ATF Proposal Status Report

AE124: Simulation-aided Instrument Optimization using Artificial Intelligence and Machine Learning Methods

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Team Members: Thomas Morris, Abigail Giles, Brianna Romasky, Irina Petrushina

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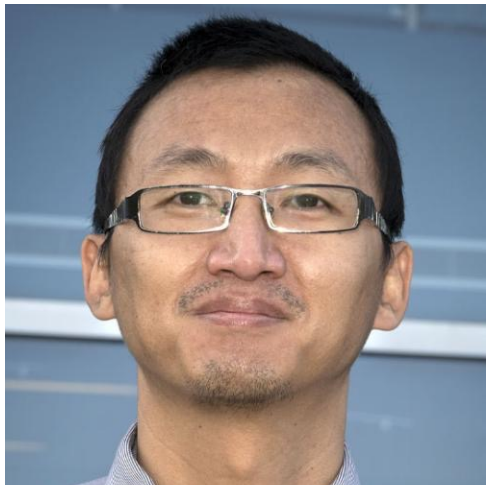
Team

Maksim Rakitin, NSLS-II

Mikhail Fedurin, ATF

Abigail Giles, NSLS-II

Thomas Morris, NSLS-II



Yonghua Du, NSLS-II

Brianna Romasky, Rutgers/ATF

Irina Petrushina, SBU/ATF

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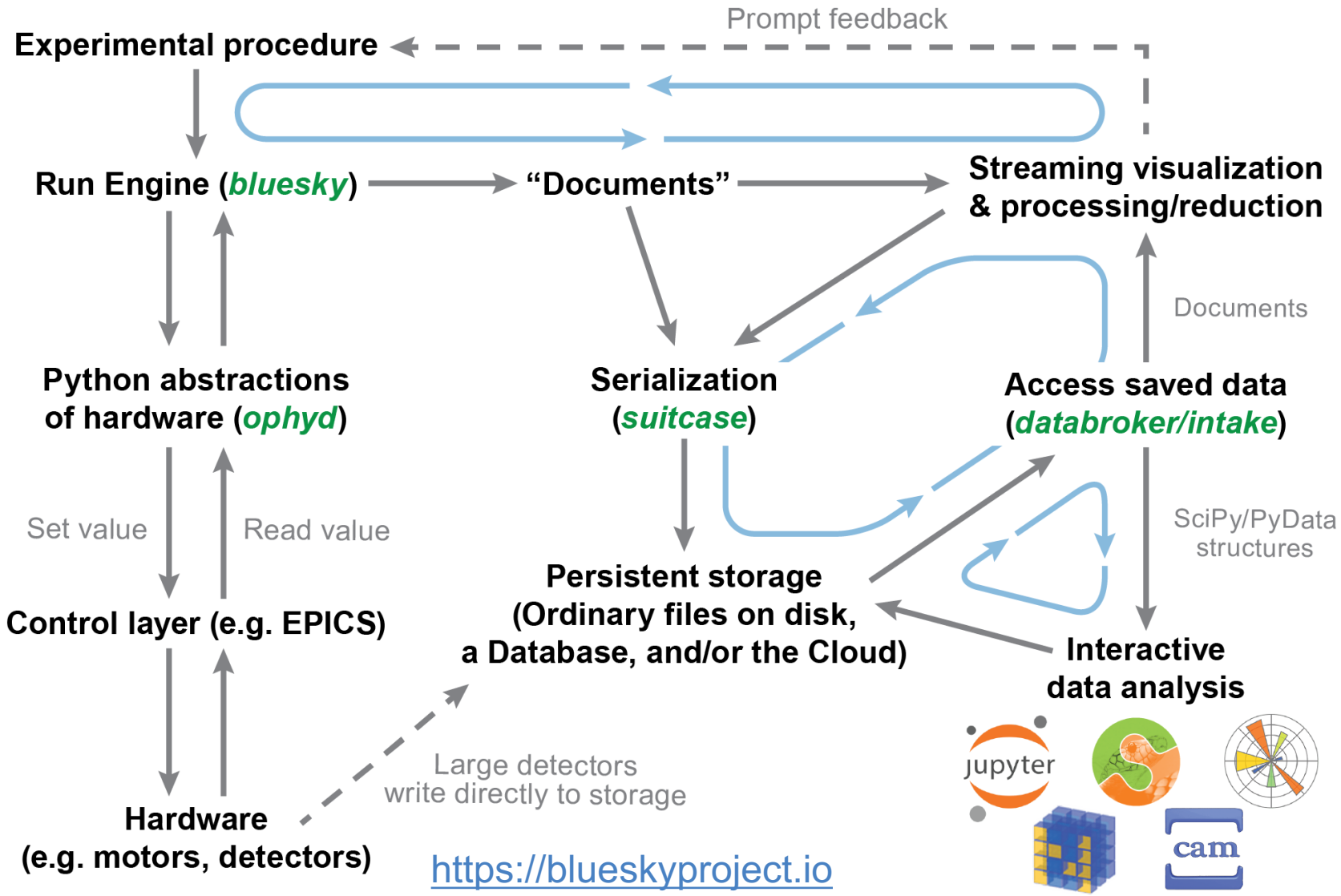
bluesky Data Collection Ecosystem



https://blueskyproject.io

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Recent achievements

- Integration of the ATF hardware with the Bluesky data acquisition framework/Ophyd abstractions:
  - Basler cameras integration via Pylon API (ATF production & emulation):
    - https://github.com/BNL-ATF/ophyd-basler
  - ATFDB Ophyd support (ATF production & emulation):
    - https://github.com/BNL-ATF/atfdb
  - IPython startup files:
    - https://github.com/BNL-ATF/profile_atf
  - MAD-X simulations via Sirepo-Bluesky:
    - https://nsls-ii.github.io/sirepo-bluesky/notebooks/madx.html
- Beamline Optimization

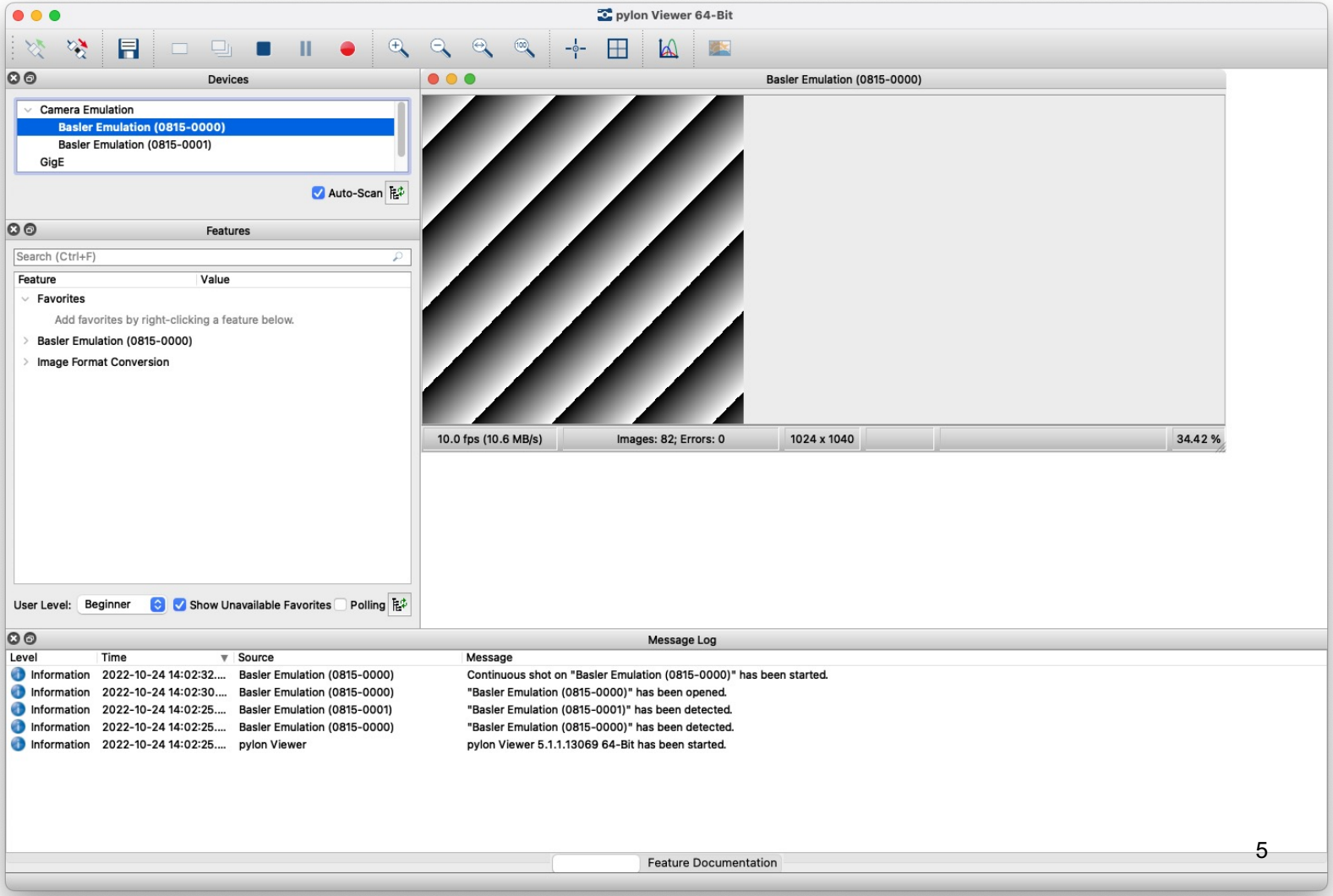
Basler cameras integration via Pylon API (emulation)

https://www.baslerweb.com/en/products/basler-pylon-camera-software-suite/

The Pylon software is available for all major platforms:

- Linux
- macOS
- Windows

Registration required, but it's free; we use v5.x.



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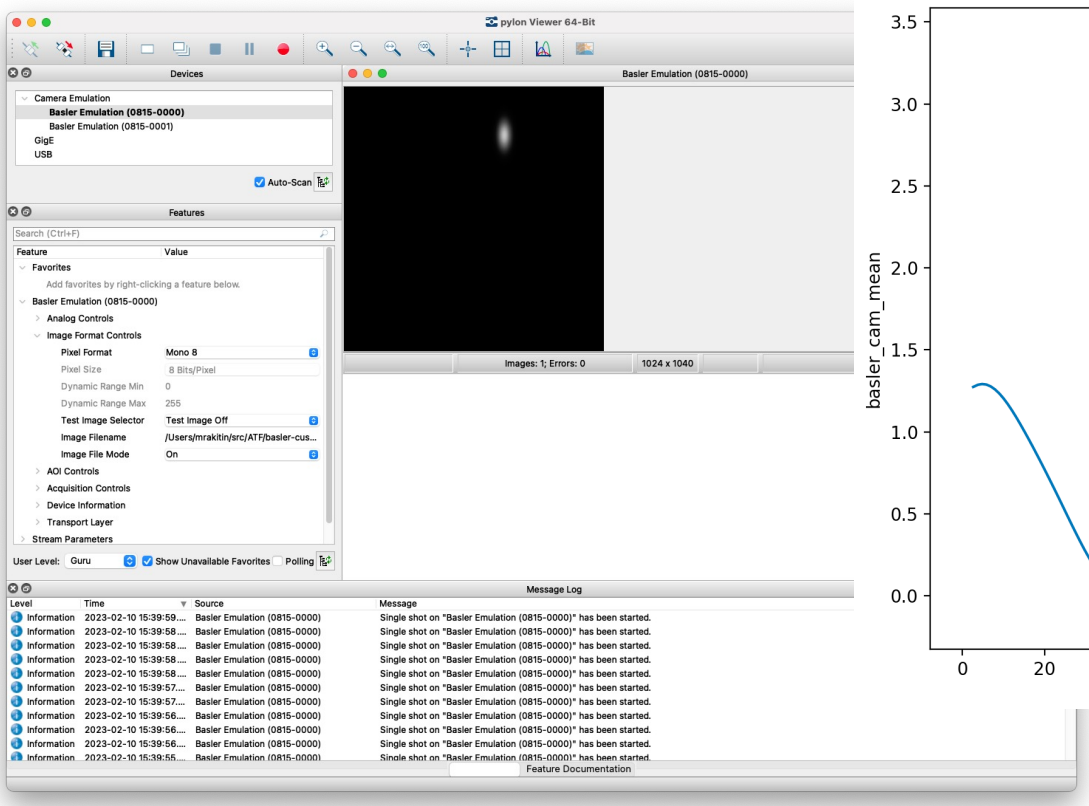
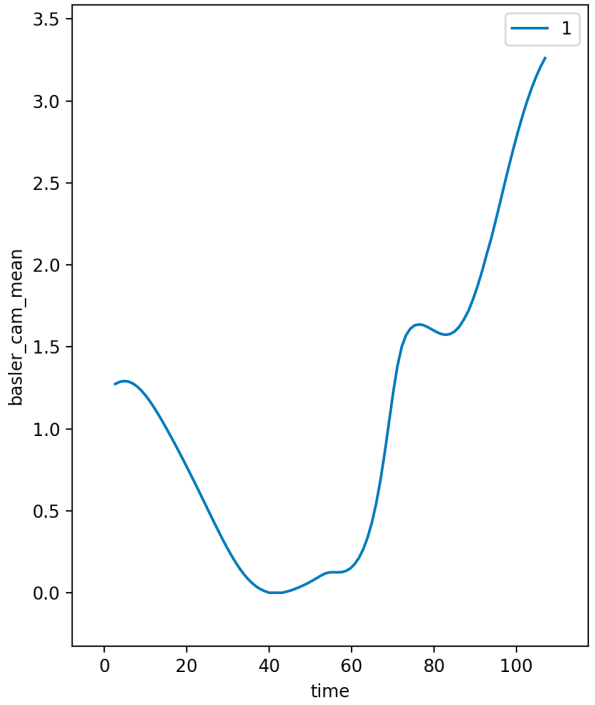
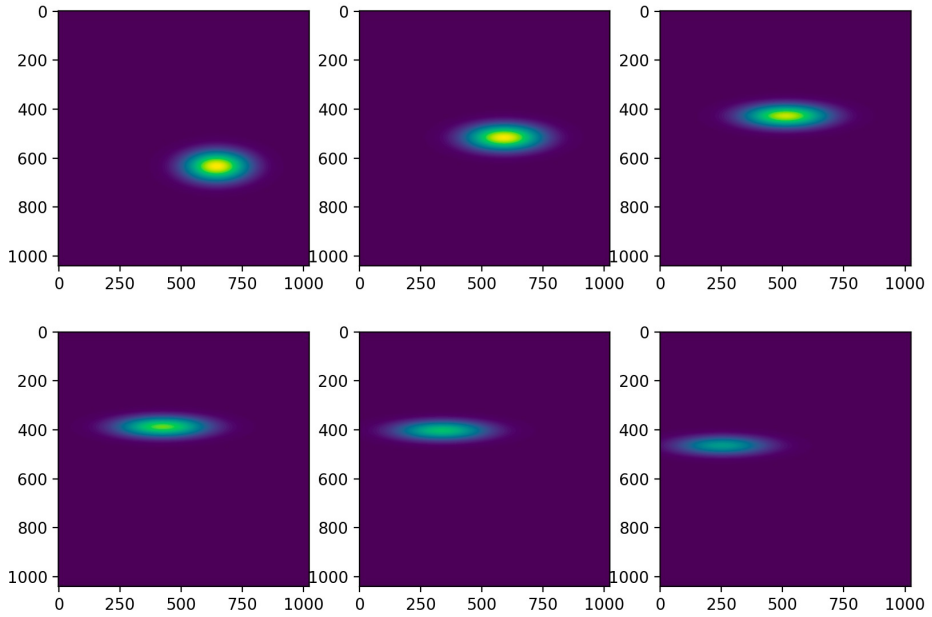
Basler cameras integration via Pylon API (realistic emulation)

https://github.com/BNL-ATF/ophyd-basler *





Live plot produced during a Bluesky "count" plan displaying the averaged signal from the emulated Basler camera with predefined images over the course of 100 individual counts.



Selected images (`data[::4][:6]`) extracted using a Databroker API (the second row's sequence is from left to right).

* Development of the ophyd-basler interface was led by T. Morris.

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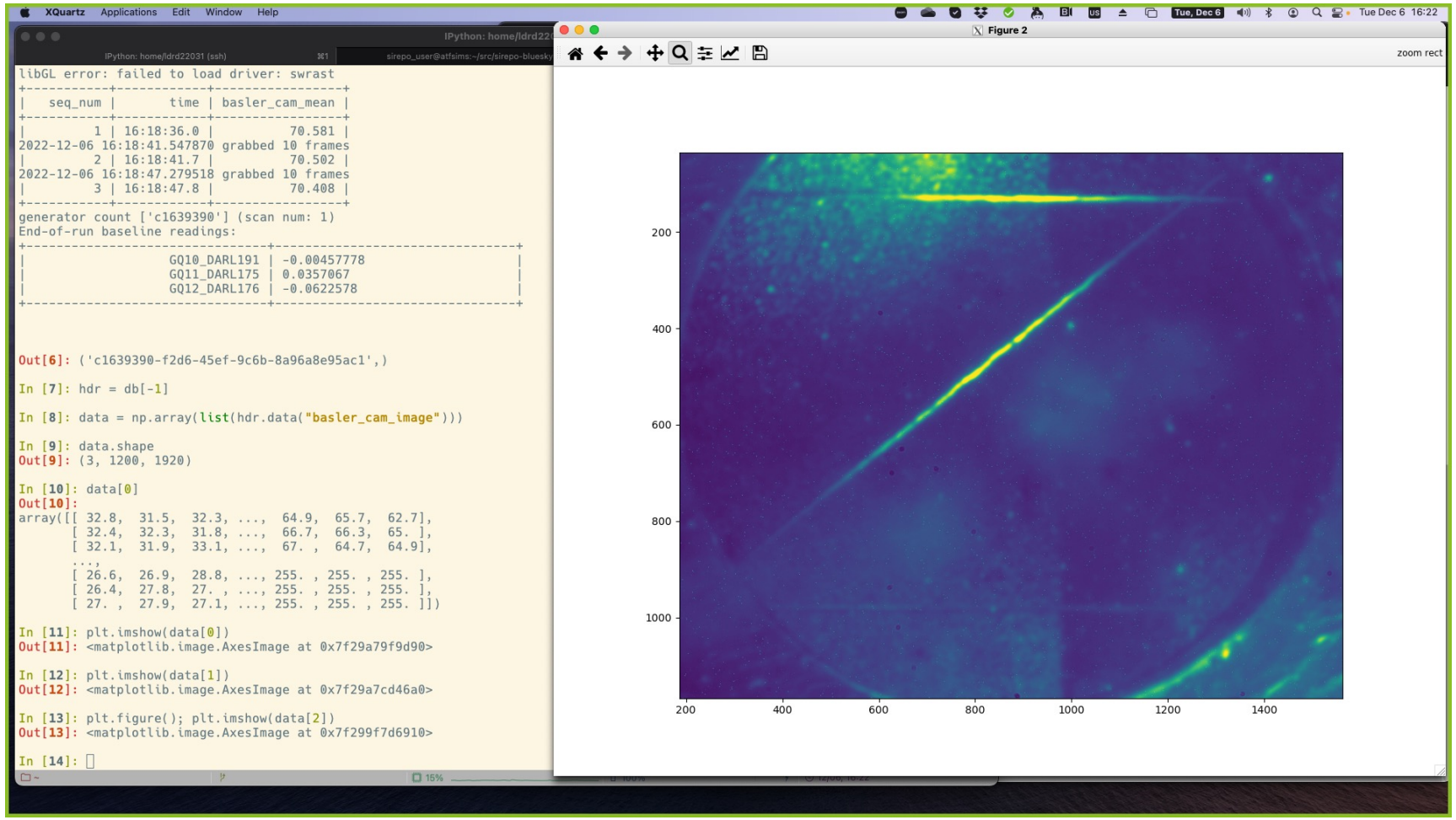
Basler cameras integration via Pylon API (ATF production)

https://github.com/BNL-ATF/ophyd-basler



ATFDB Ophyd support (ATF production & emulation)

Vista Control Systems, Inc.

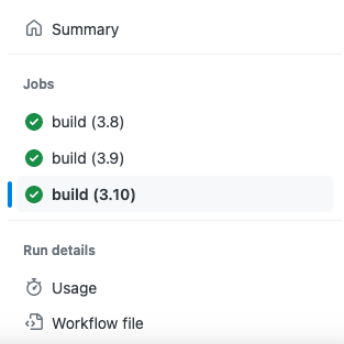
https://www.vista-control.com/about_vista.html

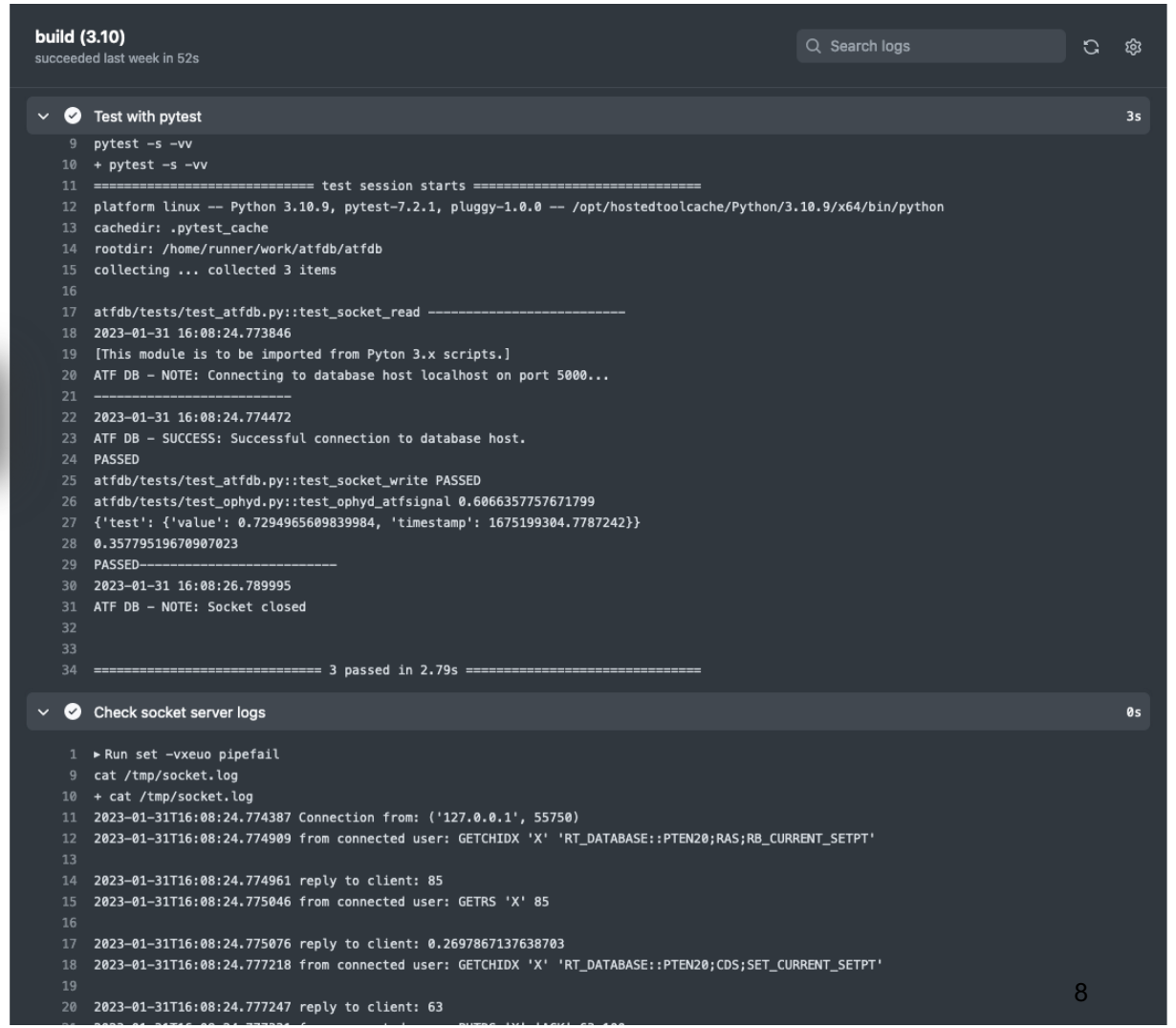
```
class FrameGrabber(Device):
    db = "FRAME3_DB"
    psname = "FGR3"
    xpos = Cpt(
        ATFSignalRO,
        db=db,
        psname=psname,
        read_suffix="RCX;CENTROID_X",
        write_suffix="RCX;CENTROID_X",
        kind="hinted",
    )
    ypos = Cpt(
        ATFSignalRO,
        db=db,
        psname=psname,
        read_suffix="RCY;CENTROID_Y",
        write_suffix="RCY;CENTROID_Y",
        kind="hinted",
    )
    xsig = Cpt(
        ATFSignalRO,
        db=db,
        psname=psname,
        read_suffix="RSX;SIGMA_X",
        write_suffix="RSX;SIGMA_X",
        kind="hinted",
    )
```

```
fg3 = FrameGrabber(name="fg3")
```

https://github.com/BNL-ATF/atfdb

Support of ATFDB components





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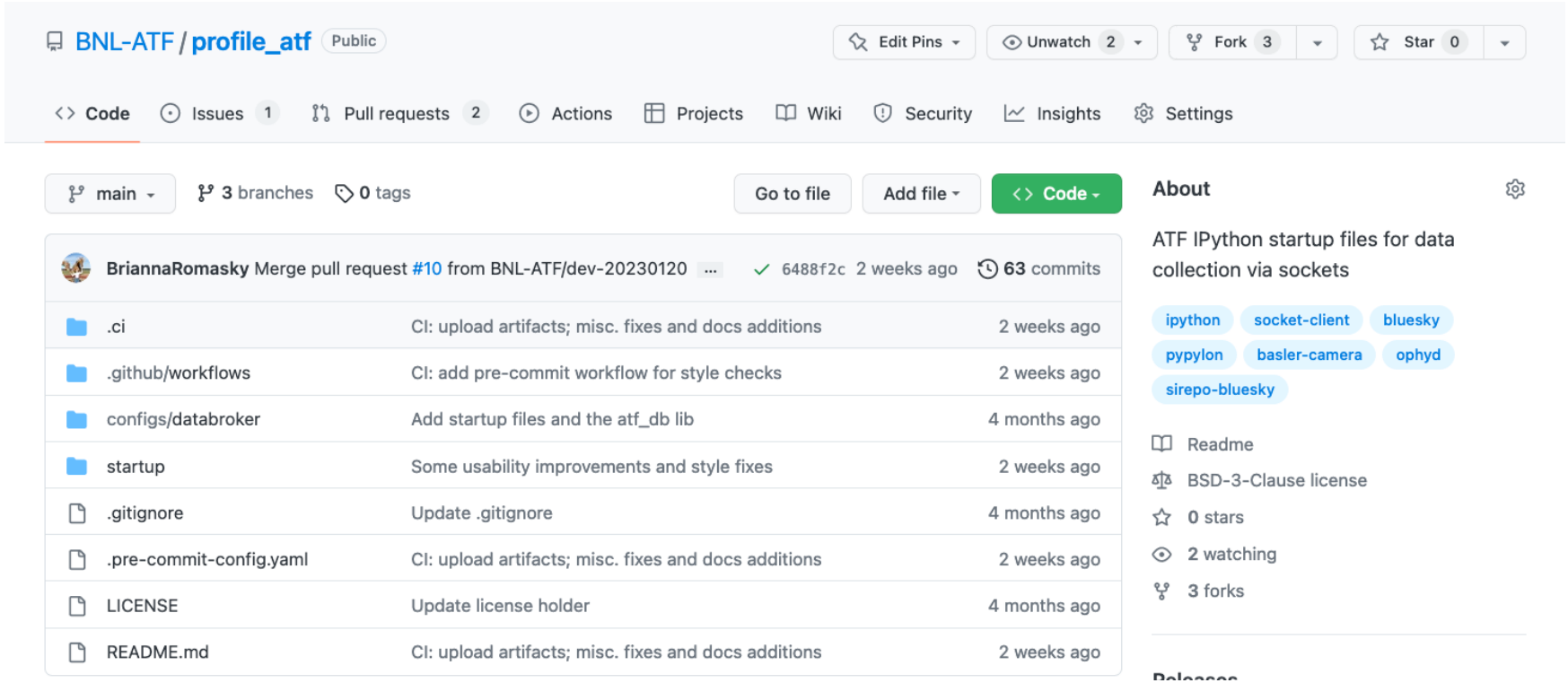
IPython startup files

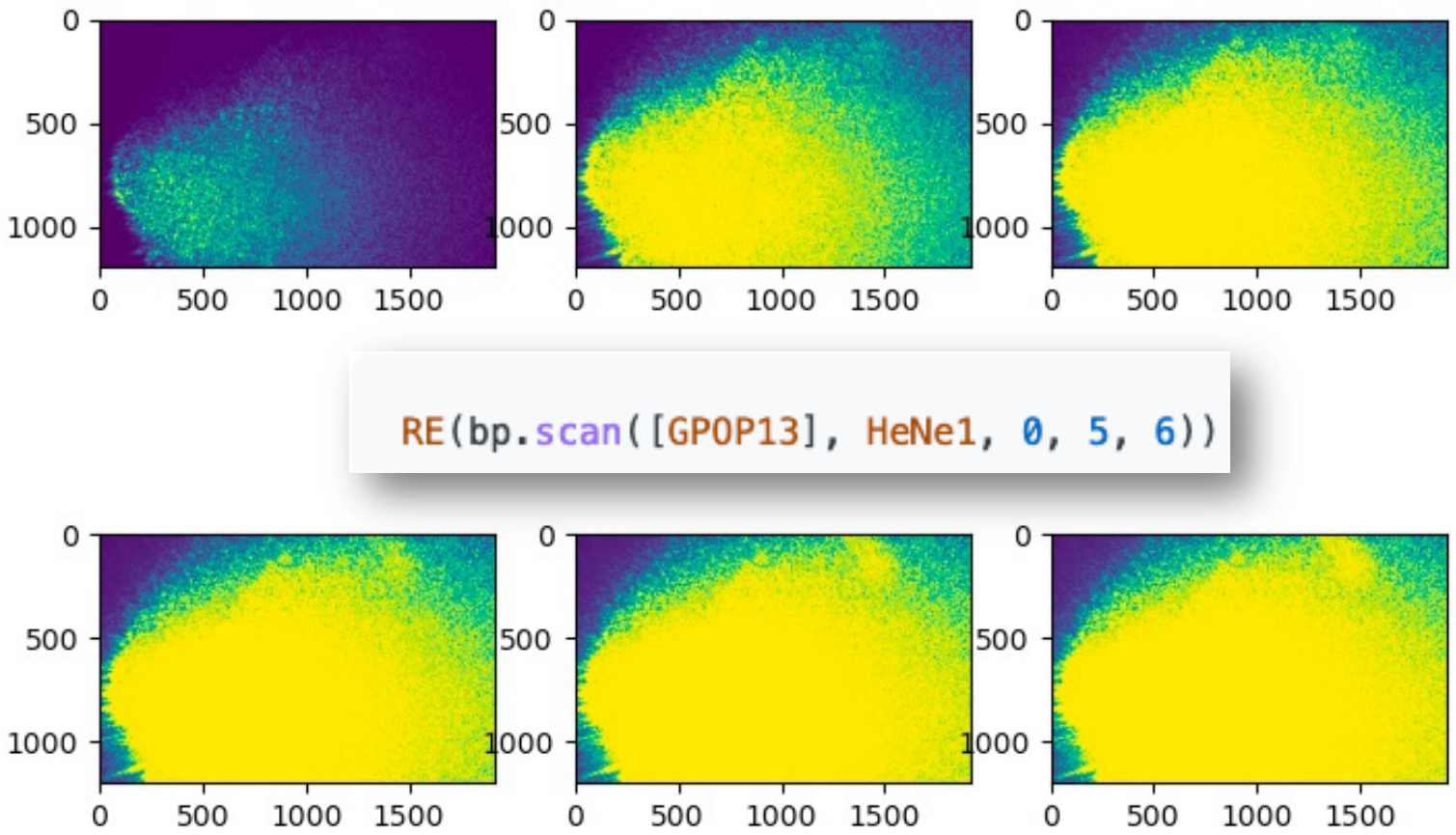
https://github.com/BNL-ATF/profile_atf




```
profile_atf
├── LICENSE
├── README.md
├── configs
│   └── databroker
│       └── local.yml
└── startup
    ├── 00-base.py
    ├── 10-devices.py
    ├── 20-madx.py
    ├── 30-basler.py
    ├── 80-utils.py
    ├── 90-plans.py
    └── 99-cleanup.py

3 directories, 10 files
```

Scans with Bluesky (controlled over Pylon API & ATFDB)

https://github.com/BNL-ATF/profile_atf

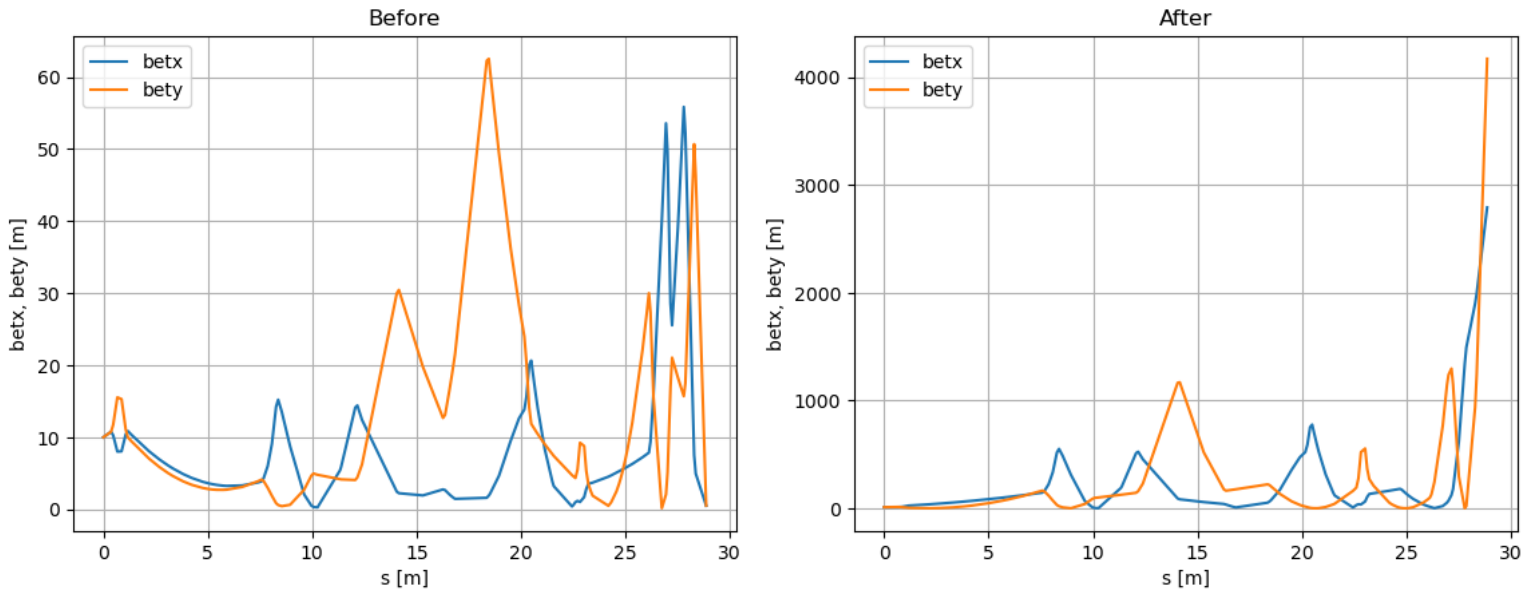


Results of the Bluesky scan performed at ATF where the *HeNe* laser intensity was captured by a Basler camera as the laser intensity increased. Exposure time: 0.667 s

MAD-X simulations via Sirepo-Bluesky

https://nsls-ii.github.io/sirepo-bluesky/notebooks/madx.html

```
%run -i ../../../examples/prepare_flyer_env.py

import matplotlib.pyplot as plt

from sirepo_bluesky.sirepo_bluesky import SirepoBluesky
from sirepo_bluesky.madx_flyer import MADXFlyer
from sirepo_bluesky.sirepo_ophyd import create_classes

connection = SirepoBluesky("http://localhost:8000")

data, schema = connection.auth("madx", "00000002")
classes, objects = create_classes(connection.data,
                                  connection=connection,
                                  extra_model_fields=["rpnVariables", "commands"])
globals().update(**objects)

madx_flyer = MADXFlyer(connection=connection,
                       root_dir="/tmp/sirepo-bluesky-data",
                       report="elementAnimation250-20")

(uid1,) = RE(bp.fly([madx_flyer]))
hdr1 = db[uid1]
tbl1 = hdr1.table(stream_name="madx_flyer", fill=True)
print(tbl1)
```



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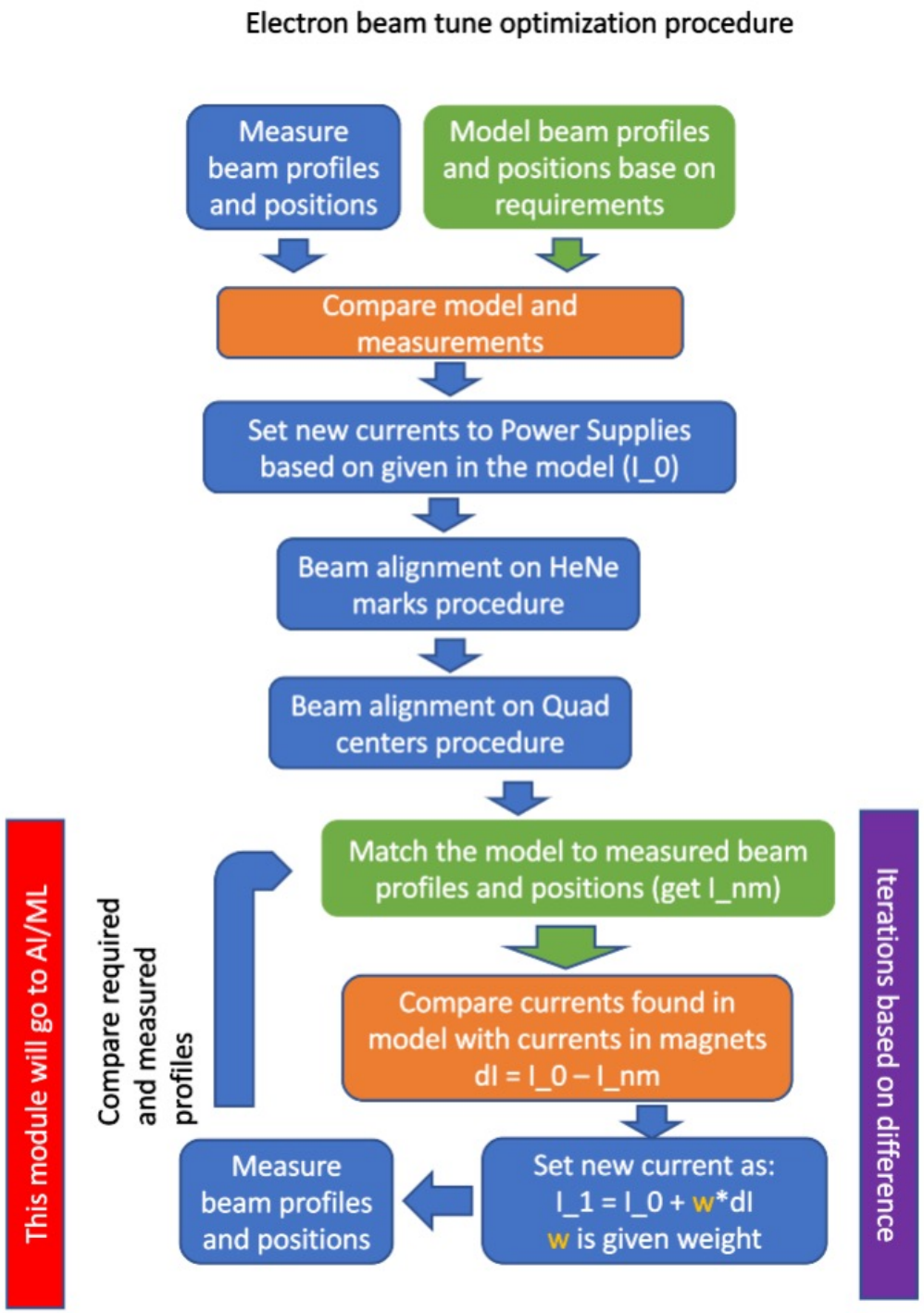
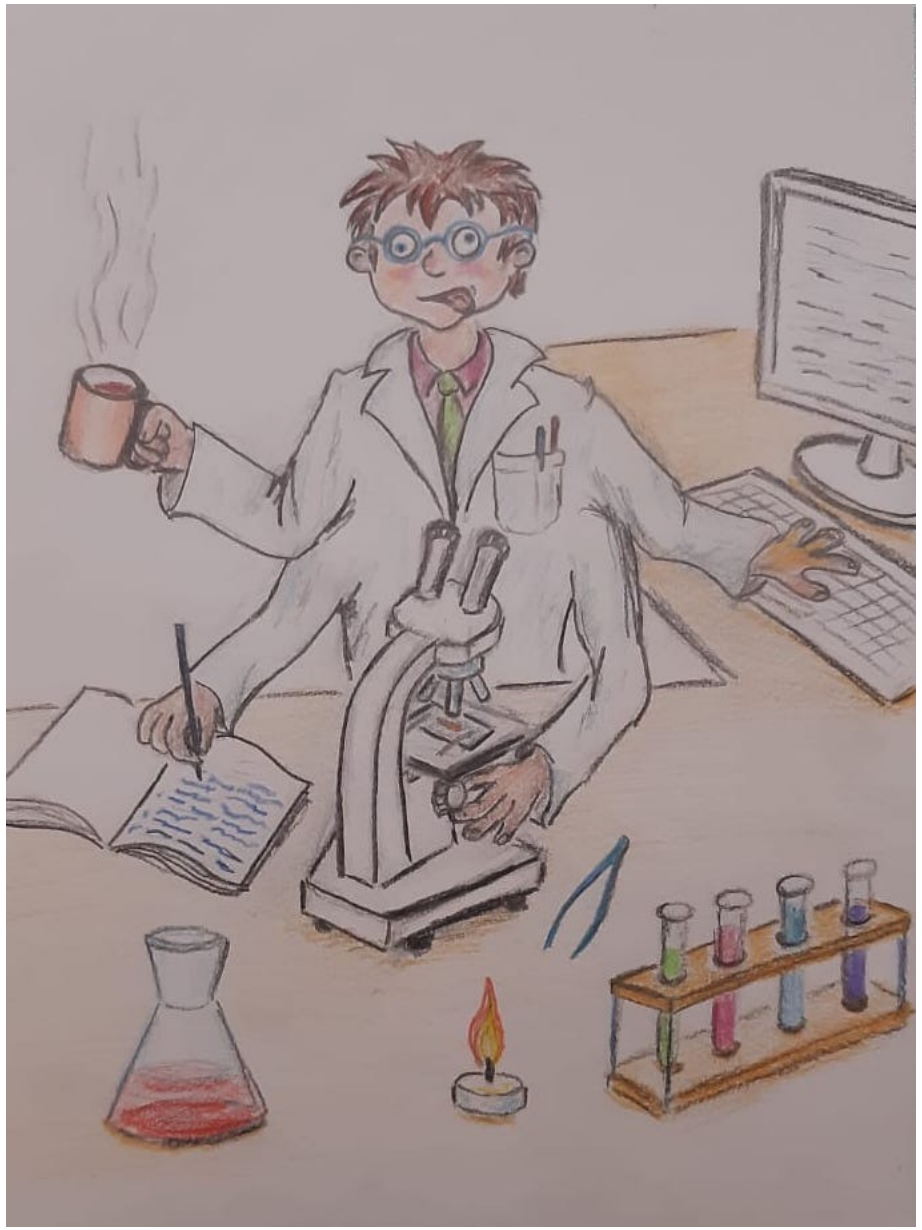
Mix:

* Vista
* Basler
* Sirepo/MAD-X



Multi-dimensional optimization



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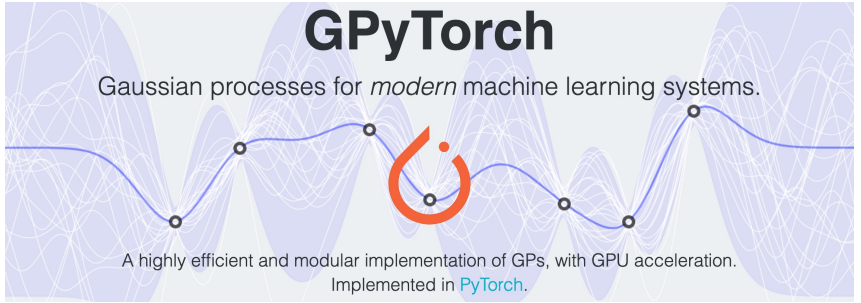
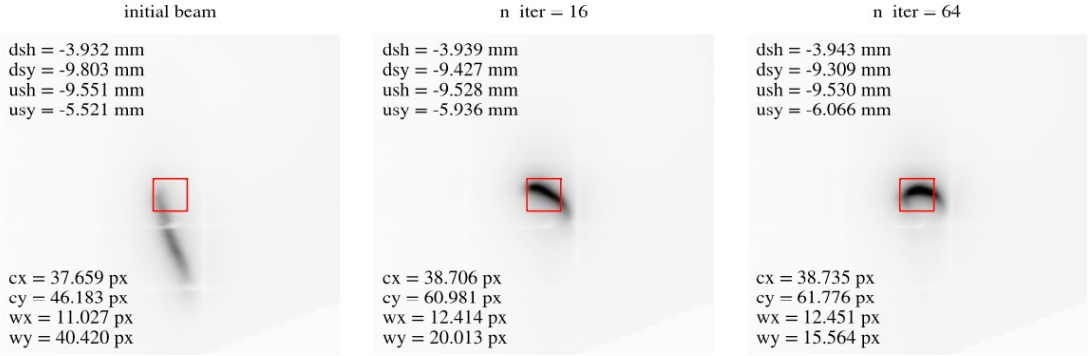
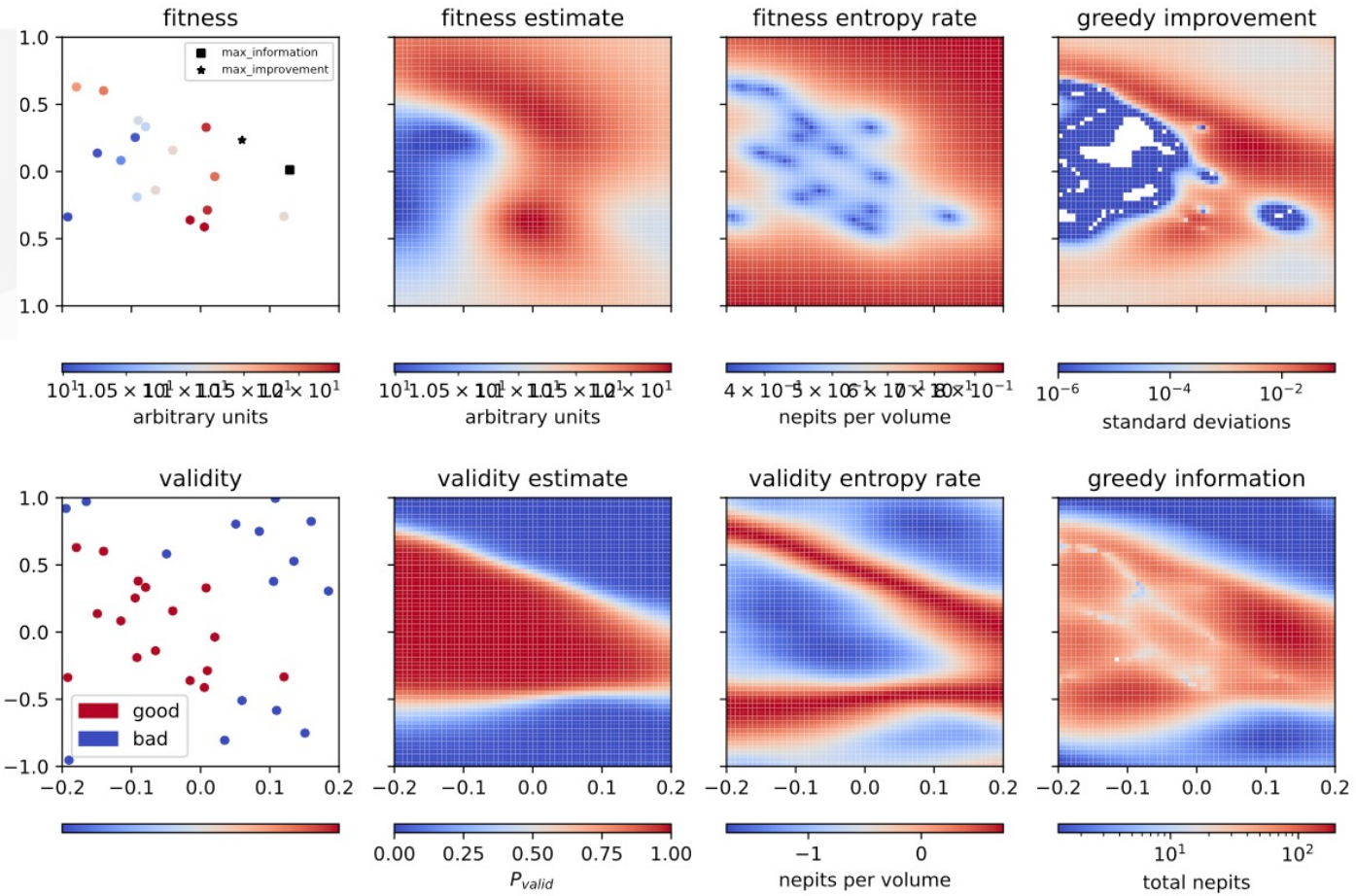
Beamline Optimization





Auto-alignment of the toroidal mirror at NSLS-II TES. The evolution of the beam shape and position can be seen clearly after 16 and 64 iterations.

T. W. Morris, M. Rakitin, A. Giles, J. Lynch, A. L. Walter, B. Nash, D. Abell, P. Moeller, I. Pogorelov, and N. Goldring "On-the-fly optimization of synchrotron beamlines using machine learning", Proc. SPIE 12222, Optical System Alignment, Tolerancing, and Verification XIV, 122220M (3 October 2022); https://doi.org/10.1117/12.2644996



Optimization based on Gaussian Processing (GP)

Sirepo/Shadow3 simulations

e-Beam requirements

- No special requirements, the team can be using the beam in a “parasitic” mode for collecting the data from ongoing experiments.

- With the active learning, we will need to modify steering magnet parameters (DARL*)

Future Plans

- Perform integration and stress testing of the Ophyd abstractions at the ATF beamlines.
- Develop the alignment procedures and integrate them with the MAD-X simulation data.
- Apply the GP optimization routines to the ATF hardware using multi-parameter optimization (8+ dimensions) – a few **2-to-4-hour** periods will be very useful for these studies.