First results from the full-scale prototype for the Fluorescence detector Array of Single-pixel Telescopes

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(https://www.fast-project.org)
Outlines

- FAST Motivation / Concept
- FAST Prototypes:
  - 2014 single-pixel telescope
  - 2016 full-scale prototype
  - 2017 iterative designs
- Data and Simulations
  - UHECRs, TA CLF (UV laser)
  - FAST-only reconstruction
- Future Plans
Lack of statistics in highest-energy UHECR bins
- Need a detector with huge aperture

Discrepancies in TA-Auger energy spectra at high energies

Interesting behaviors at high energies:
- Increase in elongation rate?
- GZK recovery?
- Different Auger/TA GZK thresholds?
Nitrogen fluorescence detectors
common instruments for UHECR measurement

Finely-pixelated camera:
- ex: Auger FD (440 PMTs), TA FD
- Expensive!
- High coverage difficult

FAST: 4 pixels
- Low-cost design
- Embraces hybrid detection:
  - Geometry / Timing information: SD/FD array
Comparison of FAST / TA FD field of view
Huge-aperture FD Array targeting the highest-energy UHECRs

- Each telescope: 4 PMTs, $30° \times 30°$ field of view (FoV)
- Each station: 12 telescopes, 48 PMTs, $30° \times 360°$ FoV

Triangular grid with 20km spacing

- 500 stations $\Rightarrow$ 150,000 km$^2$
  - Auger: 3,000 km$^2$
  - TA: 762 km$^2$

Not possible to entertain FD Array with expensive, highly-pixelated cameras
- Stable operation under high background
- Detection of 16 highly significant showers

2016: first Full-Scale FAST prototype
- Remote operation

2017: 2 iterative prototypes to be assembled in September
1st Full FAST Prototype (2016)

- 4 8-inch PMTs (Hamamatsu R5912-03MOD)
  - Calibrated at UChicago
- UV band-pass filter (ZWB3)
- Segmented mirror of 1.6 m diameter
  - D. Mandat et al, 2017 JINST 12 T07001
- Externally triggered by TA FD
  - Shared field of view with Black Rock Mesa site

DAQ System:
- Remotely Operated
- HV Monitoring System
1st Prototype Remote Operation

- Fully remote operation
  - Automated shutdown procedure
  - Monitoring via IP camera
- Total operation time > 200h
- Search for reconstructed events in shared field-of-view with TA FD

18 events found by January (120 hours)

Highest event: $E=10^{18.55}$ eV, $R_p=3.0$ km by TA FD
2017 FAST Prototypes

- 3rd FAST prototype height reduced
- Scan in azimuth over TA CLF (vertical UV laser)
- Upgrade electronics for self-triggering with FAST
- Investigating option for FAST housing: half-size shipping container
  ✦ Cheap vs cost of custom shed
  ✦ Currently in negotiation with companies in Chicago
**TA CLF Measurement**

- Ultraviolet vertical laser at a distance of ~21 km, $\lambda = 355$ nm
- Equivalent to $\sim 10^{19.5}$ eV UHECR

**Single event**

<table>
<thead>
<tr>
<th>PMT 1</th>
<th>PMT 2</th>
<th>PMT 3</th>
<th>PMT 4</th>
</tr>
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<tbody>
<tr>
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<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
<td><img src="image4.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

**Composite event**

<table>
<thead>
<tr>
<th>PMT 1</th>
<th>PMT 2</th>
<th>PMT 3</th>
<th>PMT 4</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
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<td><img src="image8.png" alt="Graph" /></td>
<td><img src="image9.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

**Simulation vs. data**
UHECR First Light

TAFD reconstruction
$\log E = 18.08$, $R_p = 2.40$ km

Close, Cherenkov-dominated event
FAST Simulated Reconstructions

FAST hybrid reconstruction

Geometry (given by TASD)

Shower Profile (FAST)

✦ Energy: ±10%, Xmax : ±35 g/cm² at $10^{19.5}$ eV.

✦ Comparable with current FDs

FAST only reconstruction

56 EeV Simulation

✦ Simulated reconstruction with FD array of 20km spacing

✦ Under development
Summary and Future Plans

- Installed first full-scale FAST prototype in 2016
- Installing two more telescopes in September 2017 (75 x 25 degree FoV)
  - Upgrade electronics for self-triggering
  - Add all-sky camera for weather monitoring
- Plan to move one telescope to Argentina for TA-Augur cross-calibration
Backup
1st Prototype PMT Calibrations

KICP @ UChicago

Single photo electron

Detection efficiency (QE×CE)

YAP pulser (YAlO₃:Ce scintillator + ²⁴¹Am source) attached on each PMT surface

TA UV LED used for on-site calibration

used in AIRFLY experiment
Airplane events

- External trigger from TA includes triggers on airplane events
- Overwhelmingly common...