A Presentation and Description for the General Public of Events of Interest Using the Atlantis Event Display

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My Summer REU:

1- Understanding the ATLAS project,
- the ATLAS detector,
- the Standard Model,
- certain key events of interest for ATLAS physicists,
- these events' signatures in the ATLAS detector (how they would appear).

2- Learning the purpose and commands for Atlantis (an event display for ATLAS),
- preparing a cycling event display in Atlantis of several key events that ATLAS physicists are looking for.

3- Preparing several posters describing:
- the ATLAS detector,
- the Standard Model,
- some key events of interest,
- these events' signatures in the ATLAS detector,
- how to discern and identify them in the various images in the Atlantis cycling event display.

The Goals of the Posters-

1- To capture the attention of passersby with a well designed and visually pleasing display.

2- Teach the "captured" passerby about ATLAS and describe what to get out of the display.

THE ATLAS EXPERIMENT

1800 Physicists
150 Universities
35 Countries

CERN is the European Center for Nuclear Research. It is a particle physics laboratory on the border of France and Switzerland. At CERN, scientists study the interaction of high energy particles by accelerating them together at very high speeds inside a tunnel located 100 meters underground.

The Large Hadron Collider (or LHC) at CERN is the highest energy accelerator in the world. It uses magnetic fields 40,000 times stronger than the Earth's to accelerate and smash protons together at 99.9999% the speed of light in an attempt to see what physics exist at these high energies. We have yet to probe the science at these energies.

The accepted model of particle physics, known as the Standard Model, describes the universe around us very accurately. It has been revised and corrected many times and answers many of the questions of the structure and stability of matter with its six quarks, six leptons,and the four forces.

However, many questions remain unanswered.

For example:

- Why are there three types of quarks and leptons of each charge?
- Is there some pattern to their masses?
- Are there more types of particles and forces to be discovered at yet higher-energy accelerators?
- Are the quarks and leptons really fundamental, or do they, too, have substructure?
- What particles form the dark matter in the universe?
- How can the gravitational interactions be included in the Standard Model?

Questions such as these are the motivation that drive particle physicists to build and operate new accelerators, such as the LHC with the ATLAS detector, in the hope that higher-energy collisions can provide some clues to their answers.

The ATLAS detector resides 100 meters underground. It is cylindrical in shape and is 45 meters long and 25 meters in diameter. It weighs approximately 7,000 tons!

One of the main goals of the ATLAS program is to discover and study the Higgs particle. The Higgs particle is of critical importance in particle theories and is directly related to the concept of particle mass. What is the Higgs particle?

The Higgs Boson

Why do the fundamental particles have mass, and why are their masses different? It is remarkable that a concept as familiar as mass was not understood until the proposal of the Standard Model.

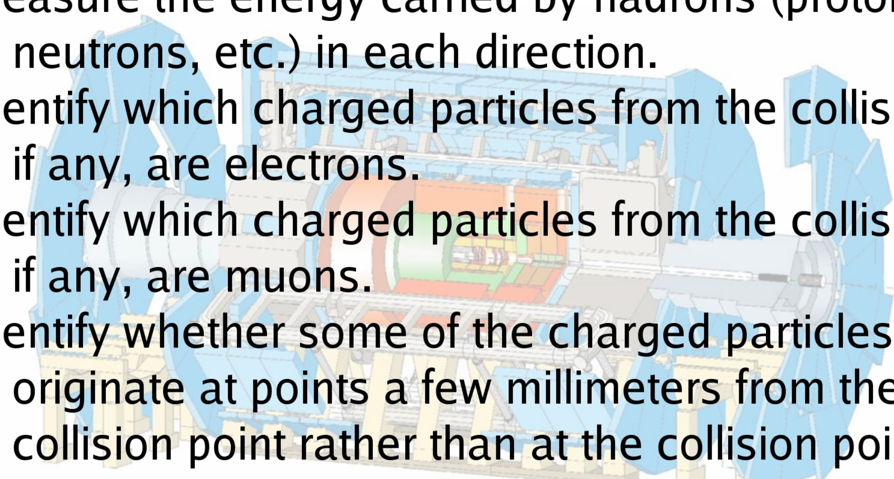
Most of us are familiar with electric, magnetic, and gravitational fields. A person in Earth's gravitational field feels a force. Electromagnetic waves (such as radio waves) travel through space in the same way that ripples in a pond travel through water. If the pond was described in quantum language, the water surface that carries the waves would be called a "field".

The Standard Model proposes that there is another field not yet observed, a field that is almost indistinguishable from empty space. We call this the Higgs field. We think that all of space is filled with this field, and that by interacting with this field, particles acquire their masses. Particles that interact strongly with the Higgs field are heavy, while those that interact weakly are light.

The Higgs field has at least one new particle associated with it, the Higgs particle (or Higgs boson). The ATLAS detector at the LHC will be able to detect this particle if it exists. This would be one of the greatest scientific discoveries ever!

The discovery of the Higgs mechanism is just one discovery that ATLAS physicists hope to make.

What must a detector be capable of doing?

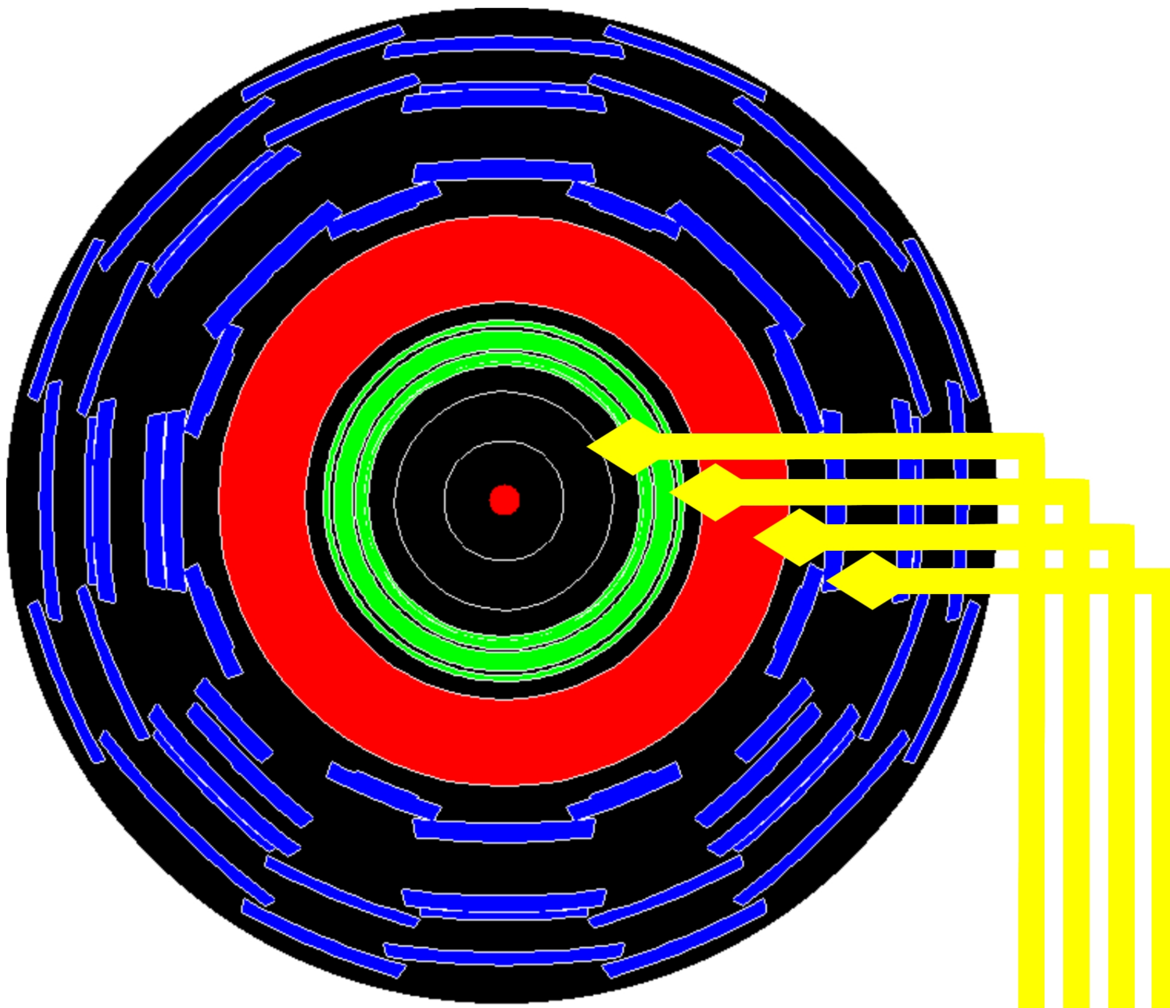


1) Measure the directions, momenta, and signs of charged particles.
2) Measure the energy carried by electrons and photons in each direction from the collision.
3) Measure the energy carried by hadrons (protons, neutrons, etc.) in each direction.
4) Identify which charged particles from the collision, if any, are electrons.
5) Identify which charged particles from the collision, if any, are muons.
6) Identify whether some of the charged particles originate at points a few millimeters from the collision point rather than at the collision point itself (signaling a particle's decay a few millimeters from the collision point).
7) Infer (through momentum conservation) the presence of undetectable neutral particles such as neutrinos.
8) Have the capability of processing the above data fast enough to permit flagging about 10-100 potentially interesting events per second out of the billion collisions per second that occur, and recording the measured information.
9) The detector must also be capable of long and reliable operation in a very hostile radiation environment.

(This information courtesy of www.atlas.ch)

THE ATLAS DETECTOR

Subdetectors of Interest (Cross-Sectional View)



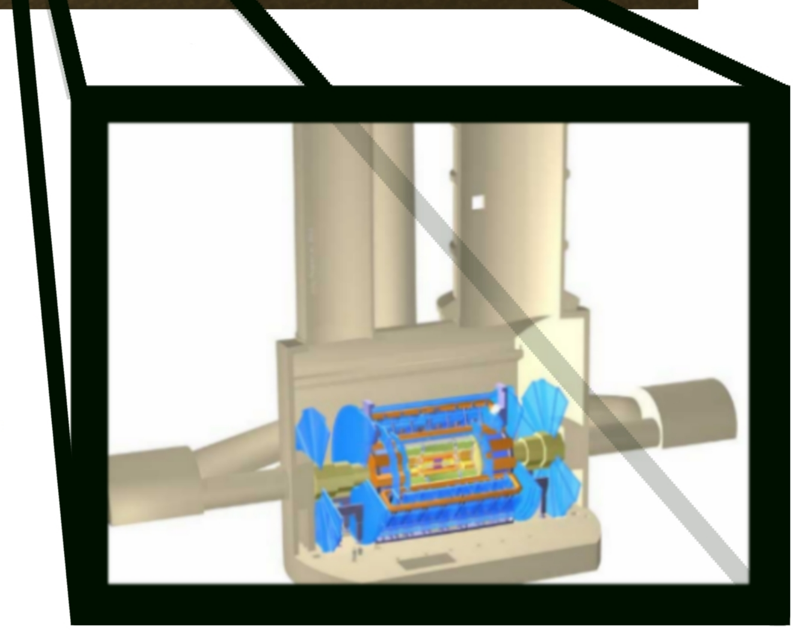
Inner Detector - measures the paths and momenta of all charged particles

Electromagnetic Calorimeter - measures some energy of Hadronic jets, but primary purpose is to measure energy of Photons and Electrons

Hadronic Calorimeter - measures remaining energy of Hadronic jets and confirms existence of Muons

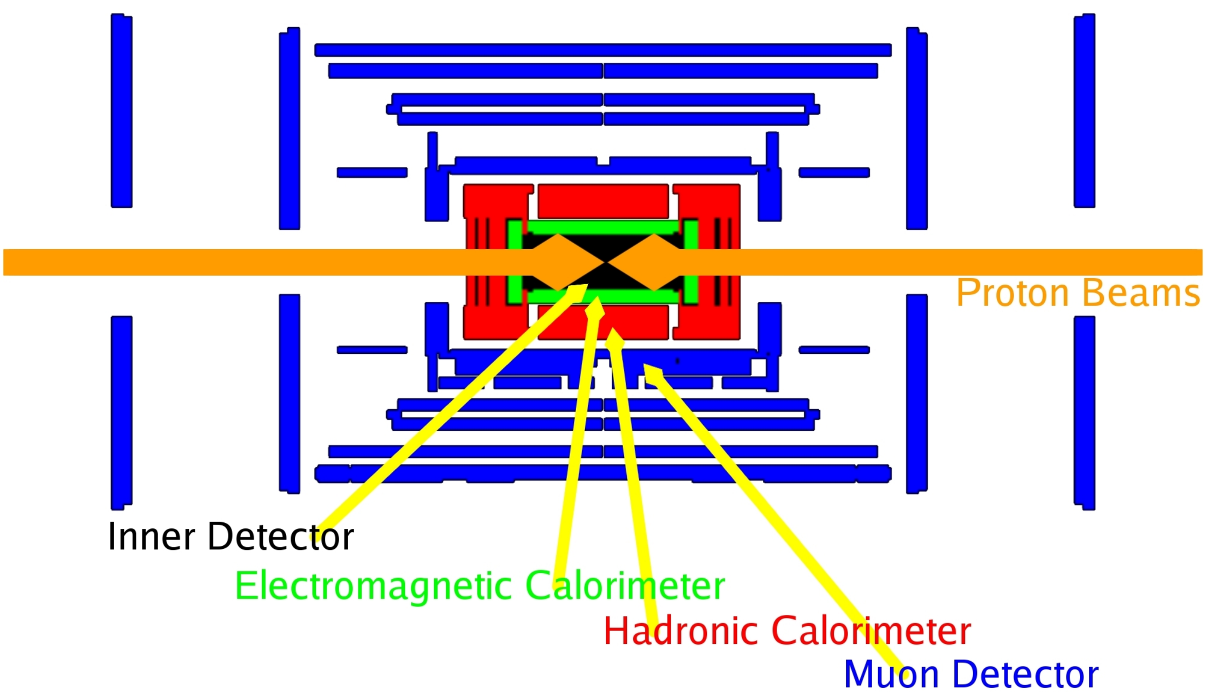
Muon Detector - measures paths and momenta of Muons

Above- A cutaway view showing the ATLAS detector (in the ground), the LHC ring, and the surface buildings.



Right- The ATLAS detector.

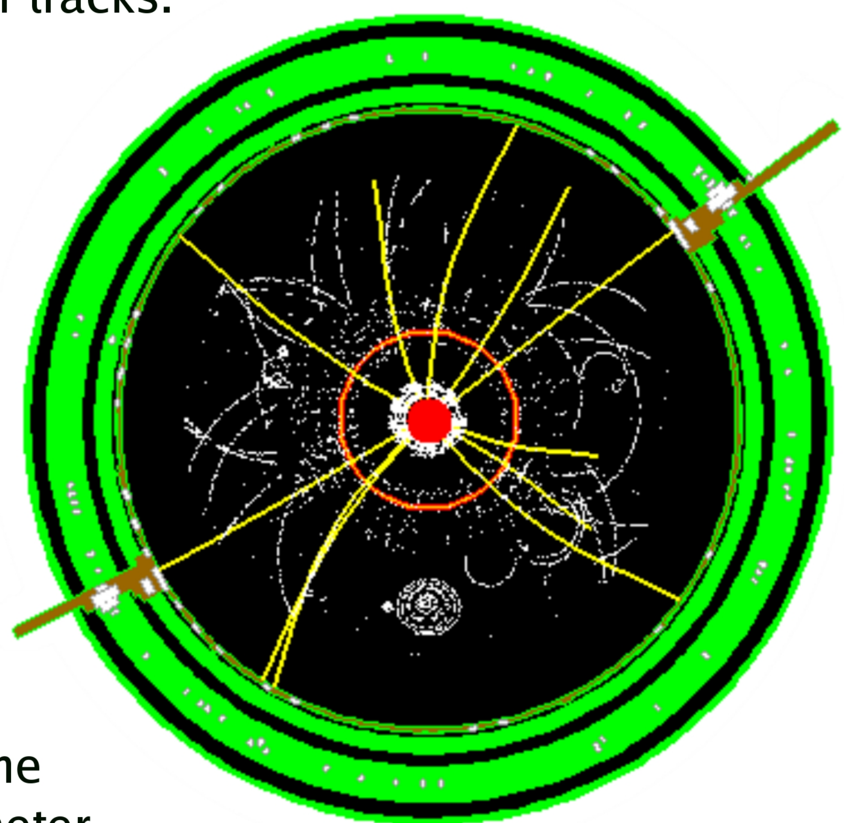
Below- The top view of the detectors of interest.



What are ATLAS physicists looking for?

Hundreds of particles of various types
are created in each proton-proton collision.

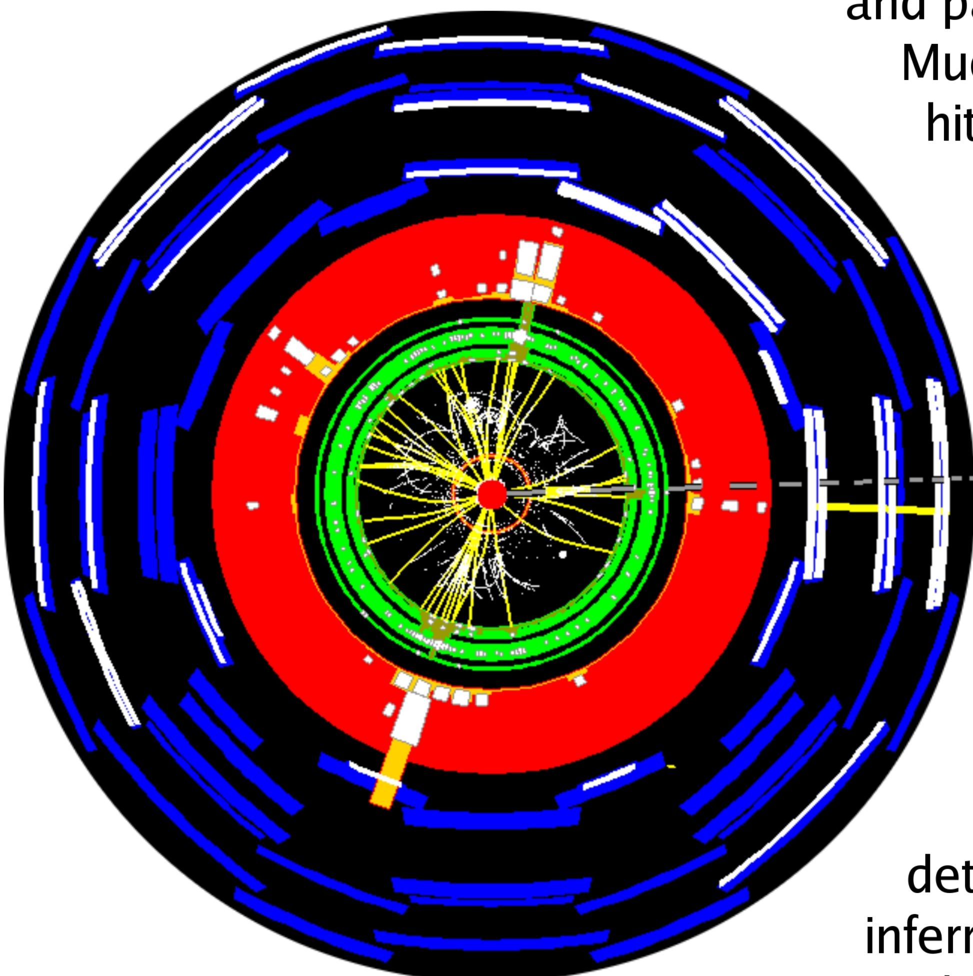
The Inner Detector allows us to calculate the momenta of charged particles. Magnets cause the particles' tracks to curve to help us find their momenta, which are represented in all images as the white dots and yellow lines (or tracks) in the Inner Detector. Particles with higher momenta have straighter tracks.



Physicists look for key indicators of certain decays of interest. For example, a Z boson can decay into two electrons, which interact in the Electromagnetic Calorimeter. The electrons' energies are represented with the white rectangles in the Electromagnetic Calorimeter. The electrons' total energies are the sum of these hits and are represented as brown histograms.

(Note the electrons' paths are straight yellow lines indicating high momenta.)

A muon is a heavier type of lepton. Muons also interact in the Electromagnetic Calorimeter, but since they are heavier, they are less easily deflected and pass through to the Muon Detector. Their hits are represented in white on the Muon Detector, and a track is shown by the yellow line in the Muon Detector.



Neutrinos are not actually detected, but instead inferred due to missing energy and momentum. They are represented by the dotted gray track on the right.

Quarks turn into jets of hadrons. The hadrons' (jets') energy can be seen in the deposits, represented by the white rectangles in the Hadronic Calorimeter. The hadrons' total energies are represented by the yellow histograms. (Protons and neutrons are both types of hadrons.)

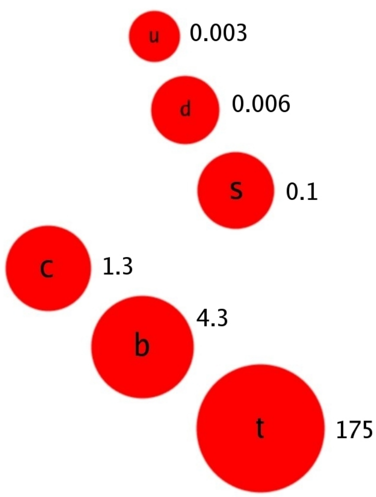
THE STANDARD MODEL

MATTER

All matter is made up of certain fundamental particles.

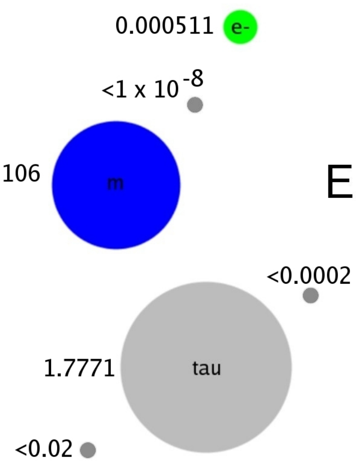
Quarks -

Up
Down
Strange
Charm
Bottom
Top

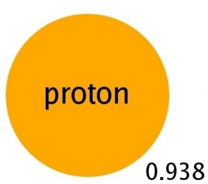


Leptons -

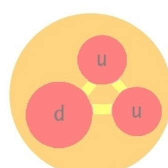
Electron
Electron Neutrino
Muon
Muon Neutrino
Tau
Tau Neutrino



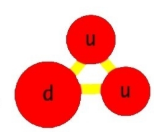
Quarks cannot exist alone and they quickly combine to form hadrons.
For example, a proton is a type of hadron - it is comprised of two up quarks and a down quark.
The Tau Lepton decays very quickly into other particles.



A proton is made up of...



...two up quarks and a down quark.

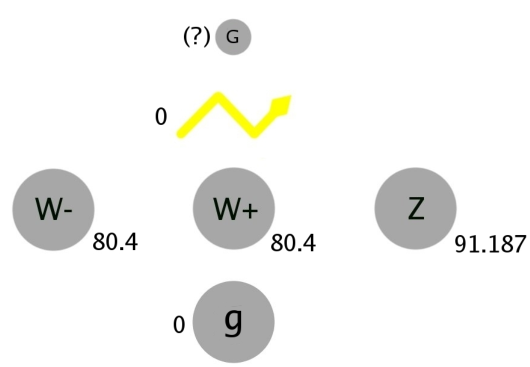


FORCE

(All numbers indicate mass in GeV / c^2)

The four fundamental forces are -

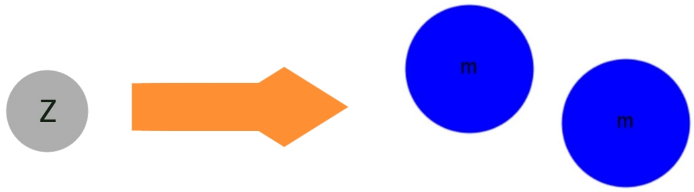
- Gravity - acts at any distance and is believed to be carried by the graviton
- Electromagnetism - acts at any distance and is carried by the photon
- Weak - acts only at very small distances and is carried by the W-, W+, or Z boson
- Strong - acts only at very small distances and is carried by the gluon



What events are ATLAS physicists looking for?

Some of the various events of interest are:

Z boson to 2 muons

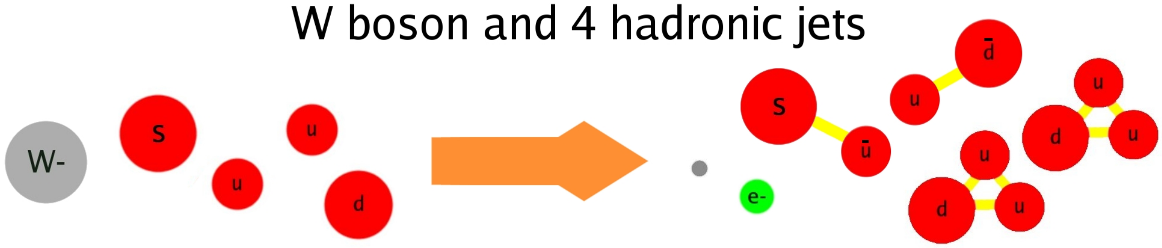


ATLAS physicists use this event to test the detector.
This is a very well known decay.

Z boson to 2 electrons

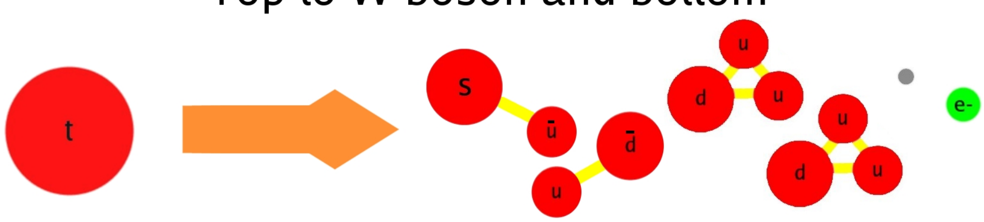
ATLAS physicists also use this event to test the detector.
This is another very well known decay.

W boson and 4 hadronic jets



In this decay the W boson (+ or -) decays to a lepton and a lepton neutrino.
Also, the quarks attract nearby quarks to form stable hadrons.

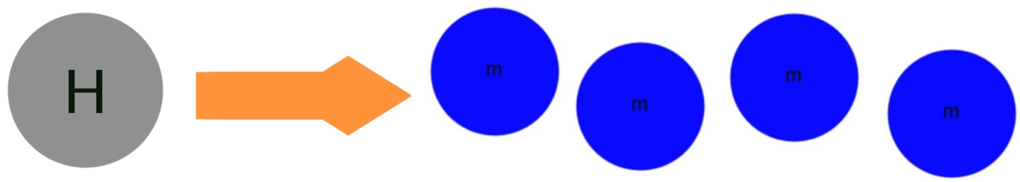
Top to W boson and bottom



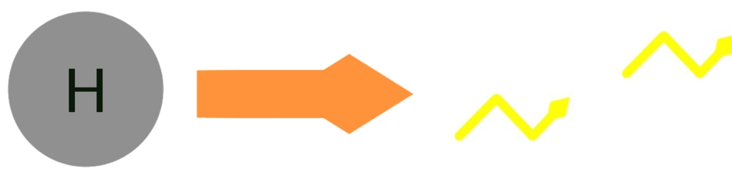
The top quark decays to a W boson and a bottom quark. The bottom quark becomes a hadronic jet, and the W boson becomes a lepton and a lepton neutrino (or two quarks). Because top quarks are produced in pairs, this event appears very similar to the last event and only very precise measurements can differentiate these events.

The Higgs boson's mass is unknown.
ATLAS physicists predict that if it has the following masses,
it will decay into the following particles:

Higgs boson (of mass 130 GeV) to 4 leptons

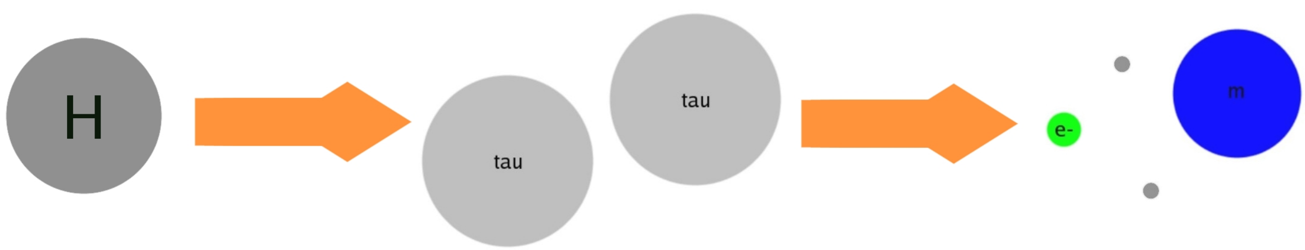


Higgs boson (of mass 120 GeV) to 2 gamma rays (photons)

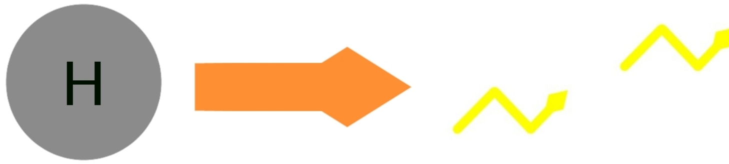


Photons resemble the electrons' signature but don't show a track in the Inner Detector.
(They will interact in the Electromagnetic Calorimeter only.)

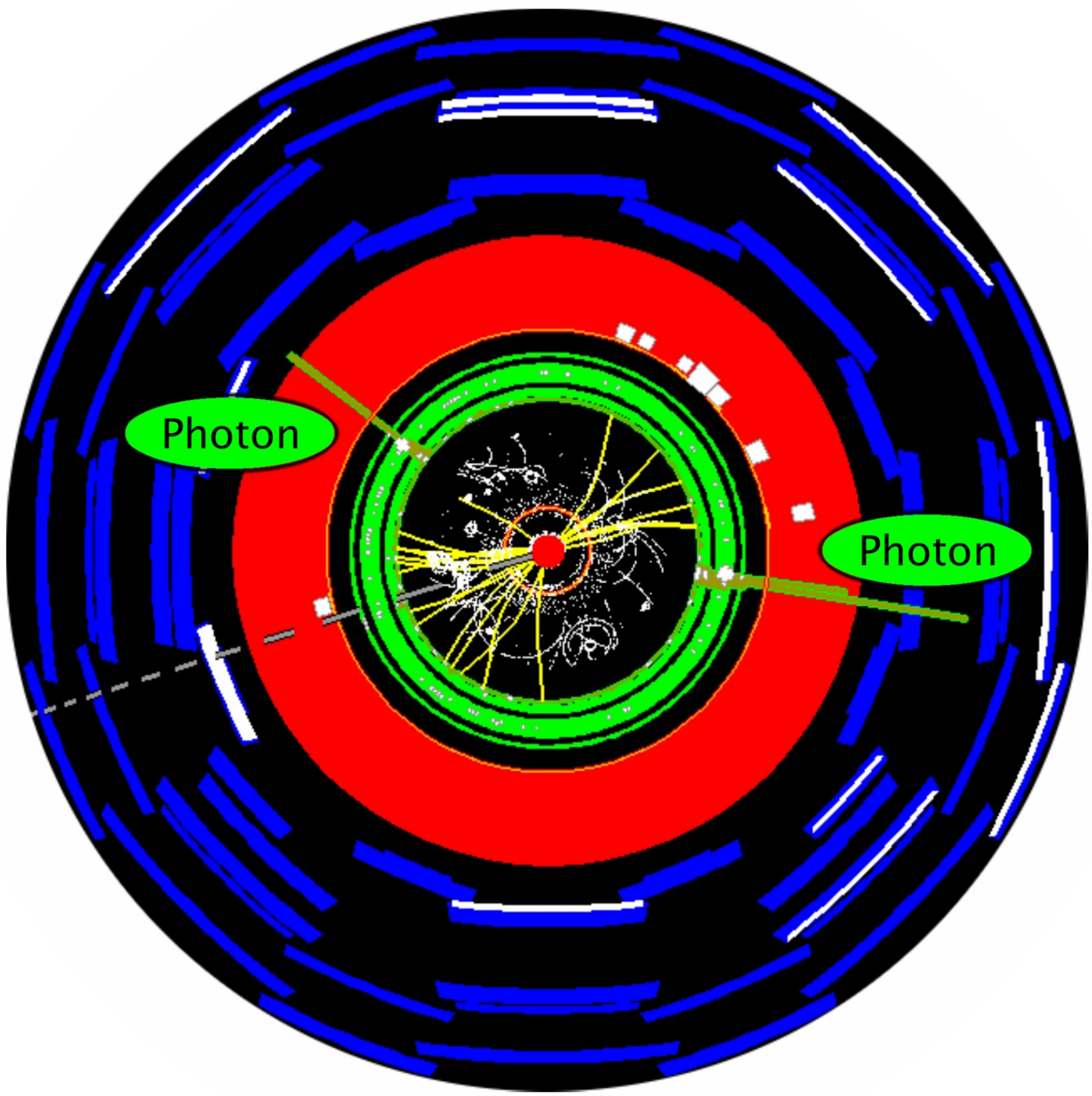
Higgs boson (of mass 115 GeV) to 2 taus



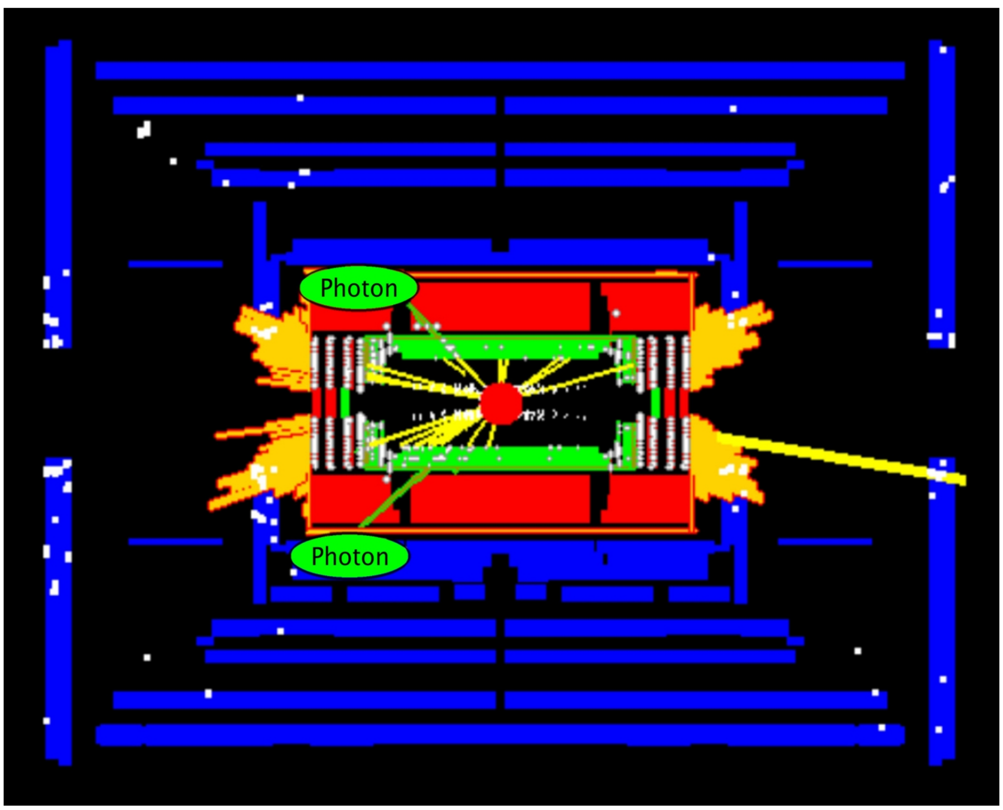
A closer look at an event-
the Higgs Boson to 2 gamma rays (photons)



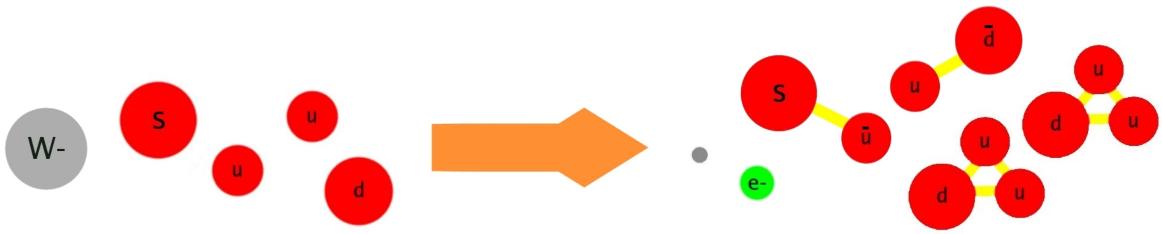
The magnets of the Inner Detector have no effect on the neutral photon and thus the photon passes through undetected, but it will leave a clear signal in the Electromagnetic Calorimeter.



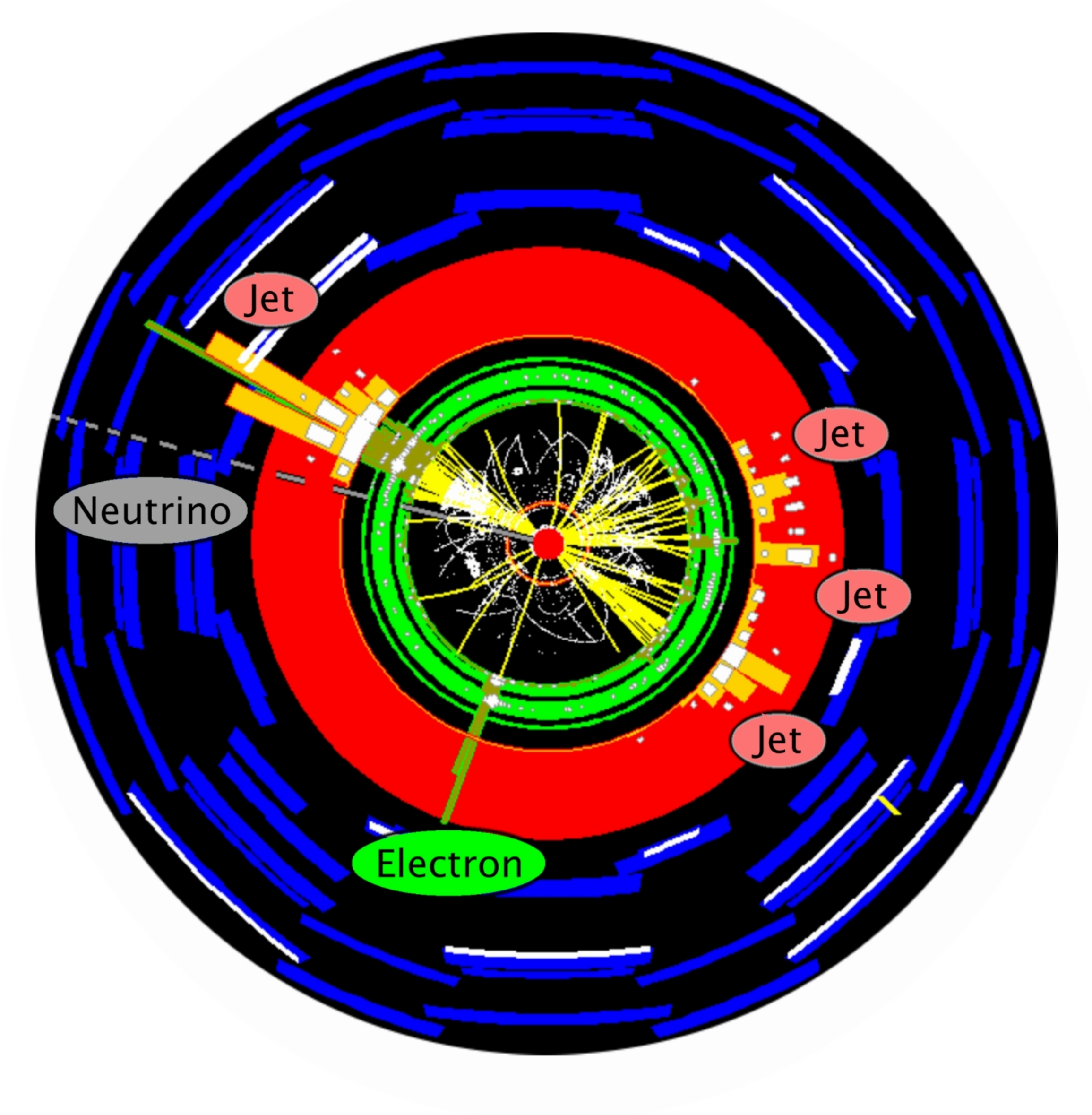
This is the top view of the Higgs to 2 gamma rays (photons) event. Again, this view is slightly more ambiguous because along the center line there appear to be jets. The proton remnants not directly involved the event of interest may collide as well, but their collisions are usuallyconsidered more glancing and less head-on.



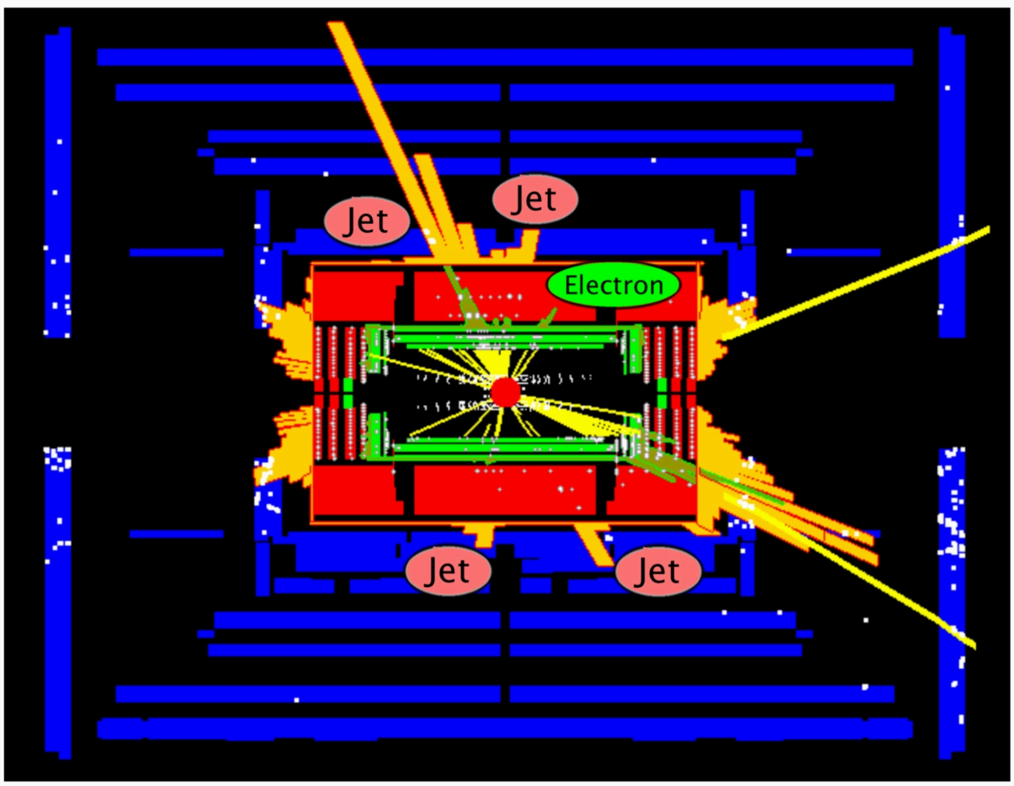
A closer look at an event-
the W boson and 4 hadronic jets



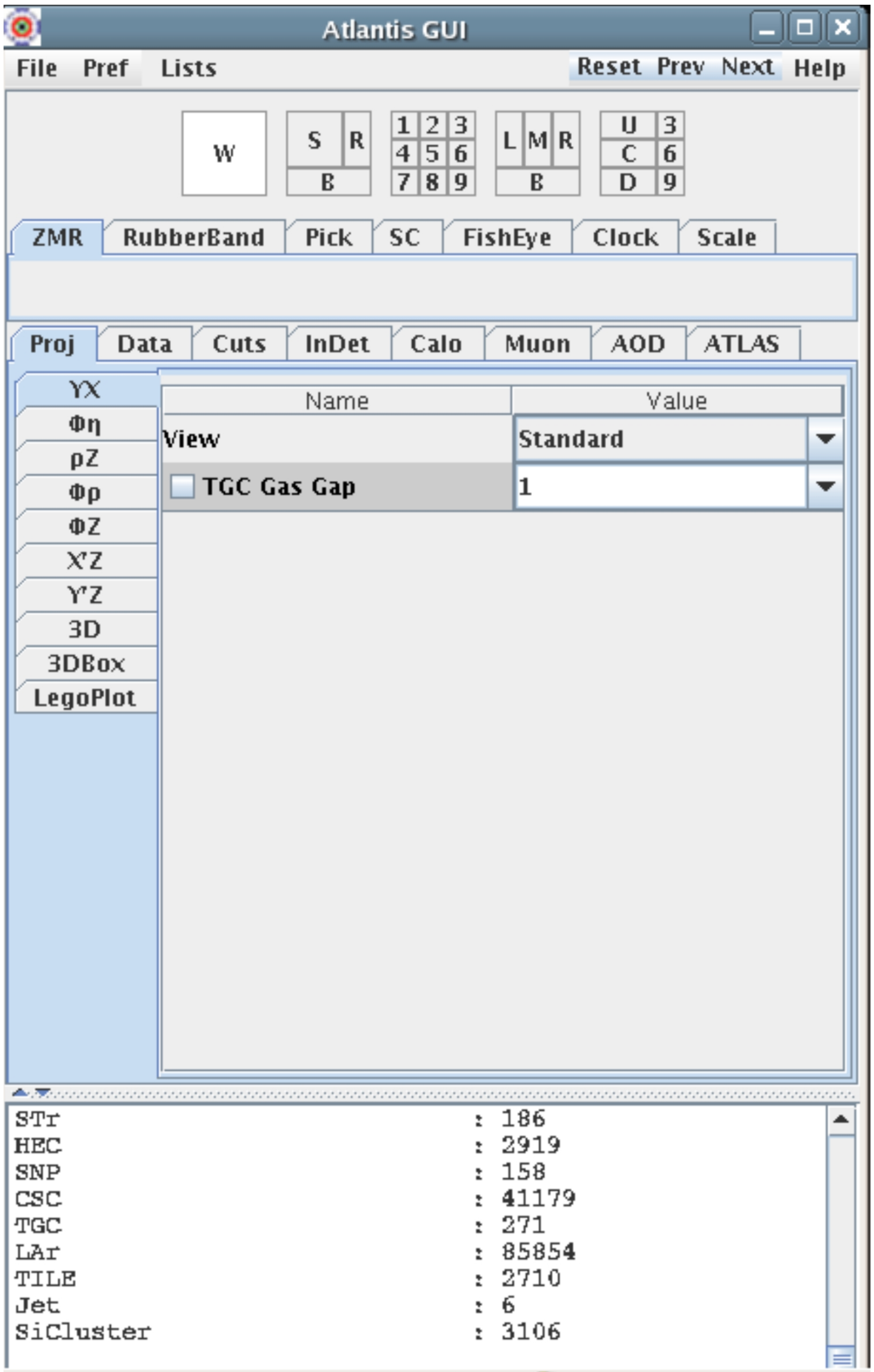
The left side of the arrow shows particles immediately following a collision. The right side of the arrow shows particles as they will appear in the detector.

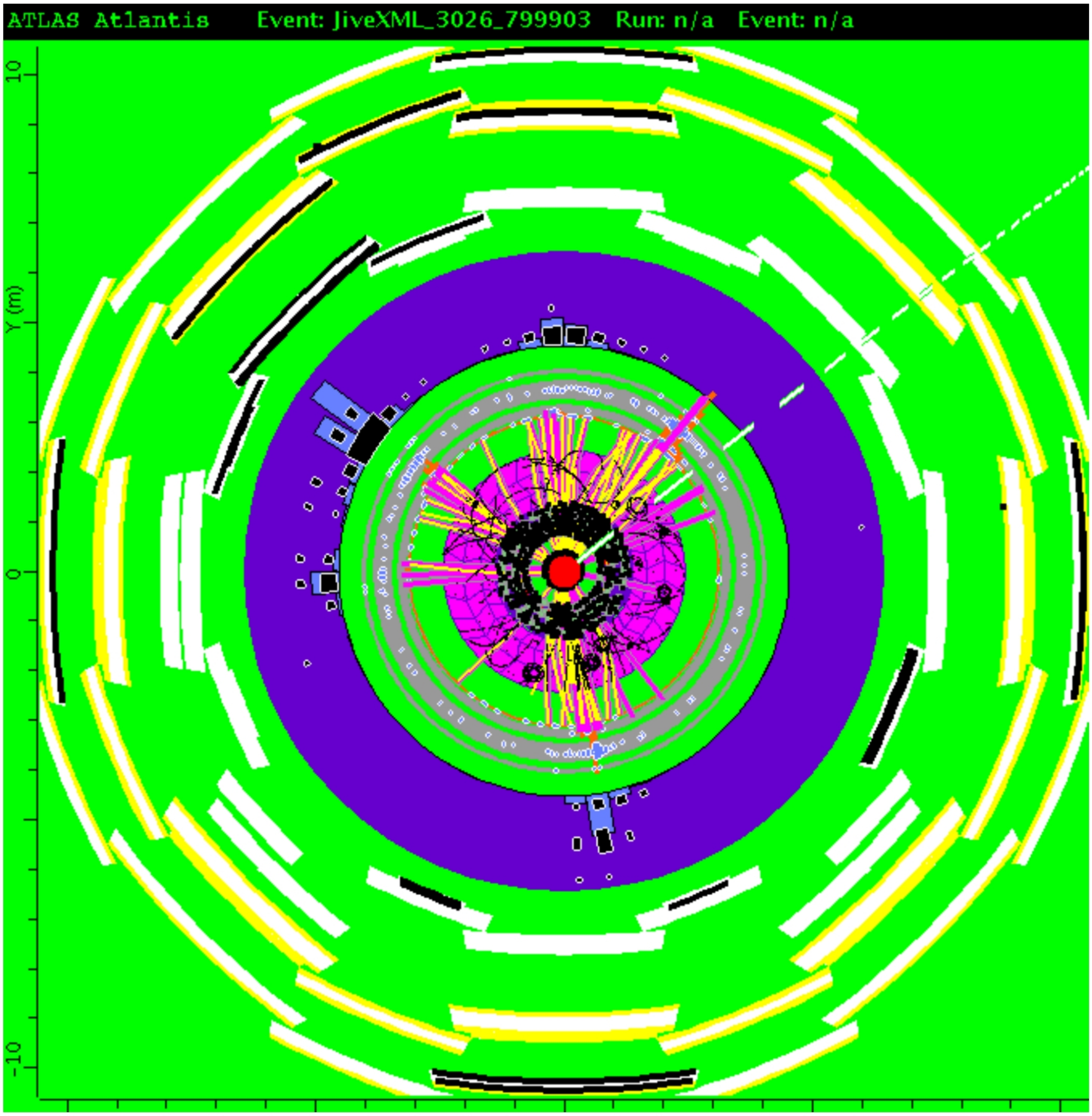


This is the top view of the W boson and 4 jets event. This view is slightly more ambiguous because along the center line there appear to be jets (in addition to the labeled jets). This is because the protons' other constituents not involved in the collision may collide as well, but their collisions are usually considered more glancing and less head-on.

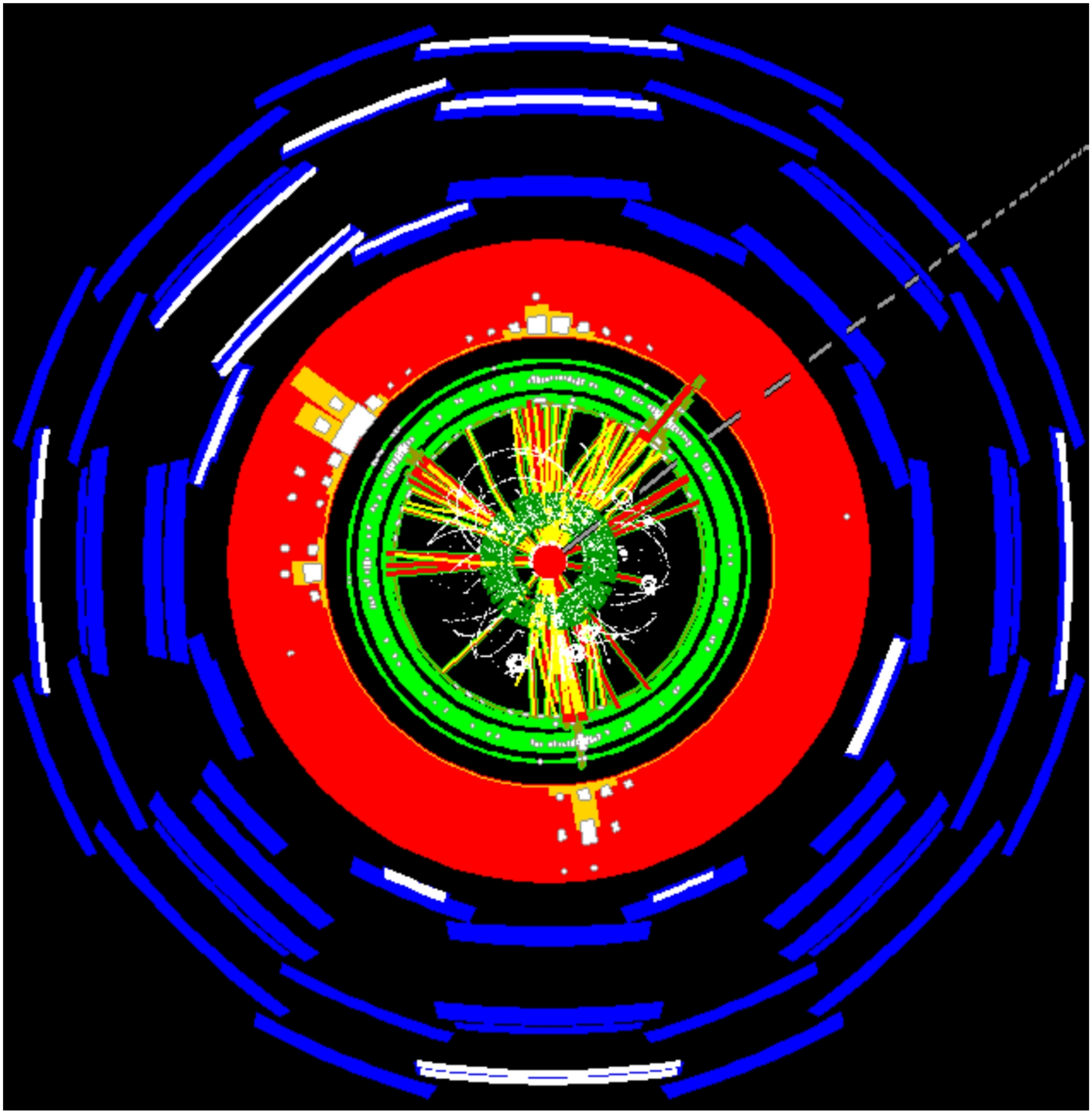


The Atlantis Controls

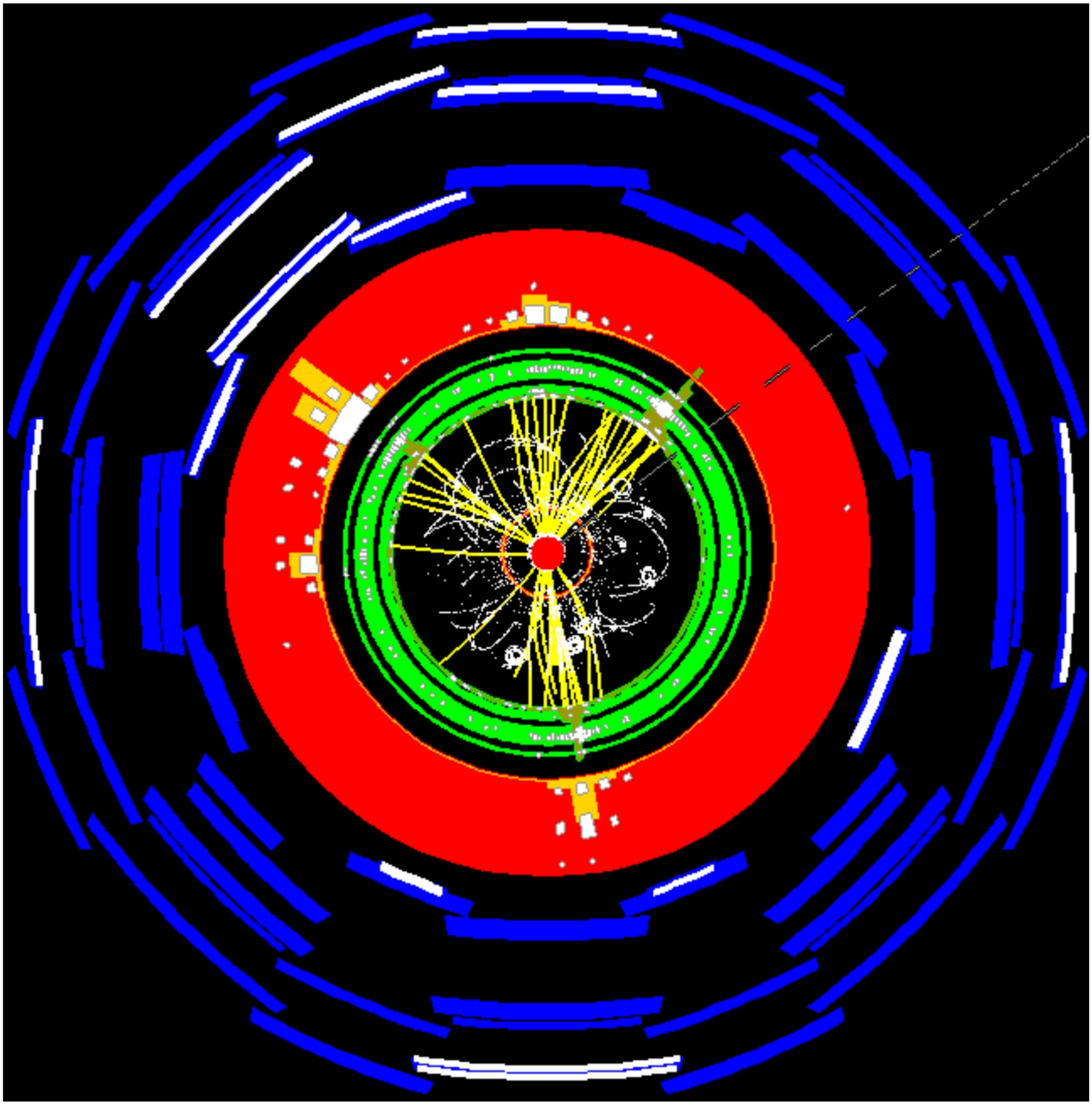




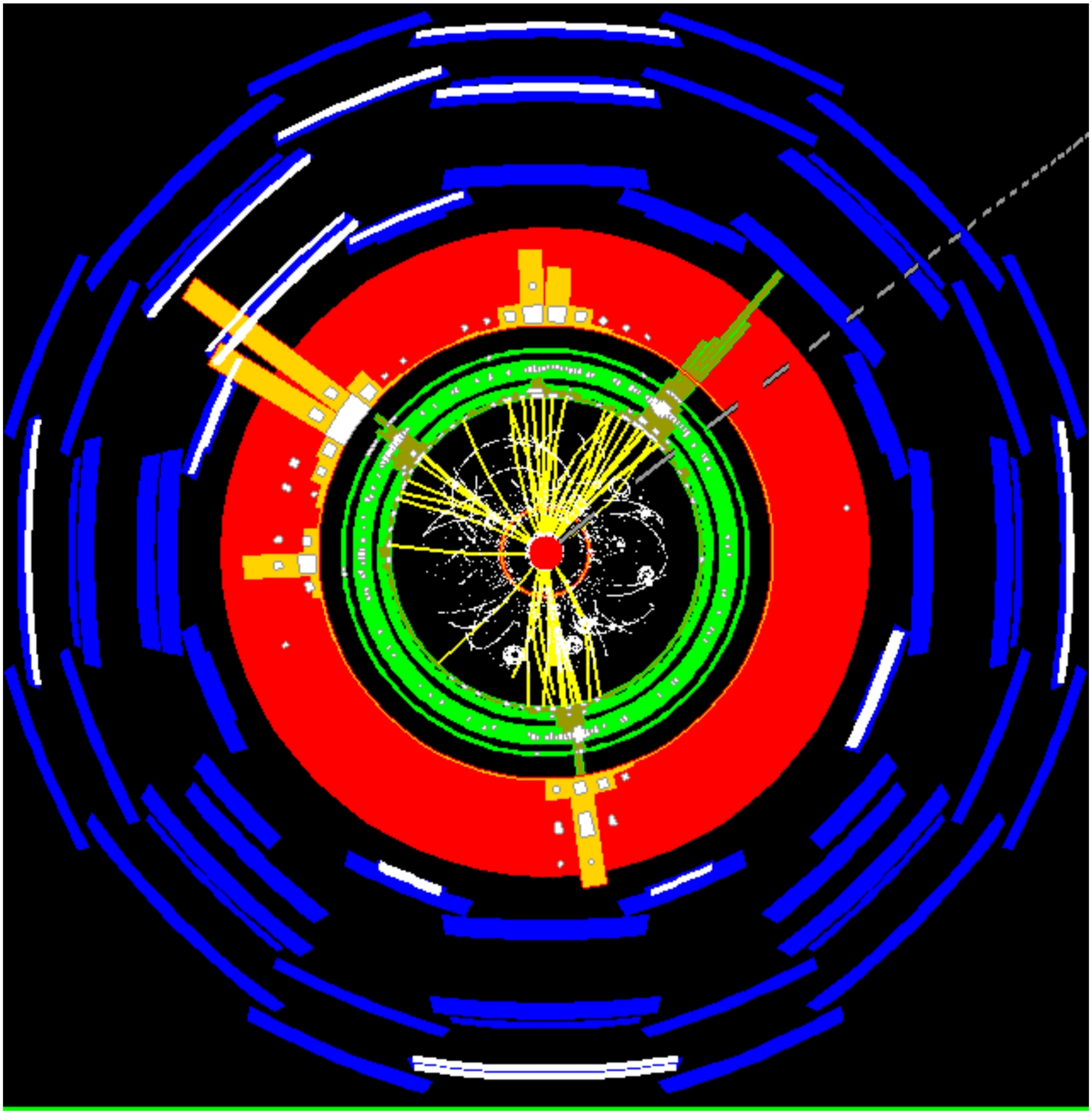
This is what Atlantis looked like
when I first opened it.
Hideous.



After changing some colors around...



After reducing some of the data...



Final image with amplification.