ULTRA-HIGH-ENERGY COSMIC-RAY ORIGIN STUDIES WITH THE TA AND TAx4 SURFACE DETECTOR

ICRR Inter-University Research Results Presentation Meeting
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PROJECT APPROVED BUDGET

Ref. No	Organization name	Principal investigator	Research proposal	New/ On going	Assessed amount（Unit: yen）			Screening result
					Goods	Travel	Total	
F01	Institute for Nuclear Reseach RAS	Grigory I. Rubtsov	Ultra-high-energy cosmic-ray origin studies with the Telescope Array and TAx4 surface detector	Ongoing	0	280,000	280,000	Approved

- Project started in 2019 FY
- Fund carry-over is requested to 2021 FY
- The application is submitted for 2021 FY

LIST OF PARTICIPANTS

No.	Name	Organization	Department	Job title	Country
1	Grigory I. Rubtsov	INR RAS	Administration	deputy director	Russia
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3.	Maxim S. Pshirkov	INR RAS	Experimental physics	researcher	Russia
4.	Sergey V. Troitsky	INR RAS	Theory department	principal researcher	Russia
5.	Mikhail Yu. Kuznetsov	INR RAS	Experimental physics	researcher	Russia
6.	Igor I. Tkachev	INR RAS	Experimental physics	head of the department	Russia
7.	Takashi Sako	University of Tokyo	ICRR	Associate professor	Japan
8.	Hiroyuki Sagawa	University of Tokyo	ICRR	Professor	Japan

RESEARCH PURPOSE

Using the data of TA Surface Detector:

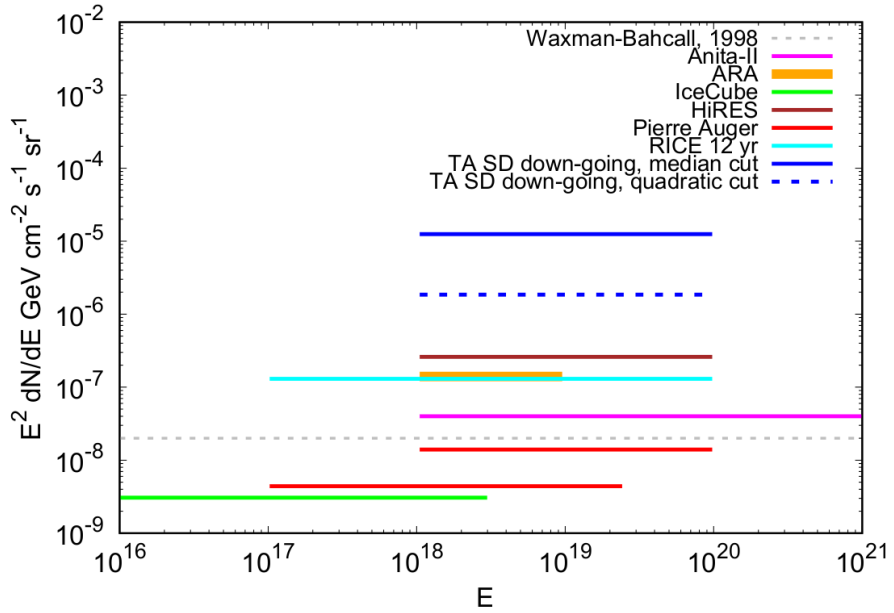
- establish the chemical composition of ultra-high-energy cosmic rays at energies from 1 EeV to 100 EeV
- search for anisotropy and sources of cosmic rays
- search for sources of ultra-high energy photons and neutrinos

THE RESULTS OF THE 2020 FY

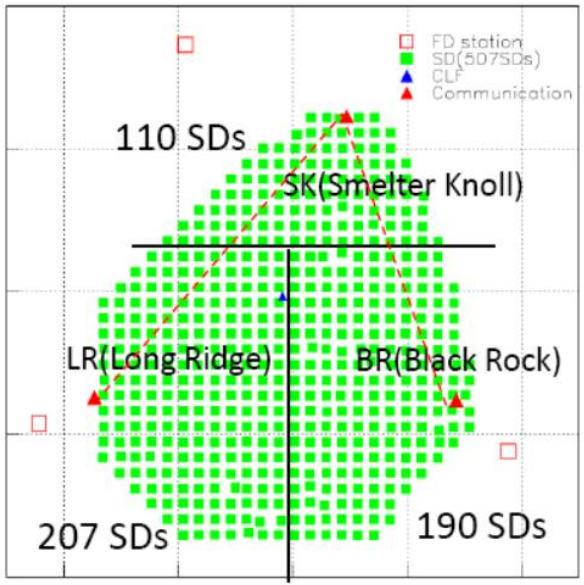
- An upper limit on the flux of UHE down-going neutrinos for E>1 EeV is derived. The analysis method is based on the Boosted Decision Trees.
- A novel approach for reconstruction of the arrival direction of the primary particle is developed based on the deep convolutional neural network. The method is using calibrated time-resolved signals of individual stations.

TA LIMIT ON DOWN-GOING NEUTRINO FLUX

$$EF_\nu < 1.85 \times 10^{-6}\ \mathrm{GeV\ cm^{-2}\ s^{-1}\ sr^{-1}}\ \ (90\%\ \mathrm{C.L.})$$



TELESCOPE ARRAY SURFACE DETECTOR



- 507 SD's, 3 m^2 each
- 680 km^2 area
- 9 years of operation (this analysis)

Largest UHECR statistics in the Northern Hemisphere

NOVEL SD RECONSTRUCTION: INPUT DATA

event data

Dimensions:
(N,N,T,2)

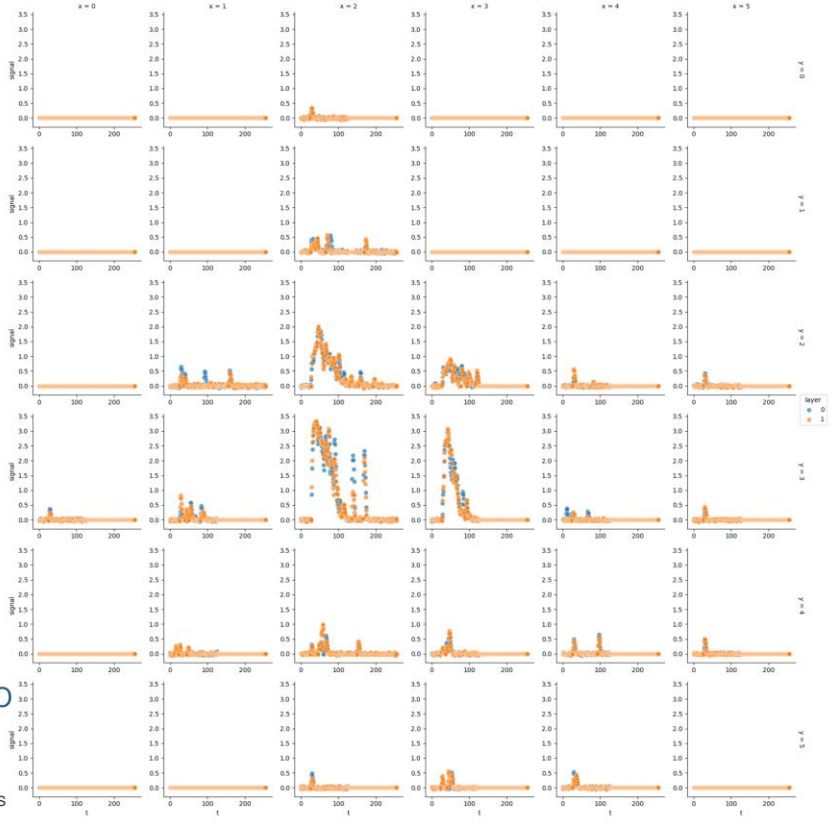
Waveform

detector layers

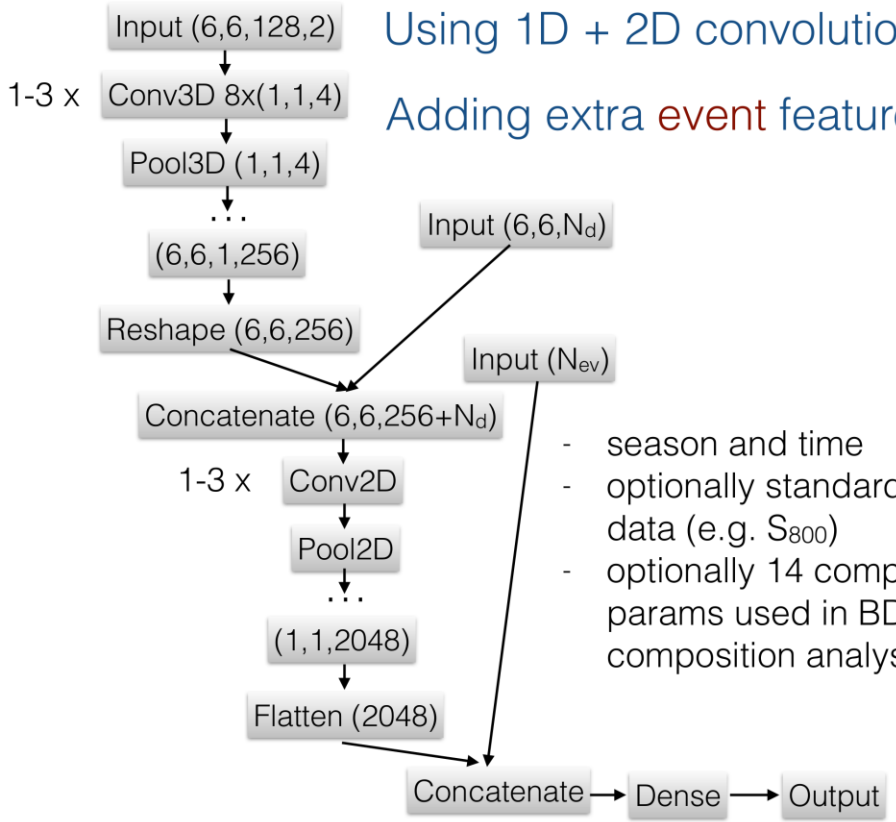
N=4-8, T=128-256*

Standard SD reconstruction is used to center image around shower core

*time unit = 20ns



NEURAL NETWORK ARCHITECTURE



Using 1D + 2D convolutions

Adding extra event features:

- season and time
- optionally standard reconstruction data (e.g. S_{800})
- optionally 14 composition sensitive params used in BDT multivariate composition analysis (arXiv:1808.03680)

NEURAL NETWORK RECONSTRUCTION RESULTS

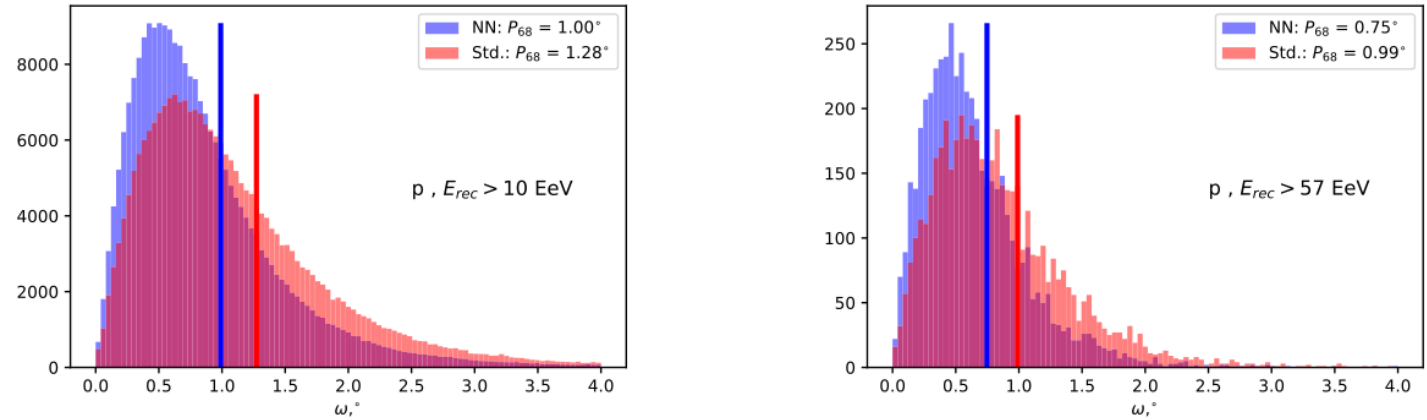


Figure 5. Angular distance ω distribution between the true and reconstructed arrival directions for the standard (red histogram) and CNN-enhanced (blue histogram) reconstructions of the proton Monte Carlo event set simulated using QGSJETII-03 hadronic model for the reconstructed energy higher than 10 EeV (left figure) or 57 EeV (right figure). Vertical lines denote the positions of 68% percentile of the distributions, i.e. the angular resolution values.

- Bottomline: neural network reconstruction provides enhanced angular resolution compared to the standard one

RECENT PUBLICATIONS

- R. U. Abbasi et al. (Telescope Array Collaboration), Mass composition of ultrahigh-energy cosmic rays with the Telescope Array Surface Detector data, Phys. Rev. D 99 (2019) 022002.
- R. U. Abbasi et al. (Telescope Array Collaboration), Search for point sources of ultra-high energy photons with Telescope Array surface detector, MNRAS 492 (2020) 3984.
- R. U. Abbasi et al. (Telescope Array Collaboration), Search for Ultra-High-Energy Neutrinos with the Telescope Array Surface Detector, J.Exp.Theor.Phys. 131 (2020) 2, 255.
- D. Ivanov, O. Kalashev, M. Kuznetsov, GR, T. Sako, Y. Tsunesada and Y. Zhezher, Using deep learning to enhance event geometry reconstruction for the telescope array surface detector, Mach. Learn. Sci. Technol. 2 (2021) 015006.

ありがとうございました。