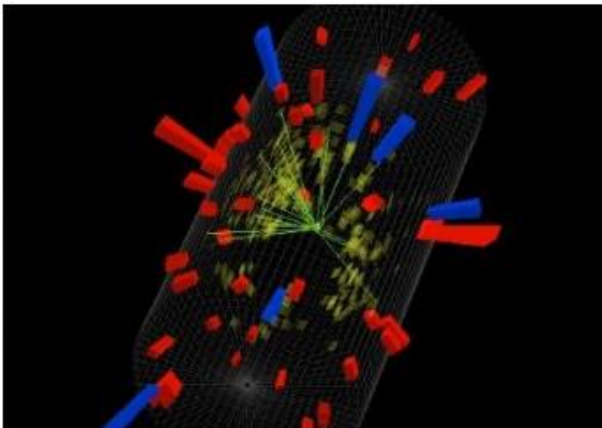
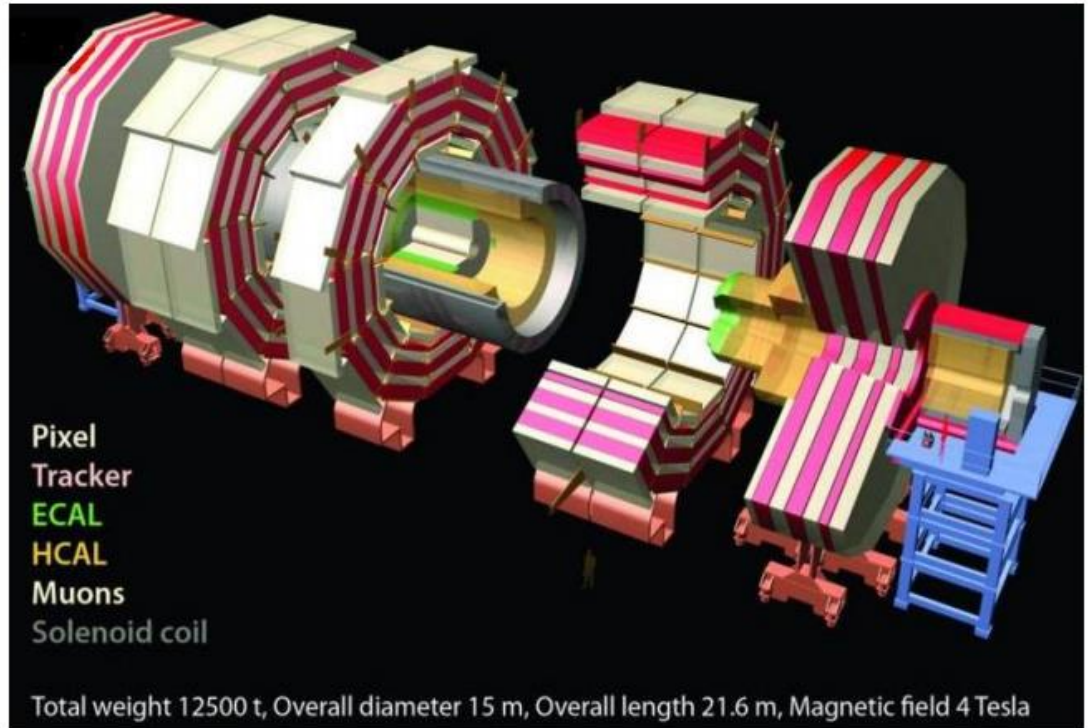




QuarkNet

BAM Masterclass

for LLFQNI 2021



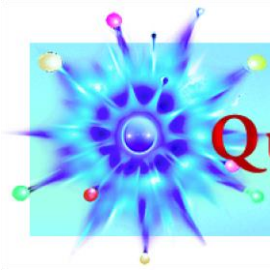
INTERNATIONAL
MASTERCLASSES
hands on particle physics



Fermilab



UNIVERSITY OF
NOTRE DAME

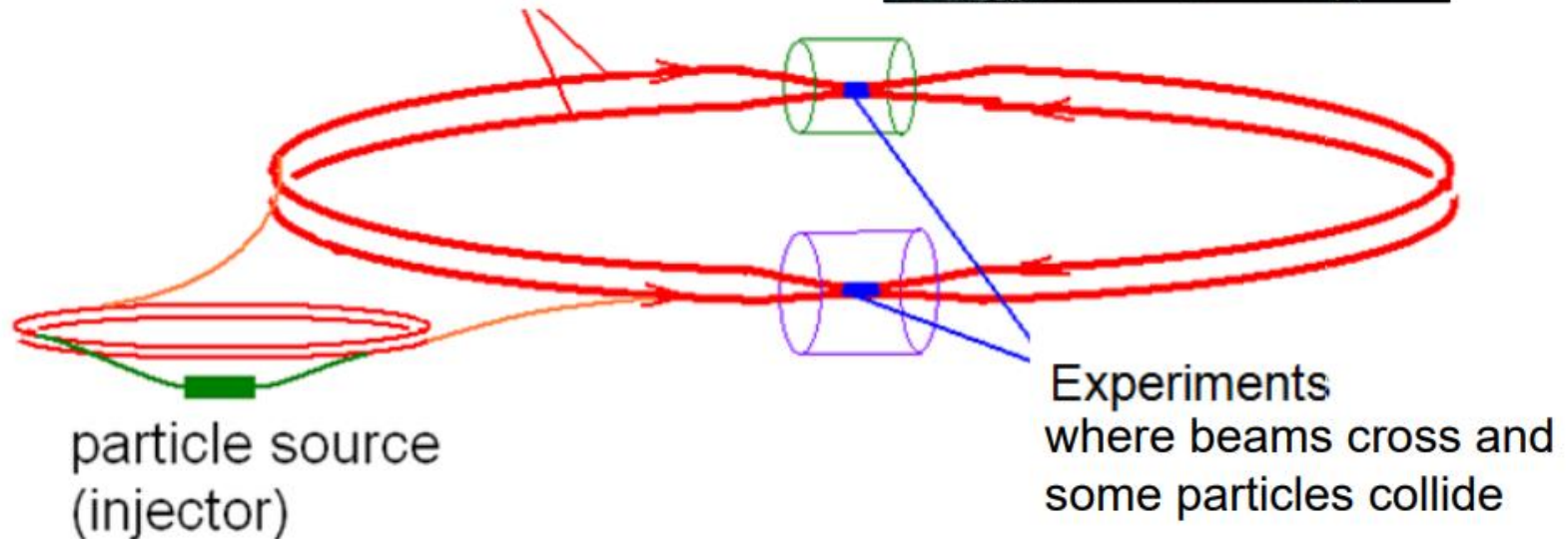


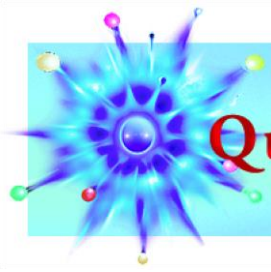
QuarkNet

The LHC and the new physics

The LHC is buried ~100 m below the surface near the Swiss-French border.

beams accelerated in large rings
(27 km circumference at CERN)



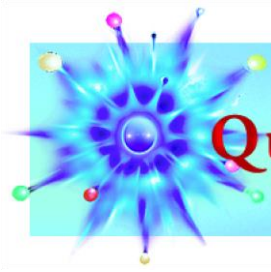


QuarkNet

The LHC and the new physics



Large Hadron Collider (LHC) at CERN – inside the tunnel.

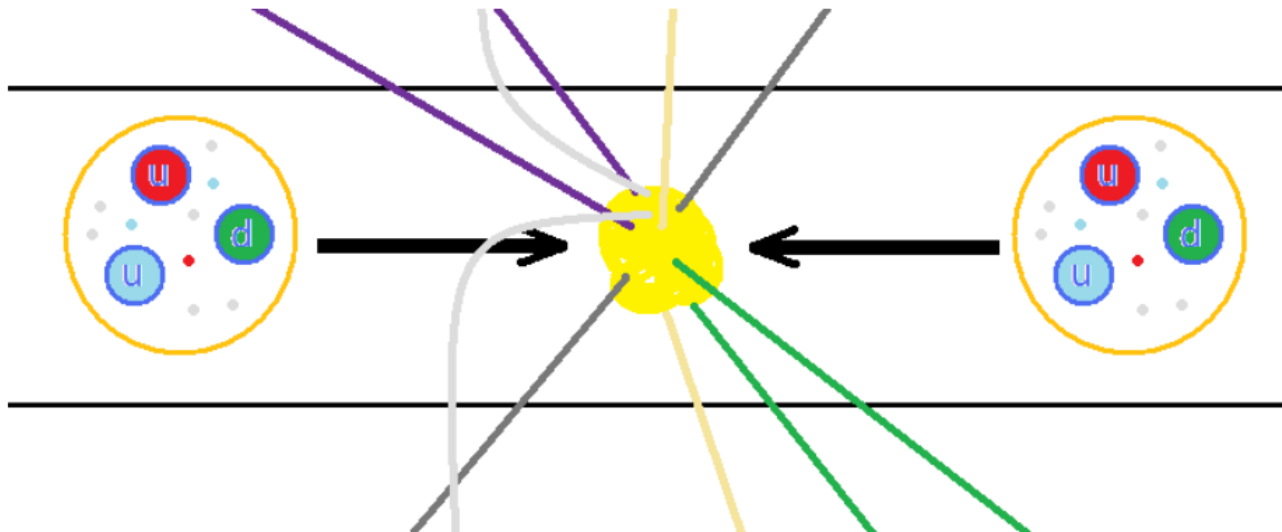


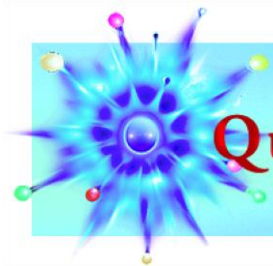
QuarkNet

Protons collide inside CMS

The LHC accelerates protons to as much as 6500 times the energy equivalent of their mass. The protons circulate in opposite directions and collide in the center of CMS.

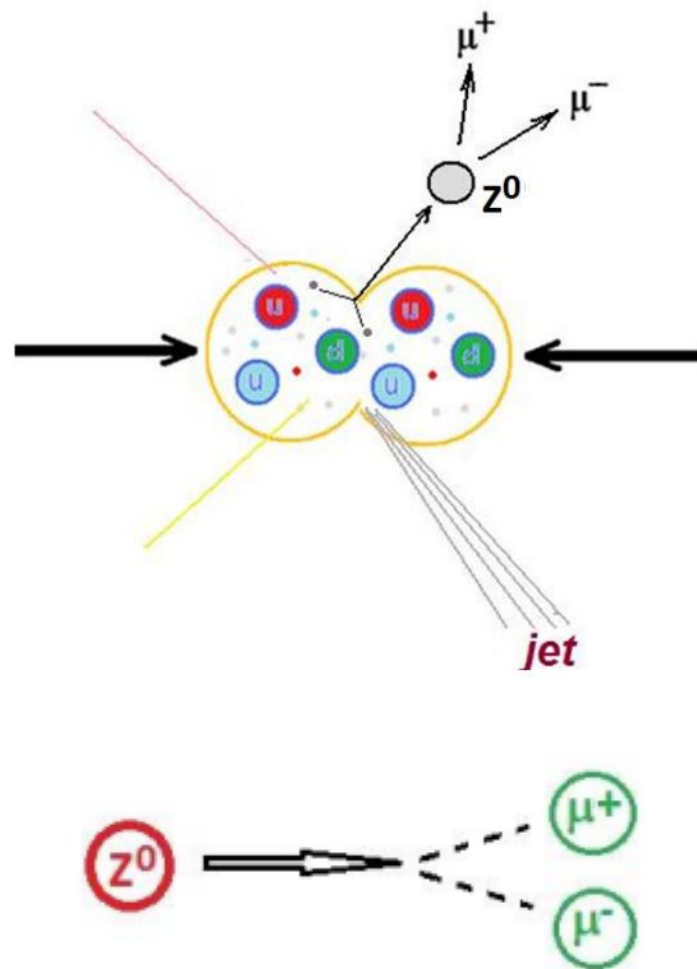
But protons are not just particles: they are more like bags of quarks and gluons. When they collide, *anything* can happen. And we are looking something specific.

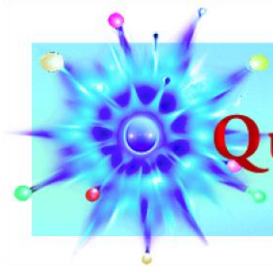




The Z boson is a neutral cousin of the W. It enables the “weak neutral current”.

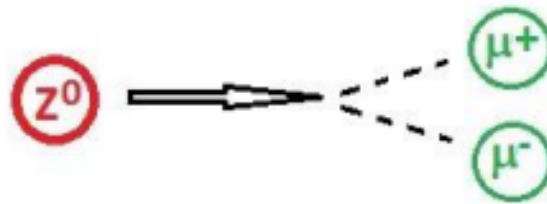
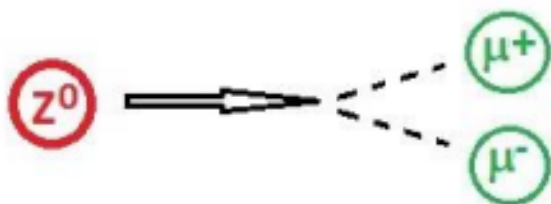
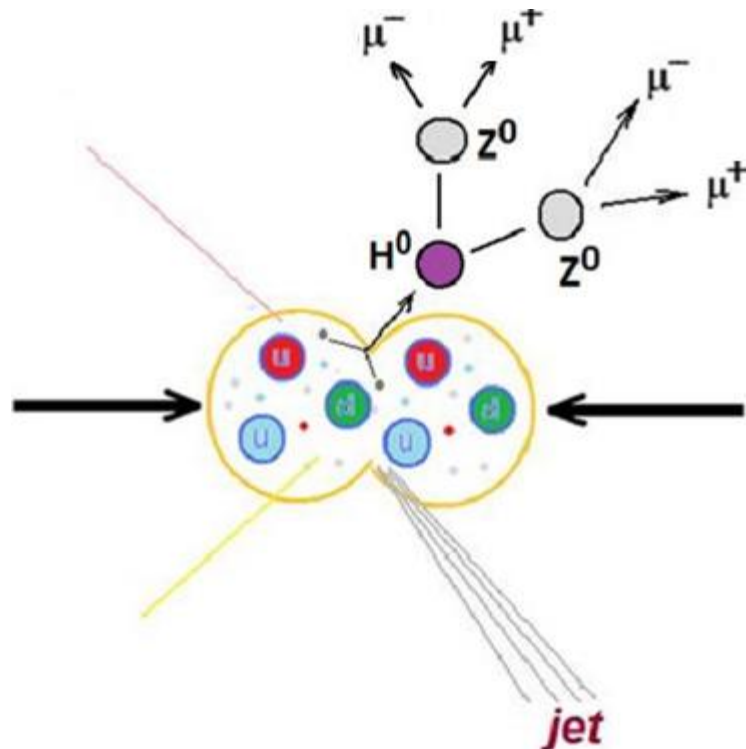
It decays into two leptons of the same type but opposite charge – electron and positron or muon and antimuon. We are only looking for muon-antimuon pairs. We will call these two-muon events.

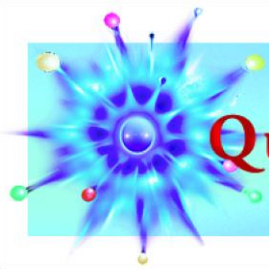




The Higgs boson is an expression of the field that gives other particles mass.

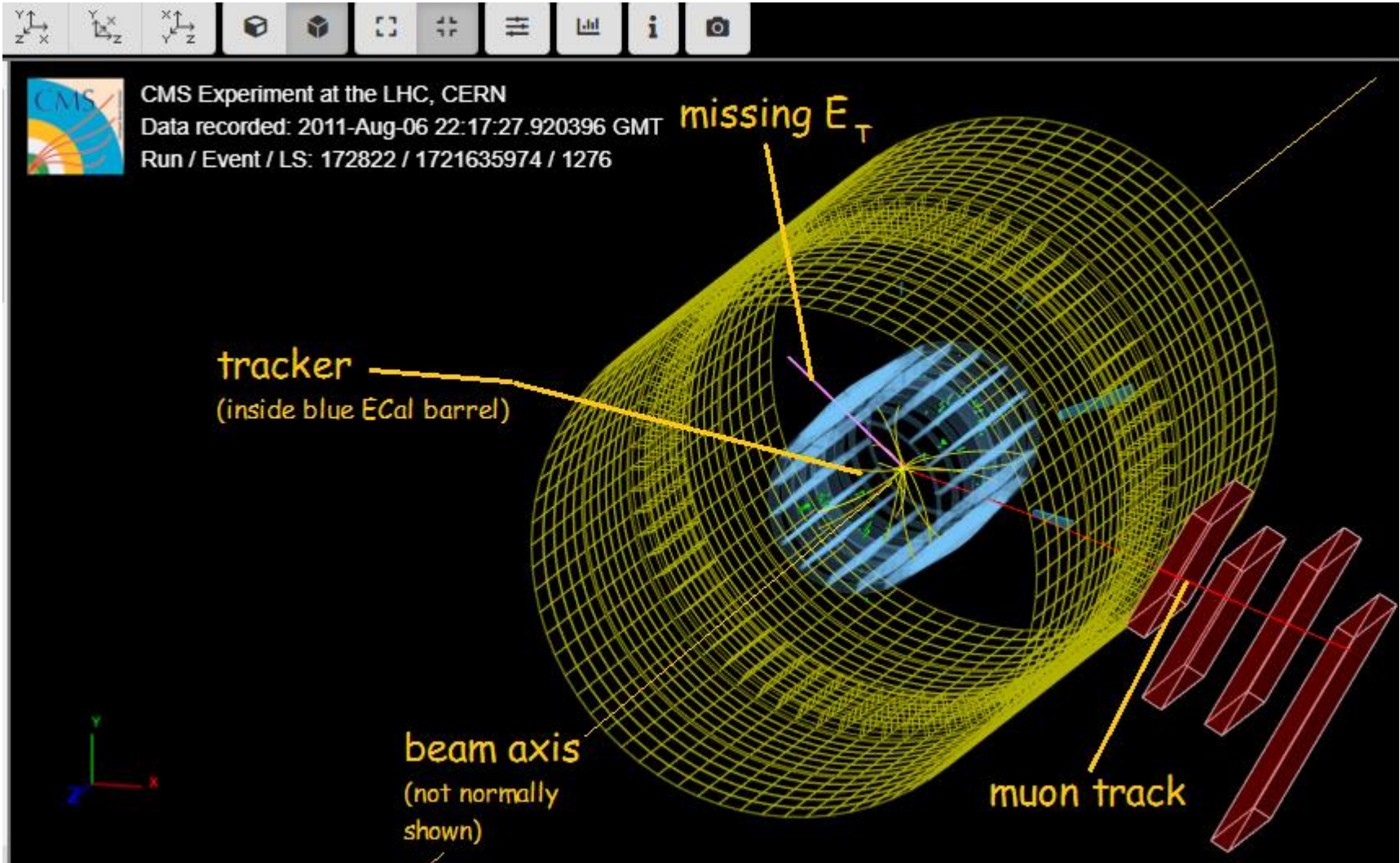
One decay mode of the Higgs is into two Z bosons, which themselves promptly decay. Thus we can get 2 muons and 2 electrons or 4 muons or 4 electrons. We will only seek 4 muon events.



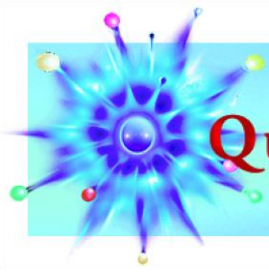


QuarkNet

iSpy event display for CMS



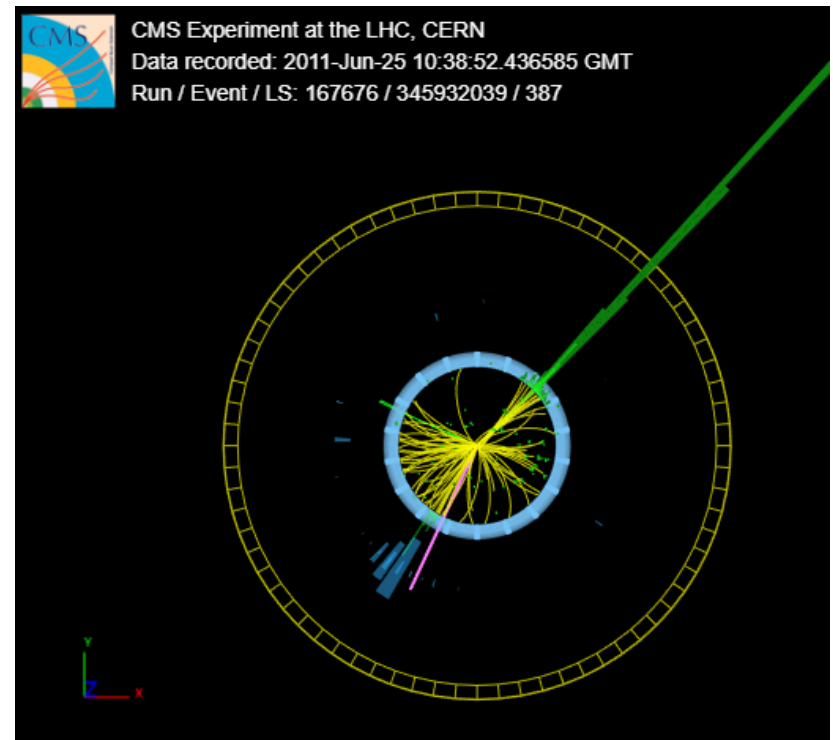
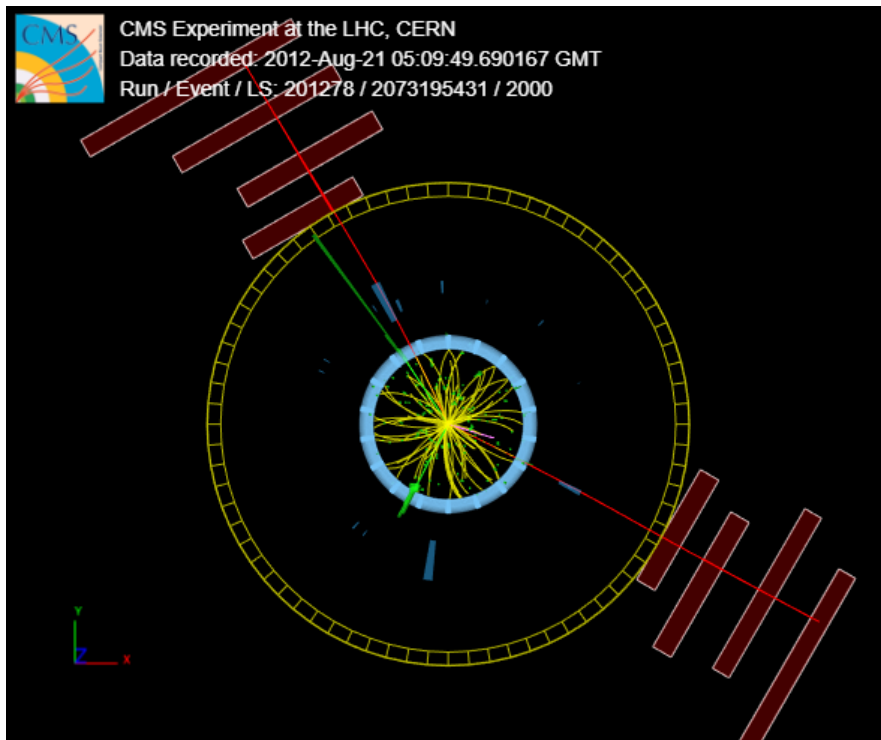
<https://www.i2u2.org/elab/cms/ispy-webgl/>

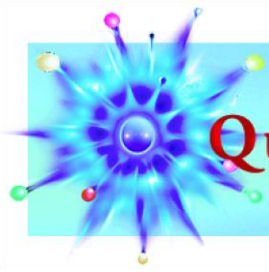


QuarkNet

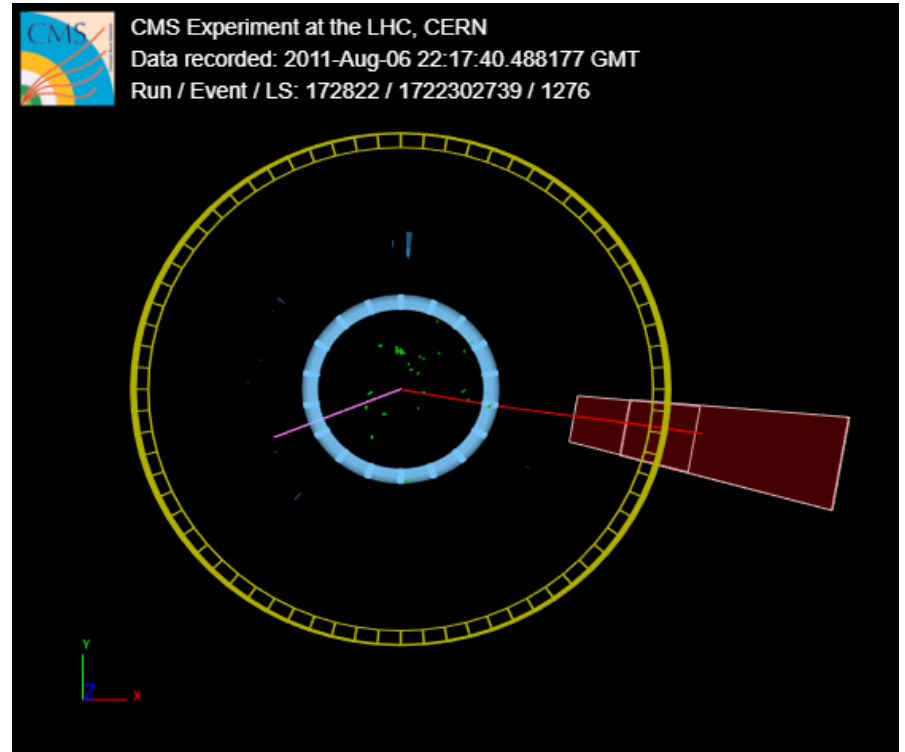
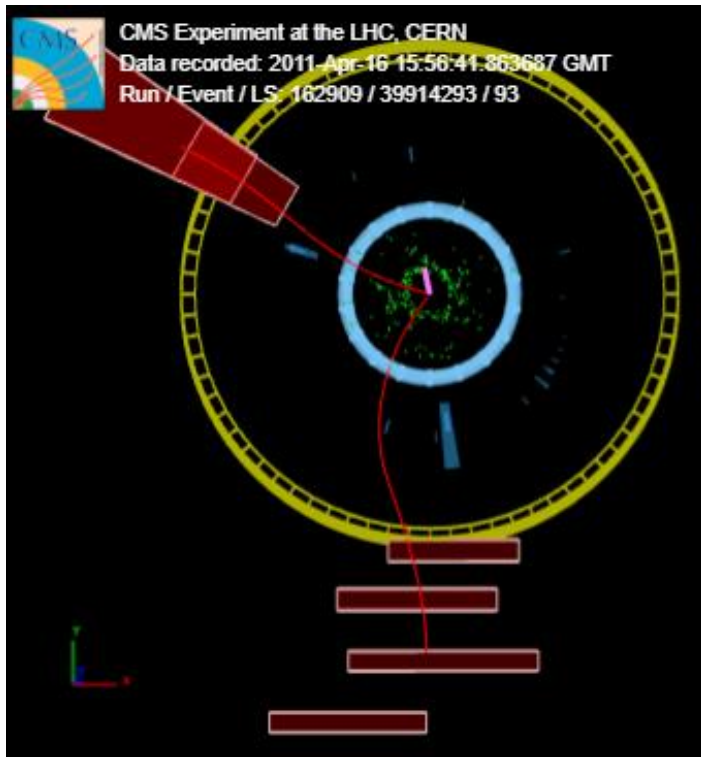
2 or 4 muons?

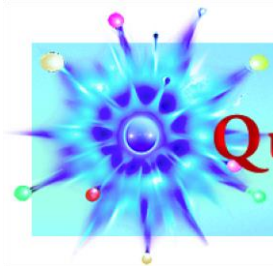
Which of these events has muons? Is it a 2- or a 4-muon event?





Which of these events has muons? Is it a 2- or a 4-muon event?

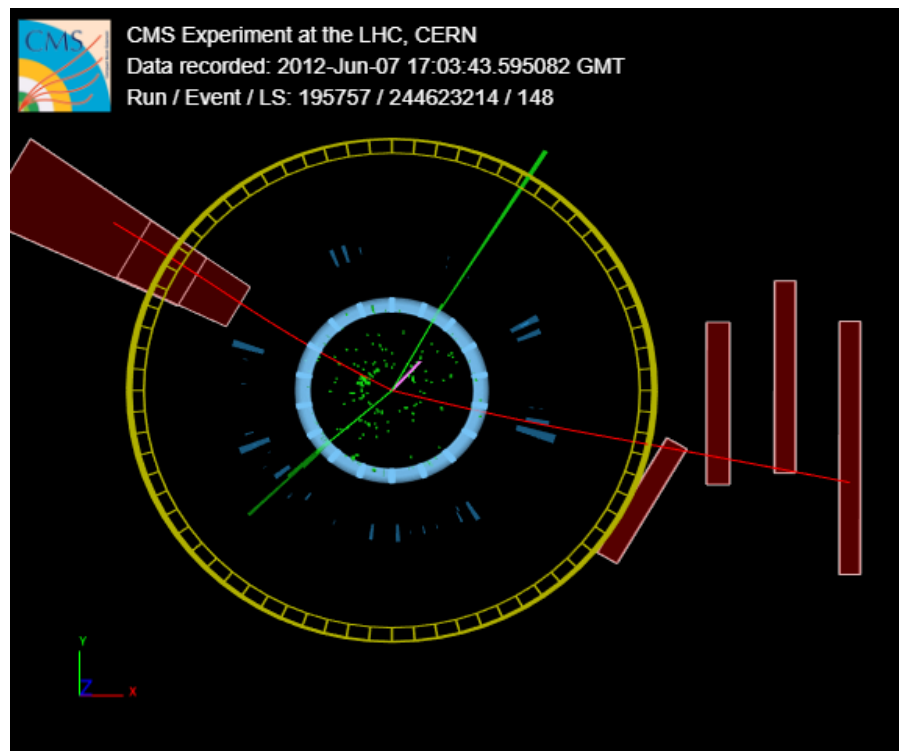
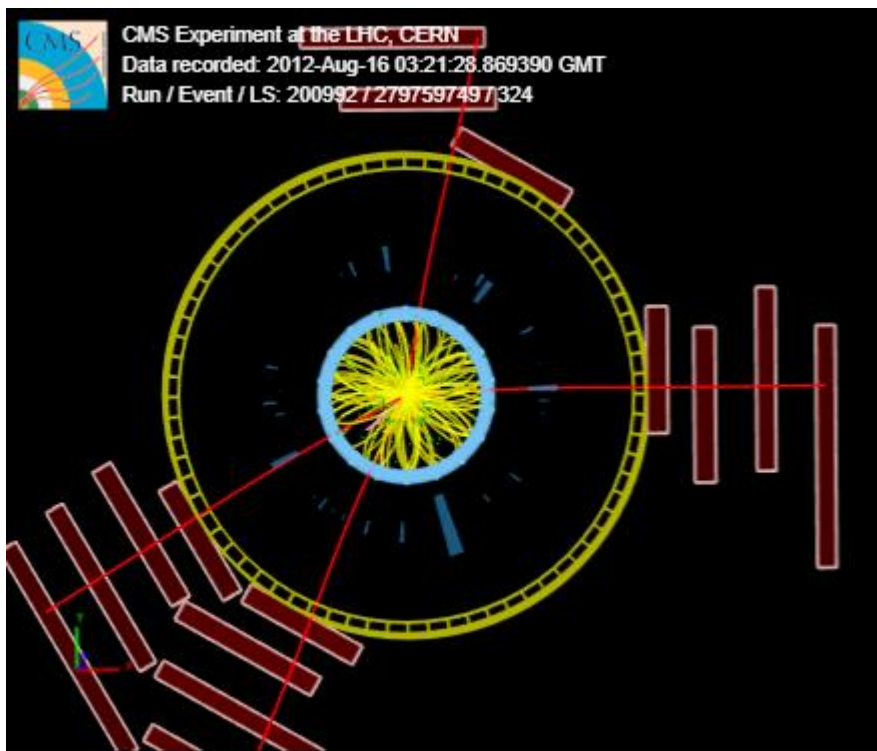


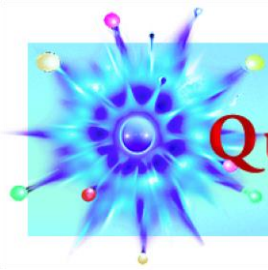


QuarkNet

2 or 4 muons?

Which of these events has muons? Is it a 2- or a 4-muon event?





Enter data on each event.

- If **1** muon, enter charge
- If **2** or **4** muons, enter mass

In the right box!

- Then choose Submit.
- Next event!

Results go to a Google sheet to show ratio and mass plots.

LLFQNI-BAM2021 Data Form

Please enter the mass from each viable 2-muon or 4-muon event

Q1. If the event is 2-muon, what is the calculated mass in GeV? Please give a pure number only with no text. (Example: 22.41)

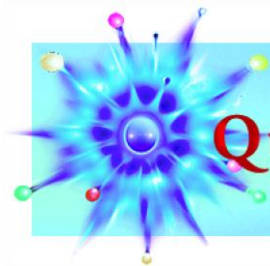
Your answer _____

Q2. If the event is 4-muon, what is the calculated mass in GeV? Please give a pure number only with no text. (Example: 79.22)

Your answer _____

Submit

<https://forms.gle/5uNzA8u2kYXvZ4y8A>



The neutral particles we hope to measure cannot be detected directly because they decay less than a nanometer from where they are created in the LHC.

CMS sees the decay products, which live longer and make it into the detector. Muons are the easiest to measure.

All else is treated as background.

