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

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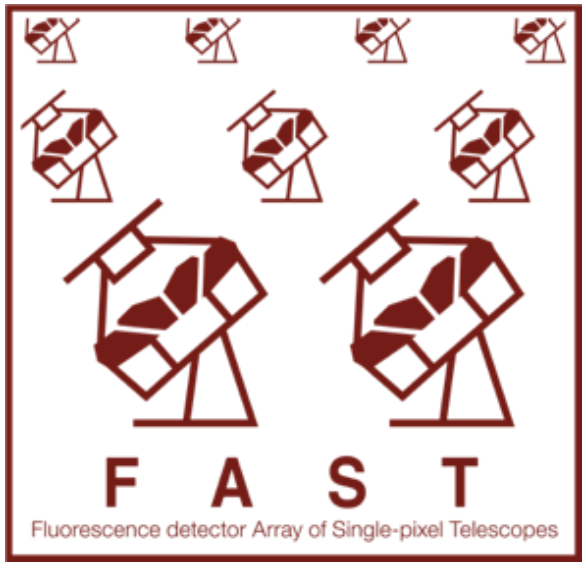
(https://www.fast-project.org)

FAST
Fluorescence detector Array of Single-pixel Telescopes

Fluorescence detector Array of Single-pixel Telescopes

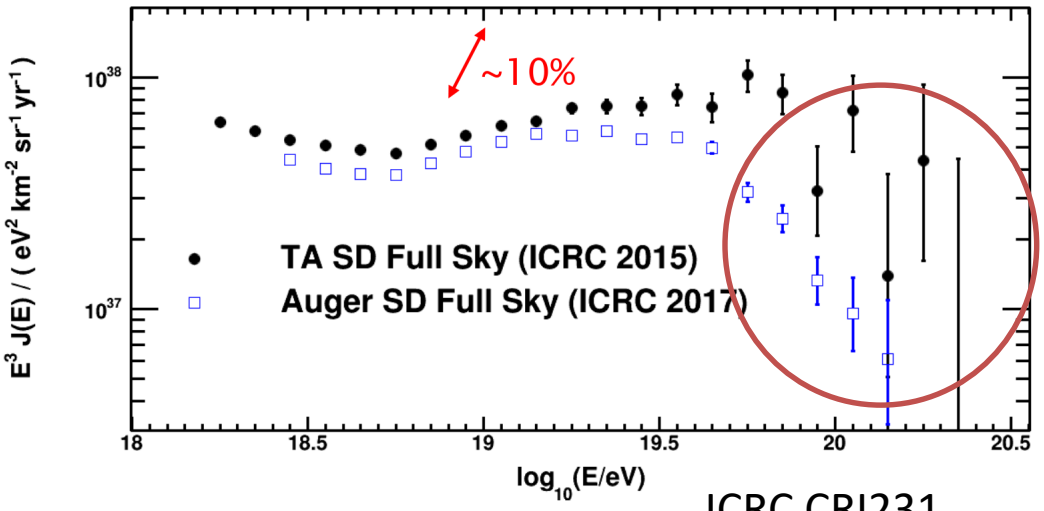
Outline

- 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

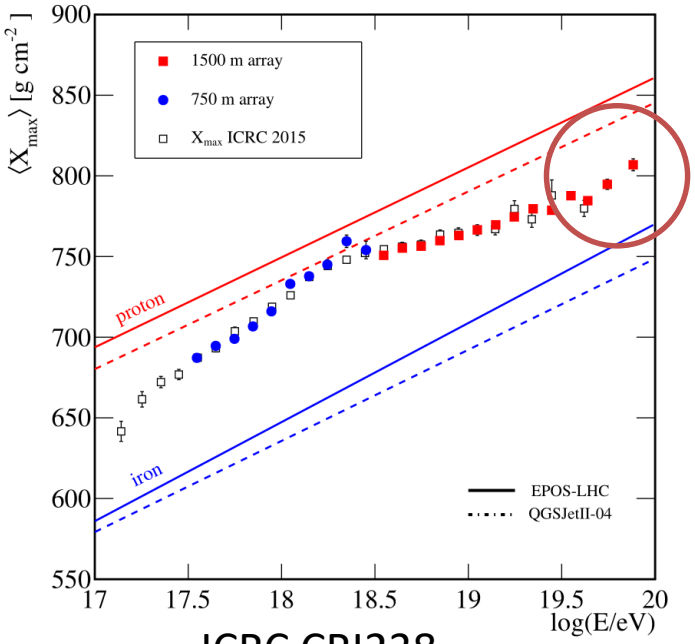


FAST Motivation

- 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?



ICRC CRI231



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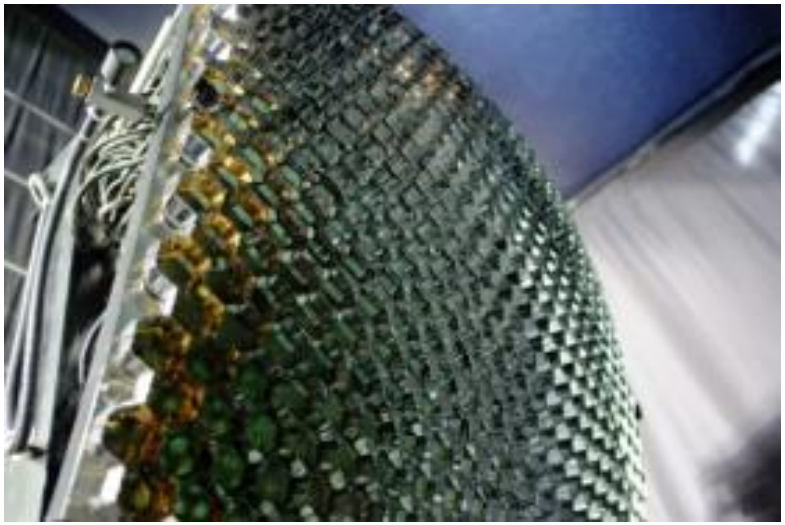
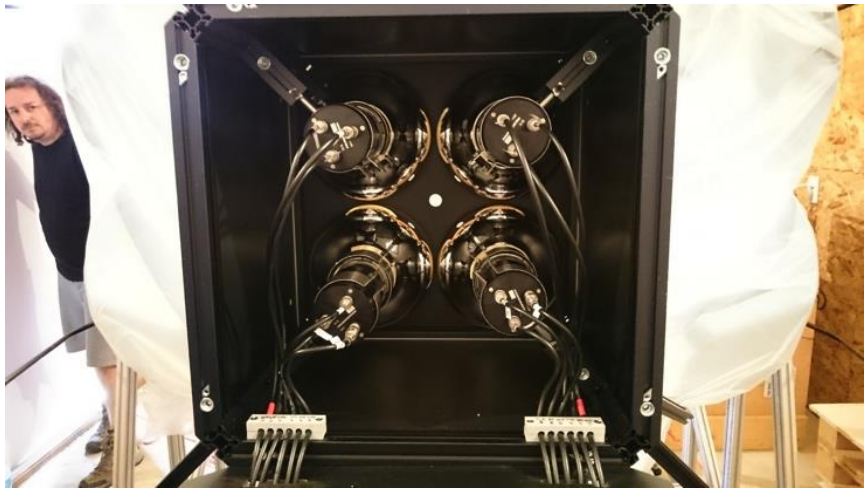
FAST Concept

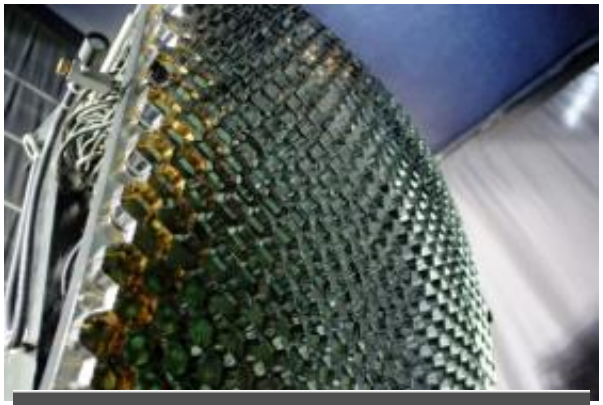
- Nitrogen fluorescence detectors common instruments for UHECR measurement
- Finely-pixelated camera:
  - ex: Auger FD (440 PMTs), TA FD
  - Expensive!
  - High coverage difficult
- FAST: 4 pixels
  - Low-cost design
  - Embraces hybrid detection:
    - Geometry / Timing information: SD/FD array

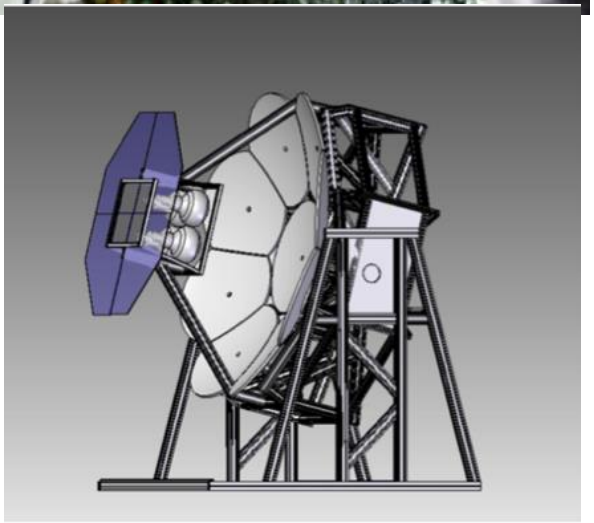


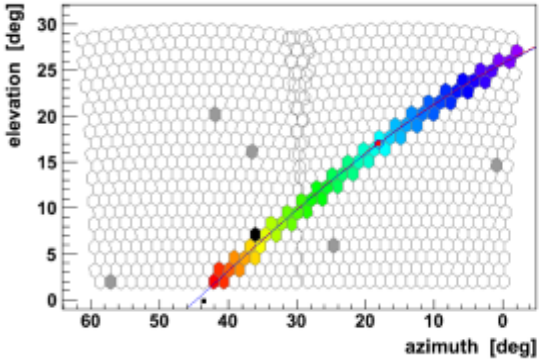


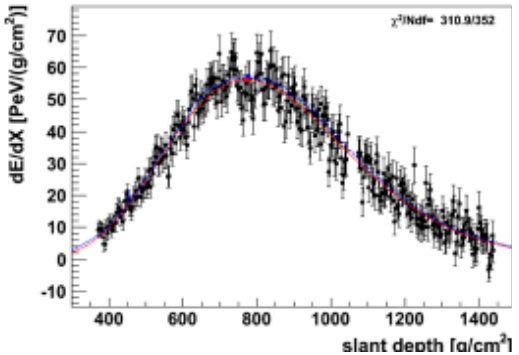
FAST
Fluorescence detector Array of Single-pixel Telescopes

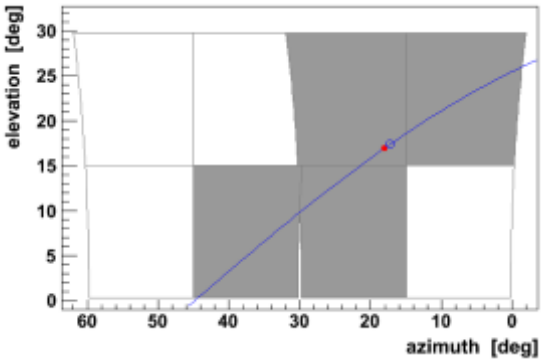
FAST vs. Traditional FD Eye

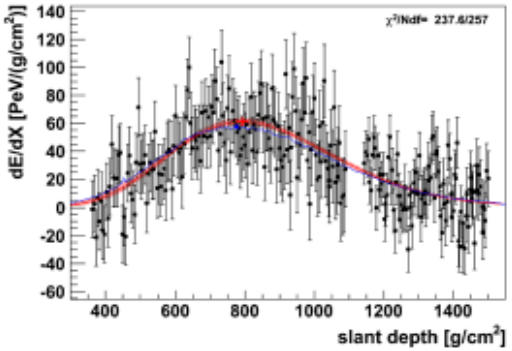


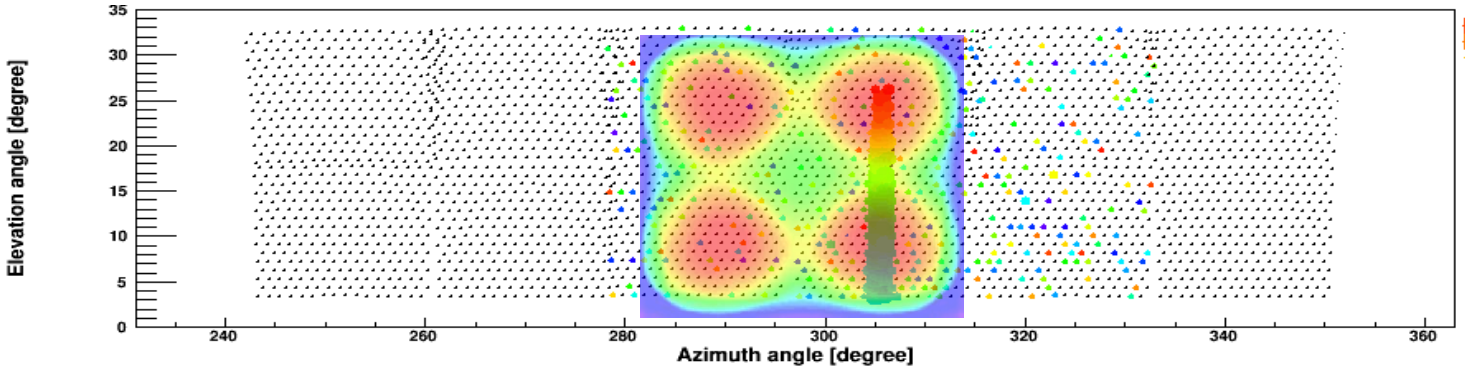








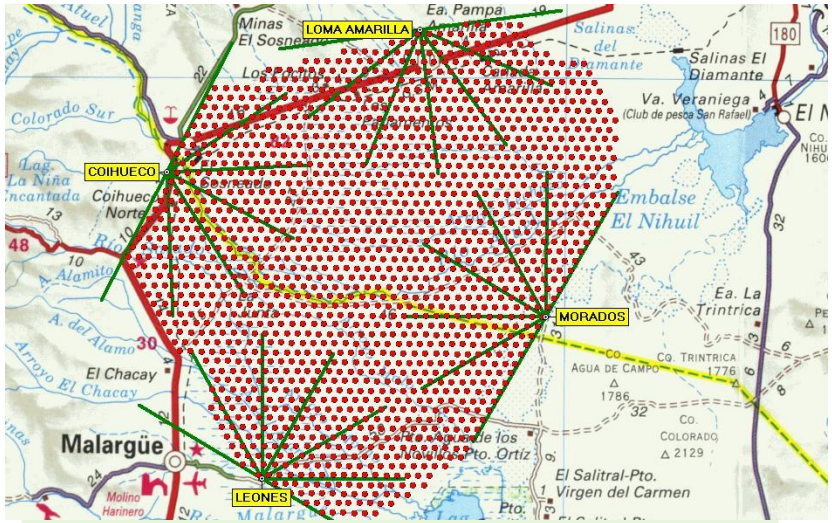




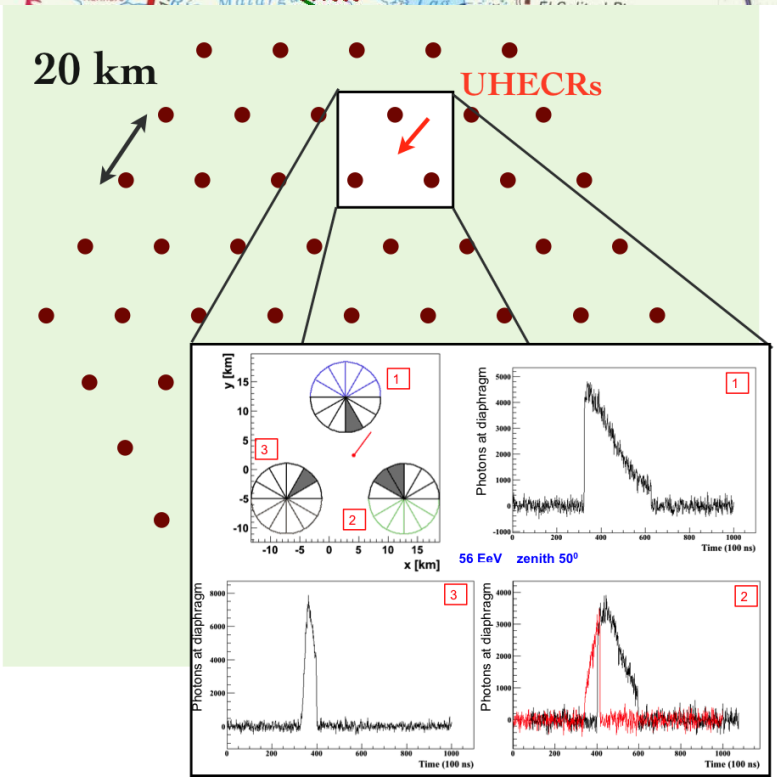
Comparison of FAST / TA FD field of view

Full FAST Array Concept

Auger Array

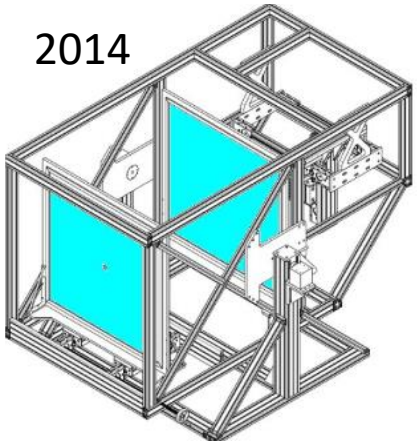


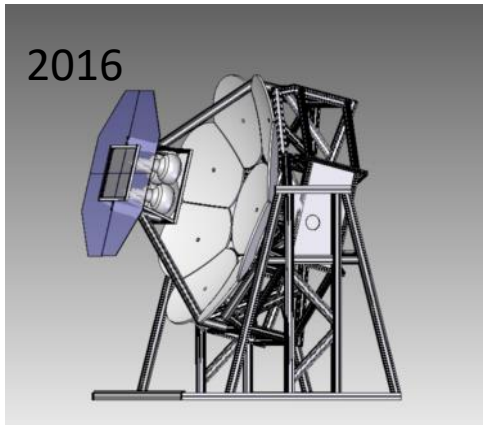
FAST Array Concept



- Huge-aperture FD Array targeting the highest-energy UHECRs
- Each telescope: 4 PMTs, 30°×30° field of view (FoV)
- Each station: 12 telescopes, 48 PMTs, 30°×360° FoV
- Triangular grid with 20km spacing
  - 500 stations ⇒ 150,000 km^2
    - Auger: 3,000 km^2
    - TA: 762 km^2
- **Not possible to entertain FD Array with expensive, highly-pixelated cameras**

FAST Prototypes at TA FD Site

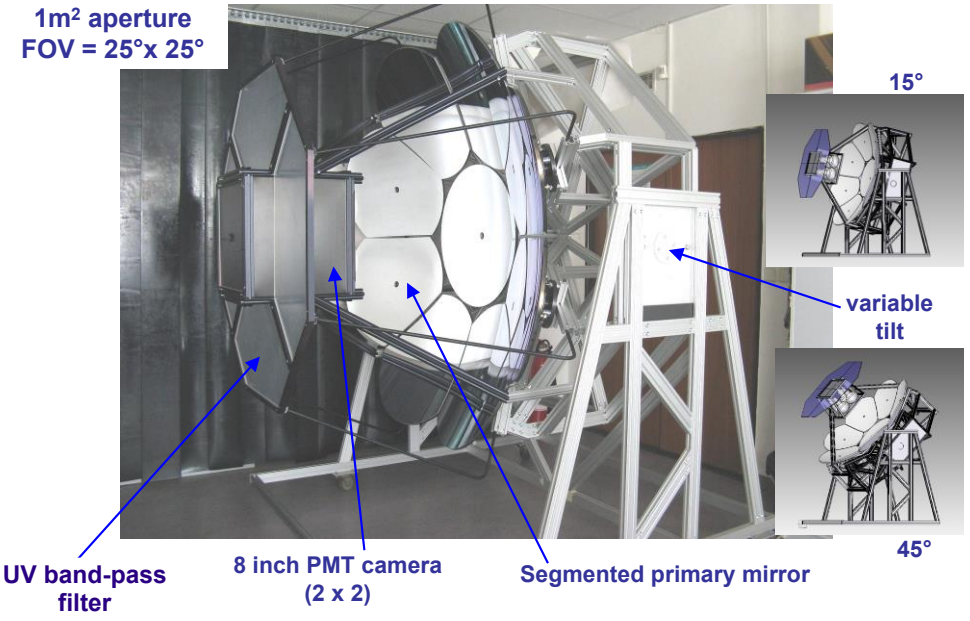




- **2014:** UHECR detections with EUSO-TA optics + single-pixel FAST camera (Astropart.Phys. 74 (2016) 64-72, arXiv: 1504.00692)
  - Stable operation under high background
  - Detection of 16 highly significant showers
- **2016**: first Full-Scale FAST prototype
  - Remote operation
- **2017**: 2 iterative prototypes to be assembled in September

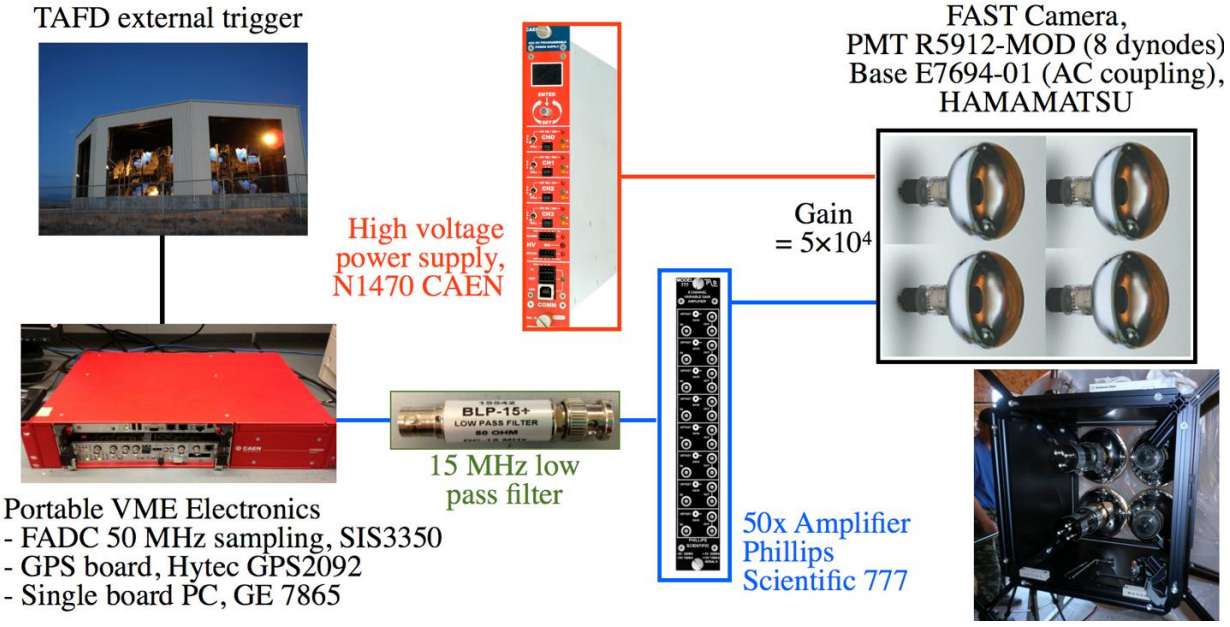
1st Full FAST Prototype (2016)

- 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:

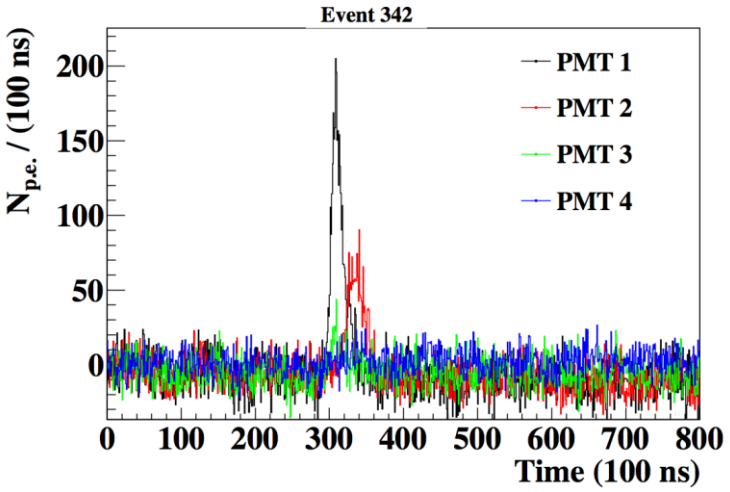
- Remotely Operated
- HV Monitoring System

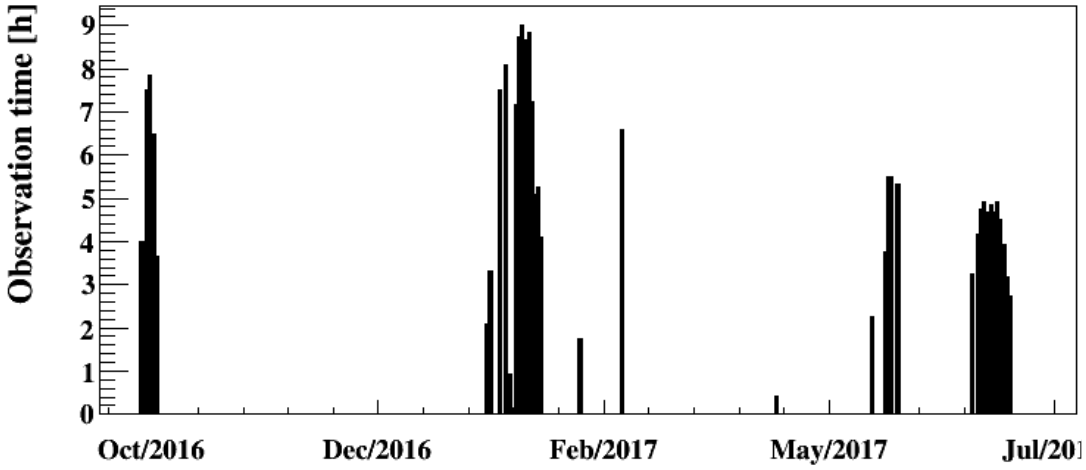


1st Prototype Remote Operation

- 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

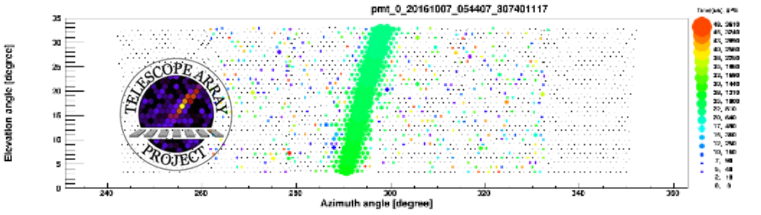
Open Close





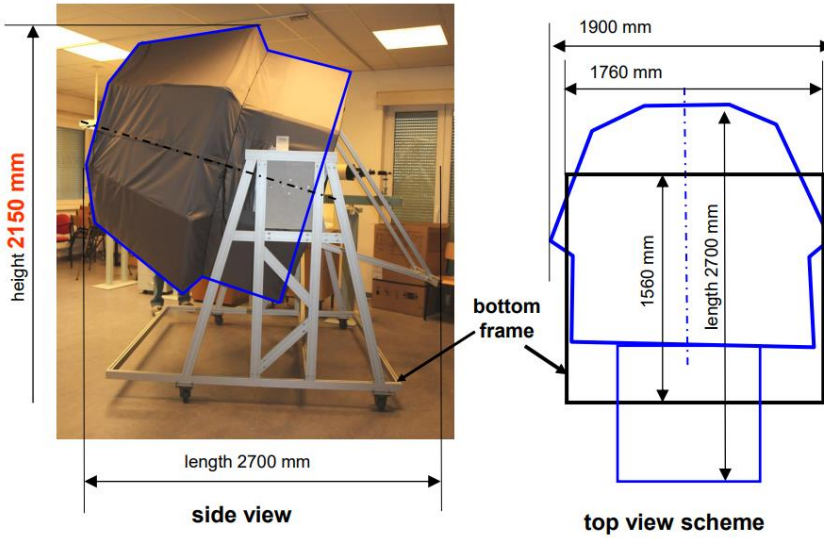
18 events found by January (120 hours)

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



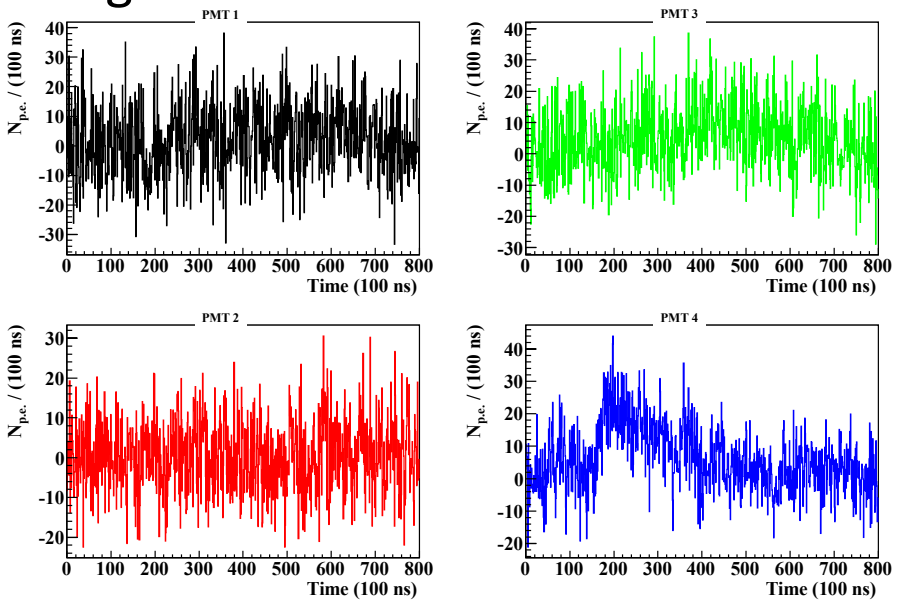
2017 FAST Prototypes

- 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

Single event

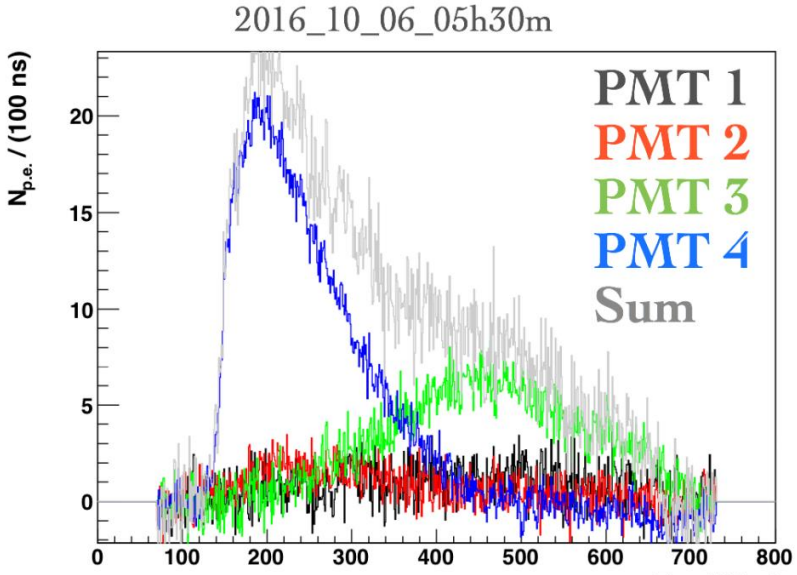


- Ultraviolet vertical laser at a distance of ~21 km, λ = 355 nm
- Equivalent to ~$10^{19.5}$ eV UHECR

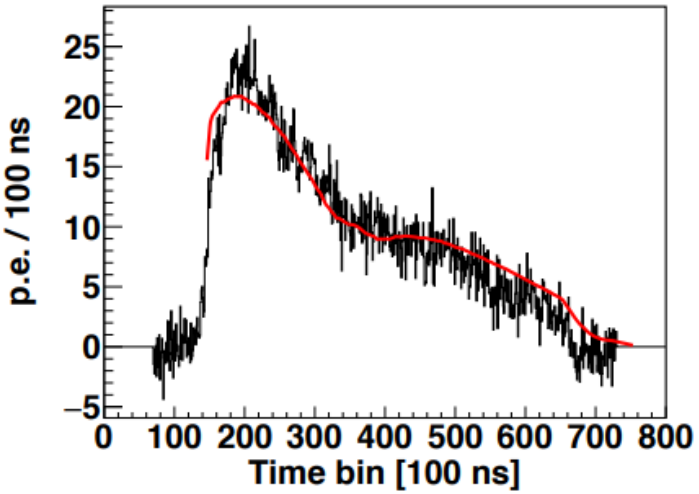
Simple TA CLF simulation:

- 4.4 mJ 355 nm laser.
- Pure molecular atmos.
- QE 20%
- Mirror reflectivity 86.03%
- UV trans. 89.46%
- FAST azimuth, elev. 300.2˚, 15˚
- FAST pos. 17 km, -12.1 km

Composite event

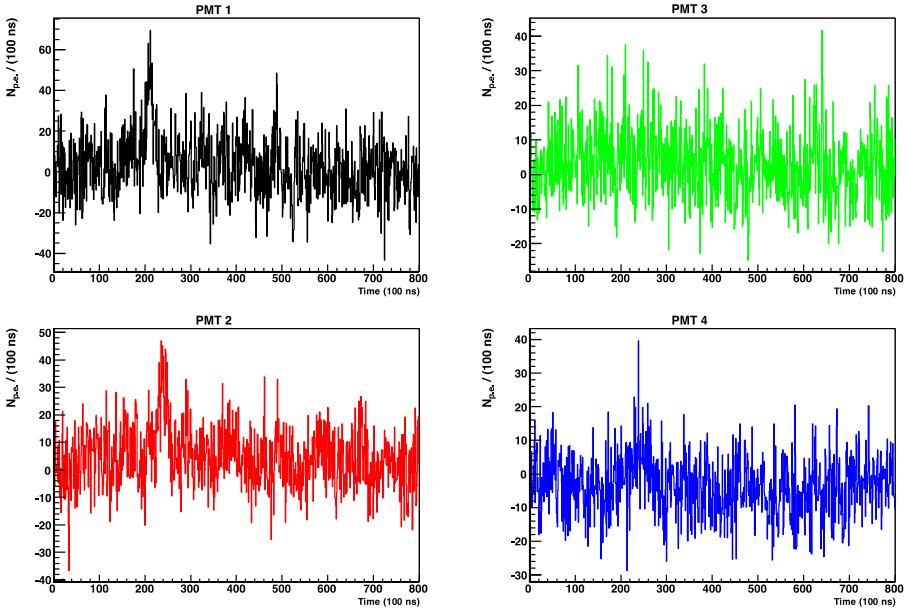


Simulation vs. data

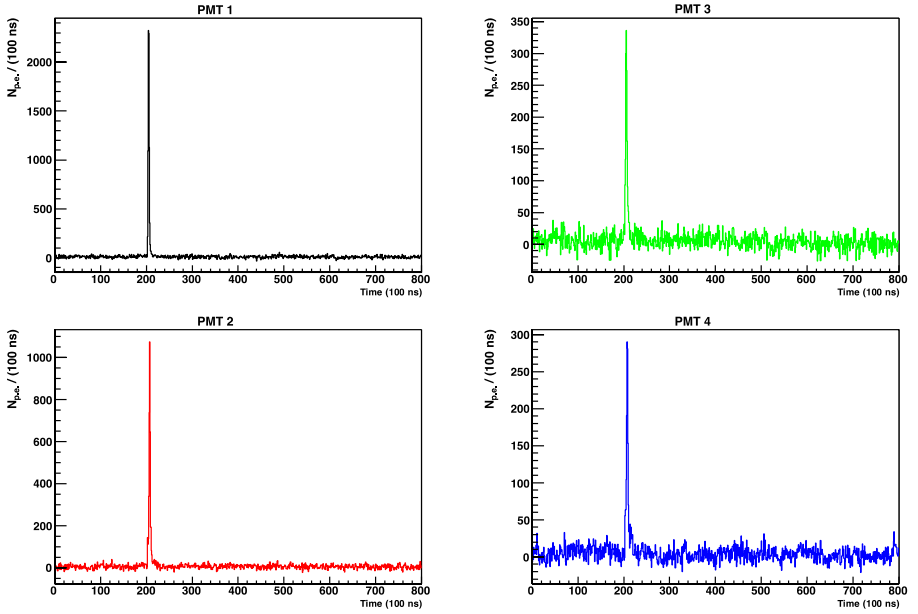


UHECR First Light

① 2016/10/05 06:37:49.525424540

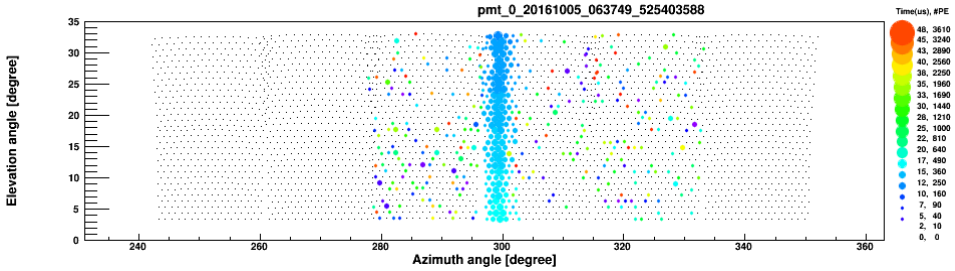


② 2016/10/05 10:25:50.781802380

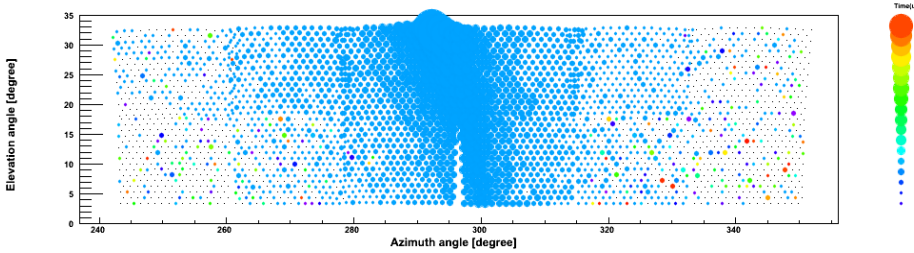


TAFD reconstruction

log$E$ = 18.08, R_p = 2.40 km



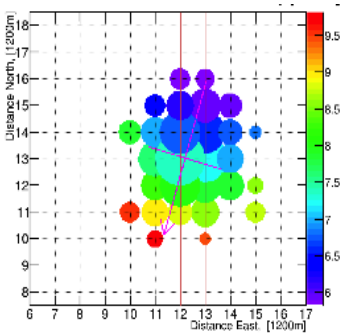
Close, Cherenkov-dominated event



FAST Simulated Reconstructions

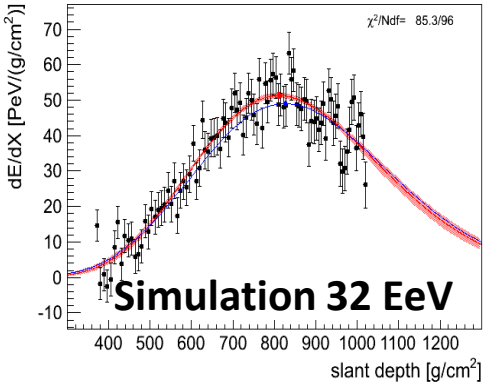
FAST hybrid reconstruction

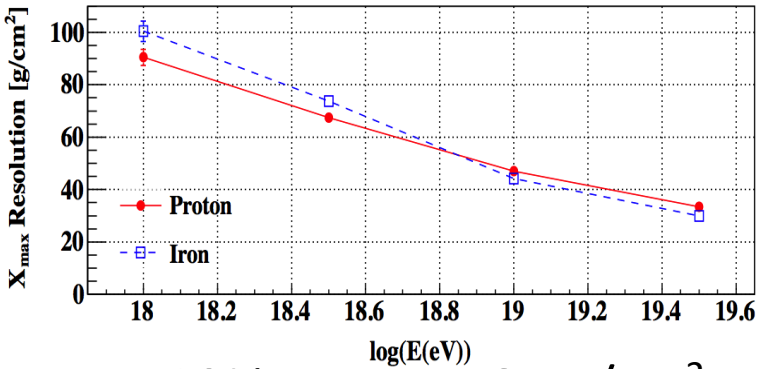
Geometry (given by TASD)



+

Shower Profile (FAST)

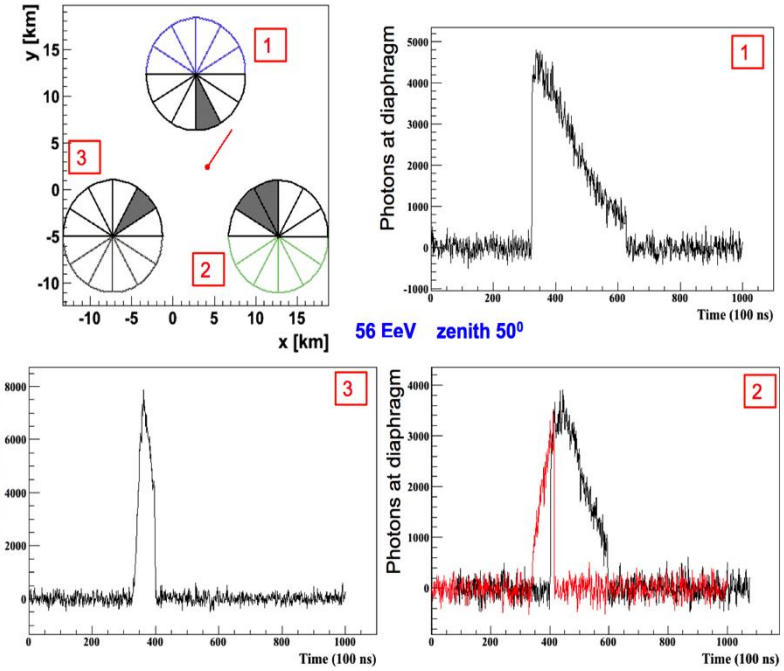




- Energy: ±10%, Xmax : ±35 g/cm^2 at $10^{19.5}$ eV.
  - Comparable with current FDs

FAST only reconstruction

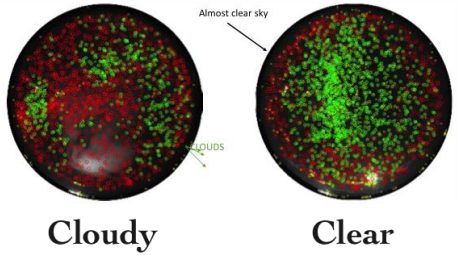
56 EeV Simulation

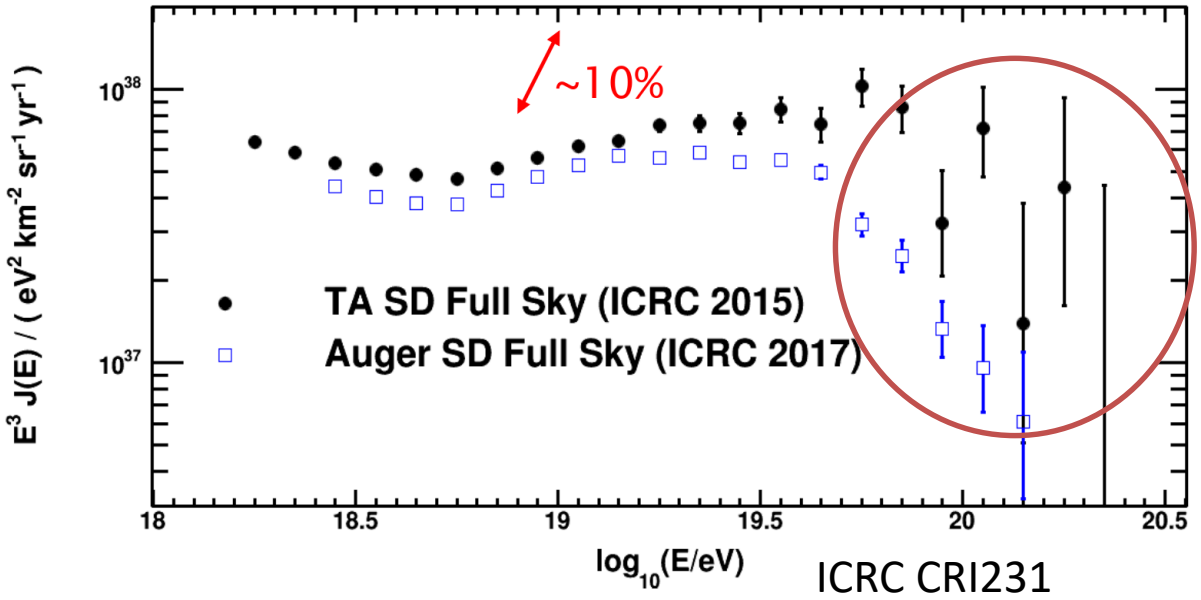


- Simulated reconstruction with FD array of 20km spacing
  - Under development

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-Auger cross-calibration





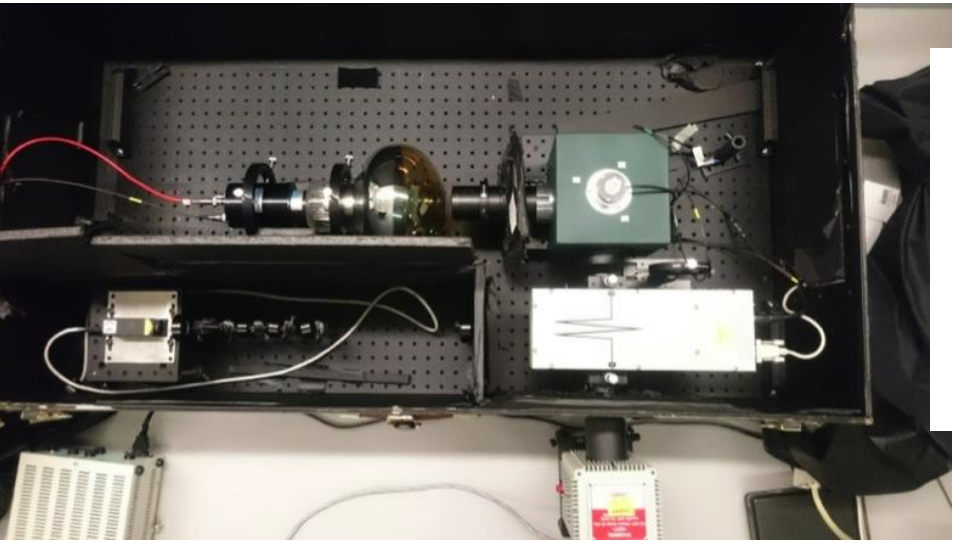
ICRC CRI231

Fluorescence detector Array of Single-pixel Telescopes

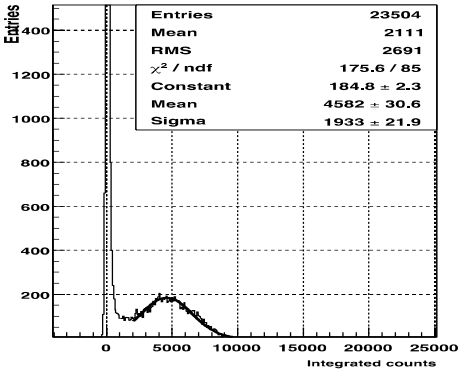
Backup

1st Prototype PMT Calibrations

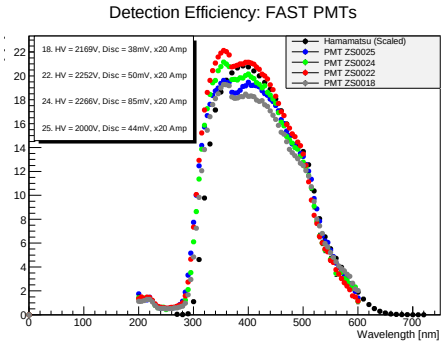
KICP @ UChicago



Single photo electron

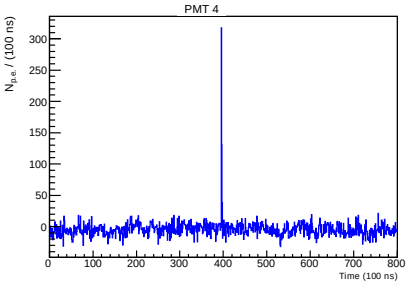


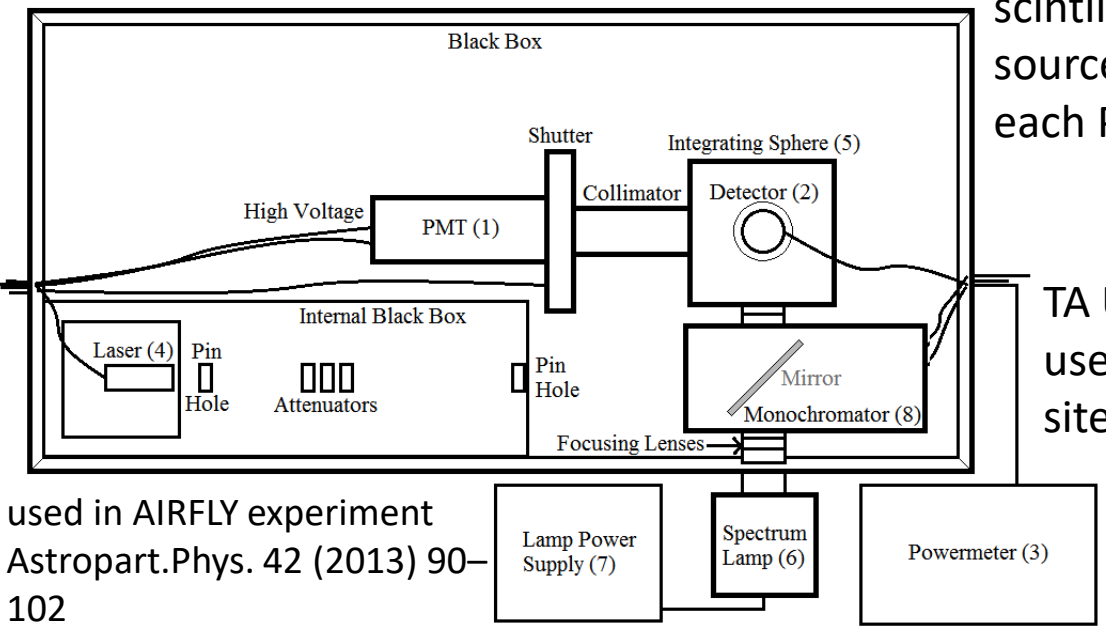
Detection efficiency (QE×CE)



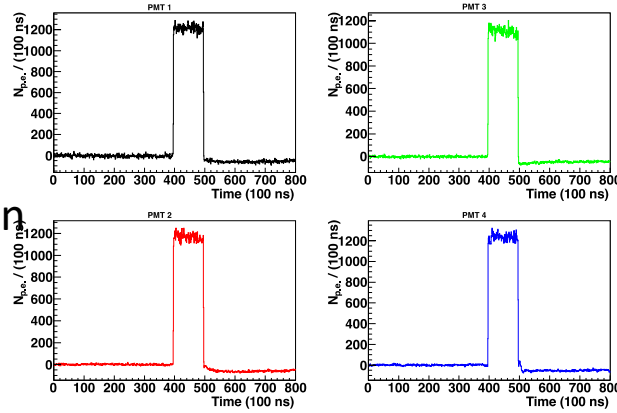
Wavelength [nm]

YAP pulser ($YAlO^3$:Ce scintillator + ^{241}Am source) attached on each PMT surface





TA UV LED used for on-site calibration



used in AIRFLY experiment Astropart.Phys. 42 (2013) 90–102

Airplane events

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