



CREDO: a global cosmic ray detection framework and its data processing challenges

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Outline

1. Motivation
2. Ultra High Energy Cosmic Rays (UHECR)
→ photons and superpreshowers
3. Generalizing UHECR detection strategy
4. CREDO (Cosmic Ray Extremely Distributed Observatory)
5. Computational challenges

UHECR - one mystery more

https://en.wikipedia.org/wiki/List_of_unsolved_problems_in_physics

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List of unsolved problems in physics

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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.

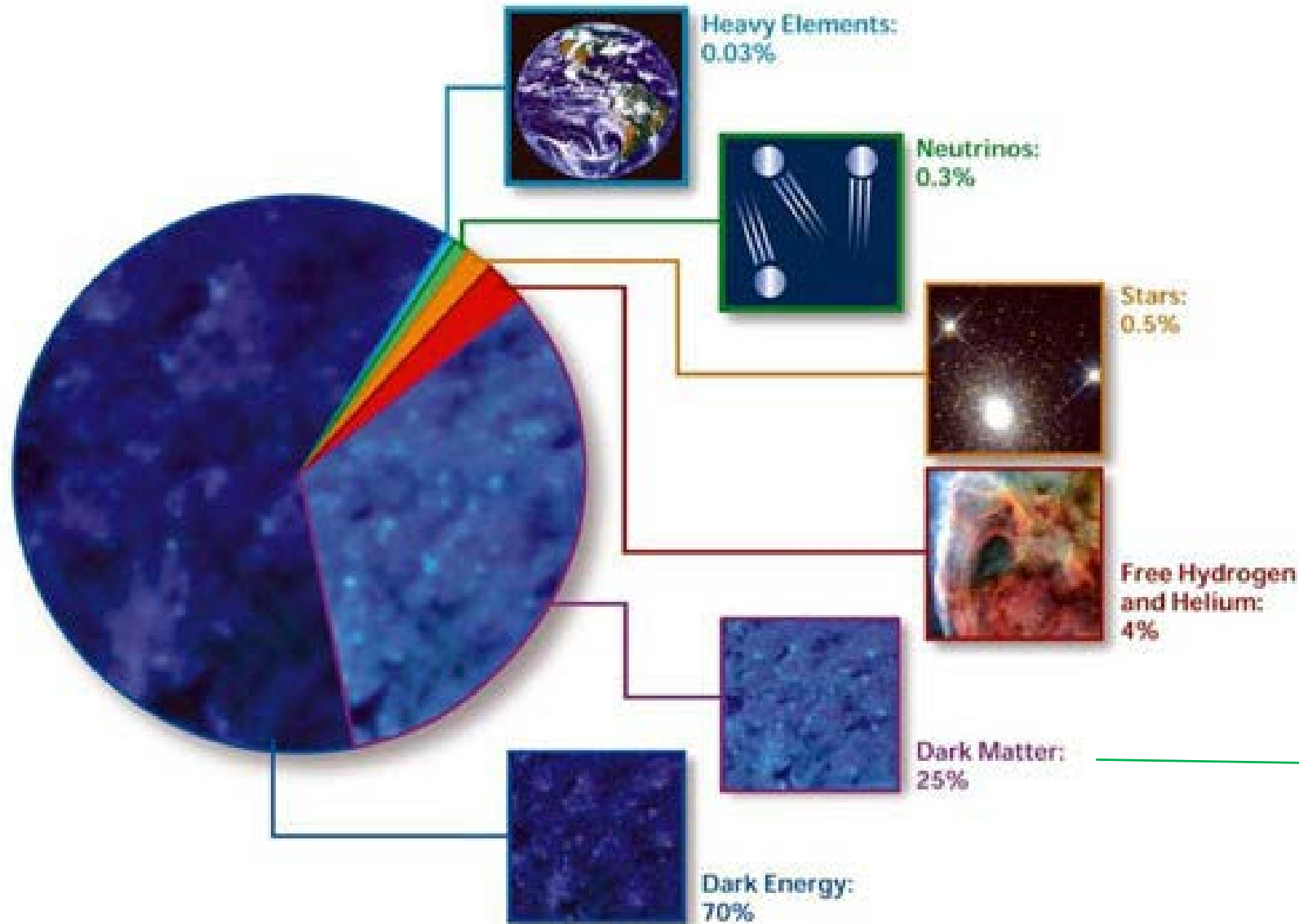
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- 1 Unsolved problems by subfield
 - 1.1 General Physics/Quantum Physics
 - 1.2 Cosmology and general relativity
 - 1.3 Quantum gravity
 - 1.4 High energy physics/particle physics
 - 1.5 Astronomy and astrophysics
 - 1.6 Nuclear physics
 - 1.7 Atomic, 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?"

COMPOSITION OF THE COSMOS



Indirect DM
search with
UHECR (Υ_{UHE} !)

Photons as UHECR: testing astrophysical scenarios

Bottom → Up: Astrophysical scenarios

acceleration of nuclei (e.g. by shock waves)

+ “conventional interactions”, e.g. with CMBR

- sufficiently efficient astrophysical objects difficult to find
- small fractions of photons and neutrinos – mainly nuclei expected

Top → Down: Exotic scenarios (particle physics)

Decay or annihilation the early Universe relics

→ hypothetic supermassive particles of energies $\sim 10^{23}$ eV

→ decay to quarks and leptons → hadronization (mainly pions)

large fraction of photons and neutrinos in UHECR flux

**DARK
MATTER!**

Experimental evidence about γ_{UHE}

γ_{UHE} $\xrightarrow{\text{no interactions / screening}}$ Earth

NOT OBSERVED

γ_{UHE} $\xrightarrow{\text{unexpected interactions, screening, ...}}$ ELECTROMAGNETIC CASCADES (SUPER-PRESHOWERS) \longrightarrow Earth

NOT TRIED SO FAR...

CREDO!

(Super-)preshowers: a must to study UHE photons

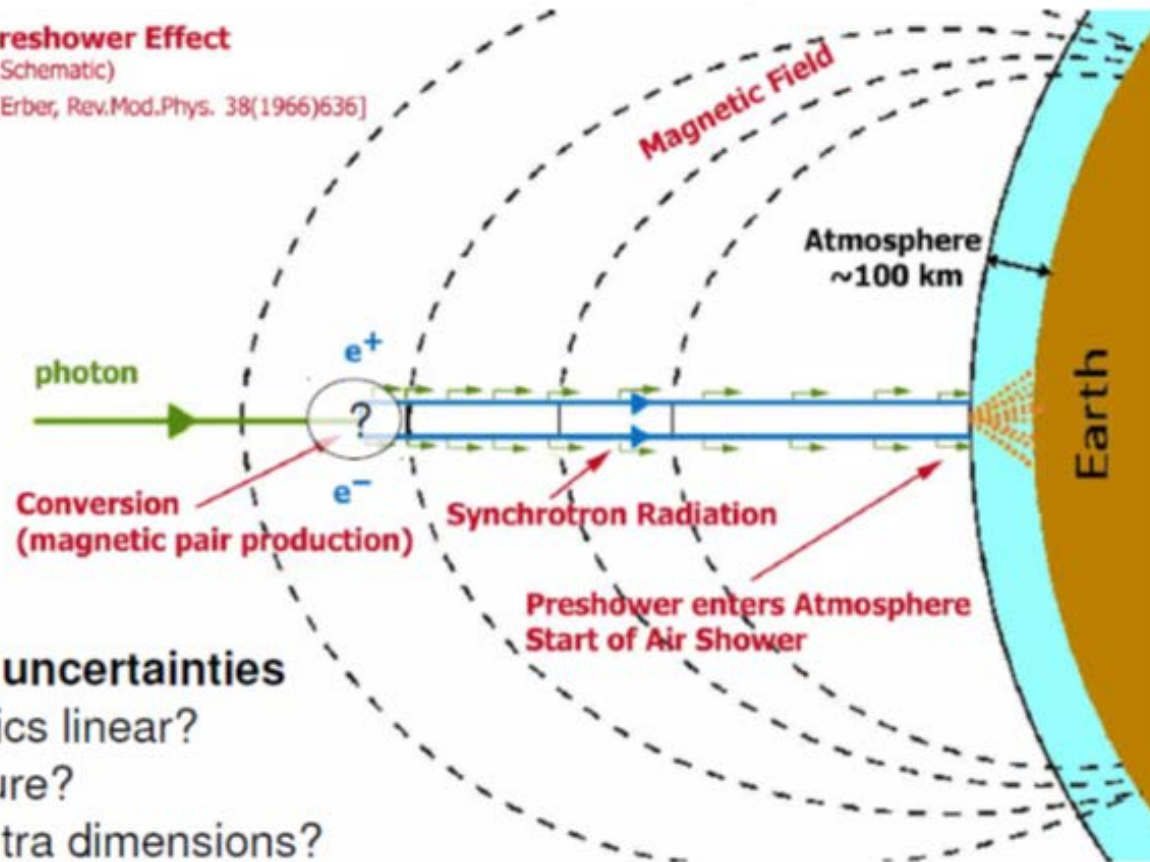
(super-)preshower:

- contains typically (**>1000**) 100 particles
- created at around (**>10000**) 1000 km a.s.l.

Preshower Effect

(Schematic)

[Erber, Rev.Mod.Phys. 38(1966)636]

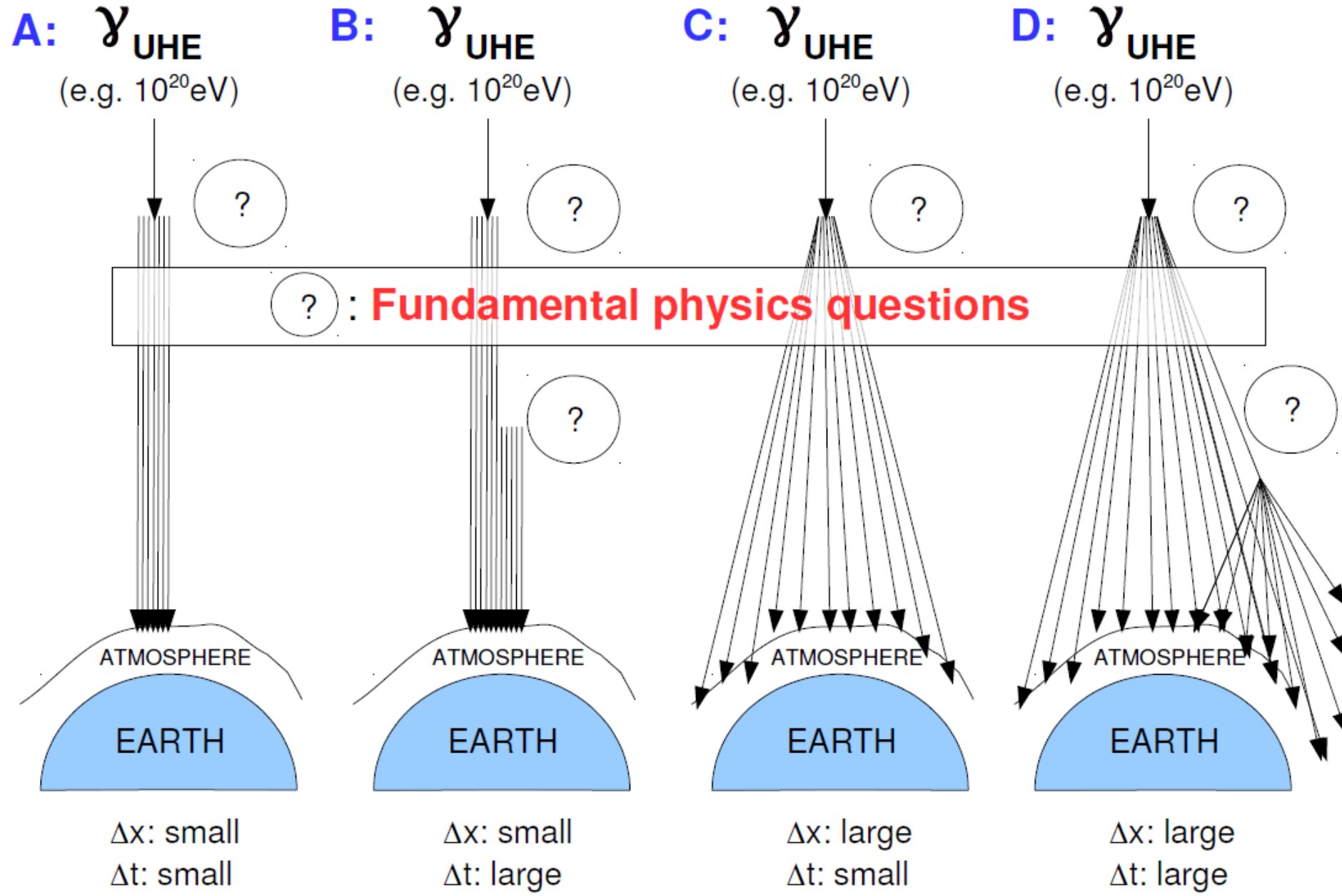


? : **fundamental uncertainties**

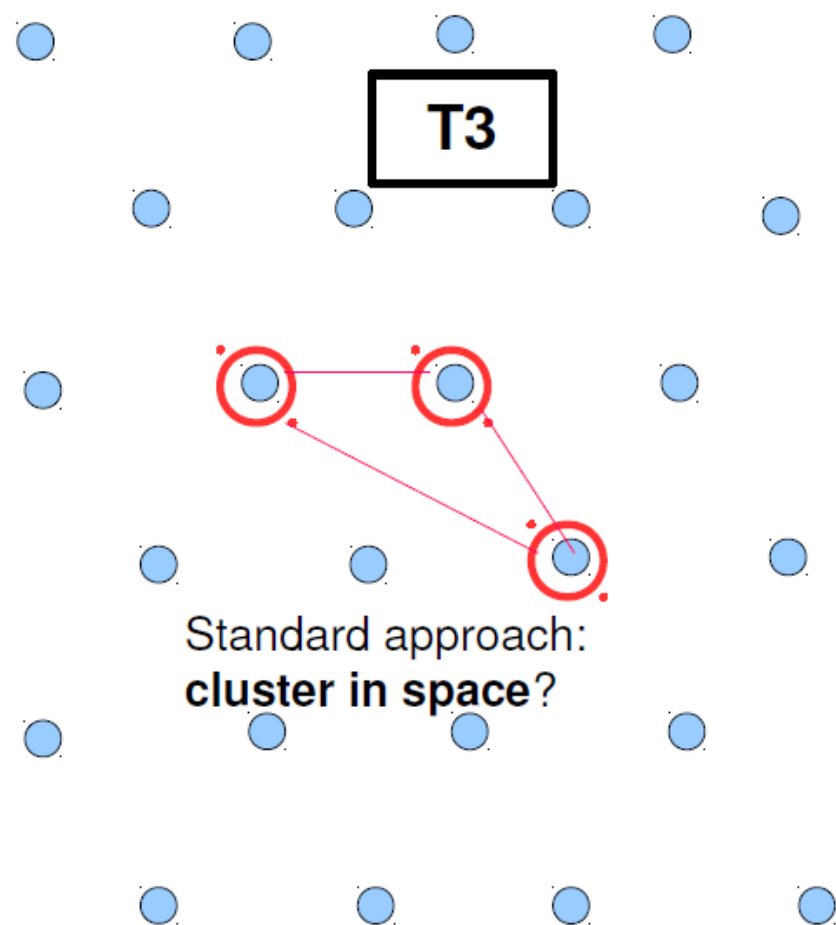
- electrodynamics linear?
- photon structure?
- spacetime: extra dimensions?

→ dependence on E and B_{\perp} (to be seen in data?)

Classes of super-preshowers

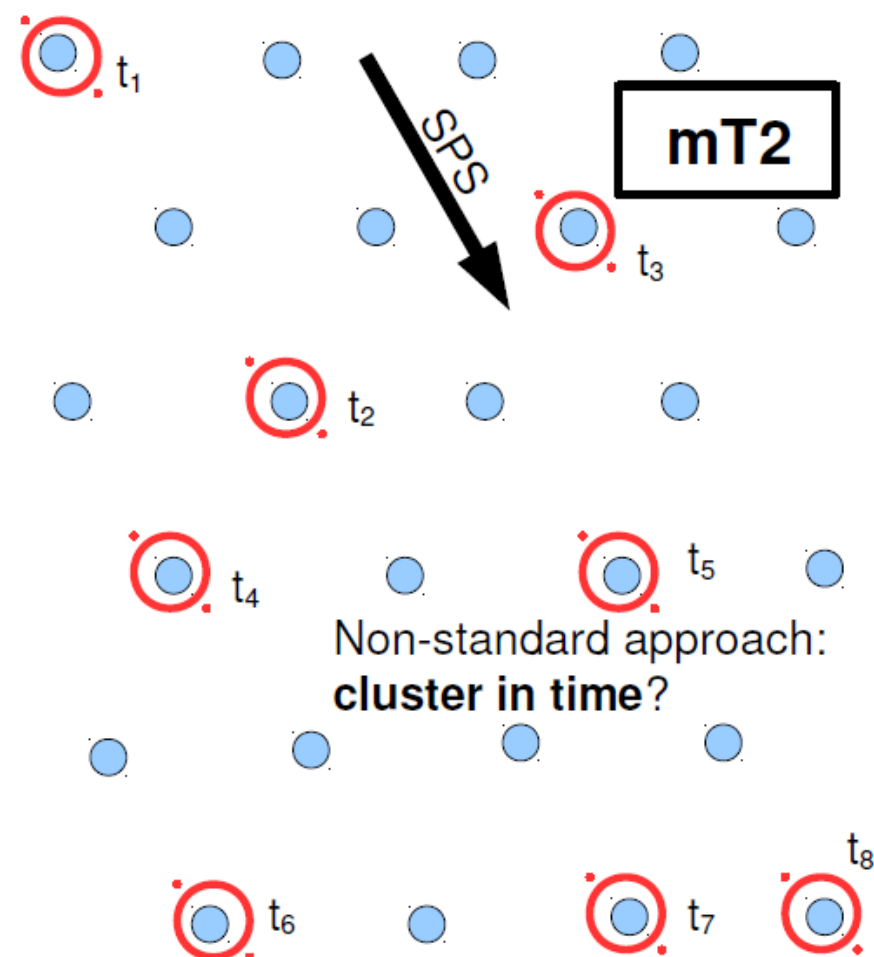


mT2: **NEW** easy trigger for super-preshowers



Standard approach:
cluster in space?

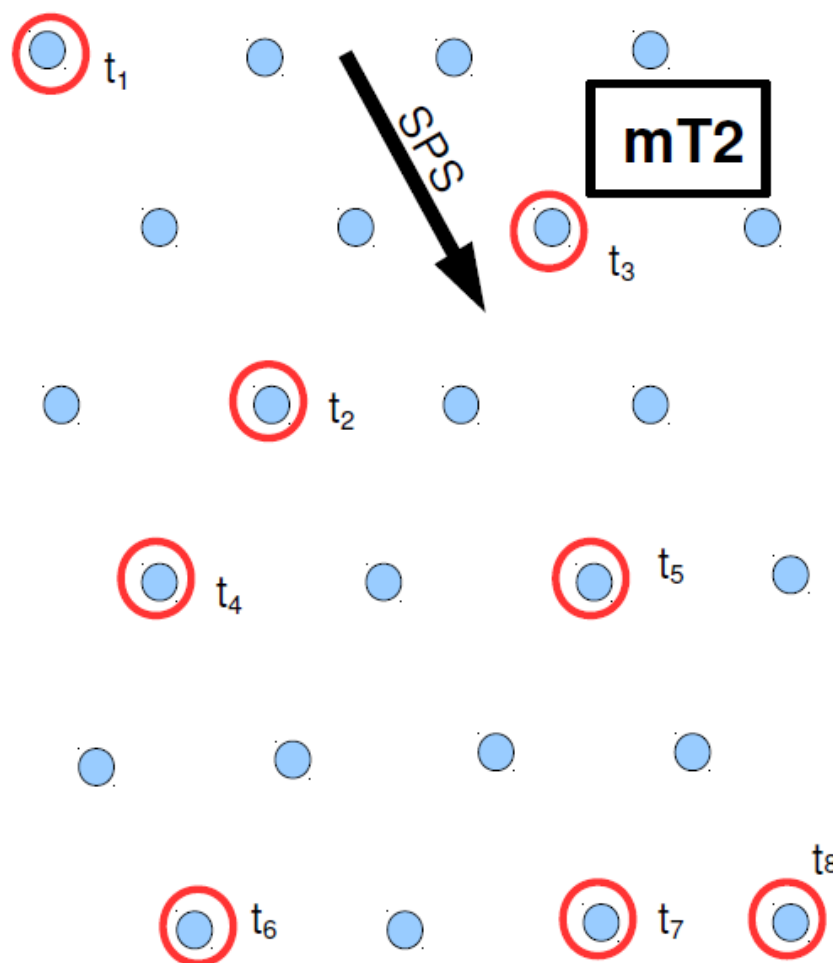
● : a cosmic-ray detector



Non-standard approach:
cluster in time?

- 1) $t_n - t_1 < \sim 1 \mu\text{s}$
- 2) $t_1 < \dots < t_n$

mT2: **NEW** easy trigger for super-preshowers



Chance for a statistical coincidence for $n=30$, assuming T2 rate 100 Hz:

$$P_{\text{acc}} = \sim 10/30! * 0.16^{30} = \text{ridiculously small chance}$$

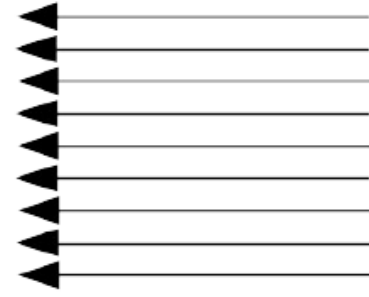
sensitivity to $n_{\text{LOW}} < n < 30$
 $n_{\text{LOW}} = ?$

mT2: easy implementation,
no hardware manipulation,
no risk, ... → **why not?**

→ **unique signature**
(of New Physics?)

CREDO

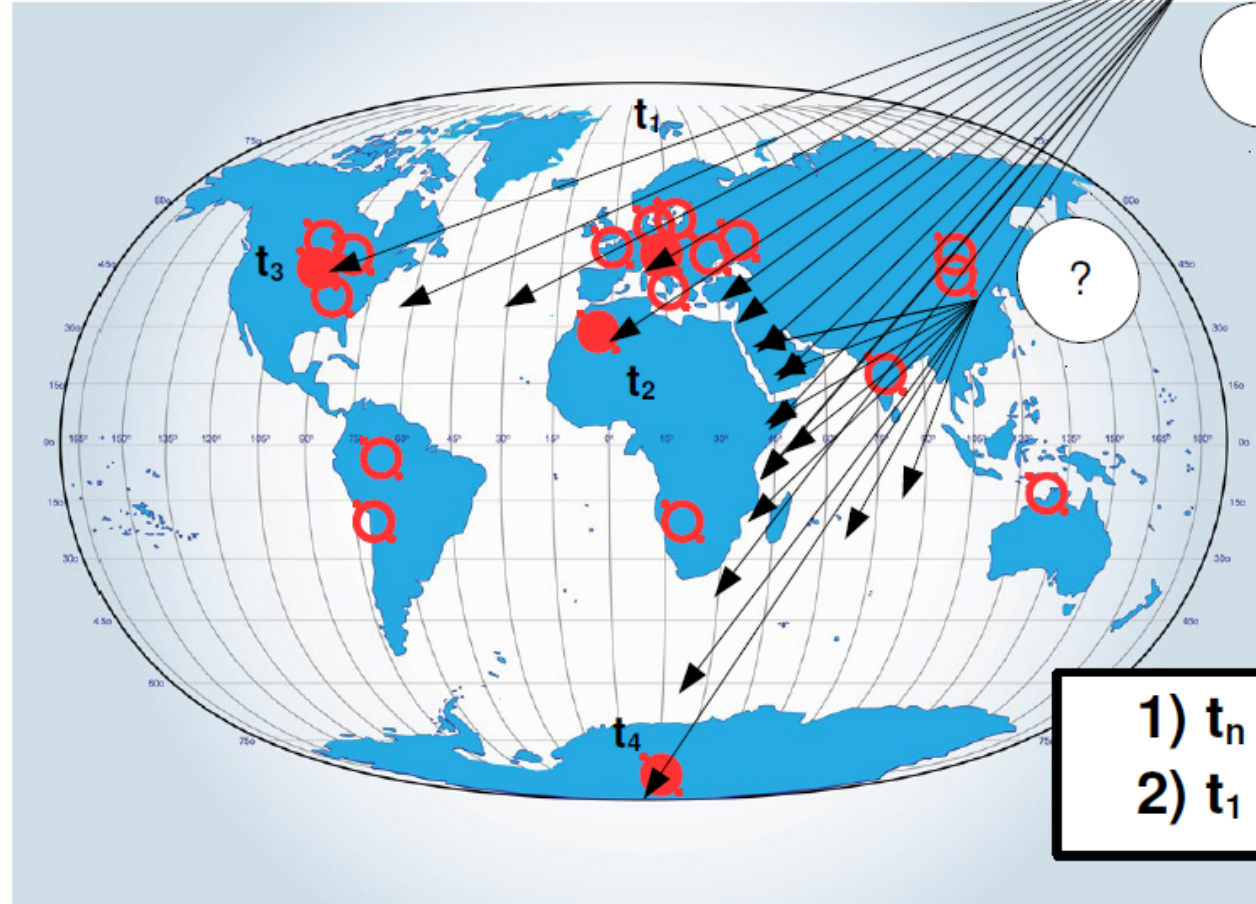
THE QUEST FOR UNEXPECTED



γ_{UHE}
(e.g. 10^{20} eV)



Citizens
strengthen
trigger
capabilities
of the
educational
arrays with
smartphone
networks



Citizens
browse the
data looking
for „improbable”
time-space
coincidences

- 1) $t_n - t_1 < \sim 1 \mu\text{s}$
- 2) $t_1 < \dots < t_n,$

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

CREDO: mission organized for super-preshowers

Cosmic-Ray Extremely Distributed Observatory

Status Feb 2017 – start
of Dark Universe
Welcome beta-testing



CREDO projects:

- CREDO array
- CREDO earthquakes
- CREDO citizen science
- Dark Universe Welcome

Central database/interface: access to everything for everybody

Large experiments and CREDO

Polish institutions participating:

1. Institute of Nuclear Physics PAS
2. Cracow University of Technology (Politechnika Krakowska)
3. CYFRONET
4. University of Science and Technology (AGH)
5. Jagellonian University

List of CREDO players:

- | | | |
|--------------------------|---|---------------------|
| • HiSPARC | } | Educational arrays |
| • Showers of Knowledge | | |
| • DECO | } | Mobile applications |
| • CRAYFIS | | |
| • Baikal-GVD (neutrinos) | | |

On the formal way to contribute:




- Pierre Auger Observatory (cosmic rays)
- MAGIC (gamma rays)

About initiating a formal way:

- ATLAS

EVERY cosmic ray detector can contribute to CREDO

Current Status: Dark Universe Welcome

Oleksandr_Sushchov    

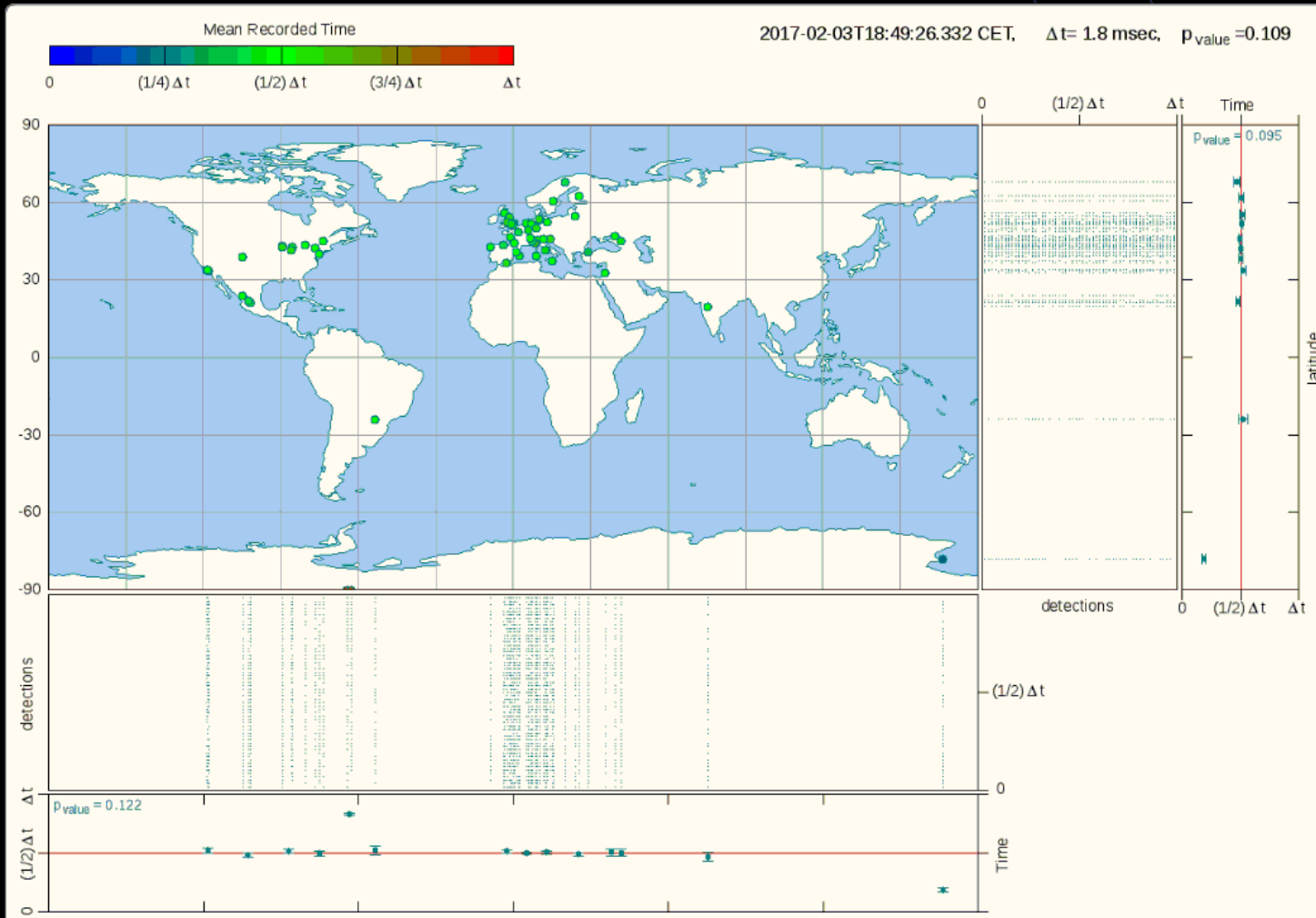
DARK UNIVERSE WELCOME

ABOUT

CLASSIFY

TALK

COLLECT



Can you see a trend on any of these graphs?

- ☐ I can see a trend on both graphs
- ☐ I can see a trend on one graph
- ☐ There isn't a trend on either graph
- ☐ Both graphs are a complete mess

Need some help with this task?

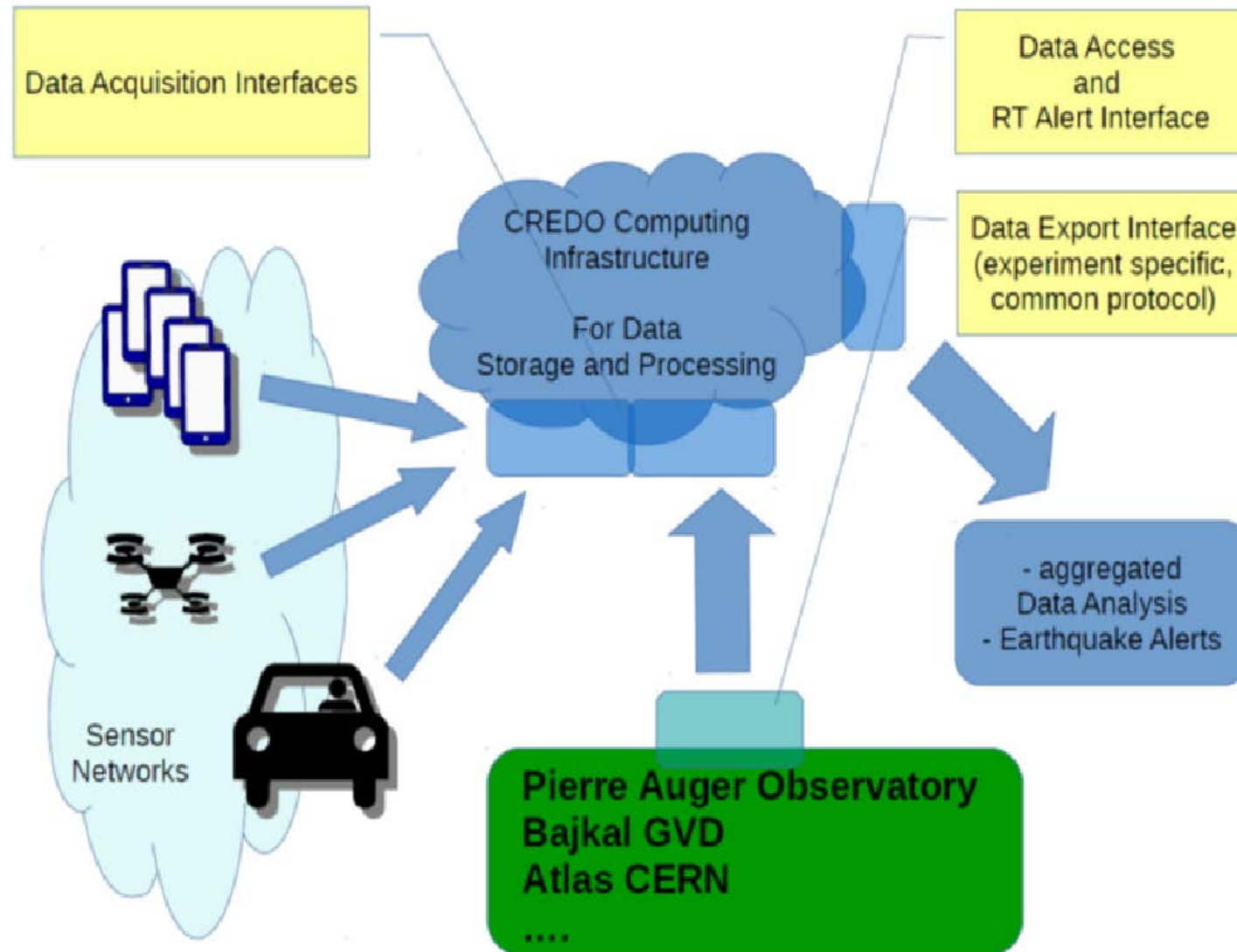
Back

Done

Show the project tutorial

FIELD GUIDE

Computational challenges



Computational challenges

Current priorities

1. Merging and storing data in universal format
2. Data analysis
3. Simulation chains

Possible ways of improvement

1. Creating database system mapping other projects' existing databases and data
2. Adopting machine learning solutions to find unexpected patterns
3. Adopt parallel computing for simulation processes
4. ?

Thank you for your attention