UNIVERSITÄT
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SEIT 1386

Discriminating the Low Energy Excess in DELight

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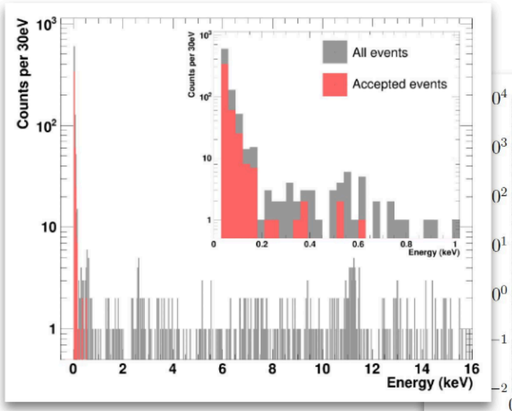
The Low Energy Excess

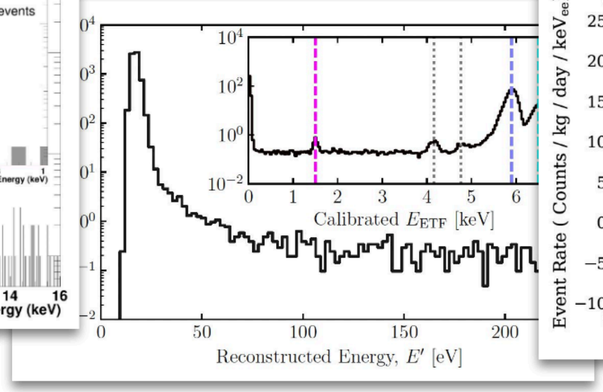
- A steeply rising background at low energies, expected to be observed in the LAMCALs

- How to reject this background?

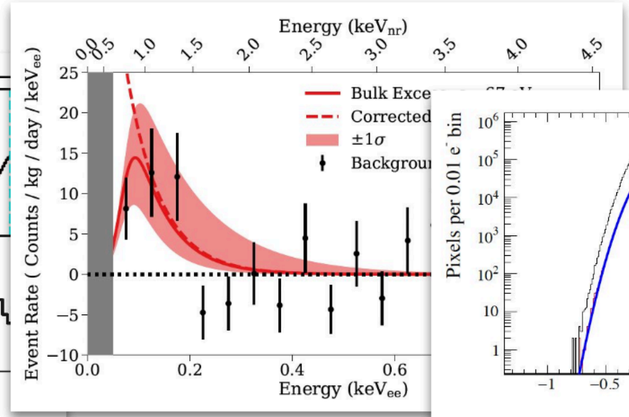
Phys. Rev. D 100, 102002



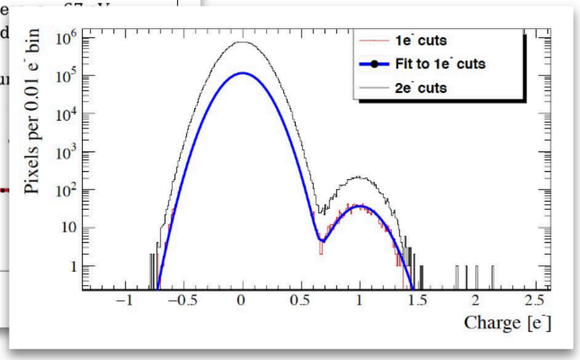
Phys. Rev. Lett. 127, 061801



Phys. Rev. Lett. 125, 241803



Phys. Rev. Lett. 125, 171802



D. Baxter and F. Wagner: EXCESS workshop: a community effort towards understanding low energy excesses

Initial Idea: Coincidence Discrimination

- First assumption (used for some preliminary sensitivity studies): we can reject a significant fraction of the LEE background using the fact that the quasiparticle (QP) signal from LHe events should be a distributed signal on many channels

- LEE events should occur on one sensor only (barring random coincidence)

Initial Idea: Coincidence Discrimination

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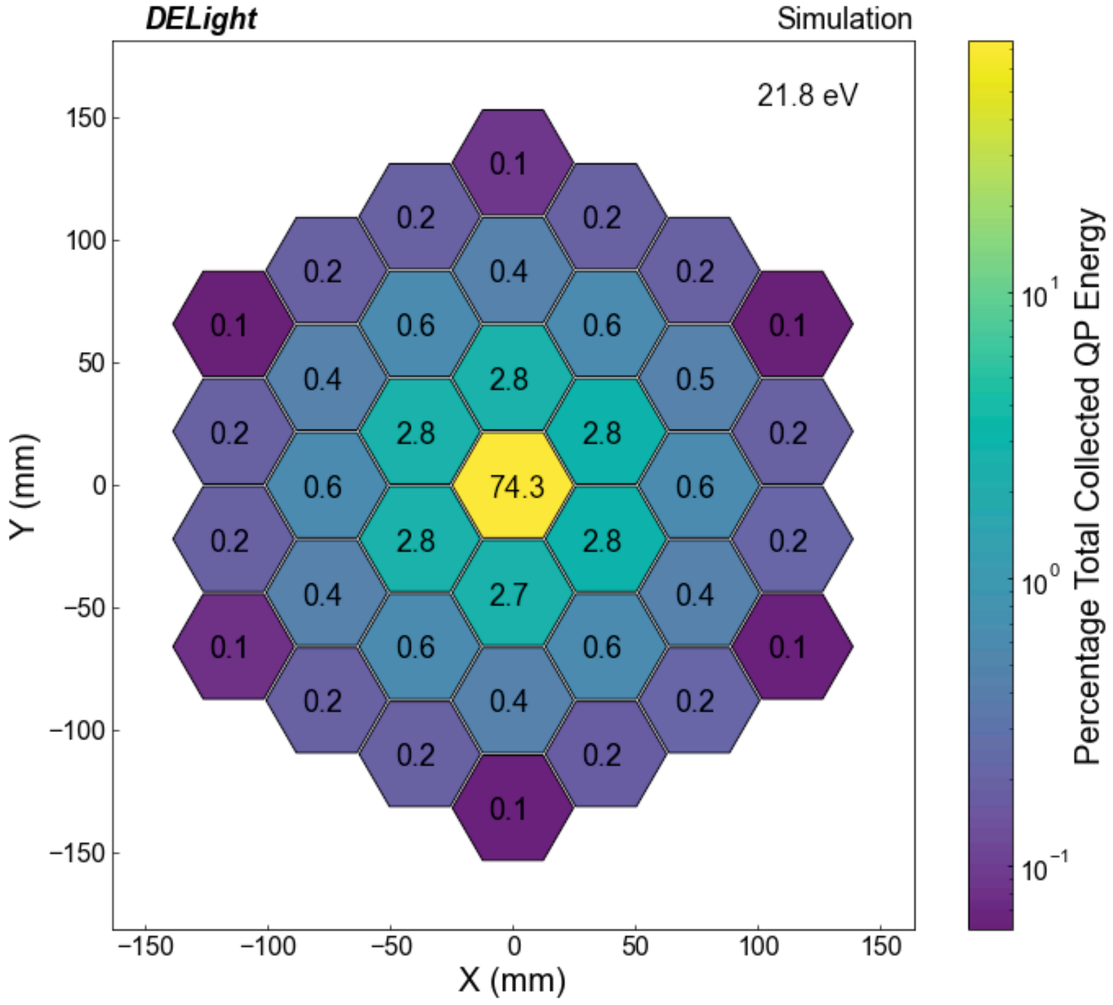
With current pancake geometry

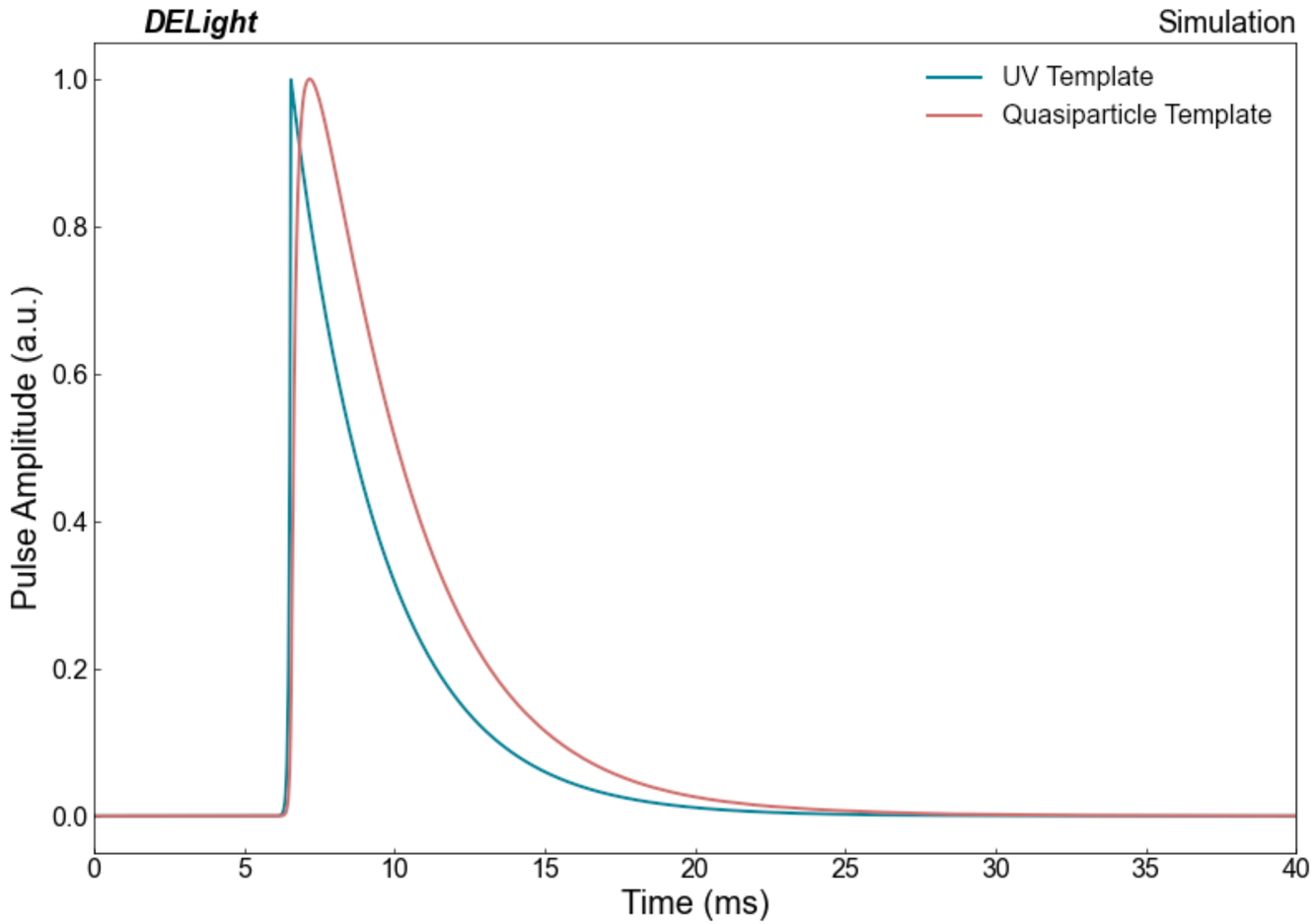
BAD ASSUMPTION!

The Distributed Quasiparticle Signal



- Example: 100eV LHe event in centre
  - Direct LAMCAL:
    100eV x 0.04 x 20 x 74% = ~60eV
    (QP collection efficiency; Adsorption gain; centre LAMCAL collection)
  - Adjacent LAMCAL:
    100eV x 0.04 x 20 x 3% = ~2.4eV
- Example: 20eV LHe event
  - Direct LAMCAL: ~12eV
  - Adjacent LAMCAL: ~0.5eV

Pulse Shape Discrimination?

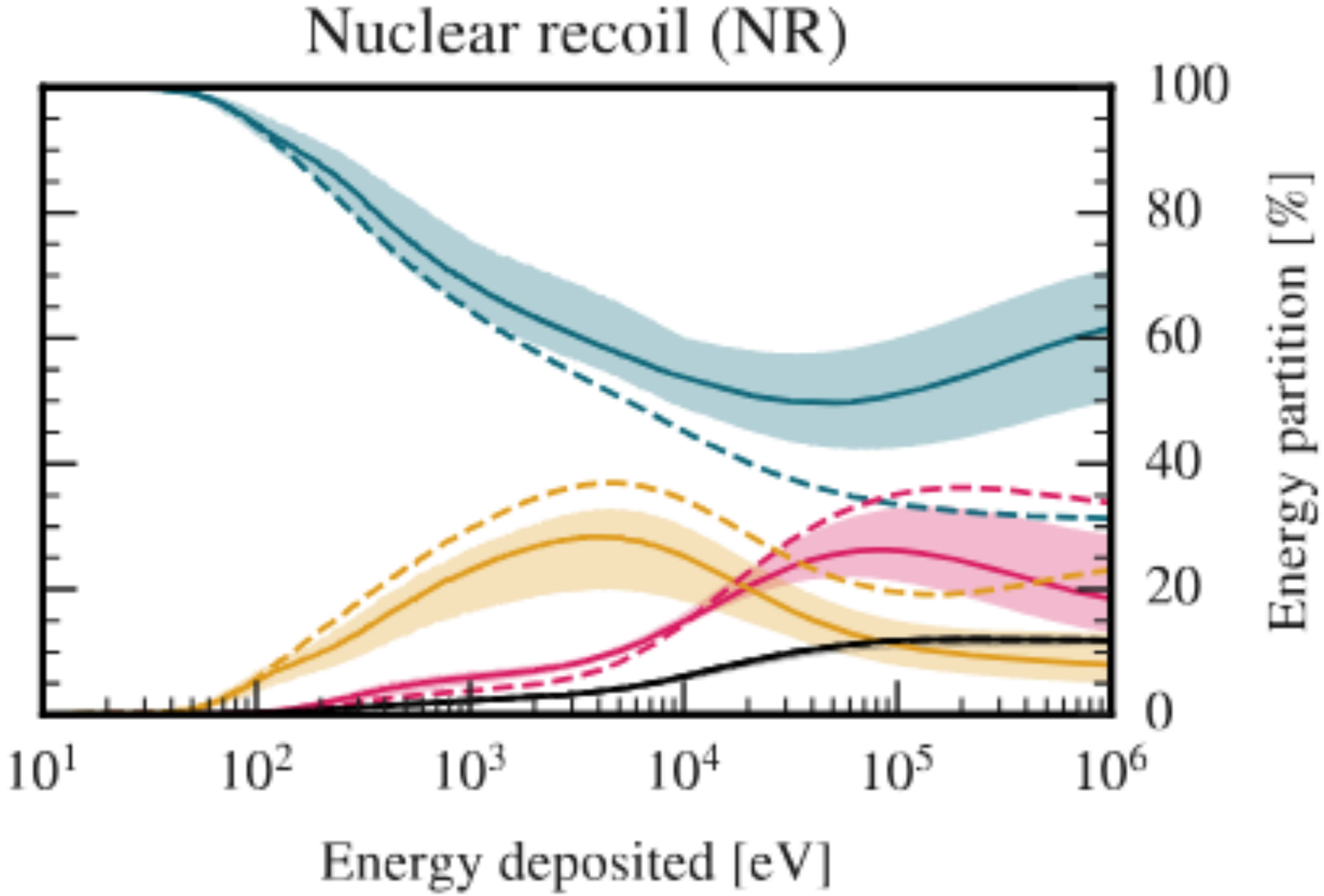


- May be able to use differences in pulse shape
- Assumption: LEE has same template as UV signal
- Pancake cell geometry QP template is quite similar
- Current template assumed for UV may not be appropriate for LAMCALs

LHe Events

- LHe signal events (nuclear recoils, NR) in the LEE range (below 200eV) deposit energy almost 100% into quasiparticles

- Only looking at the QP signal



Simulation Overview

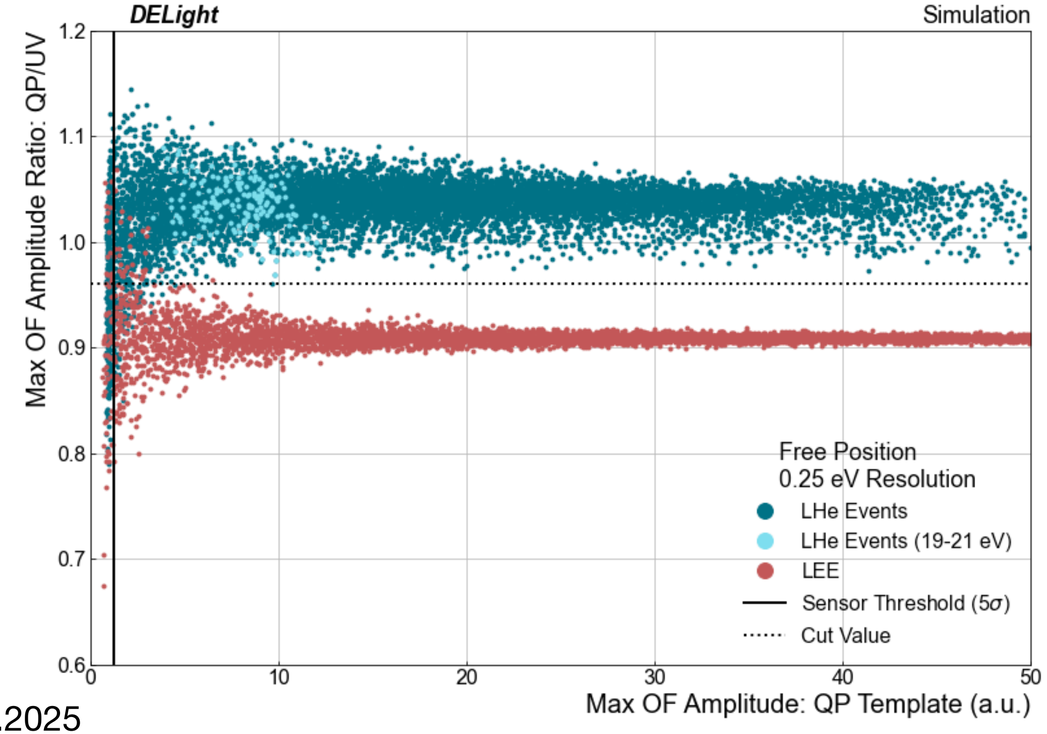
- Simulate two categories of events with random energies from 0 to 100eV
  - LHe: using trace simulator to generate QP signals on the vacuum channels for initial deposition E
  - LEE: UV template scaled by the event energy E
- Noise is added separately for different values of LAMCAL baseline resolution ranging from 0.25eV to 2eV to study the impact of the sensor resolution
- All events (LHe and LEE) are processed using OF with the QP template and also the UV template
  - For LHe events, each channel is processed (not the sum), and the maximum amplitude of the channels is taken as the energy estimator

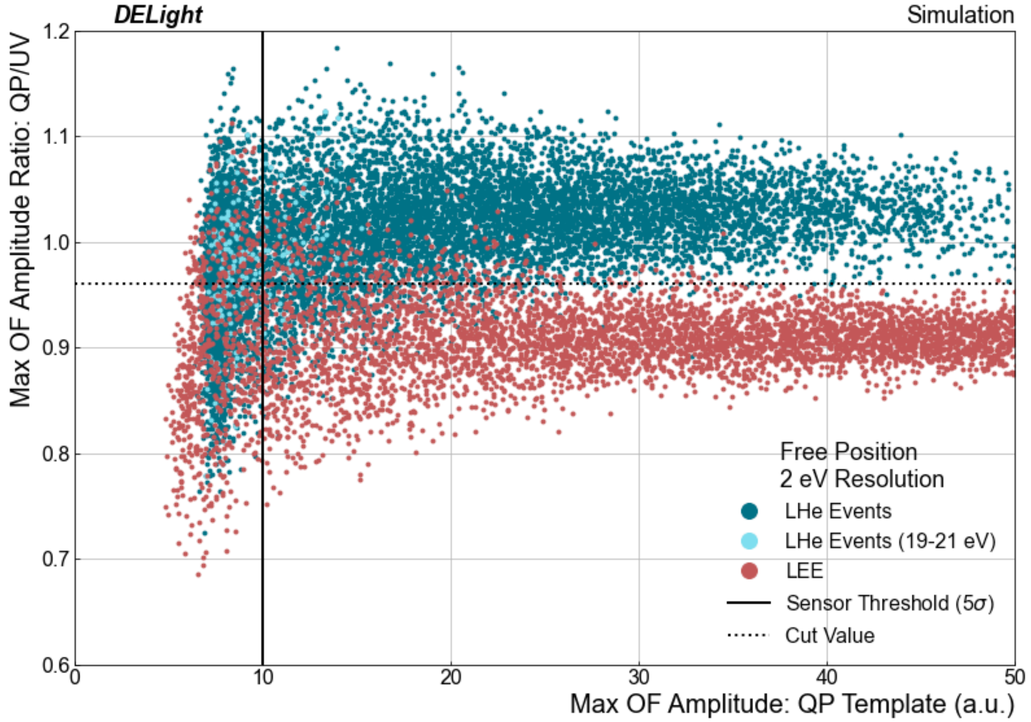
Amplitude Ratio

QP:UV Template OF Amplitude Ratio

- QP template well describes the QP events, but not the LEE events (and vice versa for the UV template)

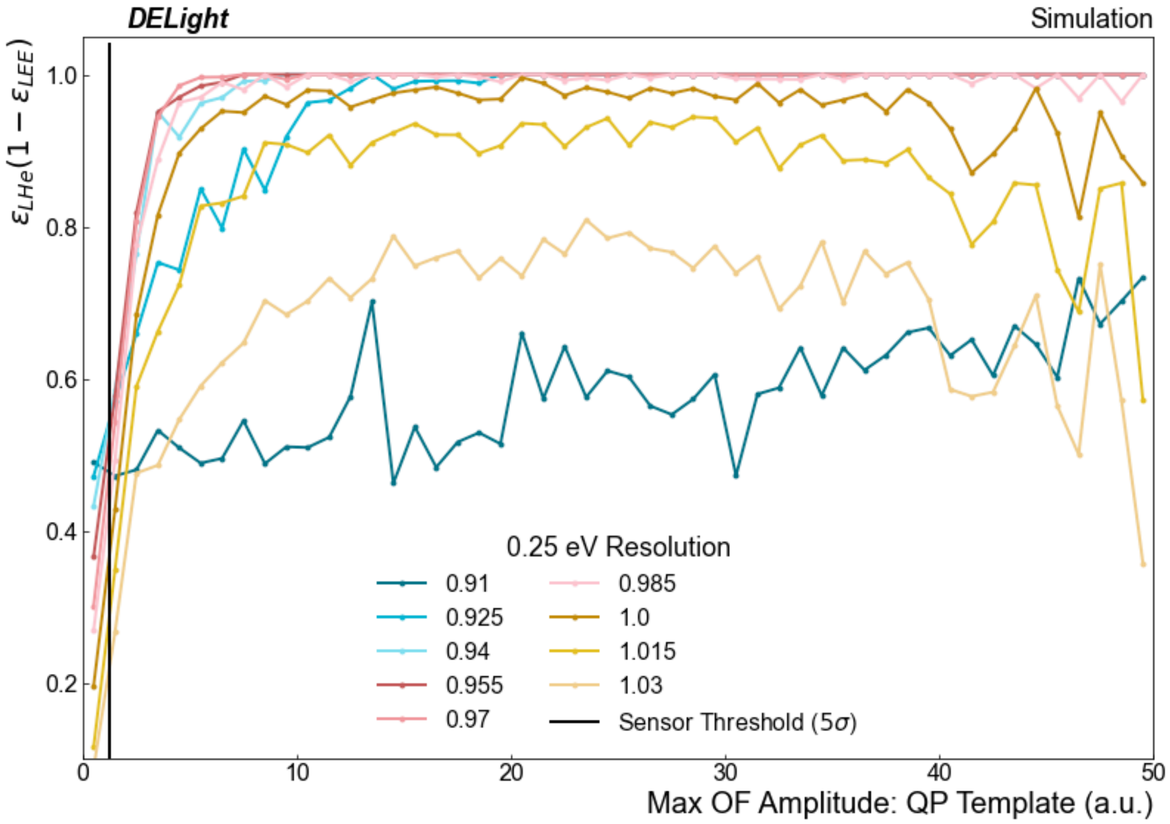
- This is very clear in the ratio of the OF amplitudes from each template





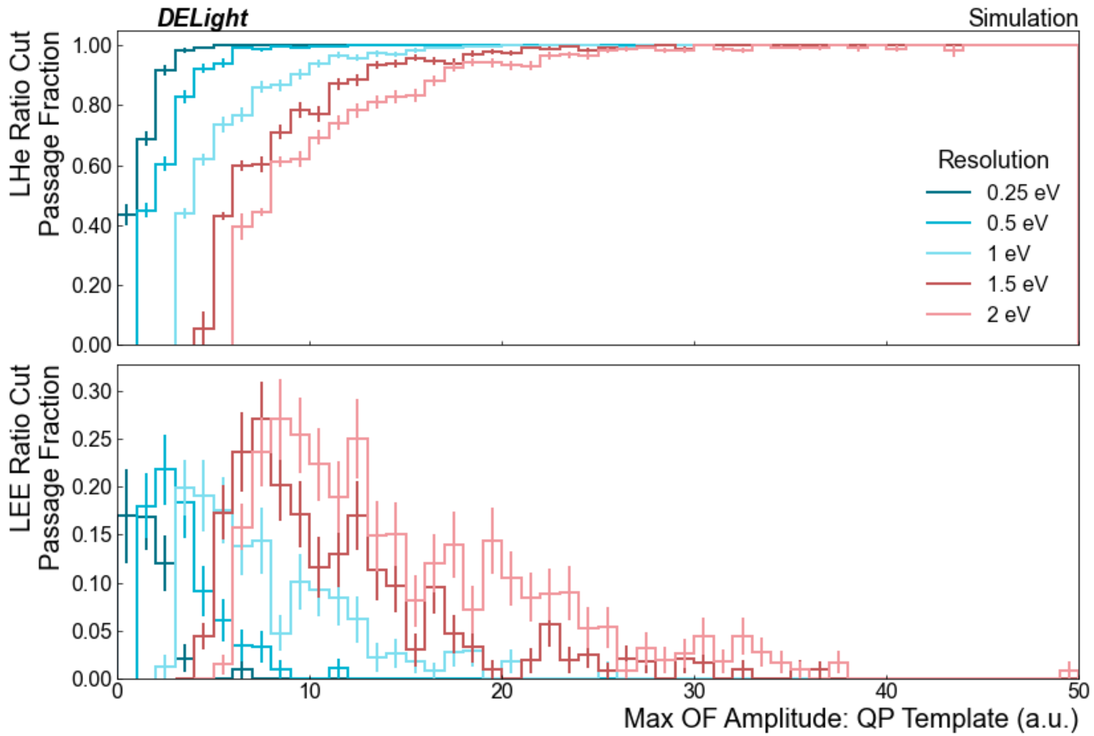
QP:UV Template OF Amplitude Ratio - Choosing Cut Value

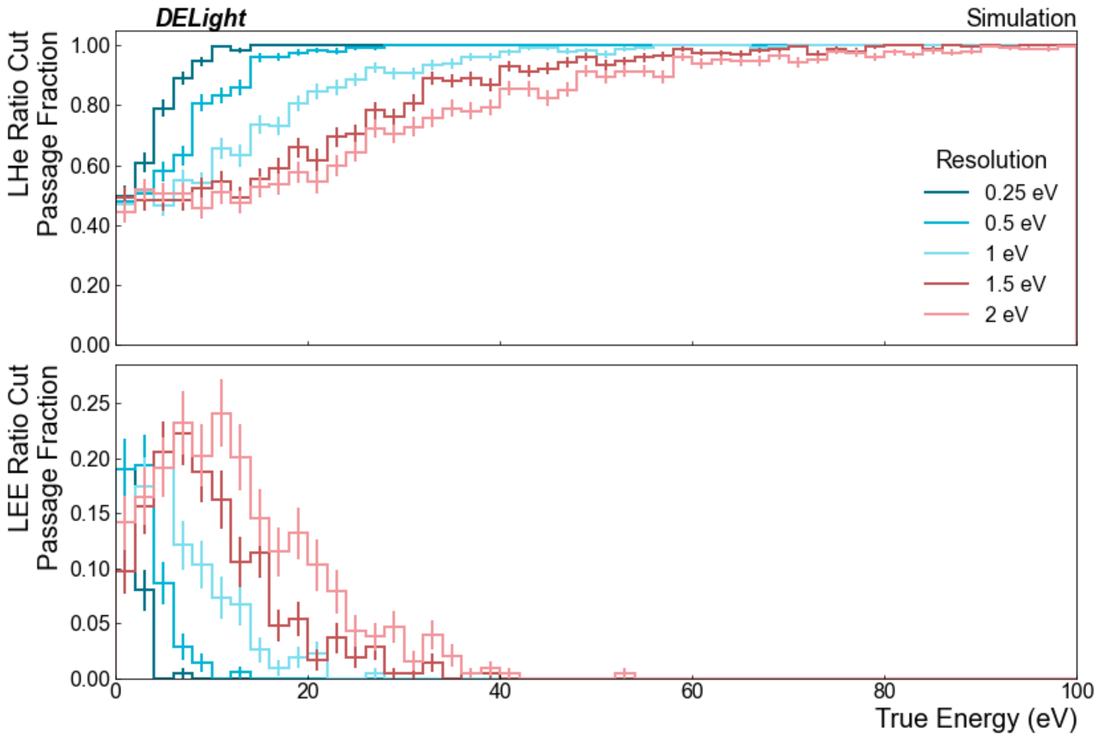
- Cut value set based on passage fractions/efficiencies ε → want to maximize $\varepsilon_{LHe}(1-\varepsilon_{LEE})$



QP:UV Template OF Amplitude Ratio Passage Fraction

- Passage fractions for each event category as a function of the QP energy estimator (left) and the true event energy (right)



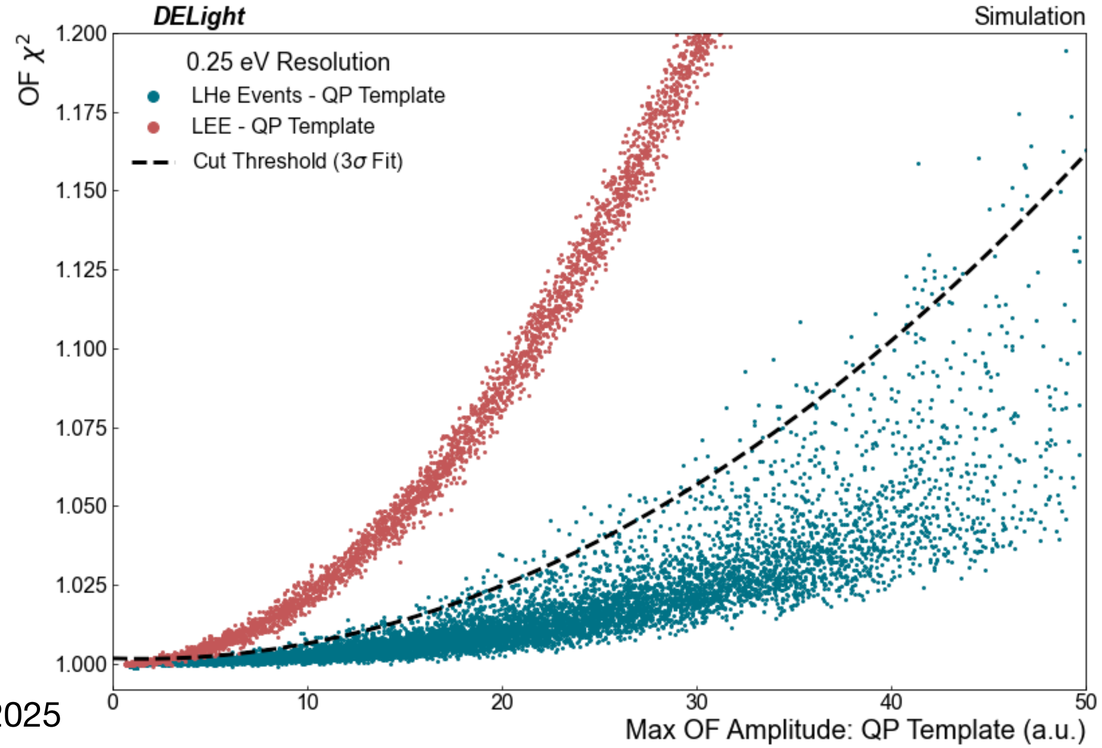


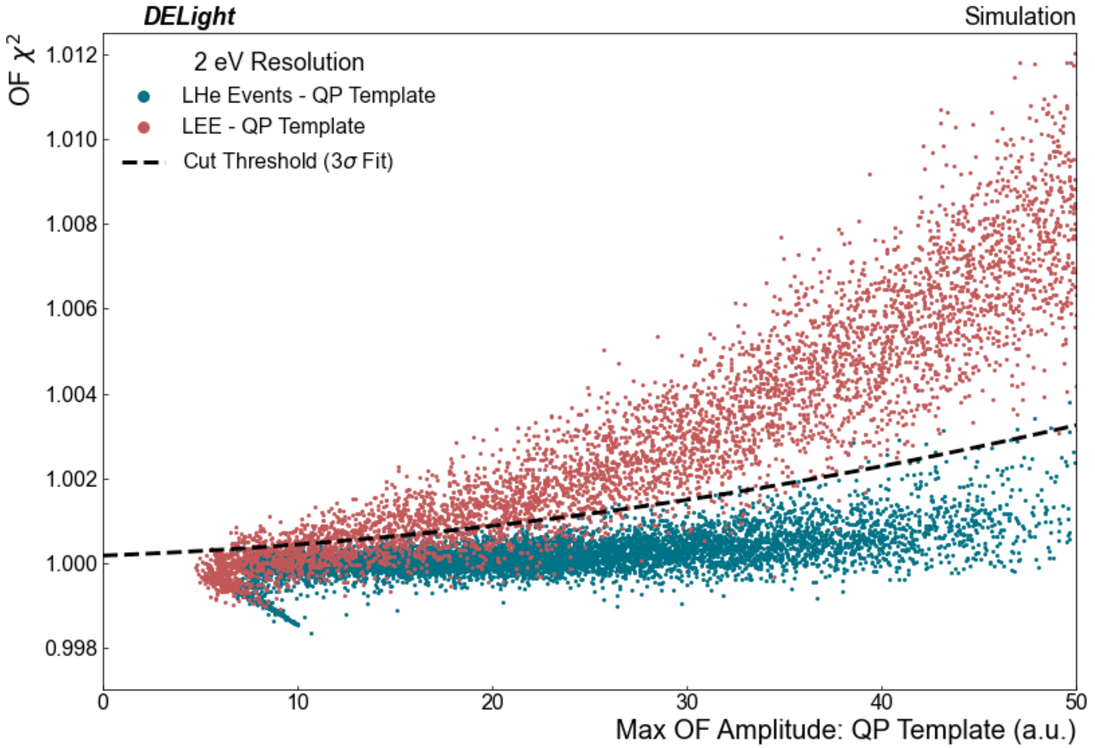
Chi2

Chi2 Cut

- The chi2 of the QP template fit is also a strong indicator of the difference in pulse shape

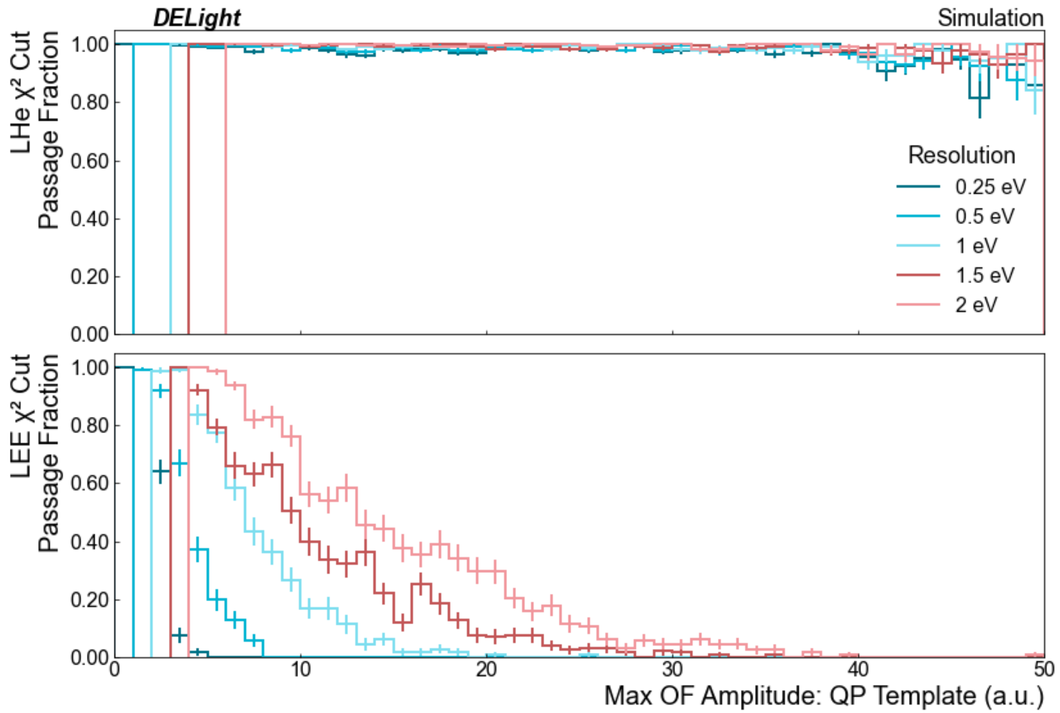
- 3σ of the distribution taken and fit with polynomial for energy-dependent cut value

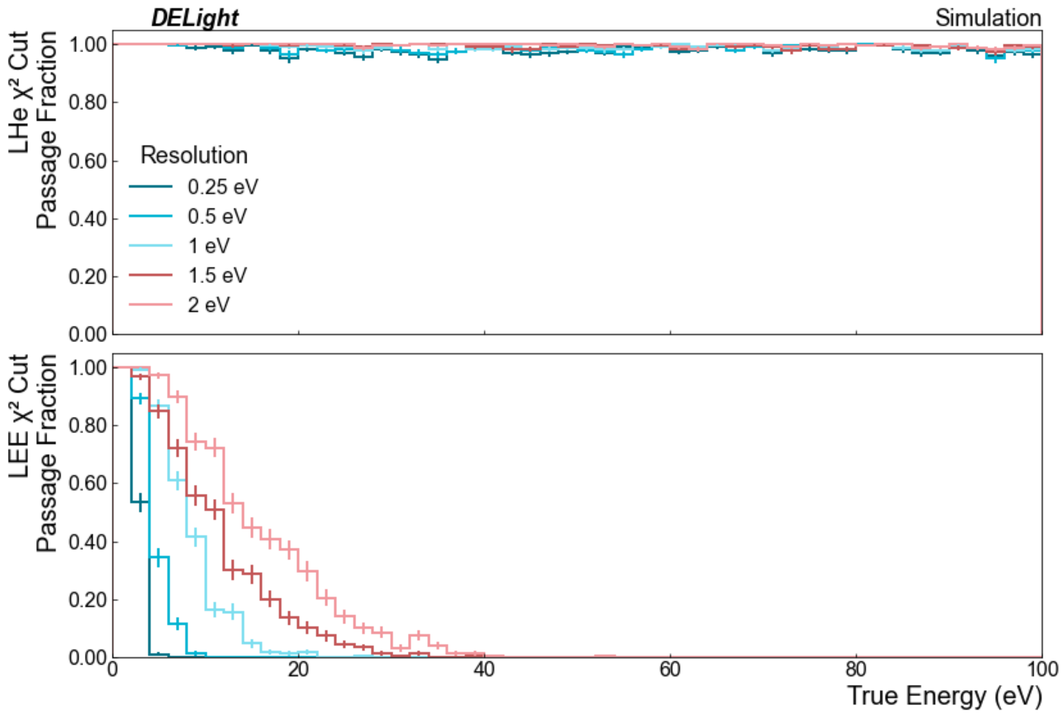




Chi2 Cut Passage Fraction

- By construction, LHe passage fraction is roughly constant
- Don’t remove as many LEE events at low energy as ratio cut, but also don’t remove LHe events



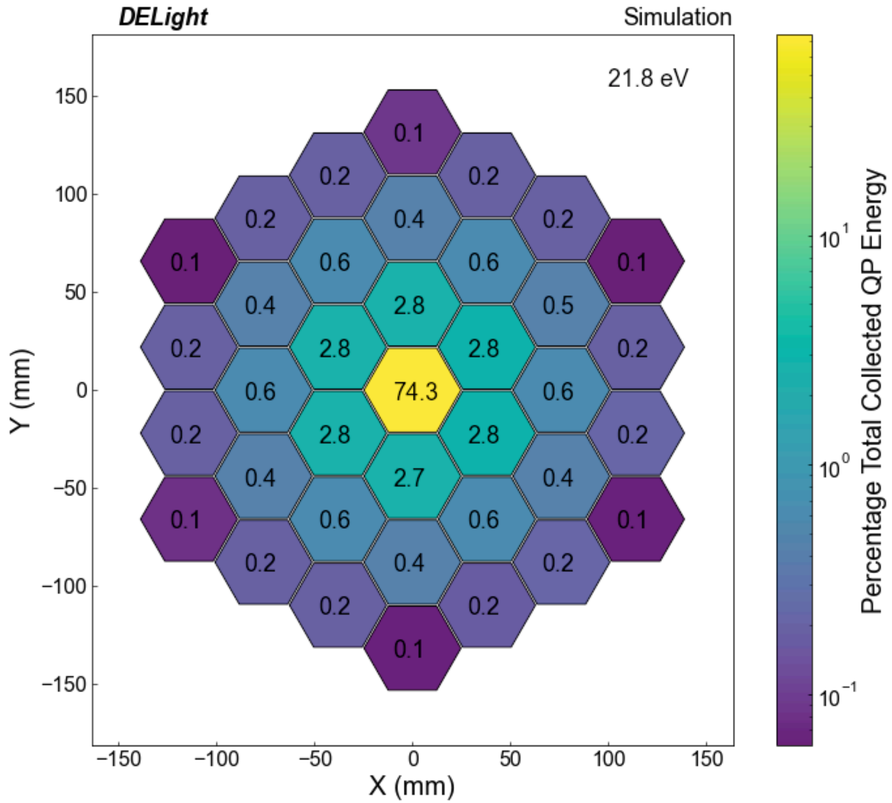


Nearest Neighbours

LEE Nearest Neighbours Cut

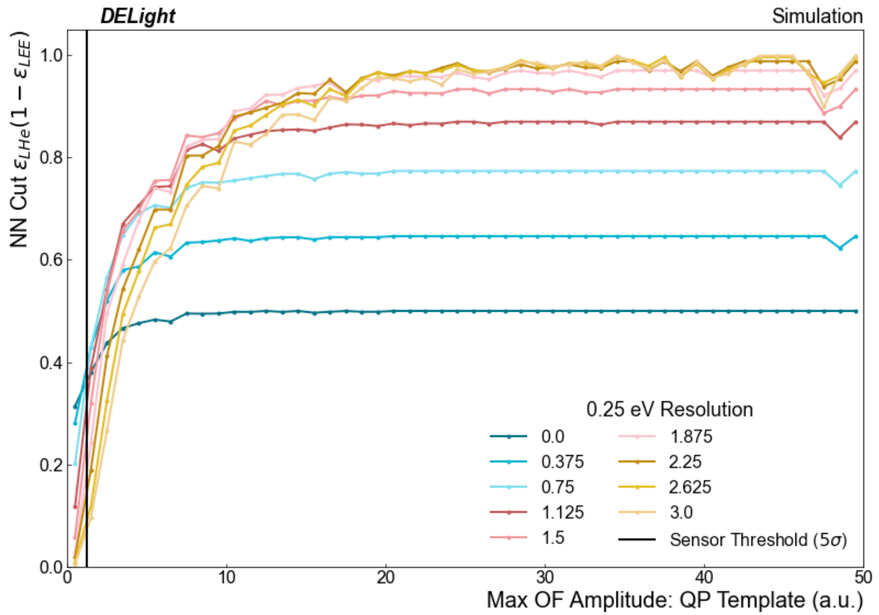
- The quasiparticle signal on the sensors surrounding the LAMCAL directly above the event location is small - but may be distinguishable from noise when considering the sum of the channels

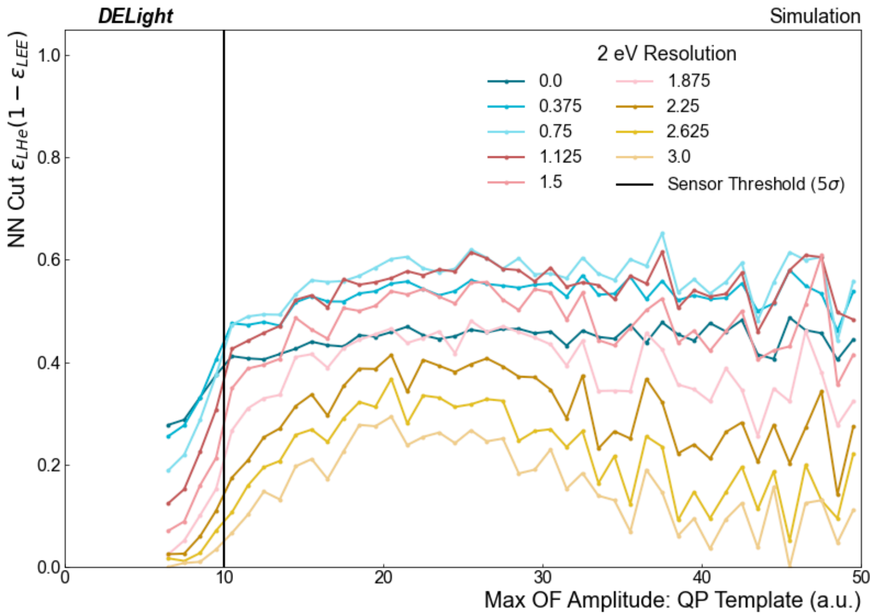
- Cut on OF0 of the summed traces of channels surrounding the channel with max amplitude



LEE Nearest Neighbours Cut

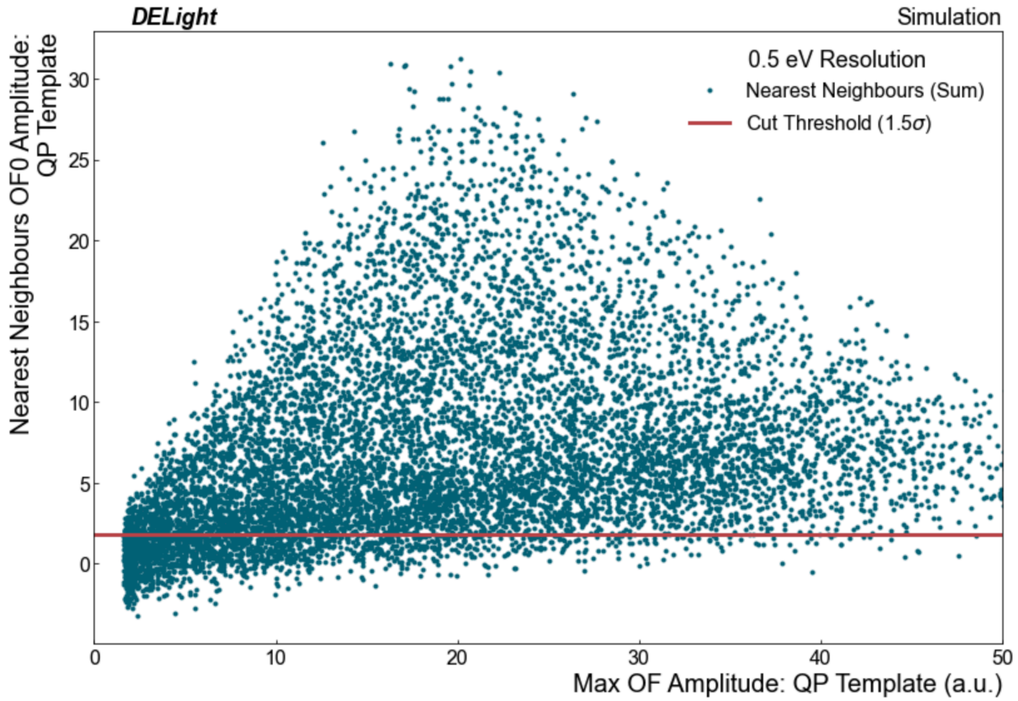
- Cut value depends on resolution
- Passage fraction of LEE events is constant in energy (expected signal is just gaussian noise on the surrounding channels)

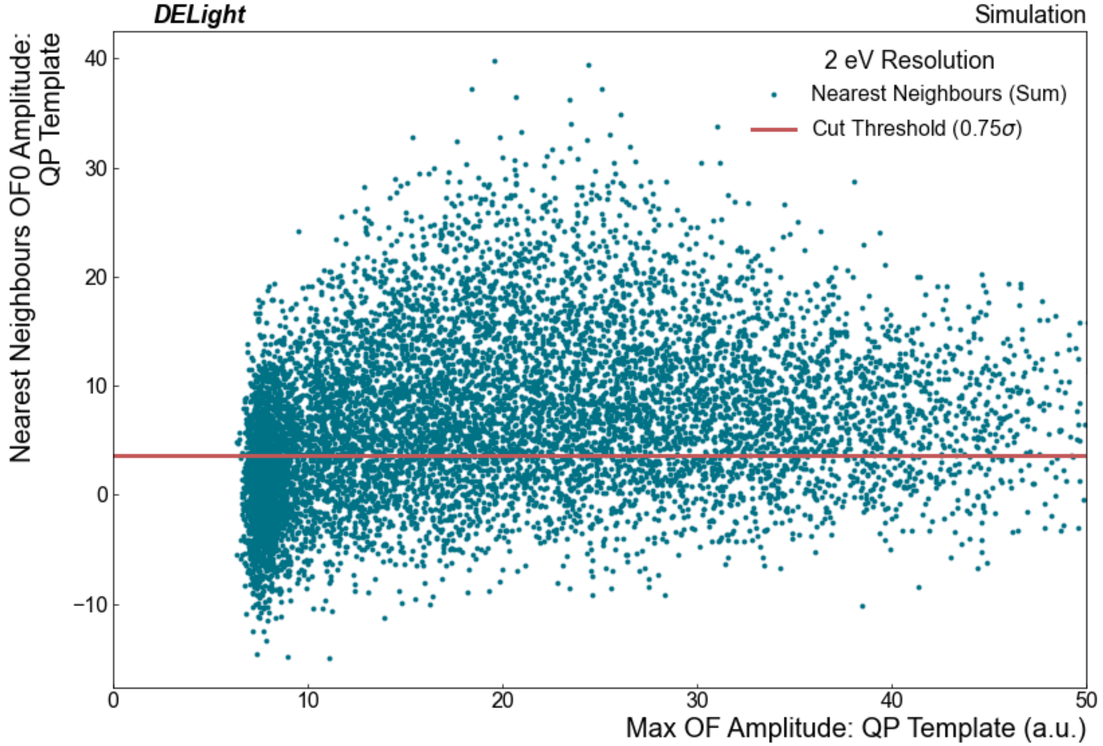




LEE Nearest Neighbours Cut: Distribution

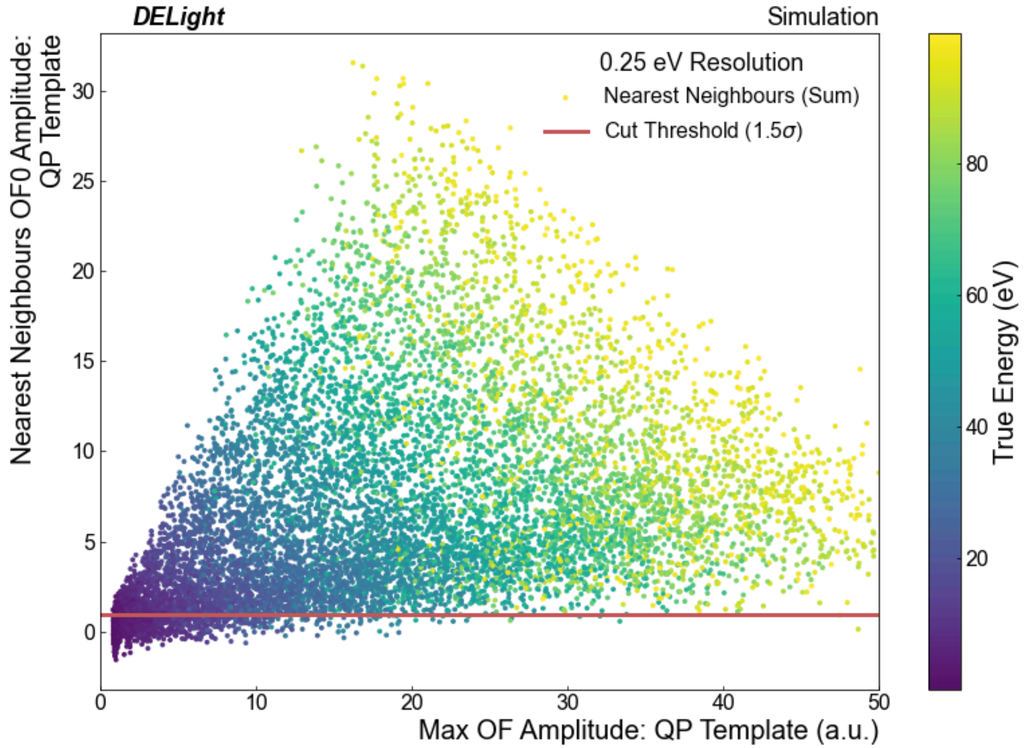
- Distribution of the nearest neighbour signal as a function of the maximum QP amplitude. Cut position marked

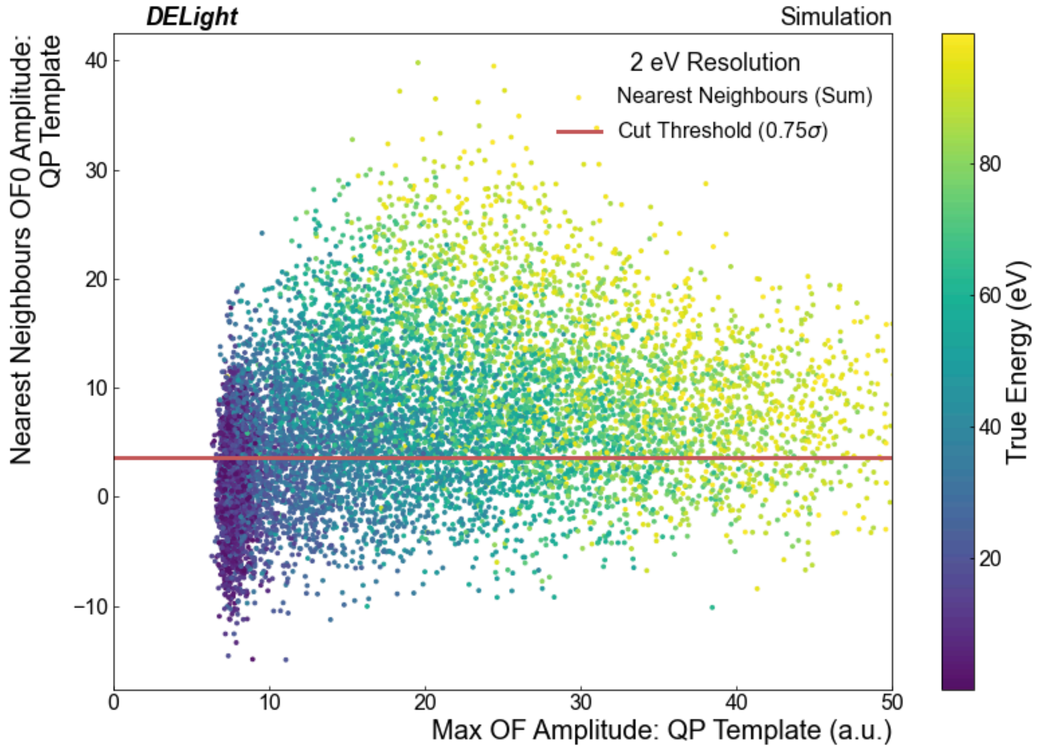




LEE Nearest Neighbours Cut: Distribution

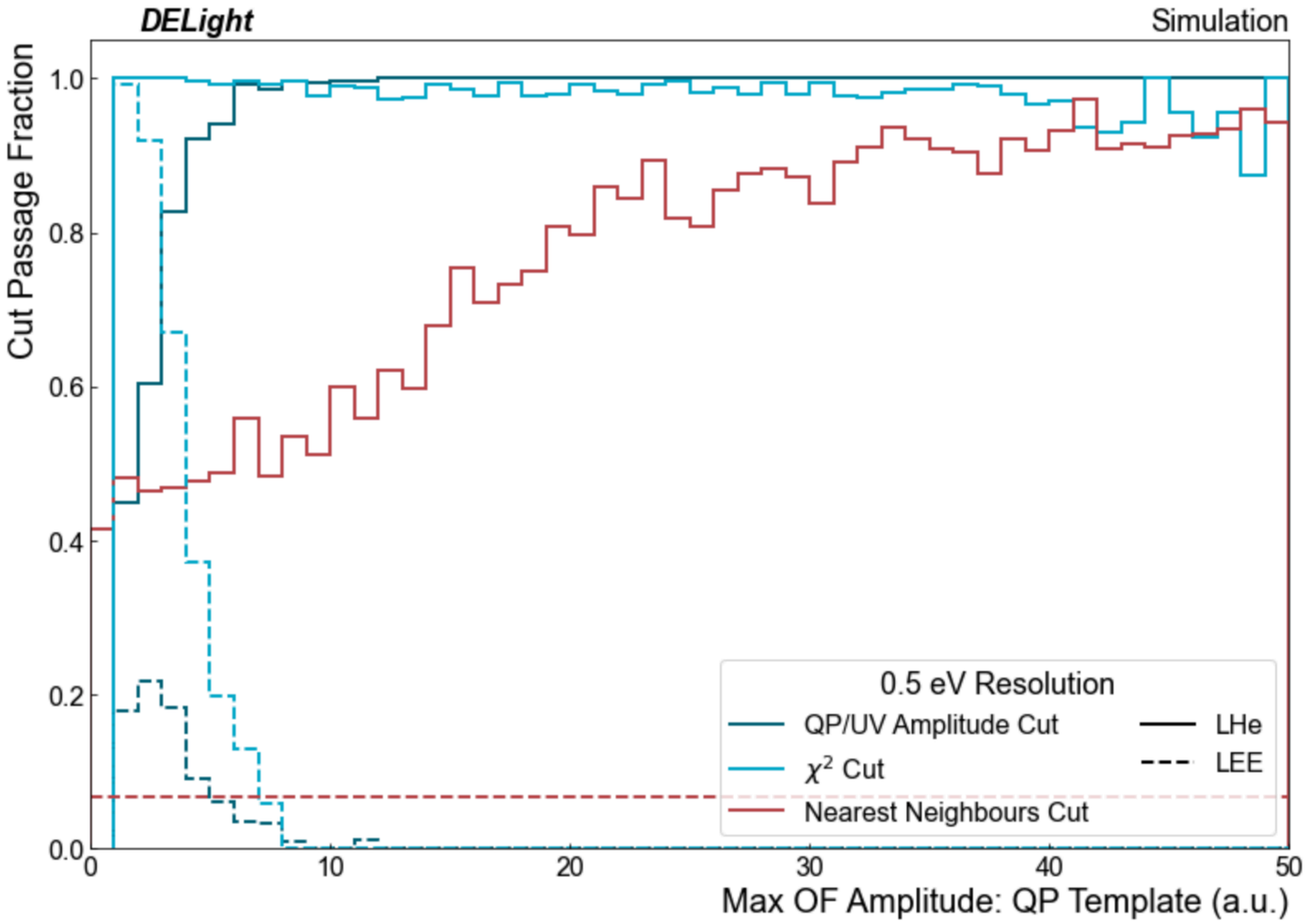
➡ Same plots, event energy indicated by colour



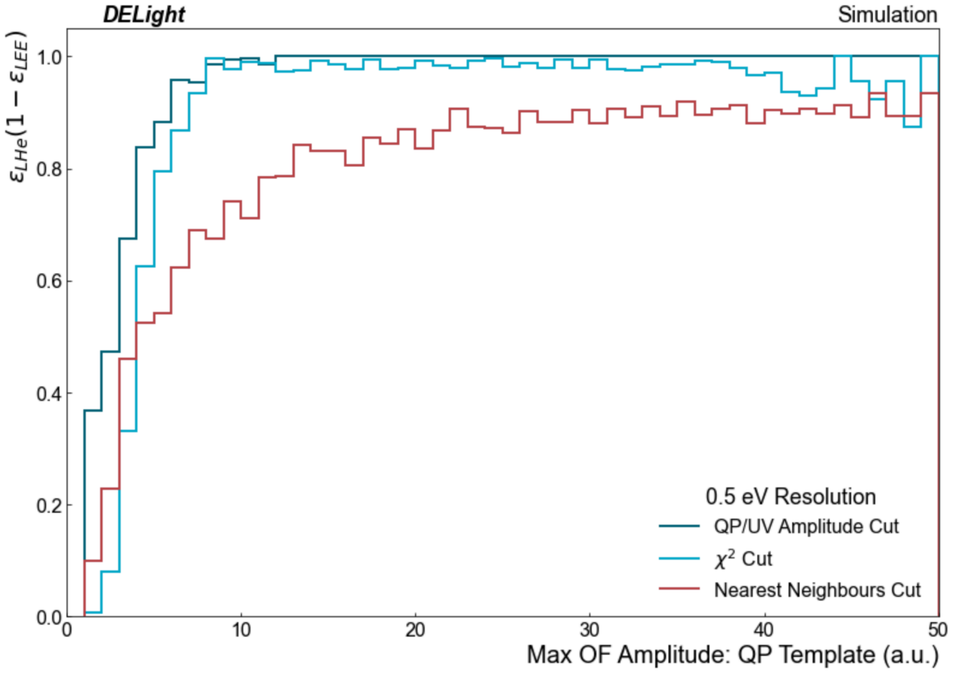


Summary

LEE Cut Summary

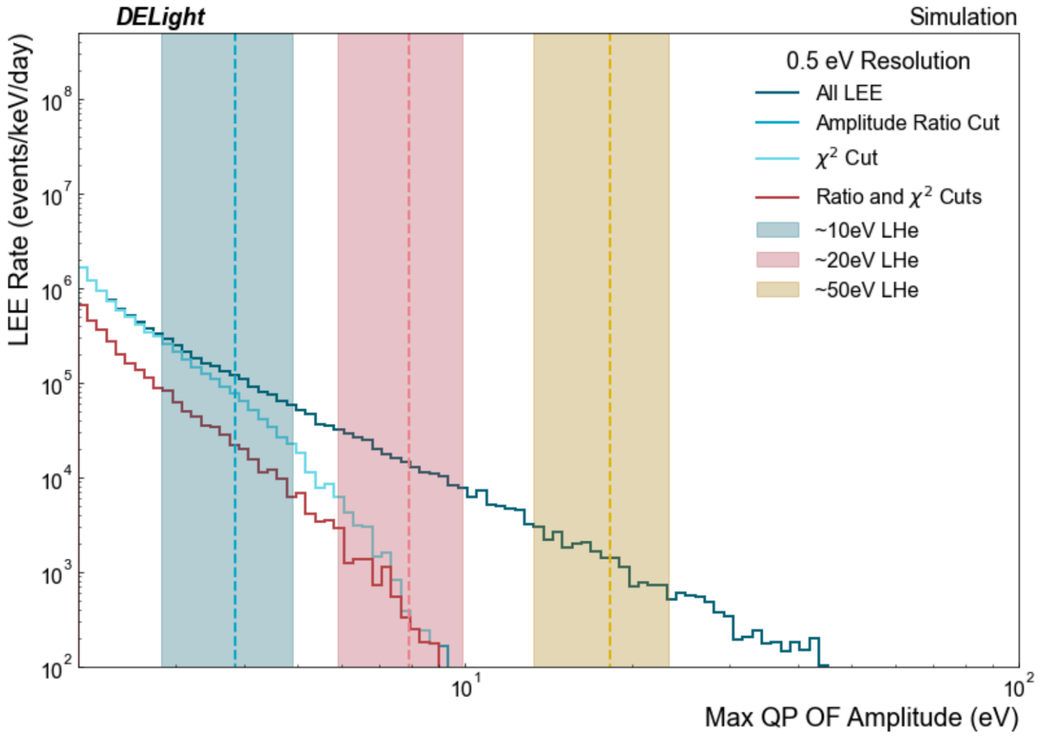


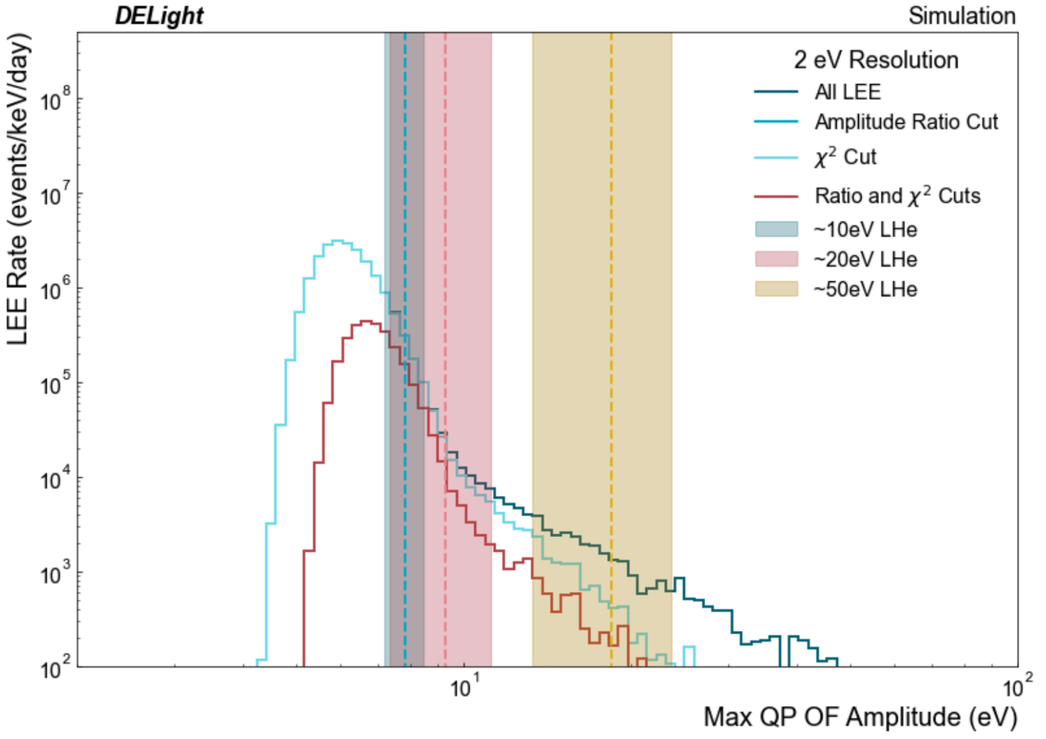
- Chi2 and amplitude cuts perform better than NN cut, but are highly pulse shape dependent



Impact of Cuts on LEE

- Shape of LEE taken from CRESST measurement [SciPost Phys. Proc. 12, 013 (2023)]
- Impact of cuts at certain LHe event energies depends completely on sensor resolution
- Y axis scale is arbitrary, and plots do not show impact on LHe events.





Conclusions

- Different avenues for reducing the impact of the LEE:
  - Cuts: pulse shape (chi2, amplitude ratio) and signal distribution (nearest neighbours)
  - Measurement of the LEE without LHe volume - constrain background in PLR limits
- Current caveats:
  - Are LEE events in LAMCALs truly like UV signal?
  - What is the LAMCAL pulse shape?
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Analysis note in progress!