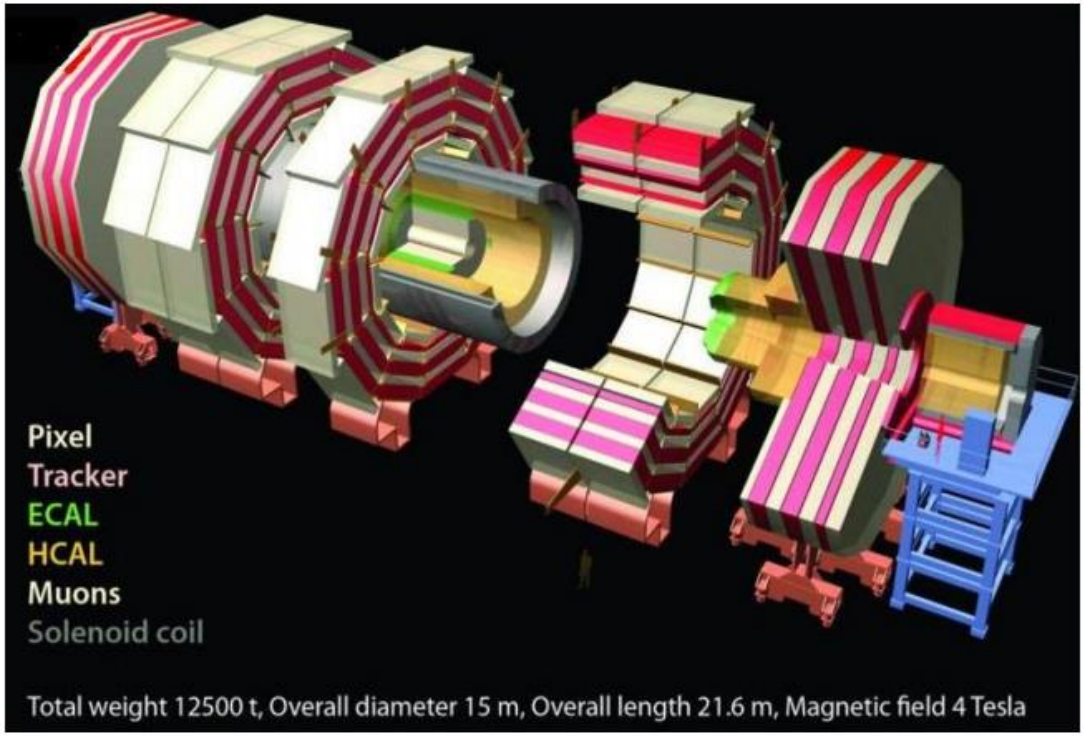
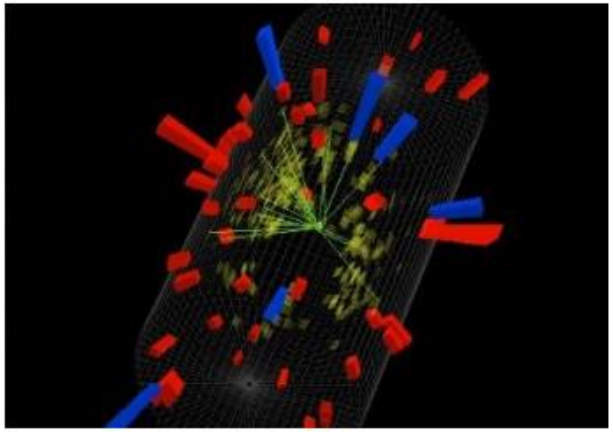
QuarkNet

BAMC Masterclass





INTERNATIONAL MASTERCLASSES

hands on particle physics

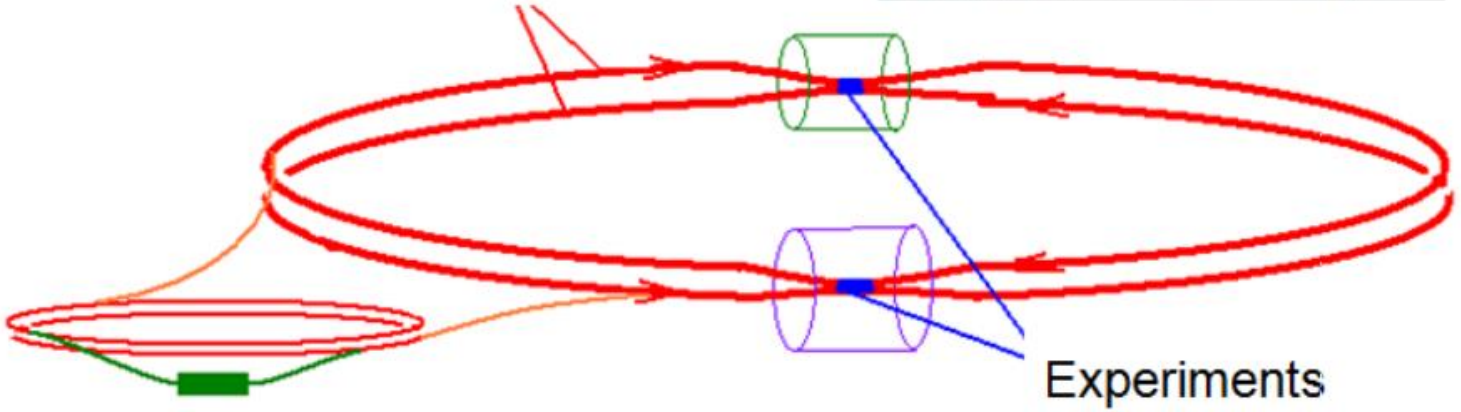
Fermilab

UNIVERSITY OF NOTRE DAME

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)



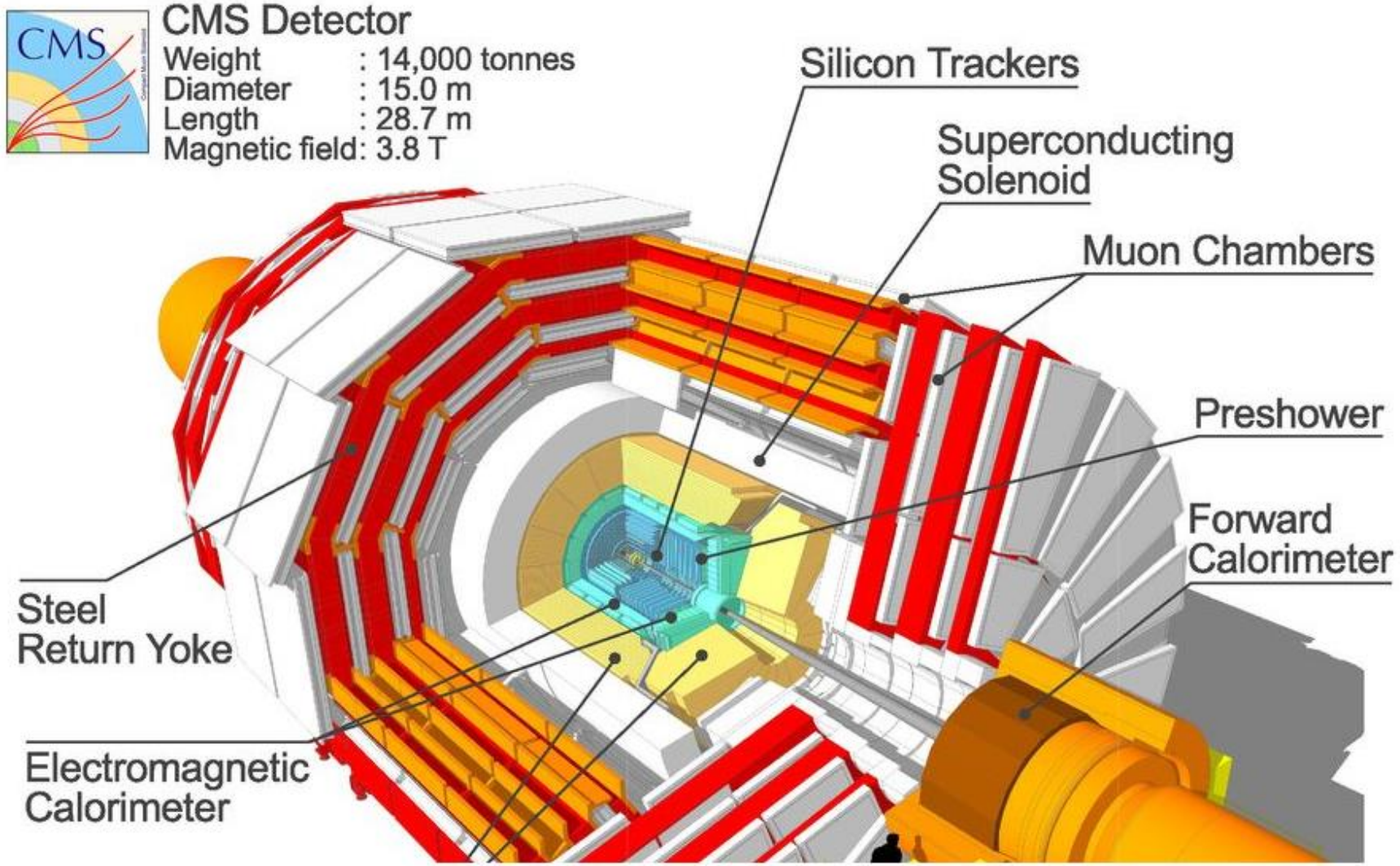
particle source
(injector)

Experiments
where beams cross and
some particles collide

The LHC and the new physics

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

The Compact Muon Solenoid (CMS)

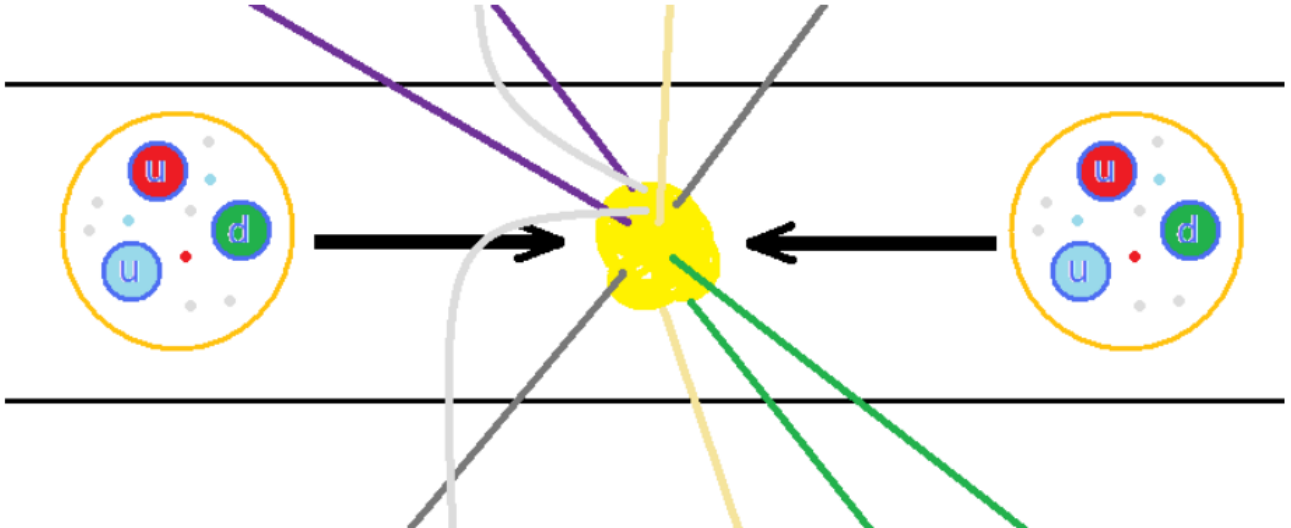


Let's take a closer look at the real thing.

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.

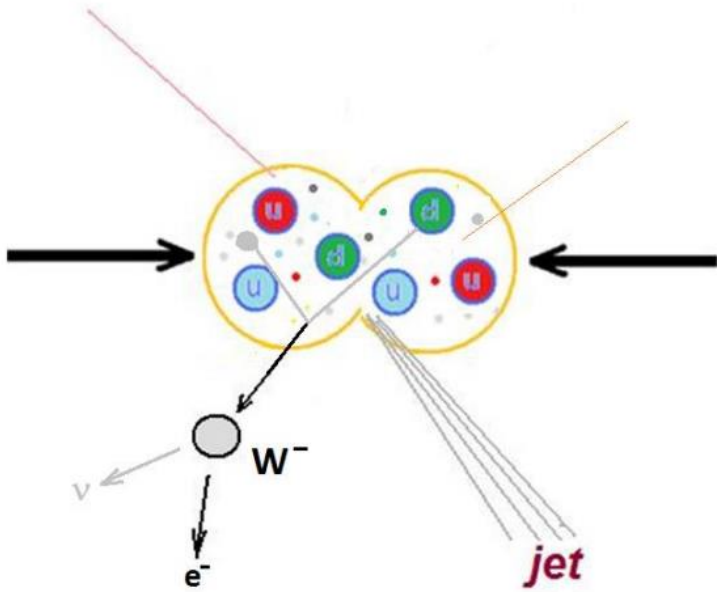
But protons are not just particles: they are more like bags of quarks and gluons. When they collide, *anything* can happen. And we are looking something specific.

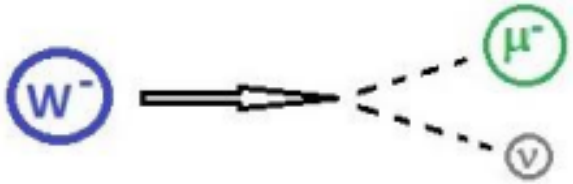


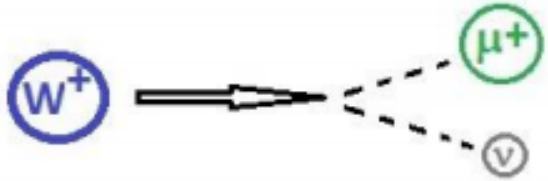
One-muon events

The + or – charged W boson enables radioactive decay by transforming neutrons into protons.

It decays into a neutrino and another lepton (electron or muon). Since CMS cannot detect the neutrino directly and we only look at muons, we can call this a one-muon event.



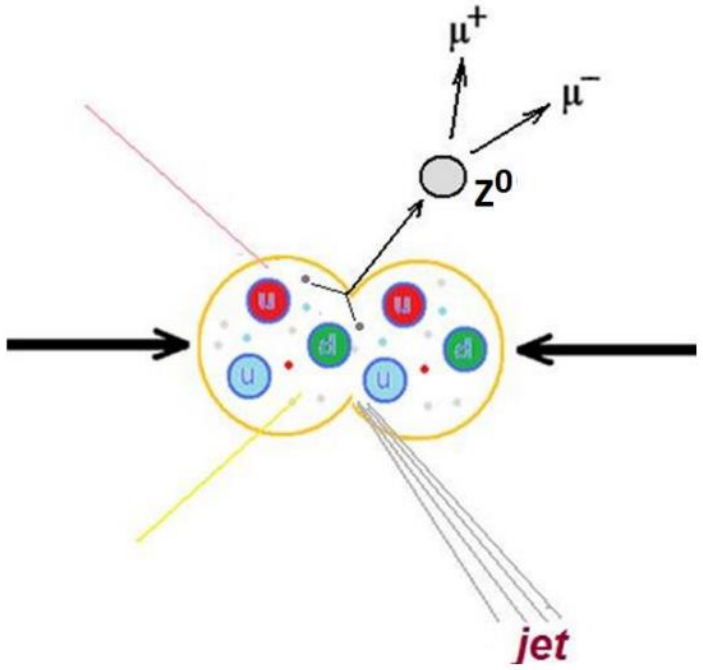


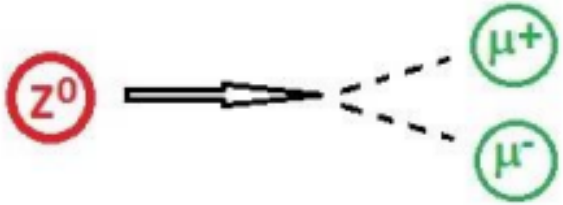


Two-muon events

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.

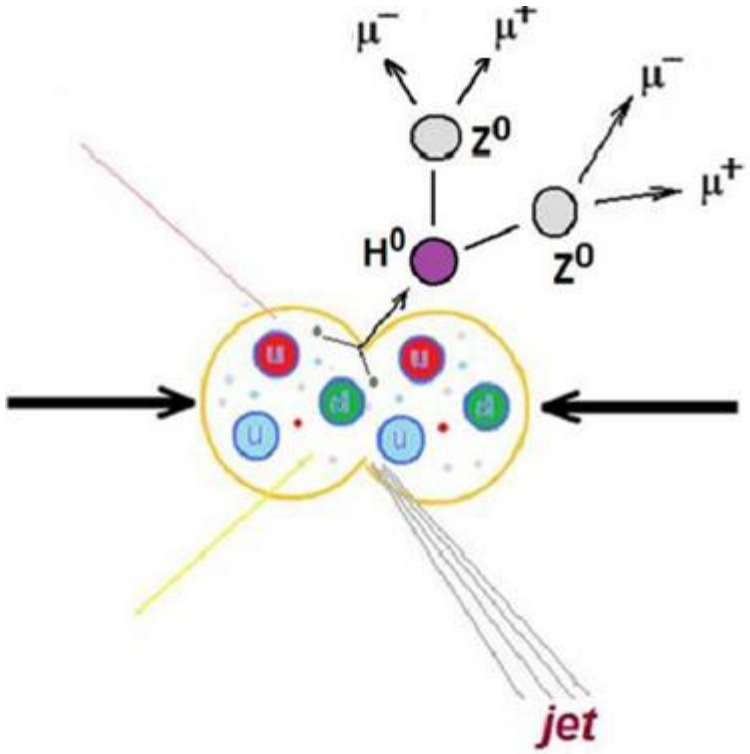


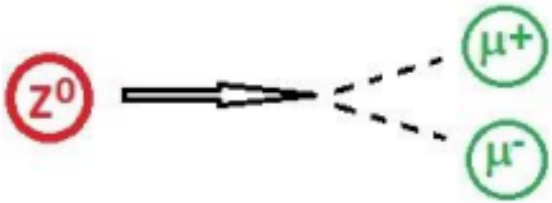


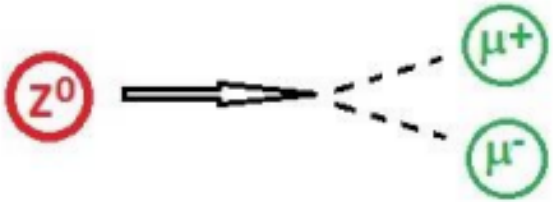
Four-muon events

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

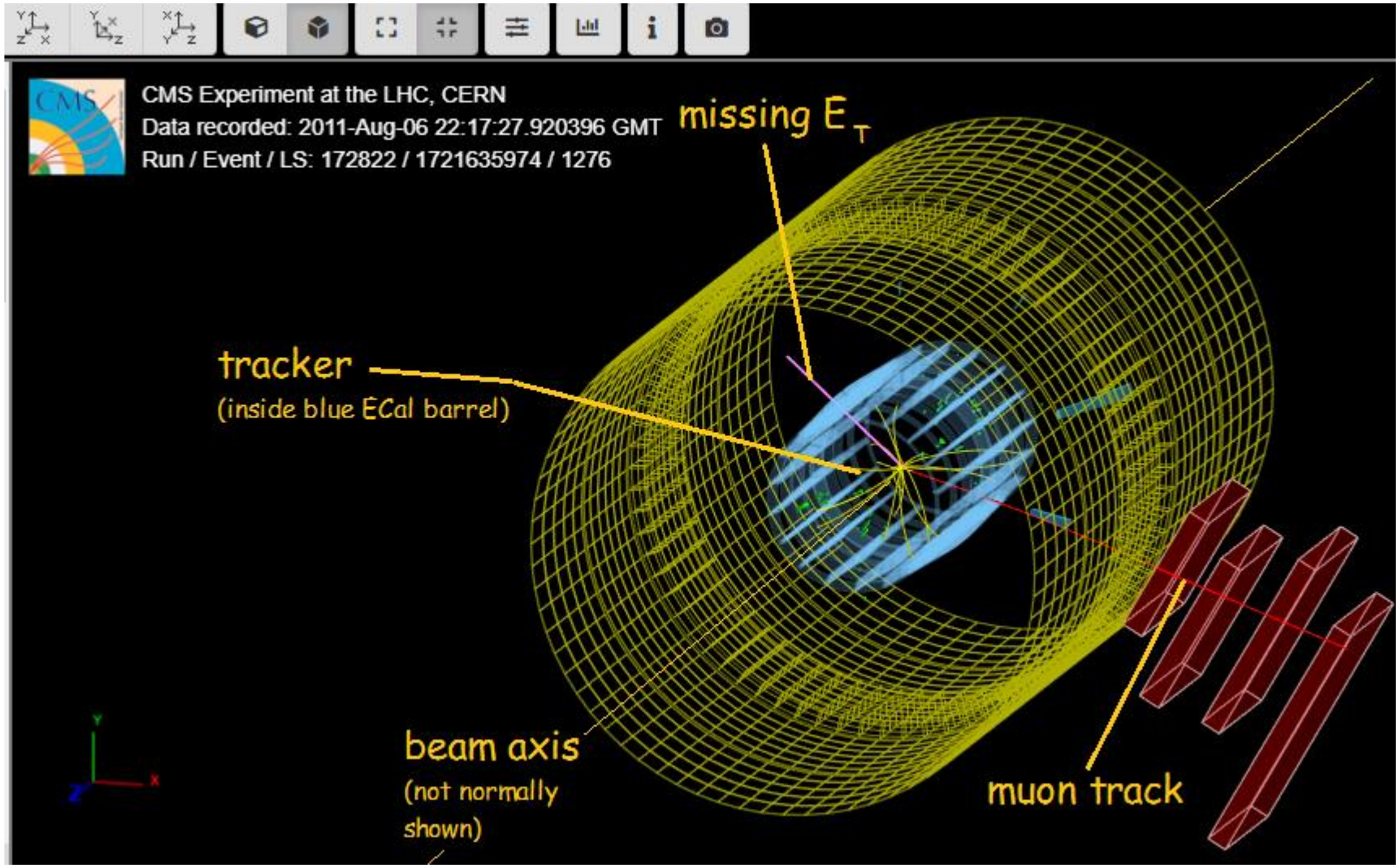
One decay mode of the Higgs is into two Z bosons, which themselves promptly decay. Thus we can get 2 muons and 2 electrons *or* 4 muons *or* 4 electrons. We will only seek 4 muon events.





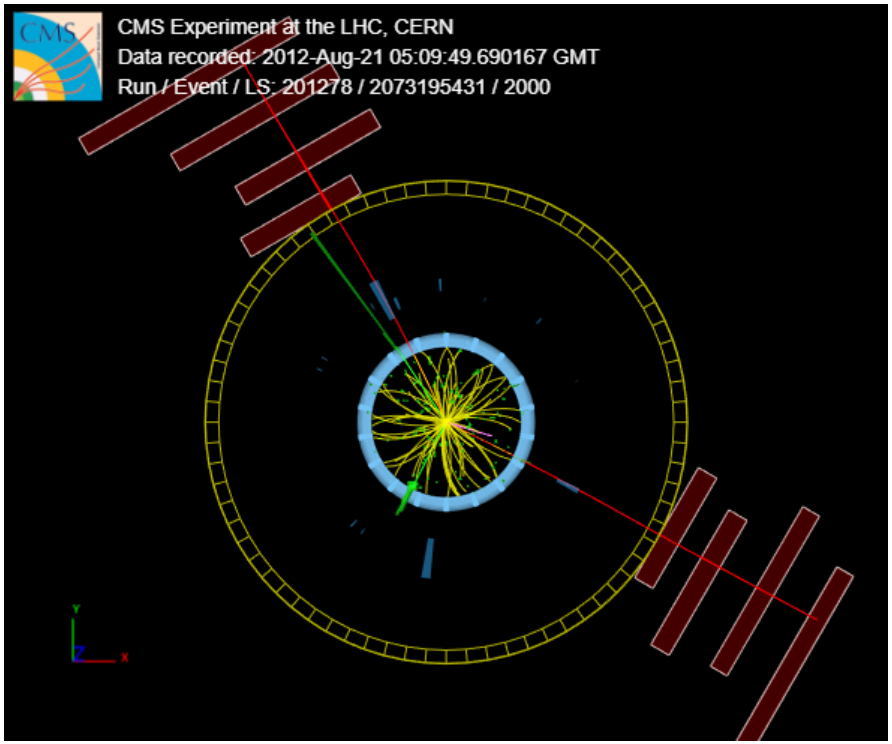


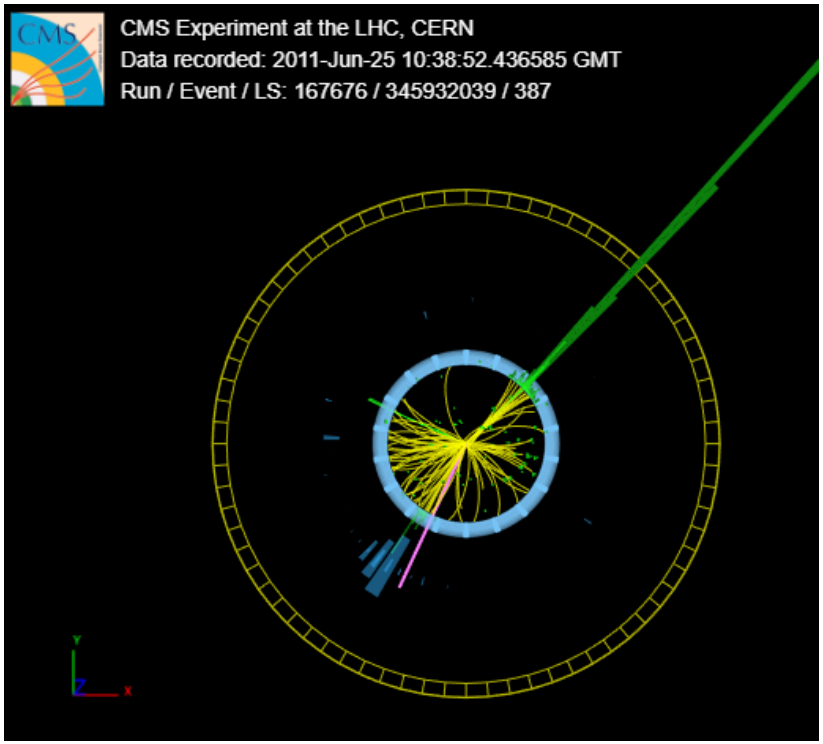
iSpy event display for CMS



1, 2, or 4 muons?

Which of these events has muons? Is it a 1-, 2-, or 4-muon event?





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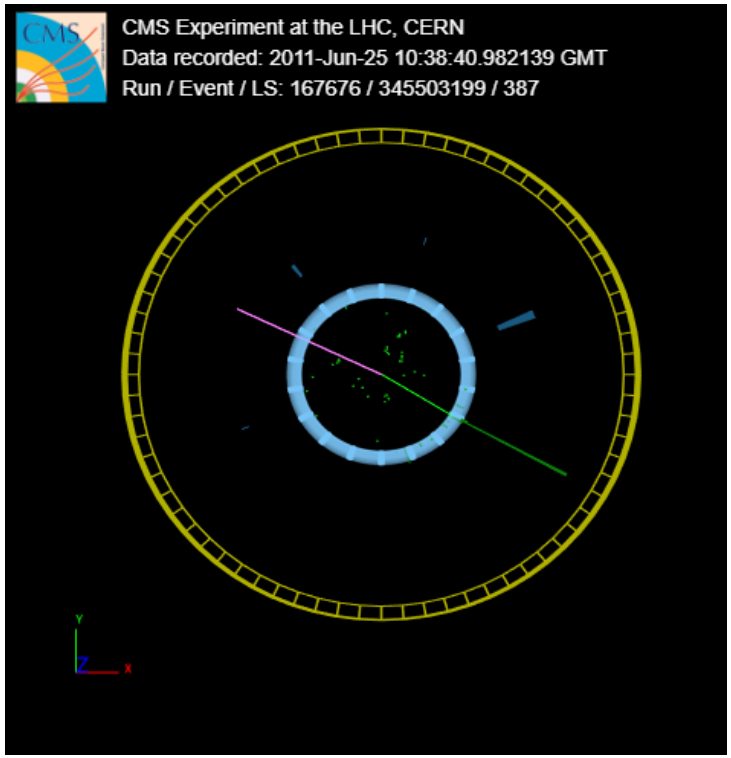

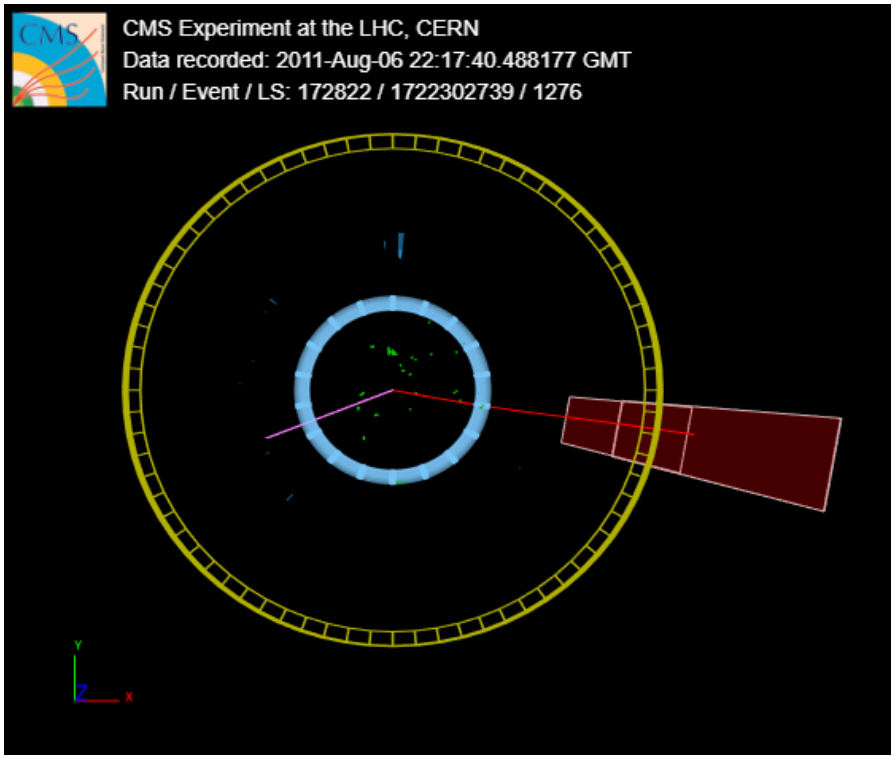

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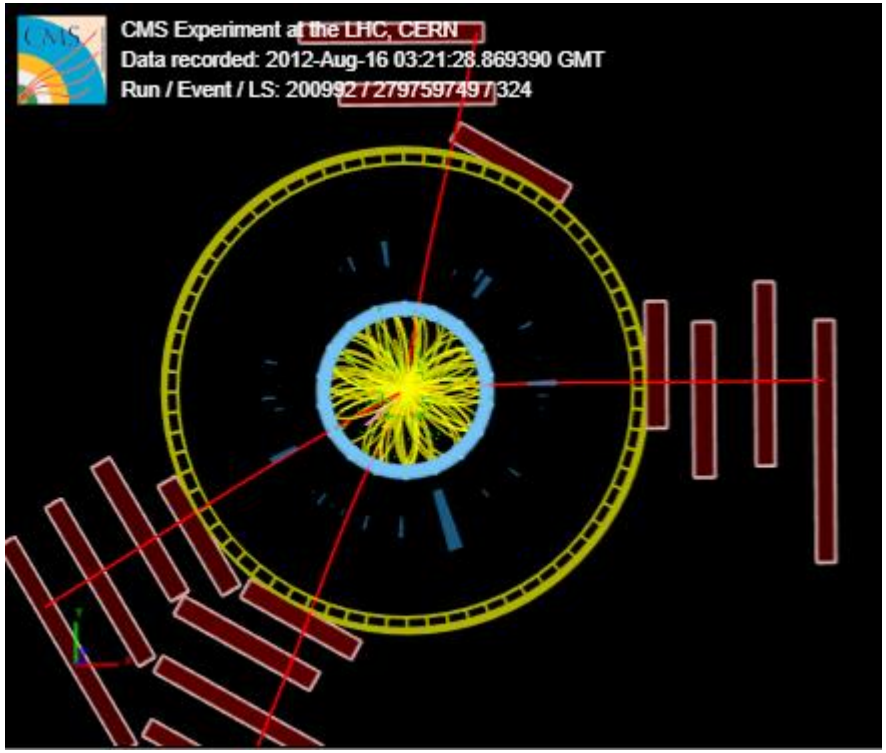
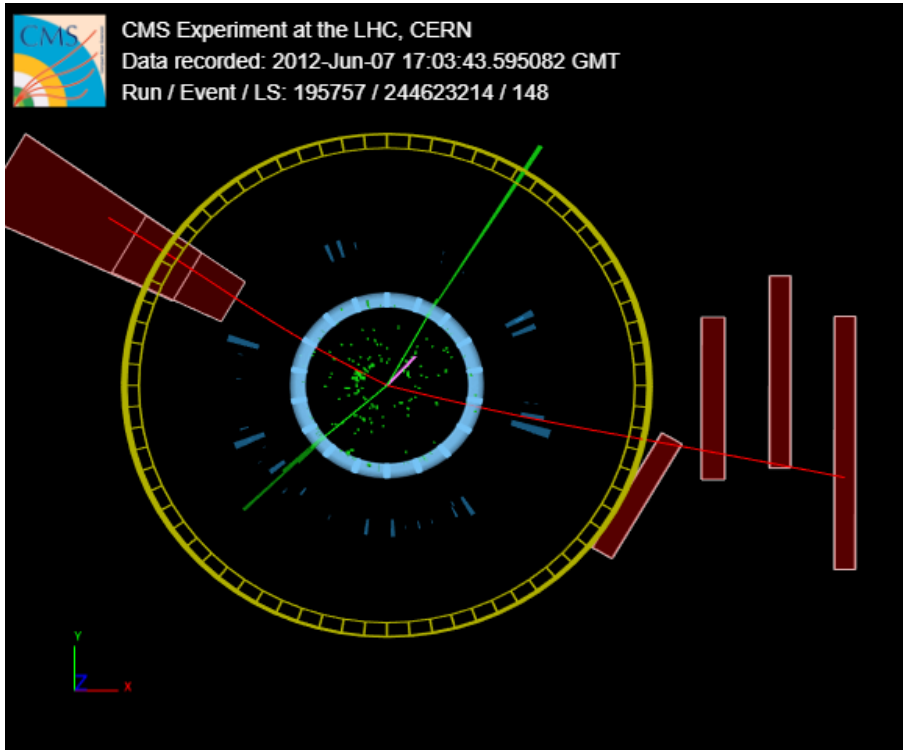
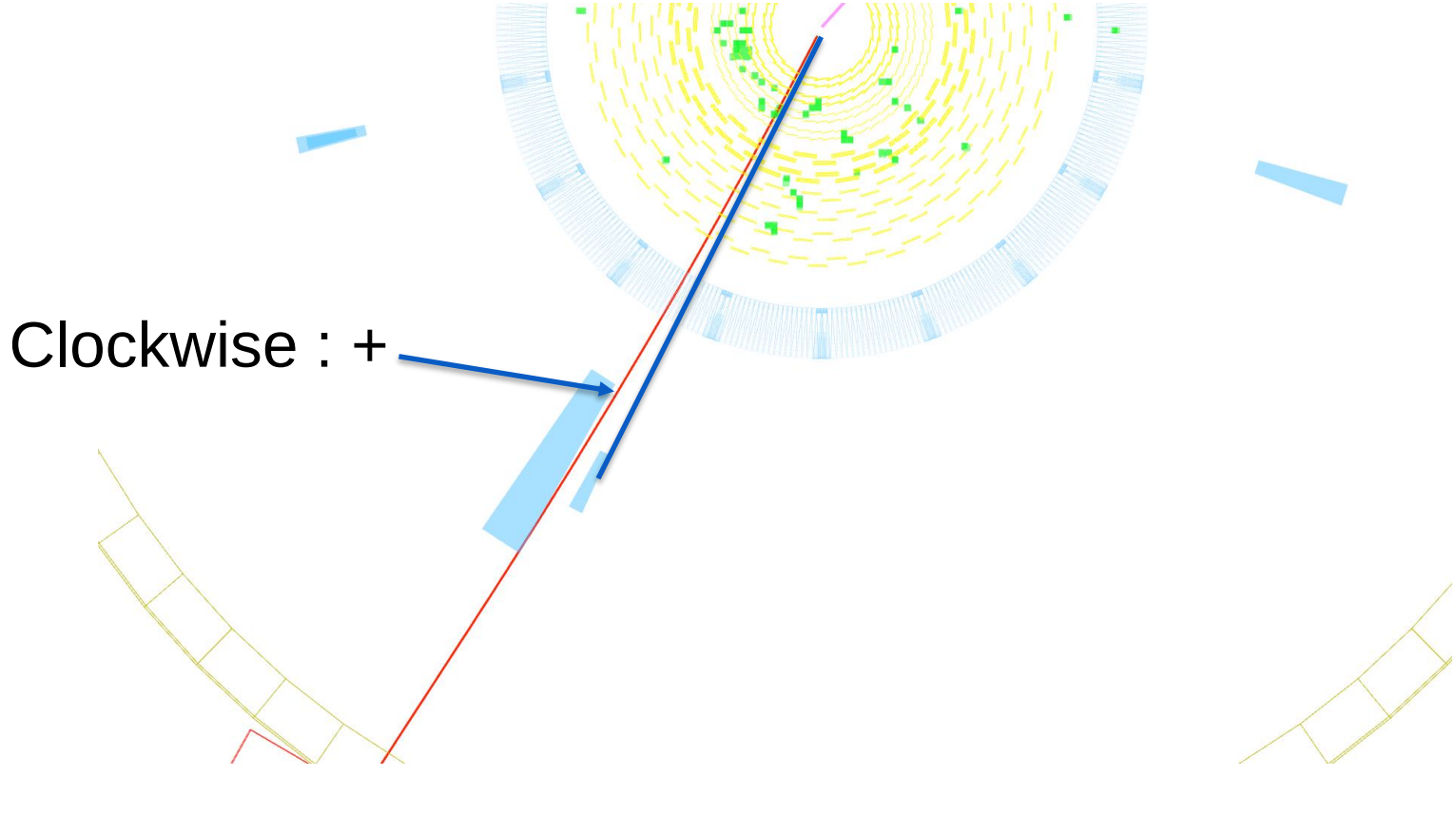




Charge of W from muon

Can you distinguish W+ from W- using track curvature?



Results

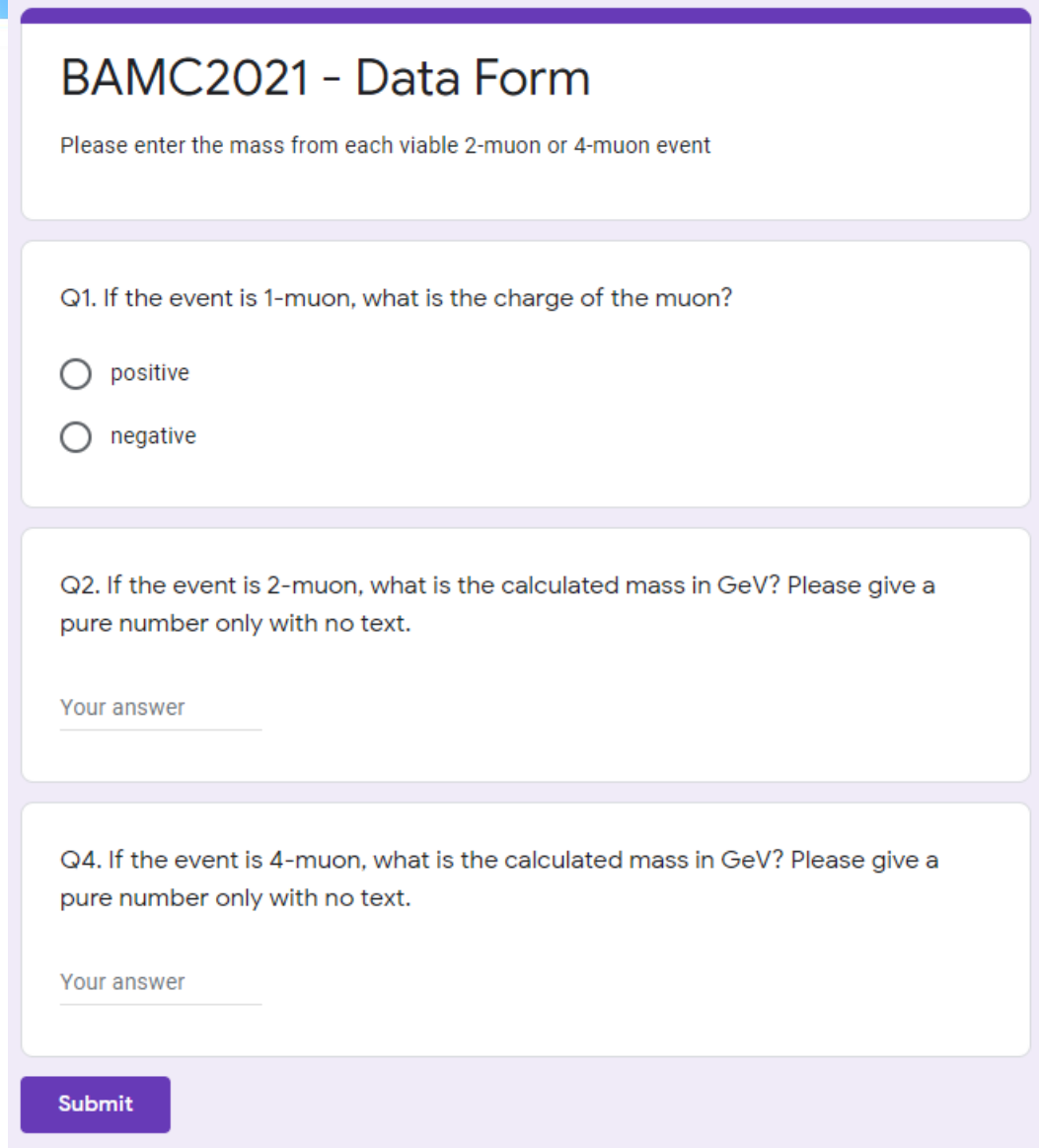
Enter data on each event.

- 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.



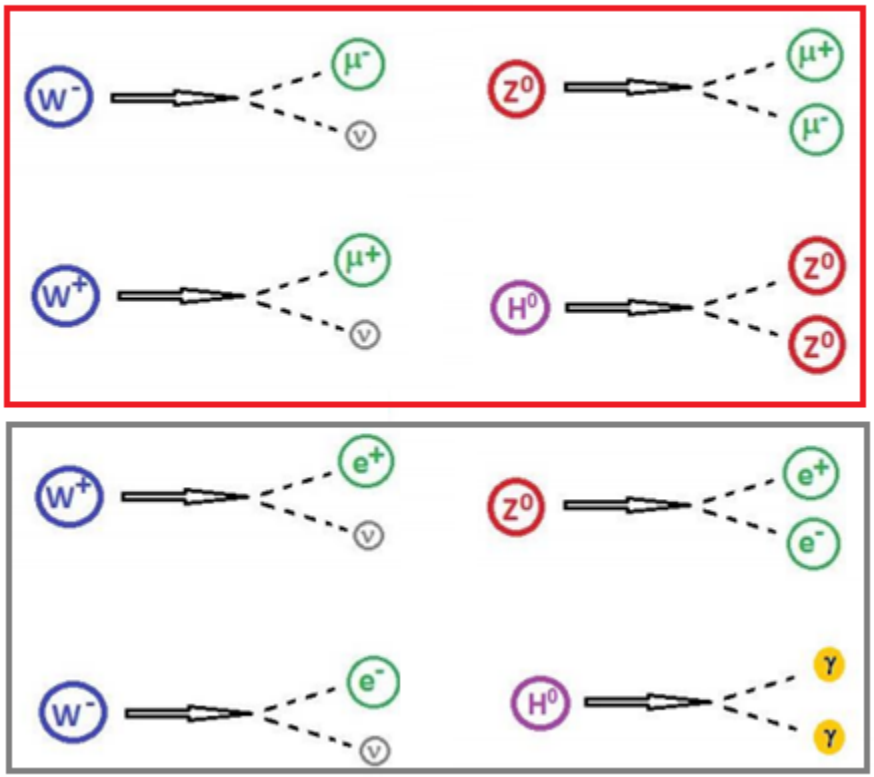
https://forms.gle/ppiEgkU2oZUbY3G17

Decay summary

Because bosons only travel a tiny distance before decaying, CMS does not "see" them directly.

CMS *can* detect :

- electrons
- muons
- photons



CMS can infer:

- neutrinos from "missing energy"