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Report on Théo Hugues PhD dissertation

The title of the thesis of Théo Hugues is “Search for Dark Matter with Liquid Argon Detectors”. The manuscript is made of 158 pages divided into 6 chapters (two really shorts being the introduction and the conclusion) plus 3 annexes.

The first chapter is an introduction on the work performed by Théo including a brief presentation of the different chapters.

The second chapter contains an introduction on dark matter. An historical overview is given with a complete description of the cosmological and astrophysical observations. In this chapter, Théo presents the different candidates which could describe the nature of dark matter. Each candidate of the dark matter is briefly described giving the reader a clear picture of the state of the art in the present dark matter knowledge. The chapter ends with a description of the different methods to detect dark matter: Théo presents the different techniques spanning from indirect to direct detection, emphasizing the complexities of running and past experiments, and giving the status of the present experimental limits. In this chapter Théo succeeds in making a clear and pedagogic synthesis of his theoretical and experimental knowledge.

Chapter three deals with the Liquid Argon detectors since the two experiments on which Théo works are based on such a technology. Théo explains in detail the properties of Liquid Argon in particular related to the scintillation process. The background related issues are also mention. The two detectors on which Théo works on are discussed: DarkSide-50 and DEAP-3600. The synthetic descriptions he makes allows the reader to clearly understand the analysis works he will describe in the following chapters.

Chapters four and five are the core of Théo’s thesis work.

In chapter four Théo describes the study he performed on the sensitivity to inelastic boosted dak matter with DEAP-3600. This is an original work since he

investigated a new category of particle (iBDM of inelastic Boosted Dark Matter) and the sensitivity of DEAP-3600 to observe it. As an introduction of this work, Théo presented the different theoretical models and using simulations he reproduced the energy spectra showing a very good agreement compared to previous studies. The analysis is then performed on several days of data taking. Théo developed a signal model and a code to estimate the sensitivity, for that he optimized the data selection cuts and the background model. Théo showed that DEAP-3600 has an interesting potential for the search of iBDM and this chapter ends with a perspective to improve the sensitivity of the experiment.

Chapter five describes the second important part of the work performed by Théo. The goal of this work is the search for dark matter annual modulation with DarkSide-50. An annual modulation of the dark matter event rate should be induced by the Earth's orbital motion around the Sun. To search for such a signal, Théo looks at the detector stability through periodicity analysis using the Lomb-Scargle algorithm applied on the residual of the data. An important point was first to subtract a background fit function with short lived isotopes in order not to impact the analysis. He analysed also the impact of the variation of slow and environmental control sensors around the cryogenic system still using Lomb-Scargle periodograms and calculation of correlation coefficients. Simulations were developed to assess the significance of the results for the dark matter search as well as the correlation coefficient between the data event rate and sensors values. The analysis has been finalized and Théo presented the expected exclusion limits for different energy ranges.

In both chapter four and five, Théo shows that he developed important skills in using statistical tools, and in performing data analysis. Moreover his work shows a complete physicist profile under both theoretical and experimental point of view.

Chapter six is just a brief summary and conclusion of Théo's thesis work.

To summarize, the thesis of Théo Hugues is well written and clear. It presents a complete analysis work on two different experiments and two different topics related to the search of dark matter. The thesis shows a deep understanding of Théo of the experimental setups, and on the data analysis. The presented work is a first milestone towards a possible search of inelastic boosted dark matter in DEAP-3600 and a completed analysis for the search of dark matter annual modulation with DarkSide-50.

Summing up, I consider the doctoral thesis of Théo Hugues to be a valuable contribution and to meet the criteria prescribed by the law for a doctoral dissertation. Therefore, I request that this dissertation be admitted to a public defense.

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