

Template Based SiPM Signal Processing

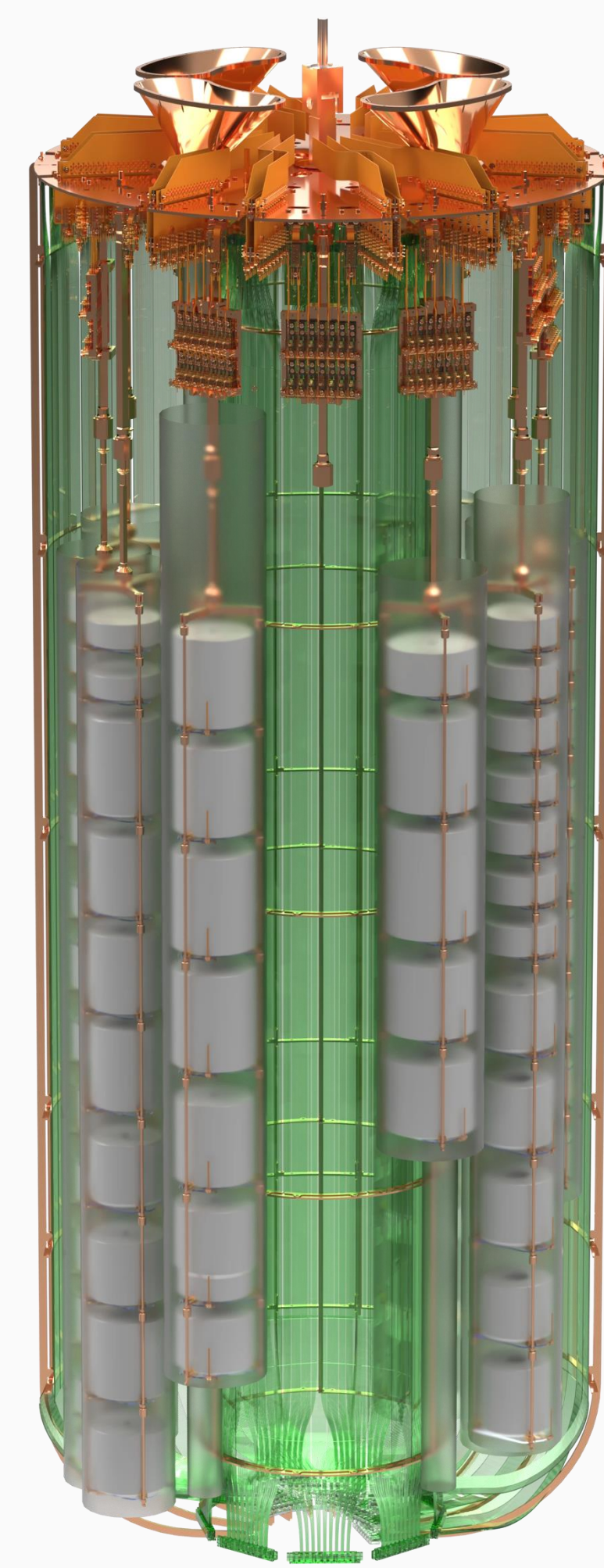
George Marshall (University of Washington),
on behalf of the LEGEND Collaboration



Background

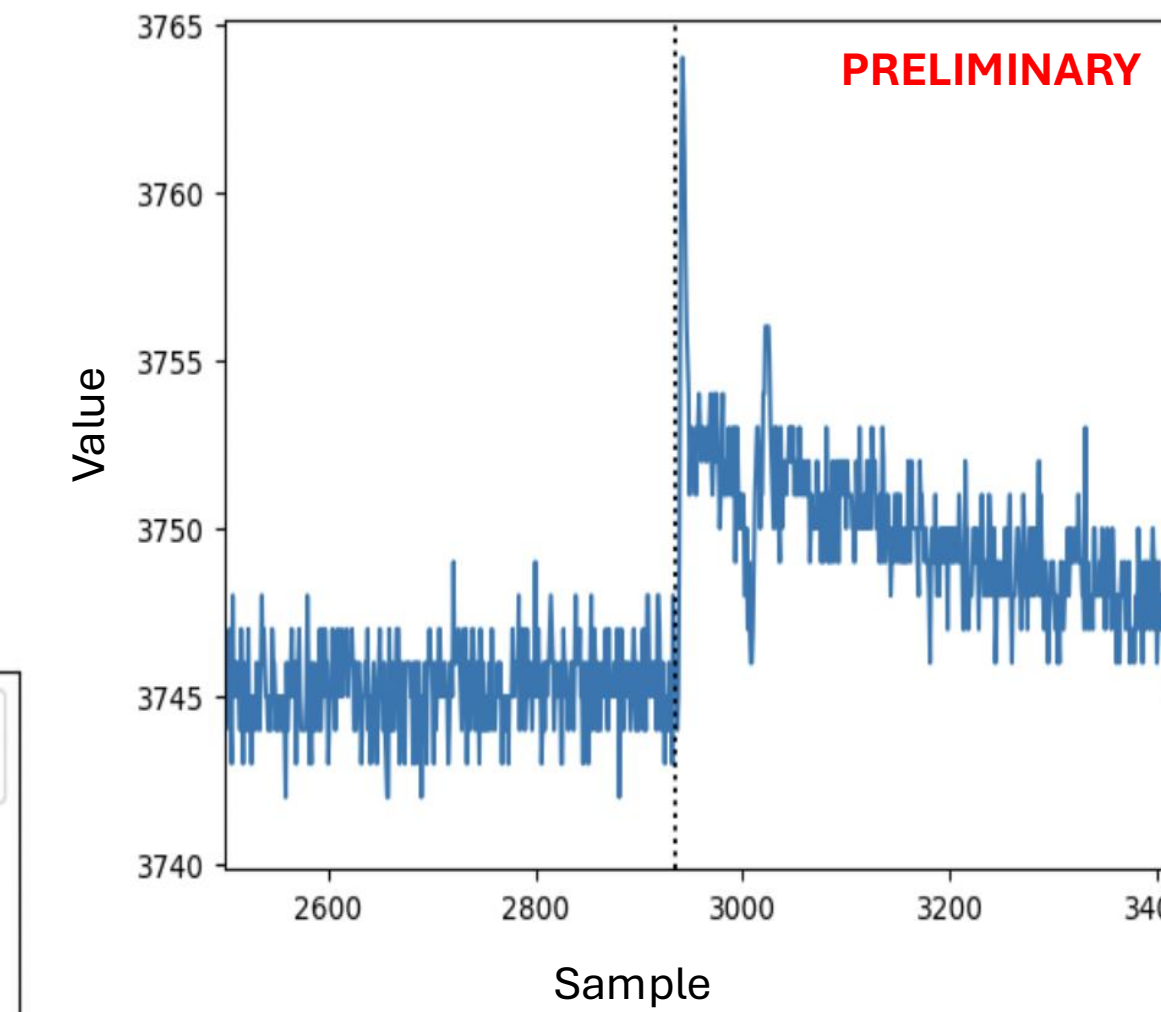
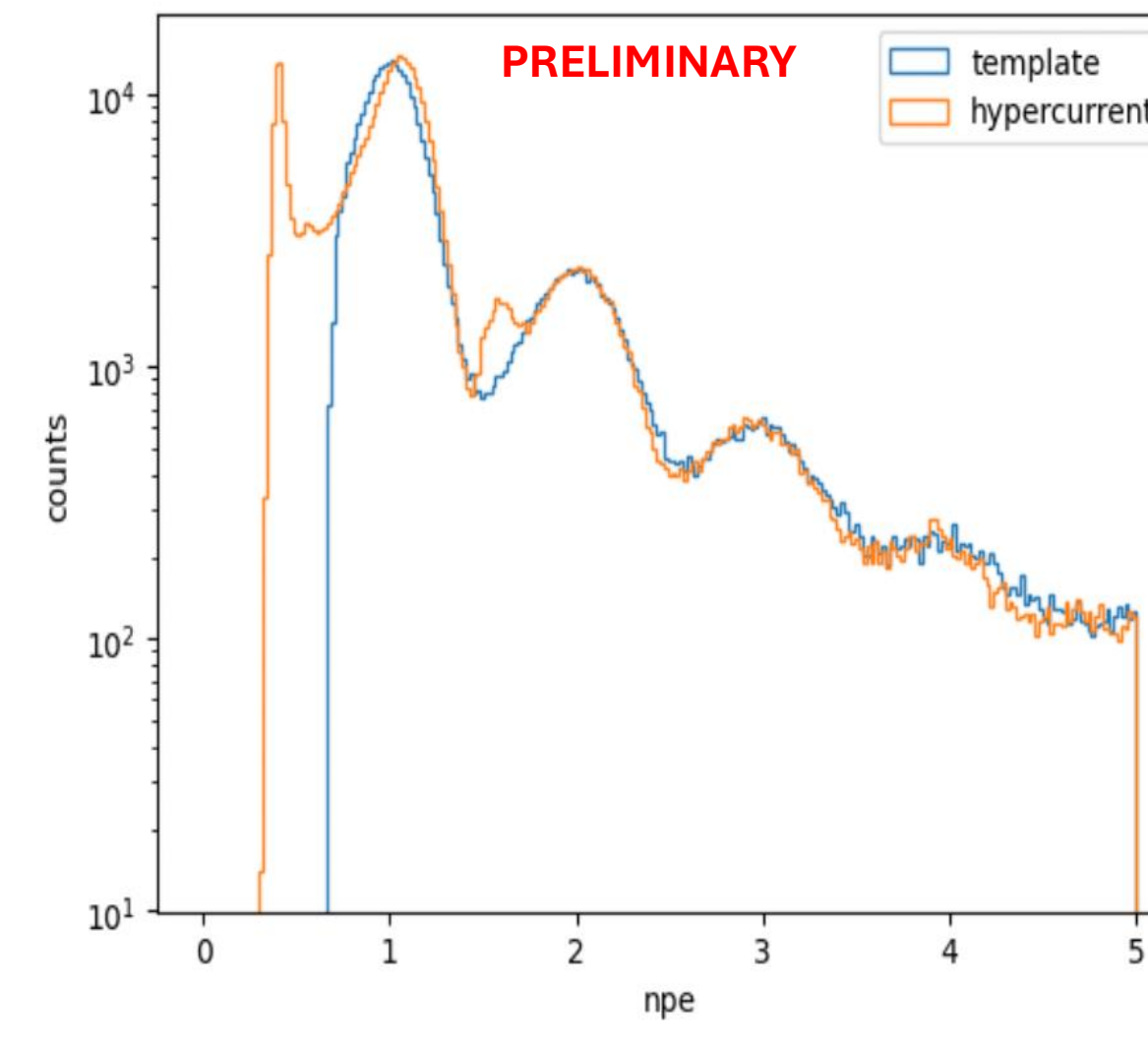
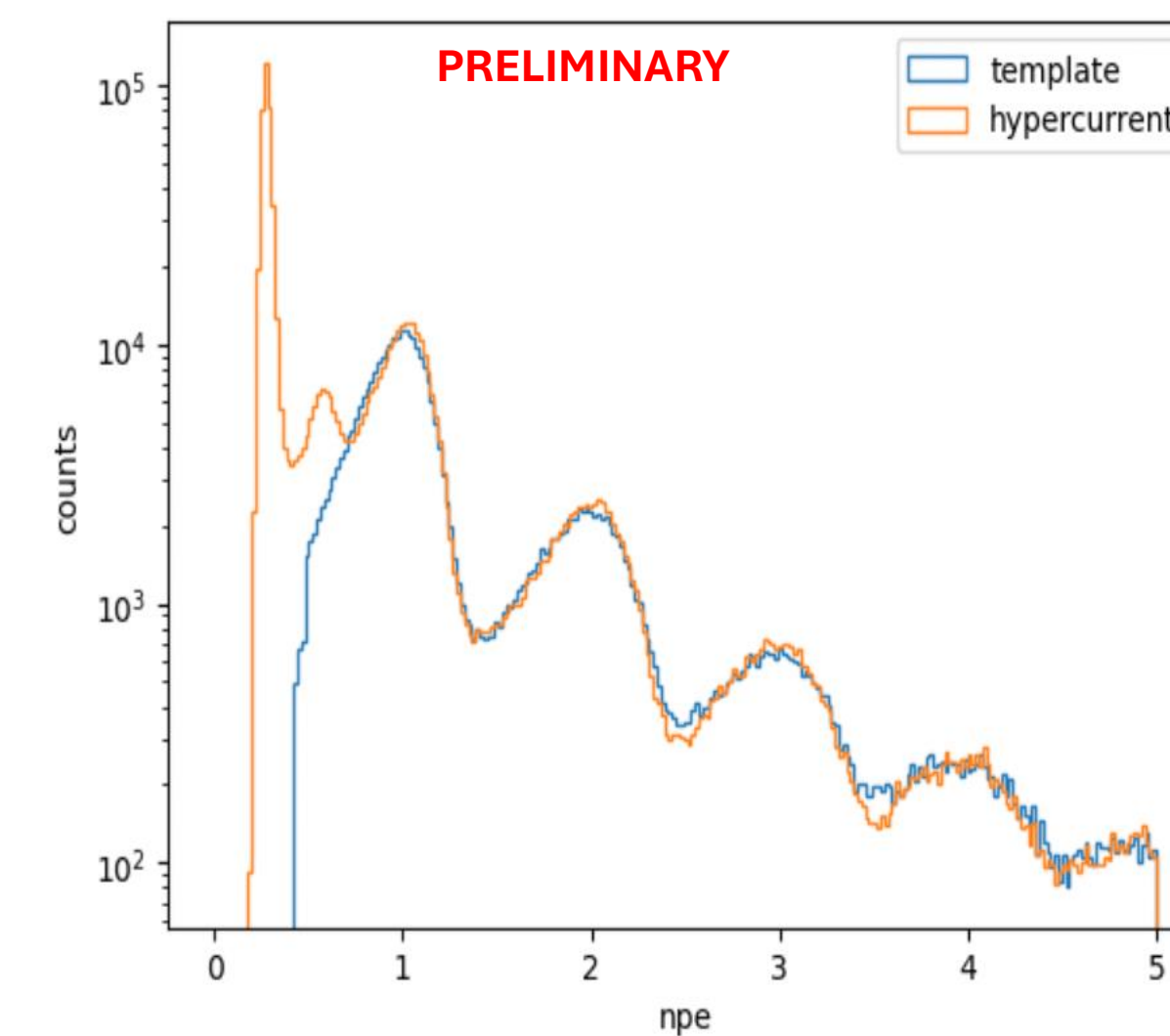
- LEGEND-200 is searching for neutrinoless double beta decay
- Heart of the detector is an array of 60 High Purity Germanium detectors
- These are immersed in liquid Argon and surrounded by wavelength shifting fibres which are coupled to SiPMs
- Allows us to veto any events where we see light

- 60 SiPM channels
- 9 sipms per channel each with own:
 - Rising edge shape
 - Decay constants
- Broadly 3 different SiPM decay shapes due to manufacturing
- Generally have to work on derivative due to these different decays and to handle pileup



Results

- Ran over 1 run and compared spectra with old method (hypercurrent) against new template method
- Template method performs comparatively for good channels
- Template method gives more gaussian spectra for bad channels
 - Fewer extra peaks
 - Less tailing



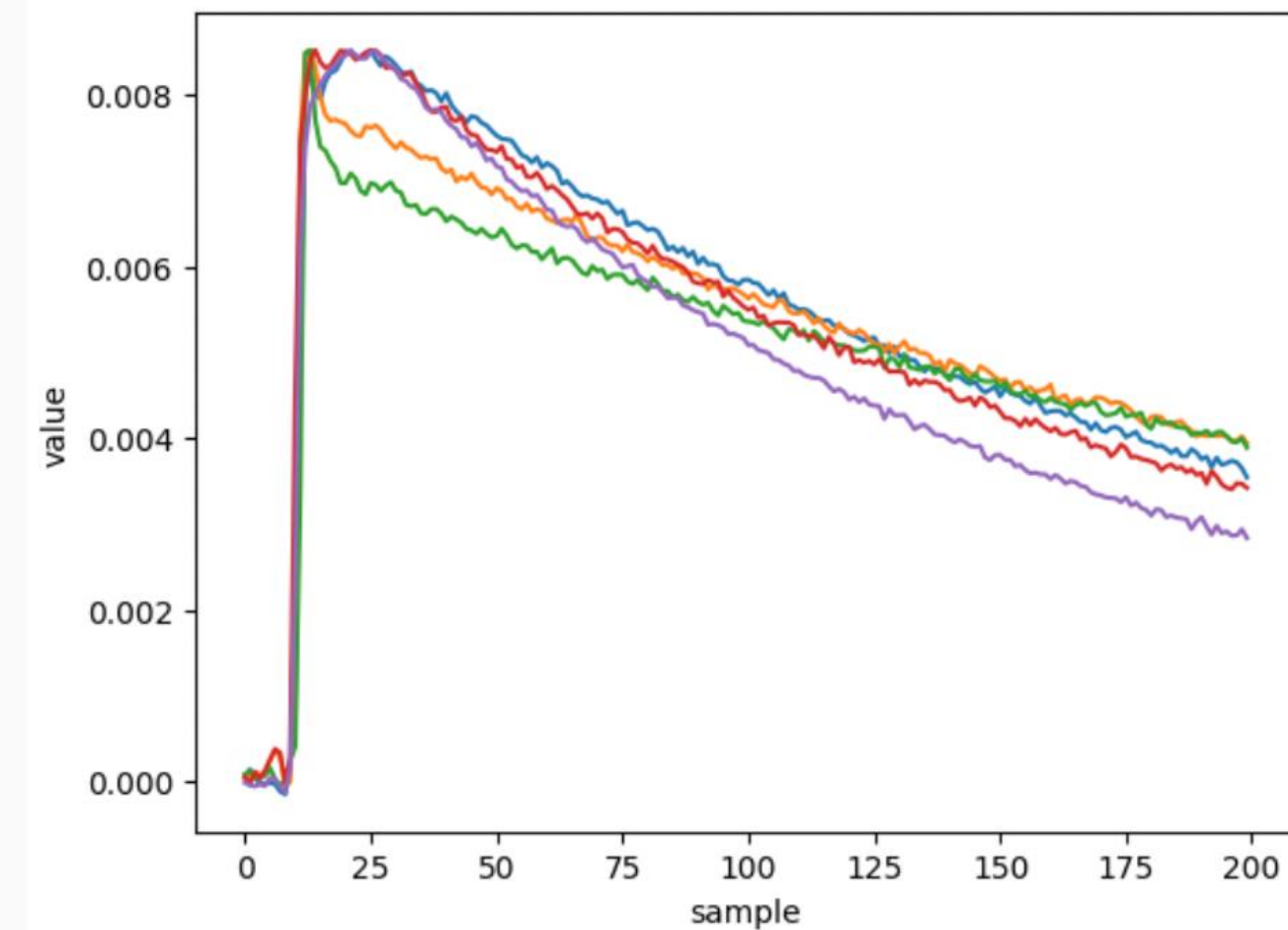
- Template method able to reject crosstalk on baseline/tail
 - Should enable use to improve efficiency of system

Next Steps

- Scale this method out to more data
- Evaluate crosstalk rejection
- Evaluate efficiency improvement

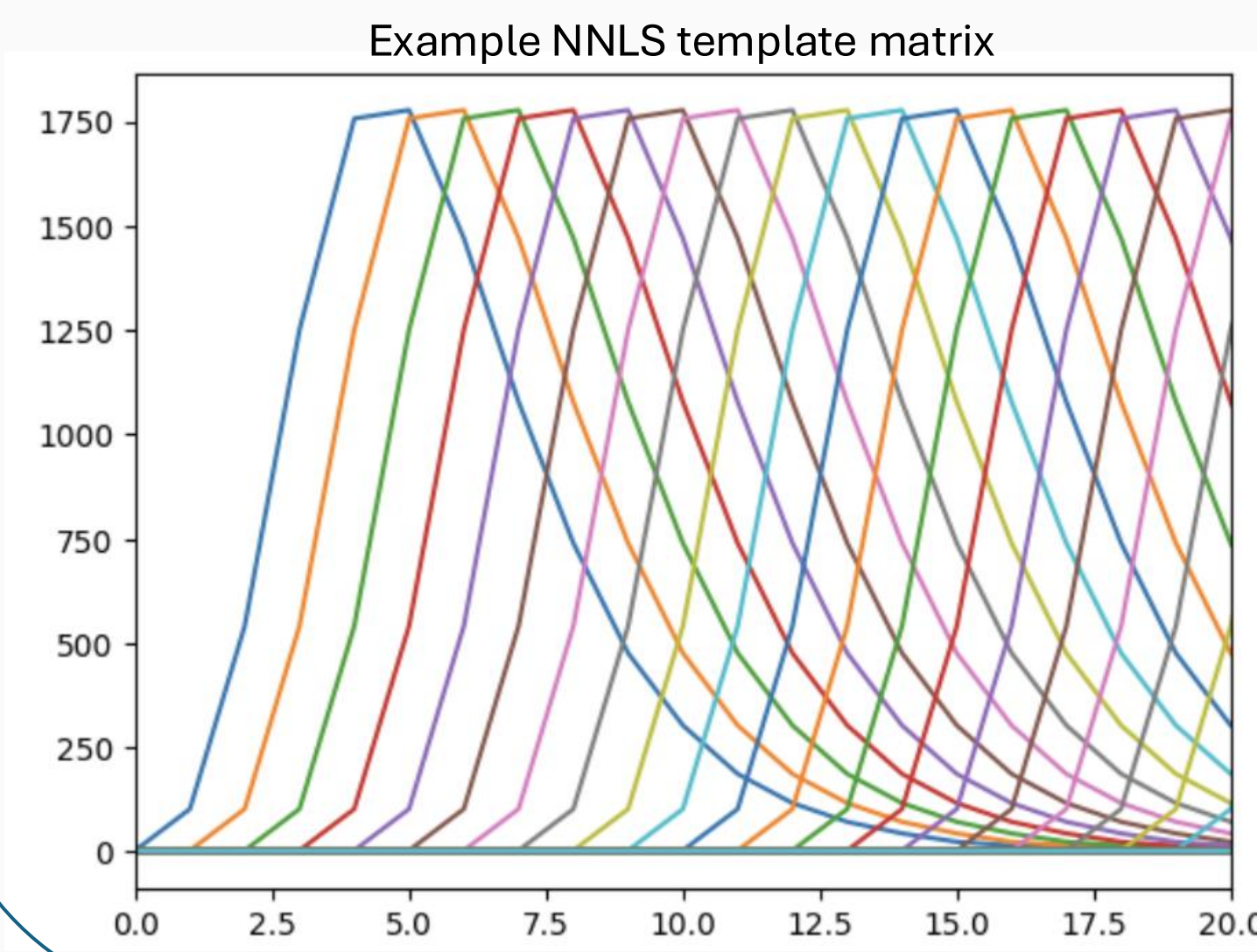
Template Building

- No dedicated flasher/ calibration source – build templates directly from data
- Use Kmeans clustering to separate out different SiPMs up to a max of 9 per channel
- Average each cluster and upsample using novel t0 less technique
- Fit decay tail with double pole zero

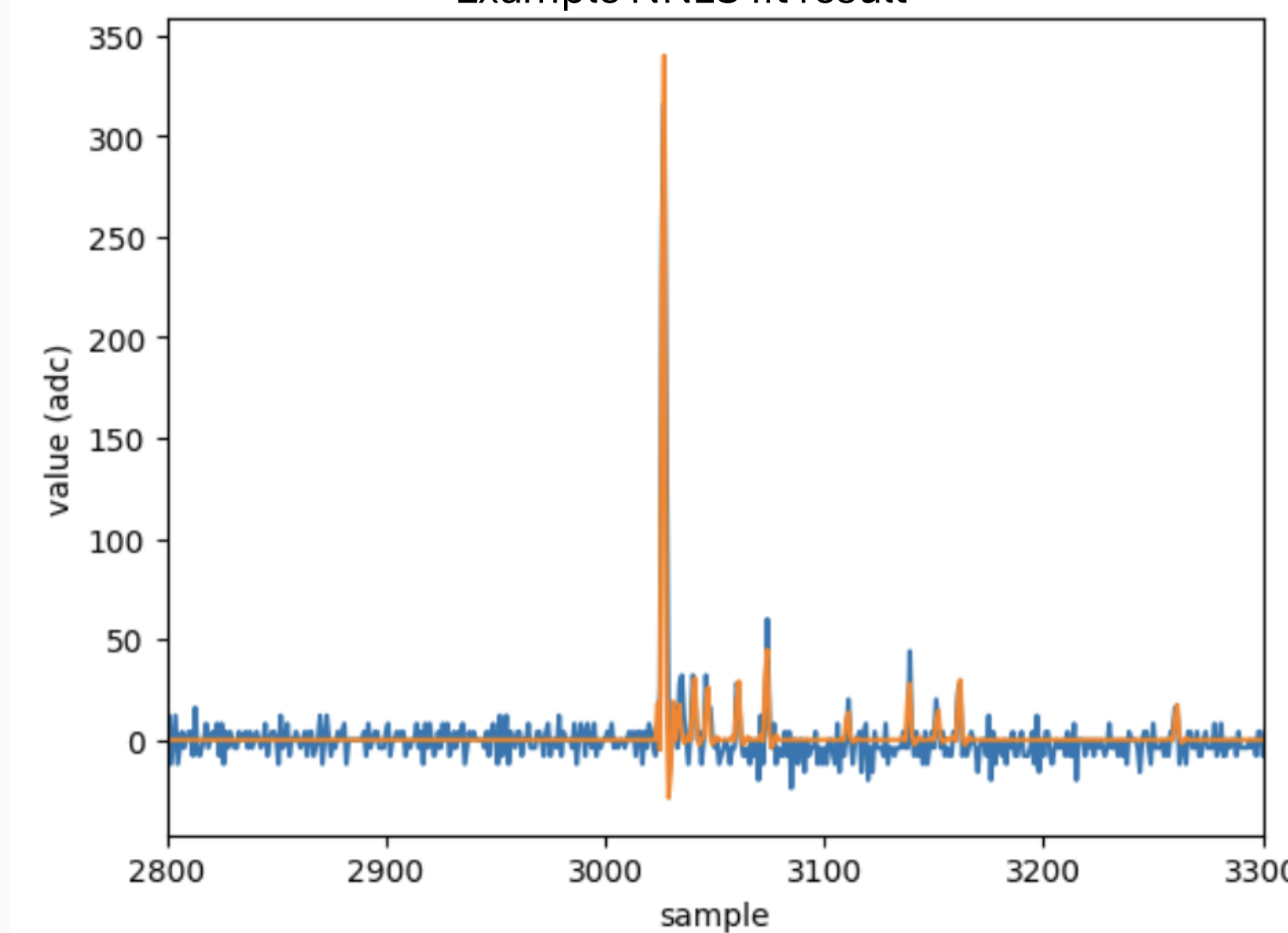


NNLS fitting

- Use NNLS fitting technique for each waveform
- Fit in derivative space with single template
- Matrix of templates sweeping through each time point



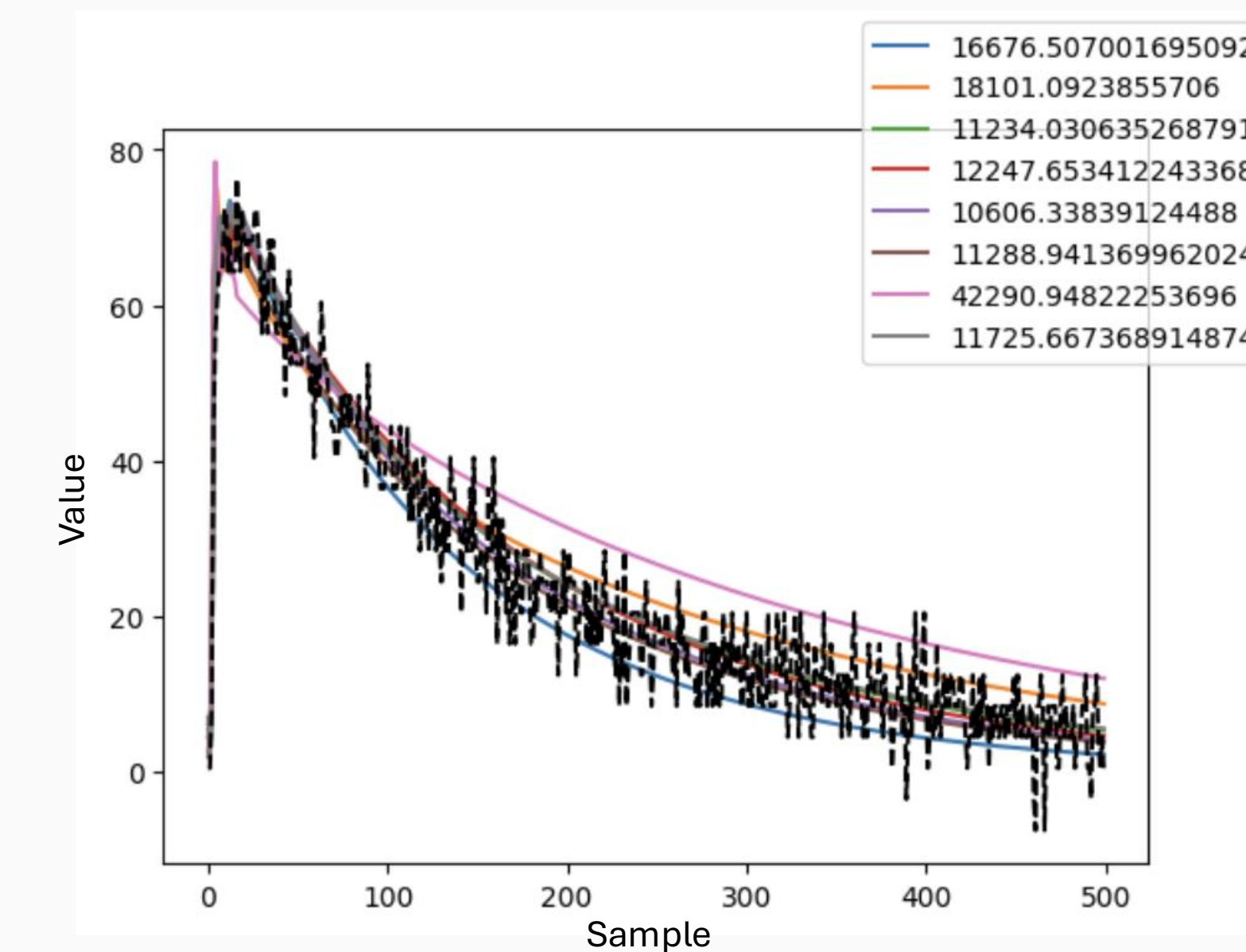
Example NNLS fit result



- Iterative technique choose one template which minimises residual
- Least squares fit
- Remove if below some threshold
- Repeat until no new template above threshold

Template Selection

- Take output from NNLS and run second stage to fit with all templates
- Iterate through NNLS solutions evaluating each template
- Refit with this template to fine tune solution
- Choose the template that minimises Chi-square
- Compare solution also to flat template in waveform space to ensure solution is needed
 - This also removes crosstalk which does not follow standard signal shape
- Return list of energies, t0s and templates
- Energy can then be calibrated in next step



LEGEND Institutions

Example Templates

Centre for Energy, Environmental and Technological Research
Comenius Univ.
Czech Technical Univ. in Prague and IEAP
Daresbury Laboratory
Duke Univ. and Triangle Universities Nuclear Laboratory
Gran Sasso Science Institute
Hochschule RheinMain
Indiana Univ. Bloomington
INFN – Sezione di Napoli
Institute for Nuclear Research Russian Academy of Sciences
Jagiellonian Univ.
Joint Institute for Nuclear Research
Joint Research Centre Geel
Laboratori Nazionali del Gran Sasso

Laboratori Nazionali di Frascati
Lancaster Univ.
Leibniz Institute for Crystal Growth
Leibniz Institute for Polymer Research
Los Alamos National Laboratory
MPI for Nuclear Physics
MPI for Physics
National Research Centre "Kurchatov Institute"
National Research Nuclear Univ. MEPhI
National Taiwan University (NTU)
North Carolina State Univ.
Oak Ridge National Laboratory
Polytechnical Univ. of Milan
Princeton Univ.

Roma Tre Univ. and INFN
South Dakota School of Mines and Technology
Technical Univ. of Dresden
Technical Univ. of Munich
Tennessee Technological Univ.
Univ. of California and Lawrence Berkeley National Laboratory
Univ. College London
Univ. of L'Aquila and INFN
Univ. of Cagliari and INFN
Univ. of California San Diego
Univ. of Houston
Univ. of Liverpool
Univ. of Milan and INFN

Univ. of Milano Bicocca and INFN
Univ. of New Mexico
North Carolina at Chapel Hill
Univ. of Padova and INFN
Univ. of South Carolina
Univ. of South Dakota
Univ. of Tennessee, Knoxville
Univ. of Texas at Austin
Univ. of Tuebingen
Univ. of Warwick
Univ. of Washington and Center for Experimental Nuclear Physics and Astrophysics
Univ. of Zurich
Williams College

