Corrections to Signal Saturation on DEAP-3600

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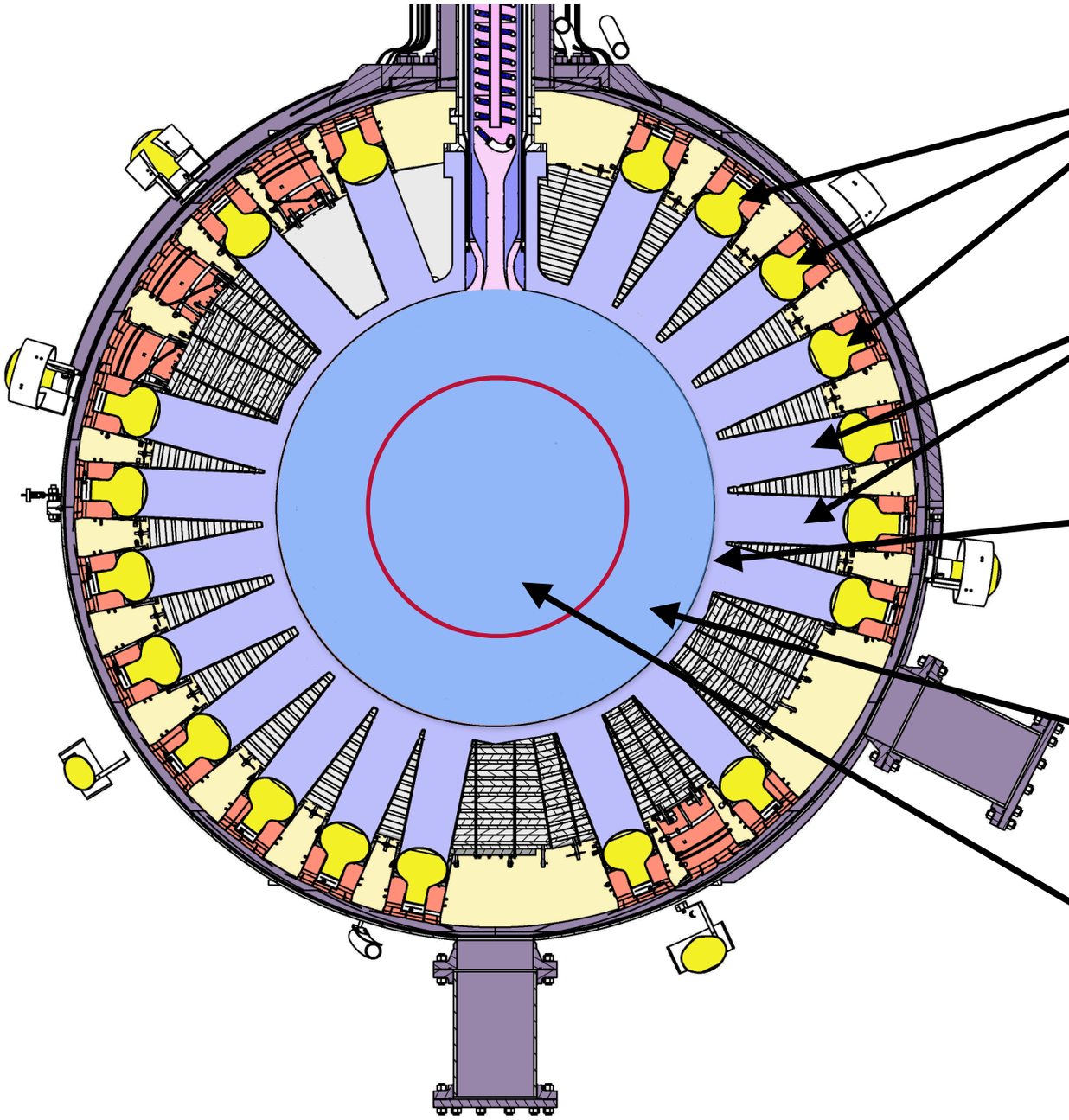
May 29, 2017
CAP Congress
Queen's University

Introduction
To DEAP-3600

DEAP-3600



255 Photomultiplier Tubes (PMTs)

Acrylic Light Guides

85 cm radius Acrylic Vessel

3600 kg Liquid Argon Target

1 Tonne Fiducial Target Mass

DEAP-3600

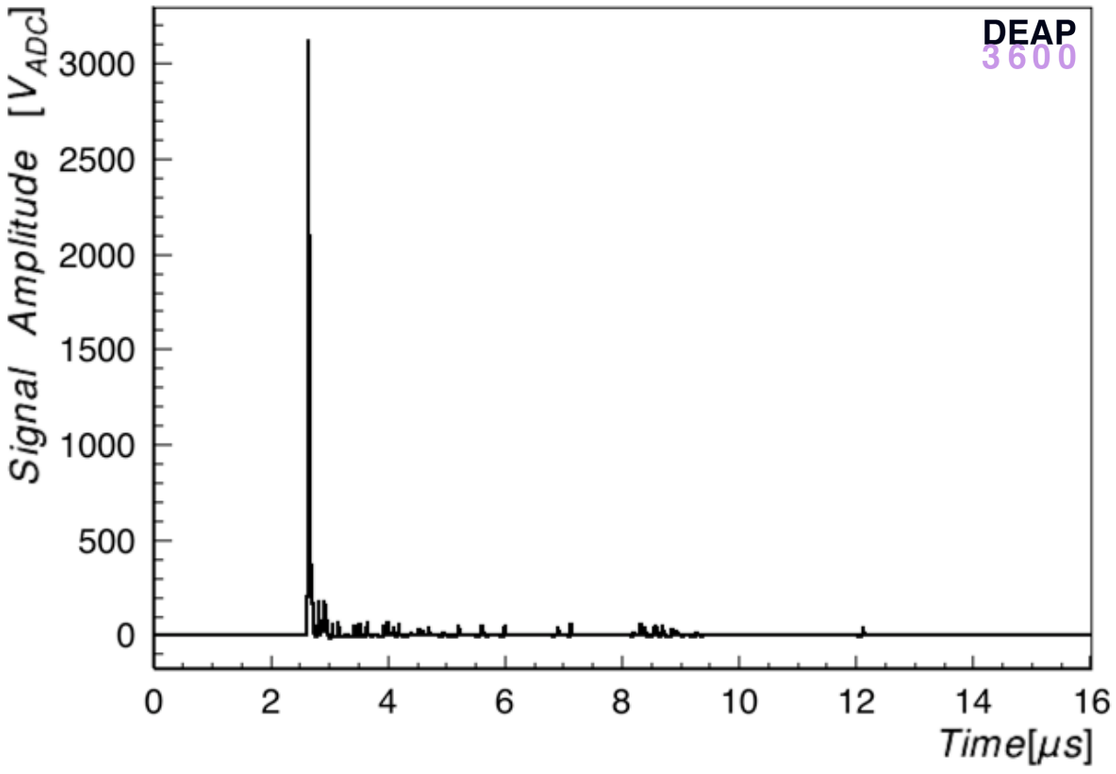
Dark matter **E**xperiment using **A**rgon **P**ulse-shape discrimination

DEAP-3600

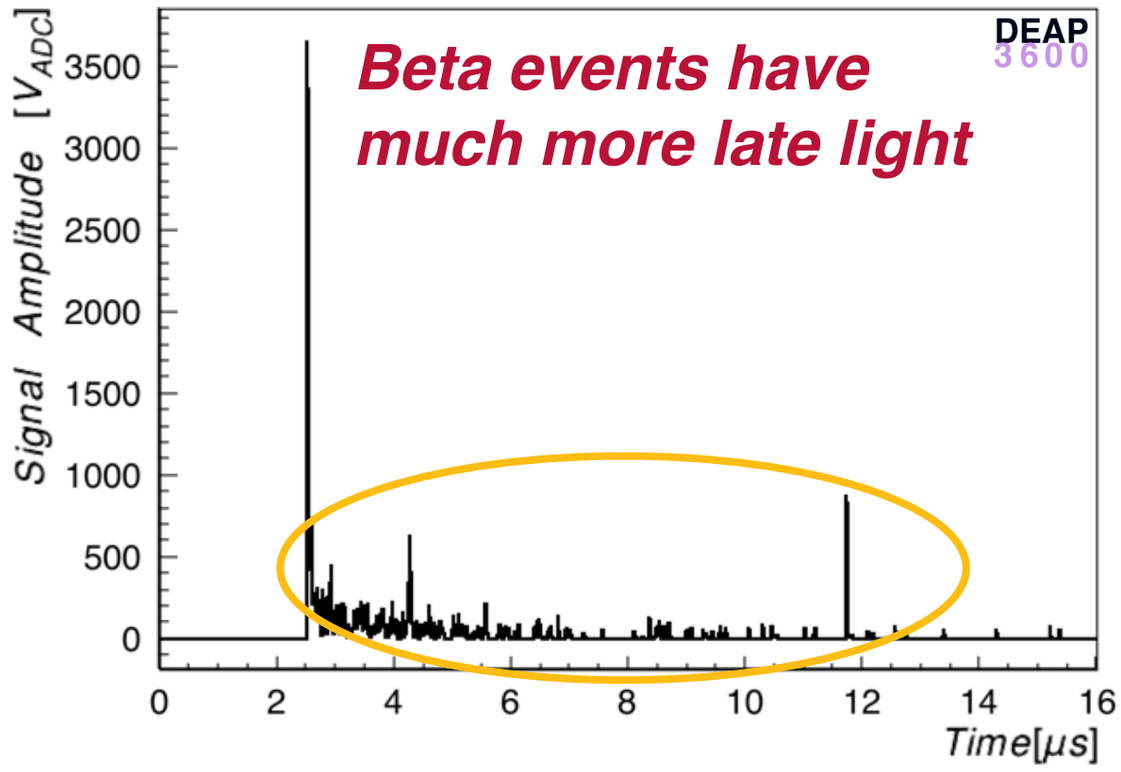
Dark matter **E**xperiment using **A**rgon **P**ulse-shape discrimination

- Interactions from Betas/Gammas favour the triplet excited state ($\tau = 1.6\ \mu$s), nuclear recoils favour singlet state ($\tau = 7$ ns)

Alpha Nuclear Recoil Event



^{39}Ar Beta Event

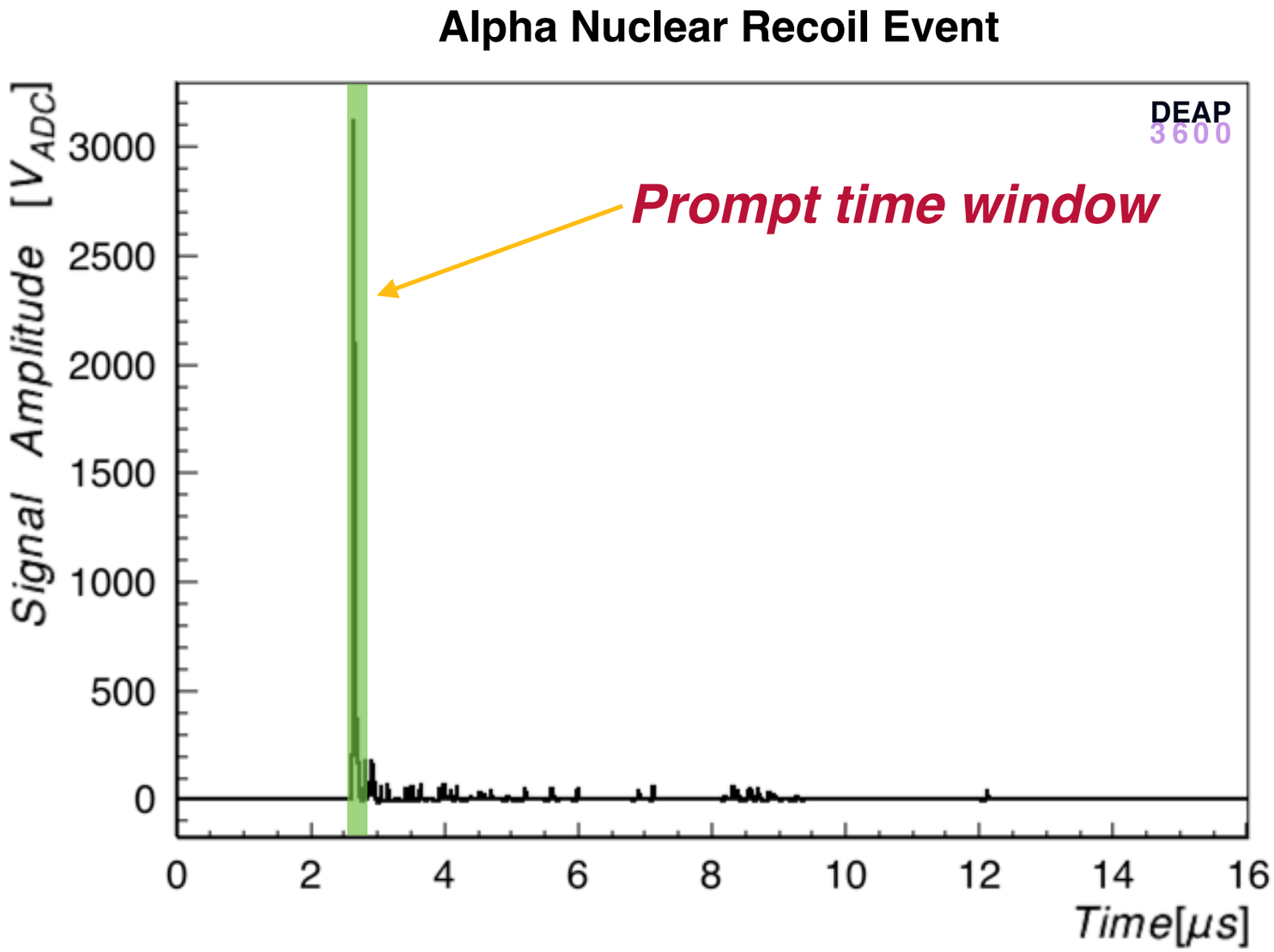


DEAP-3600

Dark matter **E**xperiment using **A**rgon **P**ulse-shape discrimination

- Characterized by the quantity F_{prompt}

$$F_{prompt} = \frac{\int_{-50\mathrm{ns}}^{150\mathrm{ns}} V(t)dt}{\int_{-50\mathrm{ns}}^{15\mu\mathrm{s}} V(t)dt}$$



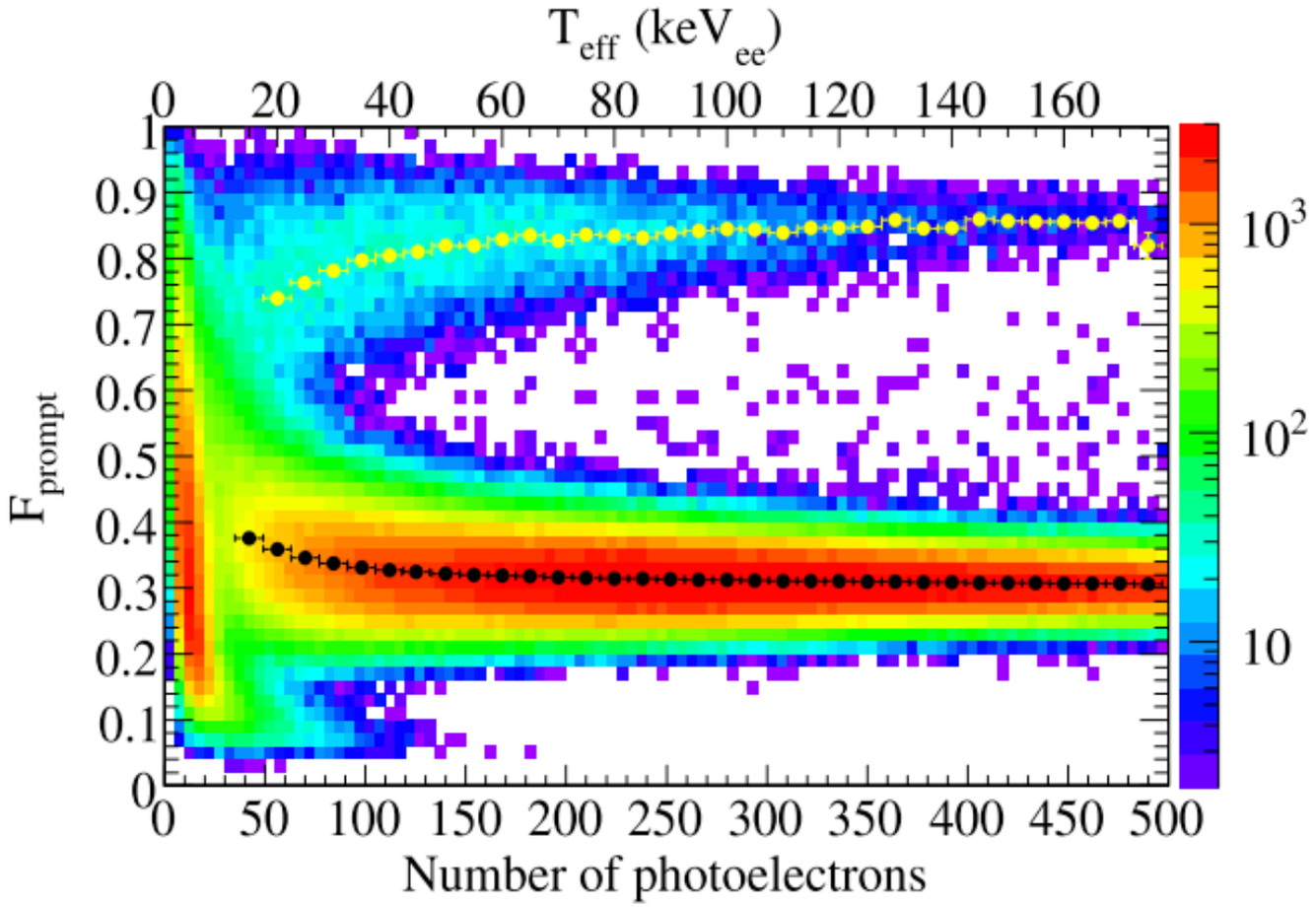
DEAP-3600

Dark matter **E**xperiment using **A**rgon **P**ulse-shape discrimination

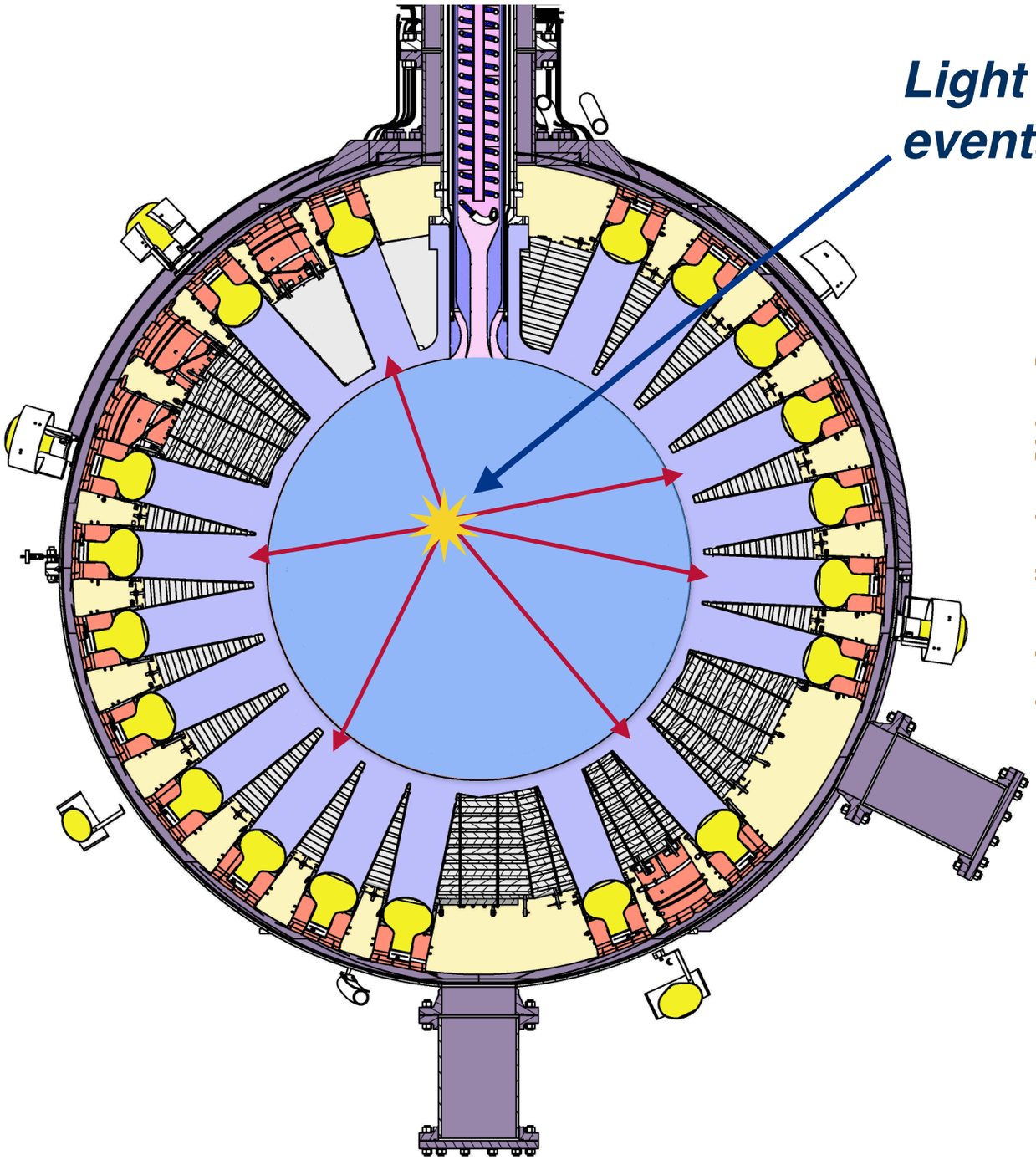
- Characterized by the quantity F_{prompt}

$$F_{prompt} = \frac{\int_{-50\mathrm{ns}}^{150\mathrm{ns}} V(t)dt}{\int_{-50\mathrm{ns}}^{15\mu\mathrm{s}} V(t)dt}$$

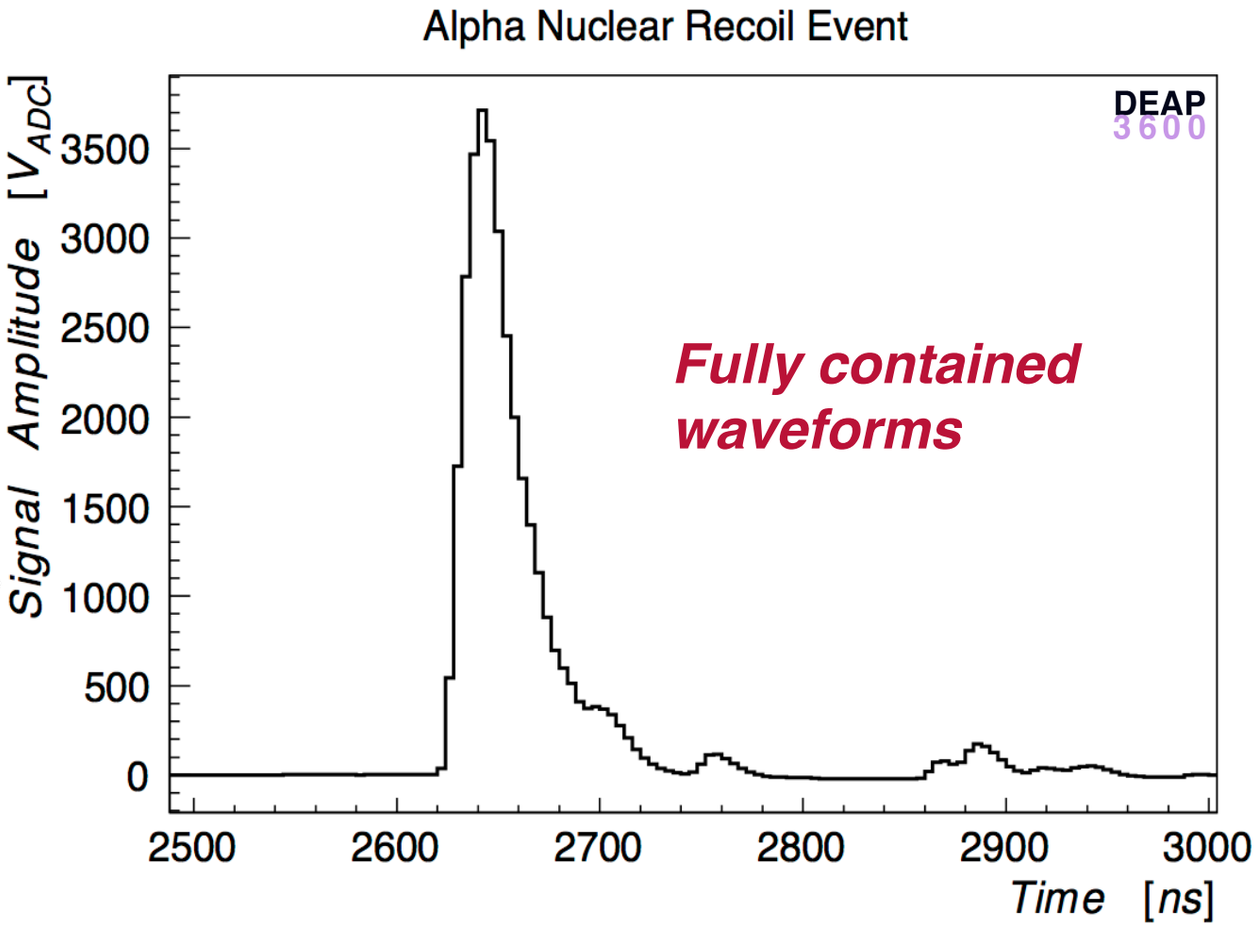
- Electron recoil backgrounds such as ^{39}Ar beta decay have lower F_{prompt} than nuclear recoils and are rejected

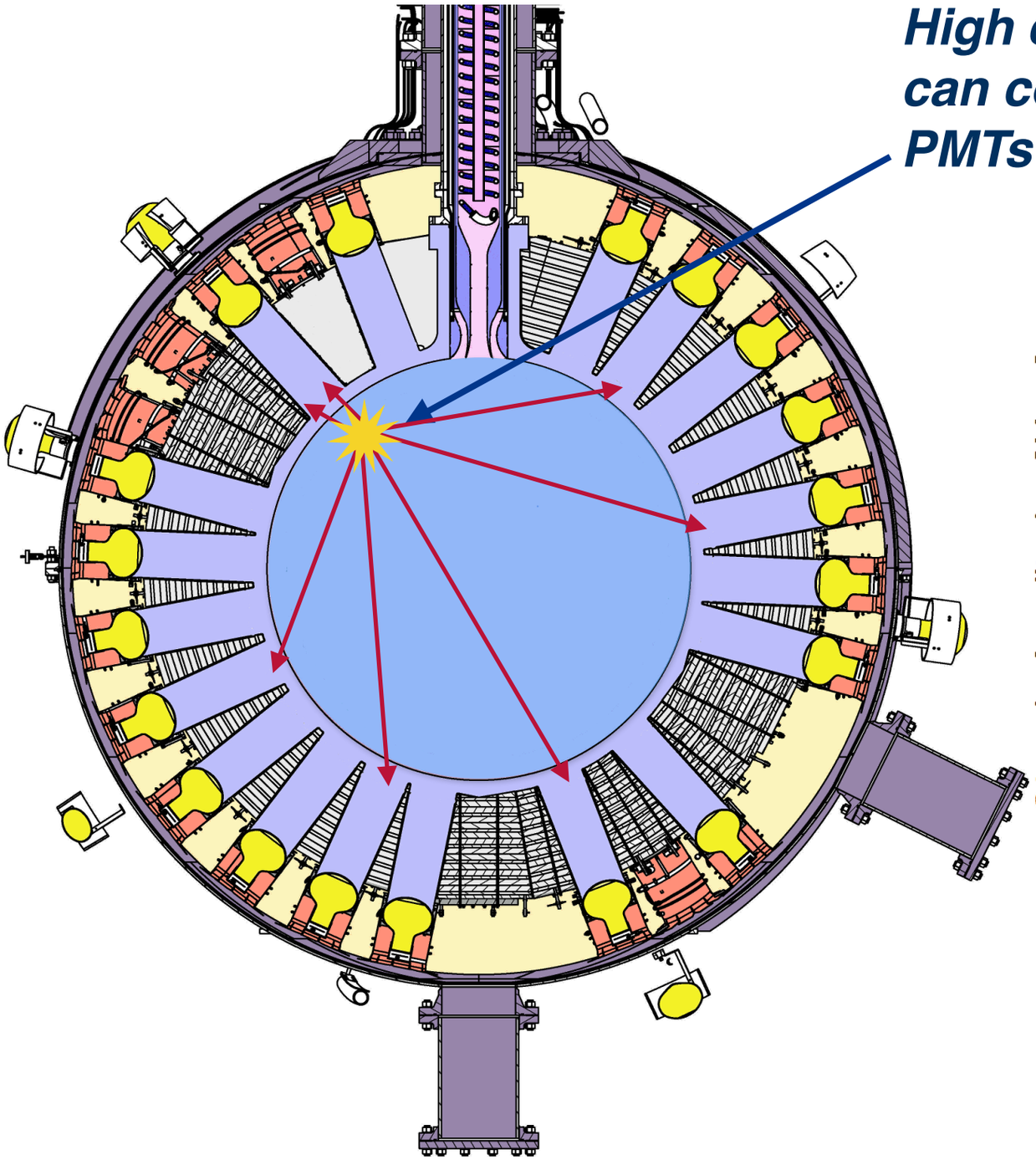


Overview of Signal Saturation

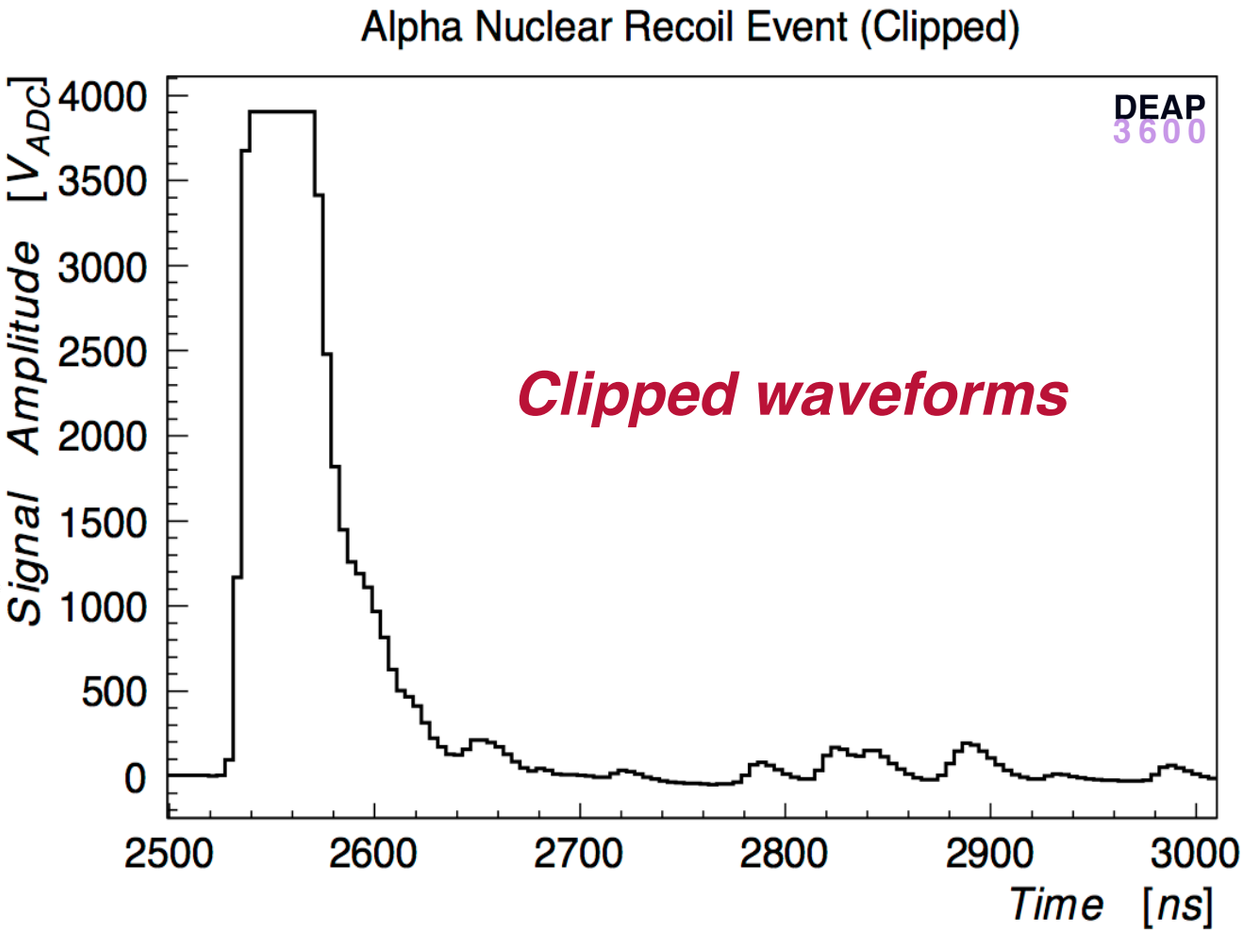


Light from central and/or low energy events spreads isotropically



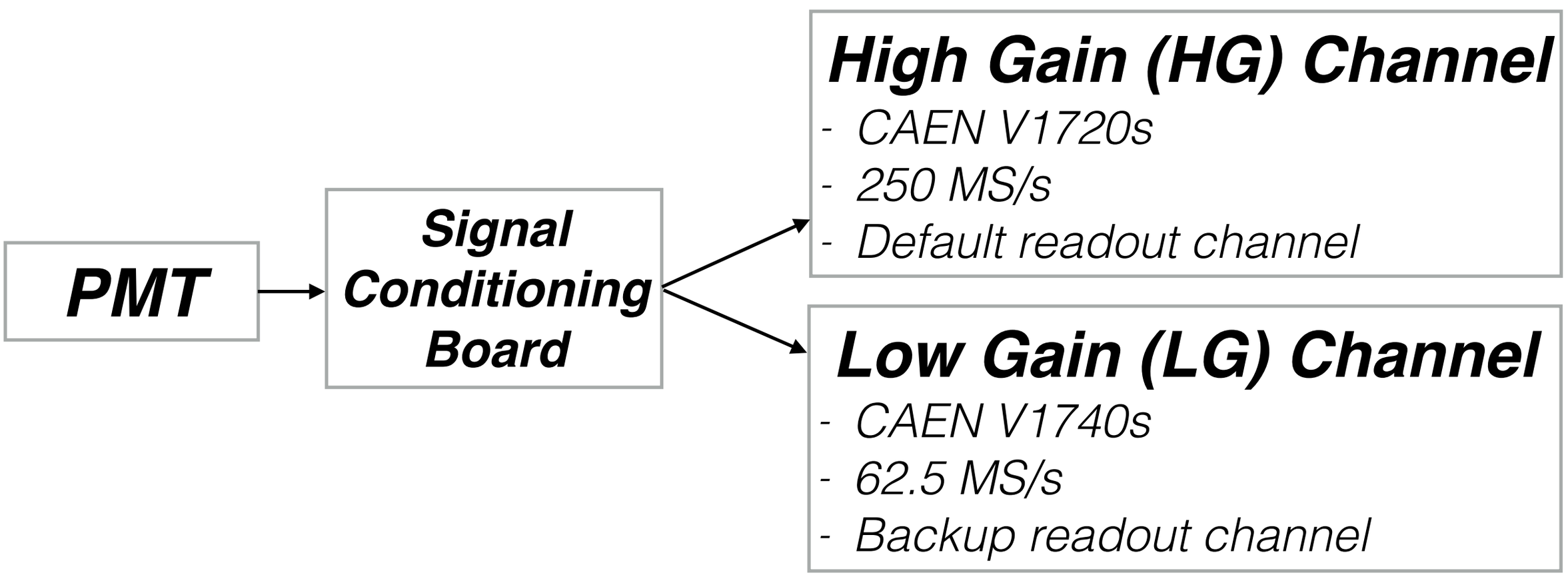


High energy and/or surface events can concentrate more light in a few PMTs



Front-End Electronics for DAQ in DEAP-3600

- Each PMT outputs data to two digitization channels:



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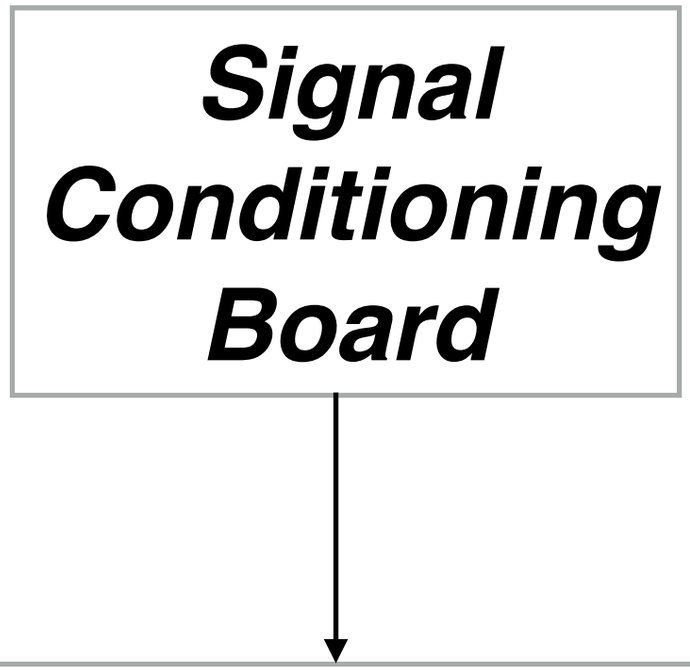
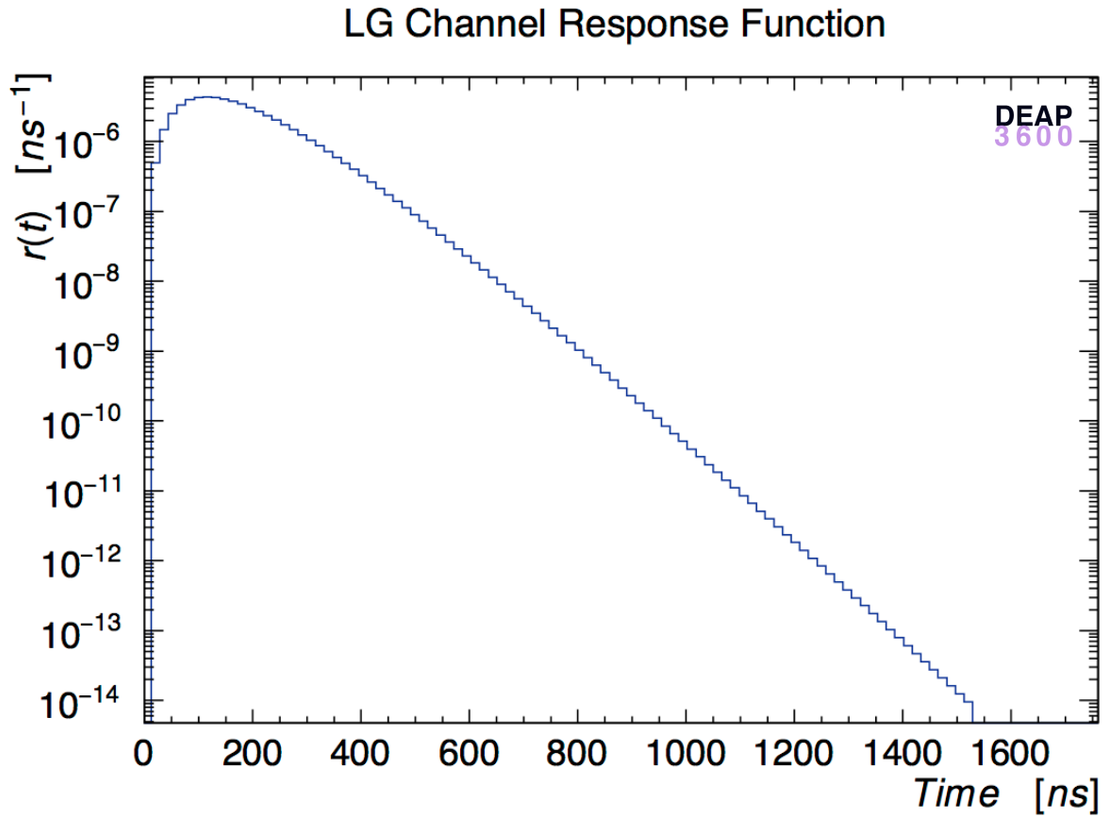
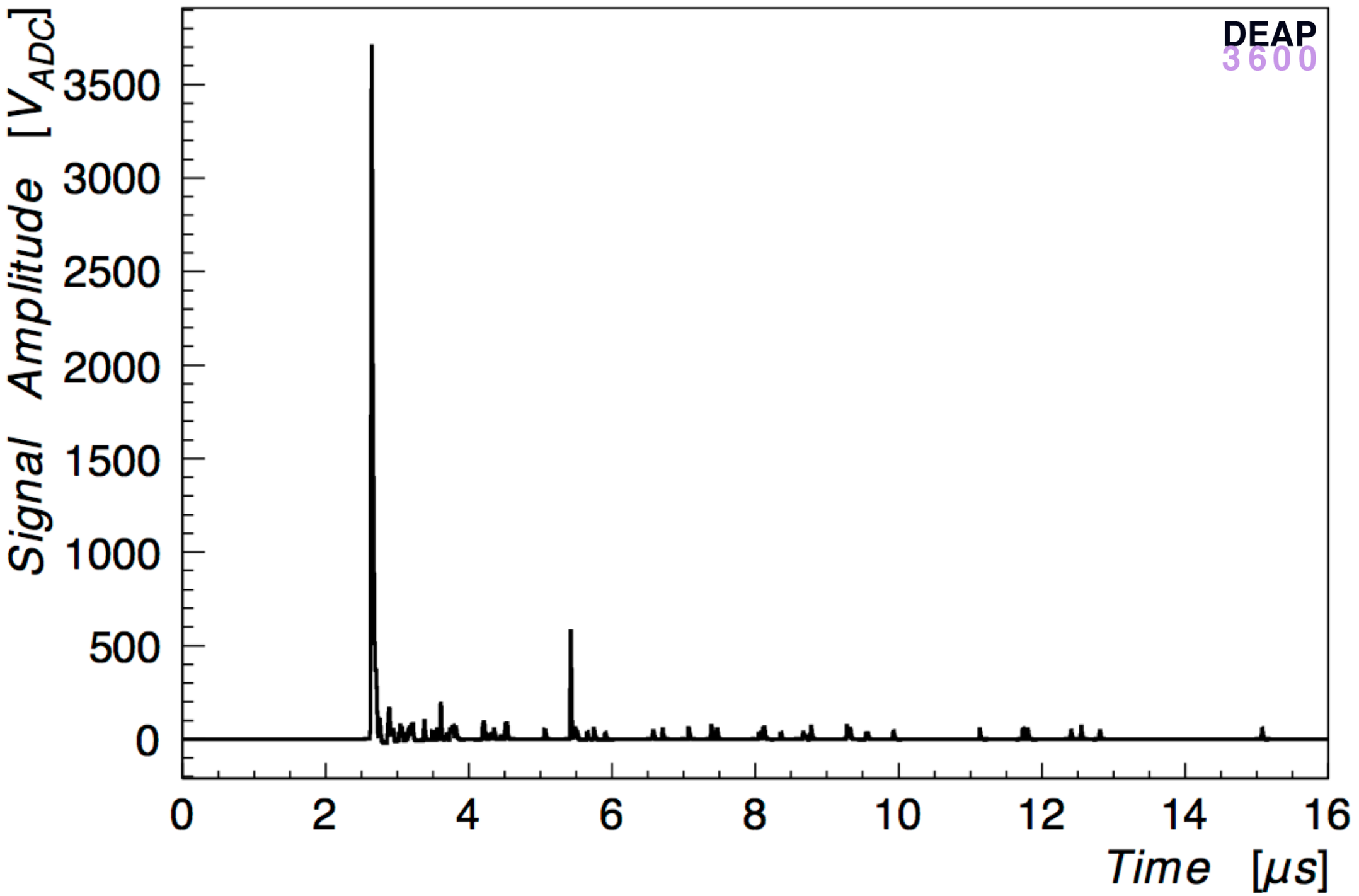


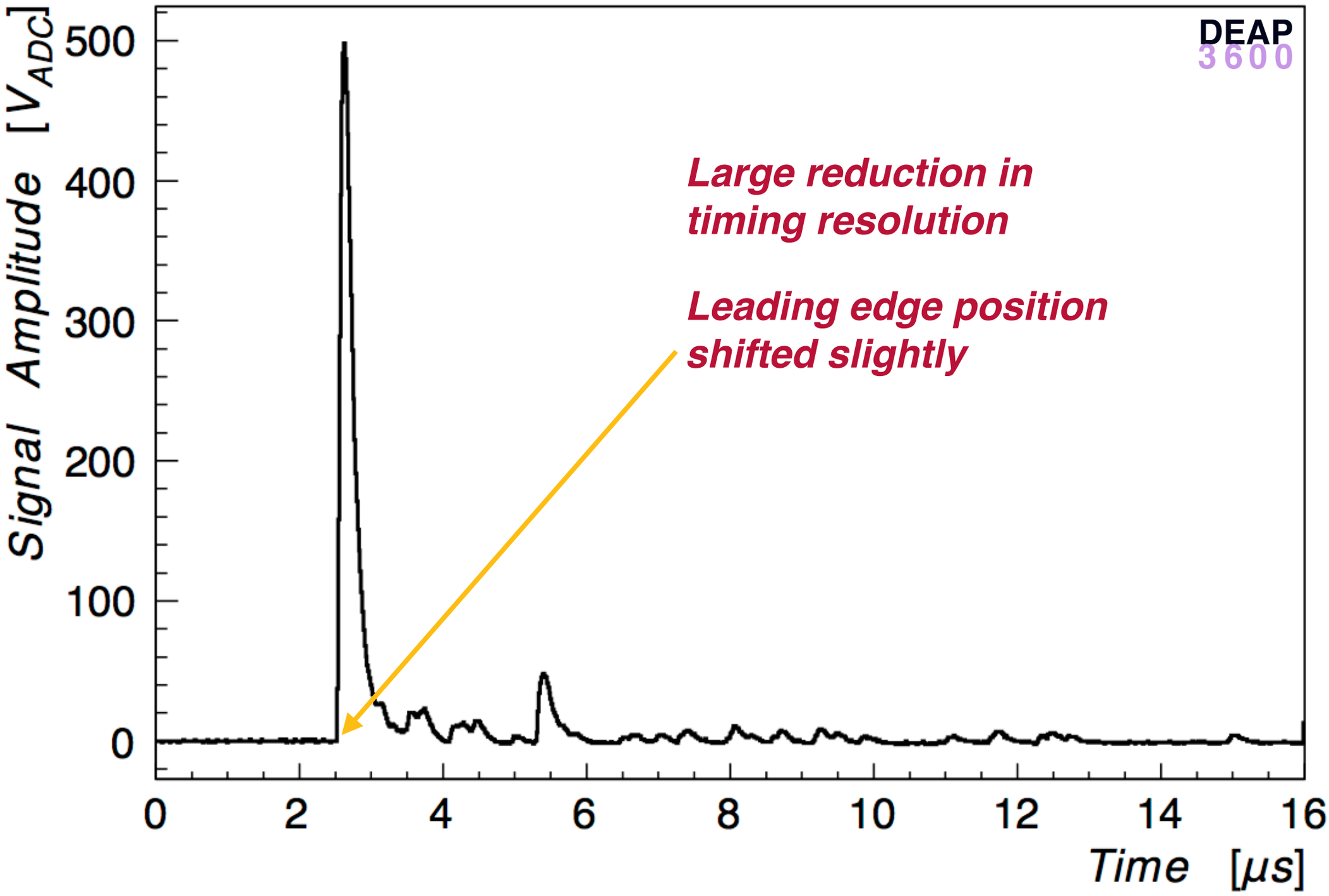


- LG channel is stretched along time axis to account for disparity in resolution

Alpha Nuclear Recoil Event: Raw HG Waveform



Alpha Nuclear Recoil Event: Raw LG Waveform



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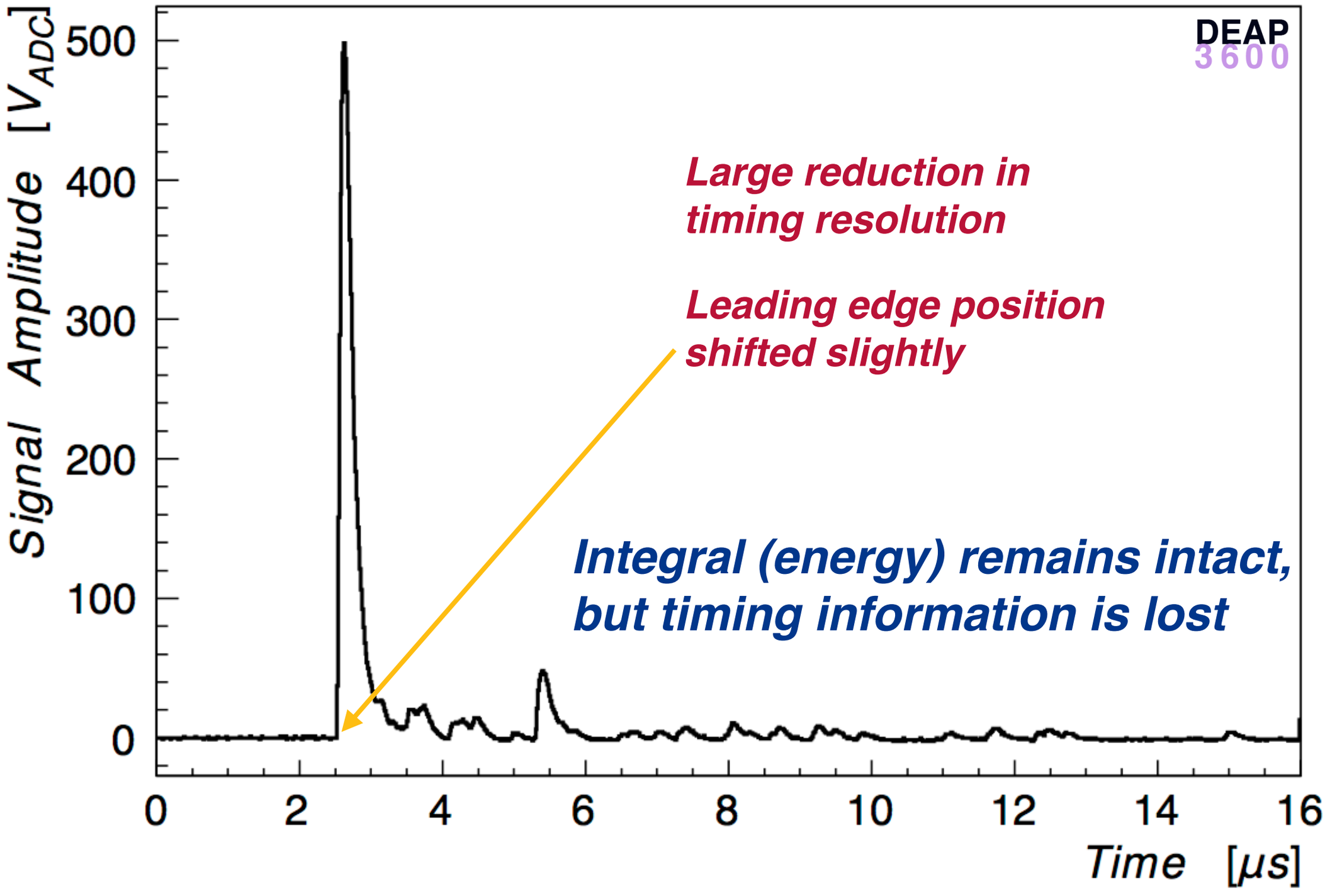


Motivation

- Clipping is problematic for characterizing detector energy response and high energy surface backgrounds

- Goal is to determine clipped portion of waveforms while maintaining time precision

- Waveforms corrected via deconvolution of LG traces

Correction Algorithm

Main Stages of The Algorithm

Find Clipped HG Waveform

Load LG Waveform and Response Function

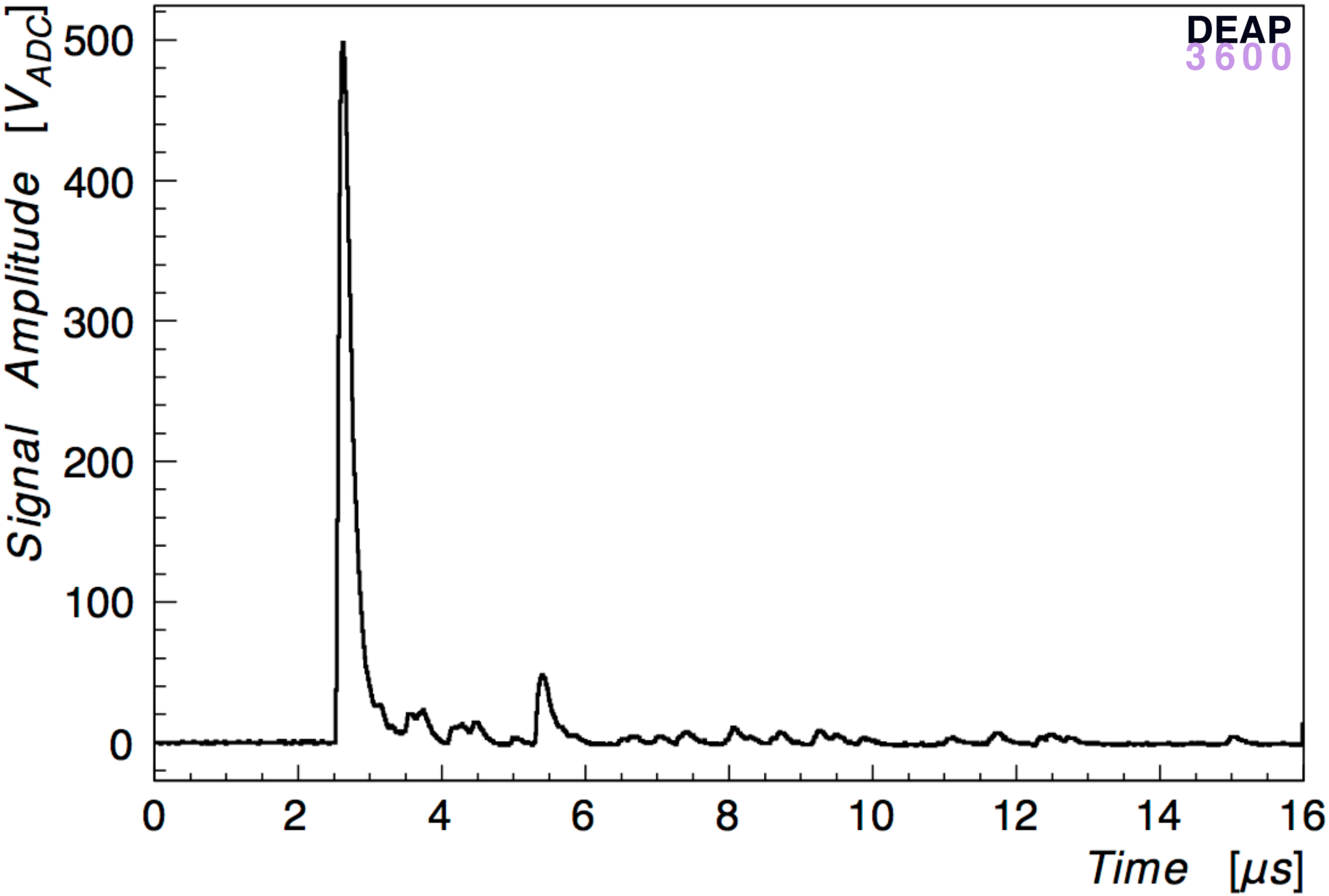
- Modify binning to match HG channel sampling time

Perform Deconvolution on LG waveform

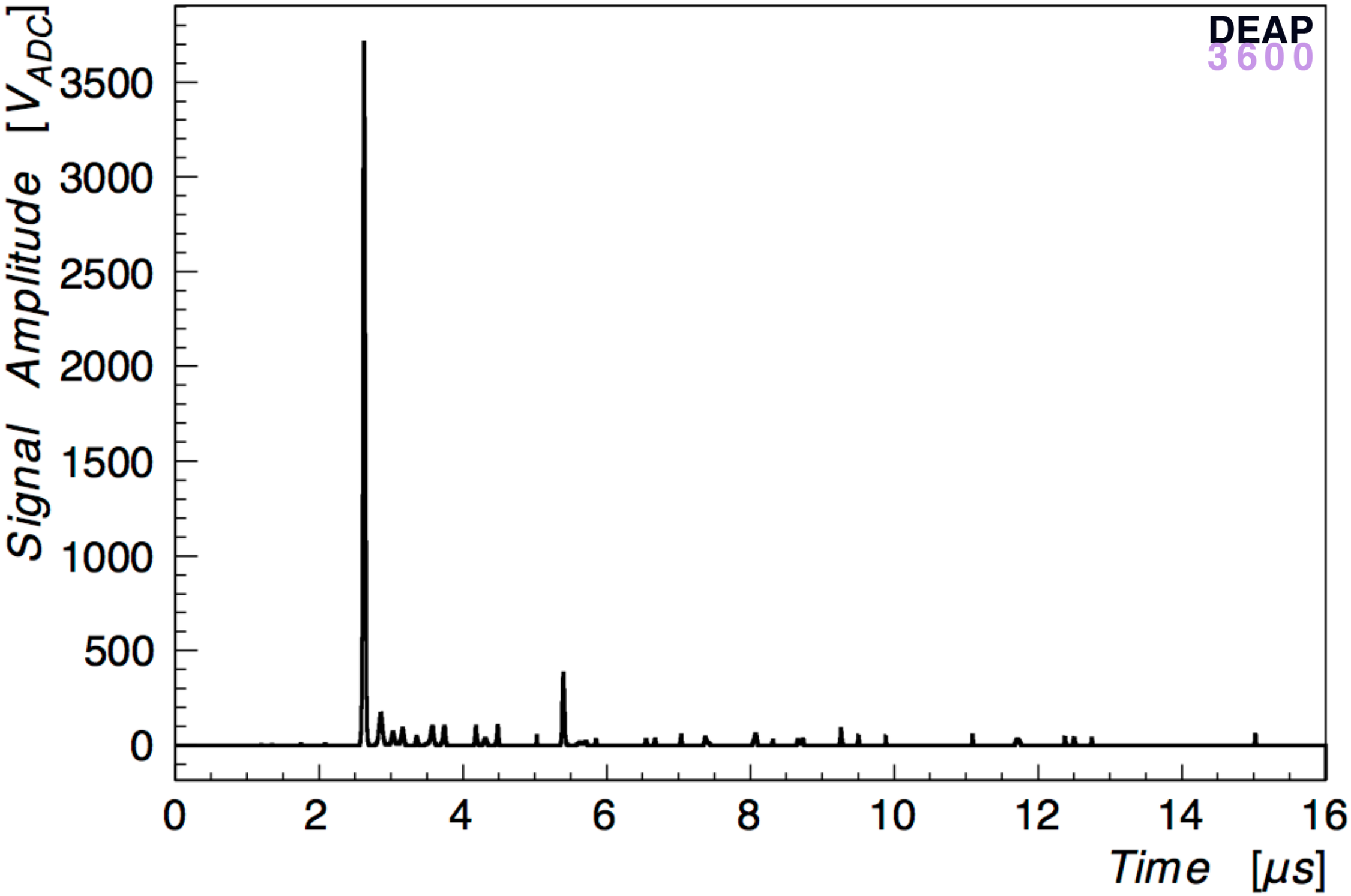
Scale deconvolved LG waveform up to HG channel amplitude

Calculate Energy, F_{prompt} corrections

Alpha Nuclear Recoil Event: Raw LG Waveform



Alpha Nuclear Recoil Event: Processed LG Waveform



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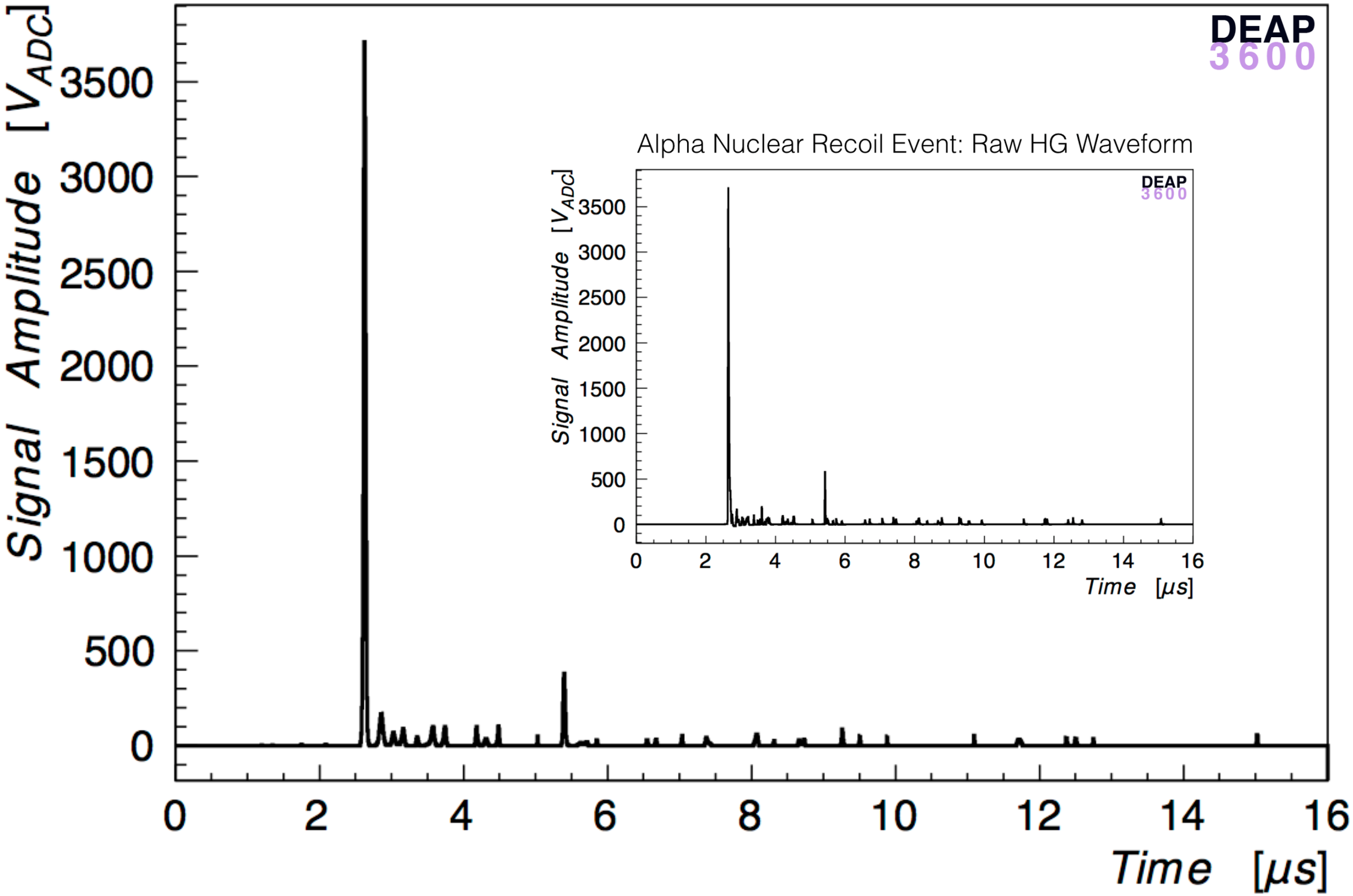
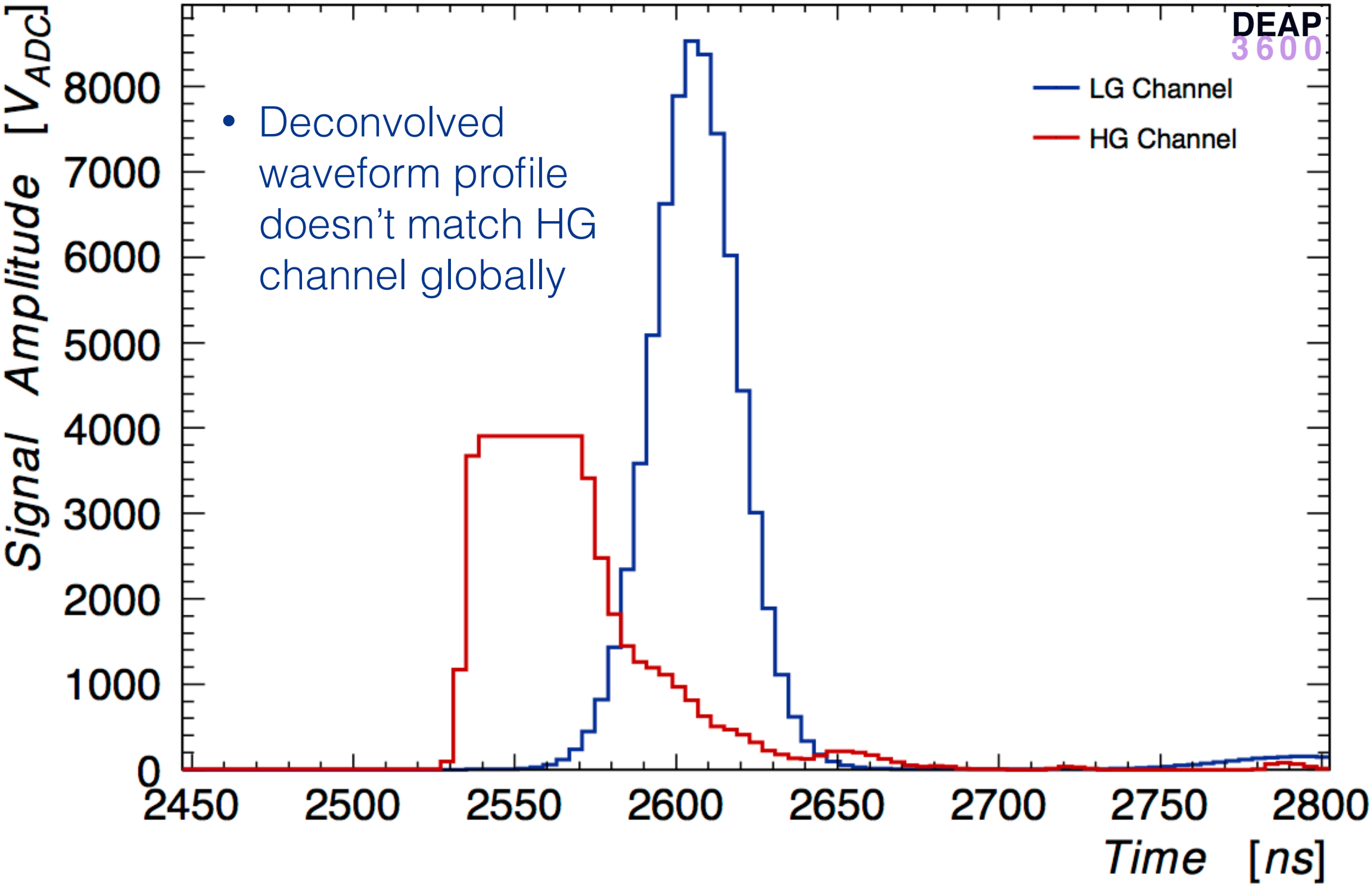


Comparing Clipped HG and Processed LG Waveforms

- Deconvolved waveform profile doesn't match HG channel globally



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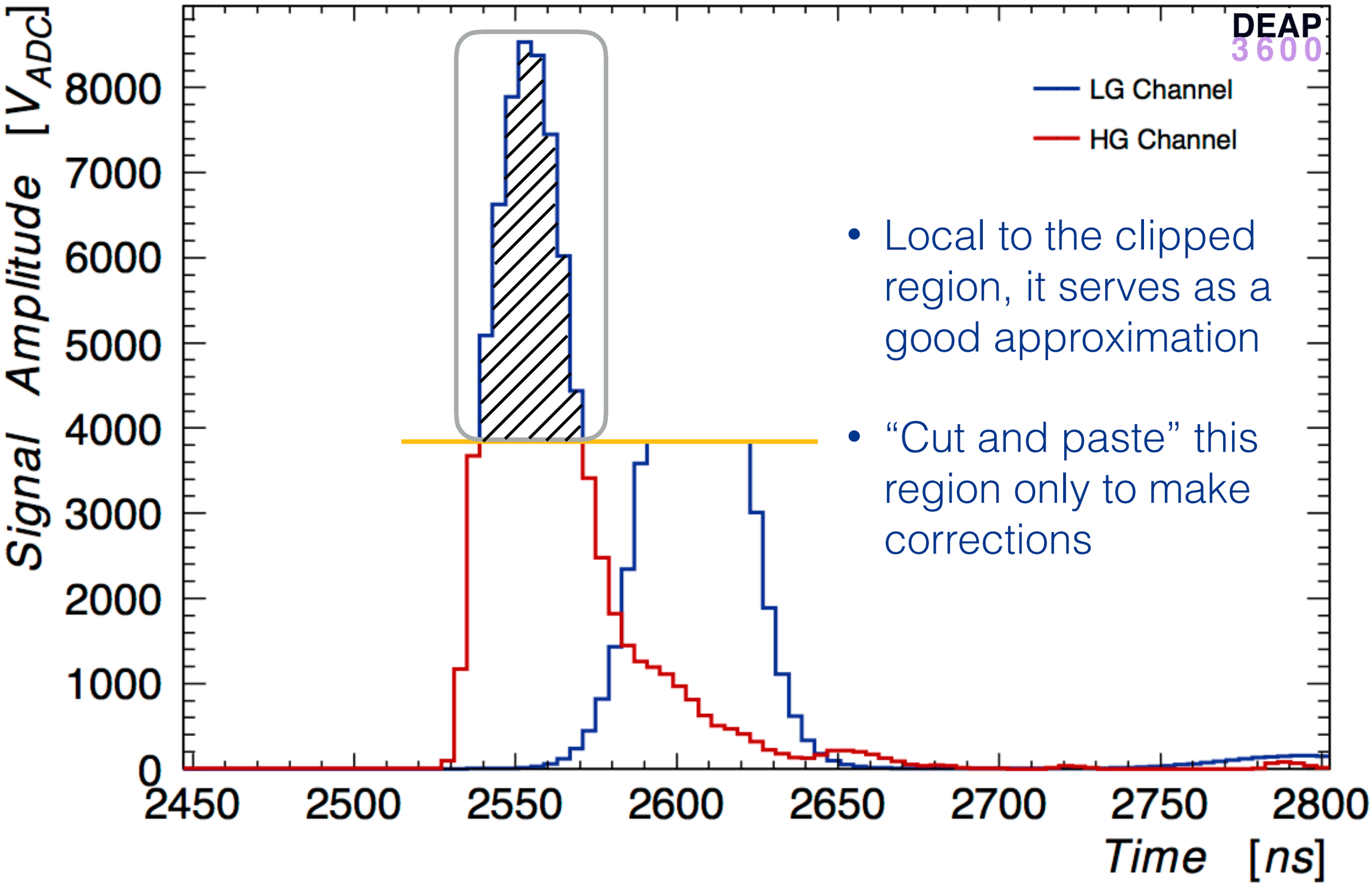
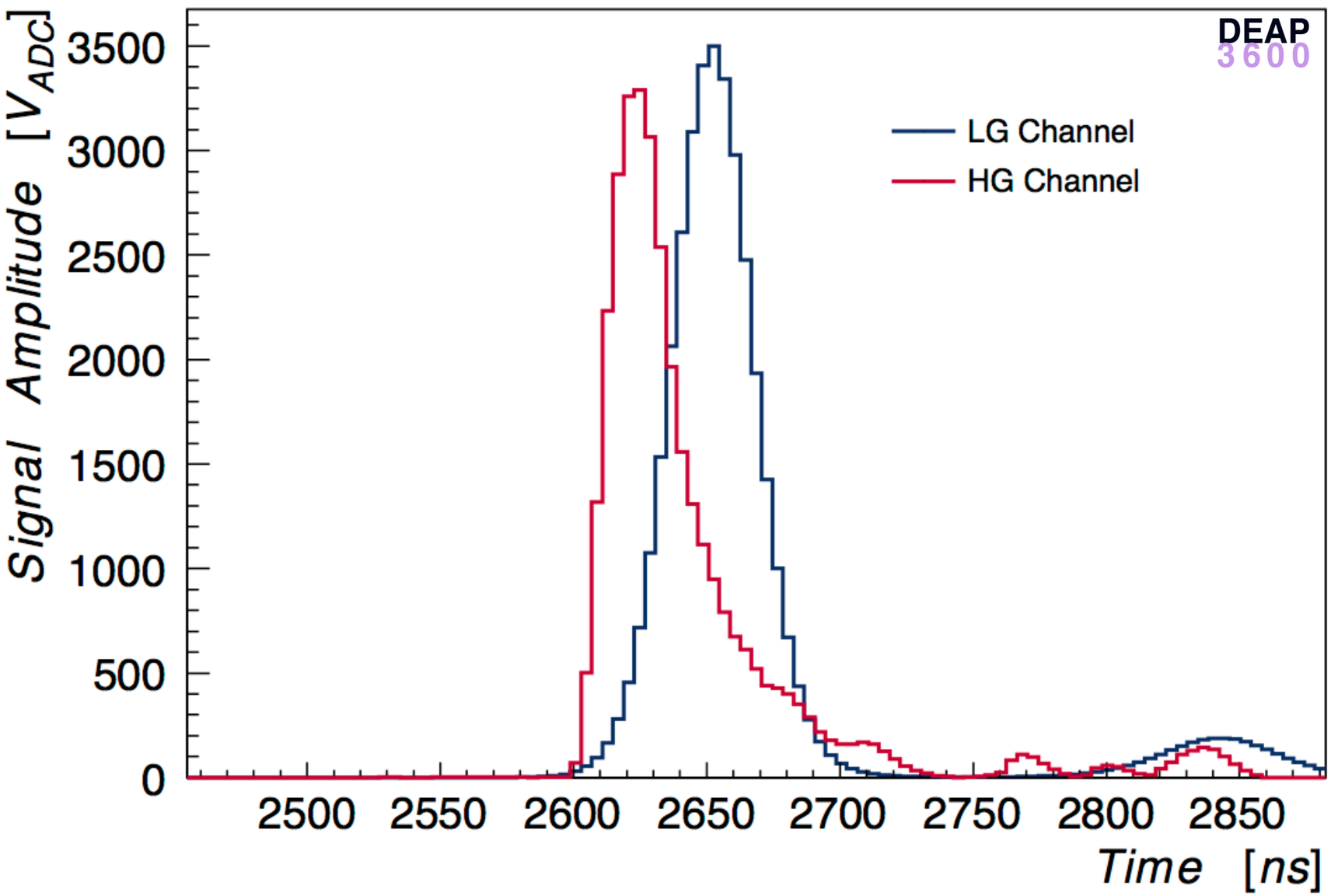
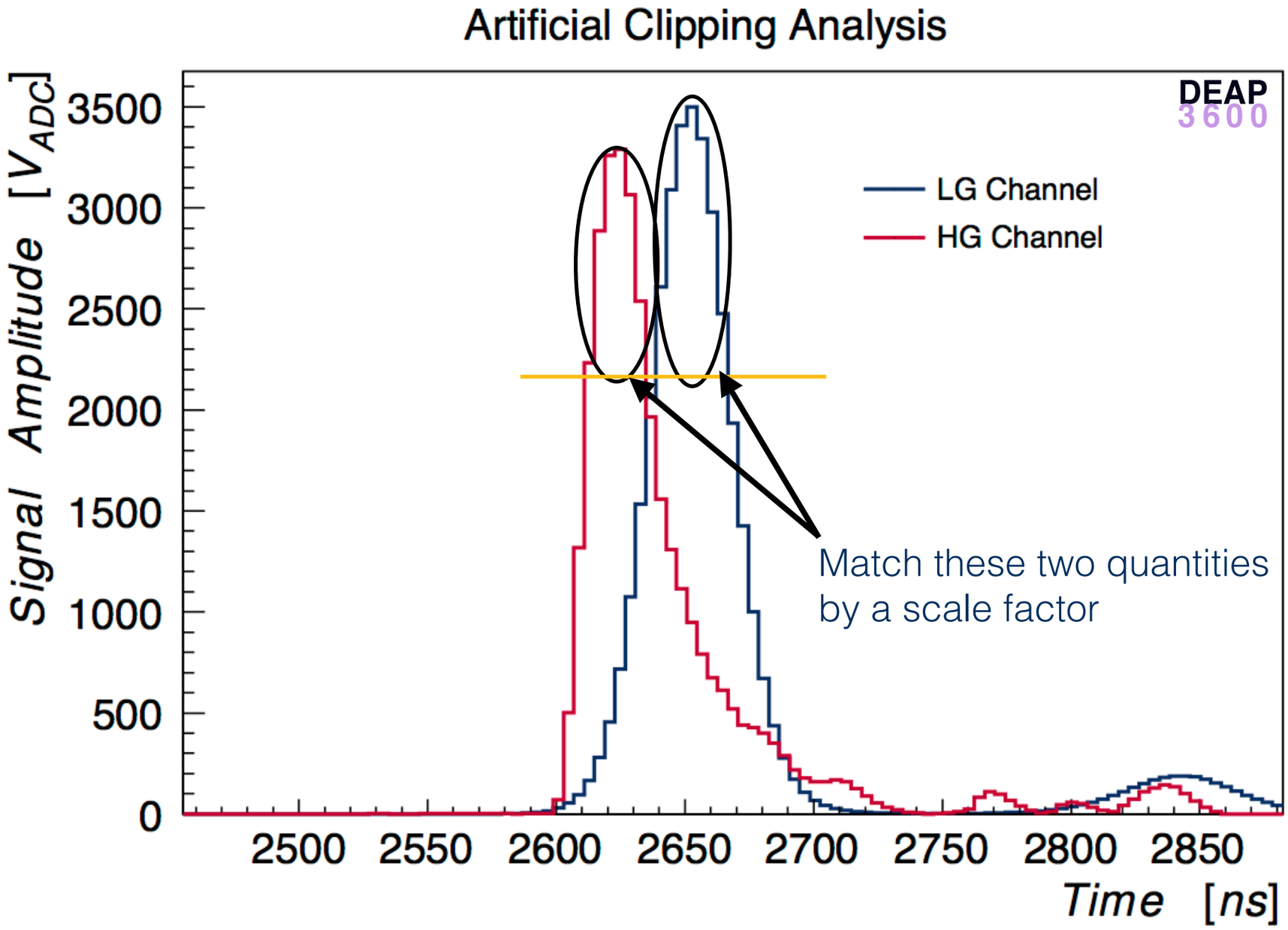


- Local to the clipped region, it serves as a good approximation
- "Cut and paste" this region only to make corrections

Artificial Clipping Analysis



- To test this idea, compute artificially clipped energies in complete HG pulses
- Compare to artificially clipped energy in processed LG counterparts



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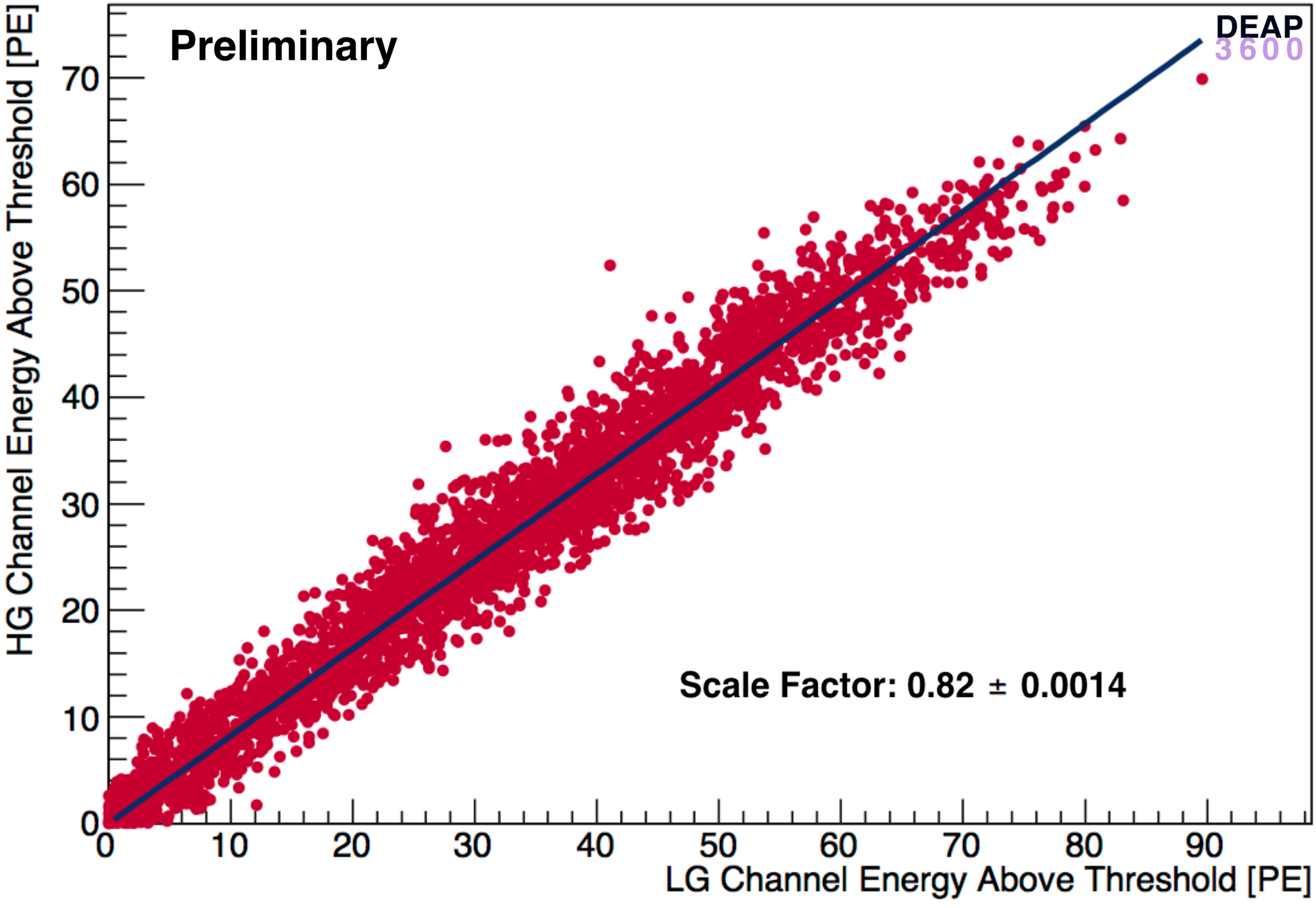
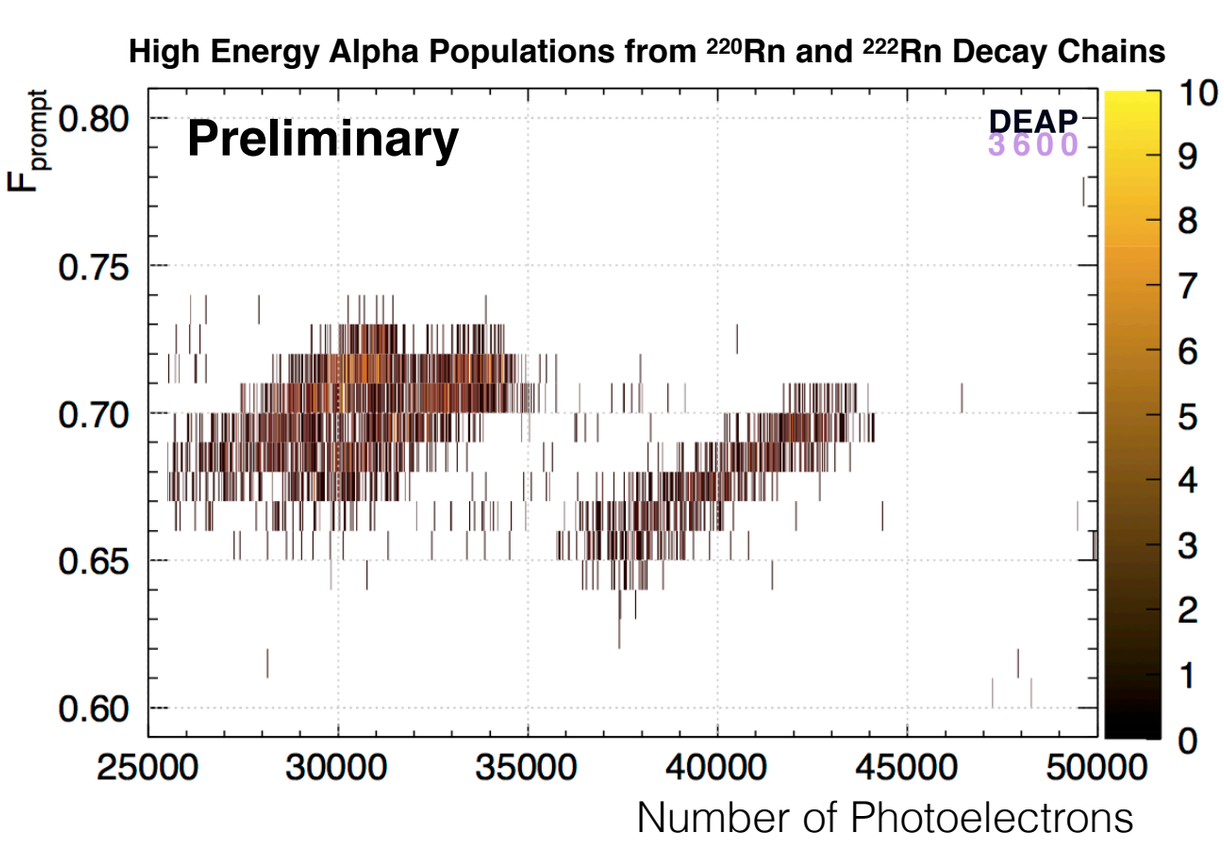
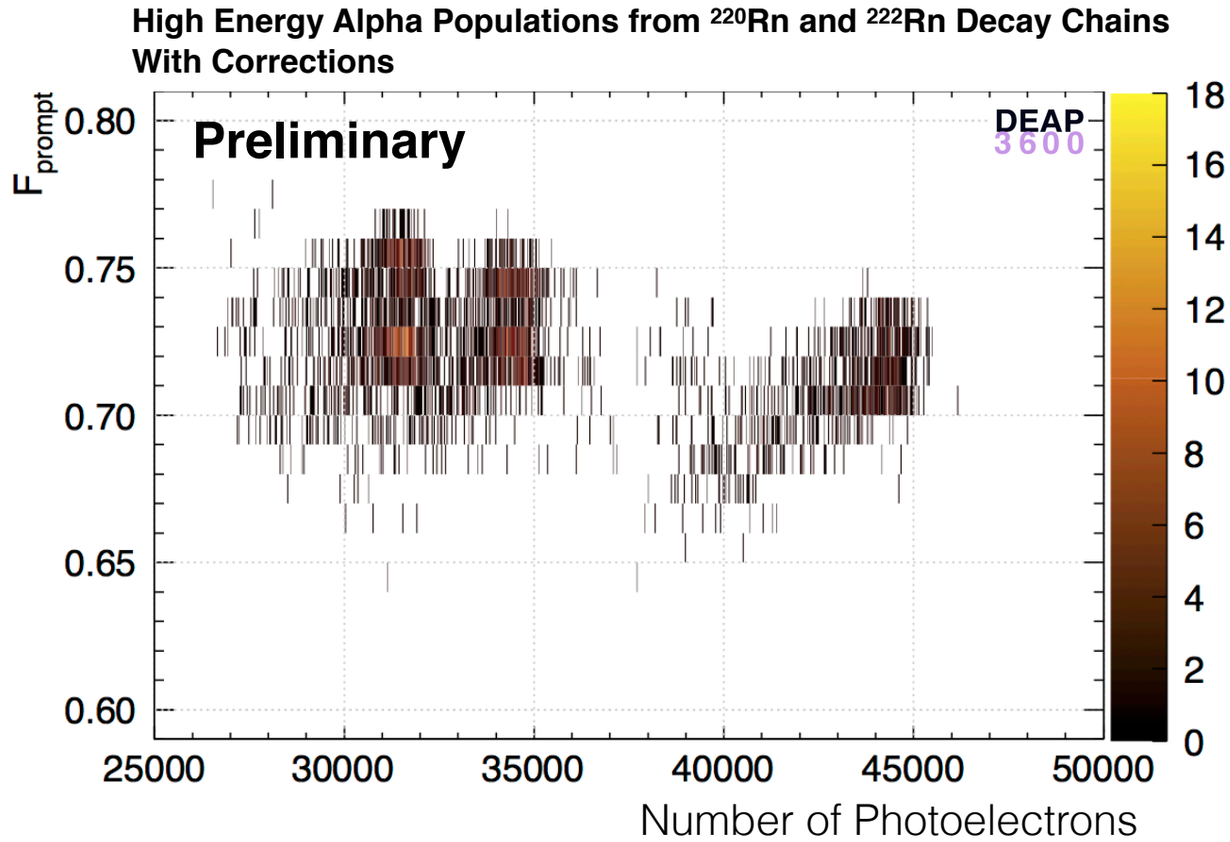
Measuring the LG to HG Energy Scale Factor



Corrections to Alpha Events

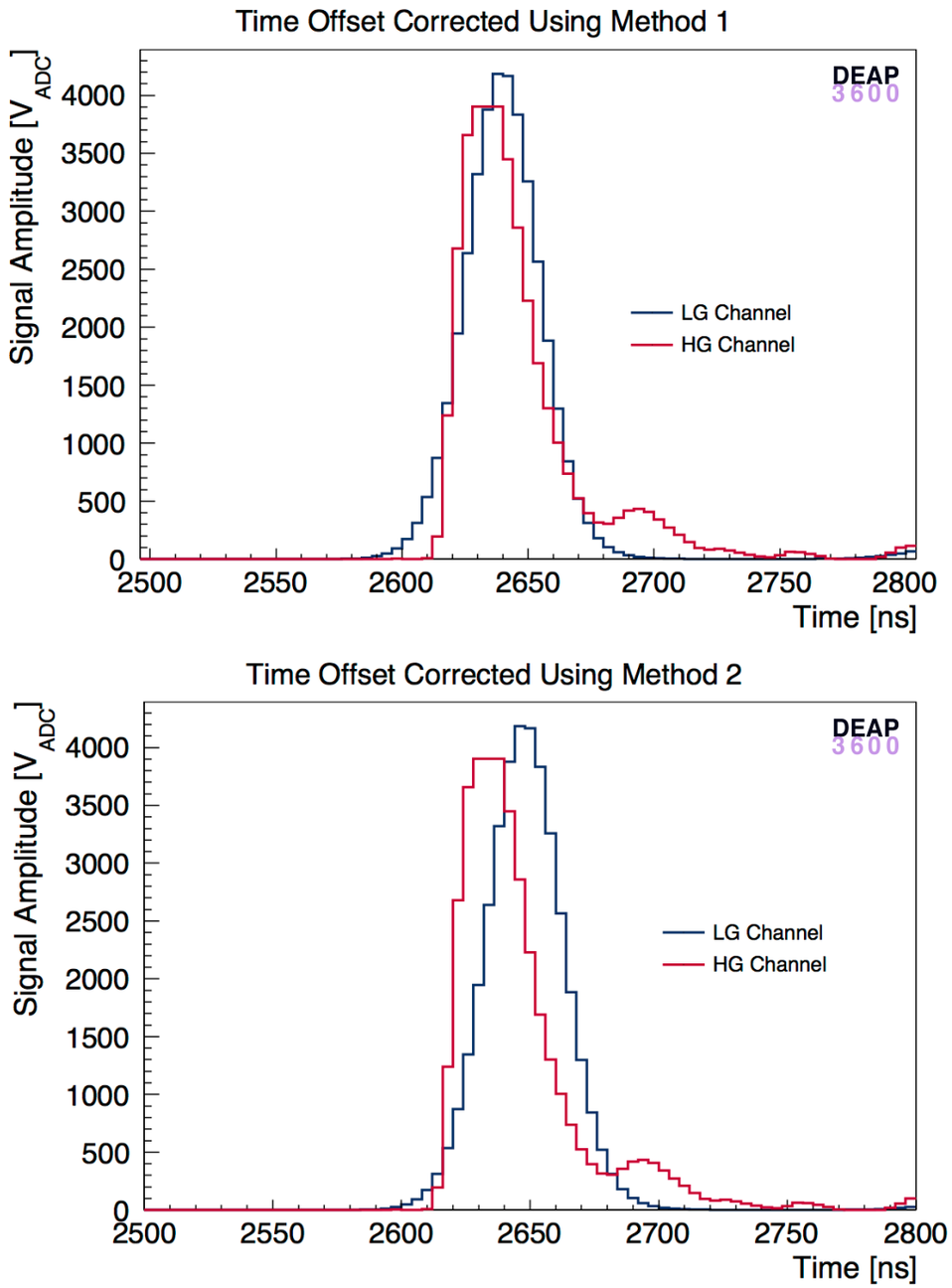




- Clipping spreads Alpha populations into diagonal distributions
- Corrections alleviate most of the spreading, though further refinement of the method is ongoing

Extra Slides

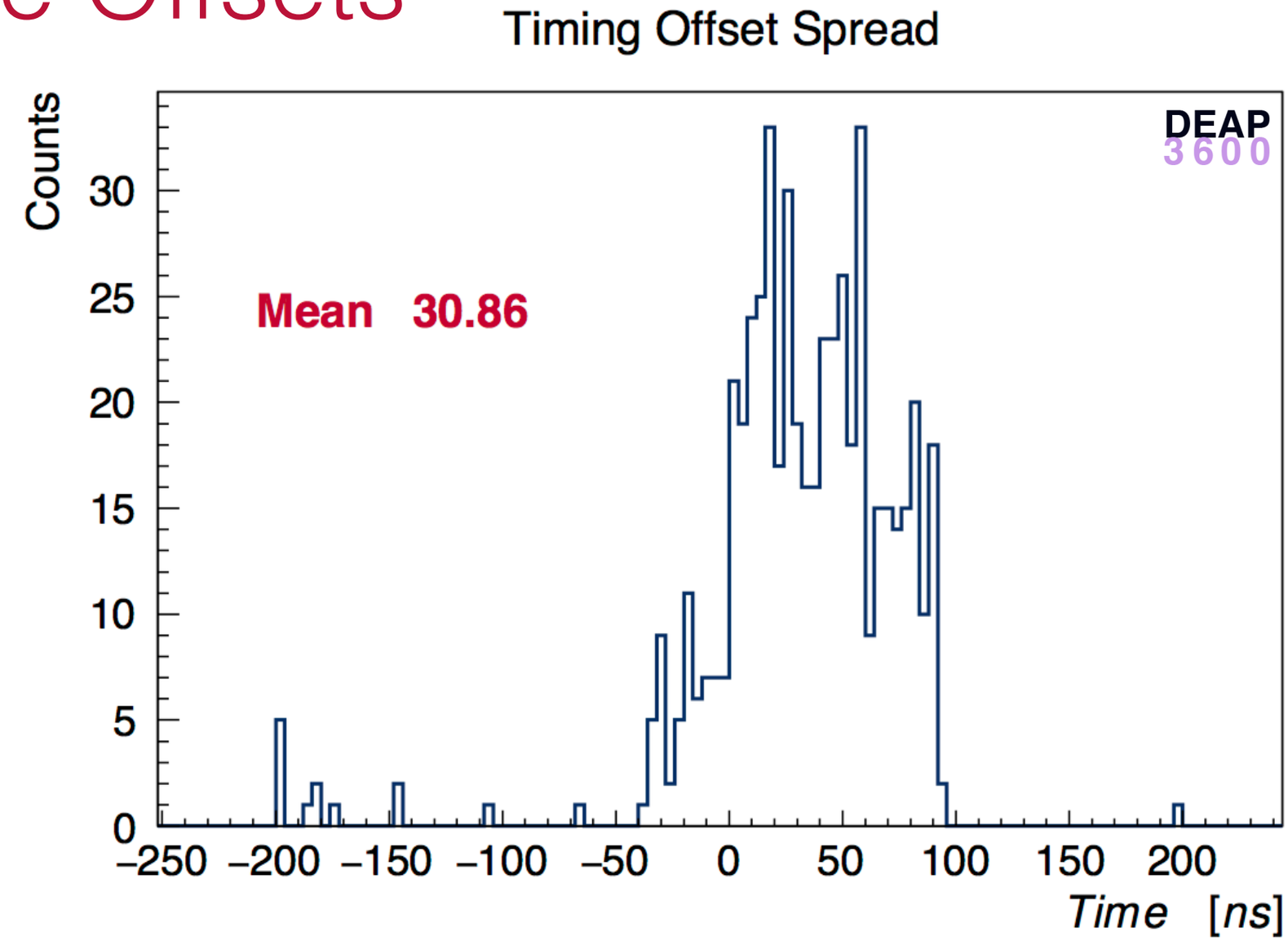
Time Offsets



- Method 1: Find and list time difference between all combinations of the top 3 dark noise peaks in each waveform. The mode of this list is the true time difference

- Method 2: Perform correlation calculation, location of minimum is true time difference

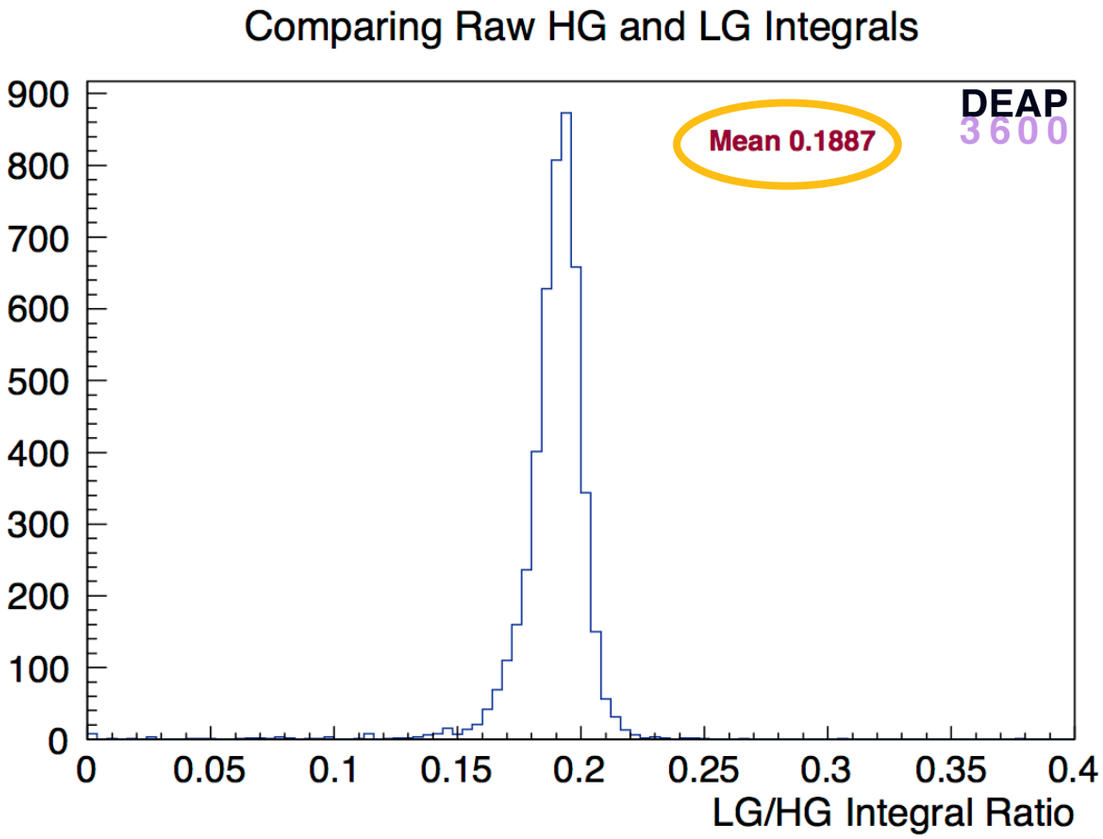
Time Offsets

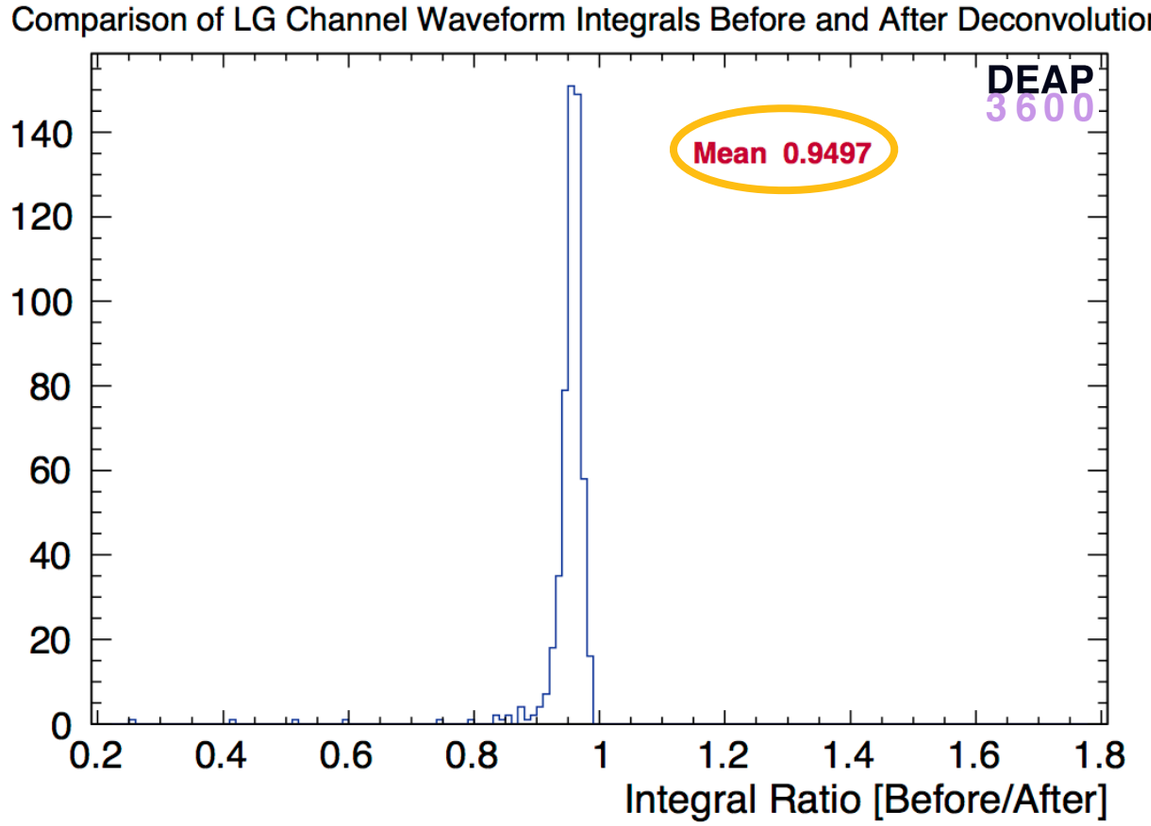


- Histogram showing the distribution measured time differences using method 1 in 4 ns time bins

Rescaling After Deconvolution

- Time resolution restored after deconvolution, but waveform integrals in LG and HG channels still differ
- Want to show proportionality between HG, LG (raw), and LG (processed) waveforms





Rescaling factor: $\frac{0.9497}{0.1887}$