ARENA 2012 - Acoustic and Radio EeV Neutrino Detection Activities

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Book of abstracts

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Radio Detection in Dense Matter: Balloon, telescope, satellite

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Radio Detection in Dense Matter: Balloon, telescope, satellite

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LUNASKA neutrino search with the Parkes and ATCA telescopes

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The Moon is used as a target volume for ultra-high energy neutrino searches with terrestrial radio telescopes. The LUNASKA project has conducted observations with the Parkes and ATCA telescopes; and, most recently, with both of them in combination. We present an analysis of the data obtained from these searches, including validation and calibration results for the Parkes-ATCA experiment, as well as a summary of prospects for future observations.

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Searching for neutrino radio flashes from the Moon with LOFAR

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Detection of ultra-high-energy neutrinos requires vast natural detector volumes of ice or rock. The Moon itself is the largest detector mass available. Earthbound radio telescopes can search the Lunar surface for radio flashes, produced by neutrinos through the Askaryan mechanism. A new generation of low-frequency, digital radio arrays, spearheaded by LOFAR, will allow for searches of unprecedented sensitivity.

The NuMoon program aims to use LOFAR to search the Moon for neutrino or cosmic-ray induced radio flashes. In this talk I will present the progress that is being made to prepare the instrument for NuMoon science runs, and discuss the experimental challenges and expected sensitivity.

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Lunar Imaging and Ionospheric Calibration for the Lunar Cherenkov Technique

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The Lunar Cherenkov technique is a promising method for UHE neutrino and cosmic ray detection which aims to detect nanosecond radio pulses produced during particle interactions in the Lunar regolith. For low frequency experiments, such as NuMoon, the frequency dependent dispersive effect of the ionosphere is an important experimental concern as it reduces the pulse amplitude and subsequent chances of detection. We present continuing results from a new method to calibrate the dispersive effect of the ionosphere on Lunar Cherenkov pulses via Faraday rotation measurements of the Moon's polarised emission combined with geomagnetic field models. We also extend this work to include radio imaging of the Lunar surface, which provides information on the physical and chemical properties of the Lunar surface that may affect experimental strategies for the Lunar Cherenkov technique.

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Lunar Space Missions for Observation of Ultrahigh-Energy Cosmic Rays and Neutrinos

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Two stages of a lunar experiment with the regolith as a target for the interaction of ultrahigh-energy cosmic rays and neutrinos are described. The first stage deals with the LORD experiment within the framework of the Luna-Glob space mission scheduled for the nearest future. The current status of the LORD-instrumentation development is discussed. The aperture of the lunar orbital radio detector exceeds all existing ground-based arrays. Successful realization of the LORD experiment will make it possible to start the second stage of the program. Multi-satellite lunar orbital systems are proposed to increase the measurement statistics and accuracy.

Radio Detection in Air / 58

Overview of MHz air shower radio experiments and results

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After 10 years of efforts, important progress have been made in the field of radio-detection of extensive air showers in the MHz range. The geomagnetic contribution has been proven to be dominant. A secondary process in the shower (probably related to the excess of charges in the shower) has also been detected. The correlation between the detected electric field and the nature and energy of the primary cosmic ray is on the way to be established through both simulation and data. I will present the main experiments in this field and review their main results.

Radio Detection in Air / 30

Recent developments at the Auger Engineering Radio Array

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The first phase of the Auger Engineering Radio Array (AERA) has been deployed in the fall of 2010. Currently, the array consists currently of 24 stations distributed over an area of 0.5 km^2. AERA has two different objectives. The first one is to measure cosmic-ray events and to provide the necessary data to improve our understanding of radio emission from air showers. The second objective is to develop and test the instrumentation for the next generation of MHz radio-detection setups for air shower studies based on self-triggering methods.

With this first phase of AERA self-triggered events have been registered and were used for physics analysis. Moreover, various types of hardware and different trigger strategies for the next stages including cross-triggering with the surface detector are being tested with the current setup.
The talk will firstly report the current status of the detector. Then, it will focus on the available events and show comparisons between measured data and simulations and summarize the ongoing analyses. Finally we will discuss the plan for the next phase in 2012-2013.

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Energy Estimation for Cosmic Rays Measured with the Auger Engineering Radio Array

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The Auger Engineering Radio Array (AERA) is located within the Pierre-Auger Observatory and currently consists of 24 self-triggered radio stations. Observation of radio signals from cosmic rays is confirmed by the surface detector (SD) stations of the observatory which provide well calibrated information on the cosmic ray energies and arrival directions. The response of the radio stations has been thoroughly calibrated to enable reconstruction of the incoming electric field. For estimating the cosmic ray energy we use the maximum absolute value of the measured electric field vector corrected for the incoming direction and the distance to the shower core. Performing an energy calibration using the SD information we observe that the defined radio energy estimator provides an approximately linear dependency on the cosmic ray energy.

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Spectral index analysis of the data from the Auger Engineering Radio Array

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The first stage of the Auger Engineering Radio Array has been deployed at the Pierre Auger Observatory in Argentina and is taking data. It measures radio signals in the MHz range from air showers induced by cosmic rays with energies above 10^17 eV. It is overlooked by the fluorescence telescopes and is located in a dense part of the particle detector array. This allows for cross-calibration of the individual techniques and therefore this is an excellent location to study radio emission from extensive air showers.
The index of the measured frequency spectra of the cosmic-ray-induced signals changes with the distance of the detector to the shower axis and with the zenith angle. The observed dependencies are in agreement with simulations. We are investigating whether the spectral index can be used as a tool to determine the composition of cosmic rays.

Acoustic Detection / 34

Acoustic Neutrino Detection in Water

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The acoustic neutrino detection technique is a promising approach for future large-scale detectors with the aim of measuring the small expected flux of ultra-high energy cosmogenic neutrinos. This talk will focus on the application of the technique in water, based on site studies performed with different acoustic test arrays. Though the technique is intriguingly simple, challenges arise from e.g. anisotropic sound propagation, ambient noise or transient background in a natural environment. We will discuss those challenges and the strategies to face them, as well as developments in the simulation of the acoustic signal and hardware developments for sensors and calibration sources. Furthermore, current physics results towards the acoustic detection of ultra-high energy neutrinos in water will be presented. The acoustic detection technique will be investigated further in the next generation of Cherenkov neutrino telescopes that is currently prepared. We will discuss the technical implementation into those large optical detectors that is based on the experience gained with the acoustic test arrays.

Acoustic Detection / 6

Acoustic Neutrino Detection in Ice: Past, Present and Future

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Acoustic neutrino detection is a promising technique to instrument the large volumes required to measure the small expected flux of ultra-high energy cosmogenic neutrinos. Using ice as detection medium allows for coincident detection of neutrino interactions with acoustic sensors, radio antennas and optical light sensors with the benefit of cross calibration possibilities or independent measurements of the the same event. We will review the past development of the field and discuss its current status and challenges. Results from site exploration studies, mainly by the South Pole Acoustic Test Setup (SPATS) which has been codeployed with the IceCube neutrino telescope at South Pole, and current physics results will be presented. Current ideas for the design, calibration, and deployment of acoustic sensors for new projects will be shown. The possible role of the acoustic technique in future in-ice neutrino detectors will be discussed.

Acoustic Detection / 36

Combined Opto-Acoustical Sensor Modules for KM3NeT

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The use of acoustical sensors in combination with optical sensors within one sensor module is a promising alternative to the standard design of deep-sea neutrino telescopes with separate acoustical and optical devices. These so-called Opto-Acoustical Modules comprise at least one sensor of each type inside the same glass housing. In this combination it is possible to determine the module position and orientation by acoustical triangulation without the need for additional external receivers. An adapted data readout scheme with custom-designed acoustical sensors also allows for extended analysis objectives like deep-sea observations or acoustical particle detection. The electro-magnetic interference of the different sensors within a module is the main challenge for the feasibility of Opto-Acoustical Modules. Prototypes with different geometrical arrangements and numbers of sensors have to be studied in order to demonstrate and optimise the overall applicability of these modules.

This presentation describes first results obtained for two different designs measured in different laboratories.

Acoustic Detection / 7

Acoustic positioning system in ice for the Enceladus Explorer

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The IceMole, a combination of melting and drilling probe, which is able to move and steer through ice and take samples while doing so, can be used to install instruments in ice. An improved design of the prototype developed by the FH Aachen, the Eceladus Explorer, could be used to explore water filled cracks on the Saturn moon Enceladus some day. Before starting a space mission to Enceladus the next step will be the exploration of the Taylor Glacier in the Antarctica. The probe will operate in this similar, smaller scale scenario in order to test the functionality of itself and its inner systems. The icecraft will be equipped in addition to an inertial navigation system with an acoustic positioning system. The acoustic system, composed of receivers in the probe itself and several emitters (pinger) on the glacier surface, will determine the position of the IceMole by measuring the signal propagation time and triangulation, which requires a solid knowledge of the propagation of acoustic signals in ice. Especially the characteristics of this glacier ice, such as the speed of sound and the acoustic attenuation length, which depend on the density and temperature of the ice, have to be known. A method to determine these properties during the operation of the IceMole will be developed.
In this talk we will give an overview over the project. We will present the status of the development of the acoustic surface system and we will show the results of first measurements in glacier ice.

Radio Detection in Dense Media / 52

Ground Based Radio Detection in Dense Matter

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We report on experimental efforts (ARA, ARIANNA, etc) which seek neutrino detection using englacial radio receivers. By exploiting the Askaryan effect, such embedded sensors can achieve detection thresholds of order 100 PeV, and thereby attain excellent sensitivity to the expected cosmogenic neutrino flux. Current status, comparison of existing experiments and future prospects will be reviewed.

Radio Detection in Dense Media / 24

The Askaryan Radio Array

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The Askar'yan Radio Array (ARA), a neutrino detector to be situated at the South Pole next to the IceCube detector, will be sensitive to ultrahigh-energy cosmic neutrinos above 0.1 EeV and will have the greatest sensitivity within the favored energy range from 0.1 EeV up to 10 EeV. Neutrinos of this energy are guaranteed by the current observations of the GZK-cutoff by the HiRes and the Pierre Auger Observatories. The detection method is based on Cherenkov emission by a neutrino induced cascade in the ice, coherent at radio wavelengths, which was predicted by Askar'yan in 1962 and verified in beam tests at SLAC in 2006.
The detector is planned to consist of 37 stations with 16 antennas each, deployed at depth of up to 200 m under the ice surface. During the last two polar seasons (2010 -2011, 2011 - 2012), a prototype station and a first detector station were successfully deployed and are taking data. These data have been and are currently being analyzed concerning different measurement conditions, which are the ambient noise background and the properties of the South Pole ice sheet. A worldwide collaboration of people is working on the planning, construction and data analysis of the detector array.
This presentation will give a report on the status of the ARA detector and show recent results from the recorded data.

Radio Detection in Dense Media / 27

Measurement of a phase of a radio wave reflected from rock salt and ice irradiated by an electron beam for detection of ultra-high-energy neutrinos

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We had reported a reflection effect of a radio wave from rock salt irradiated by an X-ray or a 2MeV-electron beam. The beam irradiation had given rise to increases in temperature and consequently permittivity in the rock salt. The radio wave had been reflected due to the irregularity of the permittivity in the rock salt. In this conference we report measurements of phase changes as well as amplitude changes of a radio wave reflected from not only rock salt but also ice. A coaxial tube was filled with rock salt or ice and an open end was irradiated by the 2MeV-electron beam. We found that the amount of the phase change was in accord with the propagation delay of the radio wave due to the increase of the permittivity in the media. The reflection effect is expected in all dielectrics whose permittivities depend on their temperatures. When a GZK neutrino interacts with the detection media, the energy is dissipated to the location to rise the temperature. The radio-wave-reflection effect would be applicable to detect ultra-high-energy neutrinos in all kinds of detection media made of solid dielectrics with a gigantic mass and a long attenuation length for a radio wave such as an ice sheet at Antarctica as well as a huge rock salt dome, and in the future at the moon's crust. A phased-array radar with a peak power of 1 GW (Equivalent Isotropic Radiation Power) could detect around10 GZK neutrinos per year within the fiducial mass of 50 Gt.

Radio Detection Theory / 54

Theory and simulations of air shower radio emission

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A precise understanding of the radio emission from extensive air showers is of fundamental importance for the design of cosmic ray radio detectors as well as the analysis and interpretation of their data.

In recent years, tremendous progress has been made in the understanding of the emission physics both in macroscopic and microscopic frameworks. A consistent picture has emerged: the emission stems mainly from time-varying transverse currents and a time-varying charge excess; in addition, Cherenkov-like compression of the emission due to the refractive index gradient in the atmosphere can lead to high-frequency contributions in the signal.

In this overview talk, I will discuss this the emission physics as it is understood today, present the signatures that experiments are expected to see and exploit, and conclude with a description of the models currently on the market.

Radio Detection Theory / 11

Simulating radio emission from air showers with CoREAS

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In the Monte Carlo simulation code REAS, radio emission from air showers is calculated using the "endpoint formalism". No assumptions on the emission mechanism have to be made in this parameter-free approach.

REAS simulations are based on particle distributions which have been simulated with CORSIKA and then exported as 4-dimensional histograms. During the histogramming, however, information is lost. For example, the geomagnetically induced dipole moment of the electron-positron distribution is not conserved, and the preferred outward drift of secondary particles is not reflected in the histogrammed distributions either.

For an even more precise simulation of the radio emission, we have thus implemented the endpoint formalism directly into CORSIKA. This new simulation code, named CoREAS, takes into account the full complexity of air shower physics without any approximations. In this presentation we will describe the concept and implementation of CoREAS and present simulation results including realistic refractive index effects in the atmosphere.

Radio Detection Theory / 12

The EVA code; Macroscopic modeling of radio emission from air showers based on full MC simulations including a realistic index of refraction.

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A comprehensive overview of the newly developed EVA-code will be given by making a direct comparison to the MGMR-code. Both codes perform a macroscopic calculation of radio emission from cosmic-ray-induced air showers. The MGMR-model is based on parameterized shower distributions ignoring the lateral extend of the shower. Furthermore, all calculations ignored Cherenkov effects. To take into account Cherenkov effects and include realistic showers in combination with shower-to-shower fluctuations we have developed the EVA-code (Electric fields, using a Variable index of refraction in Air shower simulations code). The EVA-code is a full Monte-Carlo simulation for radio emission from cosmic-ray-induced air showers. The EVA-code makes use of the finite dimensions of the particle distributions to overcome the divergences in the fields due to Cherenkov effects without making any approximations.

Radio Detection Theory / 13

First results from EVA simulations; Cherenkov effects and the chemical composition of the initial cosmic ray.

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We discuss the first results of macroscopic calculations based on full Monte-Carlo simulations including a realistic index of refraction using the EVA-code. Due to the finite refractivity Cherenkov effects play an important role in radio emission from air showers. We show that the observed frequency spectrum depends strongly on the distance from the shower core. At the Cherenkov angle the high frequency components have the largest power. It follows that the Lateral Distribution Function of the radio emission can be used as an excellent probe to determine the shower maximum and thus give a handle on the chemical composition of the initial cosmic ray. Furthermore, we show how Cherenkov effects affect the two main emission mechanisms, the geomagnetic emission and the charge-excess emission.

Radio Detection Theory / 18

Ultra High Frequency Geomagnetic Radiation from Extensive Air Showers

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Using the ZHAireS Monte Carlo code, we show that the Fourier-spectrum of the radio emission of inclined air showers can have a sizable intensity up to the GHz frequency range. At these frequencies, only the fraction of shower development seen at an angle close to the Cherenkov angle contributes to the observable emission, which is mainly due to the geomagnetic and charge excess mechanisms. At ground level, the maximum emission at high frequencies is concentrated in an elliptical region related to the intersection with ground of a Cherenkov cone with origin close to shower maximum. Moreover, the lateral distribution of the signal at ground contains information on the shower longitudinal profile. In this work we characterize this effect which can be very important for ground-based radio experiments aiming at detecting molecular bremsstrahlung radiation in the GHz range - a different mechanism not included in ZHAireS simulations. We also show that the simulated spectrum is consistent with the pulses detected by ANITA attributed to radio emission from UHECRs.

Radio Detection in Air / 4

Cosmic Ray Measurements with LOPES: Status and Recent Results

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LOPES is a digital antenna array at the Karlsruhe Institute of Technology, Germany, for cosmic-ray air-shower measurements. Triggered by the co-located KASCADE-Grande air-shower array, LOPES detects the radio emission of air showers via digital radio interferometry. We will summarize the status of LOPES and recent results concerning the understanding of the radio emission and the reconstruction of air-shower properties from the radio signal. We will present an update of results on the successful reconstruction of energy and arrival direction of the primary particles. Even more important for many particle and astrophysics questions is the reconstruction of the atmospheric depth of the shower maximum, Xmax, which yields information on the type of the primary particle and its interaction with the atmosphere. We found experimental evidence that radio measurements are indeed sensitive to the longitudinal development of air showers, since we observe a correlation between the slope of radio-lateral distributions and measurements of the muon-tracking detector of KASCADE-Grande. Moreover, since recently improved REAS simulations come close to the measurements, they are used as input for the reconstruction of Xmax. Unfortunately, at LOPES, the Xmax precision is limited by the high level of anthropogenic radio background, but the developed methods can be
transferred to next generation experiments with lower background.

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Comparison of LOPES measurements with CoREAS and REAS 3.1 simulations

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In the previous years, LOPES emerged as a very successful experiment measuring the radio emission from air showers in the MHz frequency range. In parallel, the theoretical description of radio emission was developed further and REAS 3.1 became a well-respected simulation Monte Carlo code. REAS 3.1 as well as CoREAS are based on the endpoint formalism, i.e. no assumptions on the emission mechanism have to be made. While REAS 3.1 is based on histograms derived from CORSIKA simulations, CoREAS is directly implemented into CORSIKA without beeing affected by possible lost of information due to histogramming the particle distributions. In the newest versions of REAS and CoREAS, a realistic atmospheric refractive index is considered.
To improve the understanding of the emission processes and judge the quality of CoREAS and REAS 3.1, we compare the theoretical predictions of both codes with high-quality events measured by LOPES. We present results concerning the lateral distribution and the absolute amplitude at a typical distance to the shower axis of the radio signal. Moreover, we compare the dependence of the amplitude and the slope parameter of the lateral distribution function with shower parameters.

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Reconstructing energy and Xmax of cosmic ray air showers using the radio lateral distribution measured with LOPES

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In the previous decades, remarkable progress has been made in the detection of electromagnetic emission from cosmic ray air showers. The LOPES experiment, a digital radio interferometer located at KIT (Karlsruhe Institute of Technology), obtained considerable results for the detection at MHz frequencies.
Aiming to become competitive with the well-established investigation methods, radio detection has the main purpose of retrieving the complete information from a high-energy cosmic ray, e.g. arrival direction, energy and type of the primary particle.
Features of the radio lateral distribution function (LDF) are explored in this work for a precise reconstruction of two fundamental air shower parameters: the primary energy and the shower Xmax. The method presented here has been developed on
(REAS3-)simulations, and is applied to LOPES measurements. Despite the high human-made noise at the LOPES site, it is possible to reconstruct both the energy and Xmax for individual events. While the energy resolution is promising and comparable to the one of the co-located KASCADE-Grande experiment, the investigation shows that for a Xmax resolution better than 30 g/cm2, a region with a lower human-made noise level would be needed.

Radio Detection in Air / 53

Some possible interpretations from data of the CODALEMA experiment

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The purpose of the CODALEMA experiment, installed at the Nançay Radio Observatory (France), is to study the radio-detection of cosmic rays of ultra high energy. Distributed over an area of 0.25 km2, the original device has a centralized acquisition, and uses in coincidence an array of particle detectors and an array of active dipoles. A new analysis of energy observables is presented from this system, taking advantage of anterior results like the geomagnetic effect or the contribution of the charge excess. Since early in 2011, a new array of radio-detectors, consisting of 60 stand-alone and self-triggered stations, is being deployed over an area of 1.5 km2 around the initial configuration. This new development leads to specific constraints to be discussed in term of recognition of cosmic rays and in term of analysis of wave-front.

Related Subjects / 49

Data analysis challenges of gravitational-wave astronomy

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Gravitational waves are radiative solutions of space-time dynamics predicted by Einstein's theory of General Relativity. A world-wide array of large-scale and highly-sensitive interferometric detectors constantly scrutinizes the geometry of the local space-time with the hope to detect deviations that would sign an impinging gravitational wave from a remote astrophysical source. Finding the rare and weak signature of gravitational waves buried in non-stationary and non-Gaussian instrument noise is a particularly challenging problem. We will give an overview of the data-analysis techniques and associated observational results obtained so far by Virgo (in Europe) and LIGO (in the US), alongwith the prospects offered by the up-coming advanced versions of those detectors.

Acoustic Detection / 3

In situ study of efficiency and angular coverage of acoustic sensors of the South Pole Acoustic Test Setup

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The South Pole Acoustic Test Setup (SPATS) consists of four strings,
each instrumented with seven acoustic sensors and transmitters frozen
in the upper 500 m of IceCube holes. SPATS sensors have been extensively studied in the laboratory at changing temperatures and pressure in air, water and ice. It was however impossible to create conditions like in deep ice at the South Pole. We present here different methods to investigate angular coverage and efficiency of the acoustic sensors after deployment. The corresponding results are used to discuss the reliability of SPATS detector measurements. We conclude with an outlook about the applicability of the described methods to future acoustic or hybrid detectors for cosmogenic neutrino measurements in ice.

Acoustic Detection / 29

Compact array calibrator for UHE neutrino acoustic detection

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In situ acoustic calibration devices should play a very important role to assure the right performance of sensors and detectors for the acoustic detection of ultra-high energy neutrinos in underwater telescopes. Moreover, they provide evidences for the feasibility evaluation of the technique and for the efficiency determination of the entire detector. Following previous studies, relating with parametric acoustic generation, a first prototype of a compact acoustic array able to mimic the acoustic neutrino signal (a very directive transient bipolar signal with 'pancake' directivity) is presented. The compact array developed has practical features such as easy handling, operation and versatile functionality. The transmitter is able to work in different frequency ranges, for different application modes, being possible to carry out several tasks related with acoustics in underwater neutrino telescopes: emission of neutrino-like signals, calibration of sensor sensitivities and responses, emission of signals for positioning, etc. The design, construction and characterization of the prototype are described. A propagation simulation study of experimental signals over km distances is also discussed.

Acoustic Detection / 32

A Linear Array Hydrophone Transmitter for the calibration of acoustic UHE Neutrino Telescopes

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The calibration and design of an eighth hydrophone linear array has been developed for the generation of emulated Ultra High Energy (UHE) neutrino-induced pulses. This acoustic array simulates the acoustic pulse created from a UHE neutrino interaction in water by generating a coherently emitted acoustic bipolar pulse. The calibrator is developed using signal processing methods using experimental measurements to characterise the hydrophone system. An 8 channel PIC hydrophone array module has been built for processing and control. A linear array simulation for the neutrino pulses production has been studied in order to predict the directivity and shape of the acoustic bipolar pulse at the ANTARES neutrino detector. The calibrator was deployed above the ANTARES site in September 2011. The result of the analysis of the first sea campaign over ANTARES will be presented.

Keywords: Array hydrophone calibration; UHE neutrinos;
Acoustic detection; PIC module; array simulation.

Acoustic Detection / 9

Performance of the Aachen Acoustic Laboratory and results from comparative studies in water and ice.

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To investigate acoustic ice properties under laboratory conditions and to test the thermo-acoustic model, the Aachen Acoustic Laboratory (AAL) was founded as a part of the acoustic working group (SPATS) within the IceCube collaboration.
The AAL provides a test facility setup with a proper infrastructure to study acoustics and thermo-acoustics in a large volume of water and ice. The control on the freezing process, the ice quality, the temperature monitoring at different phases of the medium and the laser-based thermo-acoustic sound generation are the key ingredient of the setup.
The AAL setup provides the possibility for the characterization of a wide range of acoustic transducer, sensor/transmitter calibration, study of the thermo-acoustic sound generation, study of the acoustic properties of the ice, water as well as the water/ice interfaces, and R of new types of acoustic transducers (PVDF-based) as an alternative to standard PZTs.
In this document the different parts of the AAL setup are described,
results on the commissioning of the laser based thermo-acoustic sound generation are presented and the performance of the absolute sensor calibration method in water and ice is discussed.

Acoustic Detection / 37

Towards high energy neutrino acoustic detector in Lake Baikal: current status and perspectives.

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We report the present status and perspectives of the feasibility study to detect cosmic neutrinos acoustically in Lake Baikal. The results of a background studies are presented. It was shown that most of the detected background neutrino-like pulses come from the lake surface. This fact has been used in project of an acoustic prototype detector that consists of compact modules with 4-channel antennas each, arranged above the Baikal Neutrino Telescope at shallow depths and "listens" the deep-water layers of the lake. The results of test experiments and of data taking with the detector are presented.

Acoustic Detection / 40

Simulation Chain for Acoustic Ultra-high Energy Neutrino Detectors in Water

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Acoustic neutrino detection is a promising approach for large-scale ultra-high energy neutrino detectors in water. In this contribution, a Monte Carlo simulation chain for acoustic neutrino detection devices in water will be presented. The simulation chain covers the generation of the acoustic pulse produced by a neutrino interaction and its propagation to the sensors within the detector. Currently, ambient and transient noise models for the Mediterranean Sea and simulations of the data acquisition hardware, similar to the one used in ANTARES/AMADEUS, are implemented. A pre-selection scheme for neutrino-like signals based on matched filtering is employed, as it can be used for on-line filtering. To simulate the whole processing chain for experimental data, signal classification and acoustic source reconstruction algorithms are integrated. An overview of the design and capabilities of the simulation chain will be presented, and some applications and preliminary studies will be discussed.

Related Subjects / 33

Search for Ultra-high energy cosmic neutrinos with the IceCube neutrino observatory.

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We review the present status of the search for ultra-high energy cosmic neutrinos with the conventional methods. The IceCube neutrino observatory has currently realised the best sensitivity on detection of neutrinos in the energy range around EeV, by the standard neutrino detection technique measuring ultra-violet Cherenkov light emissions. The most updated results from the data obtained by the increased instrumentation volume of the IceCube optical sensor array are reported, followed by discussions on its implication to origin of ultra-high energy cosmic rays. The another conventional technique using deeply penetrating airshowers also provides a capability to search for ultra-high energy neutrinos by a giant cosmic ray airshower detector. We briefly mention the published results obtained by the Pierre Auger observatory and the future outlook by the planned JEM-EUSO mission.

Microwave Detection / 57

GHz detection activities for air showers: Experiments, accelerator measurements, theory

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GHz detection activities for air showers: Experiments, accelerator measurements, theory

Microwave Detection / 19

Cosmic-Ray Observation via Microwave Emission (CROME)

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The CROME experiment is a new setup to study microwave radiation from air showers. The GHz radiation is measured with several parabolic antennas, each equipped with a multiple-receiver camera operating in the extended C band (3.4--4.2 GHz). Data are taken in coincidence with cosmic-ray showers detected by the KASCADE-Grande experiment. The overall experimental setup will be presented and different methods used for determining sensitivity, pointing, and time synchronization of the detectors will be discussed. It is shown that the CROME setup is well-suited for the detection of pulses of a few nanoseconds as expected from cosmic-ray showers. An overview of the first detected air shower events is given.

Microwave Detection / 20

On the microwave signal of air showers measured with CROME

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Microwave radiation from high-energy air showers has been observed in the C band with the CROME setup. The properties of these showers as reconstructed by KASCADE-Grande will be presented. The features of the detected GHz signals will be discussed and compared with Monte Carlo predictions for different emission mechanisms, taking into account the reconstruction uncertainties of KASCADE-Grande.

Microwave Detection / 60

Extensive air shower detection with CROME in the L-Band

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Extensive air showers are detected via particle measurements on the ground, the energy deposition in the atmosphere or via MHz-radio waves produced mainly by charged particles moving in the magnetic field of the earth. In addition, emission is predicted due to molecular bremsstrahlung. The Cosmic-Ray Observation via Microwave Emission (CROME) setup at the Karlsruhe Institute of Technology (KIT) consists of several antennas in the L-band, the C-band and the Ku-band. The KASCADE-Grande detector, which triggers the CROME experiment, provides calibrated measurements of air showers at the same location. In this talk the setup of a L-Band antenna, the signal chain including the data acquisition and first results will be presented. Long-term background measurements to determine the environmental background noise which show temporary monofrequent emitting interferences will be discussed.

Microwave Detection / 43

Detection of cosmic rays using microwave radiation at the Pierre Auger Observatory

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Radiation in the microwave band from the passage of charged particles has been measured in accelerator test beams. This radiation could provide a new technique for ultra-high energy cosmic rays, its main advantage being the possibility to instrument a large area, with 100% duty cycle and virtually no atmospheric attenuation, using relatively cheap equipment. Cosmic ray detection in the GHz band is being actively pursued at the Pierre Auger Observatory with three different set-ups: MIDAS and AMBER are prototypes of an imaging parabolic dish detector, while EASIER instruments a surface detector tank with a radio receiver of wide angular coverage. The status of microwave R activities at Auger, including the first event detected by EASIER, will be reported.

Microwave Detection / 23

Development of 12 Parabolas Observation System to Detect MBR from Airshowers.

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An observation system of MBR from extensive airshowers is being developed on a roof of the Konan University in Japan. This system consists of 12 parabolas with 1.2 diameters. Each parabola has a 12 GHz receiver. The signals from the receivers are digitized by 65 MS/s FADC. Field of view of each parabola is about 1.5 degrees and this system covers 6 times 4.5 square degrees. Test observation has been started since March this year and measuring noises from the city nearby. The detail of this MBR observation system and its extension plan will be presented.

Microwave Detection / 44

Measurements of the GHz emission by a 3 MeV electron beam.

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The MAYBE (Microwave Air Yield Beam) Experiment is dedicated to the study of the microwave emission from particle beams in the light of its possible use in the detection of ultra high energy cosmic rays.
Measurements of the microwave emission from an electron-beam where performed at the 3 MeV electron Van de Graaff facility of the Argonne National Laboratory. Results include the measured spectrum between 1 and 15 GHz, the polarization, and the scaling of the power with respect to the beam intensity. MAYBE measurements provide further insight on microwave emission as a detection technique for ultra-high energy cosmic rays.

Microwave Detection / 21

Towards Determining the energy of the UHECRs observed by the ANITA detector.

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The Antarctic Impulsive Transient Antenna (ANITA) is a balloon-borne radio experiment designed to discover ultra-high energy cosmic neutrinos. The ANITA detector has completed one prototype and two full-scale flights above the Antarctic continent. Two direct and fourteen reflected cosmic ray events of the ultra-high energy were observed during the first full scale flight and several others in the second flight. We present a Monte Carlo technique and analysis developed to determine the energy of the primary cosmic ray particles from the ANITA data.

Radio Detection Theory / 35

Simulation of radio emission from cosmic ray air shower with SELFAS2

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We present a microscopic computation of the radio emission from air showers initiated by ultra-high energy cosmic rays in the atmosphere. The strategy adopted is to compute each secondary particle contribution of the electromagnetic component and to construct the total signal at any location. SELFAS2 is a code which doesn't rely on air shower generators like AIRES or CORSIKA and it is based on the concept of air shower universality which makes it completely autonomous. Each positrons and electrons of the air shower are generated randomly following relevant distributions and tracking them along their travel in the atmosphere. We show in this paper that the radio emission is mainly due to the time derivative of the transverse current and the time derivative of the charge excess (see also [1]). The time derivative of the transverse current created by systematic deviations of charges in the geomagnetic field is usually dominant compared to the charge excess contribution except for the case of an air shower parallel to the geomagnetic field.

Related Subjects / 55

The cosmic triad: cosmic rays, gamma-rays and neutrinos

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The existence of ultra-high energy (UHE) cosmic-rays (CRs) is a strong motivation for neutrino astronomy at very high energies; it seems unavoidable that UHE CRs undergo hadronic interactions with radiation backgrounds or matter prior to their arrival at Earth. Mesons produced in these interactions quickly decay and release a flux of high-energy neutrinos and gamma-rays. Neutrino observatories have long been searching for the faint neutrino signals from extra-galactic sources that are smoking-gun signals of these hadronic interactions - so far without success. I will try to put this into perspective. What can we learn from this non-observation about candidate sources of UHE CRs? And what can we expect to see in the future?

Radio Detection in Air / 0

Detecting Radio Emission from Cosmic Rays with LOFAR

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LOFAR (the Low Frequency Array) is the largest radio telescope in the world for observing low frequency radio emission from 10 to 240 MHz. In addition to its use as an interferometric array, LOFAR is now routinely used to detect cosmic ray induced air showers by their radio emission.

The LOFAR core in the Netherlands has a higher density of antennas than any other dedicated cosmic ray experiment. On an area of nearly 5 km^2 about 1800 antennas are installed. They measure the radio emission from air showers with unprecedented precision and, therefore, give the perfect opportunity to disentangle the physical processes which cause the radio emission in air showers. In parallel to ongoing astronomical observations LOFAR is triggered by a particle detector (LORA) to record the time series containing the cosmic ray pulses.

Cosmic rays have been measured with LOFAR since June 2011. We will present the results of the first year of data. Special emphasis will be put on the reconstruction chain and the lateral signal distribution.

Radio Detection in Air / 5

Tunka-Rex: a Radio Antenna Array for the Tunka Experiment

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Tunka-Rex (Tunka radio extension) will be an array of about 20 antennas at the Tunka experiment close to Lake Baikal in Siberia. The antennas will be connected directly to the data acquisition of the Tunka main detector, a 1 km² large array of 133 non-imaging photomultipliers observing the Cherenkov light of air showers in dark and clear nights. This allows to cross-calibrate the radio signal with the Cherenkov signal of the same air showers - in particular with respect to the energy and the atmospheric depth of the shower maximum, Xmax. Consequently, theoretical predictions can be tested whether in rural regions with low radio background the radio precision comes indeed close to the precision of the established fluorescence and air-Cherenkov techniques. At a mid-term perspective, due to its higher duty-cycle, Tunka-Rex can then enhance the effective observing time of Tunka by an order of magnitude, at least in the interesting energy range above 100 PeV. Moreover, Tunka-Rex is very cost-effective, e.g., by using economic Short Aperiodic Loaded Loop Antennas (SALLAs). Thus, the results of Tunka-Rex and the comparison to other sophisticated radio arrays will provide crucial input for future large-scale cosmic-ray observatories, for which measurement precision as well as costs per area have to be optimized.

Radio Detection in Air / 31

Prospects for an air-shower radio extension to IceCube

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With its 1km3 in-ice sensor array complemented by a 1km2 surface array of ice-Cherenkov tanks for particle detection, the IceCube observatory is not only the largest neutrino telescope but also one of the world's most competitive instrument for studying cosmic rays in the PeV to EeV regime. In particular, studying high-energy muons from
the shower core in coincidence with particle flux on the surface yields a handle on cosmic ray composition in the energy range where the transition from galactic to extra-galactic sources should occur.

Further augmenting the IceCube observatory with an array of radio sensor in the 10-100MHz regime will additionally allow for observation of the geomagnetic radio emission from the air shower. Reflecting the whole shower development, this radio signal will not only provide for significantly reducing the systematic errors involved with the sampling approaches, but will also result in an additional, independent handle on the shower maximum. Such a triple-technology array should therefore significantly improve the understanding of cosmic rays.

I will present first results from exploratory instrumentation deployed at the SouthPole, indicating its suitability for this approach. In addition, first performance studies using a detailed MonteCarlo simulation including IceCube/IceTop and the radio array will be shown, and prospects for the installation of a test array will be discussed.

Radio Detection Theory / 48

A semi-analytic treatment of radio emission from air showers

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A fast semi-analytic frequency domain calculation for the radio emission from cosmic ray air showers is presented. The shower is treated as a smooth macroscopic current source, separable in cartesian "shower"-coordinates, which facilitates calculation of phase coherence at a remote detector. Time delays account for geometry and varying index of refraction along the shower profile. Current distributions are described as the product of longitudinal, transverse, and shower thickness profiles, with additional parameters to account for creation of charge excess, and transverse currents due to multiple soft coulomb scattering and magnetic deflections. Comparisons are made to REAS 3.0, without index of refraction, and to COREAS with index of refraction.

Radio Detection Theory / 39

Electromagnetic radiation in the Tamm problem

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The 'Tamm Problem' (Tamm, 1939) is the calculation of the electromagnetic radiation emitted by a particle travelling a finite distance at a uniform (relativistic) velocity in a medium. It is exactly the problem which needs to be solved in Monte-Carlo simulations of the radio-emission from individual particles. The two main formulas used in calculations - the ZHS algorithm and the endpoint formulation - both use approximations in their derivations, the effect of which in realistic problems is currently unclear.

In this contribution, the ZHS and endpoint solutions to the Tamm problem are compared using simple toy experiments. In order to resolve questions on each method's accuracy, a new approach to the problem is presented, which attempts to make none of the assumptions inherent in these previous formulas. The applicability of the ZHS and endpoint approaches is then re-assessed in light of this information.

Radio Detection Theory / 22

Radio emission from Air Showers. Comparison of theoretical approaches.

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While the fluorescence and the ground counter techniques of the ultra-high energy cosmic rays (UHECR) detection were being developed for decades, the interest in the radio detection diminished after the initial experiments in the 1960s. As a result, the fluorescence and the surface array techniques are more mature today, providing more reliable measurements of the primary cosmic particle energy, chemical composition and the inelastic cross-section. The advantages of the radio technique are 100% duty cycle and lower deployment and operational costs. Thus, the radio technique can greatly complement the fluorescence and the ground array detection and can also work independently. With the ANITA balloon detector observing UHECRs and the success of LOPES, CODALEMA and other surface radio detectors, the radio technique got a significant boost in recent years. Reliable Monte Carlo (MC) simulations are needed in order to obtain the energy and other parameters of the primary cosmic ray particle from the radio observations. Several MC techniques like,
ZHairesS and the Endpoint Formalism, were proposed in recent
years. While they seem to reproduce some of the observed data quite
well, there is a divergence between the different approaches under
certain conditions. In this work we derive these approaches from
Maxwell''s equations, discuss their similarity and limitations that
are applicable to the UHECR air showers and to the proposed experiment at SLAC.

Poster Contributions / 15

LOPES-3D - vectorial measurements of radio emission from cosmic ray induced air showers

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LOPES is an ever evolving radio antenna array co-located within the KASCADE-Grande air-shower particle-detector array at the Karlsruhe Institute of Technology (KIT). It measures the radio emission from cosmic-ray induced air showers via digital radio interferometry at energies larger than 10^16.5 eV. In its latest setup, called LOPES-3D, it is able to measure all three components of the electric field vector of the radio emission from air showers. This will allow a better comparison with emission models. The measurement of the vertical component will increase the sensitivity to inclined showers. By measuring all three components of the electric field vector LOPES-3D will demonstrate by how much the reconstruction accuracy of primary cosmic ray parameters will increase. Thus LOPES-3D will evaluate the usefulness of vectorial measurements for large scale applications. As a first step to vectorial analysis the treatment of the antenna gain pattern in the analysis software was improved. This new vectorial treatment of the gain pattern is presented and first results obtained using this technique are shown. The data taken with LOPES-3D are compared with former results of LOPES using a statistical approach.

Poster Contributions / 42

On polarization effects of radio emission from extensive air showers

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Radio emission is one of the processes that Extensive Air Showers (EAS) produce in the air. The LOPES (LOFAR Prototype Station) experiment at KIT Campus North, on site of the KASCADE-Grande experiment in Germany, was a certain period of its lifetime configured to measure polarized signals from EAS. Polarization characteristics of the radio signals are important aspects in verifying the radio emission mechanisms. The geomagnetic effect is considered the dominant contribution in the radio emission process, while the net charge excess developed in the shower may contribute significantly, depending on the geometry of the air shower and the position of the observer. Aspects of shower geometry related to polarization effects will be discussed, based on LOPES radio data, KASCADE-Grande reconstructed air shower observables, as well as sophisticated simulation predictions.

Poster Contributions / 17

On the Attenuation of the Vavilov--Cherencov Radio Emission Induced by Ultrahigh-energy Cosmic-ray Cascades in a Solid Medium

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The influence of the electron-hole plasma on the Ascaryan effect caused by cosmic-ray cascades in a solid medium is discussed. It is shown that screening the radio emission attaining detectors aimed at registration of particles of energies exceeding 10^20 eV should be taken into account. We state that the radio-emission absorption is strong in pure Antarctic ice but is less significant in the lunar regolith. Therefore, the lunar orbital radio detector registering ultrahigh-energy cosmic rays and neutrinos allows the particle of energies up to 10^22-- 10^23 eV to be detected.

Poster Contributions / 59

Readout & DAQ of KM3NeT

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The KM3NeT consortium is preparing to build a multi-cubic-kilometre sized deep-sea neutrino telescope in the Mediterranean Sea. Thousands of detector modules and sensors will be operated remotely and all their data will stream continuously to shore for neutrino detection, detector calibration, environmental monitoring and Sea- and Earth-Sciences observations.
The readout concept of KM3NeT, the data transmission to shore and the DAQ system, described here, can be applied to any remote sensor networks covering large observational volumes.

Poster Contributions / 46

Search for Microwave Signals from Air Showers with the Electron Light Source at Telescope Array

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The Electron Light Source (ELS) is a linear accelerator to produce bunches of 40 MeV electrons that are used to calibrate the fluorescence telescopes of Telescope Array (TA). The beam is shot vertically up into the air and resembles an air shower of $10^{16.5}$ eV. A measurement campaign has been started to search for microwave emission from air showers by placing GHz antennas at close distance to the ELS beam. Initial measurements were done with a parabolic reflector of 2.3 m diameter and C band receivers. The experimental setup and some results from the first measurements will be shown.

Poster Contributions / 8

Studies on radio emission of neutrino induced showers in salt

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Calculations of radio emission of neutrino induced showers in large volumes observing the generated radio waves, are reported. The medium chosen is salt, one of the media originally proposed by Askaryan, which can be found in large volumes throughout the world, including in Romania.
We have performed simulations of neutrino-nucleon charged-current and neutral-current interactions using the HERWIG code, in the 10^12-10^17 eV energy range. Subsequently we have injected all of the resulted particles in GEANT4 code, for the low energy primaries, and in AIRES code, for the higher energies, for the simulation of realistic showers for all neutrino primaries.
The calculation of the radio signal was performed considering the entire shower evolution, by taking into account in the equations the longitudinal profile.

The aim of this study is to investigate how different interactions can be discriminated in an experiment for detection of high energy particles based on registering the radio emission from the showers they initiate.