

Auger-Italy Meeting 3-5 February 2025

AugerPrime overview

Antonella Castellina

INFN, Sezione di Torino



Phase II: exploiting the richness of extensive air showers













Composition information can be derived from

Measure of the longitudinal development of the extensive air showers (EAS) while crossing the atmosphere Fluorescence telescopes

Discrimination between the electromagnetic and muonic components of the EAS

→ Water Cherenkov Stations and Scintillators

Measure of the radio emission of EAS ► Radio antennas

Direct measure of the muonic component
Underground detectors

performing hybrid measurements and applying new analysis techniques





Deployment

- WCD (UUB+SPMT) and SSD completed in summer 2023
- RD completed in December 2024

RD

3000

310

23

~3

• UMD completion foreseen in mid 2025 (UMD-SD433 already completed, UMD-SD750 73%)



		SD			FD
lg(E/eV)	433	750	1500	hybrid	Cherenkov
16.8	118000				48000
17.5	3700	81000			4400
18.0	270	5600		13000	
18.5	24	460	106000	3000	
19.0	5	88	13400	650	
19.5			1000	50	
19.8			100	~ 5	
20.0			12	~ 1	
20.0			14	1	







Deployment

- WCD (UUB+SPMT) and SSD completed in summer 2023
- RD completed in December 2024

RD

3000

310

23

~3

• UMD completion foreseen in mid 2025 (UMD-SD433 already completed, UMD-SD750 73%)



		SD			FD
lg(E/eV)	433	750	1500	hybrid	Cherenkov
16.8	118000				48000
17.5	3700	81000			4400
18.0	270	5600		13000	
18.5	24	460	106000	3000	
19.0	5	88	13400	650	
19.5			1000	50	
19.8			100	~ 5	
20.0			12	~ 1	
20.0			14	1	







Deployment

- WCD (UUB+SPMT) and SSD completed in summer 2023
- RD completed in December 2024
- UMD completion foreseen in mid 2025 (UMD-SD433 already completed, UMD-SD750 73%)



		SD			FD
lg(E/eV)	433	750	1500	hybrid	Cherenkov
16.8	118000				48000
17.5	3700	81000			4400
18.0	270	5600		13000	
18.5	24	460	106000	3000	
19.0	5	88	13400	650	
19.5			1000	50	
19.8			100	~ 5	
20.0			12	~ 1	
20.0			14	1	





Array performance

- Smooth transition in data taking of high quality events
- »Luminosity« curves from Phase I to Phase II reflect the same







AugerPrime - SDEU Working Group

- Started in 2021
- Bi-weekly meetings (Tuesdays 16:00 CET)
- Minutes and slides in <u>https://www.auger.unam.mx/AugerWiki/SDEU_Front_Page</u>
- Open work packages
 - Performance of modified TPCBs
 - RD Effects on SSD / WCD
 - Check for UMD interference on SD
 - LPMT commissioning / quality cuts
 - check of online calibration [Fabio GSSI]
 - LPMT calibration: 1 vs. 3 fold histogram trigger
 - monitoring / calibration of full bandwidth / compatibility VEM TBD
 - define monitoring alarms
 - check PMT-mask
 - define quality cuts
 - monitor noise situation
 - list for cabling checks
 - sPMT quality cuts [Gialex, Alessio TO/CT]
 - identify bad sPMTs
 - cross-check bad LPMTs for sPMT-calibration
 - estimate influence of 'low-signal' conditions (air)
 - SSD commissioning / quality cuts
 - online calibration calibration task [Matteo, Gabriella, Daniele LE]
 - signal timing

Tiina, Dave and Martin

Italy involvement: GSSI, LE, TO [now also CT/PA for PMT test-bed]

- signal accuracy for all PMTs
- GPS time offset (for hybrids) [Fabio GSSI]
- Triggers
 - ToT rate (summer)
 - Low ToT-rate stations
 - ToT stations with 3 PMTs
 - check full efficiency threshold
 - lightning problems
- are all station affected?
- ToTd
- \circ MoPS

Other actions currently on-going:

- patterns in up-time
- modification of TPCBs, deployed with RD-digitizers
- Keep high priority for PMT maintenance [Antonio, Francesco TO]
- cabling: to be checked / corrected when hatch cover is opened
- grounding: check status of grounding rod in wet areas



AugerPrime - towards ICRC2025

Aim: Establishing a Phase II data set to

- showcase e.g.
 - hybrid events,
 - average LDFs,
 - signal ratios (S_{SSD}/S_{WCD} or similar)
- or more quantitively
 - comparisons between UB/UUB (signal accuracy, time resolution, calibration)
 - spectrum (without exposure, but normalized to reference point?)

Phase II data currently undergoing commissioning many issues in calibration / foundations / DPA/OffLine very low human-power !



Phase II targets in the production

	1500 m	750 m	433 m	Othe
SD	SD SDHAS	SDInfill SDInfillHAS	SD433	
SD+FD	Golden GoldenHAS	GoldenInfill GoldenInfillHAS	GoldenSD433	Hybri
SD+UMD		MD-SD750	MD-SD433	
SD+RD	RD-SDHAS			
FD				FDMo BrassH



AugerPrime - towards ICRC2025

TASK FORCE: Established at the 2024 November meeting

- TF leaders
 - Carla Bonifazi
 - David Schmidt
 - Darko Veberic
- Limited time of about 4 months
 - Deadline for ICRC2025 abstracts submission: March 1

AIM: address and validate the items needed to get high quality data

- Define and validate bad periods and hexagon calculation
- Define and validate Quality cuts for all the PMTs (WCD large and small, SSD)
- Define and validate the OffLine version including all the needed information



Task	Subtask	Assignment								
PMT quality cuts (Phase II)	Define cuts	Max Stadelmaier [MI] (C+	+, ADST, Offline)	Carla Bonifazi	^{3onifazi} AugerPrime - towar)2		
	Implement in merging scripts	Isabelle Lhenry-Yvon [Orsa production scripts)	Isabelle Lhenry-Yvon [Orsay] (C++, merging/ production scripts)							
	Run Offline Phase II productions with new PMT-cut merged files	 Berenika Cermakova [KIT] (C++, ADST, Offline) Nicolas Gonzalez [ITeDA, Torino] Max Stadelmaier [MI] (C++, ADST, Offline) 			People approached personally to get direct commitment Bi-weekly meetings					
	Assess impact on reconstructions (station/event loss, residuals, outliers, etc.) relative to previous iteration of cuts									
Bad Periods (Phase II)	Set up continuous Offline production of SD targets for 1500, 750, and 433 m arrays	David Schmidt (C++, ADST, Offline)		Carla Bonifazi	Specific meetings for each sub-task, handled by the coordin					
	Modify and automate script for dumping variables	Darko Veberic (C++, ADST, Offline)								
	Modify Bad Period scripts to ensure proper calculation for Phase II and perform production for available data set	Isabelle Lhenry-Yvon (C++, merging/production scripts)				lta	Italy involvement: MI. LE.			
Validation of production		Phase I	Phase II				, , , , , , , , , , , , , , , , , , ,	,		
targets (events / hexagon as function of time,	SD-1500 vertical	Adriel MOCELLIN (Mines)	Adriel MOCELLIN (Mines)	Darko Veberic	; S(1000) SSD	Fix SSD status in Offline	Matteo Conte (LE) (C++, ADST)	Dav		
distributions of zenith/azimuth, distributions of	SD-1500 inclined	Jorge CARAÇA- VALENTE BARRERA	Jorge CARAÇA- VALENTE BARRERA			Implement data-driven LDF and signal uncertainties from Luis Bellm in	Matteo Conte (LE)	_		
shower sizes / muon	SD-750 vertical	Marta Bianciotto (TO)	Marta Bianciotto (TO)				ScintillatorLDFFinder Check LDF residuals	Kevin Cheminant / Matteo Conte (LE)	_	
gain/loss in event statistics, etc.)	SD-433 vertical	José Ochoa (ITeDA)	José Ochoa (ITeDA)				Define event selection (e.g. hottest station has scintillator) and check energy/zenith-	ר Kevin Cheminant (ADST, Offline)		
	FD hybrid	Nikolas DENNER (Praque)	Nikolas DENNER (Prague)	Alexey, Francesco		Check distributions for outliers/issues	Kevin Cheminant (ADST, Offline)			
	UMD SD-750	Joaquin, Marina, Nico	Joaquin, Marina, Nico	Federico Sanchez Belen Rodriguez	Validation of UUB (WCD+SSD) simulations	Check that integration window makes sense (starts where it should not clearly cutting off signals)	Margita KUBATOVA (Prague)	Ale		
	UMD SD-433	Ezequiel	Ezequiel			Compare magnitudes of SSD and WCD signals for fixed MC energy (UB vs. UUB)	Margita KUBATOVA (Prague)			
	Universality	Lorenzo Apollonio (MI)	Lorenzo Apollonio (MI)	Darko Veberic	UMD module/channel quality cuts	Identify remaining unmasked broken modules/channels (they're there)	TBD	Be		
		Max Stadelmaier (MI)	Max Stadelmaier (MI)			Ensure they are masked in Offline reconstruction	TBD			









Variable	Description of necessary work
S(1000), S(450), E, and â from the classic WCD vertical LDF reconstruction	 PMT quality cuts in place Validation of the production data (SD-1500 and SD-750 targets)
N ₁₉ and â from the classic WCD horizontal reconstruction	 PMT quality cuts in place Validation of the production data (SD-1500)
S(1000) for the SSD LDF reconstruction	 Implement LDF parameterization signal uncertainty model from L Bellm Check LDF residuals Quality criteria for use of S(1000 analysis (e.g. hottest station muchave SSD) preferably resulting energy-independent efficiency
	 Efficiency of SSD LDF reconstru- as a function of energy
X_{\max} and R_{μ} from Universality reconstruction (preliminary)	 Get Universality code running a (currently crashing) Validate X_{max} and R_µ values corrout of reconstruction (e.g. comp with Phase I distributions and G Hybrids for Phase II)
$\rho(450)$ and ρ_{35} from the UMD reconstruction	 Validate ρ(450) / ρ₃₅ coming out reconstruction with official Offlin
E, X_{max} , and \hat{a} from the FD reconstruction (only up until the end of 2023)	 Validate X_{max} and energy reconstruction with UUB timing information
Electromagnetic energy from the RD reconstruction	TBD
Hexagon (exposure) and Bad Periods files for the SD-1500 and SD-750	 Offline production with functionit Dump required variables to calc bad periods and send to Isabell Have a look at Bad Periods and they make sense

k		
e ion data sets argets)	AugerP	
e ion data sets	Quantities to	
erization and from Luis	High quality multi-hyb	
f S(1000) for tion must resulting in	Selection of events red detectors	
econstruction		
nning again		
ues coming g. compare s and Golden		
ning out of al Offline tag		
timing		
unctioning tag to calculate Isabelle ods and see if		

rime - towards ICRC2025

produce and validate

brid event selection

	Selection of events recorded by several detectors		Identify events of various multi-h configurations Plot LDFs, time traces





- Commissioning must continue
- It has to be strictly linked to maintenance
- The monitoring is fundamental

- Publications
 - SDEU: AugerPrime Surface Detector Electronics [JINST 18 (2023)]- TO
 - SSD: collaboration review phase LE
- Contributions to ICRC:
 - UMD results
 - RD Reconstruction
 - First physics results (?)
 - CDAS
 - Electronics
 - RD status

All groups should consider to contribute to the service tasks and to the analysis of Phase II data





Hybrid measurements and data complementarity



14



sPMT cross-calibration

$$S_{\text{SPMT}}/\text{VEM} = \beta Q_{\text{SPMT}}/(\text{ADC counts})$$

- WCD PMTs vs sPMT





FD calibration: XY Scanner

- Scan complete telescope aperture (~1700 positions) with uniformly emitting, absolutely calibrated light source on rail system
- Permanent infrastructure installed at all telescopes
- 23/27 telescopes measured at least once / 4 in LL missing. Another currently ongoing.
- Systematic uncertainty in absolute calibration of the fluorescence detectors of 6% (as compared to 9% with former large-diameter source)
- Reduction to 4% by improving setup for light source calibration expected
- E.g. mirror cleaning in HEAT 1 increases the signal by 7% (campaign ongoing identifying/eliminating inconsistencies)











Assembled ACQ board





Example of assembled SiPM board

σ

of them



Example of a 😩

yet ested

Š tested σ

solved en Đ 0 S een ອ 2 CITIROC has CBs Δ





1111





e set at





RD calibration

2019

- Based on procedures established in Auger Engineering Radio Ar
- Elements:
 - Lab measures of response of hardware components (e.g. temperature dependence of radio signals under expected fie conditions)
 - Simulation + measurement of directional response of full signature (drone important for validation, especially in regime with ground r which are more difficult to model)
 - Milky Way radio emission source for absolute calibration (models in 30-80 MHz frequency band compared with measurem
- Essentially no aging effects observed in calibration procedure $(0.3 \pm 1.4)\%$ / decade



ray (AERA)) Uncertainty (propagated to primary energy)				
eld	~5%				
nal chain reflections,	~10%				
nents)	~6%				
	Goal: < 10% AERA 14%				
	EAST-WEST				
┺ ┙					

2020

Measured power dataset:



Simulated dataset + fitted noise







