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Book of Abstracts

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Session 6 / 1

Simulation and measurement of the suppression of radon induced background in the KATRIN experiment

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The objective of the Karlsruhe Tritium Neutrino experiment (KATRIN) at the Karlsruhe Institute of Technology (KIT) is the measurement of the effective electron neutrino mass with a sensitivity of 200 meV/c^2. A central component is the Main Spectrometer (MS), a MAC-E filter type electrostatic high pass filter for electrons. It measures the energy of β-electrons from tritium decay close to the endpoint at 18.6 keV with high precision at a low count rate of 10^{-2} cps in the last eV of the spectrum. The target value for the background rate in the KATRIN design is 10^{-2} cps. The large ultra-high-vacuum chamber of the MS has a volume of 1240 m^3 and is operated at an ultra-low pressure in the range of 10^{-11} mbar, which is required to reduce the background rate. The pumping system of the MS consists of turbo-molecular pumps and large-scale getter pumps (SAES St707 non-evaporable getter (NEG) strips). The NEG strips (^{219}Rn, $t_{1/2} = 3.9$ s), as well as the stainless steel walls (^{220}Rn, $t_{1/2} = 56$ s) are known to emanate small amounts of radon atoms, increasing the intrinsic background rate by 0.5 cps, if no further countermeasures are taken.

Therefore, three LN2-cooled cryogenic baffles (1.7-m diameter), made of L-shaped copper panels, have been installed in front of the NEG-pumps, reducing the transmission of radon into the main volume. Radon from the walls and welds of the vacuum chamber, which is directly emanated into the main volume, has to be removed quickly enough before it decays. However, radon does not stick to a cold surface indefinitely. It either desorbs after a limited sojourn time, or it decays into polonium while still on the cold baffle. In the first case, it can contribute again to the background rate.

This talk describes the simulation of the effectiveness of the radon suppression with the Test-Particle Monte Carlo (TPMC) code MolFlow+ and presents data from an extensive measurement program. The simulation takes the effect of the half-lifes of the different radon isotopes into account, as well as the temperature dependent sojourn time of radon on a cold surface. By comparing measured rates with TPMC simulations for different sojourn times (temperatures), we learned more about possible surface conditions of the baffles (Cu, Cu2O, H2O) and the corresponding desorption enthalpies. The measurements with the MS showed that the radon suppression with cold baffles works sufficiently well, so that the remaining background is no longer radon dominated. This work has been supported by the German BMBF (05A14VK2).

Summary:

Short-lived radon isotopes are a serious source of background for the measurement of the neutrino mass with the KATRIN experiment. This talk describes a method to suppress the radon rate with cold baffles in the ultra-high vacuum chamber of the KATRIN Main Spectrometer and compares simulations with measured data. The effectiveness of the method depends not only on the half-life of the radon isotopes, but also on the temperature of the cryogenic baffles.

Session 6 / 2

A model for Rydberg-atom induced backgrounds resulting from deposition of Rn progeny in the KATRIN Main Spectrometer

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The KArlsruhe TRItium Neutrino (KATRIN) experiment aims to determine the effective mass of the electron antineutrino
with an unsurpassed sensitivity of 200 meV/c^2 in a direct model-independent approach.
Located at the Karlsruhe Institute of Technology (KIT) the experiment uses a MAC-E filter type electrostatic Main Spectrometer (MS) to investigate the tritium β-decay spectrum close to the kinematic endpoint at 18.6 keV.
With a target count rate for the spectrometer design of about 10^{-2} cps in the endpoint region it is in the same order of magnitude as the signal.
The 1240-m^3 ultra-high vacuum vessel of the MS, with its 1222-m^2 of inner stainless steel surfaces, represents the major background contributer in the experiment.

From 2013 - 2016, the characteristics of the MS background were studied in a series of dedicated commissioning measurements.
The findings could not be reconciled with any background models for MAC-E filter spectrometers at that time, thus requiring the development of a new model.
The background is best described by the generation of low-energy background electrons in the volume of the MS via the ionization of hydrogen Rydberg atoms
by black body radiation from the room temperature walls of the vacuum chamber.
Recent results from measurements in autumn 2016 indicate a link between the generation of these Rydberg atoms
and the deposition of the radon progeny ^{210}Pb on inner surfaces of the spectrometer.

This talk will give an overview of background processes in a MAC-E filter in general,
before discussing in detail the findings of the commissioning measurements with the KATRIN Main Spectrometer.
Based on the characteristics of the MS background, the newly established model for a Rydberg-atom induced background process will be introduced.
The identification of a conversion electron signature from ^{210}Pb decay in the background spectrum of the MS will be presented, which can be linked to the generation of Rydberg atoms.
Finally, possible methods to reduce this unexpected background component and its influence on the sensitivity of the KATRIN experiment will be discussed.

This work has been supported by the German BMBF (05A14VK2).

Summary:

A dominant background contribution was found in the KATRIN Main Spectrometer, which cannot be reconciled with any existing background models for MAC-E filter based spectrometers.
This talk will summarize the experimental findings and introduce a newly established background model based on the thermal ionization of Rydberg-atoms, produced in the decay of the Rn progeny ^{210}Pb, deposited on the wall of the spectrometer chamber.

Session 4 / 3

Low radioactivity underground argon for low-level radiation detectors

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There is a growing need for argon that has a lower concentration of ³⁹Ar than that found in argon derived from the atmosphere. This isotope is the limiting background for any argon-based low-level radiation detector, such as argon dark matter detectors and low-level argon radiation detectors for environmental measurements (e.g., ³⁹Ar age dating). In the atmosphere, cosmic-ray neutrons and protons produce ³⁹Ar through ⁴⁰Ar(n,2n) and ⁴⁰Ar(p,np) reactions. Deep underground, away from cosmic rays, one would expect to find argon that is free of ³⁹Ar.
For 5 years Princeton University, Fermilab, and PNNL extracted and purified nearly 200 kg of underground argon (UAr) that was shown to have only 0.73 mBq/kg of ³⁹Ar, where atmospheric argon contains 1.0 Bq/kg. This UAr was primarily for the DarkSide-50 dark matter experiment, and the next generation of argon dark matter experiments will require 10s of tons of UAr. Additionally, other UAr needs must be met.
In this talk we will describe the success and challenges of the original UAr extraction and purification, and how production challenges were identified later as minor contaminations in the source gas. We will also describe future UAr productions and other possible sources of UAr.

Summary:

A comprehensive overview of low radioactivity underground production past, present, and future.

Session 6 / 4

The Background Model and radio-assays for the LZ experiment

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The LZ dark matter experiment will require an unprecedented low background rate within its fiducial volume, defining strict constraints on radioactivity from construction materials. The radioactive background is further mitigated through the combination of powerful self-shielding from liquid xenon, 3D event vertex reconstruction, and external veto detector systems. An aggressive screening campaign with cutting-edge instrumentation including underground gamma spectroscopy, mass spectrometry, radon emanation measurements, and neutron activation is underway to measure the trace levels of radioisotopes in materials to ensure the experiment reaches a sensitivity to spin-independent WIMP-nucleon scattering below 3x10-48 cm2. These assays, together with measurements of exposure to airborne contaminants during experiment construction, inform the high-precision LZ Background Model against which the statistical significance of any potential signal will be evaluated. This talk will present the status of the assay facilities, our radio-purity campaign, and the experiment's Background Model.

Session 4 / 5

On-line ^{222}Rn purification for liquid xenon detectors by means of cryogenic distillation

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The radioactive noble gas radon is an important source of internal background in many dark matter experiments based on liquid xenon. Due to emanation, ^{222}Rn is permanently released into the detectors' liquid xenon targets. Careful material selection based on their radon emanation rate is a powerful strategy to mitigate background. In order to achieve further radon reduction, we discuss the concept and the successful operation of an continuously operated radon removal system for liquid xenon detectors. Thereby, the separation of radon from xenon is done by means of cryogenic distillation, a technique suitable even at concentrations down to the 10^{-15} mol/mol level.

Session 6 / **6**

Search for neutrinoless double beta decay with GERDA Phase II

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The GERDA experiment is designed to search for neutrinoless
double beta decay of Ge-76. In its second phase 37 HPGe detectors enriched
in the isotope Ge-76 are directly immersed into liquid argon.
The radio-pure cryogenic liquid acts as passive and active shield
and as a cooling medium for the detectors simultaneously.
Recently a half-life limit on 0vbb decay of Ge-76 of
T1/2 > 5 *10^25 yr has been published.
The background rate in the energy region of
interest, after pulse shape discrimination and liquid argon veto
cuts, is in the range ~few counts/ROI ton yr. This makes GERDA the
first 0vbb experiment that has a background so low that <1 counts
are expected in the RoI within the anticipated life time of the experiment.
The experimental efforts needed to reach this low
background level will be discussed and the current understanding
of the background sources will be presented.

Poster Session - Board: 1 / **7**

PEN: A new optically active low background structural material

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Polyethylene Naphtalate (PEN) is a mechanically very favorable polymer. Earlier it was found that thin foils made from PEN can have very high radio-purity, if compared to other commercially available foils. In fact, PEN is already in use for low background signal transmission applications (cables).
Recently it has been realized that PEN also has favorable scintillating properties.
In combination, this makes PEN a very promising candidate as a self-vetoing structural material in low background experiments. Components instrumented with light detectors could be built from PEN. This includes detector holders, detector containments, signal transmission links, etc.
The current R&D towards qualification of PEN as a self-vetoing low background structural material will be presented. A possible application within an experiment for the search of neutrinoless double beta decay will be shown.

Session 2 / 8

Application of AMS for the analysis of primordial nuclides in high purity copper.

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The sensitivity of experiments in rare event physics like for example dark matter detection crucially depends on the background level. Therefore, all material surrounding the detectors requires low contamination of radionuclides in order not to create additional background. A significant contribution originates from the primordial actinides thorium and uranium and the progenies of their decay chains. At the Maier Leibnitz Laboratorium in Munich the applicability of ultrasensitive Accelerator Mass Spectrometry (AMS) for the direct detection of thorium and uranium impurities in a copper matrix was tested for the first time. For this special purpose, Th and U were extracted from the ion source as a copper compound. Different samples of copper, high purity copper and of a copper alloy were investigated. The lowest concentrations achieved in AMS measurements so far were (1.4+-0.6) x 10-11 g/g for thorium and (7+-4) x 10-14 g/g for uranium which correspond to (56+-16)μBq/kg and (0.9+-0.5)μBq/kg, respectively. The particular requirements on the AMS technique and the developed procedure will be presented.

Session 3 / 9

Development of the database for low-background studies in Kamioka

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Needless to say, it is important to select ultra-low background materials for dark matter and $0\nu\beta\beta$ detectors. All materials and components must be evaluated before the detector construction.

This presentation will focus on developing a database for such purpose based on the open source database, Persephone (radiopurity.org). The aim of this project is to share information on low-radioactivity materials measured by several techniques in Kamioka observatory among Japanese community.
Improvements of the functions of the database and the typical contents will be shown. In addition, several running programs for screening low-radioactive materials at Kamioka will be discussed.

Session 7 / 11

Radon Plate-out Measurements for Polyethylene and Copper at SNOLAB

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Neutrons are a challenging background for dark matter direct detection experiments such as the Super Cryogenic Dark Matter Search (SuperCDMS), and can come from contamination within common shielding materials such as polyethylene and copper. We present measurements of the alpha-activity accumulation on surfaces due to exposure to the elevated level of radon present deep underground at SNOLAB. Surface contamination from plate-out and implantation of radon daughters can give rise to neutron and gamma-ray backgrounds from (α,n) and Bremsstrahlung interactions. To help characterize these backgrounds, large-area samples were exposed underground for approximately three months in the planned SuperCDMS SNOLAB experiment location while simultaneously monitoring several environmental factors. Predictions of the radon-daughter plate-out rate are compared to the resulting surface activities, obtained from high-sensitivity measurements of alpha emissivity using the XIA UltraLo-1800 spectrometer at SMU. A predictive model is discussed for these materials placed in similar environmental conditions.

Session 6 / 12

Background mitigation techniques and projections for the CUORE experiment

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The Cryogenic Underground Observatory for Rare Events (CUORE) will search for the neutrinoless double-beta ($0\nu\beta\beta$) decay of ^{130}Te using a 19 tower array of 988 high-resolution TeO_2 bolometers. The goal of CUORE is to reach a 2×10^{26} year 1-sigma sensitivity on the ^{130}Te $0\nu\beta\beta$ decay half-life, which CUORE can achieve if the background index is the order of 10^{-2} counts·keV^{-1}·kg^{-1}·y^{-1} or less.
We will discuss the status of the CUORE experiment, in particular, the background mitigation techniques employed by CUORE. We will also present the results from CUORE-0, a single-tower array of 52 bolometers that ran from 2013 to 2015 at LNGS and was used to validate these background mitigation techniques.

Session 5 / 13

Cosmogenic Induced Backgrounds for the MAJORANA DEMONSTRATOR Experiment

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Neutrino-less double beta ($0\nu\beta\beta$) decay experiments probe for such rare events that the suppression and understanding of backgrounds are major experimental concerns. Cosmogenic induced isotopes have the potential to be a major background for such experiments. For the MAJORANA DEMONSTRATOR Experiment 76Ge isotope is used as both detector and source. The isotopes 68Ge and 60Co are cosmogenically produced when the Germanium materials are near Earth's surface. The decay of these isotopes can mimic events in the $0\nu\beta\beta$ region of interest. For this reason, the enriched materials were minimized and closely monitored for surface exposure time during detector production. Cosmogenic induced backgrounds, primarily tritium, also have a major impact for any low energy campaign for the MAJORANA DEMONSTRATOR. In this talk I will present the estimation of cosmogenic backgrounds for the enriched 76Ge detectors and the extraction of the low energy events from our early data sets.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, the Particle Astrophysics and Nuclear Physics Programs of the National Science Foundation, and the Sanford Underground Research Facility. We acknowledge the support of the U.S. Department of Energy through the LANL/LDRD Program.

Session 7 / 14

Low background materials and fabrication techniques for Cables and connectors of the Majorana Demonstrator

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The Majorana Collaboration is searching for the neutrinoless double-beta decay of the nucleus 76Ge. The Majorana Demonstrator is an array of germanium detectors deployed with the aim of implementing background reduction techniques suitable for a 1-tonne 76Ge-based search (LEGEND). These germanium detectors operate in an ultra-pure vacuum cryostat at 80K. One special challenge of an ultra-pure environment is to develop reliable cables, connectors, and electronics that do not significantly contribute to the radioactive background of the experiment. In this talk I will highlight the experimental requirements and how these requirements were met for the Majorana Demonstrator, including plans to upgrade the wiring for higher reliability in late 2017. I will also highlight requirements for LEGEND and R&D efforts underway to meet these additional requirements.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, the Particle Astrophysics and Nuclear Physics Programs of the National Science Foundation, and the Sanford Underground Research Facility.

Session 6 / 15

Contamination Control and Assay Results for the MAJORANA DEMONSTRATOR Ultra Clean Components

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The MAJORANA DEMONSTRATOR is a neutrinoless double beta decay experiment utilizing enriched Ge-76 detectors in 2 separate modules inside of a common compact shield at the Sanford

Underground Research Facility. The DEMONSTRATOR has developed specialized processes for producing ultra-pure copper and plastic components and world leading assay sensitivities to validate their cleanliness. The experiment is now operating, and initial data provides new insights into the success of cleaning and processing. Post production copper assays after the completion of Module 1 showed an increase in U and Th contamination in finished parts compared to starting bulk material. A revised cleaning method and additional round of surface contamination studies prior to Module 2 construction provided evidence that more rigorous process control can reduce surface contamination. This talk will describe assay results, comparison to MAJORANA DEMONSTRATOR data, and discuss further studies proposed to take advantage of assay capabilities for the purpose of ultra clean fabrication and process design.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, the Particle Astrophysics and Nuclear Physics Programs of the National Science Foundation, and the Sanford Underground Research Facility.

Session 1 / 16

Overview of World Underground Facilities

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Underground laboratory, especially deep underground laboratory has been very important and key platform for many rare events experiments such as dark matter direct detection, double beta decay, solar neutrino experiments, and the quite long-standing proton decay experiments, and so on. Most of these rare event experiments are the crucial approach to search for new physics above the Standard Model of particle physics. Many underground laboratories have been constructed in the last decades over the world and provided the underground spaces to run quite diversified science projects. Some of the experiments have achieved very important physical results.

Summary:

This talk will introduce the recent development and prospects of the underground laboratories and the experiments run or planed therein. Some main parameters, characteristics and auxiliary facilities of these different underground laboratories will also covered in this talk.

Session 2 / 18

Measuring radioactive contamination using ICP-MS

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The Super-Kamiokande Gadolinium project (SK-Gd) aims to measure Supernova Relic Neutrino by adding Gadolinium Sulfate into the Super-Kamiokande. Before loading, radioactive contamination (e.g. U, Th) in Gadolinium Sulfate should be purified.
At present, purification of Gadolinium Sulfate is in progress, however there is no way to measure radioactive contamination in Gadolinium Sulfate with ppq level.

At the end of 2016, new ICP-MS was installed in Kamioka to measure radioactive in Gadolinium Sulfate.
For more precise ICP-MS measurement, we are now developing new method that extracting radioactive contamination from Gadolinium Sulfate.
In the conference, the ICP-MS measurement and new technique of chemical extraction will be presented.

Session 2 / **19**

Precise measurement of Pb210 and Po210 contamination in bulk copper

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e have established the new method to measure the Pb210/Po210 contamination in bulk copper using low background alpha counter. We measured the various kinds of copper and found that even oxygen free copper contaminates a few tens mBq/kg of Pb210. By electrolytic refining, most of Pb210 is removed. But small amount of Pb210 remain in the refined coppers. Also we found that Pb210 contamination of 6N copper is estimated to be equal or less than a few mBq/kg. This method to measure the bulk Pb210/Po210 contamination can apply to other materials.

Session 5 / **20**

Cosmogenic activation: recent results

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Activation of materials is known to cause background events in underground experiments that may affect the sensitivity of these experiments to rare event searches. The most common source of activation is the exposure of materials to cosmic rays at the surface of the Earth but other various sources of neutrons may also be dangerous. Different computer codes provide estimates of the production rates of radioactive isotopes due to activation but their results are sometimes inconsistent. High-sensitivity experiments looking for dark matter, neutrinoless double beta decay or neutrinos from various sources, although affected by activation, provide crucial tests of models used in the codes. In this talk I review recent calculations and measurements of activation rates.

Poster Session - Board: 2 / **21**

An Ar-gas ionization chamber for alpha particle detection at the Yangyang underground laboratory.

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A high-sensitivity ionization detector for measuring alpha particles in a laminar sample has been operating in the Yangyang underground laboratory.
The alpha counter is used to assay detector materials, especially their surface contamination, for the COSINE dark matter experiment and the AMoRE double beta decay experiment.
Using distinct rise time, this instrument describes characteristic signals from ionization electrons produced from the sample tray and veto those from other sources.
The detector can reach a sensitivity as low as 0.0001 count/cm^2/hr.
Low-background measurements will be presented along with studies of various surface treatments, cleaning methods, and artificial contamination.

Session 1 / **22**

Copper Electroforming Service at Laboratorio Subterráneo de Canfranc

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Ultra-pure construction materials are required for the next generation experiments on neutrino physics and dark matter. Copper has excellent mechanical, electrical and, thermal properties and is easily purified by electrochemical methods. Electroforming is an electrochemical process that enables the manufacture of metallic parts with high chemical and radioactive purity, process reproducibility and good mechanical properties. Therefore, the electroforming of copper pieces has been reported to be an effective way to obtain high-pure copper needed for the construction of these low-background experiments.

To support the construction of the experiments at the Laboratorio Subterráneo de Canfranc (LSC) in Spain, a Copper Electroforming Service (CES) is in operation. The technique, set-up and results of the electroformed copper pieces obtained at the CES are presented. Results from several gamma spectrometry measurements and ICP-MS assays on electroformed copper are reported.

Session 1 / **23**

China Jinping underground Laboratory (CJPL): Status and prospect

Author: Hao Ma[1]

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China Jinping underground laboratory (CJPL) is the deepest laboratory in the world and an ideal site for particle physics, astrophysics and other low background experiments. It is located in the Jinping Mountain, Sichuan Province, southwest China, with an overburden of about 2400m. The laboratory

is operated by Tsinghua University and Yalong River Hydropower Development Company, LTD. The scientific project at CJPL is mainly focused on dark matter experiment and low background screening techniques. This paper will give an overview of conditions, status and future plan of the laboratory. Main experiments and scientific activities carried out at CJPL will also be presented.

Poster Session - Board: 3 / **24**

MoO3 purification for searching on neutrinoless double beta decay for AMoRE

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The AMoRE (Advanced Mo based Rare process Experiment) is searching for neutrinoless double beta ($0\nu\beta\beta$) decay of 100Mo using radiopure molybdate-based crystals. 100Mo is one of the favorite isotopes in searches for $0\nu\beta\beta$ decay due to high energy release, $Q\beta\beta$=3034 keV and quite large natural abundance, 9.82%. Since there are no commercially available molybdenum compounds with required purity levels, one of the important stages of the program is the deep purification of initial materials which intended to reduce the internal radioactive contamination. This study discusses approaches to purify initial Molybdenum Oxide 99.95 % purity grade. A double sublimation, fractional crystallization and co-precipitation from aqueous solution were used as purification methods. The other important requirements for the study are its high performance, high efficiency of purification and minimal irretrievable losses of material. In order to check effectiveness of purification, concentrations of impurities (Sr, Ba, Pb, Th and U) were measured by ICP-MS and radioactivity was checked by HPGe detectors at Yangyang underground laboratory in Korea.

Summary:

The purification method presented in this report have shown good separation of Sr, Ba, Pb, Th and U from initial molybdenum oxide powder with high recovery yield for final product. Moreover, sublimation and recrystallization do not require the use of large quantities of expensive ultrapure reagents. At present time, this study is ongoing to improve data and search advanced purification method.

Session 4 / **25**

Experience of gas purification and radon control in Borexino

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Borexino, located at the Gran Sasso Laboratory, is a liquid scintillator detector with active mass of 278 tons. The main goal of the experiment is the real-time registration of sub-MeV solar neutrinos through their elastic scattering on electrons. The lack of directionality of the light emitted by the scintillator makes it impossible to distinguish neutrino-scattered electrons from electrons due to natural radioactivity. This leads to a crucial requirement of the Borexino technology, namely an extremely low radioactive contamination of the detection medium. This has been achieved after very extensive R&D studies, and presently the detector purity is at an unprecedented level, never achieved so far in any other project. In this sense the Borexino detector is very unique world-wide and allows to study extremely week processes. Thanks to its very low background level, the collaboration was able to register in real-time almost entire spectrum of the solar neutrinos, including the most fundamental low energy pp neutrinos.

An important measure to achieve in Borexino the required radio-purity was careful material screening with very sensitive devices. For this purpose the world's most sensitive gamma ray spectrometer –GeMPI –was developed (detection limit of <10 micro_Bq/kg for U/Th). Even more important was the elimination of Rn-222 sources. Rn-222 is a relatively long-lived radioactive noble gas isotope which may diffuse into the fiducial volume of the liquid scintillator. A screening technique dedicated to measurements of Rn-222 with a few atom sensitivity will be discussed along with results obtained from various subsystems of Borexino. Studies of very weak radon diffusion/permeation through the Borexino scintillator vessel will also be outlined. One of the crucial points in the experiment was the radio-purity of gases used for blanketing, purging or purification purposes. A dedicated plant, which continuously produces almost Rn-222-free nitrogen (less than 1 atom in 4 m3 at STP) at high flow-rate (up to 200 m3/h) was installed underground. It is based on cryo-adsorption of radon from nitrogen liquid phase. We also successfully searched for nitrogen with a particularly low argon (below ppb) and krypton (below 0.1 ppt) concentrations. A special logistic procedures and a cryogenic system were developed in order to maintain the purity and make it possible to deliver the nitrogen to the experimental site. This is still the radio-purest gas used by any experiment ever. Production of synthetic air with a very low Rn-222 level by mixing oxygen with radon-free nitrogen will also be briefly described.

Session 7 / 26

Removal of Rn-222 daughters from metal surfaces

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Surface contamination with long-lived daughters of Rn-222 is of great interest for experiments looking for rare events. These include the detection of low energy solar neutrinos, searches for neutrinoless double beta decay or searches or dark matter. Decays of Pb-210, Bi-210 and finally Po-210 may contribute significantly to the experiments'background, especially when they appear close or directly in the active volumes.

We will present the first measurements of natural contamination of metal surfaces with Po-210 (U-238 chain, T1/2 = 138 days). Measurements were performed with an ultra-low background, large-areas alpha spectrometer. The instrument allows to study the surface contamination down to about 100 alpha decays per day and per m2. Copper, stainless steel and titanium samples of the size of 43x43 cm and 1 mm thick were investigated. The assay showed no detectable surface contamination of stainless steel and copper covered with a protective foil against contamination with the air-born Po-210. Unprotected surfaces of titanium and commercial ETP (electroformed) copper showed significant surface polonium activity.

By attributing the counts in the registered spectra in the range of 1.5 MeV to 6 MeV to sub-surface Po-210 we could also investigate the bulk Po-210 contamination (alphas coming from different depths can populate the spectrum up to the 5.3 MeV, which including the energy resolution of the device, was extended to 6 MeV). The estimated sensitivity for the bulk contamination for e.g. copper is about 50 mBq/kg, which is presently the best limit (assuming secular equilibrium in the Pb-210 –Bi-210 –Po-210 it hold also for Pb-210). Significant amounts of polonium were detected in stainless steel, titanium, and unexpectedly also in the ETP copper.

We also studied the two most popular surface cleaning methods, which are etching and electro-polishing. They were applied to the investigated copper, stainless steel and titanium samples. In the course of this study we established for the first time an etching procedure, which influences (reduces) significantly the copper surface activity. For stainless steel and titanium reduction by one order of magnitude was achieved. Electro-polishing of copper and steel reduced their surface Po-210 by a factor of about 20, what is consistent with our previous studies performed for samples artificially loaded with high Po activity.

Session 4 / 27

The purification study on the Liquid Scintillator for JUNO

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The Jiangmen Underground Neutrino Observatory (JUNO) is under construction in the south of China which aims to measure the neutrino mass hierarchy and neutrino oscillation parameters by studying the reactor neutrinos from two nearby nuclear power plants 53km away. JUNO is also designed to has good capabilities of researches such as supernova neutrinos, geo-neutrinos, solar neutrinos and so on. The energy resolution of JUNO central detector will reach 3% at 1MeV, corresponding to at least 1,100 photoelectrons (pe) per MeV of deposited energy. The central detector consists of 20,000 tons of liquid scintillator(LS) in a acrylic ball with the diameter of 35.4 meters. The proper manipulation of the LS is needed for two reasons: on one hand to ensure the degree of transparency which has to contribute to the overall light yield of the experiment, and on the other to keep the radiopurity of the liquid itself at least in the 10^-15 g/g range (in term of U and Th contaminations). The study on the techniques include alumina absorption column, distillation, water extraction, and gas stripping will be reported and the prototype test of the combined techniques checked with one of the AD detector of Day Bay, whose scintillator replaced with the purified one, will be introduced, too.

Session 6 / 28

Background free double-beta decay investigation with CUPID-0

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A convincing observation of neutrino-less double beta decay (0nu;DBD) pivots on the possibility of operating high-energy resolution detectors in background-free conditions. The CUPID-0 experiment is the first step of a next generation project based on cryogenic calorimeters equipped with light detectors able to measure the scintillating light produced in the scintillating absorbers for particle identification. In 2016 we completed the assembly of 26 Zn⁸²Se scintillating calorimeters (about 2times;10²⁵ 0nu;DBD emitters), and started the data taking. In this contribution we present the status and the preliminary results of CUPID-0 and the perspectives of a next generation project based on this technology.

Session 8 / 29

Impact and Mitigation of Naturally Occurring ^{32}Si

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The recent observation by the DAMIC experiment of ~80 events/day/kg, associated with trace levels of ^{32}Si in their CCDs, is a concern for future Si-based dark matter detectors. These data suggest a ^{32}Si concentration of ~1 in 10^{18} Si atoms. With a half-life of order 153 years, any geologically aged silicon source should be nearly devoid of ^{32}Si. Yet the DAMIC silicon is only two orders of magnitude lower in ^{32}Si concentration than seawater silica (1 in 10^{16}), which is expected to be in equilibrium with atmospherically produced ^{32}Si. This surprisingly high ^{32}Si concentration in ultra-high resistivity silicon may reflect two disparate factors: first, the silicon production is focused on chemical purity and primarily on elements that impact electrical properties; second, silicon metal comes from mining operations that use large quantities of water to move material and reduce dust. Silica gels can form in the early stages of mining and ore processing that could capture atmospheric ^{32}Si and introduce it into the metallurgical supply. We have examined the issues related to detecting and mitigating ^{32}Si in high-resistivity silicon. Radiation counting appears to be the most reliable detection method at concentrations this low but requires us to work with gaseous phases such as SiF_4. We have a plan to detect ^{32}Si in commodity silicon that may lead to a method to reduce its concentration in our crystal supply chain. An alternative mitigation plan is to obtain depleted SiF_4 developed for the Avogadro Project. We will discuss prospects for a sensitive detection method and mitigation strategies to ensure that precursor materials for future detectors will be greatly reduced in ^{32}Si.

Summary:

^{32}Si is a radioactive isotope with low natural abundance. It is created in the upper atmosphere and has been measured in rain and ocean waters. It is a source of unwanted background radiation in the DAMIC experiment. We are in the process of developing methods to detect and mitigate ^{32}Si in commodity silicon.

Poster Session - Board: 4 / **30**

Performance of a silicon PIN photodiode based radon detector for low radioactivity environment

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It is very important to monitor the amount of radon (Rn-222) in the underground experiments such as rare decay and dark matter experiments with ultra low background requirements. The radioactivity from the radon can be a significant background source to the experiments and need to be measured precisely. We have upgraded a radon detector with a volume of ~70 L which was used in the KIMS (Korean Invisible Matter Search) experiment by replacing with a Hamamatsu silicon PIN photodiode and a Hamamatsu pre-amplifier. The positively charged radon's daughter particles (Po-214 and Po-218 mostly) produced in the air of the detector chamber are collected by the photodiode in a negative high voltage. The energy resolutions of alpha particles emitted from the decays of the daughter particles are measured to be better than 0.6% with very clean signals to be be identified. We also have had about 3 months of data with the air sealed after closing the chamber. The half-lifetimes of Rn-222 from two daughter particles measured together with the background level of the chamber are going to be presented.

Session 8 / 31

Progress in Ultra-Low-Radioactive titanium production

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Basic principles of titanium production together with very high technological culture of titanium industry predefined a possibility to develop a technological cycle of the ultra-low-radioactive titanium (ULR-Ti) production. It was confirmed experimentally that it is possible to produce a titanium sponge with a level of contaminations below 1 mBq/kg of U and Th within an industrial Kroll-process. At the next step ULR-Ti sponge was converted into the construction titanium of VT-00 grade using EB-vacuum melting followed by bi-directional cold rolling and annealing to avoid a recontamination and keep the material as pure as the original sponge. The mechanical properties of the manufactured ULR-Ti fit demands for the VT-00 grade. Hence, this material could be used for production of cryostats, containment tanks, passive shielding and other mechanical elements of the modern low-background detectors. It was also tested and confirmed that a laser welding is preferable to an arc welding in order to keep ULR-Ti original purity. The mass of the first ULR-Ti bunch produced for test purposes and spent for radio-purity and mechanical tests at different production stages was of a scale of tens kilos. The jump from a laboratory kilos scale to the tons scale needs additional investigations. But it should be noted, that current kilos scale samples where manufactured by the standard industrial processes.

Session 4 / 33

Radon Mitigation for the SuperCDMS SNOLAB Dark Matter Experiment

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A potential background for the SuperCDMS SNOLAB dark matter experiment is from radon daughters that have plated out onto detector surfaces. To reach background requirements, understanding plate-out rates during detector fabrication as well as mitigating radon in surrounding air is critical. A radon mitigated cleanroom planned at SNOLAB builds upon a system commissioned at the South Dakota School of Mines & Technology (SD Mines). The ultra-low radon cleanroom at SD Mines has air supplied by an optimized vacuum-swing-adsorption radon mitigation system that has achieved > 1000× reduction for a cleanroom activity consistent with zero and < 0.067 Bq/m^3 at 90% confidence. Our simulation of this system, validated against calibration data, provides opportunity for increased understanding and optimization for this and future systems.

Session 7 / **34**

A review and outlook for the removal of radon-generated Po-210 surface contamination

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The next generation low-background detectors operating deep underground aim for unprecedented low levels of radioactive backgrounds.
The deposition and presence of radon progeny on detector surfaces is an added source of energetic background events.
In addition to limiting the detector material's radon exposure in order to reduce potential surface backgrounds, it is just as important to clean surfaces to remove inevitable contamination. Such studies of radon progeny removal have generally found that a form of etching is effective at removing some of the progeny (Bi and Pb), however more aggressive techniques, including electropolishing, have been shown to effectively remove the Po atoms. In the absence of an aggressive etch, a significant fraction of the Po atoms are believed to either remain behind on the surface or redeposit from the etching solution back onto the surface. We explore the chemical nature of the aqueous solution and an electrolytic cell potential to control the oxidation state of Po thereby maximizing the Po ions remaining in the etching solution of contaminated Cu surfaces. We present a review of the previous studies of surface radon progeny removal and our findings on the role of an electrolytic cell and Po oxidation in the preparation of a clean etching technique.

Poster Session - Board: 5 / **35**

Sodium Iodide (NaI) Purification for Searching on Dark matter for the COSINE

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The COSINE collaboration has developed low-background NaI crystals for searching for dark matter. The sensitivity of the experiment is limited by the radioactive background inside the crystal. Therefore, purification of raw powder is essential to grow the low-background of NaI crystal. Recrystallization method is one of the purification technique of powder based on different solubility at different temperature. Recrystallization method was used to remove the natural radioactive isotope impurities from NaI powder. Content of impurities in initial and purified NaI powder was measured by Inductively Coupled Plasma Mass Spectrometer (ICP-MS) analysis. This method has shown effective removing of the impurities, such as K, Pb and etc., in the initial NaI powder.

Summary:

The recrystallization method had shown effective removing of the impurities, such as Ba, K, Pb, and Sr in the initial NaI powder. In this time, this study is ongoing to improve the decontamination factor and recovery efficiency.

Session 7 / **36**

On the DEAP-3600 in-situ resurfacing.

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The DEAP-3600 experiment is a single-phase detector that uses 3600 Kg of liquid argon to search for Dark Matter at SNOLAB, Sudbury, Canada, 6800 ft. underground. The
projected sensitivity to the spin-independent WIMP-nucleon cross-section is 10^{-46} cm^2 for a WIMP mass of 100 GeV.
One of the primary sources backgrounds to the WIMP search are alpha decays occurring on the surface of the experiment, which could mimic the expected signal. The work reported here focuses on the development and operation of a custom designed robot, the Resurfacer, aimed at removing 500 microns from the most inner layer of the detector's surface, thus removing any contamination introduced during the construction phase.

Session 6 / **38**

A New Tool for (α,n) Yield Calculations and Radiogenic Neutron Backgrounds in DEAP-3600

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Neutron-induced nuclear recoils present one of the dominant backgrounds in many low-background experiments. These neutrons are largely radiogenic in origin, coming from fission and (α,n) reactions in detector components. The (α,n) neutron production rate in a material depends on the composition of the material as well as the energies of the α decays that occur within it. In this talk, we will present NeuCBOT, a new tool for calculating the (α,n) yields and neutron energy spectra for arbitrary materials exposed to contamination from a given set of α energies or α-emitting isotopes, and we will benchmark these calculations against calculations made by SOURCES-4A and various measured yields.

We will discuss these yield calculations in the context of DEAP-3600, a dark matter detector located at SNOlab, searching for nuclear recoils produced by Weakly Interacting Massive Particles. Using NeuCBOT and Geant4 simulations, we will predict the neutron-induced nuclear recoil backgrounds in DEAP-3600. We will then present in-situ measurements of neutron interactions in DEAP-3600 to show that these predictions are consistent with our observations, and that the neutron backgrounds are within the experiment's design goals.

Summary:

I will be presenting a new neutron yield calculator, NeuCBOT, as well as discussing the expected neutron backgrounds in DEAP-3600, including in-situ limits on the neutron background rate, consistent with these predictions.

Session 6 / **39**

Status of the SABRE experiment and background characterization

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The SABRE (Sodium-iodide with Active Background REjection) experiment is designed to search for WIMP dark matter via detection of an annually modulating signal.
The DAMA/LIBRA experiment claims the observation of a modulation compatible with dark matter detection. However, the candidate dark matter signal has not yet been confirmed by other experiments. SABRE will perform a high sensitivity search for a modulating signal using an array of NaI(Tl) crystals with unprecedented radio-purity, state-of-the-art phototubes, an active background veto, and ultra-pure-water shielding. The project comprises twin detectors installed at LNGS (Italy) and at SUPL (Australia). This solution will reduce seasonal and local systematic biases and will allow a more detailed study of the potential signal.
This talk will give an overview of the project, will describe recent developments, and will present a preliminary background model based on simulations and radio-purity measurements.

Session 7 / **40**

Development of a low alpha emitting μ-PIC for NEWAGE direction-sensitive dark matter search

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The NEWAGE detector is a gaseous micro-TPC using μ-PIC. We found the main background sources are alpha rays from the radioactive contaminations in the μ-PIC. So, low alpha emitting μ-PICs have been developed. The performance of these μ-PICs will be presented.
We set up a surface alpha ray counter using micro TPC in Kamioka mine. We measured surface alpha ray emission rate of the μ-PIC. The result will be presented.

Session 6 / **41**

Status of NEWS-G Experiment

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News Experiment With Sphere- Gaseous (NEWS-G) detector is a world wide collaboration based on spherical gas detector for Light Dark Matter search.
The first low radioactivity spherical detector, SEDINE (60 cm diameter), installed at LSM on 2012 is continuing to take data. The next detector, 140 cm in diameter, will be fabricated using remarkable ultra-low radioactivity (few microBq/kg).
This large detector will first arrive at LSM. The spherical copper vessel will undergo inner surface cleaning (to remove the radon daughter from surface) then it will be mounted at its shield, before transportation and installation at its final location at SNOLAB (for physic runs).
Status of SEDINE and its perspectives will be presented. Also, study and progress on the fabrication of the new large detector, all material selections and first design will be shown.

Poster Session - Board: 6 / **42**

Low radioactivity and Multi- disciplinarily Underground Laboratory of Modane (LSM)

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The Modane Underground Laboratory (LSM) is located 1700 m (4800 m.w.e) below Fréjus peak (Alpes chain) mountain in the middle of the Fréjus tunnel between France/Italy. The LSM is a multi-disciplinary platform for the experiments requiring low radioactivity environment. Several experiments in Particle and Astroparticle Physics, low-level of High Purity of Germanium gamma ray spectrometry, biology and home land security hosted in the LSM. It's equipped by Anti-Radon facility where all of the detectors are under Radon depleted Air. I'll present the LSM structure and briefly reviewed of all experiments are installed in.

Session 7 / 43

Measurements of surface radioactivity by Alpha/Beta detection

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Surface contamination is an important background in many $2\beta0\nu$ or dark matter searches.
For example, gammas or betas can leak in the neutron recoil band if they sit on the surface of the bolometers like in Edelweiss or CDMS experiments. For $2\beta0\nu$ experiments like CUORE, degraded surface alphas can get into the $2\beta0\nu$ region and can not be distinguished from a $2\beta0\nu$ event. In experiments like SuperNemo the ^{208}Tl and ^{214}Bi contamination in the thin $2\beta0\nu$ sources, which may produce two electrons, is one of the most critical source of background.

In this talk I will describe and present the performances of some large area detectors used nowadays in the low-background community to assay surface contaminations by alpha/beta detection. This review includes the XIA low-background alpha spectrometer, the BiPo-3 detector and the BetaCage.

Poster Session - Board: 7 / **44**

Mobility and lifetime of 220-Rn daughters

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Noble (argon, xenon) or inert (nitrogen) gases are extensively utilized in experiments looking for rare nuclear events at low energies, for which reduction of backgrounds is crucial. Highly radio-pure detectors (e.g. HPGe diodes in LAr, LAr/LXe TPCs) are in direct contact with the gases, being exposed to the intrinsic impurities during assembly, handling and operation. Therefore ^{222}Rn daughters plating out on the detectors' surfaces (especially long-lived ^{210}Pb) may significantly contribute to the overall background index.

A measurement method of mobility and ionic lifetime of alpha emitters from the ^{220}Rn decay chain is presented, based on a teflon-made, 20 cm tube, instrumented on one end with a large area (1 cm^2) Si-PIN diode as alpha-particle detector. Opposite to the detector a ^{228}Th surface alpha-source is placed on a movable holder. The high voltage divider resistors, located in the groove outside the tube, form the electric field. The alpha-activity registered by the diode varies with the field strength and the source distance for each gas tested. Opposite polarities of ions produced in energetic alpha and beta decays were tested.

The choice of ^{220}Rn chain over ^{222}Rn is based on the fact that the shorter nuclear life-time of ^{220}Rn and ^{216}Po allows for easy determination of their mobility and ionic lifetime in the setup described. A typical mobility of positively charged Po-216 measured is on the order of 1.3 cm^{2}s^{-1}V^{-1}, while the ionic lifetime is approximately 10 s (and much longer for ultra-pure gases).

Foreseen are measurements of the ionic properties in cryogenic liquids, being highly relevant for such setups as DarkSide (LAr TPC) or Gerda (HPGe in LAr), where energetic alpha or beta decays present in the ^{222}Rn products entering the experiments' active volumes may mimic the signal of interest for these experiments. Properties of the ionized ^{222}Rn daughters deduced from the conducted measurements are therefore outlined.

Session 2 / 45

Low Radioactivity Techniques based on ICP-MS at Peking University

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1. A brief introduction to the trace analysis lab for Low Radioactivity Techniques at Peking University
2. Isotope dilution analysis using radioactive tracers for U and Th Cu Polymethyl Methacrylate (PMMA） Stainless Steel

Session 8 / 46

MoO3 and NaI powder purification for AMoRE and COSINE to make ultra-low background crystals

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The AMoRE (Advanced Mo based Rare process Experiment) is searching for neutrinoless double beta decay of 100Mo using radiopure molybdate-based crystals. The COSINE collaboration is searching for dark matter with ultra-low background NaI crystals either to confirm or to refute the DAMA signal. Since there are no commercially available powders with required purity levels to grow Mo-based crystal and NaI crystal, one of important programs in the Center for Underground Physics at IBS in Korea is the purification of initial materials to reduce the internal radioactive contamination. In the purification of MoO3 powder, a double sublimation, fractional crystallization and co-precipitation from aqueous solution were used as purification methods. The other important requirements for the study are its high performance, high efficiency of purification and minimal irretrievable losses of material. In the purification of NaI, we used recrystallization method to remove radioactive isotope impurities, mainly K, from NaI powder. In order to check effectiveness of purification, concentrations of impurities (K, Sr, Ba, Pb, Th and U) were measured by ICP-MS and radioactivities were checked by HPGe detector at Yangyang underground laboratory in Korea.

Session 2 / **47**

Development and implementation of an ultra low background Array of HPGe detectors

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The Center for Underground Physics (CUP) of IBS has developed in collaboration with CANBERRA an ultra low background Array of 14 p-type coaxial HPGe detectors, each having a 70% relative efficiency.

This instrument has been designed and constructed with materials selected in radio purity to reach the lowest possible intrinsic background. The contribution to the instrument background due to the contamination in primordial radionuclide of all the raw materials has been evaluated by performing Monte Carlo simulations and comparing them to measured gamma spectra of the sample materials (using other HPGe detector systems).

To further reduce the external radioactive background, a dedicated shielding has been designed and the Array is currently installed in the Y2L underground laboratory. The expected sensitivity of the instrument allows to perform rare decays searches such as the measurement of 180mTa decay.

In this contribution the development of the instrument, the installation and the preliminary background measurement will be presented.

Session 8 / **48**

Organic Scintillator and Tellurium Purification Techniques of the SNO+ Double Beta Decay Experiment

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SNO+ will be a successor to the Sudbury Neutrino Observatory (SNO) that will be filled with an organic liquid scintillator and optimized to maximize its sensitivity to neutrinoless double beta (NLDBD). The project will be executed in three phases; In the first phase, that is currently approaching completion, the detector will be filled with light water, that would then be displaced by 780 metric tonnes of purified Linear Albylbenzene (LAB) into phase two. After evaluation of internal backgrounds, the LAB scintillator will be recirculated and loaded with an organometallic form of a tellurium complex that will initiate phase three and the NLDBD physics mode. The entire operation is anticipated to complete by the end of 2018.
In this talk, I will introduce the three main ingredients of the liquid scintillator: the LAB, the telluric acid and the diol used in the complex synthesis process, along with their purification techniques that have been developed by the SNO+ collaboration. I will conclude by presenting the performance of the achieved scintillator cocktail and the NLDBD sensitivity of the SNO+ experiment.

Poster Session - Board: 8 / **49**

Background reduction and status of the SuperNemo experiment

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The SuperNemo experiment is looking for neutrinoless double beta decay using the combination of tracking and calorimeter techniques. The aim of SuperNemo is to achieve a sensitivity for the neutrinoless double-beta decay half-life of 10^{26} y and Majorana mass scales ~ 50- 100 meV.
The first module of SuperNemo which is under construction, will contain 7kg of ^{82}Se as $2\beta0\nu$ source, in the form of thin foils. To achieve the sensitivity goals, the calorimeter, the tracker and the $2\beta0\nu$ sources have been constructed taking very special care on the radiopurity.
The calorimeter employing 8-inch low radioactivity PMTs coupled to polystrene scintillators is completed. The production of the tracker modules is also completed and dedicated measurements indicate that the Rn activity at the required level of 150 μBq/m^3 can be achieved with reasonable flow-rates. The source production is ongoing and long-term dedicated radiopurity measurements have been performed.
In this talk I will present the fabrication of the source foils and their radiopurity measurement, the control of the Rn diffusion and emanation as well as selected results of the material screening. I will also present the status of the construction of the first SuperNemo module.

Poster Session - Board: 9 / **50**

Status of the Y2L HPGe laboratory for low background measurements

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The YangYang underground Laboratory (Y2L) has a dedicated facility, managed by CUP, for the low background gamma spectroscopy measurements with High Purity Germanium (HPGe) detectors. Three detectors are currently operating: two 100% relative efficiency p-type and one well-type HPGe detector. The radioactive background of all these instruments have been improved with dedicated shieldings and they are used to perform low background measurements for the material selection of rare physics events experiments such as AMoRE and COSINE. The status of the Y2L HPGe low background measurement laboratory will be presented.

Poster Session - Board: 10 / **51**

DAQ optimization, signal processing and simulations for an ultra low background HPGe detectors Array

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In the Y2L underground laboratory, a newly developed ultra low background Array of 14 HPGe detectors has been recently installed and is currently operating. To register single and coincidence spectra of all the detectors it was necessary to develop a dedicated DAQ system and analysis software.

The low radioactive background of the Array can be exploited to perform not only high sensitivity material selection for rare event physics experiment but also for the measurements of rare decays. Monte Carlo simulations, based on Geant4, have been performed to evaluate the expected sensitivity of the instrument concerning the measurement of 180mTa rare decay. The details of the DAQ system, signal processing and simulation results will be presented in this contribution.

Session 2 / **52**

New and Improved Tools for More Sensitive ICP-MS Assays

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This presentation will discuss two areas of recent research at Pacific Northwest National Laboratory: the determination of K in ultralow background detector materials and the automation of complex sample separations for the ultrasensitive determination of U and Th.

Along with the U and Th decay series species, 40K is a naturally-occurring radioactive contaminant that can cause problematic backgrounds in rare-event physics detectors. As such, its characterization and screening is required to ensure sufficiently low levels are introduced to the detector to meet sensitivity specifications. This presentation will discuss the operation and advantages of a triple-quadrupole ICP-MS for the quick and sensitive determination of 40K in NaI scintillator crystals, as well as in polymers and copper.

A second brief discussion will focus on exploring the advantages and performance of a newly installed and employed automated anion exchange separation system used for assays. The automated system mimics the demanding work that would previously be conducted manually by a chemist. The automated anion exchange separation removes much of the matrix, such as copper, in an acid dissolved solution while retaining and preconcentrating the U and Th for later detection by ICP-MS. This study also directly benefits our ultrasensitive polymer assay method, which employs the dry ashing of polymers in ultralow background electroformed copper crucibles. The metal residue (i.e., U and Th) remaining in the copper crucible is completely dissolved and separated using the automated system, just as for copper assay.

Poster Session - Board: 11 / **53**

Radon Daughter Plateout

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Rare event searches work very hard to identify and procure radiopure materials for detector components. These components may be contaminated after manufacture with long-lived ^{210}Pb, produced by the decay of atmospheric radon. We will show how the rate of radon daughter plateout can vary by orders of magnitude due to various environmental factors including material type, surface orientation, and ventilation.

Poster Session - Board: 12 / **54**

The BetaCage: An Ultra-sensitive Screener for Surface Contamination

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Material screening for identifying low-energy electron emitters and alpha-decaying isotopes is now a prerequisite for rare-event searches (e.g., dark-matter direct detection and neutrinoless double-beta decay) for which surface radiocontamination has become an increasingly important background. The BetaCage, a gaseous neon time-projection chamber, is a proposed ultra-sensitive (and nondestructive) screener for alpha and beta-emitting surface contaminants to which existing screening facilities are insufficiently sensitive. The expected sensitivity is 0.1 betas (per keV-m^2-day) and 0.1 alphas (per m^2-day), where the former will be limited by Compton scattering of external photons in the screening samples and (thanks to tracking) the latter is expected to be signal-limited; radioassays and simulations indicate backgrounds from detector materials and
radon daughters should be subdominant. We will report on details of the background
simulations and detector design that provide the discrimination, shielding, and radiopurity necessary to reach our sensitivity goals for a chamber with a 95x75 cm^2 sample area positioned below a 40 cm drift region and monitored by crisscrossed anode and cathode planes consisting of 151 wires and 112 wires, respectively.

Session 8 / **55**

Improving background levels of $CaWO_4$ detectors for the CRESST dark matter search

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The CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) experiment, its third phase has successfully started in summer 2016, aims at the direct detection of dark matter particles. CRESST uses $CaWO_4$ crystals operated as cryogenic detectors at a temperature of ~10mK. During recent years, the intrinsic radiopurity of $CaWO_4$ crystals, the capability to reject recoil events from alpha-surface contamination and the energy threshold were improved significantly. In the talk I will discuss the various techniques to reduce external and crystal-intrinsic background levels, including purification methods of raw materials for CaWO4 crystal growth. I will conclude that these improvements strongly increase the sensitivity of CRESST detectors, in particular, for light-mass dark matter particles.

Session 2 / **56**

Development of CANDLES Low Background HPGe Detector and Half-life Measurement of Ta-180m

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Low background HPGe detector is commonly used as high energy resolution gamma-ray spectrometer for radioactivity measurement. At Kamioka Underground Observatory (2700 m.w.e.), a HPGe detector system was developed in CANDLES Experimental Hall for material screening, tantalum-180m (^{180m}Ta) half-life measurement and multipurpose use.

To improve the sensitivity for the detector system, various background reduction techniques were employed, including hermatic shieldings design, suppression of radon gas effect, and off-line analysis. A new type of pulse shape discrimination (PSD) method was specially developed for coaxial Ge detector. Using the new PSD method, microphonics noise and Compton background event at energy region less than 200 keV can be rejected effectively. In addition, Monte Carlo simulation by GEANT4 was constructed to acquire the detection efficiency and study the interaction of gamma-rays with detector.

Among all nuclear isomers that exist in nature, ^{180m}Ta has the longest half-life of more than 10^{16} years, which is yet to be finalized up until now. The low background HPGe detector system of CANDLES Collaboration was utilized to achieve the most sensitive detection of ^{180m}Ta decay. Two phases of tantalum physics run were completed, which Phase II has upgraded shielding system. By combining the Tantalum Phase I and Phase II result, total livetime of 358.2 days was obtained. With various low background techniques and long-term measurement, the world most stringent half-life limit of ^{180m}Ta has been successfully achieved.

Session 4 / **57**

Constraining Radon backgrounds in LZ

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The Lux-Zeplin (LZ) dark matter detector will be a dual-phase Xe TPC with a 5.6 tonne fiducial volume located at the Sanford Underground Research Facility.

To reduce the background event rate resulting from β-decay of radon decay progeny, LZ has embarked on a comprehensive program to screen detector materials for radon emanation. We will present the status of this screening program, expected radon levels given present screening results, a summary of some recent measurements, and some mitigation strategies.

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TEST

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Testing

Session 2 / **60**

Searching for very small amounts of radioactivity by NAA

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Neutron Activation Analysis (NAA) is an established trace element analysis technique. It has important applications in the determination of very small amounts of natural radioactivity and is routinely used in the preparation of low energy low event rate experiments. In this talk I will introduce NAA and describe its use in the EXO-200 and nEXO projects, putting it into the context of the broader radioassay program.

Session 6 / 61

The R&D progress of the Jinping Neutrino Experiment

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Thanks to the 2400 m overburden and the long distance to commercial reactors, the China Jinping Underground Laboratory (CJPL) is an ideal site for low background neutrino experiments. The Jinping Neutrino Experiment will perform an in-depth research on solar neutrinos, geo-neutrinos and supernova relic neutrinos. Many efforts were devoted to the R&D of the experimental proposal. A new type of liquid scintillator, with high light-yield and Cherenkov and scintillation separation capability, is being developed. The assay and selection of low radioactive stainless-steel (SST) was carried out. A wide field-of-view of 90 degree and high-efficiency of 98% light concentrator is developed. At the same time, the design, construction and initial operation status of a 1-ton prototype will also be discussed. The 1-ton prototype is constructed and placed underground at Jinping laboratory. The purpose of the prototype is to 1) test the performance of several key detector components, like acrylic, pure water, using of ultra-high molecular weight polyethylene rope, 2) understand the neutrino detection technology with liquid scintillator and slow liquid scintillator and 3) measure the in-situ Jinping underground background, like fast neutron.

Session 2 / 62

Ultra-trace element determination by neutron activation analysis in acrylic material

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The radio purity of materials is the essential condition upon which rely the latest experiments in nuclear and particle physics. In fact, from the radio purity of the materials depends the most reduction of the experiment intrinsic background.

In cases of observation of neutrino oscillation, double beta and dark matter, the greatest risk is the fact that the common radioactive background - generated from the decay product of radio

nulides such 232Th, 238U and 40K - goes to exactly overlap in the observable energy regions of interest.

As a natural effect it is crucial to develop high-sensitivity analysis techniques to select the most suitable materials to be used in the experiment in order to reduce the radioactivity contribution at the background coming from the different components of the detector.

Acrylic is a widely used material in many experiments in the physics of rare events, in particular it's often used in the main part of the detector for its optical and mechanical properties. Therefore it is of fundamental importance its careful selection.

A methodology based on neutron activation analysis (NNA) combined with treatment of the sample surfaces has been developed to determine K, Th and U content in some acrylic samples. Particular attention was paid to the preparation of the sample to be irradiated, by phase of realization up to the handling and final cleaning.

By this methodology a ppt level has been achieved. The reported limit on the presence of 40K in acrylic are among the best ever achieved.

Session 6 / 63

Performance of upgraded shielding system in CANDLES

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CANDLES aims to measure neutrino-less double beta decays using ^{48}Ca which has the highest Q value (4.27 MeV) among all isotope candidates of double beta decays. A distinction in the measurement is an active veto system using liquid scintillator. Large amount of external backgrounds reacted in LS can be removed by taking advantage of the pulse shape difference between CaF_2 and liquid scintillator. Thanks to the high Q value and LS active veto system, background candidates are well limited in CANDLES.

Remained backgrounds are ^{208}Tl, pile-up events of ^{212}Bi-^{212}Po from ^{232}Th decays in CaF_2 crystals, and high energy gamma rays from neutron captures on rock and stainless steel tank. Since gamma rays from neutron captures was found to be the most serious background, shielding system consisted of lead and B-contained rubber sheet was constructed from year 2015 to year 2016. Performance of the constructed shielding system will be reported in the talk.

Session 8 / 64

Developing Radiopure Copper Alloys for High Strength Low Background Applications

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High purity copper continues to play an important role for ultra-low-background detectors. Measurements of rare nuclear decays, e.g. neutrinoless double-beta decay, and searches for dark matter can require construction materials that have high thermal and electrical conductivity with bulk radiopurity less than one micro-Becquerel per kilogram. However, experiments currently using components constructed of radiopure electroformed copper struggle with design of structural and mechanical parts due to the physical properties of pure copper. A higher strength material which possesses many of the favorable attributes of copper yet remains radiopure is desired. A number of copper alloying candidates which may provide improved mechanical performance and adequate radiopurity were considered. Development of an electrodeposited copper-chrome alloy from additive-free electrolyte systems is discussed. The resulting material is shown to possess high strength and meets the aforementioned radiopurity goals.

Session 1 / **65**

Recent Updates at the BHUC

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The Black Hills State University Underground Campus (BHUC) located at the Sanford Underground Research Facility in South Dakota was completed in the fall of 2015. Since that time, four ultra-low background, high-purity germanium detectors have been relocated to its class 1,000 cleanroom. More plans are underway for additional germanium detectors as well as other specialized low-background systems such as the BetaCage and a liquid scintillation detector.

Session 6 / **66**

CALDER: cryogenic light detectors for background-free searches

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CALDER is a R&D project for the development of cryogenic light detectors with an active surface of 5x5cm^2 and an energy resolution of 20eV RMS for visible and UV photons.
These devices can enhance the sensitivity of next generation large mass bolometric detectors for rare event searches, providing an active background rejection method based on particle discrimination.
A CALDER detector is composed by a large area Si absorber substrate with superconducting kinetic inductance detectors (KIDs) deposited on it.
The substrate converts the incoming light into athermal phonos, that are then sensed by the KIDs.
KID technology combine fabrication simplicity with natural attitude to frequency-domain multiplexing, making it an ideal candidate for a large scale bolometric experiments.
We will give an overview of the CALDER project and show the performances obtained with prototype detectors both in terms of energy resolution and efficiency.

Session 2 / 67

Improving the limits of detection of low background alpha emission measurements

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Alpha particle emission –even at extremely low levels –is a significant issue in the search for rare events (e.g., double beta decay, dark matter detection). Traditional measurement techniques require long counting times to measure low sample rates in the presence of much larger instrumental backgrounds. To address this, a commercially available instrument developed by XIA uses pulse shape analysis to discriminate alpha emissions produced by the sample from those produced by other surfaces of the instrument itself. Experience with this system has uncovered two residual sources of background: cosmogenics and radon emanation from internal components. An R&D program is underway to enhance the system and extend the pulse shape analysis technique further, so that these residual sources can be identified and rejected as well.

In this paper, we review the theory of operation and pulse shape analysis techniques used in XIA's alpha counter, and briefly explore data suggesting the origin of the residual background terms. We will then present our approach to enhance the systems ability to identify and reject these terms. Finally, we will describe a prototype system that incorporates our concepts and demonstrates their feasibility.

Session 3 / 68

The Radiopurity.org Material Database

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Rare-event searches —such as dark matter and neutrinoless double-beta decay experiments —at deep underground laboratories have stringent radiopurity requirements for their construction materials. Researchers have to determine the radiopurity specifications for all physical elements of the experiment, then source, assay, and acquire these components. Over the last several decades, researchers in the low-background physics community have accumulated thousands of radioassay results for these materials. An community-wide effort to provide a flexible platform for storing and disseminating these results have been realized at http://www.radiopurity.org. In this talk, I will describe the current status of this platform.

Session 1 / 69

A development of an ultra-low radioactivity measurement facility at the Center for Underground Physics in Korea

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As a few ultra-low background rare decay experiments at the Yangyang underground laboratory in Korea are being prepared and under operation, a number of ultra-low radioactivity detectors are being developed. For a screening of raw materials or detector components, an ICP-MS, an argon gas ionization counter, a ZnS counter, and a number of High Purity Germanium (HPGe) detectors are developed, installed, tested, and used. A silicon PIN photodiode based radon detector was upgraded and is being prepared for a measurement of the air from a radon reduction system which is expected to make a very low level of radon such as 10 mBq/m3. An array of 14 HPGe detectors was installed recently and is being prepared for an efficient measurement of background gamma rays from samples with bigger volumes. As candidates of detector materials, various types of scintillation crystals such as CaMoO4, Li2MoO4, and NaI(Tl) have been grown with purified raw materials and tested for their radioactivity background levels with the above mentioned instruments. In this contribution, a summary of their developments and preliminary performances together with a future plan will be presented.

Session 3 / 70

Radiopurity Databases for Detector Development

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Modern rare-event search experiments are developed in iterations with years of engineering work being informed by a number of competing inputs. Every iteration of the design and the construction process must be validated to satisfy radioactivity-related background requirements. Published materials assay results and compilations such as radiopurity.org form an extremely useful starting point for initial estimates for design feasibility. Development of a real experiment requires tracking of many samples and measurements, specific batches of available materials or parts they represent, materials handling methods, analysis preparation and more. This requires a combination of database-like functionality and log-booking functionality that must be intuitive and encourage use. The experiment design process can be streamlined by convenient interfaces between the radiopurity

data, Monte Carlo simulation data, and detector design models. I will present a number of general features and specific solutions used to achieve these goals, drawing largely on experience from the EXO collaborations and databases being implemented at the Center for Underground Physics, and elsewhere.

Session 8 / 71

Precursors preparation for growth of low-background scintillation crystals

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Precursors play important role in obtaining crystals with preassigned functional properties. Impurities in precursors significantly influence optical properties, radiation hardness and light output of scintillating crystals, concentration of impurities directly correlates with radioactive background of scintillating crystals. As an example, during BGO growth the methods of purification and synthesis of were shown to influence optical and scintillation properties of grown crystals as well as their radiation hardness. Radiation-hard BGO crystals were obtained when using complex approach to synthesis and purification of bismuth oxide. First stage was pyrometallurgical processing with removal of lead and other active impurities (e.g. iron). Second stage was vacuum distillation of Bi and direct oxidation. In cases when low-background crystals are required third stage of polonium removal by processing with metallic sodium is added. Such specially prepared precursors procure the highest quality of grown crystals.
A goal of obtaining crystals for rare events registration is an even more unique task. From one side, crystals with the best scintillating properties are required. From the other, own radioactive background, especially in a certain range of elements, should be extremely low.
In our presentation we will talk about approaches and methods of purification and synthesis of MoO3, Li2CO3 and Na2CO3 and recuperation of MoO3 from residuals after crystal growth and crystal processing. We will discuss the questions about methods'efficiency and achieved results in impurities concentrations. Results of ZnWO4, ZnMoO4, Li2MoO4, Na2Mo2O7 crystal growth and their scintillation properties, including own radioactive background, will be presented.