Optical properties of the JUNO liquid scintillator with the SHELDON project

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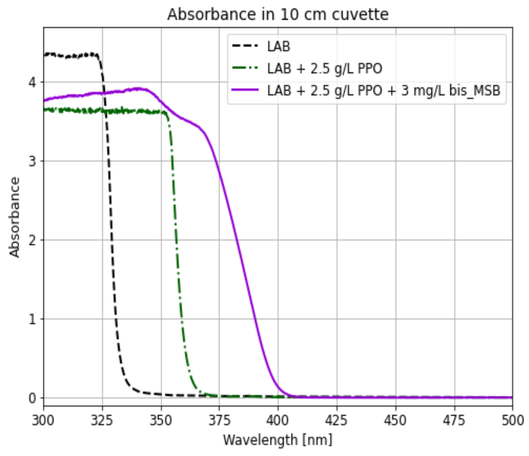
Introduction

The Jiangmen Underground Neutrino Observatory, JUNO, is a massive experiment located in Kaiping, in south China. As a detection medium, it exploits 20 kton of liquid scintillator, a mixture of LAB, PPO and Bis-MSB, whose detection process is based on the conversion of the energy deposited by interacting particles into light.
Thanks to its huge mass and its excellent energy resolution (3% at 1 MeV), JUNO will be a cutting-edge experiment in neutrino physics, with the main goal of determining the Neutrino Mass Ordering. To accomplish that, it is necessary to fully understand the optical properties of its liquid scintillator (JUNO LS).
For this purpose the Physics Department of University of Milan, has set up the SHELDON (Separation of cHErenkov Light for Directionality Of Neutrino) facility, which consists of different units, each designed to analyze specific optical properties: fluorescence time profile, absorption and emission spectra, Cherenkov contribution, refractive index and group velocity. In this poster I will present the optical characterization performed on the JUNO LS produced by the JUNO purification plants **[1]**.

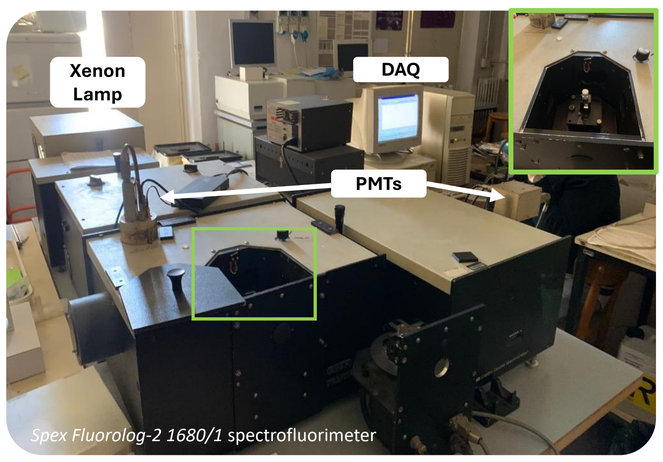
Absorption and Emission spectra

JUNO LS recipe was developed to **maximize the optical coupling** between its **emission spectrum** and the optical acceptance range of **JUNO photomultiplier tubes**, and **reduce the self absorption** of the fluorescence light **[2]**.

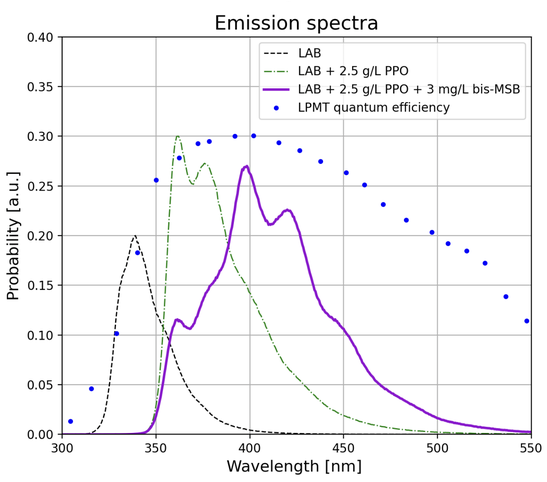
JASCO V-760
spectrophotometer



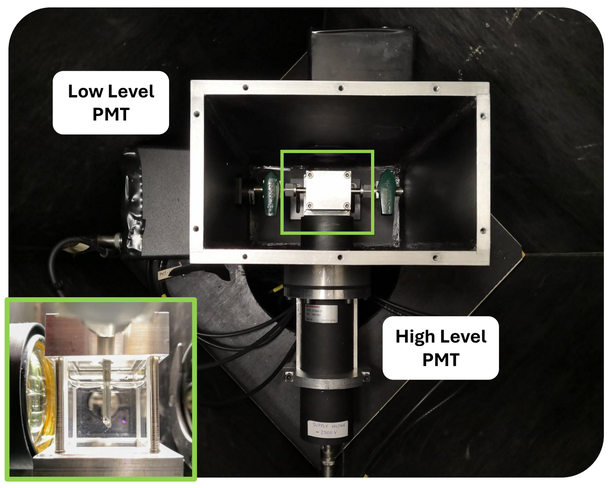
In collaboration with University of Perugia



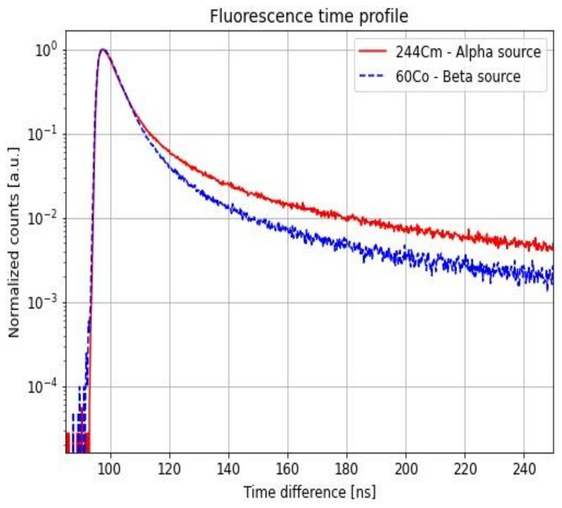
Spex Fluorolog-2 1680/1 spectrofluorimeter

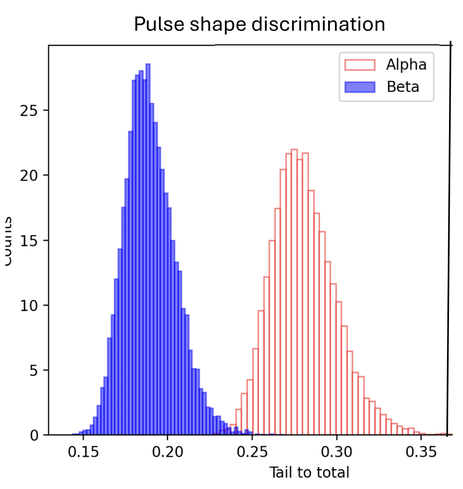


Fluorescence Time profiles

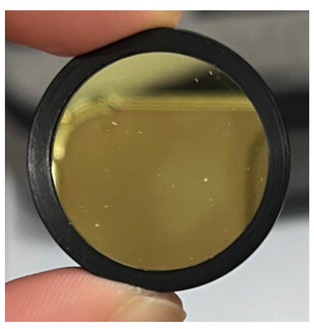


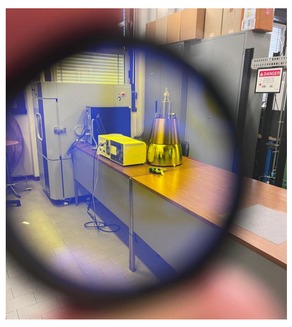
The knowledge of the **fluorescence time profiles** of the scintillator via **small-scale setups** are fundamental for JUNO: both for **position and time reconstruction**, but also for **particle identification** through the **Pulse Shape Discrimination**.
The measurements are performed exploiting the **Time Correlated Single Photon-Counting Technique [2].**



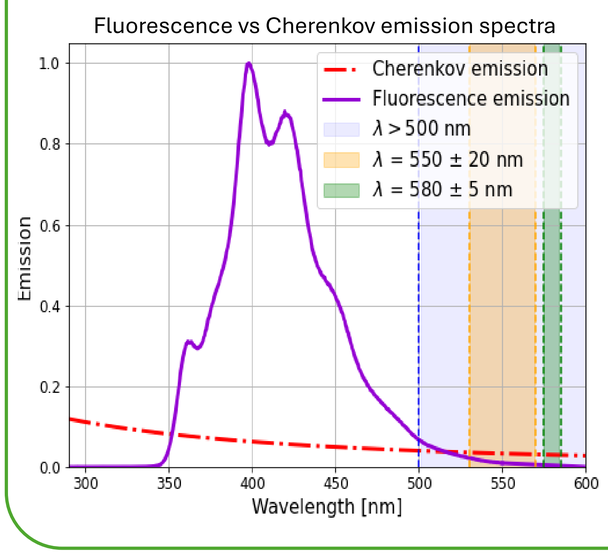


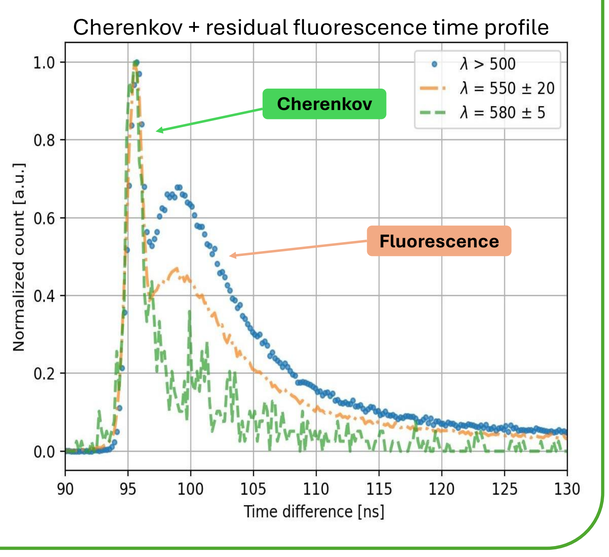
Cherenkov Contribution



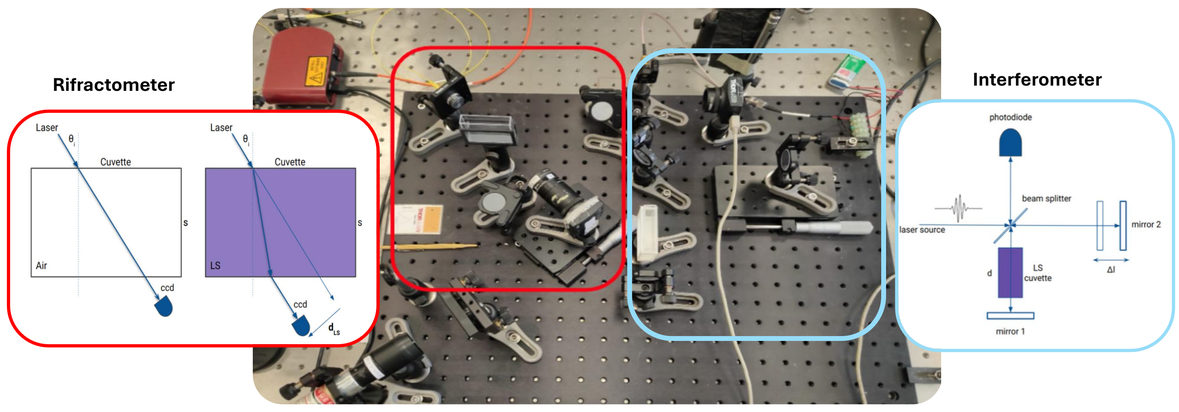


Cherenkov radiation is a **second order light emission** in liquid scintillator. It has the peculiarity of **preserving the information on the direction** of the particle that produced it. It can also **impact the energy reconstruction** due to its absorption in the UV-region and re-emission as fluorescence. It is important to know the **Cherenkov to scintillation ratio [2]**.

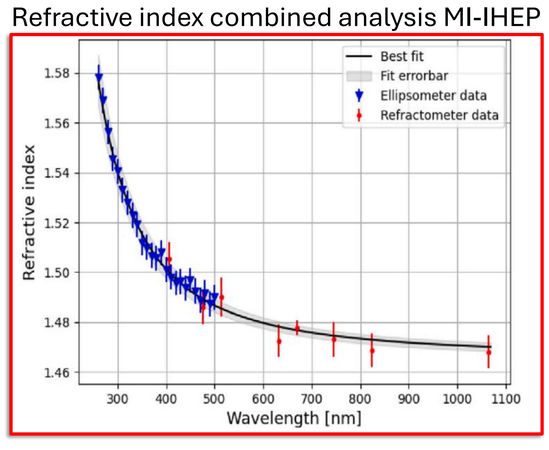




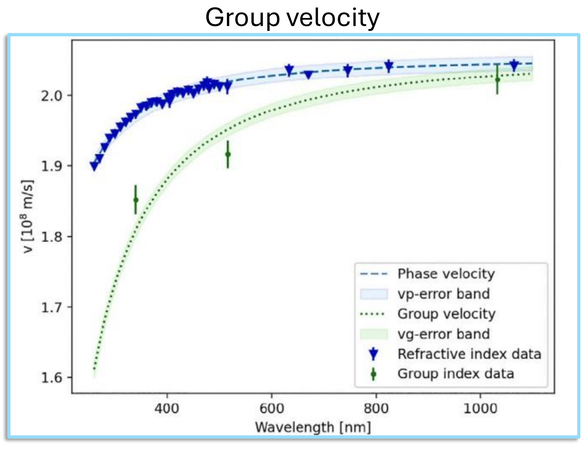
Refractive Index and Group Velocity



Refractive index combined analysis MI-IHEP



Group velocity



Ellipsometer measurements made by the Institute of High Energy Physics (Beijing) **[3]**

References

[1] C. Landini et al., Distillation and gas stripping purification plants for the JUNO liquid scintillator, Nucl. Instrum. Meth. A 1069 (2024) 169887 [arXiv:2406.01381].

[2] M.Beretta et al., Fluorescence emission of the JUNO liquid scintillator, Journal of Instrumentation 20 (2025) P05009 [arXiv:2501.09988].

[3] H.S. Zhang et al., Refractive index in the JUNO liquid scintillator, Nucl. Instrum. Meth. A 1068 (2024) 169730 [arXiv:2405.19879].

Future Plans

The SHELDON project has been funded for new upgrades.
A possible upgrade includes a distillation section to purify the liquid scintillator samples, and a new apparatus dedicated to the Light Yield study.
The project will be devoted to the optical characterization of new innovative liquid scintillators.