PCSIM – Parallel neural Circuit SIMulator

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Outline

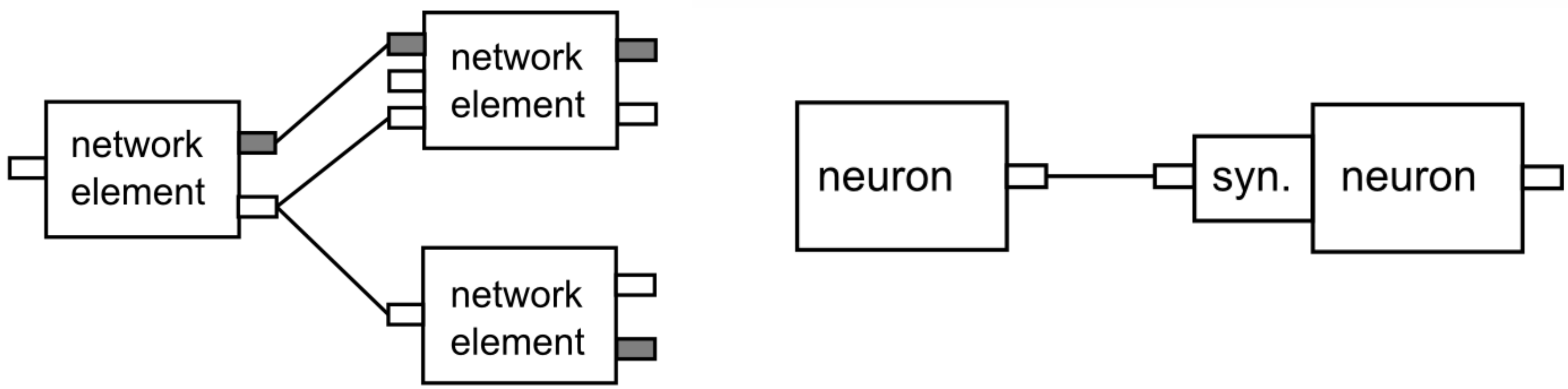
- PCSIM overview
- Bidirectional Python interface
- Network construction framework
  - Basic constructs
  - Distributed wiring algorithms
    - Supported connectivity patterns
    - Efficiency and scaling

PCSIM – Parallel neural Circuit SIMulator

- Supports distributed simulation of large spiking and analog neural networks with point neuron models.
- Implemented in C++ with a primary interface in Python
  - there is a new Java interface
- Runs under Linux, possible to port on other GNU based systems.
- Experimental support for loading NetworkML files
- Supports the standardized PyNN interface.

PCSIM – Parallel neural Circuit SIMulator Ctd.

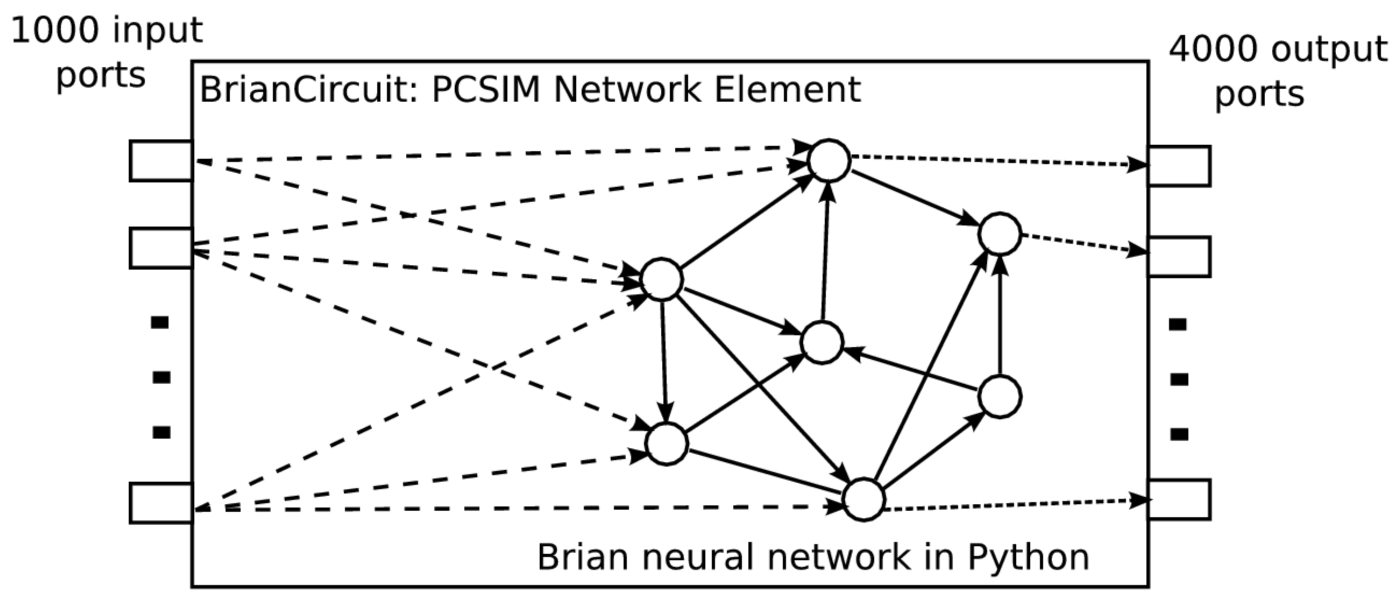
- **Generic** network elements
  - multiple input and output, spiking and analog ports
  - suitable for hybrid simulations of spiking and analog elements, more abstract modules, neuromodulators.



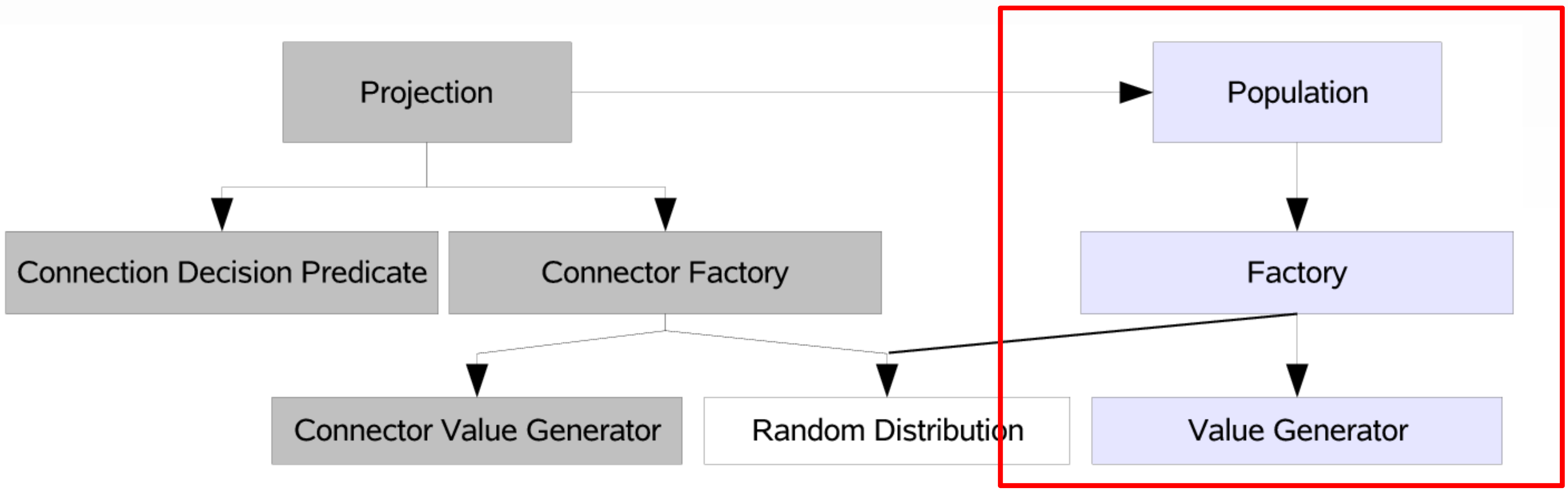
Bidirectional Python Interface: Brian Network in PCSIM

```
class BrianCircuit(PySimObject):
  def __init__( self ):
    .
    self.registerSpikingOutputPorts(arange(4000))
    self.registerSpikingInputPorts(arange(1000))
    input = PCSIMInputNeuronGroup(1000, self)
    .
    .
    self.brian = brian.Network(input, P, Ce,
                               Ci, Cinp )
    .

  def reset(self, dt):
    .
    .

  def advance(self, ai):
    .
    .
    self.brian.update()
    self.brian.clock.tick()
    .
```

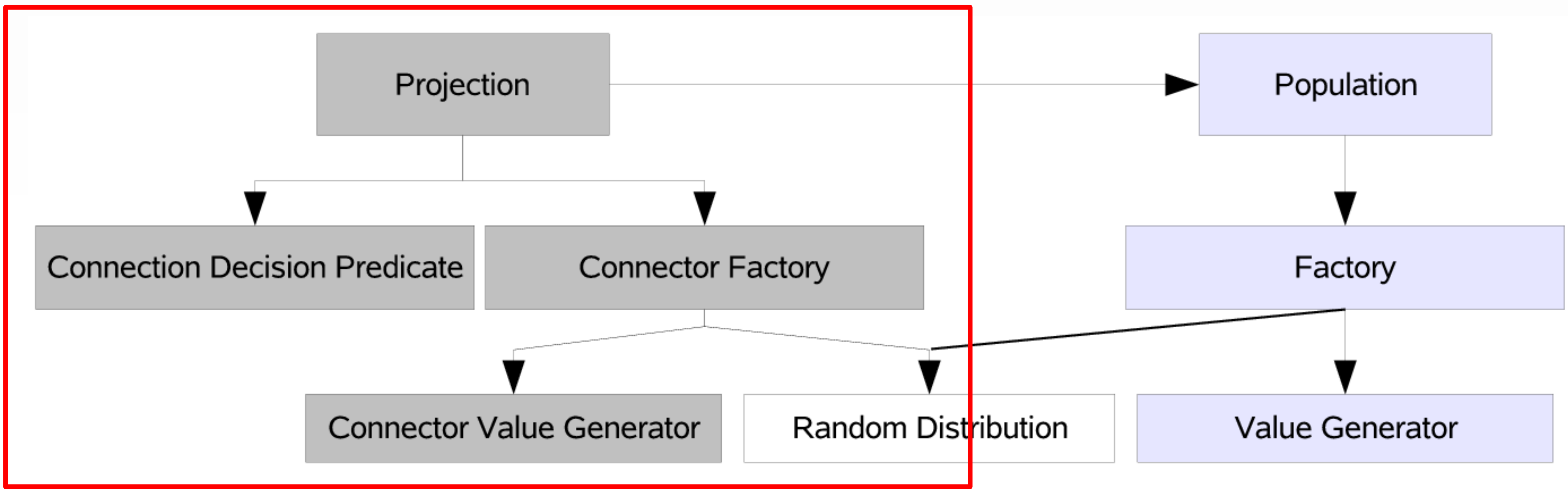
```
net = SingleThreadNetwork()
pycirc = BrianCircuit()
pycirc_id = net.add(pycirc)
.
.
net.simulate(2.0)
```



Network Construction: Creating Neurons



Network Construction: Creating Connections



Distributed Wiring Algorithms

- Different types of connectivity patterns available
  - **Random –** decision whether to make a connection sampled from a Bernoulli Distribution
  - **Degree based** - the input/output degree of neurons is sampled from a arbitrary random distribution
  - **Predicate based** - independently deciding for each pair of neurons whether to connect them, probabilistically, based on their attributes

- **Example**: creating patchy long -range lateral connections of V1 neurons (Buzas et al. 2006)
  - The probability to connect neurons i and j is

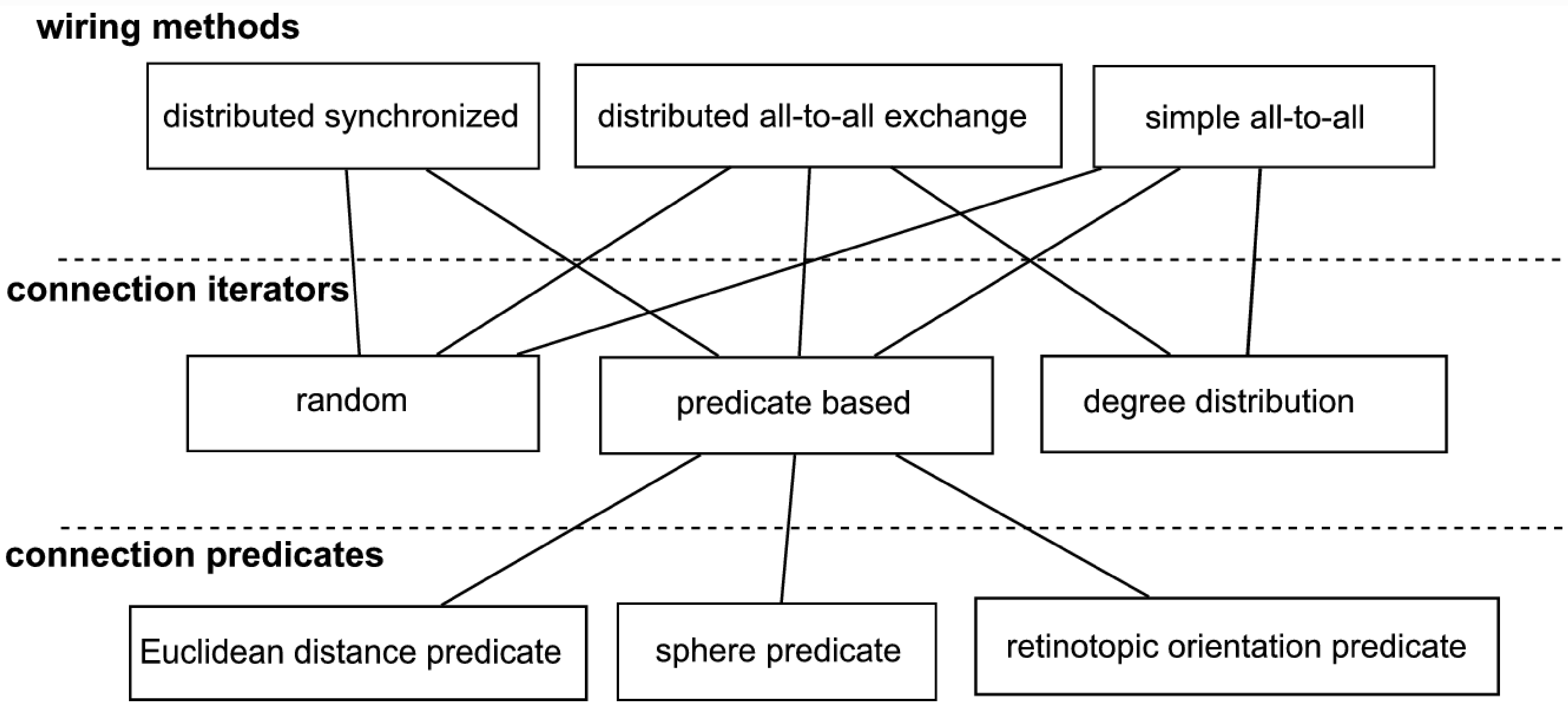
$$P(\mathbf{l_i}, \mathbf{l_j}, \phi_i, \phi_j) = C\, G(\mathbf{l_i}, \mathbf{l_j})\, V(\phi_i, \phi_j)$$

$$G(\mathbf{l_i}, \mathbf{l_j}) = e^{-\frac{|\mathbf{l_i} - \mathbf{l_j}|^2}{2\sigma^2}}$$

$$V(\phi_i, \phi_j) = e^{\kappa \cos 2(\phi_i - \phi_j)}$$

where l_i and l_j are the lateral coordinates,
ϕ_i and ϕ_j are the orientation preferences of neurons i and j and
C, κ, σ are parameters.

Three Levels of the Wiring Algorithms



Wiring Methods

- **distributed synchronized**
  - Each node creates both its outgoing and incoming connections.
  - no MPI communication
  - A pair of nodes use the same RNG seeds when creating connections between them in order to synchronize.

- **distributed all-to-all exchange**
  - Each node creates its incoming connections.
  - Created connections are communicated through MPI.

Distributed Wiring Algorithms: Scalability

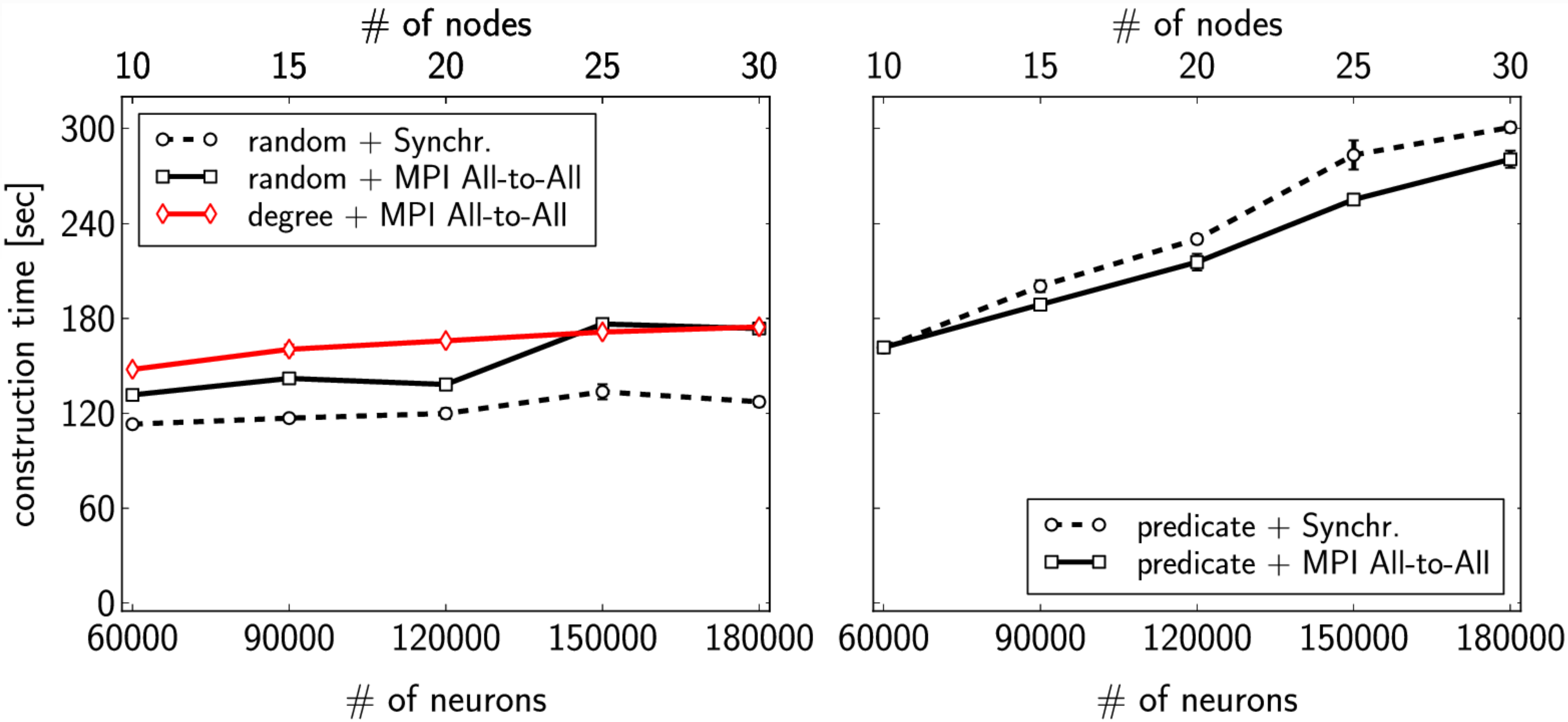
- We measured the construction time of a model where the number of used nodes increase proportionally with the number of neurons.

- In the performed experiments there are
  - 6000 neurons per node
  - on average 10000 input connections per neuron for all wiring algorithms

- Wiring methods tested:
  - Distributed Synchronized
  - Distributed All-To-All Exchange

- Wiring algorithms tested:
  - **random**
  - **degree** – each neuron has exactly 10000 input connections
  - **predicate** – distance dependent connection probability

Measured Construction Time



If you want to try out PCSIM

- The home page is: http://www.igi.tugraz.at/pcsim
  - User manual & examples
  - Tutorial & exercises

- The source is hosted at

  http://www.sourceforge.net/projects/pcsim

- Active mailing list at Sourceforge

- Released under GNU Public License

- Publication about PCSIM

  Pecevski D, Natschläger T and Schuch K (2009) PCSIM: a parallel simulation environment for neural circuits fully integrated with Python. *Front. Neuroinform.* 3:11.