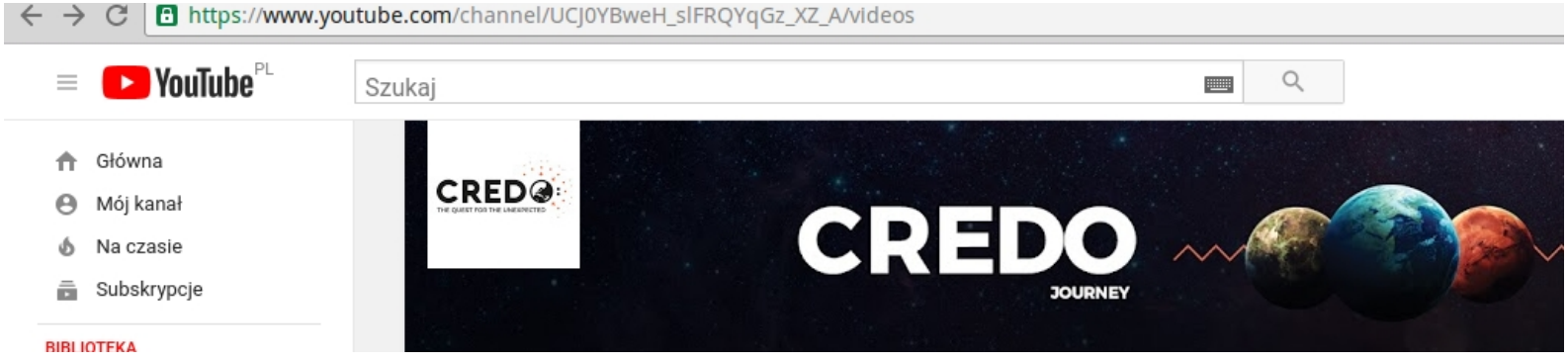
Cosmic-Ray Extremely Distributed Observatory*: the update

Piotr Homola□, the CREDO Collaboration

□) Institute of Nuclear Physics
Polish Academy of Sciences, Kraków, Poland
*) http://credo.science

take home physics:

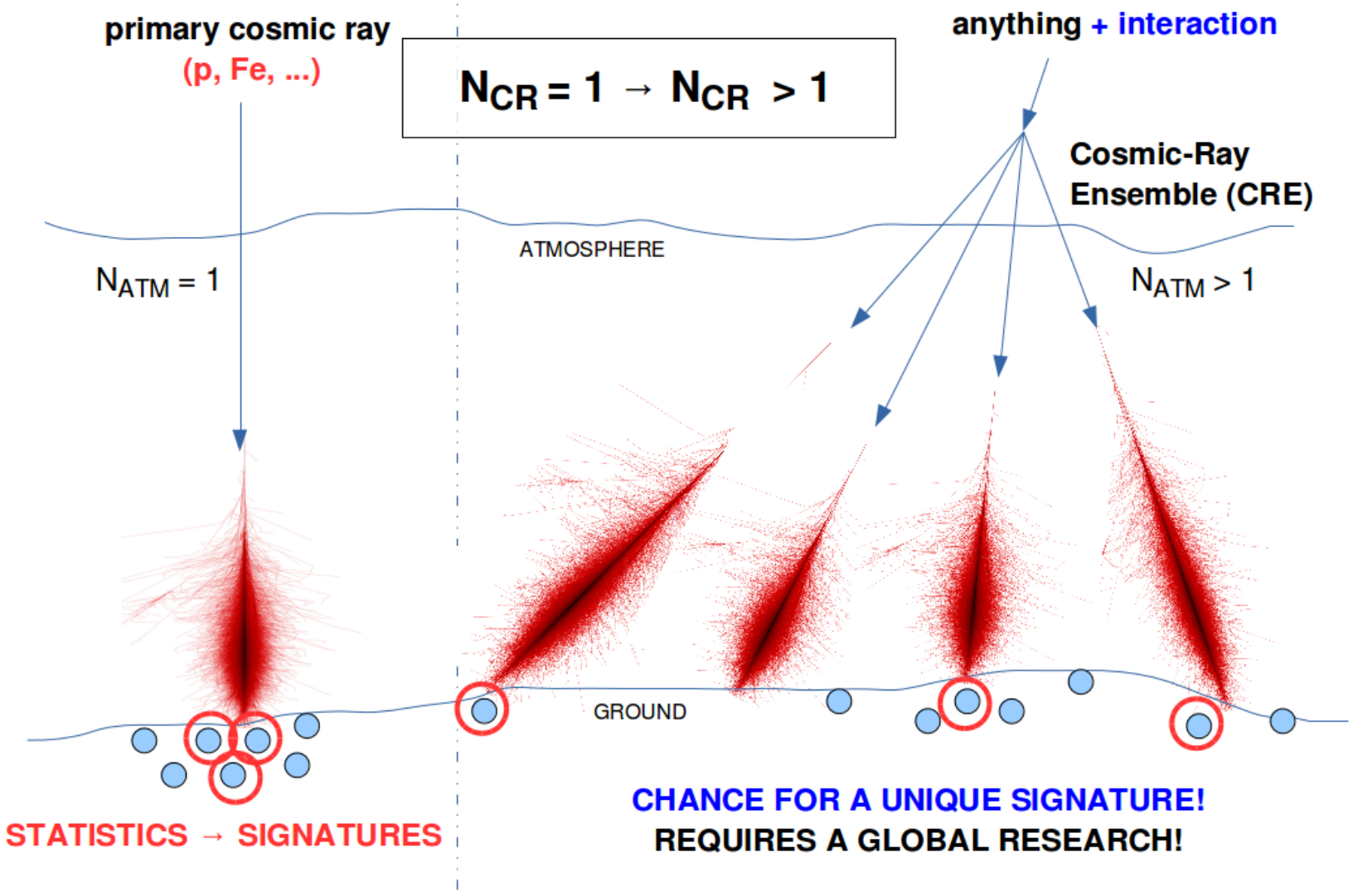
$N_{CR} >= 1$


https://www.youtube.com/channel/UCJ0YBweH_slFRQYqGz_XZ_A/videos
YouTube PL
Szukaj
Główna
Mój kanał
Na czasie
Subskrypcje
BIBLIOTEKA
CREDO
JOURNEY


CREDO
CREDO
JOURNEY
Odtwórz
https://youtu.be/iqwDj4k3mC0
0:07 / 1:53
HD

CREDO
THE QUEST FOR THE UNEXPECTED

Key Research Topic: Cosmic Ray Ensembles (CRE) - large scale cosmic-ray correlations ($N_{CR} > 1$)



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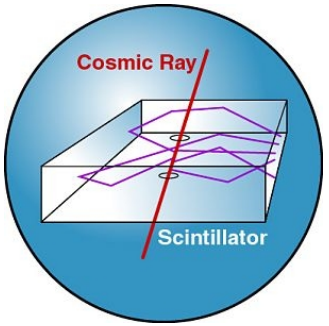
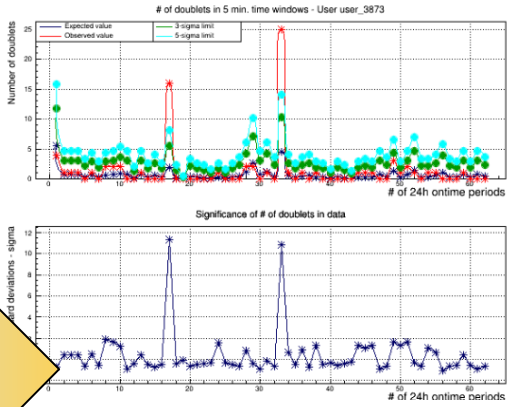
infrastructure: globally distributed network of technologically diverse particle sensors + central data processing and sharing





Distributed data acquisition (expert and non-expert)

Central database, processing, interfaces (Cyfronet AGH-UST)

Scientific and societal benefits (publications, education, engagement)

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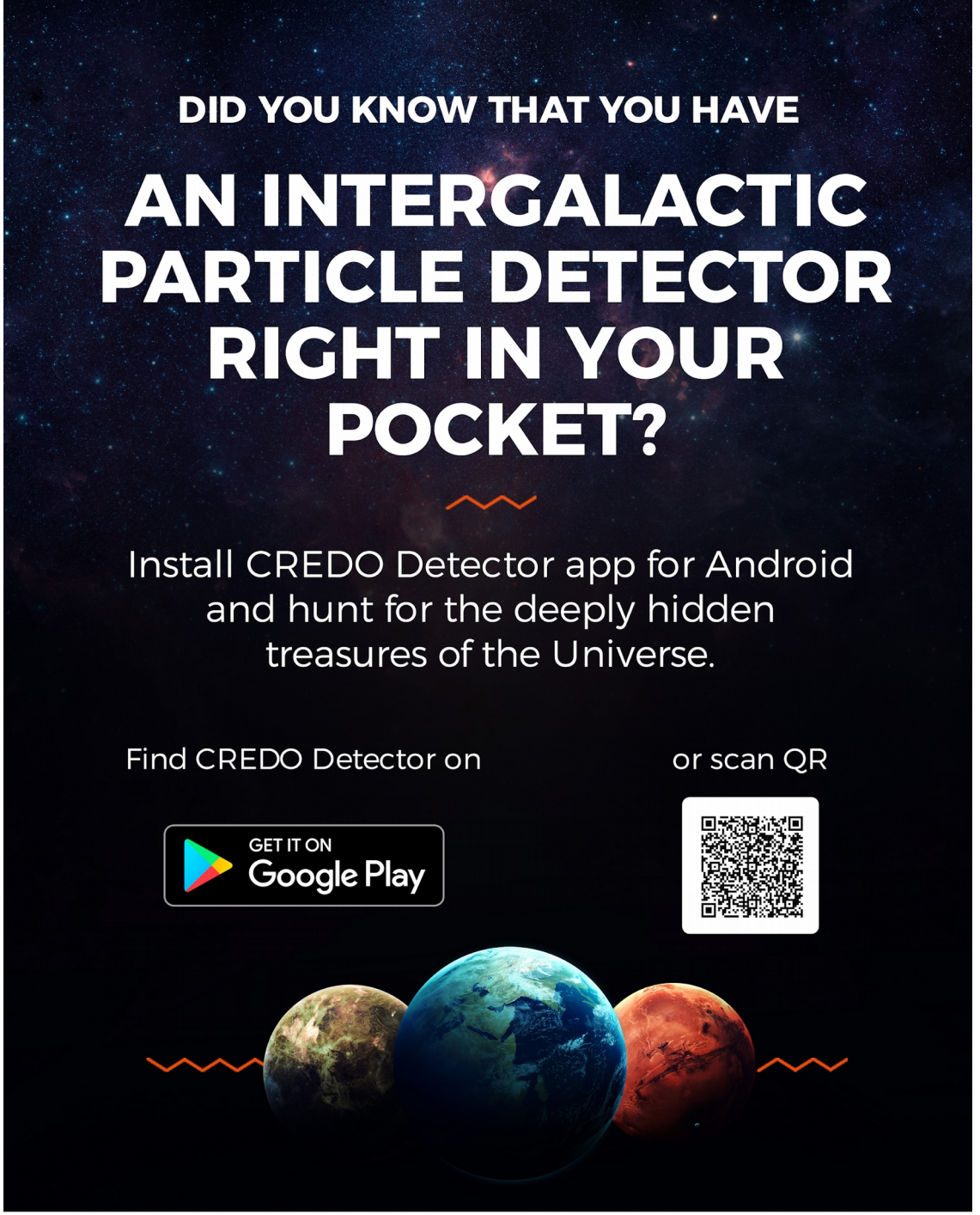
THE QUEST FOR THE UNEXPECTED

1st achievement (4.10.2018):
signal from the first automatized, mass participation scientific experiment on the CREDO infrastructure

mobile app → data → scaling up → first results → dissemination

The CREDO Detector



mobile application

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

CREDO

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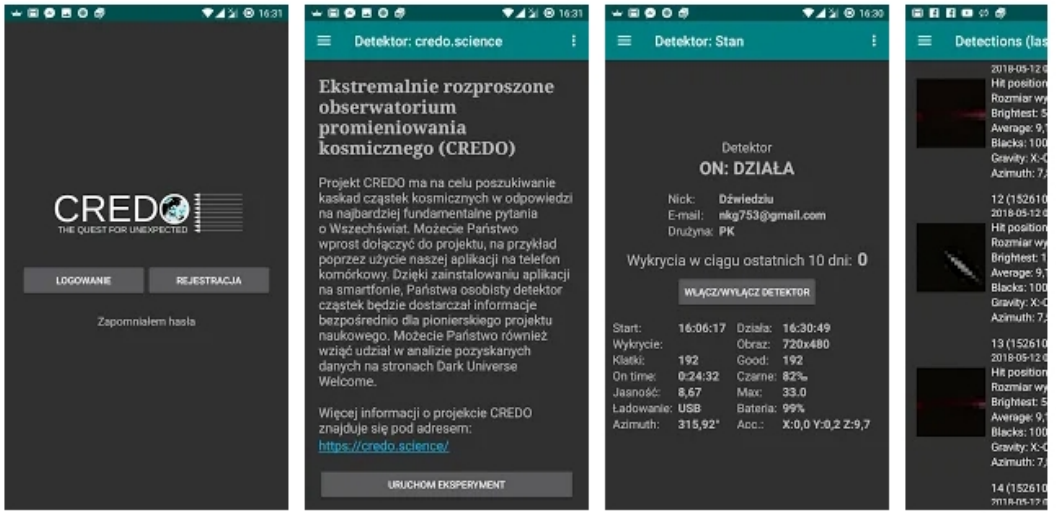
CREDO Detector

IFJ PAN Edukacja

Nadzór rodzicielski

Dodaj do listy życzeń

Zainstaluj



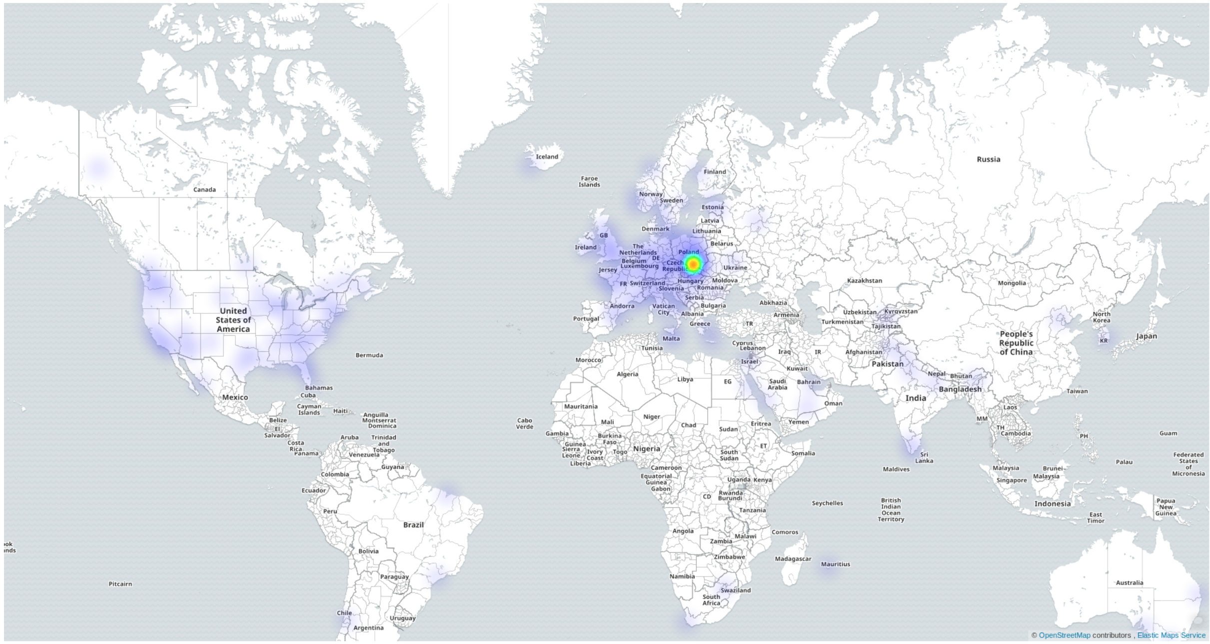
data acquisition!

key work:

Piotr Poznański (PK/IFJ)

Michał Niedźwiecki (PK)

CREDO: planetary mission



Statistics from launch to May 17th 2019

~2 917 742 detections

App running sums up to **958 years** looking for particles

7395 users with at least 1 detections

10472 devices

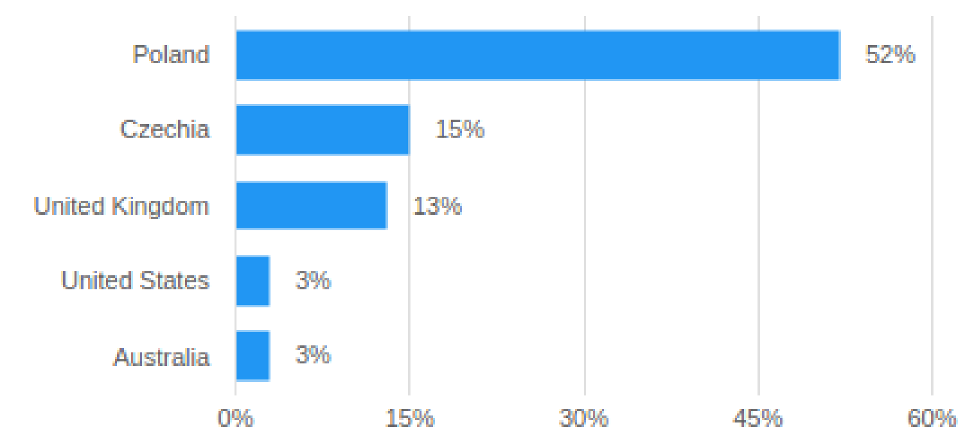
2533 teams

Installs by country

51.87% installs in Poland 11.38K installs

Top countries

14.71% installs in Czechia 11.38K installs



CREDO Detector: what do we see?

key work: **Tadeusz Wibig, Niraj Dhital**
publication perspective: I) 6 months (air showers); II) 9 months (muons)

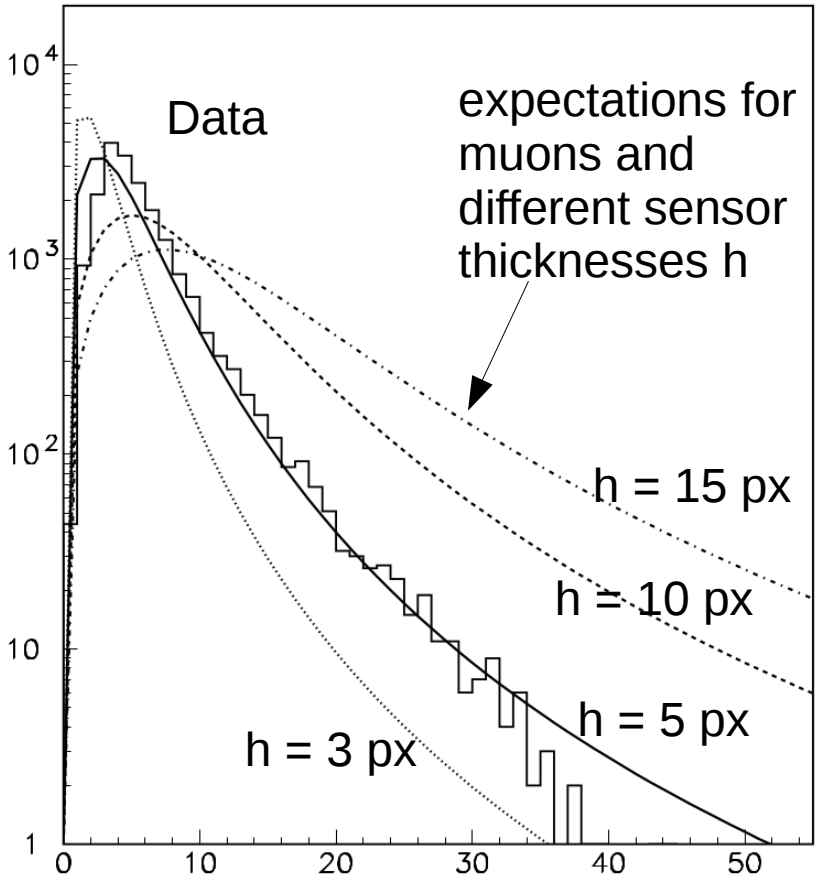
muons ?

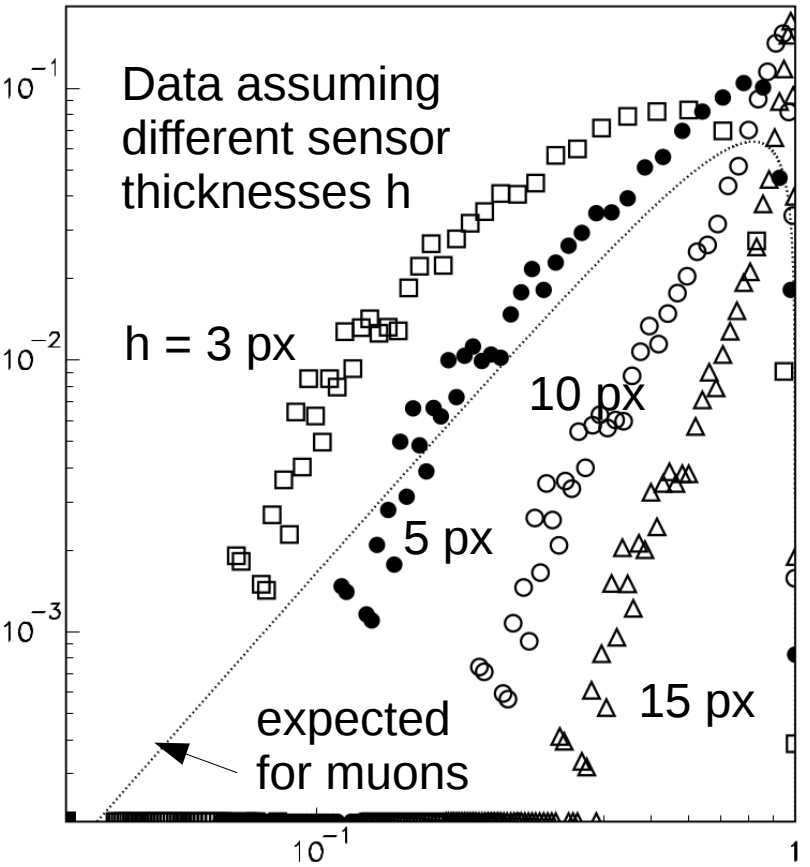
air showers ?

CREDO Detector: what do we see?

Device 1397: ~60000 particle track candidates (1 year)

User ID 1510; device id 1397

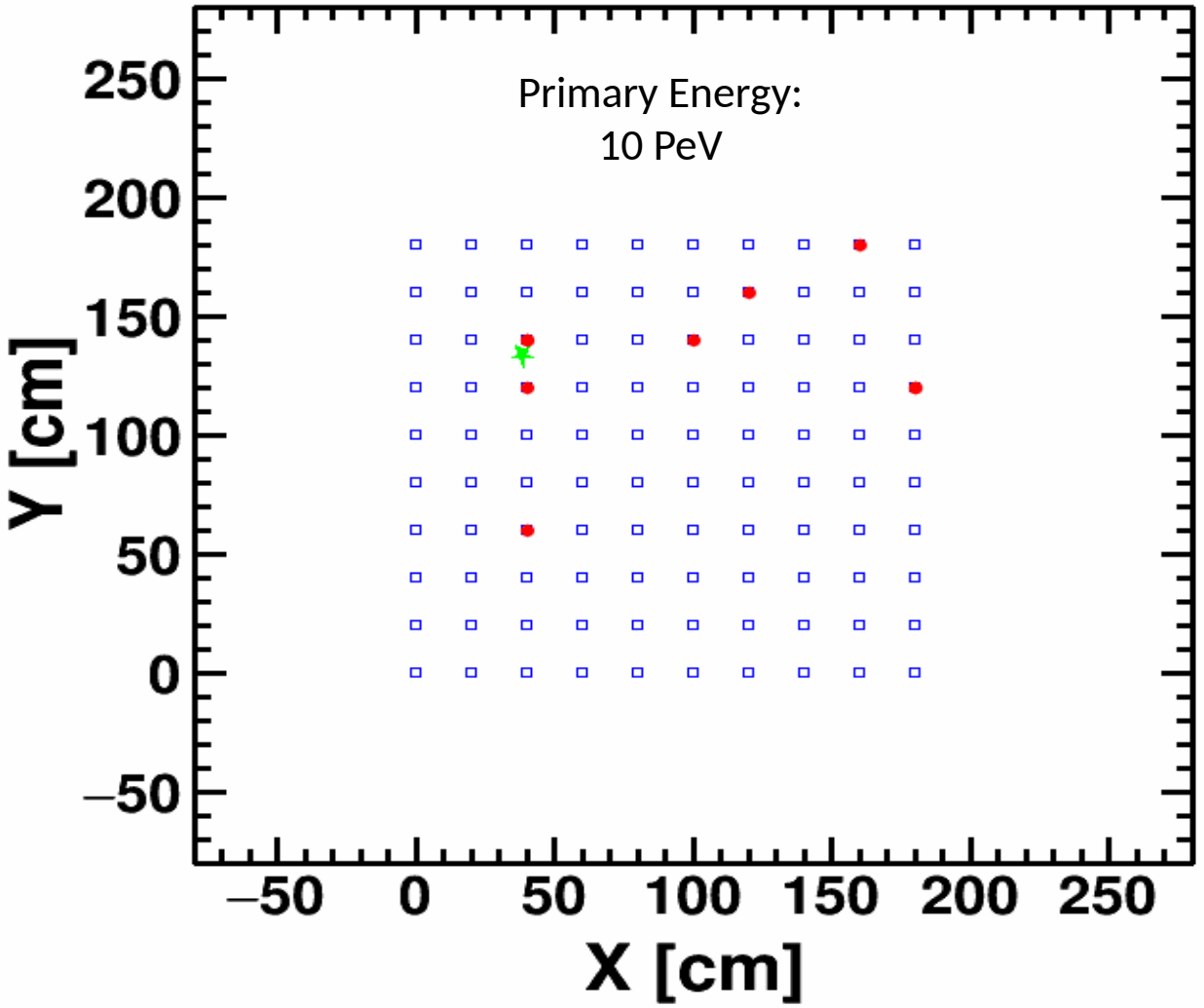




Credit: Tadeusz Wibig, CREDO

Smartphone camera sensor: Prospects of EAS

[It is assumed that all particles above 1 GeV are detected by the camera sensor]



Credit: Niraj Dhital, CREDO

It might be possible to detect extensive air showers with smartphone detectors, a component of CREDO.

CREDO

THE QUEST FOR THE UNEXPECTED

… Particle Hunters League and Marathon!

Not only for schools!

key work:

- Sławomir Stuglik (CREDO)

- Jarosław Szczepaniak (teacher)

- Jolanta Sulma (CREDO, teacher)

CREDO
THE QUEST FOR THE UNEXPECTED

… Particle Hunters League and Marathon!

Not only for schools!

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
ŁazyGalactic	2857
credogosia	2773
FASOLKI	2556
Nakielanie	2506
lonisko	2385

March 2019: ~ 1200 participants from ~ 60 schools!

CREDO

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

fot. Ireneusz Kochanek / FILMNET

CREDO Memorandum of Understanding

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 (8)
- Russia (1)
- Slovakia (1)
- Ukraine (2)
- USA (3)

OPEN to all cosmic people/experiments at no cost/obligation!

(even if you are not ready/willing to share the data then you can only take data/tools to enrich your studies/outreach)

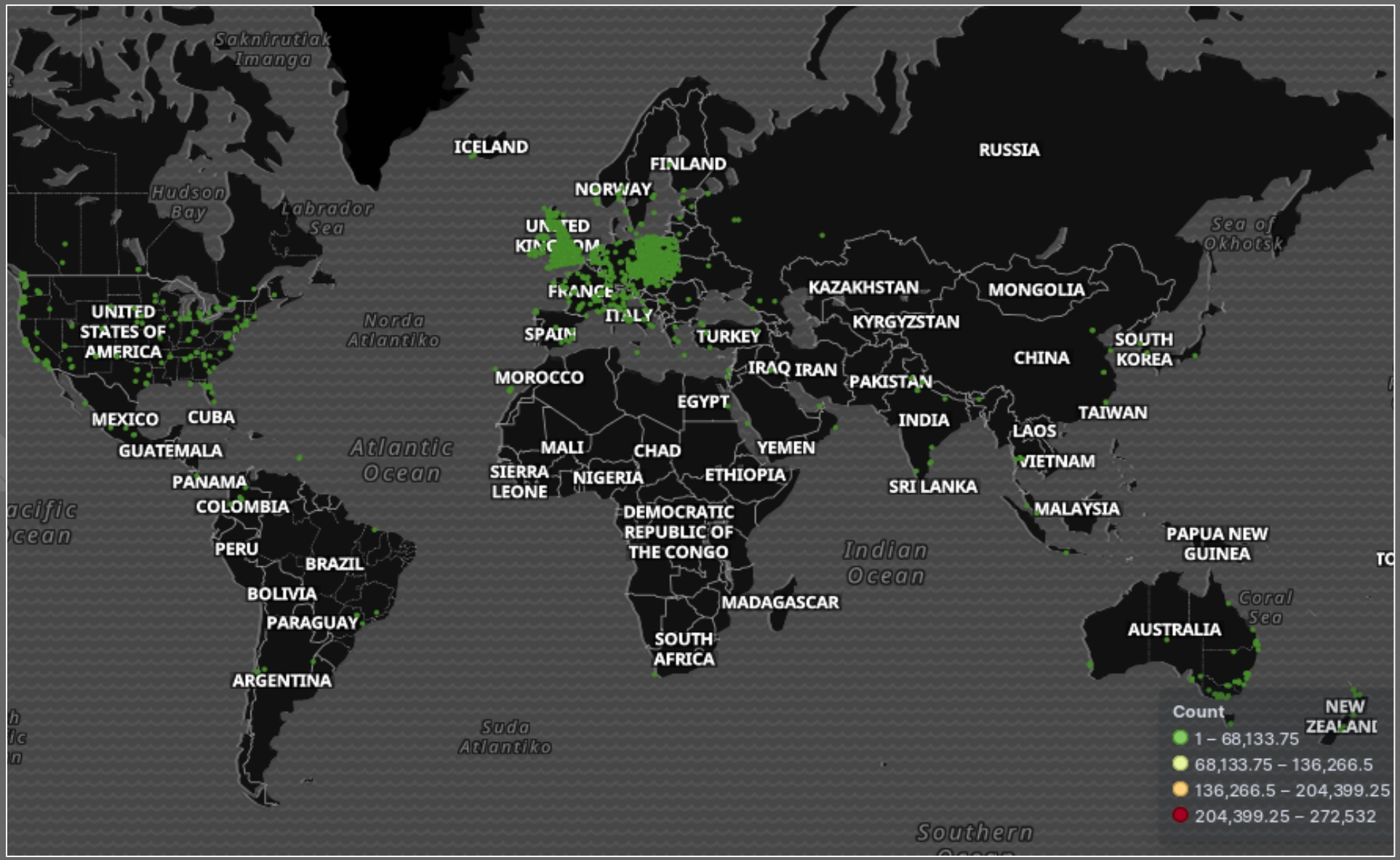
CREDO

THE QUEST FOR THE UNEXPECTED

Looking forward!

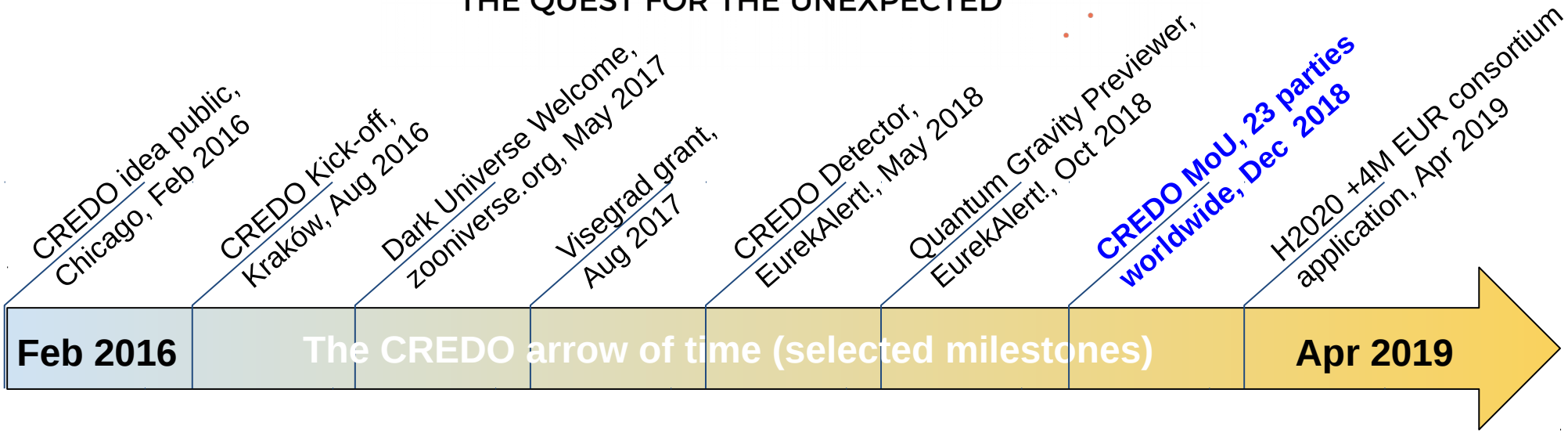
Extremely **D**istributed **O**bservatory

Location of users since the launch

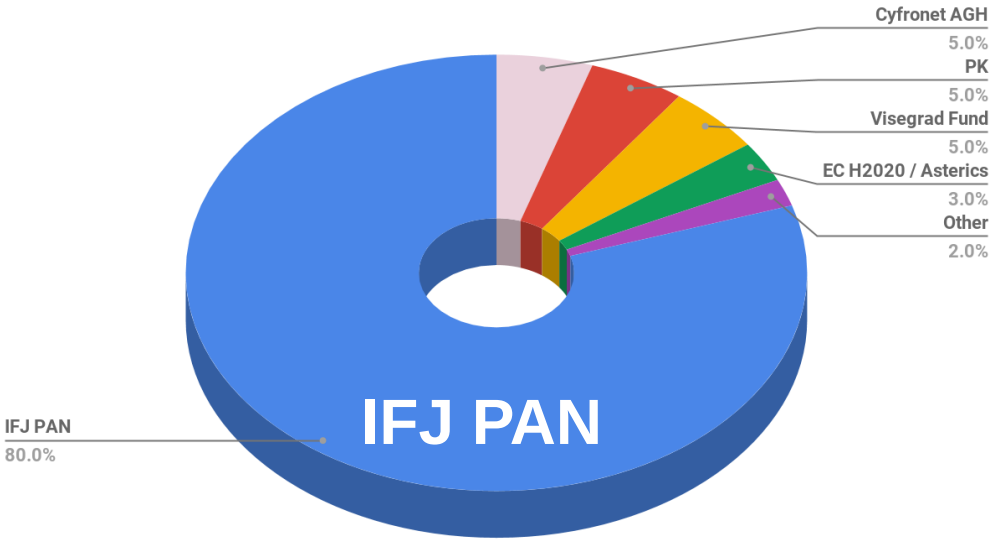


CREDO

THE QUEST FOR THE UNEXPECTED

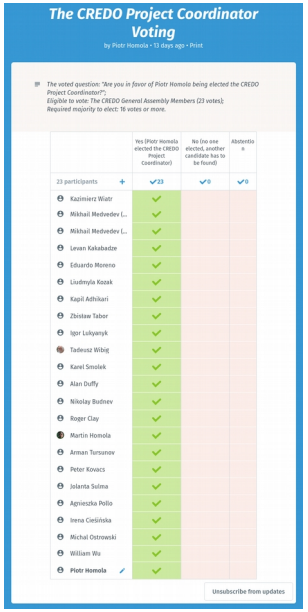


CREDO Investors



The CREDO Project Coordinator Voting by the CREDO General Assembly 31.01.2019:

Piotr Homola
(IFJ PAN)



$N_{CR} > 1$ scenarios motivated by data!

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

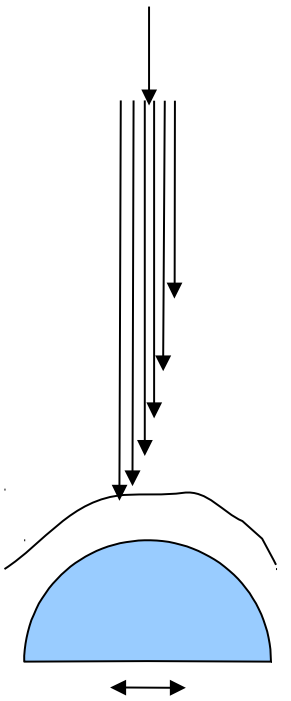
(Received 7 April 1983)

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 150 000 such showers in a period of 18 months between October 1980 and April 1982.

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

PH: Correlated cosmic rays?

$N_{CR} > 1$?



Year = 1981

$N_{obs} = 32$

$N_{exp} = 1$

$E = 3x10^{15}eV$

Δt ~5 min.

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THE QUEST FOR THE UNEXPECTED

Perspectives (5 years)

Infrastructure:

- Open hardware low-price sensor (2-3 years)
- First appearance on infrastructure roadmaps (2-5 years)
- First integrations with astro multi-messenger networks and open data clouds: LOD, AMON, GCN (2-5 years)
- **Reinforcement Learning System:** (2-5 years, PhD project ongoing)

Science:

- First publications (from now on)
- Identification of individual muons and air showers (1-2 years)
- CRE monitoring / alerts / limits (2-3 years)
- First interdisciplinary studies (2-3 years)

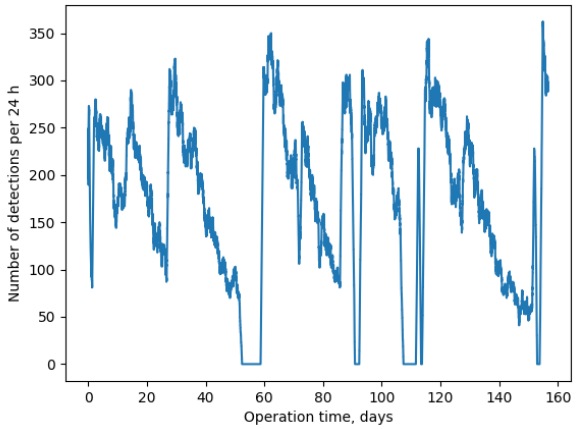
Education:

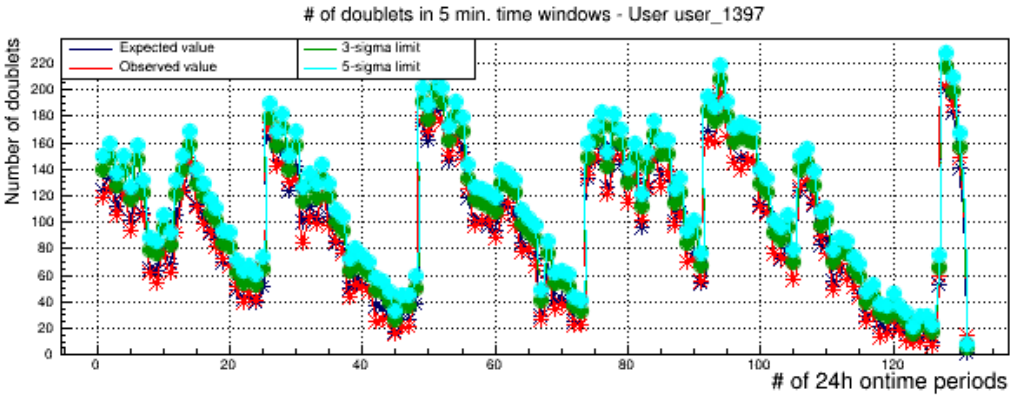
- Mass participation online experiments (from now on)
- First PhD (1-2 years)
- First governmental program with low-price sensors (2-3 years)
- Gamification system for user retention (2-3 years)

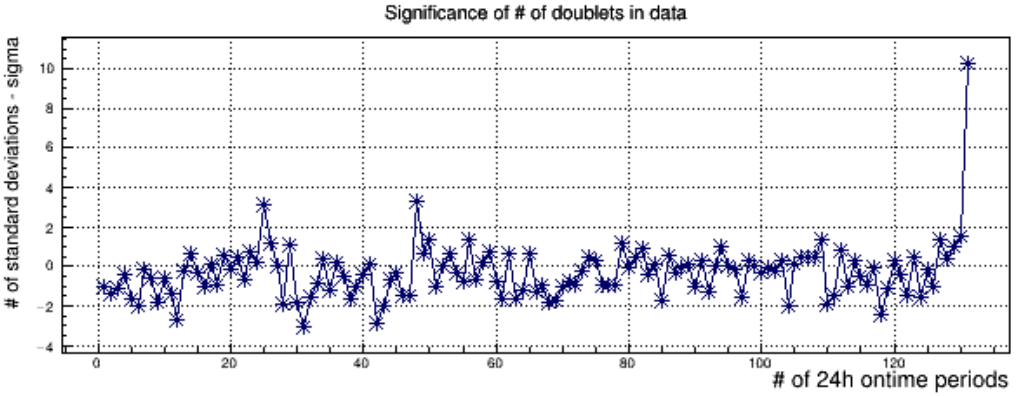
CREDO Monitor: the prototype automated alerting tool

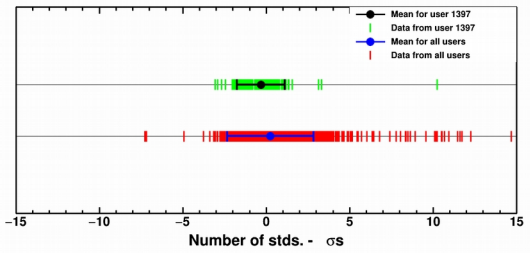
key work:

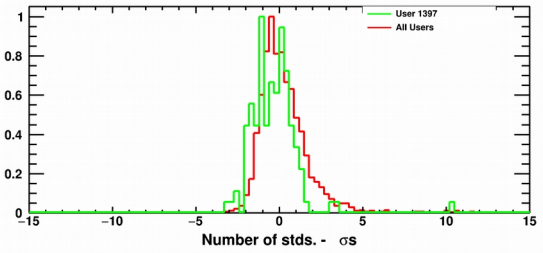
Kevin Almeida Cheminant, Oleksandr Sushchov, Dominik Ostrogórski







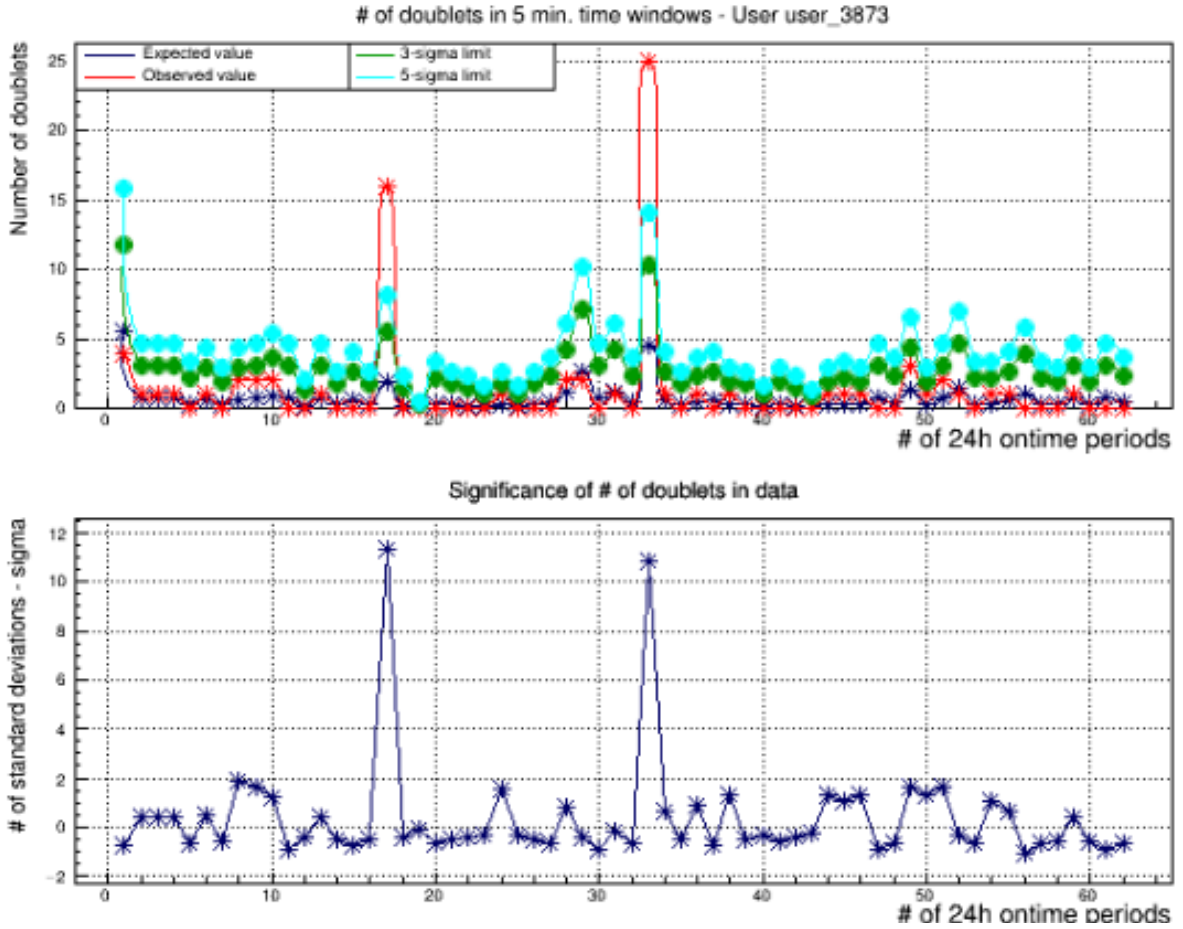




https://credo.science/quantum-gravity-previewer/
https://www.eurekalert.org/pub_releases/2018-10/thni-cfl100418.php

Quantum Gravity Previewer: online experiment!

Cumulative number of hit pairs („doublets”) within 5 min, in a single device



expected from random
observed

→ **10σ**

(significance)

by Kevin Almeida Cheminant, for the CREDO Collaboration

When do we see a cluster of arrivals?

4 October 2018: CREDO's first light!

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

EurekAlert! The Global Source for Science News | 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

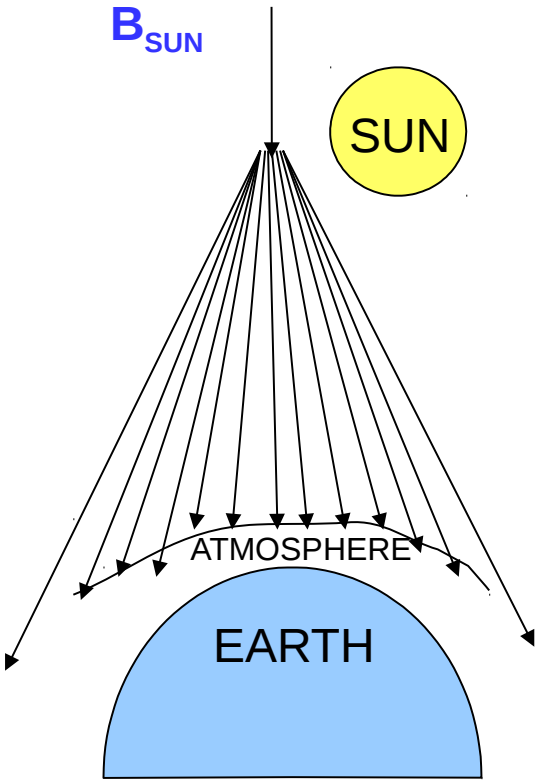
FUNDER
International Visegrad Fund (IVF)

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

Super-preshowers (SPS) from the vicinity of the Sun

γ_{UHE}

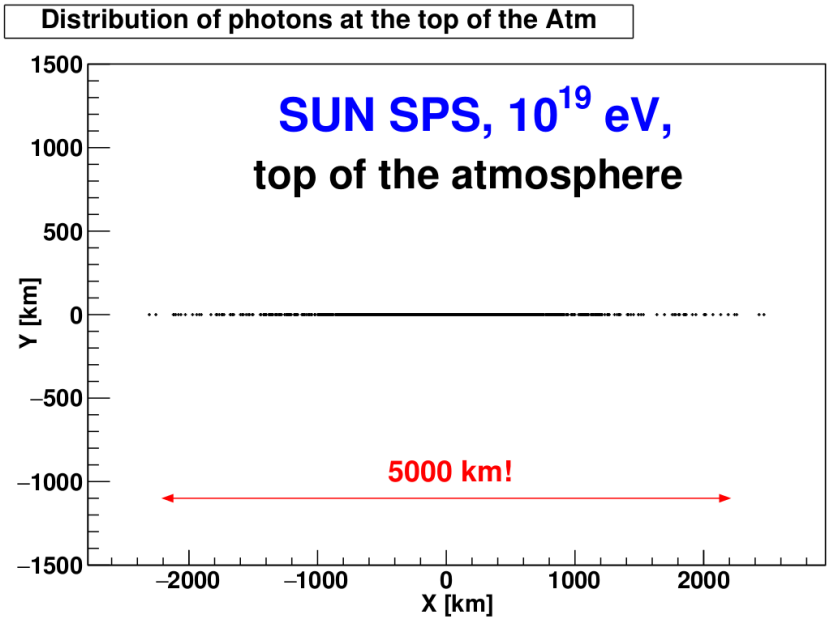
(e.g. 10^{20}eV)



[OUT OF SCALE :]

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

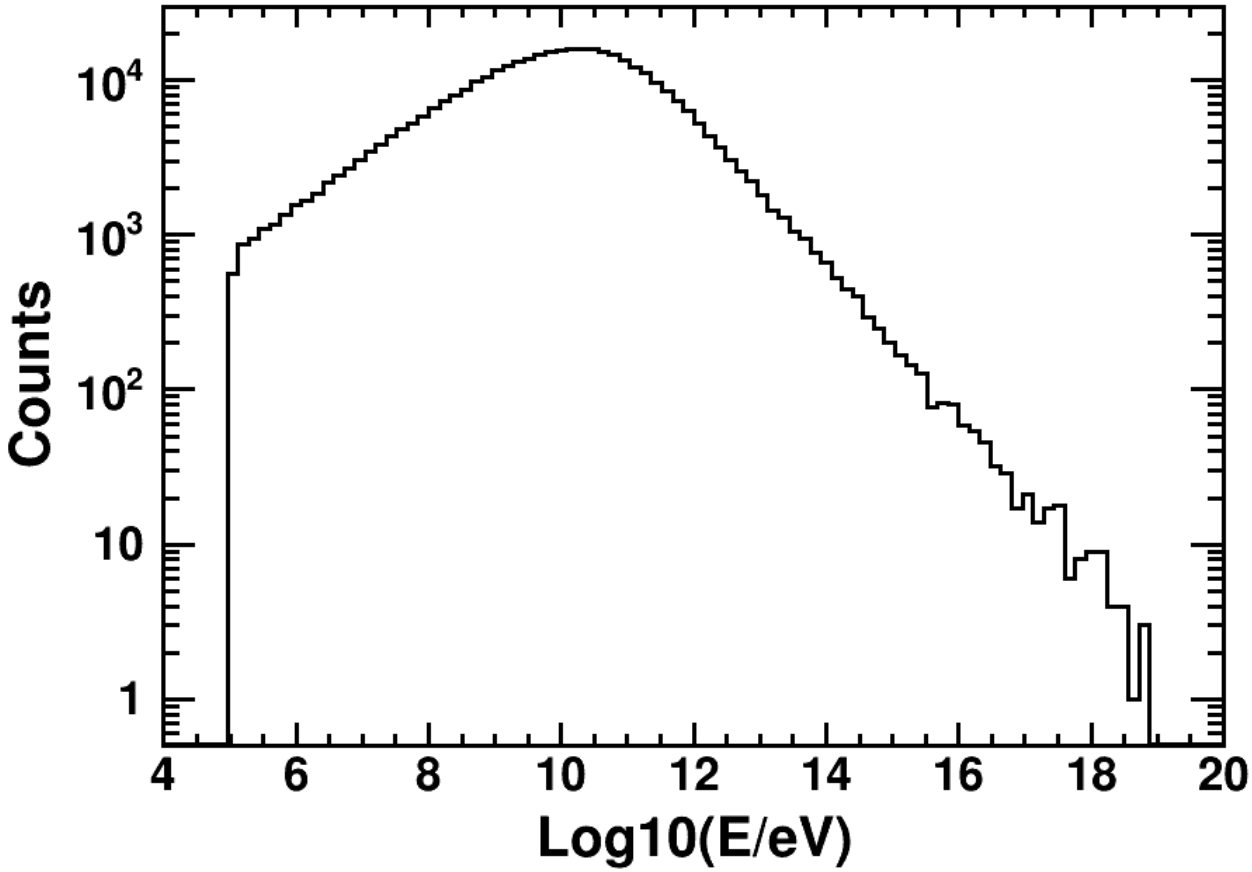
→ N. Dhital, 2018
complete energy spectrum: extent
~ thousands of km

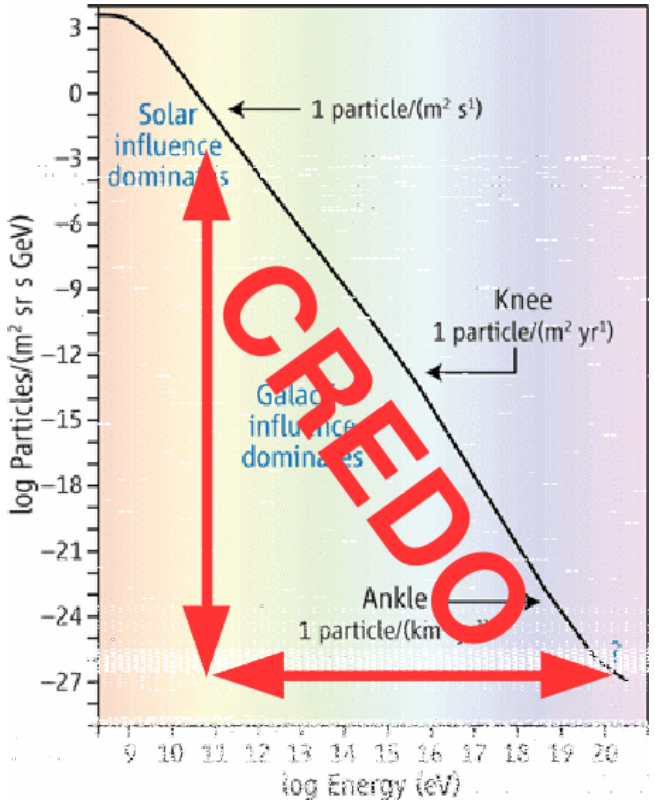


Distribution of photons ($E > 10^{13}$ eV) at the top of the atmosphere.
$E_\gamma = 10$ EeV, Impact parameter $= 2.5 R_S$.

$N_{CR} > 1$ → observable (line even 10000 km wide), **not yet tried**

Energy distribution of SPS photons

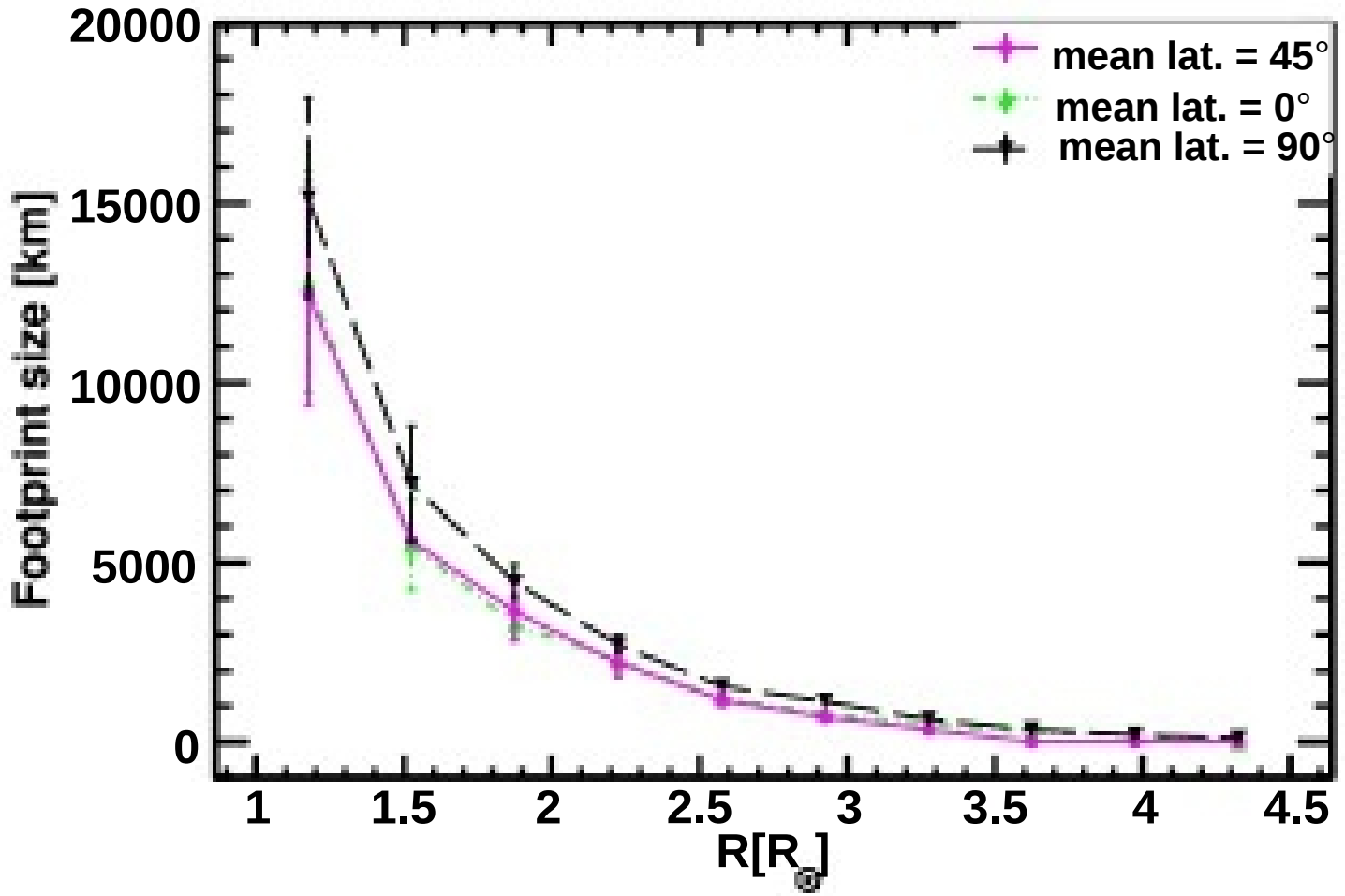




Energy Distribution of photons for the same SPS.

[a single event containing photons of energies spanning the whole cosmic-ray energy spectrum!]

Super preshower: A CRE scenario



Size of footprint of super-preshower at a distance of 1 AU from the Sun as a function of impact parameter for primary photon of energy 100 EeV.

Horizon for N_{CR}>1 : ~500 Mpc

Super preshower: A CRE scenario

status: submitted (https://arxiv.org/abs/1811.10334)

Air shower walls: yet not checked chance for unobserved physics in the available cosmic-ray signal and background data?

N. Dhital,[1,*] P. Homola,[1] D. Góra,[1] H. Wilczyński,[1] K. Almeida Cheminant,[1] G. Bhatta,[2] T. Bretz,[3] D.A. Castillo,[4] A. Cwiida,[5] A.R. Duffy,[6] B. Bluyik,[7] P. Jagoda,[8,*] M. Kasztelan,[9] K. Kopański,[1] P. Kovacs,[10] M. Kręglicki,[1] V. Nazari,[1] M. Niedźwiecki,[11] D. Ostrogórski,[1] K.Smelcey,[12] K. Smolek,[13] J. Stasielak,[1] O. Sushchov,[1] T. Wibig,[14,15] K. Woźniak,[1] J. Zamora-Saa,[16] and B. Zinchenko[10]

(The CREDO Collaboration)

[1]*Institute of Nuclear Physics PAN, Cracow, 31-342, Poland*
[2]*Astronomical Observatory of the Jagiellonian University, 30-244 Cracow, Poland*
[3]*RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany*
[4]*Joint Institute for Nuclear Research, Dubna, Russia*
[5]*Cracow University of Technology, 31-155 Cracow, Poland*
[6]*Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Hawthorn, VIC 3122, Australia*
[7]*Astronomical Observatory of Taras Shevchenko National University of Kyiv, Kyiv 03053, Ukraine*
[8]*AGH University of Science and Technology, 30-059 Cracow, Poland*
[9]*National Centre for Nuclear Research, 05-400 Otwock-Świerk, Poland*
[10]*Institute for Particle and Nuclear Physics Wigner Research Centre for Physics, Hungarian Academy of Sciences, H-1525 Budapest, Hungary*
[11]*Institute of Telecomputing, Faculty of Physics, Mathematics and Computer Science, Cracow University of Technology, 31-155 Cracow st., Poland*
[12]*Institute of Telecomputing, Faculty of Physics, Mathematics and Computer Science, Cracow University of Technology, 31-155 Cracow, Poland*
[13]*Institute of Experimental and Applied Physics, Czech Technical University in Prague, Prague, Czech Republic*
[14]*University of Łódź, Faculty of Physics and Applied Informatics, 90-236 Łódź, Poland*
[15]*Cosmic Ray Laboratory, Astrophysics Division, National Centre for Nuclear Research, 90-236 Łódź, Poland*
[16]*Universidad Andres Bello, Departamento de Ciencias Físicas, Facultad de Ciencias Exactas, Avenida República 498, Santiago, Chile*

Propagation of ultra-high energy photons in the solar magnetosphere gives rise to cascades comprising thousands of photons. We study the cascade development using Monte Carlo simulations and find that the photons in the cascades are spatially extended over hundreds of kilometers as they arrive at the top of the Earth's atmosphere. We compare results from simulations which use two models of the solar magnetic field, and show that although signatures of such cascades are different for the models used, for practical detection purposes in the ground-based detectors, they are similar.

A paper on the simulation results submitted to a peer reviewed journal.

Another paper on the simulation program in preparation.

Smartphone camera sensor: Prospects of EAS

2019-04-09 11:14:23.744	
2019-04-09 11:11:25.251	
2019-04-09 11:11:25.251	
2019-04-09 11:07:38.481	

How likely is it to have multiple particles from a shower simultaneously hitting a camera sensor?

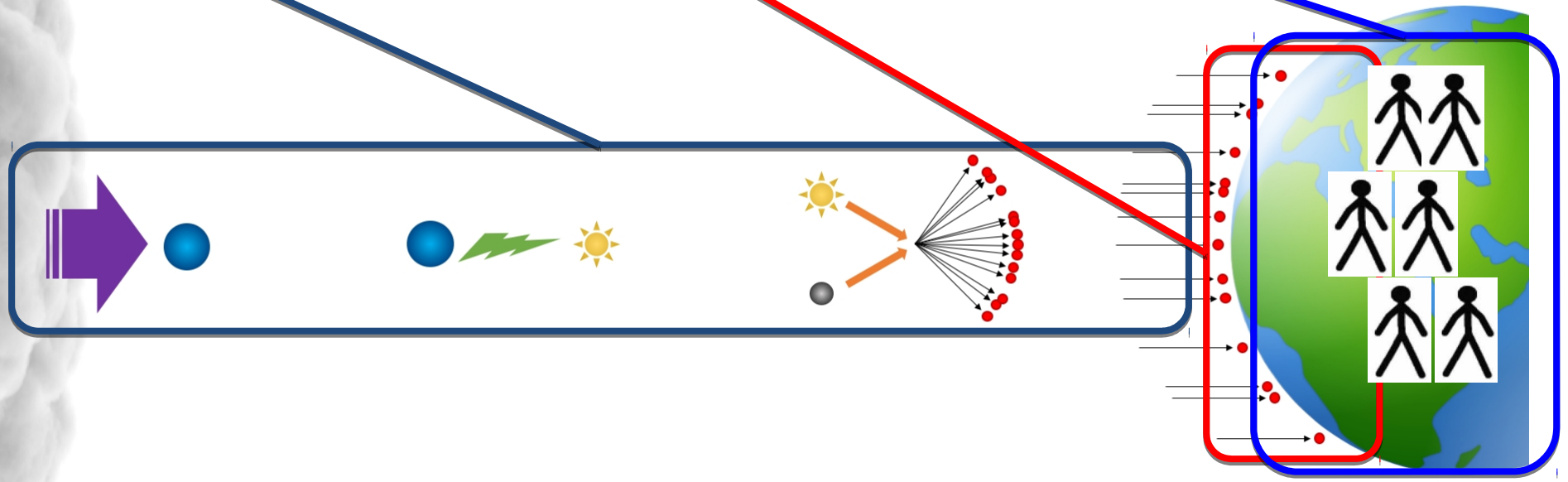
CREDO
THE QUEST FOR THE UNEXPECTED

The sequence

CRE Scenarios / Simulations

data

Public engagement (scaling up)



Super Massive Particles formed in the early Universe

Super massive particle decays to a very high energy photon

High energy photon collision creates lots of low energy photons

Low energy photons in a super-preshower are detected on the Earth

CREDO

THE QUEST FOR THE UNEXPECTED

… Particle Hunters and anti-artifact filters … and CIR (CREDO Internal Report) repository

CIR-003-2019

Histogram analysis of detections based on pixel values in the grayscale

CIR(CREDO Internal Report)-003-2019

S.Stuglik[1,2], P.Homola[1]

[1] *Institute of Nuclear Physics PAN, Cracow 31–342, Poland*
[2] *Pedagogical University of Cracow, Cracow 30–084, Poland*

1. Introduction

The purpose of this report is to analyse the already available CREDO Detector [1] dataset in order to deliver the prototype anti-artifact filters. While we keep on saving all the data sent to the server by the app, it is essential to distinguish between the tracks that are likely to be produced by penetrating radiation (cosmic or local, with properly covered cameras) and the artifacts produced, either unintentionally or by purpose, using visible light (uncovered cameras), or other "solutions". Our analysis is the first step in this direction: we propose universal and simple filter thresholds as the first approximation to data cleaning, hoping that the next, more advanced approaches will come soon. Certainly, given the technological variety of the smartphone detector cloud universal filters cannot be considered a final solution: thresholds that are tuned to one device might completely block signal in the other, nevertheless we consider our analysis useful: it helps to understand the data set as a whole and better plan the improvements. The cost of simplicity is mainly related to cutting off some real radiation-made tracks - we agree on that keeping in mind that these tracks are not lost and they can be re-admitted to the visible data set with the new generation anti-artifact algorithms. We encourage everyone to contribute to the improvements of these algorithms. We also emphasize that all the

When the mean of all detections was calculated, the first histogram was produced, showing that most of the detections have an average value less than 20/25. However, the charts of individual devices showed how varied the average detection values of users depending on the device. Therefore, the first brightness threshold has been set to 50 (2x max).

The next value that can be obtained in the detection analysis is the value of its brightest pixel (the following histogram).

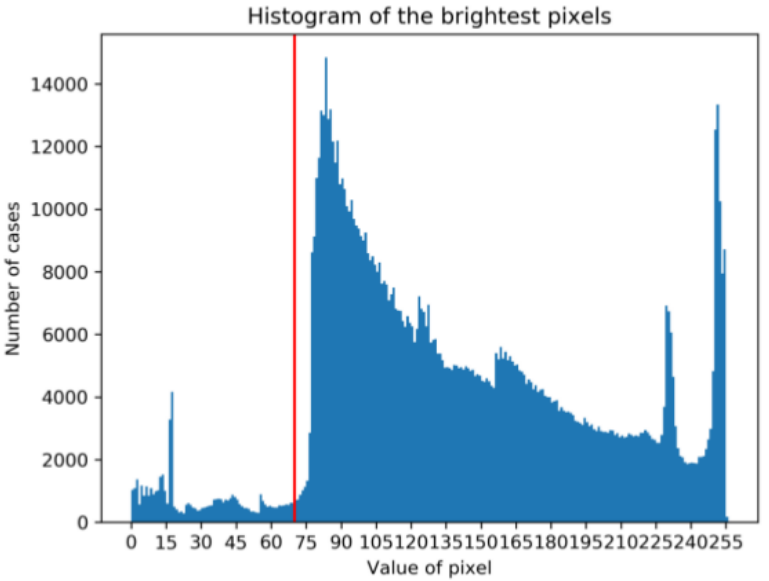
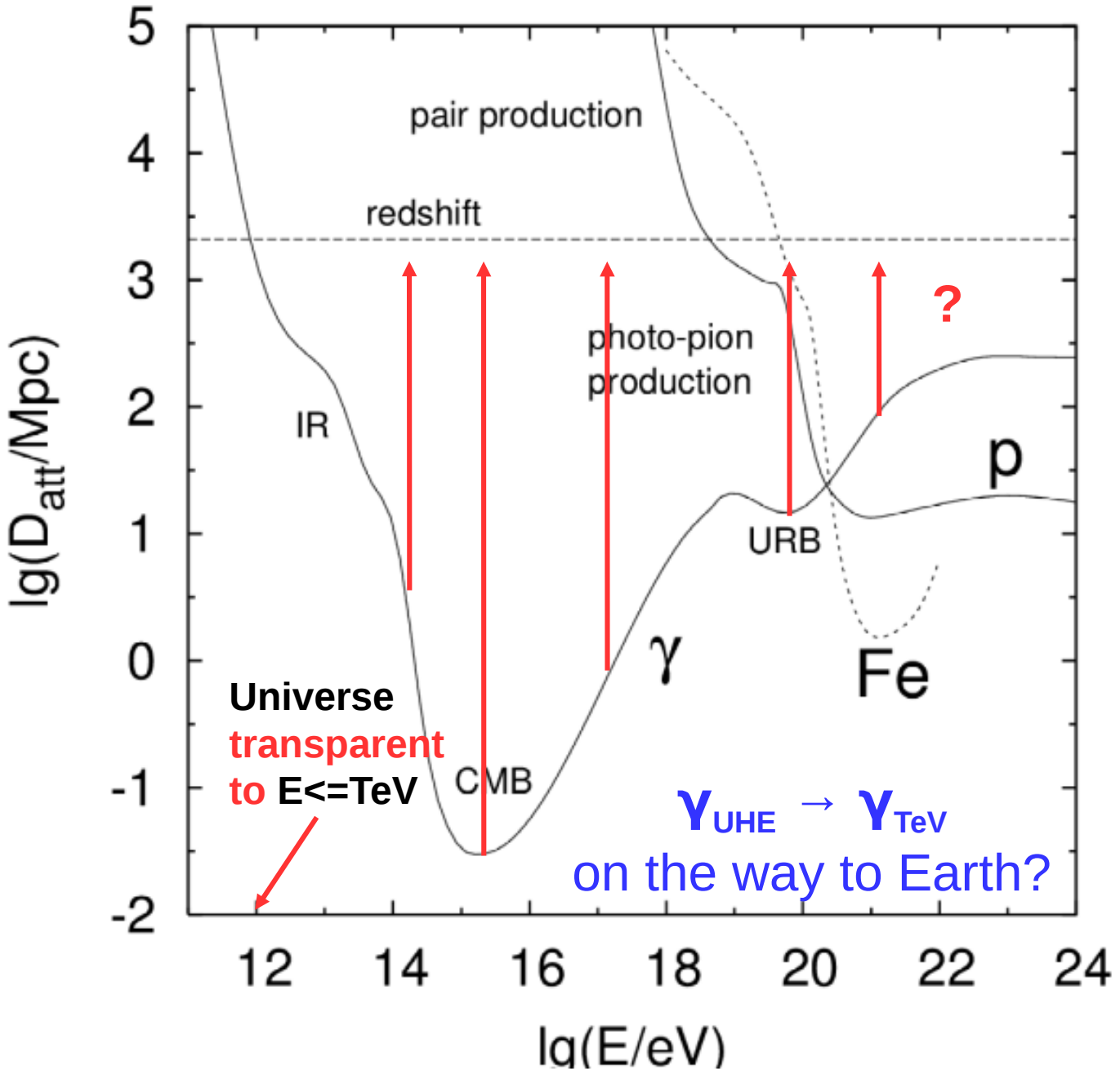


Fig. 3 Histogram of the brightest pixel for all users

The CREDO Journey by **Sławek Stuglik** @ IFJ PAN:

2016: Summer practice (P. Homola) -> 2017 Eng. Thesis (K. Woźniak) -> 2018 Employment (R. Kamiński) -> 2019 MSc Thesis (ongoing, P. Homola) -> ? PhD studies considered

CRE horizon?


pair production
redshift
photo-pion production
IR
CMB
URB
?
p
γ
Fe
Universe transparent to E<=TeV
γUHE → γTeV on the way to Earth?
lg(Datt/Mpc)
lg(E/eV)
5
4
3
2
1
0
-1
-2
12
14
16
18
20
22
24

Smartphone camera sensor: Prospects of EAS

With a sampling frequency of 20 frames/sec, expected number of random muons per frame in a typical smartphone camera sensor (area 0.25 cm^2) is

$$1\ min^{-1}cm^{-2} \times 0.25cm^2 \times 50ms = 0.0002$$

Assuming the CREDO detector app runs all the time, in one year, expected number of doublets is

$$356 \times 24 \times 3600 \times 20 \times (1 - P(0) - P(1)) \approx 12$$

Flux of cosmic rays with $E > 10^{16}eV \approx 7$ per year per m^2 .

Flux of cosmic rays with $E > 10^{15}eV \approx 650$ per year per m^2 .

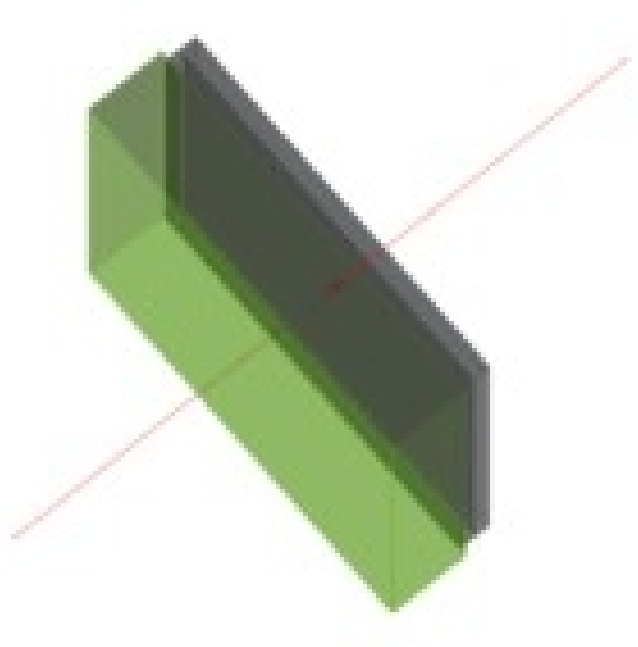
Have to check after simulations of low energy showers.

Will be updated after new simulations of low energy showers.

Smartphone camera sensor: Further Steps

Simulations of response of air shower particles with AllPix2.

- AllPix2: A generic, open source simulation framework for Si pixel detectors.
- Uses Geant4 for charge carrier deposition.
- Propagation of charge carriers in Si using a drift-diffusion model.

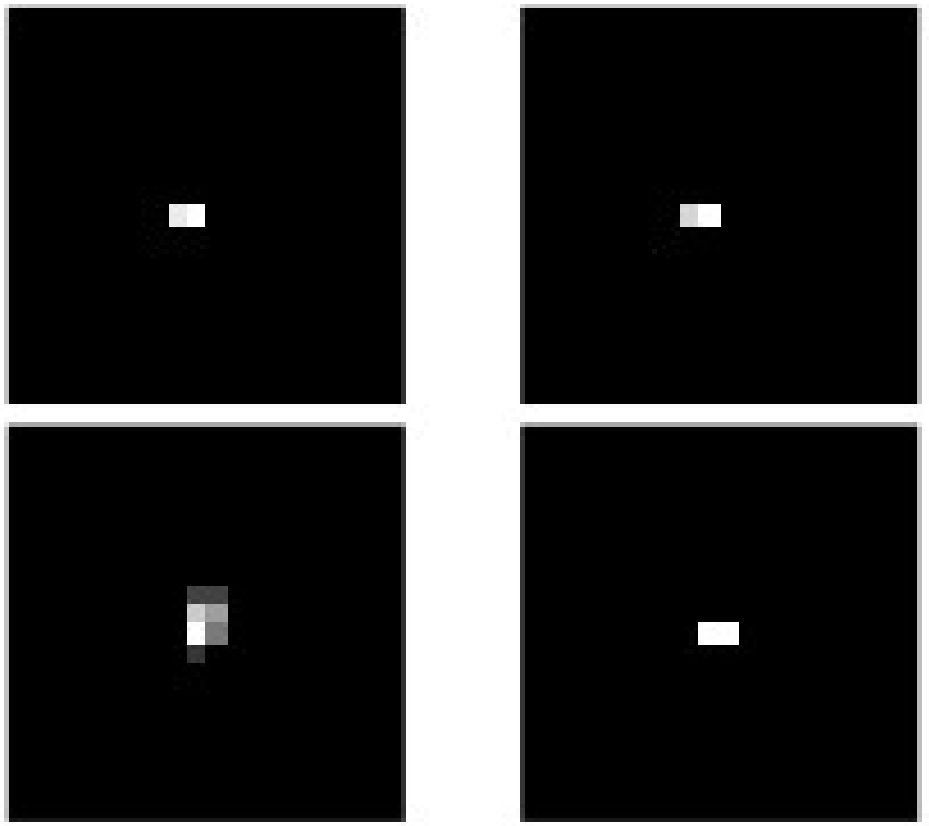


Simulation setup

Smartphone camera sensor: Further Steps

Simulations of response of air shower particles with AllPix$_2$.

Some examples of simulated muon hits in smartphone detectors.

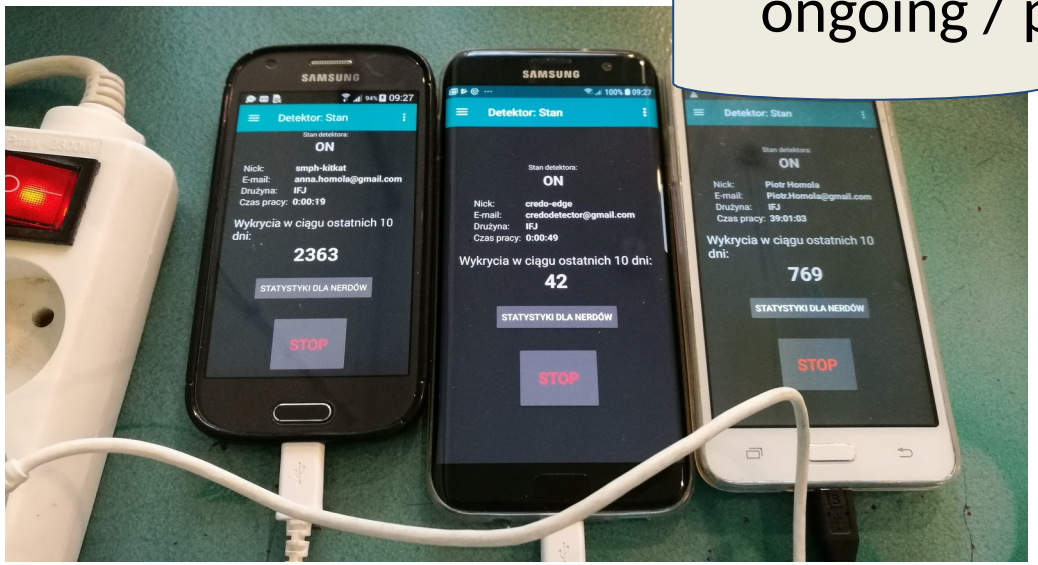


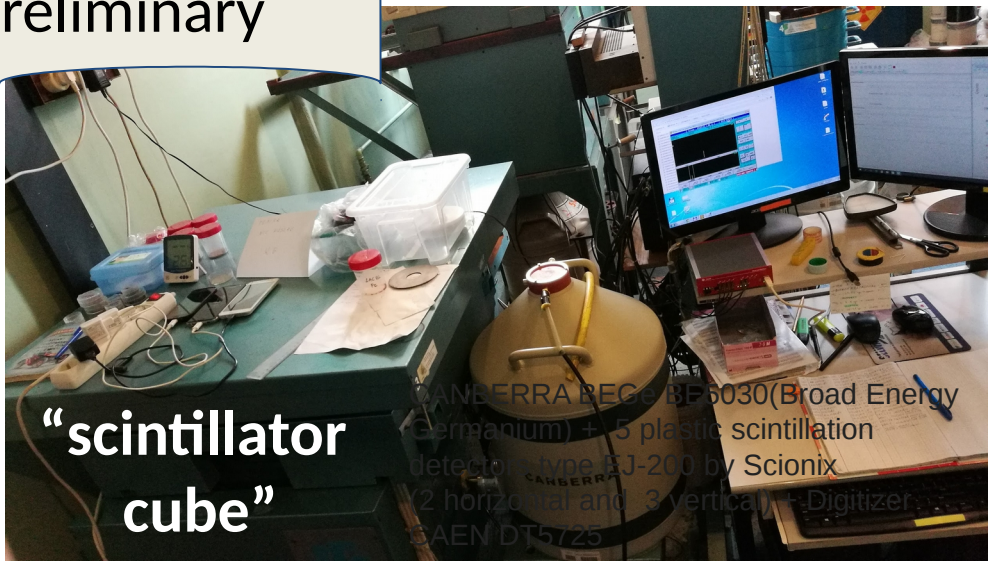
Simulation of response of cosmic ray particles to the camera sensors is feasible.

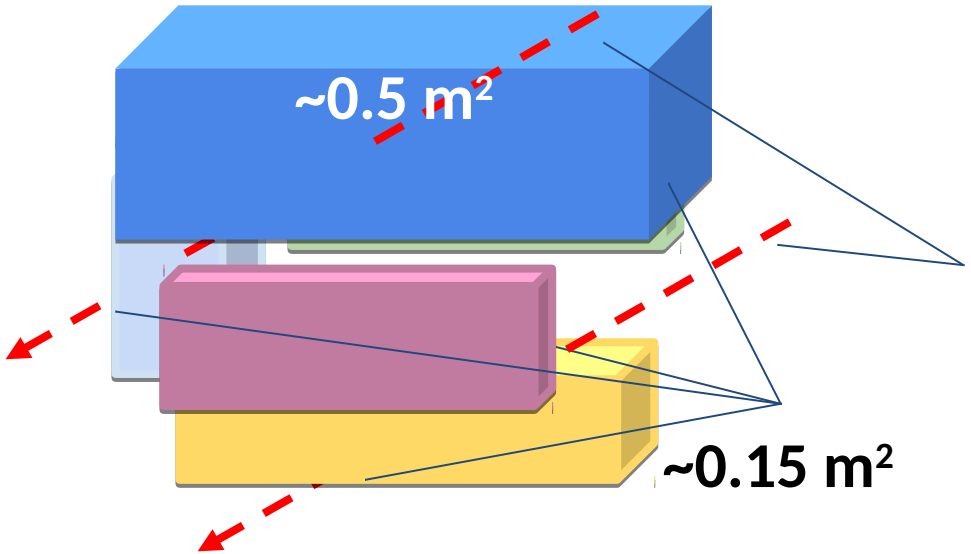
Smartphone detections: calibration for air showers and muons with scintillator plates

key work at IFJ PAN: Krzysztof Gorzkiewicz, Piotr Homola

ongoing / preliminary







Events registered simultaneously in at least 3 different detectors
= air showers (N_{muon}>1)

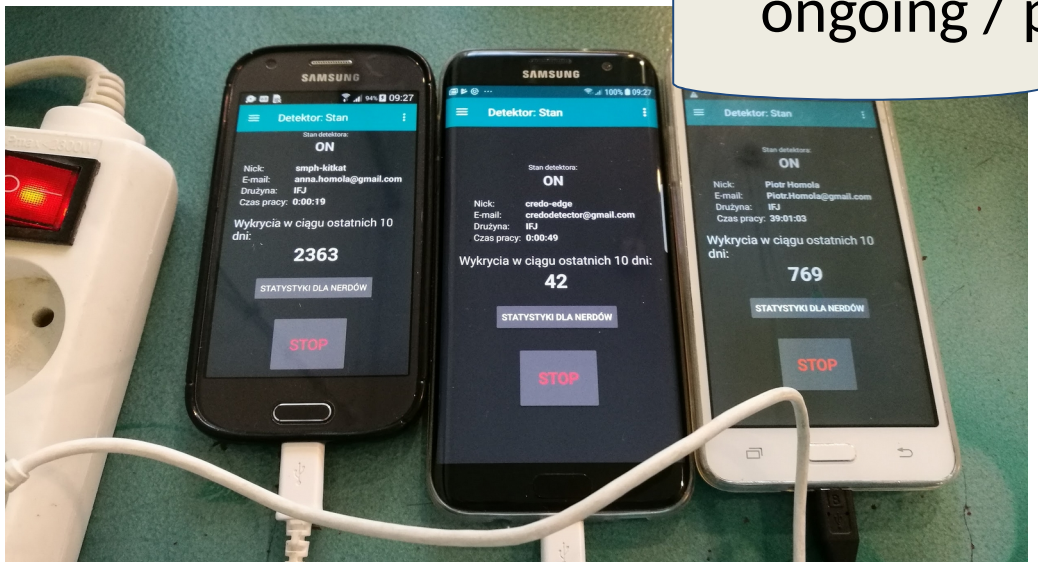
observed ~15000 / day

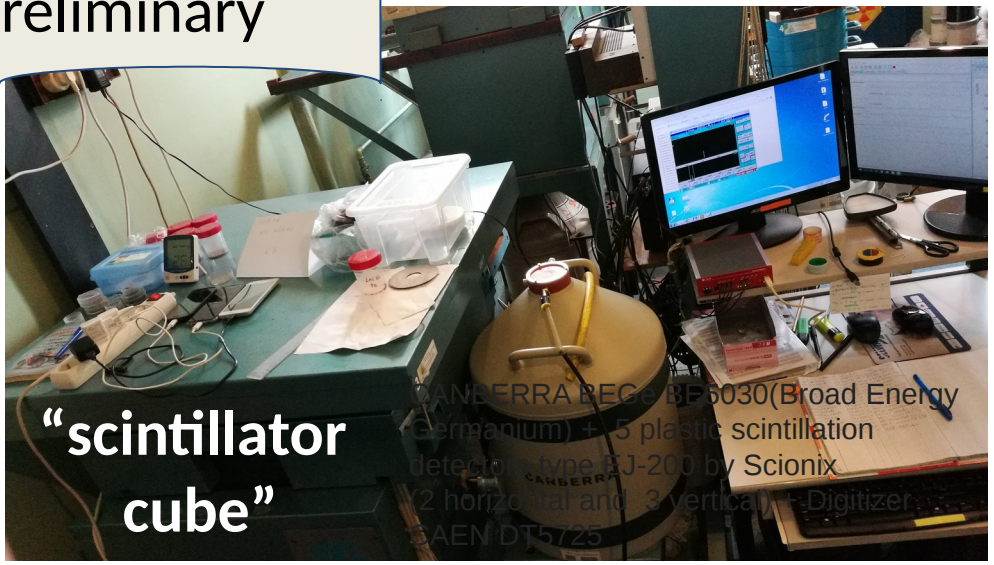
(cf. c.a. 10000 10^{12} eV air showers expected per m^2 per day, verifying with simulations in progress - N. Dhital)

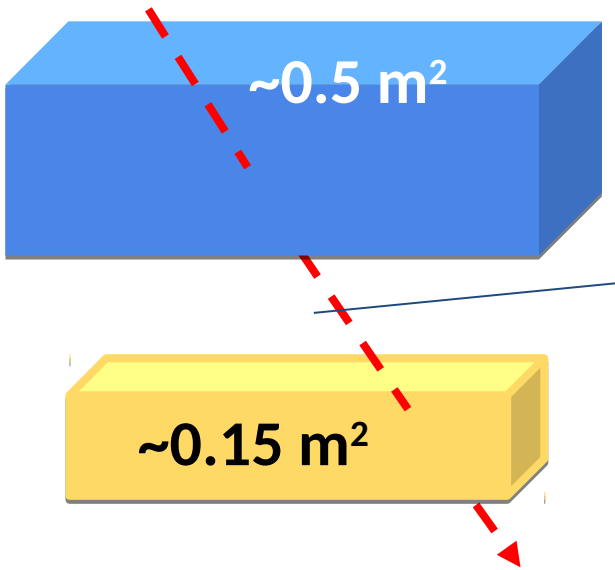
Smartphone detections: calibration for air showers and muons with scintillator plates

key work at IFJ PAN: Krzysztof Gorzkiewicz, Piotr Homola

ongoing / preliminary







Events registered simultaneously in the top and bottom detectors = air shower muons

observed ~400,000 / day

(compatible with background vertical muons expected per 0.15 m² per day, data analysis in progress - N. Dhital, P. Homola)

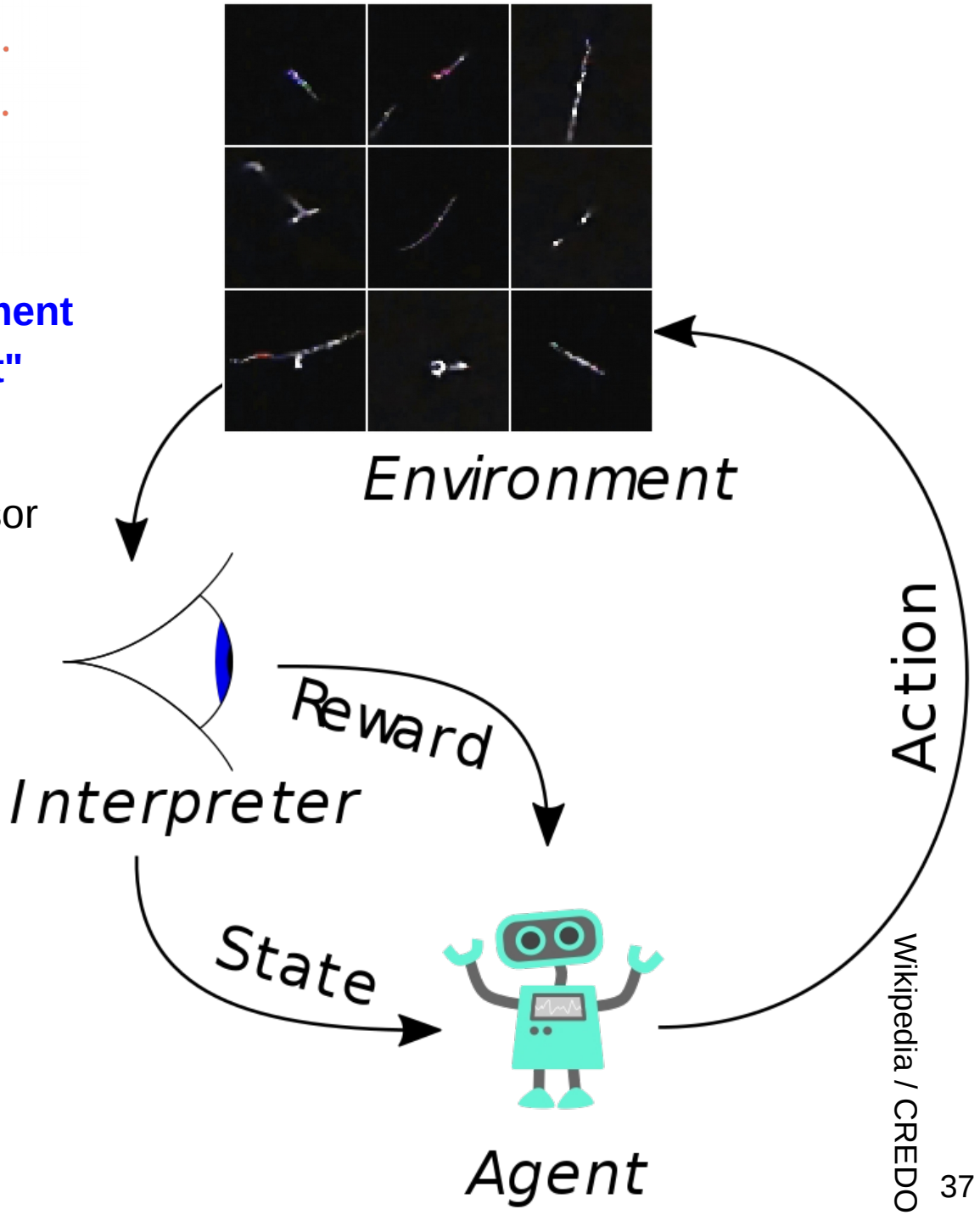
CREDO

THE QUEST FOR THE UNEXPECTED

"Citizen science support for reinforcement learning - a case of CREDO experiment"

Michał Niedźwiecki (PK) - PhD topic
Robert Kamiński (IFJ PAN) - supervisor
Krzysztof Rzecki (PK) - assistant supervisor

PhD/publication perspective: 24 months



Wikipedia:
machine learning paradigms:
- supervised learning
- unsupervised learning
- **reinforcement learning**

Wikipedia / CREDO