



A proposed **ground-array** detector network, composed of smartphones!

- Atmospheric fluorescence
- Cherenkov telescopes
- Radio frequency
- Ground arrays



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Pierre Auger Observatory



What are we looking for?



GZK Limit





Rare+Exotic Events



exotic processes \Rightarrow unique signatures

Pierre Auger Observatory



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Rare+Exotic Events









Smartphones are: ^(tiny) Particle Detectors

Camera Sensor



(Active area: ~0.2 cm²)



(Gamma rays on Smartphone)



Smartphones are: Mobile Laboratories









Our goal: *network* a large number of smartphones into a worldwide observatory!





http://crayfis.io

The App: Internals



Scan video for bright pixels. Upload any hits to our server.

Shower Reconstruction: PAO

1,5 km

6999998 9999999999999999999999999

Auger: highly sensitive detectors w/ picosecond timing



Air-shower Likelihood

During a shower event, the expected number of particle hits is:

$$\lambda = A\epsilon \cdot \rho(x, y) + \eta$$

- active area
- ϵ detection eff.
- ho LDF [particles/m²]
- η noise term



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Probability of seeing nothing: $P_0(x,y) = e^{-\lambda}$



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Likelihood function, given phones that were / weren't hit:

$$L(E_0, \theta, \phi, s) = \prod_i P_0(x_i, y_i) \prod_j (1 - P_0(x_j, y_j))$$

no hit hit

How Many Phones? (for UHE air showers)



How Many Phones? (for UHE air showers)



How Many Phones? (or people)





Scaling Up



Clusters are better than Uniform

Scaling Up



Clusters are better than Uniform



Are (smartphones + detectors) better than smartphones?



Q: Are (smartphones + detectors) better than smartphones?

- A: ... probably yes!
 - Improve timing resolution
 - Reduce combinatorial backgrounds
 - Better constrain likelihood for particle density
 - Allow simultaneous observation in multiple channels (e.g. radio)

CRAYFIS: Current Status

✓ Android app is more-or-less stable

➡ iOS version expected by end of summer

✓ Web/DAQ infrastructure ready to go

Main challenge:

Modeling **pixel response** to shower constituents



(optimistic) Roadmap

- October: Muon beam time at CERN
- Winter: iOS version of CRAYFIS app

• End-of-Year:

Hopefully reasonable CMOS modeling + trigger validation

• Next year: Wide release

Phones can see muons and gamma rays

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Phones can see muons and gamma rays

- Under the right conditions, can even compete with the state-of-the-art UHECR search!
- Combination with other networks may enhance sensitivity
- There's never been a global observatory of this scale...

who knows what else we may find!

The End!

If you have an **android** phone and still want to crash-test, download a binary at this super-secret URL!

http://credo2016.crayfis.io



Trigger Calibration



Set **trigger threshold** to maintain average event rate of ~0.1Hz (at full scale, corresponds to roughly **reddit-level traffic**)

CRAYFIS web backend



Combinatorial BGs



Photon Sensitivity



What do Photons Look Like?

Usually: a single pixel high above threshold



What do Photons Look Like?

Sometimes we get interesting tracks:



Muon Sensitivity

Ongoing efforts:

Scintillator muon telescope

- Phone camera is only ~0.1cm²
- Very low SNR

Underground laboratories

- ... they stole our phones! :(
- Higher radiogenic BG's





Muon Sensitivity We're HEPex-perts! We can simulate them!

(Ultimately we need accurate MC anyways)



SEM image of pixel from Samsung Galaxy S6



(crude) GEANT model

