Calibration of the JUNO pre-detector OSIRIS

Tobias Sterr[1] and Rosmarie Wirth[2]
on behalf of the JUNO collaboration
[1] Eberhard Karls Universität Tübingen
[2] Universität Hamburg

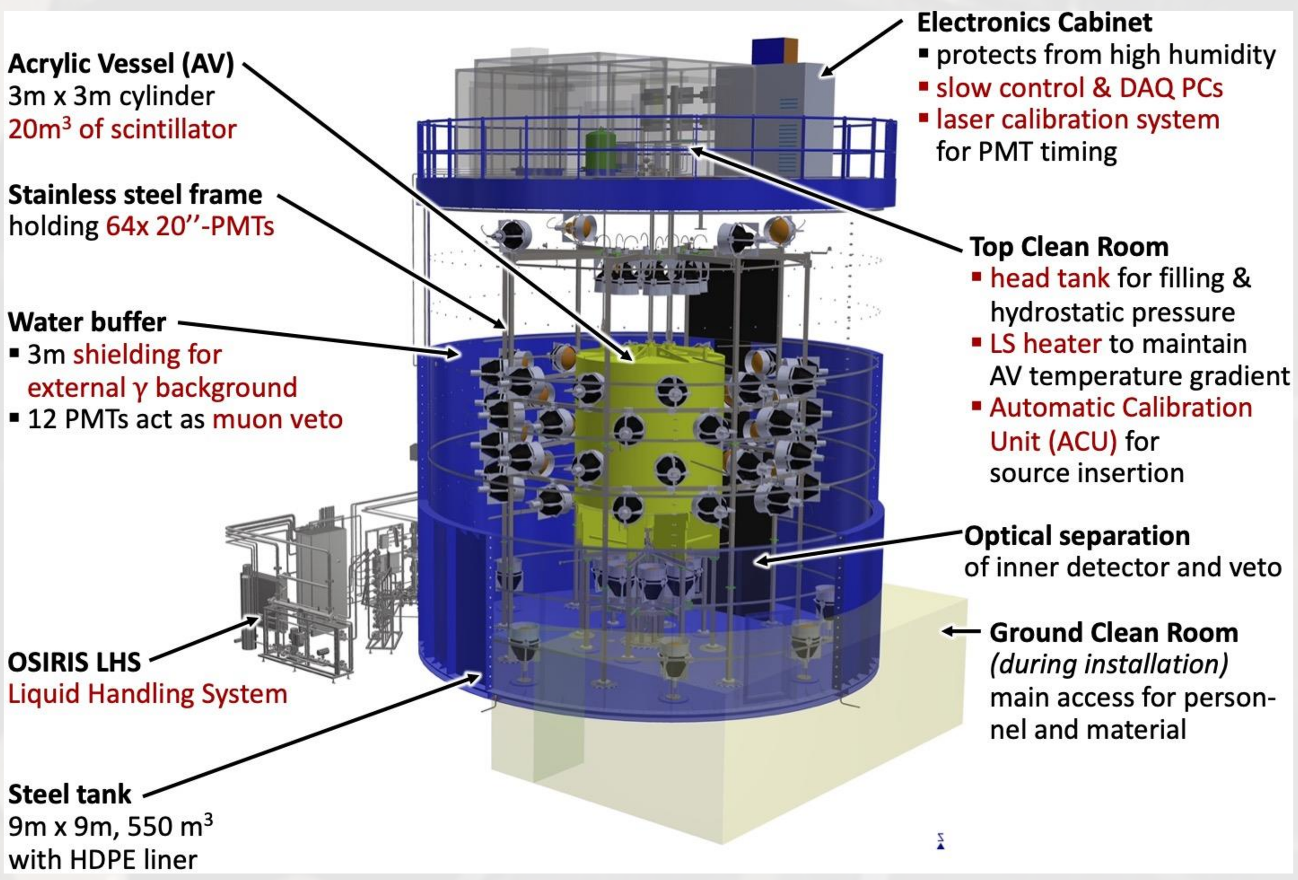
Funded by
DFG Deutsche Forschungsgemeinschaft
German Research Foundation

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

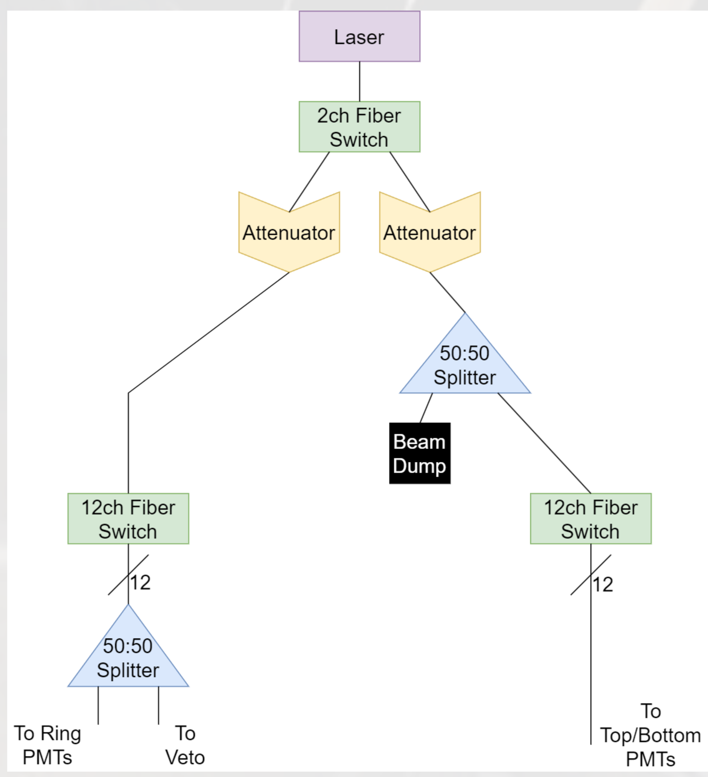
General

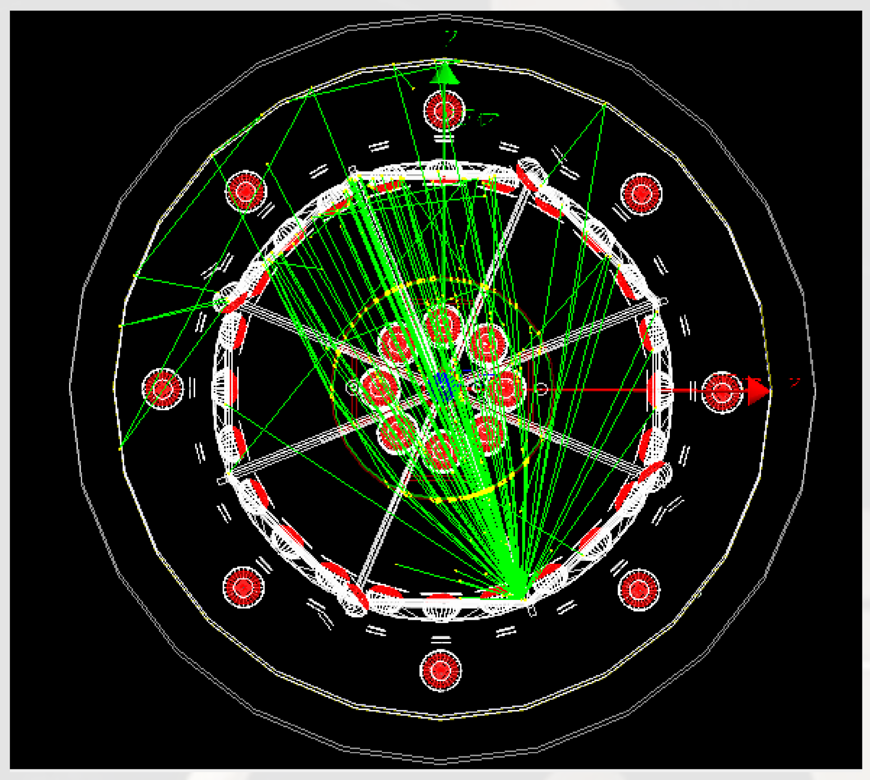
OSIRIS, the Online Scintillator Internal Radiation Investigation System, is a pre-detector of the Jiangmen Underground Neutrino Observatory (JUNO) which is responsible for the radio purity assessment of the liquid scintillator (LS) filled into the main detector of JUNO. The 3m x 3m cylindrical, central acrylic vessel is surrounded by 64 JUNO LPMTs and can hold approximately 18t of LS. This vessel is embedded into a 9m x 9m steel tank which is filled with ultra pure water and equipped with twelve additional PMTs to serve as a water muon Cherenkov veto.
OSIRIS features a batch and a continuous mode, providing the opportunity for extensive measurements of a sample and of continuing LS screening, respectively. OSIRIS main goal is the monitoring of the purity of the LS filled into JUNO and will reach a sensitivity to the Uranium and Thorium chain of 10^{-15} g/g of LS which crucial to reach JUNOs desired resolution of 3% at 1MeV[1] .



Laser Calibration System (LCS)

To provide the charge and timing calibration to OSIRIS, the LCS was developed. It features 24 diffused light injection points distributed in both central volume and veto of OSIRIS. The light distribution system of the LCS starts with the pico-second laser (σ≈80ps) and contains additional beam switches and splitters as well as additional attenuators to compensate for differences in the light intensity (see bottom left).
To guarantee an ideal distribution of the light injection points in the detector volume, a dedicated branch of the OSIRIS simulation was used to define the best spots of the diffusers (see bottom right).

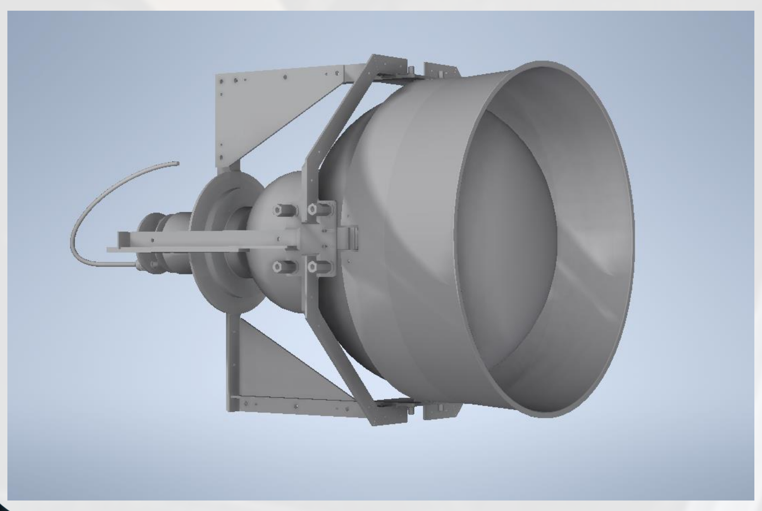




Left: Opto-mechanic cascade of the LCS
Right: Geant4 simulation of a beam of a diffuser mounted on the PMT ring. A lensing effect of round, LS filled vessel can be seen, which is one of the main causes of the comparably high number of diffusers used in the detector.

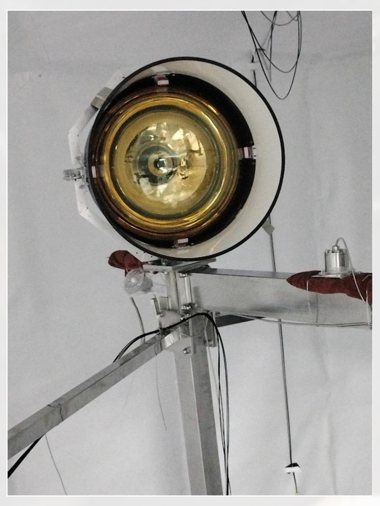
The PMTs of OSIRIS

The photo multiplier tubes (PMTs) of OSIRIS are identical to the micro channel plate (MCP) PMTs of JUNO. Each PMT is mounted into a holder which also includes an electro magnetic shielding (see below). Every three PMTs are connected to one general control unit (GCU) which is then fed out of the detector and connected to a back-end card (BEC). During standard Operation, the system uses a multiplicity trigger with an option to be triggered externally in the case of a calibration run[2].



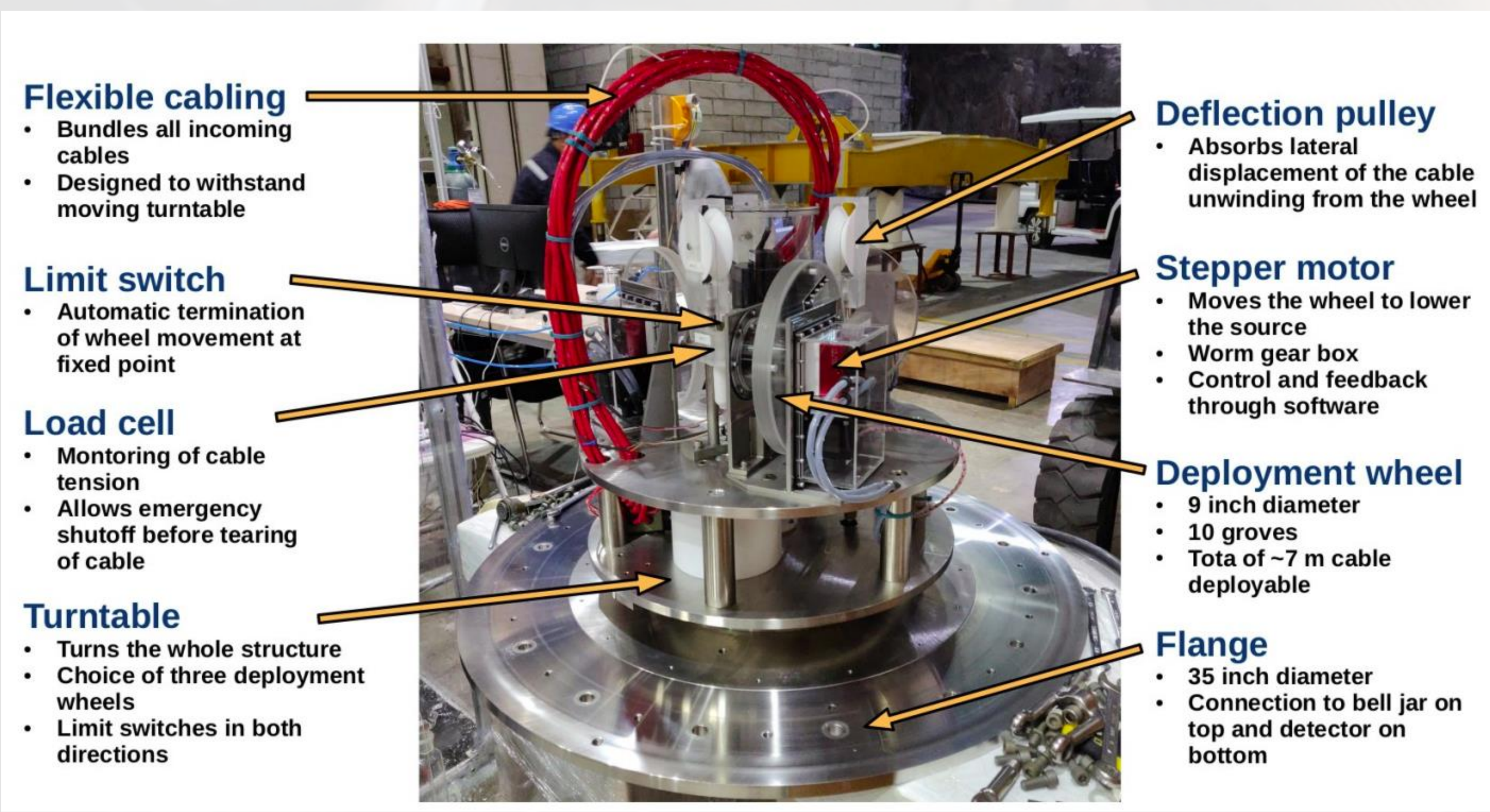
Left: Render of the complete LPMT assembly as used in OSIRIS

Right: Installed veto PMT of OSIRIS



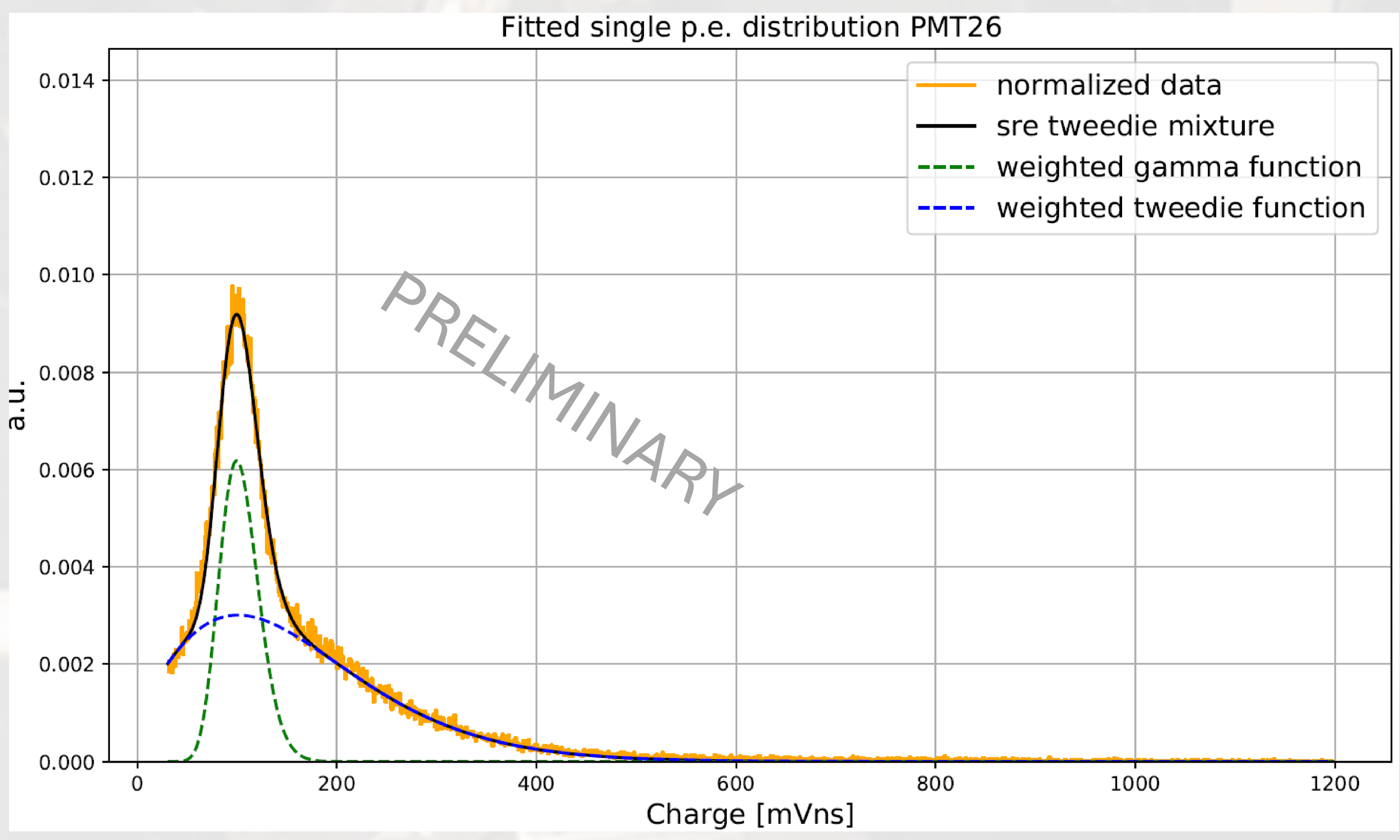
Automated Calibration Unit (ACU)

The ACU is one of the two calibration systems of OSIRIS and responsible for energy- and vertex calibration. It features three different sources: A high activity source (≈10kBq) consisting of ^{137}Cs, ^{60}Co and ^{56}Zn, a low activity potassium source and a pulsed LED (redundancy to the laser system, see top left box). The device is controlled via LabVIEW and completely integrated into the slow control of OSIRIS, which allows it to be fully integrated into the automated calibration schemes of the OSIRIS run control. A description of the system can be found in the picture below[1].



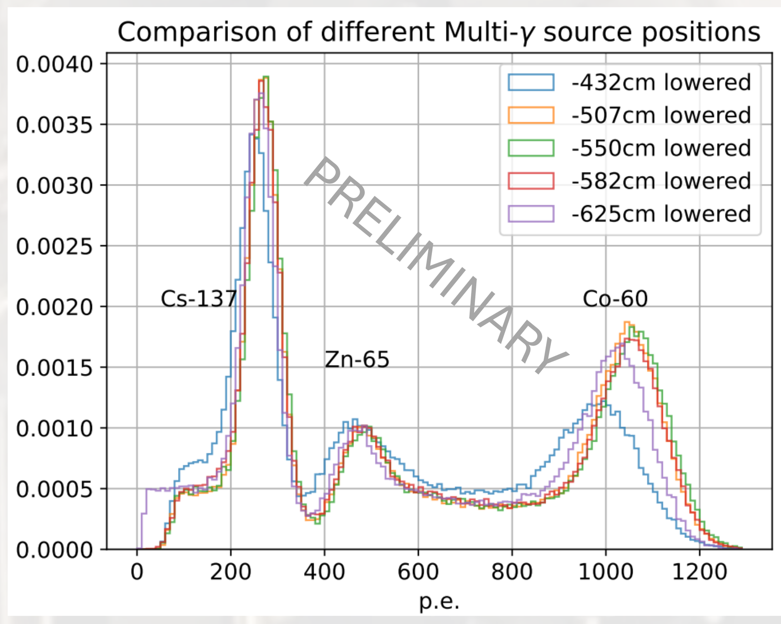
Preliminary Calibration Results

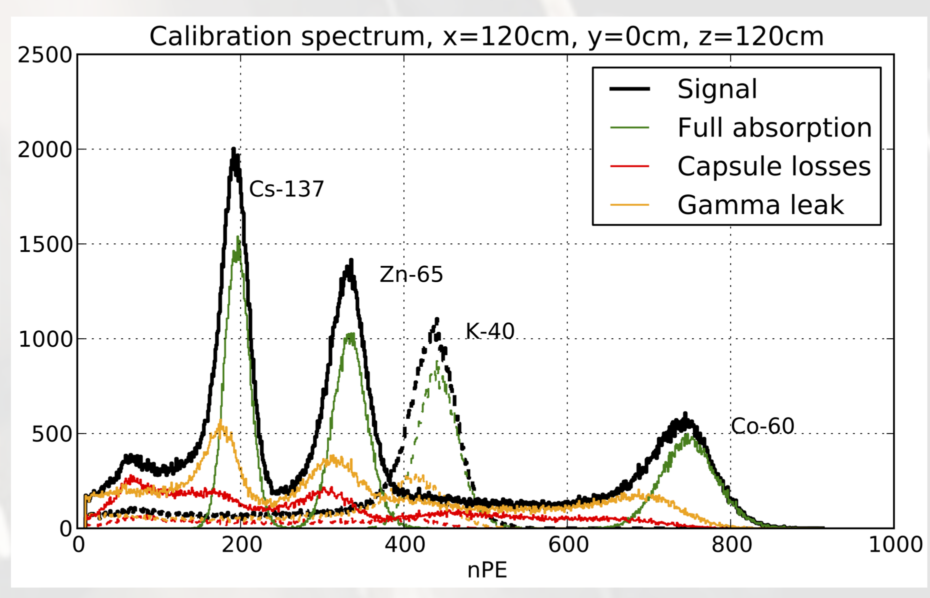
Due to the novel MCP used in JUNO, charge calibrating of the detector is less straight forward than in the case of a standard dynode PMT. OSIRIS doesn't use a simple Gaussian to model the single p.e. response, but a sum of a weighted tweedie and a weighted gamma function (see plot below). Using data taken by the LCS, this method is currently used to define and adjust the final charge calibration algorithm for OSIRIS.



Exemplary fit of the single p.e. peak of a MCP PMT using the OSIRIS fitting model of a sum of weighted gamma and weighted tweedie function.

During the building phase of OSIRIS, several calibration measurements have been performed. These measurements include LCS measurements in air and nitrogen as well as ACU source measurements in water and LS after the completion of the detector. As an example for the later, a spectrum of the energy of the high activity source at different heights has been produced (left) and compared to the expected, simulated result (right) using the charge definition and fit from above, where PMT gain is defined by the weighted tweedie function and a simulation not including the PMT response:





Left: Measured energy spectrum of the high activity source at different heights. Y-scale is a.u., x-scale photo electrons. Color is the depth of the source relative to the ACU with -550cm being the center of the acrylic vessel.
Right: Same, simulated spectrum also including the low activity potassium source. Differences in peaks heights are due to half lives of the respective isotope.

[1]: Abusleme, A., Adam, T., Ahmad, S. et. al. „The design and sensitivity of JUNO's scintilator radiopurity pre-detector OSIRIS", *Eur.Phys.J.C* **81**, 973 (2021)
[2]: Abusleme, A., Adam, T., Ahmad, S. et. al. „Mass testing and characterization of 20-inch PMTs for JUNO", *Eur.Phys.J.C* **82**, 1168 (2022)