

**AGU FALL
MEETING**

1–17 December 2020



Characteristics of Currents in Upward Flashes Transferring Negative Charge to Ground

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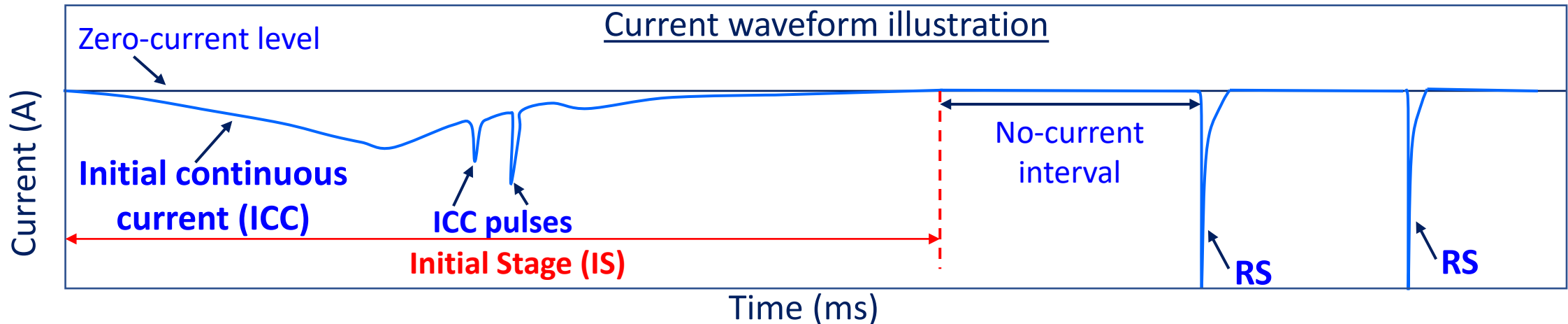
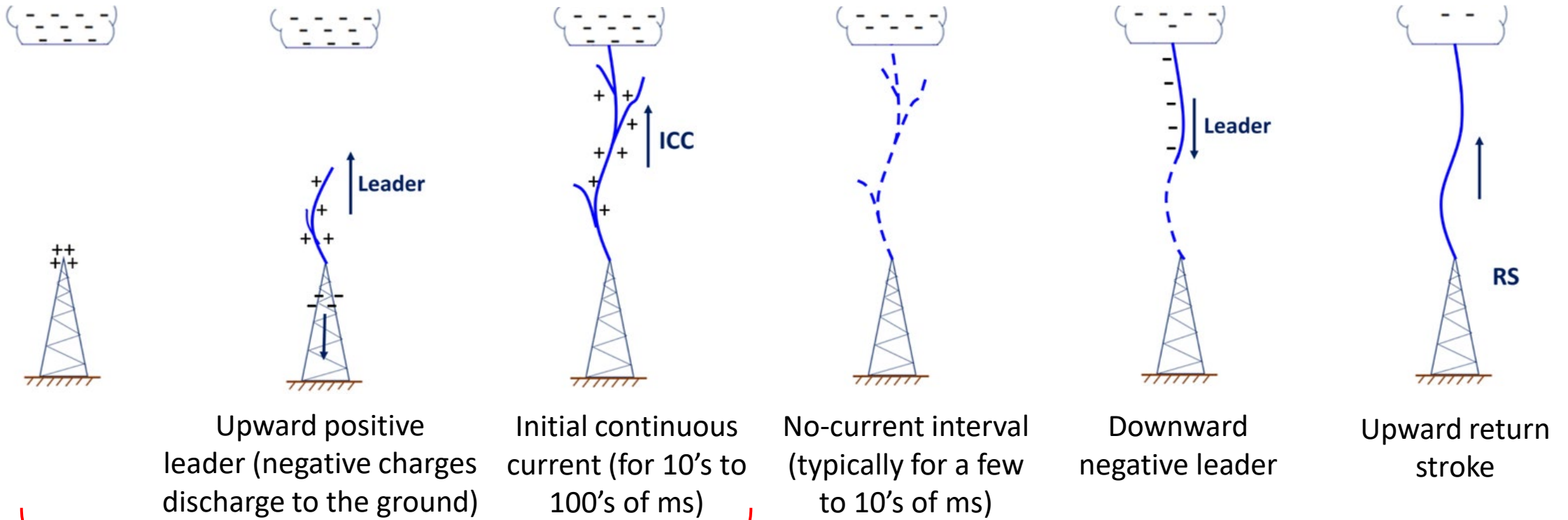
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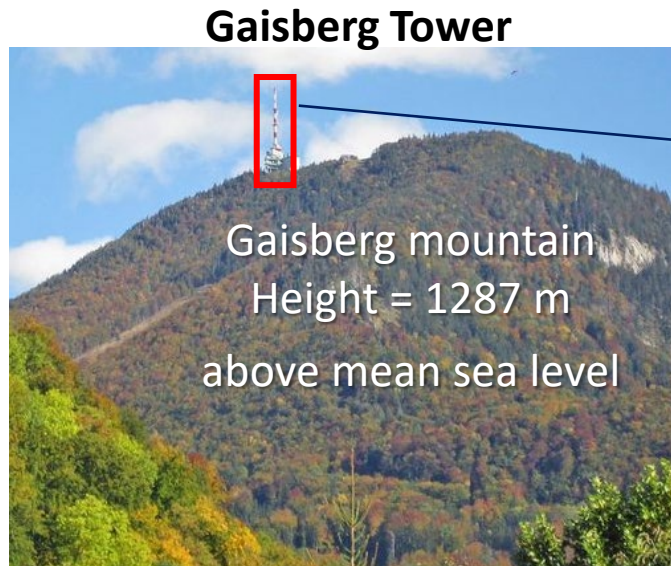
Characteristics of Currents in Upward Flashes Transferring Negative Charge to Ground

- Processes in Upward Negative Flashes
- Instrumentation and Data
- Charge Transferred by Upward Negative Flashes
 - Initial Stage
 - Return Strokes
- Return Stroke Current Waveform Characteristics
- Summary

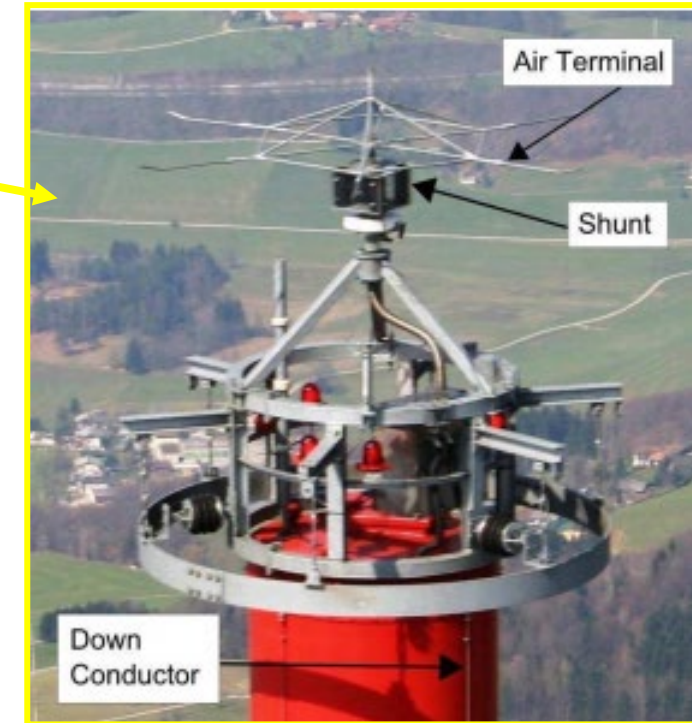
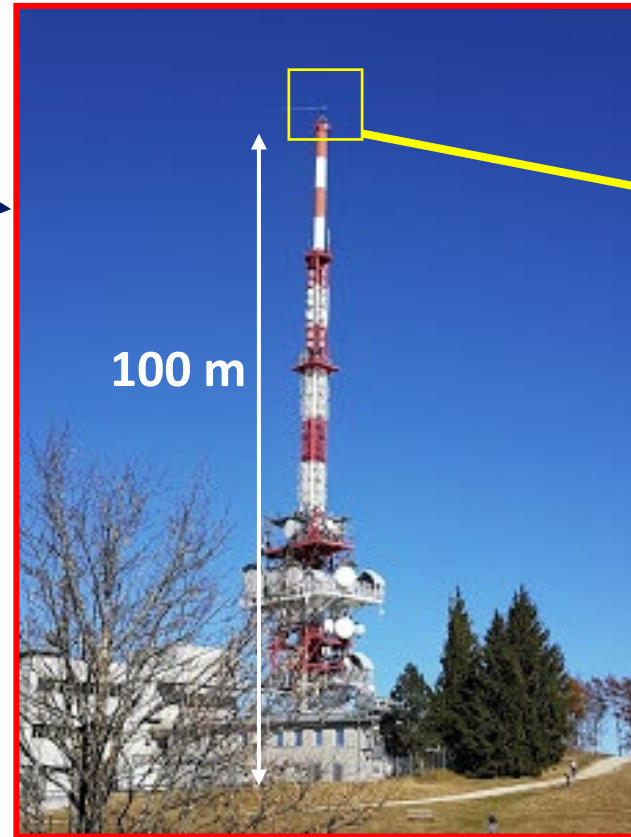
Upward Negative Lightning



Current Measurement System at the GBT



Source: <http://www.salzburg.info>

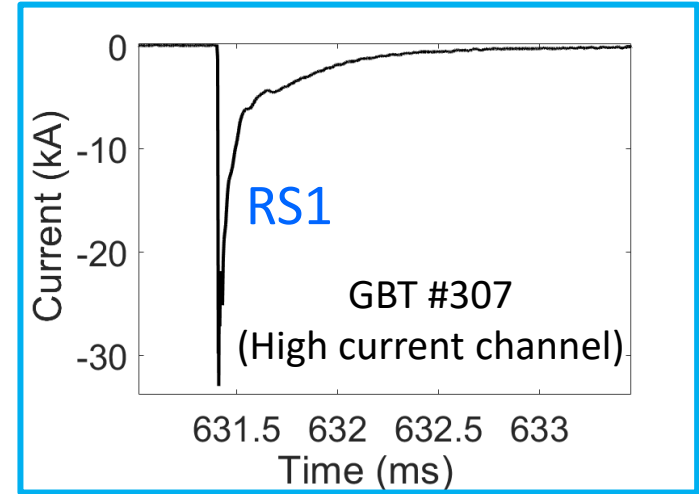
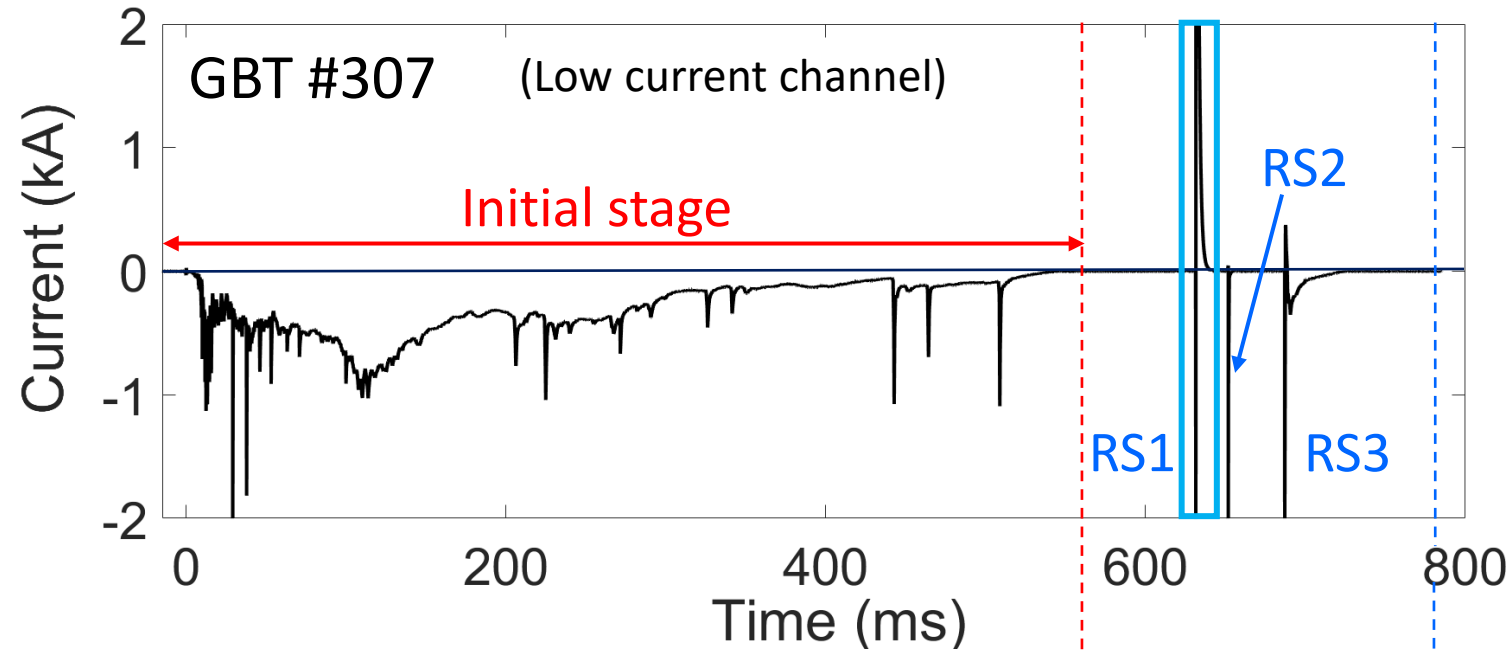


The GBT is located on the Gaisberg mountain at a height of 1287 m above sea level.

Current measurement system details:

- 0.25 m Ω shunt impedance.
- Two current measurement channels with ± 40 kA and ± 2 kA vertical-scale limits.
- Polarity of current determined when value ≥ 20 A.

Charge Transfer Computation

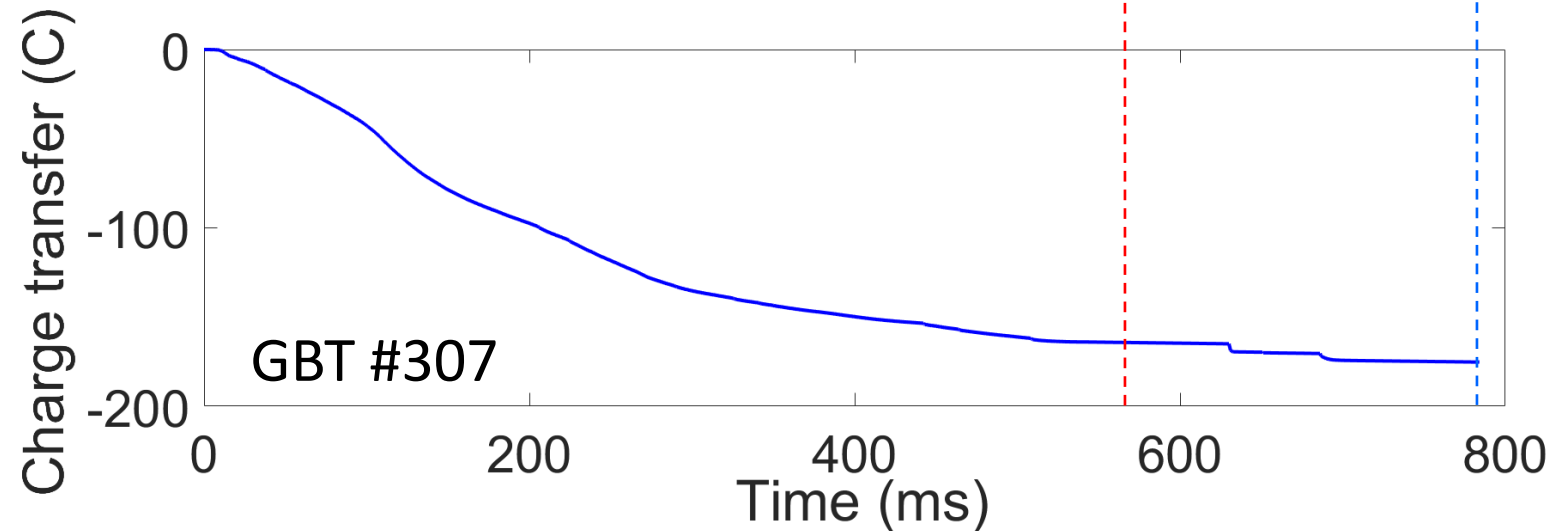


* The high-current channel measurement was used for all RSs.

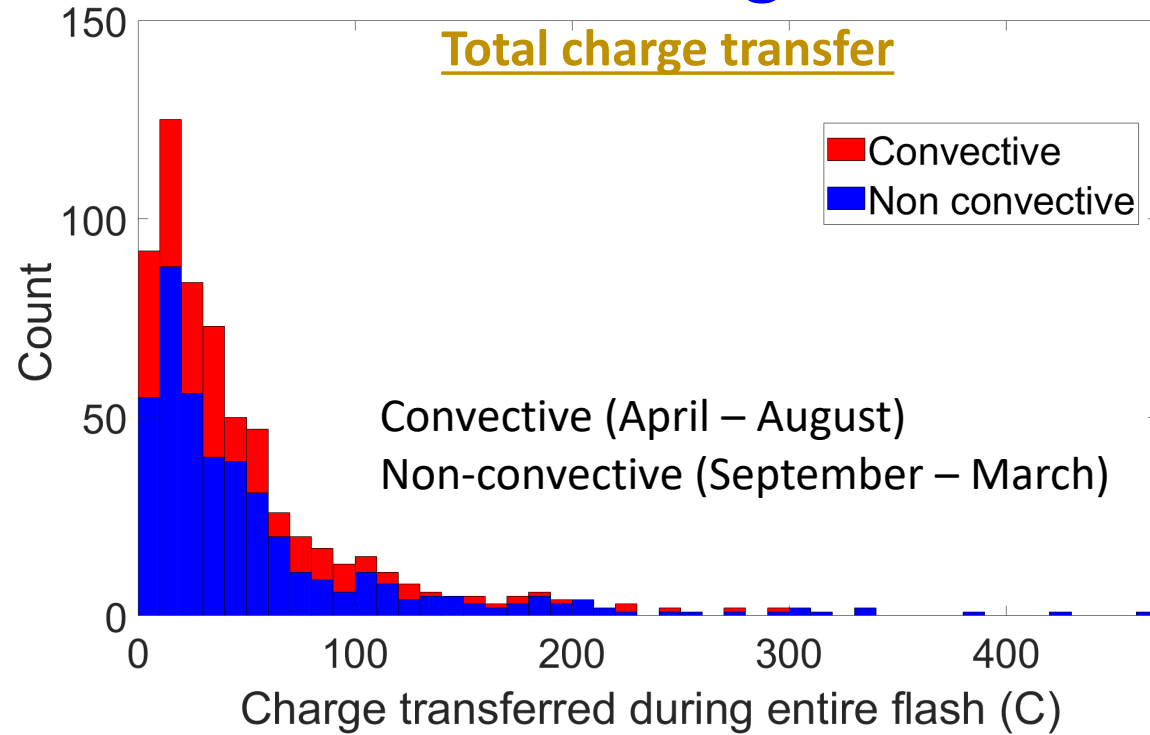
Charge transfer is determined by the integral of current over time.

$$Q = \int_{t_1}^{t_2} I dt$$

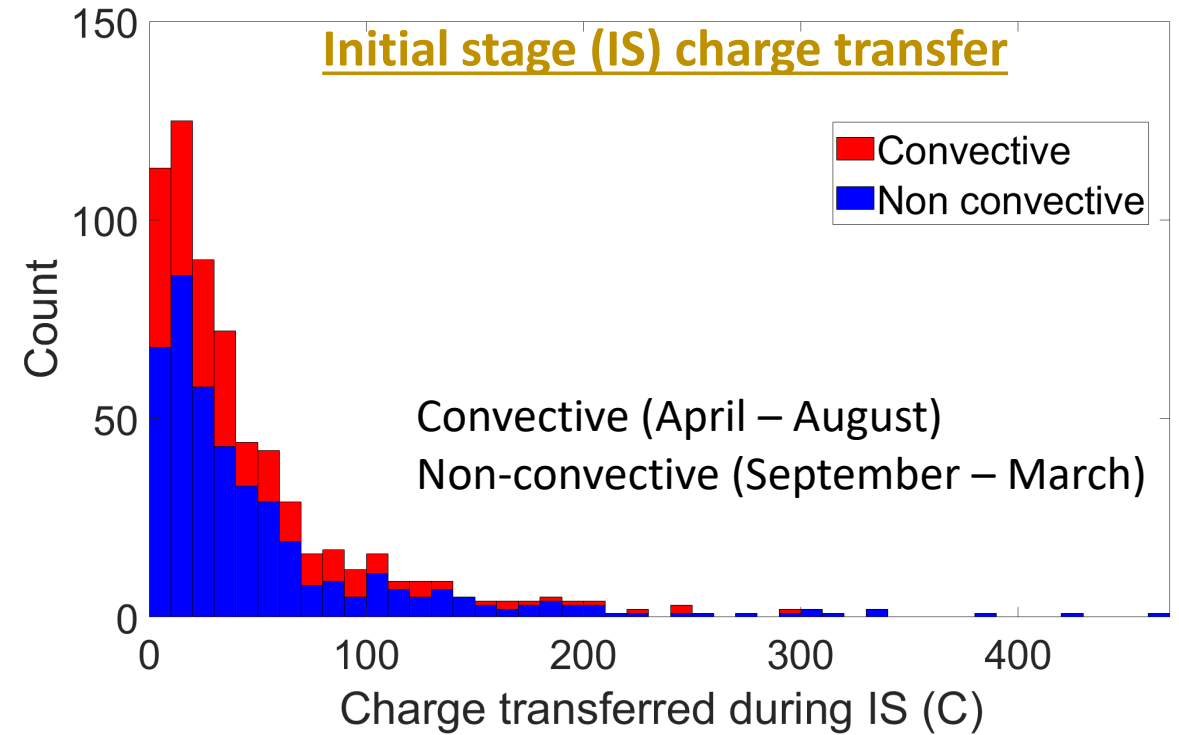
$$Q_{\text{flash}} = Q_{\text{IS}} + Q_{\text{RS}}$$



Charge Transferred in Different Seasons



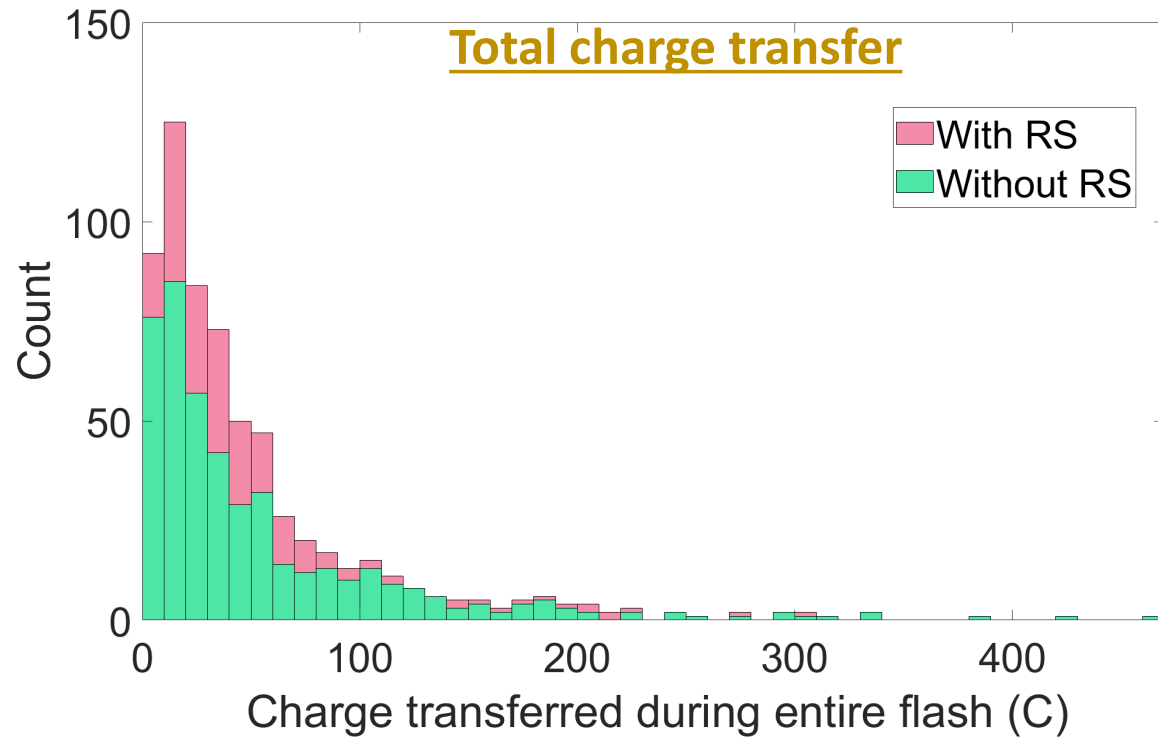
| | Convective | Non convective | All |
|-------------------|------------|----------------|-----------|
| N | 216 | 423 | 639* |
| AM (C) | 47 | 56 | 53 |
| Median (C) | 32 | 34 | 33 |
| GM (C) | 28 | 32 | 31 |
| SD (C) | 50 | 67 | 62 |
| Min (C) | 0.04 | 1.2 | 0.04 |
| Max (C) | 290 | 463 | 463 |



| | Convective | Non convective | All |
|-------------------|------------|----------------|-----------|
| N | 226 | 425 | 651 |
| AM (C) | 45 | 53 | 50 |
| Median (C) | 28 | 30 | 29 |
| GM (C) | 25 | 29 | 28 |
| SD (C) | 49 | 66 | 61 |
| Min (C) | 0.04 | 0.49 | 0.04 |
| Max (C) | 290 | 463 | 463 |

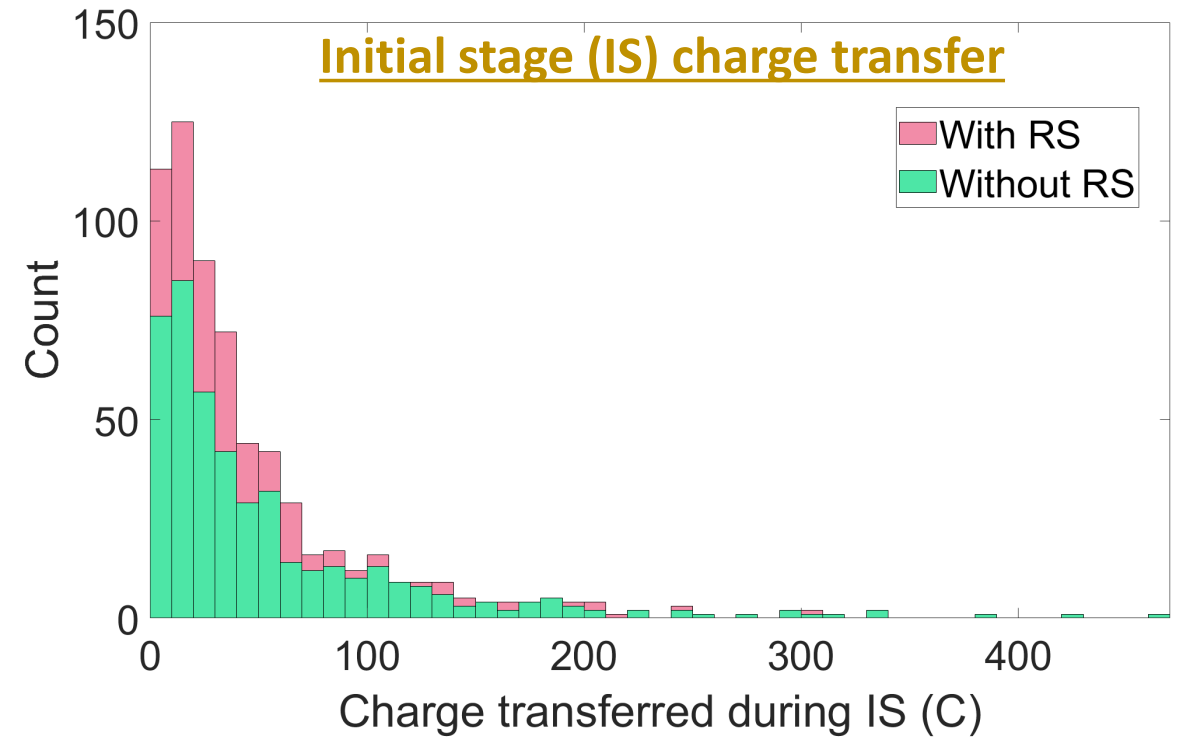
*For 12 negative flashes containing 52 return strokes the high current measurement data were not available.

Charge Transferred by Flashes with and without RS



| | With RS | Without RS | All |
|-------------------|-----------|------------|-----------|
| N | 195 | 444 | 639* |
| AM (C) | 48 | 55 | 53 |
| Median (C) | 34 | 32 | 33 |
| GM (C) | 32 | 30 | 31 |
| SD (C) | 50 | 66 | 62 |
| Min (C) | 1.3 | 0.04 | 0.04 |
| Max (C) | 305 | 463 | 463 |

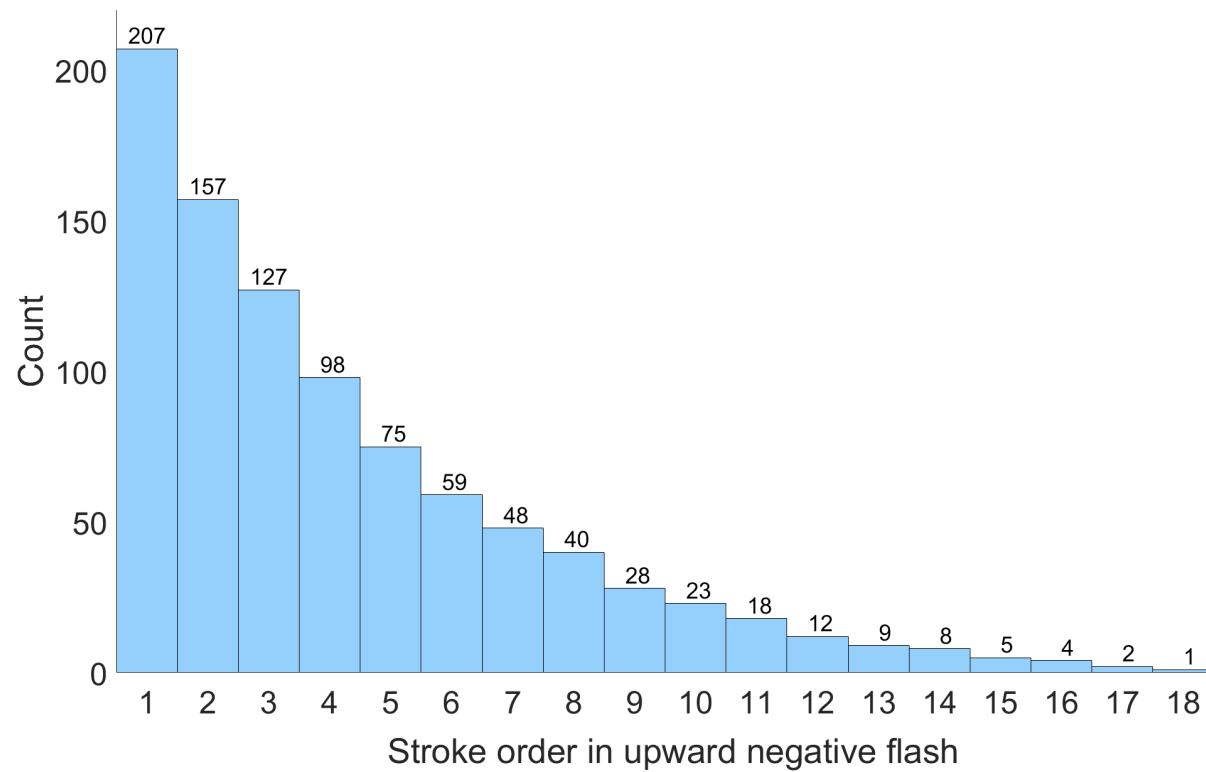
*For 12 negative flashes containing 52 return strokes the high current measurement data were not available.



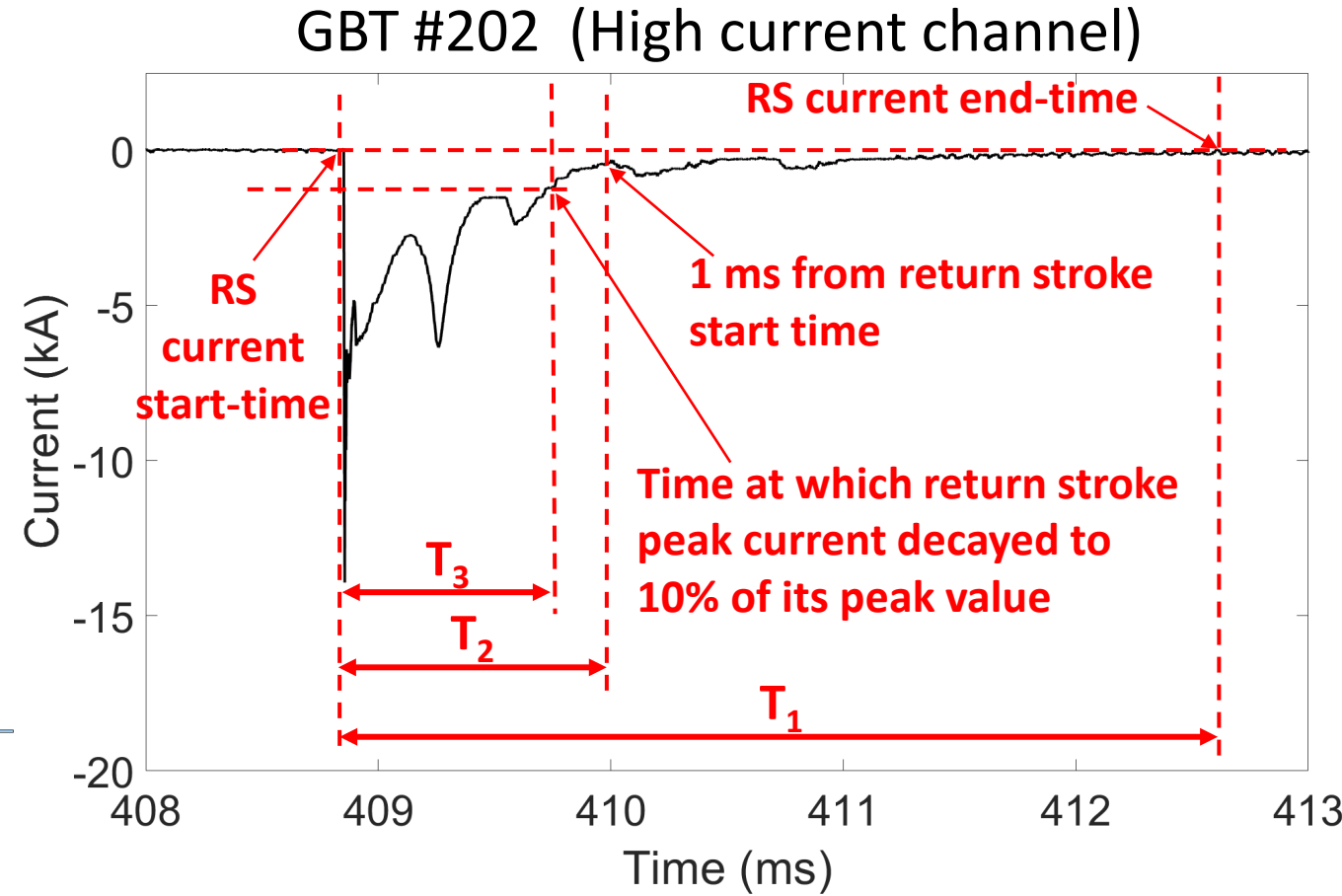
| | With RS | Without RS | All |
|-------------------|-----------|------------|-----------|
| N | 207 | 444 | 651 |
| AM (C) | 41 | 55 | 50 |
| Median (C) | 27 | 32 | 29 |
| GM (C) | 24 | 30 | 28 |
| SD (C) | 46 | 66 | 61 |
| Min (C) | 0.49 | 0.04 | 0.04 |
| Max (C) | 304 | 463 | 463 |

Median IS duration: 283 ms (With RS) and 271 ms (Without RS)

Return Stroke Order and Durations

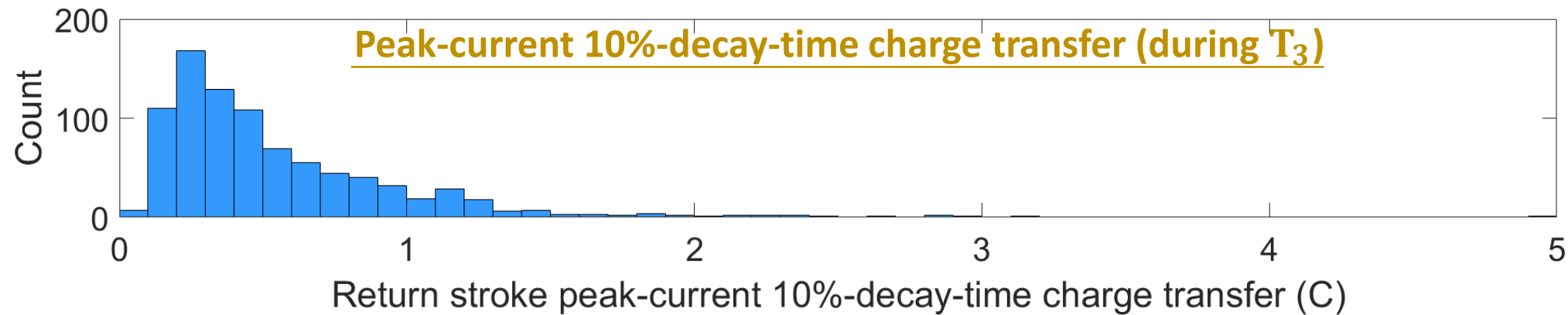
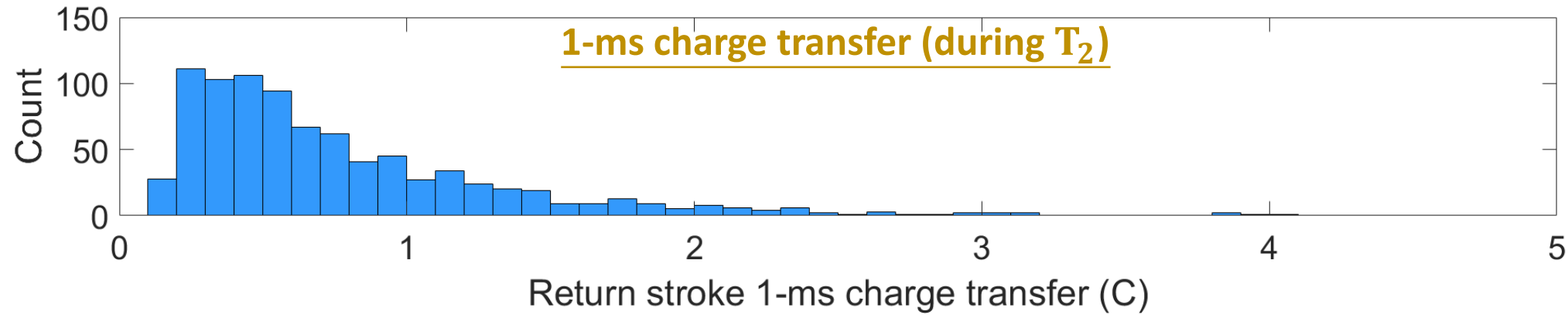
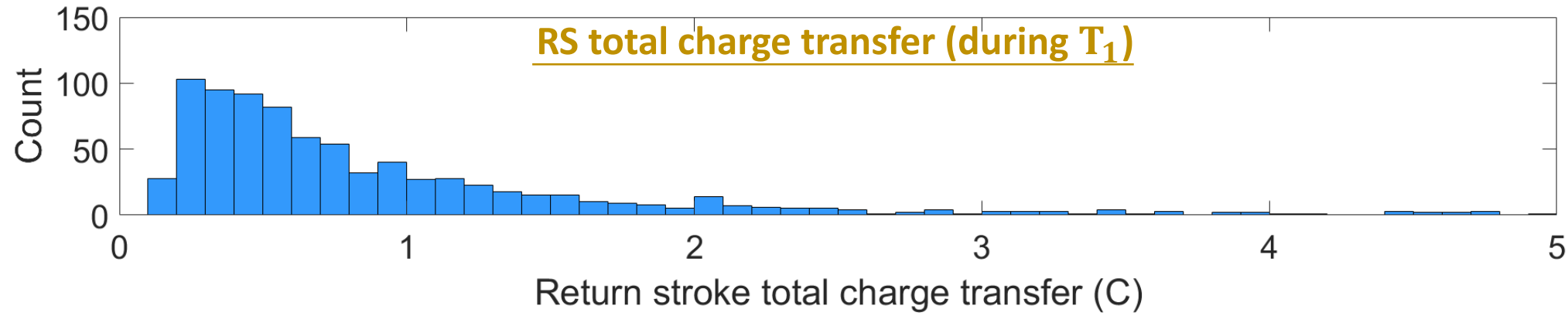


921 return strokes in 207 flashes
Average multiplicity = 4.4 return strokes per flash

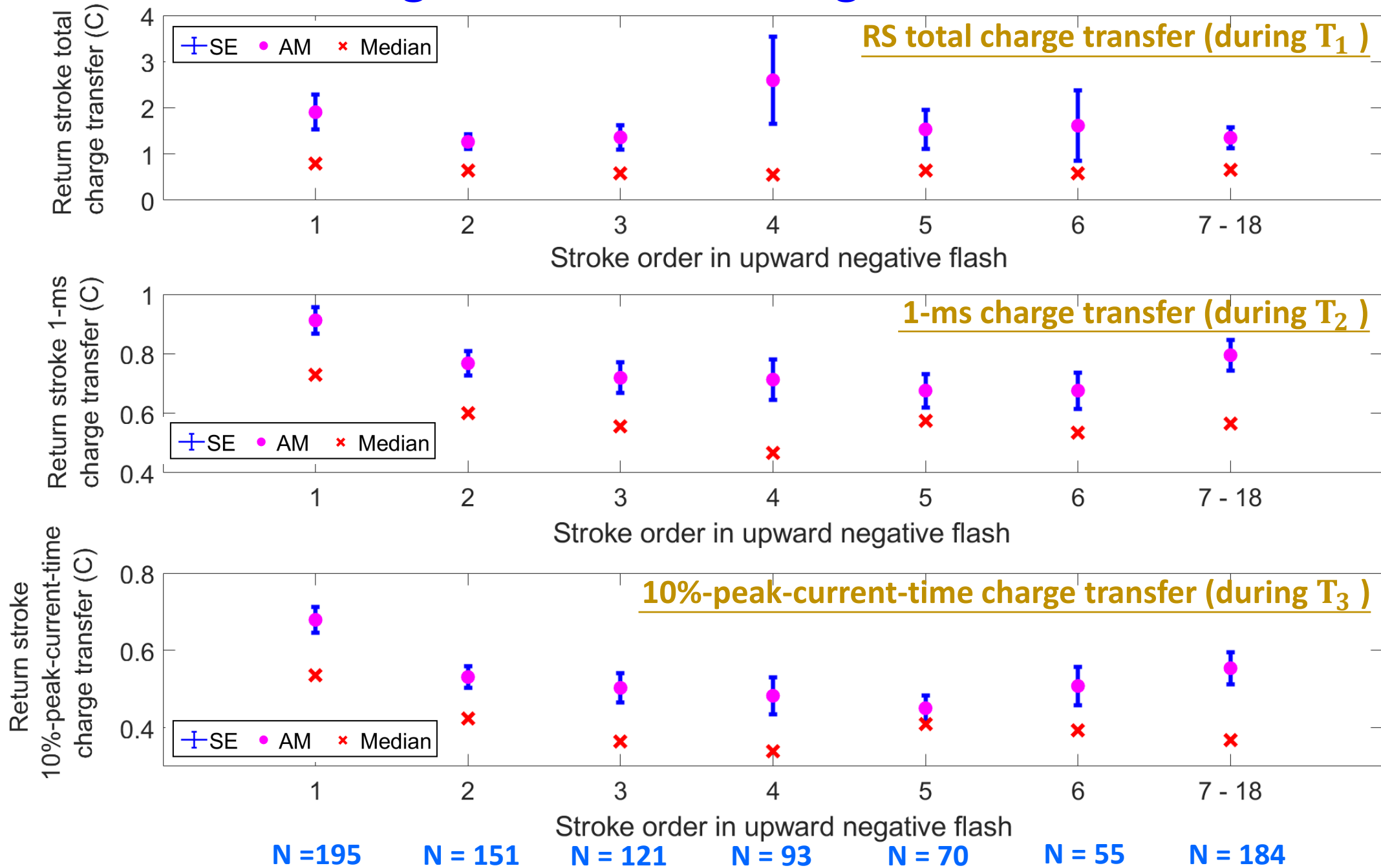


T_1 = Return stroke total duration
 T_2 = 1 ms from return stroke start time
 T_3 = Time from return stroke start at which current decayed to 10% of peak value

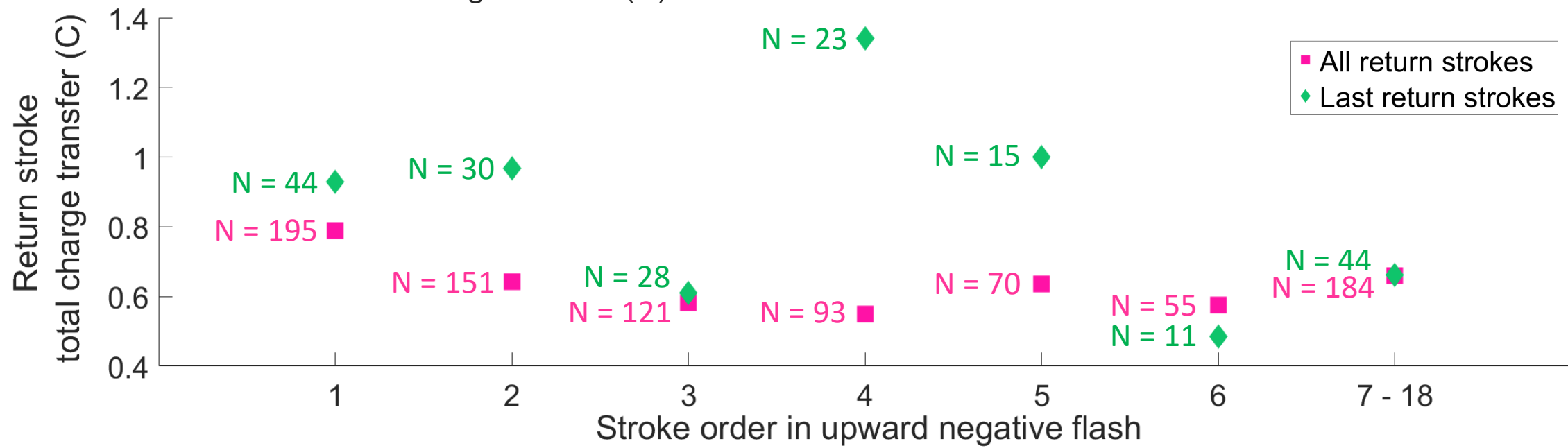
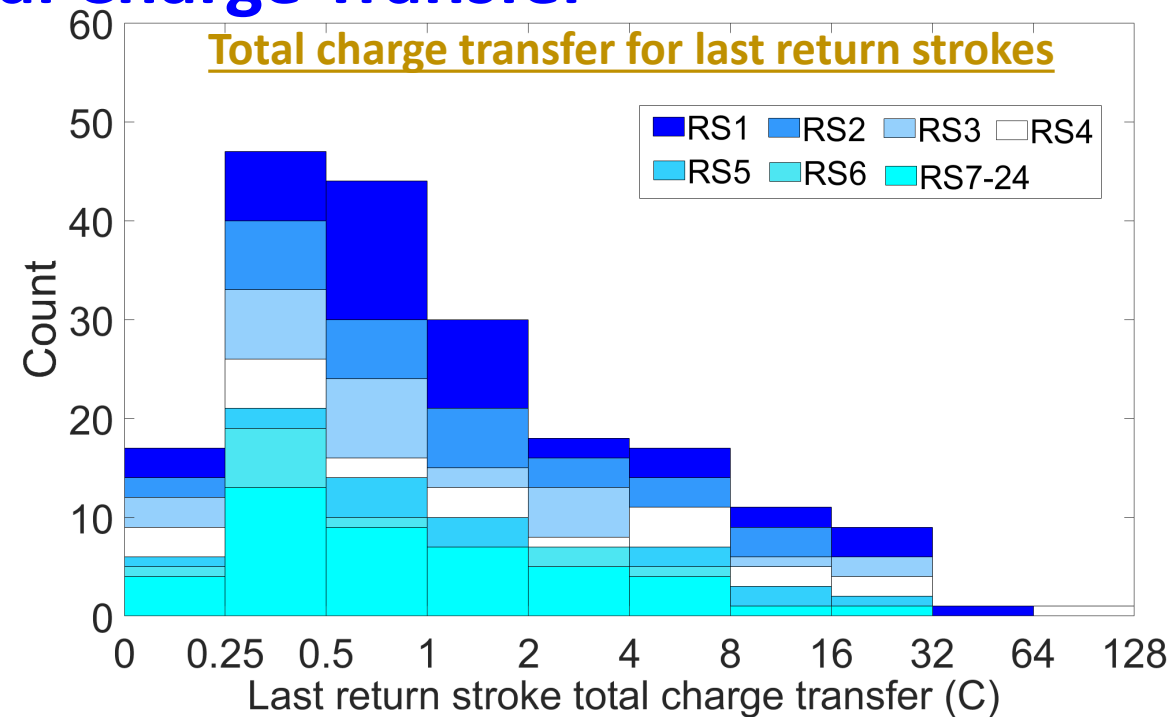
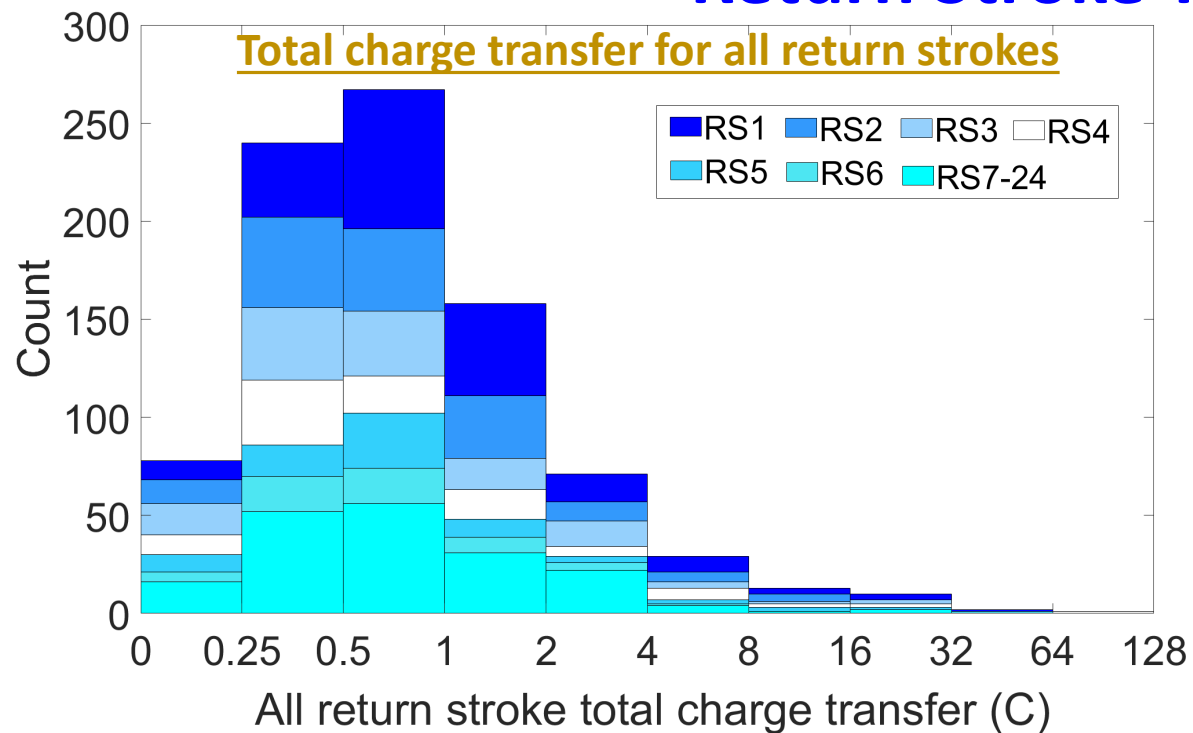
Charge Transferred during Return Strokes



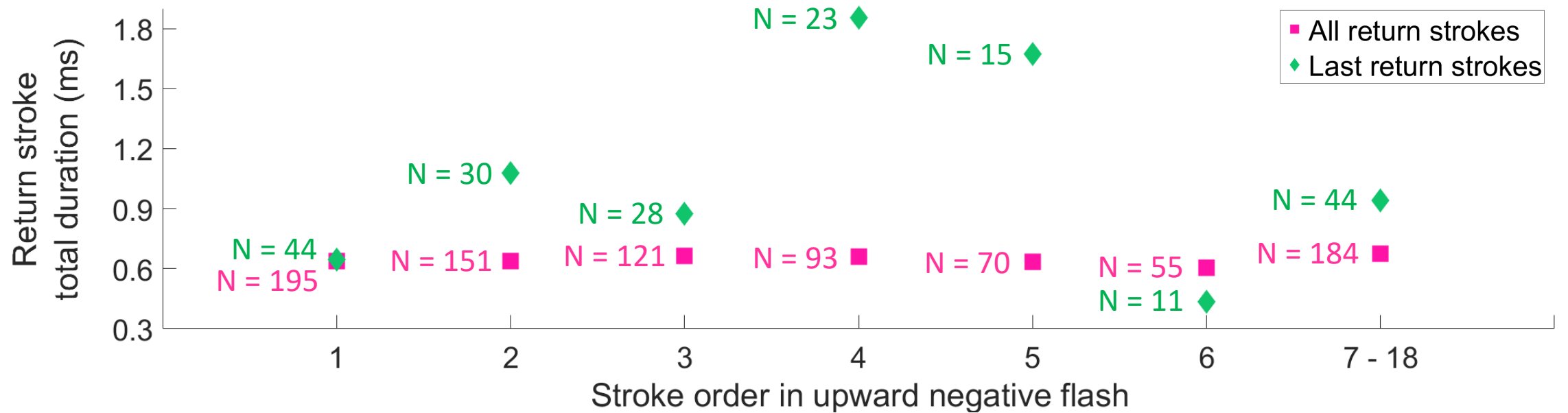
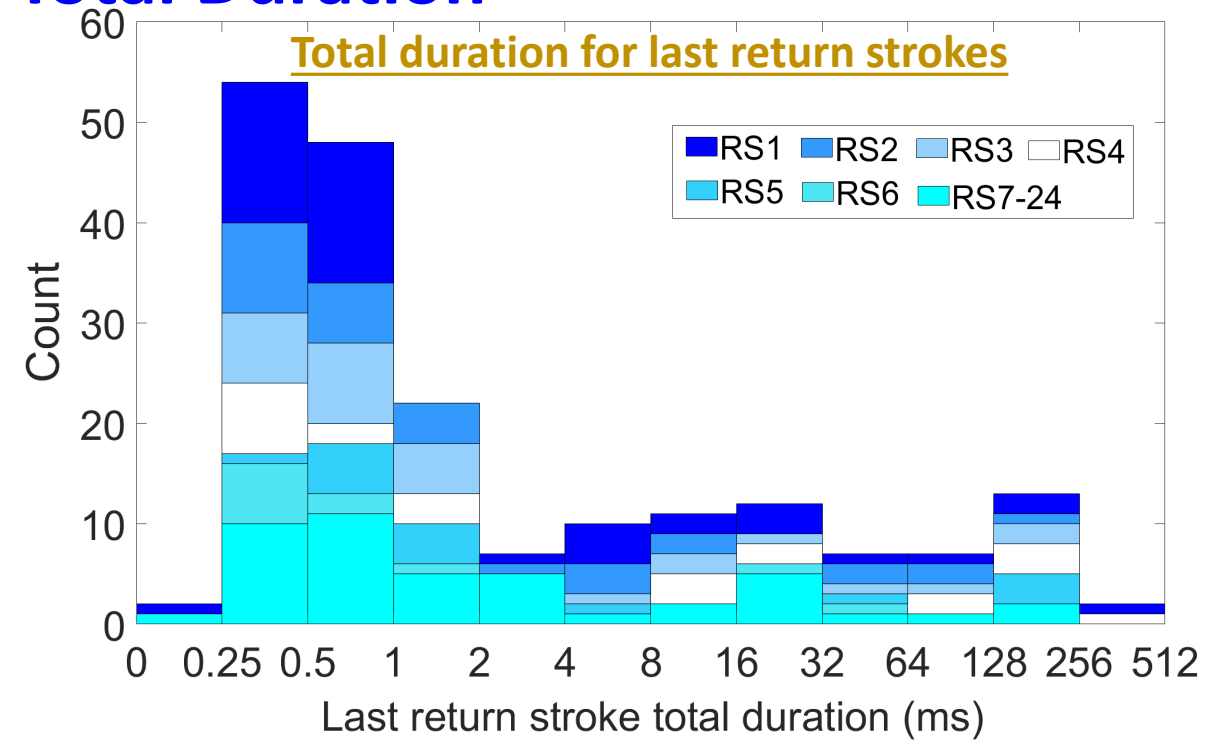
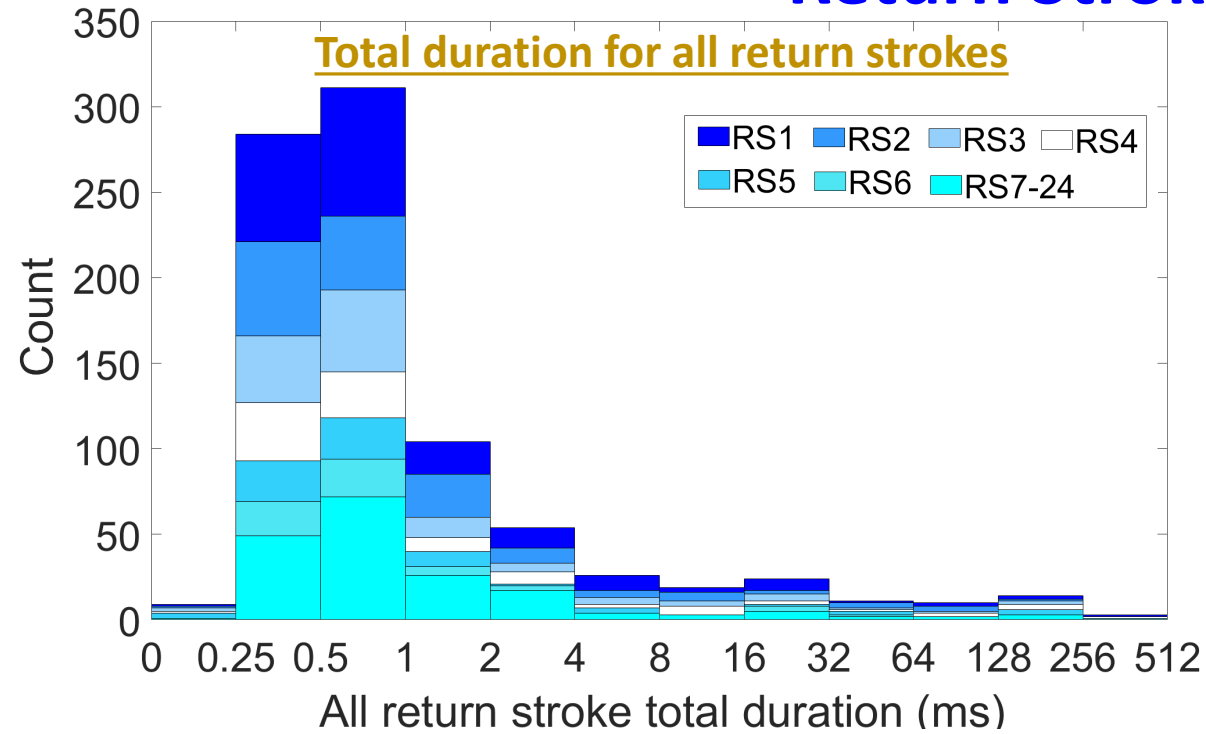
Charge Transferred during Return Strokes



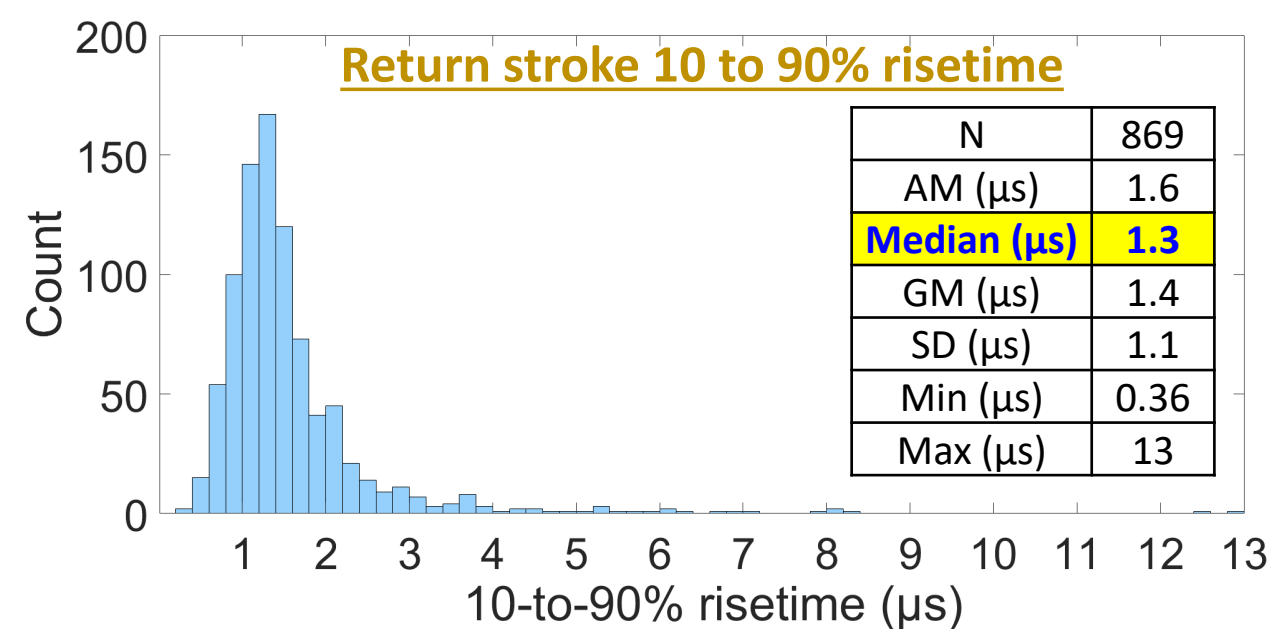
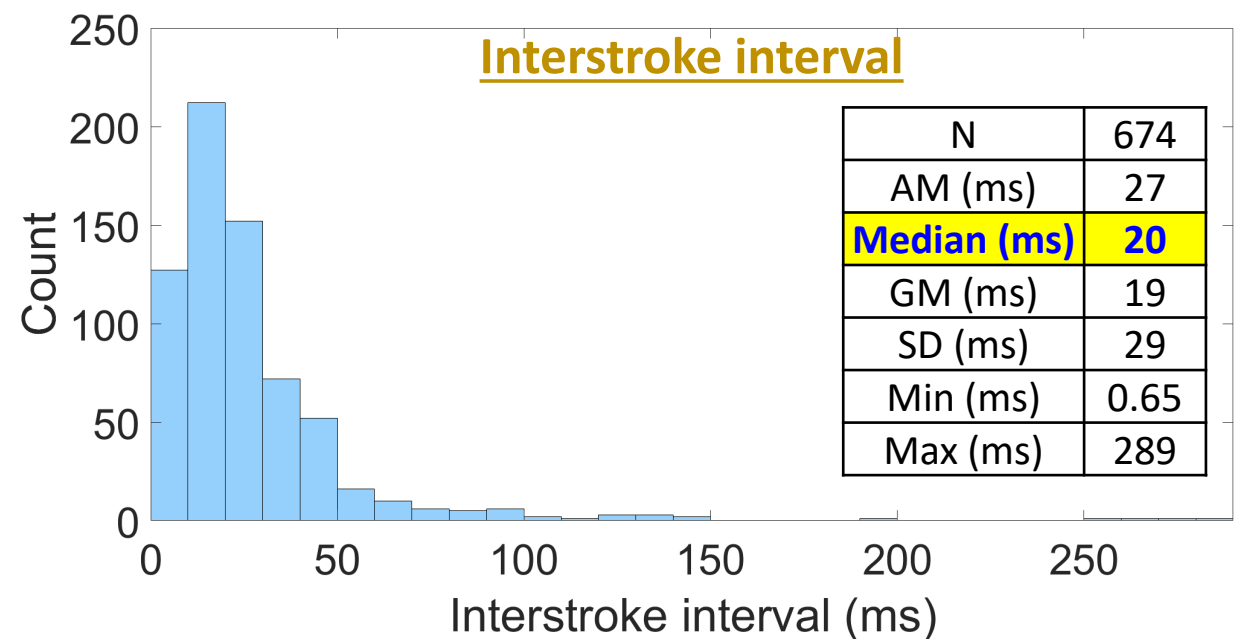
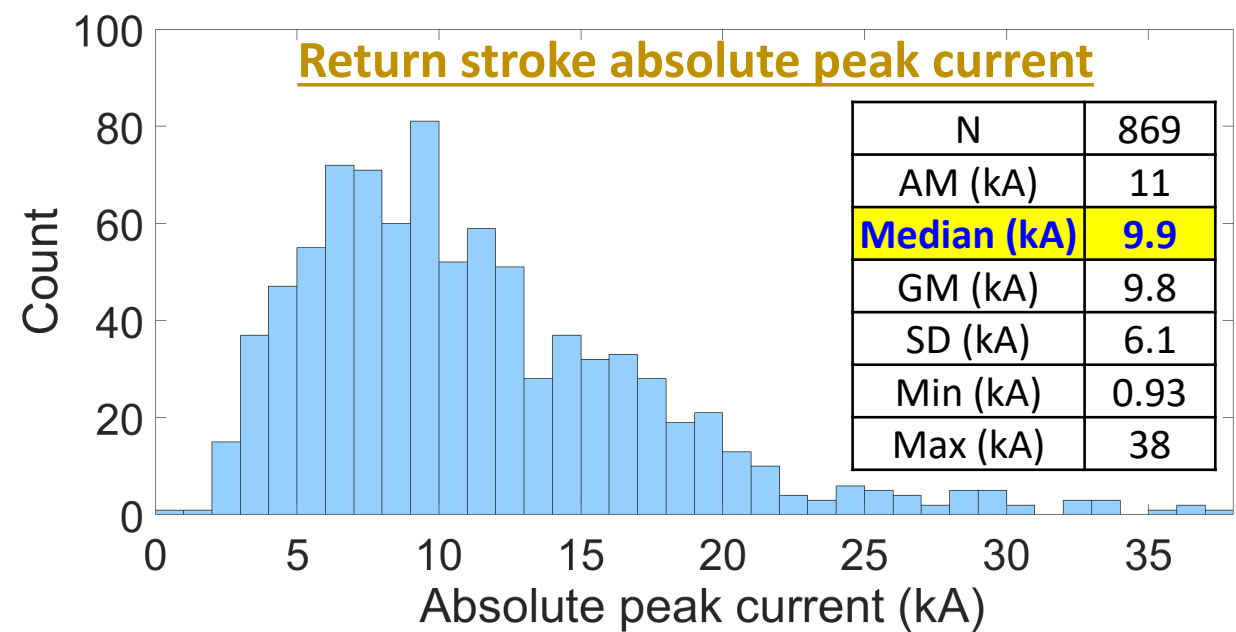
Return Stroke Total Charge Transfer



Return Stroke Total Duration



Return Stroke Characteristics



Summary

- In this study we examined current waveforms of 651 negative upward flashes that occurred at the Gaisberg Tower in Salzburg, Austria, from 2000 through 2018.
- **65%** of these flashes occurred during the non-convective season (September–March) while **35%** occurred during the convective season (April–August).
- **69%** of the upward flashes comprised of initial stage only and **31%** comprised of both initial stage and return strokes. In flashes with return strokes, there were **4.4 strokes per flash on average**.
- Median total charge transferred during upward flashes was **33 C for 639 flashes**.
- Flashes with initial stage only transferred more charge than that transferred during the initial stage of flashes with return strokes.
- Median charge transferred by return strokes was **0.65 C for 869 strokes**.
- Compared to all return strokes, last strokes in flashes had somewhat longer durations and they transferred larger amounts of charge.

Thank you !