

Васильев С.И.

*Эксперимент LEGEND 200:
обработка данных программой
Rugata*

План доклада

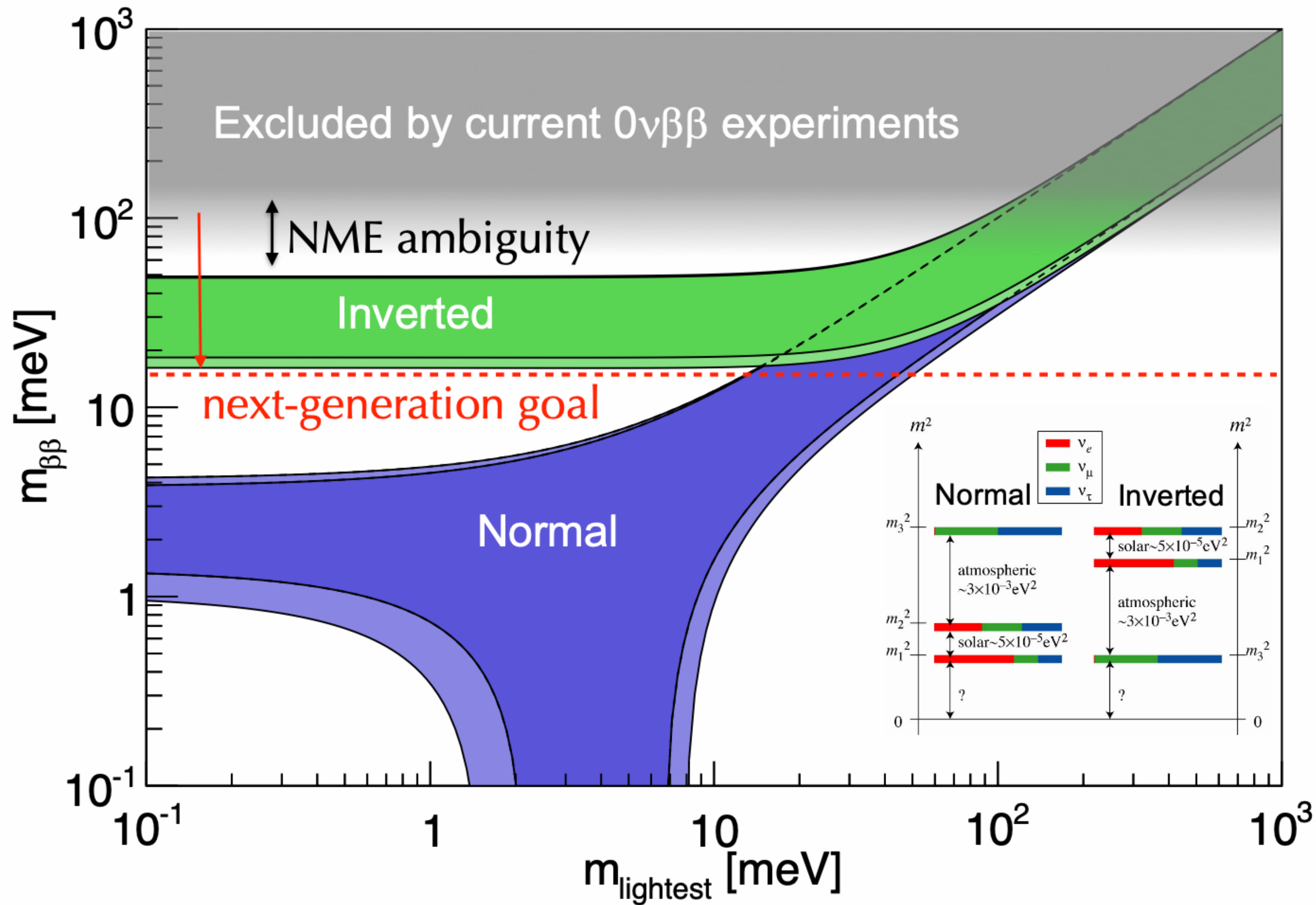
- Эксперимент LEGEND -200 (кратко)
- Программа Ругата



LEGEND

Large Enriched
Germanium Experiment
for Neutrinoless $\beta\beta$ Decay

[Home](#) [Collaboration](#) [Contact us](#)



Advantages of ^{76}Ge :

- Ge diodes are **intrinsically high purity**
- Natural abundance of 7.4%, with demonstrated ability to **enrich to > 86%**
- Excellent energy resolution – **0.13% at 2039 keV**
- HPGe crystals act as both source and detector (**high detection efficiency**)
- $Q_{\beta\beta} = 2.039$ MeV, **above most backgrounds**
- Reasonably **slow $2\nu\beta\beta$ rate** ($T_{1/2} = 1.9 \times 10^{21}$ y)
- Powerful **background rejection from pulse shape analysis**



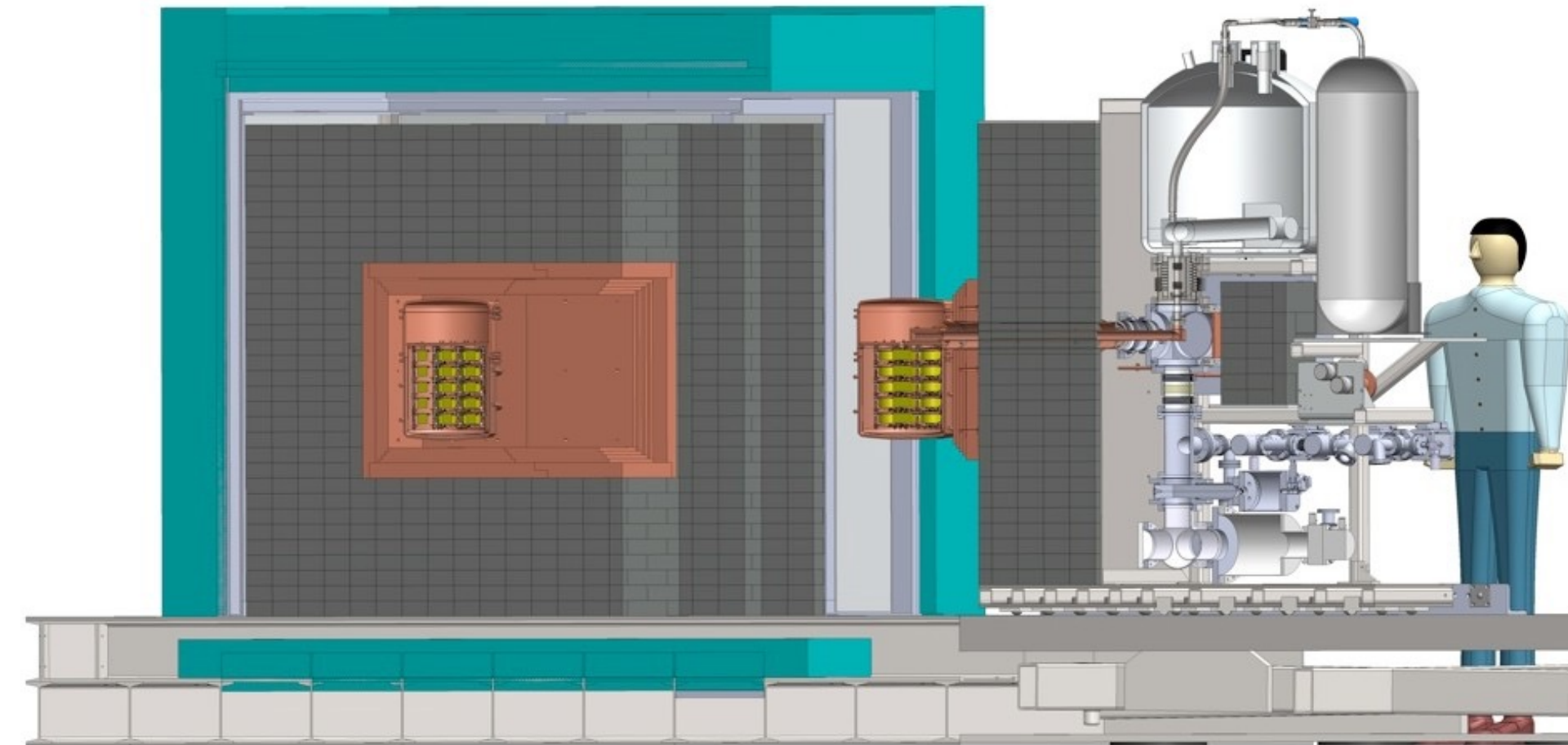
GERDA



- **Design:** Ge crystals submerged in liquid Argon at LNGS, Italy
- **Shield:** LAr, H₂O
- **Phase I:** 18 kg enr-Ge (2011)
- **Phase II:** 20 kg enr-Ge (2013)



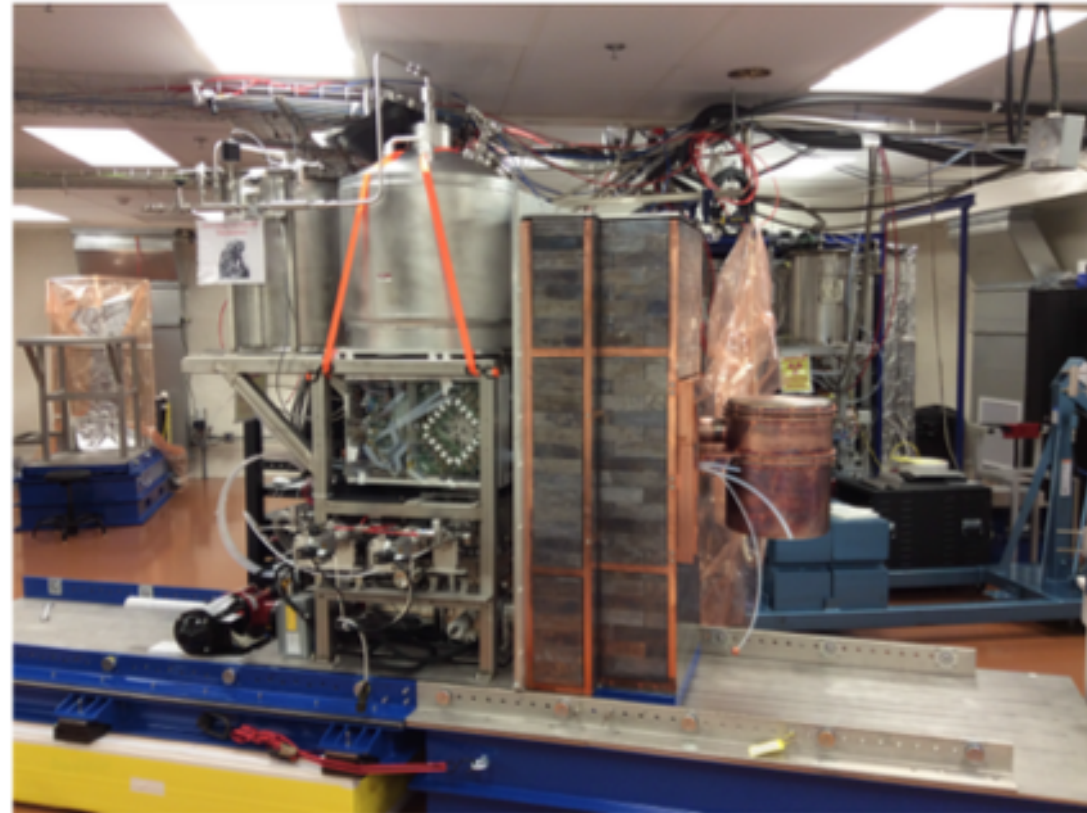
MAJORANA



- **Design:** Ge crystals in high-purity electroformed copper cryostats at Sanford Lab, US
- **Shield:** copper, lead
- **DEMONSTRATOR:** 30 kg of enr-Ge

Open exchange of knowledge and technologies
Future goal: merge for tonne-scale experiment

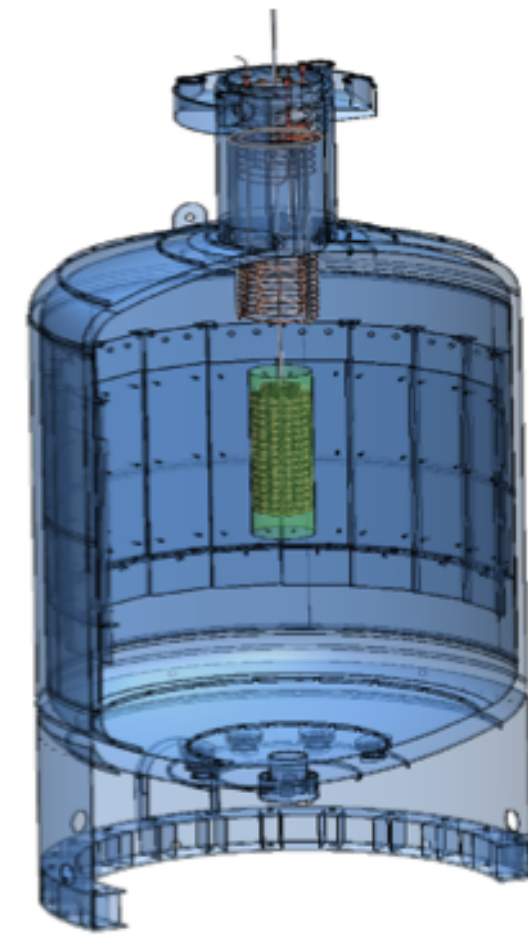
The Best of MAJORANA & GERDA



MAJORANA

- Radiopurity of nearby parts (FETs, cables, Cu mounts, etc.)
- Low noise electronics improves PSD
- Low energy threshold (helps reject cosmogenic background)

MAJORANA achieved best energy resolution: 2.5 keV FWHM at $Q_{\beta\beta}$



Both

- Clean fabrication techniques
- Control of surface exposure
- Development of large point-contact detectors
- Lowest background and best resolution $0\nu\beta\beta$ experiments



GERDA

- LAr veto
- Low-A shield, no Pb

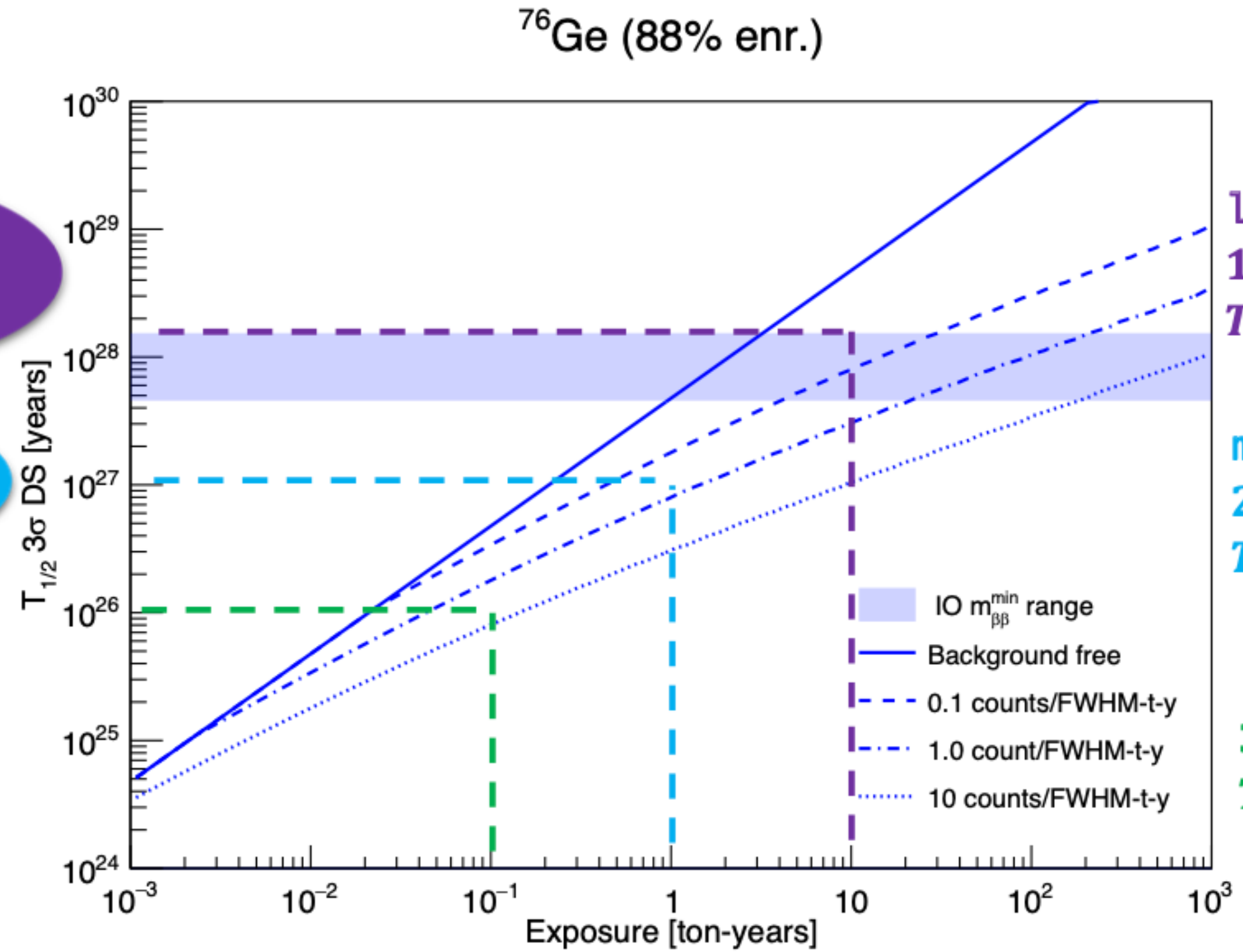
GERDA achieved the lowest background index:
 5×10^{-4} cts/(keV · kg · yr)
LEGEND-200 needs only x3-5 better.

Moving forward

**LEGEND
1000**

**LEGEND
200**

**GERDA
MAJORANA**



long-term
1 ton
 $T_{1/2}^{0\nu} > 10^{28}$ yr

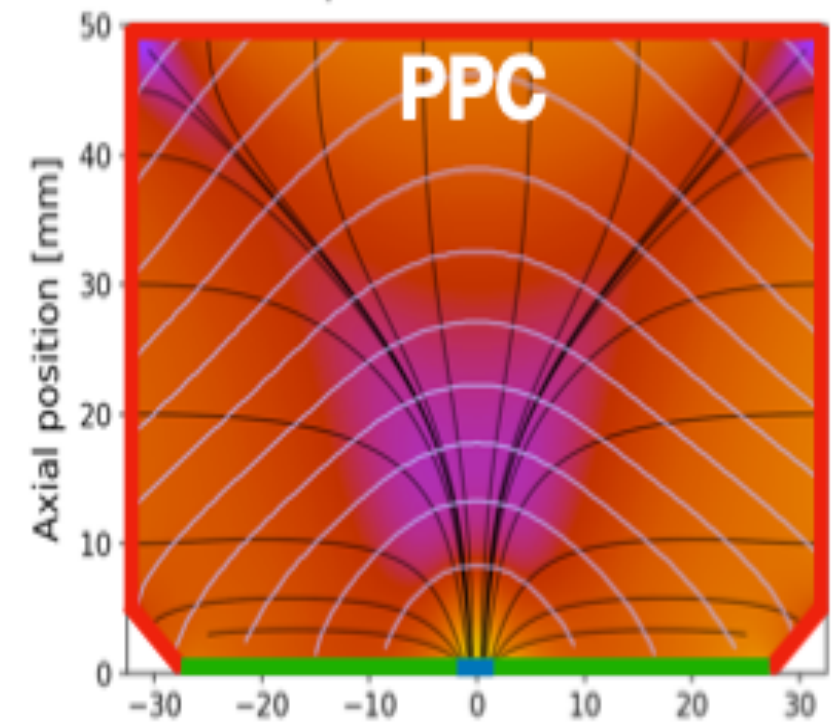
mid-term
200 kg
 $T_{1/2}^{0\nu} > 10^{27}$ yr

running/ended
30 kg
 $T_{1/2}^{0\nu} > 10^{26}$ yr

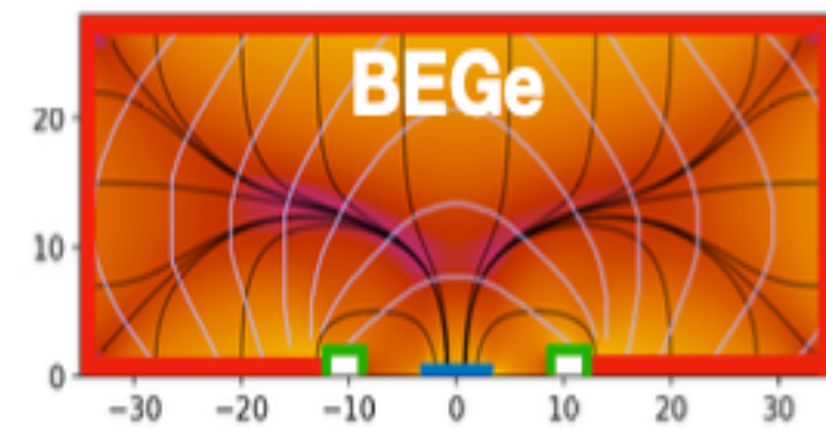
- IO $m_{\beta\beta}^{\min}$ range
- Background free
- 0.1 counts/FWHM-t-y
- 1.0 count/FWHM-t-y
- 10 counts/FWHM-t-y

LEGEND-200 Detectors Types

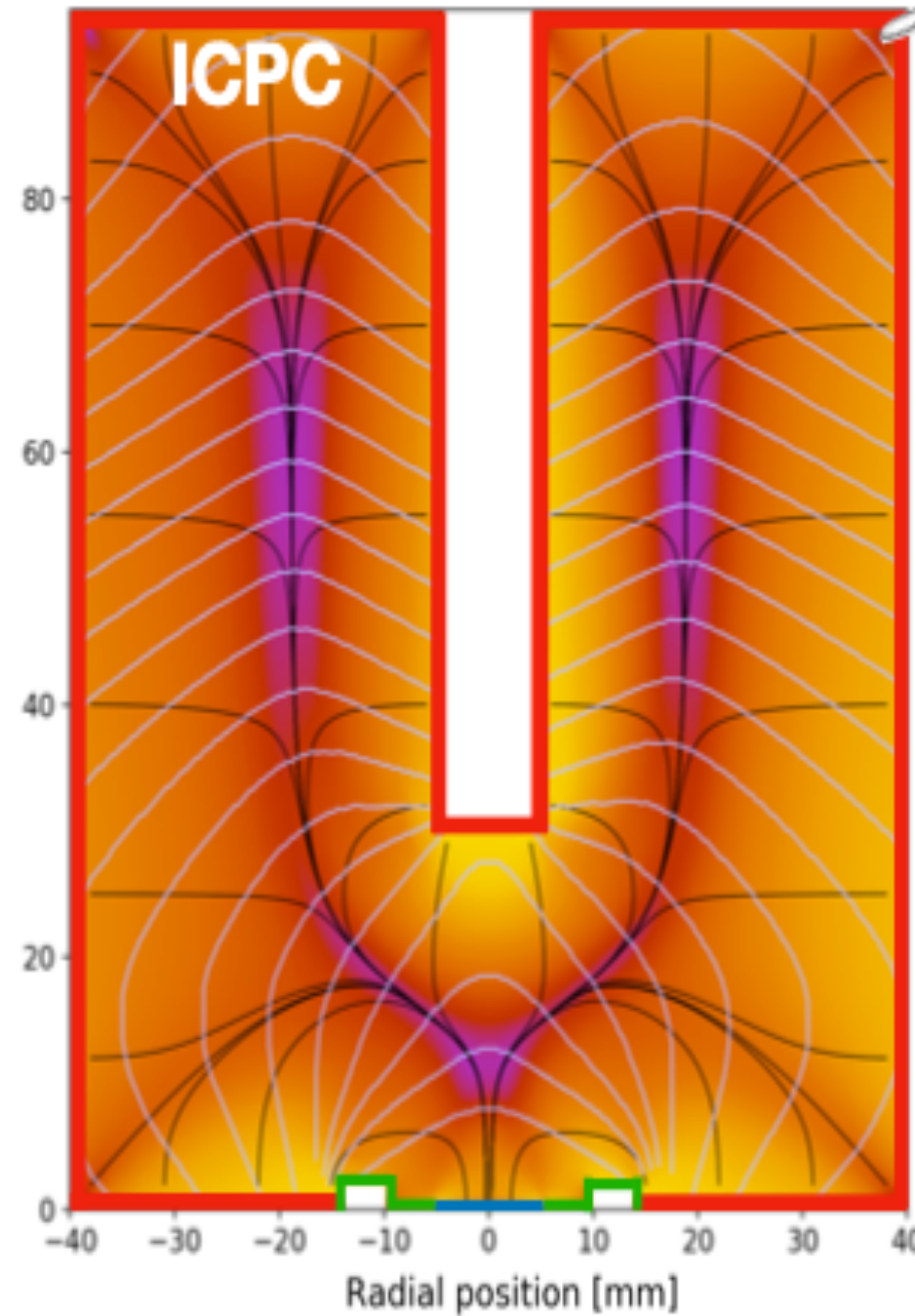
New



p+ point contact (PPC)
35 MJD detectors (29.7 kg)



Broad Energy Germanium (BEGe)
28 GERDA detectors (19.0 kg)



Inverted coaxial point contact (ICPC)
≈80 new detectors (≈150 kg)

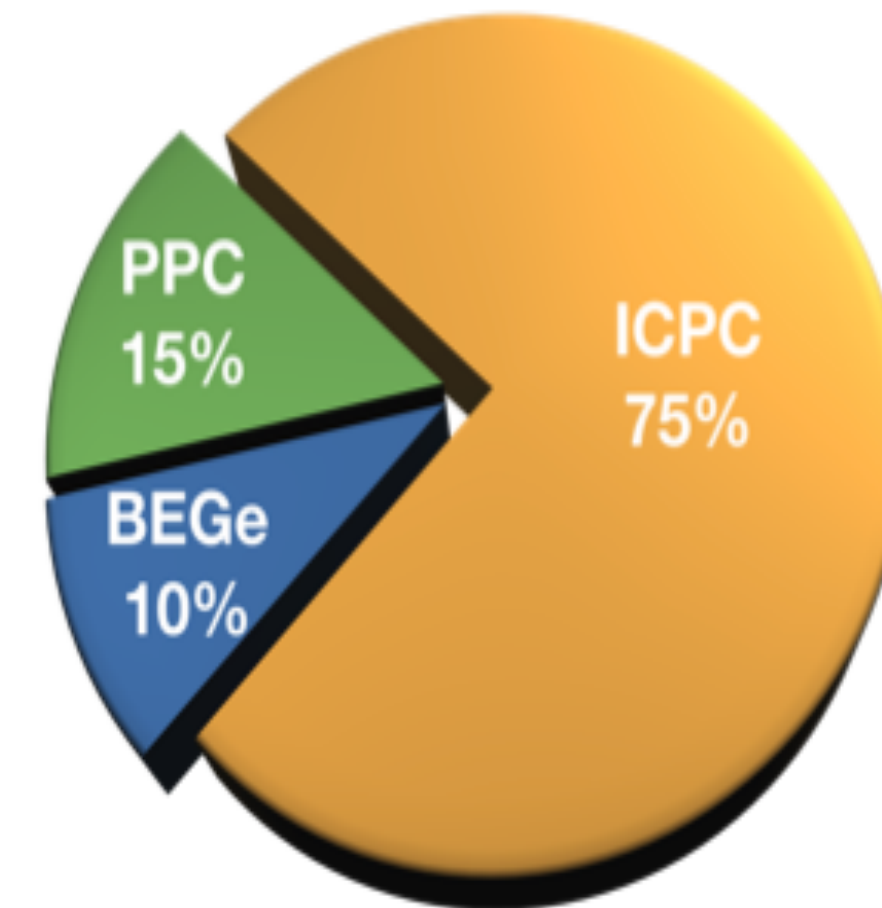
5 ICPC detectors
already deployed in
GERDA Phase II+

Surfaces:

- n+ electrode
- p+ electrode
- passivation

Advantages new ICPC detectors:

- Significantly larger (x2-4)
- Fewer channels, less background
- Better surface-volume-ratio (30-40%)
- Similar ΔE , PSD performance



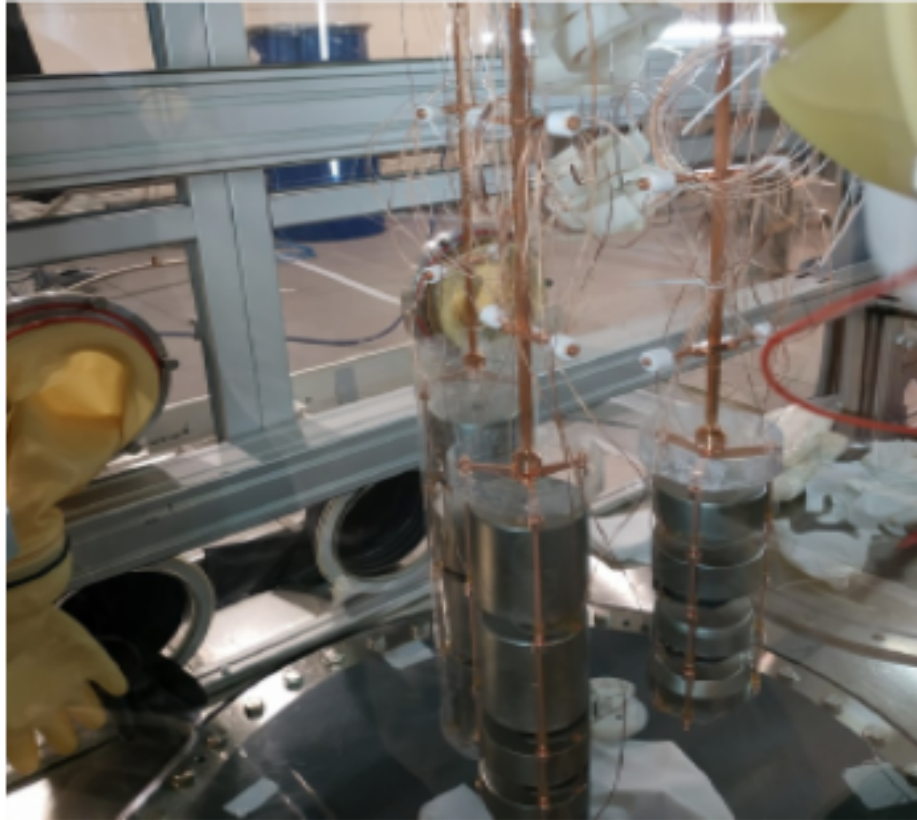
Detector composition L-200

**23 ICPC
detectors
already
produced**

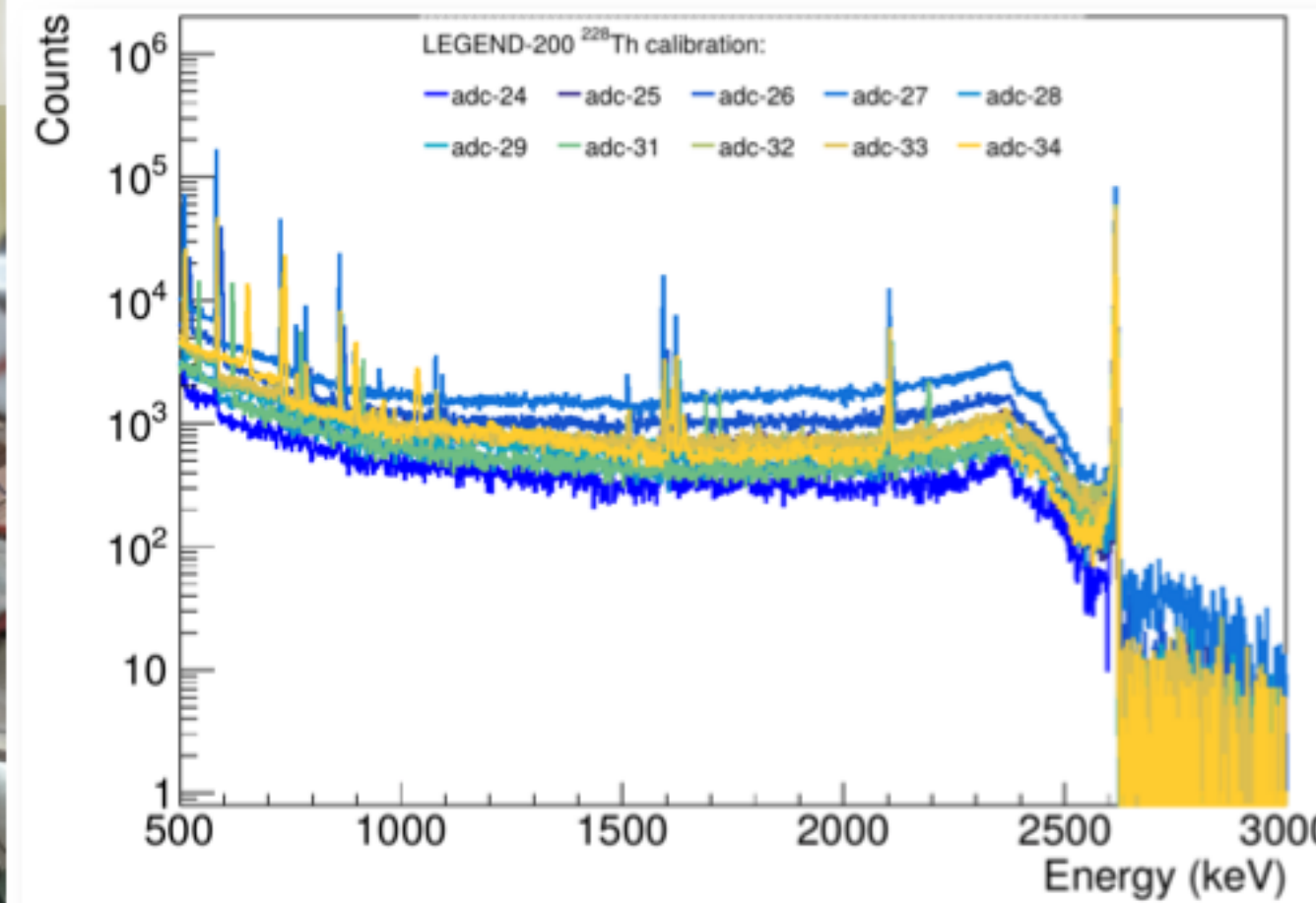
LEGEND-200 ongoing LNGS program



String preparation at LNGS using GERDA infrastructure

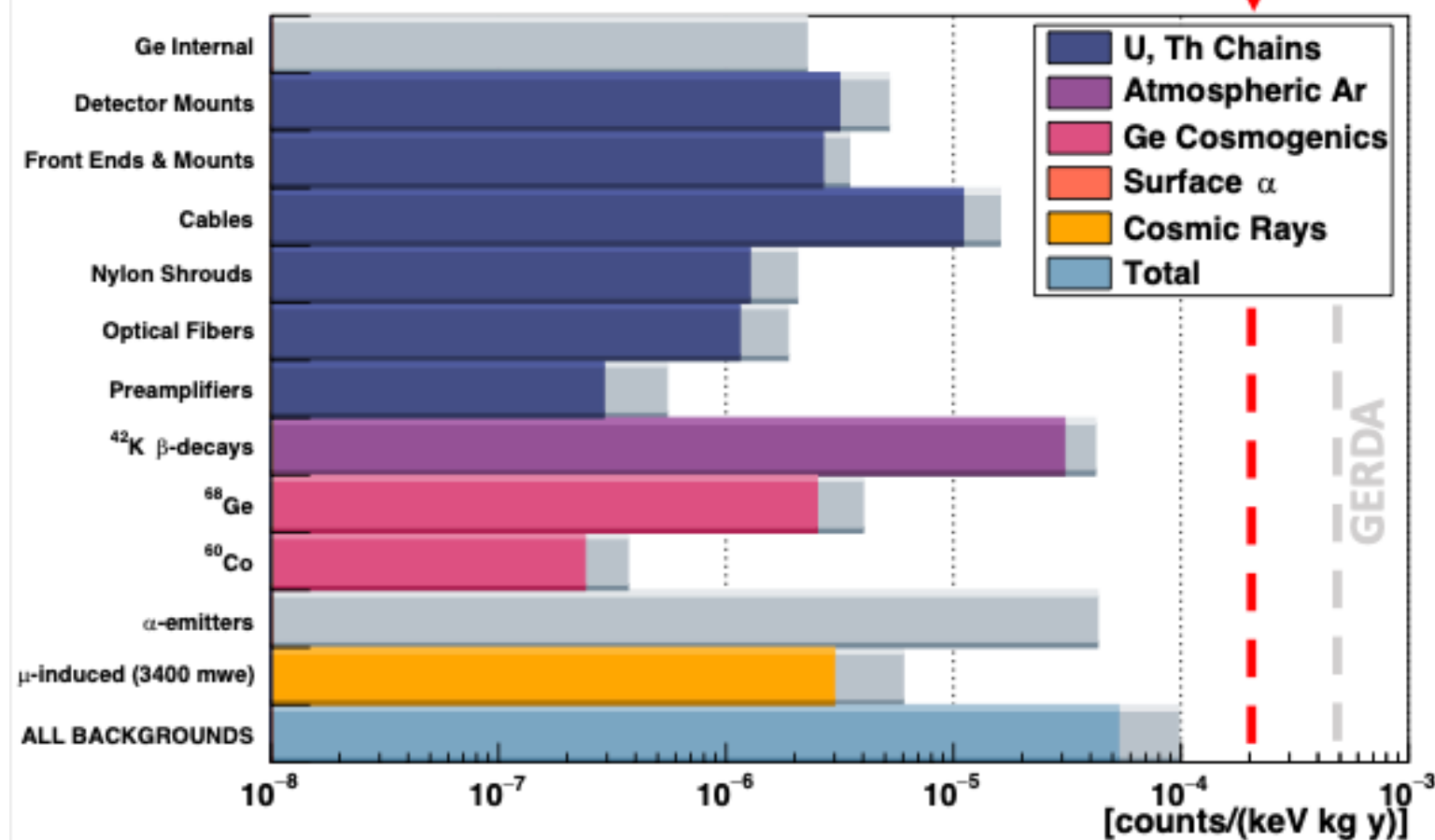


First calibration spectra in March 2020



- Ongoing since Feb 2020
- **GERDA detectors + 4 L200 ICPC + 5 MJD PPC detectors operating in liquid argon**
- First tests of new DAQ, calibration system under real conditions
- First spectra taken using new head electronics
- Data taking still ongoing while LNGS activities are impacted by COVID

LEGEND-200 background Goal



- **Background contributions near $Q_{\beta\beta}$ after all cuts (NB: design exposure = 1 t · yr)**
- Monte Carlo + data-driven projections of Ge U/Th, ^{42}K , α based on GERDA, MJD data
- All others: Monte Carlo + assay-based projections
- Grey bands indicate uncertainties in assays and background rejection

01 July 2020

Neutrino2020 conference - ^{76}Ge 0vbb decay

30

Computing Resources

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Collaboration-wide computing Resources for LEGEND are available at these sites:

- [Resources at NERSC](#): Simulation, data processing and storage
- [Resources at MPIK](#) linux cluster: 6000 cores (200 per user by default), few PB disk space, contact for account B. Schwingenheuer

[Wiki Home](#) 

- [Collaboration Resources](#)
- [New Members](#)
- [Code of](#)

[NERSC](#) (US [National Energy Research Scientific Computing Center](#)) has allocated storage and computing resources for LEGEND. Future allocation (to be supported by US DOE) will depend on the need of the experiment. The LEGEND contact person is Alan Poon. All LEGEND members may apply for a [user account \(see below\)](#).

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[Wiki Home](#) 

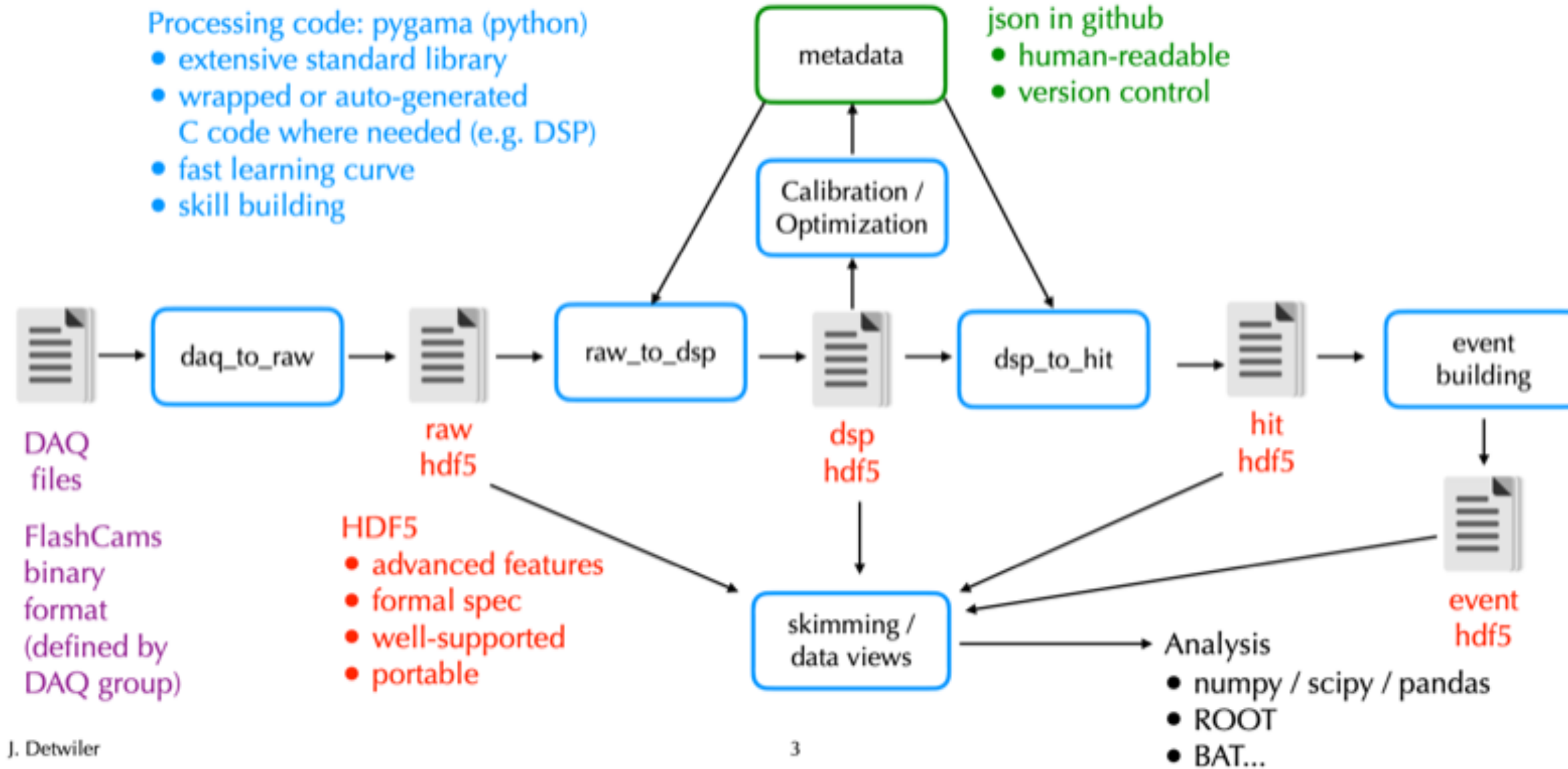
Pygama

what is it?

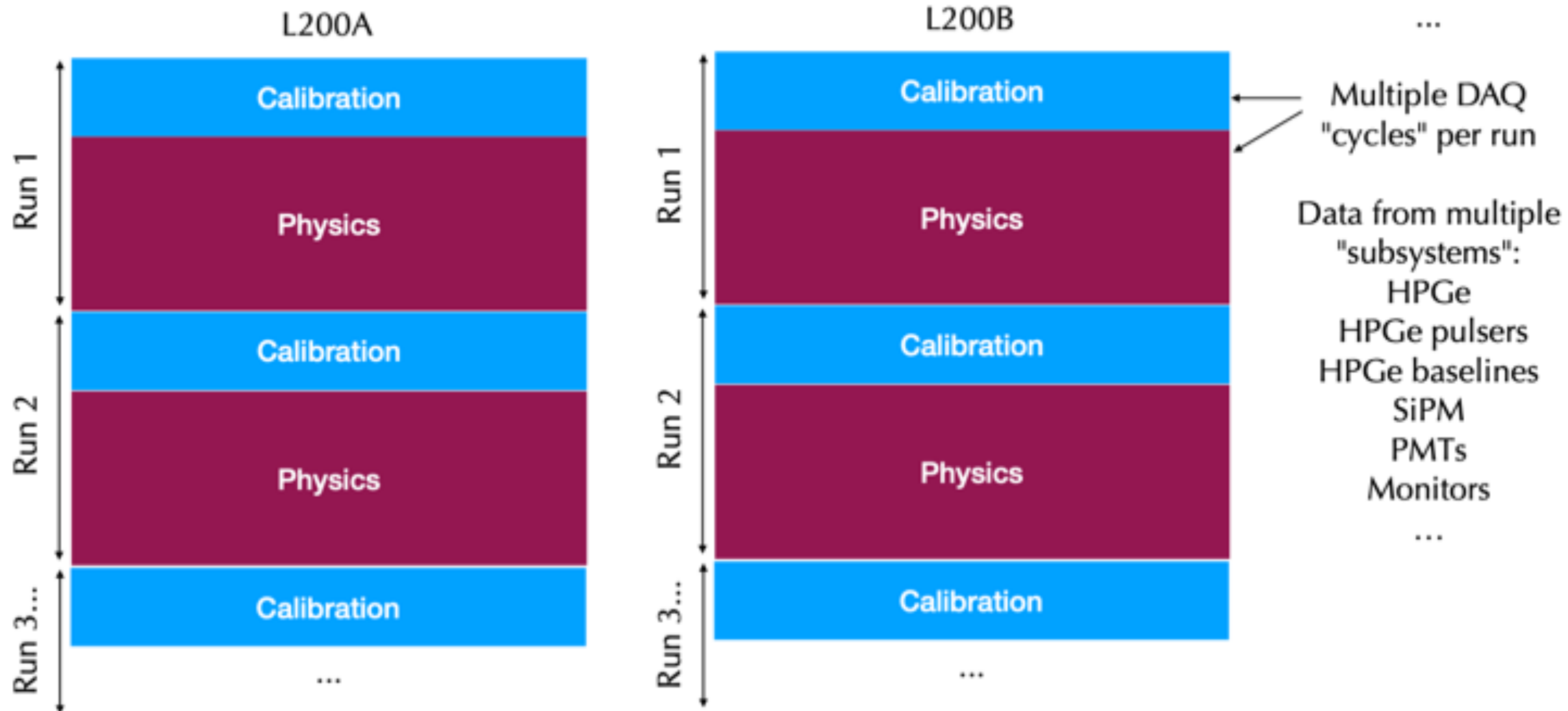
A “modern” python module for reading waveform digitizer data, and doing high-performance offline digital signal processing (DSP), mainly using numpy, pandas, and HDF5 (h5py), currently in working proof-of-concept stage originally developed by Ben Shanks and Sam Meijer (UNC)

The screenshot shows the GitHub repository page for `legend-exp/pygama`. At the top, it displays the repository name and a navigation bar with links for Code, Issues (0), Pull requests (0), Wiki, Insights, and Settings. Below this, a description reads: "Python package for decoding and processing digitizer data with pandas". A statistics bar shows 103 commits, 1 branch, 0 releases, and 3 contributors. A "Branch: master" dropdown and a "New pull request" button are visible. The commit history shows a recent commit by `wisecg` with the message "mj60 processing successful!". Below the commit list, there are three folders: `docs` (toggle cythonizing), `examples` (clean up jason's PR), and `experiments` (mj60 processing successful!).

Data Pipeline Birds-Eye View



LEGEND Data Taking Scheme



Connection to nxcloud01.nersc.gov



Please type your username and password to login.



Username

Password

Save this password in the connection file

Back OK



NERSC_VASILYEV

822 607

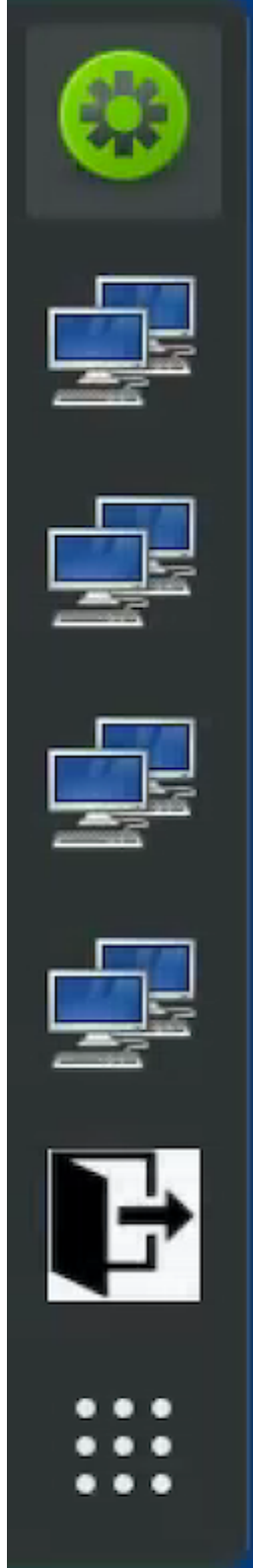
Changes in  14 Seconds




Tokens


Requests


Settings



Cori



vasilyev@cori07:~

File Edit View Search Terminal Help

Compute Resources:

Cori: Available.

Global Filesystems:

Community File System (CFS): Available.

DNA: Available.

Data Transfer Nodes: Available.

Global Common: Available.

Global Homes: Available.

ProjectB: Available.

Mass Storage Systems:

HPSS Archive (User): Available.

HPSS Regent (Backup): Available.

----- Service Status as of 2021-03-17 22:10 PDT -----

All services are available.

----- Next Planned Outage -----

HPSS Archive (User): 04/11/21 7:00-04/16/21 17:00 PDT, Scheduled Maintenance

Cori: 04/21/21 7:00-20:00 PDT, Scheduled Maintenance

For all planned outages, see: <https://www.nersc.gov/live-status/motd/>For past outages, see: <https://my.nersc.gov/outagelog-cs.php/>

vasilyev@cori07:~>

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For past outages, see: <https://my.nersc.gov/outagelog-cs.php/>

```

vasilyev@cori06:~> cd /global/project/projectdirs/legend/data
vasilyev@cori06:/global/project/projectdirs/legend/data> cd ~/
vasilyev@cori06:~>
vasilyev@cori06:~>
vasilyev@cori06:~>
vasilyev@cori06:~>
vasilyev@cori06:~> ls -l /global/project/projectdirs/legend/data
total 11
lrwxrwxrwx 1 lgnddata legend 33 Mar 6 2020 cage -> /global/cfs/cdirs/m2676/data/cage
lrwxrwxrwx 1 lgnddata legend 40 Jan 26 09:29 coincidence -> /global/cfs/cdirs/m2676/data/coincidence
drwxrws--- 4 lgnddata legend 4096 Nov 4 2019 detector_char
lrwxrwxrwx 1 lgnddata legend 37 Jan 26 09:29 flashcam -> /global/cfs/cdirs/m2676/data/flashcam
lrwxrwxrwx 1 lgnddata legend 36 Jan 26 09:30 galatea -> /global/cfs/cdirs/m2676/data/galatea
lrwxrwxrwx 1 lgnddata legend 40 Jan 21 2020 hades -> /global/cfs/projectdirs/m2676/data/hades
drwxr-sr-x 5 lgprod legend 4096 Feb 10 22:33 legend-metadata
lrwxrwxrwx 1 lgnddata legend 39 Jan 21 2020 lngs -> /global/cfs/projectdirs/m2676/data/lngs
lrwxrwxrwx 1 lgnddata legend 39 Jan 21 2020 ornl -> /global/cfs/projectdirs/m2676/data/ornl
lrwxrwxrwx 1 lgnddata legend 39 Jan 21 2020 surf -> /global/cfs/projectdirs/m2676/data/surf
drwxrws--- 3 legend legend 4096 Mar 18 2020 test_data
vasilyev@cori06:~> ls -l /global/project/projectdirs/legend/data/lngs/pgt
total 6
drwxr-s--- 29 lgnddata legend 4096 Aug 24 2020 daq
drwxr-sr-x 3 lgprod legend 4096 Sep 14 2020 dsp
drwxr-sr-x 3 iguinn legend 4096 Aug 16 2020 dsp_iguinn
drwxr-sr-x 5 lgprod legend 4096 Jul 28 2020 raw
drwxrws--- 4 lgprod legend 4096 Mar 11 12:04 v00.00
drwxrws--- 4 lgprod legend 4096 Mar 11 10:04 v01.00
vasilyev@cori06:~>
vasilyev@cori06:~>

```

```
vasilyev@cori06:~>
vasilyev@cori06:~>
vasilyev@cori06:~>
vasilyev@cori06:~>
vasilyev@cori06:~>
vasilyev@cori06:~> ls -l /global/project/projectdirs/legend/data/lngs/pgt/daq
total 3242
drwxr-s--- 2 lgnddata legend 16384 Jul 19 2020 run0001-fc-daq-test
drwxr-s--- 2 lgnddata legend 16384 Jul 19 2020 run0002-fc-daq-test
drwxr-s--- 2 lgnddata legend 4096 Jul 19 2020 run0003-fc-daq-test
drwxr-s--- 2 lgnddata legend 4096 Jul 19 2020 run0004-spm-vbias-scan
drwxr-s--- 2 lgnddata legend 4096 Jul 19 2020 run0005-spm-nightrun-s2th
drwxr-s--- 2 lgnddata legend 4096 Jul 19 2020 run0006-spm-longrun-N0th
drwxr-s--- 2 lgnddata legend 4096 Jul 19 2020 run0007-spm-longrun_1-N0th
drwxr-s--- 2 lgnddata legend 4096 Jul 19 2020 run0018-new-head-elec
drwxr-s--- 2 lgnddata legend 32768 Jul 19 2020 run0019-baseline-test-new-head
drwxr-s--- 2 lgnddata legend 4096 Jul 19 2020 run0020-baseline-test-new-head
drwxr-s--- 2 lgnddata legend 16384 Jul 19 2020 run0021-baseline-test-new-head
drwxr-s--- 2 lgnddata legend 4096 Jul 19 2020 run0022-baseline-test-new-head
drwxr-s--- 2 lgnddata legend 32768 Jul 19 2020 run0023-baseline-test-new-head
drwxr-s--- 2 lgnddata legend 524288 Jul 19 2020 run0024-baseline-test-new-head-new-daq
drwxr-s--- 2 lgnddata legend 32768 Jul 19 2020 run0026-test-4chan-genius
drwxr-s--- 2 lgnddata legend 65536 Jul 19 2020 run0027-midjune-4gs-2mima-1mama
drwxr-s--- 2 lgnddata legend 32768 Jul 8 2020 run0028-mid-june-sipm-test
drwxr-x---+ 2 lgnddata legend 4096 Jul 15 2020 run0029-test
drwxr-x--- 2 lgnddata legend 524288 Aug 19 2020 run0030-mid-july-test
drwxr-s--- 2 lgnddata legend 4096 Aug 19 2020 run0031-pulser-test
drwxr-s--- 2 lgnddata legend 16384 Aug 19 2020 run0032-newcalib
drwxr-s--- 2 lgnddata legend 131072 Aug 20 2020 run0033-calib-with-pulser3hz
drwxr-s--- 2 lgnddata legend 16384 Aug 20 2020 run0034-rate-rest
drwxr-s--- 2 lgnddata legend 131072 Aug 23 2020 run0035-calib-pulser-seq
drwxr-s--- 2 lgnddata legend 16384 Aug 24 2020 run0036-pulser-vs-bl
drwxr-s--- 2 lgnddata legend 16384 Aug 24 2020 run0037-pulser-vs-bl
drwxr-s--- 2 lgnddata legend 32768 Aug 24 2020 run0038-pulser-vs-bl-hq
vasilyev@cori06:~>
vasilyev@cori06:~> du -sh /global/project/projectdirs/legend/data/lngs/pgt/daq
8.4T /global/project/projectdirs/legend/data/lngs/pgt/daq
vasilyev@cori06:~>
vasilyev@cori06:~>
vasilyev@cori06:~>
vasilyev@cori06:~>
```

```
vasilyev@cori07:~>
vasilyev@cori07:~> shifter --image legendexp/legend-base:latest bash
bash-5.0$
bash-5.0$ git clone https://github.com/legend-exp/pygama.git
Cloning into 'pygama'...
remote: Enumerating objects: 79, done.
remote: Counting objects: 100% (79/79), done.
remote: Compressing objects: 100% (46/46), done.
remote: Total 6977 (delta 35), reused 61 (delta 32), pack-reused 6898
Receiving objects: 100% (6977/6977), 10.09 MiB | 16.60 MiB/s, done.
Resolving deltas: 100% (4818/4818), done.
bash-5.0$
bash-5.0$ pip install -e pygama --user
Obtaining file:///global/u1/v/vasilyev/pygama
Requirement already satisfied: numpy in /opt/anaconda3/lib/python3.8/site-packages (from pygama==0.5) (1.19.2)
Requirement already satisfied: scimath in ./local/lib/python3.8/site-packages (from pygama==0.5) (4.2.0)
Requirement already satisfied: numba in /opt/anaconda3/lib/python3.8/site-packages (from pygama==0.5) (0.51.2)
Requirement already satisfied: parse in ./local/lib/python3.8/site-packages (from pygama==0.5) (1.16.0)
Requirement already satisfied: GitPython in ./local/lib/python3.8/site-packages (from pygama==0.5) (3.1.7)
Requirement already satisfied: tinydb in ./local/lib/python3.8/site-packages (from pygama==0.5) (4.1.1)
Requirement already satisfied: pyFFTW in ./local/lib/python3.8/site-packages (from pygama==0.5) (0.12.0)
Requirement already satisfied: h5py in /opt/anaconda3/lib/python3.8/site-packages (from pygama==0.5) (2.10.0)
Requirement already satisfied: pandas in /opt/anaconda3/lib/python3.8/site-packages (from pygama==0.5) (1.1.3)
Requirement already satisfied: matplotlib in /opt/anaconda3/lib/python3.8/site-packages (from pygama==0.5) (3.3.2)
Requirement already satisfied: scipy in /opt/anaconda3/lib/python3.8/site-packages (from scimath->pygama==0.5) (1.5.2)
Requirement already satisfied: traits in ./local/lib/python3.8/site-packages (from scimath->pygama==0.5) (6.1.1)
Requirement already satisfied: llvmlite<0.35,>=0.34.0.dev0 in /opt/anaconda3/lib/python3.8/site-packages (from numba->pygama==0.5) (0.34.0)
Requirement already satisfied: setuptools in /opt/anaconda3/lib/python3.8/site-packages (from numba->pygama==0.5) (50.3.1.post20201107)
Requirement already satisfied: gitdb<5,>=4.0.1 in ./local/lib/python3.8/site-packages (from GitPython->pygama==0.5) (4.0.5)
Requirement already satisfied: six in /opt/anaconda3/lib/python3.8/site-packages (from h5py->pygama==0.5) (1.15.0)
Requirement already satisfied: pytz>=2017.2 in /opt/anaconda3/lib/python3.8/site-packages (from pandas->pygama==0.5) (2020.1)
Requirement already satisfied: python-dateutil>=2.7.3 in /opt/anaconda3/lib/python3.8/site-packages (from pandas->pygama==0.5) (2.8.1)
Requirement already satisfied: pyparsing!=2.0.4,!2.1.2,!2.1.6,>=2.0.3 in /opt/anaconda3/lib/python3.8/site-packages (from matplotlib->pygama==0.5) (2.4.7)
Requirement already satisfied: kiwisolver>=1.0.1 in /opt/anaconda3/lib/python3.8/site-packages (from matplotlib->pygama==0.5) (1.3.0)
Requirement already satisfied: cyclor>=0.10 in /opt/anaconda3/lib/python3.8/site-packages (from matplotlib->pygama==0.5) (0.10.0)
Requirement already satisfied: certifi>=2020.06.20 in /opt/anaconda3/lib/python3.8/site-packages (from matplotlib->pygama==0.5) (2020.12.5)
Requirement already satisfied: pillow>=6.2.0 in /opt/anaconda3/lib/python3.8/site-packages (from matplotlib->pygama==0.5) (8.0.1)
Requirement already satisfied: smmap<4,>=3.0.1 in ./local/lib/python3.8/site-packages (from gitdb<5,>=4.0.1->GitPython->pygama==0.5) (3.0.4)
Installing collected packages: pygama
  Running setup.py develop for pygama
Successfully installed pygama
bash-5.0$
bash-5.0$
```

```
bash-5.0$  
bash-5.0$  
bash-5.0$  
bash-5.0$  
bash-5.0$  
bash-5.0$  
bash-5.0$  
bash-5.0$ cd /global/homes/v/vasilyev/pygama/experiments  
bash-5.0$ ls -l  
total 35  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 coherent  
drwxr-xr-x 2 vasilyev vasilyev 4096 Mar 20 02:05 datagroup  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 example  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 hades  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 hades_test  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 lh5_update  
drwxr-xr-x 3 vasilyev vasilyev 512 Mar 20 02:05 lpgta  
drwxr-xr-x 3 vasilyev vasilyev 4096 Mar 20 02:05 mj60  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 mjd  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 ncsu  
drwxr-xr-x 3 vasilyev vasilyev 4096 Mar 20 02:05 oppi  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 scarf  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 surf  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 tumbisi  
bash-5.0$  
bash-5.0$ cd lpgta  
bash-5.0$ ls -l  
total 86  
-rw-r--r-- 1 vasilyev vasilyev 1094 Mar 20 02:05 LPGTA.json  
-rw-r--r-- 1 vasilyev vasilyev 4148 Mar 20 02:05 LPGTA_dsp.json  
-rw-r--r-- 1 vasilyev vasilyev 2175 Mar 20 02:05 LPGTA_runDB.json  
-rwxr-xr-x 1 vasilyev vasilyev 710 Mar 20 02:05 config_ecal.json  
drwxr-xr-x 2 vasilyev vasilyev 512 Mar 20 02:05 cori_slurm  
-rw-r--r-- 1 vasilyev vasilyev 211 Mar 20 02:05 ecalDB.json  
-rwxr-xr-x 1 vasilyev vasilyev 34880 Mar 20 02:05 energy_cal.py  
-rwxr-xr-x 1 vasilyev vasilyev 4957 Mar 20 02:05 file_checks.py  
-rw-r--r-- 1 vasilyev vasilyev 1118 Mar 20 02:05 gamma_lines.txt  
-rwxr-xr-x 1 vasilyev vasilyev 7455 Mar 20 02:05 processing.py  
-rwxr-xr-x 1 vasilyev vasilyev 5517 Mar 20 02:05 setup.py  
bash-5.0$  
bash-5.0$  
bash-5.0$  
bash-5.0$ ./ processing.py --dg --d2r -n 100 # d2r ---->22 daq to raw
```

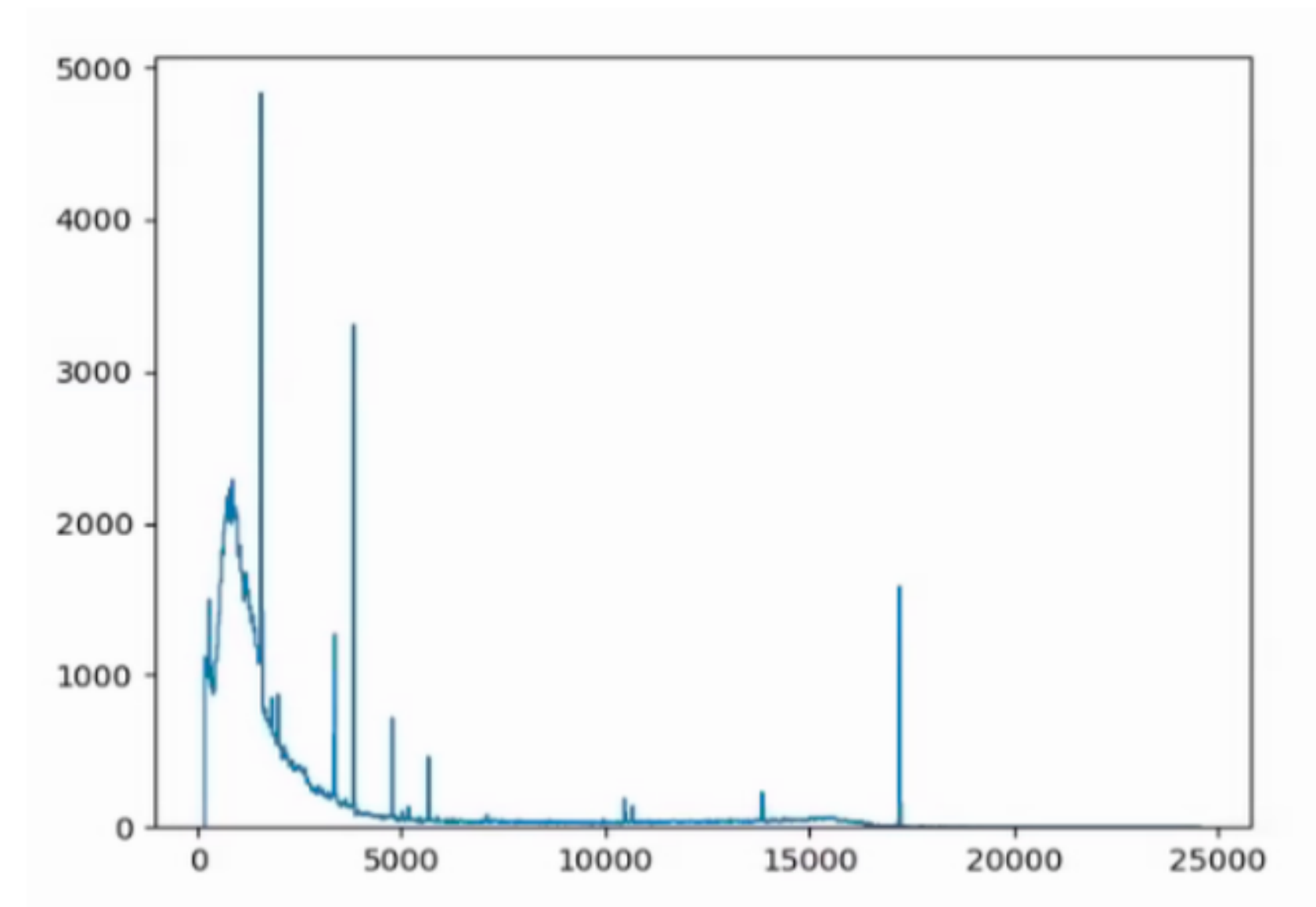
File Edit View Search Terminal Help

```
vasilyev@cori08:~> shifter --image legendexp/legend-base:latest bash
bash-5.0$
bash-5.0$ cd /global/project/projectdirs/legend/data/lngs/pgt/raw/geds
bash-5.0$
bash-5.0$ h5dump -n LPGTA_r0030_20200723T224507Z_phys_geds_raw.lh5
HDF5 "LPGTA_r0030_20200723T224507Z_phys_geds_raw.lh5" {
FILE_CONTENTS {
group      /
group      /g024
group      /g024/raw
dataset    /g024/raw/baseline
dataset    /g024/raw/channel
dataset    /g024/raw/energy
dataset    /g024/raw/ievt
dataset    /g024/raw/numtraces
dataset    /g024/raw/packet_id
dataset    /g024/raw/timestamp
group      /g024/raw/tracelist
dataset    /g024/raw/tracelist/cumulative_length
dataset    /g024/raw/tracelist/flattened_data
group      /g024/raw/waveform
dataset    /g024/raw/waveform/dt
dataset    /g024/raw/waveform/t0
dataset    /g024/raw/waveform/values
dataset    /g024/raw/wf_max
dataset    /g024/raw/wf_std
group      /g025
group      /g025/raw
dataset    /g025/raw/baseline
dataset    /g025/raw/channel
dataset    /g025/raw/energy
dataset    /g025/raw/ievt
dataset    /g025/raw/numtraces
dataset    /g025/raw/packet_id
dataset    /g025/raw/timestamp
group      /g025/raw/tracelist
dataset    /g025/raw/tracelist/cumulative_length
dataset    /g025/raw/tracelist/flattened_data
group      /g025/raw/waveform
```

Browsing Data With h5py

- In h5py, groups are dictionaries and datasets are numpy arrays

```
bash-3.2$ python
'''
>>> import h5py
>>> f = h5py.File('/global/project/projectdirs/legend/data/lngs/pgt/raw/
geds/LPGTA_r0030_20200723T141228Z_calib_geds_raw.lh5', 'r')
>>> f.keys()
<KeysViewHDF5 ['g024', 'g025', 'g026', 'g028', 'g029', 'g030', 'g031',
'g032', 'g033', 'g034', 'g035', 'g036', 'g037', 'g038', 'g039', 'g040']>
>>> f['g024'].keys()
<KeysViewHDF5 ['raw']>
>>> f['g024/raw'].keys()
<KeysViewHDF5 ['baseline', 'channel', 'energy', 'ievt', 'numtraces',
'packet_id', 'timestamp', 'tracelist', 'waveform', 'wf_max', 'wf_std']>
>>> f['g024/raw/energy'][:20]
array([ 1229,  1034,  1784,  1568, 17208,   811,  1512,   968,   574,
         846,   287,  1159,   651,   525,  3114,   753,  1368,  2428,
        246,  1566], dtype=uint16)
>>> import matplotlib.pyplot as plt
>>> plt.hist(f['g024/raw/energy'], bins=1000, histtype='step')
'''
>>> plt.show()
```



Basic Histogram Fitting

- Some convenience functions in pygama

```
import matplotlib.pyplot as plt
import pygama.analysis.histograms as pgh
import pygama.analysis.peak_fitting as pga
import pygama.utils as pgu
import pygama.io.lh5 as lh5

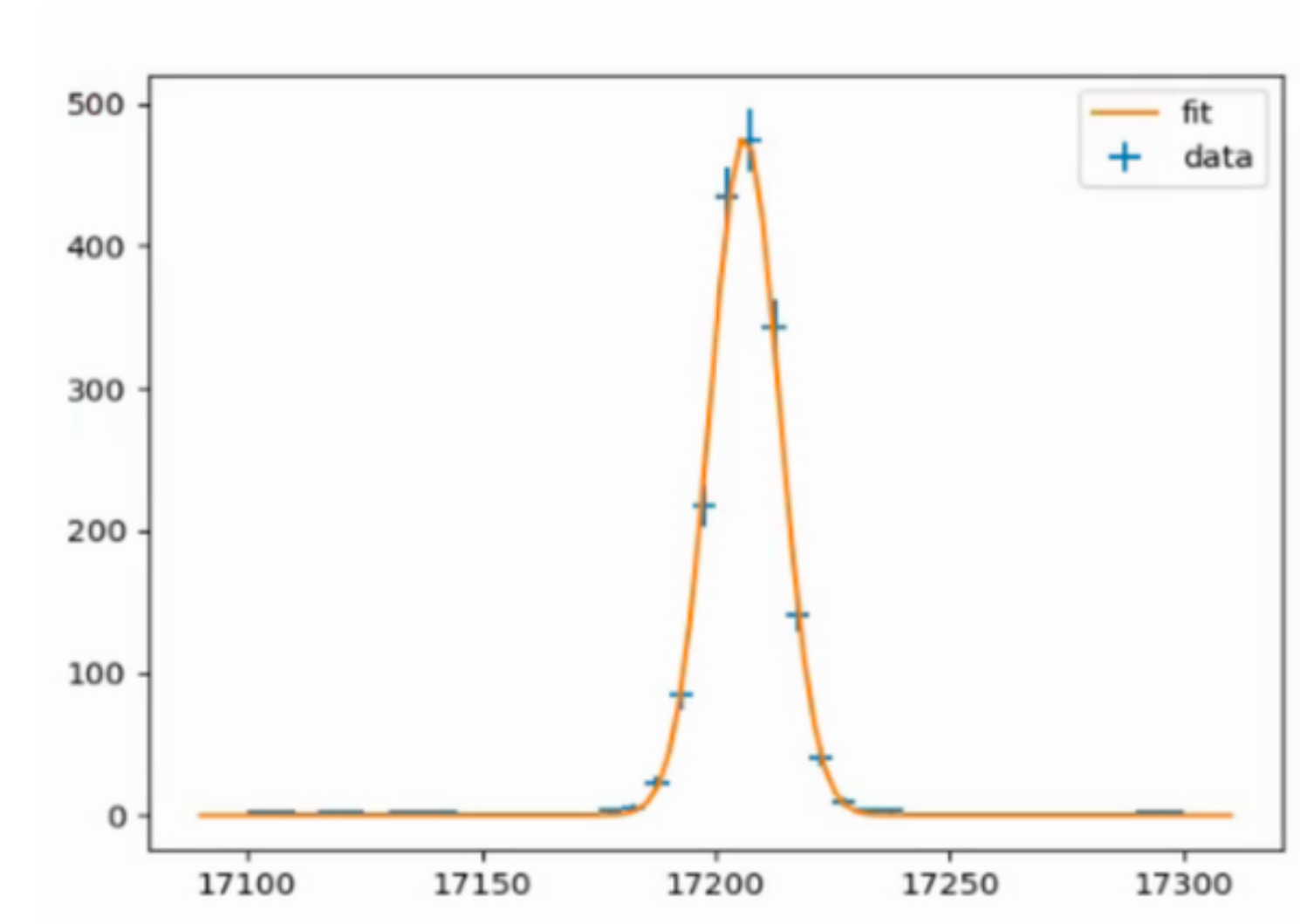
lh5_store = lh5.Store()
energies = lh5_store.read_object('g024/raw/energy', '/global/project/projectdirs/
legend/data/lngs/pgt/raw/geds/LPGTA_r0030_20200723T141228Z_calib_geds_raw.lh5')

hist, bins, var = pgh.get_hist(energies.nda, range=(17100,17300), dx=5)
pgh.plot_hist(hist, bins, var, label="data")

pars, cov = pga.fit_hist(pga.gauss, hist, bins, var=var, guess=[17210,30,3000])
pgu.print_fit_results(pars, cov, ['mu', 'sig', 'A'])
pgu.plot_func(pga.gauss, pars, label="fit")

plt.legend(loc=1)

plt.show()
```



mu = 17206.25 +/- 0.21
sig = 7.40 +/- 0.16
A = 8.85e+03 +/- 2.5e+02

- Also recommended: pyroot

Quick Plot of a Waveform

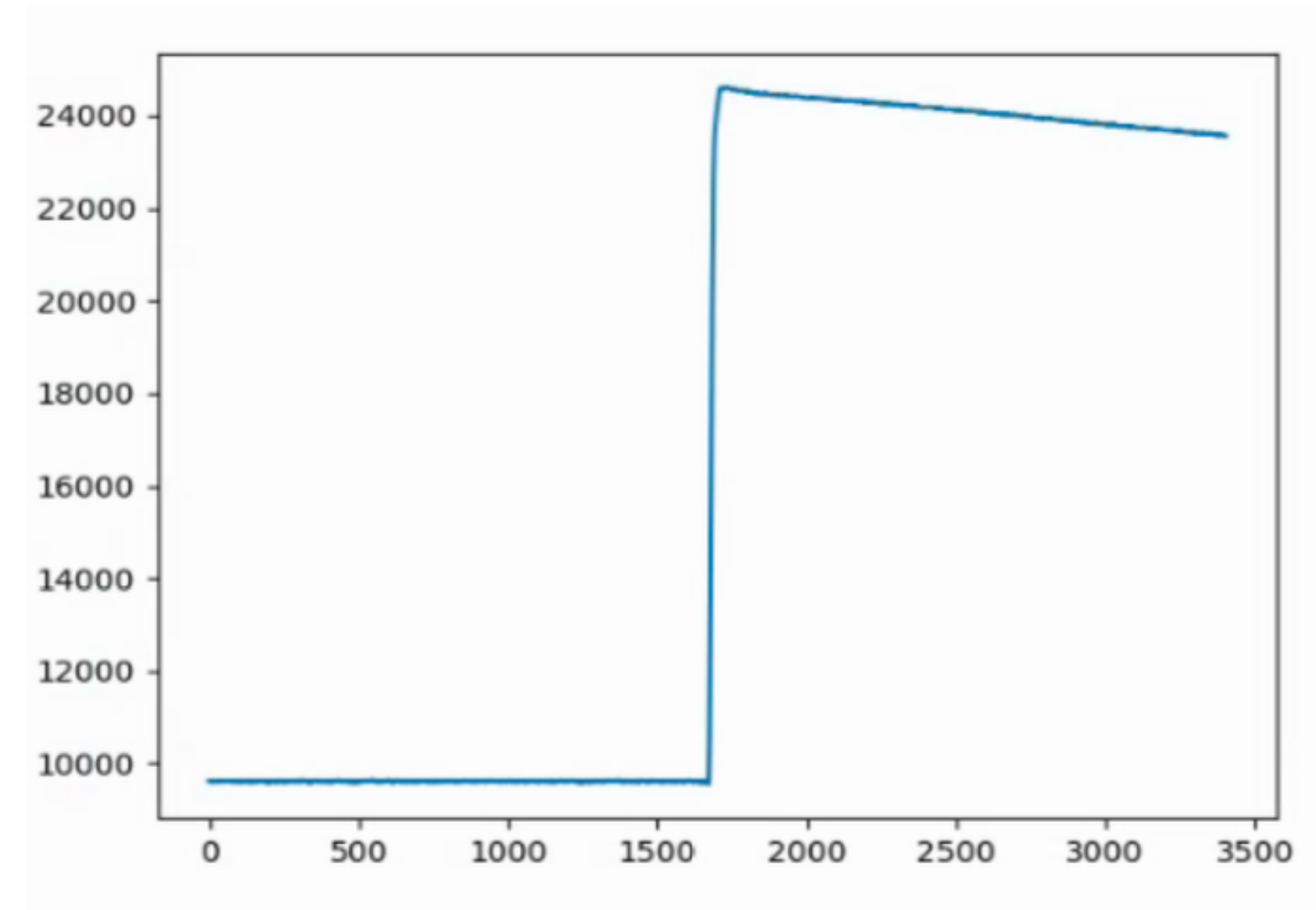
- Using h5py / numpy / matplotlib

```
bash-4.2$ pyopenh5 $LPGTA_DATA/raw/geds/  
LPGTA_r0030_20200729T185834Z_phys_geds_raw.lh5  
opening hdf5 file /global/project/projectdirs/legend/data/lngs/pgt/  
raw/geds/LPGTA_r0030_20200729T185834Z_phys_geds_raw.lh5 as f...  
>>> import numpy as np  
>>> import matplotlib.pyplot as plt  
>>> wf = f['g024/raw/waveform/values'][1,:]  
>>> plt.plot(np.arange(len(wf)), wf)  
[<matplotlib.lines.Line2D object at 0x2aaac1234460>]  
>>> plt.show()
```

- Shell function pyopenh5 in *sh:

```
pyopenh5() {  
    echo "opening hdf5 file $1 as f..."  
    python -i -c "import h5py; f = h5py.File('$1', 'r')"  
}
```

- Also see Ian's talk



vasilyev@cori08:~

File Edit View Search Terminal Help

```
}  
}  
bash-5.0$  
bash-5.0$ cd /global/project/projectdirs/legend/data/lngs/pgt/dsp/geds  
bash-5.0$  
bash-5.0$ h5dump -n LPGTA_r0030_20200723T224507Z_phys_geds_dsp.lh5  
HDF5 "LPGTA_r0030_20200723T224507Z_phys_geds_dsp.lh5" {  
FILE_CONTENTS {  
group /  
group /dsp_info  
dataset /dsp_info/dsp_config  
dataset /dsp_info/h5py_version  
dataset /dsp_info/hdf5_version  
dataset /dsp_info/numpy_version  
dataset /dsp_info/pygama_branch  
dataset /dsp_info/pygama_date  
dataset /dsp_info/pygama_revision  
dataset /dsp_info/pygama_version  
dataset /dsp_info/python_version  
dataset /dsp_info/timestamp  
group /g024  
group /g024/dsp  
dataset /g024/dsp/A_10  
dataset /g024/dsp/AoE  
dataset /g024/dsp/bl  
dataset /g024/dsp/bl_sig  
dataset /g024/dsp/trapE  
group /g025  
group /g025/dsp  
dataset /g025/dsp/A_10  
dataset /g025/dsp/AoE  
dataset /g025/dsp/bl  
dataset /g025/dsp/bl_sig  
dataset /g025/dsp/trapE  
group /g026  
group /g026/dsp  
dataset /g026/dsp/A_10  
dataset /g026/dsp/AoE  
dataset /g026/dsp/bl
```

dev pygama / pygama / dsp / _processors / Go to file Add file ...

This branch is 3 commits ahead, 12 commits behind master. Pull request Compare

SamuelBorden Reordered factory function so ... 44b415c 18 days ago History

..		
__init__.py	change processor folder name back	13 months ago
asym_trap_filter.py	first sample needs to be divided by rise or th...	2 months ago
current.py	Changed parsing of variable names in Proces...	11 months ago
cuspid_filter.py	Add cuspid filter numba processor	11 months ago
fftw.py	Added power spect and timepoints to dsp_co...	7 months ago
fixed_time_pickoff.py	Parse units with in Processing Chain. Pickoffs...	11 months ago
gaussian_filter1d.py	Reordered factory function so that kernel isn'...	18 days ago
linear_fit.py	Use linear fit to measure tail_rc	11 months ago
linear_slope_fit.py	changed linear slope intercept and added m...	last month
log_check.py	readded processor list, added docstring to lo...	last month
mean_stdev.py	change processor folder name back	13 months ago
min_max.py	removed the 2nd function definition	last month
param_lookup.py	Added param_lookup processor, which sets a...	11 months ago

pole_zero.py	implement double pole-zero correction	3 months ago
presum.py	Added presuming processor	5 months ago
time_point_frac.py	Added time point calculators	12 months ago
time_point_thresh.py	Changed time_point_thresh to be more reliabl...	7 months ago
trap_filter.py	Revert "Cleaned up some unnecessary impor...	4 months ago
trap_norm.py	Revert "Cleaned up some unnecessary impor...	4 months ago
trap_pickoff.py	out[i] should be based on wf values prior to i,...	2 months ago
zac_filter.py	ZAC processor with factory function	11 months ago

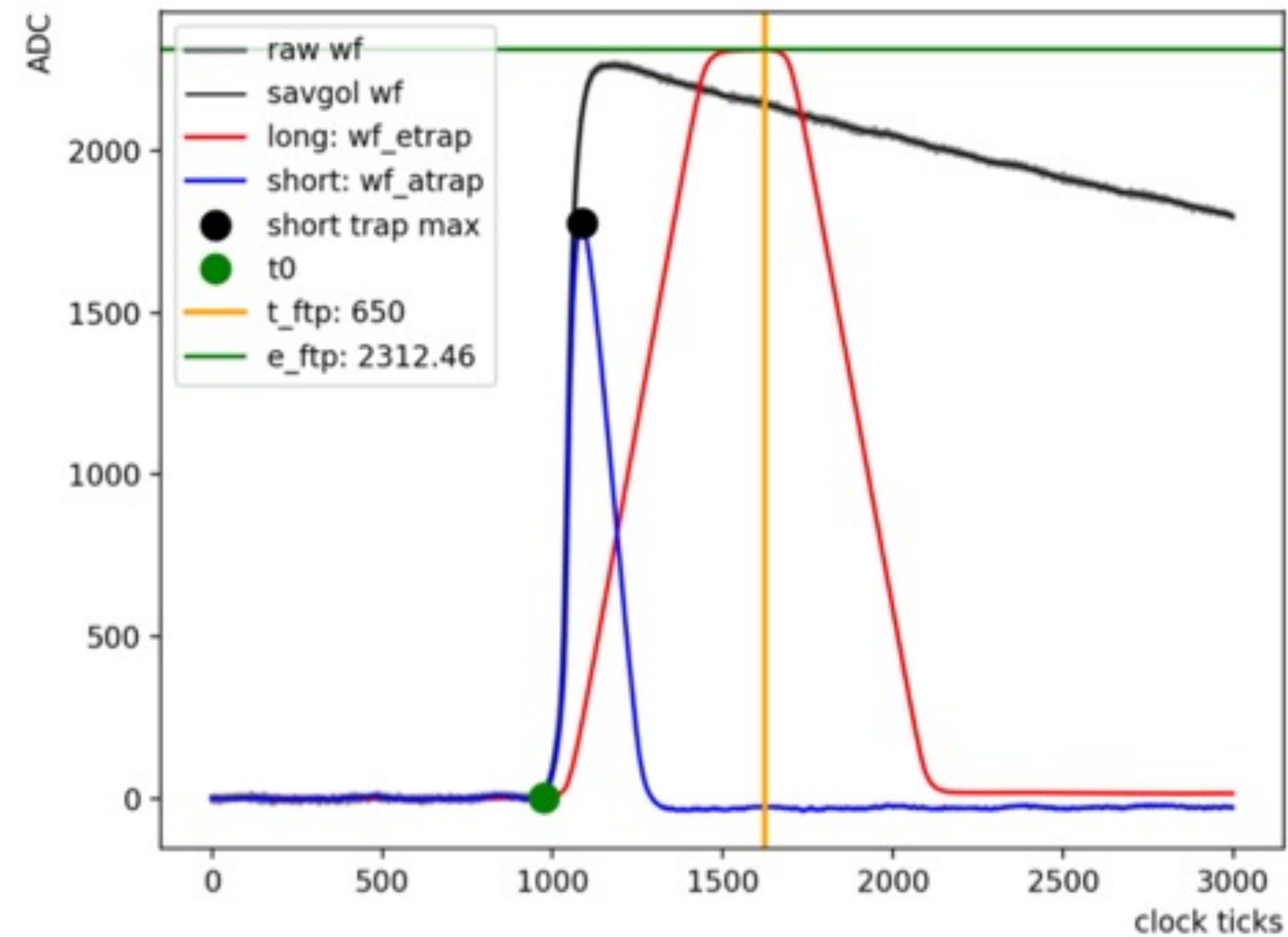
energy w/ fixed-time-pickoff

using asymmetric trapezoid (no extra code, just another instance of the trap processor)

find the t_0 of the waveform. This corrects for charge trapping

take the max of a pole-zero corrected energy trapezoid.

This is a **really good energy estimator**





```
[sergeys-MacBook-Pro-3:~ sergey$  
[sergeys-MacBook-Pro-3:~ sergey$  
[sergeys-MacBook-Pro-3:~ sergey$  
[sergeys-MacBook-Pro-3:~ sergey$  
[sergeys-MacBook-Pro-3:~ sergey$  
[sergeys-MacBook-Pro-3:~ sergey$ docker pull legendexp/legend-software  
Using default tag: latest  
latest: Pulling from legendexp/legend-software  
2d473b07cdd5: Already exists  
3a8a5ba51c2c: Already exists  
0ed164d7e244: Already exists  
5edf53068de9: Already exists  
9bc49f67e6c9: Already exists  
59c1ad3c161b: Already exists  
21bf9c34217b: Already exists  
c6a6db5dff76: Pulling fs layer
```

```
sergeys-MacBook-Pro-3:~ sergey$  
sergeys-MacBook-Pro-3:~ sergey$ docker images  
REPOSITORY          TAG          IMAGE ID      CREATED      SIZE  
majorana/mjds2      latest      33e8f8673bbf  4 weeks ago  9.18GB  
legendexp/legend-software latest      b34785b38f13  5 weeks ago  17.6GB  
sergeys-MacBook-Pro-3:~ sergey$
```

in .bash_profile

```
export LPGTA_DATA="/home/user/LPGTA_Test"
export LEGEND_META="/home/user/legend-metadata"

buildmajorana() {
    xhost + 127.0.0.1
    docker run -it -e DISPLAY=host.docker.internal:0 -v /Users:/home:consistent -w="/home" majorana/mjds2:late
st
}

buildlegend() {
    xhost + 127.0.0.1
    docker run -it -e DISPLAY=host.docker.internal:0 -v "$HOME":"/home/user" -v "$HOME/legend-base":"/root":
delegated -p 8888:8888 -p 14500:14500 legendexp/legend-software
}

buildlegend2() {
    xhost + 127.0.0.1
    docker run -it -e DISPLAY=host.docker.internal:0 -v "$HOME":"/home/user" -v "$HOME/legend-base":"/root":
delegated -p 8888:8888 -p 14500:14500 legendexp/legend-base:latest
}

pyopenh5() {
    echo "opening hdf5 file $1 as f..."
    python3 -i -c "import h5py; f = h5py.File('$1', 'r')"
}
}
```

```
sergey — com.docker.cli ◀ docker run -it -e DISPLAY=host.docker.internal:0 -v /Users/sergey:/home/user -v ~/leg...
[sergeys-MacBook-Pro-3:~ sergey$
[sergeys-MacBook-Pro-3:~ sergey$ buildlegend
127.0.0.1 being added to access control list
[bash-4.2# ls /
anaconda-post.log bin buildworker dev etc home lib lib64 media mnt opt proc root run sbin srv
[ sys tmp usr var
[bash-4.2# ls /opt
anaconda3 cmake g4simple gears julia julia-1.3 julia-1.6 legend-python rh
[clhep dcraw geant4 hdf5 julia-1.0 julia-1.5 legend-julia-tutorial nodejs root
[bash-4.2#
[bash-4.2# cd /home/user
[bash-4.2# source .bash_profile
[bash-4.2# cd pygama/experiments/lpgta
[bash-4.2# ls -l
total 1132
-rw-r--r-- 1 root root 1106 Mar 22 21:25 LPGTA.json
-rw-r--r-- 1 root root 4148 Mar 13 05:49 LPGTA_dsp.json
-rw-r--r-- 1 root root 1064184 Mar 13 22:41 LPGTA_fileDB.h5
-rw-r--r-- 1 root root 2175 Mar 13 05:49 LPGTA_runDB.json
-rwxr-xr-x 1 root root 710 Mar 13 05:49 config_ecal.json
drwxr-xr-x 7 root root 224 Mar 13 05:49 cori_slurm
-rw-r--r-- 1 root root 211 Mar 13 05:49 ecalDB.json
-rwxr-xr-x 1 root root 34880 Mar 13 05:49 energy_cal.py
-rwxr-xr-x 1 root root 4957 Mar 13 05:49 file_checks.py
-rw-r--r-- 1 root root 1118 Mar 13 05:49 gamma_lines.txt
-rwxr-xr-x 1 root root 7205 Mar 13 05:49 processing.py
-rwxr-xr-x 1 root root 5517 Mar 13 05:49 setup.py
-rwxr-xr-x 1 root root 3693 Mar 13 05:52 test_datagroup.py
[bash-4.2# ./processing.py --dg --d2r --o --v
Processing settings:
$LPGTA_DATA = /home/user/LPGTA_Test
$LEGEND_META = /home/user/legend-metadata
overwrite? True
```



```

[bash-4.2#
[bash-4.2# ./processing.py --dg --r2d --o --v
Processing settings:
$LPGTA_DATA = /home/user/LPGTA_Test
$LEGEND_META = /home/user/legend-metadata
  overwrite? True
  limit wfs? inf
files to process:
                unique_key  run  ...                               hit_file  hit_path
0  lpgta-run30-20200723T141228  30  ...  LPGTA_r0030_20200723T141228Z_calib_{sysn}_hit.lh5  /hit/{sysn}

[1 rows x 16 columns]
Opened file /home/user/LPGTA_Test_2//raw/geds/LPGTA_r0030_20200723T141228Z_calib_geds_raw.lh5
Processing parameters: ['bl', 'bl_sig', 'wf_blsb', 'wf_pz', 'wf_trap', 'trapE', 'wf_atrap', 'tp_max', 'tp_0',
'trapEftp', 'ct_corr', 'curr10', 'A_10', 'AoE', 'tp_10', 'tp_50', 'tp_80', 'tp_90', 'dcr_raw']
Required input parameters: ['waveform']
Copied output parameters: []
Processed output parameters: ['trapE', 'trapEftp', 'ct_corr', 'bl', 'bl_sig', 'A_10', 'AoE', 'tp_max', 'tp_0',
, 'tp_10', 'tp_50', 'tp_80', 'tp_90', 'dcr_raw']
Database lookup: using default value of 400*us for db.pz_const
Processing table: raw ...
Progress : [#####] 100.0% Done...
Done. Writing to file /home/user/LPGTA_Test_2//dsp/geds/LPGTA_r0030_20200723T141228Z_calib_geds_dsp.lh5
Done processing. Time elapsed: 18.94 min.
[bash-4.2#

```

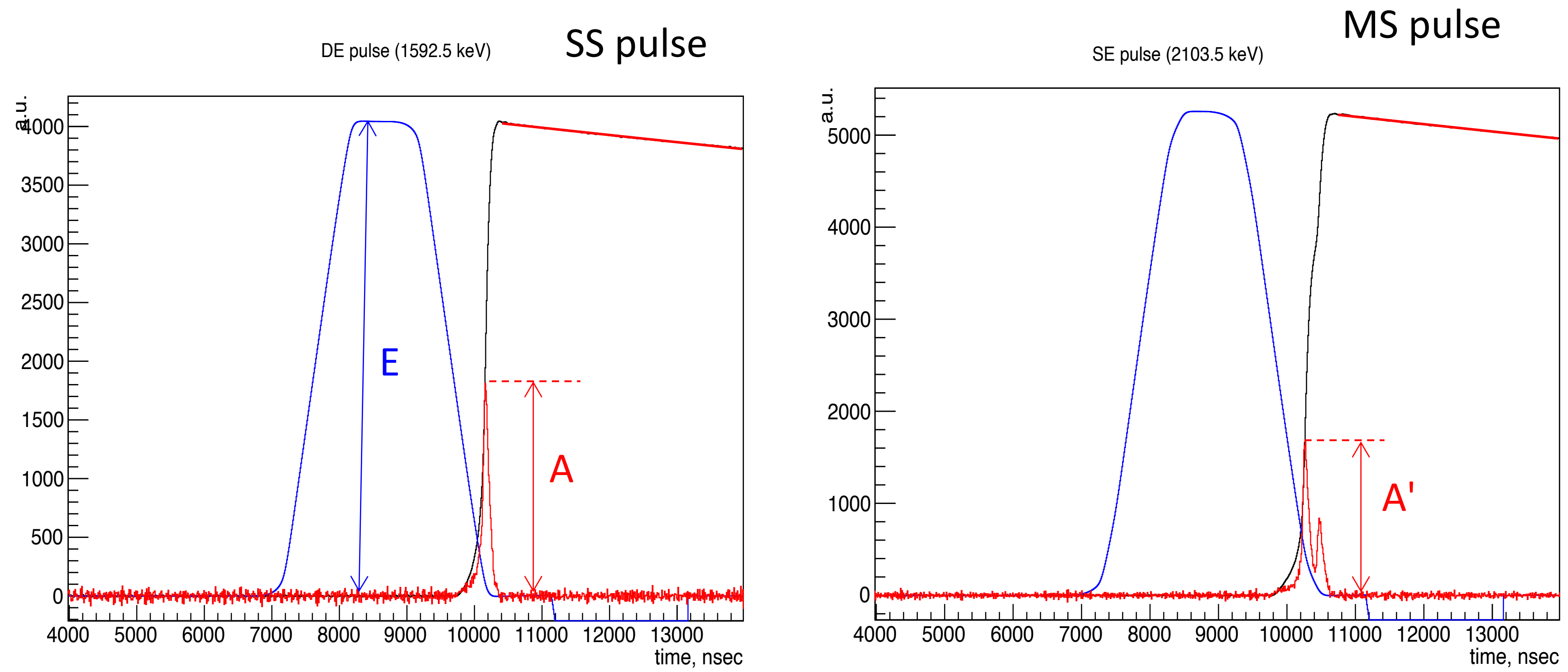
```
sergey — com.docker.cli ◀ docker run -it -e DISPLAY=host.docker.internal:0 -v /Users/sergey:/home/user -v ~/legend-base:/root:del...
[bash-4.2# h5dump -n LPGTA_r0030_20200723T141228Z_calib_geds_dsp.lh5
HDF5 "LPGTA_r0030_20200723T141228Z_calib_geds_dsp.lh5" {
FILE_CONTENTS {
  group      /
  group      /dsp_info
  dataset    /dsp_info/dsp_config
  dataset    /dsp_info/h5py_version
  dataset    /dsp_info/hdf5_version
  dataset    /dsp_info/numpy_version
  dataset    /dsp_info/pygama_branch
  dataset    /dsp_info/pygama_date
  dataset    /dsp_info/pygama_revision
  dataset    /dsp_info/pygama_version
  dataset    /dsp_info/python_version
  dataset    /dsp_info/timestamp
  group      /g024
  group      /g024/dsp
  dataset    /g024/dsp/A_10
  dataset    /g024/dsp/AoE
  dataset    /g024/dsp/bl
  dataset    /g024/dsp/bl_sig
  dataset    /g024/dsp/ct_corr
  dataset    /g024/dsp/dcr_raw
  dataset    /g024/dsp/tp_0
  dataset    /g024/dsp/tp_10
  dataset    /g024/dsp/tp_50
  dataset    /g024/dsp/tp_80
  dataset    /g024/dsp/tp_90
  dataset    /g024/dsp/tp_max
  dataset    /g024/dsp/trapE
  dataset    /g024/dsp/trapEftp
  group      /g025
  group      /g025/dsp
  dataset    /g025/dsp/A_10
  dataset    /g025/dsp/AoE
  dataset    /g025/dsp/bl
  dataset    /g025/dsp/bl_sig
  dataset    /g025/dsp/ct_corr
  dataset    /g025/dsp/dcr_raw
```

```

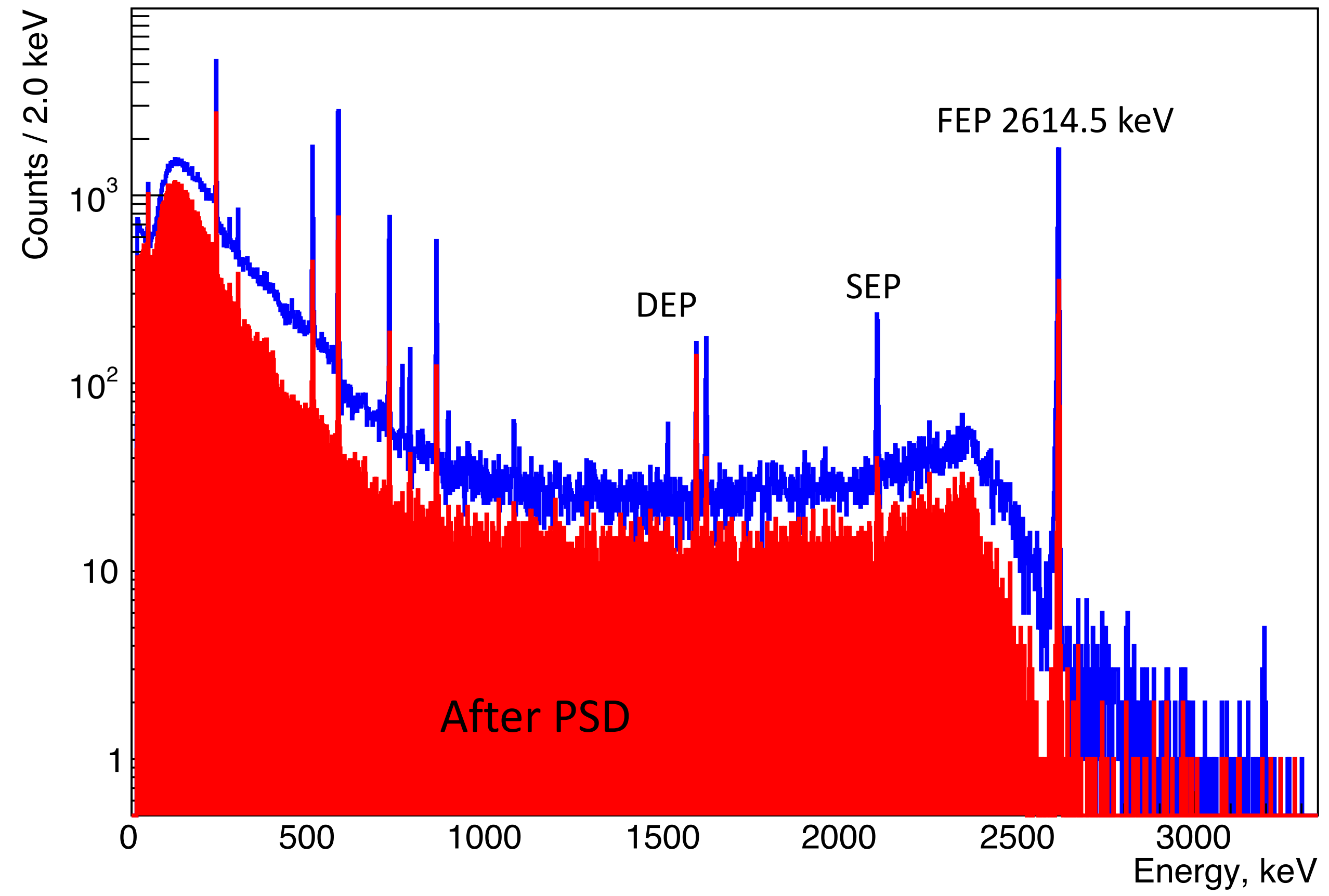
Test_of_Waveform_by_PyROOT.py
Test_of_Waveform_by_PyROOT.py
Test_of_Waveform_by_PyROOT.py > No Selection
1  from ROOT import *
2  from math import *
3  import h5py
4  import pandas as pd
5  import numpy as np
6  import time
7
8  f= h5py.File('./raw/geds/LPGTA_r0030_20200723T141228Z_calib_geds_raw.lh5','r')
9
10 myfile = TFile('Test_of_Waveform_by_PyROOT.root','RECREATE')
11
12 hmax = TH1F( 'hmax', 'hmax',40000,0.0,40000.0 )
13 hmax_dif = TH1F( 'hmax_dif', 'hmax_dif',40000,0.0,40000.0 )
14 hmax_dif_ch = TH1F( 'hmax_dif_ch', 'hmax_dif_ch',4000,0.0,4000.0 )
15 h_Energy = TH1F( 'h_Energy', 'h_Energy',40000,0.0,40000.0 )
16 h_E_keV = TH1F('h_E_keV','h_E_keV',3350, -0.0300538, 3346.090)
17 hxh_E_keV = TH2F('hxh_E_keV','A o E',3350, -0.0300538, 3346.090,1000,0.0,2.0)
18 h_E_keV_090 = TH1F('h_E_keV_090','h_E_keV_090',3350, -0.0300538, 3346.090)
19 h_E_keV_095 = TH1F('h_E_keV_095','h_E_keV_095',3350, -0.0300538, 3346.090)
20 h_E_keV_096 = TH1F('h_E_keV_096','h_E_keV_096',3350, -0.0300538, 3346.090)
21 h_E_keV_097 = TH1F('h_E_keV_097','h_E_keV_097',3350, -0.0300538, 3346.090)
22 h_E_keV_098 = TH1F('h_E_keV_098','h_E_keV_098',3350, -0.0300538, 3346.090)
23 h_E_keV_099 = TH1F('h_E_keV_099','h_E_keV_099',3350, -0.0300538, 3346.090)
24
25 ar1=np.array(f['g033/raw/energy'])
26 ar2=np.array(f['g033/raw/waveform/values'][0])
27 nmb=ar2.shape[0]
28
29 for index in range(ar1.shape[0]):
30
31     h_Energy.Fill(ar1[index])
32     h_E_keV.Fill(ar1[index]/11.954)
33
34     h = TH1F( 'h', 'h',nmb,0.0, 3401*16)
35     my_series = pd.Series(f['g033/raw/waveform/values'][index,:nmb])
36     for ind,value in enumerate(my_series):
37         h.SetBinContent(ind,value)
38

```

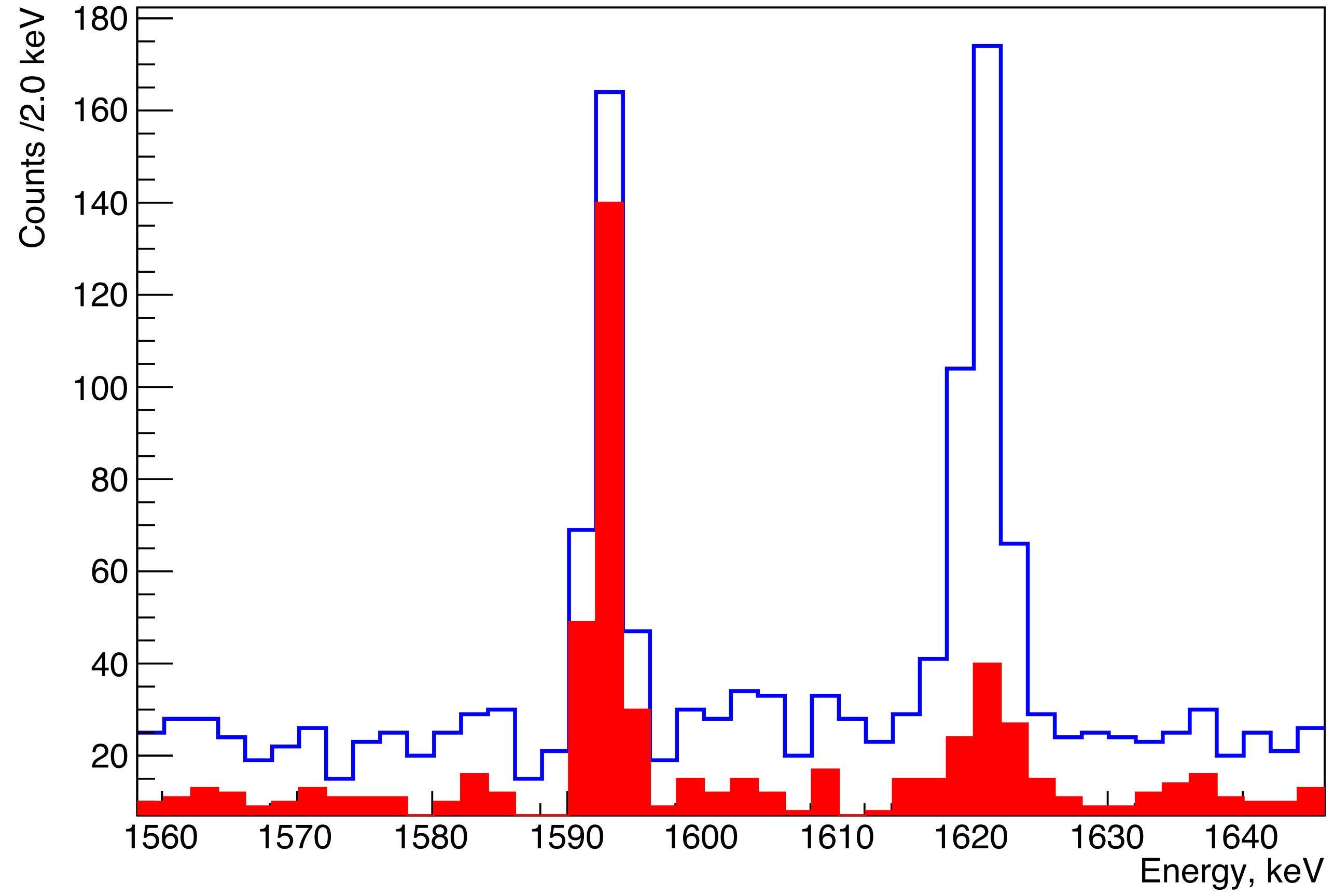
Pulse Shape Discrimination (PSD)



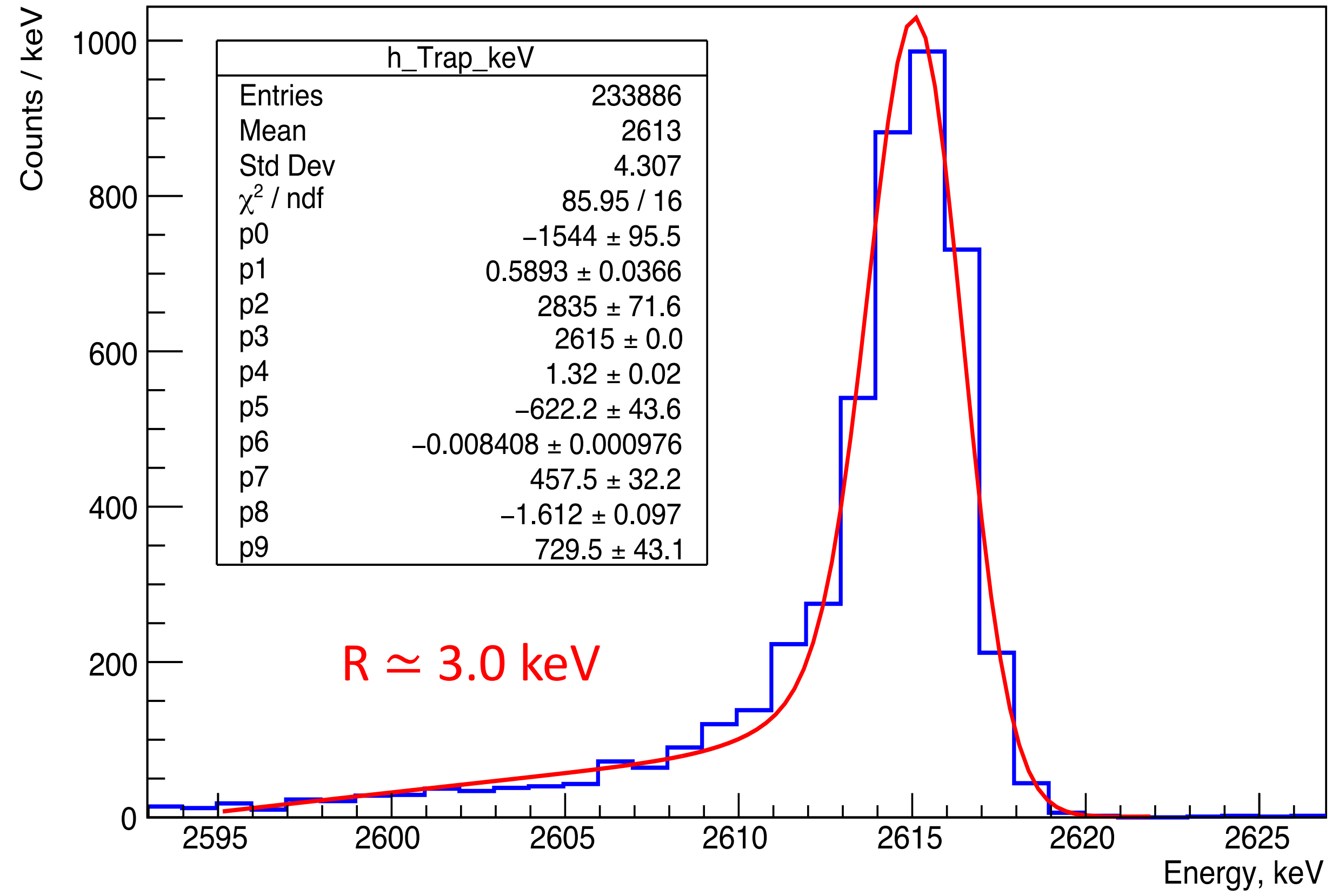
Th -228 h_E_keV



h_E_keV



h_Trapping_keV



Спасибо за внимание !