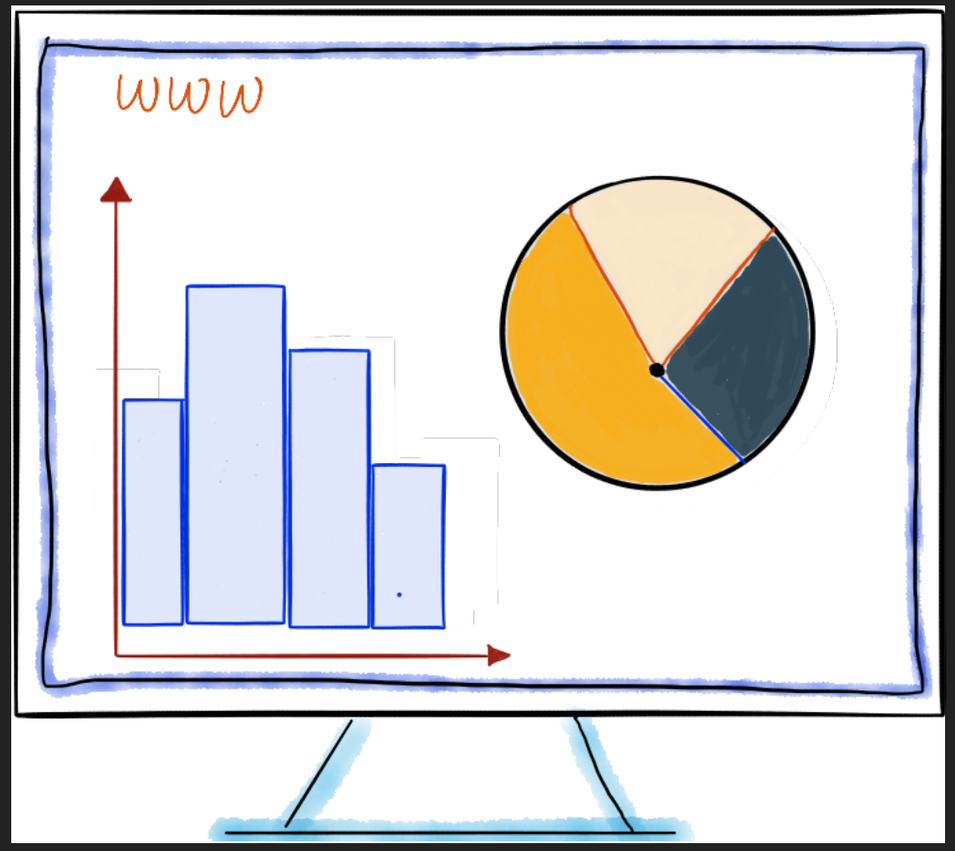
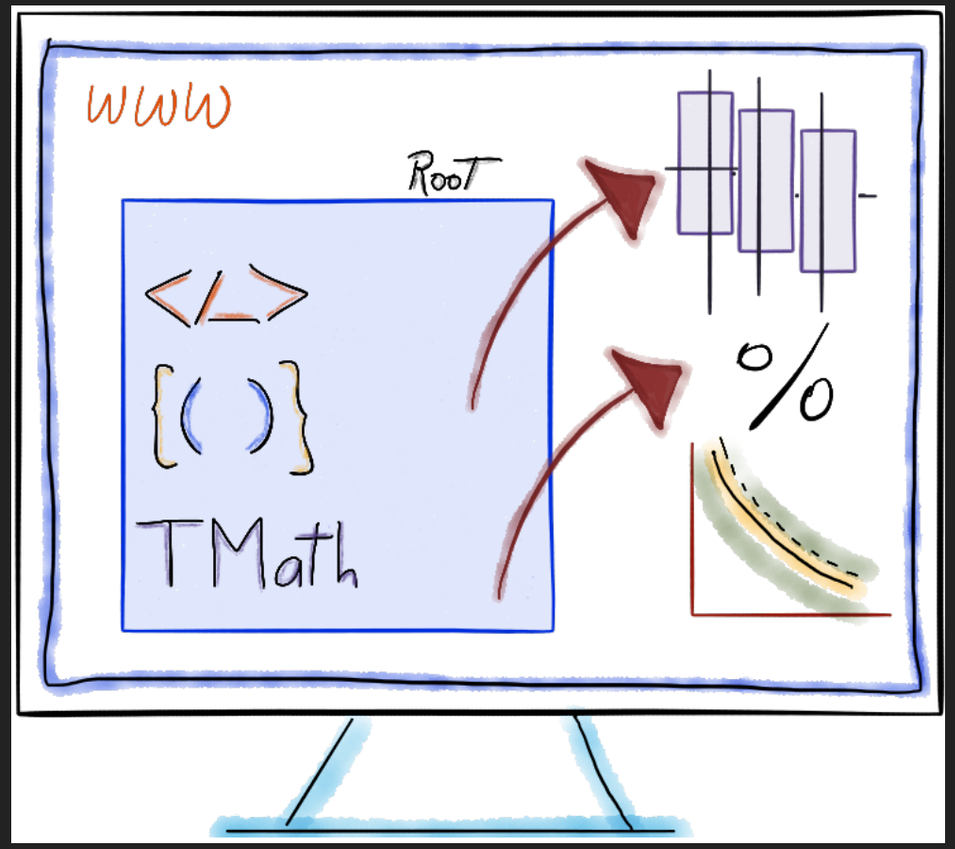


ATLAS OPEN DATA

MAKING YOUR OWN PARTICLE PHYSICS DISCOVERIES

OUTLINE

- What is ATLAS Open Data?
- How to make your own particle physics discoveries?
- What does it have to do with Maths Methods?
- Questions throughout!



WHO AM I?

ABOUT ME

- 1st year PhD student
- In ATLAS group
- Part of Experimental Particle Physics (EPP)
- New to Sussex

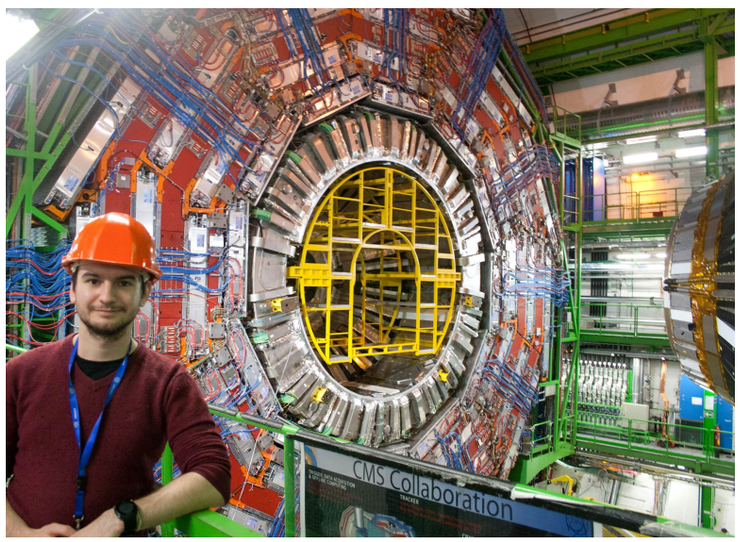
ATLAS OPEN DATA TEAM @ SUSSEX

Kerim Suruliz
Post-doc

Kate Shaw
Lecturer

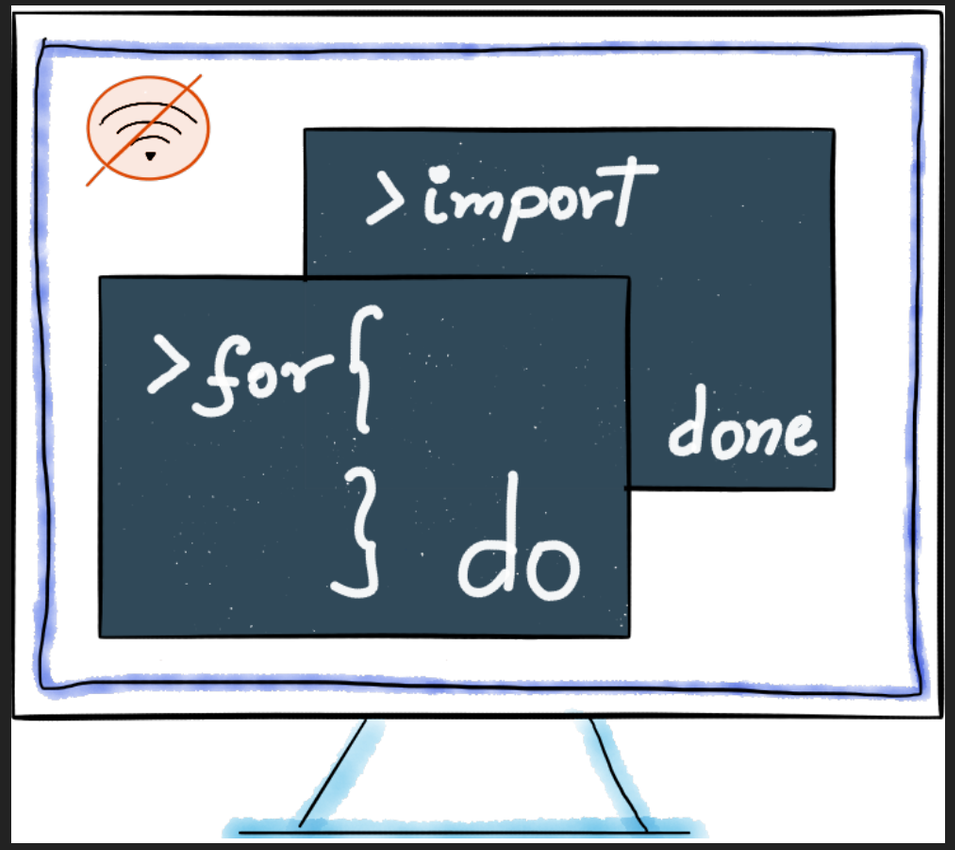
Lily Asquith
Lecturer

Josh McKeown
3rd Year student



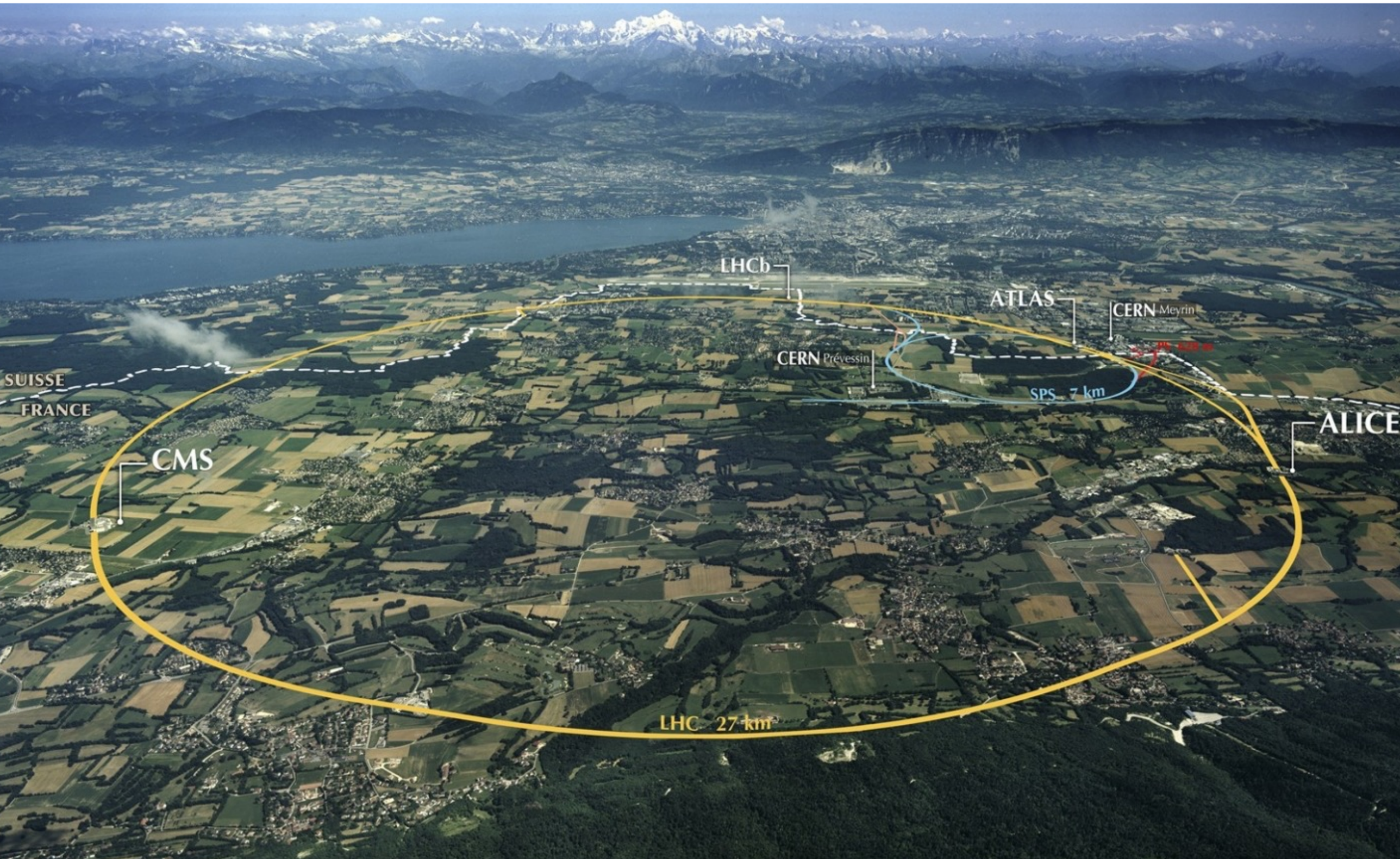
Tom Stevenson
Post-doc

ATLAS EXPERIMENT



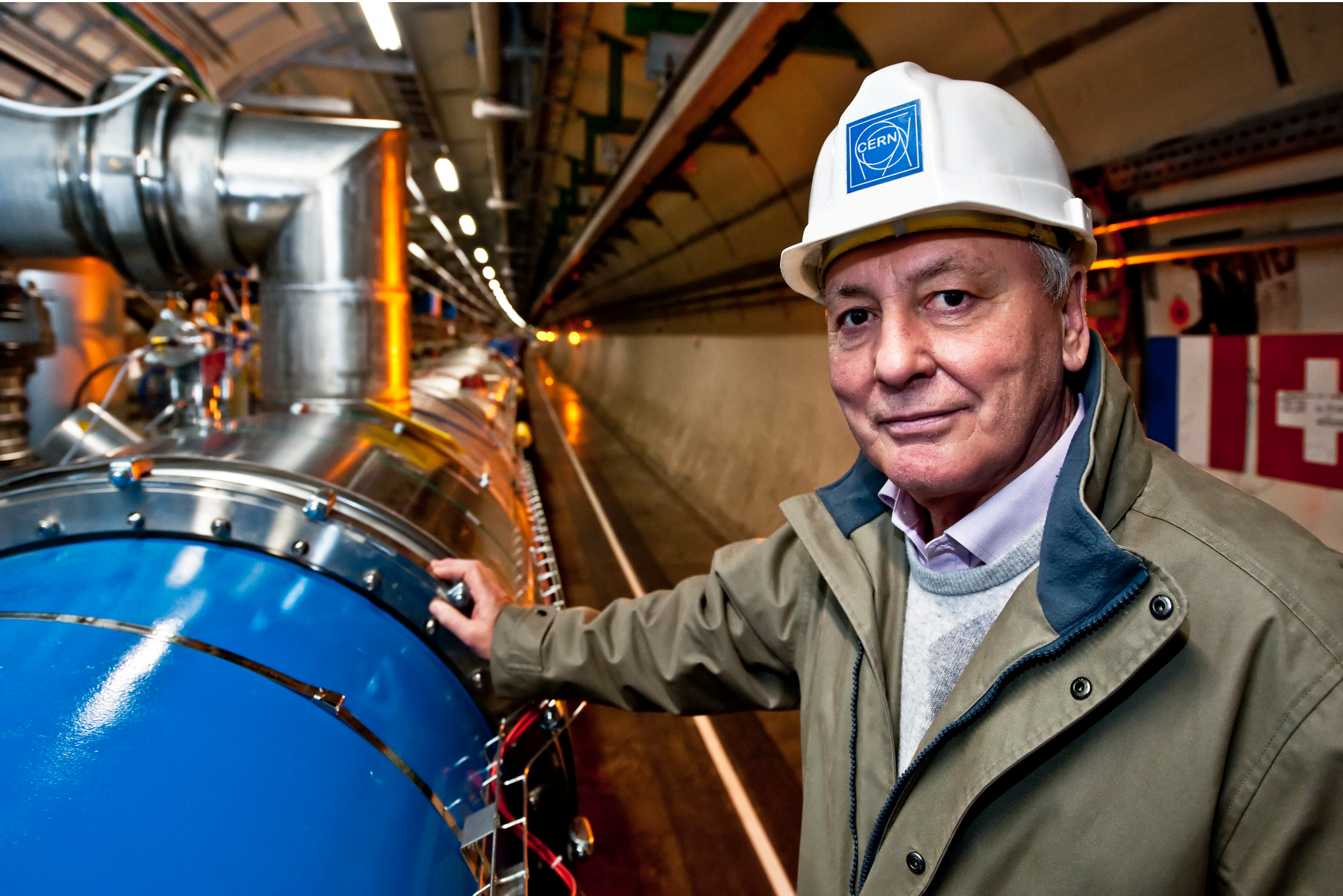
WHAT IS ATLAS OPEN DATA?

THE LARGE HADRON COLLIDER (LHC) @ CERN

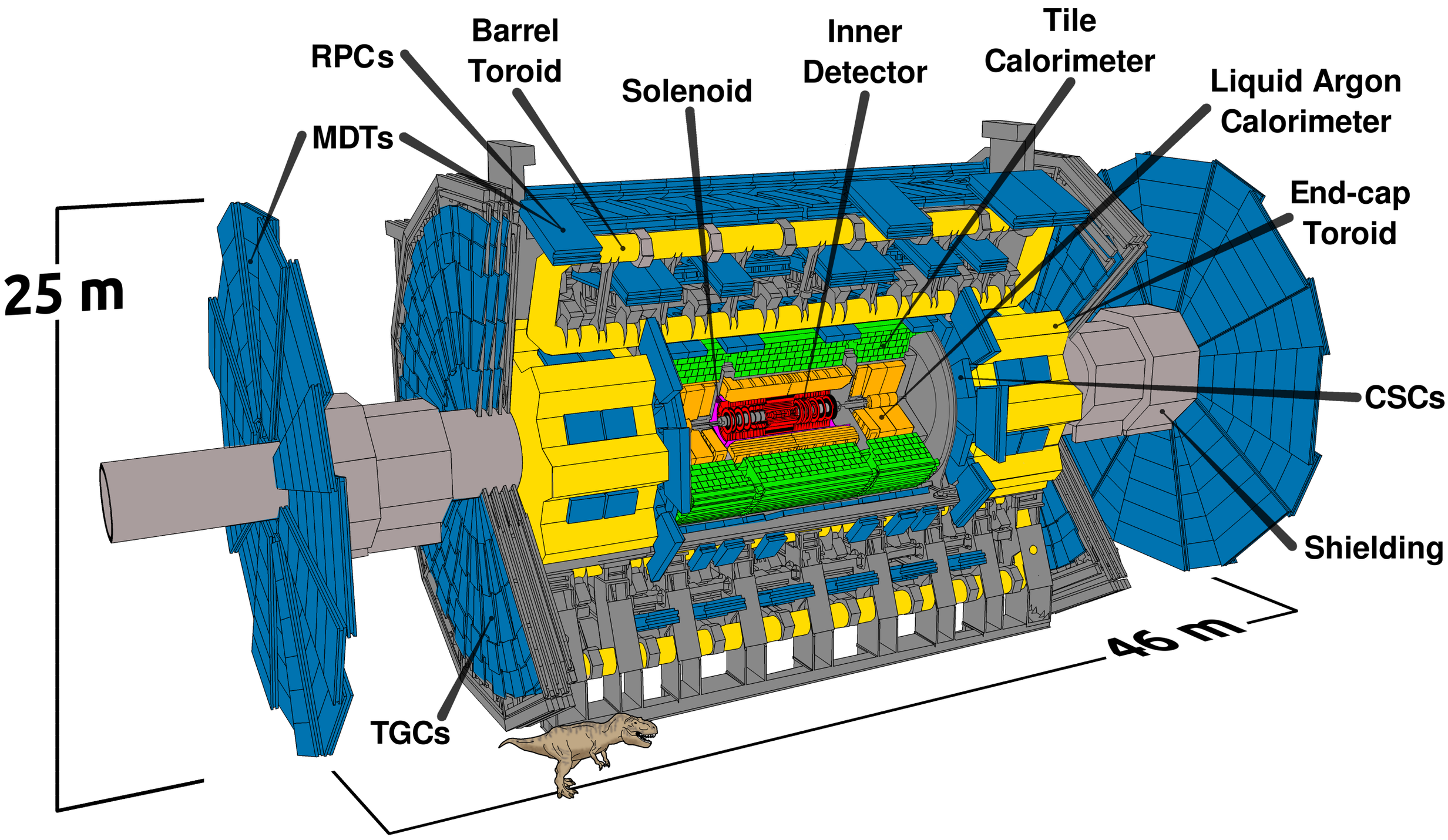


THE LARGE HADRON COLLIDER (LHC) @ CERN

LYN EVANS – LHC PROJECT LEADER



THE ATLAS DETECTOR



THE ATLAS DETECTOR

INTRO VIDEO

OPEN DATA

- Definition: Release data publicly
- For ATLAS:
  - visualise data
  - download & use data
  - open-source software for you to make your own discoveries

WHAT & WHO?

- Education, training, outreach
- Public data, educational tools
- Software, platforms, analysis examples
- Analyse ATLAS data, learn particle physics techniques
- Who? YOU! (University students)

AVAILABLE DATA

- Real data from 100 trillion proton–proton collisions
- Simulations of Standard Model & Beyond Standard Model processes

PARTICLES TO STUDY

up

charm

top

gluon

Higgs

down

strange

bottom

photon

dark
matter

electron

muon

tau

Z

electron
neutrino

muon
neutrino

tau
neutrino

W

ATLAS EXPERIMENT

(ANTI)PARTICLES TO STUDY

anti-up

anti-charm

anti-top

gluon

Higgs

anti-down

anti-strange

anti-bottom

photon

positron

anti-muon

anti-tau

Z

anti-electron neutrino

anti-muon neutrino

anti-tau neutrino

W

dark matter

ATLAS EXPERIMENT

WHAT IS ATLAS OPEN DATA?

WEBSITE

take our 15 seconds survey!... ...or do you have 60 seconds?! DOWNLOAD COMMUNITY

open data ATLAS

Get Started
Documentation, Histogram Analyser, Analysis Browser

Web Analysis
Documentation, Analysis ROOTbooks

Data & Tools
Documentation, Datasets, Software, Virtual Machines

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Access Open Data from the ATLAS Experiment at CERN

The ATLAS data from 100 trillion proton collisions is now public! This marks the world's first open release of 8 TeV data, gathered from the Large Hadron Collider in 2012.

ATLAS Open Data guides you through how to visualise the data, how to download and use the data, and even provides open-source software for you to make your own discoveries. **Check the introductory video and get started now!**

Provide Feedback

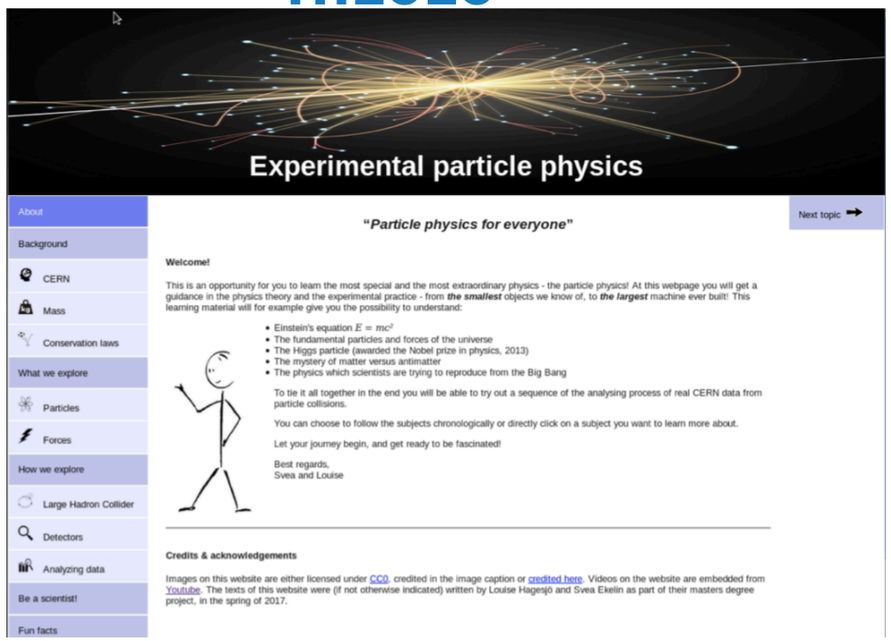
Note! ATLAS Open Data is primarily aimed at University students, postgraduate and external researchers. Please read more in Target section

- opendata.atlas.cern

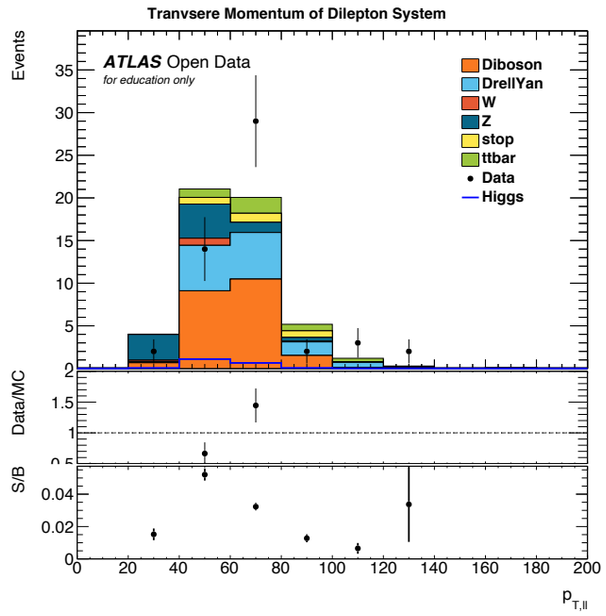
ATLAS EXPERIMENT

WHAT IS ATLAS OPEN DATA?

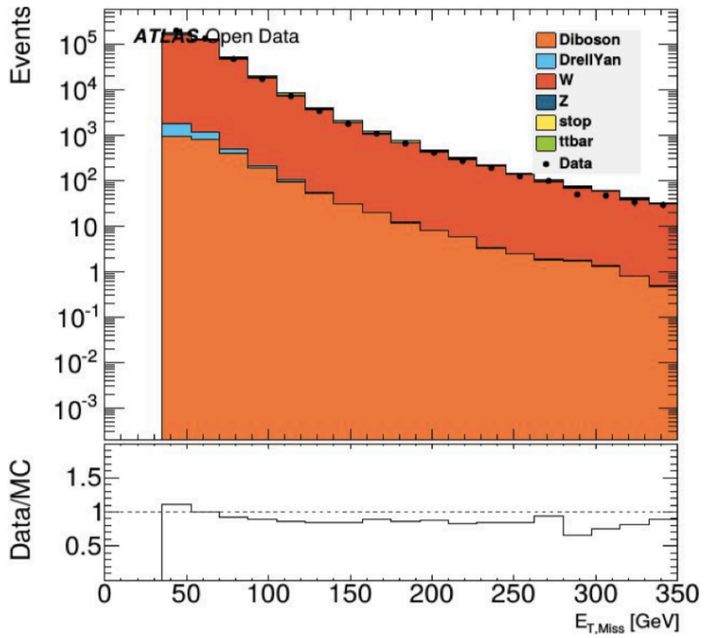
THESES



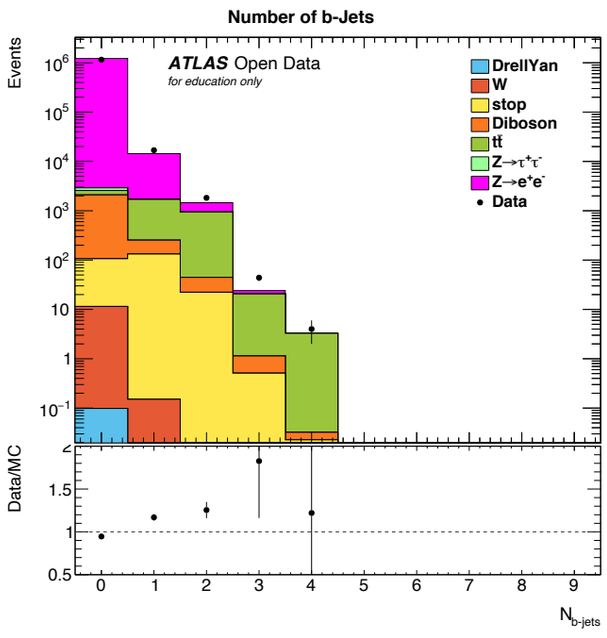
[Making ATLAS Data from CERN Accessible to the General Public: The Development and Evaluation of a Learning Resource in Experimental Particle Physics]



[Reconstruction of the invariant masses of bosons of the Standard Model using public data from ATLAS Open Data]

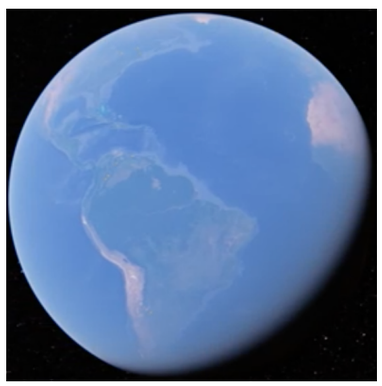


[Perspectives and Evaluation of Dark Matter production in association with a light quark, a heavy quark (b-quark) or an electroweak boson in particle colliders at a centre-of-mass energy of (√s)=8 TeV]

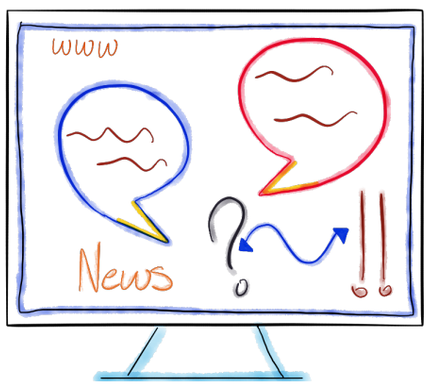


[Enabling Open Science with the ATLAS Open Data project at CERN]

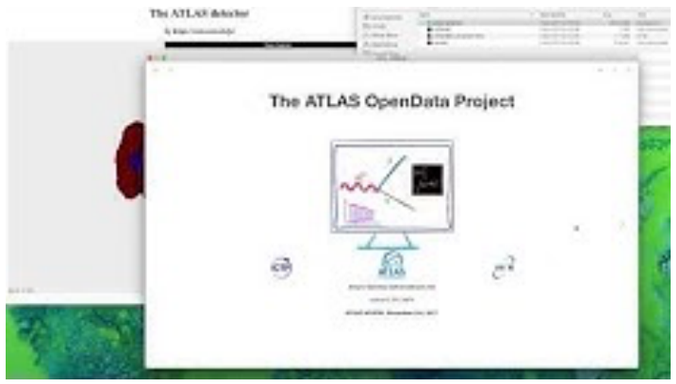
VIDEOS



[People using & creating ATLAS Open Data & Tools]

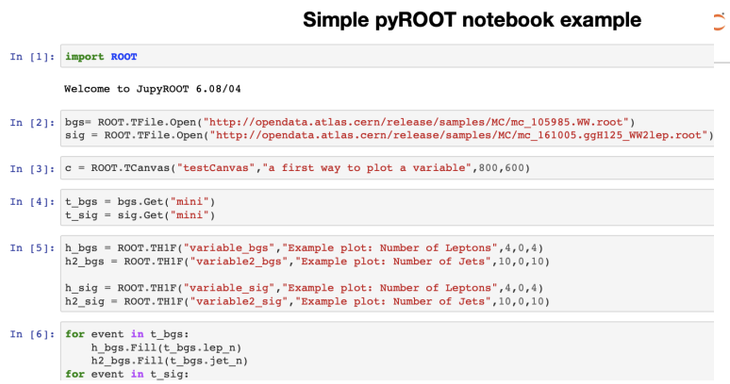


[ATLAS Open Data website Community]

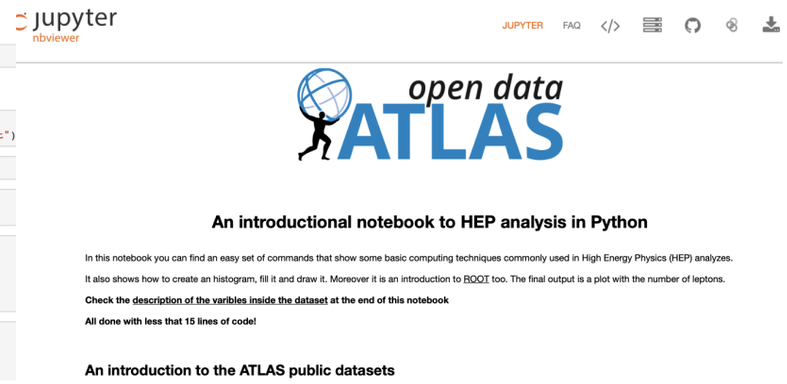


[ATLAS OpenData demo apps]

[Getting the Virtual Machine set and run]



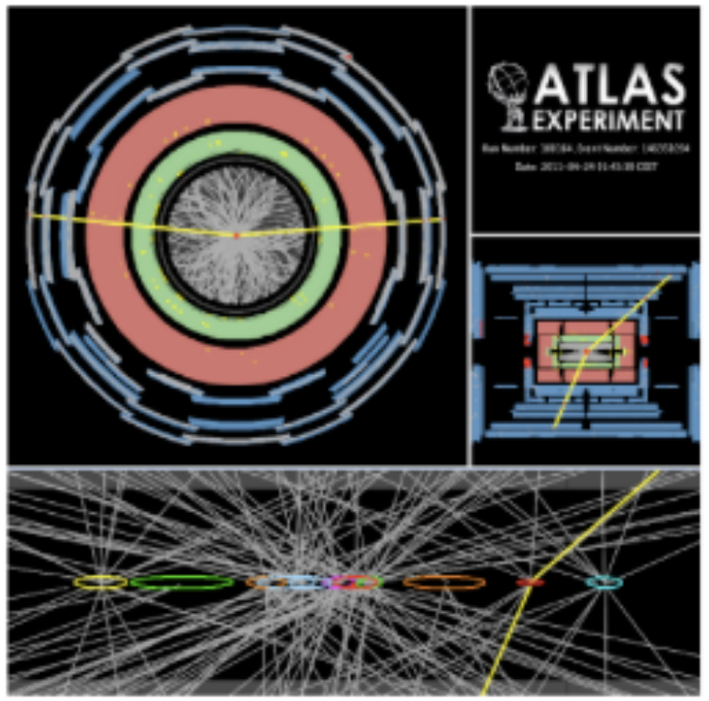
[Intro to notebooks + Open Data]



[ATLAS Open Data: Raw Jypyter notebook creation]

ATLAS EXPERIMENT

ATLAS events



Beams of protons are accelerated around the Large Hadron Collider (LHC) and are brought to collision at the centre of the ATLAS detector. The collisions produce debris in the form of new particles which fly out in all directions. Over a billion particle interactions take place in the ATLAS detector every second.

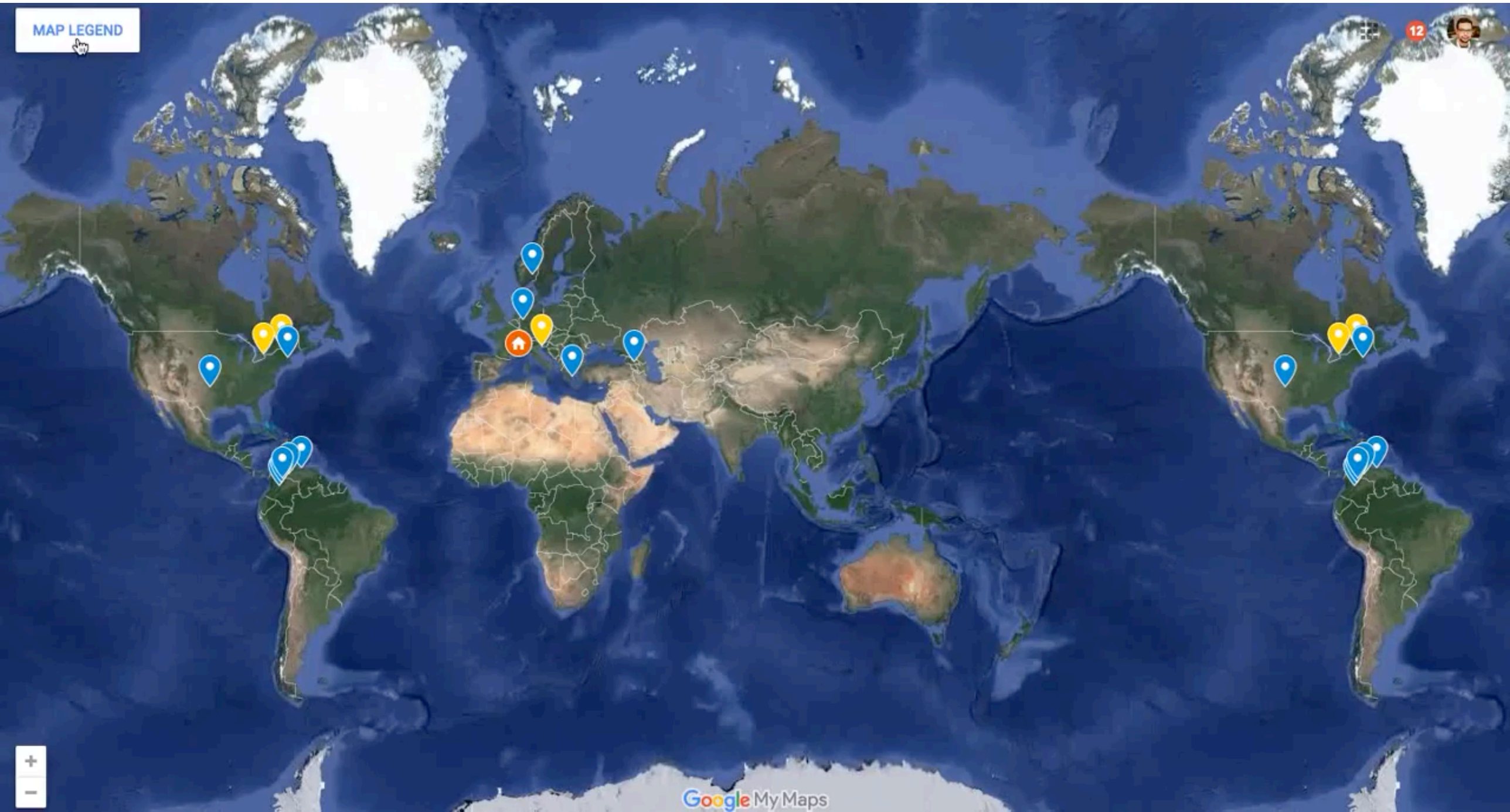
The protons within the two beams are grouped in bunches which are squeezed down in size to increase the chances of a collision. In the released data, the bunches crossed every 50 ns. There were about 30 collisions on average per **bunch-crossing**.

An **event** is the data resulting from a particular bunch-crossing.

Pile-up is defined as the average number of particle interactions per bunch-crossing. It is directly correlated with the instantaneous luminosity.

Luminosity is one of the most important parameters of the LHC. The higher the luminosity, the more data the experiments can gather to allow them to observe rare processes. However, increasing luminosity increases pile-up. This presents a challenge for physics analyses as it makes successfully identify collisions of interest harder.

ATLAS OPEN DATA AND FRIENDS AROUND THE WORLD



WORLDWIDE USE

California

Montréal

ZPATH

Lund

Dortmund

Göttingen

Michigan

HYPATIA

Maastricht

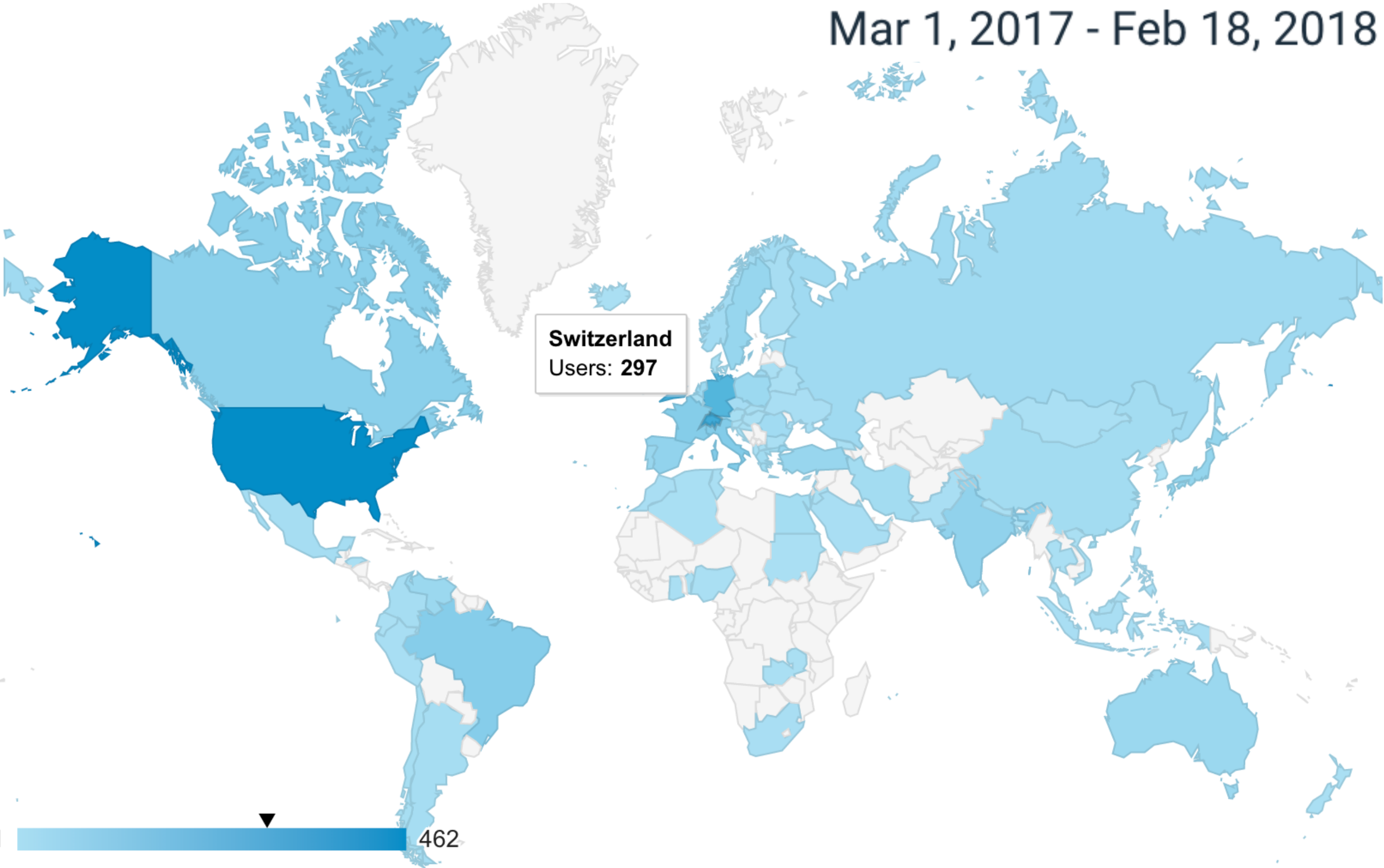
Dresden

Creative Commons

CEVALE2VE

Valencia

WORLDWIDE USE



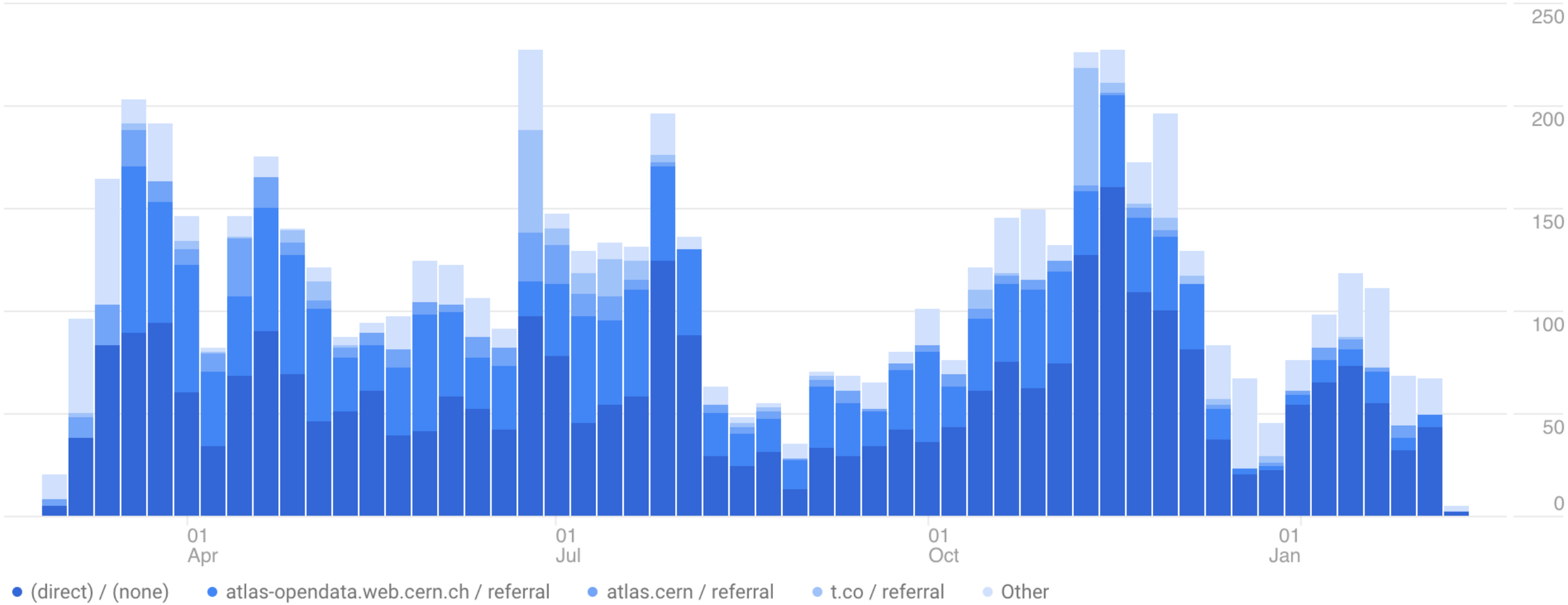
Country	Users	Sessions	Pages / Session
	2,534 % of Total: 100.00% (2,534)	6,035 % of Total: 100.00% (6,035)	3.24 Avg for View: 3.24 (0.00%)
1. United States	**462** (17.61%)	957 (15.86%)	3.20
2. Switzerland	**297** (11.32%)	771 (12.78%)	3.32
3. United Kingdom	**286** (10.90%)	548 (9.08%)	3.93
4. Germany	**238** (9.07%)	625 (10.36%)	3.45
5. Italy	**110** (4.19%)	289 (4.79%)	3.76
6. France	**101** (3.85%)	126 (2.09%)	3.32
7. Brazil	**100** (3.81%)	276 (4.57%)	3.58
8. Canada	**88** (3.35%)	271 (4.49%)	2.87
9. India	**72** (2.74%)	129 (2.14%)	3.71
10. Spain	**68** (2.59%)	150 (2.49%)	3.12

WORLDWIDE USE

How do you acquire users?

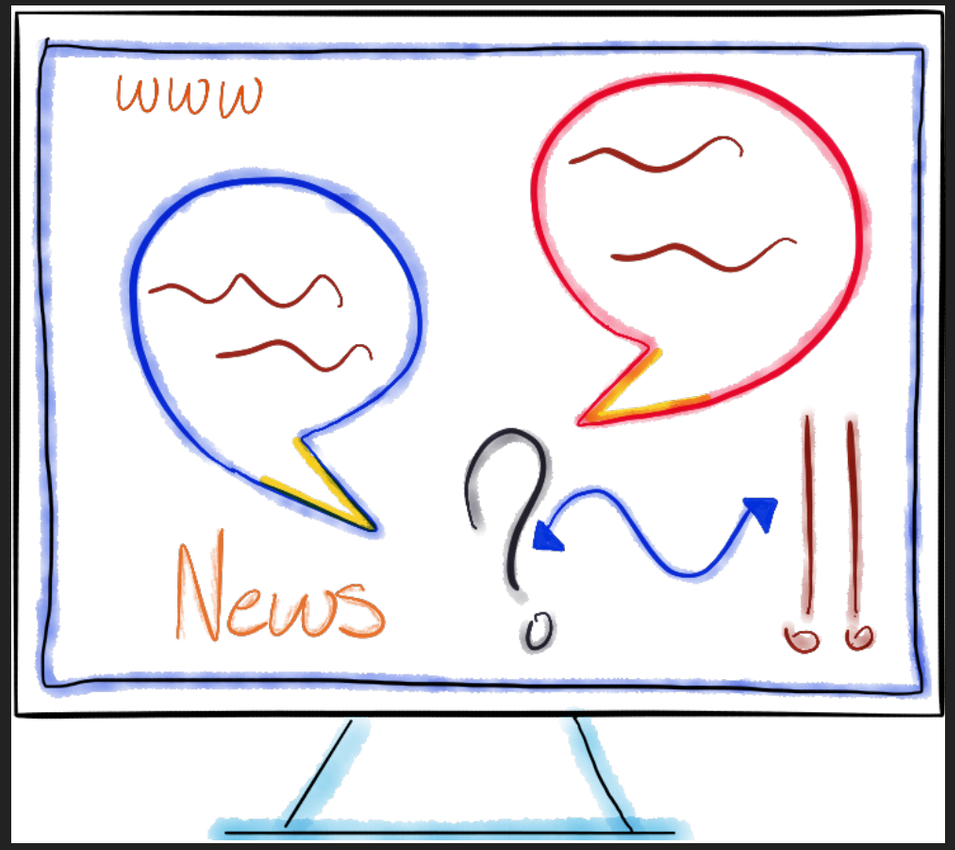
Mar 1, 2017 - Feb 18, 2018

Traffic Channel | **Source / Medium** | Referrals



Last 12 months

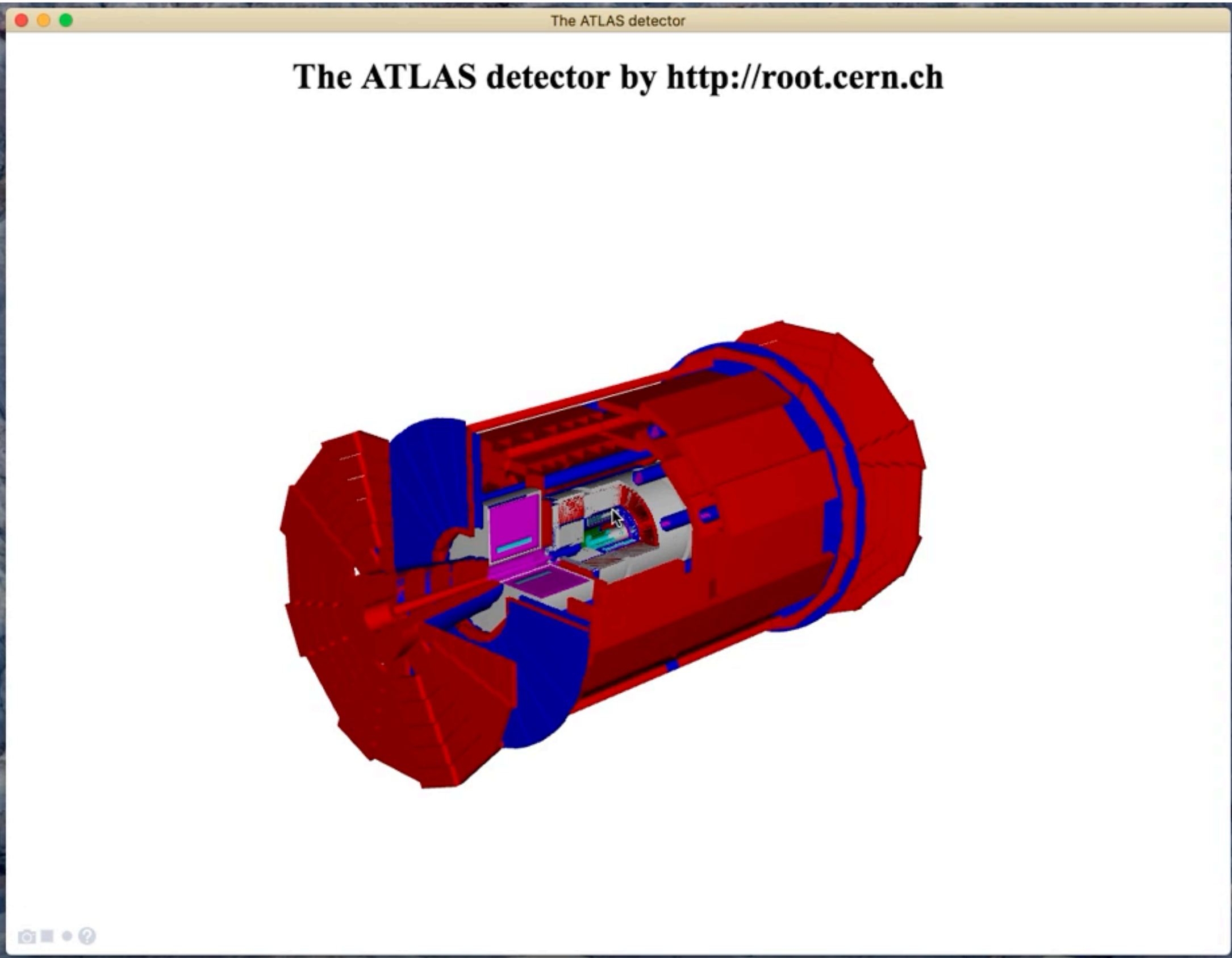
ACQUISITION REPORT



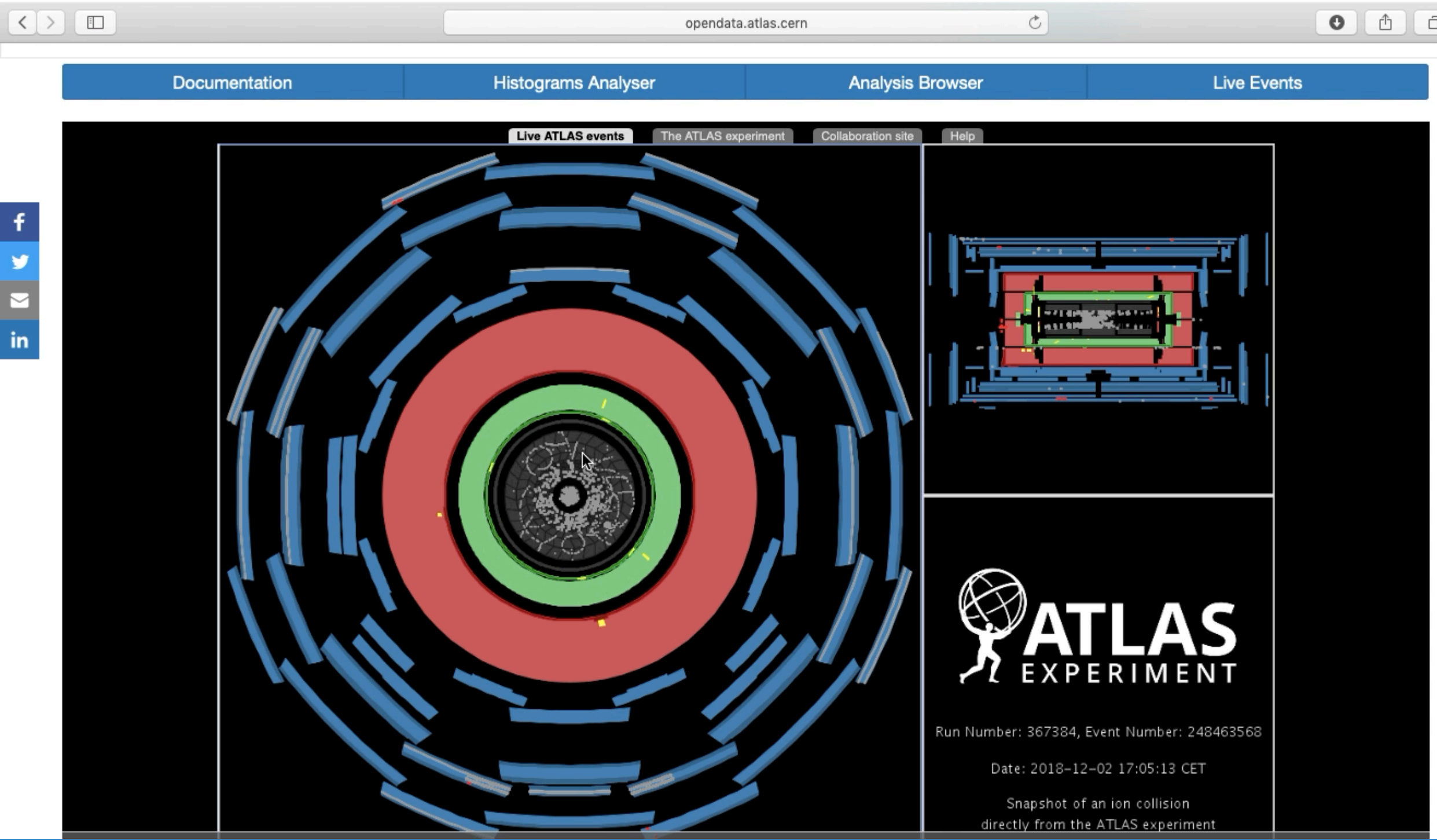
HOW TO MAKE YOUR OWN PARTICLE PHYSICS DISCOVERIES?

GET STARTED

ATLAS DETECTOR VISUALISATION



LIVE EVENT DISPLAYS



HISTOGRAM ANALYSER

open data ATLAS

Get Started
Documentation, Histogram Analyser, Analysis Browser

Web Analysis
Documentation, Analysis ROOTbooks

Data & Tools
Documentation, Datasets, Software, Virtual Machines

Get Started - Histograms Analyser

Physicists use cuts to select events of interest. Cuts are made that preferentially remove the unwanted processes (background) but leave the desired process (signal). It is useful to have a good understanding of the physics processes involved when applying cuts. **The 4 processes displayed in Histogram Analyser are *H → WW*, *WW*, $t\bar{t}$ and *Z***. Each process is represented by a different colour. **Make cuts using your cursor**.

Do you want to know more? Check the **Documentation**

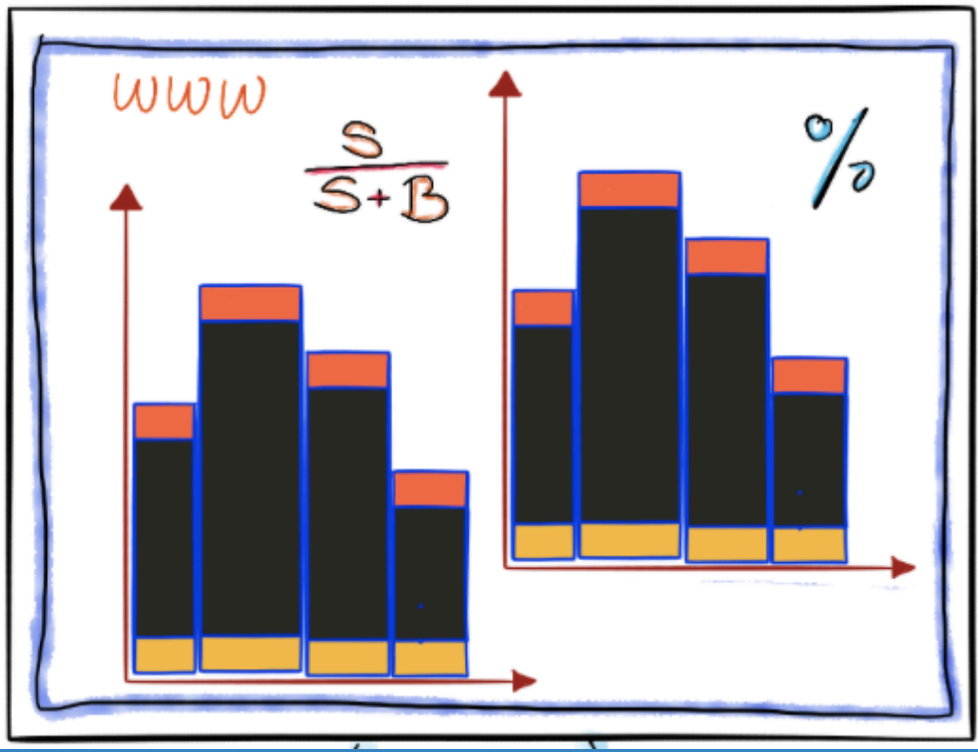


FIGURE OUT THE STEPS TO DISCOVER THE HIGGS

ANALYSIS BROWSER

open data ATLAS

Get Started
Documentation, Histogram Analyser, Analysis Browser

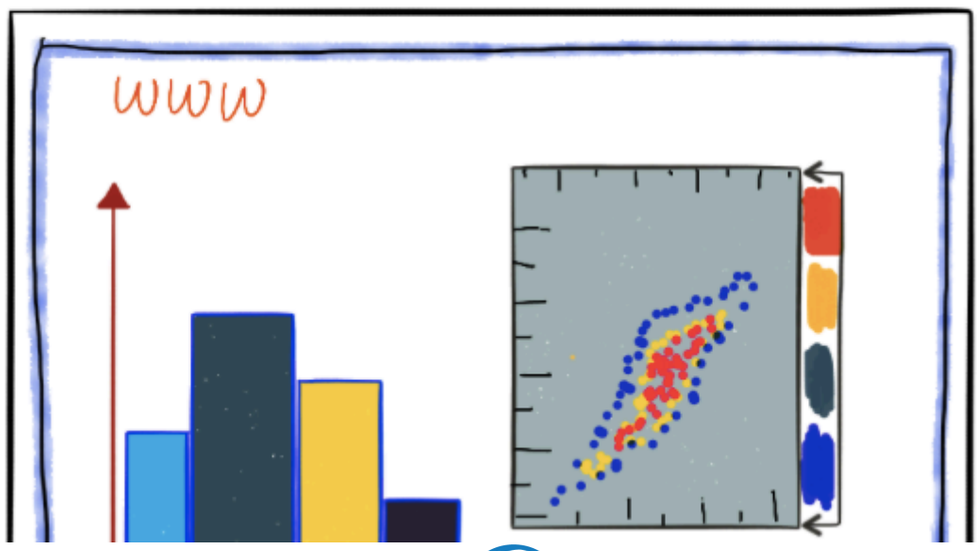
Web Analysis
Documentation, Analysis ROOTbooks

Data & Tools
Documentation, Datasets, Software, Virtual Machines

Get Started - Analysis Browser

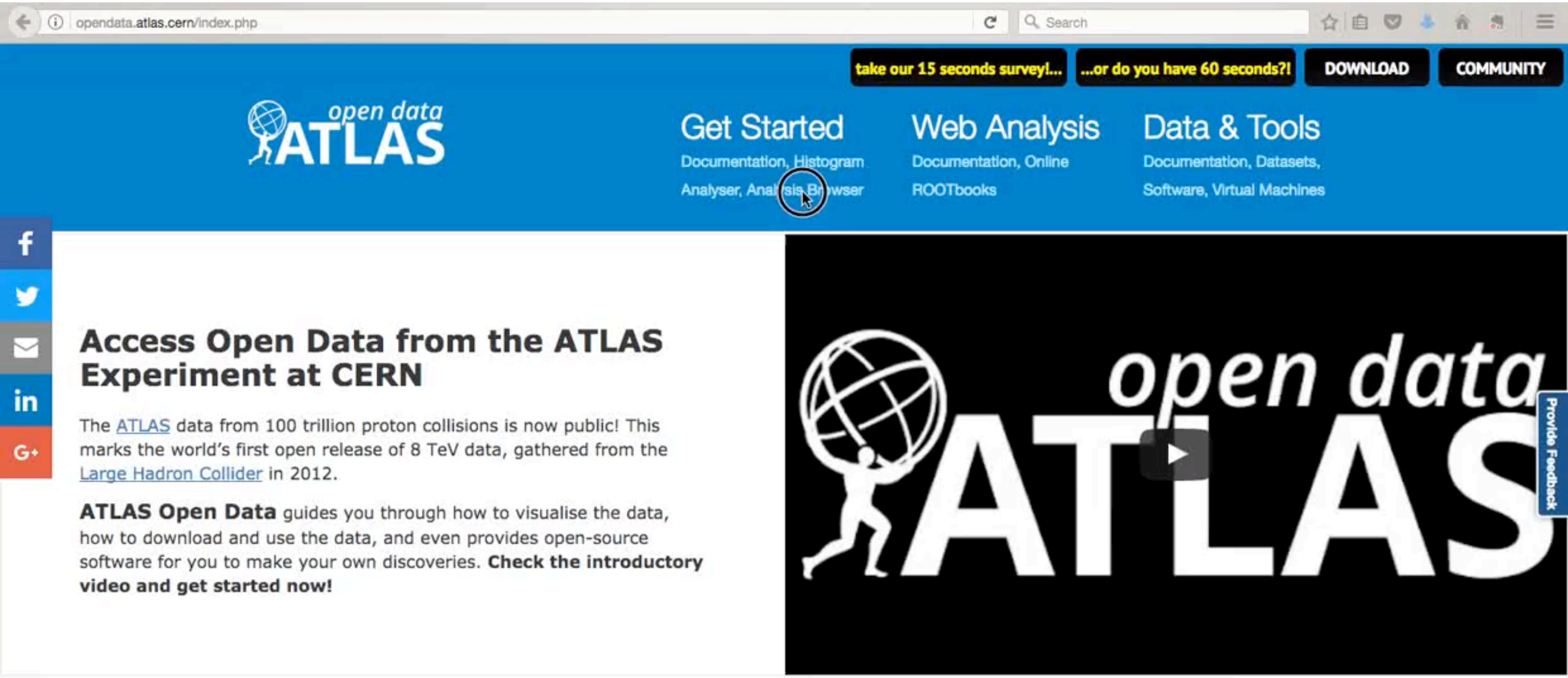
Look into the plots! A web based **tool for displaying and analysing data and Monte-Carlo** simulated data. Select a dataset using the drop-down menu *(second text box)* or a complete physics analysis tab: It is like **a *live* scientific paper!** click into the plot, zoom into the data-points, set a logaritmic scale and more.

Do you want to know more? Check the **Documentation**

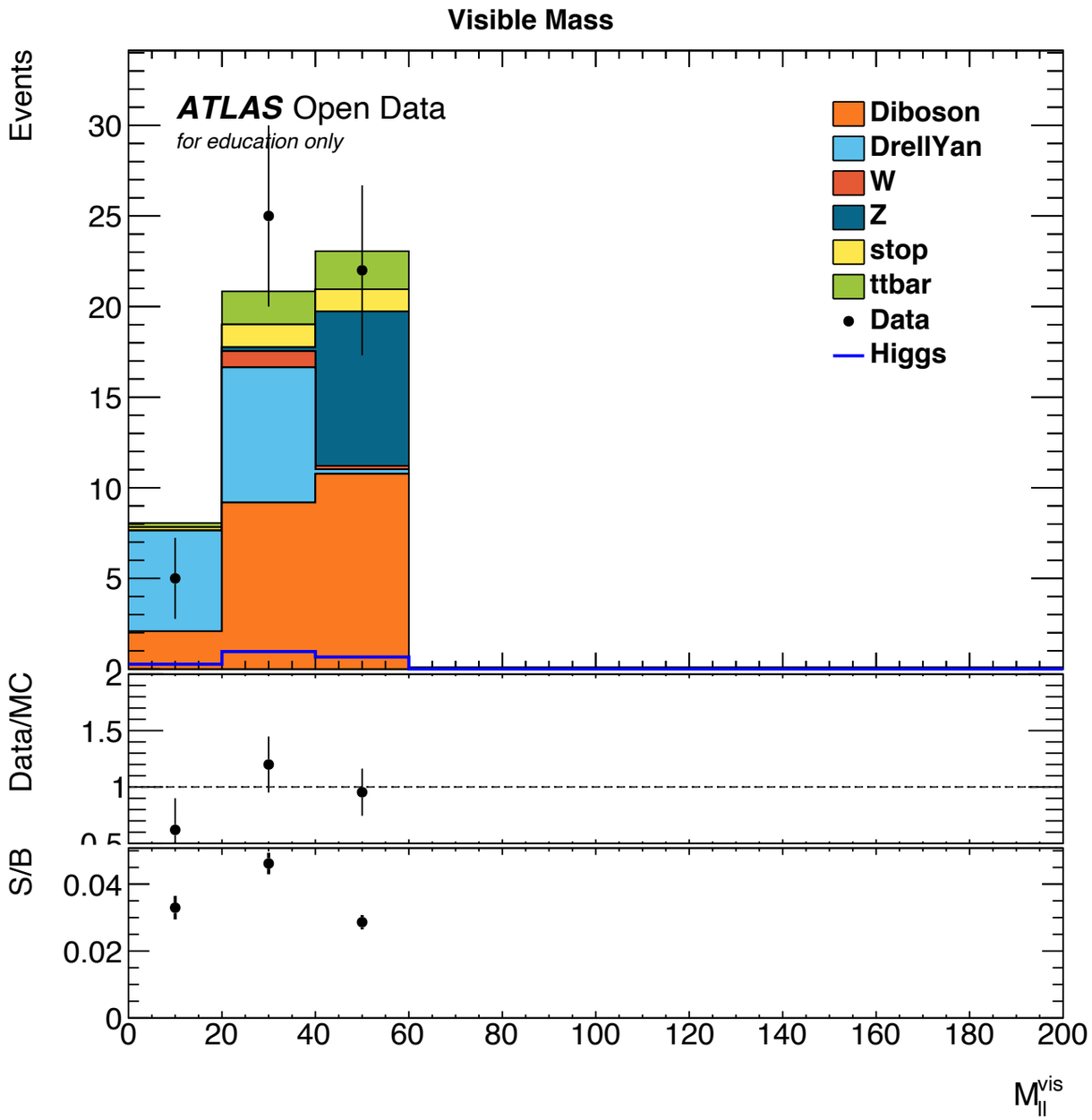


ATLAS EXPERIMENT

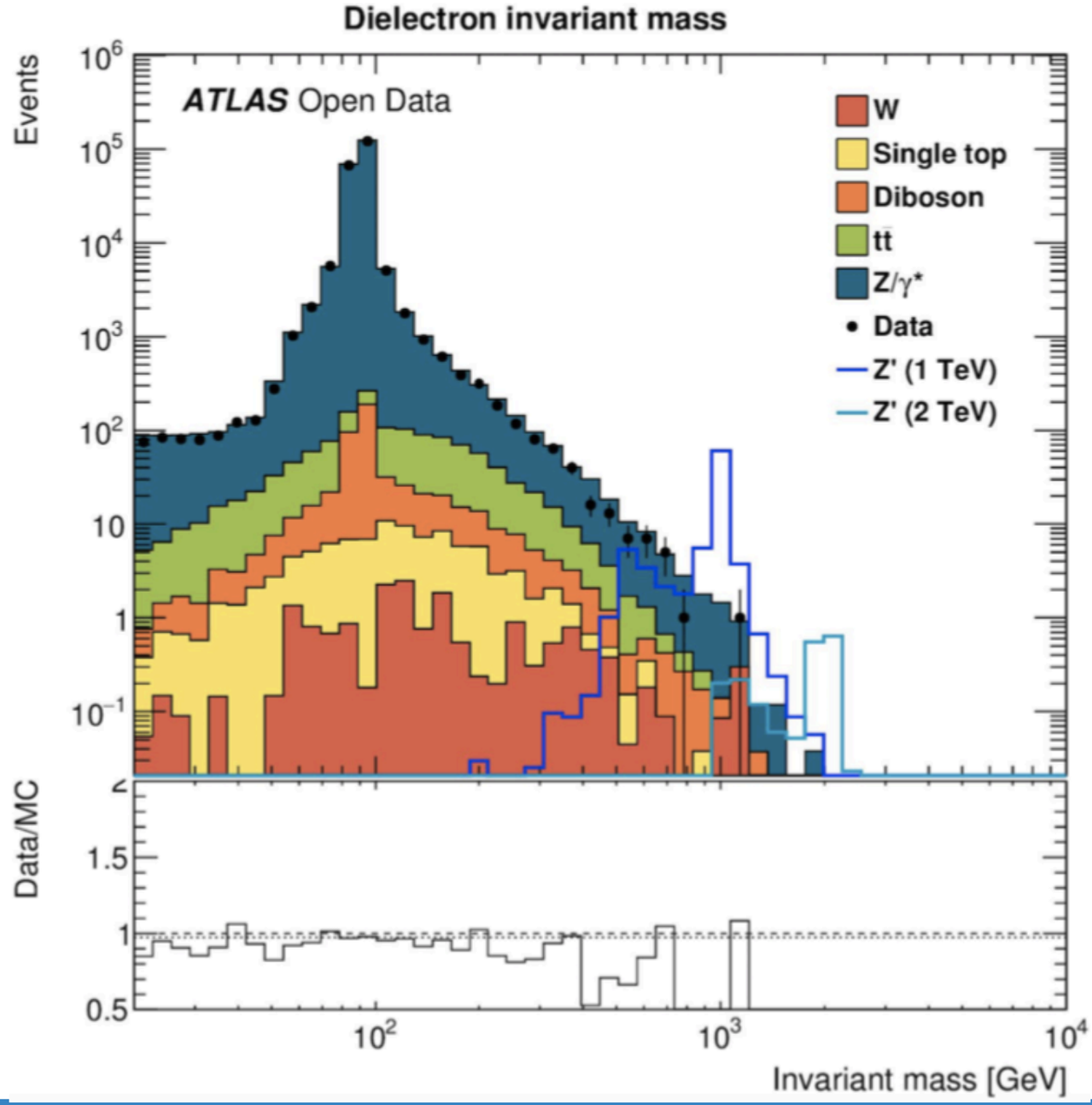
LEARN USING AN INTERACTIVE PHYSICS PAPER

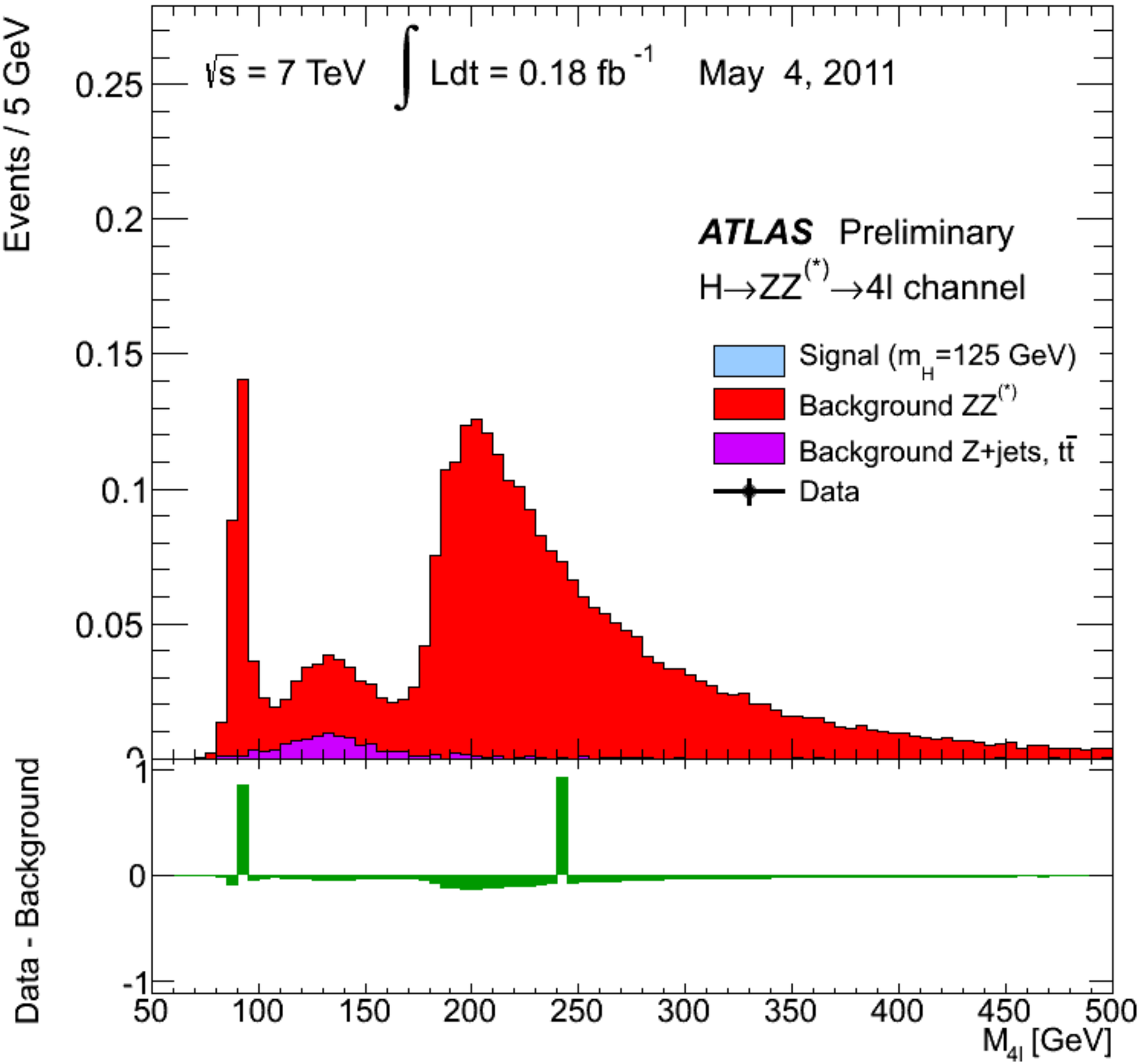


H → WW ANALYSIS

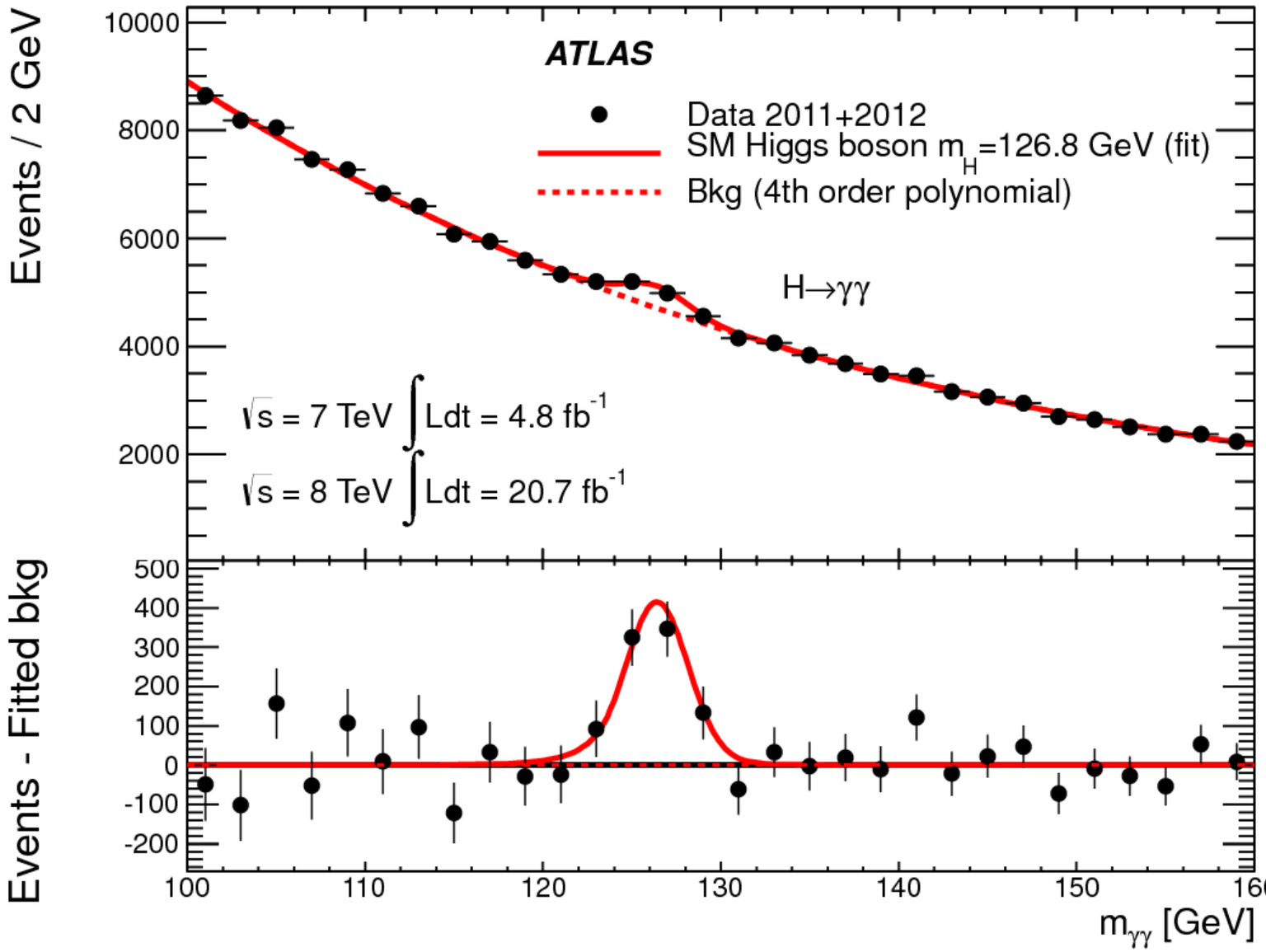


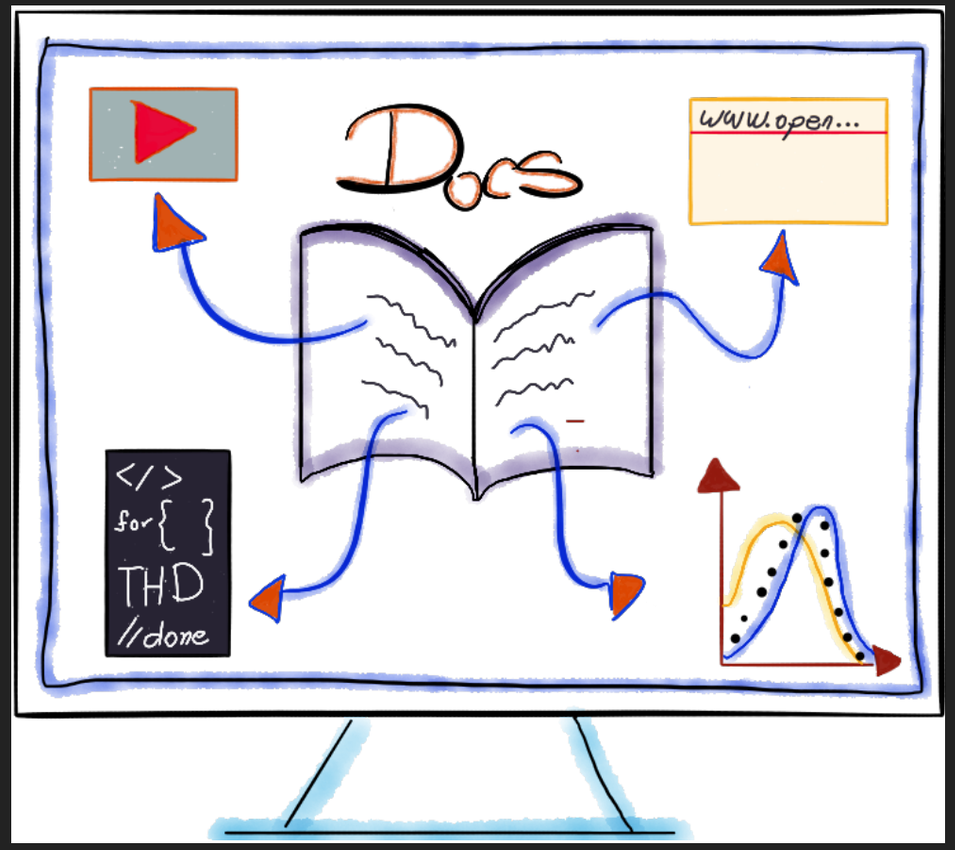
Z' ANALYSIS (DARK MATTER)




Events / 5 GeV
√s = 7 TeV ∫ Ldt = 0.18 fb-1 May 4, 2011
ATLAS Preliminary
H→ZZ(*)→4l channel
Signal (mH=125 GeV)
Background ZZ(*)
Background Z+jets, tt̄
Data
Data - Background
M4l [GeV]

HIGGS BOSON DISCOVERY PLOT





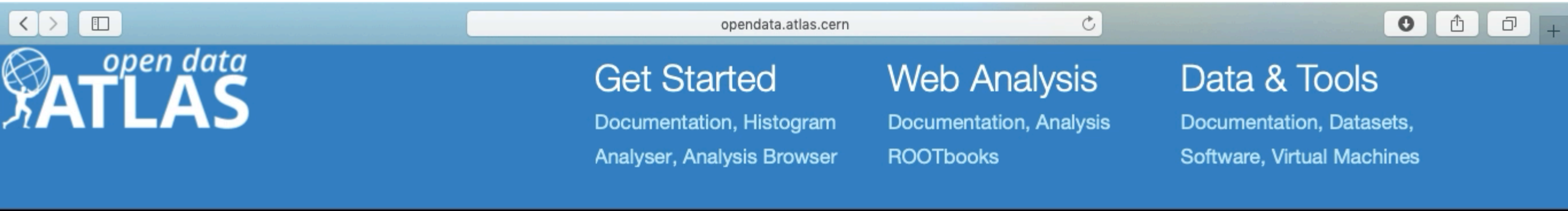
WHAT DOES THIS HAVE TO DO WITH MATHS METHODS?

PROGRAMMING

- All user analysis scripts in Python
- Jupyter notebooks for interactive code writing

WEB ANALYSIS

WEB ANALYSIS ROOTBOOKS



WHAT DOES THIS HAVE TO DO WITH MATHS METHODS?

INTRO TO HIGH ENERGY PHYSICS ANALYSIS

jupyter nbviewer

JUPYTER FAQ

open data ATLAS

An introductional notebook to HEP analysis in Python

In this notebook you can find an easy set of commands that show some basic computing techniques commonly used in High Energy Physics (HEP) analyzes.

It also shows how to create an histogram, fill it and draw it. Moreover it is an introduction to ROOT too. The final output is a plot with the number of leptons.

Check the description of the varibles inside the dataset at the end of this notebook

All done with less that 15 lines of code!

An introduction to the ATLAS public datasets

ONTO MORE DIFFICULT ANALYSES…

jupyter nbviewer

JUPYTER FAQ

notebooks / november_2017_v-1.0

open data ATLAS

A more difficult notebook in python

In this notebook you can find a more difficult program that shows further high energy physics (HEP) analysis techniques.

The following analysis is searching for events where Z bosons decay to two leptons of same flavour and opposite charge (to be seen for example in the Feynman diagram).

ATLAS EXPERIMENT

USING PYTHON FOR PARTICLE PHYSICS

Simple pyROOT notebook example

In [1]:
```
import ROOT
```

```
Welcome to JupyROOT 6.08/04
```

In [2]:
```
bgs= ROOT.TFile.Open("http://opendata.atlas.cern/release/samples/MC/mc_105985.WW.root")
sig = ROOT.TFile.Open("http://opendata.atlas.cern/release/samples/MC/mc_161005.ggH125_WW2lep.root")
```

In [3]:
```
c = ROOT.TCanvas("testCanvas","a first way to plot a variable",800,600)
```

In [4]:
```
t_bgs = bgs.Get("mini")
t_sig = sig.Get("mini")
```

In [5]:
```
h_bgs = ROOT.TH1F("variable_bgs","Example plot: Number of Leptons",4,0,4)
h2_bgs = ROOT.TH1F("variable2_bgs","Example plot: Number of Jets",10,0,10)

h_sig = ROOT.TH1F("variable_sig","Example plot: Number of Leptons",4,0,4)
h2_sig = ROOT.TH1F("variable2_sig","Example plot: Number of Jets",10,0,10)
```

In [6]:
```
for event in t_bgs:
    h_bgs.Fill(t_bgs.lep_n)
    h2_bgs.Fill(t_bgs.jet_n)
for event in t_sig:
```

USING PYTHON WITH SPECIAL RELATIVITY

Simple pyROOT notebook example using TLorentz Vectors

In [1]:
```
import ROOT
```

```
Welcome to JupyROOT 6.08/04
```

In [2]:
```
## f = ROOT.TFile.Open("mc_105986.ZZ.root")
## f = ROOT.TFile.Open("mc_147770.Zee.root")
f = ROOT.TFile.Open("http://opendata.atlas.cern/release/samples/MC/mc_147770.Zee.root")
```

In [3]:
```
c = ROOT.TCanvas("testCanvas","a first way to plot a variable",800,600)
```

In [4]:
```
t = f.Get("mini")
```

In [5]:
```
h = ROOT.TH1F("variable","Example plot: Number of Leptons",4,0,4)
```

In [ ]:
```
h_Mll = ROOT.TH1F("h_Mll","Invariant mass of the two Leptons",50,0,200)
```

In [ ]:
```
for event in t:
    """This is the cut #1: request at least 2 leptons"""
    if t.lep_n > 1:
        """Let's define one TLorentz vector for each, e.i. two vectors!"""
        leadingLep = ROOT.TLorentzVector(t.lep_pt[0], t.lep_eta[0], t.lep_phi[0], t.lep_E[0])
        secondLep  = ROOT.TLorentzVector(t.lep_pt[1], t.lep_eta[1], t.lep_phi[1], t.lep_E[1])
```

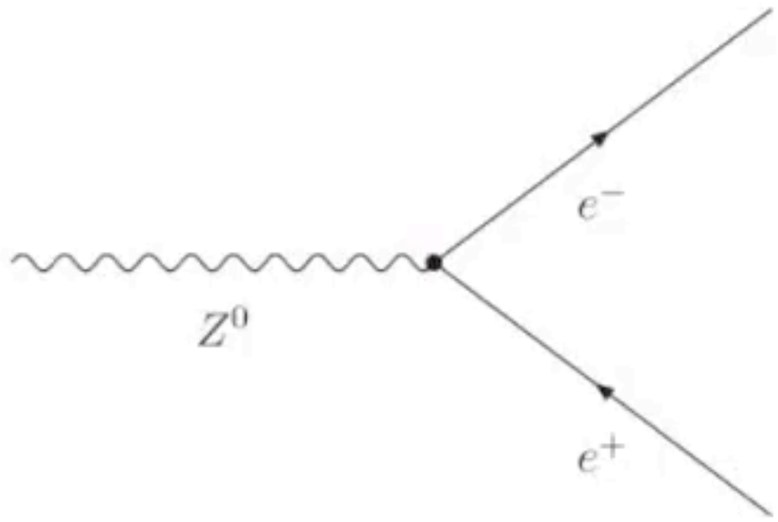
WHAT DOES THE CODE DO?

File Edit View Insert Cell Kernel Help ROOT C++

Markdown CellToolbar

open data ATLAS

Example of the reconstruction of the invariant Mass of the Z boson in C++



Introduction Let's take a current ATLAS Open Data sample and create a histogram:

In [1]:
```
%jsroot on
```

DATA & TOOLS

DATA & TOOLS

Data & Tools

Now that you have learned to visualise data and use code for analysis, you are ready to take an in-depth look at ATLAS data. **Start your analysis now!** In this section, you can download the full datasets, install a virtual machine and learn how to execute analysis software.

Explore:

- **Documentation:** a step-by-step guide to downloading datasets, software and virtual machines
- **Datasets:** download the ATLAS datasets
- **Software:** download and run analysis software
- **Virtual Machines:** download and prepare a virtual machine to run on your computer

WHAT DOES THIS HAVE TO DO WITH MATHS METHODS?

DATA & TOOLS FRAMEWORK

atlas-outreach-data-tools / Pull requests Issues Marketplace Explore

atlas-outreach-data-tools / atlas-outreach-data-tools-framework

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Python software framework for the ATLAS OpenData project

4 commits 1 branch 2 releases 1 contributor

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artfisica to clean Latest commit 099fb10 on 6 Feb

Analysis	First version for ATLAS collaboration review before 2016 release	3 years ago
Configurations	First version for ATLAS collaboration review before 2016 release	3 years ago
Input	First version for ATLAS collaboration review before 2016 release	3 years ago
Output	First version for ATLAS collaboration review before 2016 release	3 years ago
Plotting	First version for ATLAS collaboration review before 2016 release	3 years ago
PlotResults.py	First version for ATLAS collaboration review before 2016 release	3 years ago
README.md	Adding missing s in documentation to run Plotting code	3 years ago
RunScript.py	First version for ATLAS collaboration review before 2016 release	3 years ago

README.md

WHAT DOES THIS HAVE TO DO WITH MATHS METHODS?

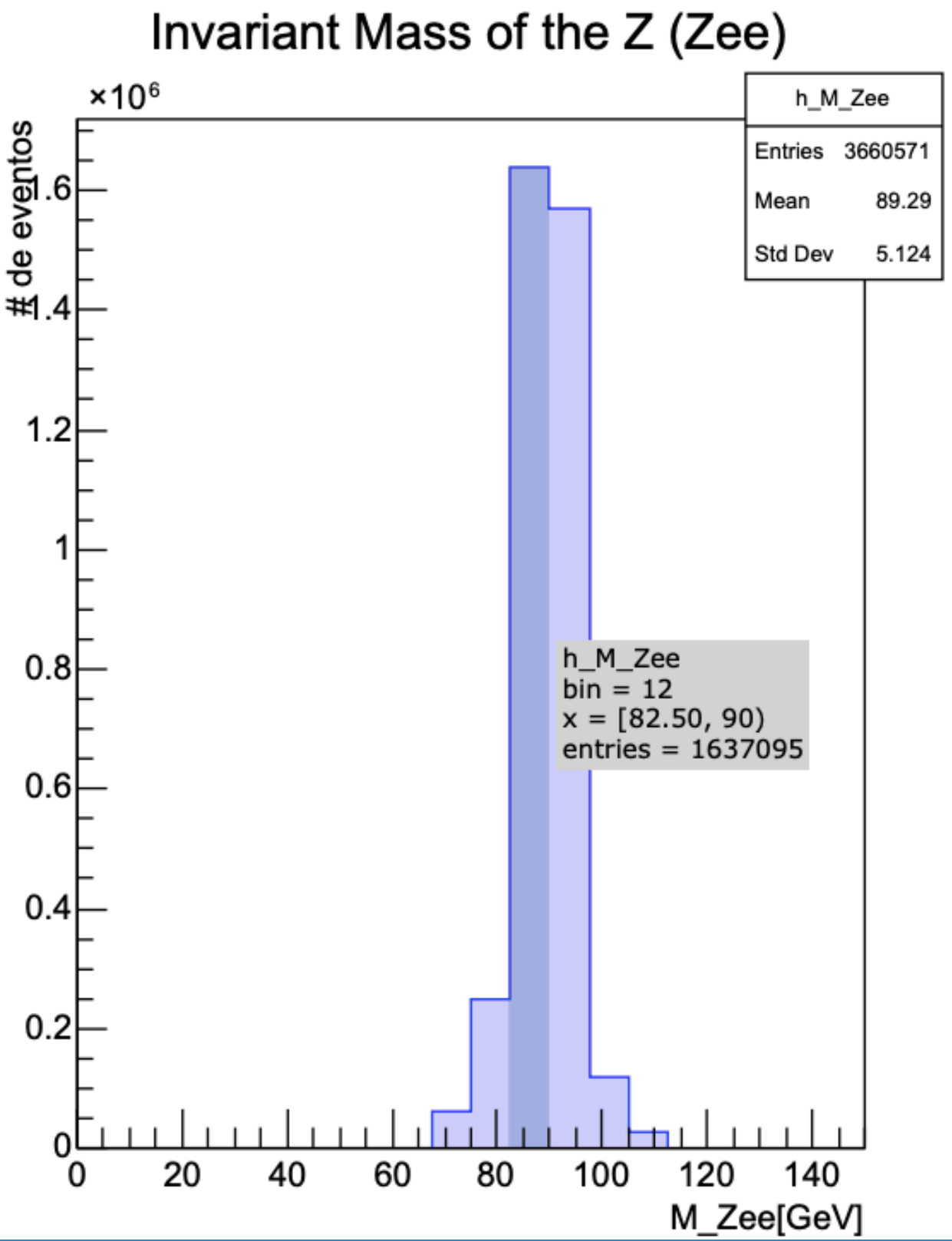
ANALYSIS.PY

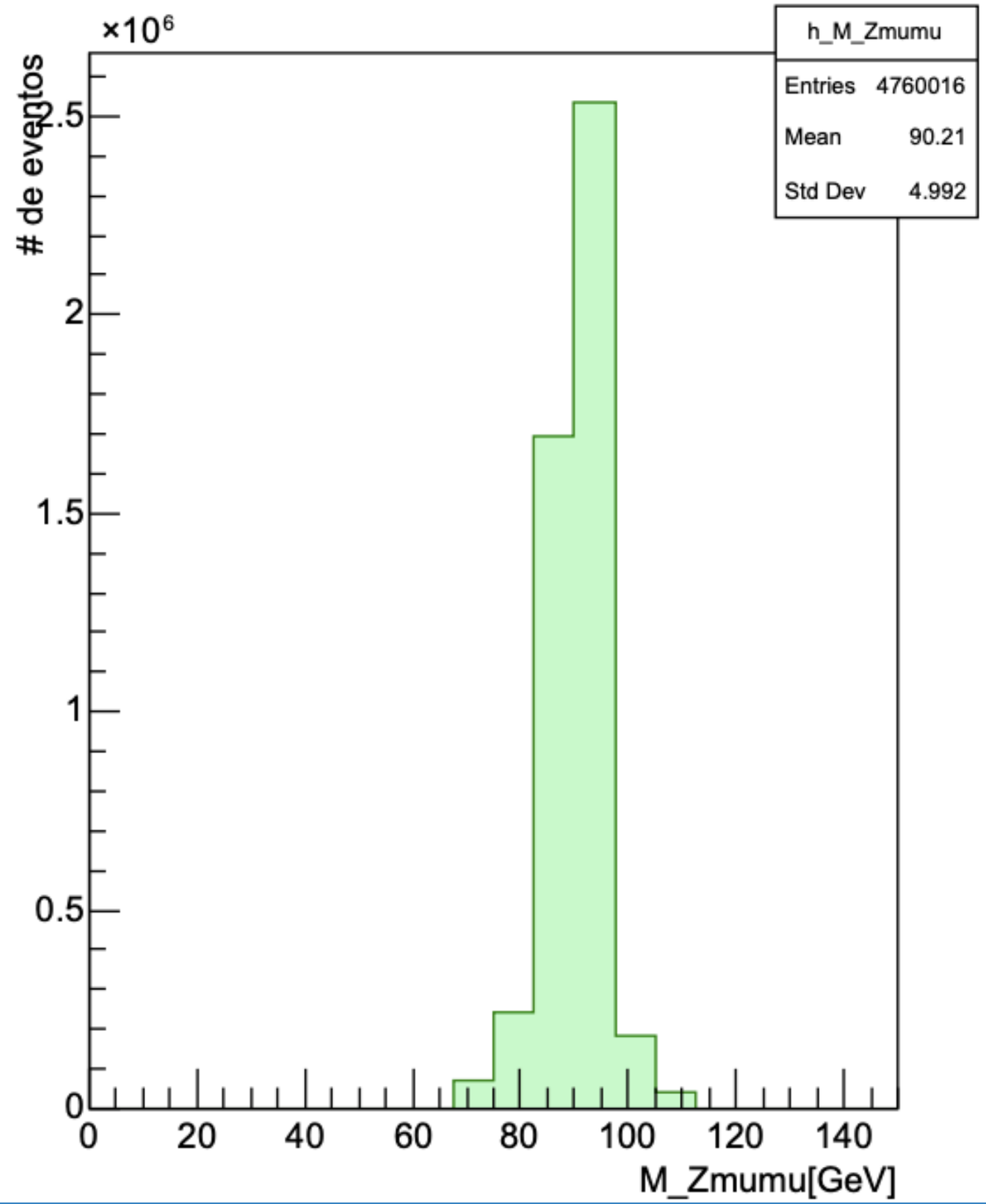
```
54      # retrieving objects
55      eventinfo = self.Store.getEventInfo()
56      weight = eventinfo.scalefactor()*eventinfo.eventWeight() if not self.getIsData() else 1
57      self.countEvent("no cut", weight)
58
59      # apply standard event based selection
60      if not AH.StandardEventCuts(eventinfo): return False
61      self.countEvent("EventCuts", weight)
62
63      # Lepton Requirements
64      GoodLeptons = AH.selectAndSortContainer(self.Store.getLeptons(), AH.isGoodLepton, lambda p: p.pt())
65      if not (len(GoodLeptons) == 2): return False
66      self.countEvent("2 high pt Leptons", weight)
67
68      leadLepton  = GoodLeptons[0]
69      trailLepton = GoodLeptons[1]
70
71      # test Z candidate
72      if not (leadLepton.charge() * trailLepton.charge() < 0): return False
73      if not (abs(leadLepton.pdgId()) == abs(trailLepton.pdgId())): return False
74      if not (abs((leadLepton.tlv() + trailLepton.tlv()).M() - Constants.Z_Mass) < 20): return False
```

RESEARCH PLACEMENTS (RP)

- New Research Placement on ATLAS Open Data starting this year!
- “The ATLAS experiment provides Open Data, allowing students to access real proton-proton collision data collected by ATLAS, along with tools, software, documentation all accessible on the ATLAS Open Data website http://opendata.atlas.cern and CERN Open Data Portal http://opendata.cern.ch”…

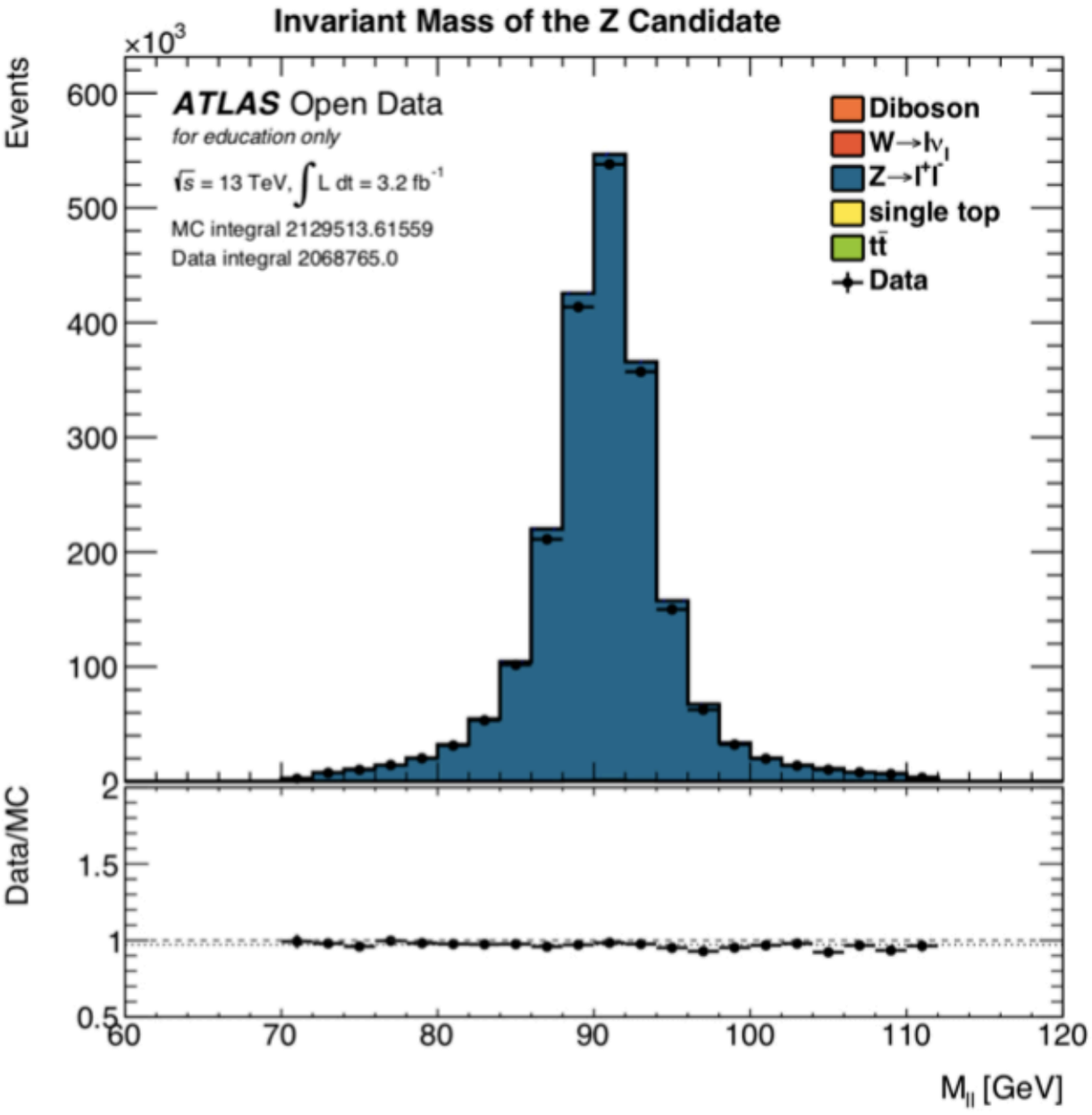
3RD YEAR PARTICLE PHYSICS COURSE @ SUSSEX





WHAT DOES THIS HAVE TO DO WITH MATHS METHODS?

FINAL YEAR PROJECTS



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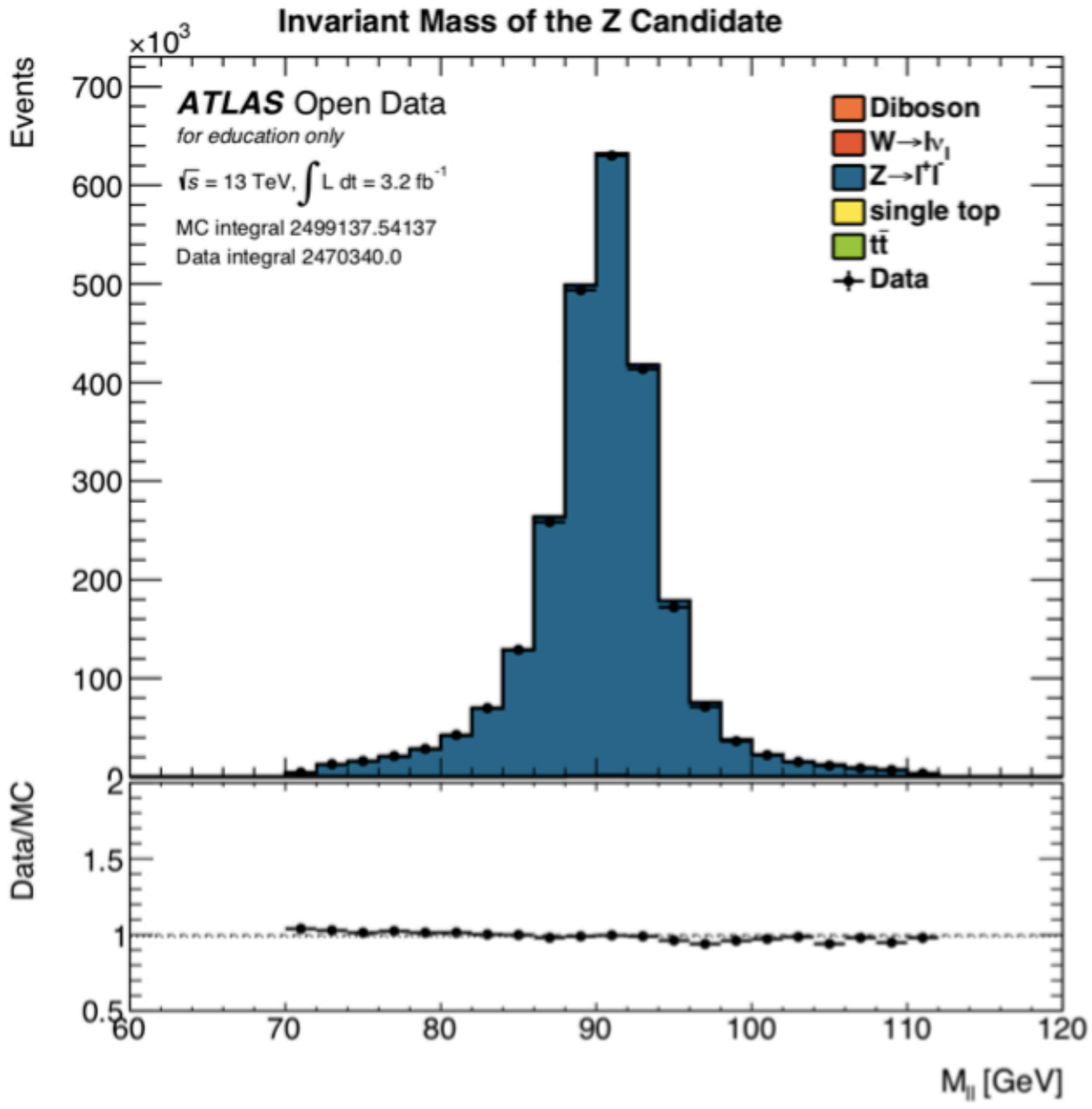

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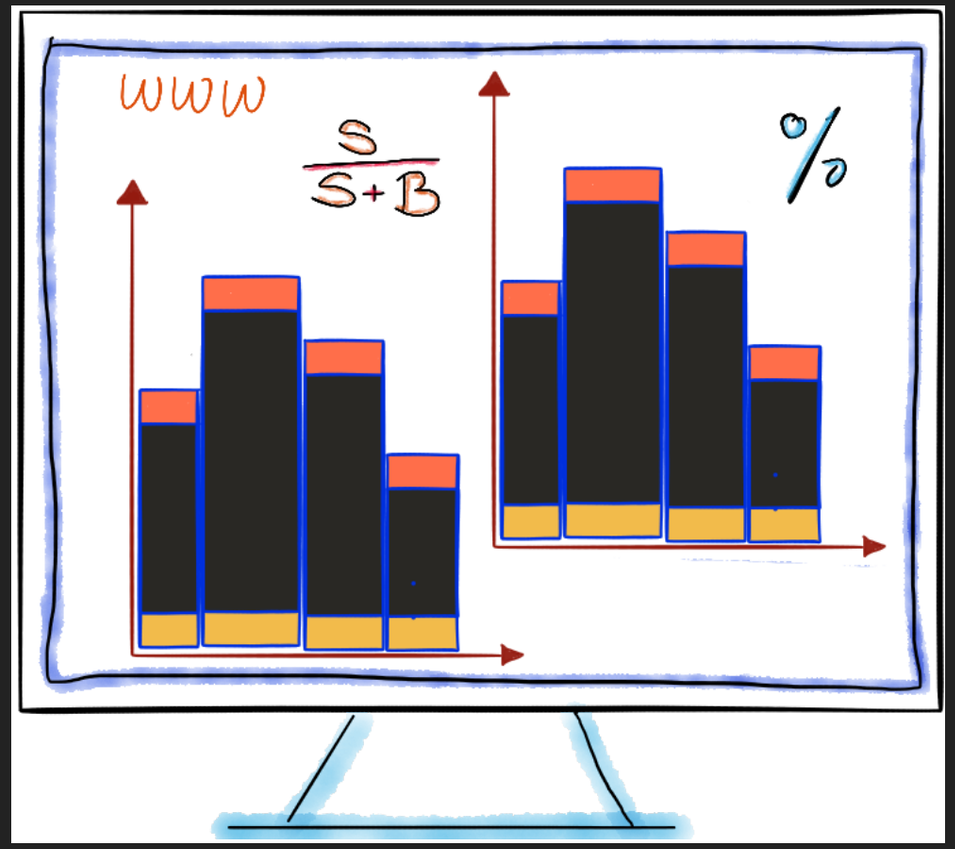


WHAT TO TAKE HOME?

SUMMARY

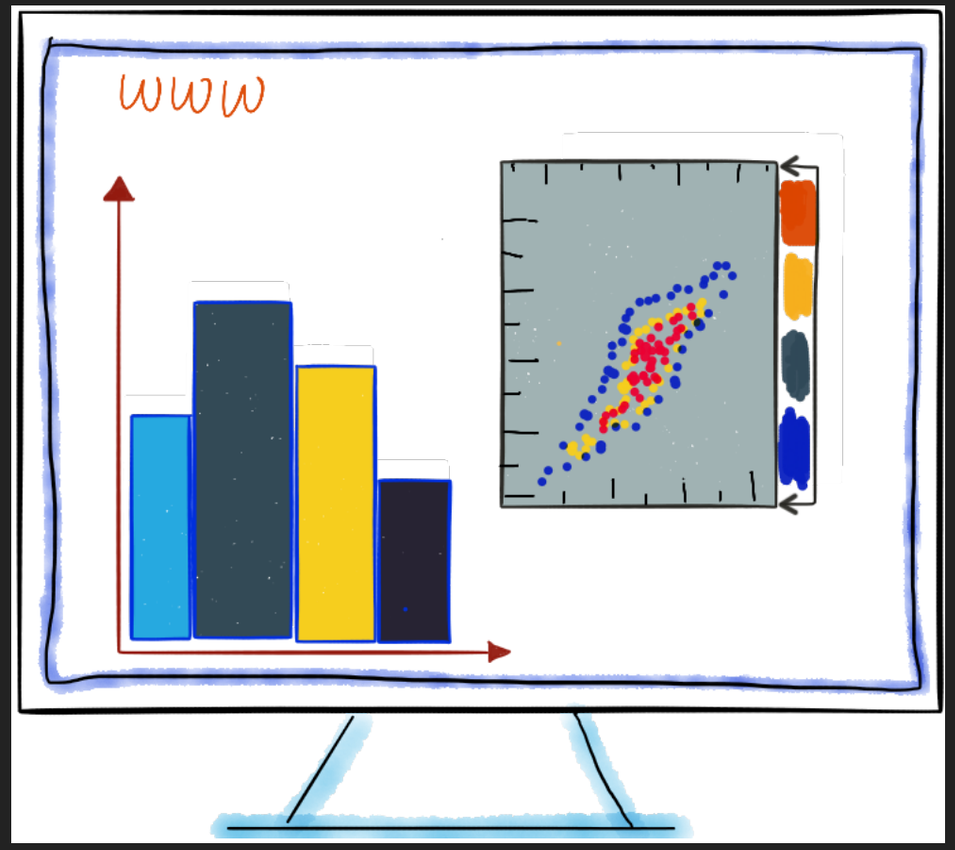
- There's lots YOU can do with ATLAS Open Data already
- ATLAS Open Data is aimed at students just like you
- Head to opendata.atlas.cern to get started
- There'll be lots more you can do as you keep learning

THANKS!

- meirin.oan.evans@cern.ch
- me338@sussex.ac.uk

- Any questions?

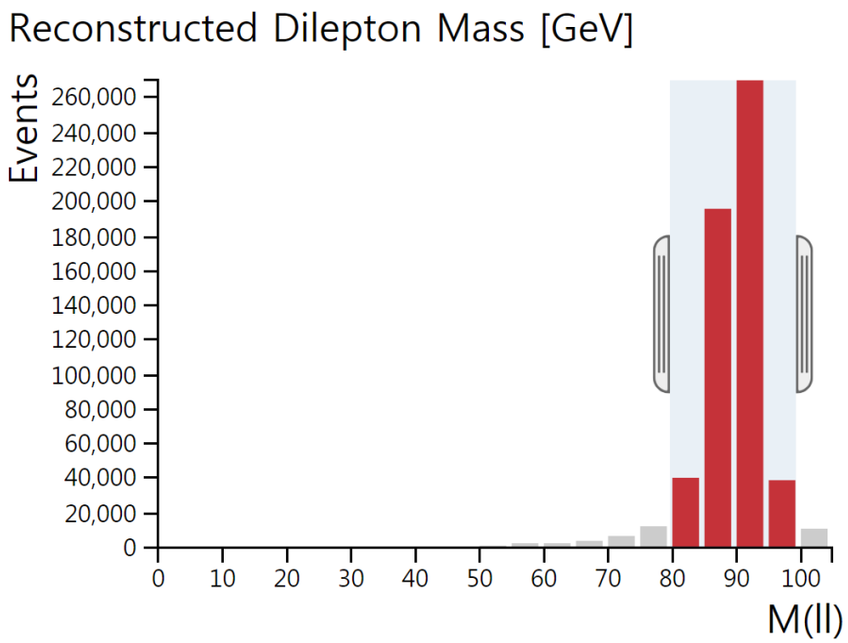
opendata.atlas.cern



BACKUP

ARTICLES

[ATLAS' Higgs ML Challenge data open to public]



[Explore LHC Data on new ATLAS educational platform]

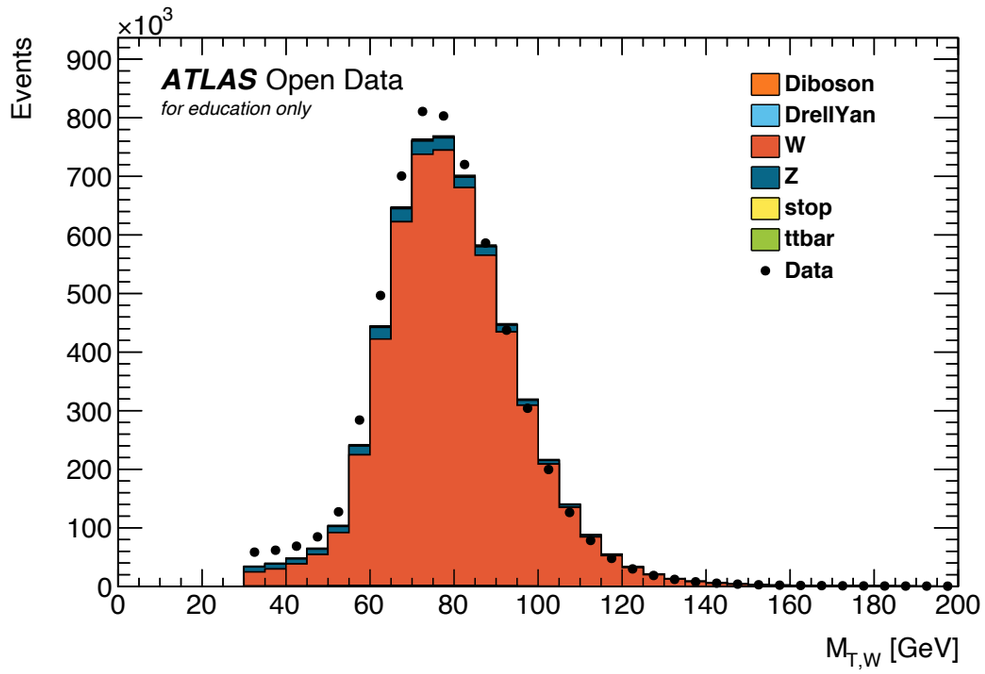
[Dortmund students work with ATLAS data]

[Boosting high-energy physics education around the world with ATLAS Open Data]

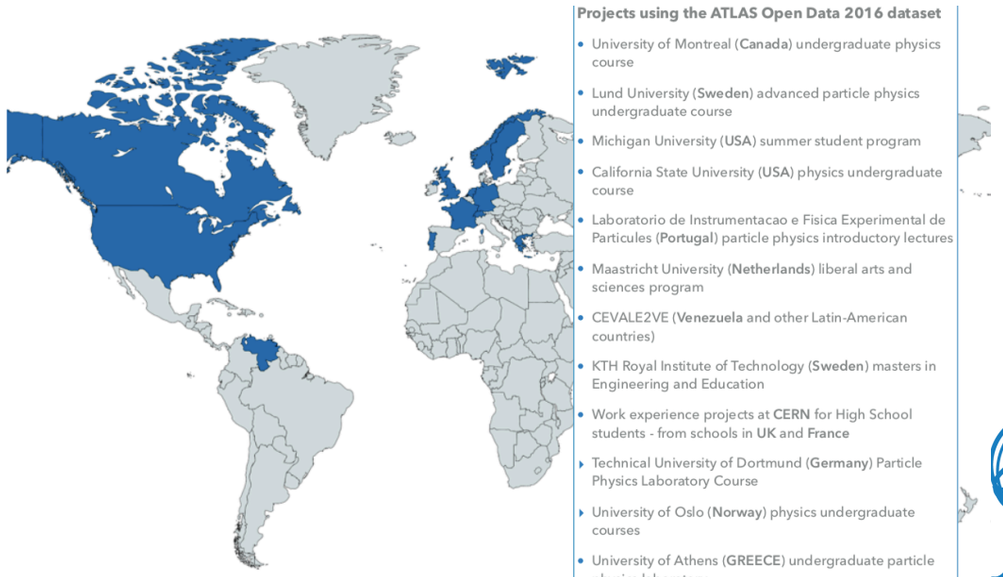
ATLAS EXPERIMENT

REVIEWS

[Review of ATLAS Open Data Dataset](#) written after dataset release



[Review of ATLAS Open Data 8 TeV datasets, tools & activities](#) written after user feedback



WORLDWIDE USE

Final year projects Sussex

UNIVERSITY OF SUSSEX

Lab course Dortmund

Lab course Göttingen

Lab course Manchester

The University of Manchester

Lab course Dresden

Web-based interactive learning tool Georgia

ATLAS TRACER

VIRTUAL MACHINE

MACHINE LEARNING

- We’re in constant contact & communication with other groups looking at public data
- Like ATLAS Machine Learning