# Water Cherenkov Detectors in Precision Agriculture: A Novel Approach for High-Resolution Soil Moisture Monitoring

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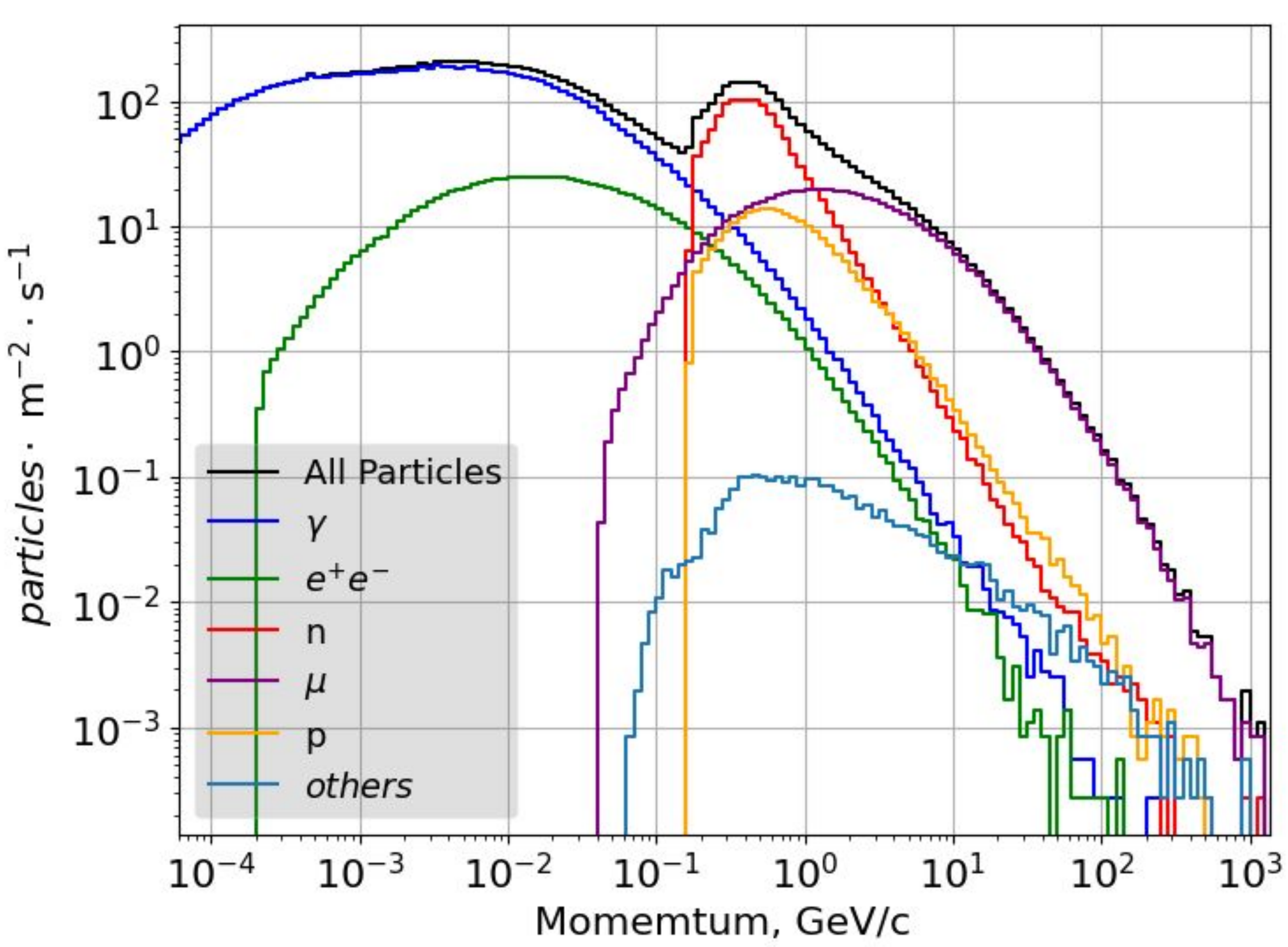
## Abstract

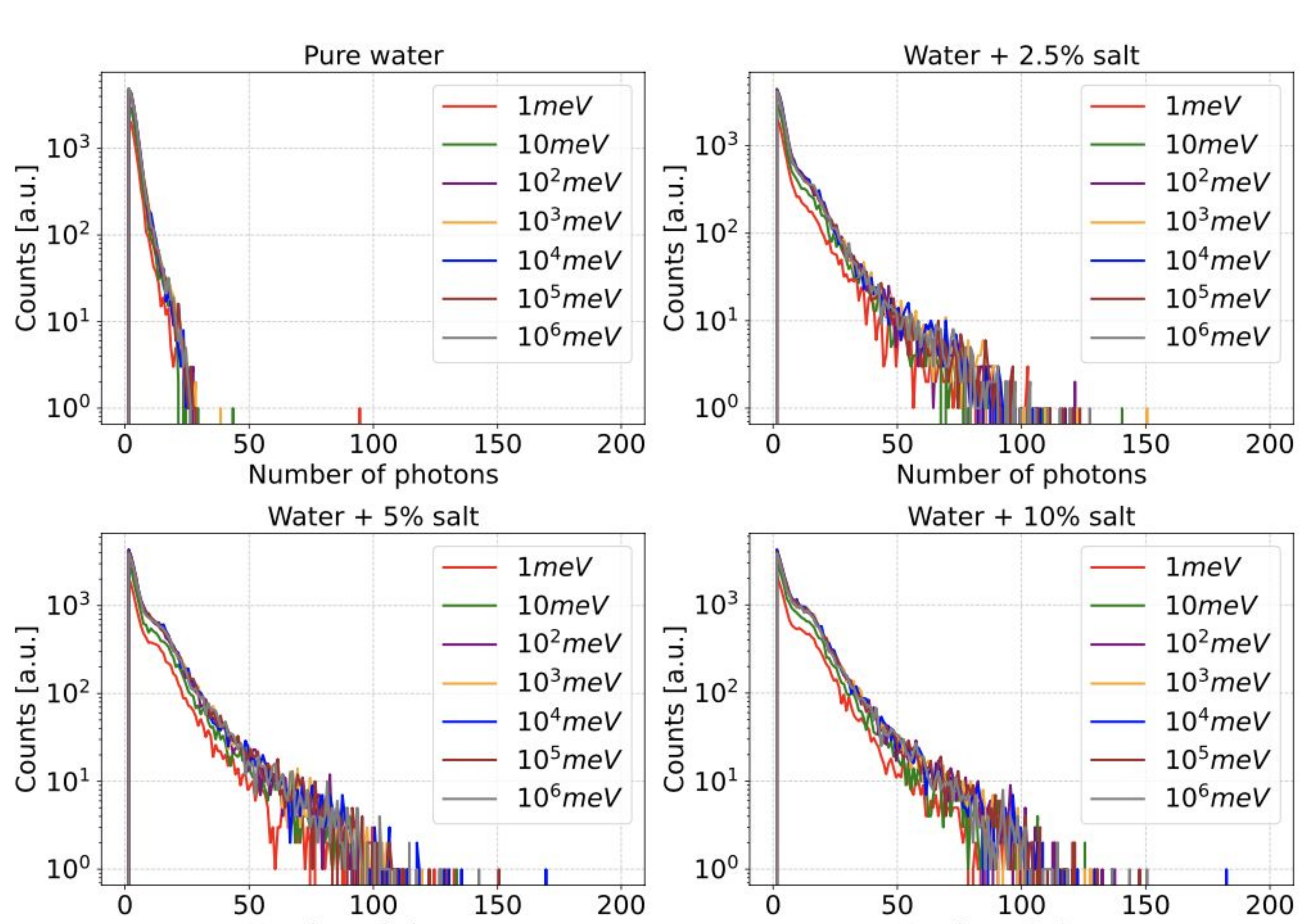
This work analyzes the capability of a water Cherenkov detector (WCD) to detect thermal neutrons. The response of a salt-doped WCD is presented for both monochromatic thermal neutrons and natural thermal neutron flux emitted from dry soil at the altitude of Bucaramanga (Colombia). To achieve this, the ARTI framework is used to estimate the expected neutron flux at that altitude, while MEIGA is employed to simulate the Cherenkov detector response in Geant4. The results are highly relevant for practical applications, demonstrating that Cherenkov detectors could be integrated into precision agriculture systems. Moreover, it is shown that their cosmic ray detection range can be extended through the use of nontoxic and low-cost materials.

## Atmospheric Neutron simulations




The momentum spectra of secondary particles at ground level in Bariloche, Argentina, simulated using the ARTI framework. A cutoff at approximately 200 MeV/c is observed in the neutron spectrum, corresponding to the low-energy threshold of the simulation.

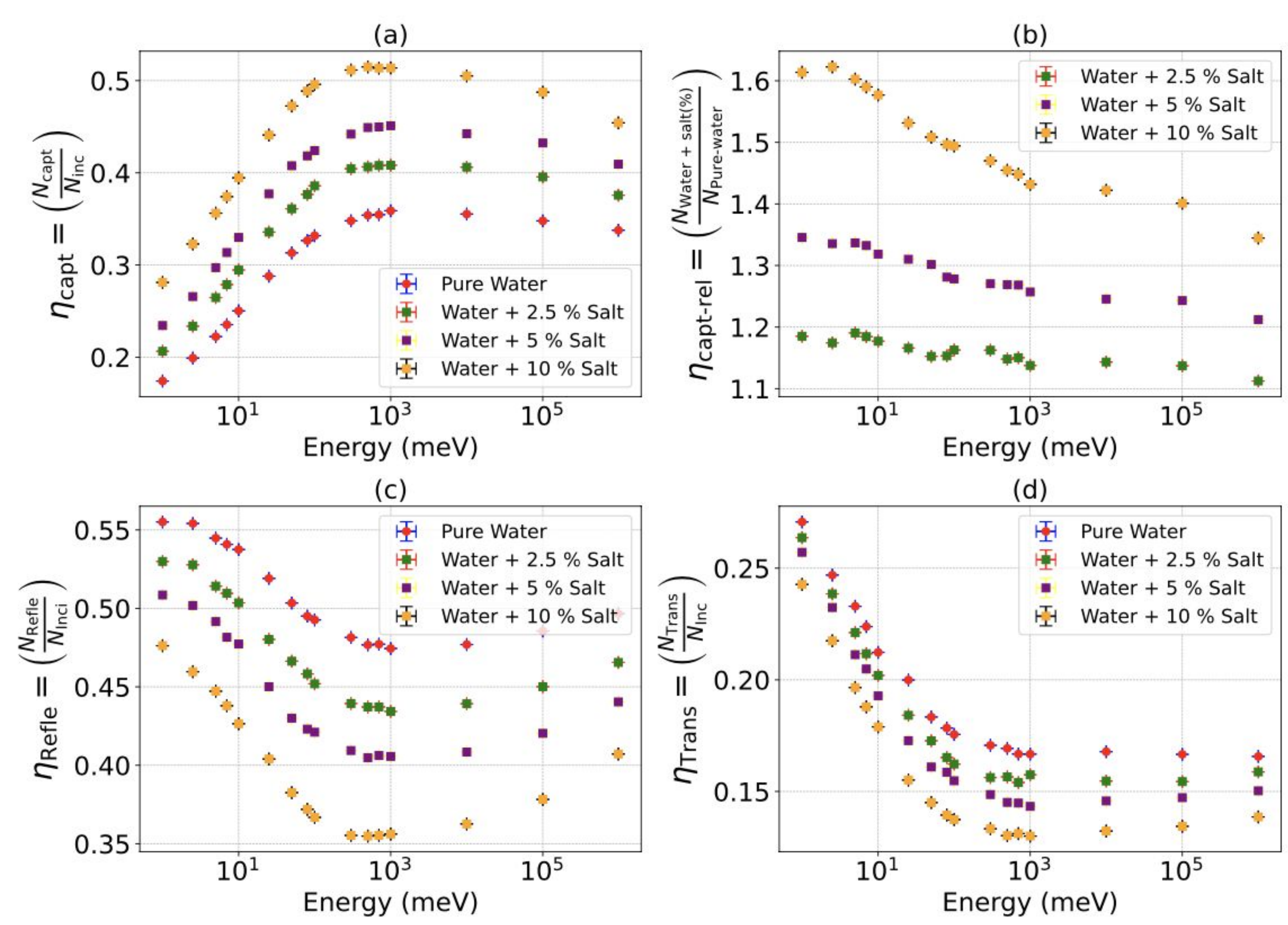
## Enhanced Water Cherenkov Detector simulations




The simulation was structured in three main steps.

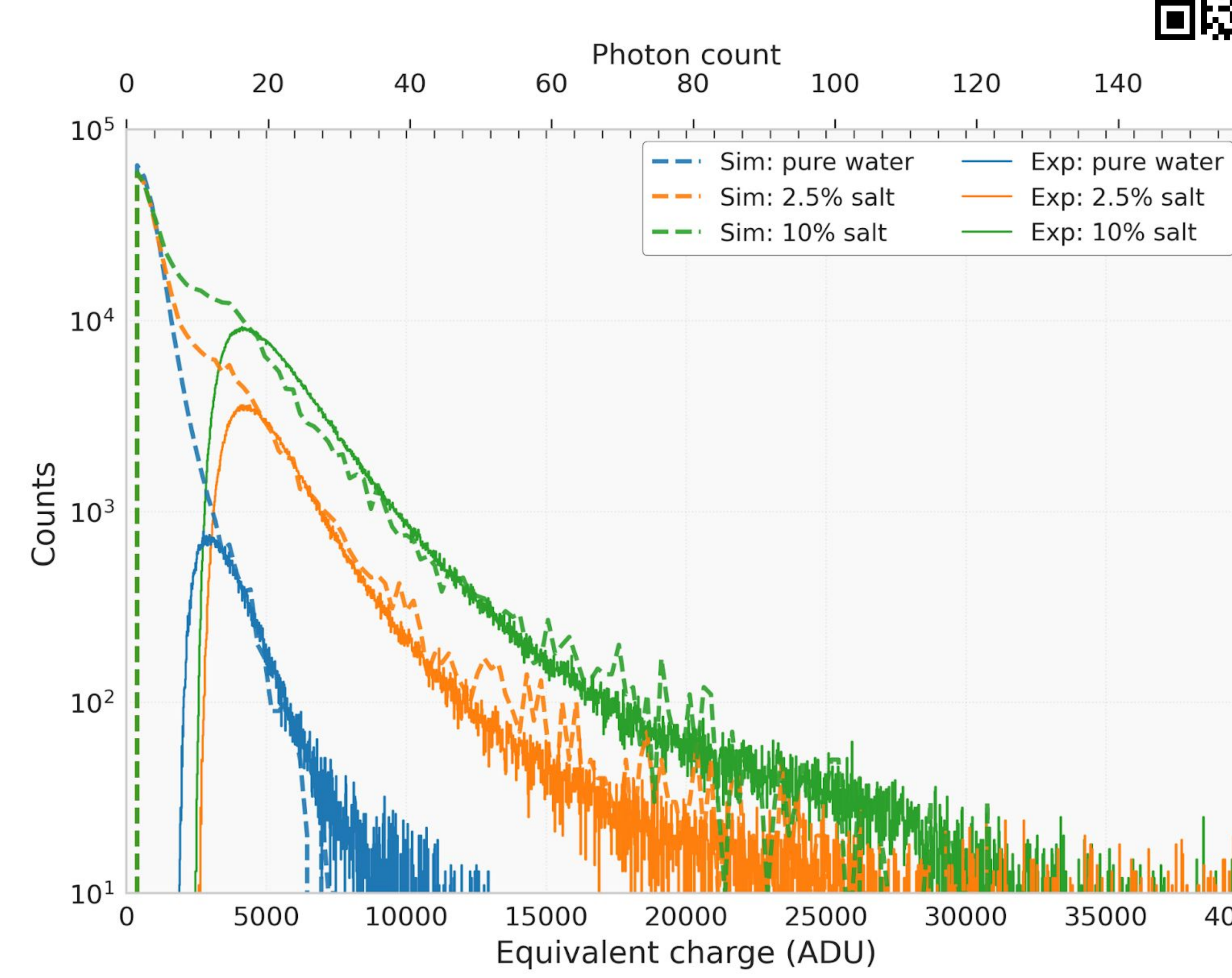
- First, we validated the MEIGA implementation by reproducing published results, ensuring consistency in geometry, materials, and neutron physics.
- Second, we evaluated the detector's sensitivity to thermal neutrons by injecting isotropic beams from 1 meV to 1 keV and recording photon yields. This allowed us to compare the energy-dependent efficiency for pure water and salt-doped configurations.
- Finally, we simulated continuous exposure to a realistic cosmic neutron flux over 12 hours, quantifying the impact of NaCl doping on detection rates.

## Evaluation for thermal regime




Detector response to 100000 monochromatic neutrons incident vertically on the tank in an energy range from 1 meV to 1 keV. Four detector volume configurations are compared: pure water (red), water with 2.5 \% salt (green), water with 5 \% salt (purple) and water with 10 \% salt (orange). Figure (a) shows the fraction of neutrons captured in the detector volume. Figure (b) represents the relative capture in salt media with respect to pure water. Figure (c) shows the fraction of reflected neutrons, and figure (d) corresponds to the fraction of neutrons transmitted through the detector volume.

## Results




Comparison between the experimental spectrum obtained using a $^{241}$AmBe source shielded with lead and the simulated Cherenkov photon spectra produced by prompt gamma rays from neutron captures in each medium, as they interact with atomic electrons. The experimental spectra exhibit an artificial low-energy cutoff due to the trigger threshold applied during data acquisition.