Cosmic collisions

CERN's IT faces the challenges of Run 2

NA62
The kaon factory will take data until 2018

SIXTY YEARS OF JINR
Celebrating the institute's past, present and future
Covering current developments in high-energy physics and related fields worldwide

CERN Courier is distributed to member-state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August. The views expressed are not necessarily those of the CERN management.

Editor Antonella Del Rosso
Books editor Virginia Greco
CERN, 1211 Geneva 23, Switzerland
E-mail cern.courier@cern.ch
Fax +41 (0) 22 76 69070
Web cern.courier.com

Advisory board Luis Alvarez-Gaume, Peter Jenni, Christine Sutton, Claude Amstler, Roger Balej, Philippe Bloch, Roger Forty

Laboratory correspondents:
Argonne National Laboratory (US) Tom LeCompte
Brookhaven National Laboratory (US) P Yamin
Cornell University (US) D G Cassel
DESY Laboratory (Germany) Till Mundzeek
EMFSC (Italy) Anna Cavallini
Enrico Fermi Centre (Italy) Guido Piragino
Fermi National Accelerator Laboratory (US) Katie Yurkewicz
Forschungszentrum Jülich (Germany) Markus Buescher
GSI Darmstadt (Germany) Peter Hagemann
INFN (Italy) Antonella Varaschin
Jefferson Laboratory (US) Steven Corneliusen
KEK National Laboratory (Japan) Saeo Okada
Lawrence Berkeley Laboratory (US) Spencer Klein
Los Alamos National Laboratory (US) Rajan Gupta
NCSL (US) Ken Kingery
Nikhef (Netherlands) Robert Fleischer
Novosibirsk Institute (Russia) S Edelman
Orsay Laboratory (France) Anne-Marie Lutz
PSI Laboratory (Switzerland) P-R Kettle
Saclay Laboratory (France) Elisabeth Locci
Science and Technology Facilities Council (UK) Jane Binks
SLAC National Accelerator Laboratory (US) Farnaz Khadem
TRUMF Laboratory (Canada) Marcello Pavan

Produced for CERN by IOP Publishing Ltd
IOP Publishing Ltd, Temple Circus, Temple Way, Bristol BS1 6HG, UK
Tel +44 (0)117 929 7481

Publisher Susan Curtis
Production editor Lisa Gibson
Technical Illustrator Alison Tovey
Group advertising manager Chris Thomas
Advertisement production Katie Graham
Marketing & Circulation Angela Gage

Head of B2B & Marketing Jo Allen
Art director Andrew Giaquinto

Advertising
Tel +44 (0)117 930 1026 (for UK/Europe display advertising) or +44 (0)117 930 1164 (for recruitment advertising);
E-mail: sales@cerncourier.com; fax +44 (0)117 930 1178

General distribution: CERN Adressee, CERN, 1211 Geneva 23, Switzerland
E-mail: courier-adresse@cern.ch
In certain countries, to request copies or to make address changes, contact:
China Yaou Jiang, Institute of High Energy Physics, PO Box 918, Beijing 100049, People’s Republic of China
E-mail: jiangyo@mail.ihep.ac.cn
Germany Antje Brandes, DESY, Notkestr. 85, 22607 Hamburg, Germany
E-mail: desypr@desy.de
UK Mark Wells, Science and Technology Facilities Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1SZ
E-mail: mark.wells@stfc.ac.uk
US/Canada Published by Cern Courier, 8N246 Willow Drive, St Charles, IL 60175, US. Periodical postage paid in St Charles, IL, US
Fax +1 630 377 1569. E-mail: creative_mailing@att.net
POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147, St Charles, IL 60174, US

Published by European Organization for Nuclear Research, CERN, 1211 Geneva 23, Switzerland
Tel +41 (0) 22 767 61 11. Telefax +41 (0) 22 767 65 55
Printed by Warners (Midlands) plc, Bourne, Lincolnshire, UK

© 2016 CERN ISSN 0304-288X

---

CERN Courier

Volume 56 Number 5 June 2016

5 Viewpoint

7 News
• Data to physics • Short but intense... • CMS benefits from higher boosts for improved search potential in Run 2 • Theatre of Dreams: LHCb looks to the future • ATLAS explores the dark side of matter • ALICE probes small-system dynamics with charm production at the LHC • MoEDAL releases new mass limits for the production of monopoles • BEPCII reaches its design luminosity

13 ScienceWatch

15 Astrowatch

16 Features
CERN’s IT gears up to face the challenges of LHC Run 2
Complex collision events challenge computing requirements.

21 Data preservation is a journey
Taking on the challenge of preserving “digital memory”.

24 NA62: CERN’s kaon factory
The experiment is fully in the data-taking period.

27 Particle flow in CMS
Algorithm aims to identify and fully reconstruct particles coming from collisions.

29 AugerPrime looks to the highest energies
The world’s largest cosmic-ray experiment, the Pierre Auger Observatory, is embarking on its next phase, named AugerPrime.

33 Interactions & Crossroads

37 Faces & Places

44 Recruitment

47 Bookshelf

50 Archive

---

On the cover: Artist’s rendering of a cosmic-ray air shower with a surface detector of the Pierre Auger Observatory in Argentina. (Image credit: Montage: Helmholtz Alliance for Astroparticle Physics /A Chantelauze; Photo: University of Adelaide/S Saffi; Cosmic Shower: ASPERA/Novapix/L Bret.)
Since the start of its operations in 2004, the Auger Observatory has illuminated many of the open questions in cosmic-ray science. For example, it confirmed with high precision the suppression of the primary cosmic-ray energy spectrum for energies exceeding $5 \times 10^{19} \text{eV}$, as predicted by Kenneth Greisen, Georgiy Zatsepin and Vadim Kuzmin (the “GZK effect”). The collaboration has searched for possible extragalactic point sources of the highest-energy cosmic-ray particles ever observed, as well as for large-scale anisotropy of arrival directions in the sky (CERN Courier December 2007 p5). It has also published unexpected results about the specific particle types that reach the Earth from remote galaxies, referred to as the “mass composition” of the primary particles. The observatory has set the world’s most stringent upper limits on the flux of neutrinos and photons with EeV energies (1 EeV = $10^{18} \text{eV}$). Furthermore, it contributes to our understanding of hadronic showers and interactions at centre-of-mass energies well above those accessible at the LHC, such as in its measurement of the proton–proton inelastic cross-section at $\sqrt{s} = 57 \text{TeV}$ (CERN Courier September 2012 p6).

**AugerPrime looks to the highest energies**

The world’s largest cosmic-ray experiment, the Pierre Auger Observatory in Mendoza Province, Argentina, is embarking on its next phase, named AugerPrime.

Since the start of its operations in 2004, the Auger Observatory has illuminated many of the open questions in cosmic-ray science. For example, it confirmed with high precision the suppression of the primary cosmic-ray energy spectrum for energies exceeding $5 \times 10^{19} \text{eV}$, as predicted by Kenneth Greisen, Georgiy Zatsepin and Vadim Kuzmin (the “GZK effect”). The collaboration has searched for possible extragalactic point sources of the highest-energy cosmic-ray particles ever observed, as well as for large-scale anisotropy of arrival directions in the sky (CERN Courier December 2007 p5). It has also published unexpected results about the specific particle types that reach the Earth from remote galaxies, referred to as the “mass composition” of the primary particles. The observatory has set the world’s most stringent upper limits on the flux of neutrinos and photons with EeV energies (1 EeV = $10^{18} \text{eV}$). Furthermore, it contributes to our understanding of hadronic showers and interactions at centre-of-mass energies well above those accessible at the LHC, such as in its measurement of the proton–proton inelastic cross-section at $\sqrt{s} = 57 \text{TeV}$ (CERN Courier September 2012 p6).

The current Auger Observatory

The Auger Observatory learns about high-energy cosmic rays from the extensive air showers they create in the atmosphere (CERN Courier July/August 2006 p12). These showers consist of billions of subatomic particles that rain down on the Earth’s surface, spread over a footprint of tens of square kilometres. Each air shower carries information about the primary cosmic-ray particle’s arrival direction, energy and particle type. An array of 1600 water-Cherenkov surface detectors, placed on a 1500 m grid covering 3000 km², samples some of these particles, while fluorescence detectors around the observatory’s perimeter observe the faint ultraviolet light the shower creates by exciting the air molecules it passes through. The surface detectors operate 24 hours a day, and are joined by fluorescence-detector measurements on clear moonless nights. The duty cycle for the fluorescence detectors is about 10% that of the surface detectors. An additional 60 surface detectors in a region with a reduced 750 m spacing, known as the infill array, focus on detecting lower-energy air showers whose footprint is smaller than that of showers at the highest energies. Each surface-detector station (see image above) is self-powered
by a solar panel, which charges batteries in a box attached to the tank (at left in the image), enabling the detectors to operate day and night. An array of 153 radio antennas, named AERA and spread over a 17 km² area, complements the surface detectors and fluorescence detectors. The antennas are sensitive to coherent radiation emitted in the frequency range 30–80 MHz by air-shower electrons and positrons deflected in the Earth’s magnetic field.

**The motivation for AugerPrime and its detector upgrades**

The primary motivation for the AugerPrime detector upgrades is to understand how the suppressed energy spectrum and the mass composition of the primary cosmic-ray particles at the highest energies are related. Different primary particles, such as γ-rays, neutrinos, protons or heavier nuclei, create air showers with different average characteristics. To date, the observatory has deduced the average primary-particle mass at a given energy from measurements provided by the fluorescence detectors. These detectors are sensitive to the number of air-shower particles versus depth in the atmosphere through the varying intensity of the ultraviolet light emitted along the path of the shower. The atmospheric depth of the shower’s maximum number of particles, a quantity known as $X_{\text{max}}$, is deeper in the atmosphere for proton-induced air showers relative to showers induced by heavier nuclei, such as iron, at a given primary energy. Owing to the 10% duty cycle of the fluorescence detectors, the mass-composition measurements using the $X_{\text{max}}$ technique do not currently extend into the energy region $E > 5 \times 10^{19}$ eV where the flux suppression is observed. AugerPrime will capitalise on another feature of air showers induced by different primary-mass particles, namely, the different abundances of muons, photons and electrons at the Earth’s surface. The main goal of AugerPrime is to measure the relative numbers of these shower particles to obtain a more precise handle on the primary cosmic-ray composition with increased statistics at the highest energies. This knowledge should reveal whether the flux suppression at the highest energies is a result of a GZK-like propagation effect or of astrophysical sources reaching a limit in their ability to accelerate the highest-energy primary particles.

The key to differentiating the ground-level air-shower particles lies in improving the detection capabilities of the surface array. AugerPrime will cover each of the 1660 water-Cherenkov surface detectors with planes of plastic-scintillator detectors measuring 4 m². Surface-detector stations with scintillators above the Cherenkov detectors will allow the Auger team to determine the electron/photon versus muon abundances of air showers more precisely compared with using the Cherenkov detectors alone. The scintillator planes will be housed in light-tight, weatherproof enclosures, attached to the existing water tanks with a sturdy support frame, as shown above. The scintillator light will be read out with wavelength-shifting fibres inserted into straight extruded holes in the scintillator planes, which are bundled and attached to photomultiplier tubes. Also above, an image shows how the green wavelength-shifting fibres emerge from the scintillator planes and are grouped into bundles. Because the surface detectors operate 24 hours a day, the AugerPrime upgrade will yield mass-composition information for the full data set collected in the future.

The AugerPrime project also includes other detector improvements. The dynamic range of the Cherenkov detectors will be extended with the addition of a fourth photomultiplier tube. Its gain will be adjusted so that particle densities can be accurately measured close to the core of the highest-energy air showers. New electronics with faster sampling of the photomultiplier-tube signals will better identify the narrow peaks created by muons. New GPS receivers at each surface-detector station will provide better timing accuracy and calibration. A subproject of AugerPrime called AMIGA will consist of scintillator planes buried 1.3 m under the 60 surface detectors of the infill array. The AMIGA detectors are directly sensitive to the muon content of air showers, because the electromagnetic components are largely absorbed by the overburden.
The AugerPrime Symposium

In November 2015, the Auger scientists combined their biannual collaboration meeting in Malargüe, Argentina, with a meeting of its International Finance Board and dignitaries from many of its collaborating countries, to begin the new phase of the experiment in an AugerPrime Symposium. The Finance Board endorsed the development and construction of the AugerPrime detector upgrades, and a renewed international agreement was signed in a formal ceremony for continued operation of the experiment for an additional 10 years. The observatory’s spokesperson, Karl-Heinz Kampert from the University of Wuppertal, said: “The symposium marks a turning point for the observatory and we look forward to the exciting science that AugerPrime will enable us to pursue.”

While continuing to collect extensive air-shower data with its current detector configuration and publishing new results, the Auger Collaboration is focused on finalising the design for the upgraded AugerPrime detectors and making the transition to the construction phase at the many collaborating institutions worldwide. Subsequent installation of the new detector components on the Pampa Amarilla is no small task, with the 1660 surface detectors spread across such a large area. Each station must be accessed with all-terrain vehicles moving carefully on rough desert roads. But the collaboration is up to the challenge, and AugerPrime is foreseen to be completed in 2018 with essentially no interruption to current data-taking operations.

For more information, see auger.org/augerprime.

Résumé

Lancement d’AugerPrime