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

ICRR Inter-University Research Results Presentation Meeting
February 21th, 2023.

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 in 2020 and 2021 FY
- Spending: visit of group member M.Kudenko to ICRR
- The application is submitted for 2023 FY

LIST OF PARTICIPANTS

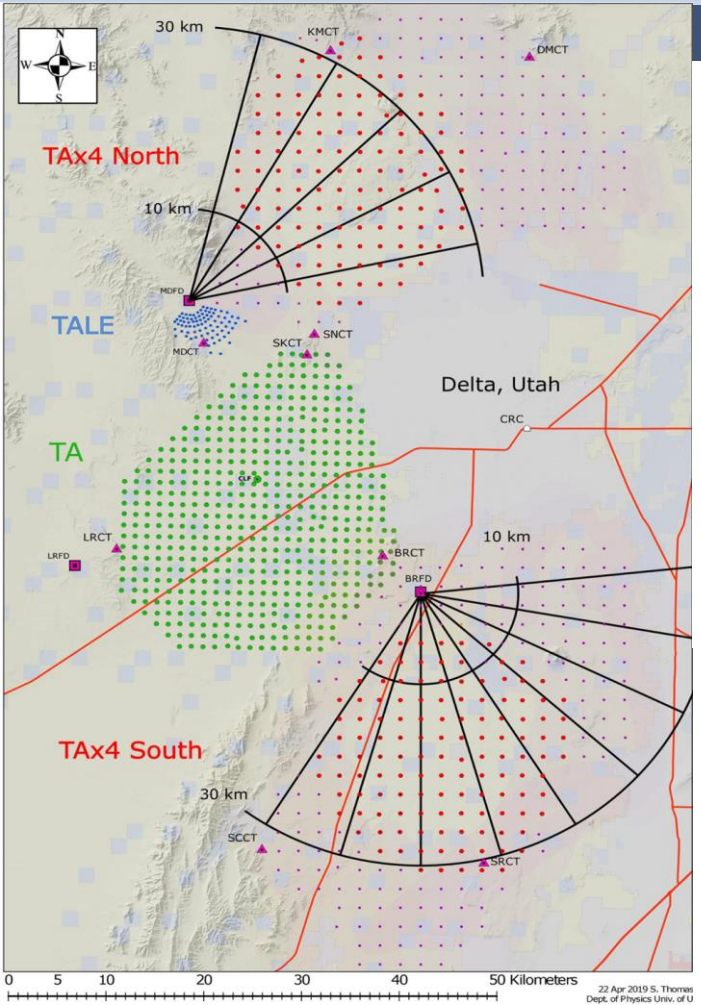
No.	Name	Organization	Department	Job title	Country
1	Grigory I. Rubtsov	INR RAS	Administration	deputy director	Russia
2	Oleg E. Kalashev	INR RAS	Theory department	senior researcher	Russia
3.	Maxim S. Pshirkov	INR RAS	Experimental physics	researcher	Russia
4.	Sergey V. Troitsky	INR RAS	Theory department	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
9.	Maria Kudenko	INR RAS	Theory department	student	Russia

RESEARCH PURPOSE

- Determine the chemical composition of the ultra-high-energy cosmic rays from 1 EeV to 100 EeV using the data of TA and TAx4 Surface Detector.
- Search for ultra-high energy photons with the TALE Fluorescence Detector
- Search for anisotropy and sources of cosmic rays, photons and neutrinos.

THE RESULTS OF THE 2022 FY

- An architecture of the deep learning method for identifying primary particle types of the TA SD events has been developed. The method is based on the chain of two neural networks. The first works as a classifier for individual events, while the second predicts fractions of elements in an ensemble of events based on the inference of the first network.
- The classifier employs full time-resolved signals from all triggered TA SD stations along with 16 composition-sensitive observables.

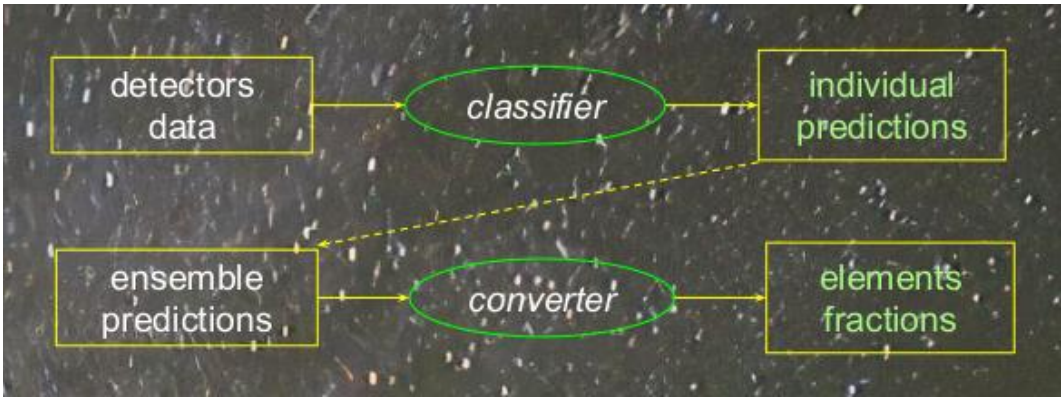


TELESCOPE ARRAY PROJECT

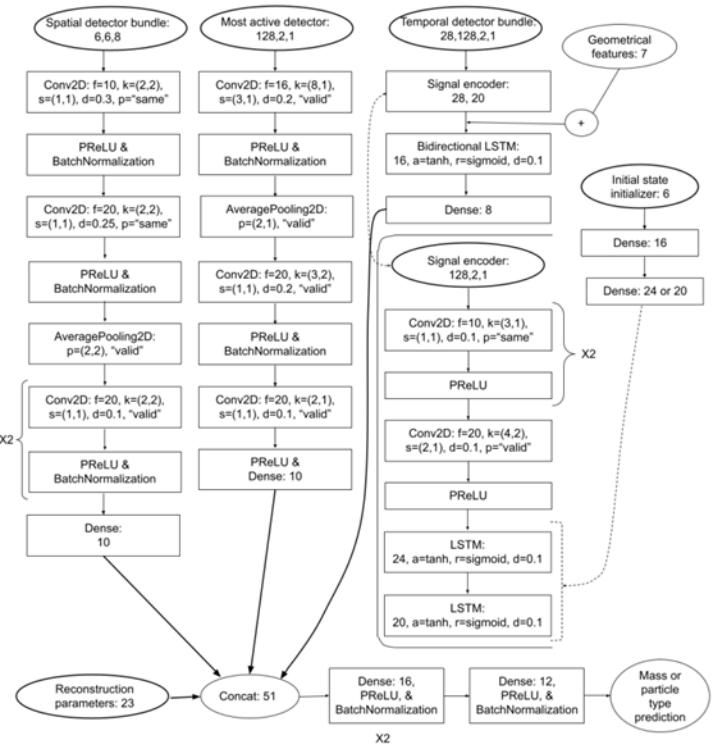
- Largest statistics in the Northern hemisphere
- TA SD is operating since May 2008
- Extension: TAx4

MACHINE LEARNING ARCHITECTURE

- Two stages, both using neural network
- 1st stage: classifier for individual events
- 2nd stage: analysis of the ensemble of events



1ST STAGE: NEURAL NETWORK 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

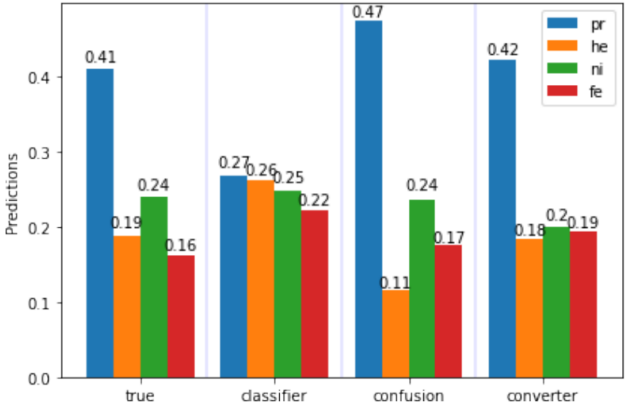
TA, Phys.Rev.D 99 (2019) 02200

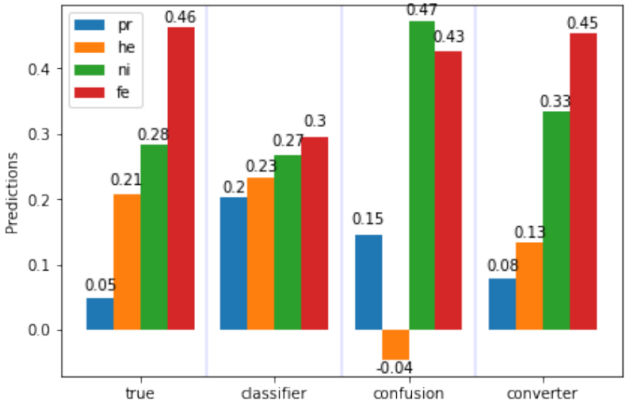
Output:

- particle type (p, He, N, Fe)

2ND STAGE: CONVERTER OF THE PREDICTION FOR THE ENSEMBLE

Two examples of the ensemble composition estimate





2ND STAGE: CONVERTER OF THE PREDICTION FOR THE ENSEMBLE

energy bin, log scale	18–18.25	18.25–18.5	18.5–18.75	18.75–19	> 19
averaged MAE	0.072	0.053	0.048	0.043	0.038

Table 3. MAE between true and reconstructed fractions of elements, averaged over the elements for different energy bins.

- We estimate the composition of the dataset with reasonable accuracy, while the types of particles for individual event are unknown

RECENT PUBLICATIONS

- O. Kalashev, I. Kharuk, M. Kuznetsov, G. Rubtsov, T. Sako, Y. Tsunesada, Ya. Zhezher, Deep learning method for identifying mass composition of ultra-high-energy cosmic rays, JINST 17 (2022) P05008.
- 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.
- 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。