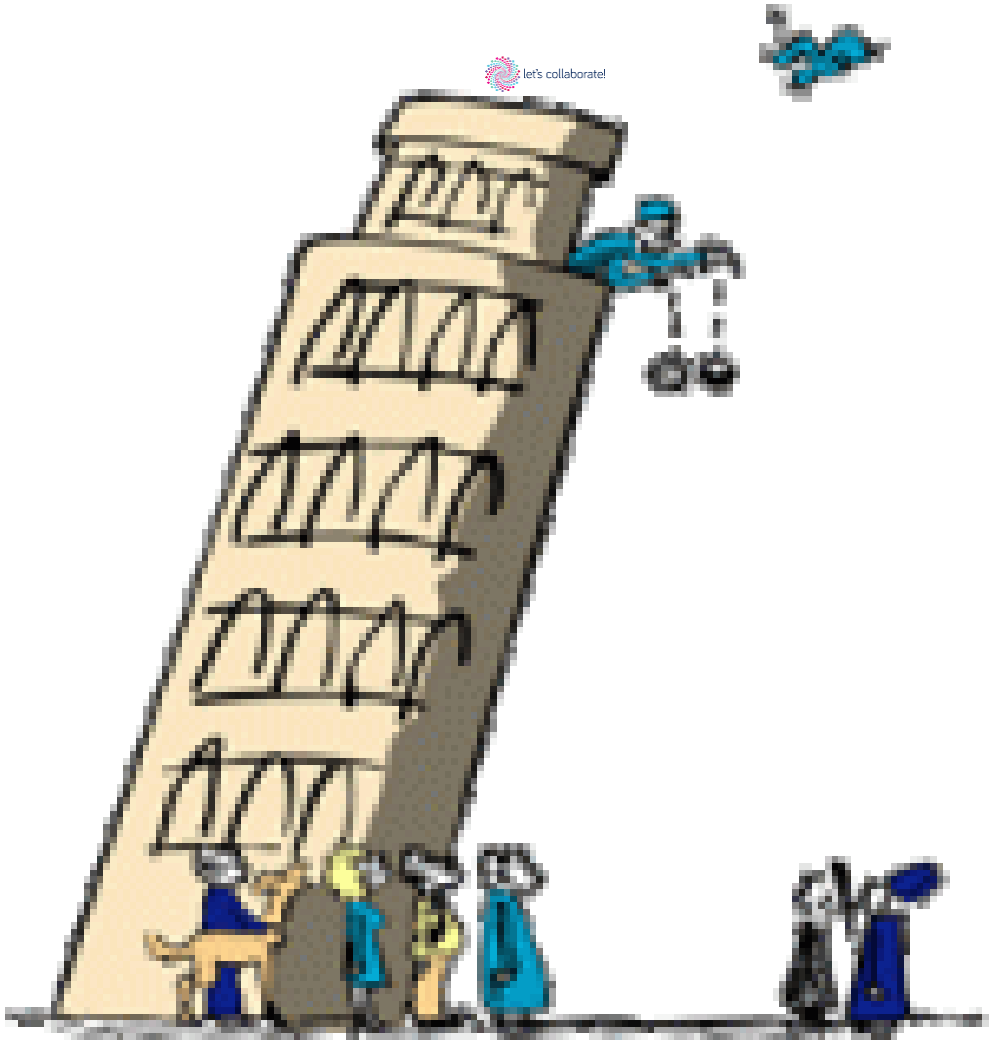
DATA ANALYSIS

Determining g – HS experiment

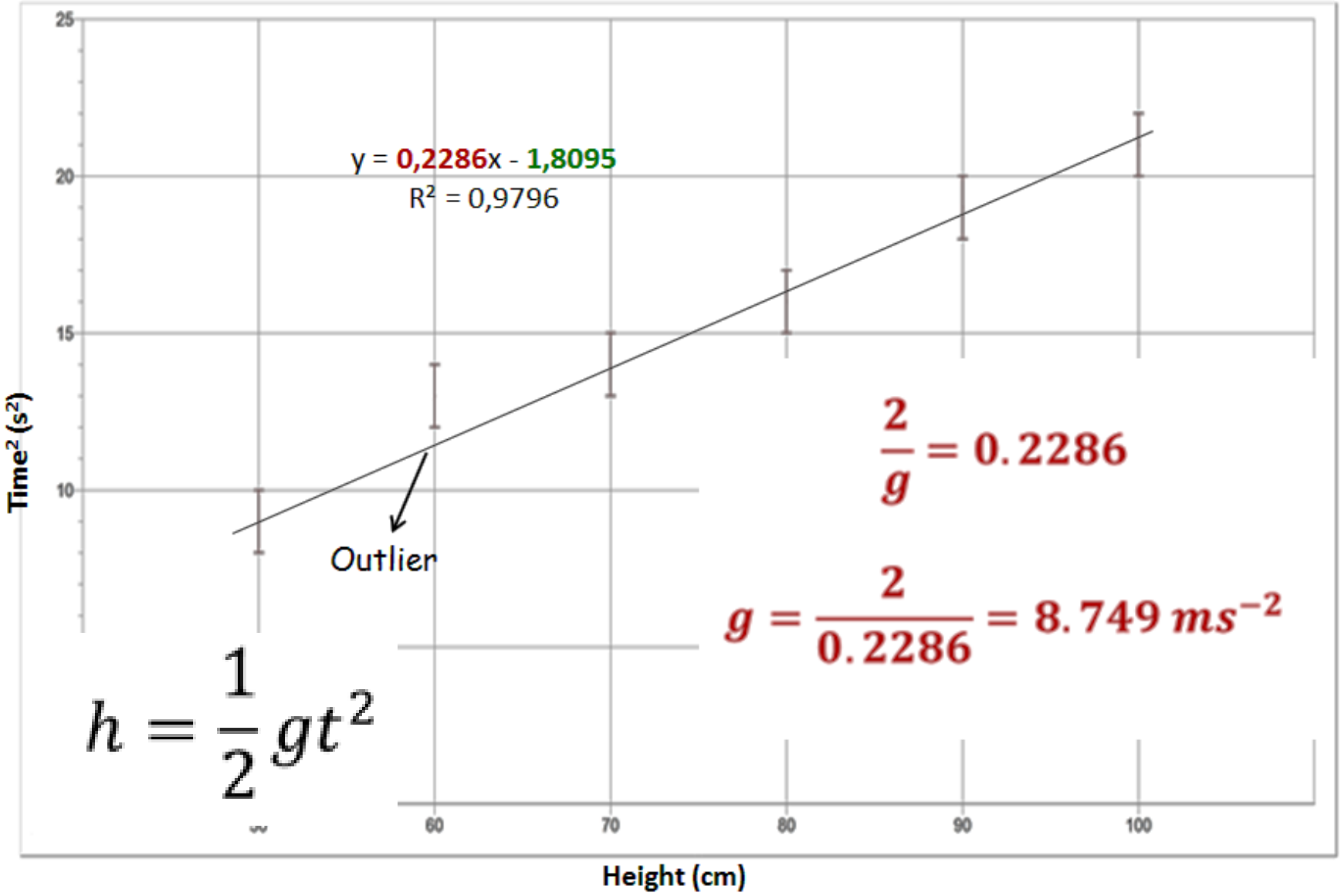


$$h = \frac{1}{2} g t^2$$

Determining g – HS experiment

Height (m)	Time (s)					Average Time (s)	Uncertainty (s)
	trial 1	trial 2	trial 3	trial 4	trial 5		
4.323	0.93	1.01	0.98	1.02	0.94	0.976	0.045
5.275	1.31	1.38	1.23	1.33	1.38	1.326	0.075
5.581	1.55	1.68	1.63	1.75	1.56	1.634	0.1
8.359	0.96	1.03	1.01	1.01	1.01	1.004	0.035
11.753	0.88	0.88	0.88	0.91	0.95	0.9	0.035

Determining g – HS experiment



$$h = \frac{1}{2} g t^2$$

$$\frac{2}{g} = 0.2286$$

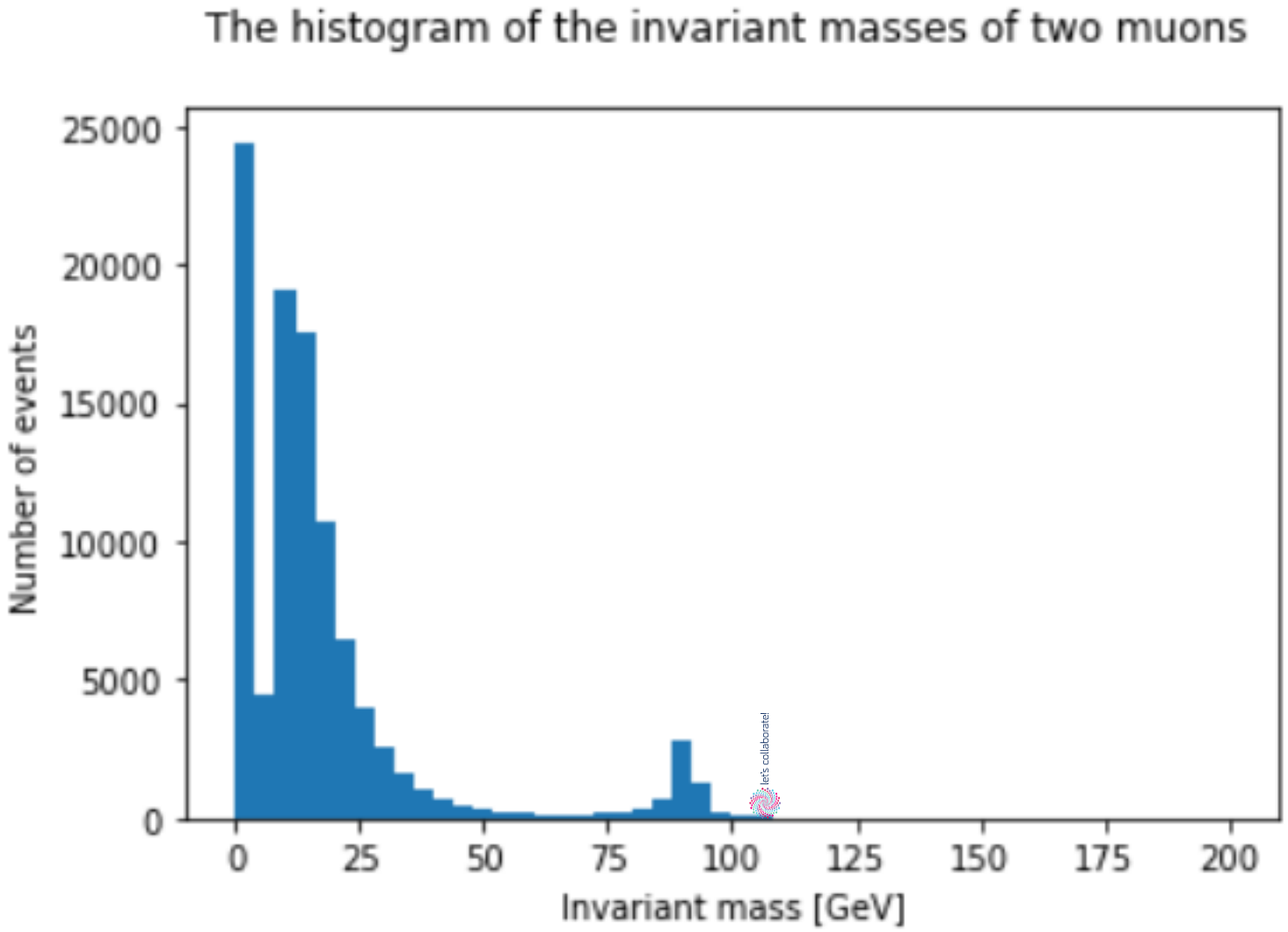
$$g = \frac{2}{0.2286} = 8.749\ ms^{-2}$$

Data table from the particle detector…

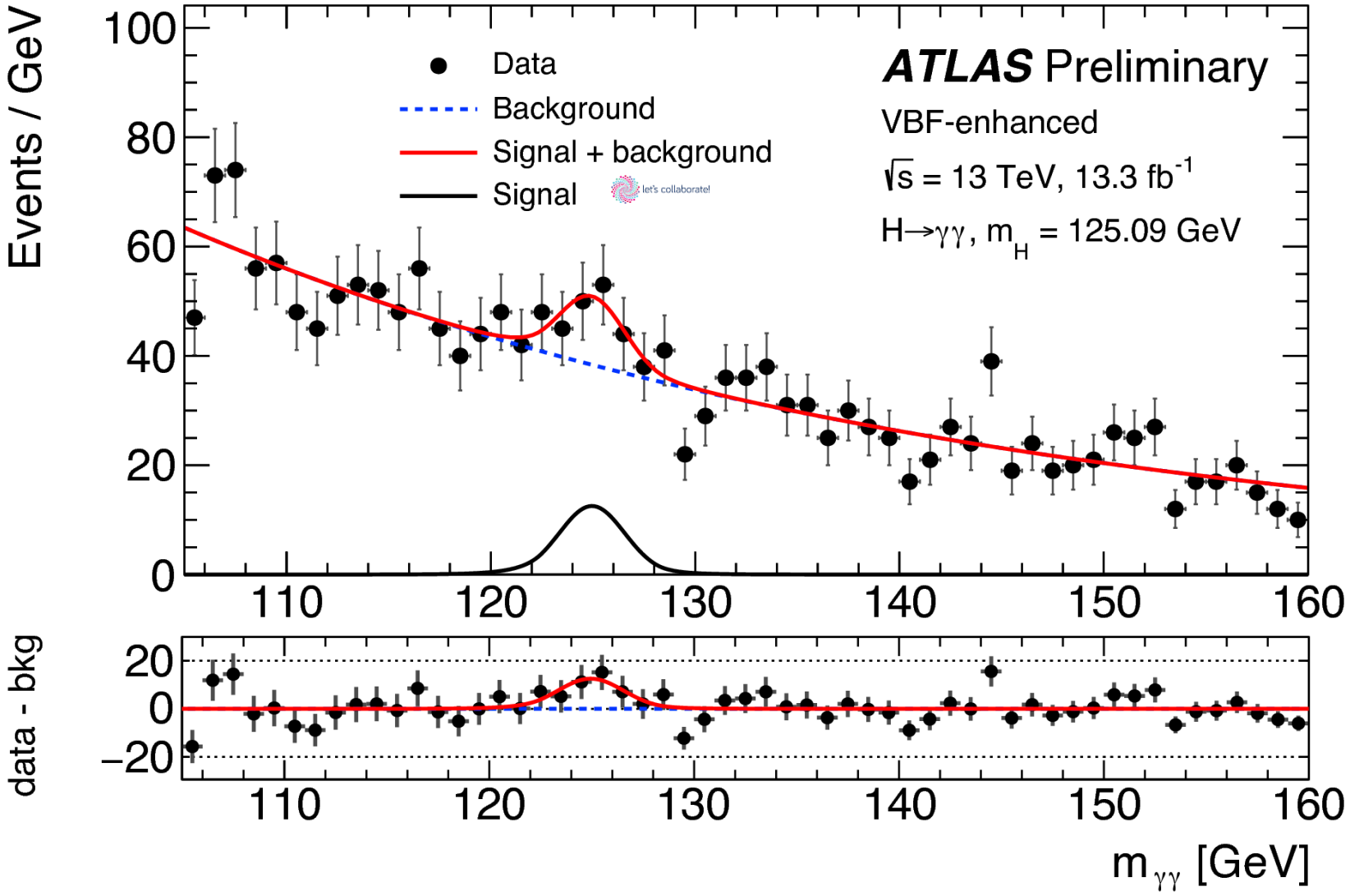
```
In [6]: dataset=pd.read_csv('C:/Users/Isabel/Documents/CERN/cms-jupyter-materia
   ...: ls-english-master/Data/Zmumu_Run2011A.csv')

In [7]: dataset
Out[7]:
        Run       Event       pt1       eta1      phi1  Q1      dxy1  \
0    165617    74969122  54.70550 -0.432396  2.574210   1 -0.074544
1    165617    75138253  24.58720 -2.052200  2.866570  -1 -0.055437
2    165617    75887636  31.73860 -2.259450 -1.332290  -1  0.087917
3    165617    75779415  39.73940 -0.712338 -0.312266   1  0.058481
4    165617    75098104  41.29980 -0.157055 -3.040770   1 -0.030463
5    165617    77255513  38.94250  0.352210 -2.264920  -1  0.038368
6    165617    76042048  42.82780 -0.954909 -0.241833  -1  0.051331
7    165617    76661162  17.35930 -1.480880 -1.704590  -1  0.141148
8    165617    77076988  38.15110 -0.870204  1.716480   1 -0.083988
9    165617    77459740  51.64370 -1.215330  1.867000  -1 -0.082574
10   165617    76405662  42.47140 -0.669585 -1.630270  -1  0.072769
11   165617    76583723  34.51040  0.747187 -1.621030   1  0.074875
12   165617    76179155  45.06240 -1.945880 -1.034740   1  0.084812
13   165617    75954345  33.50150  0.815032 -1.210450  -1  0.086110
14   165617    78956967  12.36590 -1.939010 -2.588570   1  0.077146
15   165617    77629816  43.24040  2.085250 -1.348880  -1  0.080776
16   165617    78897689  40.52480  0.615439 -2.414700   1  0.022800
17   165617    78700766  38.99490 -1.295750 -0.583314  -1  0.071123
18   165617    78348203  26.06280 -1.204130  2.036310   1 -0.083516
19   165617    78693707  21.39860 -1.686450  0.090534   1  0.026345
20   165617    78814907  26.45570 -1.303620  1.412150  -1 -0.069671
21   165617    78974110  41.44110  1.535720  1.315320   1 -0.066548
22   165617    80578768  34.61500  1.433280 -2.317280  -1  0.029877
23   165617    80284893   3.46369 -0.770495 -2.889680  -1 -0.014957
24   165617    80456027  38.88250  1.280970  2.002440   1 -0.091024
25   165617    79285182  46.85490 -1.527400  0.606702   1 -0.013381
26   165617    79848134  58.68770 -1.021260  0.836241   1 -0.031928
27   165617    79997894  36.41990  1.543270  1.897660   1 -0.083796
28   165617    79973412  34.65230  1.378200  1.242720  -1 -0.066831
29   165617    80814088  81.39010 -1.165510  1.359540   1 -0.066260
...     ...         ...       ...       ...       ...  ..       ...
10553  173692  1294976715  28.78210  1.328580  1.407350   1 -0.062354
10554  173692  1294924620  71.71350  1.026810 -1.690150  -1  0.068170
10555  173692  1295047932  71.07110 -0.500784 -1.675680   1  0.070272
10556  173692  1294961297  24.79900 -1.829720  1.591100  -1 -0.069658
10557  173692  1295309621  13.17360 -1.977100  2.467650  -1 -0.085066
10558  173692  1294681424  48.88620  0.908995  2.218520  -1 -0.086377
10559  173692  1295113744  37.94820 -0.446353 -1.445680   1  0.074889
10560  173692  1296382198  27.62610  1.365850 -1.510140   1  0.068986
10561  173692  1295818522  44.43670  1.132310  0.462685  -1  0.008330
10562  173692  1295875802  44.37540 -0.231891  3.097220   1 -0.051325
10563  173692  1296591036  30.58910 -1.827060 -1.036090   1  0.088614
10564  173692  1296043907  27.99150 -1.148680 -0.342203   1  0.069249
10565  173692  1296985256  18.97240  0.277090 -2.057490   1  0.044894
10566  173692  1297181344  34.34350  0.576123 -1.124240  -1  0.085634
10567  173692  1297661914  51.51280 -1.368060 -1.490620  -1  0.081069
```

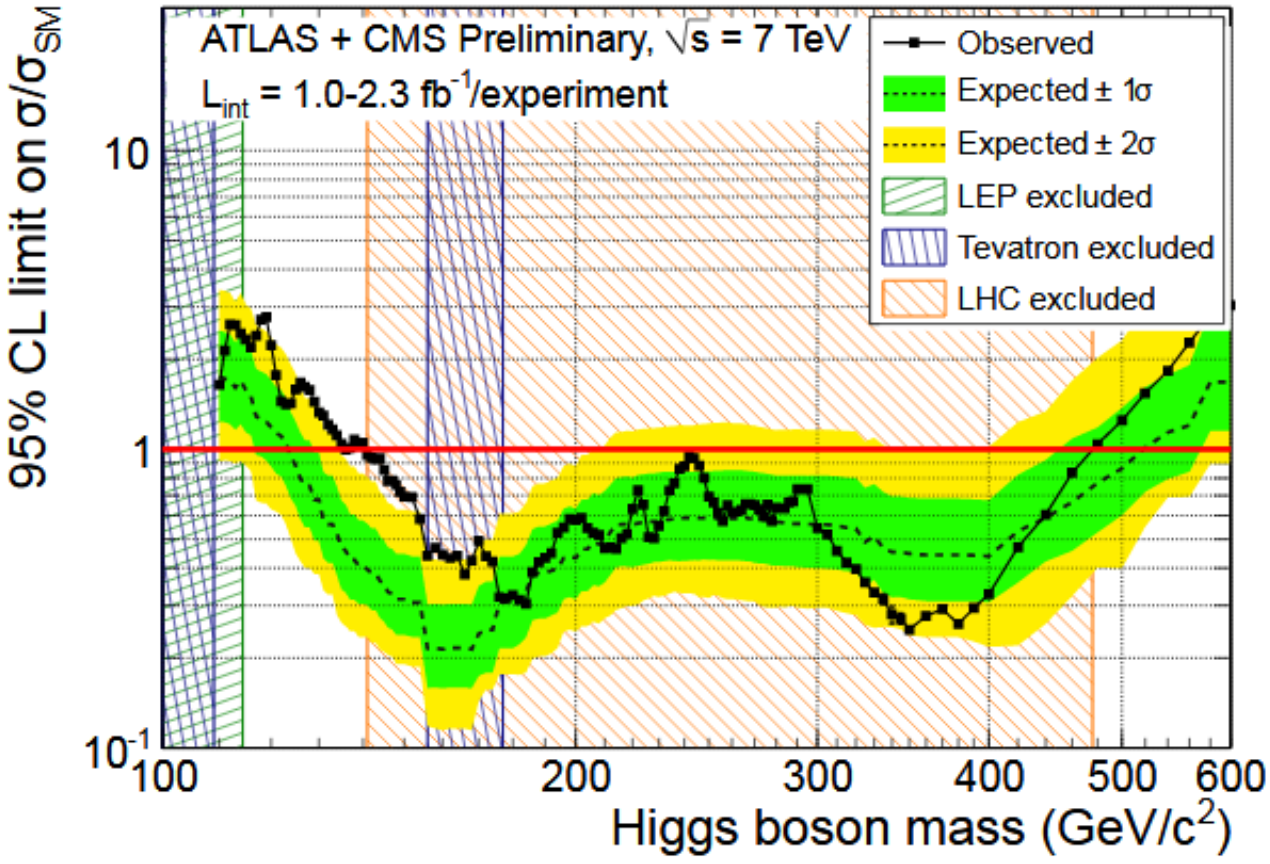
Analysis of data

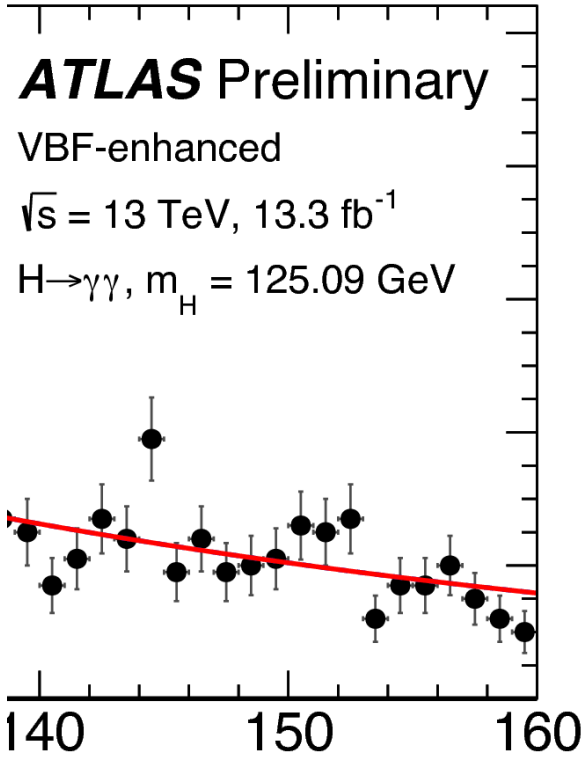


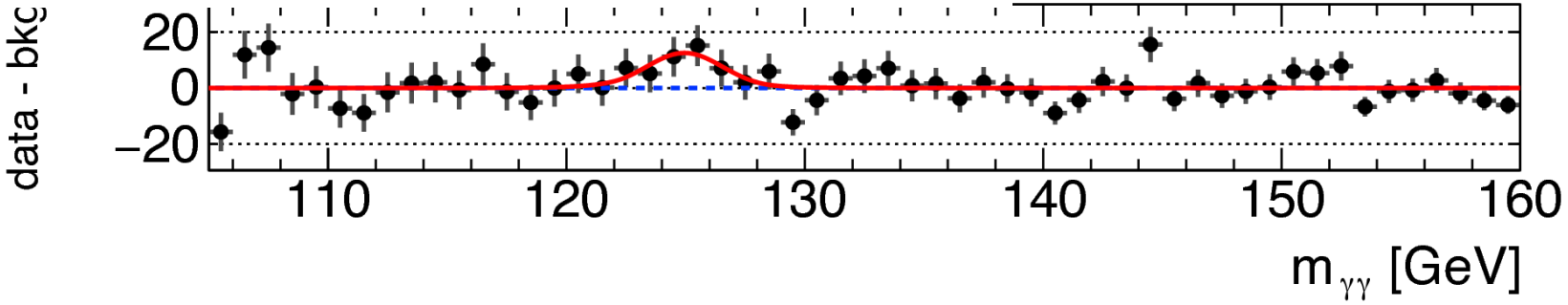
Analysis of data



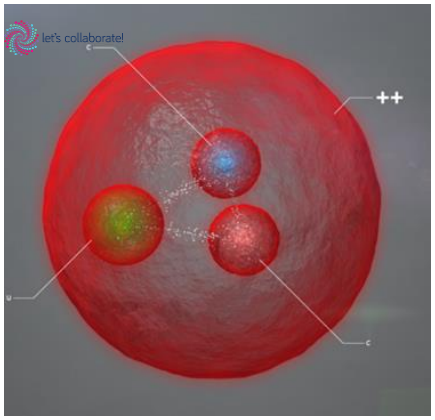
Analysis of data

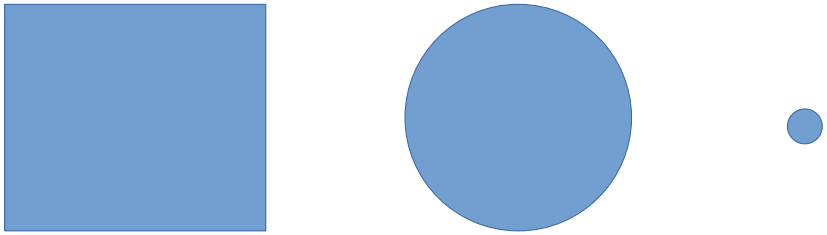






Models: only what actually matters



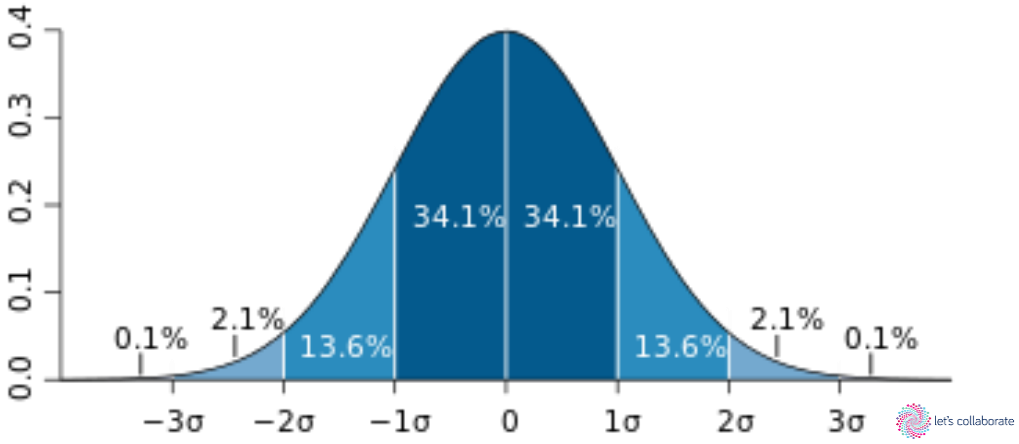


Take measurements of only what the theory/model needs, the rest are details...

Statistics and distributions

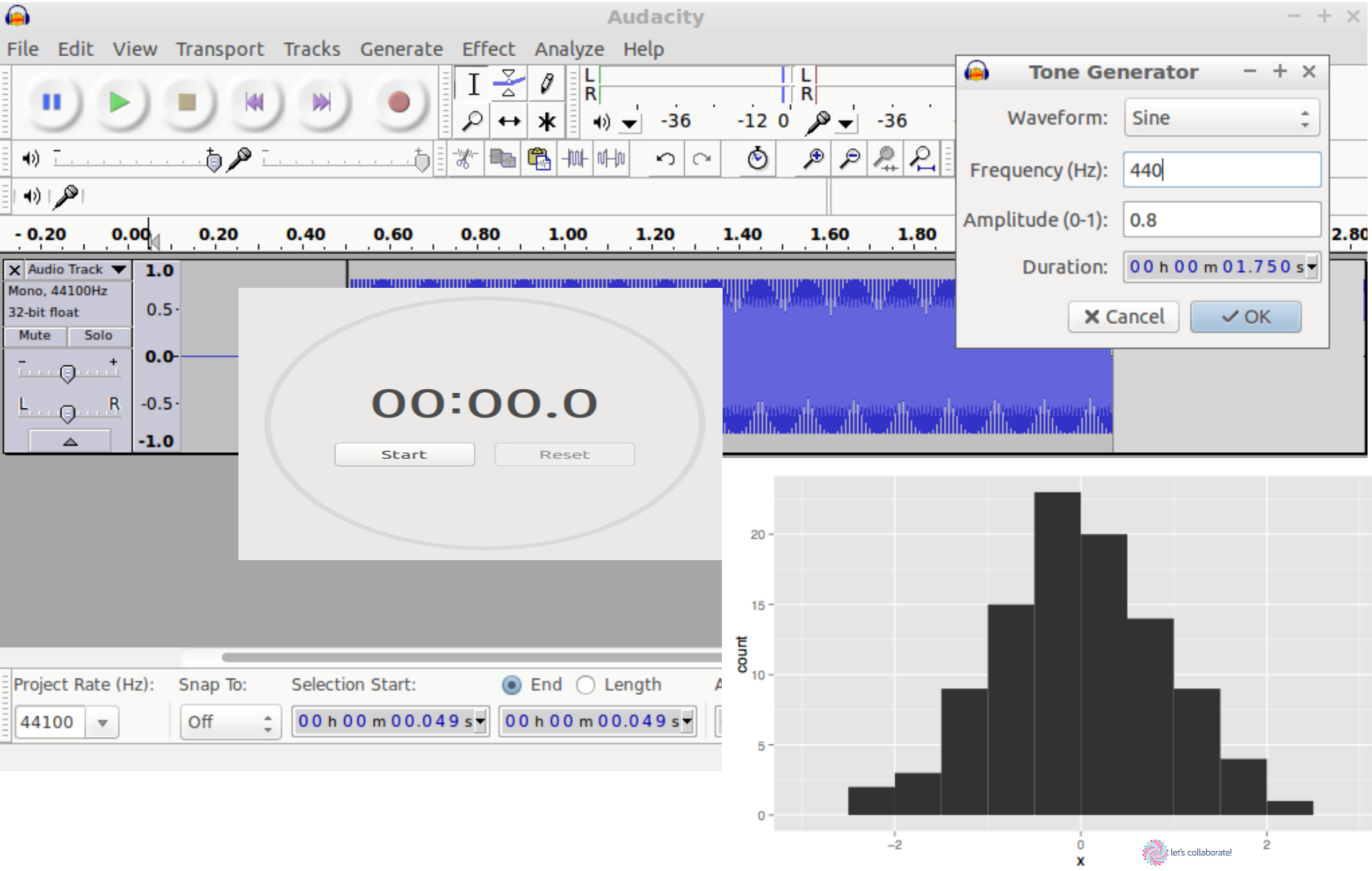
Galton Board

Mean
Standard deviation
68-95-99.7 rule

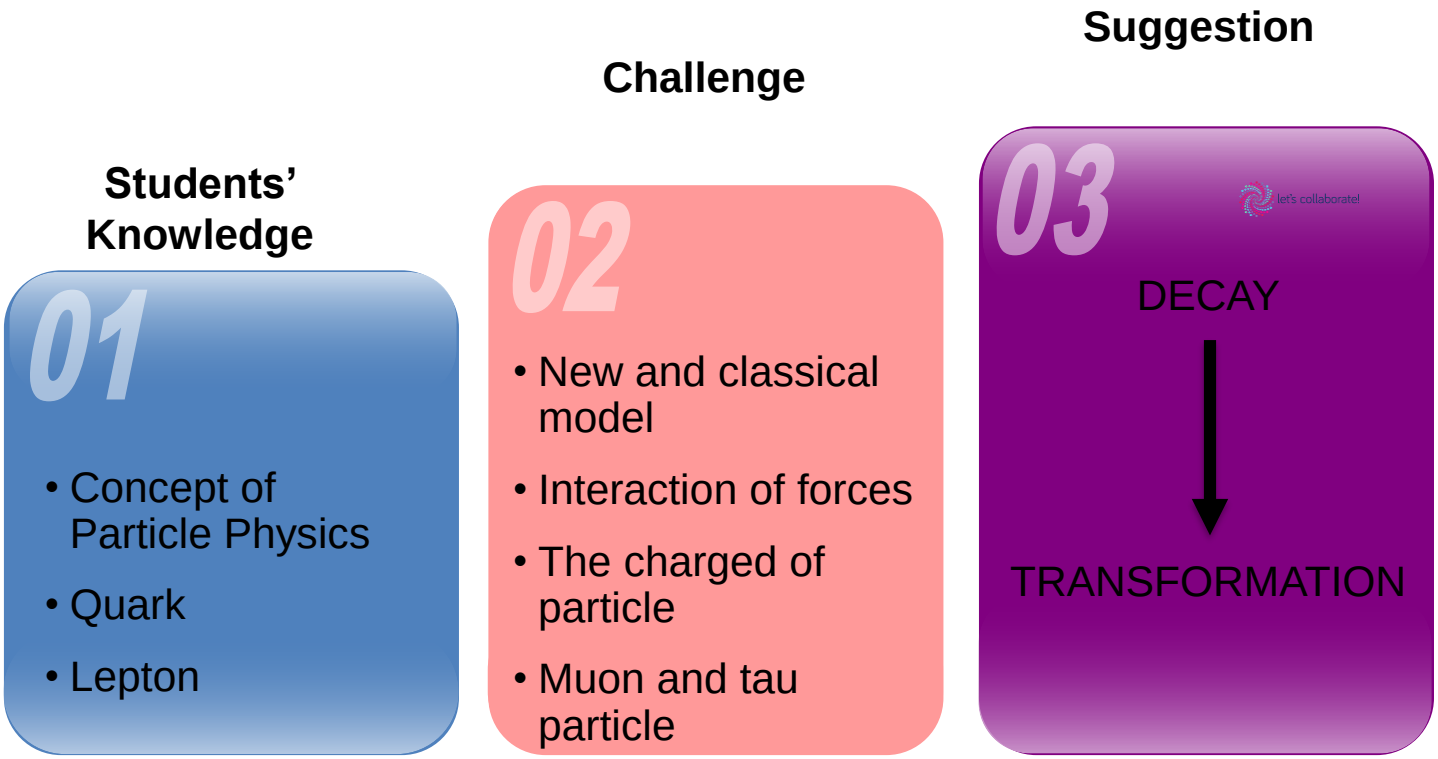


HEP: 5 sigma rule (99.9999426697%)

Statistics and distributions: an example

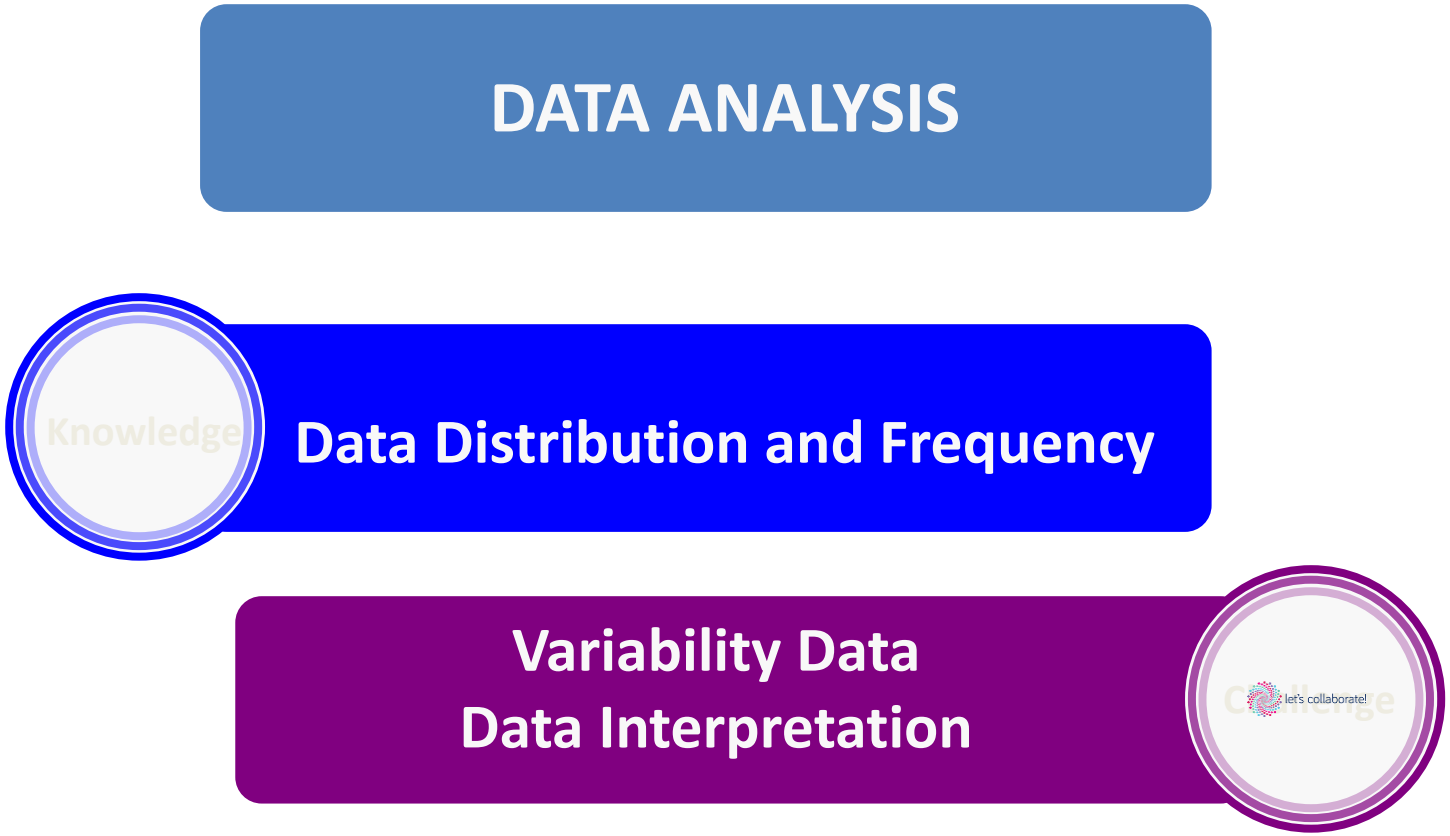


Conception & Challenge



Tuzan & Solbes (2016), Gourlay (2017), Woithe, Wiener, and Veken (2017)

Conception & Challenge



Cooper and Shore (2017)

Data analysis resources:

https://github.com/cer ructions and links for the task.

https://github.com/cm er steps in data analysis

statistics).

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ion t ;).

http://opendata.cern.ch/ education and research resources provided by CERN

https://scool.web.cern.ch/ CSV data files and other teaching resources.

Useful papers for teachers

Tuzon P, Solbes J. Particle physics in high school: A diagnose study. Plos ONE. 2016; 11(6):1-9. doi:10.137/journal.pone

Gourlay H. Learning about A level physics students' understanding of particle physics using concept mapping. IOP Science Physics Education. 2017; 52: 1-8.

Woithe J, Wiener G, Veken, F. Let's have a coffee with the standard model of particle physics. IOP Science Physics Education. 2017; 52: 1-9. doi: 10.1088/1361-6552/aa5b25.

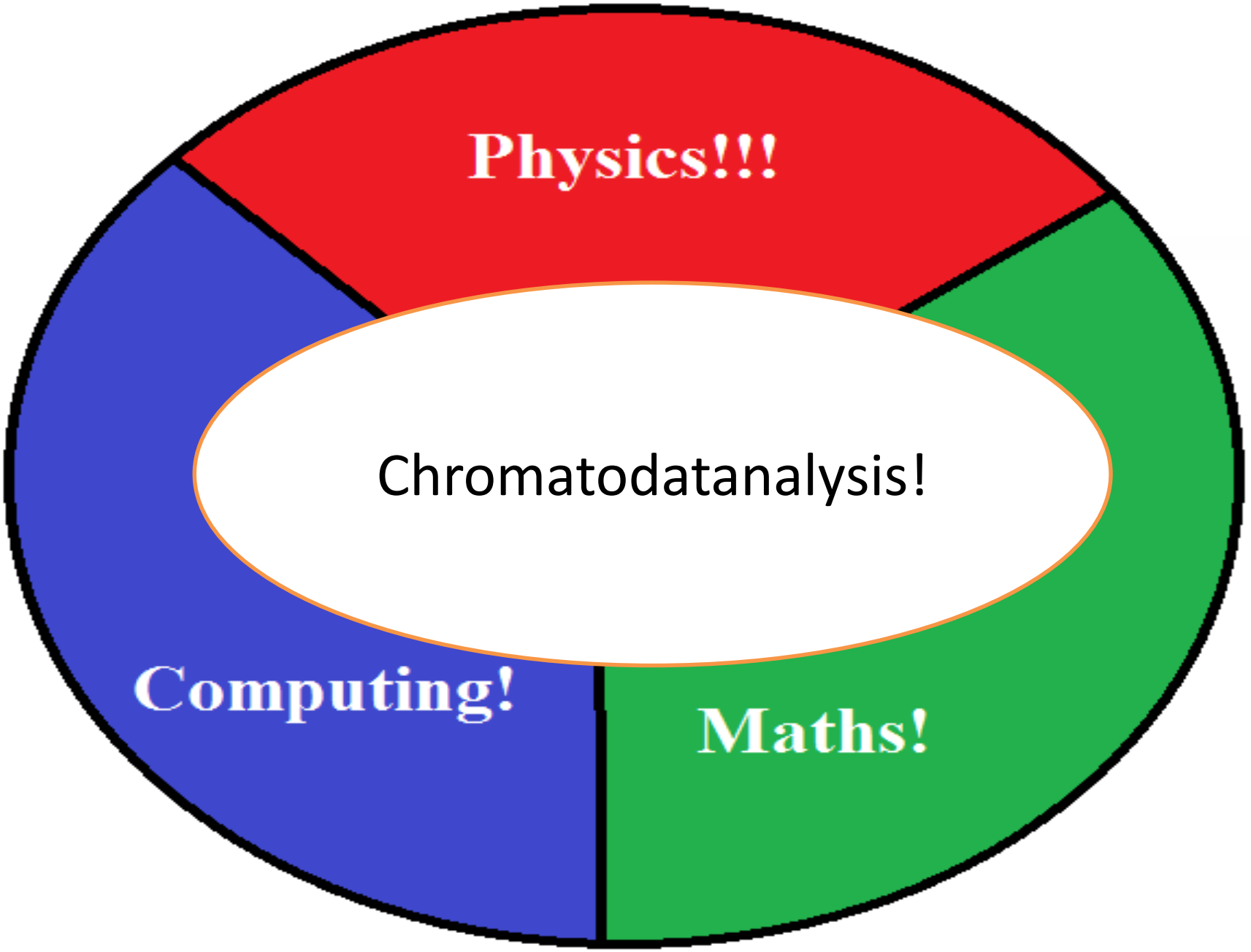
Wiener G, Schmeling S, Hopf M. Introducing 12 year-olds to elementary particles. IOP Science Physics Education. 2017; 52: 1-7. doi: 10.1088/1361-6552/aa6cfe.

Student's activities

http://neutrino-classroom.org/TeachersGuideJuly2015/NeutrinoClassroomTeachersGuide-EditedJuly2015.pdf - Particle physics activities for high school physics students.

http://slideplayer.com/slide/8518655/ - Use of Cosmic Ray eLab to teach the research process.

http://www.i2u2.org/elab/cosmic/home/project.jsp - High school students use cutting-edge tools to do scientific investigations.


Physics!!!
Chromatodatanalysis!
Computing!
Maths!

Complex but enjoyable. Opportunities:

In [9]:
```
compare = pd.read_csv('C:\cern data/energy_compare.csv')
```

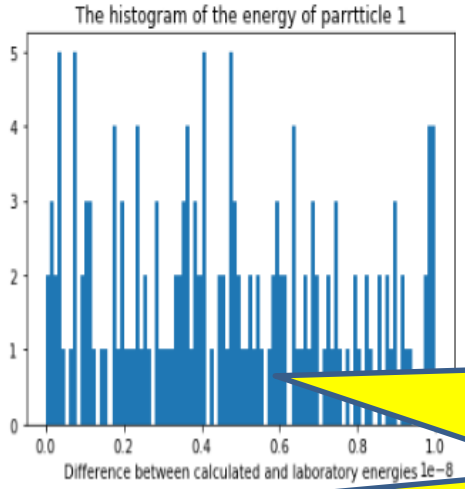
Below, we subtract the table value of energy from the calculated data.

In [10]:
```
Compare = E - compare.E1
```

Next, we plot a histogram of the differences.

Optional// We can make a smilar user-input function as before and ask pupils to find where the values are.

In [11]:
```
plt.hist(Compare, bins = 100, range=(0,0.00000001))
plt.xlabel('Difference between calculated and laboratory energies')
plt.ylabel('Events')
plt.title('The histogram of the energy of parrtticle 1')
plt.show()
```



Task can be repeated for the second pa... challenge.

0 10 20 30 40

1. Pupils are introduced to writing functions and importing program libraries.

let's collaborate!

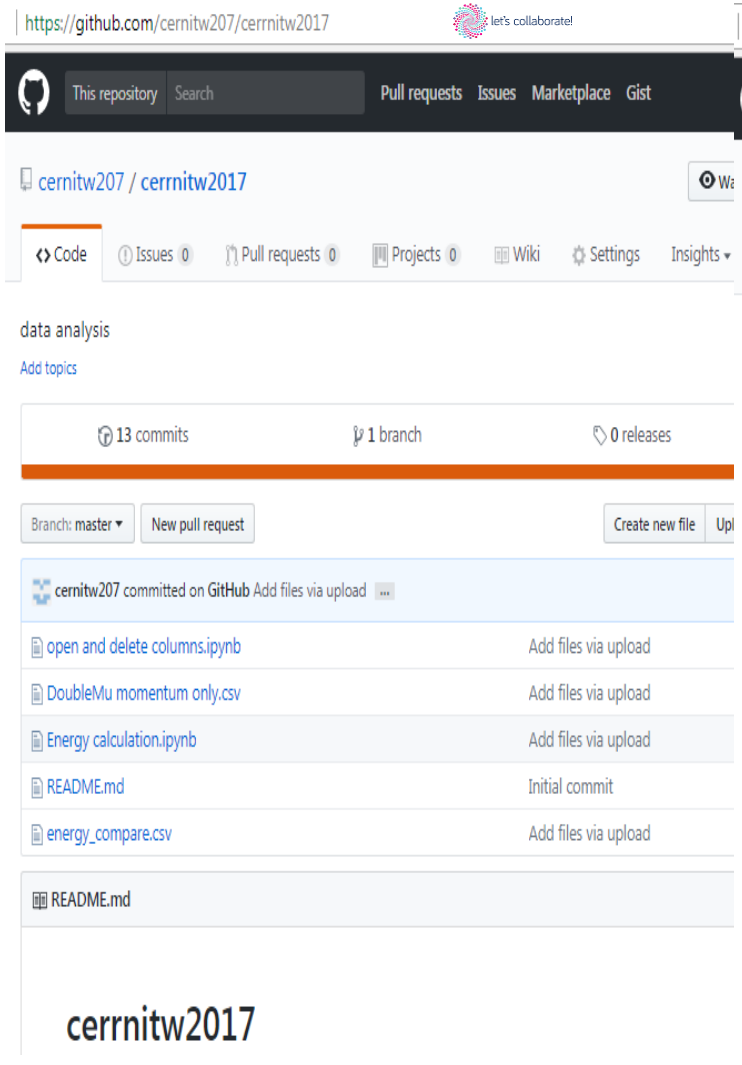
2. Pupils then proceed to calculation of the total momentum of a particle and the relativistic energy that it contains .

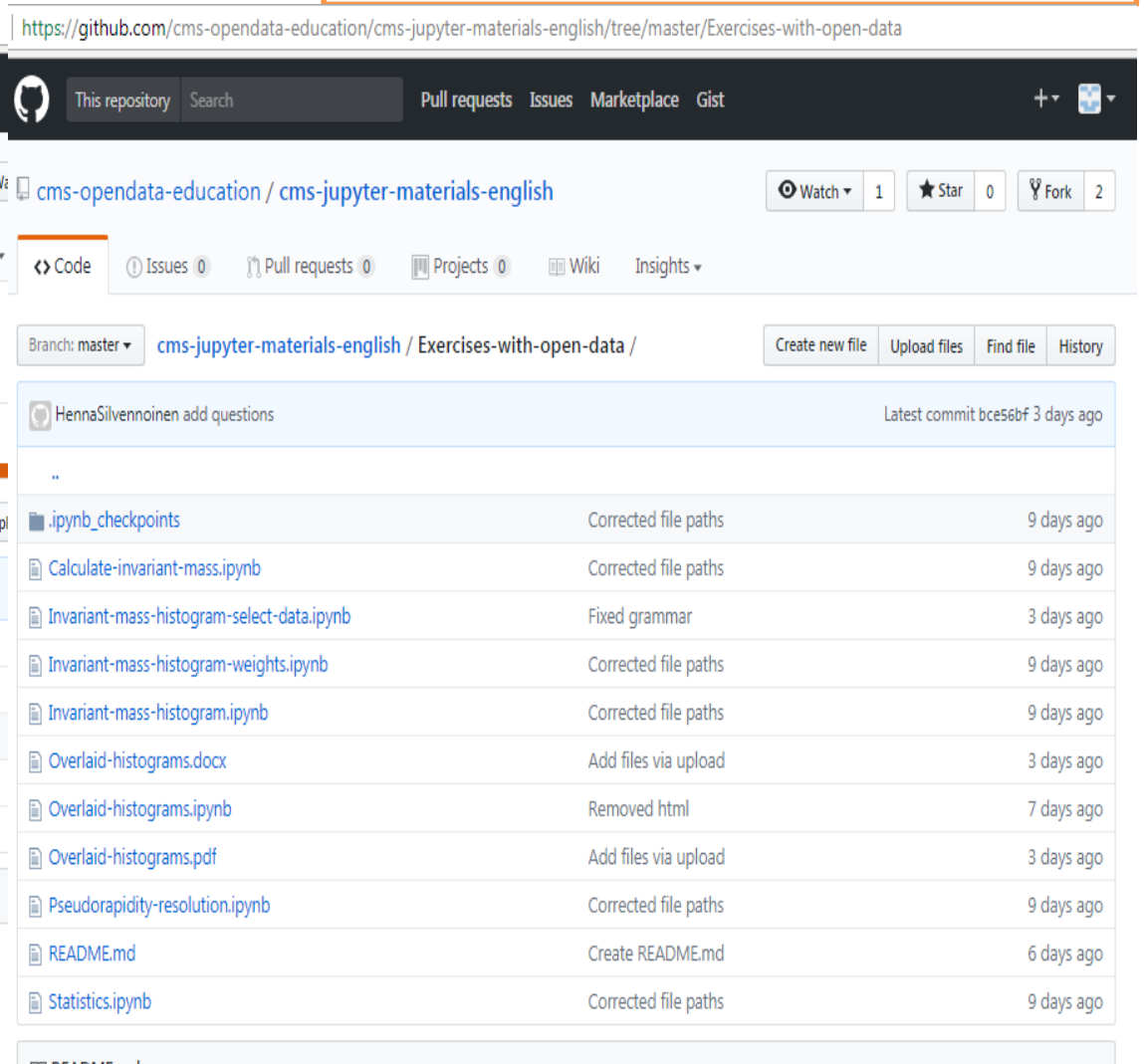
3. In the final stage of the task pupils have to compare the data from CERN to their calculated value.

Chromodatanalysis!

Data files and instructions are all saved in Github.

The task fits well in other resources that have been developed by teachers and could be used as a starting point for data analysis using Python.





Thank you!

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Special thanks to Mira and Henna for helping us!

let's collaborate!

Link:

- https://github.com/cernitw207/cerrnitw2017
  TASK, instructions, useful links.