CRI Rapporteur

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ICRC 2021

Berlin, Germany

07/22/2021

Outline / CRI Sessions

- Cosmic Rays Astrophysics
  - 01 Magnetic fields and CR propagation
  - 12 Galactic Particle Acceleration, including PIC
  - 11 UHECR Acceleration
- Air Shower Physics
  - 03 Muon Puzzle and EAS modeling
  - 10 EAS reconstruction and analyses
- Experiments and Detectors
  - 07 Where to go in UHECR observations
  - 13 New Instrumentation and Tools for EAS Detection
  - 08 Radio Observations of Cosmic Rays
- Physics Results
  - 04 CR Energy Spectrum
  - 05 CR Mass composition
  - 06 CR Anisotropies
  - 02 Constraining UHECR SOURCES
  - 09 Atmospheric and geophysical phenomena

- A great majority of the slides in this presentation were extracted from the “Discussion Record” presentations, kindly provided to me by the respective session conveners.
- Otherwise, they were the Executive Summary slides provided by the contributors themselves.

Convener: Glennys Farrar | Tess Jaffe

Session 01: Magnetic fields and CR propagation

Extragalactic

Arjen Rene van Vliet: Extragalactic magnetic fields and directional correlations of ultra-high-energy cosmic rays with local galaxies and neutrinos

Yutaka Ohira: Magnetic field generation by the first cosmic rays

Rafael Alves Batista: CRPropa 3.2: A framework for high-energy astroparticle propagation

Andrey Saveliev: Multimessenger Constraints on Intergalactic Magnetic Fields from Flaring Objects (**July 16 @ 18h)**

Alexander Korochkin: Sensitivity reach of gamma-ray measurements for cosmological magnetic fields

Lots of talks about UHECR anisotropies, cross-correlations, etc., all of which relate to the magnetic field. 1470, 233, 902, 1230, 1415,

Alex Kääpä: Transition from Galactic to extragalactic cosmic rays. PLENARY SESSION TOMORROW July 13

Galactic scale

Thomas Fitoussi: Faraday rotation constraints on large scale halo model

Ralf-Jürgen Dettmar: Magnetic field structure in halos of star-forming disk galaxies

Stefano Gabici: Giant cosmic ray halos around M31 and the Milky Way **(July 19th @ 18h)**

Elena Orlando: Interstellar cosmic-ray spectra (1) just outside the heliosphere and (2) in the local medium: are they the same? 19 July @ 18h

Ellis Owen: Empirical assessment of cosmic ray propagation in magnetised molecular cloud complexes, 15 July @ 12pm

Tess Jaffe: Constraining magnetic fields at Galactic scales. PLENARY SESSION TOMORROW July 13

Small-scales/Turbulence

Marco Kuhlen: Cosmic Ray Small-Scale Anisotropies in Slab Turbulence

Yoann Génolini: Local turbulence and the dipole anisotropy of galactic cosmic rays

Gwenael Giacinti: Simulations of the cosmic-ray anisotropy down to TeV energies

Ottavio Fornieri: Phenomenology of CR scattering on pre-existing MHD modes

[44] **Nicolò Pinciroli Vago**: On the Use of Convolutional Neural Networks for Turbulent Magnetic Field Helicity Classification

Observations

Theory

Extragalactic: Rafael Alves Batista

CRPropa 3.2: a framework for high-energy astroparticle propagation

Rafael Alves Batista *for the* **CRPropa team**
Rabdoud University Nijmegen

What is this contribution about?

- CRPropa: public framework for the propagation of high-energy particles
- treatment of CRs, neutrinos, gamma rays, electrons
- 1D, 3D, and "4D" simulations possible

Why is it relevant?

- CRPropa enables a self-consistent interpretation of observations with **multiple messengers**
- **modular design** enables easy customisation for various applications in astroparticle physics
- treatment of interactions above TeV (for CRs) and GeV (for gamma rays)

What have we done?

- improved algorithm for Galactic CR propagation
- new Galactic magnetic field models
- targeting algorithm to speed up 3D/4D simulations
- native treatment of electromagnetic interactions
- new channels for photon production
- new interpolation methods

What is the result?

- advanced public code for multimessenger studies at high- and ultra-high energies

crpropa.desy.de

CR/Propa

Galactic scale: Ralf-Jurgen Dettmar

.-J. Dettmar et al.: Magnetic field structure in halos of star-forming disk galaxies

The large scale magnetic field distribution in star-forming disk galaxies is observed via the polarized radiocontinuum emission in a sample of edge-on galaxies by the CHANG-ES JVLA project

This is important input for generalized models of magnetic fields in disk galaxies and will help to constrain the origin of magnetic fields in galaxies.

The data of individual galaxies from the sample have been stacked to derive a typical "mean" polarization signature and thus a "mean" magnetic field structure.

This average shows again the X-shaped structure in the polarization pattern that was reported before for the most prominent cases such as NGC 891 or NGC 5775.

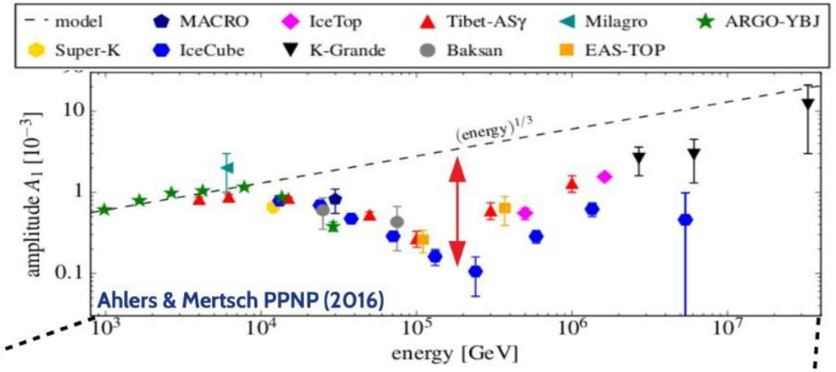
Data: NRAO, NASA, ESA
Composiion: Jayanne English (U. Manitoba)

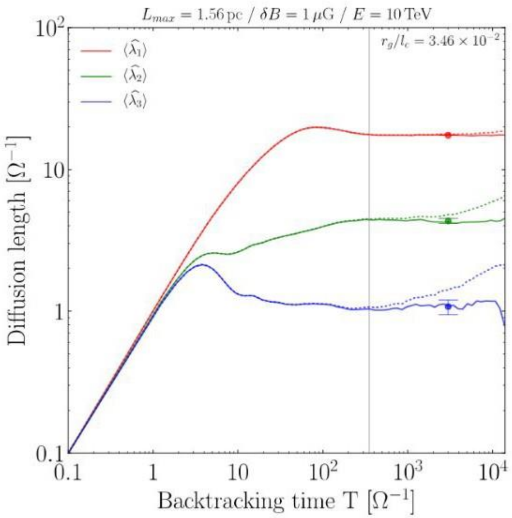
Local Turbulence and the Dipole Anisotropy of Galactic Cosmic Rays

Origin of the dipole anisotropy ?

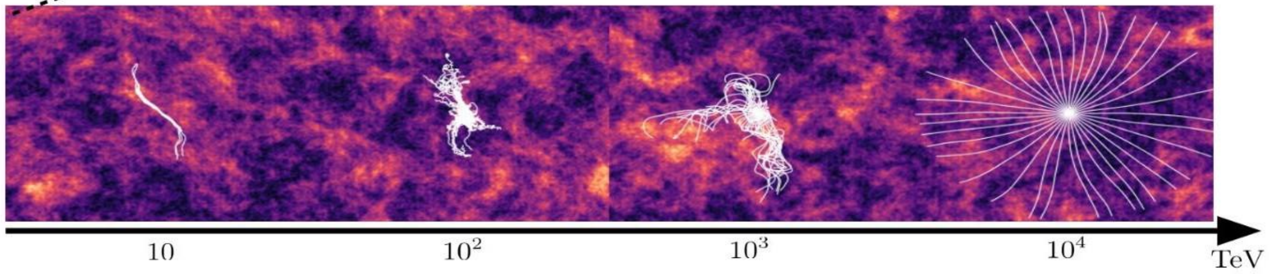
Local CR current: $\boldsymbol{j}_{\rm CR} = -\boldsymbol{K} \cdot \nabla\Psi$

→ Distribution of sources and halo geometry halo?
→ Structure of local magnetic field?





→ Test-particle simulations in **isotropic 3D turbulence**



$$K_{local} = \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} \longrightarrow \begin{bmatrix} \lambda & 0 & 0 \\ 0 & \lambda & 0 \\ 0 & 0 & \lambda \end{bmatrix}$$

Y.G. et Ahlers (to appear)

1- Anisotropic local diffusion tensor
2- Energy dependence of the anisotropy

12 Galactic Particle Acceleration, including PIC

Convener: Elena Amato | Martin Pohl (NOT COVERED; See CRD)

- Magnetic-field amplification: What are the dominant processes, the location, and the saturation level?

(Fraschetti, Bohdan, Zacharegkas)

- Soft particle spectra: Do we understand the origin?

(Caprioli, Pohl, Das)

- Electron acceleration: What do we miss for DSA injection?

(Morris, Kumar, Niemiec)

- Maximum energy and time-integrated spectral yield: Relation to DSA spectra at fixed time?

(Yokoyama, Inoue, Kamijima, Pfrommer, Vieu)

- Precursor waves: Do we understand their role?

(Weidl, Gupta, van Marle, Iwamoto)

11 UHECR Acceleration

Convener: Damiano Caprioli | Andrew Taylor

- The session will feature the contributions below, presented via their executive summary:
- S. O'Sullivan (with B. Reville): Particle acceleration at the **discontinuous flow boundary of collimated cylindrical jets**
- R. Mbarek: Ultra-High-Energy **Cosmic Rays and Neutrinos** from **relativistic jets of Active Galactic Nuclei**
- E. de Gouveia Dal Pino: UHECR acceleration by **magnetic reconnection in relativistic jets** and the origin of very high energy emission
- Z. Zhang: Acceleration of ultrahigh-energy cosmic rays in the **early afterglows of gamma-ray bursts**

- A discussion will follow, hinged on the the following pivotal questions:

• Where is the *present frontier* of UHECR acceleration research? What area of UHECR acceleration is presently most contested?

• What are the currently *favored candidate UHECR sources*? Where are the present observational limitations hindering our ability to probe these candidate accelerators?

• What *future observations* are now needed to take the field beyond the current research frontier? Are the next generation instruments planned sufficient in order to take the community forward? (gamma-ray observatories, cosmic-ray observatories, others?)

• What lessons can we learn from the *Galactic cosmic ray acceleration community*?

- Beyond the identification of the UHECR source class, what questions should we strive to answer?

03 Muon Puzzle and EAS modeling

Convener: Hans Dembinski | Anatoli Fedynitch | Dennis Soldin

Session overview

- We sorted your contributions selected by the ISPC according to these three topics:

  1. Measurements of muons and tests of hadronic interactions with air showers (summarized by Dennis Soldin)

  2. Shower modifications and Muon Puzzle (summarized by Anatoli Fedynitch)

  3. Air shower modelling (summarized by Hans Dembinski)

- Each of us gives a summary of 10-15 minutes

- Followed by three separate discussion sessions (15-20 Minutes)

- During the discussion session, you should ask questions to the speakers as if you would normally do in the 3 minutes between ordinary talks

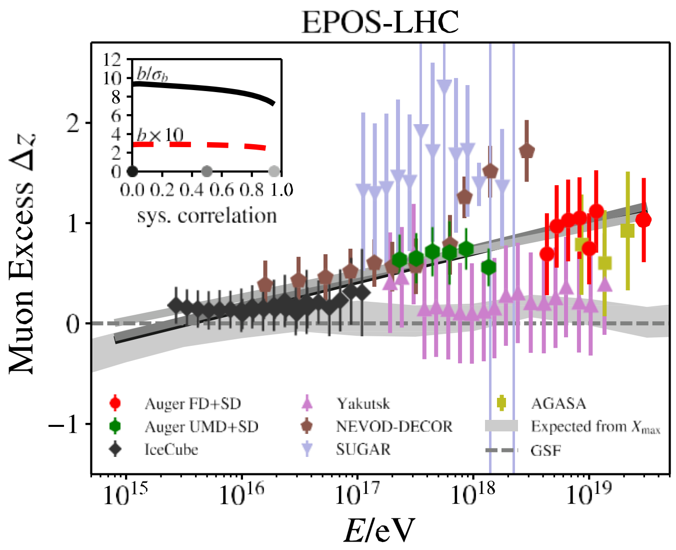
- Enjoy the muon puzzle!

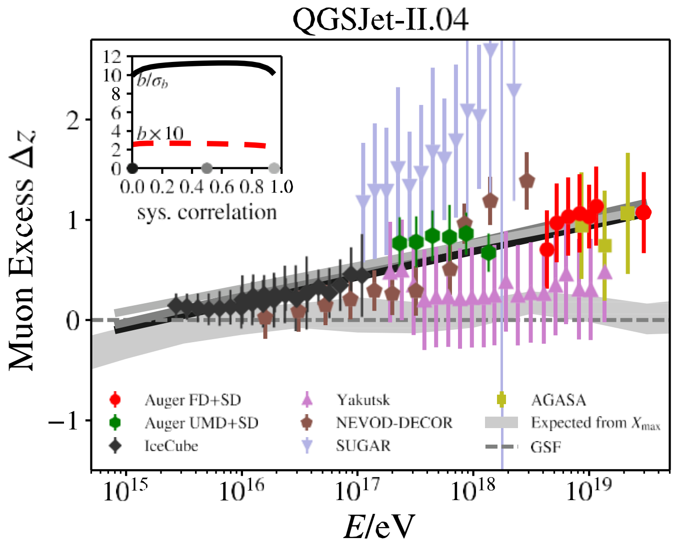
Executive Summary

Update on the Combined Analysis of Muon Measurements from Nine Air Shower Experiments

UNIVERSITY OF DELAWARE
BARTOL RESEARCH INSTITUTE

Dennis Soldin for the EAS-MSU, IceCube, KASCADE-Grande, NEVOD-DECOR, Pierre Auger, SUGAR, Telescope Array, and Yakutsk EAS Array Collaborations
(Working Group for Hadronic Models and Shower Physics - WHISP)





<u>What is this contribution about?</u>

- The combined meta-analysis of measurements of atmospheric muons in EAS from a few PeV to tens of EeV by nine experiments

<u>What has been done?</u>

- Cross-calibration of the energy scales of experiments and subtraction of the mass-dependence of the muons measurements
- Fit to the data with a systematic statistical analysis and comparison with current hadronic interaction model predictions

<u>Results:</u>

- Muon excess w.r.t. all model predictions is observed in data, increasing with EAS energy
- The slope of the fit to this excess is significant at σ(EPOS-LHC) and σ(QGSJet-II.04)
- When removing individual experiments from the fit, slope significant with about $\gtrsim 3\sigma$(EPOS-LHC) and $\gtrsim 5\sigma$(QGSJet-II.04)

Session overview

Hadron Cascades in CORSIKA 8

R. Ulrich, A. Fedynitch, T. Pierog, M. Reininghaus, F. Riehn for the CORSIKA 8 Project

Muon number rescaling in simulations of air showers

(1) Nataliia Borodai, (2) Ralph Engel, (1) Dariusz Góra (presenter), (1) Jan Pękala, (2) Tanguy Pierog, (2) Markus Roth, (1) Jaroslaw Stasielak, (2) Michael Unger, (2) Darko Veberic and (1) Henryk Wilczyński

(1) *Institute of Nuclear Physics PAN, Radzikowskiego 152, Cracow, Poland*

(2) *Karlsruhe Institute of Technology (KIT), Institute for Astroparticle Physics, Karlsruhe, Germany*

Modified Characteristics of Hadronic Interactions

Jiri Blazek[a], J. Vicha[a], J. Ebr[a], R. Ulrich[b], T. Pierog[b] and P. Travnicek[a]

When heavy ions meet cosmic rays : potential impact of QGP formation on the muon puzzle

Tanguy Pierog

Karlsruhe Institute of Technology, Institut für Astrophysicalphysik, Karlsruhe, Germany

With S.Baur, H.Dembinski, M. Perlin, R.Ulrich and K.Werner

Collective flow in ultra high energy cosmic rays within CORSIKA

Maowu Nie (聂茂武)

New physics Air-Shower simulations for UHECR above 50 TeV

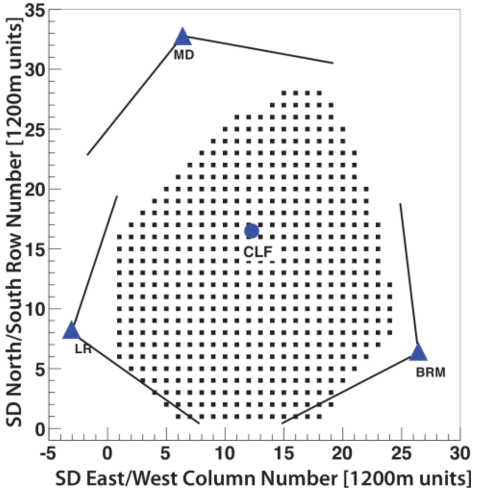
S. Romanopoulos[1], V. Pavlidou[1], T. Tomaras[1,2]

1: Institute of Astrophysics, FORTH

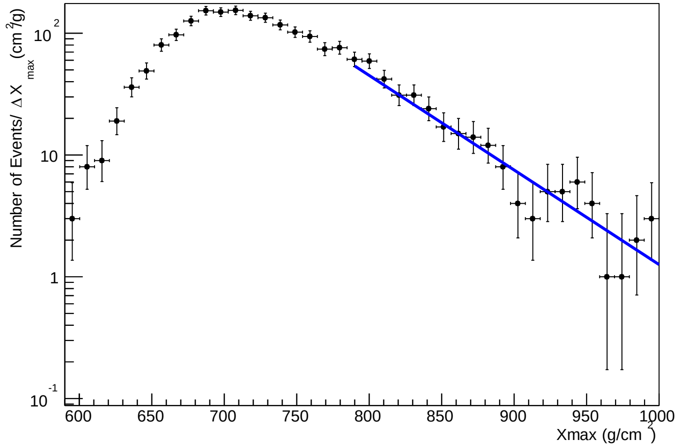
2: University of Crete

PoS(ICRC2021)296: p-p, p-air cross-sections studied with TA

Rasha Abbasi, William Hanlon for Telescope Array collaboration



BRM = Black Rock Mesa
LR = Long Ridge

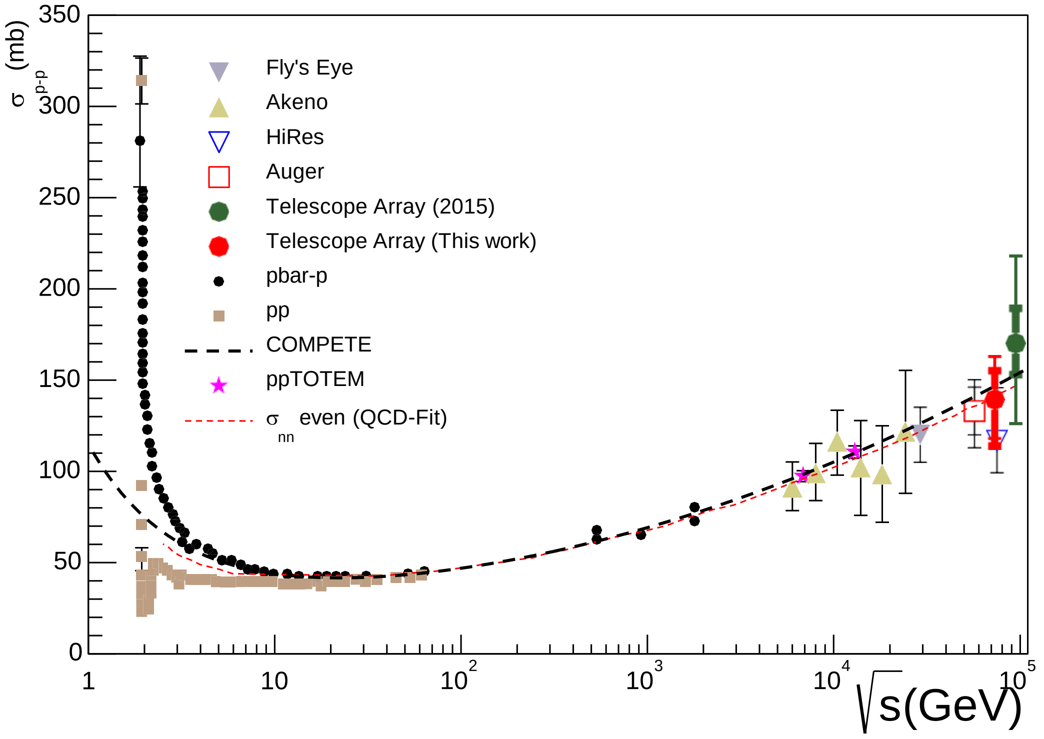


Fit of exponential tail of X_{max} distribution

E = $10^{18.2}$ to 10^{19} eV → sqrt(s) = 73 TeV

$f^{8=4;}_{?-08A}$ = 520.1 ± 35.8 [Stat.] $^{+25.3}_{-42.9}$[Sys.] mb

$f^{C>C}_{??}$ = 139.4± $^{+23.4}_{-21.3}$ [Stat.] $^{+15.7}_{-25.4}$[Sys.] mb



- Size of statistical sample increased by factor 4 compared to previous study by using BRM & LR combined with TA SD (timing)
- Same method (k-factor): fit slope of X_{max} tail and convert to p-air cross-section using models
- Latest hadronic interaction models used: QGSJet01, SIBYLL-2.3, QGSJetII.04, EPOS-LHC
- Analysis passes many systematic checks
- Systematic uncertainty from photon and helium background based on experimental limits; σ^{pp} computed with Glauber and BHS model

10 EAS reconstruction and analyses

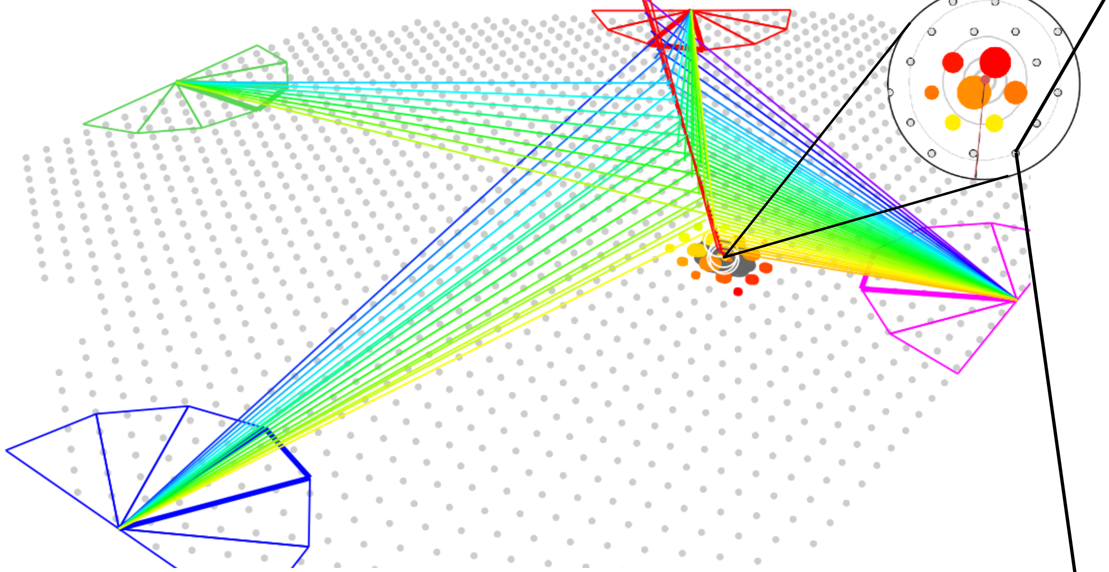
Convener: Markus Roth | Zhen Cao

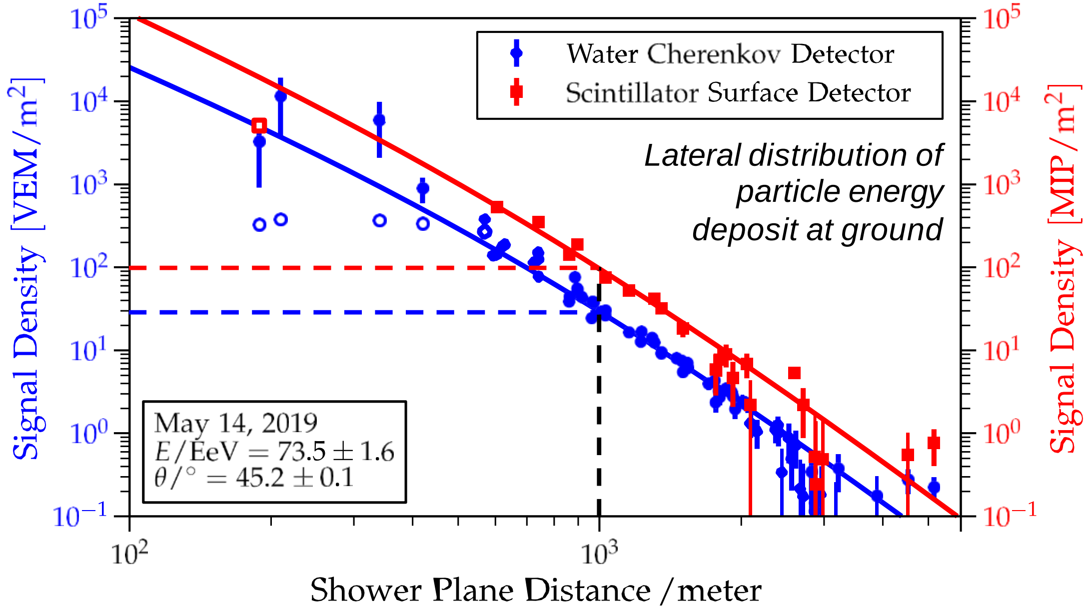
Today's agenda

8 minutes	**Calibration** (4 min. presentation + 4 min discussion) • The Energy Scale Calibration using the Moon Shadow of LHAASO-WCDA Detector / Yanjin Wang
16 minutes	**Muon reconstruction** (4 min. presentation + 4 min discussion for each contribution) • Reconstruction of Nearly-Horizontal Muons in the HAWC Observatory / R. Wayne Springer • Muography for the Colombian Volcanoes (MuTe) / Luis Nunez
16 minutes	**Air shower reconstruction** (4 min. presentation + 4 min discussion for each contribution) • Simulation study for the future IceCube-Gen2 surface array / Agnieszka Leszczyńska • ~~TAx4 Hybrid Simulation and Reconstruction / Ricardo Gonzalez~~ • Reconstruction of Events Recorded with the Water-Cherenkov and Scintillator Surface Detectors of the Pierre Auger Observatory / David Schmidt
- minutes	~~**Validation** (4 min. presentation + 4 min discussion)~~ • ~~A study of the Moon shadow by using GRAPES-3 muon telescope / Meeran Zuberi~~
8 minutes	**Simulation** (4 min. presentation + 4 min discussion) • Neutron production in extensive air showers / Ralph Engel
24 minutes	**Machine Learning and physics driven analysis** (4 min. presentation + 4 min discussion for each contribution) • A Complete Model of the Signal in Surface Detector Arrays and its Application for the Reconstruction of Mass-sensitive Observables / Max Stadelmaier • TA SD energy and arrival direction estimation using deep learning / Oleg Kalashev • Event-by-event reconstruction of X_{max} with the Surface Detector of the Pierre Auger Observatory / Jonas Glombitza
Remaining time	**General discussion (remaining time)**

Reconstruction of Events Recorded with the Water-Cherenkov and Scintillator Surface Detectors of the Pierre Auger Observatory

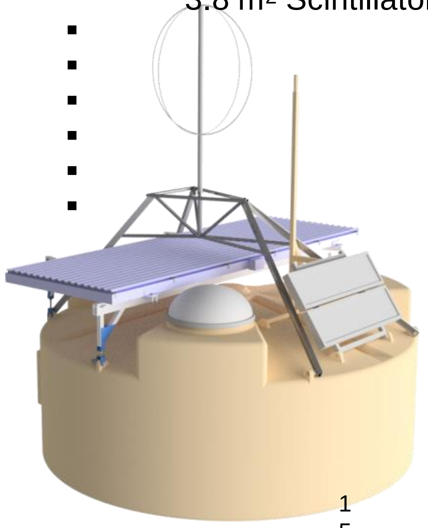
David Schmidt (KIT) on behalf of the Pierre Auger Collaboration



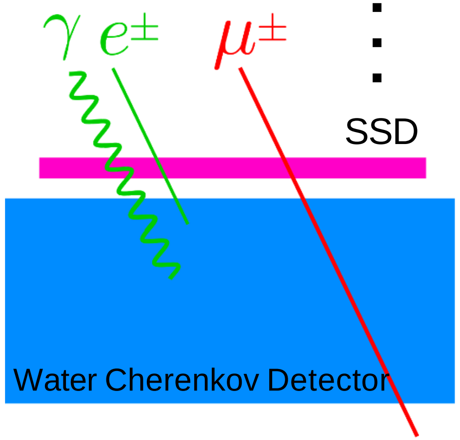


Featured hardware upgrade:

3.8 m^2 Scintillator Surface Detector (SSD)



AugerPrime Surface Detector Station



- Differing detector responses
- Disentangle muonic and electromagnetic shower components

At the level of *individual stations*…
- Calibration
- Integration window
- Signal uncertainties

At the level of the *event*…
- Geometry
- Lateral distribution function
- Shower size

PIERRE AUGER OBSERVATORY

Discussion session 07 - CRI: Where to go in UHECR observations?

- Performance of the 433 m surface array of the Pierre Auger Observatory
- Status and performance of the underground muon detector of the Pierre Auger Observatory
- The upgrade of the Pierre Auger Observatory with the Scintillator Surface Detector
- Current status and prospects of surface detector of the TAx4 experiment
- Update on the TAx4 Fluorescence Detectors
- The status of the TALE surface detector array and a TALE infill project
- The Surface Array planned for IceCube-Gen2
- First air-shower measurements with the prototype station of the IceCube surface enhancement
- Cosmic ray studies with SWGO
- GCOS - The Global Cosmic Ray Observatory
- Progress and future prospect of the CRAFFT project for the next generation UHECR observation
- An overview of the JEM-EUSO program and results
- Main results of the TUS experiment on board the Lomonosov satellite
- The Mini-EUSO telescope on board the International Space Station: Launch and first results
- Science and mission status of EUSO-SPB2
- The Fluorescence Telescope on board EUSO-SPB2 for the detection of Ultra High Energy Cosmic Rays
- Detection of Above the Limb Cosmic Rays in the Optical Cherenkov Regime Using Sub-Orbital and Orbital Instruments
- Prospects for Cross-correlations of UHECR Events with Astrophysical Sources with Upcoming Space-based Experiments

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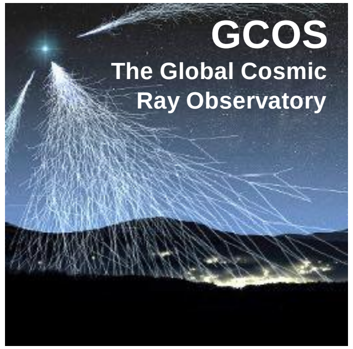
Discussion session 07 - CRI: Where to go in UHECR observations?

time

SWGO
The Southern Wide-field Gamma-ray Observatory

SKA
SQUARE KILOMETRE ARRAY

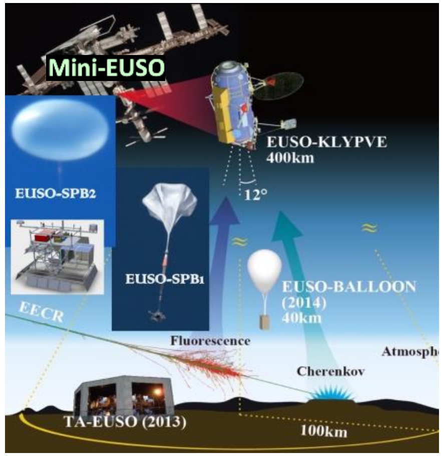
ICECUBE
SOUTH POLE NEUTRINO OBSERVATORY



TELESCOPE ARRAY PROJECT

PIERRE AUGER OBSERVATORY

JEM-EUSO



TUS

energy

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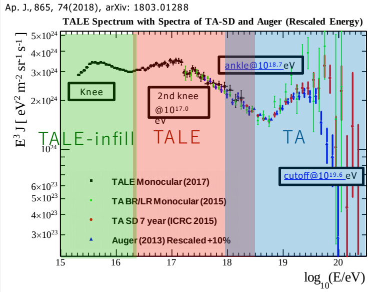
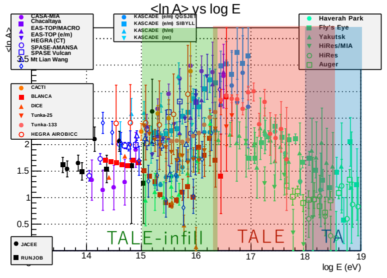
Jörg R. Hörandel, Angela Olinto

One page executive summary

Introduction

Extension of TALE: TALE-infill





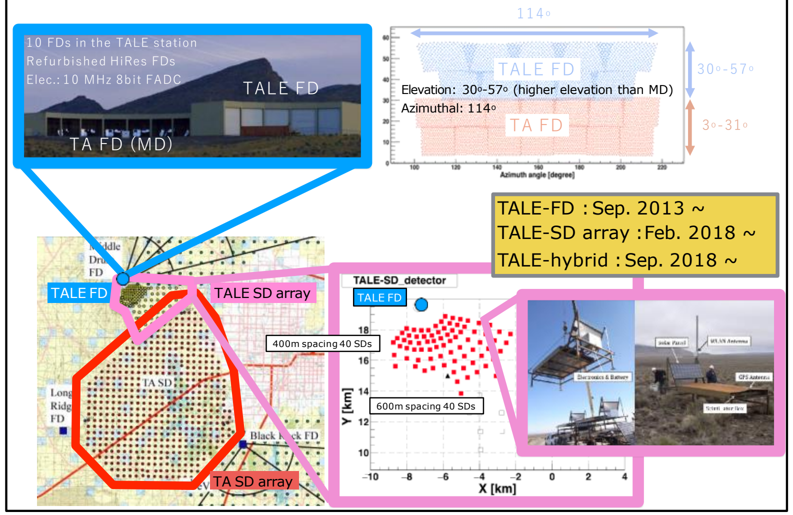
TALE + TALE-infill "hybrid" covering "knee" to "ankle":

＊Detailed studies of spectrum and composition
<= Hybrid observation with FDs plus SDs
＊Anisotropy study
<= Uniform + high statistics with SD array

TALE hybrid

TALE hybrid

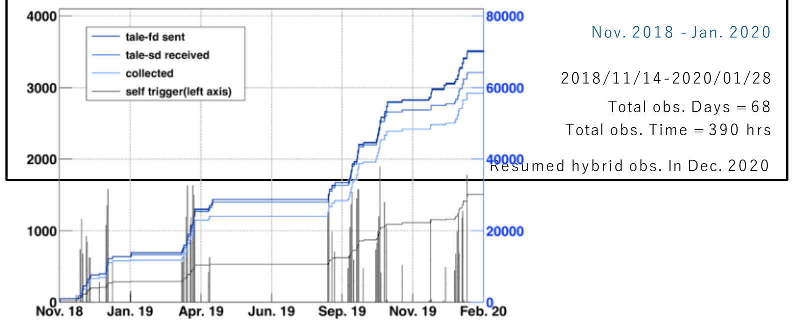
10 FDs + 80 SDs in TA site



TALE hybrid operation status

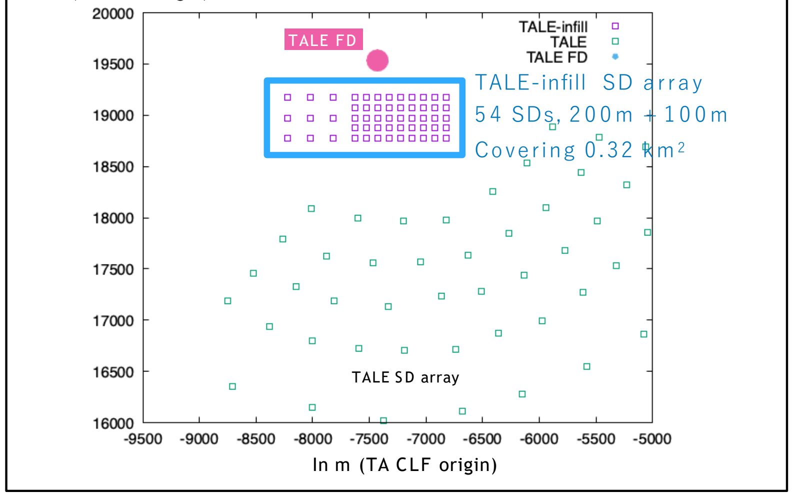
80 SDs covering about 20 km^2
Routine operation from Oct. 2018
Triggering condition:
SDs of >0.3 MIPs within +-32us of TALE FD trigger

tale hybrid trigger events plot

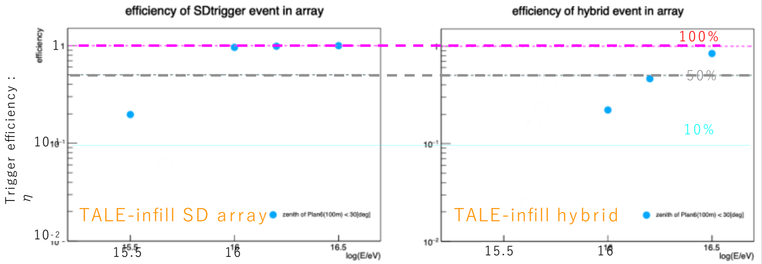


TALE-infill project

Extension of TALE: TALE-infill



Triggering efficiency of TALE-infill hybrid



5% efficiency energy ~ mode energy :
TALE-infill SD array : logE ~ 15.3
TALE-infill hybrid : logE ~ 15.8

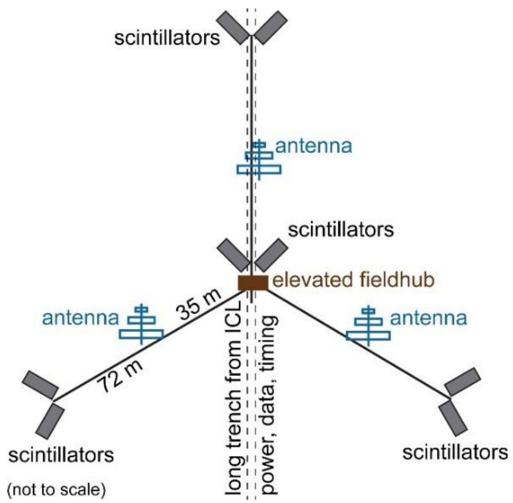
Future IceCube-Gen2 Surface Array

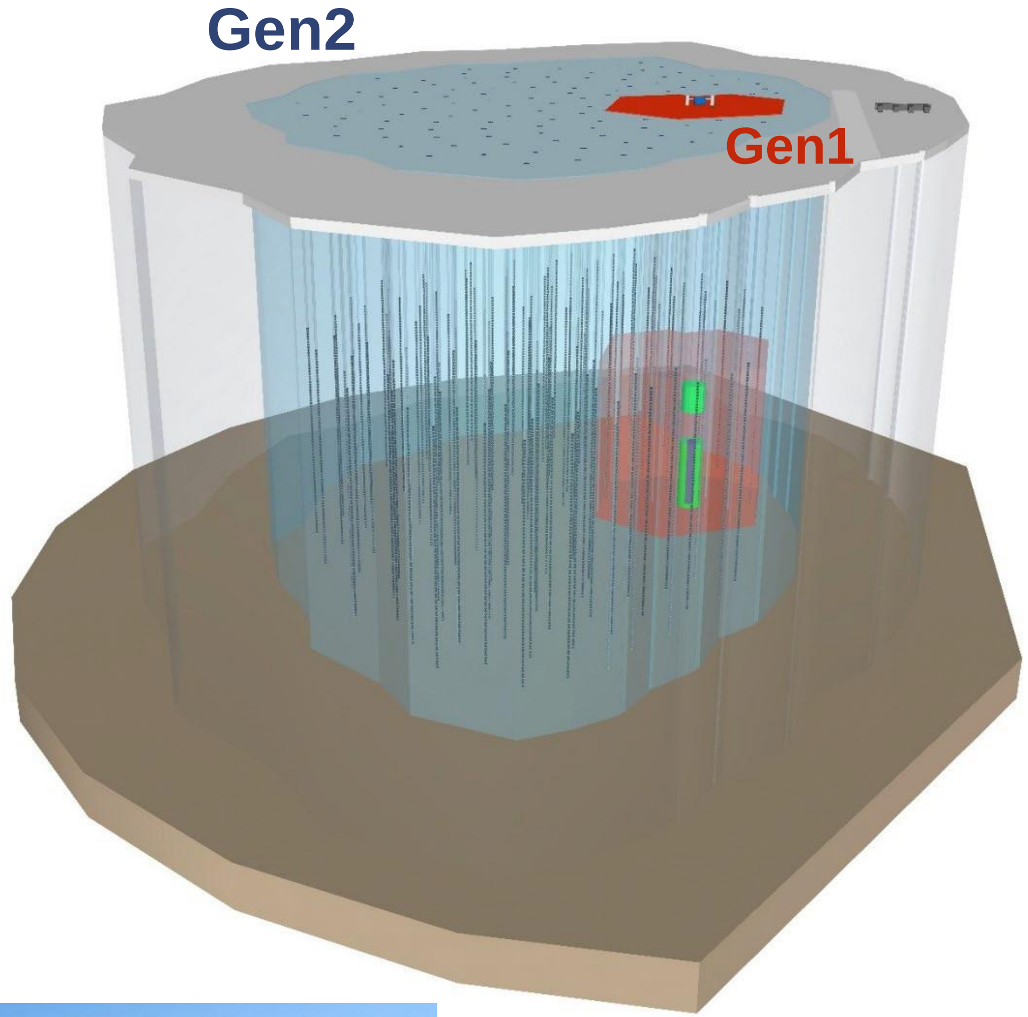
Key Features:

- Higher aperture than Gen1
  - 8−10× aperture surface only
  - > 30× aperture for coincidences with optical in-ice array
- Energy range: 0.5 PeV to Ankle
- Radio for increasing accuracy at galactic-to-extragalactic transition

Science Case (selection):

- Veto for neutrino detection
- Hadronic interactions
  - muon spectroscopy
  - prompt muons
- Most energetic *Galactic* CR
  - mass, anisotropy, search for photons





Surface Array Layout:

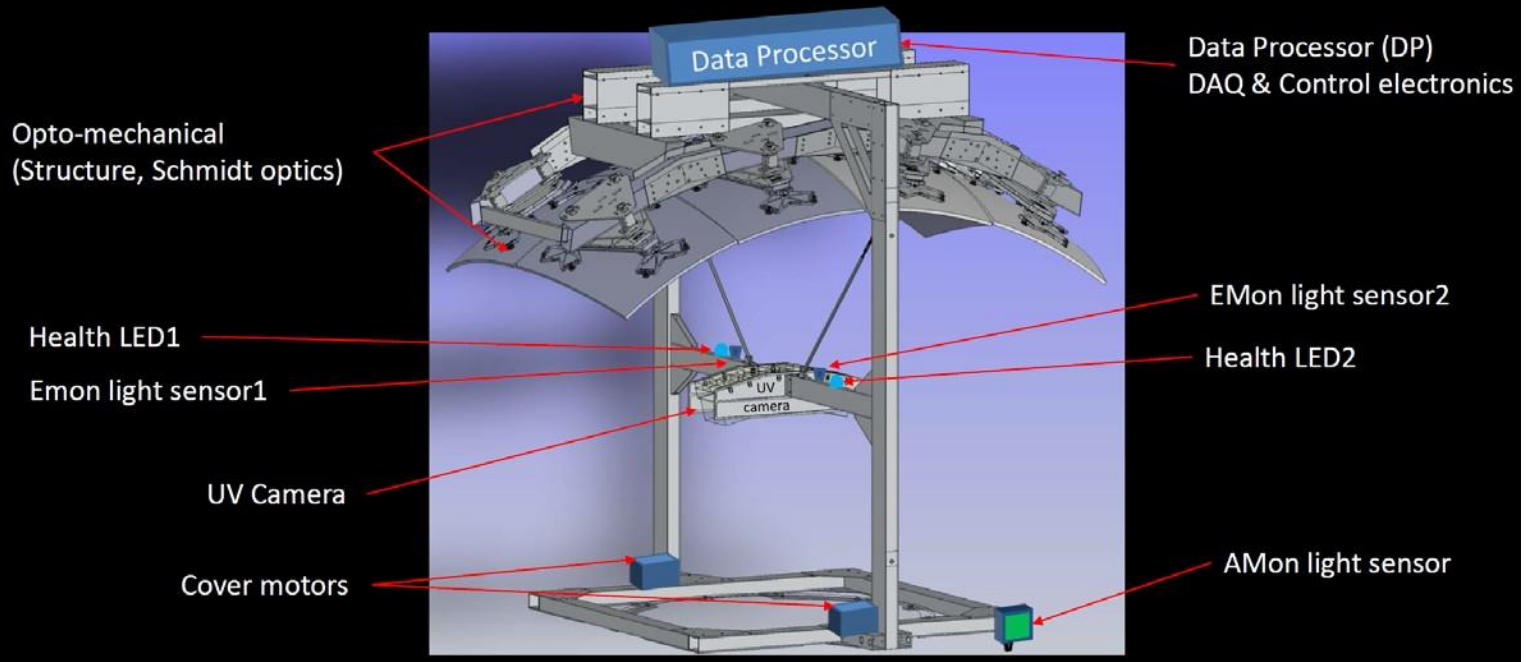
One station for each of the 120 optical strings.

Each station has 4 pairs of scintillators + 3 antennas.

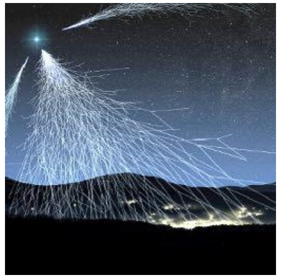
Frank G. Schroeder (IceCube-Gen2 Coll.), ICRC 2021

The Fluorescence Telescope on board EUSO-SPB2 for the detection of Ultra High Energy Cosmic Rays

- Second-generation instrument
- Status of the art for this kind of technology
- With respect to the telescopes which flew on previous missions, upgrades introduced on
  - Optics (Schmidt telescope) ➔ lower energy threshold
  - Focal surface
    - 3 times larger ➔ greater collection power
    - shorter temporal resolution 1 µs ➔ lower energy threshold
  - General architecture (redundancy, lower dead time) ➔ greater collection power
- The telescope should allow for the first observation of extensive air showers using the fluorescence technique from suborbital space
- It is an important step to demonstrate the possibility to study Ultra High Energy Cosmic Ray from Space.
- The construction of the telescope sub-systems is now underway and the whole instrument is on the way for a scheduled launch in early 2023 from Wanaka, New Zealand.



GCOS - The Global Cosmic Ray Observatory



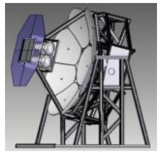
- World-wide initiative to conduct multi-messenger astroparticle physics beyond 2030

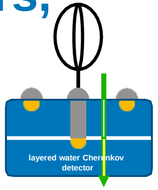
- MM-APP has started: GW sources, IceCube neutrinos, and follow-ups, …
  key results from Telescope Array & Pierre Auger Observatory (anisotropies, mass composition)

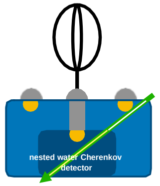
- building on this knowledge, it is time to prepare for a Global Cosmic Ray Observatory after 2030

- aim for multi-purpose observatory:
  sources of UHE particles (charged CRs, neutrinos, gamma rays), connection to GWs,
  dark matter searches, fundamental physics, particle physics, geophysics and atmospheric science

- considering different detection concepts, including layered/nested water Cherenkov detectors,
  radio antennas, and fluorescence light telescopes







- workshop with >200 participants in May 2021
  to discuss path to define physics case and develop concepts for detection technologies

- we plan a follow-up workshop at the end of 2021/begin of 2022 with the goal
  to write a roadmap for multi-messenger astroparticle physics (CRs, GAs, NUs, GWs) beyond 2030
  and a Global Cosmic Ray Observatory

→ theatre of dreams, 21 July

GCOS homepage: http://particle.astro.ru.nl/gcos

13 New Instrumentation and Tools for EAS Detection

Convener: Toshihiro Fujii | Marco Casolino

	Chair	No.	Title	TIME	Presenter
			INTRODUCTION	5	MC
	Chair MC		**SUMMARY FROM CRD**	5	SC/JK
			HECR		
		113	Study of the Electron-Neutron Detector Array (ENDA) in Yangbajing, Tibet	2	Dixuan Xiao
		342	Test of the Electron-Neutron Detector Array (ENDA) in Laboratory	2	Fan Yang
		1100	An Advanced Triggerless Data Acquisition System for GRAPES-3 Muon Detector	2	Atul Jain
		384	Sensitivity of the Tibet hybrid experiment (Tibet-III + MD) for primary proton spectra between 30 TeV and a few hundreds of TeV's	2	Daichi Kurashige
			UHECR		
		746	AugerPrime Upgraded Unified Board: The New Front-End Electronics	2	Giovanni Marsella
		504	Development of autonomous observation system for next-generation cosmic ray telescope	2	Takayuki Tomida
		505	Progress in optimizing the detection surface structure of CRAFFT	2	Yuto Kubota
		669	Towards a full and realistic simulation framework for the Extreme Energy Events experiment	2	Stefano Grazzi
		144	Latest results of ultra-high-energy cosmic ray measurements with prototypes of the Fluorescence detector Array of Single-pixel Telescopes (FAST)	2	Toshihiro Fujii
		867	EUSO-SPB2 Telescope Optics and Testing	2	Viktoria Kungel
EUSO		1001	Integration and qualification of the Mini-EUSO telescope on board the ISS	2	Giorgio Cambiè
		411	Overview of the Mini-EUSO μs trigger logic performance	2	Matteo Battisti
			RADIO AIR SHOWERS		
		1291	Efficiency estimation of self-triggered antenna clusters for air-shower detection	2	Pavel Bezyazeekov
		1155	Adaptive predictor as trigger mechanism for cosmic ray radio signals corrupted by Gaussian noise	2	Clara Watanabe
		1199	Denoising cosmic rays radio signal using Wavelets techniques	2	Clara Watanabe
RADIO		646	Development of a scintillation and radio hybrid detector array at the South Pole	2	Marie Oehler
		1429	Development of drone-borne aerial calibration pulser system for radio observatories of ultra-high energy air showers	2	Chung-Yun Kuo
		631	Reconstruction of sub-threshold events of cosmic-ray radio detectors using an autoencoder	2	Polina Turishcheva
		461	Tunka-Rex Virtual Observatory	2	Vladimir Lenok
	Chair TF		**GAMMA**		
		243	Tools and Procedures for the ASTRI Mini-Array Calibration	2	Teresa Mineo
		62	ROBAST 3	2	Akira Okumura
		1280	Calibration of LHAASO-WFCTA	2	Long Chen
		1281	The YAG Lidar System Applied in LHAASO	2	Qinning Sun
LHAASO		1275	Application of the nitrogen laser calibration system in LAASO-WFCTA	2	Xin Li
		1111	Status of simulation and data comparison of wcda-1	2	hanrong wu
			SIMULATIONS		
		1444	Status of the novel CORSIKA 8 air shower simulation framework	2	Antonio Augusto Alves Junior
		624	Electromagnetic Shower Simulation for CORSIKA 8	2	Jean-Marco Alameddine
CORSIKA 8		104	CORSIKA below the knee	2	Tadeusz Wibig
		63	Electrical signals induced in detectors by cosmic rays: a reciprocal look at electrodynamics	2	Philipp Windischhofer
			DETECTOR ELECTRONICS		
		93	Simulation of single, double, and triple layer GEM detectors	2	Aera JUNG
		1385	Acquisition of data from a Water Cherenkov Detector based on an on purpose acquisition card	2	Eduardo Moreno Barbosa
		1301	Pulse Shape Discrimination for Online Data Acquisition in Water Cherenkov Detectors Based on FPGA/SoC	2	Luis Guillermo Garcia Ordonez
			CALIBRATION		
		1453	New coordinate-tracking detector on drift chambers for registration of muons in near-vertical EAS	2	Vladislav Vorobev

Discussion Session

08 Radio Observations of Cosmic Rays

Conveners: Stijn Buitink, Frank Schröder, João Torres de Mello Neto

- We have selected 5 themes to discuss:
  Simulation & signal processing
  Highly inclined showers
  From the knee to the ankle
  Interferometry
  Cosmic rays in dense media

- Per theme there are a few selected talks. We will first invite you to ask questions about these talks specifically. Authors are welcome to share their screen to show plots, etc.

- After that we invite questions / remarks about the theme *in general*.

- Please continue the discussions afterwards in the discussion fields on the conference website so everybody can read along.

Simulation and signal processing

New simulation codes and signal processing techniques are being developed to support larger and increasingly complex radio experiments. What new possibilities are emerging and what challenges still lie ahead?

Selected for discussion:

- Simulations of radio emission from air showers with CORSIKA 8 (Nikolaos Karastathis)
- Radio-Morphing: a fast, efficient and accurate tool to compute the radio signals from air-showers (Simon Chiche)
- Classification and Denoising of Cosmic-Ray Radio Signals using Deep Learning (Abdul Rehman)

Further reading/viewing:

Adaptive predictor as trigger mechanism for cosmic ray radio signals corrupted by Gaussian noise (Clara Watanabe)
Denoising cosmic rays radio signal using Wavelets techniques (Clara Watanabe)
Reconstruction of sub-threshold events of cosmic-ray radio detectors using an autoencoder (Polina Turishcheva)
Parametrization of the Relative Amplitude of Geomagnetic and Askaryan Radio Emission from Cosmic-Ray Air Showers using CORSIKA/CoREAS Simulations (Ek Narayan Paudel)
Efficiency estimation of self-triggered antenna clusters for air-shower detection (Pavel Bezyazeekov)

Highly inclined air showers

Observing highly inclined air showers is a key strategy to reach ultra-high energies or to search for showers from the direction of mountain ranges. This introduces new challenges in simulation, reconstruction, and triggering.

Selected for discussion:

- Reconstructing inclined extensive air showers from radio measurements (Tim Huege)
- First results from the AugerPrime Radio Detector (Tomáš Fodran)
- Self-trigger radio prototype array for GRAND (Yi Zhang)
- TAROGE-M: Radio Observatory on Antarctic High Mountain for Detecting Near-Horizon Ultra-High Energy Air Showers (Shih-Hao Wang)
- TAROGE experiment and reconstruction technique for near-horizon impulsive radio signals induced by Ultra-high energy cosmic rays (Yaocheng Chen)

Further reading/viewing:

A reconstruction procedure for very inclined extensive air showers based on radio signals (Valentin Decoene)
CoREAS simulations of inclined air showers predict refractive displacement of the radio-emission footprint (Marvin Gottowik)
Optimization of CoREAS simulations for the GRAND project (Chao Zhang)
The depth of the shower maximum of air showers measured with AERA (Felix Schlüter)
Expected performance of the AugerPrime Radio Detector (Felix Schlüter)
Radio Simulations of Upgoing Extensive Air Showers Observed from Low-Earth Orbit (Andres Romero-Wolf)

From the knee to the ankle

Radio arrays are now contributing to cosmic ray physics below the ankle. What further role can radio play? What can radio contribute to hadronic physics in the shower? How close can radio observation get to the knee?

Selected for discussion:

- Simulation Study of the Observed Radio Emission of Air Showers by the IceTop Surface Extension (Alan Coleman)
- Performance of SKA as an air shower observatory (Stijn Buitink)
- Cross-calibrating the energy scales of cosmic-ray experiments using a portable radio array (Katharine Mulrey)

Further reading/viewing:

Results on mass composition of cosmic rays as measured with LOFAR (Arthur Corstanje)
The depth of the shower maximum of air showers measured with AERA (Bjarni Pont)
Updates from the OVRO-LWA: Commissioning a Full-Duty-Cycle Radio-Only Cosmic Ray Detector (Kathryn Plant)
Cosmic Ray Detection at the Murchison Radio-astronomy Observatory – a pathfinder for SKA-Low (Alexander Williamson)
Estimation of aperture of the Tunka-Rex radio array for cosmic-ray air-shower measurements (Vladimir Lenok)
On the cosmic-ray energy scale of the LOFAR radio telescope (Katharine Mulrey)
Tunka-Rex Virtual Observatory (Vladimir Lenok)
Development of a scintillation and radio hybrid detector array at the South Pole (Marie Oehler)
First air-shower measurements with the prototype station of the IceCube surface enhancement (Hrvoje Dujmovic)

Interferometry

Interferometry is a basic tool in radio astronomy but not yet widely applied by cosmic-ray observatories. What are the opportunities and challenges?

Selected for discussion:

- Expected performance of interferometric air-shower measurements with radio antennas (Felix Schlüter)
- Modeling and Validating RF-Only Interferometric Triggering with Cosmic Rays for BEACON (Andrew Zeolla)

Further reading/viewing:

Searching for RF-Only Triggered Cosmic Ray Events with the High-Elevation BEACON Prototype (Daniel Southall)

Cosmic rays in dense media

Radio detection of showers in dense media is mostly known as a technique to search for very-high energy neutrinos. However, it also offer unique opportunities for detection of cosmic rays.

Selected for discussion:

- Simulation and Optimisation for the Radar Echo Telescope for Cosmic Rays (Rose Stanley)
- The Zettavolt Askaryan Polarimeter (ZAP) mission concept: radio detection of ultra-high energy cosmic rays in low lunar orbit. (Andres Romero-Wolf)
- The NuMoon Experiment: Lunar Detection of Cosmic Rays and Neutrinos with LOFAR (Godwin Krampah)

Further reading/viewing:

See also discussion session on radio detection of neutrinos

04 CR Energy Spectrum

Convener: Ioana Maris | Yoshiki Tsunesada

- Energy spectrum measurements:12 + 2 contributions from 6 experiments
- Energy range: 10^{12} eV to 10^{20} eV
- Low energy (10^{12} ~ 10^{15} eV): MAGIC, HAWC, GRAPES-3, LHAASO
  - Imaging Cherenkov telescopes, water Cherenkov tanks, scintillation counters / High altitudes
  - Mass-resolved energy spectra
- Mid energy (10^{14} ~ 10^{18}eV): Pierre Auger Observatory and Telescope Array
  - Low-energy extension of Auger and TA
  - High-elevation angle FD (HEAT, TALE-FD)
  - Infill arrays (Auger 750m, TALE-SD, NICHE)
- High energy (10^{18} ~ 10^{20} eV): Pierre Auger Observatory and Telescope Array
  - Auger + TA

Low-Energy Results (E = 10^{12} - 10^{15} eV)

1	751	Protons Spectrum from MAGIC Telescopes data	Petar Temnikov
2	1355	Preliminary Cosmic Ray Results from the HAWC's Eye Telescopes	Florian Rehbein
3	731	The all-particle cosmic ray energy spectrum measured with HAWC	Jorge Antonio Morales-Soto
4	1046	HAWC measurements of the energy spectra of cosmic ray protons, helium, and heavy nuclei in the TeV range	Juan Carlos Arteaga Velazquez
5	1220	Cosmic ray energy spectrum and composition measurements from the GRAPES-3 experiment: Latest results	Fahim Varsi
6	1079	The Energy Spectrum of Cosmic Ray Proton and Helium above 100TeV Measured by LHAASO Experiment	Zhiyong You
7	944	Study of Energy Measurement of Cosmic Ray Nuclei with LHAASO	hu liu

HAWC measurements of the energy spectra of cosmic ray protons, helium and heavy nuclei in the TeV range

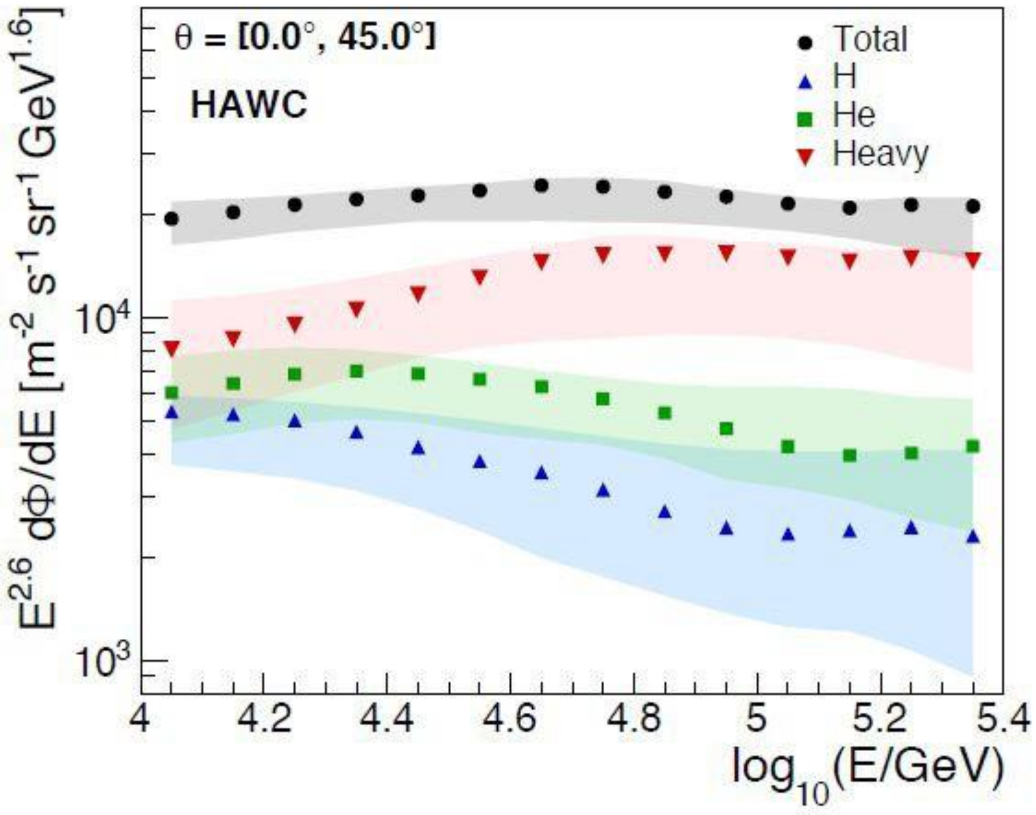
J. C. Arteaga-Velázquez for the HAWC collaboration

Description of the analysis

- We have unfolded the elemental energy spectra for H, He and heavy nuclei (Z >2) for E (per particle) = [10, 251] TeV from a high-statistical sample of HAWC data.

Results

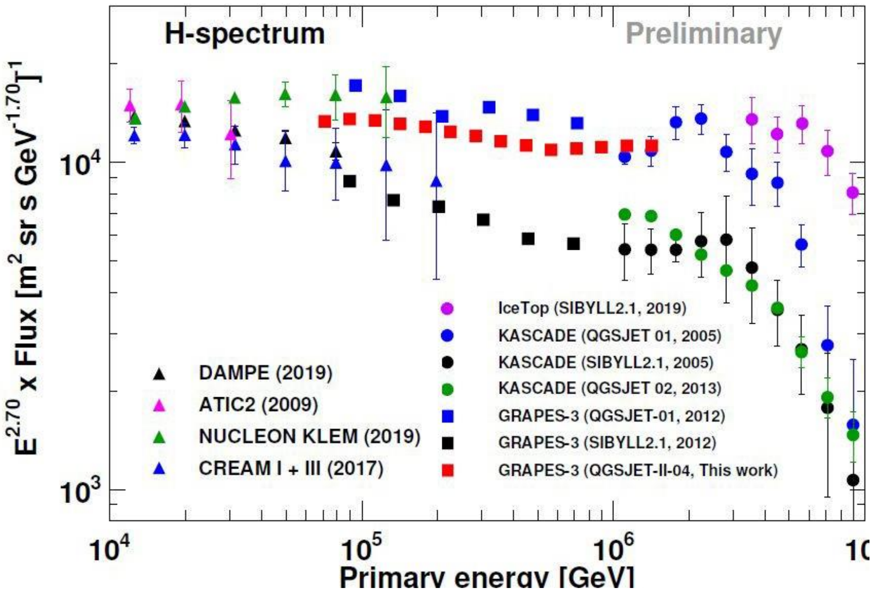
- HAWC results reveal individual softenings at tens of TeV, whose positions move to higher energies for heavy primaries.
- HAWC confirms the TeV knee-like features observed recently by DAMPE (2019&2021) for the spectra of H and He.
- Cosmic ray composition becomes heavier at high energies within the primary energy range 10 - 100 TeV.
- HAWC hints to possible hardenings close to 100 TeV in the spectra of H and He.

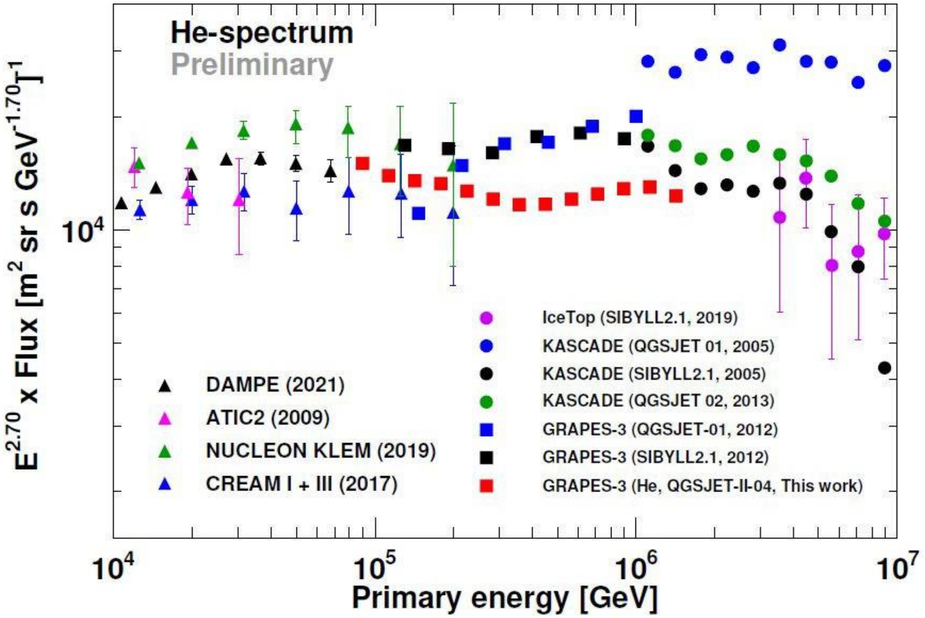


Recent measurements of the cosmic ray energy spectrum and composition from the GRAPES-3 experiment

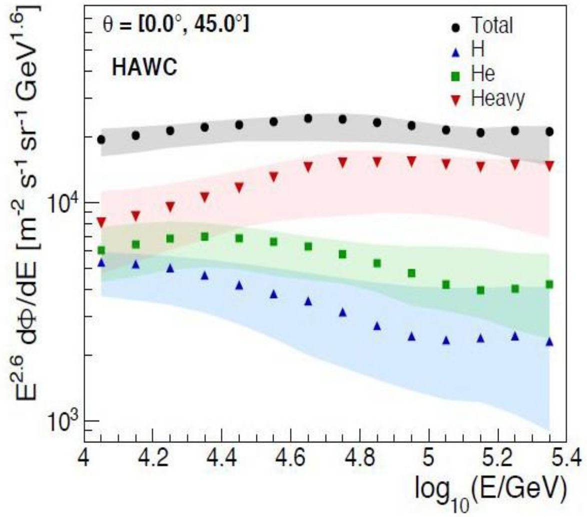
#1220 Fahim Varsi, GRAPES-3

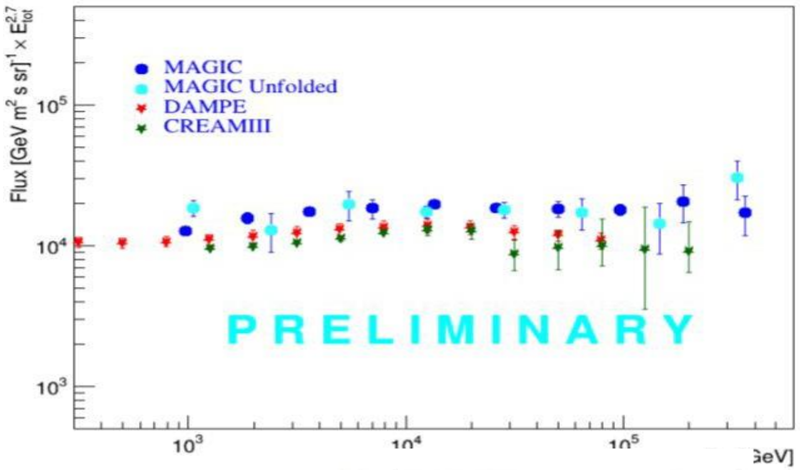
- we are presenting the latest results on elemental energy spectrum for proton and helium in the energy range from 50 TeV to 1 PeV.
- This energy range is a bridge between the direct observations and indirect observation.
- In this analysis, the relative composition of H, He, N and Al+Fe is measured by minimizing muon multiplicity distribution of simulated primaries with the observed muon multiplicity distribution. The elemental energy spectrum of proton and helium are generated.
- The elemental energy spectrum of proton and helium are consistent with CREAM I-III and NUCLEON KLEM (within error) at low energy and proton spectrum is consistent with KASCADE (QGSJET-01, 2005).

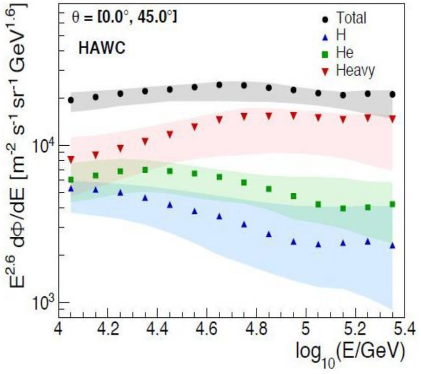


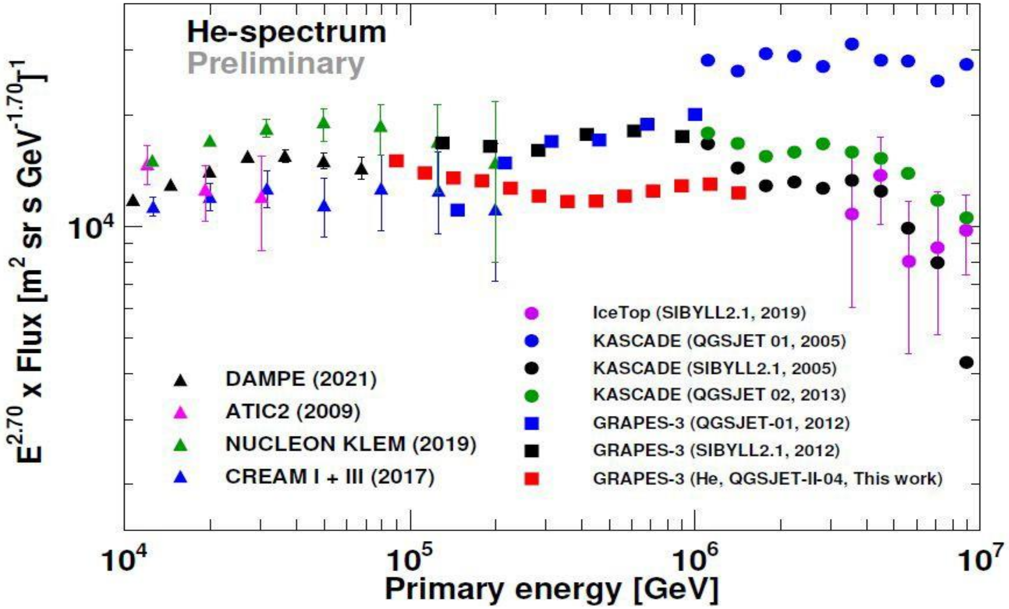


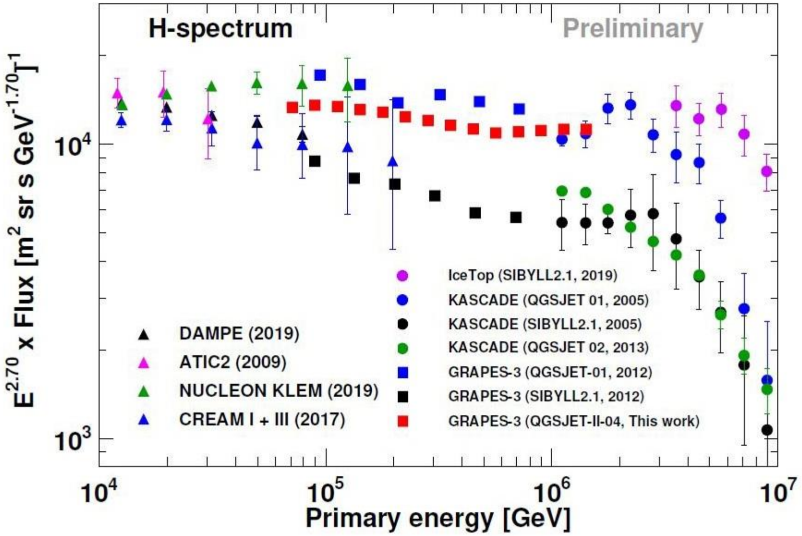
Spectra for He and proton





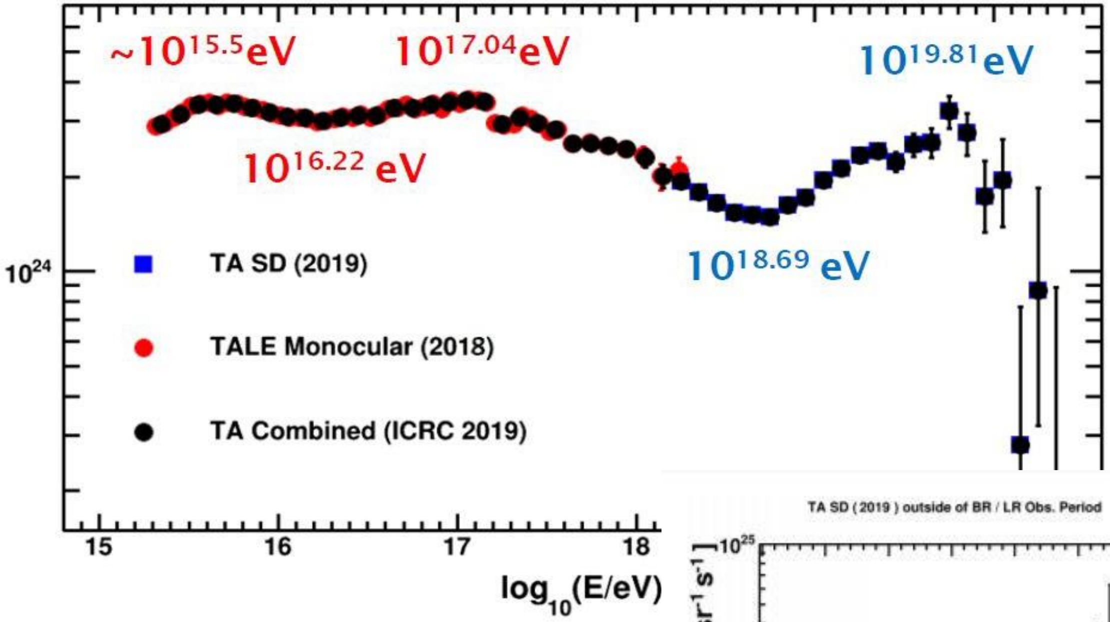






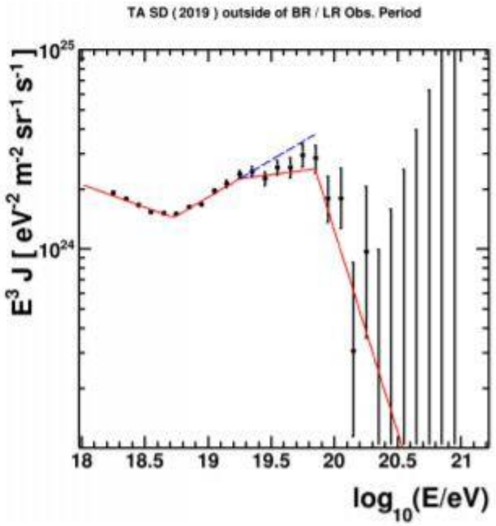
High-Energy Results (E > 10^{15} eV)

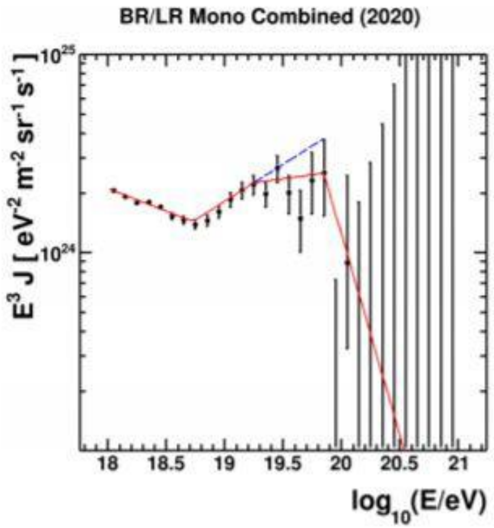
6	726	Energy spectrum and the shower maxima of cosmic rays above the knee region measured with the NICHE detectors at the TA site	Yugo Omura
7	933	Cosmic ray energy spectrum in the 2nd knee region measured by the TALE-SD array	Koki Sato
8	851	Cosmic Ray Energy Spectrum measured by the TALE Fluorescence Detector	Tareq AbuZayyad
9	819	Recent measurement of the Telescope Array energy spectrum and observation of the shoulder feature in the Northern Hemisphere	Dmitri Ivanov
10	800	TA Monocular Spectrum Measurement	Douglas Bergman
11	691	Energy spectrum of cosmic rays measured using the Pierre Auger Observatory	Vladimír Novotný
12	793	Joint analysis of the energy spectrum of ultra-high-energy cosmic rays measured at the Pierre Auger Observatory and the Telescope Array	Yoshiki Tsunesada

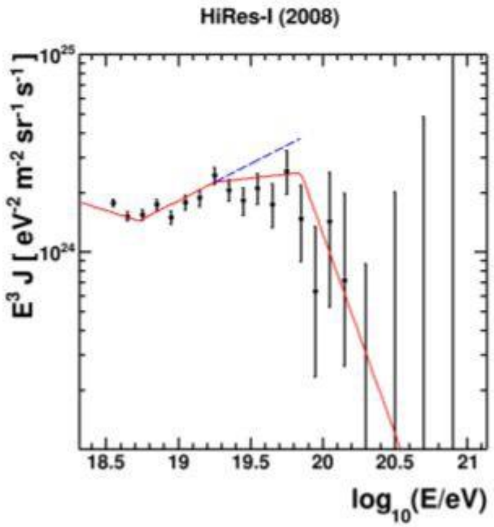


Recent measurement of the Telescope Array energy spectrum and observation of the shoulder feature in the Northern Hemisphere

#819, Dmitri Ivanov







- Pierre Auger found a spectrum hardening in 10^{19} – $10^{19.5}$ eV range
- Combining TA SD, FD and HiRes data, we observe the same *Shoulder* feature in the Northern Hemisphere at $10^{19.25\pm0.03}$ eV with a 5.3 σ significance:

Energy spectrum of cosmic rays measured using the Pierre Auger Observatory

Executive summary

Vladimír Novotný [a] for the Pierre Auger Collaboration [b]

[a] Institute of Particle and Nuclear Physics, Charles University, Prague, Czech Republic
[b] Observatorio Pierre Auger, Av. San Martín Norte 304, 5613 Malargüe, Argentina

PIERRE AUGER OBSERVATORY

What is this contribution about?

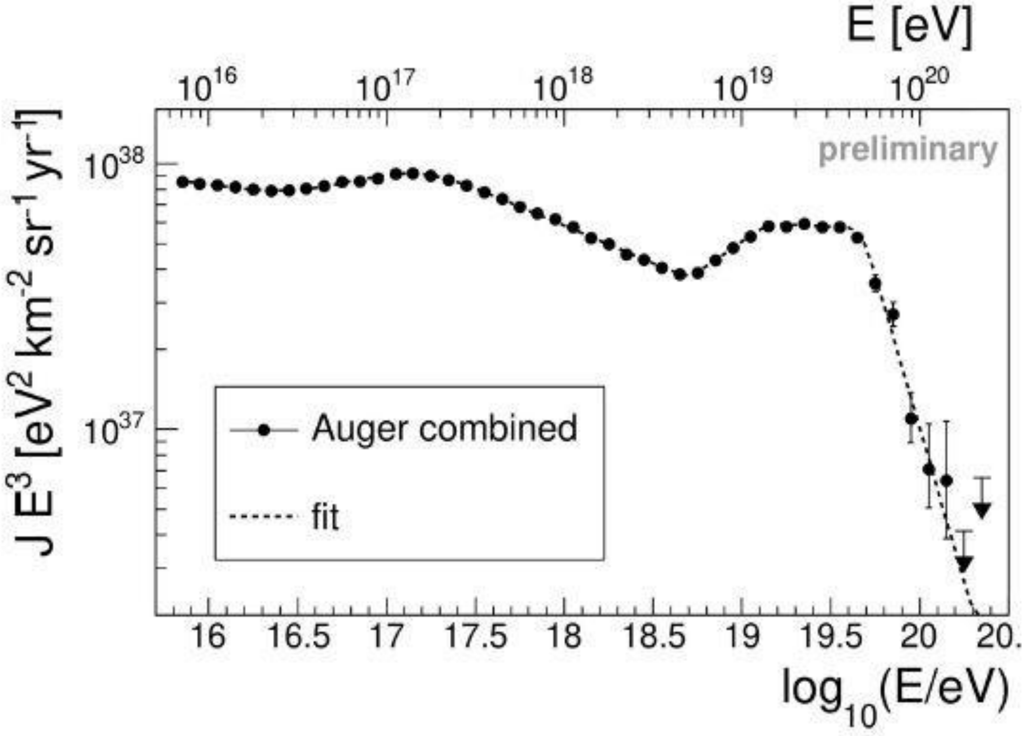
We present the **energy spectrum** of cosmic rays **from 6 PeV up to the highest energies**.

It is a combination of **five different measurements** performed at the Pierre Auger Observatory.

Why is it relevant/interesting?

We report for the first time the **low-energy ankle**.

A **consistent energy scale** has been used for all measurements.



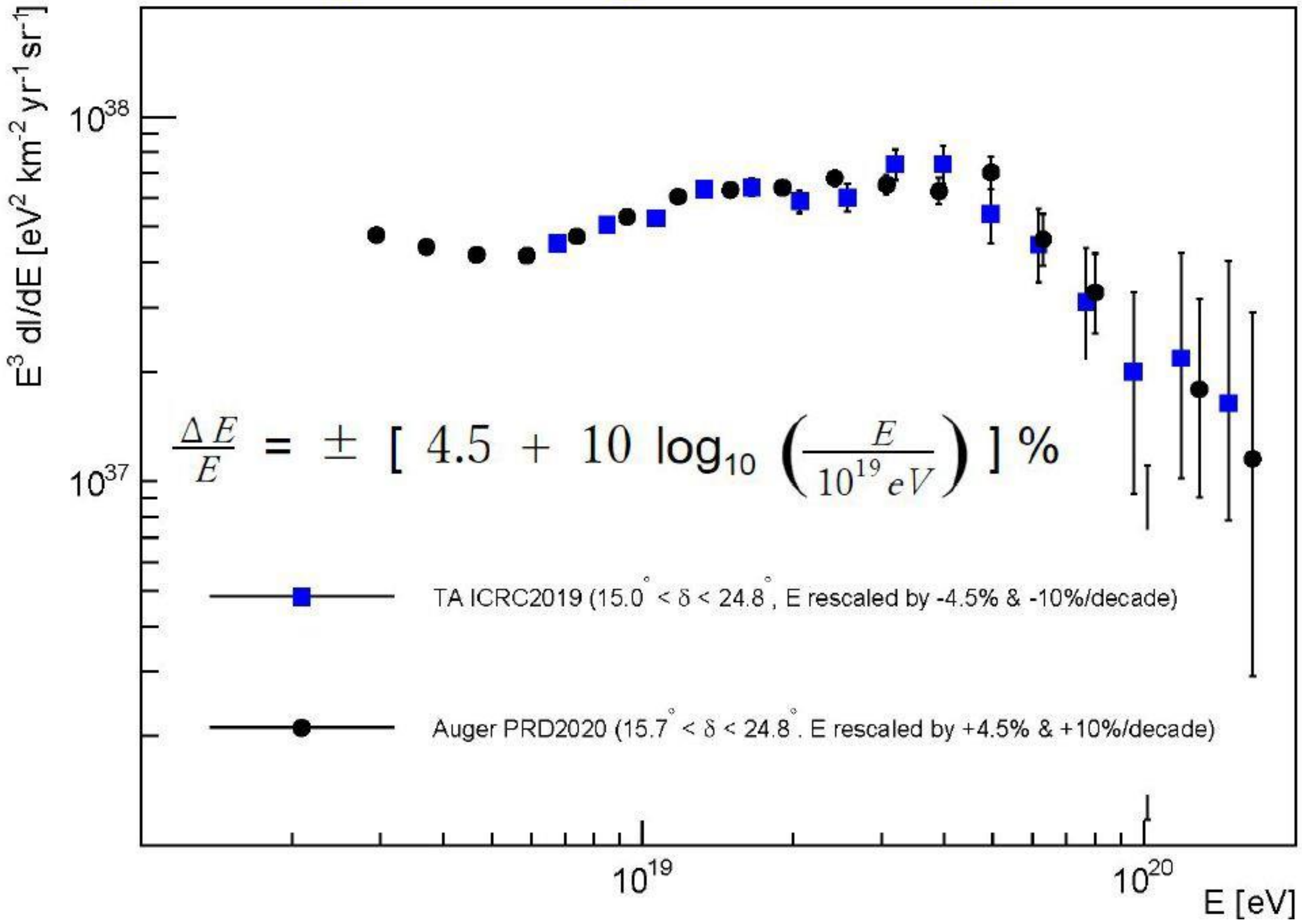
What has been done?

The low-energy **threshold was decreased** by **Cherenkov-dominated events** reconstructed using the Profile-Constrained Geometry fit.

What is the result?

Five breaks in the energy spectrum are reported together with **six** consecutive power-law **spectral indices**.

Common band spectrum (shift + E-dependent shift)



Yoshiki Tsunesada, #793

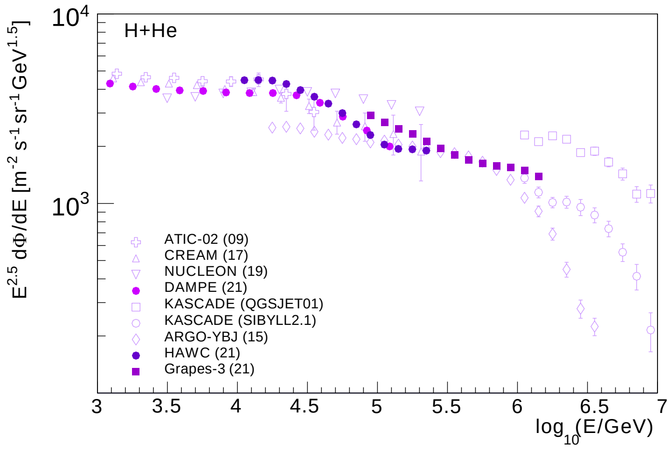
Session Schedule

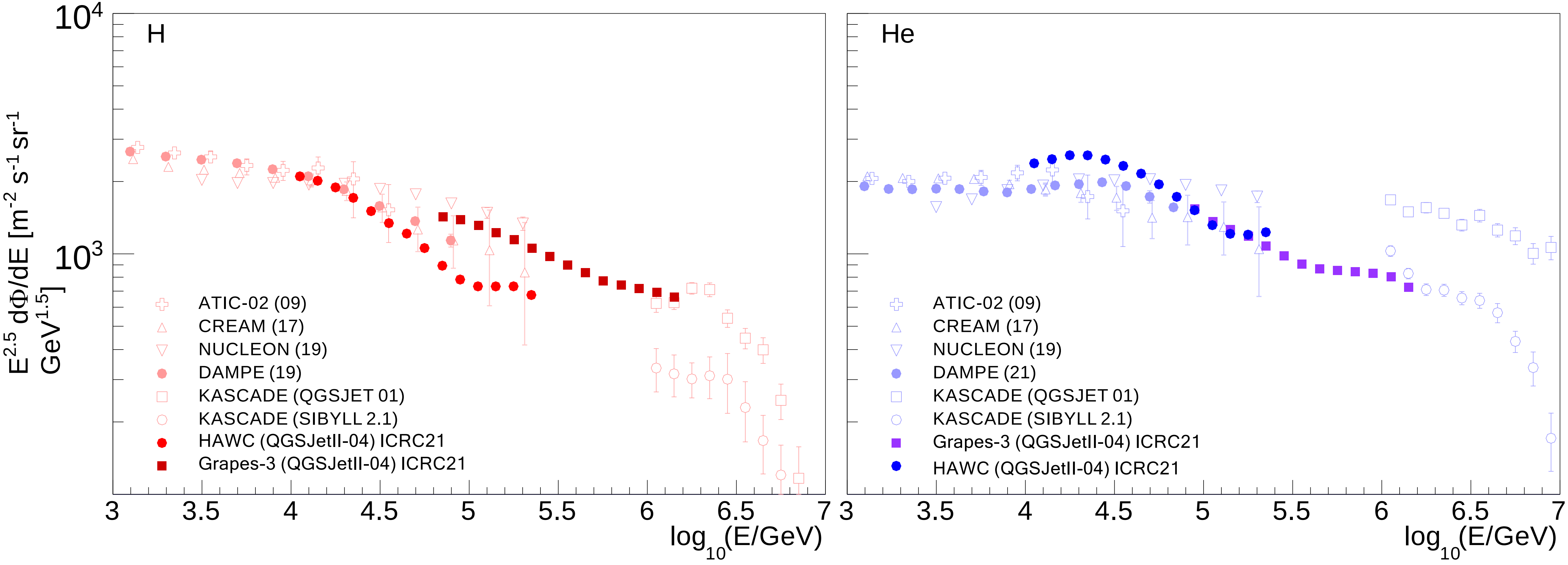
05 CR Mass composition

Convener: Michael Unger | Tom Gaisser

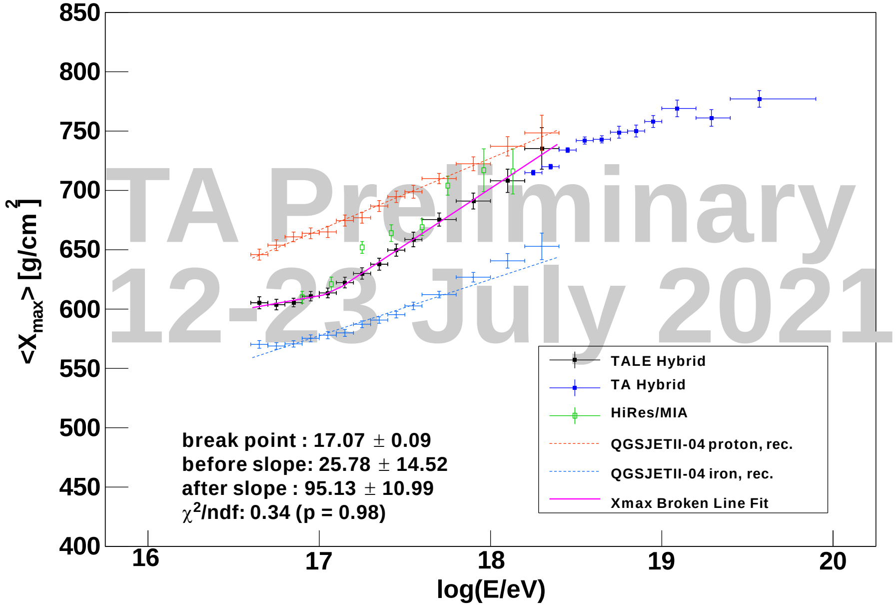
- **18:00 Introduction (TKG/MU)** 5”
- **18:05 Conn. to direct measurements (TKG)** 10”
  - Juan Carlos Arteaga-Velazquez: HAWC p, He, . . .
  - Fahim Varsi: Composition with Grapes 3
  - discussion
- **18:15 From the Knee to the Ankle (TKG)**
  - Keitaro Fujita: Composition TALE-Hybrid
  - Tareq AbuZayyad: Composition TALE-Cherenkov
  - Andreas Haungs: Composition IceTop
  - Dmitriy Kostunin: Reanalysis of KASCADE compo.
  - Donghwa Kang: Composition KASCADE-Grande
  - discussion
- **18:45 Radio Technique (MU)** 10”
  - Bjarni Pont: X_{max} with AERA 2”
  - Arthur Corstanje: X_{max} with LOFAR 2”
  - discussion 6”
- **18:55 UHE (MU)** 35”
  - Yana Zhezher: TA SD composition 2”
  - Heungsu Shin: TA X_{max} 2”
  - Eleonora Guido: Composition Fit Auger 2”
  - Doug Bergman: Composition Fit TA 2”
  - Yana Zhezher: Composition Anisotropy with TA 2”
  - Eric Mayotte: Composition Anisotropy with Auger 2”
  - discussion 23”

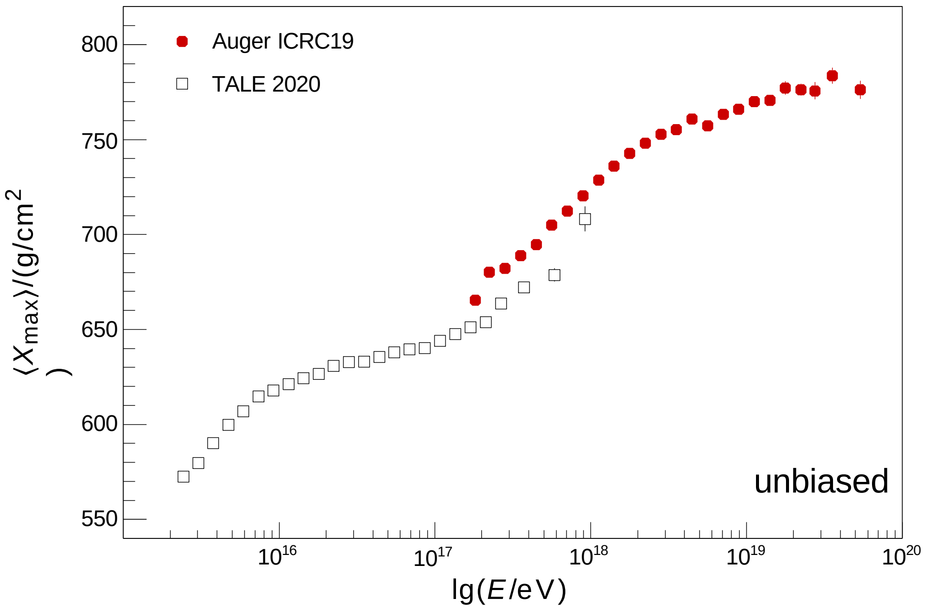
Grapes and HAWC Summary (Juan Carlos and Fahim)

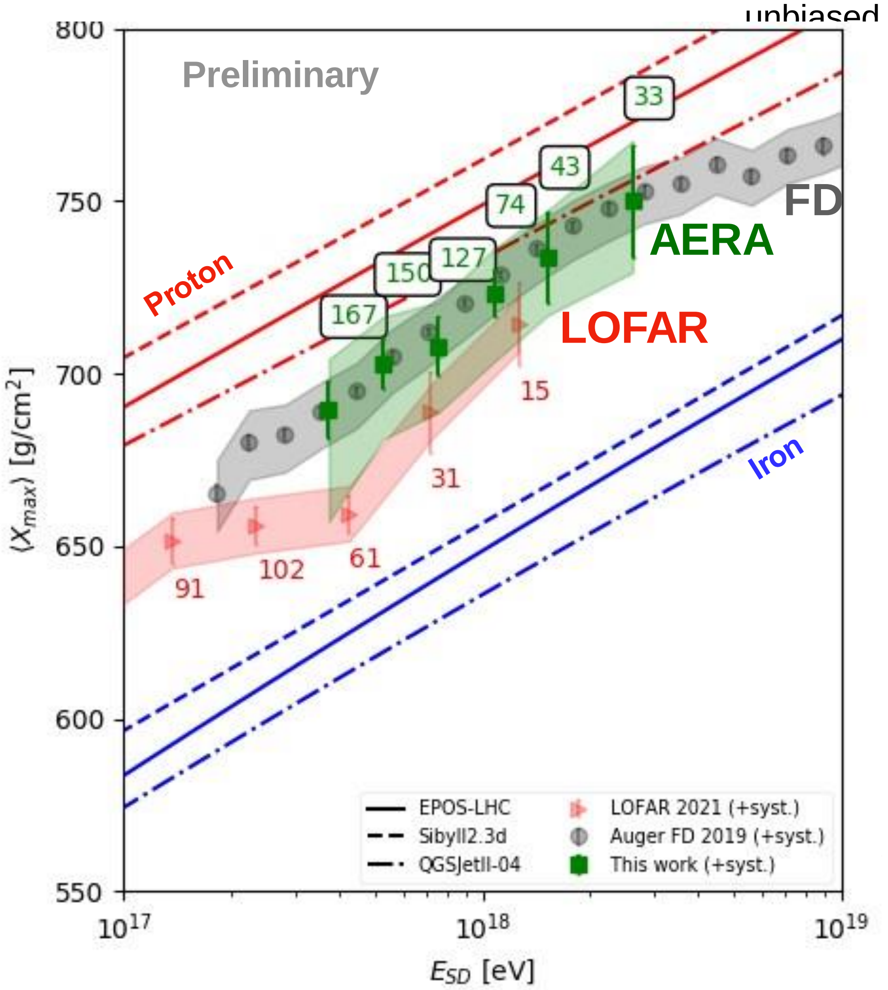


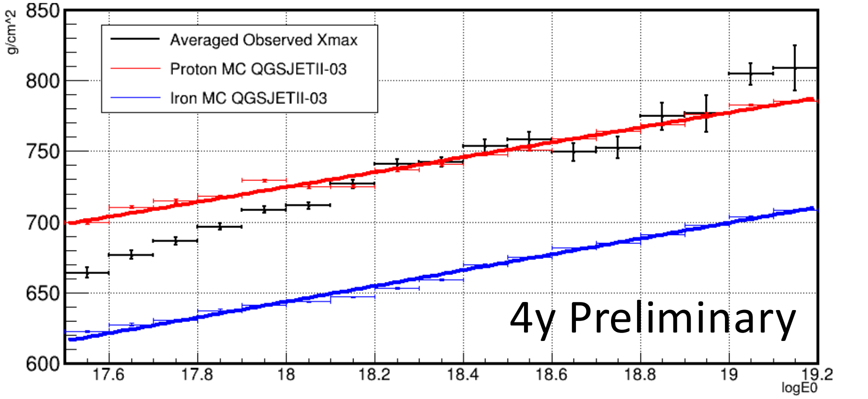


Xmax Composition Results









Eric Mayotte: Auger Composition Anisotropy (1/2)

X_{max} moments of the on- and off-plane

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PIERRE AUGER OBSERVATORY

Integrated difference (off - on) above $10^{18.7}$ eV

$\Delta \; X_{max}) = 9.1 \pm 1.6^{+2.1}_{-2.2}$ g/cm^2

$\Delta\,\sigma(X_{max}) = 5.9 \pm 2.1^{+3.5}_{-2.5}$ g/cm^2

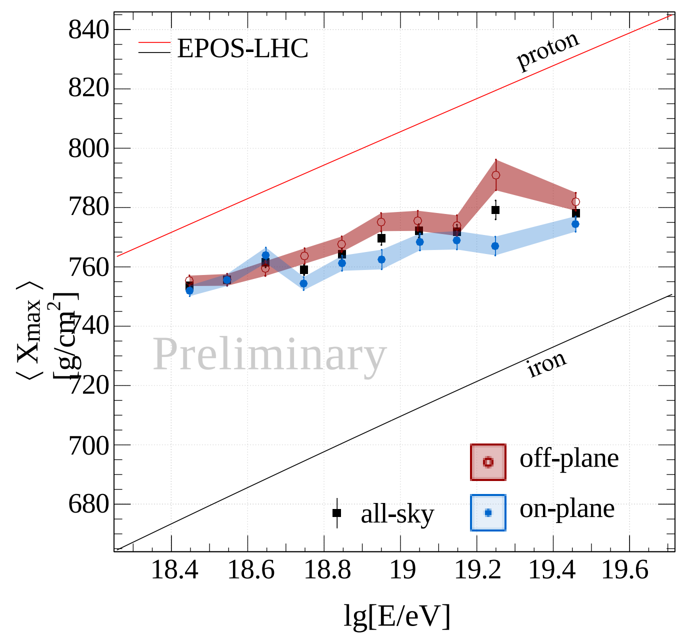
$X^t_{max} = X_{max} - (X^{Fe}_{max})(E)$ using EPOS

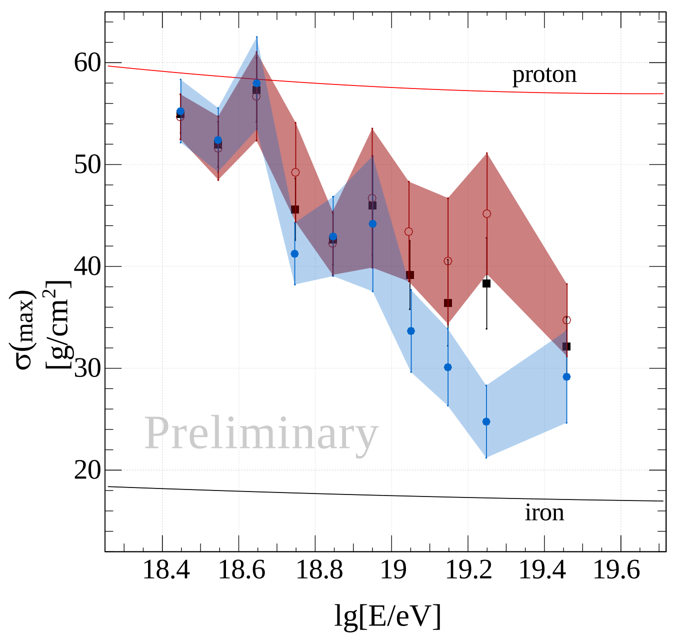
Above $10^{18.7}$ eV:

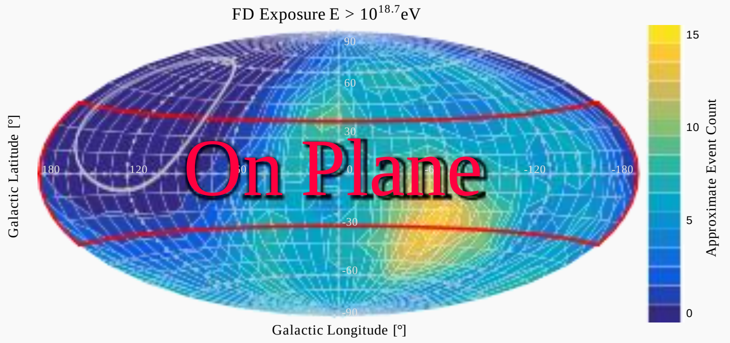
1424 events on-plane

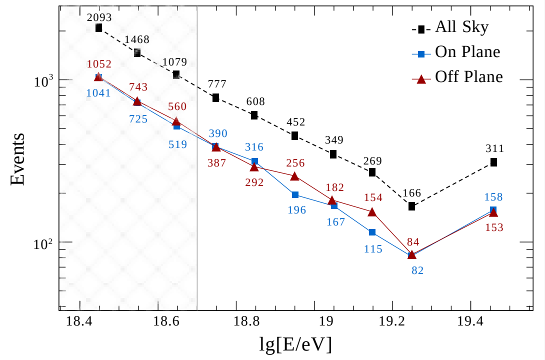
1508 events off-plane

Shallower and narrower on-plane X_{max} distribution indicates heavier mean mass as compared to off-plane









(A) Sub-TeV anisotropy observations

06 CR Anisotropies

Convener: Markus Ahlers | Peter Tinyakov

- **Miguel Valesco** : Anisotropy of Protons and Light Primary Nuclei in Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS

06 CR Anisotropies

Convener: Markus Ahlers | Peter Tinyakov

- **Frank McNally** : Observation of Cosmic Ray Anisotropy with Nine Years of IceCube Data
- **Wei Gao** : Observation of large-scale anisotropy in the arrival directions of CR with LHAASO
- **Medha Chakraborty** : Large-scale CR anisotropy measured by GRAPES-3

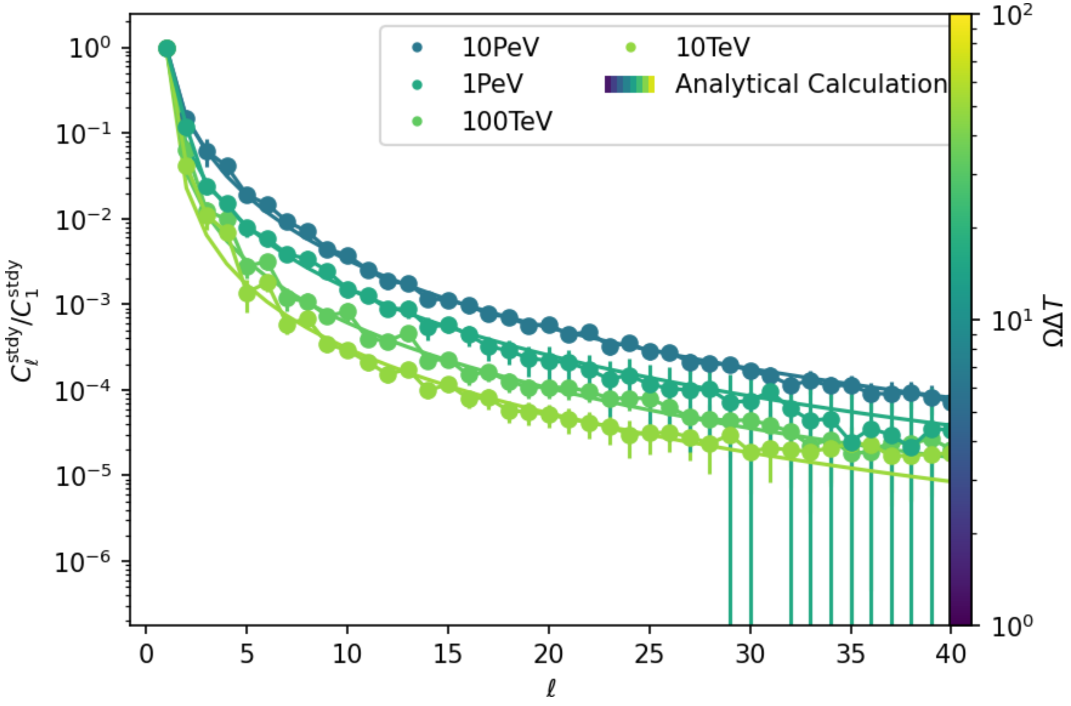
(C) TeV-PeV anistropy simulation and interpretation

06 CR Anisotropies

Convener: Markus Ahlers | Peter Tinyakov

- **Gwenael Giacinti :** Simulations of the CR anisotropy down to TeV energies
- **Marco Kuhlen :** simulation and analytic calculation of power spectru
- **Yoann Genolini :** Local Turbulence and Dipole Anisotropy of Galactic CR

Small Scale Anisotropies in Slab Turbulence



- Magnetic field turbulence leads to small scale anisotropies.
- Small scale anisotropies contain information on the turbulent magnetic field.
- We predict the angular power spectrum both analytically and numerically.

⇒ The numerical and analytical results agree well. The next step is the application to observational data.

(D) 1 − 100 EeV anisotropy observations

- **Rogerio M. de Almeida** : Large-scale and multipolar anisotropies of CR detected by Auger with $E > 4$ EeV
- **Jonathan Biteau** : The UHECR sky above 32 EeV viewed from Auger
- **Igor Tkachev** : TA anisotropy summary
- **Toshiyuki Nonaka** : Anisotropy search in UHECR spectrum in the Northern hemisphere using TA surface detector
- **Toshihiro Fujii** : Update on large-scale CR anisotropy search at highest energies by TA
- **Jihyun Kim** : Hotspot Update and a New Excess of Events on the Sky Seen by TA
- **Peter Tinyakov** : UHECR dipole and quadrupole in the latest data from Auger and TA
- **Amando di Matteo** : UHECR arrival directions in the latest data from Auger and TA and nearby galaxies

UHECR sky > 32 EeV from the Pierre Auger Observatory

Anisotropy search in the toe region with Auger phase 1 data spanning 2004-2020 (17 years!)

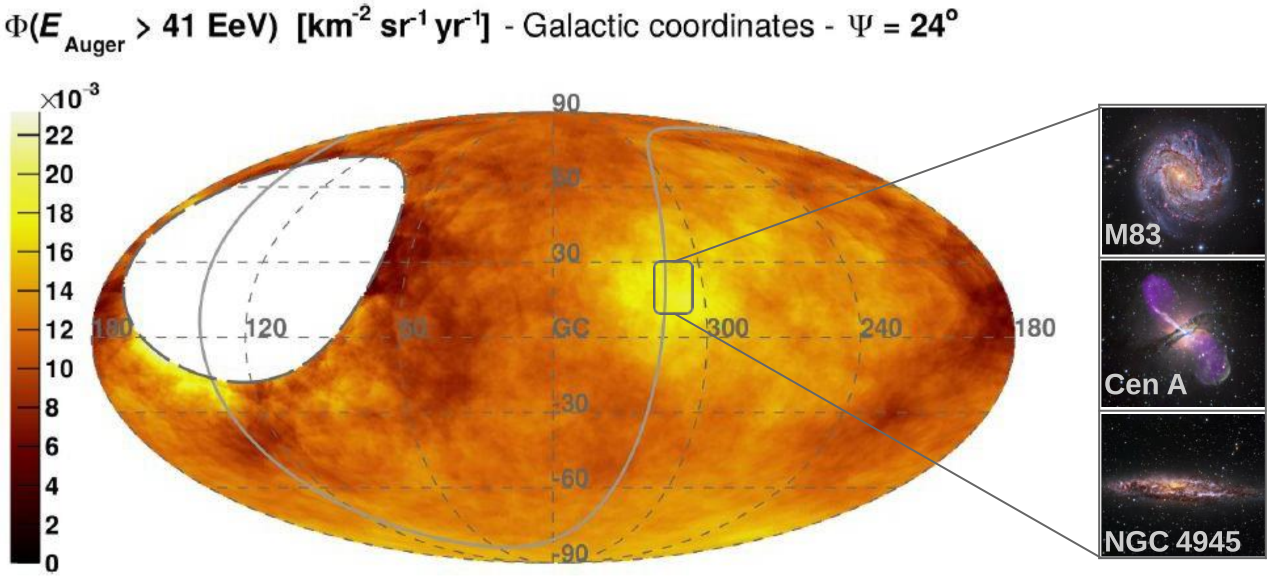
~4σ from search in Centaurus region, confirmed by catalog-based searches.

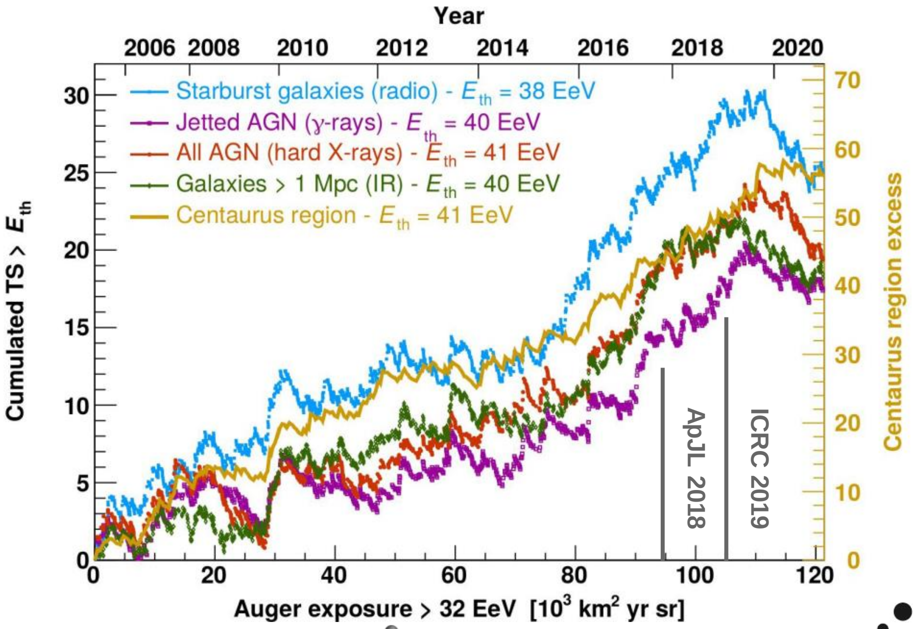
Largest signal from starburst galaxies but **no compelling evidence for catalog preference**

For all these searches: most significant signal at **E_{th} = 38-41 EeV** on top-hat scale **Ψ = 23-27°** with signal fraction **α = 5-15%**

Evolution of signal: compatible with **linear growth within expected variance, 5σ reach expected in 2025-30**

Most important evidence for UHECR anisotropy around the toe from a single observatory → **UHECR source ID is near?**

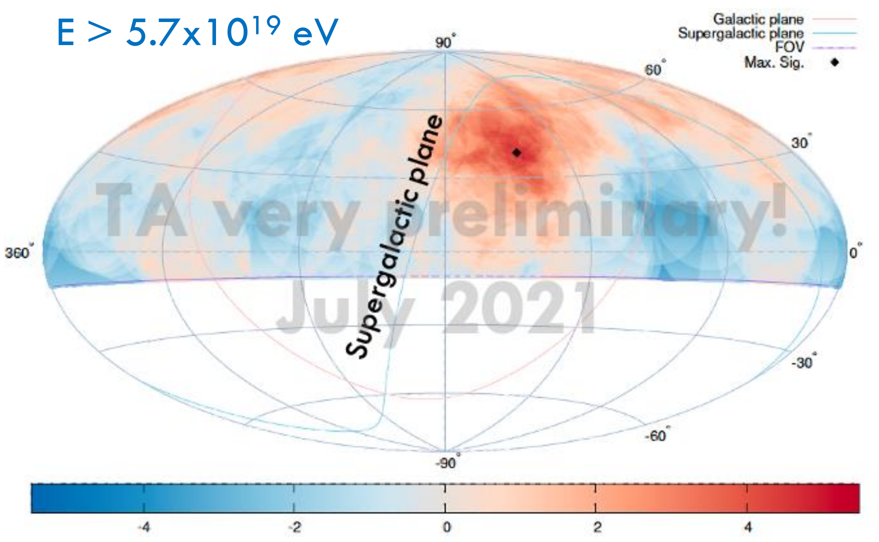




Hotspot update and a new excess of events on the sky seen by the Telescope Array experiment

Jihyun Kim (University of Utah) for the TA collaboration

Update on the hotspot: 12-year SD data

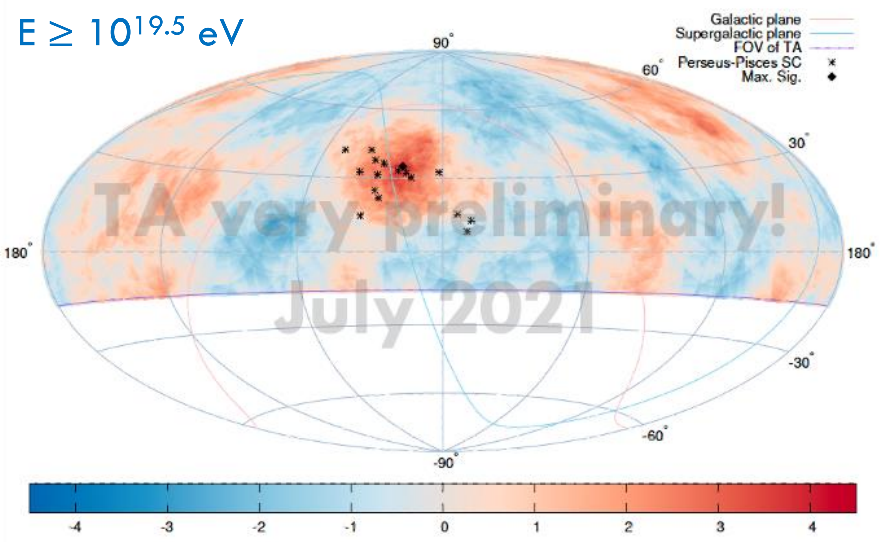


Significance map in the equatorial coords.

- 179 events with $E > 5.7\times10^{19}$eV
- 5.1σ at (144.0°, 40.5°) with 25°-circle

  40 obs. events / 14.6 iso. events
- **Post-trial probability:** $P(S_{MC} > 5.1\sigma) = 6.8\times10^{-4}$ ➔ **3.2σ**

New excess of events: 11-year SD data



Significance map in the equatorial coords.

- 558 events with $E \geq 10^{19.5}$ eV
- 4.2σ at (19.0°, 35.1°) with 20°-circle

  59 obs. events / 31.5 iso. events

-Chance prob. of having an excess on top of the Perseus-Pisces supercluster ➔ **3.7σ**

-We have persistent hints of intermediate angular scale anisotropies, the **hotspot**, at the highest energies, $E \geq 5.7\times10^{19}$ eV, near the Ursa Major group. (**S_{post} ~3.2σ**)

-A **new excess** appears in slightly lower energy events with the local Li-Ma significance of ~4.2σ.

- Behind the new excess, there is **the Perseus-Pisces supercluster**.

-Having an excess on top of the Perseus-Pisces supercluster by chance is rare (~**3.6σ**).

-More analyses, such as cross-correlation analysis between the data and the Perseus-Pisces supercluster, are underway.

(F) 1 − 100 EeV anisotropy simulation and interpretation

06 CR Anisotropies

Convener: Markus Ahlers | Peter Tinyakov

- **Chen Ding :** Imprint of LSS on UHECR Sky
- **Rodrigo Lang :** Origin of UHECR: distance to nearest source and the dipole
- **Ryo Higuchi :** Effects of Galactic magnetic field on the UHECR anisotropy studies

Constraining UHECR sources

ONLINE ICRC 2021
THE ASTROPARTICLE PHYSICS CONFERENCE
Berlin | Germany

37th International
Cosmic Ray Conference
12–23 July 2021

Cosmic Ray Indirect: Session 02

Convener: Foteini Oikonomou | Kohta Murase

- **12:00 Introduction (KM/FO)** 5’’
- **12:05 What can we learn from the UHECRs themselves?** 20’’
- Di Matteo (Anisotropy) 2’’
- Bister (Combined fit sensitivity) 2’’
- Bakalova (Single source contribution at highest energies) 2’’
- Farrar (Transient source of highest energy Galactic CRs) 2’’
- Discussion 12’’
- **12:25 General tools and multimessenger constraints** 15’’
- Biteau (source catalogue/UHECR arrival direction application) 2’’
- Muzio (fit to multimessenger data) 2’’
- Eichmann(thermal to non-thermal elemental abundances) 2’’
- Discussion 9’’
- **12:40 Gamma-ray Bursts and Starburst Galaxies** 15’’
- Rudolph (GRB/LL GRB models and UHECR combined fit) 2’’
- Samuelsson (GRB/LL GRB maximum UHECR energy) 2’’
- Condorelli (starburst galaxy combined fit) 2’’
- Discussion 9’’
- **12:55 Active Galactic Nuclei** 20’’
- Rodrigues (jetted AGN combined fit and blazar modelling) 2’’
- Merten (FR0 galaxies) 2’’
- Das (UHECRs from TeV gamma-ray emitting BL Lacs) 2’’
- Morejon (Cen A as source of UHECRs) 2’’
- Discussion 12’’
- **General Discussion/Closing Remarks** 15’’

(*What can we learn from the UHECRs themselves? Arrival Direction Anisotropies*)

UHECR arrival directions in the latest data from the original Auger and TA surface detectors and nearby galaxies

Executive Summary

Armando di Matteo[a], Luis Anchordoqui, Teresa Bister, Jonathan Biteau, Lorenzo Caccianiga, Rogério de Almeida, Olivier Deligny, Ugo Giaccari, Diego Harari, Jihyun Kim, Mikhail Kuznetsov, Ioana Maris, Grigory Rubtsov, Peter Tinyakov, Sergey Troitsky and Federico Urban on behalf of the Pierre Auger[b] and Telescope Array[c] Collaborations

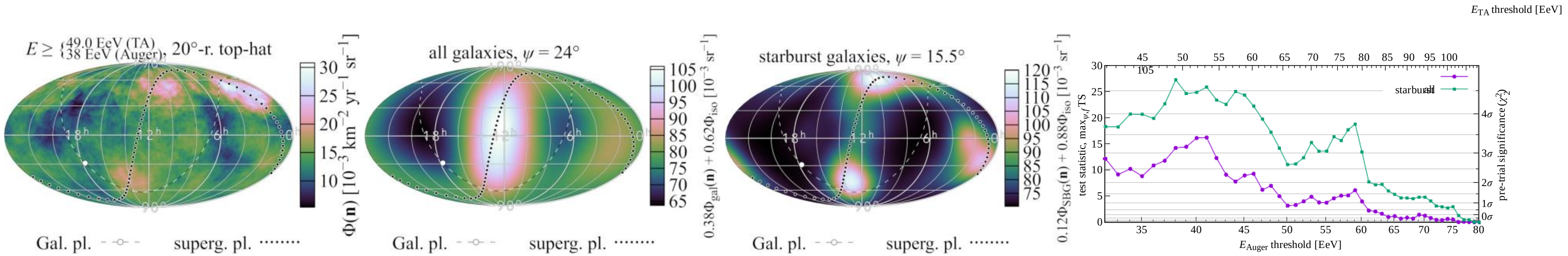
[a] INFN Sezione di Torino, Via Pietro Giuria 1, 10125 Torino, Italy
[b] Observatorio Pierre Auger, Av. San Martín Norte 304, 5613 Malargüe, Argentina
[c] Telescope Array Project, 201 James Fletcher Bldg, 115 S. 1400 East, Salt Lake City, UT 84112-0830, USA

What is this contribution about?

A search for medium-scale anisotropies in the distribution of UHECR arrival directions detected using the Pierre Auger Observatory and Telescope Array surface detector arrays

Why is it relevant/interesting?

The origins of UHECRs is still not known, but at the highest energies they are not expected to be able to freely travel for cosmological distances, so their sources must be in nearby galaxies and we would like to eventually identify them. Several hints have already been reported (Pierre Auger coll., *ApJL* **853** (2018) L29; Telescope Array coll., *ApJ* **899** (2020) 86).



What has been done?

We searched for correlations with a catalog of galaxies of all types (1 Mpc ≤ D < 250 Mpc) and one of starburst galaxies (1 Mpc ≤ D < 130 Mpc) using a log-likelihood-ratio test.

What is the result?

Correlation with starburst galaxies (= $15.5^{\circ}{}^{+5.3^\circ}_{-3.2^\circ}$ scale, = $11.8\%^{+5.0\%}_{-3.1\%}$ signal fraction; 4.2 post-trial significance) and with all galaxies (= $24^{\circ}{}^{+13^\circ}_{-8^\circ}$, = $38\%^{+28\%}_{-14\%}$; 2.9 post-trial)

Cosmographic model of the astroparticle skies

400,000 galaxies within 1 Gyr to constrain the astroparticle skies (arXiv:2105.11345, Biteau+ 2021 ApJS in press)

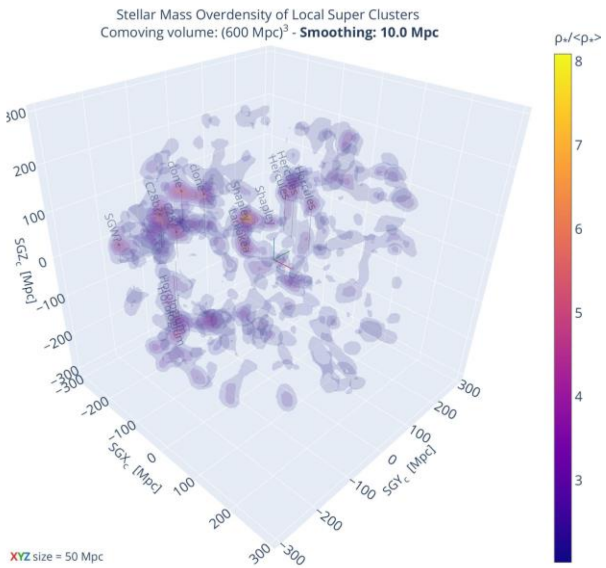
Expands on near-infrared catalogs proposed gravitational-wave (GW) community: **improved distance & completeness estimates**

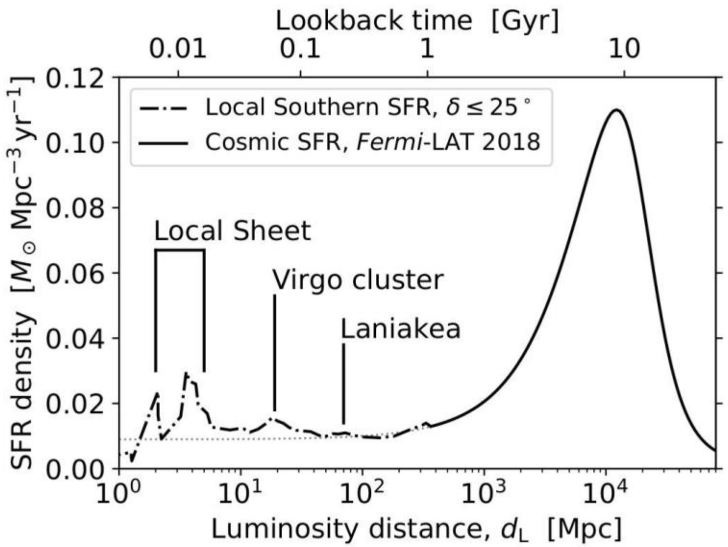
Provides **stellar mass and star formation rate (SFR) estimate for each galaxy**, with resolution & bias X-checked against deep fields

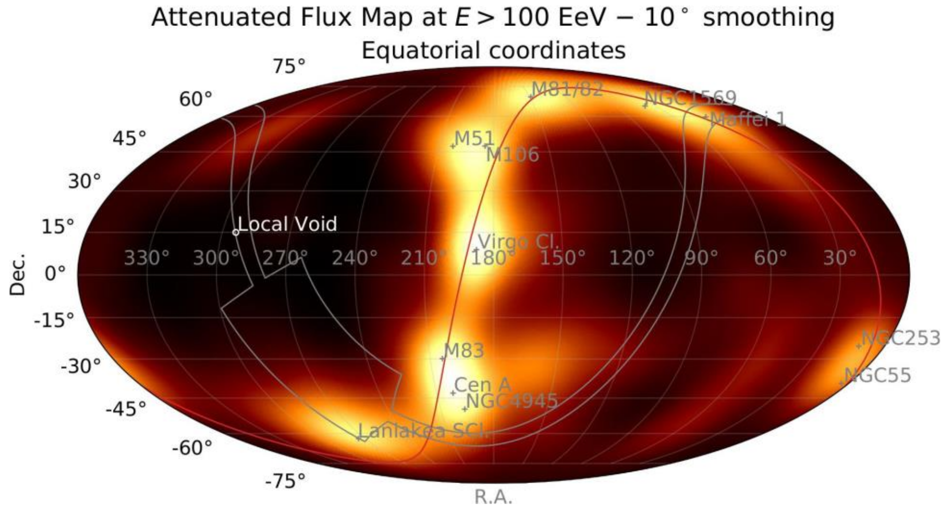
Of interest to ν, ɣ-ray, GW and UHECR wide field-of-view searches: latter explored in this ICRC contribution

Local overdensity impact on **UHECR spectrum, composition, and flux maps**, in a transient UHECR scenario (production ∝ SFR)

Constraints on transient rate: **promising match with UHECR data**. Skymap discrepancies: likely **confinement on cluster scales.**

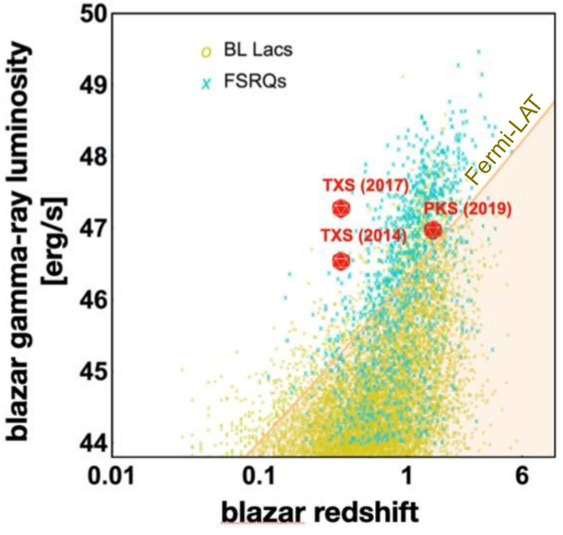




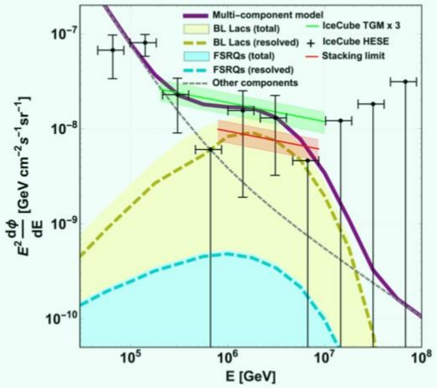


AGN as neutrino sources in the PeV and EeV regimes

Xavier Rodrigues

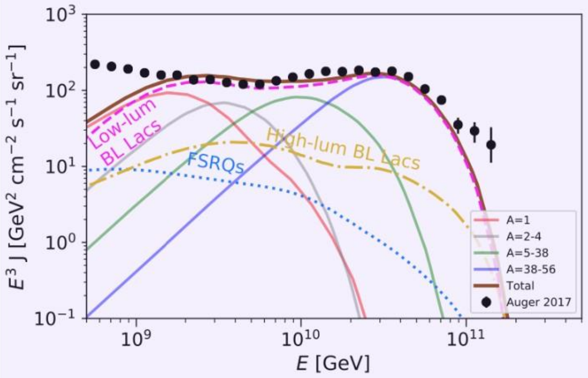


Scenario 1: AGN accelerate CRs up to max 10 PeV

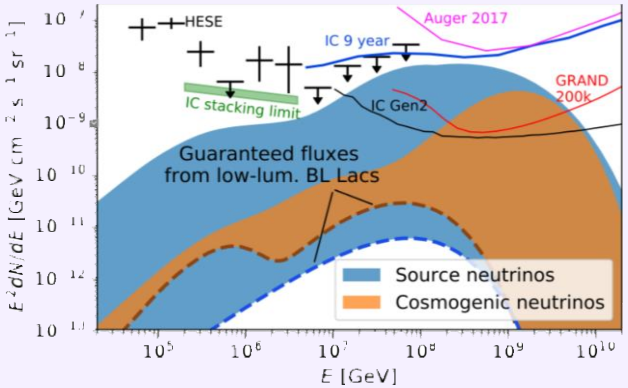


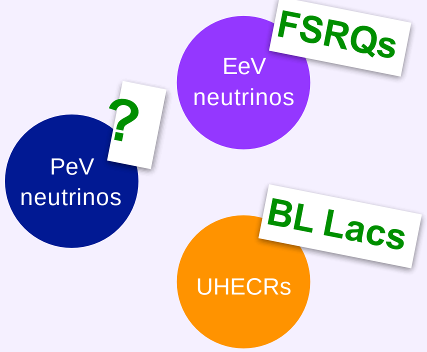
Palladino, XR, Gao & Winter, ApJ 871 (2019)

Scenario 2: AGN accelerate CRs up to ~EeV

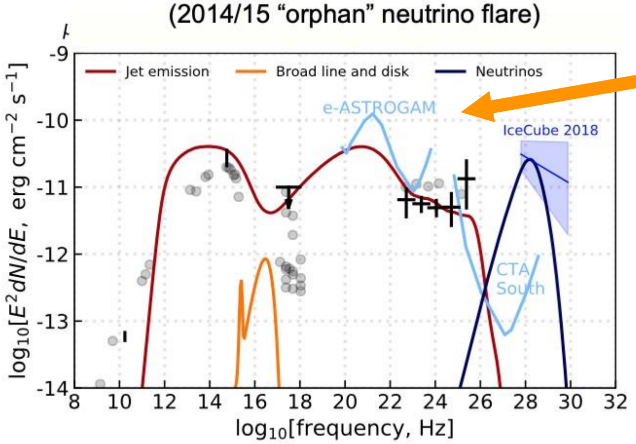


XR, Heinze, Palladino, van Vliet, Winter, PRL 126 (2021)





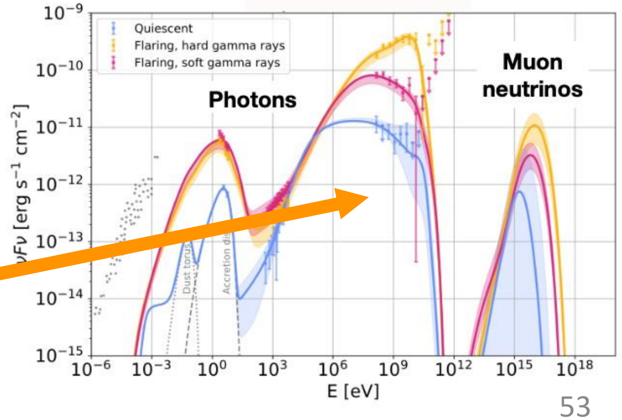
Dedicated modelling shows us that each source is a source



XR, Gao, Fedynitch, Palladino, Winter, ApJ L874 (2019)

Low gamma-ray fluxes; MeV bump

Gammas ~ neutrinos



XR, Garrappa, Gao, Paliya, Franckowiak & Winter, ApJ 912 (2021)

(*Gamma-ray Bursts and Starburst Galaxies*)

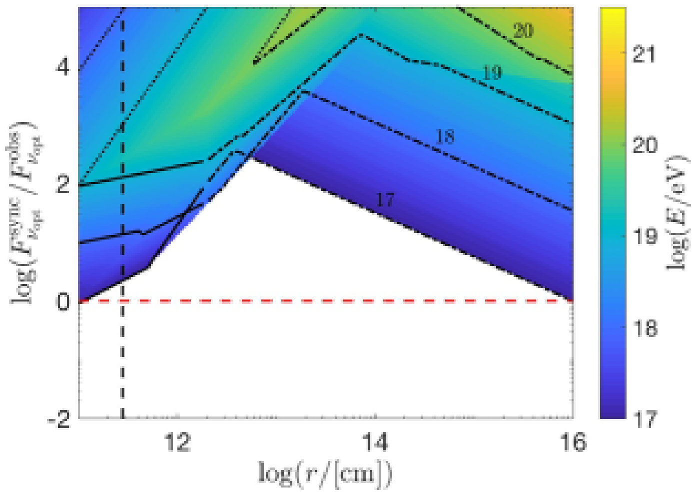
Problematic connection between UHECRs and LLGRBs

Filip Samuelsson, Damien Bégué, Felix Ryde, Asaf Pe'er, Kohta Murase

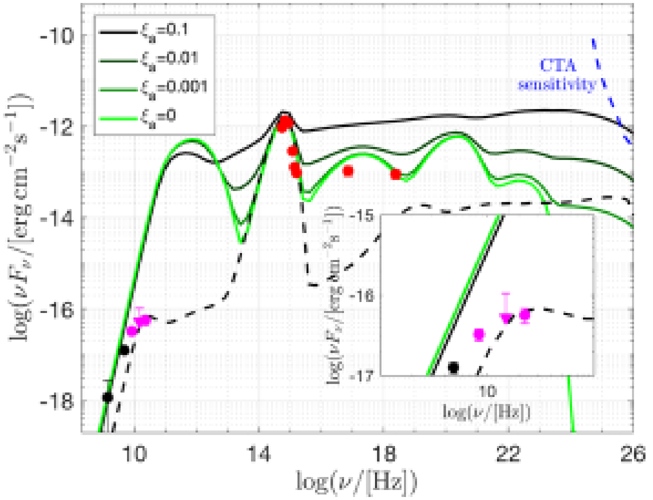
Samuelsson et al. (2019) ApJ, 876:93, Samuelsson et al. (2020) ApJ, 902:148

Idea: Use the synchrotron emission from the primary electrons as an additional messenger and compare the emission with observations of GRB 060218.

Results prompt phase:
The high magnetic field required for UHECR acceleration lead to immense optical emission from the electrons



Results afterglow phase:
The high energy budget required for observed UHECR flux lead to immense radio emission from the electrons



Conclusions: Emission from electrons is a powerful additional tool in UHECR multi-messenger studies. Mildly relativistic outflows of LLGRBs unlikely to be the main sources of UHECRs.

09 Atmospheric and geophysical phenomena

Convener: Roberto Mussa | Rasha Abbasi

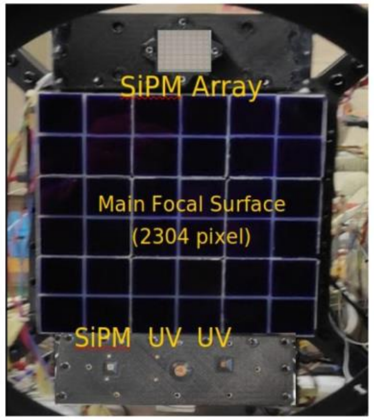
Interdisciplinary science with Cosmic Ray Detector Facilities

Fertile interchange with many sectors of Geophysics:

- Transient Luminous Events (TLEs) : Elves, Gigantic Jets , etc ...
- Terrestrial Gamma Ray Flashes (TGFs) on Surface Arrays
- Conditions for Thunderstorm Ground Enhancements (TE)
- Thunderstorm effects on EAS reconstruction
- Lightning parametrization
- Cloud detection from ground and space
- Reconstruction of laser beams from satellites
- Detection of relativistic dust particles
- Detection of O(100 TeV) cosmic ray bursts

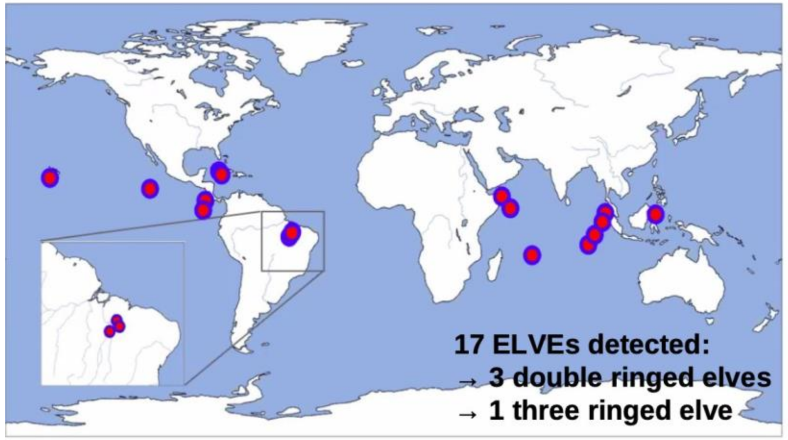
Observation of ELVES with Mini-EUSO telescope on board the ISS

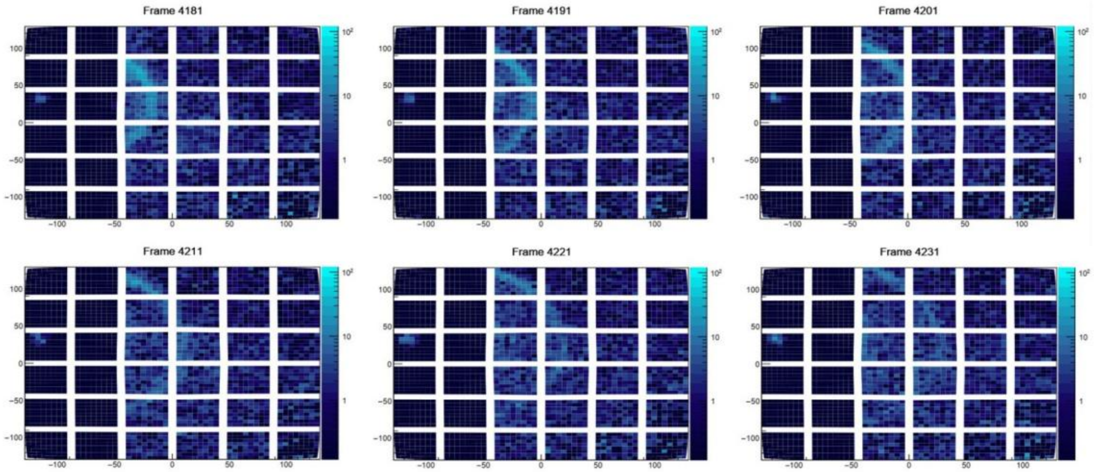
L. Marcelli on behalf of the JEM-EUSO Collaboration



Mini-EUSO main sensors:
- Ultraviolet telescope with 25 cm diameter Fresnel lenses
  (48x48 pixels, FoV= 40 deg, ~320x320 km^2, 2.5 μs and above)
- Near Infrared camera (1280x960 pixels, FoV=33.2x24.8 deg, 231x174 km^2, 1s)
- Visible camera (1280x960 pixels, FoV=33.2x24.8 deg, 231x174 km^2, 4s)
- SiPM (8x8 pixels) and UV sensors

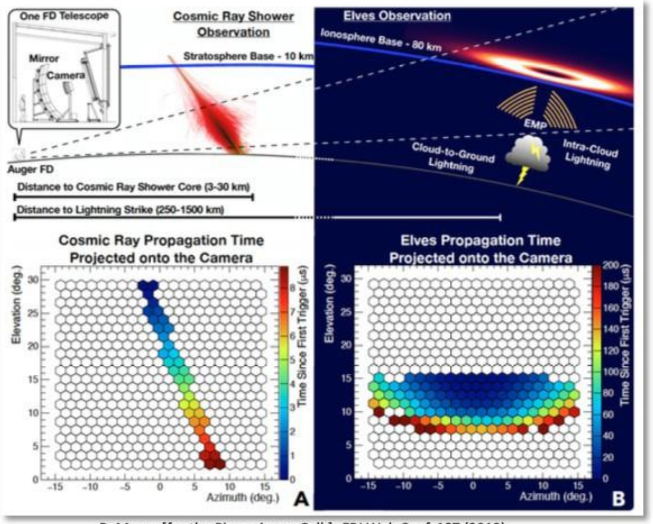
ELVE Lifetime: About 400 μs
Time sampling: 2.5 μs → 200 frames
Pixel size: 4.7 km at 90 km → 240x240 km^2
Pictures are 10 frames apart -> 25 μs (2,5 μs x 10)
Left columns of PMTS working at low voltage (about 1/1000 sensitivity)





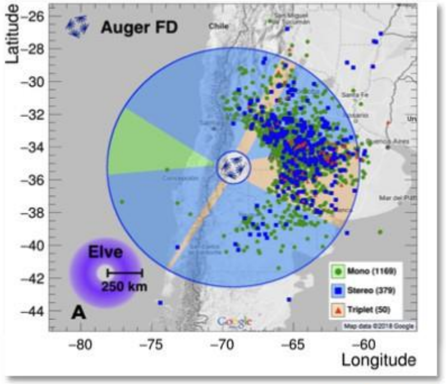
Study on multi-ELVES in the Pierre Auger Observatory

Adriana Vásquez-Ramírez on behalf of the Pierre Auger Collaboration



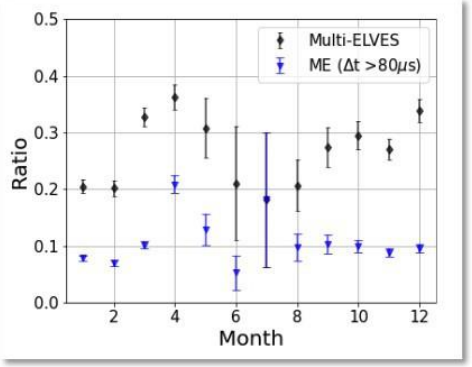
R. Mussa [for the Pierre Auger Coll.], *EPJ Web Conf.* **197** (2019) .

- Fluorescence Detector (FD) time resolution: 100 ns (re-binning to 2µs)
- Since 2014 the FD readout and triggering system were updated to detect ELVES with a high efficiency.
- Trace length extended from 300 µs to 900 µs in 2017.

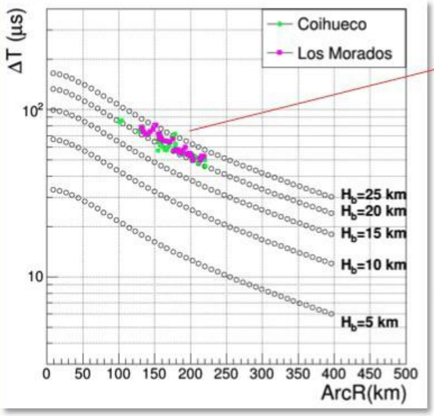


Viewing footprint for ELVES: $3x10^6$ km^2

A. Aab et al. [Pierre Auger Coll.], *Astr. Soc. P.* **7** (2020).

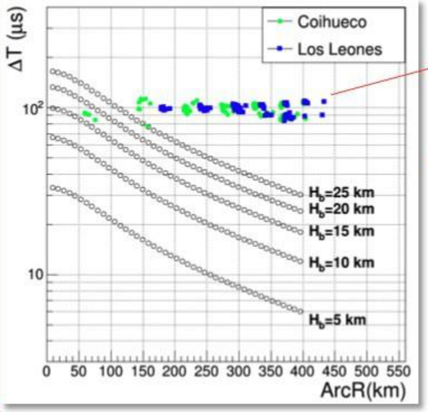


Ratio of multi-ELVES, and ME to total per month



EMP ground reflection mechanism candidate

Very few events



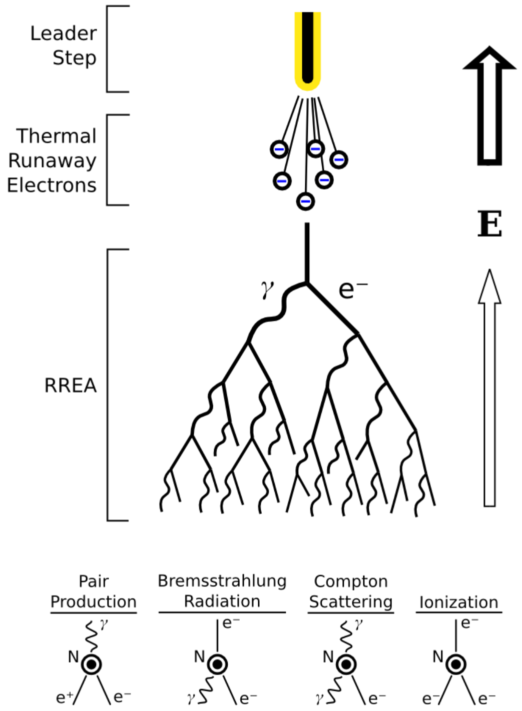
?

Many multi-ELVES with almost constant ΔT > 80 µs

Insight Into Lightning Initiation via Downward Terrestrial Gamma-ray Flash Observations at Telescope Array

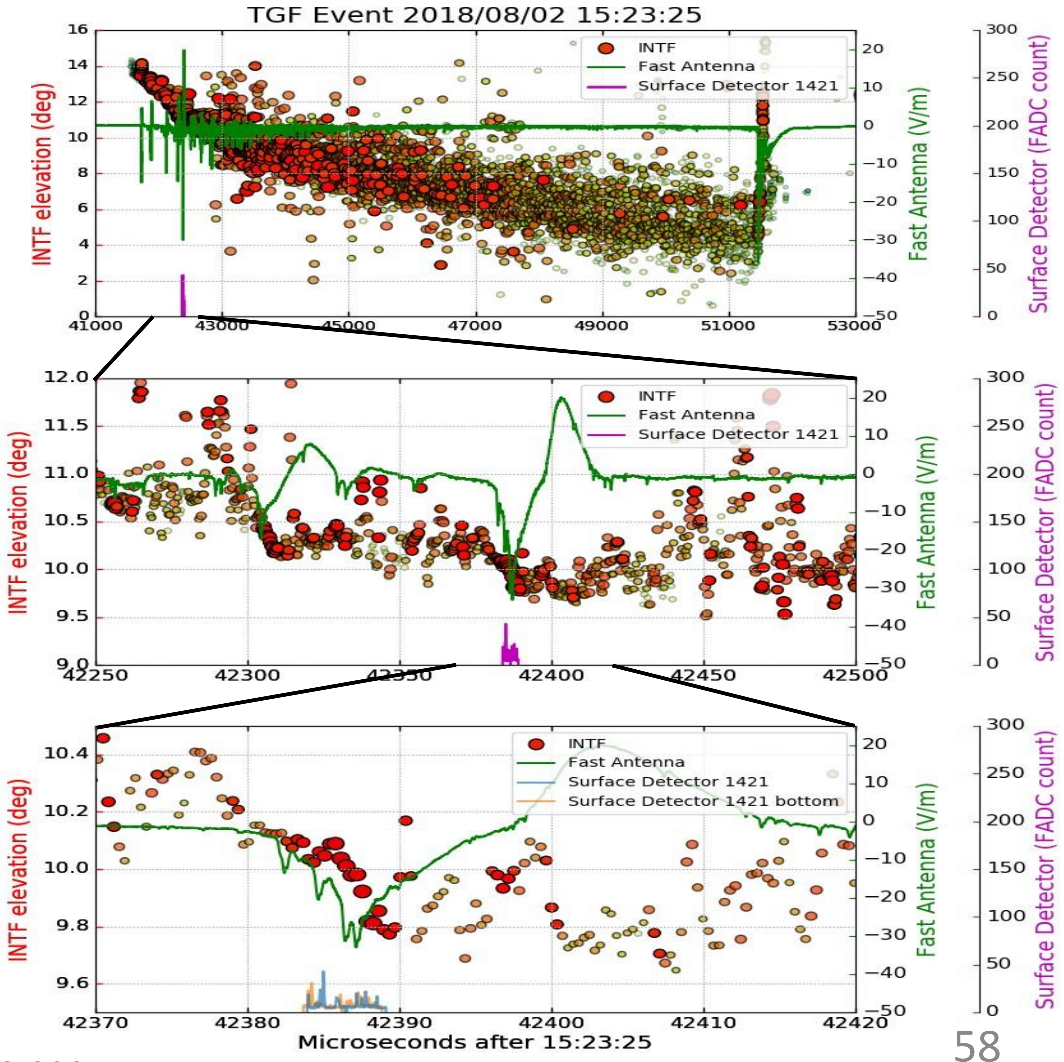
Summary Slide

- Downward TGFs occur during strong IBPs in the initial leader steps of downward negative lightning
  - Additionally correlated with fast negative breakdown and sub-pulses

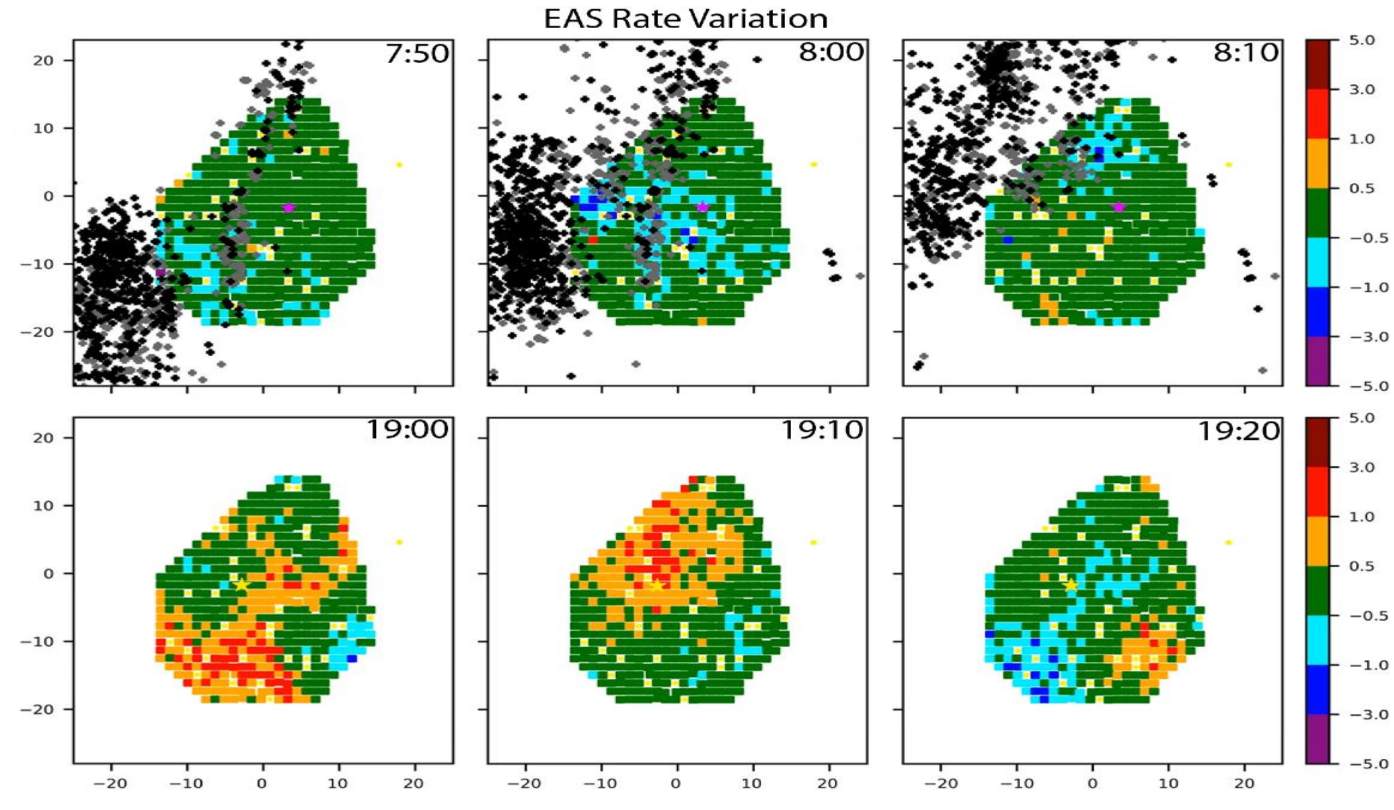


- Evidence of individual gamma-rays with energies of at least 6.5 MeV
- Finding published in JGR: Atmospheres

10.1029/2019JD031940



Observation of Variations in Cosmic Ray Showers During Thunderstorms and Implications for Large-Scale Electric Field Changes



- Observations of variations in the cosmic ray EAS rate (1-3)% in magnitude.
- First observations of thunderstorms progressing in 10s of minutes over 700 km^2.
- Interpret the observations via simple Corsika simulation electric field model 0.2-0.4 GV

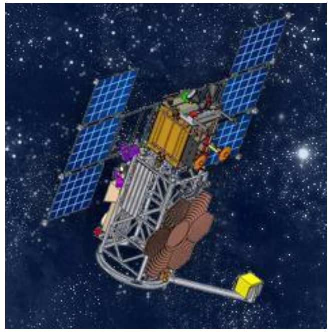
Rasha Abbasi
Loyola University Chicago
For the Telescope Array Collaboration

Relativistic dust grains: a new subject of research with orbital fluorescence detectors

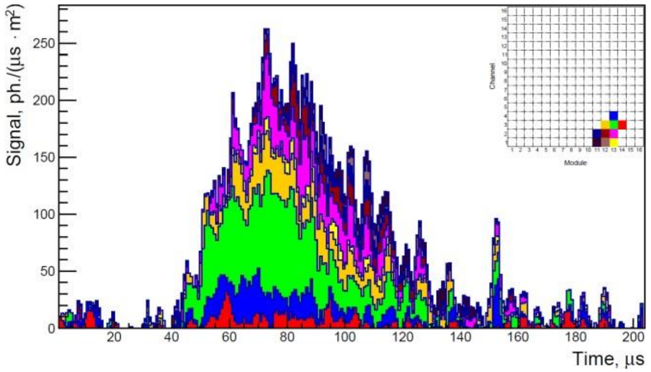
09 Atmospheric and geophysical phenomena

Convener: Roberto Mussa | Rasha Abbasi

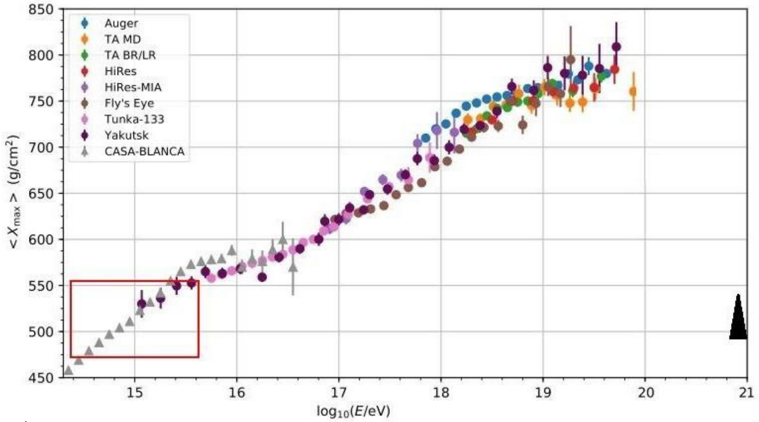
TUS is a first orbital fluorescent detector of ultra-high-energy cosmic rays



- ✓It was launched aboard the Lomonosov spacecraft on 04/28/2016. Time of operation until 12.2017 (with interruptions)
- ✓More than 200 thousand events registered
- ✓The total exposure ~ 1550 km^{2}sr yr.



- ✓ The TUS161003 event was registered on 3 October 2016.
- ✓ No potential sources of artificial UV light were identified on ground. The signal was registered in perfect observational conditions without any noticeable clouds.



Mean depth of maximum of EASs vs. energy of primary cosmic rays according to data of different experiments. The black triangle shows estimations for the TUS161003 event.

- ✓ The slant depth of the shower maximum was estimated from the light curve as ≤ 480-550 g/cm^2, which geometrically corresponds to altitudes ~7.5 – 8.5 km above the ground.
- ✓ If we consider the atmosphere to be a target for a cluster of nucleons (a dust grain) containing N_n = 10^6 nucleons in atomic and molecular states, with the primary energy of E_0 ~ 10^{21} eV and energy per nucleon Nn = E_0/N_n = 10^{15} eV. Applying the superposition model to this impact process, one should expect as a final observable picture the sum of N_n EASs with the total energy approximately equal to E_0.
- ✓ The Mini-EUSO telescope that currently operates at the International Space Station and the future EUSO-SPB2, K-EUSO, and the POEMMA missions can extend the capabilities of TUS and the ground-based detectors and shed new light on this hypothesis.

Summary

- The amount of work presented at this conference is nothing short of impressive.
- Progress is being made on all fronts. Several important contributions, the results of significant effort by individuals and groups, were likely missed in this conference summary.
- Nonetheless, I hope that I managed to provide you a concise yet fairly complete picture of what was presented in the CRI track at this ICRC2021 conference.
- Thank you.