The TAx4 experiment

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Outline

• Motivation of the TAx4 experiment
• Design of the TAx4 Surface Detector (SD) array
• Design of TAx4 SDs
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• Summary
Indications of anisotropy: hotspot observed by the TA experiment

Arrival directions of $E > 57$ EeV cosmic rays

Significance map

- TA experiment 5 years observation, 72 events with $E > 57$ EeV
- Max. local significance: $5.1 \sigma$
- Observed: 19 events, Expected from isotropy: 4.5 events in the direction
- Chance probability to exceed the local significance $5.1 \sigma$: $3.4 \sigma$
- First observation of anisotropy at the highest energies with high significance

500 SDs, 2.08 km spacing for
4 × TA SD detection area (~3000 km²)
combined with TA SD
accepted by Japan in April 2015
165 SDs were assembled in Utah
in Jan. and Feb. 2017
Applied to build 2 Fluorescence Detector (FD) stations (4+8 HiRes Telescopes)
accepted by US NSF in 2016
→ Take 19 years TA SD data
Take 16.3 years SD and FD hybrid data
Design of the TAx4 SD array

- $E > 57$ EeV: reconstruction efficiency $> 95\%$
- Angular resolution: $2.2^\circ$
- Energy resolution: $\sim 25\%$
Design of TAx4 SDs

Inside of the scintillator box

- Solar panel for wireless communication
- Planar antenna for wireless communication
- Scintillator box
- Stainless steel box for the electronics and a battery

- 2 layers 3 m² 1.2 cm thick plastic scintillators
- Calibration of signals using single muon
- DAQ with 2.4 GHz wireless communication
- 6 new communication towers
Design of TAx4 SDs

PMT: Hamamatsu R8619
(PMTs in TA SD: ET9124)

- Quantum efficiency ~ 20 % at 500 nm (~ 10% ET9124)
- Pulse linearity ~ 50 mA (25 mA ET9124)
- Position dependence of the output signal on the photo cathode < ~ 10%

→ Change of the arrangement of wavelength shifting fibers

Total length of fibers ~ 33% of TA SD
Construction of 165 TAx4 SDs

- 173 scintillator boxes were assembled in Japan in winter 2015 and summer 2016.
- 4-5 scintillator boxes were assembled per day by about 10 people.
- New 77 scintillator boxes will be assembled next month.
- 165 SDs were assembled by 8 people in Utah in Jan.-Feb. 2017.
Staking for 550 TAx4 SD sites

- 327 sites were visited with ATVs was done last month.
- 4 teams 8 people 8 days
- The line of sight to the temporary communication tower was checked.
- The rest of 223 sites will be staked using a helicopter.
- Survey of the environment will be done by the Bureau of the Land Management.

→ Ready to deploy TAx4 SDs!

Temporary towers were placed at the com. tower sites
Calibration using single muon

Number of photo electrons corresponding to the single muon peak of each layer of SD:

\[ 19.0 \pm 3.3 \]
within the distribution of TA SD

\[ 24.6 \pm 7.2 \]

Mean value of the Gaussian obtained by fitting ADC distribution of pedestal run

Typical charge ADC distribution obtained by taking coincidence of 2 layers of the SD

Relative single peak of sampled scintillators before the assembly (1 sample per (50/100))

16 scintillators are used for 1 SD
Linearity of PMTs were measured with 2 LEDs inside of SDs.

Y-axis: Non-linearity of output current from PMTs
X-axis: Output current from PMTs (1 count ~ 0.01 mA)

Linearity of all assembled PMTs was checked.
Non-linearity < 10% when the output current < 40 mA

→ No influence on the standard SD analysis, but provides more utility.
Timing accuracy

- Internal clock of SD electronics is calibrated using GPS 1PPS from the GPS timing receivers (M12M i-Lotus).
- All the GPS timing receivers were checked.
- Relative timing was measured from one particular standard SD electronics and GPS receiver.
- Fluctuation of 1pps is estimated to be about 9.4 ns. : similar quality to TA SDs.
- 1pps timing offset < 16.7 ns

An example of distribution of relative timing:
1σ: 13.3 ns → fluctuation: $13.3/\sqrt{2} = 9.4$ ns

1pps timing offset < 16.7 ns
Future prospects

Assumption:
The hotspot comes from 1 source with 10 deg. Gaussian $\sigma$.
Oversampling 20° radius circle

$N_{\text{total}}$: 305 events, 21 TA SD equivalent years
$N_{\text{BG}}$: 244 events isotropic background
$N_{\text{source}}$: 61 events (21 events and 40 events for 2 separated sources)

Assumption:
The hotspot comes from 2 separated sources with $1\sigma=10$ deg. and with $1\sigma=5$ deg..
Oversampling 15° radius circle
Future prospects

- Energy spectrum: more detailed spectrum shape at the highest energies with \( \sim 21 \) TA SD equivalent years data
- Composition: \( X_{\text{max}} \) using SDFD hybrid events with high statistics will be also provided.
- Anisotropy of energy spectrum may be showing up.

T. Nonaka et al. 7/18 bd 175
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**Summary**

- Construction of TAx4 SDs and FDs was funded.
- **173** scintillator boxes of SDs were already assembled.
- 2 FD stations will be also constructed in the near future.
- Staking of 550 locations will be done this autumn.
- **77** new TAx4 scintillator boxes will be assembled in Japan next month.
- **250** TAx4 SDs will be complete this winter in total.
- Similar or better performance of TAx4 SDs than TA SDs are realized for now.
  - Tighter distribution of single muon peak: **19.0±3.3 photo electrons**.
  - Non-linearity <**10%** is checked when the output current of PMTs is < **40 mA**.
  - Timing accuracy of each SD: fluctuation is about **9.4 ns**. Offset is less than **16.7 ns**.
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