Quality Control of PEN wavelength shifters for DarkSide-20k veto

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On behalf of the DarkSide-20k Collaboration

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2. National Center for Nuclear Research

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Outline

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II. ArGSet

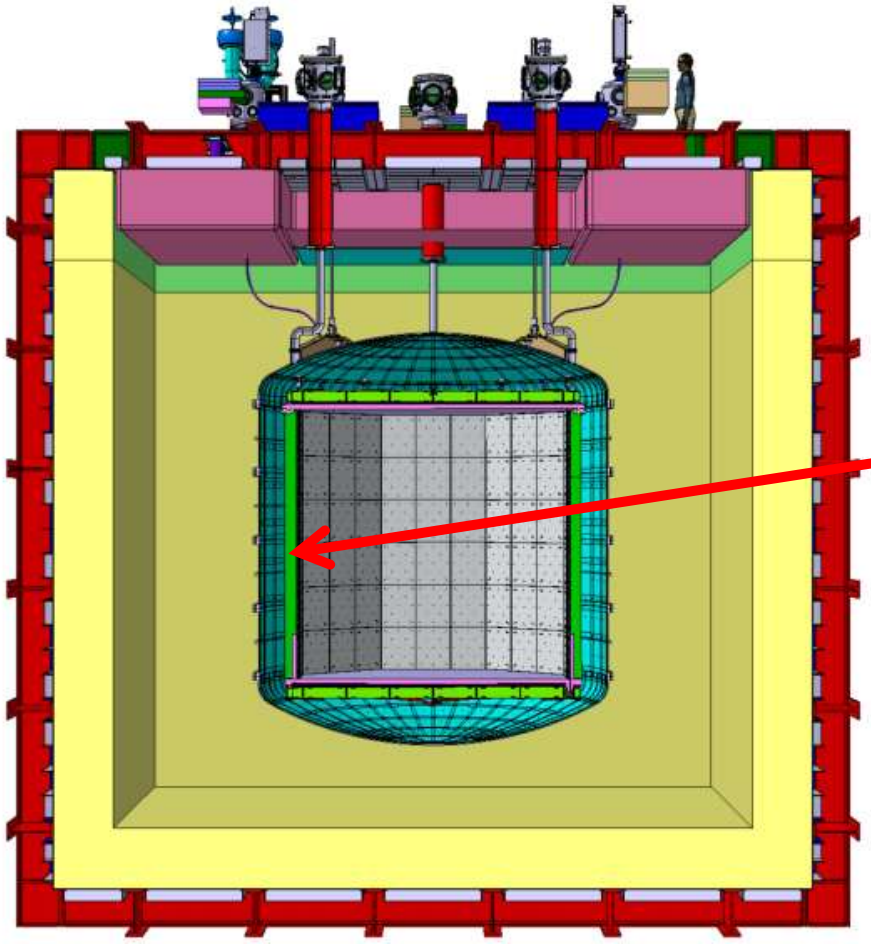
- ✓ SiPM characterization

III. Data Analysis

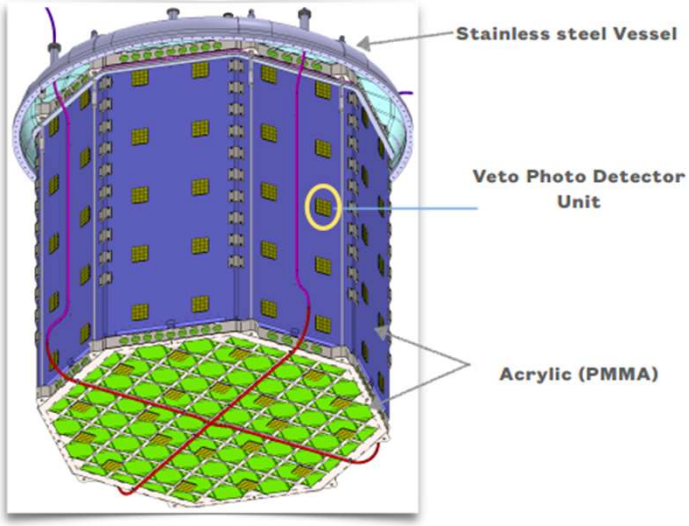
- ✓ Event selection cuts
- ✓ Argon triplet lifetime verification
- ✓ Full WF charge distribution

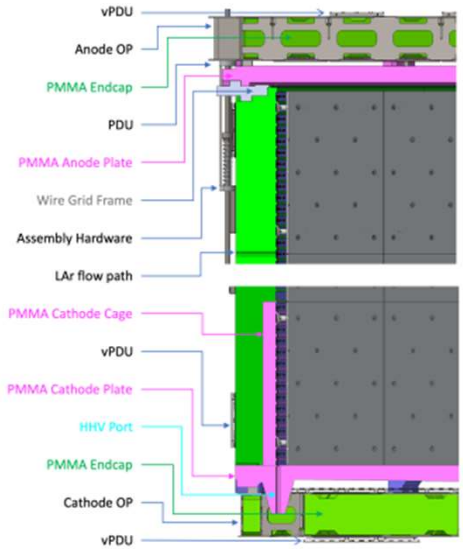
IV. Summary and Conclusion

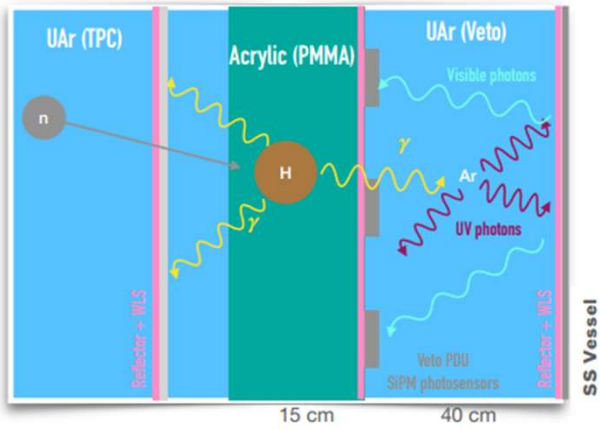
DarkSide-20k neutron veto



DarkSide-20k neutron veto







- Neutrons can mimic WIMP signal. **PSD** is useless against neutron events.
- The UAr volume between the SS vessel and **PMMA** serves as a veto volume with **~40 cm thickness.**

Veto Working Principle

- Neutrons are moderated in the acrylic shell and then captured by **Hydrogen**.
- H emits γ-rays **2.2 MeV.**
- γ-rays interact in the liquid argon buffers.
- LAr scintillation light is wavelength shifted and detected by **~1920 SiPM-based photosensors**.

Slide courtesy: I. Ahmad (IDM 2024)

PEN rolls

- Polyethylene naphthalate (PEN) is proposed alternate material to tetraphenyl butadiene (TPB).

- PEN rolls:
  More than 4000 m2 of PEN procured and available at AstroCeNT in form of rolls. Sufficient excess material available for quality control tests.

- Roll:
  Length = 2 km
  Width = 1.2 m

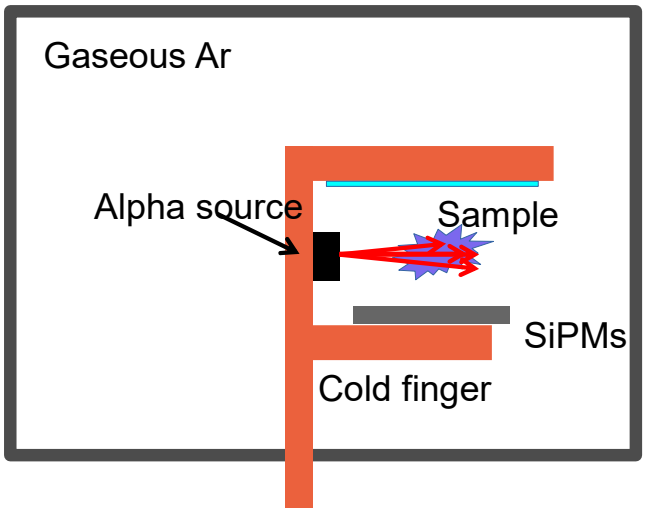
- The rolls undergo uniformity test.

PEN quality control strategy

- Keep witness samples from each sheet of PEN to be installed in the detector
- Before sheet production test the uniformity of the roll with ~50 samples:
  - Each sample to be measured at 190 nm excitation with a spectrophotometer equipped with an integrating sphere
  - Subset of samples to be tested with 128 nm excitation at room temperature
  - Several samples to be tested at 128 nm and in cryogenic conditions (currently the main bottleneck)
- Correlate cryogenic measurement result with other methods

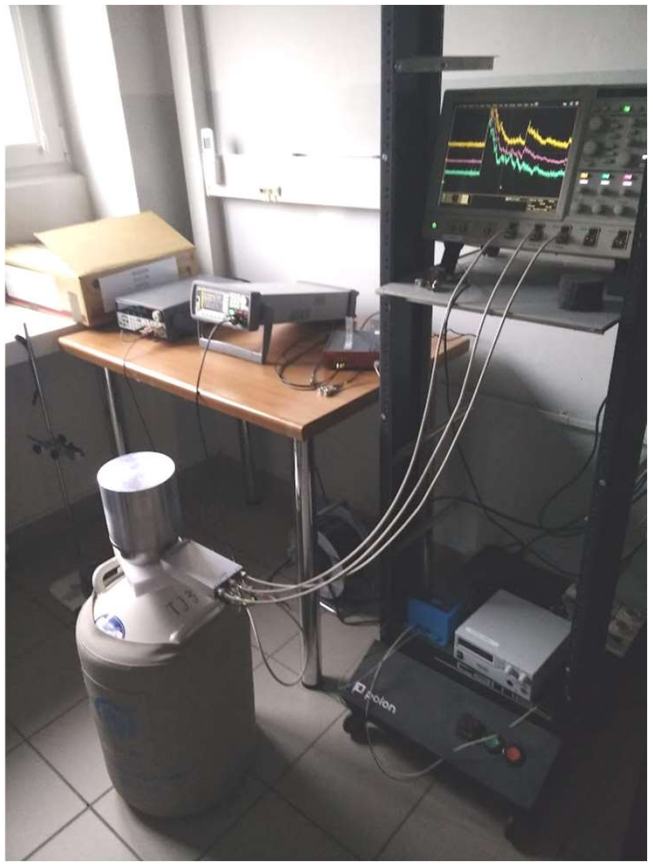
ArGSet

- An ArGon Gas Setup for measurement of Wavelength Shifting Efficiency (WSLE)
- WLSE depends on the excitation wavelength AND temperature
- ArGSet is an alpha-excited gaseous Ar cell with a cryogenic stage



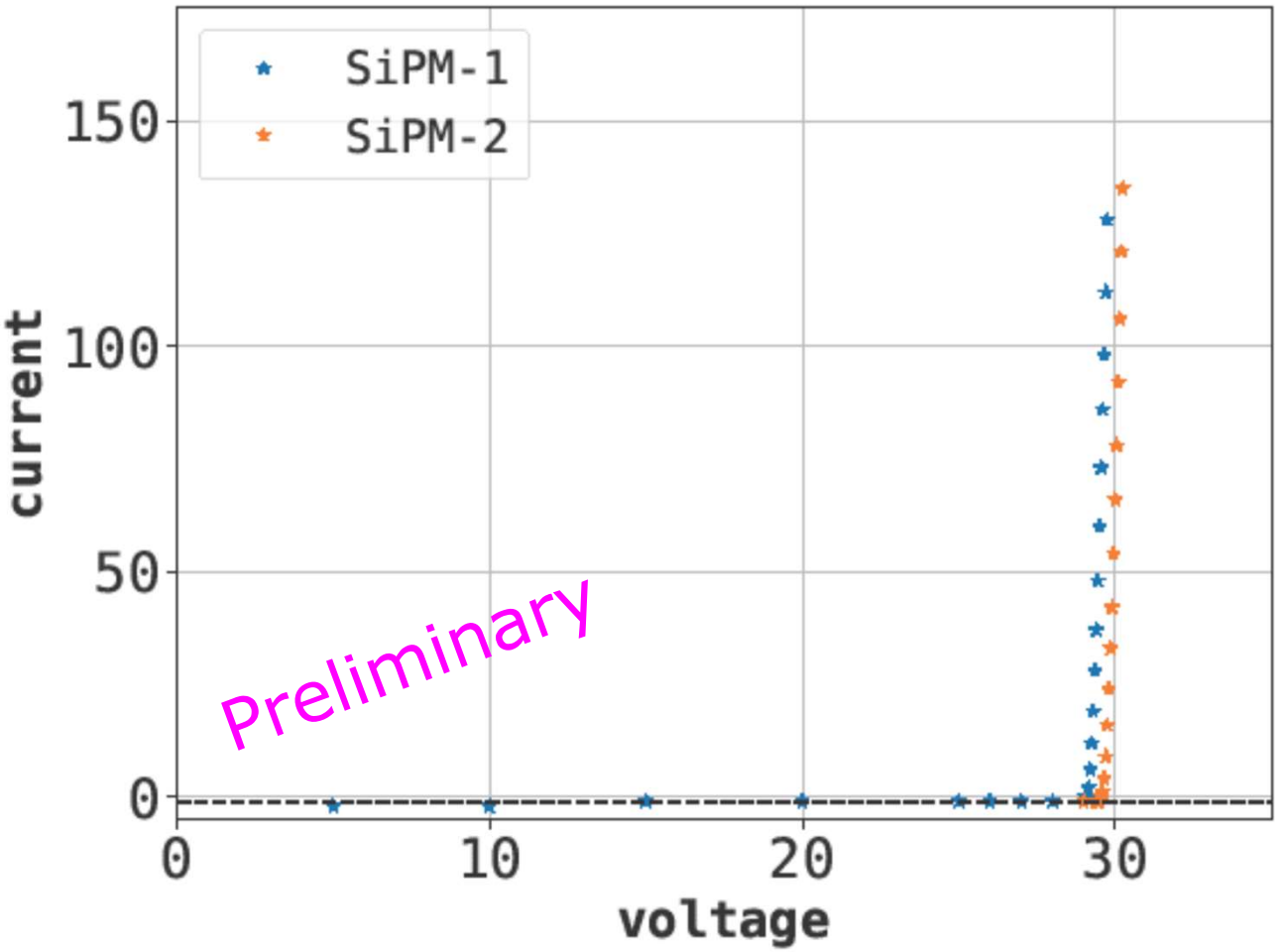
Outer vacuum jacket

Two SiPMs: Hamamatsu S14160



Ref: Kuzniak, LIDINE-2023

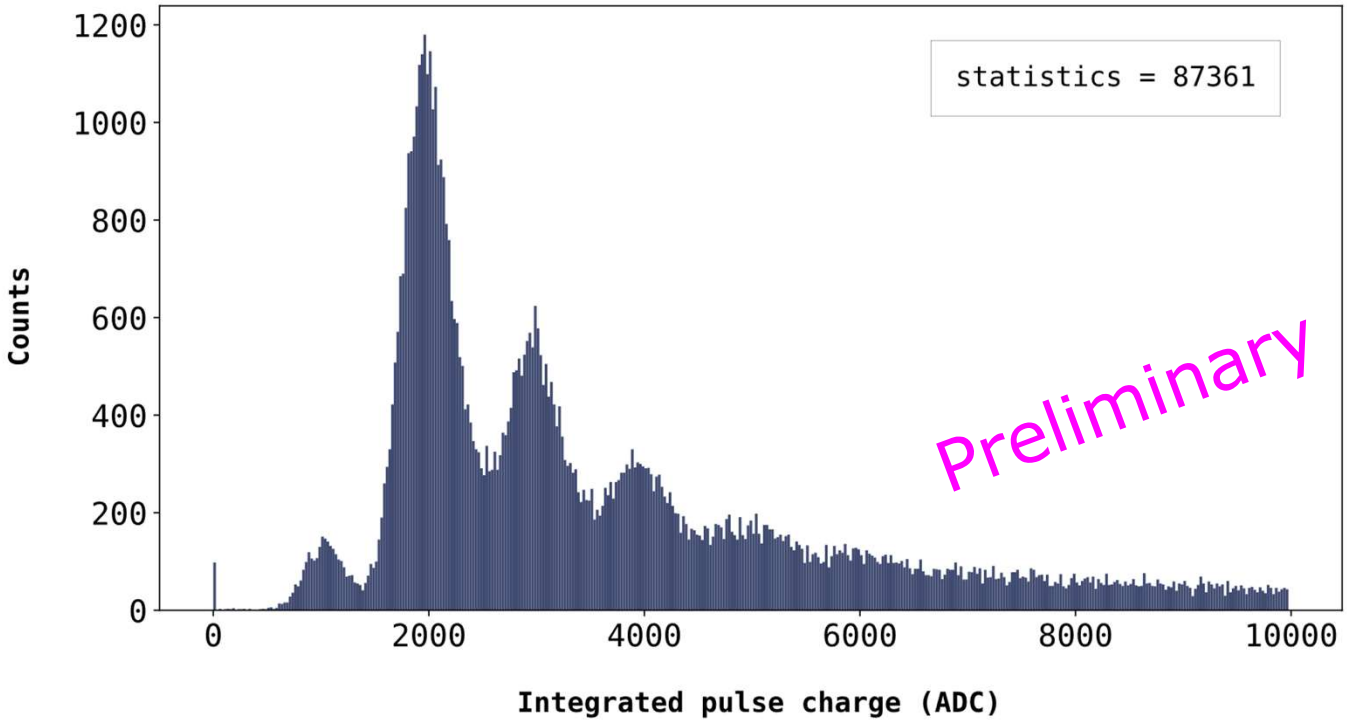
VI curve



- Found the breakdown voltage for both SiPM's
- The SiPM are operated at the same Over-Voltage, i.e., gains balanced.

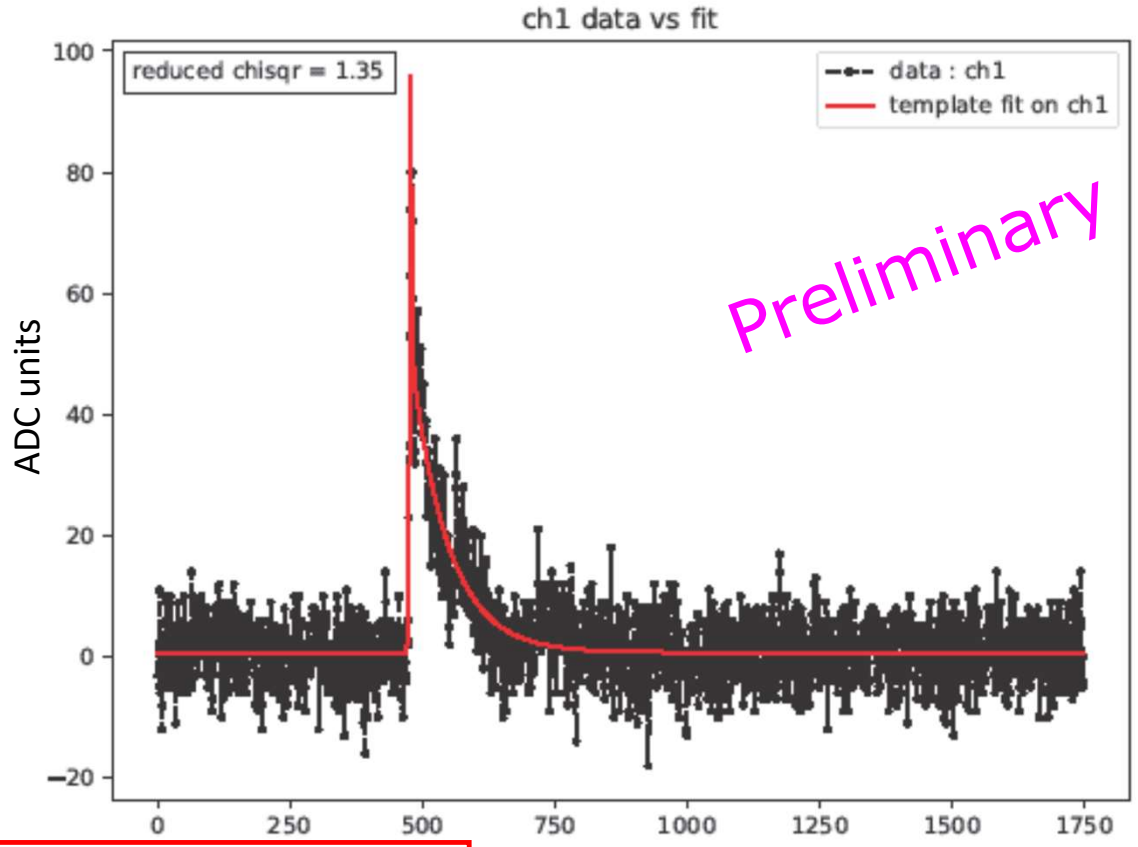
PhotoElectron Charge Spectrum (fingerplot)

- Cell is in vacuum (no Ar)
- Data taken with LED pulser.
- SiPM at Liquid Nitrogen temperature.
- Filtered waveform from summation of two SiPM's
- AR filter is tuned to waveform for these SiPM's (see next slide).
- SPE charge: 1564 +/- 14.57 (ADC)
- SNR: 4.47



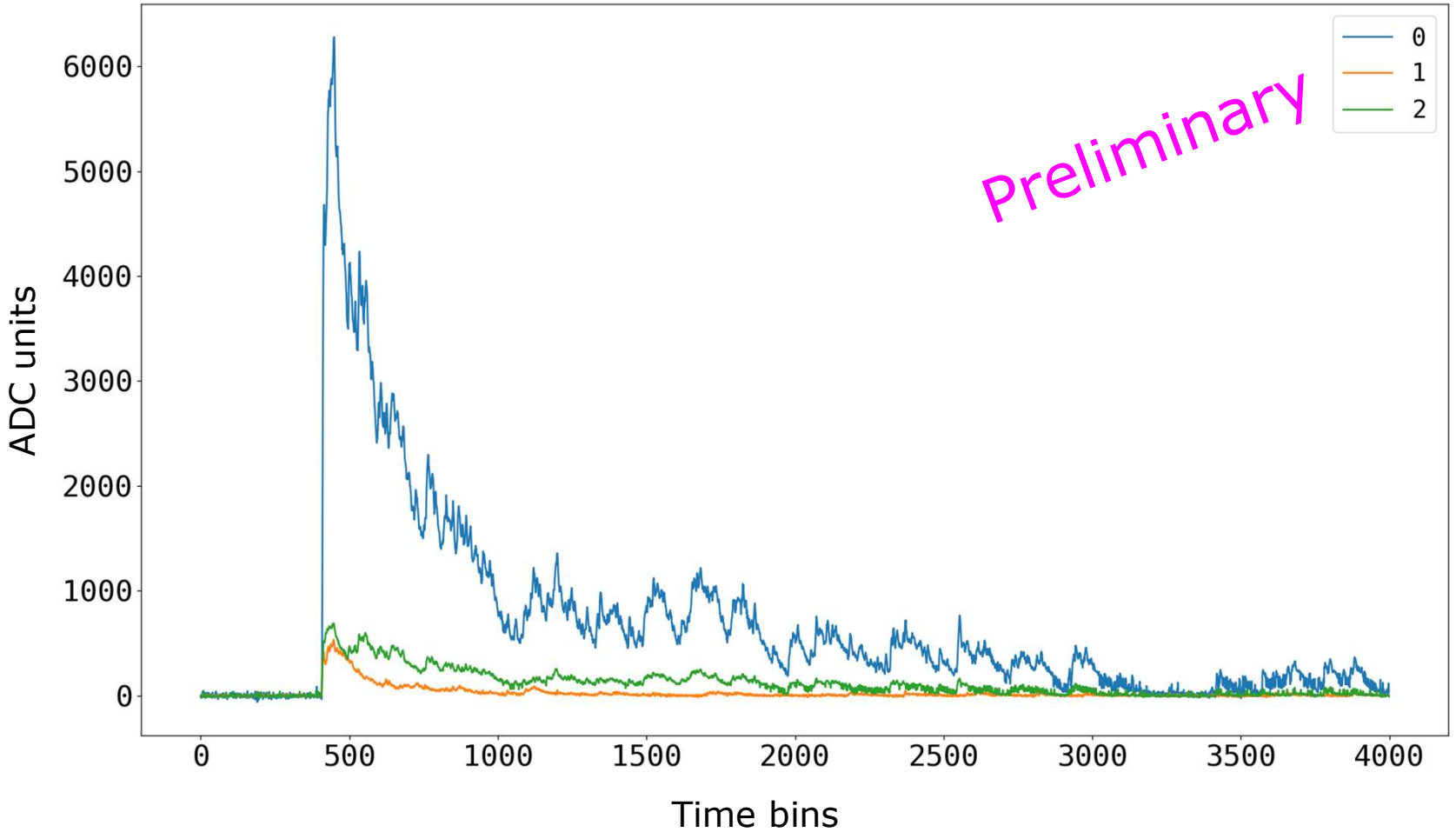
AR filter optimization

- Auto-regressive (AR) Filter used to reduce noise
- AR filter parameters were tuned accordingly to match the pulse parameters



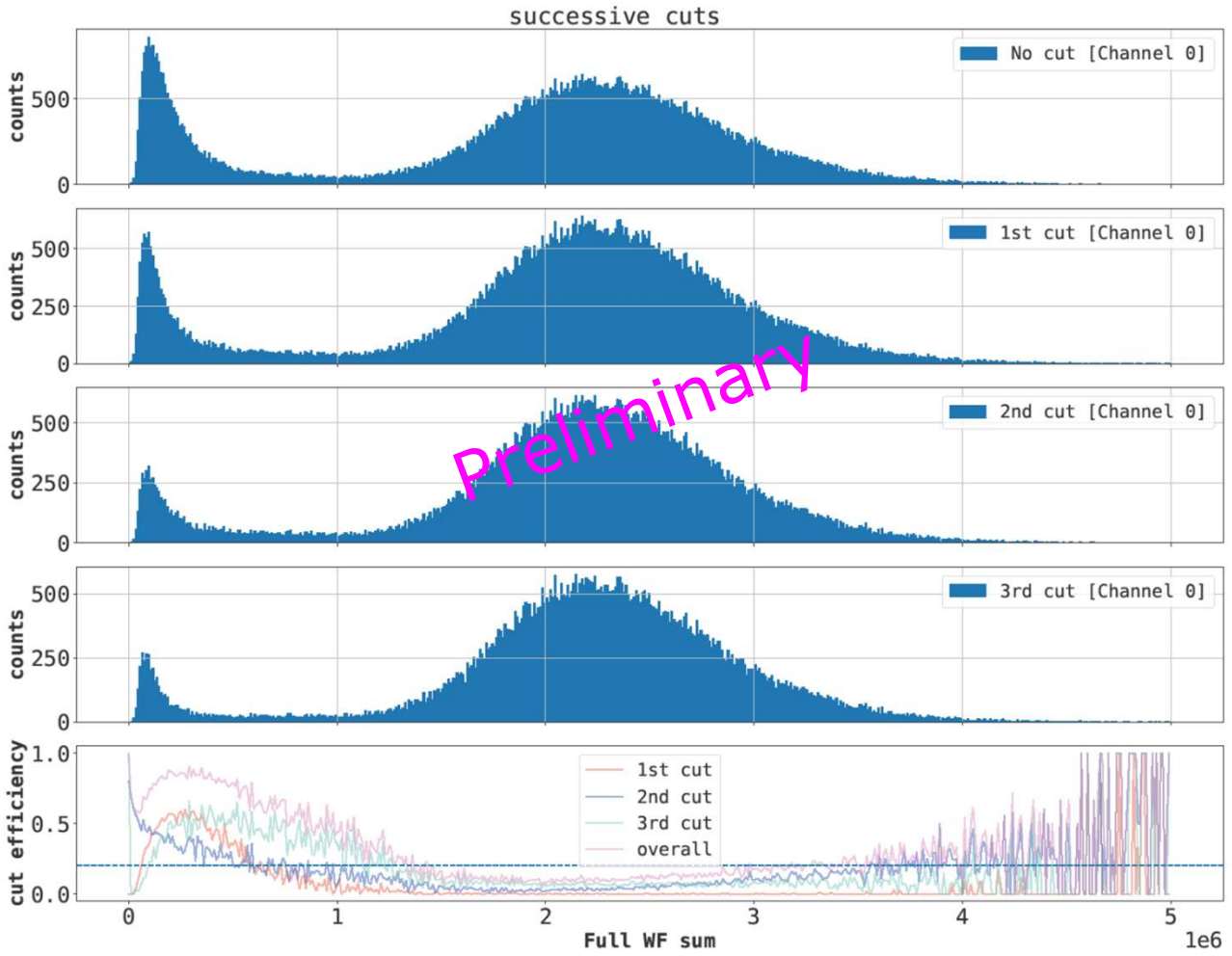
$$(1-\alpha) * gauss(t-t0) + \alpha * heaviside(t-t0) * \frac{exp\left(-\frac{t-t0}{\tau}\right)}{\tau}$$

Raw waveform

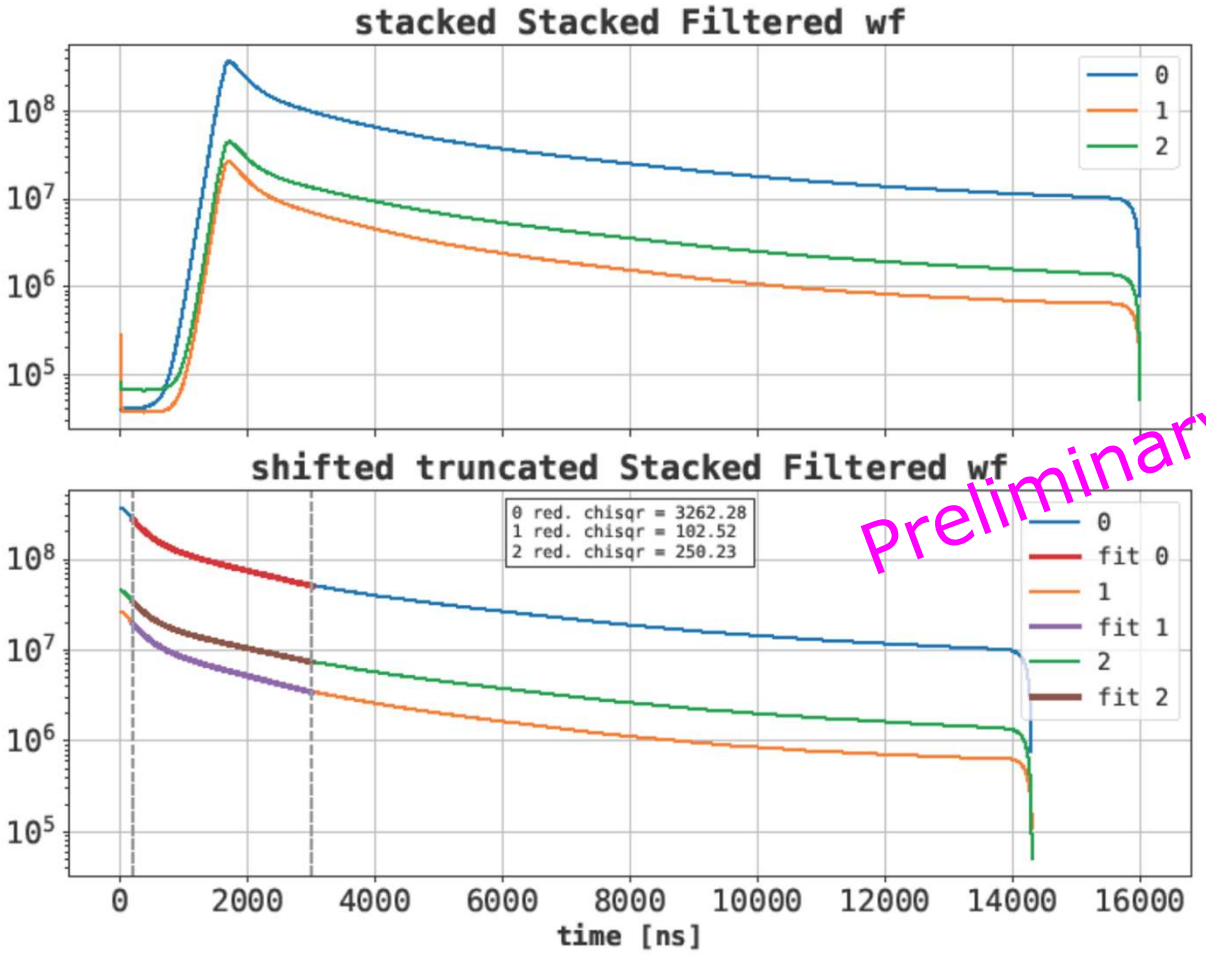


Event selection cuts

- Events selection cuts are based on following quantities:
- 1st cut: Sum of PreTrigger window
- 2nd cut: Centre of Mass for waveform
- 3rd cut: Time separation between pulses in SiPM-1 and SiPM-2

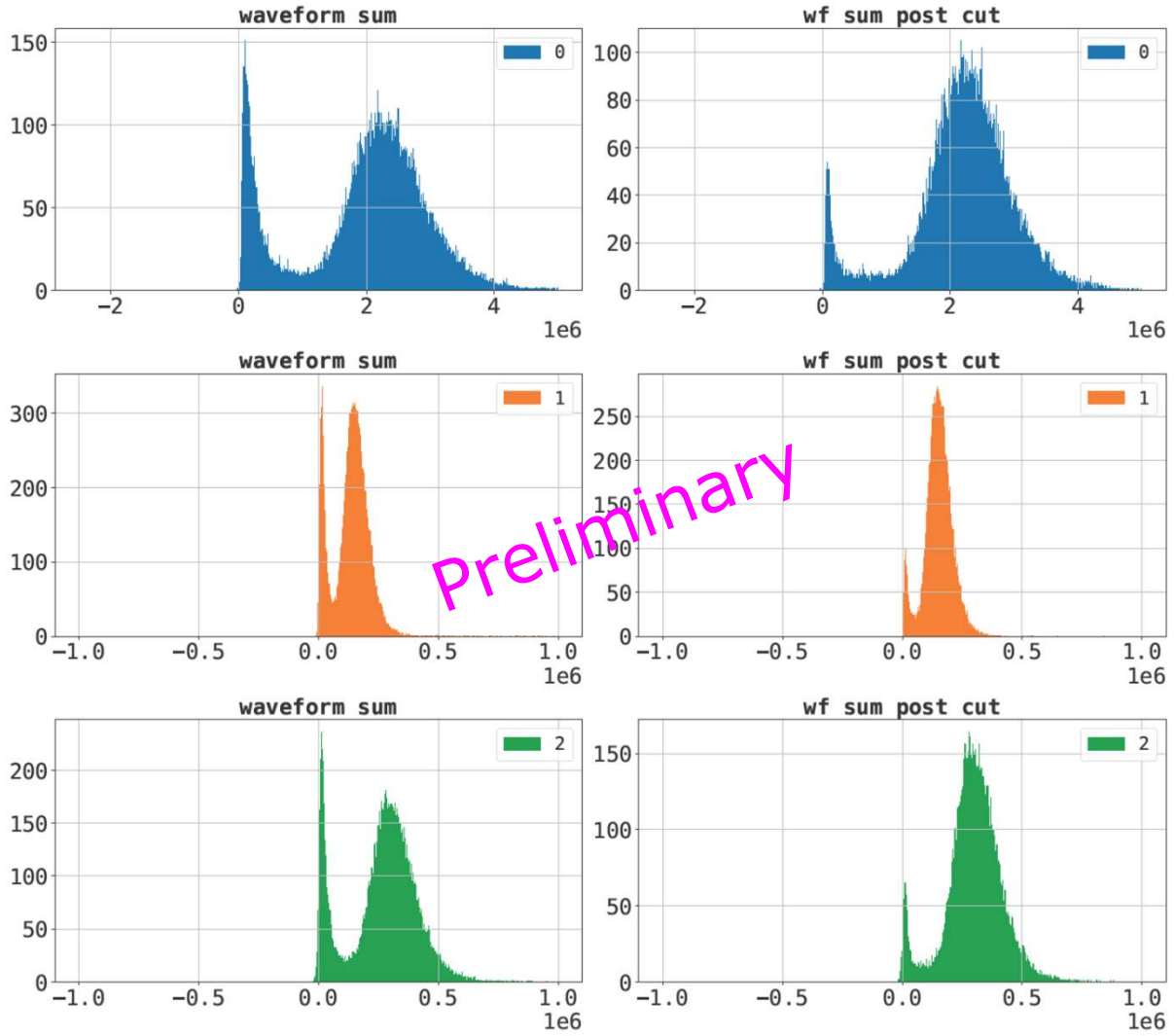


Cross check of gaseous Ar triplet time constant



Mean lifetime =
2450 +/- 2.722 ns

Comparison of charge distribution before and after applying the cuts

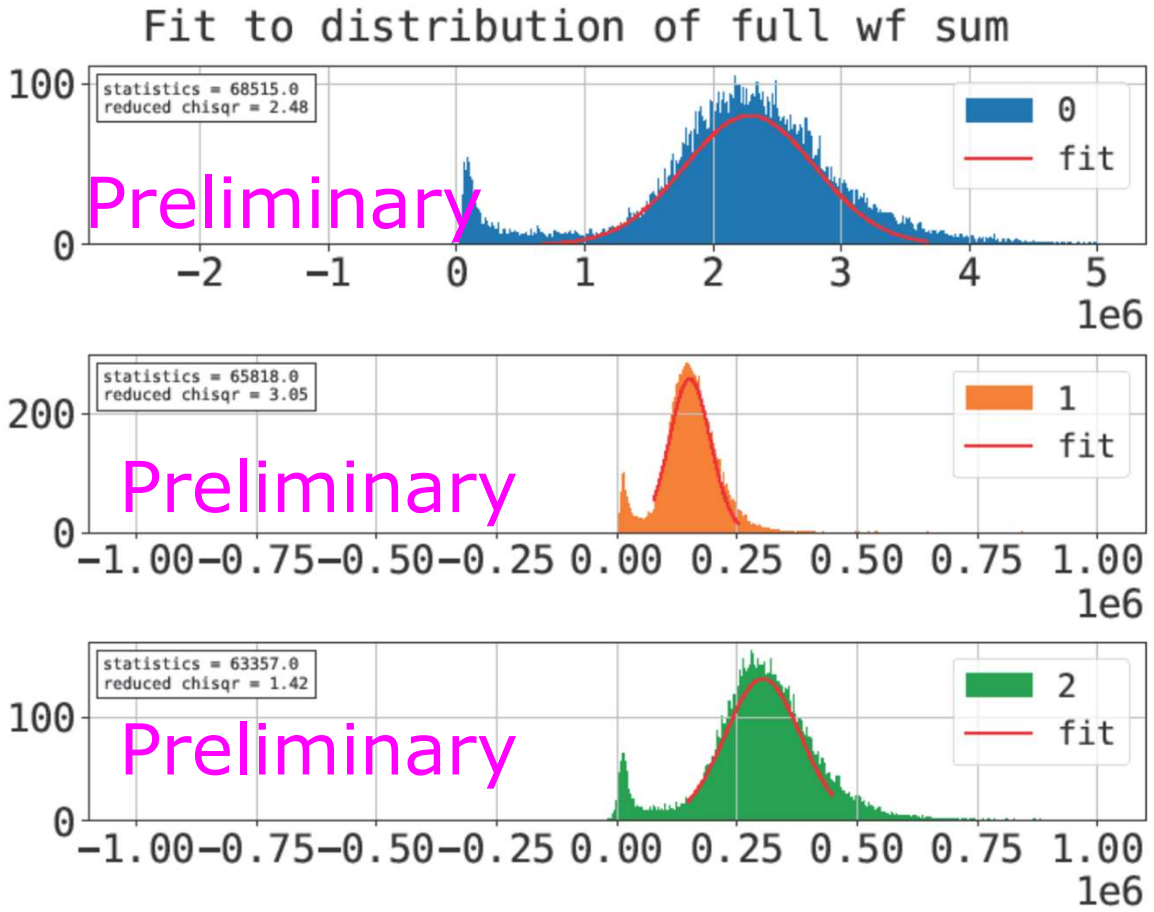


Charge distribution post cut

	Ch 0
Integral (ADC)*Mean*	2.286e+06
Photoelectrons N_{pe}	1462

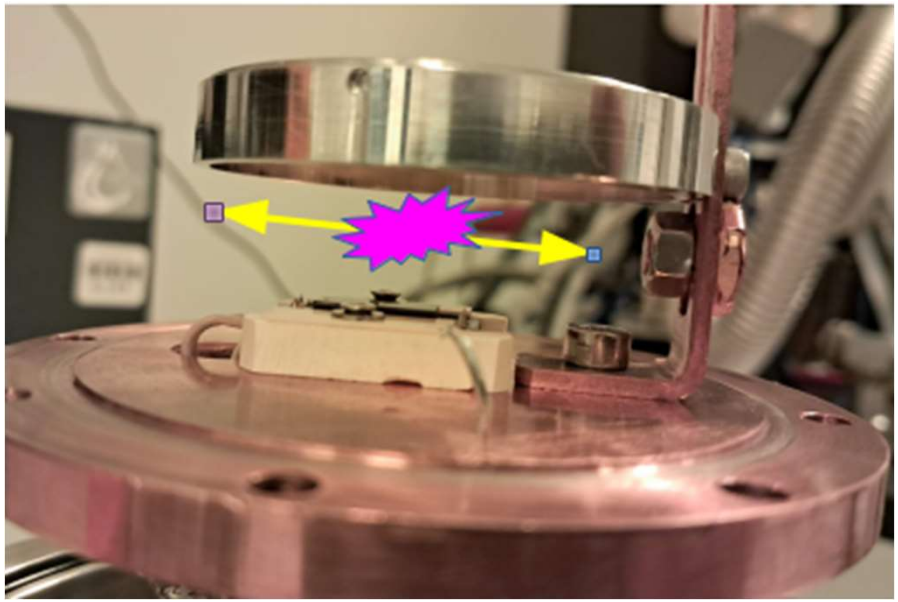
Preliminary

- Number of detected photoelectrons from an alpha scintillation event is consistent with expectations



Status

- Following the SiPM calibration, collected cryogenic data for 4 PEN samples and TPB reference samples (twice)
- Revealed instrumental issues:
  - Intermittent noise – efficiently removed with cuts in most of the runs – likely a grounding issue to be investigated and fixed
  - Asymmetry of signal collected in both SiPMs varies from run to run
    - Could be a hint of Ar pressure different between runs
    - Dangerous, as it can move the position of the Bragg maximum/primary VUV light source
    - Under investigation, pressure transducer to be added
    - Working out a correction for the collected data
  - Temperature stability acceptable for several hours of data taking
- Comparison of samples as soon as the varying assymetry issue is understood
- For now planning to proceed with the room temperature and near UV measurements



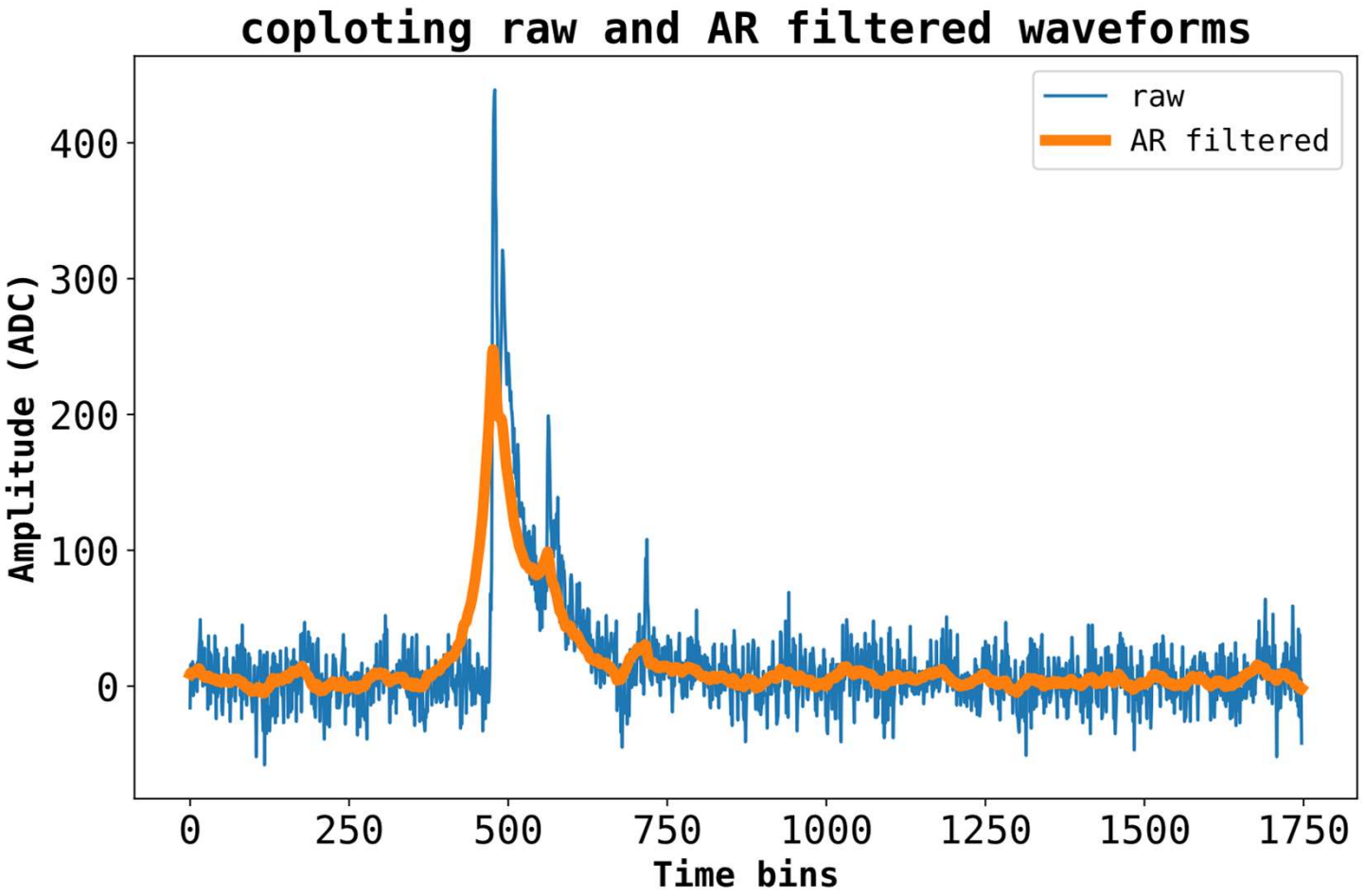
Summary

- A low temperature setup for measurement of wavelength shifting efficiency at VUV wavelength is presented
  - Overall the light yield and performance consistent with expectations
- SiPM calibration and analysis flow is in now place
- The application for quality control of PEN wavelength shifters is discussed:
  - Several samples already measured, but more work on systematic needed for a robust comparison
  - Better control/monitoring of gaseous Ar pressure is likely needed
- Starting to characterize larger quantities of PEN samples:
  - With near UV excitation at room temperature
  - With VUV at room temperature

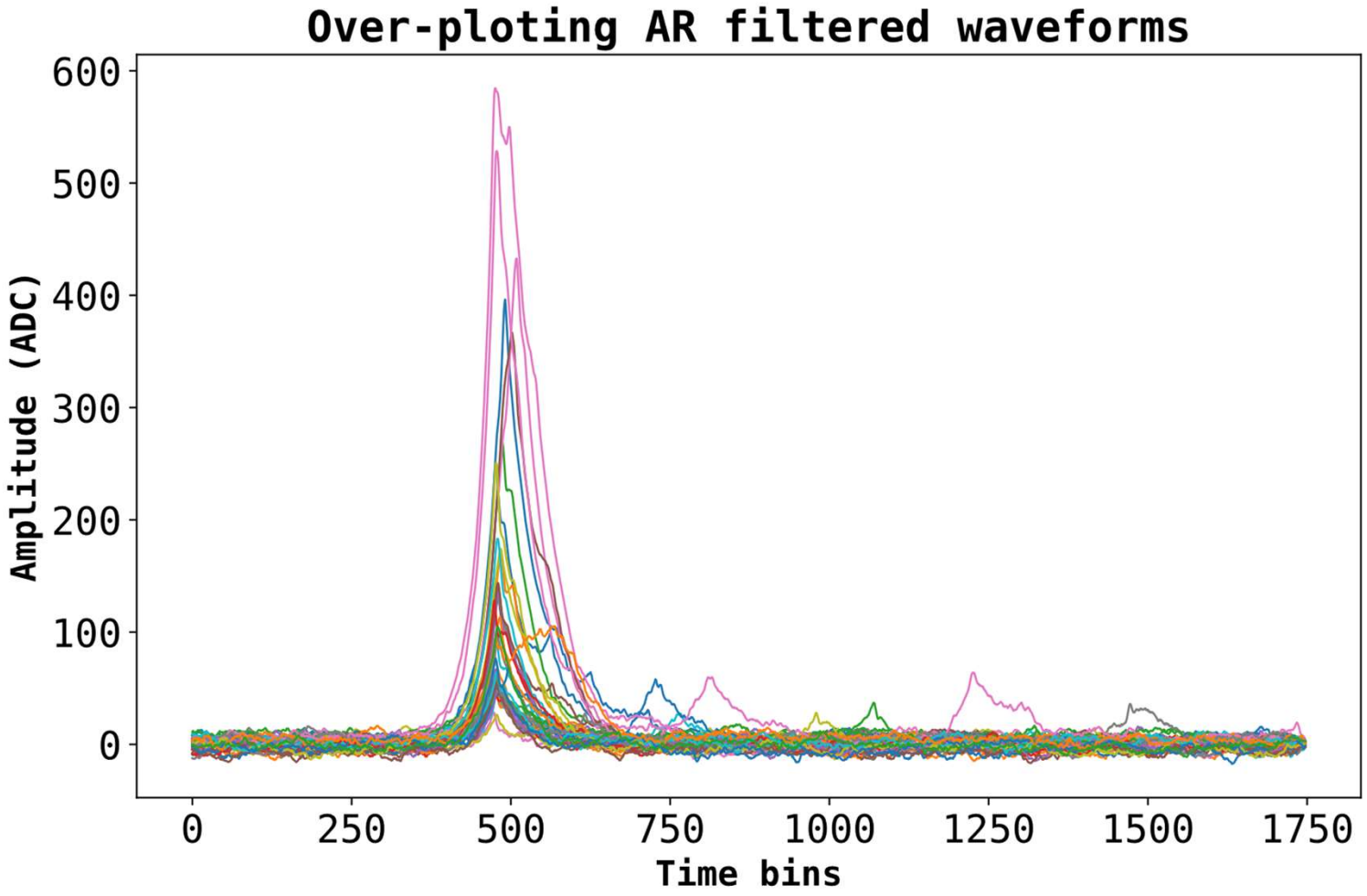
Thank You

back up slides

Raw vs AR filtered WF



AR filtered


Over-ploting AR filtered waveforms
Amplitude (ADC)
600
500
400
300
200
100
0
0
250
500
750
1000
1250
1500
1750
Time bins

Charge distribution post cut

	Ch 0
$Mean$	2.286e+06
N_{pe}	1462