



# RAL MASTERCLASSES

Julie Kirk, **Emmanuel Olaiya**, Sophy Palmer

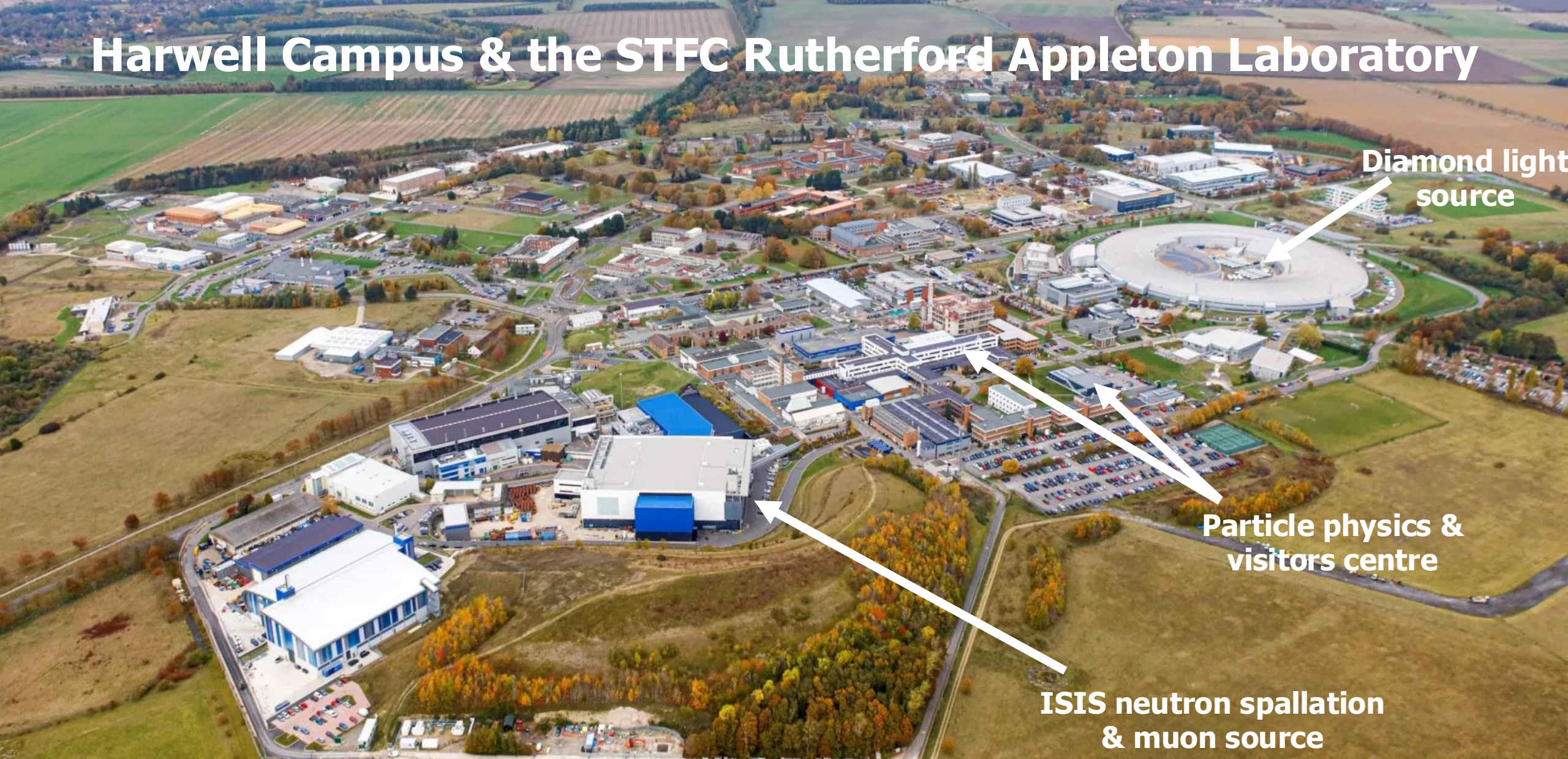
<https://www.ppd.stfc.ac.uk/Pages/Particle-Physics-Masterclass.aspx>

September 6<sup>th</sup> 2024

IOP



# Harwell Campus & the STFC Rutherford Appleton Laboratory



Diamond light source

Particle physics & visitors centre

ISIS neutron spallation & muon source

**RAL PPD is: ATLAS, CMS, LHCb, HK, T2K, DUNE, LUX/LZ, MIGDAL, UK's WLCG T1 Computing centre**



# RAL MASTERCLASS

- Annual event over 4 days (Tues-Fri)
  - Targeting mainly A' level standard
- 1 day online, 3 days in person
- Around 1000 people for online masterclass
- 180 students per day for each of the 3 in person days
  - 180 student limit dictated by auditorium capacity
- RAL masterclasses are always oversubscribed for the in person days!



# ONLINE MASTERCLASS

- During COVID we held the masterclass online
  - Due to the success we decided to continue providing an online masterclass
- 1 day during Masterclass week
  - Open to everyone!
- Just under 1 000 students connect
- Find that students connect from all around the world
- For the workshop we use a computer farm at RAL to spin up hundreds of containers. We issue hundreds of usernames and passwords to schools before the online day.
- For students who join independently, we advise that they use mybinder or Google Colab to participate in the workshop

STFC Rutherford Appleton Laboratory  
Online Particle Physics Masterclass 2024

Programme: FINAL

Tuesday 12 March 2024  
This event will take place via Zoom

Joining link:

<https://ukri.zoom.us/j/99449034715?pwd=OTEvNGRNMkRrYzJbGF0QWhuR0dRQT09>

Meeting ID: 994 4903 4715

Passcode: 615221

09:15 - 09:30	Arrive and Welcome
09:30 - 10:15	Talk: An Introduction to the Standard Model, Emmanuel Olaiya (Particle Physics Department)
10:15 - 11:45	Virtual Tour <ul style="list-style-type: none"><li>• The tour will consist of a short introduction followed by a virtual tour of one of our particle accelerators</li></ul>
11:45 - 12:45	Lunch
12:45 - 13:15	Talk: An introduction to the Large Hadron Collider Alison Elliot (Particle Physics Department)
13:15 - 14:45	LHC Data Workshop <ul style="list-style-type: none"><li>• The computer workshop will consist of a short introduction followed by an interactive session, with support for schools and students from the Particle Physics Department in breakout rooms, led by Sam Harper (Particle Physics Department)</li><li>• Link to join: <a href="https://ukri.zoom.us/j/97718332312">https://ukri.zoom.us/j/97718332312</a></li><li>• Meeting ID: 977 1833 2312</li></ul>
14:45 - 15:00	Quiz, Questions and Wrap-up
15:00	END



# IN PERSON DAYS

- We run 3 in person days, each day with 180 students
  - These days are oversubscribed and we could fill 9 in person days with the demand.
- We make a big effort to select schools from a range of backgrounds
- We provide food for the day for the students
- Schools have to arrange their own transport to and from RAL
- We have schools from as far as Newcastle attend

STFC Rutherford Appleton Laboratory  
Particle Physics Masterclasses 2024

## Programme

Wednesday 13, Thursday 14 March 2024

09:30 - 10:00	Arrive, refreshments – R22 coffee lounge
10:00 - 10:05	Welcome, Lecture Theatre
10:05 - 10:20	Talk: A Very Brief Guide to Accelerators
10:20 - 10:55	Talk: Fundamentals of Particle Physics
11.05 - 11.25	Introduction to tour or computer workshop
11:25 - 12:20	Workshops and tours
12:20 - 13:10	Lunch - R112 Visitor Centre
13:10 - 13:55	Talk: The Large Hadron Collider
14.05 - 14.25	Introduction to tour or computer workshop
14:25 - 15:20	Workshops and tours (swapped groups)
15.25 - 15.35	Refreshments – R22 coffee lounge
15.35 - 15.55	Talk: Big Data and the LHC
16:00 - 16.30	Q&A, /quiz /panel discussion
16.30	END

If you have any queries please look at the website:  
<https://www.ppd.stfc.ac.uk/Pages/Particle-Physics-Masterclass.aspx>  
or contact the Schools Team  
on [visitral@stfc.ac.uk](mailto:visitral@stfc.ac.uk)



# LECTURES

- Four lectures
  - A Very Brief Guide to Accelerators
  - Fundamentals of Particle Physics
  - An Introduction to the Large Hadron Collider
  - Big Data and the LHC

• Lectures available on YouTube

• See

<https://www.ppd.stfc.ac.uk/Pages/Particle-Physics-Masterclass.aspx> for slides and videos







# TOURS

- We are fortunate at RAL to be able to take the students on tours of the Diamond and ISIS experiments, where students learn more about accelerators and how scientists probe matter
- ISIS: Neutron and Muon beam production used to probe matter
- Diamond: UK's national synchrotron science facility
- We receive great feedback about the tours!



# WORKSHOPS

- In our workshops students analyse real data (using LHC opendata) to find the Higgs boson
- The students use python and practice the physics they learned during the day
- Use jupyter notebooks, downloaded and run on computer sticks with linux OS
  - Jupyter notebooks are executable coding environments with a web browser interface
    - <https://github.com/olaiya/zbo> son-exercise



# WORKSHOPS

The screenshot shows a GitHub repository page for 'olaiya/zboson-exercise'. The repository contains several files: DoubleMuRun2011A.csv, Exercise.ipynb, README.md, requirements.txt, and reset.sh. The README file is open, showing the title 'Particle physics data-analysis with CMS open data'. The README text includes instructions for users, a section for opening the exercise with Binder (with a red arrow pointing to the 'launch binder' button), a section for opening the exercise with Google Colab (with a red arrow pointing to the 'Open in Colab' button), and a section for downloading the material to be opened with Jupyter Notebook. The right side of the screenshot shows a Jupyter Notebook interface with a progress bar at 100.0%.

- Want to enable students to be able to continue learning beyond the masterclass at RAL

- All you need is a browser and internet

Click to run on mybinder

Click to run on Google Colab

myBinder and Colab are online containers that run jupyter notebooks



Exercise - Jupyter Notebook

https://notebooks.google.com/jupyter/user/olaiya-zboson-exercise-34hmkw/notebooks/Exercise.ipynb

Jupyter Exercise Last Checkpoint: 4 minutes ago (autosaved)

Python 3 (pykernel)

Memory: 323.6 MB / 4 GB

### Looking at the muon pair invariant mass spectrum

Below is the histogram published by the CMS experiment of the invariant mass of muon pairs. Does it look like yours??

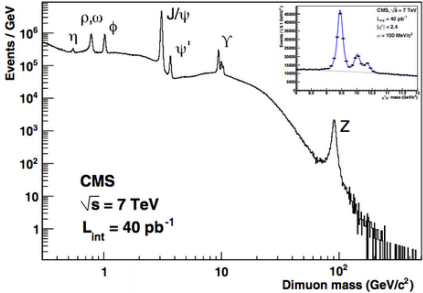


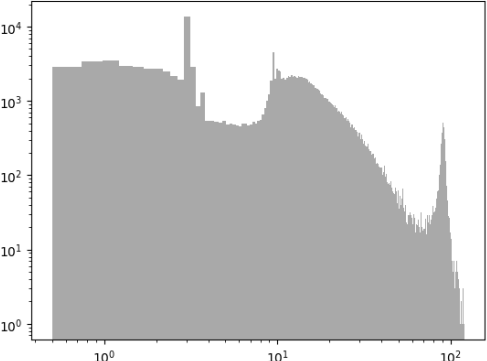
Image 8: The histogram of the invariant masses published by the CMS experiment. © CMS Collaboration [5]

Not quite.... That's because the CMS plot uses log scales on the axes to make the plot clearer.

We can change our plot to log axes using `plt.yscale('log')` and `plt.xscale('log')`

Try that in the cell below

```
In [8]: #You need to add you plt.hist line here
# set log scales on x and y axes
plt.hist(invariant_mass_1, no_bins, range=(0.5,120.), color="darkgrey")
plt.yscale('log')
plt.xscale('log')
plt.show()
```



Answer

Now it should look more similar.

The plot shows a smooth 'background' of random coincidences and on top of that some 'peaks'

Each of these peaks is evidence for a particle decaying to muon pairs. The peaks corresponding to known particles and have been given labels in the CMS plot.

You can use the Particle Data Group [website](https://pdg.lbl.gov/) if you want to know more about these particles. If we saw a peak at a point where no known particle was expected, this would be evidence of a new particle discovery.

# USING MYBINDER FOR THE COMPUTER EXERCISE

- Students can run the exercises at home needing only a browser and an internet
- You are not limited to what is in the notebook
  - You can create your own cells and perform your own analyses
- Issue: you lose your work after each session
- Solution: Use Google colab
  - With a gmail account you can save your work to google drive so your work persists from session to session

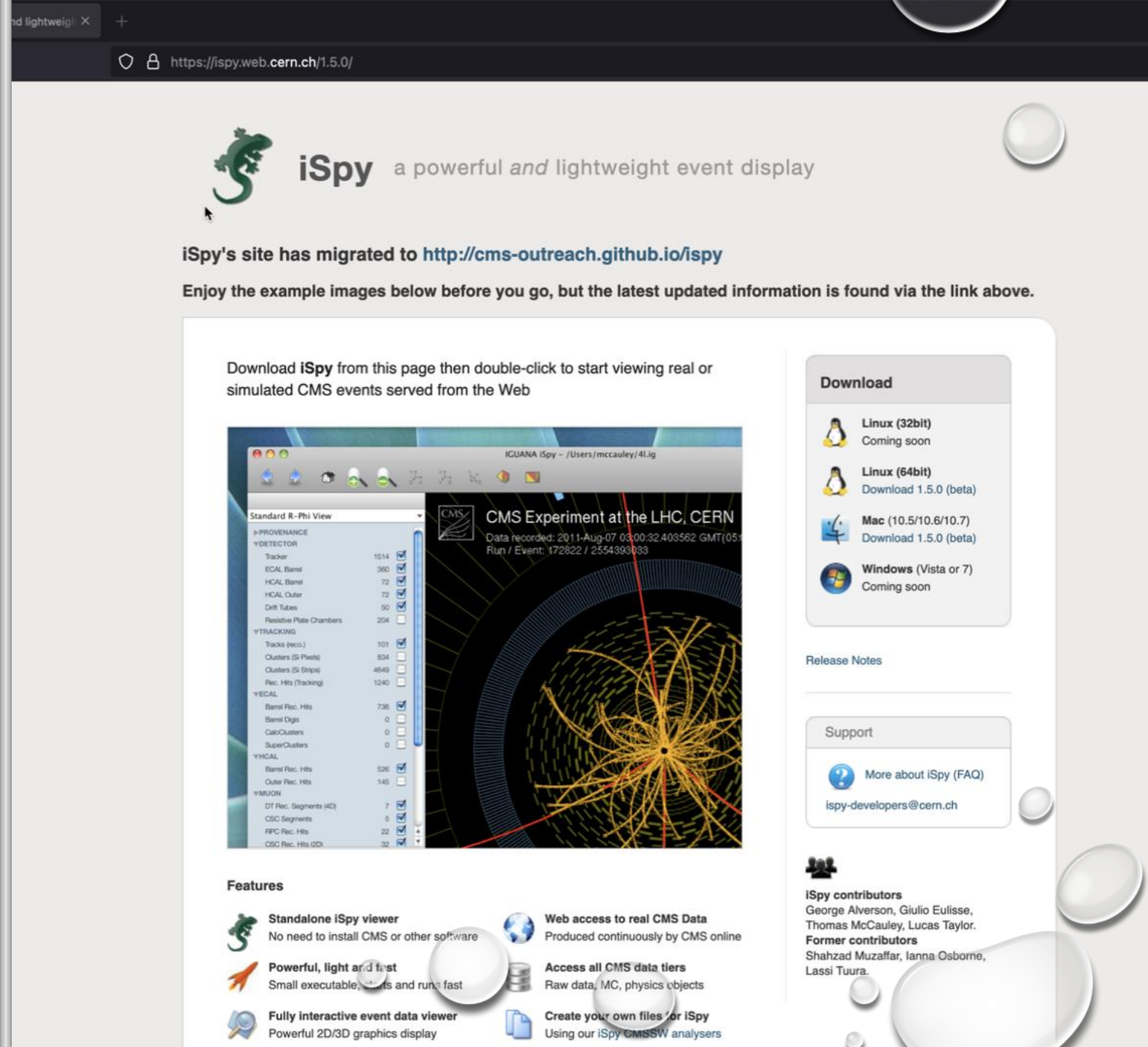
# WORKSHOPS

- The notebooks are a great way for students learn about coding, the Standard Model and physics analysis
- For those who are not new to python and the Standard Model the notebooks are fantastic
- However, feedback indicates that for the students who have just been introduced the python and the Standard Model find the notebooks too much to grasp within an hour!
- Students who have some previous exposure to python and the Standard Model seem to really like the notebooks
- Can we use something more straightforward for the workshops and have the notebooks as an at home/school longer project?




# HARWELL OPEN WEEK WORKSHOPS

- During the last week of June the Harwell site which includes RAL was open to schools and the public
- For schools we had a masterclass like event
  - 400 students over 2 days
- We were able to test out another idea for the workshops.
- We used CMS's iSpy Web



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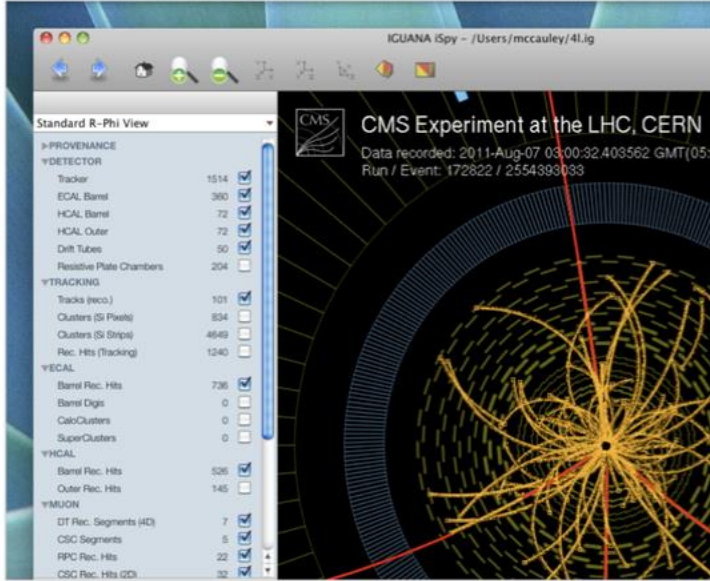
https://ispy.web.cern.ch/1.5.0/

 **iSpy** a powerful *and* lightweight event display





iSpy's site has migrated to <http://cms-outreach.github.io/ispy>

Enjoy the example images below before you go, but the latest updated information is found via the link above.

Download **iSpy** from this page then double-click to start viewing real or simulated CMS events served from the Web





**Download**

-  **Linux (32bit)**  
Coming soon
-  **Linux (64bit)**  
Download 1.5.0 (beta)
-  **Mac (10.5/10.6/10.7)**  
Download 1.5.0 (beta)
-  **Windows (Vista or 7)**  
Coming soon







Release Notes

Support

-  More about iSpy (FAQ)
- [ispy-developers@cern.ch](mailto:ispy-developers@cern.ch)

 **iSpy contributors**  
George Alverson, Giulio Eulisse, Thomas McCauley, Lucas Taylor.  
**Former contributors**  
Shahzad Muzaffar, Ianna Osborne, Lassi Tuura.

**Features**

-  **Standalone iSpy viewer**  
No need to install CMS or other software
-  **Web access to real CMS Data**  
Produced continuously by CMS online
-  **Powerful, light and fast**  
Small executable, starts and runs fast
-  **Access all CMS data tiers**  
Raw data, MC, physics objects
-  **Fully interactive event data viewer**  
Powerful 2D/3D graphics display
-  **Create your own files for iSpy**  
Using our iSpy CMS SW analysers

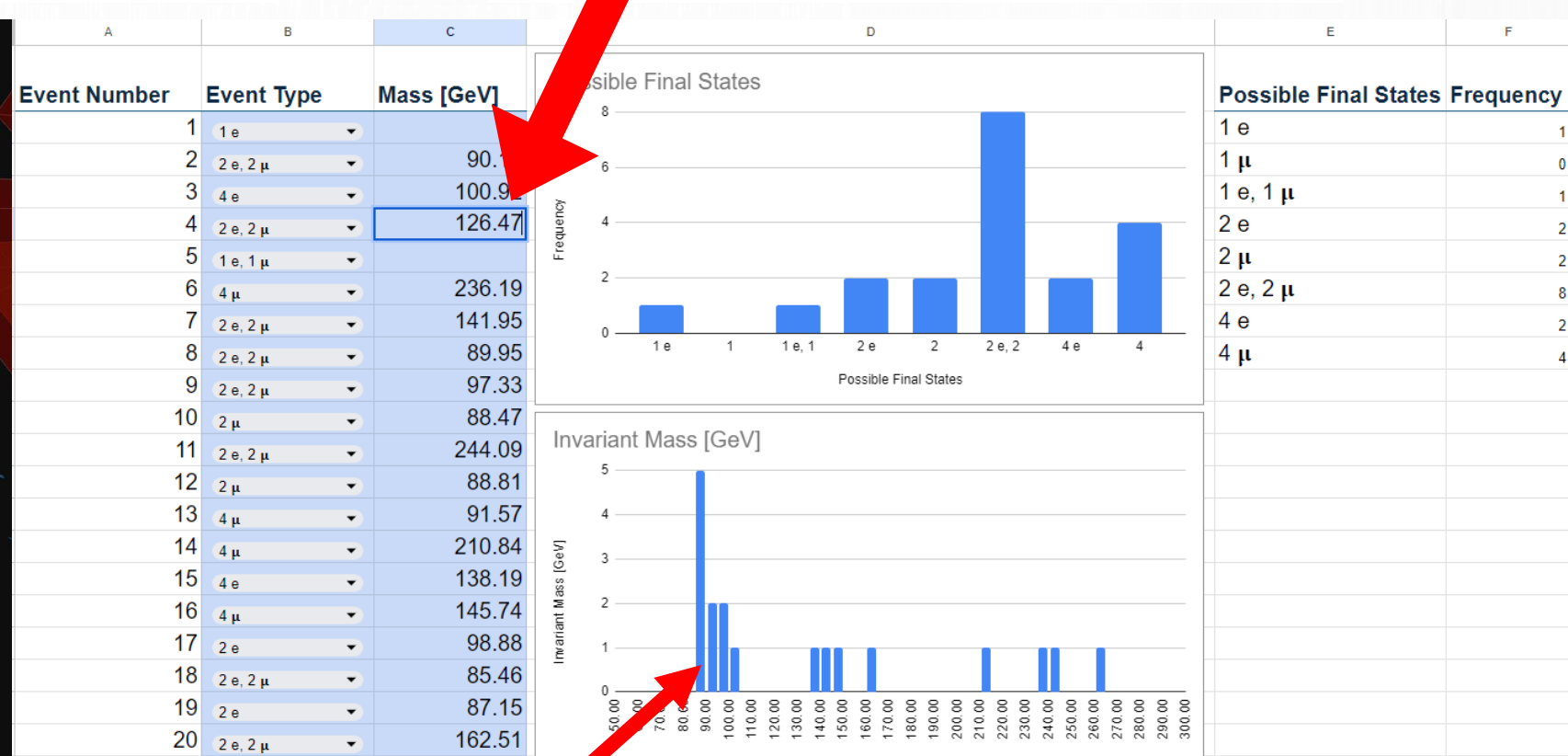
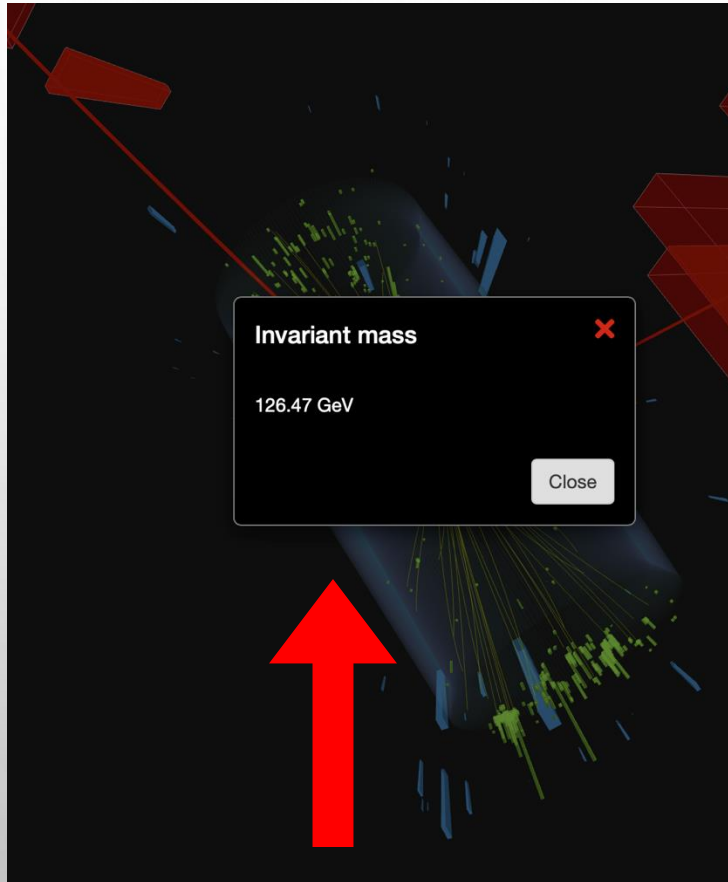




# FILL IN THE INVARIANT MASS

1. CLICK TO SELECT ALL PARTICLES and press "M"

2. ENTER INVARIANT MASS INTO SPREADSHEET



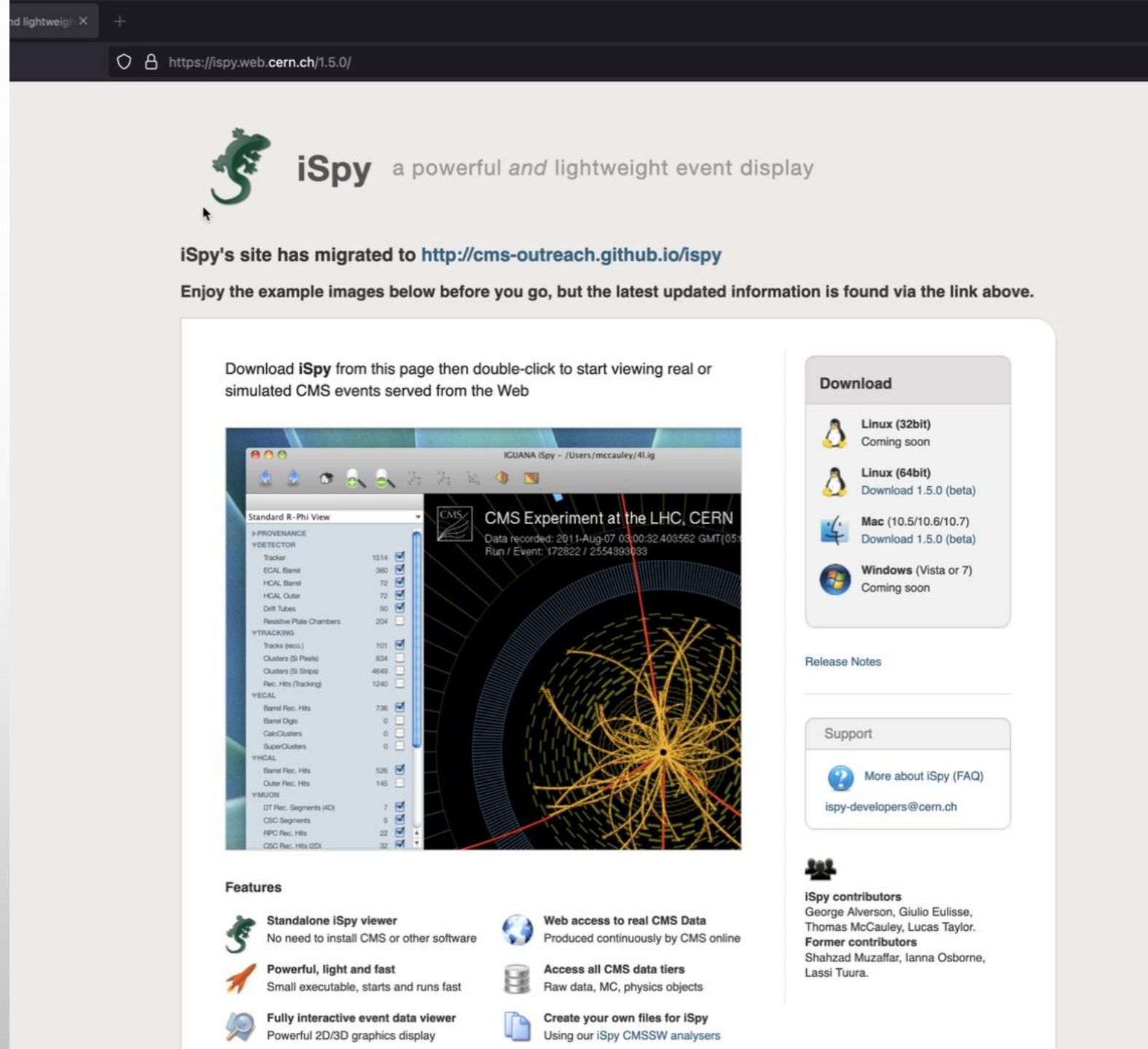
3. PLOTS POPULATE AUTOMATICALLY

Each student (pair) has a distinct dataset. They enter data into a Google Sheet to populate their histogram. There is also a Google sheet that is linked to all of the students sheets and shows a histogram for all their data. We show the students the effect of adding all their data at the end of the workshop

Independently students can make out the Z peak. When we add all their data you start to see hints of a Higgs peak


# FUTURE WORKSHOPS

- Based on the feedback from Harwell Open Week, very few students struggled with iSpy
- We will likely use it for our next masterclass in March 2025!



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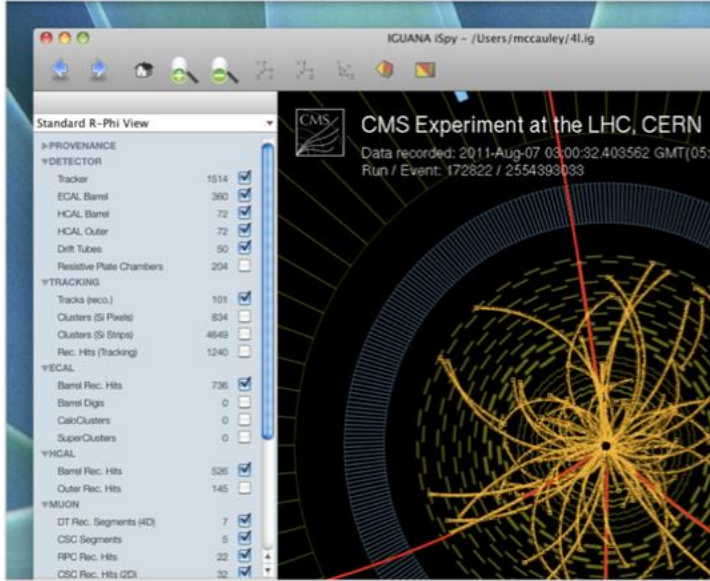
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# QUIZ

- Spend the last 30 minutes of the day getting feedback from the students and then finish with a particle physics quiz.
  - All on slido
  - The feedback really helps us tailor the masterclass
- Winner of the quiz get a prize
  - Typically something bought from the CERN shop



# IRIS

- Institute of Research In Schools (IRIS) is a charity that provides 11-18 years with the opportunity to participate in cutting-edge STEM research and collaborate with leading universities
- In collaboration with Oxford University (Alan Barr), we work with IRIS to provide school children the opportunity to analyse LHC data
  - Use ATLAS opendata
- Students analyse ATLAS data using jupyter notebooks
- RAL hosts the accounts for the students and provides the online computing for the students to use
- At the end of the project (typically spans a year) the students produce a poster on their findings and how they achieved them
- Over 300 students participated last year.
  - Roughly 50% were female!
    - We are still trying to understand how we achieved this number



# IRIS

- We now run a one day masterclass for a few schools that participate in the IRIS Big Data: ATLAS project a week or two after our main masterclass week
- Last year we won an award for the best project!
- This year during the run up to Harwell Open Week we had weekly meetings with a school participating in the IRIS project. We helped them with any questions regarding their work and any general physics questions



# CONCLUSION

- The RAL particle physics masterclass is a popular annual event that is oversubscribed
  - Show we are doing something right
- Feedback from the masterclass is always positive
- Jupyter notebooks are a great way for students to learn about programming, analysis and particle physics
  - Would be nice to set up an infrastructure where school children can learn about the above like we do with the IRIS school children but requiring less teacher/university support
- There are lots of masterclasses in the UK. Can work together on a practical that the kids can use?