Plans of Telescope Array: Extensions of "Telescope Array"

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On behalf of the Telescope Array collaboration

The Telescope Array collaboration

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26 institutes, ~120 scientists

Extension plans:

1. Extend energy range of sensitivity

   TALE (TA Low energy Extension)

2. Extend effective detection area

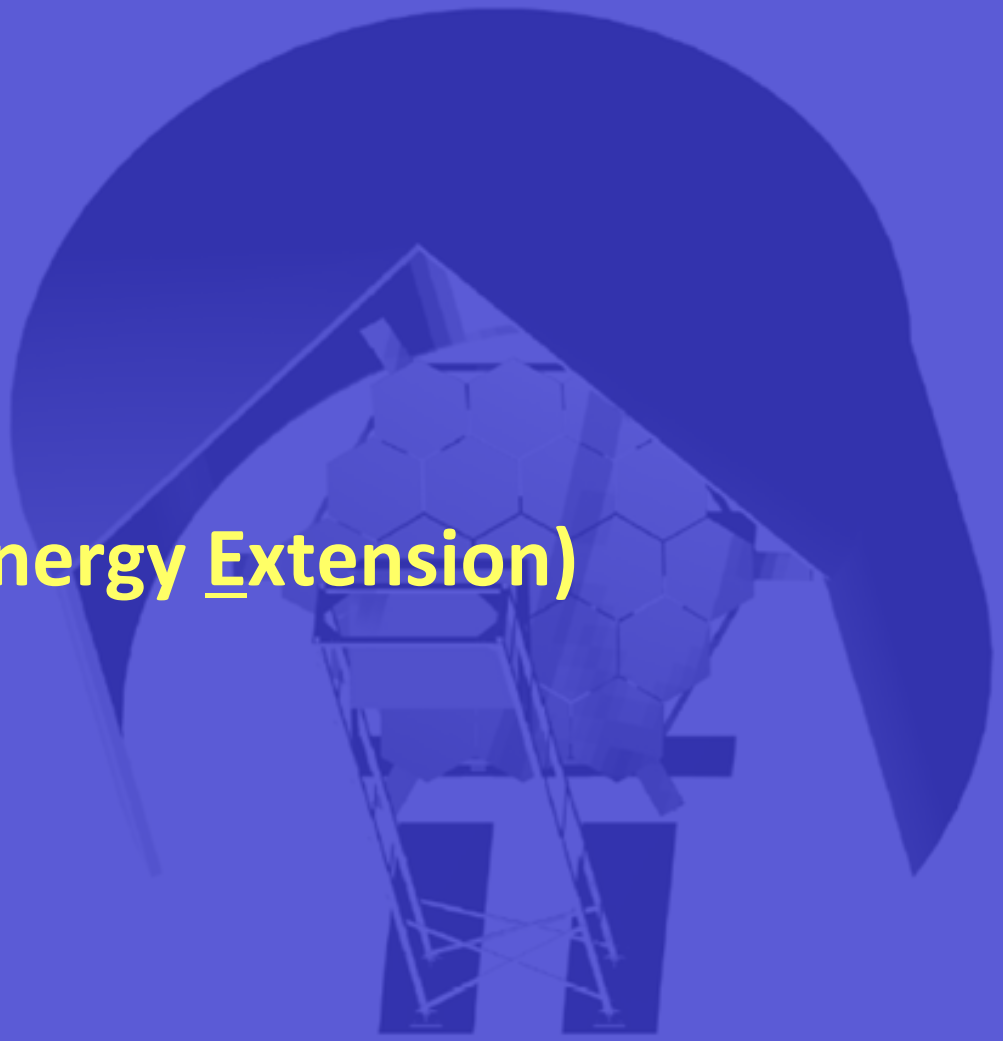
   2-1. Next Telescope Array (tentative name)

   2-2. Further extension

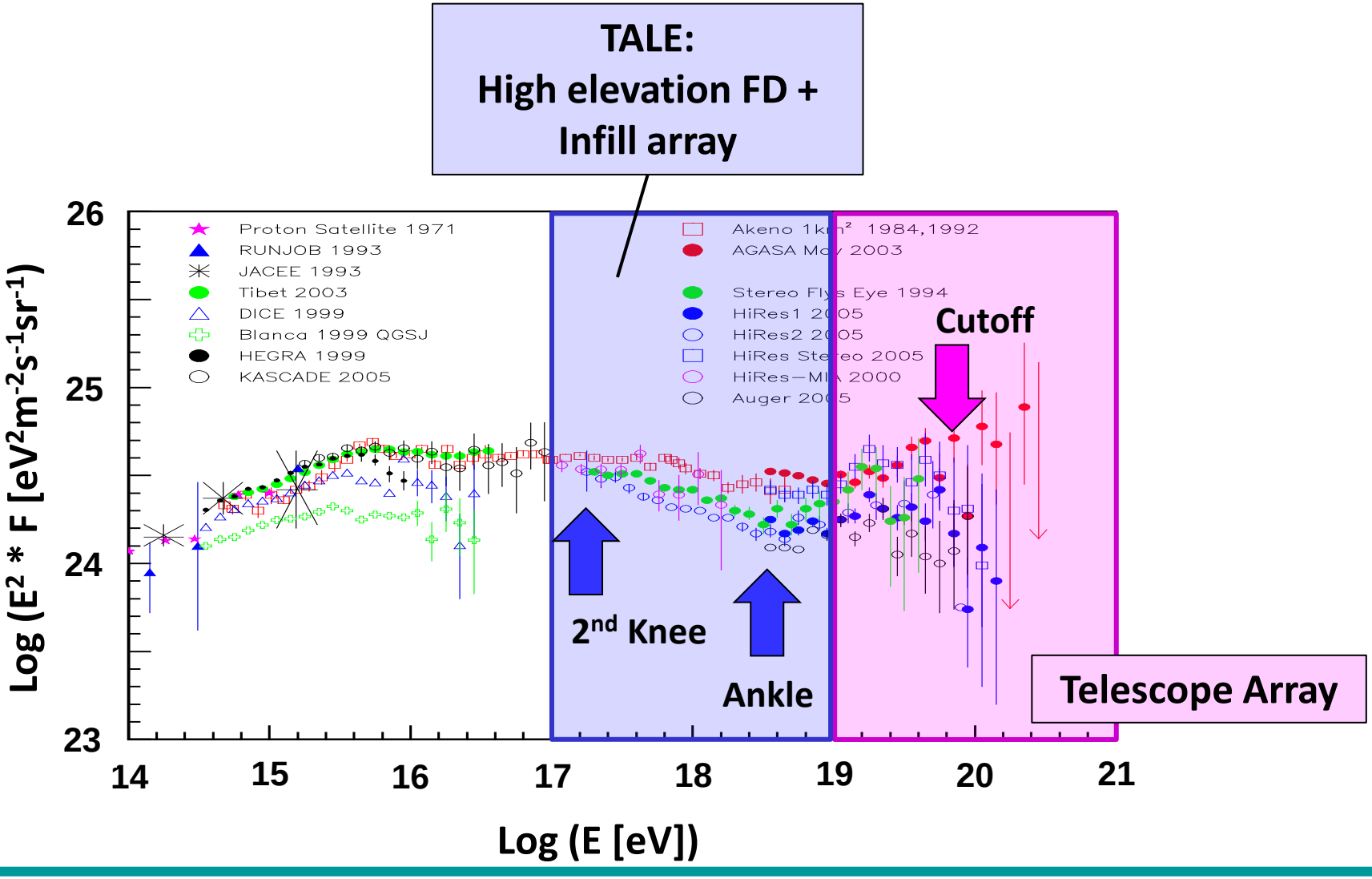
Extension 1:

TALE

(Telescope Array Low energy Extension)



TALE (TA Low energy Extension)



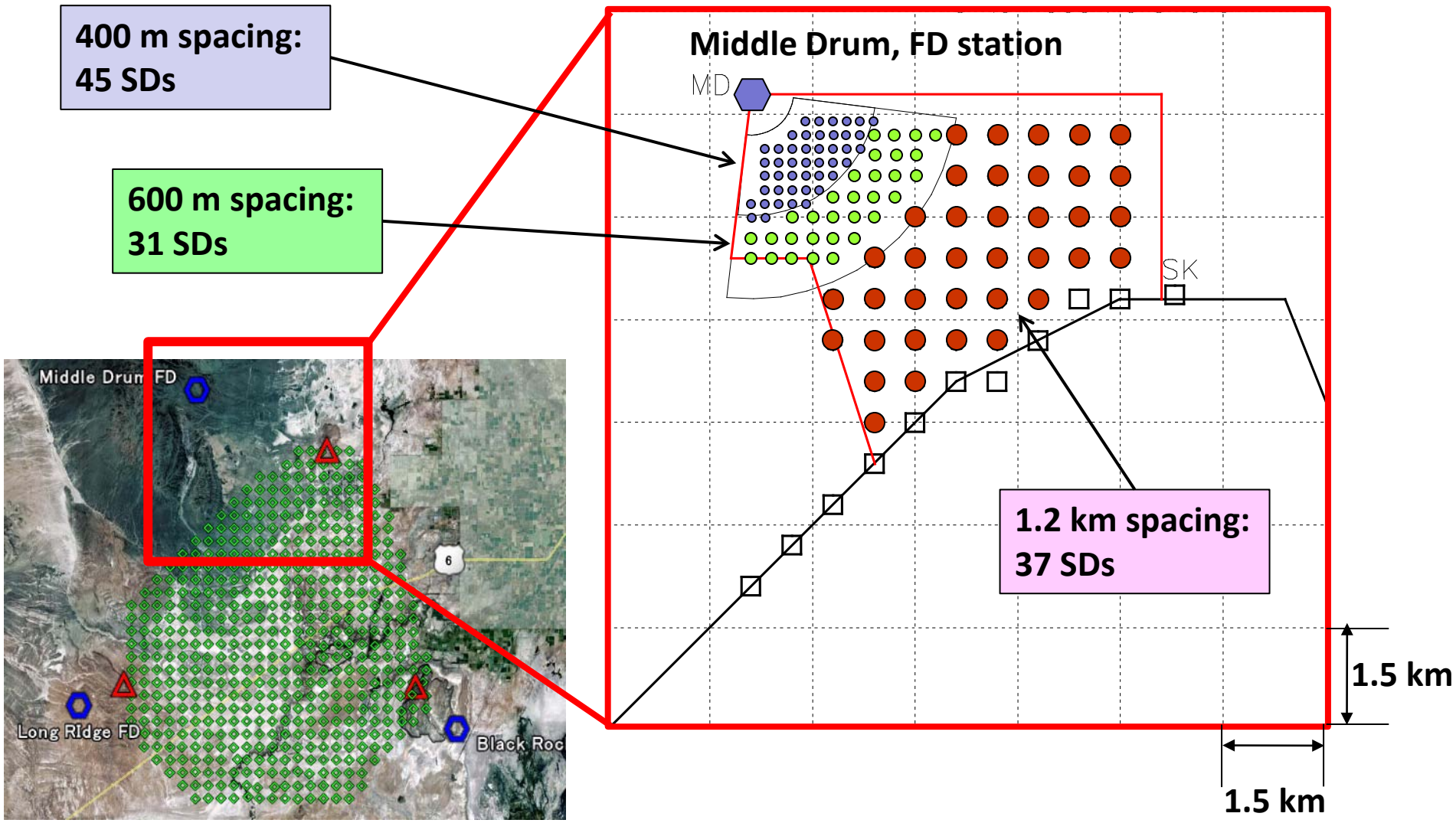
Aim of study

- **Seamlessly covers the energy range from 10^{17}eV to 10^{20}eV**
  ~10^{17}eV : 2nd knee, ~$10^{18.6}$eV : ankle, ~$10^{19.8}$eV : cutoff

- **Energy spectrum and Composition with large statistics**
  Measure not only energy spectrum, and also primary composition with one set of detectors, at the same place and simultaneously
  ~10^{17}eV : 2nd knee : Galactic CR ⇔ Extra Galactic CR ?
  ~$10^{18.6}$eV : ankle : GCR ⇔ EGCR ? p + gamma → e^++e^- + N ?
  ~$10^{19.8}$eV : GZK ? Heavy primary ?

- **Cross-calibrations of different types of detectors at the same place**
  Stereo FD ←→ Ground detectors
  Stereo ←→ Hybrid
  FD calibrations with Electron Light Source (=Electron LINAC)
  Test of hadron interaction models

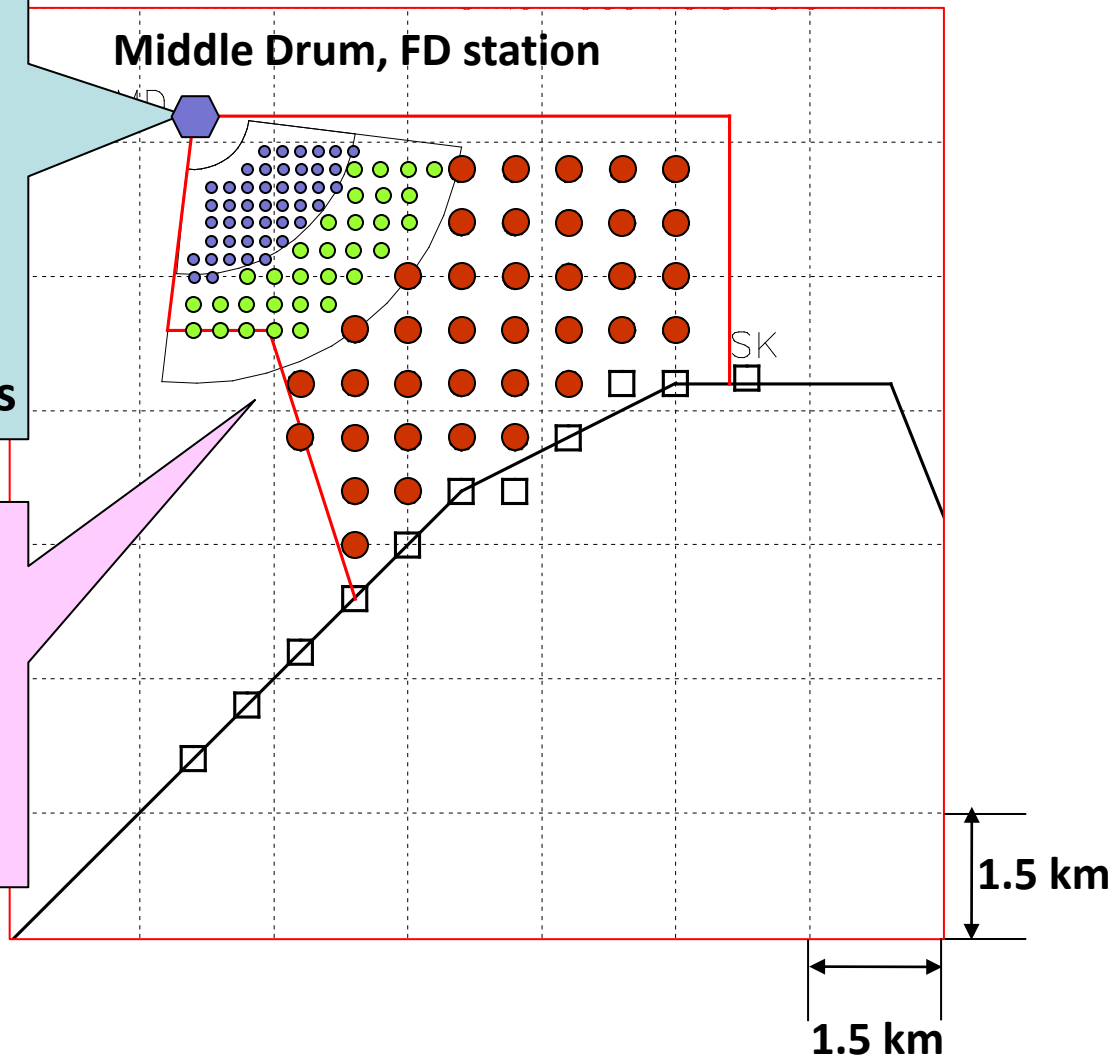
Draft Layout for TALE



Draft Layout for TALE

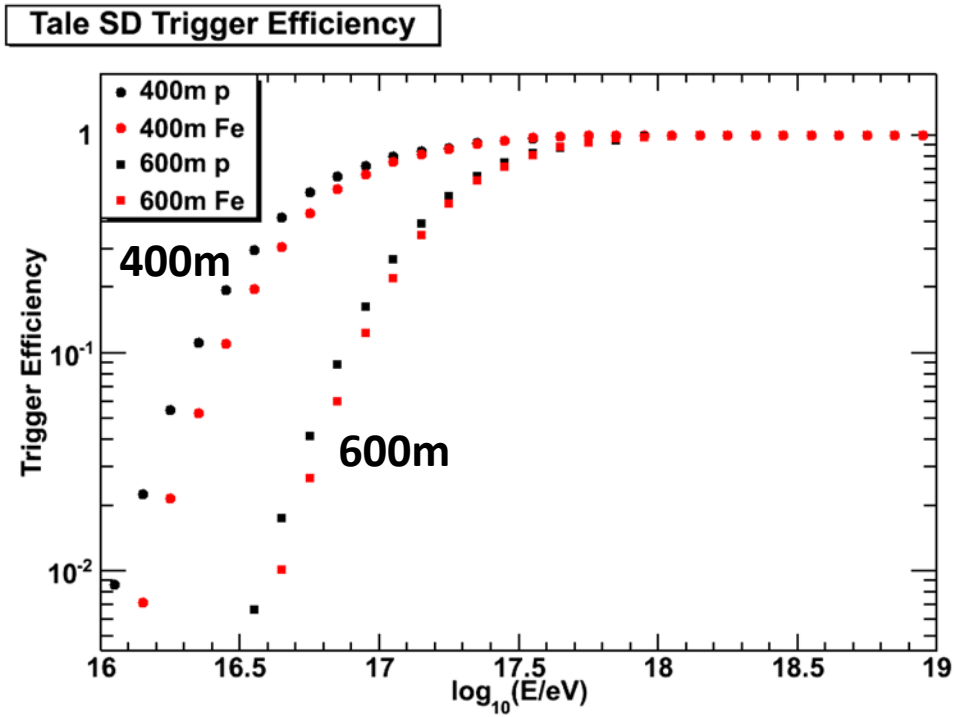
Extend FD field of view @MD :
Add 11 telescopes to MD
→Cover 3° - 59° in elevation
90° in azimuth
HiRes-2 mirrors,
Reconditioned HiRes-2 electronics

113 new SD counters:
45 at 400m spacing, r<3km
31 at 600m spacing, r>3km
37 to build up from main SD array, at 1200m spacing



Rates

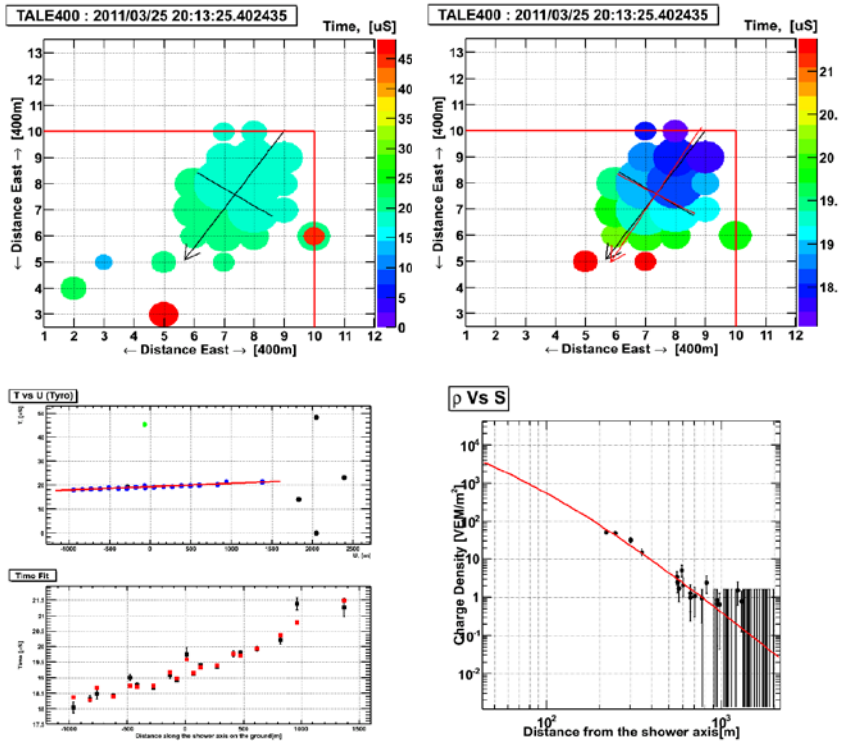
- 0.14 Hz of cosmic rays hit infill array
  (18.9 km^2, θ<60^o, E > $10^{16.5}$ eV)
- 0.046 Hz within the 400m spacing part
- Infill array Efficiency:
  - 50%, $10^{16.5}$ – $10^{17.5}$ eV, 400m
  - 10%, $10^{16.5}$ – $10^{17.5}$ eV, 600m



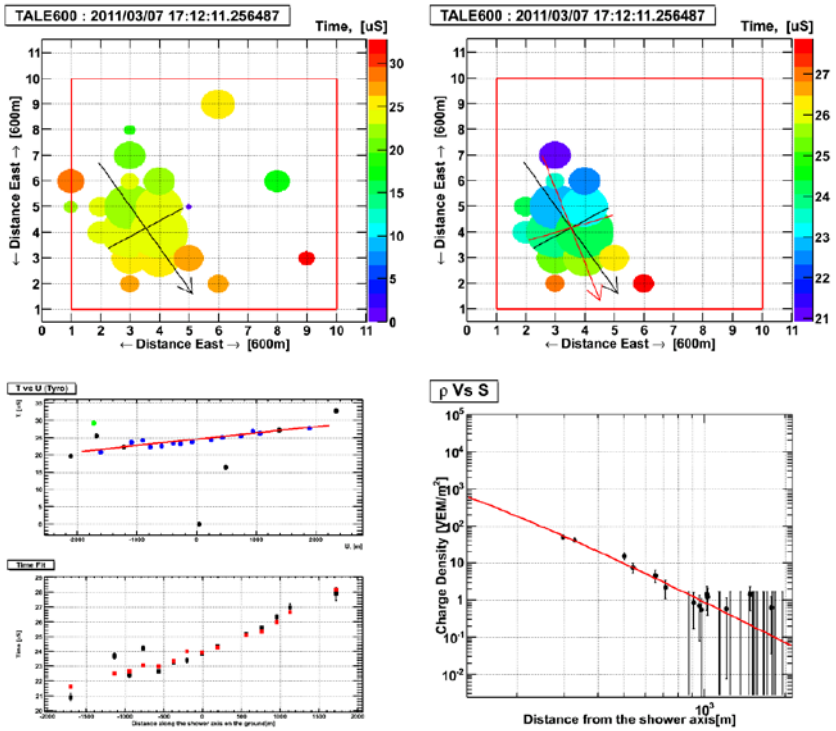
- SD trigger rate ~ 2/min
- Hybrid trigger rate ~ 0.14 Hz*0.05 eff =0.4/min

Event display

400m spacing, $10^{17.5}$ eV



600m spacing, $10^{18.0}$ eV



Extension 2-1:

Next Telescope Array

(tentative name)

Aim of study …

Large amount of statistics of UHECR events and….

- **Discoveries of UHECR origins -> Study acceleration and propagation**
  - More events for Anisotropy Study/Search point sources
    - Large effective area, large duty factor, good angular resolutions
  - Energy spectra for each origins (directions)
    - Good energy resolution

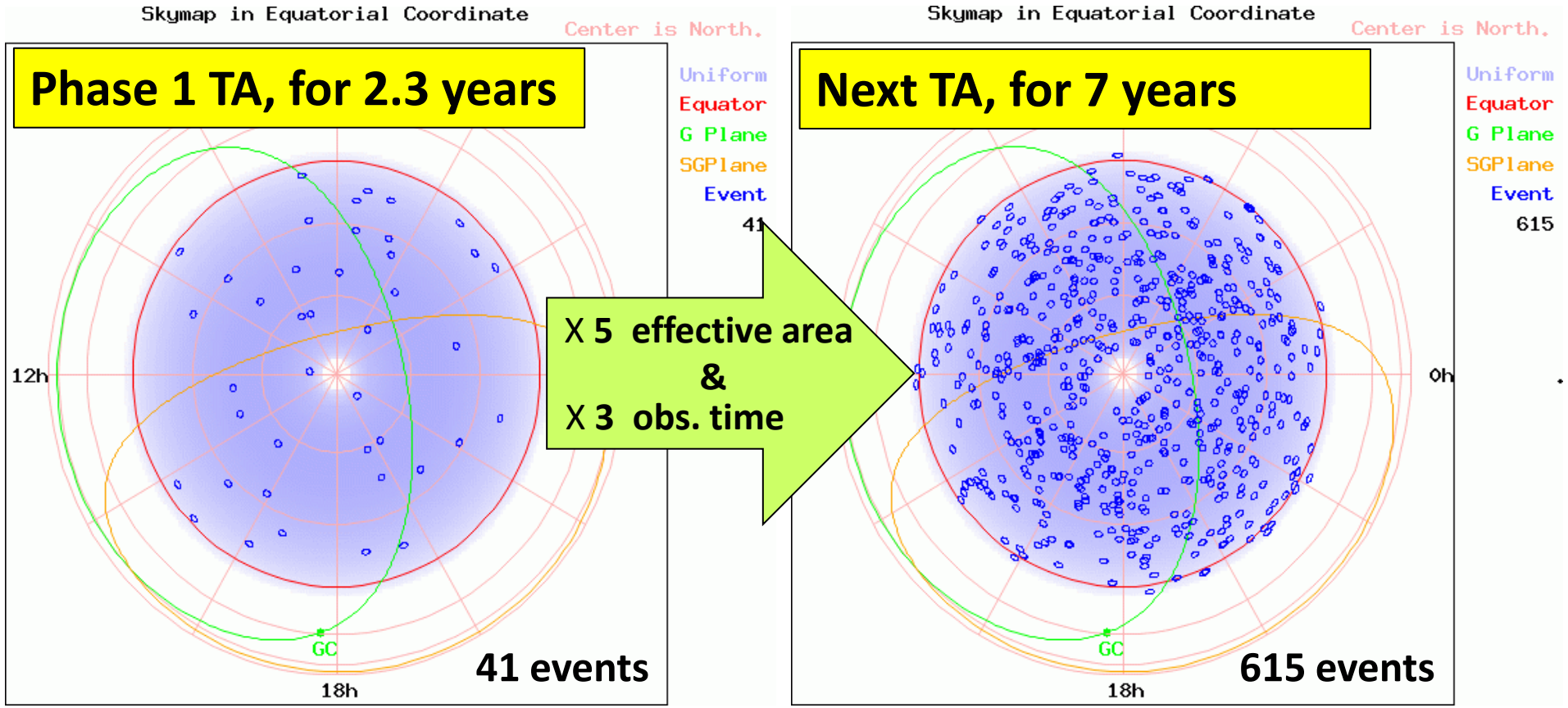
As a first step of extension, concentrate these points!

- **Study primary composition**
  - Phase 1 TA cannot finish for high energy end, $E > 10^{20}$ eV
- **Northern hemisphere**
  - ←→ Auger south
    - In a complementary style
  - Different sources, different spectra, different composition …..
- **Sensitivity for UHE neutrinos**

Statistics: Need more events

E > 40 EeV, Zen. < 45°

Simulated events (Isotropic)
By T. Okuda



Next TA

Next TA: extend SD area, (Phase 1 TA) X 5

Size estimation

- SD array: Area = 3,400 km^2

  (Phase 1 TA) 680 km^2 per 507 SDs -> 1.34 km^2/SD, 1.2 km span

  (Next TA) 1.5km span -> 2.09 km^2/SD

  3,400 km^2 / 2.09 ~ 1,630 SDs

Cost estimation

- SD array:

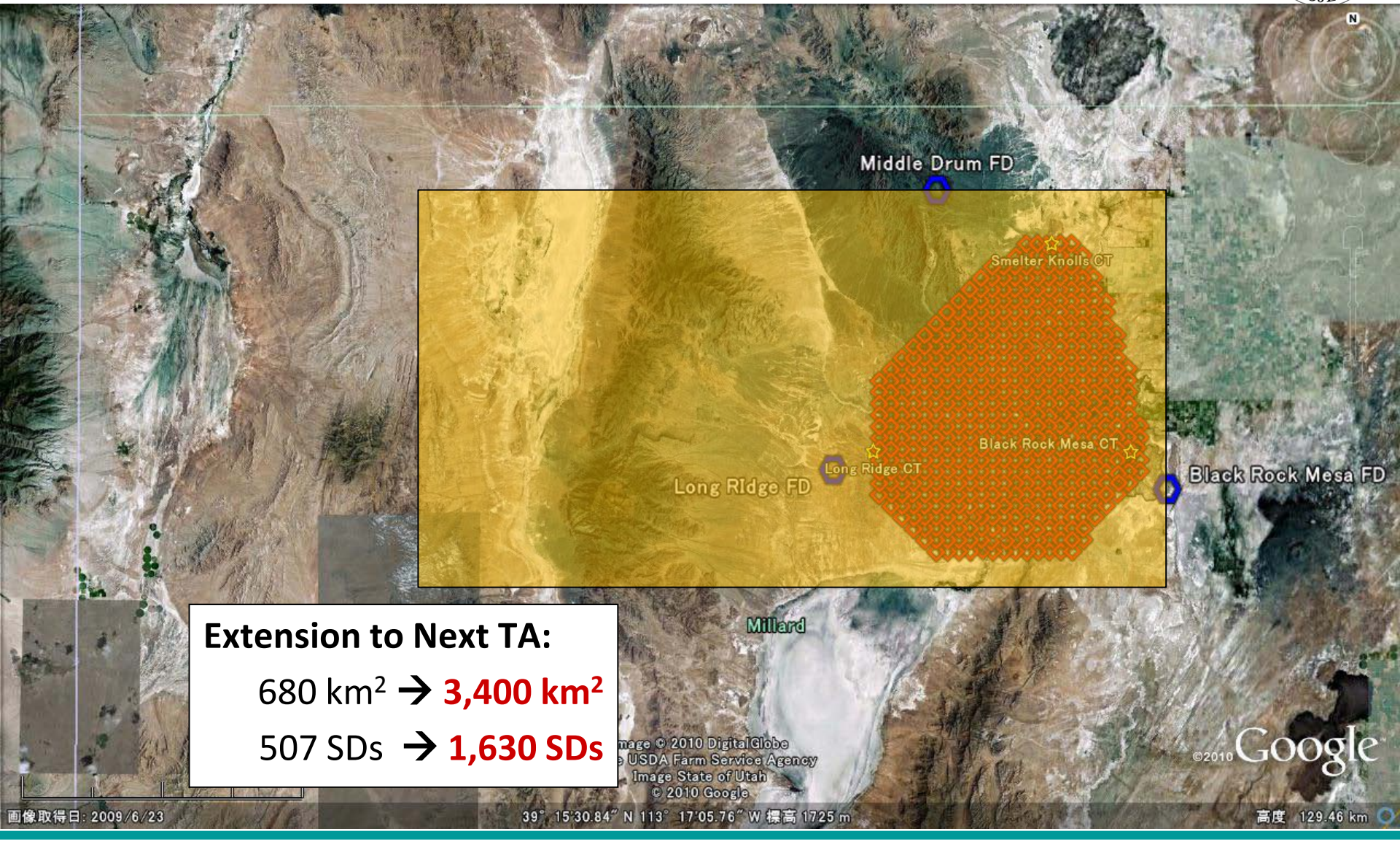
  (Phase 1 TA) $10,000 per SD, including deployment cost

  (Next TA) (1,626-507) SDs x $10,000 ~ $11.2M

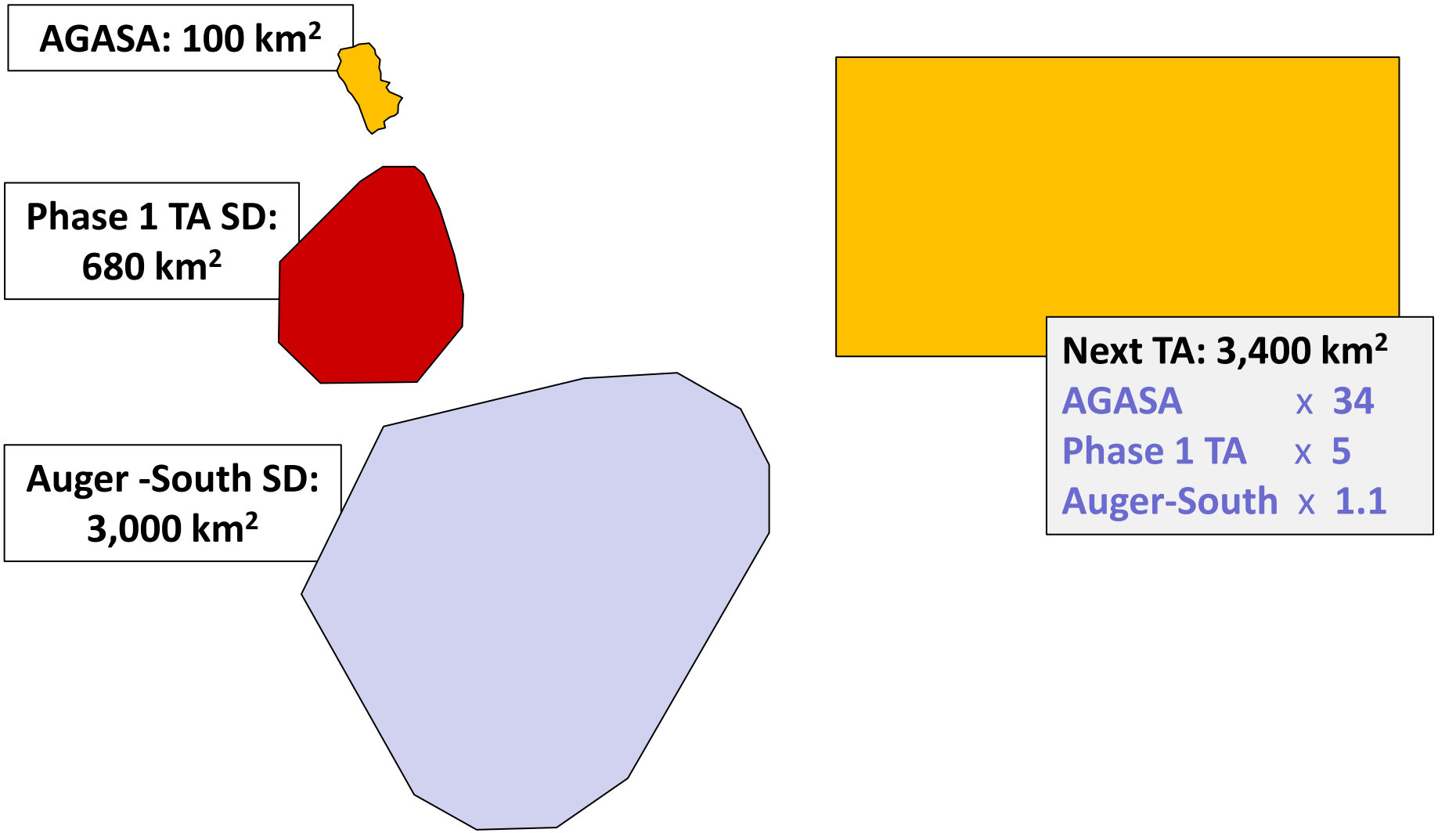
  re-deploy: 507 X $3,000 ~ $1.5M

  → In total ~ $13M

Current TA and Next TA



Next TA and other detectors



Extension 2-2:

Further extension

Aim of further study …

Huge amount of statistics of UHECR events and….

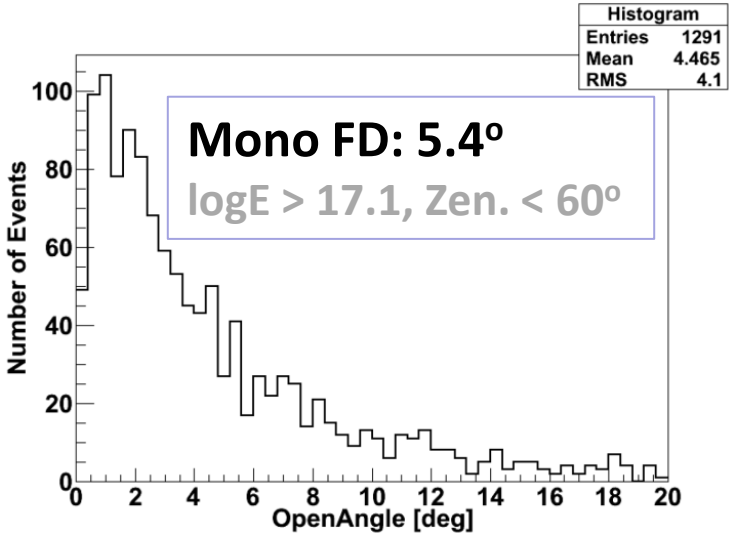
- **Discoveries of UHECR origins -> Study acceleration and propagation**
  - More events for Anisotropy Study/Search point sources
    - Effective area, large duty factor, good angular resolutions
  - Energy spectra for each origins (directions)
    - Good energy resolution

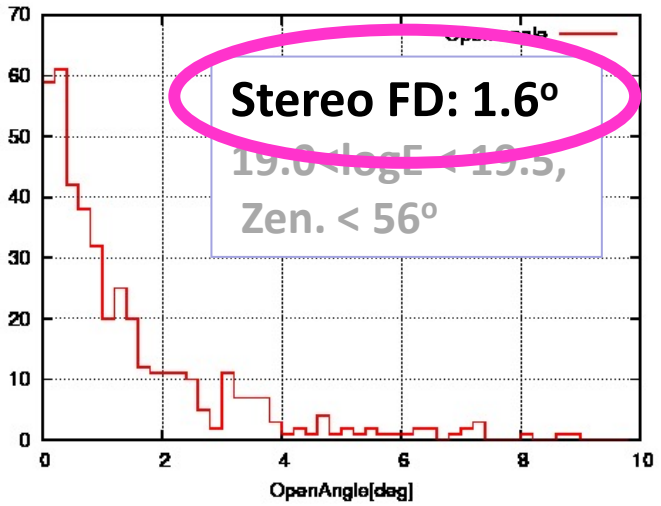
- **Study primary composition**
  - Phase 1 TA cannot finish for high energy end, $E > 10^{20}$ eV

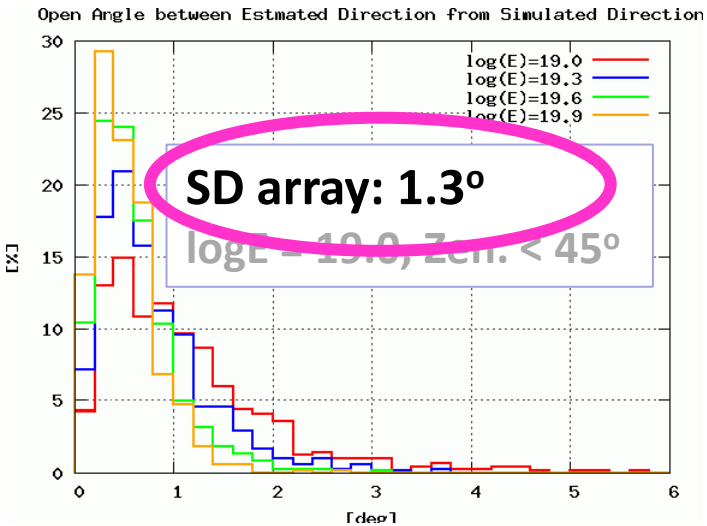
- **Northern hemisphere**
  - ←→ Auger south
    - In a complementary style
  - Different sources, different spectra, different composition …..

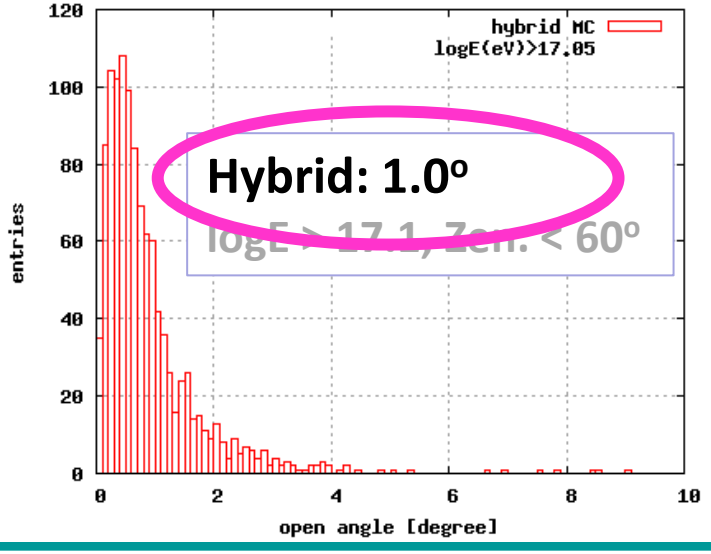
- **Sensitivity for UHE neutrinos**

Good angular resolution: Stereo, SD or Hybrid



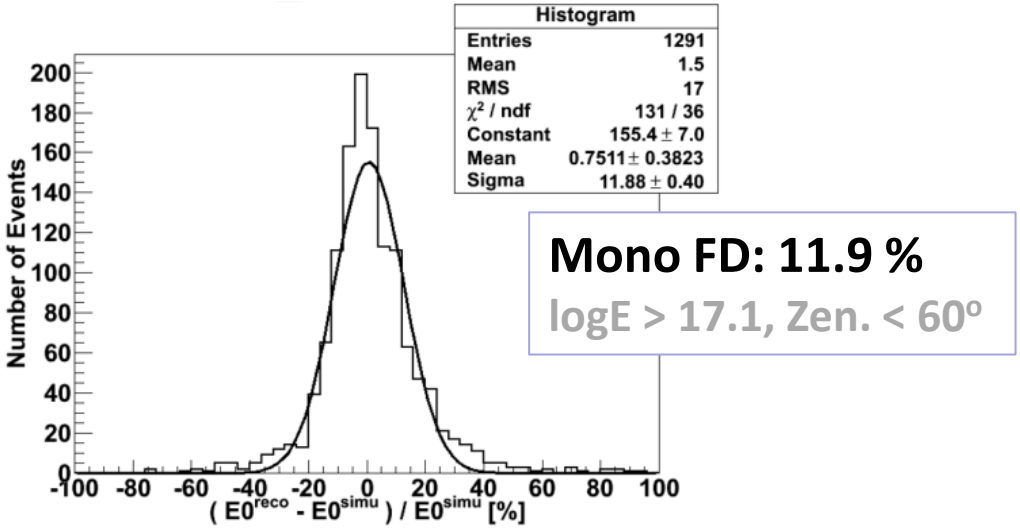






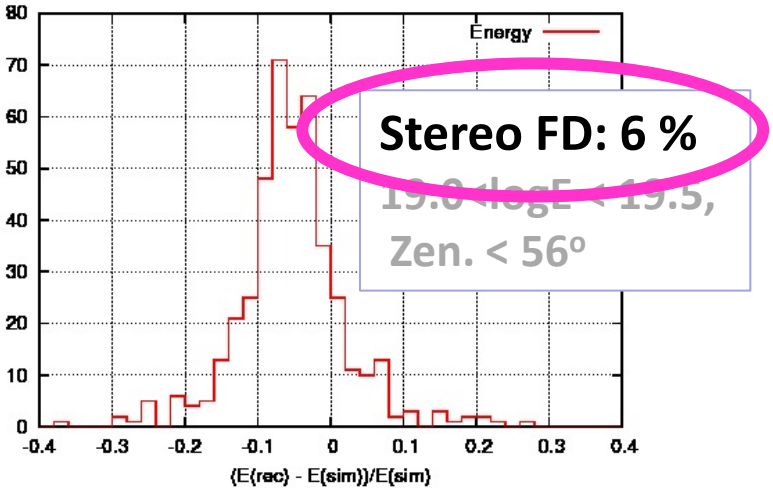
Good Energy resolution

Stereo or Hybrid



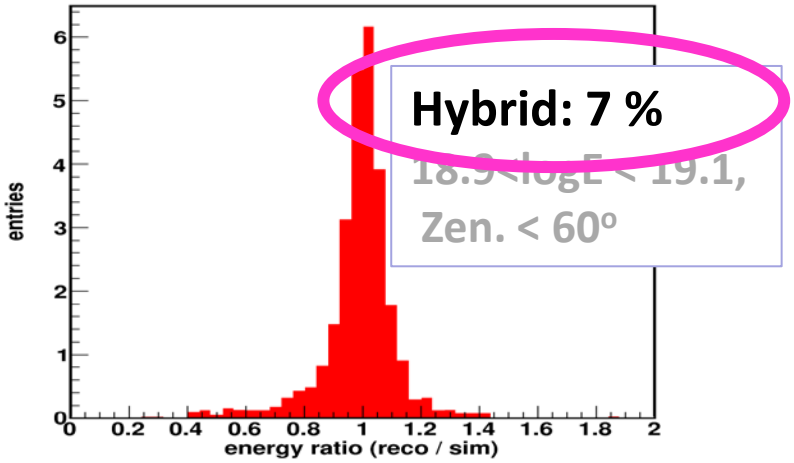
Mono FD: 11.9 %

logE > 17.1, Zen. < 60°



Stereo FD: 6 %

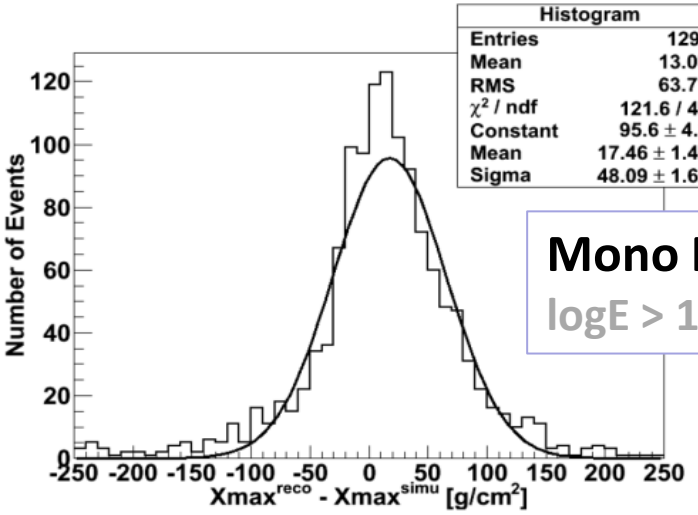
19.0<logE< 19.5,
Zen. < 56°



Hybrid: 7 %

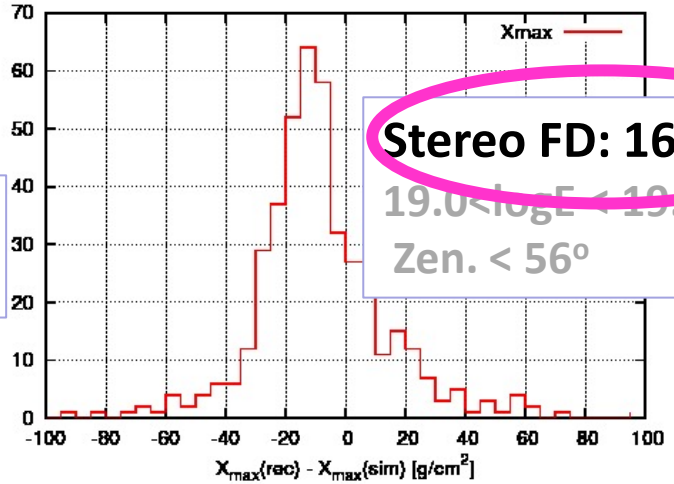
18.9<logE< 19.1,
Zen. < 60°

Good Xmax resolution: Stereo or Hybrid



Mono FD: 48.1 g/cm²

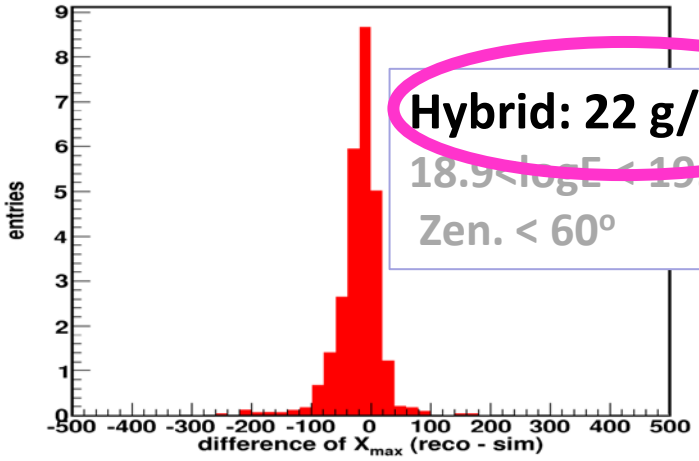
logE > 17.1, Zen. < 60°



Stereo FD: 16 g/cm²

19.0<logE < 19.5,

Zen. < 56°



Hybrid: 22 g/cm²

18.9<logE < 19.1,

Zen. < 60°

Way of achieving ….

- Good angular resolution: SD array/Stereo FD/Hybrid
- Good energy resolution: FD + Electron Light Source
- Composition measurement: FD

And also we need huge statistics, so that answer is ….

Hybrid = SD array + mono FD

or

Stereo FD array

Giant hybrid or stereo FD

Hybrid (…especially SD array part)

- 100 % duty factor
- Cost

  …per exposure, cheaper than FD ?
- Site-nonspecific...possible to install them anywhere

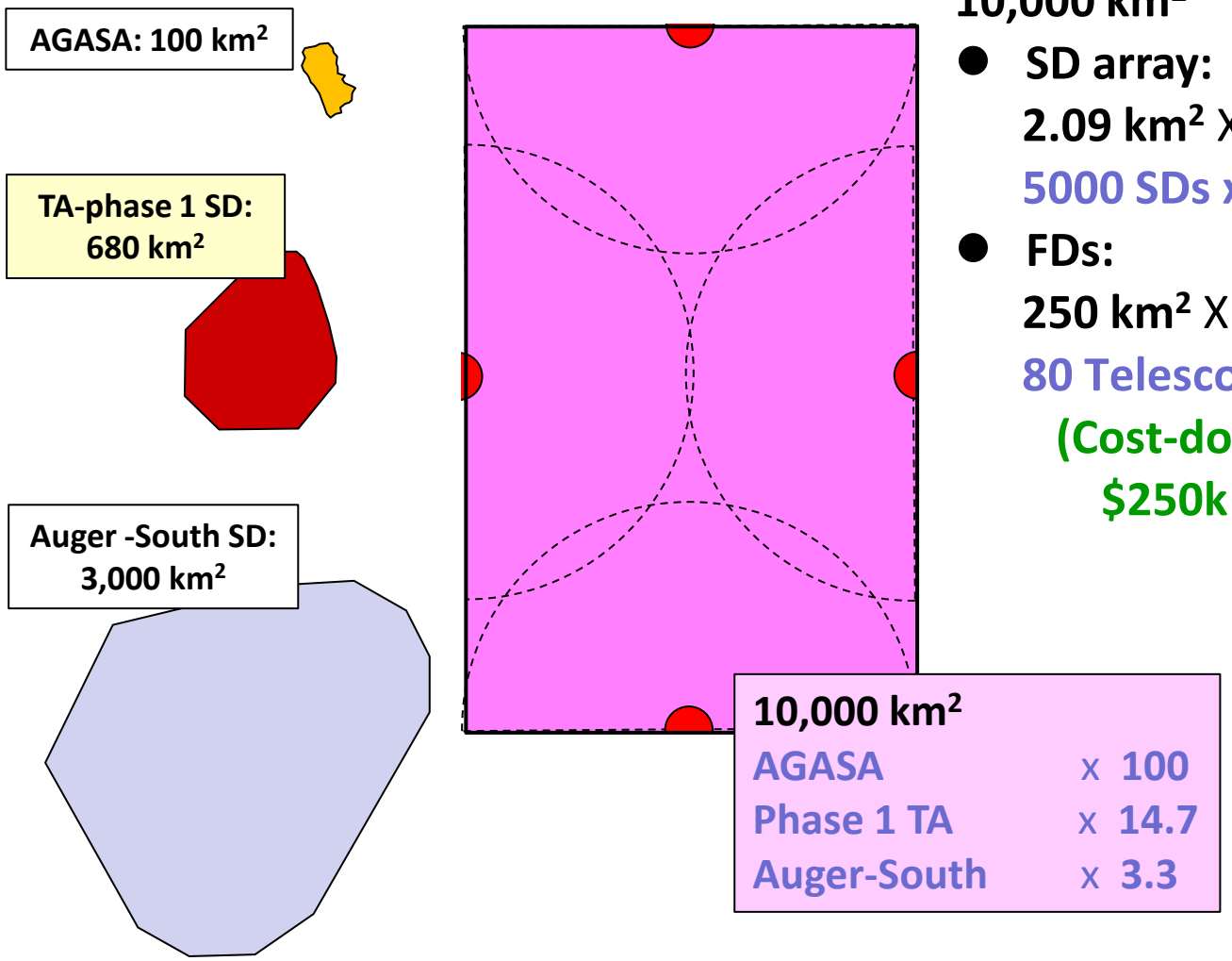
  …for education, understanding and support of the residents, outreach

Stereo FD

- Less environmental impact
- Easy to operate (?) ← One station of phase 1 TA is remote-controlled
- Not so expensive ?

  … expect cost-down with
  - ✓ using mirrors of smaller area,
  - ✓ telescopes with optical correctors,
  - ✓ electronics, etc…

Huge Hybrid detector

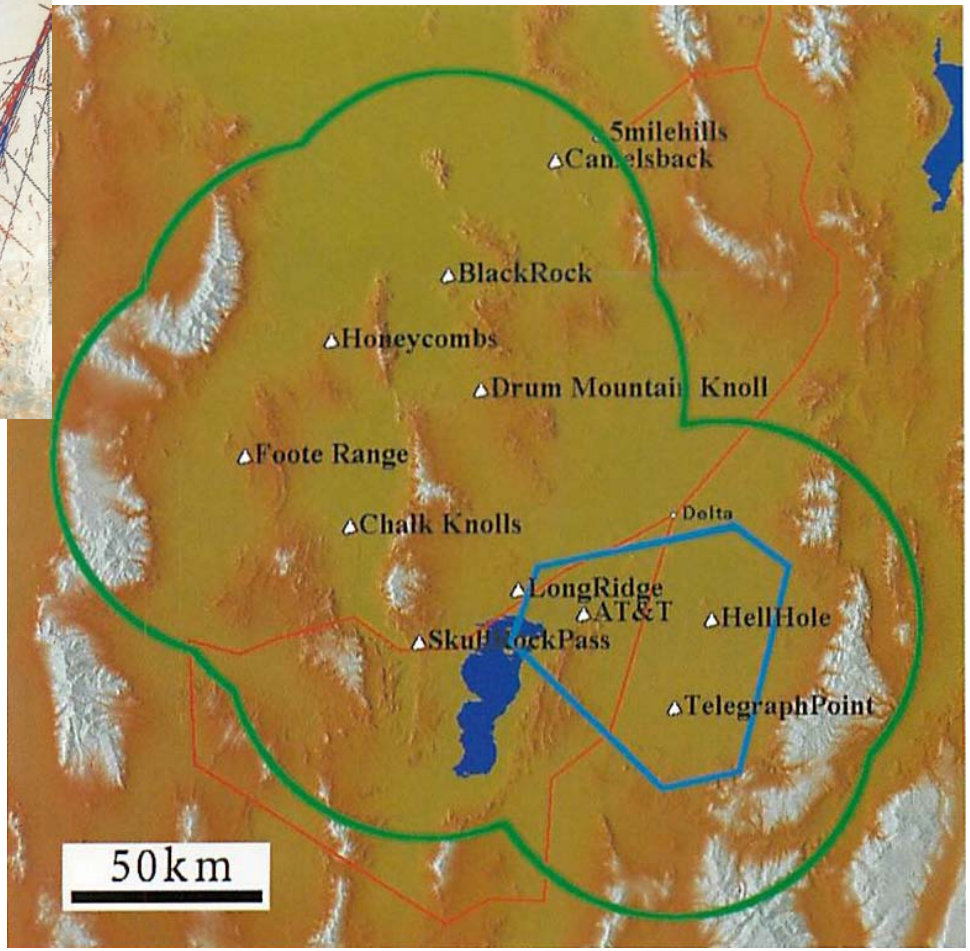


10,000 km²

- **SD array:**
  2.09 km² X 5,000 SDs
  5000 SDs x $10,000 = $50M
- **FDs:**
  250 km² X 40 X 2 Telescopes
  80 Telescopes x $150,000 = $12M
  (Cost-down expected,
  $250k → $150k per telescope)

In total … $62M

Giant stereo FD array: Original Design of TA



10 Stations

40 Telescopes/site

400 tele. X $0.15M

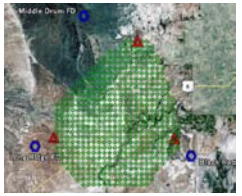
= $60M

Aperture:

65,000 km^2 sr @10^{20}eV

(it is not purely stereo)

Phase 1 TA



Summary

1. **Low Energy Extension = “TALE”**
   - Large elevation angle FD + SD array = Hybrid
   - Energy range extend down to 10^{17} eV

2. **Extension of area = “Next TA” (tentative name)**
   - (Phase 1 TA) X 5 SD array = 3,400 km^2
   - Concentrate to anisotropy/point source study

3. **Further extension**
   - Hybrid or Stereo FD array

And new detection methods (Bistatic Radar, ….)