International Workshop on Next Generation Nucleon Decay and Neutrino Detectors (NNN18)

Wednesday, 31 October 2018 - Sunday, 4 November 2018

UBC Robson Square

Book of Abstracts

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Low-energy neutrino detection with Borexino

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Borexino is the world radio-purest large-volume liquid-scintillator detector placed at the Laboratori Nazionali del Gran Sasso in Italy. Since the start of its data taking in May 2007, it has provided several measurements of solar neutrinos, important for the understanding of our star, as well as of the neutrino properties. In particular, Borexino has performed the first spectroscopic measurements of the pp, 7Be, and pep solar neutrinos, the measurement of the 8B neutrinos with the 3 MeV energy threshold, and has provided the best current limit on the CNO solar neutrinos and on the effective neutrino magnetic moment. The talk will describe in detail the newly updated solar neutrino results, based on the Phase-2 data with significantly lowered radioactive background. Borexino results on geoneutrinos, antineutrinos emitted along the decay of long-lived radioactive elements inside the Earth, will be also presented. The talk will be given in name of Borexino Collaboration.

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The MCP-PMT for Neutrino Detector

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Microchannel plate (MCP) is always used in the small PMTs as the electron multiplier for the fast timing detection, which greatly improved the time resolution of PMT. The large scaler neutrino detectors, such as SuperK, DayaBay, JUNO and HyperK, need the large area PMTs for the large photocathode coverage and less electronic channels. Usually there was only one type of 20 inch PMT based on the Dynode part by the Hamamastu company in Japan.
Researchers at IHEP have conceived a new concept of large area MCP-PMT several years ago. The small MCP units replace the bulky Dynode chain in the large PMTs. In addition the transmission and reflection photocathode in the same glass bulb to enhance the efficiency of photoelectron conversion. After several years R&D, the 20 inch MCP-PMT was successfully produced. This type of PMT has large sensitive area, high QE, and large P/V for good single photoelectron detection. Compensating the PMT performances, cost, radioactivity, the JUNO ordered 15000 pic 20-inch MCP-PMT from the NNVT in Dec.2015. The MCP-PMT collaboration group finished to build the mass production line and batch test facility in Nanjing in 2016. From 2017 to 2019, all the 20-inch PMTs will be produced and tested one by one in NNVT for JUNO. This presentation will talk about the R&D, the mass

production and batch test result of the 7K pieces of MCP-PMT prototypes for JUNO.
Further more, the QE of this type of MCP-PMT is improved from 28% to 34%@410nm in 2018, and this new technology has already used on the PMT mass production. And also in 2018, another Flower-liked MCP-PMT was designed with the TTS less than 5ns, and this new type of 20 inch MCP-PMT has already evaluated by the PMT group in LHAASO and HyperK.

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WATCHMAN: Neutrino Physics and Non-Proliferation

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WATCHMAN (Water Cherenkov Monitor of AntiNeutrinos) is an international collaboration
whose purpose is to demonstrate the feasibility of using a gadolinium-doped water Cherenkov detector
to detect electron anti-neutrinos emitted by distant nuclear reactors. Nuclear reactors produce high fluxes
of anti-neutrinos during operation and have been exploited by many experiments during the entire epoch
of experimental neutrino physics. Given the high fluxes, WATCHMAN aims to demonstrate a method to determine the existence or non-existence of hidden reactors at distances of hundreds of kilometers away
from a detector location. The key game-changing ingredient is gadolinium-loaded water as the detection
medium which enables neutron detection and thus detection of the delayed coincidence signal induced
by electron anti-neutrino interactions with free protons. This technology can feasibly be scaled to megatons of mass - making detection of low-power reactors at long distances possible. WATCHMAN employs a kiloton-scale detector in the Boulby Mine in the United Kingdom to measure anti-neutrinos from the Hartlepool reactor complex. The current status of the project will be discussed.

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Status and physics prospects of Jinping Neutrino Experiment

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The China Jinping Underground Laboratory (CJPL), which has the lowest cosmic-ray muon flux and the lowest reactor neutrino flux of any laboratory, is ideal to carry out low-energy neutrino experiments. With two detectors and a total fiducial mass of 2000 tons for solar neutrino physics, the Jinping neutrino experiment will have the potential to identify the neutrinos from the CNO fusion cycles of the Sun, to cover the transition phase for the solar neutrino oscillation from vacuum to matter mixing, and to measure the geo-neutrino fluxes, including the Th/U ratio. A 1-ton prototype has been taking data since 2017, where development of the slow liquid scintillator is being carried out. This talk will review the project and cover the recent progress.

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Energy Reconstruction in NOvA with Regression Convolutional Neural Networks

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NOvA is a long-baseline accelerator neutrino oscillation experiment. It uses the upgraded NuMI beam from Fermilab and measures electron neutrino appearance and muon neutrino disappearance at its Far Detector in Ash River, Minnesota. NOvA aims to resolve the mass hierarchy, the CP violation and the octant of theta23. We will focus on the development and application of deep learning to the reconstruction tasks at NOvA. NOvA is a pioneer to use convolutional neural networks for event classification and particle identification in the neutrino community. Recently, we developed regression convolutional neural networks to estimate electron neutrino energy with direct raw detector pixel inputs. Compared with kinematics-based energy reconstruction, this method shows a significantly better energy resolution. The regression CNN also shows smaller systematic uncertainties from the simulation of neutrino interactions.

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Spectral Sorting of Photons Using Dichroic Winston Cones

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Large-scale neutrino detectors typically observe photons created by interactions inside of the target volume. These detectors deploy a wide variety of technologies, most commonly water, ice, or scintillator targets surrounded by PMTs. The detected photons carry information that goes unused, most notably the wavelength, which can indicate the production method and travel time of the photon. In particular, in scintillator detectors, wavelength can be used to discriminate Cherenkov from scintillation light due to the broad wavelength distribution of Cherenkov light. This discrimination provides a method for reconstructing the direction of the events, which is crucial for identifying solar neutrino interactions. A novel method for sorting photons by their wavelengths is introduced using Winston cone concentrators made of dichroic filters. Using two or more different types of dichroic filters can provide valuable wavelength information with minimal photon loss.

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The T2K ND280 upgrade project

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The T2K neutrino oscillation experiment established the $\nu_\mu \to \nu_e$ appearance with only 10\% of the original beam request of 7.8×10^{21} 30 GeV protons on target (p.o.t.). In view of the J-PARC program of upgrades of the beam intensity, the T2K-II proposal requires to run up to 20×10^{21} p.o.t., i.e. an

increase in the exposure by more than a factor 10 aimed at establishing CP violation at 3 σ level for a significant fraction of the possible δ_{CP} values. The Hyper-K proposal consists in a further increase by a factor 10 of the far detector mass. Facing the potential increase of statistics by two orders of magnitude, it is of great importance to undertake a vigorous program of near detector upgrades, with the aim of reducing the overall statistical and systematic uncertainties at the appropriate level of better than 4\%.

The T2K collaboration has launched in 2017 the upgrade project for its near detector ND280. In January 2018 the proposal has been submitted to the CERN SPSC (CERN-SPSC-P357) and to the JPARC PAC. The project aims at installing innovative detectors to significantly increase the physics capabilities. It includes two High-Angle TPCs, a highly segmented Scintillator Detector built with the Super-FGD technology (arXiv:1707.01785, 2018_JINST_13_P02006), and TOF detectors.

The rectangular TPCs will be built with a light field cage and resistive Micromegas detectors for the charge readout. The SuperFGD is based on small plastic scintillator cubes (appr. 1cm side) read-out by three WLS fibers, providing detailed informations for tracking and PID. TOF will complement the TPC and SuperFGD PID information and determine the track direction. With these detectors we will reach a full polar angle coverage for Charged Current Neutrino interactions, improve the tracking performance for low energy pions and protons, and select a clean electron neutrino sample.

We will report on the goals of the project and its development program including prototypes, beam tests at CERN and in Japan in 2018, and projected performances.

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Neutron detection in the water phase of SNO+ experiment

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Efficient detection of neutrons in water is important because of its physics applications. For example, neutron detection could enable the detection of neutrinos via inverse beta decay or help suppress neutron-accompanied backgrounds. However, observing neutrons in pure water Cherenkov detectors is a challenging task due to the low energy of the 2.2 MeV gamma emitted upon capture. SNO+ is a multipurpose neutrino experiment that began taking data with pure water in May, 2017, and will soon begin filling scintillator. A first observation of reactor neutrinos in water may be achievable with the low trigger threshold of the SNO+ detector. We present studies of neutron detection in the SNO+ experiment based on an AmBe calibration source.

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STRAW –STRings for Absorption length in Water

Authors: Andreas Gaertner[1]; Christian Fruck[1]; Elisa Resconi[1]; Felix Henningsen[1]; Kilian Holzapfel[1]; Laszlo Papp[2]; Michael Boehmer[1]; Rea Immacolata Carmen[1]

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Recent results presented by IceCube have demonstrated the potential of large instrumented volume type detectors for multi-messenger astronomy using neutrinos. Conducting deep astronomical observations with such type of detector requires increasing the sensitivity and therefore mostly the

detector volume by around 2 orders of magnitude, a goal that might not be achievable with a single installation. Constructing a detector array of about 10 times the size of IceCube on the northern hemisphere in the ocean would mark a milestone towards real Neutrino astronomy.

STRAW is a pathfinder instrument for such an installation, consisting of two 120 m long instrumented strings, developed by the Technical University Munich in collaboration with the University of Alberta and Ocean Networks Canada (ONC). It has been deployed this year at Cascadia basin at 2.6 km b.s.l., in the northern Pacific, off the Canadian coast. The goal of the instrument is characterizing this site, which thanks to ONC is already equipped with an extensive power and data communication infrastructure, in terms of optical properties and bioluminescence. We will introduce this new instrument and show first preliminary results from our measurements.

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Search for Supernova Neutrinos with the LVD Experiment

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The Large Volume Detector (LVD) is continuously taking data since 1992 at the INFN Gran Sasso National Laboratory (Italy). The experiment, 1 kton of liquid scintillator organized in 840 counters, is sensitive in the neutrino channels to burst expected from a gravitational stellar collapse. Full detection probability is foreseen in the case of an unexpected event in the Milky Way, d<25 kpc. At greater distances, up to 60 kpc, the trigger efficiency is limited but always better than 50%.

We have searched, both in on-line and off-line mode, for impulsed neutrino signals in LVD data collected in 26 years of operations. No evidence of such a signal has been found either in standalone mode or in coincidence with other neutrino detectors. The 90% c.l. upper limit on the rate of core collapse and failed supernova explosions out to distances of 25 kpc is found to be 0.09 event/year.

Methods and results of this analysis will be here discussed.

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Sterile neutrino searches with the ICARUS detector

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The 760 ton ICARUS T600 detector performed a successful three-year physics run at the underground LNGS laboratories studying neutrino oscillations with the CNGS neutrino beam from CERN, and searching for atmospheric neutrino interactions. ICARUS performed a sensitive search for LSND like anomalous ν_e appearance in the CNGS beam, which contributed to constrain the allowed parameters to a narrow region around $\Delta m^2 \sim eV^2$, where all the experimental results can be coherently accommodated at 90% C.L. After a significant overhauling at CERN, the T600 detector has now been placed in its experimental hall at Fermilab. It will be soon exposed to the Booster Neutrino Beam to search for sterile neutrino within the SBN program, devoted to definitively clarify the open questions of the presently observed neutrino anomalies.
The proposed contribution will address ICARUS achievements, its status and

plans for the new run and the ongoing analyses also finalized to the next physics run at Fermilab.

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First Results From ARIADNE: A 1-ton dual-phase LArTPC with optical readout.

Authors: Adam Roberts[1]; Kostas Mavrokoridis[1]

[1] *University of Liverpool*

ARIADNE is a 1-ton two-phase liquid argon (LAr) time projection chamber (TPC) featuring a novel optical readout method. The detector uses a Thick Gas Electron Multiplier (THGEM) in the extraction region to generate secondary scintillation light which is imaged using 4 Electron-Multiplying (EM)CCD cameras to produce high resolution images of particle interactions within the detector.

This approach has many potential improvements over current readout techniques. A combination of the high level of gain achievable in the THGEM and the single-photon sensitivity of the EMCCDs give's sensitivity at low energies. The EMCCDs have 1 million pixels each giving the detector its high resolution.

Using optical readout also allows the readout electronics to be positioned externally to the cryostat, reducing the need for cold electronics and giving easy access for live maintenance and upgrades.

ARIADNE underwent testing and commissioning runs in Liverpool at the end of 2017, followed by a beam line test at the CERN East Area in 2018. This was the first beam line test of an optical dual phase TPC for a detector of this scale. Initial results from these tests will be presented.

http://hep.ph.liv.ac.uk/ariadne

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Detection of electron anti-neutrino at Jinping

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The China Jinping Underground Laboratory (CJPL) with the lowest cosmic-ray muon flux and the lowest reactor neutrino flux of any laboratory is ideal to carry out low-energy neutrino experiments for solar neutrino, geo-neutrino and supernova neutrino physics studies. At present, a 1-ton prototype for Jinping Neutrino Experiment of which the target material is liquid scintillator is deployed in CJPL and Monte Carlo study for detectors in future is in progress. The R&D efforts are made particularly on construction of low background facility, including the measurements of radiative backgrounds, the simulation studies of all materials to be used in the proposed detectors. In that poster, I will present the progress of the studies together with the evaluation of geo-neutrino signal in a few hundred ton scale of Gd-loaded liquid scintillator detector.

Systemtics and Analysis technique Parallel / 58

Systematics, calibration and analysis techniques in JUNO

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The Jiangmen Underground Neutrino Observatory(JUNO) is a liquid scintillator detector aiming to determine the neutrino mass hierarchy and to perform precision measurements of neutrino mixing parameters by detecting reactor antineutrinos at a baseline of 53 km. JUNO physics programme also serves for the detection of supernova neutrinos, geoneutrinos and solar neutrinos. In order to achieve the main physics goals, we face the challenge of achieving the unprecedented energy resolution < 3% at 1 MeV. Introducing 26K 3" PMTs brings the multi-calorimeter concept into the reality to help event reconstructions and reduction of the non-stochastic component in the energy response. In this talk, we will share ideas of how to treat systematics uncertainties, calibration and analysis techniques to tackle challenges in JUNO.

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Preliminary design study for Jinping neutrino experiment

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Jinping underground neutrino experiment kton-detector will be built in the future. We use the simulation software —Jinping Simulation Analysis Package(JSAP) based on Geant4 for simulating and optimizing the kton-detector structure. Each part of the detector is likely to have uranium, thorium, potassium or radon radioactive isotopes, which will be our background. Based on some simulations, we learned that some components of high radioactive elements is the main source of background, and found that radioactive background will be reduced by an order of magnitude due to 0.5-meter water shield. Therefore, kton-detector preliminary structure is as follows. The center of the detector is a spherical inner acrylic vessel filled with slow liquid scintillator with 11-meter radius and surrounded by pure water. Photomultiplier tubes are settled between 13 and 14 meters from the center, and supported by low radioactive stainless steel frame. The outermost layer of detector is a cylindrical low radioactive stainless steel tank with 30 m in both diameter and height . We imported radioactivity measurements for different materials from SNO and Borexino experiments, and then estimated the kton-detector background produced by the radioactive isotopes of the detector material. We find the solar neutrino signals are significant at this background level.

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Review of Double Beta Decay Experiments

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Neutrinoless double beta (0nbb) decay violates lepton number conservation and it requires two characteristic neutrino properties; non-zero mass and Majorana nature of the neutrino. Assuming the minimal mechanism of the decay, it would constrain the neutrino mass hierarchy and mass scale. In nature, more than 60 of isotopes are known as double beta decay nuclei, however, there is no perfect isotope for the experiment, thus various experiments with different isotope and technique

are operated and proposed. In this talk, recent results and future 0nbb decay experiments will be reviewed.

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SoLid: Latest results and futures plans

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The SoLid experiment is a short-baseline (6-9 m) nuclear reactor experiment that targets to measure the antineutrino flux and search for the possible existence of one or more additional neutrino types. SoLid is searching for an oscillation pattern in the energy spectrum of the $\bar{\nu_e}$'s emitted by the SCK.CEN BR2 reactor at Mol in Belgium. This measurement will provide confirmation or exclusion of the so-called reactor anomaly. The SoLid detector is a highly segmented detector of 5 modules of 10 planes of 16×16 cubes that uses a novel technology. The cubes are a combination of PVT and 6LiF:ZnS scintillators, in a way that two 6LiF:ZnS sheet layers (of ~ 250 μm thickness) are attached to each PVT cube (of 5×5×5 cm^3). The fine segmentation and the hybrid technology of the detector allows the clear identification of the neutrino signals and reducing backgrounds significantly. The experiment has been taking data for around one year and the analysis of the data is in progress.

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The Central Detector of JUNO

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Jiangmen Underground Neutrino Observatory (JUNO) is an experiment under construction in Southern China. It aims to determine the neutrino mass hierarchy, to measure precisely the oscillation parameters by detecting reactor neutrinos from nuclear power plants, to observe supernova neutrinos, to study the atmospheric, solar neutrinos and geo-neutrinos, and to perform exotic searches.
As the core detector of JUNO, the central detector (CD) is designed to measures reactor antineutrinos via inverse beta decay. The CD system consists of an inner transparent sphere of 35.4 m in diameter and an outer support structure of 40.1 m in diameter. The inner sphere is made of acrylic which contains the 20 kilotons of liquid scintillator (LS). The outer support structure is made of stainless steel which can hold 18,000 20"PMTs and 25,000 3"PMTs to detect the photons from LS.And the goal for its energy resolution is 3%/√E which will reach the highest level in the world.
Several challenges have been overcome for the largest liquid scintillator detector in the world,such as the compatibility of the sphere material, the mechanics of the stainless steel structure and the CD prototype.

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Model-independent reconstruction of full flavor supernova neutrino spectra in future large liquid-scintillitor detectors

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The fortunate observation of neutrino events from the SN1987A explosion in the Large Magellanic Cloud is a milestone in both neutrino physics and neutrino astronomy. The sparse data, however, can't provide us the accurate energy spectra of supernova neutrinos. Currently many worldwide neutrino detectors runnning or under construction have better detection capbilities of core collapse supernova neutrinos. For example the future liquid-scintillator detector with a 20kton designed fiducial mass of JUNO, can register about 5000 events from the inverse beta decay given a typical SN at 10kpc. Here we propose a model-independent combined method gathering the events from inverse beta decay, neutrino-proton elastic scattering as well as neutirno-electron elastic scattering to unfold the true energy spectra of full flavor supernova neutrinos directly. Many different numerical models are also applied to check the validity of the method. Furthermore, even for a more complicated scenario with flavor conversion, this combined method shows a great potential to reconstruct the true neutrino spectra emitted from the core of supernove. One trial with flavor conversion from MSW resonance effect at the enevolope of supernova is illustrated in this work.

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IceCUBE detector system

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Update on the *hep* solar neutrino limit from the three-phase SNO dataset

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The spectrum of solar neutrinos from the *pp* chain has been studied in depth by a variety of underground detectors. However, neutrinos from the *hep* reaction ($^3\mathrm{He} + p^+ \rightarrow {}^4\mathrm{He} + e^+ + \nu_e$) remain unobserved due to the small theoretical branching ratio (2×10^{-7} per *pp* termination). The SNO detector has a unique sensitivity to neutrino energies above the ^{8}B spectrum endpoint (~15 MeV) through the *hep* spectrum endpoint (~18.8 MeV) due to the charged current interaction on deuterium, which allows a more precise extraction of the underlying neutrino energy spectrum. The SNO collaboration previously published a world-leading limit in 2006 only using the first heavy water phase with 306.4 days of data. An updated status report on the analysis of the *hep* neutrino spectrum from all three phases of SNO (1170.2 days) will be presented in this poster.

Detector parallel / 66

The IceCube Neutrino Observatory: Detector Status and Designs for the Future

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The IceCube Neutrino Observatory is a cubic-kilometer-scale neutrino detector and cosmic ray air shower array at the geographic South Pole. The detector consists of over 5400 digital optical modules (DOMs), with 98.5% of modules still taking data. High detector uptime and a real-time Iridium satellite link have helped to facilitate recent astrophysical neutrino discoveries. Prototype air shower detectors have recently been installed, exploring the enhancement of the IceTop surface array with scintillators, radio antennas, and air Cherenkov telescopes. Furthermore, electronics and mechanical designs are well underway for the next stage of the experiment, the IceCube Upgrade, consisting of seven new detector strings at the core of the current array. Several improvements are planned for the Upgrade, including DOMs with larger photocathode area and segmented sensors; improved timing and communications protocols; in-DOM waveform feature extraction; and new precision calibration devices. We will present the status of detector development for the Upgrade as well as plans for a next-generation neutrino facility at the South Pole, IceCube–Gen2.

Detector parallel / 67

DUNE electronics, trigger and DAQ

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Deep Underground Neutrino Experiment (DUNE), which is consist of two neutrino detectors placed near and far of Fermilab, will address several questions in neutrino physics. In addition, It intends to facilitate the study of neutrinos from the supernova and search for proton decay.
The liquid argon time projection chamber (LArTPC) technology has been adopted to detect the neutrino interactions with argon atoms from neutrinos beams produced in Fermilab arriving at expected times to Sanford underground research facility.
The LArTPC can detect neutrinos with energies as low as a few MeV to GeV, by collecting the ionized electrons and photons produced by the interactions of charged particles in the liquid argon.
The combination of sample rate and a number of channels in TPC and photodetector readouts produce a very large volume of the data stream. In addition to the volume of data, the rarity of the presumable supernova's neutrinos and proton decay events will need more design requirements for the DUNE DAQ architecture like compression algorithms, an online trigger system and algorithms.
In this talk, I will review DUNE electronics from DAQ front-end read-out to the trigger along with the requirements and challenges that shaped the DUNE far-detector DAQ architecture.

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HALO-1kt: A massive helium and lead observatory for supernova neutrinos

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HALO-1kt is a supernova neutrino observatory which would leverage 1000 tonnes of lead from the decommissioned OPERA experiment to create a low cost and low maintenance neutrino detector. It

is to be sited at LNGS, and is intended to operate as a scaled up version of the original HALO. Due to its sensitivity to ν_e, it is complementary to water Cherenkov and liquid scintillator-based detectors. Design is currently in progress.

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The Astroparticle and Exotic Physics program of MicroBooNE

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MicroBooNE is a liquid argon time projection chamber (LArTPC) with an 85-ton active mass situated on the Booster Neutrino Beam at Fermilab. Some of the experiment goals are investigating the excess of electron-like events observed in MiniBooNE, performing cross-section measurements of neutrino interactions in argon and gaining knowledge about the operation and the detector physics of LArTPCs in preparation for the future Deep Underground Neutrino Experiment (DUNE). In addition, MicroBooNE can be used to search for rare events and physics beyond sterile neutrino oscillations. This talk will focus on two topics: the search for heavy sterile neutrinos with mass in the hundreds of MeVs range, produced through mixing with active neutrinos, and decaying within the detector; and the development of a novel approach for detecting core-collapse supernova neutrinos based on a parallel continuous readout stream and an alert from the Supernova Early Warning System (SNEWS) that triggers a search back in the continuous stream.

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LEGEND: The Large Enriched Germanium Experiment for Neutrinoless Double-Beta Decay

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The lepton number violating process of neutrinoless double-beta decay could result from the physics beyond the Standard Model needed to generate the neutrino masses. Taking different approaches, the current generation of ^{76}Ge experiments, the MAJORANA DEMONSTRATOR and GERDA, lead the field in both the ultra-low background and energy resolution achieved. The next generation of neutrinoless double-beta decay experiments requires increased mass and further reduction of backgrounds to maximize discovery potential. Building on the successes of the MAJORANA DEMONSTRATOR and GERDA, the LEGEND collaboration has been formed to pursue a tonne-scale ^{76}Ge experiment, with discovery potential at a half-life beyond 10^{28} years. The collaboration aims to develop a phased neutrinoless double-beta decay experimental program, starting with a 200 kg measurement using the existing GERDA cryostat at LNGS. I will discuss the plans and physics reach of LEGEND, and the combination of R&D efforts and existing resources being employed to expedite physics results.

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Systematics in Hyper-Kamiokande experiment

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Hyper-Kamiokande is a next-generation underground water-Cherenkov detector, which is to be constructed from 2020. The physics program of Hyper-K includes a nucleon-decay search, a CP-phase measurement in the lepton sector with an accelerator neutrino beam, the determination of the neutrino mass hierarchy with atmospheric neutrinos, and the observation of astrophysical neutrinos.

Thanks to the large water volume of the detector and planned beam power upgrade of J-PARC, the CP-phase measurement is expected to be limited by systematics rather than statistics after several years of operation. The main sources of systematics are the neutrino beam
flux, neutrino-nucleus interaction modeling, final-state and secondary interactions of hadrons, and detector mis-modeling.

In this talk, our current understanding of these uncertainties, ongoing work including efforts by the T2K and Super-K collaborations, and future strategies are presented.

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R&D on Water-based Liquid Scintillator for the Theia experiment

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Recent developments in the field of liquid scintillator chemistry and fast-timing photosensors paved the way for a new generation of large-scale detectors, such as Theia, capable of tackling a broad range of physics issues. Water-based Liquid Scintillator (WbLS) is a novel detection medium that combines the advantages of pure water, including low attenuation, accurate direction reconstruction, and low cost, and those of liquid scintillator, including high light yield and low-threshold detection. A lot of effort is currently being put into developing WbLS and understanding its intrinsic properties.
This poster will focus on two major R&D focuses: the continuous recirculation and filtration of WbLS using nanofiltration and the separation of Cherenkov and scintillation light, both emitted by WbLS thanks to its water and scintillator components, and its use as an energy reconstruction and particle identification tool.

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Analysis and Systematic Uncertainty Experience from MicroBooNE

Author: Salvatore Davide Porzio[1]

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The MicroBooNE detector is a Liquid Argon Time Projection Chamber (LArTPC) with an 85-ton active mass, situated at Fermilab in the Booster Neutrino Beam and designed to study short-baseline

neutrino physics. Its main physics goals include the investigation of the anomalous excess of electron-like events observed in MiniBooNE, the measurement of low-energy, neutrino-argon cross-sections and the development of liquid argon technology for the future experiments of the Short-Baseline Neutrino (SBN) and DUNE physics programs. This talk will review the experience gained by MicroBooNE in producing physics results with a LArTPC detector, recent results and the strategy for estimating systematic uncertainties.

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ProtoDUNE SP R&D

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ProtoDUNE-SP is the single-phase DUNE Far Detector prototype that was recently built at CERN and is in operation since September 2018. ProtoDUNE-SP is a crucial part of the DUNE effort towards the construction of the first DUNE 10-kt fiducial mass far detector module (17 kt total LAr mass), but also a significant experiment in its own right. With a total liquid argon (LAr) mass of 0.77 kt, it represents the largest monolithic single-phase LArTPC detector to be built to date. In this talk I will give an overview on the construction and commissioning phase of the detector. Furthermore, preliminary results based on the first data collected during beam and cosmic runs will be discussed.

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Uncertainties from Neutrino Interactions at T2K

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The oscillation analysis at T2K, even with limited statistics, has needed to improve and constrain the model of neutrino interactions in order to reach its current sensitivity. I review the interaction model, some of the most important uncertainties in the model for the oscillation analysis, and techniques for constraining those uncertainties through measurements of neutrino interactions.

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Interaction Modeling Uncertainties at MINERvA

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MINERvA began its cross section measurement program with a default model that looks very different than the used in its most recent measurement. I summarize the improvements and the measurements that have driven those changes. Recent data highlights areas in need of future refinement. I also discuss how the results of these improvements may be utilized by other experiments for their modeling.

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Machine Learning Techniques on NOvA

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The NOvA experiment has made measurements of the disappearance of νμ and the appearance of νe in the NuMI beam at Fermilab including the neutrino mass hierarchy and the CP violating phase. Key to these measurements is the application of machine learning methods for identification of neutrino flavor and energy reconstruction. These methods require rigorous validation to both understand and develop. I will present applications of machine learning used in NOvA analyses as well as data driven techniques for validation.

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DUNE Analysis Methods and Systematic Uncertainties

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The twin challenges facing the DUNE long-baseline analysis are to extract the maximum statistical power from the Far Detector data while minimizing the impact of systematic uncertainties.

The liquid argon TPCs that make up the DUNE Far Detector will provide outstanding spatial resolution, and should allow neutrino flavours to be separated with high efficiency and purity. However, taking full advantage of this information requires improvements in the state-of-the-art in pattern recognition and particle identification. I
will describe our reconstruction algorithms, and the various deep-learning techniques we are employing in pursuit of this goal.

With the large datasets expected, the second challenge, to minimize systematic uncertainties grows in importance. I will discuss our main sources of uncertainty, how we plan to evaluate their impact, and the
ways in which the analysis procedures are intended to mitigate them.

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Details of Systematic Uncertainties at NOvA

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I will present the details of the systematic uncertainties at NOvA for the latest measurements of both (anti)neutrino electron appearance and muon disappearance, as well as the systematic uncertainties associated with recent cross section results. NOvA is a long-baseline neutrino experiment which utilizes two basically fully active, finely segmented, liquid scintillator detectors: a Near Detector located at Fermilab, IL, and a Far Detector located in Ash River, MI, and situated roughly 14 mrad off Fermilab's NuMI beam. Using this narrow-band beam of mostly muon neutrinos we study the oscillation of these neutrinos over the 810 km baseline, which can be interpreted to give insights into the neutrino mass ordering, CP violation in the neutrino sector, and the flavor content of the third neutrino mass eigenstate, as well as tests of the three-neutrino paradigm. Using the high statistics neutrino sample in the Near Detector we can also make precision cross section measurements.

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Test Beam Experiments for the Future Generation of LBL Experiments

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The next generation of LBL experiments is currently under preparation. These future experiments will profit from new and high intensity neutrino beams which will allow very large samples of data to be collected. A deep understanding and strong constraint of the systematic uncertainties is thus mandatory to achieve precision measurements and to allow the experiments to fulfil their physics goals.

In this talk I review some of the recent test-beam experiments which address key topics for the preparation of the future generation of LBL experiments.

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Neutrino Interaction Uncertainties in Long Baseline Oscillation Experiments

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Uncertainties on neutrino-nucleus scattering cross sections are among the dominant systematics in long-baseline neutrino oscillation experiments, despite partial cancellation from near detector measurements. I will review the most important issues facing current experiments, and discuss what is required for next generation precision measurements.

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Deep Learning Techniques Overview

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Machine Learning at MINERvA

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Machine Learning in MicroBooNE

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Systematic Uncertainties for Atmospheric Neutrino Measurements

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Systematic errors in Borexino Solar and Geoneutrino Analyses

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Borexino is the world radio-purest large-volume liquid-scintillator detector placed at the Laboratori Nazionali del Gran Sasso in Italy. Since the start of its data taking in May 2007, it has provided several measurements of solar neutrinos and geoneutrinos. Recently, Borexino has released new results concerning comprehensive spectroscopy of the pp-chain solar neutrinos. The talk will brifely summarize the latest Borexino results and will then focus on the description of the main sources of the systematic uncertainties. Since both solar and geoneutrino analyses are important scientific goals of the future large-volume liquid-scintillator experiments, particular attention will be payed to the description of methods developed for the estimation of the dominant systematic errors.

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Review of Short Baseline Neutrino Experiments

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In this talk, I will review the present landscape in short baseline neutrino experiments as it relates to sterile neutrino physics. After describing recent results from short baseline reactor and accelerator experiments, I will focus on recent results from the MicroBooNE experiment, as it systematically builds towards a definitive test of the MiniBooNE low energy excess. In addition, I will report on the status of the Short-Baseline Neutrino (SBN) program as a whole, which is designed to fully address the LSND and MiniBooNE anomalies.

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Liquid Scintillator development

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Review of photo-detectors for huge detectors

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Large Area Picosecond Photo-detectors

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20" PMT development for Hyper-K

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Electronics for E61 multi-PMTs

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We propose using multi-PMTs (mPMTs) for the photosensors for the E61 near detector (as well as a fraction of Hyper-K photosensors). Our mPMT design has nineteen 3" PMTs enclosed in water-tight pressure vessel, providing excellent spatial imaging of the Cherenkov light ring. This talk will describe the design of the signal digitization electronics for the E61 mPMTs. We will start by explaining the key requirements that drive the design, including the requirements for precision hit time and charge resolution; these requirements are balanced by equally strong requirements for low power, low cost and high reliability electronics. E61 also has additional requirements related to handling the large rate of pile-up events from the high-intensity J-PARC neutrino beam. We will describe an electronics designs based on low power 100-200MSPS ADC with on-board signal processing in the FPGA. We will also briefly describe our work on HV design for the PMTs.

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The T2K ND280 upgrade project

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ArgonCube: LArTPC R&D for the DUNE Near Detector

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R&D on pixel readout for DUNE near detector

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DUNE signal processing

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Light detection in DUNE

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T2K neutrino and anti-neutrino oscillation results

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T2K is a long-baseline neutrino oscillation experiment sited in Japan, consisting of three main components: the JPARC proton accelerator facility that provides a beam of mainly muon neutrinos; a suite of near detectors, INGRID and ND280, that characterize the neutrino beam prior to oscillations; and Super-Kamiokande that acts as the T2K far detector. The far detector beam information is compared with that from the near detector in order to determine the neutrino oscillation parameters. Importantly, T2K also has sensitivity to CP violation via its predicted effect on neutrino vs antineutrino oscillations. T2K has recently increased its data set significantly, allowing for new statements on CP violation in the lepton sector. The latest results will be presented in this talk.

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Introduction: Status of HyperK and opportunities

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Physics with higher energy neutrinos at HyperK

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Satellite Workshop / 101

Neutrino astrophysics at HyperK

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HyperK detector

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HyperK analysis and systematics

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T2HKK - Korean detector for HyperK

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Analysis and Systematics

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