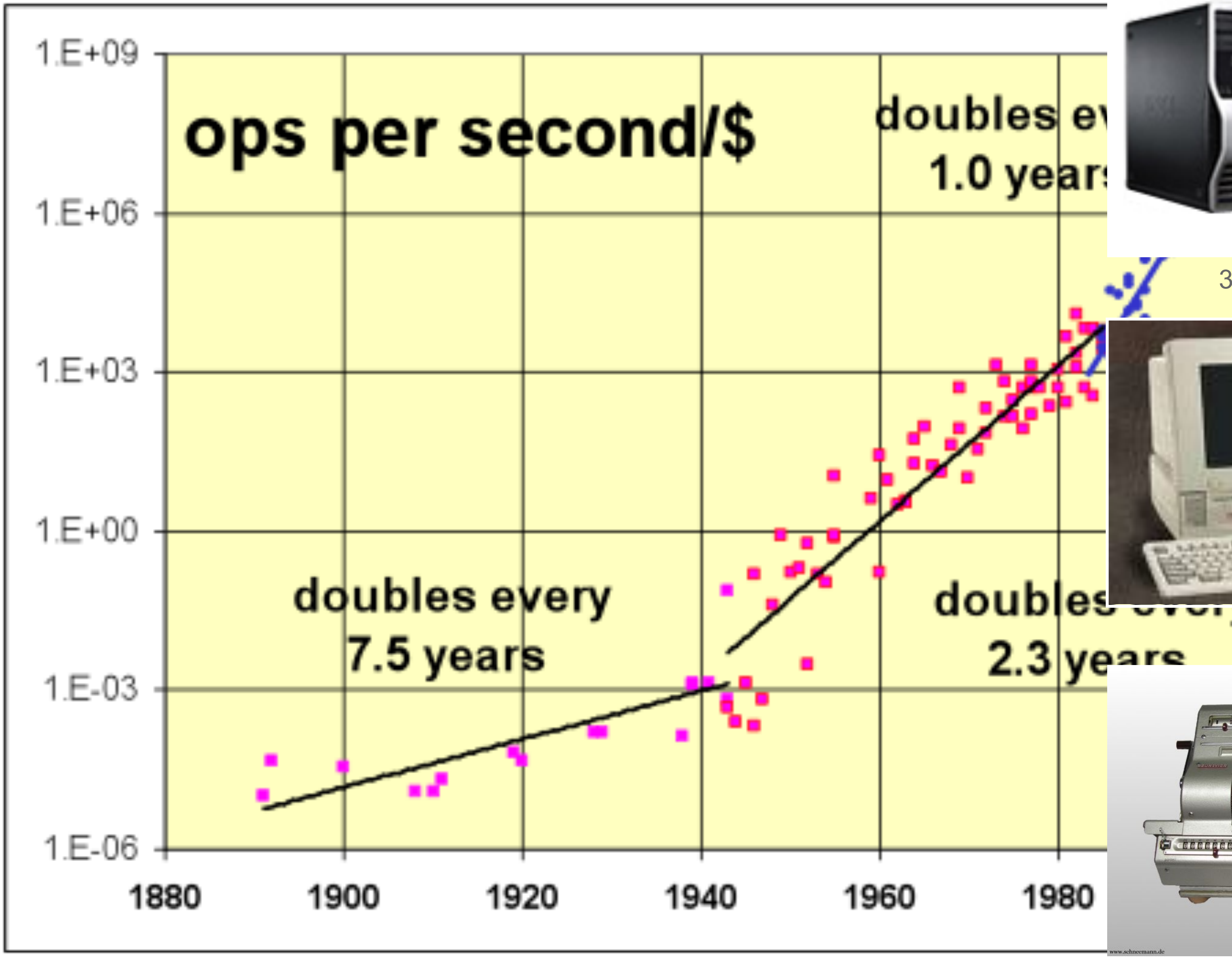
BIOE332 LECTURE 5: NEUROGRID

BEN VARKEY BENJAMIN

KWABENA BOAHEN

SPRING 2012-2013

24-April-2013

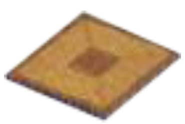


Jim Gray 2001

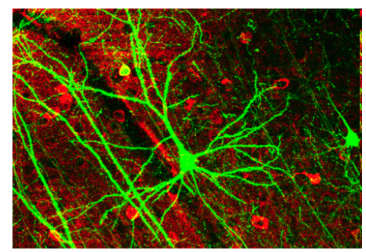
3GHz Dell Precision

100Mz Compaq

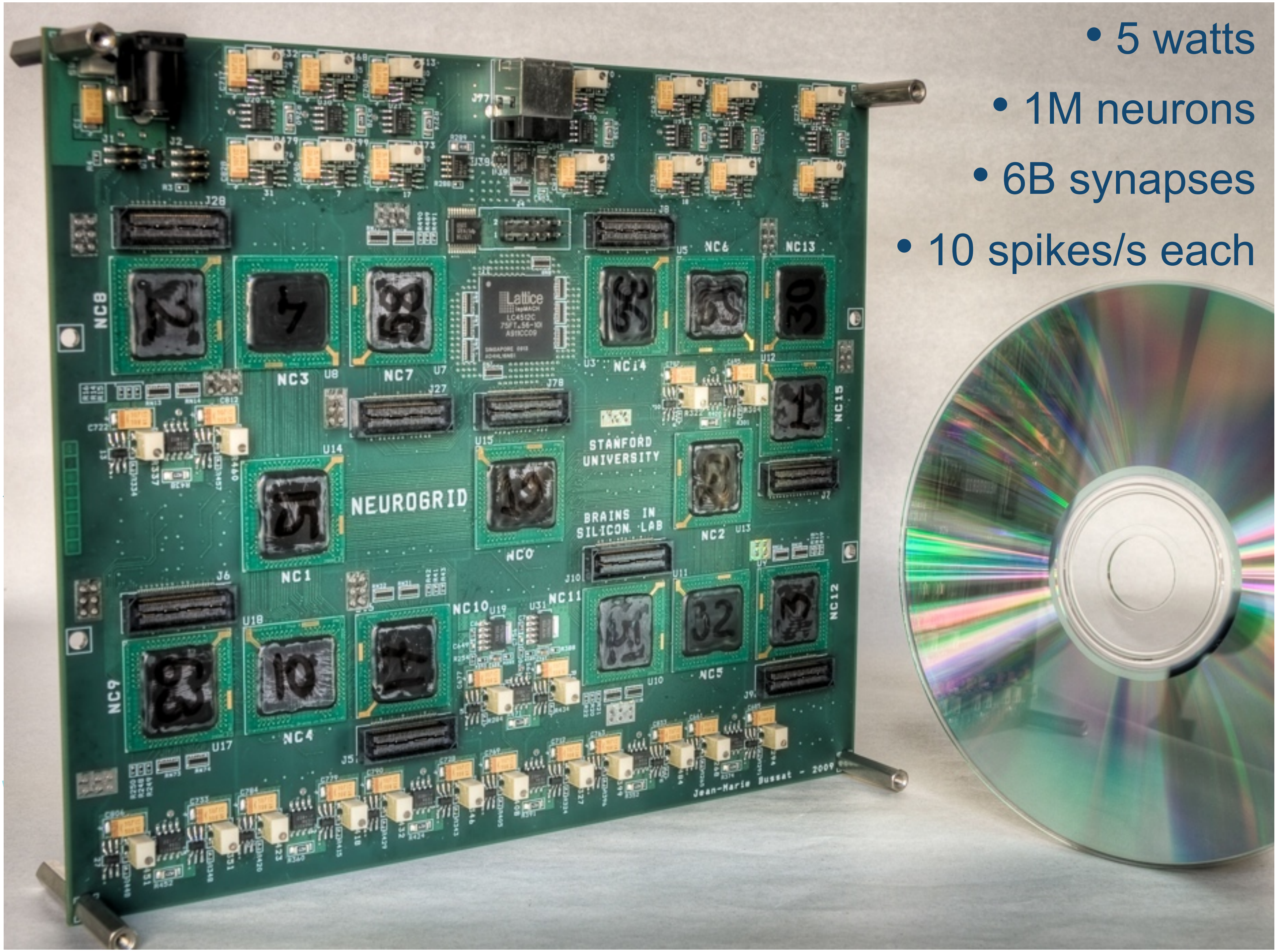
Brunsviga Model 20



2 Cores



4 Cores



- 5 watts
- 1M neurons
- 6B synapses
- 10 spikes/s each

NEUROGRID = 22 BG RACKS

	Chip	Board
Neurons	65K	1.0M
Syn/s	3.9G	63G
Watts	150m	5.0

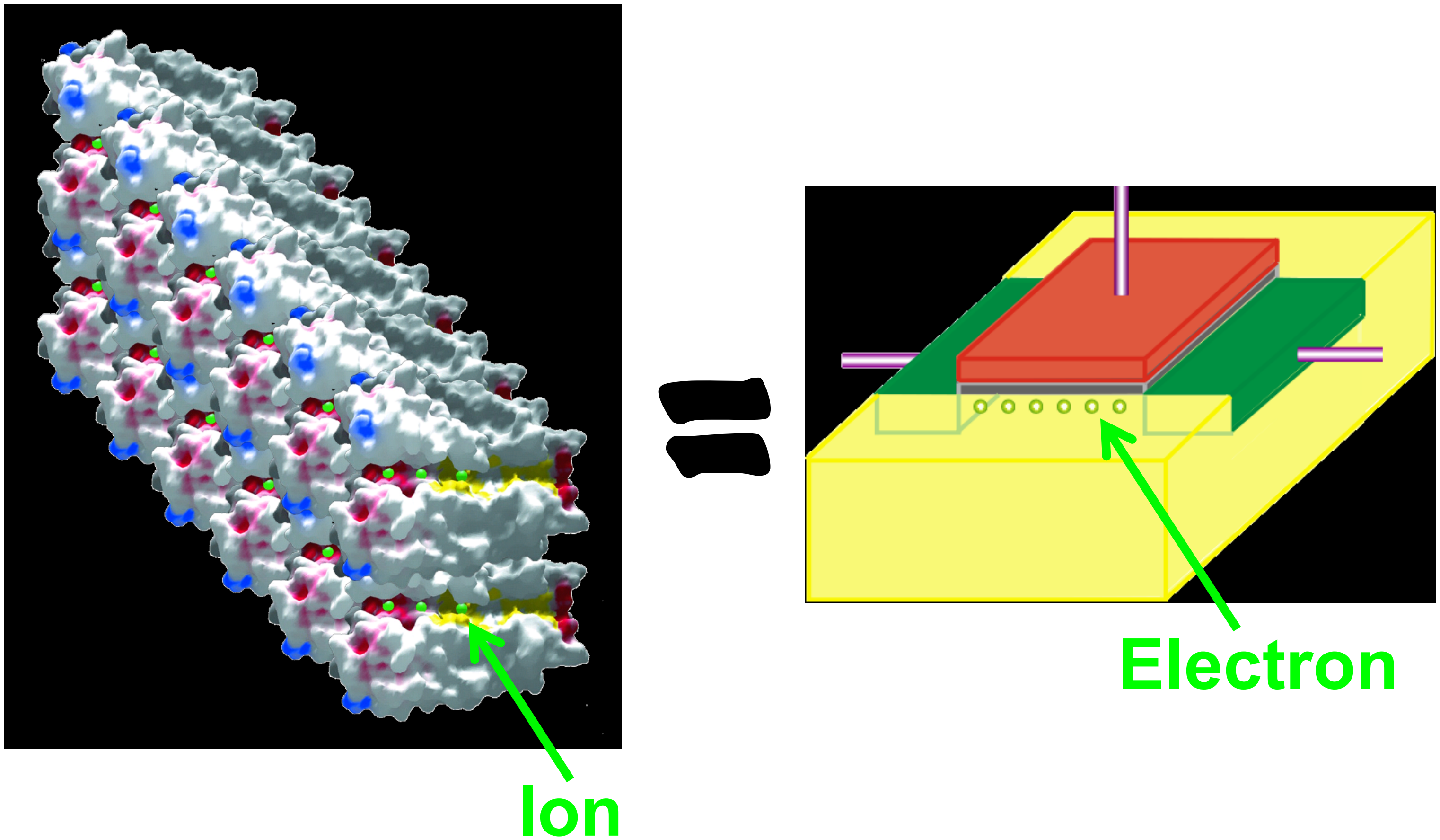
Syn/s	1	63G
Flops	1K	63T
Bytes/s	66	4.2T
Watts	10µ	0.63M

- 5W vs. 630,000W

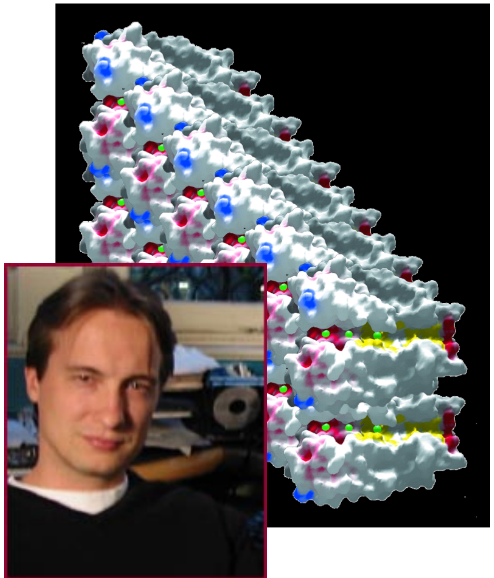
TOPICS COVERED

- What does a Neurogrid neuron have?
  - Upto four types of gating-variable populations
    - Every neuron in a chip have the same four types
  - Upto four types of synaptic populations
    - Every neuron in a chip have the same four types
  - Soma and dendrite
- How do Neurogrid neurons communicate?
  - Vertical, horizontal connections
  - Dendritic arbor
  - Bouton clusters

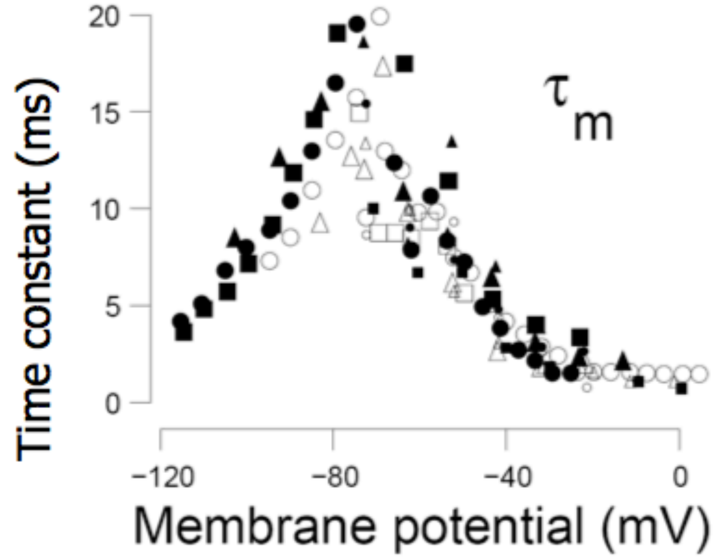
NEUROGRID NEURON


Ion
Electron

Ion-channel population

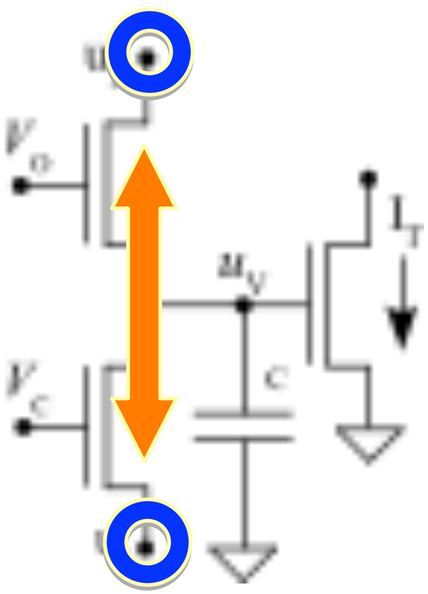


Kai Hynna

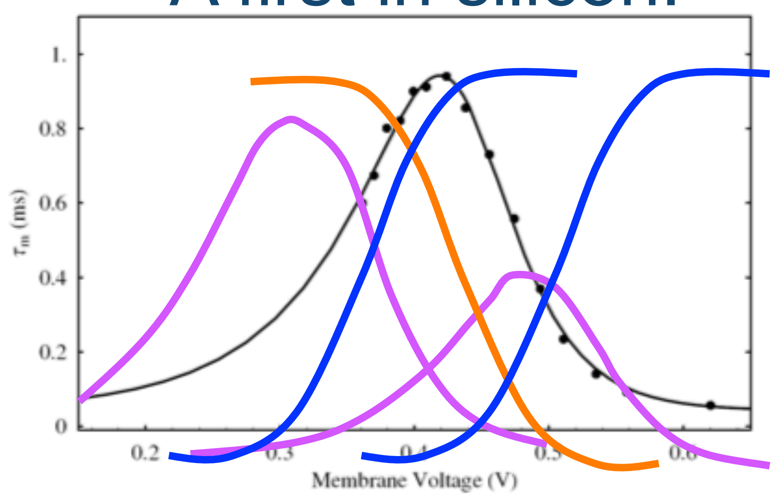


Huguenard & McCormick 1992

Transistor analog

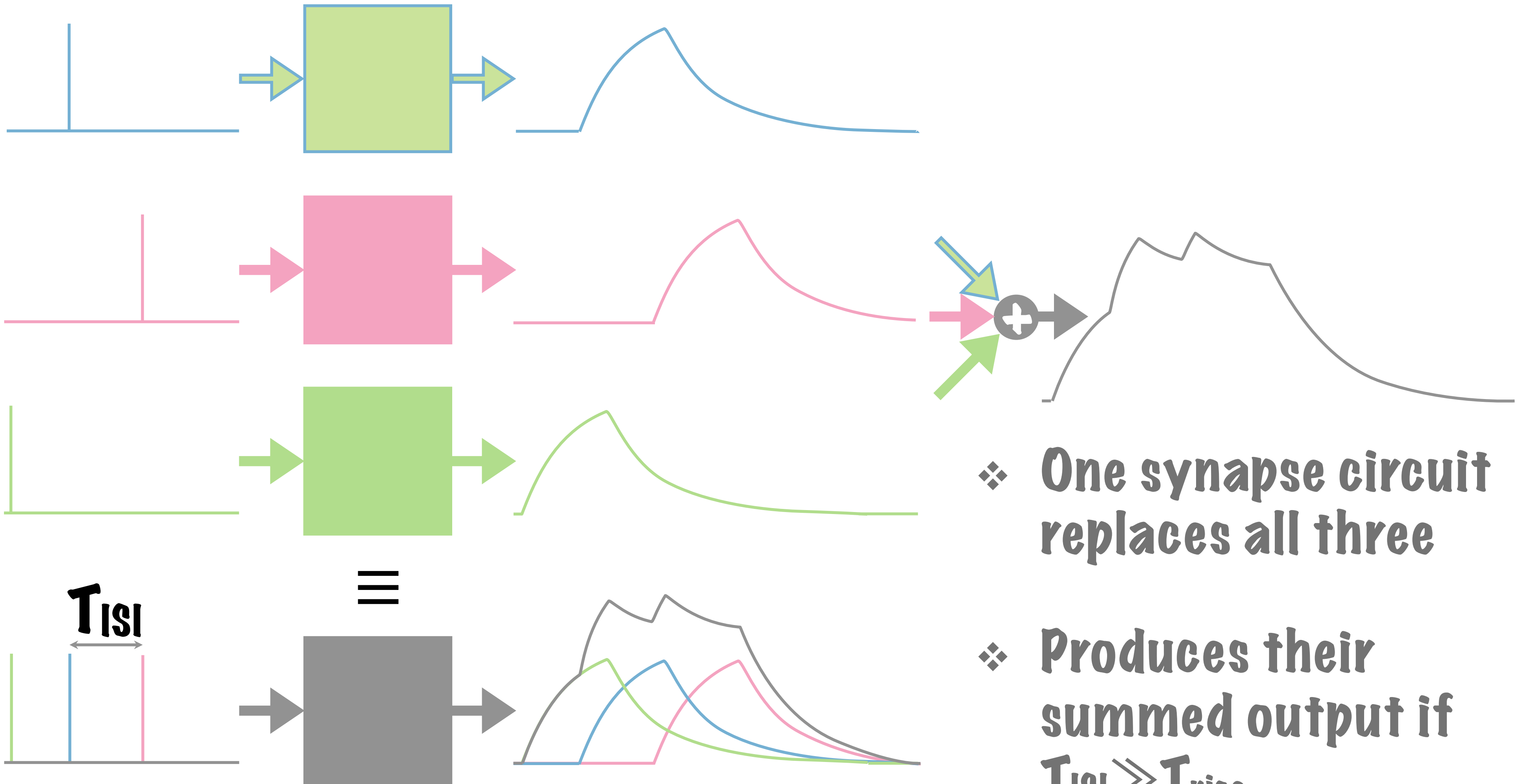


A first in silicon!



Hynna & Boahen 2006

SUPERPOSABLE SYNAPSE CIRCUIT



- One synapse circuit replaces all three
- Produces their summed output if $T_{ISI} \gg T_{rise}$

SOMA CIRCUIT

- $$\tau \dot{v} = -v + \frac{1}{2} v^2 + i_{in}$$

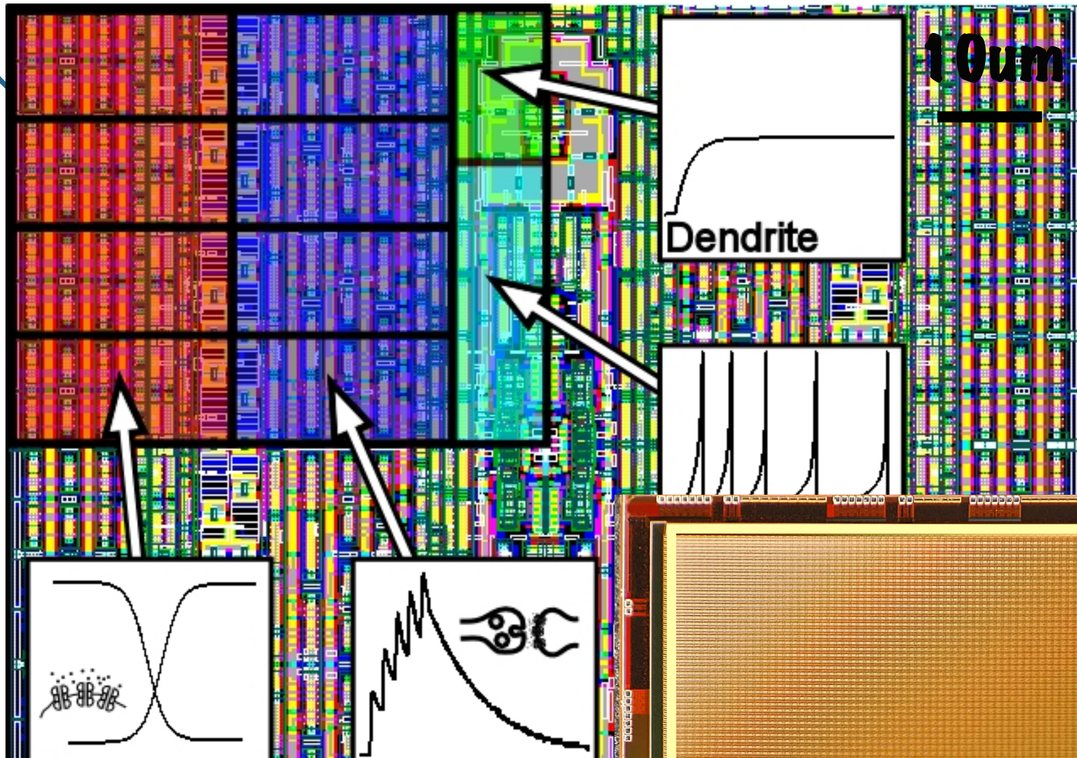
Quadratic neuron

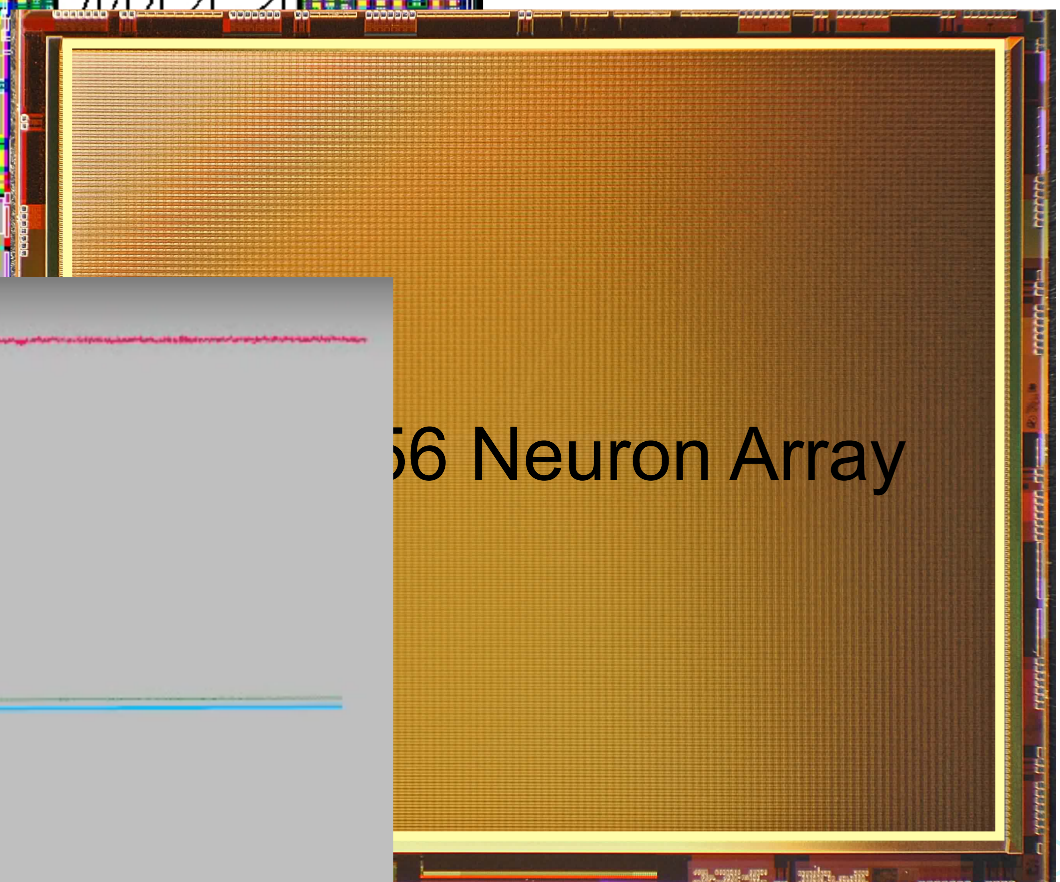
DENDRITE CIRCUIT

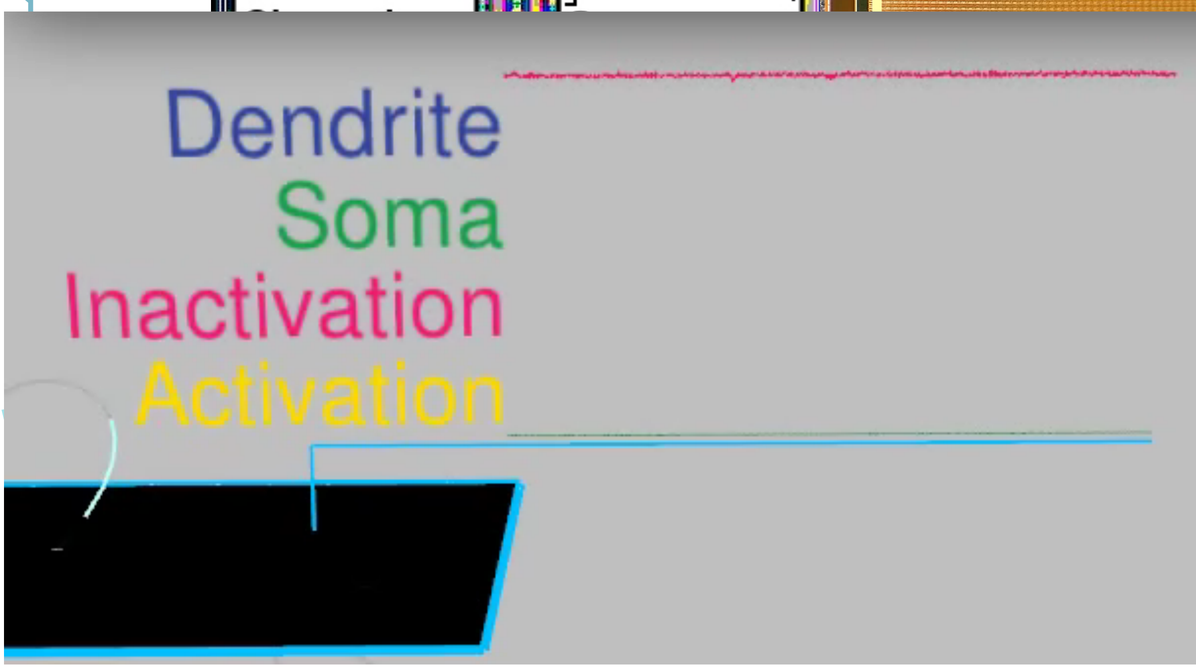
- $$\tau\dot{v} = -v + i_{in}$$

Passive dendrite

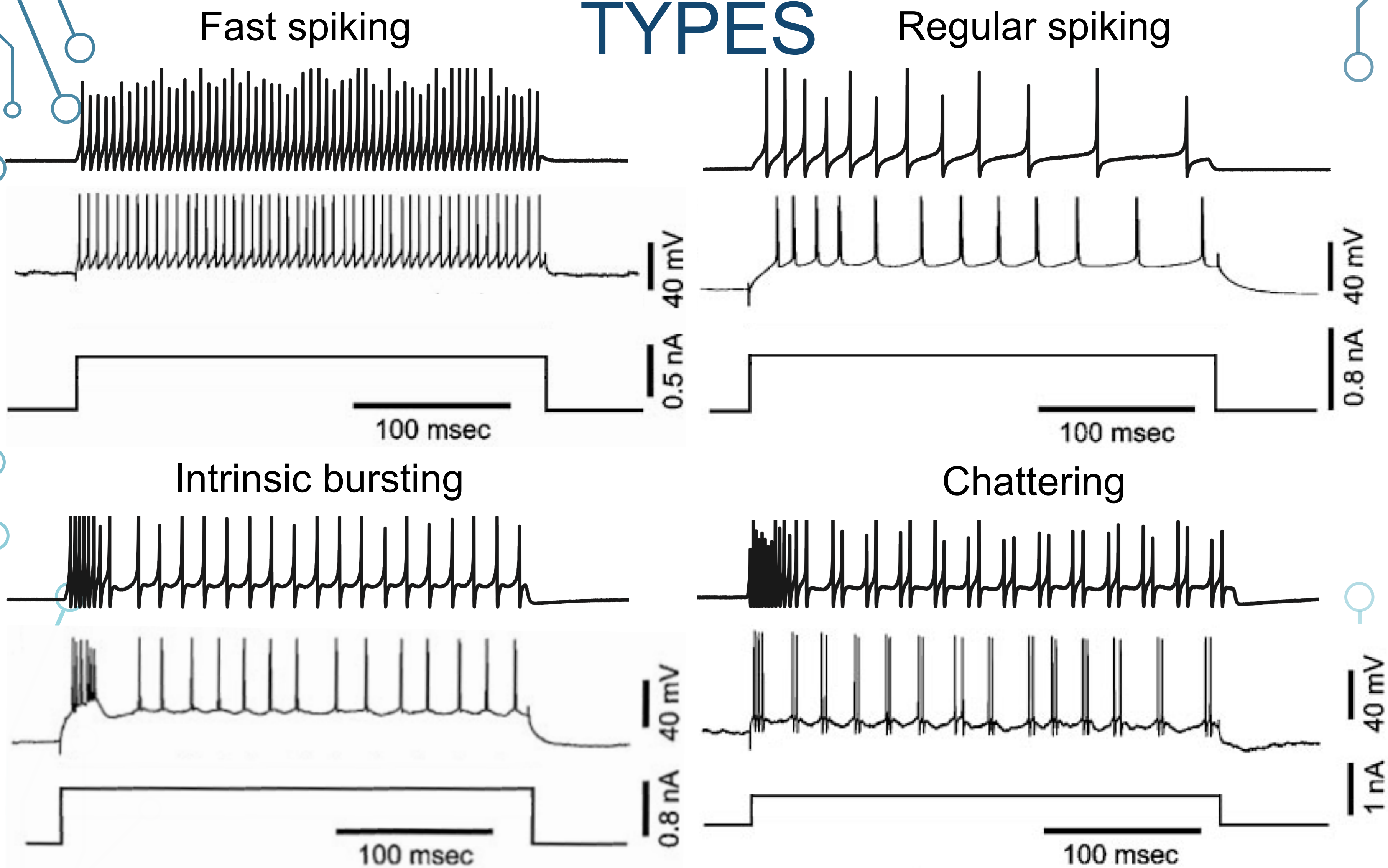
65,536 neurons
23M transistors
160 mm^2
0.18 um CMOS
50-150 mW





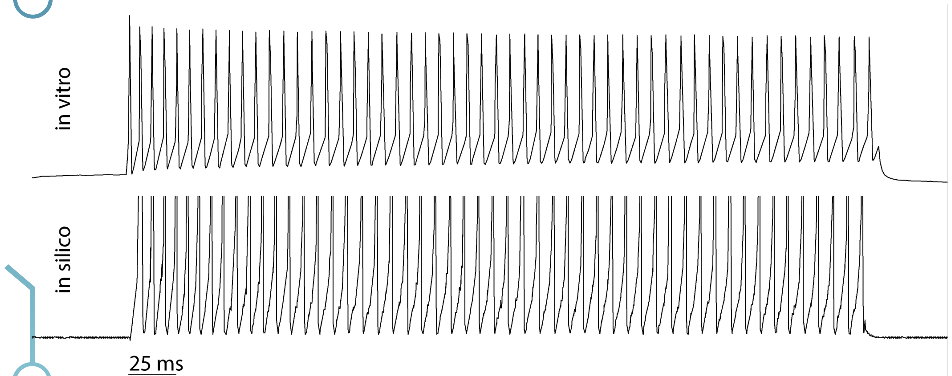


MODELING CORTICAL CELL TYPES

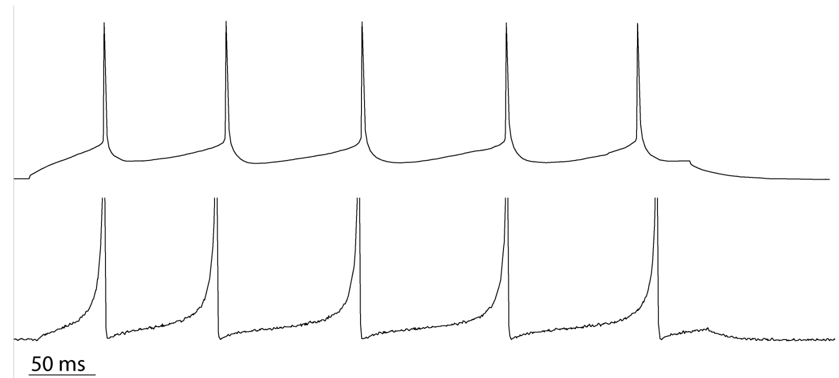


MODELING CORTICAL CELL TYPES

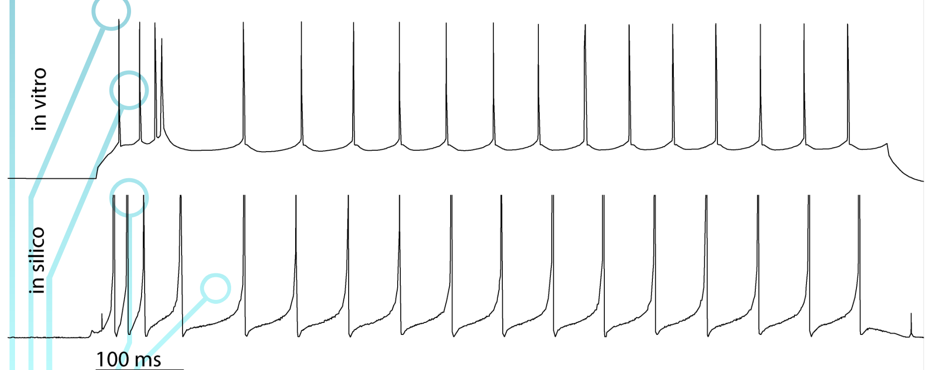
Fast spiking



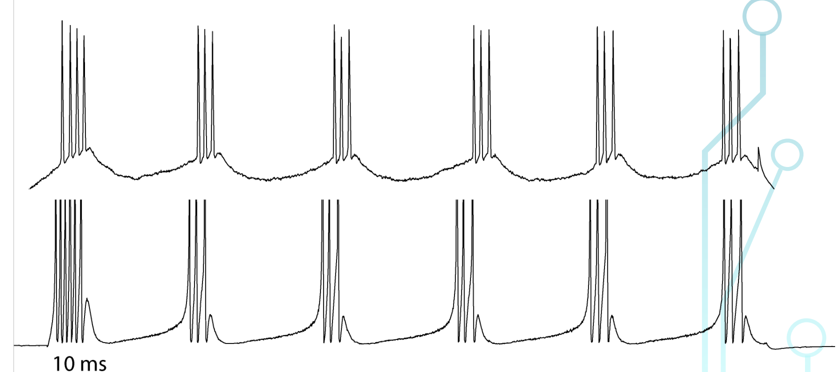
Regular spiking



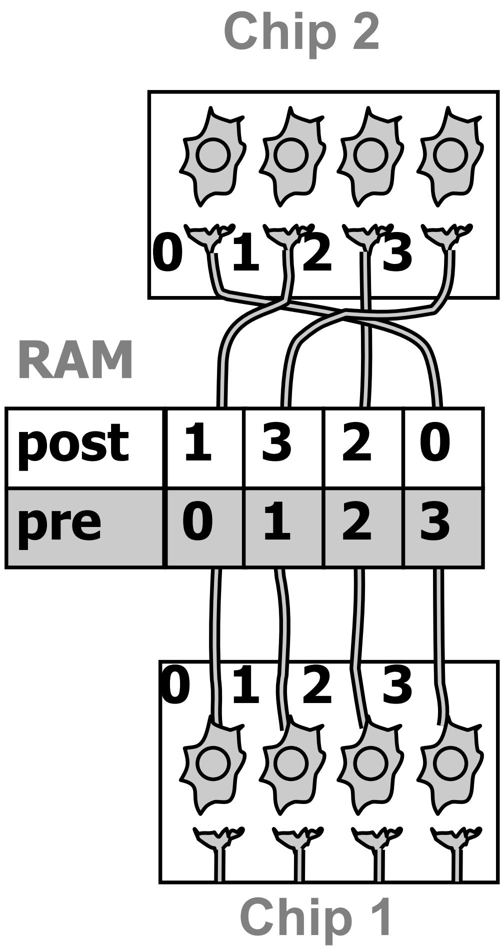
Intrinsic bursting



Chattering

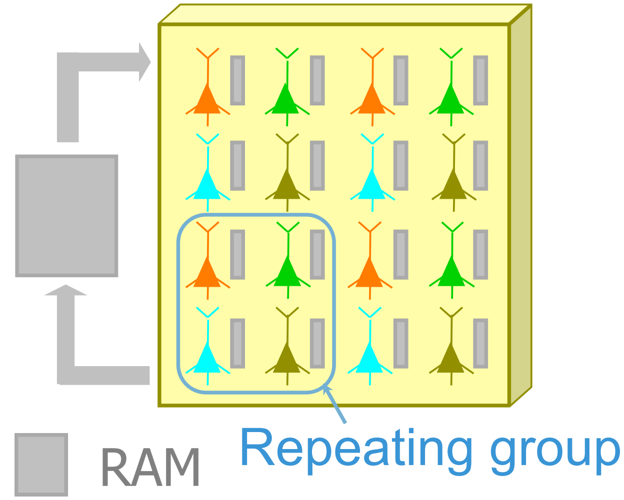


NEUROGRID COMMUNICATION

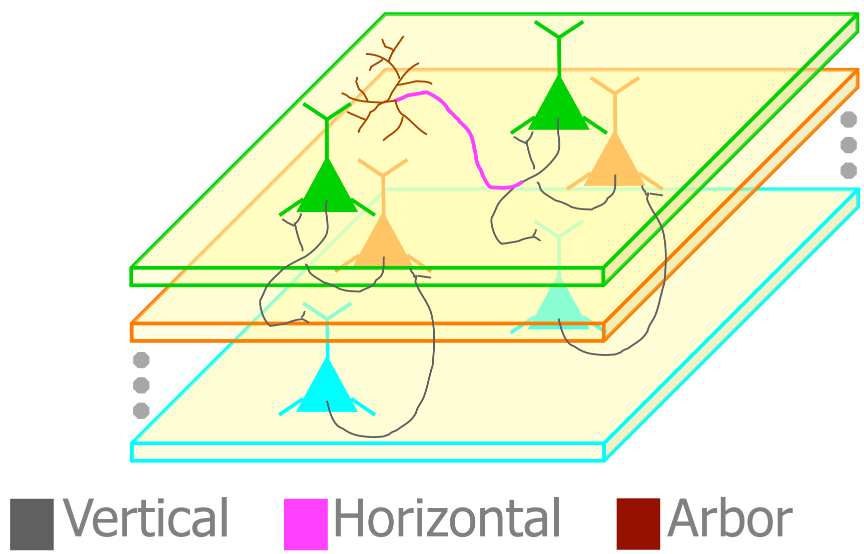


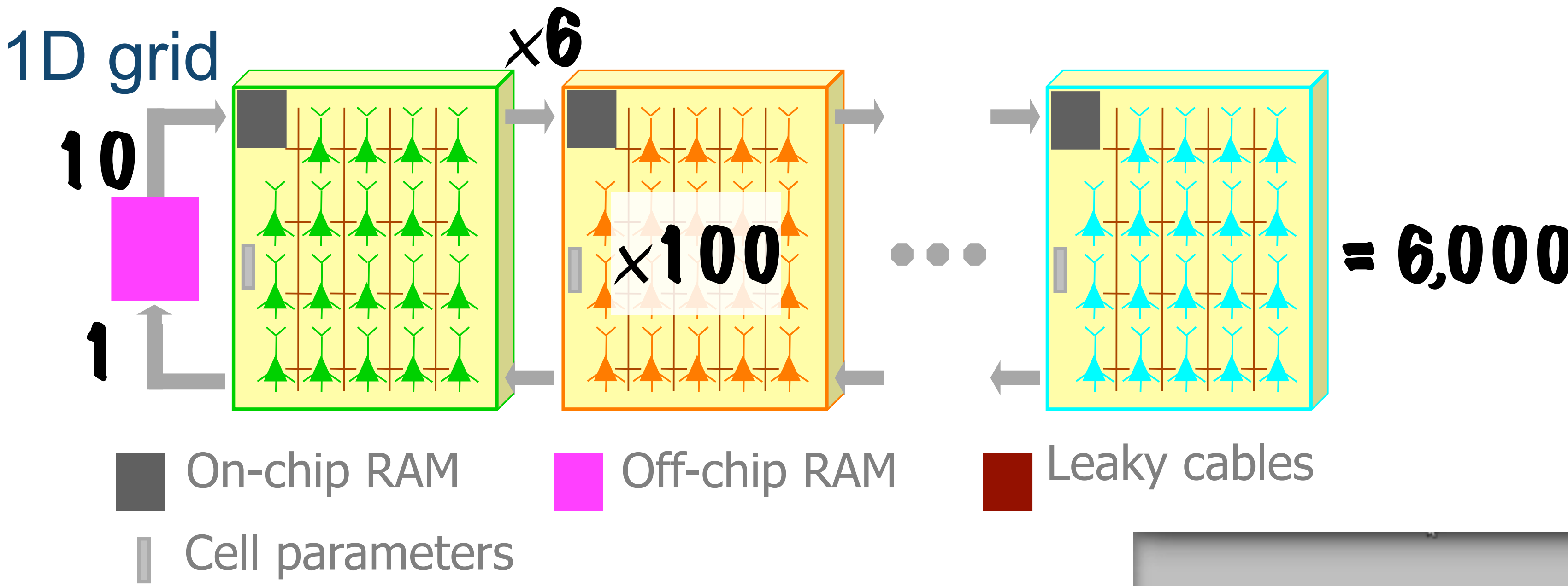
Sivilotti 1992
Mahowald 1994
Deiss et al. 1999
Boahen 2001
Boahen 2004
Merolla et al. 2007

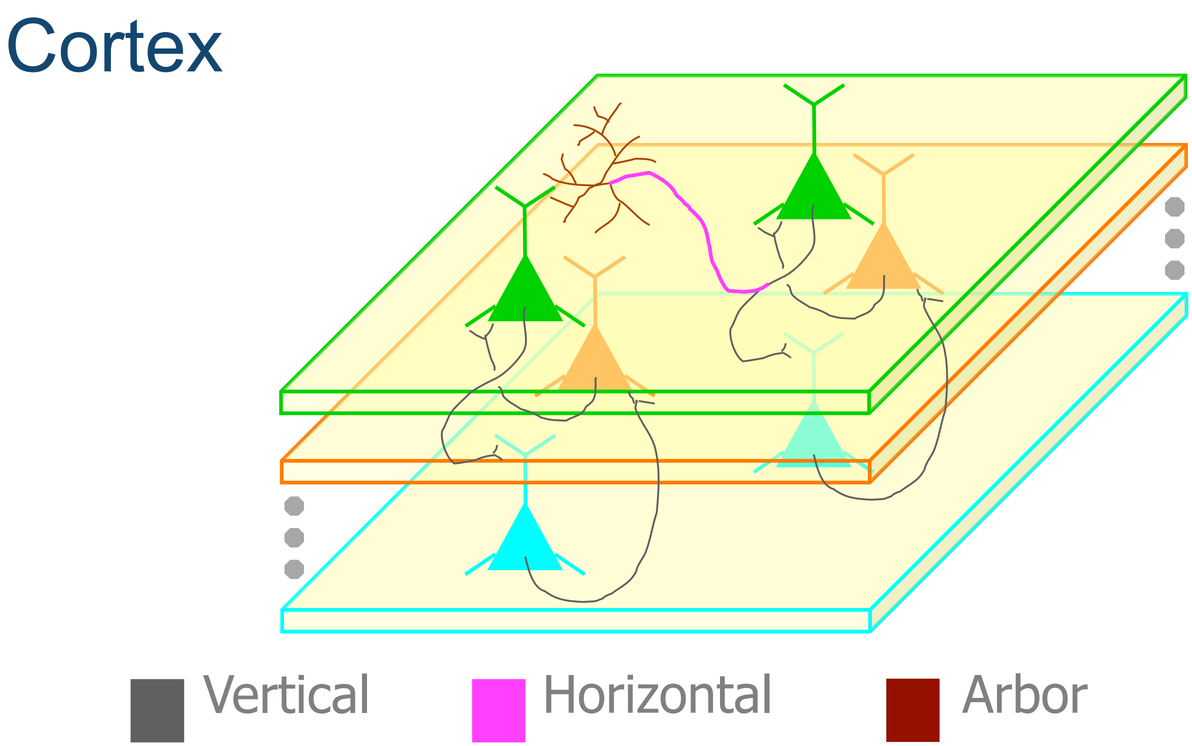
Neuromorphic chip

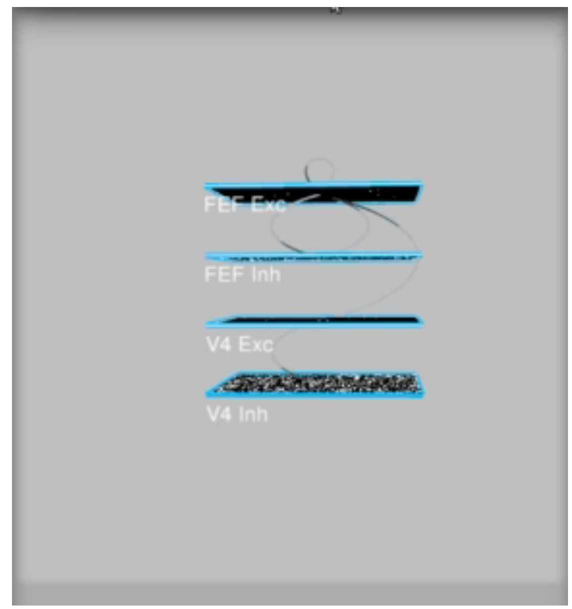


Cortex

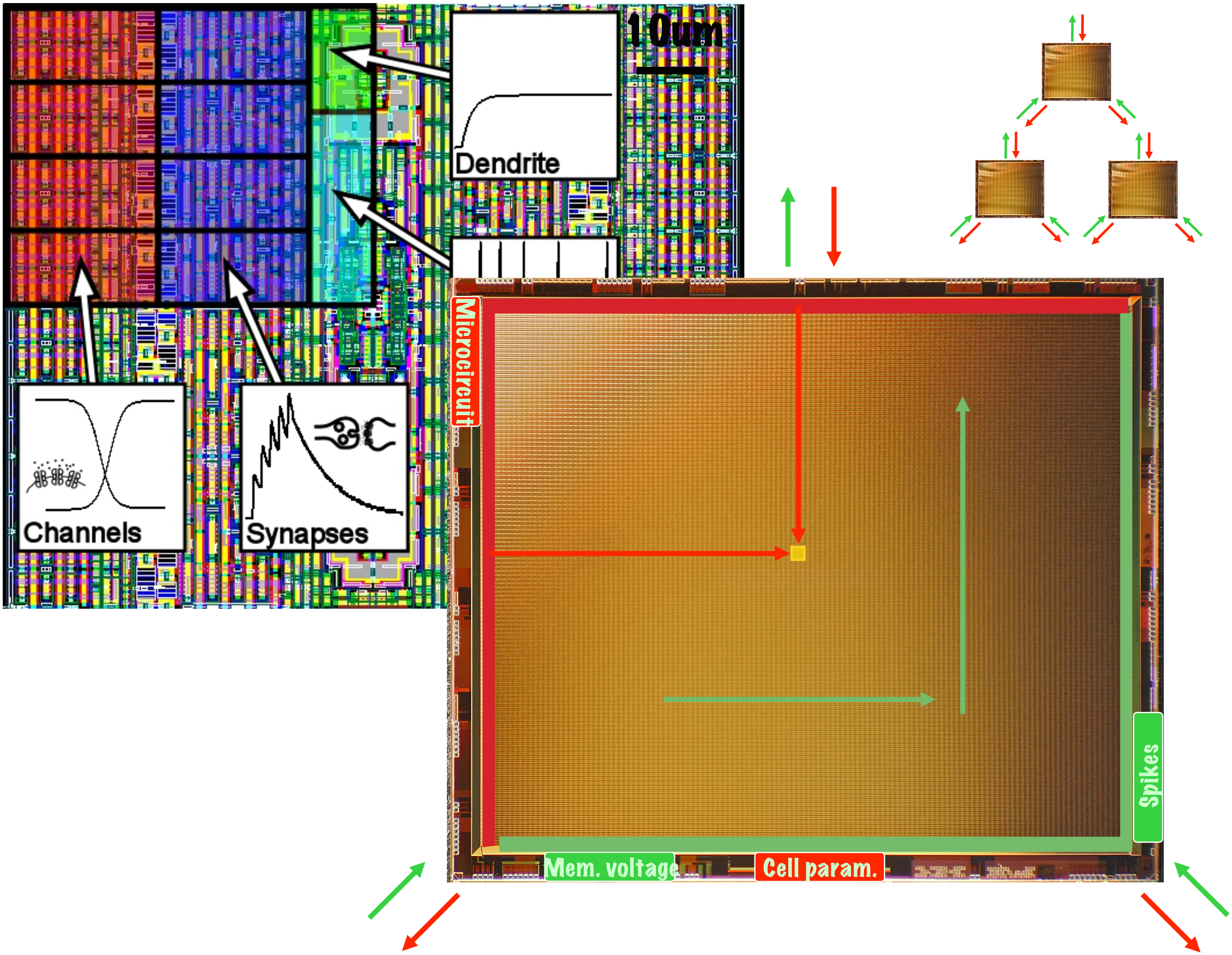




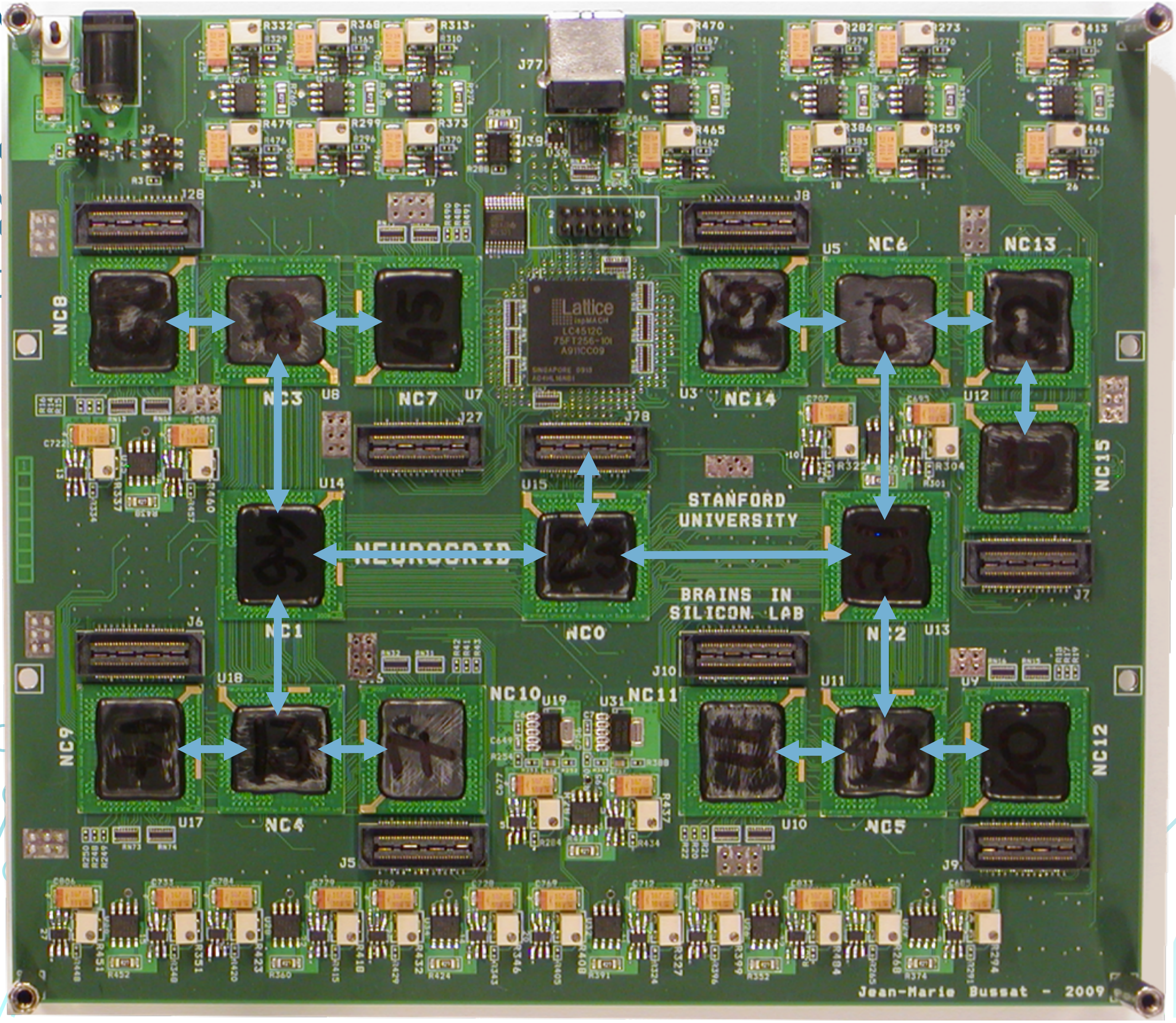


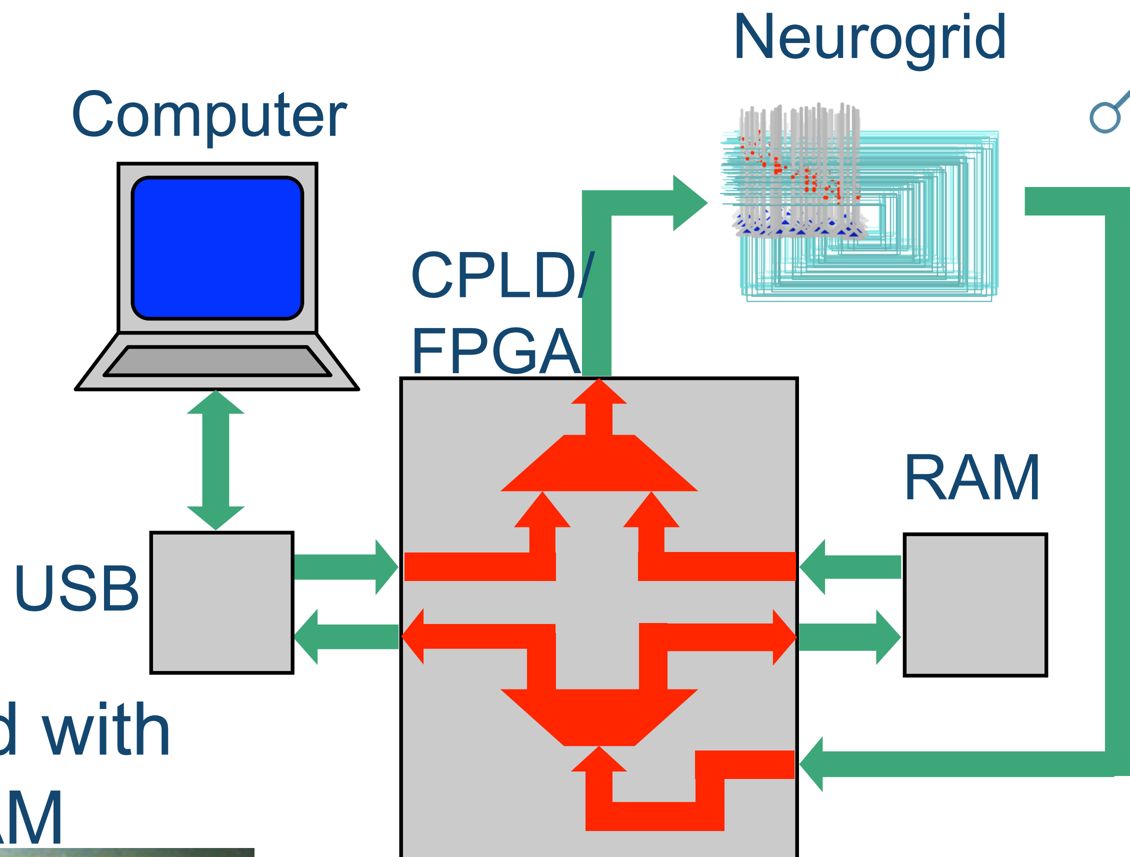


Model with 65K neurons and 70M synapses

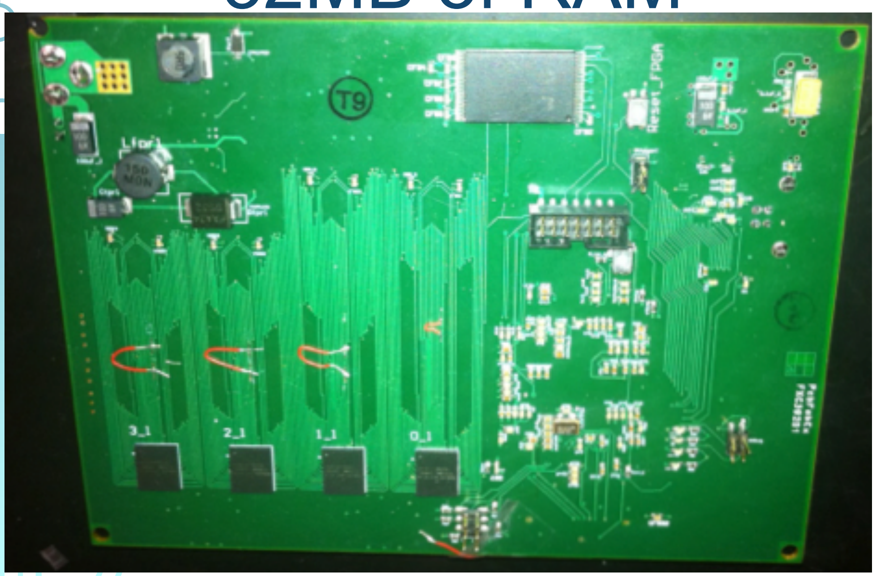


10um
Dendrite
Channels
Synapses
Microcircuit
Spikes
Mem. voltage
Cell param.


NC8
NC3
NC7
NC6
NC13
NC14
NC15
NC1
NC0
NC2
NC9
NC4
NC10
NC11
NC5
NC12
NEUROGRID
STANFORD
UNIVERSITY
BRAINS IN
SILICON LAB
Jean-Marie Bussat - 2009



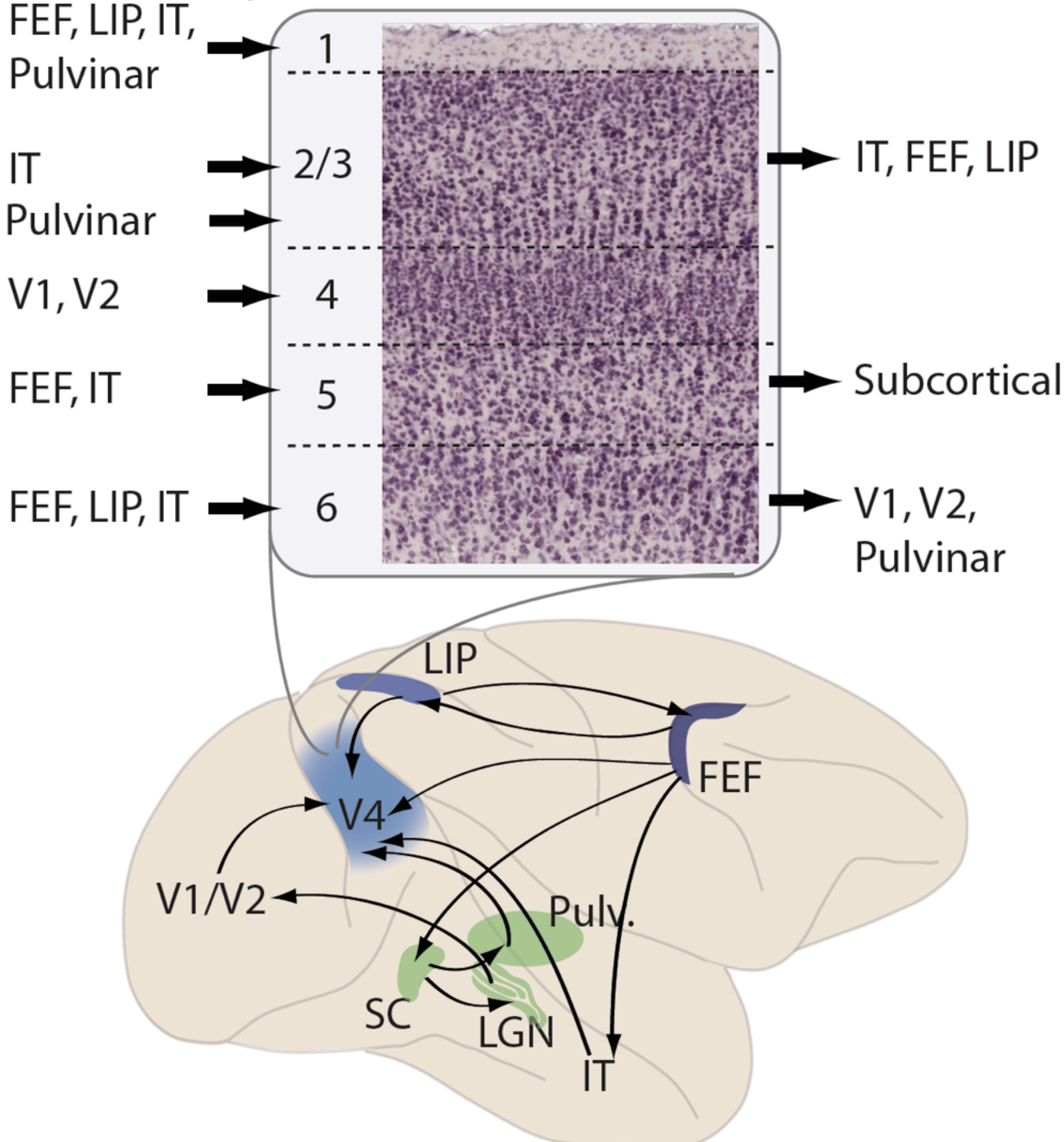
Daughter Board with 32MB of RAM



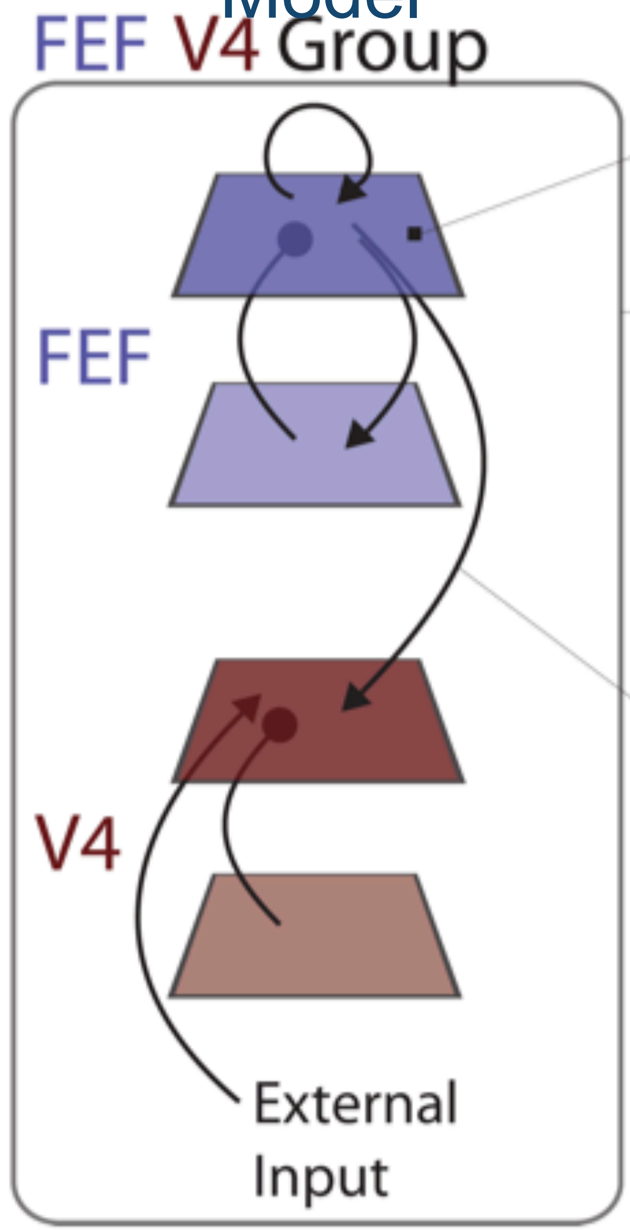
EXAMPLE

SIMULATING A V4-FEF CORTICAL MODEL ON NEUROGRID

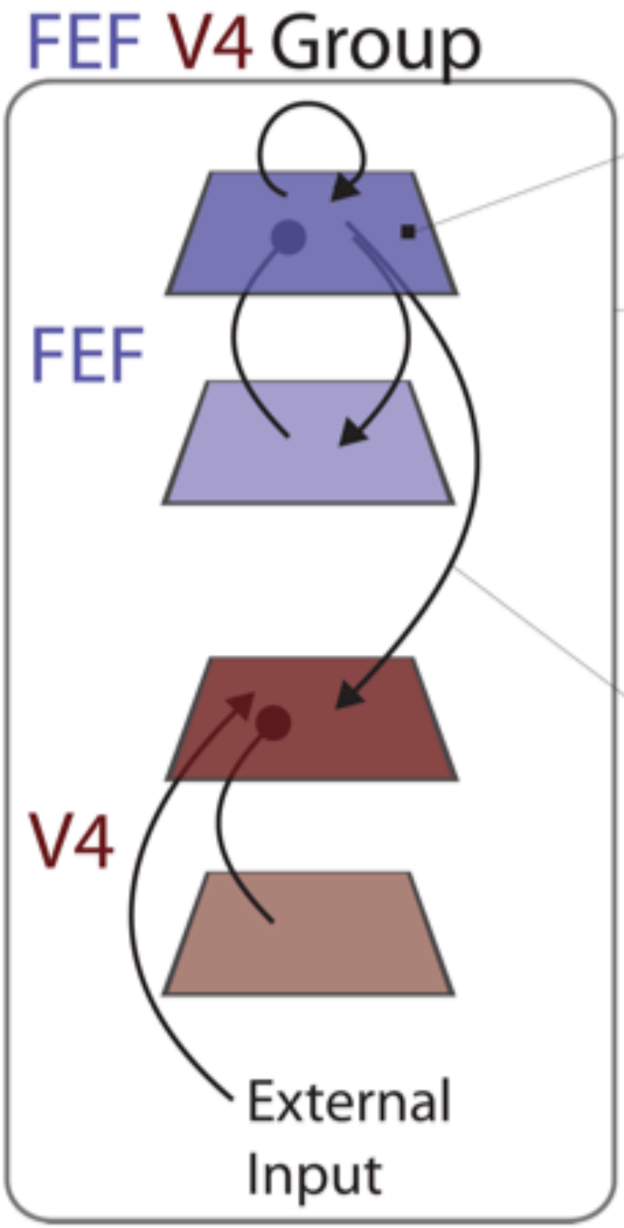
Possible projections subserving spatial attention in V4



V4-FEF Model



Programming the model on Neurogrid



Step 1: Describe Neuron Model

```
fef_layer1_soma = Soma("quadratic", {"tau_ref": 1e-3, "tau":
fef_layer1_neuron = Neuron("quadratic", fef_layer1_soma)
```

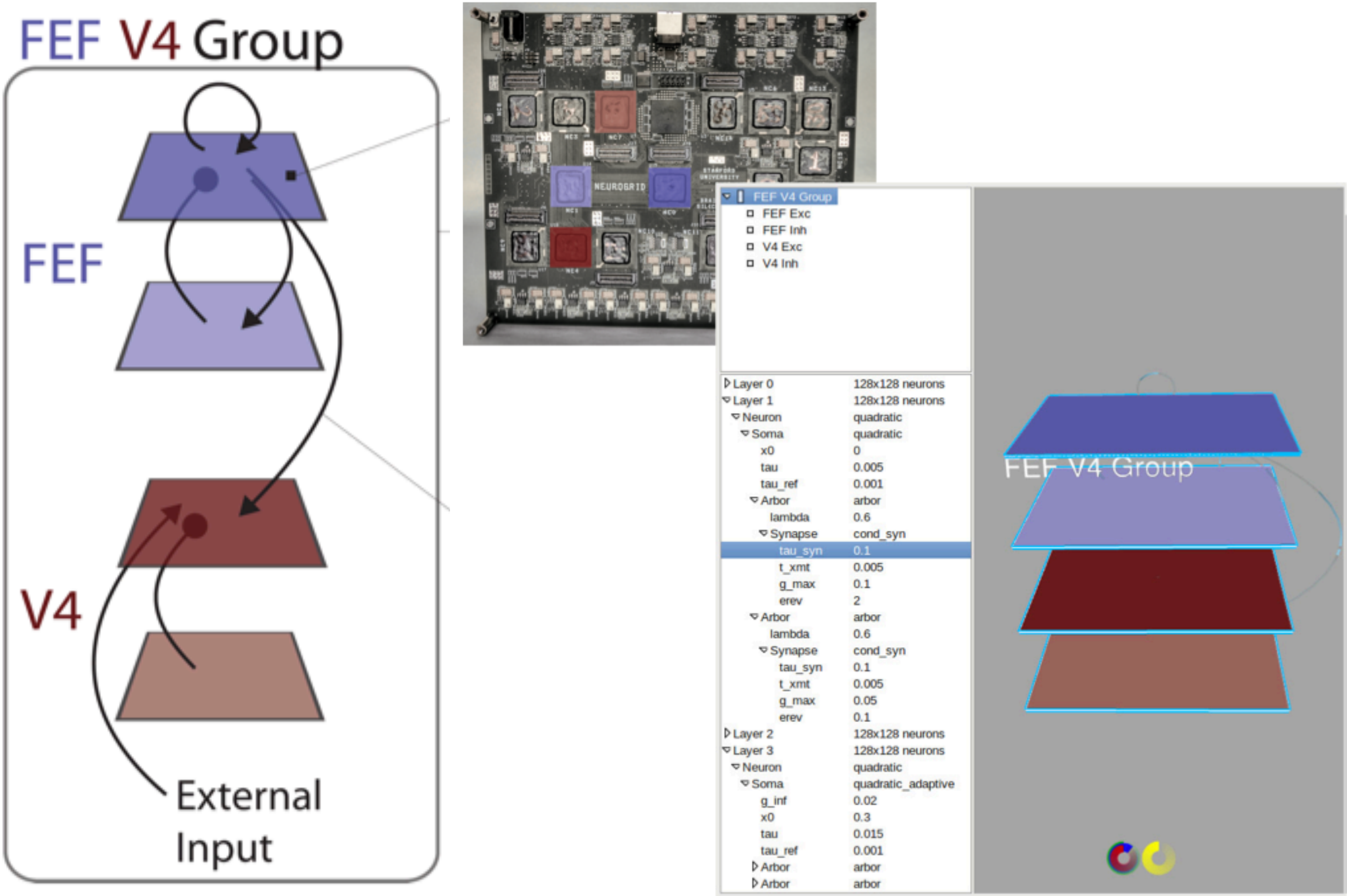
Step 2: Describe Network Heirarchy

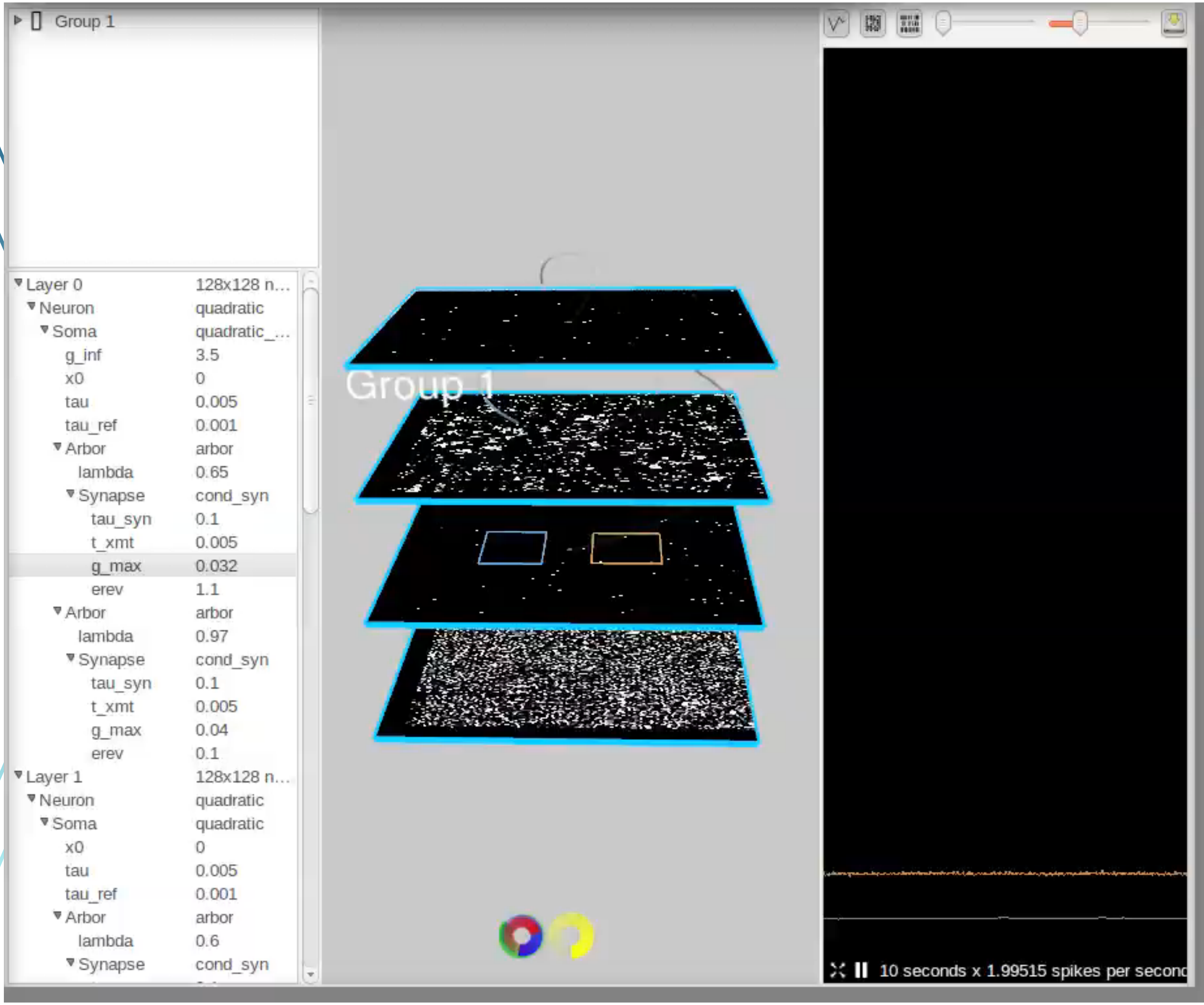
```
fef_v4_group = Group("FEF V4 Group")
fef_layer1 = Pool(fef_layer1_neuron, width, height)
fef_layer2 = Pool(fef_layer2_neuron, width, height)
v4_layer1 = Pool(v4_layer1_neuron, width, height)
v4_layer2 = Pool(v4_layer2_neuron, width, height)
fef_v4_group.AddChild(fef_layer1)
fef_v4_group.AddChild(fef_layer2)
fef_v4_group.AddChild(v4_layer1)
fef_v4_group.AddChild(v4_layer2)
```

Step 3: Describe Connnections

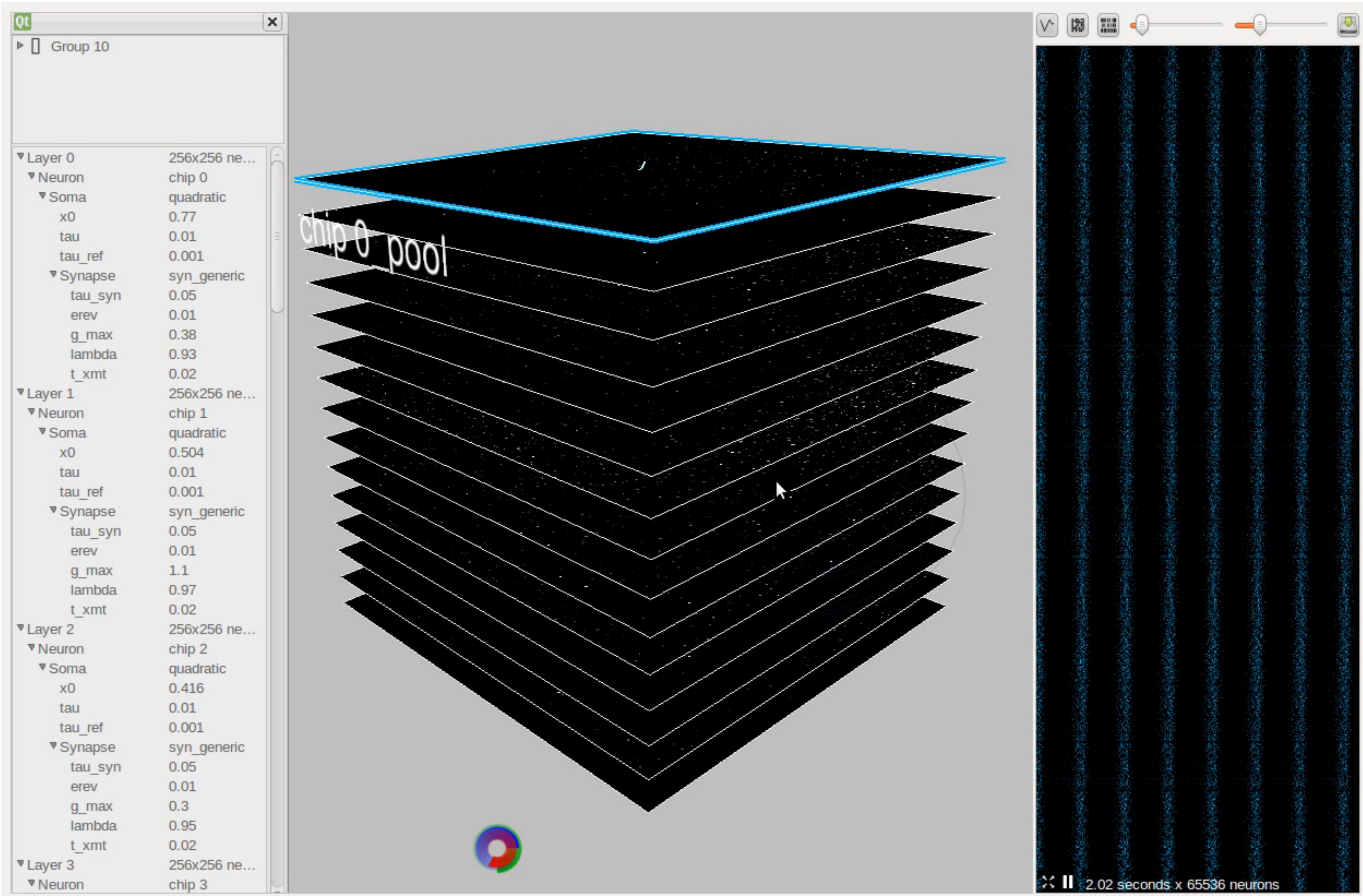
```
fef_v4_group.VerticalProject(fef_layer1.Output(0), v4_layer1.
```

Running the model on Neurogrid




Group 1
Layer 0 128x128 n…
Neuron quadratic
Soma quadratic_…
g_inf 3.5
x0 0
tau 0.005
tau_ref 0.001
Arbor arbor
lambda 0.65
Synapse cond_syn
tau_syn 0.1
t_xmt 0.005
g_max 0.032
erev 1.1
Arbor arbor
lambda 0.97
Synapse cond_syn
tau_syn 0.1
t_xmt 0.005
g_max 0.04
erev 0.1
Layer 1 128x128 n…
Neuron quadratic
Soma quadratic
x0 0
tau 0.005
tau_ref 0.001
Arbor arbor
lambda 0.6
Synapse cond_syn
Group 1
10 seconds x 1.99515 spikes per second


John Arthur
Paul Merolla
Anand Chandrasekaran
Chris Sauer
Jean-Marrie Bussat
Rodrigo Alvarez
Kai Hynna
Ben Benjamin
Peiran Gao
Nick Steinmetz
Daniel Niel
Emmett McQuinn
Swadesh Choudhary
Tirin Moore
NIH Director's Pioneer Award


Group 10
Layer 0 256x256 ne...
Neuron chip 0
Soma quadratic
x0 0.77
tau 0.01
tau_ref 0.001
Synapse syn_generic
tau_syn 0.05
erev 0.01
g_max 0.38
lambda 0.93
t_xmt 0.02
Layer 1 256x256 ne...
Neuron chip 1
Soma quadratic
x0 0.504
tau 0.01
tau_ref 0.001
Synapse syn_generic
tau_syn 0.05
erev 0.01
g_max 1.1
lambda 0.97
t_xmt 0.02
Layer 2 256x256 ne...
Neuron chip 2
Soma quadratic
x0 0.416
tau 0.01
tau_ref 0.001
Synapse syn_generic
tau_syn 0.05
erev 0.01
g_max 0.3
lambda 0.95
t_xmt 0.02
Layer 3 256x256 ne...
Neuron chip 3
chip 0_pool
2.02 seconds x 65536 neurons

FOR THIS CLASS

- Single-compartment, fast or regular-spiking neuron with quadratic or cubic positive feedback
- Conductance-based synapses with arbitrary Erev
- Local arbors with programmable space-constant
- No dendrite; no channels; no NMDA (not calibrated)
- USB Bandwidth: 2.5 to 10 Mspk/sec (burst mode)
- Daughterboard Fanout x Spike-Rate: 5 Mspk/sec
- Weights using probabilistic synapses