A users view on exploiting the control system in MDs

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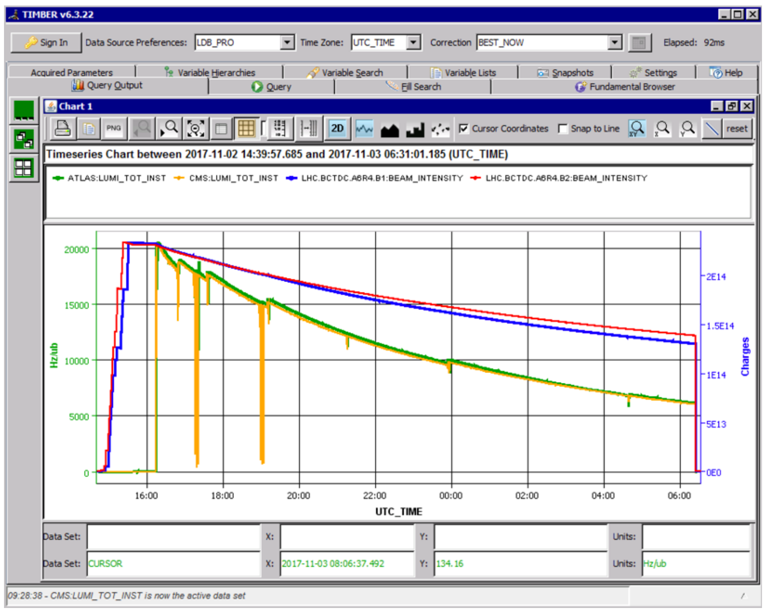
8th Evian Workshop - December 2017

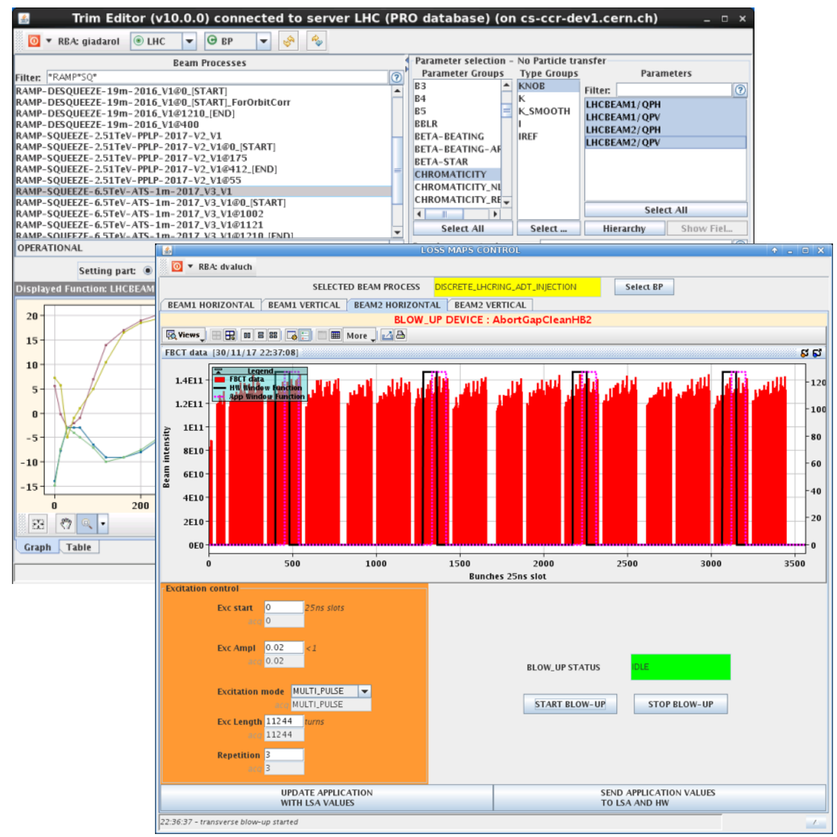
Introduction

Focusing on two types of activity

Extraction and analysis of data from the logging service (CALS)

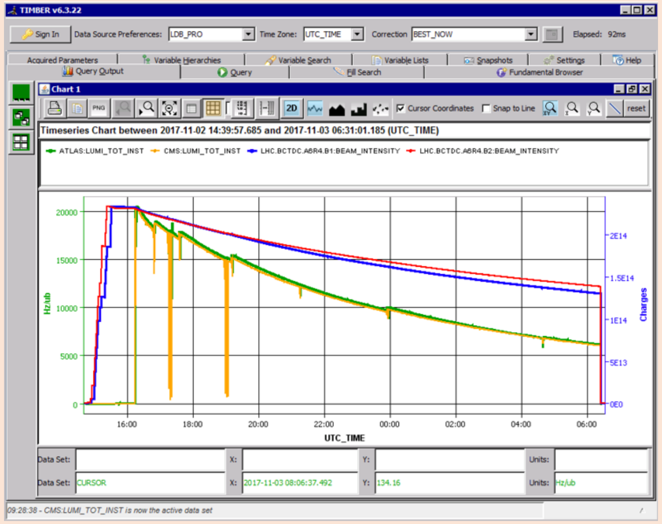


Interaction with LHC equipment



Analysis of logged data: the “classical paradigm”

1. **Extract the data** from Logging System and store on local drive (e.g. using Timber)

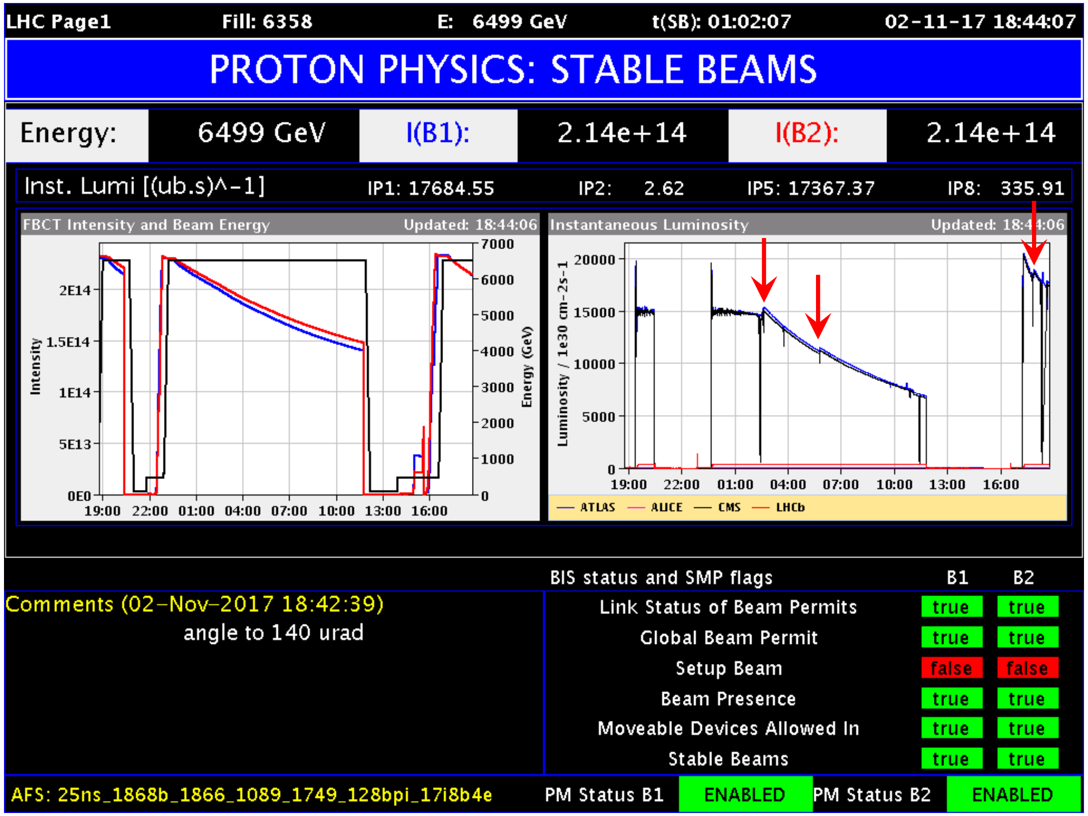


2. **Parse** downloaded file
3. **Perform “the analysis”** (data manipulation, correlations, plotting, etc.)

But this does not work efficiently when the analysis needs to interact with the data extraction…

A practical example: analysis of Xing angle anti-leveling

- For **all physics fills in 2017** we want to know:
  - After how much **time in Stable Beams** (SB) the **first angle reduction** was applied
  - By **how much** was the crossing angle changed
  - What was the **average bunch intensity** at the moment of the change
- With the approach described before we would need to **download** and **store** the required data for the **entire run**, **parse** the files, do the **processing** → **>1 day** of work



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A possible algorithm combining **data retrieval** and with **some logics**

For all fills of the 2017 p-p run:
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A lot less data: download one intensity point per fill instead of the full run!

But this cannot be done with Timber…

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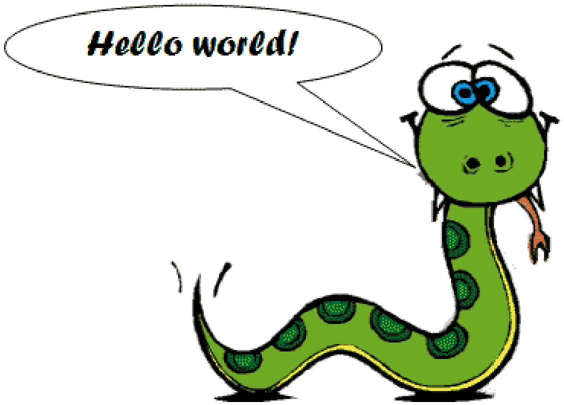
But this cannot be done with Timber…

- The conventional/supported way of interacting with the logging system with full flexibility is to use the **Java API** (Application Program Interface) provided by BE-CO
- Unfortunately Java is not part of the background for the average physicist and has a quite long learning curve…

An interesting middle ground: Python

Python is an open-source general-purpose language and is a **very popular choice for scientific computing** (e.g. data analysis, calculations, numerical simulations)

→ In fact many of us are already using it



- Very **fast learning curve**
- Simple, flexible, and **concise** → development generally faster than with other languages: ideal for quick **prototyping**, **testing** new ideas
- Prone to **interactive development**
- Used and supported by a **large community** (if you have a question, you just have to write it on google)
- It comes with solid and complete set of **tools for numerical analysis and plotting** (numpy, scipy, matplolib, pandas)

"Hello world" in Java

```
public class HelloWorld
{
  public static void main(String[] args)
   {
     System.out.println("Hello, World!");
   }
}
```

"Hello world" in Python

```
print "Hello, World!"
```

PyTimber

Users developed a python module (**PyTimber**) to **access the logging via python**

→ Proved to be very handy as many of us are already using python for data analysis, simulations etc.

It is a python **wrapper of the CALS Java API** (made using Jpype)

- Hides most of the "java technicalities" providing a **user-friendly** but **scriptable** interface
- Started like a "personal" project, it spread very fast (>100 users across CERN) and further evolved by **community development** (based on GitHub)
- Made available and regularly used within the **SWAN environment**, developed by the LHC experiment for **interactive data analysis** using **cloud computing** resources (you can do everything in your web browser)

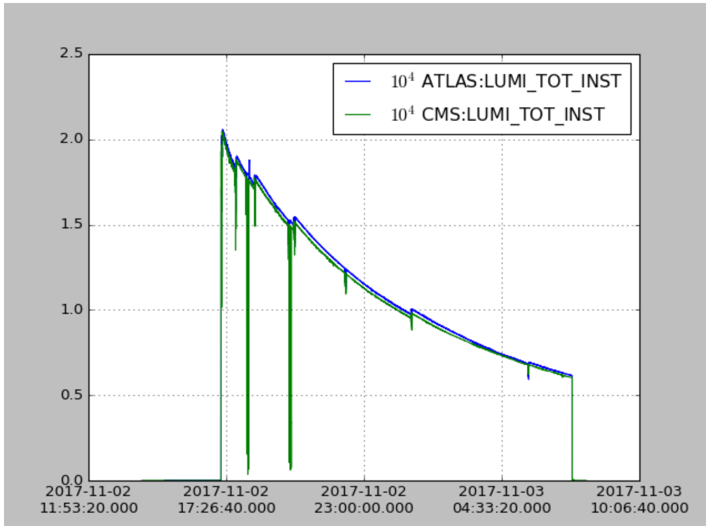
Example: download and plot LHC luminosities

```
import pytimber, pylab
ldb = pytimber.LoggingDB()

data = pytimber.DataQuery(ldb,
     ["ATLAS:LUMI_TOT_INST","CMS:LUMI_TOT_INST"],
     "2017-11-02 14:00:00", “2017-11-0308:00:00”)

data.plot_2d()

pylab.show()
```



Authors: R. De Maria, T. Levens, C. Hernalsteens, M. Betz, M. Fitterer, R. Castellotti

For more info: *github repository*

Xing angle example: PyTimber implementation

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With PyTimber these 11 steps can be implemented in ~30 lines of python ☺

```
for filln in xrange(first_fill, last_fill):

    fill_data = ldb.getLHCFillData(filln)
    bmode_dict = build_dict_bmodes(fill_data)

    if 'STABLE' not in bmode_dict.keys():
        print 'No stable beams'; continue

    t_start_stable = bmode_dict['STABLE']['startTime'][0]
    t_end_stable = bmode_dict['STABLE']['endTime'][0]

    ang_var_start = ldb.get([ang_varname],
            t1 = t_start_stable , t2 = 'last')

    ang_var_duringSB = ldb.get([ang_varname],
            t1 = t_start_stable, t2 = t_end_stable)

    if len(ang_var_duringSB[ang_varname][0])==0:
        print 'No crossing change'; continue

    t_1st_change = ang_var_duringSB[ang_varname][0][0]
    t_1st_change_h_list.append((t_1st_change - t_start_stable)/3600.)

    ang_1st_change_list.append(ang_var_duringSB[ang_varname][1][0])
    ang_start_fill_list.append(ang_var_start[ang_varname][1][0])

    inten_vars_start_SB = ldb.get([intenB1_varname, intenB2_varname,
                               nbunB1_varname, nbunB2_varname],
                                t1 = t_start_stable, t2 = 'last')

    inten_vars_at_change = ldb.get([intenB1_varname, intenB2_varname],
                                 t1 = t_1st_change, t2 = 'last')

    avg_bint_start_SB = inten_vars_start_SB[intenB1_varname][1][0]\
                        /inten_vars_start_SB[nbunB1_varname][1][0]
    avg_bint_at_change = inten_vars_at_change[intenB1_varname][1][0]\
                        /inten_vars_start_SB[nbunB1_varname][1][0]

    avg_bint_start_SB_list.append(avg_bint_start_SB)
    avg_bint_at_change_list.append(avg_bint_at_change)
    nbun_list.append(inten_vars_start_SB[nbunB1_varname][1][0])
    filln_list.append(filln)
```

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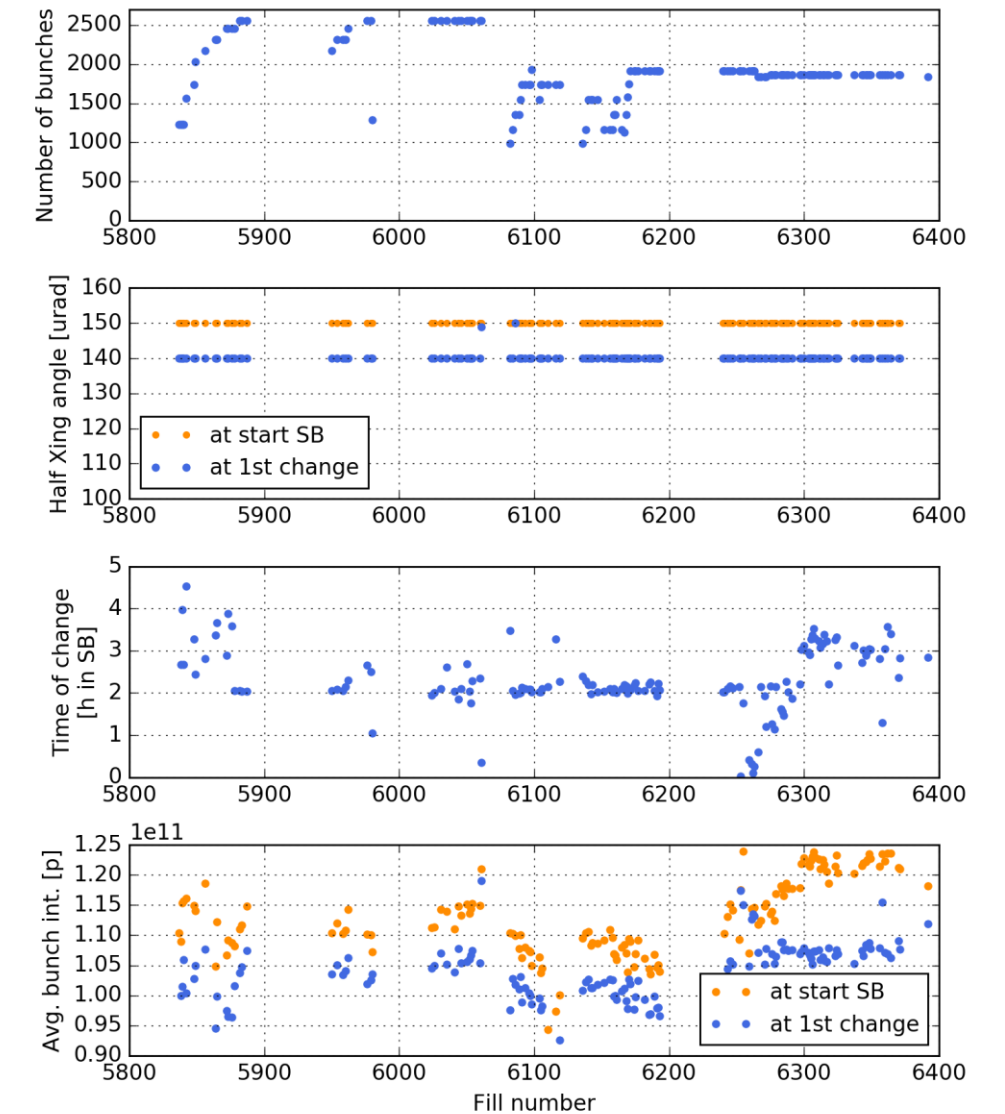
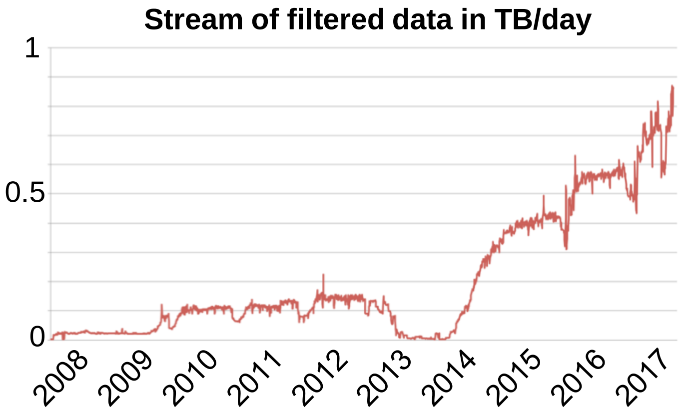
```
for filln in xrange
    fill_data = ldb
    bmode_dict = bu

    if 'S
        p

    t_sta
    t_end

    ang_v

    ang_v

    if le
        p

    t_1st
    t_1st

    ang_1
    ang_s

    inten

    inten

    avg_b

    avg_b

    avg_b
    avg_b
    nbun
    filln
```

Code put together in **~1.5h**
Execution time: **3.5 mins**



The future of the Logging System: NXCALS



BE-CO presently working on **full renovation of the Logging System** to fulfill growing needs:

→ New **NXCALS** system is under development

→ Based on **Hadoop**/**Spark** technology (open source, leading players in the "Big Data" world)

→ **Migration of data** from the present system and **analysis** of all present **use-cases** are **ongoing**

→ Message from the developers: "Give us more people, it will be faster!" :-)

Features of the new system:

- Better **horizontal scalability** (good performance in spite of growing size of stored data, >1 PB)
- Possibility of using **"Big Data" toolset**. Change of paradigm:
  - User does not download data to his local machine but **sends analysis code** to be executed directly by the distributed storage/computing resources
- **Present Java API will be maintained** (present applications, including PyTimber, will still work)
- Plus other and more advanced ways of interacting with the system (python, jupyter, spark, swan…)

For more info: *gitlab repository*, wiki

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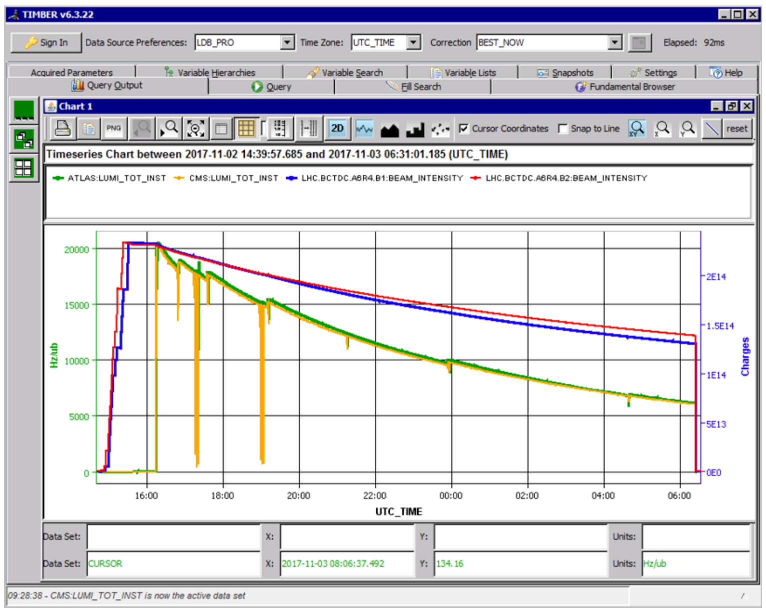
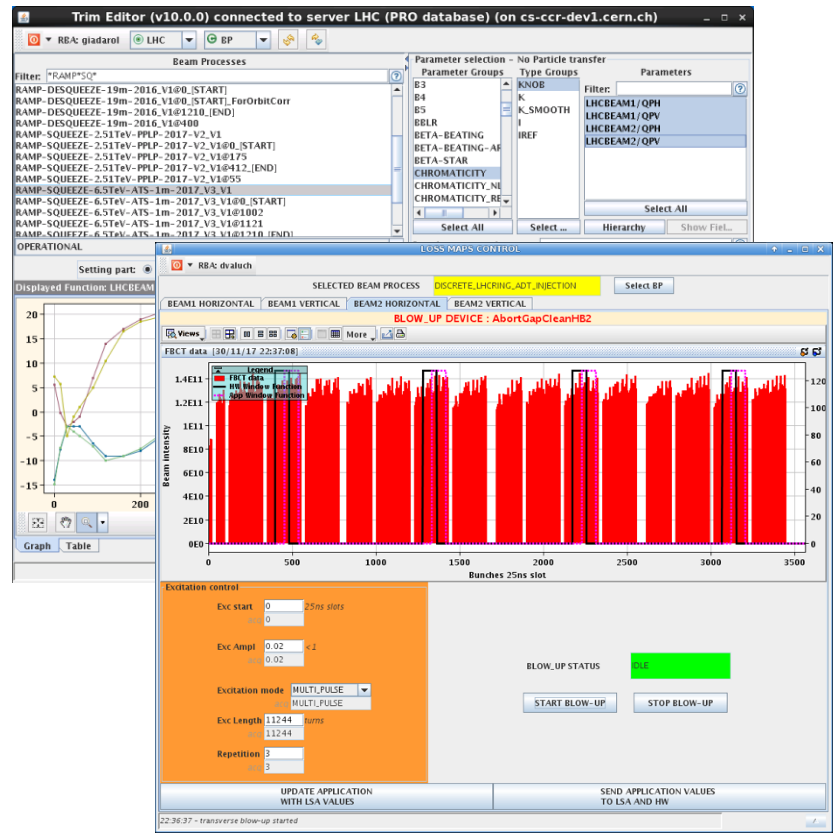


Interaction with LHC equipment



Interaction with LHC equipment

Machine Studies often require **interacting with LHC equipment**, in particular when using diagnostics from beam instrumentation, RF, etc.

→ Often this is not only a passive observation of published data but requires sending commands, settings, triggers …

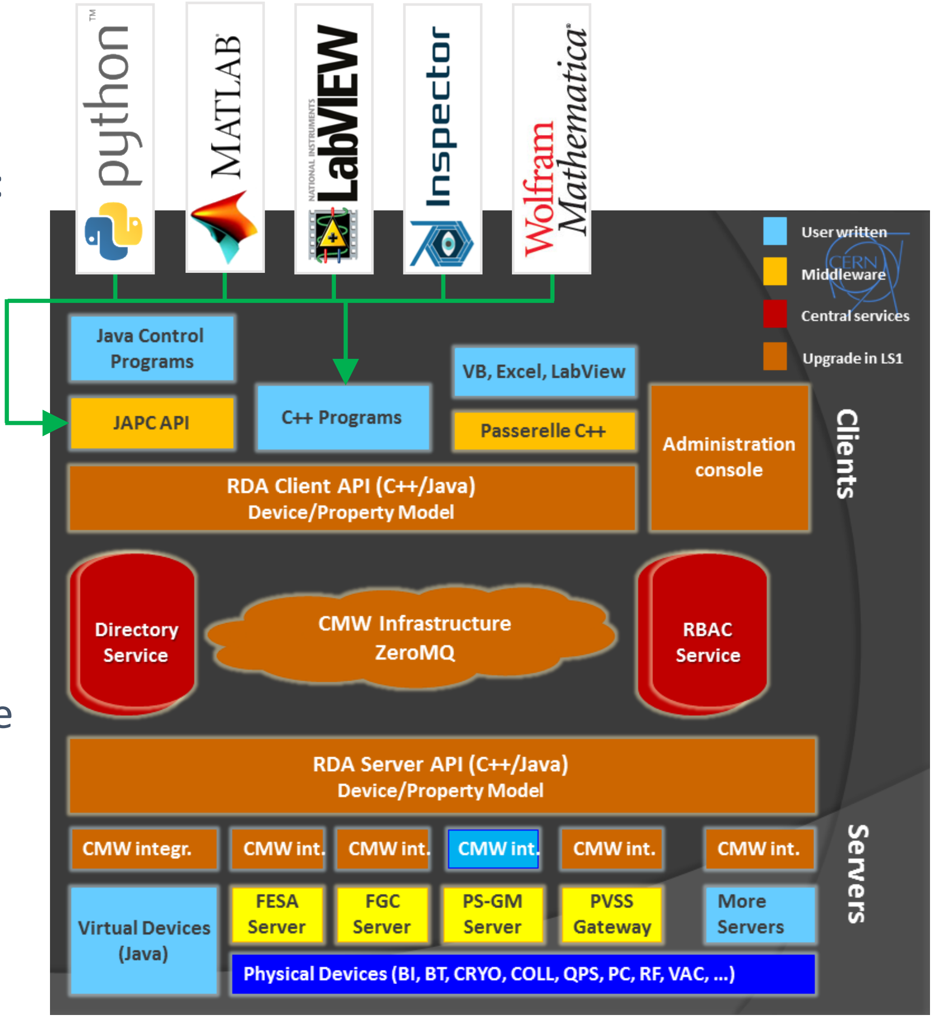
The convectional way is to use the existing **applications** (mostly written in Java), but this does **not cover many cases** of interest for MDs, notably:

- Commissioning of **new devices**
- Experiments with **unconventional usage** of existing devices

Several approaches adopted:

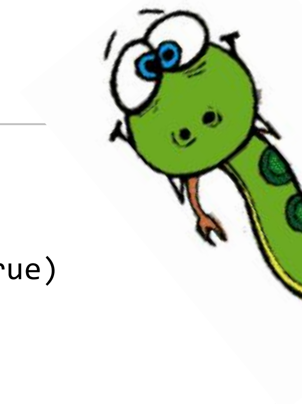
- Develop **ad-hoc java applications** (requires time and expertise)
- Use **scripting language:**

  → **Tools** have been developed to hide some of the complexity and allow for more agile development, common choices: **PyJAPC** and **Inspector**



More info on the different options available at: https://wikis.cern.ch/display/ST/Libraries+Available

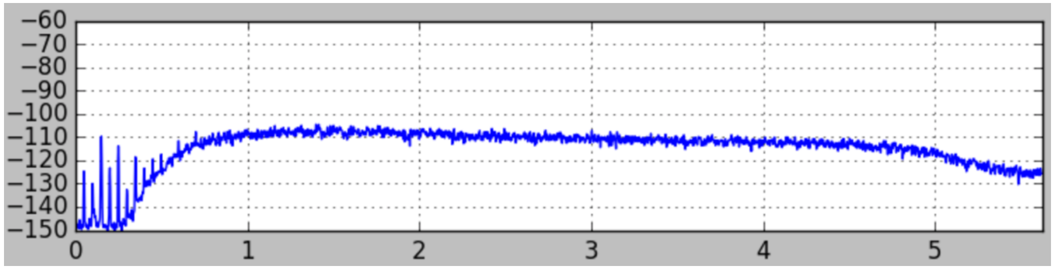
PyJAPC



- **PyJAPC** is a simplified **python interface to accelerator hardware** (e.g. FESA)
- Implementation makes use of JPype to call functions of the "Java API for Parameter Control" (JAPC) directly from Python
- It can be used without knowing anything about the underlying JAPC API
- For more complex functionality it is possible to manually call the relevant JAPC functions from Python

Example: plot BBQ spectrum

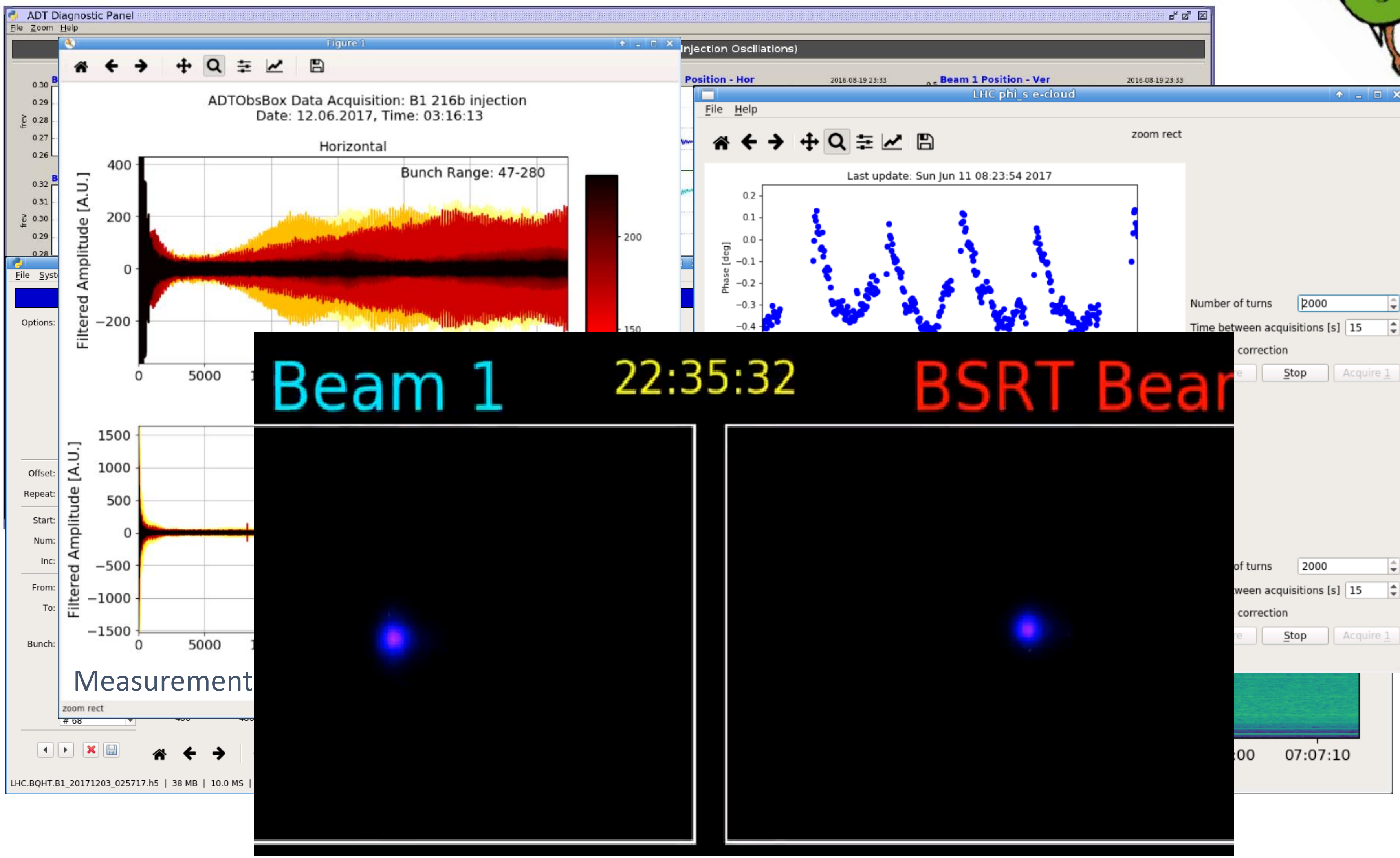
```
# instantiate pyjapc object
import pyjapc
japc = pyjapc.PyJapc(selector="LHC.USER.ALL",
           incaAcceleratorName="LHC", noSet=True)

# RBAC login
japc.rbacLogin(loginDialog=True)

# Get vector data from LHC BBQ
v = japc.getParam(
 "LHC.BQ.ONDEMAND.B1/SummaryMeasurement#averageMagnitudeH")

# plot
import numpy as np; import pylab as pl
xVect = np.linspace(0, 11e3/2, len(v), endpoint=False )
pl.plot(xVect/1e3, v, label=par)

# RBAC Logout
japc.rbacLogout()
```



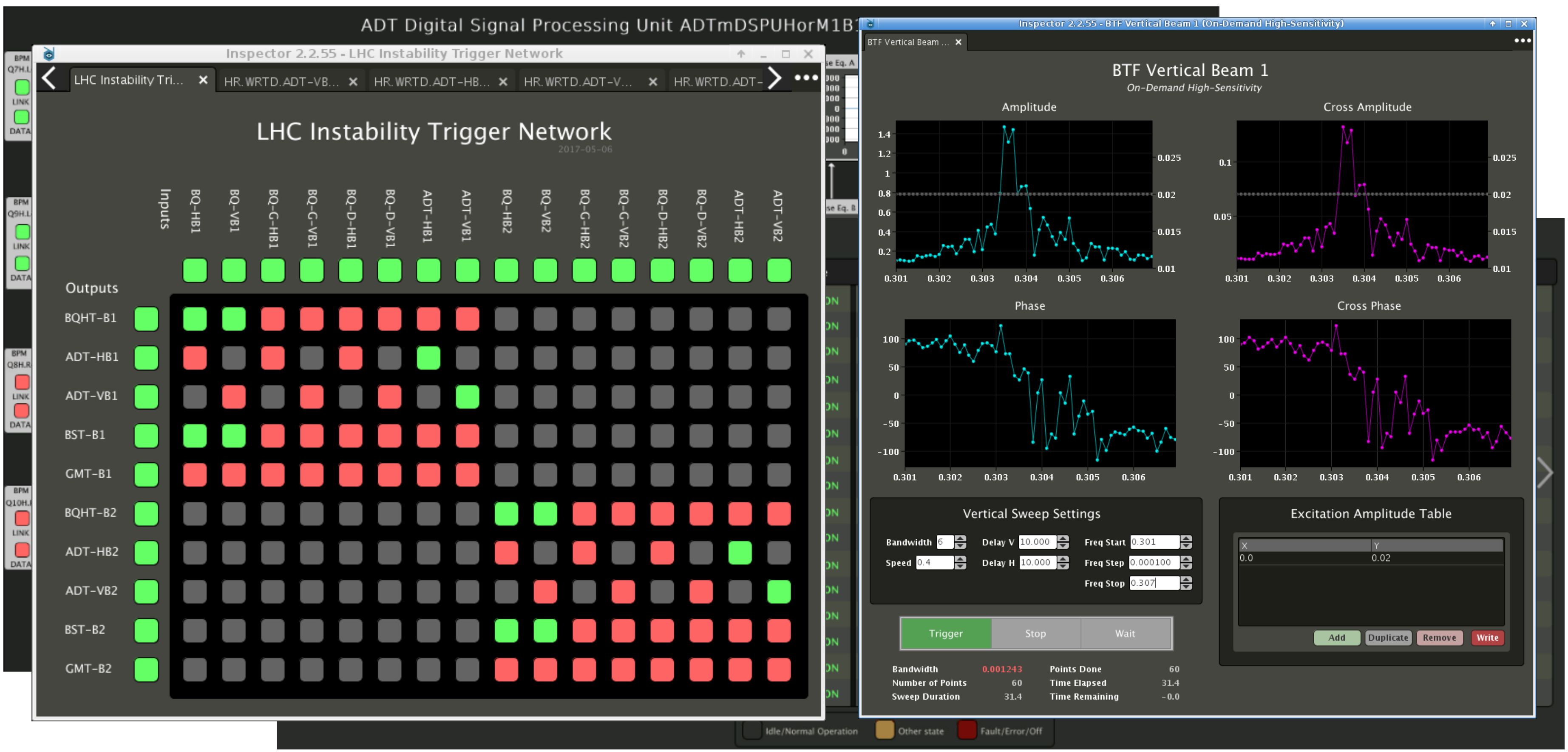
Authors: M. Betz, T. Levens

For more info: documentation, wikis, gitlab repository

- Under the hood of many familiar CCC windows



- Tool for the development of control applications using **graphical programming**
- Based on java API (JAPC)
- Allows fast development of **Graphical User Interfaces (GUIs) and displays**
- Used for several **expert interfaces** and **MD tools**



Authors: B. Lefort et al.

For more info: wiki

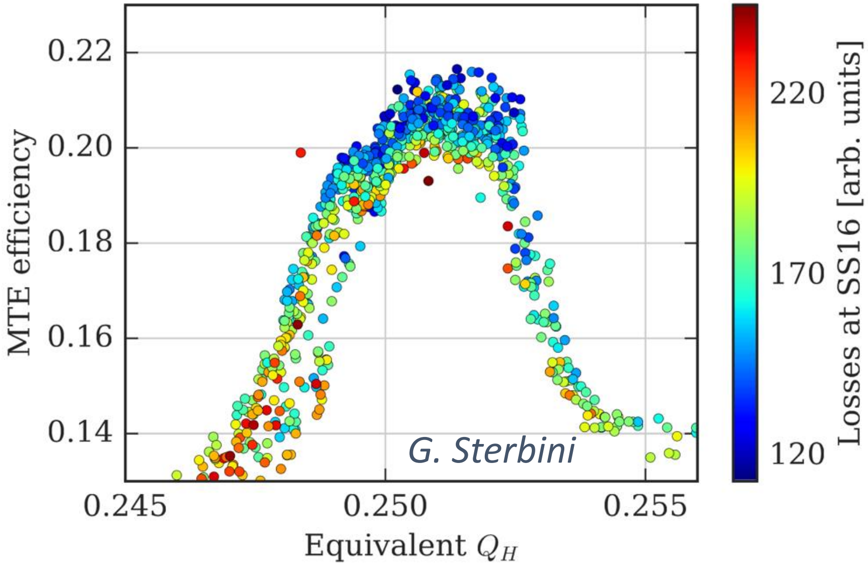
A lot of useful information stored in the **LSA database** (functions, trim history, knob definitions)

- "Conventional" access via **operational applications** (e.g. LHC Trim) or through the **Java API** (only within the Technical Network)
- Recently a **python wrapper** (via Jpype) has been developed → **PjLSA**
  - Only read functions available for now
  - **Accessible** also from the General Purpose Network (**GPN**) within CERN
  - Can be easily **combined with PyTIMBER and PyJAPC** obtaining a **complete scriptable toolbox** for machine studies

In the **injectors** similar tools are used also to automatically send settings and perform **automatic scans**

→ What is the potential for the LHC?

Example: Optimization of transverse excitation for **PS multi-turn extraction**



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Authors: R. De Maria, M. Hostettler, V. Baggiolini

From MD and expert tools to more general usage

Many of the tools developed for Machine Studies and commissioning of new equipment have **potential to become useful in the LHC daily life**

→ Common perception that that this should be further pursued

See for example D. Jacquet at Evian 2016

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What can we practically do to facilitate this process?

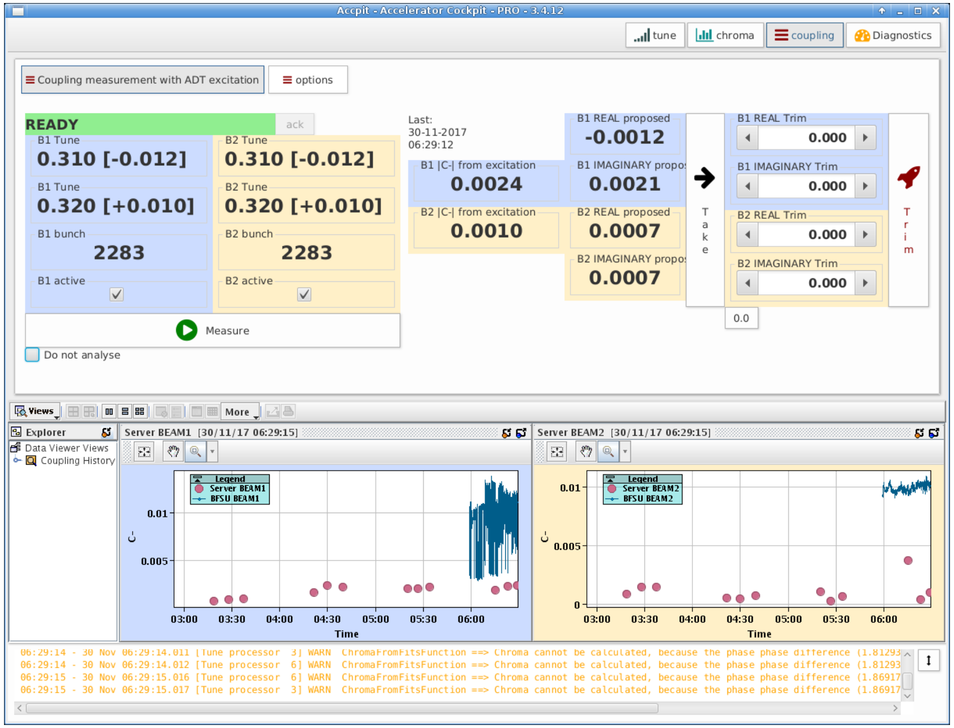
From the BE-CO and BE-OP:

- **Guidelines** and **feedback** on how to develop and maintain (semi-)operational tools within the LHC software ecosystem
- **Accept the python invasion**: this is already happening to some extent (see next slide)
- An agile way to develop **Graphical User Interfaces** (GUIs), e.g. inspector-like

From the MD/equipment groups:

- Code written respecting **basic programming good practices** (a basic training course is often a very good investment ☺)
- Understand and **respect guidelines** defined above
- Minimal commitment for **maintenance** and **support**

Example: **Linear Coupling Measurement**
(ABP/RF development embedded in OP application)



Evolution of python support

Until recently python **not officially supported by BE-CO** (e.g. no official python installation available in Technical Network) ☹

Some **infrastructure built by the users** themselves:

- Different **python installations** available in AFS/NSF user public folders (e.g. BI install.)
- For python tools based on java APIs (pytimber, pyjapc, pjlsa) **CommonBuild Dependency Manager** has been developed (by T. Levens) to automatically identify **java dependencies**, downloads required jars, and setup the required Java Virtual Machine (JVM) within python

Growing **interest and support from BE-CO** in the latest period ☺:

- Python usage (via web-server) **supported in the new CommonBuild** (CBNG) developed by BE-CO-APS
- Contribution in the development of **PjLSA**
- Setup of the **Python Focus Group** (chaired by J. Gonzales Cobas), first objectives:
  - Provide a common forum for python
  - Setup **supported python installation(s)** in the Technical Network (based on LHC Computing Grid) → should be available for the 2018 run
  - Setup basic environment for deployment and maintenance of python applications

Summary

- Several **solutions developed by the MD community** to fully exploit the potential of the LHC hardware and control system in a **flexible** and experimental **way**

- In particular, we start having a **complete and powerful python toolbox** (PyTimber, PyJPAC, PjLSA, PyLogbook) developed **collaboratively** across different teams
  - → Interact with logging, LSA, LHC hardware and perform advanced data analysis all in the same environment
  - → We have only scratched the surface of the potential behind that

- Tools developed for equipment commissioning and Machine Studies **can evolve and prosper the LHC software ecosystem**…

…if we work together to make it happen!

Thanks for your attention!