



PHYSICS HIGH-LEVEL APPLICATIONS AND TOOLKIT FOR ACCELERATOR SYSTEM

AN OVERVIEW OF FRIB HIGH-LEVEL PHYSICS APPLICATIONS DEVELOPMENT

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

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U.S. DEPARTMENT OF
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1 DESIGNED ARCHITECTURE

- Introduction
- Device Abstraction

2 KEY FEATURES

- Virtual Accelerator
- Online Model

3 CONCLUSIONS

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3 CONCLUSIONS

ACCELERATOR SYSTEM

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

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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

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ACCELERATOR SYSTEM

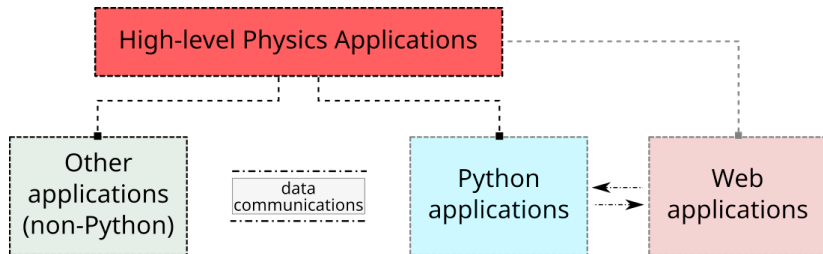
- particle source, beam transport, end stations, ...
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High-level Physics Applications = Physics Algorithms + Controls Software

SOFTWARE SOLUTION UPON PYTHON PROGRAMMING LANGUAGE



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

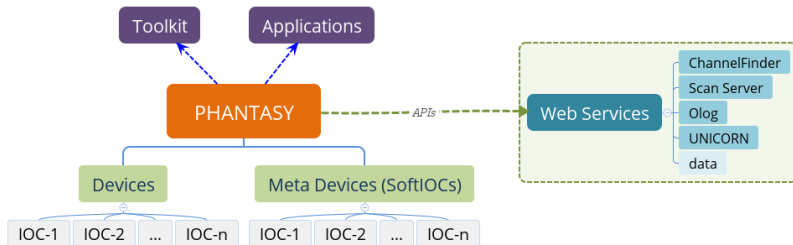
FEATURES HIGHLIGHT

- 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

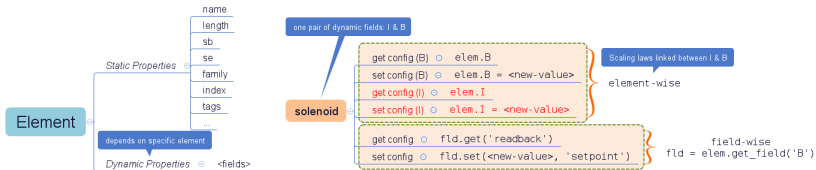
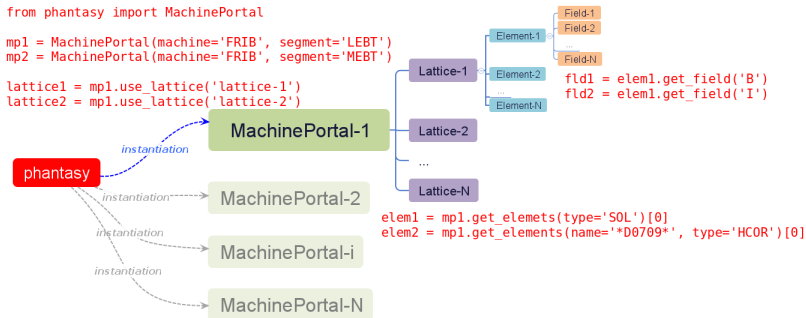
Virtual accelerators, orbit correction, parameters scan/optimization, ...

MODELING ARCHITECTURE: OVERVIEW

```
from phantasy import MachinePortal
```

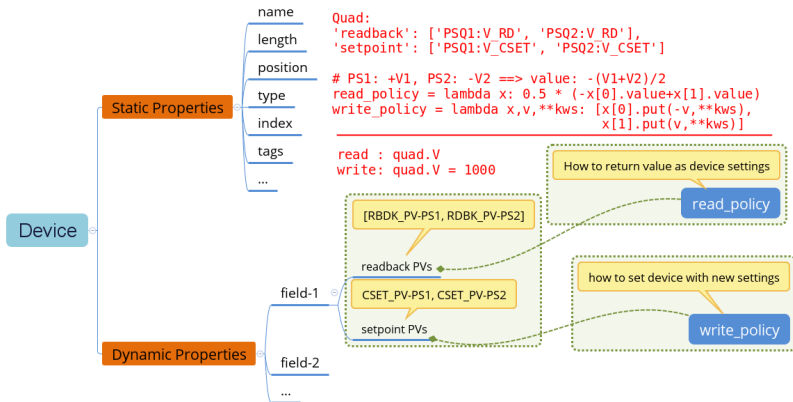
```
mp1 = MachinePortal(machine='FRIB', segment='LEBT')
mp2 = MachinePortal(machine='FRIB', segment='MEBT')
```

```
latt1 = mp1.use_lattice('lattice-1')
latt2 = mp1.use_lattice('lattice-2')
```



MODELING ARCHITECTURE: DEVICE ABSTRACTION

Information abstraction and aggregation:



MODELING ARCHITECTURE: DEVICE ABSTRACTION

Information abstraction and aggregation:

CS-Studio

File Edit Search CS-Studio Window Help

Channel Viewer

Query: |

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:BPM	0.0
V_1:LS1_CB08:CAV5_D1707:AMPL_CSET	tong	CAV	58.47364286	V_1	setpoint	AMP	LS1_CB08:CAV	0.3
V_1:LS1_CB04:CAV4_D1440:AMPL_CSET	tong	CAV	31.78159494	V_1	setpoint	AMP	LS1_CB04:CAV	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:CAV	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	64.37132888	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:CAV	0.3
V_1:LS1_CB04:CAV1_D1420:AMPL_RD	tong	CAV	29.7838691	V_1	readback	AMP	LS1_CB04:CAV	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:CAV	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:CAV	0.3
V_1:LS1_CB03:CAV4_D1376:AMPL_CSET	tong	CAV	25.40917042	V_1	setpoint	AMP	LS1_CB03:CAV	0.3
V_1:LS1_CB03:CAV6_D1392:AMPL_RSET	tong	CAV	27.00920826	V_1	readset	AMP	LS1_CB03:CAV	0.3
V_1:LS1_CB08:CAV1_D1675:PHA_CSET	tong	CAV	55.27356718	V_1	setpoint	PHA	LS1_CB08:CAV	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

tong

1 DESIGNED ARCHITECTURE

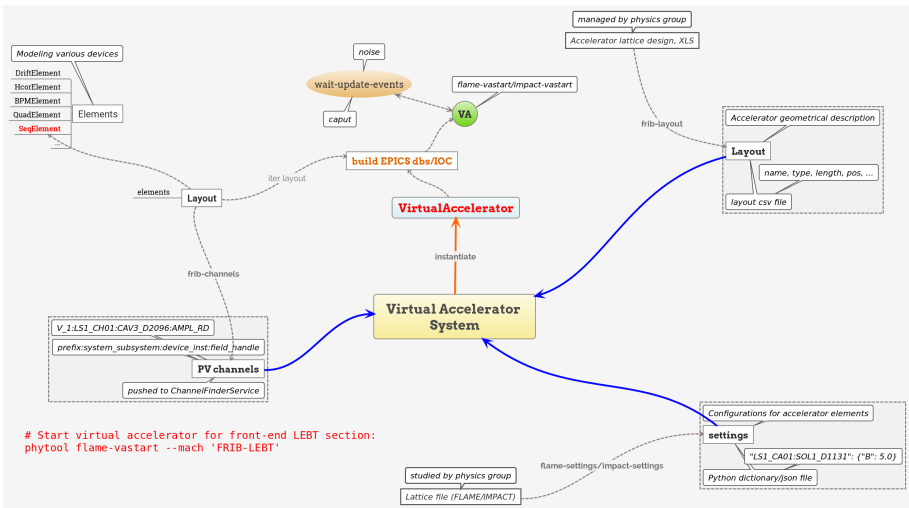
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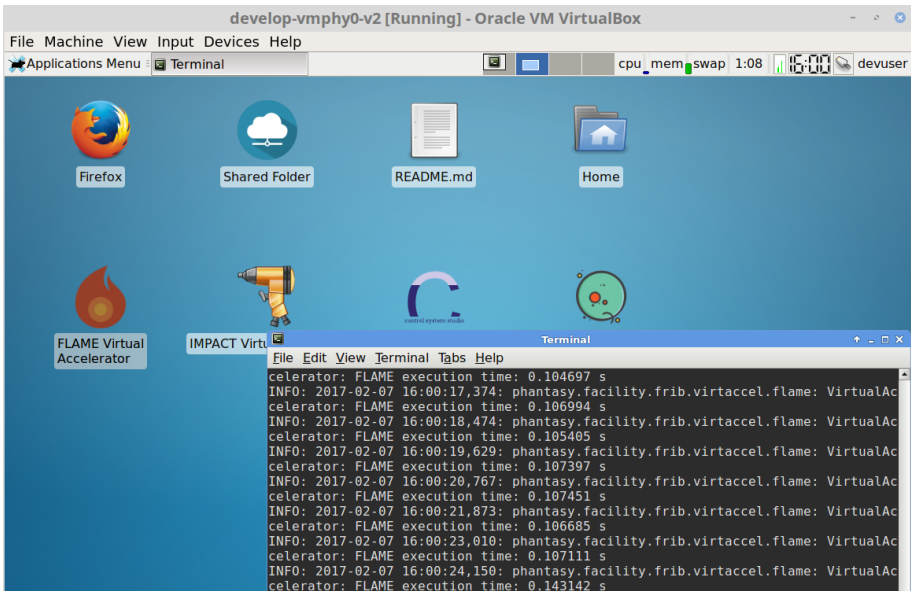
VIRTUAL ACCELERATOR

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



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The screenshot shows a VirtualBox window titled "develop-vmphy0-v2 [Running] - Oracle VM VirtualBox". The desktop environment includes icons for Firefox, Shared Folder, README.md, Home, FLAME Virtual Accelerator, and IMPACT Virtual Accelerator. A terminal window is open in the foreground, displaying a series of log messages for the Virtual Accelerator.

```
celerator: FLAME execution time: 0.104697 s
INFO: 2017-02-07 16:00:17,374: phantasy.facility.frib.virtaccel.flame: VirtualAc
celerator: FLAME execution time: 0.106994 s
INFO: 2017-02-07 16:00:18,474: phantasy.facility.frib.virtaccel.flame: VirtualAc
celerator: FLAME execution time: 0.105405 s
INFO: 2017-02-07 16:00:19,629: phantasy.facility.frib.virtaccel.flame: VirtualAc
celerator: FLAME execution time: 0.107397 s
INFO: 2017-02-07 16:00:20,767: phantasy.facility.frib.virtaccel.flame: VirtualAc
celerator: FLAME execution time: 0.107451 s
INFO: 2017-02-07 16:00:21,873: phantasy.facility.frib.virtaccel.flame: VirtualAc
celerator: FLAME execution time: 0.106685 s
INFO: 2017-02-07 16:00:23,010: phantasy.facility.frib.virtaccel.flame: VirtualAc
celerator: FLAME execution time: 0.107111 s
INFO: 2017-02-07 16:00:24,150: phantasy.facility.frib.virtaccel.flame: VirtualAc
celerator: FLAME execution time: 0.143142 s
```

INTERACTIVE PYTHON SCRIPTING ENVIRONMENT

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

```
In [1]: import phantasy
In [2]: from phantasy import disable_warnings
        disable_warnings()
In [3]: mp = phantasy.MachinePortal(machine='LEBT')
In [4]: print(mp.get_all_types())
        ['EQUAD', 'HCOR', 'SOL', 'CAV', 'VCOR', 'BEND', 'EBEND', 'PM']
In [5]: sol = mp.get_elements(type='SOL')[0]
In [6]: sol
Out[6]: FE_SCS1:SOLR_D0704 [SOL] @ sb=0.232854
In [7]: sol.fields
Out[7]: ['I', 'B']
In [8]: sol.B
Out[8]: -0.0002778574013224189
In [9]: sol.get_field('B')
Out[9]: [PHY] Field 'B' of 'FE_SCS1:SOLR_D0704'
In [10]: sol.B/sol.I
Out[10]: -0.00289
```

← import Python package/module

← model LEBT section, high-level abstraction

← General method to locate device(s)/element(s)

← All valid dynamic fields, EPICS related

← Attribute with dynamic names, depends on specific element

← Get full control of dynamic field if needed

← The linked unit scaling law

UNICORN

Interpret the unit between physics and engineering

- 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 CONVERSION WEB APPLICATION



[Home](#) [Functions](#) [Help](#)

Functions

Show 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				
<pre>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', -6.16e-4) if 0 <= x < x1: return a1 + b1 * x + c1 * x * x elif x <= 200: return a2 + b2 * x + c2 * x * x</pre>				
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](#)

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UNICORN: UNIT CONVERSION 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

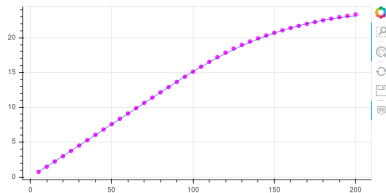
```
def f(x, **kws):  
    x1 = kws.get('x1', 89.6)  
    a1 = kws.get('a1', 0.0)  
    b1 = kws.get('b1', 0.15)  
    c1 = kws.get('c1', 2.24e-5)  
    a2 = kws.get('a2', -5.12)  
    b2 = kws.get('b2', 0.264)  
    c2 = kws.get('c2', -6.14e-4)  
    if 0 <= x < x1:  
        return a1 + b1 * x + c1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

URI

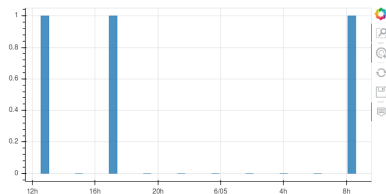
http://127.0.0.1:5000/functions/FE_MEBT:Q_D1057-P

URI-API

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



TREND (X:T, Y:HIT#)



UNICORN: UNIT CONVERSION WEB APPLICATION

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

Logout

File Edit View Insert Cell Kernel Help

Python 2

Code 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]: {'function': {'u'args': 'u'x,k',
  u'author': 'u'admin',
  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'ndef': '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]: {'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)

Computing Platform Home Activity [user1](#) Logout

Welcome to the Computing Platform for High-level Physics Controls of FRIB Accelerator.

Guideline

Login via [here](#), for new user, sign up [first](#);
Click the user name to access user configuration management;
◦ Update basic user information via [✎](#)
◦ Update service via [✎](#)
Click **Service Name** to control service;
Click **Notebook URL** to get access into notebook.

Computing Platform **Container Configuration** [user1](#) Logout

User Information

CONTAINER_ID
5ca84c2009

CONTAINER_NAME
peaceful_lichterman

CONTAINER_ID
5ca84c2009

Notebook URL
user1/

CONTAINER_STATUS
running

CREATOR
compadmin

DESCRIPTION
I'm the first user

NAME
user1

NOTEBOOK_URL
[user1/](#)

TWESTAMP
2017-11-28 10:26:05 EST

URI
[/user1](#)

Service
phyppp-1.6-ss

Section
LEBT

Data Path

LEBT
MEBT
LS1

Start

Cancel Update

Computing Platform Home Activity [user1](#) Logout

peaceful_lichterman

Status RUNNING

Stop Start Pause Resume

Owner
user1

Image
tongzhang/phyppp-release-1.6-ss

ID
5ca84c200944877v88d513b7ad6e6d08282295394306cfa5b006ae072a1d51d

Uptime
0:01:12.573517

Ports
[*31000, *32000]

jupyter [Logout](#)

Files Running Clusters

Select items to perform actions on them.

Upload New

Notebook list empty.

DEPLOYMENT (II)

```
1 TOKEN = 6520fbd2223339e729c99b4f1730f1dd2098b57c3f3d692a37ba6fecc553
2 ETHO ?= enx18dbf2615ea9
3 IPNOW := $(shell ifconfig $(ETHO) | \
4 /bin/grep "inet addr" | \
5 awk -F:' ' '{print $2}' | \
6 awk '{print $1}')
7 IMAGE_MNB := "tonyjiang/phyapps-notebook:latest"
8 IMAGE_PROXY := "jupyter/configurable-http-proxy"
9 DPATH := $(shell pwd)
10
11 deploy: proxy mnb
12 stop: stop-proxy stop-mnb
13
14 stop-proxy:
15     @docker container stop proxy
16     @docker container rm proxy
17
18 stop-mnb:
19     @docker container stop mnb
20     @docker container rm mnb
21
```

make deploy
make stop

```
22 proxy:
23     @docker run -d \
24         -e CONFIGPROXY_AUTH_TOKEN=$(TOKEN) \
25         --name=proxy \
26         --net=host \
27         -v $(shell pwd)/ssl:/ssl \
28         $(IMAGE_PROXY) \
29         --log-level debug \
30         --ssl-key /ssl/key.pem \
31         --ssl-cert /ssl/cert.pem \
32         --ip $(IPNOW) \
33         --port 8000 \
34         --default-target http://127.0.0.1:5050
35
36 mnb:
37     @docker run -t -d \
38         -e PROXY_TOKEN=$(TOKEN) \
39         -e PROXY_BASE="http://127.0.0.1:8001/api/routes" \
40         -e DPATH=$(DPATH) \
41         -p 5050:5050 \
42         --name=mnb \
43         --net=host \
44         -v /var/run/docker.sock:/var/run/docker.sock \
45         $(IMAGE_MNB)
```

1 DESIGNED ARCHITECTURE

2 KEY FEATURES

3 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!