PyCBC: a device independent approach to CBC analysis

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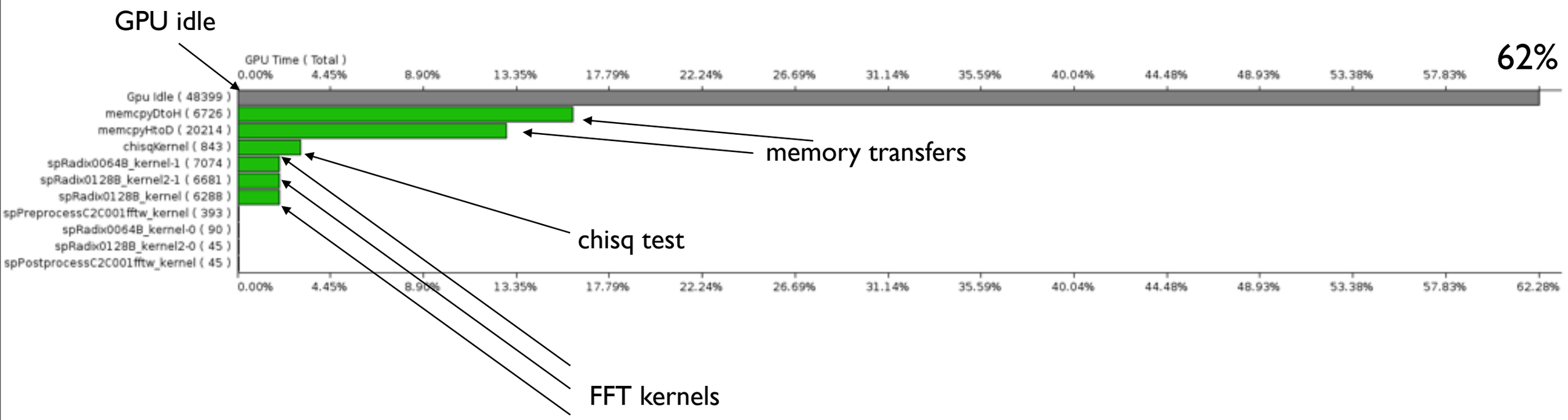
Previous work

- Acceleration of lalapps_inspiral by GPUs obtained a **speedup factor of 15** by performing all FFTs and the chi-squared test on a GPU. (CUDA) https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=40432
- Results of profiling: largest portions of time spent...
  - transferring memory to and from the GPU
  - running computations on the CPU (GPU is idle)
- **Conclusion:** a redesign focused on transparent GPU acceleration is needed



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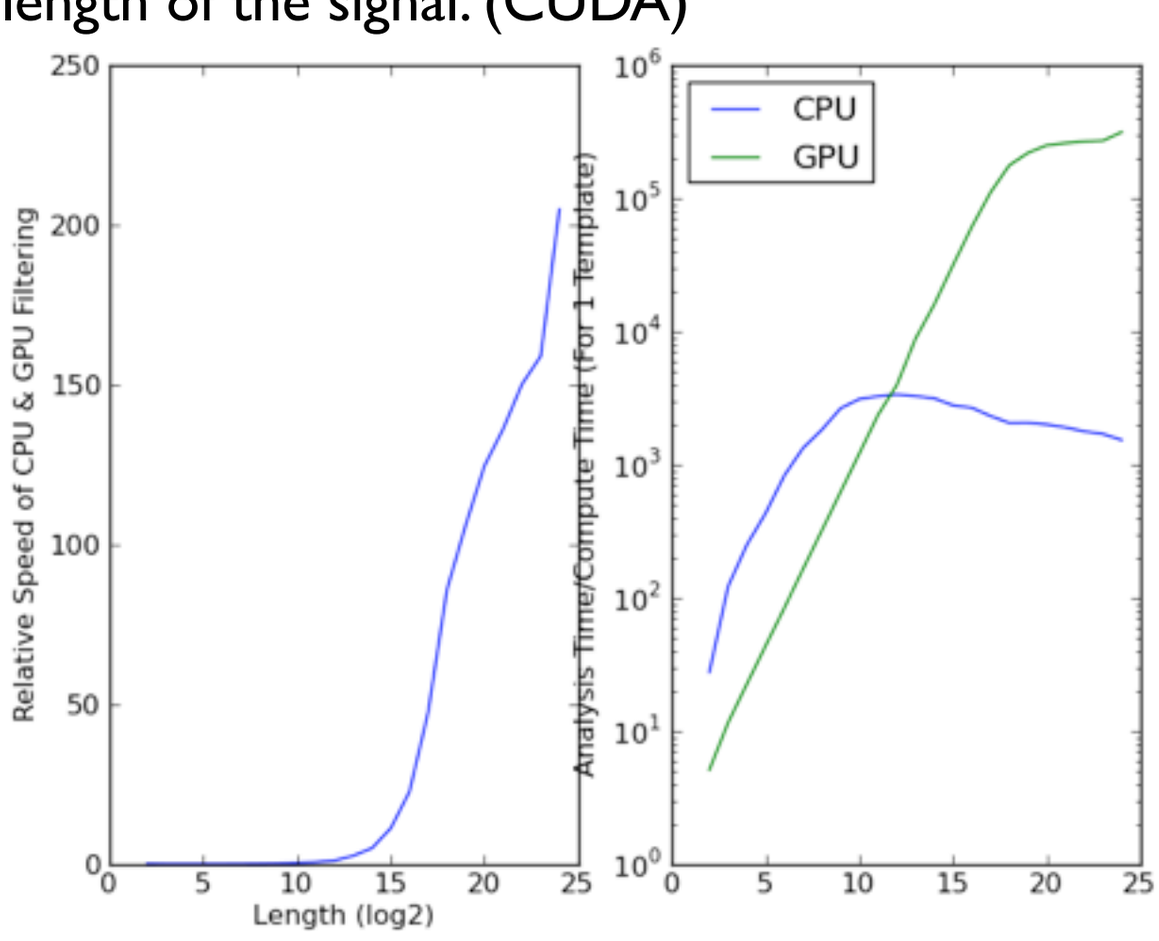
Preliminary Acceleration Investigations

- To optimize this, we need to implement more of the search engine (i.e., the whole hot loop) on the GPU.
  - The Budapest group has shown a possible **speedup factor of 92** by porting the search engine completely to the GPU. (OpenCl) http://www.grid.kfki.hu/twiki/bin/view/RmkiVirgo/GPU_inspiral
  - The Syracuse group has shown even large gains (**speedup factor of 200**) are possible depending on the length of the signal. (CUDA)



Coding for the future

- Speed not the only issue
- We want something sustainable and that can bring us into the Adv. Detector Era
- Targeting offline compute intensive searches

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Requirements of a novel software framework for CBC analysis

- Design Requirements:
  - flexible (easily reconfigurable from the top layer)
    - decouple algorithm from implementation
  - transparent processing on different architectures
  - transparent memory management
  - better readability

- Code Requirements:
  - modularity and simple API
    - simple processing python objects (object oriented design)
    - new features are encapsulated in new objects or extensions of existing objects
    - robustness from unit tests
  - bindings to 3rd party libraries (e.g., lalsuite, fftw, numpy, etc.)
  - auto documentation (epydoc)

Inspiral processing graphs

- Planned how this code will look based on lalapps_inspiral
  - in particular where different processes will be run
- Created processing graphs
  - Shows how functions and kernels are called and where they live (layers)
  - Shows how data flows
  - Shows memory objects
    - Where they live
    - Who is the owner
    - Which kind of data do they hold
    - How long they live

Pycbc signal processing graph for single detector search pipeline using GPUs

Start

Python

StrainData

Injector

Resampler
16kHz -> 4096Hz

Highpass Filter

Straindata.
Convert()

SWIG WRAP

SWIG WRAP

SWIG WRAP

SWIG WRAP

clayer

real_vector_double_t s(t)

real_vector_single_t s(t)

GPU

libraries
(lal etc.)

frame_cpp

NRWaveInject

files

.gwf

.xml

Legend:

Data flow

Object destroyed

Function call

Composition (right side object
belongs to left side object)

Software layer

t

real_vector_single_t

Time domain data

real_vector_single_t

Frequency domain data

Pycbc signal processing graph for single detector search pipeline using GPUs

Python

[typ. 10^3] ParameterSpace

Straindata. Segmenting()

Overwhitening Filter

Straindata *= Overw.-Filt

TemplateBank

TemplateBank. PreConditionData()

Overwhiten render()

Straindata. render()

SWIG WRAP

SWIG WRAP

SWIG WRAP

SWIG WRAP

_vector_single_t s(t)

[typ. 15 segments freq data from typ 256s timedomain data -> (N=2^20)] complex_vector_single_t stilde(f) (Python list of datavector_cpu)

FFTs of overlapping input data

real_vector_single_t 1/Sn(f) alias inverse PSD alias overwhitening filter N=2^20

median - inverse

__mul()

render

render

IFFT - truncate - FFT (inplace)

[ ] complex_vector_single_t stilde(f)

real_vector_single_t 1/Sn(f)

GLUE XMLread

.xml

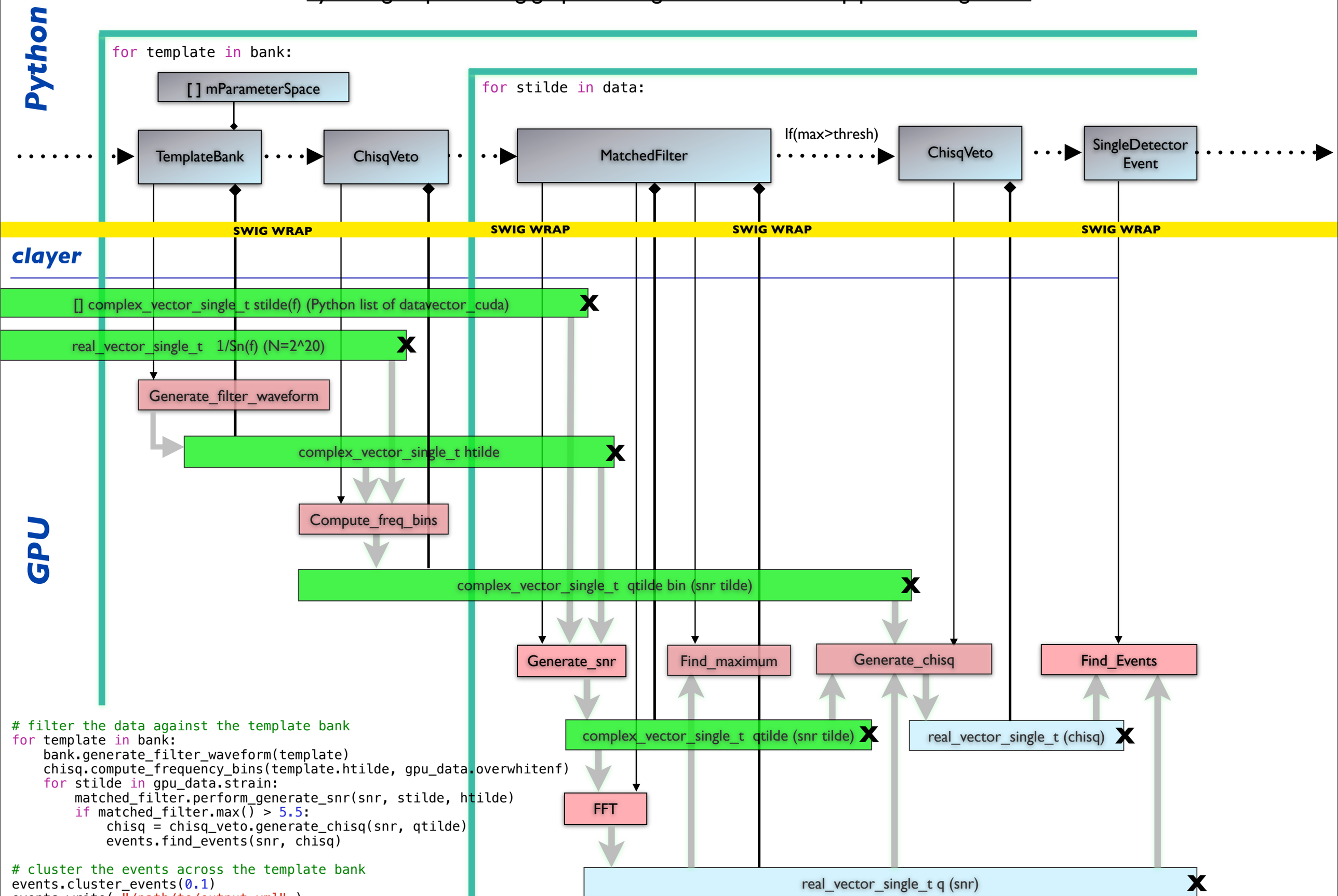
clay

GPU

GLUE/ Lal

files

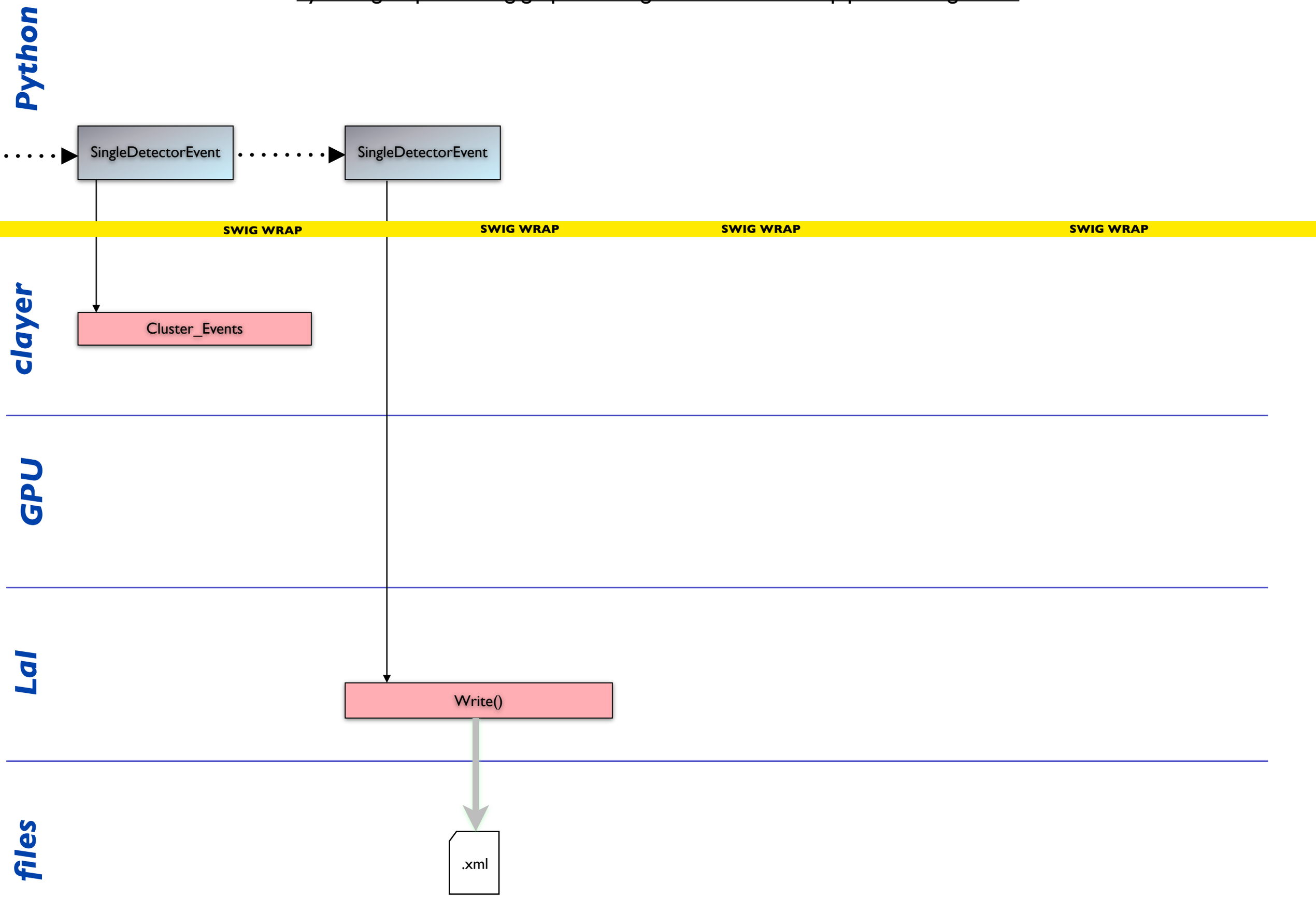
Pycbc signal processing graph for single detector search pipeline using GPUs



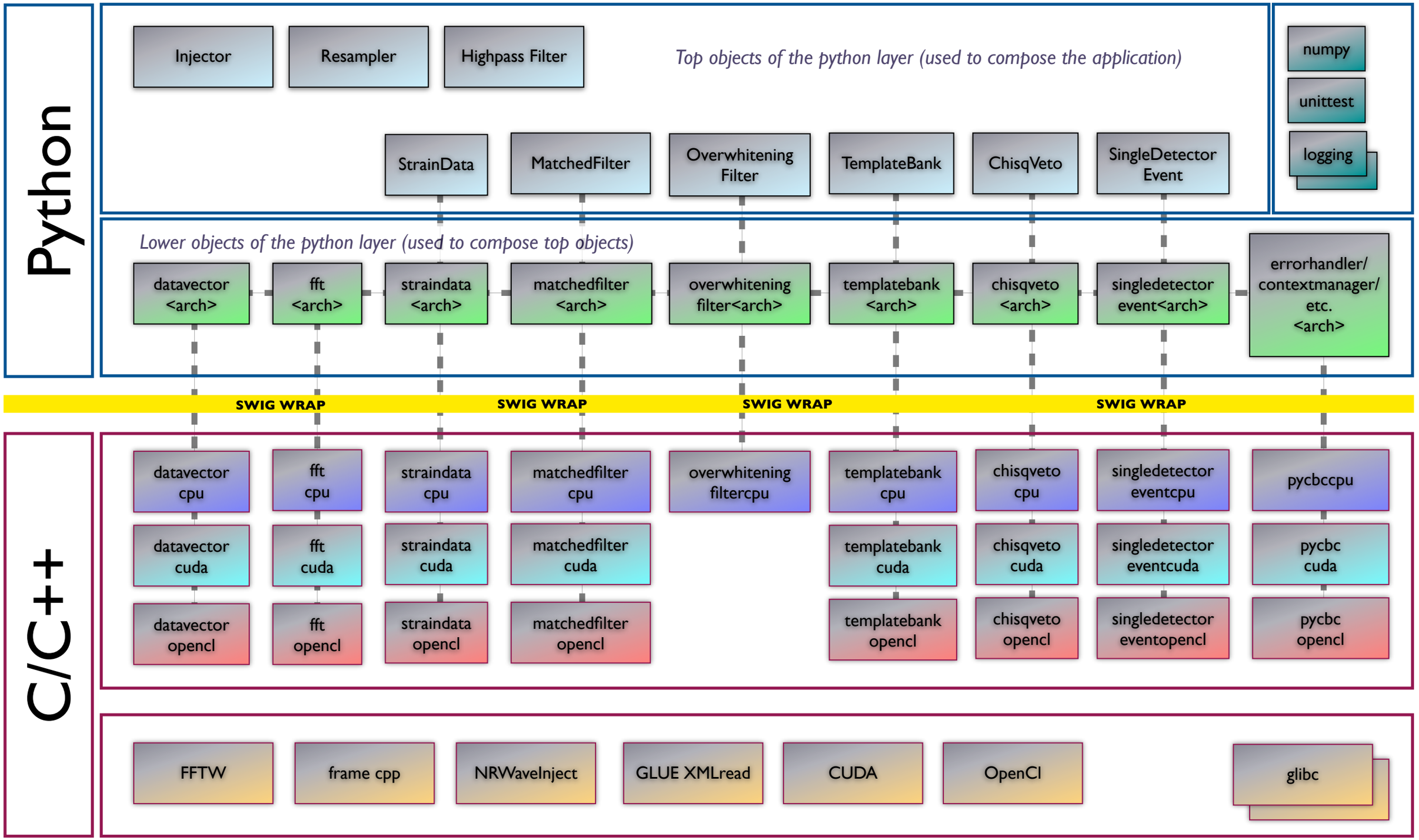

```
# filter the data against the template bank
for template in bank:
    bank.generate_filter_waveform(template)
    chisq.compute_frequency_bins(template.htilde, gpu_data.overwhitenf)
    for stilde in gpu_data.strain:
        matched_filter.perform_generate_snr(snr, stilde, htilde)
        if matched_filter.max() > 5.5:
            chisq = chisq_veto.generate_chisq(snr, qtilde)
            events.find_events(snr, chisq)

# cluster the events across the template bank
events.cluster_events(0.1)
events.write( "/path/to/output.xml" )
```

Pycbc signal processing graph for single detector search pipeline using GPUs



Pycbc Layers and packages



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Inspiral analysis in a single slide...

```
import sys
import random

# preliminary hard coded path to packages
sys.path.append('/Users/kawies/dev/src/pycbc')

from pycbc.pycbc import CPUDeviceContext as ProcessingTargetContext

from pycbc.straindata.straindata_cpu import StrainDataCpu as StrainData
from pycbc.templatebank.templatebank_cpu import TemplateBankCpu as TemplateBank
from pycbc.matchedfilter.matchedfilter_cpu import MatchedFilterCpu as
MatchedFilter
from pycbc.chisqveto.chisqveto_cpu import ChisqVetoCpu as ChisqVeto
from pycbc.singledetectorevent.singledetectorevent_cpu import
SingleDetectorEventCpu as SingleDetectorEvent
from pycbc.datavector.datavectorcpu import real_vector_single_t as
SnrResultTimeSeries

import logging

logging.basicConfig(level=logging.DEBUG,
                    format='%(name)s %(asctime)s %(levelname)s %(message)s',
                    filename='pycbc_min_pipeline.log',
                    filemode='w')

logger= logging.getLogger('pycbc.main_script')


start_message = 'Starting pycbc single detector minimal pipeline ...'
logger.debug(start_message)
print start_message

# setup straindata
search_time = 128 # typ design spec: 2048
sample_freq = 256 # typ design spec: 4096
length =      search_time * sample_freq
segments = 15
gps_start_time= 871147532
gps_end_time= gps_start_time + search_time
interferometer = "H1"

# setup chisq veto
chisq_bins = 16

# setup event finder
snr_threshold = 5.5

with ProcessingTargetContext(1) as context:

    strain_data = StrainData(gps_start_time, gps_end_time,
                        segments, sample_freq,
                        interferometer, context)

    # initialize straindata w/ noise
    for i in range(length):
        tmp = random.uniform(-1,1)
        strain_data.time_series[i] = tmp

    # convert straindata to single precision
    strain_data.convert_to_single_preci()

    # segmenting straindata and transform into frequency domain
    strain_data.perform_fft_segments()

    # transfer straindata to appropriate memory space on target device
    strain_data.render()

    # create 5 templates (testing the iterator of TemplateBank)
    bank = TemplateBank(5, strain_data.segments_length,
                           strain_data.segments_delta_x, context)
    logger.debug("instantiated TemplateBank w/ waveform length: {0}"
                 .format(bank.waveform_length))

    # create matched filter (only generate_snr() has to be implemented
    # for the minimal pipeline)
    matched_filter = MatchedFilter(strain_data.segments_length, context)
    logger.debug("instantiated MatchedFilter w/ length: {0}".format
    (matched_filter.length))

    # instantiate result vectors
    snr = SnrResultTimeSeries(strain_data.segments_length,
                              strain_data.segments_delta_x, context)
    logger.debug("instantiated SnrResultTimeSeries as {0}".format(repr(snr)))

    # instantiate chisq_veto
    chisq_veto = ChisqVeto(strain_data.segments_length, chisq_bins, context)
    logger.debug("instantiated ChisqVeto as {0}".format(repr(chisq_veto)))

    # instantiate event finder
    events = SingleDetectorEvent(snr_threshold, context)
    logger.debug("instantiated SingleDetectorEvent as {0}".format(repr(events)))

    # filter the data against the template bank
    for template in bank:
        htilde = bank.perform_generate_waveform(template)
        for stilde in strain_data:
            matched_filter.perform_generate_snr(stilde, htilde, snr)
            if matched_filter.max() > snr_threshold:
                chisq = chisq_veto.generate_chisq(snr, qtilde)
                events.find_events(snr, chisq)

    # cluster the events across the template bank
    events.cluster_events(0.1)
    events.write("/path/to/output.xml")

    # leaving the ProccessingTargetContext NOW (destroy the device context)
    ###############################################################################

end_message = '... end of pycbc single detector minimal pipeline.'
logger.debug(end_message)
print end_message
```

Current Status

- Codes in progress
  - prototype OpenCL implementation (Budapest)
  - prototype CUDA implementation (Syracuse)
  - prototype framework (AEI)
  - working on integrating different implementations

- Started work as a GPU project
- Currently in a stage where we are rewriting lalapps_inspiral and want to open it up to the group
- Starting to have regular telecons (Tuesdays 2 hours before the CBC telecon)
- For discussion, please mail cbc+pycbc@gravity.phys.uwm.edu
- Can view repository at https://sugwg-git.phy.syr.edu/dokuwiki/doku.php?id=pycbc:home