SIREN PMT Angular Response with WCTE Cosmic data

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PMT Angular response in WCTE

The quantity of interest: how PMT light collection varies with photon incidence angle

– Expressed per mPMT group, as a function of cos(theta) w.r.t. the PMT nominal directions

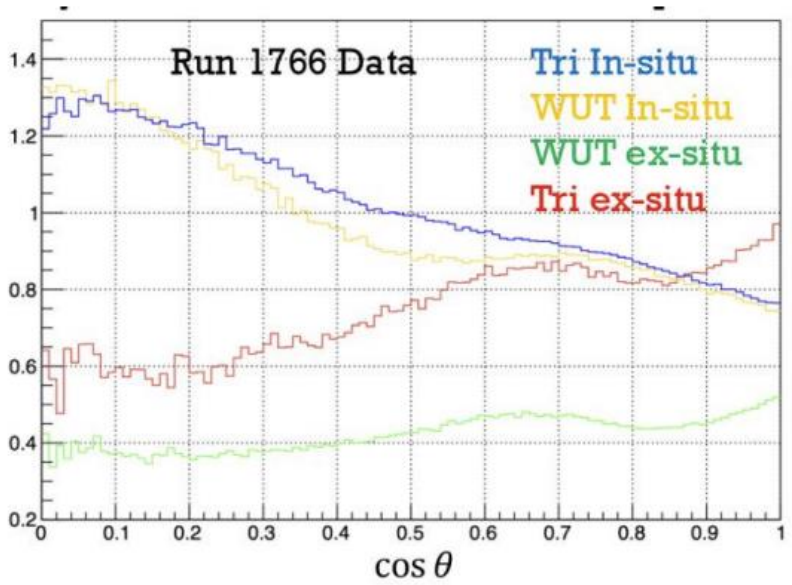
What is has been done with fiTQun in CosmicAnalysis/FitAngularResponse.c

– Uses cosmic muons; for each PMT inside the 42 deg Cherenkov cone it solves where on the track the photon was emitted

– Selects hits with time residual in +/- 2 ns; rejects events with >0.8% of charge at t_res < -2 ns; requires photon path > 100 cm

–2D histograms of charge*distance vs. costh are used to extract the angular response per mPMT (type).

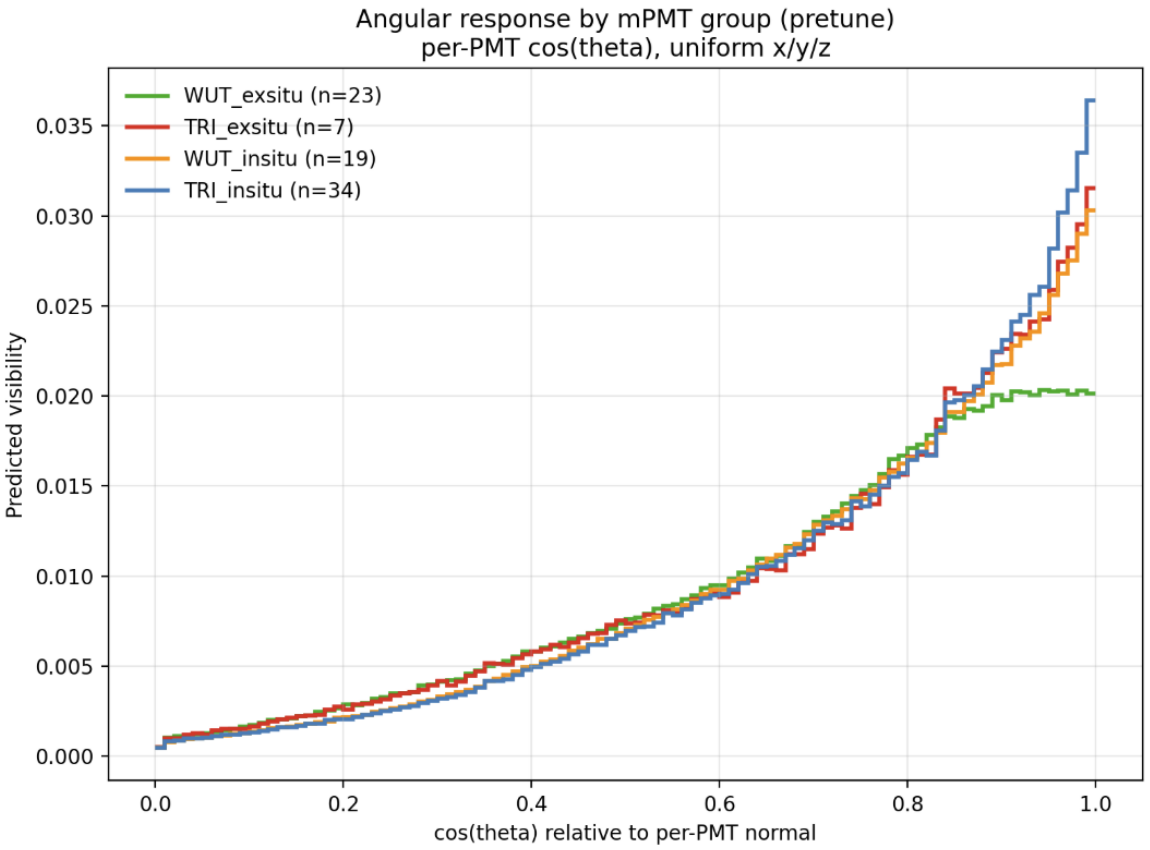
– Efficiency = data / nominal MC, bin by bin.



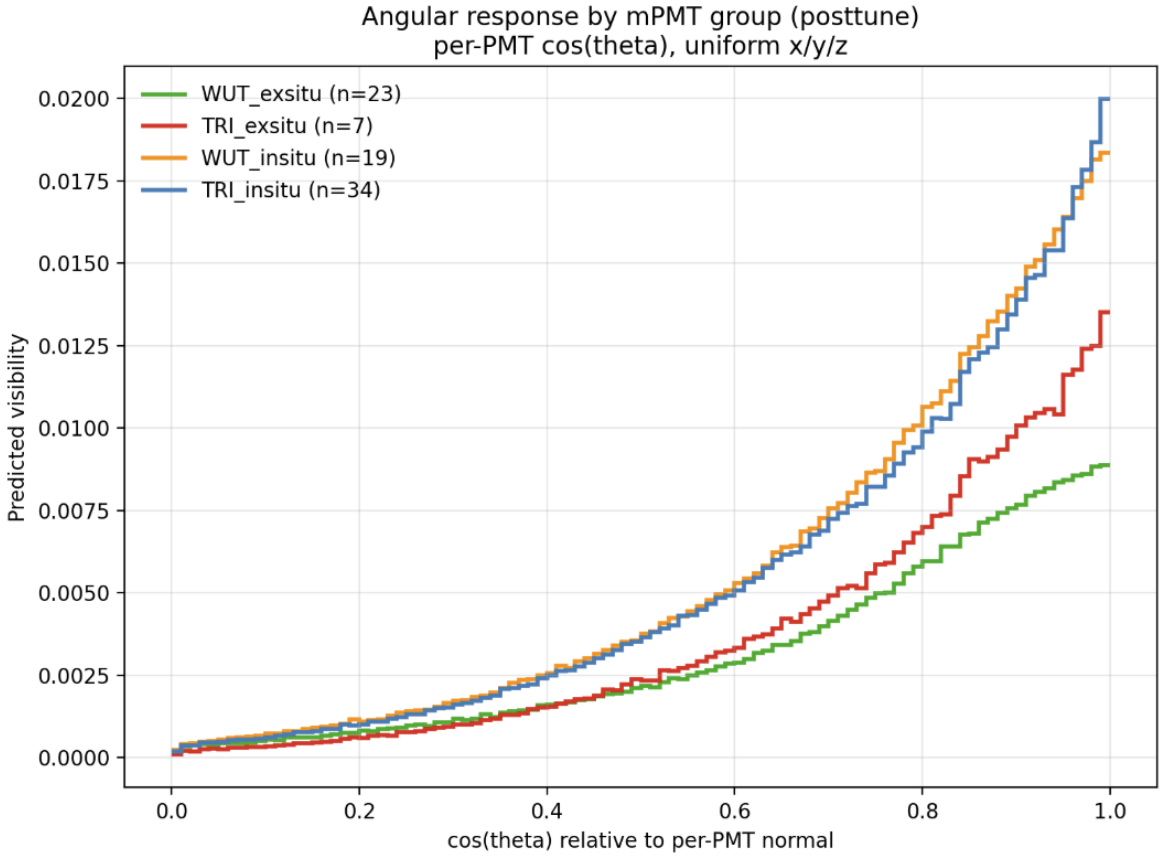
How the angular response is computed in SIREN

1. **Sample the tank**
   - 2,955 source points on a uniform grid (17x, 17y, 15z), r < 1500 mm, |z| < 1300 mm
2. **Evaluate the model**
   - For each (source, mPMT) pair the photon direction is aimed from the source at that module; OpticSiren returns predicted charge for all 1843 PMTs at once
   - Compute the visibility (fraction of emitted photons that PMT detects)
3. **Assign an incidence angle**
   - cos(theta) between the PMT nominal direction and the PMT->source direction;
4. **Bin and average**
   - 100 uniform cos(theta) bins on [0,1]; equal-width bins carry equal solid angle since dOmega = -d(cos theta) dphi. Mean visibility per bin for each mPMT, then mean over mPMTs in each group
5. **Match the ROOT selection**
   - Minimum distance 1000 mm, the same cut as FitAngularResponse.c
   - Bad channels: In per-PMT mode they are masked individually, exactly as the ROOT macro does, so a mPMT module survives with its remaining good PMTs
6. **Take the ratio**
   - posttune / pretune, bin by bin

Per-PMT angular response

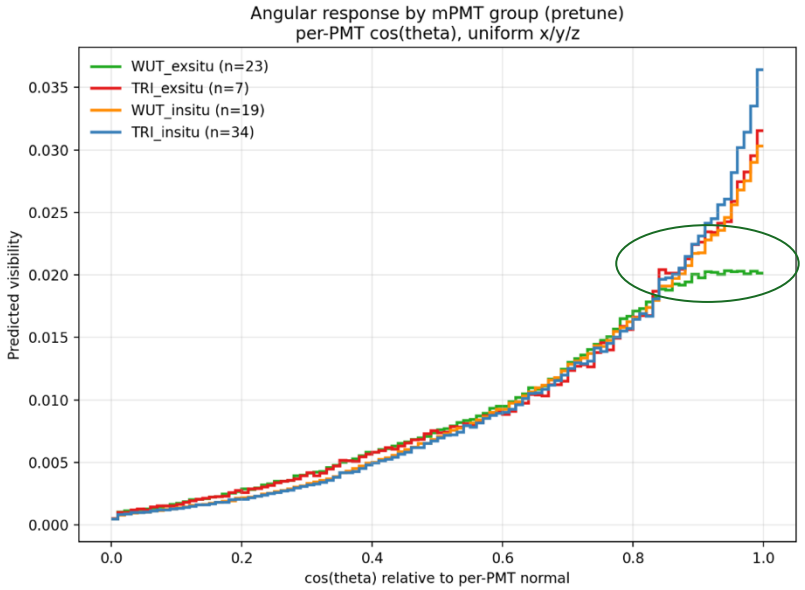


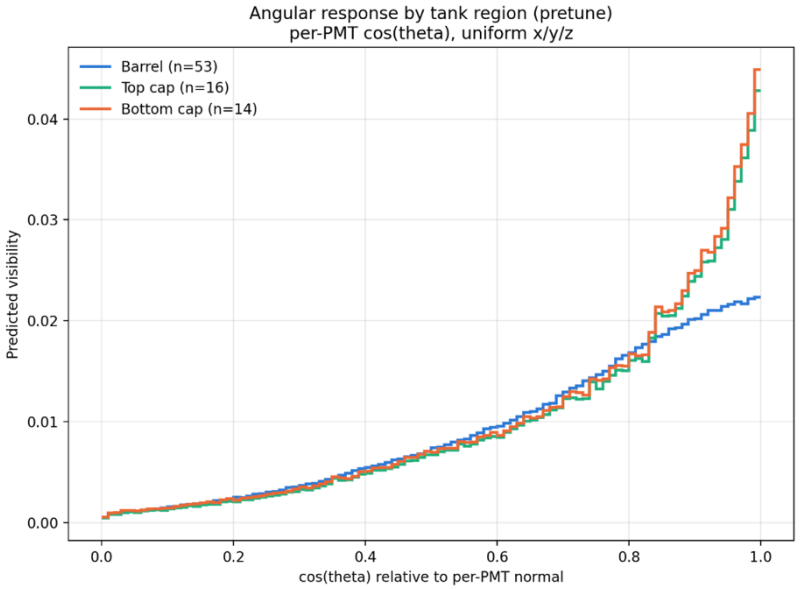
pretune

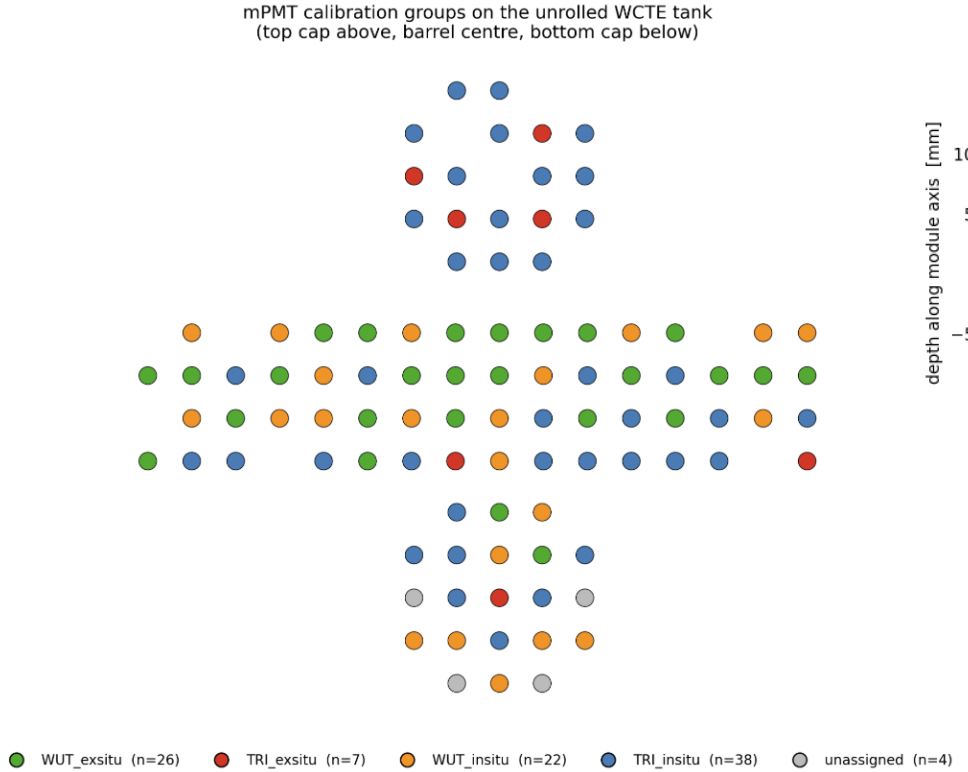


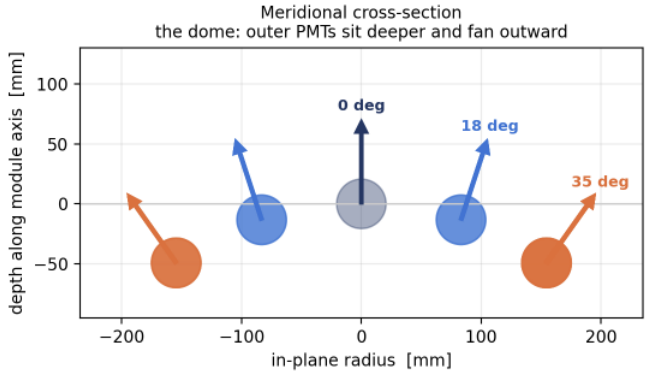
posttune

The pre-tune WUT_exsitu differs with others





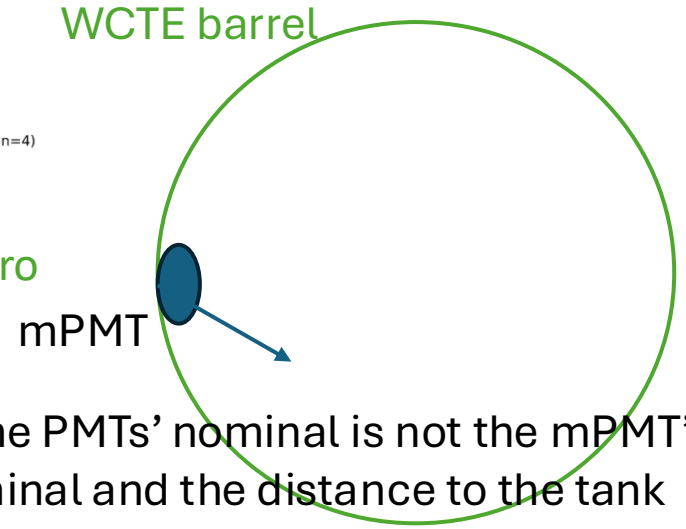




mPMT layout

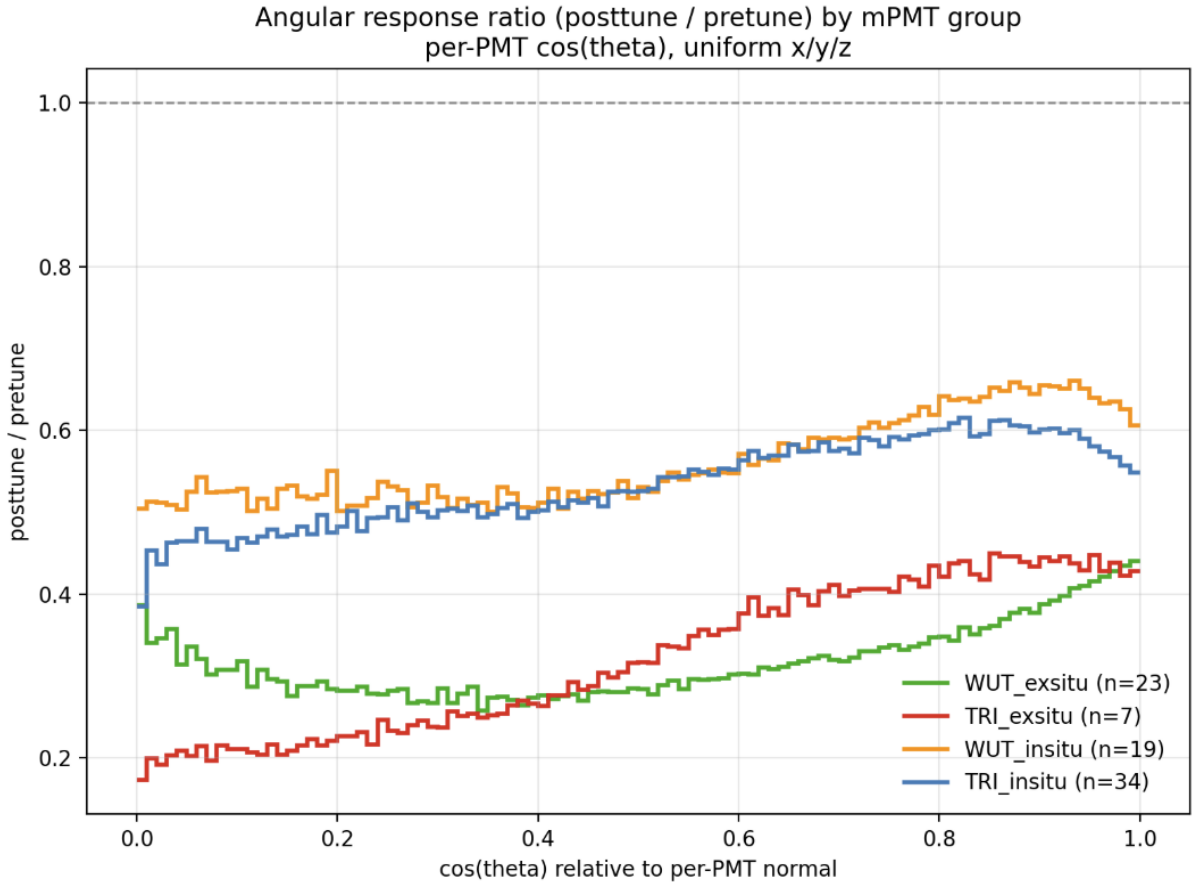
WUT_exsitu sits lowest because it has almost no cap modules (24 of 26 barrel, zero top cap) to lift its average.

Maybe due to the curvature of the tank barrel?

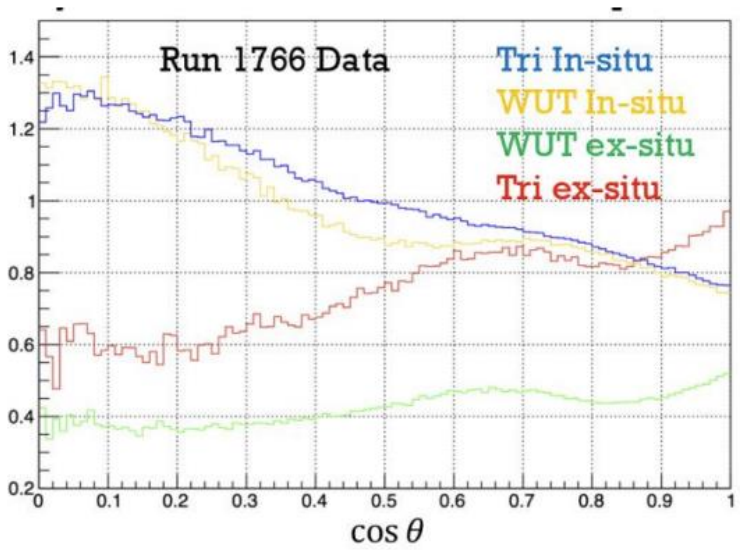


Some PMTs' nominal is not the mPMT's nominal and the distance to the tank edge is shorter than the diameter

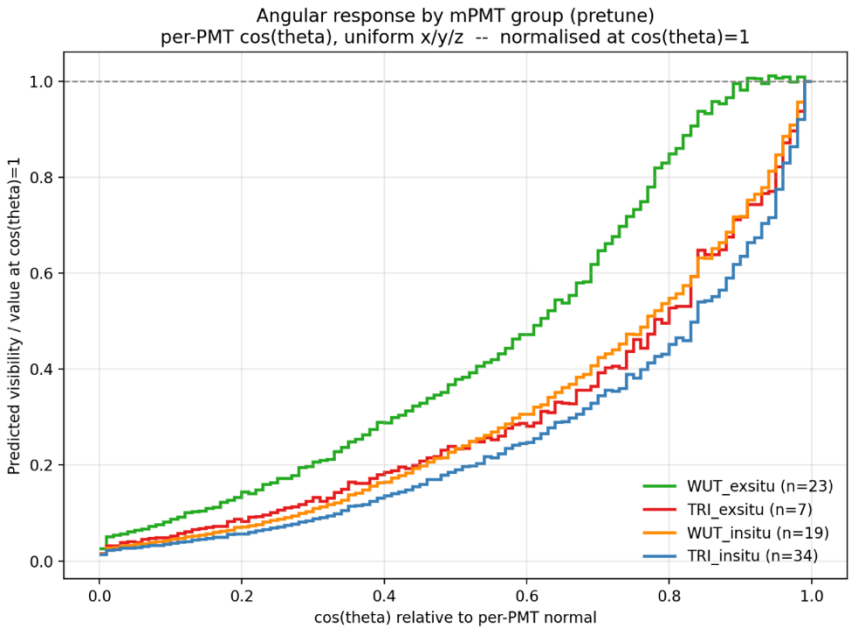
Angular response ratio: posttune / pretune

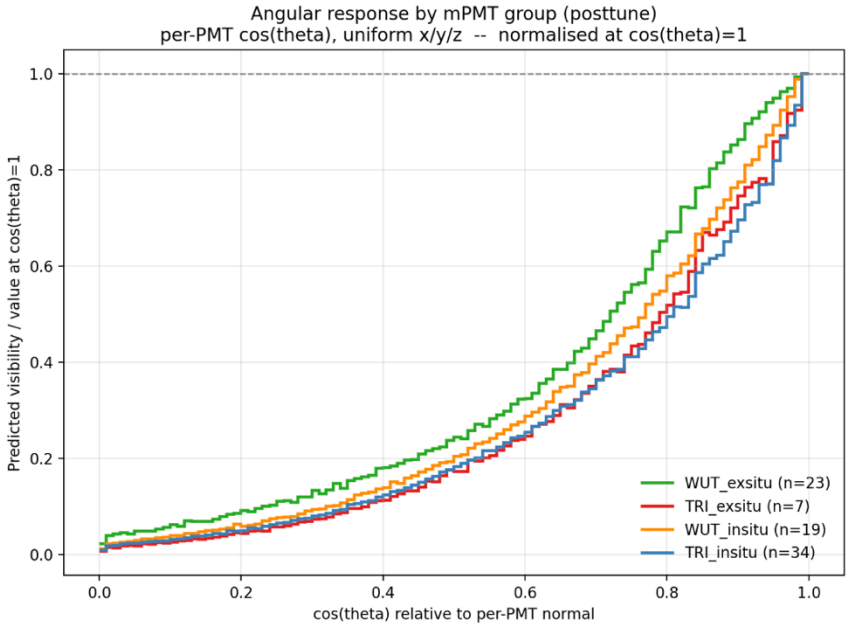


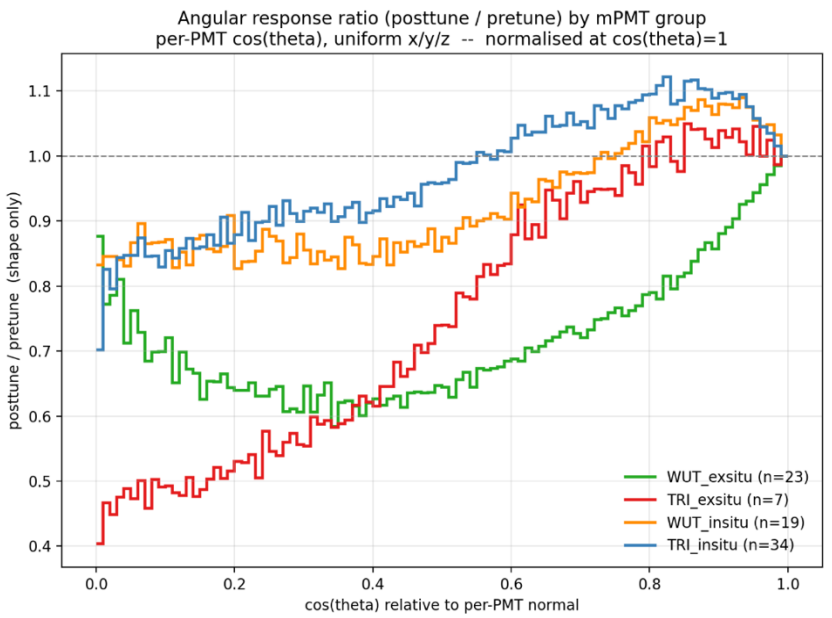
Ka Ming's plot with cosmic data and fiTQun (data/MC)

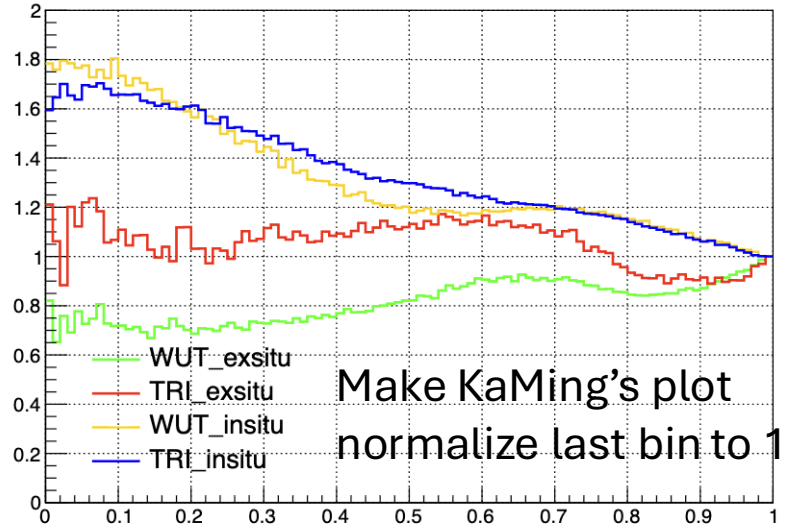


Normalize the last bin (costheta=1) to 1









summary

- Extract the mPMT angular response from OpticSiren, compare the pre-tune and post-tune angular response
- The pre-tune angular response are almost same among 4 groups, the only difference found in WUT-exsitu may due to the curvature of the tank barrel
- postune has a similar tendency as in Ryotaro's laser study
- Normalize the last bin (costheta=1) to 1 to make it easy to be compared with other WCTE calibration studies.