A Ray-Tracing simulation study for the dark matter new generation detector PICO-500

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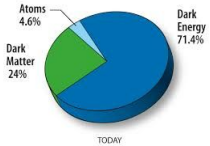
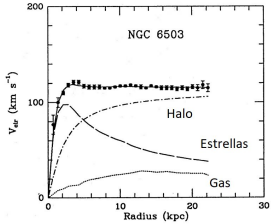
Introduction

1.-What is dark matter?



1.1.- Clues of the existence of dark matter

Galaxy Rotation Curves

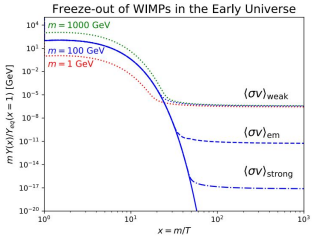


Gravitational lensing

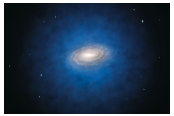
Galaxy Clusters Colision

1.2.- Candidates to dark matter

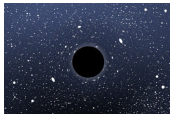
WIMPs



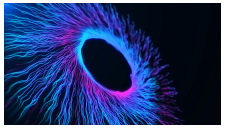
MACHOs



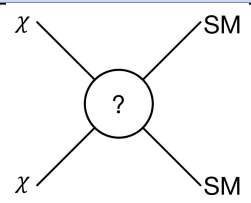
Primordial Black Holes



Axions

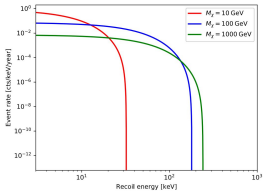


2.- How to detect dark matter?

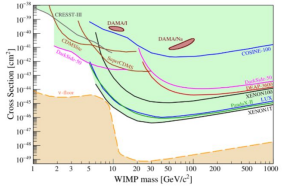


2.1.- Direct Detection

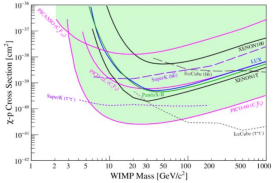
WIMP masses



SI

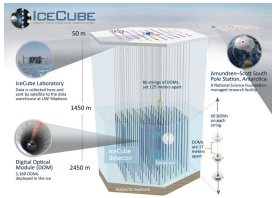


SDp

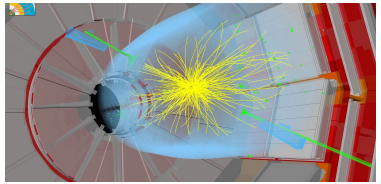


2.2.- Indirect Detection

IceCube

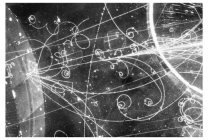


LHC

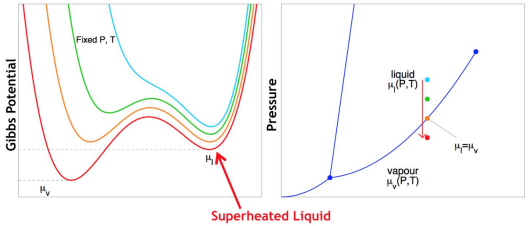


The PICO project

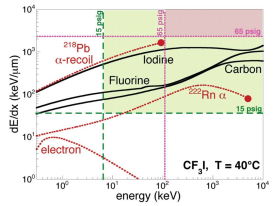
3.- Bubble Chambers



Superheated Fluids



Bubble chambers as dark matter detectors

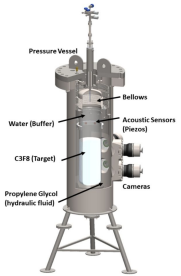


4.- PICO experiments

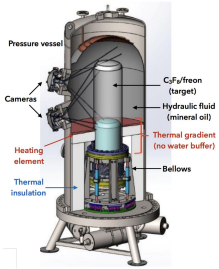
PICASSO + COUPP = PICO

PICO-2L

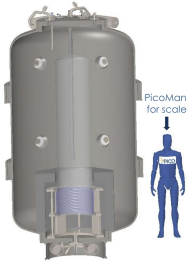
PICO-60



PICO-40L



PICO-500

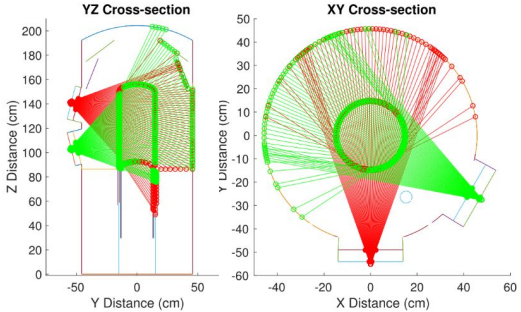


Optical Simulation for PICO-500

5.- Previous Concepts

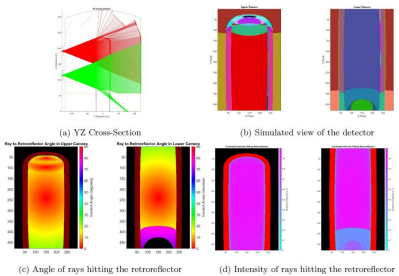
Retroreflectivity

Ray-Tracing

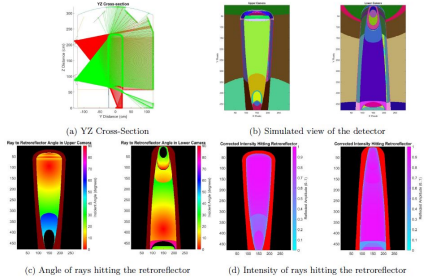


6.- Viewports Configuration

Straight ports

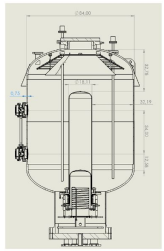


Inclined ports

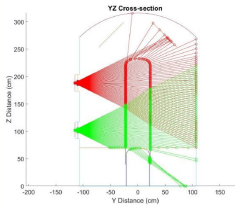


7.- Optimal Position for the cameras

First Design

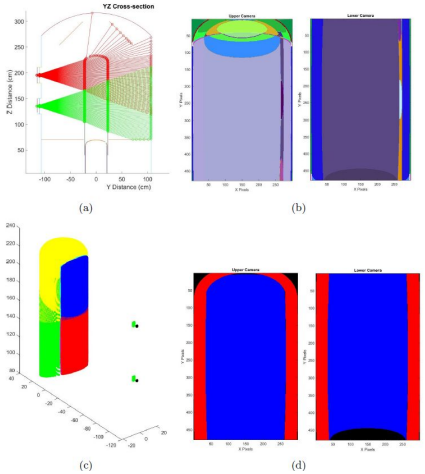


(a) First drawing of the detector.



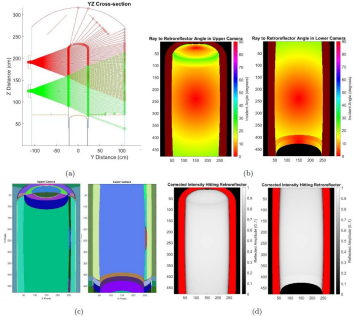
(b) YZ cross section figure

Results

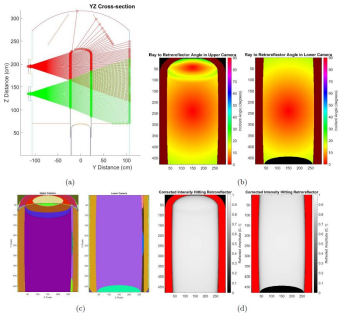


8.- Retroreflector Design

Bottom Retroreflector



Top Retroreflector



Conclusions

From the results shown here, the design team of PICO-500 concluded that the straight viewport was the best option. The parameters found in the simulations for the optimal position for cameras could vary in the future due to technical restrictions or some eventualities. That's why the development of the ray-tracing code is very important, so we can adjust easily the new constraints into the code and generate a new set of optimal values.

In this study we didn't only achieve to adapt the program to the new experiment PICO-500, but also to develop a new methodology to find the optimal positions with a program that was originally developed to test retroreflector designs.

Currently, the PICO collaboration is working in the last steps of the design for PICO-500, which consist in various different topics, here I showed one of them: The optical analysis via ray-tracing simulation.

A future work following this line will be to adapt the program for spatial localization of the bubbles in the chamber for PICO-500. This step is going to be necessary to analyse the results when PICO-500 starts to operate, which is planned to be in 2021.

Acknowledgements

I'd like to thank to my supervisor from the University of Alberta, Dr. Carsten Krauss for the opportunity to participate in the PICO collaboration, as well as Dr. Cesar Castromonte for being my supervisor for my topics of investigation course where I developed this study even further. Finally, this work wouldn't be possible without the funding from the UARE program and the diffusion of the program by the "Oficina Central de Cooperación Internacional y Convenios" of the Universidad Nacional de Ingeniería of Peru.