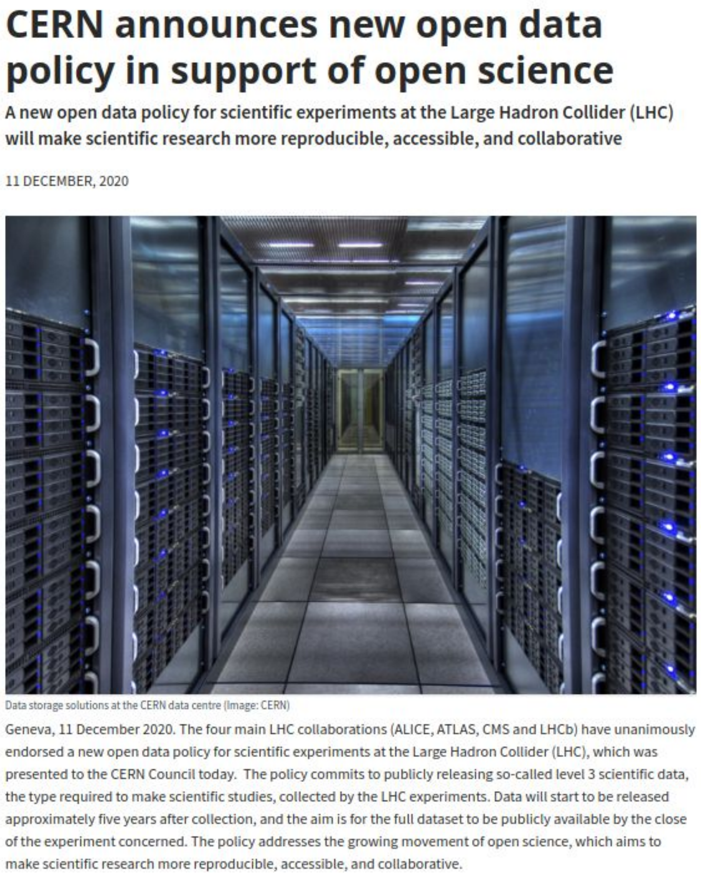
LHC experiments and their Open Data

LHCP 2021

Edgar F. Carrera
On behalf of the ALICE, ATLAS, CMS, and LHCb Collaborations
Universidad San Francisco de Quito, Ecuador

June 9, 2021

CERN Open Data Policy for LHC experiments



CERN announces new open data policy in support of open science

A new open data policy for scientific experiments at the Large Hadron Collider (LHC) will make scientific research more reproducible, accessible, and collaborative

11 DECEMBER, 2020

Data storage solutions at the CERN data centre (Image: CERN)

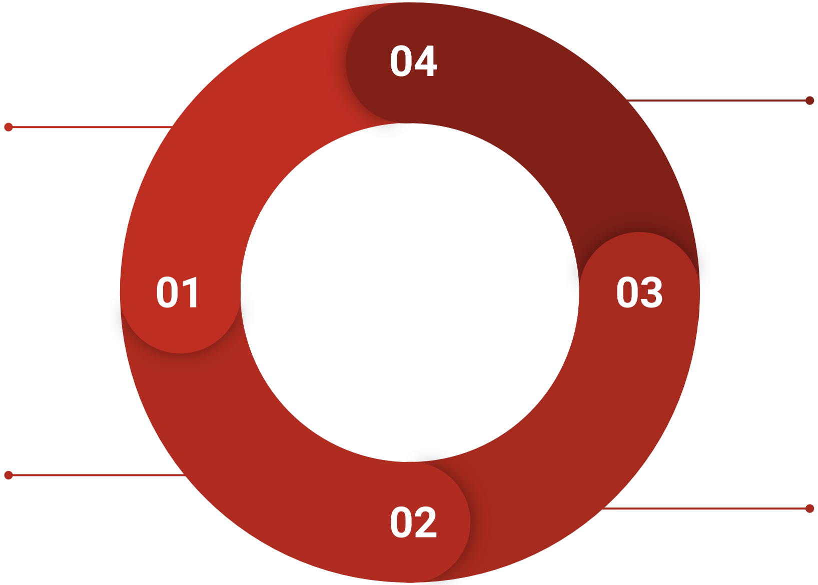
Geneva, 11 December 2020. The four main LHC collaborations (ALICE, ATLAS, CMS and LHCb) have unanimously endorsed a new open data policy for scientific experiments at the Large Hadron Collider (LHC), which was presented to the CERN Council today. The policy commits to publicly releasing so-called level 3 scientific data, the type required to make scientific studies, collected by the LHC experiments. Data will start to be released approximately five years after collection, and the aim is for the full dataset to be publicly available by the close of the experiment concerned. The policy addresses the growing movement of open science, which aims to make scientific research more reproducible, accessible, and collaborative.

- CERN committed to openness and preservation for a long time
- Policy relates to data collected by LHC experiments
- Endorsed by all LHC experiments
- Different levels of abstraction:

- ● Level 1 (published results and numerical information (likelihoods))
- ● Level 2 (outreach and education)
  - ○ simplified format
- ● Level 3 (reconstructed data)
  - ○ research quality
  - ○ latency/embargo periods apply
  - ○ restrictions apply
- ● Level 4 (raw data)

Level 3 (reconstructed data)

- All LHC experiments share common strategies for Level 1, 2, and 4.
- Level 3 strategies differ, within a common ground.
- LHC experiments will release:



Calibrated reconstructed data

- Including provenance data, simulated samples, example workflows and documentation

Periodically

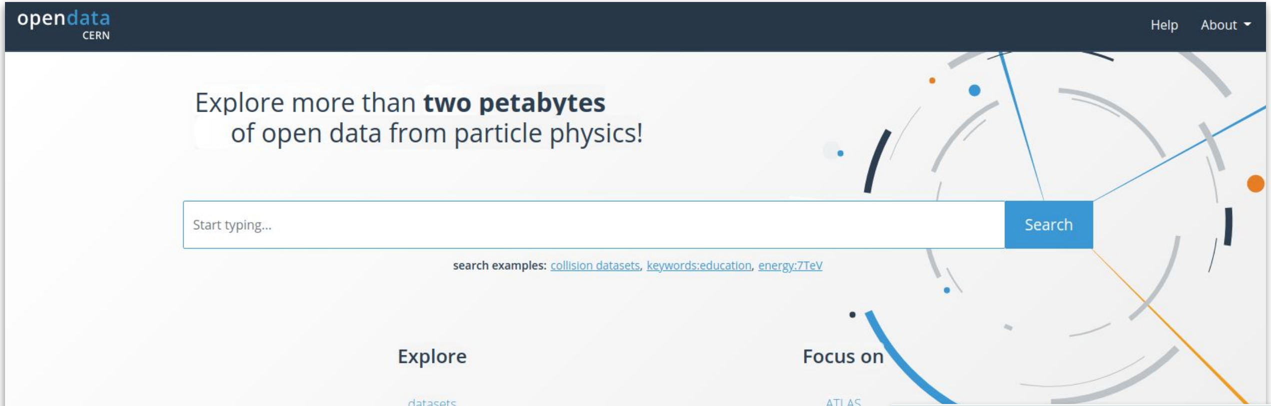
- With an appropriate latency period.
- Data releases within 5 years of the conclusion of run period.
- Timeline defined by experiments but full datasets will be made public at the end of the collaborations
- Some data may be withheld if active analyses ongoing

Using the CERN Open Data Portal (CODP)

And may offer association programs

- External authors may not get access to cumulative knowledge within the collaborations
- Association programs may be provided

CERN Open Data Portal (CODP)



Explore more than **two petabytes** of open data from particle physics!

Start typing... | Search

search examples: collision datasets, keywords:education, energy:7TeV

Explore

- datasets
- software
- environments
- documentation

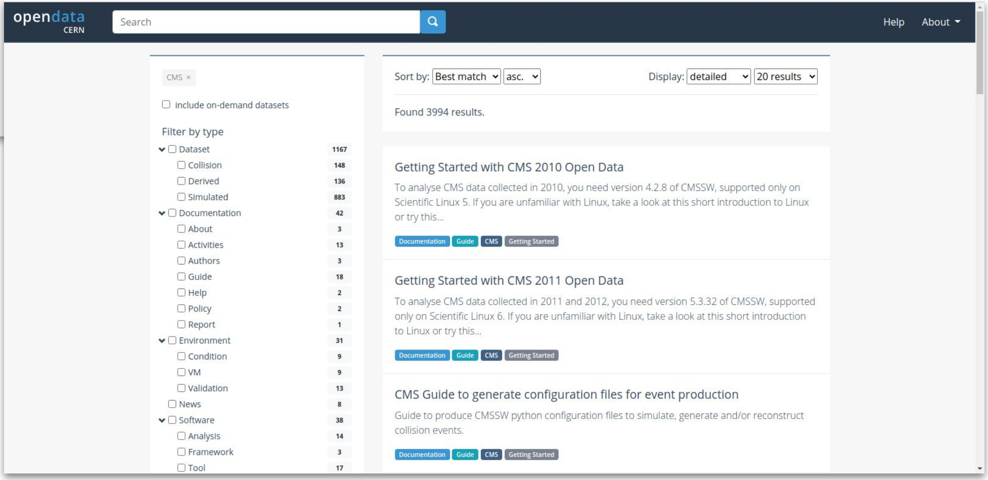
Focus on

- ATLAS
- ALICE
- CMS
- LHCb
- OPERA
- Data Science

https://opendata.cern.ch/

- Access point to data
- Also software and documentation

- Products shared under open licenses
- Issued with a Digital Object Identifier (DOI) to make them citable



☐ include on-demand datasets

Filter by type

☐ Dataset	1167
☐ Collision	148
☐ Derived	136
☐ Simulated	883
☐ Documentation	42
☐ About	3
☐ Activities	13
☐ Authors	3
☐ Guide	18
☐ Help	2
☐ Policy	2
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☐ VM	9
☐ Validation	13
☐ News	8
☐ Software	38
☐ Analysis	14
☐ Framework	3
☐ Tool	17

Sort by: Best match asc. Display: detailed 20 results

Found 3994 results.

Getting Started with CMS 2010 Open Data

To analyse CMS data collected in 2010, you need version 4.2.8 of CMSSW, supported only on Scientific Linux 5. If you are unfamiliar with Linux, take a look at this short introduction to Linux or try this...

Documentation Guide CMS Getting Started

Getting Started with CMS 2011 Open Data

To analyse CMS data collected in 2011 and 2012, you need version 5.3.32 of CMSSW, supported only on Scientific Linux 6. If you are unfamiliar with Linux, take a look at this short introduction to Linux or try this...

Documentation Guide CMS Getting Started

CMS Guide to generate configuration files for event production

Guide to produce CMSSW python configuration files to simulate, generate and/or reconstruct collision events.

Documentation Guide CMS Getting Started

ALICE open data for RESEARCH

Release Policy:

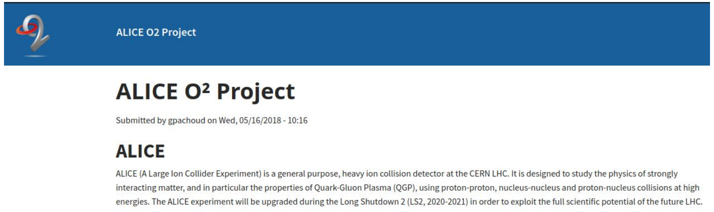
- Public data releases expected periodically
- Needed appropriate latency period to allow (true for all experiments):
  - thorough understanding of the data
  - reconstruction and calibrations
  - scientific exploitation of the data
- Aim to commence data releases within five years of the conclusion of the run period
- Size of the released datasets commensurate with the amount of data collected

Data Products and computing environment:

- Conversion of Run 1 and Run 2 ESD and AOD into new AOD format (based on ALICE O2 Project)
- Also derived nanoAOD considered
- Real (HI) and simulated datasets in new AOD format expected
- Related software via VM and/or containers

Current status and timeline:

- 5% (7%) of Pb-Pb (pp) 2010 ESD datasets released
- Conversion into new AOD format expected by the end of 2021
- Expect to populate CODP with new AOD from 2022

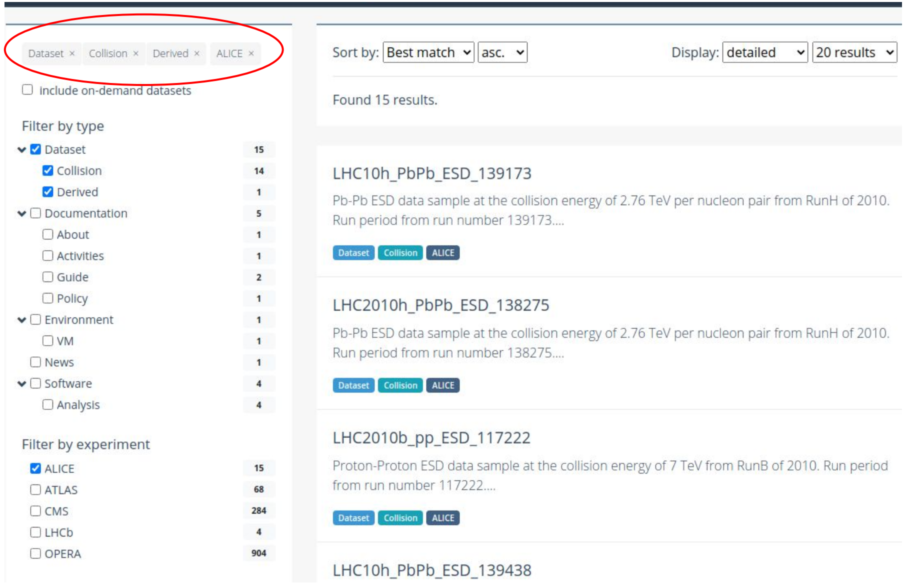

ALICE O2 Project

ALICE O² Project

Submitted by gpachoud on Wed, 05/16/2018 - 10:16

ALICE

ALICE (A Large Ion Collider Experiment) is a general purpose, heavy ion collision detector at the CERN LHC. It is designed to study the physics of strongly interacting matter, and in particular the properties of Quark-Gluon Plasma (QGP), using proton-proton, nucleus-nucleus and proton-nucleus collisions at high energies. The ALICE experiment will be upgraded during the Long Shutdown 2 (LS2, 2020-2021) in order to exploit the full scientific potential of the future LHC.



□ Include on-demand datasets

Filter by type

☑ Dataset	15
☑ Collision	14
☑ Derived	1
□ Documentation	5
□ About	1
□ Activities	1
□ Guide	2
□ Policy	1
□ Environment	1
□ VM	1
□ News	1
□ Software	4
□ Analysis	4

Filter by experiment

☑ ALICE	15
□ ATLAS	68
□ CMS	284
□ LHCb	4
□ OPERA	904

Sort by: Best match asc. Display: detailed 20 results

Found 15 results.

LHC10h_PbPb_ESD_139173

Pb-Pb ESD data sample at the collision energy of 2.76 TeV per nucleon pair from RunH of 2010. Run period from run number 139173....

LHC2010h_PbPb_ESD_138275

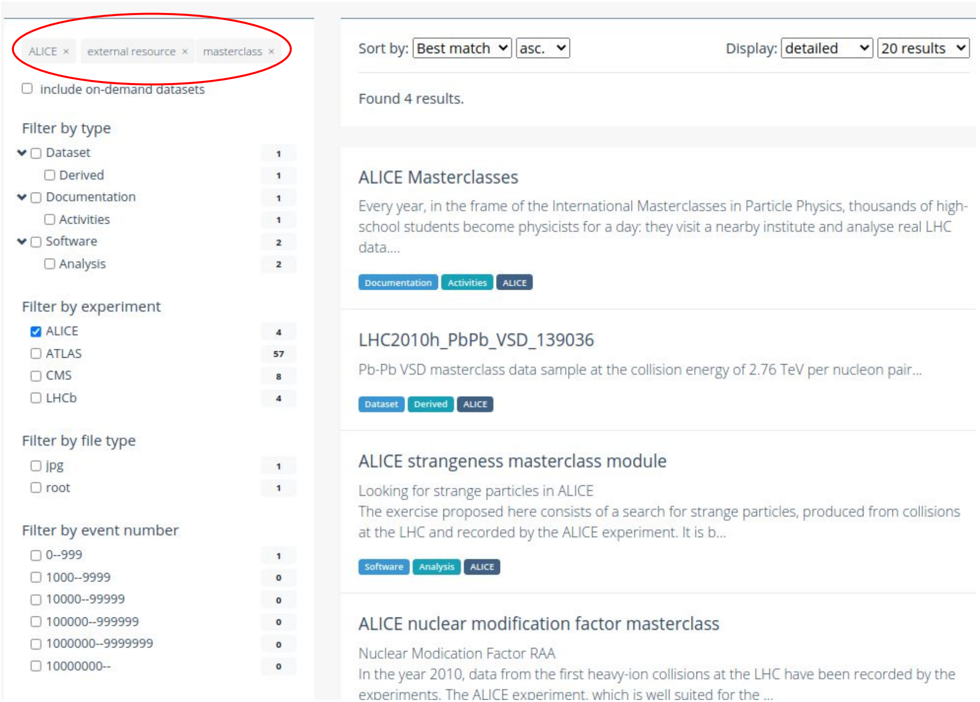
Pb-Pb ESD data sample at the collision energy of 2.76 TeV per nucleon pair from RunH of 2010. Run period from run number 138275....

LHC2010b_pp_ESD_117222

Proton-Proton ESD data sample at the collision energy of 7 TeV from RunB of 2010. Run period from run number 117222....

LHC10h_PbPb_ESD_139438

ALICE open data for OUTREACH AND EDUCATION



ALICE × external resource × masterclass ×

☐ include on-demand datasets

Filter by type

☐ Dataset	1
☐ Derived	1
☐ Documentation	1
☐ Activities	1
☐ Software	2
☐ Analysis	2

Filter by experiment

☑ ALICE	4
☐ ATLAS	57
☐ CMS	8
☐ LHCb	4

Filter by file type

☐ jpg	1
☐ root	1

Filter by event number

☐ 0--999	1
☐ 1000--9999	0
☐ 10000--99999	0
☐ 100000--999999	0
☐ 1000000--9999999	0
☐ 10000000--	0

Sort by: Best match asc. Display: detailed 20 results

Found 4 results.

ALICE Masterclasses

Every year, in the frame of the International Masterclasses in Particle Physics, thousands of high-school students become physicists for a day: they visit a nearby institute and analyse real LHC data....

Documentation Activities ALICE

LHC2010h_PbPb_VSD_139036

Pb-Pb VSD masterclass data sample at the collision energy of 2.76 TeV per nucleon pair...

Dataset Derived ALICE

ALICE strangeness masterclass module

Looking for strange particles in ALICE

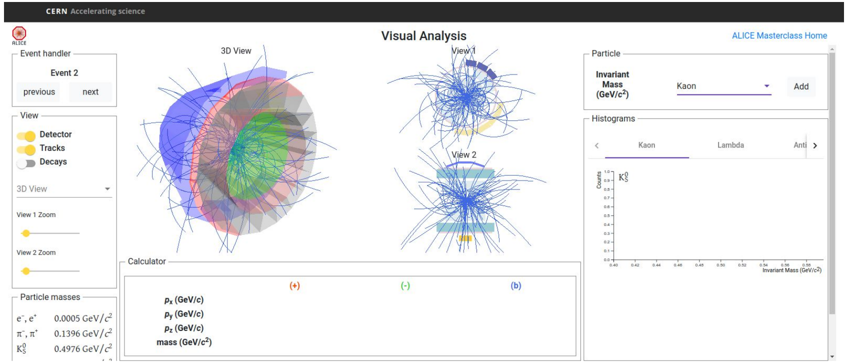
The exercise proposed here consists of a search for strange particles, produced from collisions at the LHC and recorded by the ALICE experiment. It is b...

Software Analysis ALICE

ALICE nuclear modification factor masterclass

Nuclear Modication Factor RAA

In the year 2010, data from the first heavy-ion collisions at the LHC have been recorded by the experiments. The ALICE experiment, which is well suited for the ...

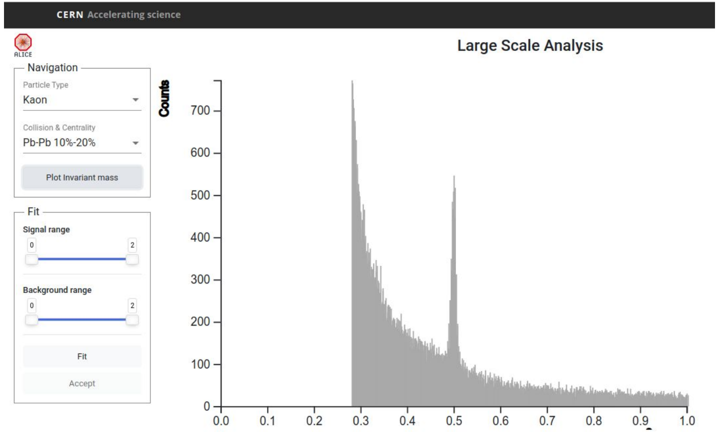


Event 2

3D View

Invariant Mass (GeV/c^2): Kaon

e^-, e^+	0.0005 GeV/c^2
π^-, π^+	0.1396 GeV/c^2
K^0_S	0.4976 GeV/c^2



Particle Type: Kaon

Collision & Centrality: Pb-Pb 10%-20%

- ESD files in COPD have also been used for outreach and education
- new version of the ALICE - strange particles masterclass exercise is web-based: https://alice-web-masterclass.web.cern.ch/ (all data sets needed are provided by the web server)

ATLAS open data for Research

Release Policy:

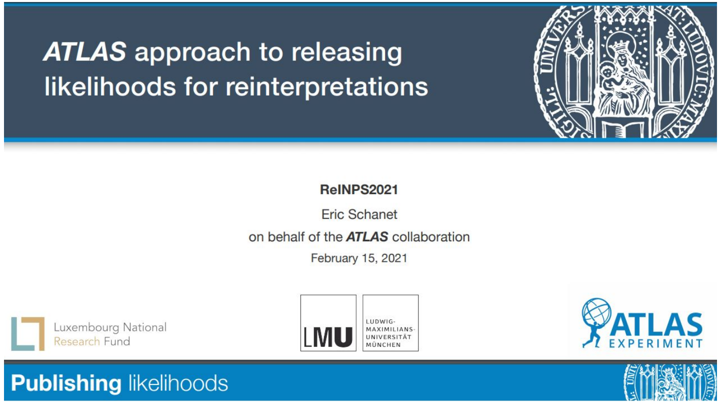
- Preparing periodic releases in alignment with new CERN-LHC policy
- Appropriate latency period needed to understand and scientifically exploit the data

Data Products and computing environment:

- Full likelihoods released (level 1 data) for reinterpretation
- Real and simulated datasets in PHYSLITE format (calibrated objects and information to compute systematics)
- Associated software (containers)

Current status and timeline:

- Only datasets for education purposes released so far.
- Association programs established (case-by-case for external proposals) for specific analyses
- Special datasets may also be approved for release



***ATLAS* approach to releasing likelihoods for reinterpretations**

ReINPS2021

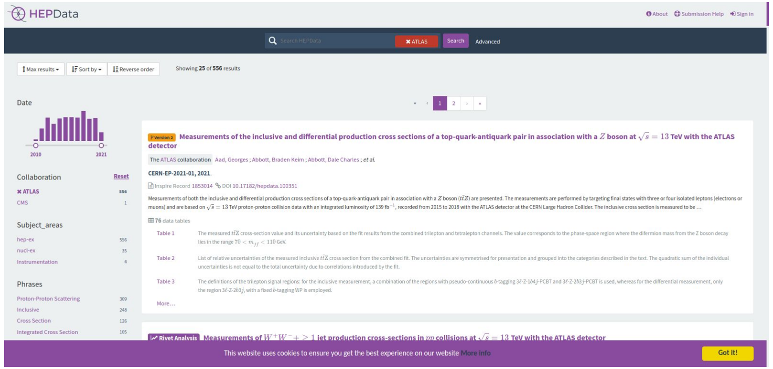
Eric Schanet

on behalf of the ***ATLAS*** collaboration

February 15, 2021

Luxembourg National Research Fund
LMU
LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN
ATLAS EXPERIMENT

Publishing likelihoods



Showing 25 of 556 results

Collaboration Reset

ATLAS 556

CMS 1

Subject_areas

hep-ex 556

nucl-ex 35

Instrumentation 4

Phrases

Proton-Proton Scattering 309

Inclusive 248

Cross Section 126

Integrated Cross Section 105

Measurements of the inclusive and differential production cross sections of a top-quark-antiquark pair in association with a Z boson at $\sqrt{s} = 13$ TeV with the ATLAS detector

The ATLAS collaboration Aad, Georges ; Abbott, Braden Keim ; Abbott, Dale Charles ; *et al.*

CERN-EP-2021-01, 2021.

Inspire Record 1853014 DOI 10.17182/hepdata.100351

Measurements of both the inclusive and differential production cross sections of a top-quark-antiquark pair in association with a Z boson ($t\bar{t}Z$) are presented. The measurements are performed by targeting final states with three or four isolated leptons (electrons or muons) and are based on $\sqrt{s} = 13$ TeV proton-proton collision data with an integrated luminosity of 139 fb^{-1}, recorded from 2015 to 2018 with the ATLAS detector at the CERN Large Hadron Collider. The inclusive cross section is measured to be …

76 data tables

Table 1 The measured $t\bar{t}Z$ cross-section value and its uncertainty based on the fit results from the combined trilepton and tetralepton channels. The value corresponds to the phase-space region where the difermion mass from the Z boson decay lies in the range $70 < m_{ff} < 110$ GeV.

Table 2 List of relative uncertainties of the measured inclusive $t\bar{t}Z$ cross section from the combined fit. The uncertainties are symmetrised for presentation and grouped into the categories described in the text. The quadratic sum of the individual uncertainties is not equal to the total uncertainty due to correlations introduced by the fit.

Table 3 The definitions of the trilepton signal regions: for the inclusive measurement, a combination of the regions with pseudo-continuous b-tagging 3ℓ-Z-1b4j-PCBT and 3ℓ-Z-2b3j-PCBT is used, whereas for the differential measurement, only the region 3ℓ-Z-2b3j, with a fixed b-tagging WP is employed.

More…

Measurements of $W^+W^- + \geq 1$ jet production cross-sections in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

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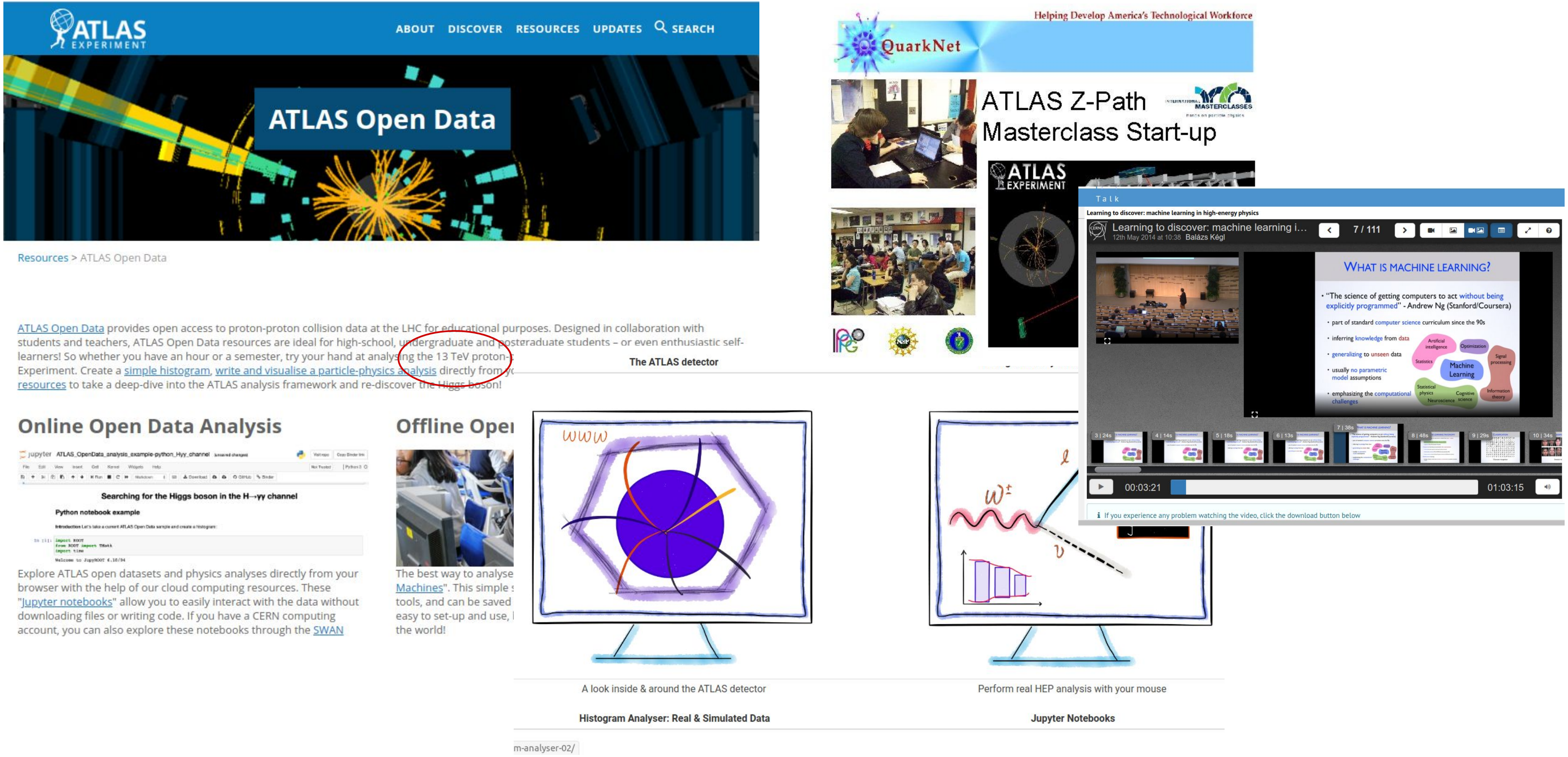
ATLAS open data for Outreach and Education



Resources > ATLAS Open Data

ATLAS Open Data provides open access to proton-proton collision data at the LHC for educational purposes. Designed in collaboration with students and teachers, ATLAS Open Data resources are ideal for high-school, undergraduate and postgraduate students – or even enthusiastic self-learners! So whether you have an hour or a semester, try your hand at analysing the 13 TeV proton-
Experiment. Create a simple histogram, write and visualise a particle-physics analysis directly from y
resources to take a deep-dive into the ATLAS analysis framework and re-discover the Higgs boson!

Online Open Data Analysis

Searching for the Higgs boson in the H→γγ channel

Python notebook example

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

```
In [1]: import ROOT
        from ROOT import TMath
        import time
Welcome to JupyROOT 6.16/04
```

Explore ATLAS open datasets and physics analyses directly from your browser with the help of our cloud computing resources. These "Jupyter notebooks" allow you to easily interact with the data without downloading files or writing code. If you have a CERN computing account, you can also explore these notebooks through the SWAN

Offline Ope

The best way to analyse
Machines". This simple
tools, and can be saved
easy to set-up and use,
the world!

Helping Develop America's Technological Workforce

ATLAS Z-Path Masterclass Start-up

The ATLAS detector

A look inside & around the ATLAS detector

Perform real HEP analysis with your mouse

Histogram Analyser: Real & Simulated Data

Jupyter Notebooks

m-analyser-02/

Talk

Learning to discover: machine learning in high-energy physics

Learning to discover: machine learning i...
12th May 2014 at 10:38 Balázs Kégl

WHAT IS MACHINE LEARNING?

- "The science of getting computers to act without being explicitly programmed" - Andrew Ng (Stanford/Coursera)
  - part of standard computer science curriculum since the 90s
  - inferring knowledge from data
  - generalizing to unseen data
  - usually no parametric model assumptions
  - emphasizing the computational challenges

If you experience any problem watching the video, click the download button below

CMS open data for Research

Release Policy:

- 50% after 6 years and
- 100% within 10 years of data taking
- Limit of 20% if data taking still planned
- 100% at the end of collaboration
- CB approval always needed (which can modify the dates and sizes)

Data Products and computing environment:

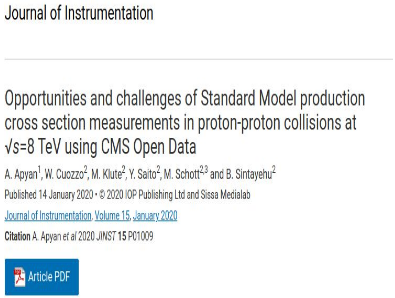
- Real and simulated datasets in AOD (Run 1) format
- MiniAOD and nanoAOD (Run 2 and beyond)
- VM and Docker containers with CMSSW software
- Trigger info and conditions database (align., calib, etc.) through CVMFS
- Data quality and luminosity information tools
- Additional level-1 (numerical info) through Inspire and HEPData.

Current status and timeline:

- Most pp data from Run 1 released (2010-2012)
- First batch of HI Run 1 data released in 2020
- Few other datasets released for, e.g., machine learning studies (including Run 2 simulations)
- First Run 2 release expected by the end of 2021 or early 2022

Usage:

- About 30 articles* produced (SM, BSM, computing)
- About 15 published in indexed journals


Journal of Instrumentation

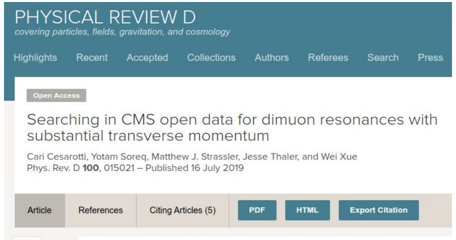
Opportunities and challenges of Standard Model production cross section measurements in proton-proton collisions at √s=8 TeV using CMS Open Data

A. Apyan[1], W. Cuozzo[2], M. Klute[2], Y. Saito[2], M. Schott[2,3] and B. Sintayehu[2]

Published 14 January 2020 • © 2020 IOP Publishing Ltd and Sissa Medialab

Journal of Instrumentation, Volume 15, January 2020

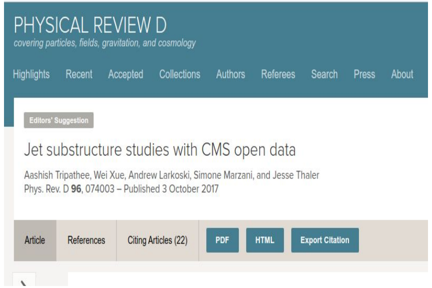
Citation A. Apyan *et al* 2020 *JINST* **15** P01009


PHYSICAL REVIEW D

covering particles, fields, gravitation, and cosmology

Searching in CMS open data for dimuon resonances with substantial transverse momentum

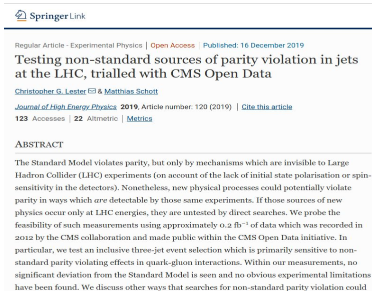
Cari Cesarotti, Yotam Soreq, Matthew J. Strassler, Jesse Thaler, and Wei Xue
Phys. Rev. D **100**, 015021 – Published 16 July 2019


PHYSICAL REVIEW D

covering particles, fields, gravitation, and cosmology

Jet substructure studies with CMS open data

Aashish Tripathee, Wei Xue, Andrew Larkoski, Simone Marzani, and Jesse Thaler
Phys. Rev. D **96**, 074003 – Published 3 October 2017



Regular Article - Experimental Physics | Open Access | Published: 16 December 2019

Testing non-standard sources of parity violation in jets at the LHC, trialled with CMS Open Data

Christopher G. Lester & Matthias Schott

Journal of High Energy Physics **2019**, Article number: 120 (2019) | Cite this article

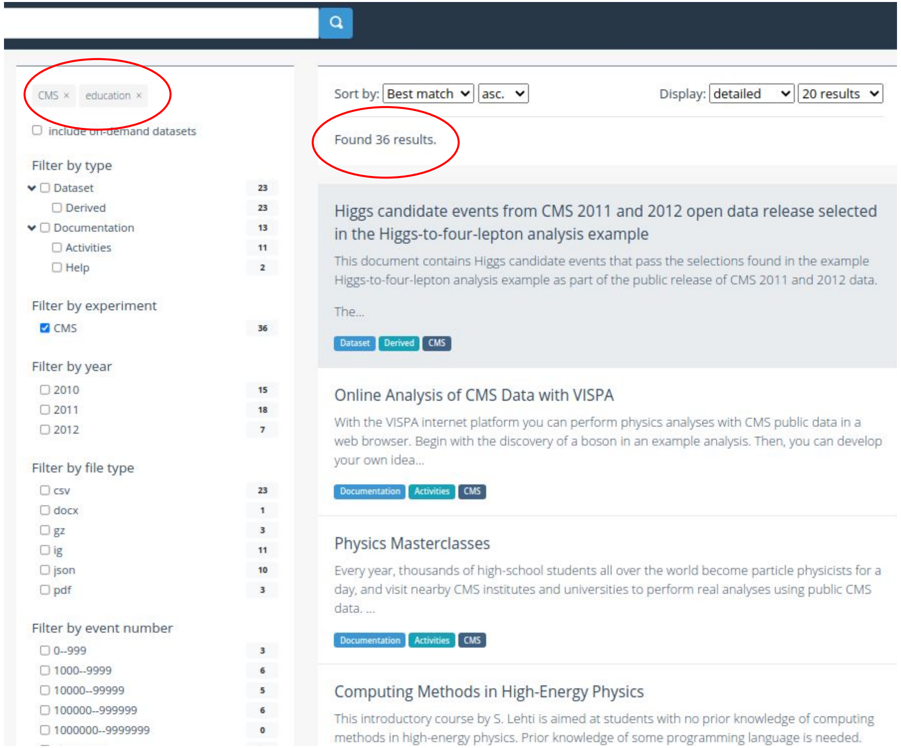
123 Accesses | **22** Altmetric | Metrics

ABSTRACT

The Standard Model violates parity, but only by mechanisms which are invisible to Large Hadron Collider (LHC) experiments (on account of the lack of initial state polarisation or spin-sensitivity in the detectors). Nonetheless, new physical processes could potentially violate parity in ways which *are* detectable by those same experiments. If those sources of new physics occur only at LHC energies, they are untested by direct searches. We probe the feasibility of such measurements using approximately 0.2 fb^{-1} of data which was recorded in 2012 by the CMS collaboration and made public within the CMS Open Data initiative. In particular, we test an inclusive three-jet event selection which is primarily sensitive to non-standard parity violating effects in quark-gluon interactions. Within our measurements, no significant deviation from the Standard Model is seen and no obvious experimental limitations have been found. We discuss other ways that searches for non-standard parity violation could

*link not exact but a reference

CMS open data for Outreach and Education



CMS × education ×

☐ include on-demand datasets

Filter by type

☐ Dataset	23
☐ Derived	23
☐ Documentation	13
☐ Activities	11
☐ Help	2

Filter by experiment

☑ CMS	36

Filter by year

☐ 2010	15
☐ 2011	18
☐ 2012	7

Filter by file type

☐ csv	23
☐ docx	1
☐ gz	3
☐ ig	11
☐ json	10
☐ pdf	3

Filter by event number

☐ 0--999	3
☐ 1000--9999	6
☐ 10000--99999	5
☐ 100000--999999	6
☐ 1000000--9999999	0

Sort by: Best match asc. Display: detailed 20 results

Found 36 results.

Higgs candidate events from CMS 2011 and 2012 open data release selected in the Higgs-to-four-lepton analysis example

This document contains Higgs candidate events that pass the selections found in the example Higgs-to-four-lepton analysis example as part of the public release of CMS 2011 and 2012 data.

The...

Dataset Derived CMS

Online Analysis of CMS Data with VISPA

With the VISPA internet platform you can perform physics analyses with CMS public data in a web browser. Begin with the discovery of a boson in an example analysis. Then, you can develop your own idea...

Documentation Activities CMS

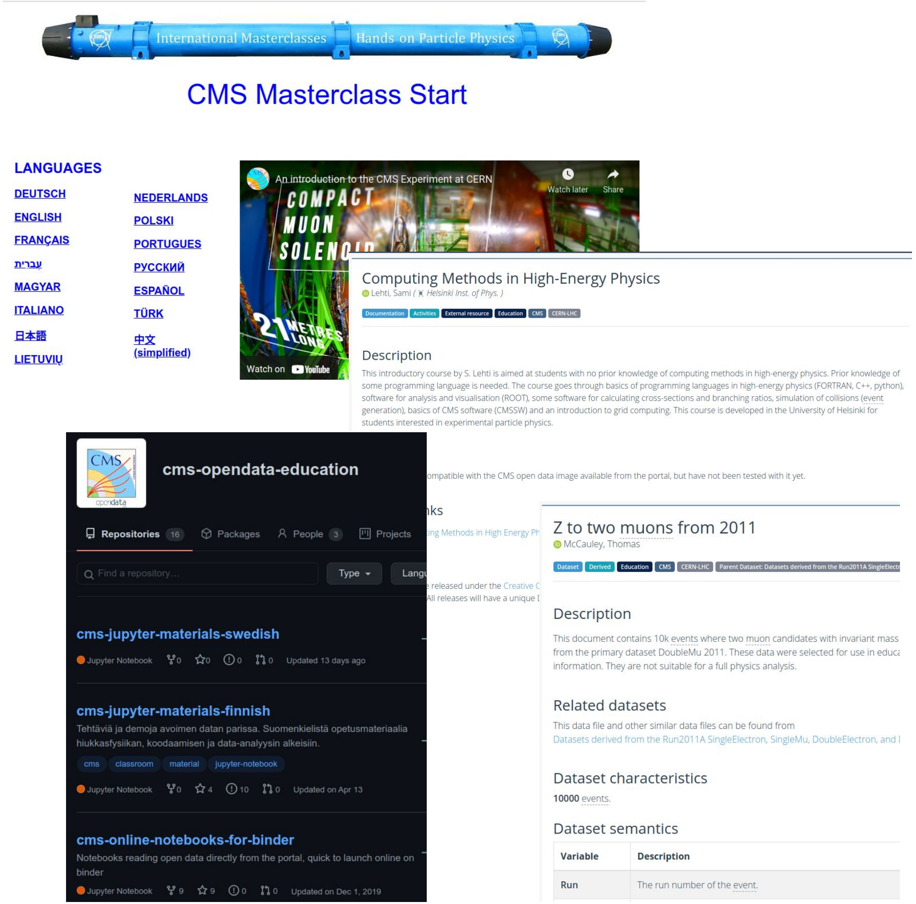
Physics Masterclasses

Every year, thousands of high-school students all over the world become particle physicists for a day, and visit nearby CMS institutes and universities to perform real analyses using public CMS data. ...

Documentation Activities CMS

Computing Methods in High-Energy Physics

This introductory course by S. Lehti is aimed at students with no prior knowledge of computing methods in high-energy physics. Prior knowledge of some programming language is needed.



International Masterclasses
Hands on Particle Physics

CMS Masterclass Start

LANGUAGES

DEUTSCH
ENGLISH
FRANÇAIS
עברית
MAGYAR
ITALIANO
日本語
LIETUVIŲ
NEDERLANDS
POLSKI
PORTUGUES
РУССКИЙ
ESPAÑOL
TÜRK
中文 (simplified)

An introduction to the CMS Experiment at CERN
Watch later
Share
COMPACT MUON SOLENOID
21 METRES LONG
Watch on YouTube

Computing Methods in High-Energy Physics

Lehti, Sami (Helsinki Inst. of Phys.)

Documentation Activities External resource Education CMS CERN-LHC

Description

This introductory course by S. Lehti is aimed at students with no prior knowledge of computing methods in high-energy physics. Prior knowledge of some programming language is needed. The course goes through basics of programming languages in high-energy physics (FORTRAN, C++, python), software for analysis and visualisation (ROOT), some software for calculating cross-sections and branching ratios, simulation of collisions (event generation), basics of CMS software (CMSSW) and an introduction to grid computing. This course is developed in the University of Helsinki for students interested in experimental particle physics.

ompatible with the CMS open data image available from the portal, but have not been tested with it yet.

nks

ing Methods in High Energy Ph

e released under the Creative C

All releases will have a unique [

cms-opendata-education

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cms-jupyter-materials-swedish

Jupyter Notebook 0 ☆0 0 0 Updated 13 days ago

cms-jupyter-materials-finnish

Tehtäviä ja demoja avoimen datan parissa. Suomenkielistä opetusmateriaalia hiukkasfysiikan, koodaamisen ja data-analyysin alkeisiin.

cms classroom material jupyter-notebook

Jupyter Notebook 0 ☆4 10 0 Updated on Apr 13

cms-online-notebooks-for-binder

Notebooks reading open data directly from the portal, quick to launch online on binder

Jupyter Notebook 9 ☆9 0 0 Updated on Dec 1, 2019

Z to two muons from 2011

McCauley, Thomas

Dataset Derived Education CMS CERN-LHC Parent Dataset: Datasets derived from the Run2011A SingleElectr

Description

This document contains 10k events where two muon candidates with invariant mass from the primary dataset DoubleMu 2011. These data were selected for use in educa information. They are not suitable for a full physics analysis.

Related datasets

This data file and other similar data files can be found from Datasets derived from the Run2011A SingleElectron, SingleMu, DoubleElectron, and I

Dataset characteristics

10000 events.

Dataset semantics

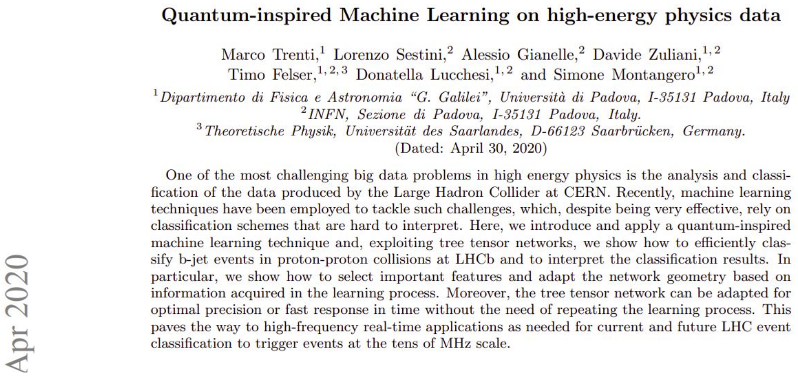
Variable	Description
Run	The run number of the event.

LHCb open data for RESEARCH, OUTREACH AND EDUCATION

Release Policy:
- 50% after 5 years and
- 100% after 10 years (from the end of LHC running period)
- Some restrictions may apply but 100% at the end of collaboration.

Data Products and computing environment:
- Real and simulated data in DST and microDST formats
- Associated software (containers)
- Calibration tools (at user's responsibility)

Current status and timeline:
- Small sample of simulated events released in 2020 for quantum-inspired machine learning techniques (led to paper pre-print)
- Otherwise, releases currently limited to outreach and education



Apr 2020

Quantum-inspired Machine Learning on high-energy physics data

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Timo Felser,[1,2,3] Donatella Lucchesi,[1,2] and Simone Montangero[1,2]

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One of the most challenging big data problems in high energy physics is the analysis and classification of the data produced by the Large Hadron Collider at CERN. Recently, machine learning techniques have been employed to tackle such challenges, which, despite being very effective, rely on classification schemes that are hard to interpret. Here, we introduce and apply a quantum-inspired machine learning technique and, exploiting tree tensor networks, we show how to efficiently classify b-jet events in proton-proton collisions at LHCb and to interpret the classification results. In particular, we show how to select important features and adapt the network geometry based on information acquired in the learning process. Moreover, the tree tensor network can be adapted for optimal precision or fast response in time without the need of repeating the learning process. This paves the way to high-frequency real-time applications as needed for current and future LHC event classification to trigger events at the tens of MHz scale.

LHCb@InternationalMasterclasses

Join us on a journey to the smallest pieces of matter! Learn what is happening 100 meters
the ground at the European Organization for Nuclear Research (CERN). In the Large H
Collider with a circumference of 27 kilometers, the experiments ALICE, ATLAS, CMS, and
press
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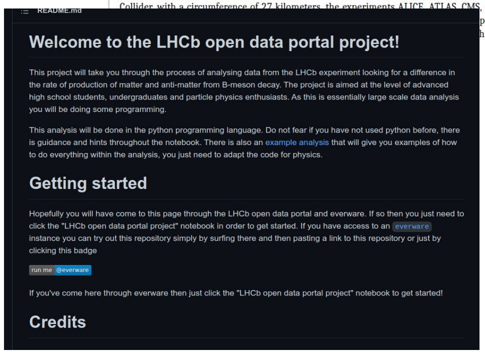


README.md

Welcome to the LHCb open data portal project!

This project will take you through the process of analysing data from the LHCb experiment looking for a difference in the rate of production of matter and anti-matter from B-meson decay. The project is aimed at the level of advanced high school students, undergraduates and particle physics enthusiasts. As this is essentially large scale data analysis you will be doing some programming.

This analysis will be done in the python programming language. Do not fear if you have not used python before, there is guidance and hints throughout the notebook. There is also an example analysis that will give you examples of how to do everything within the analysis, you just need to adapt the code for physics.

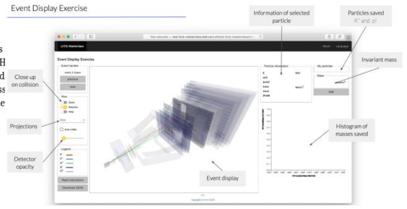
Getting started

Hopefully you will have come to this page through the LHCb open data portal and everware. If so then you just need to click the "LHCb open data portal project" notebook in order to get started. If you have access to an everware instance you can try out this repository simply by surfing there and then pasting a link to this repository or just by clicking this badge

run me @everware

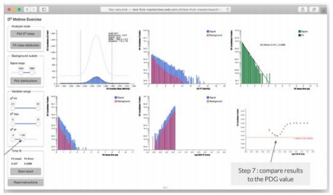
If you've come here through everware then just click the "LHCb open data portal project" notebook to get started!

Credits



Event Display Exercise

Information of selected particle
Particles saved K+ and pi-
Invariant mass
Close up on collision
Projections
Detector opacity
Histogram of masses saved
Event display



Summary

- LHC experiments at CERN have recently (Dec, 2020) announced a new, revitalized policy on open data
- The new policy puts emphasis on the release of Level 3 (research quality) scientific data
- LHC experiments have agreed to start releasing Level 3 data as soon as 5 years after data taking periods end, and to make 100% of such data available after the end of each collaboration.
- While strategies differ and some restrictions are imposed, all the LHC experiments are committed to open data for research.
- All LHC experiments have made important contributions to outreach and education using their open data.

Backup slides

Summary of common L1, L2 and L4 strategies

- **Level 1 (published results):**
  - Peer-reviewed publications available with Open access
  - Make public additional information and data at the time of publication (in portals such as HEPData)
  - The data made available may include simplified or full binned likelihoods, as well as unbinned likelihoods based on datasets of event-level observables extracted by the analyses.
  - Reinterpretation of published results possible through analysis preservation and direct collaboration with external researchers.
- **Level 2 (outreach and education):**
  - Dedicated subsets of data are used, selected and formatted to provide rich samples to maximise their educational impact, and to facilitate the easy use of the data.
  - Data are released with a schedule and scope determined by each experiment.
  - Data are provided in simplified, portable and self-contained formats suitable for educational and public understanding purposes.
  - Not intended or adequate for the publication of scientific results.
  - Lightweight environments to allow the easy exploration of these data may be provided.
  - Data accessible through the CERN Open Data Portal.
- **Level 4 (raw data):**
  - Not intended for release
  - Small samples may be approved for release if useful for, e.g., the development of new reconstruction algorithms.