Astroparticle Physics in Germany

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Analysis optimisation for energies above 10 TeV for imaging atmospheric Cherenkov telescopes.

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The High Energy Stereoscopic System (H.E.S.S.) is a ground-based gamma-ray instrument that consists of five Cherenkov telescopes located in Namibia. H.E.S.S. operates in the energy range from a few tens of GeV to more than 50 TeV and the nominal analysis methods are optimised to achieve the best sensitivity at energies of about 1 TeV. The work presented in this contribution aims at optimising analysis techniques to improve the sensitivity above 10 TeV.
For high energies, existing systems are mainly limited by gamma-ray statistics. In addition, standard analysis accepts events only within ~2.5 deg offset (physical field of view of the cameras). Extending this range up to ~4.5 deg offset would lead to an increase of the effective field of view and photon statistics, which would result in an improvement of the sensitivity in the high-energy domain. In this contribution, an improved method that is capable of reconstructing events with offsets up to 4.5 degrees will be presented.

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mDOM - a multi-PMT optical module for future deep ice neutrino telescopes

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Optical modules are the “eyes” of neutrino telescopes, registering the Cherenkov light from charged particles created in neutrino interactions in the surrounding medium.
In the framework of a planned upgrade of the current IceCube Neutrino Observatory as well as a future next-generation neutrino telescope at the South Pole, new optical modules are being developed which are expected to significantly enhance detector sensitivity. One such concept is the multi-PMT digital optical module (mDOM). Inside a pressure vessel it features 24 three-inch PMTs

pointing isotropically in all directions. The contribution provides an overview of the current status in the mDOM development.

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The IceTop Enhancement for Improved Air-Shower Measurements

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The IceCube Neutrino Observatory, located at the South Pole, detects neutrinos of the highest energy in the Universe. IceTop, the surface array of IceCube measures cosmic rays, and acts as a veto for the in-ice observatory. An enhancement of IceTop using scintillation and radio detectors is foreseen. Two prototype scintillation detector stations have been deployed at the Pole in the austral summer of 2017/2018. The features of the detectors as well as the detailed simulations of the future scintillation array will be shown. Apart from this it is planned to deploy prototype radio antennas operating at 50-350 MHz, which includes the optimal band of 100-190 MHz thereby improving the signal-to-noise ratio. The results of the studies for the radio enhancement will also be shown.

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B-Anomalies and Leptoquark Searches

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In the Standard Model (SM) the electroweak coupling of the leptons to the gauge bosons is flavour independent, therefore the SM shows Lepton-Universatity (LU). Flavour-Changing-Neutral-Currents (FCNC) are absent in the SM at tree-level, this implies that decays reliant on FCNC's are sensitive to the existence of new particles. The recently discovered anomalies in the semi-leptonic decay of B-Mesons, are a fascinating hint at physics beyond the SM and possible Lepton-Flavour-Violation. A particle motivated by Grand Unified Theories like e.g the Pati-Salam Model, carrying both lepton and baryon number the Leptoquark (LQ) could explain these anomalies.

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Towards a multi-instrument and reproducible gamma-ray data analysis

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The analysis and combination of data from different gamma-ray instruments involves the use of collaboration proprietary software and case-by-case methods. The effort of defining a common data format for high-level gamma-ray data, named Data Level 3 (DL3), has already started driven by the very-high-energy (VHE, E $>$ 100\,GeV) community, as required by the future Cherenkov Telescope Array (CTA). CTA will be the next generation of Imaging Atmospheric Cherenkov Telescope (IACT), and will operate as an Open Observatory.

We present the first fully-reproducible, multi-instrument gamma-ray analysis, combining data from *Fermi-LAT*, and from the four existing IACTs (FACT, H.E.S.S., MAGIC and VERITAS), to produce a joint fit of the Crab Nebula spectrum. In this poster, relying on a DL3 prototype format and small data samples released by the participating collaborations, we allow a combined multi-instrument analysis within the context of open-source software.
Aspects of the statistical uncertainty and systematic error evaluation, as well as how to achieve full reproducibility, will also be discussed.

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H.E.S.S. observations of the Small Magellanic Cloud

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The Small Magellanic Cloud is the second-nearest star-forming galaxy to our Milky Way at a distance of about 60 kpc with major star-formation episodes at 6 Gyr, 0.7 Gyr and 10 Myr ago. This makes the Small Magellanic Cloud an ideal target to study objects related to young stellar populations over a wide range of age.
The Magellanic Clouds are currently the only galaxies for which individual sources and large-scale emission can be resolved by ground-based Cherenkov telescopes. Therefore, they offer the unique possibility to study the connection of the Galactic population of VHE gamma-ray sources and the "integrated" diffuse emission seen from e.g other star-forming galaxies. In the last years extensive surveys of the Magellanic Clouds were performed with the H.E.S.S. telecopes resulting in an energy flux sensitivity comparable to the brightest TeV gamma-ray sources in the Milky Way. This allows us to compare the TeV source populations in the Milky Way, the Large Magellanic Cloud and the Small Magellanic Cloud.
In this contribution I will show the results for the H.E.S.S. survey of the Small Magellanic Cloud. I will discuss potential gamma-ray source populations, which include supernova remnants, pulsars, pulsar wind nebulae and high-mass X-ray binaries, and compare them to those of the Milky Way and known sources in the Large Magellanic Cloud.

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Building the Medium Size Telescope Structures for the Cherenkov Telescope Array

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The Cherenkov Telescope Array (CTA) is the next generation ground-based observatory for gamma-ray astronomy at very high energy. It will operate with unprecedented sensitivity in the energy range between 20 GeV and 300 TeV. Its sensitivity in the core energy range will be dominated by up to 40 Medium Size Telescopes (MSTs) deployed at two sites located on both hemispheres. Besides hosting the Science Data Management Center as well as the participation to the development of the Large and Small Size Telescopes, a major contribution given by Germany to CTA (being pursued with international partners) concerns the implementation of the MSTs, especially the MST structures and the FlashCam Cherenkov cameras. A prototype of an MST structure based on a modified Davies-Cotton design with a reflector of 12m diameter has been constructed in Berlin. It is currently in an advanced prototype phase. We present the current status of the design, commissioning and performance of the prototype telescope structure. In addition, future plans will be discussed.

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Performance of the KATRIN Source and Transport Section during First Tritium measurement campaign

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The Karlsruhe Tritium Neutrino (KATRIN) experiment aims to determine the effective neutrino mass with a sensitivity of $m_\nu = 0.2$ eV/c^2 (90% C.L.) using electrons from the tritium β-decay.
In the source and transport section the β-electrons are produced in the windowless gaseous tritium source (WGTS) and magnetically guided through two pumping sections to the spectrometer section, where their energy is analyzed.

In order to achieve a constant decay rate, the gas column density inside the WGTS has to be stabilized and monitored.
Therefore, a Laser-Raman spectroscopy (LARA) setup measuring the gas constituents and a forward beam monitor (FBM) sitting at the edge of the flux tube are installed.
Furthermore the tritium flow has to be reduced by at least 14 orders of magnitude before entering the spectrometers, where it would induce a background signal.

During the first tritium measurement campaign all introduced components ran simultaneously for the first time.
In this poster the results will be presented.

This work was supported by BMBF (05A17VK2), BMBF (05A17PX3), GRK1694, KSETA and the HGF.

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The Cosmic-Ray Shadow of the Moon and Sun in IceCube - Seven Years of Data and Simulations

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The shadowing effect of the Moon and Sun in TeV cosmic rays has been measured with high statistical significance by several experiments. Unlike particles from the direction of the Moon, however, charged particles passing the Sun are deflected due to the solar magnetic field.

We present a comparison of seven years of data taken with the IceCube Neutrino Observatory and simulations that were developed in order to predict the cosmic-ray shadows of Moon and Sun detected by IceCube. While the results for the Moon shadow verify a stable detector, the results for the Sun shadow exhibit a clear variation following the well-known 11-year solar cycle. The observed variation is overall reproduced by the theoretical models of the coronal and heliospheric magnetic fields.

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SENSE - Ultimate Low Light-Level Sensor Development

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SENSE - Ultimate low light-level sensor development is a project funded by the EC Horizon 2020 as FET Open Coordination and Support Action (CSA).
The aim of SENSE is to coordinate research and development efforts in academia and industry in low light-level (LLL) sensoring.

Therefor we prepared a European R&D roadmap towards the ultimate LLL sensor and with the experts group the progress with respect to the roadmap will be monitored.
In collaboration with several labs, experienced in measuring photosensors, a common characterization of SiPMs with standardized measurements and analysis procedures is developed. Further cooperation especially with industrial partners is in preparation.
Another main aspect of the project is the dissemination of results and the communication between all involved partners and interested parties. The SENSE website, including the SENSE forum, provides all kind of information related to photosensors and allows for communication between all involved actors. In the future a database containing the results of SiPM characterization is planned.

Several outreach activities and special trainings for students are also part of the project and will be extended in the future.

The consortium has four partners: DESY (Coordinator), Germany; UNIGE, Switzerland; MPP, Germany and KIT, Germany. Several international experts on all parts of LLL developments are involved in the expert or working group of the project.

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News from the AP Community: MPG

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A novel method for the absolute calibration of fluorescence telescopes

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The Pierre Auger Observatory is the largest detector for the measurement of cosmic rays at ultra-high enrgies. It combines two detection techniques to measure air showers. A 3000 km^{2} surface array of 1600 water cherenkov detectors, and 27 fluorescence telescopes. The calorimetric energy measurement with the fluorescence telescopes is used to cross-calibrate the surface detector.

The fluorescence telescopes are currently calibrated with a light source called "the drum". It is a large lambertian light source mounted on the outside of the UV filters to illumintate the whole aperture at once. The operation of this light source IS challenging in terms of both, time and manpower. Here we present first results from a new method to calibrate the fluorescence telescopes in which an absolutely calibrated small light source insede an ulbricht sphere is mounted on an xy scanner outside of the aperture. The combination of many measurements at different positions can be superimposed to obtain the same uniform ilumination of the whole optical system as previously achieved with the drum.

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Tidally disrupted stars as possible common origin of UHECRs and neutrinos

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The origin of ultra-high energy cosmic rays (UHECRs) is still one of the biggest unsolved questions in astrophysics. We present a novel approach combining the knowledge about neutrinos and cosmic rays at the highest energies to give an alternative, joint solution to this question with Tidal Disruption Events (TDEs). TDEs are processes where stars are torn apart by the strong gravitational force close to a massive or super-massive black hole. Some of these objects happen to launch a relativistic jet, where particles may be accelerated in internal shocks.

We simulate the photo-hadronic interactions in the TDE jet as well as in the propagation through extra-galactic space in a combined source-propagation model, which is a key novelty of our work beyond the state-of-the-art. We demonstrate that it is possible to fit the UHECR spectrum and composition and describe PeV neutrino data simultaneously if a nuclear cascade develops in the source. Out of the fit procedure we obtain the necessary abundance and power of such events in order to draw a self-consistent picture, which is compatible with current constraints and which is testable by further observations.

0

Robust measurement of supernova ν_e spectra with future neutrino detectors

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Measuring precise all-flavor neutrino information from a supernova is crucial for understanding the core-collapse process as well as neutrino properties. We present new techniques to detect supernova ν_e in various near future water Cherenkov and liquid scintillator detectors. We show that the addition of gadolinium will allow Super-Kamiokande to detect supernova ν_e in substantial numbers and it can considerably constrain neutrino emission parameters. Large liquid scintillator detector like JUNO will also be able to detect these neutrinos and provide strong constraints on the spectrum.

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Precision High Voltage at the KATRIN Experiment

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The Karlsruhe Tritium Neutrino (KATRIN) experiment aims to determine the neutrino mass by measuring the tritium beta spectrum using an integrating spectrometer (MAC-E filter). The sensitivity goal of 0.2 eV/c² (90% C.L.) requires the spectometer's energy scale to be stable up to 60 meV. This translates to a stability requirement of 3 ppm for the high voltage system that creates the retarding potential (18.6 kV) inside the spectrometer.

KATRIN's high voltage system meets these requirements with precision power supplies and high precision monitoring using two custom-built high voltage dividers, which were developed in cooperation with the German national metrology institute PTB. Regular calibration measurements show a sub-ppm stability of the dividers over the last years. A newly developed system for absolute calibration of the voltage dividers on HV potential allows to perform these calibration measurements on-site at KATRIN.

The precision monitoring system is complemented by an independent comparision of the energy scale to a nuclear standard. This is achieved by spectroscopic measurements of mono-energetic conversion electrons from Kr-83m electron capture decays utilizing different source formats (implanted, condensed, gaseous).

The poster will give a detailled overview of KATRIN's high voltage system and its performance during recent commissioning measurements. This project is supportet by BMBF under contract number 05A17PM3.

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The XENONnT TPC

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The XENONnT Experiment for direct dark matter search exploits the liquid xenon-based Time Projection Chamber (LXeTPC) technology to detect WIMP-nucleus interaction. The experience from the previous phases of the project led to the design of the XENONnT low-background TPC, with an active volume of 5.9 t of xenon and a drift length of 1.5 m, leading to a projected sensitivity $\sigma_{SI} = 1.6 \times 10^{-48} cm^2$ in 20 $t \times y$.

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Performance of the Cherenkov Telescope Array

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The Cherenkov Telescope Array (CTA) will be the world's largest and by far most sensitive observatory for high-energy gamma rays. It will be capable of detecting gamma rays in the energy range from 20 GeV to more than 300 TeV from extremely faint sources with unprecedented energy and directional precision. The performance of the future CTA observatory derived from detailed Monte Carlo simulations is presented in this contribution for the two CTA sites in Paranal (Chile) and on the La Palma island (Spain).

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The Wavelength-shifting Optical Module (WOM)

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Large-area low-noise photon sensors with single-photon detection capability play a vital role for many detectors in astroparticle physics, such as neutrino telescopes. In conventional photo-multipliers scintillation light from radioactive decays typically dominates over the thermionic noise, both of which increase with the size of the photosensitive area. Using wavelength-shifting and light-guiding technologies, the Wavelength-shifting Optical Module (WOM) vastly increases the photo-sensitive area while keeping the dark noise rate constant. In a geometry geared towards future extensions of the IceCube neutrino observatory, more than 40% of the light is captured on tubes of 9cm diameter and 90cm length, thus increasing the signal-to-noise ratio by at least an order of magnitude. We show results of the efficiency optimization and prototype evaluation and first steps towards a batch production of modules, as well as present ideas to further increase the SNR by another order of magnitude.

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First tritium measurements with KATRIN

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The **KA**rlsruhe **TRI**tium **N**eutrino (KATRIN) experiment is designed to measure an integrated electron energy spectrum of tritium β-decay to determine the electron neutrino mass $m(\nu_e)$ with a sensitivity of 0.2 eV/c2 (90% C.L.). By
probing the tritium β-spectrum close to its endpoint at 18.6 keV, the experiment investigates the absolute neutrino mass scale in a model-independent way.
The 70 m long KATRIN beam line comprises a windowless gaseous tritium source (WGTS), a transport and pumping section, two tandem electrostatic retardation spectrometers, and a segmented silicon detector. In preparation for nominal tritium operations, a measurement campaign with a gas mixture of 0.5 % tritium in deuterium was carried out in May and June 2018. This successful first tritium campaign allows to characterize hardware performance and systematic effects, and to establish overall stability of the systems. This poster reports an overview of the current status of the experiment, focusing on the results of the recent first data-taking period with tritium. This project is supported by BMBF project 05A17VK2, the Helmholtz Association, and the Helmholtz Young Investigator Group VH-NG-1055.

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FlashCam — A fully-digital Cherenkov camera

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The FlashCam Cherenkov camera is one of the proposed cameras for the medium-sized telescopes (MSTs) of the Cherenkov Telescope Array (CTA). With a foreseen production of 15+ cameras, the project aims to be one of the major German contributions to CTA, in close cooperation with the University of Zürich and University of Innsbruck.

The FlashCam design follows a novel, fully-digital and modular architecture with highly-integrated, PMT-based photodetector modules and a fully-digital readout electronics with Ethernet-based data acquisition as key building blocks. A full-scale prototype camera has been in operation for nearly three years and was used to verify the performance and reliability of the FlashCam design, and to characterise the environmental and longterm stability.

In autumn 2017, the camera was installed and operated on the MST prototype telescope in Berlin-Adlershof for six weeks. The installation and commissioning took <2 days and was followed by successful observations of air showers against the bright Berlin night sky and smooth longterm remote operation.

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Modeling the ambient condition in the Galactic Center and the prospect of neutrino detection

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The diffuse γ-rays emitting from ca. 250 pc around the Galactic Center (GC) at some GeV to tens of TeV energies indicate a PeVatron. The exact identification of the source cannot be announced without a complemented picture of the GC. However, the H.E.S.S. group and Gaggero et al. (2017) suggest one centrally located source due to a $1/r$ radial progression of the cosmic-ray (CR) energy density. Though, in this calculation, the geometrical structures of the observed region were not considered.
The complex structure of the massive gas clouds and the dense star cluster containing many OB stars in the GC requires an equitable model of the ambient condition. The Propagation of CR protons and electrons is highly influenced by the magnetic field, the location, and density of the molecular gas clouds, and the ambient photon field.
We are aimed at modeling a realistic 3D distribution of these field for our region of interest (ROI):

- a 3D mass distribution is constructed by three constituents: diffuse intercloud medium, dense molecular clouds, inner 20 pc.
- the geometrical structure, the direction, and strength of the magnetic field are based on observed non-thermal filaments and dense molecular gas structures.
- we consider 3D photon field and consider additionally locally field such as the dominant star clusters Arches, Quintuplet and Central Star Cluster.

Finally, the reproduction of the radial distribution of non-thermal radio flux and γ-ray measured by Fermi and especially by H.E.S.S. is intended for predicting the neutrino spectrum.
The simulation of CR propagation is performed via the tool CRPropa at a high accuracy. In doing so, a full picture of the GC is given and the real role of electrons and SgrA* or other sources can be investigated. However, our semi-analytical studies which consider geometrical structures, require additional sources located at distance $\sim$ 120pc and therefore do not suggest just one centrally located source.

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Neutron Veto for XENONnT

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The currently operating XENON1T experiment at the Laboratori Nazionali del Gran Sasso (LNGS) is the first ton-scale dual-phase xenon time projection chamber (TPC) aiming for the direct detection of dark matter in the form of Weakly Interacting Massive Particles (WIMPs). It has achieved world-leading sensitivity with a science exposure of 1.0 tonne x year.
For the next phase of the XENON Project, XENONnT is an upgrade on a fast time-scale that exploits the fact that the outer cryostat and much of the infrastructure was already designed for a larger detector. In order to take full advantage of reduced backgrounds in XENONnT, a neutron veto system is introduced to tag neutron-induced nuclear recoil background. The focus has been on two different options, Gadolinium (Gd) loaded liquid scintillator and a Gd-loaded water Cherenkov detector.

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Silicon Photomultipliers in Liquid Xenon Time Projection Chambers

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Liquid Xenon Time Projection Chambers (LXeTPC) are detectors used in rare event searches for Dark Matter and neutrinoless double beta decay, or
in Compton cameras. LXe offers a combination of scintillation light and ionization that can be used to build large, uniform 3D position
sensitive detectors. We test the feasibility of replacing the commonly used photomultiplier tubes (PMTs) by SiPMs in such a detector. Most
commercially available SiPMs are not sensitive to the scintillation light of xenon in the VUV regime at 178nm, so a special design or
treatment is neccesary to increase sensitivity. We operate a test stand to measure the sensitivity, crosstalk and afterpulse properties
of three VUV-sensitive SiPM samples in liquid xenon, using scintillation light of a 241Am source immersed in liquid xenon.

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Reconstructed properties of the sources of ultra-high-energy cosmic rays and their dependence on the extragalactic magnetic field

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Ultra-high-energy cosmic rays (UHECR) are an important topic of current research. At present, neither their sources nor the properties of the sources are known. To address this issue, we use four-dimensional simulations of the propagation of UHECR based on the Monte-Carlo code CRPropa 3. These simulations are much more realistic than those used in previous studies. The simulations take into account, among others, the cosmological evolution of the universe, the extragalactic background light (EBL), and the extragalactic magnetic field (EGMF). On this basis, we study which energy spectrum and chemical composition of the UHECR must be assumed at their sources to obtain an energy spectrum and a chemical composition of the simulated UHECR arriving at the Earth that are in the best possible agreement with the corresponding UHECR data measured by the Pierre Auger Observatory. We find that the energy spectrum and chemical composition at the sources that are reconstructed in this way depend only moderately on the assumed EBL but strongly on the EGMF. This demonstrates that in simulation studies the EGMF must be carefully taken into account. Furthermore, we present an astrophysical scenario that correctly reproduces the measured energy spectrum, chemical composition, and anisotropy of UHECR and discuss possible further applications of CRPropa for the interpretation of multimessenger astronomy data.

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GRAND - the Giant Radio Array for Neutrino Detection

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One of the most pressing open questions in astrophysics is: what is the origin of ultra-high-energy cosmic rays (UHECRs)?
The Giant Radio Array for Neutrino Detection (GRAND) aims to answer it by discovering the secondary UHE neutrinos produced in UHECR interactions.
Involving collaborators worldwide, including from Germany, GRAND is planned as a large-scale UHE observatory with 200 000 radio antennas covering an area of 200 000 km^2, designed to discover UHE neutrinos even if their flux is low. The detection principle is based on the measurement of the radio emission from extensive air showers induced by UHE particles in the atmosphere. Here, Grand will be sensitive not only to neutrinos, but also to UHECRs and UHE gamma rays.
For UHE neutrinos, GRAND aims to reach a sensitivity of $\sim 10^{-10}$ GeV $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}$ in 3 years, a factor-of-100 improvement over potential upgrades of existing detectors. Further, GRAND aims for an aperture to cosmic rays above 10^{10} GeV that is 20 times larger than in Auger, and a sensitivity to a flux of UHE gamma rays that is 10 times better.
In this contribution we will present the science goals, preliminary design, performance goals and current status of the GRAND project.

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Low energy neutrino detectors

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Multimessenger Astronomy with the Pierre Auger Observatory – Gravitational Wave Follow-up Searches Neutrinos and Photons

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The surface detector array of the Pierre Auger Observatory is sensitive to neutrinos at energies above 0.1 EeV and photons at energies above 10 EeV (ultra-high energy (UHE) neutrinos and photons). This sensitivity, together with the observatory's large acceptance makes it a complementary and competitive instrument to other neutrino and photon detectors, which mostly have their peak sensitivities at lower energies.

UHE neutrinos and photons are produced both at UHE cosmic ray (UHECR) sources and during UHECR propagation with complementary physical properties to UHECRs. This makes them a promising signal which will help address open questions concerning the nature of UHECRs.

In 2015 the LIGO Collaboration made the first direct detection of astrophysical gravitational waves (GW) from a binary black hole (BBH) merger, opening a new, complementary view of the universe and therefore potentially also of UHECRs. In August 2017 the LIGO/Virgo Collaborations observed for the first time a binary neutron star (BNS) merger and sent an immediate alert to pre-established partners, including the Pierre Auger Collaboration.

We present the status and results of the UHE neutrino follow-up searches performed with the Pierre Auger Observatory, triggered by LIGO/Virgo BBH and BNS GW events. We discuss the impact

of the results in terms of constraints on physical properties of the GW sources individually and as astrophysical source populations. Furthermore, we also introduce a new approach for GW follow-up searches using UHE photons which is currently under preparation.

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Calibration of IceCube's ice properties with logging devices

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The IceCube neutrino observatory uses $1\,\mathrm{km}^3$ of the natural Antarctic ice near the geographic South Pole as optical detection medium. When charged particles, such as neutrino secondaries, pass through the ice, Cherenkov light is emitted. This is detected by IceCube's optical modules and from all signals an event is reconstructed.
With growing knowledge of the optical ice properties in the instrumented volume, the precision of reconstruction and thus the impact of IceCube's scientific results was increased.

Sensor developments for future upgrades of IceCube can take advantage of the increased Cherenkov light intensity at lower wavelength. Therefore a logging device is in preparation to measure the absorption and scattering length of UV light in-situ.

Furthermore, a new kind of signatures produced by exotic particles can be detected by using light emission from luminescence and neutron captures. These processes are highly dependent on the ice structure, impurities, pressure and temperature. Therefore further logging devices are in preparation to measure these ice properties in-situ.

For the measurements a $1.7\,\mathrm{km}$ deep and $12.5\,\mathrm{cm}$ hole is used which was recently drilled near the IceCube site and filled with Estisol 140. The small diameter of the hole is a challenge for the construction of the experiments and the design of the photomultiplier read-out electronics inside the pressure vessels.
The three nearly completed logging devices will be presented as well as the experiments and two independent solutions for the read-out.

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AugerPrime Engineering Array Status and Analysis

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In September 2016, the major phase of the AugerPrime upgrade of the Pierre Auger Observatory started with the installation of the first scintillator detectors on top of the existing water-Cherenkov detectors. By enabling a complementary measurement of the electromagnetic and muonic components of air showers, the new detectors provide an improvement in the analysis of cosmic rays, for example the mass composition of the primary particles. This poster will focus on the status and performance of the upgraded surface detector stations deployed in the Engineering Array of the Observatory. In addition, we present studies on the data quality and first analysis results of AugerPrime

stations in immediate vicinity of each other which are located inside grid of dense stations, where the energy threshold is around ~$10^{16.5}$ eV, yielding in high event statistics.

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Training and learning activities within SENSE

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SENSE - Ultimate low light-level sensor development, is a European project with the aim to coordinate research and development efforts in academia and industry in low light-level (LLL) sensoring.
In the framework of SENSE several training and learning activities are and shall be developed. The aim is to introduce the topic of LLL sensor R&D and to attract young researchers to technology development. This includes training events during summer school, virtual training sessions accessible from the website and also the development of show case experiments.
In this context an experiment for the measurement of cosmic muons is currently developed at KIT: It consists of thermal cans that act as water-cherenkov-detectors. Muons passing through this detectors produce photons which, in contrast to previous experiments, are measured using state-of-the-art SiPMs. The usage of SiPMs has several advantages: They are more robust compared to PMTs and they work without high voltage which is especially important for a hands-on-experiment for students. To capture the photons within the thermal can wavelength shifting fibres, like used in the IceCube and the AugerPrime scintillators, are attached to the SiPM.
This show-case experiment should be used for trainings with high school or young university students.

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Observation of Horizontal Air Showers with AERA

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The Auger Engineering Radio Array (AERA) is the radio detector of the Pierre
Auger Observatory. It measures the radio emission of cosmic-ray air showers with energies above ~ 0.1 EeV. Horizontal air showers (HAS) with a zenith angle larger than 60° are especially interesting as the signal is distributed over a large area of several km². Recently, the calibration of the antennas was extended up to a zenith angle of 80° and the reconstruction is improving to deal with the new challenges of HAS.
We will present a first analysis of 561 measured events and the potential of

a detection of air showers using a sparse radio antenna array, compatible with
the 1500 m distance between the 1600 surface detector stations of the observatory. A combination of the radio measurement with the particle information of the surface detector stations can be used to study composition for HAS at the highest energies and to extend the radio energy calibration beyond EeV energies.

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Investigation of Deep Learning based Algorithms at the Pierre Auger Observatory

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The surface detector of the Pierre Auger Observatory measures the footprint of ultra-high energy cosmic ray induced air showers on ground level. The reconstruction of the primary cosmic ray properties like energy, direction and mass is based on the measured signal in the stations. It can be improved by separating the muonic and electromagnetic component of the air shower, which can be achieved by a hardware upgrade or algorithmically.

Recently, great progress has been made in the fields of machine translation, image classification and speech recognition by using deep neural networks and associated techniques (*deep learning*). In physics research the usage of deep learning based methods has only recently begun, but is already showing very promising results.

On this poster we present the application scope for deep learning based algorithms for the surface detector of the Pierre Auger Observatory. We show that adapting these new techniques on air shower physics would allow for another standalone reconstruction tool and could improve present reconstructions [1]. In addition we discuss the potential to estimate the measured muon content of extensive air showers when measured at ground [2]. Finally, we investigate a new method to refine current air shower simulations by reducing mismatches between data and simulations [3].

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Background Reduction and Modeling for XENON1T

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XENON1T is the world-leading experiment in the search for WIMP dark matter. Its unprecedented sensitivity is owed to its large sensitive mass, but, in part, also to the mitigation and understanding of experimental backgrounds. To this end, the XENON collaboration has pioneered the removal of the intrinsic contaminant ^{85}Kr by cryogenic distillation to sub-ppt levels. For the next stage of the XENON project, XENONnT, it is planned to apply the same principle to ^{222}Rn. This isotope currently

represents the single largest background contribution in the electronic recoil regime where events can mimic nuclear recoils of WIMPs. An online removal of radon would be a game changer not only for WIMP searches, but also for other rare event studies such as double electron capture and inelastically scattering dark matter. The detailed background models for these physics channels are constructed by matching Monte Carlo simulations to measured data. The Münster XENON group is involved in both background mitigation and modeling. Its contributions in these areas will be presented on the poster. This work is supported by BMBF under contract 05A17PM2 and by DFG through the Research Training Group ”GRK 2149: Strong and Weak Interactions – from Hadrons to Dark Matter”.