TT 103: Superconductivity: Cryogenic Particle Detectors

Time: Thursday 17:15–18:30 Location: H 2053

Invited Talk TT 103.1 Thu 17:15 H 2053

From Fundamental Principles to Applications: Cryogenic Micro-Calorimeters — •Christian Enss, Sebastian Kempf, Loredana Gastaldo, and Andreas Fleischmann — Kirchhoff-Institut für Physik, Universität Heidelberg, INF 227, 69120 Heidelberg

Magnetic micro-calorimeters (MMCs) are state of the art cryogenic particle detectors which belong to the most sensitive devices to measure the energy of single quanta. They are composed of an absorber suited for the particles to be detected which is in close thermal contact with a paramagnetic temperature sensor. Together the two are coupled to a thermal bath through a weak thermal link. Fundamentally the energy resolution of such a detector is limited by thermal fluctuations between the absorber/sensor system and the thermal bath. Their universal applicability for particles and radiation as well as their high resolving power, broad bandwidth and linear response make them today a popular choice in many different experiments. Applications include X-ray spectroscopy, neutrino physics, material analysis, mass spectrometry and nuclear forensic. Currently, MMCs are used in several international projects like AMoRE, ECHo and SPARC. We will discuss the operating principle, the basic material science research behind their realization, the status of development and various recent applications.

TT 103.2 Thu 17:45 H 2053

Optimization of metallic magnetic calorimeter arrays with embedded ^{163}Ho for the ECHo experiment — •Federica Mantegazzini and the ECHo collaboration — Kirchhoff-Institute for Physics, Heidelberg University, Germany.

The ECHo experiment aims to determine the electron neutrino mass via the analysis of the calorimetrically measured electron capture spectrum of ^{163}Ho. The detector technology is based on metallic magnetic calorimeters (MMC) and the implantation of ^{163}Ho has been selected as method to enclose the source in the detectors, showing already good performances for activity values up to 1 Bq. Since the sensitivity of the ECHo experiment strongly depends on the total acquired statistics, the activity per pixel needs to be increased, taking into account two constraints: the resulting unresolved pile-up events fraction and the supplementary heat capacity due to the implanted ions. We have developed a novel experimental technique for the determination of the specific heat per ^{163}Ho ion, based on the simultaneous measurement of two MMC pixels with identical geometry which differ only because of the ^{163}Ho ions implanted in one of the two. At an operational temperature of 20 mK for an activity of about 1 Bq, the heat capacity increases of less than 3%. Therefore, a total activity of the order of 10 Bq per pixel - as required in order to keep the unresolved pile-up fraction under control - can be implanted without strongly affecting the detector performance. In this contribution, the development and the characterisation of the new microfabricated detector arrays is presented.

TT 103.3 Thu 18:00 H 2053

Microwave SQUID multiplexing of metallic magnetic calorimeters — •M. Wegner, D. Richter, F. Ahrens, L. Gastaldo, A. Fleischmann, S. Kempf, and C. Enss — Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany.

The most promising readout technique for large arrays of metallic magnetic calorimeters (MMCs) is microwave SQUID multiplexing (μMUXing), in particular since MMCs require a large bandwidth per channel. Each channel of a μMUX consists of a non-hysteretic rf-SQUID which is inductively coupled to a superconducting microwave $\lambda/4$ resonator. Due to the mutual inductance between SQUID and resonator and the flux dependence of the SQUID inductance, a signal in the MMC is transduced into a resonance frequency shift which can be detected by continuously monitoring the resonator transmission. By coupling many readout channels, each having a unique resonance frequency, to a common feedline, this technique allows for a simultaneous readout of hundreds of detectors.

In this contribution we present a full characterization of our state-of-the-art μMUX having 32 readout channels. By providing sufficient bandwidth per channel, we are able to resolve the fast intrinsic signal rise time of MMCs. The measured energy resolution is $\Delta E_{\mathrm{FWHM}} = 11\,\mathrm{eV}$. Based on the results of our comprehensive device characterization, we developed and fabricated a next-generation multiplexer chip. We will discuss our latest multiplexer design and will show our most recent experimental results.

TT 103.4 Thu 18:15 H 2053

On the interplay between kinetic inductance fraction and Kerr non-linearities in superconducting resonators for millimeter wave detection — •Francesco Valenti[1], Fábio Henriques[1], Nataliya Maleeva[1], Uwe Von Lüpke[1], Lukas Grünhaupt[1], Patrick Winkel[1], Sebastian T. Skacel[1], Alexander Bilmes[1], Alexey V. Ustinov[1,3], Florence Lévy-Bertrand[2], Alessandro Monfardini[2], and Ioan M. Pop[1] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Institut Néel, CNRS and Université Grenoble Alpes, Grenoble, France — [3]Russian Quantum Center, National University of Science and Technology MISIS, Moscow, Russia

Following their proof-of-concept paper published in 2003, in the span of ten years Microwave Kinetic Inductance Detectors (MKIDs) found both widespread scientific interest in the superconducting electronics community and in technological applications as particle detectors. We explore the possibility of using Granular Aluminum (GrAl) with the goal of decreasing the Noise Equivalent Power (NEP) of the resulting MKIDS. One of the most attractive features of GrAl films is the wide-range tunability of the sheet resistance, which is in turn directly linked to the kinetic inductance. To exploit this resource we propose a theoretical model for the dependence of the NEP with the kinetic inductance fraction of the detector. We quantify the interplay between kinetic inductance fraction and non-linearities and we determine the kinetic inductance fraction value that gives the lowest NEP.