FRIB

Physics High-level Applications and Toolkit for Accelerator System

An overview of FRIB high-level physics applications development

Tong Zhang

Controls Physicist

E-mail: zhangt@frib.msu.edu

Presented at EPICS Collaboration Meeting, 11-15 June 2018, APS, ANL

MICHIGAN STATE UNIVERSITY

U.S. DEPARTMENT OF ENERGY | Office of Science

This material is based upon work supported by the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661, the State of Michigan and Michigan State University. Michigan State University designs and establishes FRIB as a DOE Office of Science National User Facility in support of the mission of the Office of Nuclear Physics.

Acknowledgements

Dylan Maxwell, Martin Konrad, Daron Chabot, Eric Berryman, Steven Beher, Diego Omitto, Guobao Shen, Michael Davidsaver, Steven Lidia

Kei Fukushima, Harry He, Tomofumi Maruta, Takashi Yoshimoto, Jonathan Wong, Alexander Plastun, Qiang Zhao, Yue Hao, Steve Lund, Peter Ostroumov, Masanori Ikegami

Outline

1. Designed Architecture
   - Introduction
   - Device Abstraction
2. Key Features
   - Virtual Accelerator
   - Online Model
3. Conclusions

Outline

Accelerator System

- particle source, beam transport, end stations, ...
- devices: optics, diagnostics, ...
- distributed controls units: EPICS input & output controllers (IOCs)

ACCELERATOR SYSTEM

- particle source, beam transport, end stations, ...
- devices: optics, diagnostics, ...
- distributed controls units: EPICS input & output controllers (IOCs)

ACCELERATOR SYSTEM

- particle source, beam transport, end stations, ...
- devices: optics, diagnostics, ...
- distributed controls units: EPICS input & output controllers (IOCs)

Introductions to High-level Physics Applications

Accelerator System

- particle source, beam transport, end stations, ...
- devices: optics, diagnostics, ...
- distributed controls units: EPICS input & output controllers (IOCs)

High-level Physics Applications

- Final goal: operating accelerator facility
- Purpose: have robust and functional beam tuning algorithms
- Solution: software environment for high-level physics controls

Accelerator System

- particle source, beam transport, end stations, ...
- devices: optics, diagnostics, ...
- distributed controls units: EPICS input & output controllers (IOCs)

High-level Physics Applications

- Final goal: operating accelerator facility
- Purpose: have robust and functional beam tuning algorithms
- Solution: software environment for high-level physics controls

Accelerator System

- particle source, beam transport, end stations, ...
- devices: optics, diagnostics, ...
- distributed controls units: EPICS input & output controllers (IOCs)

High-level Physics Applications

- Final goal: operating accelerator facility
- Purpose: have robust and functional beam tuning algorithms
- Solution: software environment for high-level physics controls

Introductions to High-level Physics Applications

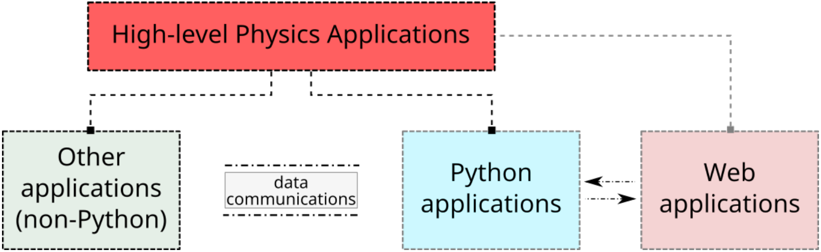
Accelerator System

- particle source, beam transport, end stations, ...
- devices: optics, diagnostics, ...
- distributed controls units: EPICS input & output controllers (IOCs)

High-level Physics Applications

- Final goal: operating accelerator facility
- Purpose: have robust and functional beam tuning algorithms
- Solution: software environment for high-level physics controls

High-level Physics Applications = Physics Algorithms + Controls Software



Fundamental Requirements

- Quick prototyping: dynamic programming language
- Functional: plenty of third-party packages
- Agile development: develop → build → test → deploy

PHANTASY

Physics High-level Applications aNd Toolkit for Accelerator SYstem

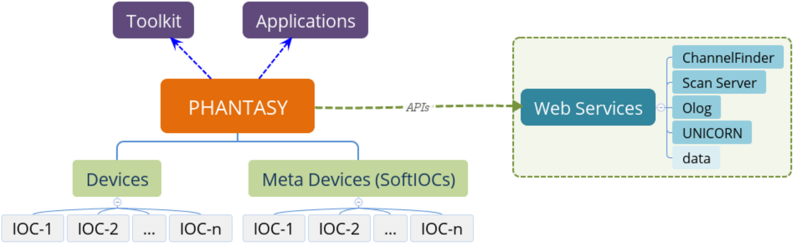
Features Highlight

- Device configuration management
- Device abstraction
- Online modeling
- Python interactive scripting environment for high-level controls
- Virtual accelerator based on EPICS control environment
- Web service integration (channelfinder, UNICORN, scanserver)

Deployment

- Target OS: Debian 8 (Jessie)
- Main packages: *python-phantasy, phantasy-machines*
- Physics model engines: *python-flame, python-impact*

Physics Applications Architecture



Toolkit

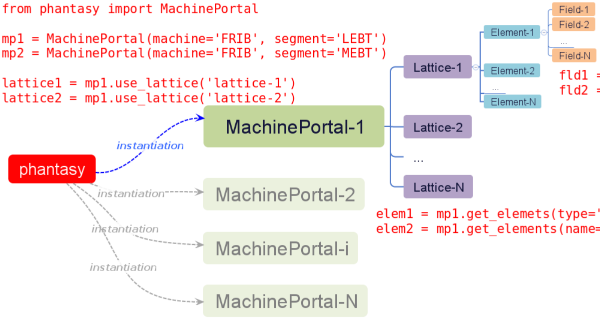
CLI commands, data management, convenient scripts, ...

Applications

Virtual accelerators, orbit correction, parameters scan/optimization, ...

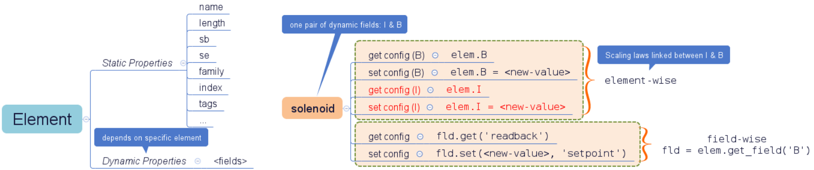
Modeling Architecture: Overview

```python
from phantasy import MachinePortal

mp1 = MachinePortal(machine='FRIB', segment='LEBT')
mp2 = MachinePortal(machine='FRIB', segment='MEBT')

lattice1 = mp1.use_lattice('lattice-1')
lattice2 = mp1.use_lattice('lattice-2')
```

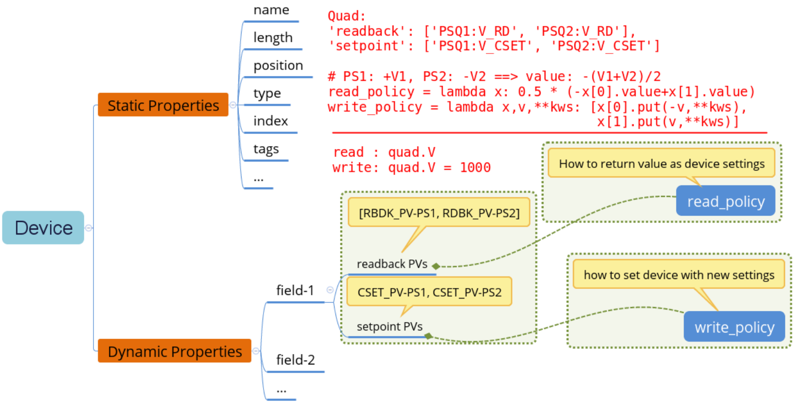



```python
fld1 = elem1.get_field('B')
fld2 = elem1.get_field('I')
```

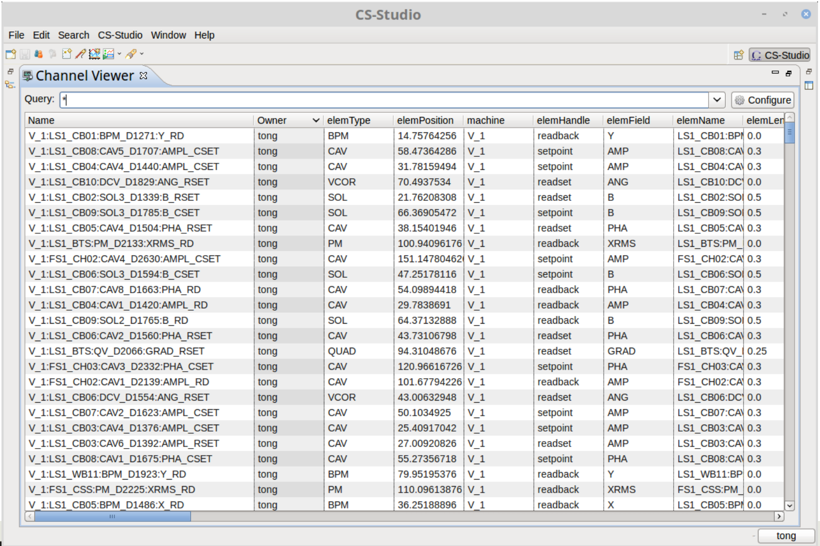
```python
elem1 = mp1.get_elemets(type='SOL')[0]
elem2 = mp1.get_elements(name='*D0709*', type='HCOR')[0]
```



Information abstraction and aggregation:



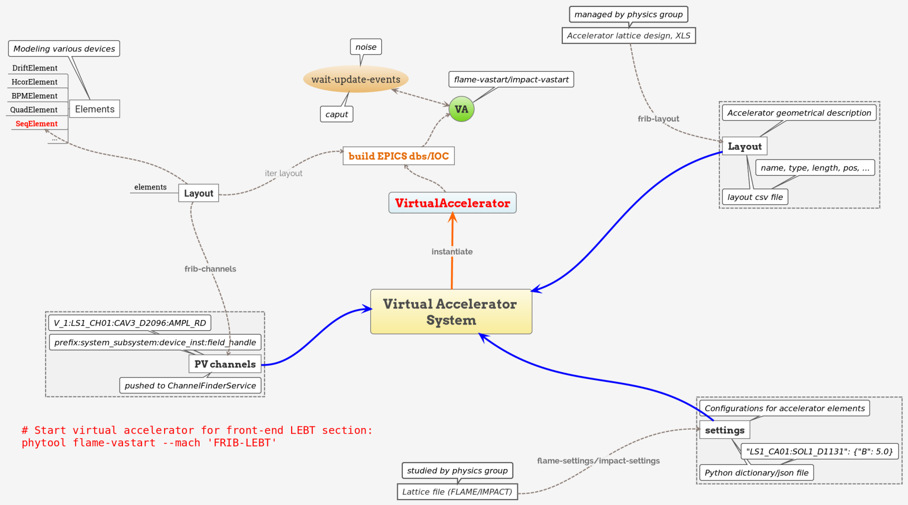
Information abstraction and aggregation:



Name	Owner	elemType	elemPosition	machine	elemHandle	elemField	elemName	elemLen
V_1:LS1_CB01:BPM_D1271:Y_RD	tong	BPM	14.75764256	V_1	readback	Y	LS1_CB01:BP	0.0
V_1:LS1_CB08:CAV5_D1707:AMPL_CSET	tong	CAV	58.47364286	V_1	setpoint	AMP	LS1_CB08:CA	0.3
V_1:LS1_CB04:CAV4_D1440:AMPL_CSET	tong	CAV	31.78159494	V_1	setpoint	AMP	LS1_CB04:CA	0.3
V_1:LS1_CB10:DCV_D1829:ANG_RSET	tong	VCOR	70.4937534	V_1	readset	ANG	LS1_CB10:DC	0.0
V_1:LS1_CB02:SOL3_D1339:B_RSET	tong	SOL	21.76208308	V_1	readset	B	LS1_CB02:SO	0.5
V_1:LS1_CB09:SOL3_D1785:B_CSET	tong	SOL	66.36905472	V_1	setpoint	B	LS1_CB09:SO	0.5
V_1:LS1_CB05:CAV4_D1504:PHA_RSET	tong	CAV	38.15401946	V_1	readset	PHA	LS1_CB05:CA	0.3
V_1:LS1_BTS:PM_D2133:XRMS_RD	tong	PM	100.94096176	V_1	readback	XRMS	LS1_BTS:PM_	0.0
V_1:FS1_CH02:CAV4_D2630:AMPL_CSET	tong	CAV	151.14780462	V_1	setpoint	AMP	FS1_CH02:CA	0.3
V_1:LS1_CB06:SOL3_D1594:B_CSET	tong	SOL	47.25178116	V_1	setpoint	B	LS1_CB06:SO	0.5
V_1:LS1_CB07:CAV8_D1663:PHA_RD	tong	CAV	54.09894418	V_1	readback	PHA	LS1_CB07:CA	0.3
V_1:LS1_CB04:CAV1_D1420:AMPL_RD	tong	CAV	29.7838691	V_1	readback	AMP	LS1_CB04:CA	0.3
V_1:LS1_CB09:SOL2_D1765:B_RD	tong	SOL	64.37132888	V_1	readback	B	LS1_CB09:SO	0.5
V_1:LS1_CB06:CAV2_D1560:PHA_RSET	tong	CAV	43.73106798	V_1	readset	PHA	LS1_CB06:CA	0.3
V_1:LS1_BTS:QV_D2066:GRAD_RSET	tong	QUAD	94.31048676	V_1	readset	GRAD	LS1_BTS:QV_	0.25
V_1:FS1_CH03:CAV3_D2332:PHA_CSET	tong	CAV	120.96616726	V_1	setpoint	PHA	FS1_CH03:CA	0.3
V_1:FS1_CH02:CAV1_D2139:AMPL_RD	tong	CAV	101.67794226	V_1	readback	AMP	FS1_CH02:CA	0.3
V_1:LS1_CB06:DCV_D1554:ANG_RSET	tong	VCOR	43.00632948	V_1	readset	ANG	LS1_CB06:DC	0.0
V_1:LS1_CB07:CAV2_D1623:AMPL_CSET	tong	CAV	50.1034925	V_1	setpoint	AMP	LS1_CB07:CA	0.3
V_1:LS1_CB03:CAV4_D1376:AMPL_CSET	tong	CAV	25.40917042	V_1	setpoint	AMP	LS1_CB03:CA	0.3
V_1:LS1_CB03:CAV6_D1392:AMPL_RSET	tong	CAV	27.00920826	V_1	readset	AMP	LS1_CB03:CA	0.3
V_1:LS1_CB08:CAV1_D1675:PHA_CSET	tong	CAV	55.27356718	V_1	setpoint	PHA	LS1_CB08:CA	0.3
V_1:LS1_WB11:BPM_D1923:Y_RD	tong	BPM	79.95195376	V_1	readback	Y	LS1_WB11:BP	0.0
V_1:FS1_CSS:PM_D2225:XRMS_RD	tong	PM	110.09613876	V_1	readback	XRMS	FS1_CSS:PM_	0.0
V_1:LS1_CB05:BPM_D1486:X_RD	tong	BPM	36.25188896	V_1	readback	X	LS1_CB05:BP	0.0

Outline

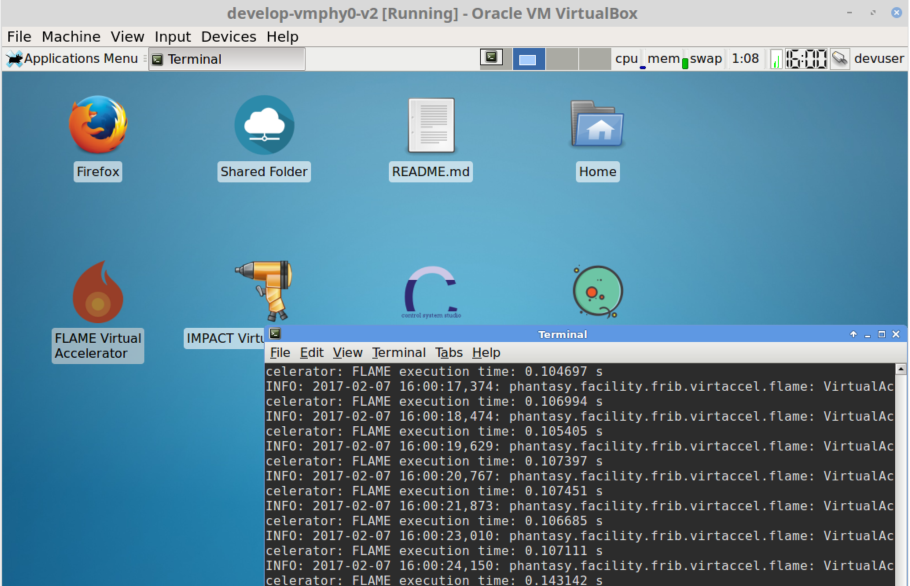
Create EPICS controls environment for development, physics behavior simulated by model engine (FLAME, IMPACT).



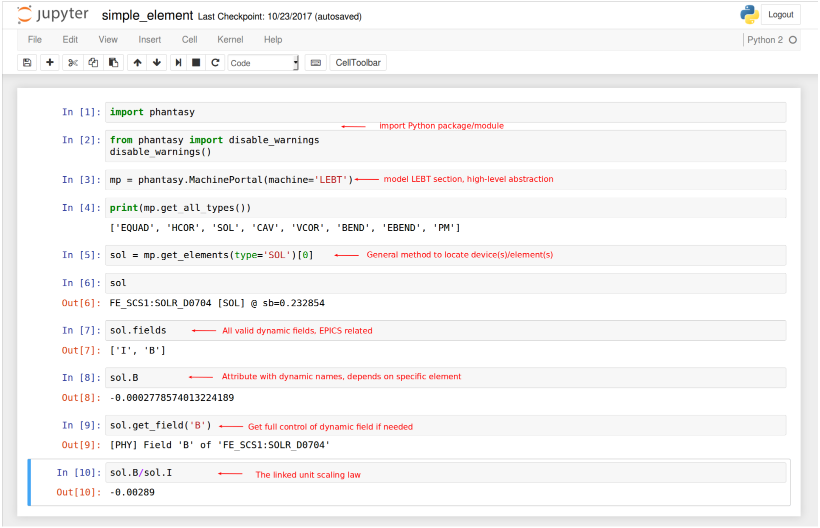

```
# Start virtual accelerator for front-end LEBT section:
phytool flame-vastart --mach 'FRIB-LEBT'
```

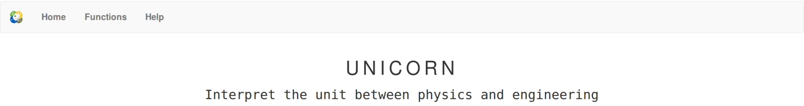
Virtual Accelerator

Create EPICS controls environment for development, physics behavior simulated by model engine (FLAME, IMPACT).



Create a full-featured high-level abstracted software environment, Accelerator Physicists focus on solving physics problems.





- REST APIs to evoke scaling laws: Python-client or web page
- Represent devices with an informative way
- Manage scaling rules in a friendly way
- Debian package:
    - Web application: *unicorn-webapp*
    - Python interface: *python-unicorn, python3-unicorn*

UNICORN: Unit Convertion Web application

Home Functions Help

Functions

Show 10 entries

Search:

	Name	Description	Invoked	Definition	Last Updated
—	FE_MEBT:Q_D1057-P	I to G	3	def f(x, **kws): x1 = kws.get('x1', …	2018-06-05 09:26:21 EDT

Function Definition

```
def f(x, **kws):
    x1 = kws.get('x1', 89.6)
    a1 = kws.get('a1', 0.0)
    b1 = kws.get('b1', 0.15)
    c1 = kws.get('c1', 2.24e-5)
    a2 = kws.get('a2', -5.12)
    b2 = kws.get('b2', 0.264)
    c2 = kws.get('c2', -6.14e-4)
    if 0 <= x < x1:
        return a1 + b1 * x + c1 * x * x
    elif x <= 200:
        return a2 + b2 * x + c2 * x * x
```

	Name	Description	Invoked	Definition	Last Updated
+	FE_MEBT:Q_D1057-N	G to I	1	def f(x, **kws): x1 = kws.get('x1', …	2018-06-05 09:27:48 EDT

Showing 1 to 2 of 2 entries (filtered from 64 total entries)

Previous 1 Next

UNICORN: Unit Convertion Web application

Home Functions Help

Inspection of Function: FE_MEBT:Q_D1057-P

e.g.: {"x":1, "y":2}... output...

ARGS

x,x1,a1,b1,c1,a2,b2,c2

AUTHOR

uadmin

DESCRIPTION

I to G

INVOKED

3

LASTIN

{"x": 20.0}

LASTOUT

3.00896

NAME

FE_MEBT:Q_D1057-P

TIMESTAMP

2018-06-05 09:26:21 EDT

UDEF

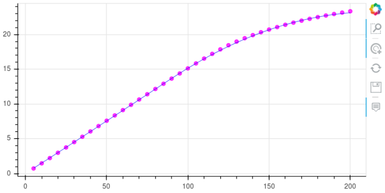
```
def f(x, **kws):
    x1 = kws.get('x1', 89.6)
    a1 = kws.get('a1', 0.0)
    b1 = kws.get('b1', 0.15)
    c1 = kws.get('c1', 2.24e-5)
    a2 = kws.get('a2', -5.12)
    b2 = kws.get('b2', 0.264)
    c2 = kws.get('c2', -6.14e-4)
    if 0 <= x < x1:
        return a1 + b1 * x + c1 * x * x
    elif x <= 200:
        return a2 + b2 * x + c2 * x * x
```

URI

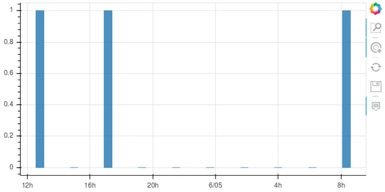
http://127.0.0.1:5000/functions/FE_MEBT:Q_D1057-P

URI-API

DATA CURVE (ENGINEERING (X:I)→PHYSICS (Y:B/G))



TREND (X:T, Y:HIT#)



UNICORN: UNIT CONVERTION WEB APPLICATION

jupyter Untitled1 Last Checkpoint: 4 minutes ago (unsaved changes)

Logout

File Edit View Insert Cell Kernel Help Python 2

CellToolbar

In [1]:
```
import unicorn
```

In [2]:
```
# admin client to UNICORN service
admin_client = unicorn.AdminClient('http://localhost/unicorn')
```

In [ ]:
```
# get all functions
admin_client.get()
```

In [4]:
```
# get function by name
admin_client.get(name='FE_SCS1:SOLR_D0704-P')
```

Out[4]:
```
{u'function': {u'args': u'x,k',
  u'author': u'uadmin',
  u'code': u"def f(x, **kws):\n    k = kws.get('k', -2.89e-3)\n    return k * x\n",
  u'description': u'I to B',
  u'invoked': 3,
  u'lastin': u'{"x": 10.0}',
  u'lastout': u'-0.028900000000000002',
  u'name': u'FE_SCS1:SOLR_D0704-P',
  u'timestamp': u'2018-05-22 11:00:12 EDT',
  u'udef': u"def f(x, **kws):\n    k = kws.get('k', -2.89e-3)\n    return k * x",
  u'uri': u'http://localhost:5000/functions/FE_SCS1:SOLR_D0704-P',
  u'uri-api': u'http://localhost:5000/api/v1.0/functions/FE_SCS1:SOLR_D0704-P'}}
```

In [5]:
```
# api client, the base url + '/api/v1.0'
api_client = unicorn.ApiClient('http://localhost/unicorn/api/v1.0')
```

In [6]:
```
# get function execution result
api_client.get('FE_MEBT:Q_D1057-P', x=20)
```

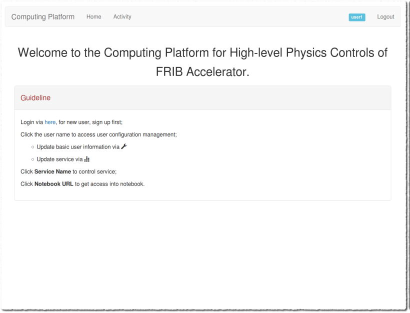
Out[6]:
```
{u'result': 3.00896}
```

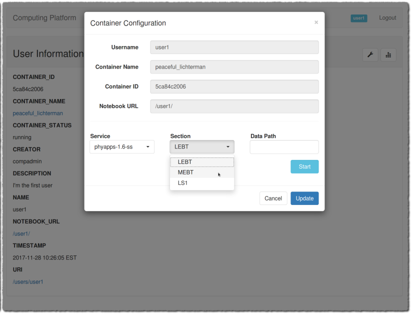
In [7]:
```
# get result from reverse function
api_client.get('FE_MEBT:Q_D1057-N', x=3.00896)
```

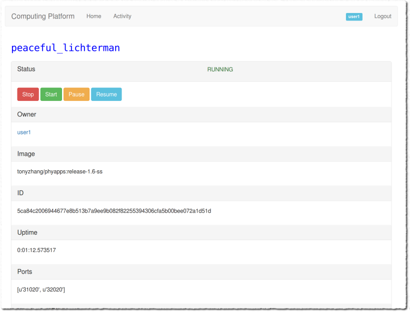
Deployment (I)

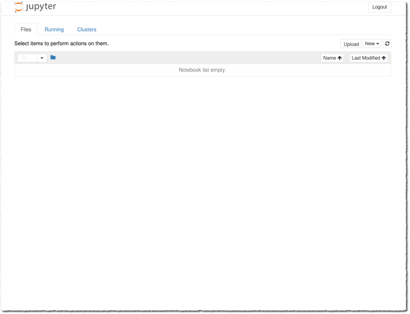
- FRIB controls network
  git → stash → jenkins → puppet → target workstations
- Local development
  VirtualBox Appliance
- Cloud development
  Docker container based web computing platform (configurable-proxy, docker images)

Deployment (II)









Deployment (II)

```
TOKEN = 6520fbd2223339e729c99b4f1730f1dd2098b57c3f3d692a37ba6fecc553
ETH0  ?= enx18dbf2615ea9
IPNOW := $(shell ifconfig $(ETH0) | \
          /bin/grep "inet addr" | \
          awk -F':' '{print $$2}' | \
          awk '{print $$1}')
IMAGE_MNB := "tonyzhang/phyapps-notebook:latest"
IMAGE_PROXY := "jupyter/configurable-http-proxy"
DPATH := $(shell pwd)

deploy: proxy mnb
stop: stop-proxy stop-mnb

stop-proxy:
    @docker container stop proxy
    @docker container rm proxy

stop-mnb:
    @docker container stop mnb
    @docker container rm mnb

proxy:
    @docker run -d \
        -e CONFIGPROXY_AUTH_TOKEN=$(TOKEN) \
        --name=proxy \
        --net=host \
        -v $(shell pwd)/ssl:/ssl \
        $(IMAGE_PROXY) \
        --log-level debug \
        --ssl-key /ssl/key.pem \
        --ssl-cert /ssl/cert.pem \
        --ip $(IPNOW) \
        --port 8000 \
        --default-target http://127.0.0.1:5050

mnb:
    @docker run -t -d \
        -e PROXY_TOKEN=$(TOKEN) \
        -e PROXY_BASE="http://127.0.0.1:8001/api/routes" \
        -e DPATH=$(DPATH) \
        -p 5050:5050 \
        --name=mnb \
        --net=host \
        -v /var/run/docker.sock:/var/run/docker.sock \
        $(IMAGE_MNB)
```

```
make deploy
make stop
```

Outline

Conclusions

- Established Python-based software infrastructure for high-level physics controls
- The solution for systematic high-level device abstraction
- Dedicated web application and Python interface for units interpretation
- Continuous integration and delivery at FRIB

Future Plans

- Operation: develop mature physics algorithms into soft-IOCs
- Python ecosystem: data management

Thank you for your attention!