# NEUTRINO2010, XXIV International Conference on Neutrino Physics and Astrophysics, Athens, GREECE

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# Book of Abstracts

# Contents

**0**

## Double Chooz calibration

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The current best limit on the neutrino mixing angle theta-13 (sin2(2theta13) <˜ 0.15 @90% C.L.) was established by Chooz experiment conducted in the French Ardennes over a decade ago. Another experiment, the Double Chooz, is being prepared at the same site and is aiming to surpass the current limit by almost an order of magnitude. Extensive calibration program is necessary to achieve claimed sensitivity. Described in this poster are dedicated embedded and deployable calibration systems developed for the Double Chooz experiment.
Overview of the experiment, design of available calibration tools, as well as expected performance, are presented.

**1**

## Variation of the neutrino beam at diffraction of electron neutrino on bent crystals

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At the diffraction of a neutrino beam on a bent crystal the neutrino beam density increases when approaching the focus, which accelerates the processes of mixing and oscillations and the processes of the transformation of electron neutrinos into muon neutrinos and tau neutrinos with masses exceeding the mass of electron neutrinos by several orders. In the focus there will be the maximal density of heavy neutrinos. Further transformation of neutrinos into even heavier particles is possible until a related particle without charge and having moment like a neutron-type particle or hydrogen-type plasma is formed like in the process ν(e) + n –> e- +p on the Sun, where ν(e) is electron neutrino, n is neutron, e- is electron and p is proton. This will lead to a significant increase of the interaction of heavy neutrino with matter. Such possibility is thought to be promising for the purpose of creating a new kind of renewable energy or for the analysis of the matter condition, which is beyond the limits of exposure and for analyses by other methods; for example, for the evaluation of the Earth matter seismic activity at a significant depth from the surface in the conditions of a brewing earthquake like in the case of the predicted strongest earthquake in California with the magnitude equal to 8 and the probability of 60% within 30 years (in the nowadays mass media information, the force of the earthquake is said to be even stronger, i.e. with the magnitude equal to 9). The method of increasing the neutrino beam density due to the diffraction on bent crystals at bringing the secondary extinction of the crystals to a minimum and, consequently, the beam density to a maximum can be considered as a method for investigating the expected Universe compression.

**2**

## Contribution of charged Higgs bosons of a two Higgs doublet model, to the anomalous magnetic moment of Dirac neutrinos

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We calculate the contribution of a charged Higgs boson to the anomalous magnetic moment of the neutrino, where the charged Higgs comes from a two Higgs doublet model with the standard gauge group, in which we consider right-handed Dirac neutrinos in the spectrum. We determine the parameter space in the mixing angles and couplings that maximizes such a contribution for them to be observable in experiments.

**3**

## Improved limits on b+EC and ECEC processes in 112Sn

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New limits on b+EC and ECEC processes in 112Sn have been obtained using a 380 cm3 HPGe detector and an external source consisting of 100 g enriched tin (94.32% of 112Sn). A limit with 90% C.L. on the 112Sn half-life of 1.3•10ˆ21 y for the ECEC(0v) transition to the 0+3 excited state in 112Te (1871.0 keV) has been established. This transition is discussed in the context of a possible enhancement of the decay rate. The limits on other b+EC and ECEC processes in 112Sn were obtained on the level of (0.1-1.6)•10ˆ21 y at the 90% C.L. In addition, it has been demonstrated that, in the future larger-scale experiments, the sensitivity to the ECEC(0v) processes for 112Sn can reach the order of 10ˆ26 y. Thus there is a chance of detecting the b+EC(2v) transition of 112Sn to the ground state and ECEC(2v) transition to the 0+1 excited state.

**4**

## Double Beta Decay: The MAJORANA Project

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The MAJORANA collaboration is pursuing the development of the so-called MAJORANA DEMONSTRATOR. The DEMONSTRATOR is intended to perform research and development towards a tonne-scale germanium-based experiment to search for the neutrinoless double-beta decay of 76Ge.
The
DEMONSTRATOR can also perform a competitive direct dark matter search for light WIMPs in the 1-10 GeV/c2 mass range. It will consist of approximately 60 kg. of germanium detectors in an ultra-low background shield located deep underground at the Sanford Underground Laboratory in Lead, SD. The DEMONSTRATOR will also perform background and technology studies, and half of the detector mass will be enriched germanium. This talk will review the motivation, design, technology and status of the DEMONSTRATOR.

**5**

## Measuring the Low Energy Nuclear Quenching Factor in Liquid Argon for a Coherent Neutrino Scatter Detector

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Coherent neutrino-nucleus scattering (CNS) is an as-yet undetected, flavor-independent neutrino interaction predicted by the Standard Model. One primary reason the CNS interaction has yet to be observed is the very low energy depositions (less than ˜1 keV for MeV-scale neutrinos). Another challenge is that in argon and many other detection media, nuclear recoils produce less observable energy per unit energy deposited than electron recoils. This ratio of observed nuclear and electronic energy depositions is unknown in argon at energies involved in CNS interactions. CNS has a predicted cross section in argon, which for the energies of 1-10 MeV is ˜2 orders of magnitude greater than that of inverse-beta decay and thus offers the potential for a compact, flavor-blind neutrino detector. There are a variety of applications that could benefit from detecting the CNS interaction, such as antineutrino-based nuclear reactor monitoring, and astrophysics (solar and supernova neutrino detection). Our goal is to deploy a dual-phase detector with a 10 kg active mass (or 10/1.4 active volume) at a nuclear reactor to observe the CNS interaction. We are currently developing a small dual phase argon detector prototype for the purpose of measuring the ratio of nuclear to electronic observed energy deposition (nuclear quenching factor). We discuss the commissioning of the detector and the progress towards measuring the nuclear quenching factor for liquid argon at recoil energies of a few keV.

**6**

## Cosmic Neutrino Background Limits at the KATRIN Experiment and Beyond

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The KATRIN experiment is a tritium endpoint experiment designed to search for the absolute mass of the electron neutrino. Tritium also presents an interesting possibility for searches for the cosmic neutrino background from the Big Bang via the thresholdless process of neutrino capture. I will present a calculation of the KATRIN's sensitivity to this process and present ideas for future searches of the cosmic neutrino background.

**7**

## Underground studies and R&D towards a water Čerenkov Megaton detectors in Europe.

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MEMPHYS is a 0.5 Mton scale Water Čerenkov detector proposed for a deep underground installation - possible sites are under study in the European FP7 design study LAGUNA. It is dedicated to nucleon decay, neutrinos from supernovæ, solar and atmospheric neutrinos, as well as neutrinos from a future super-beam or beta-beam. Its performance with neutrino beams includes the posibility of measuring the mixing angle θ13 , the CP violating phase δ and mass hierarchy. One R&D item currently being carried out is MEMPHYNO, a small-scale prototype with the main purpose of serving as a test bench for new photodetection and data acquisition solutions, such as grouped readout and systems. In this poster we review the MEMPHYS physics reach and present the status of the MEMPHYNO prototype.

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# Supersymmetric model for neutrino masses with two dark matter candidates

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We discuss a supersymmetric extension of the radiative seesaw model for neutrino masses. The model can induce the tri-bimaximal neutrino mixing and have two dark matter candidates. One of them is the lightest neutralino appeared in the $R$-parity conserved MSSM. The other one is a right-handed neutrino with mass of O(1) TeV. The latter one is metastable and its longevity is guaranteed by a $Z_2$ subgroup of anomalous $\mathrm{U}(1)_X$ gauge symmetry, which forbids the neutrino mass generation at tree level. The flavour structure causing both the tri-bimaximal mixing and the smallness of neutrino mass eigenvalues may be partially related to this anomalous $\mathrm{U}(1)_X$. We study the phenomenology of the model such as the dark matter relic abundance, the lepton flavor violating processes and also the direct and indirect searches of dark matter.

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## Rephasing invariant parametrization for neutrino mixing

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Based on a rephrasing invariant parametrization, the neutrino mixing in matter is studied under the three-flavor framework. We derive the evolution equations for the parameters as functions of the induced neutrino mass. These evolution equations are found to preserve approximately some characteristic features of the mixing matrix, resulting in solutions which exhibit striking patterns as the induced mass varies. The approximate solutions are compared to numerical integrations and found to be quite accurate. Certain intriguing properties of the parameters and the mixing matrix are also discussed.

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## 'Magical' properties of a 2540 km baseline Superbeam experiment

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The three outstanding problems of neutrino physics are the determination of (a) $\theta_{13}$, (b) mass hierarchy and (c) CP violation. All three of these can be measured by observing $\nu_\mu \to \nu_e$ oscillations at long baselines. Owing to various parameter degeneracies, disentagling the information on each of them is very complicated. While the proposed 7500 km long magic baseline' experiment simplifies the task considerably, the intense beam required for such an experiment seems futuristic by current standards. As an alternative, we highlight themagical' properties of the 2540 km baseline. We propose a superbeam experiment at this much shorter baseline with a narrow band NuMI-like beam, and demonstrate the ability of this single setup to distinguish between the two mass hierarchies. This, we show, is possible with a moderate exposure and by running the experiment in the neutrino mode only. Our results hold up to fairly small values of $\theta_{13}$ and irrespective of the value of the CP violating parameter. Unlike the magic baseline, it may also be possible to use this setup to measure CP violation in neutrino oscillation experiments.

**11**

## MiniBooNE, LSND, and the Sterile Neutrino Mystery

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This poster reviews global fits to sterile neutrino oscillation models in light of the latest neutrino and antineutrino oscillation results from the MiniBooNE experiment. The analysis presented investigates the validity of the three-active plus one-sterile (3+1) and three-active plus two-sterile (3+2) CPT-conserving neutrino oscillation hypotheses, given constraints from past short-baseline appearance and disappearance experiments. One of the main conclusions is that large incompatibilities exist between neutrino and antineutrino experimental data sets in both scenarios. The differences found between neutrino and antineutrino data sets cannot be easily accommodated in a (3+2) model, even when CP-violation is allowed, due to strong constraints from $\nu_\mu$ and $\nu_e$ disappearance experiments. Future sources of constraints to these models, as well as alternative oscillation schemes, are discussed.

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# Track and shower energy resolution in the MINOS charged current analysis

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The energy resolution of the MINOS detectors is an important factor in the sensitivity of our measurement of the “atmospheric” neutrino oscillation parameters.
Better energy resolution more clearly resolves the oscillation dip and allows us to more tightly limit the mass splitting and mixing angle.

We present a method for improving MINOS’s energy resolution for hadronic showers, using a kNN (k-Nearest-Neighbour) algorithm.

We also present parametrizations of MINOS’ track and shower resolutions that allow the dataset to be subdivided into quantiles of energy resolution.

We show the sensitivity improvement obtained from both of these techniques.

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# Experiment TGV-2 –search for double beta decay of 106Cd

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Investigation of double beta decay processes (EC/EC, β+/EC, β+ β+) of 106Cd was performed at the Modane underground laboratory (4800 m w.e.) using a low-background spectrometer TGV-2 (Telescope Germanium Vertical). The detector part of the TGV-2 is composed of 32 HPGe planar type detectors with the sensitive volume of 2040 mm2 x 6 mm each. The total sensitive volume of

detectors is as large as 400 cm3. The total mass of the detectors is ˜3 kg. The detectors are mounted one over another together with double beta emitters in a common cryostat. Double beta emitters were ˜50 μm thick foils of 106Cd (enrichment 75%) with a diameter of 52 mm inserted between the entrance windows of the neighbouring detectors. The distance between the detectors and the emitters was about 1.5 mm. The energy resolution of detectors ranged from 3.0 to 4.0 keV at 1332 keV (60Co). The detector part of TGV-2 was surrounded by a copper shielding (>20 cm), a steel airtight box against radon, a led shielding (>10 cm), and an antineutron shielding made of borated polyethylene (16 cm). Two experimental runs were performed to search for double beta decay of 106Cd. In the first run 12 samples of 106Cd with a total mass of ˜10 g and 4 samples of natural Cd with a total mass of ˜3.2 g were measured during ˜1 yr. In the second run 16 samples of 106Cd with a total mass of ˜13.6 g were studied during ˜1.5 yr. Additional experimental runs were performed with 16 samples of natural Cd and without samples to measure background in the regions of interest. The coincidences between two characteristic KX-rays of palladium detected in neighbouring detectors were analyzed to search for 2νEC/EC decay of 106Cd to the ground 0+ state of 106Pd. The search for 0νEC/EC resonance decay of 106Cd was based on the analysis of KX(Pd) –γ2741 keV and KX(Pd) –γ2229 keV –γ511.9 keV coincidences. Investigations of other branches of 106Cd decay –EC/EC decay to the 2+,511.9 keV and 0+,1334 keV excited states of 106Pd, and β+/EC, β+ β+ decays to the ground and excited states of 106Pd were based on the analysis of KX-511 keV, KX-622 keV, 511 keV-511 keV and 511 keV-622 keV coincidences. New limits (at 90% CL) on half-lives of 0νEC/EC resonant decay of 106Cd–T1/2 > 1.7 × 10ˆ20 yr and 2νEC/EC decay of 106Cd (0+g.s. –0+g.s.) –T1/2 > 4.2 × 10ˆ20 yr were obtained in a preliminary calculation of data accumulated in the TGV-2 experiment.
This work was partly supported by RFBR under grant 08-02-00790.

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## NEXT: a gaseous-Xe TPC for the neutrinoless double-beta decay

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Double beta decay (DBD) experiments are one of the most active research topics in Neutrino Physics. The measurement of the neutrinoless mode DBD could give unique information on the neutrino mass scale as well as the neutrino Majorana/Dirac nature. Current generation of experiments aim at detector target masses at the 100 kg scale, while the next generation will need to go to the few tons in order to completely explore the inverse hierarchy models of neutrino mass. Very good energy resolutions and ultra-low background levels are the two main experimental requirements for a successful experiment. NEXT (Neutrino Experiment with a Xenon TPC) is a project to look for the neutrinoless double beta decay of Xe136 in the Canfranc Underground Laboratory (LSC) in the Spanish Pyrenees. It has been approved by the LSC scientific committee and has been funded by the Consolider Program of the Spanish Ministry of Science to carry out the construction of 100 kg enriched high-pressure xenon gas (HPGXe) TPC. The merit of the proposal lies on the excellent energy resolution achievable by the electroluminscence signal in pure Xe, and the background rejection power provided by the topological information of the electron tracks obtained by a photosensor array (SiPMs, APDs or PMTs) or a Micromegas plane. We will report on the progress of the experiment and especially the results of the first generation of prototypes studying both the electroluminiscence signal and the charge amplification signal with Micromegas in pure HPGXe.

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## Proton Decay Searches with a Liquid Argon Detector at DUSEL

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Liquid Argon Time Projection Chambers (LAr TPCs) are ideally suited for the study of neutrino interactions thanks to precision detection capabilities that make them the modern day equivalent of bubble chambers. Liquid argon detectors on the scale of 20 kilotons are currently envisioned for the future long-baseline neutrino program in the United States. The same features that make these detectors excellent for studies of neutrino physics will also enable them to conduct proton decay searches that will significantly improve upon existing lifetime limits. I will display preliminary ideas for the ultimate LAr TPC experiment that could be conducted at the Deep Underground Science and Engineering Laboratory (DUSEL) in South Dakota as part of the world-class Intensity Frontier program that is currently being planned in the United States. Initial studies of proton decay searches with this detector will be presented and compared with the Water Cerenkov experiment that is also planned for DUSEL.

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## Search for a neutrino signal from LS I +61 303 with IceCube based on a time-dependent emission model

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The IceCube neutrino observatory is nearly complete, with 79 of the planned 86 strings deployed. Projected to be fully completed next austral summer, it will cover an instrumented volume of 1kmˆ3 of deep ice, tagging neutrinos by detecting the Cerenkov light emissions of neutrino-induced leptons and hadronic showers.

We present a model-dependent point source search for a neutrino signal from LS I +61 303, a high mass X-ray binary system. The model considered here is based on MWL observations, notably Fermi, and assumes that the broad band activity of the system is due to high energy protons interacting with the dense matter and radiation field of the massive star. Making basic assumptions on the geometry of the binary system, the model predicts the time-dependence of the neutrino emissions.

These predictions are used to constrain the neutrino signal search. Assuming their validity, this alternative model-dependent approach has an enhanced discovery potential and is complementary to generic time-dependent and steady point sources searches. The model and the analysis method will be described, and sensitivities in addition to results based on the 22 and 40 string IceCube configurations will be presented.

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## Leptogenesis without violation of B − L

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We study the possibility of generating the observed baryon asymmetry via leptogenesis in the decay of heavy Standard Model singlet fermions which carry lepton number, in a framework without Majorana masses above the electroweak scale. Such scenario does not contain any source of total lepton number violation besides the Standard Model sphalerons, and the baryon asymmetry is generated by the interplay of lepton flavour
effects and the sphaleron decoupling in the decay epoch.

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## The DCBA experiment searching for neutrinoless double beta decay

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Neutrinoless double beta decay (0nuBB) takes place when neutrinos are Majorana neutrinos, which are essential in the so-called seesaw mechanism to describe the reason why existing neutrinos are so light. Heavy parts of Majorana neutrinos in the seesaw mechanism play important roles in the theory of Leptogenesis to explain the asymmetry of matter and anti-matter in the early universe. The observation of 0nuBB would be an evidence of the seesaw mechanism and the Leptogenesis. In the DCBA (Drift Chamber Beta-ray Analyzer) experiment, we measure the momentum and obtain the kinetic energy of individual beta ray of double beta decay from Nd-150 or Mo-100 by drift chamber trackers installed in a uniform magnetic field. The particle identification ability of the magnetic trackers is useful to eliminate backgrounds such as alpha particles, positrons and cosmic rays. A prototype called DCBA-T2 has been constructed and now in the engineering operation with thin plates of natural Mo, which includes 9.6% Mo-100. We have several candidates of two neutrino double beta decay events. The energy resolution has been measured using internal conversion electrons from Bi-207 and about 150 keV (FWHM) has been obtained around 1 MeV. This is corresponding to the sum energy resolution of 6.5% (FWHM) at the Q-value of Nd-150 (3.37 MeV). For improving energy resolution, we are now constructing another prototype DCBA-T3. Its energy resolution is estimated to be less than 5% (FWHM) at 3.37 MeV by simulation studies using Geant4. In order to study the effective neutrino mass down to 0.05 eV, a future plan temporarily called Magnetic Tracking Detector (MTD) is designed on the basis of DCBA-T2 and T3.

**Summary**:

Majorana neutrinos are postulated in both theories of neutrinoless double beta decay (0nuBB) and seesaw mechanism. The observation of 0nuBB would be an evidence of the seesaw mechanism, and support

the Leptogenesis scenario of early universe. The DCBA experiment measures kinetic energy of individual beta ray in 0nuBB with powerful background rejection capability. A prototype called DCBA-T2 is in the engineering operation, and another one DCBA-T3 with better energy resolution is under construction. For the future project, MTD is designed on the basis of DCBA-T2 and T3 in order to study the absolute mass scale of Majorana neutrino down to 0.05 eV.

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## Neutrino electromagnetic properties

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A review on neutrino electromagnetic properties is given. The problem of the neutrino form factors (in particular, the neutrino electric charge form factor and charge radius, dipole magnetic and electric and anapole form factors) definition and calculation within different gauge models is considered. The neutrino magnetic (diagonal and transition) moments in the Standard Model and beyond are discussed in detail. Available experimental constraints on neutrino electromagnetic properties and the most recent experimental limits on neutrino magnetic moments are also reviewed. The important neutrino electromagnetic processes involving neutrino couplings with photons and possible astrophysical applications are discussed.

**Summary**:

The proposed talk is based on the review paper by

C.Giunti (INFN, Turin, Italy and myself

title: "Neutrino electromagnetic properties"

published in Phys.Atom.Nucl. 72 (2009) 2151-2187, arXive:0812.3646 (hep-ph).

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## Search for Sterile Neutrino Mixing in the MINOS Experiment

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In this poster, we present a search for disappearance of active neutrinos over a baseline of 735 km using the NuMI neutrino beam and the MINOS detectors. The data analyzed correspond to an exposure of $7.1 \times 10^{20}$˜protons-on-target. MINOS utilizes the most powerful neutrino beam currently in operation measured in two locations: a Near detector at Fermilab, 1˜km downstream of beam production, and a Far detector, 734˜km further away, in Northern Minnesota. By comparing the neutral-current selected spectrum at the Far detector with the expectation derived from the Near detector measurement, the hypothesis that neutrino oscillations occur between active and sterile neutrino flavours can be tested. The poster characterizes the MINOS ability to measure neutral-current neutrino interactions, outlines the event selection methods employed and describes results obtained for three-flavour and four-flavour neutrino oscillation models.

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## Measurement of the off-axis NuMI Neutrinos

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\textheight 9.2in
\begin{document}

\begin{center}{\bf Measurement of the off-axis NuMI Neutrinos}\\
Zelimir Djurcic\\
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\end{center}
\normalsize

Fermi National Accelerator Laboratory has two beam lines that produce neutrinos: the Booster Neutrino Beam (BNB) and the NuMI beam line.
The BNB beam is designed for use by the MiniBooNE experiment.
Motivated by the LSND observation of an excess of observed $\bar{\nu}_e$ events above Monte Carlo prediction in a $\bar{\nu}_\mu$ beam,
the MiniBooNE experiment was designed to test the neutrino oscillation interpretation of the LSND signal in both neutrino
and anti-neutrino modes.
The MiniBooNE collaboration has performed a search for $\nu_\mu \to \nu_e$ oscillations with $6.486 \times 10^{20}$ protons on target (POT),
the results of which showed no evidence of an excess of $\nu_e$ events for neutrino energies above 475 MeV.
Despite having observed no evidence for oscillations above 475 MeV, the MiniBooNE $\nu_\mu \to \nu_e$ search observed a sizable excess (128.8±43.4 events) at low energy,
between 200-475 MeV.
Although the excess is incompatible with LSND-type oscillations, several hypotheses, including sterile neutrino oscillations with CP violation,
anomaly-mediated neutrino-photon coupling,
and many others,
have been proposed that provide a possible explanation for the excess itself.
In some cases, these theories offer the possibility of reconciling the MiniBooNE $\nu_e$ excess with the LSND $\bar{\nu}_e$ excess.
The MiniBooNE collaboration also reported initial results from a search for
$\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations,
using a data sample corresponding to $3.386 \times 10^{20}$ POT.
No significant excess of events
has been observed, both at low energy, 200-475 MeV, and at high energy,
475-1250 MeV, although the data are inconclusive with respect to antineutrino
oscillations at the LSND level. MiniBooNE will be showing additional anti-neutrino data in this conference.\\
The NuMI beam produces neutrinos for the MINOS
experiment and it will be supplying the NO$\nu$A experiment with neutrinos. The MiniBooNE detector observes neutrinos from the NuMI beamline,
at an off-axis angle of 6.3 degrees.
Samples of charged current quasi-elastic (CCQE) $\nu_\mu$ and $\nu_e$ interactions were analyzed.
The high rate and simple topology of $\nu_\mu$ CCQE events
provided a useful sample for understanding
the $\nu_\mu$ spectrum and verifying the MC prediction for
$\nu_e$ production.

The first result of the analysis is published in
P.~Adamson {\it et al.}, Phys. Rev. Lett. {\bf 102}, 211801 (2009), arXiv:0809.2447 [hep-ex] and show that reliable predictions for an off-axis beam can be made.
After the demonstration of the off-axis concept, useful in limiting backgrounds in searches for the oscillation transition $\nu_\mu \to \nu_e$, the analysis
is directed toward examing the low energy region and searching for oscillation.
In this way it complements the analysis done at MiniBooNE using the BNB neutrino and antineutrino BNB, but with different systematics.
The current off-axis accelerator based long baseline experiments, in particular the NOvA, would benefit from understanding and careful calibration of the off-axis beam
components that may be extrapolated to NOvA off-axis position as the NOVA
will use same NuMI beam and will be plastic liquid scintillation detector similar to MiniBooNE.\\
The analysis is being performed by forming a correlation between the large statistics $\nu_\mu$ CCQE sample
and $\nu_e$ CCQE, and by tuning the prediction to the data simultaneously.
Considering various sources of systematic uncertainty, a covariance matrix in bins of $E_\nu$ is constructed,
which includes correlations between $\nu_e$ CCQE (oscillation signal and background) and $\nu_\mu$ CCQE samples.
This covariance matrix is used in the $\chi^2$ calculation of the oscillation fit.
The result is that the prediction is being constrained, i.e. tuned to the data,
and common systematic components in $\nu_e$ and $\nu_\mu$ CCQE samples cancel.
The cancellation results from the fact that the majority of the events in both
$\nu_e$ and $\nu_\mu$ CCQE samples originate from pure charged current interaction
of neutrinos sharing same parent mesons, effectively sharing same cross-section and beam systematic components.
This is a method equivalent to forming a ratio between
near and far detectors in two-detector experiments where the near detector detects $\nu_\mu$ CCQE events, while the far detector samples $\nu_e$ CCQE events.
Progress in the analysis and any available results will be discussed.

\end{document}

**24**

# Detection of solar neutrinos by coherent scattering on high Debye temperature monocrystals

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The possibility of detecting solar neutrinos by coherent scattering on high Debye temperature monocrystals such as sapphire is presented and discussed. Preliminary experimental results estimate that 0-430 keV solar neutrinos flux produces observable torque for a high-sensitive torsion balance. Our experiment gives a result for the diurnal force as predicted by Weber's theory of enhanced solar neutrinos coherent scattering.

**Summary**:

We prepared a robust, simple and dedicated torsion balance, designed to evidence interaction neutrinos with a force sensitivity varying between 10-6 and 10-8 dyne, i.e. comparable with those reported by

Weber.The torsion balance uses two alternatives for the pendulum assembly with wolfram and molibdenum gold plated annealed wires having diameters of (25-50)micrometers and the length between (27-100)cm.The Sun as a well-defined neutrino source also provides extremely important opportunities to investigate nontrivial neutrino properties such as nonzero mass and mixing, because of the wide range of matter density and the great distance from the Sun to the Earth.Observation of solar neutrinos directly address the theory of stelar structure and evolution , which is the bases of the standard model (SSM).
Experimentally we used sapphire and lead. A diurnal effect is predicted as the position of the Sun changes relative to the balance. We have been observing the diurnal efect when the Sun is in direction of the line normal to the diameter joing the two masses.
The results are consist with Weber's hypothesis of very large cross sections for neutrinos incident on stiff perfect crystals.

**25**

## Measurement of the solar 8B neutrino rate with 3 MeV energy threshold in the Borexino detector

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We report the measurement of neutrino electron elastic scattering from 8B solar neutrinos with 3 MeV energy threshold by the Borexino detector at Gran Sasso Laboratories. The rate of solar neutrino induced electron scattering events above this energy in Borexino is 0.217+-0.038 (stat)+-0.008 (syst) c/d/100 t, in good agreement with the predicted rate by the Standard Solar Model and including the LMA-MSW neutrino oscillation model. Assuming the 8B neutrino flux predicted by the high metallicity Standard Solar Model, the average 8B neutrino survival probability above 3 MeV is measured to be 0.29+-0.10.
(On behalf of the Borexino Collaboration)

**26**

## Search for a Diffuse Flux of Muon Neutrinos with the ANTARES Telescope

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The ANTARES high-energy neutrino telescope is a three-dimensional array of photomultipliers distributed over 12 lines installed in the Mediterranean Sea. The detector has been operated in partial configurations since March 2006 and was completed in May 2008.
The main goal of the experiment is the search for high-energy neutrinos from astrophysical sources. A neutrino telescope in the Northern hemisphere includes the Galactic Centre in its field of view and is complementary to the IceCube Antarctic telescope. The detector is optimized for the detection of muon neutrinos, since at energies above 1 TeV muons resulting from charged current interactions can travel kilometers and are almost collinear with the parent neutrinos.

In this analysis, the search for very-high energy (E>100 TeV) extraterrestrial muon neutrinos from unresolved sources is presented. If the sensitivity of point source search techniques is too small to detect neutrino fluxes from individual sources, it is possible that many sources could produce

an excess of events over the expected atmospheric neutrino background. The sensitivity of the ANTARES detector to diffuse neutrinos is evaluated from MonteCarlo simulations using the Model Rejection Potential technique. The different detector configurations from Dec. 2007 to Dec. 2009 are considered when analyzing data, with an equivalent livetime of 330 days. The results are presented and the upper limit for diffuse flux neutrinos is shown.

**27**

## Photomultiplier Tube Assemblies For the Daya Bay Experiment

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The Daya Bay Reactor Neutrino Experiment is expected to measure $\sin^2(2\theta_{13})$ to 0.01 or better by performing a relative measurement of flux and energy spectrum of antineutrinos observed with inverse β decay events in the near and far antineutrino detectors. The antineutrino detectors will be placed in water pools and surrounded by at least 2.5m of water to suppress background. The water pools are also served as Cherenkov counters for tagging cosmic-ray muons that can generate background. Details of the photomultiplier tube assemblies used in the antineutrino detectors and the water Cherenkov counters will be presented.

**28**

## Recent Results and Future Prospects of the South Pole Acoustic Test Setup

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The feasibility and specific design of an acoustic sensor array as part of a large volume ultra high energy neutrino detector at the South Pole depends strongly on the acoustic ice properties and the noise condition in that area. The South Pole Acoustic Test Setup - "SPATS" has been built to evaluate these problems. Four strings, co-deployed in IceCube holes down to 400 m-500 m, carry seven acoustic stations each. The three sensors of each station register artificial sound signals produced by SPATS transmitters or a movable transmitter used in yet water-filled holes at different depths. Also sound from re-freezing bore-holes and other anthropogenic sources is received by SPATS.

The observed signals allow for the measurement of the sound speed versus depth and the sound attenuation in ice down to 400 m. Corresponding results will be shown. The efficiency and precision with which sound sources can be located in the vicinity of the detector will be given. A preliminary upper limit for the absolute noise level will be estimated. The prospects of acoustic neutrino detection within these conditions will be discussed.

**30**

# Neutrino masses in a multi-Higgs model with A_4 symmetry

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Presently we know that neutrino oscillation data are well described by massive neutrinos which makes the flavor problem still more interesting: why is there a mixing angle hierarchy in the quark sector but not in the lepton sector? In an attempt to answer this and others open questions we propose a multi-Higgs extension of the standard model with Abelian and non-Abelian discrete symmetries. In this model the fermionic degrees of freedom (plus right-handed neutrinos) of the standard model gauge symmetry also transform non-trivially under the discrete symmetries $A_4 \otimes Z_3 \otimes Z_3' \otimes Z_3''$. The flavor problem is be solved since due to discrete symmetries each charge sector has its own Higgs scalars and the mass matrix entries depend mainly on VEVs. In this situation the VEVs related to the neutrino masses are small, in the range of keV-MeVs, and it would imply the existence of light scalars or pseudoscalar that may be in trouble with experimental and theoretical results. In order to avoid this and also problems with flavor changing neutral currents in the quark sector, we allow the soft breakdown of the $A_4$ symmetry with diagonal and non-diagonal $\mu^2$-terms. Although the model has many scalar doublets, triplets and singlets, we analyzed the scalar potential with three doublets, having all of them small VEVs, and we show in which conditions all scalars are massive enough to be in agreement with the experimental and theoretical point of views.

**32**

# Solar and atmospheric neutrinos as background sources for the direct dark-matter search

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In direct dark-matter search experiments, neutrinos coherently scattering off nuclei can produce similar events as Weakly Interacting Massive Particles (WIMPs). Calculations show, that in such experiments, for solar neutrinos a count rate of a few events per ton of target mass and year of exposure are expected. This count rate strongly depends on the nuclear recoil-energy thresholds achieved in the WIMP-search experiments. We demonstrate that solar neutrinos can be a serious background: To reach sensitivities better than ˜1*exp(-10) pb for the WIMP-nucleon cross section, the solar neutrino events have to be rejected by cuts with nuclear recoil-energy thresholds of approximately >2 keV for calcium tungstate, >3 keV for xenon, >5 keV for germanium, and >8 keV for argon as target material. Next-generation experiments should not only focus on a reduction of the present energy thresholds but mainly on an increase of the target masses. Atmospheric neutrinos limit the achievable sensitivity for background-free direct dark matter search to >1*exp(-12) pb.

**33**

# Physics goals and sensitivity of NOvA

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NOvA is an accelerator neutrino oscillation experiment designed to make
precise measurements of the neutrino mixing parameters associated with the atmospheric mass-squared splitting. By studying oscillations along a 810 km baseline, NOvA has the potential to produce measurements that are sensitive to the neutrino mass hierarchy and to the values of theta13 and the CP-violating phase. In addition, NOvA may potentially answer the question of whether theta23 is non-maximal by performing a precision measurement of the value of theta23. A discussion of how NOvA is sensitive to theses terms and the estimated precision to which these terms can be measured will be presented.

**34**

## Indirect WIMP search for the Sun and the galactic center in Super-Kamiokande

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We perform the indirect WIMP search using upward going muons(upmu) in Super-Kamiokande. We used from SK-I to SK-III dataset(3149.2 days) for this analysis. This search was done for the direction of the Sun and Galactic center. For the search of the Sun,no significant event excess was observed, and limit of WIMP induced upmu flux and limit of SD cross section was obtained. For the search of the Galactic center, no significant excess was observed. We calculated the limit of upmu flux.

**35**

## Search for supernova relic neutrinos at Super-Kamiokande

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The diffuse supernova relic neutrino signal is of great interest due to
its correlation to cosmological parameters such as star formation rates.
This signal has never been seen. Currently inverse beta decay of
anti-neutrinos in the Super-Kamiokande (SK) detector provides the world's
best upper flux limit of 1.2 nu_e_bar events cm^2 s^-1, E_nu_bar > 19.3
MeV, which is very close to many theoretical predictions. A new method of
tagging radioactive backgrounds from cosmic ray muon spallation, improved
event reconstruction and selection, as well as addition of new data and a
new signal extraction method allows us to lower the energy threshold and
improve the sensitivity of the analysis. These new methods as well as
results using SK-I, SK-II, and SK-III data are presented.

**36**

# Neutrino physics and dark matter searches at SNOLAB

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SNOLAB is an underground laboratory with an extensive experimental program in astroparticle physics focused on neutrino physics, such as double beta decay, solar and supernova neutrinos, and dark matter research. The international facility is located near Sudbury Ontario Canada in the Vale Inco Creighton Mine at a depth of 2 km to shield experiments from cosmic rays. The laboratory provides infrastructure and support within a clean environment (better than class 2000) to avoid contamination. SNOLAB is an expansion of the laboratory constructed for the successful experiment SNO (Sudbury Neutrino Observatory).
Currently running experiments are DEAP-1 (Dark matter Experiment with Argon and Pulse-shape discrimination) and PICASSO (Project In CAnada to Search for Supersymmetric Objects), while the experiments under design are SNO+, HALO, DEAP-3600 and MiniCLEAN.
SNO+ is a liquid scintillator detector to study low energy solar neutrinos, geoneutrinos, reactor neutrinos, neutrinoless double beta decay and for supernova search, HALO is a neutrino detector for the observation of galactic supernovas while DEAP3600 and MiniCLEAN are single phase detectors of LAr or LNe for direct detection of dark matter using scintillation light.
SNOLAB has been progressively creating a significant amount of space for active international research on astroparticle physics that contributes to the world program of underground facilities. The status of the experimental program at SNOLAB is presented in this poster.

**37**

# Search for GUT monopoles at Super-Kamiokande

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GUT monopoles captured by the Sun's gravitation are expected to catalyze proton decays via the Callan-Rubakov process. In this scenario, protons, which initially decay into pions, will ultimately produce nu_e, nu_mu and nu_mu_bar. After going through neutrino oscillation, all neutrino species appear when they arrive at the Earth, and can be detected by a 50000 ton water Cherenkov detector, Super-Kamiokande. A search for low energy neutrinos from the Sun (in the visible energy range from 18 to 55 MeV) has been carried out with Super-Kamiokande and is expected to give the cross section and velocity dependent limit on the monopole flux, F < 7 x 10-24 cm-2 s-1 sr-1 for beta=10-3 and sigma=1mb at 90%C.L. This is a much more stringent limit than the current best cosmic-ray supermassive monopole flux limit: F < 1 x 10-15 cm-2 s-1 sr-1 for 1.1 x 10-4 < beta < 0.1.

**38**

# Neutrino properties and new physics with neutrino telescopes

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We describe studies of new physics at neutrino telescopes.
We also discuss how atmospheric neutrino data from neutrino telescopes can be used for studies of neutrino oscillations.

**39**

## CUORICINO results for two-neutrino double beta decay and rare decays to excited states

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CUORE is a bolometric experiment currently under construction at the Laboratori Nazionali del Gran Sasso, Italy.
Its main purpose is the search for neutrinoless double beta decay of Te-130.
Thanks to its big mass, excellent energy resolution and very low background, it also offers the possibility to investigate other rare processes with unprecedented sensitivity.
CUORE comes after CUORICINO, a pilot experiment that took data at the Laboratori Nazionali del Gran Sasso in the years 2003-2008.
The poster will present the analysis of several double beta decay modes of Te-130 other than the neutrinoless mode on the ground state, carried out on the Cuoricino data.

**40**

## Proposed experiment to measure $\gamma$-rays in high resolution hadron beam experiments $O(p,p')X$ and $O(^3He,t)X$ and the detection of $\gamma$-rays in $\nu -^{16} O$ reactions

**Author:** Takaaki Mori[1]

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The $\gamma$-rays produced from excited nuclei in neutral-current (NC) neutrino-oxygen (even charged-current (CC) $\nu - O$) interactions have not been measured at $E_\nu = 10 - 100$ MeV. They are very important, since they will add extra signals or become unexpected background in Supernova neutrino detection. Neutrinos at $E_\nu = 20 - 100$ MeV are expected to excite $1^-$ , $1^+$ and $2^-$ (giant resonances) in NC reactions $O(\nu,\nu')O^*$, which decay to $^{15}N^* + p$ and $^{15}O^* + n$; the $\gamma$-rays are produced from $^{15}N^*$ and $^{15}O^*$. But, no
previous experiments have checked such expectations. We show a proposed experiment to measure the $\gamma$-ray spectrum produced in the hadron beam experiments $O(p,p')X$ ($\Delta T$=0,1) and $O(^3He,t)X$ ($\Delta T$=1) at RCNP(Osaka). They will give the information on the Fermi and Gamov-Teller transition strength from the ground state to the excited states of the oxygen, associated with the $\gamma$-ray production. Such experiment will further develop an initial measurement of the $\gamma$-ray spectrum in $O(p,2p)N$ reaction at RCNP (K.Kobayashi et al., nucl-ex/0604006).

**41**

## Massive neutrino in a rotating medium: new neutrino trapping mechanisms in neutron stars

**Author:** Ilya Balantsev[1]

**Co-authors:** Alexander Studenikin [1]; Yury Popov [1]

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We obtain the exact solution of the Dirac equation for the neutrino wave function in the presence of medium and evaluated the neutrino energy spectra for two particular cases: 1) neutrino propagation in transversally moving with increasing speed medium and 2) neutrino propagation in rotating medium. It is shown that in both cases the neutrino energies are quantized in a way as the electron energy is quantized in a constant magnetic field. These phenomena can be important for astrophysical applications, for instance, for physics of rotating neutron stars.

Reference

I. Balantsev, Yu. Popov, A.Studenikin, Nuovo Cimento C, 32, 2009, 53.

**42**

## CUORE-0 Detector for Double Beta Decay

**Author:** Claudia Rusconi[1]

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The CUORE (Criogenic Underground Observatory for Rare Events) experiment will search for the neutrinoless double beta decay of 130Te with the bolometric technique, with an expected sensitivity of about 50meV on the neutrino effective mass.
CUORE-0 is the first CUORE tower, that will be assembled and operated in the near future in the Gran Sasso underground laboratory. In this poster, the technical details of the detector and its scientific potential are presented and discussed. We provide an accurate description of the detector structure, of the radio-clean assembly procedure and of the basic components of the elementary module.
On the basis of the background expectation for CUORE-0, we estimate and present the physics reach of this experiment, that will be one of the most sensitive search for neutrinoless double beta decay worldwide in the next years. Its planned sensitivity will improve the limit set by Cuoricino in a few months after the start-up.

**43**

## Water-based Liquid Scintillator for Large-scale Neutrino Experiment

**Author:** Minfang Yeh[1]

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The pure liquid scintillation detector has the common features of high light yield, adequate attenuation length and long stability. However its high cost, less material compatibility and extensive liquid handling often raise special concerns, particularly the chemical safety in the confined space of underground laboratories. The water-based liquid scintillator (W-LS) is of great interest to large scale physics experiments, e.g., nucleon decay, due to its simplicity of liquid handling and cost-efficiency. The conventional scintillation cocktail designed for α- or β-emitting nuclides in aqueous solution often forms opaque micro-emulsion and is instable in water. To make feasible W-LS of many tens of kTon as the target mass for neutrino experiments, extensive R&D in mass-producible liquid scintillator and water chemistry are essential. At BNL, 8 to 20% of organic liquid scintillator loaded in water medium have been prepared and stable for more than 6 months since synthesis. The preparation and performance, i.e., photon production, attenuation length and lifetime, of newly developed W-LS will be presented.

*Research sponsored by the U.S. Department of Energy, Office of Nuclear Physics and
Office of High Energy Physics, under contract with Brookhaven National Laboratory –
Brookhaven Science Associates.

**44**

## Measurement of nu-e-bar - Electron Scattering Cross-Section with a CsI(Tl) Scintillating Crystal Array at the Kuo-Sheng Nuclear Power Reactor

**Authors:** Henry Wong[1]; Muhammed Deniz[1]

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The nu-e-bar electron elastic scattering cross-section was measured with a CsI(Tl) scintillating crystal array having a total mass of 187˜kg. The detector was exposed to an average reactor nuetrino flux of 6.4 X 10ˆ{12} ˜ cmˆ{-2}sˆ{-1} at the Kuo-Sheng Nuclear Power Station. The experimental design, conceptual merits,
detector hardware, data analysis and background understanding of the experiment will be discussed. We will present final resuls with 29882/7369 kg-days of Reactor ON/OFF data, on the measured cross-section, the standard electroweak parameters sinˆ2 theta_W and (g_V,g_A), the test on charged-current neutral-neutral interference, as well as limits on neutrino magnetic moments and charger radius. We will also present constraints on non-standard interactions based on this data set.

**Summary**:

Reference :
M. Deniz et al., TEXONO Collaboration, arXiv:0911.1597 (2009). http://arxiv.org/abs/0911.1597

**45**

## Sensitivity Enhancement for the Searches of Neutrino Magnetic Moments through Atomic Ionization

**Author:** Henry Wong[1]

**Co-authors:** Hau-Bin Li [1]; Shin-Ted Lin [1]

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A new detection channel on atomic ionization for possible neutrino electromagnetic interactions was identified and studied. Orders of magnitude enhancement in sensitivities can be expected when the energy transfer to the target is of the atomic-transition scale. Interaction cross-section induced by neutrino magnetic moments (mu_nu) was evaluated. New upper limit of mu_nu < 1.3×10^{−11} μ_B at 90% confidence level was derived using current data with reactor neutrinos. Potential reaches of future experiments are discussed. Experiments with sub-keV sensitivities can probe mu_nu to 10^{−13} μ_B. Positive observations of mu_nu in this range would imply that neutrinos are Majorana particles. Analysis with new data will be presented.

Reference :
H.T. Wong, H.B. Li and S.T. Lin, arXiv:1001.2074 (2010).

**46**

## Some constraints on new physics by atmospheric neutrinos

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Using the formalism by Kimura, Takamura and Yokomakura, the analytic oscillation probability is derived in the presence of new physics in propagation for high energy. While the components \epsilon_{ee}, \epsilon_{e\tau}, \epsilon_{\tau\tau} are allowed to remain relatively large (as was shown by Friedland & Lunardini), it turns out that \epsilon_{e\mu} and \epsilon_{\mu\tau} have conflict with the atmospheric neutrino data at high energy, i.e., their existence contradicts with the behavior P_{\mu\mu}=1-\sin^2(\Delta m^2L/4E). Partial analysis with \epsilon_{\mu\tau} and \epsilon_{\tau\tau} was done by G. Mitsuka at nufact08, and his result was |\epsilon_{\mu\tau}| < 0.015. Since the oscillation probability at high energy has dependence on \epsilon_{e\mu}^2+\epsilon_{\mu\tau}^2, it is expected that \epsilon_{e\mu} is constrained as strongly as \epsilon_{\mu\tau}, although it has to be confirmed by numerical computations. The present bound on |\epsilon_{e\mu}| is approximately 0.3, so atmospheric neutrinos appear to give us stronger constraints.

**48**

## Underground Cosmic-Ray Muons and Spallation Neutrons in the Aberdeen Tunnel Laboratory, Hong Kong

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The Aberdeen Tunnel Laboratory in Hong Kong is about 50 km southwest of the Daya Bay Experimental site. It has a vertical overburden of 668 m.w.e. in the middle of the Hong Kong Island. In the laboratory, a muon tracker and a neutron detector have been built to measure the flux and angular distribution of the underground cosmic-ray muons, and spallation neutrons produced by these muons.

The muon tracker consists of 150 plastic scintillator hodoscopes and proportional tubes, arranged in staggered order on six layers. Fours layers cover the neutron detector from above. Two layers are put under the neutron detector. The firing pattern of these detectors can be reconstructed to yield the angular information and position of the cosmic-ray muons that reach the neutron detector.

The coincidence of the muon tracker detectors is used to trigger the neutron detector, which contains 760 liters of LAB-based liquid scintillator doped with 0.1% gadolinium to enhance neutron capture. Delayed coincidence of scintillations due to a muon and its spallation neutrons will identify the muonic events from background.

The status of the Aberdeen Tunnel Experiment will be presented.

**49**

## Development of InP solid state detector and liquid scintillator containing indium complexes for a measurement of pp/7Be solar neutrinos

**Author:** Yoshiyuki Fukuda[1]

**Co-authors:** Hiroyuki Sekiya [2]; Kayoko Kasai [1]; Shigetaka Moriyama [2]; Toshio Namba [3]

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A large volume radiation detectors using a semi-insulating Indium Phosphide (InP) photodiode have been developed for Indium Project on Neutrinos Observeation for Solar interior (IPNOS) experiment. The volume has achieved to 20 mmˆ3, and this is world largest size among InP detector observed gamma-rays at hundred keV region. This detector was desined to measure the scintillation light from Liquid Xenon in order to detect gammas emitted by excited state of 115Sn decay. For another possibility for IPNOS experiment, we have also developed an organic liquid scintillaor which contains indium complexes, and the luminescence of indium complexes was studied. Here we report the performance of InP detector and the gamma-ray-induced luminescence of indium complexes containing 8-quinolinol ligand.

**50**

## Neutron Spectrum Measured in Aberdeen Tunnel Underground Laboratory with a Multisphere Neutron Spectrometer

**Author:** Hao Liu[1]

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Neutrons from natural radioactivity and spallation reactions initiated by cosmic ray muons represent a major source of background for underground neutrino experiments. A set of multisphere neutron spectrometer was developed. It consisted of 8 Bonner Spheres, made of high-density polyethylene, with diameter from 12.7 cm (5 in) to 30.84 cm (12 in). Lead shells with 1 cm and 2 cm thickness were added to the 15.24 cm (6 in) sphere to increase the detection efficiency of high-energy neutrons (E > 10 MeV). The response matrices of the detectors were calculated with Geant4 from 1 eV to 1 GeV. The neutron spectrum inside the Aberdeen Tunnel Underground Laboratory, with an overburden of ˜660 m.w.e., was measured with the neutron spectrometer which was calibrated with an AmBe source. The neutron spectrum and flux were deduced by unfolding the measured count rates using a genetic algorithm.

**51**

## UHE neutrino detection with the surface detector of the Pierre Auger Observatory

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The Pierre Auger Observatory has the capability of detecting ultrahigh energy neutrinos of all flavours above 0.1 EeV. The method adopted is to search for very inclined showers produced close to the detector. The properties of such showers that start deep in the atmosphere are different at ground level from those showers initiated in the upper atmosphere by protons or nuclei. The neutrino events will have a significant electromagnetic component leading to a broad time structure of detected signals in water Cherenkov tanks in contrast to nucleonic-induced showers. In this poster we present two analysis that are being used to identify neutrino
candidates under different conditions, one for “down-going”neutrinos and the other for “earth skimming”tau neutrinos. We show that the configuration of the surface detectors of the Auger Observatory has a satisfactory discrimination power against the larger background of nucleonic showers over a broad angular range. No candidates were found on data collected from 1 January 2004 to 28 February 2009. A limit on the diffuse neutrino flux is presented.

**52**

## Construction of the Double Chooz Far Detector

**Authors:** Daniel Greiner[1]; Dennis Dietrich[1]; Josef Jochum[1]; Markus Röhling[1]

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The Double Chooz Experiment is a reactor neutrino disappearance experiment which aims at a precise measurement of the neutrino mixing angle theta_13. It will consist of two identical detectors, one in near and one in farther distance to the two reactors. The target of the detectors are two liquid scintillator filled acrylic vessels.This Poster will show in detail the construction of the far detector, which has started data taking recently.

**53**

## New results for muon neutrino to electron neutrino oscillations in the MINOS experiment

**Author:** Ruth Toner[1]

**Co-authors:** Gregory Pawloski [2]; Lisa Whitehead [3]

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MINOS is a long-baseline neutrino oscillation experiment situated along Fermilab's high-intensity NuMI neutrino beam. MINOS has completed an updated search for muon neutrino to electron neutrino transitions, observation of which would indicate a non-zero value for the neutrino mixing angle theta_13. The present 7x10ˆ20 protons-on-target data set represents more than double the exposure used in the previous analysis. The new result and its implications are presented.

**Summary**:

Abstract for a poster for Neutrino 2010, from the MINOS nue appearance analysis group.

**54**

## The solar neutrino results of Super-Kamiokande III

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The results of the third phase of the Super-Kamiokande solar neutrino measurement are presented and compared to the first and second phase results. With improved detector calibrations, a full detector simulation, and analysis methods, the systematic uncertainty on the total neutrino flux was educed compared with SK-I. A global oscillation analysis is carried out using SK-I, II, and III, and is combined with the results of other solar neutrino and KamLAND reactor experiments; its results are also presented.

**55**

## New Results from the ANITA Search for Ultra-High Energy Neutrinos

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The ANITA (ANtarctic Impulsive Transient Antenna) experiment is an innovative balloon-borne radio telescope, designed to detect coherent Cherenkov emission from cosmogenic ultra-high energy neutrinos with energy greater than 10ˆ18 eV. The second flight of the ANITA experiment launched on December 21st, 2008, and collected data for 30 days. This new data set allows for the most sensitive

investigation to date of GZK neutrino flux models, which offer the exciting possibility of independently revealing the sources of the highest energy cosmic rays. I will present results of the analysis of the ANITA-II data set, and discuss calibration techniques, analysis methods, and background rejection.

**56**

## Nuclear physics aspects of neutrino oscillations

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Neutrino oscillations and nuclear physics are closely connected. Current investigations of long baseline experiments like MiniBooNE, K2K and T2K address questions such as what are the mass-differences, what are the values of the mixing angles, but also search for CP violation in neutrino interactions. A critical quantity is the neutrino energy which is directly related to the oscillation parameters. It cannot be measured but has to be reconstructed from the detected particles. Since all present experiments use nuclear targets, the final particle yields are influenced by the nuclear medium and in particular by final-state interactions. On the basis of state of the art coupled channel transport calculations we will discuss the importance of nuclear effects for oscillation experiments and give various examples, in particular we will address the question of energy reconstruction.
Supported by DFG.

**57**

## Measurement of the neutrino contamination in MiniBooNE's anti-neutrino CCQE sample

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The anti-neutrino charged current quasi-elastic (CCQE) sample at MiniBooNE suffers from a significant neutrino-induced CCQE background. Particle identification at MiniBooNE does not involve charge selection, so we must rely on other methods for measuring this contamination. The lepton production angle is used to perform a linear, two-template fit to data to measure this rate. Consistent results across different energy bins indicate that MiniBooNE's relativistic Fermi gas Monte Carlo model overestimates this rate on an absolute scale by around 10%, which excludes the default Monte Carlo prediction at the one sigma level. Across all energies, the neutrino contamination rate is determined to be $19.5 \pm 5.4\%$.

**58**

## The Daya Bay Muon Veto System

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The goal of the Daya Bay reactor neutrino experiment is to measure $\theta_{13}$ with a sensitivity in $\sin^2(2\theta_{13})$ of 0.01. To achieve this, the cosmic ray induced backgrounds must be reduced to a low level. Daya Bay's muon veto system will consist of a 2.5 m active water shield and RPCs. The muon tagging efficiency of the combined system is expected to be greater than 99.5%. The details of the muon system and estimates of the expected backgrounds will be described.

**59**

# Measurements of Atmospheric Neutrinos using the MINOS Detector.

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This poster presents the latest atmospheric neutrino results from the MINOS experiment. The results are based on a data set of 1657 live-days, and combine together observations of contained vertex neutrino interactions and neutrino-induced upward muons in the MINOS far detector. The measured curvature of muons in the MINOS magnetic field is used to separate neutrinos and anti-neutrinos, and the observed ratio of neutrinos to anti-neutrinos is compared to the Monte Carlo expectation. The data are separated into bins of L/E resolution, and a maximum likelihood fit to the observed L/E distributions is used to determine the oscillation parameters separately for neutrinos and anti-neutrinos. Confidence limits are placed on the difference between these oscillation parameters.

**60**

# The CERN Neutrino Beam to Gran Sasso : performance summary and future prospects

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The CNGS facility (CERN Neutrinos to Gran Sasso) aims at directly detecting νμ→ντ neutrino oscillations. An intense νμ beam (1017 νμ per day) is generated at CERN and directed over 732 km towards the Gran Sasso National Laboratory, LNGS, in Italy, where two large and complex detectors, OPERA and ICARUS, are located. Having resolved successfully some initial issues occurred since its commissioning in 2006, the facility completed two years of smooth operations in 2008 and 2009 with a total of 5.44×1019 protons delivered on target. The experience gained in operating this 500 kW neutrino beam facility will be reviewed briefly. Highlights of the beam performance and future long-term prospects will be presented.

**61**

## "Search for neutrinos from diffuse dark matter annihilation in Super-Kamiokande"

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This work presents a search for a signal from diffuse dark matter annihilation in atmospheric neutrino data of Super-Kamiokande-I, -II and -III. We focus on the signal arising from a diffuse source of dark matter annihilation in the Milky Way halo. We consider the scenario with dark matter particles annihilating directly to two neutrinos, equally to all flavors. In such a case, resulting neutrino energy would be the same as the mass of annihilating relic particles. Thus, annihilation induced neutrinos would introduce a characteristic modification to the observed atmospheric neutrino energy spectra. One could also expect that neutrinos from diffuse dark matter annihilation would have an isotropic zenith angle distribution. The Super-Kamiokande data set of 2806 days of exposure was investigated for the presence of such a signatures. In this analysis we assume that collected data could be described by two components: dark matter induced neutrinos (signal) and atmospheric neutrinos (background). We try to find the best combination of signal and background that would fully explain the data. We allow to vary the oscillation parameters that are related to estimation of atmospheric neutrino background and vary the hypothetical contribution from simulated dark matter signal. In this approach we can constrain the number of dark matter induced events which are compatible with the data. The search could be also related to dark matter decay scenarios.

**62**

## Supernova Detection with SNO+

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An exciting component of the research program for SNO+ is the potential to detect neutrinos from a supernova. A core-collapse supernova in our galaxy is expected to produce a significant number of events in a short time period in the SNO+ liquid scintillator. Though supernova explosions in our galaxy are rare, occurring on average three times per century, the potential knowledge that can be gained from the observation of neutrinos from a galactic supernova is great, making preparations vital. The core of a collapsing star has conditions that occur nowhere else in the universe. In this unique environment, neutrinos are expected to interact with each other through collective effects induced by neutrino-neutrino forward scattering, which would lead to neutrino flavour transformations in addition to the matter-enhanced transformations associated with the MSW effect. The implications of observing the effects of collective interactions will be discussed, as well as methods to identify their presence or absence. Calculations of the number of neutrinos that may be detected

by SNO+ during a core-collapse supernova will be presented, and the role of SNO+ in the SuperNova Early-Warning System (SNEWS) will be explained.

**63**

## T2K First Result with Neutrino Beam Monitor "INGRID"

**Author:** Masashi Otani[1]

**Co-authors:** Akihiro Minamino [1]; Atsuko Ichikawa [1]; Autiero Dario [2]; Besnier Magali [3]; Bronner Christophe [3]; Chaussard Lionel [2]; Chie Matsumura [4]; D.Tran Phuong [3]; Declais Yves [2]; Drapier Olivier [3]; Ferreira Oscar [3]; Gonin Michel [3]; Kazuhiro Yamamoto [4]; Masashi Yokoyama [5]; Moreau Francois [3]; Tatsuya Kikawa [1]; Tsuyoshi Nakaya [1]

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T2K is a long baseline neutrino oscillation experiment aiming at a precise measurement of νμ disappearance and a search for νe appearance. It utilizes the J-PARC proton synchrotron to produce the muon neutrino beam, which is measured by the near detectors and the Super-Kamiokande detector. The neutrino beam axis is directed 2.5 degrees away from the Super-Kamiokande direction in order to maximize sensitivity to the neutrino oscillation measurement. INGRID(Interactive Neutrino GRID) monitors the neutrino beam direction with the precision of better than 1mrad.
It is located 280m downstream of the neutrino production target and consists of sixteen identical modules arranged in a cross around ±5 m of the beam center. Seven modules are placed in horizontal direction, other seven are in vertical and two are off-diagonal position. Each module has the sandwich structure of nine target iron plates and eleven scintillator tracking planes. It is a 1.2m cube and weights 6.7 ton. The neutrino beam profile is reconstructed with the number of neutrino interactions at each module and the beam axis direction is determined from the beam profile center. We started physics data taking from the beginning of 2010. The results from INGRID are presented together with the detector design and performance.

**64**

## GADZOOKS; Research and Development For The Next Generation of Water Cherenkov Detectors

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The proposed introduction of a soluble gadolinium [Gd] compound into water Cherenkov detectors with 0.2% loading will result in greater than 90% of the neutrons capturing on the Gd. The delayed 8 MeV gamma cascades produced by these captures in coincidence with a prompt positron signal serve to uniquely identify electron anti-neutrinos interacting via inverse beta decay. Such coincidence detection greatly reduces backgrounds, allowing a large Gd-enhanced water Cherenkov detector to make the first observation of the diffuse supernova neutrino background and high precision measurements of Japan's reactor anti-neutrino flux. Now a dedicated Gd test facility is under construction in the Kamioka Mine, home of the Super-Kamiokande [SK] detector. This new facility

will house a stainless steel tank filled with 200 tons of water and lined with 240 50-cm photomultiplier tubes, a specially designed water system for filtration and gadolinium recovery, and multiple devices for evaluating the quality of the water in the tank. Successful running of this new facility will demonstrate that adding Gd salt to SK is both safe for the detector and is capable of delivering the expected physics benefits.

**65**

## Prospects for Measuring Neutrino-Nucleus Coherent Scattering at Stopped-Pion Neutrino Sources

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Coherent neutral current neutrino-nucleus elastic scattering has never been observed. Although the cross-section is very high, nuclear recoil energies are very small. However, detection of the process may
be within the reach of the new generation of low-threshold detectors. A promising prospect for the detection of this process is an experiment at a high flux stopped-pion neutrino source. The physics potential for such a measurement at future facilities will be explored.

**67**

## Antineutrino Detectors for a High-Precision Measurement of the Neutrino Mixing Angle theta13 at Daya Bay

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The Daya Bay reactor neutrino experiment is designed to measure the last unknown neutrino mixing angle with a sensitivity of sin22θ13<0.01 by measuring the flux and spectrum of reactor antineutrinos at varying distances from the Daya Bay nuclear power plant. The experiment will use eight identical liquid scintillator detectors with 20-ton target mass each at distances ranging from 0.3-2 km from the power plant. A novel concept of this oscillation search is the relative measurement of the antineutrino flux between multiple, identical detectors. To achieve the experimental sensitivity relative detector systematics will be controlled to <0.4%. We will describe the design and construction of the Daya Bay antineutrino detectors and experimental methods for the control of the detector-related systematic uncertainties.

**68**

## Studying neutrinos from nearby supernovae with IceCube

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With just a few neutrinos detected, Supernova SN1987A set stringent limits on the mass of the anti-electron neutrino, its lifetime, magnetic moment, and the number of lepton flavors. Current generation of detectors are capable of detecting many orders of magnitude more neutrinos, allowing us to study details of the gravitational collapse of supernovae and properties of neutrinos.

Upon completion during the next austral summer, IceCube will consist of 5160 photomultiplier tubes spread in a grid over ˜ 1 kmˆ3 in the deep Antarctic ice at the geographic South Pole. Though designed to search for neutrinos from astrophysical sources with energies ranging from 10ˆ11 to 10ˆ21 eV, IceCube is able to detect MeV neutrinos produced in nearby supernovae out to the Magellanic Clouds by looking for a collective rise in the photomultiplier rates. The current status of IceCube and its sensitivity to neutrinos from galactic supernovae, sensitivity to electron neutrinos from the deleptonization burst, and possible studies of neutrino properties including theta-13 and mass hierarchy will be presented.

**69**

# Low temperature magnetic calorimeters for high precision measurements of 163-Ho and 187-Re spectra

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The analysis of calorimetric spectra of beta or electron-capture decay isotopes with especially low Q-value represents a very attractive method to determine the electron neutrino and antineutrino mass. The most suitable isotope in the beta decay branch is the 187-Re (Q about 2.5 keV) while, on the electron capture side, the 163-Ho (Q about 2.5 keV) is the best candidate known. Extremely precise detector arrays are needed to reach a sub-eV sensitivity for the neutrino mass. We present results obtained with low temperature magnetic calorimeters designed for measuring respectively the low energy calorimetric spectrum of 187-Re and 163-Ho. Metallic magnetic calorimeters are low temperature energy dispersive detectors composed of an energy absorber in tight thermal contact with a paramagnetic temperature sensor which resides in a small magnetic field. The change of magnetization following the absorption of energy is measured as a change of flux in a low noise high bandwidth dc-SQUID. The performance achieved in response time and energy resolution together with the possibility to run thousands of channels by means of microwave multiplexing show that magnetic calorimeters are an interesting choice for a large scale experiment as MARE.

**71**

# Cuoricino analysis for background rejection and study of DBD systematics

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Cuoricino was an array of 62 bolometric detectors whose main purpose was to study a limit on neutrinoless double beta decay ("0nuDBD") of 130Te.
Such rare process is a powerful probe for two of the main uncovered questions concerning neutrinos:

their Dirac/Majorana character and their mass hierarchy.
We present the main steps of Cuoricino data analysis: starting from raw pulses and ending to the experimental spectrum where the limit on 0nuDBD counts is estimated.
More in detail, we will focus on the following parts of the analysis:
- the optimum filter technique applied to raw data, which is used not only for the detector's resolution improvement but also for pileup rejection and pulse shape recognition.
- the background modeling, showing the main strategies used in Cuoricino to study the weight of all the possible sources that contributes to the spectrum in the region of interest (2.5 - 2.6 MeV), such as environmental and cosmogenical radioactivity or the bulk and surface contaminations of the whole experimental setup.
We will also discuss the statistical tool leading to the stimation of the Cuoricino "0nuDBD" limit. The latter consists of a maximum likelihood approach fixing an upper bound for this process at 90\% C.L. We present also a toy model to investigate its systematic uncertainties such as the dead time of the whole experiment, energy calibration, detector response function and background spectral shape.

**72**

## Magnetic moment induced transition of neutrino between different mass states in matter

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We consider the process of neutrino radiative transition between different mass states in medium. The neutrino wave functions, used in calculations of the process rate and power, are obtained within the method of exact solutions of the modified Dirac equation in medium. The contribution of magnetic moment induced transition is analyzed in details. It is shown how the background matter could influence the process substantially through the modification of initial and final neutrino states. We study the most important cases for the process total rate with different sets of parameters typical for astrophysical applications.

**73**

## Large Scale Production of the Liquid Scintillator for the Double Chooz Experiment

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The Double Chooz Experiment aims at the measurement of the only not-yet-determined neutrino mixing angle θ13 using neutrinos from the commercial nuclear reactors in Chooz, France. Precise measurement of this angle is highly important in order to direct the formulation of unification theory and moreover, the feasibility of future leptonic CP violation parameter observation. Liquid scintillator is the key detector component in Double Chooz. Commissioning two types of scintillators in the innermost part of the detector is designed to achieve high detection efficiency, high energy resolution and signal reconstruction together with a powerful background rejection for neutrino observation. The scintillator installed in the very center is identified as Neutrino Target, which is Gadolinium-loaded, while a Gamma-Catcher scintillator without Gadolinium surrounds the Neutrino Target. To satisfy the above mentioned requirements, they are newly developed to assure the long term stability including the characteristics of high light yield, light transparency and adapted density.

In the poster, scintillator properties in their final large scale production and careful procedure for the filling of the Double Chooz detector will be presented.

**74**

## A Mineral Oil Monitoring System for the Daya Bay Neutrino Experiment

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The Daya Bay Reactor Neutrino Experiment expects to determine the neutrino mixing angle θ13 with a sensitivity of sinˆ2(2 θ13)=0.01 in a three-year run. Eight three-zone cylindrical Anti-neutrino Detector (AD) modules with Gd-doped Liquid Scintillator are arranged in two near halls and a far hall. In the outermost zone of each AD, 192 PMTs are mounted in the Mineral Oil (MO). The stability of the optical properties of the liquids is very important for controlling the systematic uncertainties of the experiment and thus will be monitored online. The design of a monitoring system for the MO and the results of the prototype will be presented.

**75**

## NuWro Monte Carlo generator of neutrino interactions

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NuWro is a MC generator of events which has been developed over last ˜6 years at the Wrocław University. NuWro covers neutrino-nucleon and -nucleus interactions for energies from the threshold to TeV. There are many options for the nucleus model, including Fermi gas and recently added spectral function formalism. The hadronization model has been tested on available data for charged hadrons total, forward and backward multiplicities. The intra-nuclear cascade model has been tested on neutrino data for NC1Pi0 production and on pion-nucleus data.

**76**

## Experimental Study toward Atomic Neutrino Spectroscopy

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Recently Yoshimura has pointed out a feasibility of neutrino par emission from excited atoms [1]. An atomic electron lying in excited state decays to lower state accompanying with the neutrino pair through the weak interaction.
The basic strategy of using atoms instead of nuclei is the closeness of neutrino masses to atomic energy levels. The low-lying metastable states may undergo radiative neutrino pair emission (RNPE) $|i\rangle_A \to |f\rangle_A + \gamma + \nu_i\nu_j$. A single photon spectrum will give us various information about neutrino mass. However the neutrino pair emission rate in atoms is too small to reach experimentally. It is necessary to enhance such small process to realize the neutrino mass spectroscopy using atoms.

A collection of the atoms can cooperatively emits photons owing to a correlation
between the atomic dipole moments. Such cooperative radiation is known as super-radiance [2]. The decay time of the super-radiance is proportional to $1/N$, and the radiation intensity is proportional to the square of the number of atoms $N^2$. Yoshimura {\it et al.} have proposed a macro-coherent amplification mechanism which is an extension of the idea of super-radiance of a single photon emission [3].
In Okayama University, we have started a project of neutrino spectroscopy for measuring the absolute magnitude and the nature of neutrino masses based on the principle. Since this is a newly proposed principle, we like to start verifying it experimentally. To this end, we employ two photon emission process, instead of photon and neutrino pair emission
$|i\rangle_A \to |f\rangle_A + \gamma + \gamma$.
The advantage is that the process is much bigger in rates since it is a pure QED process. There is one important mile stone to carry out this proof-of-principle
experiment; namely we need to make an ensemble of atoms that is
in a pure quantum coherent state, the necessary condition to realize
both super-radiance and macro-coherent amplification process.
We report the current status of our preliminary experiments.

[1] M. Yoshimura, Phys. Rev. D 75, 113007 (2007).
[2] R. H. Dicke, Phys. Rev. 93, 99 (1954);
[3] M. Yoshimura, C. Ohae, A. Fukumi, K. Nakajima, I. Nakano, H. Nanjo, and N. Sasao,
arXive: 0805.1970 [hep-ph] (2008).

**77**

## The International Design Study for the Neutrino Factory

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The International Design Study for the Neutrino Factory (the IDS-NF) has been established by the Neutrino Factory community to deliver the Reference Design Report (RDR) for the facility by the 2012/13 decision point identified by the Strategy Session of CERN Council. The baseline design for the facility will provide 10ˆ21 muon decays per year from 25 GeV stored muon beams. The facility will serve two neutrino detectors; one situated at source-detector distance of between 3000—5000 km, the second at 7000—8000 km. The discovery reach of the Neutrino Factory will be presented and compared with alternative techniques (beta-beam and super-beam). The motivation for measurements of the neutrino-mixing parameters with a precision approaching that with which the quark-mixing parameters are known will be reviewed briefly. Finally, the organisation of the IDS-NF and its relation to the EUROnu Design Study will be described.

**78**

## Neutrino oscillation physics with a Neutrino Factory

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We illustrate that the baseline Neutrino Factory configuration being developed within the International Design Study for the Neutrino Factory (the IDS-NF) is optimised for standard oscillation-physics measurements and for searches for new physics. The possibility that a low-energy Neutrino Factory might be an interesting alternative for large θ_{13} or, in certain physics scenarios, as part of an upgrade programme is also discussed. Finally, the crucial role played by near detectors in the determination of the standard oscillation parameters and in the search for non-standard physics at the Neutrino Factory will be presented.

**79**

## Recent Atmospheric Neutrino Results from Super-Kamiokande

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Super-Kamiokande has collected atmospheric neutrino data for more than a decade spanning four phases of the experiment. The SK-I, SK-II, and SK-III periods combined represent a 172 kiloton-year exposure totalling more than 20,000 neutrino events and SK-IV has been taking data since 2008. Presented here are recent oscillation results from the first three phases including searches for subdominant oscillation effects and a search for CPT violation.

**80**

## Accelerator systems for the International Design Study of the Neutrino Factory

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The Neutrino Factory produces high-energy neutrino beams with a well-defined flavour content and energy spectrum from the decay of intense, high-energy, stored muon beams. The muon storage rings include long straight sections that are directed toward neutrino detectors that are sited several thousand kilometers away. This poster defines the muon-beam requirements and describes the accelerator facility that is required to deliver them. We give a baseline specification for the accelerator facility and describe the accelerator subsystems of which it is comprised. We will briefly present some of the accelerator-physics challenges such a facility presents and alternative designs for some of the subsystems.

**81**

## Anomaly-Free Constraints in Neutrino Seesaw Models

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The implementation of seesaw mechanisms to give mass to neutrinos in the presence of an anomaly-free $U(1)_X$ gauge symmetry is discussed in the context of minimal extensions of the Standard Model. It is shown that type-I and type-III seesaw mechanisms cannot be simultaneously implemented with an anomaly-free local $U(1)_X$, unless the symmetry is a replica of the well-known hypercharge. For combined type-I/II or type-III/II seesaw models it is always possible to find nontrivial anomaly-free charge assignments, which are however tightly constrained, if the new neutral gauge boson is kinematically accessible at LHC. The discovery of the latter and the measurement of its decays into third-generation quarks, as well as its mixing with the standard $Z$ boson, would allow to discriminate among different seesaw realizations.

**82**

## Reactor neutrino background at the proposed LAGUNA sites

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LAGUNA (Large Apparatus for Grand Unification and Neutrino Astrophysics) is a European project aimed at the construction of a very large volume underground neutrino observatory of the next generation. At the present stage 3 detector technologies and 7 potential locations are being evaluated. The physics scope of LAGUNA includes studies, among others, of diffused supernova neutrinos and geoneutrinos in which events are overlapping with the neutrino spectrum from the fission of reactor fuel. A high flux of these reactor neutrinos, for instance in the proximity of a nuclear power plant, would significantly reduce the sensitivity of the detector to neutrinos with energy below 8 MeV. To make the comparison, a comprehensive database was assembled containing location and thermal power of all the commercial nuclear power plants operating in 2009. Using the database and the known antineutrino spectra associated with the beta decay following fission, the flux for each seven site was calculated. The calculations take into account neutrino oscillations. To make the results easier to compare, they are also given as the expected event rates in 1 kiloton of liquid scintillator (containing 10ˆ32 of free protons).

**83**

## Double Chooz: optimizing the sensitivity to theta13 with a multi-detector setup.

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One of the fundamental open issues in neutrino oscillation physics is the measurement of the mixing angle theta13, whose best upper limit to date is provided by the Chooz experiment. The eventual measurement of theta13 in reactor neutrino experiments relies on a reduction of the Chooz systematics of about 1 order of magnitude, along with a major increase of the luminosity. Provided that enough statistics are achieved with long data taking runs (˜ 3 years), fighting the systematics becomes the key towards theta13. The Double Chooz experiment aims at improving the Chooz experience by means of a long-term stability multi-detector setup. The comparison between un-oscillated reactor neutrino flux at a near site (˜400 m) and the oscillated flux at a far site (˜1km) allows for the cancellation of the reactor-related correlated errors. The detector-related systematics are kept under control by constructing two identical detectors providing accurate energy reconstruction and high signal-to-noise ratios. Phase I of Double Chooz, starting in summer 2010 with only one detector, will be able to improve the current theta13 limit with only a few months of operation, thanks to the reduction of the experimental uncertainties with respect to Chooz. Ultimate systematics reduction will be achieved in Phase II (2012) when the second detector (near site) starts taking data.

**84**

## Detectors for leptonic CP violation at the Neutrino Factory

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The Neutrino Factory is the most powerful of the proposed facilities to search for CP violation in the lepton sector via neutrino oscillations. It delivers a well known beam of electron neutrinos and muon-antineutrinos from positive muon decay (electron-antineutrinos and muon neutrinos from negative muon decay) produced in the straight sections of the storage rings in which the muons are confined at an energy of 25 GeV. Studies carried out in the framework of the International Design Study for the Neutrino Factory (the IDS-NF) show that the sensitivity to the CP violating phase and the last unknown mixing angle θ_{13} is maximised when two far detectors (at 4000 km and 7500 km) optimised to detect the sub-leading ν_e to ν_μ oscillation are combined. Several technologies are being discussed for these detectors: magnetised iron calorimeters; giant liquid argon TPCs; and totally active scintillating detectors. The IDS-NF baseline option –as a compromise between feasibility, cost, and performance –consists of two, 100 Kton magnetised iron sampling calorimeters, similar to the existing MINOS detector, but with 20 times more mass and improved performance. The other far-detector options, which have better granularity, offer an improved energy threshold and energy resolution, may be able to detect additional oscillation channels, thus improving the overall performance of the facility. However, these options are likely to be more expensive and require significant R&D. A near detector of much smaller mass for precise measurement of neutrino flux and neutrino cross-sections will be situated close to the end of the muon storage ring straight section. The various detector options will be discussed, covering the most important aspects: performance; technological challenges; as well as the R&D program and cost drivers.

**85**

## The COBRA double beta decay experiment

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The COBRA experiment is searching for double beta decay using CdZnTe semiconductor detectors. The main focus is on the isotope Cd-116. In addition to pure energy measurements pixelisation allows also for tracking capabilities, this kind of semiconductor tracker is quite unique in the field.

The current status of the experiment is shown including the latest half-life limits. Background measurements from both types of detectors are presented and an outlook for planned upgrades is presented.

**86**

## Development of the new T2K on-axis neutrino detector "INGRID proton module"

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The T2K (Tokai-to-Kamioka) long baseline neutrino oscillation experiment started in April 2009. T2K is aiming to measure the oscillation parameters associated with muon neutrino disappearance precisely and to search for electron neutrino appearance. A high intensity neutrino beam from J-PARC (Japan Proton Accelerator Research Complex) is measured with the 280m near detector complex (ND280) and the 295km far detector (Super-Kamiokande).
We have constructed INGRID (Interactive Neutrino GRID) on-axis neutrino beam monitor in the ND280 to monitor the neutrino beam direction within 1 mrad. INGRID consists of 16 identical modules and covers the 5m region from the beam center with large target mass (116ton). Each module has the sandwich structure of iron target plates and scintillator tracking plates. Charged particles other than muon, like proton and pion from neutrino interactions can not be detected by INGRID because they are stopped in the iron plates, so we are developing a new on-axis neutrino detector, "INGRID proton module", to detect them and distinguish neutrino interaction modes. The proton module (1.9m^3, 1.4ton) which consists of 1204 plastic scintillator bars with Fiber-MPPC (Multi-Pixel Photon Counter) readout will be constructed and will make its first test run in the summer 2010.
We will report the expected performance of "INGRID proton module".

**87**

## Astrophysical point source search with the ANTARES neutrino telescope

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The ANTARES neutrino telescope is located on the bottom of the Mediterranean Sea, 40 km off the French coast. The detector is installed at a depth of 2.5 km and consists of a three-dimensional array of about 900 photomultipliers tubes arranged on 12 detector lines. The ANTARES collaboration aims to detect high-energy neutrinos from extraterrestrial origin. Relativistic muons emerging from charged-current muon neutrino interactions in the detector surroundings produce a cone of Cerenkov light which allows us the reconstruction of the original neutrino direction.

The collaboration has implemented different methods to
search for neutrino point sources in the data collected since 2007.
Results obtained with these methods as well as the sensitivity of the
telescope will be presented.

**88**

## New Limits for the Violation of the Equivalence Principle from the Solar and Reactor Neutrino Observations

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A model for the Violation of the Equivalence Principle (VEP) on solar and reactor neutrinos is investigated. New limits for the VEP are obtained considering the mass-flavor mixing hypothesis and the VEP model. Our analysis shows two solutions where the VEP effects practically do not change the solar sector. In a first case, the mass scale of the reactor sector remains the same and in a second situation this scale falls slightly, becoming closer to the solar solution without VEP. We improved by two orders of magnitude the upper limits of the relevant VEP parameters.

**90**

## Final results for pion production in the HARP/PS214 experiment at CERN PS

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Final results for the production of charged forward pions in the angular range 0.025 < theta < 0.250 rad and in the momentum range 0.5 < p < 8.0 GeV/c will be presented together with final results for the production at large angles 0.35 < theta < 2.15 rad and in the momentum range 100 < p < 800 MeV/c.
Data have been taken with incident protons or pions in the range 1.5-15 GeV/c with thin Be, C, Al, Cu, Sn, Ta, Pb solid targets, with thick (1 interaction length) C, Ta, Pb solid targets (large angle production) and with N2, O2 cryogenic targets with the large acceptance HARP experiment at CERN PS.
For incident pions the presented data represent the first experimental campaign to systematically measure forward pion hadroproduction.
Results have been compared with GEANT4 and MARS MonteCarlo simulations and parametrized (for incident protons) for easy use. The results may

be useful for simulation of existing neutrino beamlines, atmospheric neutrinos fluxes, extensive air shower (by reducing the uncertainties of hadronic interaction models in the low energy range), for the tuning of available QCD inspired Monte Carlo simulations and for simulation of future Neutrino Factory beamlines.
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**91**

## Liquid Scintillator Purification and Assay R&D at SNO+

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The SNO+ detector is a renewal of the Sudbury Neutrino Observatory heavy water Cherenkov detector, whereby the original heavy water has been removed, and is to be replaced by organic liquid scintillator for the study of low energy solar neutrinos, geo-neutrinos, and neutrino-less double beta decay. The detector reuses the same 12m diameter acrylic containment vessel (AV), which will have a new hold-down net installed to support the buoyant force of the liquid scintillator within the water-filled cavity.

The science program requires extremely low levels of high-energy beta and gamma-ray background activities from 214Bi, 212Bi, and 210Bi, all from the 238U and 232Th chains, and from 40K. The initial phase of the SNO+ experiment uses the scintillator components, linear alkylbenzene (LAB) and wavelength shifter PPO, both carefully prepared with multi-stage distillation and vacuum gas stripping. To enable the removal of activity from the U-chain (most likely due to mobility of 222Rn) and from the Th chain, a re-purification system (used during the experiment) is being designed to remove effectively these radio-contaminants and their daughters (Ra, Rn, and Pb). It is also known from the SNO experiment that ex-situ radio-assay of the removed contaminants is a very valuable part of the physics analysis.

The re-purification system must have sufficient flow rate (about 150 LPM) to process the full 795 tonnes of scintillator within several days, so as not to interfere with the physics data, and also so that the scintillator can be purified on a time scale similar to the 224Ra and 222Rn half-lives (ie. about 4 days). Additionally, the purification processes must be stable against removal of the PPO, and the loaded Nd metal compound for the double-beta decay studies in a later phase. The research and development work has focused on three methods for the re-purification: liquid-liquid extraction using water (effective for Ra and K), surface-functional metal scavenging (effective for Pb and Ra), and vacuum steam stripping (effective for Rn and O2 removal). The assay method will use acid to strip and methanol to regenerate the metal scavenger media columns, followed by chemical recovery of the activity from the acid. This activity is then counted in custom beta-alpha counters using a coincidence pulse shape discrimination technique. To test the efficiencies of these methods and finalize the design for the re-purification plants, a program using "natural" radioactive spikes with 212Pb and 224Ra for the LAB has been developed. Since these contaminating elements are not soluble in organic solvents in the traditional way, recoil implantation procedures have been developed to make stable radioactive spike cocktails.

In this poster, current results for the spike production and characterization, and for purification tests for LAB with the water-extraction and metal scavenger techniques are given. The design for the full-scale purification and liquid-handling plants is also presented, along with an outline of plans for further purification and assay tests.

**92**

## Measurement of the Neutrino Beam Quality with the Muon Monitor "MUMON" in the T2K Experiment

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T2K ( Tokai-To-Kamioka ) is a long baseline neutrino oscillation experiment which uses the 30GeV proton beam produced at J-PARC ( Japan Proton Accelerator Research Complex ). The proton beam is injected onto a graphite target to generate charged pions, which are focused by three electromagnetic horns. Neutrinos are produced with muons from the pion decay. We aim the neutrino beam onto an off-axis by 2.5 degrees from the direction to the Super-Kamiokande detector to maximize the sensitivity to the oscillation measurement. The beam direction has to be measured within a 1mrad precision in order to achieve The T2K physics goal.
The muon monitor "MUMON" is located 118m away from the target and consists of two arrays of detectors, ionization chambers and silicon PIN photodiodes. It monitors the direction of the neutrino beam in real time by measuring the profile of muons which are generated along with neutrinos. In the 2009 commissioning run, we confirmed that the beam direction can be determined with a precision much better than 1mrad with MUMON. In addition, MUMON showed high sensitivity for the proton beam intensity and the position at the target and also for the current of the electromagnetic horns.
We will report on the performance of MUMON and the neutrino beam quality measured in the physics data taking in 2010.

**93**

## The Side Muon Range Detector for the T2K experiment

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The T2K-ND280 near detector is located 280m downstream from the hadron production target in J-PARC for measuring the flux, the energy spectrum and the flavor contents of the initial neutrino beam. T2K will obtain the primary goal, the measurement of the mixing angle theta 13 with comparing the characteristics with those of oscillated beam at the 295km far detector, Super-Kamiokande.
The Side Muon Range Detector (SMRD) is a surrounding detector of ND280 and optimized for energy measurement of large angle muons which are generated by charged-current neutrino interactions in the inner detectors. SMRD also works as the active veto detector and the cosmic ray trigger detector for the calibration of the detectors. The design of SMRD is multi-layered structure with wide plastic scintillators and iron yoke plates of the magnet providing dipole magnet field. For readout, multi-pixel photon counters are attached to the both ends of a WLS-fiber, which is embedded in the S-shaped groove of each counter.
The construction of SMRD was completed in 2009 and it is being commissioned with cosmic-rays and neutrino beam. The results of commissioning, the detector performance and the study with physics beam run in 2010 will be discussed in the presentation.

**94**

## Commissioning of the neutrino beam facility for the first super-beam experiment, T2K

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T2K (Tokai to Kamioka) is an accelerator based long baseline neutrino oscillation experiment. The experiment aims to discover the $\nu_e$ appearance mode and precisely measure the $\nu_\mu$ disappearance mode. A high intensity muon neutrino beam is produced at J-PARC (Japan Proton Accelerator Research Complex) and measured with a 50 kt water Cherenkov detector, Super-Kamiokande, 295 km from J-PARC. A 2.5-degree off-axis beam is used to produce a narrow energy band beam and reduce background to achieve high sensitivity.
The proton beam is extracted from the accelerator and transported to a graphite target to produce pions. These pions are focused with three electro-magnetic horns before decaying to muons and muon neutrinos. The neutrino beam direction and stability can be determined from proton and muon beam parameters. To measure these parameters and protect the beam line components from high intensity beam, several kinds of beam monitors are used: intensity, position, profile and loss monitors for proton beam and silicon PIN photodiode and ion chamber for muon beam.
Operation of the neutrino facility started from April 2009. Following beam tuning and performance studies, physics data taking started from January 2010. An overview of the neutrino facility, results of performance studies, beam parameters measured with beam monitors and prospects for higher intensity operation will be given in this presentation.

**95**

## Detector Development for the MAJORANA Demonstrator Project

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MAJORANA is a tonne-scale 76Ge neutrinoless double-beta decay experiment with the goal of probing the Majorana neutrino mass in the inverted mass hierarchy scenario. The experiment must meet the stringent requirement of fewer than 1 background count/(keV tonne yr) in the 4-keV region around the Q value of 2039 keV. The Collaboration is building a ˜60-kg prototype, the MAJORANA Demonstrator, of high purity germanium detectors, half of which will be enriched in 76Ge. Several detector options were pursued in order to assess and optimize their ability in rejecting radioactive background events that interact at multiple sites in the detectors. The most promising option is the class of p-type point-contact detectors. In this poster, the detector development program of MAJORANA is presented.

**96**

## Past, present and futures limits on theta_{13}

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The best current limit on theta_{13} comes from the CHOOZ reactor experiment. Despite the fact that CHOOZ only published one curve, there are several numbers called "the CHOOZ limit". This is because our knowledge of \delta m^2_32 has changed, but also for other reasons. I will discuss some issues in comparing the current limits and future sensitivities of CHOOZ, Double Chooz, RENO, Daya Bay, MINOS, NOvA, K2K, T2K and other future projects.

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## The PMT test facility at MPI-K Heidelberg and the Double Chooz Super Vertical Slice

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An extensive calibration of about 500 photomultiplier tubes (PMTs) has been done at MPI-K Heidelberg for the Double Chooz reactor neutrino experiment. The poster describes the experimental setup and gives an overview of the results focusing on charge distributions connected to transit times and after-pulse behavior.
After successful completion of this task the setup has become a testbed for the whole chain of Double Chooz electronics. In this setup called "Super Vertical Slice" (SVS) 30 PMTs, several Front-end Electronic modules, Waveform Digitizers and the Level-1 Trigger and Timing System are brought together in one place prior to installation at the Far Detector site. It thereby is the missing link between a single channel "slice" of the detector readout ("vertical slice") and the complete setup at Chooz with 390 Inner Detector PMTs. The SVS has already proven to be very useful in tuning and verifying the Front-end Electronics response. The electronics response in case of very high energy depositions is also being studied. The results obtained hint at the feasibility of using muon-induced isotopes, such as B12 or Michel electrons, for detector calibration, thereby influencing the experiment's calibration strategy in the early phase of data taking.
A 30 l barrel with the Gd-loaded Target scintillator is being prepared and will be used to measure scintillator properties together with the realistic electronics in place. A selection of measurement results obtained with the SVS will be presented in this poster.

**98**

## Understanding and Calibrating the Calorimeter for the T2K Near Detector

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T2K (Tokai-to-Kamioka) is a long-baseline neutrino experiment with the primary purpose of measuring the mixing angle theta-13, using a muon-neutrino beam which is produced at the J-PARC

accelerator facility and aimed towards the far detector, Super-Kamiokande. A near detector located 280m from the neutrino production target, the ND280, will be used to measure the neutrino energy spectrum, flavour content and interaction rates of the un-oscillated beam and to predict the neutrino interactions at Super-Kamiokande. The downstream module of the ND280 electromagnetic calorimeter, the DS-ECal, is now in situ and taking data. Work on calibrating and understanding the DS-ECal is ongoing and this poster will
present the attenuation correction method employed in the calibration
chain using cosmic ray data from the detector's commissioning days at CERN
and with data from Tokai.

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## Low-Z High-Power Targets for Neutrino Beams: Performance under Intense Proton Flux

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Low-Z targets, in particular graphite, have been used extensively in the production of intense neutrino beams for neutrino experiments. The reason is three-fold : (1) the yield of useful pions – parents of the neutrinos of interest –from low-Z materials is well matched to the requirements of most neutrino experiments; (2) peak energy deposition in low-Z targets is lowest; and (3) graphite exhibits superior thermal and mechanical properties that are confirmed by experience performance data from nuclear reactor operations. The need for multi-MW level operations and beams associated with proposed long baseline neutrino experiments (including LBNE), has prompted a more rigorous effort to identify potential limitations of low-Z materials and in particular graphite grades and carbon composites when operating at multi-MW levels.

This multi-faceted feasibility study is centered on an experimental effort through which proton irradiation damage of materials at fluence levels that are representative of the conditions in neutrino super-beam initiatives is assessed. Concerns that anticipated material damage due to irradiation with high power proton beams cannot be reliably extrapolated from the extensive data on neutron irradiation helped initiate a series of irradiation damage studies using the 200 MeV proton beam from the BLIP isotope production facility at Brookhaven National Laboratory (BNL). Special attention has been paid to various graphite grades, carbon composites of different structural architecture, Beryllium as well as low-Z alloys such as Albemet (alloy of Beryllium and Aluminum). Preliminary results expressed through proton fluence thresholds confirm the anticipated dissimilarities between the interactions of thermal neutrons in nuclear reactors and energetic protons interacting with the same materials. Recent experience from neutrino experiments using graphite-based targets has provided further confirmation of what has been experimentally observed. As a result, a series of analytical feasibility studies along with DPA (Displacement Per Atom) model developments have been initiated looking at the material damage dependency on proton energy and irradiation rate.

In this paper relevant experimental results from the BNL irradiation damage study will be presented along with results on the feasibility studies which, while attempting to quantify the interaction of energetic protons with the array of low-Z target materials, provide the basis for making lifetime predictions and target material choices for the LBNE experiment. Also presented in this paper are target performance results of the NuMI experiment that are put in context with the experimental observations at BNL.

**101**

## LENS - Electronics and Scintillation Lattice Testing Towards Benchmarking the Performance of LENS

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The Low-Energy Neutrino Spectroscopy (LENS) experiment is designed to precisely measure the fluxes of low-energy solar neutrinos via charged-current reactions to achieve a precision test of solar physics and the MSW-LMA flavor-conversion model through the fundamental equality of the neutrino fluxes and the precisely known solar luminosity in photons. The LENS collaboration is currently developing a prototype, miniLENS, that will demonstrate the performance and selectivity of the LENS technology. Prototypes with the same length scale as miniLENS (but smaller volume) have been built and tested at Louisiana State University to study construction techniques, PMT performance, attenuation of channeled light, as well as to benchmark optical properties of the as-built instrument to serve as input parameters into Monte Carlo simulations. The LSU prototypes are also being used to develop the data acquisition (DAQ) system for miniLENS. Results from studies of these prototypes and the status of the DAQ development will be presented.

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## Read-out system of the Double Chooz experiment.

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The Double Chooz experiment, which will use the antineutrinos produced in the Chooz nuclear power plant in France, aims at measuring theta_13 or further lowering its limit if no signal is observed. To achieve this purpose, a new concept using two detectors has been introduced: one close to the power plant to monitor the flux of electron antineutrinos emitted by the power plant and one at 1.05 km, where the disappearance is expected to be maximal. In addition, the detector design has been optimized to reduce backgrounds. The expected sensitivity at 90% C.L. is sin2(2theta_13)<0.03 (with Dmˆ2 =2.5 10ˆ-3 eVˆ2) after three years of data taking.
The aim of this poster is to present the read-out chain and data acquisition system of the Double Chooz experiment. All its components will be described in detail from the photomultiplier tube to the storage of data on disk. Special focus will be devoted to the capabilities of the 8 bits 500 MHz FADC waveform digitisers and the Level-1 trigger and timing system. Data from the preliminary performance of the ensemble will be shown. The on-line system will be also discussed focusing on the high degree of diagnosis and real time data analysis of the data monitoring system.

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## Towards a Giant Liquid Argon Observatory for Proton Decay, Neutrino Astrophysics and CP-violation in the Lepton Sector (GLACIER)

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Abstract:
The feasibility of a very massive underground liquid Argon detector (Giant Liquid Argon Charge Imaging ExpeRiment) of total mass of the order of 100 kton is considered for a next generation nucleon decay, long baseline neutrino physics and neutrino astrophysics experiment.

The detector concept envisions a volume of very pure liquid argon stored in a large non-evacuable cryogenic storage tank, conceptually similar to the LNG tanks used by the petrochemical industry. The detector is operated in double phase with charge extraction and amplification in the vapor phase, readout by appropriately segmented electrodes (LAr LEM-TPC). The method is an elegant solution for long drift paths and mm-sized readout pitch segmentation.

The LAr LEM-TPC charge imaging concept has been successfully demonstrated on small prototypes using LEM/THGEMs. The images obtained are of very high quality, owing to the charge amplification and have good measured dE/dx resolution.

Effective extrapolation to the required mass scale requires concrete R&D, for example on large area readout methods, use of alternative MPGDs (e.g. MicroMEGAS), very long drift paths, warm and cold readout electronics, liquid argon purity in non-evacuated very large volumes, etc. In this context, small setups have and are being operated, and a 250L chamber, a 1-ton chamber (ArDM-1t) and a 6m3 device are under assembly at KEK and CERN.

Additional dedicated test beam campaigns are being considered, e.g. to test and optimize the readout methods and to assess the calorimetric performance of such detectors, and to address scaling to larger fiducial masses.

Beyond these efforts, a 1000 ton detector in a short baseline neutrino beam is being contemplated, whose purpose is to acquire the necessary experience for the realization of the giant detector by building a smaller, precursor version, and using it to do important neutrino physics research.

The underground localization of a 100 kton experiment along the JPARC neutrino beam (Okinoshima island) is being investigated in collaboration with Japanese industry, and in Europe the FP7 LAGUNA design study addresses its feasibility at 7 potential sites located in Finland (Pyhäsalmi), France (Fréjus), Italy (Umbria region), Poland (Sieroszowice), Romania (Slanic), Spain (Canfranc) and United Kingdom (Boulby). The procurement of the required amount of liquid argon as well as the safety and environmental impact at the individual sites are also addressed.

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## Measuring antineutrino oscillations in MINOS as a test of CPT conservation

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The MINOS experiment has made the best measurement of the atmospheric neutrino mass splitting to date by studying the disappearance of muon neutrinos over its 735 km baseline. Since October 2009 MINOS has been running with a dedicated muon antineutrino beam and has obtained data corresponding to 1.5\times10^{20} protons on target in this configuration. Details of the analysis of these data are presented, allowing the first precision measurements of the atmospheric-regime antineutrino oscillation parameters. Any difference between the neutrino and antineutrino values could indicate CPT violation or other new physics.

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## NA61 data for T2K flux calculations

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For the NA61 and T2K Collaborations

The approved T2K neutrino oscillation physics program requires a 5% neutrino flux determination and the ability to extrapolate the neutrino flux from near to far detector with a precision of 3%. This implies a knowledge of the hadron production with an accuracy of about 10%, while present Monte Carlo models differ significantly more.
The NA61 experiment at the CERN North Area, using a 30 GeV proton beam on Carbon targets, measures hadron production over all the phase space needed by the T2K experiment and aims at producing a measurement of particle yields with a precision of 5% or better for pions and 10% for Kaons.
A thin target is used to measure the inclusive inelastic cross-section of charged pions, kaons and protons as function of momentum and angle, in the primary interactions of 30 GeV protons on Carbon. A replica of the T2K production target is also used to get a measurement of reinteractions inside the target itself and to directly measure the hadron production yields off the T2K target, which can be used as input to the neutrino beam simulation.

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# The NOvA Detectors

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NOvA is an off-axis long-baseline neutrino experiment, looking for $\nu_e$ appearance in an upgraded NuMI beam of $\nu_\mu$ to search for $\theta_{13}$ acting in subdominant $\nu_\mu \rightarrow \nu_e$ transitions. To maximize sensitivity to the resulting ∼GeV electromagnetic showers, the 15˜kton Far Detector is "totally active", comprised of liquid scintillator contained in 15.7˜m long extruded PVC cells, with the scintillation light piped out in wavelength shifting fibers then digitized by avalanche photodiodes. Civil construction at the far detector site is underway, and the smaller near detector is being assembled at Fermilab. This poster summarizes the current detector design and construction status.

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# SNO+ Liquid Scintillator Characterization: Timing, Quenching and Energy Scale

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SNO+ will be a large-volume underground liquid scintillator neutrino
experiment at the SNOLAB facility, in Sudbury, Ontario, Canada. The
physics reach of SNO+ is broad and covers many areas of neutrino physics
including neutrinoless double beta decay, geo-neutrinos, reactor and
low-energy solar neutrinos. To achieve the goals of the experiment, it is
imperative to understand the properties of the proposed linear alkyl

benzene (LAB) scintillator. This poster will describe laboratory measurements designed to investigate: (1) the scintillation light timing profiles due to alpha and beta-particle excitation of LAB, and the alpha/beta discrimination capability based on these timing distributions, (2) the electron energy scale linearity, and (3) ionization quenching in SNO+ scintillator.

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## SHINE-NA61 experiment and applications for neutrino fluxes and cosmic rays

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SHINE-NA61 experiment and applications for neutrino fluxes and cosmic rays

Large uncertainties in neutrino beam fluxes as well as for the prediction of extended air showers come from poor knowledge of the production of mesons in hadronic interactions on Carbon or atmospheric gas.

The NA61 experiment at the CERN SPS measures hadron production from collisions of pions, protons and ions on different types of targets. Its acceptance is up to 500 mrad. The particle identification and tracking are performed by dE/dx in large TPCs and TOF detectors. In 2009, an upgrade of the DAQ increased the aquisition rate until 100 Hz. The Forward TOF detector has also been enlarged, covering an extended domain.

The NA61 experiment enables to reproduce the interactions of the neutrino experiment T2K and cosmic rays experiments Auger and KASKADE. To reproduce the T2K beam, a replica of the carbon target has been exposed to SPS protons at the same energy (30 GeV), as well than a thin target dedicated to primary interactions. NA61 measured also h+C interactions at 158 GeV/c and 300 GeV/c needed for the reconstruction of the cosmic rays events of Auger and KASKADE experiments. In both case, the resolutions of these experiments will improve substantially.

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## Cosmological bounds in MaVaN models

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Mass varying neutrino (MaVaN) is a class of models which in cosmology try to explain the coincidence of dark energy density through a tracking mechanism related with neutrinos. This special model couples the quintessential scalar field with neutrino density generating an effective mass wich in turn becomes variable. Beyond its origin field, it's has been shown that MaVaN can also generate flavour conversion, in this work we analysed how the model for flavour conversion applies in cosmology and we extracted some combined bounds using cosmic microwave background, super novas, baryonic acoustic oscillations and weak lensing data.

**111**

## Tau Neutrino Searches with IceCube

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IceCube is a cubic kilometer size neutrino telescope operating in the
deep ice at the South Pole. Its scientific goals include searching for tau neutrinos of extraterrestrial origin. Although astrophysical source models typically predict only electron and muon neutrino production, after standard neutrino oscillations over astrophysical distances electron, muon and tau neutrinos are expected to arrive at the detector in equal numbers.
Ultra high energy (UHE) tau neutrinos are expected to leave identifiable signatures
inside the detection volume due both to their finite lifetime and their rich array of decay channels. By characterizing these distinctive signatures we hope to distinguish UHE tau neutrinos from muon and electron neutrinos. In addition, lower energy tau
neutrinos can produce a distinctive double pulse waveform in individual IceCube detector modules that will distinguish these interactions from other neutrino
interactions producing simpler hadronic or electromagnetic showers.
Exclusively identified tau neutrinos will have negligible atmospheric neutrino background and as such could serve as a clean signature of cosmological origin.

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## Intrinsic flavor violation for massive neutrinos

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It is shown that intrinsic neutrino flavor violation invariably occurs when neutrinos are created within the SM augmented by the known massive neutrinos, with mixing and nondegenerate masses. The effects are very small but much greater than the naive estimate $\Delta m^2/E_\nu^2$ or the branching ratio of indirect flavor violating processes such as
$\mu \to e\gamma$ within the SM.
We specifically calculate the probability (branching ratio) of pion and muon decay processes with flavor violation, such as $\pi \to \mu\bar{\nu}_e$ (two-body) and $\mu \to e\nu_\mu\bar{\nu}_\mu$ (three-body), showing nonzero results.

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## Project 8: Using Radio Frequency Techniques to Measure the Neutrino Mass from Beta Decay

**Authors:** Benjamin Monreal[1]; Joseph Formaggio[2]

**Co-authors:** Alan Rogers [2]; Brent VanDevender [3]; Daniel Furse [2]; Gray Rybka [3]; Hamish Robertson [3]; Leslie Rosenberg [3]; Michelle Leber [1]; Noah Oblath [2]; Peter Doe [3]; Richard Bradley [4]; Shepard Doeleman [2]

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We propose a novel technique by which the energy spectrum of low energy electrons can be extracted. The technique relies on the detection and measurement of coherent radiation created from the cyclotron motion of electrons in strong magnetic fields. Since the frequency of cyclotron radiation emitted by the particle depends inversely on its Lorentz boost, the detection and measurement of the coherent radiation emitted is tantamount to measuring the kinetic energy of the electron. As the technique inherently involves the measurement of a frequency in a non-destructive manner, it can, in principle, achieve a high degree of resolution and accuracy. One immediate realization of this technique is in the measurement of the endpoint spectrum from tritium beta decay, which is directly sensitive to the absolute mass scale of neutrinos. In this poster, we discuss a new experimental effort, known as Project 8, to utilize this technique towards a sensitive beta decay neutrino mass experiment.

**Summary**:

A new experimental effort, known as Project 8, utilized radio-frequency techniques to perform spectroscopy on electrons created from tritium beta decay. The technique is to be used for a future measurement of the mass of the electron neutrino from beta decay.

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## Results from a scintillator test deployment in SNO+

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The SNO+ liquid scintillator neutrino experiment is under construction in the SNOLAB facility, located approximately 2 km underground in Sudbury, Ontario, Canada. The goals of this multi-purpose experiment include precision measurements of low energy components of the solar neutrino flux and a search for the elusive neutrinoless double beta decay process through addition of neodymium in a separate phase of the experiment. A detailed understanding of the linear alkyl benzene (LAB) scintillator and its optical properties is crucial to the success of this experiment.

To this end, an acrylic cylinder capable of holding approximately 1 litre of scintillator was deployed in a water filled SNO+ detector in autumn 2008. By deploying the cylinder with an Americium Beryllium (AmBe) source (external to the cylinder), the scintillator light yield was determined in the actual detector, helping to tune the detector Monte Carlo.

The cylinder was deployed without the AmBe source to search for background contamination using a beta-alpha coincidence method. Alpha peaks from radon were used to derive Birks' constant and alpha quenching factors. The beta-alpha coincidence events were used to provide a sample of betas and alphas which were used in timing and pulse-shape discrimination studies. Three different types of LAB scintillator were studied during the test deployment, including LAB

loaded with 0.1% natural neodymium. This poster will present the design of the apparatus, preparation of the scintillator samples, results from this small scale test and their implications for the SNO+ experiment.

This work is presented on behalf of the SNO+ collaboration.

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## ANITA and the Highest Energy Cosmic Rays

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The ANITA (ANtarctic Impulsive Transient Antenna) experiment is a balloon-borne, broadband antenna array flown over the Antarctic continent, designed to detect coherent Cherenkov emission from cosmogenic neutrinos. It is also sensitive to radio emission from ultra high energy cosmic rays. The first ANITA payload completed a 35 day flight during the Austral summer of 2006-2007, observing 16 cosmic rays. Detailed Monte Carlo studies have revealed that these cosmic rays have energies of order 10ˆ{19} eV. These cosmic rays comprise the highest energy sample detected in radio.

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## Simulating GeV particles in a very large liquid scintillator detector

**Authors:** Hok Seum Wan Chan Tseung[1]; Jarek Kaspar[1]; Nikolai R. Tolich[1]; Sanshiro Enomoto[1]

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Large liquid scintillation detectors could be an alternative to water Cherenkov and liquid Argon detectors for high energy neutrino measurements, in the GeV energy range, suitable for both cosmic ray studies and a long baseline neutrino experiment. We demonstrate the ability of a 100 kton detector to distinguish the lepton flavor, discuss sensitivity to pions, and show a track finder. The research has been supported under DOE Grant #DE-FG02-97ER41020.

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## A Three-Phase Combined Analysis of the Sudbury Neutrino Observatory

**Authors:** Chris Howard[1]; Nuno Barros[2]; Pierre-Luc Drouin[3]

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Following the publication of the results from an analysis of the third phase of the experiment, and the recent release of a paper presenting a low energy threshold analysis of Phases I and II, the Sudbury Neutrino Observatory Collaboration is now performing a final joint analysis of the data collected during the entire experiment. The signal extraction process of this solar neutrino analysis is divided into two components: the measurements of 8B and hep signals. The 8B analysis combines the photomultiplier tube data from the three phases along with the results from a pulse shape analysis of the data from the neutral current detectors used during the third phase to provide the most accurate SNO measurement of the total 8B flux and the day/night energy-dependent electron neutrino survival probability. The hep analysis, which has always been statistically limited, has its sensitivity enhanced over previous measurements by the combination of the three-phase data set. The hep analysis uses the energy distortion at the end point of the data spectrum to extract the best hep flux measurement. With the new SNO results from the signal extraction process, two-flavour and three-flavour neutrino oscillation analyses are being performed with improved resolution on the oscillation parameters. An updated global fit combining all solar neutrino experiments will be presented as well.

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## Background Model for the {\sc Majorana Demonstrator} Neutrinoless Double-beta Decay Experiment

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The {\sc Majorana Demonstator} will field an array of approximately 60 kg. of high-purity germanium crystals. Some of the crystals will be enriched in the double-beta decaying $^{76}$**Ge** isotope. The {\sc Majorana Demonstrator} will search for the neutrinoless double-beta decay mode, as well as light WIMP dark matter. The primary experimental challenge is the reduction and estimation of residual radioactive backgrounds. This reduction is achieved by a combination of extremely pure and clean materials, an underground location, passive and active shielding, and data-analysis methods. This poster describes the quantitative background model of the {\sc Majorana Demonstrator} that takes into account all known sources of residual background radioactivity and the efficacy of the background mitigation schemes.

**Summary**:

The {\sc Majorana Demonstator} will field an array of approximately 60 kg. of high-purity germanium crystals. Some of the crystals will be enriched in the double-beta decaying $^{76}$**Ge** isotope. The {\sc Majorana Demonstrator} will search for the neutrinoless double-beta decay mode, as well as light WIMP dark matter. The primary experimental challenge is the reduction and estimation of residual radioactive backgrounds. This reduction is achieved by a combination of extremely pure and clean materials, an underground location, passive and active shielding, and data-analysis methods. This poster describes the quantitative background model of the {\sc Majorana Demonstrator} that takes into account all known sources of residual background radioactivity and the efficacy of the background mitigation schemes.

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## Pulse-Shape Analysis of the Proportional Counter Data from the Third Phase of the Sudbury Neutrino Observatory

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This poster presents the techniques that were developed for analyzing the data from an array of 36 strings of low background 3He proportional counters that were deployed during the third phase of the Sudbury Neutrino Observatory experiment. The counters were used to detect neutrons created by the Neutral Current interaction of solar neutrinos with deuterium; measuring the production rate of these neutrons is a direct measurement of the total flux 8B of solar neutrinos. The methods presented in this poster are aimed at substantially increasing the ratio of signal to background events. The number of neutrons in the data is determined by fitting the energy spectrum of these events. By increasing the signal-to-background ratio the total number of neutron events can be determined more accurately. We use a combination of three different pulse-shape-analysis techniques, including the use of calibration data, simulated signal and background events, and the skewness and kurtosis characteristics of the pulses. The cuts on the events were optimized to reject approximately 98% of alpha events while retaining 75% of the neutrons. The energy-spectrum fit on this cleaned data results in a significant improvement compared to previously published analysis of this data.

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# Physics Potential of the IceCube DeepCore detector

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The recent commissioning of the full DeepCore sub-array, a low-energy extension of the IceCube neutrino observatory, offers exciting opportunities for neutrino physics in the energy region of 10 GeV to 1 TeV. The improved energy reach, use of the surrounding IceCube detector as an active veto and immense size of DeepCore will produce one of the largest all-sky neutrino datasets ever acquired. DeepCore will provide sensitivity to neutrinos from possible neutralino dark matter annihilations in the earth, sun and galactic center, down to neutralino masses in the physically interesting region of about 50 GeV. Tens of thousands of atmospheric neutrinos will be detected annually after oscillating over a baseline of up to one earth diameter, opening the possibilities for a muon neutrino disappearance and tau neutrino appearance measurements. The current status of these measurements will be presented in this poster.

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# Status of the DeepCore Sub-Array at the IceCube Neutrino Observatory

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In February 2010, the IceCube collaboration completed the deployment of the "DeepCore" sub-array. Complementing the baseline detector design, DeepCore provides sensitivity to neutrinos with energies as low as about 10 GeV and thereby extends the energy reach of the observatory by almost two orders of magnitude. With the DeepCore modules concentrated in the extremely clear ice at the bottom-center of IceCube, the sub-array will utilize the surrounding IceCube detector as an active veto against the copious cosmic-ray muon background. In conjunction with its denser module spacing, the increased vetoing capability will not only lower the neutrino energy threshold but will also

increase the detection efficiency to low energy neutrinos over the full solid angle. This poster describes the design and performance of the fully deployed DeepCore sub-array, including first results from low-level triggers and online physics software filtering.

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## Neutron production by cosmic ray muons at the Sudbury Neutrino Observatory

**Author:** James Loach[1]

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Neutrons produced by cosmic ray muon interactions can be a significant background in sensitive underground experiments. The Sudbury Neutrino Observatory (SNO) is an efficient and well-calibrated neutron detector capable of measuring the rate and characteristics of neutrons produced by muon interactions in its heavy water target, light water shielding and surrounding rock. The location of the detector, beneath a rock overburden of 2092 m (5890 +/- 94 m water equivalent), means that the muon flux is particularly low in rate and high in energy. SNO's measurements, with their unique target materials and high energy muons, are important for benchmarking Monte Carlo simulations. These simulations will be used to predict the muon-induced neutron fluxes in future low background experiments.

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## Searching for high-frequency variations in the solar neutrino flux with the Sudbury Neutrino Observatory

**Author:** Aubra Anthony[1]

[1] *University of Texas at Austin*

Recent helioseismology results have pointed to the possible detection of high-frequency (periods of minutes to days) gravity-mode oscillation signals in the Sun. Periodic fluctuations in density, pressure and temperature (as would be caused by g-modes at the solar core) could potentially modulate the outgoing flux of solar neutrinos, through the close relationship between temperature and neutrino production. Density fluctuations could also affect the propagation of neutrinos through the Sun, through the MSW effect, because periodically-shifting matter densities could temporally vary the probability for neutrino oscillations to occur. The Sudbury Neutrino Observatory was an optimal laboratory for studying time dependence in the solar neutrino flux, due to excellent background elimination and real-time signal detection. This poster will show the searches that we performed with SNO neutrino data to identify any high-frequency periodic signal in the Sun, both on broad time scales, as well as those specifically relevant to recent g-mode detection claims.

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## Monitoring nuclear reactors with antineutrino detectors: the ANGRA Project

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We will describe the status of the Angra Project, aimed at developing an antineutrino detector for monitoring nuclear reactor activity. Nuclear reactors are intense source of antineutrinos and the thermal power released in the fission process is directly related to the antineutrino flux, making antineutrino detectors good candidates to become in the future a new safeguards tool for monitoring reactors through counting rates and spectral measurements.
The Angra experiment will use the Brazilian nuclear power plant Angra II, with 4 GW of thermal power, as a source of antineutrinos. A water Cherenkov detector of one ton target will be placed in a commercial container just outside the reactor containment, at about 30 m of the reactor core. A few thousand antineutrino interactions per day are expected. The shielding configuration and the event analysis strategies to overcome the large background induced by cosmic rays at ground level are being developed and will be presented.

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# In situ Calibrations of MINERvA

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The MINERvA experiment, located at Fermilab, will use the NuMI beam line for measuring neutrino-nucleus interaction rates with very high precision. In order to obtain the unprecedented precision MINERvA is capable of, sophisticated calibration techniques are applied both prior to installation and in situ. This poster will highlight some of MINERvA's calibration efforts. In particular, I will talk about calibrating PMT gains and scintillator response. MINERvA's scintillator response is calculated using radioactive sources and particle beams. I will also discus how PMT gains are calculate in situ using the light injection system.

**128**

# The Askaryan Radio Array

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One of the most tantalizing questions in astronomy and astrophysics, namely the origin and the evolution of the cosmic accelerators that produce the highest energy (UHE) cosmic rays, may be best addressed through the observation of UHE cosmogenic neutrinos. At high energies (above 10ˆ16 eV), neutrinos could be most efficiently detected in dense, radio frequency (RF) transparent media via the Askaryan effect. Building on the expertise gained by the RICE, AURA and ANITA experiments in the use of this technique in cold Antarctic ice, and the infrastructure developed in the construction of the IceCube optical Cherenkov observatory, we are currently developing an antenna array known as ARA (The Askaryan Radio Array) to be installed in boreholes extending 200 m below the surface of the ice near the geographic South Pole. The unprecedented scale of ARA, which will cover a fiducial area of 80 square kilometers, was chosen to ensure the detection of the flux of neutrinos "guaranteed" by the observation of the GZK cutoff by HiRes and the Pierre Auger Observatory. The first components of ARA are planned for installation during the austral summer of 2011-2012. Within 3 years of commencing operation, the full ARA will exceed the sensitivity of

any other instrument in the 0.1-10 EeV energy range by an order of magnitude. The primary goal of the ARA array is to establish the absolute cosmogenic neutrino flux through a modest number of events. Such an observatory would also provide an unique probe of long baseline high energy neutrino interactions unattainable with any man-made neutrino beam.

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## LENS—Indium Loaded Liquid Scintillator (InLS) Development for the LENS Experiment*

**Authors:** Liangming Hu[1]; S. Derek Rountree[2]

[1] *Brookhaven National Laboratory and Virginia Polytechnic Institute and State University*

[2] *Virginia Polytechnic Institute and State University*

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The experimental tool for LENS is charged-current capture of a neutrino on 115In, with prompt emission of an electron and delayed emission of 2 gamma rays that serve as a time and space coincidence tag. The detection medium is liquid scintillator loaded with Indium. The LENS experiment requires approximately 10 tons of Indium to be loaded into 100,000 liters of organic scintillator, prepared via liquid-liquid extraction from aqueous solutions of inorganic In compounds. The key properties of the scintillator are high metal loading (8-10%), long attenuation length at 430nm (>8m), high scintillation yield, stability on the scale of 5 years, and low environmental and health hazards in an underground environment. These goals are reached by careful pH balancing during the extraction and use of high purity front end liquids. The raw materials for the extraction must undergo purification and scrupulous quality control measures. We will present InLS recipes, liquid quality variations before/after purification measured via UV-Vis spectrometry and gas chromatography-mass spectrometry (GC-MS). We will present results on the scintillation light yield and attenuation length of the final InLS. Two different solvents, psuedocumene (PC) and linear alkylbenzene (LAB) have been used to load the In metal and achieve satisfactory figures of merit.

*This work was funded by—the National Science Foundation, Virginia Tech, LA Board of Regents and LSU. Brookhaven National Laboratory is funded by the U.S. Department of Energy

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## SNO+ Electronic Upgrades

**Author:** robert knapik[1]

**Co-authors:** Richard Bonventre [1]; Timothy Shokair [1]

[1] *University of Pennsylvania*

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The SNO+ experiment is designed to explore several topics in neutrino physics, including neutrinoless double beta decay and low energy solar neutrinos. SNO+ uses the existing Sudbury Neutrino Observatory (SNO), with the heavy water target replaced with liquid scintillator. Only a few additional modifications are needed to transition from SNO to SNO+, but one of these will be an upgrade to the electronics to handle the higher rates expected with scintillation light as compared to Cherenkov light. The primary upgrades are aimed at increasing the bandwidth for reading data from the front end electronics crates, and to the trigger system to allow for higher analog currents. For SNO, each of the 19 front-end crates digitized and recorded the PMT signals but data could only

be read out one crate at a time. With the upgrade to the new electronics, each of the 19 crates will autonomously push data to a central data acquisition computer, yielding at least a factor of 19 times more bandwidth. The autonomous readout is achieved with a field programmable gate array (FPGA) with an embedded processor. Inside the FPGA fabric a simple state machine using VHDL is configured to pull data across the VME-like bus of each crate and store the digitized PMT signals in a local memory buffer. A small C program, making use of open source Light Weight IP (LWIP) libraries, is run directly on the hardware (no operating system) to send the data via TCP/IP to the central data acquisition computer. The hybrid combination of high-level' C code andlow-level' VHDL state machine is a cost effective and flexible solution for reading out individual front end crates.

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## LENS—Low-Energy Solar Neutrino Spectrometer: Principles of Detection and Background Suppression*

**Authors:** Micah Eassa[1]; S. Derek Rountree[1]; Szymon Manecki[1]

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LENS is a low energy solar neutrino detector that will measure the solar neutrino spectrum above 115 keV, >95% of the solar neutrino flux, in real time. The objective is to measure the model independent inferred solar neutrino luminosity, test the current LMA-MSW oscillation model, probe the temperature profile of solar energy production, as well as search for active-sterile neutrino mixing using an artificial neutrino source. The fundamental neutrino reaction in LENS is charged-current based capture on 115In detected in a liquid scintillator medium. The reaction yields the prompt emission of an electron and the delayed emission of 2 gamma rays that serve as a time & space coincidence tag. Sufficient spatial resolution is used to exploit this signature and suppress background, particularly due to 115In beta decay. A novel design of optical segmentation (Scintillation Lattice or SL) channels the signal light along the three primary axes. The channeling is achieved via total internal reflection by suitable low index gaps in the segmentation. The spatial resolution of a nuclear event is obtained digitally, much more precisely than possible by common time of flight methods. Advanced Geant4 analysis methods have been developed to suppress adequately the severe background due to 115In beta decay, achieving at the same time high detection efficiency. LENS is now in the prototype phase—mini-LENS which will demonstrate the lattice design, allow benchmarking of the LENS Monte-Carlo analysis, test Indium liquid scintillator fabrication, and test electronics configurations for scale up routes to the full scale LENS detector.

*This work was funded by—the National Science Foundation, Virginia Tech, LA Board of Regents and Louisiana State University. Brookhaven National Laboratory is funded by the Department of Energy.

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## Overview of the KATRIN Detector Section

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The KATRIN detector section is the primary responsibility of the United States portion of the KATRIN collaboration. The KATRIN detector section contains five major components: the vacuum system, the focal plane detector (a monolithic PIN diode array), data acquisition electronics and software, detector calibrations, and the muon veto system. This poster will detail the specifications and commissioning status of each of the preceding sections. The planned delivery date to the KATRIN experiment in Karlsruhe Germany is August 2010.

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## Neutrino Oscillations in Quantum Mechanics and Quantum Field Theory

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A fully consistent description of neutrino oscillations requires either the quantum-mechanical (QM) wave packet approach or a quantum field theoretic (QFT) treatment. We compare these two approaches to neutrino oscillations and discuss the correspondence between them. We comment on the definition of neutrino flavor eigenstates in QFT and argue that fully consistent matrix element calculations can only be carried out in the mass basis. Finally, we discuss the dynamics of neutrino wave packets at high density and temperature in the early universe.

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## The low-energy Neutrino Factory

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To date most studies of Neutrino Factories have focused on facilities where the energy of the muon in the storage ring has been in the range of 25-50 GeV. In this contribution we present a concept for a low-energy (≈ 5 GeV) Neutrino Factory (LENF). For baselines of O(1000 km), the rich oscillation pattern at low neutrino interaction energy (0.5—3 GeV) provides the uniquely good sensitivity to leptonic CP violation and the determination of the neutrino mass hierarchy. It has been shown that the LENF outperforms any reasonable super-beam experiment. A novel neutrino detector with low energy threshold and excellent energy resolution is needed, however, in order to exploit this oscillation pattern. We will

describe the basic accelerator facility, demonstrate the methodology of the analysis and give an estimate on how well the low-energy Neutrino Factory can measure θ_{13}, CP violation, and the mass hierarchy. We discuss different options for the far detector and consider their physics reach. Moreover, we find that the experiment also has good sensitivity to non-standard interactions and that this can be enhanced by the inclusion of the electron-neutrino appearance channel. Finally, we elaborate on the detector concept that is used to exploit the electron channel and indicate what R&D is still needed.

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## A high-power target for a Neutrino Factory

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A challenging requirement for a Neutrino Factory with a highly directional neutrino beam containing ˜10ˆ{21} neutrinos/yr is a target technology which can be used with a proton beam of power levels on the order of 4 MW. We describe our concept for a target system which can operate at such beam powers and thereby generate the intense muon beams the eventual decay of which produces the neutrinos from the Neutrino Factory. Technical issues are discussed and the experimental program devised to validate the target concept is presented.

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## Procurement, production and testing of the Broad Energy Germanium (BEGe) detectors depleted in 76Ge

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The GERDA experiment employs isotopically enriched Ge detectors
to search for neutrinoless double beta decay of Ge-76. In addition to the detectors deployed in Phase I, the Phase II of the experiment will use new detectors from 37.5 kg of enriched germanium with additional rejection capabilities. Possible candidates are p-type Broad Energy Germanium detectors

(BEGe) or 18-fold segmented n-type diodes. The capability of pulse shape discrimination of Canberra commercial BEGe have been already tested and verified two groups of the collaboration. This project is aiming to demonstrate that working BEGe detectors can be produced, while maximizing the production-chain yield from the isotopically enriched material. Such production chain consisting of
• procurement of the isotopically modified material (both depletion and enrichment from ECP, Zelenogorsk, Krasnoyarsk Region, Russia),
• reduction to metal,
• chemical purification,
• crystal pulling and
• diode fabrication
is tested with material of the same history, i.e. depleted Germanium in 76Ge to 0.6%. 34 kg of depleted material (from ECP, Zelenogorsk, Krasnoyarsk Region, Russia) has been purchased by GERDA collaboration, the quality has been fourfold checked via ICPMS (LNGS, Italy and RAS, Moscow) and NAA (in Geel and Munich). Then the material underwent the reduction and purification to 6N at PPM (Pure Metals GmbH), Langelsheim, Germany. 17 zone refined bars received in June 2009, with a yield for reduction process of 91% (21.4 kg) has been sent to Canberra in Oak Ridge for crystal pulling and first crystal suitable for diode production was ready at the end of September 2009. Finally the diode fabrication is ongoing at Canberra, Olen, Belgium. GERDA collaboration aims for 5 diodes of BEGe type to evaluate the achievable mass of detectors that can be produced from 37.5 kg of enriched material.
Two depleted BEGe detectors have been produced by Canberra, they are undergoing all the Canberra internal acceptance tests and then they will be shipped to LNGS. The arrival is foreseen within March 2010. BEGe detectors will be tested and characterized in terms of energy resolution, active volume and pulse shape discrimination capabilities. Experimental results will be compared to a modelling developed and optimized for the purpose and already validated on the basis of the extensive measurements campaign of commercial BEGe detectors of two different dimensions. The modelling consists on the numerical calculation of the internal electric field and simulation of shape of pulses generated as a consequence of energy deposition at different positions.
The results of the characterization measurements and the comparison with output of the modelling will be presented in the poster.

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## A new parametrization of Mass Varying Neutrinos applied in Supernovae

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In this work we present a new parametrization, which also includes the situation described in Cirelli et. al. model, of mass varying neutrino (MaVaN) model. Our formulation presents three phenomenological advantages: the first one is that the mass square difference, which depends on the neutrino density, can increase or decrease during the neutrino propagation in some environment; secondly we can control the position in the same environment where we will have a substantial modification in the mass square difference; and finally the value of the amplitude of this mass square difference can be modified. We apply this model to a supernova case, discussing the survival probabilities for $\nu_e \to \nu_s$ and $\bar{\nu}_e \to \bar{\nu}_s$, comparing it to constraints of SN1987A, such as P_{ee}<0.5 for electronic antineutrinos. Also we analyze it in the context of the r-process nucleosynthesis, expecting to see if the condition $Y_e < 0.5$ can put bounds on the neutrino oscillation parameters in the MaVaN context model.

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## Above Ground Antineutrino Detector for Reactor Safeguards

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LLNL and SNL have been exploiting the unique characteristics of reactor antineutrinos for nearly a decade in an effort to develop an independent means of monitoring fissile material diversion for reactor safeguard programs. Recently, we have constructed a less intrusive and mobile detector, which can be deployed at any nuclear reactor complex. It is designed to be operated above ground, utilizing a non-toxic, non-flammable water based detection medium.

We have outfitted a 20-ft shipping container with a 38 cm thick passive polyethylene shield surrounding 2.5 cm of borated polyethylene to reduce ambient neutron and gamma-ray backgrounds. The active detector volume consists of one tonne of de-ionized water doped with 0.2\% $GdCl_3$. Outside of the passive shielding is an active muon veto constructed of plastic scintillator which covers 5 sides of the cubic volume. Antineutrino detection utilizes the fast coincidence (30˜$\mu$s) of the Cherenkov light produced from the prompt positron emission, from inverse beta decay, and the subsequent neutron capture on Gd.

Here we will present data from the commissioning of the system, describing the performance of the shield, active veto and water detector. We will also discuss a planned deployment of the system at the San Onofre Nuclear Generating Station, scheduled for the second quarter of 2010.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. Release number LLNL-POST-426259.

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## Searching for CP and CPT Violation in a Short Baseline Experiment: The BooNE Proposal

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The accumulated results of short baseline experiments, which includes the latest MiniBooNE results, leave open possibility CP and/or CPT violating effects observable in a short baseline setting. When the MiniBooNE has finishes its anti-neutrino run at 500 meters, there could well be anomalies in both its neutrino and anti-neutrino data whose understanding will be limited only by the systematic error inherent in a single detector experiment. Those anomalies will only be resolved by running a similar detector at a different distance from the neutrino source. This paper describes the analysis of the BooNE proposal, which seeks to relocate the MiniBooNE detector at a distance of 100-200 meters from the Booster neutrino source. With a minimum of seven times the current MiniBooNE flux, data sufficient for a complete resolution of both neutrino and anti-neutrino anomalies can be accumulated in the near position within the first year of running.

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## Using Novel Micro-channel Plate Photomultipliers in the Next Generation Water Cherenkov Neutrino Detectors

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The next generation of neutrino experiments will require massive water Cherenkov detectors to reach
the sensitivity needed to measure CP violation in the lepton sector and the neutrino mass hierarchy. Recently
the Large Area Picosecond Collaboration has begun developing new methods to fabricate a 20cm-square
thin planar multichannel plate photo-multiplier tube (MCP-PMT) at a cost comparable to those of
traditional photo-multiplier tubes. The application of these novel devices to large water Cherenkov detectors
could significantly enhance background rejection and vertex resolution in these detectors by improving spatial and timing information. We present details of the MCP-PMT fabrication method, and preliminary
results from testing and characterization facilities at Argonne National Laboratory. Preliminary results will
also be presented on the reconstruction capabilities for neutrino events in Water Cherenkov detectors.

**143**

## Exploring nuclear effects in neutrino interactions with MINERvA

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Many neutrino oscillation experiments make use of high-Z detector material in order to maximize interaction rates. To correctly interpret the data, it is necessary to well understand nuclear effects in neutrino interactions that are absent for free-nucleon targets. Such knowledge is important not only for neutrino physics but for the nuclear physics as well.
MINERvA experiment located at Fermilab is designed to precisely measure the neutrino interaction cross-sections for channels that are of interest for current and future oscillation experiments. It will also examine the above-mentioned nuclear medium effects in neutrino-induced interactions such as final state modifications in the nuclei.
My poster will outline the nuclear targets to be employed in MINERvA. I will present the expected statistics samples for C, Fe, Pb as well as the cryogenic target for current and upcoming runs. I will also describe the design specifications for water module that was recently added to our list of proposed targets. Finally, I will outline what results we expect both in near and far term perspectives.

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## The Sanford Laboratory at Homestake and the Path to DUSEL

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The former Homestake gold mine in Lead, South Dakota is currently being transformed into a laboratory to pursue underground research in biology, geology, engineering and physics. Prior to the establishment of the federal facility, an interim early science program is being offered by the South Dakota Science and Technology Authority, which currently operates the Sanford Laboratory at Homestake. The early science program is well underway with research activities on many levels, including plans to host the LUX and Majorana physics experiments on the 1480-m (4850-ft) level. The status and opportunities at the Sanford Laborarory will be presented.

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## The MINERvA Low-energy Test Beam Experiment at Fermilab

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In order to make precision measurements of neutrino-nucleus interactions, the MINERvA experiment has to be able to reconstruct the kinematics of the interaction products with sufficient accuracy.

The MINERvA Test Beam (TB) experiment is designed to serve as a calibration for the calorimetric observables used in the analysis of interactions in MINERvA. A tertiary beamline has been especially designed for this experiment and will be part of the Fermilab Test Beam facility. It's aimed at providing identified charged particles (electrons, muons, pions and protons) with well-known momentum from around 300 MeV/c. We are in the final stages of commissioning this beamline.

We are also in the process of assembling and installing the TB detector, a replica of the MINERvA detector on a smaller scale. The TB detector configuration is flexible, allowing different sectors (tracker, electromagnetic calorimeter and hadronic calorimeter) of the main detector to be reproduced and studied with the goal of providing MINERvA with a precise calibration of the detector response.

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## Three-flavor collective oscillations of supernova neutrinos

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Coherent forward scattering of neutrinos off each other leads to complex collective neutrino oscillations inside a supernova. We explore this phenomenon during the cooling stage of the explosion. Two- and three-flavor calculations of the oscillations are shown to give strikingly different results, especially for the inverted mass hierarchy. Analysis shows that the 2-flavor evolution trajectory is unstable in the 3-flavor space. Additionally, the 3-flavor evolution is shown to be partially non-adiabatic, resulting in a "mixed" spectrum. Our results could impact the interpretation of the future galactic supernova signal, the analysis of the r-process nucleosynthesis, and the predictions of the diffuse supernova neutrino background.

**Summary**:

Based on 1001.0996 (submitted to PRL) + work in preparation

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## Neutrino-neutrino interactions in core-collapse supernovae

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In core-collapse supernovae, the neutrino density is high enough to render the nu-nu interactions not negligible. In particular, they can couple the flavor evolution of neutrinos and induce collective flavor changes. We discuss the most important feature observable in the energy spectra (the so called spectral split), both in the case of luminosity equipartition among flavors and for unconstrained luminosities. The spectral
split pattern is shown to depend strongly on the initial luminosity for each flavor and the neutrino mass hierarchy. Pure collective three-flavor effects are also analyzed.

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## Recent Nucleon Decay Results from Super-Kamiokande

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Recent experimental limits on the search for nucleon decay are presented. Data from Super-Kamiokande, a water Cherenkov detector with a fiducial volume of 22,500 tons of ultra pure water, are used in the analysis. Analyses of the proton decay modes p –> e+ pi0, p –> mu+ pi0, and other key modes are shown.

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## Status and new data of the geochemical determination pp-neutrino flux by LOREX

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M.K. Pavićević, G. Amthauer, I. Aničin , B. Boev, F. Bosch, W. Brüchle , Z. Djurčić T. Faestermann, W.F. Henning, R. Jelenković, S. Niedermann, V. Pejović, P. Vermeesch, A. Weiss

LOREX, the acronym of LORandite EXperiment, is the only long-time solar neutrino experiment still actively pursued. It addresses the long-time detection of the solar neutrino flux with the thallium-bearing mineral lorandite, TlAsS2 from the mine of Allchar, FYR Mazedonia, via the neutrino-capture reaction 205Tl + ν(e) ⟶ 205Pb + e(-). The final step of LOREX would be the extraction of lorandite samples and the quantitative determination of the ratio of 205Pb / 205Tl atoms, thus providing the product of solar neutrino flux and neutrino-capture cross section, integrated over the age of lorandite 4.31 · 10ˆ6 yr. The detector offers the low threshold of only 52 keV for solar pp-neutrinos, to be compared with the next lowest 232 keV in the GALLEX and SAGE experiments. Moreover, LOREX

would be unique in view of providing the mean luminosity of the sun over the last 4.3 million years. This paper presents new data on accurate geological age of the minerals at Allchar, and in particular the erosion rate in two with thallium enriched locations: ore body Crven Dol 33 –35 m/10ˆ6 y and Central Part of 66 - 67 m/10ˆ6 y. This determination based on Accelerator Mass Spectrometry (AMS) of three independent investigation of 10Be, 26Al and 53Mn and GMI i.e. Geo-morphologic investigation. Reliable erosion rate is indispensable for proper determination of the background of 205Pb induced by cosmic radiation. Provided that this erosion rate is corroborated by more measurements of additional probes, the experiment is expected to reach an acceptable signal-to-background ratio. Finally, it is discussed how to get the still unknown capture probability of solar pp-neutrinos from 205Tl into 205Pb, in particular into its first excited state at E* = 2.3 keV, as well as how to count the extremely small number of 205Pb atoms found within the few kilograms of the mineral, needed to attain the estimated accuracy low as 30% of the final result.

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# An analytical treatment of three neutrino oscillations in the Earth

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It is shown that the Magnus expansion for the evolution operator, when implemented in the adiabatic basis, provides a convenient formalism to find approximate solutions to the problem of three neutrino oscillations in a medium with an arbitrarily varying density. This method allows us to incorporate in a simple way the Earth matter effects on the transition probabilities for neutrinos with a wide interval of energies, making possible an accurate description of such effects in the case of solar and atmospheric neutrinos.

**151**

# The JEM-EUSO Mission to Explore the Extreme Universe

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The JEM-EUSO mission will explore the origin of the extreme energy comic-rays (EECRs) above 1020 eV and and can shed new light on some topics of fundamental physics. The instrument is design to observe more than 1,000 events of EECRs above 70 EeV in its five-year operation, with an exposure larger than 1 million km2 str yr. The super-wide-field (60 degrees) telescope with a diameter of about 2.5m looks down the atmosphere of the night-side of the earth to detect near UV photons (330-400nm, both fluorescent and Cherenkov photons) emitted from the giant air-shower produced by an EECR. At these energies cosmic rays have directional information and the arrival direction map, with 1,000 events, will allow the identification of point sources of EECR, in case they exist, and of their astronomical counterparts. The comparison among the energy spectra of the spatially resolved individual sources will clarify the acceleration/emission mechanism, and also finally confirm the Greisen-Zatsepin-Kuzmin process for the validation of Lorentz invariance up to γ˜1011. Neutral components (neutrinos and gamma rays) can also be detected as well, if their fluxes are high enough. The JEM-EUSO mission is planned to be launched by a H2B rocket about 2015 and transferred to ISS by H2 Transfer Vehicle (HTV). It will be attached to the external experiment platform of "KIBO,"which completed "July 2009 by STS-127 mission"of the space shuttle. The first flight of HTV by H2B rocket was successfully done in September and October 2009.

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## Development of electron neutrino showers at mid and high altitudes in the atmosphere

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JEM-EUSO is a mission intended to detect the fluorescence light produced by the secondary charge particles generated by ultra high energy cosmic rays interacting in the Earth atmosphere. It will be installed in the Japanese Experiment Module (JEM) of the International Space Station. The very large exposure of the telescope is ideal for the detection of high energy neutrinos. The information carried by the high energy neutrino component is of grate importance for the understanding of several processes related to ultra high energy cosmic ray physics. In particular, they are produced in photo-hadronic interactions in the acceleration sites, during propagation of the cosmic rays in the intergalactic medium and as a main product of the decay of super heavy relic particles. In this work we use a combination of the PYTHIA interaction code with the CONEX shower simulation package in order to produce fast one-dimensional simulations of electron neutrino initiated air showers. We study in detail the characteristics
of longitudinal profiles of these showers which, in regions of large air density are dominated by the LPM effect. We believe that these characteristics have grate importance for its identification.

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## Survival of three-fold quasi-degenerate neutrino mass model with CP odd parity

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Discrimination of three neutrino mass patterns, namely normal hierarchical, inverted hierarchical and three-fold quasi-degenerate models, in both experimental as well as theoretical fronts, is an outstanding issue in neutrino research. Three-fold quasi-degenerate Majorana neutrino mass models with CP-parity pattern (+-+) in the three mass eigenvalues (m1, -m2,m3, exhibits a strong variation of the absolute neutrino masses with the value of the solar mixing angle, within 2-3 symmetry framework of the mass matrices. This variation leads to the prediction of solar mixing angle lower than the tribimaximal(TBM)value corresponding to absolute neutrino mass in the range m=0.1eV. However for TBM value, the neutrino mass corresponds to m=0.4eV. Lower values of neutrino mass beyond TBM solar mixing, is in good agreement with neutrino oscillation data. In fact these are far from discrimination from the bounds on absolute neutrino masses derived from neutrinoless double beta decay as well as WMAP cosmology. However this property is absent in other two classes of three-fold quasi-degenerate models with CP-parity patterns (+++) and (++-) where the prediction of neutrino mass stands at m=0.4eV for a wide range os solar mixing angle starting from TBM value and below.

**Summary**:

The new parametrization of neutrino mass matrix having 2-3 symmetry with only two parameters in case of three-fold quasi-degenerate models,simplifies the numerical analysis for evaluation of eigenvalues and mixing angles. The identification of flavour twister term which is the ratio of these two parameters, enables us to lower the solar mixing angle beyond tribimaximal mixings. In the process the absolute value of neutrino mass is also lowered from 0.4eV to 0.1eV, and this makes the model far from discrimination from the bounds given by neutrinoless double beta decay experiment as well as cosmology. The present finding is new and has important implications for future experiments.

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# T2K : Electron Neutrino Analysis at the Near Detector (ND280)

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Starting with a νμ beam T2K will search for νe appearance in the Far Detector (Super-Kamiokande) and aims to produce the first measurement of the neutrino mixing angle θ13. Beam contamination of νe will be one of the main background components. The Near Detector, ND280, is optimized for measuring the νe contamination through the reconstruction of νe interactions. The reconstructing of electron neutrinos at Near Detector and the method to estimate the νe beam contamination at Super-Kamiokande will be reviewed.

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# Neutrino bursts from gravitational stellar collapses with LVD

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The main goal of the Large Volume Detector (LVD),in the INFN Gran Sasso National Laboratory (Italy), is the study of neutrino bursts from gravitational stellar collapses. Both the detector and

the data analysis procedure have been optimized for this purpose. The modularity of the apparatus allows to obtain a duty cycle that is very close to 100%, so that the experiment is continuosly monitoring the Galaxy. The analysis is performed online, with the selection of alarms for SNEWS, and offline. In both cases, LVD is able to disentagle a cluster of neutrino signals from the background, and its sensitivity extends to the whole Galaxy. In the lack of a positive detection the 90% c.l. limit to the rate of Supernova collapses in the Galaxy is discussed.

**157**

# Radon Removal from Liquid Xenon

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The XMASS liquid xenon detector in the Kamioka mine in Japan is probing for WIMP Dark Matter candidates. Its sensitivity will ultimately be limited by the background levels that can be achieved in the experiment. Radon is of particular concern, as trace quantities of it will continuously emanate from materials in and around the detector. We describe the techniques developed in Kamioka to maintain the quality of the xenon in the detector and present the pertinent test results.

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# Solar neutrinos with non standard interactions

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The solution to the problem of the flatness of the SuperKamiokande energy spectrum as observed by the data and which the LMA scenario fails to explain is investigated within the context of neutrino non standard interactions. We assume that these interactions come as extra contributions to the $\nu_\alpha \nu_\beta$ and $\nu_\alpha e$ vertices that affect both the propagation of neutrinos through solar matter and their detection. It is found that from the many possibilities of non standard couplings, only a limited number exist that lead to a flat spectrum with a good fit to the data while keeping other event rates unchanged with the exception of the Chlorine one whose prediction is improved with respect to the LMA one.

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# Overview and physics motivation of the XMASS experiment

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The XMASS experiment, proposed as a multi-purpose underground detector using liquid xenon, is now constructing an 800 kg xenon detector in the Kamioka mine in Japan. The detector is designed especially to search for WIMP dark matter candidates. The main feature of the detector to reduce gamma ray backgrounds is the self-shielding effect of liquid xenon. In addition, the detector is located in a water tank to reduce incoming neutron backgrounds. The background event rate is expected to be as low as 1e-4 count/day/kg/keVee. The characteristics of the experiment and the sensitivity to WIMP dark matter are presented.

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## Topological phase in two flavor neutrino oscillations and imprint of the CP phase

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We show that the phase appearing in neutrino flavor oscillation formulae has a geometric and topological contribution. We identify a topological phase appearing in the two flavor neutrino oscillation formula using Pancharatnam's prescription of quantum collapses between nonorthogonal states. Such quantum collapses appear naturally in the expression for appearance and survival probabilities of neutrinos. Our analysis applies to neutrinos propagating in vacuum or through matter. For the minimal case of two flavors with CP conservation, our study shows for the first time that there is a geometric interpretation of the neutrino oscillation formulae for the detection probability of neutrino species. We also show that there is a non-trivial geometrical aspect associated with matter induced extrinsic CP violating phases when neutrinos propagate adiabatically through varying density matter. This distinction between the two cases can lead to visible consequences at the level of probability.

**163**

## The construction and performance of XMASS detector

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The XMASS 800kg liquid xenon detector is under construction in the Kamioka mine in Japan. Designed as a multi-purpose underground detector, its physics reaches include dark matter, solar neutrino and neutrinoless double beta decay, etc. The current detector is optimized for the search of WIMP dark matter candidates. The background event rate is expected to be as low as 1e-4 count/day/kg/keVee. The construction of the PMT array, xenon and water circulation system, electronics, etc. is reviewed, and the performance of PMTs, xenon circulation and purification system and the DAQ system is summarized in order to show how the designed background level is approached.

**164**

## LENA - Low Energy Neutrino Astronomy

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We propose LENA (Low Energy Neutrino Astronomy), a large ˜50kt liquid scintillator neutrino detector for particle-astrophysics, located in a deep underground laboratory. Main scientific goals of LENA are: the search for proton decay, thus probing grand unified theories; the measurement of the diffuse Supernova neutrino background; the precise determination of thermo-nuclear fusion processes by measuring solar neutrinos with high statistics; a measurement of geo-neutrinos probing Earth's models; in case of an actual galactic Supernova type II an accurate measurement of the time development and flavour content of the emitted neutrino burst. Furthermore we propose the use of LENA as a detector for a long baseline neutrino oscillation experiment. A high sensitivity on the mixing angle Theta-13 can be achieved [5]. The physics potential of LENA was determined in several Monte-Carlo studies [1,2,3] and several feasibility studies for different liquid scintillator candidates were performed recently [4]. An actual overview of the physics program and technological developments can be found in [4] as well. A possible location for LENA is currently investigated within the European LAGUNA design study.

Literature:

[1] T. Marrodan Undagoitia et al., "Search for the Proton Decay p -> K⊠⊠⊠ in the large liquid scintillator low energy astronomy detector LENA", Physics Review D 72, (2005), 075014

[2] M. Wurm et al., "Detection potential for the diffuse supernova background with the large liquid scintillator detector LENA", Phys. Rev. D75 (2007), 023007

[3] K. Hochmuth et al., "Probing the Earth's interior with the LENA detector", hep-ph/0610048

[4] T. Marrodan-Undagoitia et al., "LENA: A multi purpose detector for low energy neutrino astronomy and proton decay", J. Phys. Conf. Ser 120 (2008) 052018

[5] J. Peltoniemi, arXiv:0911.4876

**Summary**:

LENA:
- Search for proton decay
- DSNB neutrino measurement
- Supernovaburst neutrinos
- Solar neutrinos
- Geo-neutrinos
- Long baseline neutrino oscillations

**165**

## SuperNEMO - the next generation double beta decay experiment

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The SuperNEMO experiment is being designed to search for neutrinoless double beta decay to test if neutrinos are Majorana particles. The unique experimental technique follows that of the currently running NEMO-3 experiment, which successfully combines tracking and calorimetry to measure the topology and energy of the final state electrons. SuperNEMO will employ about 100kg of 82Se to

reach sensitivity to a half-life time of about 2*10^26 years, which corresponds to Majorana neutrino masses of about 50 meV, and depends on the calculated value of the nuclear matrix element. The construction of the demonstrator module with 5kg of 82Se is about to begin and, if successful, will be followed by 19 more of similar modules. We will present the current status of the SuperNEMO project including results of the R&D phase of the project.

**Summary**:

We will show details of the R&D results on calorimetry, tracking, and natural radioactivity studies.

**166**

## Search for neutrinoless double beta decay with NEMO-3

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The NEMO-3 experiment located in the Modane Underground Laboratory is searching for neutrinoless double beta decay. The experiment has been taking data since 2003 with seven isotopes. The main isotopes are 7kg of 100Mo and 1kg of 82Se. New results using 150Nd, an isotope of special interest due to its potential use in future experiments, as well as 96Zr and 116Cd will also be presented. No evidence for neutrinoless double beta decay has been found to date. The data are also interpreted in terms of alternative models, such as weak right-handed currents or Majoron emission. We will show results for the standard model double beta decay process for all seven isotopes employed in NEMO-3. These measurements are important for reducing the uncertainties on nuclear matrix elements.

**Summary**:

We will describe results not covered in the plenary talk.

**167**

## Search for Neutrinoless Double Beta Decay with CUORE

**Author:** Karsten Heeger[1]

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The search for neutrinoless double beta decay ($0\nu\beta\beta$) is the only experimental technique to probe the Majorana mass of neutrinos. Observation of $0\nu\beta\beta$ would show that neutrinos are their own antiparticles and imply lepton number violation. The Cryogenic Underground Observatory for Rare Events (CUORE) is under construction at Gran Sasso National Laboratories. It will use 988 TeO2 crystals with a total mass of 750kg operated as bolometric detectors at 10mK to search for neutrinoless double decay in 130Te and other rare events. We will present the status of CUORE as well its principal technical challenges including the cryogenics, background reduction, and calibration of the experiment. The expected sensitivity and physics potential of the experiment will be discussed.

**168**

## Search for solar neutrino radiative decays during total solar eclipses

**Authors:** Laura Patrizii[1]; Stefano Cecchini[2]

**Co-authors:** Giorgio Giacomelli [3]; Miriam Giorgini [1]; Vlad Popa [4]

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[3] *Department of Physics - Bologna, Italy*

[4] *Institutul de Stiinte Spatiale, Bucharest, Romania*

Total solar eclipses (TSEs) offer a good opportunity to look for photons produced in hypothetical radiative decays of solar neutrinos. The physics bases of such searches are briefly reviewed and the results of the analysis of data collected during the 2006 TSE from Waw an Namos, Libya are presented.

**169**

## The muon neutrino and anti-neutrino disappearance measurement with the Long-Baseline Neutrino Experiment (LBNE)

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The Long-Baseline Neutrino Experiment (LBNE) has been proposed with intense muon neutrino and anti-neutrino beams produced at Fermilab, a near detector complex, and a large far detector built in the Homestake Mine in South Dakota. The primary measurements, studies of the neutrino mass hierarchy and searches for leptonic CP non-conservation, utilize electron neutrino appearance. Muon neutrino and anti-neutrino disappearance will also be studied in great detail. In addition to enhancing the sensitivity of the primary measurements, they will produce additional sensitive measurements of parameters of the neutrino mixing matrix. This poster will detail potential results as well as the requirements these results place on the near detector complex.

**Summary**:

C. Mauger for the LBNE collaboration.

**170**

## The Mysteries of Neutrino Masses: Theory & Phenomenology

**Author:** Alexander Merle[1]

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We present the aspects of different models that attempt to successfully explain the patterns in the leptonic sector, as well as their impact on future experiments (and vice versa). Strong constraints often arise from lepton flavour violating processes, but depending on the model, these bounds could be relatively weak. Further information can be gained from neutrino exeriments, but their interpretation may not always be straightforward. Dealing carefully with all information is the key requirement to identify a possible successor of the Standard Model of Elementary Particle Physics.

**171**

## OPERA Electronic Detectors

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OPERA is an hybrid detector for the tau-neutrino appearance search in a direct way, and the Electronic Detectors (ED) have the crucial role of triggering for the neutrino events, localizing such an interaction inside the target and providing complementary kinematical information to the events. Other important task of the ED is to identify the muon since only a correct matching of such a track with a track in the emulsion connected to the vertex of the event allows to reduce the charm background to the desired level.
The ED, fully working since 2006, consist of a target tracker (scintillator strips) and a spectrometer (RPC and drift tubes). The different sub-detectors are described in the poster, as well as their performance and the physics results for the 2006-2009 data collection.

**172**

## The Emulsion Scanning System of the OPERA experiment

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The target of the OPERA detector has a modular structure. The target unit, the so-called brick, is designed according to the Emulsion Cloud Chamber (ECC) technique and it is made of lead plates acting as the neutrino target interleaved with nuclear emulsion films acting as trackers with micrometric accuracy. Bricks are placed in walls alternated with planes of scintillators providing, together with the instrumented magnetic spectrometers, the online reconstruction of the neutrino interactions and predicting the brick where the neutrino interaction presumably occurred. Doublets of emulsion films named Changeable Sheets (CS) are attached immediately downstream of each brick. They act as interface films between the brick and the electronic detectors, being a detector with a high signal to noise ratio. Their analysis with fully automated microscopes provides the brick tagging for vertex finding. In case the electronic prediction of the brick is not confirmed by the CS analysis, adjacent bricks are extracted and their CS analyzed until the brick location is confirmed. Tagged bricks are then processed and analyzed with fully automated microscopes until the neutrino vertex is found. After the vertex finding, a volume of about 2 cm3 is analyzed all around the vertex in order to confirm the primary vertex and search for decays of short living particles. In this poster we report all the analysis chain of nuclear emulsions, from the CS analysis for the brick tagging to the track follow-up in the bricks and to the search for secondary decays. We provide an estimate of the efficiencies of the different analysis steps.

**173**

## Measurement of the cosmic ray muon charge ratio with the OPERA Detector

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The OPERA detector at the Gran Sasso underground laboratory (LNGS) was used to measure the cosmic ray muon charge ratio Rμ = Nμ+/Nμ− in the TeV energy region. We updated the muon cosmic ray analysis including data of 2008 and 2009 physics runs. We computed separately the muon charge ratio for single and for multiple muon events in order to select different energy regions of the primary cosmic ray spectrum and to test the Rμ dependence on the primary composition. Rμ is also shown as a function of the "vertical surface energy"Eμ cos(theta). A fit to a simplified model of muon production in atmosphere allowed the determination of the pion and kaon charge ratios weighted by the cosmic ray energy spectrum.

**174**

## Search for Burst and Relic Supernova Neutrinos in DUSEL: Research on Gd loaded water Cerenkov detector

**Author:** Serge Ouedraogo[1]

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The observation of neutrinos emerging from a core collapse supernova will enhance our understanding of star formation, and possibly quark matter and black hole formation. To detect relic supernovae neutrinos, the Long Baseline Neutrino Experiment (LBNE) proposed a Gadolinium-doped 300 kton water Cerenkov detector that will be placed at the depth of 1480 m at the Deep Underground Science and Engineering Laboratory (DUSEL) in South Dakota, USA. This poster gives an overview of the detection mechanism of supernovae neutrino and the possibility for LBNE to detect relic neutrinos from a core collapse at the center of the Milky Way galaxy, 8.5 kpc away.

**175**

## Electron neutrino detection capabilities of the LBNE near detectors

**Author:** Robert Bradford[1]

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While the Long Baseline Neutrino Experiment (LBNE) may be noted for its proposed massive far detectors and intense beamline, the near detector complex is just as critical to the success of the experiment. The near detectors help measure the beam flux, sample

the initial flavor content of the beam, and characterize poorly measured background processes. Measurement of the electron neutrino content of the beam by the near detectors will constrain a critical background to studies of nu-e appearance. This poster will discuss the requirements
for nu-e measurements, and how this criteria will influence the design of the near detectors.

**177**

## A small Air Shower Particle Detector Array dedicated to UHE neutrinos

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**Co-authors:** Eric Lagorio [1]; François Montanet [1]; Joel Chauvin [1]; Patrick Stassi [1]

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We have developped a self powered stand-alone particle detector array dedicated to the observation of horizontal tau air showers induced by high energy neutrinos interacting in mountain rock. Air shower particle detection reach a 100% duty cycle and is free of background when compared to Cerenkov light or radio techniques, then better suited for rare neutrino event search. A specific topoligical mountain to valley configuration was found and the first array is under deployment on an inclined slope at an altitude of 1500 m facing at south to alps mountain near the city of Grenoble (France).A full simulation has been performed. A detailed cartography and elevation map allowed to extract a neutrino energy dependent mountain tomography chart. Together with a decaying tau air shower simulation the array acceptance was evaluated between 100 TeV and 100 EeV; The effective surface is determined from the shower lateral extension at array location, then much greater than the physical array surface.The single array exposure will be 1014 cm2.sr.y at 100 PeV.
The array is made with only five detectors and all the embedded electronics,HV supply and communication system are powered locally via a 2m2 solar power station.
Several independant arrays can be deployed on the same site, and some other sites are already under study. At last, special care is dedicated to the pedagogical and outreach aspects of such a cosmic ray detector .

**178**

## Improved Scintillators Materials for Compact Electron Antineutrino Detectors *

**Author:** Peter Dijkstra[1]

**Co-authors:** Heinrich Wörtche [1]; Wesley Browne [2]

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Developments in the fields of chemistry and material science provide new components which could improve the performance of liquid scintillation antineutrino detectors e.g. used for the monitoring of nuclear reactors. These compounds can ensure more efficient, stable, and safer operation of these detectors.

Current detectors have issues regarding size, toxicity, flammability, quantum efficiency, stability, and spatial resolution for the vertex detection. For compact detectors (x 100 L active volume) Improvement of these issues with existing liquid scintillation cocktails can be obtained by means of

developing stable and efficient neutron capture agents comprising of boron or lithium containing coordination compounds, improvement of dopant and optimising solvent characteristics. Focus points of the new detector material design are compact, robust, direction sensitivity and low quenching factor.

- Supported by The Northern Netherlands Provinces (SNN). This project is co-financed by the European Union, European Fund for Regional Development and The Ministry of Economic Affairs, Peaks in the Delta.

**Summary**:

Innovative use of chemical compounds is expected to ensure improvement of compact antineutrino detectors efficiencies.

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## A-DEPENDENCE DIFFRACTION DISSOCIATION (DD) PHENOMENA AFTER NEUTRINO INTERACTION WITH NUCLEI

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A-DEPENDENCE DIFFRACTION DISSOCIATION (DD) PHENOMENA AFTER NEUTRINO INTERACTION WITH NUCLEI

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We present a calculation of A-dependence DD phenomena after neutrino interaction with nuclei, usin

1. N.N. Nikolaev and B.G. Zakharov // Z. Phys. C. 1991. V. 49. P. 607.
2. N.N. Nikolaev and B.G. Zakharov // Z. Phys. C. 1992. V. 53. P. 331.
3. N.N. Nikolaev, B.G. Zakharov and V.R. Zoller // Z. Phys. A. 1995. V. 351. P. 435.
4. C. Adloff, S. Aid, M. Anderson et al. // Preprint # 97-009 (DESY, Hamburg, 1997).
5. J. Breitweg, M. Derrick, D. Krakauer et al. //Phys. Lett. B. 1998. V. 421. P. 368.
6. M.R. Adams, S. Aid, P.L. Anthoni et al. // FERMILAB-Pub-95/396-E
7. О.К. Егоров // ЯФ. 2002. Т. 65. С. 881.
8. О.К. Егоров, В.А. Рябов // ЯФ. 2004. Т. 67. С. 2190.

**Summary**:

We saw, that our experimental results for Ag and Br niclei for $\sigma$DD/$\sigma$DIP close to
NZZ model prediction.

**180**

## Status of MICE, the international muon ionization cooling experiment

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Muon ionization cooling provides the only practical solution to prepare high brilliance beams necessary for a neutrino factory or muon colliders. The muon ionization cooling experiment (MICE) is under development at the Rutherford Appleton Laboratory (UK). It comprises a dedicated beam line to generate a range of input emittance and momentum, with time-of-flight and Cherenkov detectors to ensure a pure muon beam. A first measurement of emittance is performed in the upstream magnetic spectrometer with a scintillating fiber tracker. A cooling cell will then follow, alternating energy loss in liquid hydrogen and RF acceleration. A second spectrometer identical to the first one and a particle identification system provide a measurement of the outgoing emittance.
In June 2010 it is expected that the beam and all detectors will be commissioned and the time of the first measurement of input beam emittance closely approaching.
The plan of steps of measurements of emittance and cooling, that will follow in the rest of 2010 and later, will be reported.

**181**

## The first of six steps of the MICE program: beam line and first measurement of beam emittance.

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The primary aim of the MICE beam line is to provide ˜500 muons in a one millisecond long pulse at a rate of about 1Hz for measurements of cooling on a muon-by-muon basis. The beam is obtained by dipping a target in the 800MeV/c ISIS rapid cycling synchrotron at Rutherford Appleton Laboratory (UK). It has been commissioned in 2008-2009 and now routinely produces beams of protons, pions, muons and electrons in the energy range of 100-450 MeV/c which will be also available for neutrino detector developments. Particle identification is provided with two Cherenkov detectors, three time-of-flight hodoscopes with time resolution of <60 ps and and a lead-fiber electron pre-shower.
Particle production rates have been measured. First low intensity muon beams, of the purity requested for the study of ionization cooling, have been generated. A first rough measurement of its emittance was also performed, anticipating the precise measurement with the magnetic trackers in the subsequent steps.

**182**

## MICE: its program of ionization cooling measurements in the subsequent steps

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The international Muon Ionization Cooling Experiment (MICE) collaboration has undertaken the construction of a complete unit cell of a muon ionization cooling channel for test in a muon beam at RAL. The main cooling devices are three 35 cm long liquid hydrogen tanks interspaced with two RF half cells each comprising four 200 MHz RF cavities to be operated at 8MV/m, that can be cooled to liquid Nitrogen temperature. The whole is embedded in a series of solenoid magnets providing the optics. The experiment will be executed in steps. Measurements can also be performed on solid absorbers, including wedge-like absorbers allowing study of 6D cooling by exchange between transverse and longitudinal emittance. The set of cooling experiments to be performed and the progress on the construction of the cooling elements is described.

**183**

## Particle production cross-sections by 30 GeV protons on Carbon at the NA61/SHINE experiment

**Author:** Tomasz Jan Palczewski[1]

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This poster presents preliminary results from a fixed target experiment NA61/SHINE (SHINE = SPS Heavy Ion Neutrino Experiment). The NA61 experiment is a continuation of NA49 at CERN SPS which was designed to measure hadron yields from a large range of beam and targets. NA61 detector is a hadron spectrometer which consists of system of Time Projection Chambers (TPCs), Time of Flight detectors (TOF) and Projectile Spectator Detectors (PSD). NA61 has excellent capabilities for momentum,charge and mass measurements. This poster presents performance of the NA61 detector. A long term physics goal of NA61/SHINE experiment is to search for the critical point of strongly interacting matter and study in details the onset of deconfinement [1,2]. The second important goal is to study hadron production needed for neutrino (T2K) and cosmic-ray (Pierre Auger and KASKADE) experiments. This poster is focused on the second subject, it presents measurement of hadron production cross sections from proton-Carbon interactions at 31GeV/c for the T2K experiment at J-PARC [3,4]. For the improvement of the neutrino simulations it is important to have a better knowledge of the pion and kaon production. Three different methods of the pion spectra extractions used in the NA61 experiment are discussed. Finally, preliminary dsigma/dp distributions in several intervals of emission angles of charged pion in p+C interactions at 31GeV/c are shown. The general trend of the distributions is similar to that generated using some recently developed Monte Carlo models.
[1] N.Antoniou et al. [NA49-Collaboration], CERN SPSC-2006-034, (2006).
[2] N.Antoniou et al. [NA61/SHINE Collaboration], CERN SPSC-2007-019, (2007).
[3] T2K Collaboration (Y. Hayato for the collaboration), Nucl.Phys.Proc.Suppl.143:
269-276,2005.
[4] T2K Collaboration (D. Karlen for the collaboration), Nucl.Phys.Proc.Suppl.159:
91-96,2006.

**184**

## CP VIOLATION IN NEUTRINO OSCILLATIONS FROM EC/Beta+ DECAYING ION BEAMS

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The next generation of long baseline neutrino oscillation experiments will aim at determining the unknown mixing angle theta(13), the type of neutrino mass hierarchy and CP-violation. We discuss the separation of these properties by means of the energy dependence of the oscillation probability and we consider an hybrid setup which combines the electron capture and the beta+ decay from the same radioactive proton-rich ion with the same boost. We study the sensitivity to the mixing angle and the CP-phase, the CP discovery potential and the reach to determine the type of neutrino mass hierarchy. The analysis is performed for different boosts and baselines. We conclude that the combination of the two decay channels, with different neutrino energies, achieves remarkable results.

**185**

## The Case for a Large Scale Underwater Neutrino Telescope

**Author:** Petros Rapidis[1]

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(For the KM3NeT collaboration)
The KM3NeT consortium has completed a Technical Design Report (TDR) for a proposed multi-cubic-kilometer sized underwater neutrino telescope that will be deployed in the Mediterranean Sea. Highlights of the contents of the TDR will be presented in three poster presentations. In this first of three presentations we will focus on the physics case for the KM3NeT.
The physics reach of a large scale underwater neutrino telescope in the Mediterranean (the KM3NeT) will be described. The proposed device will be able to detect neutrinos interacting in the nearby sea water or the underlying sea floor that have energies above 100 GeV. We have performed extensive MC simulations of its behavior to determine its sensitivity to various neutrino sources. The sensitivity to galactic or extragalactic point sources of neutrinos, to neutrinos associated with GRBs, and to any diffuse flux of cosmic neutrinos will be shown and compared to the reach of the currently operating IceCube telescope. In addition the capability of the KM3NeT for detecting dark matter candidate particles (WIMPs, neutralinos, ···) through their annihilation into neutrinos will also be shown.

**186**

## Towards a Design for a Large Scale Underwater Neutrino Telescope, Test Deployments, and the Site Studies

**Author:** Petros Rapidis[1]

[1] *National Center for Scientific Research "Demokritos" (NRCPS)*

(For the KM3NeT collaboration)
The KM3NeT consortium has completed a Technical Design Report (TDR) for a proposed multi-cubic-kilometer sized underwater neutrino telescope that will be deployed in the Mediterranean Sea. Highlights of the contents of the TDR will be presented in three poster presentations. In this second of three presentations we will focus on the proposed design options for such a device, and also discuss some recent test deployments and studies at the possible sites.

A large underwater neutrino telescope is in essence a three dimensional lattice of light detecting devices (optical modules –OMs) deployed in the deep sea. The OMs register the Cherenkov light produced by the passage of charged secondaries (primarily muons) from neutrino interactions. The time and amplitude of the detected light pulses are used to reconstruct the muon trajectories and from these infer the neutrino directions. At this time, two alternative designs for the OMs and their arrangement are being considered: a multi-PMT OM option with many smaller pmts housed in a glass sphere and deployed as a single vertical string structures, and an alternative where the OMs are deployed in clusters with some lateral extent. Besides the two designs, recent deployment of test structures in the Ionian Sea will be described. The proposed sites (near the Peloponnese, Sicily, and Toulon) have been the subject of significant oceanographic studies to determine the relevant sea water and sea environmental parameters for the neutrino telescope.

**187**

## The Detection Units of KM3NeT (Optical Modules) and Readout Schemes

**Author:** Petros Rapidis[1]

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(For the KM3NeT collaboration)
The KM3NeT consortium has completed a Technical Design Report (TDR) for a proposed multi-cubic-kilometer sized underwater neutrino telescope that will be deployed in the Mediterranean Sea. Highlights of the contents of the TDR will be presented in three poster presentations. In this first of three presentations we will focus on the details of the construction of the optical modules of the telescope and the proposed readout schemes.
The basic unit of an underwater neutrino telescope is the Optical Module (OM), a pyrex glass sphere capable of withstanding the great pressure of the deep sea (3 to 4.5 km water depth) where the telescope will be deployed. The glass spheres house photomultipliers, either a single large PMT or many smaller ones, which register the Cherenkov light arising from the secondaries of neutrino interactions. The options for OMs under consideration will be described as well as the front-end electronics that will be located in the deep sea as well. The preferred proposed read-out schemes, a fully optical fiber based readout scheme where all the data gets transferred to shore, will be discussed as well as the overall data acquisition and control scheme of the detector.

**188**

## Measurement of the NuMI Neutrino Flux Using the Accompanying Muon Beam

**Author:** Laura Loiacono[1]

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To further our understanding of neutrino interactions, it is desirable to measure
absolute cross sections on nucleon and nuclear targets. Many past neutrino experiments have measured relative cross sections due to a lack of precise measurements of the incident neutrino flux, normalizing to better established reaction processes, such as quasielastic neutrino-nucleon scattering. Absolute neutrino cross sections, in contrast, are determined via $\sigma(\nu) = N(\nu)/\varphi(\nu)$, where the numerator is the measured number of neutrino interactions in a neutrino detector and the denominator is the flux of incident neutrinos, measured independently. The NuMI beam line has 3 muon monitors which can be used to, indirectly, measure the neutrino flux. The muon flux is related to the neutrino flux because one muon is produced for every muon neutrino in $\pi \text{−>} \mu\nu(\mu)$ and $K\pm \text{−>} \mu\nu(\mu)$ decays. We measure the neutrino flux generated by the NuMI beam line by measuring the daughter muon flux produced in pion and kaon decays. This is an in-situ flux measurement and is completely independent of the observed neutrino interaction rate in a neutrino detector.

The muon monitoring system consists of 3 arrays of 81 helium filled ionization chambers located approximately 720m downstream of the target. Muons must have a minimum energy of sim4, 10 and 20 GeV to penetrate muon monitor 1, 2 and, 3, respectively, providing sensitivity to the neutrino flux above E(ν) = 1.6 GeV. Furthermore, the kinematic distributions of mesons producing neutrinos can be studied by moving the meson production target longitudinally and by varying the current through the focusing horns. These studies provide a mechanism to measure of the muon spectrum which is directly related to the parent pion and kaon flux off of the NuMI target and, in turn, the neutrino flux. The two current experiments utilizing the NuMI beam, MINOS and MINERA, can use this independently determined flux to measure neutrino cross-sections via σ(ν) = N(ν)/φ(ν), where the numerator is the number of neutrino events seen in the MINOS Near Detector and MINERA Detector. We will present the measurement of the NuMI neutrino flux obtained from the muon monitoring system.

**189**

## Laser Raman Spectroscopy for KATRIN

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The aim of the Karlsruhe Tritium Neutrino experiment - KATRIN - is the direct (model-independent) measurement of the mass of the electron anti-neutrino. For that purpose a windowless gaseous tritium source - WGTS - is used, with a tritium throughput of 40g/day. In order to reach the design sensitivity of 0.2 eV/c^2 (90% C.L.) the key parameters of the tritium source, i.e. the gas inlet rate and the gas composition, have to be stabilized and monitored at the 0.2 % level (2σ).
Any small change of the tritium gas composition will manifest itself in non-negligible effects on the KATRIN measurements; therefore, precise methods to specifically monitor the gas composition have to be implemented. Laser Raman Spectroscopy is the method of choice for the monitoring of the gas composition because it is a non-invasive and fast in-line measurement technique.
An overview of the hardware setup and the current status of the system will be given and the implications on KATRIN will be discussed. This work has been partially supported by funds of the DFG (SFB/Transregio 27 "Neutrinos and Beyond").

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## MC Simulations of the dector response to low energy electrons for KATRIN

**Author:** Pascal Renschler[1]

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The Karlsruhe Tritium Neutrino experiment (KATRIN) derives the mass of the electron anti-neutrino with a sensitivity of 0.2 eV/c2 (90% C.L.) in a model-independent way from the measured energy spectrum of tritium β-decay electrons. The energy resolution of ΔE = 0:93 eV for the electrons with energy 0 < E < 18.6keV is provided by a large MAC-E spectrometer which acts as a highpass flter. The focal plane detector (FPD) is a large silicon PIN diode detecting the electrons transmitted by the spectrometer.
A full Monte Carlo simulation was developed to simulate the detector response of silicon to low-energy electrons taking into account elastic (relativistic partial wave expansion) and inelastic scattering (full dielectric formalism), ionization, the Auger cascade and surface barrier effects. In the resulting energy spectra, dead layer, backscattering and bulk plasmon effects can be observed. In the future the simulation can also be adapted for e.g. germanium or aluminum.
An overview of the simulation and good agreement with experimental data will be presented. This work has been partially supported by funds of the DFG (SFB / Transregio 27 "Neutrinos and Beyond").

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## Improvements in the Statistical Sensitivity of the MINOS Muon-Neutrino Disappearance Measurement

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The recent MINOS measurement of disappearance studies the survival of muon-neutrino charged-current interactions at the MINOS Far Detector so as to identify the neutrino flavor and total energy in the detector. Our newest results include new samples to increase the statistical sensitivity of the measurement. These include including charged-current events originating in the upstream rock surrounding MINOS, events outside the fiducial volume near the edges of the detector, and events with a non-negative muon curvature; such non-negative curvature events can arise from muon-neutrino charged-current in which the curvature is improperly measured or from charged-current interactions of antineutrinos. Each sample is considered separately. Additionally, we have implemented a new event classification algorithm which separates charged-current from neutral current interactions in the detector, making it more efficient to identify very low-energy events below oscillation maximum. We further increase our sensitivity to the oscillation parameters by using a Feldman-Cousins style analysis over the previous nuisance parameter fit for oscillations. This poster will discuss each of these analysis improvements and their impact on the 7e20 protons-on-target analysis, which doubles the data accumulated for the 2008 MINOS analysis.

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## Status of the EXO-200 experiment

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[2] *SLAC*

[3] *University of Massachussets*

A 200-kg low-background liquid Xe double beta decay detector (EXO-200) has been installed underground at the WIPP facility outside Carlsbad, NM. In addition to serving as a prototype for research and development toward a ton-scale experiment, EXO-200 is expected to provide the first measurement of the two-neutrino decay mode of 136Xe, as well as place competitive limits on the possible neutrinoless mode. All system components outside the time-projection chamber (TPC) itself were

tested in a cryogenic commissioning run last fall. The TPC was installed earlier this year, and detector electronics are now undergoing initial testing. This summer will see the liquid Xe TPC fill, final electronics commissioning, and detector calibration. An instrumentation run with natural Xe is planned before data-taking with enriched Xe.

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## Development of a Barium Tagging System for Enriched Xenon Observatory (EXO)

**Authors:** Kevin O'Sullivan[1]; Liang Yang[2]; Michelle Dolinski[1]; Tim Daniels[3]

**Co-author:** EXO collaboration

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The next generation double beta decay experiments aim to probe the
Majorana neutrino mass at or below 10 meV. To reach this sensitivity the detectors need to be ton or multi-ton scale and their radioactive backgrounds of the detectors also need to be further reduced. The Enriched Xenon Observatory (EXO) collaboration is developing a strategy for positively identifying the Ba-136 daughter nucleus of teh double beta decay of Xe-136 using laser spectroscopy methods. A highly efficient barium identification could virtually eliminate radioactive backgrounds thus dramatically improving the sensitivity to neutrinoless double beta decay. In one scheme, the barium ion will be extracted out of liquid xenon and identified, after release, in an ion trap.
Other schemes such as direct detection in liquid or ion extraction from a high pressure gas detector are also under investigation. In this poster, progress of these R&D efforts will be presented.

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## Directional Detection for Dark Matter and Neutrino Physics

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The Dark Matter Time Projection Chamber (DMTPC) collaboration has developed a direction-sensitive detector for tracking low-energy nuclear recoils. A large-scale version of this type of detector has great potential to make a definitive detection of dark matter, as well as interesting possibilities for solar-, geo-, and supernova-neutrino detection.

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## The MicroBooNE experiment

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The MicroBooNE experiment at Fermilab will use a 170-ton, liquid-argon, time-projection chamber at the Fermilab 1-GeV Booster neutrino beam to investigate the MiniBooNE low-energy anomaly: an excess of events in a search for electron-neutrino appearance in a muon-neutrino beam, which is not consistent with neutrino oscillations. MicroBooNE can distinguish between electrons and photons converting to electron-positron pairs and therefore can explore the nature of those events. In addition, MicroBooNE will make important contributions to the knowledge of neutrino cross sections at low energy transfer; these are needed for a better understanding
of the structure of the nucleon and have implications for certain searches for dark matter. Finally, as detector-technology development it constitutes an important step in the development of very large, liquid-argon detectors for the Long-Baseline Neutrino Experiment.

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## Tools and Methods for Underwater, High Energy Neutrino Telescopy

**Authors:** Antonis Leisos[1]; Apostolos Tsirigotis[1]; George Bourlis[1]; Spyros Tzamarias[1]

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We report on the structure and the performance of the HOU Reconstruction & Simulation (HOURS) software package, concerning: a) the detailed description of very large volume neutrino telescopes, including all the relevant physical and detection processes, b) signal processing techniques for timing and charge estimation of the PMT waveforms and c) the accurate reconstruction (direction and energy estimation) of high energy muons from neutrino interactions. We also report results on the optimization of various telescope configurations and on their capability in detecting/discovering galactic and extragalactic high energy neutrino sources, as well as measuring diffuse neutrino fluxes. Furthermore, we describe and evaluate the sensitivity of calibration strategies, based on the synchronous detection of Extensive Air Showers by floating EAS arrays and the underwater detector, in investigating systematical and statistical uncertainties of the neutrino telescope. Several of the results described in this report have been use for the KM3NeT Design Study.

**Openning Session (Chairs: E. Fiorini, H. Pietschmann) / 197**

## Welcome

**Corresponding Author:** tzanakos@phys.uoa.gr

**Openning Session (Chairs: E. Fiorini, H. Pietschmann) / 198**

## The Tabletop Measurement of the Helicity of the Neutrino

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**Openning Session (Chairs: E. Fiorini, H. Pietschmann) / 199**

## Neutrino Physics today, important issues and the future

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**Neutrino Mixing and Oscillations I (Chairs: S. Petkov, H. Sobel) / 200**

## Understanding and Testing Neutrino Mixing

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**Neutrino Mixing and Oscillations I (Chairs: S. Petkov, H. Sobel) / 201**

## Results from MINOS

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## Results from MINOS

**Neutrino Mixing and Oscillations I (Chairs: S. Petkov, H. Sobel) / 203**

## OPERA

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**Neutrino Beams and Sources I (Chairs: P. Dorman, N. Schmitz) / 204**

## Determining Reactor Neutrino Flux

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**Neutrino Beams and Sources I (Chairs: P. Dorman, N. Schmitz) / 205**

## Hadron Spectra Measurements (Review Talk)

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**Neutrino Beams and Sources I (Chairs: P. Dorman, N. Schmitz) / 206**

## Determining the Neutrino Flux from Accelerator Neutrino Beams

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**Neutrino Beams and Sources I (Chairs: P. Dorman, N. Schmitz) / 207**

## Techniques to Determine the Neutrino Flux in Wide Band Beam Experiments

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**Neutrino Mixing and Oscillations II (Chairs: T. Kirsten, F. Vannucci) / 208**

## New Antineutrino Oscillation Results from MiniBooNE

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**Neutrino Mixing and Oscillations II (Chairs: T. Kirsten, F. Vannucci) / 209**

## Toward solution of the MiniBoone-LSND anomalies

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**Neutrino Mixing and Oscillations II (Chairs: T. Kirsten, F. Vannucci) / 210**

## Status of T2K

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**Neutrino Mixing and Oscillations II (Chairs: T. Kirsten, F. Vannucci) / 211**

## Status of NOvA

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## LUCIFER: Scintillating bolometers for the search of Neutrinoless Double Beta Decay

**Author:** Marco Vignati[1]

**Co-author:** LUCIFER Collaboration

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The nature of neutrino mass is one of the frontier problems of particle physics.
Neutrinoless Double Beta Decay (0nuDBD) is a powerful tool to measure the neutrino mass and to test possible extensions of the Standard Model.
Bolometers are excellent detectors to search for this rare decay, thanks to their good energy resolution and to the low background conditions in which they can operate. The current challenge consists in the reduction of the background, represented by environmental gamma's and alpha's, in view of a zero background experiment.
We present the LUCIFER R&D, funded by an European grant, in which the background can be reduced by two orders of magnitude with respect to the present generation experiments. The technique is based on the simultaneous bolometric measurement of the heat and of the scintillation light produced by a particle, that allows to discriminate between beta and alpha particles. The gamma background is reduced by choosing 0nuDBD candidate isotopes with transition energy above the environmental gamma's spectrum.
The prospect of this R&D will be discussed, together with a comparison with the leading experiments of the field.

**Neutrino Beams and Sources II (Chairs: M. Goodman, A. Rubbia) / 213**

## Strategies for Future Accelerator Neutrino Physics

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**Neutrino Beams and Sources II (Chairs: M. Goodman, A. Rubbia) / 214**

## Super Beams (Review)

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**Neutrino Beams and Sources II (Chairs: M. Goodman, A. Rubbia) / 215**

## Beta Beams

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**Neutrino Beams and Sources II (Chairs: M. Goodman, A. Rubbia) / 216**

## Steps toward a Neutrino Factory

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**Future Detectors and Experiments I (Chairs: A. Bettini, L. Votano) / 217**

## Planned Underground Facilities

**Corresponding Author:** n.j.t.smith@rl.ac.uk

**Future Detectors and Experiments I (Chairs: A. Bettini, L. Votano) / 218**

## Status and initial commissioning of ICARUS

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**Future Detectors and Experiments I (Chairs: A. Bettini, L. Votano) / 219**

## Liquid Argon Neutrino Detector Development at Fermilab

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**Future Detectors and Experiments I (Chairs: A. Bettini, L. Votano) / 220**

## Development towards a Giant Liquid Argon Observatory in Japan

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**Neutrino Mixing and Oscillations III (M. Lindner, M. Shaevitz) / 221**

## Phenomenology and Models

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**Neutrino Mixing and Oscillations III (M. Lindner, M. Shaevitz) / 222**

## Results and Prospects for SNO

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**Neutrino Mixing and Oscillations III (M. Lindner, M. Shaevitz) / 223**

## Solar and Terrestrial Neutrino Results from Borexino

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**Neutrino Mixing and Oscillations III (M. Lindner, M. Shaevitz) / 224**

## Results from Super-Kamiokande

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**Neutrino Mixing and Oscillations IV (Chairs: G. Feldman, V. Garvin) / 225**

## Status of the DOUBLE CHOOZ Reactor Experiment

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**Neutrino Mixing and Oscillations IV (Chairs: G. Feldman, V. Garvin) / 226**

## Status of the Daya Bay Reactor Neutrino Experiment

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**Neutrino Mixing and Oscillations IV (Chairs: G. Feldman, V. Garvin) / 227**

## Status of the RENO Reactor Neutrino Experiment

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**Neutrino Mixing and Oscillations IV (Chairs: G. Feldman, V. Garvin) / 228**

## Cooperative Monitoring of Reactors using Antineutrinos

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**Neutrino Mixing and Masses I (Chairs: B. Kayser, K. Zuber) / 229**

## Neutrinoless Double Beta Decay in Particle Physics

**Corresponding Author:** werner.rodejohann@mpi-hd.mpg.de

**Neutrino Mixing and Masses I (Chairs: B. Kayser, K. Zuber) / 230**

## Introduction to double beta decay experiments and CUORE

**Corresponding Author:** maura.pavan@mib.infn.it

**Neutrino Mixing and Masses I (Chairs: B. Kayser, K. Zuber) / 231**

## The Enriched Xenon Observatory (EXO)

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**Neutrino Mixing and Masses I (Chairs: B. Kayser, K. Zuber) / 232**

## Scintillator-based experiments in Double Beta Decay

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**Neutrino Mixing and Masses II (Chairs: A. de Gouvea, G. Gratta) / 233**

## Tracking-based experiments in Double Beta Decay

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**Neutrino Mixing and Masses II (Chairs: A. de Gouvea, G. Gratta) / 234**

## Semiconductor-based experiments in Double Beta Decay

**Corresponding Author:** marik.barnabe-heider@mpi-hd.mpg.de

**Neutrino Mixing and Masses II (Chairs: A. de Gouvea, G. Gratta) / 235**

## Introduction to direct neutrino mass measurements and KATRIN

**Corresponding Author:** thomas.thuemmler@kit.edu

**Neutrino Mixing and Masses II (Chairs: A. de Gouvea, G. Gratta) / 236**

## Lepton flavor violation experiments (Review)

**Corresponding Author:** donato.nicolo@pi.infn.it

**Astrophysical/Cosmological Neutrinos I (Chairs: U. Katz, S. Pakvasa) / 237**

## UHE Cosmic Rays and Neutrinos

**Corresponding Author:** venya.berezinsky@lngs.infn.it

**Astrophysical/Cosmological Neutrinos I (Chairs: U. Katz, S. Pakvasa) / 238**

## Observation of UHE Cosmic Rays and upper limit on the diffuse neutrino flux by the Pierre Auger Observatory

**Corresponding Author:** dariusz.gora@ik.fzk.de

**Astrophysical/Cosmological Neutrinos I (Chairs: U. Katz, S. Pakvasa) / 239**

## Physics and astrophysics with GeV and TeV gamma-ray

**Corresponding Author:** justinv@stanford.edu

**Astrophysical/Cosmological Neutrinos II (Chairs: S. Katsanevas, N. Mondal) / 240**

## Introduction to Neutrino Telescopes and Results from Icecube

**Corresponding Author:** elisa.resconi@mpi-hd.mpg.de

**Astrophysical/Cosmological Neutrinos II (Chairs: S. Katsanevas, N. Mondal) / 241**

## High-Energy Neutrino Astronomy with the ANTARES Deep –Sea Telescope

**Corresponding Author:** gisela.anton@physik.uni-erlangen.de

**Astrophysical/Cosmological Neutrinos II (Chairs: S. Katsanevas, N. Mondal) / 242**

## The KM3NeT Project: Neutrinos in the Deep-Sea

**Corresponding Author:** petros.afentoulis.rapidis@cern.ch

**Astrophysical/Cosmological Neutrinos II (Chairs: S. Katsanevas, N. Mondal) / 243**

## Radiodetection of Neutrino

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**Neutrino Interactions I (Chairs: A. Bodek, J. Morfin) / 244**

## Challenges in the current Theoretical Picture

**Corresponding Author:** luis.alvarez@ific.uv.es

**Neutrino Interactions I (Chairs: A. Bodek, J. Morfin) / 245**

## Modeling Neutrino-Nucleus Interactions: Do We Need a New Paradigm?

**Corresponding Author:** omar.benhar@roma1.infn.it

**Neutrino Interactions I (Chairs: A. Bodek, J. Morfin) / 246**

## Recent Experimental Results: quasi-elastic Scattering

**Corresponding Author:** morgan.wascko@cern.ch

**Neutrino Interactions I (Chairs: A. Bodek, J. Morfin) / 247**

## Recent experimental results: resonant pion production

**Corresponding Author:** mtzanov@pizero.colorado.edu

**Neutrino Interactions II / Neutrino Mixing and Masses III (Chairs: S. Elliott, T. Nakaya) / 248**

## Recent experimental results: coherent pion production

**Corresponding Author:** leslie.loris.camilleri@cern.ch

**Neutrino Interactions II / Neutrino Mixing and Masses III (Chairs: S. Elliott, T. Nakaya) / 249**

## Neutrino Interactions: results by Neutrino 2012 and beyond

**Corresponding Author:** dharris@fnal.gov

**Neutrino Interactions II / Neutrino Mixing and Masses III (Chairs: S. Elliott, T. Nakaya) / 250**

## Neutrino mass calorimetric searches in the MARE experiment

**Corresponding Author:** angelo.nucciotti@mib.infn.it

**Neutrino Interactions II / Neutrino Mixing and Masses III (Chairs: S. Elliott, T. Nakaya) / 251**

## Matrix Elements for Double Beta Decay

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**Astrophysical/Cosmological Neutrinos III (Chairs: G. Fogli, C, Weinheimer) / 252**

## Twenty years of LUNA and Solar Neutrinos

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**Astrophysical/Cosmological Neutrinos III (Chairs: G. Fogli, C, Weinheimer) / 253**

## Precision cosmology as a neutrino laboratory

**Corresponding Author:** yvonne.wong@physik.rwth-aachen.de

**Astrophysical/Cosmological Neutrinos III (Chairs: G. Fogli, C, Weinheimer) / 254**

## Developments in Leptogenesis

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**Future Detectors and Experiments II (Chairs: M Divan, Y. Suzuki) / 255**

## Physics at planned Underground Facilities

**Corresponding Author:** cmauger@lanl.gov

**Future Detectors and Experiments II (Chairs: M Divan, Y. Suzuki) / 256**

## Large Underground Water Cerenkov Detectors

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**Future Detectors and Experiments II (Chairs: M Divan, Y. Suzuki) / 257**

## Large Underground Liquid Scintillator Detectors

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**Future Detectors and Experiments II (Chairs: M Divan, Y. Suzuki) / 258**

## Large Underground Solid Scintillator Detectors

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## Poster Session

**Public Lecture: Neutrinos Get Under Your Skin! (Boris Kayser - Fermilab) / 260**

## Neutrinos Get Under Your Skin!

**Astrophysical/Cosmological Neutrinos IV (Chairs: J. Adams, D. Vignaud) / 261**

## Supernova Modeling: Progress and Challenges

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**Astrophysical/Cosmological Neutrinos IV (Chairs: J. Adams, D. Vignaud) / 262**

## Flavor oscillations of supernova neutrinos

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**Astrophysical/Cosmological Neutrinos IV (Chairs: J. Adams, D. Vignaud) / 263**

## Detectors for Supernova Neutrinos

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**Future Detectors and Experiments III (Chairs: W.C. Louis III, S. Wojcicki) / 264**

## Project 8: Measuring Neutrino Mass using Radio-Frequency Techniques

**Corresponding Author:** josephf@mit.edu

**Future Detectors and Experiments III (Chairs: W.C. Louis III, S. Wojcicki) / 265**

## The Homestake Neutrino Detector: Oscillations, Nucleon Decay, and Astrophysics at DUSEL

**Corresponding Author:** rsvoboda@physics.ucdavis.edu

**Future Detectors and Experiments III (Chairs: W.C. Louis III, S. Wojcicki) / 266**

## Exploring New Features of Neutrino Oscillations with Low Energy Monoenergetic Neutrinos

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**Future Detectors and Experiments III (Chairs: W.C. Louis III, S. Wojcicki) / 267**

## DAEdALUS

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**Future Detectors and Experiments III (Chairs: W.C. Louis III, S. Wojcicki) / 268**

## The LENS Experiment: Spectroscopy of Low Energy Solar Neutrinos

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**SESSION III (Chairs: Akhmedov, F. von Feilitzsch) / 269**

## Neutrinos and LHC

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**SESSION III (Chairs: Akhmedov, F. von Feilitzsch) / 270**

## Dark Matter (Review)

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**SESSION III (Chairs: Akhmedov, F. von Feilitzsch) / 271**

## New Geo-neutrino Measurement with KamLAND

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**SESSION III (Chairs: Akhmedov, F. von Feilitzsch) / 272**

## Geo-Neutrino Review

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**CLOSING SESSION (Chair: J. Schneps) / 273**

## Summary and prospects of theory and phenomenology

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**CLOSING SESSION (Chair: J. Schneps) / 274**

## Experimental Summary

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**CLOSING SESSION (Chair: J. Schneps) / 275**

## Report from the INC

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## Conclusion

**EVENING POSTER TALKS I (Chairs: N. Saoulidou, E. Stiliaris) / 277**

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## 44 presentations