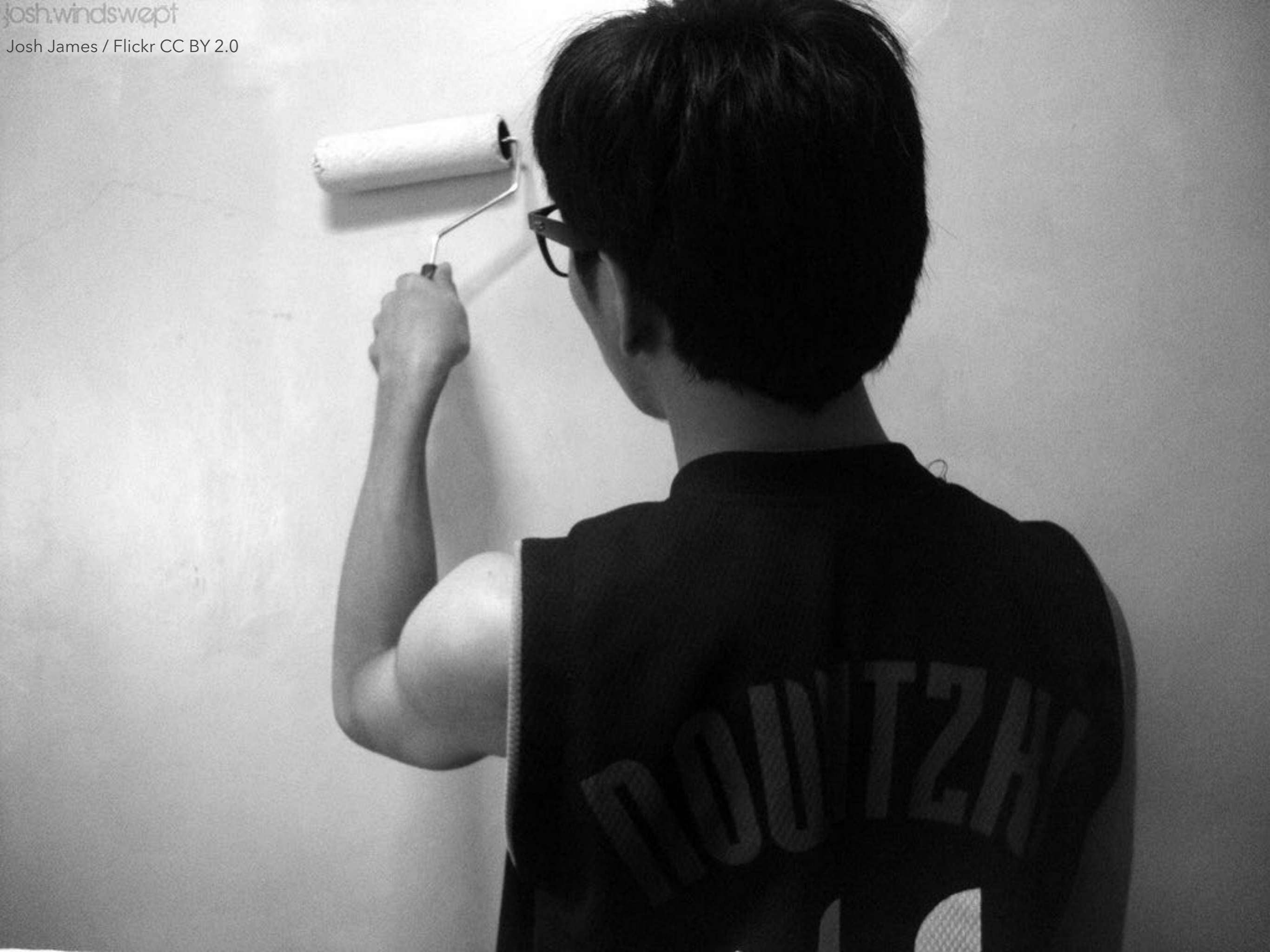


Uso de datos públicos del CERN en el aula

Una invitación y una microguía

Motivación:

Imaginemos una clase de pintura para nuestros alumnos que consistiera sobre todo en esto:



| | |
|---|---|
| $\sqrt{6.42.53}$ $\begin{array}{r} -4 \\ \hline 242 \\ -225 \\ \hline 01753 \\ \cdot \\ \hline 1509 \\ \hline 0244 \end{array}$ | 253 <hr/> $2 \times 2 = 4$ <hr/> $45 \times 5 = 225$ <hr/> $503 \times 3 = 1.509$ <hr/> |
|---|---|

$$64253 = 253^2 + 244$$

Hay alternativas...







Diana González Yuste
The October Press, Alicante

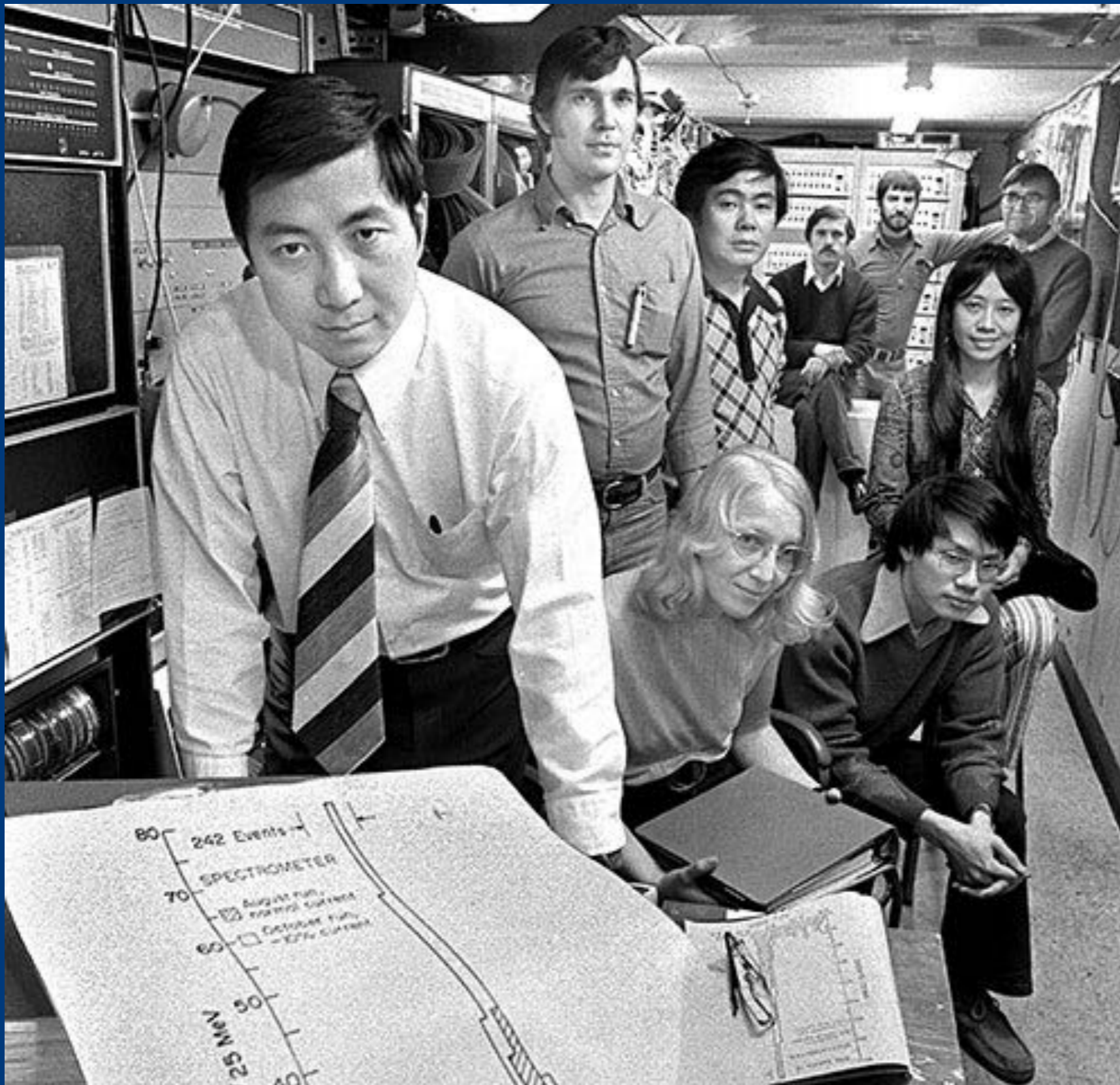


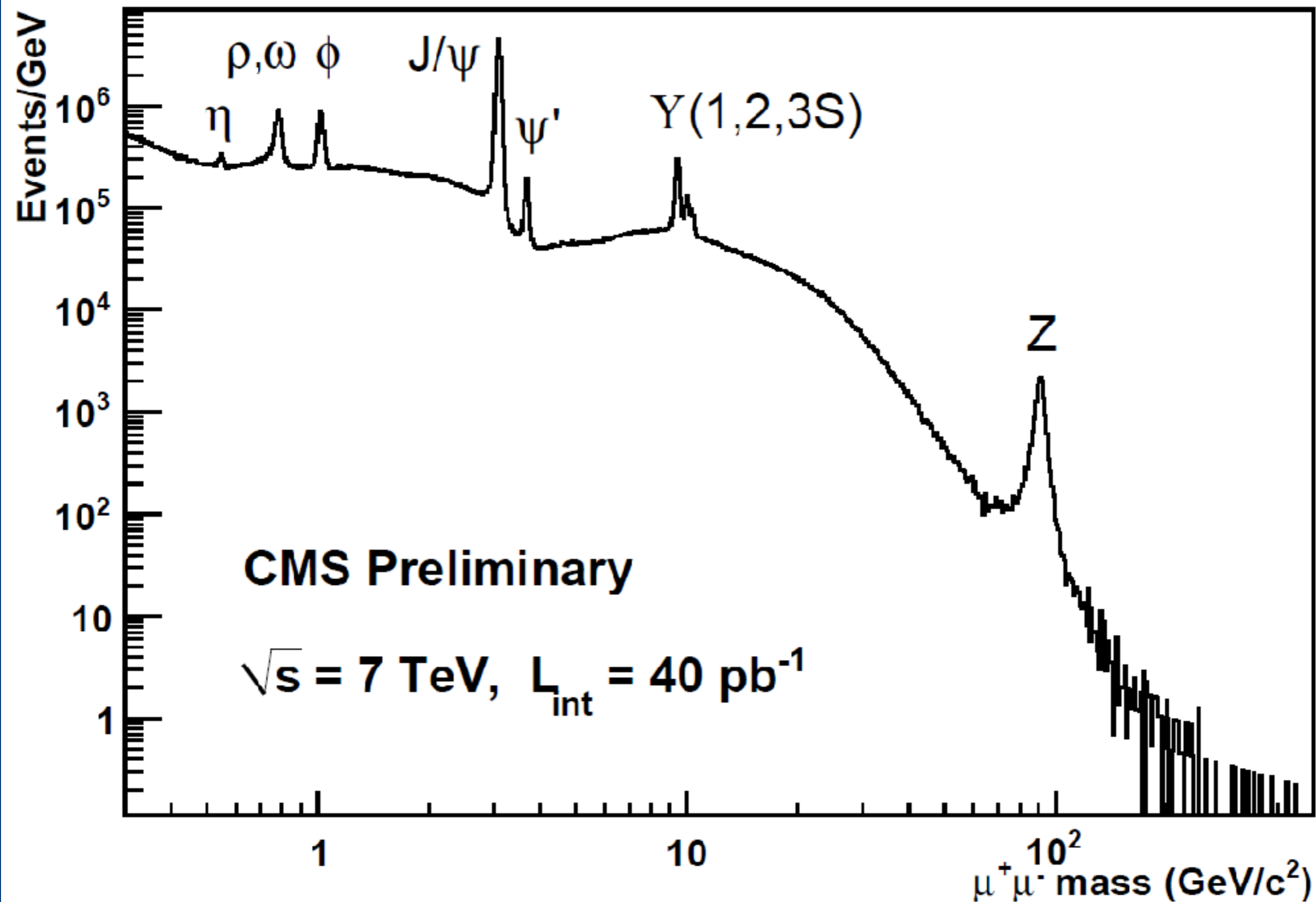


Begoña V.

Flickr CC BY-NC-SA 2.0

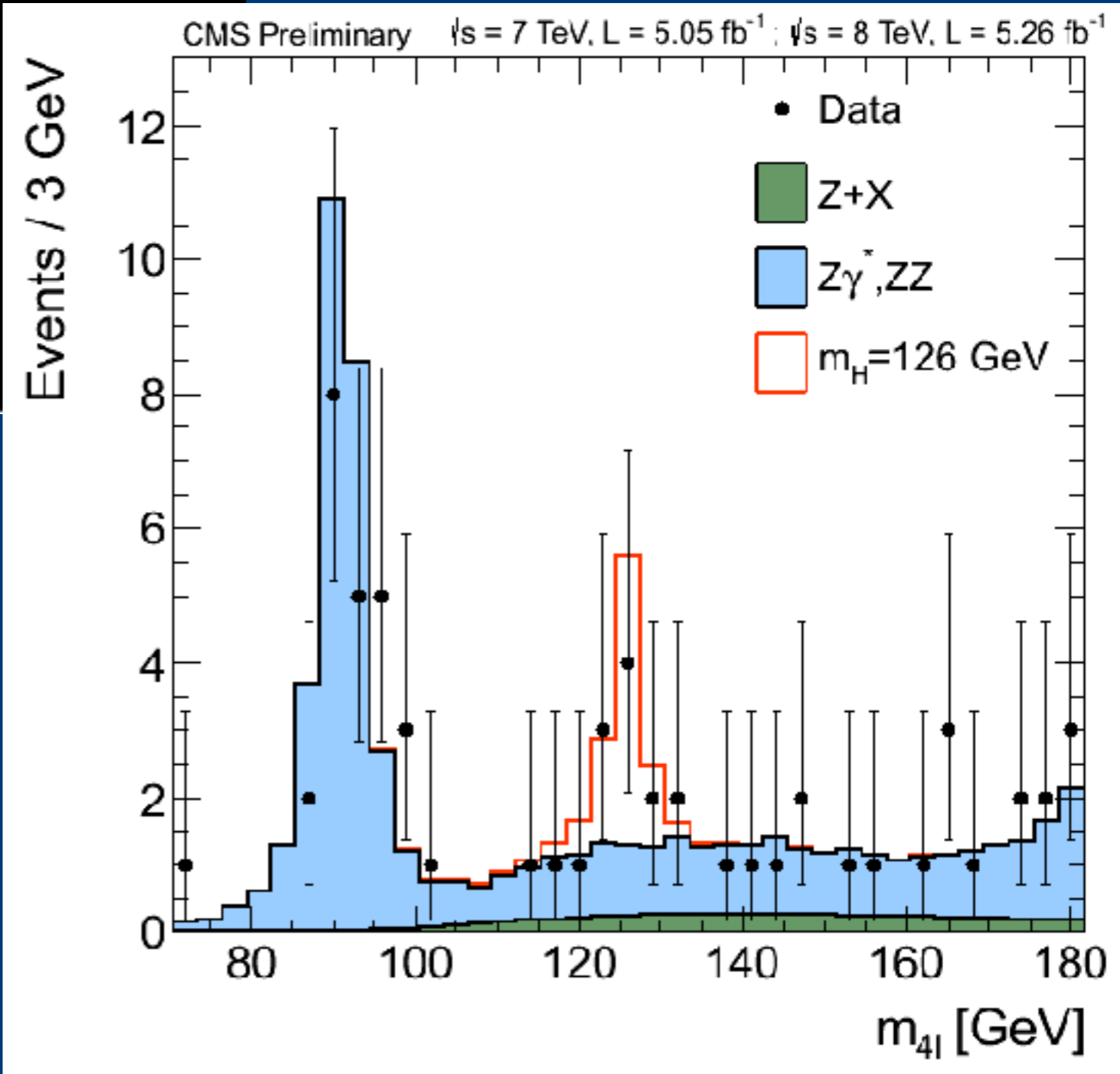
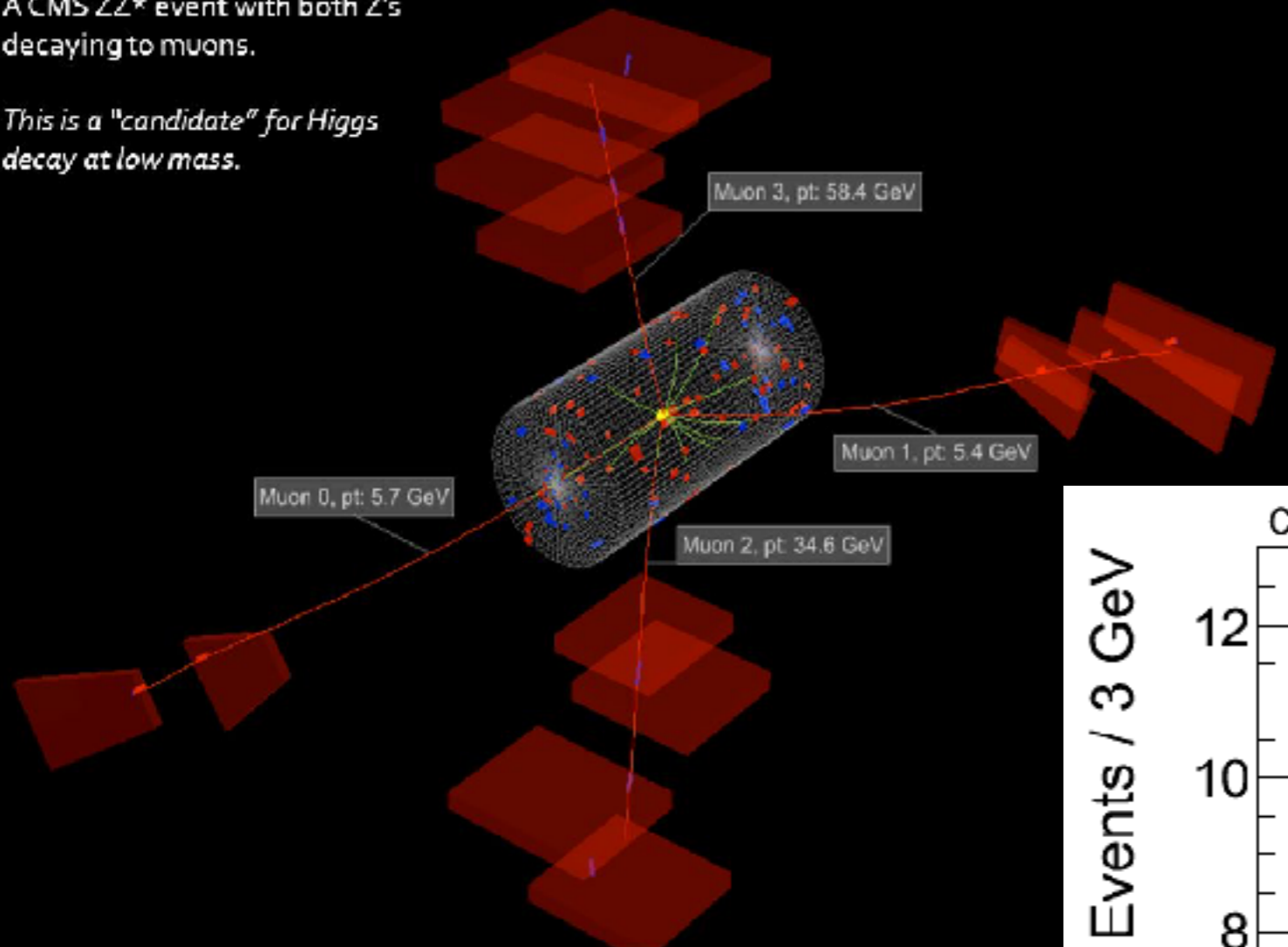
Motivación





A CMS ZZ* event with both Z's decaying to muons.

This is a "candidate" for Higgs decay at low mass.

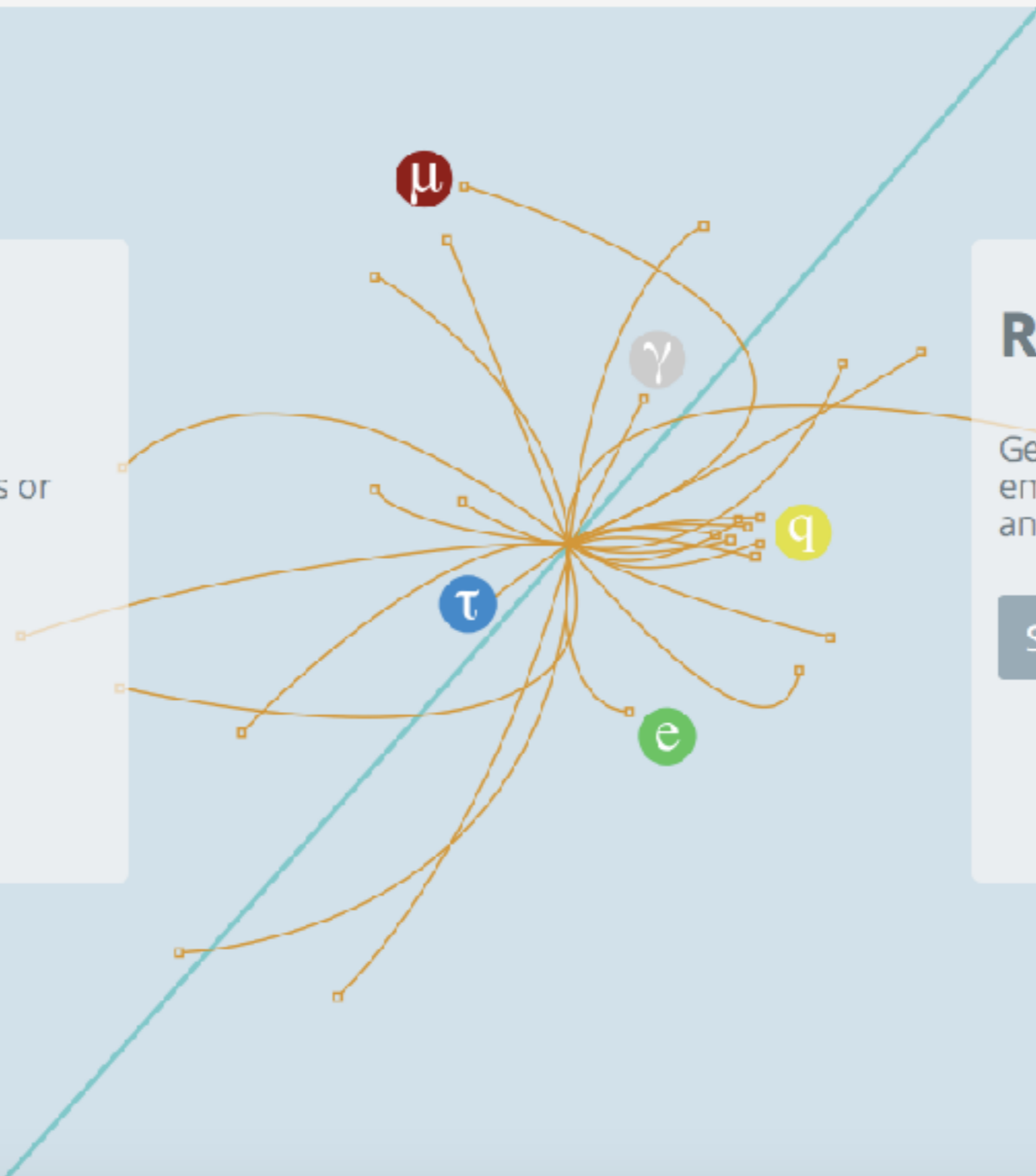


Dónde encontrar material apropiado y cómo usarlo

Education

Visualise events, check reconstructed data, run tools or build your own!

Start learning



Research

Get the genuine working environments, virtual machines and datasets to start your research

Start analysing

Education



The CMS (Compact Muon Solenoid) experiment is one of two large general-purpose detectors built on the Large Hadron Collider (LHC). Its goal is to investigate a wide range of physics such as the characteristics of the Higgs boson, extra dimensions or dark matter.

[Explore CMS >](#)



ALICE

ALICE (A Large Ion Collider Experiment) is a heavy-ion detector designed to study the physics of strongly interacting matter at extreme energy densities, where a phase of matter called quark-gluon plasma forms. More than 1000 scientists are part of the collaboration.

[Explore ALICE >](#)



The ATLAS (A Toroidal LHC Apparatus) experiment is a general-purpose detector exploring topics like the properties of the Higgs like particle, extra dimensions of space, unification of fundamental forces and evidence for dark matter candidates in the Universe.

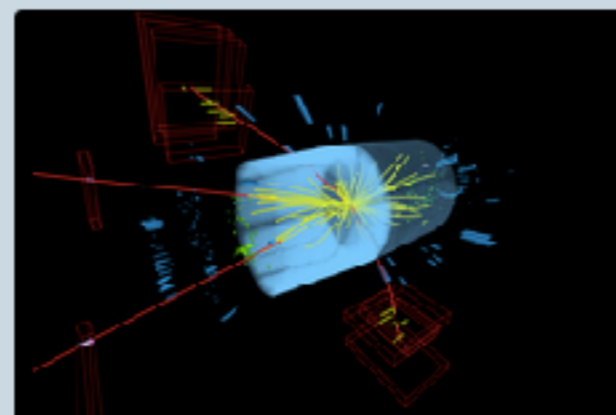
[Explore ATLAS >](#)



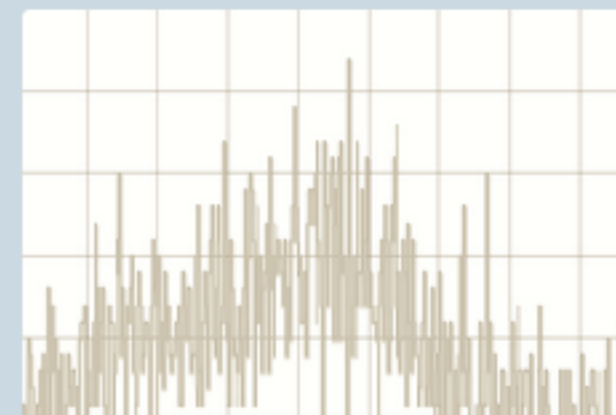
The LHCb (Large Hadron Collider beauty) experiment aims to record the decay of particles containing b and anti-b quarks, known as B mesons. The detector is designed to gather information about the identity, trajectory, momentum and energy of each particle.

[Explore LHCb >](#)

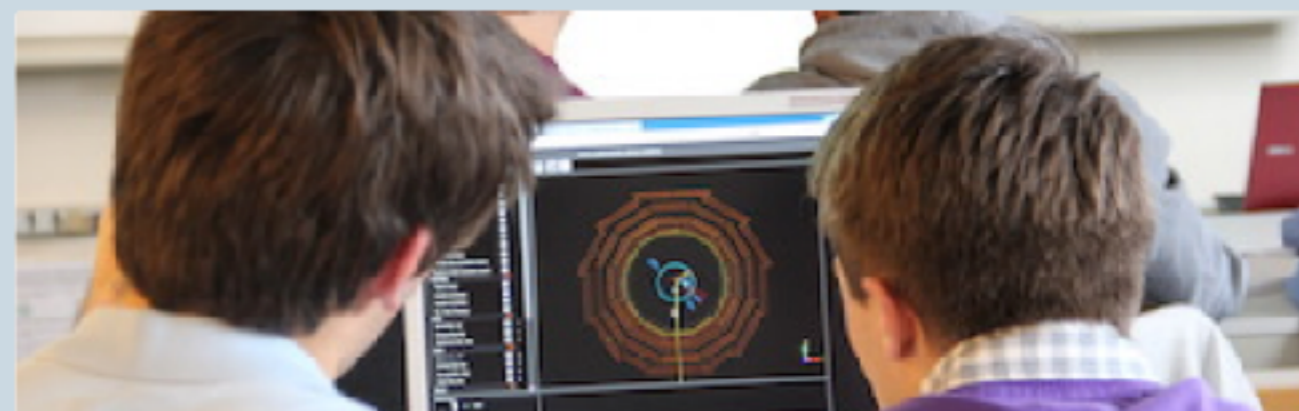
For education purposes, the complex primary data need to be processed into a format (examples below) that is good for simple applications. Get in touch if you wish to build your own applications similar to those shown here



[Visualise events >](#)



[Visualise histograms >](#)

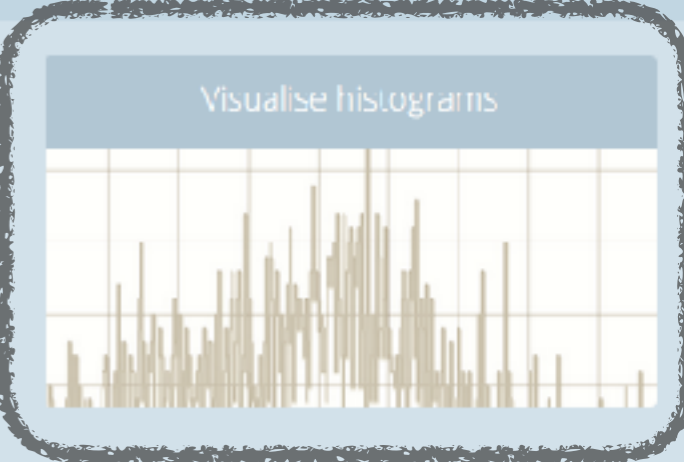
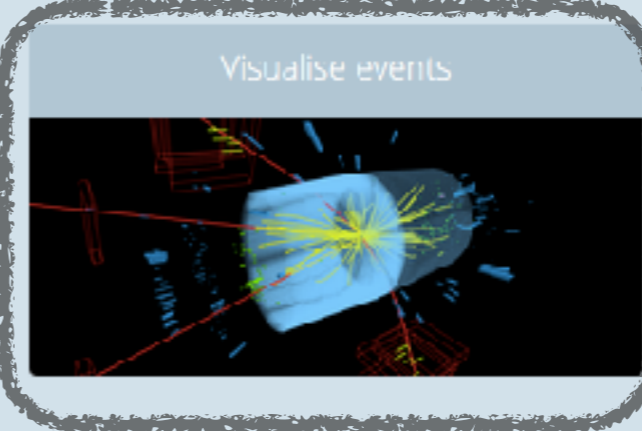


[Learning Resources >](#)

Search bar with a magnifying glass icon and the text "Search".

Home > Education > CMS

The CMS (Compact Muon Solenoid) experiment is one of two large general-purpose particle physics detectors built on the Large Hadron Collider (LHC) at CERN in Switzerland and France. The goal of CMS is to investigate a wide range of physics, including properties of the recently discovered Higgs boson as well as searches for extra dimensions and particles that could make up dark matter.



CMS Derived Datasets

This collection includes data that have been derived from the CMS primary datasets

Years: 2010, 2011

Total records:

59

CMS Tools

This collection includes tools with which the CMS open data can be accessed and used

Years: 2010, 2011

Total records:

17

CMS Learning Resources

This collection includes learning resources that use CMS public data

Total records:

6

Search

Home > CMS > CMS Derived Datasets

CMS Derived Datasets

This collection includes data that have been derived from the CMS primary datasets. The data may be reduced in the sense that (a) only part of the information is kept or (b) only part of the events are selected. Datasets include those which may be accessed using the VM image of the CMS environment or those which are adapted for other tools and applications. The tools and instructions to access and use these data are linked to each record.

Muons and electrons in PAT candidate format derived from /Mu/Run-2010B-Apr21ReReco-v1/AOD primary dataset

Preprocessed data for the two-lepton/four-lepton analysis example

Collection CMS-Derived-Datasets DOI 10.7483/OPENDATA.CMS.RJW2.QP44 Author Rodriguez Marrero, Ana

Parent Dataset /Mu/Run-2010B-Apr21ReReco-v1/AOD

Muons and electrons in PAT candidate format derived from /Electron/Run-2010B-Apr21ReReco-v1/AOD primary dataset

Data preprocessed for the two-lepton/four-lepton analysis example

Collection CMS-Derived-Datasets DOI 10.7483/OPENDATA.CMS.HHTK.9FS2 Author Rodriguez Marrero, Ana

Parent Dataset /Electron/Run-2010B-Apr21ReReco-v1/AOD

MC: single top sample from the CMS HEP Tutorial

MC: single top sample generated with Powheg, triggered on simulated isolated Muons with $p_T > 24$ GeV corresponding to an integrated luminosity of 50 fb⁻¹.

Collection CMS-Derived-Datasets Author Sander, Christian; Schmidt, Alexander

more >

Una posibilidad sencilla: usar una muestra *limpia* de *dimuones* para redescubrir la partícula J/ψ o el bosón Z

The events in this derived dataset were selected because of the presence of precisely two muons with invariant mass between 2-110 GeV, one of which is a high-quality "global" muon.

dimuon

Search

Any Collection

- CMS Derived Datasets (5)
- CMS Primary Datasets (3)
- CMS Tools (2)
- CMS Validation Utilities (2)

Showing records 1 to 10 out of 12 results.

Dimuon event information derived from the Run2010B public Mu dataset

This document contains 100k dimuon events selected from the Mu dataset from Run2010B. Each line corresponds to an event. The main file contains all 100k events

| | | | |
|------------|--------------------------------|----------------|----------------------------------|
| Collection | CMS-Derived-Datasets | Author | McCauley, Thomas |
| DOI | 10.7483/OPENDATA.CMS.CB6H.MFFA | Parent Dataset | /Mu/Run-2010B-Apr21ReReco-v1/AOD |

Dimuon events with invariant mass range 2-5 GeV for public education and outreach

The collaboration approved 2000 dimuon events around the J/ψ for use in education and outreach. This record contains the necessary files for these use-cases

| | | | |
|------------|--------------------------------|--------|------------------|
| Collection | CMS-Derived-Datasets | Author | McCauley, Thomas |
| DOI | 10.7483/OPENDATA.CMS.SW96.PFX3 | | |

Dimuon events for use in outreach and education

The CMS collaboration has approved the release of 100k dimuon events in the invariant mass range 2-110 GeV for use in outreach and education. This document contains the files for this release.

| | | | |
|------------|--------------------------------|--------|------------------|
| Collection | CMS-Derived-Datasets | Author | McCauley, Thomas |
| DOI | 10.7483/OPENDATA.CMS.4M97.35Q9 | | |

Event files for CMS masterclass exercise 2014

This document collects event information for use in the 2014 CMS masterclass exercise. It contains previously-released data: 800 events each of W to $mumu$ and enu , 75 events each of Z to ee and $mumu$, 100 dimuon events between 2-100 GeV, 50 dimuon events between 2-12 GeV (i.e. J/ψ and u psilon), three 4-lepton Higgs candidate events and ten di-photon Higgs candidate events.

| | | | |
|------------|----------------------|--------|------------------|
| Collection | CMS Derived Datasets | Author | McCauley, Thomas |
|------------|----------------------|--------|------------------|

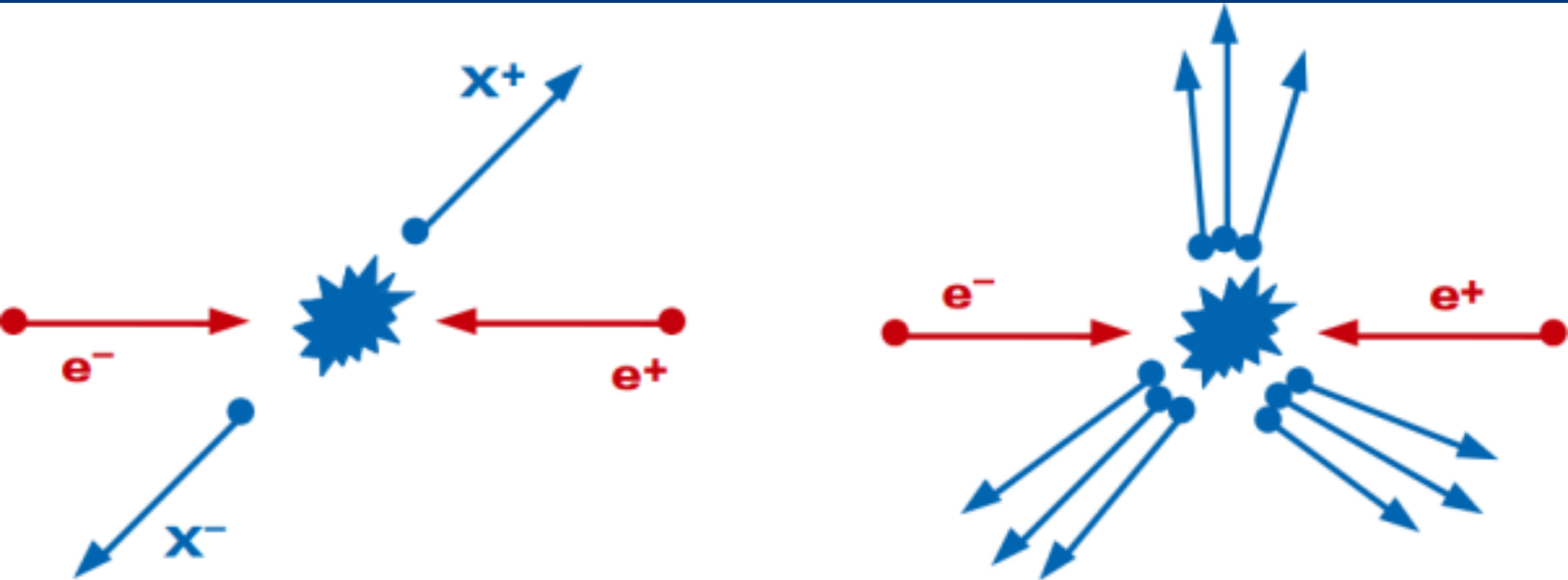
Herramientas necesarias:

1. Entendimiento básico del funcionamiento de un detector
2. Ley de conservación de la energía y el momento (E, \vec{p})
3. Expresión relativista de la energía de una partícula:

$$E^2 = (pc)^2 + (mc^2)^2$$

Aquí están los detalles:

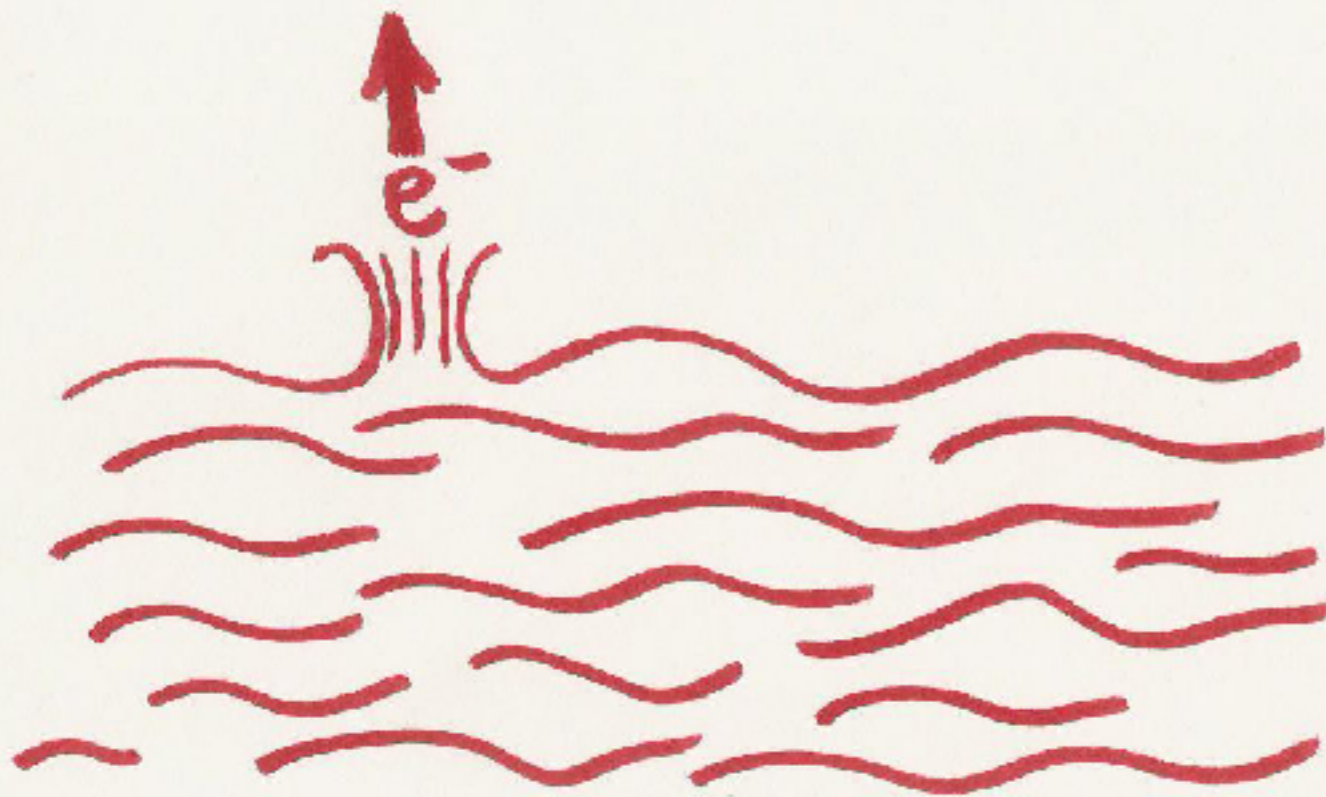
<https://fbarradass.wordpress.com/2011/05/13/%C2%BFcomo-saber-si-se-ha-descubierto-una-particula-1/>



Cuando chocan un electrón y un positrón a altas energías hay muchas posibilidades distintas; en primer lugar podrían “rebotar” sin más (colisión elástica), pero más comúnmente se aniquilan y como resultado **final** aparecen nuevas partículas como

- ◆ parejas partícula / antipartícula (e^+/e^- , μ^+/μ^- ...)
- ◆ hadrones (partículas compuestas por quarks)...





UN ELECTRÓN LIBRE NO ES UNA BOLITA CARGADA, ES MÁS BIEN UNA EXCITACIÓN ESPECIAL DEL **CAMPO ELECTRÓNICO**

PARA LA QUE SE CUMPLE

$$E^2 = (pc)^2 + (m_e c^2)^2$$

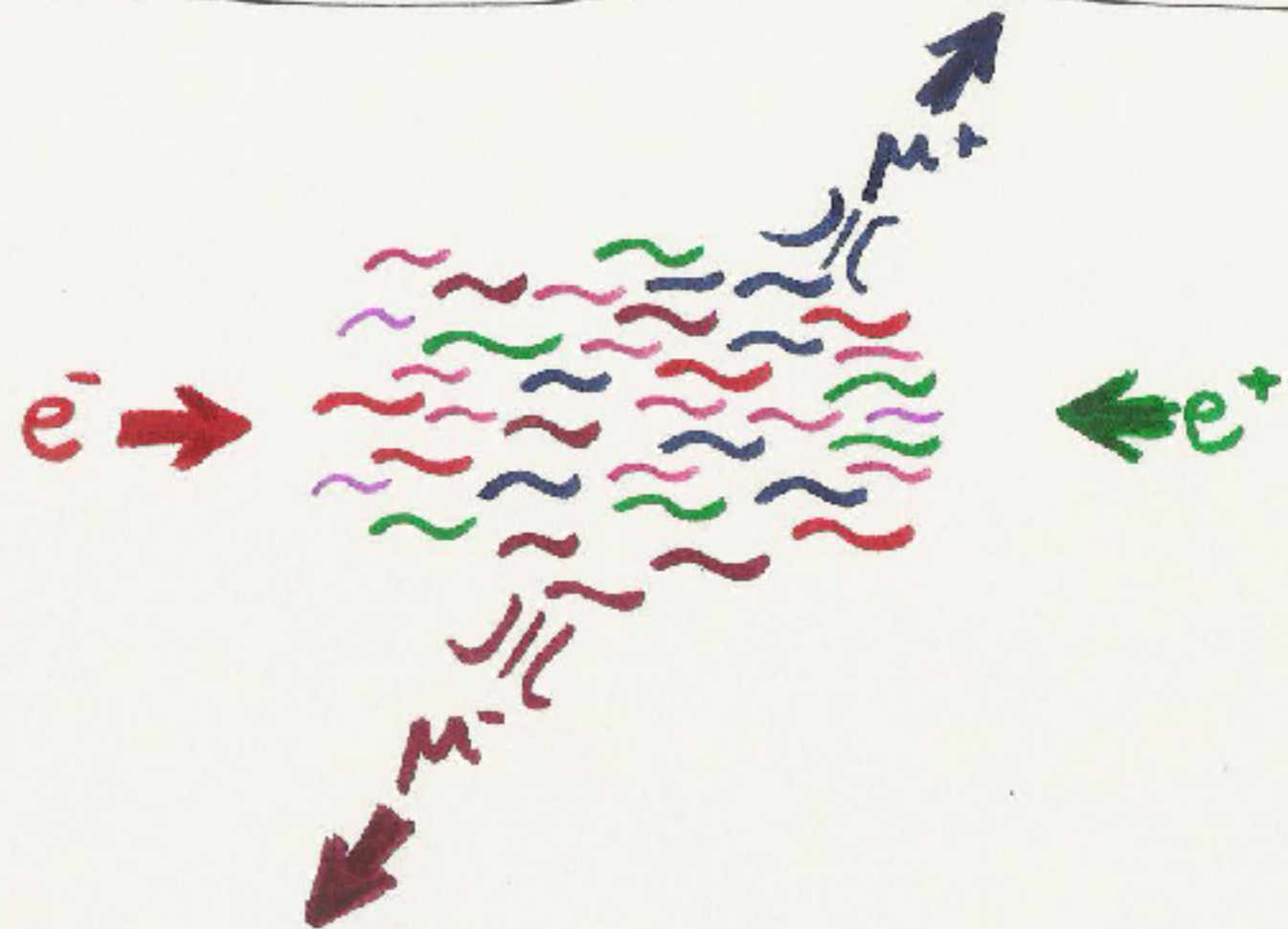
EN UNA COLISIÓN, POR EJEMPLO

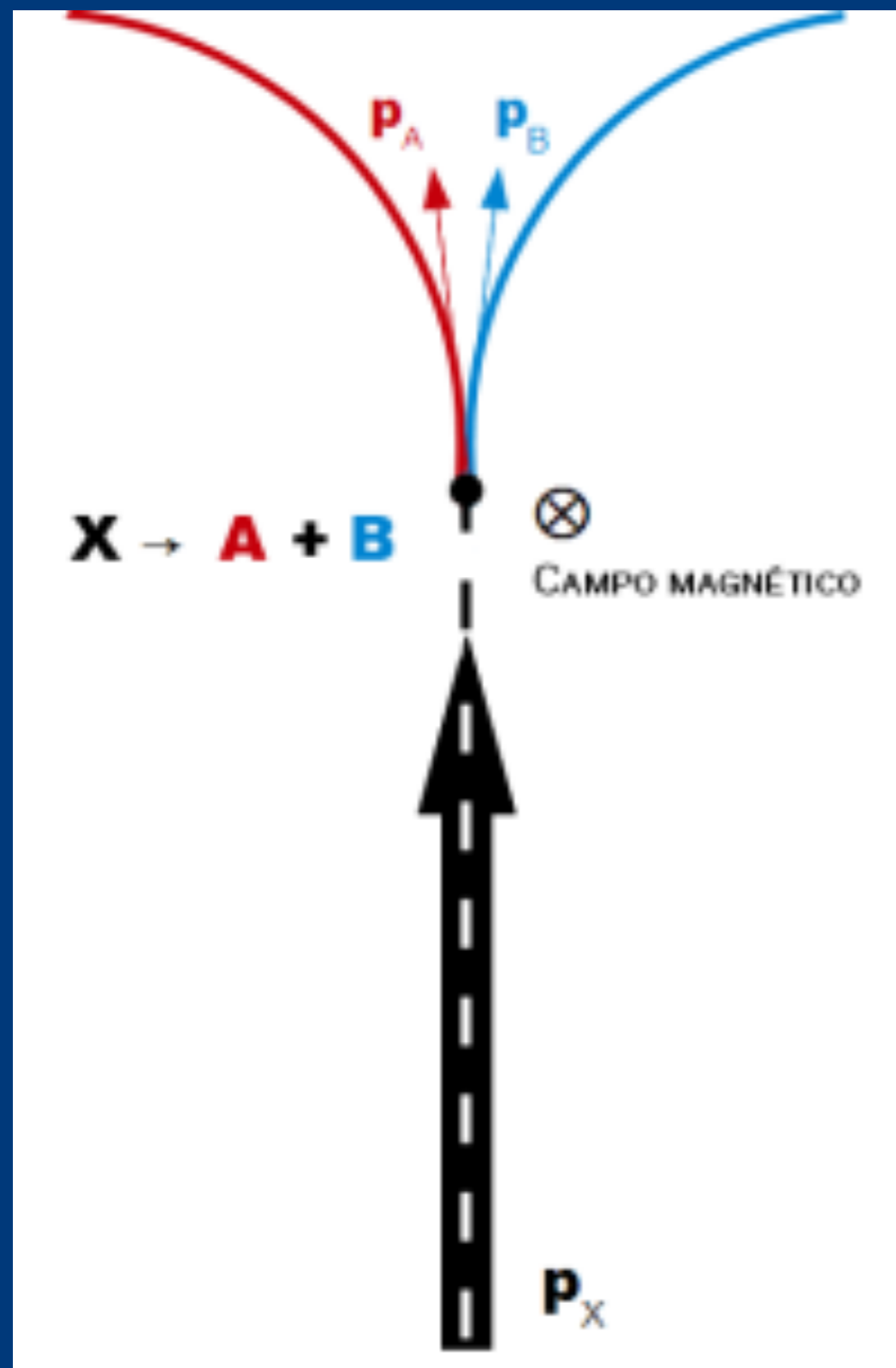
$e^+ e^-$

LA ENERGÍA DE LOS CAMPOS QUE "LLENAN" EL ESPACIO SE PUEDE REDISTRIBUIR DANDO LUGAR A NUEVAS EXCITACIONES TIPO PARTÍCULA, EN ESTE

CASO **DOS MUONES**

$\mu^+ \mu^-$





$$X \rightarrow A + B$$

$$\vec{p}_X = \vec{p}_A + \vec{p}_B$$

$$E_X = E_A + E_B$$

$$E = \left(\vec{p}^2 c^2 + m^2 c^4 \right)^{\frac{1}{2}}$$

$$E_X^2 = \vec{p}_X^2 c^2 + M_X^2 c^4$$

$$M_X = \frac{1}{c^2} \left(E_X^2 - \vec{p}_X^2 c^2 \right)^{\frac{1}{2}}$$

$$M_X = \frac{1}{c^2} \left[(E_A + E_B)^2 - c^2 (\vec{p}_A + \vec{p}_B)^2 \right]^{\frac{1}{2}}$$

<http://opendata.cern.ch/search?cc=CMS-Derived-Datasets&ln=en&jrec=51>

Showing records 51 to 59 out of 59 results.

Example CSV output file for SUSYBSMAnalysis-RazorFilter

This file contains events from the Multijet primary dataset from the CMS open data release, and computes the razor variables MR and Rsq, used in supersymmetric particle searches. More details on the razor variables can be found in Phys. Rev

Collection CMS-Derived-Datasets DOI 10.7483/OPENDATA.CMS.GACK.GEJA Author Duarte, Javier

Parent Dataset /Multijet/Run2010B-Apr21ReReco-v1/AOD

Dimuon event information derived from the Run2010B public Mu dataset

This document contains 100k dimuon events selected from the Mu dataset from Run2010B. Each line corresponds to an event. The main file contains all 100k events

Collection CMS-Derived-Datasets Author McCauley, Thomas

DOI 10.7483/OPENDATA.CMS.CB8H.MFFA Parent Dataset /Mu/Run-2010B-Apr21ReReco-v1/AOD

Muons a Dimuon events for use in outreach and education

Preprocess

The CMS collaboration has approved the release of 100k dimuon events in the invariant mass range 2-110 GeV for use in outreach and education. This document contains the files for this release.

Collection CMS-Derived-Datasets Author McCauley, Thomas

DOI 10.7483/OPENDATA.CMS.4M97.3SQ9

<http://opendata.cern.ch/record/303>

Dimuones: parejas de muones (aquí de cargas opuestas) $\mu^+\mu^-$ "de buena calidad"

Dimuon events for use in outreach and education

McCauley, Thomas

Cite as: [McCauley, T. \(2014\). Dimuon events for use in outreach and education. CERN Open Data Portal. DOI: \[10.7483/OPENDATA.CMS.4M97.3SQ9\]\(#\)](#)

Collection **CMS Derived Datasets** Accelerator CERN-LHC Experiment CMS

Description

The CMS collaboration has approved the release of 100k dimuon events in the invariant mass range 2-110 GeV for use in outreach and education. This document contains the files for this release.

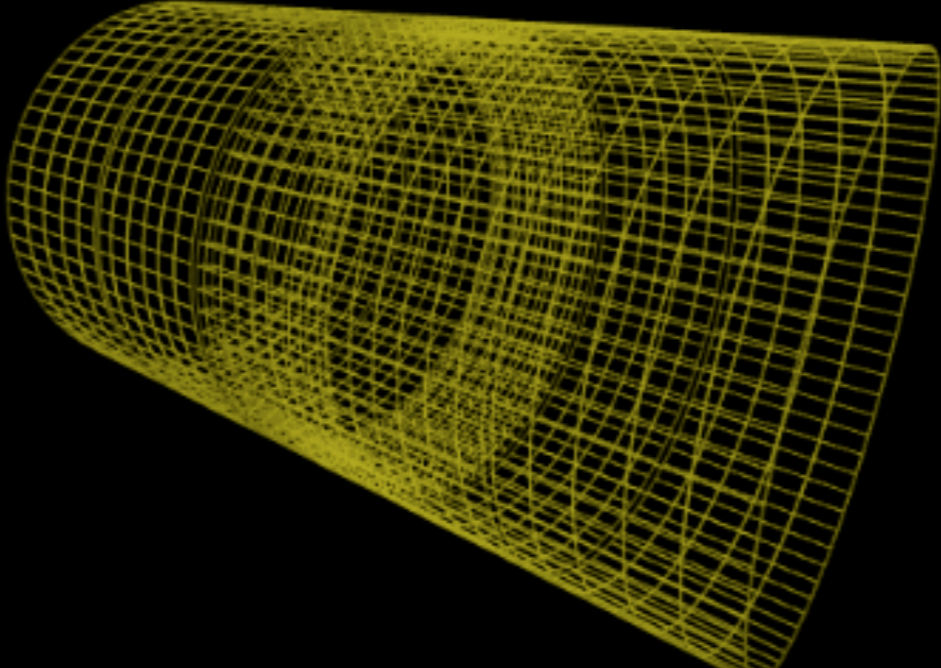
Preview

iSpy WebGL

Navigation icons: Home, Search, View, Rotate, Settings, Info

Detector i

- Pixel Barrel
- Pixel Endcap (+)
- Pixel Endcap (-)
- Tracker Inner Barrel
- Tracker Outer Barrel
- Tracker Inner Detector (+)
- Tracker Inner Detector (-)
- Tracker Endcap (+)
- Tracker Endcap (-)
- ECAL Barrel
- ECAL Endcap (+)



CMS

| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|------|--------|------------|---------|----------|----------|----------|--------------|---------------|---------------|----|---------|-------|
| 1 | Type | Run | Event | E1 | px1 | py1 | pz1 | pt1 | eta1 | phi1 | Q1 | E2 | px2 |
| 2 | GT | 140124 | 1007912007 | 13.7061 | 4.88649 | -2.5086 | 12.5569 | 5.4928006044 | 1.564708153 | -0.4742899747 | 1 | 3.67389 | -0.68 |
| 3 | GT | 140124 | 1007957044 | 9.09052 | -2.16135 | -2.96392 | -8.31686 | 3.6682769237 | -1.5571370107 | -2.2008651123 | -1 | 3.80945 | 0.787 |
| 4 | GG | 140124 | 1008000431 | 6.81754 | 5.76035 | 3.23987 | -1.67015 | 6.6089628339 | -0.2500945607 | 0.5123463528 | 1 | 19.1486 | 12.8 |
| 5 | GT | 140124 | 1008032300 | 31.8853 | -5.85709 | 2.78331 | -31.2188 | 6.48477585 | -2.2753268595 | 2.6979782463 | 1 | 4.26886 | -1.50 |
| 6 | GT | 140124 | 1008075983 | 13.5527 | 1.18694 | -2.35966 | -13.2924 | 2.641367426 | -2.3187715021 | -1.1047411075 | 1 | 4.36207 | 1.19 |

iSpy WebGL dimuon-Jpsi_3.ig:Events/Run_140124/Event_1027160502 [10 of 100]

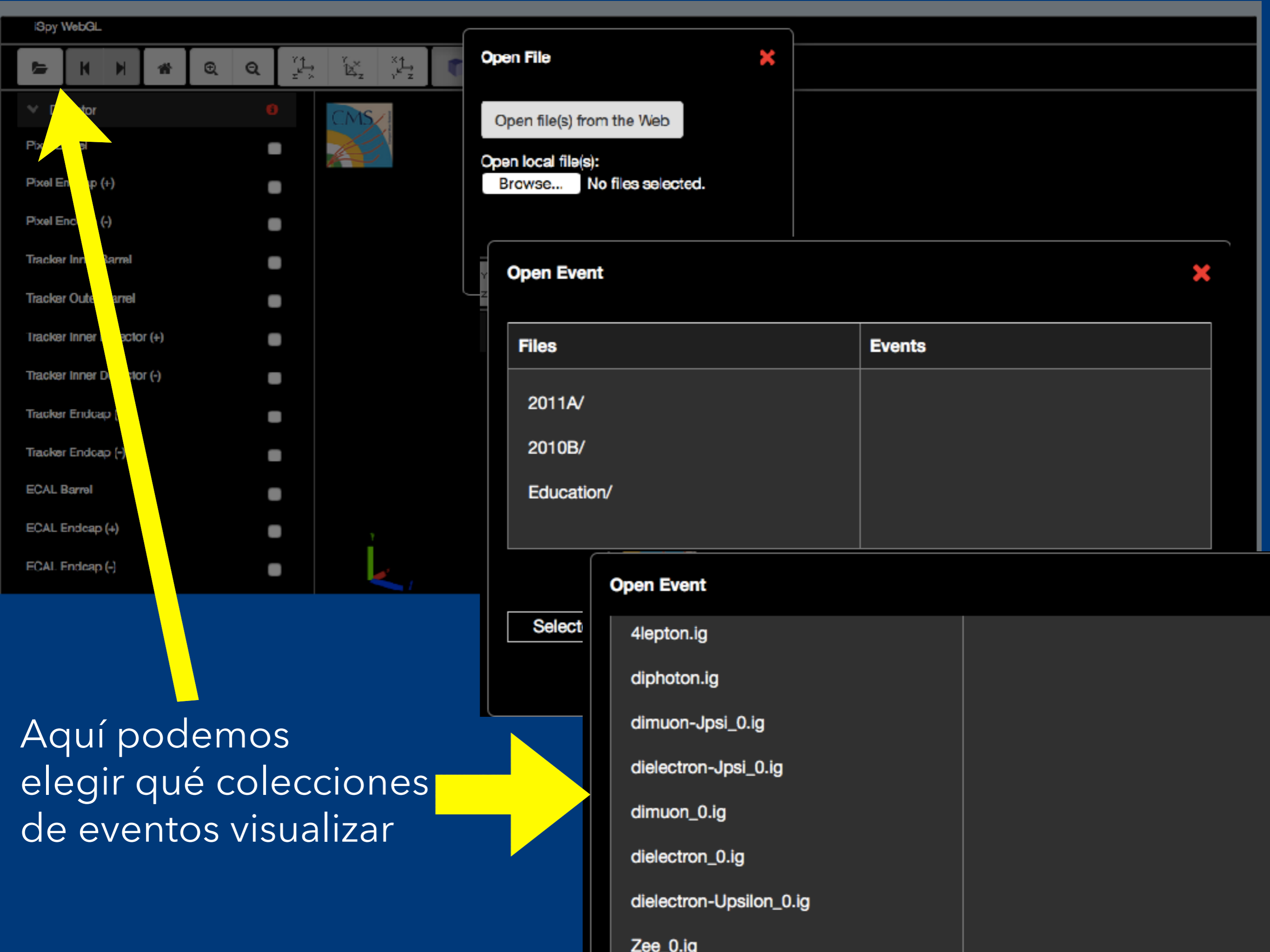
Navigation:

Detector i

- Pixel Barrel
- Pixel Endcap (+)
- Pixel Endcap (-)
- Tracker Inner Barrel
- Tracker Outer Barrel
- Tracker Inner Detector (+)
- Tracker Inner Detector (-)
- Tracker Endcap (+)
- Tracker Endcap (-)
- ECAL Barrel
- ECAL Endcap (+)
- ECAL Endcap (-)
- HCAL Barrel

CMS Experiment at the LHC, CERN
 Data recorded: 2010-Jul-14 09:01:35.633975 GMT
 Run / Event / LS: 140124 / 1027160502 / 1158

Click on a name under "Provenance", "Tracking", "ECAL", "HCAL", "Muon", and "Physics" to view contents in table



Aquí podemos elegir qué colecciones de eventos visualizar

| | Type | Run | Event | E1 | px1 | py1 | pz1 | pt1 |
|---|------|--------|------------|----------|-------------|------------|-----------|----------|
| 1 | GT | 140124 | 1007912007 | 13.70610 | 4.88649000 | -2.5086000 | 12.556900 | 5.492801 |
| 2 | GT | 140124 | 1007957044 | 9.09052 | -2.16135000 | -2.9639200 | -8.316860 | 3.668277 |
| 3 | GG | 140124 | 1008000431 | 6.81754 | 5.76035000 | 3.2398700 | -1.670150 | 6.608963 |

| | Q1 | E2 | px2 | py2 | pz2 | pt2 |
|----|----------|------------|--------------|----------|------------|-----|
| 1 | 3.67389 | -0.6832500 | 0.529614000 | 3.56917 | 0.8644776 | |
| -1 | 3.80945 | 0.7874280 | -0.775826000 | -3.64400 | 1.1054179 | |
| 1 | 19.14860 | 12.8875000 | 12.388700000 | -6.86217 | 17.8764522 | |

En los archivos .csv con los datos la última columna contiene ya las masas invariables calculadas, pero puede ser una buena idea que las calculemos nosotros mismos a partir de las energías y momentos.

$$M_X = \frac{1}{c^2} \left[(E_1 + E_2)^2 - c^2 (\vec{p}_1 + \vec{p}_2)^2 \right]^{\frac{1}{2}}$$

Y ahora...

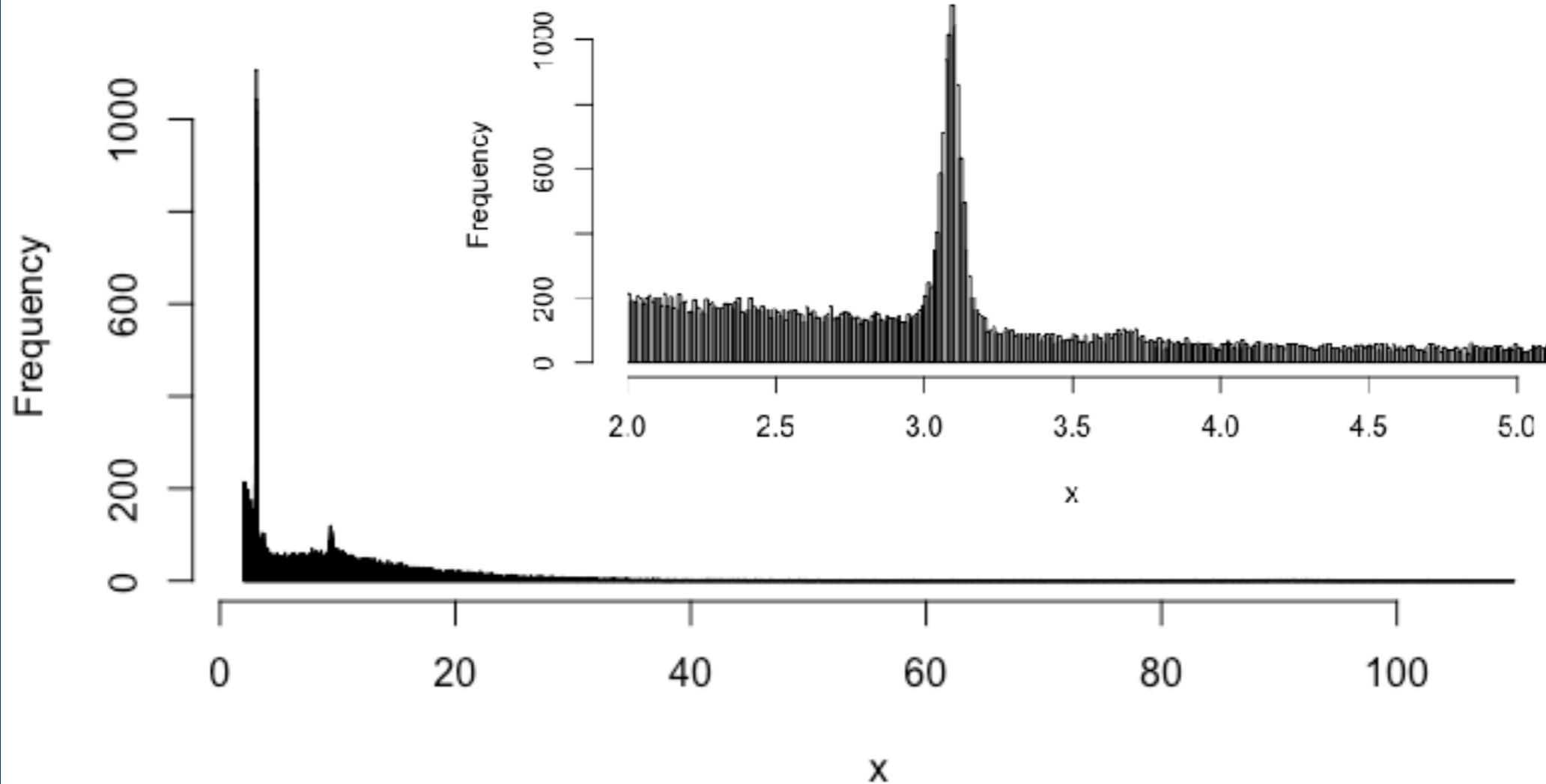
manos a la obra

Herramientas:

Por el momento sólo histogramas de M

- Hoja de cálculo: *Excel* sí, *LibreOffice Calc* no :-_(
- Algo más potente, como **R**

Histogram of x



Para una muestra mayor y mejor elaborada, ver:

https://indico.cern.ch/event/577111/contributions/2659823/attachments/1498147/2337588/R-histogramas-para-CMS_public_dimuons_2010_2-110GeV.html

