TT 63: Poster Session: Cryogenic Particle Detectors and Cryotechnique

Time: Thursday 15:00–18:30 Location: Poster D

TT 63.1 Thu 15:00 Poster D

Metallic Magnetic Calorimeters for high resolution X-ray Spectroscopy — •S. Allgeier[1], M. Friedrich[1], J. Geist[1], D. Hengstler[1], C. Schötz[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], S. Trotsenko[4], T. Morgenroth[4], M.O. Herdrich[2], G. Weber[2,4], G. Märtin[2,4], Th. Stöhlker[2,3,4], G.A. Kazakov[5], S.P. Stellmer[5], and T. Schumm[5] — [1]KIP, Heidelberg University — [2]Helmholtz-Institute Jena — [3]GSI Darmstadt — [4]IOQ, Jena University — [5]Vienna University of Technology

Metallic magnetic calorimeters are energy dispersive particle detectors which provide a high energy resolution over a wide range of energies as well as an excellent linearity. They are operated at millikelvin temperatures and convert the energy of a single absorbed particle into a temperature rise, which leads to a magnetization change in an attached paramagnetic sensor read out by a SQUID. Presently we are adopting our 64-pixel MMC series of maXs-20,-30,-200 and polarmaXs to measurements at CRYRING (GSI/FAIR, Darmstadt) for next generation QED test on hydrogen-like Uranium. We present the newly developed sidearm with a 32-channel-read-out-chain including the cryogenic SQUID-amplifier-modules. In addition we present the micro-fabricated detector array maXs-30 which is optimized for high resolution X-ray spectroscopy at energies up to 30 keV and the detector array polarmaXs for polarization sensitive high resolution X-ray spectroscopy and discuss their performances.

TT 63.2 Thu 15:00 Poster D

Development of the First Prototype of an MMC-Based Detector for Light Dark Matter Direct Detection — •Arnulf Barth[1], Klaus Eitel[2], Christian Enss[1], Andreas Fleischmann[1], Loredana Gastaldo[1], Sebastian Kempf[1], Bernhard Siebenborn[2], and Marc Weber[2] — [1]Kirchhoff Institute for Physics, Heidelberg University. — [2]Institute for Nuclear Physics, Karlsruhe Institute of Technology.

The use of low temperature detectors in the search for the direct interaction of dark matter (DM) particles in a suitable target has opened the possibility to reach high sensitivities even at masses well below $1\,\mathrm{GeV}/c^2$. We present the design for a low-threshold detector optimized for the search of light DM particles based on metallic magnetic calorimeters (MMCs) with a germanium (Ge) crystal as a scattering target. The interaction of a DM particle in the Ge crystal would create two different kinds of excitations: phonons and electron-hole pairs. We discuss the design of a 3-fold MMC system for the measurement of the temperature increase of the Ge crystal, and how the temperature signal can be amplified via the Neganov-Trofimov-Luke effect to ensure a high sensitivity. A first detector prototype has already been developed. We describe the fabrication steps and a first characterization of the performance.

TT 63.3 Thu 15:00 Poster D

Development of MMC based combined photon and phonon detector for rare event searches — •Freerik Forndran[1], Felix Ahrens[1], Christian Enss[1], Andreas Fleischmann[1], Loredana Gastaldo[1], Sebastian Kempf[1], Yong-Hamb Kim[2], Daniel Unger[1], and Clemens Velte[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]IBS Center for Underground Physics, Daejeon, Rep. of Korea.

In the search for rare events, a simultaneous measurement of photons and phonons produced after an event in a scintillating crystal operated at mK temperatures enables an efficient background rejection. This is due to the fact that the light yield depends on the mass, allowing for particle discrimination. This approach can be used for an investigation of the neutrinoless double beta decay as well as for a direct detection of dark matter. We present the design of a combined photon and phonon detector based on metallic magnetic calorimeters (MMCs). Simulations predict an energy resolution of $\Delta E_{\mathrm{FWHM}} < 10\,\mathrm{eV}$, a signal rise time of $\tau_0 < 50\,\mu\mathrm{s}$ and a signal decay time of $\tau_1 < 10\,\mathrm{ms}$ for the photon detector and $\Delta E_{\mathrm{FWHM}} < 100\,\mathrm{eV}$, $\tau_0 < 200\,\mu\mathrm{s}$ and $\tau_1 < 10\,\mathrm{ms}$ for the phonon detectors. The combined photon and phonon detector design will be described with emphasis on the tower design of the detector setup able to host several crystals. The challenges of the fabrication steps will be discussed. In conclusion we will present the characterization of first prototypes of photon and phonon detectors.

TT 63.4 Thu 15:00 Poster D

Low Temperature MMC Detector Arrays for the IAXO — •Daniel Unger, Christian Enss, Andreas Fleischmann, Lisa Gamer, Loredana Gastaldo, Daniel Hengstler, Sebastian Kempf, and Dennis Schulz for the iaxo collaboration — Kirchhoff Institute for Physics, Heidelberg University

The International Axion Observatory (IAXO) is searching for axions or axion-like particles generated in the Sun. A large magnetic field is used to convert solar axions to photons via the Primakoff effect. The major part of the expected spectrum considering only axion-photon coupling covers an energy range up to 10 keV with its maximum at about 3 keV. X-ray detectors with high efficiency in this energy range and low intrinsic background are required. Low temperature metallic magnetic calorimeters (MMCs) fulfil these requirements and can reach very low thresholds below 100 eV.

We present the design of a new detector system for the IAXO experiment with the possibility to operate two different kinds of two-dimensional MMC arrays. The setup is designed to host a large MMC array with moderate energy resolution aiming to discover events related to axions. If axions were discovered the focus would move to study the spectral shape. In this case a smaller MMC array featuring a higher energy resolution would replace the initial array using the same setup.

We show the current status of the platform and discuss methods to recognize background events based on pulse shape analysis and event coincidence in several pixels.

TT 63.5 Thu 15:00 Poster D

CryoGenX - A High-resolution Spectrometer for Advanced Nuclide Analysis — •Kevin Phelan[1,4], Andreas Fleischmann[1], Matthias Bühler[2], Theo Hertrich[2], and Michael Huber[3] — [1]Kirchhoff Institut für Physik, Universität Heidelberg — [2]Low Temperature Solutions UG — [3]PAYR Engineering GmbH — [4]Kaon GmbH

The EuroStars CryoGenX project is developing a complete, cryogenic detector system for x- and gamma-rays up to 200 keV. Target markets are non-destructive analysis for nuclear forensics, materials analysis and nuclear metrology for medical applications.

Cryogenic detectors can resolve energies where nuclear forensics communities have difficulty identifying the content and origin of nuclear active materials. A commercially available system could prove to be very useful for nuclear metrology, non-proliferation inspection and medical radiology.

There are currently two approaches for quantifying radioactive samples. Mass spectrometry with wet-chemistry is accurate but costly and complicated. Semiconductor detectors are easy but inaccurate. CryoGenX combines the advantages of both, ensuring fast, accurate results without destroying the samples, and with no radioactive waste.

The cryogenics is based on a very small ADR. The detectors are based on the MMC / MPT concept and will be tailored for a combination of energies and working temperatures. The SQUID read-out, cryostat automation and extensive data analysis including spectral information, peak identification and high-level analytics and file handling are all highly integrated.

TT 63.6 Thu 15:00 Poster D

MOCCA: a 4k-pixel molecule camera for the position and energy resolved detection of neutral molecule fragments — •Dennis Schulz[1], Steffen Allgeier[1], Christian Enss[1], Andreas Fleischmann[1], Lisa Gamer[1], Loredana Gastaldo[1], Julia Hauer[1], Sebastian Kempf[1], Sebastian Spaniol[2], Oldřich Novotný[2], and Andreas Wolf[2] — [1]Heidelberg University — [2]Max Planck Institute for Nuclear Physics, Heidelberg

The MOCCA detector is a 4k-pixel high-resolution molecule camera based on metallic magnetic calorimeters and read out with SQUIDs that is able to detect low-energy neutral molecule fragments. It will be deployed at the Cryogenic Storage Ring CSR at the Max Planck Institute for Nuclear Physics in Heidelberg, a storage ring built to prepare and store molecular ions in their rotational and vibrational ground states, enabling studies on electron-ion interactions. To reconstruct the reaction kinematics, MOCCA measures the energy and position of incident particles on the detector, even with multiple particles hitting the detector simultaneously. Using different read-out techniques,

MOCCAs 4096 pixel can be read out by using only 32 SQUID channels in total.

We present the most recent data from measurements of the MOCCA detector at 10 mK with a 6 keV photon source, demonstrating low crosstalk between rows and columns of the detector, the read-out principle and the energy resolution measured to be below 200 eV.

TT 63.7 Thu 15:00 Poster D

Measurement of low energy electron capture spectra to test the impact of high order processes — •Tobias Schmitt[1] and Martin Brass for the ECHo-Collaboration[2] — [1]Kirchhoff-Institute of Physics, Heidelberg University, Germany — [2]Institute of Theoretical Physics, Heidelberg University, Germany.

The neutrino mass can be determined by analyzing the shape of the endpoint region of electron capture spectra. The best candidate for this investigation is ^{163}Ho due to its low Q-value. Recent measurements of high statistic ^{163}Ho spectra, performed by the ECHo collaboration, showed that available theories can not describe the spectral shape. The deviations are on the order of 5 percent of the total spectrum. Nowadays, the best description of the ^{163}Ho spectrum is obtained using ab-initio calculations for the capturing process of the electron. To be able to better understand the excitations in which a ^{163}Dy atom can be left after an EC-process occurred in ^{163}Ho, we decided to study the calorimetrically measured EC spectrum of ^{193}Pt. With its low Q-value of 56 keV, which means ^{193}Pt can not undergo 1s-capture and the large atomic number it shares two important properties with ^{163}Ho. The larger energy interval will also provide more spectral lines for comparison with theories. At the same time it will provide a check that the theoretical description is not just fitted to the ^{163}Ho spectrum but indeed well understood. We will give a status report on the detector design, ^{193}Pt enclosure, and the completed experimental platform we developed with the goal to measure a ^{193}Pt electron capture spectrum.

TT 63.8 Thu 15:00 Poster D

Superconducting GHz Resonators for Microwave SQUID Multiplexing of Metallic Magnetic Calorimeters — •Felix Ahrens, Mathias Wegner, Patrick Paluch, Andreas Fleischmann, Christian Enss, and Sebastian Kempf — Kirchhoff Institute for Physics, Heidelberg University, Germany

Microwave SQUID multiplexing is the most promising way to read out large metallic magnetic calorimeter (MMC) detector arrays. Here, high quality superconducting GHz resonators are used for frequency encoding. The resonators are designed to have a bandwidth of ∼1 MHz to maintain the very fast signal rise time of MMCs. The frequency spacing between two neighbouring channels is set to ∼10 MHz to yield a crosstalk level below 10^{-4}. The bandwidth of the resonators is adjusted by tuning the coupling capacitor for each resonator based on simulations of the couplers' electromagnetic properties.

We investigate quarter-wave CPW transmission line (TLR) and lumped element resonators (LER) formed by a meander shaped inductor and an interdigital capacitor (IDC). The resonance frequency f_r of TLRs is set by adjusting the physical length of the resonator, whereas for LERs the number of IDC fingers is adjusted. Moreover, LERs allow to perform a post-production fine-tuning of the resonance frequency using a tile-and-trim process. We will present different aspects related to the fabrication, characterisation and optimisation of superconducting resonators to be used in a microwave SQUID multiplexer as well as our present tile-and trim process.

TT 63.9 Thu 15:00 Poster D

Effect of different host material for implantation of Ho-163 in metallic magnetic calorimeters — Martin Neidig, Benjamin Raach, Christian Enss, Andreas Fleischmann, •Loredana Gastaldo, Sebastian Velte, Federica Mantegazzini, and Clemens Velte — Kirchhoff Institute for Physics, Heidelberg University

The ECHo experiment has been designed for determining the value of the effective electron neutrino mass by the analysis of the endpoint region of the Ho-163 spectrum. The measurement of the Ho-163 spectrum is performed using low temperature metallic magnetic calorimeters (MMCs) with Ho-163 enclosed in the absorber. To achieve high sensitivity, detector performance as energy and time resolution are fundamental. In the process of optimizing MMCs for ECHo we have tested different materials for hosting Ho-163: gold, silver and aluminum. For that, high purity 163Ho has been implanted at Mainz University in three different MMC arrays having different implantation layers. We discuss the signal shape obtained with the different detectors as function of temperature as well as the energy resolution at the operating temperature of about 20 mK. In addition, we have also investigated if different host material could influence the decay mode for the electron capture in Ho-163. We present the comparison of Ho-163 spectra acquired with the different detectors and discuss the results at the light of available theories.

TT 63.10 Thu 15:00 Poster D

Specific Heat of Dilute Alloys of Holmium in Noble Metals at Low Temperatures — •Matthew Herbst, Clemens Velte, Andreas Reifenberger, Federica Mantegazzini, Andreas Fleischmann, Loredana Gastaldo, Andreas Reiser, Sebastian Kempf, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, D-69120 Heidelberg

We investigate dilute alloys of holmium in gold and silver in order to determine the impact of their specific heat on the performance of the microcalorimeters in the neutrino mass experiment ECHo. In particular, we focus on alloys with atomic concentrations of $x_{Ho} = 10^{-2} - 10^{-4}$ at temperatures between 10 mK and 800 mK. Due to the large total angular momentum $J = 8$ and nuclear spin $I = 7/2$ of holmium, the specific heat of Ag:Ho and Au:Ho depends on the detailed interplay of various interactions. This makes it unfeasible to accurately determine the specific heat of these materials numerically. Instead, we acquire the desired information through experiment, using three different experimental set-ups. The results from measurements on five holmium alloys show that the specific heat of these materials is dominated by a large Schottky anomaly with its maximum at $T \approx 250$ mK, which we attribute to hyperfine splitting and crystal field interactions. RKKY and dipole-dipole interactions between the holmium atoms cause additional, concentration-dependent effects. We find no significant difference between Ag:Ho and Au:Ho, and conclude that alloys with $x_{Ho} \approx 1\%$ are suitable for the ECHo project at $T \leq 30$ mK.

TT 63.11 Thu 15:00 Poster D

A versatile demagnetization refrigerator — •Alexander Regnat[1,2], Jan Spallek[1,2], Christopher Duvinage[1], Klaus Eibensteiner[1], Nico Huber[1], Carolina Burger[1], Anh Tong[1] und Christian Pfleiderer[1] — [1]Physik-Department, Technische Universität München, Germany — [2]kiutra GmbH, München, Germany

Cooling devices providing temperatures well below 1 K are a key prerequisite for modern research and development, e.g., in materials science, quantum applications and the cooling of sensors and detectors. Here we present a versatile and compact demagnetization refrigerator for the cryogen-free, continuous generation of sub-Kelvin temperatures.

TT 63.12 Thu 15:00 Poster D

Pulse Tube Cryocoolers: Solutions for "Dry" Cooling of Low Noise Applications at 4 K — •Jens Falter[1], Bernd Schmidt[1,2], Jack Schmidt[1,2], André Schirmeisen[1,2], and Günter Thummes[1,2] — [1]TransMIT-Center for Adaptive Cryotechnology and Sensors, Giessen, Germany, — [2]Institute of Applied Physics (IAP), Justus-Liebig-University Giessen, Germany

Among the family of regenerative cryocoolers, Pulse Tube Coolers (PTCs) distinguish themselves from Gifford-McMahon- or Stirling coolers by the absence of cold moving parts. This features a long live operation with low vibration of the PTC and less maintenance compared to conventional cryocoolers - making them attractive for low noise applications. Since their invention, 4 K PTCs [1] have become an excellent alternative for "dry" cooling of cryogenic experiments without liquid helium ("wet cooling") even below 4 K. Besides their advantages, PTCs – like all other regenerative cryocoolers – suffer from two intrinsic effects due to the periodic compression and expanding cycles in the cold head: a periodic elastic deformation ("breathing") of the thin walled pulse- and regenerator-tubes, which leads to residual vibrations and a periodic variation in temperature. Here we present unique applications of double-staged 4 K PTC based cryostats. By adapting the cooling power to the requirement of the experiment[2], the intrinsic effects of the PTC are minimized. Further decoupling and damping of the mechanical and thermal variations provide an excellent environment even for cooling of sensitive devices.

[1] G. Thummes et al., Cryogenics 38 (1998)
[2] B. Schmidt et al., Cryogenics 88 (2017)

TT 63.13 Thu 15:00 Poster D

Design of a scanning confocal microscope for fluorescence spectroscopy of single-photon sources at mK temperatures — •Marcel Schrodin[1], Philip Schneider[1], Christoph Sürgers[1],

and Wolfgang Wernsdorfer[1,2,3] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Institut Néel, CNRS and Université Joseph Fourier, Grenoble, France — [3]Institute for Nanotechnology, Karlsruhe Institute of Technology

In recent years, different kinds of single-photon sources such as color centers in diamond, single molecules, and quantum dots became the focus of attention in the wide filed of quantum technology. Many experiments already exploit the single emitter characteristics in ambient conditions. However, a comprehensive investigation of single-photon sources and an integration in quantum devices still requires cryogenic temperatures.

We want to present the design of a scanning confocal microscope for fluorescence spectroscopy of single-photon sources at mK temperatures and will show first proof-of-principle results. The optical design is based on a high-NA objective and an optical fiber which guides both the excitation and response of the sample. On-axis scanning of the sample is provided by an xyz-positioning setup. For cryogenic operation, these parts are put into a home-built table-top dilution refrigerator with 20 mK base temperature. Special care has been taken to minimize the vibrations present in the proximity of the sample.