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Book of Abstracts

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WG4 overview

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WG5 overview

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Neutrino oscillation physics

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Leptogenesis via Neutrino Oscillation Magic

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NOvA

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Short baseline neutrino experiment

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JUNO

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Electron scattering for neutrino scattering

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Tensions in neutrino-nucleus modeling

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MiniBooNE & MicroBooNE

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Sterile neutrino search from disappearance measurements at Daya Bay and MINOS/MINOS+

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A brief announcement from IUPAP Neutrino Panel

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The current status KEK and J-PARC accelerators for neutrino experiments

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This presents the current status of the J-PARC main ring synchrotron (MR) beam operation and upgrade plans for neutrino experiments. The MR provides 30 GeV protons with two extraction modes; fast extraction (FX) for the long baseline neutrino oscillation experiment, T2K, and slow extraction (SX) for experiments in the hadron experimental facility. At present, achieved beam intensities are 2.6 ×1014 protons per pulse (ppp) with cycle time 2.48 s (500 kW) in the FX mode. In order to increase the beam power, an upgrade plan of replacing the magnet power supplies is in progress. After the replacement, the cycle time will be shortened about a half and increase the beam power two times larger for the FX. Further upgrades, mainly for the rf system, are also in schedule to increase number of protons per pulse. The goal of these upgrades is to reach 1.3 MW beam power for the neutrino experiments. We present future plans for Muti-MW at KEK and J-PARC.

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WG3 : Accelerator Physics

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FNAL accelerator status

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Search results on lepton number violation at the LHC

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Muon physics

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Pulsed muon beam experiments

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Working Group:

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Ultra Slow Muon and Low Energy Muon

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For the studies of surface/subsurface, nano materials and multi layered thin films, as well as for the fundamental physics like g-2 experiments, we must have muon beam, that has sufficiently low energy to stop on or near the surface of the sample. To perform such studies, so called slow (low energy) muons are required with energy that is of the order of several eV to a few tens of keV, far lower than the energies available from the conventional muon beams.
There exist two experimental techniques. One is the low energy ¥mu^{+} which can be generated through the cryogenic moderation method using Van der Waals solids such as solid Ar or N2, has been developed in the following four steps. Another is the ultra slow pulsed muons which can be generated by the resonant ionization of thermal Muonium atoms generated from the surface of a hot tungsten foil, placed at the intense pulsed surface muon beam line.
In this contribution, the latest status of the Ultra Slow Muon Microscopy project at J-PARC MUSE, will be reported, as well as brief status of the low energy For the studies of surface/subsurface, nano materials and multi layered thin films, as well as for the fundamental physics like g-2 experiments, we must have muon beam, that has sufficiently low energy to stop on or near the surface of the sample. To perform such studies, so called slow (low energy) muons are required with energy that is of the order of several eV to a few tens of keV, far lower than the energies available from the conventional muon beams.
There exist two experimental techniques. One is the low energy ¥mu{+} which can be generated through the cryogenic moderation method using Van der Waals solids such as solid Ar or N_{2}, has been developed in the following four steps. Another is the ultra slow pulsed muons which can be generated by the resonant ionization of thermal Muonium atoms generated from the surface of a hot tungsten foil, placed at the intense pulsed surface muon beam line.
In this contribution, the latest status of the Ultra Slow Muon Microscopy project at J-PARC MUSE, will be reported, as well as brief status of the low energy ¥mu^{+}.

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WG4 : Muon Physics

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Status of neutrino-nucleus generators and comparisons between generators

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Overview of new detector technology for neutrino experiments

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Photo sensor developments for neutrino experiments

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DUNE

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Hyper-Kamiokande

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Physics beyond PMNS

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Working Group:

Poster session - Board: 10 / **10**

Test of tri-direct CP symmetry models by accelerator neutrino oscillations

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Origin of neutrino masses are realized with a series of flavour symmetry models while the tri-direct CP-symmetry stands out among them. Here we briefly review the peculiar features of tri-direct CP-symmetry models, focusing on neutrino mixing parameters and their predicted correlations. The number of parameters to describe neutrino mixings is reduced to four due to the new symmetry. It is straightforward to probe these models with current and future neutrino oscillation experiments based on accelerator neutrino beams, and has a potential to discriminate different benchmark scenarios. We find that the degeneracy problems in constraining model parameters get worse, but a combination of different experiments will nail down fundamental neutrino mixing parameters predicted by the underlying theory.

Working Group:

WG1 : Neutrino Oscillation Physics

Poster session - Board: 106 / **106**

Radiation study of the target station for the EMuS baseline scheme

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The Experimental Muon Source (EMuS) is a proposed facility at China Spallation Neutron Source (CSNS). EMuS, which is an additional platform to CSNS, aims to provide muon beams for different applications such as neutrino physics, muSR, etc. The baseline design uses up to 25kW proton beam. The target station of EMuS is consist of a long carbon target in conical shape, a superconducting capture solenoids system that produce adiabatic magnetic field and shields inside the solenoids to protect them from radiation. The target is situated in the superconducting solenoids and second particles are collected forwardly. As a result, high radiation is produced in the target station. In this presentation, we will present the radiation study for the baseline scheme. We firstly report the study for the 5kW proton beam.

- The most radiation vulnerable material is the epoxy which is used as the insulator and the material to bond the cables. It can tolerate a maximum of 7MGy dose before it experiences a 10% degradation in its shear modulus. We optimize the tungsten shield position, thickness and materials. Results show that after the optimization, the peak doses on all the cables satisfy this 7MGy limit for a 10 year operation.
- Another radiative effect we should consider is the neutron fluence on the superconducting solenoids. The electrical conductivity of the stabilizer of the solenoids degrade in high-flux neutron environment, which can lead to instability of the superconducting system. Our calculation shows that the aluminum stabilized cable can stand for a 5-month continuous run after it needs to be warmed up to room temperature to get the full recovery.
- We have also performed the thermal analysis for superconducting solenoids considering the helium cooling and the aluminum 1100 thermal bridge. Results show the superconducting solenoid system can safely run for 5 months.

Our simulation show a reliable target design for the 5kW proton beam regarding the radiation. Studies for the 25 kW beam are also started.

- As the radiation level is much higher for the 25 kW beam, we update the design. The layout of the superconducting solenoids should be changed, and more shields need to be equipped. Our early study show a hybrid-shield-design can satisfy the requirement for the dose on the solenoids.

More studies will be carried out in the future for the 25 kW proton beam case.

Working Group:

WG3 : Accelerator Physics

Poster session - Board: 115 / **115**

Pulsed Neutrinos from Mu*STAR Accelerator-Driven Subcritical Reactors

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Subcritical nuclear reactors, such as Mu*STAR, are driven by a proton accelerator to generate fissions that are primarily initiated by spallation neutrons from an internal target. The fission chain dies quickly over a few tens of ns, such that it is possible to have neutrinos produced in bunches that are separated by intervals that can be varied according to the accelerator proton RF frequency or any subharmonic of it. We discuss some of the options for this mode of operation and opportunities for experimental exploitation.

Working Group:

WG3 : Accelerator Physics

Poster session - Board: 116 / **116**

Measuring the space charge effect in ProtoDUNE-SP

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The ProtoDUNE-SP detector is a 1/20 scale prototype, located at the CERN Neutrino Platform, of the planned first module of the DUNE far detector. Utilising single phase liquid argon TPC detection technology, ProtoDUNE-SP has successfully validated full scale prototype components and collected test beam and cosmic ray data to reduce systematic uncertainties in the future far detector. Space charge is the build-up of slow moving positive ions in a TPC. Due to the surface location of ProtoDUNE-SP, space charge has a large effect on the electric field and therefore on the position and number of ionisation electrons reaching the anode plane. As a result, measuring the magnitude of the space charge effect is required in order to allow accurate reconstruction of events. By selecting cosmic ray tracks with a known interaction time, a map of position distortions can be developed and the space charge effect in ProtoDUNE-SP determined. Using tracks passing through the anode plane greatly improves coverage in regions of the detector compared to cathode crossing tracks only, and a method of identifying anode piercing tracks is presented here.

Working Group:

WG1 : Neutrino Oscillation Physics

Poster session - Board: 117 / **117**

Neutrino Oscillations at dual-baseline

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There have been discussions on the neutrino oscillation experiment with two baselines such as T2HKK. We study this dual-baseline system to utilize the oscillation probabilities at two different baselines but with the same beam. We define a dual-baseline asymmetry exploiting the information at two baselines that can be helpful in determining the mass hierarchy and the CP phase in the neutrino sector. This presentation, which will focus on the Non-Standard Interaction part, will be complementary to the oral presentation of Sushant K. Raut.

Working Group:

WG1 : Neutrino Oscillation Physics

Poster session - Board: 121 / **121**

A dual-baseline asymmetry for neutrino oscillations

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The proposed T2HKK experiment involves placing a neutrino detector in Korea in the path of the T2HK beam, to collect data at an additional baseline of 1100 km. This setup will allow the measurement of neutrino oscillation probabilities at two different baselines with the same beam. We define a dual-baseline asymmetry relevant for setups with two components with different baselines. We find that the asymmetry gets enhanced at specific energies corresponding to the oscillation minima of one baseline. Using analytic considerations we demonstrate the possibility of using this asymmetry to distinguish between the mass hierarchies and measure the CP phase with good precision at the T2HKK experiment. We also discuss the possibility of exploring new physics with this asymmetry.

Working Group:

WG1 : Neutrino Oscillation Physics

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3DST-S in the DUNE Near Detector

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DUNE is a frontier experiment of long-baseline neutrino oscillation with a far detector at SURF and a near detector at FNAL. Three-Dimensional Projection Scintillator Tracker – Spectrometer (3DST-S) is a system to be included as a component detector in the near detector complex. It is placed downstream of a liquid-Ar time-projection chamber (TPC), and a high-pressure gas-Ar TPC. The 3DST-S detector consists of a 3D array of 1cm x 1cm x 1cm scintillator cubes, and is surrounded by a gas-Ar TPC, and an ECAL in a magnetic field. The combination provides comprehensive measurements on the active scintillator target to obtain the conditions on beam monitoring, as well as the constraints on Ar-neutrino interaction models. Full reconstruction of neutrino events is expected from its capability of neutron detection. In this presentation, we will introduce the 3DST physics performance and show the results of simulation studies.

Working Group:

WG1 : Neutrino Oscillation Physics

Poster session - Board: 124 / **124**

Study of \nu_{\mu}-CC Interaction in Resonance Region Using Nomad Data

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Neutrino-nucleus interactions in the resonance (RES) region is one of the most important interaction modes for the current and future generation long-baseline neutrino oscillation experiments. It is also sensitive to nuclear effects, including fermi motion, initial state nucleon correlations, and final state interactions etc., which affect event topology and neutrino energy reconstruction, and contribute to the systematic uncertainty for oscillation measurements. We present study of the \nu_{\mu} charge current interactions in the resonance region using high-statistics, high-resolution NOMAD data. Constraints on related nuclear effects are also discussed.

Working Group:

WG2 : Neutrino Scattering Physics

Poster session - Board: 125 / **125**

Neutrino self-interaction and MSW effects on the supernova neutrino-process

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We study the nuclear abundances produced from neutrino process in supernova (SN) explosion. We consider the neutrino oscillation effects as neutrino scattering not only with matter, $i.e.$ electron background, but also neutrinos themselves in SN environment. The changed neutrino spectrum by ν oscillation are affected to ν-nucleus reaction rate, so that the abundances during SN explosion change. The different shape of ν spectrum after oscillation depend on neutrino luminosity and averaged energy for each flavor by SN model. We investigate two different SN model for oscillation: one is the SN1987A model with equivalent neutrino luminosity for each flavor and consider only cooling phase of SN explosion with fixed neutrino temperature [1][2]. Second model is simulated SN explosion data in [3]. We average 6 models data and consider accretion and cooling phase. Our focusing elements for oscillation effect are ^{7}Li,^{11}B [4], ^{92}Nb [5], ^{98}Tc [6] and ^{138}La, which are mainly produced by neutrino reactions.

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[6] T. Hayakawa, Heamin Ko, Myung-Ki Cheoun, M. Kusakabe, T. Kajino, M. D. Usang, S. Chiba, K. Nakamura, A. Tolstov, K. Nomoto, M. A. Hashimoto, M. Ono, T. Kawano, G. J. Mathews, Phy. Rev. Lett. 121, 102701, (2018).

Working Group:

WG1 : Neutrino Oscillation Physics

Poster session - Board: 126 / **126**

A search for parity violation in muonic atoms using a segmented calorimeter

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In the standard model of particle physics, the Weinberg angle is an energy dependent parameter which describes the mixing of the electromagnetic and weak interactions. The modified minimal subtraction scheme predicts the scale dependence of the Weinberg angle precisely.

Measurements of the Weinberg angle at various energy scales are essentially important as a precision test of the standard model and search for new physics. The Weinberg angle can be determined via the neutral current interactions. At the low energy scale, a measurement of atomic parity violation (APV) is the most powerful method. In APV experiments, a parity-odd transition induced by the neutral current interaction between the electron and nucleus is observed. The most precise result was obtained by the experiment using cesium atom [1].

An APV experiment using muonic atoms provides a unique opportunity to search for physics beyond the standard model. In particular, the models predicting lepton-universality breaking are important candidates to be tested. In 1990s, several precursor experiments were carried out at Paul Scherrer Institute [2]. However, no parity-odd transition was observed because of difficulties in the experiment. To revisit this topic, a new experiment using high-intensity pulsed muon beamnand a segmented calorimeter with fast signal-processing is proposed.

The process of interest is the 1S-2S magnetic dipole (M1) transition with single photon emission. The transition is parity-odd and the emission angle of x-rays is asymmetric like the electrons from parity-violating muon decay. The angular asymmetry of x-ray emissions is measured by the calorimeter with a large solid angle and high-rate capability. In this presentation, experimental overview and status of detector development will be discussed.

[1]: J. Guena, M. Lintz, and M. A. Bouchiat, Phys. Rev. A 71, 042108 (2005).
[2]: K. Kirch et al., Phys. Rev. Lett. 78, 4363 (1997).

Working Group:

WG4 : Muon Physics

Poster session - Board: 33 / **33**

Hierarchy independent sensitivity to leptonic δ_{CP} with low energy atmospheric neutrinos

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One of the important unknowns in neutrino oscillation physics is the
the leptonic CP phase δ_{CP}. Because of ambiguity between δ_{CP} and neutrino mass hierarchy, experiments have to be designed in such a way as to measure these parameters independent of each other. Long baseline experiments like DUNE is exclusively designed to measure δ_{CP} in regions without hierarchy ambiguity and atmospheric neutrino experiments like INO are designed to measure hierarchy without δ_{CP} ambiguity. However atmospheric neutrinos are not usually used to probe δ_{CP}. Here we present the study that, at sub GeV energies atmospheric neutrinos can be used to probe δ_{CP} irrespective of mass hierarchy. We show that when the events are binned as a function of $(E_l, \cos\theta_l)$, the energy and direction of the final state leptons,a consistent distinction between various δ_{CP} values is obtained. Since there is no sensitivity to the mass ordering/hierarchy, δ_{CP} can be measured without hierarchy ambiguity at these energies. A χ^2 analysis assuming a generic detector with perfect resolutions and efficiencies, and which can separate charged current $\nu_e, \overline{\nu}_e, \nu_\mu$ and $\overline{\nu}_\mu$ events will also be discussed.

Working Group:

WG1 : Neutrino Oscillation Physics

Poster session - Board: 42 / **42**

Experimental Muon Source (EMuS) Target Station Shielding Design for "Baby Scheme"

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The Experimental Muon Source (EMuS) project at China Spallation Neutron Source (CSNS) in Dongguan aims at building a competitive muon source providing both a low-energy surface muon beam and a high energy decay muon beam for muon science. Highly polarized positive surface muons are used in muon spin rotation (μSR) spectrometers in order to study material properties in condensed matter physics, chemistry and biology, especially in studying magnetic systems; higher momentum muons can be employed in non-invasive analysis of materials, such as bulk-sensitive elemental analysis with negative muons, or muon radiography techniques. EMuS uses up to 25 kW proton beam hitting on a graphite target to produce the muon beam with a conventional magnet side collection target station and an advanced forward superconducting solenoid capture target station, so called as "Baby" scheme and "Baseline" scheme respectively. Extremely high radiation produced from the target has to be shielded in order to safeguard the magnet system and the surrounding environment for proper functioning and operation. Therefore, a proper shielding of magnet and environment becomes a key factor of its successful design. We present here the preliminary design and application of hybrid nature of shielding for the EMuS experiment for "Baby" scheme.

Working Group:

WG3 : Accelerator Physics

Poster session - Board: 64 / **64**

Development of Monte Carlo simulation and reconstruction algorithms for T2K-WAGASCI experiment

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T2K-WAGASCI is an experiment to measure neutrino interactions at the J-PARC neutrino beam line. WAGASCI modules have a three-dimensional grid structure of plastic scintillator bars and water, both of which form the neutrino interaction target. The Proton Module is a fully-active tracking detector consisting of only scintillator strips, therefore plays a role of plastic target. These neutrino detectors are surrounded by two side muon range detectors and a magnetized downstream muon range detector called Baby MIND. Baby MIND consists of iron-core magnet planes, with a magnetic field strength of 1.5 T, and scintillator tracking planes. It enables a reduction of the neutrino background for measurements with antineutrinos and vice versa.

The physics run with the full detector setup is planned in November 2019. The aim of this run is to measure double differential cross sections with respect to muon angle and momentum. The results will be compared against neutrino interaction models and are therefore important in the selection process for appropriate ones. A Monte Carlo simulation for the physics run was developed and has been tuned based on measurement results. Algorithms for reconstruction of track, momentum and charge were also developed and improved based on results of the simulation study. In this poster, the physics performance of the T2K-WAGASCI experiment evaluated with the simulation and the improved algorithms will be shown.

Working Group:

WG1 : Neutrino Oscillation Physics

Poster session - Board: 66 / **66**

Prospect and status of the physics run of the NINJA experiment

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Neutrino-nucleus interaction is a major source of the systematic uncertainty for neutrino oscillation experiments.
The NINJA experiment aims to measure the neutrino-water interactions precisely with a nuclear emulsion detector called Emulsion Cloud Chamber (ECC).
Nuclear emulsion has sub-micron position resolution and it allows us to detect short tracks of low momentum secondary charged particles such as protons.

In the NINJA experiment, a muon detector is placed downstream of ECC because ECC cannot get information of muons from ν_μ charged current interactions by itself.
In contrast with its good position resolution, nuclear emulsion doesn't have timing information and too many tracks are accumulated in the detector during the whole experiment.
Therefore, the position resolution of the muon detector is not enough to connect the muon tracks to ECC one by one.
The NINJA experiment solves this problem by using a scintillator tracker between the muon detector and ECC, which has equivalent timing resolution and better position resolution.

The NINJA experiment is planning a physics run with a 68 kg water target from this November. Since the target mass is larger than previous runs, a larger tracker covering 1m $\times$ 1m area is needed.

In this presentation, we will show the status of preparation for the physics run, especially about development of the new scintillator tracker.

Working Group:

WG2 : Neutrino Scattering Physics

Poster session - Board: 71 / **71**

KM3NeT/ORCA: status and prospects

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The KM3NeT collaboration is currently building the next generation of large-volume water Cherenkov neutrino telescopes in the Mediterranean Sea abysses. ORCA, the denser of the two detectors under construction, will instrument about 6 Mton of sea water. It is optimised for the detection of atmospheric neutrinos with energies above several GeV. The main research target of the ORCA detector is the measurement of the neutrino mass ordering and atmospheric neutrino oscillation parameters, while the detector is also sensitive to a wide variety of other physics topics, such as dark matter, non-standard interactions and sterile neutrinos. The presentation will provide an overview of the ORCA detector and
introduce its research programme. The projected sensitivity of the detector to the neutrino mass ordering will be shown, alongside prospects for early analyses of data collected with a small sub-array of the detector during construction phase.

Working Group:

WG1 : Neutrino Oscillation Physics

Poster session - Board: 72 / **72**

Neutrino oscillation results of the OPERA experiment in the CNGS beam

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The OPERA experiment was designed to observe the appearance of tau neutrino in the muon neutrino CNGS beam. This goal was successfully reached by observing a high purity sample of ν_τ charged current (CC) interaction candidate events. Additionally, it was possible to isolate samples of ν_e and ν_μ CC candidates, as well as neutral current candidate events. These four samples were used to put additional constraints on parameters of both standard neutrino mixing model and the

3 + 1 sterile model. This talk will review the methodology of measuring neutrino interactions using the OPERA apparatus and give an overview of all results on neutrino oscillations produced by the experiment. In particular, a joint analysis of ν_τ and ν_e samples will be shown which excludes a significant fraction of the sterile neutrino phase space allowed by MiniBooNE appearance analysis.

Working Group:

WG1 : Neutrino Oscillation Physics

Poster session - Board: 86 / **86**

Search for heavy Majorana neutrinos at LHC using the CMS detector

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We present a search for heavy Majorana neutrinos, using pp collision data collected with the CMS detector at the centre-of-mass energy of 13 TeV in 2016. The search targets for heavy neutrino in the Type-I seesaw mechanism where the mass ranges from 20 GeV to 1300 GeV, which is wider range than the study performed using the 8 TeV data. The vector boson fusion production channel is also considered in addition to the s-channel, which improves the sensitivity for masses above several hundreds of GeV. We set upper limits on mixing parameters with standard model neutrinos as a function of heavy neutrino mass.

Working Group:

WG5 : Neutrinos Beyond PMNS

Poster session - Board: 89 / **89**

Neutrinos from Accelerator in the KISTI-5 supercomputing era

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In November 2018, KISTI-5 supercomputer has launched. It is the heterogeneous machine of 25.3 PF Cray 3112-AA000T with Intel Xeon Phi KNL (Knight Landing) 7250 processor which has 68 cores per processor. The goal of this presentation is to discuss the application and usages of Intel KNL-based system of KISTI-5 supercomputer for neutrinos from accelerators.

First, the world is made of dark energy, dark matter and the Standard Model particles. The Standard Model is the last frontier of universe. Evolving universe is towards a unified description of the nucleus. Let us show some of potential works – physics beyond the Standard Model, simulation, evolving universe and so on.

Second, the Standard Model in particle physics is refined. However, new physics beyond the Standard Model, such as dark matter, requires thousand to million times of simulation events compared to those of the Standard Model. Thus, the development of software is required. Let us show the current status and future plan for these.

Working Group:

WG3 : Accelerator Physics

Satellite meeting / 91

Review of Neutrino Experiments in Korea

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Satellite meeting / 92

Overview of Korean Neutrino Observatory (KNO) Project

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Satellite meeting / 169

Hyper-Kamiokande Project

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Satellite meeting / 94

Particle Physics at KNO

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Satellite meeting / 95

Astronomy at KNO

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KNO Detector R&D

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Panel Discussion for Future Efforts and Plans

Satellite meeting / 93

Korean Efforts on KNO Realization

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New Results from Double Chooz

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New Results from RENO

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Daya Bay: Recent Results and Status

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The Daya Bay Reactor Neutrino Experiment has accumulated the largest sample of reactor antineutrino interactions to date and will continue operating until the end of 2020. The experiment consists of eight identically designed antineutrino detectors placed underground at different baselines from six 2.9 GWth nuclear reactors. In this talk I will give an overview of our recent results, including our latest measurement of the oscillation parameters that drive the disappearance of electron antineutrinos at short baselines with a 1958-day data set, as well as the first simultaneous extraction of the individual antineutrino spectra from 235U and 239Pu with commercial reactors. I will also briefly review the prospects for the experiment.

Working Group:

Working Group 1 / 98

Neutrino oscillation studies in JUNO

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The neutrino oscillation is the first observed phenomenon beyond the standard model, which can be interpreted in the framework of three neutrino mixings. It is governed by three mixing angles, two mass-squared differences, and one Dirac CP violation phase. The neutrino mass ordering, CP violation phase and the octant of θ_{23} remain unknown and could be measured by next-generation neutrino oscillation experiments. Jiangmen Underground Neutrino Observatory (JUNO) consists of a 20 kiloton liquid scintillator detector, which primarily aims to determine the neutrino mass orderings by measuring the reactor antineutrino oscillation pattern at a baseline of about $53\,\mathrm{km}$. A $3\sim4\sigma$ significance to resolve mass orderings could be reached after 6 years of operation benefiting from its unprecedented 3\% energy resolution at 1 MeV. Besides, JUNO is able to perform measurements at an accuracy of better than 1\% to oscillation parameters $\sin^2\theta_{12}, \Delta m^2_{21}$ and Δm^2_{32}. In this talk, neutrino oscillation studies in JUNO will be reviewed.

Working Group:

WG1 : Neutrino Oscillation Physics

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Recent Results from Super-Kamiokande

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Status and results from the ANTARES and KM3NeT-ARCA neutrino telescopes

Authors: Paolo Fermani[1]; on behalf of the ANTARES and KM3NeT collaboration[None]

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In the Mediterranean Sea there are two neutrino telescopes: ANTARES, currently the largest one, has been operating for more than 10 years. ANTARES provides unprecedented sensitivity for neutrino source searches in the Southern Sky at TeV energies, so that valuable constraints can be set on the origin of the cosmic neutrinos discovered by the IceCube detector. ANTARES has also constrained the neutrino emission from possible Dark Matter annihilation in massive objects like the Sun or the Galactic Centre, and measures the neutrino oscillation parameters in the atmospheric sector.
Building on the ANTARES experience, a new, much larger detector with improved design and technologies is under construction on two sites in the Mediterranean sea: KM3NeT. Deployed off the coast of Sicily, the ARCA detector (Astroparticle Research with Cosmics in the Abyss) will be dedicated to the detection of high-energy astrophysical neutrinos. When completed, the KM3NeT-ARCA detector will exceed one kilometre cube dimensions, with an excellent angular resolution in the reconstruction of signatures of neutrino of all flavors in a very clear deep-sea water environment. Thanks to its position on the Northern hemisphere, KM3NeT-ARCA can observe up-going neutrinos from the majority of the Galactic Plane. Along with studying the neutrino fluxes from different astrophysics sources, it will look for neutrinos from Dark Matter annihilation. The latest results from ANTARES and the perspectives of the KM3NeT-ARCA detector will be presented.

Working Group:

WG1 : Neutrino Oscillation Physics

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KM3NeT-ORCA

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Latest Results on Neutrino Oscillation from the IceCube Neutrino Observatory

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The IceCube Neutrino Observatory is a cubic-km size detector consisting of 5000 light sensors buried within the ice of the South Pole. Together with its inner array DeepCore (which has a lower energy threshold of ˜ 5GeV), IceCube detects neutrinos of all flavours by recording the Cherenkov light emitted by both neutral and charged current interactions within the ice. Given its ˜GigaTon detection volume and sensitivity to a wide range of energies and baselines, IceCube is well suited to perform neutrino oscillation measurements, using neutrinos produced by cosmic rays in the atmosphere.

Neutrino oscillation is an important probe for exploring the limits of current paradigms in particle physics, and offers an experimental handle to find evidence for new physics. IceCube does so by performing precision measurements of the properties of oscillations, such as muon neutrino disappearance and tau neutrino appearance. It can also probe the neutrino mass ordering, and test multiple theoretical predictions of new physics, such as the existence of sterile neutrinos and Non-Standard Interactions (NSI). This talk will present the latest neutrino oscillation results from the IceCube Collaboration

Working Group:

WG1 : Neutrino Oscillation Physics

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Using low energy atmospheric neutrinos for precision measurement of mixing parameters

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By formulating a new perturbative framework we try to reveal characteristic features of neutrino oscillation which are relevant for possible precision measurement of mixing parameters. Most notably, we show that the effect of CP phase is larger by a factor of ˜10 compared to conventional LBL experiments such as T2HK and DUNE. I also mention possible ways for improving uncertainty of atmospheric neutrino flux at low energies.
(based on arXiv:1904.07853, together with some later progress)

Working Group:

WG1 : Neutrino Oscillation Physics

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Details of the new NOvA oscillation analyses

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NOvA is a world-leading long-baseline neutrino oscillation experiment. It uses the 700 kW NuMI beam at Fermilab to send muon neutrinos to two functionally identical detectors, located slightly off the beam axis. The Near Detector is located underground in Fermilab, while the much bigger 14 kton Far Detector sits on the surface, 810 km further away, in Minnesota. They share the same experimental design in an effort to largely reduce the flux and cross-section systematics uncertainties. They are composed of plastic cells filled with liquid scintillator. The fine granularity allows the detection and identification of particle interactions in the detectors, notably muon and electron neutrino interactions. Thus, NOvA can measure the electron neutrino and antineutrino appearance rates, as well as the muon neutrino and antineutrino disappearance rates, in order to constrain the neutrino oscillations parameters, the neutrino mass hierarchy and the CP-violating phase δ_{CP}. This talk will present in details some of the techniques and tools used in the latest NOvA oscillation analyses, combining both neutrino and antineutrino data.

Working Group:

WG1 : Neutrino Oscillation Physics

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Recent T2K Neutrino Oscillation Results

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T2K is a long baseline neutrino experiment producing a beam of muon neutrinos at the Japan Particle Accelerator Research Centre on the East coast of Japan and measuring their oscillated state 295 km away at the Super Kamiokande detector. Since 2016 T2K has doubled its data in both neutrino and antineutrino beam modes. Coupled with improvements in analysis techniques this has enabled the experiment to make world leading measurements of the PMNS oscillation parameters \Delta_m^{2}*{32}, sin^2(\theta*{23}) and the CP violating phase \delta_{CP}. In particular the CP conserving values of \delta_{CP} now appear to be disfavoured at the 95\% CL and there are regions of parameter space excluded at the 99.7\% CL. This talk will describe these results and the analysis improvements that have enabled them.

Working Group:

WG1 : Neutrino Oscillation Physics

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Overview of ESSνSB experiment to measure δ_{CP}

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In this talk I will discuss the capability of the ESSνSB experiment to measure leptonic CP phase δ_{CP}. In particular I will discuss, (i) sensitivity for different baseline options, (ii) the effect of systematic errors and (iii) optimisation of the neutrino to antineutrino run ratio. In addition I will also present a comparative analysis between T2HK and ESSνSB, pointing out the physics differences between these two experiments in measuring δ_{CP}.

Working Group:

WG1 : Neutrino Oscillation Physics

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DUNE Oscillation Physics

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Physics potential of Hyper-Kamiokande for neutrino oscillation measurements

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Hyper-Kamiokande (Hyper-K) is a next generation underground water Cherenkov neutrino detector. It will serve as a far detector for a long baseline neutrino oscillation experiment using the J-PARC neutrino beam, with sensitivity to exclude CP conservation over a range of parameter space. Hyper-K has a broad physics program, with further sensitivity to proton decay, atmospheric neutrinos, and neutrinos from astronomical sources. The experimental set-up will be described as well as the physics potential, with particular reference to the sensitivity for CP violation.

Working Group:

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Status of the detector design studies for ESSnuSB

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The European Spallation Source Neutrino Super Beam (ESSnuSB) project aims at a discovery of leptonic CP violation with a precise measurement of the CP phase angle. ESSnuSB is characterized by an intense neutrino beam to be produced at the ESS by a 5-MW proton beam, and the placement of the far detector at the second oscillation maximum.

Preliminary performance assessments of different near-detector designs and of the far water Cherenkov detector, based on Geant4 simulations and a previously developed Cherenkov ring reconstruction algorithm, will be presented. Possible detector media and geometries will be discussed in the context of particle identification and energy reconstruction.

Working Group:

WG1 : Neutrino Oscillation Physics

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Dune ND

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First Results from Singe-Phase ProtoDUNE at CERN Neutrino Platform

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Working Group:

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ARIADNE: A novel photographic 1-ton dual-phase LArTPC

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ARIADNE, a state-of-the-art 1-ton two-phase Liquid Argon Time Projection Chamber (LAr TPC), features a game-changing photographic readout utilising photon sensitive cameras to image the secondary scintillation light produced in THGEM holes. ARIADNE underwent testing at the T9 beam line, CERN East Area in Spring 2018. ARIADNE is the first two-phase LAr TPC with photographic capabilities to be positioned at a charged particle beamline, and we successfully imaged beautiful LAr interactions with 1 mm track resolution at momenta between 0.5 GeV to 8 GeV. Recently, we have been successfully working on a further enhancement of the detector by integrating an ultra-fast imaging system based on the well-established TimePix3 sensor. With this technology we have now created a dream TPC in which you can take videos of particle interactions with ns time resolution and mm spatial resolution just based on light. The system is ideal for colossal dual phase LAr neutrino detectors. Results from the beam-test and the 3D TimePix3 TPC system will be presented detailing the many benefits and capabilities of this technology.

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

Working Group:

WG1 : Neutrino Oscillation Physics

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The double calorimetry system in JUNO

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The JUNO detector was designed to achieve 3% energy resolution which required 18k high quantum efficiency 20-inch PMTs (LPMTs) closely packed around liquid scintillator (LS) target ball. Beside this, 25k 3-inch PMTs (SPMTs) were also designed to install between the gaps of LPMTs to make a double calorimetry system to improve and extend JUNO physics, such as improving energy resolution, muon reconstruction, supernova neutrino detection and so on.
Now PMTs are producing, include 15k MCP LPMTs from Chinese NNVT company, 5k Dynode LPMTs from Japanese Hamamatsu company and 26k SPMTs from Chinese HZC company. Until now more than 15k LPMTs and SPMTs are produced respectively. Performance test data so far indicate that both LPMTs and SPMTs perform as expected. Both system's high voltage divider, potting, cabling, connector have passed the production readiness review. The splitter, electronics and underwater box are all making good progress.

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The upgrade of the T2K Near Detector ND280

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In view of the J-PARC program of upgrades of the beam intensity, the T2K collaboration is preparing towards an increase of the exposure aimed at establishing leptonic CP violation at 3 σ level for a significant fraction of the possible δ_{CP} values. To reach this goal, an upgrade of the T2K near detector ND280 has been launched, with the aim of reducing the overall statistical and systematic uncertainties at the appropriate level of better than 4\%.
We have developed an innovative concept for this neutrino detection system, comprising the totally active Super-Fine-Grained-Detector (SuperFGD), two High Angle TPC (HA-TPC) and six TOF planes.
The SuperFGD, a highly segmented scintillator detector, acting as a fully active target for the neutrino interactions, is a novel device, (JINST 13 (2018) no.02, P02006; NIM A923 (2019) 134), with dimensions of ˜2x1.8x0.6 m3 and a total mass of about 2 tons. It consists of about 2x106 small scintillator cubes each of 1 cm3. Each cube is covered by a chemical reflector. The signal readout from each cube is provided by wavelength shifting fibers inserted connected to micro-pixel avalanche photodiodes MPPCs. The total number of channels will be ˜60,000. We have demonstrated that this detector, providing three 2D projections, has excellent PID, timing and tracking performance, including a 4π angular acceptance, especially important for short proton and pion tracks.
The HA-TPC will be used for 3D track reconstruction, momentum measurement and particle identification. These TPC, with overall dimensions of 2x2x0.8 m3, will be equipped with 32 resistive Micromegas. The thin field cage (3 cm thickness, 4% rad. length) will be realized with laminated panels of Aramid and honeycomb covered with a kapton foil with copper strips. The 34x42 cm2 resistive bulk Micromegas will use a 500 kOhm/square DLC foil to spread the charge over the pad plane, each pad being appr. 1 cm2. The front-end cards, based on the AFTER chip, will be mounted on the back of the Micromegas and parallel to its plane.
The time-of-flight (TOF) detector will allow to reject events generated in the passive areas of the detector and improve particle identification. The TOF will consist of 6 planes with about 5 m2 surface area surrounding the SuperFGD and the TPCs. Each plane will be assembled with 2.2 m long cast plastic scintillator bars with light collected by arrays of large-area MPPCs from two ends. The time resolution at the bar centre is 150 ps.
In Summer 2018 we have tested prototypes of the SuperFGD, the resistive Micromegas and the TOF in a CERN PS test beam with excellent results.
We have recently completed the detailed TDR describing all the components of the ND280 Upgrade (arXiv:1901.03750). The project has been recently approved by CERN as part of the Neutrino Platform (NP07). In this talk we will report on the design of these detectors, their performance, the results of the test beam and the plan for the construction.

Working Group:

WG2 : Neutrino Scattering Physics

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First physics run of the WAGASCI-BabyMIND detector with full setup

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WAGASCI-BabyMIND is a set of new neutrino detectors to measure the neutrino cross-section with the T2K neutrino beam. It is composed of neutrino detectors made of water and scintillator surrounded by muon range detectors made of iron and scintillator. The downstream muon range detector is magnetized to discriminate the charge of the muons. It is located in the same building as ND280 but at the different off-axis angle from ND280. The WAGASCI experiment has just completed in summer 2018 its commissioning run with a reduced setup. The next physics run with the full setup is scheduled to start at the end of May 2019 and will last approximately a month. More physics runs are scheduled later this year and in the next years. In this talk, we will present the preliminary results of the first full setup run and the future prospect of the neutrino cross section measurement with the WAGASCI-BabyMIND detector.

Working Group:

WG2 : Neutrino Scattering Physics

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Nuclear emulsion detector for future neutrino research - NINJA and EMPHATIC -

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Nuclear emulsion is a three dimensional tracking detector with sub-micron resolution. Thanks to its high spatial resolution, emulsion can detect short-length low energy tracks and measure track angle precisely in neutrino/hadron interactions. Moreover, the emulsion has 4 pi solid angle acceptance (it's also useful to measure low energy tracks) and can use target materials flexibly, not only carbon and iron, but also water. These detector capabilities of nuclear emulsion are suitable to measure neutrino/hadron interaction precisely and therefore it is used in NINJA experiment and EMPHATIC experiment to reduce the systematic uncertainties from neutrino cross-sections and neutrino flux in current and future neutrino oscillation experiments.
In this talk, I will talk the latest developments in nuclear emulsion technology and the status/future prospects of NINJA and EMPHATIC.

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ENUBET

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The knowledge of initial flux, energy and flavor of current neutrino beams is currently the main limitation for a precise measurement of neutrino cross sections. The ENUBET ERC project (2016-2021) is studying a facility based on a narrow band neutrino beam capable of constraining the neutrino fluxes normalization through the monitoring of the associated charged leptons in an instrumented

decay tunnel. Since March 2019, ENUBET is also a CERN Neutrino Platform project (NP06/ENUBET) developed in collaboration with CERN A&T and CERN-EN.

In ENUBET, the identification of large-angle positrons from Ke3 decays at single particle level can potentially reduce the νe flux uncertainty at the level of 1%. This setup would allow for an unprecedented measurement of the νe cross section at the GeV scale. Such an experimental input would be highly beneficial to reduce the budget of systematic uncertainties in the next long baseline oscillation projects (i.e HyperK-DUNE). Furthermore, in narrow-band beams, the transverse position of the neutrino interaction at the detector can be exploited to determine a priori with significant precision the neutrino energy spectrum without relying on the final state reconstruction.

This contribution will present the final design of the ENUBET demonstrator, which has been selected on April 2019 on the basis of the results of the 2016-2018 testbeams. It will also discuss advances in the design and simulation of the hadronic beam line. Special emphasis will be given to a static focusing system of secondary mesons that, unlike the other studied horn-based solution, can be coupled to a slow extraction proton scheme. The consequent reduction of particle rates and pile-up effects makes the determination of the νμ flux through a direct monitoring of muons after the hadron dump viable, and paves the way to a time-tagged neutrino beam. Time-coincidences among the lepton at the source and the neutrino at the detector would enable an unprecedented purity and the possibility to reconstruct the neutrino kinematics at source on an event by event basis. We will also present the performance of positron tagger prototypes tested at CERN beamlines, a full simulation of the positron reconstruction chain and the expected physics reach of ENUBET.

Working Group:

WG2 : Neutrino Scattering Physics

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First cross section measurement of neutrino charged current interactions in the iron ECC

Author: Hitoshi Oshima[1]

Co-authors: Hiroshi Shibuya [1]; Satoru Ogawa [1]; Tomokazu Matsuo [1]; Yusuke Morimoto [1]; Yusuke Kosakai [1]; Kousaku Mizuno [1]; Hideaki Takagi [1]; Tsutomu Fukuda [2]; Tsuyoshi Nakaya [3]; Ayami Hiramoto [3]; Yoshinari Hayato [4]

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Understanding of neutrino-nucleus interactions for energies around 1 GeV is of great importance to us because one of the major systematic uncertainties in current neutrino oscillation experiments comes from nuclear effects in those interactions.
The NINJA collaboration aims to study neutrino-nucleus interactions in the energy range of hundreds of MeV to a few GeV by using emulsion-based detector. Nuclear emulsion is well suited for precise measurement of positions and angles of interacting particles since it has sub-micron spatial resolution. It is capable of detecting slow protons as low as 200 MeV/c, which is its advantage over other detectors.
In this talk, we use the data collected in 2016, corresponding to 0.40×10^{20} protons on target. Based on a few hundred events in the target, we will present a measurement of the neutrino charged current cross section on iron with the emulsion cloud chamber (ECC). This is the first measurement using the iron ECC in this energy region.

Working Group:

WG2 : Neutrino Scattering Physics

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SHIP

Author: TBD[None]

Working Group:

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Status of SBND

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Status of JSNS2 experiment

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JSNS2 experiment is a sterile neutrino experiment being prepared at J-PARC MLF beam line. The experiment directly tests the LSND sterile neutrino result using the same neutrino (muon decay at rest) and the same detection reaction (inverse beta decay), yet much better S/N ratio, statistics and energy resolution. The group is now constructing the detector aiming at starting the data taking soon. In this presentation, I will talk about the experiment and its status.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Sterile Neutrinos search via NC disapperance at NOvA

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Three-flavor neutrino oscillations have successfully explained a wide range of neutrino oscillation data. However, the excess of events as seen by the LSND and MiniBooNE experiments and the deficit

of events seen at the GALLEX and SAGE experiments when exposed to a calibration source can be interpreted as short-baseline neutrino oscillations consistent with the existence of a sterile neutrino state with a mass near 1 eV.

While these results are tantalizing, they are not conclusive, as they are in tension with null results from other short-baseline experiments and disappearance searches in long-baseline and atmospheric experiments. Resolving the issue of the existence of light sterile neutrinos has profound implications for both particle physics and cosmology.

The NOvA (NuMI Off-Axis νe Appearance) experiment may help clarify the situation by searching for disappearance of active neutrinos from the NuMI (Neutrinos from the Main Injector) beam over a baseline of 810 km. In this talk, I will present the latest results from NOvA on searching for oscillations of active neutrinos into sterile neutrinos by looking for a deficit of neutral current events relative to expectations, using an antineutrino beam.

Working Group:

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Sterile Neutrino Searches with IceCube

Author: Joshua Hignight[None]

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The IceCube neutrino observatory is a cubic km neutrino telescope located at the geographic South Pole and can detect neutrinos with energies up to a few PeV. DeepCore is an infill array of the IceCube Neutrino Observatory that lowers the detectable energies of neutrinos to as low as 5 GeV. This wide range of atmospheric neutrinos allow for a broad range of particle physics, from measuring standard neutrino oscillations to probing BSM physics. In this talk I will discuss two different methods to search for sterile neutrinos utilizing the IceCube detector.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Detector Physics with MicroBooNE

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With many current and future neutrino experiments relying on Liquid Argon Time Projection Chamber (LArTPC) technology, characterizing the performance of these detectors is critical. The MicroBooNE experiment is capable of performing numerous measurements to better understand the technology. These include identification and filtering of excess TPC noise, signal calibration, recombination, and measurements of drift electron attenuation. MicroBooNE, residing on the surface, can also provide important information about cosmic ray induced space charge in the TPC volume and the subsequent deformations to the electric field. This talk will provide a detailed overview of the subtleties of understanding LArTPC technology and developing calibration techniques towards extracting physics measurements.

Working Group:

WG1 : Neutrino Oscillation Physics

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NOvA

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Recent Cross-section Measurements from MicroBooNE

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MicroBooNE is a liquid argon time projection chamber in the Booster Neutrino Beam at Fermilab. The large event rate and 3 mm wire spacing of the detector provide high-statistics, precise-resolution imaging of neutrino interactions leading to low-threshold, high-efficiency event reconstruction with full angular coverage. As such, this is an ideal place to probe neutrino-argon interactions in the hundreds-of-MeV to few-GeV energy range, and to study the impact of nuclear effects through detailed measurements of hadronic final states. This talk will present recent measurements of neutrino interactions in MicroBooNE, including inclusive charged-current interactions, neutral-pion production, and measurements of low-energy protons.

Working Group:

WG2 : Neutrino Scattering Physics

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Hadron Production Measurements from interactions of 60 GeV/c π^+ with Carbon and Beryllium with NA61/SHINE

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In 2016, NA61/SHINE, a fixed target experiment at the CERN SPS, recorded interactions of 60 GeV/c π^+ with thin carbon and beryllium targets. Three analyses were performed to measure total cross sections and doubly differential cross sections of produced hadrons. A total cross section analysis was used to determine the total production and total inelastic cross sections for the two reactions. A V0 analysis was used to measure spectra of the produced neutral hadrons: K^0_S, Λ and $\bar{\Lambda}$. Finally, a dE/dx analysis was used to measure spectra of the produced charged hadrons: π^+, π^-, K^+, K^-

and protons. These measurements will allow NOνA, DUNE and other neutrino experiments to constrain their neutrino flux predictions and make more precise measurements of neutrino oscillation parameters.

Working Group:

WG1 : Neutrino Oscillation Physics

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COHERENT

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The Neutrino Elastic-scattering Observation experiment with NaI[Tl] crystal (NEON)

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Standard-Model predicted coherent elastic neutrino-nucleus scattering is interesting for measuring neutrino properties but is not yet detected for reactor neutrinos. For this measurement, we will use an array of NaI[Tl] crystals which show advantages for high light yields as a low threshold detector. The Hanbit reactor site in Korea provides 2.8 GW of thermal power and neutrino flux at detector 24m distant from reactor core is measured to be $7.02 \times 10^{12}/cm^2/s$. The current R&D shows that a light yield of a crystal is more than 20 PE/keV which would make a sub-keV scintillation signal accessible. Our experiment will include a total of 8 kg target mass with a liquid scintillator veto for various backgrounds, and lead, cooper, and polyethylene for further environmental background shielding.

Working Group:

WG2 : Neutrino Scattering Physics

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Electron versus muon neutrino induced cross sections in charged current quasi-elastic processes

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Elastic neutrino-electron scattering within the effective field theory approach

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Elastic neutrino-electron scattering provides an important tool for normalizing neutrino flux in modern experiments. This process is subject to large radiative corrections. We determine the Fermi effective theory performing the one-loop matching to the Standard model at the electroweak scale with subsequent running down to low energies. Based on this theory, we analytically evaluate virtual corrections and distributions with one radiated photon beyond the electron energy spectrum and provide the resulting scattering cross sections quantifying errors for the first time. We discuss the relevance of radiative corrections depending on conditions of modern accelerator-based neutrino experiments.

Working Group:

WG2 : Neutrino Scattering Physics

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One pion production in nucleon and nuclei

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Working Group 2 / 207

Influence of cross section uncertainties on oscillation analysis

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Working Group 2 / 208

Report on Trento Workshop 'Testing and Improving Models of Neutrino Nucleus Interactions in Generators'

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Towards a better understanding of neutrino-16O NCQE: study of the gamma-rays from knocked out neutron-16O interaction

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Neutral Current Quasi Elastic interactions (NCQE) of atmospheric neutrinos with 16O is a source of irreducible background for Supernova Relic Neutrinos (SRN) searches in water Cherenkov detectors like Super Kamiokande.
To get a better understanding of this background, T2K measures NCQE cross section via gamma rays emitted by 16O de-exciting after its interaction with a neutrino. However, there are large systematic errors on this measure as it is very difficult to separate the gamma rays emitted by the initial interaction of neutrino and 16O from the secondary gamma rays emitted by the interaction of knocked out neutrons and 16O. To solve this problem, the rate of secondary gamma ray production is determined by T2K using Monte Carlo simulations, but the results don't match the data and present high uncertainties, due to the lack of experimental data for photon emission from neutron interaction above 20 MeV.
Therefore, at the Research Center for Nuclear Physics of Osaka University (RCNP), an experiment was realized at the end of 2018 to measure the secondary gamma ray production cross section. This presentation will focus on this new experiment using a neutron beam at two different energies (30 MeV and 250 MeV) on a water target. Gamma rays are studied with high precision by using an High Purity Germanium detector (HPGe). In order to measure the production cross section, two other detectors are also used: an organic liquid scintillator to get the neutron flux and a CsI(Tl) scintillator for scattered neutron background estimation.

Working Group:

WG2 : Neutrino Scattering Physics

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Neutral Current events and new physics at nuSTORM

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WG2 Discussion

Working Group:

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MINERvA

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J-PARC Neutrino Beamline and 1.3 MW Upgrade

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Novel Approaches to High-Power Proton Beams

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Neutrino Source for Strile Neutrino Searches

Author: Tomoyuki Konno[1]

[1] *Kitasato University*

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Design Studies of the LBNF/DUNE Target

Author: Chris Densham[1]

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Radiation Damage Experiments (RaDIATE)

Author: David Senor[1]

[1] *PNNL*

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The HiRadMat and high power targetry

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Intense and high-energy proton beams are impacted onto fixed targets within the CERN's accelerator complex to produce secondary particles (such as neutrons, antiprotons, kaons, pions, etc.) for physics experiments. A consolidation program of some of these particle-producing targets is currently ongoing at CERN. This includes the antiproton and neutron production targets (AD-Target and n_TOF Target respectively). At the same time, the Beam Dump Facility (BDF) Project study, aiming at exploring feebly interacting particles and employing a high power production target, has been launched. These different projects involve extensive R&D activities to assess the specific challenges related to the thermomechanical response of these high power targets: (i) For the AD-Target the main challenge lies in the extreme dynamic loading of its high-density core, constituted by a high-density refractory metal. (ii) For the n_TOF target lays in the behavior of a soft material such as Pb under the highly dynamics thermal loads induced by the primary beam impacts and the delicate balance between the physics reach and the required reliability. (iii) For BDF the challenge lies in the high power density and respective cooling as well as in the implementation of manufacturing techniques capable of guaranteeing an effective target cooling and high reliability.
Some of these R&D activities have profited from the execution of proton-beam experiments using the CERN's HiRadMat facility, which provide intense and fast extracted 440 GeV/c proton beams for testing targets and accelerator components while monitoring their response by means of online instrumentation. This contribution will provide a summary of these activities, which could also be transversally applied to the design of future high power neutrino targets.

Working Group:

WG3 : Accelerator Physics

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ESSnuSB Linac Design and Beam Dynamics

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The ESS neutrino superbeam project is being studied as an upgrade to the European Spallation Source. This would entail the addition of an H− source to the existing beamline to send H− pulses in between proton pulses, effectively doubling the beam power from five to ten megawatts. An obstacle to smooth operation is the intra-beam stripping of H− within bunches, preliminary beam transport simulations are performed to quantify the magnitude of such losses. Recent design work is also reviewed, including the added cavities for increasing beam energy from 2 to 2.5 GeV and favored bunch pulsing schemes

Working Group:

WG3 : Accelerator Physics

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The accumulator ring for the ESSnuSB project - a progress report

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The 2.0 GeV, 5 MW proton linac for the European Spallation Source, ESS, will have the capacity to accelerate additional pulses and send them to a neutrino target, providing an excellent opportunity to produce an unprecedented high performance neutrino beam, the ESS neutrino Super Beam (ESSnuSB). ESSnuSB aims at measuring, with precision, the CP violating angle at the 2nd oscillation maximum using a megaton-scale Water Cherenkov detector located a few hundred kilometres from the neutrino source. In order to comply with the acceptance of the target and horn systems that will produce the neutrino super beam, the long pulses from the linac must be compressed by about three orders of magnitude with minimal particle loss. This will be achieved through multi-turn charge-exchange injection in an accumulator, which should be able to accommodate over 2E14 protons. Several design challenges are encountered, such as space charge forces, low-loss injection with phase space painting, a reliable charge stripping system, efficient collimation, and e-p instabilities. This report focuses on the progress of the accumulator design, with multi-particle simulations of the injections procedure.

Working Group:

WG3 : Accelerator Physics

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The Design Study of the Target Station for the ESS Neutrino Super Beam Project

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The ESSnuSB project proposes the production of a European neutrino Super Beam for the discovery of the CP symmetry violation in the leptonic sector. For this purpose, an upgrade is under design of the 5 MW, 2 GeV proton beam from the LINAC of the European Spallation Source, currently under construction in Lund (Sweden), to obtain an additional 5 MW power beam dedicated to the neutrino production, without therefore reducing the neutron production efficiency. The additional proton beam will be then directed to an accumulator and split through a switchyard in four beams, each of 1.25 MW power. The secondary beam will be delivered to a target station consisting of four target-horn collectors, a decay tunnel, and a beam dump. A dedicated design study of the Target Station is required to optimize the lifetime of the horn, regarding mechanical and thermal constraints, and the CP sensitivity of the experiment. The current status of this design study is here presented. This project is supported by a COST Action and an EU H2020 Design Study.

Working Group:

WG3 : Accelerator Physics

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Development of New Proton Beam Monitors for J-PARC 1.3 MW Upgrade

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Working Group:

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Novel RF Hadron Beam Monitor

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Working Group:

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Development of New Muon Monitors for J-PARC Neutrino Experiment

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NuMI Neutrino Beam Operations and Megawatt Upgrade

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Fermilab's NuMI (Neutrinos at the Main Injector) provides an intense, high-energy flux of muon-neutrinos toward the far detector in Ash River, Minnesota for the NOvA experiment. It's neutrino beamline target system is under upgrade with the goal to make the beamline components and associated support systems robust at beam power up to 1 MW. This talk will cover the NuMI beam operation status, the upgrade project scope, issues to be addressed, schedule, the implementation plans and status.

Working Group:

WG3 : Accelerator Physics

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Updated design studies at 25 kW for EMuS at CSNS

Author: Nikolaos Vassilopoulos[1]

Co-author: on behalf of EMuS

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EMuS (Experimental Muon Source) at CSNS (China Spallation Neutron Source) is a multidisciplinary project concerning very intense muon and pion beams mainly for muSR applications and particle physics. EMuS provides very intense beams by having as target system a unique superconducting capture solenoid incorporating a conical graphite target, with forward collection of muons and pions, and extraction of spent protons. Updated studies for the target station design and muon/pion rates at 25 kW/CSNS-II are presented as well as the neutrino beam intended for low energy neutrino cross sections measurements. In parallel, the layouts of the related downstream muon and pion beamlines are discussed. In addition, a typical muSR beamline with quadruple collection foreseen as starting scheme of the project is also presented.

Working Group:

WG3 : Accelerator Physics

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Design of nuSTORM facility for a potential implementation at CERN

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In nuSTORM facility pions are injected into the storage ring and a resulting circulating muon beam creates a neutrino flux with a perfectly know flavour content and spectrum. This makes nuSTORM an ideal laboratory to measure precisely neutrino interactions and to search for sterile neutrinos. Moreover, it may also offer to test novel concepts required for a future Muon Collider, like 6D cooling of muon beams, etc. The update of the injection line design and a novel hybrid storage ring design based on a fixed field accelerator (FFA) lattice combined with a production straight containing quadrupoles is presented and its performance is evaluated. Details of a potential implementation at CERN site is also discussed.

Working Group:

WG3 : Accelerator Physics

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Progress on Muon Ionization Cooling Demonstration with MICE

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The Muon Ionization Cooling Experiment (MICE) at RAL has collected extensive data to study the ionization cooling of muons. Several million individual particle tracks have been recorded passing through a series of focusing magnets in a number of different configurations and a liquid hydrogen or lithium hydride absorber. Measurement of the tracks upstream and downstream of the absorber has shown the expected effects of the 4D emittance reduction.
Further studies are providing now more and deeper insight.

Working Group:

WG3 : Accelerator Physics

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Measurement from MICE of Coulomb multiple scattering and energy loss

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Multiple Coulomb scattering and energy loss are well known phenomena experienced by charged particles as they traverse a material. However, from recent measurements by the MuScat collaboration, it is known that the simulation code (GEANT4) available at the time overestimated the scattering of muons in low Z materials. Updates to GEANT4 have brought the simulations in line with the MuScat data and these new models can be validated over a larger range of momentum, 170-250 MeV/c, with MICE data. This is of particular interest to the Muon Ionization Cooling Experiment (MICE) collaboration which has the goal of measuring the reduction of the emittance of a muon beam induced by energy loss in low Z absorbers. MICE took data without magnetic field suitable for multiple scattering measurements in the spring of 2016 using a lithium hydride absorber and in the fall of 2017 using a liquid hydrogen absorber. The measurement in lithium hydride is reported here along with the preliminary measurements in liquid hydrogen. In the fall of 2016 MICE took data with magnetic fields on and measured the energy loss of muons in a lithium hydride absorber. These data are all compared with the Bethe-Bloch formula and with the predictions of various models, including the default GEANT4 model.

Working Group:

WG3 : Accelerator Physics

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Transverse/longitudinal emittance exchange in MICE

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The Muon Ionization Cooling Experiment, MICE, has demonstrated transverse emittance reduction through ionization cooling. Transverse ionization cooling can be used either to prepare a beam for acceleration in a neutrino factory or for the initial stages of beam cooling in a muon collider. Later stages of ionization cooling in the muon collider require the longitudinal emittance to be manipulated using emittance exchange and reverse emittance exchange, where emittance is exchanged from and to longitudinal phase space respectively. A wedge absorber within the MICE cooling channel has been used to experimentally demonstrate reverse emittance exchange in ionization cooling. Parameters
for this test have been explored in simulation and applied to experimental configurations using a wedge absorber when collecting data in the MICE beam. This analysis of reverse emittance exchange is presented in detail.

Working Group:

WG3 : Accelerator Physics

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WG3 Discussion

Working Group:

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Progress and scientific activities of the Japanese DC muon facility

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We started to provide DC muon beams to world wide users in 2015 at Osaka, Japan. The DC muon facility was built in Research Center of Nuclear Physics (RCNP) of Osaka University, and was named MuSIC.
In MuSIC, muons are generated using 392 MeV protons hitting a Graphite target. Then, all charged secondary particles are immediately captured by a 3.5 Tesla magnetic field. This particle capture system is the most unique feature of the MuSIC system. A radiation tolerant superconducting solenoid magnet was developed for the system. The captured pions and muons are transported by a 2 Tesla large-bore solenoid channel. The muon intensity at the end of the transport solenoid was measured as about 10 ^{8}/s for 1 μA proton beam in 2012. This successful demonstration is a great milestone toward the COMET experiment, which plans to use 10 ^{10}/s with a 56 kW proton beam at J-PARC. The second pion capture system designed for the COMET experiment is now under construction.
On the other hand, in 2013, the MuSIC transport solenoid was expended by a 18 m-long normal-conducting beam line to start muon programs at RCNP. After the beam line commissioning, finally official operations for users were started from November 2015. Sixteen user experiments have been already performed by 2019. The DC muon beam from the MuSIC beamline offers new opportunities to various users not only particle and nuclear physicists, but also material scientists, archaeologists and so on.
Progress and prospects of the RCNP-MuSIC facility will be presented in this paper.

Working Group:

WG4 : Muon Physics

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Status and Future Prospect of Muon Target at J-PARC MLF

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A pulsed muon beam with unprecedented intensity will be generated by a 3-GeV 333-microA proton beam on a muon target made of 20-mm thick isotropic graphite at J-PARC MLF MUSE (Muon Science Establishment). The energy deposited by a 1-MW proton beam is estimated to be 3.9kW in the muon target. The first muon beam was successfully generated on September 26th, 2008. Gradually upgrading the beam intensity, continuous 300-kW proton beam has been operated by a fixed target method without replacements till June of 2014. However, the lifetime of the fixed target will be less than 1 year by the proton-irradiation damage of graphite through 1-MW proton beam operation. To extend the lifetime, a muon rotating target, in which the radiation damage is distributed to a wider area, had been developed. In the rotating target, the lifetime of the bearings will have a dominant influence on the lifetime of the muon target. Disulfide tungsten is employed as solid lubricant for the bearings. The muon rotating target was installed in September, 2014. The stable operation by 500-kW proton beam has been conducted since April, 2018 without replacement. On 3rd July 2018, 935-kW proton operation for 1 hour was successfully completed. Furthermore, on 3rd July of 2019, 1-MW proton operation for 12 hours will be conducted.

In this presentation, the status and future prospect of the muon target at J-PARC MLF MUSE will be introduced.

Working Group:

WG3 : Accelerator Physics

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Development of next generation muon beams at Paul Scherrer Institute

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The Paul Scherrer Institute (PSI) provides the world′s highest intensity muon beam up to $\sim 10^8\ \mu^+/\mathrm{s}$ at $28\,\mathrm{MeV/c}$ momentum. The HiMB project aims to improve this rate by two orders of magnitude. Meanwhile, the muCool collaboration is developing a device which converts a standard surface μ^+ beam of cm-size and MeV-energy into a beam of 1 mm-size and 1 eV-energy by achieving a compression of 6-dimensional phase space by 10 orders of magnitude with an efficiency of 10^{-3}.

This talk will focus on the working principle of the muCool project, the various results obtained so far and the aims of the 2019 test beam. Some information about the HiMB project will be also presented. These works are supported by the SNF projects: 200020_172639 and 20021_137738.

Working Group:

WG4 : Muon Physics

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Design and development of a tungsten pion production target for the Mu2e experiment

Author: Christopher Densham[1]

Co-authors: Tristan Davenne [2]; Joe O'Dell [2]; Peter Loveridge [2]; Steve Werkema [3]; Kevin Lynch [4]; James Popp [4]; Robert Bernstein [3]; Vitaly Pronskikh [3]; Larry Bartoszek [5]; Patrick Hurh ; David Pushka [6]; Geoff Burton [2]; Nathan O'Donoghue [2]; Eric Harvey-Fishenden [2]

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The Mu2e experiment at Fermilab will search for the neutrino-less conversion of a muon to an electron in the field of a nucleus. Negative muons will be produced from the decay of pions generated by the interaction of an 8 GeV proton beam with a tungsten target. The target will be installed in the

bore of a production solenoid within a graded magnetic field so as to maximise the production and capture of low energy negative pions. Pion production is maximised in a dense and compact target material with a high atomic number. For a beam power of 8 kW the refractory metal tungsten is the most suitable material that is able in principle to directly radiate the 560 W heat load to the solenoid shield without the need for a coolant. However, the dimensions that optimise pion production are similar to those of a pencil, and the high operating temperature presents many engineering challenges that need to be overcome for a target to have the required lifetime, combined with significant radiological safety issues. This talk will present the development of the design and some innovative materials testing that has resulted in a potential compromise solution with a realistic chance of a 1-year lifetime.

Working Group:

WG3 : Accelerator Physics

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Mu2e Muon Beam Optimization

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Mu2e is a new experiment under construction at Fermilab, which will search for coherent neutrinoless conversion of muons to electrons. In order to reach its projected single-event sensitivity of 3×10^{-17}, Mu2e will create the most intense muon beam ever developed, with 10^{10} muons per second stopping in the stopping target. Optimization of this muon beam for Mu2e will be discussed.

Working Group:

WG3 : Accelerator Physics

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Status of Standard Model prediction for muon g-2

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I will talk about the current status of the Standard Model (SM) prediction for the muon g-2. Currently, there is more than 3.5 sigma discrepancy between the experimental value of the muon g-2 and the SM prediction for it. In the SM prediction, the hadronic contribution is the largest source of the uncertainty. The leading-order (LO) hadronic contribution, which is one of the most uncertain contributions among the hadronic contributions, can be evaluated by using the experimental data of e+ e- –> hadrons as input. Thanks to the recent precise data on e+ e- –> pi+ pi- and the improved theoretical method to combine data, the precision of the prediction for the LO hadronic contribution has now been reduced to the level of 0.4 %. I will give an overview of these situations.

Working Group:

WG4 : Muon Physics

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Status and Future Plans of the g-2 Experiment at Fermilab

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The measurement of the anomalous muon magnetic moment, $a_\mu \equiv (g_\mu - 2)/2$, more than a decade ago by the Brookhaven (BNL) E821 experiment differs at a 3.7σ level from the theoretical predictions from the Standard Model (SM). This result is among the largest observed deviations from the SM and comprises a hint of physics beyond the Standard Model.
The new Muon g-2 experiment at Fermilab, E989, set out to confirm or dissolve this discrepancy by determining a_μ to a precision of 140 parts per billion, a four-fold improvement over the E821 measurement. In its first two physics runs (2017/18 and 2019) more than a factor two in statistics with respect to BNL has been collected. An overview of the experimental technique will be discussed, along with an update of the analysis of the Run-1 data, a Run-2 overview and an outlook on the upcoming Run-3 starting in fall 2019.

Working Group:

WG4 : Muon Physics

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Muon g-2/EDM Experiment at J-PARC

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The anomalous magnetic moment of muon can be calculated by the Standard Model (SM) that takes into account quantum electrodynamics (QED), electroweak, and hadronic contributions, however, the current experimental results do not agree with the theoretical expectation by more than 3σ. This may imply a presence of the New Physics, therefore, precision measurements of the muon anomaly is crucial. The latest experimental results were obtained by E821 at the Brookhaven National Laboratory (BNL) with a uncertainty of 0.54 ppm, and its successor, Muon $g{-}2$ Experiment at the Fermi National Accelerator Laboratory (FNAL) is in operation to reduce the uncertainty. In the Japan Proton Accel- erator Research Complex (J-PARC), another experiment for the precision measurement of the muon anomaly as well as the electric dipole moment of muon is being developed using a new experimental approach. Instead of using storage ring with a magic momentum of muon as E821 and FNAL, a storage magnet with a 3-dimensional injection of a reaccel- erated thermal muon beam will be used. Since the experimental approaches are different, sources of important systematic uncertainties of the measurements are different, there- fore, it is critical to obtain consistent results from the experiments. In this presentation, experimental designs, progress, status, and future prospects are discussed.

Working Group:

WG4 : Muon Physics

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Spectroscopy of the Muonium Hyperfine Structure at J-PARC

Authors: Yasuhiro Ueno[1]; Mitsushi Abe[2]; Seiso Fukumura[3]; Hiromi Iinuma[4]; Sohtaro Kanda[1]; David Kawall[5]; Naritoshi Kawamura[2]; Kenji M Kojima[6]; Akihiro Koda[2]; Yasuyuki Matsuda[7]; Tsutomu Mibe[2]; Shoichiro Nishimura[2]; Kenichi Sasaki[2]; Yutaro Sato[2]; Shun Seo[7]; Koichiro Shimomura[2]; Patrick Strasser[2]; Kazuo S. Tanaka[8]; Toya Tanaka[7]; Hiroyuki A. Torii[7]; Hiroshi Yamaguchi[2]; Takashi Yamanaka[9]; Hiromasa Yasuda[7]

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Muonium is the bound state of a positive muon and an electron. Muonium Spectroscopy Experiment Using Microwave (MuSEUM) is a new precise measurement of muonium hyperfine structure (MuHFS) at Japan Proton Accelerator Research Complex (J-PARC).

There are two major motivations for this new measurement.

1. Test of the bound-state Quantum Electrodynamics (QED). Muonium is a purely leptonic system and the theoretical calculation of its hyperfine structure is more precise than that of hydrogen. By comparing the experimental result and the theoretical calculation, one can test the bound-state QED precisely.
2. Contribution to the search for BSM physics via muon g-2. Muon anomalous magnetic moment, a_μ, is known for the 3σ tension between the experimental value at BNL and the theoretical value from the standard model. Two new experimental projects to measure muon g-2 more precisely (100 ppb) are ongoing at J-PARC and Fermilab using a muon storage ring. To extract a_μ, these storage ring experiments need an input parameter, μ_μ/μ_p, which can be precisely determined by the MUHFS spectroscopy. MuSEUM determines the parameter with a precision of 10 ppb, a factor of twelve improvement from the precursor experiment at Los Alamos Meson Physics Facility (LAMPF), without assuming the bound-state QED is correct.

The lack of the statistics was the most dominant source of the uncertainty in the precursor experiments at LAMPF. New intense pulsed muon beam at J-PARC has opened the opportunity to improve the experimental result. A new muon beam line at J-PARC, H-Line, with ten times more muon intensity is under construction and will be ready for use in a few years. In future, more intense pulsed muon beam source can accelerate the improvement of the precision.

In this presentation, we report the recent results of the measurement at very weak field and the study of the systematic uncertainty. We also mention the future prospect, including preparation for high field measurement.

Working Group:

WG4 : Muon Physics

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The MUSE experiment at PSI: Status and Plans

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The MUSE experiment at PSI is part of a suite of experiments that aim to resolve the proton radius puzzle that has surfaced over the past decade. MUSE is particularly interesting because it attempts to determine the proton radius through simultaneous measurements of muon-proton scattering and electron-proton scattering, in addition to performing these reactions with positive and negative leptons. This not only reduces systematic uncertainties but also provides sensitivity to two-photon exchange contributions which may be responsible for some of the discrepancies seen in earlier experiments. MUSE has almost completed its commissioning phase and is scheduled to start data collection this fall. The current status and plans of the MUSE experiment will be presented.

Working Group:

WG4 : Muon Physics

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Searches for lepton flavour and lepton number violation in K+ decays

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The NA62 experiment at the CERN SPS is designed to measure the branching ratio of the K+→π+νν decay, very precisely predicted below 10exp[-10] by the SM. NA62 took data in 2016-2018 and collected a large sample of charged kaon decays into final states with multiple charged particles. The sensitivity to a range of lepton flavour and lepton number violating kaon decays provided by this data set improves over the previously reported measurements. Results from the searches for these processes with a partial NA62 data sample are presented.

Working Group:

WG4 : Muon Physics

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B-flavour anomalies in b->sll and b->clnu transitions at LHCb

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The concept of lepton universality, where the muon and tau particles are simply heavier copies of the electron, is a key prediction in the Standard Model (SM). In models beyond the SM, lepton universality can be naturally violated with new physics particles that couple preferentially to the second and third generation leptons. Over the last few years, several hints of lepton universality violation have been seen in both b->c and b->s semileptonic beauty decays. This presentation will review these anomalies and give an outlook for the near future. Other probes of NP in highly suppressed b-hadron decays will also be discussed.

Working Group:

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Search for BSM physics related to lepton universality and flavour anomalies with the ATLAS detector

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Physics beyond the Standard Model could manifest itself through effects on lepton universality or flavour anomalies, such as the ones hinted at by flavour factories. Lepton-flavour violation (LVF) would be a striking signature of such new physics; the ATLAS experiment has multiple searches for such signal in the decay of the Higgs boson, the Z boson and of a heavy neutral gauge boson, Z'. Searches for leptoquarks (LQ), which are predicted by many new physics theories to describe the similarities between the lepton and quark sectors of the Standard Model, could also offer an explanation for the flavour anomalies. The broad program of ATLAS in direct searches for leptoquarks, coupling to the first-, second- or third-generation particles, will also be reviewed.

Working Group:

WG4 : Muon Physics

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The hunt for lepton flavor violation with the Mu3e experiment

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The Mu3e experiment will search for the charged lepton flavor violating decay $\mu^+ \to e^+e^-e^+$ with a targeted branching ratio sensitivity of 10^{-16}. The sensitivity goal drives the experimental design: To distinguish the neutrinoless signal decay from background processes, excellent momentum, vertex and time resolutions of the detector system are required. An ultra-thin silicon pixel tracking detector will be constructed, complemented by a scintillating fibre and a scintillating tile detector which add precise time information to the tracks. To conduct the experiment within a reasonable time, the detector will have to cope with electrons and positrons originating from muon decays at rates up to 10^9 per second. The trigger-less readout system collects the detector data, reconstructs tracks and selects events online for offline analysis. This talk describes the current status of design and construction of the Mu3e experiment and emphasizes the progress made in the development of the readout system.

Working Group:

WG4 : Muon Physics

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MEG II Status and Plan

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The MEG II experiment at Paul Scherrer Institute (PSI) in Switzerland intends to achieve a sensitivity to search for muon decay to electron and gamma as good as 6x10ˆ{-14}. The detector upgrade from the MEG experiment, which set the limit of 4.2x10ˆ{-13} at 90% C.L., is intensively in progress toward the start of physics data acquisition in 2020. We present the status and plan of MEG II experiment.

Working Group:

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Status of the DeeMe Experiment, an Experimental Search for μ-e Conversion at J-PARC MLF

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The DeeMe experiment is planned to search for muon-to-electron conversion at J-PARC MLF. Our goal is to measure the process with a single event sensitivity of 1×10^{-13} or 2×10^{-14} for a graphite or silicon carbide target. That is one or two orders of magnitude better than the current upper limits, 7×10^{-13} for a gold target by the SINDRUM-II experiment at PSI and 4.6×10^{-12} for a titanium target by the experiment at TRIUMF. In this talk, the current status of the DeeMe experiment will be presented.

Working Group:

WG4 : Muon Physics

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Search for charged lepton flavor violation in J-PARC: COMET experiment

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As the lepton number and lepton flavor are conserved quantities in Standard Model, observation of charged lepton flavor violation (cLFV) process will provide clues on beyond-Standard model theories. COMET is an experiment at J-PARC, Japan, which will search for neutrinoless conversion of muons into electrons in the field of a nucleus (μ− + N ⟶ e− + N); a lepton flavor violating process. The experimental sensitivity goal for this process is order of 10ˆ−15 for Phase-I and 10ˆ−17 for Phase-II experiment, which is a factor of 100−10000 improvements correspondingly over existing limits. Recent progresses in facility and detector development will be presented, along with COMET Phase-I and Phase-II experimental schedule.

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Searching for Muon to electron conversion : The Mu2e experiment at Fermilab

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The Mu2e experiment will measure the charged-lepton flavor violating (CLFV) neutrino-less conversion of a negative muon into an electron in the field of a nucleus. Mu2e will improve the previous measurement by four orders of magnitude, reaching a 90% C.L. sensitivity to CLFV conversion rates of 8×10^{-17} or larger. The experiment will reach mass scales of nearly 10^4 TeV, far beyond the direct reach of colliders. It will be sensitive to a wide range of new physics, complementing and extending other CLFV searches. Mu2e is under design and construction at the Muon Campus of Fermilab, and we expect to start taking physics data in 2023. I will present the physics motivation for Mu2e, the detector design, and the current experimental status.

Working Group:

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Mu2e-II : next generation muon conversion experiment

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Muon decay with light boson emission in muon atoms

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The charged lepton flavor violation (CLFV) is a good probe to search for new physics beyond the standard model. If there is a neutral boson X which is lighter than muon and has CLFV interaction, a muon can decay into an electron and an X, i.e. $\mu \to eX$. The search for this process is expected to constraint the property of X. In this talk, we focus on a search for the rare decay of muon in a muonic atom. We show general quantitative calculation for the electron spectrum.

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Status of the AlCap experiment

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COMET (J-PARC) and Mu2e (Fermilab) are two experiments currently under construction that aspire to discover the neutrino-less muon to electron conversion BSM process. As a cooperation between

the two experiments, AlCap was created to measure low energy particle emission spectra after nuclear muon capture in target materials aluminium and titanium. These measurements are important for understanding noise hit rates and radiation damage in COMET and Mu2e's detector systems. AlCap also explored muonic x-ray measurement methods that could be used for muon normalization. This talk will report the preliminary results collected at the Paul Scherrer Institut in Switzerland during the 2015 run.

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WG4 : Muon Physics

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The Belle II Experiment: Status and Prospects

Authors: Ida Peruzzi[1]; Kunxian Huang[2]

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[2] *National Taiwan University*

The Belle II experiment at the SuperKEKB energy-asymmetric e^+e^- collider is a substantial upgrade of the B factory facility at the Japanese KEK laboratory. The design luminosity of the machine is 8×10^{35} cm^{-2}s^{-1} and the Belle II experiment aims to record 50 ab^{-1} of data, a factor of 50 more than its predecessor. With this data set, Belle II will be able to measure the Cabibbo-Kobayashi-Maskawa (CKM) matrix, the matrix elements and their phases, with unprecedented precision and explore flavor physics with B and charmed mesons, and τ leptons. Belle II has also a unique capability to search for low mass dark matter and low mass mediators. From February to July 2018, the machine has completed a commissioning run, achieved a peak luminosity of 5.5×10^{33} cm^{-2}s^{-1}, and Belle II has recorded a data sample of about 0.5 fb^{-1}. Regular operations, with full detector, have started in March 2019. In this presentation, we will review the status of the Belle II detector, the results from the early data, and the prospects for the study of rare decays , in the quest of uncovering New Physics.

Working Group:

WG4 : Muon Physics

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Searches for LFV and LNV at Belle II

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The Belle II experiment is a substantial upgrade of the Belle detector and will operate at the SuperKEKB energy-asymmetric e^+e^- collider. The design luminosity of the machine is 8×10^{35} cm^{-2}s^{-1} and the Belle II experiment aims to record 50 ab^{-1} of data, a factor of 50 more than its predecessor. From February to July 2018, the machine has completed a commissioning run and main operation of SuperKEKB has started in March 2019. Belle II has a broad τ physics program, in particular in searches for lepton flavor and lepton number violations (LFV and LNV), benefiting from the large cross section of the pairwise τ lepton production in e^+e^- collisions. We expect that after 5

years of data taking, Belle II will be able to reduce the upper limits on LF and LN violating τ decays by an order of magnitude. Any experimental observation of LFV or LNV in τ decays constitutes an unambiguous sign of physics beyond the Standard Model, offering the opportunity to probe the underlying New Physics. In this talk we will review the τ lepton physics program of Belle II.

Working Group:

WG4 : Muon Physics

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Development of very slow negative muon beam

Authors: Hiroaki Natori[1]; Yasuhiro Miyake[1]; Yukinori Nagatani[1]; Patrick Strasser[1]; Soshi Takeshita[1]; Taihei Adachi[1]

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The J-PARC muon facility is trying to improve the sophistication of muon beam, so that we can respond to requests of material property study and particle physics study, or we can explore a brand new frontier of the usage of muon beam. I will focus on a development of slow negative muon beam in my talk.

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A search for Majoranality of neutrinos in muon decay using a positron polarimeter

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It is an unsolved problem of prime importance whether the neutrinos are Dirac or Majorana paricles. The Majoranality of neutrinos is predicted in the presence of V+A interactions. It appeares as a time-reversal (T) symmetry breaking term in the general form of the differential decay rate of muons [1]. Positrons from muon decays are mostly polarized in the longitudinal direction. However, the T-violating term results in the transverse polarization of the positron which is perpendicular to both the muon spin and the positron momentum. It gives a clear evidence of the Majoranality of neutrinos without contributions from the standard model background. The polarization of positrons can be analyzed via the spin dependence of the annihilation-in-flight with electrons [2]. Towards a search for the T-violating effect, we propose a new experiment to measure the decay positron's polarization with a magnetized foil, a segmented calorimeter, and high-intensity pusled muon beam at J-PARC. A positron polarimeter for the experiment is designed using GEANT4-based Monte-Carlo simulation. In this presentation, a measurement method and details of the polarimeter will be discussed.

[1] M. Doi, T. Kotani, H. Nishiura, K. Okuda, and E. Takasugi, Progress of Theoretical Physics 67, 281 (1982).
[2] N. Danneberg et al., Phys. Rev. Lett. 94, 021802 (2005).

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Non-standard interactions at a decay-at-rest experiment

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We consider a hybrid setup consisting of neutrino data from T2HK along with antineutrinos from a muon decay-at-rest (muDAR) source. Such a setup has already been studied before in the context of standard oscillations. We now explore the ability of this setup to measure charged-current non-standard interactions (NSIs) of neutrinos that can affect the production and detection of neutrinos. We find that the standard measurements are robust under the presence of NSIs. Further we highlight interesting correlations between the standard and non-standard CP-violating phases. This setup can also improve the constraints on purely leptonic NSIs which can only be probed using setups involving muon decay.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Invisible neutrino decays at the MOMENT experiment

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We investigate invisible decays of the third neutrino mass eigenstate in future accelerator neutrino experiments using muon-decay beams such as MuOn-decay MEdium baseline NeuTrino beam experiment (MOMENT). MOMENT has outstanding potential to measure the deficit or excess in the spectra caused by neutrino decays, especially in muon neutrino/antineutrino disappearance channels. Such an experiment will improve the constraints of the neutrino lifetime. Compared with exclusion limits in the current accelerator neutrino experiments T2K and NOvA under the stable neutrino assumption, we expect that MOMENT gives the better bound. The non-decay scenario is expected to be excluded by MOMENT at a confidence level of more than 3 sigma, if the best fit results in T2K and NOvA are confirmed. We further find that reducing systematic uncertainties is more important than the running time. Finally, we find some impact of neutrino invisible decays on the precision measurement of other oscillation parameters.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Search for heavy neutrinos with the ATLAS detector

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Multiple theories beyond the Standard Model predict the existence of heavy neutrinos, such as the Type I or Type III seesaw mechanisms which can explain the light neutrino masses, or left-right symmetric models which restore parity symmetry in weak interactions at higher energy scale and predict right-handed counterparts to the weak gauge bosons. Searches for such heavy Majorana or Dirac neutrinos with the ATLAS detector, which can also lead to boosted or also displaced signatures, will be presented using proton-proton data from the LHC at a center-of-mass energy of 13 TeV.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Tests of neutrino mass models at CMS

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The latest results and prospects of searches for heavy neutrinos at the CMS experiment will be presented.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Prompt tau neutrinos at the LHC

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We investigate tau neutrinos from heavy flavor hadrons (prompt neutrinos) that can be explored at a high rapidity LHC experiment. A large number of tau neutrinos can be produced in pp collision at the LHC in the very forward region (y>6.5), where its main source is Ds mesons since the weak boson contribution is negligible. Abundant production of tau neutrinos will allow the precise study of tau neutrino charged current interactions, which can be used to test lepton universality. In addition, it will provide the opportunity to probe the mixing between the sterile neutrinos and tau neutrinos. We present a prediction of the fluxes and the event rates of the prompt tau neutrinos as well as muon neutrinos focusing on the configuration of FASER, a recently approved experiment. Also, we describe the sterile neutrino masses and mixing angles that can be constrained by tau neutrinos from the LHC.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Study of tau-neutrino production at the CERN SPS

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DsTau is a project at the CERN SPS to study tau-neutrino production aiming at providing important data for future ν_τ studies. A precise measurement of the ν_τ cross section would enable a search for new physics effects in ν_τ CC interactions. It also has practical importance for the next generation experiments for neutrino oscillation studies and astrophysical ν_τ observations. The practical way of producing a ν_τ beam is by the sequential decay of D_s mesons produced in high-energy proton interactions. However, there is no experimental measurement of the D_s differential production cross section in fixed target experiments using proton beams, which leads to a large systematic uncertainty on the ν_τ flux estimation. The DsTau project aims to reduce the systematic uncertainty in the current ν_τ cross section measurement to 10% or below, by measuring the D_s differential production cross section (especially longitudinal dependence). For this purpose, emulsion detectors with spatial resolution of 50 nm will be used allowing the detection of $D_s \to \tau \to X$ double kinks in a few mm range. During the physics run, 2.3×10^8 proton interactions will be collected in the tungsten target, and 1000 $D_s \to \tau$ decays are expected to be detected. Results from the pilot run in 2018 will be presented together with a prospect for a physics run in 2021 and 2022.

Working Group:

WG2 : Neutrino Scattering Physics

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Neutrino Oscillation measurements and BSM physics searches with Neutrino Telescopes in the Mediterranean

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The KM3NeT Collaboration is currently building the next generation of large-volume (km3-size) water-Cherenkov neutrino telescopes to the bottom of the Mediterranean sea. The denser of the two detectors is called ORCA, which is optimised for the detection of atmospheric neutrinos with energies above ~1 GeV. The main research target of the ORCA detector is the measurement of the neutrino mass ordering and atmospheric neutrino oscillation parameters. The detector will also be sensitive to a wide variety of other topics searching for effects beyond the Standard Model, such as tau appearance, non-standard interactions and sterile neutrinos. Similar studies from the ANTARES telescope will also be discussed.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Neutrino oscillations and PMNS unitarity with IceCube/DeepCore and the IceCube Upgrade

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The IceCube neutrino observatory uses a cubic-km of glacial South Pole ice instrumented with over 5000 optical sensors to detect Cherenkov light produced by atmospheric and astrophysical neutrino interactions. A central region of the detector in the deepest ice, known as DeepCore, is more densely instrumented, allowing neutrinos with energies as low as ~5 GeV to be detected. The upcoming IceCube Upgrade will increase the instrumentation density once again and lower the energy threshold even further, as well as offering significantly improved reconstruction and calibration performance.

At these energies, the oscillation of atmospheric muon neutrinos to tau neutrinos can be simultaneously observed in both the disappearance and appearance channels, constraining the poorly measured tau sector of the PMNS matrix. These measurements significantly contribute to global tests of PMNS unitarity and the standard oscillation picture, constraining the presence of additional neutrino states and other BSM physics. This talk will present recent IceCube/DeepCore tau neutrino appearance results and future prospects with the IceCube Upgrade.

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Prospects for BSM physics searches and NSI at Hyper-K and T2HKK

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The Super-Kamiokande and T2K substantially developed our understanding of oscillations by observing the sub-dominant electron-neutrino appearance channel. The next-generation Hyper-Kamiokande experiment will build on this with much higher statistics, enabling precision tests of the Standard PMNS picture. In the baseline design of 2 tanks at Kamioka, a detailed investigation of oscillations can be made in the vicinity of the first oscillation maximum, and at short baselines using the near detector. More interesting tests can be preformed if the second tank is located in Korea, as this give access to a higher L/E regime that is three times higher than any previous long-baseline experiment. As well as benefits to the PMNS measurements, a new experimental regime makes it possible to resolve BSM models - such as non-standard interactions - which are statistically degenerate on a single baseline.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Neutral Current events and new physics at nuSTORM

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The nuSTORM facility will provide \nu_e and \nu_\mu beams from the
decay of low energy muons confined within a storage ring. The
instrumentation of the ring, combined with the excellent knowledge of
muon decay, will make it possible to determine the neutrino flux at
the %-level or better. The neutrino and anti-neutrino event rates are
such that the nuSTORM facility serving a suite of near detectors will
be able to measure \nu_eN and \nu_\muN cross sections with the %-level
precision required to allow the next generation of long-baseline
neutrino-oscillation experiments to fulfil their potential.
The physics potential of nuSTORM also includes exquistely sensitive
searches for light sterile neutrinos such as those that have been
postulated to explain the LSND or MiniBOONE results. The study
conducted for delineating the sterile neutrino sensitvity reach of
nuSTORM used charged current muon and antimuon events. However, there
will also be a large number of neutral current events, which may
contribute to enhance the sensitvity of nuSTORM. In this work we
investigate the usefulness of neutral current events to probe sterile
neutrinos and other new physics at nuSTORM.

Working Group:

WG1 : Neutrino Oscillation Physics

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SEARCH FOR EXOTIC DECAYS WITH NA62

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The features of the NA62 experiment at the CERN SPS – high-intensity setup, trigger-system flexibility, high-frequency tracking of beam particles, redundant particle identification, and high-efficiency photon vetoes – make NA62 particularly suitable to search for long-lived, weakly-coupled particles within Beyond the Standard Model (BSM) physics, using kaon and pion decays as well as operating the experiment in dump mode.
Searches for Heavy Neutral Lepton (HNL) production in charged kaon decays using the data collected by the NA62 experiment are reported. Upper limits are established on the elements of the extended neutrino mixing matrix for HNL masses in the range 130-450 MeV, improving on the results from previous HNL production searches.
Latest results on production searches of Dark Photons (DP) in neutral pion decays at NA62 are also presented, together with sensitivity results for production and decay searches of Axion-Like Particles (ALP), and prospects for future data taking at the NA62 experiment.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Neutrino physics with the SHiP experiment at CERN

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The SHiP Collaboration has proposed a general-purpose experimental facility operating in beam dump mode at the CERN SPS accelerator with the aim of searching for light, long-lived exotic particles of Hidden Sector models. The SHiP experiment incorporates a muon shield based on magnetic sweeping and two complementary apparatuses. The detector immediately downstream of the muon shield is optimised both for recoil signatures of light dark matter scattering and for tau neutrino physics, and consists of a spectrometer magnet housing a layered detector system with heavy target plates, emulsion film technology and electronic high precision tracking. The second detector system aims at measuring the visible decays of hidden sector particles to both fully reconstructible final states and to partially reconstructible final states with neutrinos, in a nearly background free environment. The detector consists of a 50 m long decay volume under vacuum followed by a spectrometer and particle identification with a rectangular acceptance of 5 m in width and 10 m in height. Using the high-intensity beam of 400 GeV protons, the experiment is capable of integrating 2×10^{20} protons in five years, which allows probing dark photons, dark scalars and pseudo-scalars, and heavy neutrinos with GeV-scale masses at sensitivities that exceed those of existing and projected experiments. The sensitivity to heavy neutrinos will allow for the first time to probe, in the mass range between the kaon and the charm meson mass, a coupling range for which baryogenesis and active neutrino masses can be explained. The sensitivity to light dark matter reaches well below the elastic scalar Dark Matter relic density limits in the range from a few MeV/c^2 up to 200 MeV/c^2. The tau neutrino deep-inelastic scattering cross-sections will be measured with a statistics a thousand times larger than currently available, with the extraction of the F_4 and F_5 structure functions, never measured so far, and allow for new tests of lepton non-universality with sensitivity to BSM physics. Following the review of the Technical Proposal, the CERN SPS Committee recommended in 2016

that the experiment and the beam dump facility studies proceed to a Comprehensive Design Study phase. These studies have resulted in a mature proposal submitted to the European Strategy for Particle Physics Update.

Working Group:

WG5 : Neutrinos Beyond PMNS

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Radiative neutrino mass models and the flavour anomalies

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After reviewing the motivation for radiative neutrino mass generation and a systematic approach to the construction of such models, I will present a specific model that features two scalar leptoquarks and a vector-like coloured fermion doublet. As well as generating neutrino mass at loop level, this theory can also fit the data hinting at lepton flavour universality violation in semi-leptonic B-meson decays. Muon to electron conversion on nuclei turns out to be a key experimental probe.

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Status of the HOLMES experiment to directly measure the electron neutrino mass with a calorimetric approach.

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The measurement of neutrino mass is still one of the most compelling issues in modern particle physics. Beta or electron capture (EC) spectrum end-point study is currently the only experimental method which can provide a model independent measurement. The HOLMES experiment aims at directly measuring the neutrino mass with a calorimetric approach: the source is embedded inside the detector and the energy released in the decay process is entirely contained, except for the fraction taken away by the neutrino. Both the issues related to the use of an external source and the systematic uncertainties arising from decays on excited final states are eliminated. The main goal of the HOLMES project is reaching a neutrino mass statistical sensitivity as low as 1 eV. In order to do this the released energy will be measured using 16 sub-arrays of Transition Edge Sensor based micro-calorimeters (64 TES for each array) with 163Ho source (EC) embedded inside. 163Ho is chosen as source for its very low Q-value (2.8 keV), the proximity of the end-point to resonance M1 and its half-life (4570 y). These features are optimal to reach simultaneously a reasonable activity to have sufficient statistics in the end-point, reducing the pile-up probability and have a small quan- tity of 163Ho embedded in the detector not to alter significantly its heat capacity. Each TES will have an energy resolution of ≈ 1 eV FWHM, a time resolution of about 1 μs and will be read out using microwave multiplexed rf-SQUIDs in combination with a ROACH2 based digital acquisition system. An activity of 300 Bq will be implanted in each micro-calorimeter allowing to collect about 3 × 1013 decays in three years. HOLMES will be an important step forward in the direct neutrino mass measurement with a calorimetric approach as an alternative to spectrometry and will also establish the potential of this approach to extend the sensitivity down to 0.1 eV and lower. In this contribution, we show the HOLMES experiment with its physics reach and technical challenges, along with its status and perspectives. In particular we will present the status of the HOLMES activities concerning the 163Ho isotope production, purification and implantation, the TES pixel design and optimization, the multiplexed array read-out characterization, the cryogenic set-up installation.

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New physics searches with SHIP

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The SHiP Collaboration has proposed a general-purpose experimental facility operating in beam dump mode at the CERN SPS accelerator with the aim of searching for light, long-lived exotic particles of Hidden Sector models. The SHiP experiment incorporates a muon shield based on magnetic sweeping and two complementary apparatuses. The detector immediately downstream of the muon shield is optimised both for recoil signatures of light dark matter scattering and for tau neutrino physics, and consists of a spectrometer magnet housing a layered detector system with heavy target plates, emulsion film technology and electronic high precision tracking. The second detector system aims at measuring the visible decays of hidden sector particles to both fully reconstructible final states and to partially reconstructible final states with neutrinos, in a nearly background free environment. The detector consists of a 50 m long decay volume under vacuum followed by a spectrometer and particle identification with a rectangular acceptance of 5 m in width and 10 m in height. Using the high-intensity beam of 400 GeV protons, the experiment is capable of integrating 2×10ˆ20 protons in five years, which allows probing dark photons, dark scalars and pseudo-scalars, and heavy neutrinos with GeV-scale masses at sensitivities that exceed those of existing and projected experiments. The sensitivity to heavy neutrinos will allow for the first time to probe, in the mass range between the kaon and the charm meson mass, a coupling range for which baryogenesis and active neutrino masses can be explained. The sensitivity to light dark matter reaches well below the elastic scalar Dark Matter relic density limits in the range from a few MeV/cˆ2 up to 200 MeV/cˆ2. Following the review of the Technical Proposal, the CERN SPS Committee recommended in 2016 that the

experiment and the beam dump facility studies proceed to a Comprehensive Design Study phase. These studies have resulted in a mature proposal submitted to the European Strategy for Particle Physics Update.

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New Physics and the Leptonic CP Phase Measurement

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The leptonic CP phase has profound physical consequences due to its possible connection with leptogenesis for explaining the existence of matter in the Universe. To some extent, the leptonic CP phase is even more important than the Higgs boson that provide mass for all fundamental particles. If we cannot understand the existence of matter, why we need to care about their mass. However, the current accelerator experiments for CP phase measurement suffer from new physics such as non-unitarity mixing (NUM) and (vector, scalar, dark) non-standard interactions (NSI). It is necessary to find extra experimental configuration to guarantee CP sensitivity at T2(H)K, NOvA, DUNE, and T2HKK.

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Sterile Neutrinos in Astrophysical Environments : Big Bang Nucleosynthesis and Supernova Neutrino Process

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Albeit great success in the discovery of neutrino oscillations, inconsistency between three-neutrino model and observed neutrino data has left a conundrum in neutrino physics called "neutrino anomalies". The sterile neutrino, as a hypothetical particle, coined to resolve the anomalies. Although some

ambiguities related to the nuclear physics in reactors should be disentangled, the sterile neutrino, as a possible solution, has aroused lots of intensive discussions in the astrophysics as well as the neutrino physics.

In this presentation, we show effects of the sterile neutrino on two astrophysical environments; one is big bang nucleosynthesis (BBN) and the other is supernova (SN) neutrino process. First, in BBN, we assume that sterile neutrinos can propagate the five-dimensional bulk space [1]. In this model, the effective mixing angle between sterile and active neutrinos depends on energy, which may give rise to a resonance effect. By solving a rate equation including the mixing effects, we determine the energy density of sterile neutrinos in the early universe and constrain sterile-active mixing parameters by using the observational data of primordial abundances [2].

Second, we investigate the sterile-active neutrino oscillation effects on the SN neutrino process [3]. In this study, adopting 3+1 mixing parameters in IceCube and shortbase line experiments [4], we find multiple resonances in SN environments. For the source of sterile neutrinos, we use two scenarios [5]; the first one is that sterile neutrinos can be produced only by mixing with active neutrinos and the second one is that sterile neutrinos can be produced via scattering between electron neutrinos and matter. Our result shows that the analysis of observed SiC X grains [6] excludes the first scenario, while the viability of the second scenario depends on the sterile neutrino temperature and the neutrino mass hierarchy.

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Search for Dark Matter and BSM Physics with the IceCube Neutrino Observatory

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The IceCube detector is a multipurpose neutrino observatory located at the South Pole. With an instrumented volume of a cubic kilometer, IceCube can detect neutrino fluxes from all flavors in the GeV - PeV energy range. In the recent years IceCube has heralded the birth of neutrino astronomy with the discovery of an astrophysical neutrino flux. Besides its astrophysical program IceCube is also at the forefront of indirect searches for dark matter and physics beyond the standard model. In this contribution I will review the latest results of IceCube as a particle physics detector.

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Reactor short baseline neutrino experiments including NEOS.

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Mixing among three active neutrinos with three mass states has been well established.
A new mixing between sterile and active neutrinos with an eV-scale mass state is suggested by the results from numbers of short baseline experiments. Measuring electron antineutrinos from a nuclear reactor at very short baseline may reveal such active-to-sterile neutrino oscillation.

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Sterile neutrino searches with the ICARUS detector

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The ICARUS collaboration employed the 760-ton T600 detector in 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 the constraints the allowed parameters to a narrow region around 1 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 where installation activities are in progress. It will be soon exposed to the Booster Neutrino Beam to search for sterile neutrino within the Short Baseline Neutrino (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 at Fermilab and the ongoing developments of the analysis tools needed to fulfill its physics program.

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Status of the MicroBooNE Low-energy Excess Search

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The primary goal of MicroBooNE is to address the origin of the excess of low energy electromagnetic-like events observed by MiniBooNE. This talk will present MicroBooNE's progress towards a low-energy excess result, including the status of targeted searches for both single-photon-like and electron-like events.

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