



# Gearing up for Auger@TA phase II Which Auger micro-array to deploy at TA?



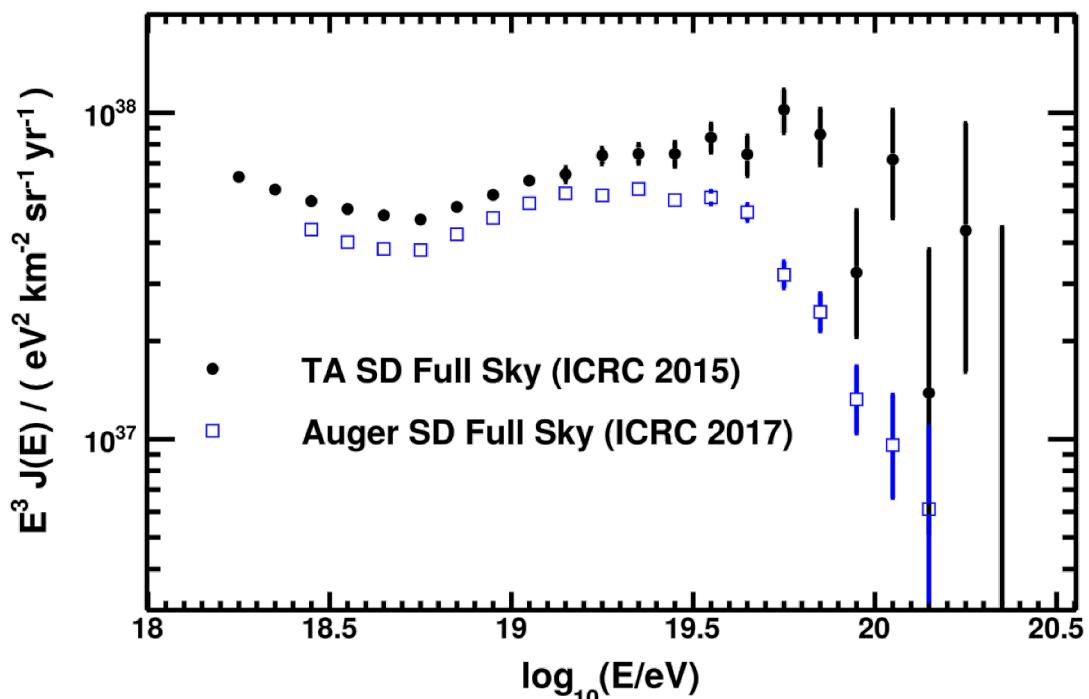
Fred Sarazin, Jeff Johnsen, Chasen Henderson, Colton Schnaitter  
Physics Department, Colorado School of Mines



Fred Sarazin (fsarazin@mines.edu)  
Physics Department, Colorado School of Mines

Auger analysis meeting, Nijmegen (NL), Jun 24-28, 2019

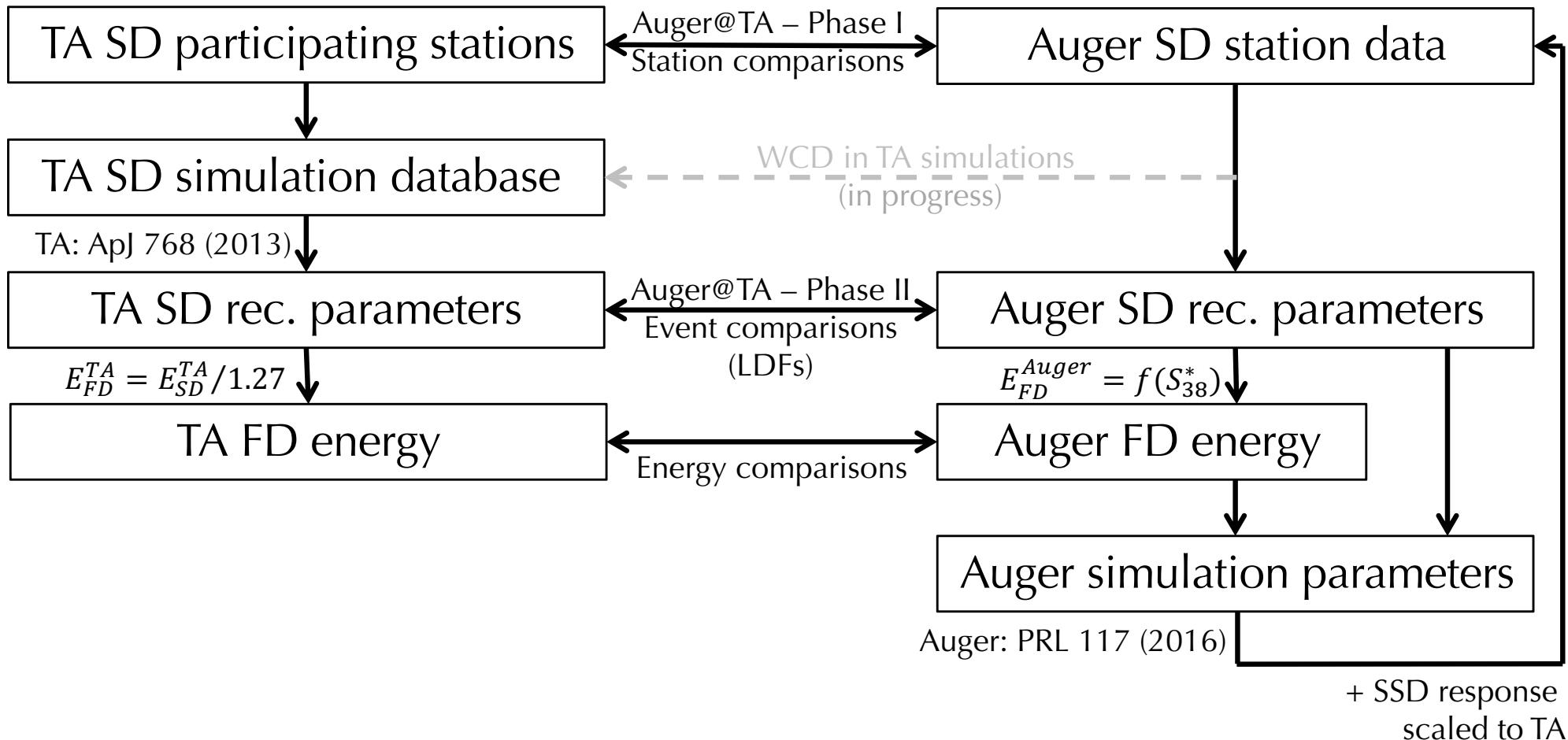
- Auger and TA spectra can be reconciled around the ankle by scaling the energy by 10.4%. However, disagreement around the flux suppression is apparent.
- What are the sources of the discrepancy?
  - Unknown detector and/or reconstruction biases?
  - Difference between the northern and southern UHECR skies?
- Auger@TA joint experimental effort aims at examining the former hypothesis through two phases.
  - Phase I: perform station-level comparisons (data taking still in progress, JINST paper at EB level)
  - **Phase II: perform event-level comparisons**



*From: D.Ivanov, ICRC 2017, PoS 498  
Auger and TA WG on spectrum*



## Auger@TA phase II – planned data analysis



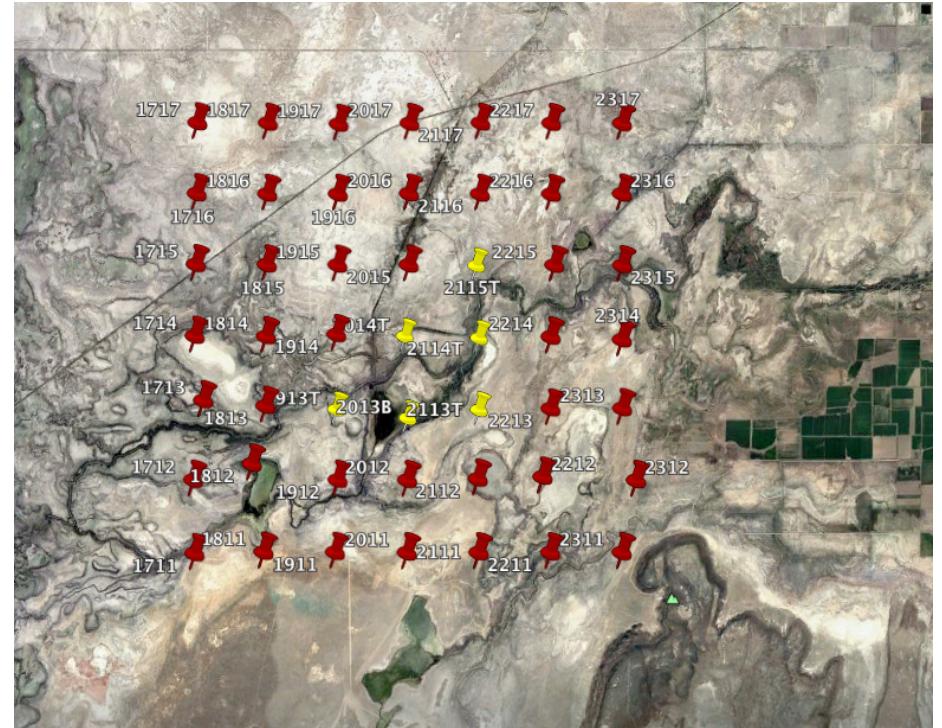
$S_{38}^*$ : estimator adapted to micro-array spacing



**UHECR 2018**

## Phase II: deployment and operation of an Auger micro-array

- Planned location of the Auger micro-array inside TA [yellow pins]
  - Independent trigger
  - Independent reconstruction
  - "Hybrid" Auger–TA reconstruction
  - ...



- Auger North SD stations ready to deployed at the TA CRC
- Communication system being tested at CWRU
- Array simulation under way at Mines



## Auger@TA phase II – what should we deploy in the field?

### (1) CHOICE OF THE MICRO-ARRAY PATTERN:

- *Original plan: co-locate 6 Auger (North) stations with 6 TA stations*
  - *Location identified*
  - *Pros: 6x more station data comparison / deployment on surveyed locations*
  - *Cons: not the Auger grid for reconstruction / the 6 stations form a triangle, not ideal from a topological standpoint*
- **New plan: deploy an Auger hexagon at TA**
  - Possible locations identified
  - Pros: "true" comparison of Auger and TA on their baseline grid element / Seven stations with larger spacing (more exposure)
  - Cons: only one (central) location with co-located stations

### (2) AUGER NORTH VS SOUTH STATIONS:

- *Original plan: deploy and operate Auger North tanks with Auger North electronics (largely untested)*
- **New plan: deploy and operate Auger North tanks with Auger South electronics** recovered from Malargüe after Upgrade. Need PMT base retrofitting, radio swap, etc...



## Auger@TA phase II – performance of the micro-array

### BENCHMARKING MICRO-ARRAY PERFORMANCE WITH SIMULATIONS:

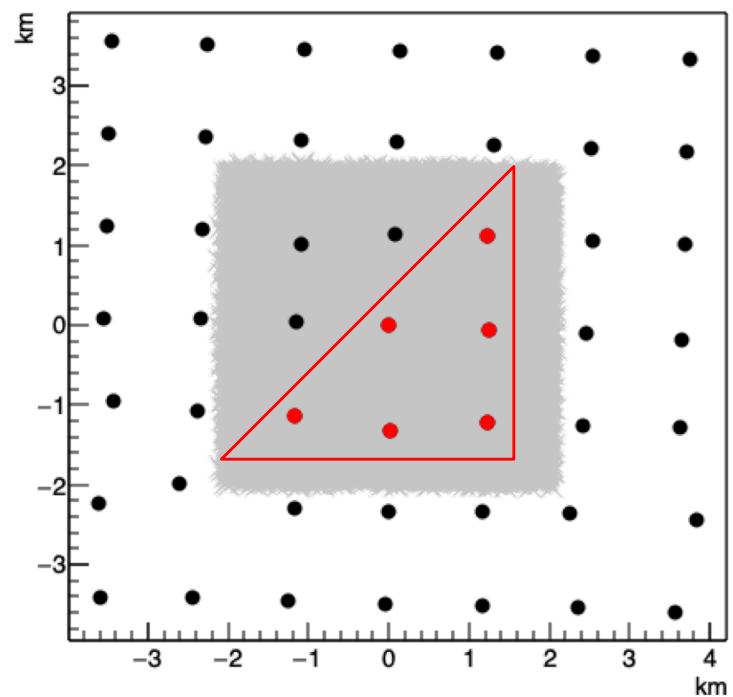
- Create two (large-ish) arrays with hexagonal (Auger) and square (TA) patterns
- Insert the respective micro-arrays at the center
- Throw showers with core locations near the micro-array
- Reconstruct showers with both the large array and micro-array
- Based on reconstruction parameters, deduce a simple geometrical “metric” to select showers most likely to yield accurate reconstruction parameters.

### SIMULATIONS:

- Shower library: Napoli
- Hadron. model: EPOS-LHC (protons)
- Energy range: [3,10] EeV
- Zenith angle:  $\theta < 65^\circ$  - flat in  $\cos(\theta)$
- 1000 showers thrown 32 times each

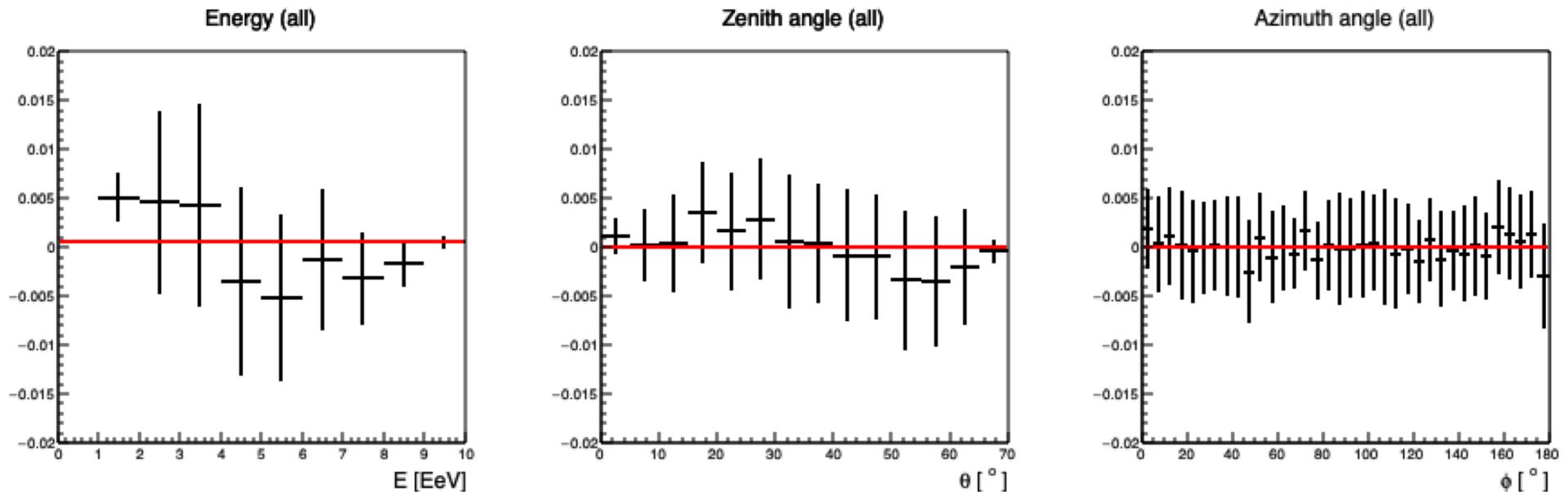
Triangular micro-array in TA regular square arrangement

- × Core locations of the simulated showers  
Large arrays made of 49 stations



## Auger@TA phase II – simulating the micro-arrays

- Simulations are performed individually in each case (large/micro square/hexagonal arrays) using the same shower dataset but thrown randomly within the  $4 \times 4 \text{ km}^2$  range.
- Slight differences are observed in the reconstruction performance, but those are small  $< 1\%$ .



- Reconstruction comparisons are made between the large / micro arrays of the same pattern.



## Auger@TA phase II – statistics

**Metric:**

$$M = \frac{1}{N_{\mu a}} \sum_{i=1}^{N_{\mu a}} (r_i - r_{core})$$

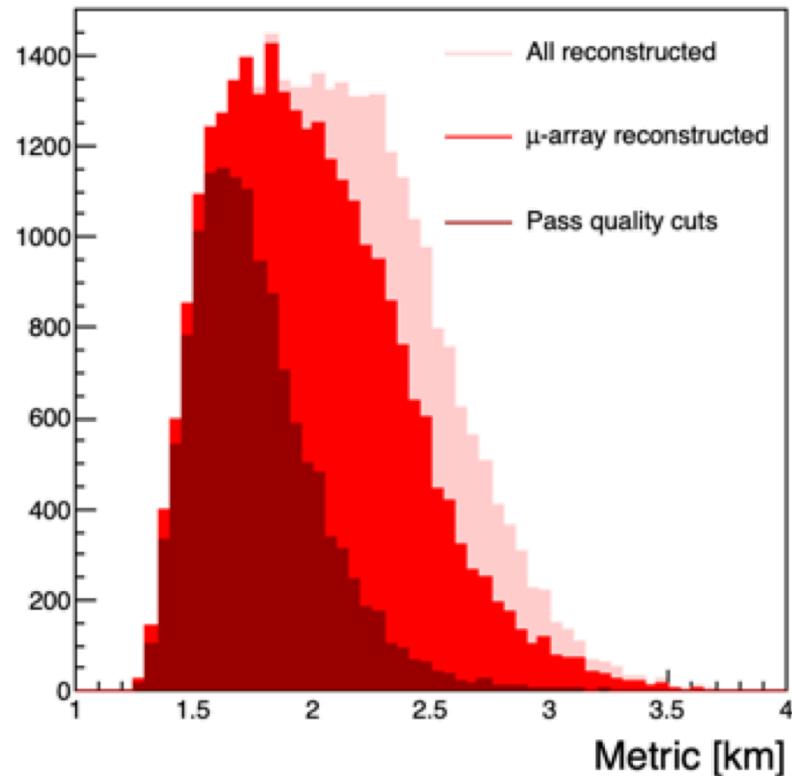
**Quality cuts:**

$$\Delta E/E = 0.20$$

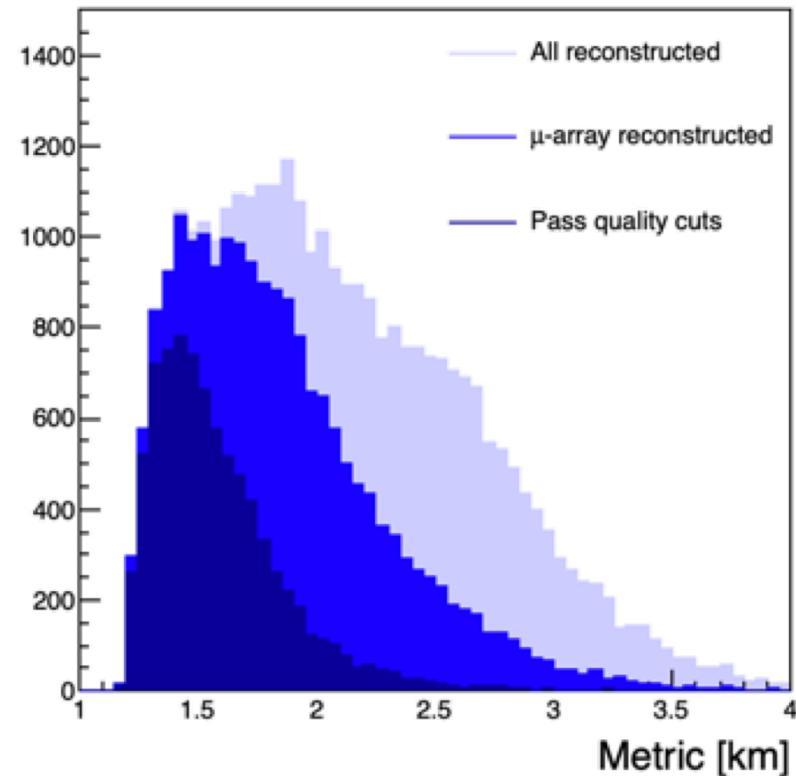
$$\Delta\theta = 2^\circ$$

$$\Delta\phi \sin \theta = 3^\circ$$

Hexagon array

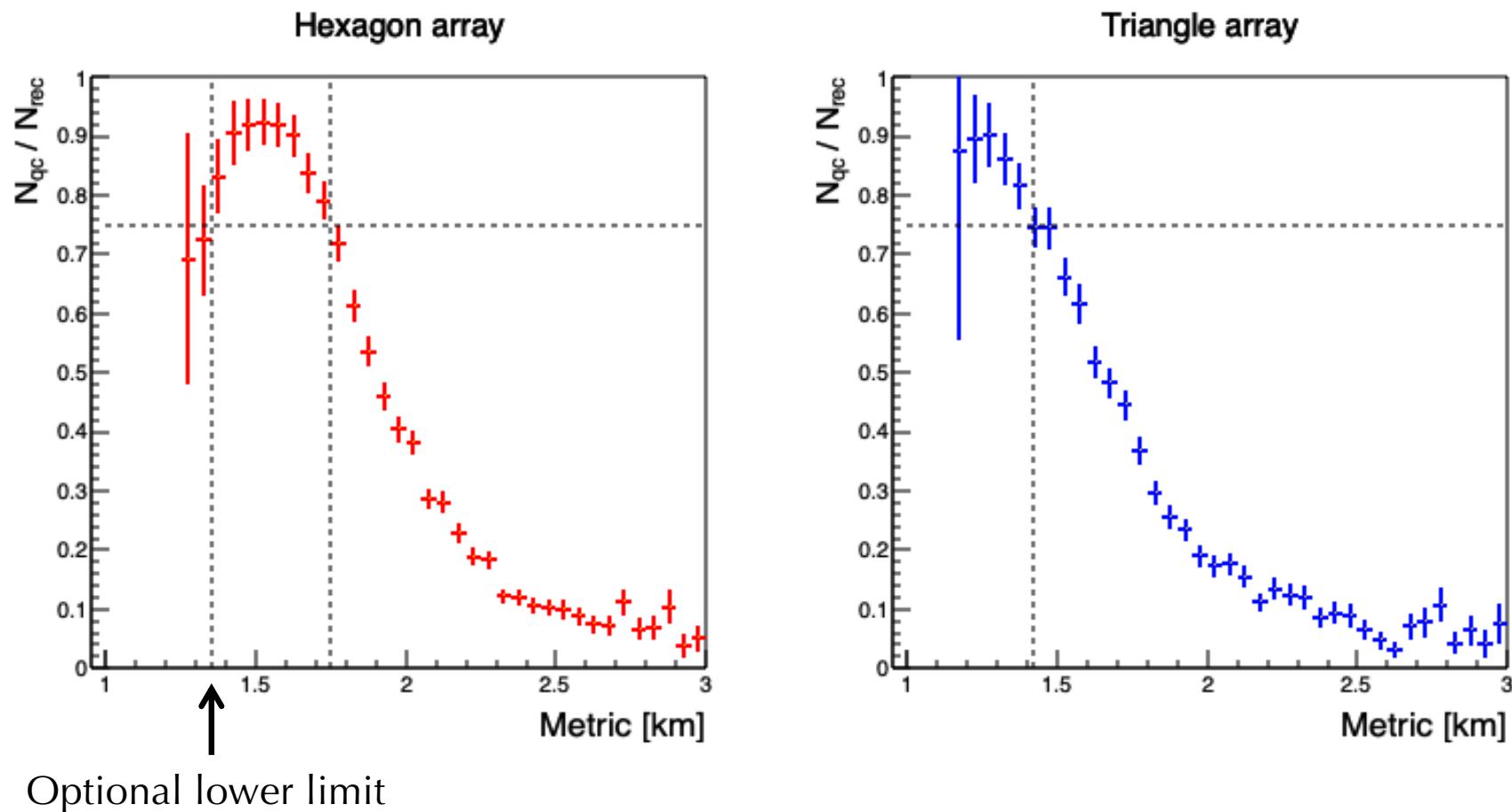


Triangle array



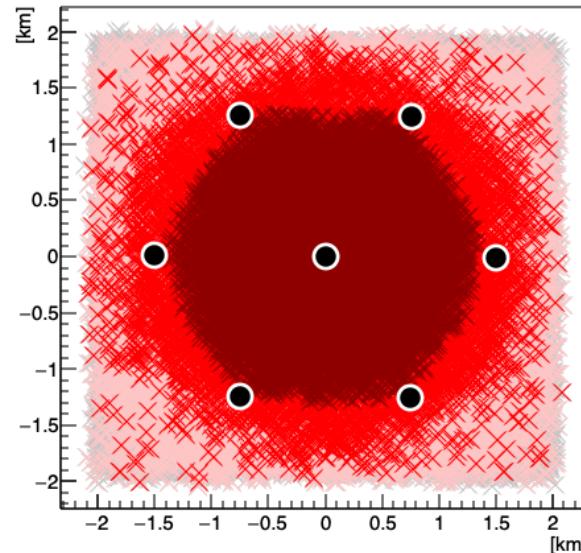
## Auger@TA phase II – metric selection

- Metric selection based on 75% of the micro-array reconstructed showers pass the quality cuts

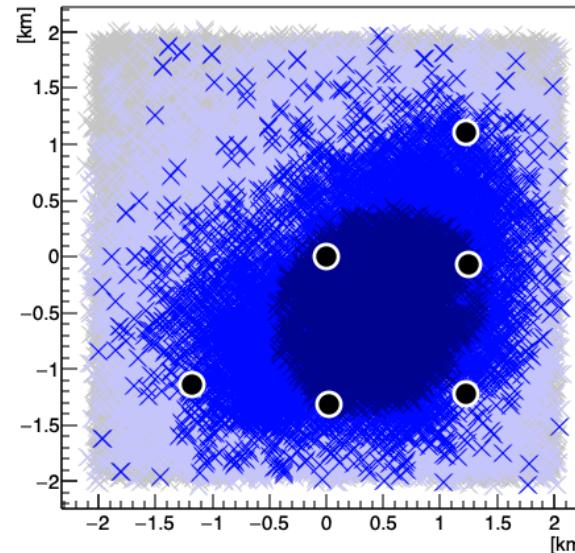


## Auger@TA phase II – selected showers

**HEXAGON**

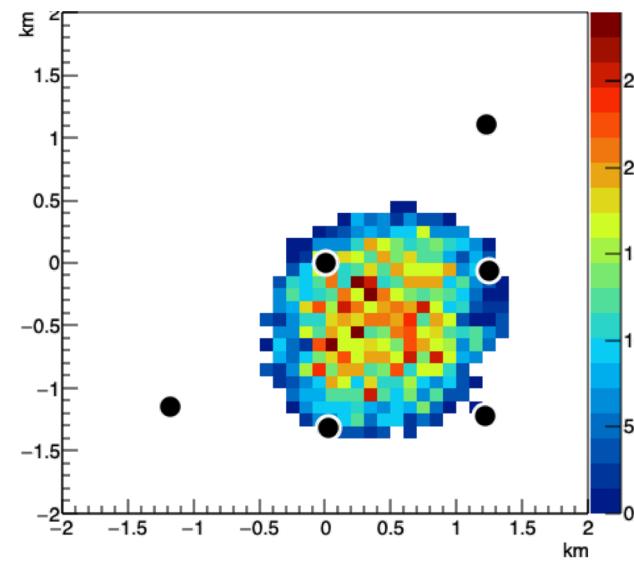
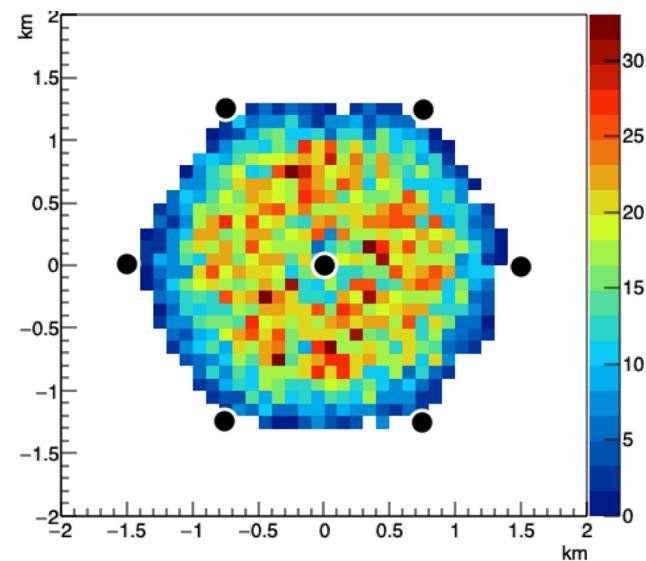


**TRIANGLE**



Dark colors:  
events selected by the metric

Density plot:  
events selected by the metric

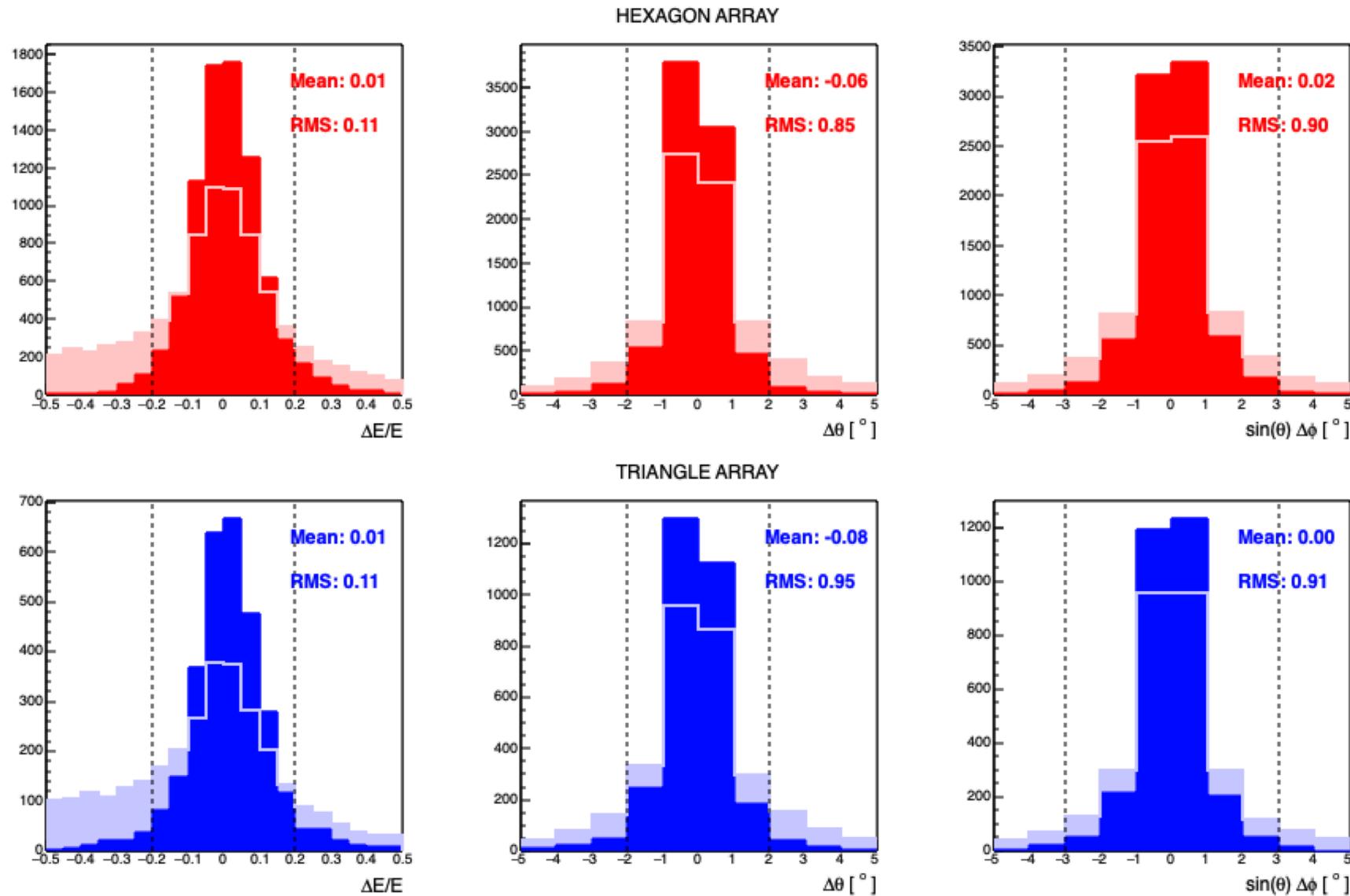


Preliminary predicted coinc.  
rates with TA (CWRU):

- Hexagon ( $\text{month}^{-1}$ ):
  - 7 core contained
  - 11 not contained
- Triangle ( $\text{month}^{-1}$ ):
  - 5 core contained
  - 10 not contained



## Auger@TA phase II – metric performance



## Selection biases

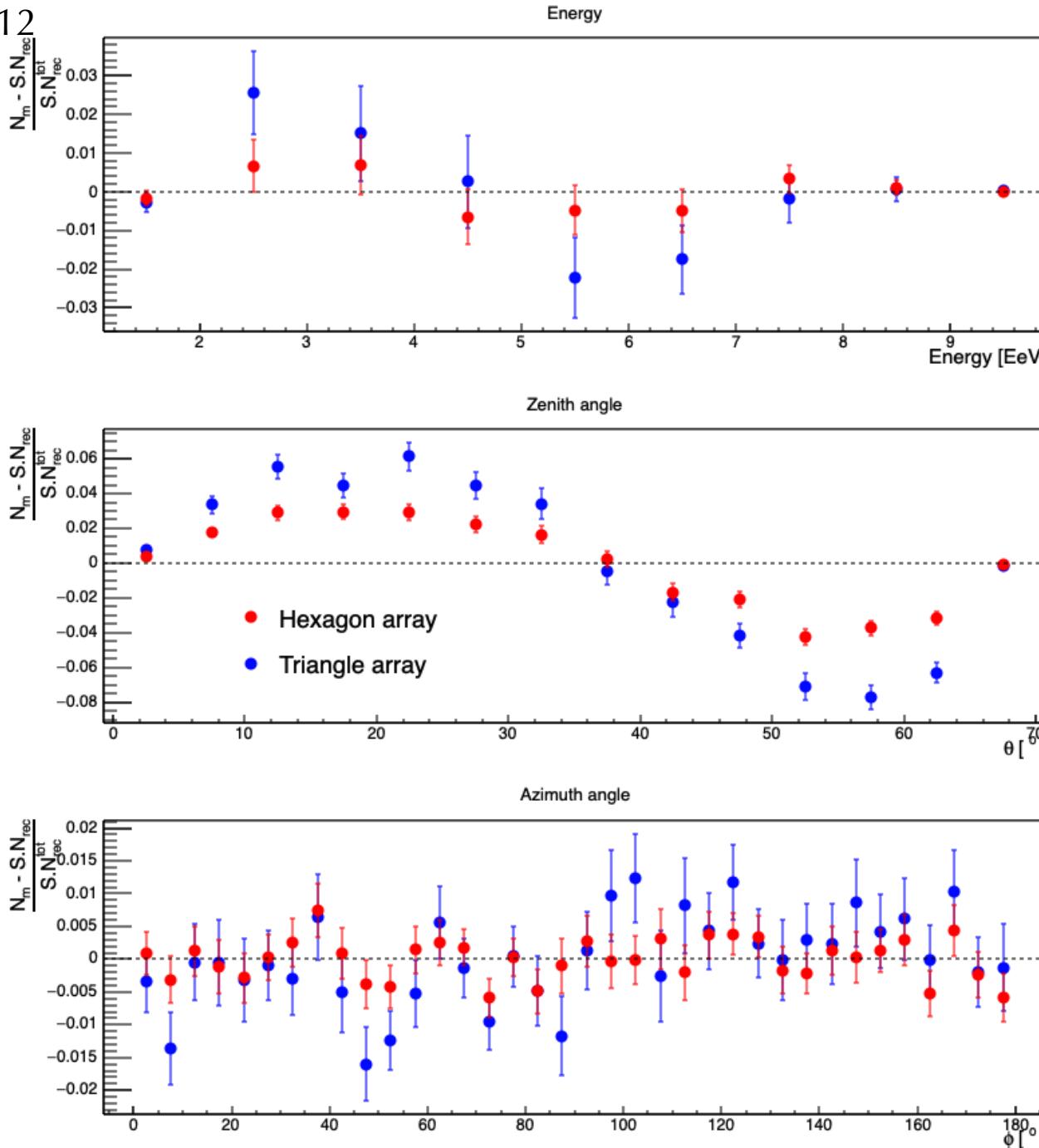
- The metric cut induces a bias in the distribution of reconstructed showers compared to all the showers reconstructed by the micro-array

$$B = \frac{N_m - S \cdot N_{rec}}{S \cdot N_{rec}^{tot}}$$

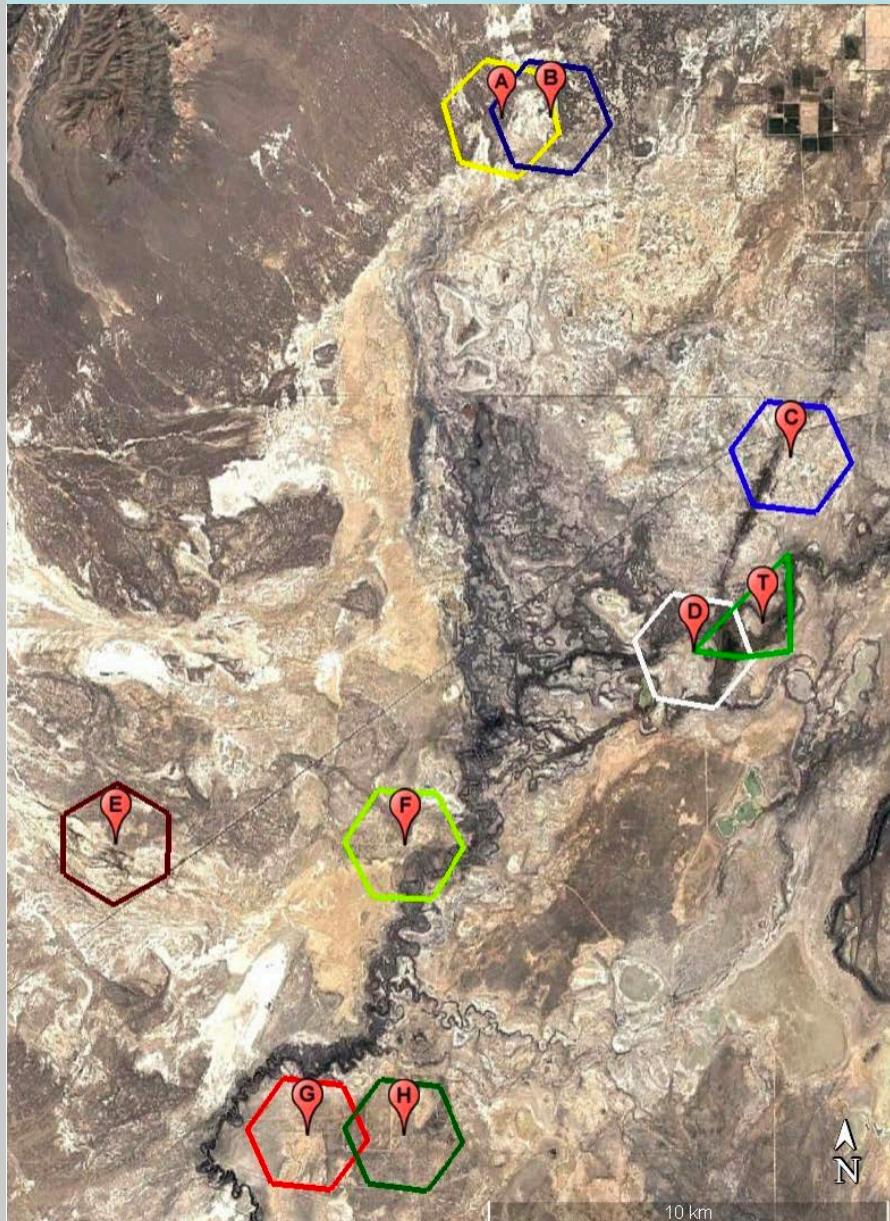
$N_m$ : number of showers reconstructed after metric selection per bin

$N_{rec}$ : number of showers reconstructed by micro-array per bin

$S = N_m^{tot} / N_{rec}^{tot}$ : scaling factor to normalize both distributions



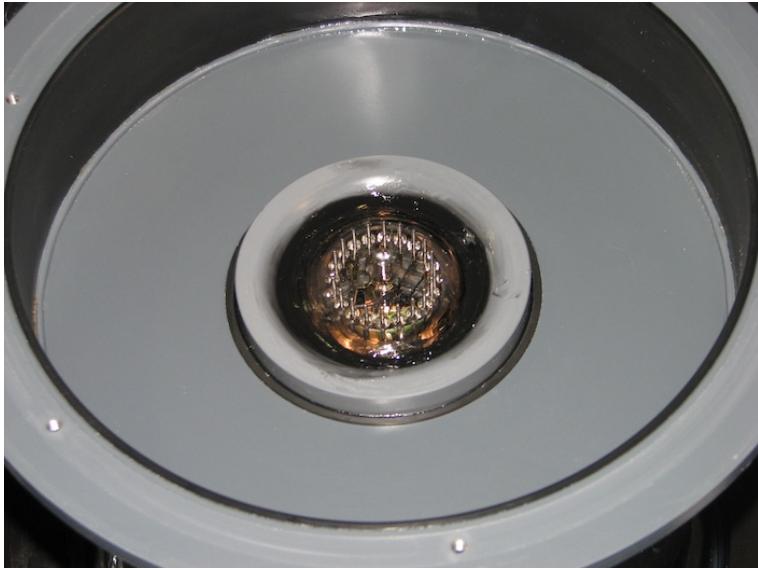
## Summary &amp; timeline



- Hexagon micro-array more suitable for Auger-TA comparisons
- Hexagon micro-array outperforms the triangle one
- There are possible locations. One more location to consider is centered around TA CLF for convenience.
- White paper for Auger@TA phase II to be prepared and to be submitted to TA colleagues
- Deployment early next year (funding permitting)



## Auger south electronics for the Auger North tanks



- The Auger North electronics is largely untested (never left the prototype stage) and would be a source of concerns in a Auger – TA comparison
- We propose to reconfigure the Auger North SDs with Auger South electronics. Requires new bases for PMTs. Also communication system needs to be reworked.
- This can be done at CWRU (funding permitting)

## SD cross-calibration (Auger@TA) Working Group members

### AUGER

#### Mines

- Jeff Johnsen (PhD)
- Fred Sarazin
- Orlen Wolf

#### Case Western (CWRU)

- Corbin Covault
- Ryan Lorek (PhD)
- Sean Quinn (now UCLA)
- Robert Sabin

#### KIT

- David Schmidt (PhD)

#### Auger

- Ricardo Sato

### TELESCOPE ARRAY

#### ICRR / Tokyo

- Hiroyuki Sagawa
- Nonaka Toshiyuki
- Takashi Sako
- Ryuji Takeishi

#### Kyoto

- Toshihiro Fujii (also Auger)

**New members welcome!**



# THE END

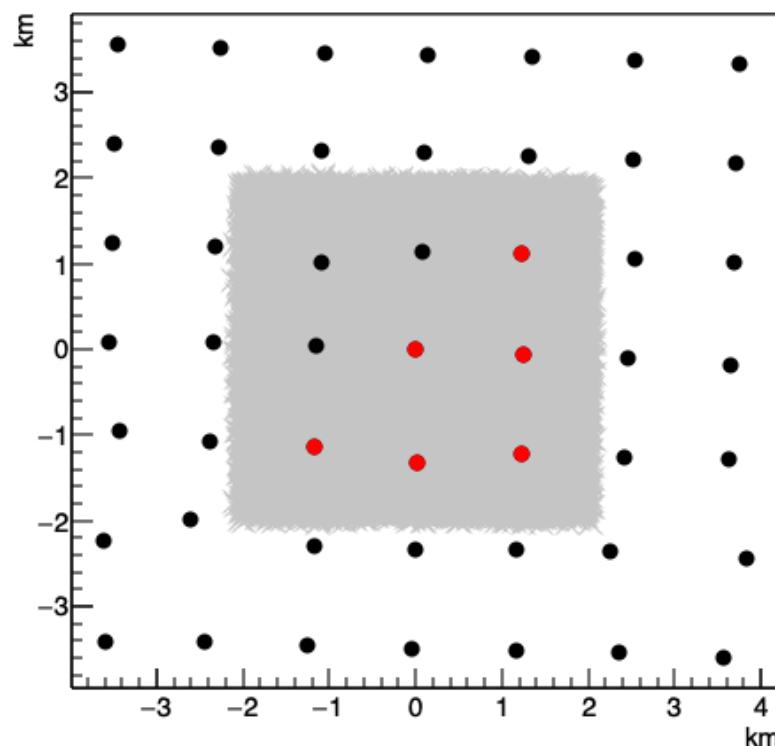


Fred Sarazin (fsarazin@mines.edu)  
Physics Department, Colorado School of Mines

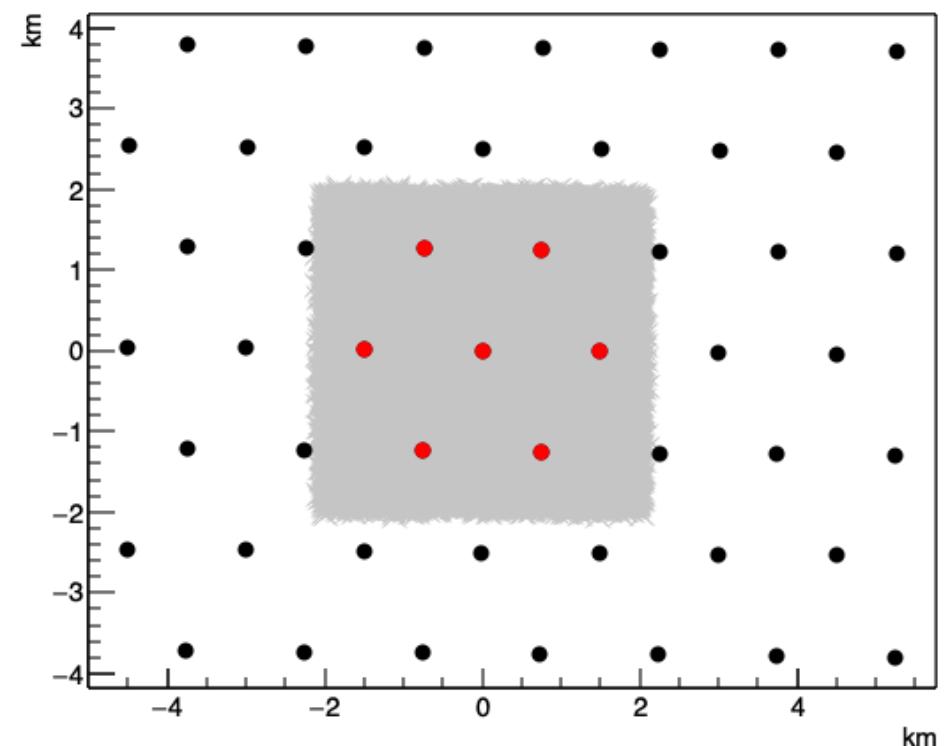
Auger analysis meeting, Nijmegen (NL), Jun 24-28, 2019

## Auger@TA phase II – simulating the micro-arrays

TRIANGLE



HEXAGON



✗ Core locations of the simulated showers  
Large arrays made of 49 stations

