# TVB-NEST: Bridging multiscale activity by co-simulation

## Step-by-step learn how to perform a co-simulation embedding spiking neural networks into large-scale brain networks using TVB.

### Izhikevich Spiking network model in NEST

For every neuron $i$ in region node $n$ modelled in NEST as a spiking network:

Membrane

potential:

$$\dot{V}_m = n_2 V_m^2 + n_1 V_m + n_0 140 - U_m/C - g_{AMPA}(V_m - E_{AMPA}) - g_{GABA}(V_m - E_{GABA}) -$$

where the conductances follow the equations:

$$\dot{g}_{AMPA} = -g_{AMPA}/\tau_{AMPA} + \left[\sum_k \delta(t - t_k)\right]_{Exc}$$

$$\dot{g}_{GABA} = -g_{GABA}/\tau_{GABA} + \left[\sum_k \delta(t - t_k)\right]_{Inh}$$

$$\dot{g}_{BASE} = -g_{BASE}/\tau_{BASE} + \left[\sum_k \delta(t - t_k)\right]_{BASE}$$

and recovery variable:

$$\dot{U}_m = a(bV_m - U_m)$$

When $V_m > V_{th}$ , $V_m$ is set to $c$, and $U_m$ is incremented by $d$.

# WORKFLOW:

In [1]:

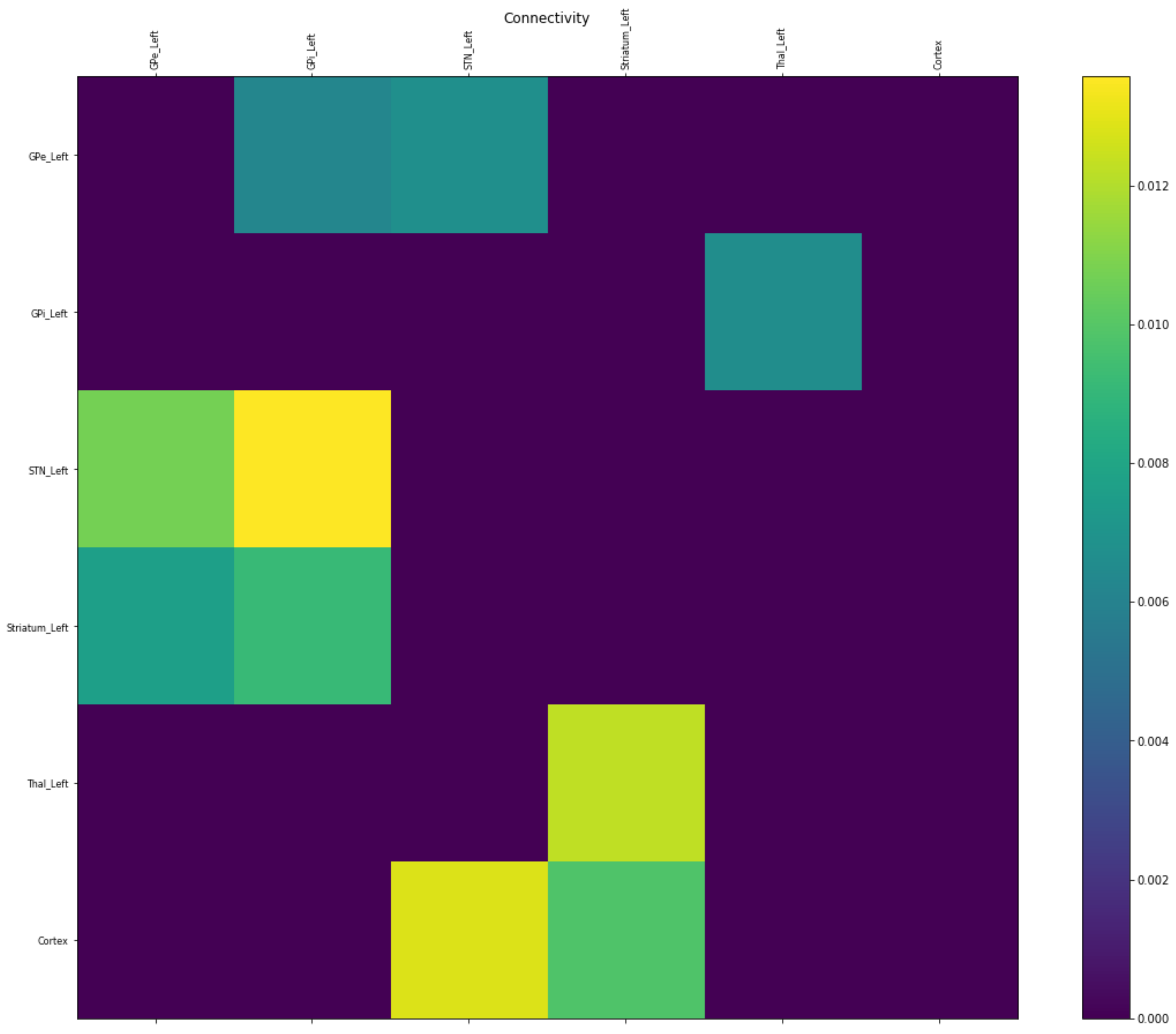
```
from collections import OrderedDict
import time
import numpy as np

from tvb.basic.profile import TvbProfile
TvbProfile.set_profile(TvbProfile.LIBRARY_PROFILE)

from tvb_multiscale.tvb_nest.config import *
home_path = "/home/docker/packages/tvb-multiscale/examples"
working_path = os.path.join(home_path, "notebooks")
data_path = os.path.join(home_path, "data")
config = Config(output_base=os.path.join(working_path, "outputs_Izhikevich_ne
config.figures.SHOW_FLAG = True
config.figures.SAVE_FLAG = True
config.figures.FIG_FORMAT = 'png'
config.figures.DEFAULT_SIZE= config.figures.NOTEBOOK_SIZE
FIGSIZE = config.figures.DEFAULT_SIZE

from tvb_multiscale.core.plot.plotter import Plotter
plotter = Plotter(config.figures)
```

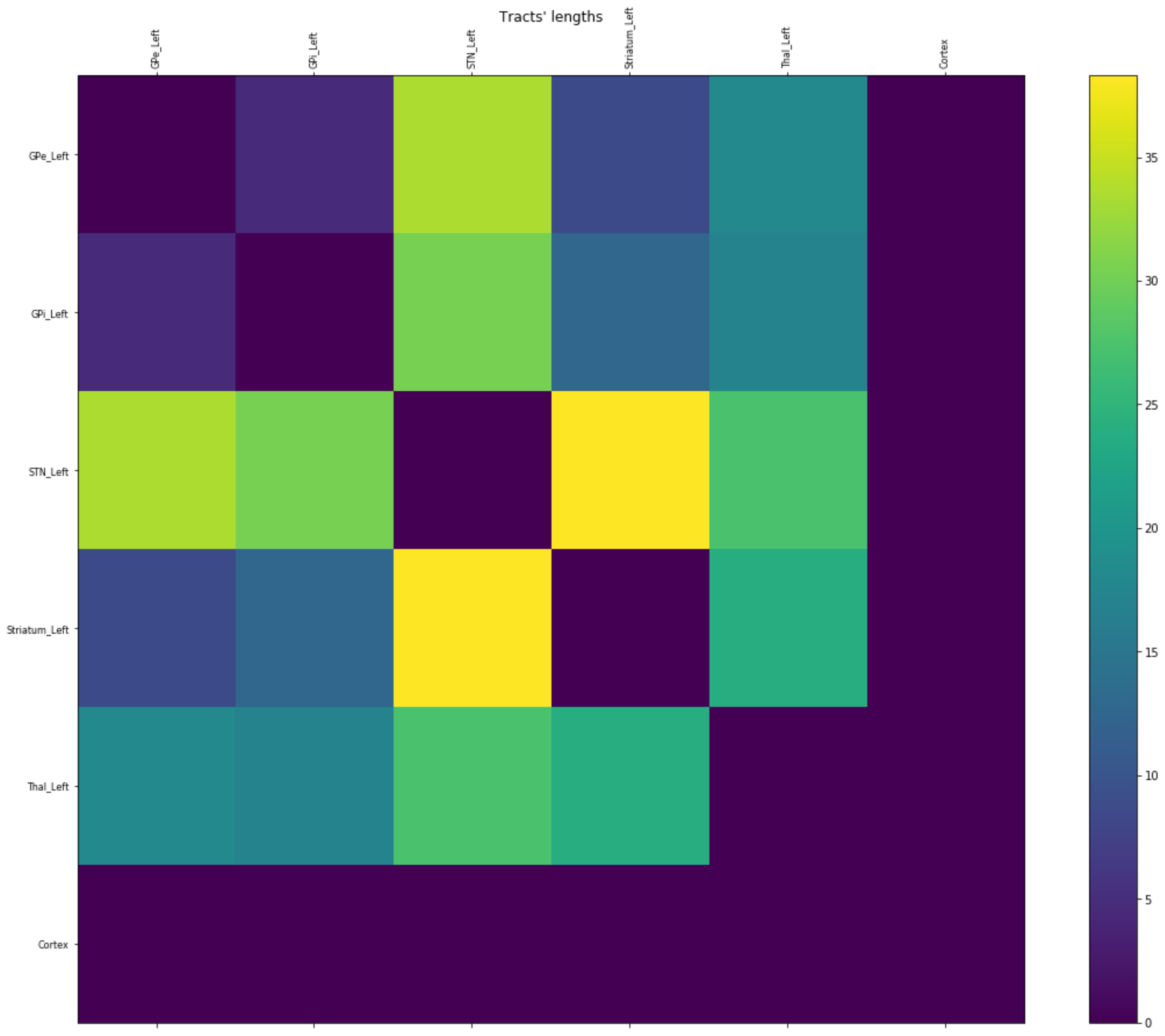
```
# For interactive plotting:
# %matplotlib notebook

# Otherwise:
%matplotlib inline
```

## 1. Load structural data (minimally a TVB connectivity) & prepare TVB simulator (region mean field model, integrator, monitors etc)

In [2]:
```
from tvb.simulator.models.reduced_wong_wang_exc_io import ReducedWongWangExcI

# ---------------------------------------------------------------------------
# ----Uncomment below to modify the simulator by changing the default options
# ---------------------------------------------------------------------------

from tvb.datatypes.connectivity import Connectivity
from tvb.simulator.cosimulator import CoSimulator
from tvb.simulator.integrators import HeunStochastic
from tvb.simulator.monitors import Raw  # , Bold, EEG


conn_path = os.path.join(data_path, "basal_ganglia_conn_incl_cortex")

w=np.loadtxt(os.path.join(conn_path, "opti_CON1_lh_weights_incl_cortex.txt"))
c=np.loadtxt(os.path.join(conn_path, "aal_plus_BG_centers_incl_cortex.txt"), 
rl= np.loadtxt(os.path.join(conn_path, "aal_plus_BG_centers_incl_cortex.txt")
t= np.loadtxt(os.path.join(conn_path, "BGplusAAL_tract_lengths_incl_cortex.tx

# Keep only the BG and a single Cortex node:
c = c[:11]
rl = rl[:11]
rl[10] = "Cortex"
w = w[:11][:, :11]
t = t[:11][:, :11]

# Keep only left hemisphere and the Cortex:
inds = np.arange(0,10,2).astype("i").tolist() + [10]
c = c[inds]
rl = rl[inds]
print("Region labels:\n%s" % rl)
# 0. GPe_Left, 1. GPi_Left, 2. STN_Left, 3. Striatum_Left, 4. Thal_Left, 5. C
w = w[inds][:, inds]
t = t[inds][:, inds]

#load the optimized weights to use for iSN and Cortex connections
import scipy.io as sio
weights=sio.loadmat(os.path.join(conn_path,"OutputSim_Patient01.mat")) # weig

# % loadedParams ={
# %              'D1GPi_probs': probs[0],
# %              'D1GPi_weights'  : weights[0],
# %              'D2GPe_probs'   : probs[1],
# %              'D2GPe_weights'  : weights[1],
# %              'GPeSTN_probs'   : probs[2],
# %              'GPeSTN_weights'  : weights[2],
# %              'STNGPe_probs'   : probs[3],
# %              'STNGPe_weights'  : weights[3],
# %              'STNGPi_probs'   : probs[4],
# %              'STNGPi_weights' : weights[4],
# %               'GPeGPi_probs'    : probs[5],
# %               'GPeGPi_weights'  : weights[5],
# %               'GPeGPe_probs'    : probs[6],
# %               'GPeGPe_weights'  : weights[6],
# %               'GPiGPi_probs'    : probs[7],
# %               'GPiGPi_weights'  : weights[7],
# %               'GPiThal_probs'   : probs[8],
# %               'GPiThal_weights'  : weights[8],
# %               'ThaliSN_probs'   : probs[9],
# %               'ThaliSN_weights'  : weights[9],
# %               'ThaldSN_probs'   : probs[10],
# %               'ThaldSN_weights'  : weights[10],
# %               'dSNdSN_probs'    : probs[11],
# %               'dSNdSN_weights'  : weights[11],
# %               'iSNiSN_probs'    : probs[12],
# %               'iSNiSN_weights'  : weights[12],
# %               'CdSN_probs'    : probs[13],
# %               'CdSN_weights'  : weights[13],
# %               'CiSN_probs'    : probs[14],
# %               'CiSN_weights'  : weights[14],
# %               'CSTN_probs'    : probs[15],
# %               'CSTN_weights'  : weights[15],
# %               'V1Inh_probs'     : probs[16],
# %               'V1Inh_weights'   : weights[16],
# %               'InhV1_probs'     : probs[17],
# %               'InhV1_weights'   : weights[17],
# %               'InhInh_probs'    : probs[18],
# %               'InhInh_weights'  : weights[18]}

# dSN = dSN, iSN = iSN from now on

wGPeGPe = weights["X"][0, 6+19]   # "GPe" -> "GPe"
wGPiGPi = weights["X"][0, 7+19]   # "GPe" -> "GPe"
wdSNdSN = weights["X"][0, 11+19]   # "IdSN" -> "IdSN"
wiSNiSN = weights["X"][0, 12+19]   # "IiSN" -> "IiSN"
wThiSN = weights["X"][0, 9+19]    # "Eth" -> "IiSN"
# wThdSNtoThiSN = wThiSN / w[4, 3]
w[5, 2] = weights["X"][0, 15+19]  # "CxE" -> "Estn"
w[5, 3] = weights["X"][0, 13+19]  # "CxE" -> "IdSN"
wCrtxiSN = weights["X"][0, 14+19] # "CxE" -> "IiSN"
# wCrtxdSNtoCrtxiSN = weights["X"][0, 14+19] / w[5, 3]
wCtxEtoI = weights["X"][0, 16+19] # "CxE" -> "CxI"
wCtxItoE = weights["X"][0, 17+19] # "CxI" -> "CxE"
wCtxItoI = weights["X"][0, 18+19] # "CxI" -> "CxI"

# Finally form the TVB Connectivity
connectivity=Connectivity(region_labels=rl, weights=w, centres=c, tract_lengt

# Normalize connectivity weights
# connectivity.weights = connectivity.scaled_weights(mode="region")
# connectivity.weights /= np.percentile(connectivity.weights, 99)
# connectivity.weights[connectivity.weights > 1.0] = 1.0
connectivity.speed = np.array([4.0])
connectivity.configure()

#white_matter_coupling = coupling.Linear(a=0.014)
# Create a TVB simulator and set all desired inputs
# (connectivity, model, surface, stimuli etc)
# We choose all defaults in this example
simulator = CoSimulator()
#simulator.use_numba = False
model_params = {}
simulator.model = ReducedWongWangExcIO(**model_params)

simulator.connectivity = connectivity
simulator.integrator = HeunStochastic()
simulator.integrator.dt = 0.1
simulator.integrator.noise.nsig = np.array([0.001])

mon_raw = Raw(period=1.0)  # ms
simulator.monitors = (mon_raw, )

plotter.plot_tvb_connectivity(simulator.connectivity);
```

```
Region labels:
['GPe_Left' 'GPi_Left' 'STN_Left' 'Striatum_Left' 'Thal_Left' 'Cortex']
```





## 2. Build and connect the NEST network model (networks of spiking neural populations for fine-scale regions, stimulation devices, spike detectors etc)

In [3]:
```
from tvb_multiscale.tvb_nest.nest_models.builders.models.basal_ganglia_izhike

# Select the regions for the fine scale modeling with NEST spiking networks
number_of_regions = simulator.connectivity.region_labels.shape[0]
#including cortex node:
nest_nodes_ids = [0, 1, 2, 3, 4, 5]  # the indices of fine scale regions mode

# Build a NEST network model with the corresponding builder
nest_model_builder = BasalGangliaIzhikevichBuilder(simulator, nest_nodes_ids,
#                                                  dt=float(simulator.integ
#                                                  weights=np.array(simulat
#                                                  delays=np.array(simulato
#                                                  region_labels=np.array(s
#                                                  model=simulator.model,
#                                                  coupling_a=float(simulat
#                                                  G=float(simulator.model.
                                                 )



# Using all default parameters for this example


# or...
```

```python
# # ------------------------------------------------------------------------
# # ----Uncomment below to modify the builder by changing the default options
# # ------------------------------------------------------------------------
from copy import deepcopy

population_neuron_model = "izhikevich_hamker"

nest_model_builder.population_order = 200 # reduce for speed

# When any of the properties model, params and scale below depends on regions
# set a handle to a function with
# arguments (region_index=None) returning the corresponding property

nest_model_builder.params_common = \
    {"E_rev_AMPA": 0.0, "E_rev_GABA_A": -90.0, "V_th": 30.0, "c": -65.0,
     "C_m": 1.0, "I_e": 0.0,
     "tau_rise": 1.0, "tau_rise_AMPA": 10.0, "tau_rise_GABA_A": 10.0,
     "n0": 140.0, "n1": 5.0, "n2": 0.04}

nest_model_builder._paramsI = deepcopy(nest_model_builder.params_common)
nest_model_builder._paramsI.update({"a": 0.005, "b": 0.585, "d": 4.0})
nest_model_builder._paramsE = deepcopy(nest_model_builder.params_common)
nest_model_builder.paramsStr = deepcopy(nest_model_builder.params_common)
nest_model_builder.paramsStr.update({"V_th": 40.0, "C_m": 50.0,
                                     "n0": 61.65, "n1": 2.59, "n2": 0.02,
                                     "a": 0.05, "b": -20.0, "c": -55.0, "d":

nest_model_builder.Igpe_nodes_ids = [0]
nest_model_builder.Igpi_nodes_ids = [1]
nest_model_builder.Estn_nodes_ids = [2]
nest_model_builder.Eth_nodes_ids = [4]
nest_model_builder.Istr_nodes_ids = [3]
#including cortex node:
nest_model_builder.Crtx_nodes_ids = [5]

I_nodes_ids = nest_model_builder.Igpe_nodes_ids + nest_model_builder.Igpi_nod
E_nodes_ids = nest_model_builder.Estn_nodes_ids + nest_model_builder.Eth_node

# #including cortex node: we do not need any other external stimulation
# nest_model_builder.Estn_stim = {"rate": 500.0, "weight": 0.009}
# nest_model_builder.Igpe_stim = {"rate": 100.0, "weight": 0.015}
# nest_model_builder.Igpi_stim = {"rate": 700.0, "weight": 0.02}


def paramsE_fun(node_id):
    paramsE = deepcopy(nest_model_builder._paramsE)
    if node_id in nest_model_builder.Estn_nodes_ids:
        paramsE.update({"a": 0.005, "b": 0.265, "d": 2.0, "I_e": 3.0})  # dic
    elif node_id in nest_model_builder.Eth_nodes_ids:
        paramsE.update({"a": 0.02, "b": 0.25, "d": 0.05, "I_e": 3.5}) # dicti
    elif node_id in nest_model_builder.Crtx_nodes_ids:
        paramsE.update({"a": 0.02, "b": 0.2, "d": 6.0,"c": -72.0, "I_e": 50.0
    return paramsE

def paramsI_fun(node_id):
    # For the moment they are identical, unless you differentiate the noise p
    paramsI = deepcopy(nest_model_builder._paramsI)
    if node_id in nest_model_builder.Igpe_nodes_ids:
        paramsI.update({"I_e": 12.0})
    elif node_id in nest_model_builder.Igpi_nodes_ids:
        paramsI.update({"I_e": 30.0})
    elif node_id in nest_model_builder.Crtx_nodes_ids:
        paramsI.update({"c": -72.0,"a": 0.02, "b": 0.2, "d": 6.0, "I_e": 0.0}
    return paramsI
```

```
# Populations' configurations
# When any of the properties model, params and scale below depends on regions
# set a handle to a function with
# arguments (region_index=None) returning the corresponding property
nest_model_builder.populations = [
    {"label": "E", "model": population_neuron_model,
     "params":  paramsE_fun,
     "nodes": E_nodes_ids,  # Estn in [2], Eth in [4], Cortex in [5]
     "scale": lambda node_id: 3.0 if node_id in nest_model_builder.Crtx_nodes_
    {"label": "I", "model": population_neuron_model,
     "params": paramsI_fun,
     "nodes": I_nodes_ids,  # Igpe in [0], Igpi in [1], Cortex in [5]
     "scale": lambda node_id: 0.75 if node_id in nest_model_builder.Crtx_node
    {"label": "IdSN", "model": population_neuron_model,
     "params": nest_model_builder.paramsStr,
     "nodes": nest_model_builder.Istr_nodes_ids,  # IdSN in [3]
     "scale": 1.0},
    {"label": "IiSN", "model": population_neuron_model,   # IiSN in [3]
     "params": nest_model_builder.paramsStr,
     "nodes": nest_model_builder.Istr_nodes_ids,  # None means "all"
     "scale": 1.0}
]

# Within region-node connections
# When any of the properties model, conn_spec, weight, delay, receptor_type b
# set a handle to a function with
# arguments (region_index=None) returning the corresponding property

synapse_model = "static_synapse"
conn_spec = {"allow_autapses": True, "allow_multapses": True, 'rule': "all_to
             "indegree": None, "outdegree": None, "N": None, "p": 0.1}

within_node_delay = 1.0

class WeightFun(object):

    def __init__(self, wGPeGPe, wGPiGPi, wCtxItoI):
        self.wGPeGPe = -np.abs(wGPeGPe)
        self.wGPiGPi = -np.abs(wGPiGPi)
        self.wCtxItoI = -np.abs(wCtxItoI)

    def __call__(self, node):
        if node == 0:
            return self.wGPeGPe  # GPe -> GPe
        elif node == 1:
            return self.wGPiGPi  # GPi -> GPi
        elif node == 5:
            return self.wCtxItoI  # CxI -> CxI


# for each connection, we have a different probability
nest_model_builder.populations_connections = [
     #        source    ->    target
    {"source": "I", "target": "I",  # I -> I This is a self-connection for po
     "model": synapse_model, "conn_spec": conn_spec,#.update({"p": 0.2}),
     "weight": WeightFun(wGPeGPe, wGPiGPi, wCtxItoI), "delay": within_node_de
     "receptor_type": 0, "nodes": I_nodes_ids},  # None means apply to all
    {"source": "IdSN", "target": "IdSN",  # IdSN -> IdSN This is a self-conne
     "model": synapse_model, "conn_spec": conn_spec,
     "weight": -wdSNdSN, "delay": within_node_delay,
     "receptor_type": 0, "nodes": nest_model_builder.Istr_nodes_ids},
    {"source": "IiSN", "target": "IiSN",  # IiSN -> IiSN This is a self-conne
     "model": synapse_model, "conn_spec": conn_spec,
     "weight": -wiSNiSN, "delay": within_node_delay,
     "receptor_type": 0, "nodes": nest_model_builder.Istr_nodes_ids},
    {"source": "E", "target": "I",           # "CxE" -> "CxI" #
     "model": synapse_model, "conn_spec": conn_spec,
     "weight": wCtxEtoI, "delay": within_node_delay,
     "receptor_type": 0, "nodes": nest_model_builder.Crtx_nodes_ids},  # None
    {"source": "I", "target": "E",           # "CxI" -> "CxE"
     "model": synapse_model, "conn_spec": conn_spec,
     "weight": -wCtxItoE, "delay": within_node_delay,
     "receptor_type": 0, "nodes": nest_model_builder.Crtx_nodes_ids}  # None
    ]



# Among/Between region-node connections
# Given that only the AMPA population of one region-node couples to
# all populations of another region-node,
# we need only one connection type

# When any of the properties model, conn_spec, weight, delay, receptor_type b
# depends on regions, set a handle to a function with
# arguments (source_region_index=None, target_region_index=None)

from tvb_multiscale.core.spiking_models.builders.templates import scale_tvb_w

# NOTE!!! TAKE CARE OF DEFAULT simulator.coupling.a!
nest_model_builder.global_coupling_scaling = 1.0 # nest_model_builder.couplin
# if we use Reduced Wong Wang model, we also need to multiply with the global
# nest_model_builder.global_coupling_scaling *= nest_model_builder.G

class TVBWeightFun(object):
    tvb_weights = np.array([])
    global_coupling_scaling = 1.0
    sign = 1

    def __init__(self, tvb_weights, global_coupling_scaling=1.0, sign=1):
        self.tvb_weights = tvb_weights
        self.global_coupling_scaling = global_coupling_scaling
        self.sign = sign

    def __call__(self, source_node, target_node):
        return scale_tvb_weight(source_node, target_node, self.tvb_weights,
                                scale=self.sign*self.global_coupling_scaling)

tvb_delay_fun = \
    lambda source_node, target_node: \
        np.maximum(nest_model_builder.tvb_dt, tvb_delay(source_node, target_n

# Total excitatory spikes of one region node will be distributed to
nest_model_builder.nodes_connections = [
    #         source     ->      target
    {"source": "IdSN", "target": "I",              # "IdSN" -> "Igpi"
     "model": synapse_model, "conn_spec": conn_spec,
     "weight": TVBWeightFun(nest_model_builder.tvb_weights, nest_model_builde
     "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
     "receptor_type": 0,
     "source_nodes": nest_model_builder.Istr_nodes_ids,
     "target_nodes": nest_model_builder.Igpi_nodes_ids},  # None means apply
    {"source": "IiSN", "target": "I",              # "IiSN" -> "Igpe"
     "model": synapse_model, "conn_spec": conn_spec,
     "weight": TVBWeightFun(nest_model_builder.tvb_weights, nest_model_builde
     "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
     "receptor_type": 0,
     "source_nodes": nest_model_builder.Istr_nodes_ids,
     "target_nodes": nest_model_builder.Igpe_nodes_ids},  # None means apply
    {"source": "I", "target": "I",              # "Igpe" -> "Igpi"
```

```
         "model": synapse_model, "conn_spec": conn_spec,
         "weight": TVBWeightFun(nest_model_builder.tvb_weights, nest_model_builde
         "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
         "receptor_type": 0,
         "source_nodes": nest_model_builder.Igpe_nodes_ids,
         "target_nodes": nest_model_builder.Igpi_nodes_ids},  # None means apply
        {"source": "I", "target": "E",              # "Igpi" -> "Eth"
         "model": synapse_model, "conn_spec": conn_spec,
         "weight": TVBWeightFun(nest_model_builder.tvb_weights, nest_model_builde
         "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
         "receptor_type": 0,
         "source_nodes": nest_model_builder.Igpi_nodes_ids,
         "target_nodes": nest_model_builder.Eth_nodes_ids},  # None means apply t
        {"source": "I", "target": "E",             # "Igpe" -> "Estn"
         "model": synapse_model, "conn_spec": conn_spec,
         "weight": TVBWeightFun(nest_model_builder.tvb_weights, nest_model_builde
         "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
         "receptor_type": 0,
         "source_nodes": nest_model_builder.Igpe_nodes_ids,
         "target_nodes": nest_model_builder.Estn_nodes_ids},  # None means apply
        {"source": "E", "target": "IdSN",   # "Eth" -> ["IdSN"]
         "model": synapse_model, "conn_spec": conn_spec,
         "weight": TVBWeightFun(nest_model_builder.tvb_weights, nest_model_builde
         "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
         "receptor_type": 0,
         "source_nodes": nest_model_builder.Eth_nodes_ids,
         "target_nodes": nest_model_builder.Istr_nodes_ids},  # None means apply
        {"source": "E", "target": "IiSN",   # "Eth" -> ["IiSN"]
         "model": synapse_model, "conn_spec": conn_spec,
         "weight": wThiSN,
         "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
         "receptor_type": 0,
         "source_nodes": nest_model_builder.Eth_nodes_ids,
         "target_nodes": nest_model_builder.Istr_nodes_ids},  # No
        {"source": "E", "target": "I",          # "Estn" -> ["Igpe", "Igpi"]
         "model": synapse_model, "conn_spec": conn_spec,
         "weight": TVBWeightFun(nest_model_builder.tvb_weights, nest_model_builde
         "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
         "receptor_type": 0,
         "source_nodes": nest_model_builder.Estn_nodes_ids,
         "target_nodes": nest_model_builder.Igpe_nodes_ids + nest_model_builder.I
#       {"source": "E", "target": "E",          # "CxE" -> "Eth"
#        "model": synapse_model, "conn_spec": conn_spec,
#        "weight": TVBWeightFun(nest_model_builder.tvb_weights, nest_model_buil
#        "delay": lambda source_node, target_node: tvb_delay_fun(source_node, t
#        "receptor_type": 0,
#        "source_nodes": nest_model_builder.Crtx_nodes_ids,
#        "target_nodes": nest_model_builder.Eth_nodes_ids},  # None means apply
        {"source": "E", "target": "E",          # "CxE" -> "Estn"
         "model": synapse_model, "conn_spec": conn_spec,
         "weight": TVBWeightFun(nest_model_builder.tvb_weights, nest_model_builde
         "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
         "receptor_type": 0,
         "source_nodes": nest_model_builder.Crtx_nodes_ids,
         "target_nodes": nest_model_builder.Estn_nodes_ids},  # None means apply
        {"source": "E", "target": "IdSN",          # "CxE" -> "IdSN"
         "model": synapse_model, "conn_spec": conn_spec,
         "weight": TVBWeightFun(nest_model_builder.tvb_weights, nest_model_builde
         "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
         "receptor_type": 0,
         "source_nodes": nest_model_builder.Crtx_nodes_ids,
         "target_nodes": nest_model_builder.Istr_nodes_ids},  # None means apply
        {"source": "E", "target": "IiSN",          # "CxE" -> "IiSN"
         "model": synapse_model, "conn_spec": conn_spec,
         "weight": wCrtxiSN, # TVBWeightFun(nest_model_builder.tvb_weights,
                                # wCrtxdSNtoCrtxiSN * nest_model_builder.global_c
         "delay": lambda source_node, target_node: tvb_delay_fun(source_node, tar
         "receptor_type": 0,
         "source_nodes": nest_model_builder.Crtx_nodes_ids,
         "target_nodes": nest_model_builder.Istr_nodes_ids}  # None means apply t
         ]

    # Creating  devices to be able to observe NEST activity:

    nest_model_builder.output_devices = []

    #          label <- target population
    for pop in nest_model_builder.populations:
        connections = OrderedDict({})
        connections[pop["label"] + "_spikes"] = pop["label"]
        nest_model_builder.output_devices.append(
            {"model": "spike_recorder", "params": {"record_to": "ascii"},
             "connections": connections, "nodes": pop["nodes"]})  # None means ap

    # Labels have to be different

    connections = OrderedDict({})
    #               label    <- target population
    params = {"interval": 1.0, "record_to": "ascii",
              'record_from': ["V_m", "U_m", "I_syn", "I_syn_ex", "I_syn_in", "g_AM
    for pop in nest_model_builder.populations:
        connections = OrderedDict({})
        connections[pop["label"]] = pop["label"]
        nest_model_builder.output_devices.append(
            {"model": "multimeter", "params": params,
             "connections": connections, "nodes": pop["nodes"]})  # None means ap


    #Create a spike stimulus input device
    nest_model_builder.input_devices = [
    #     {"model": "poisson_generator",
    #      "params": {"rate": nest_model_builder.Estn_stim["rate"], "origin": 0.0
    #      "connections": {"BaselineEstn": ["E"]},  # "Estn"
    #      "nodes": nest_model_builder.Estn_nodes_ids,  # "Estn"
    #      "weights": nest_model_builder.Estn_stim["weight"], "delays": 0.0, "rec
    #     {"model": "poisson_generator",
    #      "params": {"rate": nest_model_builder.Igpe_stim["rate"], "origin": 0.0
    #      "connections": {"BaselineIgpe": ["I"]},  # "Igpe"
    #      "nodes": nest_model_builder.Igpe_nodes_ids,  # "Igpe"
    #      "weights": nest_model_builder.Igpe_stim["weight"], "delays": 0.0, "rec
    #     {"model": "poisson_generator",
    #      "params": {"rate": nest_model_builder.Igpi_stim["rate"], "origin": 0.0
    #      "connections": {"BaselineIgpi": ["I"]},  # "Igpi"
    #      "nodes": nest_model_builder.Igpi_nodes_ids,  ## "Igpi"
    #      "weights": nest_model_builder.Igpi_stim["weight"], "delays": 0.0, "rec
    #     {"model": "ac_generator",
    #      "params": {"frequency": 30.0, "phase": 0.0, "amplitude": 1.0, "offset"
    #                 "start": 1.0},  # "stop": 100.0  "origin": 0.0,
    #      "connections": {"DBS_Estn": ["E"]}, # "Estn"
    #      "nodes": nest_model_builder.Estn_nodes_ids,      # "Estn"
    #      "weights": 1.0, "delays": 0.0}
           ]  #

    # ---------------------------------------------------------------------------
    # ---------------------------------------------------------------------------
    # ---------------------------------------------------------------------------


    nest_network = nest_model_builder.build_spiking_network()
```

```
2020-11-26 15:28:10,300 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - Loading a NEST instance...
2020-11-26 15:28:10,300 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - Loading a NEST instance...
2020-11-26 15:28:10,304 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - NEST_INSTALL_DIR: /home/docker/env/neurosci/nest_build
2020-11-26 15:28:10,304 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - NEST_INSTALL_DIR: /home/docker/env/neurosci/nest_build
2020-11-26 15:28:10,311 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - NEST_DATA_DIR: /home/docker/env/neurosci/nest_build/share/nest
2020-11-26 15:28:10,311 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - NEST_DATA_DIR: /home/docker/env/neurosci/nest_build/share/nest
2020-11-26 15:28:10,317 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - NEST_DOC_DIR: /home/docker/env/neurosci/nest_build/share/doc/nest
2020-11-26 15:28:10,317 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - NEST_DOC_DIR: /home/docker/env/neurosci/nest_build/share/doc/nest
2020-11-26 15:28:10,323 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - NEST_MODULE_PATH: /home/docker/env/neurosci/nest_build/lib/nest
2020-11-26 15:28:10,323 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - NEST_MODULE_PATH: /home/docker/env/neurosci/nest_build/lib/nest
2020-11-26 15:28:10,331 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - PATH: /home/docker/env/neurosci/nest_build/bin:/usr/local/sbin:/usr/loc
al/bin:/usr/sbin:/usr/bin:/sbin:/bin
2020-11-26 15:28:10,331 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - PATH: /home/docker/env/neurosci/nest_build/bin:/usr/local/sbin:/usr/loc
al/bin:/usr/sbin:/usr/bin:/sbin:/bin
2020-11-26 15:28:10,339 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - LD_LIBRARY_PATH: /home/docker/env/neurosci/nest_build/lib/nest::/home/d
ocker/env/neurosci/nest_build/lib/nest
2020-11-26 15:28:10,339 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - LD_LIBRARY_PATH: /home/docker/env/neurosci/nest_build/lib/nest::/home/d
ocker/env/neurosci/nest_build/lib/nest
2020-11-26 15:28:10,347 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - SLI_PATH: /home/docker/env/neurosci/nest_build/share/nest/sli
2020-11-26 15:28:10,347 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - SLI_PATH: /home/docker/env/neurosci/nest_build/share/nest/sli
2020-11-26 15:28:10,353 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - NEST_PYTHON_PREFIX: /home/docker/env/neurosci/nest_build/lib/python3.7/
site-packages
2020-11-26 15:28:10,353 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - NEST_PYTHON_PREFIX: /home/docker/env/neurosci/nest_build/lib/python3.7/
site-packages
2020-11-26 15:28:10,362 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - system path: ['/home/docker/env/neurosci/nest_build/lib/python3.7/site-
packages', '/home/docker/packages/tvb-multiscale/examples/notebooks', '/home/d
ocker/env/neurosci', '/usr/lib/python37.zip', '/usr/lib/python3.7', '/usr/lib/
python3.7/lib-dynload', '', '/home/docker/env/neurosci/lib/python3.7/site-pack
ages', '/home/docker/env/neurosci/lib/python3.7/site-packages/NESTML-3.1.post
0.dev0-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/typi
ng-3.7.4.3-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/
sympy-1.6.2-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-package
s/odetoolbox-2.0-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-pac
kages/astropy-2.0.3-py3.7-linux-x86_64.egg', '/home/docker/env/neurosci/lib/py
thon3.7/site-packages/antlr4_python3_runtime-4.8-py3.7.egg', '/home/docker/en
v/neurosci/lib/python3.7/site-packages/mpmath-1.1.0-py3.7.egg', '/home/docker/
env/neurosci/lib/python3.7/site-packages/pytest-6.1.2-py3.7.egg', '/home/docke
r/env/neurosci/lib/python3.7/site-packages/toml-0.10.2-py3.7.egg', '/home/dock
er/env/neurosci/lib/python3.7/site-packages/py-1.9.0-py3.7.egg', '/home/docke
r/env/neurosci/lib/python3.7/site-packages/pluggy-0.13.1-py3.7.egg', '/home/do
cker/env/neurosci/lib/python3.7/site-packages/packaging-20.4-py3.7.egg', '/hom
e/docker/env/neurosci/lib/python3.7/site-packages/iniconfig-1.1.1-py3.7.egg',
'/home/docker/env/neurosci/lib/python3.7/site-packages/importlib_metadata-2.0.
0-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/attrs-20.
3.0-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/zipp-3.
4.0-py3.7.egg', '/home/docker/packages/tvb_data', '/home/docker/packages/tvb-r
oot/scientific_library', '/home/docker/env/neurosci/lib/python3.7/site-package
s/numexpr-2.7.1-py3.7-linux-x86_64.egg', '/home/docker/env/neurosci/lib/python
3.7/site-packages/networkx-2.5-py3.7.egg', '/home/docker/env/neurosci/lib/pyth
on3.7/site-packages/Mako-1.1.3-py3.7.egg', '/home/docker/packages/tvb-root/fra
mework_tvb', '/home/docker/env/neurosci/lib/python3.7/site-packages/Werkzeug-
1.0.1-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/tvb_l
ibrary-2.0.9-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-package
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on3.7/site-packages/tvb_data-2.0-py3.7.egg', '/home/docker/env/neurosci/lib/py
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neurosci/lib/python3.7/site-packages/simplejson-3.17.2-py3.7-linux-x86_64.eg
g', '/home/docker/env/neurosci/lib/python3.7/site-packages/python_keycloak-0.2
2.0-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/pyAesCr
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site-packages/nibabel-3.2.0-py3.7.egg', '/home/docker/env/neurosci/lib/python
3.7/site-packages/gevent-20.9.0-py3.7-linux-x86_64.egg', '/home/docker/env/neu
rosci/lib/python3.7/site-packages/FormEncode-2.0.0-py3.7.egg', '/home/docker/e
nv/neurosci/lib/python3.7/site-packages/flask_restplus-0.13.0-py3.7.egg', '/ho
me/docker/packages/tvb-root/tvb_contrib', '/home/docker/packages/tvb-multiscal
e', '/usr/lib/python3/dist-packages', '/home/docker/.local/lib/python3.7/site-
packages', '/home/docker/.local/lib/python3.7/site-packages/ANNarchy-4.6.9.7-p
y3.7-linux-x86_64.egg', '/usr/local/lib/python3.7/dist-packages', '/home/docke
r/env/neurosci/lib/python3.7/site-packages/IPython/extensions', '/home/docke
r/.ipython']
2020-11-26 15:28:10,362 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
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ages', '/home/docker/env/neurosci/lib/python3.7/site-packages/NESTML-3.1.post
0.dev0-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/typi
ng-3.7.4.3-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/
sympy-1.6.2-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-package
s/odetoolbox-2.0-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-pac
kages/astropy-2.0.3-py3.7-linux-x86_64.egg', '/home/docker/env/neurosci/lib/py
thon3.7/site-packages/antlr4_python3_runtime-4.8-py3.7.egg', '/home/docker/en
v/neurosci/lib/python3.7/site-packages/mpmath-1.1.0-py3.7.egg', '/home/docker/
env/neurosci/lib/python3.7/site-packages/pytest-6.1.2-py3.7.egg', '/home/docke
r/env/neurosci/lib/python3.7/site-packages/toml-0.10.2-py3.7.egg', '/home/dock
er/env/neurosci/lib/python3.7/site-packages/py-1.9.0-py3.7.egg', '/home/docke
r/env/neurosci/lib/python3.7/site-packages/pluggy-0.13.1-py3.7.egg', '/home/do
cker/env/neurosci/lib/python3.7/site-packages/packaging-20.4-py3.7.egg', '/hom
e/docker/env/neurosci/lib/python3.7/site-packages/iniconfig-1.1.1-py3.7.egg',
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0-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/attrs-20.
3.0-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/zipp-3.
4.0-py3.7.egg', '/home/docker/packages/tvb_data', '/home/docker/packages/tvb-r
oot/scientific_library', '/home/docker/env/neurosci/lib/python3.7/site-package
s/numexpr-2.7.1-py3.7-linux-x86_64.egg', '/home/docker/env/neurosci/lib/python
3.7/site-packages/networkx-2.5-py3.7.egg', '/home/docker/env/neurosci/lib/pyth
on3.7/site-packages/Mako-1.1.3-py3.7.egg', '/home/docker/packages/tvb-root/fra
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ibrary-2.0.9-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-package
s/tvb_gdist-2.0.2-py3.7-linux-x86_64.egg', '/home/docker/env/neurosci/lib/pyth
on3.7/site-packages/tvb_data-2.0-py3.7.egg', '/home/docker/env/neurosci/lib/py
thon3.7/site-packages/sqlalchemy_migrate-0.13.0-py3.7.egg', '/home/docker/env/
neurosci/lib/python3.7/site-packages/simplejson-3.17.2-py3.7-linux-x86_64.eg
g', '/home/docker/env/neurosci/lib/python3.7/site-packages/python_keycloak-0.2
2.0-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/pyAesCr
ypt-0.4.3-py3.7.egg', '/home/docker/env/neurosci/lib/python3.7/site-packages/p
sutil-5.7.3-py3.7-linux-x86_64.egg', '/home/docker/env/neurosci/lib/python3.7/
site-packages/nibabel-3.2.0-py3.7.egg', '/home/docker/env/neurosci/lib/python
3.7/site-packages/gevent-20.9.0-py3.7-linux-x86_64.egg', '/home/docker/env/neu
rosci/lib/python3.7/site-packages/FormEncode-2.0.0-py3.7.egg', '/home/docker/e
nv/neurosci/lib/python3.7/site-packages/flask_restplus-0.13.0-py3.7.egg', '/ho
me/docker/packages/tvb-root/tvb_contrib', '/home/docker/packages/tvb-multiscal
e', '/usr/lib/python3/dist-packages', '/home/docker/.local/lib/python3.7/site-
packages', '/home/docker/.local/lib/python3.7/site-packages/ANNarchy-4.6.9.7-p
y3.7-linux-x86_64.egg', '/usr/local/lib/python3.7/dist-packages', '/home/docke
r/env/neurosci/lib/python3.7/site-packages/IPython/extensions', '/home/docke
r/.ipython']
```

```
2020-11-26 15:28:10,578 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - Trying to install module izhikevich_hamkermodule...
2020-11-26 15:28:10,578 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - Trying to install module izhikevich_hamkermodule...
2020-11-26 15:28:10,616 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - DONE installing module izhikevich_hamkermodule!
2020-11-26 15:28:10,616 - INFO - tvb_multiscale.tvb_nest.nest_models.builders.
base - DONE installing module izhikevich_hamkermodule!
2020-11-26 15:28:11,172 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model spike_
recorder for E_spikes created!
2020-11-26 15:28:11,172 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model spike_
recorder for E_spikes created!
2020-11-26 15:28:12,008 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model spike_
recorder for I_spikes created!
2020-11-26 15:28:12,008 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model spike_
recorder for I_spikes created!
2020-11-26 15:28:12,620 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model spike_
recorder for IdSN_spikes created!
2020-11-26 15:28:12,620 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model spike_
recorder for IdSN_spikes created!
2020-11-26 15:28:12,836 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model spike_
recorder for IiSN_spikes created!
2020-11-26 15:28:12,836 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model spike_
recorder for IiSN_spikes created!
2020-11-26 15:28:13,062 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model multim
eter for E created!
2020-11-26 15:28:13,062 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model multim
eter for E created!
2020-11-26 15:28:13,564 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model multim
eter for I created!
2020-11-26 15:28:13,564 - INFO - tvb_multiscale.core.spiking_models.devices -
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eter for I created!
2020-11-26 15:28:14,000 - INFO - tvb_multiscale.core.spiking_models.devices -
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eter for IdSN created!
2020-11-26 15:28:14,000 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model multim
eter for IdSN created!
2020-11-26 15:28:14,157 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model multim
eter for IiSN created!
2020-11-26 15:28:14,157 - INFO - tvb_multiscale.core.spiking_models.devices -
<class 'tvb_multiscale.core.spiking_models.devices.DeviceSet'> of model multim
eter for IiSN created!
2020-11-26 15:28:14,314 - INFO - tvb_multiscale.core.spiking_models.network -
<class 'tvb_multiscale.tvb_nest.nest_models.network.NESTNetwork'> created!
2020-11-26 15:28:14,314 - INFO - tvb_multiscale.core.spiking_models.network -
<class 'tvb_multiscale.tvb_nest.nest_models.network.NESTNetwork'> created!
```

In [4]:
```python
print(nest_network.print_str(connectivity=False))
```

```
--------------------------------------------------------------------------------
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```

```
--------------------------------------------------------------------------------
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NESTNetwork:

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SpikingBrain - Regions: ['GPe_Left', 'GPi_Left', 'STN_Left', 'Striatum_Left',
'Thal_Left', 'Cortex']
Regions' nodes:


--------------------------------------------------------------------------------
----------------------
NESTRegionNode - Label: GPe_Left
Populations ['I']:

--------------------------------------------------------------------------------
----------------------

NESTPopulation - Label: I
model: izhikevich_hamker
200 neurons: 1...200
parameters: {'a': array([0.005]), 'archiver_length': 0, 'b': array([0.585]),
'beta_Ca': array([0.001]), 'C_m': array([1.]), 'Ca': array([0.]), 'c': array
([-65.]), 'consistent_integration': True, 'd': array([4.]), 'E_rev_AMPA': arra
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lse, 'g_AMPA': array([0.]), 'g_GABA_A': array([0.]), 'g_L': array([0.]), 'glob
al_id': [[1, 200]], 'I': array([0.]), 'I_e': array([12.]), 'I_syn': array
([0.]), 'I_syn_ex': array([0.]), 'I_syn_in': array([0.]), 'local': True, 'mode
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452e+258]), 'receptor_types': [{'activity': 0, 'noise': 1}, {'activity': 0, 'n
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y': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1},
{'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noi
se': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activit
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NESTRegionNode - Label: GPi_Left
Populations ['I']:

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NESTPopulation - Label: I
model: izhikevich_hamker
200 neurons: 201...400
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NESTRegionNode - Label: STN_Left
Populations ['E']:

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NESTRegionNode - Label: Striatum_Left
Populations ['IdSN', 'IiSN']:

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NESTPopulation - Label: IiSN
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NESTRegionNode - Label: Thal_Left
Populations ['E']:

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NESTPopulation - Label: E
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NESTRegionNode - Label: Cortex
Populations ['E', 'I']:

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NESTPopulation - Label: E
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y': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1},
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y': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1},
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ise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activit
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y': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1},
 {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'no
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 {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'no
ise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activit
y': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1},
 {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'no
ise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activit
y': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1},
 {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'no
ise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activit
y': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1},
 {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'no
ise': 1}, {'activity': 0, 'noise': 1}, {'activity': 0, 'noise': 1}, {'activit
y': 0, 'noise': 1}, {'activity': 0, 'noise': 1}], 'recordables': array([('g_AM
PA', 'g_GABA_A', 'g_L', 'I', 'I_syn', 'I_syn_ex', 'I_syn_in', 'U_m', 'V_m')],
      dtype=object), 'synaptic_elements': [{}, {}, {}, {}, {}, {}, {}, {}, {},
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 {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {},
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 {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {},
 {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {},
 {}, {}, {}, {}, {}, {}, {}, {}], 't_ref': array([10.]), 't_spike': array([-
1.]), 'tau_Ca': array([10000.]), 'tau_minus': array([20.]), 'tau_minus_triple
t': array([110.]), 'tau_rise': array([1.]), 'tau_rise_AMPA': array([10.]), 'ta
u_rise_GABA_A': array([10.]), 'thread': 0, 'thread_local_id': -1, 'U_m': array
([-14.4]), 'V_m': array([-72.]), 'V_min': array([-1.79769313e+308]), 'V_th': a
rray([30.]), 'vp': 0, 'n1': array([5.]), 'n2': array([0.04]), 'r': array
([0.]), 'n0': array([140.])},
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Input Devices:

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Output Devices:

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DeviceSet - Name: E_spikes, Model: spike_recorder,
Devices:
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E_spikes_STN_Left: NESTSpikeRecorder - Model: spike_recorder
NodeCollection(metadata=None, model=spike_recorder, size=1, first=1951)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/E_spikes_STN_Left-1951-0.dat',), 'frozen': False, 'glo
bal_id': 1951, 'label': 'E_spikes_STN_Left', 'local': True, 'model': 'spike_re
corder', 'n_events': 0, 'node_uses_wfr': False, 'origin': 0.0, 'precision': 3,
'record_to': 'ascii', 'start': 0.0, 'stop': 1.7976931348623157e+308, 'thread':
0, 'thread_local_id': -1, 'time_in_steps': False, 'vp': 0}
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E_spikes_Thal_Left: NESTSpikeRecorder - Model: spike_recorder
NodeCollection(metadata=None, model=spike_recorder, size=1, first=1952)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/E_spikes_Thal_Left-1952-0.dat',), 'frozen': False, 'gl
obal_id': 1952, 'label': 'E_spikes_Thal_Left', 'local': True, 'model': 'spike_
recorder', 'n_events': 0, 'node_uses_wfr': False, 'origin': 0.0, 'precision':
 3, 'record_to': 'ascii', 'start': 0.0, 'stop': 1.7976931348623157e+308, 'thre
ad': 0, 'thread_local_id': -1, 'time_in_steps': False, 'vp': 0}
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E_spikes_Cortex: NESTSpikeRecorder - Model: spike_recorder
NodeCollection(metadata=None, model=spike_recorder, size=1, first=1953)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/E_spikes_Cortex-1953-0.dat',), 'frozen': False, 'globa
l_id': 1953, 'label': 'E_spikes_Cortex', 'local': True, 'model': 'spike_record
er', 'n_events': 0, 'node_uses_wfr': False, 'origin': 0.0, 'precision': 3, 're
cord_to': 'ascii', 'start': 0.0, 'stop': 1.7976931348623157e+308, 'thread': 0,
'thread_local_id': -1, 'time_in_steps': False, 'vp': 0}
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DeviceSet - Name: I_spikes, Model: spike_recorder,
Devices:
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I_spikes_GPe_Left: NESTSpikeRecorder - Model: spike_recorder
NodeCollection(metadata=None, model=spike_recorder, size=1, first=1954)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/I_spikes_GPe_Left-1954-0.dat',), 'frozen': False, 'glo
bal_id': 1954, 'label': 'I_spikes_GPe_Left', 'local': True, 'model': 'spike_re
corder', 'n_events': 0, 'node_uses_wfr': False, 'origin': 0.0, 'precision': 3,
'record_to': 'ascii', 'start': 0.0, 'stop': 1.7976931348623157e+308, 'thread':
0, 'thread_local_id': -1, 'time_in_steps': False, 'vp': 0}
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I_spikes_GPi_Left: NESTSpikeRecorder - Model: spike_recorder
NodeCollection(metadata=None, model=spike_recorder, size=1, first=1955)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/I_spikes_GPi_Left-1955-0.dat',), 'frozen': False, 'glo
bal_id': 1955, 'label': 'I_spikes_GPi_Left', 'local': True, 'model': 'spike_re
corder', 'n_events': 0, 'node_uses_wfr': False, 'origin': 0.0, 'precision': 3,
'record_to': 'ascii', 'start': 0.0, 'stop': 1.7976931348623157e+308, 'thread':
0, 'thread_local_id': -1, 'time_in_steps': False, 'vp': 0}
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I_spikes_Cortex: NESTSpikeRecorder - Model: spike_recorder
NodeCollection(metadata=None, model=spike_recorder, size=1, first=1956)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/I_spikes_Cortex-1956-0.dat',), 'frozen': False, 'globa
l_id': 1956, 'label': 'I_spikes_Cortex', 'local': True, 'model': 'spike_record
er', 'n_events': 0, 'node_uses_wfr': False, 'origin': 0.0, 'precision': 3, 're
cord_to': 'ascii', 'start': 0.0, 'stop': 1.7976931348623157e+308, 'thread': 0,
'thread_local_id': -1, 'time_in_steps': False, 'vp': 0}
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DeviceSet - Name: IdSN_spikes, Model: spike_recorder,
Devices:
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IdSN_spikes_Striatum_Left: NESTSpikeRecorder - Model: spike_recorder
NodeCollection(metadata=None, model=spike_recorder, size=1, first=1957)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/IdSN_spikes_Striatum_Left-1957-0.dat',), 'frozen': Fal
se, 'global_id': 1957, 'label': 'IdSN_spikes_Striatum_Left', 'local': True, 'm
odel': 'spike_recorder', 'n_events': 0, 'node_uses_wfr': False, 'origin': 0.0,
'precision': 3, 'record_to': 'ascii', 'start': 0.0, 'stop': 1.7976931348623157
e+308, 'thread': 0, 'thread_local_id': -1, 'time_in_steps': False, 'vp': 0}
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DeviceSet - Name: IiSN_spikes, Model: spike_recorder,
Devices:
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IiSN_spikes_Striatum_Left: NESTSpikeRecorder - Model: spike_recorder
NodeCollection(metadata=None, model=spike_recorder, size=1, first=1958)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/IiSN_spikes_Striatum_Left-1958-0.dat',), 'frozen': Fal
se, 'global_id': 1958, 'label': 'IiSN_spikes_Striatum_Left', 'local': True, 'm
odel': 'spike_recorder', 'n_events': 0, 'node_uses_wfr': False, 'origin': 0.0,
'precision': 3, 'record_to': 'ascii', 'start': 0.0, 'stop': 1.7976931348623157
e+308, 'thread': 0, 'thread_local_id': -1, 'time_in_steps': False, 'vp': 0}
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DeviceSet - Name: E, Model: multimeter,
Devices:
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E_STN_Left: NESTMultimeter - Model: multimeter
NodeCollection(metadata=None, model=multimeter, size=1, first=1959)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/E_STN_Left-1959-0.dat',), 'frozen': False, 'global_i
d': 1959, 'interval': 1.0, 'label': 'E_STN_Left', 'local': True, 'model': 'mul
timeter', 'n_events': 0, 'node_uses_wfr': False, 'offset': 0.0, 'origin': 0.0,
'precision': 3, 'record_from': ('V_m', 'U_m', 'I_syn', 'I_syn_ex', 'I_syn_in',
'g_AMPA', 'g_GABA_A', 'g_L'), 'record_to': 'ascii', 'start': 0.0, 'stop': 1.79
76931348623157e+308, 'thread': 0, 'thread_local_id': -1, 'time_in_steps': Fals
e, 'vp': 0}
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E_Thal_Left: NESTMultimeter - Model: multimeter
NodeCollection(metadata=None, model=multimeter, size=1, first=1960)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/E_Thal_Left-1960-0.dat',), 'frozen': False, 'global_i
d': 1960, 'interval': 1.0, 'label': 'E_Thal_Left', 'local': True, 'model': 'mu
ltimeter', 'n_events': 0, 'node_uses_wfr': False, 'offset': 0.0, 'origin': 0.
0, 'precision': 3, 'record_from': ('V_m', 'U_m', 'I_syn', 'I_syn_ex', 'I_syn_i
n', 'g_AMPA', 'g_GABA_A', 'g_L'), 'record_to': 'ascii', 'start': 0.0, 'stop':
 1.7976931348623157e+308, 'thread': 0, 'thread_local_id': -1, 'time_in_steps':
False, 'vp': 0}
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E_Cortex: NESTMultimeter - Model: multimeter
NodeCollection(metadata=None, model=multimeter, size=1, first=1961)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/E_Cortex-1961-0.dat',), 'frozen': False, 'global_id':
 1961, 'interval': 1.0, 'label': 'E_Cortex', 'local': True, 'model': 'multimet
er', 'n_events': 0, 'node_uses_wfr': False, 'offset': 0.0, 'origin': 0.0, 'pre
cision': 3, 'record_from': ('V_m', 'U_m', 'I_syn', 'I_syn_ex', 'I_syn_in', 'g_
AMPA', 'g_GABA_A', 'g_L'), 'record_to': 'ascii', 'start': 0.0, 'stop': 1.79769
31348623157e+308, 'thread': 0, 'thread_local_id': -1, 'time_in_steps': False,
 'vp': 0}
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DeviceSet - Name: I, Model: multimeter,
Devices:
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I_GPe_Left: NESTMultimeter - Model: multimeter
NodeCollection(metadata=None, model=multimeter, size=1, first=1962)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/I_GPe_Left-1962-0.dat',), 'frozen': False, 'global_i
d': 1962, 'interval': 1.0, 'label': 'I_GPe_Left', 'local': True, 'model': 'mul
timeter', 'n_events': 0, 'node_uses_wfr': False, 'offset': 0.0, 'origin': 0.0,
'precision': 3, 'record_from': ('V_m', 'U_m', 'I_syn', 'I_syn_ex', 'I_syn_in',
'g_AMPA', 'g_GABA_A', 'g_L'), 'record_to': 'ascii', 'start': 0.0, 'stop': 1.79
76931348623157e+308, 'thread': 0, 'thread_local_id': -1, 'time_in_steps': Fals
e, 'vp': 0}
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I_GPi_Left: NESTMultimeter - Model: multimeter
NodeCollection(metadata=None, model=multimeter, size=1, first=1963)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/I_GPi_Left-1963-0.dat',), 'frozen': False, 'global_i
d': 1963, 'interval': 1.0, 'label': 'I_GPi_Left', 'local': True, 'model': 'mul
timeter', 'n_events': 0, 'node_uses_wfr': False, 'offset': 0.0, 'origin': 0.0,
'precision': 3, 'record_from': ('V_m', 'U_m', 'I_syn', 'I_syn_ex', 'I_syn_in',
'g_AMPA', 'g_GABA_A', 'g_L'), 'record_to': 'ascii', 'start': 0.0, 'stop': 1.79
76931348623157e+308, 'thread': 0, 'thread_local_id': -1, 'time_in_steps': Fals
e, 'vp': 0}
------------------------------------------------------------------------------
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I_Cortex: NESTMultimeter - Model: multimeter
NodeCollection(metadata=None, model=multimeter, size=1, first=1964)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/I_Cortex-1964-0.dat',), 'frozen': False, 'global_id':
 1964, 'interval': 1.0, 'label': 'I_Cortex', 'local': True, 'model': 'multimet
er', 'n_events': 0, 'node_uses_wfr': False, 'offset': 0.0, 'origin': 0.0, 'pre
cision': 3, 'record_from': ('V_m', 'U_m', 'I_syn', 'I_syn_ex', 'I_syn_in', 'g_
AMPA', 'g_GABA_A', 'g_L'), 'record_to': 'ascii', 'start': 0.0, 'stop': 1.79769
31348623157e+308, 'thread': 0, 'thread_local_id': -1, 'time_in_steps': False,
 'vp': 0}
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DeviceSet - Name: IdSN, Model: multimeter,
Devices:
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IdSN_Striatum_Left: NESTMultimeter - Model: multimeter
NodeCollection(metadata=None, model=multimeter, size=1, first=1965)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/IdSN_Striatum_Left-1965-0.dat',), 'frozen': False, 'gl
obal_id': 1965, 'interval': 1.0, 'label': 'IdSN_Striatum_Left', 'local': True,
'model': 'multimeter', 'n_events': 0, 'node_uses_wfr': False, 'offset': 0.0,
 'origin': 0.0, 'precision': 3, 'record_from': ('V_m', 'U_m', 'I_syn', 'I_syn_
ex', 'I_syn_in', 'g_AMPA', 'g_GABA_A', 'g_L'), 'record_to': 'ascii', 'start':
 0.0, 'stop': 1.7976931348623157e+308, 'thread': 0, 'thread_local_id': -1, 'ti
me_in_steps': False, 'vp': 0}
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DeviceSet - Name: IiSN, Model: multimeter,
Devices:
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IiSN_Striatum_Left: NESTMultimeter - Model: multimeter
NodeCollection(metadata=None, model=multimeter, size=1, first=1966)
parameters: {'element_type': 'recorder', 'file_extension': 'dat', 'filenames':
('/home/docker/packages/tvb-multiscale/examples/notebooks/outputs_Izhikevich_n
est/res/nest_recordings/IiSN_Striatum_Left-1966-0.dat',), 'frozen': False, 'gl
obal_id': 1966, 'interval': 1.0, 'label': 'IiSN_Striatum_Left', 'local': True,
'model': 'multimeter', 'n_events': 0, 'node_uses_wfr': False, 'offset': 0.0,
 'origin': 0.0, 'precision': 3, 'record_from': ('V_m', 'U_m', 'I_syn', 'I_syn_
ex', 'I_syn_in', 'g_AMPA', 'g_GABA_A', 'g_L'), 'record_to': 'ascii', 'start':
 0.0, 'stop': 1.7976931348623157e+308, 'thread': 0, 'thread_local_id': -1, 'ti
me_in_steps': False, 'vp': 0}
```

## 3. Build the TVB-NEST interface

In [5]:
```python
from tvb_multiscale.tvb_nest.interfaces.builders.models.red_ww_basal_ganglia_

# Build a TVB-NEST interface with all the appropriate connections between the
# TVB and NEST modelled regions
tvb_nest_builder = \
    RedWWexcIOBuilder(simulator, nest_network, nest_nodes_ids,
                      exclusive_nodes=True) # , populations_sizes=populations_

tvb_to_nest_mode = None  # "rate" # with none we get the NEST-only part here
nest_to_tvb = False

tvb_nest_model = tvb_nest_builder.build_interface(tvb_to_nest_mode=tvb_to_nes
```

```
2020-11-26 15:28:21,936 - INFO - tvb_multiscale.core.interfaces.base - <class
'tvb_multiscale.tvb_nest.interfaces.models.RedWWexcIO'> created!
2020-11-26 15:28:21,936 - INFO - tvb_multiscale.core.interfaces.base - <class
'tvb_multiscale.tvb_nest.interfaces.models.RedWWexcIO'> created!
2020-11-26 15:28:21,941 - INFO - tvb_multiscale.tvb_nest.interfaces.models - <
class 'tvb_multiscale.tvb_nest.interfaces.models.RedWWexcIO'> created!
2020-11-26 15:28:21,941 - INFO - tvb_multiscale.tvb_nest.interfaces.models - <
class 'tvb_multiscale.tvb_nest.interfaces.models.RedWWexcIO'> created!
```

In [6]:
```python
print(tvb_nest_model.print_str(detailed_output=True, connectivity=False))
```

```
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RedWWexcIO TVB-NEST Interface
```

## 4. Configure simulator, simulate, gather results

In [7]:
```python
# Configure the simulator with the TVB-NEST interface...
simulator.configure(tvb_spikeNet_interface=tvb_nest_model)
```

```
# ...and simulate!
t = time.time()
simulation_length=110.0
transient = 10.0 # simulation_length/11
results = simulator.run(simulation_length=simulation_length)
# Integrate NEST one more NEST time step so that multimeters get the last tim
# unless you plan to continue simulation later
simulator.run_spiking_simulator(simulator.tvb_spikeNet_interface.nest_instanc
print("\nSimulated in %f secs!" % (time.time() - t))
```

```
Simulated in 8.536161 secs!
```

In [8]:
```
# Clean-up NEST simulation
simulator.tvb_spikeNet_interface.nest_instance.Cleanup()
```

## 5. Plot results and write them to HDF5 files

In [9]:
```
# set to False for faster plotting of only mean field variables and dates, ap
plot_per_neuron = False
MAX_VARS_IN_COLS = 3
MAX_REGIONS_IN_ROWS = 10
MIN_REGIONS_FOR_RASTER_PLOT = 9
# from examples.plot_write_results import plot_write_results
# populations = []
# populations_sizes = []
# for pop in nest_model_builder.populations:
#     populations.append(pop["label"])
#     populations_sizes.append(int(np.round(pop["scale"] * nest_model_builder
# plot_write_results(results, simulator, populations=populations, populations
#                    transient=transient, tvb_state_variable_type_label="Stat
#                    tvb_state_variables_labels=simulator.model.variables_of_
#                    plot_per_neuron=plot_per_neuron, plotter=plotter, config
```

In [10]:
```
# If you want to see what the function above does, take the steps, one by one
try:
    # We need framework_tvb for writing and reading from HDF5 files
    from tvb_multiscale.core.io.h5_writer import H5Writer
    writer = H5Writer()
except:
    writer = False

from tvb.contrib.scripts.datatypes.time_series import TimeSeriesRegion
from tvb.contrib.scripts.datatypes.time_series_xarray import TimeSeriesRegion

# Put the results in a Timeseries instance
from tvb.contrib.scripts.datatypes.time_series import TimeSeriesRegion

source_ts = TimeSeriesXarray(  # substitute with TimeSeriesRegion fot TVB lik
        data=results[0][1], time=results[0][0],
        connectivity=simulator.connectivity,
        labels_ordering=["Time", "State Variable", "Region", "Neurons"],
        labels_dimensions={"State Variable": list(simulator.model.variables_o
                           "Region": simulator.connectivity.region_labels.tol
        sample_period=simulator.integrator.dt)
source_ts.configure()

t = source_ts.time

# # Write to file
# if writer:
#     writer.write_tvb_to_h5(TimeSeriesRegion().from_xarray_DataArray(source_
#                                                                      connect
#                            os.path.join(config.out.FOLDER_RES, source_ts.ti
source_ts
```

```
del source_ts
```

In [11]:
```
# # Plot TVB time series
# source_ts.plot_timeseries(plotter_config=plotter.config,
#                           hue="Region" if source_ts.shape[2] > MAX_REGIONS_
#                           per_variable=source_ts.shape[1] > MAX_VARS_IN_COL
#                           figsize=FIGSIZE);
```

In [12]:
```
# # TVB time series raster plot:
# if source_ts.number_of_labels > MIN_REGIONS_FOR_RASTER_PLOT:
#     source_ts.plot_raster(plotter_config=plotter.config,
#                           per_variable=source_ts.shape[1] > MAX_VARS_IN_COL
#                           figsize=FIGSIZE);
```

In [13]:
```
# # Focus on the nodes modelled in NEST:
# n_spiking_nodes = len(simulator.tvb_spikeNet_interface.spiking_nodes_ids)
# source_ts_nest = source_ts[:, :, simulator.tvb_spikeNet_interface.spiking_n
# source_ts_nest.plot_timeseries(plotter_config=plotter.config,
#                                hue="Region" if source_ts_nest.shape[2] > MA
#                                per_variable=source_ts_nest.shape[1] > MAX_V
#                                figsize=FIGSIZE, figname="Spiking nodes TVB
```

In [14]:
```
# # Focus on the nodes modelled in NEST: raster plot
# if source_ts_nest.number_of_labels > MIN_REGIONS_FOR_RASTER_PLOT:
#     source_ts_nest.plot_raster(plotter_config=plotter.config,
#                                per_variable=source_ts_nest.shape[1] > MAX_V
#                                figsize=FIGSIZE, figname="Spiking nodes TVB
```

## Interactive time series plot

In [15]:
```
# # ...interactively as well
# # For interactive plotting:
# %matplotlib notebook
# plotter.plot_timeseries_interactive(source_ts)
```

## Spiking Network plots

In [16]:
```
from tvb_multiscale.tvb_elephant.spiking_network_analyser import SpikingNetwo
# Create a SpikingNetworkAnalyzer:
spikeNet_analyzer = \
    SpikingNetworkAnalyser(spikeNet=nest_network,
                           start_time=t[0], end_time=t[-1],
                           period=simulator.monitors[0].period, transient=tra
                           time_series_output_type="TVB", return_data=True,
                           force_homogeneous_results=True, connectivity=simul
```

## Plot spikes' raster and mean spike rates and correlations

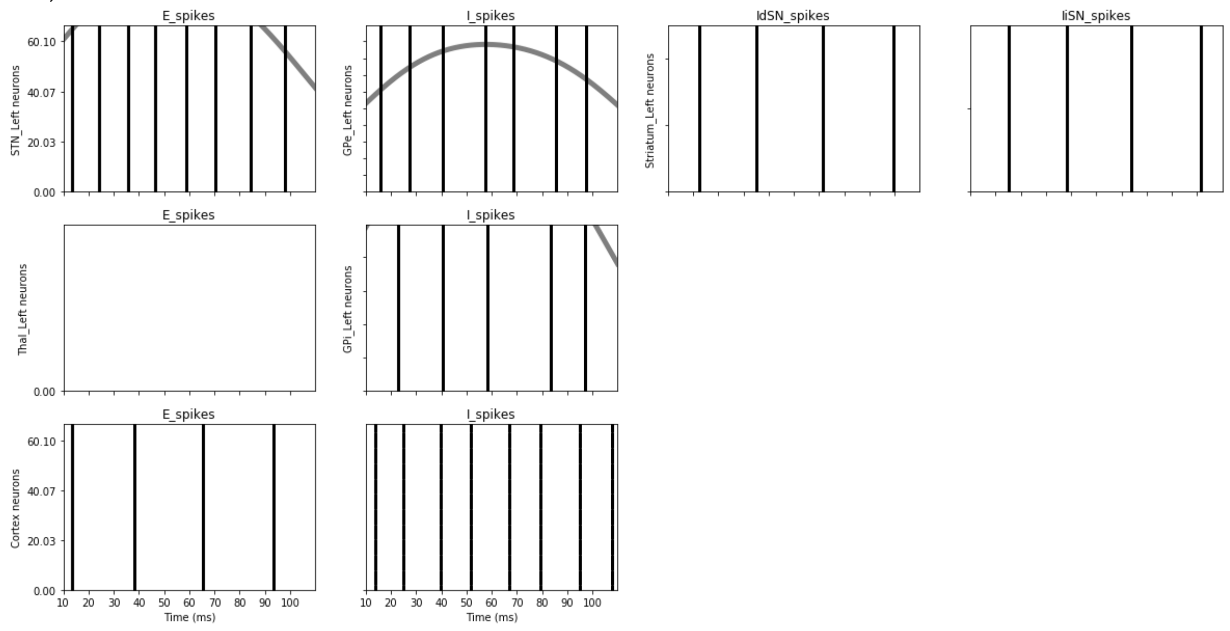
In [17]:
```
# Spikes rates and correlations per Population and Region
spikes_res = \
    spikeNet_analyzer.\
        compute_spikeNet_spikes_rates_and_correlations(
            populations_devices=None, regions=None,
            rates_methods=[], rates_kwargs=[{}],rate_results_names=[],
            corrs_methods=[], corrs_kwargs=[{}], corrs_results_names=[], bin_
            data_method=spikeNet_analyzer.get_spikes_from_device, data_kwargs
            return_devices=False
        );
```

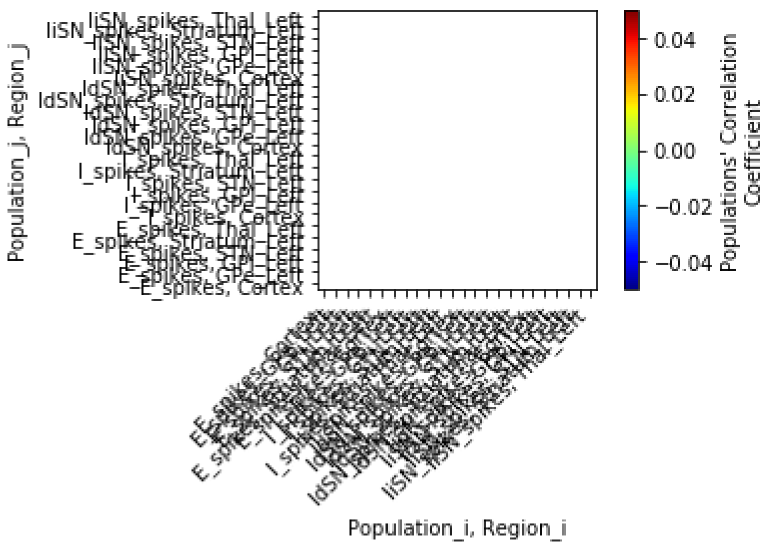
```
/home/docker/env/neurosci/lib/python3.7/site-packages/elephant/conversion.py:9
```

```
90: UserWarning:Correcting 400 rounding errors by shifting the affected spikes
into the following bin. You can set tolerance=None to disable this behaviour.
/home/docker/env/neurosci/lib/python3.7/site-packages/elephant/conversion.py:9
90: UserWarning:Correcting 150 rounding errors by shifting the affected spikes
into the following bin. You can set tolerance=None to disable this behaviour.
/home/docker/env/neurosci/lib/python3.7/site-packages/elephant/conversion.py:9
90: UserWarning:Correcting 200 rounding errors by shifting the affected spikes
into the following bin. You can set tolerance=None to disable this behaviour.
/home/docker/env/neurosci/lib/python3.7/site-packages/elephant/conversion.py:4
95: UserWarning:Binning discarded 10950 last spike(s) in the input spiketrain.
/home/docker/env/neurosci/lib/python3.7/site-packages/elephant/spike_train_cor
relation.py:510: UserWarning:Detected empty spike trains (rows) in the binned_
spiketrain.
/home/docker/env/neurosci/lib/python3.7/site-packages/elephant/spike_train_cor
relation.py:517: RuntimeWarning:invalid value encountered in true_divide
```

In [18]:
```
if spikes_res:
    print(spikes_res["mean_rate"])
    print(spikes_res["spikes_correlation_coefficient"])
    # Plot spikes' rasters together with mean population's spikes' rates' tim
    if plotter:
        plotter.plot_spike_events(spikes_res["spikes"], rates=spikes_res["mea
        from tvb_multiscale.core.plot.correlations_plot import plot_correlati
        plot_correlations(spikes_res["spikes_correlation_coefficient"], plott
```

```
<xarray.DataArray "Mean Populations' Spikes' Rates" (Population: 4, Region: 6)
>
array([[0.04004004,        nan,        nan, 0.08008008,        nan,
        0.        ],
       [0.08008008, 0.07007007, 0.05005005,        nan,        nan,
               nan],
       [       nan,        nan,        nan,        nan, 0.04004004,
               nan],
       [       nan,        nan,        nan,        nan, 0.04004004,
               nan]])
Coordinates:
  * Region      (Region) object 'Cortex' 'GPe_Left' ... 'Thal_Left'
  * Population  (Population) object 'E_spikes' 'I_spikes' ... 'IiSN_spikes'
<xarray.DataArray "Populations' Correlation Coefficient" (Population_i: 4, Pop
ulation_j: 4, Region_i: 6, Region_j: 6)>
array([[[[nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan]],

        [[nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan]],

        [[nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan]],
...
        [[nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan]],

        [[nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan]],

        [[nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan],
         [nan, nan, nan, nan, nan, nan]]]])
Coordinates:
  * Population_i  (Population_i) object 'E_spikes' 'I_spikes' ... 'IiSN_spike
s'
  * Region_i      (Region_i) object 'Cortex' 'GPe_Left' ... 'Thal_Left'
  * Population_j  (Population_j) object 'E_spikes' 'I_spikes' ... 'IiSN_spike
s'
  * Region_j      (Region_j) object 'Cortex' 'GPe_Left' ... 'Thal_Left'
2020-11-26 15:28:36,674 - ERROR - tvb.contrib.scripts.datatypes.time_series_xa
rray - Cannot access index 3 of labels ordering: ('Time', 'Population', 'Regio
n')!
2020-11-26 15:28:36,678 - ERROR - tvb.contrib.scripts.datatypes.time_series_xa
rray - Cannot access index 3 of labels ordering: ('Time', 'Population', 'Regio
n')!
```





```
In [19]: if spikes_res and writer:
             writer.write_object(spikes_res["spikes"].to_dict(),
                                 path=os.path.join(config.out.FOLDER_RES,  "Spikes") +
             writer.write_object(spikes_res["mean_rate"].to_dict(),
                                 path=os.path.join(config.out.FOLDER_RES,
                                                   spikes_res["mean_rate"].name) + ".h
             writer.write_tvb_to_h5(TimeSeriesRegion().from_xarray_DataArray(
                                       spikes_res["mean_rate_time_series"]._data,
                                        connectivity=spikes_res["mean_rate_time_series
                                    os.path.join(config.out.FOLDER_RES,
                                                 spikes_res["mean_rate_time_series"].t
                                    recursive=False);
             writer.write_object(spikes_res["spikes_correlation_coefficient"].to_dict(
                                 path=os.path.join(config.out.FOLDER_RES,
                                                   spikes_res["spikes_correlation_coef
```

```
2020-11-26 15:28:39,242 - INFO - tvb_multiscale.core.io.h5_writer - Starting t
o write dict to: /home/docker/packages/tvb-multiscale/examples/notebooks/outpu
ts_Izhikevich_nest/res/Spikes.h5
2020-11-26 15:28:39,242 - INFO - tvb_multiscale.core.io.h5_writer - Starting t
o write dict to: /home/docker/packages/tvb-multiscale/examples/notebooks/outpu
ts_Izhikevich_nest/res/Spikes.h5
2020-11-26 15:28:39,281 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,281 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,293 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,293 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,311 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/STN_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> times:
[ 1.675  1.675  1.675 ... 97.95  97.95  97.95 ] !

2020-11-26 15:28:39,311 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/STN_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> times:
[ 1.675  1.675  1.675 ... 97.95  97.95  97.95 ] !

2020-11-26 15:28:39,319 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/STN_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> senders:
[401. 402. 403. ... 598. 599. 600.] !

2020-11-26 15:28:39,319 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/STN_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> senders:
[401. 402. 403. ... 598. 599. 600.] !

2020-11-26 15:28:39,328 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,328 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,333 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,333 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,341 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/Thal_Left" (2 members)> dataset <cla
ss 'numpy.ndarray'> times:
[] !

2020-11-26 15:28:39,341 - WARNING - tvb_multiscale.core.io.h5_writer -
```

```
Failed to write to <HDF5 group "/E_spikes/Thal_Left" (2 members)> dataset <cla
ss 'numpy.ndarray'> times:
[] !

2020-11-26 15:28:39,347 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/Thal_Left" (2 members)> dataset <cla
ss 'numpy.ndarray'> senders:
[] !

2020-11-26 15:28:39,347 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/Thal_Left" (2 members)> dataset <cla
ss 'numpy.ndarray'> senders:
[] !

2020-11-26 15:28:39,363 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,363 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,370 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,370 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,378 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/Cortex" (2 members)> dataset <class
'numpy.ndarray'> times:
[ 1.1   1.1   1.1  ... 93.25 93.25 93.25] !

2020-11-26 15:28:39,378 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/Cortex" (2 members)> dataset <class
'numpy.ndarray'> times:
[ 1.1   1.1   1.1  ... 93.25 93.25 93.25] !

2020-11-26 15:28:39,389 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/Cortex" (2 members)> dataset <class
'numpy.ndarray'> senders:
[1201. 1202. 1203. ... 1798. 1799. 1800.] !

2020-11-26 15:28:39,389 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/E_spikes/Cortex" (2 members)> dataset <class
'numpy.ndarray'> senders:
[1201. 1202. 1203. ... 1798. 1799. 1800.] !

2020-11-26 15:28:39,403 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,403 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,412 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,412 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,419 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/I_spikes/GPe_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> times:
[ 3.075  3.075  3.075 ... 97.4   97.4   97.4  ] !

2020-11-26 15:28:39,419 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/I_spikes/GPe_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> times:
[ 3.075  3.075  3.075 ... 97.4   97.4   97.4  ] !

2020-11-26 15:28:39,431 - WARNING - tvb_multiscale.core.io.h5_writer -
```

```
Failed to write to <HDF5 group "/I_spikes/GPe_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> senders:
[  1.   2.   3. ... 198. 199. 200.] !

2020-11-26 15:28:39,431 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/I_spikes/GPe_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> senders:
[  1.   2.   3. ... 198. 199. 200.] !

2020-11-26 15:28:39,442 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,442 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,448 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,448 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,459 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/I_spikes/GPi_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> times:
[ 1.575  1.575  1.575 ... 97.175 97.175 97.175] !

2020-11-26 15:28:39,459 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/I_spikes/GPi_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> times:
[ 1.575  1.575  1.575 ... 97.175 97.175 97.175] !

2020-11-26 15:28:39,467 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/I_spikes/GPi_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> senders:
[201. 202. 203. ... 398. 399. 400.] !

2020-11-26 15:28:39,467 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/I_spikes/GPi_Left" (2 members)> dataset <clas
s 'numpy.ndarray'> senders:
[201. 202. 203. ... 398. 399. 400.] !

2020-11-26 15:28:39,476 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,476 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,482 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,482 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,492 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/I_spikes/Cortex" (2 members)> dataset <class
'numpy.ndarray'> times:
[  2.6   2.6   2.6 ... 107.7 107.7 107.7] !

2020-11-26 15:28:39,492 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/I_spikes/Cortex" (2 members)> dataset <class
'numpy.ndarray'> times:
[  2.6   2.6   2.6 ... 107.7 107.7 107.7] !

2020-11-26 15:28:39,508 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/I_spikes/Cortex" (2 members)> dataset <class
'numpy.ndarray'> senders:
[1801. 1802. 1803. ... 1948. 1949. 1950.] !

2020-11-26 15:28:39,508 - WARNING - tvb_multiscale.core.io.h5_writer -
```

```
Failed to write to <HDF5 group "/I_spikes/Cortex" (2 members)> dataset <class
'numpy.ndarray'> senders:
[1801. 1802. 1803. ... 1948. 1949. 1950.] !

2020-11-26 15:28:39,519 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,519 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,526 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,526 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,570 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/IdSN_spikes/Striatum_Left" (2 members)> datas
et <class 'numpy.ndarray'> times:
[ 3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925  3.925
 22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4
 22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4
 22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4
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 22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4   22.4
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2020-11-26 15:28:39,570 - WARNING - tvb_multiscale.core.io.h5_writer -
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2020-11-26 15:28:39,615 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/IdSN_spikes/Striatum_Left" (2 members)> datas
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2020-11-26 15:28:39,615 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/IdSN_spikes/Striatum_Left" (2 members)> datas
et <class 'numpy.ndarray'> senders:
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 795. 796. 797. 798. 799. 800.] !

2020-11-26 15:28:39,628 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,628 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> times to h5 file as a numpy array dataset !

2020-11-26 15:28:39,636 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,636 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> senders to h5 file as a numpy array dataset !

2020-11-26 15:28:39,682 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/IiSN_spikes/Striatum_Left" (2 members)> datas
et <class 'numpy.ndarray'> times:
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   4.675   4.675   4.675   4.675   4.675   4.675   4.675   4.675   4.675
   4.675   4.675   4.675   4.675   4.675   4.675   4.675   4.675   4.675
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2020-11-26 15:28:39,682 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/IiSN_spikes/Striatum_Left" (2 members)> datas
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2020-11-26 15:28:39,722 - WARNING - tvb_multiscale.core.io.h5_writer -
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2020-11-26 15:28:39,722 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/IiSN_spikes/Striatum_Left" (2 members)> datas
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  873.  874.  875.  876.  877.  878.  879.  880.  881.  882.  883.  884.
  885.  886.  887.  888.  889.  890.  891.  892.  893.  894.  895.  896.
  897.  898.  899.  900.  901.  902.  903.  904.  905.  906.  907.  908.
  909.  910.  911.  912.  913.  914.  915.  916.  917.  918.  919.  920.
  921.  922.  923.  924.  925.  926.  927.  928.  929.  930.  931.  932.
  933.  934.  935.  936.  937.  938.  939.  940.  941.  942.  943.  944.
  945.  946.  947.  948.  949.  950.  951.  952.  953.  954.  955.  956.
  957.  958.  959.  960.  961.  962.  963.  964.  965.  966.  967.  968.
  969.  970.  971.  972.  973.  974.  975.  976.  977.  978.  979.  980.
  981.  982.  983.  984.  985.  986.  987.  988.  989.  990.  991.  992.
  993.  994.  995.  996.  997.  998.  999. 1000.  801.  802.  803.  804.
  805.  806.  807.  808.  809.  810.  811.  812.  813.  814.  815.  816.
  817.  818.  819.  820.  821.  822.  823.  824.  825.  826.  827.  828.
  829.  830.  831.  832.  833.  834.  835.  836.  837.  838.  839.  840.
  841.  842.  843.  844.  845.  846.  847.  848.  849.  850.  851.  852.
  853.  854.  855.  856.  857.  858.  859.  860.  861.  862.  863.  864.
  865.  866.  867.  868.  869.  870.  871.  872.  873.  874.  875.  876.
  877.  878.  879.  880.  881.  882.  883.  884.  885.  886.  887.  888.
  889.  890.  891.  892.  893.  894.  895.  896.  897.  898.  899.  900.
  901.  902.  903.  904.  905.  906.  907.  908.  909.  910.  911.  912.
  913.  914.  915.  916.  917.  918.  919.  920.  921.  922.  923.  924.
  925.  926.  927.  928.  929.  930.  931.  932.  933.  934.  935.  936.
  937.  938.  939.  940.  941.  942.  943.  944.  945.  946.  947.  948.
  949.  950.  951.  952.  953.  954.  955.  956.  957.  958.  959.  960.
  961.  962.  963.  964.  965.  966.  967.  968.  969.  970.  971.  972.
  973.  974.  975.  976.  977.  978.  979.  980.  981.  982.  983.  984.
  985.  986.  987.  988.  989.  990.  991.  992.  993.  994.  995.  996.
  997.  998.  999. 1000.  801.  802.  803.  804.  805.  806.  807.  808.
  809.  810.  811.  812.  813.  814.  815.  816.  817.  818.  819.  820.
  821.  822.  823.  824.  825.  826.  827.  828.  829.  830.  831.  832.
  833.  834.  835.  836.  837.  838.  839.  840.  841.  842.  843.  844.
  845.  846.  847.  848.  849.  850.  851.  852.  853.  854.  855.  856.
  857.  858.  859.  860.  861.  862.  863.  864.  865.  866.  867.  868.
  869.  870.  871.  872.  873.  874.  875.  876.  877.  878.  879.  880.
  881.  882.  883.  884.  885.  886.  887.  888.  889.  890.  891.  892.
  893.  894.  895.  896.  897.  898.  899.  900.  901.  902.  903.  904.
  905.  906.  907.  908.  909.  910.  911.  912.  913.  914.  915.  916.
  917.  918.  919.  920.  921.  922.  923.  924.  925.  926.  927.  928.
  929.  930.  931.  932.  933.  934.  935.  936.  937.  938.  939.  940.
  941.  942.  943.  944.  945.  946.  947.  948.  949.  950.  951.  952.
  953.  954.  955.  956.  957.  958.  959.  960.  961.  962.  963.  964.
  965.  966.  967.  968.  969.  970.  971.  972.  973.  974.  975.  976.
  977.  978.  979.  980.  981.  982.  983.  984.  985.  986.  987.  988.
  989.  990.  991.  992.  993.  994.  995.  996.  997.  998.  999. 1000.
  801.  802.  803.  804.  805.  806.  807.  808.  809.  810.  811.  812.
  813.  814.  815.  816.  817.  818.  819.  820.  821.  822.  823.  824.
  825.  826.  827.  828.  829.  830.  831.  832.  833.  834.  835.  836.
  837.  838.  839.  840.  841.  842.  843.  844.  845.  846.  847.  848.
  849.  850.  851.  852.  853.  854.  855.  856.  857.  858.  859.  860.
  861.  862.  863.  864.  865.  866.  867.  868.  869.  870.  871.  872.
  873.  874.  875.  876.  877.  878.  879.  880.  881.  882.  883.  884.
  885.  886.  887.  888.  889.  890.  891.  892.  893.  894.  895.  896.
  897.  898.  899.  900.  901.  902.  903.  904.  905.  906.  907.  908.
  909.  910.  911.  912.  913.  914.  915.  916.  917.  918.  919.  920.
  921.  922.  923.  924.  925.  926.  927.  928.  929.  930.  931.  932.
  933.  934.  935.  936.  937.  938.  939.  940.  941.  942.  943.  944.
  945.  946.  947.  948.  949.  950.  951.  952.  953.  954.  955.  956.
  957.  958.  959.  960.  961.  962.  963.  964.  965.  966.  967.  968.
  969.  970.  971.  972.  973.  974.  975.  976.  977.  978.  979.  980.
  981.  982.  983.  984.  985.  986.  987.  988.  989.  990.  991.  992.
  993.  994.  995.  996.  997.  998.  999. 1000.  801.  802.  803.  804.
  805.  806.  807.  808.  809.  810.  811.  812.  813.  814.  815.  816.
  817.  818.  819.  820.  821.  822.  823.  824.  825.  826.  827.  828.
  829.  830.  831.  832.  833.  834.  835.  836.  837.  838.  839.  840.
  841.  842.  843.  844.  845.  846.  847.  848.  849.  850.  851.  852.
  853.  854.  855.  856.  857.  858.  859.  860.  861.  862.  863.  864.
  865.  866.  867.  868.  869.  870.  871.  872.  873.  874.  875.  876.
  877.  878.  879.  880.  881.  882.  883.  884.  885.  886.  887.  888.
  889.  890.  891.  892.  893.  894.  895.  896.  897.  898.  899.  900.
  901.  902.  903.  904.  905.  906.  907.  908.  909.  910.  911.  912.
  913.  914.  915.  916.  917.  918.  919.  920.  921.  922.  923.  924.
  925.  926.  927.  928.  929.  930.  931.  932.  933.  934.  935.  936.
  937.  938.  939.  940.  941.  942.  943.  944.  945.  946.  947.  948.
  949.  950.  951.  952.  953.  954.  955.  956.  957.  958.  959.  960.
  961.  962.  963.  964.  965.  966.  967.  968.  969.  970.  971.  972.
  973.  974.  975.  976.  977.  978.  979.  980.  981.  982.  983.  984.
  985.  986.  987.  988.  989.  990.  991.  992.  993.  994.  995.  996.
  997.  998.  999. 1000.] !

2020-11-26 15:28:39,746 - INFO - tvb_multiscale.core.io.h5_writer - dict has b
een written to file: /home/docker/packages/tvb-multiscale/examples/notebooks/o
utputs_Izhikevich_nest/res/Spikes.h5
2020-11-26 15:28:39,746 - INFO - tvb_multiscale.core.io.h5_writer - dict has b
een written to file: /home/docker/packages/tvb-multiscale/examples/notebooks/o
utputs_Izhikevich_nest/res/Spikes.h5
2020-11-26 15:28:39,751 - INFO - tvb_multiscale.core.io.h5_writer - Starting t
o write dict to: /home/docker/packages/tvb-multiscale/examples/notebooks/outpu
ts_Izhikevich_nest/res/Mean Populations' Spikes' Rates.h5
2020-11-26 15:28:39,751 - INFO - tvb_multiscale.core.io.h5_writer - Starting t
o write dict to: /home/docker/packages/tvb-multiscale/examples/notebooks/outpu
ts_Izhikevich_nest/res/Mean Populations' Spikes' Rates.h5
2020-11-26 15:28:39,770 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:39,770 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:39,777 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:39,777 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:39,782 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 file "Mean Populations' Spikes' Rates.h5" (mode r+)>
 dataset <class 'numpy.ndarray'> dims:
['Population' 'Region'] !

2020-11-26 15:28:39,782 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 file "Mean Populations' Spikes' Rates.h5" (mode r+)>
 dataset <class 'numpy.ndarray'> dims:
```

```
['Population' 'Region'] !

2020-11-26 15:28:39,795 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 file "Mean Populations' Spikes' Rates.h5" (mode r+)>
 dataset <class 'numpy.ndarray'> data:
[[0.04004004        nan        nan 0.08008008        nan 0.        ]
 [0.08008008 0.07007007 0.05005005        nan        nan        nan]
 [       nan        nan        nan        nan 0.04004004        nan]
 [       nan        nan        nan        nan 0.04004004        nan]] !

2020-11-26 15:28:39,795 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 file "Mean Populations' Spikes' Rates.h5" (mode r+)>
 dataset <class 'numpy.ndarray'> data:
[[0.04004004        nan        nan 0.08008008        nan 0.        ]
 [0.08008008 0.07007007 0.05005005        nan        nan        nan]
 [       nan        nan        nan        nan 0.04004004        nan]
 [       nan        nan        nan        nan 0.04004004        nan]] !

2020-11-26 15:28:39,807 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:39,807 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:39,813 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:39,813 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:39,820 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region" (2 members)> dataset <class 'n
umpy.ndarray'> dims:
['Region'] !

2020-11-26 15:28:39,820 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region" (2 members)> dataset <class 'n
umpy.ndarray'> dims:
['Region'] !

2020-11-26 15:28:39,828 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region" (2 members)> dataset <class 'n
umpy.ndarray'> data:
['Cortex' 'GPe_Left' 'GPi_Left' 'STN_Left' 'Striatum_Left' 'Thal_Left'] !

2020-11-26 15:28:39,828 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region" (2 members)> dataset <class 'n
umpy.ndarray'> data:
['Cortex' 'GPe_Left' 'GPi_Left' 'STN_Left' 'Striatum_Left' 'Thal_Left'] !

2020-11-26 15:28:39,837 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:39,837 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:39,844 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:39,844 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:39,850 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population" (2 members)> dataset <clas
s 'numpy.ndarray'> dims:
['Population'] !

2020-11-26 15:28:39,850 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population" (2 members)> dataset <clas
```

```
s 'numpy.ndarray'> dims:
['Population'] !

2020-11-26 15:28:39,863 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population" (2 members)> dataset <clas
s 'numpy.ndarray'> data:
['E_spikes' 'I_spikes' 'IdSN_spikes' 'IiSN_spikes'] !

2020-11-26 15:28:39,863 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population" (2 members)> dataset <clas
s 'numpy.ndarray'> data:
['E_spikes' 'I_spikes' 'IdSN_spikes' 'IiSN_spikes'] !

2020-11-26 15:28:39,882 - INFO - tvb_multiscale.core.io.h5_writer - dict has b
een written to file: /home/docker/packages/tvb-multiscale/examples/notebooks/o
utputs_Izhikevich_nest/res/Mean Populations' Spikes' Rates.h5
2020-11-26 15:28:39,882 - INFO - tvb_multiscale.core.io.h5_writer - dict has b
een written to file: /home/docker/packages/tvb-multiscale/examples/notebooks/o
utputs_Izhikevich_nest/res/Mean Populations' Spikes' Rates.h5
2020-11-26 15:28:40,085 - INFO - tvb_multiscale.core.io.h5_writer - Starting t
o write dict to: /home/docker/packages/tvb-multiscale/examples/notebooks/outpu
ts_Izhikevich_nest/res/Populations' Correlation Coefficient.h5
2020-11-26 15:28:40,085 - INFO - tvb_multiscale.core.io.h5_writer - Starting t
o write dict to: /home/docker/packages/tvb-multiscale/examples/notebooks/outpu
ts_Izhikevich_nest/res/Populations' Correlation Coefficient.h5
2020-11-26 15:28:40,100 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:40,100 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:40,105 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:40,105 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:40,112 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 file "Populations' Correlation Coefficient.h5" (mode
 r+)> dataset <class 'numpy.ndarray'> dims:
['Population_i' 'Population_j' 'Region_i' 'Region_j'] !

2020-11-26 15:28:40,112 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 file "Populations' Correlation Coefficient.h5" (mode
 r+)> dataset <class 'numpy.ndarray'> dims:
['Population_i' 'Population_j' 'Region_i' 'Region_j'] !

2020-11-26 15:28:40,153 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 file "Populations' Correlation Coefficient.h5" (mode
 r+)> dataset <class 'numpy.ndarray'> data:
[[[[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]]


 [[[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
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   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]]


 [[[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
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   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
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  [[nan nan nan nan nan nan]
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   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]]


 [[[nan nan nan nan nan nan]
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   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
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  [[nan nan nan nan nan nan]
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   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
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   [nan nan nan nan nan nan]
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   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]]]] !

2020-11-26 15:28:40,153 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 file "Populations' Correlation Coefficient.h5" (mode
 r+)> dataset <class 'numpy.ndarray'> data:
[[[[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
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   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
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  [[nan nan nan nan nan nan]
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   [nan nan nan nan nan nan]]]


 [[[nan nan nan nan nan nan]
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   [nan nan nan nan nan nan]]

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   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

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   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]]


 [[[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]]


 [[[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]

  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]
  [[nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]
   [nan nan nan nan nan nan]]]] !

2020-11-26 15:28:40,171 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:40,171 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:40,181 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:40,181 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:40,187 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population_i" (2 members)> dataset <cl
ass 'numpy.ndarray'> dims:
['Population_i'] !

2020-11-26 15:28:40,187 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population_i" (2 members)> dataset <cl
ass 'numpy.ndarray'> dims:
['Population_i'] !

2020-11-26 15:28:40,196 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population_i" (2 members)> dataset <cl
ass 'numpy.ndarray'> data:
['E_spikes' 'I_spikes' 'IdSN_spikes' 'IiSN_spikes'] !

2020-11-26 15:28:40,196 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population_i" (2 members)> dataset <cl
ass 'numpy.ndarray'> data:
['E_spikes' 'I_spikes' 'IdSN_spikes' 'IiSN_spikes'] !

2020-11-26 15:28:40,207 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:40,207 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:40,220 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:40,220 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:40,235 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region_i" (2 members)> dataset <class
 'numpy.ndarray'> dims:
['Region_i'] !

2020-11-26 15:28:40,235 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region_i" (2 members)> dataset <class
 'numpy.ndarray'> dims:
['Region_i'] !

2020-11-26 15:28:40,249 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region_i" (2 members)> dataset <class
 'numpy.ndarray'> data:
['Cortex' 'GPe_Left' 'GPi_Left' 'STN_Left' 'Striatum_Left' 'Thal_Left'] !

2020-11-26 15:28:40,249 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region_i" (2 members)> dataset <class
 'numpy.ndarray'> data:
```
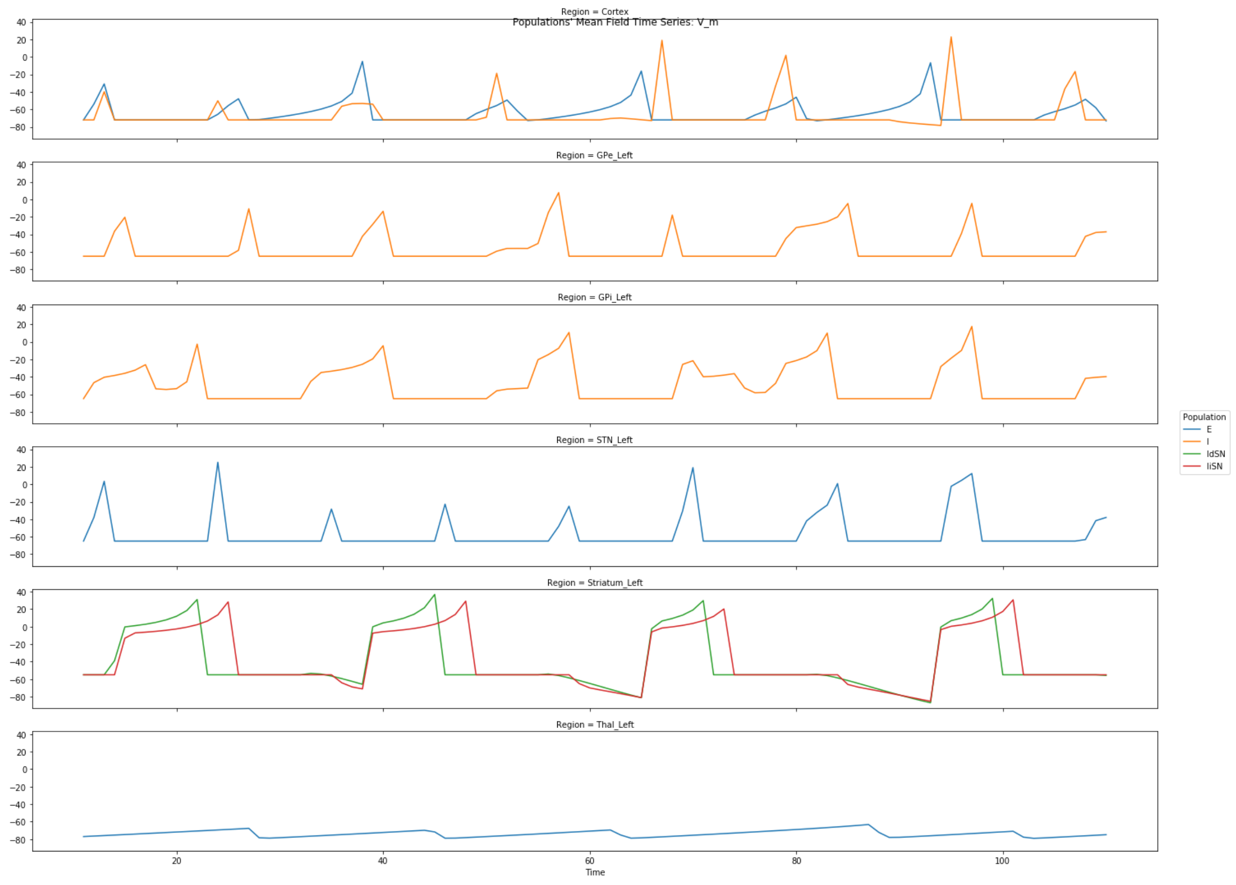

```
['Cortex' 'GPe_Left' 'GPi_Left' 'STN_Left' 'Striatum_Left' 'Thal_Left'] !

2020-11-26 15:28:40,273 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:40,273 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:40,284 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:40,284 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:40,296 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population_j" (2 members)> dataset <cl
ass 'numpy.ndarray'> dims:
['Population_j'] !

2020-11-26 15:28:40,296 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population_j" (2 members)> dataset <cl
ass 'numpy.ndarray'> dims:
['Population_j'] !

2020-11-26 15:28:40,311 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population_j" (2 members)> dataset <cl
ass 'numpy.ndarray'> data:
['E_spikes' 'I_spikes' 'IdSN_spikes' 'IiSN_spikes'] !

2020-11-26 15:28:40,311 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Population_j" (2 members)> dataset <cl
ass 'numpy.ndarray'> data:
['E_spikes' 'I_spikes' 'IdSN_spikes' 'IiSN_spikes'] !

2020-11-26 15:28:40,325 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:40,325 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'tuple'> dims to h5 file as a numpy array dataset !

2020-11-26 15:28:40,343 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:40,343 - WARNING - tvb_multiscale.core.io.h5_writer -
Writing <class 'list'> data to h5 file as a numpy array dataset !

2020-11-26 15:28:40,362 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region_j" (2 members)> dataset <class
 'numpy.ndarray'> dims:
['Region_j'] !

2020-11-26 15:28:40,362 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region_j" (2 members)> dataset <class
 'numpy.ndarray'> dims:
['Region_j'] !

2020-11-26 15:28:40,371 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region_j" (2 members)> dataset <class
 'numpy.ndarray'> data:
['Cortex' 'GPe_Left' 'GPi_Left' 'STN_Left' 'Striatum_Left' 'Thal_Left'] !

2020-11-26 15:28:40,371 - WARNING - tvb_multiscale.core.io.h5_writer -
Failed to write to <HDF5 group "/coords/Region_j" (2 members)> dataset <class
 'numpy.ndarray'> data:
['Cortex' 'GPe_Left' 'GPi_Left' 'STN_Left' 'Striatum_Left' 'Thal_Left'] !

2020-11-26 15:28:40,396 - INFO - tvb_multiscale.core.io.h5_writer - dict has b
een written to file: /home/docker/packages/tvb-multiscale/examples/notebooks/o
utputs_Izhikevich_nest/res/Populations' Correlation Coefficient.h5
```

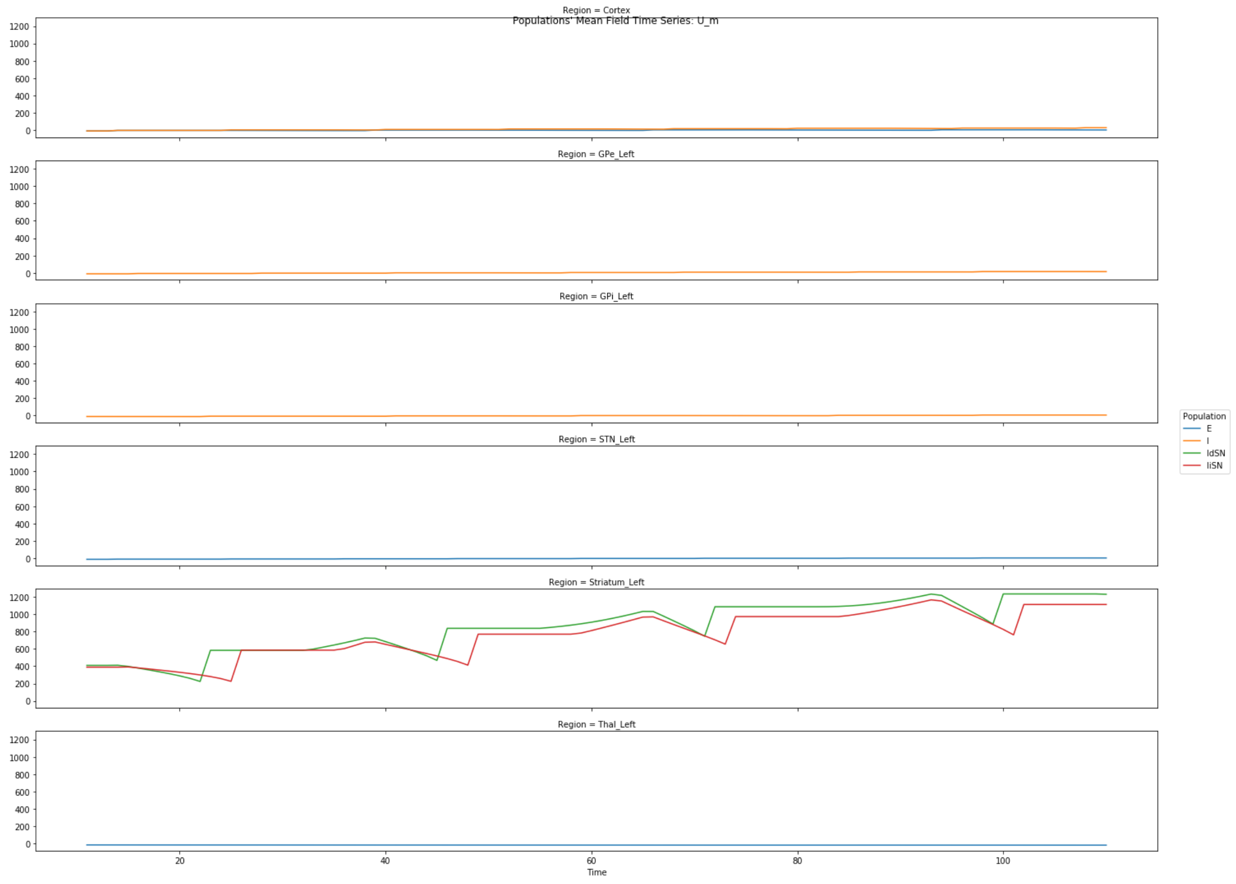
```
2020-11-26 15:28:40,396 - INFO - tvb_multiscale.core.io.h5_writer - dict has b
een written to file: /home/docker/packages/tvb-multiscale/examples/notebooks/o
utputs_Izhikevich_nest/res/Populations' Correlation Coefficient.h5
```

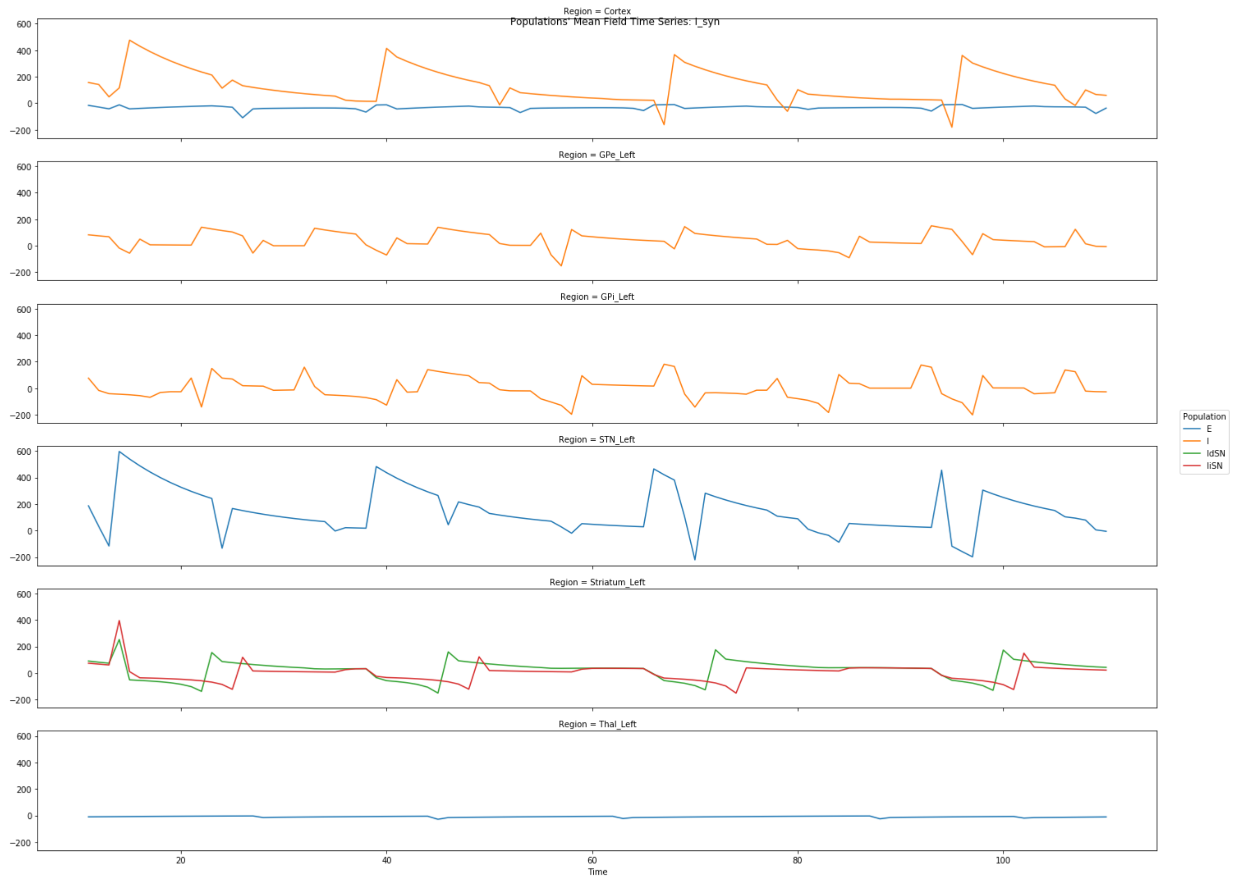
## Get SpikingNetwork mean field variable time series and plot them

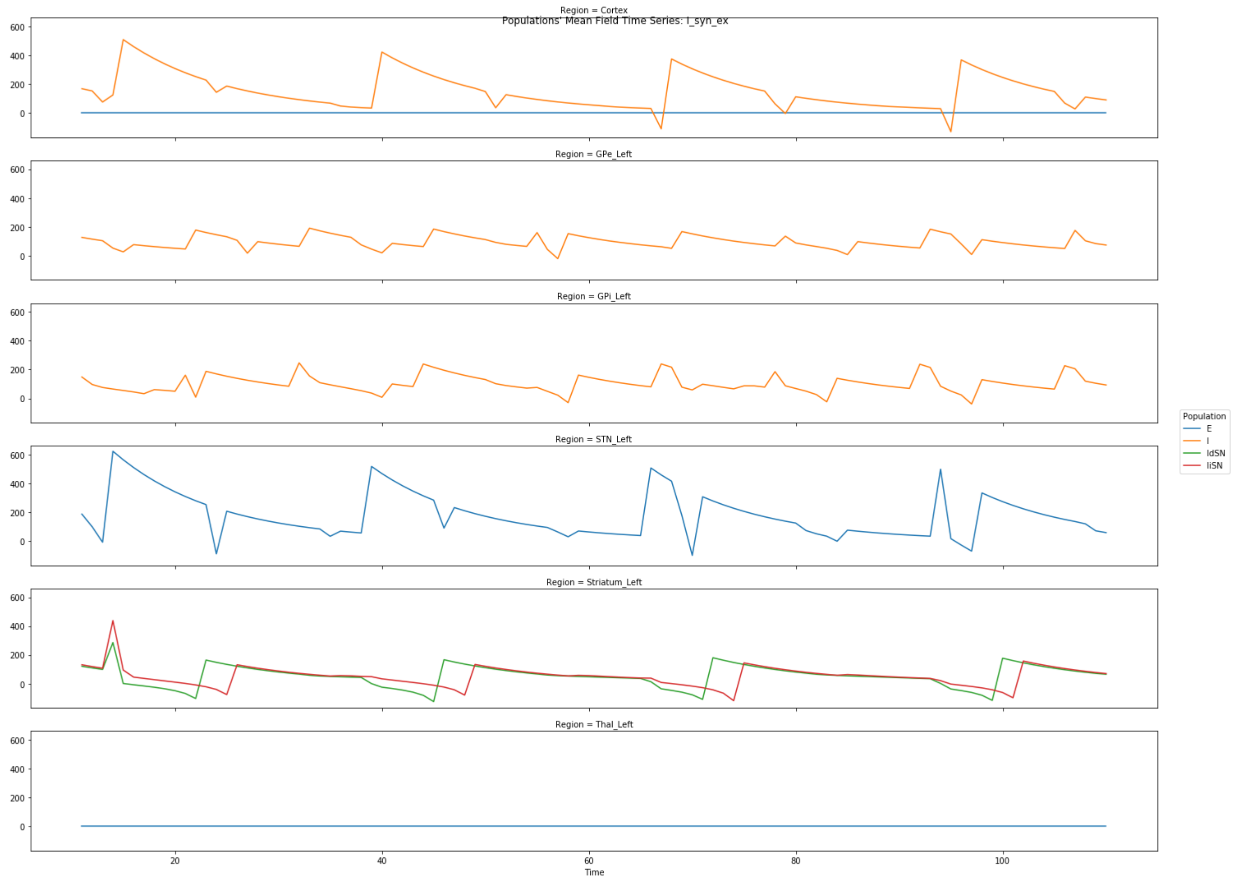
In [20]:

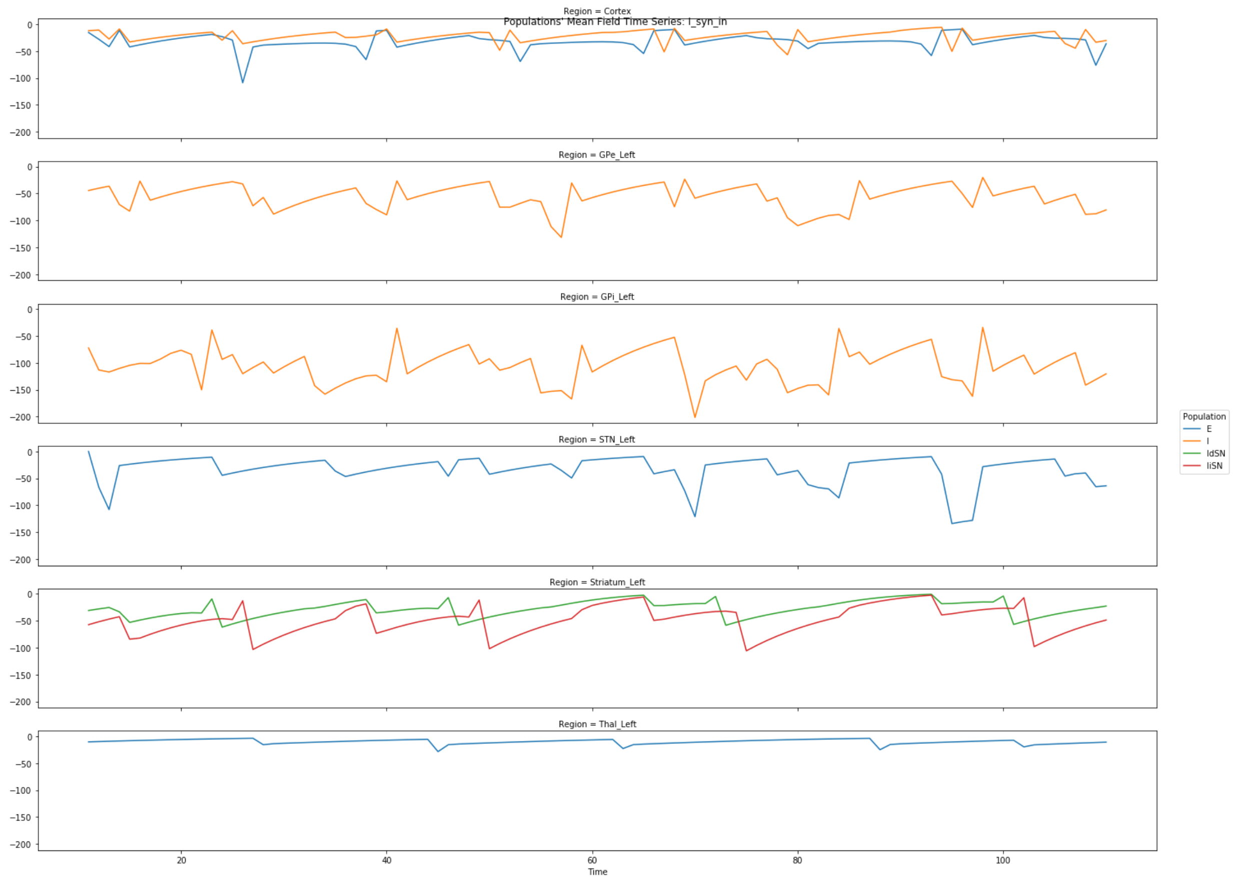
```
# Continuous time variables' data of spiking neurons
if plot_per_neuron:
    spikeNet_analyzer.return_data = True
else:
    spikeNet_analyzer.return_data = False
spikeNet_ts = \
    spikeNet_analyzer. \
         compute_spikeNet_mean_field_time_series(populations_devices=None, re
                                                 computations_kwargs={}, data_
if spikeNet_ts:
    if plot_per_neuron:
        mean_field_ts = spikeNet_ts["mean_field_time_series"]  # mean field
        spikeNet_ts = spikeNet_ts["data_by_neuron"]  # per neuron data
    else:
        mean_field_ts = spikeNet_ts
    if mean_field_ts and mean_field_ts.size > 0:
        mean_field_ts.plot_timeseries(plotter_config=plotter.config,
                                      per_variable=mean_field_ts.shape[1] > M
        if mean_field_ts.number_of_labels > MIN_REGIONS_FOR_RASTER_PLOT:
            mean_field_ts.plot_raster(plotter_config=plotter.config,
                                      per_variable=mean_field_ts.shape[1] > M
                                      linestyle="--", alpha=0.5, linewidth=0.
else:
    mean_field_ts = None
```

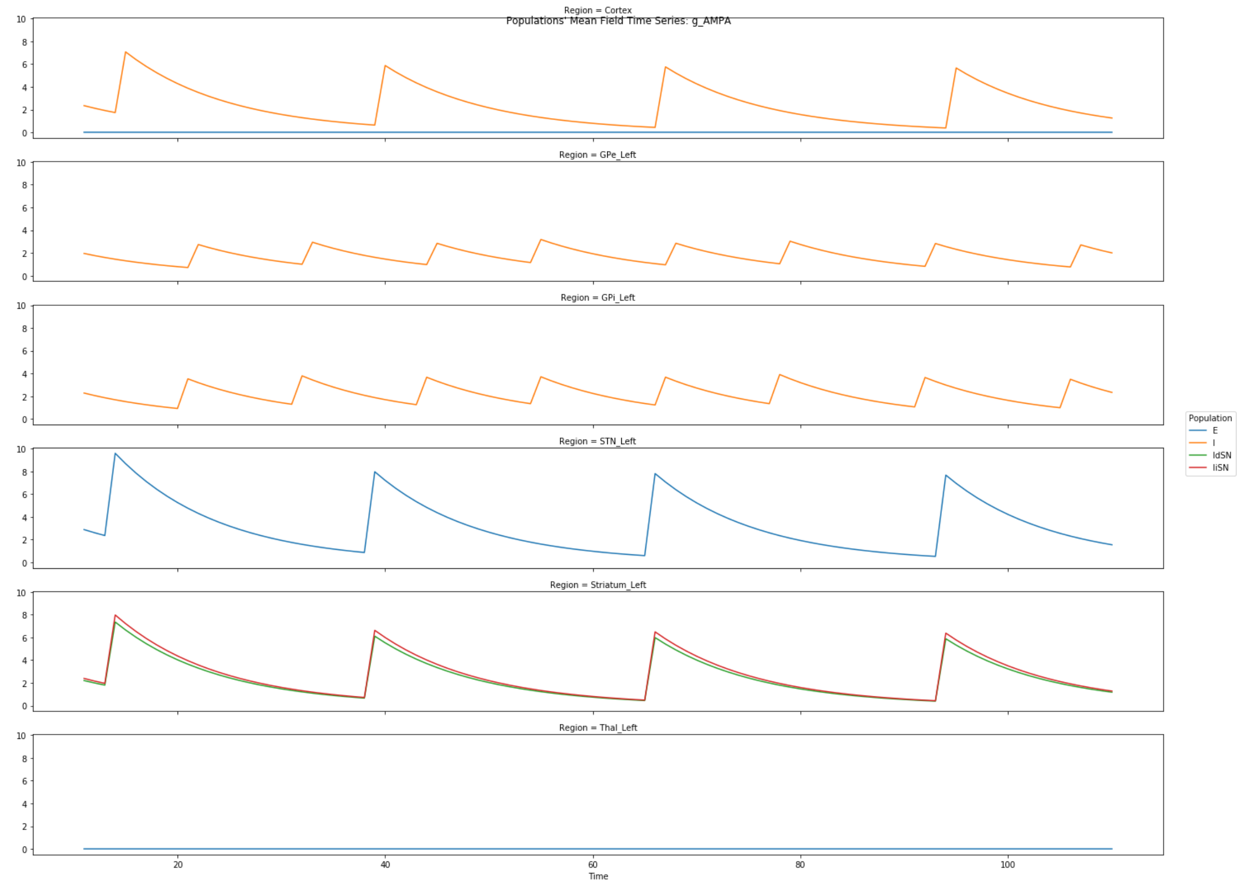


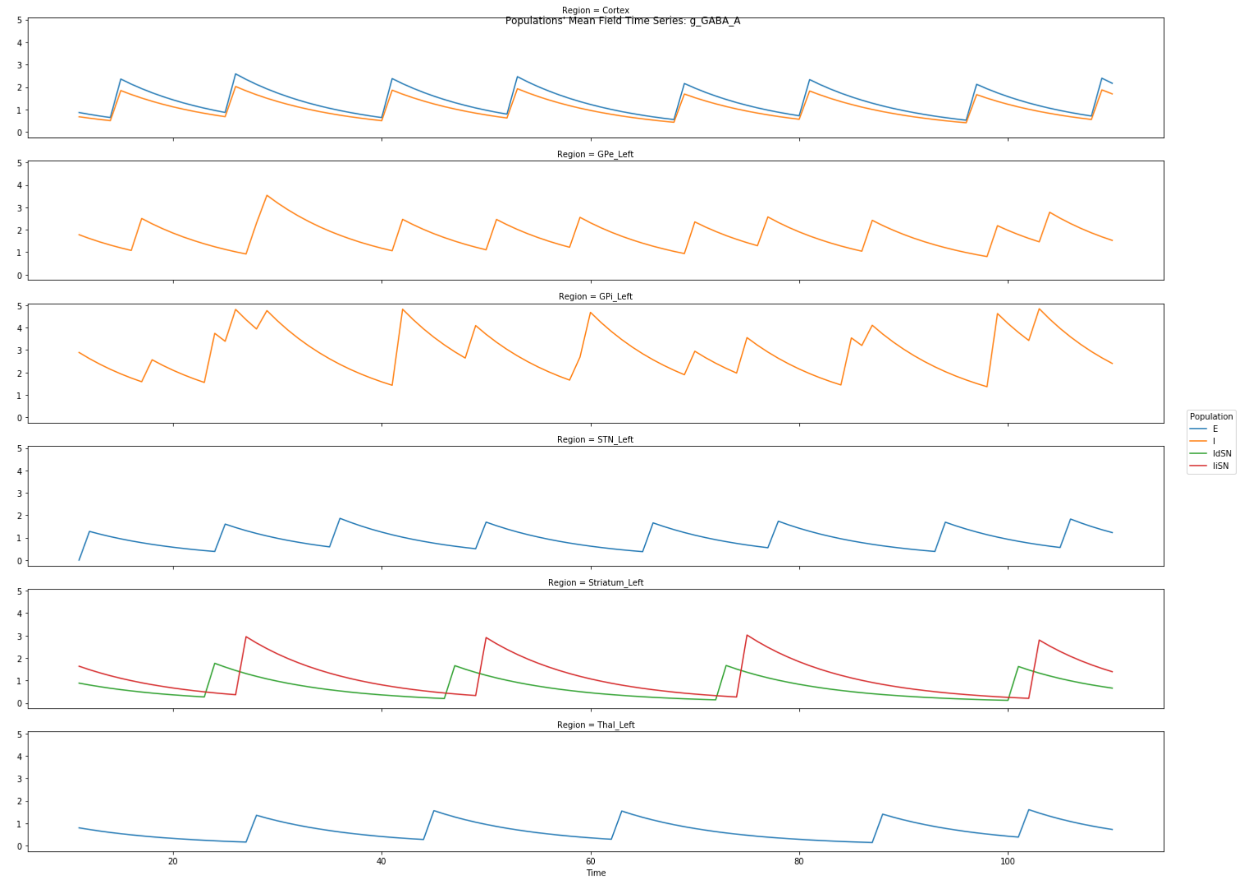

Populations' Mean Field Time Series: U_m
Region = Cortex
Region = GPe_Left
Region = GPi_Left
Region = STN_Left
Region = Striatum_Left
Region = Thal_Left
Time
Population
E
I
IdSN
IiSN

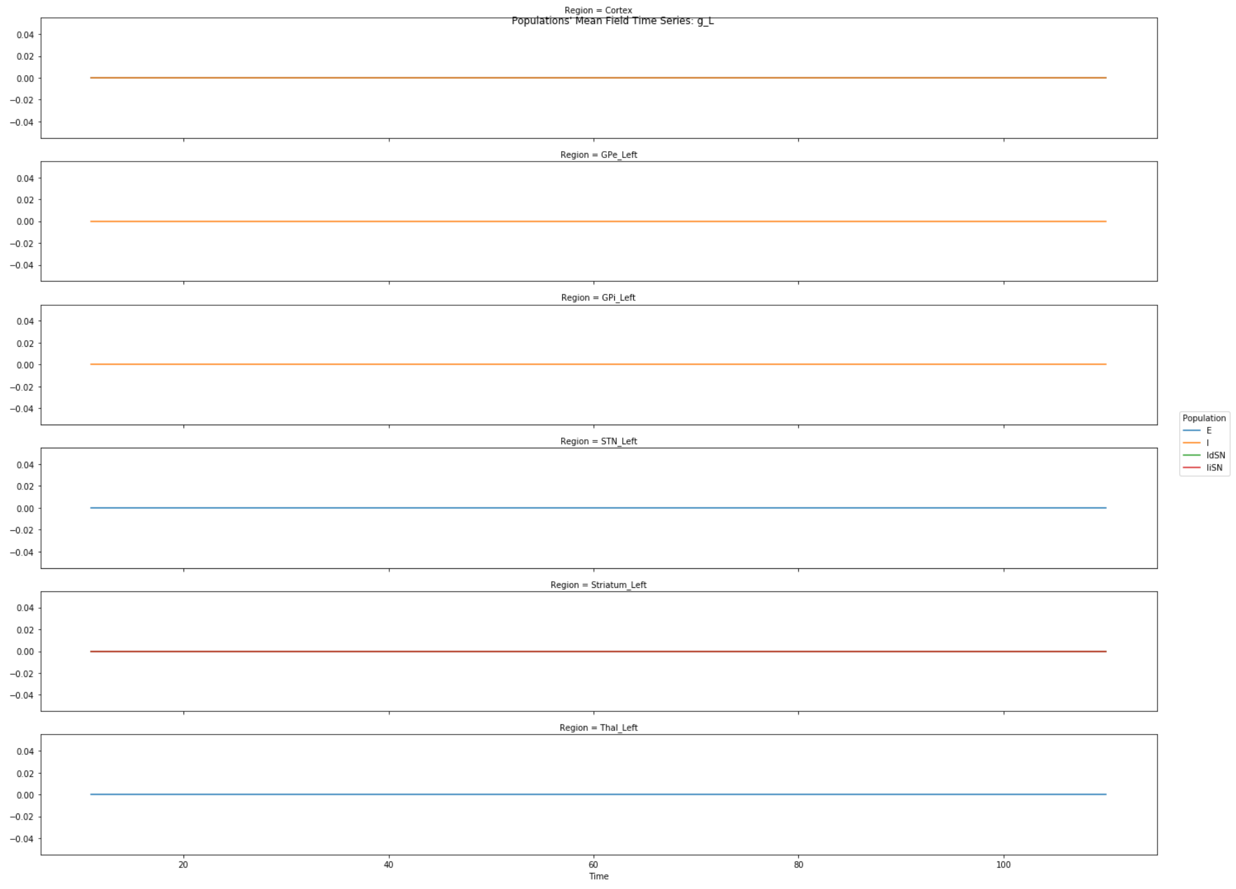

Populations' Mean Field Time Series: I_syn
Region = Cortex
Region = GPe_Left
Region = GPi_Left
Region = STN_Left
Region = Striatum_Left
Region = Thal_Left
Time
Population
E
I
IdSN
IiSN


Populations' Mean Field Time Series: I_syn_ex
Region = Cortex
Region = GPe_Left
Region = GPi_Left
Region = STN_Left
Region = Striatum_Left
Region = Thal_Left
Time
Population
E
I
IdSN
IiSN


Populations' Mean Field Time Series: I_syn_in
Region = Cortex
Region = GPe_Left
Region = GPi_Left
Region = STN_Left
Region = Striatum_Left
Region = Thal_Left
Time
Population
E
I
IdSN
IiSN


Populations' Mean Field Time Series: g_AMPA
Region = Cortex
Region = GPe_Left
Region = GPi_Left
Region = STN_Left
Region = Striatum_Left
Region = Thal_Left
Population
E
I
IdSN
IiSN
Time


Populations' Mean Field Time Series: g_GABA_A
Region = Cortex
Region = GPe_Left
Region = GPi_Left
Region = STN_Left
Region = Striatum_Left
Region = Thal_Left
Population
E
I
IdSN
IiSN
Time

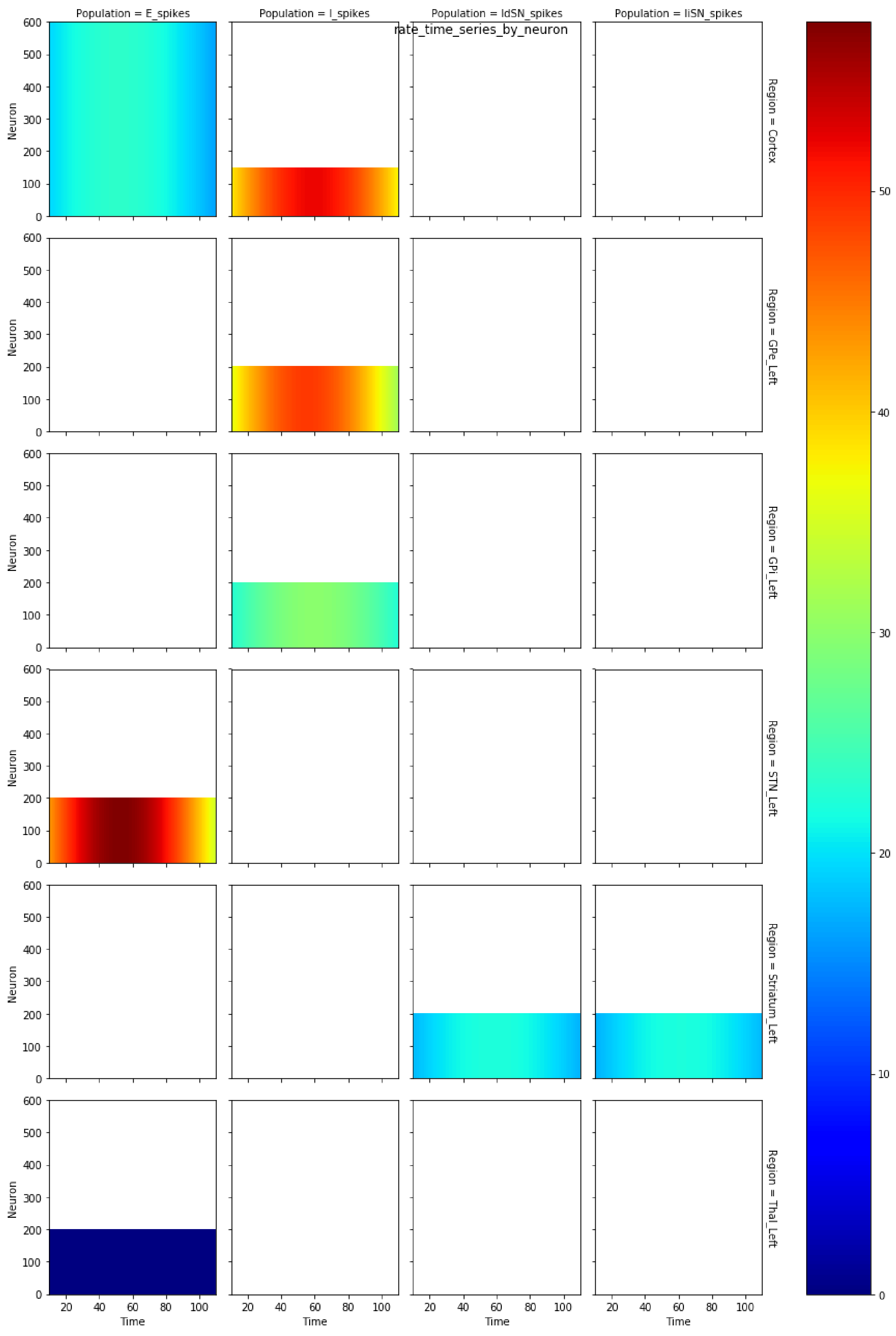


In [21]:
```
# Write results to file:
if mean_field_ts and writer:
    writer.write_tvb_to_h5(TimeSeriesRegion().from_xarray_DataArray(
                                  mean_field_ts._data,
                                  connectivity=mean_field_ts.connectivit
                           os.path.join(config.out.FOLDER_RES, mean_field_ts.
                           recursive=False)
```

## Compute per neuron spikes' rates times series and plot them

In [22]:
```
if spikes_res and plot_per_neuron:
    from tvb.simulator.plot.base_plotter import pyplot
    spikeNet_analyzer.return_data = False
    rates_ts_per_neuron = \
        spikeNet_analyzer. \
            compute_spikeNet_rates_time_series(populations_devices=None, regi
                                               computations_kwargs={}, data_k
                                               return_spikes_trains=False, re
    if rates_ts_per_neuron is not None and rates_ts_per_neuron.size:
        # Regions in rows
        row = rates_ts_per_neuron.dims[2] if rates_ts_per_neuron.shape[2] > 1
        if row is None:
            # Populations in rows
            row = rates_ts_per_neuron.dims[1] if rates_ts_per_neuron.shape[1]
            col = None
        else:
            # Populations in columns
            col = rates_ts_per_neuron.dims[1] if rates_ts_per_neuron.shape[1]
        pyplot.figure()
        rates_ts_per_neuron.plot(y=rates_ts_per_neuron.dims[3], row=row, col=
        plotter.base._save_figure(figure_name="Spike rates per neuron")
        # del rates_ts_per_neuron # to free memory
```

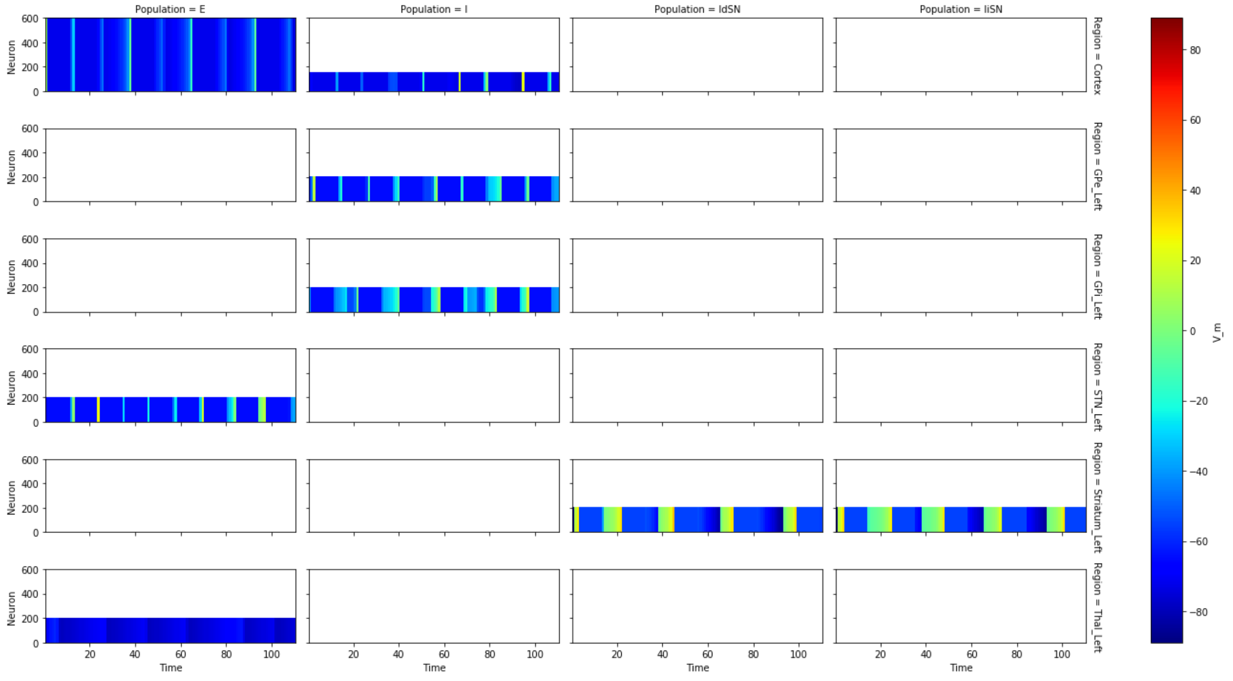
```
<Figure size 432x288 with 0 Axes>
```



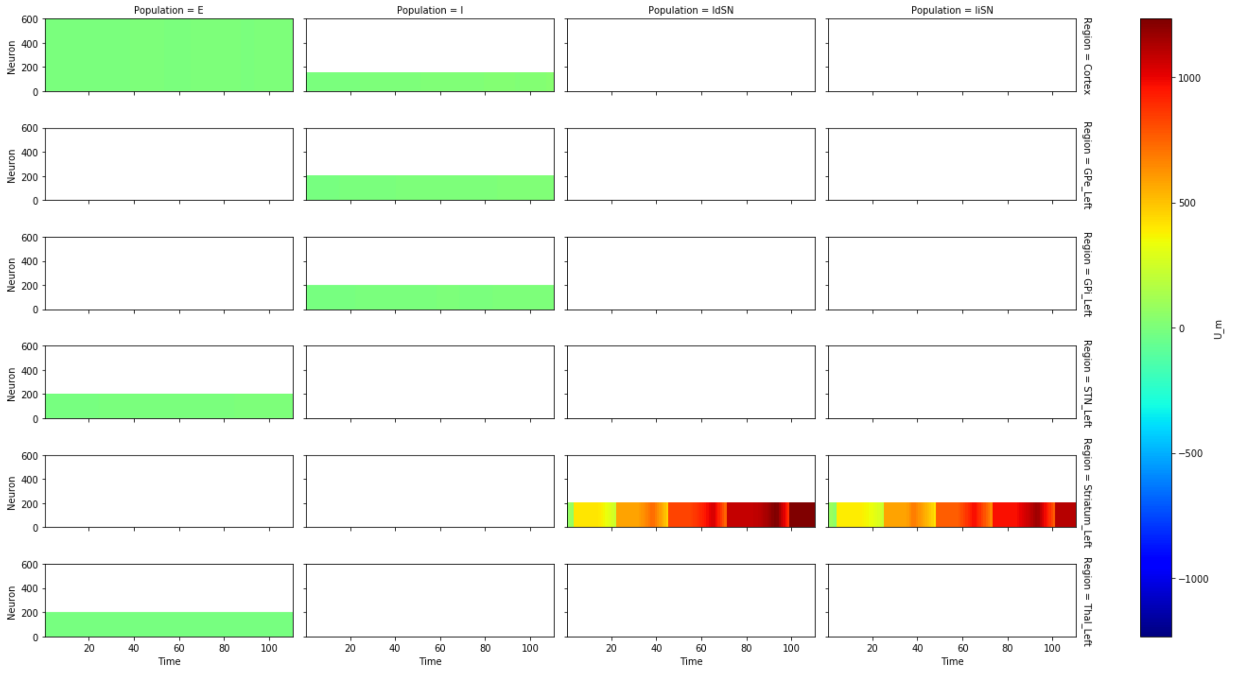
## Plot per neuron SpikingNetwork time series

In [23]:
```
# Regions in rows
if plot_per_neuron and spikeNet_ts.size:
    row = spikeNet_ts.dims[2] if spikeNet_ts.shape[2] > 1 else None
    if row is None:
        # Populations in rows
        row = spikeNet_ts.dims[3] if spikeNet_ts.shape[3] > 1 else None
        col = None
    else:
        # Populations in cols
         col = spikeNet_ts.dims[3] if spikeNet_ts.shape[3] > 1 else None
    for var in spikeNet_ts.coords[spikeNet_ts.dims[1]]:
        this_var_ts = spikeNet_ts.loc[:, var, :, :, :]
        this_var_ts.name = var.item()
        pyplot.figure()
        this_var_ts.plot(y=spikeNet_ts.dims[4], row=row, col=col, cmap="jet",
        plotter.base._save_figure(
            figure_name="Spiking Network variables' time series per neuron: %
    del spikeNet_ts # to free memory
```

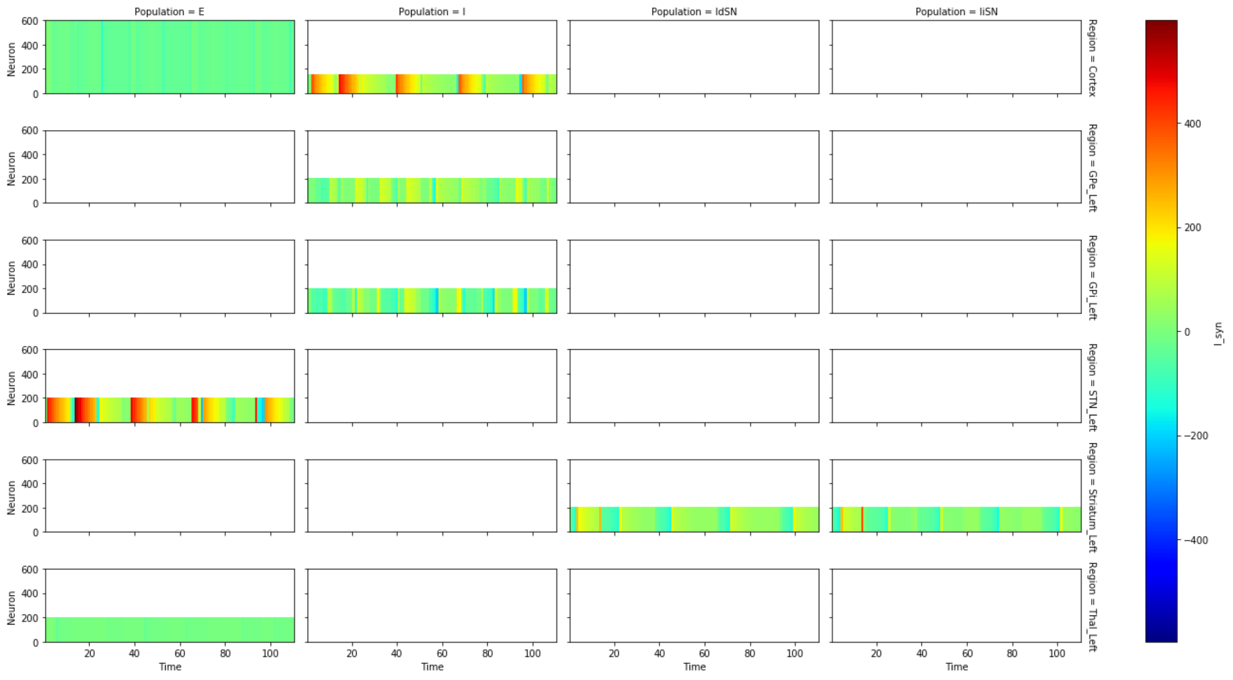
```
<Figure size 432x288 with 0 Axes>
```



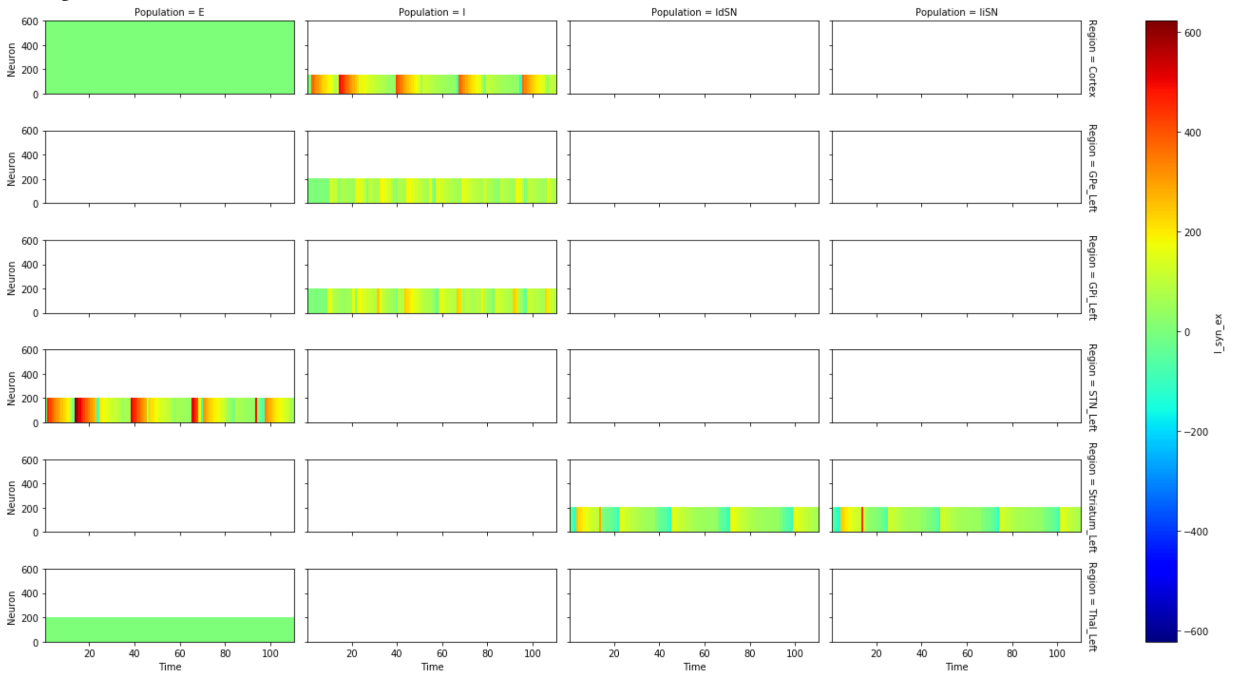
```
<Figure size 432x288 with 0 Axes>
```



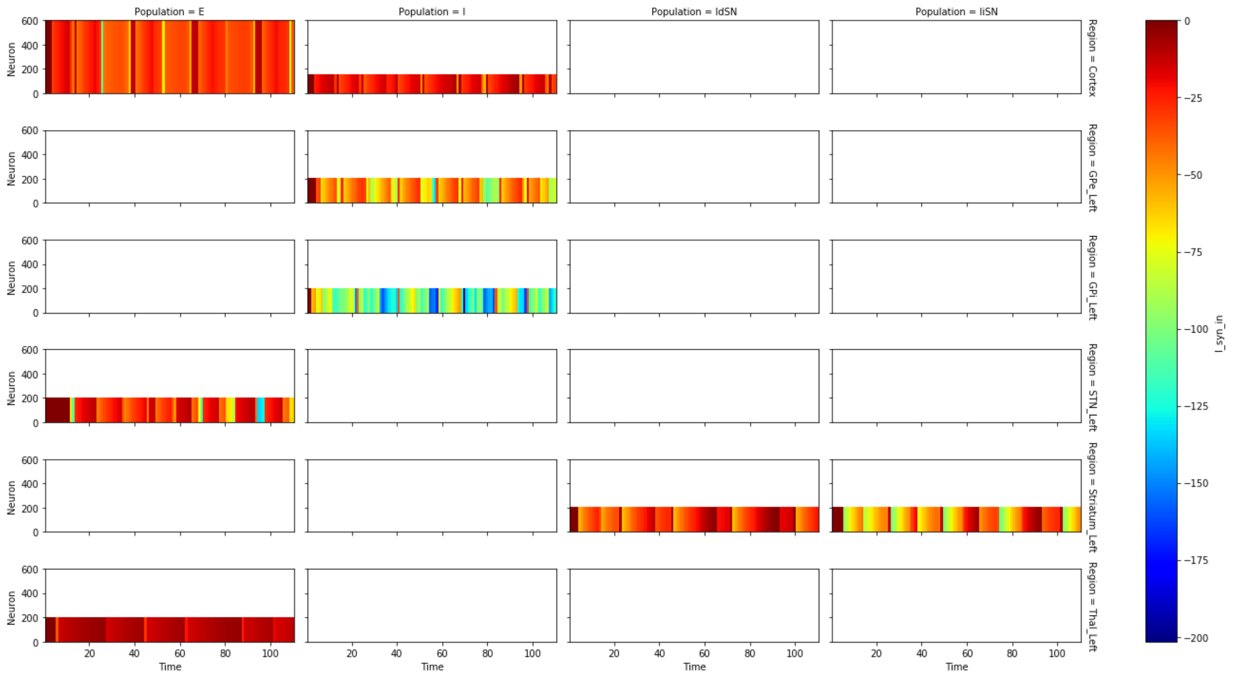
```
<Figure size 432x288 with 0 Axes>
```


Population = E
Population = I
Population = IdSN
Population = IiSN
Region = Cortex
Region = GPe_Left
Region = GPi_Left
Region = STN_Left
Region = Striatum_Left
Region = Thal_Left
Neuron
Time
I_syn

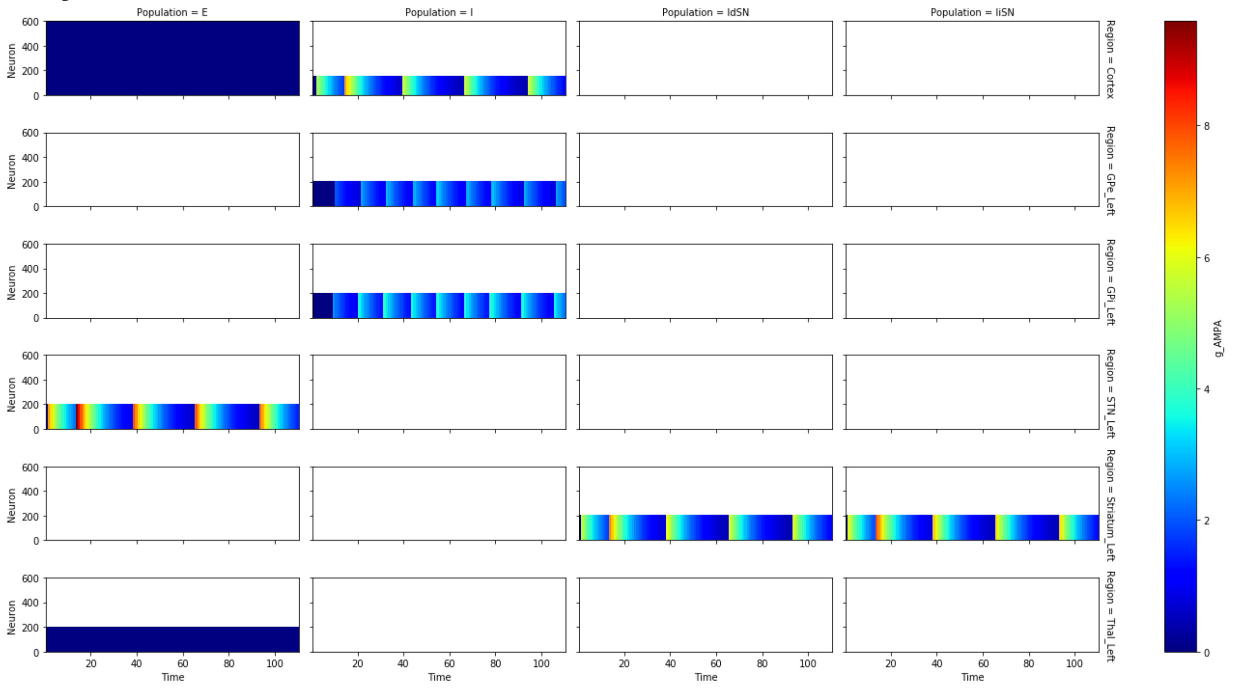
```
<Figure size 432x288 with 0 Axes>
```


Population = E
Population = I
Population = IdSN
Population = IiSN
Region = Cortex
Region = GPe_Left
Region = GPi_Left
Region = STN_Left
Region = Striatum_Left
Region = Thal_Left
Neuron
Time
I_syn_ex

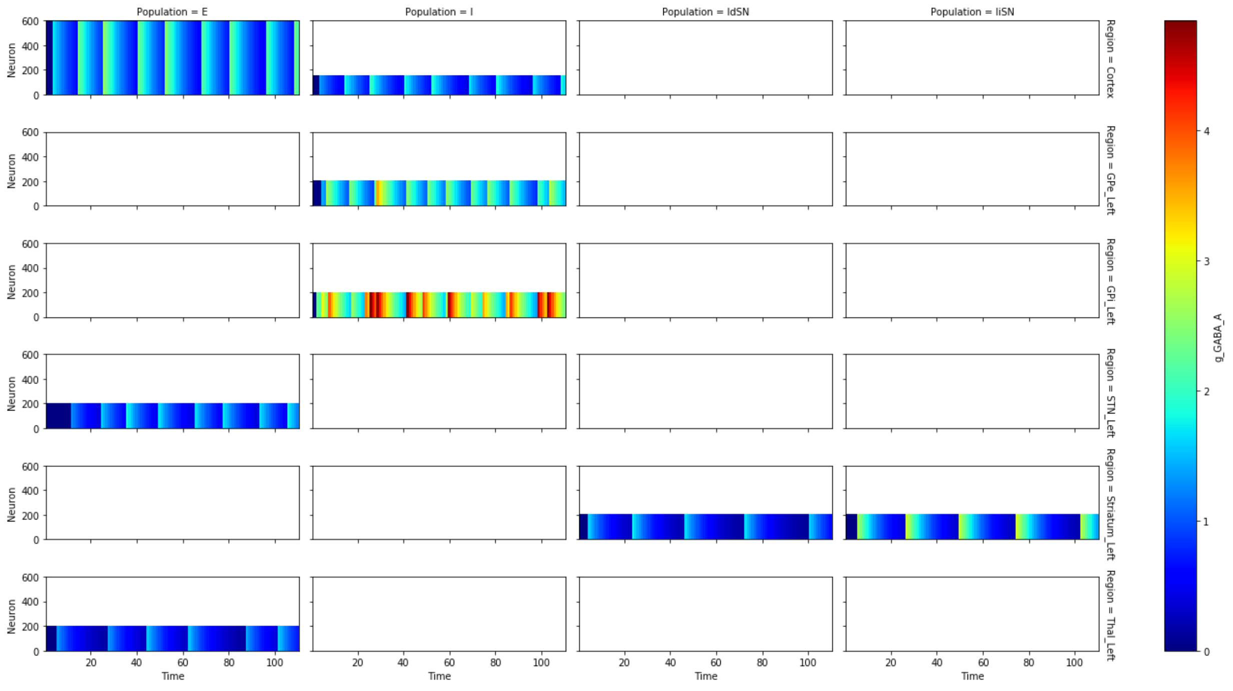
```
<Figure size 432x288 with 0 Axes>
```


Population = E
Population = I
Population = IdSN
Population = IiSN
Region = Cortex
Region = GPe_Left
Region = GPi_Left
Region = STN_Left
Region = Striatum_Left
Region = Thal_Left
Neuron
Time
I_syn_in

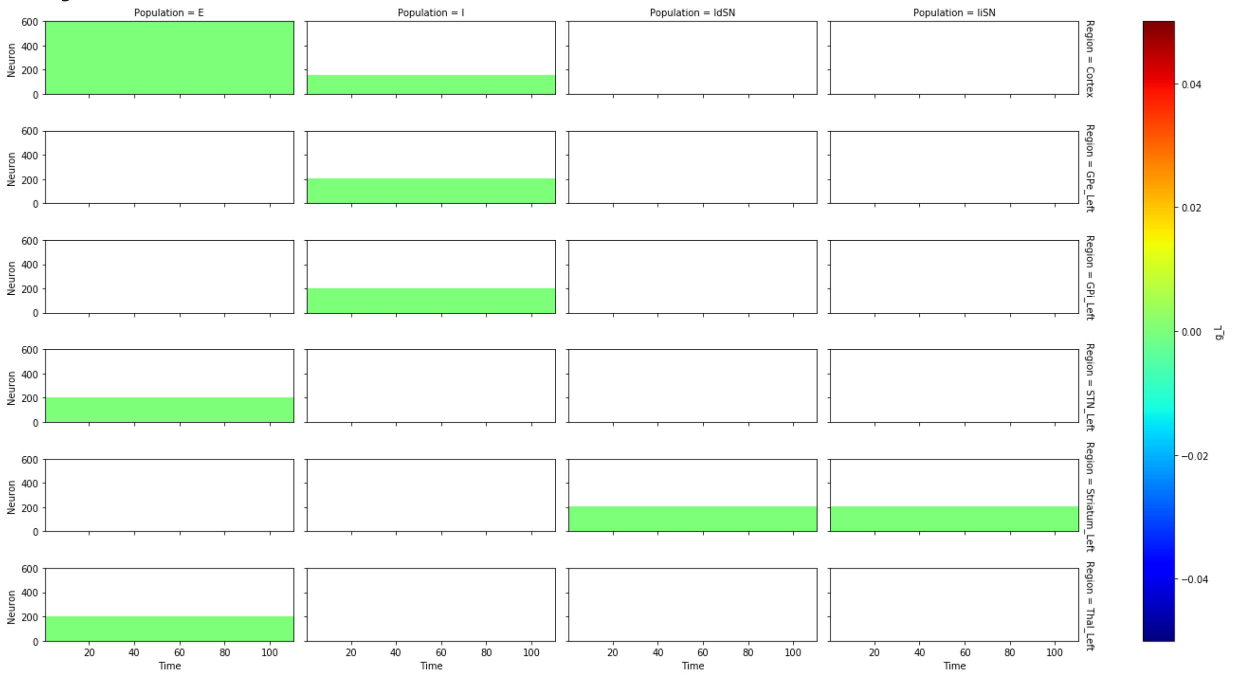
```
<Figure size 432x288 with 0 Axes>
```


Population = E
Population = I
Population = IdSN
Population = IiSN
Region = Cortex
Region = GPe_Left
Region = GPi_Left
Region = STN_Left
Region = Striatum_Left
Region = Thal_Left
Neuron
Time
g_AMPA

```
<Figure size 432x288 with 0 Axes>
```



```
<Figure size 432x288 with 0 Axes>
```



## References

1 Sanz Leon P, Knock SA, Woodman MM, Domide L, Mersmann J, McIntosh AR, Jirsa VK (2013) The Virtual Brain: a simulator of primate brain network dynamics. Frontiers in Neuroinformatics 7:10. doi: 10.3389/fninf.2013.00010 https://www.thevirtualbrain.org/tvb/zwei https://github.com/the-virtual-brain

2 Ritter P, Schirner M, McIntosh AR, Jirsa VK (2013). The Virtual Brain integrates computational modeling and multimodal neuroimaging. Brain Connectivity 3:121–145.

3 Jordan, Jakob; Mørk, Håkon; Vennemo, Stine Brekke; Terhorst, Dennis; Peyser, Alexander; Ippen, Tammo; Deepu, Rajalekshmi; Eppler, Jochen Martin; van Meegen, Alexander; Kunkel, Susanne; Sinha, Ankur; Fardet, Tanguy; Diaz, Sandra; Morrison, Abigail; Schenck, Wolfram; Dahmen, David; Pronold, Jari; Stapmanns, Jonas; Trensch, Guido; Spreizer, Sebastian; Mitchell, Jessica; Graber, Steffen; Senk, Johanna; Linssen, Charl; Hahne, Jan; Serenko, Alexey; Naoumenko, Daniel; Thomson, Eric; Kitayama, Itaru; Berns, Sebastian; Plesser, Hans Ekkehard
NEST is a simulator for spiking neural network models that focuses on the dynamics, size and structure of neural systems rather than on the exact morphology of individual neurons.
For further information, visit http://www.nest-simulator.org.
The release notes for this release are available at
https://github.com/nest/nest-simulator/releases/tag/v2.18.0

4 Baladron, J., Nambu, A., & Hamker, F. H. (2019).
The subthalamic nucleus-external globus pallidus loop biases exploratory decisions towards known alternatives: A neuro-computational study.
European Journal of Neuroscience, 49:754–767. https://doi.org/10.1111/ejn.13666

5 Maith O, Villagrasa Escudero F, Ülo Dinkelbach H, Baladron J, Horn, A, Irmen F, Kühn AA, Hamker FH (2020).
A computational model-based analysis of basal ganglia pathway changes in Parkinson’s disease inferred from resting-state fMRI
European Journal of Neuroscience, 00:1–18. https://doi.org/10.1111/ejn.14868

```
In [ ]:
```