Improved measurements of timing and optical properties of the JUNO liquid scintillator with SHELDON

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on behalf of the SHELDON research team

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ICHEP 2022 BOLOGNA

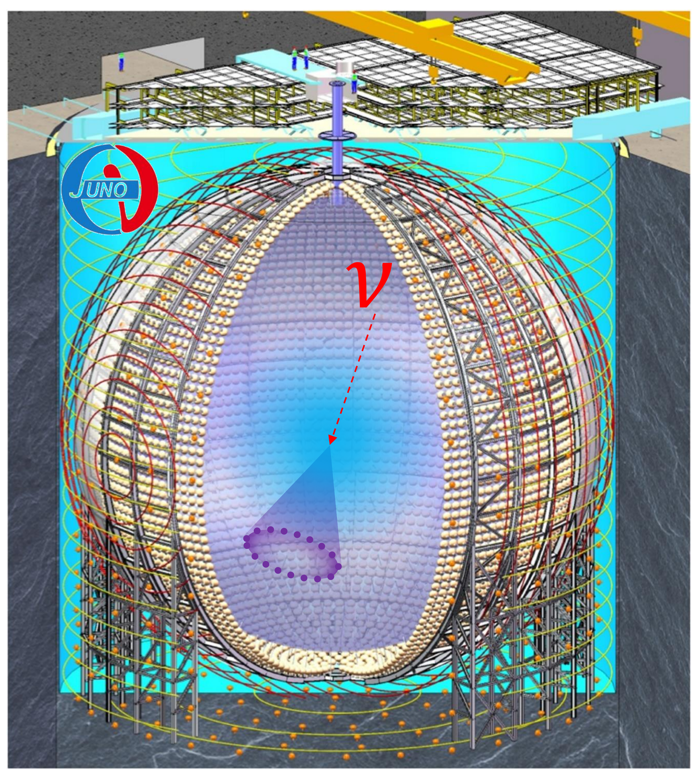
Introduction

JUNO (**J**iangmen **U**nderground **N**eutrino **O**bservatory) is a multipurpose liquid scintillator detector [1, 2]

Site: Kaiping laboratory (China), 700 m underground, 53 km distant from two nuclear power plants

Physics goals: Neutrino Mass Ordering, solar neutrinos, supernova neutrinos, geoneutrinos, atmospheric neutrinos, proton decay

Detector: 20 kton of organic liquid scintillator (LAB + 2.5 g/L PPO + 3 mg/L bisMSB) in acrylic vessel, more than 40000 PMTs. High light yield, transparency and radiopurity.



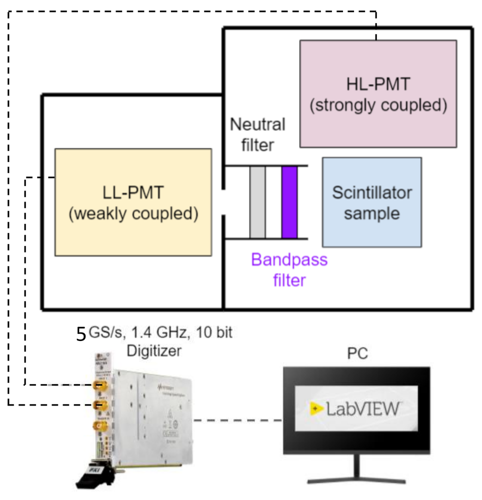
Scintillation light is isotropic and does not provide any information on direction. A few **Cherenkov** light is emitted, potentially providing information on the **neutrino direction**. Cherenkov light also introduces nonlinearities in the **energy response** and affects the **energy resolution** of the detector.

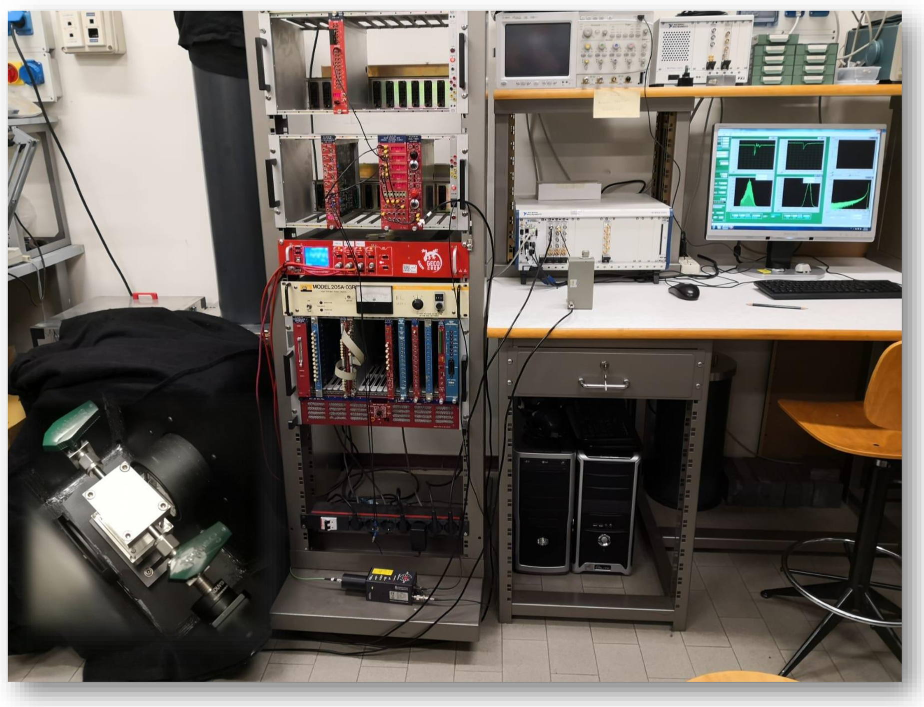
SHELDON (**S**eparation of **CHE**renkov **L**ight for **D**irectionality **O**f **N**eutrinos) is a small-scale setup to study the scintillator mixture that is going to be used in JUNO.

SHELDON has 2 **goals:**
measurement of **fluorescence** parameters (as in ref. [3])
measurement of **Cherenkov** light yield (as in ref [4])

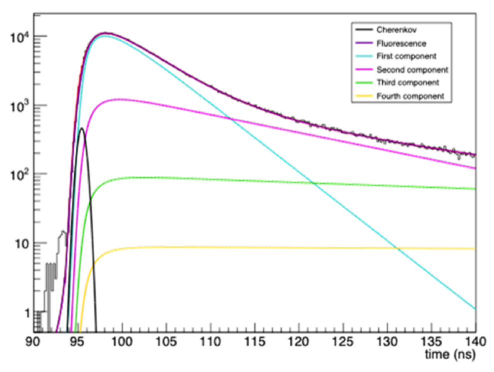
Setup

- scintillator cuvette provided with pipes for N2 bubbling
- 2 PMTs (strongly and weakly coupled to the scintillator)
- Time-Correlated Single Photon Counting technique [5]
- optical filters (neutral+"colored")
- 1600 ns long acquisition window
- sampling rate of 5 GS/s each ch.
- software CFD (to reduce jitter)
- LabVIEW DAQ software





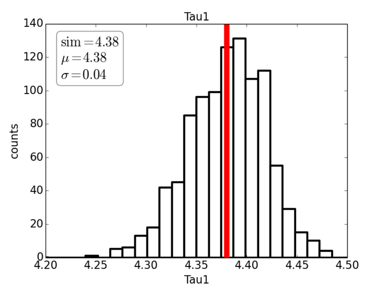
Method



The likelyhood fit includes:
- 4 exp. contributions (rise+decay)
- Cherenkov contribution
- Impulse Response Function

$$F_{tot}(t) = N\left(f_{Ch}\,\delta(t-t_0) + (1-f_{Ch})\sum_{d=1}^{4}\frac{q_d}{\tau_d-\tau_r}\left(e^{-t/\tau_d}-e^{-t/\tau_r}\right)\right) * \mathrm{IRF}(t)$$

MC study to assess the uncertainty related to the fitting procedure and validate the analysis method.

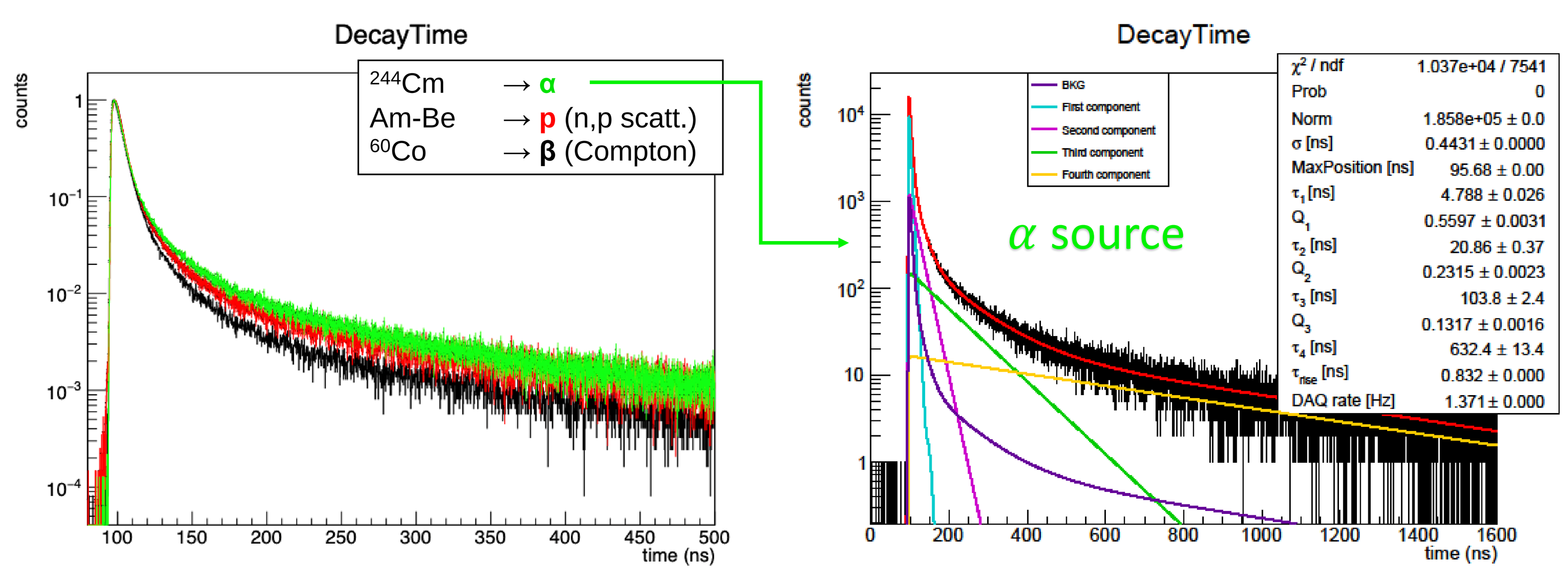


The features of the setup and the analysis method make SHELDON sensitive to slow scintillation components and to the contribution of Cherenkov light

Measurements

Fluorescence parameters

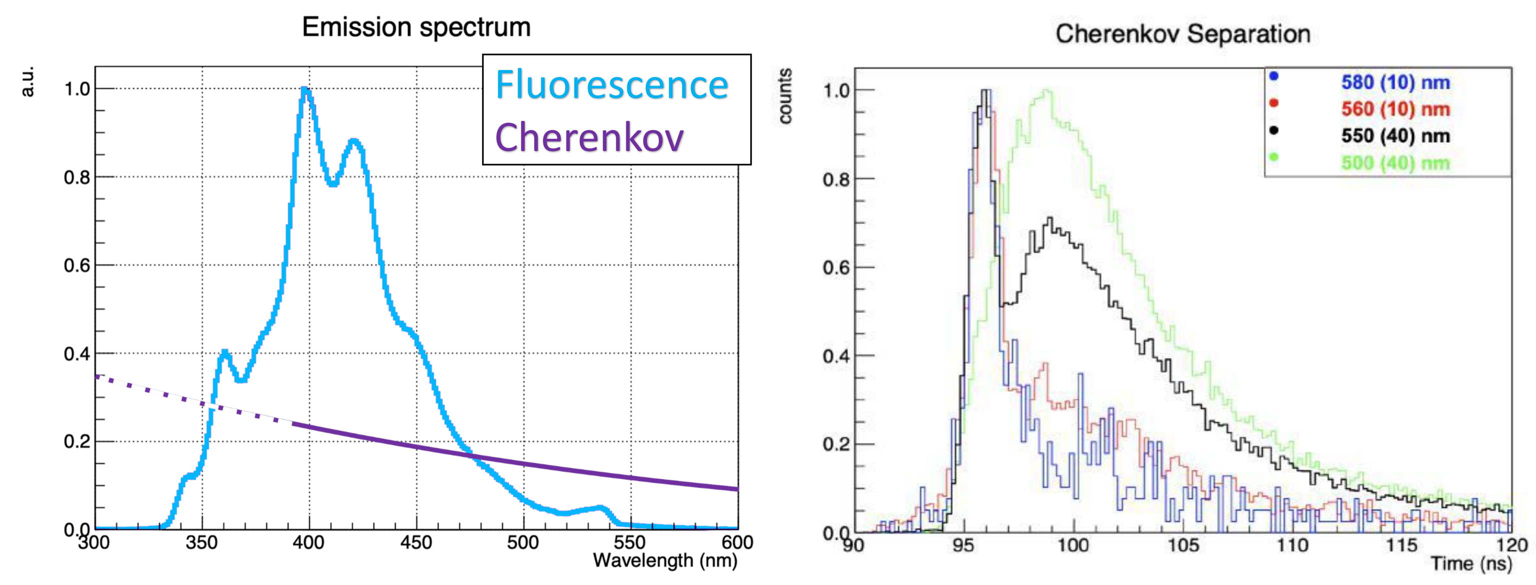
We measured the time distribution of emitted light with α/β/p sources. The fit includes a background contribution due to muons and the Cherenkov contribution (when present).



These measurements will improve **Pulse Shape Discrimination** (PSD), which is fundamental to reject the background in JUNO.

Separation of Cherenkov light

We measured the scintillator emission spectrum and the time distribution of emitted light at different wavelengths to study the timing features of Cherenkov and scintillation light



These measurement will improve the understanding of the **energy response** and will refine **reconstruction performances**

Next steps

- include the measured scintillation parameters in the official JUNO MC code (SNIPER)
- measure the refractive index of the LS in the UV spectrum to better model Cherenkov emission
- measure the group velocity of UV light in the LS to improve position reconstruction further

JUNO overview talks @ ICHEP

JUNO's physics prospects
Jie Cheng, 8 Jul 2022, 15:15

The JUNO detector: design concept and status
Alessandra Carlotta Re, 8 Jul 2022, 15:30

References

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[2] *Progress in Particle and Nuclear Physics*, **2022**, *123*, 103927
[3] Lombardi, P. *et al* 2012 *Nuclear Instruments and Methods in Physics Research A* 701 (2013) 133–144134
[4] T. Kaptanoglu *et al* 2019 *JINST* 14 T05001
[5] L. M. Bollinger and G. E. Thomas *Review of Scientific Instruments* 32, 1044-1050 (1961)