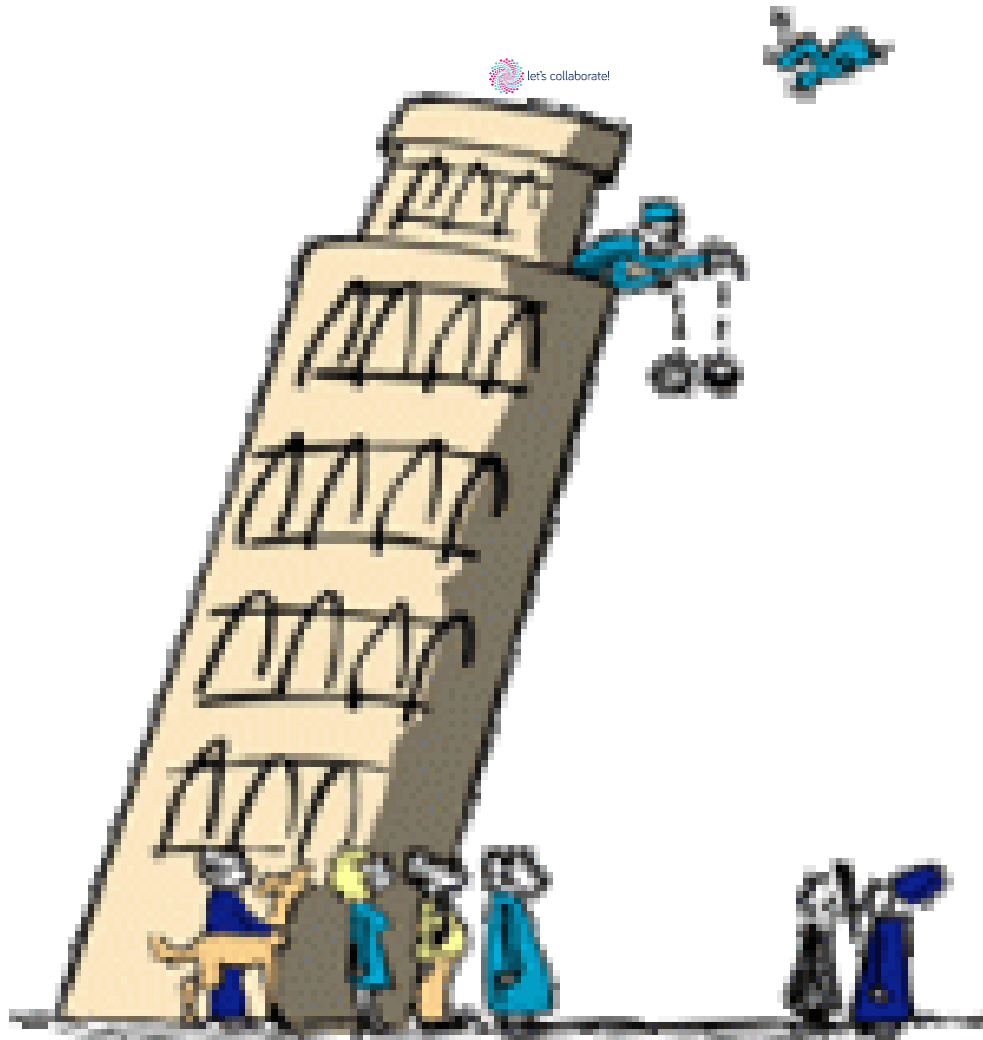


DATA ANALYSIS

Determining g – HS experiment

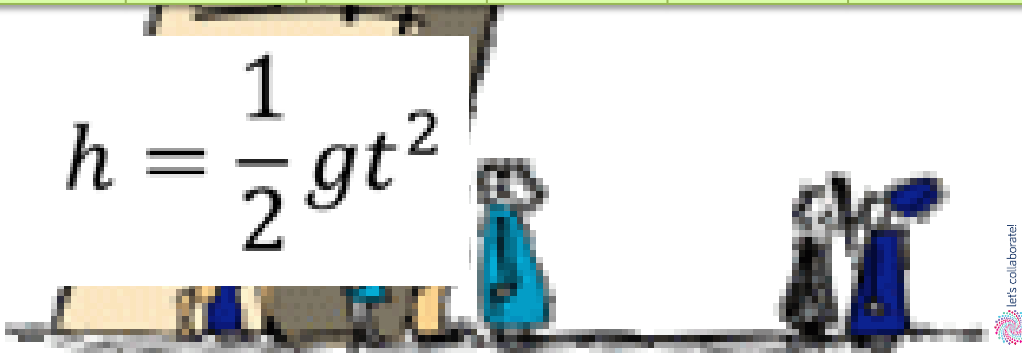


$$h = \frac{1}{2}gt^2$$

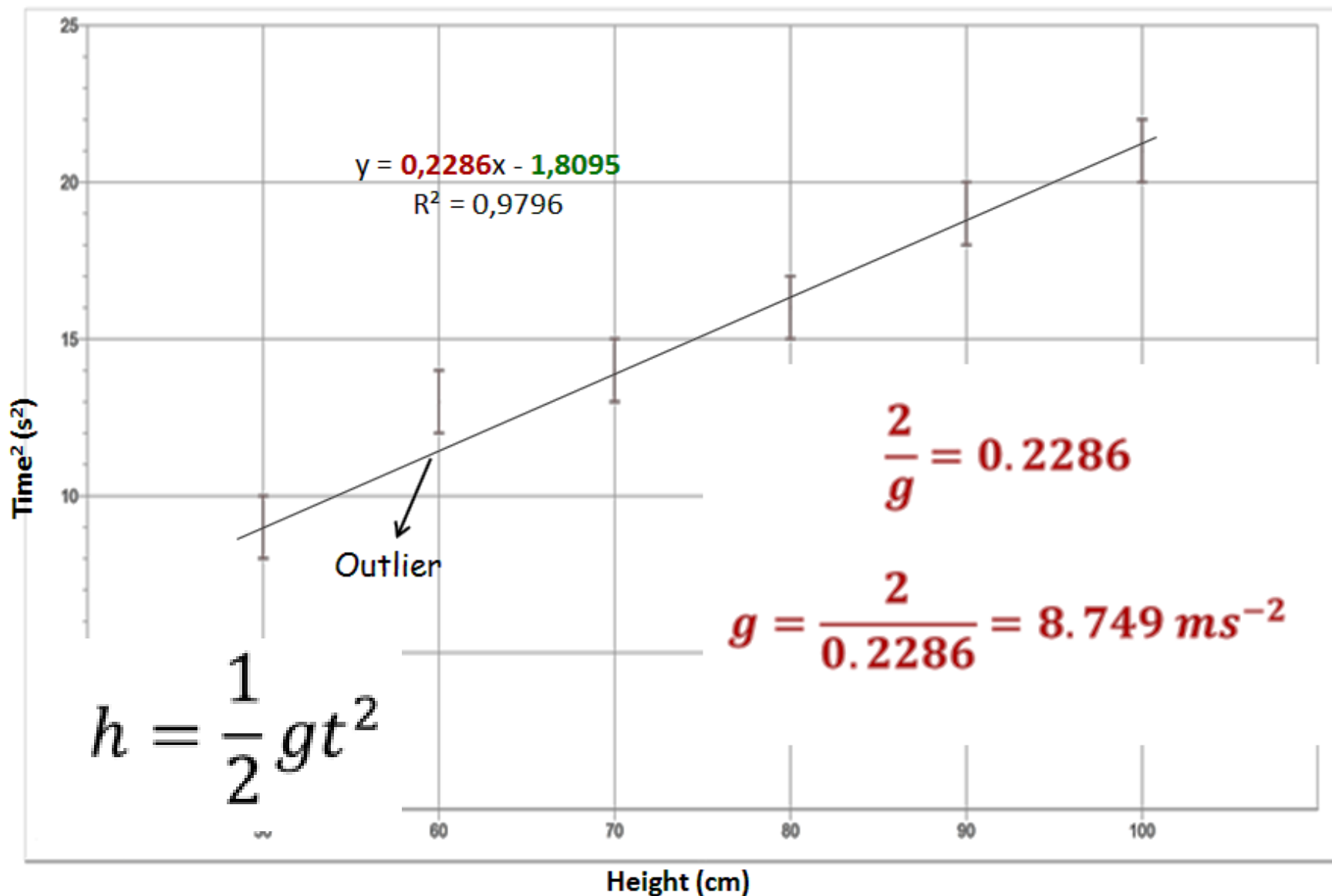
Determining g – HS experiment

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

$$h = \frac{1}{2}gt^2$$



Determining g – HS experiment



Data table from the particle detector...

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

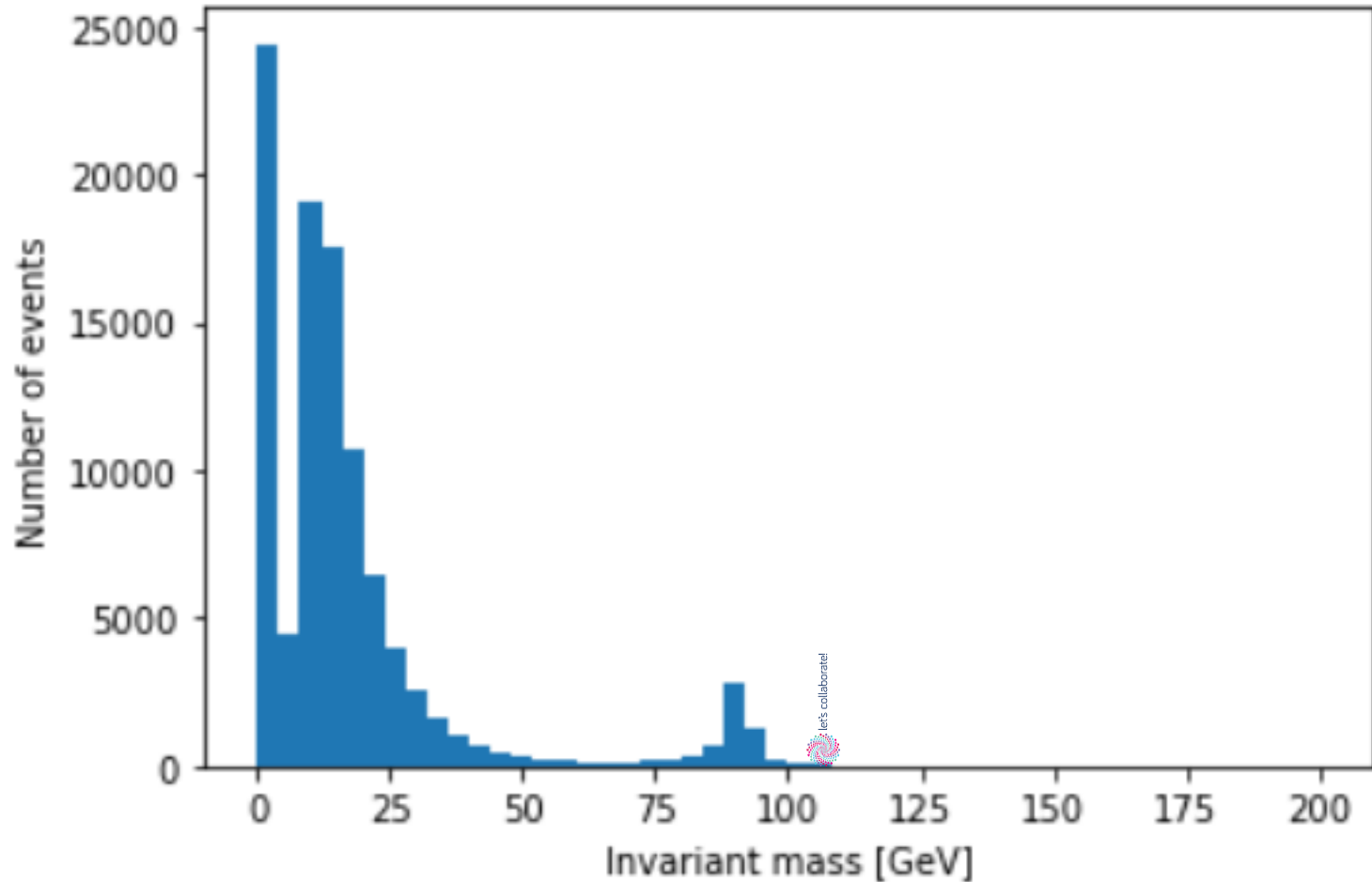
```
In [7]: dataset
```

```
Out [7]:
```

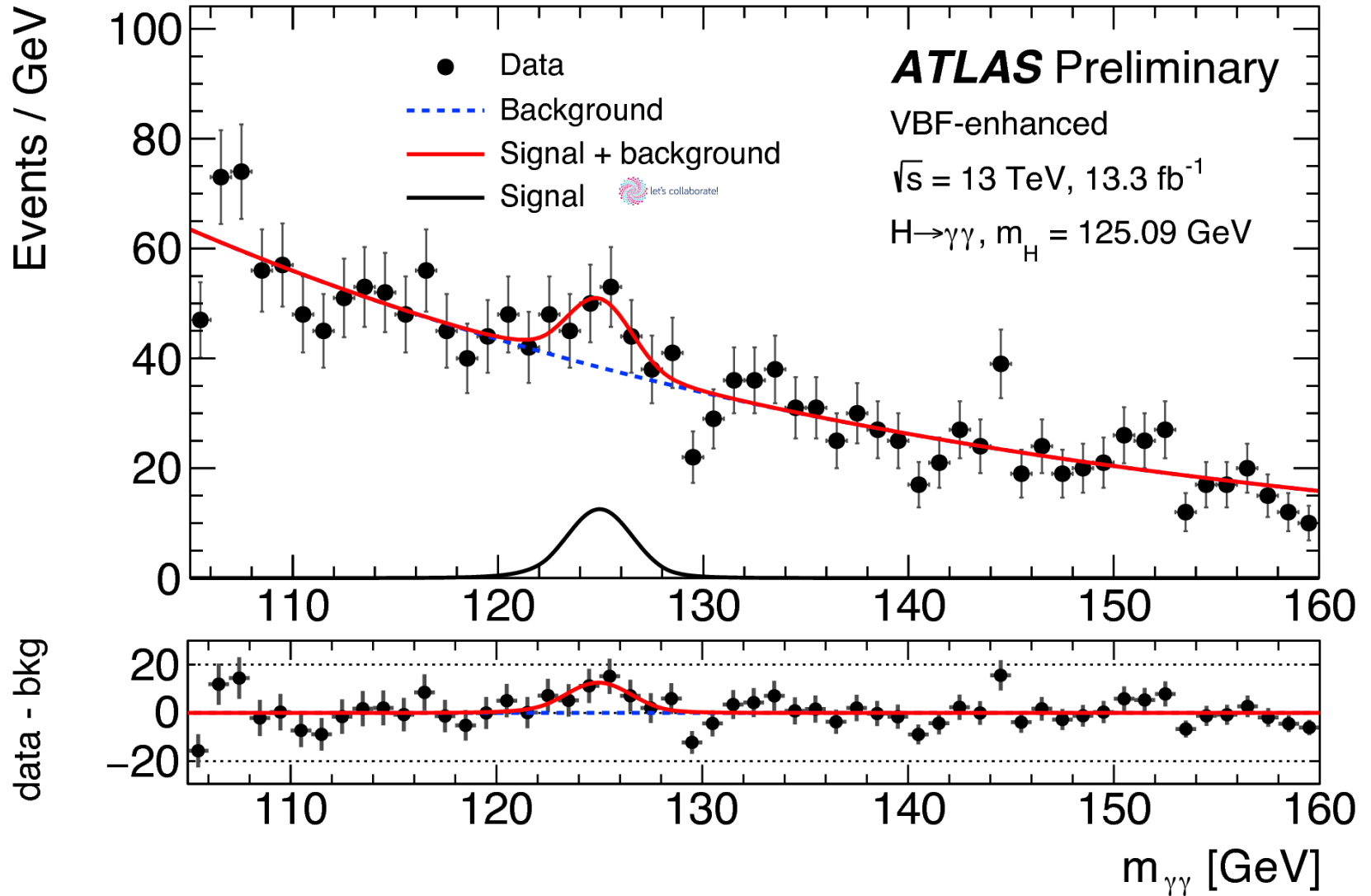
	Run	Event	pt1	eta1	phi1	Q1	dxy1
0	165617	74969122	54.70550	-0.432396	2.574210	1	-0.074544
1	165617	75138253	24.58720	-2.052200	2.866570	-1	-0.055437
2	165617	75887636	31.73860	-2.259450	-1.332290	-1	0.087917
3	165617	75779415	39.73940	-0.712338	-0.312266	1	0.058481
4	165617	75098104	41.29980	-0.157055	-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	2.036210	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	51.51780	-1.368060	-1.490620	-1	0.081069

Analysis of data

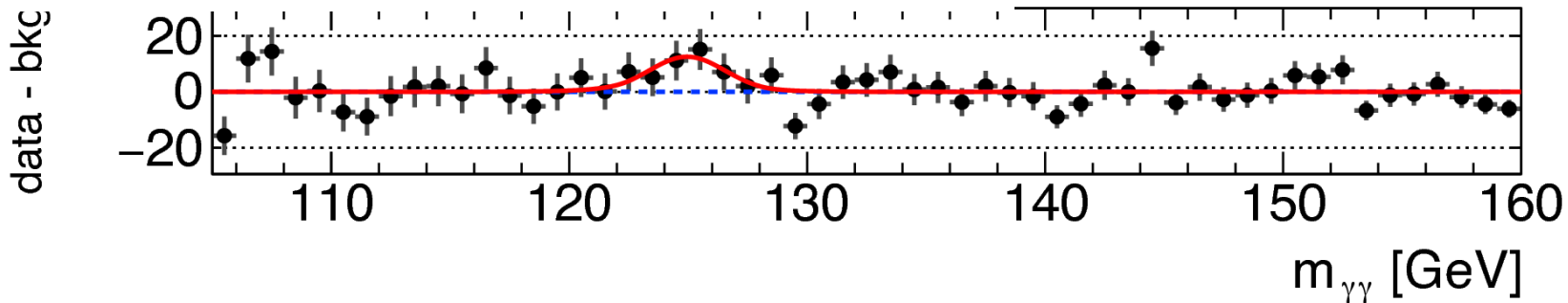
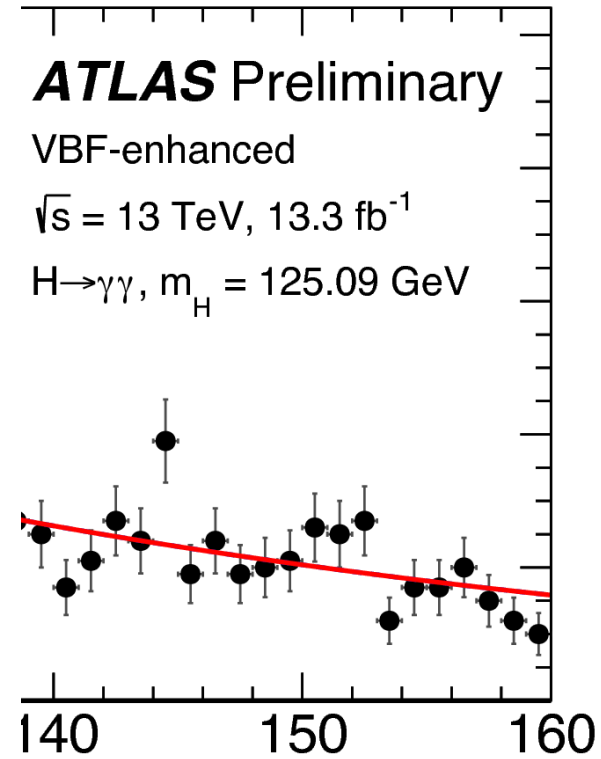
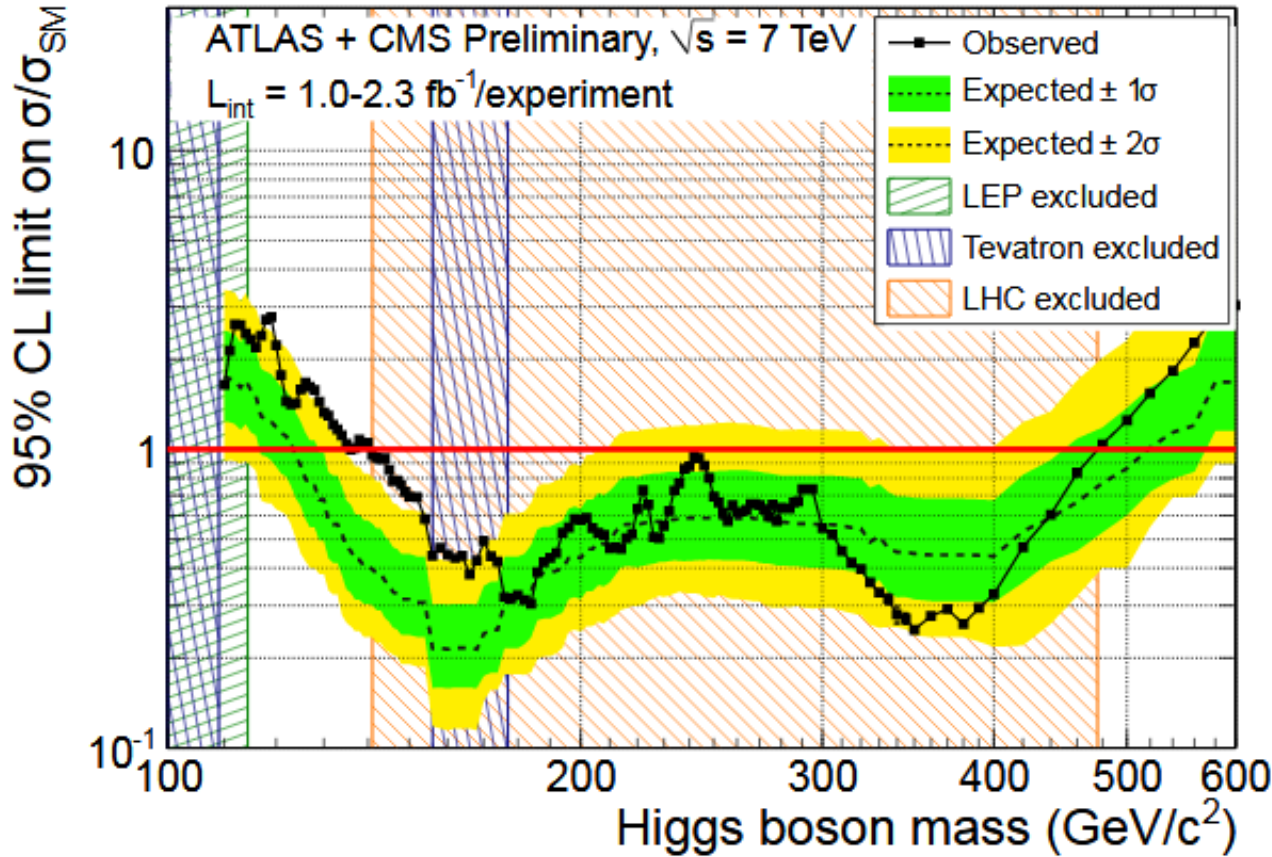
The histogram of the invariant masses of two muons



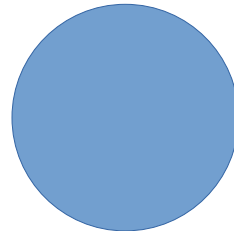
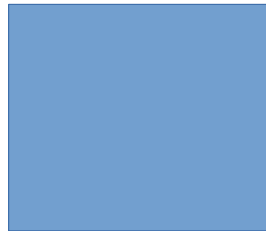
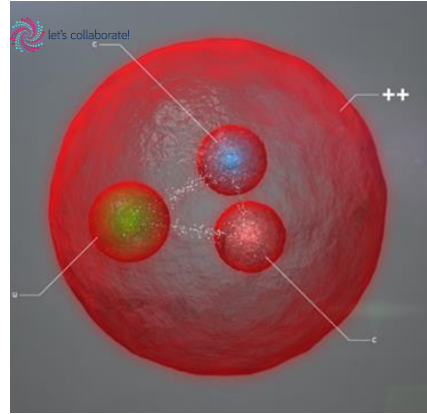
Analysis of data



Analysis of data



Models: only what actually matters



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

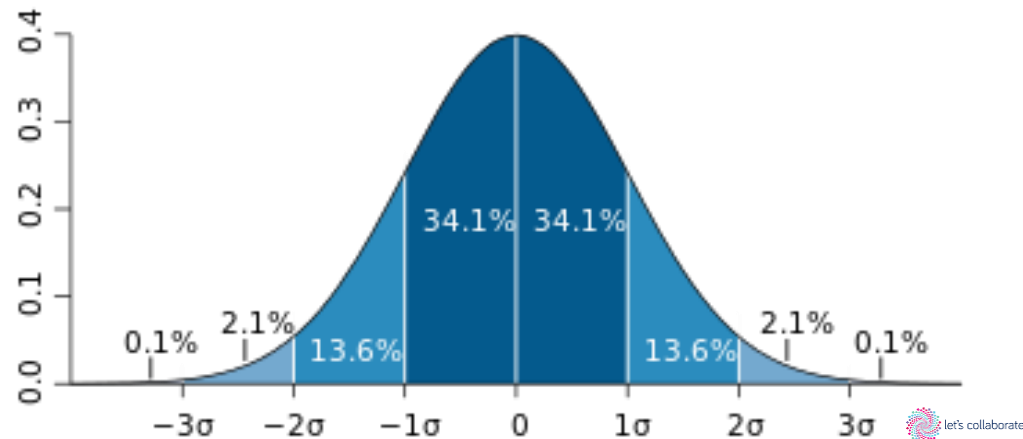
Statistics and distributions

Galton Board

Mean

Standard deviation

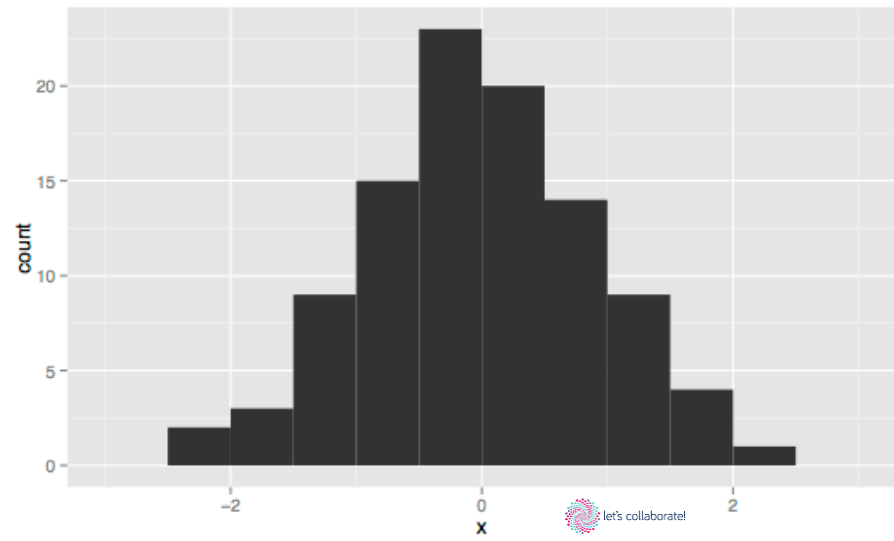
68-95-99.7 rule



HEP: 5 sigma rule (99.9999426697%)

Statistics and distributions: an example

The screenshot shows the Audacity audio editor interface. A 'Tone Generator' dialog box is open, showing a sine wave with a frequency of 440 Hz and an amplitude of 0.8. A large '00:00.0' time display overlay is centered on the screen, with 'Start' and 'Reset' buttons below it. The background shows a blue audio waveform on a track.



Conception & Challenge



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

Conception & Challenge

DATA ANALYSIS

Knowledge

Data Distribution and Frequency

**Variability Data
Data Interpretation**

let's collaborate!



Data analysis resources:

<https://github.com/cei>

<https://github.com/cn>



ructions and links for the task.

er steps in data analysis

statistics).

Anaconda for Data Science

Empowering Everyone on the Team

Data Scientist

- Advanced analytics with Python & R
- Simplified library management
- Easily share data science notebooks & packages

Developer

- Support for common APIs & data formats
- Common language with data scientists
- Python extensibility with C, C++, etc..

Ops

- Validated source of up-to-date packages including indemnification
- Agile Enterprise Package Management
- Supported across platforms

Data Engineer

- Powerful & efficient libraries for data transformations
- Robust processing for noisy dirty data
- Support for common APIs & data formats

Business Analyst

- Collaborative interactive analytics with notebooks
- Rich browser based visualizations
- Powerful MS Excel integration

Computational Scientist

- Rich set of advanced analytics
- Trusted & production ready libraries for numerics
- Simplified scale up & scale out on clusters & GPUs



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

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

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Useful papers for teachers

Tuzon P, Solbes J. Particle physics in high school: A diagnose study. Plos ONE. 2016; 11(6):1-9. doi:10.1371/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.

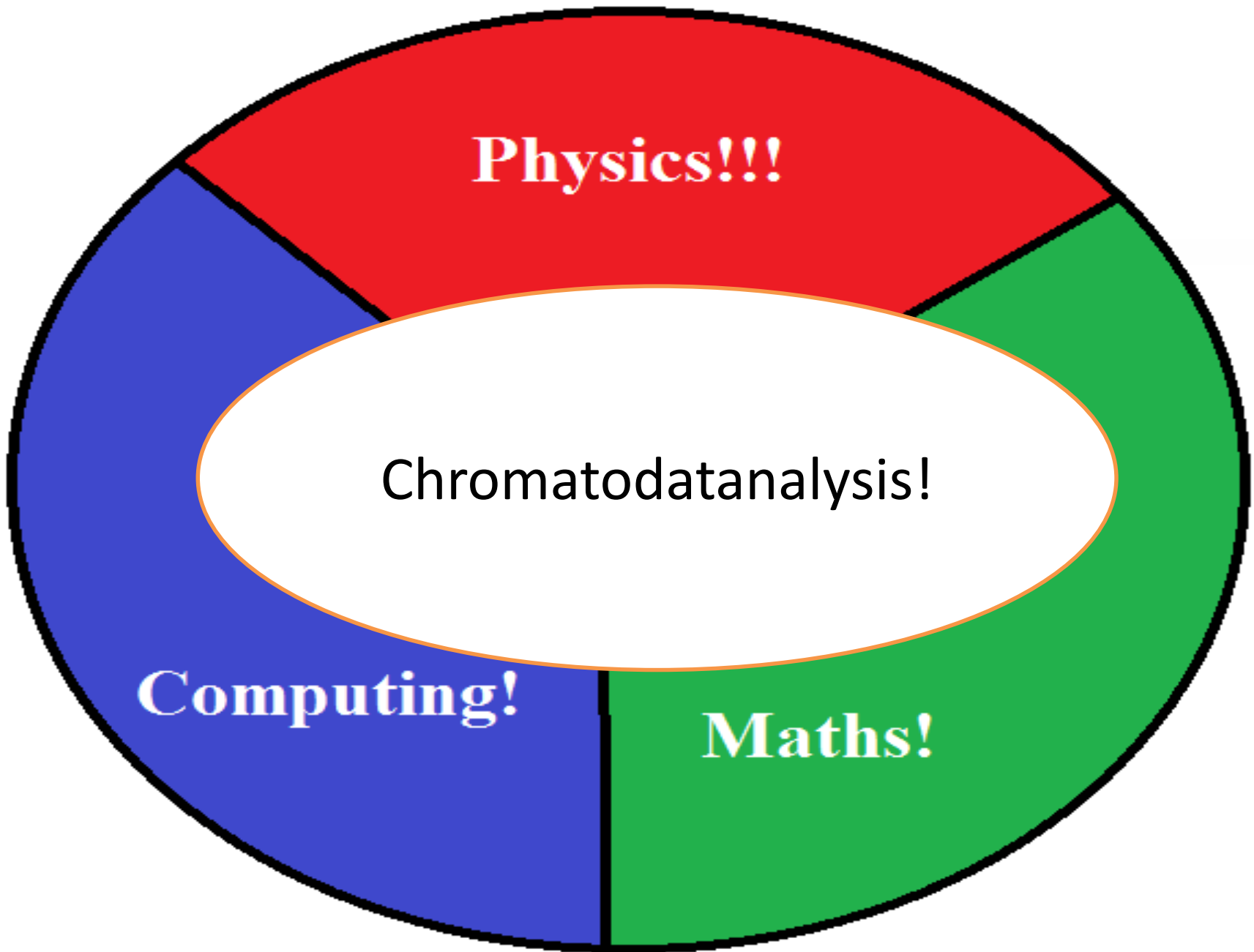
Wiener G, Schmeling S, Hopf M. Introducing 12 year-olds to elementary particles. IOP Science Physics Education. 2017; 52: 1-7. doi: 10.1088/1361-6552/aa6cfe.

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.



Complex but enjoyable. Opportunities:

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

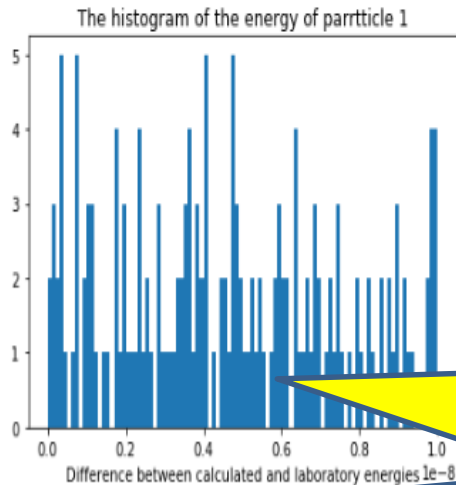
Below, we subtract the table value of energy from the calculated data.

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

Next, we plot a histogram of the differences.

Optional// We can make a similar 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 parrticle 1')  
plt.show()
```



Task can be repeated for the second particle challenge.

0 10 20 30 40

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


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.

<https://github.com/cernitw207/cernitw207> 

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data analysis
Add topics


13 commits 1 branch 0 releases

Branch: master New pull request Create new file Upload files

cernitw207 committed on GitHub Add files via upload

- open and delete columns.ipynb Add files via upload
- DoubleMu momentum only.csv Add files via upload
- Energy calculation.ipynb Add files via upload
- README.md Initial commit
- energy_compare.csv Add files via upload

README.md



<https://github.com/cms-opendata-education/cms-jupyter-materials-english/tree/master/Exercises-with-open-data>

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- ..
- .ipynb_checkpoints Corrected file paths 9 days ago
- Calculate-invariant-mass.ipynb Corrected file paths 9 days ago
- Invariant-mass-histogram-select-data.ipynb Fixed grammar 3 days ago
- Invariant-mass-histogram-weights.ipynb Corrected file paths 9 days ago
- Invariant-mass-histogram.ipynb Corrected file paths 9 days ago
- Overlaid-histograms.docx Add files via upload 3 days ago
- Overlaid-histograms.ipynb Removed html 7 days ago
- Overlaid-histograms.pdf Add files via upload 3 days ago
- Pseudorapidity-resolution.ipynb Corrected file paths 9 days ago
- README.md Create README.md 6 days ago
- Statistics.ipynb Corrected file paths 9 days ago

README.md

Thank you!

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Isabel Vives

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Special thanks to Mira and
Henna for helping us!



let's collaborate!

Link:

- <https://github.com/cernitw207/cernitw2017>
TASK, instructions, useful links.

