Discussion Session # 56

New and Future Instruments for Ground-based Gamma-ray Astronomy

(Including those undergoing relevant upgrades)

Ulisses Barres de Almeida (CBPF, Brazil)
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Session Webpage
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Discussion Session # 56

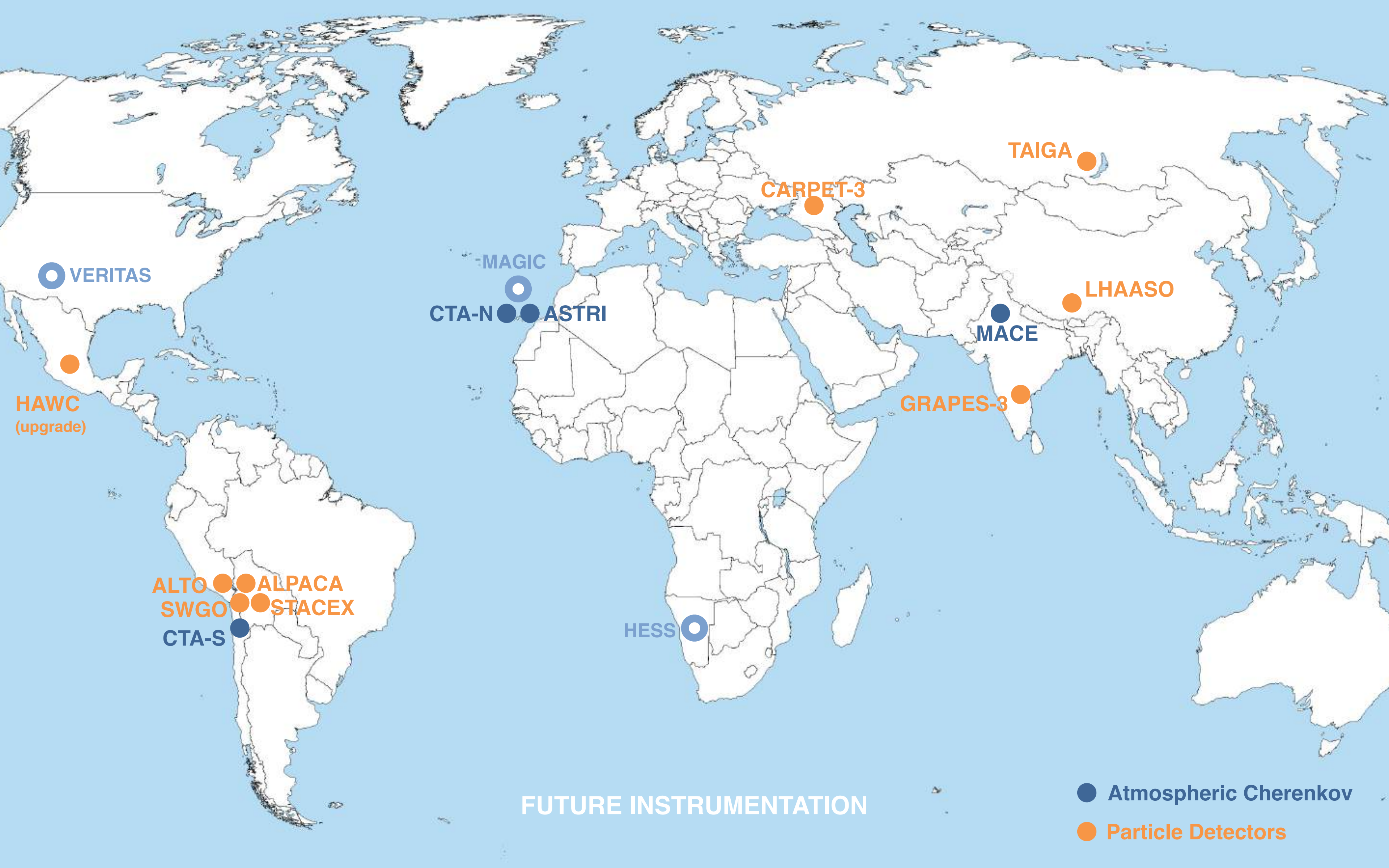
Structure of the Session

Block 01 - Atmospheric Cherenkov Telescopes
12:00 - 12:40 CEST

- CTA (O. Gueta)
- CTA-LST (D. Mazin)
- CTA-SST (R. White)
- pSCT (B. Mode)
- ASTRI Mini-Array (L. Antonelli)
- LST SiPM Camera (M. Heller)
- FlashCam (B. Bi)
- NectarCam (T. Armstrong)
- MACE (K. Yadav)

Block 02 - Ground Particle / Hybrid Arrays
12:40 - 13:30 CEST

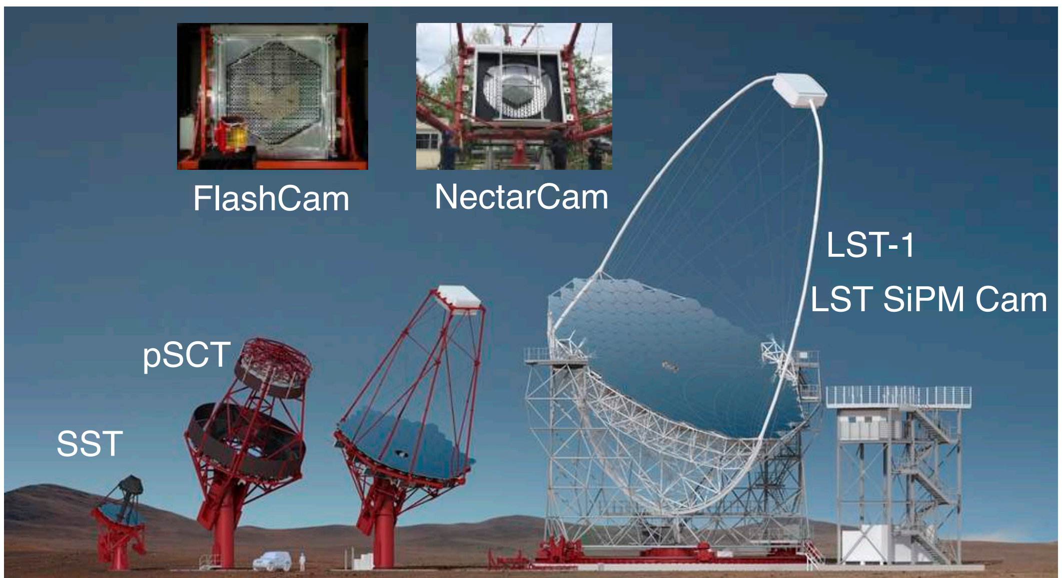
- LHAASO-WCDA (C. Liu)
- LHAASO-KM2A (Y. Nan and J. Liu)
- TAIGA (N. Budnev)
- Carpet-3 (V. Romanenko)
- GRAPES-3 (D. Pattanaik)
- SWGO (H. Schoorlemmer)
- ALTO-CoMET (M. Senniappan)
- ALPACA (T. Sako)
- STACEX (G. Fernandez)
- HAWC's eye (J. Serna-Franco)


VERITAS
MAGIC
CTA-N
ASTRI
TAIGA
CARPET-3
LHAASO
MACE
GRAPES-3
HAWC
(upgrade)
ALTO
ALPACA
SWGO
STACEX
CTA-S
HESS
FUTURE INSTRUMENTATION
Atmospheric Cherenkov
Particle Detectors

Block 1

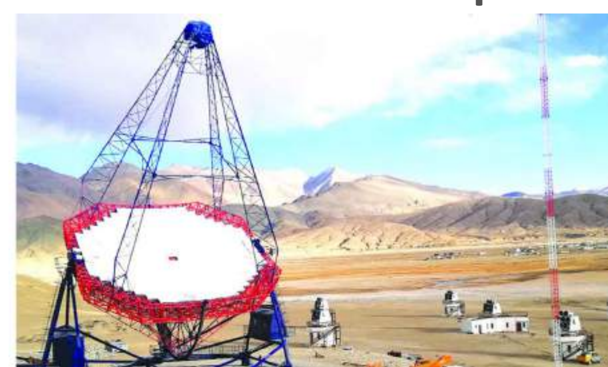
Future Imaging Atmospheric Cherenkov Telescopes

Cherenkov Telescope Array

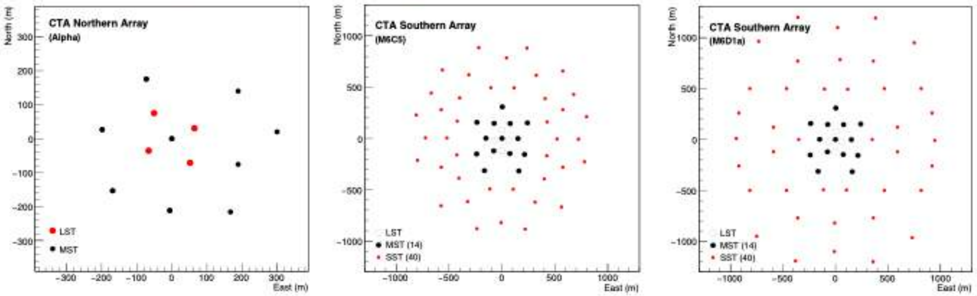


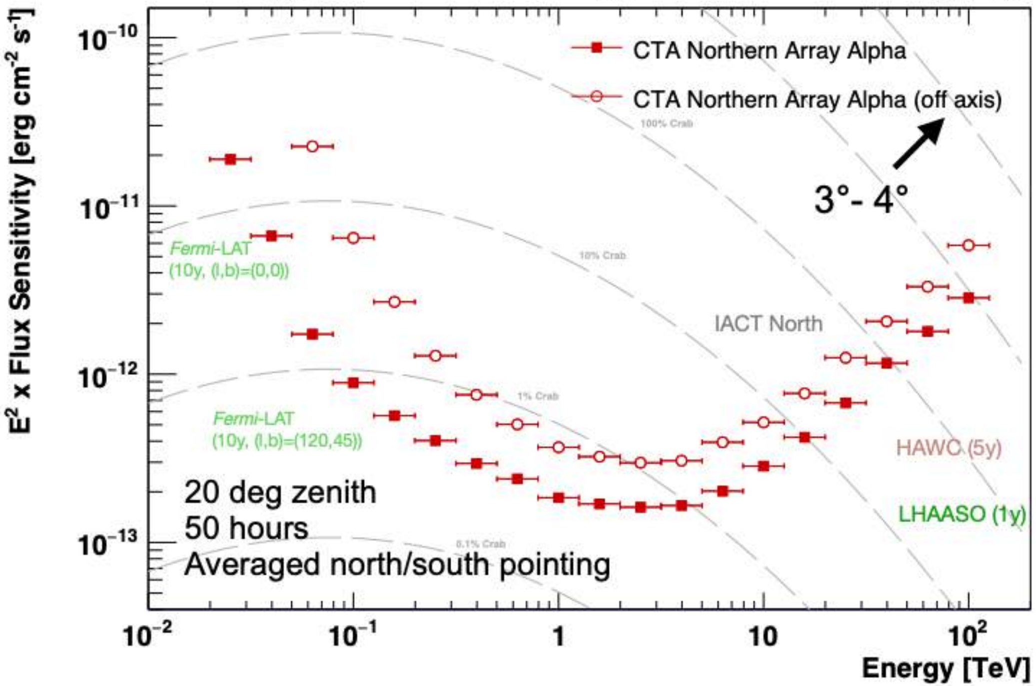
ASTRI mini-array

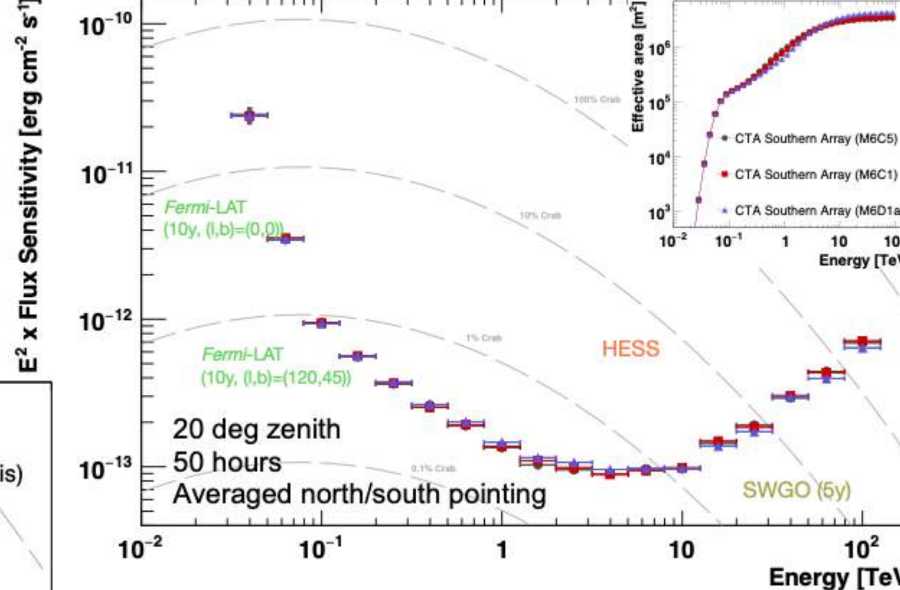
MACE Telescope

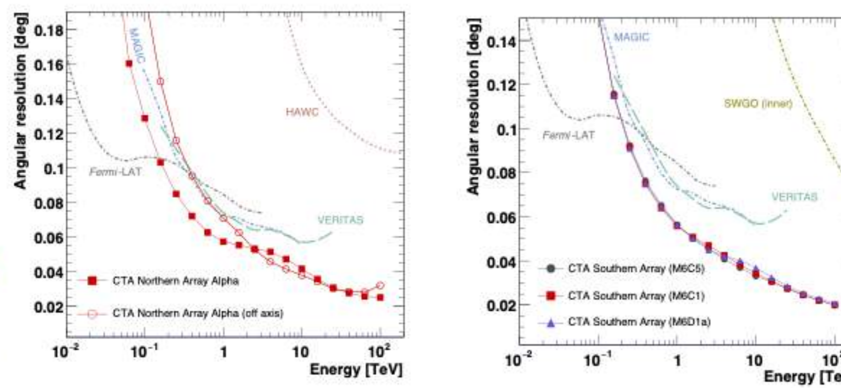


CTA: layout, design and performance









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O. Gueta

Status and results of LST-1 of CTA

First scientific contribution!

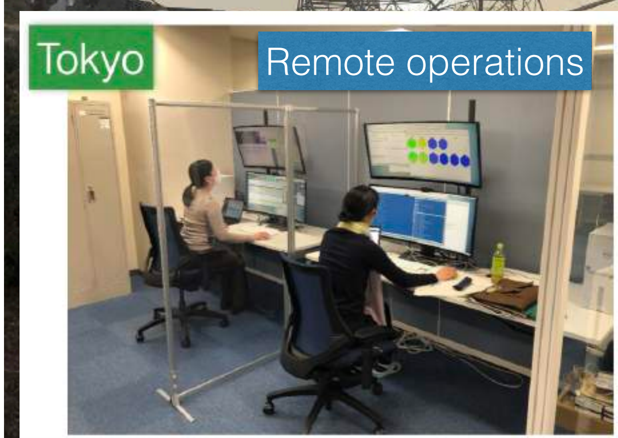
[Previous | Next]

Detection of very-high-energy gamma-ray emission from BL Lac with the LST-1

ATel #14783; *Juan Cortina for the CTA LST collaboration*
on 13 Jul 2021; 21:03 UT
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

Subjects: TeV, VHE, Request for Observations, AGN, Blazar, Transient

Several γ-ray sources during technical runs



D. Mazin

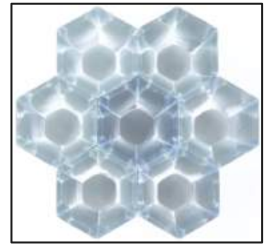
The LST Advanced SiPM Camera

- The proposed design shall take full advantage of the SiPM characteristics
  - ✦ Gain in duty-cycle, robustness, stability, self-calibration, etc…

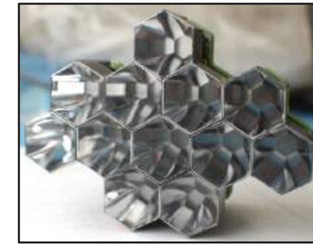
- The Advanced SiPM Camera must:
  - ✦ **outperform** the existing camera over the entire energy range
  - ✦ be **upgradable/reprogrammable**

- Baseline design:
  - ✦ Decreasing pixel size **from 0.1° to 0.05°**
    - Factor 4 in number of pixels
    - Tailored for Deep Learning based analysis
  - ✦ Going for **fully digital readout**
    - Real-time analysis
    - Real stereoscopic trigger

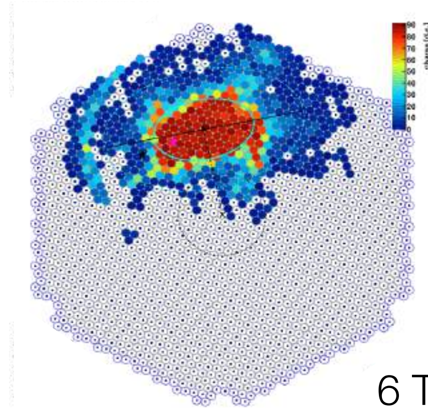
- Many challenges to tackle:
  - ✦ **Power consumption**
  - ✦ **Data throughput**
  - ✦ **Cost**
  - ✦ **5 years to complete 1st prototype**

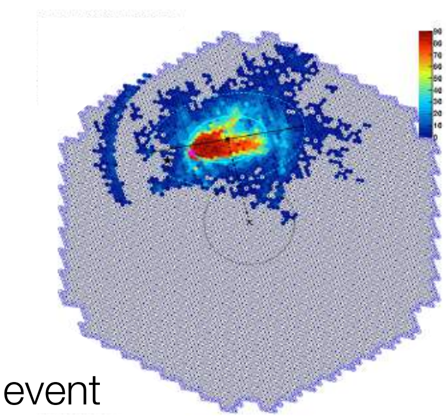


LST PMT camera **(0.1°)**



LST SiPM camera (**0.05°)**





6 TeV proton event

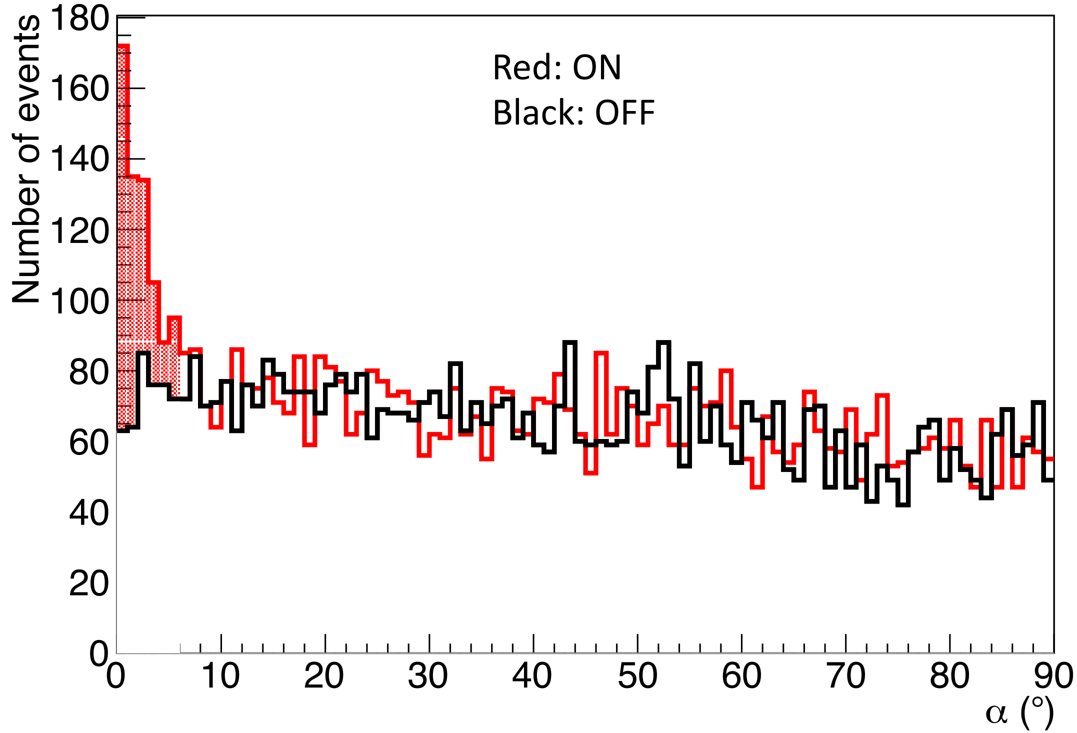
M. Heller on behalf of the CTA-LST Project - ICRC 20/07/2021

Summary

- The calibration of the FlashCam camera at MPIK shows excellent performance:
  - The camera runs dead time free at a trigger rate up to **30 kHz**
  - The non-linear regime extends the dynamic range up to **3,000 p.e.**
  - The charge resolution complies with the CTA benchmarks
- The FlashCam camera has run smoothly in CT5 for more than one and a half years
- The performance of the camera was stable and excellent:
  - The camera was available for data taking more than **98 %** of the time
  - Neither a single channel nor electronics board broke during operation
  - The internal temperature is controlled to be between **26 and 32 °C** throughout the whole year, with an RMS of less than **0.1 °C** during a 28-minute run and less than **1.5 °C** in one year
  - The PMT gains dropped roughly by **4 %** in one year, and the gain spread increased from **2.5 % to 4 %**
  - The trigger time spreads within a **± 500 ps** range
  - The trigger system was stable with a dead time significantly below **0.1 %**
- Science verification observations on several targets have been done
- The observation results have been reported in a companion poster presentation (16/07, 18:00)

pSCT Detection of Crab Nebula

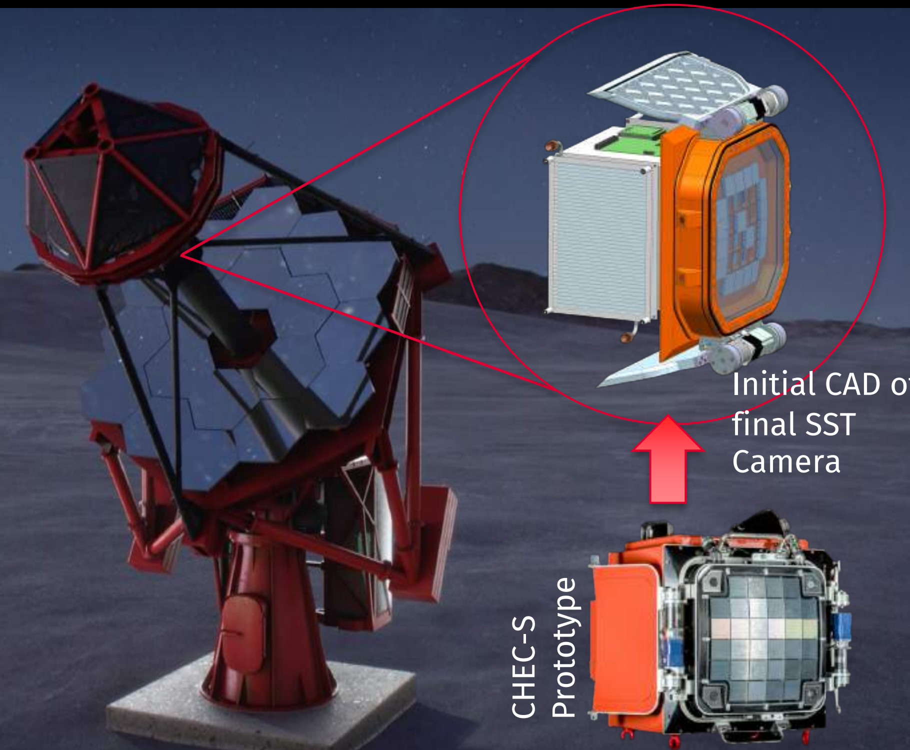
- Prototype Schwarzschild-Couder Telescope for CTA
- Prototype at the Fred Lawrence Whipple Observatory, AZ, USA
- 17.6 hours ON, 17.6 hours OFF, partial camera, $\alpha < 6°$
- Li-Ma significance of 8.6 σ
- Corresponds to average significance rate of 2.05 $\frac{\sigma}{\sqrt{t}}$, where t is the exposure time in hours
- C. Adams et al., *Detection of the Crab Nebula by the 9.7 m prototype Schwarzschild-Couder Telescope,* Astroparticle Physics **128** (2021) 102562.
- Ongoing upgrade to camera and subsystems to meet design sensitivity



The Small-Sized Telescopes for the Southern Site of the Cherenkov Telescope Array

Richard White (MPIK)
for the CTA SST Project

- CTA-South will contain 37 SSTs
  - Aimed at the highest energies (1 to >100 TeV)
  - ~1.5 arcminute angular resolution
- Based on the ASTRI & CHEC-S prototypes
- Telescope
  - Dual-Mirror Design
  - 4.3 m diameter primary
  - 1.8 m diameter secondary
- Camera
  - Compact (~50 x 60 x 60 cm)
  - 2048 SiPM pixels (6 mm^2)
  - Full waveform readout (1 GSa/s)
- SST Programme has been established and is working to optimise the design

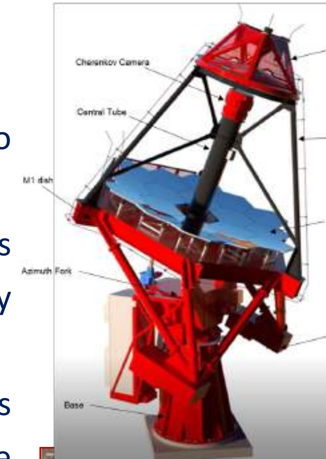


R. White

The ASTRI Mini-Array @ Teide Observatory

L.A. Antonelli for the ASTRI Project

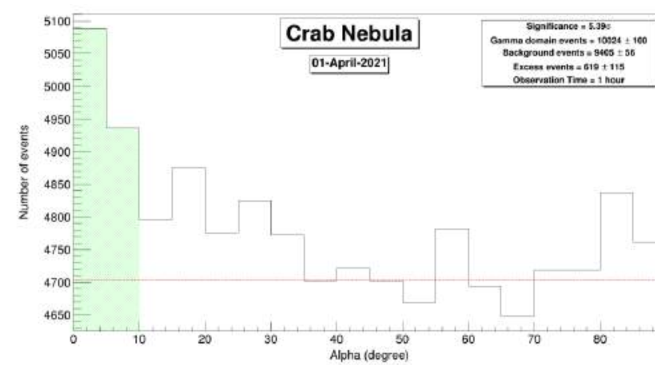
- ASTRI Mini Array is an International project leaded by INAF aimed to observe the northern gamma ray sky in the 1 – 200 TeV energy range.
- ASTRI Mini-Array is composed by 9 dual-mirror Cherenkov telescopes ASTRI-type to be deployed at Observatorio del Teide (Tenerife, Canary Islands) from the end of 2021.
- ASTRI Mini-Array Project is providing all the systems and sub-systems (hardware, software and infrastructures) needed for operating the telescopes, acquiring, archiving, analysing and distributing scientific data.
- Thanks to its sensitivity better than current IACTs (E > 5 TeV), its Energy/Angular resolution: ~10% / ~0.05° (E=10 TeV) and the Wide FoV (>10° - with homogeneous off-axis acceptance), ASTRI Mini-Array is going to play a major role in the observation of the gamma ray sky at the higher energies.
- The ASTRI Mini-Array will start scientific observations in 2024 with a 4 (core science) + 4 (observatory science) year program.



Status update of MACE gamma ray telescope

- MACE location: Hanle, Ladakh, India
- Site has unique advantages : Longitude (78^0 E), altitude (4270m asl) and clear nights
- Energy threshold of the telescope ~ 20 GeV
- Being low energy threshold instrument, distant AGN and pulsar are prime targets for MACE
- Remote operation from BARC, Mumbai
- Light collector: parabolic consisting of indigenously developed diamond turned aluminium honeycomb facets
- Camera 1088- PMT based camera: pixels resolution 0.125^0, capable of acquiring 1KHz event rate
- Crab Nebula detection ~ 80 sec.
- Installations completed, trial observations being conducted

Trial observations of Crab Nebula (for the purpose of status update)



K. Yadav

Discussion points: block 1

- YOUR QUESTIONS FIRST!

Discussion points: block 1

- YOUR QUESTIONS FIRST!

But, in case it does not flow…

- The SCTs have a wider field of view and better resolution, ideal for surveys, but are not part of the CTA alpha configuration; what is the foreseen timescale for addition of SCTs to the CTA array and the expected impact / strategy in revisiting CTA's early legacy survey programme?
- What are the principal factors in the decision for the final MST camera of CTA? Are important science operation impacts expected from the choice of one or another?
- MACE has great potential at the lowest energies: what are the prospects for very fast transient follow-ups, and how is your expected stereoscopic energy reconstruction at the lowest energies?
- How will the early science of LSTs be delivered, before CTA is working?
- What would be the impact of the SiPMs on the energy detection threshold of LST camera, and energy reconstruction at the low-energy spectral end?
- The ASTRI mini-array has unique combination of sensitivity and flexibility of operation, and should start working soon. Synergies with the particle array instruments like LHAASO are obvious. More than being a pathfinder for CTA, are there plans to long-term operation of the mini-array in the North?
- CTA-C will have a strong legacy KSP programme in the first decade; by the time, LHAASO and perhaps SWGO will be working in both hemispheres; how the results from these survey instruments are expected to shape the CTA-C KSP programme?

Block 2

Future Particle / Hybrid Arrays

SWGO HAWC

Imaging Atmospheric Cherenkov Array

RPC Carpet

STACEX

muons

Water Cherenkov Detectors

muons

LHAASO

muons

TAIGA

Atmospheric Cherenkov Timing Array

Plastic Scintillator Array

muons

Atmospheric Cherenkov Timing Array

ALTO

ALPACA

GRAPES-3

muons

muons

muons

Liquid Scintillator Array

Carpet-3

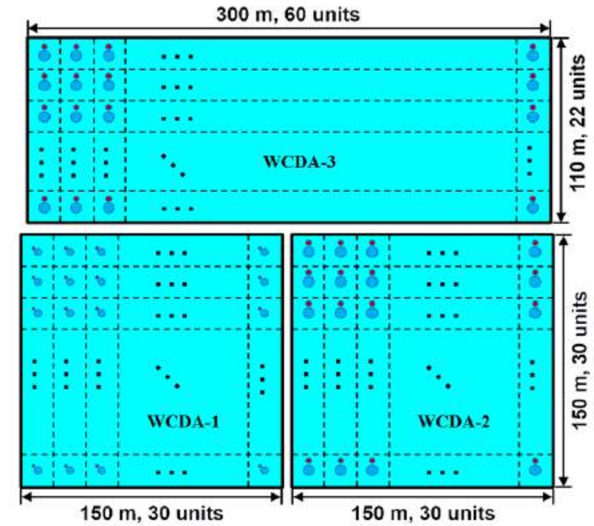
Proportional Counter Array

Operations of the LHAASO-WCDA

- Objective: ~100TeV - 30TeV gamma-ray sky;
- Divided into 3 separate arrays:

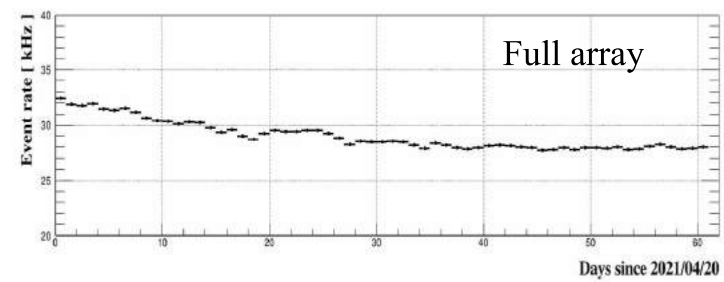
PMT	TTS (ns)	Dynamic range (PEs)	Manufacturer	Model number	Layout
8-inch	<3	1 - 4,000	Hamamatsu	CR-365	WCDA-1
1.5-inch	-	20 - 200,000	HZC Photonics	XP-3960	WCDA-1
20-inch	<6.5	1 - 1,800	NNVT	GDB-6203	WCDA-2&3
3-inch	-	1 - 3,000	HZC Photonics	XP-72B22	WCDA-2&3

More information and performance of PMTs are presented in ID-167, 1126, 1164



- Three phases:

Phases	Threshold (PEs)	Trigger model	Rate (kHz)	Raw data (TB/day)
WCDA-1 2019/4/16 - 2020/3/12	1/3	20 groups	20	3
Half array 2020/3/16 – 2021/3/4	1/3	15 hits, pattern	80	15
Full array 2021/3/5 – now	8inch: 1/3 20inch: 1	30 hits, pattern	30	12



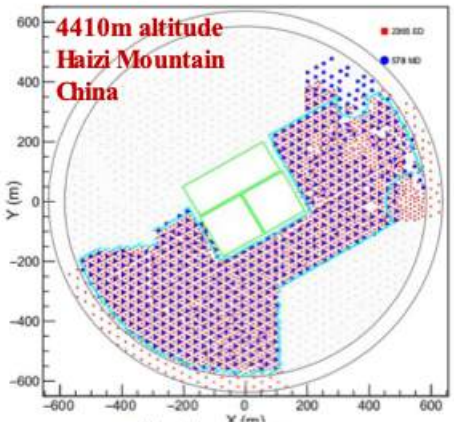
The preliminary analysis results are presented in other contribution in this conference: ID-897, 969, 1079, 1081, 1103.

The performances of the LHAASO-KM2A tested by the observation of cosmic-ray Moon shadow

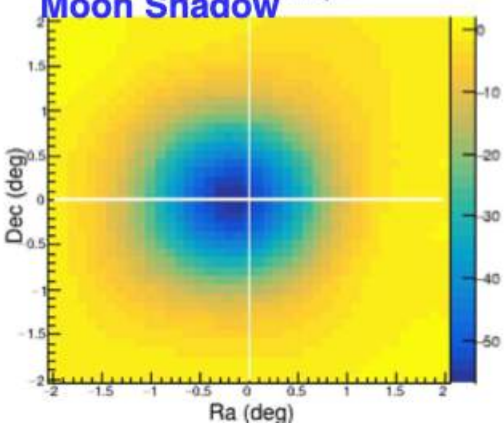
Y. C. Nan, S. Z. Chen, C. F. Feng on behalf of the LHAASO Collaboration E-mail: nanyc@ihep.ac.cn

LHAASO-1/2KM2A

- Time range: Nov 2019-Dec 2020
- Average duty circle: 90%



Moon Shadow



Scientific goals

- The ultra-high energy gamma-ray astronomy
- ...

The performance of 1/2 KM2A

- The **pointing error** is 0.02° ± 0.01° ;
- The observed **angular resolution** is in agreement with that from the simulation;
- The **relationship** between the **displacement** of the Moon shadow along the E-W direction and **Nfit** is also calculated to satisfy $((0.60 \pm 0.19)Nfit^{(0.36\pm 0.08)}$;
- Detector(the position of the Moon shadow, and the angular resolution) is very **stable** as time goes by.;
- **The pointing accuracy** on different dec bands is the same which is very important for the position of the ultra-high energy gamma sources observed by 1/2 KM2A in LHAASO.

More details can be found: https://pos.sissa.it/395/350

Y.C. Nan

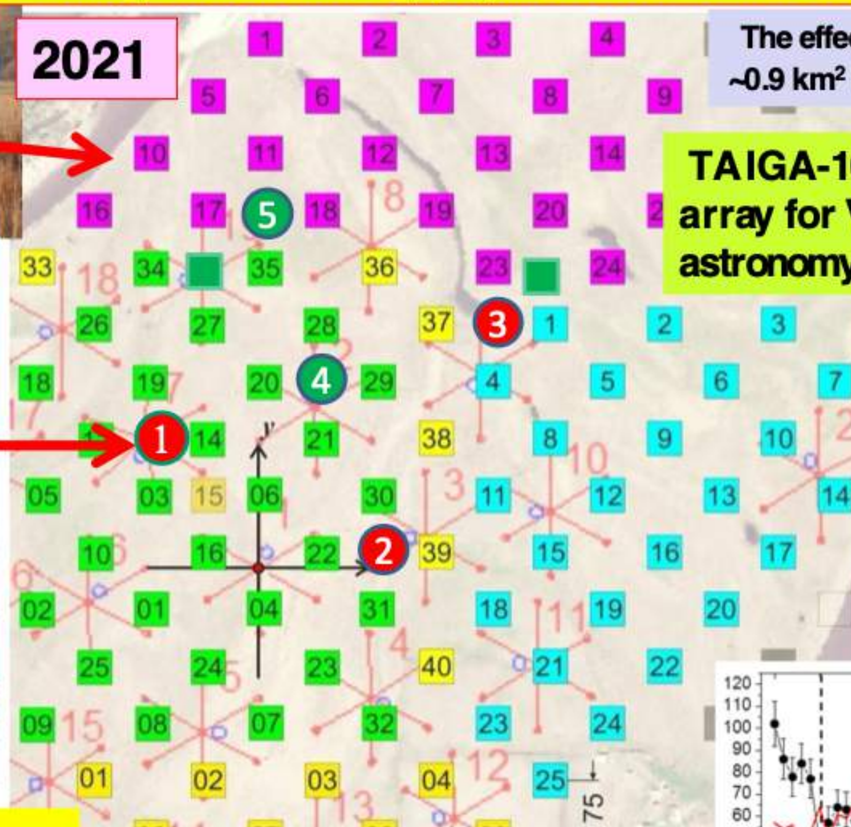
N.Budnev, L. Kuzmichev,
R. Mirzoyan for
TAIGA collaboration

The TAIGA - a hybrid detector for very High energy gamma-ray astronomy and cosmic ray physics in the Tunka valley, Siberia, Russia

TAIGA-HiSCORE

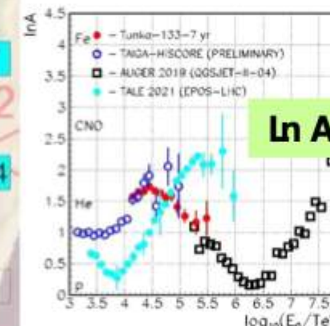
IACT in operation

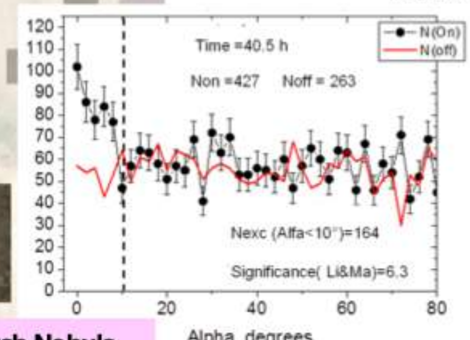
New IACT in 2022 and 2023y



The effective area for 5 IACT – ~0.9 km² at an energy of 20 TeV.

TAIGA-10 - 10 km² area array for VHE gamma-ray astronomy (> 50 TeV)





Crab Nebula

TAIGA – HiSCORE (timing):
angular resolution
~0.25° (for 68% E_{gamma} > 100 TeV)
TAIGA-IACT (imaging) &
TAIGA-Muon
- Gamma/ hadron separation

5 Hybrid events with E>100 TeV

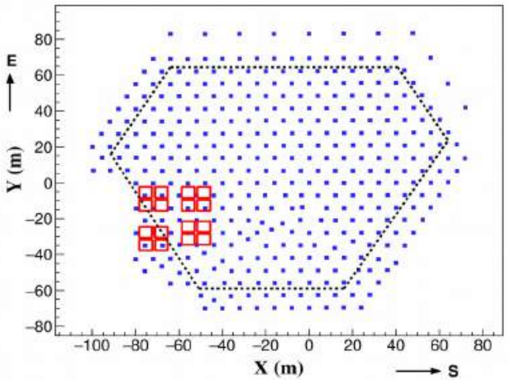
N. Budnev

Search for multi-TeV gamma rays from the Crab Nebula with the GRAPES-3 experiment

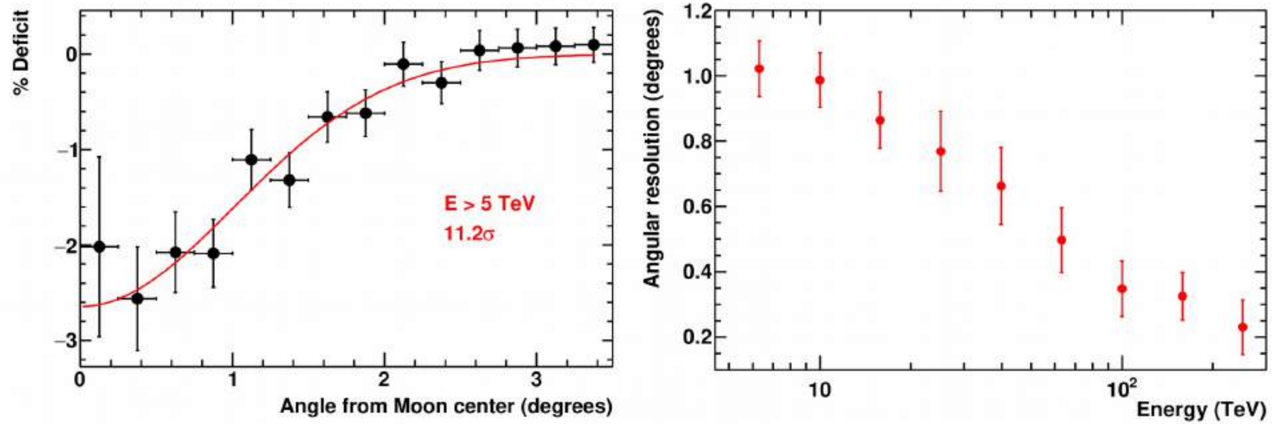
Diptiranjan Pattanaik, for the GRAPES-3 collaboration [PoS (ICRC2021)870]

GRAPES-3 array

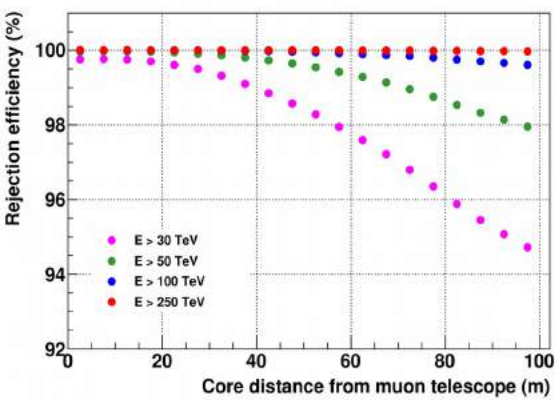
- Dense array of 400 SDs (25000 m²)
- Muon telescope (560 m²)



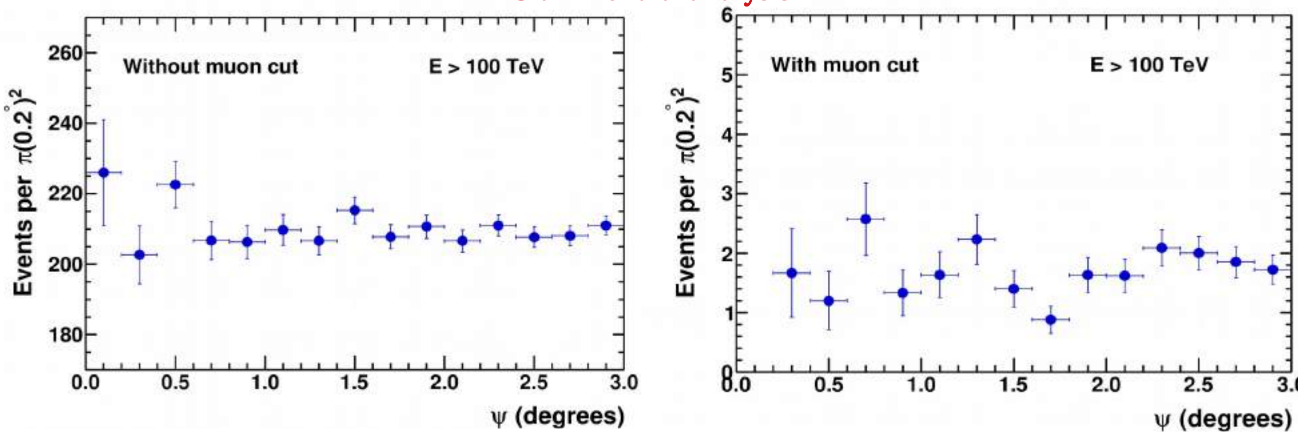
Angular resolution from the Moon shadow [PoS (ICRC2021)391]



CR rejection efficiency (%)



Crab Nebula analysis



D. Pattanaik

Baksan Neutrino Observatory of
Institute for Nuclear Research of the
Russian Academy of Sciences

The Carpet-3 EAS array: a current status

Romanenko Viktor, vsrom94@gmail.com
for the Carpet-3 Collaboration

Abstract

The Carpet-3 extensive air shower array (EAS) is now under construction at the Baksan Neutrino Observatory (43°16'37.2"N 42°41'24.0"E and 1700 meter above sea level). The array is located at an altitude 1700 meters above sea level, and it consists of surface detection stations, situated close to each other for best sensitivity to extensive air showers with lower energy, and of an underground muon detector with a continuous area of 410 m^2. The energy threshold for vertical muons is 1 GeV. The main aim of the array is to study the primary gamma radiation with energy above 100 TeV. The design of the Carpet-3 EAS array gives a possibility to carry out research on the composition of primary cosmic rays around the knee. It is planned that the Carpet-3 EAS array will be in full operation by the end of 2021.

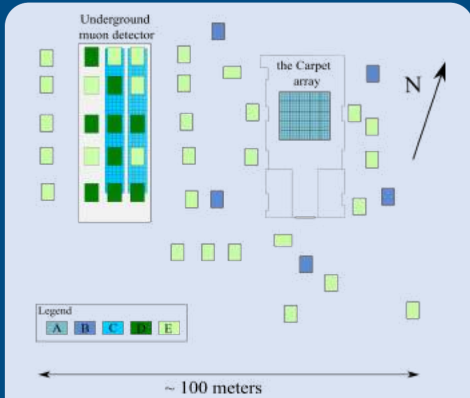


Figure 1. General scheme of the Carpet-3 facility.

(A) The Carpet array: 400 liquid scintillator (196 m2)
(B) 5 ground detector with 18 liquid scintillator (~9 m2) in each
(C) Underground muon detector: 410 plastic scintillators (410 m2))
New ground-based detectors, 9 plastic scintillators (9 m2) in each
(D) Ready to operate
(E) Detectors without plastic scintillators. Will be installed during 2021

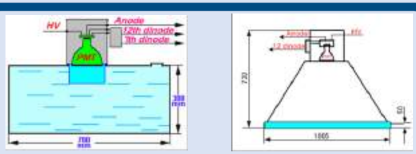
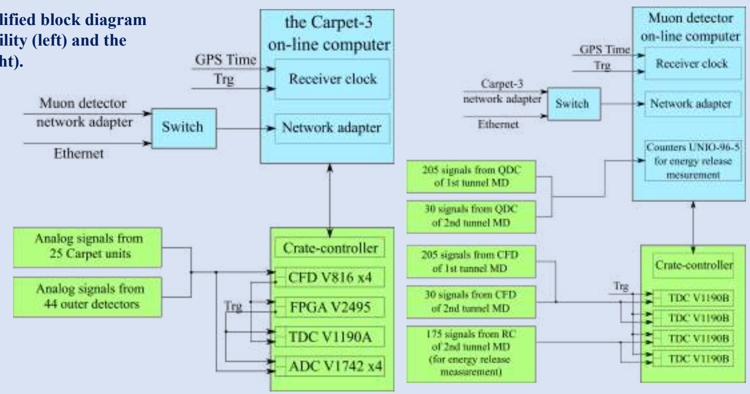
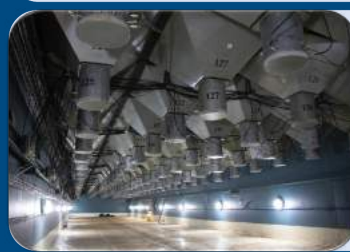


Figure 2. Scheme of a liquid scintillator (left) and a plastic scintillator counter (right).

Figure 3. The simplified block diagram of the Carpet-3 facility (left) and the muon detector (right).





The underground Muon Detector (MD), 410 m^2, 1 GeV threshold

Consists of two tunnels with dimensions 41x5 meters. It fills with standard plastic scintillation counters (Figure 2, right). 235 counters are equipped with the new electronics other 175 counters are equipped with old electronics (MD of the Carpet-2 EAS array) which will be upgraded in the future. New counters are using the constant fraction discriminator (CFD) to fix the time of arrival of the event and after to fed to the TDC for the measurements. The logarithmic converter of charge to the sequence of logic pulses (QDC) for measuring energy deposition in each counter. 175 counters are using the logarithmic resistor-capacitor (RC) module that converts the charge of the analog pulse to a logic signal of variable duration, where the charge is proportional to its duration and after to fed to the TDC for the measurements. The block diagram is shown in Figure 3 on the right.

DAQ System of Surface array

- (A) Crate controller
- (B-E) Caen CFD V816 (x4).
- (F) Caen TDC V1190 (x1)
- (G-I) Caen ADC V1742 (x3)
- and will be updated in the future

The surface array will consist of 39 new detectors, 5 old detectors, and 25 Carpet's modules. As shown in figure 1. The block diagram of the Carpet-3 EAS array data acquisition system is shown in figure 3, left. The analog signal from all detectors comes to the analog-to-digital converter (ADC) for the calculation of energy release in the detector also to the constant fraction discriminator (CFD) to fix the time of arrival of the signal. Signals from the CFD are sent to the time-to-digital converter (TDC) to measure the arrival time of the event. The trigger is generated using an FPGA based on signals from the CFD.

The Carpet-3 collaboration participants list

D. D. Dzhappuev,[1] Yu. Z. Afashokov,[1] I. M. Dzaparova,[1,2] T. A. Dzhatdoev,[3,1] E. A. Gorbacheva,[1] I. S. Karpikov,[1] M. M. Khadzhiev,[1] N. F. Klimenko,[1] A. U. Kudzhaev,[1] A. N. Kurenya,[1] A. S. Lidvansky,[1] O. I. Mikhailova,[1] V. B. Petkov,[1,2] E. I. Podlesnyi,[4,3,1] V. S. Romanenko,[1] G. I. Rubtsov,[1] S. V. Troitsky,[1] I. B. Unatlokov,[1] I. A. Vaiman,[4,3] A. F. Yanin,[1] Ya. V. Zhezher[1,5] And K. V. Zhuravleva[1]

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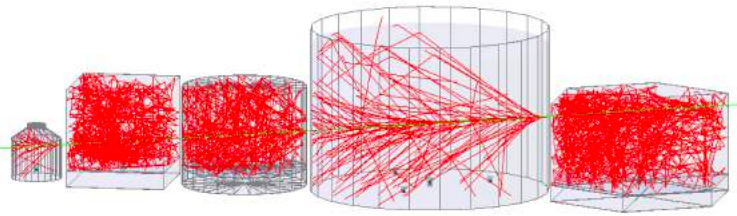
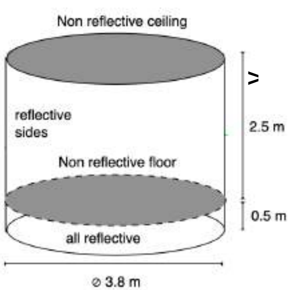
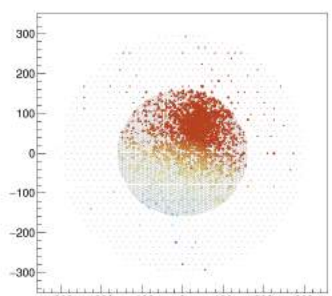
Simulating the performance of the Southern Wide-view Gamma-ray Observatory

Flexible Framework

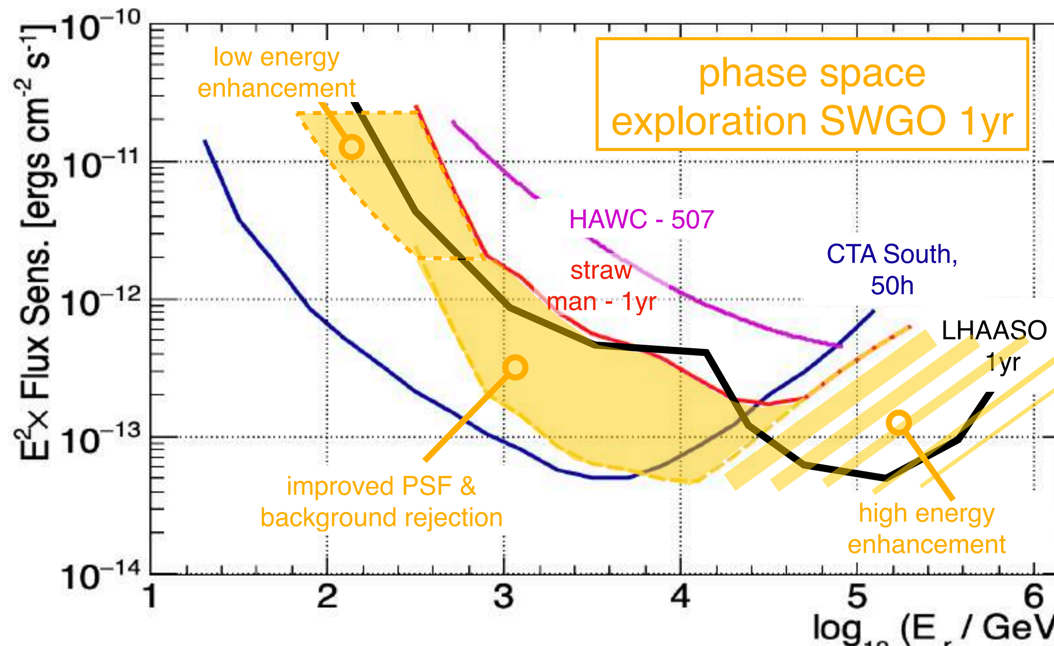


Starting Point





Exploration — coming year



Harm Schoolermmer

Expected performance of the ALTO particle detector array designed for 200 GeV - 50 TeV gamma-ray astronomy

M. Senniappan, Y. Becherini, M. Punch, S. Thoudam, T. Bylund, G. Kukec Mezek, J-P. Ernenwein

Linnéuniversitetet

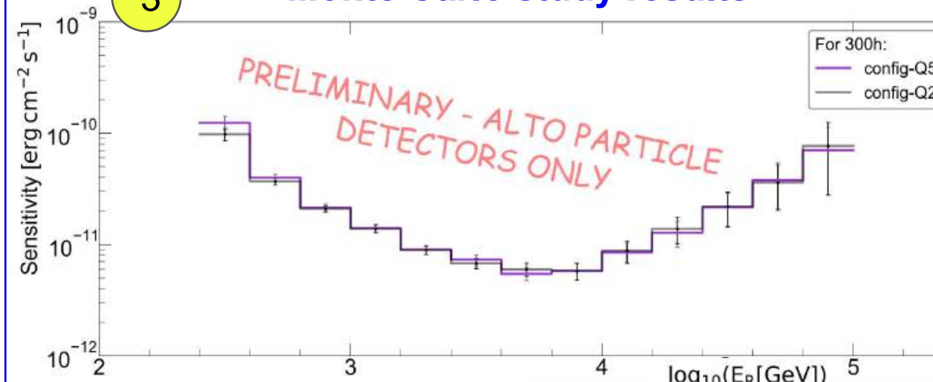
CoMET

1 The CoMET R&D project

Science goal: Extra-galactic gamma-ray astronomy

- The Cosmic Multiperspective Event Tracker (CoMET) R&D project focuses on the ground-based detection of very-high energy (VHE) gamma rays from 200 GeV to 50 TeV
- The future observatory is planned to be established at an altitude of ~5 km a.s.l. and it has a wide FoV of ~2 sr
- The proposed design consists of, (i) **an array of particle detectors (ALTO) to detect extensive air showers** (ii) atmospheric Cherenkov Light Collectors (CLiC)

3 Monte Carlo study results



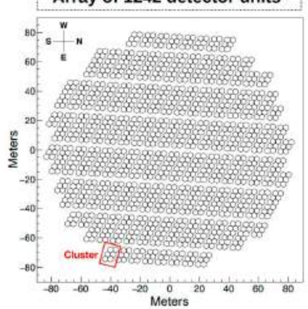
Expected spectral response for point-like VHE gamma-ray sources

VHE gamma-ray source	Approximate time to reach a 5-σ detection for config-Q2
GRB 180720B *	~ 38 seconds
PKS 2155-304 flare	~ 24 minutes
GRB 190114C	~ 31 minutes
Crab Nebula	~ 17 hours
PG 1553+113 flare	~ 21 days
PKS 2155-304 quiescent	~ 33 days

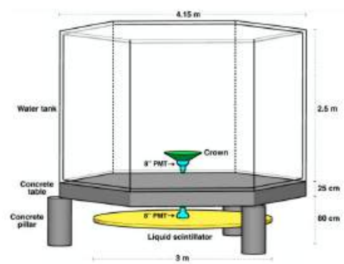
* Extrapolated to the time of Gamma-ray Burst (GRB) alert

2 Design of the ALTO particle detector array

Array of 1242 detector units



A single detector unit



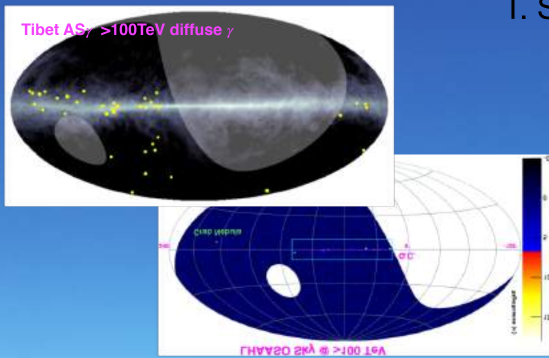
4 ALTO prototype

T. Sako

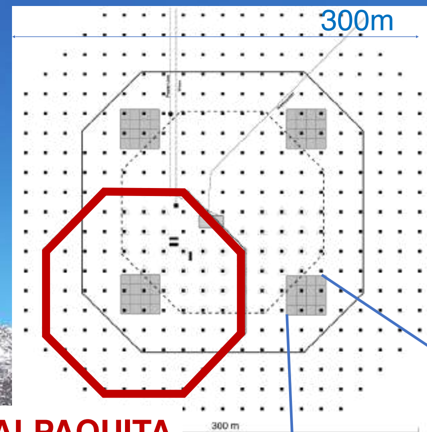
ICRC2021; ID777

Current status of ALPACA for exploring sub-PeV gamma-ray sky in Bolivia

T. Sako (ICRR, Univ. of Tokyo) for the ALPACA Collaboration



Exciting sub-PeV sky in North

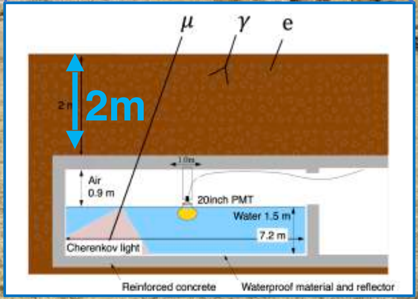


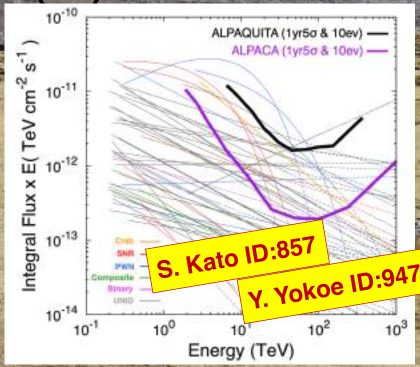
Infrastructure is ready
2021 ALPAQUITA will start
2022. ALPACA (half density)
2023.+ ALPACA (high density)
Future Mega (m²) ALPACA for PeV

Let us go to South, Bolivia!!

4,740 m above sea level
(16° 23′ S, 68° 08′ W)

ALPACA is a new array with Tibet type UG muon detectors





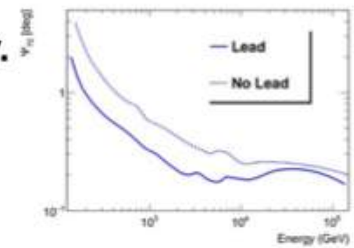
S. Kato ID:857

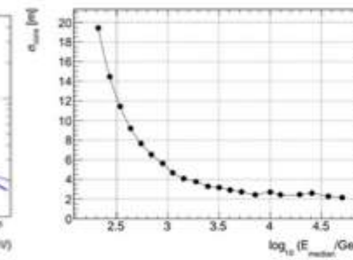
Y. Yokoe ID:947

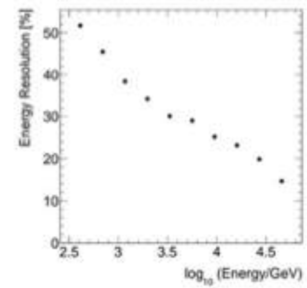
STACEX – Summary

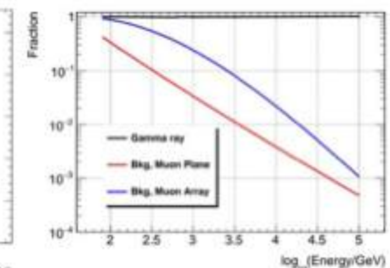
Gonzalo Rodríguez-Fernandez from Istituto Nazionale di Astrofisica

- We propose a gamma-ray observatory based on RPCs array.
  - Place at high altitude (~ 5km) on southern hemisphere.
  - Dimensions 150x150 m^2
  - A Lead plane of 1 Rad. Length above the RPCs
  - An array of Muon detectors buried on 2.4 m of soil

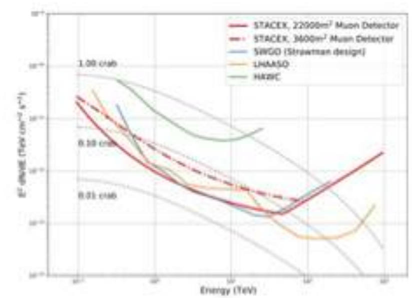






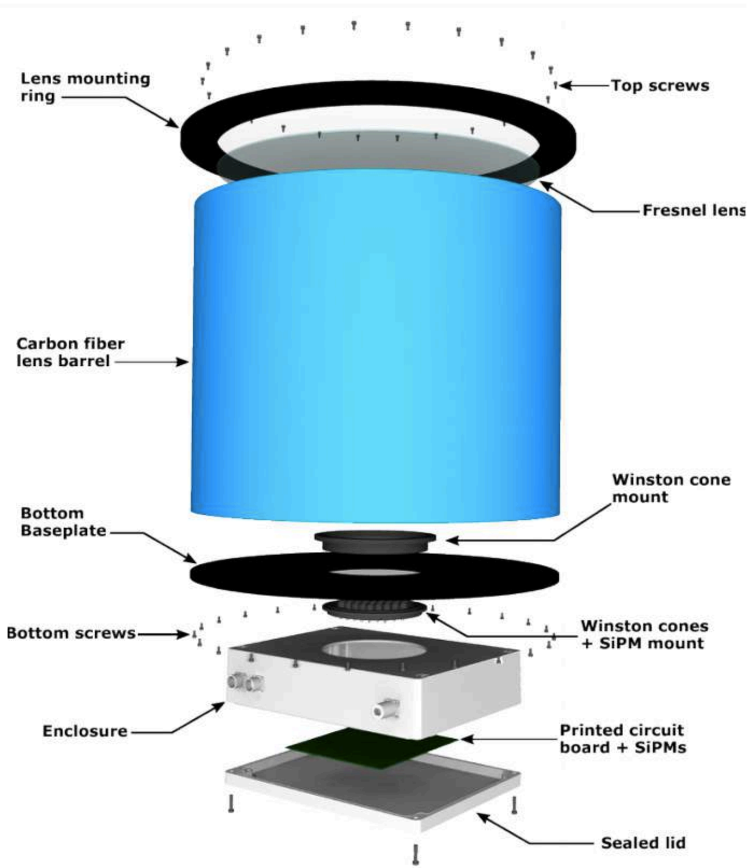


- From preliminary simulations we obtain:
  - Energy range from 100 GeV to 10 PeV
  - Angular resolution 0.24° for E > 1 TeV
  - Core resolution ~2 m for E > 10 TeV
  - Energy resolution of 22% for E > 10 TeV
  - Background free for energies above ~ 50 Te
  - Array LHAASO-like (scintillators + muon detectors) around the carpet (>0.5 km2) to increase the effective area above 100 TeV

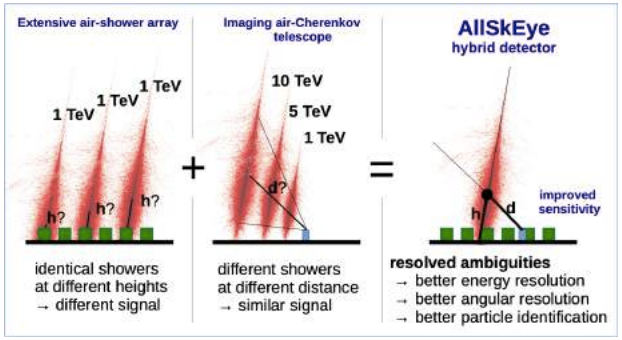


Simulation Performance of a 55 Imaging Air-Cherenkov Telescopes HAWC's Eye Array at High Altitude

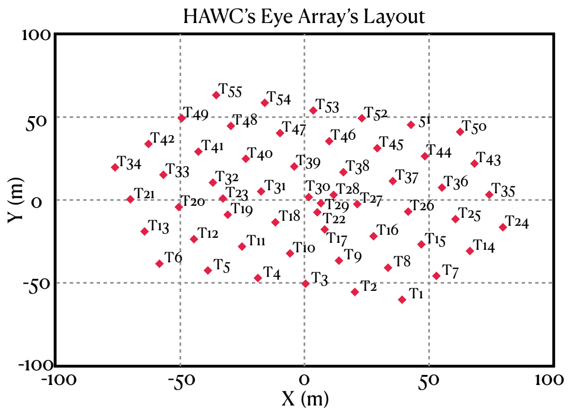
Imaging Air-Cherenkov Telescope HAWC's Eye



Motivation



HAWC's Eye Array Layout

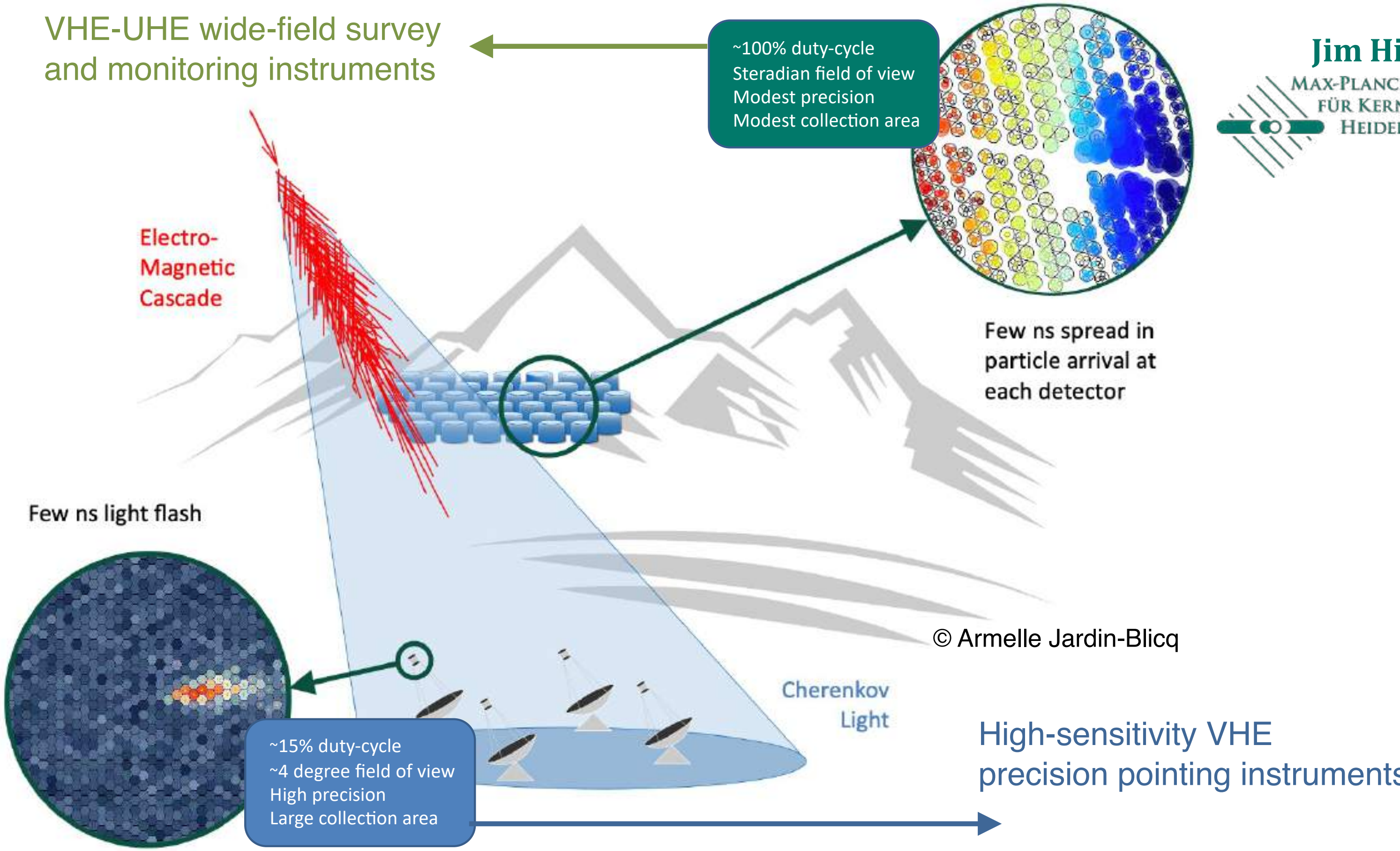


Results and Conclusions

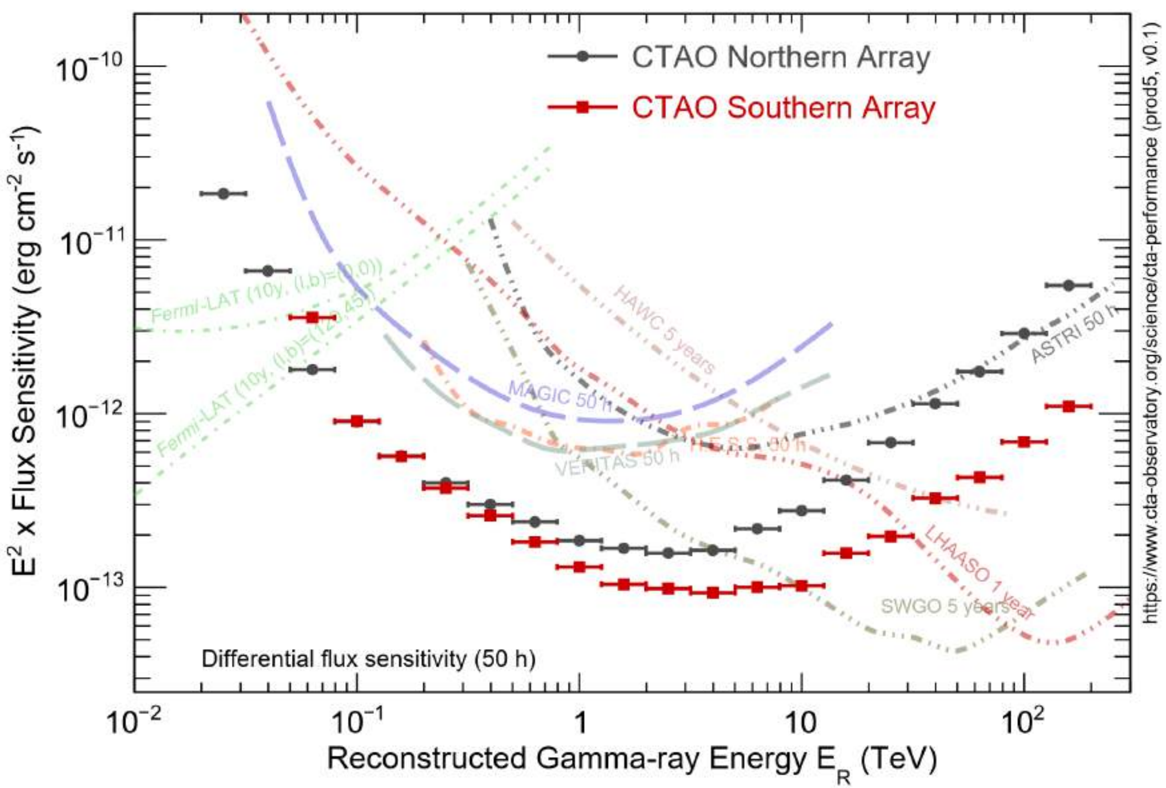
J. Franco-Serna

Synergies

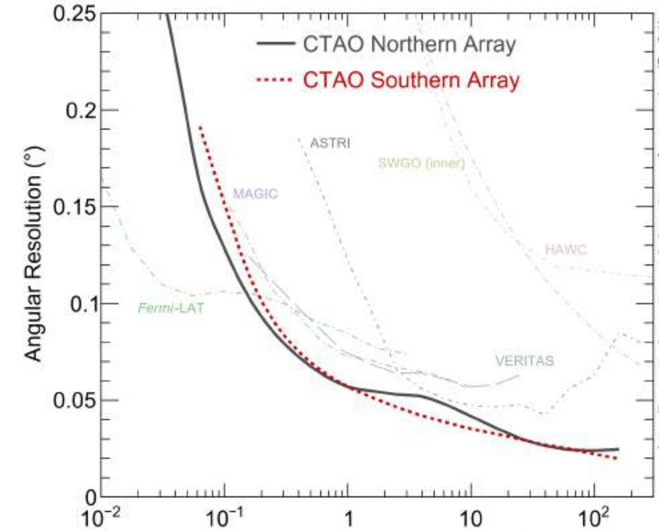
Jim Hinton
Max-Planck-Institut
für Kernphysik
Heidelberg



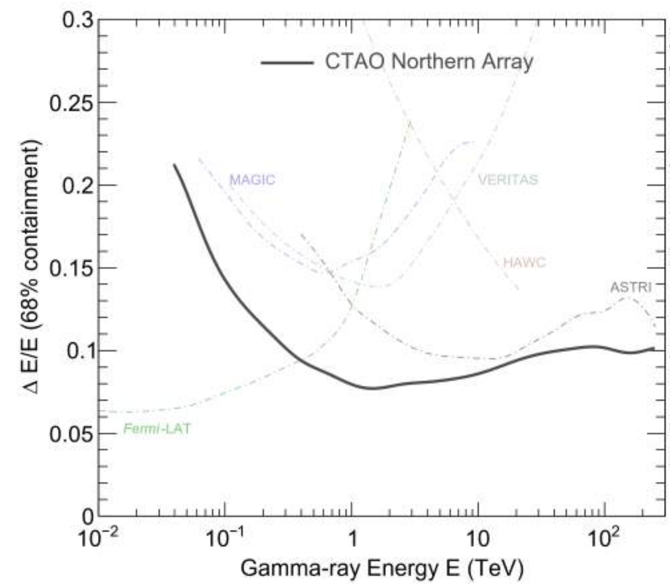
Synergies



CTAO Northern Array
CTAO Southern Array
Fermi-LAT (10y, (l,b)=(0,0))
Fermi-LAT (10y, (l,b)=(120,45))
MAGIC 50 h
VERITAS 50 h
H.E.S.S. 50 h
HAWC 5 years
ASTRI 50 h
LHAASO 1 year
SWGO 5 years
Differential flux sensitivity (50 h)
E² x Flux Sensitivity (erg cm⁻² s⁻¹)
Reconstructed Gamma-ray Energy E_R (TeV)
https://www.cta-observatory.org/science/cta-performance (prod5, v0.1)



CTAO Northern Array
CTAO Southern Array
ASTRI
SWGO (inner)
MAGIC
HAWC
Fermi-LAT
VERITAS
Angular Resolution (°)
https://www.cta-observatory.org/science/cta-performance (prod5, v0.1)



CTAO Northern Array
MAGIC
VERITAS
HAWC
ASTRI
Fermi-LAT
Δ E/E (68% containment)
Gamma-ray Energy E (TeV)
https://www.cta-observatory.org/science/cta-performance (prod5, v0.1)

Discussion points: block 2

- YOUR QUESTIONS FIRST!

ONLINE ICRC 2021 THE ASTROPARTICLE PHYSICS CONFERENCE Berlin | Germany 37th International Cosmic Ray Conference 12–23 July 2021

Discussion points: block 2

- YOUR QUESTIONS FIRST!

But, in case it does not flow…

- Regarding the water source for ALPACA, when do you plan to conclude the evaluation of potential water sources? When do plan to start operate the WCD of Alpaquita along with the scintillator array?
- What was TAIGA's low energy threshold in the Crab and Mkn 421 observations respectively? And in which range have you been able to do satisfactory spectral reconstruction, if spectral analysis already available?
- What is the current status of technological development and planned installation site for STACEX?
- Could you describe further the current upgrade status for GRAPES-3, and expected impact for gamma-rays observations?
- Could you describe further the current upgrade status or plans for Carpet-3? Why do you use liquid scintillator in the ground array of Carpet-3, instead of the same plastic scintillators used in the underground muon detector?
- Is the full LHAASO-WCD already operational, or when is it planned to? Also, the WCD and KM2A seem to be conceived as different experiments. Could they be used in hybrid mode in order to improve the overall sensitivity of the detector over the range few TeV to several tens TeV?
- Concerning the phase space exploration for SWGO: could you explain what are the main array parameters being investigated to explore performance at different energy ranges, and how these parameters might be or not tied / constrained by given detector solutions under consideration (e.g. tanks or lake / pond deployment)?
- HAWC's eye: can you comment on the magnitude of improvement on energy and angular resolution expected?
- What's the planned altitude and installation site for ALTO, and what is the principal expected performance contribution of the possible air-Cherenkov array extension?