



ULTRA-HIGH-ENERGY COSMIC-RAY ORIGIN STUDIES WITH THE TA AND TAX4 SURFACE DETECTOR

ICRR Inter-University Research Results Presentation Meeting
January 25th, 2022.

Grigory I. Rubtsov (INR RAS, Moscow)

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	378,800	378,800	Approved

- Project started in 2019 FY
- Fund carry-over is requested to 2022 FY
- The application is submitted for 2022 FY
(no additional funds requested for 2022 FY)

LIST OF PARTICIPANTS

No.	Name	Organization	Department	Job title	Country
1	Grigory I. Rubtsov	INR RAS	Administration	deputy director	Russia
2	Oleg E. Kalashev	INR RAS	Theory department	senior researcher	Russia
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

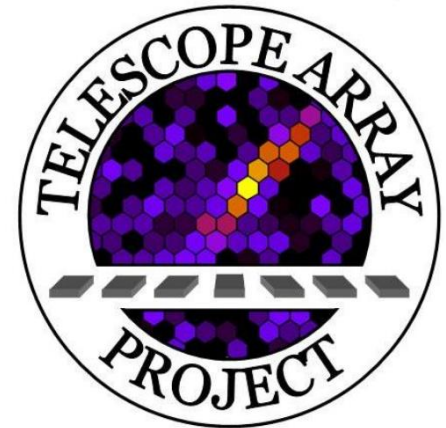
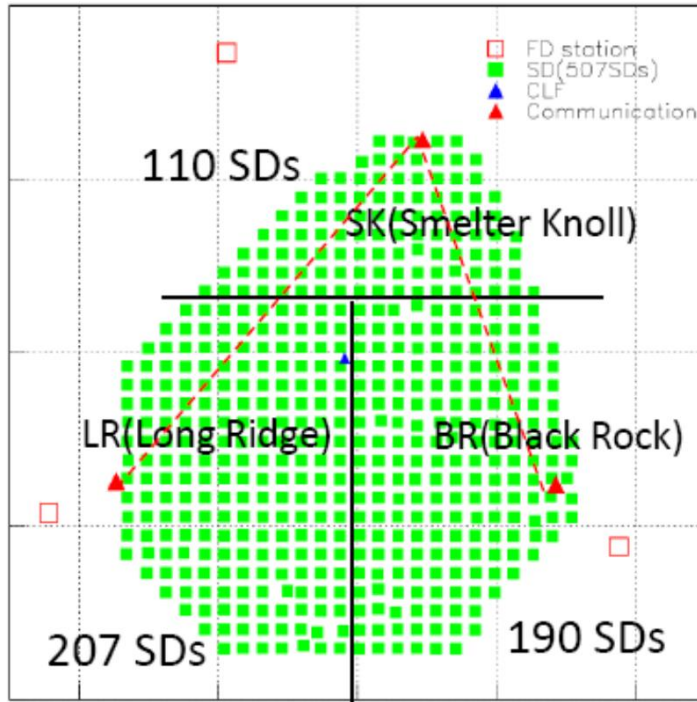
Using the data of TA and TAx4 Surface Detector:

- Establish chemical composition of the ultra-high-energy cosmic rays at energy range 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 2021 FY

- The neural network classifier has been developed for identifying primary particle type. The classifier employs full time-resolved signals from all triggered TA SD stations along with 16 composition-sensitive observables.
- Implementation of the new classifier have substantially increased the efficiency of the photon candidate selection compared to the previous analysis with the classifier based on the Boosted Decision Trees.
- The preliminary photon flux limits with the new classifier are presented at ICRC'2021.

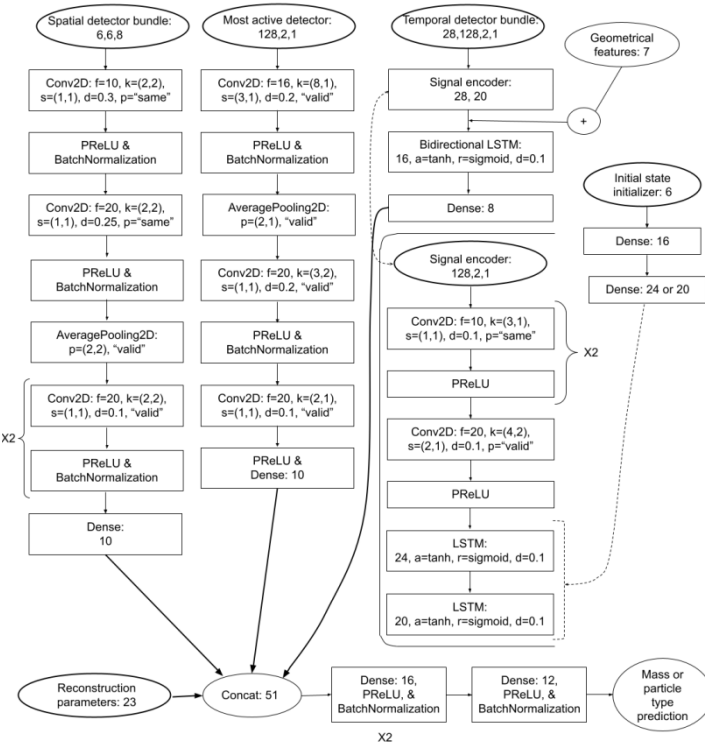
TELESCOPE ARRAY SURFACE DETECTOR



- ▶ 507 SD's, 3 m² each
- ▶ 680 km² area
- ▶ operating since May 2008

Largest UHECR statistics in the Northern Hemisphere

NEURAL NETWORK P- γ CLASSIFIER



Input:

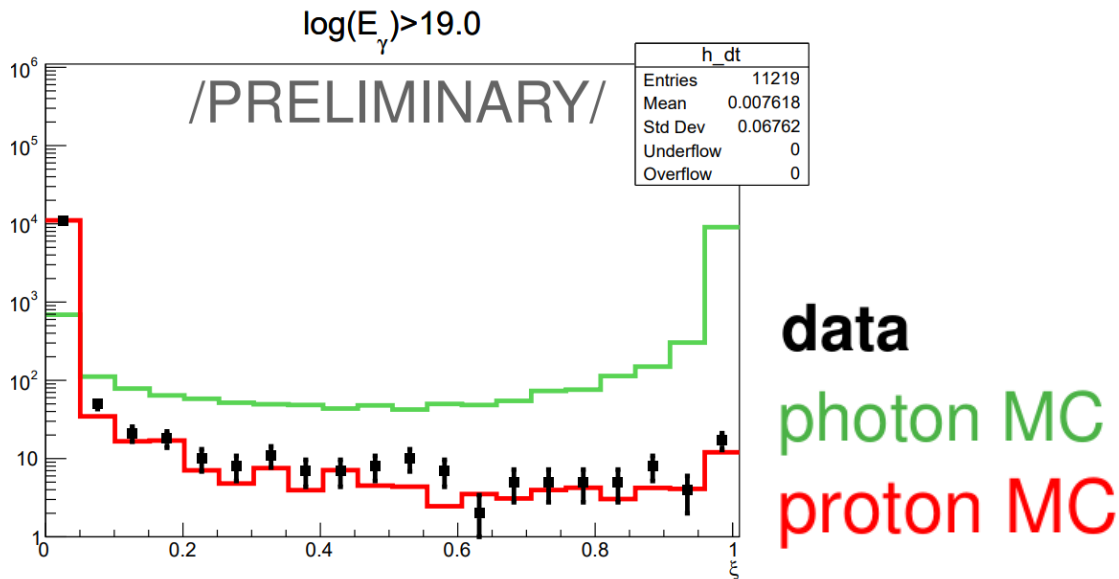
- ▶ incidence time and integral signal for 6x6 SD stations
- ▶ time-resolved signals for all triggered stations ordered by the front arrival time
- ▶ composition-sensitive event features

TA, Phys.Rev.D 99 (2019) 02200

Output:

- ▶ The value $\xi \in [0, 1]$ for an event. ξ is close to 0 for proton-induced showers and to 1 for γ -induced.

CLASSIFIER RESULT FOR DATA AND MC



Efficient separation of proton and photon-induced events

PHOTON CANDIDATE EVENTS

energy cut	event date and time	comment
$E_0 > 10^{19.0}$ eV	2010-10-04 16:58:42	
	2011-07-27 08:06:15	
	2011-09-16 19:40:56	
	2012-05-01 00:59:15	
	2012-07-06 01:49:11	
	2012-09-07 01:55:45	
	2013-08-27 22:38:37	
	2014-07-31 21:19:19	
	2014-08-14 09:46:58	
	2014-08-23 02:39:15	
	2014-09-27 07:54:35	
	2015-07-19 01:03:04	
	2017-09-12 18:32:59	
2018-08-02 15:25:51		
2018-10-03 04:03:48		
2019-04-30 22:43:17		

PHOTON CANDIDATE EVENTS

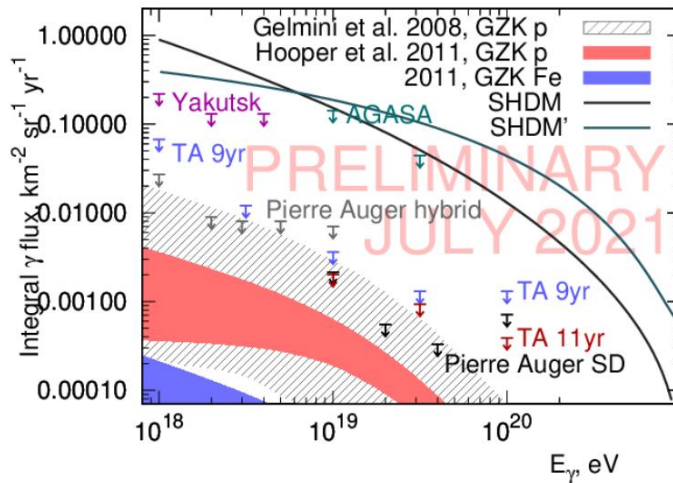
energy cut	event date and time	comment
$E_0 > 10^{19.0}$ eV	2010-10-04 16:58:42	TGF candidate event
	2011-07-27 08:06:15	TGF candidate event
	2011-09-16 19:40:56	TGF candidate event
	2012-05-01 00:59:15	
	2012-07-06 01:49:11	TGF candidate event
	2012-09-07 01:55:45	TGF candidate event
	2013-08-27 22:38:37	TGF candidate event
	2014-07-31 21:19:19	TGF candidate event
	2014-08-14 09:46:58	
	2014-08-23 02:39:15	TGF candidate event
	2014-09-27 07:54:35	TGF candidate event
	2015-07-19 01:03:04	TGF candidate event
	2017-09-12 18:32:59	TGF candidate event
	2018-08-02 15:25:51	TGF candidate event
2018-10-03 04:03:48	TGF candidate event	
2019-04-30 22:43:17	TGF candidate event	

Terrestrial Gamma-Ray Flashes candidate events are time correlated with the lightnings registered by National Lightning Detection Network

TA collaboration, JGR Atmospheres (2020)

PHOTON FLUX LIMITS

E_0, eV	$10^{19.0}$	$10^{19.5}$	$10^{20.0}$
γ candidates	16 2	11 1	5 0
$\bar{n} <$	6.72	5.14	3.09
A_{eff}	3428	5546	7875
$F_\gamma <$	2.0×10^{-3}	9.3×10^{-4}	3.9×10^{-4}



RECENT PUBLICATIONS

- D. Ivanov, O. Kalashev, M. Kuznetsov, GR, T. Sako, Y. Tsunesada and Y. Zhezher, Using deep learning to enhance event geometry reconstruction for TA SD, Mach. Learn. Sci. Tech. 2 (2021) 015006.
- I.V. Kharuk et al. (Telescope Array Collaboration), Mass composition of TA SD events using deep learning, PoS ICRC2021 (2021) 384.
- O.E. Kalashev, et al. (Telescope Array Collaboration), Telescope Array search for EeV photons, PoS ICRC2021 (2021) 864.
- 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.

ありがとうございました。