NBIA PhD-School: Neutrinos underground & in the heavens

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Niels Bohr Institute

Book of Abstracts

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Search for astrophysical neutrinos with IceCube

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The IceCube Neutrino Observatory, located at the geographic South Pole, utilizes 1 km^3 of the glacial ice and is the world's largest detector for high-energy neutrinos. IceCube searches for high-energy astrophysical neutrinos whose observation will provide a complementary view of some of the highest energy phenomena occurring in the known universe. High energy neutrinos have been predicted to be produced in astrophysical sources such as active galactic nuclei and gamma ray bursts , where cosmic rays are supposed to be accelerated to very high energies. IceCube detects the optical light emitted by the charged particles produced when neutrinos interact in the ice. When a neutrino interacts, it can transfer its energy to a single long-range particle or it can initiate a shower of many particles resulting in a localized deposition of energy and a bright nearly point-like source of light. These two possibilities lead to two rather different event signatures in IceCube. In this talk I will introduce my research which focuses on the second option looking for the point-like sources of light from the neutrino-induced showers of particles.

Problems Class/Student Talks / **1**

Detection of prompt atmospheric neutrinos with IceCube

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The IceCube neutrino telescope instruments a cubic kilometre of the Antarctic ice at the South Pole with a three-dimensional array of light sensors. It is the largest neutrino telescope and is accumulating an unprecendented number of atmospheric neutrino events. Atmospheric neutrinos are produced in air showers, when cosmic rays hit the Earth's atmosphere and interact hadronically. The conventional neutrino flux, which dominates the neutrino data measured in the GeV to TeV range, is produced by the decay of charged pions and kaons. Prompt atmospheric neutrinos are produced by the decay of heavier mesons typically containing a charm quark. Their production is strongly suppressed, but they are expected to exhibit a harder energy spectrum. Hence, they could dominate the atmospheric neutrino flux at energies above ~ 100 TeV. Such a prompt atmospheric flux component has not yet been observed. In this talk I will describe my research project which has the goal of observing prompt atmospheric neutrinos.

Problems Class/Student Talks / **0**

A Search for Astrophysical Neutrino Sources in the Southern Hemisphere using the IceCube Neutrino Observatory

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One of the most intriguing topics in physics today is to find the answers to where cosmic-rays are produced and how they are accelerated. Hadronic acceleration models suggests that cosmic-ray protons and nuclei are accelerated and they subsequently interact with ambient radiation or matter producing high-energy neutrinos through the decay of light mesons. Unlike charged particles that are bent in magnetic fields and gamma-rays that can be absorbed through interactions with the interstellar medium, neutrinos are of particular importance since they interact only weakly and hence point back to the source of emission. An observation of neutrinos from areas associated

with emission of high energy gamma-rays would not only be a key to better understanding of the acceleration mechanism but would also give unique insights of the most dense and violent regions in the Universe.

IceCube is a cubic-kilometer-scale neutrino detector located in the ultra-clear ice at the South Pole. One of the main goals is to search for localized neutrino sources. Recent development has lowered the energy threshold for southern hemisphere point-source searches by utilizing part of the detector as a veto for incoming atmospheric muons that constitutes the background. No point source has yet been found, but IceCube's limits on point sources are approaching the predictions for galactic sources. We expect results in the near future were we for the first time could get a detailed glimps of the Universe through the neutrino window. I will present recent results on a low-energy (100 GeV-50 TeV) point source search with focus on the sources in the Southern Hemisphere.

Problems Class/Student Talks / **15**

Indirect Detection of Dark Matter using IceCube

Author: Morten Medici[1]

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A short presentation of the methods used and the results achieved using IceCube for indirect detection of neutrinos from dark matter annihilation.

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Low-energy tau searches with IceCube

Author: Michael Larson[1]

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Charged-current tau neutrino signatures in IceCube have unique topologies at high energies primarily due to the decay of the tau neutrino into lower energy particles. Low energy tau particles produced in the GeV range will decay immediately, producing a shower topology similar to both neutral-current and electron neutrino interactions in IceCube. The spectrum of the parent tau neutrinos can yield information about the PMNS neutrino mixing matrix, giving a novel test of unitarity.

In this presentation, I'll be discussing the methods of identifying these low-energy showers and the impact of the proposed PINGU upgrade to IceCube on the tau neutrino appearance results.

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Author: Georg Raffelt[1]

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Diffractive studies at the LHC

Author: Simon Stark Mortensen[1]

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Diffractive processes at LHC energies constitutes about 25 % of the total cross section but are currently not well understood since diffraction belongs to the soft non-perturbative region of QCD. This talk will introduce the different kinds of diffractive processes and explain how we can gain knowledge about diffraction by tagging the proton(s) at very small scattering angles. Also, the connection between diffractive processes and cosmic rays will be discussed.

Problems Class/Student Talks / **12**

Scattering Amplitudes

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I'll explain the concepts of analyticity and unitarity in the context of multiloop scattering amplitudes.

Problems Class/Student Talks / **3**

Neutrinos and hard probes in heavy ion collisions

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One of the surprising results to come out of the LHC heavy ion programme is the observation of the Z and W bosons, which provide important information about hard scattering in nucleus-nucleus collisions. In high energy collisions neutrinos cannot be directly observed, but are rather observed through missing energy. This is already challenging in proton-proton collisions, and even more so in Pb-Pb collisions with up to 1000 times more particles produced. I will present results of the W->l \nu_l measurements in Pb-Pb collisions at the LHC and discuss how finding the missing energy of the neutrinos play an important role in these measurements.

Problems Class/Student Talks / **2**

ICARUS T600 experiment: latest results and perspectives

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Co-authors: Alessandro Menegolli [2]; Dorota Stefan [3]; Robert Sulej [4]

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The ICARUS (Imaging Cosmic And Rare Underground Signals) experiment employs the liquid Argon Time Projection Chamber (LAr TPC) technique to study Long Baseline (LBL) neutrino oscillations and rare event physics. The ICARUS T600 detector, filled with 760 tons of LAr, is placed in the underground laboratory of Gran Sasso (LNGS). It took data from 2010 to 2012 with the CNGS (Cern Neutrino to Gran Sasso) beam and, after the shutdown of this beam, it continued to collect data from cosmic rays up to June 2013, when the detector decommissioning phase began. Thanks to the LAr properties, the T600 detector allows combining the remarkable imaging capability of a bubble chamber with an excellent reconstruction of the energy deposited by charged particles.
The main purpose of this experiment is to study neutrino oscillations in an almost pure νμ beam. Latest results, here presented, are related to the νμ->νe oscillation signal possibly due to LSND anomaly, related to the hypothesis of the existence of a sterile state in the neutrino sector.
To clarify this issue, a new phase of the experiment is foreseen, which will be characterized by the realization of a ~ 1 T magnetic field inside the LAr active volume. In view of this scenario, a new software algorithm is going to be implemented for the automatic classification of electrons and positrons coming from neutrino charged current interactions that will occur in the detector.

Problems Class/Student Talks / **37**

Enceladus Explorer project

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The Enceladus Explorer project is a DLR funded feasibility study for a future space mission to the Saturn moon Enceladus. The aim of this mission is to search for life by probing liquid water pockets below the icy surface. As a terrestrial test scenario it is planned to probe brine from a liquid crevasse in Antarctica. Therefore the IceMole, a maneuverable melting probe with an ice screw for forward thrust, is in development. Partial heating of the IceMole head allows to drive curved trajectories through the ice. To monitor and control these trajectories a precise navigation system is needed. The developed navigation system consists of an inertial measurement unit and a magnetometer as well as an acoustic navigation system containing an ultra- sonic reconnaissance system, which explores the fore-field of the probe and an acoustic positioning system, which determines the absolute position of the IceMole. This talk gives an overview of the Enceladus Explorer project with a focus on the acoustic navigation system.

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ESSnuSB –The European Spallation Source Neutrino Super Beam

Author: Alexander Burgman[1]

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As is generally known today, neutrinos oscillate between possible eigenstates, but several parameters of this oscillation remain unknown. Recent results (from e.g. the T2K and MINOS experiments) favour larger values of theta_13 (the mixing angle between two mass eigenstates) than previously thought. This shifts the most favourable L/E range for oscillation detection from the first oscillation maximum to the second oscillation maximum.
The ESSnuSB (European Spallation Source Neutrino Super Beam) is a proposed facility for the study of the neutrino oscillation. It would be optimized for observations in the second oscillation maximum to yield discoveries on the CP violation in neutrino oscillations and on the mass hierarchy of the neutrinos.

Problems Class/Student Talks / **7**

The nuMSM: Successes and shortcomings

Author: Kyle Allison[1]

[1] *University of Oxford*

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I will review the Neutrino Minimal Standard Model (nuMSM) as an explanation for neutrino oscillations, dark matter, and the baryon asymmetry of the universe. If time allows, I will also discuss some of the theoretical issues that face the model.

Problems Class/Student Talks / **13**

(Re)constructing Finite Non-Abelian Flavour Groups

Author: Jim Talbert[1]

[1] *University of Oxford*

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A new, model-independent method for finding phenomenologically viable flavour groups (long used to quantise leptonic mixing angles) will be discussed.

Problems Class/Student Talks / **11**

A Perturbation Parable: Relating the neutrino oscillation parameters

Author: Soumita Pramanick[1]

[1] *Department of Physics, University of Calcutta*

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Popular lepton mixing models are in clear disagreement with the recent oscillation observation of nonzero θ_{13}. We show that by supplementing these models by a single perturbation the conflict can be addressed. Starting from a point where θ_{13} is zero and the first two neutrino mass eigenstates are degenerate leading to no solar splitting initially, we device a perturbation that splits the degeneracy as well as generates nonzero $theta_{13}$ in one stroke thereby relating them. A neutrino mass model to justify the origin of the mass matrices will also be presented that will demonstrate the execution of the procedure.

Problems Class/Student Talks / **6**

Coincidence Measurements for Gerda Phase II

Author: Katharina von Sturm[1]

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The Gerda experiment aims to find the Neutrinoless Double-Beta Decay (0nbb) in Ge76. Having concluded Phase I with a lower limit on the respective half-life which strongly disfavours the KK claim of 2004 [1][2][3], the experimental setup is currently changed to be suitable for Phase II. The modified setup will implement a new veto using the scintillation light of liquid Argon to reject background events and will be able to hold a higher detector mass as there are 30 new detectors ready for insertion. The Phase II detectors are of Broad Energy Germanium (BEGe) type which offers pulse shape analysis [4] as a powerful tool to further reduce the background. Hence, events with a topology that does not match the characteristics of 0nbb events can be recognized and efficiently rejected. To improve this technique an experiment is being set up at Laboratori Nazionali di Legnaro (LNL) implementing a BEGe test detector of depleted germanium and four coaxial detectors made of natural germanium. A collimated Cs137 source will be installed to illuminate the BEGe detector from below and the slit collimated coaxial detectors are facing the BEGe at an observation angle of 90deg. Coincident events in the BEGe and one coaxial detector at the energy of a single Compton scattered event are expected to have a single site event topology, thus matching the topology expected for a 0nbb event in Gerda. As the Cs137 source and the coaxial detectors are collimated a scan of the BEGe can be performed giving clean samples of signal like events which can be used to train a neural network or to build a pulse shape library in order to improve the pulse shape analysis technique. BEGe data from Gerda Phase I will be used to benchmark the newly developed technique and comparisons to pulse shape simulations will be performed. In this talk the setup, aim, tests and simulations done so far will be presented.

References

[1] The GERDA Collaboration, Results on Neutrinoless Double-Beta Decay of Ge76 from Phase I of the GERDA Experiment, Phys.Rev.Lett. 111 12 (2013) 122503

[2] C. Macolino on behalf of the GERDA Collaboration, Results on Neutrinoless Double-Beta Decay from GERDA Phase I, Mod.Phys.Lett.A 29 01 (2014) 1430001

[3] H.V. Klapdor-Kleingrothaus et al., Search for neutrinoless double beta decay with enriched 76Ge in Gran Sasso 1990-2003, Phys.Lett.B 586 (2004) 198-212

[4] The GERDA Collaboration, Pulse shape discrimination for Gerda Phase I data, Eur.Phys.J.C 73 10 (2013) 1

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Problems Class/Student Talks / **8**

CeSOX: an antineutrino generator to test for an eV-scale sterile neutrino

Author: Mathieu Durero[1]

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The CeSOX project aims at testing the reactor antineutrino and Gallium anomalies, which can be interpreted as oscillations of active neutrinos toward a fourth (sterile) neutrino species in the very short baseline regime. CeSOX will use an intense radioactive antineutrino source deployed at the Borexino detector to search for a 2-dimensional oscillation pattern both in energy and position in the antineutrino detection rate. The main challenges of the project reside in the source production, shielding design and manufacturing to achieve background reduction, as well as the transportation and handling of highly radioactive material at the Borexino detector. In this talk, I will first give a short summary of the project, then I will detail the current progress on the readying of the source characterization. Indeed precise knowledge of the antineutrino spectrum shape and rate are very important to achieve the best sensitivity to the possible oscillation pattern, and a particular stress is put on the source activity and spectrum measurements.

Problems Class/Student Talks / **14**

Measurements of the T2K experiment

Author: Weronika Warzycha[1]

[1] *University of Warsaw*

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The T2K is one of world's leading experiments in neutrino physics. In the past years it has provided some fundamental experimental results and new are expected to be delivered in the upcoming time. The T2K measures neutrino interactions in two detectors, far - Super Kamiokande and near - ND280. This talk will provide some vital information for the T2K experiment. Additionally, some aspects of the neutrino interactions and T2K's measurements will be highlighted.

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Searches for Dark Matter induced neutrinos.

Author: Katarzyna Frankiewicz[1]

[1] *National Centre for Nuclear Research*

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My talk will be devoted to detection and attempts to elucidating the nature of Dark Matter. In particular I will focus on searches for neutrinos, which may be produced in Dark Matter annihilation. As an example, I will discuss analysis performed at Supe-Kamiokande experiment.

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Model free data fitting

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A short description of how we try to circumvent the inherent problems of fitting data without a model, specifically using artificial neural networks is presented. Inspired by methods form PDF-estimation, I present a method for deriving honest error estimates from MC methods. Our motivation in the present study is from cosmology, mainly the Hubble diagram and accoustic oscillations.

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Model indpendent cosmological analysis of high-redshift supernova

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Lecture 1 again

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