GEM signals analysis

From deconvolved APV test-beam data to TIGER response

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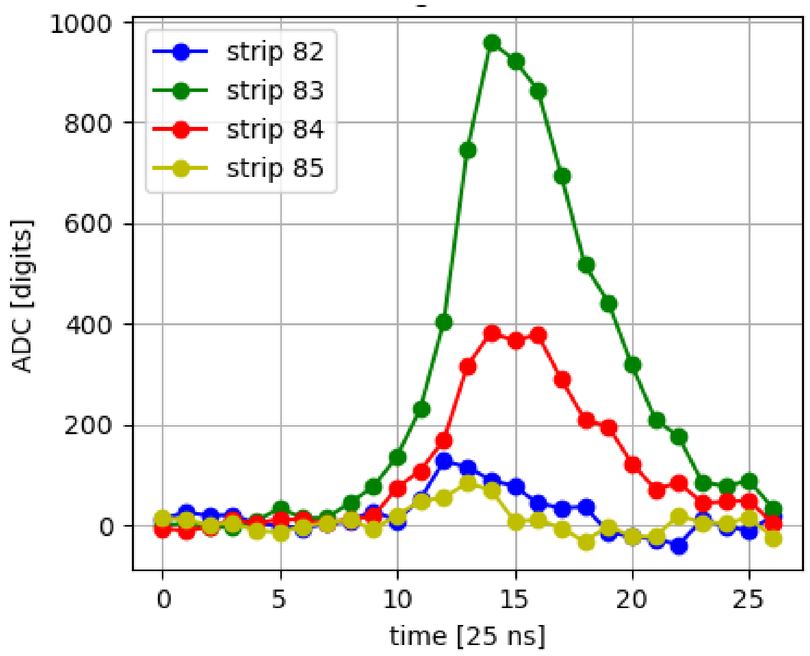
Motivation and methods

- APV/SRS provides 27 digitized samples of the amplified APV output signal with a time bin of 25ns. From this information it is possible to apply a deconvolution and thus extract the induced GEM signals with a good approximation.
- Use test-beam data, taken with APV/SRS system and planar GEMs, to extract some more detailed information about the GEM signals (duration, shape, amplitude) with a CGEM-IT-like configuration (5mm drift gap, Ar-ISO gas mixture)
- Use these signals to study the response of TIGER electronics and look for some possible optimization of TIGER configuration parameters (*integ_time*) or hints for data analysis



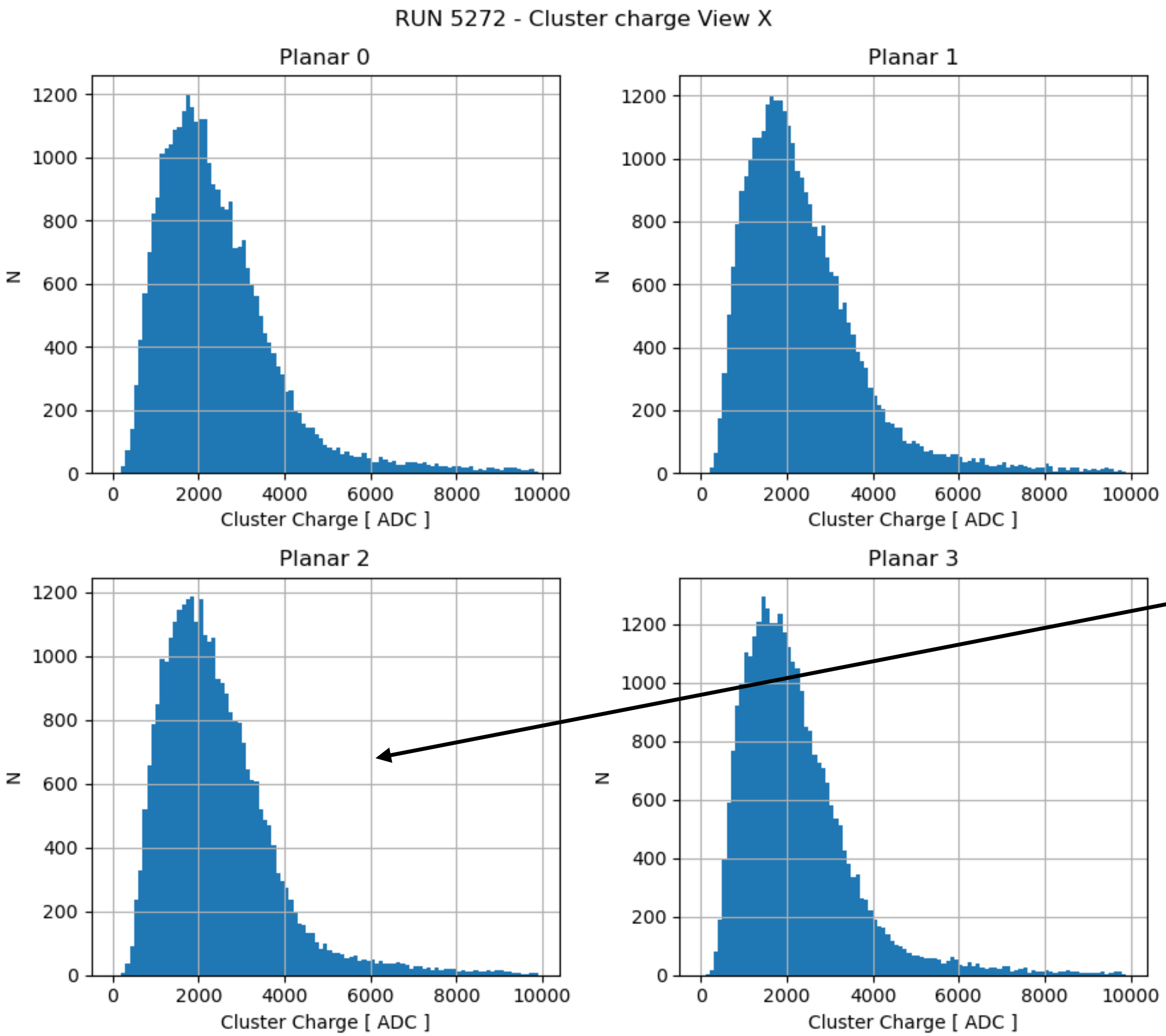
CERN – NA H4 beam line, July 2021

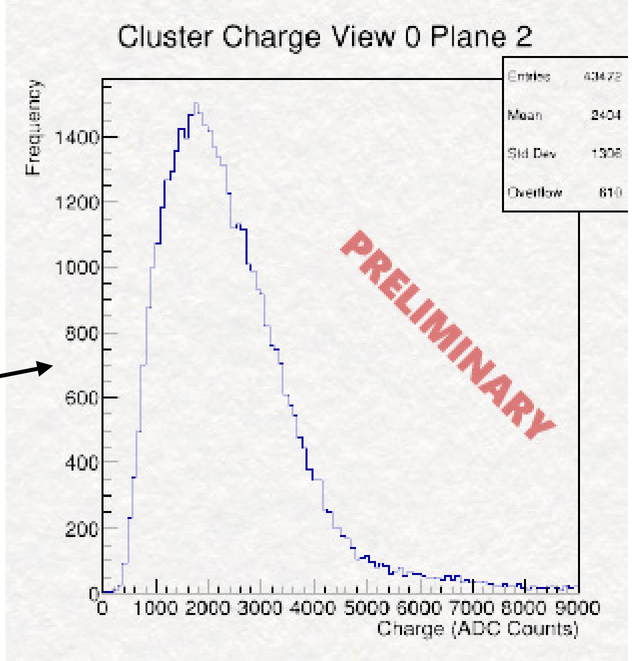
Dataset selection

- RUN
  - **5272 (HV = 825 V, angle = 0°)**
  - 5275 (HV = 835 V, angle = 45° on X-view strips)
  - 5271, 5273, 5265, 5267 also available but not shown in this talk
- Selections
  - Select higher charge cluster for each view
  - No more than one cluster with 1000 ADC cluster charge
  - At least 1 cluster for each view and planar
  - Cut events if cluster on planar 3 view-X has strips in range 0-32
  - Cut events if cluster has strips in range 0-1
  - Cut events if cluster has strips in range 126-127

➢ 31k events after these selections for RUN 5272 (100k triggers)

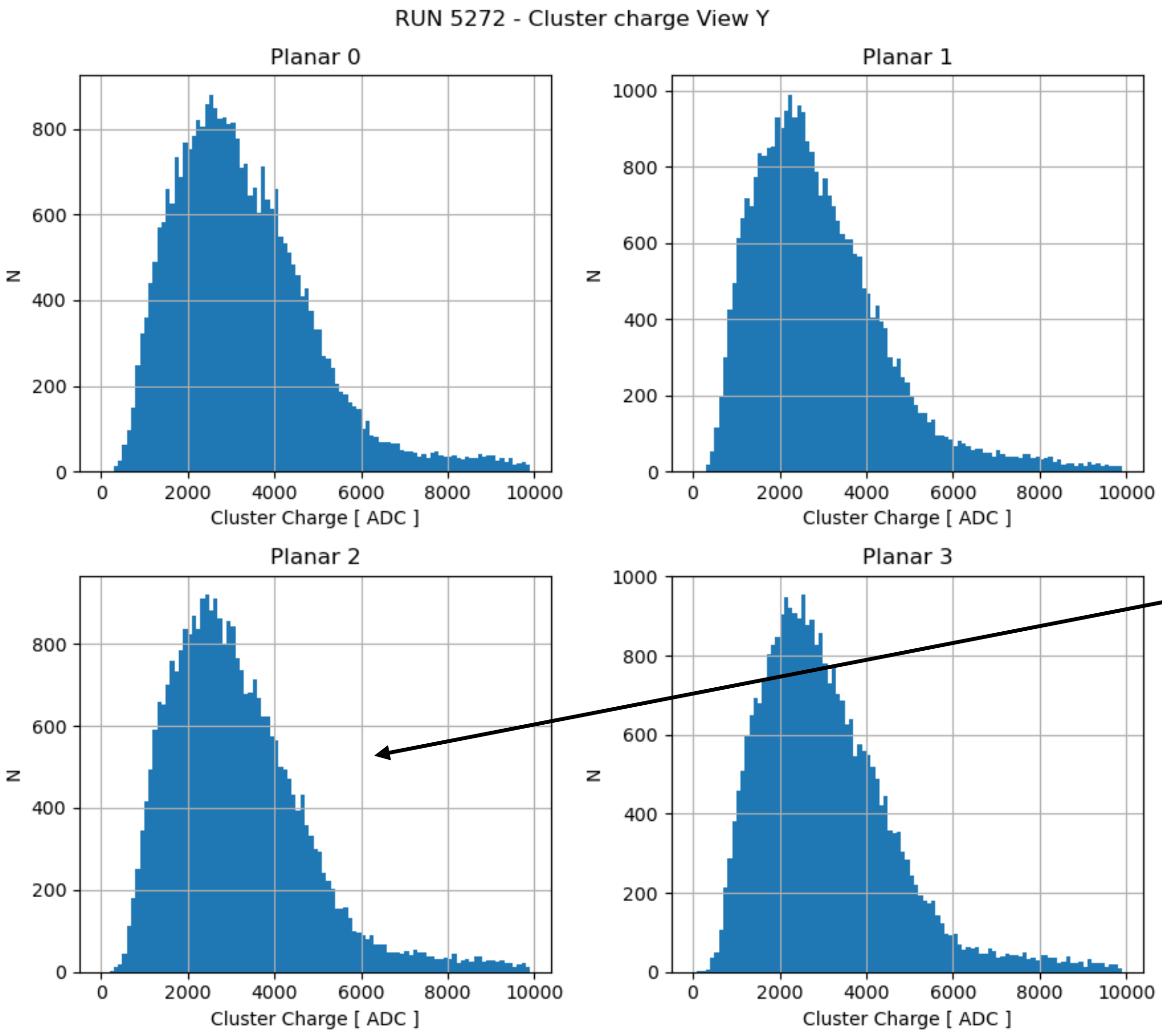
Reference plots (RUN 5272)

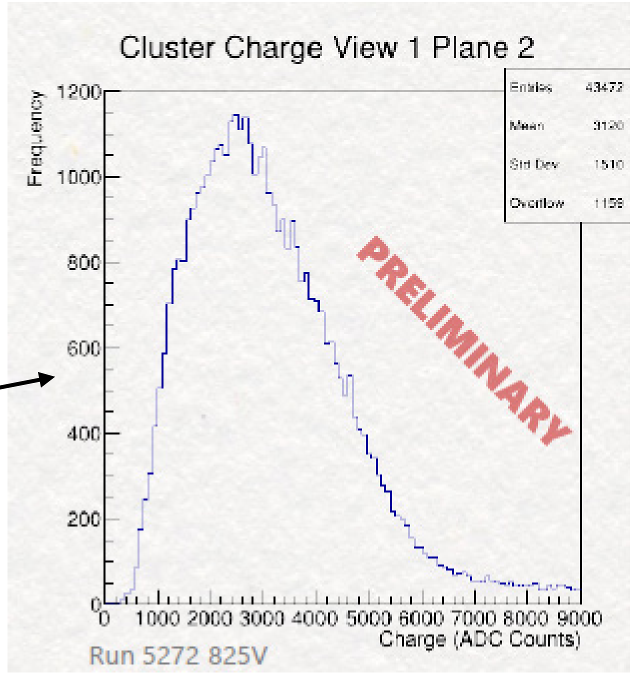




S. Gramigna

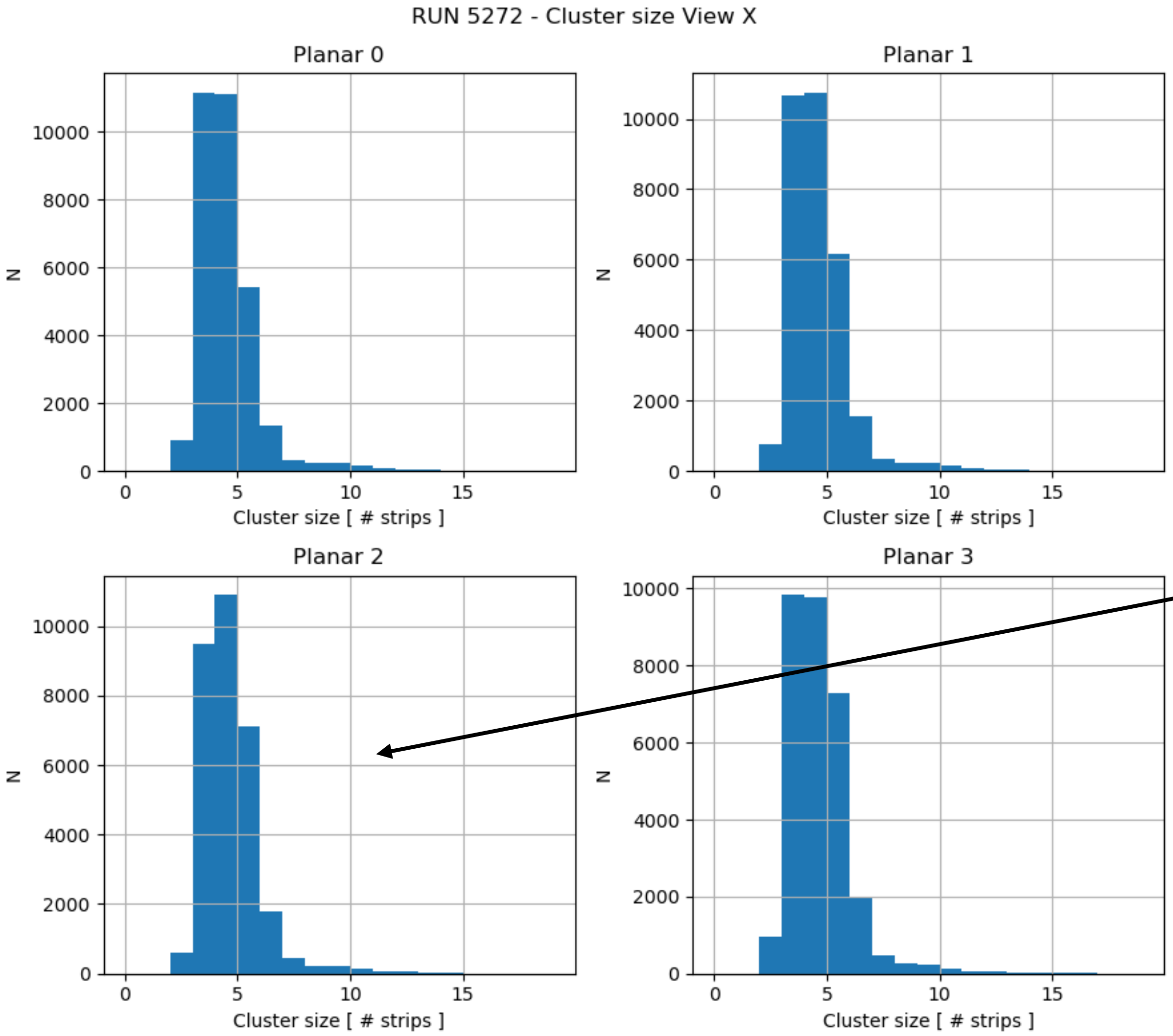
Reference plots (RUN 5272)

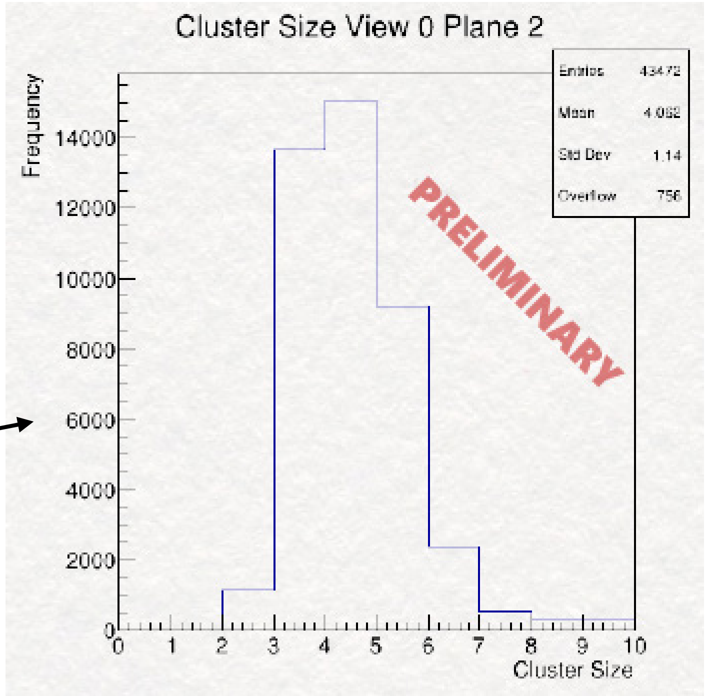




S. Gramigna

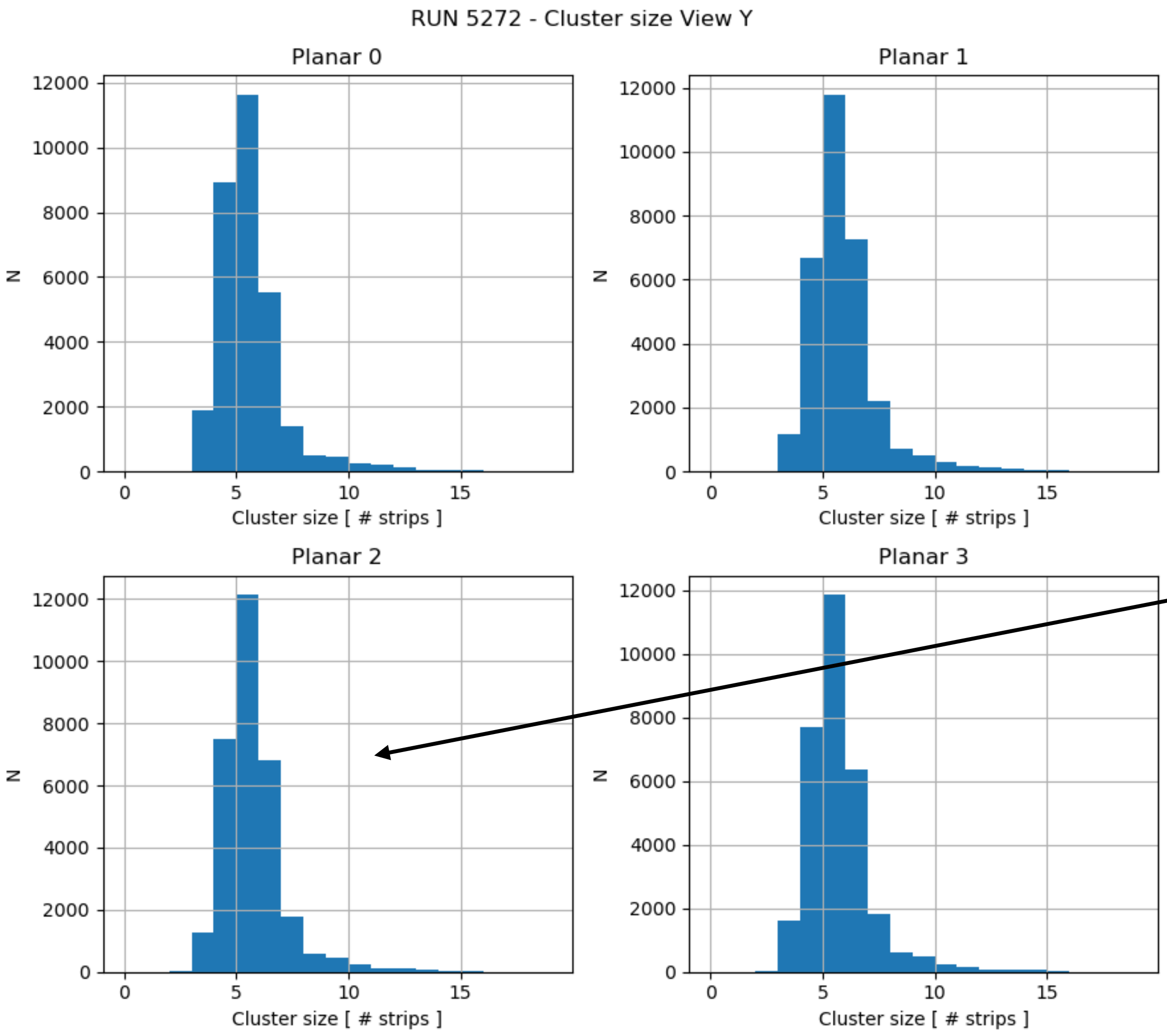
Reference plots (RUN 5272)

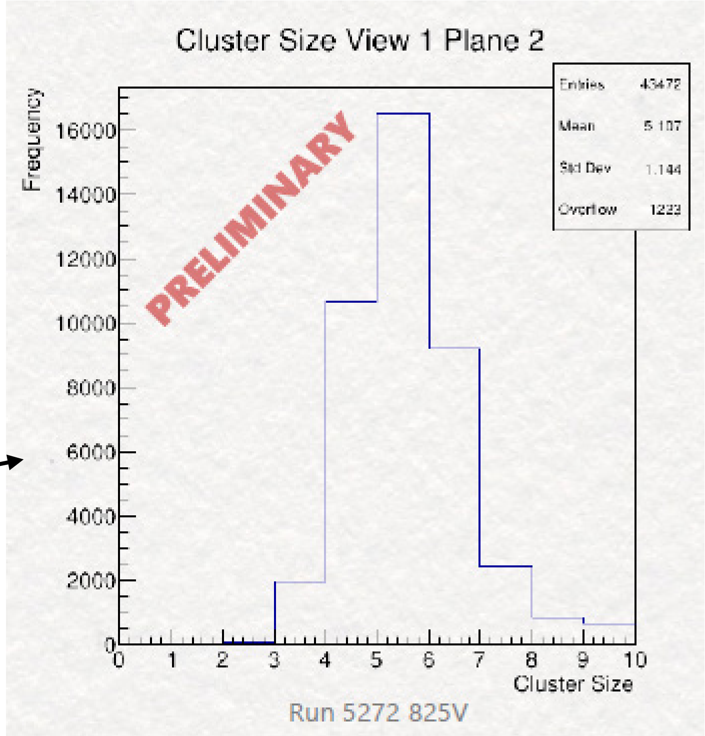




S. Gramigna

Reference plots (RUN 5272)

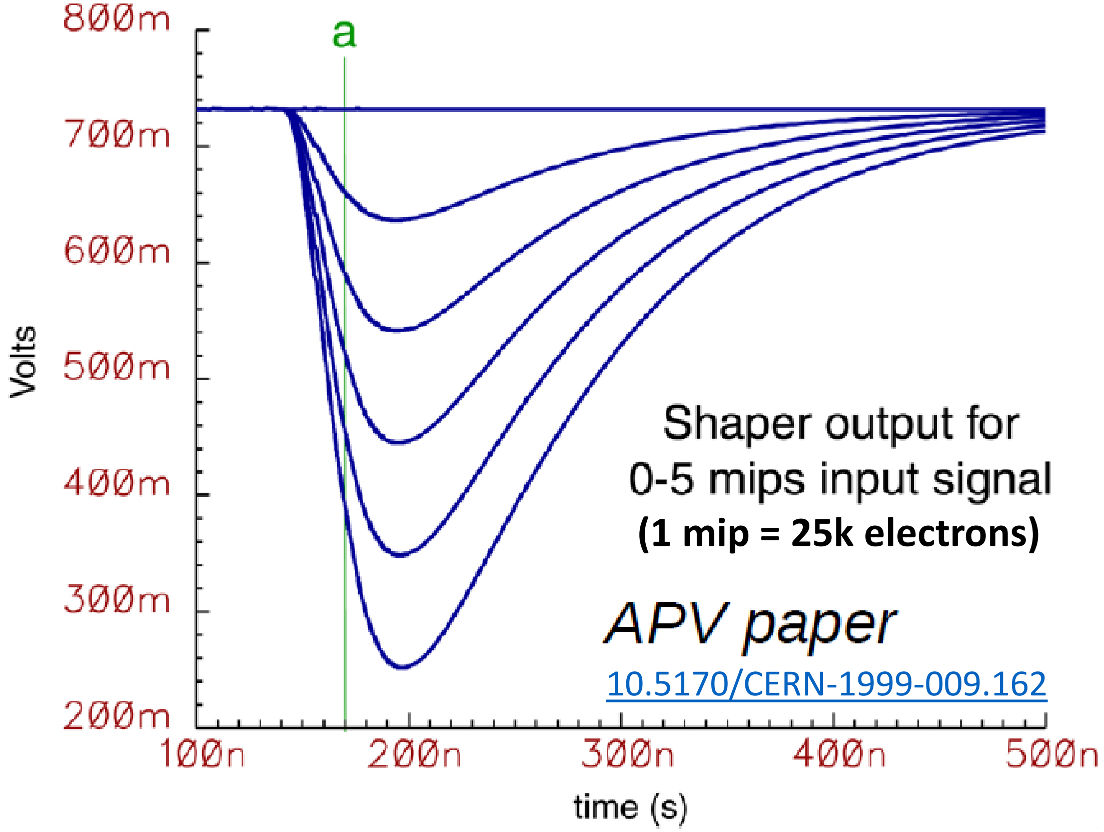


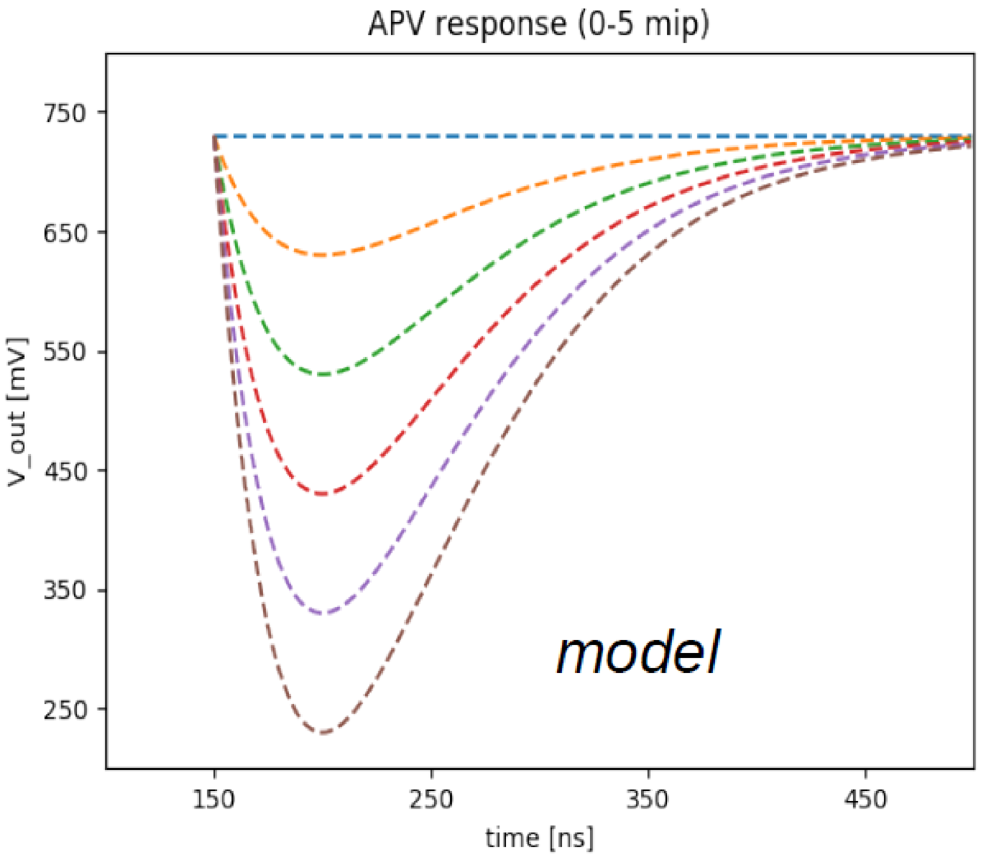


S. Gramigna

APV model

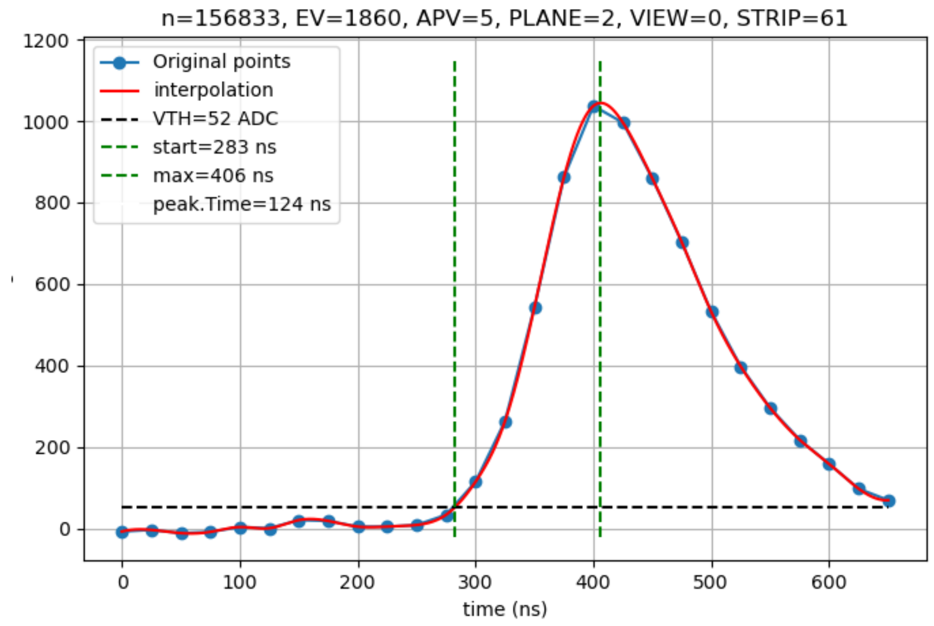
Transfer function: CR-RC shaper with 50 ns peaking time

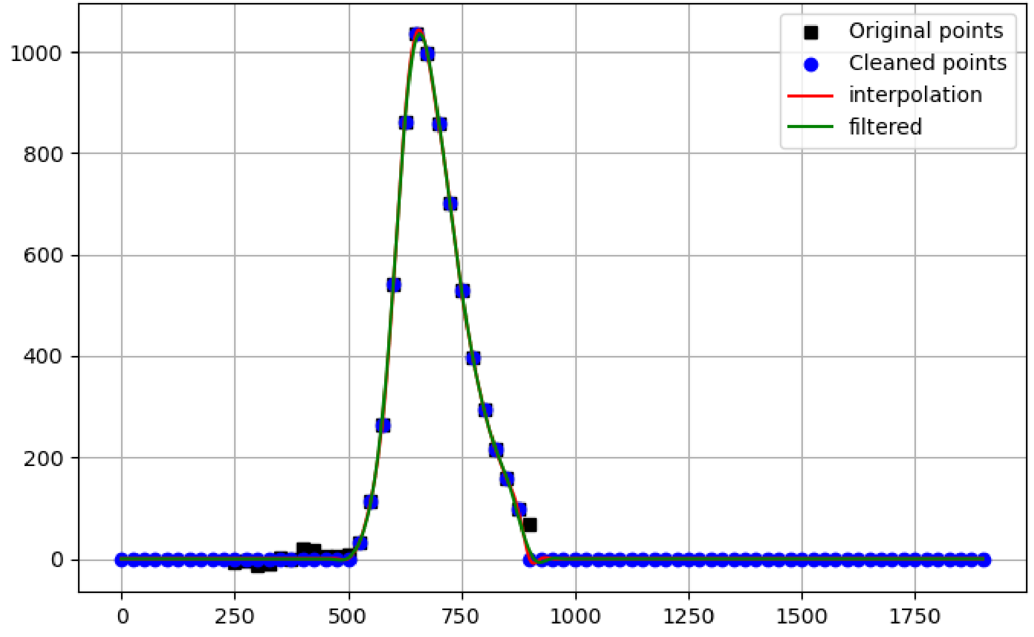




Signal deconvolution

- Clean noisy points before and after the signal (not always possible)
- Interpolate 25ns points to increase granularity of the curve to be deconvolved and apply filter to reduce large fast oscillations





Signal deconvolution

- Deconvolve using APV transfer function

$$X(s) = \mathcal{L}\{x(t)\}$$

$$Y(s) = \mathcal{L}\{y(t)\}$$

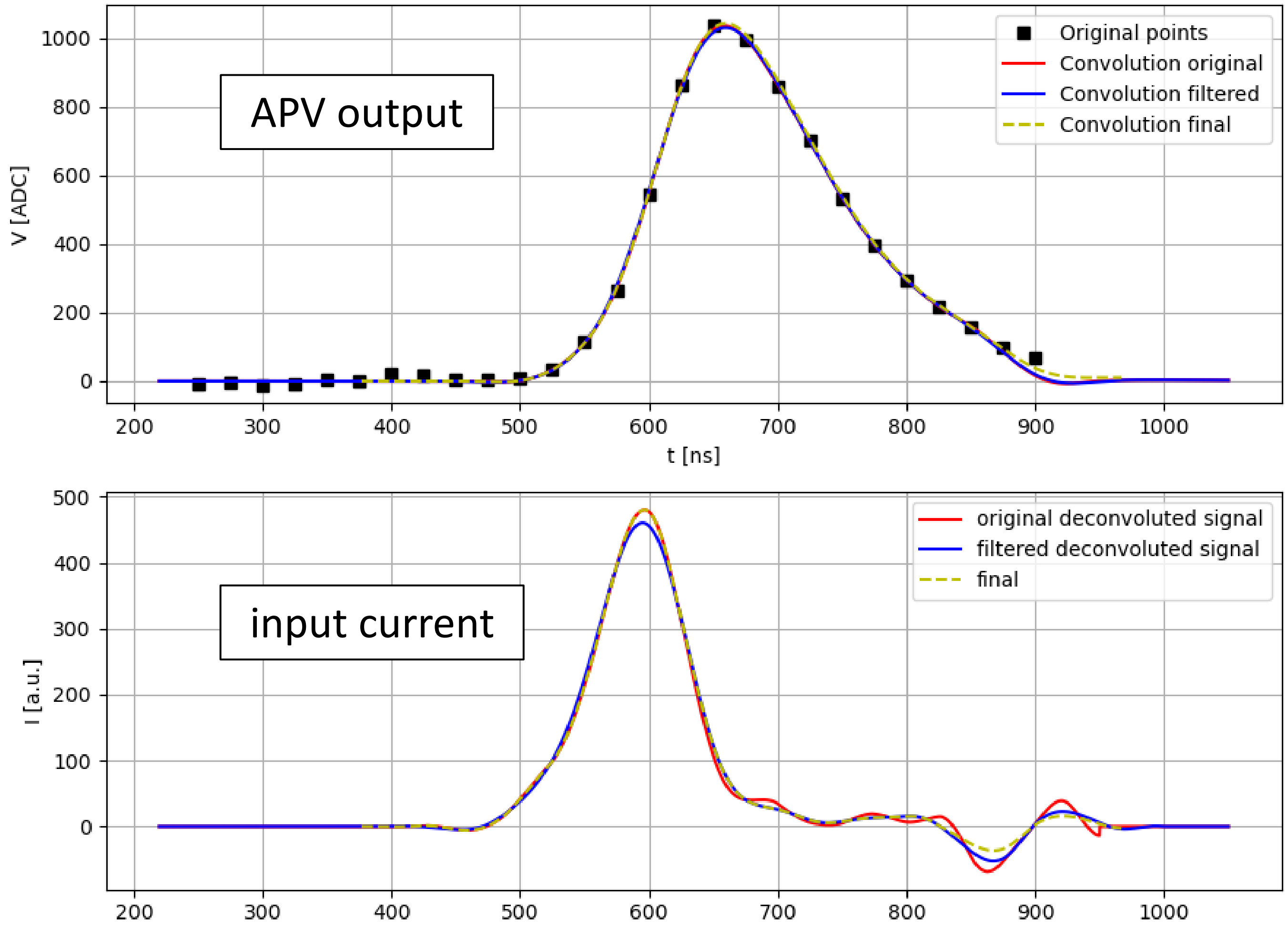
$$Y(s) = H(s)\ X(s)$$

x(t) = APV input (GEM signal)

y(t) = APV output (ADC codes)

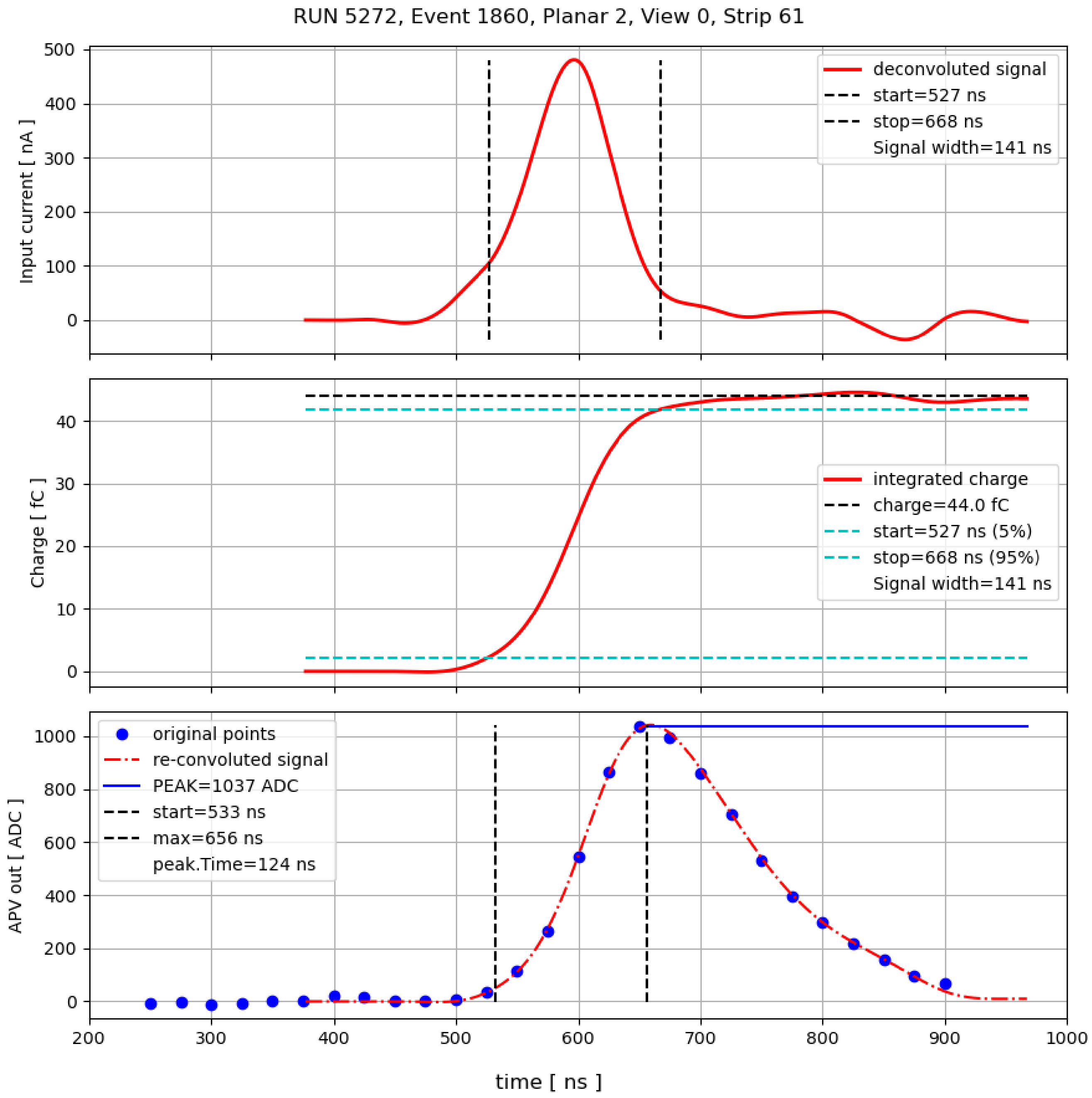
H(s) = APV transfer function

- Re-convolve to check goodness of procedure



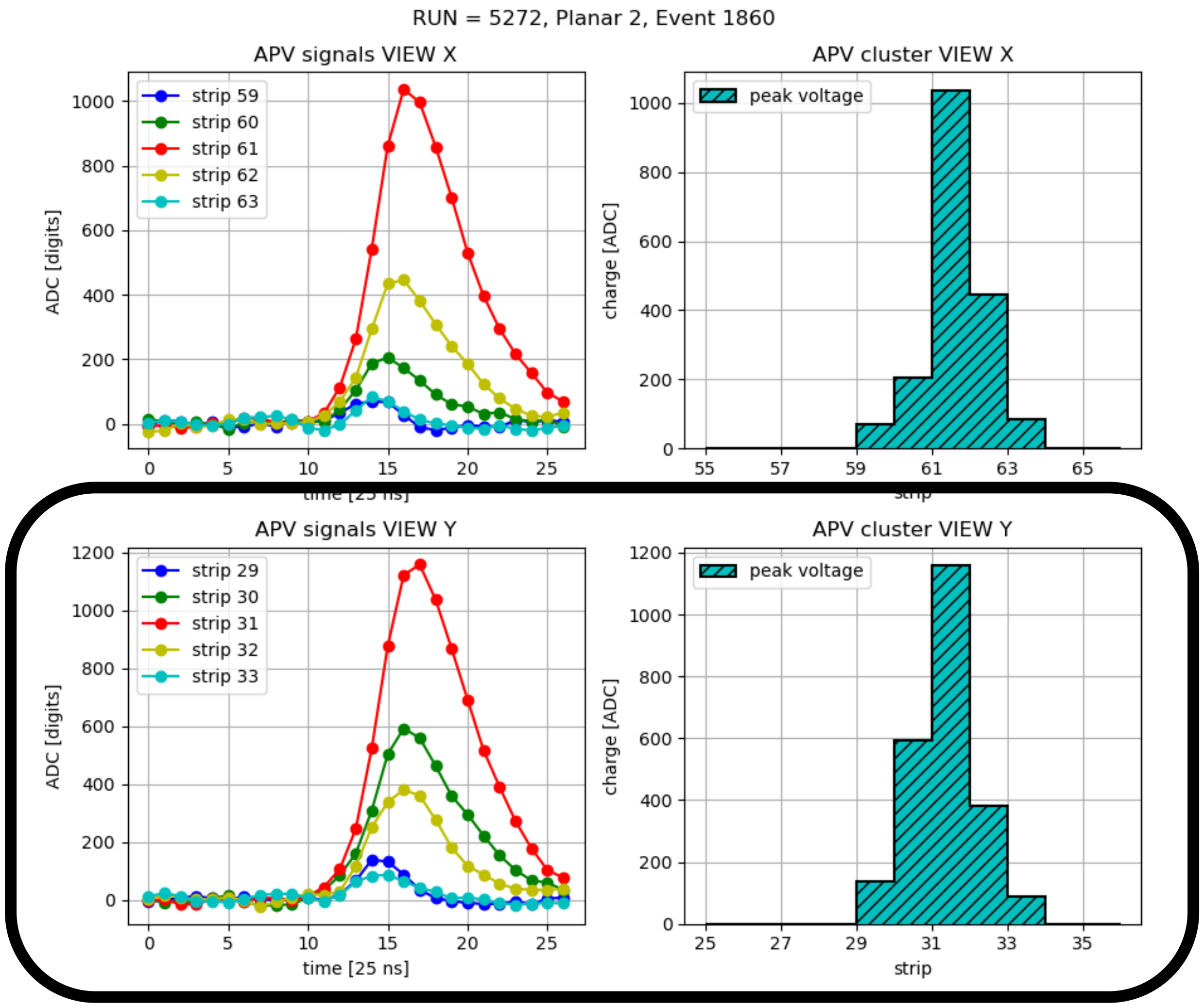
Signal deconvolution

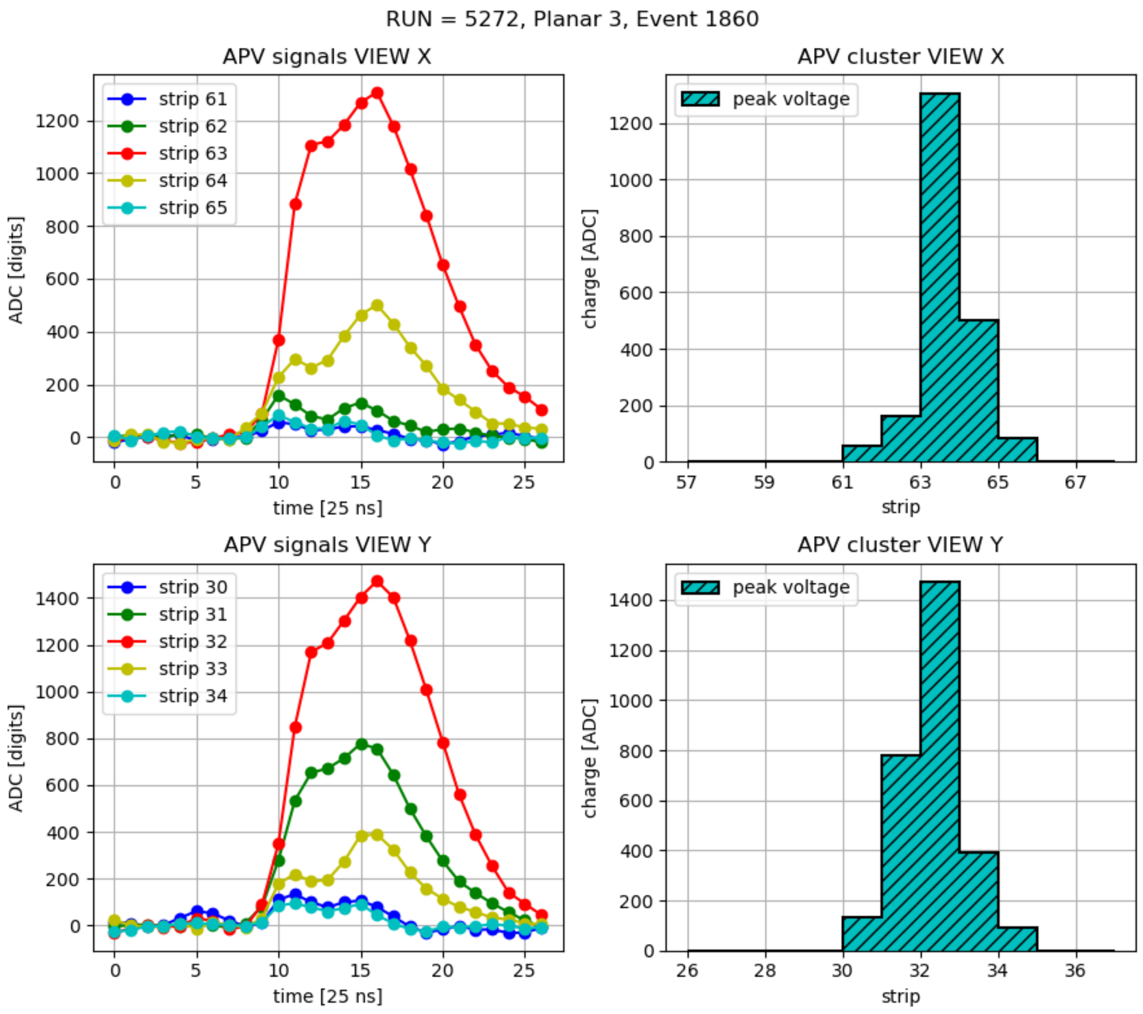
- From deconvoluted input extract signal duration and charge
- Signal duration taken as 5%-95% integrated charge time interval



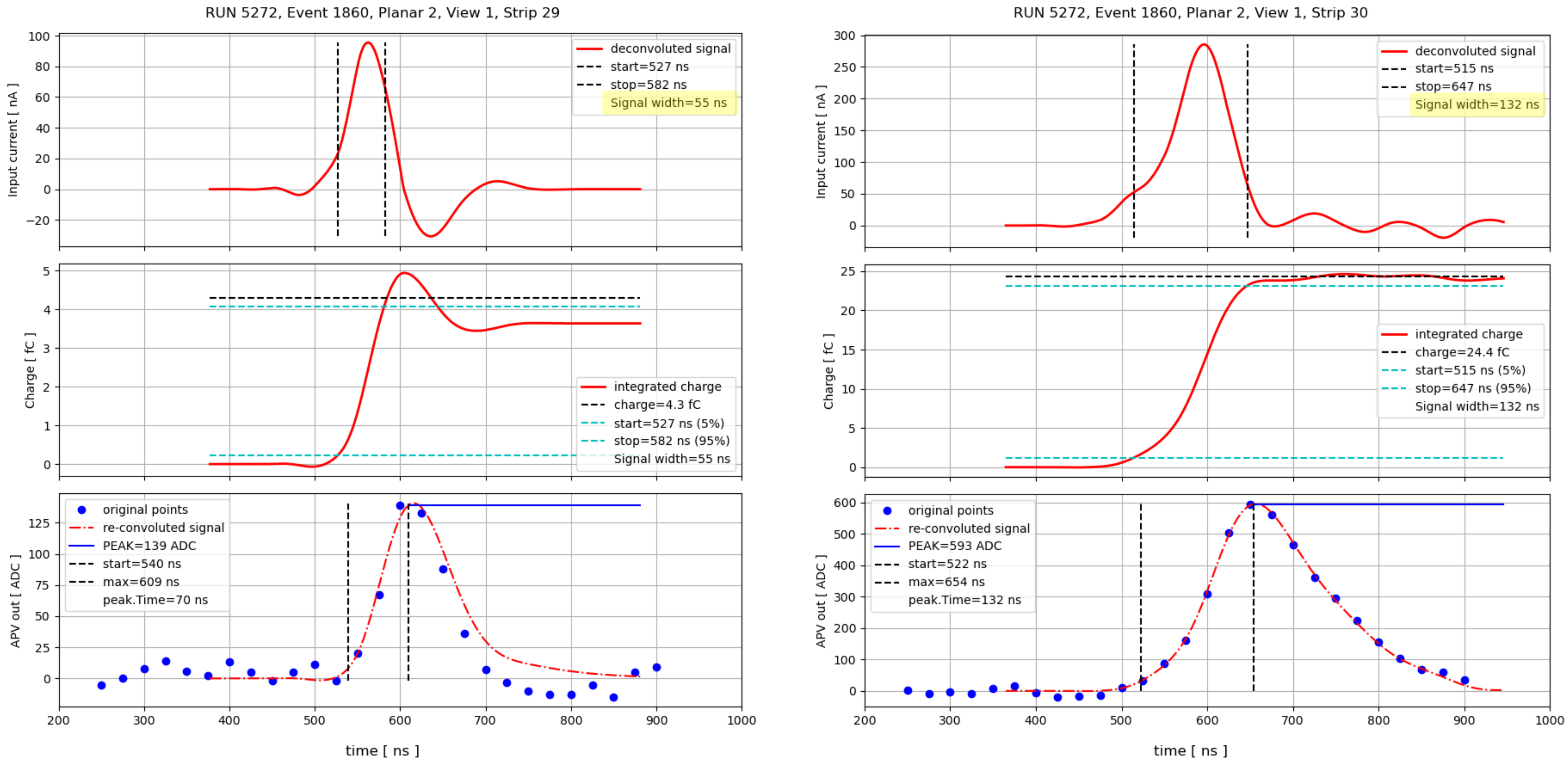
Single signal analysis

Look at one event

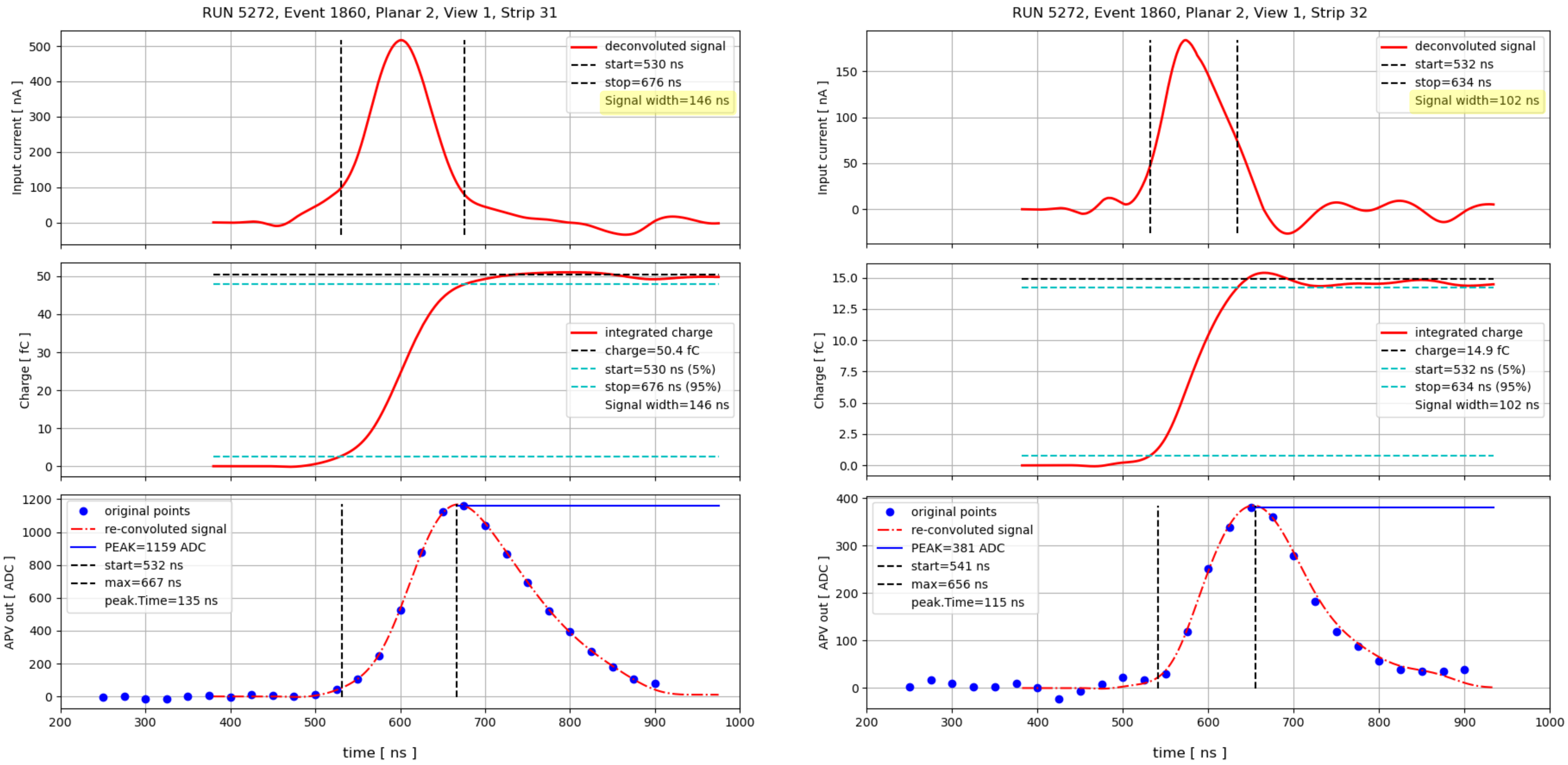




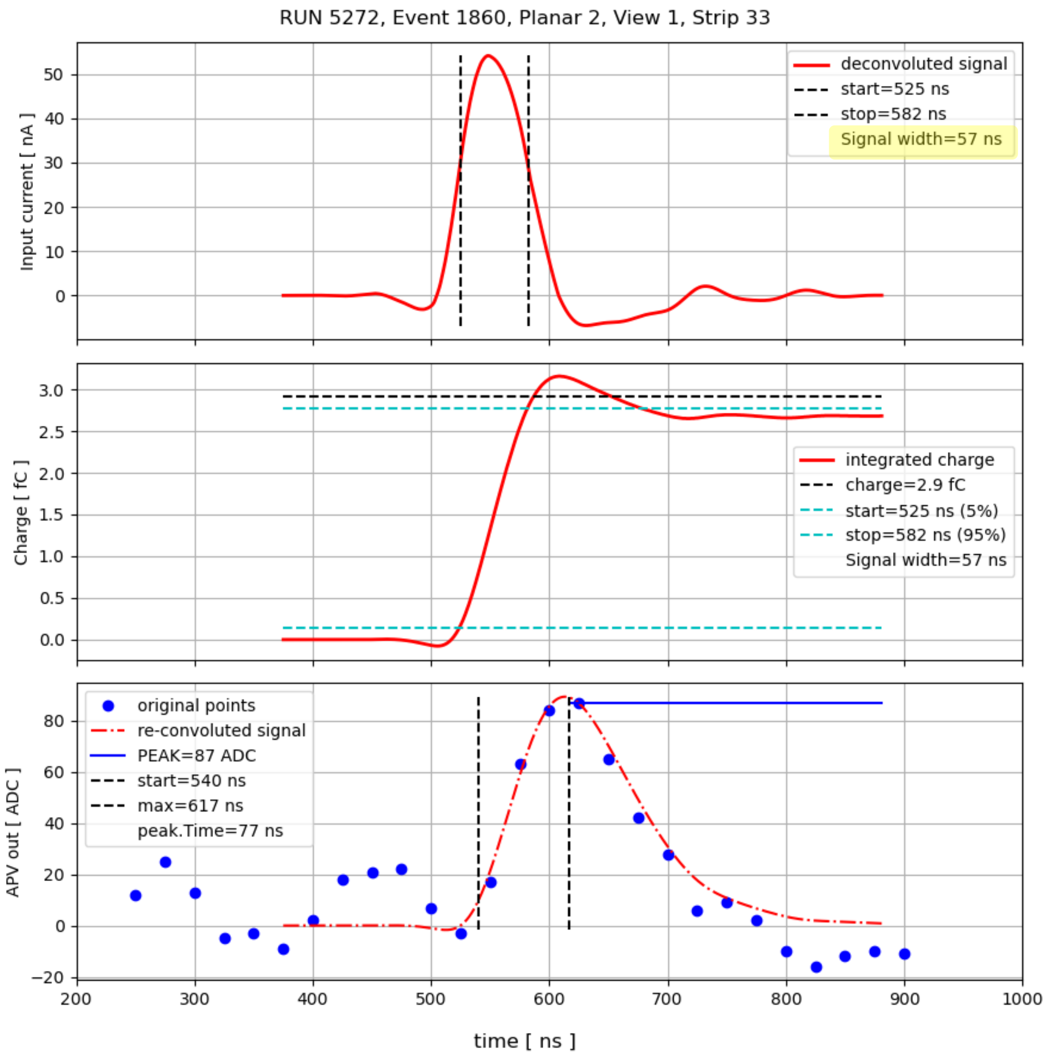
Look at one cluster (strip 29-33)



Look at one cluster (strip 29-33)



Look at one cluster (strip 29-33)



- Strips with high charge seem to have longer duration signals
- Strips in the tails of cluster (low charge) seem to have shorter duration signals
  - These strips don't see the full 5mm drift gap signal?
  - Capacitive effects?
- Let's apply some of these signals to TIGER

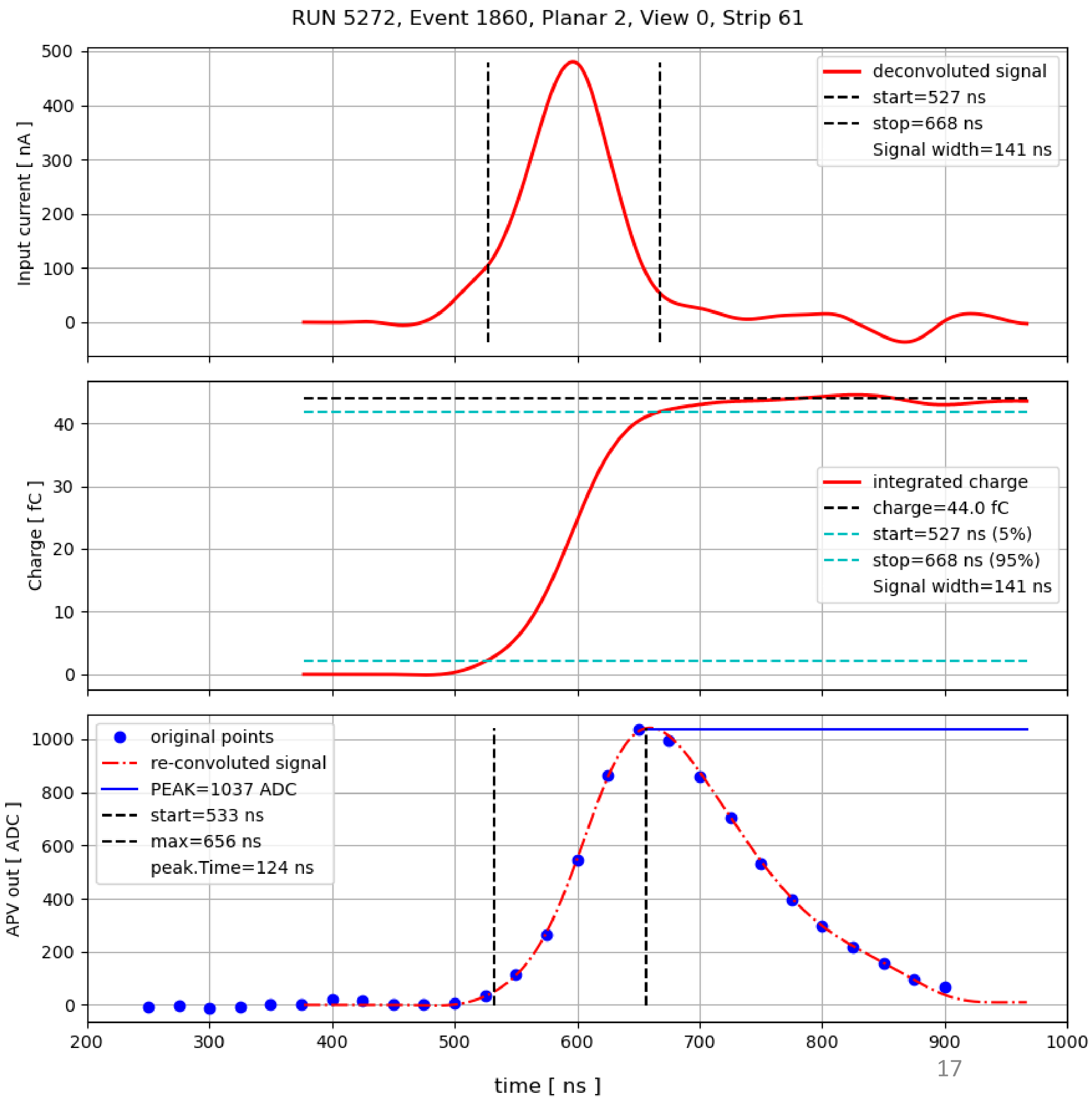
APV (1)

Input signal

- long duration: 140-150 ns
- charge: 44 fC

APV output signal

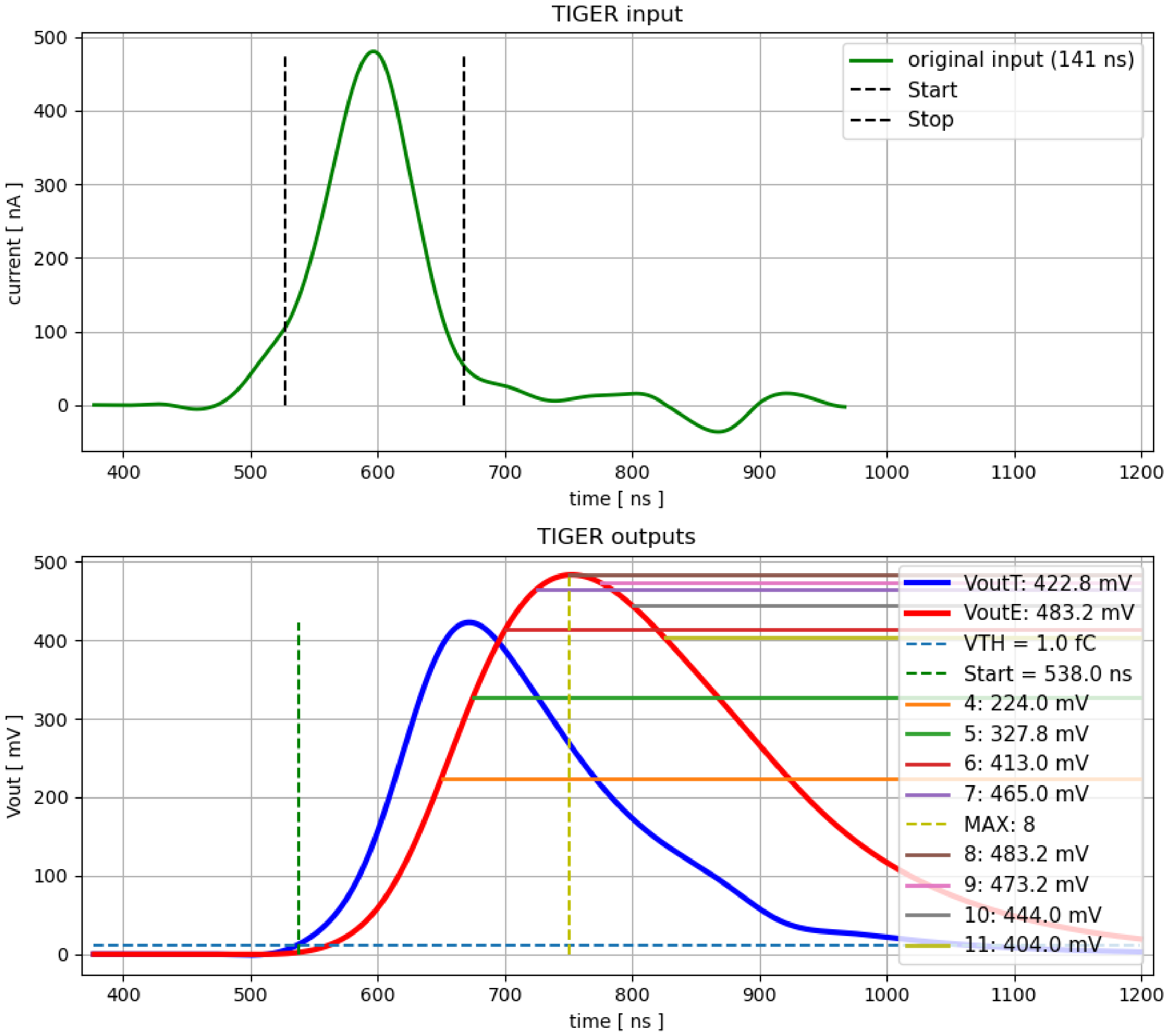
- peaking time of 124 ns vs 50 ns expected from delta input current



TIGER (1)

- Peak voltage = 483 mV
- Q = 40 fC (3-4 fC of ballistic deficit)
- MAX at *integ_time* = 8

- Sampled voltage @integ_time = 6
  - ➢ 413 mV → Q = 34 fC



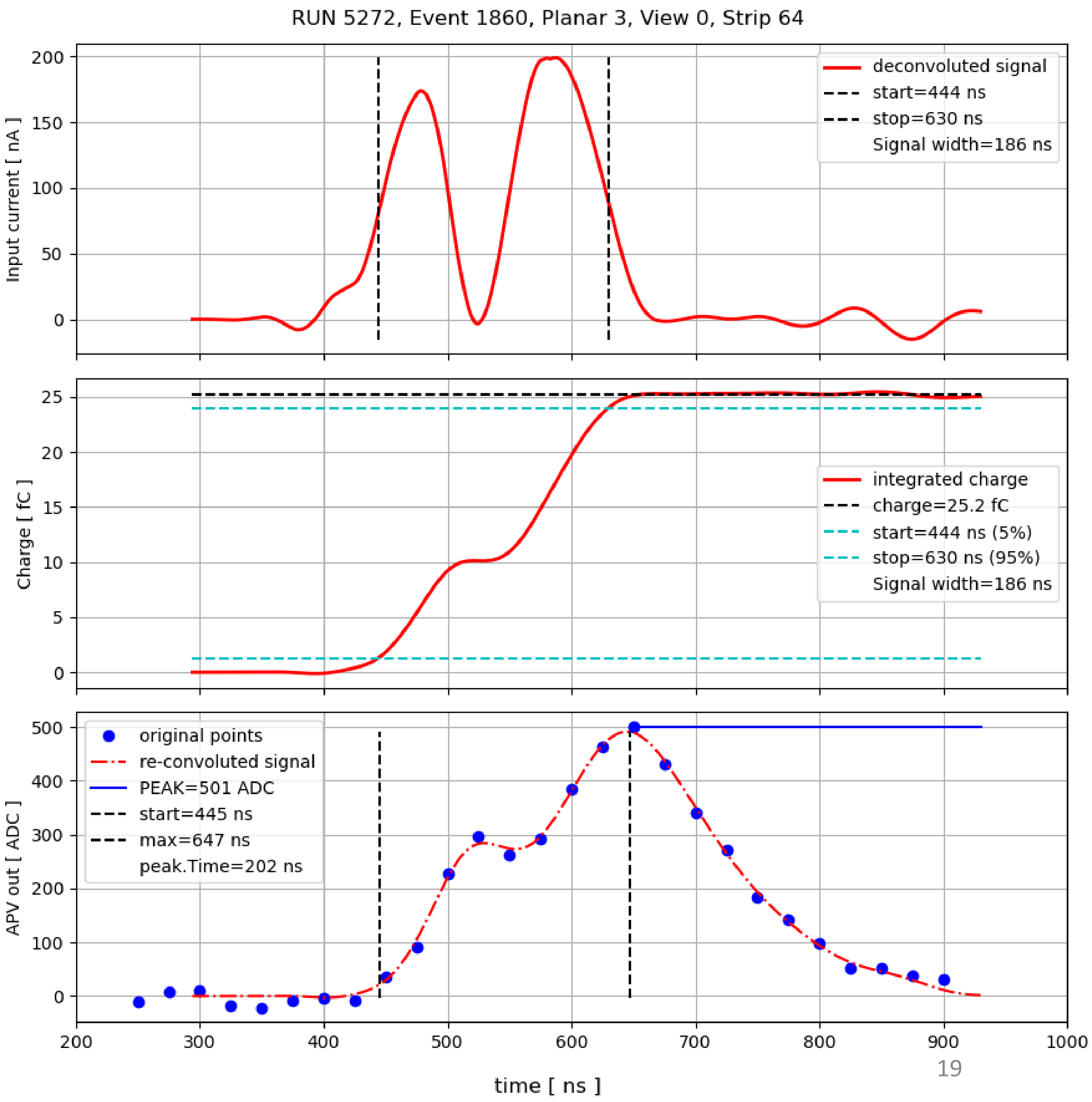
APV (2)

<u>Input signal</u>

- long duration: 180-190 ns
- charge: 25 fC

<u>APV output signal</u>

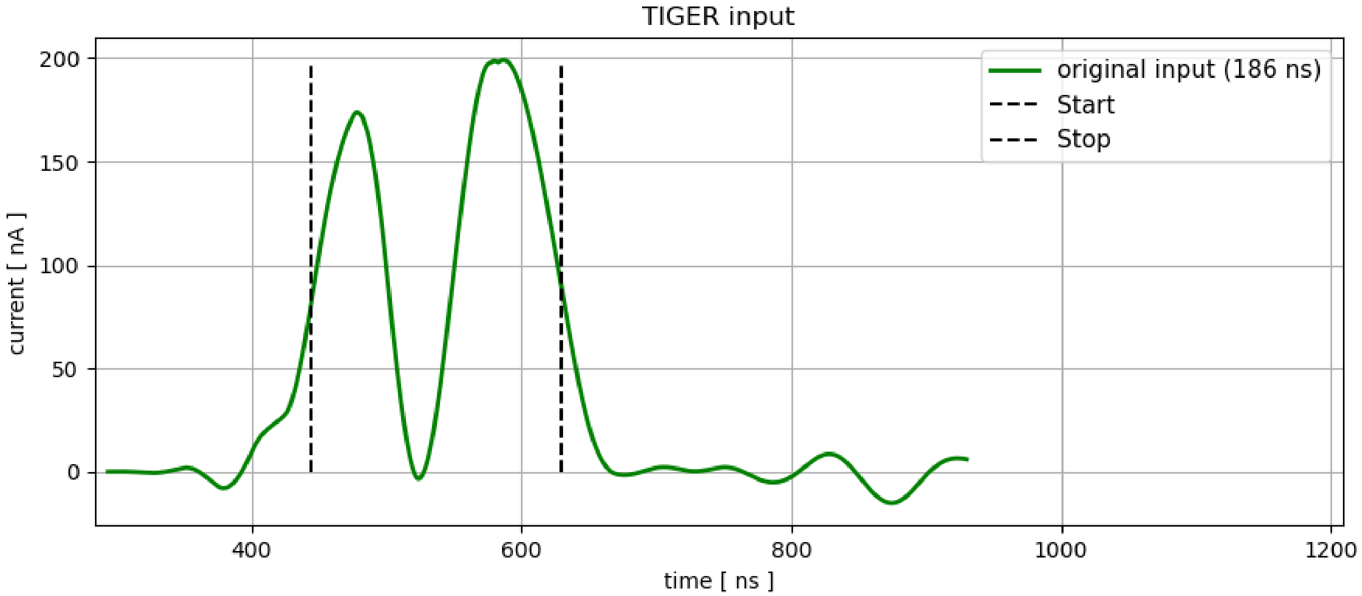
- peaking time of 200 ns vs 50 ns expected from delta input current

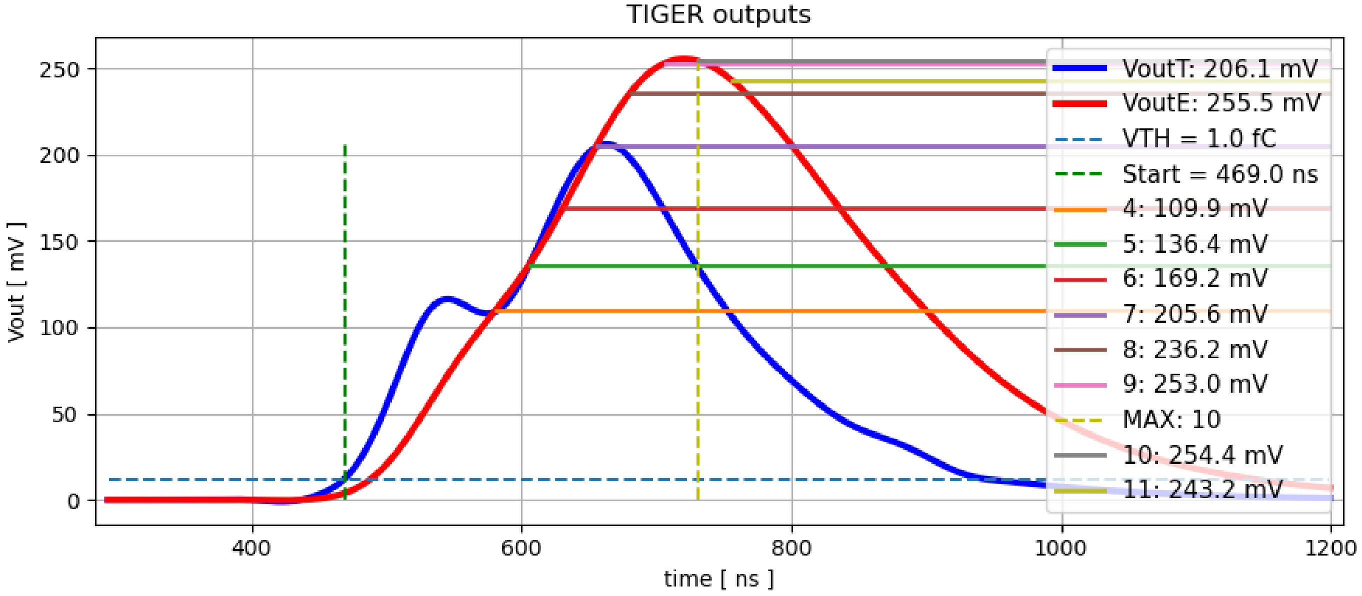


TIGER (2)

- Peak voltage = 255 mV
- Q = 21 fC (4 fC of ballistic deficit)
- MAX at *integ_time* = 10

- Sampled voltage @integ_time = 6
  - ➢ 169 mV → Q = 14 fC





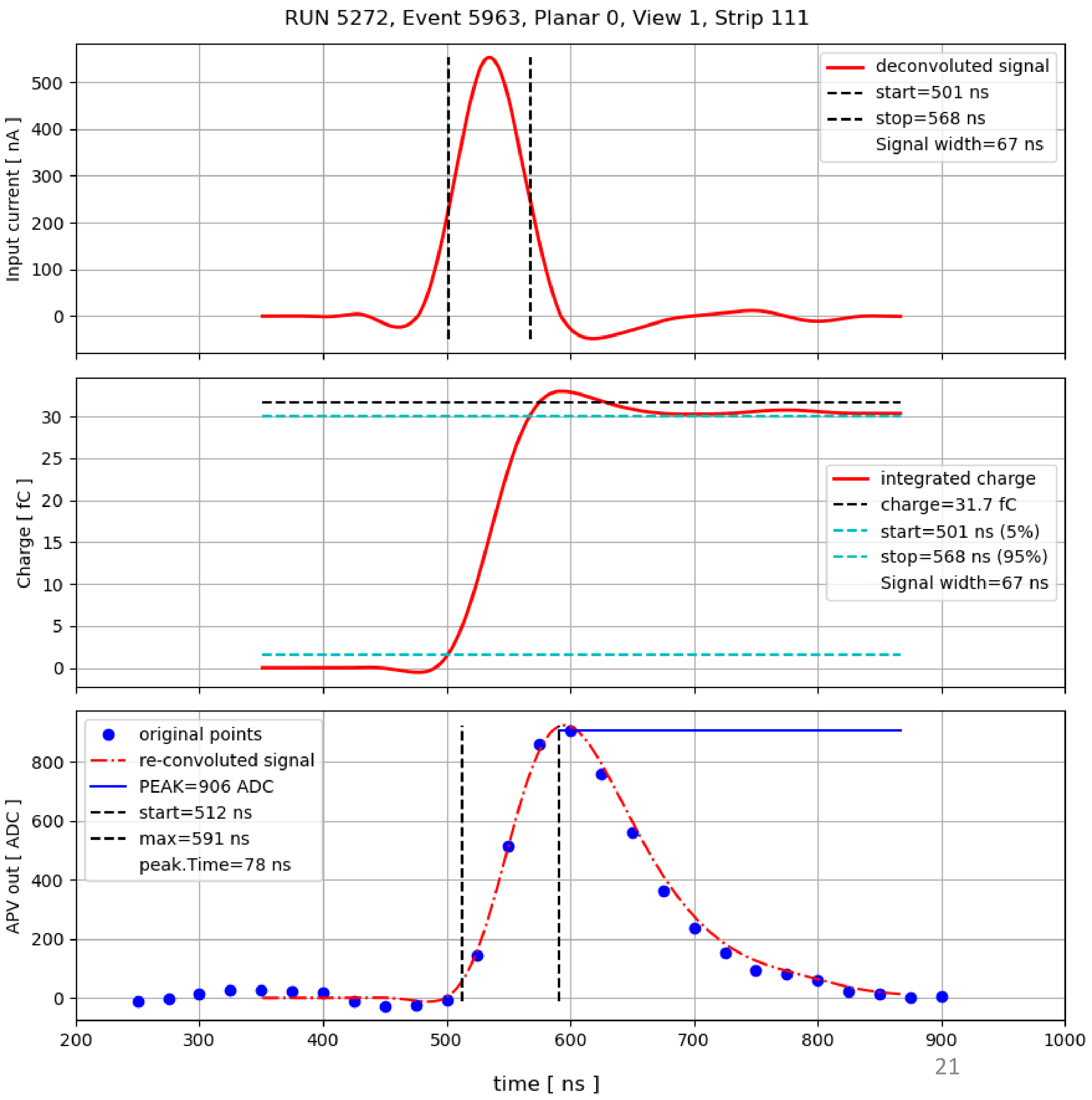
APV (3)

Input signal

- short duration: 70 ns
- charge: 32 fC

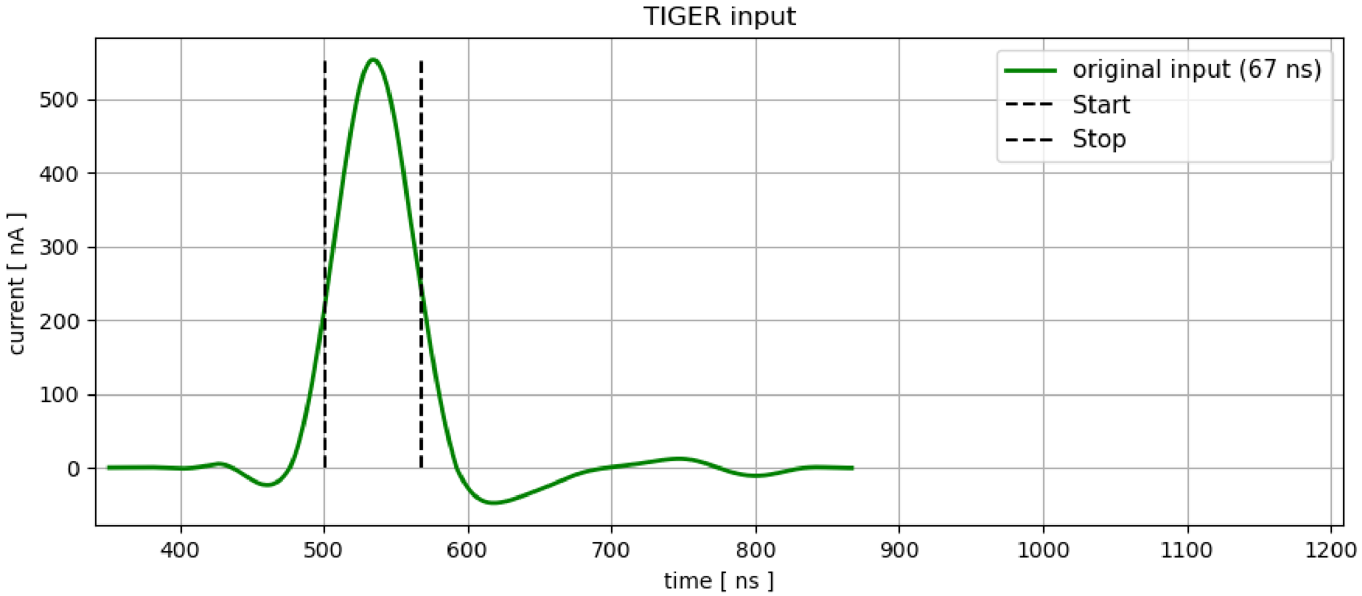
APV output signal

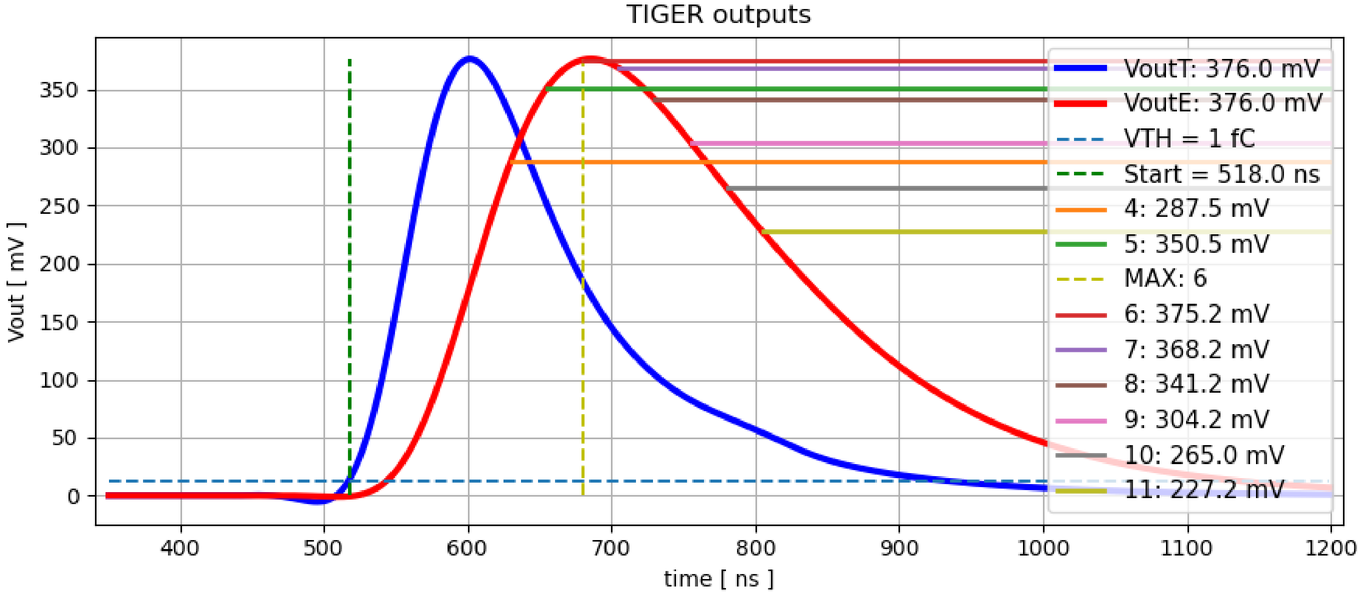
- peaking time of 80 ns vs 50 ns expected from delta input current



TIGER (3)

- MAX at *integ_time* = 6
- Peak sampled voltage = 375 mV
- Q = 31 fC (<1 fC of ballistic deficit)

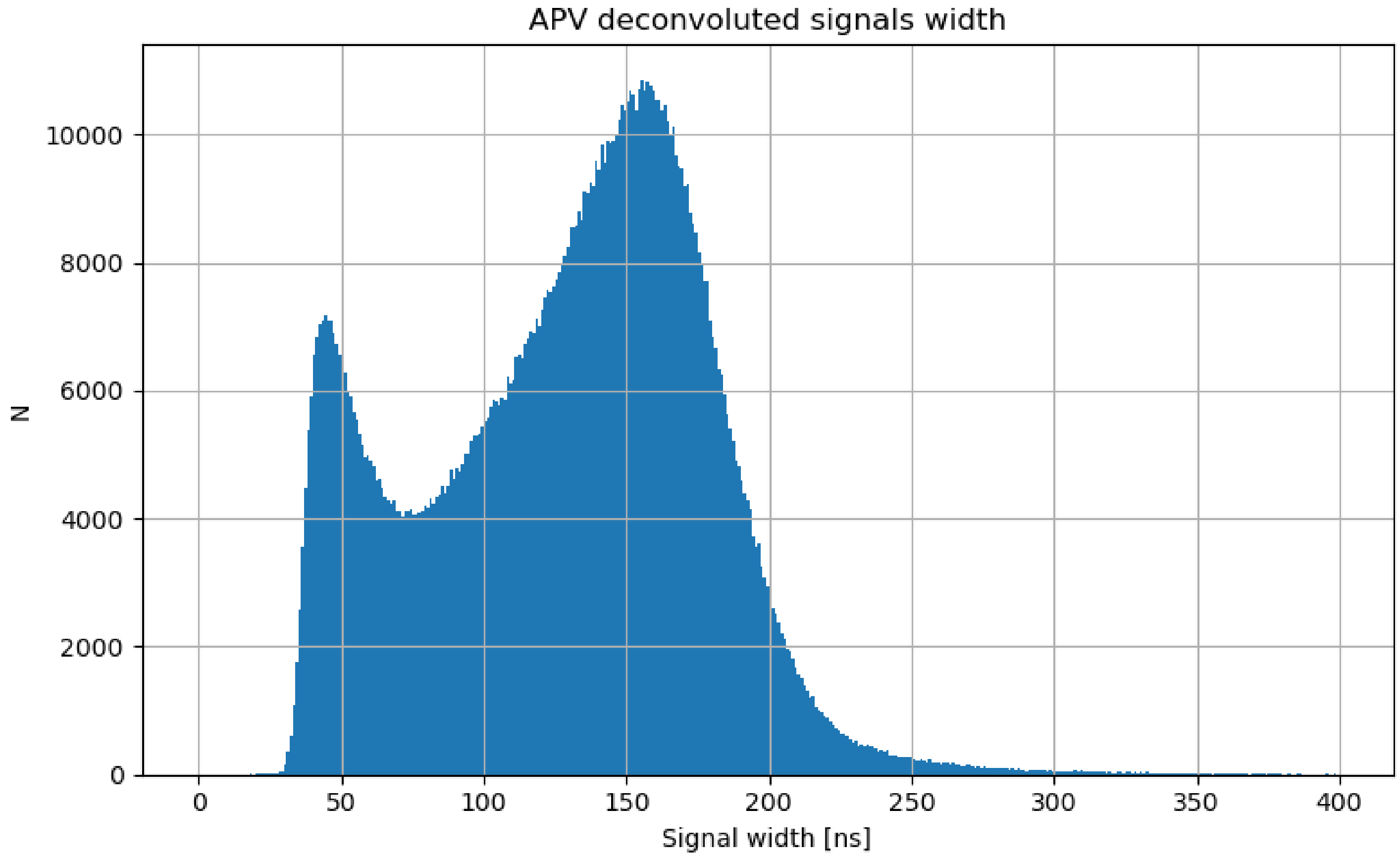




- Sampled voltage @integ_time = 6 is OK
- Sampled voltage @integ_time = 9 is 304 mV → Q = 25 fC (20% of signal is lost)

Full RUN analysis

Deconvoluted signal width (RUN 5272)

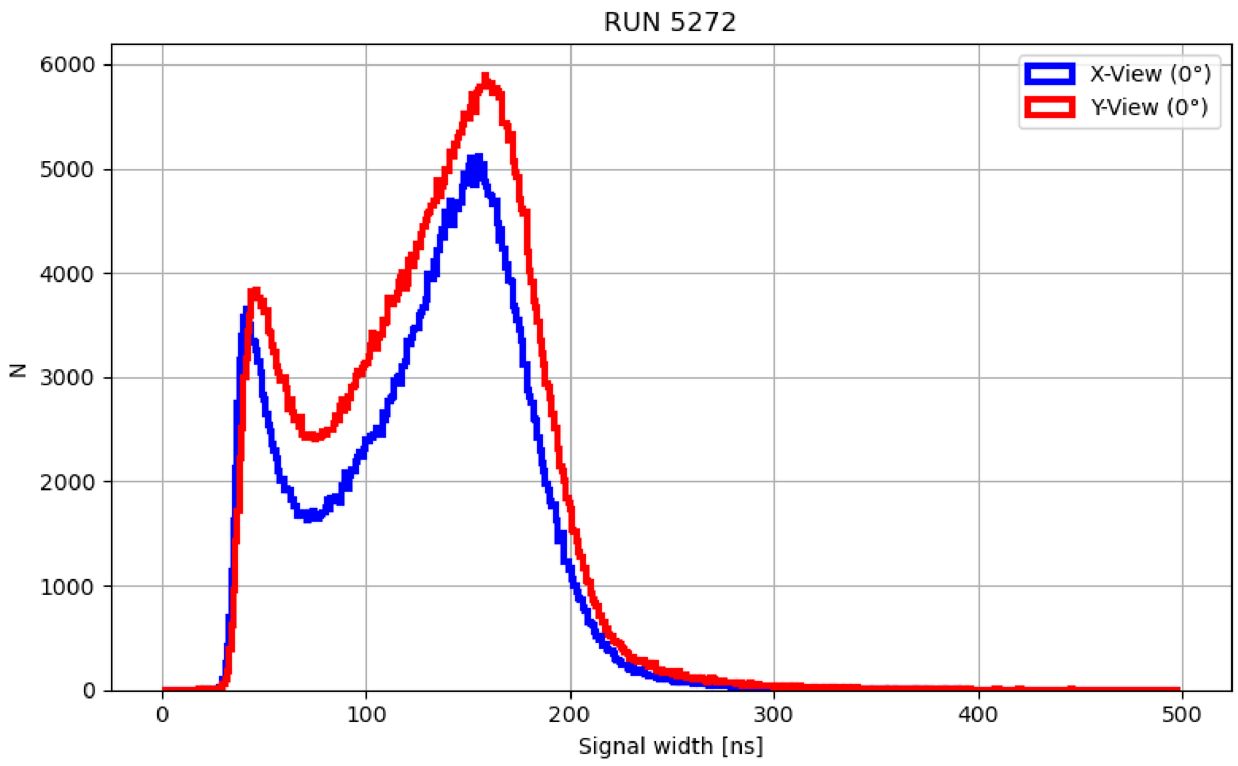


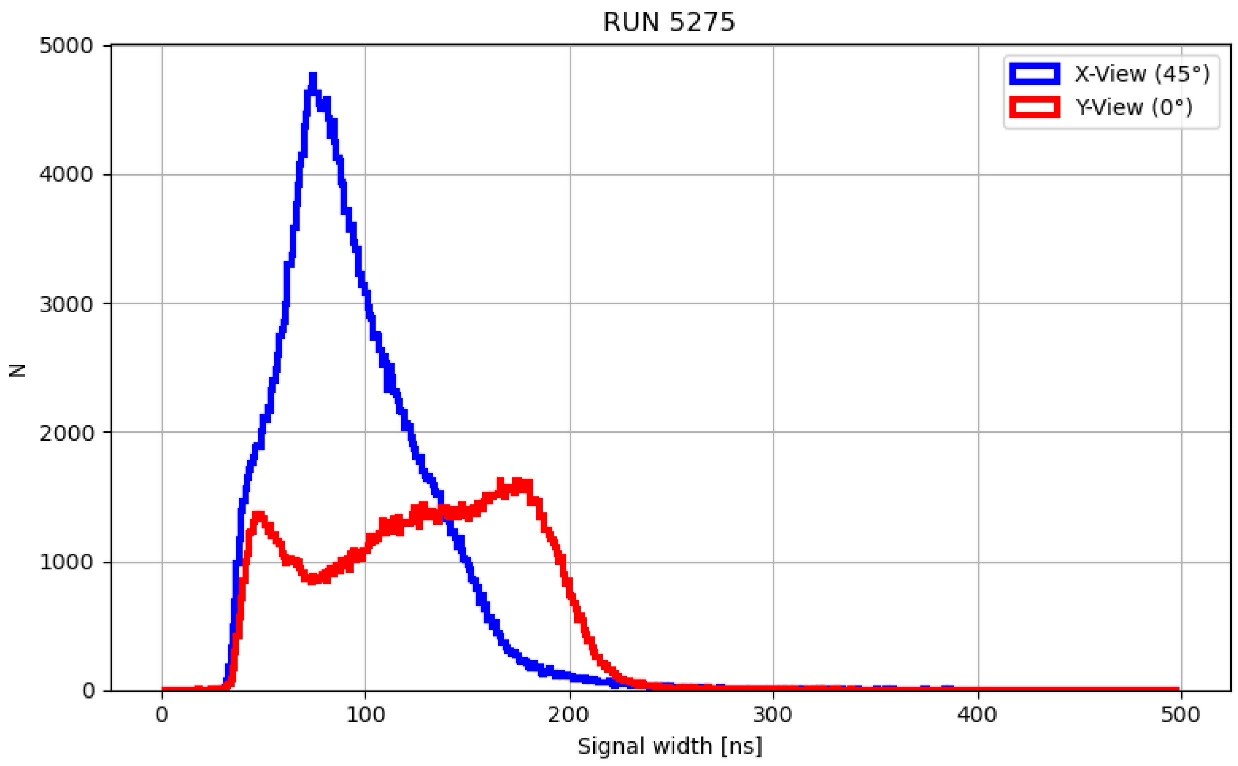
- v_d = 38 um/ns
- Induction gap = 2 mm
- Drift gap = 5 mm

- Induction time = 53 ns
- Drift time = 132 ns

- Total time = 185 ns (MAX)

Deconvoluted signal width *vs* angle



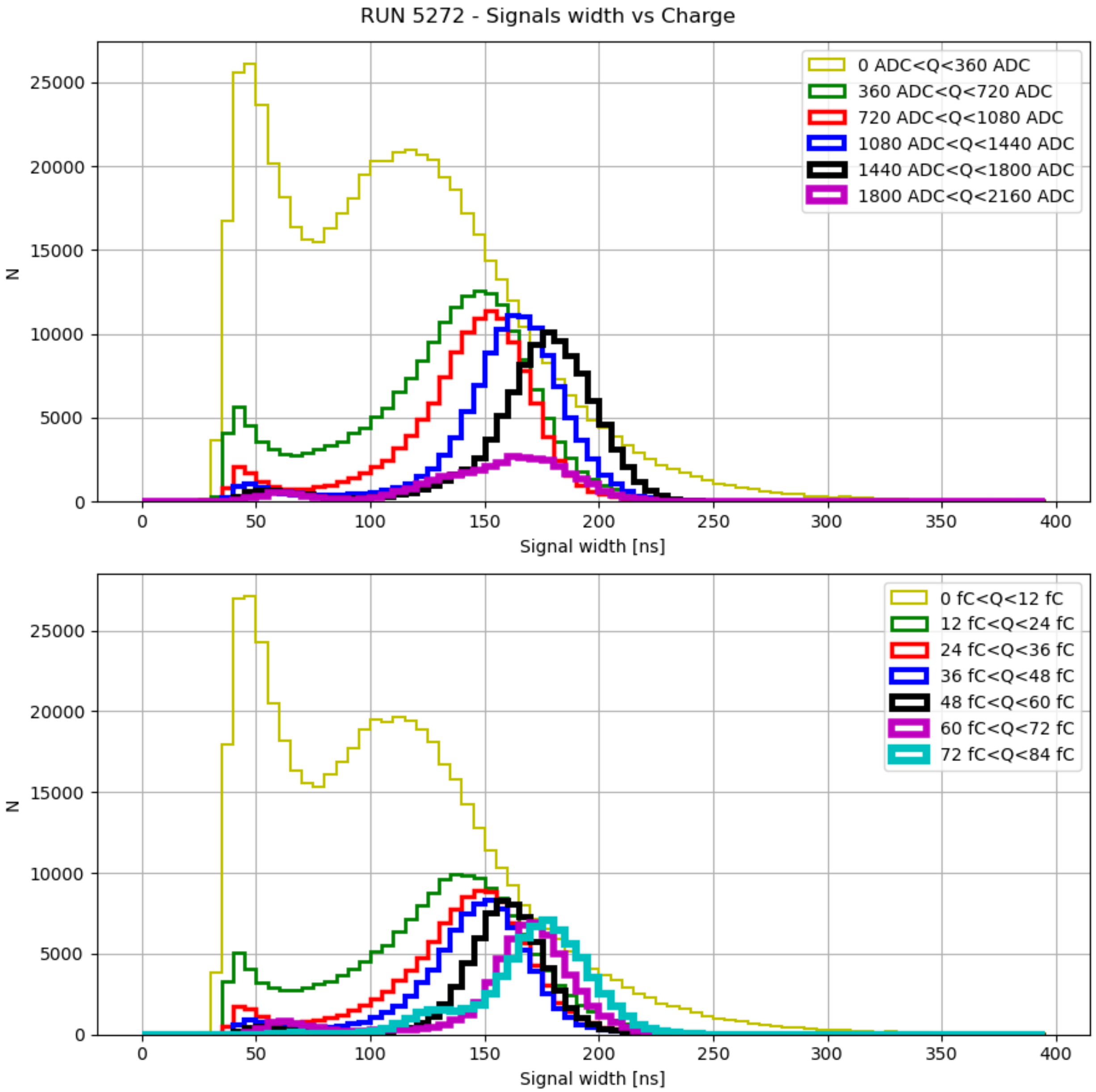


For RUN 5275 the cluster size of X-view is much higher, thus also its number of entries w.r.t. Y-view

Deconvoluted signals width *vs* charge

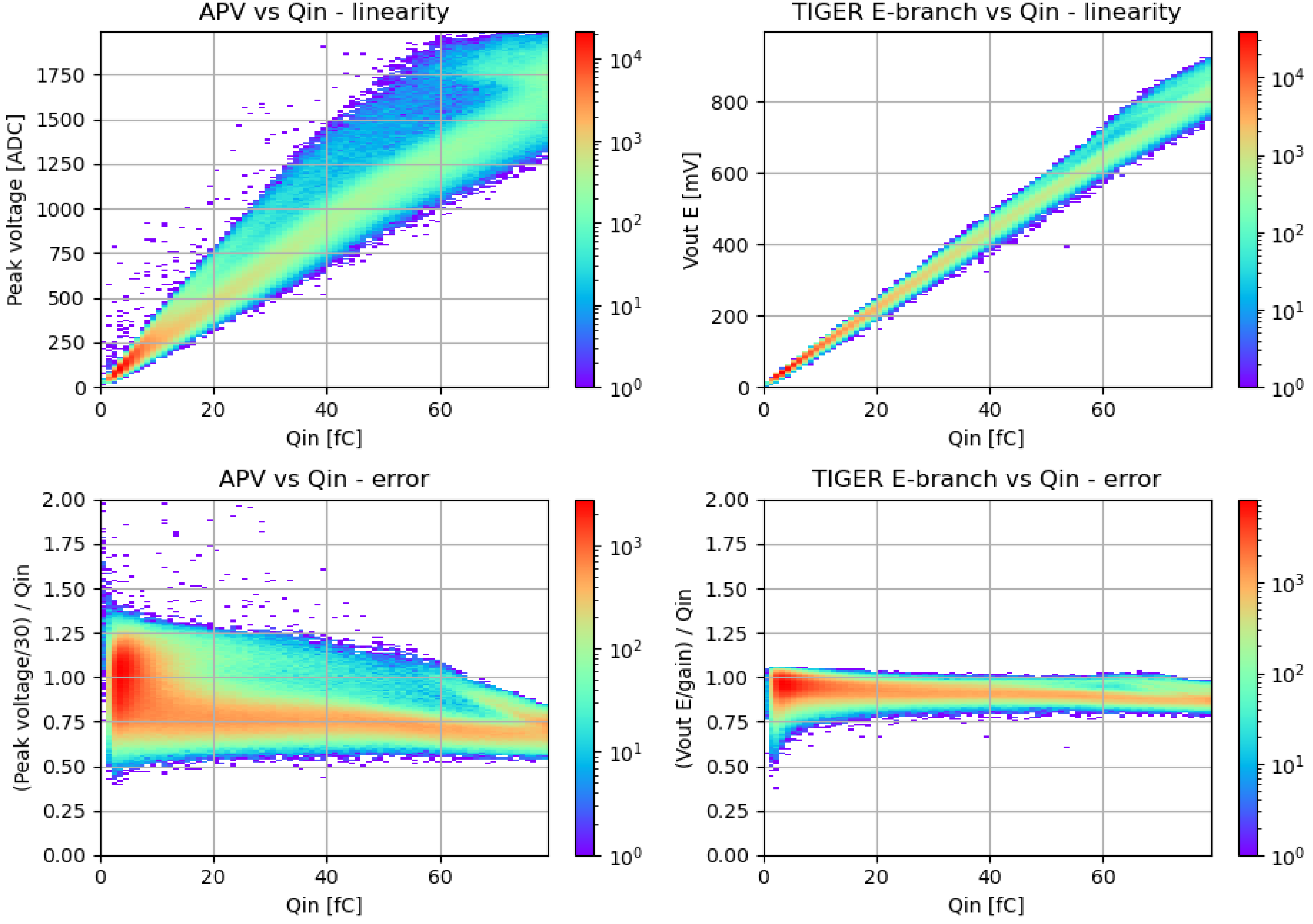
- <u>TOP</u>: charge from APV peak
- <u>BOTTOM</u>: charge from deconvoluted signal

- In both cases the low signal width peak is mainly due to the low charge signals (tails of cluster which don't see the full 5mm drift gap?)
- Small dependence of signal width on signal charge (except when saturated)



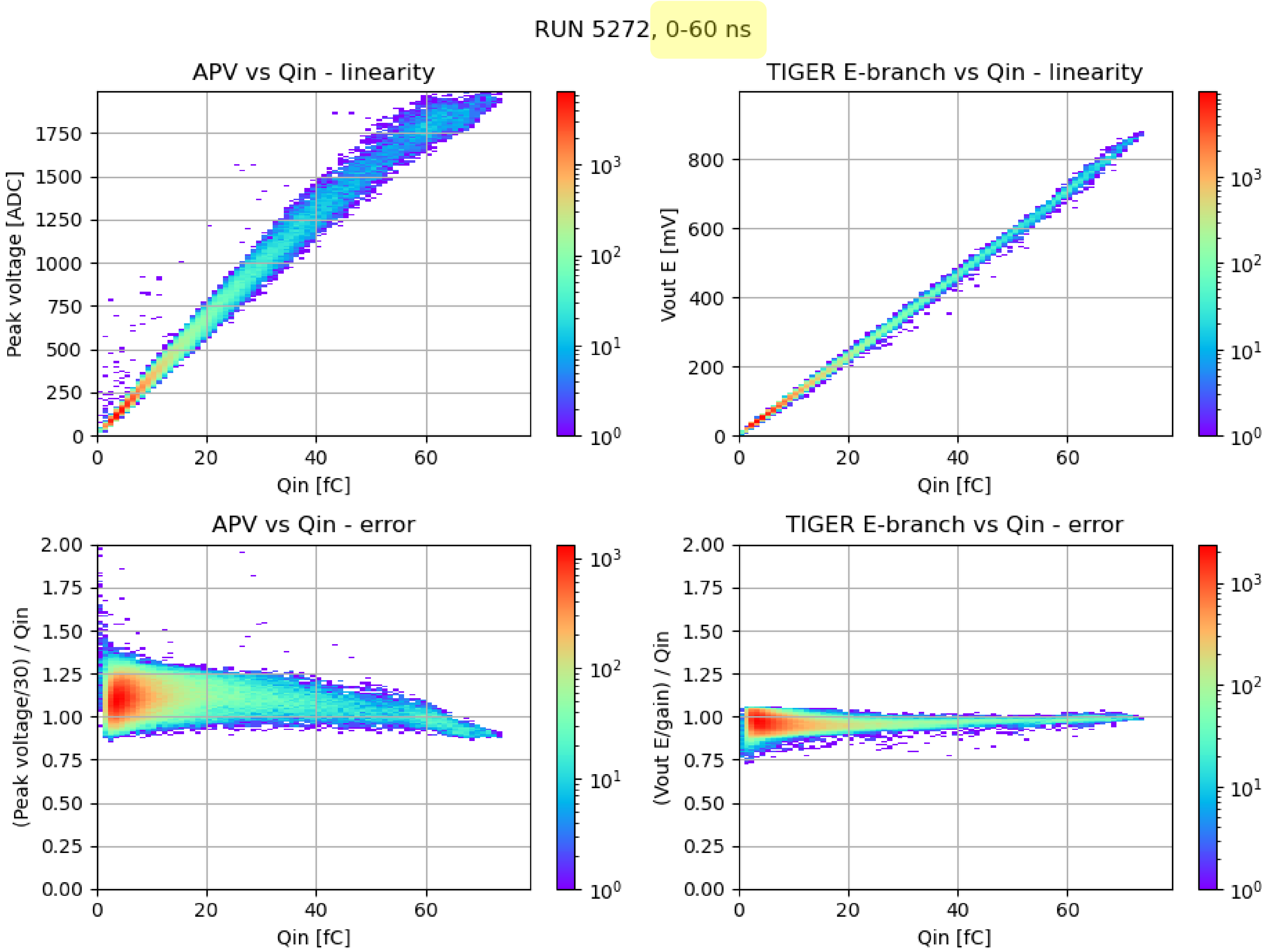
Front-End response (all)

RUN 5272, 0-1000 ns



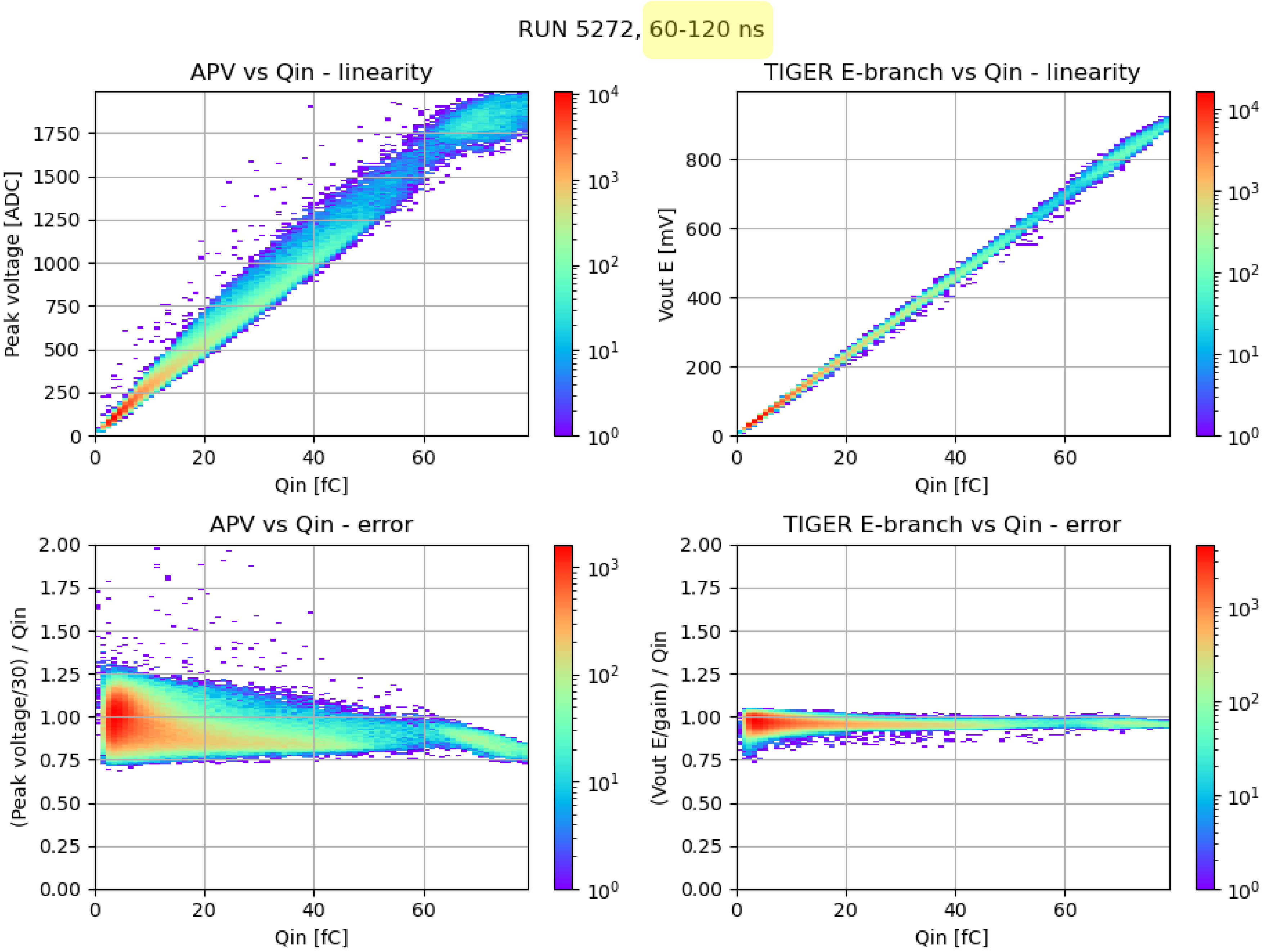
The larger shaping time of TIGER E-branch provides less sensitivity to different input signal widths (TIGER E-branch saturation not considered)

Front-End response (1)



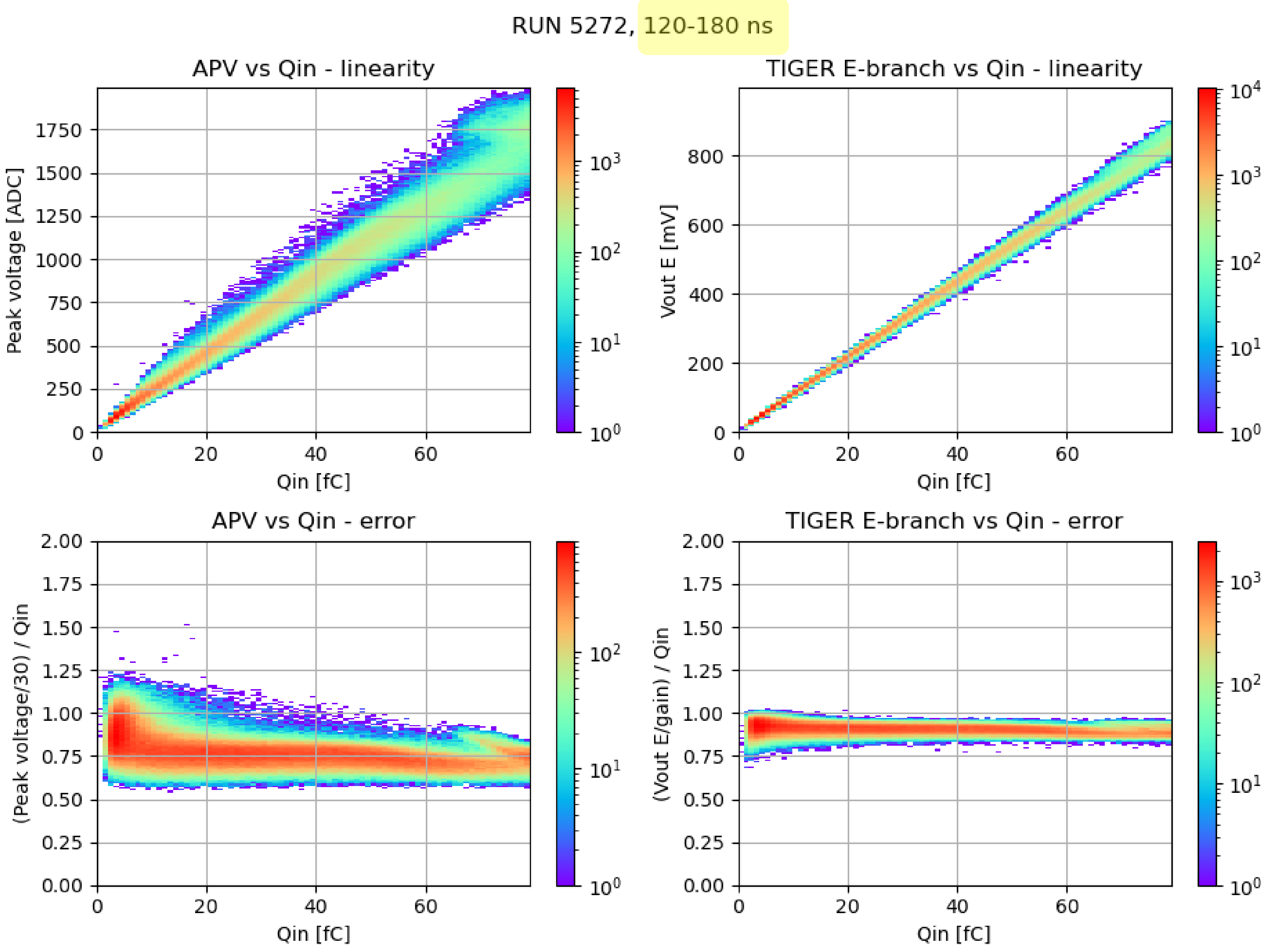
With short input signals APV charge is higher than the one from deconvolution

Front-End response (2)

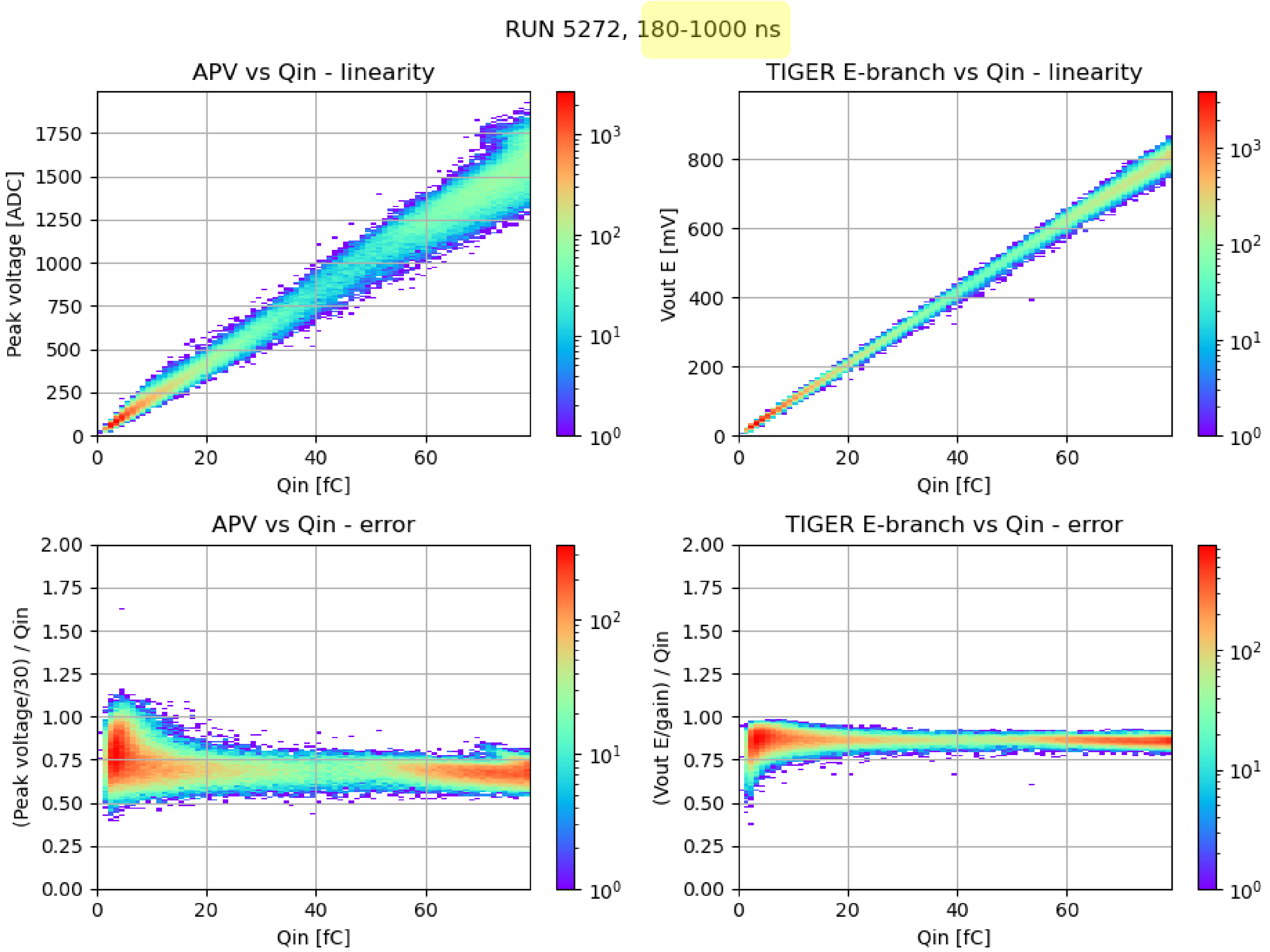


While for longer input signals APV charge is lower than the one from deconvolution (ballistic deficit)

Front-End response (3)

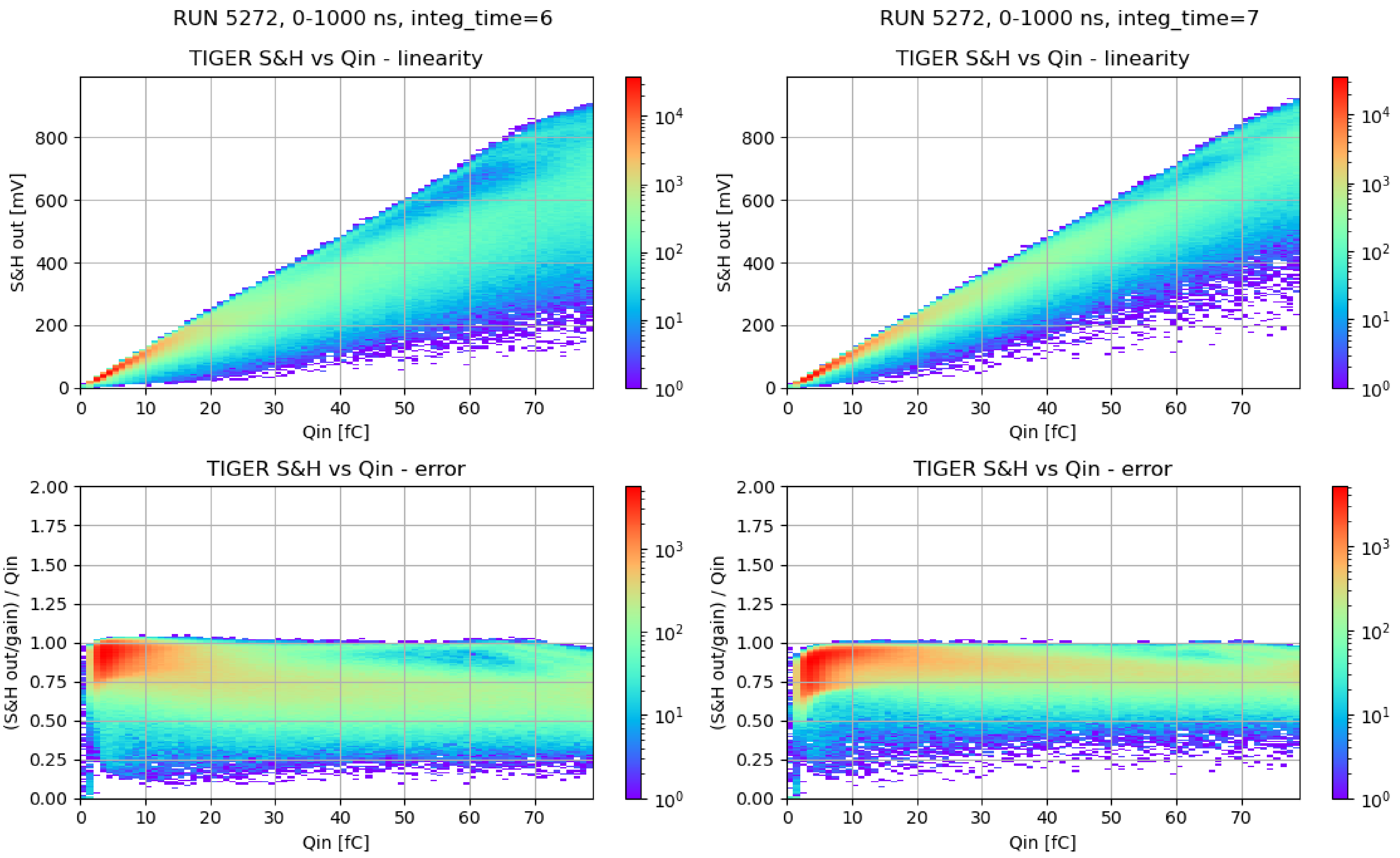


Front-End response (4)

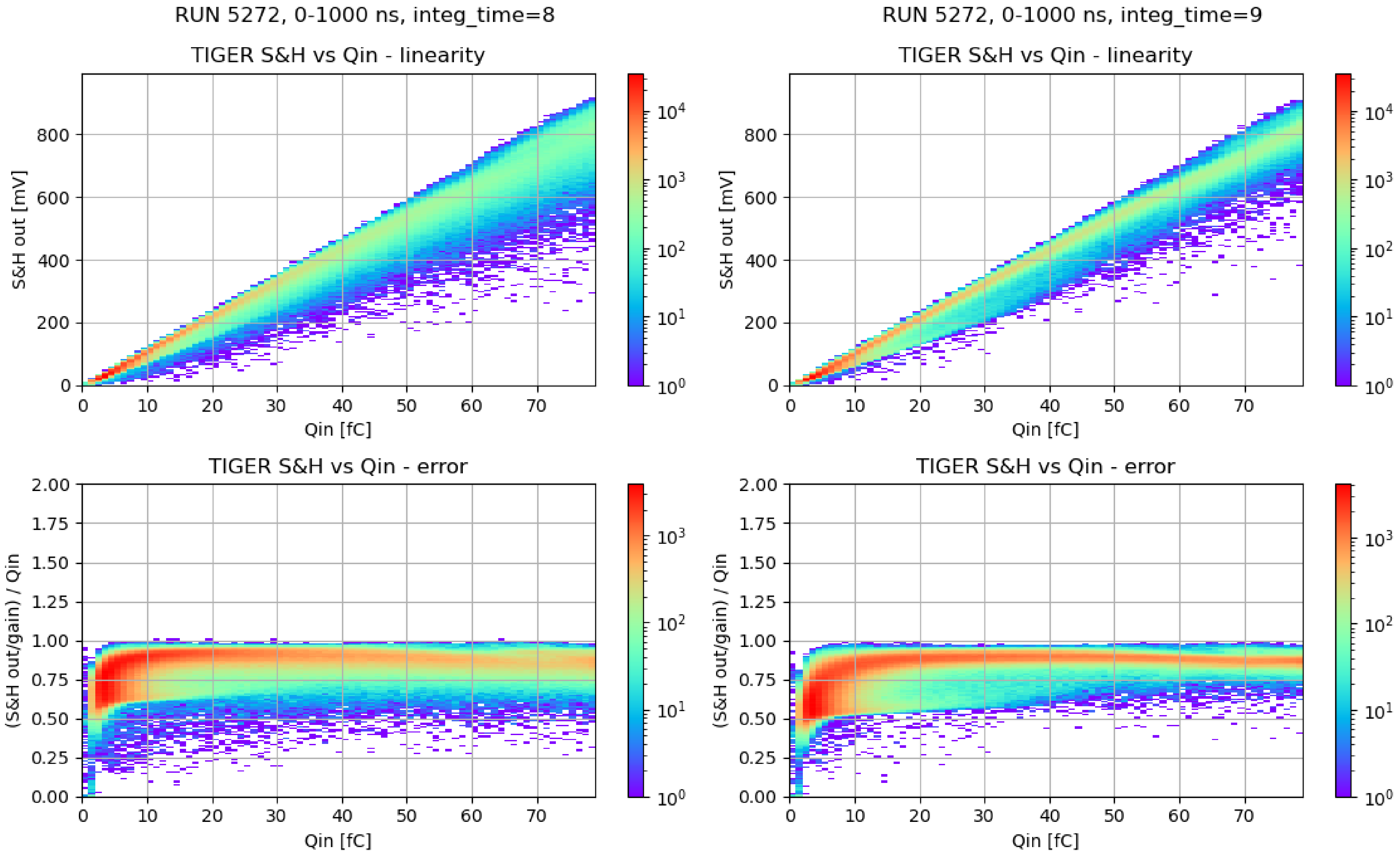


With very long input signals both electronics show some ballistic deficit, according to their shaping time

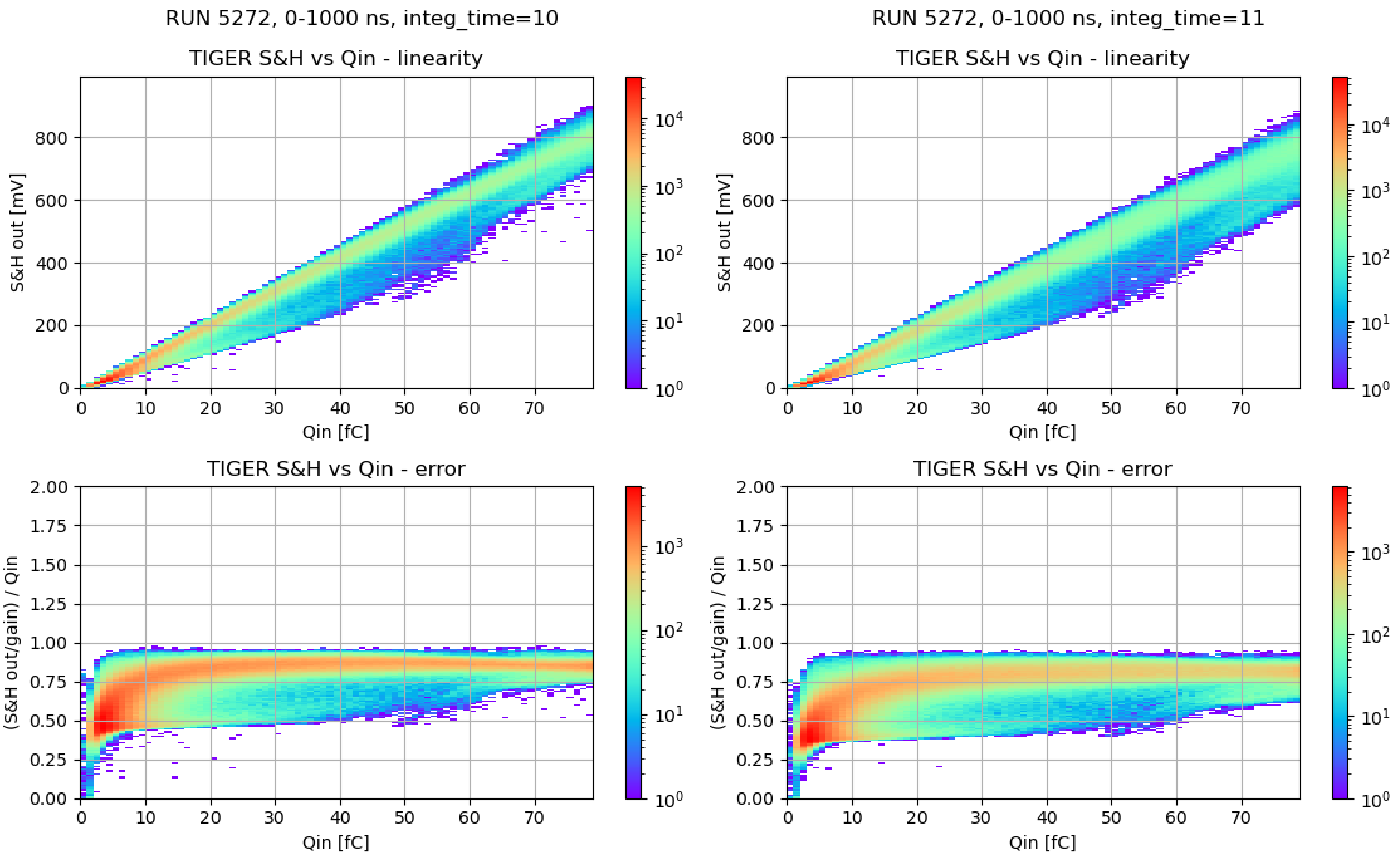
integ_time scan (all)



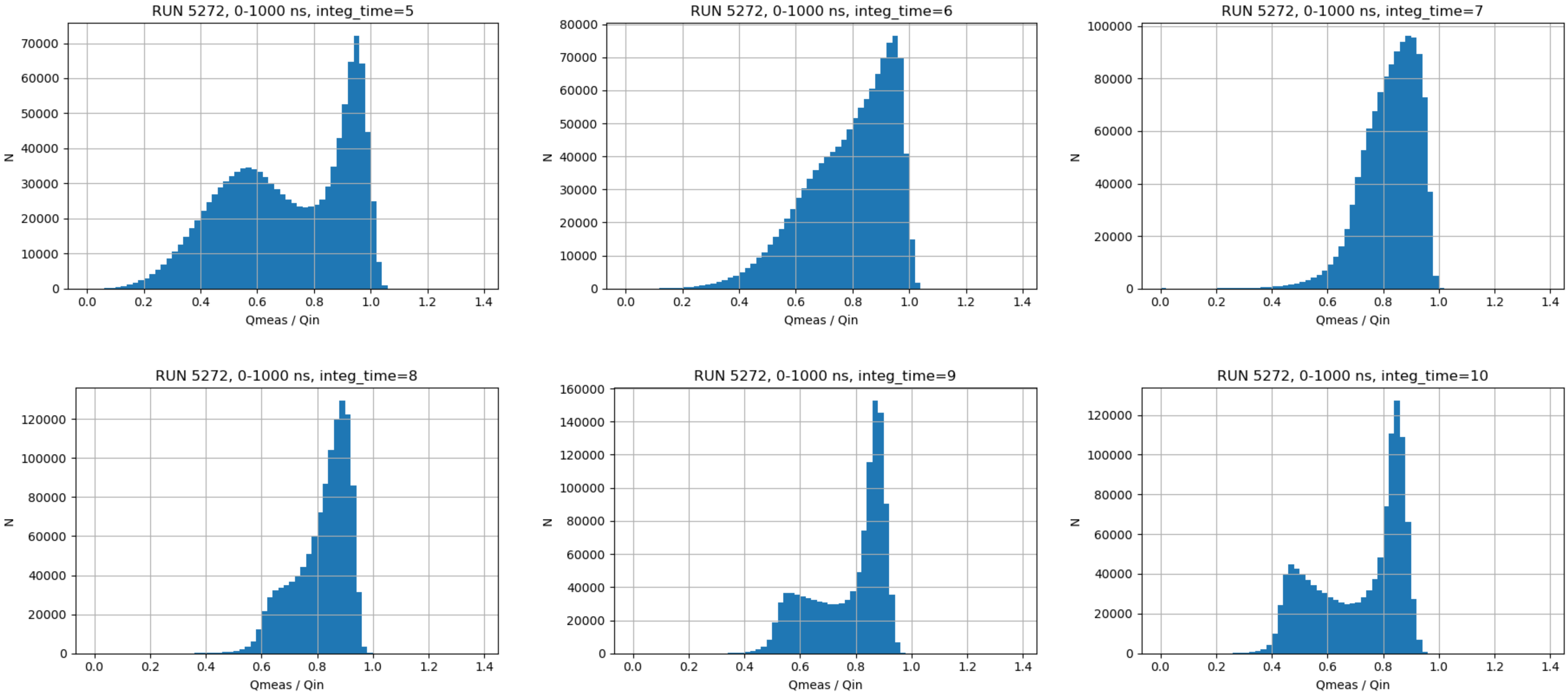
integ_time scan (all)



integ_time scan (all)



integ_time scan (all)



integ_time scan

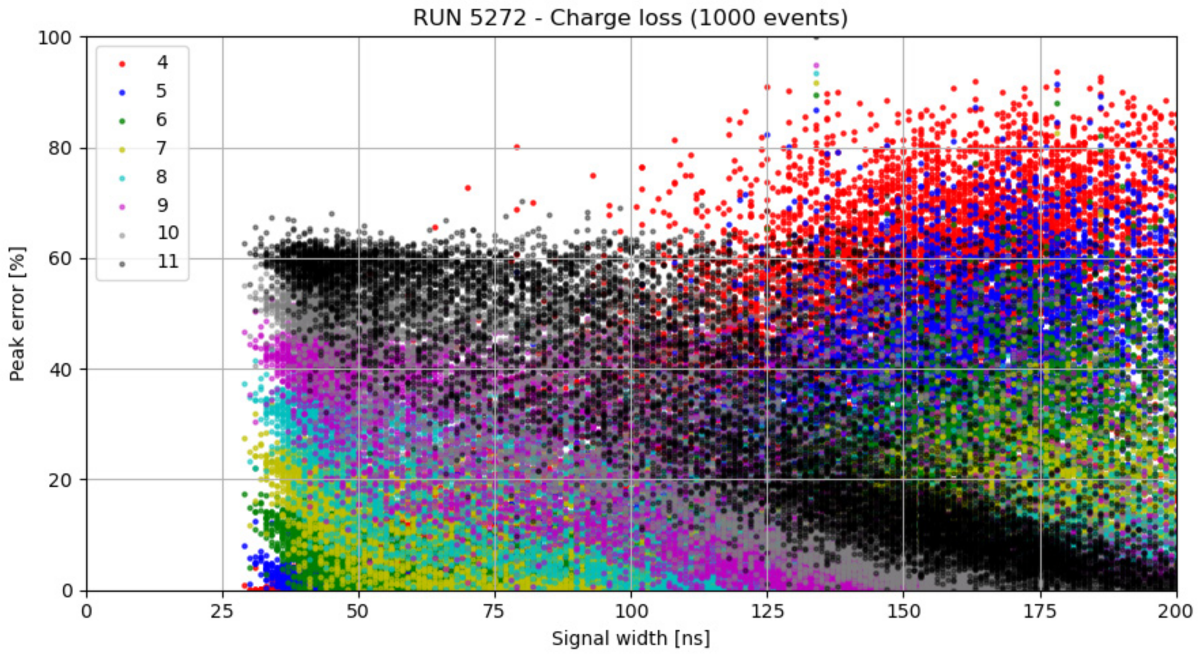
TOP: first 1000 events

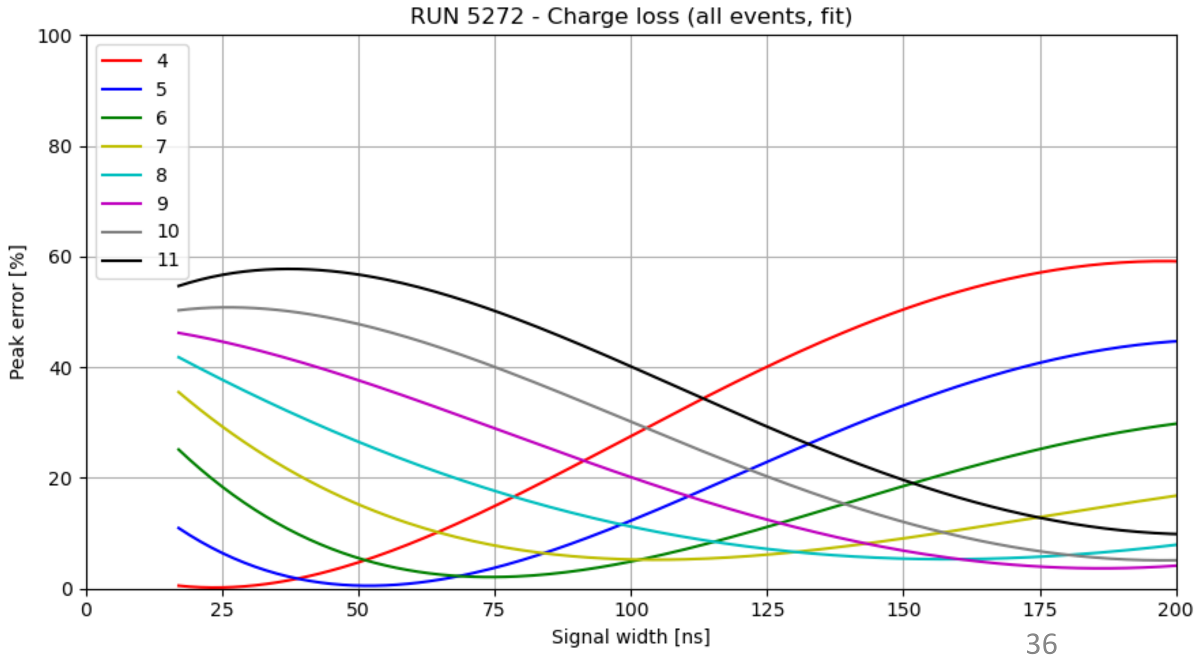
BOTTOM: all events, best fit

$$\text{Peak error} = \frac{V_{peak} - V_{sampled}}{V_{peak}} \cdot 100$$

- V_{peak} = E_branch peak voltage
- $V_{sampled}$ = S&H output

➢ This takes into account only the peak error (which can be “optimized”), not the ballistic deficit (which is fixed)



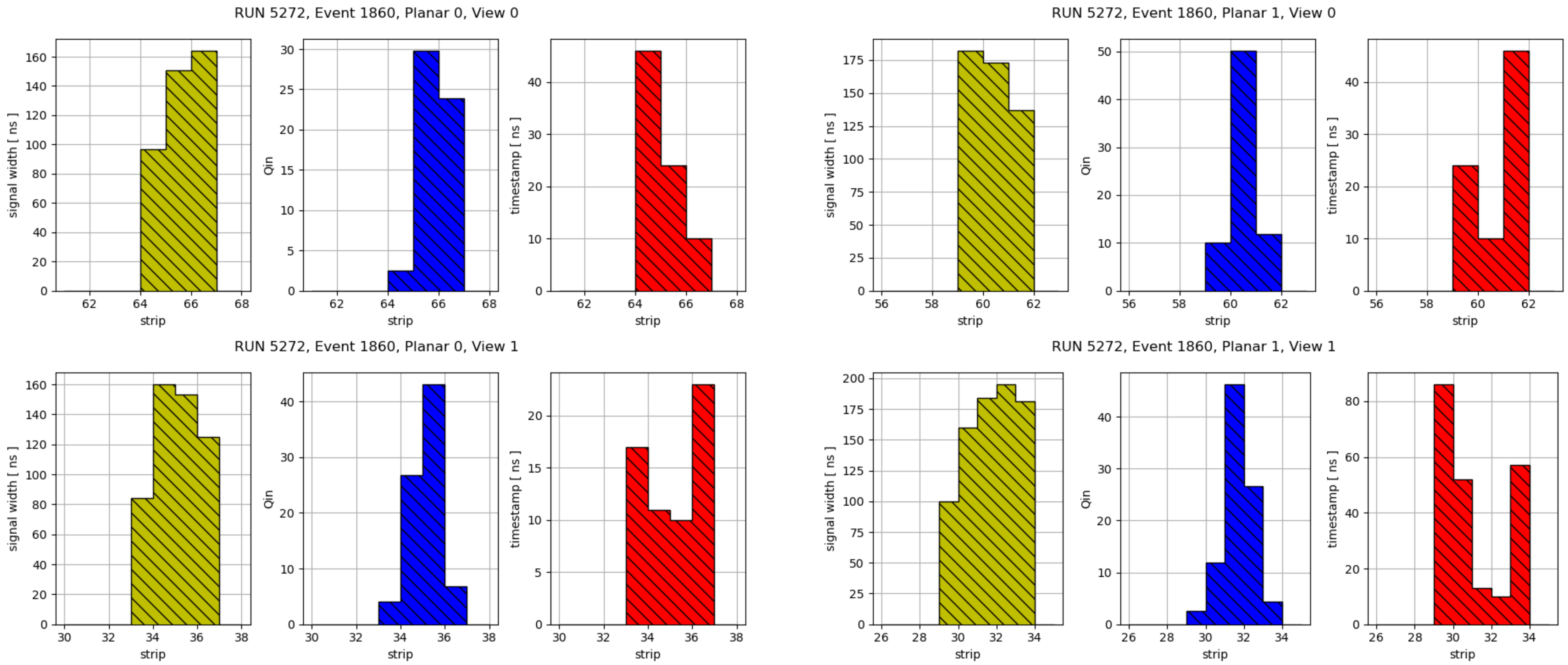


Conclusions

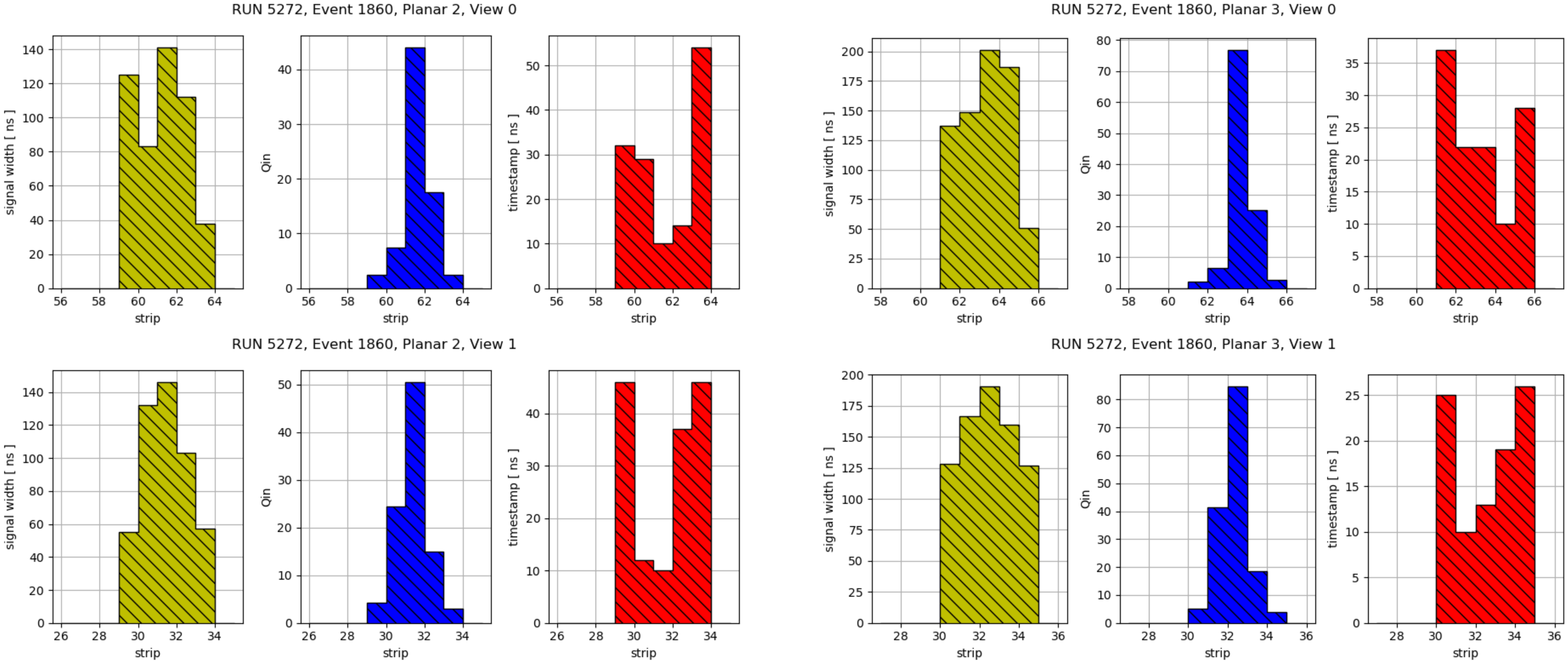
- The input signals duration plays an important role in the charge measurement (ballistic deficit + *integ_time*)
- Signals can be up to 180-200 ns and this implies that the shaped output signal peaking time is largely dependent on the input signals width
- Setting *integ_time* = 7-8 should be slightly better for these kind of signals (test beam, 0° angle), but the optimum is not the same for all the signals
  - Cluster tails seem to behave differently
  - Angled tracks have shorter duration signals and thus would require a lower *integ_time*
- This analysis provides a tool to study the characteristics of GEM signals (from real data) and the response of TIGER
  - Repeat the analysis on runs taken with different configurations (cosmic, gas mixture, 3 mm gap, CGEM geometry, magnetic field ON) and compare with GEM simulations

Backup slides

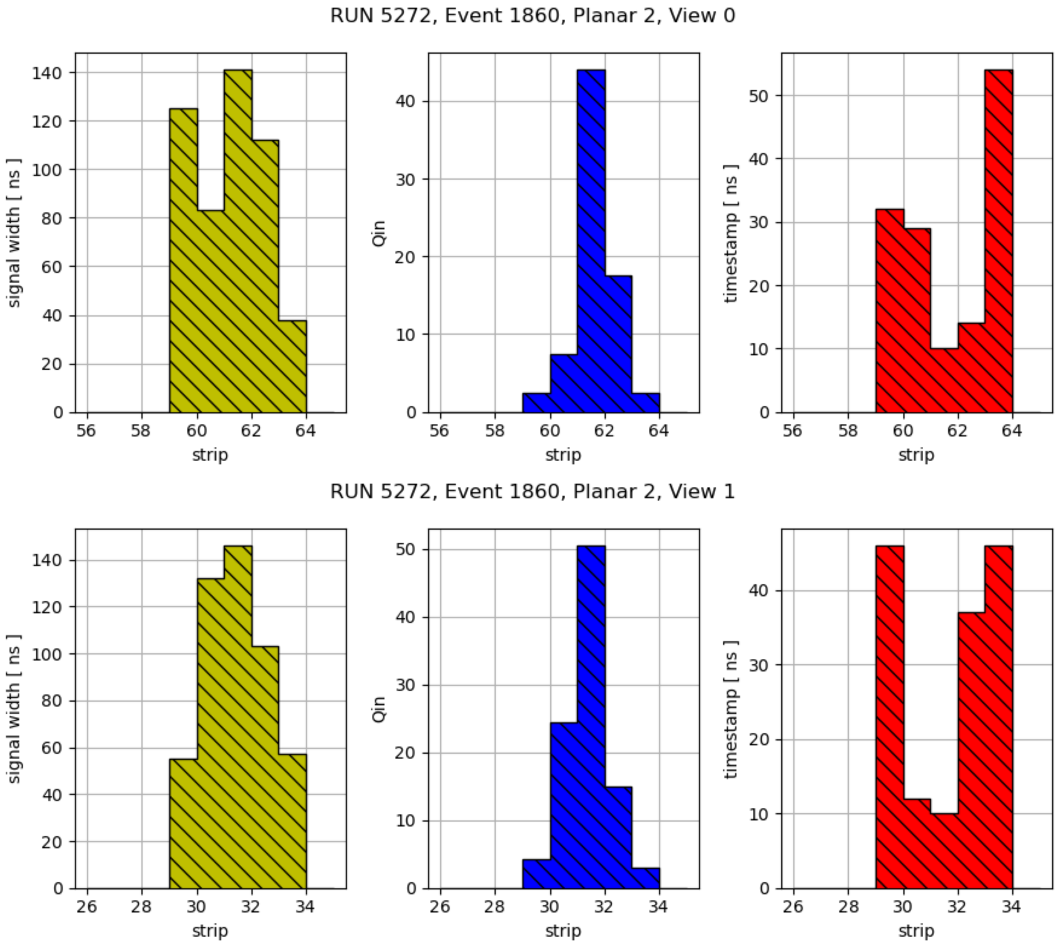
Look at one event

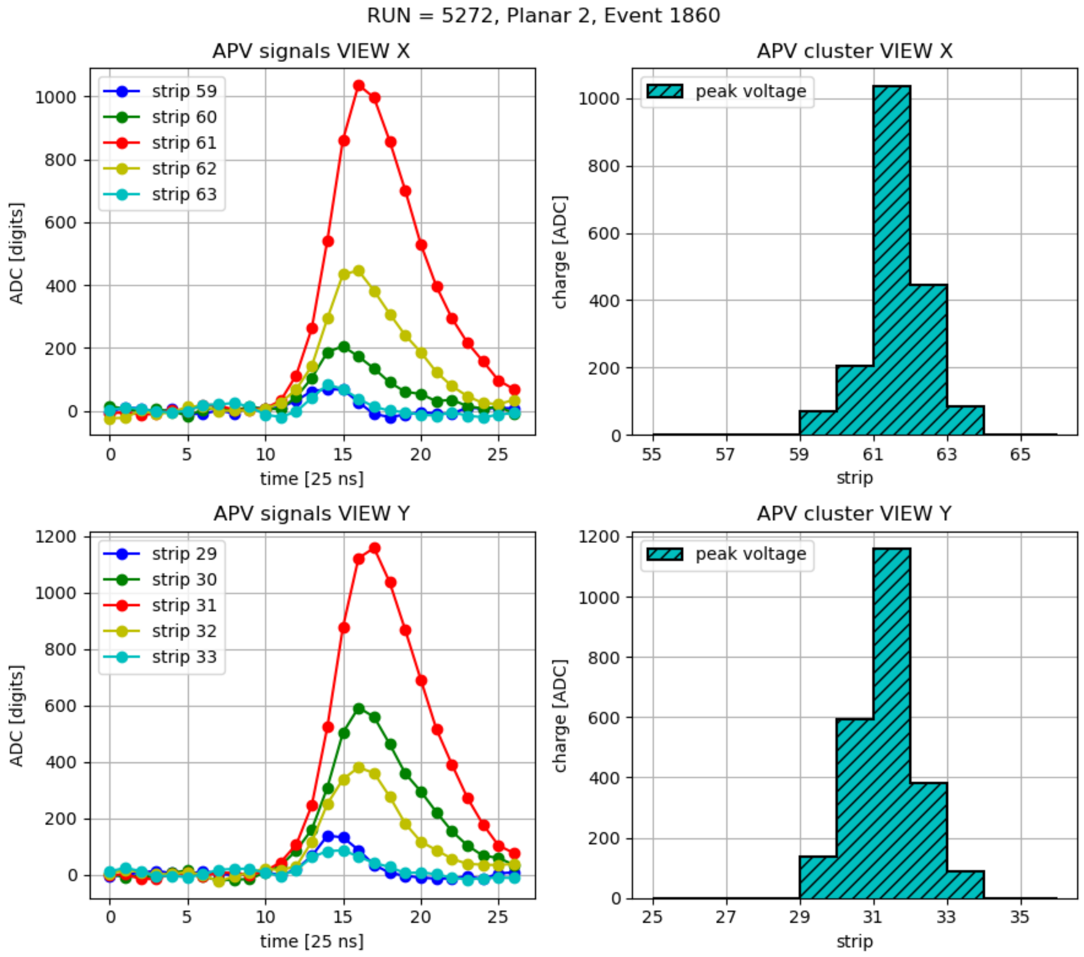


Look at one event



Look at one event

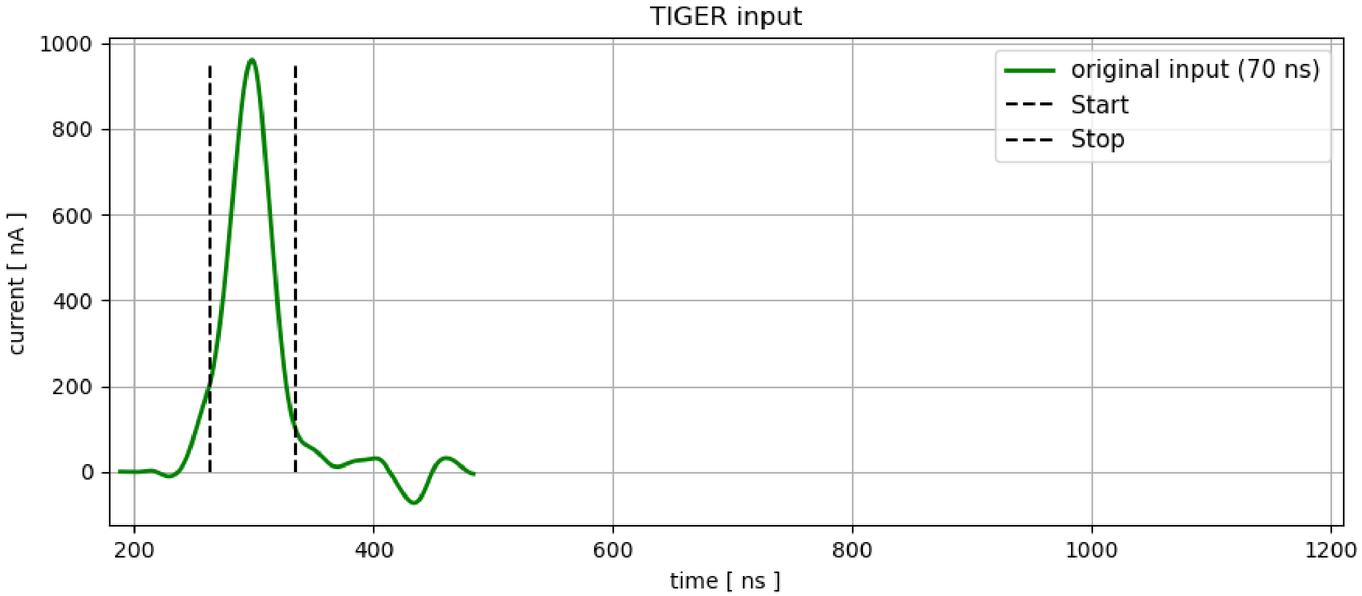


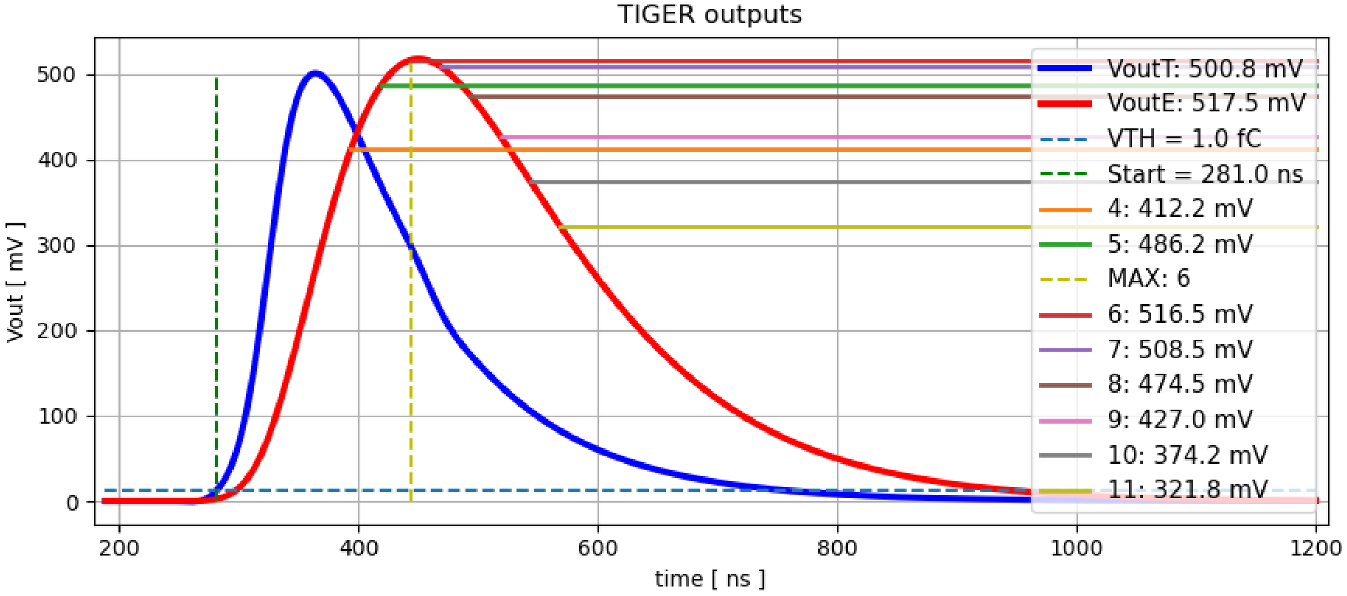


TIGER (2)

- Divide time by 2: 70 ns
- Peak voltage = 517 mV
- Q = 43 fC (almost no ballistic deficit)

- MAX at *integ_time* = 6
- Sampled voltage = 516 mV
- Q = 43 fC (peak sampled correctly)

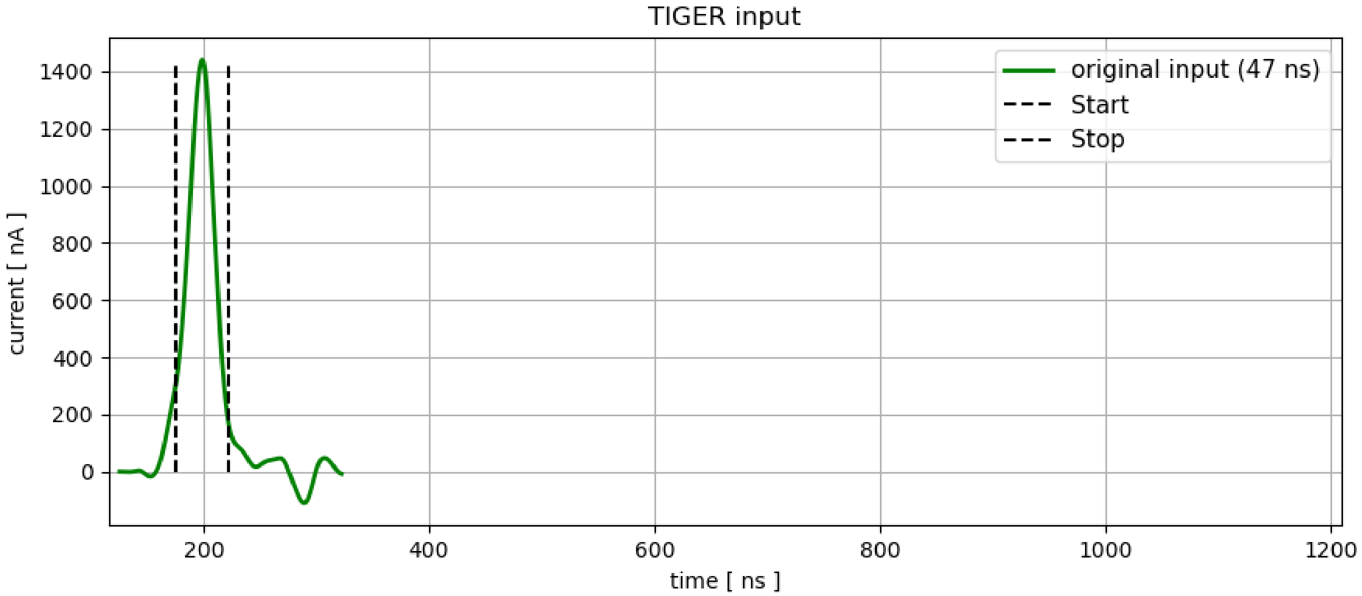


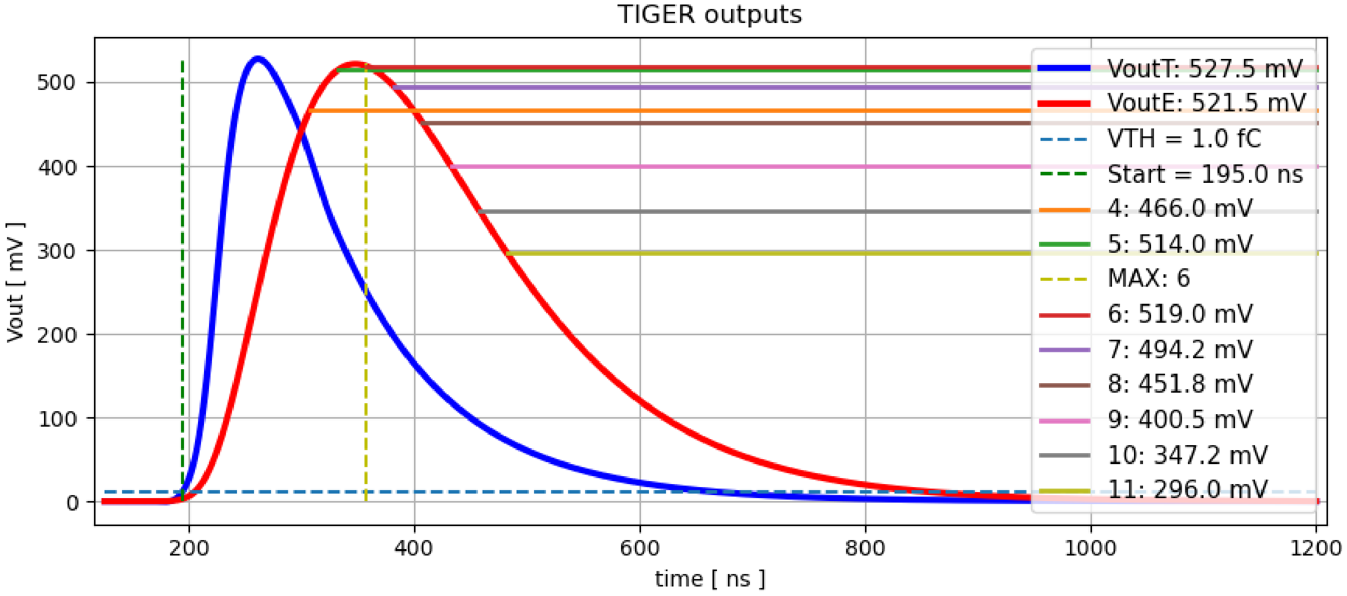


TIGER (3)

- Divide time by 3: 47 ns
- Peak voltage = 521 mV
- Q = 43.5 fC (no ballistic deficit)

- MAX at *integ_time* = 6
- Sampled voltage = 519 mV
- Q = 43.25 fC

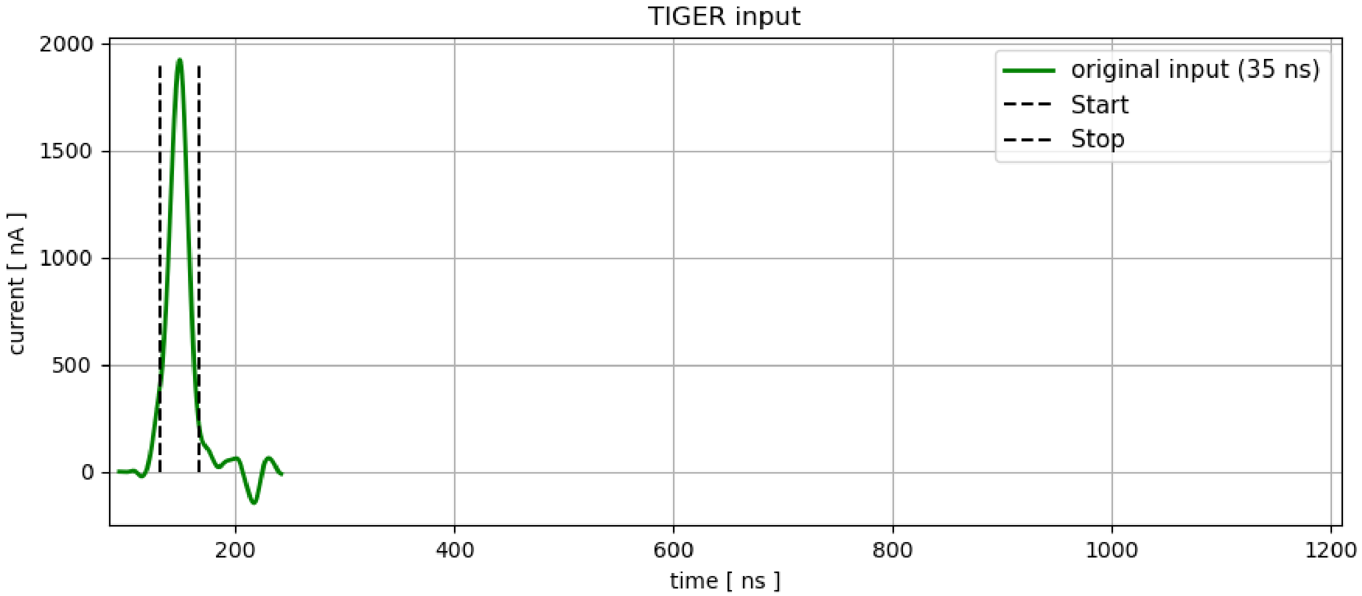


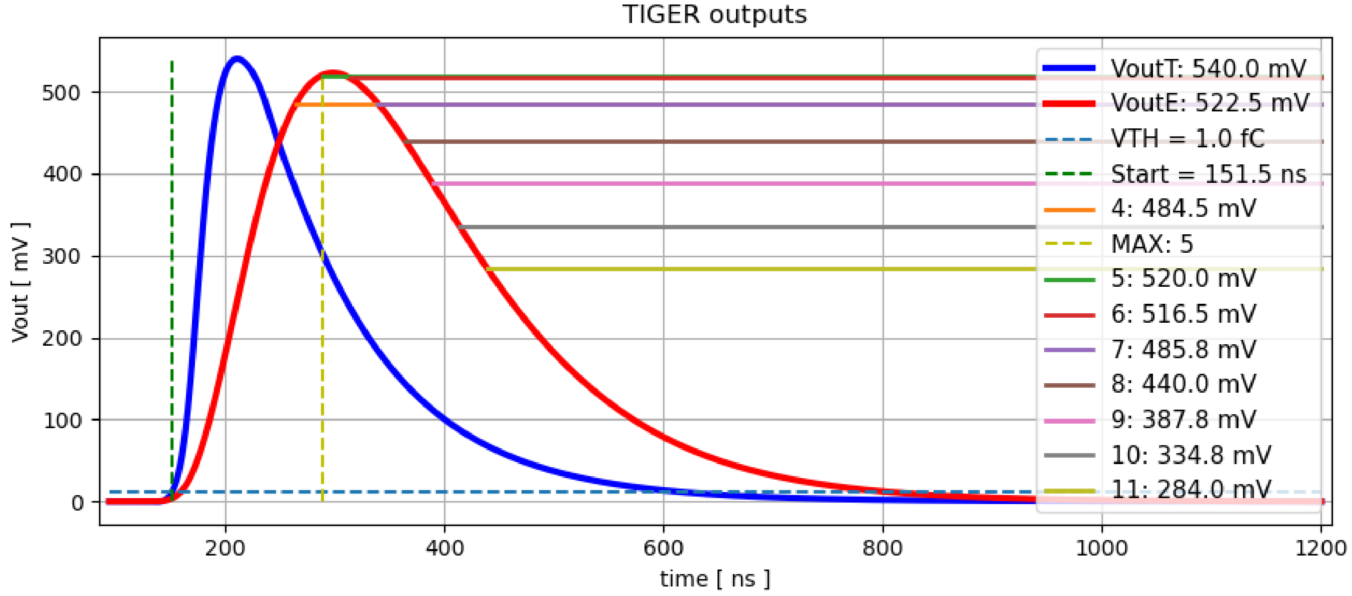


TIGER (4)

- Divide time by 4: 35 ns
- Peak voltage = 522 mV
- Q = 43.5 fC (no ballistic deficit)

- MAX at *integ_time* = 5
- Sampled voltage = 520 mV
- Q = 43.3 fC

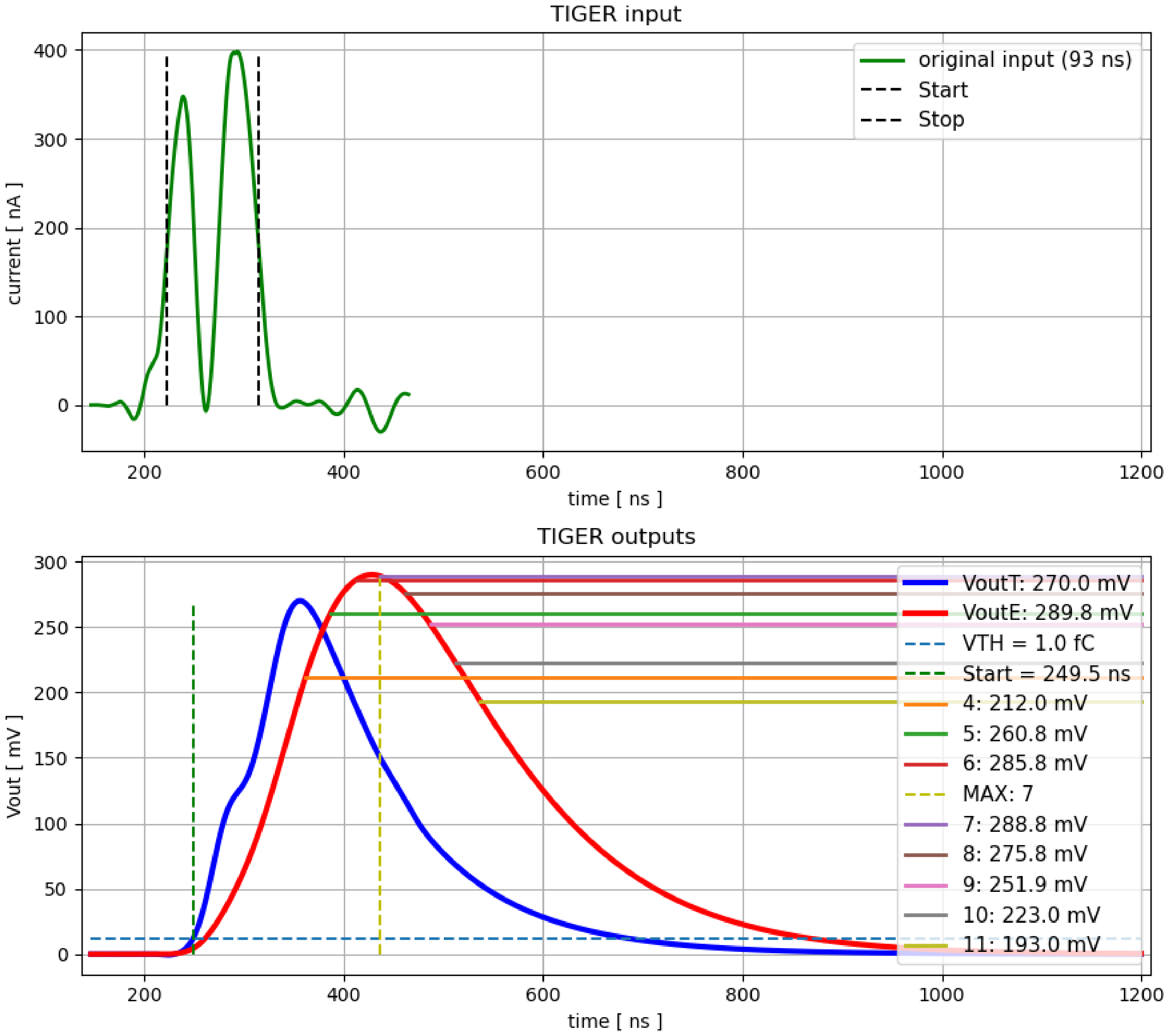




TIGER (2)

- Divide time by 2: 93 ns
- Peak voltage = 290 mV
- Q = 24 fC (almost no ballistic deficit)

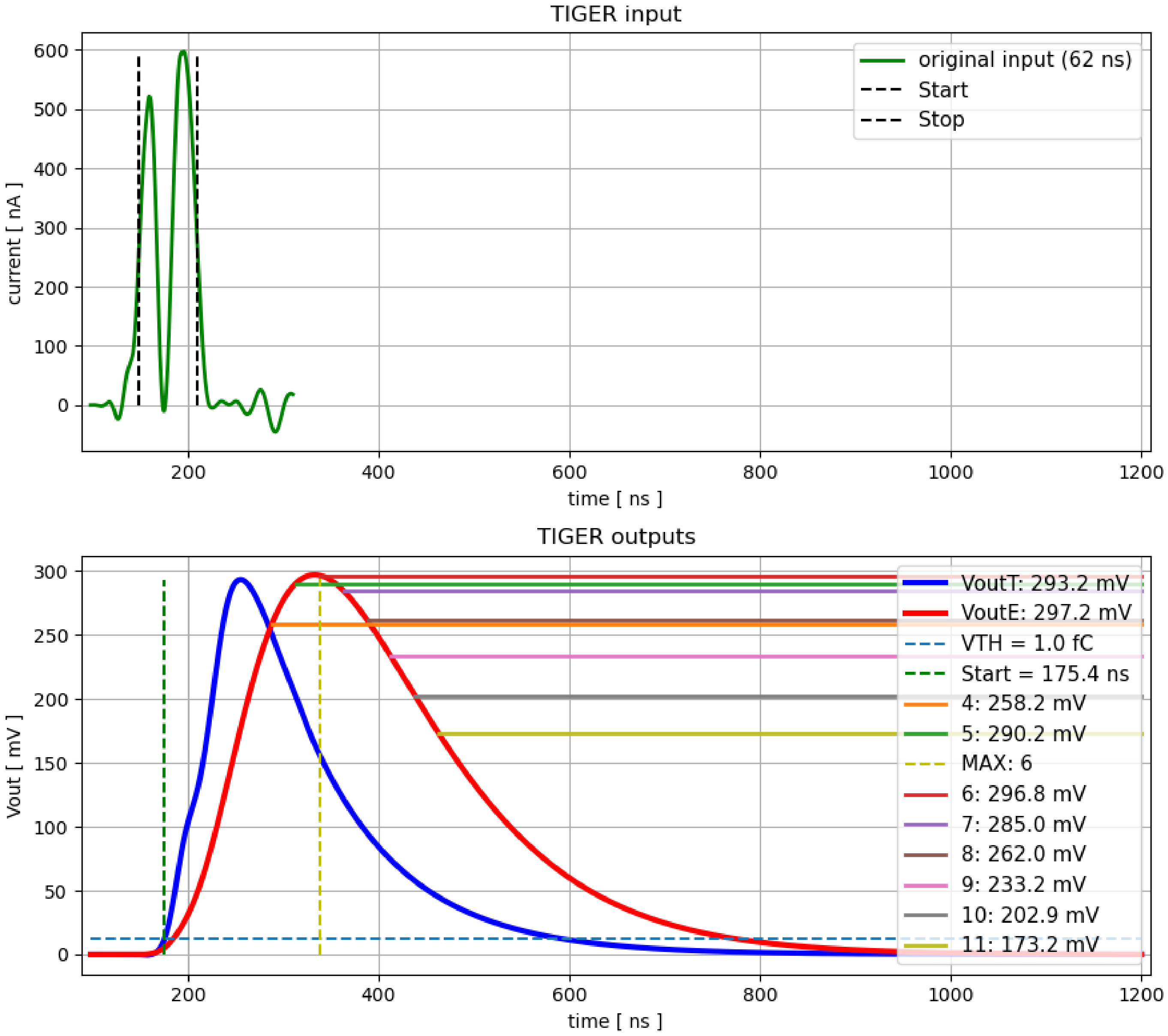
- MAX at *integ_time* = 7



TIGER (3)

- Divide time by 3: 62 ns
- Peak voltage = 297 mV
- Q = 25 fC (no ballistic deficit)

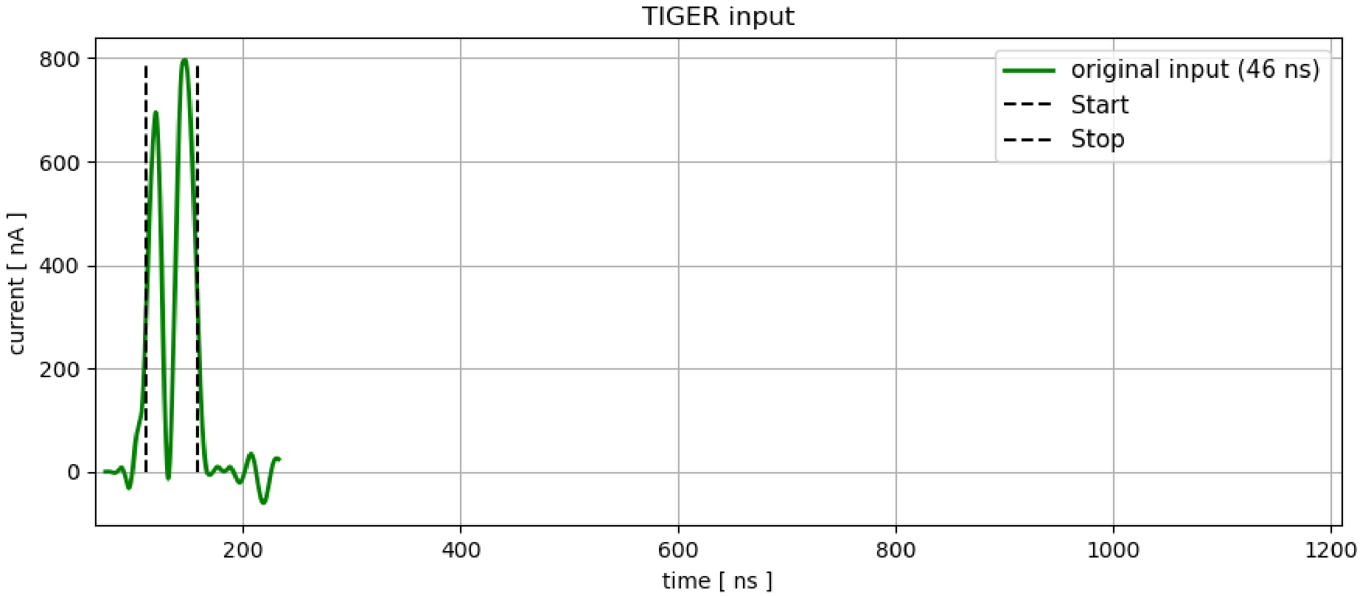
- MAX at *integ_time* = 6

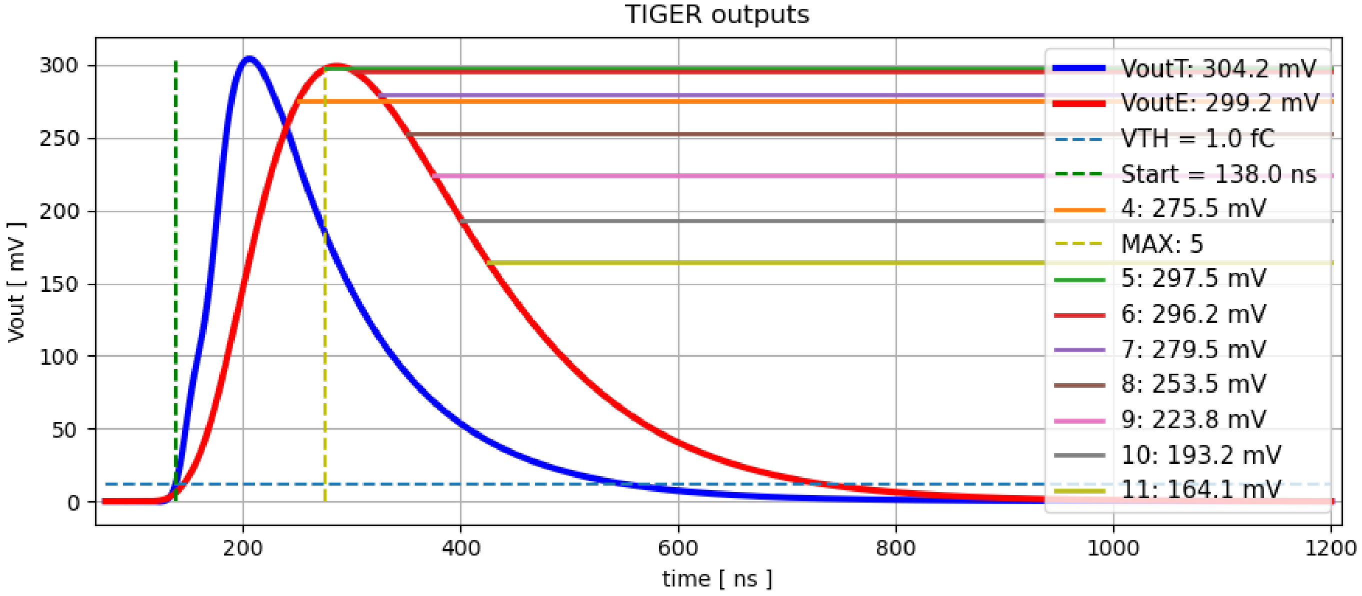


TIGER (4)

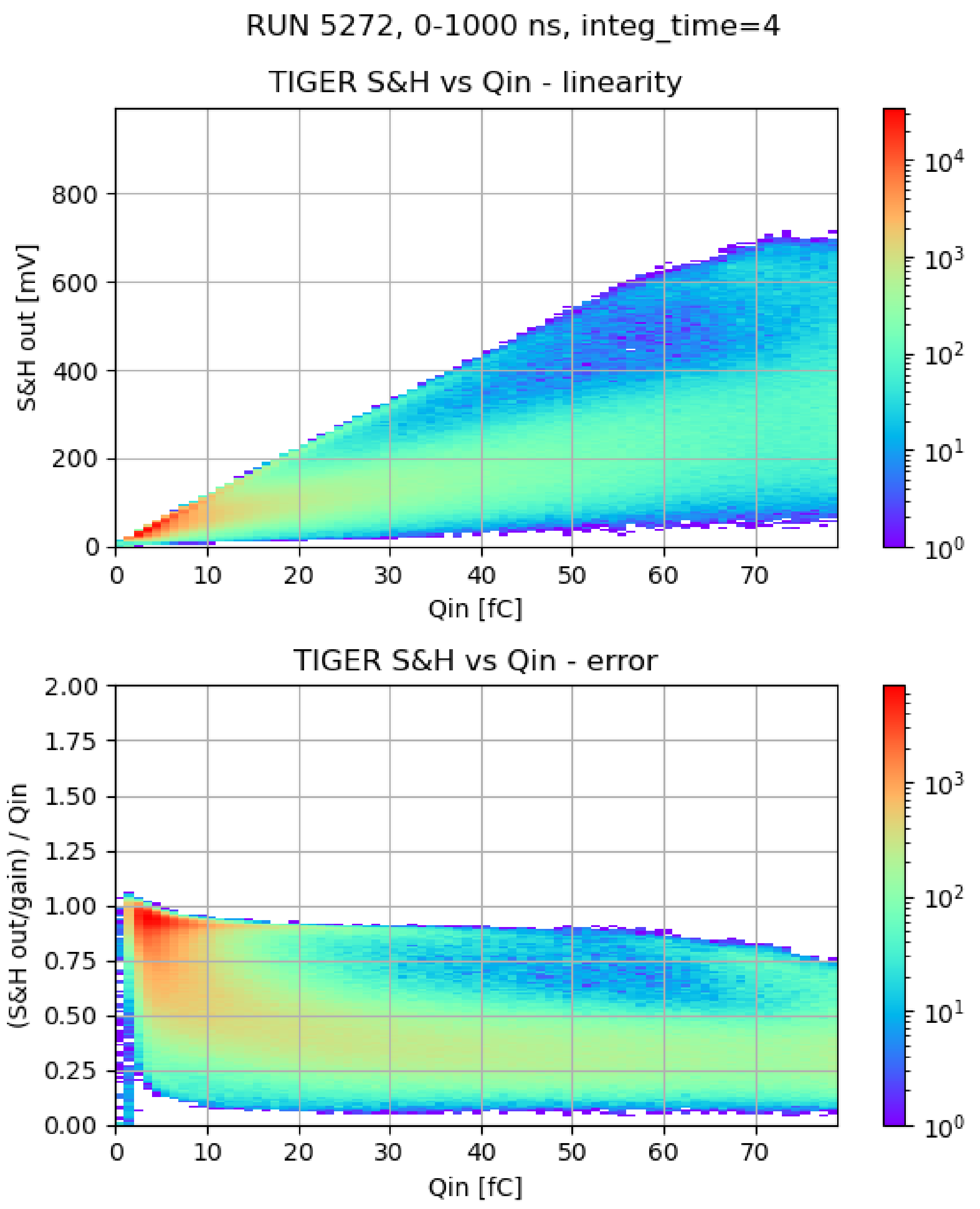
- Divide time by 4: 46 ns
- Peak voltage = 299 mV
- Q = 25 fC (no ballistic deficit)

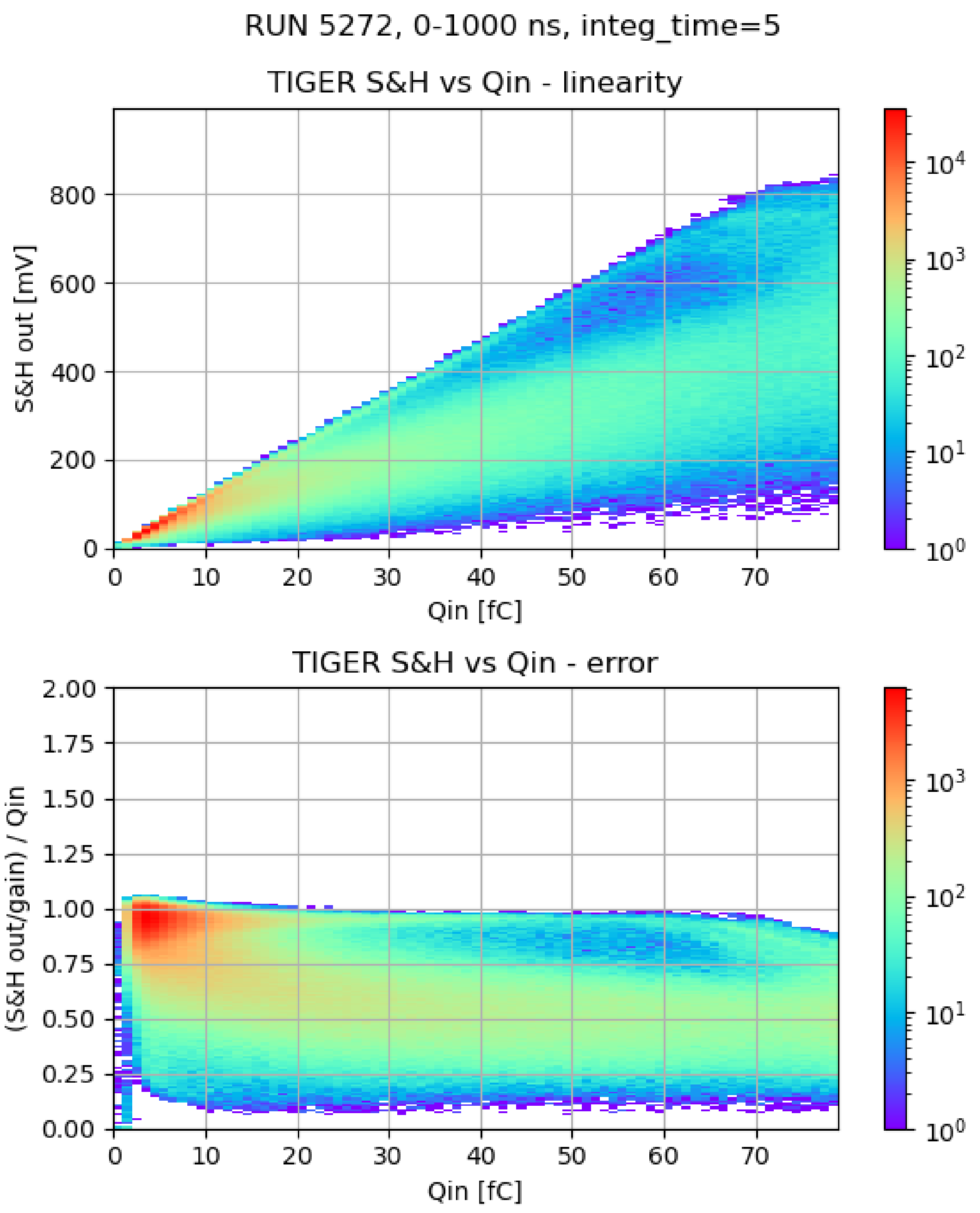
- MAX at *integ_time* = 5



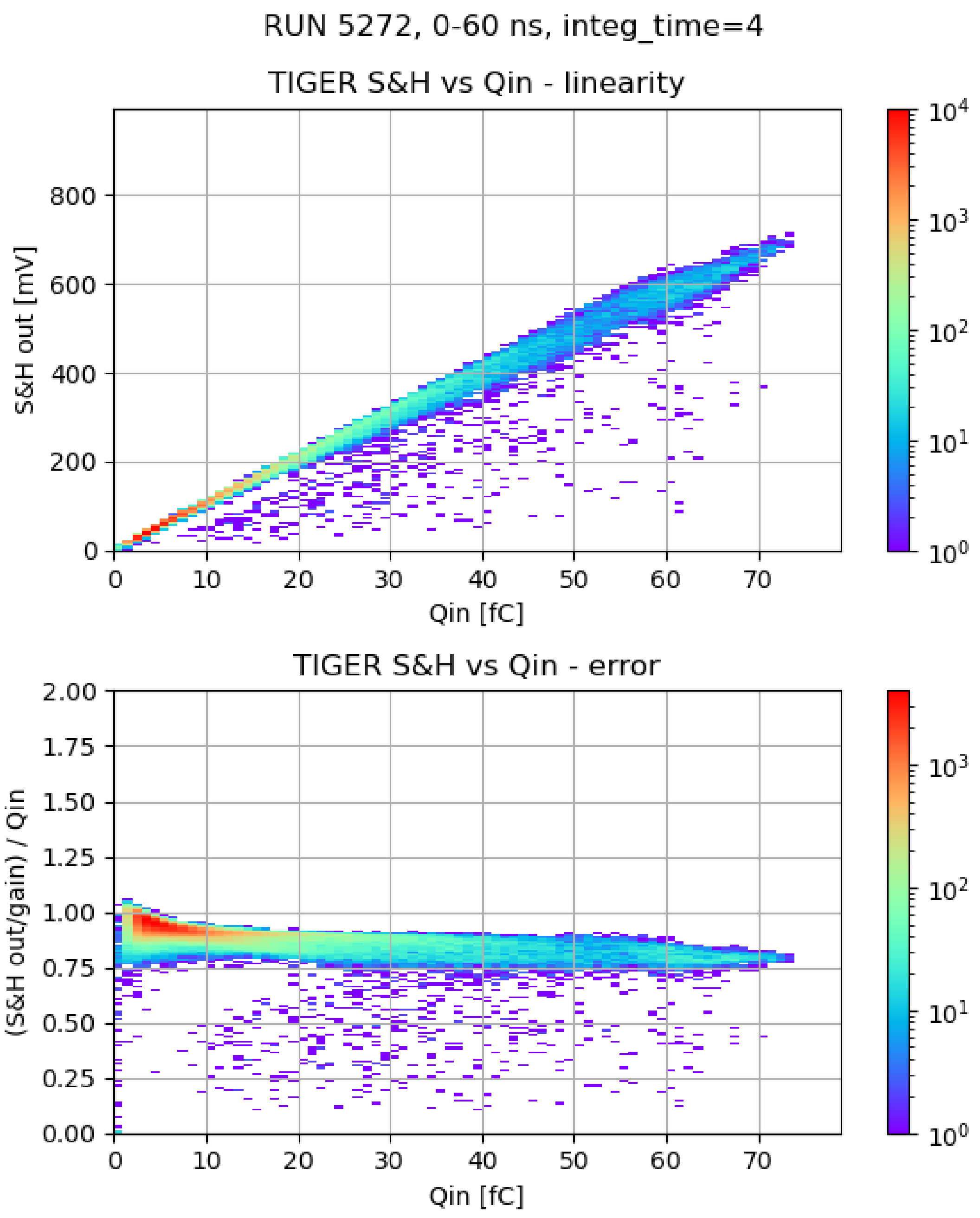


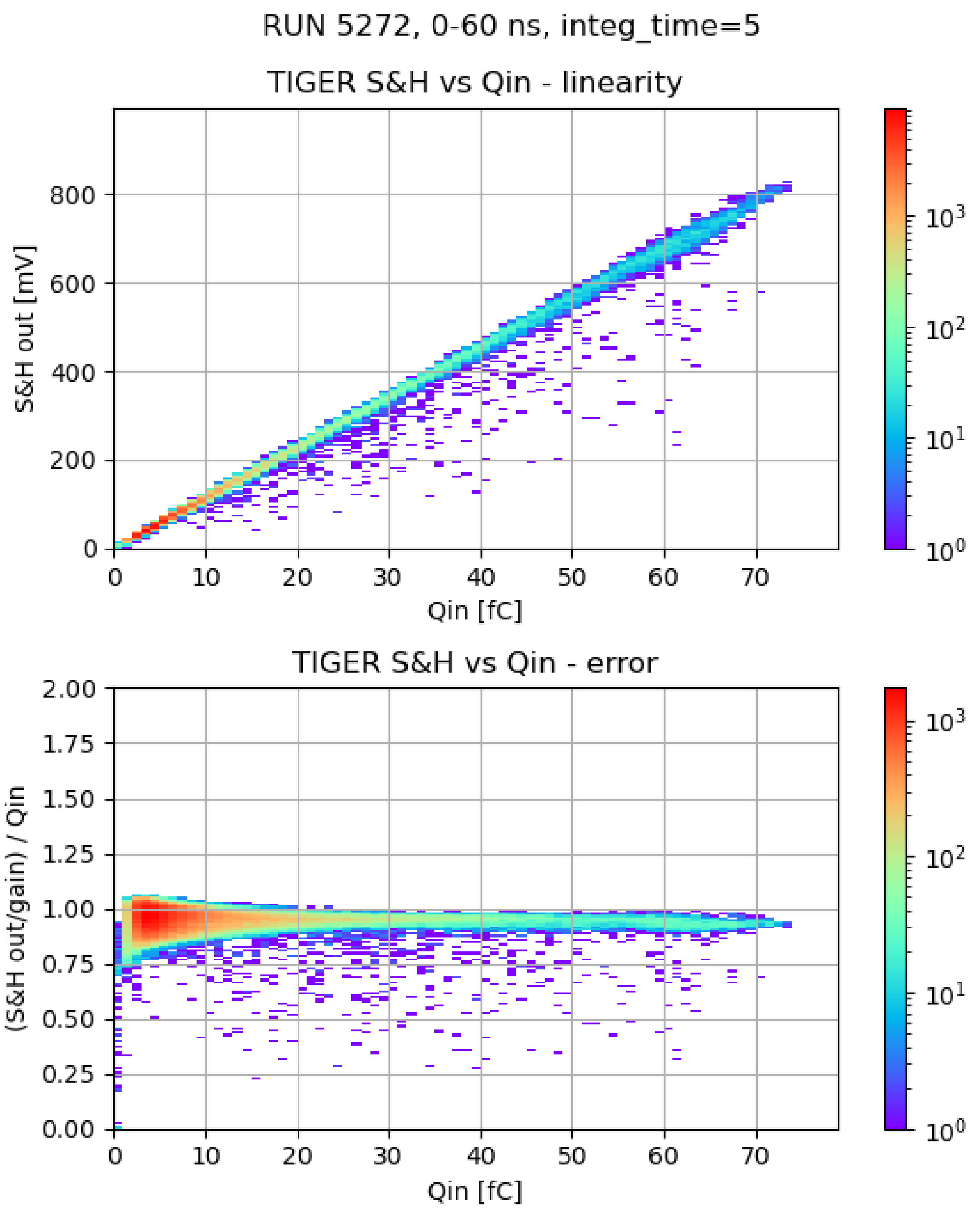
integ_time scan (all)



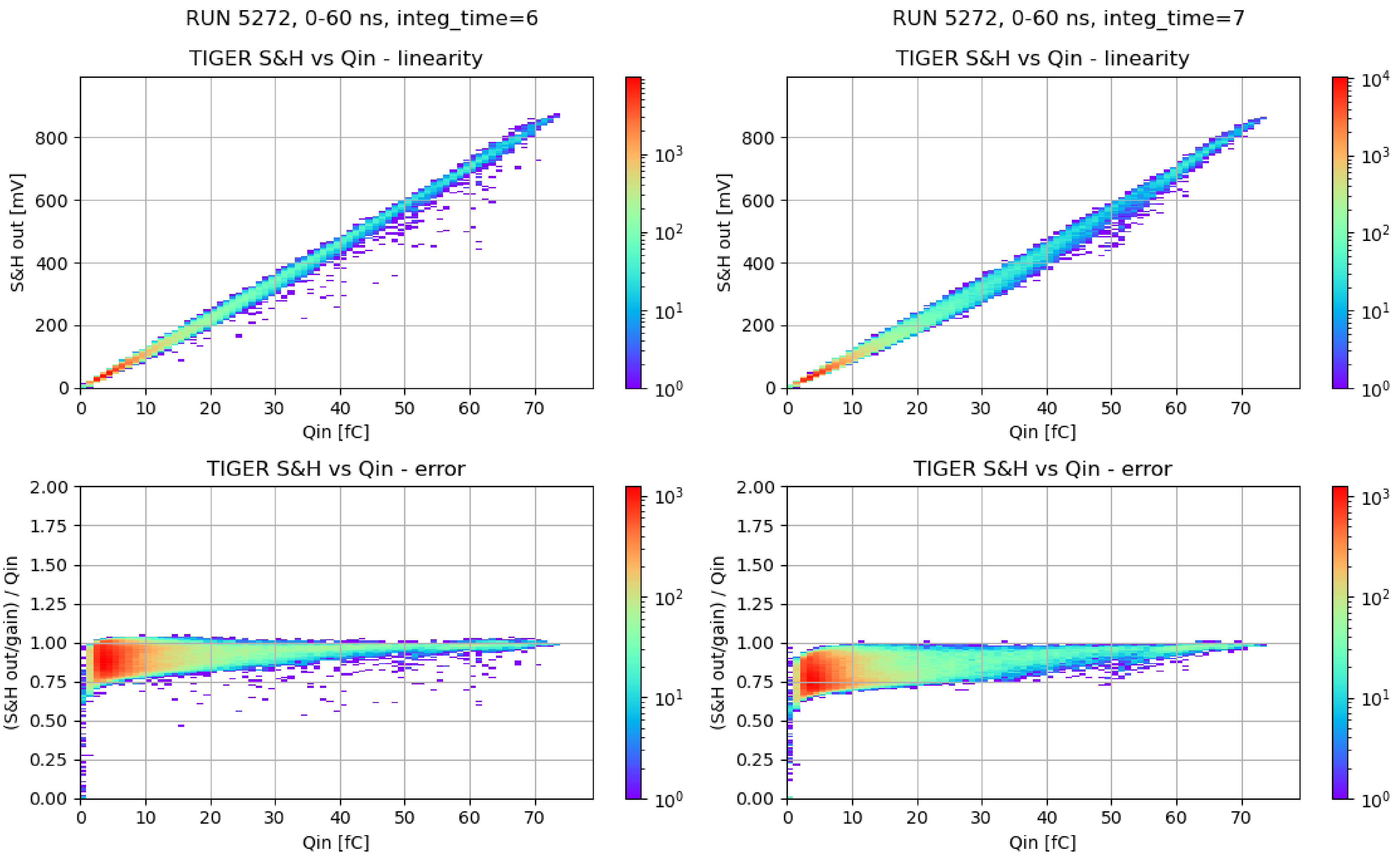


integ_time scan (short)

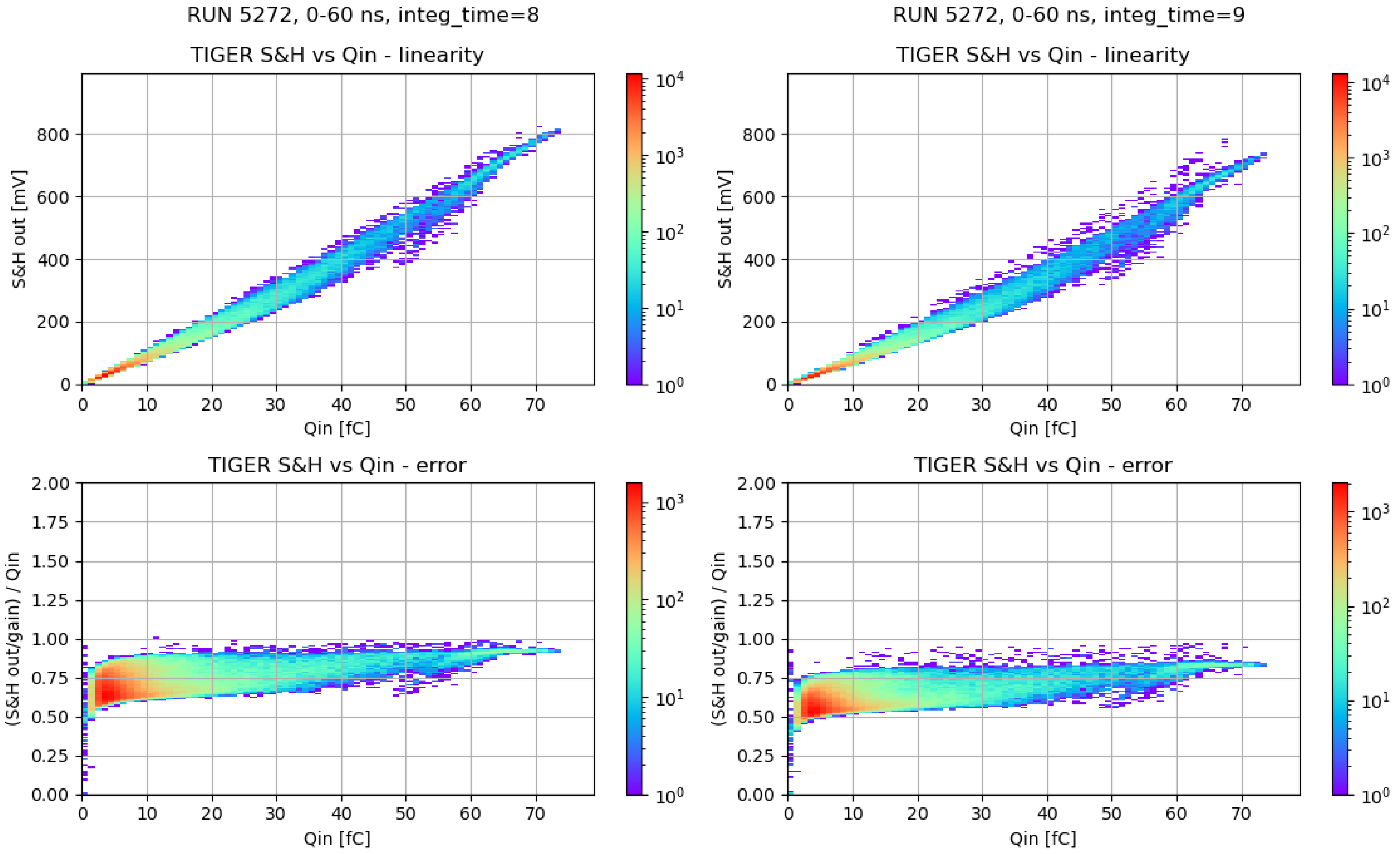




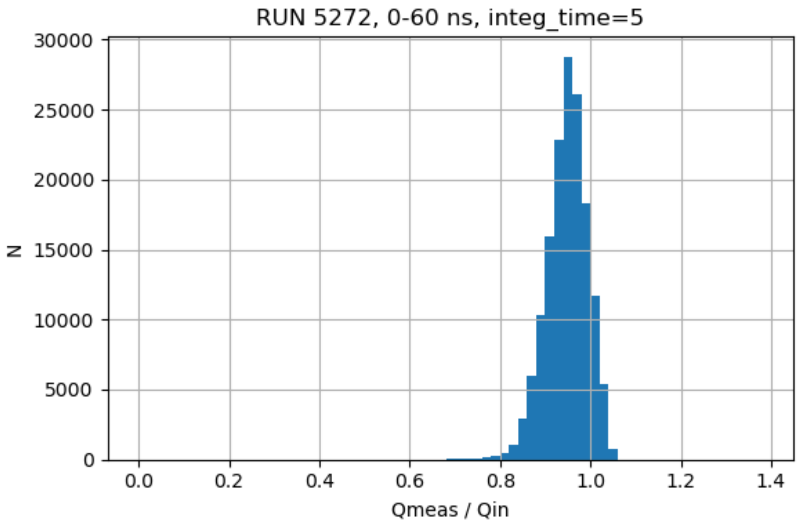
integ_time scan (short)

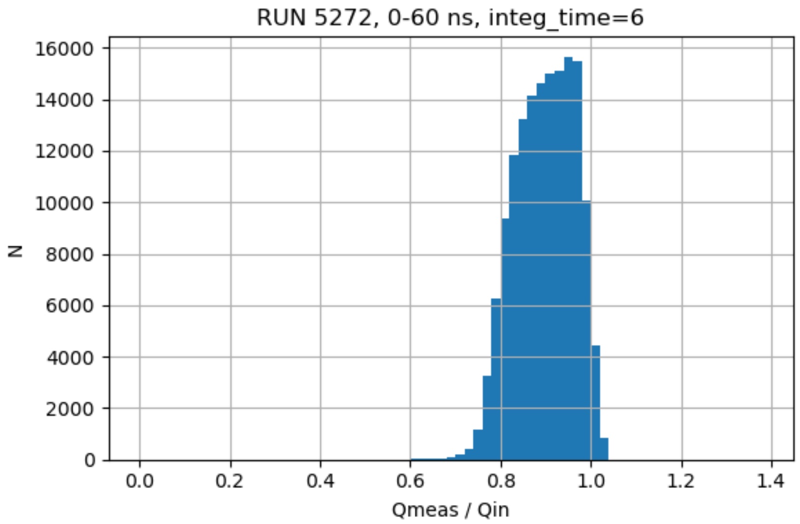


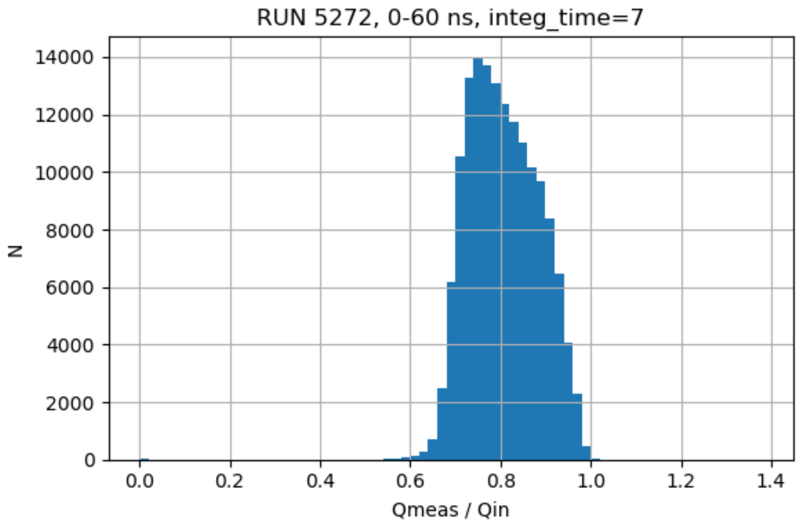
integ_time scan (short)

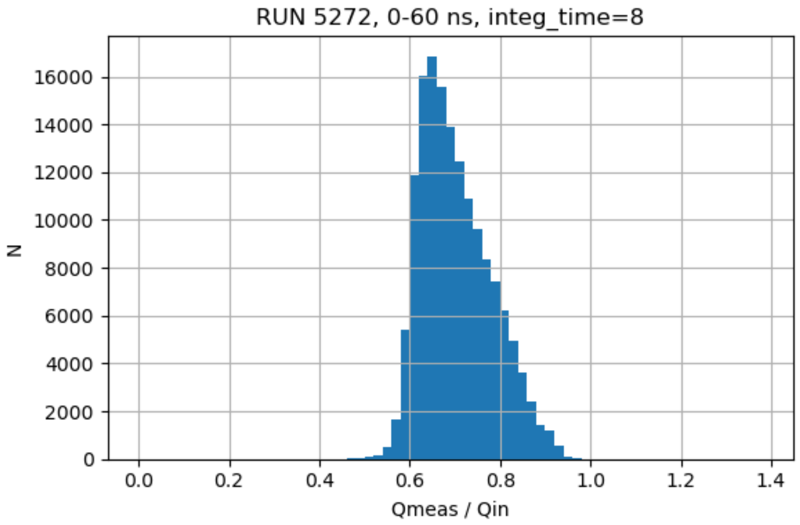


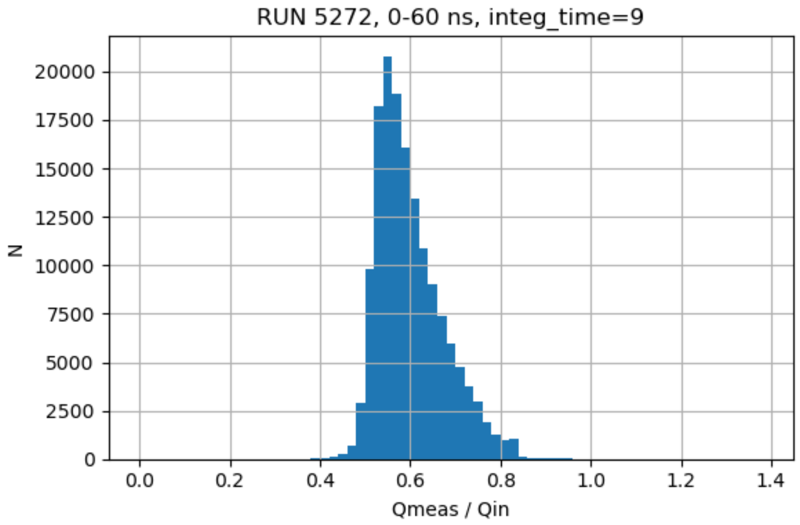
integ_time scan (short)



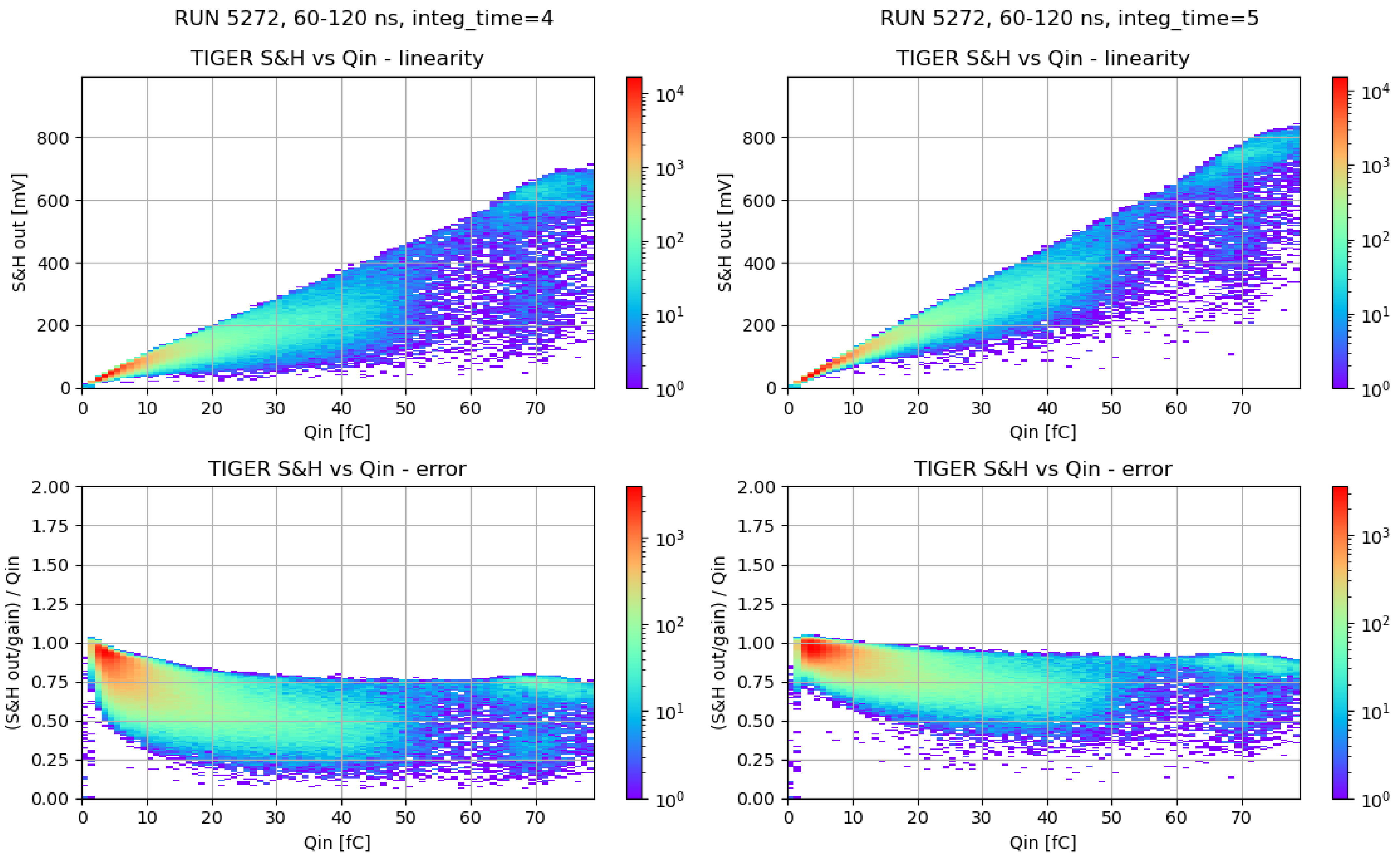




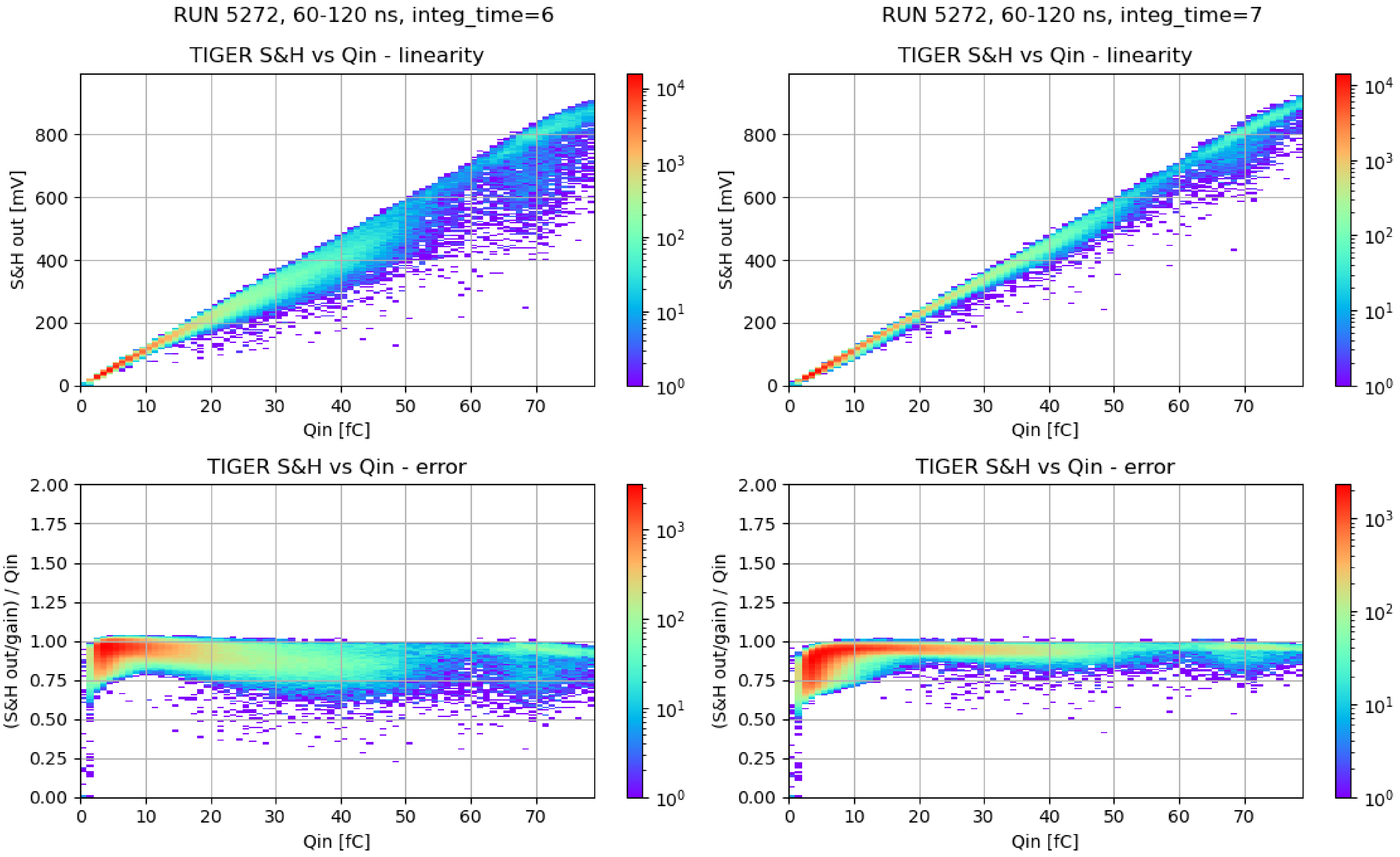




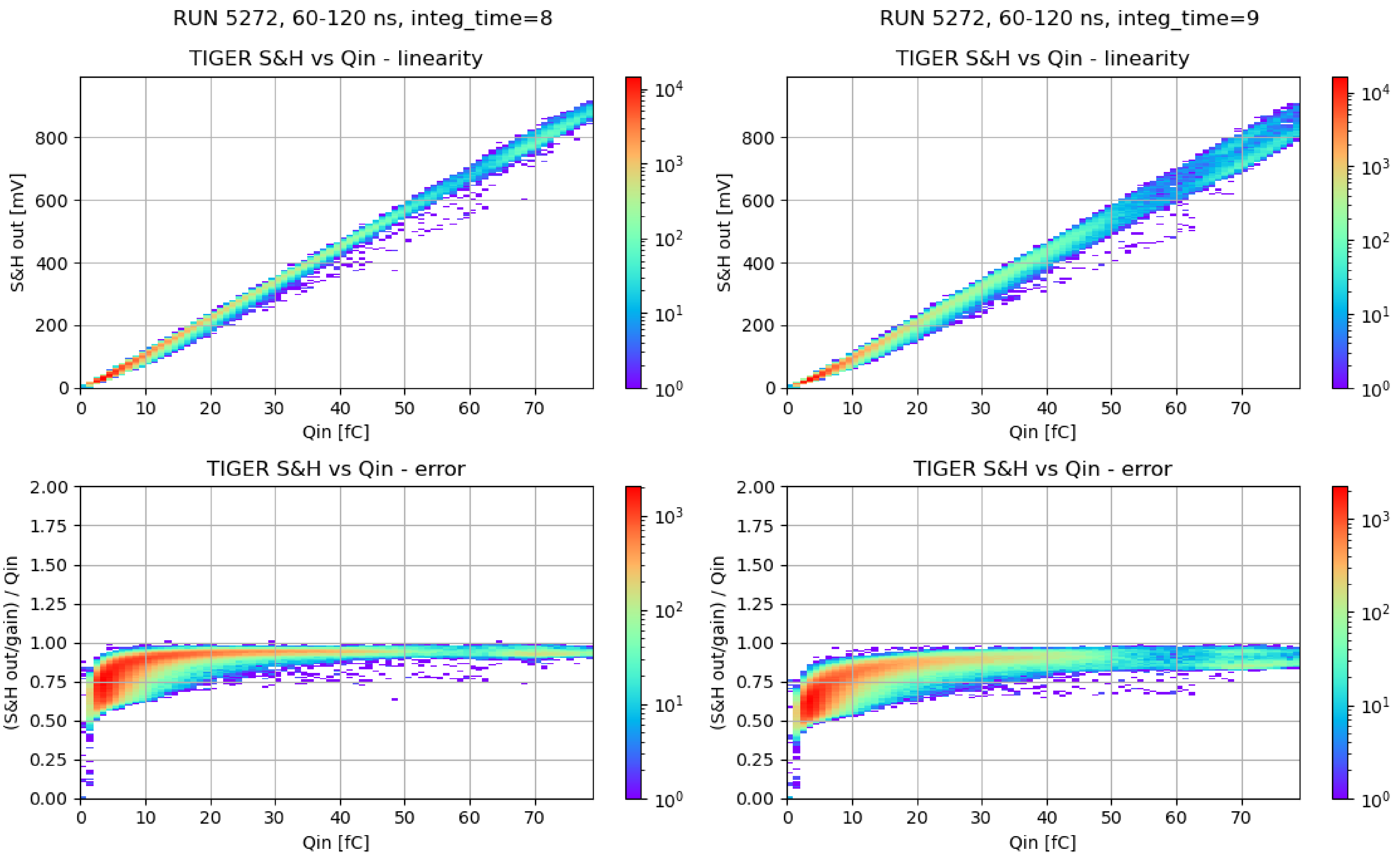
integ_time scan (medium)



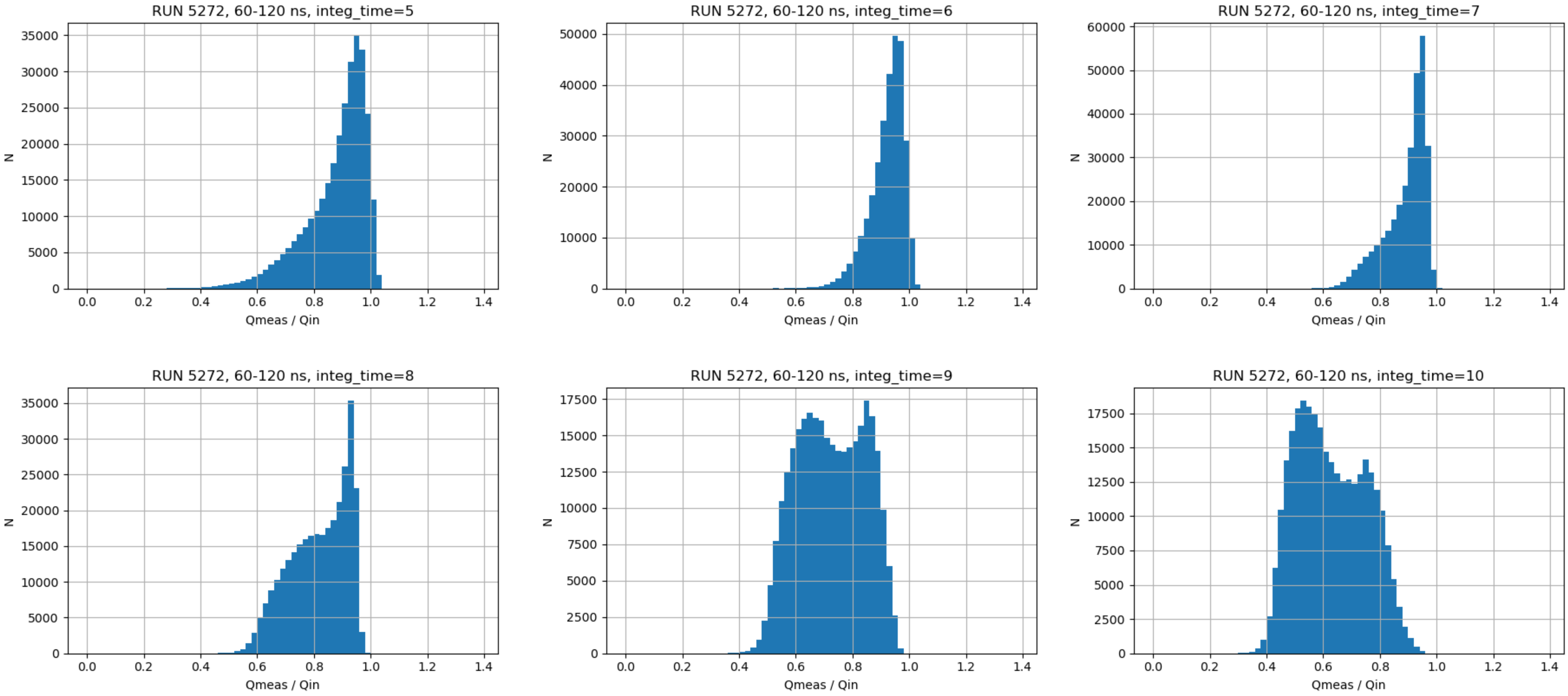
integ_time scan (medium)



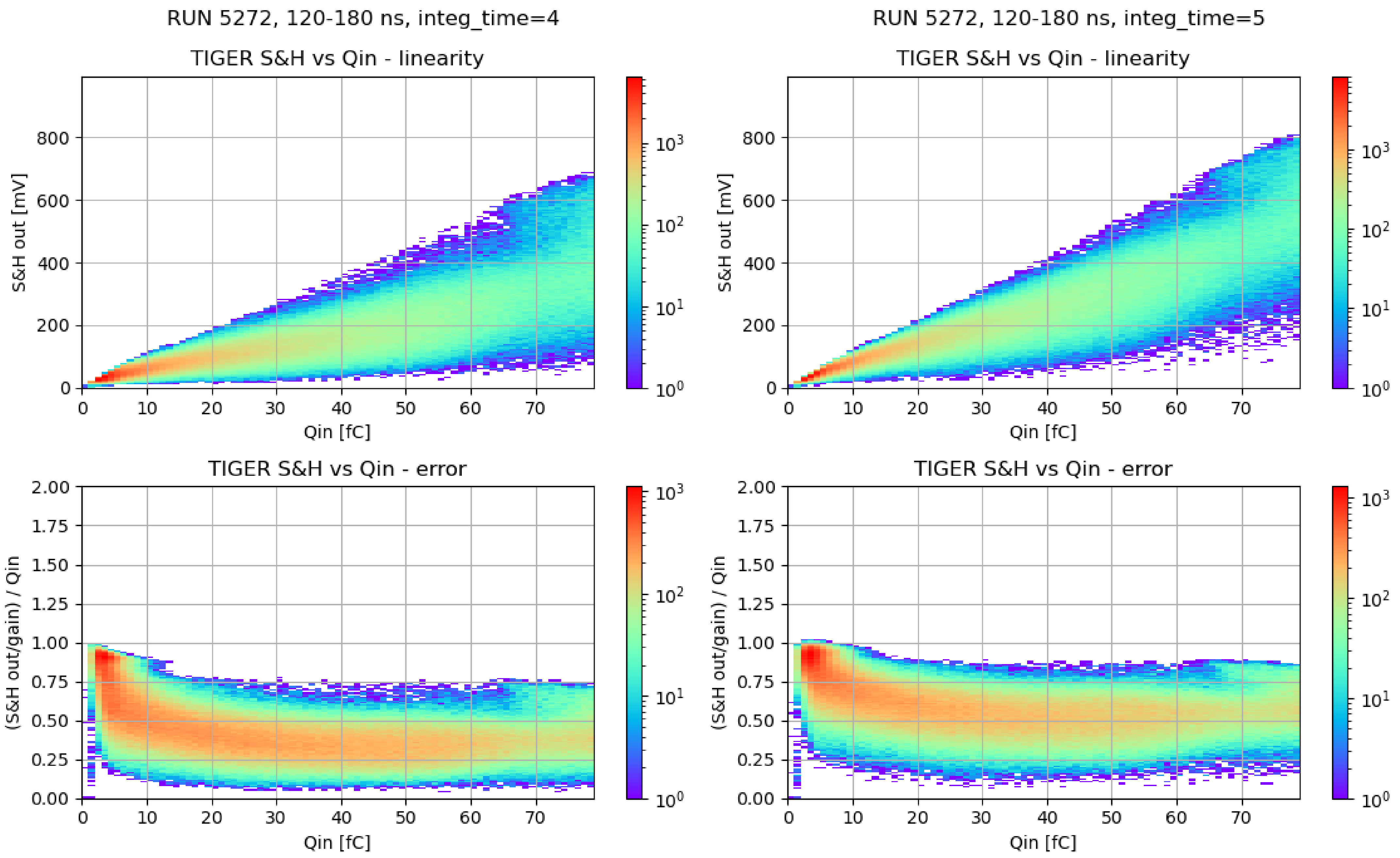
integ_time scan (medium)



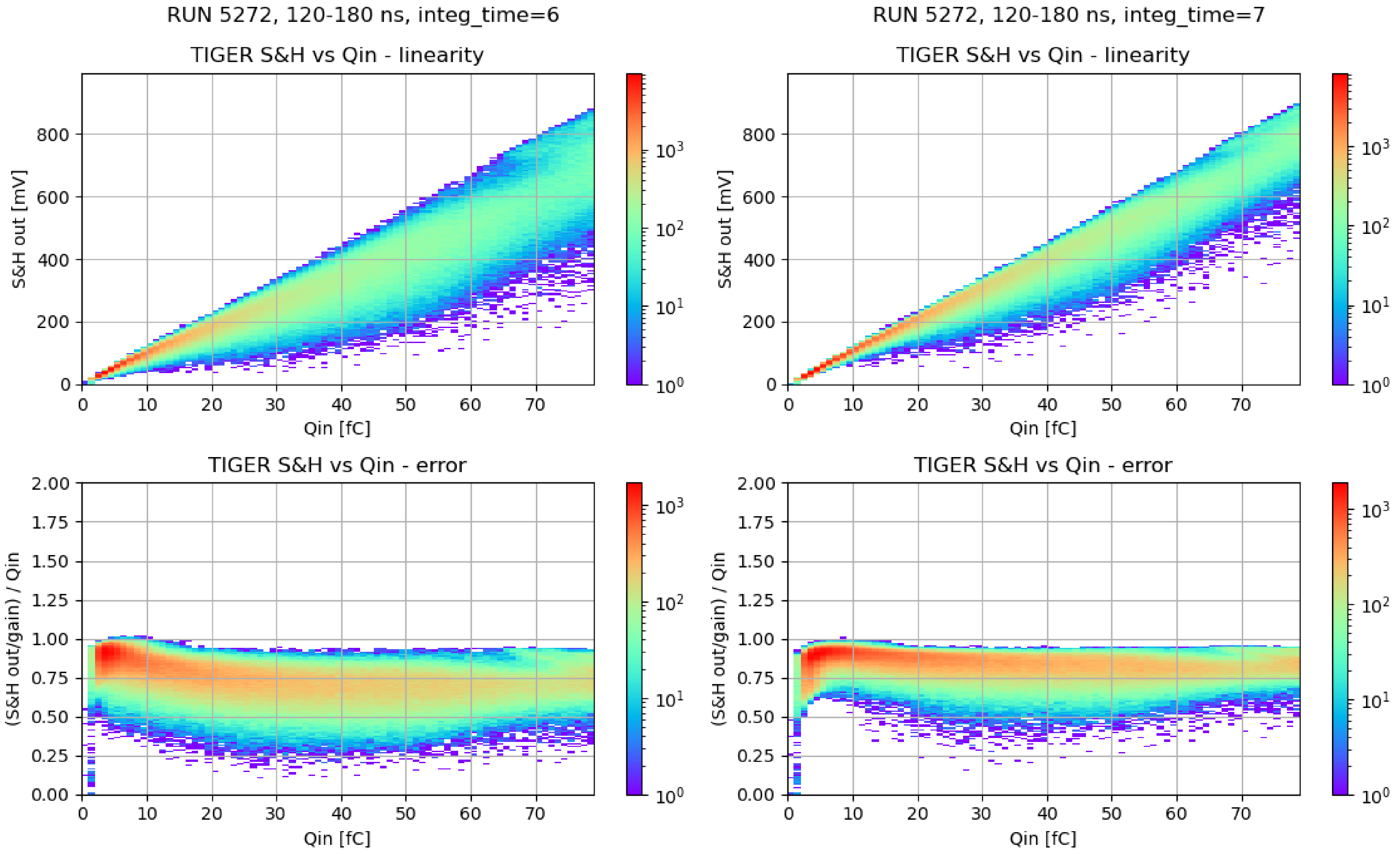
integ_time scan (medium)



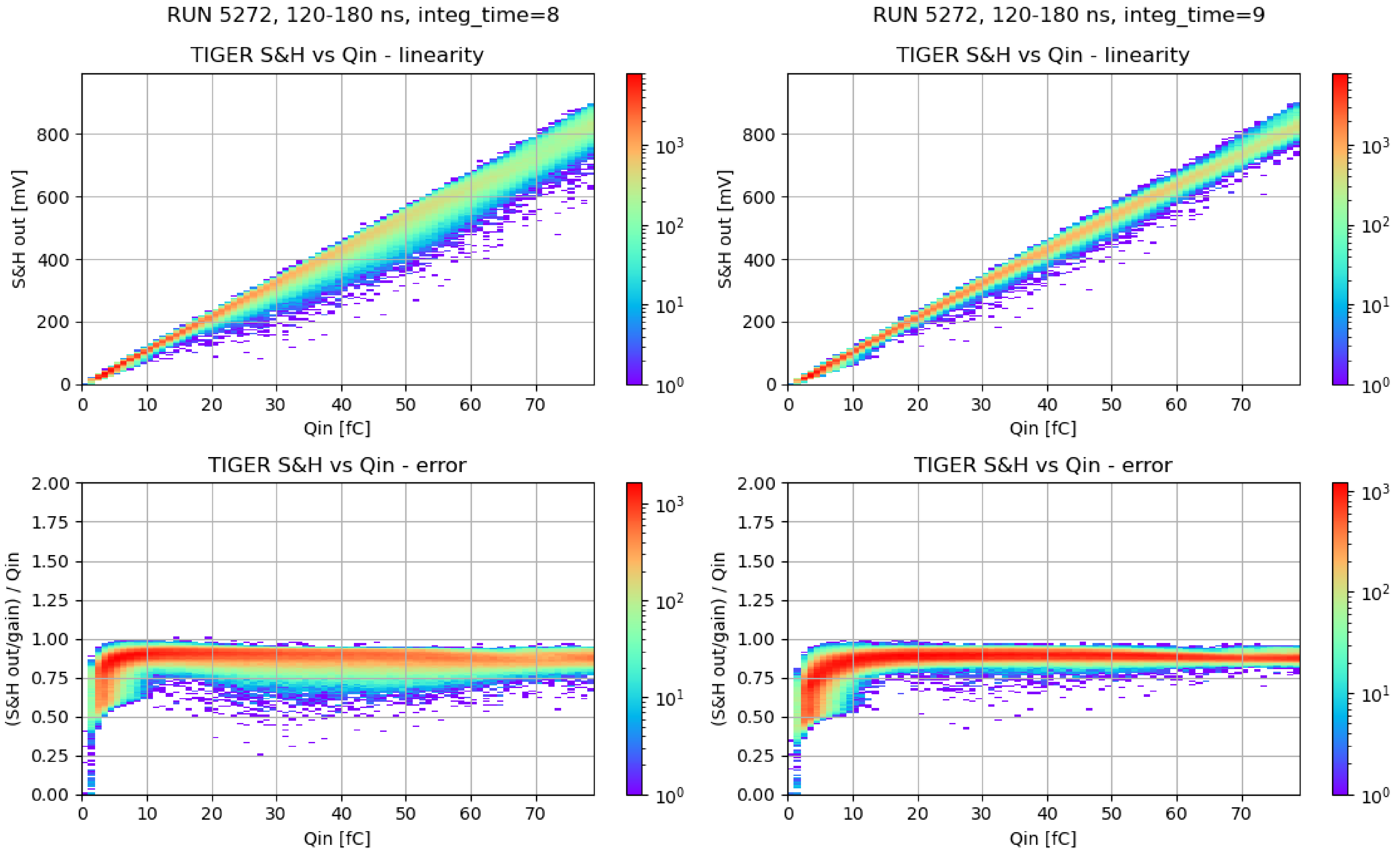
integ_time scan (long)



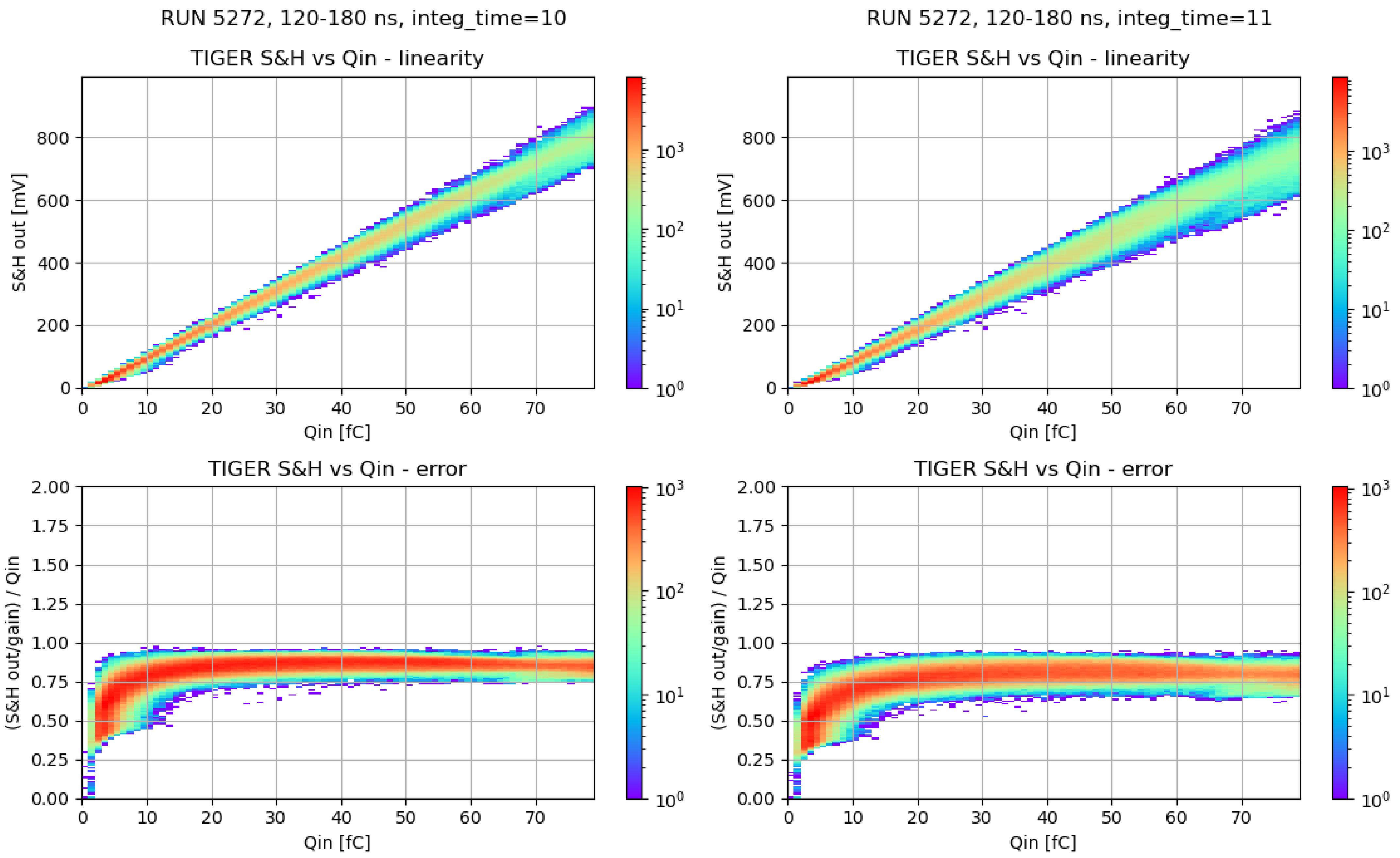
integ_time scan (long)



integ_time scan (long)



integ_time scan (long)



integ_time scan (long)