# MEA analysis report

Simulated organoid recording

**Demonstration dataset.** This report was generated from a simulated recording with known ground truth, so the accuracy of each step can be checked (section 7). No biological sample was used.

| | | | |
|---|---|---|---|
| Recording | Simulated 8 × 8 MEA, 200 um pitch | Electrodes | 64 |
| Sampling rate | 12.5 kHz | Duration | 180 s (3.0 min) |
| Input | recording.raw · SHA-256 2b106cceb29c8922… | | |

## At a glance

**48** / 64
active electrodes used for analysis

**4.40** spikes/s
median firing rate, active electrodes

**9.0** per min
network bursts

**561** ms
mean network burst duration

**73** %
of spikes inside network bursts

**0.56** STTC
mean pairwise synchrony

### Summary

Of 64 electrodes, 48 were active and used for network analysis; 1 was excluded for high noise. Activity was organised into recurring network bursts: 27 bursts in 3.0 minutes (9.0 per minute), lasting 561 ms on average and recruiting 92% of active electrodes. 73% of all spikes fell inside network bursts. Pairwise synchrony was high (mean STTC 0.56), and 725 of 1,128 electrode pairs were significantly connected.

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## 1. Quality control

1 electrode was flagged for high noise (more than 2.5 times the median noise of 3.9 µV) and 15 were below the activity threshold of 0.1 spikes/s. Detection thresholds ranged from 15.5 to 97.4 µV (median 19.4 µV). Flagged electrodes are listed below and excluded from network analyses; they stay in the electrode table.

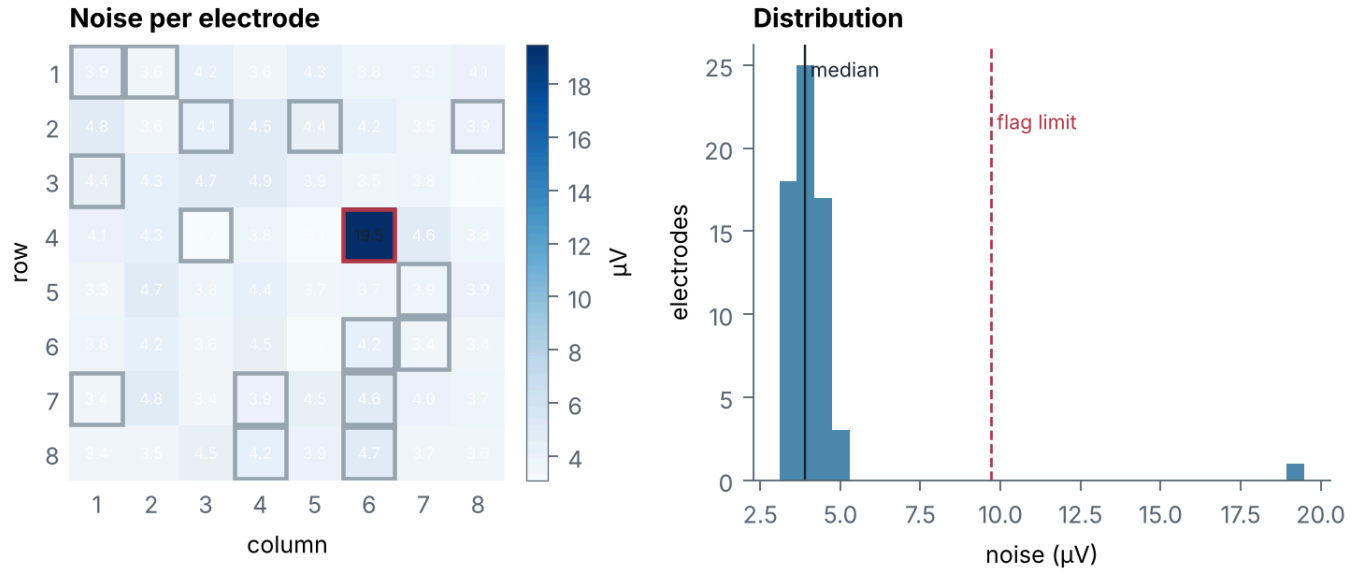



Figure 1. Left: noise per electrode, estimated from the band-passed signal (µV). Red frames mark electrodes flagged for high noise; grey frames mark electrodes below the activity threshold. Right: distribution of noise levels with the median and the flagging limit.

| Check | Value | Note |
|---|---|---|
| Electrodes recorded | 64 | |
| Active electrodes used | 48 | at least 0.1 spikes/s, not flagged |
| Below activity threshold | 15 | 11, 12, 23, 25, 28, 31, 43, 57, 66, 67, 71, 74, 76, 84, 86 |
| Flagged for high noise | 1 | 46 |
| Median noise | 3.9 µV | MAD of the band-passed signal / 0.6745 |
| Median detection threshold | 19.4 µV | 5 times the noise |
| Spikes detected | 39,358 | all electrodes |

## 2. Firing activity

Active electrodes fired at a median of 4.40 spikes/s (interquartile range 3.18 to 6.21). The median coefficient of variation of inter-spike intervals was 2.51; values well above 1 indicate bursty rather than random firing. A median of 79% of each electrode's spikes fell inside single-electrode bursts.

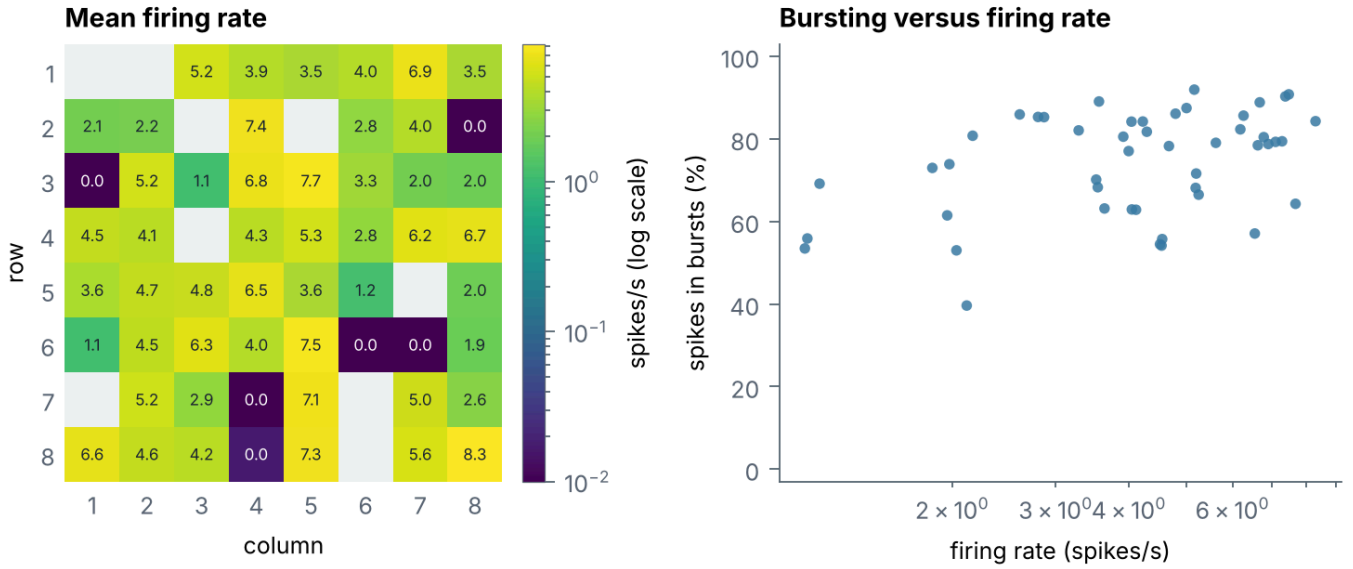



Figure 2. Left: mean firing rate per electrode on the array layout (log scale; empty cells had no detected spikes). Right: share of each active electrode's spikes that fall inside single-electrode bursts, against its firing rate.

| Metric, active electrodes | Median | Interquartile range |
|---|---|---|
| Firing rate (spikes/s) | 4.40 | 3.18 to 6.21 |
| ISI coefficient of variation | 2.51 | 2.01 to 2.89 |
| Single-electrode bursts per minute | 9.3 | 8.3 to 12.8 |
| Burst duration (ms) | 307 | 279 to 364 |
| Spikes per burst | 18.8 | 16.0 to 22.3 |
| Spikes inside bursts (%) | 79 | 64 to 84 |
| Spike amplitude (µV) | 77.6 | 54.2 to 102.2 |

## 3. Activity over time

Figure 3 shows the first 60 seconds of activity on all 48 active electrodes. The 9 shaded bands are network bursts, periods in which most electrodes fire together.

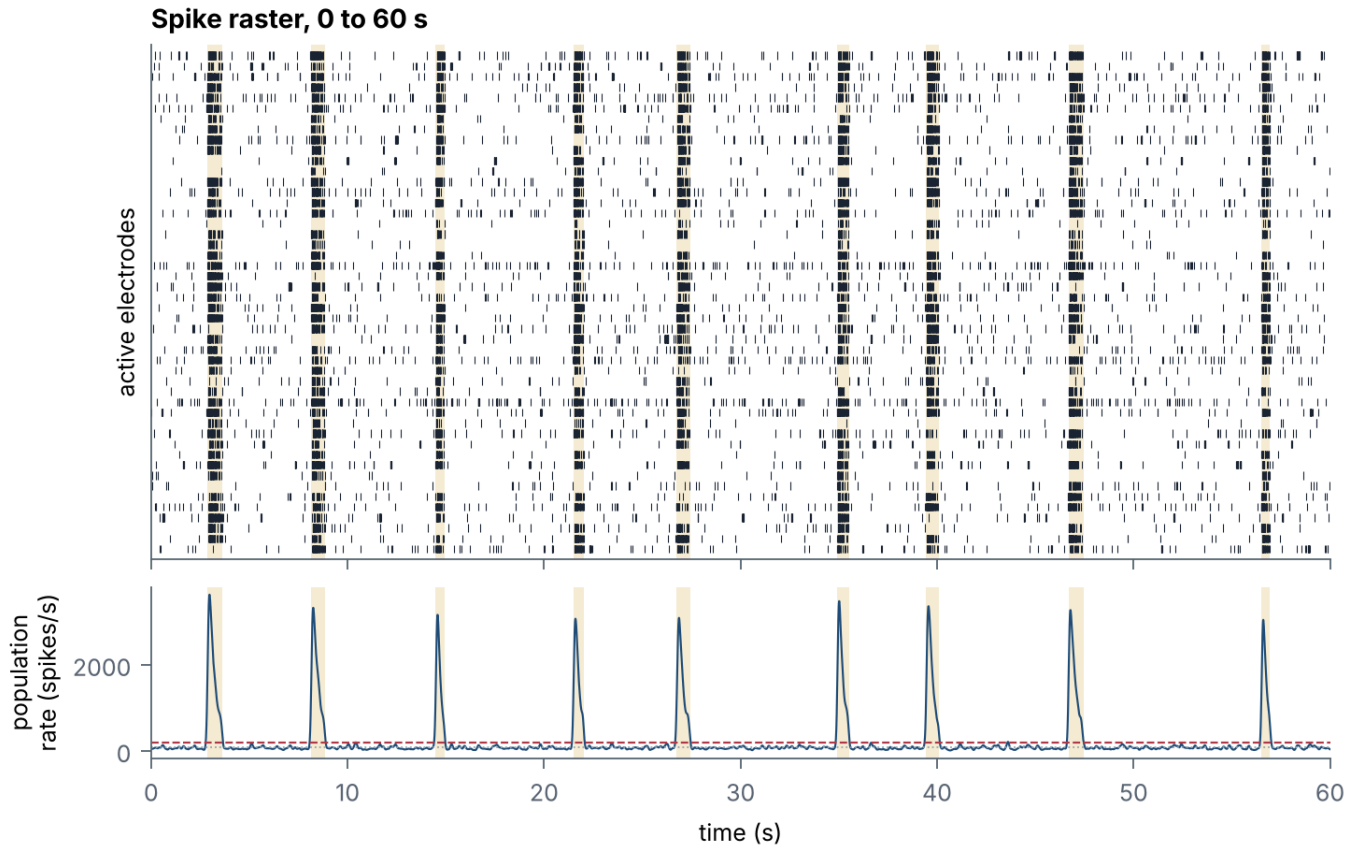



Figure 3. Top: spikes on every active electrode, ordered by position on the array. Shaded bands are detected network bursts. Bottom: population spike rate with the onset threshold (dashed) and the boundary threshold (dotted).

## 4. Network bursts

27 network bursts were detected (9.0 per minute). They lasted 561 ± 131 ms, contained 1048 spikes on average and recruited 92% of active electrodes. The interval between bursts averaged 6.6 s with a coefficient of variation of 0.25, which indicates a regular rhythm.

| Network burst metric | Value |
|---|---|
| Network bursts detected | 27 |
| Rate (per minute) | 9.00 |
| Duration, mean ± SD (ms) | 561 ± 131 |
| Spikes per burst, mean | 1,048 |
| Active electrodes recruited, mean (%) | 92 |
| Interval between bursts, mean (s) | 6.63 |
| Interval coefficient of variation | 0.25 |
| Spikes inside network bursts (%) | 72.9 |

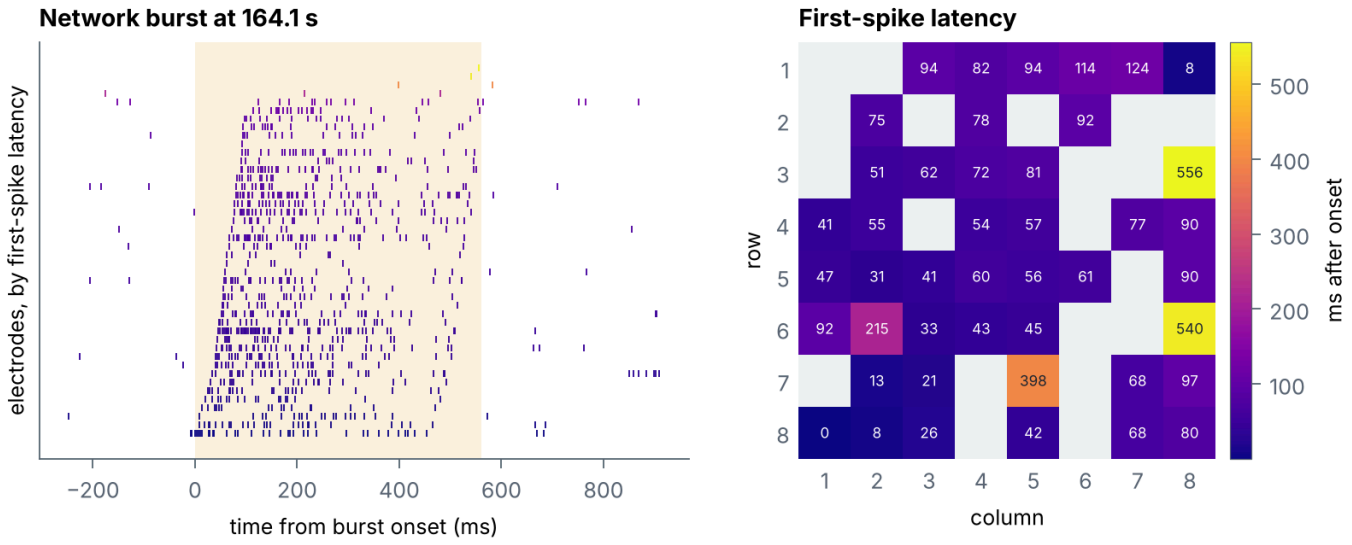



Figure 4. A representative network burst. Left: spikes ordered by the time each electrode first fired after burst onset. Right: first-spike latency on the array, showing where the burst started and how it spread.

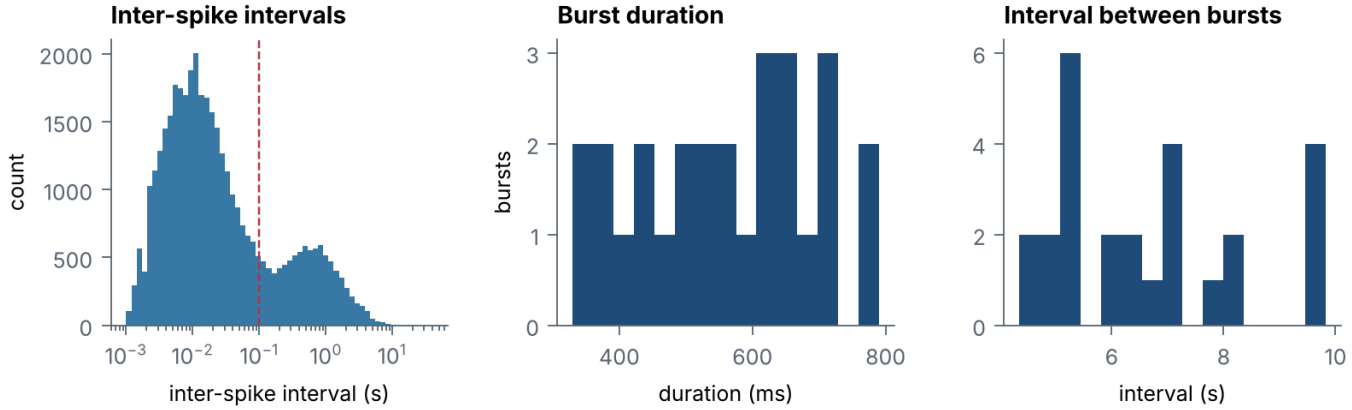



Figure 5. Left: inter-spike intervals pooled across active electrodes; the dashed line is the 100 ms burst criterion. Middle and right: network burst durations and the intervals between consecutive bursts.

## 5. Synchrony and functional connectivity

Across 1,128 pairs of active electrodes, the mean STTC was 0.56. 725 pairs (64%) exceeded all of their jittered controls, meaning their spikes lined up more tightly than burst co-activation alone would produce; these were treated as functional connections. STTC strength did not depend much on distance (Spearman ρ = -0.07), but connections were more common between close electrodes: 77% of the closest quarter of pairs against 38% of the most distant quarter (Figure 6, top right). The resulting network had a mean degree of 30.2, weighted clustering of 0.50 and 3 modules (modularity 0.06).

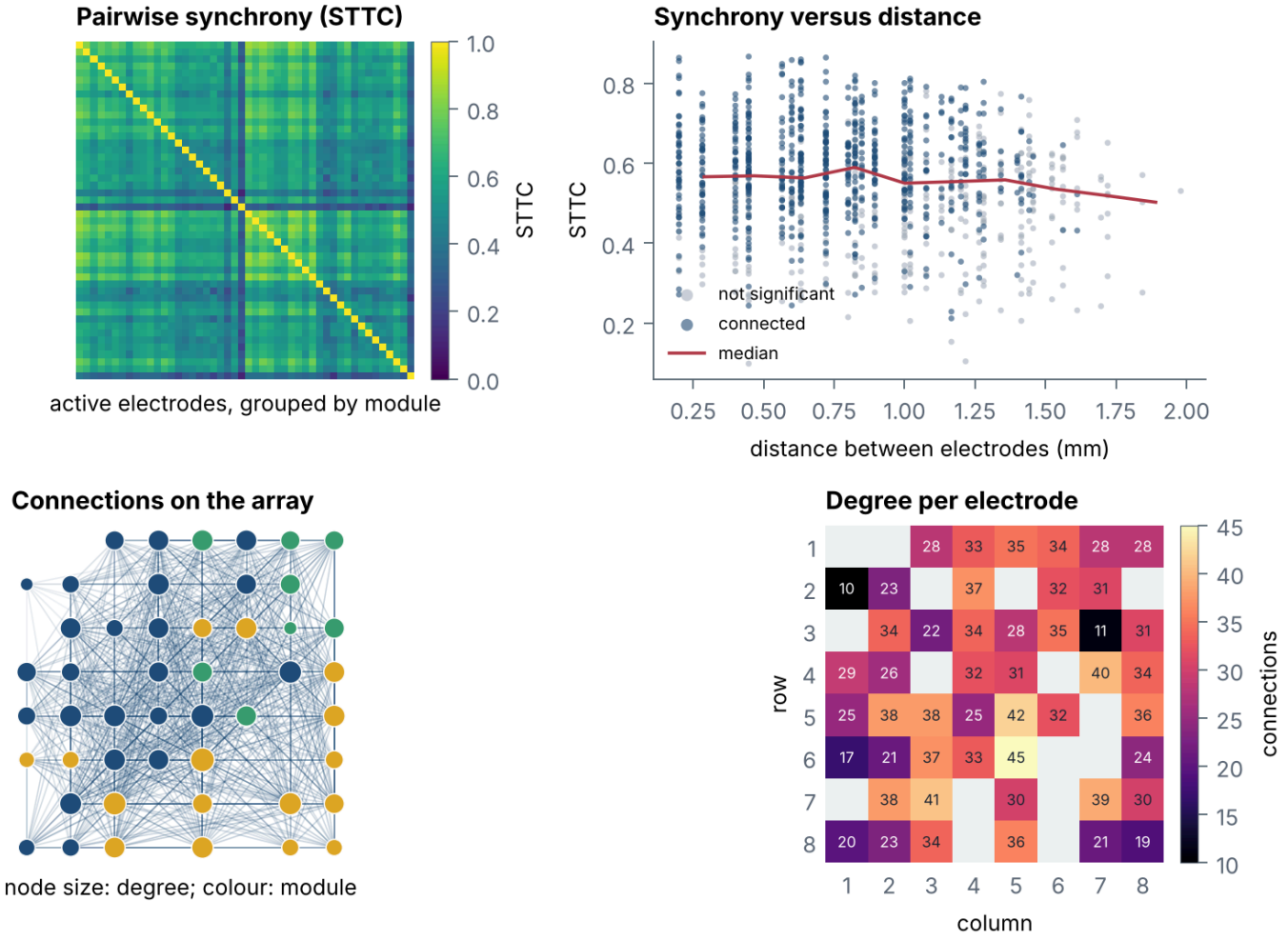



Figure 6. Top left: spike time tiling coefficient (STTC) for every pair of active electrodes, grouped by network module. Top right: STTC against distance; blue pairs passed the jitter test. Bottom left: significant connections on the array; line opacity follows STTC. Bottom right: number of connections per electrode.

| Network metric | Value |
|---|---|
| Electrode pairs tested | 1,128 |
| Mean STTC, all pairs | 0.555 |
| Significant connections | 725 (64%) |
| Mean STTC, connected pairs | 0.596 |
| STTC against distance, Spearman ρ | -0.07 |
| Density · mean degree | 0.64 · 30.2 |
| Weighted clustering coefficient | 0.504 |
| Modules · modularity Q | 3 · 0.061 |

# 6. Methods

Written so it can be pasted into a manuscript. Parameter values are filled in from this run.

Recordings were analysed with mearep 0.3.1, built on SpikeInterface 0.106.0 (Buccino et al., 2020). Raw voltage traces were band-pass filtered between 300 and 3000 Hz with a 2nd-order Butterworth filter applied forward and backward (zero phase). Noise was estimated for each electrode as the median absolute deviation of the filtered signal divided by 0.6745, on 40 randomly placed one-second segments. Spikes were detected as negative peaks below 5 times this noise level, with at most one spike per electrode within 1 ms. Electrodes firing at least 0.1 spikes/s were classed as active; electrodes with noise above 2.5 times the median were flagged and excluded from network analyses. Single-electrode bursts were defined as runs of at least 5 spikes separated by inter-spike intervals of at most 100 ms. Network bursts were detected from the population spike rate of all active electrodes (10 ms bins, Gaussian smoothing with σ = 50 ms). An event started where the rate exceeded its median plus 4 times its scaled median absolute deviation and was extended to where the rate fell below the median plus 1 times that value; events closer than 100 ms were merged. Burst boundaries were then set to the first and last 10 ms bin holding at least 10% of the burst's peak spike count, and a burst was kept if it contained at least 50 spikes and at least 35% of active electrodes fired within it. Pairwise synchrony was quantified with the spike time tiling coefficient (STTC; Cutts and Eglen, 2014) with Δt = 50 ms. A pair was treated as functionally connected when its STTC exceeded all 19 values obtained after jittering every spike of one train by a uniform random offset within ±100 ms, twice the STTC window ($p < 0.05$). This control keeps co-activation within network bursts and removes precise spike timing. Graph measures (density, degree, weighted clustering and modularity by greedy optimisation) were computed with NetworkX 3.7 (Hagberg et al., 2008).

### Parameters

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Band-pass filter | 300 to 3000 Hz, order 2, zero phase | Detection threshold | 5 × MAD noise, negative peaks |
| Minimum spike spacing | 1 ms | Active electrode | ≥ 0.1 spikes/s |
| High-noise flag | > 2.5 × median noise | Single-electrode burst | ≥ 5 spikes, ISI ≤ 100 ms |
| Network burst rate bin, smoothing | 10 ms, σ = 50 ms | Network burst thresholds | median + 4 / 1 × MAD |
| Network burst boundaries | bins ≥ 10% of the burst peak | Network burst size | ≥ 50 spikes, ≥ 35% of active electrodes |
| STTC window | Δt = 50 ms | Connection test | 19 jittered surrogates (± 100 ms), $p < 0.05$ |
| Random seed | 1 | | |

### References


1. Buccino AP, Hurwitz CL, Garcia S, et al. SpikeInterface, a unified framework for spike sorting. eLife 2020;9:e61834.
2. Cutts CS, Eglen SJ. Detecting pairwise correlations in spike trains: an objective comparison of methods and application to the study of retinal waves. J Neurosci 2014;34:14288-14303.
3. Hagberg AA, Schult DA, Swart PJ. Exploring network structure, dynamics, and function using NetworkX. Proc 7th Python in Science Conference 2008:11-15.
4. Sit TPH, et al. MEA-NAP: a flexible network analysis pipeline for neuronal 2D and 3D organoid multielectrode recordings. Cell Rep Methods 2024.

## 7. Validation against ground truth

Because this recording was simulated, every spike and every network burst is known. Across all electrodes, 99.1% of detected spikes matched a true spike within ±0.6 ms (precision) and 96.2% of true spikes were detected (recall). Leaving out the electrode flagged for high noise, precision was 99.1% and recall 98.1%. Simulated neurons whose amplitude was at least five times the noise were recovered at 98%; smaller ones at 20%, as expected for threshold detection. 27 of 27 simulated network bursts were detected (sensitivity 100%), 100% of detections matched a true burst, and the median onset error was 22 ms. Detected and true firing rates per electrode correlated with r = 0.973.

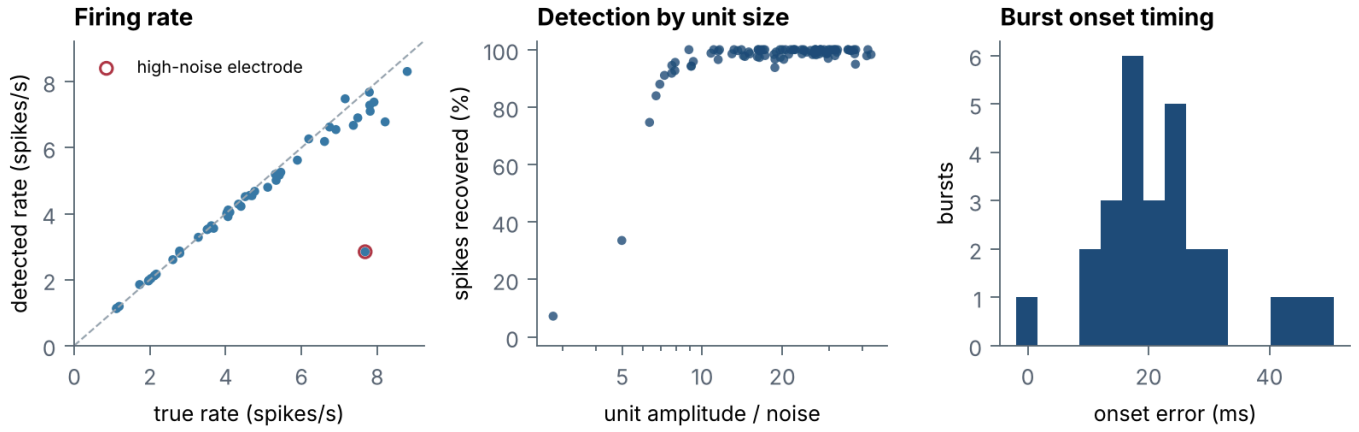



Figure 7. Left: detected against true firing rate per electrode; the circled point is the electrode flagged for high noise. Middle: share of each simulated neuron's spikes that were recovered, against its amplitude relative to the noise. Right: difference between detected and true network burst onset.

| Validation metric | Value |
|---|---|
| Spike precision, all electrodes | 99.1% |
| Spike recall, all electrodes | 96.2% |
| Spike precision, without flagged electrode | 99.1% |
| Spike recall, without flagged electrode | 98.1% |
| Recall, neurons with amplitude ≥ 5 × noise | 98.1% |
| Recall, neurons with amplitude < 5 × noise | 20.4% |
| Firing-rate correlation (r) | 0.973 |
| Network bursts, true / detected | 27 / 27 |
| Network burst sensitivity | 100% |
| Network burst precision | 100% |
| Median onset error | 22 ms |
| Matching tolerance for spikes | ± 0.6 ms |

What this shows: on a recording with realistic noise, the pipeline recovers spikes and network bursts reliably, and quality control catches the electrode where it cannot. What it does not show: performance on a particular biological preparation. For customer data we report quality flags for every electrode and, where the lab has its own analysis, compare our numbers with it.

## 8. Reproducibility and limitations

Every number in this report was produced by the command below. Running it again on the same input file gives the same results.

```
python -m mearep run --input ../data/sim01/recording.raw --format binary --meta ../data/sim01/recording.json
--truth ../data/sim01/ground_truth.npz --out ../out/v031/demo01 --report-id DEMO-0001 --dataset-name 'Simulat
ed organoid recording'
```

### Software

Python 3.13.18 · mearep 0.3.1 · SpikeInterface 0.106.0 · Neo 0.14.6 · NumPy 2.5.3 · SciPy 1.18.1 · pandas 3.0.5 · NetworkX 3.7 · Matplotlib 3.11.2

### Files delivered

| File | Contents |
|---|---|
| report.pdf / report.html | this report |
| electrodes.csv | per-electrode metrics and quality flags |
| network_bursts.csv | every detected network burst with onset, offset and size |
| sttc_pairs.csv | synchrony for every electrode pair and whether it is significant |
| summary.json | all summary numbers, parameters, software versions and input checksum |
| figs/ | all figures as PNG at 220 dpi |

### Limitations

- Threshold detection reports multi-unit activity per electrode. It does not separate individual neurons; spike sorting is outside the scope of this report.
- Network burst metrics depend on detection parameters. Keep them fixed across conditions that you compare; the values used are listed in section 6.
- Functional connections are statistical: they mean that spikes on two electrodes line up more tightly than the jitter control allows. They are not evidence of direct synapses.
- Results describe one recording. Comparisons between conditions need replicate wells or organoids and statistics across them.

### About this report

Prepared by Wellspike, Copenhagen, Denmark. The analysis pipeline is run with the help of an AI agent (Claude, by Anthropic). Each report is checked against a written quality checklist, and the founder approves every delivery.