ATLAS EXPERIMENT

Universidade do Minho
Escola de Ciências

LIP
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

os dados públicos de ATLAS como recurso pedagógico no ensino da física de partículas

13ª Escola de Professores no CERN em Língua Portuguesa

CERN, 5 de setembro de 2019

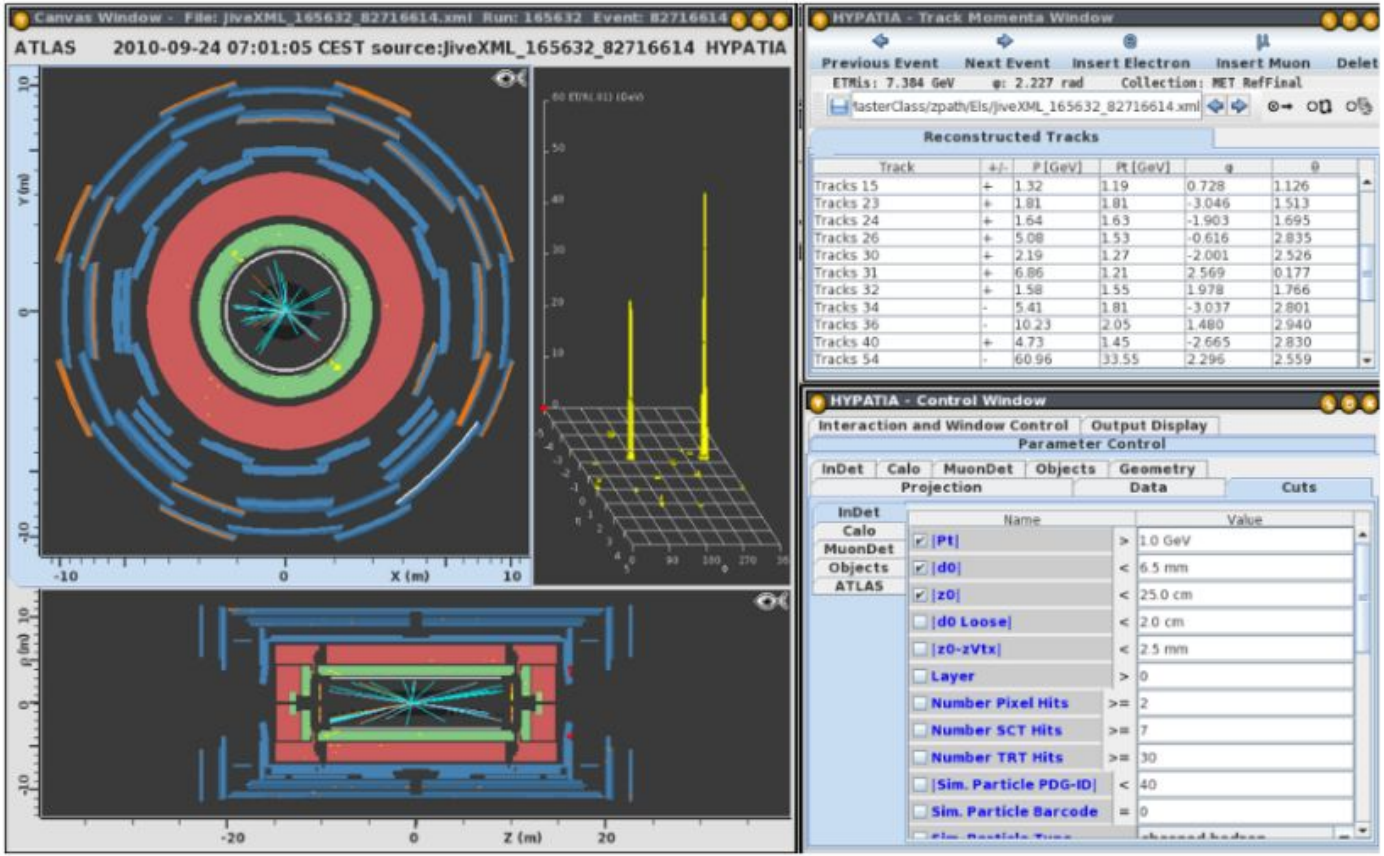
Nuno Castro

nuno.castro@cern.ch

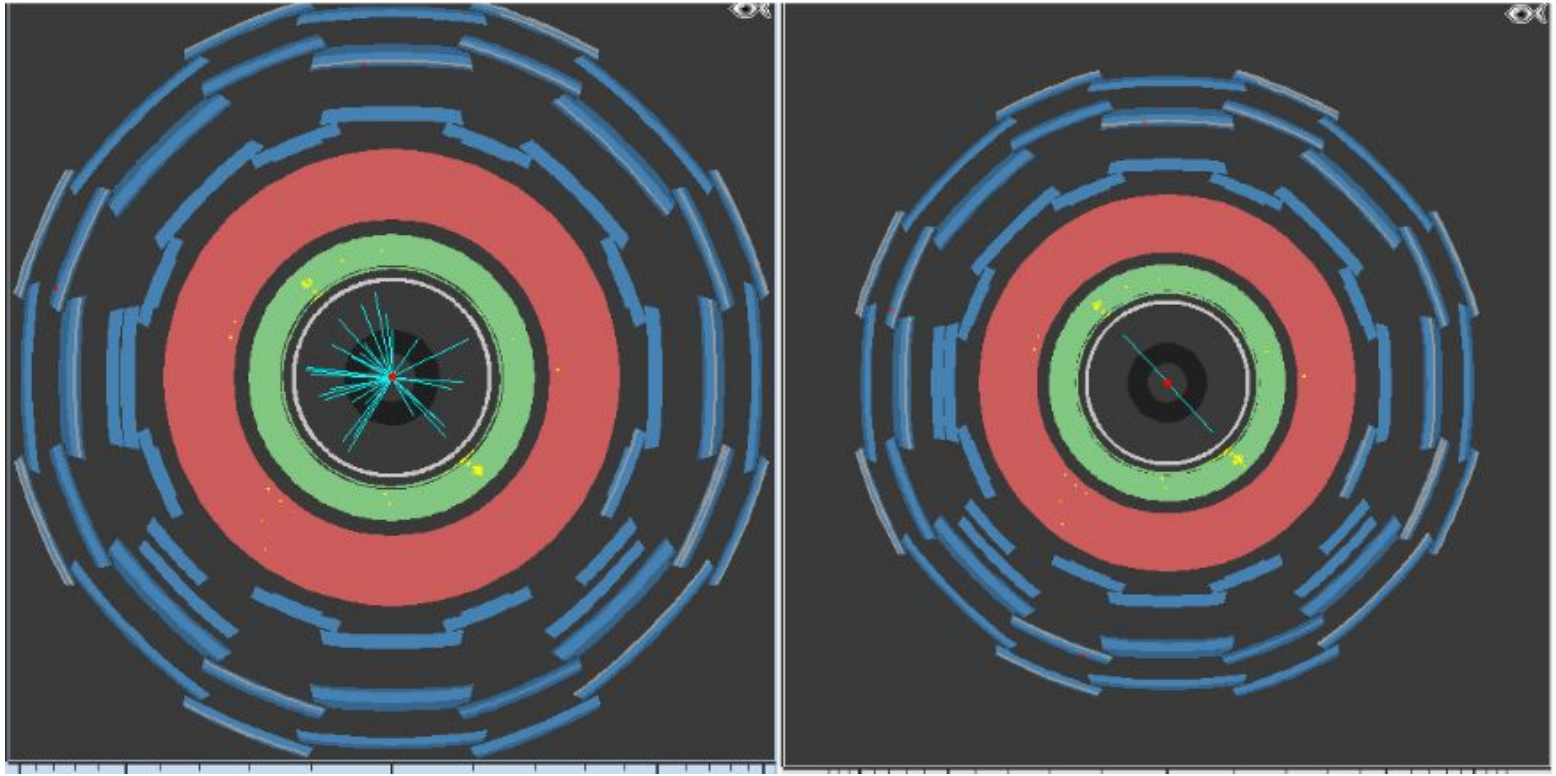
International Particle
Physics Outreach Group

INTERNATIONAL
MASTERCLASSES
hands on particle physics

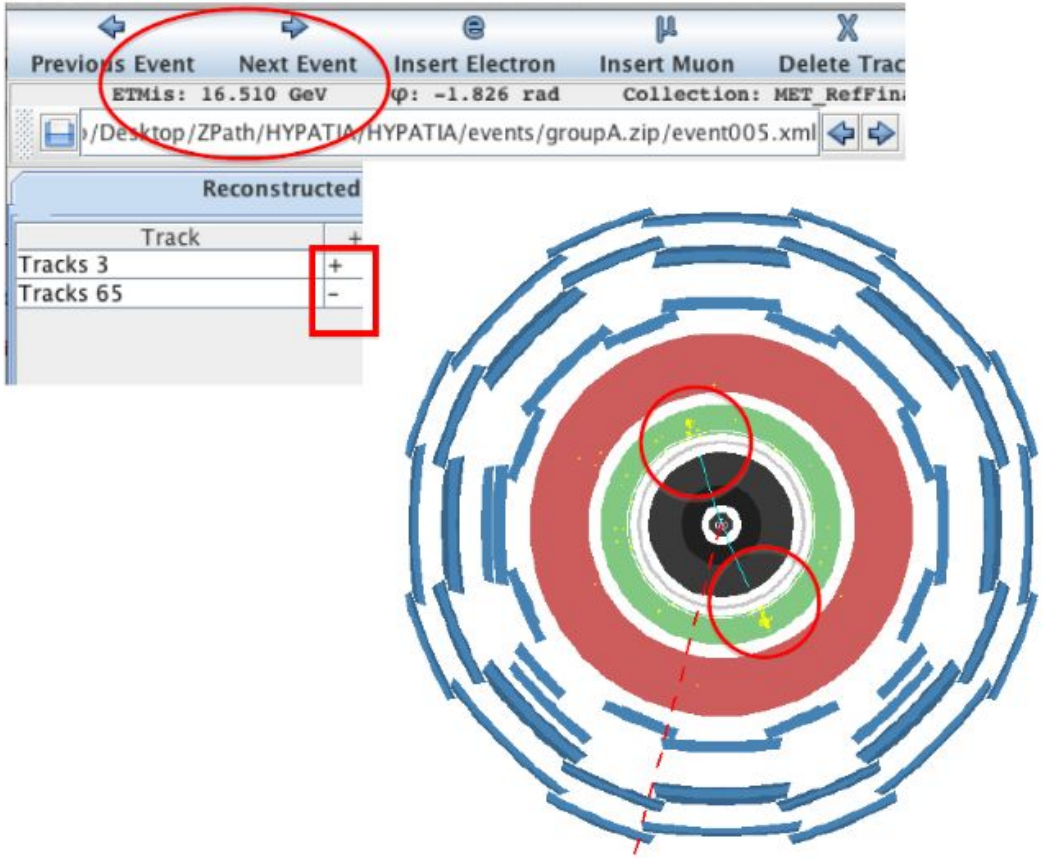
O programa HYPATIA



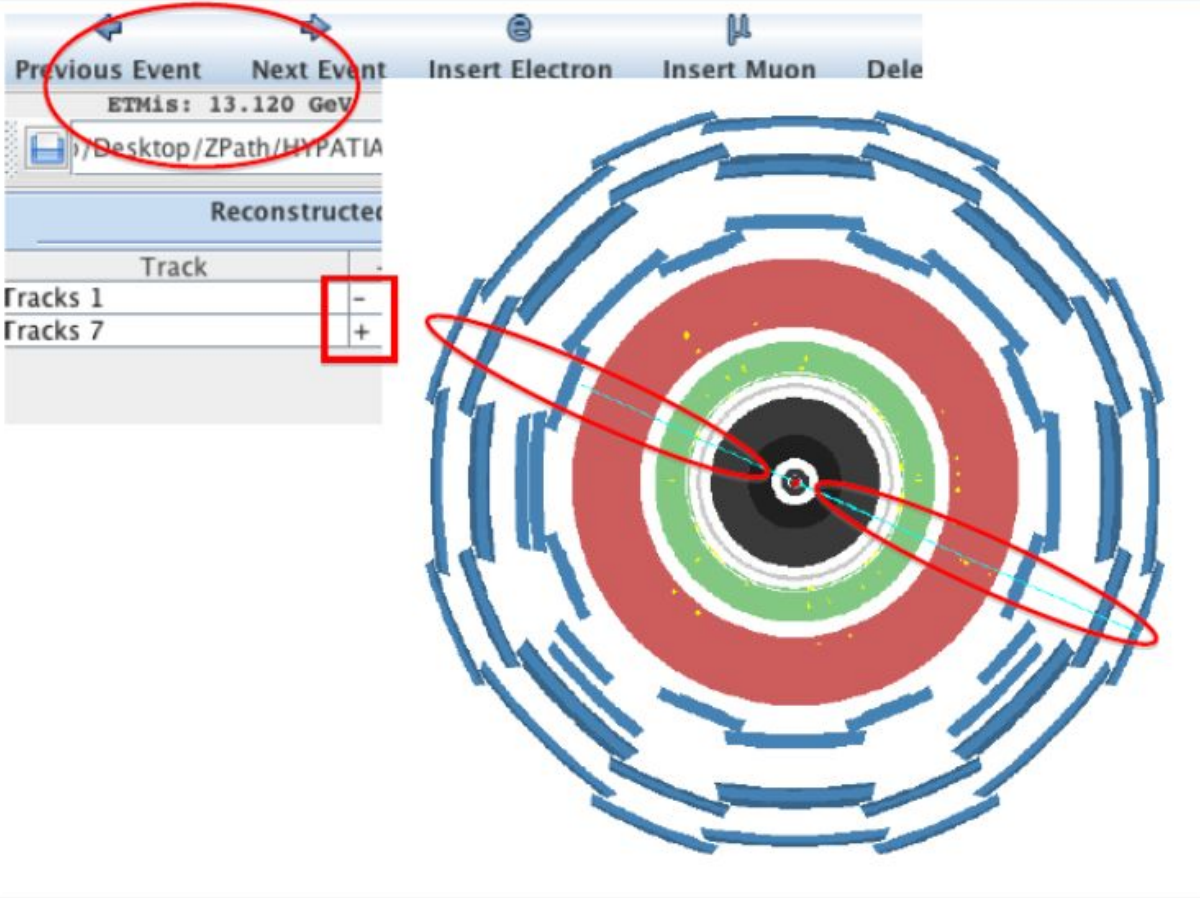
cortes: ver apenas traços com PT>25GeV



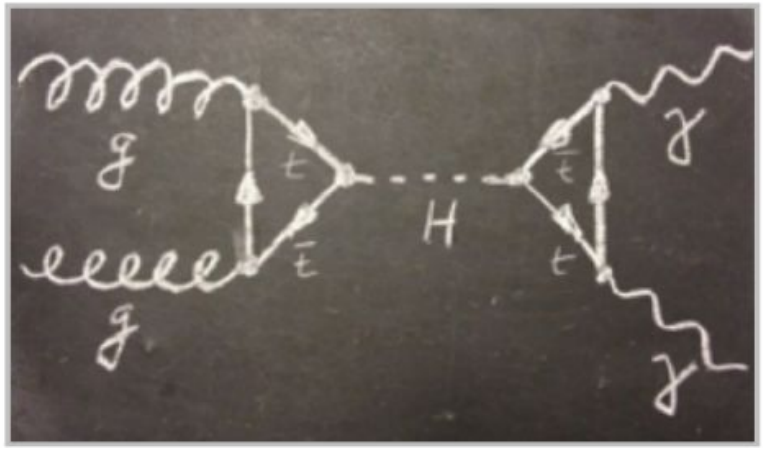
Z → e+e-

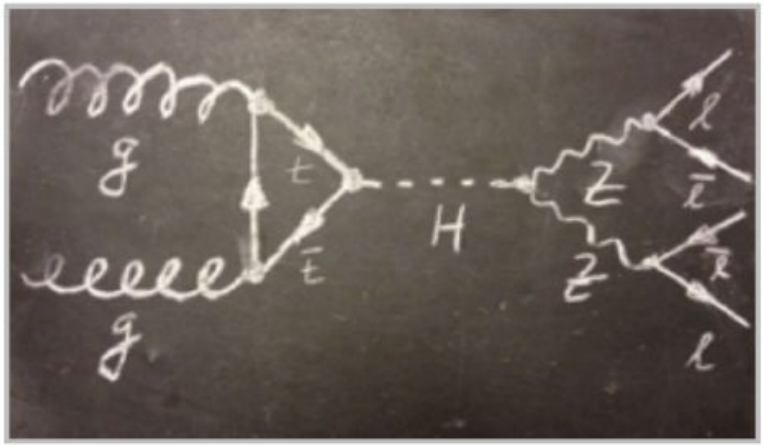

Previous Event
Next Event
Insert Electron
Insert Muon
Delete Trac
ETMis: 16.510 GeV
φ: -1.826 rad
Collection: MET_RefFin
/Desktop/ZPath/HYPATIA/HYPATIA/events/groupA.zip/event005.xml
Reconstructed
Track
+
Tracks 3
+
Tracks 65
-

Z → μ+μ-


Previous Event
Next Event
Insert Electron
Insert Muon
Dele
ETMis: 13.120 GeV
Reconstructed
Track
Tracks 1
Tracks 7

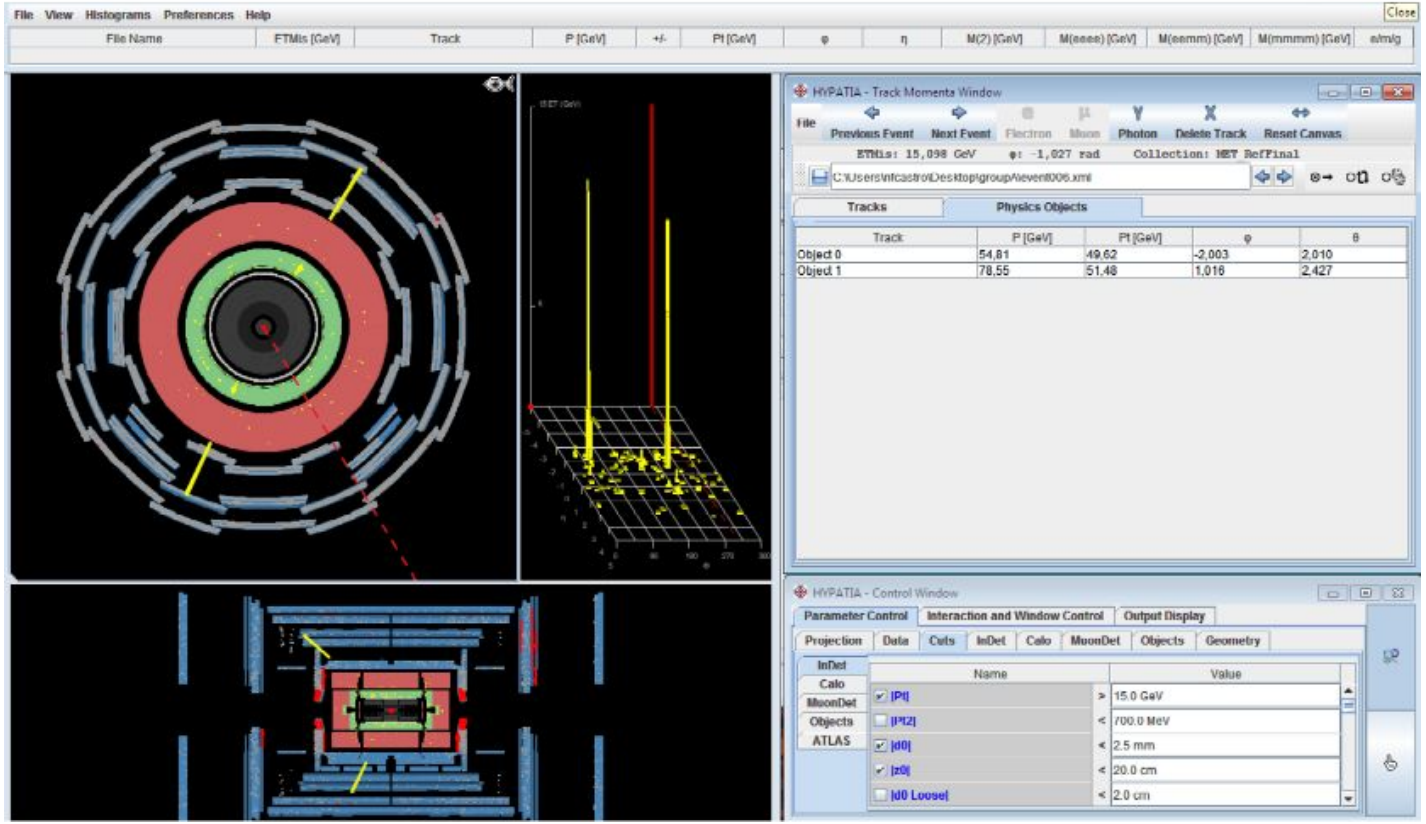
O Bosão de Higgs





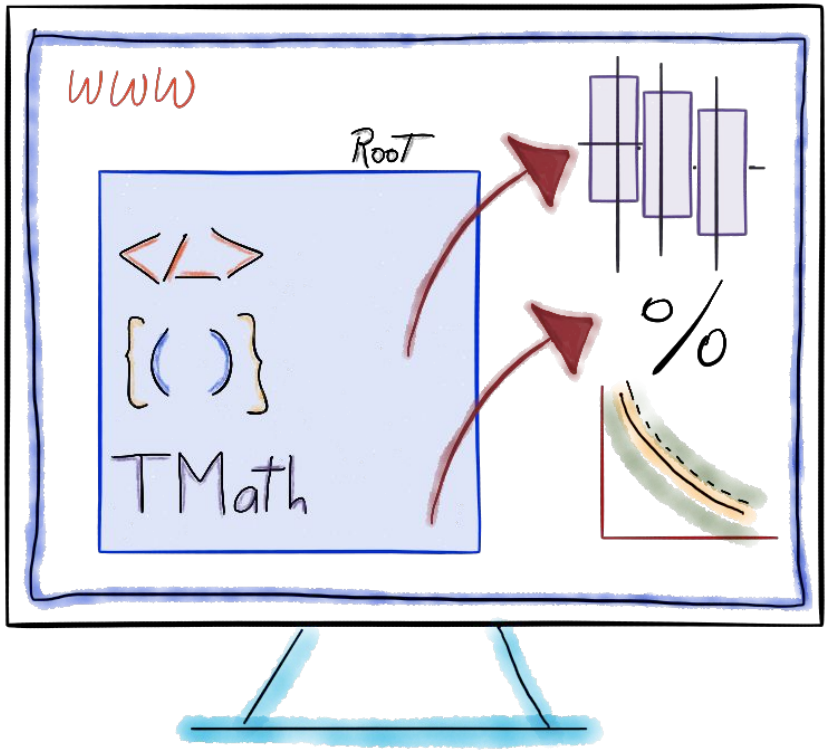
O Bosão de Higgs

$$H \rightarrow \gamma\gamma$$



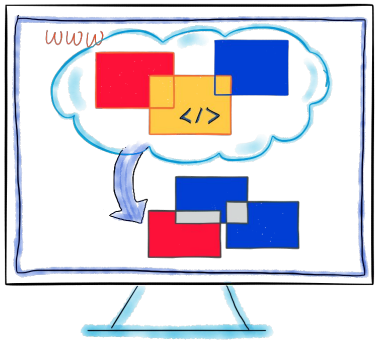
open data ATLAS

http://opendata.atlas.cern



http://opendata.atlas.cern

Documentação:
https://cheatham1.gitbooks.io/openatlasdatatools/content/



Data

The ATLAS collaboration has released 1 inverse femtobarn of data. The **ATLAS datasets** are available on this website and on the CERN open data portal.

One inverse femtobarn corresponds to approximately 100 trillion proton-proton collisions.

Simulated data

Simulated data, commonly named Monte Carlo (MC), are a key feature for the LHC experiments. These events are simulated using current theoretical models and are used to compare theory with real data.

The full simulation requires the following steps

- **Event generation**: Hadronic final states using the proton-proton collisions are generated using programs relying on theoretical calculations, phenomenological models and experimental inputs.
- **Detector Simulation**: Interaction of the generated particles inside the ATLAS detector is simulated.
- **Digitisation**: The detector response is derived from the particle interactions and it is written in a format compatible with the real output of the detector. In addition, because of the high rate of collisions in the LHC, digitised signals from several simulated events can be piled-up to create samples with a realistic experimental background.
- **Reconstruction**: Particle trajectories and energies from the detector are reconstructed. Such final samples are used by the physicists.

Comparing real data and simulated data

Real data and simulated data do not always agree. This can be due to various reasons, such as

- the conditions not being exactly the same e.g. Energy, pile-up.
- not all background processes are included in the simulated data,
- the physics has not been exactly modeled by the theory.

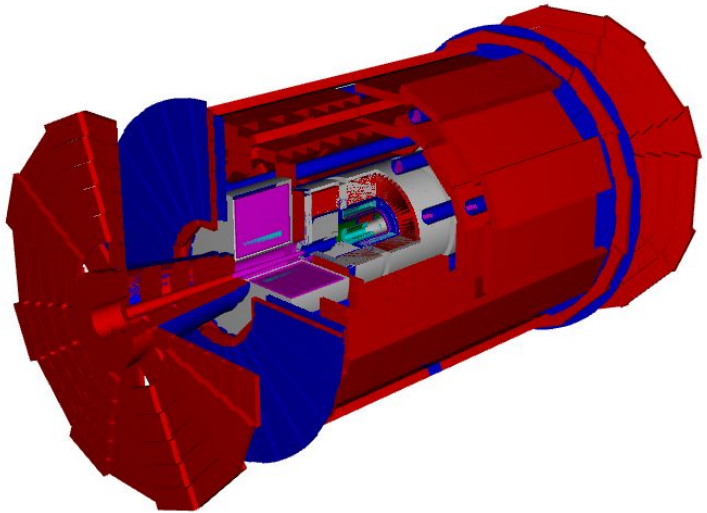
If the data and simulated data does not agree, it is important that physicists understand why.

http://opendata.atlas.cern

http://opendata.atlas.cern/visualisations/root-browser.php

The ATLAS detector | Top Pair physics analysis | ROOTbrowser

Note: take into account that the ATLAS visualization can take several seconds to load (~15 to ~30 sec) please, be patient! (updated on July 2017)



http://opendata.atlas.cern

http://opendata.atlas.cern/visualisations/root-browser.php

The ATLAS detector | Top Pair physics analysis | ROOTbrowser

you don't see the plots? click here to refresh the paper!

Top Quark Pair Analysis

Tip **use your mouse over any of the plots for more interactive options**

The LHC is a top quark factory and studying and understanding top quark physics is one of the major goals of the ATLAS physics programme. This understanding is crucial for studying rarer processes as top quark pair production is a background to virtually all processes having leptons and multiple jets in their final states. Top quark pair production can be studied in the ATLAS open data dataset in both the semileptonic and dileptonic final state. Statistics are expected to be sucient for producing detailed distributions and exploring advanced techniques like the reconstruction of the top quark pair system.

This analysis mimics a standard top quark pair selection in the semileptonic channel. The standard object selection criteria are applied. The event selection is defined as:

- Single electron or muon trigger is satisfied;
- Event in real data passes the Good Run List;
- Event has a good vertex ($N_{tracks} > 4$);
- Exactly one good lepton with $p_T > 25$ GeV;
- At least four good jets;
- At least two b-tagged jets (MV1 @70%);
- $E_T^{miss} > 30$ GeV;
- $m_T^W > 30$GeV.

Figures 1 to 4 depict the lepton kinematics of the leptons with the simulated data reproducing the real data well.

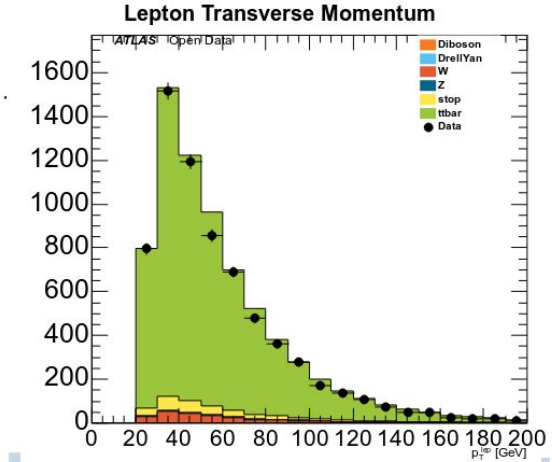


Figure 1: ***Top Analysis:*** Leading lepton transverse momentum p_T.

Lepton Energy

http://opendata.atlas.cern

http://opendata.atlas.cern/visualisations/root-browser.php

The ATLAS detector | Top Pair physics analysis | ROOTbrowser

you don't see the ROOTbrowser? click here to refresh it!

Note: the current set of histograms and plots correspond to the Top Quark Pair Analysis (updated July 2017)

Read a ROOT file

JSROOT version 4.6.0 22/08/2016

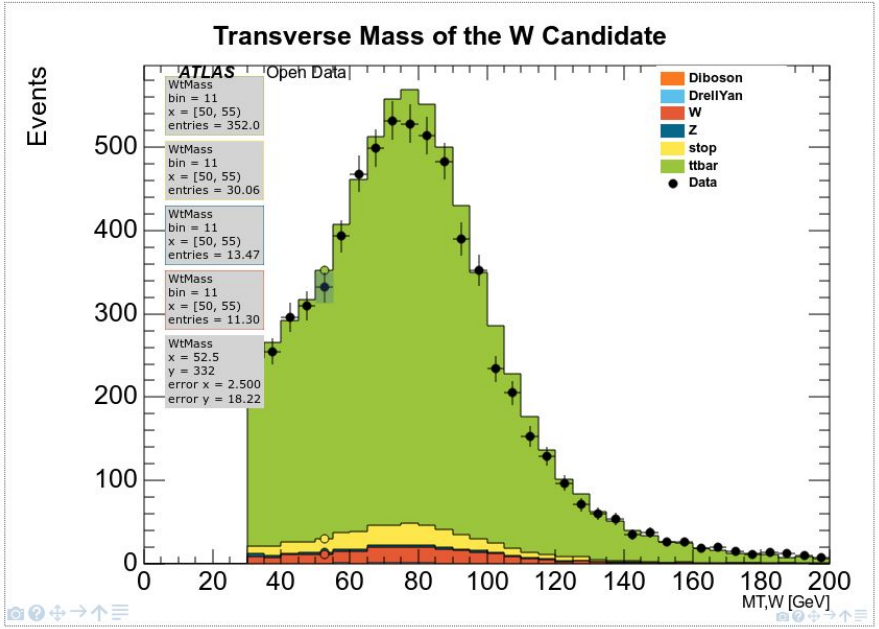
../TTbar_Analysis/ttbar_plots/WtMass.root

Read docu how to open files from other servers.

Load | Reset | simple

open all | close all | clear

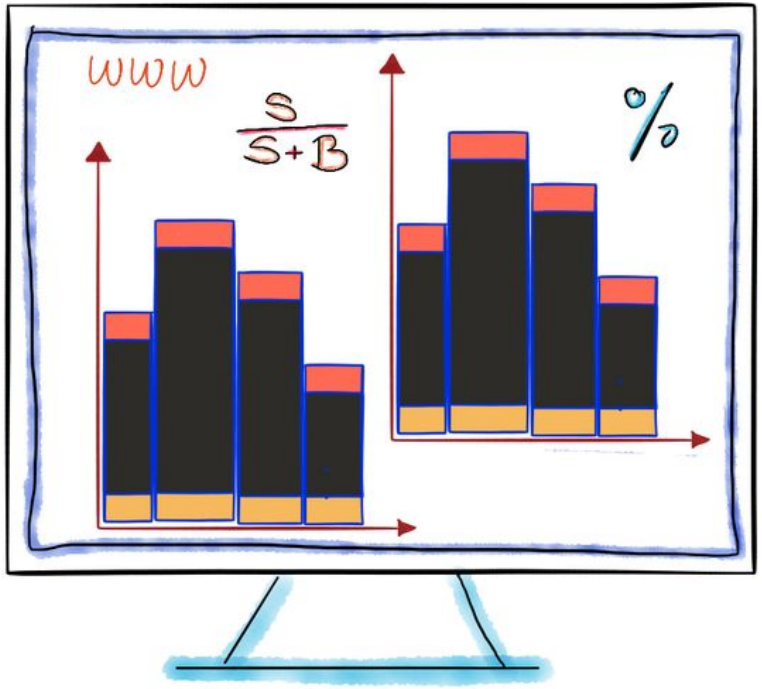
WtMass.root
WtMass;1
StreamerInfo



http://opendata.atlas.cern

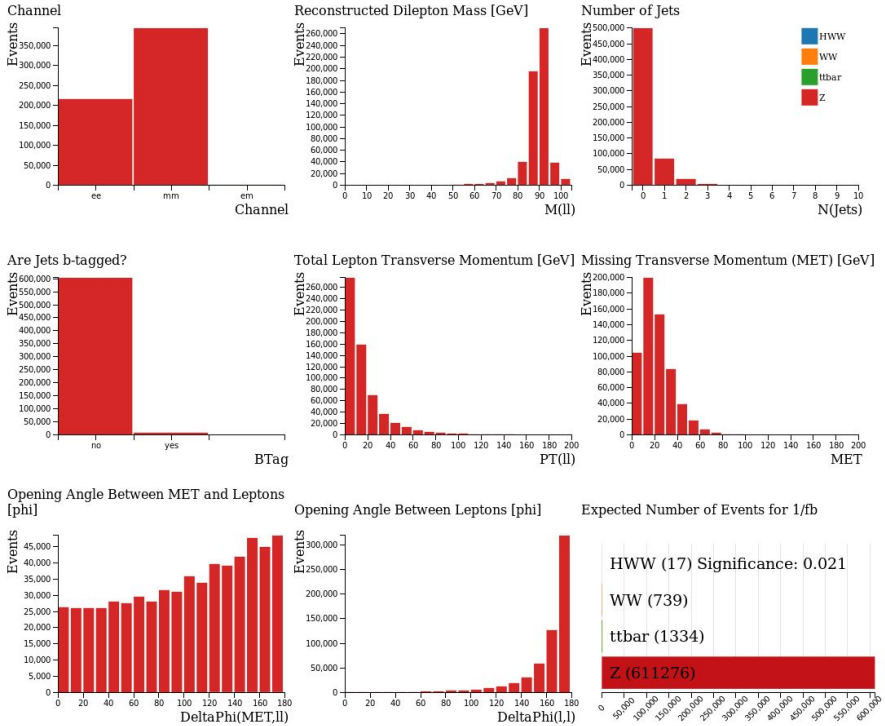
http://opendata.atlas.cern/visualisations/analyser-js.php

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**.



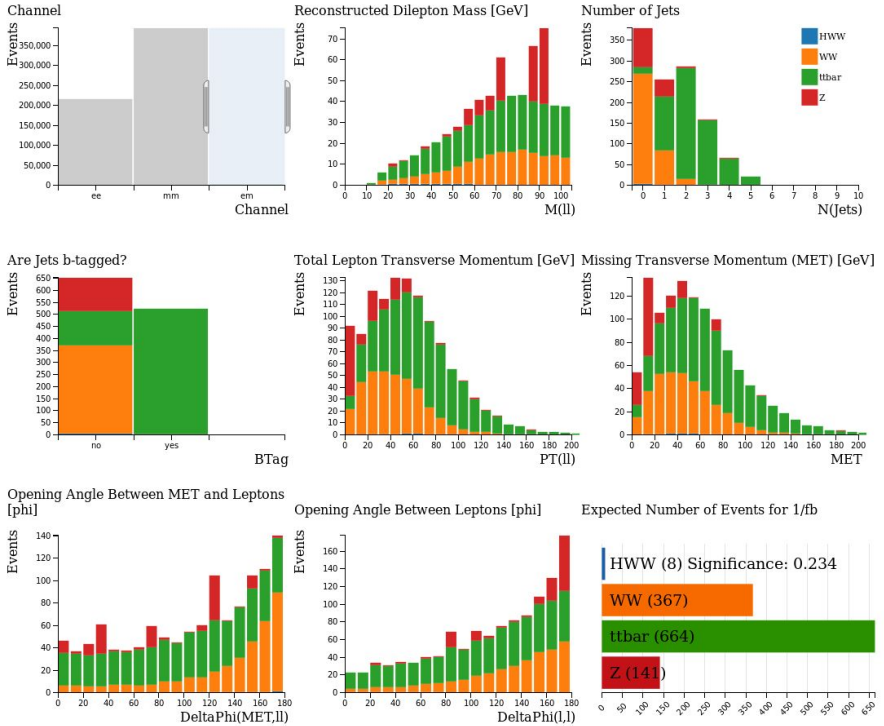
http://opendata.atlas.cern

http://opendata.atlas.cern/visualisations/analyser-js.php



http://opendata.atlas.cern

http://opendata.atlas.cern/visualisations/analyser-js.php



http://opendata.atlas.cern

Os dados (e simulação) são guardados em ficheiros root

- Organizados em trees

https://root.cern.ch/

branchname	type	description
runNumber	int	run number
eventNumber	int	event number
channelNumber	int	channel number
mcWeight	float	weight of an MC event
pvxp_n	int	number of primary vertices
vxp_z	float	z-position of the primary vertex
trigE	bool	boolean whether a standard trigger is satisfied in the egamma stream
trigM	bool	boolean whether a standard trigger is satisfied in the muon stream
passGRL	bool	signifies whether event passes the Good Run List and thus put in isGoodEvent
hasGoodVertex	bool	signifies whether the event has at least one good vertex
lep_n	int	number of preselected leptons
lep_truthMatched	vector<bool>	boolean indicating whether the lepton is matched to a truth lepton
lep_trigMatched	vector<bool>	boolean signifying whether the lepton is the one triggering the event
lep_pt	vector<float>	transverse momentum of the lepton
lep_eta	vector<float>	pseudorapidity of the lepton
lep_phi	vector<float>	azimuthal angle of the lepton
lep_E	vector<float>	energy of the lepton
lep_z0	vector<float>	z-coordinate of the track associated to the lepton wrt. the primary vertex
lep_charge	vector<float>	charge of the lepton
lep_flag	vector<int>	bitmask implementing object cuts of the top group
lep_type	vector<int>	number signifying the lepton type (e, mu, tau) of the lepton
lep_ptcone30	vector<float>	ptcone30 isolation for the lepton
lep_etcone20	vector<float>	etcone20 isolation for the lepton
lep_trackd0pvunbiased	vector<float>	d0 of the track associated to the lepton at the point of closest approach (p.c.a.)
lep_tracksigd0pvunbiased	vector<float>	d0 significance of the track associated to the lepton at the p.c.a.
met_et	float	Transverse energy of the missing momentum vector
met_phi	float	Azimuthal angle of the missing momentum vector
jet_n	int	number of selected jets
jet_pt	vector<float>	transverse momentum of the jet
jet_eta	vector<float>	pseudorapidity of the jet
jet_phi	vector<float>	azimuthal angle of the jet
jet_E	vector<float>	energy of the jet
jet_m	vector<float>	invariant mass of the jet
jet_jvf	vector<float>	JetVertexFraction of the jet
jet_trueflav	vector<int>	true flavor of the jet
jet_truthMatched	vector<int>	information whether the jet matches a jet on truth level
jet_SV0	vector<float>	SV0 weight of the jet
jet_MV1	vector<float>	MV1 weight of the jet
scaleFactor_BTAG	float	scalefactor for btagging
scaleFactor_ELE	float	scalefactor for electron efficiency
scaleFactor_JVFSF	float	scalefactor for jet vertex fraction
scaleFactor_MUON	float	scalefactor for muon efficiency
scaleFactor_PILEUP	float	scalefactor for pileup reweighting
scaleFactor_TRIGGER	float	scalefactor for trigger
scaleFactor_ZVERTEX	float	scalefactor for z-vertex reweighting

https://cds.cern.ch/record/2203649

open data ATLAS

http://opendata.atlas.cern

Three high statistics Standard Model analyses: a selection of events with one leptonically decaying W boson, a selection of leptonically decaying Z boson and a selection of semileptonic top pair production. These analyses are intended to show that the general description of the data for these important background processes is sound. They also pose the possibility to study Standard Model observables like the mass of the Z boson. Observable discrepancies are due to the simplified nature of the used ntuples.

Three low statistics Standard Model analyses: these analyses show the limitations of this dataset with respect to rare processes. They are a WZ analysis, a ZZ analysis as well as a $H \to WW$ analysis. It is possible to obtain results in these analyses and achieve educational objectives. However the statistical limitations prohibit more meaningful analyses. This point is particularly important as it demonstrates that the proposed datasets are intended for educational purposes only.

A beyond the Standard Model analysis: multiple samples of simulated data containing Z' signal events are provided to implement a simplified analysis setting exclusion limits on new physics.

This list should not be seen as an exhaustive list of all possible analyses. Further processes that may be explored include WW production, dileptonic top pair production, single top production or many others.

W Analysis
Z Analysis
Top Quark Pair Analysis
WZ Analysis
ZZ Analysis
$H \to WW$ Analysis
Z' Analysis

http://opendata.atlas.cern

```
atlas@atlas-vm:~/ATLAS-DataAndTools$ ls
Analysis  Configurations  Input  Output  PlotResults.py  Plotting  README.md  results  RunScript.py
atlas@atlas-vm:~/ATLAS-DataAndTools$
```

Analysis: Code for 7 analyses have been prepared for you

Configurations: The Configurations file for running and the PlotConf files for plotting are here

Input: Contains the data and simulated data (MC) files

Output: Your final plots are written here

Plotting: Contains files defining how your plots will look like

results: The histograms are written here when you run an analysis, which are then used for plotting

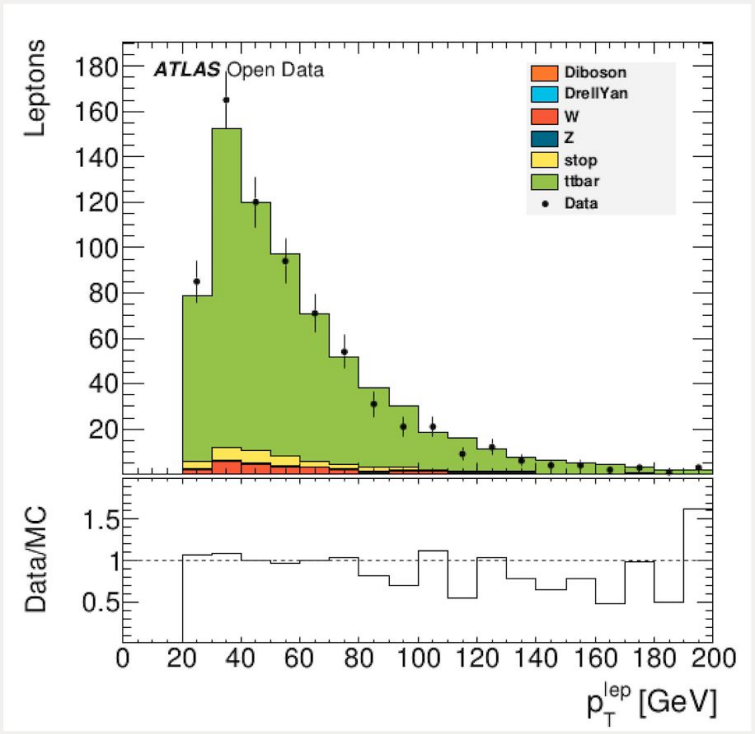
http://opendata.atlas.cern

```
python RunScript.py -a TTbarAnalysis
```

```
atlas@atlas-vm:~/ATLAS-DataAndTools$ python RunScript.py -a TTbarAnalysis -s "WW,WZ"

--------------------DISCLAIMER--------------------
This Software is intended for educational use only!
Under no circumstances does it qualify to reproduce
actual ATLAS analysis results or produce publishable
results!
--------------------------------------------------

Fri Nov 11 19:51:07 2016 Job WW: Intialization phase
Fri Nov 11 19:51:07 2016 Job WW: Adding file: Input/MC/mc_105985.WW.root
Fri Nov 11 19:51:07 2016 Job WW: Now looping over 50000 events




[====================] 100% EFT:    0s
Fri Nov 11 19:51:09 2016 EventStatistics WW.TTbarAnalysis: +-----------------------------------
------------------------+
Fri Nov 11 19:51:09 2016 EventStatistics WW.TTbarAnalysis: |                all :              1
00000 :          97327.29 |
Fri Nov 11 19:51:09 2016 EventStatistics WW.TTbarAnalysis: |          EventCuts :
49285 :          47951.86 |
Fri Nov 11 19:51:09 2016 EventStatistics WW.TTbarAnalysis: |                MET :
36460 :          35035.71 |
Fri Nov 11 19:51:09 2016 EventStatistics WW.TTbarAnalysis: |           1 Lepton :
32375 :          31193.98 |
Fri Nov 11 19:51:09 2016 EventStatistics WW.TTbarAnalysis: |               Jets :
  595 :            553.94 |
Fri Nov 11 19:51:09 2016 EventStatistics WW.TTbarAnalysis: |              btags :
    5 :             2.87 |
Fri Nov 11 19:51:09 2016 EventStatistics WW.TTbarAnalysis: |              final :
    5 :             2.87 |
Fri Nov 11 19:51:09 2016 EventStatistics WW.TTbarAnalysis: +-----------------------------------
------------------------+
Fri Nov 11 19:51:09 2016 Job WW: finished successfully. Total time:    2s
Fri Nov 11 19:51:09 2016 Job WZ: Intialization phase
Fri Nov 11 19:51:09 2016 Job WZ: Adding file: Input/MC/mc_105987.WZ.root
Fri Nov 11 19:51:09 2016 Job WZ: Now looping over 50000 events
```

http://opendata.atlas.cern

```
python PlotResults.py Configurations/PlotConf_TTbarAnalysis.py
```



http://opendata.atlas.cern

```
12  def isGoodLepton(Lepton):
13      if (abs(Lepton.pdgId()) == 11 and isGoodElectron(Lepton)): return True;
14      if (abs(Lepton.pdgId()) == 13 and isGoodMuon(Lepton)): return True;
15      return False;
16
17  def isGoodElectron(Lepton):
18      if not Lepton.isTight(): return False
19      if not Lepton.pt() > 25: return False
20      if not Lepton.isoetconerel20() < 0.15: return False
21      if not Lepton.isoptconerel30() < 0.15: return False
22      return True;
23
24  def isGoodMuon(Lepton):
25      if not Lepton.isTight(): return False
26      if not Lepton.pt() > 25: return False
27      if not Lepton.isoetconerel20() < 0.15: return False
28      if not Lepton.isoptconerel30() < 0.15: return False
29      return True;
```

http://opendata.atlas.cern

W Analysis

This analysis searches W bosons decaying to leptons.

The analysis specific event selection criteria are:

- Exactly one good lepton with p_T > 25 GeV;
- Missing ET > 30 GeV;
- Reconstructed transverse mass W > 30 GeV.

The analysis code is located in the Analysis folder. It is used to write out histograms for the individual input files which will be used for plotting purposes later. Here is a snippet from the W analysis code called WAnalysis.py:

```
46        # apply standard event based selection
47        if not AH.StandardEventCuts(eventinfo): return False
48        self.countEvent("EventCuts", weight)
49
50        # Lepton Requirements
51        goodLeptons = AH.selectAndSortContainer(self.Store.getLeptons(), AH.isGoodLepton, lambda p: p.pt())
52        if not (len(goodLeptons) == 1): return False
53        self.countEvent("1 high pt Leptons", weight)
54
55        lepton = goodLeptons[0]
56
57        # cut on W boson candidate
58        etmiss = self.Store.getEtMiss()
59        if not AH.WTransverseMass(lepton, etmiss) > 30: return False;
60        if not etmiss.et() > 30: return False
```

Look at the code directly here: WAnalysis.py

http://opendata.atlas.cern

- O projecto ATLAS Open Data, inserido na iniciativa de Open Data do CERN, fornece uma grande quantidade de dados reais de LHC, bem como de simulação e exemplos de códigos completamente funcionais

- Estas ferramentas estão disponíveis para todos e fornecem um extraordinário recurso pedagógico que permite exemplificar de uma forma muito realista como se faz uma análise de dados em física de partículas

    - Aprender fazendo é a palavra de ordem aqui!