The use of LTDs as powerful particle detectors for neutrino physics was first proposed in 1984 by Prof. E. Fiorini (E. Fiorini and T. Ninikoski, Nucl. Instrum. and Meth. **224**, p.83 (1984)). Since then, under Prof. Fiorini's lead, our group, first at Milano University, and now at Milano-Bicocca University, has been developing LTDs, mostly for neutrinoless double beta decay searches and neutrino mass endpoint experiments. The group has gained a worldwide leading position in this field carrying out many sensitive experiments and with many important technical achievements. This research activity has been supported by the INFN - through its Commissione Scientifica Nazionale 2 -, the University and the European Community. Presently, we have two main running projects - CUORE and MARE - where our group has a leading position within large international collaborations.

The purpose of the project proposed here is to start a new research and developement activity within our Milano-Bicocca group. The LTD technology we have developed so far has now reached its highest level and starts to show critical limitations. To keep our scientific and technological leadership we need to explore new more powerful techniques.

This project aims at exploiting the recent advances with microresonator detector arrays to provide new devices suitable for low temperature particle detection in next generation neutrino physics experiments. In particular we expect to produce new detector technologies addressing the need for sensitive scalable arrays for the MARE project and for simultaneous light and heat detection in a future neutrinoless double beta decay experiment (A. Nucciotti, MEDEX 2009, AIP Conference Proceedings, **1180** (2009) 81).

These ambitious goals will be pursued by research on device materials and by design optimization. The project will be lead by Dr. Peter Day, who has been pioneering the development of microresonator detector arrays since their first introduction. The project consists in a three-year program and we propose first of all to make the key developments that are necessary to enable direct neutrino mass experiments in the framework of the MARE project.

The MARE project's goal is to measure the neutrino mass with a sensitivity of the order of 0.1 eV (MARE project proposal: http://crio.mib.infn.it/wig/silicini/proposal/, A. Nucciotti, arXiv:1012.2290v1). The neutrino mass can be directly assessed by studying the kinematics of low energy nuclear beta decays, where (anti-)neutrinos are emitted by a nucleus. To balance the energy required to create the massive neutrinos emitted in the decay, the highest possible kinetic energy of the electrons is slightly reduced. This energy deficit may be determined when analysing with high precision the higher energy end of the emitted electron energy distribution. Calorimetric measurements, where one measures all the energy released in the decay except for the energy carried away by the neutrino, are an extremely interesting alternative to spectrometers like the one of the KATRIN experiment. In order to achieve high sensitivity low transition energy isotopes are preferable. MARE is a project to make a calorimetric measurement of the beta decay of Re-187, an isotope with one of the lowest transition energies known - about 2.5 keV. Another option for the MARE project is the electron capture decay of Ho-163: in this case one looks for the effect of the neutrino mass at the spectrum end-point of the atomic radiation emitted following the electron capture - mostly electrons (A. De Rujula and M. Lusignoli, Phys. Lett. B **118**, p.429 (1982)). To date two experiments have used low temperature detectors for calorimetric measurements of Re-187. These experiments, which were conducted in Milano by our group (C. Arnaboldi et al., Phys. Rev. Lett. **91**, p.161802 (2003), M. Sisti et al., Nucl. Instr. and Meth. **A 520**, p.125 (2004)) and in Genova (F. Gatti et al., Nucl.Phys. B **91**, p.293 (2001)), achieved a sensitivity on the neutrino mass of approximately 15 eV.

While Re-187 and Ho-163 require somewhat different detector designs, both approaches have very similar technical requirements, i.e. they require energy resolution and response time in the electronvolt and microsecond range, respectively. As discussed in the following section, microresonator detectors may be designed to fulfil these requirements. Equally important, the straightforward multiplexing available with these detectors makes them very appealing for the MARE project which calls for very large arrays - up to 10^5 pixels - to be able to collect total statistics of up to 10^{15} decays (A. Nucciotti et al., Astropart. Phys. **34**, p.80(2010)).

The results obtained with the prototypes developed within this project will allow the MARE collaboration to complete the process of selecting the single pixel design for the final experiment. An additional benefit of this activity will be the gained expertise in the use of microwave frequency domain multiplexing of low temperature detectors signals. This technique is the most promising for multiplexing signals from arrays of TES or MMC detectors through the use of SQUIDs. Therefore, even if one of these technologies is eventually chosen for MARE, this expertise will be very valuable for our group to maintain a key role in the MARE project.

We believe that microresonator detectors can also be very usefully applied to the neutrinoless double beta decays (0ν-DBD) searches. Searches for this extremely rare - and not yet observed - nuclear decay are the only known experimental method to probe the Majorana nature of neutrinos while providing a sensitive measurement of the (effective) neutrino mass. For this kind of experiments, the calorimetric approach, where the decay source is contained in the detector, also offers substantial advantages. One of the most sensitive calorimetric experiments being presently pursued is CUORE which will use TeO_2 low temperature detectors to search for Te-130 0ν-DBD. The CUORE detector is made up of about one thousand 700 g TeO_2 detectors cooled to about 10 mK. The CUORE effort is lead by our Milano-Bicocca group and will come into operation in the next years.

Going beyond CUORE requires both improvement of the sensitivity and extension of the search for this rare decay to as many different isotopes as possible. The sensitivity may be improved by increasing the number of channels and by reducing the background caused by background radioactive decays. Both of these issues can be approached using microresonator detectors. The multiplexing advantage of the microresonators will allow the channel count to be increased without added burden on the cryogenic system. For background rejection, our group has long been investigating new techniques for particle identification by detecting simultaneously the thermal and scintillation signals (A. Alessandrello et al., Phys. Lett. **B420**, p.109 (1998)) . This approach allows discrimination of low ionizing radiation like alpha particles - one of the most serious sources of background counts. Detectors containing various isotopes of interest - Mo-100, Se-82 and Cd-116 - have been successfully tested in this dual read-out configuration (C. Arnaboldi et al., Astropart. Phys. **34**, p. 143 (2010)). Active background rejection may also be applied to poorly scintillating materials like TeO_2 by exploiting the Cherenkov effect (T. Tabarelli de Fatis, Eur. Phys. J. **C 65**, p.359-361 (2010)): non relativistic particles such as alpha particles would be discriminated thanks to absence of photon emission. By using microresonator detector arrays designed for single photon detection in the visible - UV range it will be possible to cover the large collecting areas that will be needed for a next-generation CUORE-type experiment.

The research program covered with this project therefore deals mainly with two general issues:
1. The development of individual KIDs for Re-187/Ho-163 decay calorimetry and for light detection in neutrinoless double decay searches.
2. The operation of a small prototype KID frequency multiplexed array.

The project will have the support of our research group and will use and extend the facility for LTD development already set up by our group in Milano-Bicocca University. This includes a laboratory equipped with three dilution refrigerators and all the instrumentation necessary for radiation detector development and testing. The very first step in the project will be to acquire the know-how and skills necessary to work with micro-wave devices in a cryogenic environment. Then, at least one of our dilution refrigerators will be instrumented with the microwave cryogenic cabling, amplifiers, filters, mixers, generators etc., necessary to test and characterize the produced devices.

Step 1) will require the design, fabrication and characterization of specialized detectors. A particular focus will be on the detector and substrate material in order to achieve high sensitivity and low excess noise. Another important issue to explore is the coupling between the absorber and the detector itself.

Step 2) will require the installation and optimization of a specially designed multiplexed read-out system, together with design of properly tuned resonating devices.

The devices will be commissioned to a third party laboratory. We are exploring additional possibilities, but most likely the devices will be produced by the Micro-ElectroMechanical Systems and Radiation Detectors Research Unit (MEMSRAD) of the Fondazione Bruno Kessler (FBK) in Povo (TN). The MEMSRAD, with which we have had a long-standing collaboration, has the facilities and experience to fabricate the devices for this project in the in-house Microfabrication facility.

Finally, this project will help to establish in our department at Milano-Bicocca University a new LTD group composed of young researchers with experience with low temperature microwave devices and techniques. The combination of the long-standing excellence of our group in the field of neutrino physics and LTD technology with the expertise of a world-class expert in microwave LTDs has the potential to create a unique and very attractive environment which will benefit the particle physics research in our department and foster new opportunities for physics students oriented to experimental techniques for astroparticle physics, astrophysics or microwave electronics.

The partnership between University of Milano-Bicocca and Caltech/JPL started by this project will open the path for future scientific collaborations. This will provide valuable and unique formative opportunities to young researchers of Milano-Bicocca University through direct contacts and reciprocal exchange of visiting students and grants for young researchers.