Required imports

In [2]:
```
import sys
sys.path.append("..") # Adds higher directory to python modules path.

%matplotlib notebook

import os, time
import numpy as np
import matplotlib.pyplot as plt

import ipywidgets as widgets
from ipywidgets import interact, HBox

import scipy.signal

import pyabf # see: https://github.com/swharden/pyABF

# need this to update matplotlib plots in jupyter notebook
plt.ion()

# These two lines will auto reload imports, in particular bAnalysis
%load_ext autoreload
%autoreload 2

from bAnalysis import bAnalysis

ba = None # global bAnalysis object, used throughout this notebook
```

```
The autoreload extension is already loaded. To reload it, use:
  %reload_ext autoreload
```

Manually load an .abf file using bAnalysis

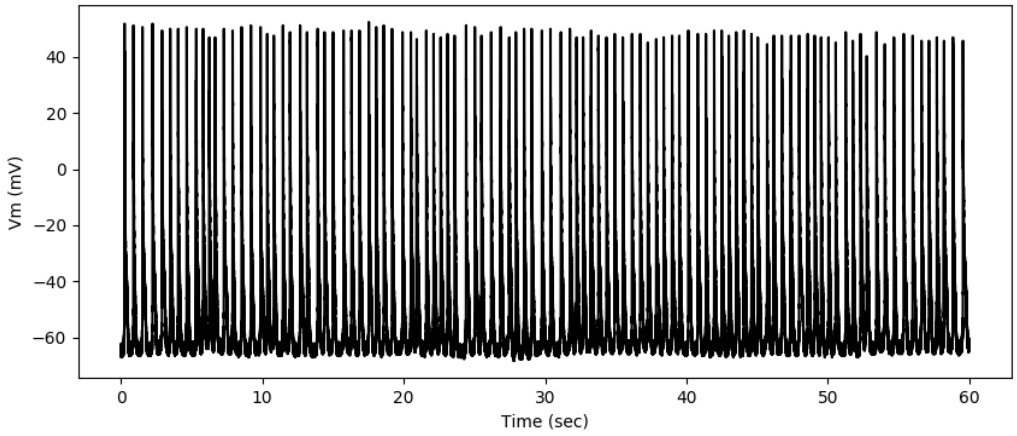
In [3]:
```
file = '../data/19114001.abf'
ba = bAnalysis.bAnalysis(file)

# ba is an object of type bAnalysis, see bAnalysis.py for its data membe
rs and member functions

# print some info about it
print(ba)

# get the sweep list
print('ba.sweepList:', ba.sweepList)

# set the sweep (there will be no output)
ba.setSweep(0)

# set a sweep that does not exist
#ba.setSweep(10)

# get dataPointsPerMs
print('ba.dataPointsPerMs:', ba.dataPointsPerMs)
```

```
file: ../data/19114001.abf
ABF (version 2.0.0.0) with 1 channel (mV), sampled at 20.0 kHz, contain
ing 1 sweep, having no tags, with a total length of 1.00 minutes, recor
ded with protocol "C:\Users\Lab\Documents\Molecular Devices\pCLAMP\Para
ms\claudia\Gapfree AP".
ba.sweepList: [0]
ba.dataPointsPerMs: 20
```

Load an abf file

In [9]:
```
#from IPython.display import clear_output

path = '../data'
files = os.listdir(path)

def fileList_callback(b):
    newValue = b['new']
    file = os.path.join(path, newValue)
    global ba
    ba = bAnalysis.bAnalysis(file)

    #clear_output()
    myAxis.clear()
    ba.plotSpikes(ax=myAxis)
    global sweeps
    sweepList.options = ba.sweepList

fileList = widgets.Select(
    options=files,
    # rows=10,
    description='fileList',
    disabled=False
)

def sweepList_callback(b):
    newValue = b['new']
    global ba
    ba.setSweep(newValue)
    #clear_output()
    myAxis.clear()
    ba.plotSpikes(ax=myAxis)

sweeps = []
sweepList = widgets.Select(
    options=sweeps,
    # rows=10,
    description='sweeps',
    disabled=False
)

def loadButton_callback(b):
    file = os.path.join(path, fileList.value)

    global ba
    ba = bAnalysis.bAnalysis(file)

    #clear_output()
    myAxis.clear()
    ba.plotSpikes(ax=myAxis)
    global sweeps
    sweepList.options = ba.sweepList

loadButton = widgets.Button(
```

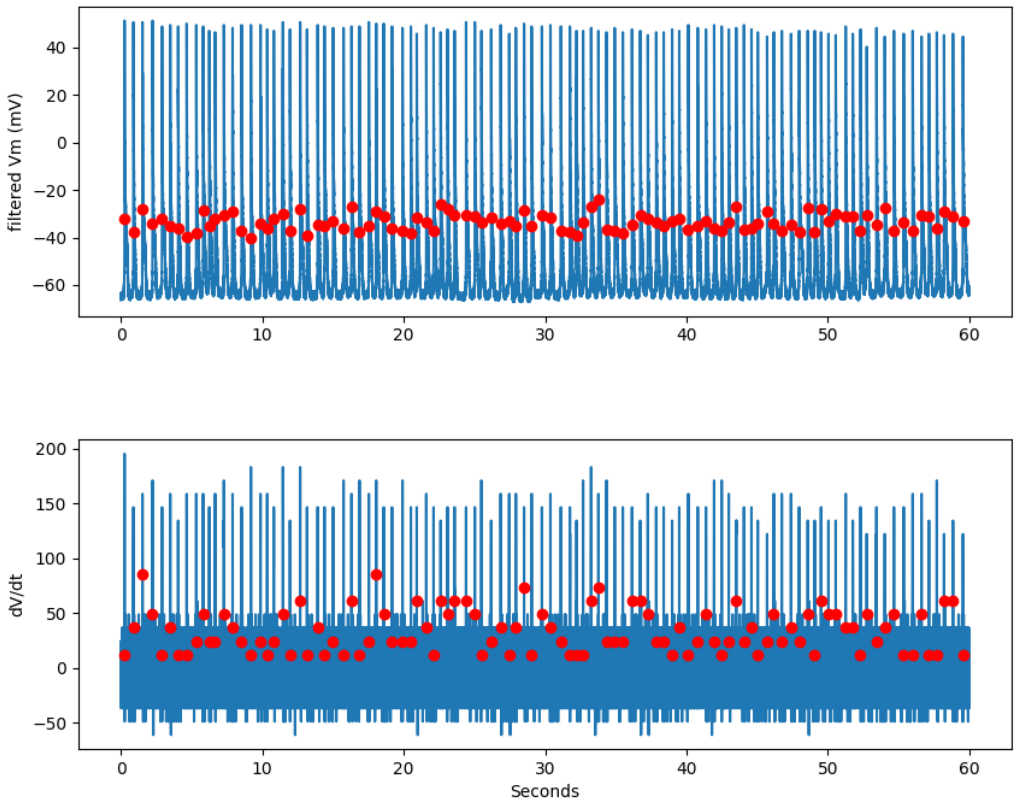
```
    description='Load',
    disabled=False,
    button_style='', # 'success', 'info', 'warning', 'danger' or ''
    tooltip='Load selected file'
)

loadButton.on_click(loadButton_callback)
sweepList.observe(sweepList_callback, names='value')
fileList.observe(fileList_callback, names='value')

fig = plt.figure(figsize=(10, 4))
myAxis = fig.add_subplot(1, 1 , 1)

HBox(children=[fileList, sweepList, loadButton])
```



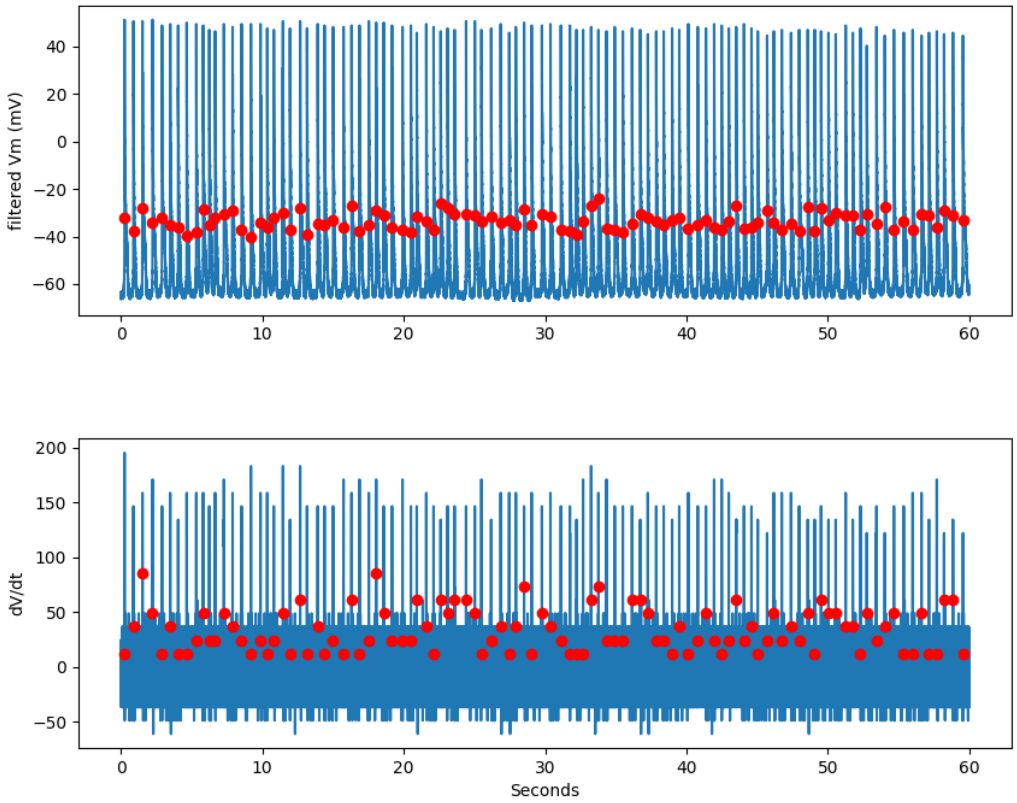
Check the derivative of Vm (dV/dt) to select threshold for spike detection.

In [10]:
```
ba.plotDeriv(medianFilter=3, dVthresholdPos=100)
```

```
spikeDetect0() dVthresholdPos: 100 medianFilter: 3 startSeconds: None s
topSeconds: None
   startSeconds: None stopSeconds: None
   startPnt: 0 stopPnt: 1199999
before stripping len(spikeTimes0): 219
after stripping len(spikeTimes0): 219
```



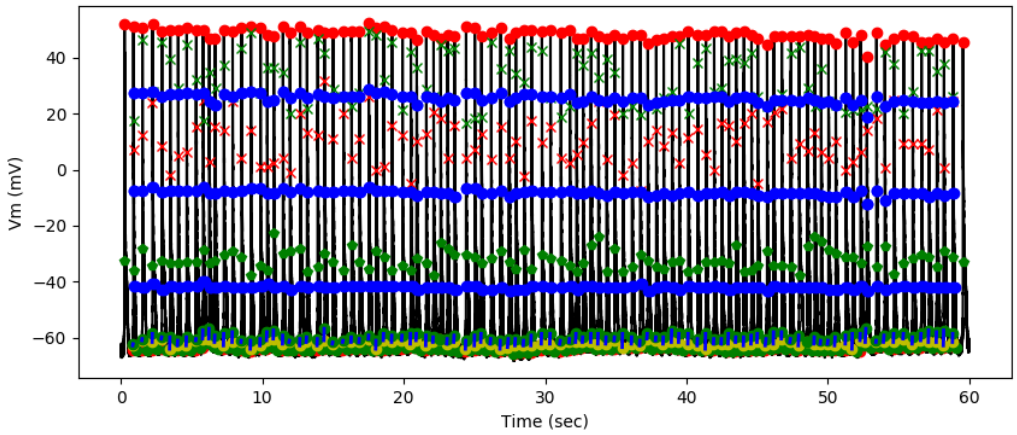

```
detected 103 spikes medianFilter: 3 dVthresholdPos: 100
```



Run spike detection with myThreshold and plot results

In [11]:
```
# load a file
#file = 'data/19114001.abf'
#ba = bAnalysis.bAnalysis(file)

# spike detect
myThreshold = 100
halfHeights = [20, 50, 80]
ba.spikeDetect(dVthresholdPos=myThreshold, halfHeights=halfHeights)

#
# plot Vm with all detected spikes (threshold, peak, pre/post min, half-
widths
fig = plt.figure(figsize=(10, 4))
myAxis = fig.add_subplot(1, 1 , 1)

ba.plotSpikes(ax=myAxis)
```

```
spikeDetect0() dVthresholdPos: 100 medianFilter: 0 startSeconds: None s
topSeconds: None
   startSeconds: None stopSeconds: None
   startPnt: 0 stopPnt: 1199999
before stripping len(spikeTimes0): 219
after stripping len(spikeTimes0): 219
bAnalysis.spikeDetect() for file ../data/19114001.abf detected 103 spik
es in 0.04 seconds
```

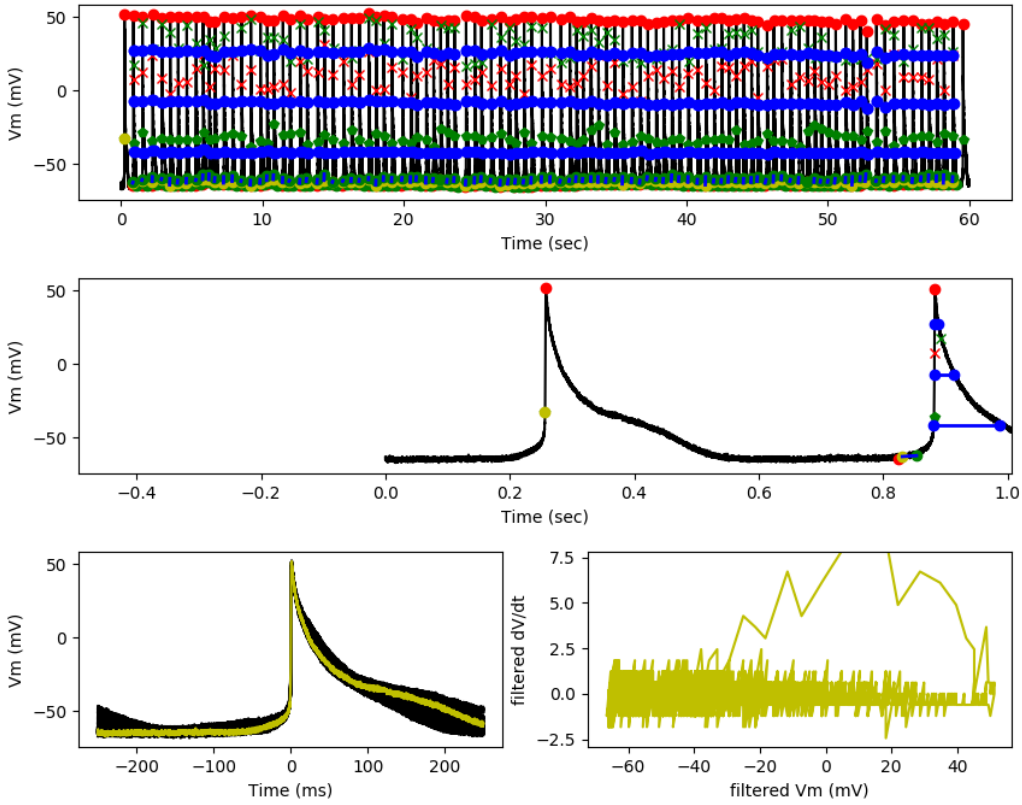


Make a spike browser

In [12]:
```
currentSpikeNumber = 1

#
# make a figure with subplots and plot it once
grid = plt.GridSpec(3, 2, wspace=0.2, hspace=0.4)

fig = plt.figure(figsize=(10, 8))
ax1 = fig.add_subplot(grid[0, 0:]) #Vm, entire sweep
ax2 = fig.add_subplot(grid[1, 0:]) #Vm, middle zoom
ax3 = fig.add_subplot(grid[2, 0]) #Vm, spike clip
ax4 = fig.add_subplot(grid[2, 1]) #phase plot

#
# plot vm
line1 = ba.plotSpikes(oneSpikeNumber=currentSpikeNumber, ax=ax1)

#
# plot middle view with intermediate x-axis
line2 = ba.plotSpikes(oneSpikeNumber=currentSpikeNumber, ax=ax2)

#
# plot all clips
line3 = ba.plotClips(oneSpikeNumber=currentSpikeNumber, ax=ax3)

#
# plot one spike phase plot
line4 = ba.plotPhasePlot(oneSpikeNumber=currentSpikeNumber, ax=ax4)

fig.show()
fig.canvas.draw()

def updatePlot(spikeNumber):
    ''' When called as an ipywidget callback, spikeNumber is a dicitonar
y !!!'''
    if isinstance(spikeNumber, dict):
        spikeNumber = spikeNumber['new']

    global currentSpikeNumber
    currentSpikeNumber = spikeNumber

    #
    # plot one spike (red circle)
    line1.set_xdata(ba.abf.sweepX[ba.spikeTimes[spikeNumber]])
    line1.set_ydata(ba.abf.sweepY[ba.spikeTimes[spikeNumber]])

    #
    # plot one spike clip
    if line3 is not None:
        line3.set_ydata(ba.spikeClips[spikeNumber])

    #
    # intermediate (x-axis) plot
    minTime = ba.abf.sweepX[ba.spikeTimes[spikeNumber]] - 0.75
```

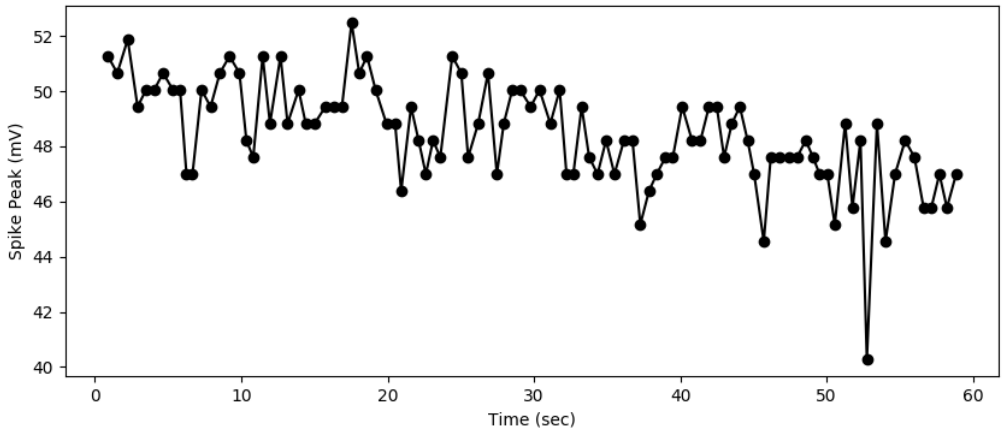
```
    maxTime = ba.abf.sweepX[ba.spikeTimes[spikeNumber]] + 0.75
    ax2.axes.set_xlim(minTime, maxTime)
    line2.set_xdata(ba.abf.sweepX[ba.spikeTimes[spikeNumber]])
    line2.set_ydata(ba.abf.sweepY[ba.spikeTimes[spikeNumber]])

    #
    # phase plot
    filteredClip = scipy.signal.medfilt(ba.spikeClips[spikeNumber],3)
    dvdt = np.diff(filteredClip)
    # add an initial point so it is the same length as raw data in abf.s
weepY
    dvdt = np.concatenate(([0],dvdt))

    line4.set_xdata(filteredClip)
    line4.set_ydata(dvdt)

    # trying to rescale the axis on each update, not working
    #ax4.autoscale_view()
    ax4.relim()

    fig.canvas.draw()

mySlider = widgets.IntSlider(
    min=0,
    max=ba.numSpikes-1,
    step=1,
    description='Spike Number',
    value=0,
    continuous_update=False)
mySlider.observe(updatePlot, names='value')

def on_slider_change(change):
    updatePlot(change['new'])

def myButton_prev_callback(b):
    global currentSpikeNumber
    currentSpikeNumber -= 1
    if currentSpikeNumber < 0:
        currentSpikeNumber = 0
    mySlider.value = currentSpikeNumber # mySlider will do an update

myButton_prev = widgets.Button(
    description='Previous Spike',
    disabled=False,
    button_style='', # 'success', 'info', 'warning', 'danger' or ''
    tooltip='Go to previous spike'
)
myButton_prev.on_click(myButton_prev_callback)


def myButton_next_callback(b):
    global currentSpikeNumber
    currentSpikeNumber += 1
    if currentSpikeNumber > ba.numSpikes - 1:
```

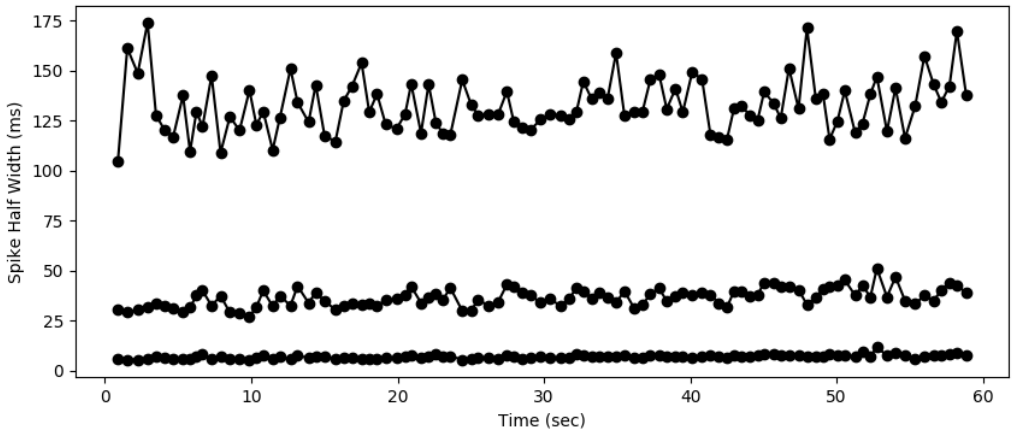
```
        currentSpikeNumber = ba.numSpikes - 1
    mySlider.value = currentSpikeNumber # mySlider will do an update

myButton_next = widgets.Button(
    description='Next Spike',
    disabled=False,
    button_style='', # 'success', 'info', 'warning', 'danger' or ''
    tooltip='Go to next spike'
)
myButton_next.on_click(myButton_next_callback)


# initial plot
updatePlot(spikeNumber=0)

# display the controls horizontally
HBox(children=[mySlider, myButton_prev, myButton_next])
```

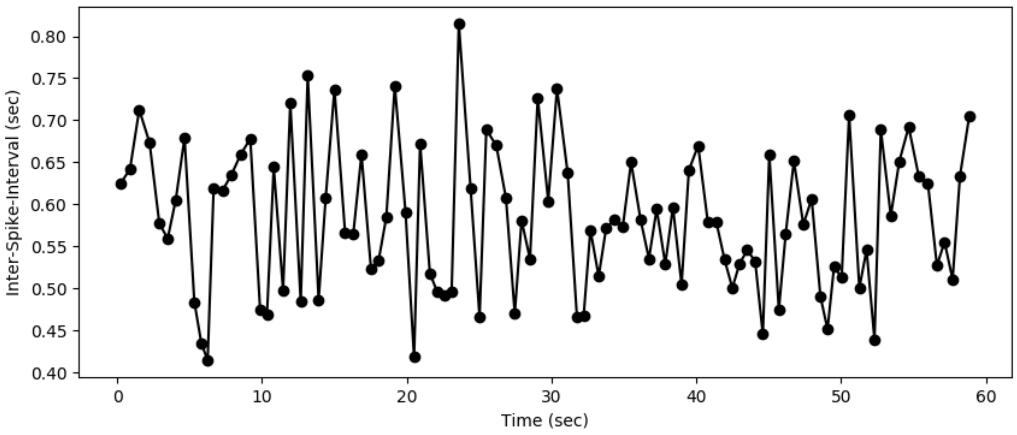


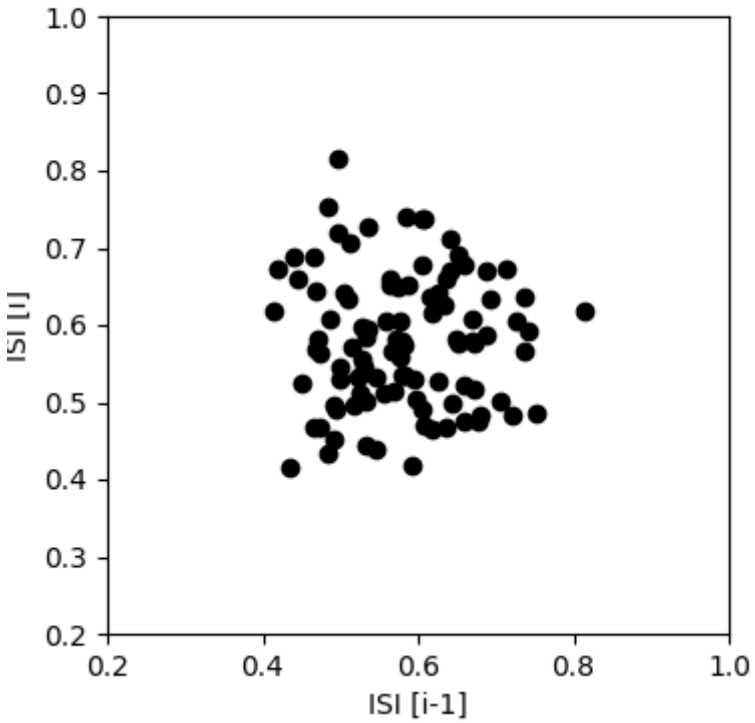
Additional analysis

In [13]:
```
#
# plot the value of each spike amplitude over time of recording
# if this is changing during the recording then there might be problems
fig = plt.figure(figsize=(10, 4))
myAxis2 = fig.add_subplot(1, 1 , 1)

ba.plotTimeSeries(stat='peak', ax=myAxis2)

#
# plot the value of each half-width for each spike over time of recordin
g
fig = plt.figure(figsize=(10, 4))
myAxis3 = fig.add_subplot(1, 1 , 1)

for i, halfHeight in enumerate(halfHeights):
    ba.plotTimeSeries(stat='halfWidth', halfWidthIdx=i, ax=myAxis3)

#
# plot ISI between each spike
fig = plt.figure(figsize=(10, 4))
myAxis4 = fig.add_subplot(1, 1 , 1)

ba.plotISI(ax=myAxis4)

#
# plot isi[i] versus isi[i-1], e.g. a 'shot plot'
# this will show us if there is history between successive intervals
# if it is a circular cloud, then there is little/no history between suc
cessive ISI's
spikeTimes_sec = [x/ba.abf.dataPointsPerMs/1000 for x in ba.spikeTimes]
isi = np.diff(spikeTimes_sec)
isi_i = isi[1:len(isi)-1]
isi_i_minus_1 = isi[0:len(isi)-2]

grid = plt.GridSpec(1, 1, wspace=0.2, hspace=0.4)
fig = plt.figure(figsize=(4, 4))
ax = fig.add_subplot(grid[0, 0:]) #Vm, entire sweep
ax.plot(isi_i_minus_1, isi_i, 'ok')
ax.axes.set_xlim(0.2, 1)
ax.axes.set_ylim(0.2, 1)
ax.set_ylabel('ISI [i]')
ax.set_xlabel('ISI [i-1]')

#
# make a report of all spike times
from IPython.display import display, HTML
df = ba.report()
# for now, just showing first 10 spikes
display(df[1:10])
# not sure what this does but might be important
#display(HTML(df.to_html()))
```


Spike Peak (mV)
52
50
48
46
44
42
40
0
10
20
30
40
50
60
Time (sec)


Spike Half Width (ms)
175
150
125
100
75
50
25
0
0
10
20
30
40
50
60
Time (sec)


Inter-Spike-Interval (sec)
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0
10
20
30
40
50
60
Time (sec)


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
ISI [i]
0.2
0.4
0.6
0.8
1.0
ISI [i-1]

	file	spikeNumber	numError	error	dVthreshold	medianFilter	halfHeights	thr
1	../data/19114001.abf	1	0	[]	100	0	[20, 50, 80]	
2	../data/19114001.abf	2	0	[]	100	0	[20, 50, 80]	
3	../data/19114001.abf	3	0	[]	100	0	[20, 50, 80]	
4	../data/19114001.abf	4	0	[]	100	0	[20, 50, 80]	
5	../data/19114001.abf	5	0	[]	100	0	[20, 50, 80]	
6	../data/19114001.abf	6	0	[]	100	0	[20, 50, 80]	
7	../data/19114001.abf	7	0	[]	100	0	[20, 50, 80]	
8	../data/19114001.abf	8	0	[]	100	0	[20, 50, 80]	
9	../data/19114001.abf	9	0	[]	100	0	[20, 50, 80]	

9 rows × 33 columns

Statistics

In [15]:
```
from scipy import stats

#
# compare spike peaks at the start and end of the recording

# build a list of spike peaks
spikePeaks = [spike['peakVal'] for spike in ba.spikeDict]

# first 10 spikes peaks
first = spikePeaks[0:10]
mean1 = np.mean(first)
std1 = np.std(first)

# last 10 spikes peaks
last = spikePeaks[len(spikePeaks)-10:len(spikePeaks)-1]
mean2 = np.mean(last)
std2 = np.std(last)

p = stats.ttest_ind(first,last)

print('Testing if there is a significant difference between the first 10
and last 10 spike peaks.')
if p[1] < 0.05:
    print('p=', p[1], ' is SIGNIFICANT')
else:
    print('p=', p[1], ' is NOT SIGNIFICANT')
```

```
Testing if there is a significant difference between the first 10 and l
ast 10 spike peaks.
p= 7.227717009995907e-08  is SIGNIFICANT
```

In [ ]:

In [ ]: