CREDO

THE QUEST FOR UNEXPECTED

CREDO science case

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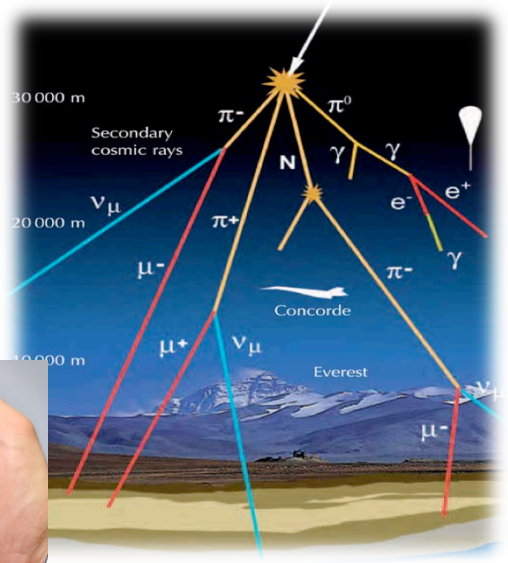
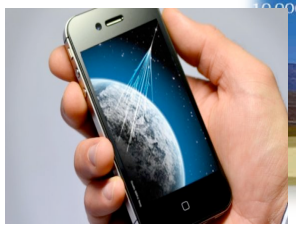
Outline:
- Introduction
- How to select muon like events from smartphone images
- Example of time clustering analysis
- CREDO and gamma rays astronomy

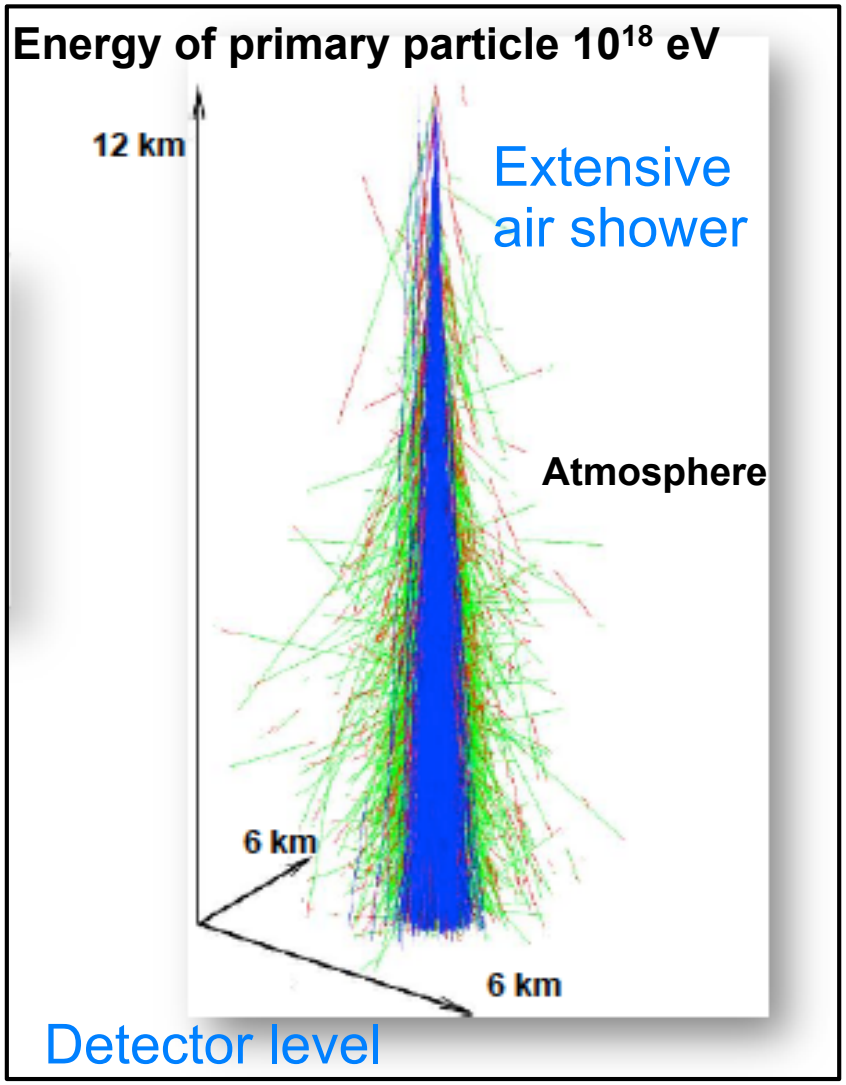


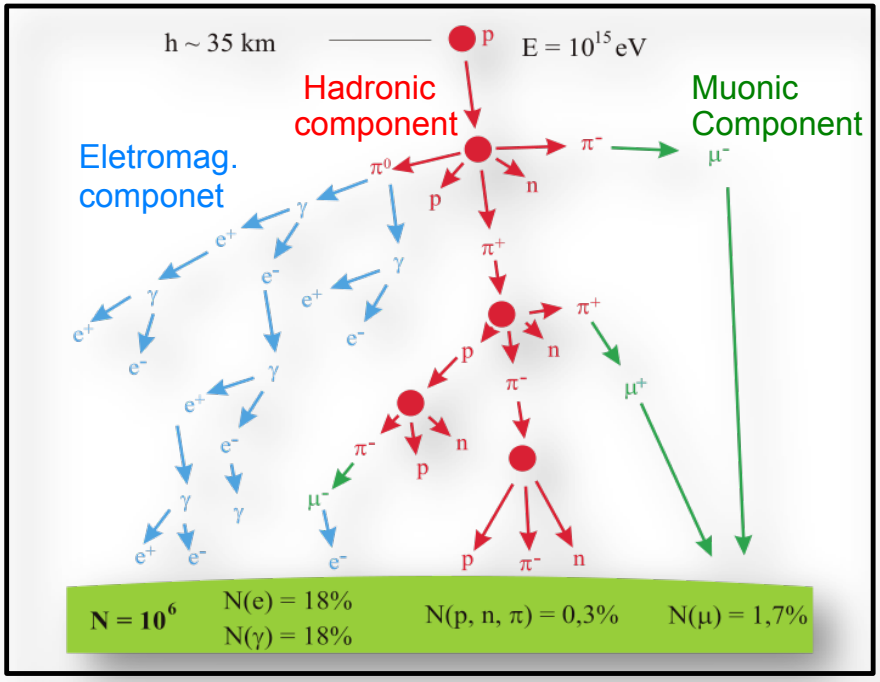


Visegrad Fund

Extensive air shower

Extensive air shower – *collision of primary particle in air produce a shower of relativistic secondary particles*



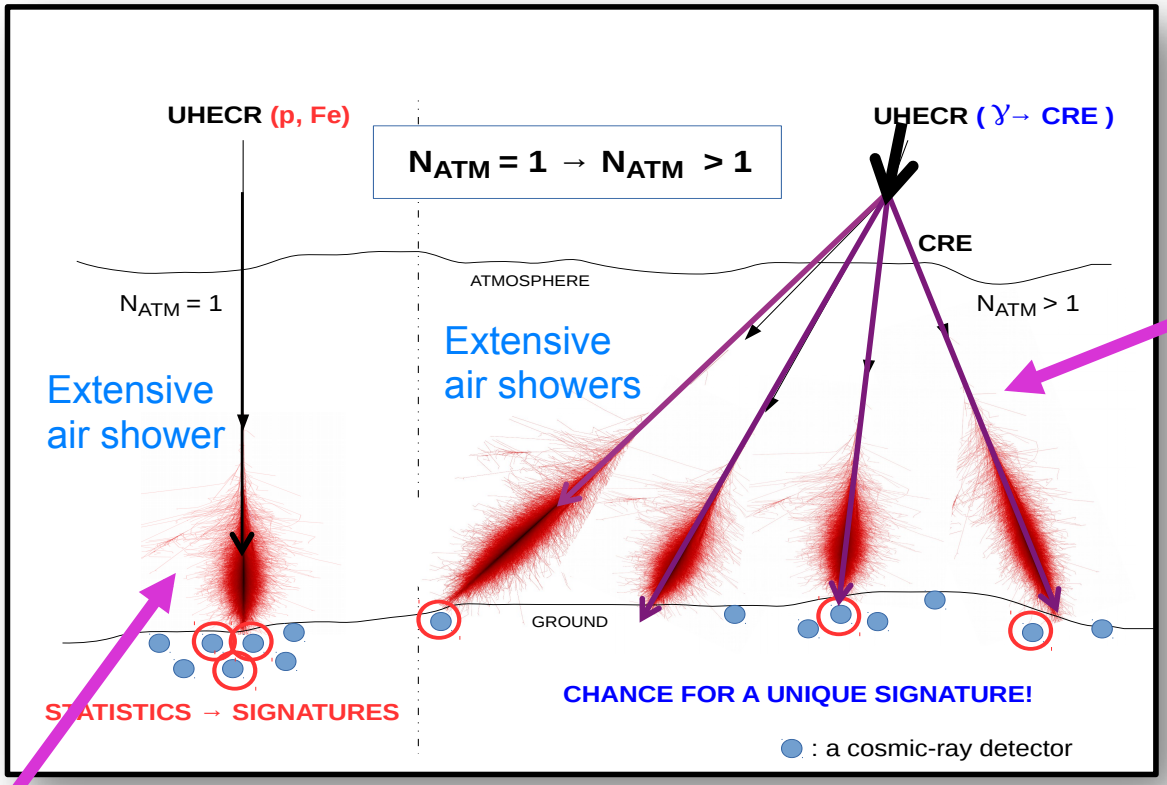


Muons are one of the EAS component

Atmospheric muons:

~70 particle per cm^2 per minutę
energy of muons ~$4*10^9$ eV (4 GeV)
at sea level

Motivation: looking for Cosmic Ray Ensambles (CRE)



New strategy:
Looking for multiple air showers correlated in time

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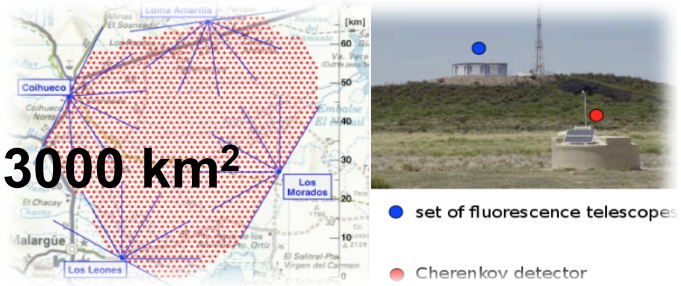
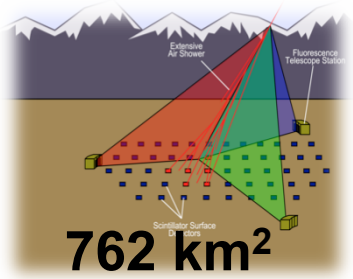
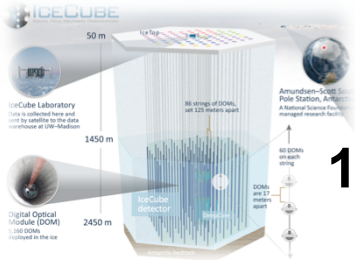
Typical strategy: looking for ONE shower i.e.
Pierre Auger Observatory, Telescope Array, IceCube ....







Looking for Cosmic Ray Ensambles (CRE)

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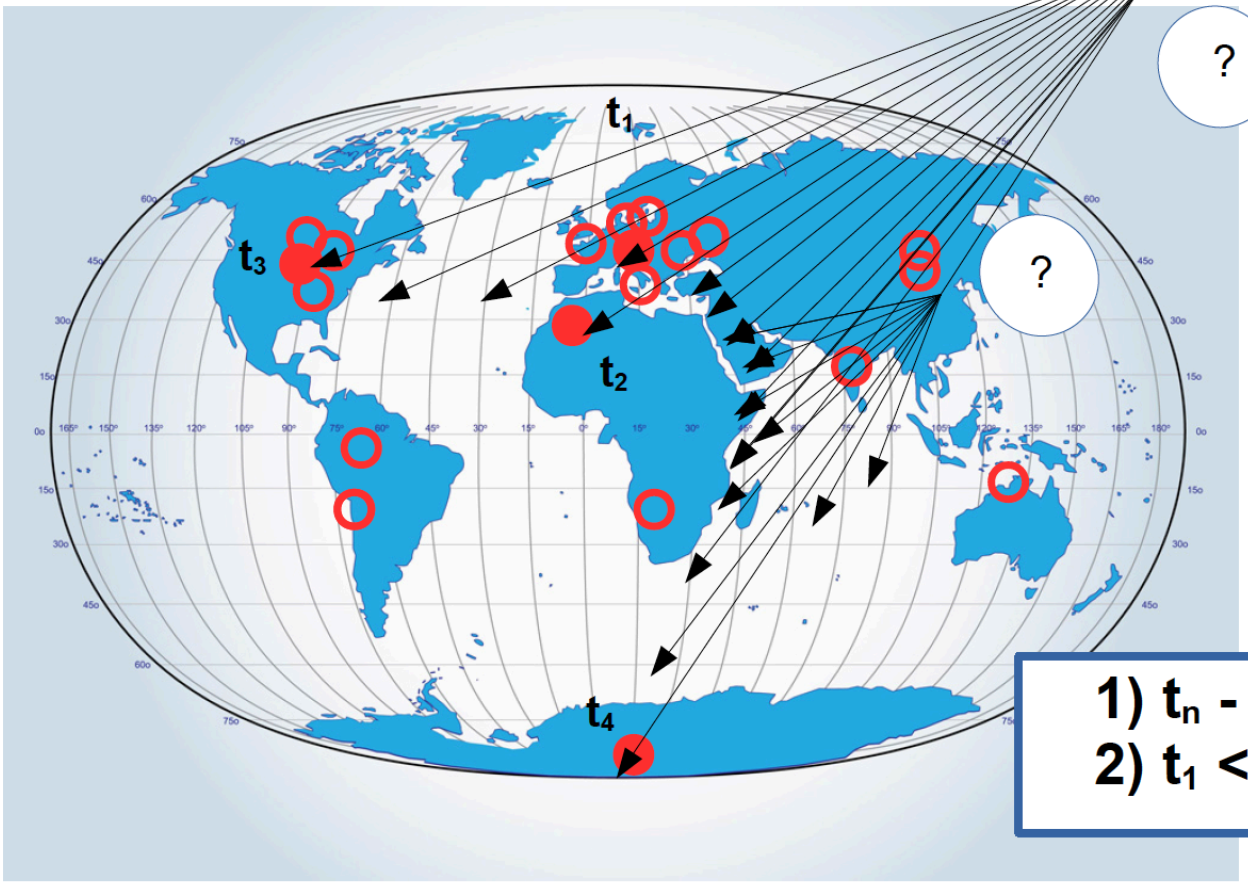
γ_{UHE}
(e.g. 10^{20}eV)

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)**

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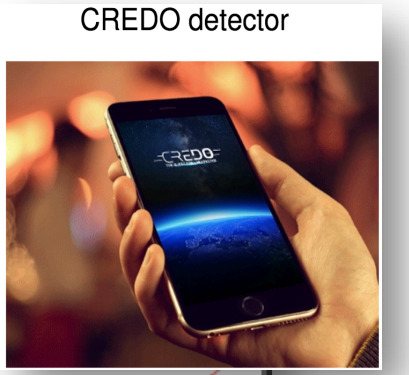
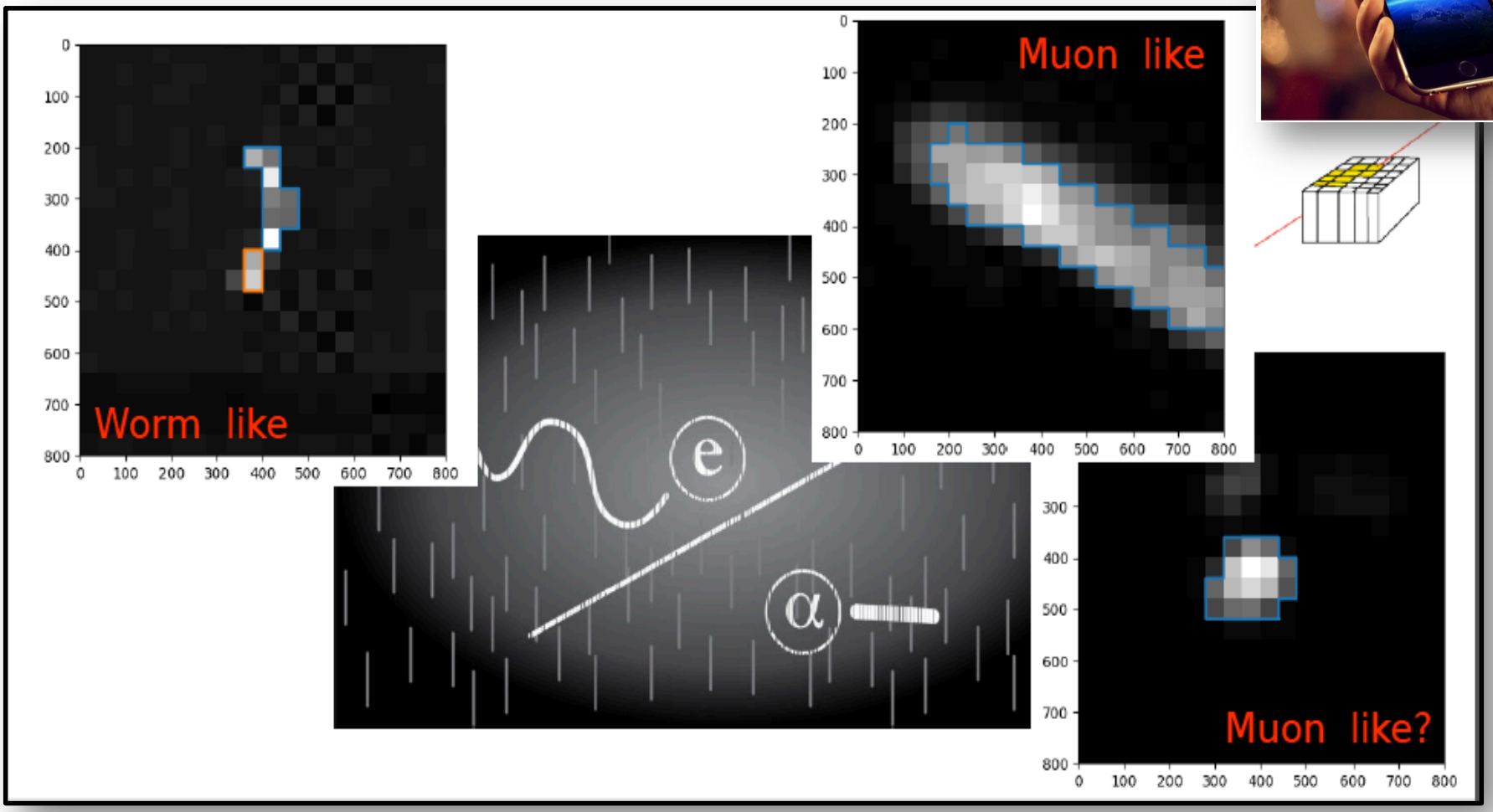
Typical classes of events from smartphones

…. from api.credo.science

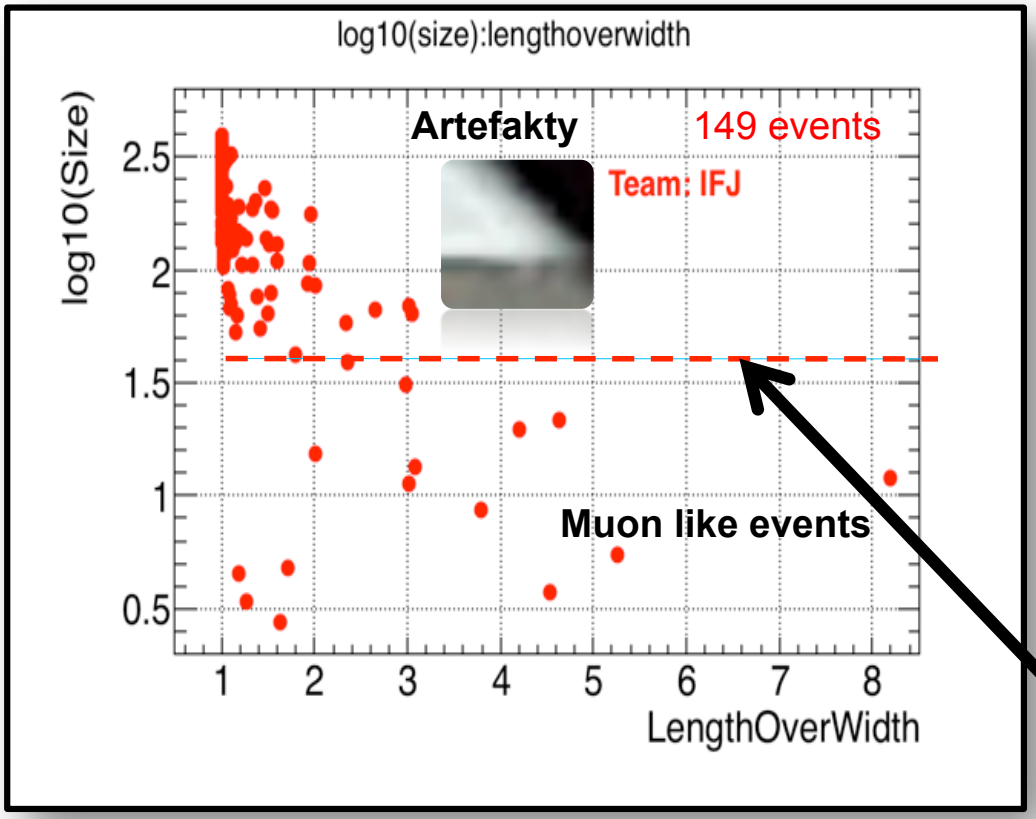




How to extract signal-like events (muon like) ?

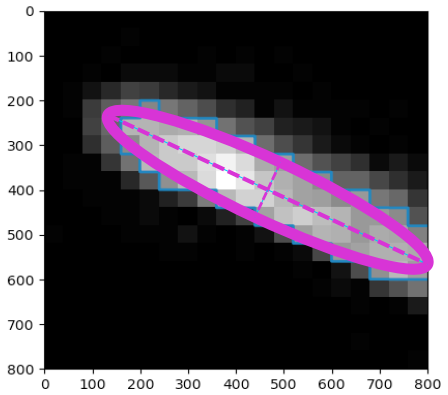
How to select muon like events from smartphone data

Simple filter



Discrimination parameters:

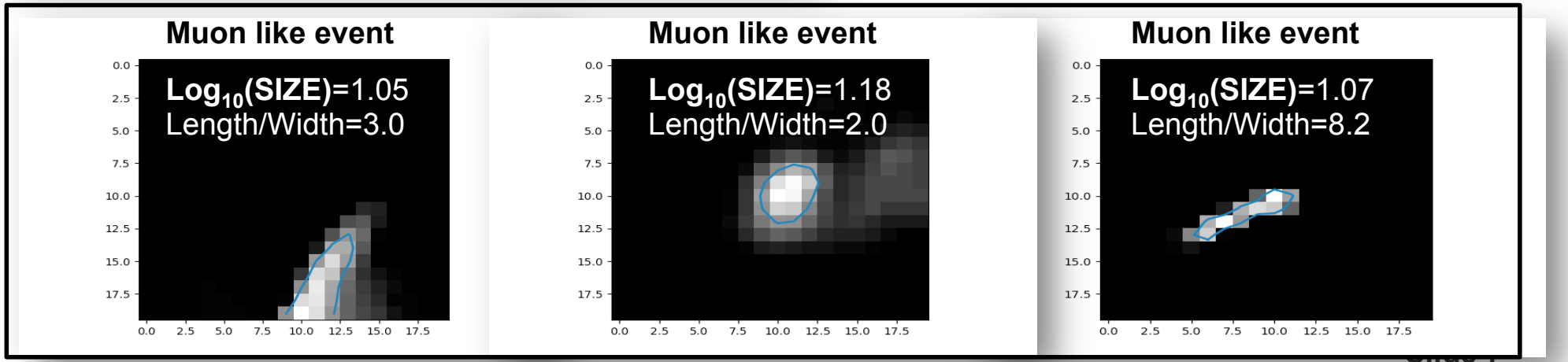
SIZE: *sum of illuminace in all pixels above certain defined threshold*



ellipse

LENGTH/WIDTH: *the ratio of major to minor axis of ellipse*

Selection criterion: $\log_{10}(\text{SIZE}) < 1.7$



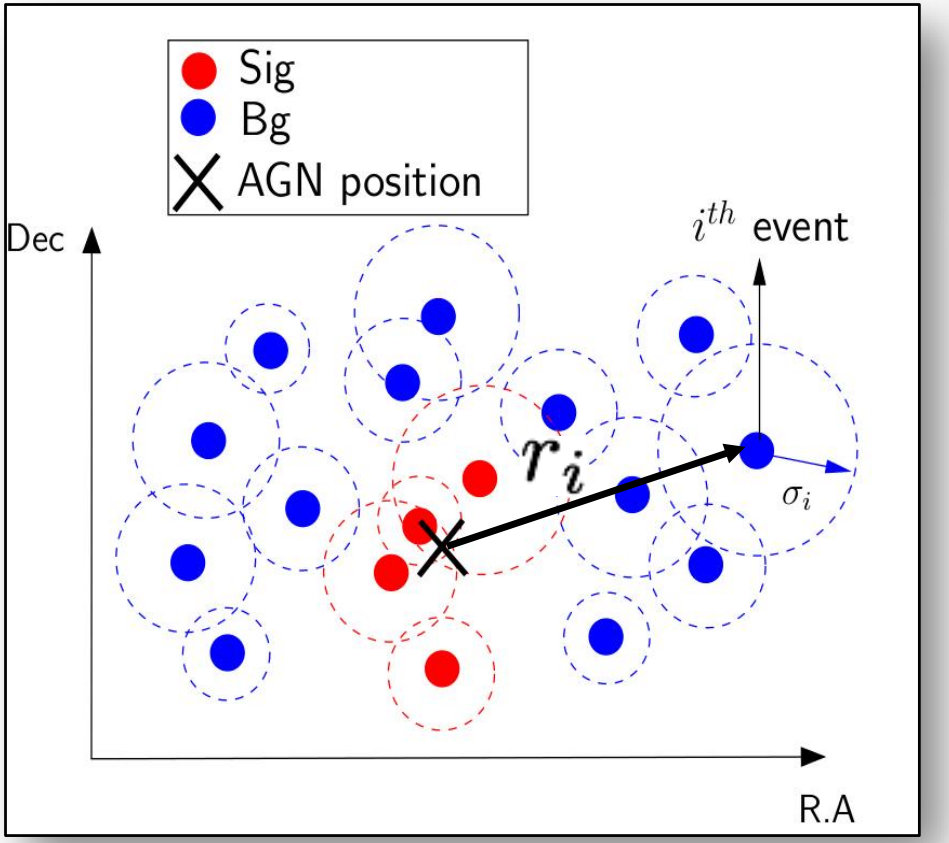
Time-clustering

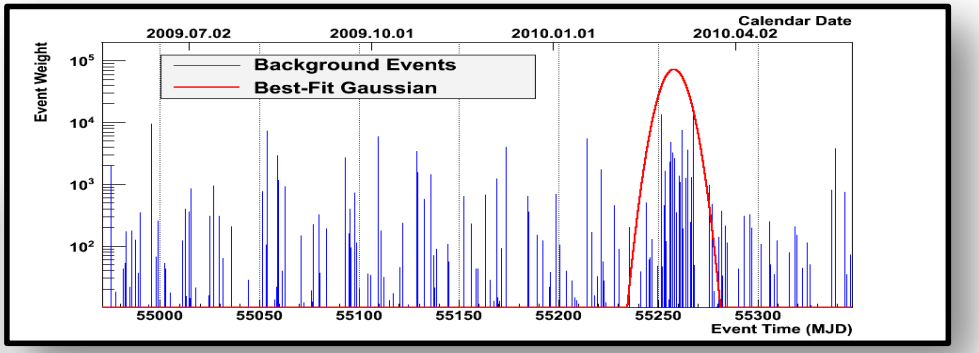
How to find the most significance cluster of events in time ?

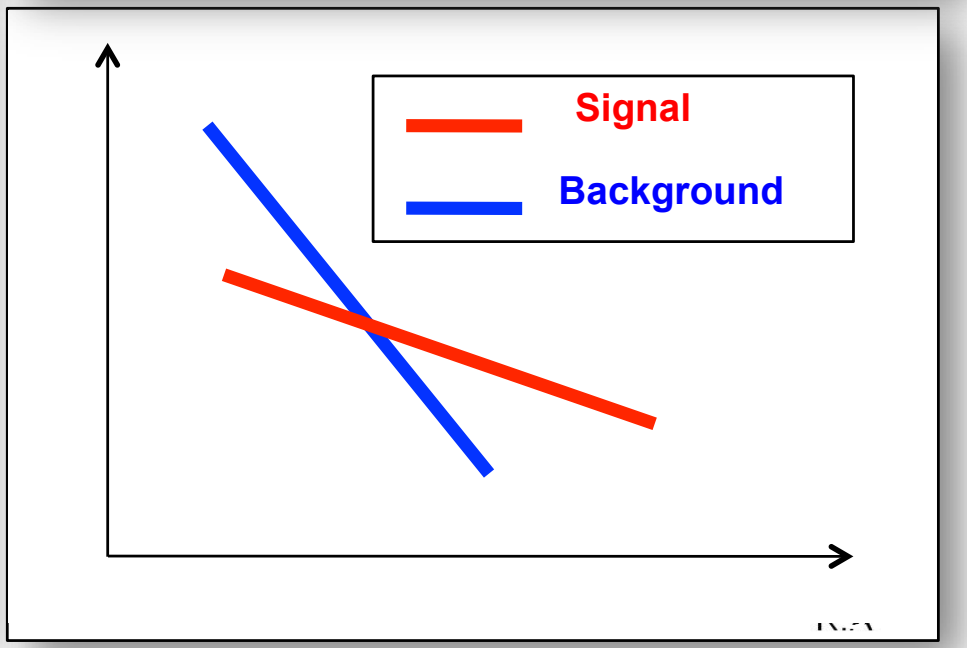
Basic concept of point-source search filter

σ_i - the angular uncertainty of event

r_i - the angular distance of event from source



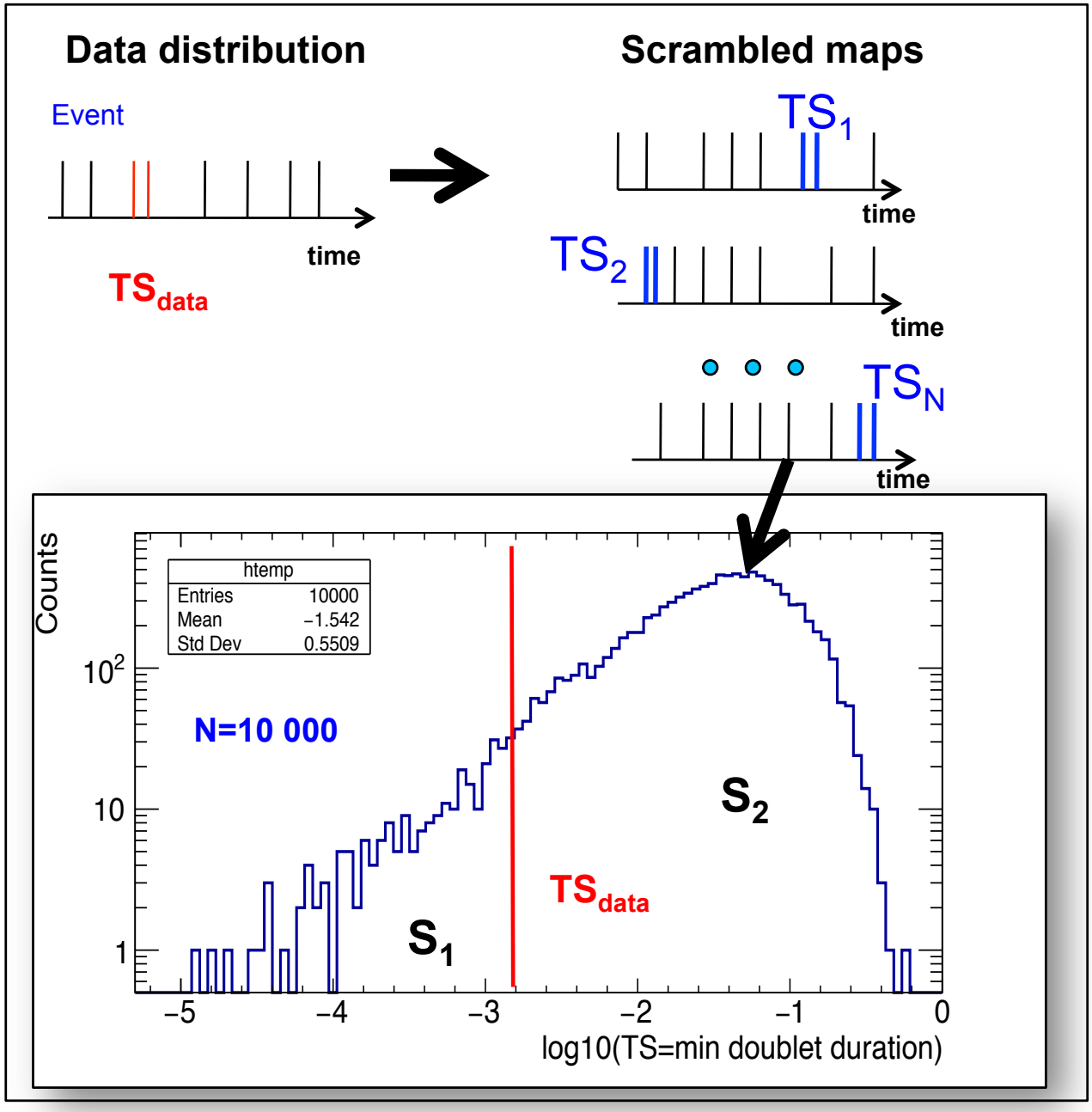




Finding point sources in the sky means to locate *an excess of events from a particular direction* over the background.

The signals events my present additional features: *different energy spectrum or time structure*

Simple method: search for cluster of events in time



Test Statistics (TS)

TS := doublet duration*

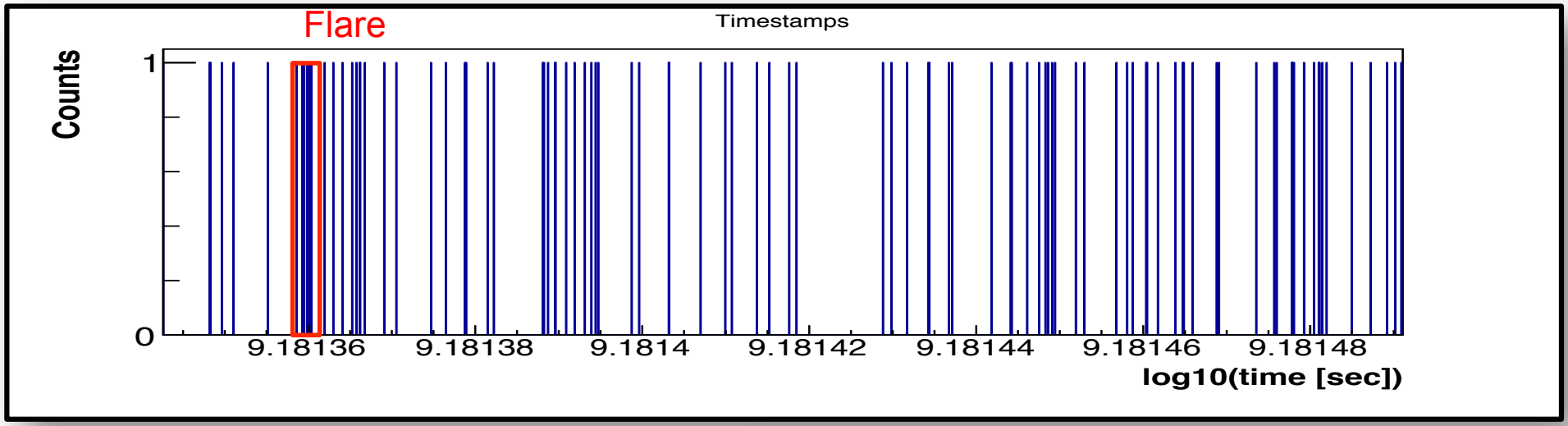
*for other multiplets different definitions was assumed

RESULT:

p-value as the fraction of events below TS_{data}

$$\text{P-value} = \frac{S_1}{S_1 + S_2}$$

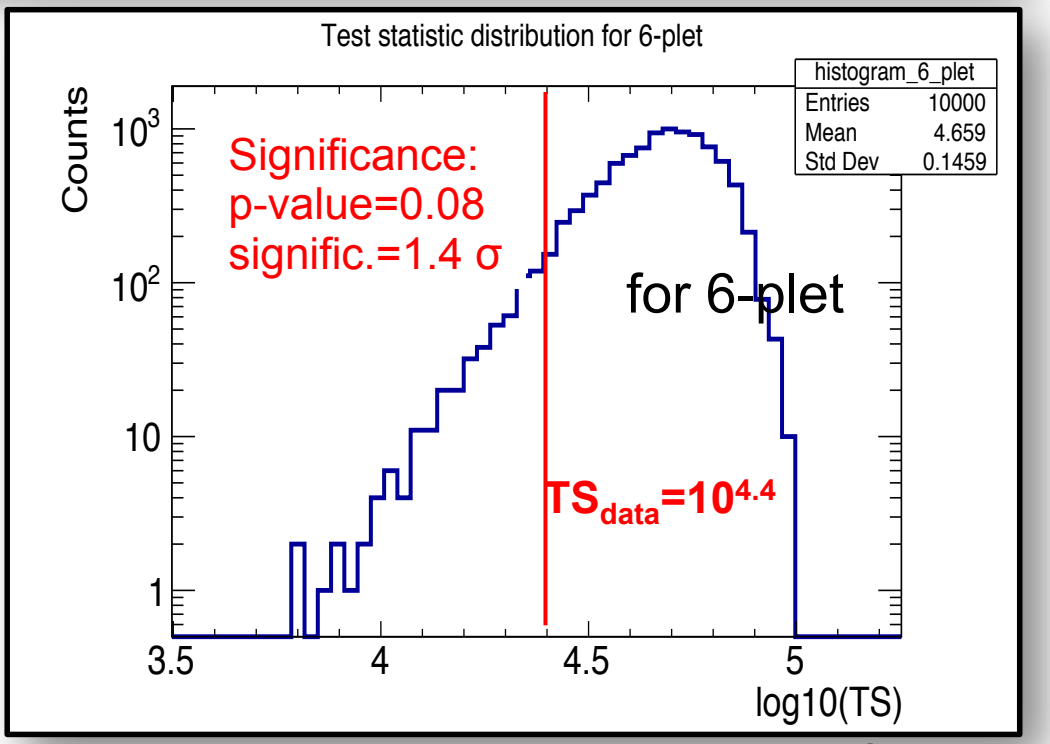
Application of the method to the smartphone data



First event: 10.02.2018 at 4h 26m 41s
Last event: 16.02.2018 at 07h 38m 56s

We consider not only doublets
but other multiplets like 3, 4, ...15-plets

Results:Flare - cluster of 6 events:
-start of possible flare:
10.02.2018 22h 49m 35s
-end of possible flare:
11.02.2018 00h 36m 16 s

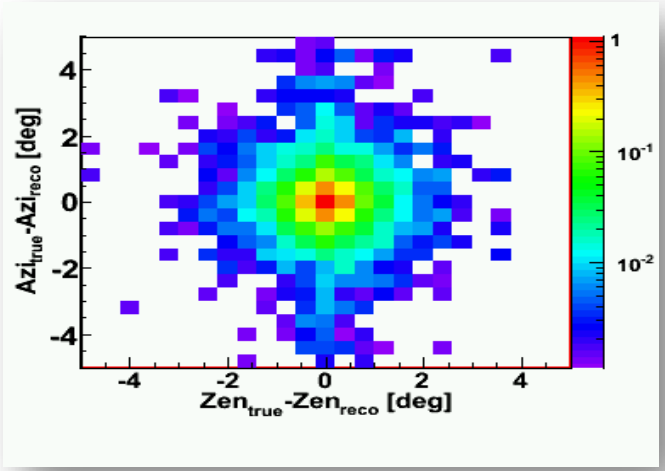


More advance time-clustering algorithm

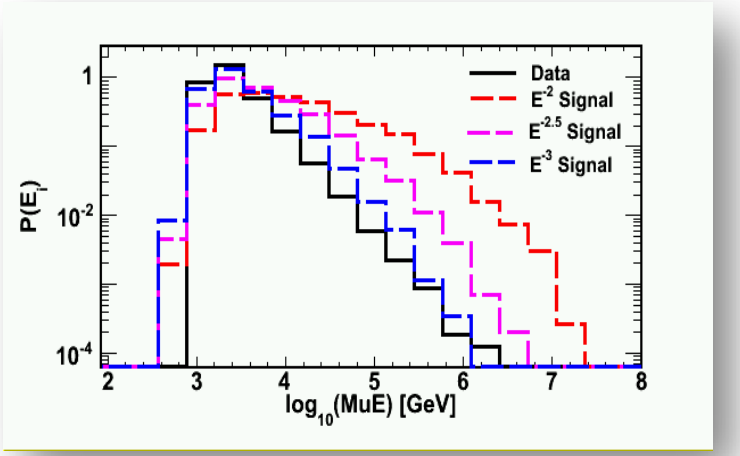
General method: an unbinned maximum likelihood

Method (J. Braun et al., Astropart. Phys.33:175,2010)

Space probability density function



Energy probability density function

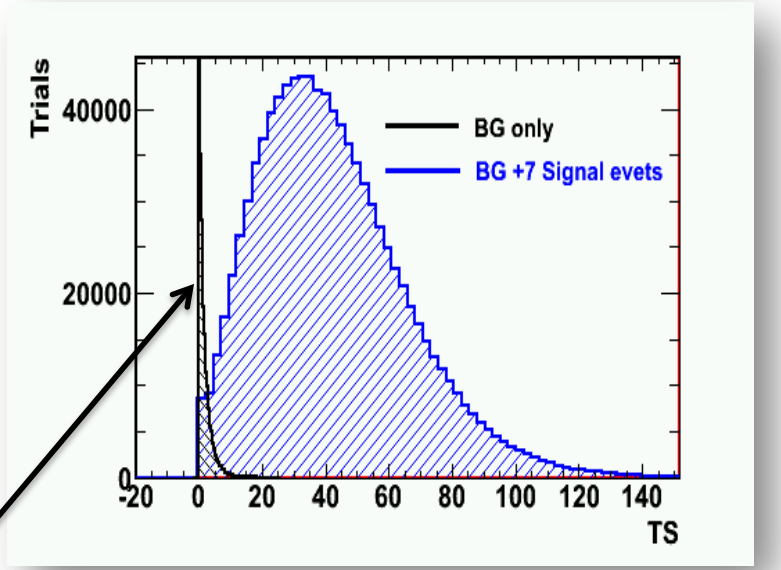


$$\mathcal{L}(n_s,\gamma)=\prod_{i=1}^{N}\left[\frac{n_s}{N}\mathcal{S}_i+(1-\frac{n_s}{N})\mathcal{B}_i\right]$$

$$\mathcal{S}_i=P^{space}(|x_i-x_s|,\sigma_i)\times P^{energy}(E_i|\gamma)\times P^{time}(\Delta t_j)$$

$$\mathcal{B}_i=\frac{1}{d\Omega}\times P_i(E_i)\times P^{time}(\theta,\phi,t_i)$$

$$TS=-2\log(\lambda)=-2\log\frac{\mathcal{L}(n_s=0)}{\mathcal{L}(n_s^f,\gamma^f)}$$



TS distribution for no signal events in data sample

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... and gamma-ray astronomy

Monte Carlo simulation chain

(1) Simulation of eletromagnetic particle by interaction with geomagnetic field (Preshower effect)

(2) Simulation of shower in air at high zenith angles

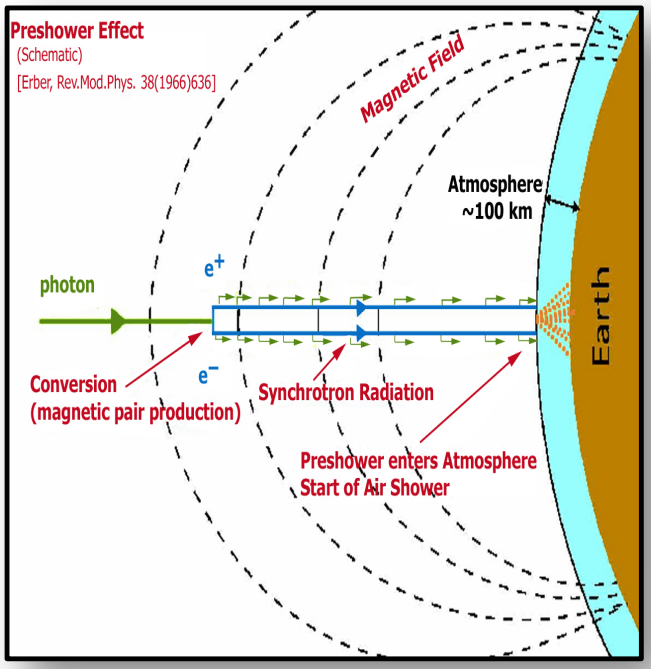
(3) Simulation of CTA responce

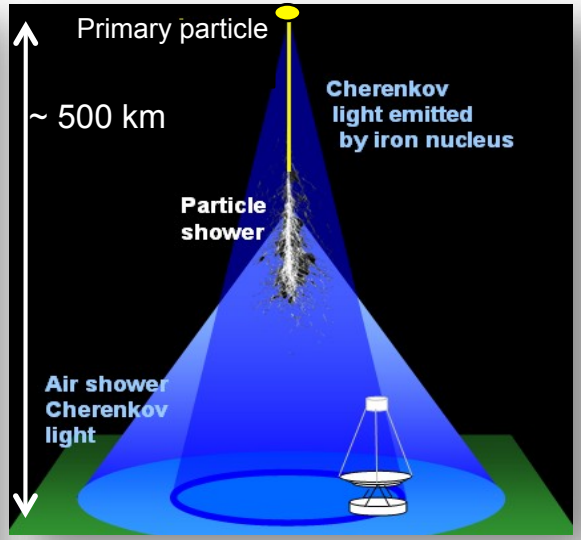
PRESHOWER → ***CORSIKA*** → ***Sim_telarray***

Homola et al., Computer Physics Commun. 184 (2005), 1468

D. Heck, et al., FZKA Report, 6019 (1998)

K. Bernlöhr, Astropart. Phys. 30 (2008), 149

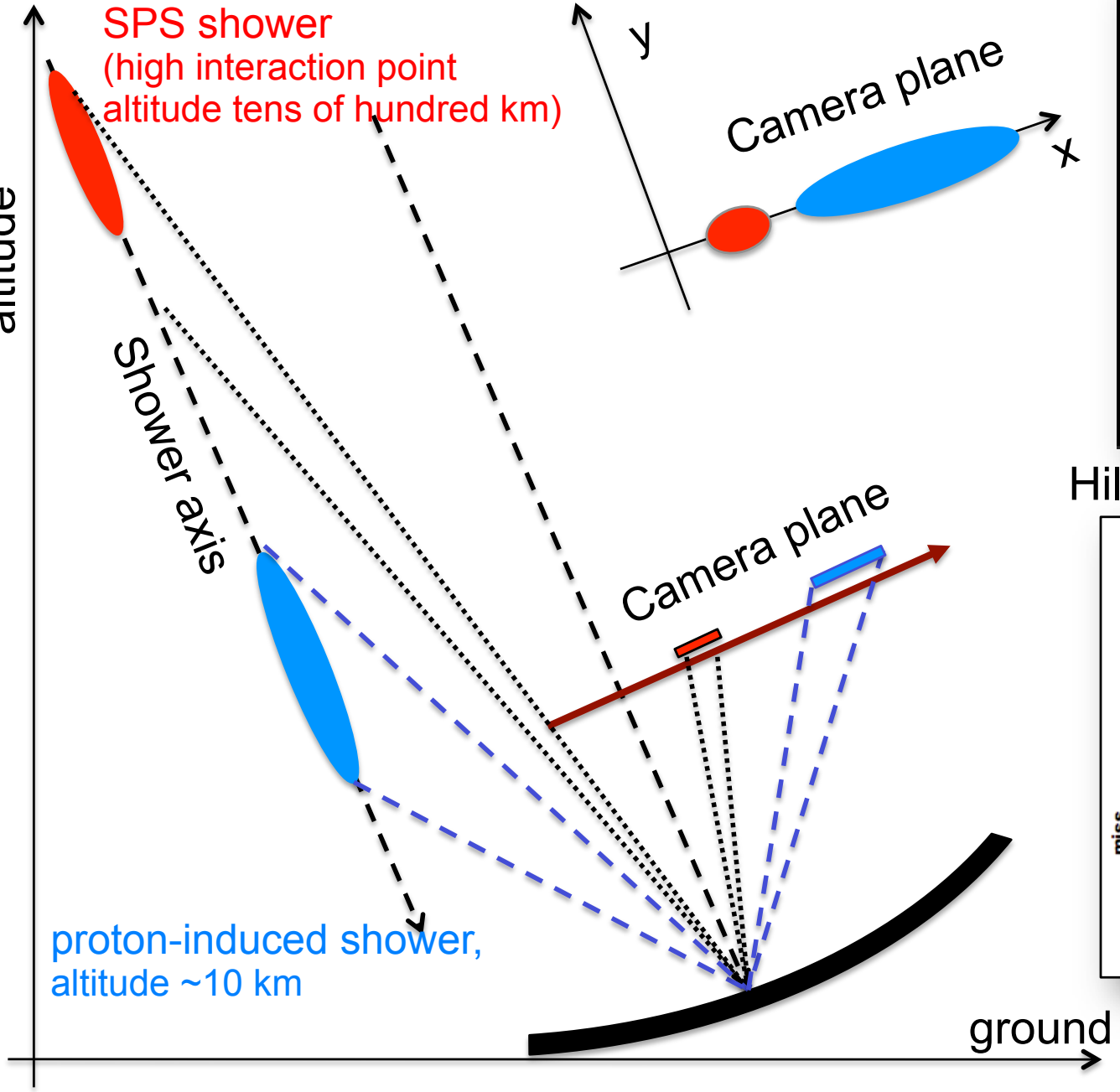


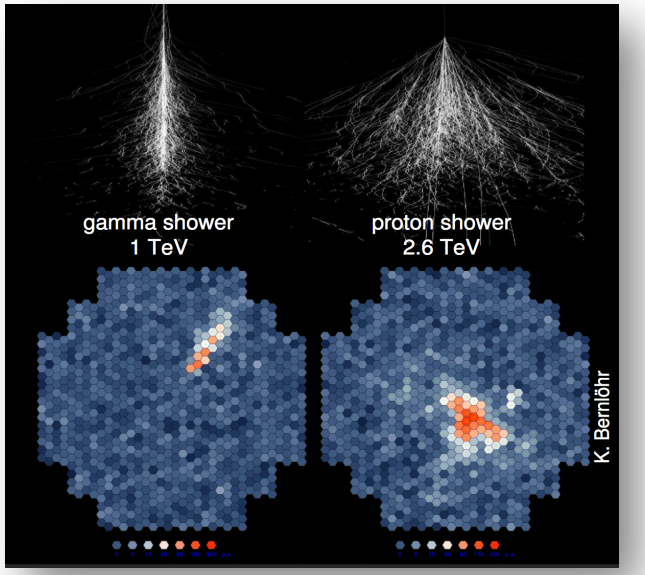


Compiled: with **CURVED-EARTH**, **CHERENKOV/IACT, THIN** option

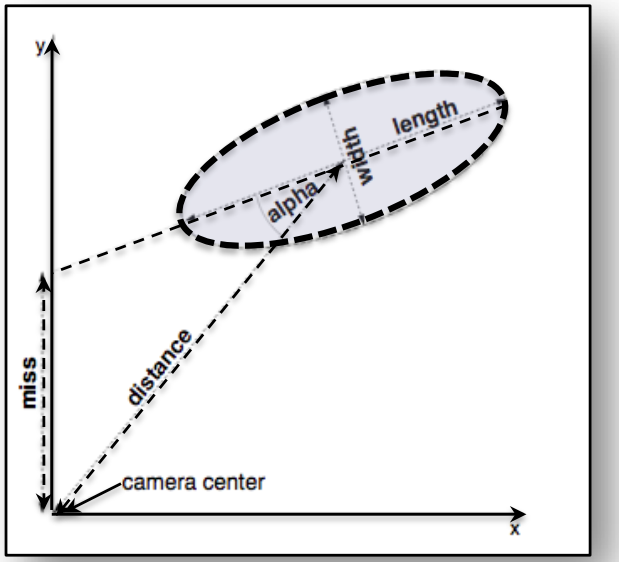
Miror optics/camera electronics simulations, with public ***Production-1*** **settings**

Towards SPS identification





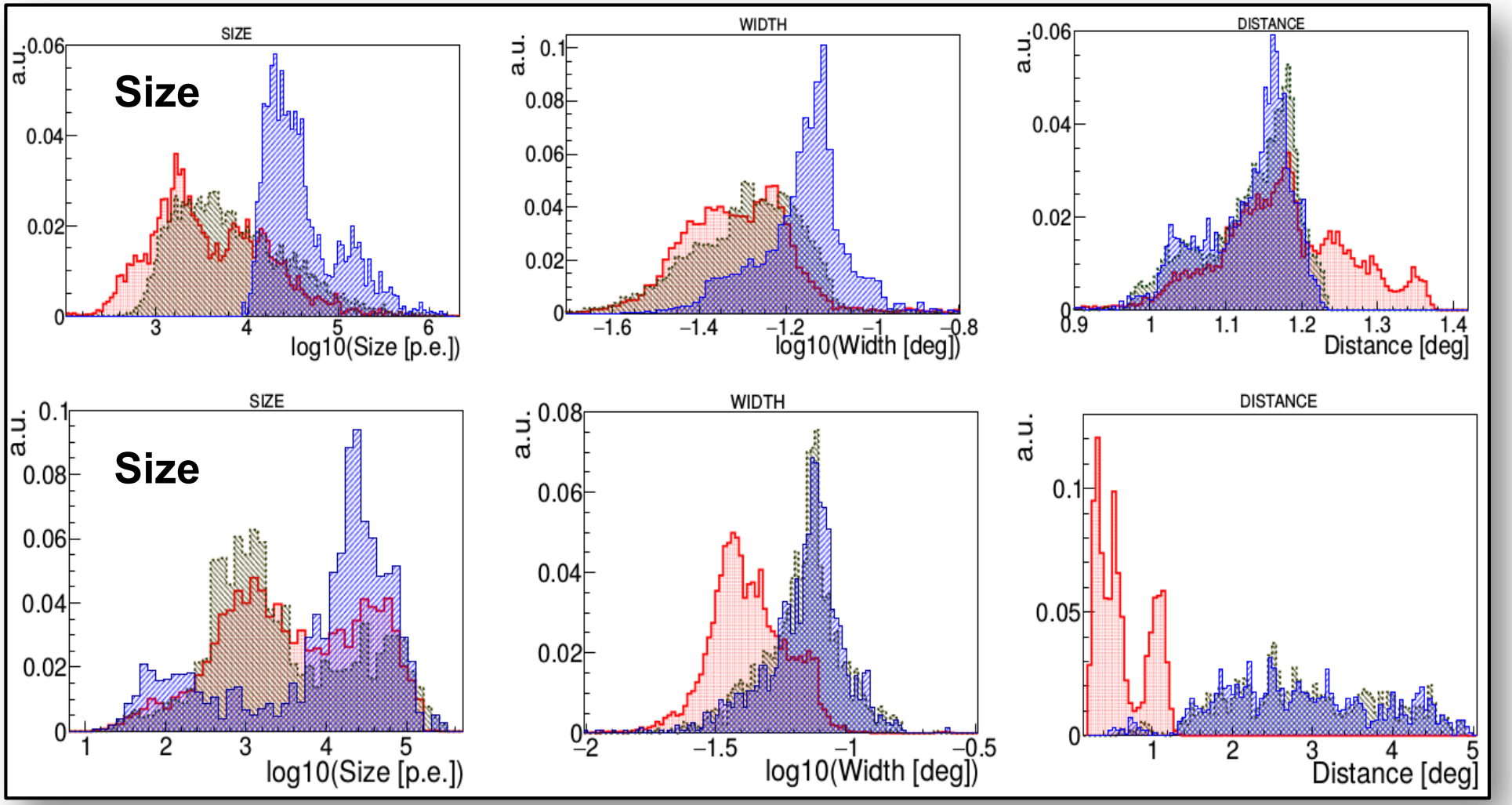
Hillas image parameters



Hillas parameters: preliminary results

Top: R_{IMP}=1300m ; bottom R_{IMP}=4000m

SPS — PROTON — PHOTON —



> Potential for **event by event discrimination** for different impact distnaces R_{IMP}
→ cut on multivariate analysis could allow discrimination with low statistics (how many events do we need?).

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.

... so stay tuned and wait for exciting results from CREDO

Visegrad Fund

Thank you for your attention