Turn Your Phone Into A Particle Detector

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Sep 28, 2015

KIAA Astroparticle Physics Workshop

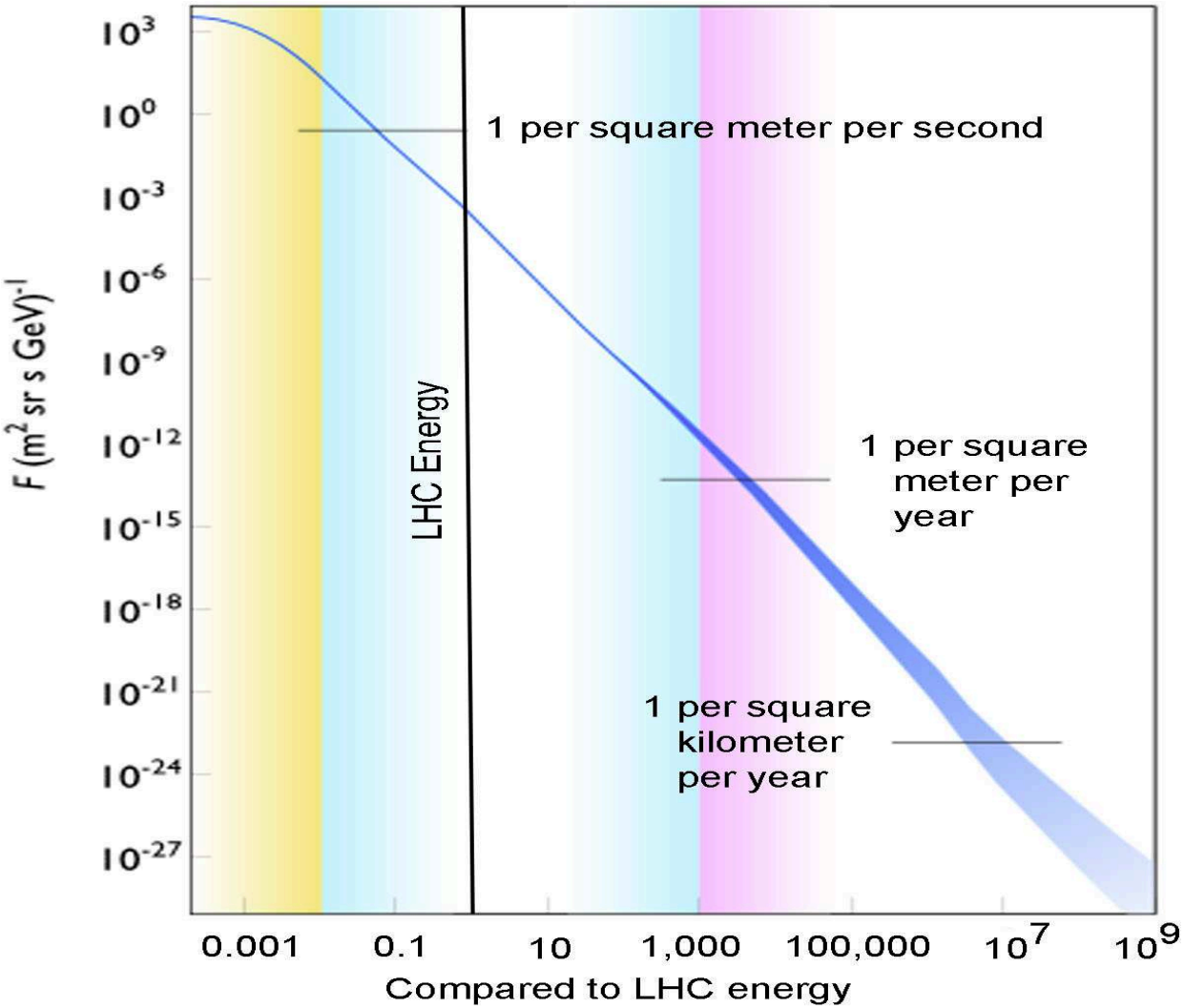
Outline: Particle Detector In Your Pocket

- CRAYFIS: Cosmic RAYs Found In Smartphones
  - CRAYFIS app
  - Pixel Detector
  - Online / Offline
  - Sensitivity
- Not Just Smartphones:
  - CCD Cameras
    - LAMOST
    - ...

Listen to Nature's Messengers: Cosmic Rays

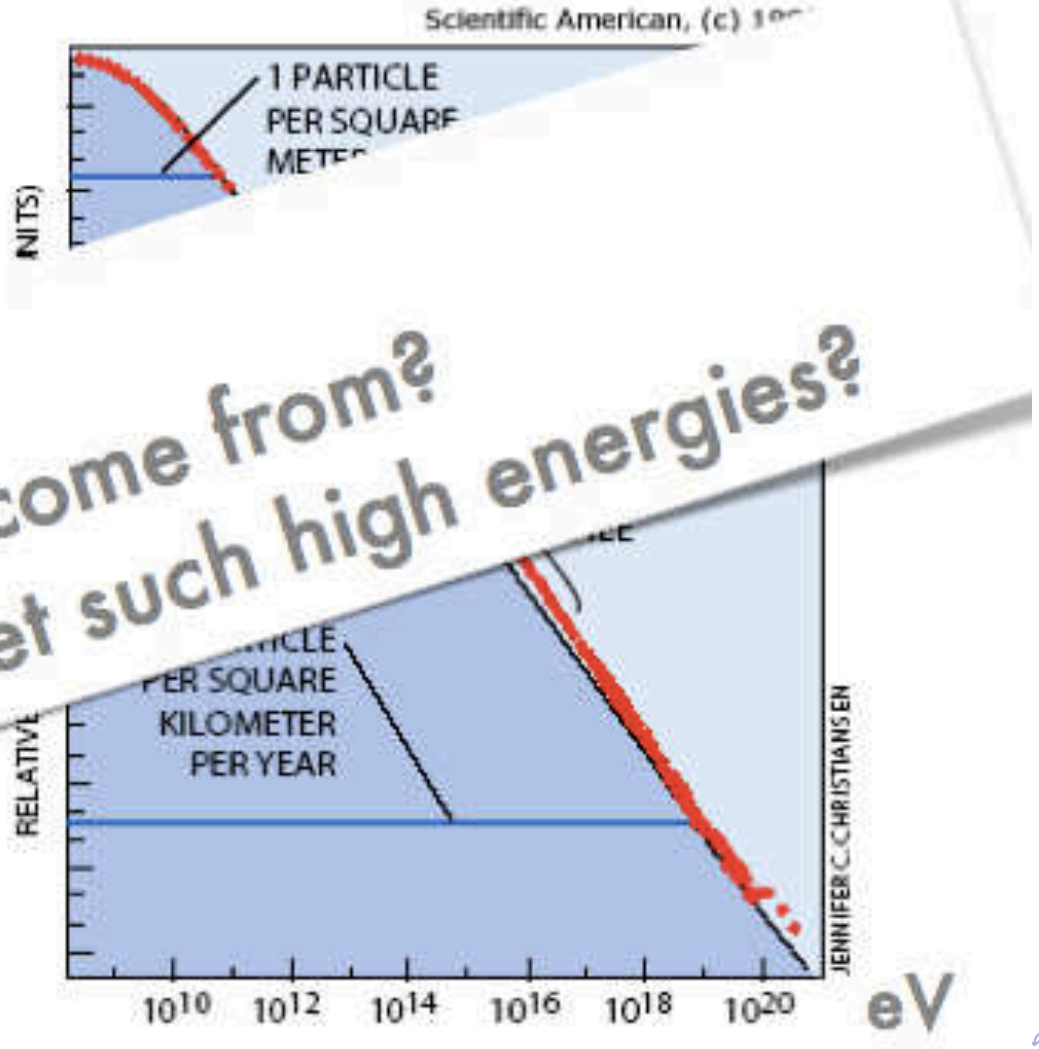
- Cosmic Rays:
  - Energetic charged particles
    - originating in outer space
  - Most primary CR:
    - protons, atomic nuclei, or electrons
  - Can have extremely high energy:
    - 10^{18} eV and above
  - Energy spectrum of primary CRs known to extend beyond 10^{20} eV
  - Compare to the world's largest particle collider LHC:
    - Designed goal: 14 TeV = 14 * 10^{12} eV
- When Cosmic Rays enter earth atmosphere:
  - collider with oxygen or nitrogen
  - produce a cascade of light secondary particles:
    - photons, electrons, muons, neutrinos...

Listen to Nature's Messengers: Cosmic Rays



- Our Universe is a high energy accelerator, and it is FREE!
- Figure: http://en.wikipedia.org/wiki/Cosmic_ray

A loose thread



What are they?
Where do they come from?
How do they get such high energies?

Cosmic RAYs Found In Smartphones

- Event Rate for Ultra High Energy Cosmic Rays:
  - @ 10^{20} eV:
  - 1 per square kilometers per century
- Can't wait for a century:
  - need as many detectors to collect data as possible

CRAYFIS Turns Your Phone Into A Particle Detector

- CRAYFIS: Cosmic RAYs Found In Smartphones
- Web: crayfis.io
- Use Phone's built-in Camera
  - can detect visible light
  - can also detect high energy particles:
    - photons: X rays, gamma rays
    - electrons, muons
- Use Phone's built-in GPS
  - for position information

Cosmic RAYs Found In Smartphones Collaboration

Whiteson
Shimmin
Strong
Brodie
Goddard
Porter
Sandy

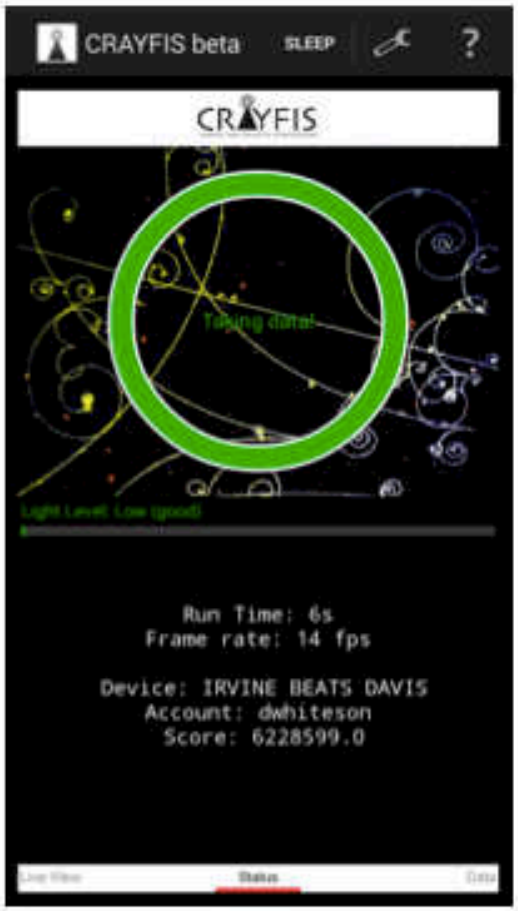
Cranmer

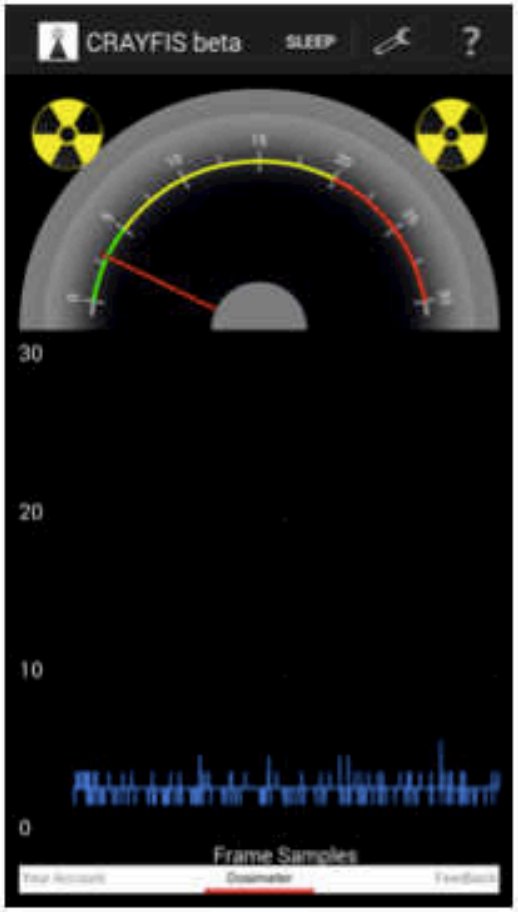
Ustyuzhanin
+2 masters st.

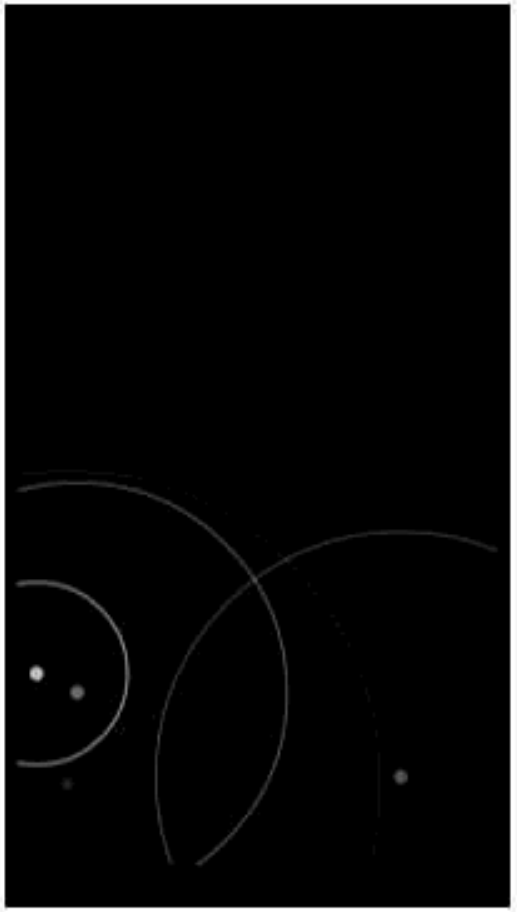
Mulhearn
Burns
Buonacarsi

Deng

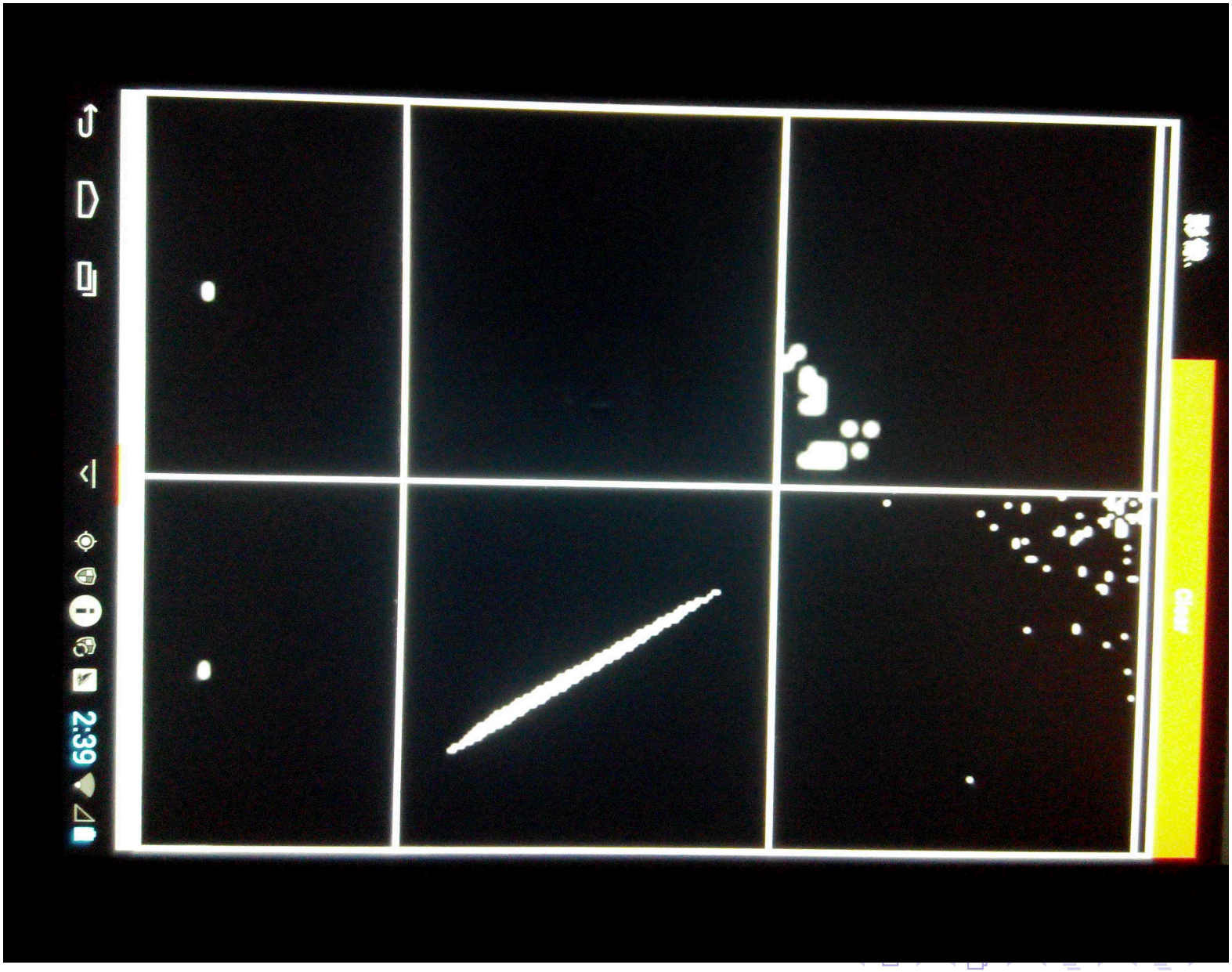
Android App


CRAYFIS beta
SLEEP
CRAYFIS
Run Time: 6s
Frame rate: 14 fps
Device: IRVINE BEATS DAVIS
Account: dwhiteson
Score: 6228599.0


CRAYFIS beta
SLEEP
30
20
10
0
Frame Samples



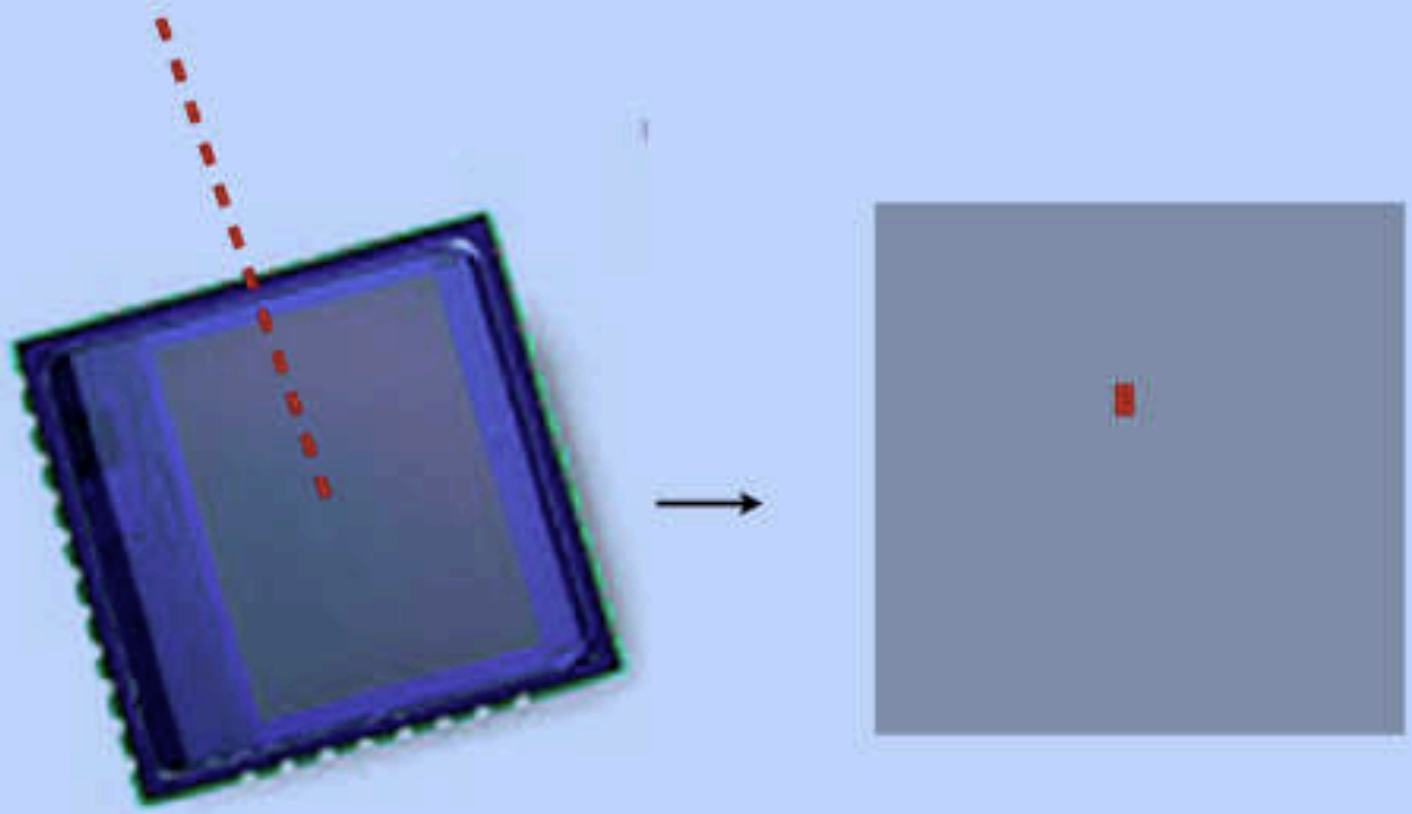
Some Photos of Cosmic Rays from My HuaWei Pad



TRY IT NOW On Your Phone

http://crayfis.io/howto-android.html

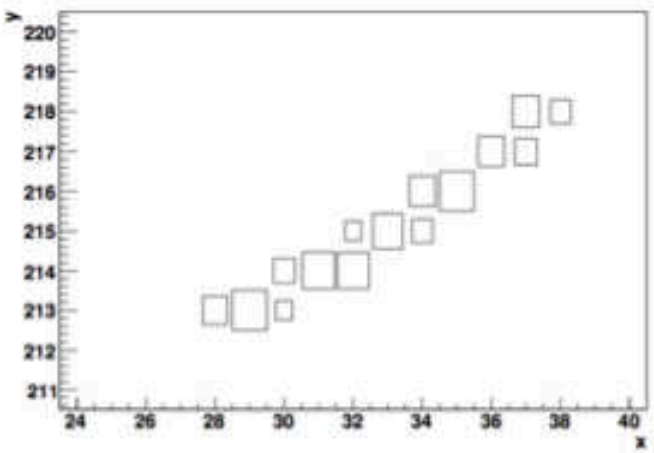
Particle detector

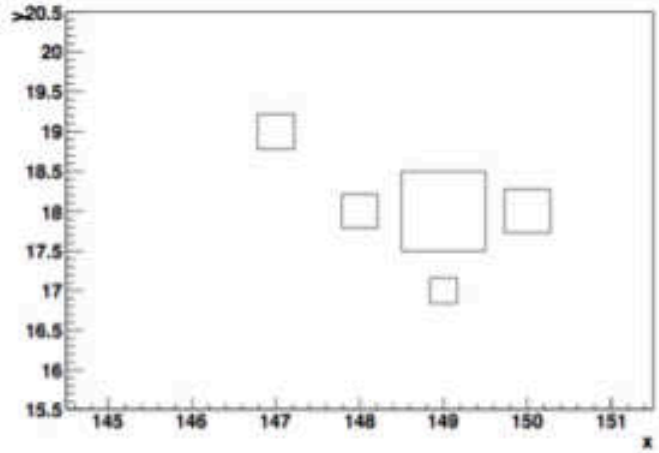


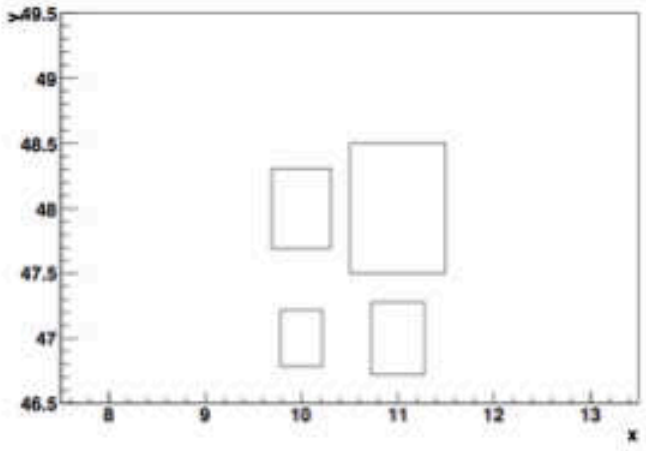
Particle incident on CMOS chip

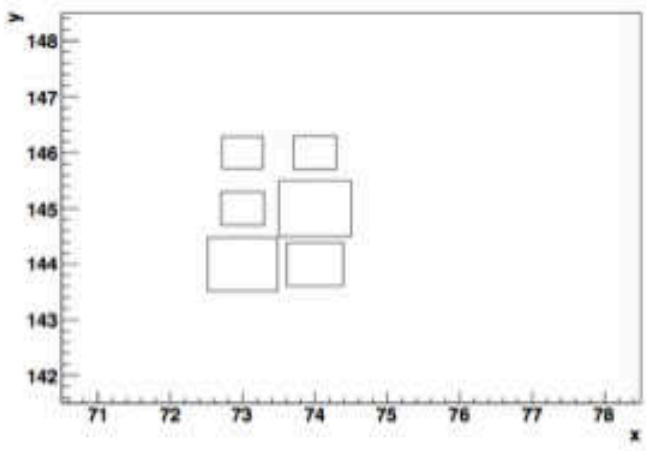
Hot pixel in image

Individual hits

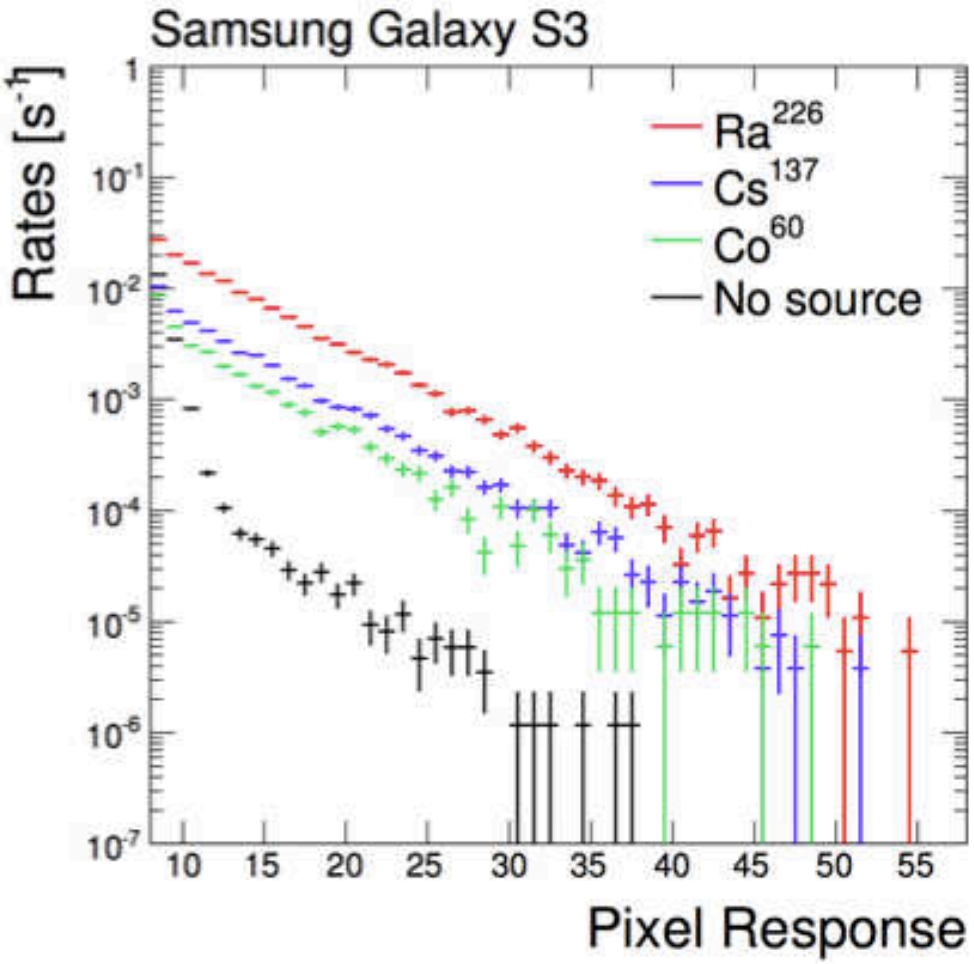








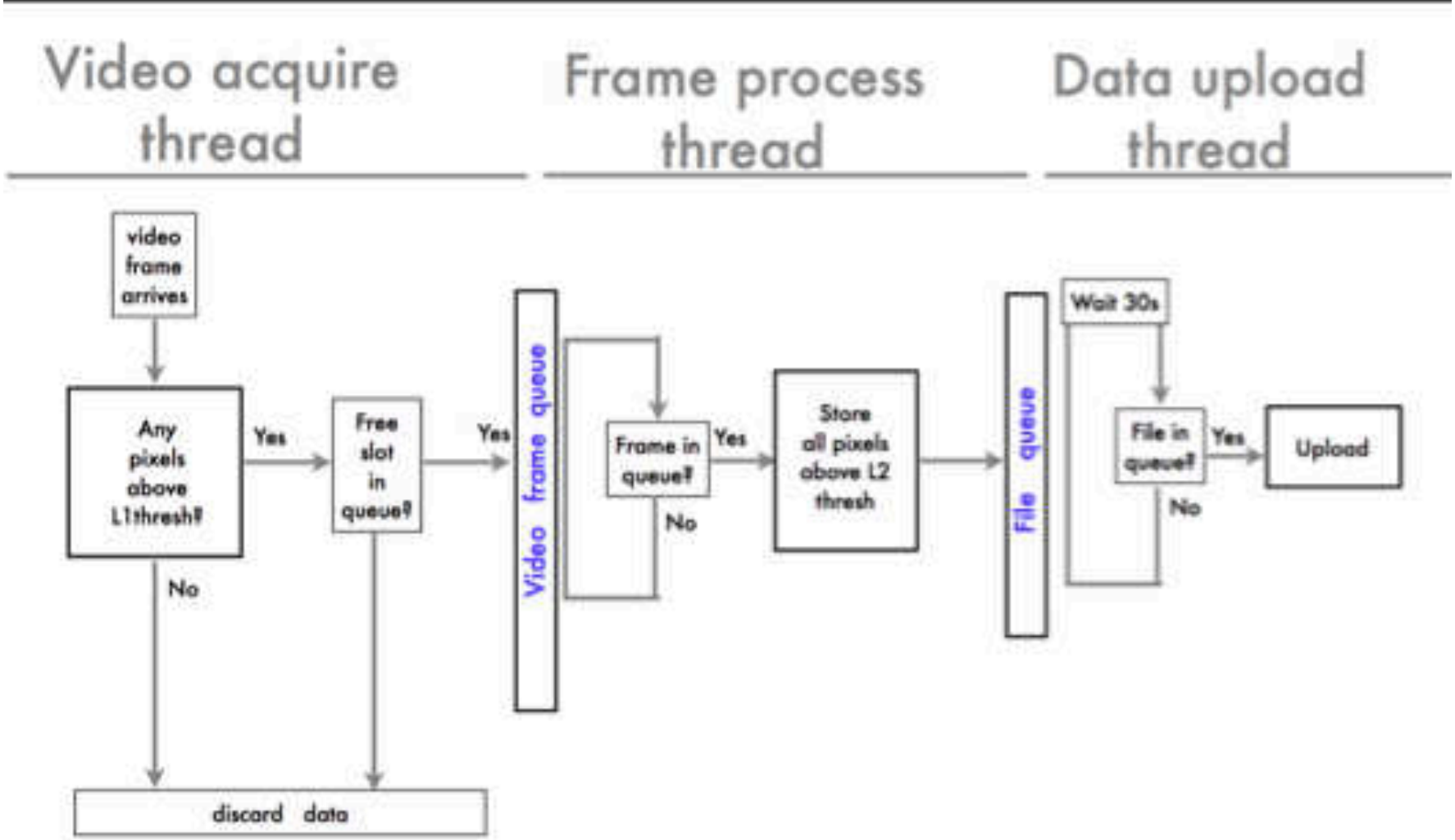
Sources



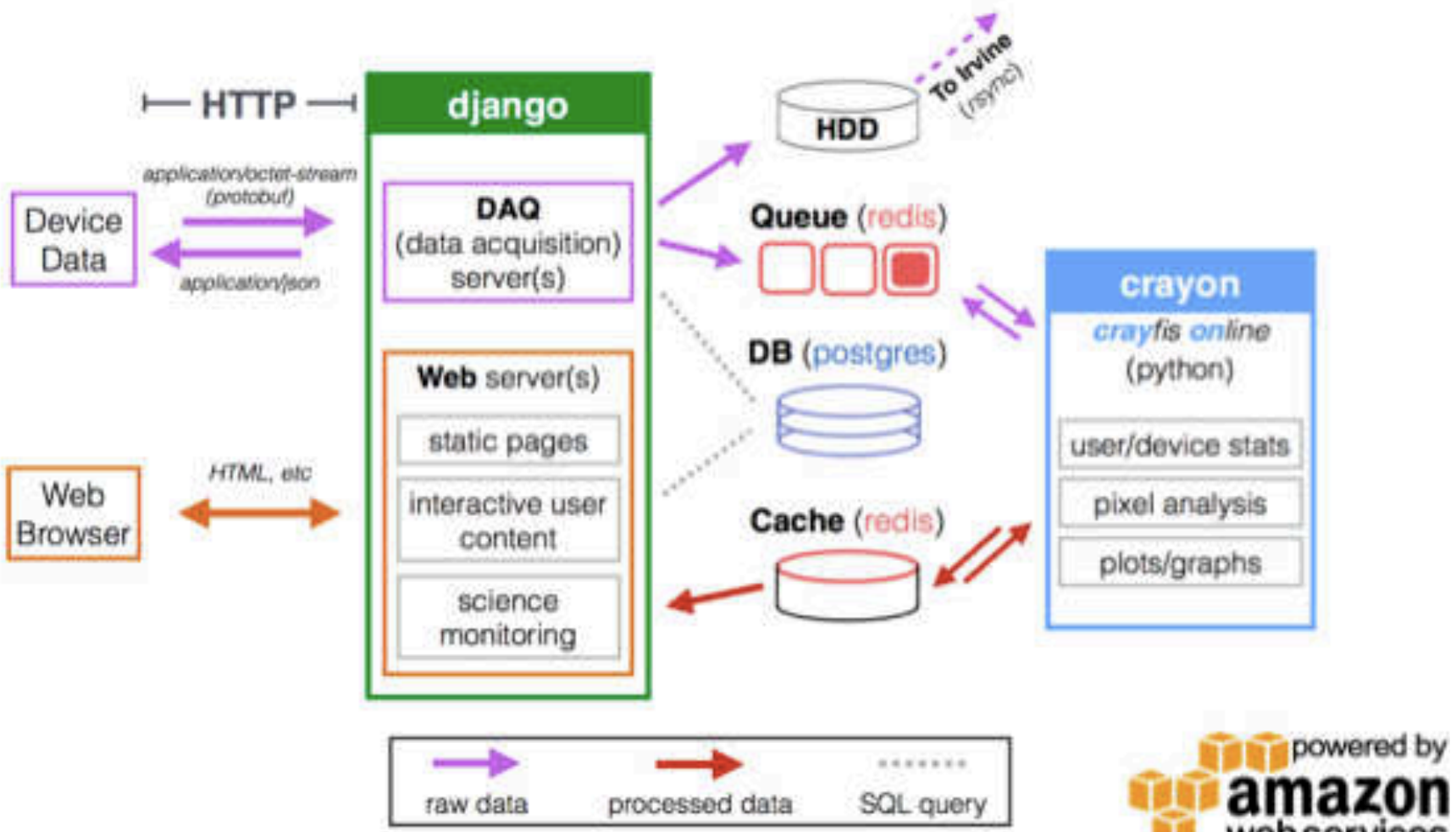
Sources held at fixed distance from phones.

Other devices give qualitatively similar spectra

Software

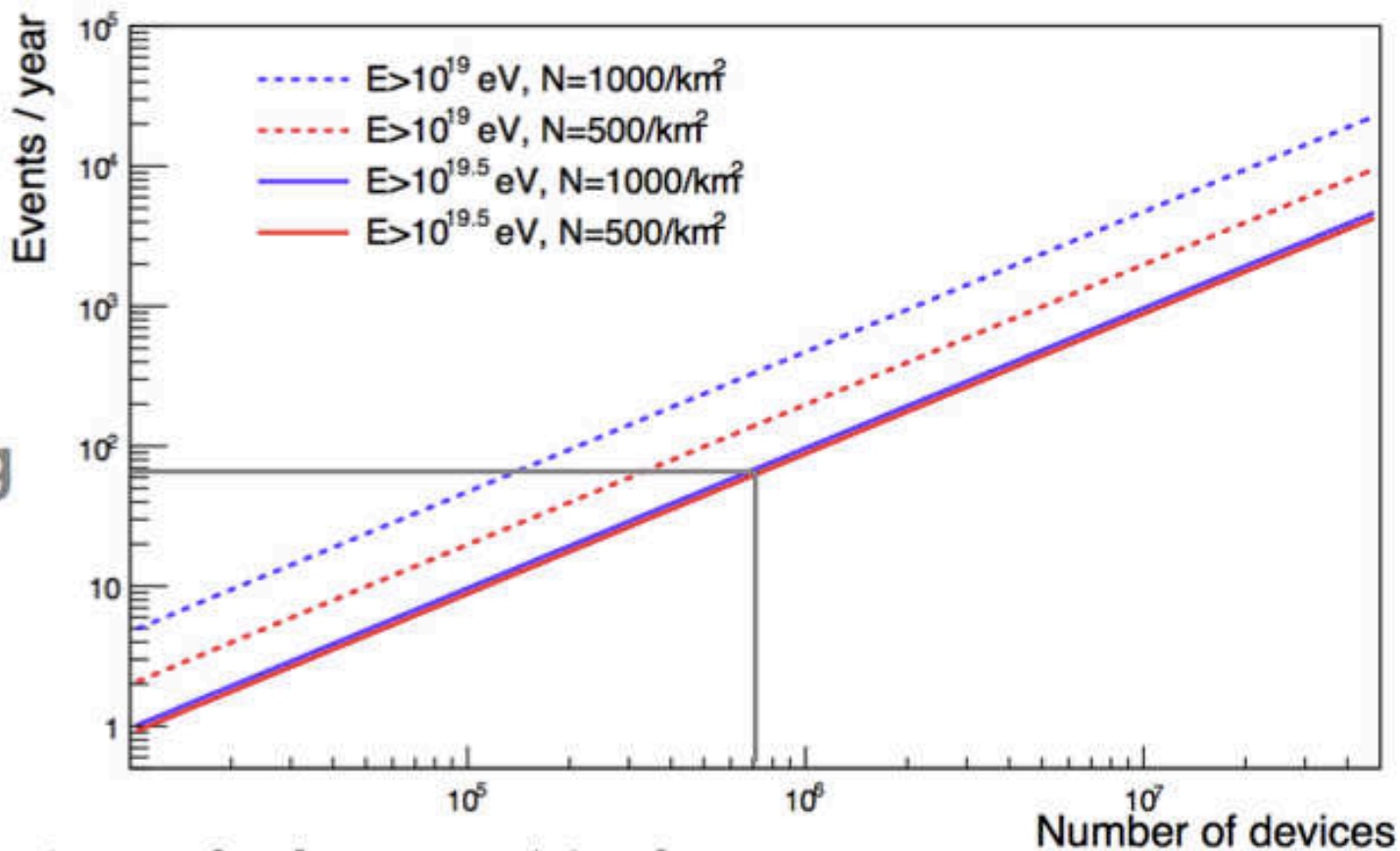

Video acquire thread
Frame process thread
Data upload thread
video frame arrives
Any pixels above L1thresh?
Yes
No
Free slot in queue?
Yes
discard data
Video frame queue
Frame in queue?
Yes
No
Store all pixels above L2 thresh
File queue
Wait 30s
File in queue?
Yes
No
Upload

DAQ


HTTP
django
To Irvine
(rsync)
HDD
application/octet-stream
(protobuf)
Device
Data
application/json
DAQ
(data acquisition)
server(s)
Queue (redis)
DB (postgres)
crayon
crayfis online
(python)
Web server(s)
static pages
interactive user
content
science
monitoring
user/device stats
pixel analysis
plots/graphs
HTML, etc
Web
Browser
Cache (redis)
raw data
processed data
SQL query
powered by
amazon
web services

How many do we need?

Auger observing power



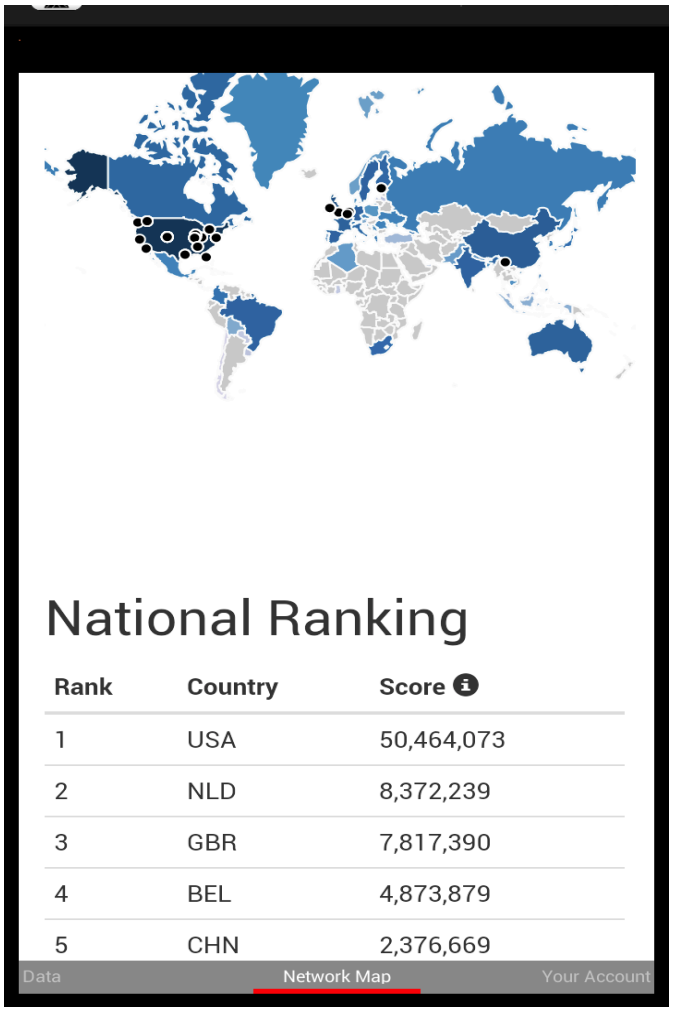
Need almost **1M** phones

Where You Could Help / Contribute (I)

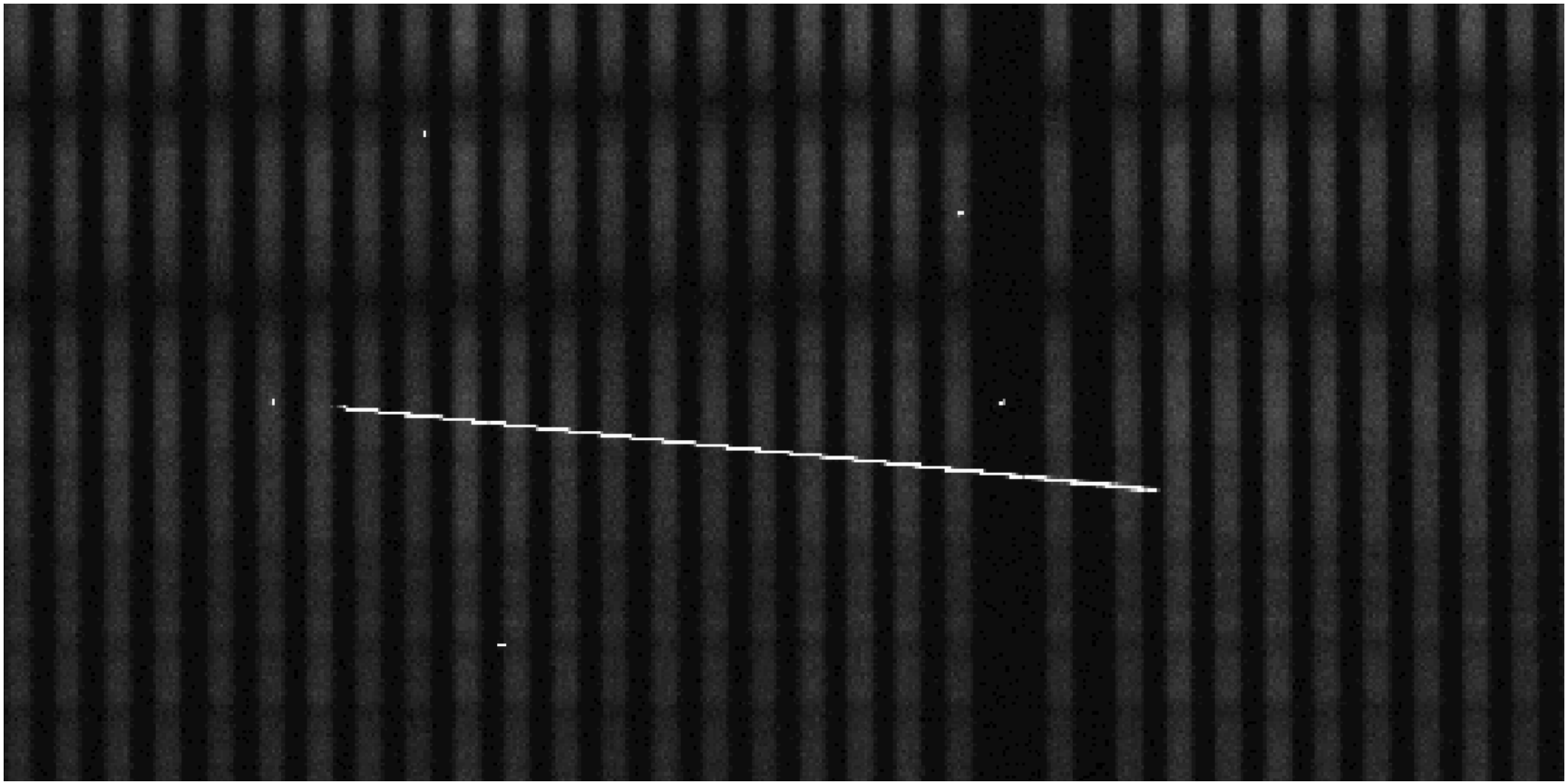
- Join our legion of beta testers
  - download current beta release (for Android system)
    - http://crayfis.io/howto-android.html
  - Run CRAYFIS on your phones
  - Data automatically sent to CRAYFIS server
- Spread the Word:
  - Help us reach our critical mass of one million users
    - Share with your friends on: WeChat, QQ, Facebook, twitter...

Where You Could Contribute (III)

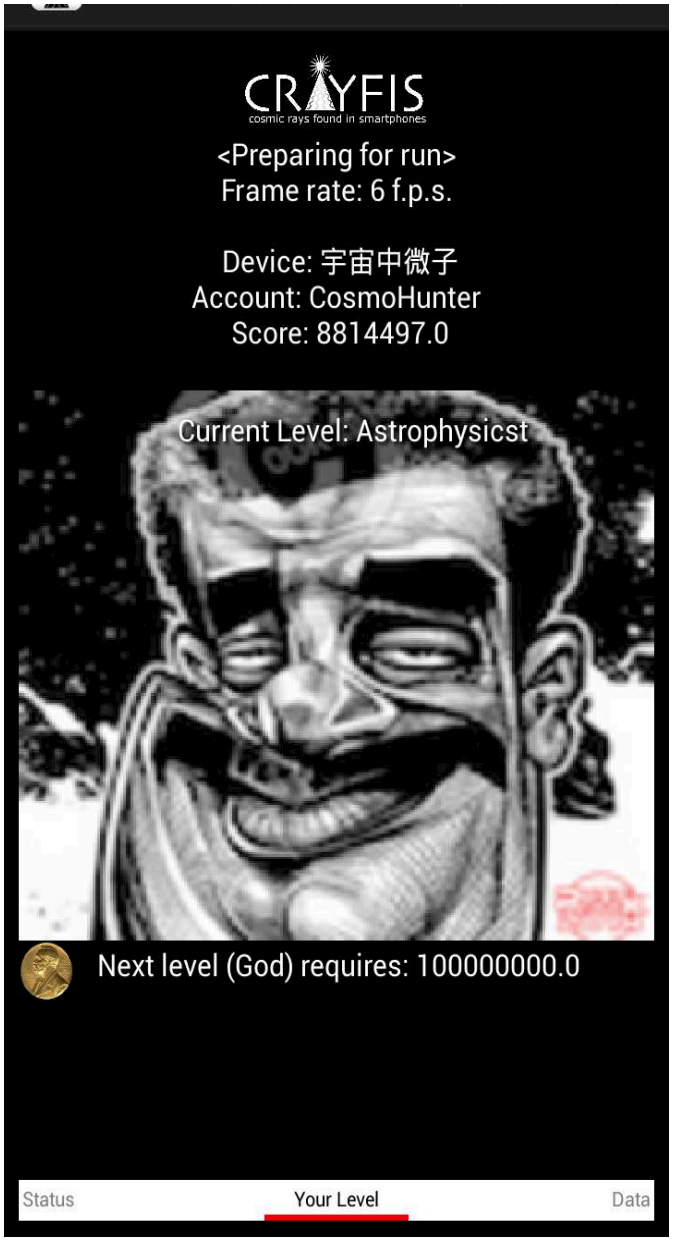
- http://dap.crayfis.io/
- Help us translate CRYFIS to your mother tongues



Cosmic Rays Recorded on CCD Camera at LAMOST



Have FUN playing CRAYFIS, Everyone!

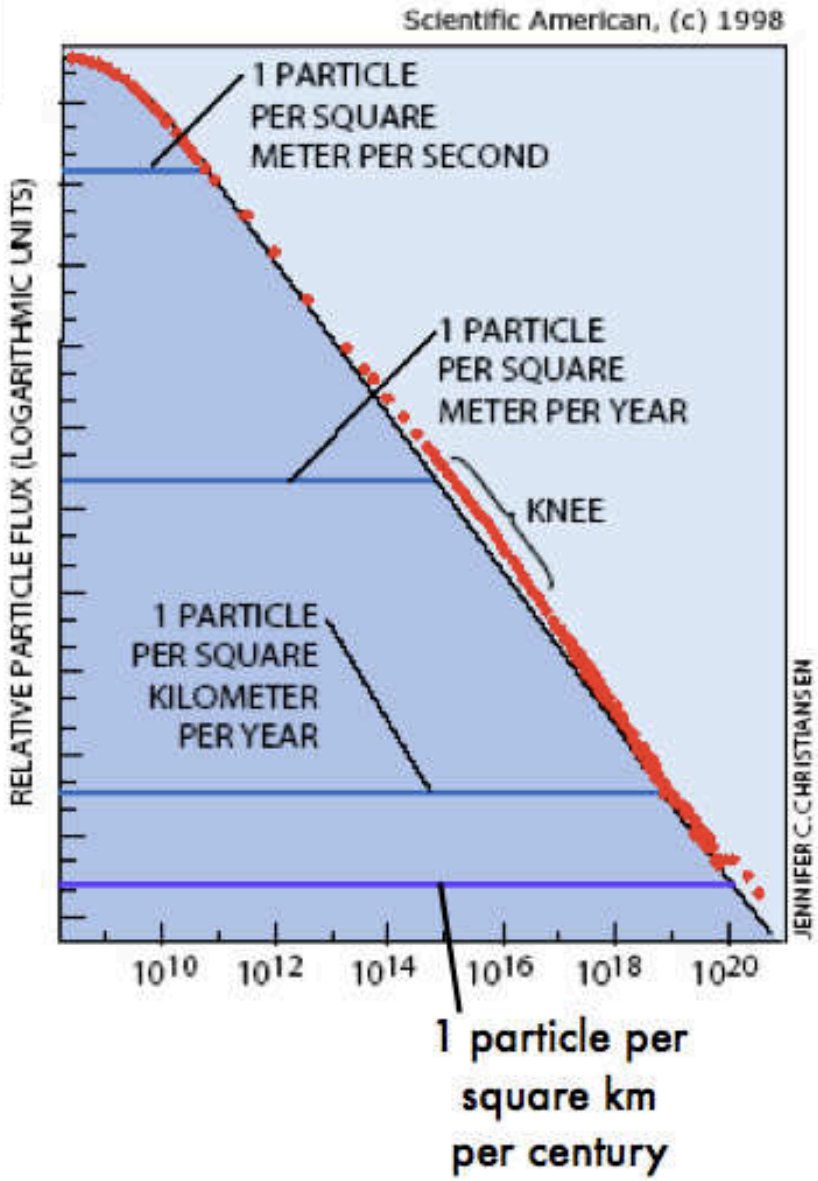


EXTRAs

The Discovery of Cosmic Rays

- Nobel Prize in 1936 to Vitor Hess
  - Observed rising radiation at rising altitudes
  - Concluded in 1912
    - a radiation of very great penetrating power
    - enters our atmosphere from above
- Our Universe is a high energy accelerator
- And it is FREE!

Earth scales



5e12 particles/year

5e8 particles/year

5e6 particles/year

Need

Wishlist

Planet-sized ground array

Existing or free devices

Wireless data upload

Remotely programmable

Maintained by dedicated shifters

Where You Could Help / Contribute (II)

- Smartphone collecting box
  - If you have some phones you no longer use
    - please donate to us for CRAYFIS data taking
    - Name: Jianrong Deng
    - Address: Datun Road. 20A,
    - ChaoYang District, Beijing 100010
    - National Astronomincal Observatories
    - Chinese Academy of Sciences
- Smartphone distributing box
  - If you would like to join the CRAYFIS data taking
  - But do not have a working phone
    - email: jdeng@nao.cas.cn
    - send your mailing address to the above email
    - First come, First get :-)

Collaboration Webpage: crayfis.io

Paper

Cornell University Library

arXiv.org > astro-ph > arXiv:1410.2895

Astrophysics > Instrumentation and Methods for Astrophysics

Observing Ultra-High Energy Cosmic Rays with Smartphone

Daniel Whiteson, Michael Mulhearn, Chase Shimmin, Kyle Brodie, Dustin Burns

(Submitted on 10 Oct 2014)

We propose a novel approach for observing cosmic rays at ultra-high energy ($> 10^{18}$~eV) by repurposir the existing network of smartphones as a ground detector array. Extensive air showers generated by cosmic rays produce muons and high-energy photons, which can be detected by the CMOS sensors of smartphone cameras. The small size and low efficiency of each sensor is compensated by the large number of active phones. We show that if user adoption targets are met, such a network will have

Connection of LHC and UHECR to the Big Bang

- The Energy at Colliders and of Ultra High Energy Cosmic Rays:
  - Recreate the Condition (Energy) as they were during the Big Bang:
    - at t $<$ 0.1 ns (10^{-10}s) after the Big Bang:
    - The earliest tick on the cosmic clock
    - Try to understand the energy condition in that first second

time(s)	E (GeV)	T (Kelvin)
10^{-37} s after Big Bang	10^{15}	10^{28}
10^{-10} s after Big Bang	10^{2}	10^{15}
of UHECR/Neutrinos	10^{11}	10^{24}
@LHC	10^{4}	10^{17}

We understand
only a few percent of the Universe so far...