Efficient "shotgun" inference of neural connectivity from highly sub-sampled activity data

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- Ran Rubin
- Yuryi Mishchenko

Model-based connectivity

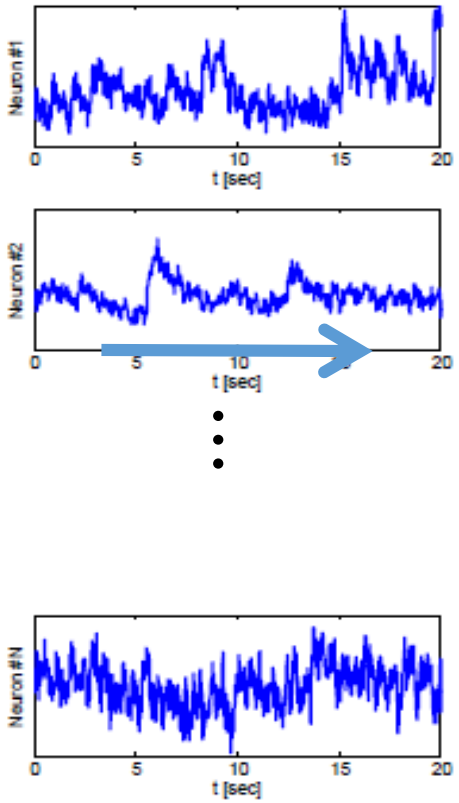
Calcium Traces

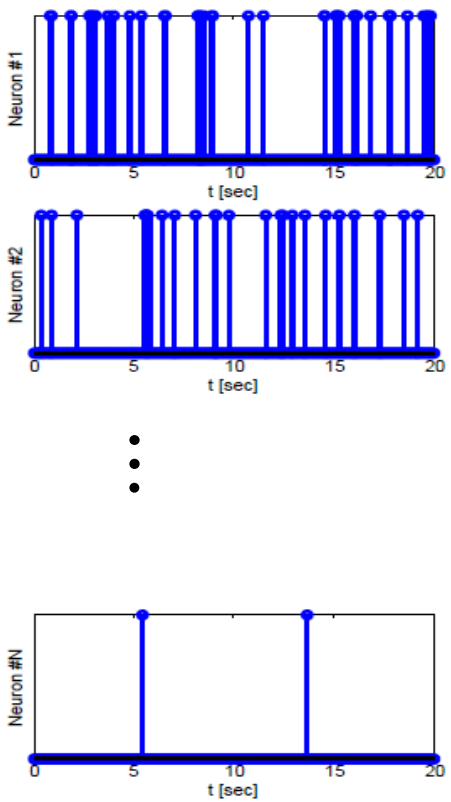
Neural Activity

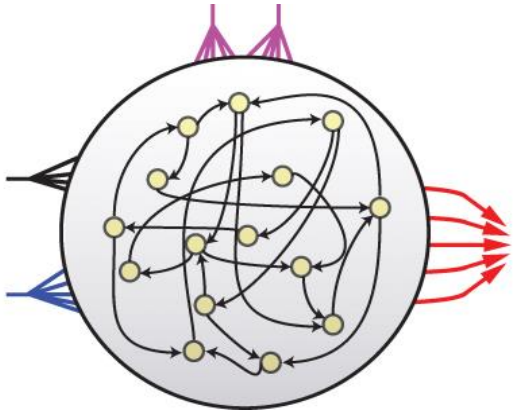
S

Model Parameters

W







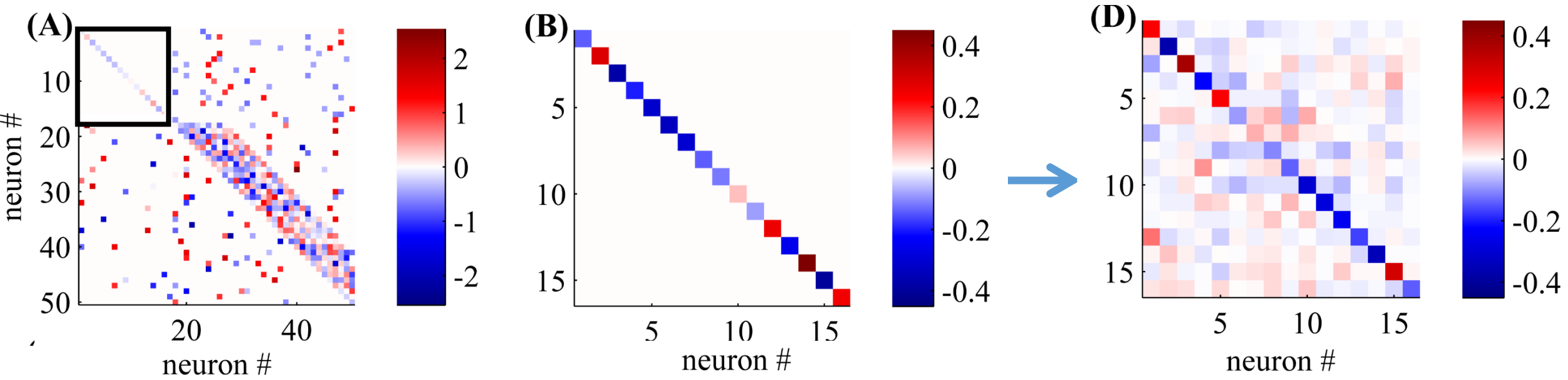
frame rate > 30Hz required!

Spiking model (GLM) can infer synaptic connectivity:
Gerhard et al. 2013
Latimer et al. 2014
Volgushev et al. 2015

… other methods (e.g. correlations) work less well

Mishchenko, Vogelstein & Paninski 2010

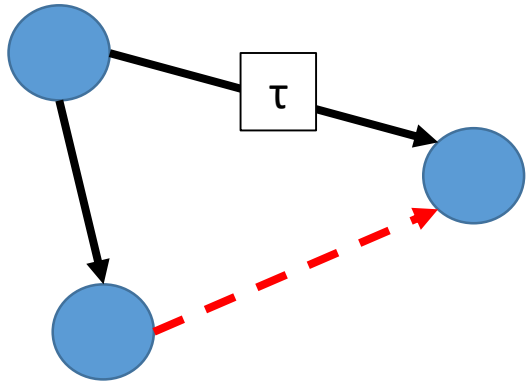
Limited scanning speed – a fundamental barrier?



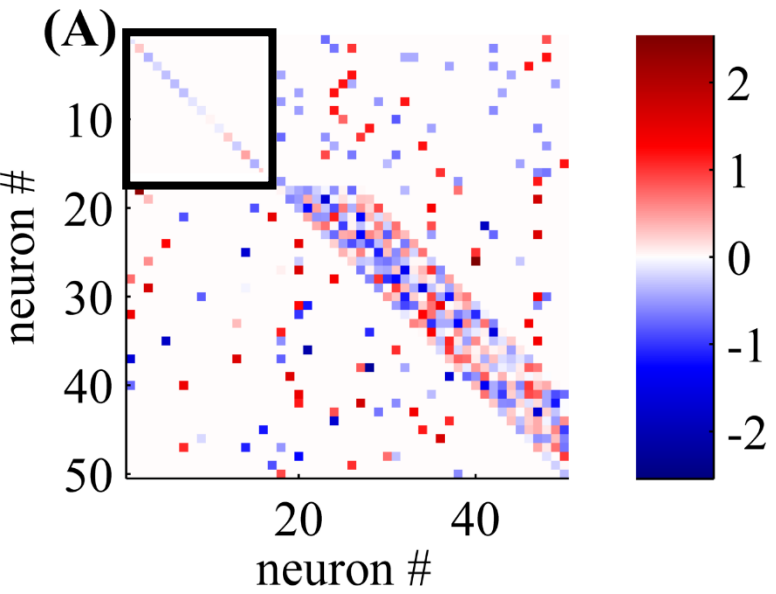
After 12 days of spike data!

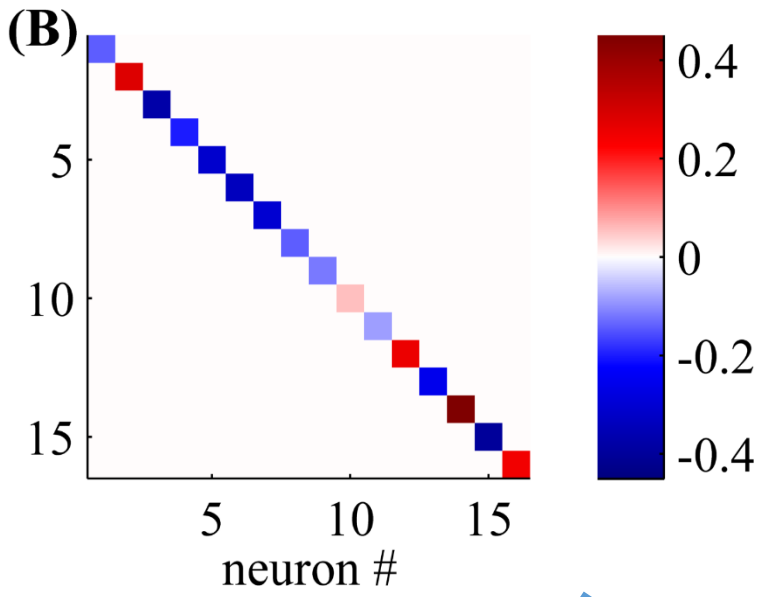
- The common input problem

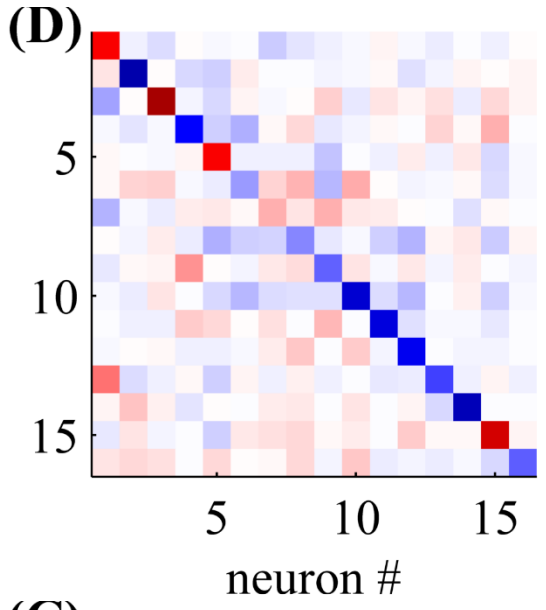
[Pillow2007, Nykamp2008, Vidne2008, Mishchenko2011,Turaga2013,Romano2014, Tyrcha2014]

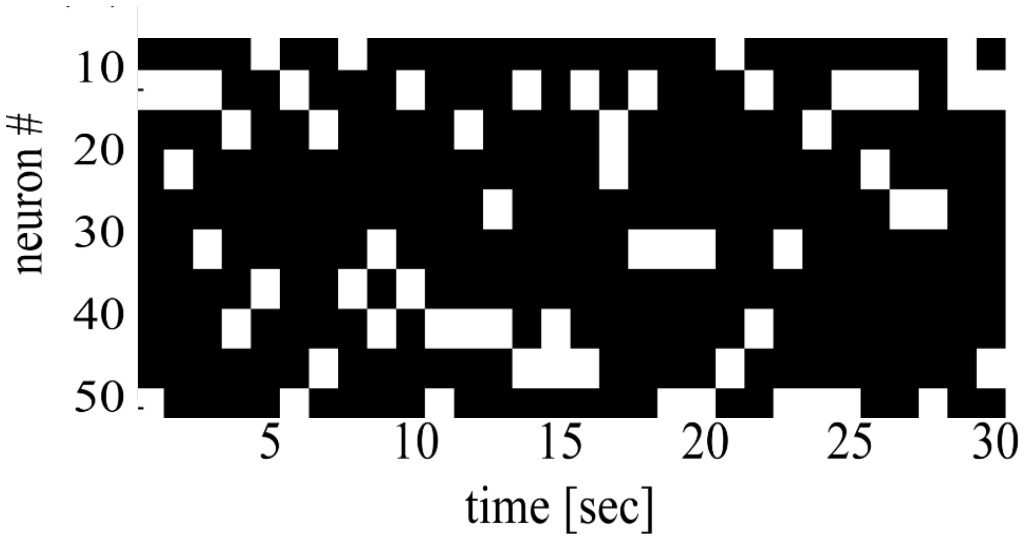


Alleviating the common input problem

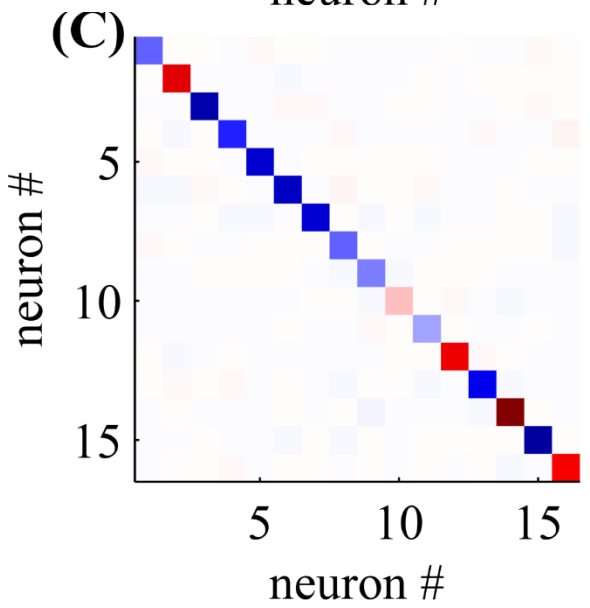








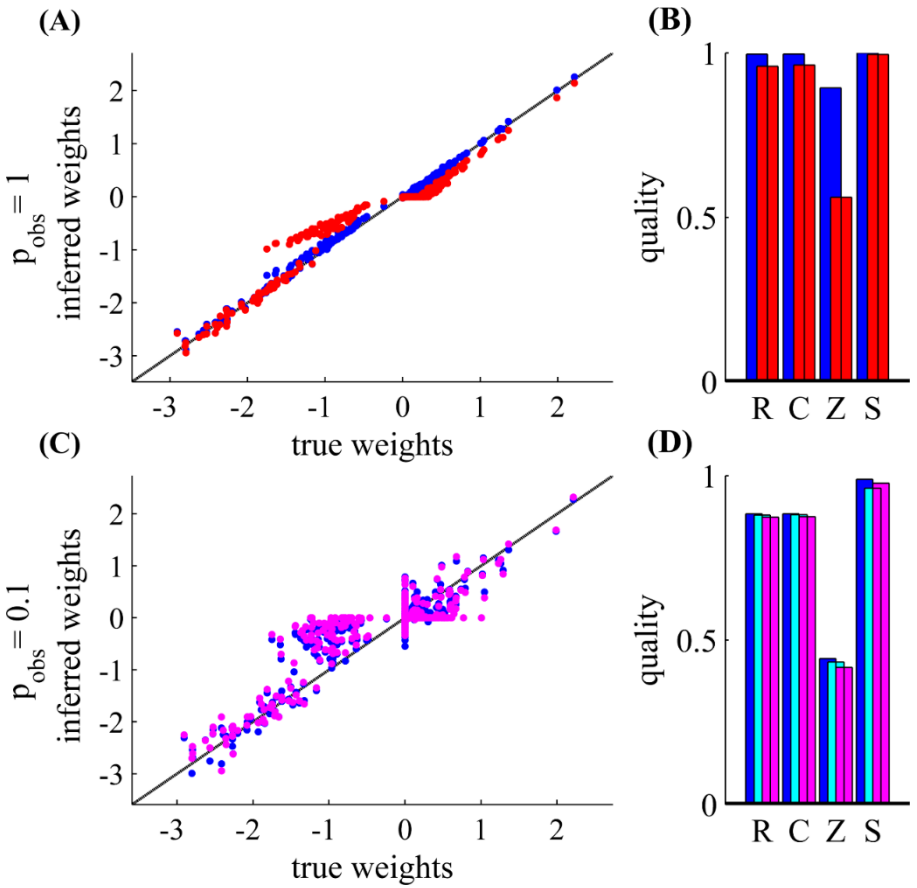
with shotgun



Main Result

- **Approximate loglikelihood and derivatives, so they only depend on the empiric second order statistics.**
- Can now handle missing observations
- Faster then original likelikelihood – $O(TN^2+N^3)$ instead of $O(TN^3)$

Inference quality maintained with approximations



- Regular MAP (red) does not improve (blue)
- Inferring missing spikes (pink+cyan) does not improve over ignoring them (blue)

Summary

Connectivity inference – main obstacles:

- Common input problem
- Low frame rate
- Experimental duration

} **Shotgun - Scanning speed is not a fundamental limit**

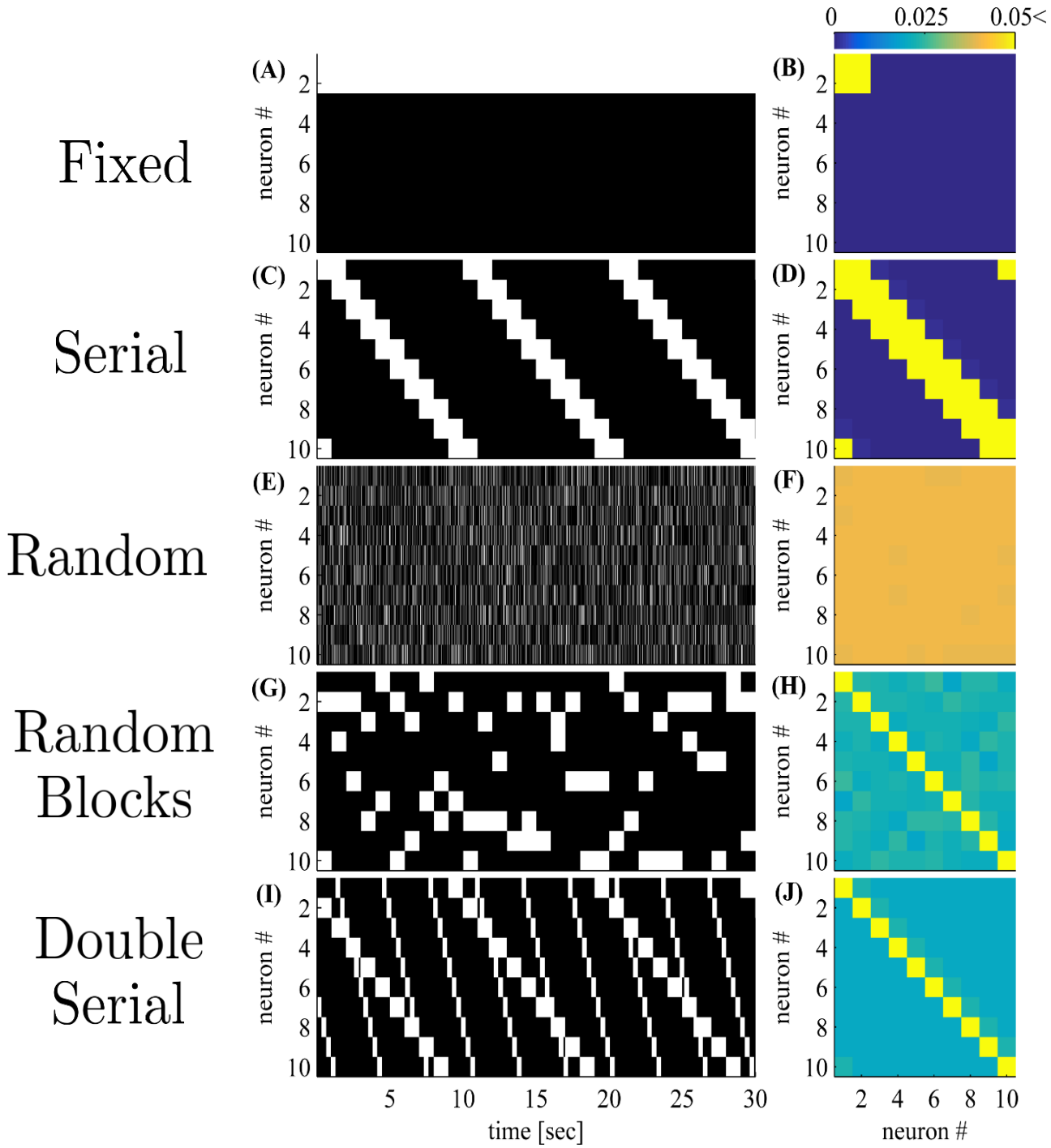
- Inferring spikes from calcium traces
- Model Mismatch
- Comparing with “ground truth”

- Inference is computationally hard

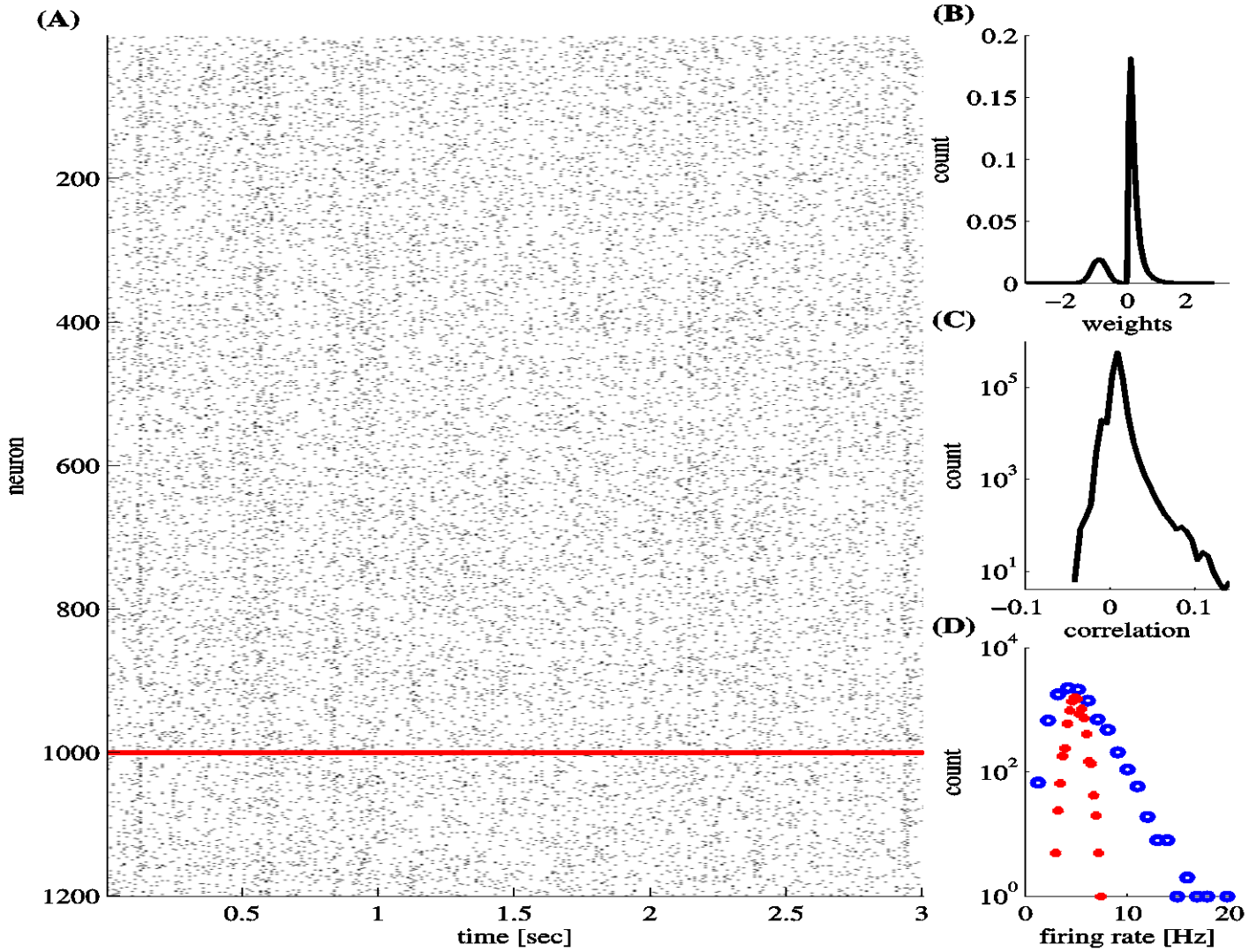
} **New inference method:**
minutes, not 10^5 hours [Zaytsev et al. 2015]

Thank you for listening!

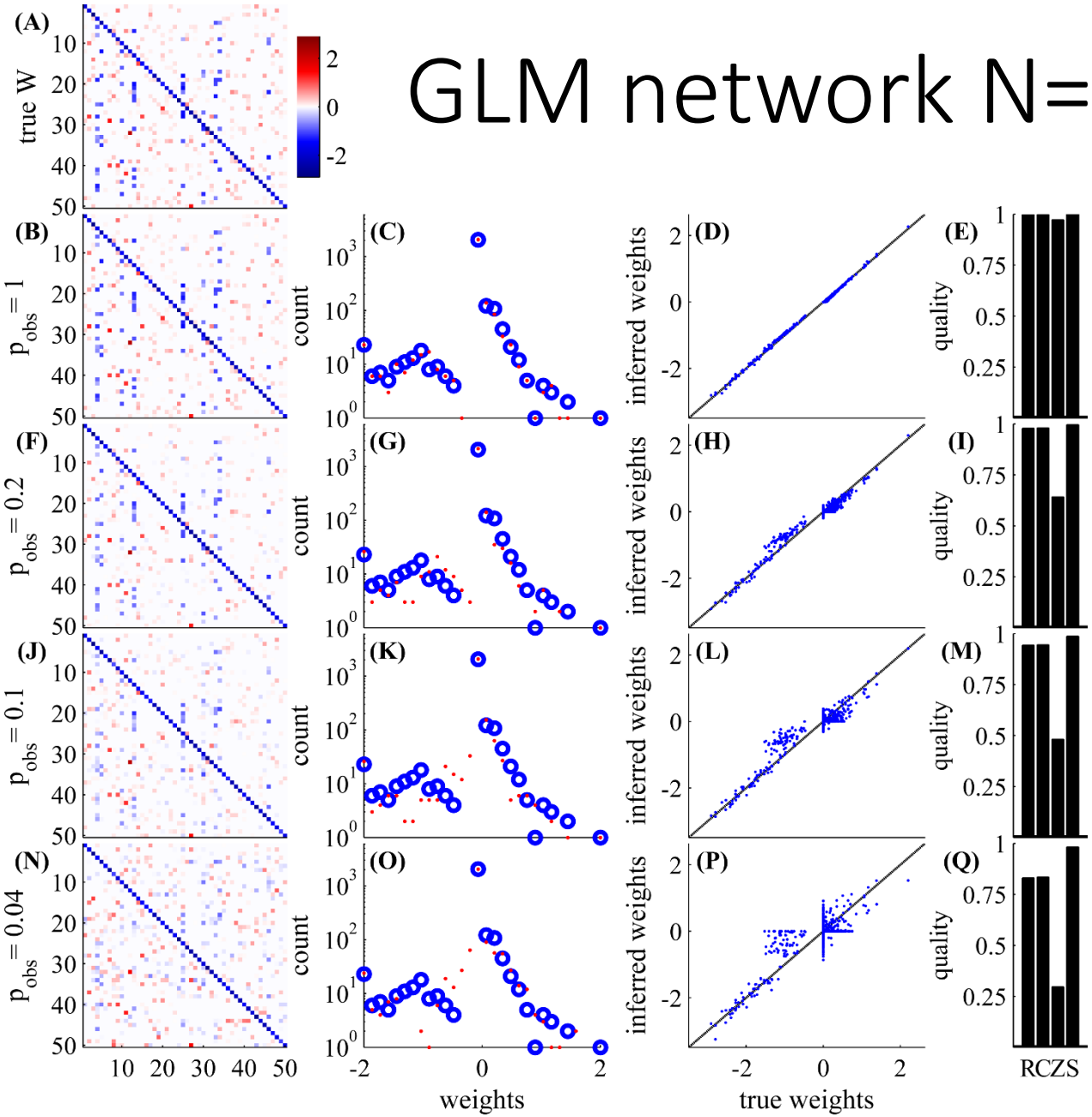
Questions?


Fixed
Serial
Random
Random Blocks
Double Serial
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
neuron #
time [sec]
0
0.025
0.05<
2
4
6
8
10
5
15
20
25
30

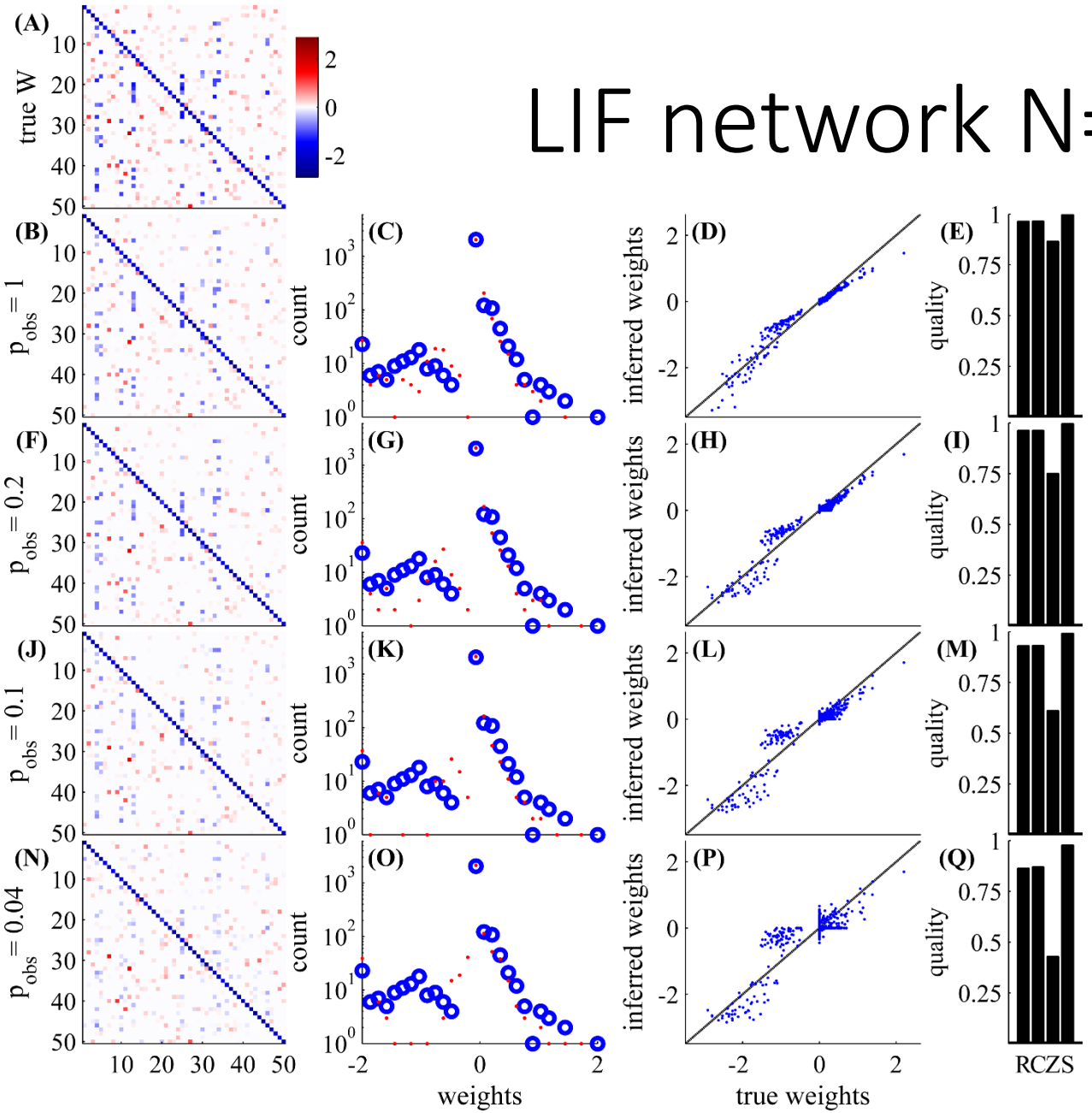
Network Simulation



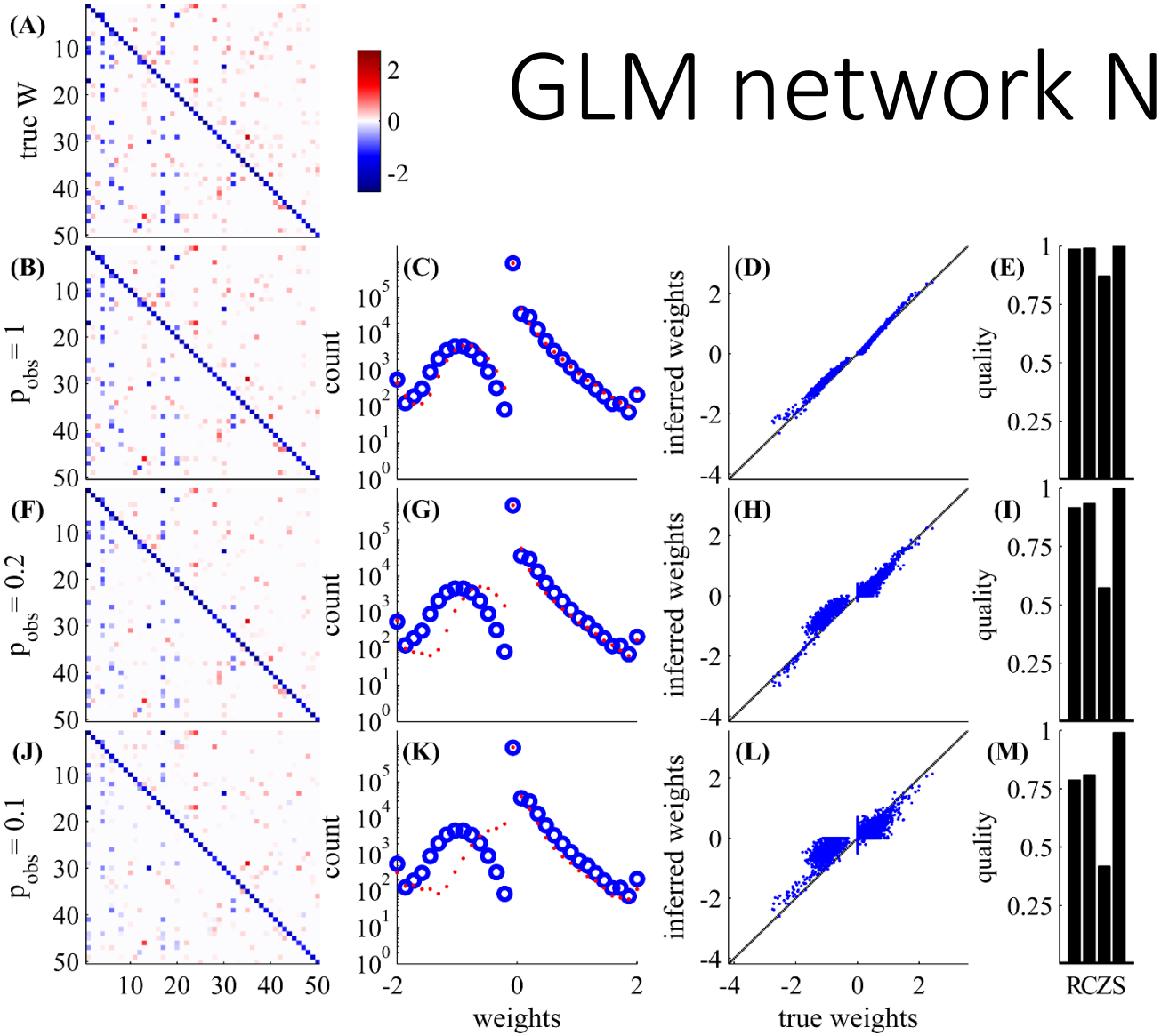
GLM network N=50



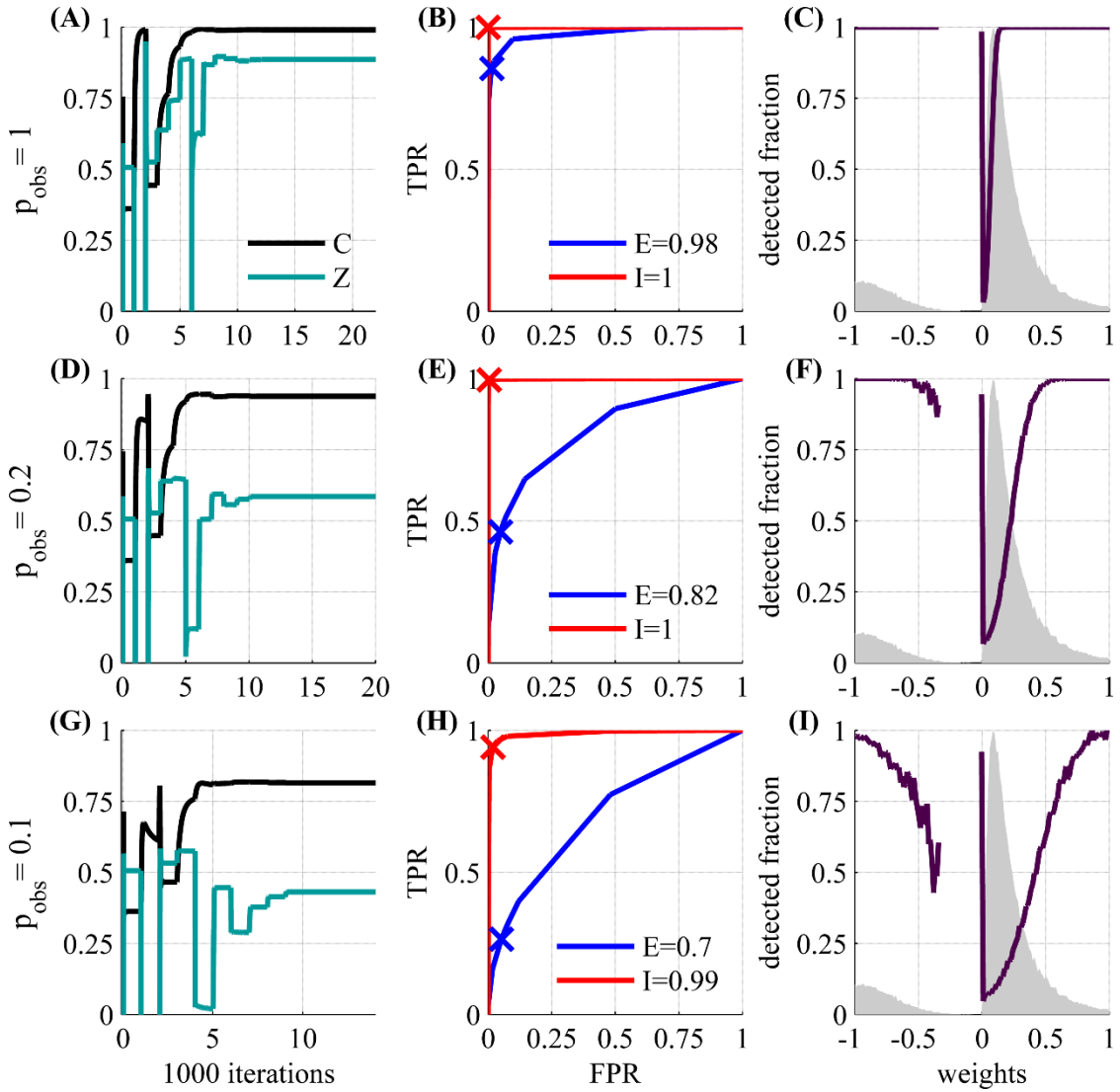
LIF network N=50



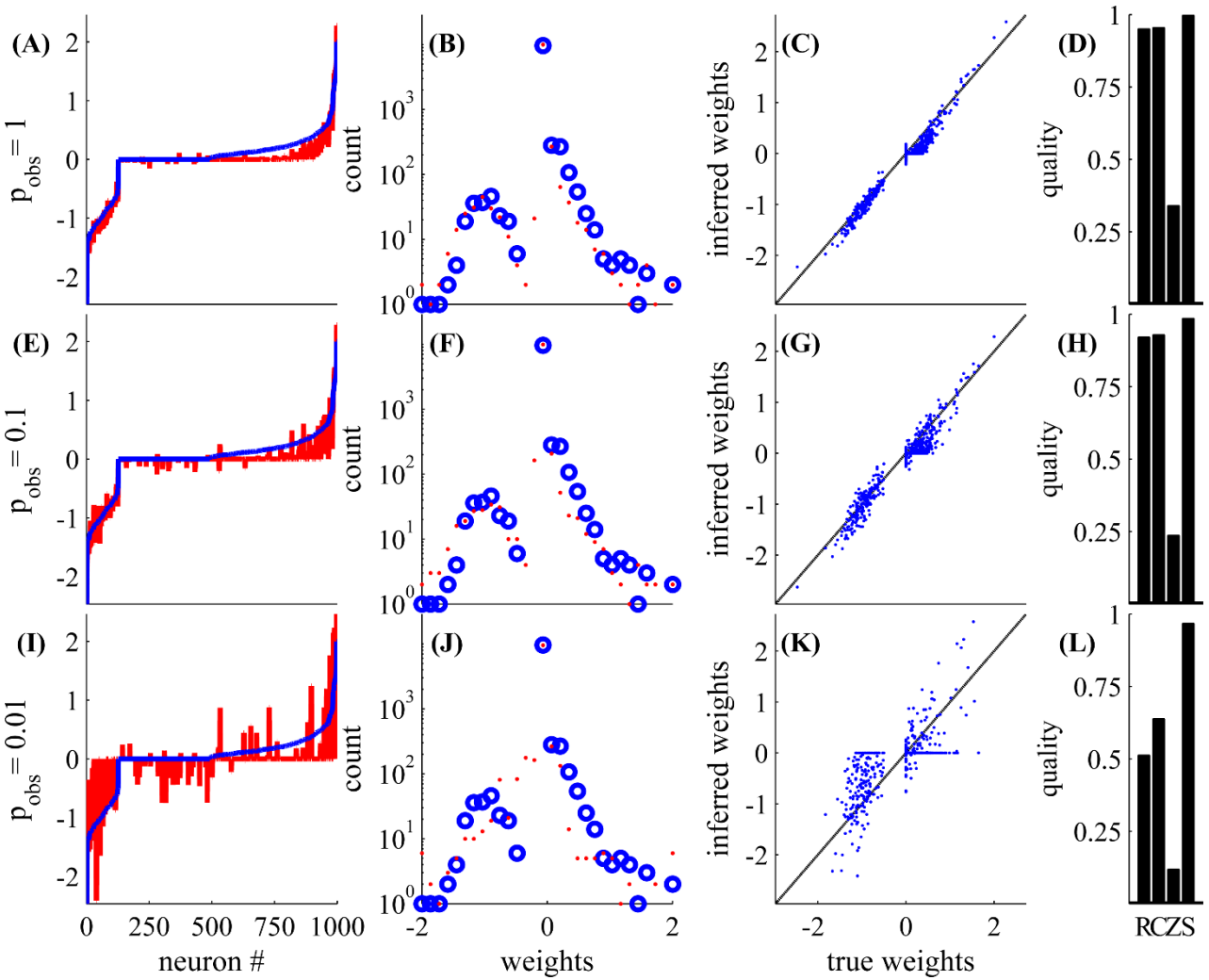
GLM network N=1000



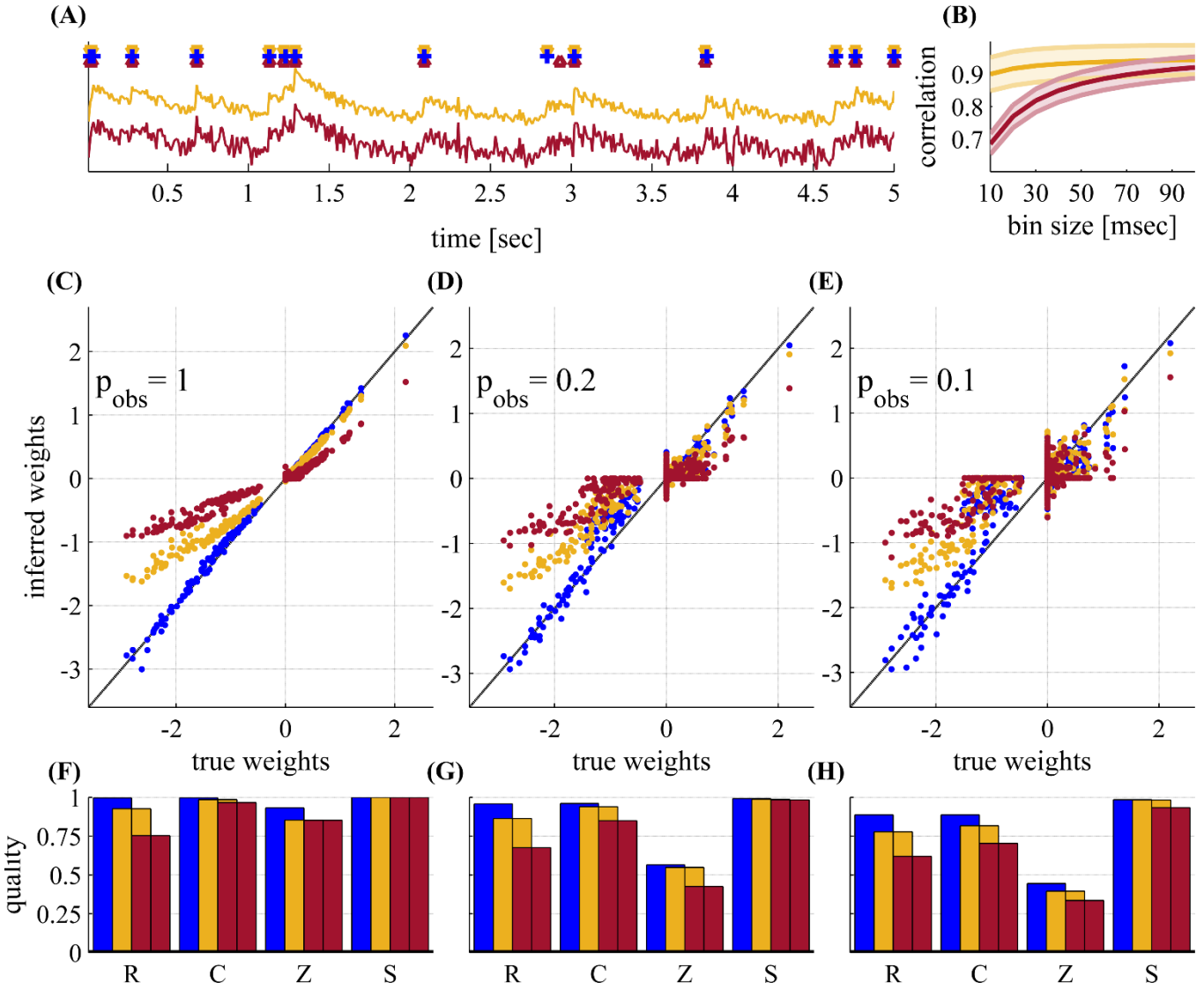
Estimation Quality –more details



Single Neuron – 10,000 inputs



Inference from Calcium data



Logistic Function Approximation