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

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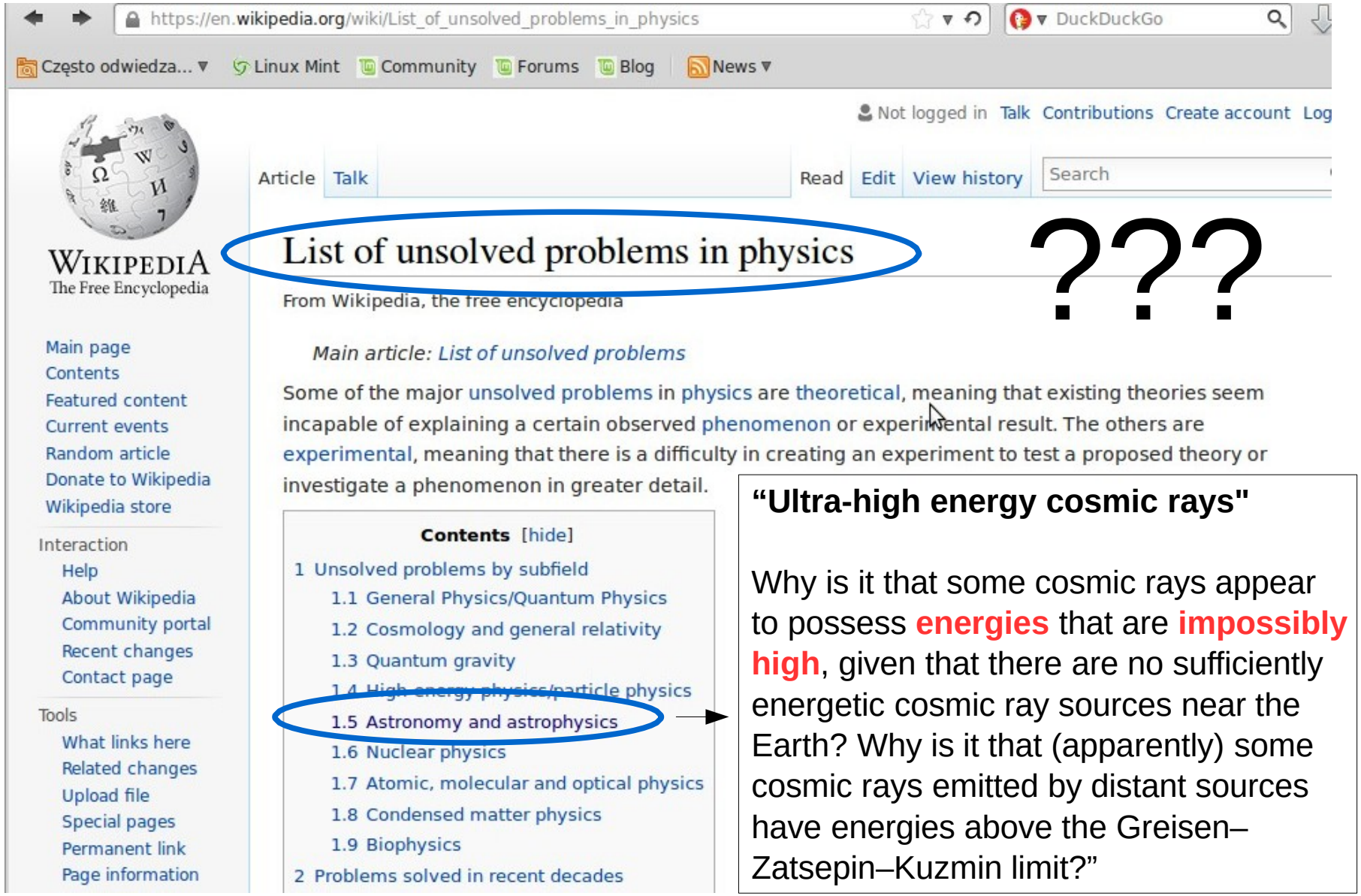
Outline

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

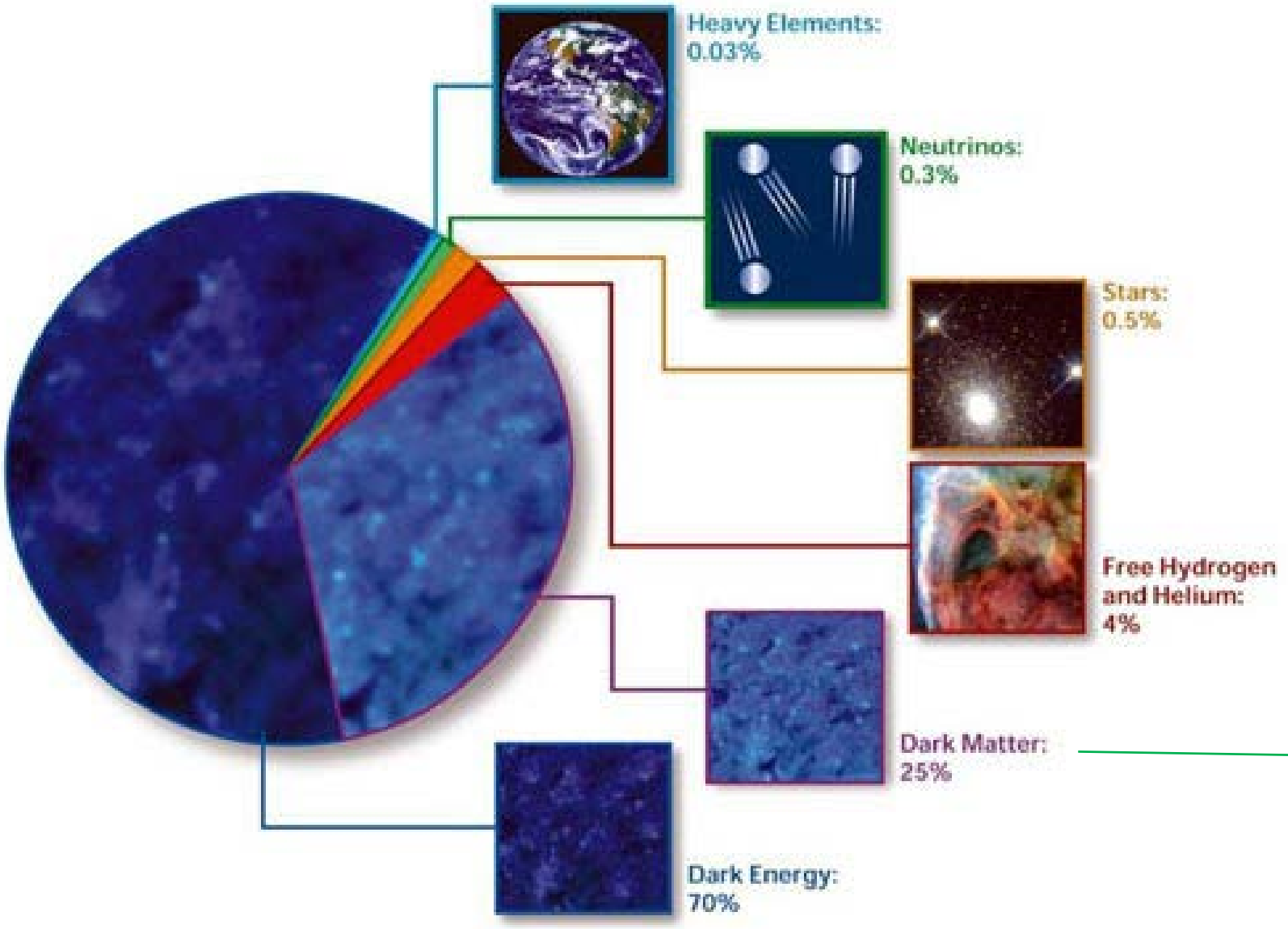
UHECR - one mystery more



“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 (γ_{UHE}!)

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

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

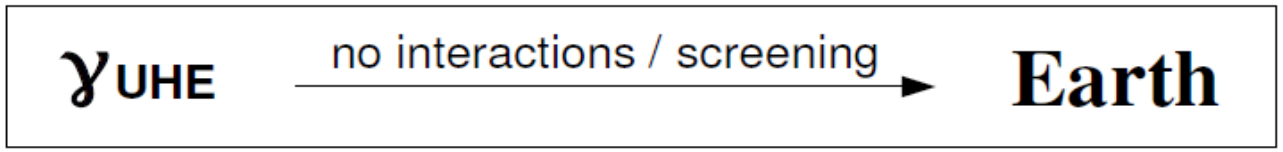
→ hypothetic supermassive particles of energies ~10^{23} eV

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

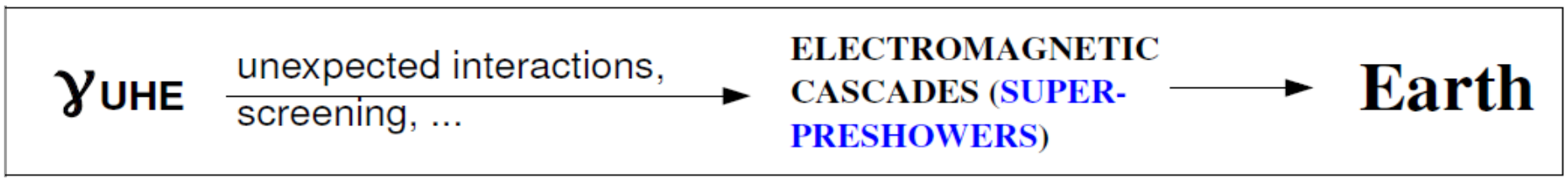
large fraction of photons and neutrinos in UHECR flux

DARK MATTER!

Experimental evidence about γ_{UHE}



NOT OBSERVED



NOT TRIED SO FAR...

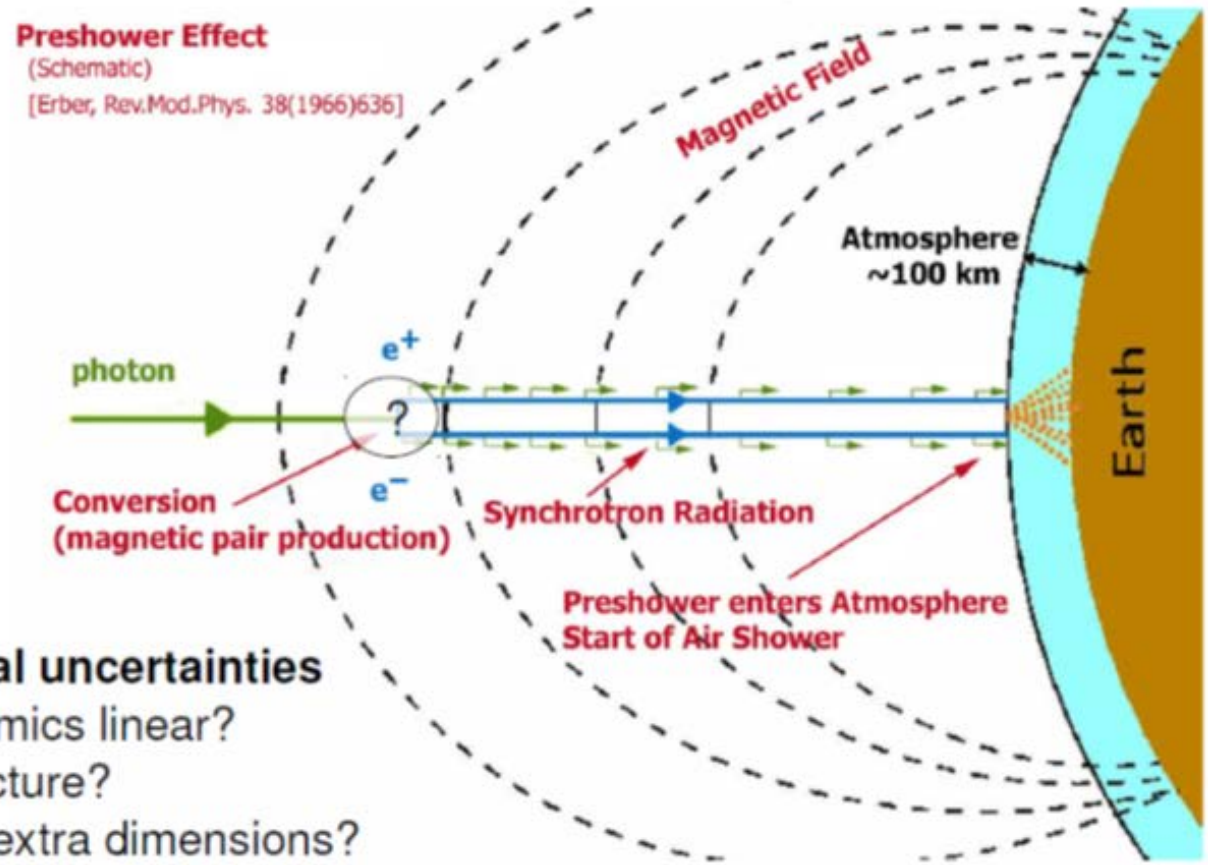
CREDO!

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

(super-)preshower:

→ contains typically **(>1000)** 100 particles

→ created at around **(>10000)** 1000 km a.s.l.

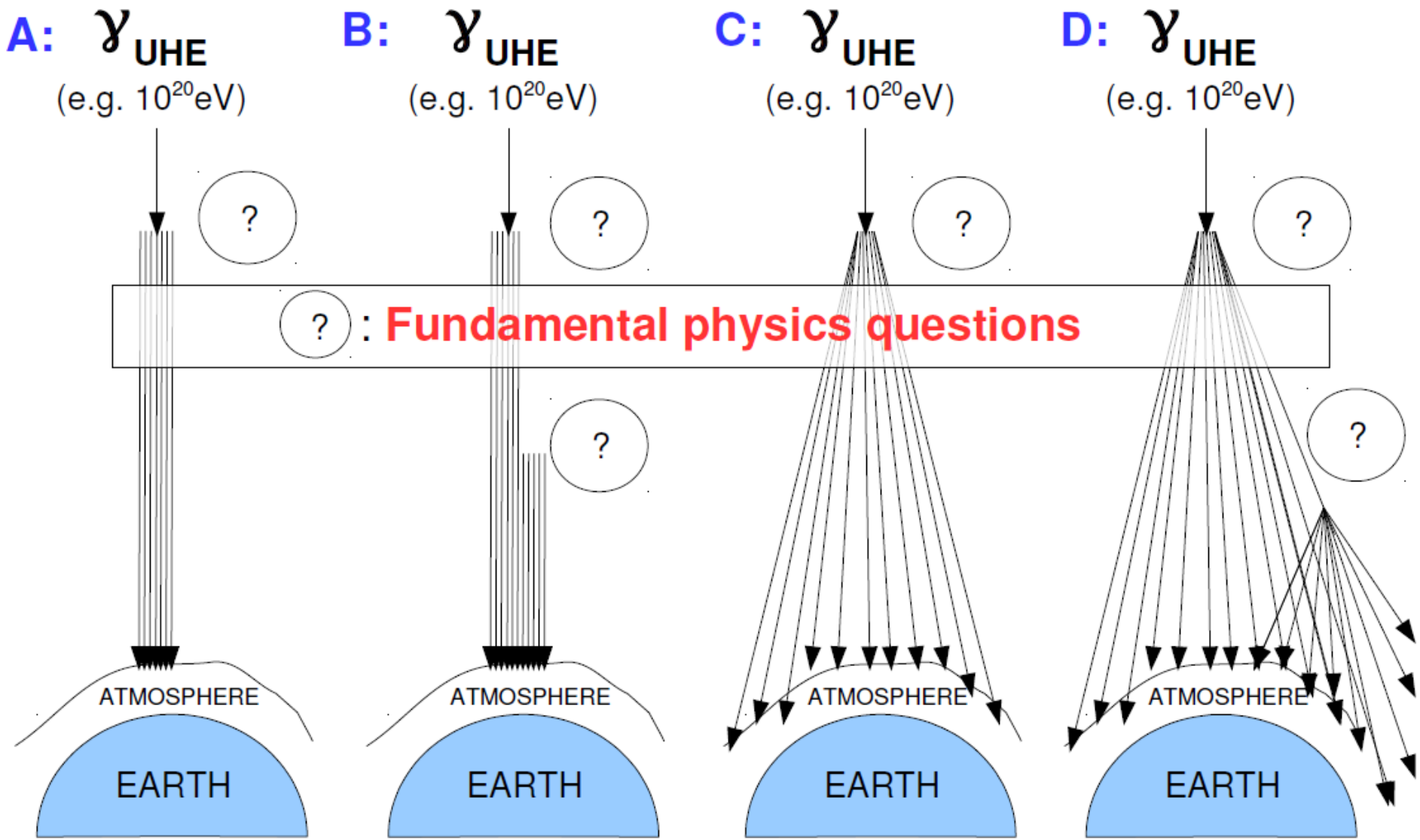


? : **fundamental uncertainties**

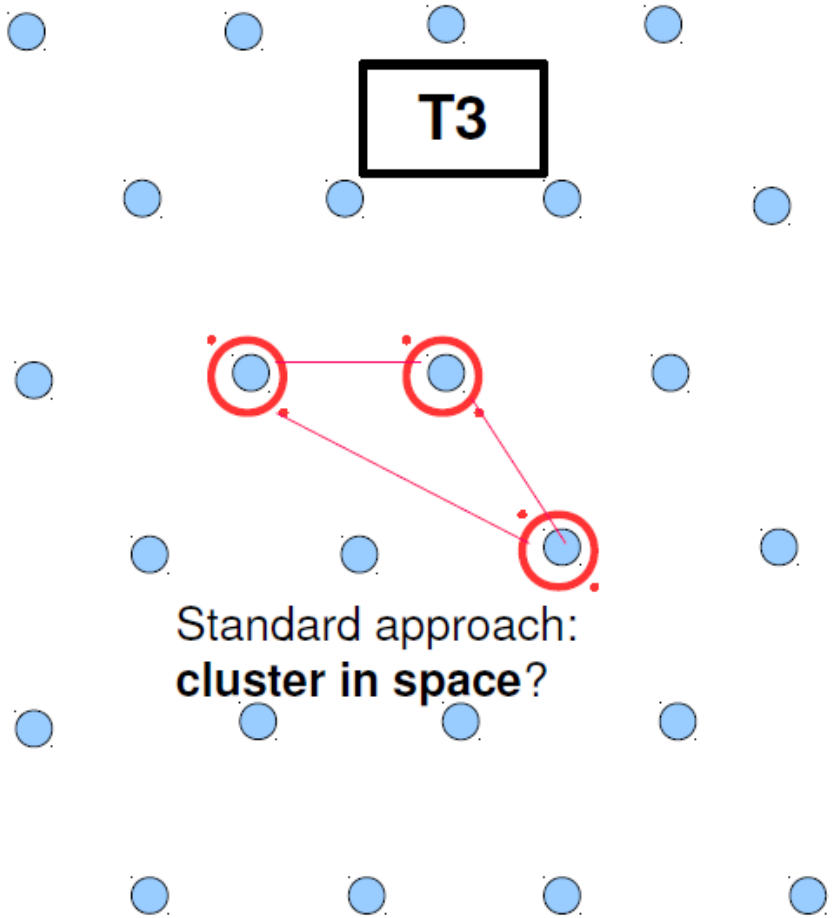
- electrodynamics linear?
- photon structure?
- spacetime: extra dimensions?

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

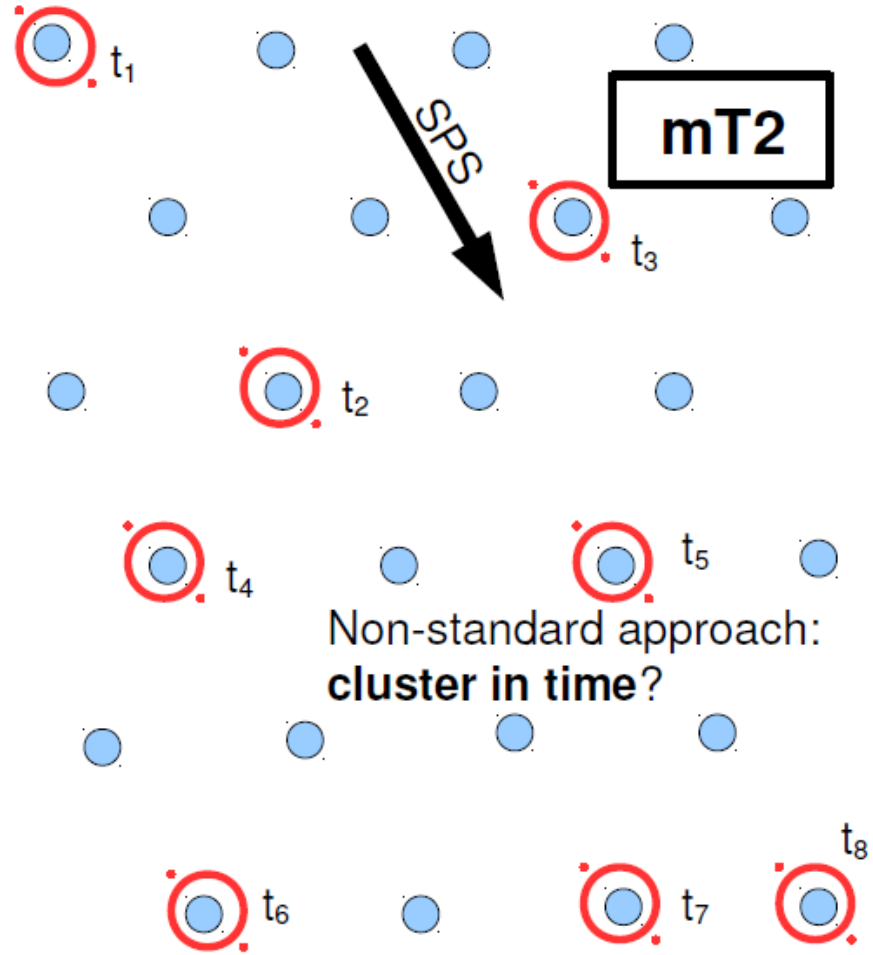
Classes of super-preshowers



mT2: NEW easy trigger for super-preshowers



Standard approach:
cluster in space?

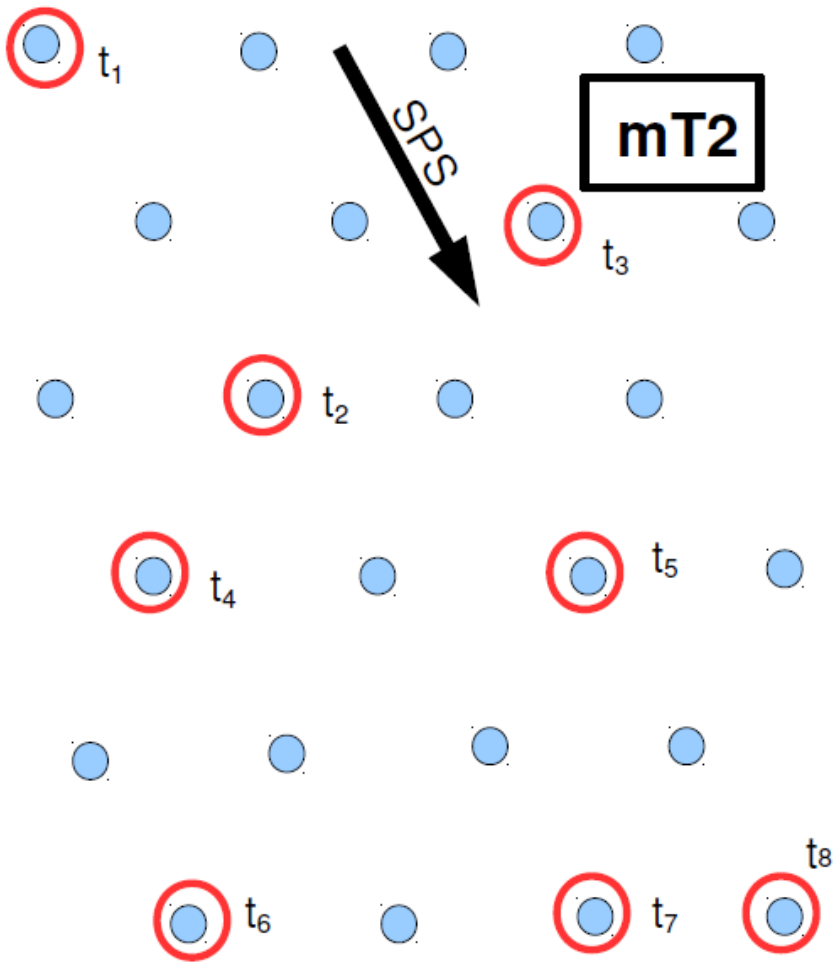


Non-standard approach:
cluster in time?

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

● : a cosmic-ray detector

mT2: NEW easy trigger for super-preshowers



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

P_{acc}=~10/30! * 0.16^{30}= ridiculously small chance

sensitivity to $n_{LOW} < n < 30$

n_{LOW} =?

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

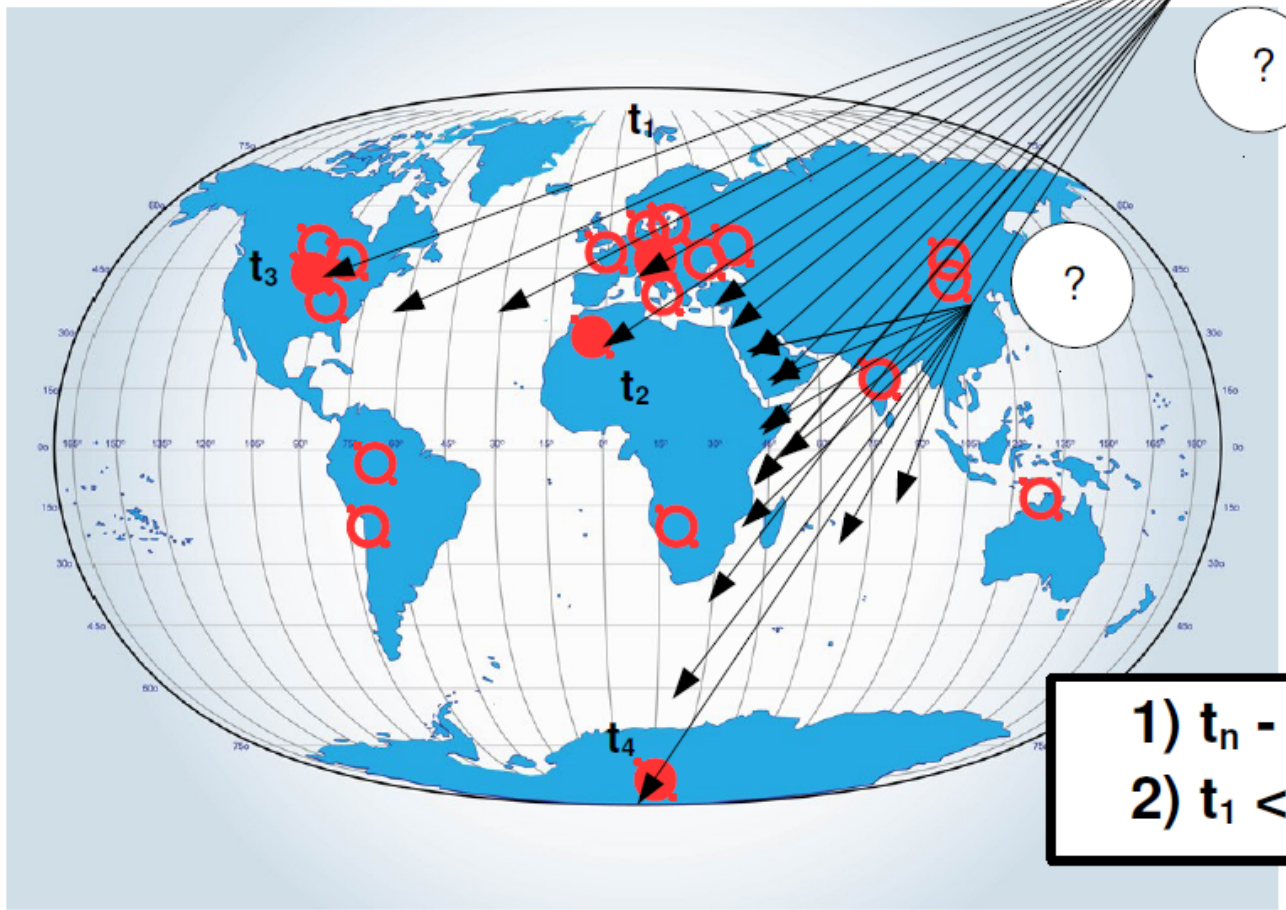
→ **unique signature**

(of New Physics?)

CREDO

THE QUEST FOR UNEXPECTED

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: mission organized for super-preshowers

Central database/interface: access to everything for everybody

CREDO projects:

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

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
- Showers of Knowledge

Educational arrays

- DECO
- CRAYFIS

Mobile applications

- Baikal-GVD (neutrinos)

On the formal way to contribute:

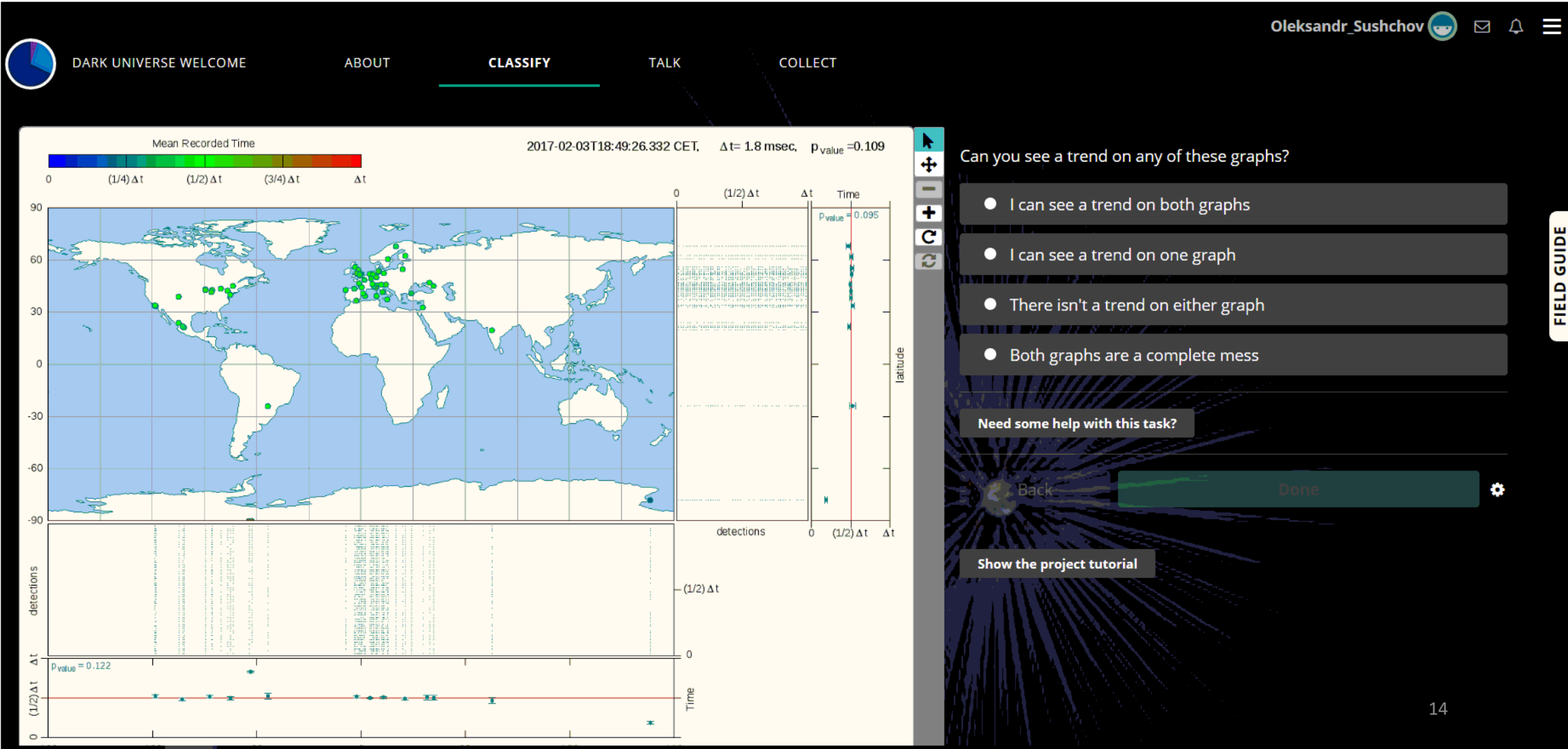
- Pierre Auger Observatory (cosmic rays)
- MAGIC (gamma rays)

About initiating a formal way:

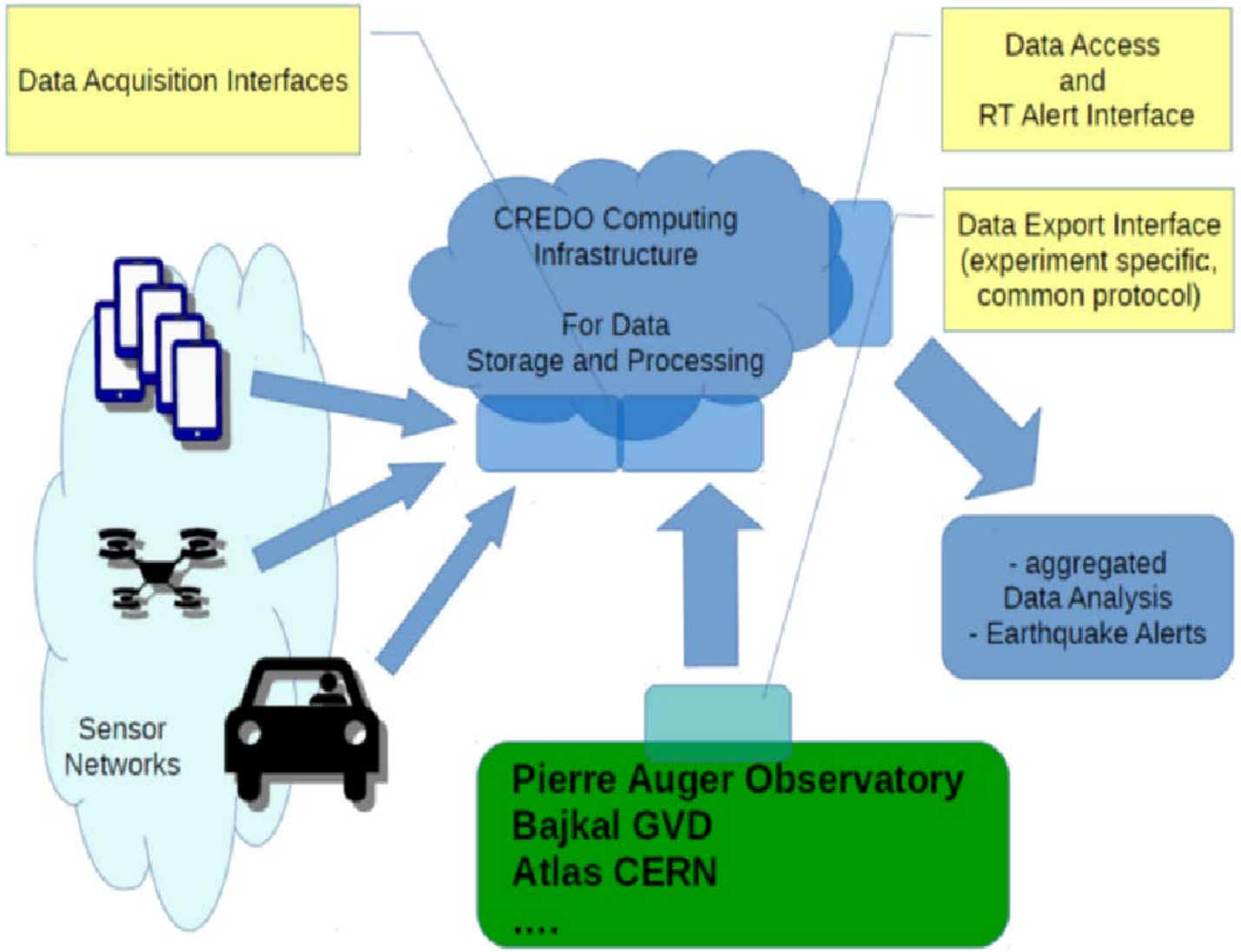
- ATLAS

EVERY cosmic ray detector can contribute to CREDO

Current Status: Dark Universe Welcome



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