Data Mining as a Service with ROOT

E. Tejedor, D. Piparo, P. Mató
on behalf of the ROOT team – EP-SFT
L. Mascetti, J. Moscicki, M. Lamanna – IT-ST

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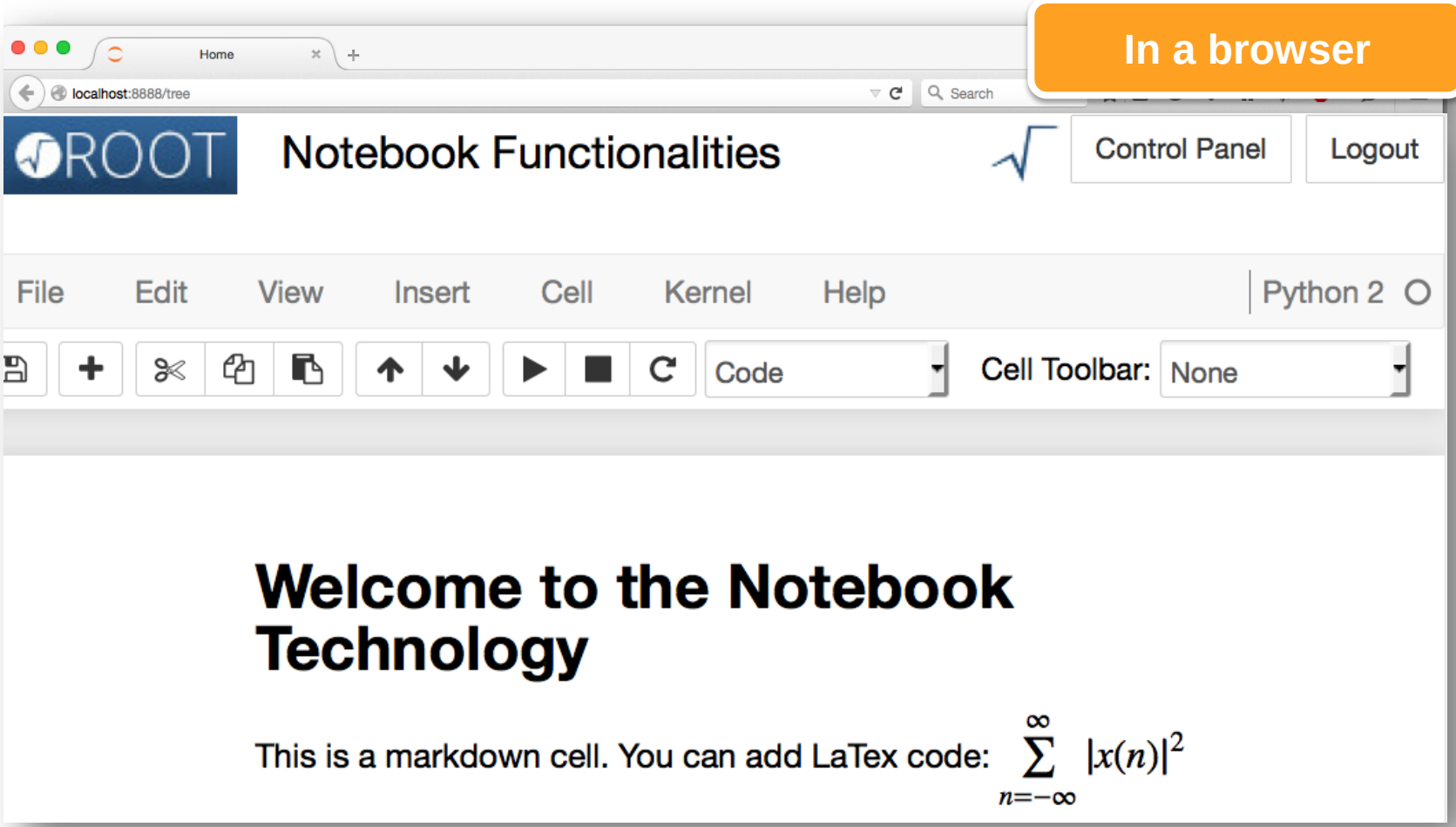
This Talk

- The DMaaS project
- Integration of ROOT with the Notebook technology
  - ROOTbooks for data analysis
- A new service: ROOT & Jupyter Notebooks within the CERN IT services' portfolio
  - Spotlight on storage: EOS, CERNBox

Introduction:
The “Notebook”



In a browser

Text and Formulas

Home

localhost:8888/tree

Search

ROOT

Notebook Functionalities

Control Panel | Logout

File | Edit | View | Insert | Cell | Kernel | Help | Python 2

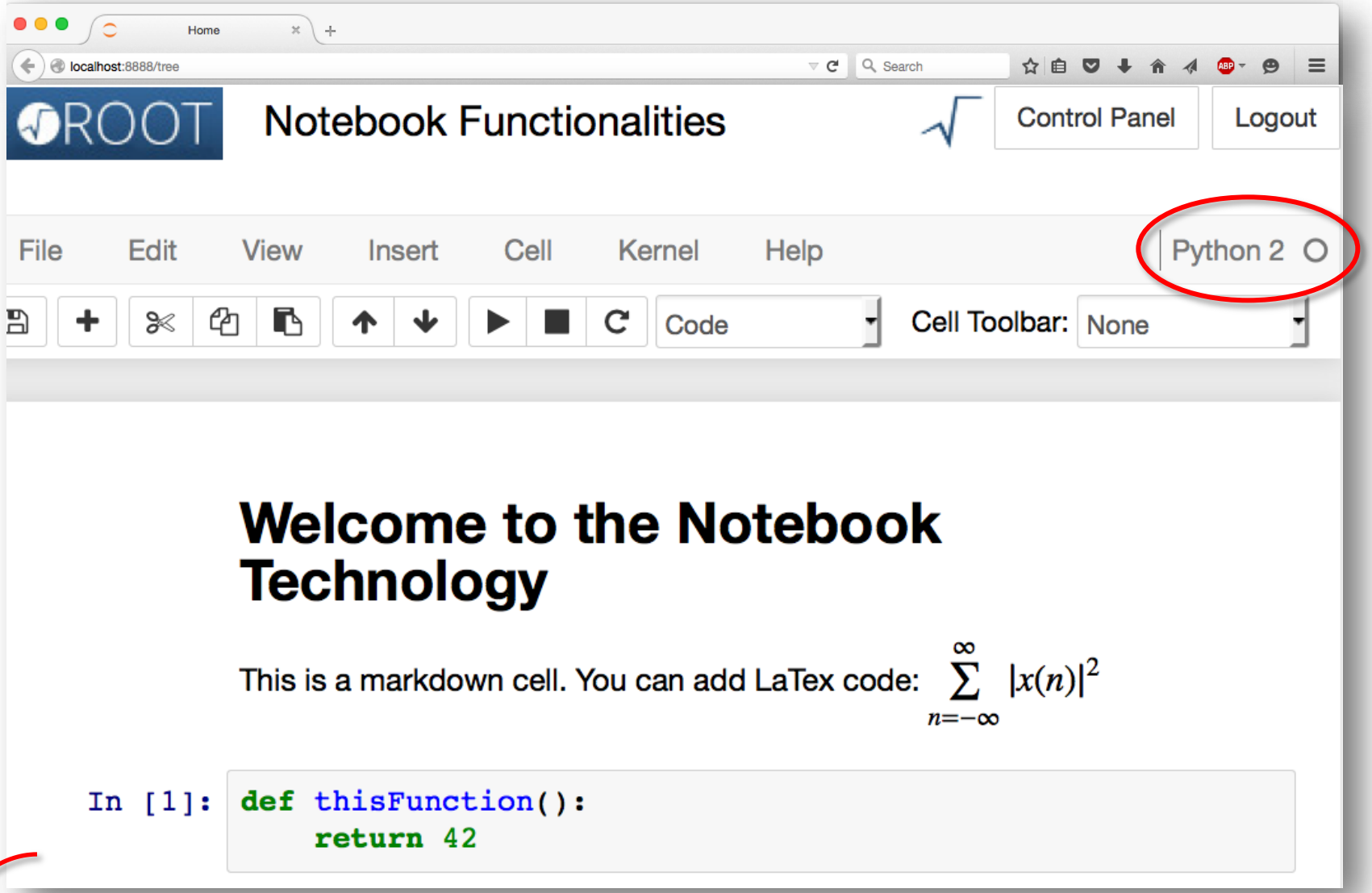
Code | Cell Toolbar: None

Welcome to the Notebook Technology

This is a markdown cell. You can add LaTex code: $\sum_{n=-\infty}^{\infty} |x(n)|^2$

In [1]:
```
def thisFunction():
    return 42
```

Code



This is a notebook in Python

Code

Home

localhost:8888/tree

ROOT

Notebook Functionalities

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Code | Cell Toolbar: None

Welcome to the Notebook Technology

This is a markdown cell. You can add LaTex code: $\sum_{n=-\infty}^{\infty} |x(n)|^2$

In [1]:
```
def thisFunction():
    return 42
```

In [2]:
```
thisFunction()
```

Out[2]: 42

Code

```
In [1]: def thisFunction():
            return 42

In [2]: thisFunction()

Out[2]: 42

In [3]: %%bash
        curl rootaasdemo.web.cern.ch/rootaasdemo/SaasFee.jpg \
        > SF.jpg
```

We can invoke commands in the shell…

Shell Commands

```
In [1]: def thisFunction():
            return 42

In [2]: thisFunction()

Out[2]: 42

In [3]: %%bash
        curl rootaasdemo.web.cern.ch/rootaasdemo/SaasFee.jpg \
        > SF.jpg
```

```
  % Total    % Received % Xferd  Average Speed   Time
  Time     Time  Current
                                 Dload  Upload   Total
  Spent    Left  Speed
100  128k  100  128k    0     0  2731k      0 --:--:--
--:--:-- --:--:-- 2787k
```

... and get their output

Shell Commands

In [1]:
```
def thisFunction():
    return 42
```

In [2]:
```
thisFunction()
```

Out[2]:
```
42
```

In [3]:
```
%%bash
curl rootaasdemo.web.cern.ch/rootaasdemo/SaasFee.jpg \
> SF.jpg
```

```
  % Total    % Received % Xferd  Average Speed   Time
  Time     Time  Current
                                 Dload  Upload   Total
  Spent    Left  Speed
100  128k  100  128k    0     0  2731k      0 --:--:--
--:--:-- --:--:-- 2787k
```

In [4]:
```
from IPython.display import Image
Image(filename="./SF.jpg",width=225)
```

In [1]:
```
def thisFunction():
    return 42
```

In [2]:
```
thisFunction()
```

Out[2]:
```
42
```

In [3]:
```
%%bash
curl rootaasdemo.web.cern.ch/rootaasdemo/SaasFee.jpg \
> SF.jpg
```

```
  % Total    % Received % Xferd  Average Speed   Time
  Time     Time  Current
                                 Dload  Upload   Total
  Spent    Left  Speed
100  128k  100  128k    0     0  2731k      0 --:--:--
--:--:-- --:--:-- 2787k
```

In [4]:
```
from IPython.display import Image
Image(filename="./SF.jpg",width=225)
```

Out[4]:

Images

In a browser

Text and Formulas

Code

Shell Commands

Images

In [1]:

In [2]:
```
thisFunction()
```

Out[2]: 42

In [3]:
```
%%bash
curl rootaasdemo.web.cern.ch/rootaasdemo/SaasFee.jpg \
> SF.jpg
```

```
  % Total    % Recei                                ed   Time
  Time     Time  Cu
                                   Dload  Upload   Total
  Spent    Left  Speed
100  128k  100  128k    0     0  2731k      0 --:--:--
--:--:-- --:--:-- 2787k
```

In [4]:
```
from IPython.display import Image
Image(filename="./SF.jpg",width=225)
```

Out[4]:

The DMaaS Project

Data mining with ROOT "as a service"

Interface: Jupyter Notebooks

Goals:

- Use ROOT only with a web browser
  - Platform independent ROOT-based data analysis
  - Calculations, input and results "in the cloud"
- Allow easy sharing of scientific results: plots, data, code
  - Storage is crucial
- Simplify teaching of data processing and programming
- Potential integration with other analysis ecosystems: R, Python, …

Integration of ROOT with Notebooks

ROOT

JupyROOT
(ROOT-Jupyter integration)

Home

localhost:8888/tree

Search

ROOT

CERNBox

Terminal

Control Panel

Logout

Files

Running

Clusters

A Choice of Kernels

Select items to perform actions on them.

Upload

New

- PresentationNotebooks
- cernbox
- HowTo_ROOT-Notebooks.ipynb
- HowTo_ROOT-Notebooks_Long.ipynb
- My First Notebook.ipynb
- Untitled.ipynb

Text File

Folder

Terminal

Notebooks

Python 2

Python 3

ROOT C++

ROOT RaaSInAction CERNBox Terminal Control Panel Logout

File Edit View Insert Cell Kernel Help Python 2

Code Cell Toolbar: None

```
In [1]: import ROOT # This triggers the integration layer
```

```
Welcome to JupyROOT 6.07/03
```

ROOT RaaSInAction CERNBox Terminal Control Panel Logout

File Edit View Insert Cell Kernel Help Python 2

Code Cell Toolbar: None

```
In [1]: import ROOT # This triggers the integration layer

        Welcome to JupyROOT 6.07/03

In [ ]: %%cpp
        auto myHisto = TH
```

TH1
TH1C
TH1D
TH1F
TH1I
TH1K
TH1S
TH2
TH2C
TH2D

C++ Cells in Python Notebooks

ROOT Tab Completion

ROOT RaaSInAction CERNBox Terminal Control Panel Logout

File Edit View Insert Cell Kernel Help Python 2

Code Cell Toolbar: None

In [1]:
```
import ROOT # This triggers the integration layer
```

```
Welcome to JupyROOT 6.07/03
```

In [2]:
```
%%cpp
auto myHisto = TH1F("h","MyData;X;Y",64,-4,4); // C++11
```

ROOT RaaSInAction CERNBox Terminal Control Panel Logout

File Edit View Insert Cell Kernel Help Python 2

Code Cell Toolbar: None

In [1]:
```
import ROOT # This triggers the integration layer
```

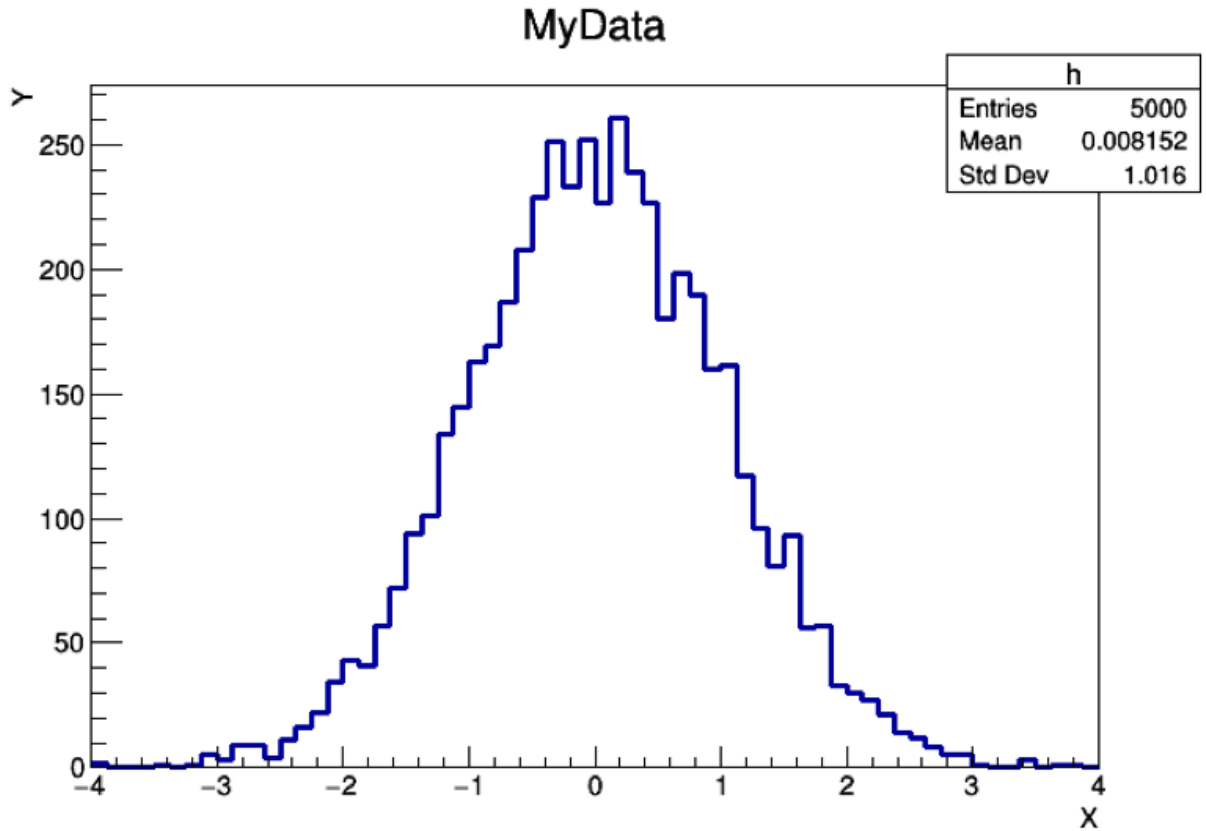
```
Welcome to JupyROOT 6.07/03
```

In [2]:
```
%%cpp
auto myHisto = TH1F("h","MyData;X;Y",64,-4,4); // C++11
```

In [3]:
```
h = ROOT.myHisto # Find the variable back in Python!
h.FillRandom("gaus")
c = ROOT.TCanvas()
h.Draw()
c.Draw()
```

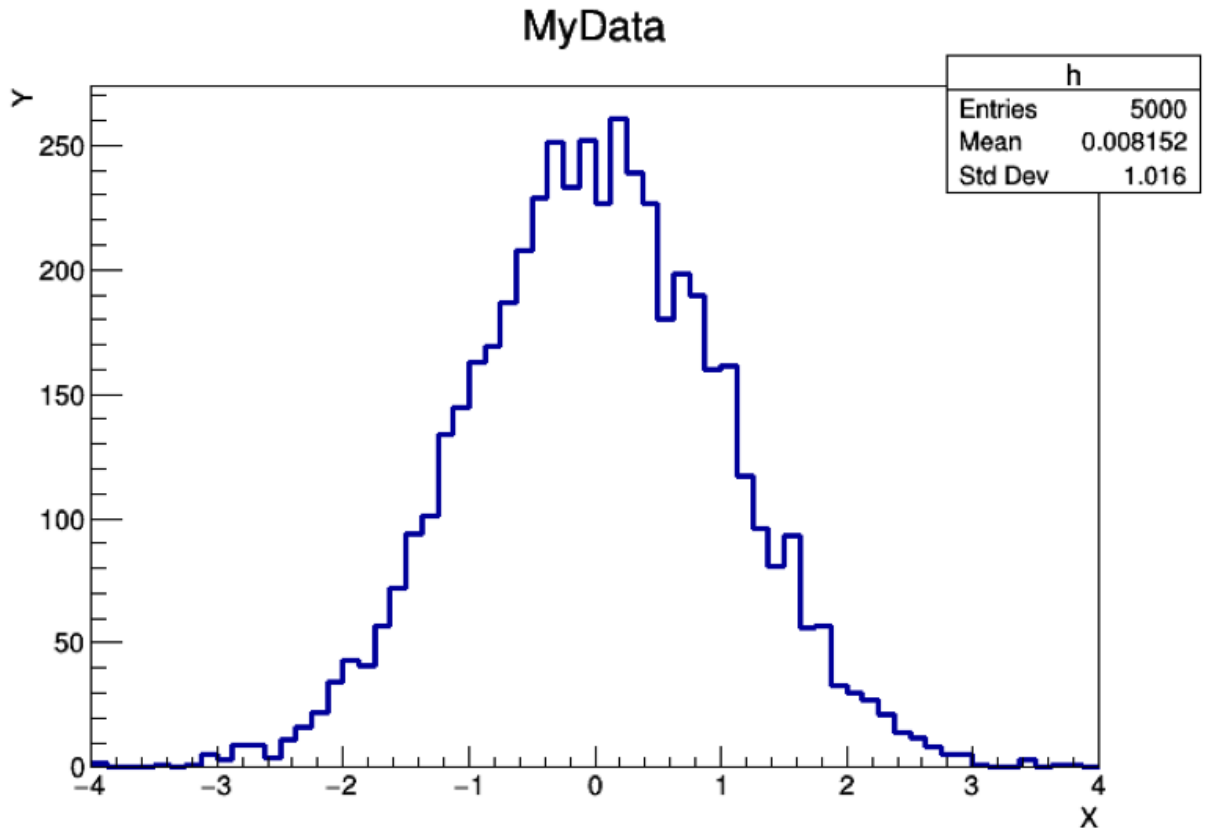
C++-Python Interoperability

```
c.Draw()
```



Seamless display of graphics

```
c.Draw()
```



Syntax Highlighting

In [4]:
```
%%cpp -d
double myG(double* x, double* par){
  auto res = (x[0]-par[1])/par[2];
  auto e = -.5 * res * res;
  return par[0] * exp(e); // declare function
}
```

In [4]:
```
%%cpp -d
double myG(double* x, double* par){
  auto res = (x[0]-par[1])/par[2];
  auto e = -.5 * res * res;
  return par[0] * exp(e); // declare function
}
```

In [5]:
```
f = ROOT.TF1("myGf",ROOT.myG,-5,5,3)
f.SetParameters(200,0,1);f.SetParNames("N","mu","sigma")
fr = ROOT.h.Fit(f,"S") # Capture printouts
```

In [4]:
```
%%cpp -d
double myG(double* x, double* par){
  auto res = (x[0]-par[1])/par[2];
  auto e = -.5 * res * res;
  return par[0] * exp(e); // declare function
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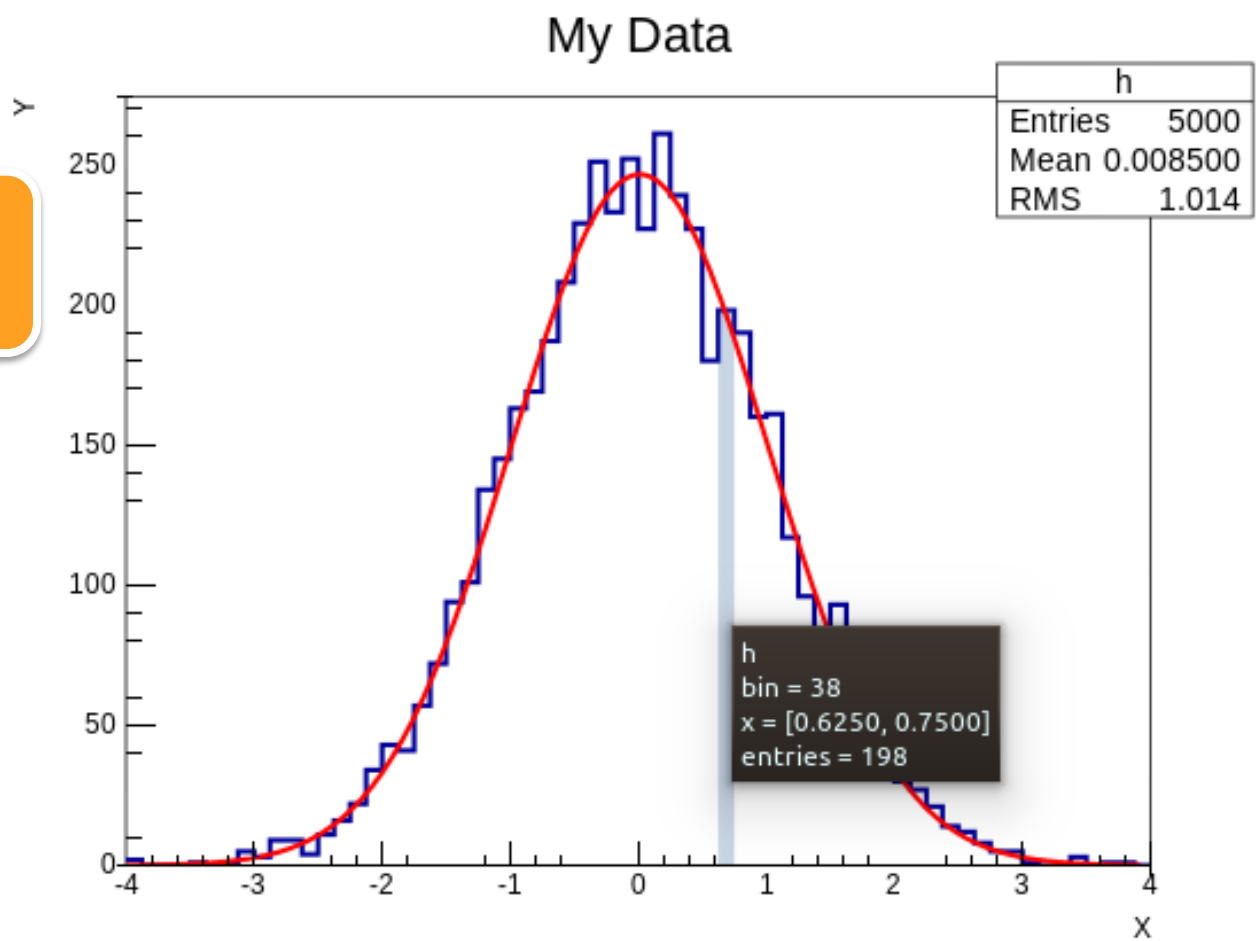
In [5]:
```
f = ROOT.TF1("myGf",ROOT.myG,-5,5,3)
f.SetParameters(200,0,1);f.SetParNames("N","mu","sigma")
fr = ROOT.h.Fit(f,"S") # Capture printouts
```

```
 FCN=47.4997 FROM MIGRAD    STATUS=CONVERGED      69 CALLS          70 TO
TAL
                     EDM=2.04372e-09    STRATEGY= 1      ERROR MATRIX ACC
URATE
  EXT PARAMETER                                   STEP         FIRST
  NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
   1  N           2.46469e+02   4.31493e+00   1.19092e-02  -5.38026e-06
   2  mu          1.04793e-02   1.43576e-02   4.87640e-05   4.15093e-03
   3  sigma       1.00316e+00   1.03818e-02   2.86307e-05  -2.55310e-04
```

```
1   N        2.46469e+02   4.31493e+00   1.19092e-02  -5.38026e-06
2   mu       1.04793e-02   1.43576e-02   4.87640e-05   4.15093e-03
3   sigma    1.00316e+00   1.03818e-02   2.86307e-05  -2.55310e-04
```

```
In [6]: ROOT.enableJSVis() # Not active by default yet!
        c.Draw()
        ROOT.disableJSVis()
```

JSROOT Visualisation



ROOT

CERNBox | Terminal | Control Panel | Logout

Files | Running | Clusters

Select items to perform actions on them.

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Text File
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Terminal

Notebooks
Python 2
Python 3
ROOT C++

A C++ ROOTbook

ROOT RIACpp CERNBox Terminal Control Panel Logout

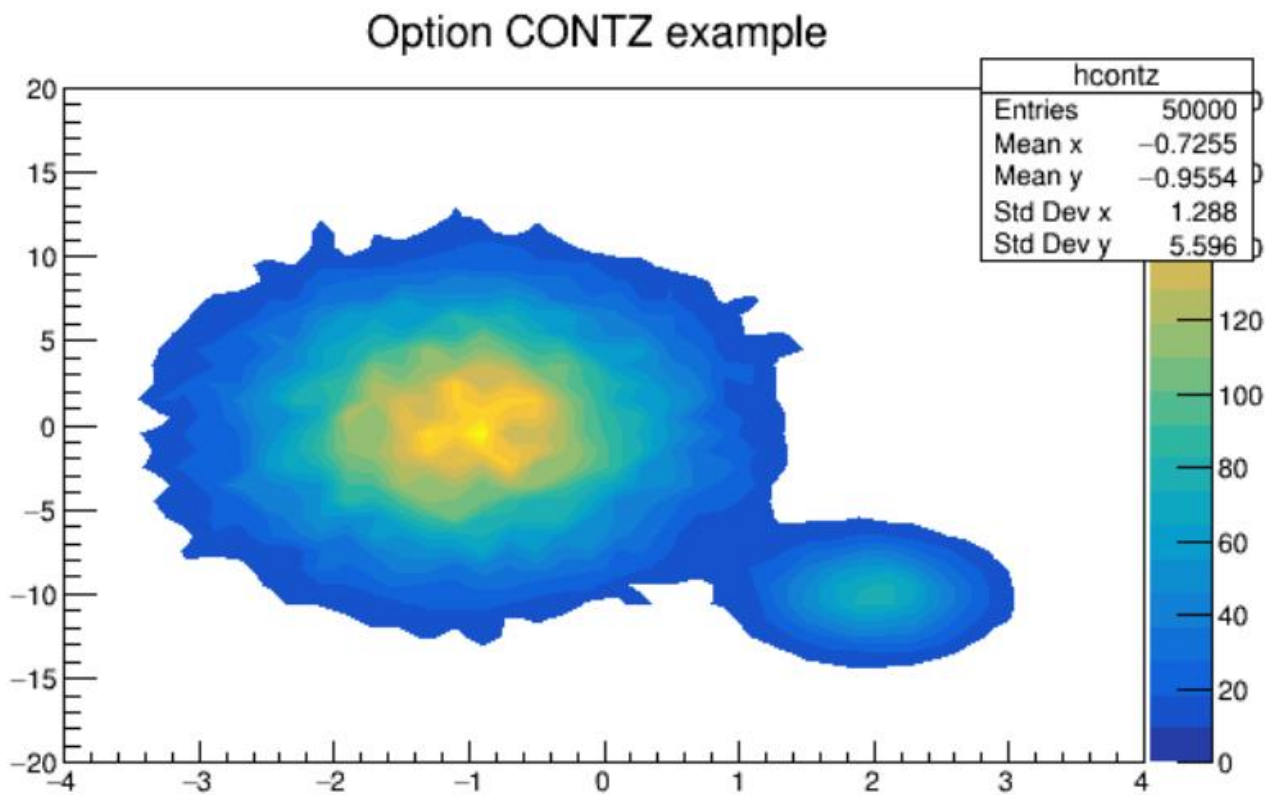
File Edit View Insert Cell Kernel Help ROOT C++

Code Cell Toolbar: None

In [1]:
```
TCanvas c1("c1","c1",600,400);
TH2F hcontz("hcontz","Option CONTZ example ",40,-4,4,40,-20,20);
Float_t px, py;
for (Int_t i = 0; i < 25000; i++) {
   gRandom->Rannor(px,py);
   hcontz.Fill(px-1,5*py);
   hcontz.Fill(2+0.5*px,2*py-10.,0.1);
}
hcontz.Draw("CONTZ");
c1.Draw();
```

A C++ ROOTbook

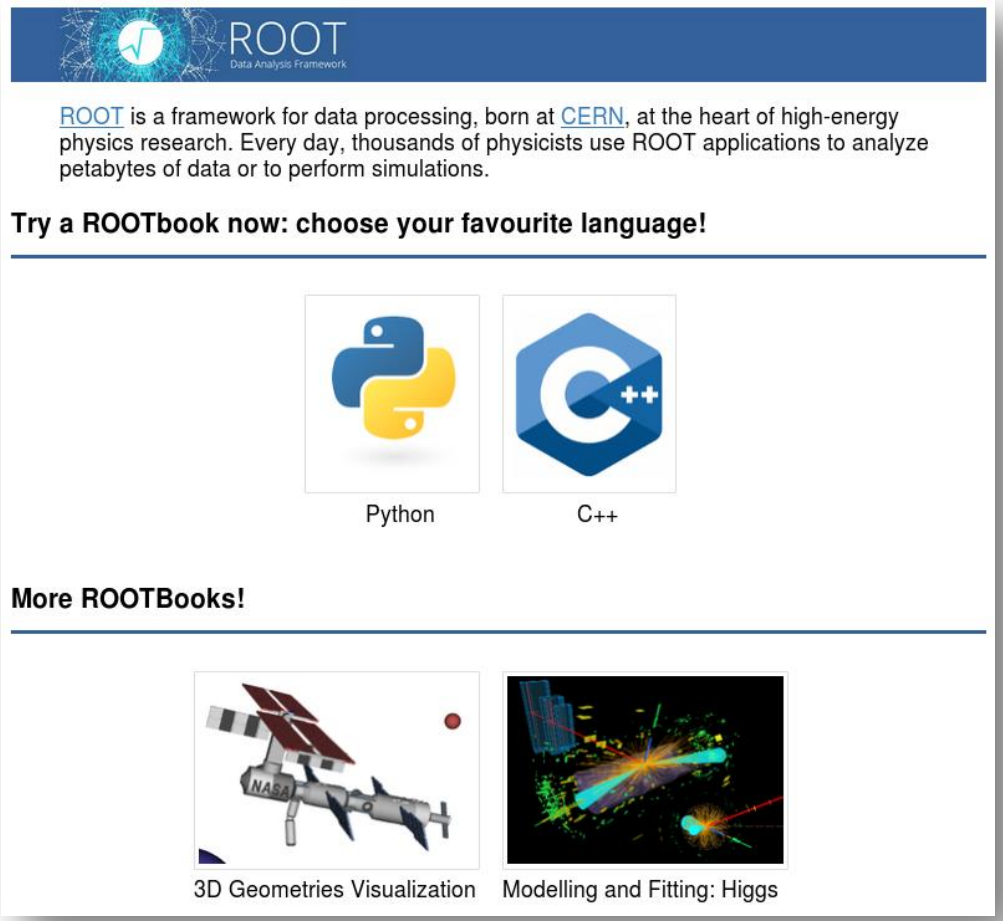
```
hcontz.Draw("CONTZ");
c1.Draw();
```



Try It Out! – ROOT Binder

binder

http://mybinder.org/repo/cernphsft/rootbinder



Anonymous access

View, Create and Run ROOTbooks!

Try It Out! - Local server

Follow some simple instructions in:

https://root.cern.ch/how/how-create-rootbook

and…

```
$ root --notebook
```

This command:

1. Starts a local notebook server
2. Connects to it via the browser

Provides a ROOT C++ kernel and the rest of ROOTbook goodies

Documentation, Links

- **ROOTbooks How-Tos**

https://root.cern.ch/howtos#Jupyter%20Notebooks

- **ROOT bindings for Jupyter**

https://github.com/root-mirror/root/tree/master/bindings/pyroot/JupyROOT

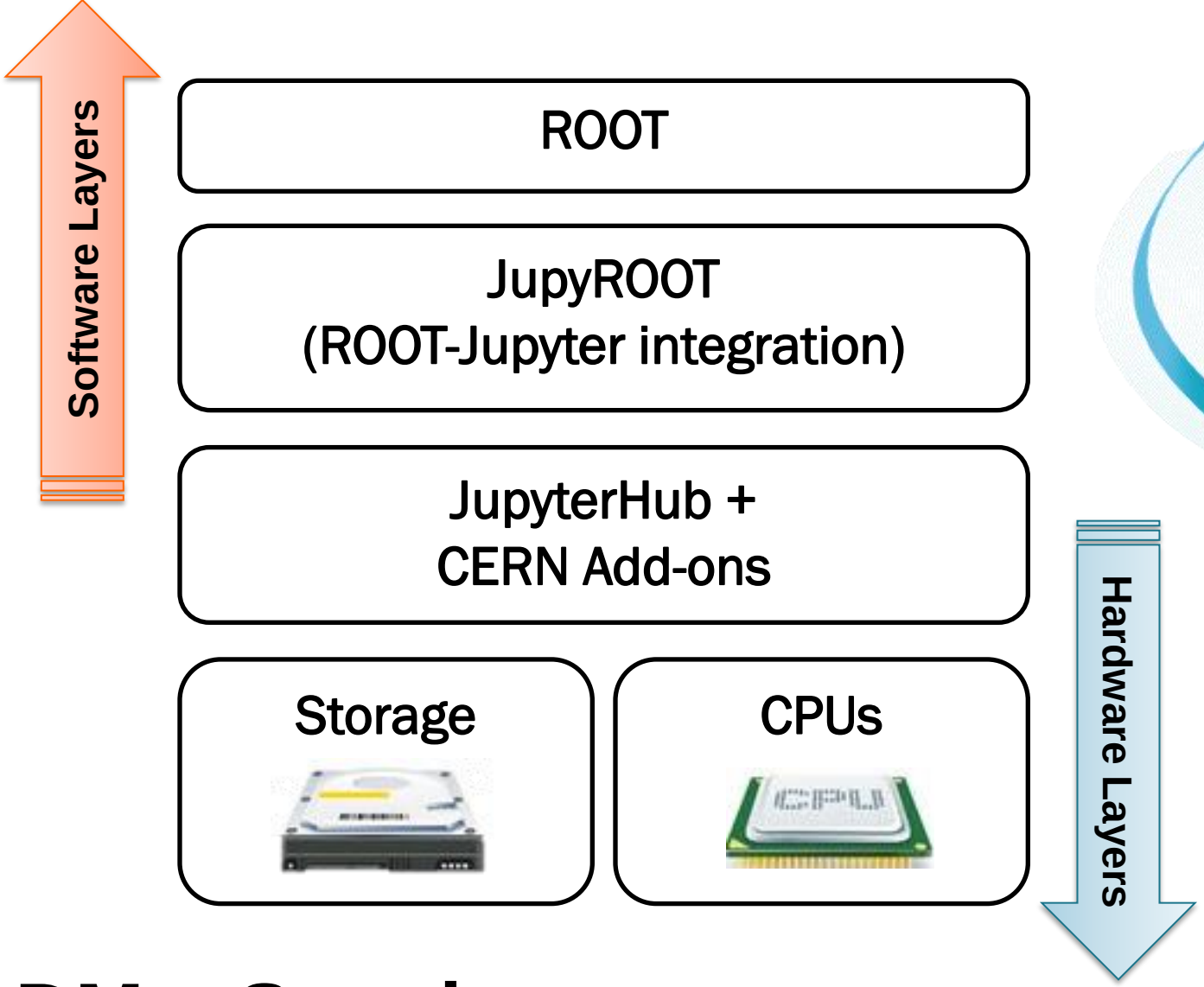
- **ROOT C++ Kernel**

https://github.com/ipython/ipython/wiki/IPython-kernels-for-other-languages

- **Examples** (15 already) from the *new* ROOT Tutorials can be found at:

https://root.cern.ch/code-examples#notebooks

both in Python and C++ (and mixed!)

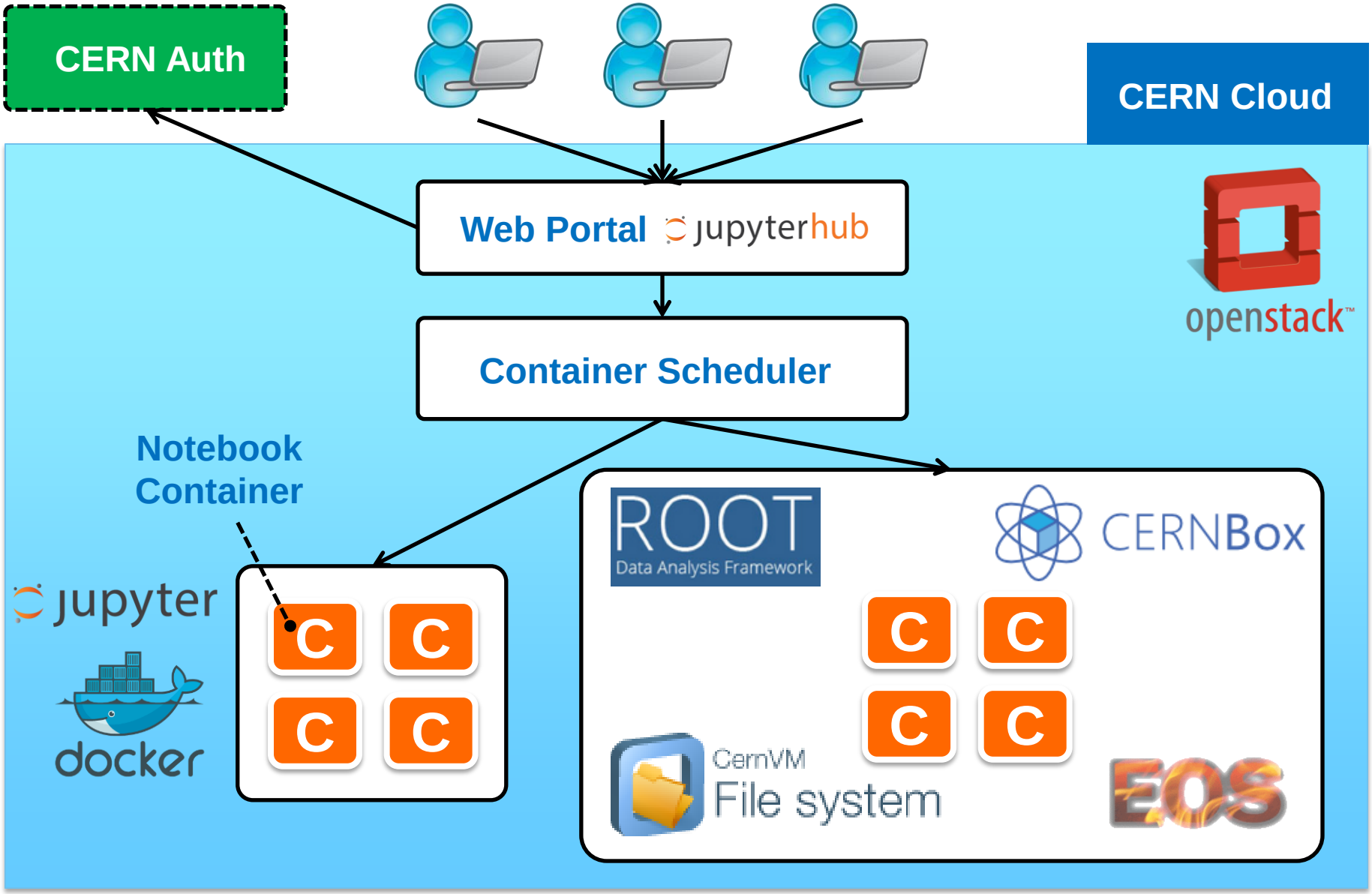


DMaaS and CERN services' Portfolio

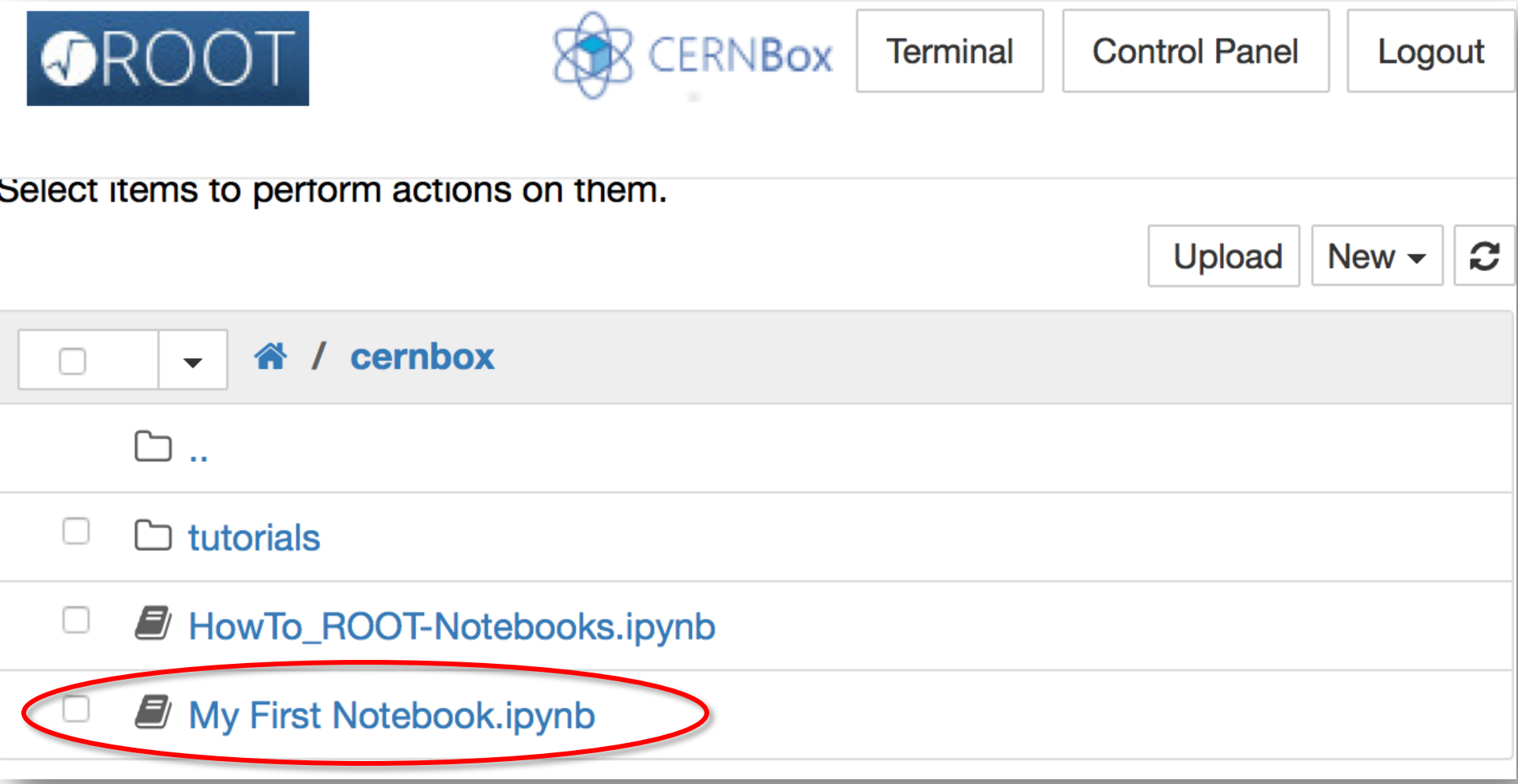
Integration With CERN's Ecosystem

- Centrally provide ROOT as a Service
- Authentication with CERN credentials
- Infrastructure: virtual machines in OpenStack Cloud
- Software distribution: CVMFS
- Storage access: CERNBox, EOS
  - All data potentially available!
- Synergy with document sharing
  - Notebook visualiser already available in Indico

Pilot Service (Distributed)



CERNBox: Store your data



CERNBox: Browse

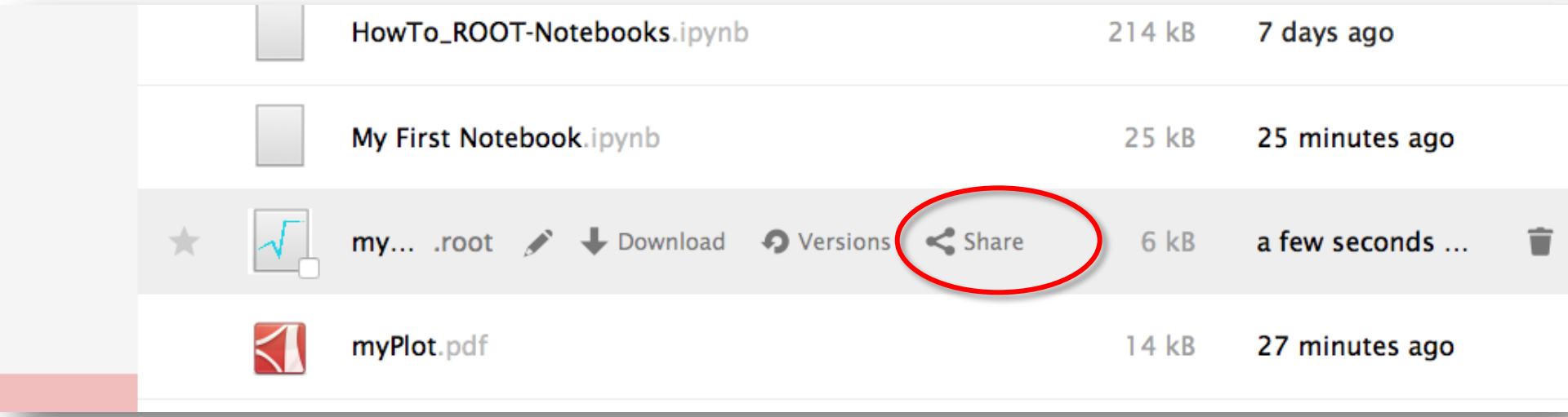
Files ▾ Help & Download Clients rw15u098 ▾

All files
Favorites
Shared with you
Shared with others
Shared by link
Deleted files

New

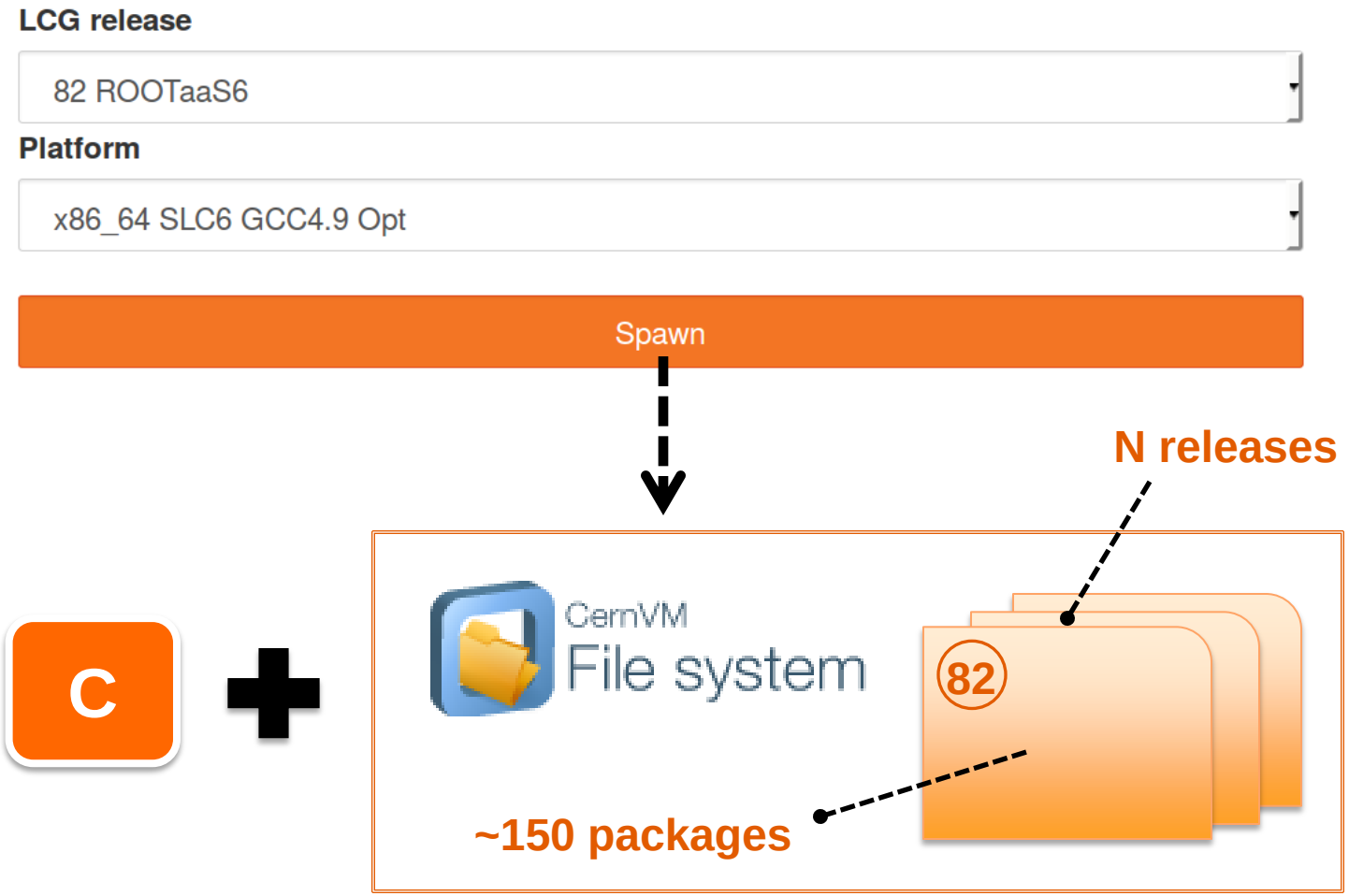
Name ▲	Size	Modified
.ipynb_checkpoints	0 kB	2 minutes ago
My First Notebook.ipynbye0opi_m	0 kB	a few seconds ago
tutorials	0 kB	7 days ago
HowTo_ROOT-Notebooks.ipynb	214 kB	7 days ago
My First Notebook.ipynb	24 kB	2 minutes ago
myOutputFile.root	6 kB	3 minutes ago
myPlot.pdf	14 kB	3 minutes ago

CERNBox: Share



CVMFS: Software Environment

- Define a custom environment via a web form:



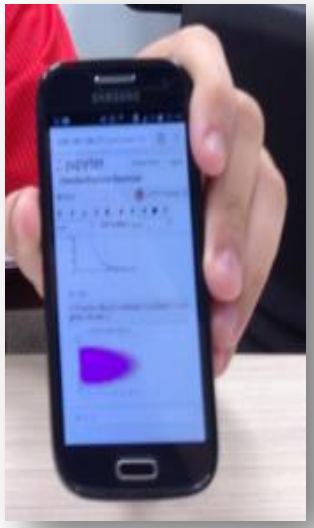
Success Stories

- CERN Summer Student Program, ROOT tutorial: Interactive notebooks offered
  - **50 participants, perfect scaling, a success!**

  https://indico.cern.ch/event/407519
- Data Science @ LHC Workshop, Multivariate analysis tutorial

  http://indico.cern.ch/event/395374/
- E-Planet exchange @ UERJ, Brazil
  - 30 participants, every day for a week, 3h a day

    https://indico.cern.ch/event/402660/



Conclusions, Plans

- ROOT is now integrated with notebooks
  - Python and C++ interactive shells
  - Tab completion, C++/Python integration, syntax highlighting, graphics inlining
  - Available now!
  - Future: leverage ROOT-R integration, TMVA, …
- Integration with the CERN services portfolio
  - Collaborating with IT department
    - Special thanks to IT-ST
  - Plan to deliver a Pilot Service in 2016