Deconvolution-based muli-peak reconstruction for the PADME Experiment

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for the PADME collaboration

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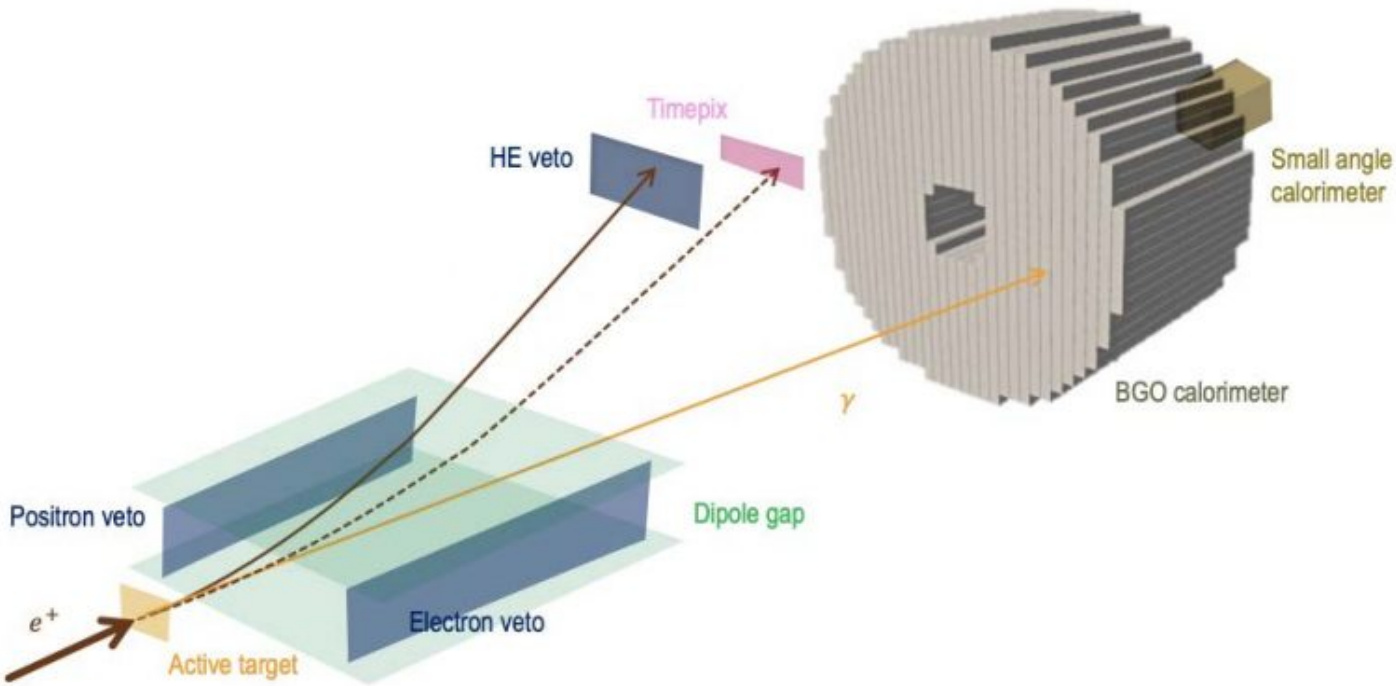
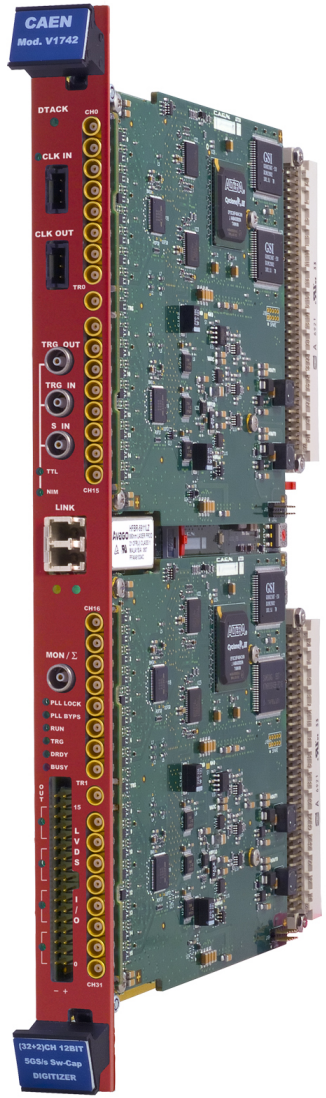

Timepix
HE veto
Small angle calorimeter
BGO calorimeter
γ
Positron veto
Dipole gap
e^+
Electron veto
Active target


CAEN
Mod. V1742
DTACK
CLK IN
CLK OUT
TRG OUT
TRG IN
S IN
TTL
NIM
LINK
MON / Σ
PLL LOCK
PLL BYPS
RUN
TRG
DRDY
BUSY
(32+2)CH 12BIT
5GS/s Sw-Cap
DIGITIZER

SAC

- 25 Cherencov detectors
- $30 \times 30 \times 140\,\mathrm{mm}^3$
- RO: PMT R13478UV

ECal

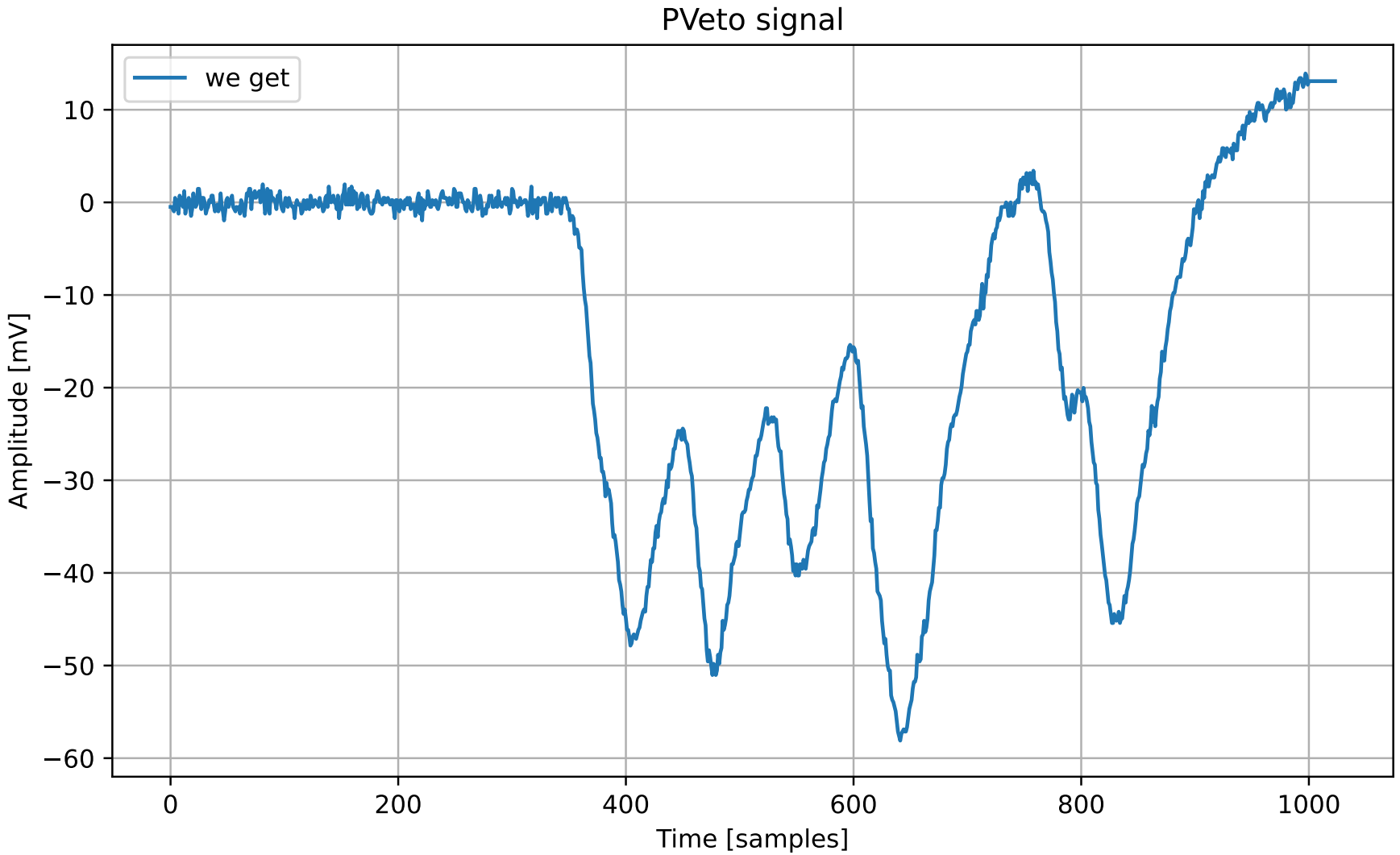
- 616 BGO scintillators
- $21 \times 21 \times 230\,\mathrm{mm}^3$
- RO: PMT HZC XP1912

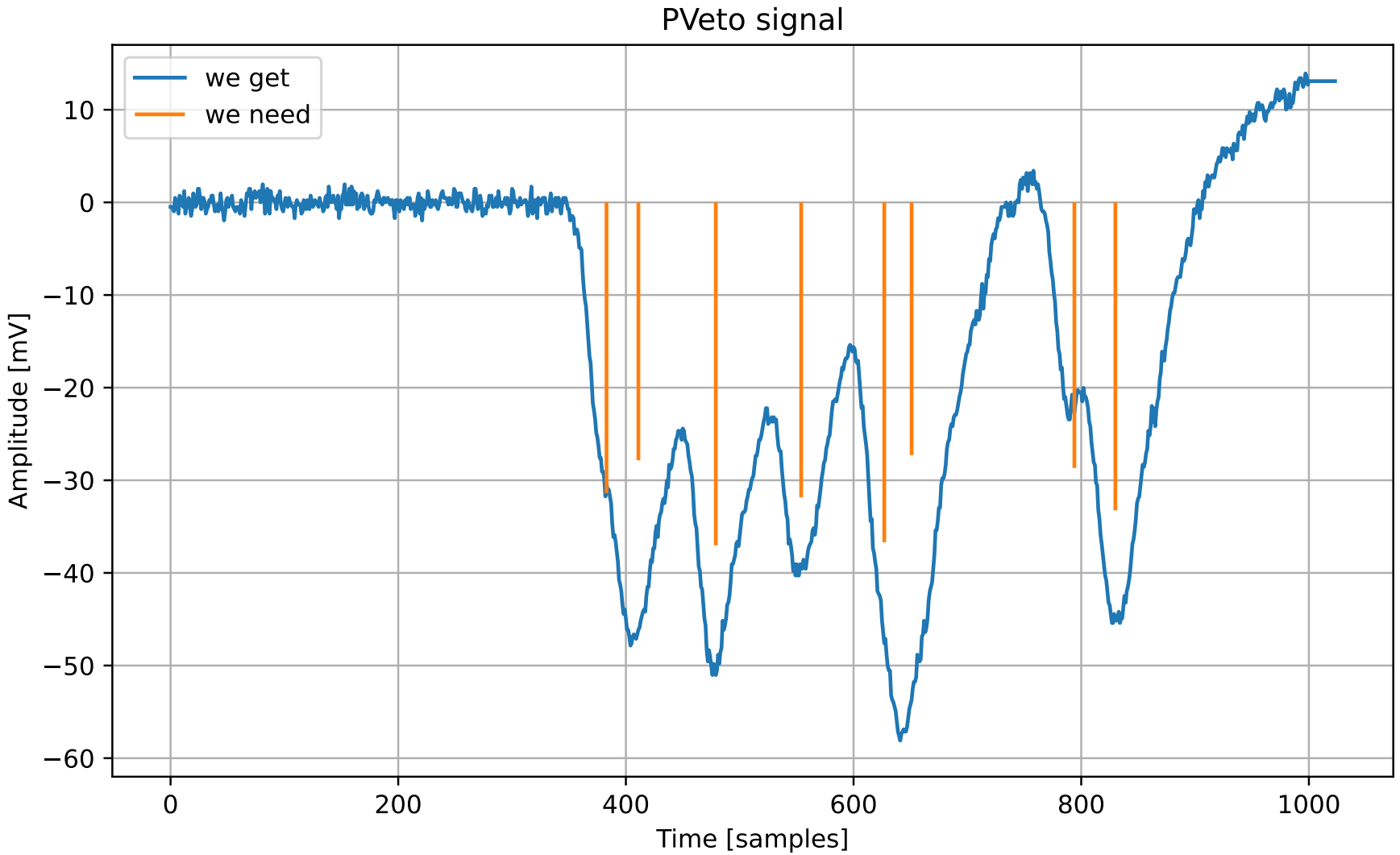
Veto

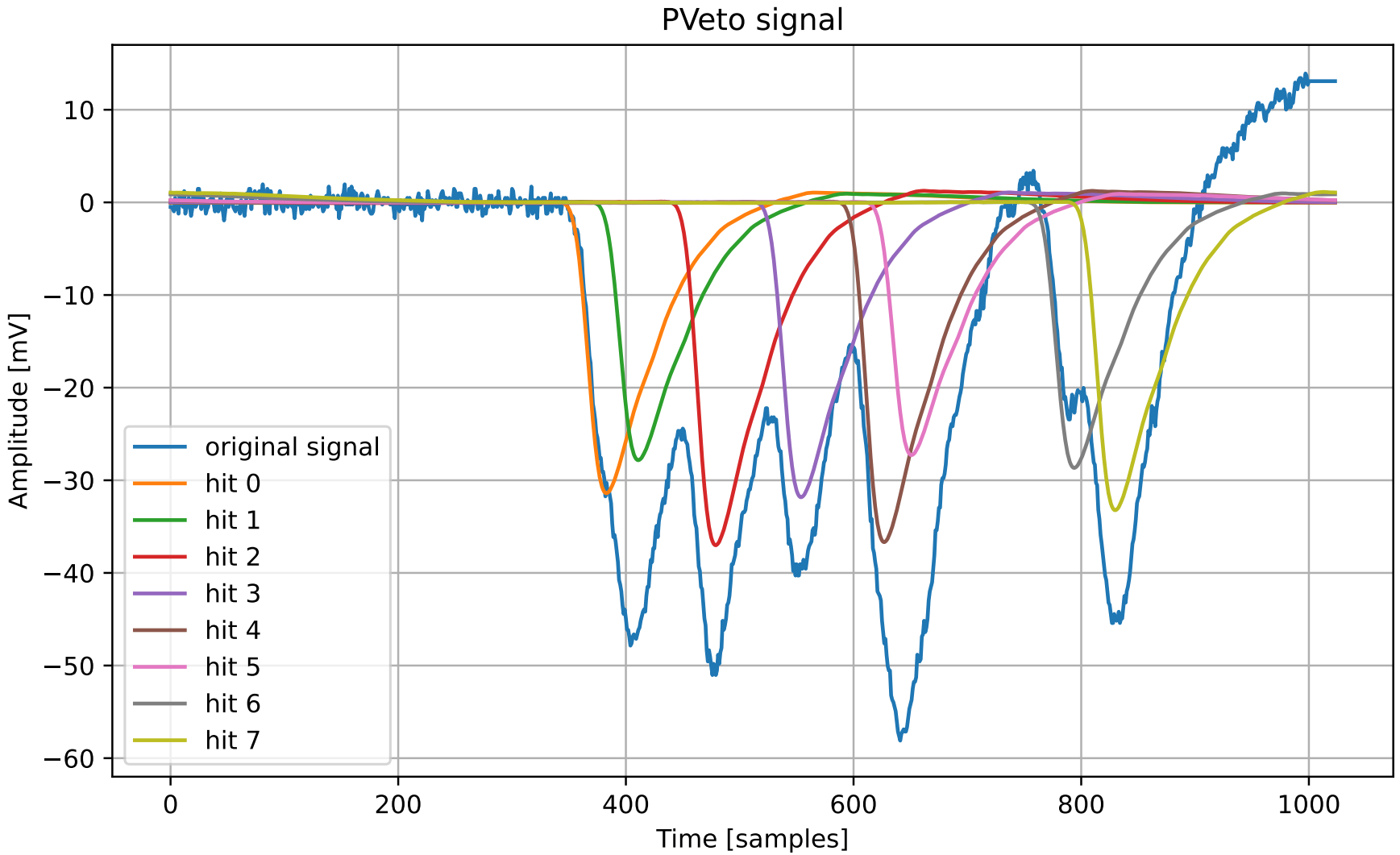
- 202 plastic scintillators
- $10 \times 10 \times 178\,\mathrm{mm}^3$
- WLS fibre BCF-92
- RO: SiPM S12572-025P

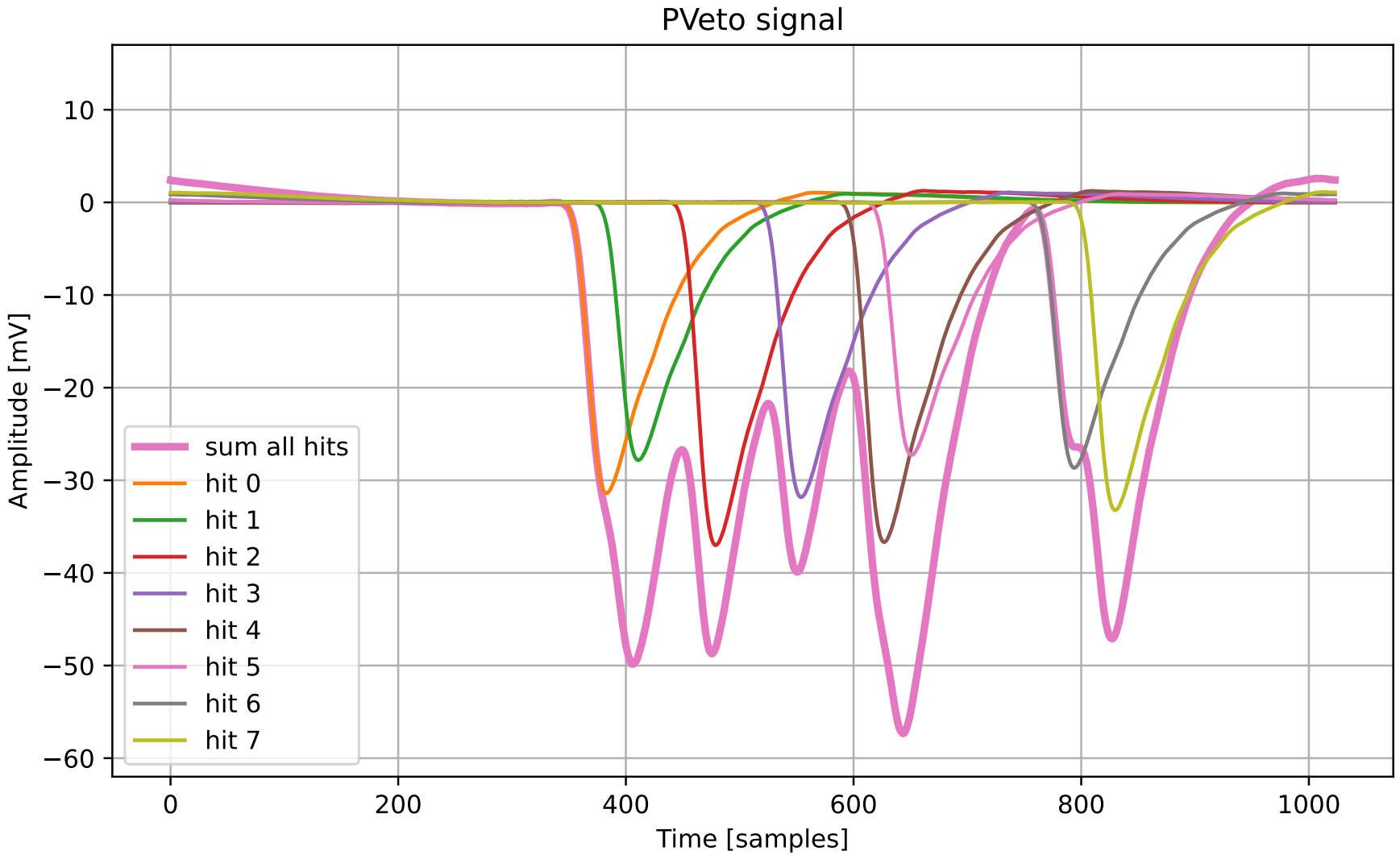
DAQ

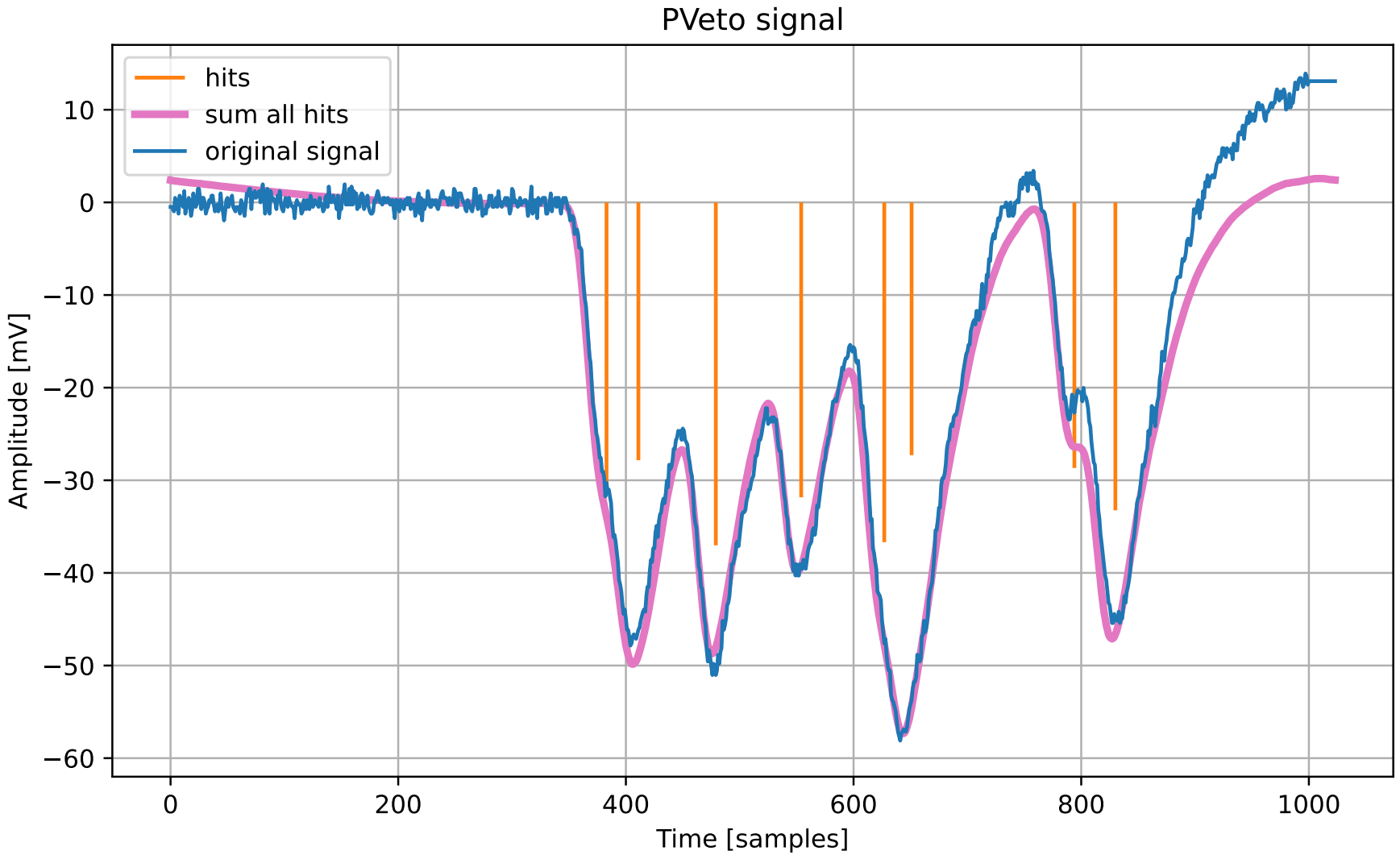
- CAEN V1742
- 2.5 GS/s
- 1 V dynamic range
- 1024 samples
- 10 bit ADC (DRS4)


PVeto signal
we get
Amplitude [mV]
Time [samples]
10
0
−10
−20
−30
−40
−50
−60
0
200
400
600
800
1000


PVeto signal
we get
we need
Amplitude [mV]
Time [samples]
10
0
−10
−20
−30
−40
−50
−60
0
200
400
600
800
1000


PVeto signal
Amplitude [mV]
Time [samples]
10
0
−10
−20
−30
−40
−50
−60
0
200
400
600
800
1000
original signal
hit 0
hit 1
hit 2
hit 3
hit 4
hit 5
hit 6
hit 7


PVeto signal
Amplitude [mV]
Time [samples]
10
0
−10
−20
−30
−40
−50
−60
0
200
400
600
800
1000
sum all hits
hit 0
hit 1
hit 2
hit 3
hit 4
hit 5
hit 6
hit 7


PVeto signal
hits
sum all hits
original signal
Amplitude [mV]
Time [samples]
10
0
−10
−20
−30
−40
−50
−60
0
200
400
600
800
1000

$$signal = hits \star irf + noise$$

$$HITS = \frac{SIGNAL}{IRF} * lowpass$$

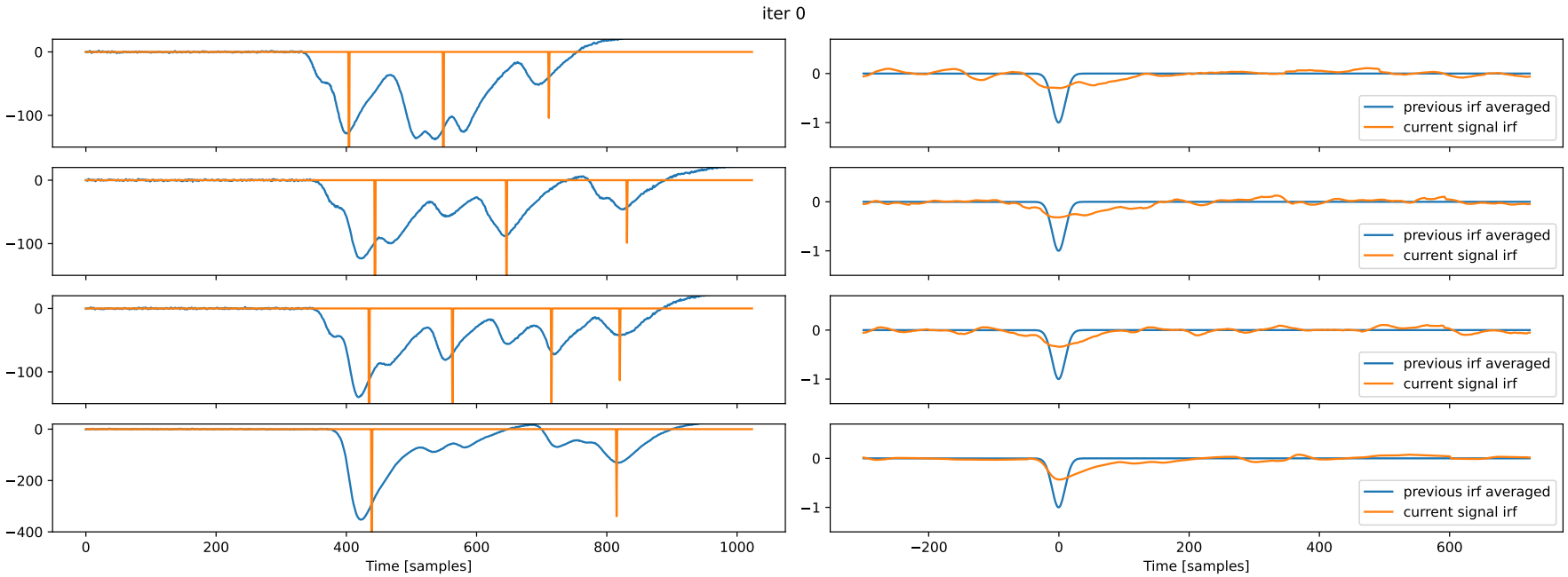
Problems

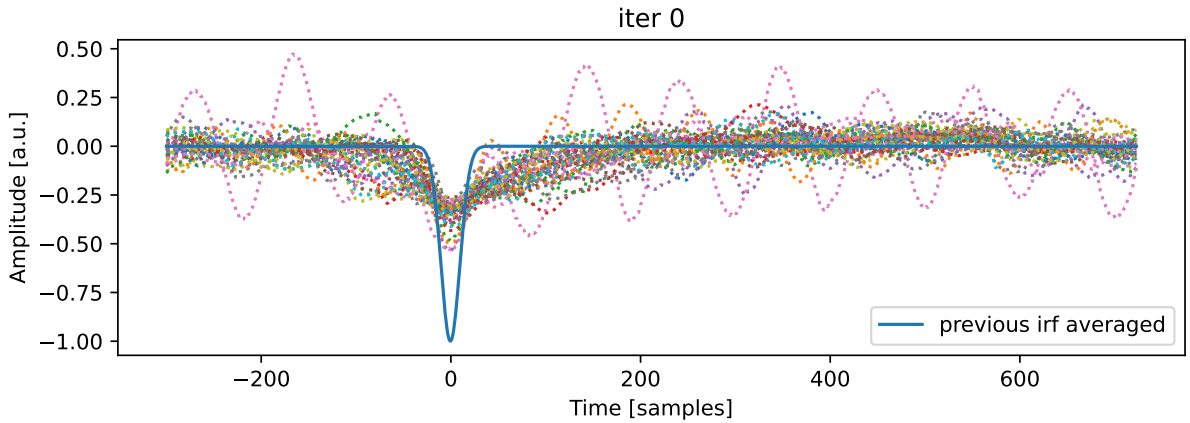
- Estimate irf
- Deconvolve signals using irf
- Deal with the noise

Iterative procedure to estimate IRF

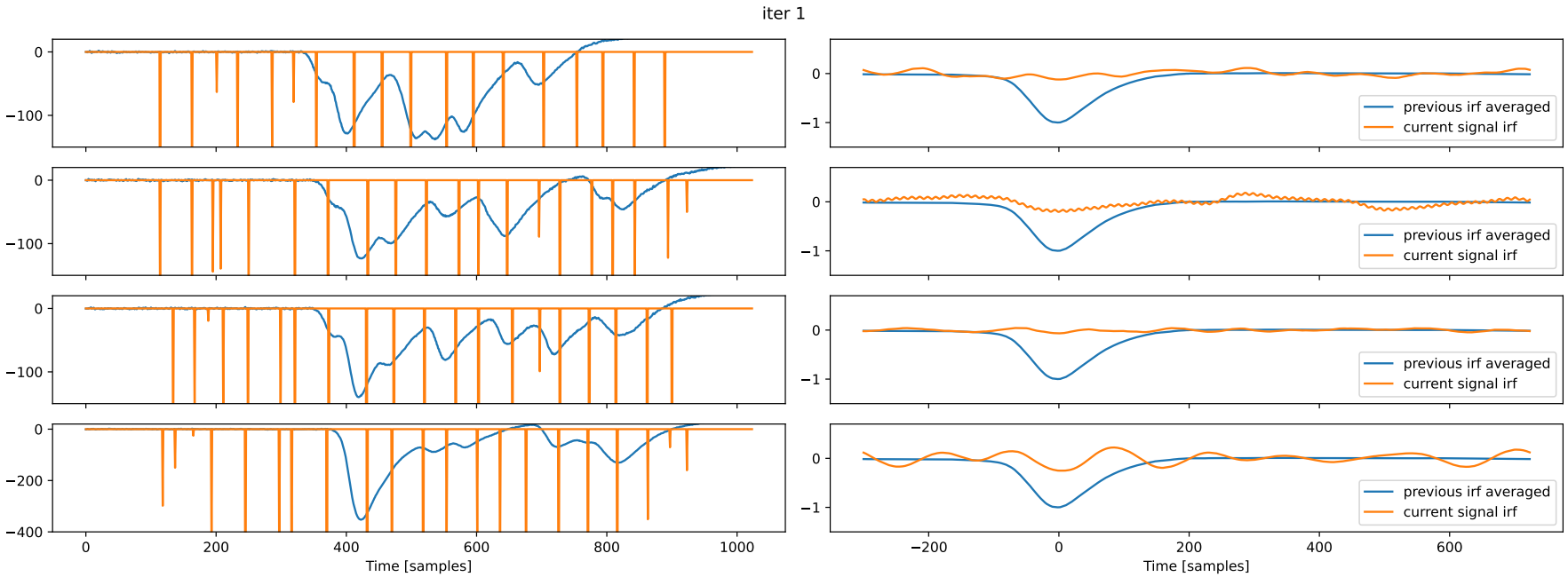
- Start with an initial estimate for the IRF
- Run multiple times (50+)
  - Run for 4000 events
    - Deconvolve current event with IRF to get estimate for the hits
    - Deconvolve current event with hits to get the new IRF
  - Update IRF with median of all IRF from the signals
- Final IRF is median of IRF from last several iterations

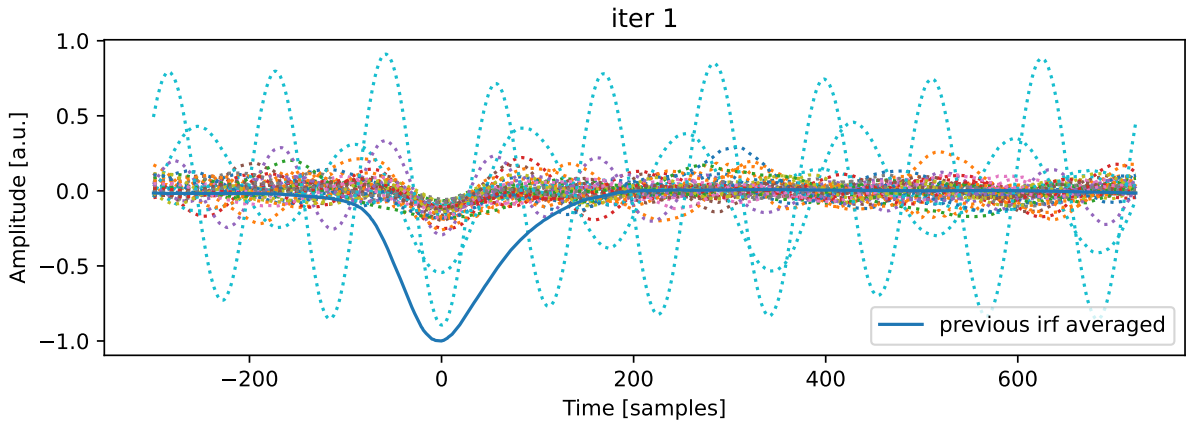
Iterations demo – iter 0



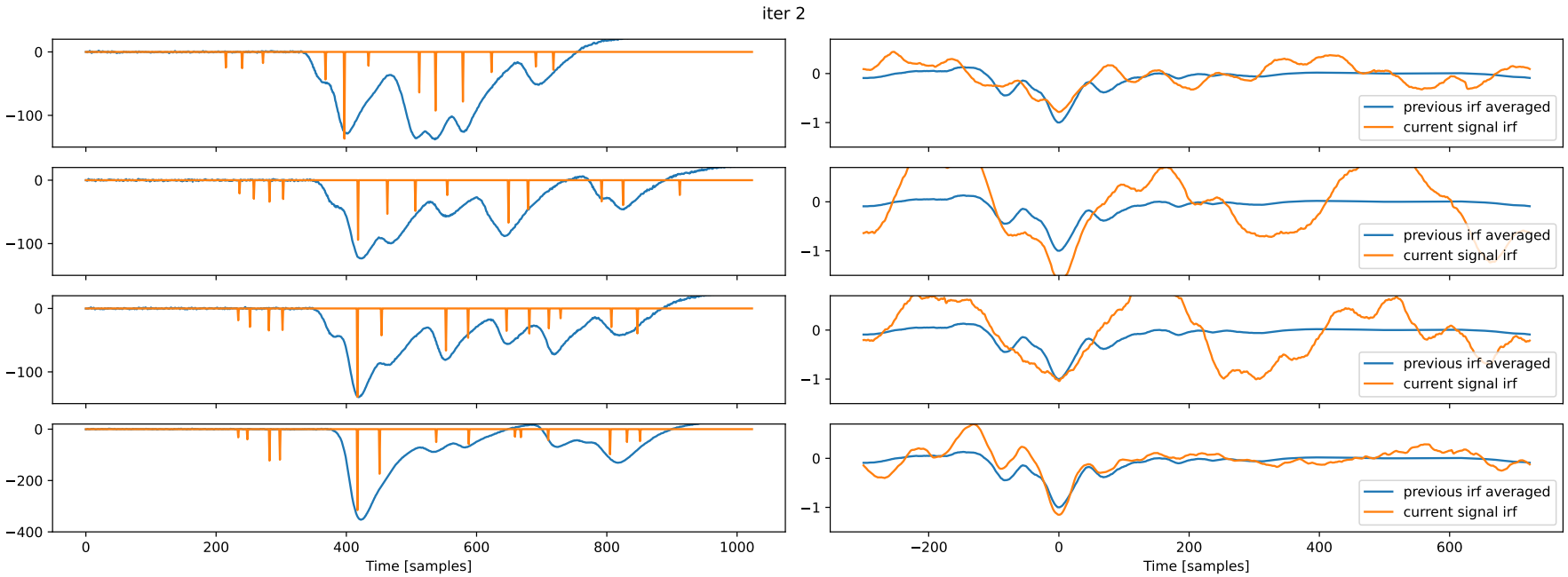


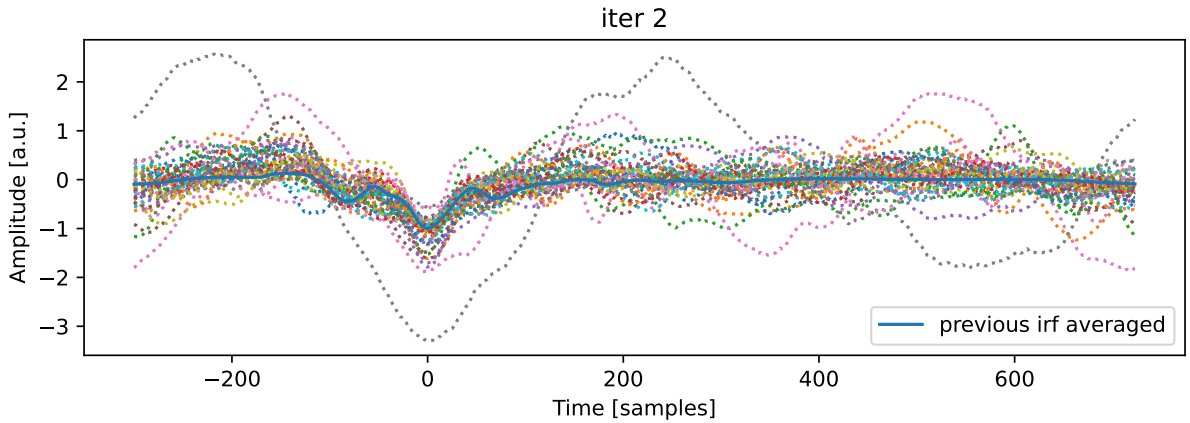
Iterations demo – iter 1



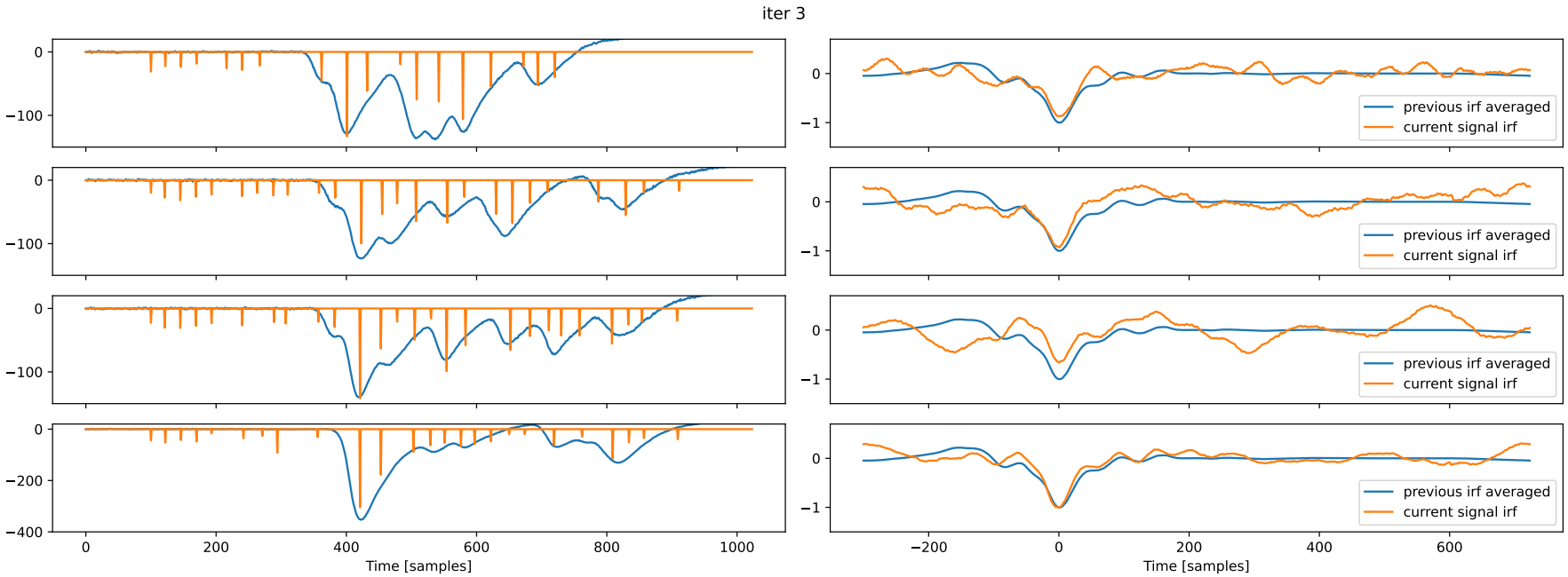


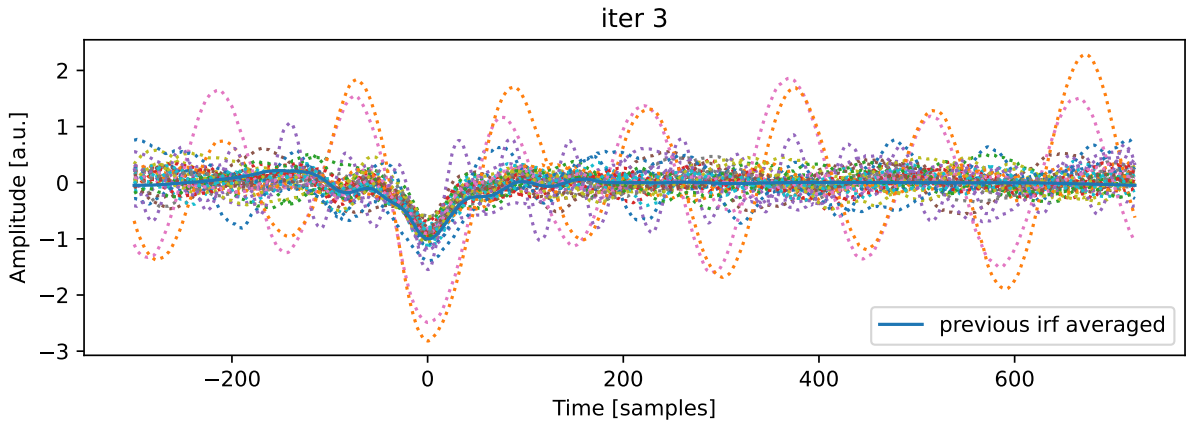
Iterations demo – iter 2



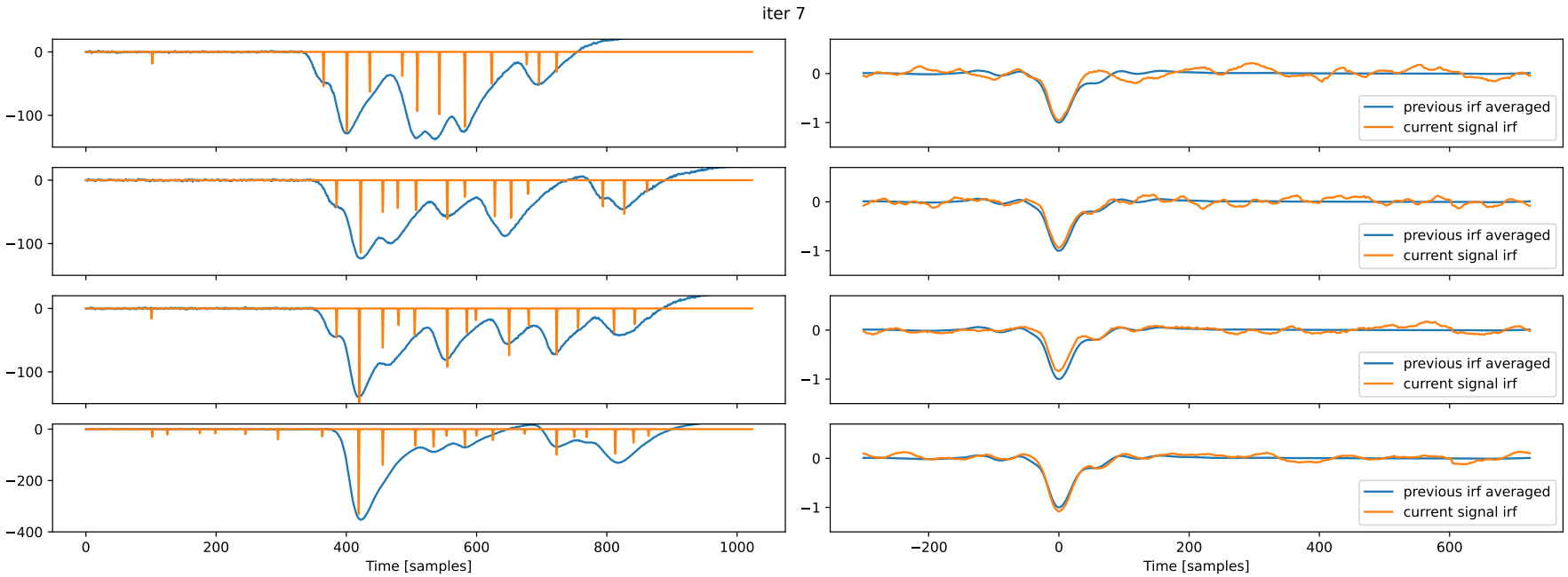


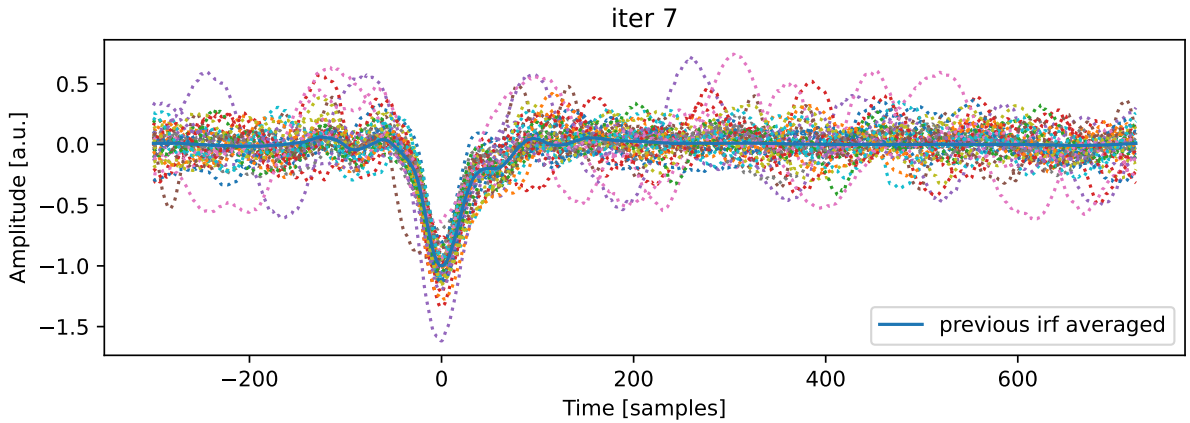
Iterations demo – iter 3



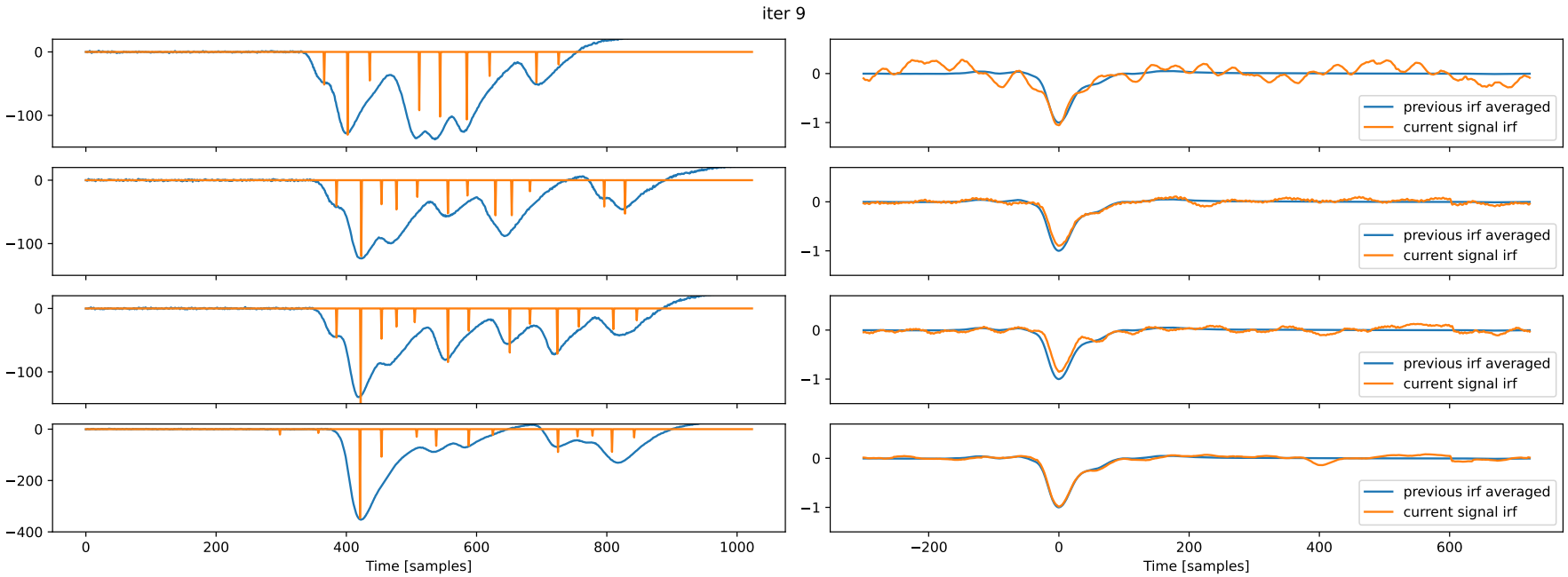


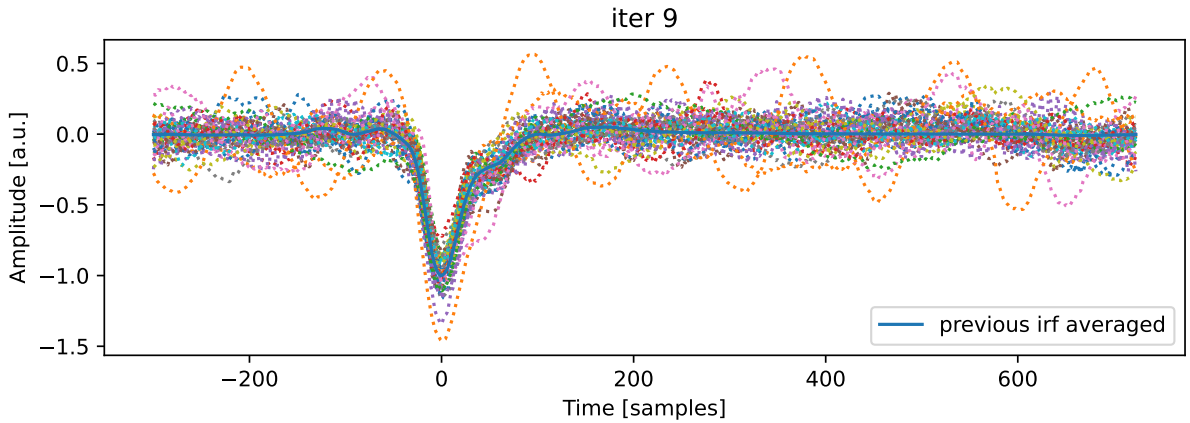
Iterations demo – iter 7



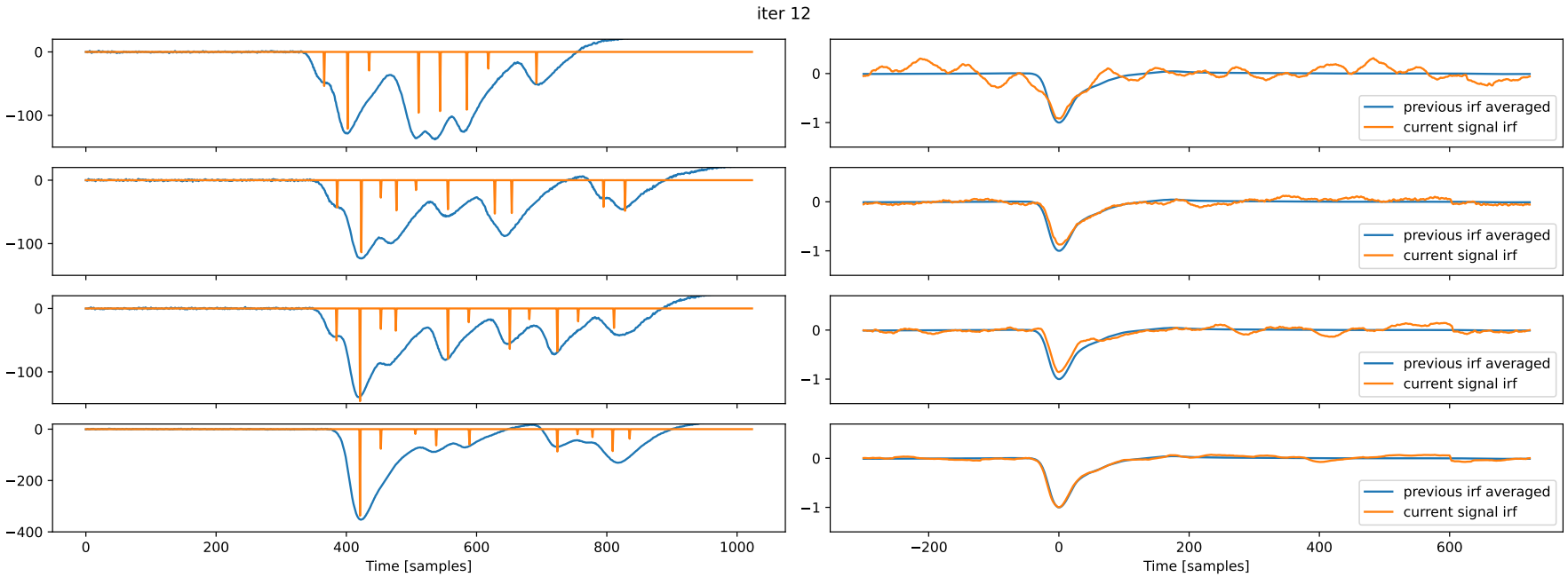


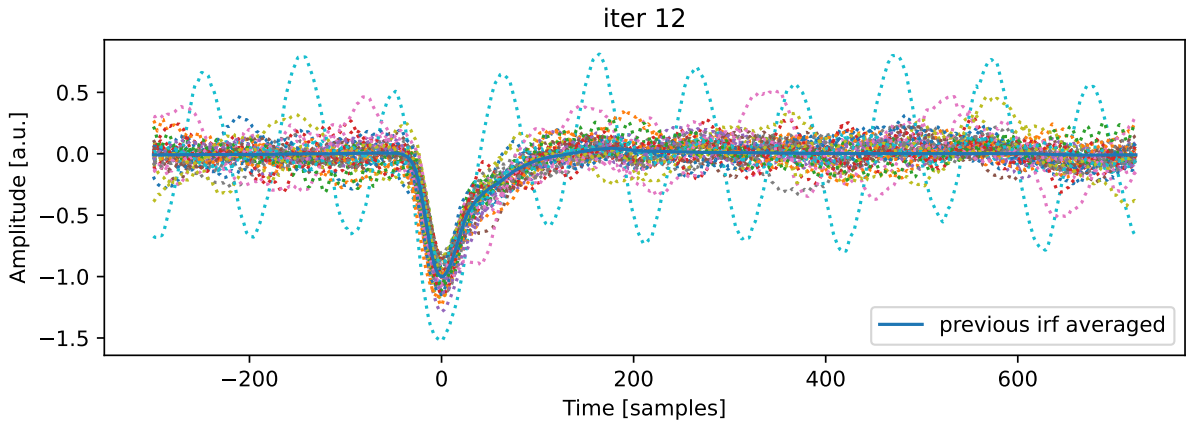
Iterations demo – iter 9



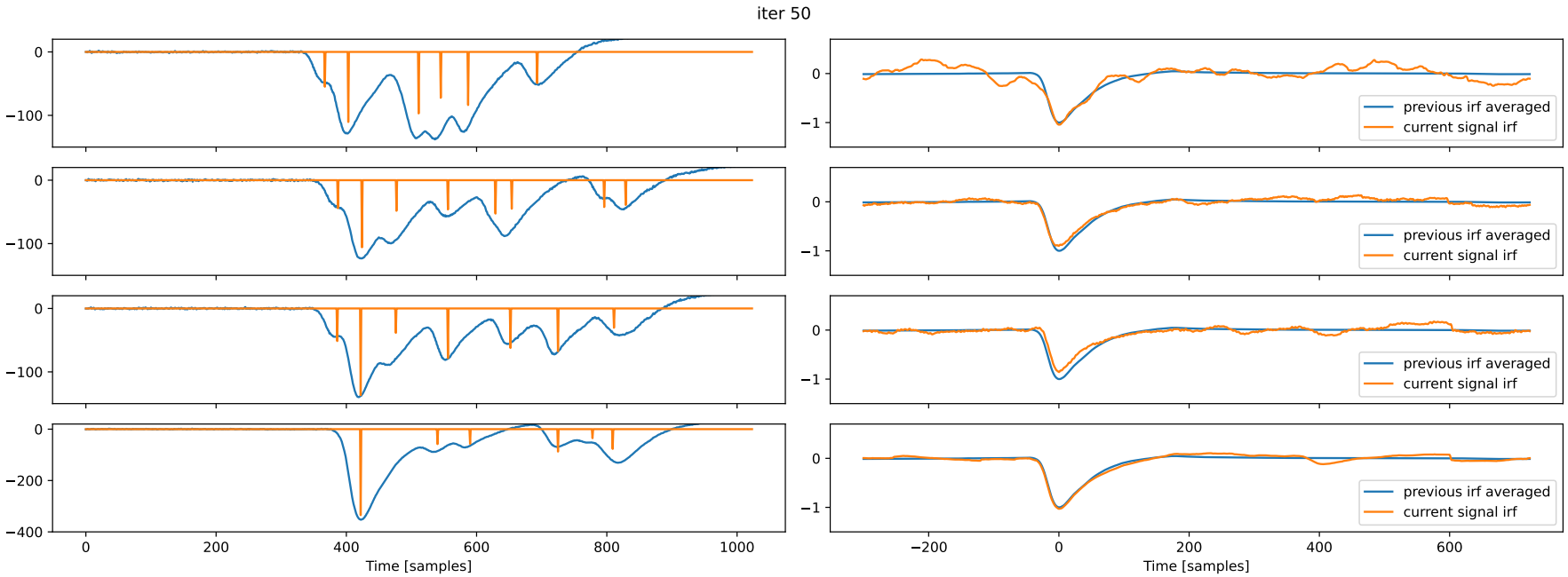


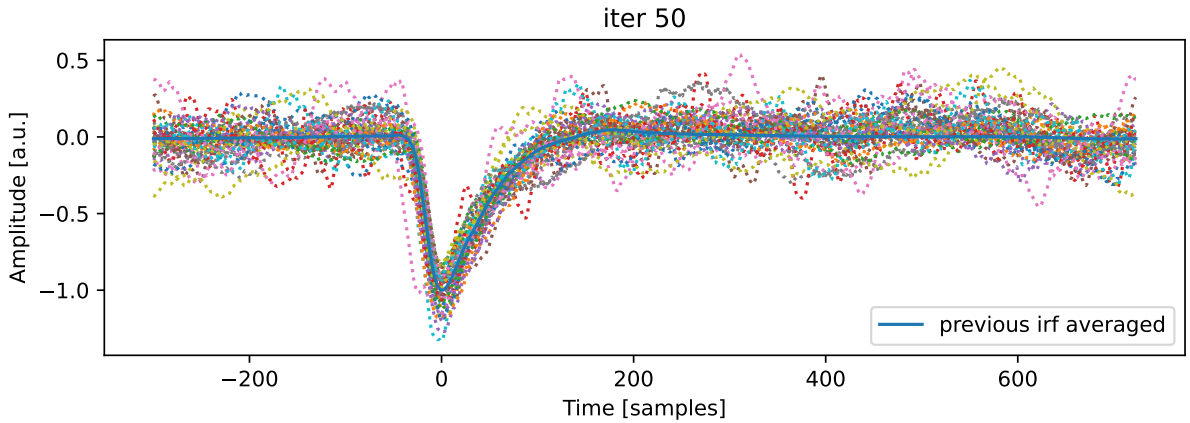
Iterations demo – iter 12



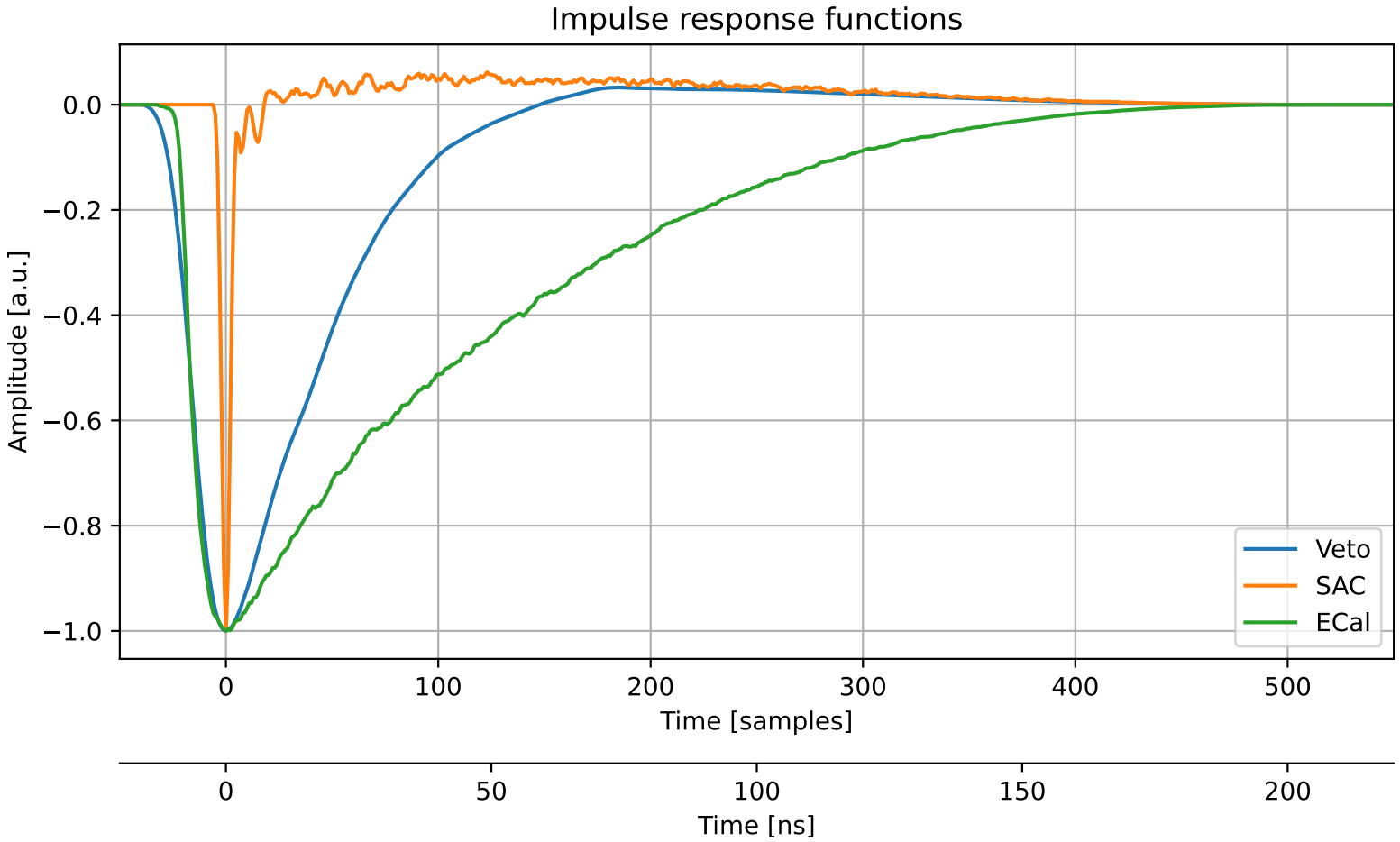


Iterations demo – iter 50





Impulse response functions



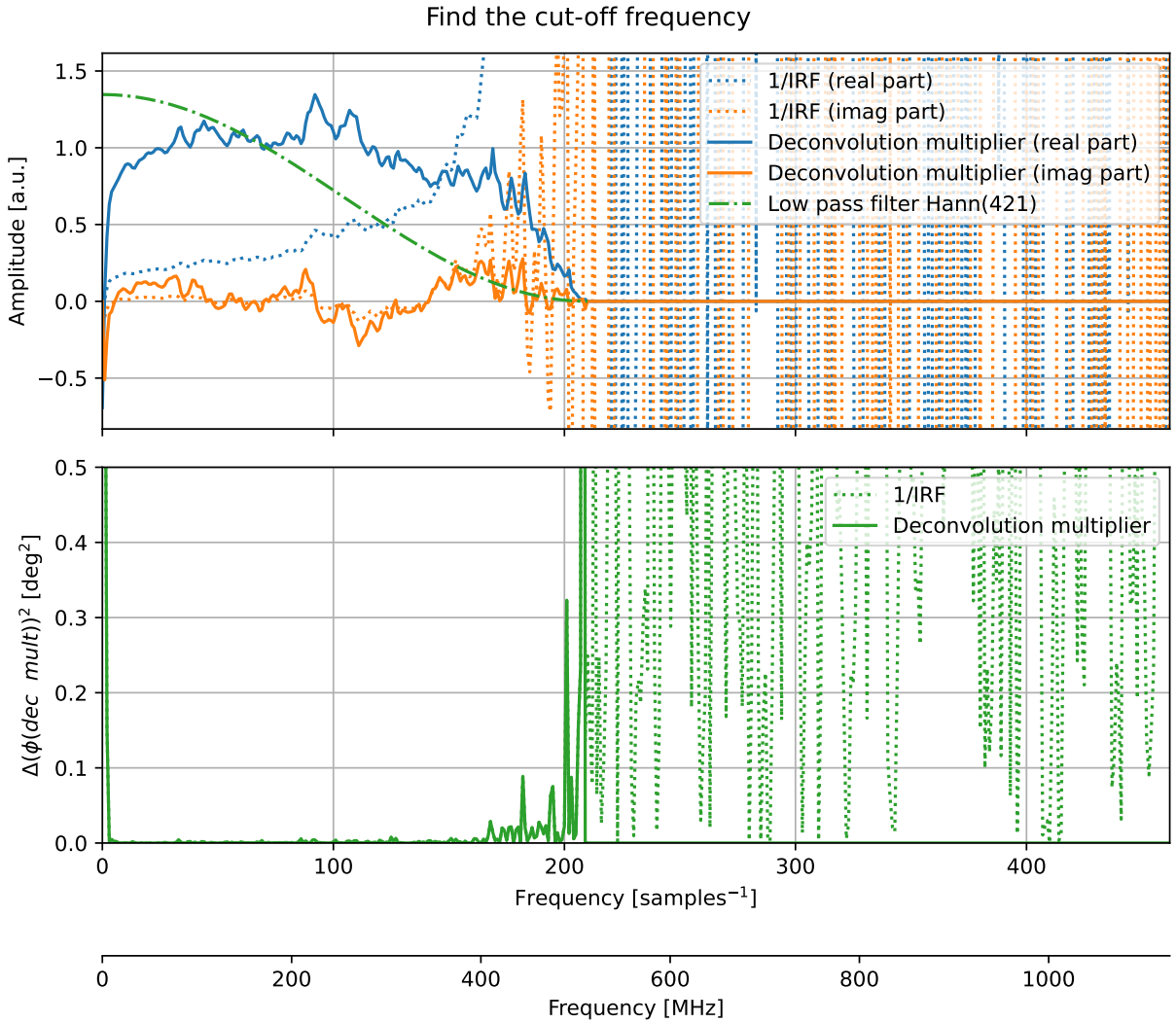
IRF inversion (1/IRF cutoff)

$$signal = hits \star irf + noise$$

$$Hits = Signal * \underbrace{\left(\frac{1}{IRF} * lowpass(cutoff) \right)}_{\text{Deconvolution multiplier}}$$

How to estimate the cutoff of the low pass filter?

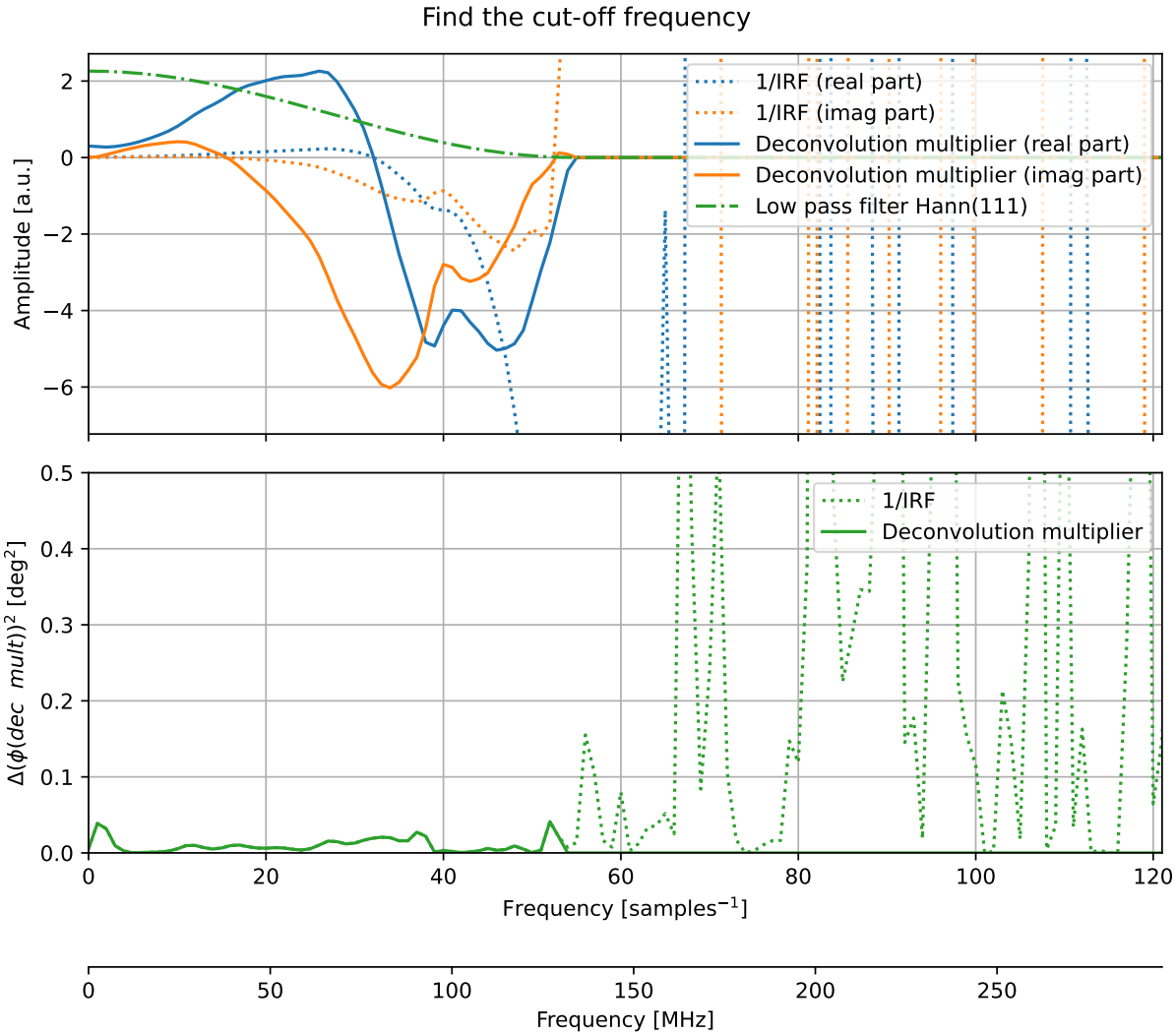
Cut-off frequency estimation – SAC



$$(\Delta(\text{Phase}\,(1/IRF))^2$$

- cutoff frequency 190 MHz@3 dB
- filter Hann(421)

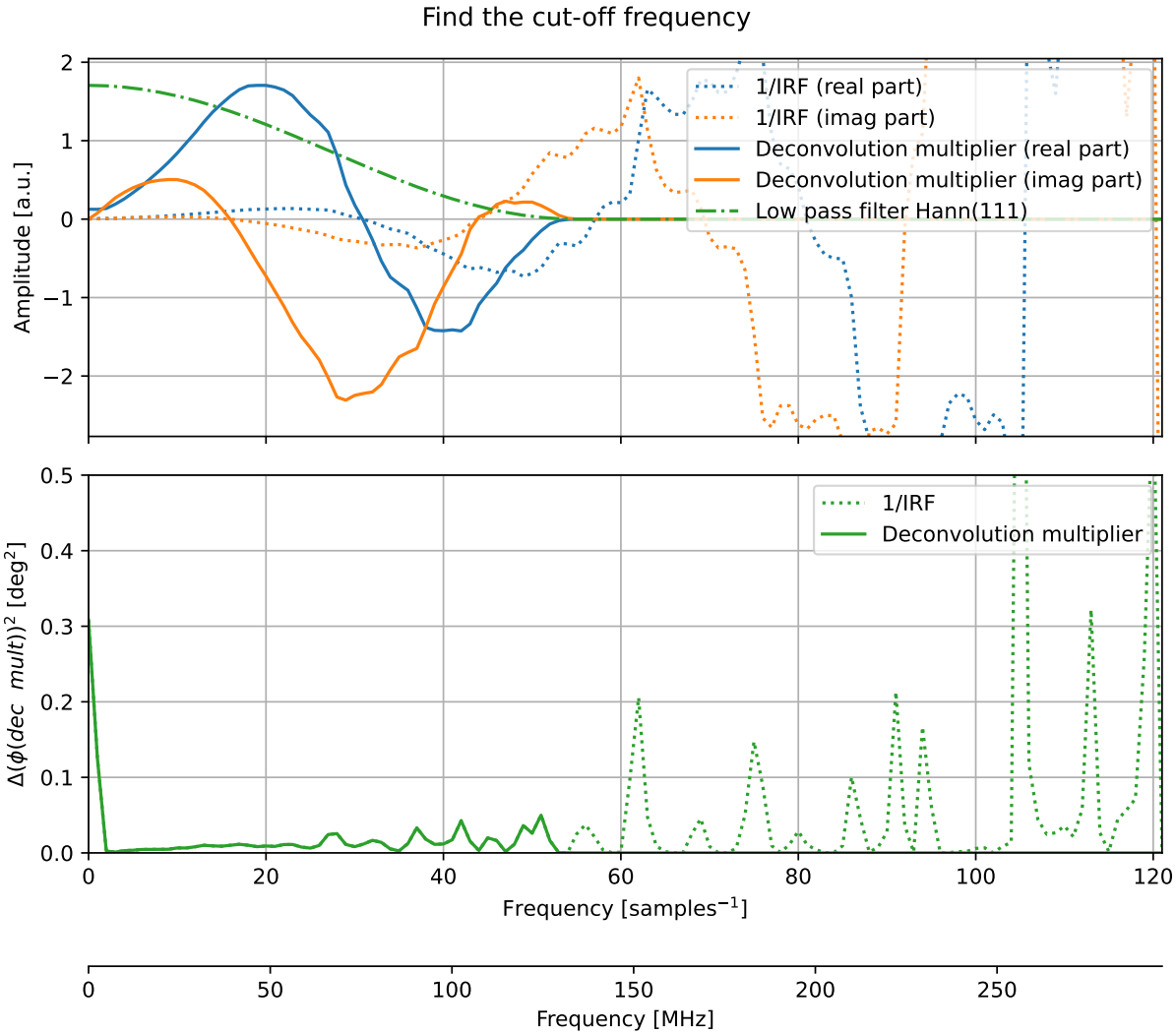
Cut-off frequency estimation – Veto



$$(\Delta(\text{Phase}\,(1/IRF))^2$$

- cutoff frequency 50 MHz@3 dB
- filter Hann(111)

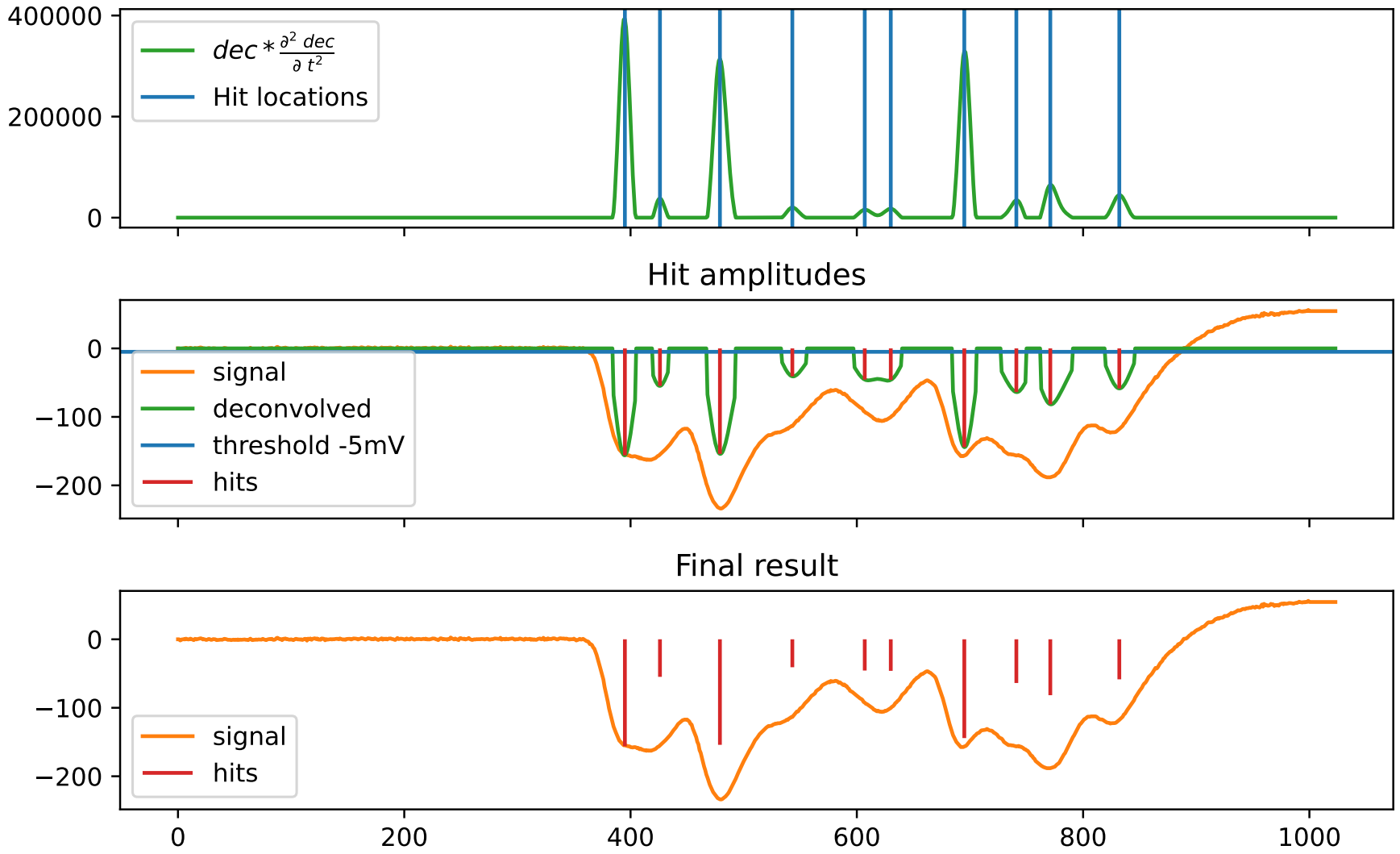
Cut-off frequency estimation – ECal



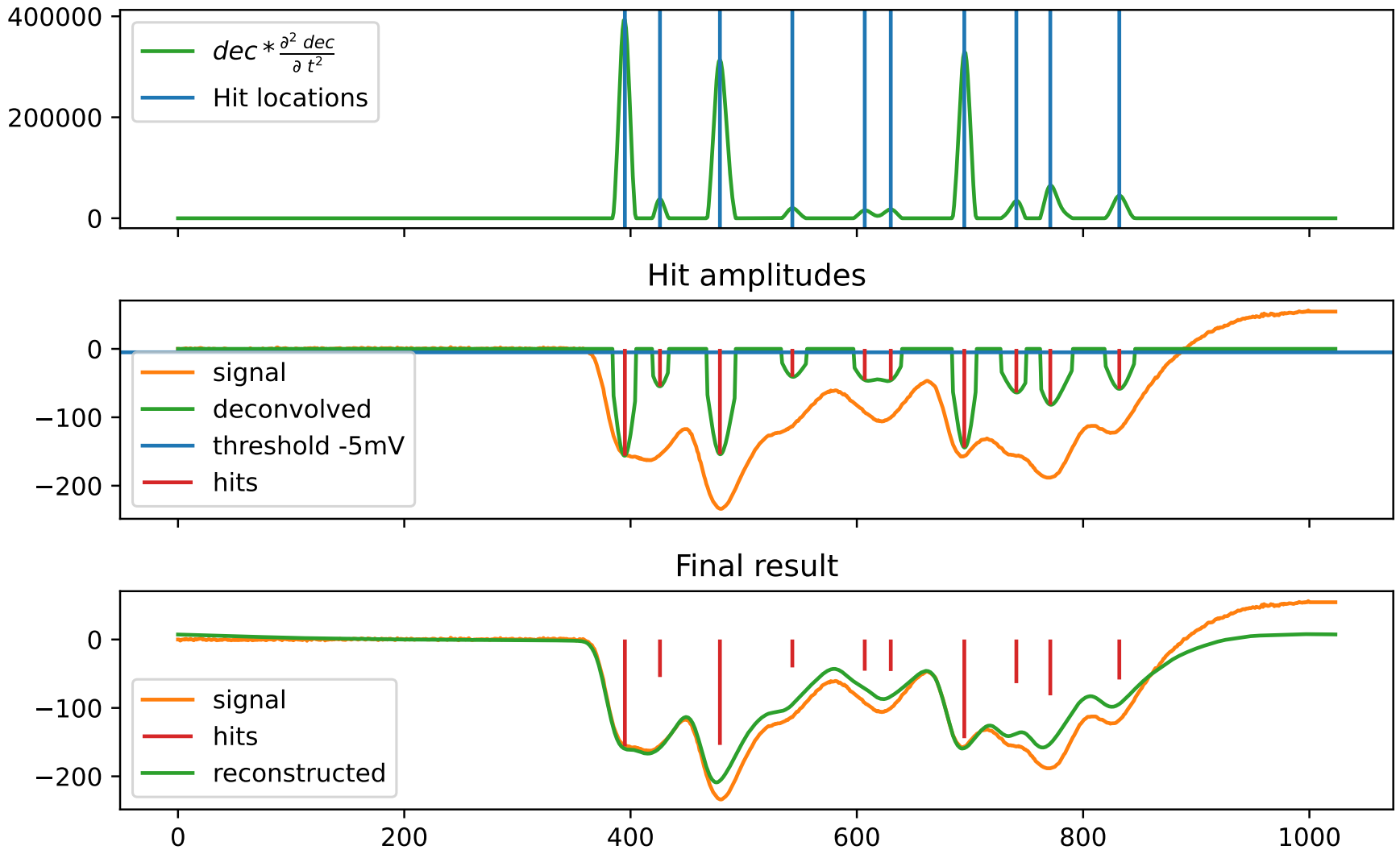
$$(\Delta(\text{Phase}\,(1/IRF))^2$$

- cutoff frequency 50 MHz@3 dB
- filter Hann(111)

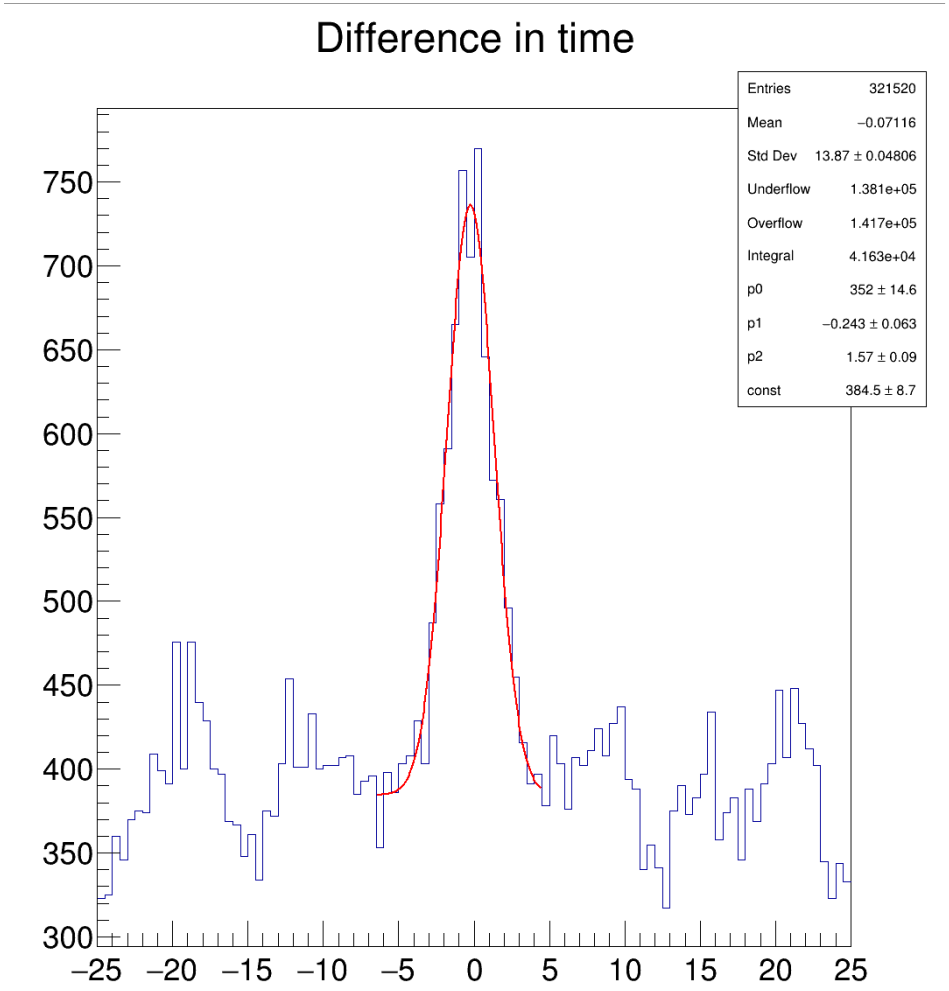
Deconvolution

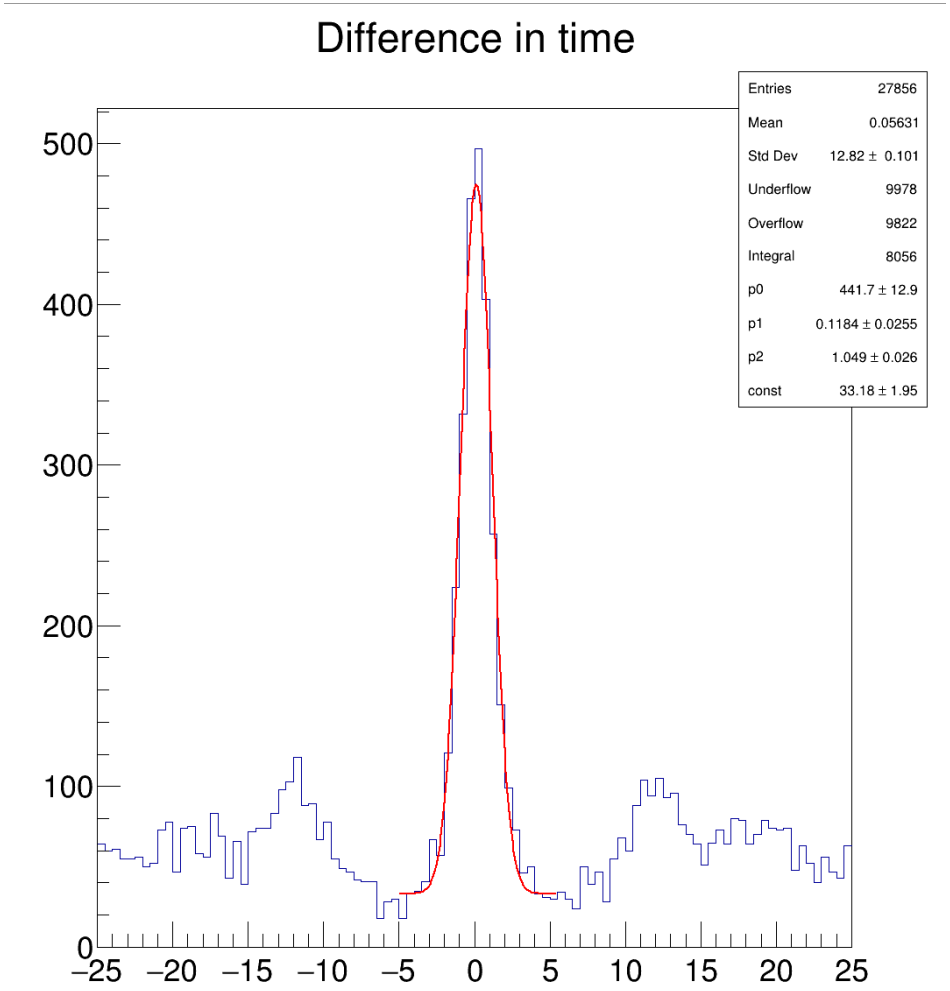


Reconstructed signal



PVeto DT ch79 ch80





Summary

Results

- Iterative procedure to estimate IRF
- Determine IRF of Veto, SAC, ECal systems
- Deconvolution multipliers calculcated

Preliminary results

- Better time resolution ($> 50\,\%$) w.r.t. current method
- Tolerant to noise
- Faster to execute w.r.t. current method
- Massive reduction in False positive errors