Formation of a forward beam of antihydrogen
Status of the ESDA analysis

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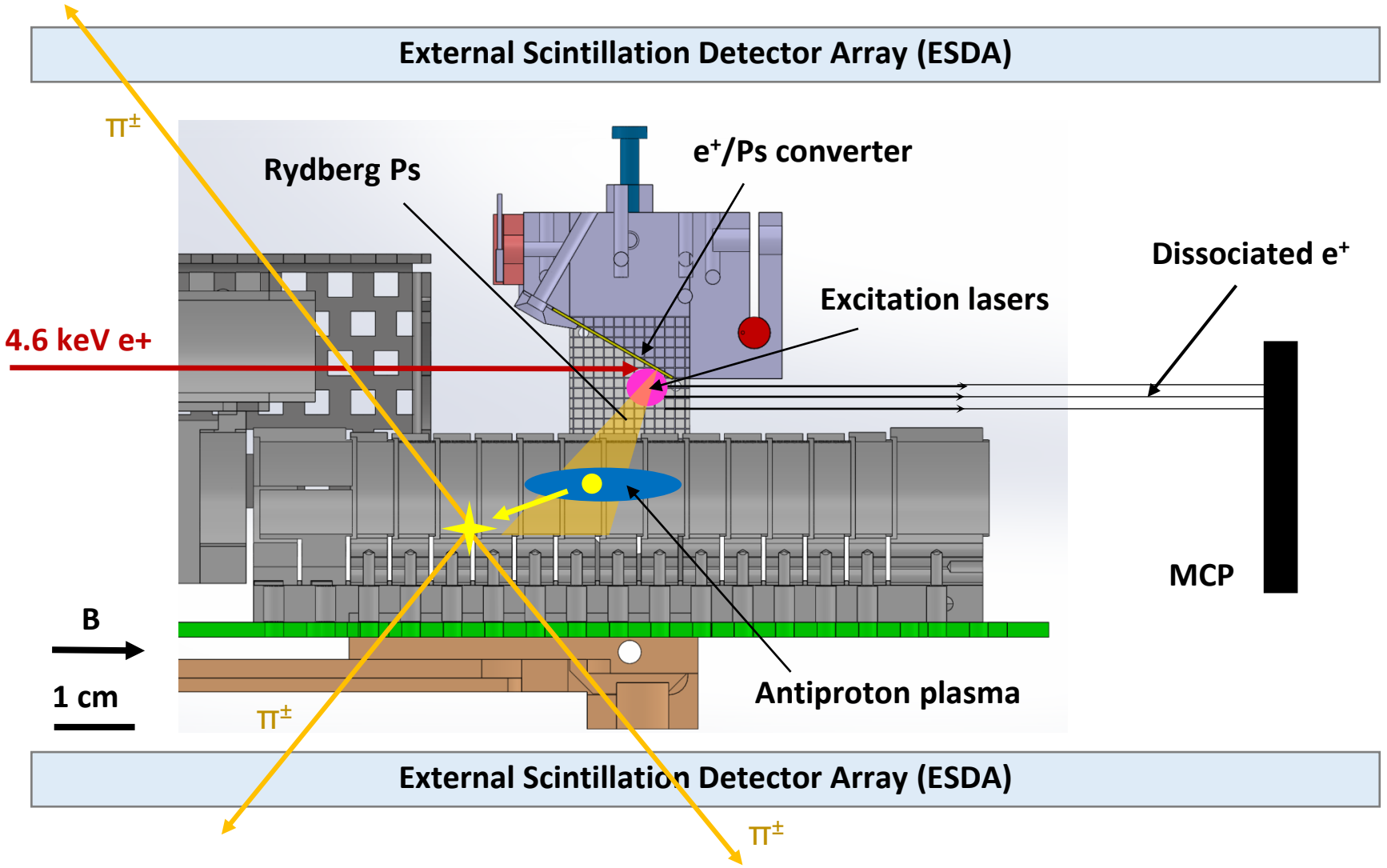
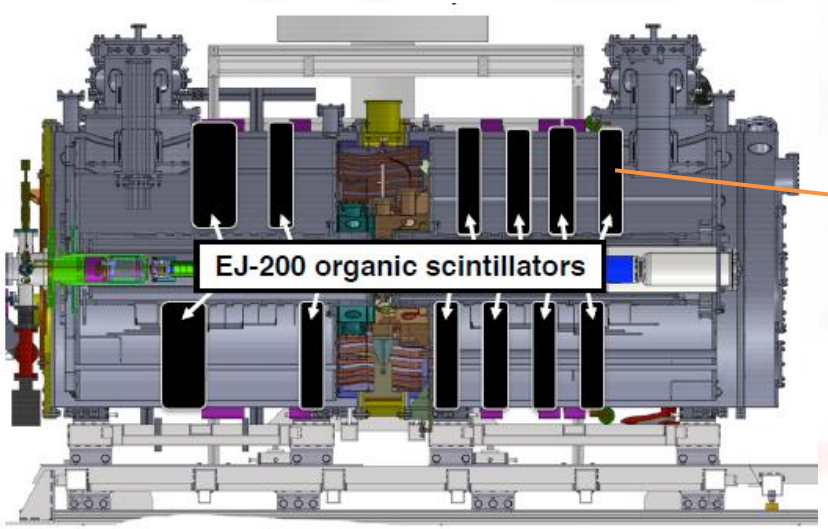
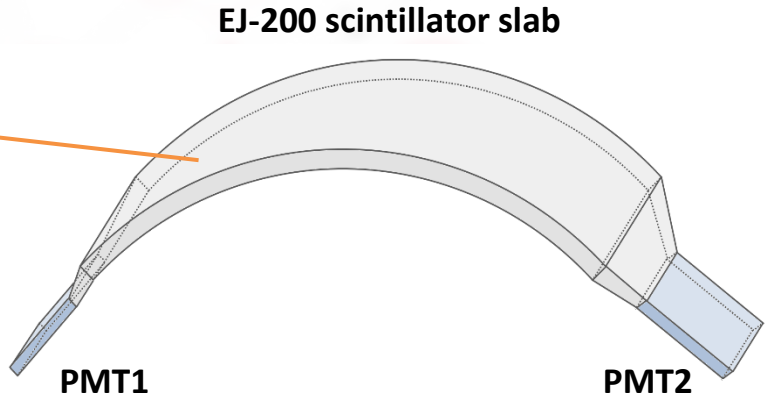
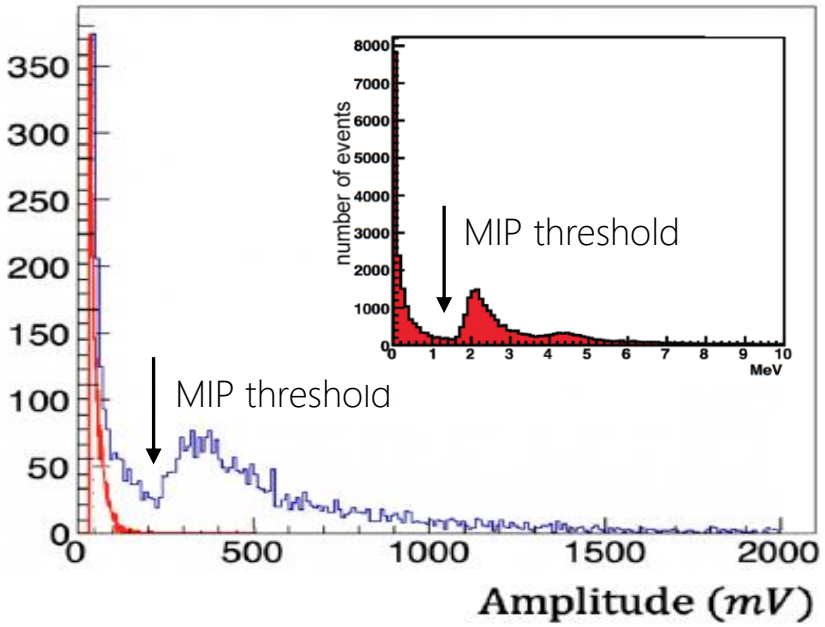
What happens when antihydrogen annihilates



Antihydrogen detector: digitized ESDA





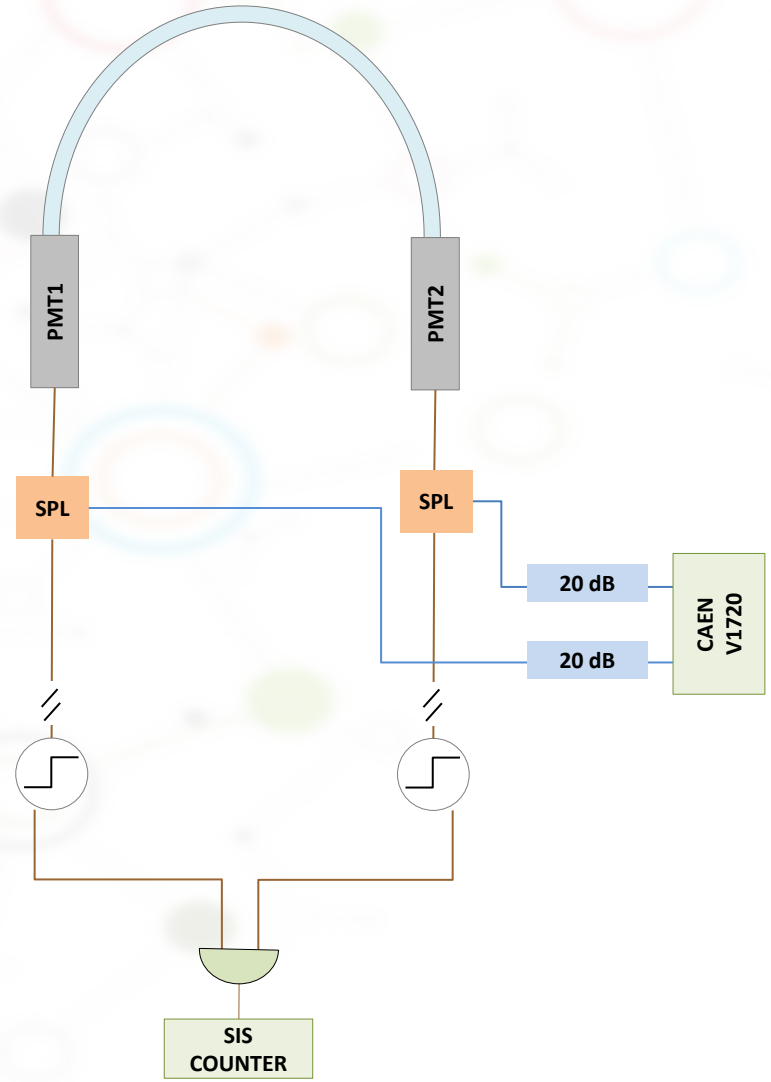


Scintillator array for MIP detection

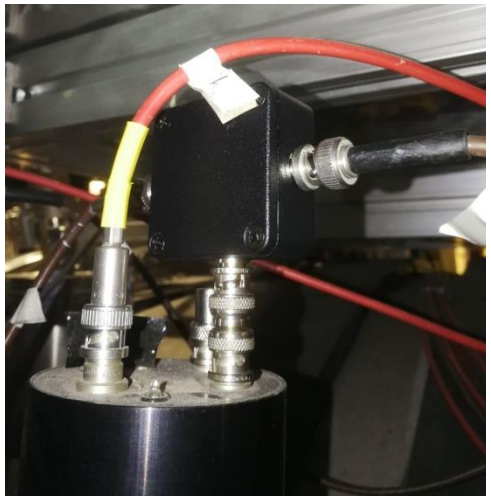
- 8 x EJ-200 scintillator slabs
- Scintillators are read at both ends with photomultipliers
- Each PMT is digitized at 250 MHz
- Software **coincidence** to reject PMT noise
- Amplitude cut to reject **gamma background**

The ESDA digitized acquisition chain in 2023

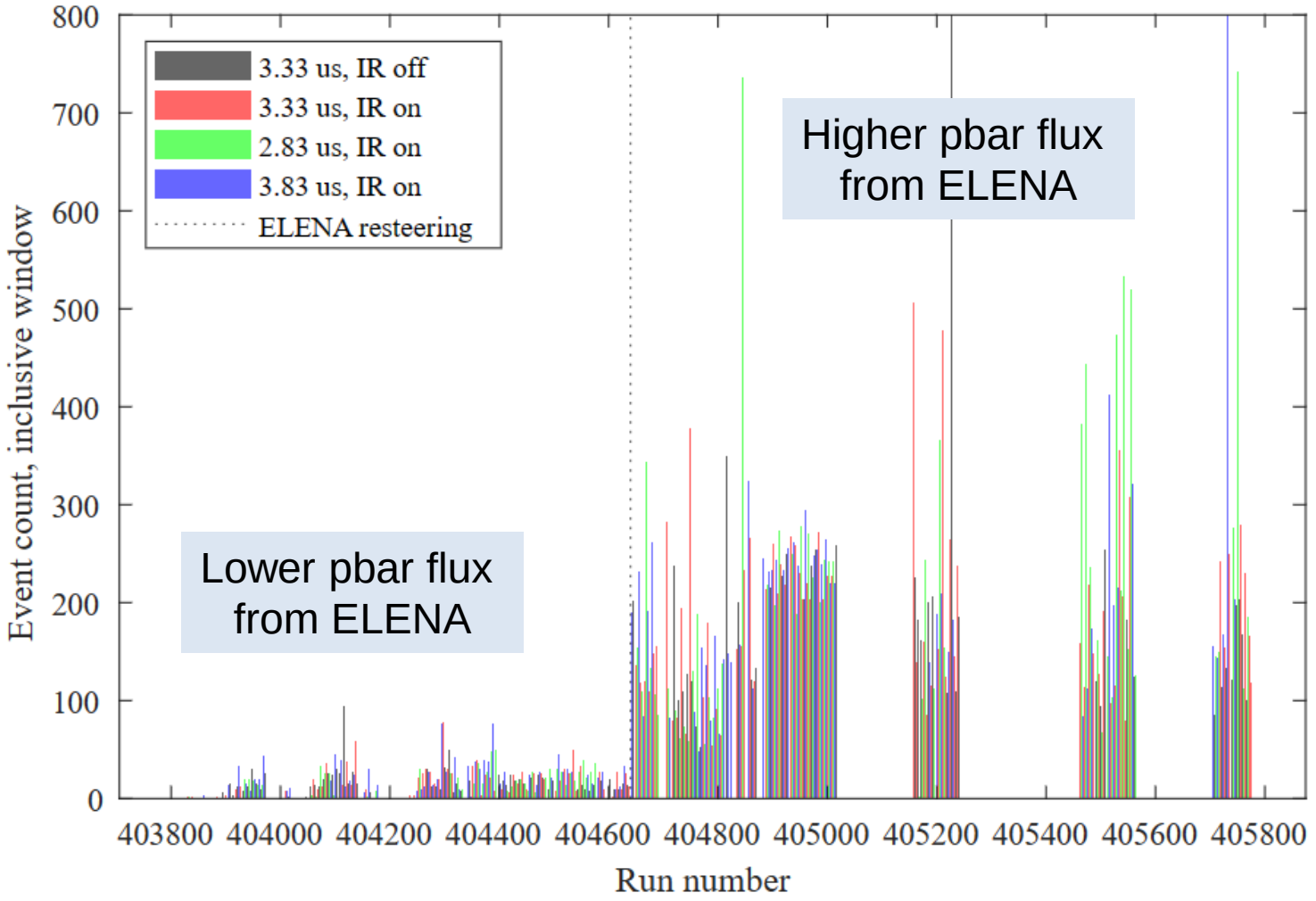
ESDA single slab, 2024 config

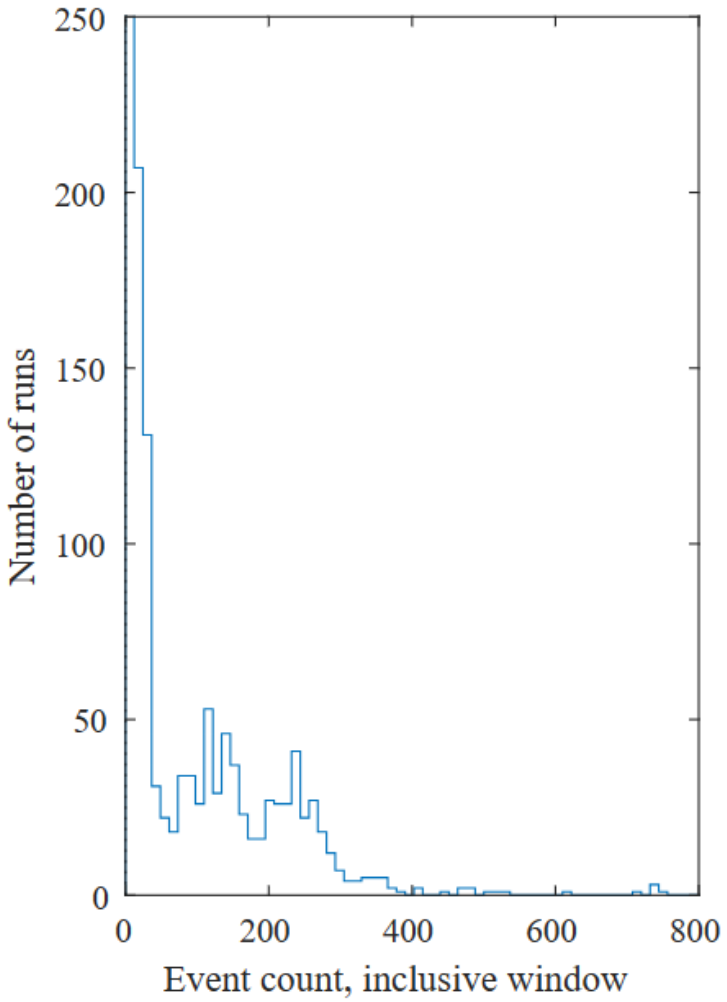


- A 50/50 splitter for each 24 PMT (8 PMT @5Tesla, 16 PMT @1Tesla)
- One end is directly connected to the discriminated acquisition chain **continuosly monitoring antiproton annihilations**
- The other end is sent to the platform where it is 20 dB attenuated and digitizer for the **acquisition of the antihydrogen signal**
- The splitter is connected directly to the PMT to minimize ringing due to the impedence mismatching.
- Splitters have been installed in vertical orientation(top) except for the 8 top PMT @1Tesla that have been installed in horizontal orientation due to lack of space (bottom)

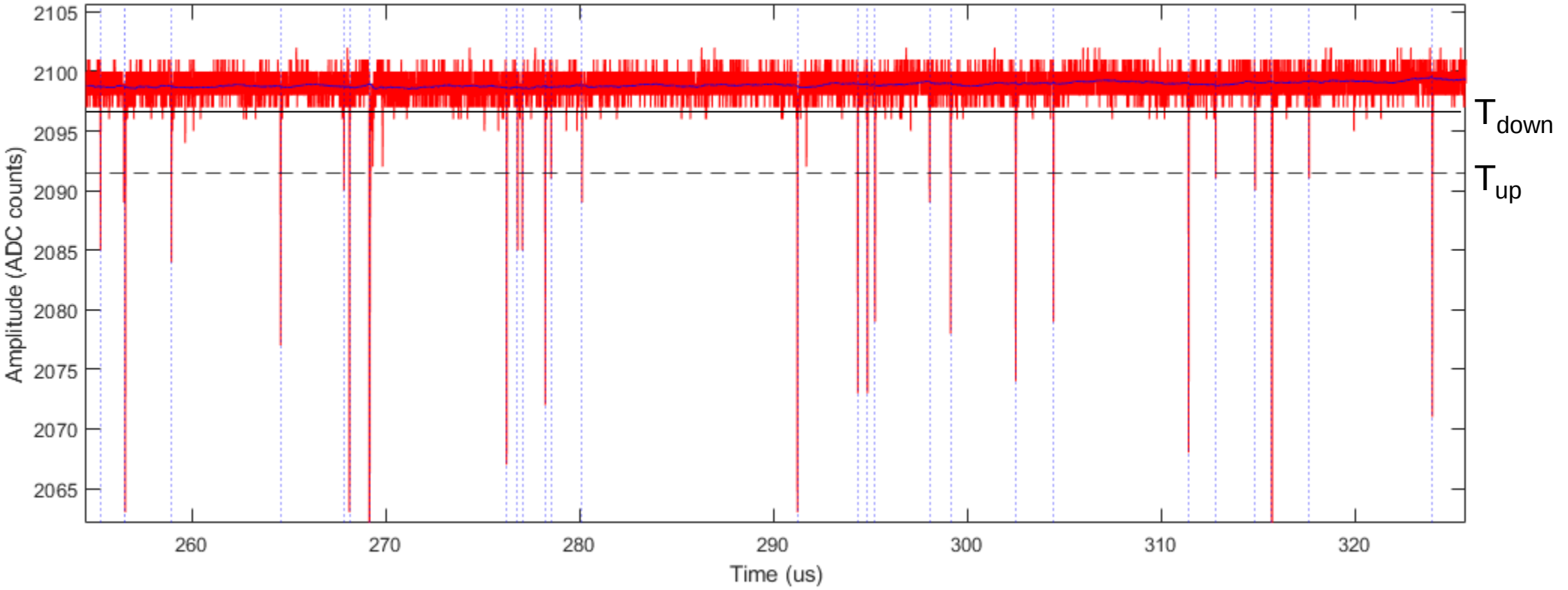


Dataset overview





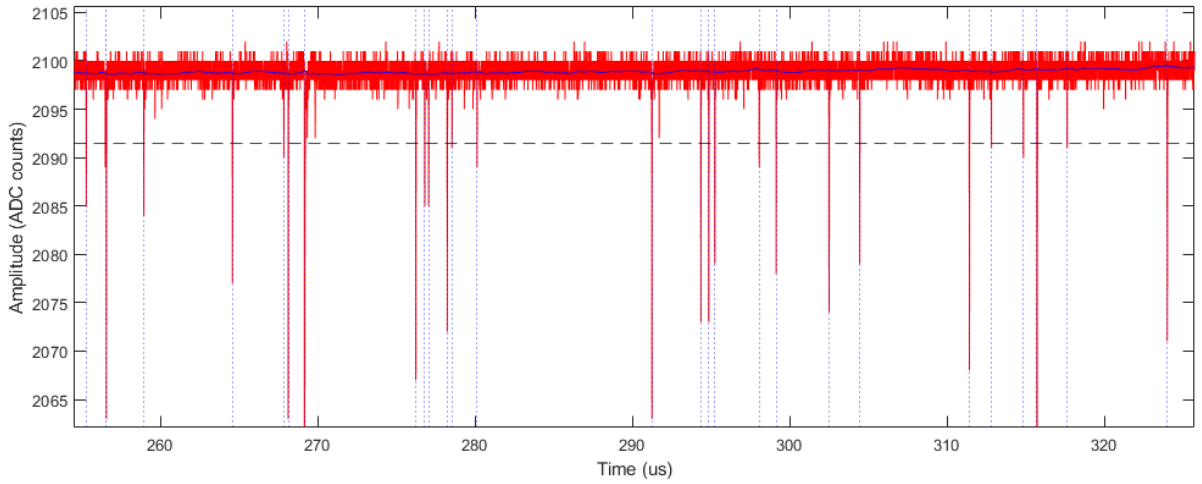
Software trigger and event discrimination



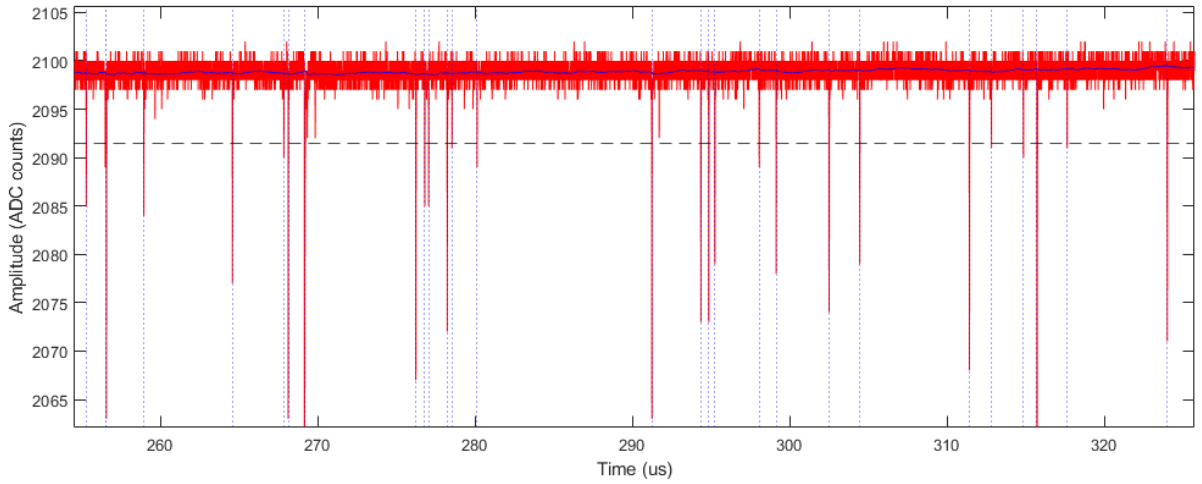
- Baseline rms-amplitude A_{rms} estimator from the first 10us of acquisition
- Baseline follower: `baseline_val = (1.0 - 0.005) * baseline_val + 0.005 .* A(i)`
- Threshold discriminator with hysteresis (T_{up} = 8 A_{rms}, T_{down} = 3 A_{rms})

Coincidence formation

PMT$_n$



PMT$_{n+1}$



Coincidences filtering

- AND on the single PMT events
- 50 ns coincidence window

List of coincident events

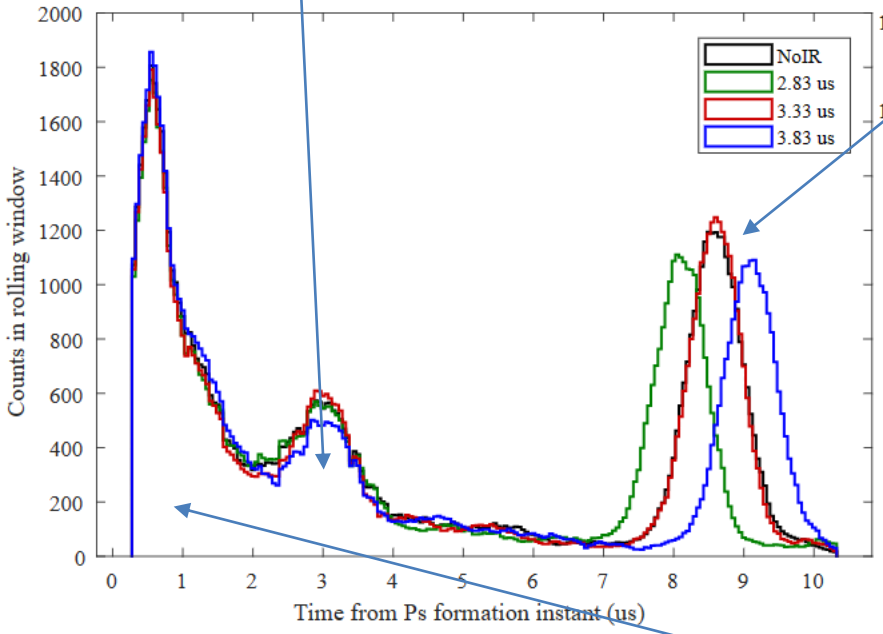
- Average time-of-arrival
- Time difference between PMTs
- Average deposited charge
- Average amplitude

Coincidence formation

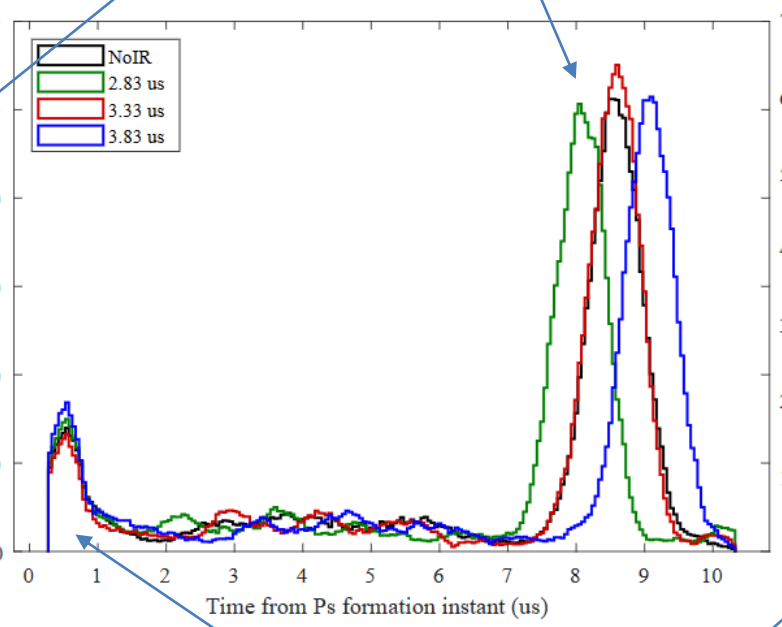
Cancelling of PMT afterpulses

No efficiency loss to pbar/Hbar detection

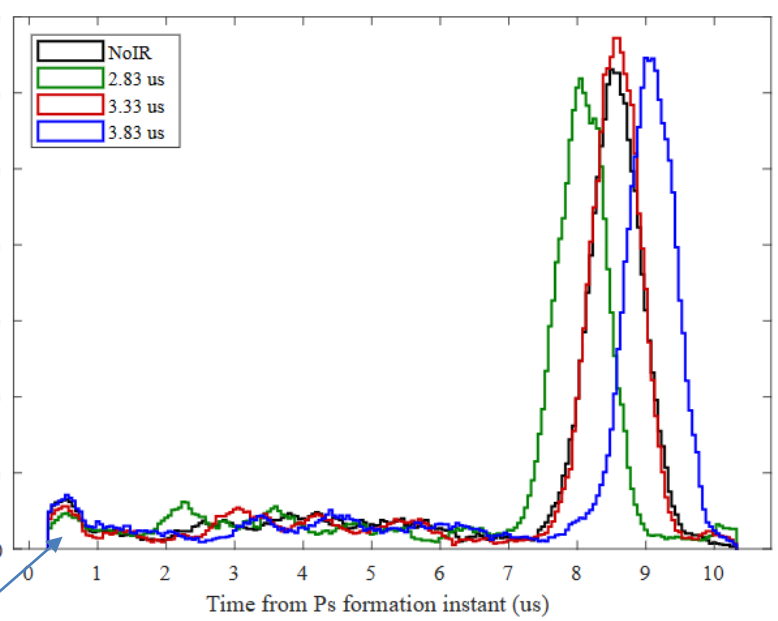
No coincidence, no charge cut



Coincidence, no charge cut

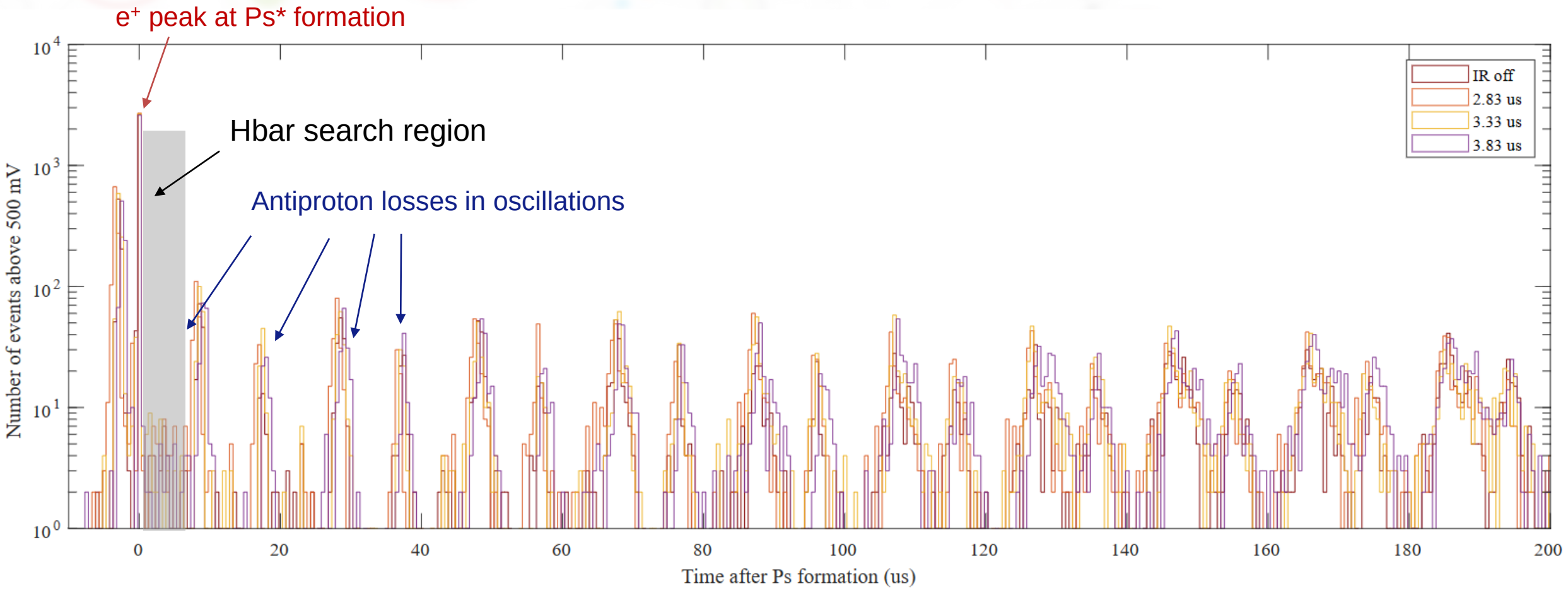


Coincidence, charge cut

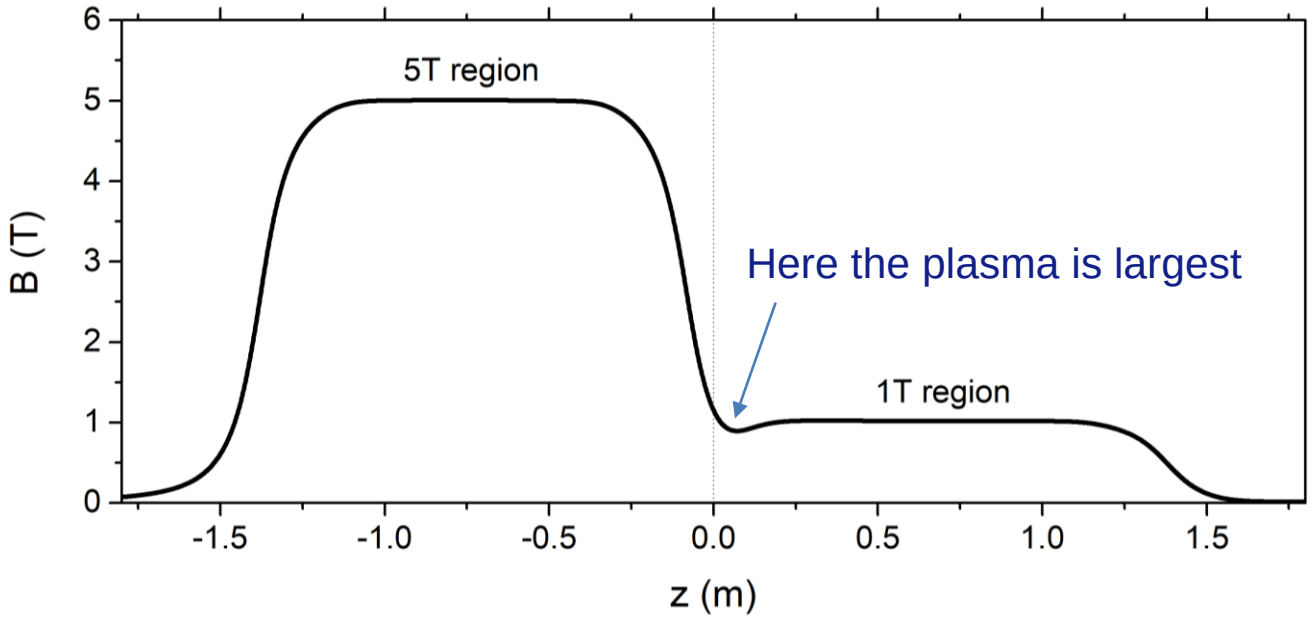


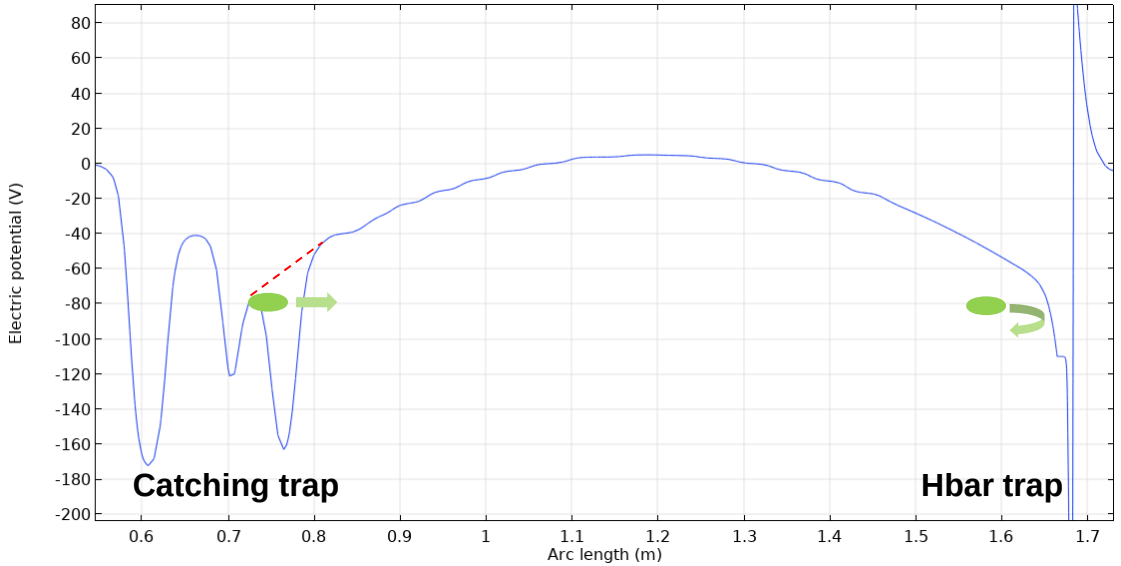
Reduction in gamma ray background

A beautiful observation of antiprotons swinging

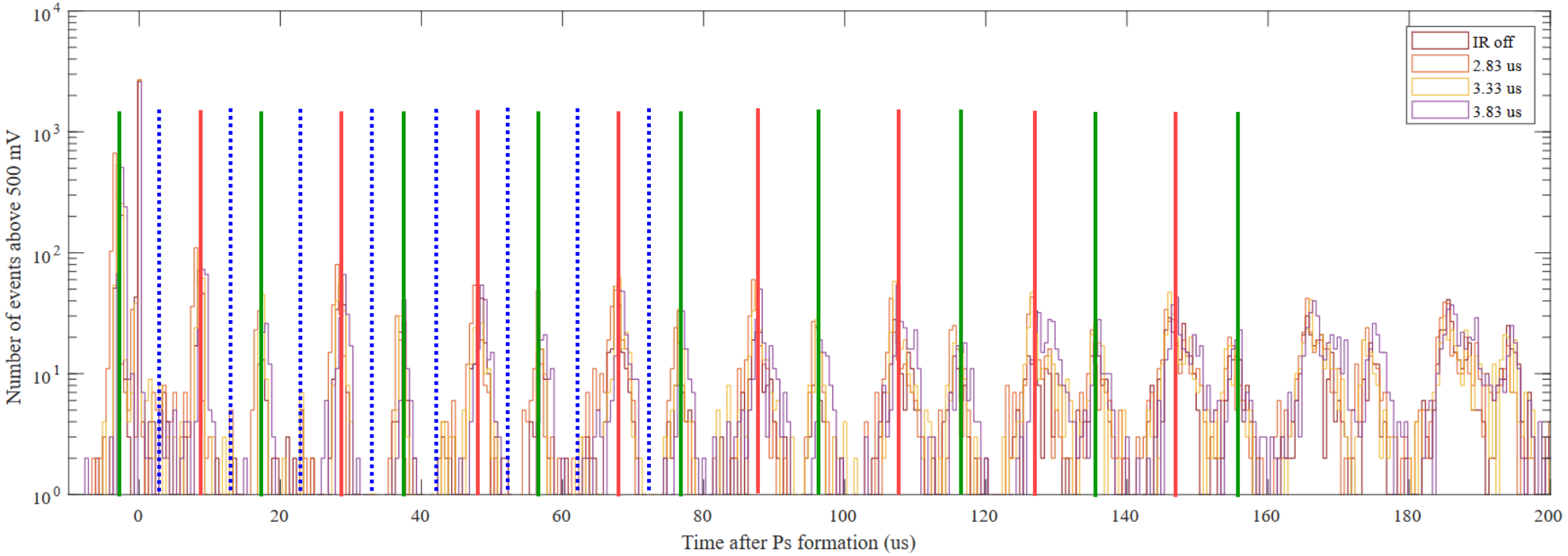


Where are losses occurring?





A beautiful observation of antiprotons swinging



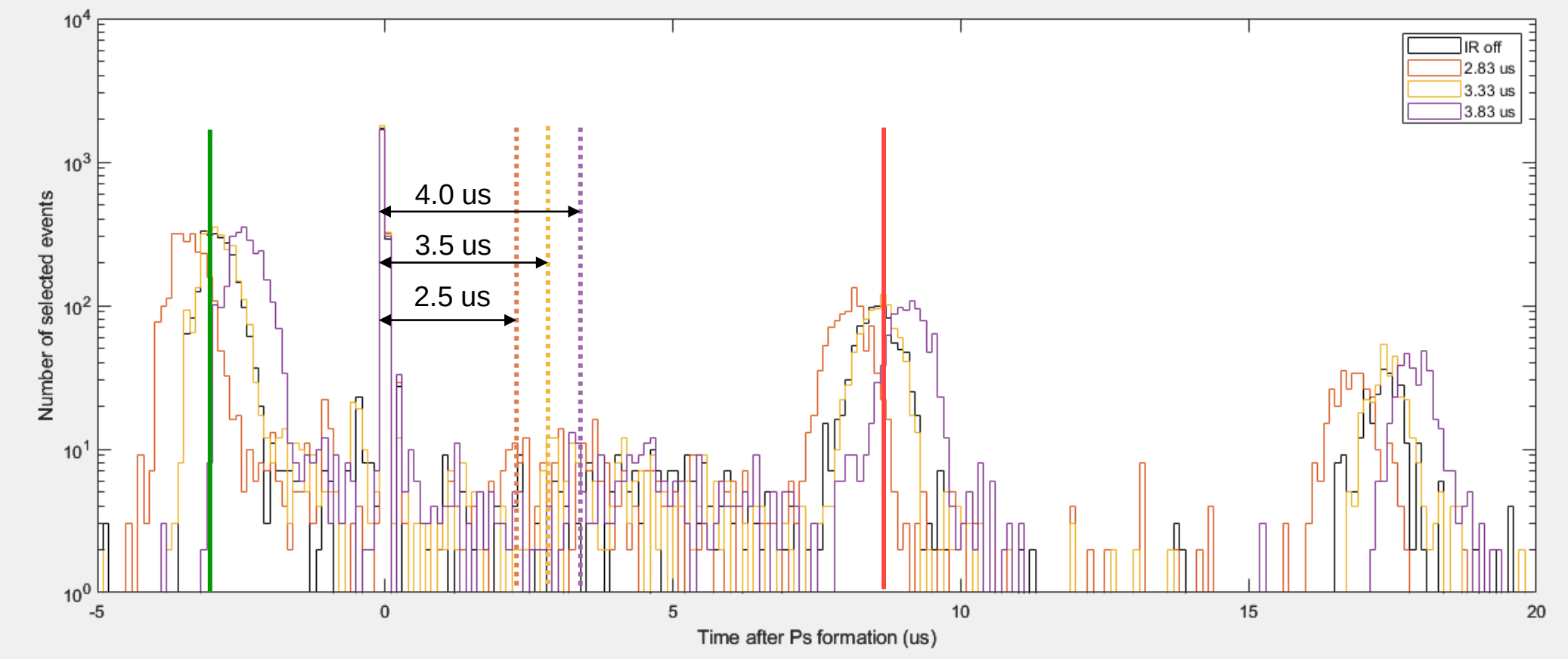
From 5T to 1T

From 1T to 5T

Midpoints

Theory: midpoints are the points of null velocity

A beautiful observation of antiprotons swinging



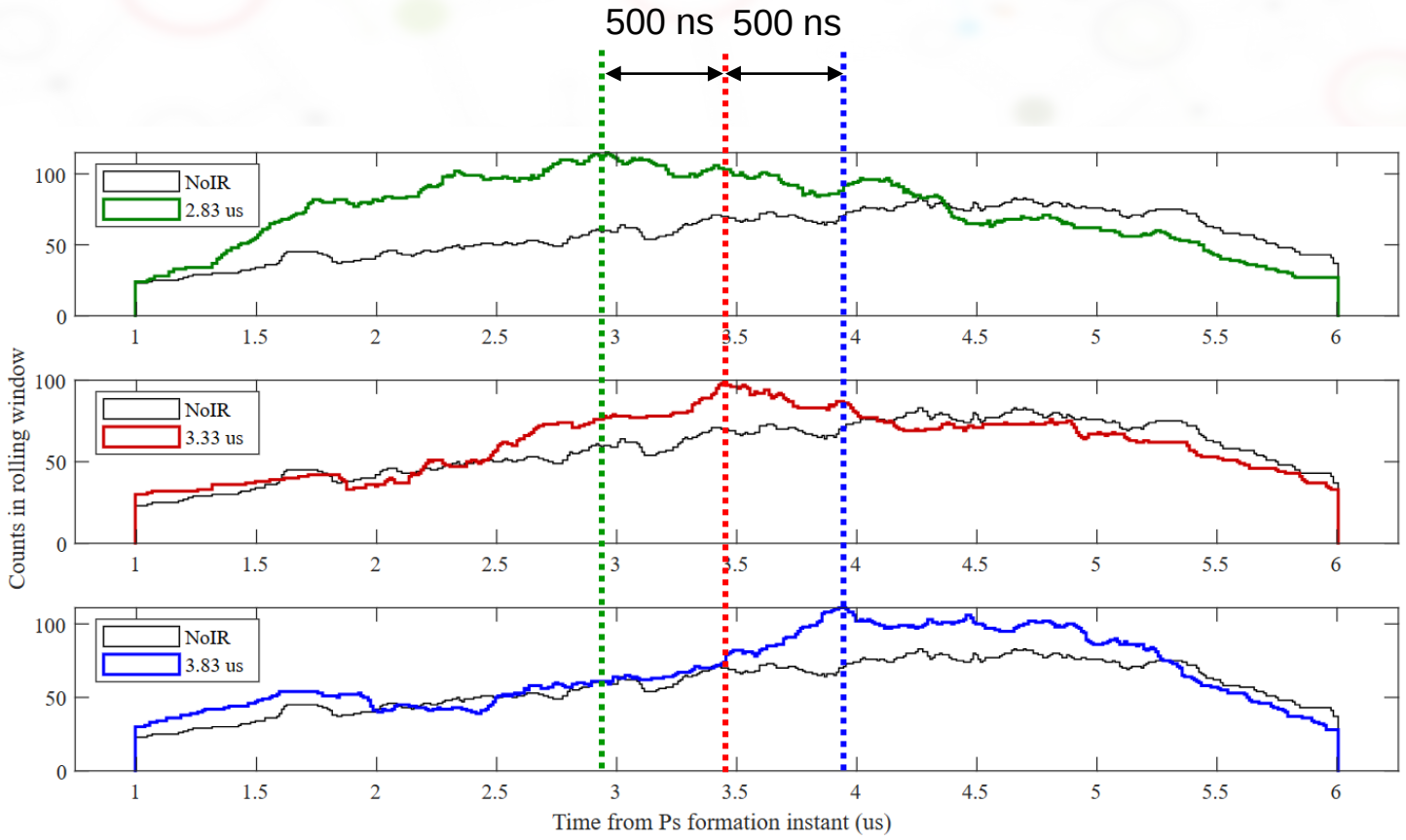
From 5T to 1T

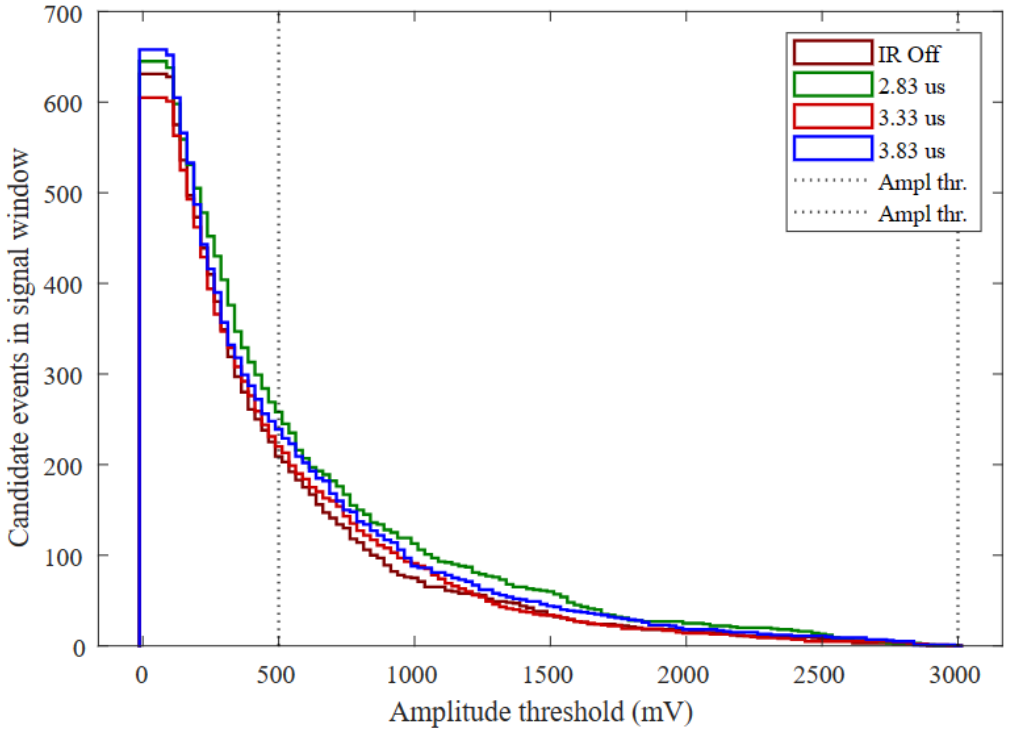
From 1T to 5T

Midpoints

Hypothetical conclusion: time calibration procedure was off by us
we were always sending positrons too early, i.e. with a forward boost

Antihydrogen signal interpretation

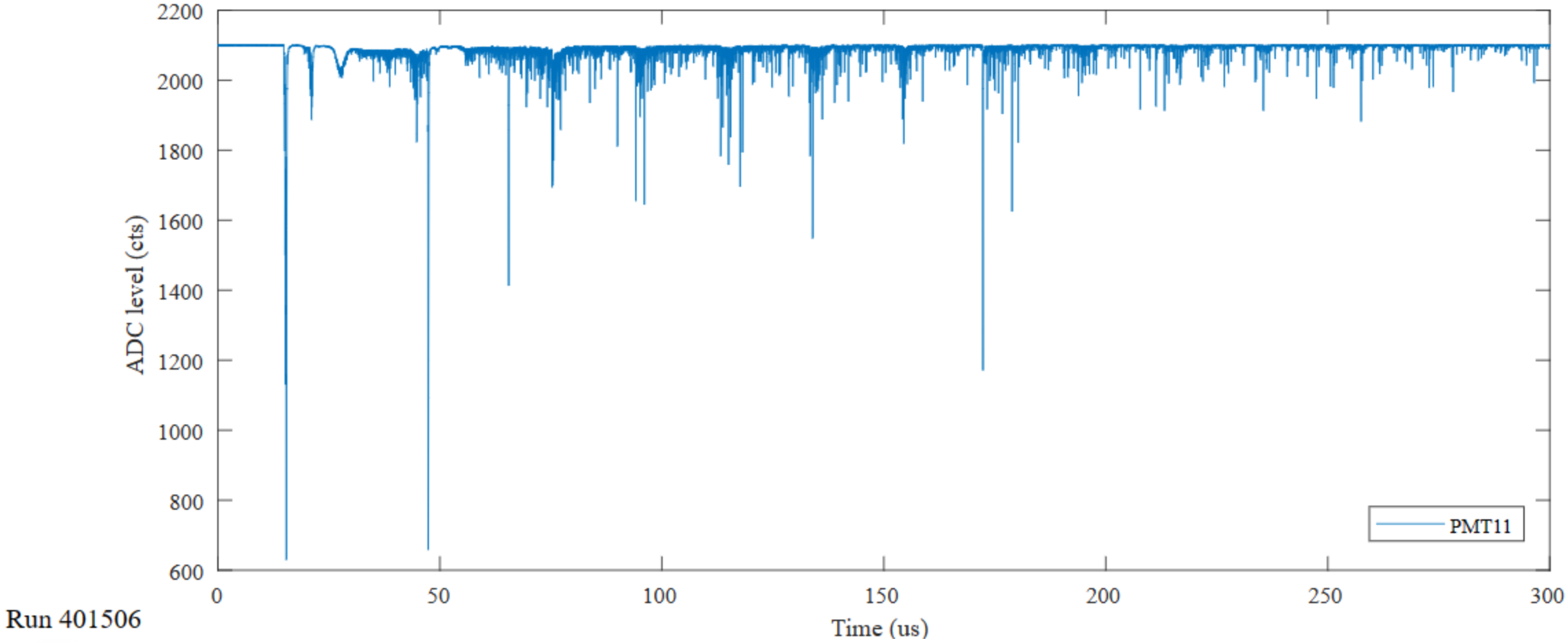




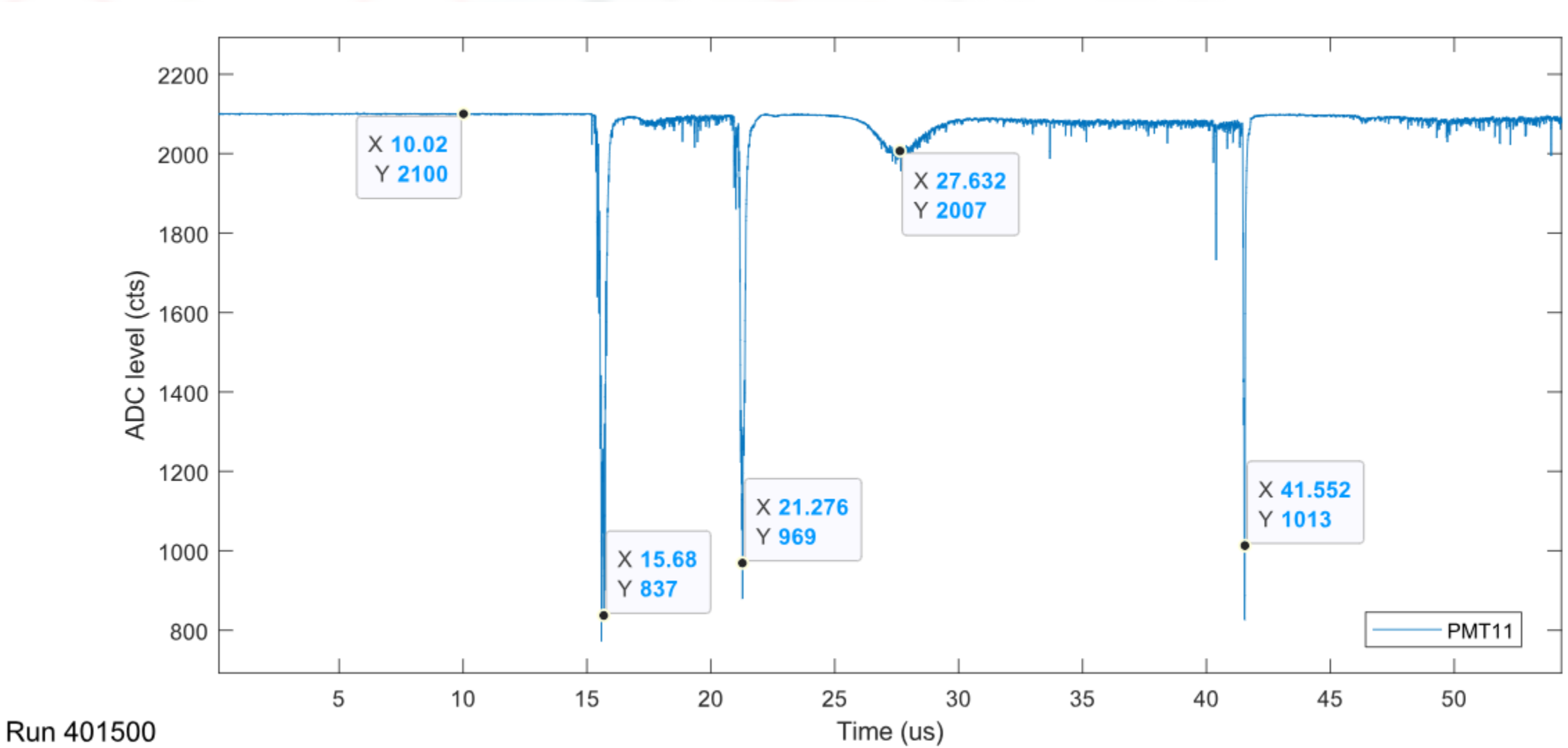
Hypothetical conclusion: most of our current Hbar is hitting the target

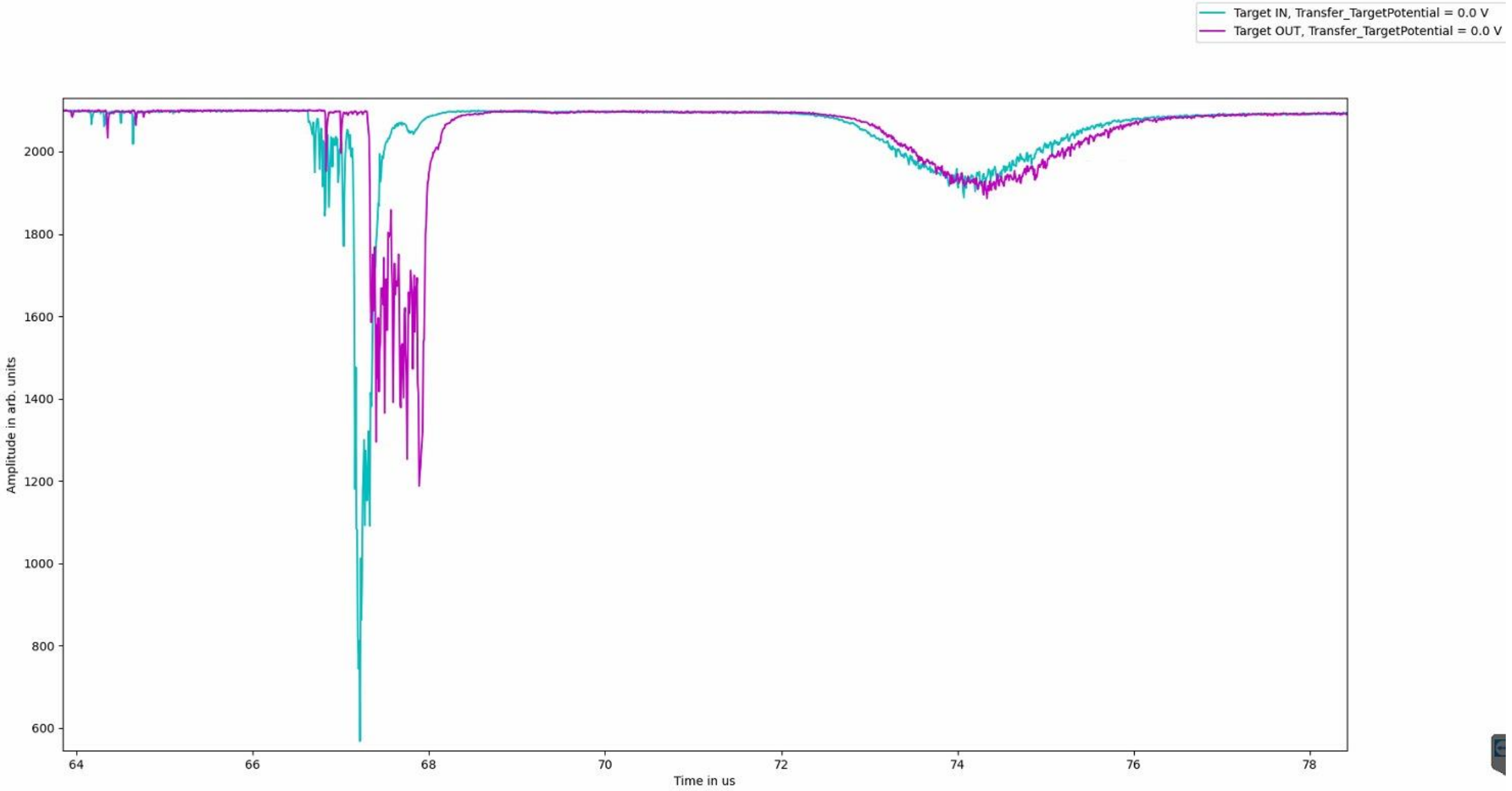
BACKUP

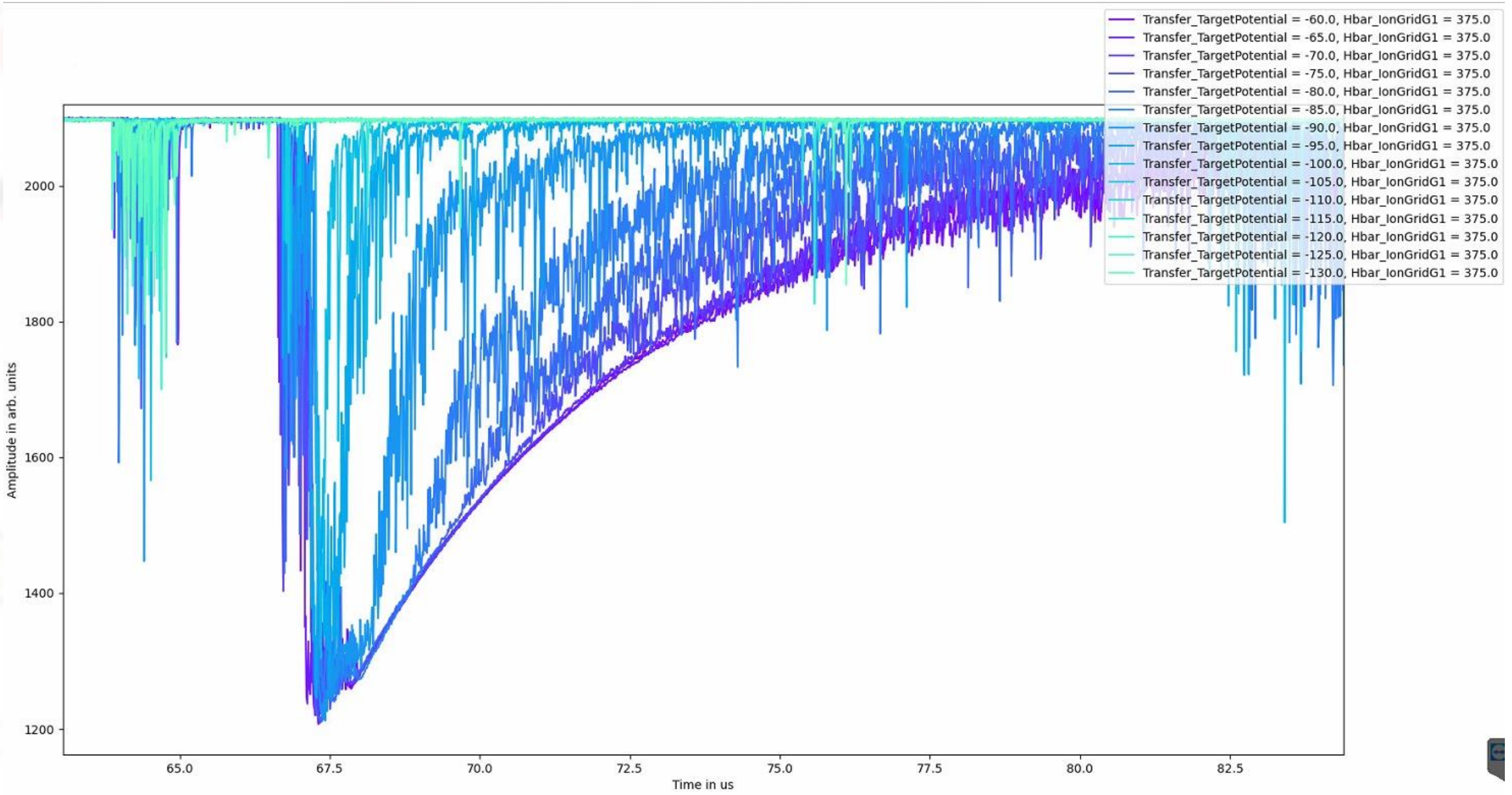
Time calibration 1



Time calibration 2




Target IN, Transfer_TargetPotential = 0.0 V
Target OUT, Transfer_TargetPotential = 0.0 V
Amplitude in arb. units
2000
1800
1600
1400
1200
1000
800
600
64
66
68
70
72
74
76
78
Time in us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Transfer_TargetPotential = -65.0, Hbar_IonGridG1 = 375.0
Transfer_TargetPotential = -70.0, Hbar_IonGridG1 = 375.0
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Transfer_TargetPotential = -85.0, Hbar_IonGridG1 = 375.0
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Amplitude in arb. units
2000
1800
1600
1400
1200
65.0
67.5
70.0
72.5
75.0
77.5
80.0
82.5
Time in us