REPORT ON MY RESEARCH ACTIVITIES

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Project goals

Since October 2012 I am in a postdoctoral position in the EDELWEISS III group within two research institutions in France: the IRFU/SPP at CEA-Saclay and the CSNSM (Centre des Sciences Nucléaires et Sciences de la Matière) at Orsay. EDELWEISS is a European collaboration that aims to directly detect dark matter in the spin-independent sector at the Laboratoire Souterrain de Modane (LSM) using ultra-pure germanium (HPGe) bolometer technique at cryogenic temperatures (18mK).

Scientific framework of the project
The dark-matter nature is one of the most fascinating problems studied by physicists in the last two decades with observations and theoretical conjectures. The direct detection represents an extremely challenging task. CEA-SPP and CSNSM are largely involved in this task with the EDELWEISS experiment. All the R&D on detectors fabrication, systematic measurements with validation of detector performances is realized at Orsay in the solid-state physics laboratory CSNSM.

Within this framework I am involved in 3 main sub-programs:

- **EDELWEISS-III installation**. Upgrade of the EDELWEISS setup with the installation and commissioning of the 36 new detectors;
- **Systematic detector studies**. Dedicated measurements at CSNSM for testing and optimizing the FID800 new detectors (surface treatment validation; understanding of charge transport in operating conditions);
- **Data Analysis**. A strong participation to the analysis of LSM data in order to measure the detector performances using in-situ calibration and background data, characterize the existing backgrounds, measure their rejection, and optimize the physics searches.

Description of the work achieved

Research program in EDELWEISS III
I played a major role in both institutions in detector R&D and fabrication, electronics, acquisition and data analysis. I was also strongly involved in the installation of the 36 new generation detectors, new cabling and the commissioning of the full setup in LSM. Another part of my job was dedicated to the characterization of the new HPGe detectors in the solid-state physics laboratory at CSNSM. The EDELWEISS-III project, fully installed at the LSM, aims at accumulating a 3000 kg.d exposure with 36 new generation "FID800" cryogenic bolometers in order to directly detect WIMP dark matter in the spin-independent sector with WIMP-nucleon cross-sections down to ~10^{-9} picobarn.

The program of the work achieved is summarized as follows:

1. **Installation and running of EDELWEISS-III.**
   I was strongly involved in the installation and commissioning of the first 6 new generation of detectors "FID800" in the cryostat at LSM between December 2012 and February 2013. This phase implied my active participation also in the data taking and monitoring of bolometers with simultaneous measurement of phonons + ionization. My role was to inspect each detector in the clean room to ensure their good behavior and their ultrasonic bounding connections. I also mounted the HPGe crystals in their copper boxes and installed them for the final cryostat setup. I was responsible in making the electronic connections and verifying the good behavior of the different measurement channels. During February 2014 and March 2014, I installed the complete setup of 36 detectors and made the electronic tests to validate the good connections with their new cabling. The final setup is now completed. Until now, I participated in more than twenty missions in the LSM tunnel to accomplish these highly specialized tasks, one of which was dedicated to the cryostat operation.

2. **Systematic Studies on detectors at CSNSM and detector preparation.**
   During the first data taking, it will be mandatory to study in detail and understand the properties of the detectors, and to optimize their response to different background sources such as gammas, beta rays and neutrons. To reach this goal I worked at CSNSM with Alexandre Broniatowski and Stefanos Marnieros where I participated in surface treatment validation and understanding of charge transport in operating conditions. In particular, to this end I carried out dedicated experiments with calibration sources at CSNSM in order to characterize the charge transport properties of the new HPGe. During this time, I acquired hands on expertise in the field of solid-state physics and in cryogenics. For example, I measured at very low temperatures (18mK) a new generation HPGe detector of 200g where we were able to obtain remarkable and new results on the effect of the detector contamination. These results were seen for the first time in germanium detectors, which allowed the publication of two articles, a presentation and two posters in California at the LTD15 conference specialized in low temperature physics. I also took important measurements concerning the charge transport and the evolution of charge collection in the detectors,

which is essential for the understanding of the germanium detectors and for modeling. In the context of detector preparation, I was involved in the detector mounting and assembling of the detectors in the clean room at CSNSM and validation of these detectors before going to the tunnel in LSM.

3. **Data Analysis for WIMP searches.**
   I was in charge of optimizing and improving the analysis program written in C++ and python by Eric Armengaud. In doing so, I made important contributions by adding new variables and corrections to the detectors, which were essential for energy resolution and gain calibration of the different measurement channels. I was specifically in charge of analyzing the first run dedicated as a test to insure the good commissioning of the six new generation detectors of the EDELWEISS III project. This analysis validated their detection efficiency and performances. In this context, I also designed for the first time an event classification based on the ionization signals of each detector, allowing to reconstruct the interaction position and multiplicity. This special analysis also allowed me to determine the active mass ("fiducial volume") of the new detectors generation. My work was compared to another analysis created by our collaborator in Lyon (France) in order to crosscheck the results and validate its coherence. After this successful venture, German collaborators now use the analysis code as a reference in order to achieve a new exploitation system able to analyze all the detectors in LSM.

Publications

Journal Papers:
EDELWEISS Papers to which my Postdoctoral work contributed directly

M.-C. Piro , A. Broniatowski, S. Marnieros, L. Dumoulin, E. Olivieri
Hot Carrier Trapping in High-Purity and Doped Germanium Crystals at Millikelvin Temperatures.
J. Low Temp. Phys. DOI 10.1007/s10909-014-1088-6 (2013).

A. Broniatowski, M.-C. Piro, S. Marnieros, L. Dumoulin, E. Olivieri
H− -Like Centers and Space-Charge Effects in Cryogenic Germanium Detectors for Dark Matter Search.
J. Low Temp. Phys. DOI 10.1007/s10909-013-1060-x (2013).

Other Journal Papers

EDELWEISS Collaboration (E. Armengaud et al.)
Axion searches with the EDELWEISS-II experiment.
J. of Cosmo. and Astro. Phys. 11(2013)067 doi:10.1088/14757516/2013/11/067.

Relevance of the project within P2IO

The present program gave me the opportunity to extend my expertise. I have acquired expertise in low background detector technique with HPGe and in the related data analysis tools. This position was a chance for me to work in a stimulating environment, in strict contact with first-class physicists operating in the most promising research in Physics. This exceptional environment allowed accelerating my formation as a mature researcher, capable of devising new solutions and leading working groups for the development of new detection technologies, in the context of an ambitious science program. My work in both CSNSM and SPP, as well as Modane, is a strong contribution to the installation and preparation of the EDELWEISS-II project. In particular, I have increase the already collaboration between both P2IO laboratories. For example, this synergy allowed to better share the detailed knowledge of detector properties studied in-situ at Modane from Saclay analysis, compared to dedicated test measurements at Orsay. I think the postdoctoral position offered enabled me to progress in the development of my career.

Future: After P2IO

My other interests concern both the research and development of new detector technologies based on innovative ideas and also the creation of new analysis methods to extract interesting physics signals. I have developed skills in software/hardware development and I have shown a good ability to acquire new knowledge. I have already demonstrated the ability to learn quickly and to manage new techniques and I have shown a remarkable capability to develop, adapt and improve the scientific tools previously used. I possess a deeper knowledge on the low background issues connected to rare event searches in particle physics and on the methods to investigate, control and eliminate radioactive contamination. This set of abilities constitutes a firm basis for other postdoctoral programs proposed. I am currently actively looking for other postdoc positions around the world with other detection techniques to acquire more competences and knowledge. For the future, I would like to build up a research project based on knowledge of detector techniques in order to develop new detection technologies and adapt it to each field of science.