Low Radioactivity Techniques 2019

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Book of Abstracts

Contents

14

A Convenient Approach to Sub-10-12g/g Level Measuring of U and Th in Acrylic

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Acrylic is widely used in low background experiments such as underground neutrino experiments and dark matter experiments around the world for its good transmittance, low radioactive background and good chemical compatibility with water and liquid scintillator. Jiangmen underground neutrino oscillation experiment (JUNO) has a 35.4 meters diameter 566-ton acrylic sphere shell for holding liquid scintillator. Its requirements for all three radioactive isotopes 238U, 232Th and 40K are less than 1 ppt (10-12 g/g). A fast and reliable measuring method for acrylic samples is needed for the quality control. We have developed a method for concentrating the radioactive isotopes in the acrylic for several times, then the samples can be measured by ICP-MS. As a result, the sensitivity can reach sub-ppt level easily, effectively and quickly. In this talk, I will give more details about our technique of concentrating the radioactive isotopes and measuring method.

28

A New Low-Background Facility in China Jinping underground Lab

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China JinPing underground Laboratory(CJPL) is the deepest underground lab with 2400 meters rock overburden. In the past dedade, two dark matter experiments(CDEX and PandaX) and one solar neutrino experiment had been settled in the Jinping-I, and 2 low-background gamma spectrometers(GeTHUs) are also put into routine measurement. Since available space room less in Jinping-I, the construction of Jinping-II had been started in Dec. 2014 and the civil engineer of it was finished in Aug. 2016. From then on, a new low-background facility in Jinping-II, called Deep Underground and ultra-low Radiation background Facility for frontier physics experiments(DURF) , is proposed by JInping lab. There are three different shielding devices to achive ultra-low background for dark matter experiments, and one underground lab of ultra-low radioactivity measurement and analysis. On Dec. 23 2016, DURF is selected to be a candidate project of National Major S&T infrastructure of China. On Dec.13 2018, the feasibility report of DURF were approved and the fund is 177 million eurs or so. In the presentation, the design and contents of DURF would be introduced detailly.

58

A new neutrinoless double beta decay experiment: R2D2

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The search for neutrinoless double beta decay could cast light on one critical piece missing in our knowledge i.e. the nature of the neutrino mass. Its observation is indeed the most sensitive experimental way to prove that neutrino is a Majorana particle. The observation of such a potentially rare process demands a detector with an excellent energy resolution, an extremely low radioactivity and a large mass of emitter isotope. Nowadays many techniques are pursued but none of them meets all the requirements at the same time. The goal of R2D2 is to prove that a spherical high pressure TPC could meet all the requirements and provide an ideal detector for the 0νββ decay search. In the proposed talk the R2D2 goal and roadmap will be discussed as well as the ongoing R&D and the future developments.

44

A study on high energy gamma intensities from the 208Tl decay with a ThO_2 powder

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The gamma transitions with E_γ > 3 MeV from decays of ^{208}Tl have not been observed and their transition intensities were known only as upper limit values. We measured a ThO_2 powder using a 100% HPGe (High Purity Germanium) detector to obtain more accurate numbers of the transition intensities. This study is expected to help understanding nuclear decay properties of the nucleus and high energy gamma backgrounds in rare decay experiments, such as neutrinoless double beta decay searches. The experimental setup, Monte Carlo simulation studies for detection efficiencies, and preliminary results are going to be presented.

19

Analysis of backgrounds for the ANAIS-112 dark matter experiment

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The **ANAIS (Annual modulation with NaI(Tl) Scintillators)** experiment aims at the confirmation or refutation of the DAMA/LIBRA positive annual modulation signal in the low energy detection rate, using the same target and technique, at the Canfranc Underground Laboratory (LSC) in Spain. ANAIS-112, consisting of nine 12.5 kg NaI(Tl) modules produced by Alpha Spectra Inc., is taking data smoothly in "dark matter search" mode since August, 2017, after a commissioning phase and operation of the first detectors during the last years in various set-ups. A large effort has been carried out within ANAIS to characterize the background of sodium iodide detectors before unblinding the data and performing the first annual modulation analysis corresponding to 1.5 years of data taking, which is about to be released.

In this presentation, the **background models** developed for all the nine ANAIS-112 detectors will be shown. Measured spectra from threshold to high energy in different conditions are well described by the models based on quantified activities independently estimated following several approaches. In the region from 1 to 6 keVee the measured, efficiency corrected background level is 3.58+-0.02 keV-1 kg-1 d-1; NaI crystal bulk contamination is the dominant background source being 210Pb, 40K, 22Na and 3H contributions the most relevant ones. The background models have also allowed to predict the evolution in time of the rates in different energy windows, supporting the assumed trends in the annual modulation analysis.

This background level obtained in the region of interest, added to the achieved 1 keVee analysis threshold (thanks to the outstanding light collection and robust filtering procedures developed), allow ANAIS-112 to be sensitive to the modulation amplitude measured by DAMA/LIBRA and to be able to explore at three sigma level in five years the DAMA/LIBRA single-out WIMP parameter region.

38

Application of surface coatings for radon emanation mitigation

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For many current detectors aimed at rare-event searches, radon is a dominating source of background. These experiments can strongly benefit from the reduction of $^{222}\mathrm{Rn}$ that is released by metallic surfaces within the setup. A new radon mitigation strategy employing thin surface coatings has been studied and significant reduction factors of the $^{220}\mathrm{Rn}$ and $^{222}\mathrm{Rn}$ emanation rates were found. Results for different deposition techniques such as sputtering, plasma deposition and electrodeposition will be summarized and outlooks on possible leads for further developments will be given.

40

Background characterization of the SABRE experiment

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SABRE (Sodium Iodide with Active Background Rejection) is a new project to search for the annually modulating signal expected from Dark Matter (DM), using an array of ultra-pure NaI(Tl) detectors surrounded by an active scintillator veto to further reduce the intrinsic and external background.
The first phase of the experiment is the SABRE Proof of Principle (PoP), a single 5-kg crystal detector to be operated inside a liquid scintillator veto at LNGS in Italy. The installation of the PoP setup has been completed in LNGS Hall C with the goal of running in 2019 and performing the first in situ measurement of the crystal background and testing the veto efficiency. According to detailed Monte Carlo simulations of the setup geometry, the crystal intrinsic and cosmogenic backgrounds will be characterized in a few months.
The second phase of SABRE will consist in twin arrays of NaI(Tl) detectors operating at LNGS (Italy) and at SUPL (Australia). By locating detectors in both hemispheres, SABRE will minimize seasonal systematic effects.

In this talk, the status report of the SABRE-PoP activities at LNGS will be presented as well as results from the most recent background model based on simulations and radio-purity measurements.

7

Background mitigation techniques for the CUORE experiment

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The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for neutrinoless double beta decay (0νββ) that has been able to reach the one-ton scale. The detector, located at the Laboratori Nazionali del Gran Sasso in Italy, consists of an array of 988 TeO_2 crystals arranged in a compact cylindrical structure of 19 towers. The construction of the experiment was completed in August 2016 with the installation, in low radon, clean room environment, of all towers in the cryostat. Following a cooldown, diagnostic, and optimization campaign, routine data-taking began in spring 2017. The first CUORE physics run, corresponding to a total TeO_2 exposure of 86.3 kg·yr resulted in the best lower limit on the ^{130}Te 0νββ half-life of $T^{0\nu}_{1/2}(^{130}\mathrm{Te}) > 1.3 \times 10^{25}$ yr (90% C.L.). In this talk, we will describe the background mitigation techniques that CUORE employed to achieve the low background rate of (0.014 ± 0.002) counts/(keV·kg·yr) in the 0νββ region of interest. We will also describe improvements to the CUORE data analysis that is expected to reduce the background rate further.

17

Background models in the low energy region: TREX-DM and IAXO-D0 setups

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TREX-DM and IAXO-D0 are gaseous TPC detectors equipped with Micromegas readout planes. TREX-DM is intended to search for low mass wimps while IAXO-D0 is a prototype of one of the detectors of the future IAXO (International Axion Observatory). In both cases, background models in the lowest energy region are essential to study the discovery potential of these experiments and to understand experimental data. To assess the expected background, all the relevant sources need to be considered, including the measured fluxes of gamma radiation, muons and neutrons at the Canfranc Laboratory (TREX-DM) or sea level (IAXO-DO), together with the activity of most of the components used in the detector and ancillary systems, obtained in a complete assay program. Dedicated analysis methods to discriminate signal and background events are also compulsory to lower background levels. The software tool used to analyse data and compute all the background contribution is REST, a data analysis framework fully integrated in ROOT and including libraries for the reconstruction and simulation of events in TPC-based detector systems. In this contribution, we will present background models for TREX-DM and IAXO-D0 detectors.

63

Coherent elastic neutrino nucleus scattering with the CONUS experiment

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Coherent elastic neutrino nucleus scattering with the CONUS experiment
speaker: Janina Hakenmüller for the CONUS collaboration
The CONUS experiment is located at the nuclear power plant of Brokdorf, Germany, at 17m distance from the reactor core. It aims at detecting coherent elastic neutrino nucleus scattering with four high-purity point contact Germanium detectors with a noise threshold in the range of a few hundred eV inside an elaborate shield.
Before the setup of the experiment, the location, especially the potential neutron-induced background, has been characterized thoroughly with Bonner Sphere measurements, gamma-ray measurements with non-shielded Ge spectrometers as well as MC simulations. It will be shown in the talk that inside the detector chamber no reactor thermal power correlated background is expected.
Moreover, the low background rate of this shallow depth experiment is achieved by a multilayer shield with increasing radiopurity towards the center including an active muon veto and layers of borated polyethylene. All materials have been selected carefully beforehand via material screening. The efficiency of these background suppression techniques will be shown as well as detailed studies of the remaining background contributions using MC simulations.
The analysis and latest results of the first full physics run based on 1 month of reactor off time and 6 months of reactor on time will be presented. An outlook on planned upgrades and midterm feasible physics goals goals with the CONUS setup will be given.

29

Conceptual design of the COSINUS experiment using cryogenic NaI detectors for direct dark matter search

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The COSINUS (Cryogenic Observatory for SIgnatures seen in Next-generation Underground Searches) project is in the final planning phase of building up the experiment at an underground site.

Crystals made of NaI will be operated as cryogenic detectors to search for DM-nucleus scattering with the aim of probing the long-standing results of the DAMA/LIBRA collaboration. Operating the detectors at milli-Kelvin temperatures allows for a two-channel read-out by simultaneously measuring the phonon and the scintillation light signal. This technique enables particle discrimination on an event-by-event basis helping to distinguish β/γ backgrounds from nuclear recoils. In order to fulfill the crucial task of background minimization, the detectors will be surrounded by a dedicated shielding setup built inside the underground laboratory.

Within this contribution, I will present results of the Geant4 simulations laying ground for the shielding concept of COSINUS, accompanied by data of detector prototype measurements and of our NaI crystals.

23

Cryogenic Detectors with Superconducting Thermometers for Light Dark Matter Direct Search

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The CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) is a direct dark matter search experiment, located at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy, where an overburden of 1400m of rock (3800m water equivalent) provides an efficient reduction of the cosmic radiation background.
In the CRESST experiment, ~25g scintillating $\mathrm{CaWO_4}$ crystals are used as target material for elastic DM-nucleus scattering and operated as cryogenic detectors at ~15mK temperatures. The simultaneous measurement of the phonon signal from each target crystal and the emitted scintillation light in a separate cryogenic light detector provide event-by-event particle identification for background suppression. In 2018, the first measurement campaign of CRESST-III was successfully completed, achieving an unprecedented energy threshold for nuclear recoils, lower than 100 eV. Such low threshold provides a significant boost in sensitivity allowing for the first time to probe dark matter particle masses as low as $160\mathrm{MeV/c^2}$.
In this contribution the latest results of CRESST-III will be presented accompanied by a brief status update on the ongoing activities of the experiment.

8

DEMETRA: Mitigation of the Radioactivity Effects in Quantum-Bits

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Superconducting circuits are emerging as leading candidates in the development of Quantum Bits (qubits). Their main limit with respect to the other technologies resides in the poor coherence time, i.e. the time in which they retain a quantum behaviour. The DEMETRA project proposes environmental radioactivity as one of the sources of decoherence: interactions in the substrates on which the qubit is deposited can release energy in the qubit, causing the loss of coherence. We propose a plan to investigate and suppress the various sources of radioactivity with the ultimate goal of improving the performance of superconducting qubits.

36

DarkSide 20-k Material Assay Campaign

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Basing on the successful operation of the DarkSide-50 detector, the DarkSide Collaboration is now constructing DarkSide-20k, a direct WIMP search detector utilizing a two-phase Liquid Argon Time Projection Chamber (LArTPC). With a rejection factor for discrimination between electron and nuclear recoils in LAr of >3×10^9, use of the veto system and utilizing silicon photomultipliers in the LAr TPC, DarkSide-20k will have a sensitivity to WIMP-nucleon cross sections of 1.2×10^-47 cm^2 (1.1×10^-46 cm^2) for WIMPs of 1 TeV/c^2 (10 TeV/c^2) mass, to be achieved during a 5 y run. To maintain the background goal of less than 0.1 events (other than neutrino-induced nuclear recoils) in the WIMP search region, DarkSide-20k must be built with special care to the construction process and materials in use. In order to achieve this goal, a dedicated working group (Materials Assay Working Group) was formed within the Collaboration. In the talk, the organization of the materials assay process, the means to manage the records of the results (database) and evaluate the expected background (neutron background budget), and assay techniques utilized to scrutinize the construction materials will be described in detail.

41

Deep Science at Boulby Underground Laboratory: Subterranean studies at the UK's deep underground science facility.

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For more than three decades UK astrophysicists have been operating experiments to search for Dark Matter 1100m below ground in a purpose-built 'low-background' facilities at Boulby mine in the North East of England. This facility - the Boulby Underground Laboratory - is one of just a few places in the world suited to hosting these and other science projects requiring a 'quiet environment', free of interference from natural background radiation. The race to find Dark Matter continues and Boulby currently supports the DRIFT/CYGNUS directional dark matter detector programme and operates a growing suite of high sensitivity Germanium detectors for material screening for future Dark Matter detectors (inc. LZ) and other rare-event studies. In the meantime the range of science projects looking for the special properties of deep underground facilities is growing and new projects operating at Boulby range from astro & particle physics to studies of geology/geophysics, climate, the environment, life extreme environments on Earth and beyond. This talk will give an overview of the Boulby Underground Laboratory, the science currently supported and plans for science at Boulby in the future.

69

Determination of 210Po in metals and electronic components down to 0.5 mBq/kg

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Determination of 210Po in metals and electronic components down to 0.5 mBq/kg
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The bottom part of the 238U chain, containing 210Pb, 210Bi and 210Po is difficult to detect. 210Pb emits low energy betas and a weak gamma (46.4 keV) with relatively low probability thus, gamma ray spectrometers have rather low sensitivity to that isotope (~Bq/kg). 210Bi and 210Po are practically pure beta and alpha emitters, respectively. Due to short ranges of alphas and betas the sensitivities of even large-surface spectrometers with respect to specific activities of Bi/Po are rather poor and reach in the best case about 50 mBq/kg (for 210Po in copper) [1].
Contamination of materials with 210Pb and its daughters is of special interest and concern for experiments looking for dark matter. Decays of 210Bi may spoil the low-energy parts of spectra of interest, and alphas emitted by 210Po may be a source of neutrons through the alpha-n reactions. Interaction of neutrons in an active part of a detector are hard to distinguish from interactions of dark matter particles, thus they pose a serious background source.
A new method to determine 210Po in various samples down to 0.5 mBq/kg (~50 ppt U equivalent)

will be presented. It is based on radio-chemical separation of 210Po from the bulk material, followed by its deposition on a silver disc and counting of the activity with a low-background alpha spectrometer. To control the chemical yield for 210Po, 209Po is added as a tracer in each measurement. Blank runs are performed to determine contribution to the signal coming from the procedure. It defines the sensitivity of the method.
Several measurements were performed for metals (copper, lead, titanium, steel) and electronic components (resistors, capacitors, LED diode) to be used in signal readout systems of low-background detectors. The obtained specific activities varied form 10 mBq/kg (electroformed copper) up to some tens of Bq/kg for discrete electronic elements. Measuring 210Po in the same sample (batch) in a time sequence allows to determine its 210Pb content.

47

Developing measurements on activated samples in order to achieve sensitivity below ppt level

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In nuclear and particle physics experiments, reduction of radioactive intrinsic background is one of the keys for the success of the experiments. In many cases the radioactive background generated from decay products of radio nuclides such as ^{232}Th, ^{238}U and ^{40}K could exactly overlap the observable energy regions of interest.
In this context it is crucial to develop high-sensitivity analysis techniques to select the most suitable materials to be used in the experiments in order to reduce the radioactive contribution in the background, specifically coming from the components that make up the central detector.
Neutron activation analysis (NAA) is a good technique to study the radioactive contamination in traces of Th, U and K within the materials. This technique allows us to achieve sensitivity at the ppt level, but sometimes it is not enough to satisfy the strong demands coming from the latest experiments.
For this purpose, we have developed a measurement methodology that combining neutron activation analysis with systems of gamma spectroscopy in ultra-low background configurations working in coincidence technique, which allows us to achieve an extreme radioactive background reduction and performs very high sensitivity gamma measurements on samples activated.
The assay developed, has shown that it is suitable to achieve sensitivity below ppt levels for Th, U and K on materials used in rare event physics experiments.

37

Developments in surface background removal for the DARWIN liquid xenon detector

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In the current state of rare-event searches, an increase in target mass is necessary to improve the experiments sensitivity. This will be the case of the multi-ton liquid xenon DARWIN detector aiming at the direct detection of dark matter as well as studying neutrino physics. Even if very low background levels have already been achieved in such detectors, further control and reduction are

both critical and challenging. A significant contribution comes from natural radioactivity. Several strategies have been adopted to tackle this issue. Materials are screened and selected for radio-purity and detector manufacturing is tightly controlled. As observed in XENON1T, for instance, a surface background coming from radon daughters can reduce the sensitivity of an experiment. Therefore, surface cleaning techniques are explored to mitigate this effect and will be extensively used for the future experiment DARWIN. The compatibility of such surface treatments with the operation of a liquid noble-gas time projection chamber is currently being demonstrated in a dedicated setup.
This talk will highlight the promising results already obtained and potential leads for future improvement.

65

Direct measurement of 13C(a,n)16O reaction towards in the s process Gamow peak

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The 13C(a,n)16O reaction is very important in astrophysical context. This reaction is the dominant neutron source for the synthesis of the main s-process component of heavy elements in thermally pulsing, low-mass AGB stars. The stellar temperature of s process in AGB translates to a Gamow window between 140 - 230 keV, far below the Coulomb barrier.
Various measurements of the low energy cross section of 13C(a,n)16O have been performed in the past, and while remarkable results have been achieved, ultimately the environmental background on the surface of the earth has been a limiting factor. The LUNA collaboration is currently performing a measurement of 13Ca,n)16O in the low-background environment of the LNGS, where the environmental neutron flux is reduced by over three magnitudes with respect to the surface.
In order to approach the Gamow peak of the 13C(a,n)16O reaction, 3He counters based high-efficiency, low background detector array was developed. However, the active suppression of the intrinsic background of the counters is becoming mandatory due to the nearly exponential drop of the cross section with decreasing energy using the Pulse Shape Discrimination (PSD) method.
In this talk, we introduce the main features of the low background experimental setup, especially the improved PSD method, and the current status of the experiment.

46

Exploration of the challenges with 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 and surrounding materials is an added source of energetic background events.

In addition to limiting the detector material's radon exposure to reduce potential surface backgrounds, it is just as important to understand the mechanisms for surfaces to attract Rn progeny and to clean surfaces to remove this inevitable contamination. Previous studies of radon progeny removal have generally found that some form of chemical cleaning can be effective at removing some of the progeny (Bi and Pb), however the ability to remove the more problematic Po atoms has had mixed results due to unfavorable chemical conditions and redeposition of Po atoms. We are studying several factors that determine and ultimately affect the presence of radon progeny contamination on clean material surfaces even after special cleaning and handling practices are utilized. We will present new findings on the dynamic competition that exists between the oxidation of Po atoms and substrate atoms during chemical etching, the limitations in removing Po atoms during chemical leaching of plastics, and the effect of electrostatics in attracting Rn progeny to clean surfaces.

6

Final results of the CUPID-0 Phase I experiment

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A convincing observation of neutrino-less double beta decay (0νDBD) relies on the possibility of operating high-energy resolution detectors in background-free conditions.
Scintillating cryogenic calorimeters are one of the most promising tools to fulfill the requirements for a next-generation experiment. Several steps have been taken to demonstrate the maturity of this technique, starting form the successful experience of CUPID-0.
The CUPID-0 experiment collected 10 kg*y of exposure, running 26 $Zn^{82}Se$ crystals during two years of continuous detector operation. The complete rejection of the dominant alpha background was demonstrated, measuring the lowest counting rate in the region of interest for this technique. Furthermore, the most stringent limit on the Se-82 0νDBD was established.
In this contribution we present the final results of CUPID-0 Phase I, including a detailed model of the background and the measurement of the 2νDBD half-life.

52

Geant4 – a general purpose simulation toolkit

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Geant4 is a software toolkit for the simulation of the passage of particles through matter. It is used very frequently in a large variety of application domains, including high energy, nuclear and accelerator physics, space science, medical physics and radiation protection. It allows to create almost arbitrary complex volumes, and to transport any particle through virtually any medium. In addition, the different physical processes defining the transport can be easily activated and deactivated. A general overview concerning the code and its capabilities will be presented. As an example concerning low background applications, we will show the performance of Geant4 when calculating the neutron production induced by radiogenic alpha-decay.

66

In-situ characterization of background sources in the NEXT experiment.

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The Neutrino Experiment with a Xenon TPC (NEXT) searches for the neutrinoless double beta decay of ^{136}Xe using a high pressure xenon gas time projection chamber. This detector technology has several key advantages, including excellent energy resolution, powerful event classification based on track topology, and favorable mass scalability. The rareness of the decay demands low-background operation and a full understanding of the various background sources. The underground operation of NEXT-White, the first phase of the NEXT experiment, has allowed for full in-situ characterization of the experiment's background.

The talk will be focused on a detailed characterization of the detector-induced backgrounds for the relevant radioactive isotopes (^{208}Tl, ^{214}Bi for $\beta\beta 0\nu$ and $\beta\beta 2\nu$, ^{60}Co and ^{40}K just for $\beta\beta 2\nu$) after 1 year of low-background operation in NEXT-White. In addition to this, we'll go over the relevance of background suppression systems (such as external shielding or radon-free air) in the background levels of the experiment with a data-driven analysis. We will also provide a preliminary estimation of the cosmogenic contribution to our background model. The talk will conclude with a discussion on the impact of the background measurements to NEXT's prospects and physics case.

26

Inductively Coupled Plasma Mass Spectrometry: An Ultrasensitive Tool for Ultralow Background Physics

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Since its first development in the mid-1980s, inductively coupled plasma mass spectrometry (ICP-MS) quickly became the 'gold standard' for quantitative elemental analysis. Through iterative optimization in design, hardware, and software, ICP-MS continues to provide ever-impressive analytical figures of merit (*e.g.*, sensitivity, resolution, *etc.*) and, thus, grow in new application arenas. It is particularly useful and now well established in the determination of naturally-occurring long-lived radioisotopes (*e.g.*, U-238, Th-232, K-40) in ultralow background (ULB) rare-event detector materials and is the focus of this talk. This presentation will briefly describe the basics of ICP-MS before providing some illustrative examples of the strengths and weaknesses of the technique as it relates to ULB material assays. The talk will also focus on how ICP-MS techniques are being employed to meet the stringent radiopurity requirements for current and next-generation ULB experiments.

62

LEGEND: Next-Generation Neutrinoless Double-Beta Decay Search in Germanium-76

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The LEGEND Collaboration was recently formed with the aim of combining of the successes of the GERDA Experiment and the Majorana Demonstrator with newly-developed technologies in a ton-scale, germanium-based experiment. The LEGEND Collaboration has established a phased deployment scheme: an initial 200-kg array (LEGEND-200), deployed in the repurposed GERDA cryostat and shielding infrastructure at LNGS, followed by a 1000-kg array (LEGEND-1000) in a newly-constructed liquid cryogen shield and veto. This phased approach allows for the rapid construction of a world-leading experiment with half-life sensitivities in excess of 10^27 yrs at modest cost, followed by a nearly-background-free experiment with 10 t-y exposure, yielding detection sensitivity for half-lives in excess of 10^28 yrs. The plans for the design and construction of LEGEND-200 and LEGEND-1000 will be discussed, with emphasis on the design choices and technological development that will allow for improvement upon the backgrounds already demonstrated in GERDA, the lowest of any 0vBB experiment to date.

76

LiquidO project

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LiquidO is a new detector concept in which a diffuse scattering "liquid" scintillating medium is readout by wavelength shifting fibres. This novel technique enables powerful particle identification and strong background rejection. LiquidO has very promising sensitivity for many neutrino physics measurements that benefit from scintillator with very high loading. This is because the transparency requirement for the scintillator can be relaxed. This talk will present the background identification capabilities of LiquidO and discuss the detector's low radioactivity background requirements.

64

Low background stainless steel for PandaX-4T dark matter experiment

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The PandaX-4T dark matter experiment includes a cryostat which contains 6T xenon at -100℃. The cryostat is the major component of the detector, which is made of low background stainless steel (SS). The SS contributes about 1/3 intrinsic background of the detector. In this talk, low background SS production process, cryostat fabrication process and possibility of suppressing SS radioactivity will be presented.

15

Low radioactivity Argon for DarkSide-20k Dark Matter search experiment

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The DarkSide-20k (DS-20k) experiment is a 20-ton active argon detector which plans to operate radio-pure underground argon (UAr) for dark matter direct searches. A major worldwide effort is on-going in order to procure the radio-pure argon required for this experiment. The Urania project will extract and purify the UAr from the CO2 wells at the Kinder Morgan Doe Canyon Facility located in Cortez (USA) at a production rate of ~100 kg/day. It will be necessary to make a chemical and radiological purification of the UAr before deployment into the LAr TPC of DS-20k. The Aria project will serve to purify the UAr using a cryogenic distillation column, called Seruci-I, located in Sardinia (Italy). The ultimate goal of Aria is to implement an upgraded column, Seruci-II, able to process about 150 kg/day of argon and to achieve an additional 39Ar depletion factor between 10 and 100. Assessing the purity of UAr in terms of 39Ar is key for the physics program of DS-20k. DART is a small (~1 liter) chamber that will measure the depletion factor of 39Ar in UAr. The detector will be immersed in the LAr active volume of ArDM (LSC, Spain), which will act as a veto for gammas stemming from the detector materials and from the surrounding rock. Data taking is planned for 2019. In this talk, I will review the status and prospects of the UAr projects for DarkSide20K.

45

Low-Background Techniques Applied within the MAJORANA DEMONSTRATOR Experiment

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The MAJORANA Collaboration is searching for neutrinoless double-beta decay in Ge-76 with an array of p-type, point-contact Ge detectors. The MAJORANA DEMONSTRATOR is comprised of 44 kg (30 kg enriched in Ge-76) of Ge detectors split between two modules contained in a low background passive and active shield at the Sanford Underground Research Facility in Lead, South Dakota. Our latest results from a modest 26 kg-yr of exposure set a half-life lower limit of 2.7x10^25 yr (90% C.L) owing to an unprecedented energy resolution of 2.5 keV FWHM and a background rate of 12 cts/(FWHM t yr) at the double-beta decay Q value of 2039 keV. The ultra-low background rate achieved in the MAJORANA DEMONSTRATOR relied on careful material selection, development of improved cleanliness protocols and cleaning procedures, and the strength of the Ge detector pulse-shape analysis routines. A description of the low radioactivity techniques applied, progress towards modeling the extremely low measured backgrounds, along with the overall physics potential of the MAJORANA program will be presented.

27

Low-radioactivity argon for low-level radiation detectors: a global overview

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The DarkSide-50 dark matter search experiment demonstrated that argon derived from underground can be highly reduced in ^{39}Ar, and since then the demand for this commodity has risen. Several fundamental physics experiments need argon that is reduced in ^{39}Ar as well as ^{42}Ar, and there are needs in other scientific fields as well (e.g., age-dating). With the increased needs for low-radioactivity underground argon come the questions of availability and how to approach the challenges associated with its production and characterization.
This talk will provide a global picture of low-radioactivity argon from the underground sources of argon through to ensuring that the extracted and purified argon is low in ^{39}Ar. The broader needs for low-radioactivity underground argon and efforts to procure it will be presented; including the primary producers of underground argon; the DarkSide collaboration. Large-scale isotope separation is also being pursued to further deplete the ^{39}Ar, as well as next generation technologies in isotope separation through distillation to shrink the size of the columns. We will also show the work being done to quantify the production mechanisms of long-lived radioactive argon isotopes in underground environments and in the atmosphere, and the techniques being pursued for measuring ^{39}Ar primarily in the age dating community, which are important for quality assurance to ensure the depletion of ^{39}Ar during the underground production and for searching for new low radioactivity underground argon sources.

22

Measurements of radioactive backgrounds in high-resistivity silicon CCDs of the DAMIC-100 experiment

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The DAMIC (Dark Matter in CCDs) experiment employs the bulk silicon of scientific-grade charge coupled devices (CCDs) to detect Dark Matter particles. DAMIC-100, a 41 g detector, is operating in the SNOLAB laboratory, located 2 km below the surface within the Vale Creighton Mine near Sudbury, Ontario, Canada. We present a powerful technique to distinguish and reject background events. Utilizing the exquisite spatial resolution of CCDs, discriminating between α and β particles, we identify spatially-correlated decay sequences over long periods. We report measurements of the radioactive contamination of ^{210}Pb and ^{32}Si in DAMIC-100 CCDs, and place limits on ^{238}U and ^{232}Th contamination. DAMIC's capability to measure contamination has significant implications for the next generation of silicon-based dark matter experiments. For example, ^{32}Si could become a dominant and irreducible background for future programs. We show that ^{32}Si levels may vary significantly in high-purity silicon, and indicate feasible methods to screen materials for fabrication of future detectors in order to push experimental sensitivity to unprecedented levels.

43

Measuring cosmogenic activation rates in active detector material

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Long-lived radioactive isotopes produced by cosmogenic activation are a major source of background for rare event searches such as dark matter and neutrinoless double beta decay. Understanding the production rates of these cosmogenic isotopes is extremely important for determining the total allowable surface residence time of detector materials during fabrication, storage, and transportation. However, experimentally measuring the production rate is difficult due to low specific activities and because several of the decays of interest produce low energy electrons and x-rays that are not easily detectable. I will discuss a measurement technique that uses a high intensity neutron beam (with a spectrum similar to cosmic ray neutrons) in conjunction with low-background self-counting methods to determine production rates in active detector materials. Based on this technique I will present results from the first experimental measurement of ^{39}Ar and ^{37}Ar cosmogenic production rates in argon, ongoing work on the first measurement of cosmogenic tritium production in silicon, and possible applications to other detector materials.

21

Muon and neutron background measurements in the shallow-underground laboratory Felsenkeller

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The new shallow-underground laboratory Felsenkeller (140\,m.w.e.) in Dresden, Germany hosts a new 5\,MV underground ion accelerator in tunnels VIII and IX, as well as a low-radioactivity counting facility. For the laboratory commissioning both the muon and neutron background were measured and matched by Monte Carlo simulations.

A portable muon detector based on the close cathode chamber design was used to determine the angular distribution intensity of the muons. At four positions in Felsenkeller tunnels VIII and IX and four in tunnel IV a muon flux map of the upper hemisphere was compiled with 0.9° angular resolution.

The data are matched by two different simulations taking into account the known geodetic features of the terrain: First, simply by determining the cutoff energy using the projected slant depth in rock and the known muon energy spectrum, and second, in a GEANT4 simulation.

The ambient neutron flux and spectrum were measured with two sets of moderated ^{3}He counters, each including a lead-lined moderator to address neutrons up to 300\,MeV energy. The data show that at a given depth, both the flux and the spectrum vary by up to a factor of 7 depending on local shielding conditions.

The neutron flux is matched by FLUKA Monte Carlo simulations, based on the known muon flux and the known composition of the wall, with excellent agreement. Also, in the 10-300 MeV neutron energy region that is almost exclusively determined by muon-induced neutrons, satisfactory agreement between data and simulation was reached.

50

Neutron Activation Analysis (NAA)

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Neutron Activation Analysis (NAA) is a powerful technique to determine trace elements in a sample, with sensitivities which can reach parts per trillion levels and below.
Nowadays, astroparticle physics experiments require extremely low backgrounds and their need to certify detector materials to sub-ppt concentrations of natural contaminants (40K, 238U, 232Th) is becoming a key issue. NAA therefore represents a valuable tool for material selection.
In this talk I will review the fundamentals of the technique and the multielement character of the method, with particular attention to the ingredients to be optimised for reaching high sensitivities, from the irradiation of the sample in a nuclear reactor to the preparation of the irradiated sample for the gamma measurement. Techniques to improve the sensitivities by means of coincident beta-gamma and gamma-gamma measurements will also be discussed.

13

Neutron production in (alpha,n) reactions: where we were and where we are now

Authors: Vitaly Kudryavtsev[1] ; Bethan Easeman[1] ; Paules Zakhary[1]

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Neutron-induced background may cause problems for many underground experiments looking for rare events. A number of computer codes are available to calculate cross-sections of (alpha,n) reactions, excitation functions and neutron yields. We have used EMPIRE2.19/3.3 and TALYS1.9 to calculate neutron production cross-sections and excitation functions, and modified SOURCES4 to evaluate neutron yields and spectra in different materials relevant to high-sensitivity underground experiments. We will report here a comparison of different models and codes with experimental data, to estimate the accuracy of these calculations.

78

Organic Liquid Scintillator Purification

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Organic Liquid Scintillator Purification
Richard Ford (SNOLAB)
We review the methods for purification of organic liquid scintillators for large low background scintillator detectors, based mainly on the experience with the Borexino and SNO+ detectors with Pseudocumine (PC) and Linear Alkylbenzene (LAB) based scintillators. We review the purity requirements and the design basis and performance of the of the purification plants. The main processes in the plants are multi-stage distillation, counter-current liquid-liquid extraction, adsorption columns, gas-stripping and filtration. We discuss purification R&D and the engineering challenges in designing and commissioning the full scale plants.

48

Overview of HPGe measurements in LPSC-Modane

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The gamma spectrometry installation from Laboratoire Souterrain de Modane welcomes the largest number of low background germanium. The installation is going through a big refurbishment allowing us to welcome much more detector in a reduced space. The new organization features a common shield and an improvement of the radon protection. The design is also ready for automatization and will welcome in a near future an automatic sample changer improving drastically the measurement capability. A comparison will be made between chemical technics and gamma spectrometry discussing the replacement of gamma spectrometer by ICP-MS. A final small subsection will present interdisciplinary projects based on the available knowledge in underground labs for biological and electronics topic.

12

Paleo-detectors: Searching for Dark Matter with Ancient Minerals

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Recently, we proposed paleo-detectors as a method for the direct detection of Weakly Interacting Massive Particle (WIMP) dark matter. In paleo-detectors, one would search for the persistent traces left by dark matter–nucleon interactions in ancient minerals. Thanks to the large integration time of paleo-detectors, relatively small target masses suffice to obtain exposures much larger than what is feasible in the conventional direct detection approach. In order to suppress backgrounds induced by radioactive contaminants such as uranium, we propose to use minerals found in marine evaporites or in ultra-basic rocks. For sufficiently radiopure target materials obtained from boreholes deep enough to avoid cosmogenic backgrounds, we identify (broadly speaking) two different background regimes. For low-mass WIMPs with masses $m_\chi < 10\,\mathrm{GeV}$, the largest contribution to the background budget comes from nuclear recoils induced by coherent scattering of solar neutrinos. For heavier WIMPs, the largest background source is nuclear recoils induced by fast neutrons arising from trace amounts of radioactivity. We consider fast neutrons from both spontaneous fission and (α,n) reactions induced by the α-particles produced in the decay chains of heavy radioactive contaminants. Even after accounting for these backgrounds, we demonstrate that paleo-detectors could potentially be sensitive to much of the remaining WIMP parameter space.

42

Production of low background scintillating crystals for underground experiments in Korea

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There are two major underground experiments in Korea, AMoRE and COSINE, searching for neutrinoless double beta decay and WIMP (Weakly Interacting Massive Particle) type dark matter respectively. The Advanced Molybdenum based Rare process Experiment (AMoRE) is searching for the neutrinoless double beta decay of 100Mo isotopes in molybdate crystals using high-resolution cryogenic detectors in milli-kelvin temperatures. Various molybdate crystals such as 48depCa100MoO4, Li2100MoO4, Na2Mo2O7, and PbMoO4 for the AMoRE phase-II with ~100 kg of 100Mo are being grown and tested. For the COSINE experiment, a mass-volume NaI(Tl) crystal growth are currently under development at the Center for Underground Physics (CUP) of Institute for Basic Science (IBS) in Korea. Both experiments require quite challenging low background levels in the crystals being developed. A review on the production of the crystals is going to be presented.

72

Radiopurity of Atmospheric Argon

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Radiopurity of Atmospheric Argon

Argon is commonly used in particle physics experiments due to its convenient ionization and scintillation properties. The high abundance of 1% in the earth atmosphere also makes it easy and cheap to procure in large quantities. Recently, atmospheric liquid argon (LAr) is successfully used in low background experiments as a target to detect dark matter (e.g. DEAP-3600) or as shielding material in neutrinoless double beta decay experiments (GERDA, LEGEND-200).
As a noble gas, argon is easy to purify from radioactive contaminations which was recently demonstrated by the DEAP-3600 experiment achieving the lowest Rn222 concentration in a large noble liquid detector of 0.15 uBq/kg. However, the cosmogenically produced radioactive isotopes Ar39 and Ar42 pose a problem for low background experiments and have to be well understood. Ar39 with about 1 Bq/kg and a beta decay endpoint of 560 keV poses a significant background for low energy WIMP searches and the daughter of Ar42, K42, with about 100 uBq/kg and 3.5 MeV beta endpoint is a gamma ray and beta background for experiments using LAr as shielding. I will discuss the intrinsic radiopurities of atmospheric argon, including recent measurements and methods of mitigation in analyses.
Furthermore, in the low background environment of current experiments, one can investigate certain argon isotopes with unprecedented precision which allows extracting interesting physics. I will briefly discuss ideas to extract nuclear structure information with precision measurements of the 1st forbidden unique shape of Ar39 and to measure the half-life of double electron capture in Ar36.

11

Reduction of Cosmogenic Radioactivity in Low Background Detectors

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The elimination of radio isotopes generated by high-energy cosmic-ray neutrons from detector materials is critically important to achieve the maximum sensitivity in, for example, dark matter, double-beta decay, and axion searches. A clear demonstration of such a reduction was observed in the low-energy spectrum from the MAJORANA DEMONSTRATOR (MJD). In particular, the beta spectrum from cosmogenic tritium, usually observed in germanium detectors, was reduced by a factor of 20 in the MJD spectrum. This was achieved by zone refining the input Ge, and by re-zone refining scrap Ge at each step, and by storing all material underground whenever it was not being used in production. The facility used by MJD, and its operation, were very costly and required significant space and infrastructure. A novel method is under development, which if successful, could purify Ge, TeO2, and possibly LiMoO4, all materials that are being used in low background experiments. The entire facility is compact, and could be operated underground. A description of the facility and techniques, as well as a progress report, will be given.

67

Removal of long-lived Rn-222 daughters from metal surfaces

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Removal of long-lived Rn-222 daughters from metal surfaces

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.
Measurements of natural surface contamination with Po-210 of aluminum, stainless steel, titanium and copper surfaces will be presented. Measurements were performed with an ultra-low background, large-areas alpha spectrometer. The instrument allows to study the surface contamination down to about 1 mBq/m2. The assay showed no detectable surface contamination for surfaces covered with protective foils,
while unprotected metals exhibited significant polonium activities.
Naturally contaminated metal surfaces were also etched and electro-polished to study the effect of Po removal. Electro-polishing was always quite effective and provided the Po activity reduction factor of about 20, what was consistent with our previous studies performed for samples artificially loaded with high Po activity. Standard etching procedures are in general less effective, especially for copper for which hardly any reduction has been observed. This is probably due to the fact that Po initially removed from the surface (sub-surface) layer is re-deposited. In
order to avoid this effect a fast multi-step process has been developed where one longer bath is replaced by several subsequent and short runs always with fresh etchant. Application of the new procedure to various copper samples resulted in Po activity reduction by more than two orders of magnitude, down to the detection limit of the instrument (1 mBq/m2).

24

Results and the Background Model from DEAP-3600

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The DEAP-3600 Collaboration recently released results describing an ultra-low background search for non-baryonic dark matter at SNOLAB, reaching a sensitivity of 3.9×10^{-45} cm^2 for a 100 GeV/c^2 WIMP mass. A background model was constructed, tuned on the sidebands, used to inform data-selection cuts, and used to predict rates in the region of interest for WIMP interactions ($0.62^{+0.31}_{-0.28}$ events in the 231-day exposure). The model includes leakage of electromagnetic events from pulse-shape discrimination; Cherenkov events; surface events with nuclear recoils or straggling alphas entering the argon; fast neutrons; and alpha decays in which only a fraction of the light enters the detector (so-called "neck events"). The background model will be discussed along with potential future improvements. Ideas of how the DEAP-3600 results informs larger liquid argon detectors will be presented.

16

Results of the background-free search for neutrinoless double beta decay with GERDA and challenges of the LEGEND experiment

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GERDA (GErmanium Detector Array) situated in the Laboratori Nazionali del Gran Sasso (LNGS) of INFN searches for the lepton-number violating neutrinoless double beta ($0\nu\beta\beta$) decay of ^{76}Ge. Bare high-purity germanium (HPGe) detectors enriched in the double beta decay isotope ^{76}Ge are deployed in liquid argon (LAr). Background discrimination is achieved both by analyzing the time profile of the charge signal of the germanium detectors (pulse shape discrimination) and by using the instrumented LAr volume as an active veto system. A background level of $\sim 10^{-3}$ counts keV^{-1} kg^{-1} yr^{-1} was reached in GERDA Phase II, which enables a background-free $0\nu\beta\beta$ search up to $100\,\mathrm{kg\ yr}$. So far, no signal was observed after $58.9\,\mathrm{kg\ yr}$ exposure. Together with Phase I data, a lower limit of $T_{1/2} > 0.9 \cdot 10^{26}$ yr (90% C.L.) [1] on the half-live of the $0\nu\beta\beta$ decay of ^{76}Ge was obtained.
The next generation $0\nu\beta\beta$ search with LEGEND (Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay) will proceed in stages: LEGEND-200 will be operated at LNGS at a depth of 3500 m.w.e. and will acquire data free of background for $1000\,\mathrm{kg\ yr}$. The subsequent ton-scale stage is referred to as LEGEND-1000. The decay of ^{77m}Ge, which is produced in-situ by cosmic muon interactions, is identified as a critical background for this stage [2].
It can be identified by detecting delayed coincidences. One goal of LEGEND-200 is to assess the efficiency to tag the ^{77m}Ge production in view of LEGEND-1000.
In this talk both the GERDA results and the analysis of delayed coincidences in LEGEND will be shown.

[1] GERDA Collaboration, submitted for publication.
[2] C. Wiesinger, L. Pandola and S. Schönert,
"Virtual depth by active background suppression: Revisiting the cosmic muon induced background of GERDA Phase II"
Eur. Phys. J. C 78 (2018) no.7, 597

25

Review of Gamma-ray spectrometry for Material Radioassay in Current and Future Generation Rare Event Search Experiments

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Gamma-ray spectrometry has helped form the backbone of material radio-assay for rare event searches for many years. There are a number of facilities worldwide that are leading the charge for the current generation of low-background experiments using both custom built and off the shelf high-purity germanium detectors.

R&D must begin in earnest now for the next generation of dark matter and neutrinoless double beta-decay experiments. Material radio-assay will form a vital part of this R&D. In order to provide a full picture of material characteristics, a wide variety of complementary techniques based both in surface and underground laboratories will need to be used. One of the key techniques for this will continue to be gamma-ray spectrometry. As a community, we are beginning to implement the improvements needed to provide germanium screening facilities with the required sensitivity reach for this exciting new era of low background physics.

This talk will review the current global state of the art in HPGe material radio-assay and will discuss future plans for even more sensitive measurements.

75

SNO+ water purification and radium and radon assay techniques

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SNO+ water purification and radium and radon assay techniques
Autor: Nasim Fatemighomi, SNOLAB

The SNO+ cavity is currently filled with 7400 tonnes of ultra pure water. The water purification system was developed for the SNO experiment prior to SNO+ and is now fully recommissioned and used to refill the SNO+ cavity and acrylic vessel. The water from Creighton mine is purified by going through series of filters, reverse osmosis units, UV light and an ion-exchanged unit. It is degassed and regassed with N2, it is then cooled down by chillers before entering the cavity. The U-238 and Th-232 content of purified water is monitored by doing regular radon and radium assays. The radon assays are done by degassing radon from water and passing it through multiple radon traps, the radium assays is performed by using columns containing membranes coated with hydrous titanium oxide (HTIO). In this talk an overview of SNO+ purification system and the status of radon and radium assays after recommissioning are given.

73

Sensitivity and advantages of laser Ablation ICPMS and comparison with other technics on several materials

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Sensitivity and advantages of laser Ablation ICPMS and comparison with other technics on several materials

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Laser Ablation Inductive Coupled Plasma Mass Spectrometry (LA-ICPMS) is a powerful new technics, not only to measure the isotopic abundances in materials, but also to scan and map them. It provides unprecedented information that can help understanding the origin of the remaining contamination in the processes of production and manufacturing. Several samples have been tested with that new technics and comparison with other verification method are presented.

9

Status of direct Dark Matter search experiment at KamLAND

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Recently, the DAMA/LIBRA collaboration confirmed observation of a modulated signal consistent with the DM hypothesis at a 13σ level. However, independent observation of the signal at another location and verification of its connection to the DM scattering off atoms are required. For that purpose, we created underground laboratory at the Kamioka mine and specialized laboratory for crystal growth in Japan where we successfully manufactured large highly radio-pure NaI(Tl) crystals. The talk covers several related subjects: 1) a status of the underground clean-room facility for the DM search at the Kamioka mine; 2) details of construction and operation of the HPGe, radon (ion-pulse ionization chamber and NaI(Tl)), a Li-loaded liquid scintillator fast neutron and 6LiF/ZnS thermal neutron detectors; 3) description of the underground test setup used to measure the radio-purity level of the NaI(Tl) crytals; 4) methods of the NaI purification and crystal growth techniques used for manufacturing of radio-pure NaI(Tl) crystals; 5) selection of the radio-pure components and test results for the new 4-inch ultra-low background Hamamatsu photomultiplier with a metal body R13444X. Also, results of the radio-purity measurements for two latest NaI(Tl) crystals (ingot 71 and 73) and their comparison to the DAMA/LIBRA detectors will be presented.

74

Status of the SABRE NaI (Tl) dark matter experiment

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Status of the SABRE NaI (Tl) dark matter experiment

Burkhant Suerfu
March 2019

Abstract
SABRE is a dark matter experiment that utilizes an array of NaI (Tl) scintillating crystals. A primary goal

of the experiment is to test the DAMA/LIBRA annual modulation signal claimed to be evidence for dark matter.
The experiment features ultra-low background NaI (Tl) crystals with liquid scintillator active veto system and twin
detector setup, one in Laboratori Nazionali del Gran Sasso, Italy (LNGS) and the other in Stawell Underground
Physics Laboratory (SUPL). Most recently, we have successfully developed a NaI (Tl) single crystal with 4 ppb
of potassium measured by inductively coupled plasma mass spectroscopy (ICP-MS), which is about 3 times lower
compared to DAMA/LIBRA crystals. In this talk, I will present an overview of the detector design followed
by the recent progresses on the development of low radioactivity NaI (Tl) crystals and the status of detector
commissioning in LNGS.

70

Studies of poly(ethylene naphthalate) for use as a structural scintillator in low background experiments

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Studies of poly(ethylene naphthalate) for use as a structural scintillator in low background experiments

Poly(ethylene naphthalate), PEN, has been observed to scintillate in the blue wavelength region, without the need for additional materials.
Combined with measurements of a high intrinsic radiopurity, this has sparked interest in the material for use in low-background experiments.
This presentation will report on measurements of custom molded PEN tiles, covering a range of scintillation and structural properties.

Speaker: Connor Hayward - Max Planck Institute for Physics

30

Study of surface contamination in ultralow background (ULB) materials

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The intrinsic radioactive contamination of detector components and surrounding materials is typically the most relevant and limiting source of background for experiments studying rare events, such as those searching for direct evidence of dark matter or neutrinoless double beta decay. Primordial radionuclides Th-232 and U-238 and their daughters, as well as K-40 are of primary concern. Based on the detector characteristics, limits on their content for each material to be included are set using simulation techniques. These limits can be extremely stringent and become even more strict with increasing mass and with greater proximity to the active target. Limits for Th-232 and U-238 can be

in the pg/g (or microBq/kg) range or even lower.
Such demanding radioactivity requirements pose a difficult challenge on the selection and confirmation of purity for materials, but also on their storage and handling after validation. At such high purity levels, surface contamination can be a major issue. Significant accumulation of radiocontaminants on material surfaces can occur during machining, transportation, handling, storage or even from exposure to air in controlled environments, such as clean rooms or glove boxes. Though care is usually taken, surface contamination processes are not fully understood and are difficult to control, oftentimes creating a "dogma-based" approach to handling materials that relies more on hunches (perhaps via informed assumptions) rather than scientific understanding. This makes even validated clean materials a potential source of limiting backgrounds, that unfortunately cannot be determined until directly observed in the detector. This study aims at providing tools to understand, identify, quantify and control surface contamination in validated ultralow background materials during design and construction of rare event detectors.

77

SuperK-Gd project

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The SuperK-Gd project is a new phase of the Super-Kamiokande experiment with Gadolinium sulfate dissolved in the ultra pure water in order to enhance very significantly the ability of the detector to tag neutrons. One of main physics motivations of SK-Gd is to discover supernova relic neutrinos by using neutron tagging to minimize the otherwise overwhelming background. However an even small radioactive contamination in the salt might spoil the low energy physics program of SuperK-Gd since it will induce background signals, some of them irreducible, all along the whole fiducial volume of the detector.
In this presentation, we discuss the status of SK-Gd project and the successful R&D result of ultra-high purity Gadolinium sulfate.

54

Surface Alpha Counting with XIA

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Next generation rare event search experiments focusing on neutrinoless double beta decay or direct dark matter detection will require ever-more stringent control of radioactive backgrounds to achieve improvements in sensitivity. A critical background arises from radon daughters plated out onto, or implanted within, detector components. The radon daughters give rise to neutron and gamma-ray backgrounds from (α,n) and Bremsstrahlung interactions, respectively. Radon "plate out" on material surfaces may result in decay daughters, such as 212Bi, detaching and entering the sensitive volume.

Current screening relies heavily on the use of high purity germanium instrumentation, however, gamma spectroscopy alone cannot distinguish between surface and bulk contamination. Surface alpha counters may be employed to provide additional information thus separating surface and bulk activity.

Surface and bulk alpha activity measurements using an ultra low background surface alpha counter, the XIA UltraLo-1800, are presented.

32

Surface and bulk Pb210/Po210 contamination study on copper and PTFE using low background alpha counter

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We have studied on surface and bulk Pb210/Po210 contamination on copper and PTFE using low background alpha counter. Copper and PTFE are the material used in various low background underground experiments such as dark matter search and neutrino double beta decay search. It is important to know the Pb210/Po210 contamination in copper and PTFE. At the last LRT workshop, we reported that we had established the method of the identification of Pb210/Po210 bulk contamination in copper using low background alpha counter. Using that method, we studied the following two issues. One is the background reduction on copper surface by electro-polish. We found that reduction factor of surface Pb210/Po210 contamination is <10^-2, but some Pb210/Po210 spread over deeper copper region. It is important not to accumulate surface Pb210/Po210 because it is difficult to remove the Pb210/Po210 perfectly by electro-polish. The other study is on the surface/bulk Pb210/Po210 study on PTFE. PTFE is the non-conductive material and easily accumulate Pb210/Po210 on the surface. Therefore it was difficult to identify on XIA UltraLo1800, that is the best low background alpha counter. But we have established the method to identify the Pb210/Po210 surface and bulk contamination. We report the method and the measurement.

18

Techniques for purification and purity analysis of various inorganic materials for the AMoRE

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The Advanced Mo based Rare process Experiment (AMoRE) searches for neutrinoless double beta decay of 100Mo in molybdate crystals, such as 40Ca100MoO4, Li2100MoO4 or Na2100Mo2O7. For such a rare event search experiment, the techniques which allow investigation and reduction of radioactive background are extremally crucial. The first step in developing highly radiopure scintillating crystals is deep radio purification of raw materials used for growing them (MoO3 and carbonates of Ca, Li or Na), quantified with precise and accurate radio-assay analysis. For the most important

component, MoO3, the purification technique consists of a sequence of vacuum sublimation, co-precipitation, and complete precipitation of Polyammonium Molybdates (PAM) from acidic solution. Produced in such a way, MoO3 contains the Th and U concentrations below 10 pg/g, the detection limit for direct ICP-MS measurement. To reach this sensitivity, an optimized sample preparation method followed by a solid phase extraction technique with UTEVA resin was applied. We will present techniques of radio purification and trace ICP-MS analysis performed at Center for Underground Physics (IBS, Korea) for different inorganic materials.

68

Tellurium Purification and Deployment in SNO+

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Tellurium Purification and Deployment in SNO+
SNO+ will be an organic liquid scintillator-based experiment located 2km underground at SNOLAB, CANADA. The primary goal of the experiment is to search for neutrinoless double beta decay by dissolving an isotope of tellurium-130 in the scintillator.
Natural tellurium will be purified underground in a form of telluric acid, and then synthesized with an organic glycol to form a complex directly soluble in Linear Alkylbenzene, a scintillator of the SNO+ detector.
In this talk I will describe the principles and commissioning status of the tellurium purification and synthesis plants. I will also outline backgrounds mitigation and reduction strategies for the neutrinoless duble beta decay search with the SNO+ experiment.

51

The ANDES Deep Underground Laboratory project

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The ANDES (Agua Negra Deep Experiment Site) project aims at the construction of an underground laboratory between Argentina and Chili, taking advantage of the construction of the Agua Negra Tunnel between the two countries. After a pre-feasibility study in 2005, the final project for the construction of the road tunnel was approved and the international tender started in 2013.
The ANDES laboratory will be the deepest laboratory in the Southern Hemisphere with a rock overburden of 1750 m. The project started in 2010 and the construction is foreseen to be done together with the tunnel in 2019.
The laboratory will be managed by a board, the Latin American Consortium for Underground Studies (CLES) composed by at least four countries: Argentina, Brazil, Chili and Mexico.
In this talk I will present the current status of the project and the general features of the laboratory.

61

The Background Control for the PandaX-4T Experiment

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The PandaX-4T dark matter experiment will utilize a two-phase liquid/gas xenon time projection chamber containing 4 tonnes of liquid xenon. The PandaX-4T detector will be located at the Jinping Underground laboratory with 2400m overburden in Sichuan, China. Multiple low background techniques are used to assay and screen materials and parts to control the intrinsic/surface backgrounds. Also krypton and radon removal systems will be applied to remove internal backgrounds. The expected background rates with cuts for 2-year exposure are 2.5 +/- 0.3 mDRU for electron recoil and 2.3 +/- 0.4 mDRU for nuclear recoil. In this talk, an overview of the PandaX-4T detector design, material screening program, background control and projected sensitivity will be presented.

4

The GeMSE Low-Background Facility for Meteorite and Material Screening

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GeMSE (Germanium Material and Meteorite Screening Experiment) is a large-volume gamma-ray spectrometer devoted to the screening of meteorite samples and the selection of materials for rare-event search experiments. Located underground at 620 m.w.e. and featuring a multi-layer shielding, its current background level is below 240 counts/day in the 100 - 2700 keV range.

GeMSE is an ideal platform for interdisciplinary use: The detector is operated fully autonomously (apart from sample changes and occasional LN2 transports) and features a user-friendly analysis and simulation framework. The latter is able to import complex 3D geometries, such that uncertainties in the efficiency calculations can be greatly reduced. This is relevant for meteoritic samples with complicated shapes.

This talk will describe the facility, the calibration and data analysis methods, and will present results on recently measured samples in both fields.

31

The Sanford Underground Research Facility

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ABSTRACT
Building on rich legacies in both mining and transformational physics research, the Sanford Underground Research Facility (SURF) has been operating for over a decade as a facility dedicated to supporting underground research in rare-process physics, as well as offering research opportunities in other disciplines such as biology, geology and engineering. SURF laboratory facilities include a Surface Campus with recently upgraded capabilities as well as two main campuses at the 4850-foot level (4300 m.w.e.) – the Davis Campus and the Ross Campus – that host a range of significant physics experiments: the LUX-ZEPLIN (LZ) dark matter experiment, the MAJORANA DEMONSTRATOR neutrinoless double-beta decay experiment and the CASPAR nuclear astrophysics accelerator. Furthermore, the BHUC laboratory dedicated to critical material assays for current and future experiments has been operating since Fall 2015. Plans to accommodate the Fermilab-led international Deep Underground Neutrino Experiment (DUNE) at the Long Baseline Neutrino Facility (LBNF) are well advanced, and initial construction has commenced. SURF is a dedicated research facility with significant expansion capability, and applications from other experiments are welcome.

49

The most modern mechanical technologies and cutting edge radio-analytical techniques merged for extremely low background achievement

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The most modern mechanical technologies and cutting edge radio-analytical techniques merged for extremely low background achievement
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The sensitivity of the experiments, searching for rare and low energy processes which could explain the most fascinating open questions of the modern physic, is limited by the radioactive background of the whole experimental apparatus. Radiometric and non-radiometric cutting edge analytical techniques have already been widely applied for the screening of the materials available on the market. Likely the new frontier of low background experiments requires new materials development, suitably studied, in order to match the thermal, mechanical and radio-purity performances needed in this field of physic.
The recent and rapid diffusion of 3D printing technologies allows producing plastic and metal parts characterized by complex geometry and reduced weight in comparison to the same structural parts obtained by traditional machining. In this project 3D printing, supported by high sensitivity analytical techniques such as ICPMS, ULL-GRS and NAA, will help the achievement of very low background conditions. The monitoring of the purity of the material during the production starting by the metal or polymer to the finished object will be discussed.

71

The nEXO Background Control Program

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The nEXO Background Control Program

A. Piepke (for the nEXO Collaboration)
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nEXO is a planned next generation double beta decay search, envisaged to utilize 5 tonnes of isotopically enriched xenon. Low energy rare event searches like this require ultra-low background rates to be scientifically successful. The nEXO collaboration has set up a vigorous background control program to develop a detector concept capable of reaching unprecedented levels of background and scientific reach. In this talk I will discuss the status of the nEXO background control effort, the methods it employs and the conclusions derived from its data.

59

Title: Noble gas purification for LZ and other liquid noble dark matter searches

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LZ will use a 10 ton dual-phase xenon Time Projection Chamber (TPC) to search for WIMP dark matter via direct detection. In order to achieve its radiopurity goals LZ, like other low-background detectors with noble element targets, faces the challenge of removing radioactive noble gases including Rn-222, Kr-85, and Ar-39. This talk will survey strategies used by various experiments to purify noble gases, with a focus on activated charcoal chromatography and radon emanation screening program employed by LZ.

5

Ultra-pure Copper Electroplating and Electroforming for Rare Event Detection Experiments

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Rare event detection experiments, such as direct dark matter and neutrino-less double beta decay searches, pose stringent limits on the experimental backgrounds in order to achieve the required

sensitivities to discover new physics. The backgrounds introduced by radioisotopes in the detector construction materials must be carefully considered. Thanks to having no long-lived radioisotopes and being easily electrochemically purified, copper is a popular choice. As a result, the development of electroforming or electrodepositing ultra-pure copper has been an area of intense research and development for future generations of rare-event experiments. An overview of the electroforming process will be given along with the achieved radiopurity, such as the ultra-pure copper produced and measured by the Pacific Northwest National Laboratory, compared to commercially available copper. The current use of electroformed copper by various experiments will also be presented, including the recent cladding type electroplating performed by the NEWS-G direct dark mater search experiment, and its predicted impact on the sensitivity. The cladding is a thin layer of electroplated copper over the commercial copper substrate. It's purpose is to reduce the impact of lead-210 that was found to be at levels higher than expected in the commercial copper. Proposed future applications of electroforming in rare-event searches will also be discussed.

35

Understanding and suppressing radioactive noble gas background in liquid xenon detectors

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In the last years, liquid xenon detectors became very popular in the field of low energy rare-event search. With the increasing size of the detectors, external radiation is no longer the dominant background source in the latest generation of experiments. Instead, the achievable radio-purity is limited by internal contamination due to radioactive noble gas impurities, in particular 85Kr and 222Rn.
Using the XENON1T dark matter experiment as example, this talk will discuss the following options for the mitigation of radioactive noble gas background: 1: Identification of sources by thorough material selection with improved screening techniques. 2: Elimination of sources with dedicated cleaning methods. 3: Understanding and avoiding re-contamination processes. 4: Online removal of radioactive noble gases during the run-time of the experiment.
The progress and obtained results of the different approaches in the XENON1T experiment will be presented and an outlook for future improvements will be given.

53

XENON1T background modeling and statistical techniques for low background experiments

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The XENON1T detector is a dual-phase time projection chamber devoted to dark matter searches through their scattering off xenon atoms in a 2 tonne liquid xenon target. The background rate in the central volume of the XENON1T detector is the lowest achieved so far with a liquid xenon-based direct detection experiment. In this talk I describe the response model of the detector, the challenges of background modeling as well as the used techniques. In a low background experiment is often hard to asses the expected distribution of events due to lack of statistics and to many subtle effects. I describe a novel technique to introduce a well motivated systematic uncertainty to background model based on a calibration sample, which can be relevant to other low background experiments.