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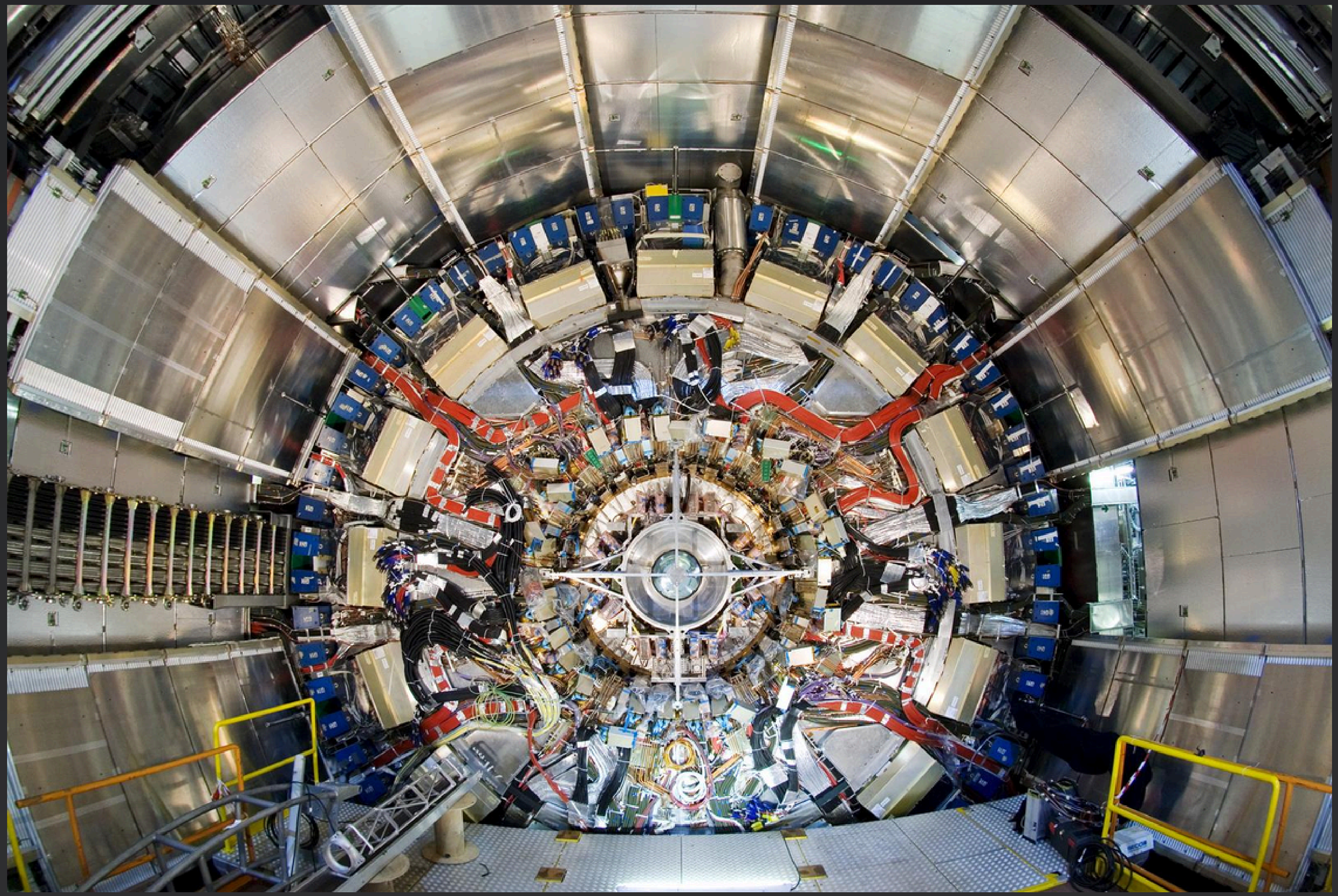


THE ATLAS DETECTOR

How we detect particles at ATLAS

University of Victoria

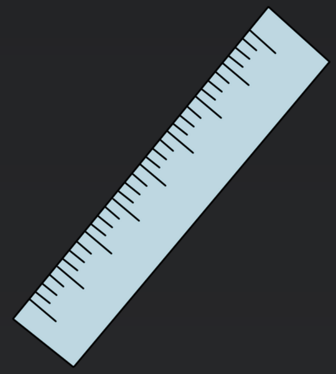
Let's accelerate in!

A QUICK RECAP

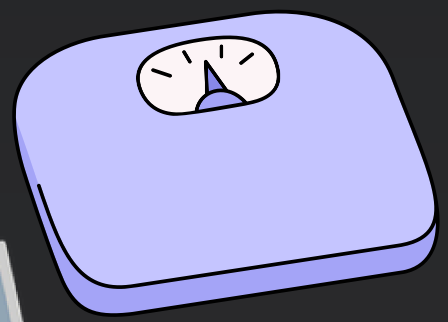
- The Large Hadron Collider accelerates protons within a 27km ring. The ring is a 100m underground.
- The two proton beams are made to cross at specific points within the ring called Interaction points.
- 4 major LHC experiments/detctors are located at each of the points. They are housed in caverns, also a 100m underground
- One of these is the ATLAS detector, a general purpose detector that is used to analyze the outcome of the proton collisions
- But what is the ATLAS detector and how does it do that?

AT LAST ATLAS*

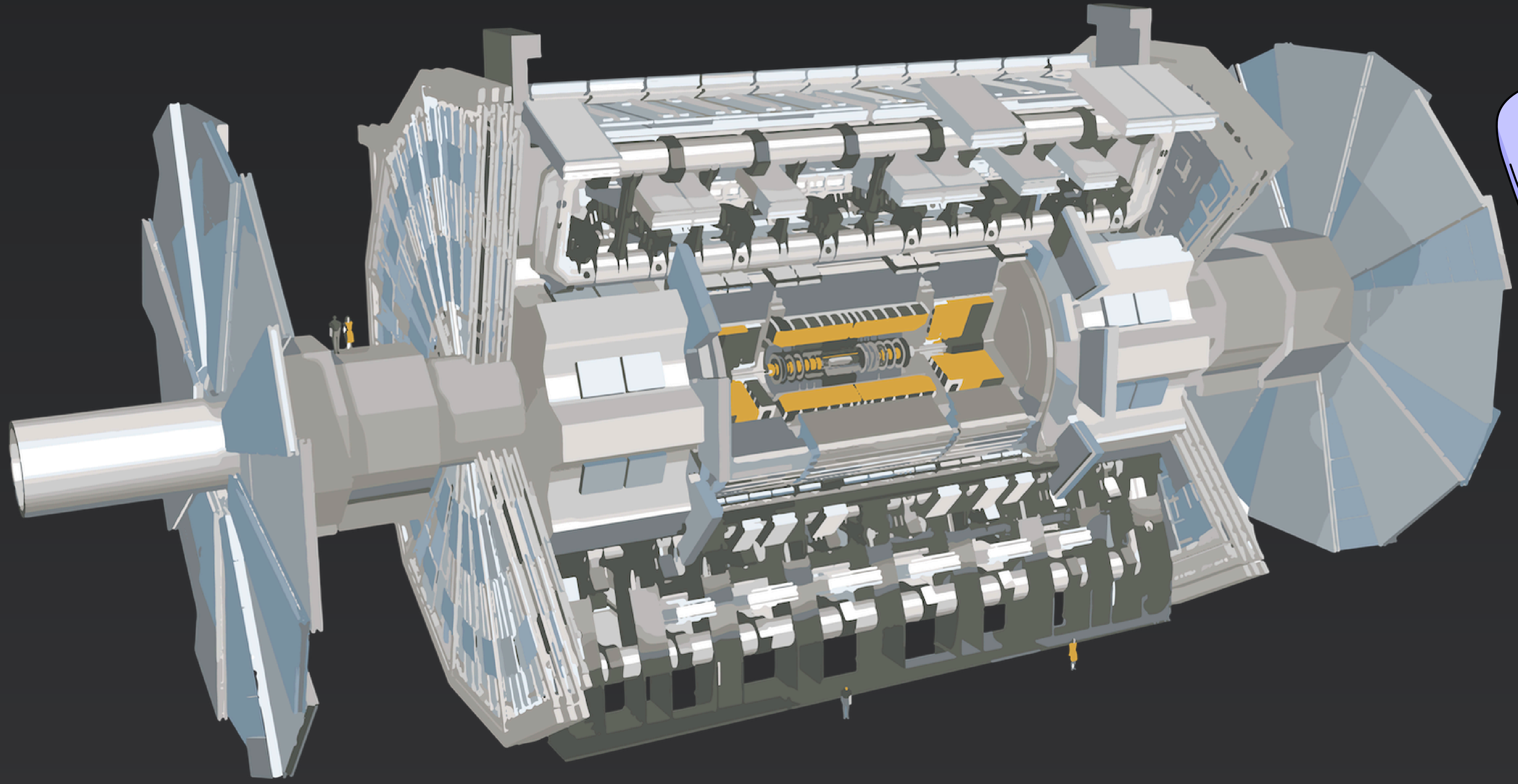
- One can think of ATLAS as a very (very) big camera.



25m high, 46 m long



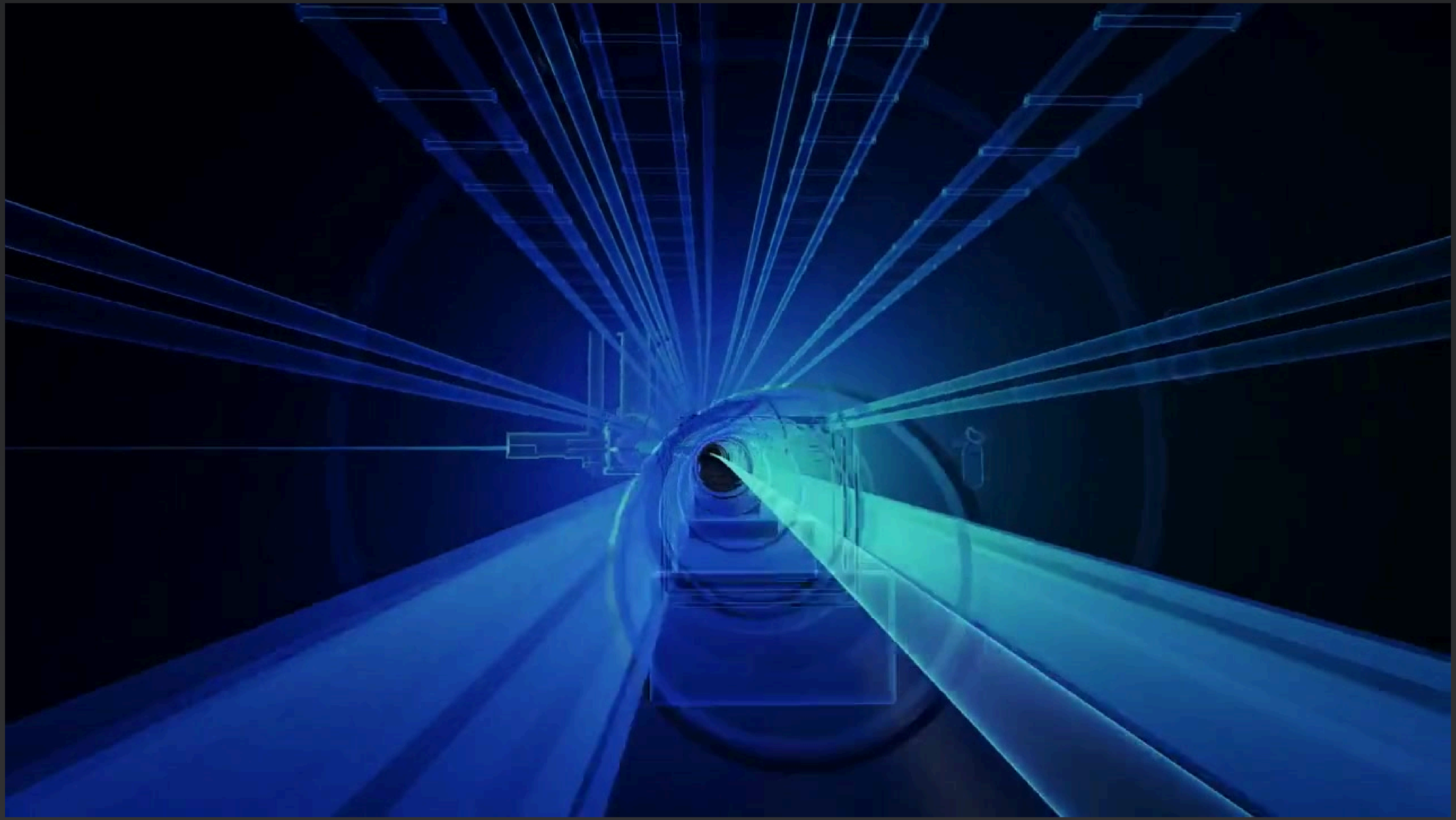
7,000,000kg



- ATLAS is made of several subdetectors that wrap concentrically in layers around the collision point.
- The detector also consists of a huge magnet system (~2T) bends the paths of charged particles. 2T is roughly the strength of 2000 refrigerator magnets combined

*A Toroidal LHC ApparatuS

AT LAST ATLAS*



- The center of the detctor is where the collision point occurs.
- Protons are very very small. 100 billion protons in a bunch are fired towards another bunch of a 100 billion protons, every 25 nano seconds (0.000000025 s)
- But only ~60 proton collisions occur per bunch crossing. Very very small.
- So we do this over and over again. 40 Million times a second!!
- From protons that do collide, the camera captures tracks and hits as the particles pass transversely through the detector.

*A Toroidal LHC ApparatuS

WHAT PARTICLES ARE WE DETECTING

Electrons, muons

- These are **electrically charged**, so they will **bend** in a magnetic field, and also will interact with other material (via **ionization**).

Neutrinos

- Do not interact with the detector.
- Use conservation of Energy-momentum. After accounting for all detectable particles, any imbalance in the transverse momentum should have come from a neutrino

Hadrons (mesons, baryons)

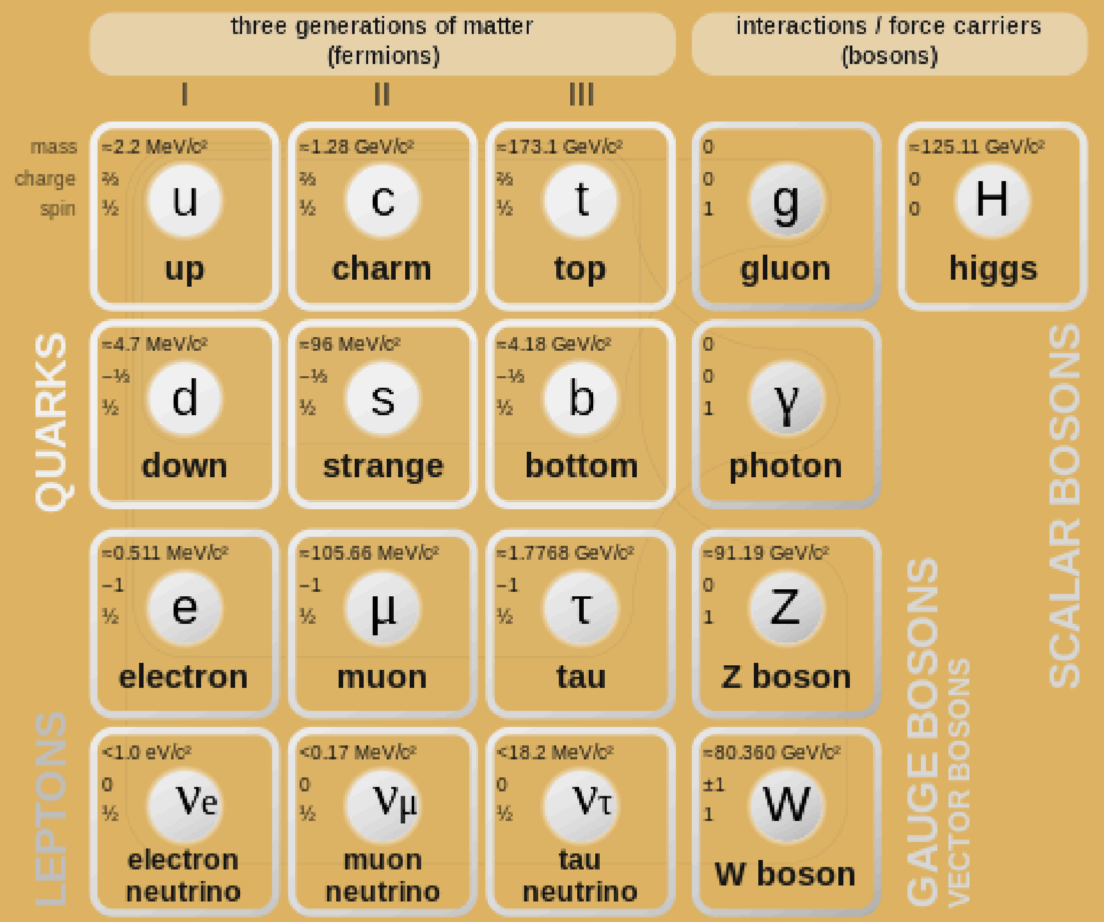
- High energy hadrons interact with atomic nuclei in matter causing a cascade of reactions
- If **charged**, they will **bend** in a magnetic field, and will **ionize** material.
- These mostly include protons (which are baryons), and pions and kaons (which are mesons).

Photons

- Energetic photons interact electromagnetically with a nucleus to create an electron-positron pair.

Particles that have a very small lifespan are not directly detected by ATLAS. Their decay products are detected, and by observing these, we can trace back to their origin (more in the next talk)

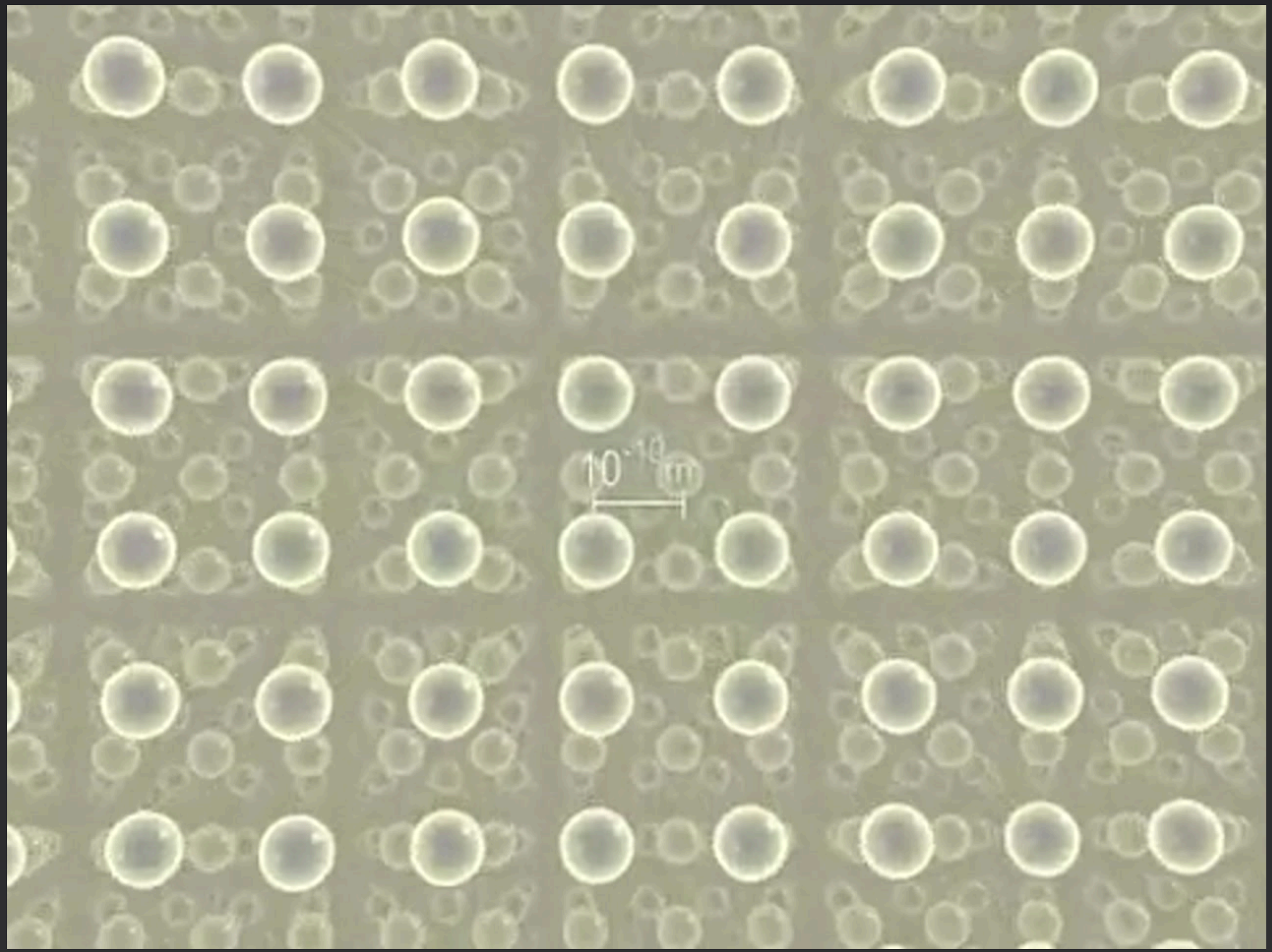
Standard Model of Elementary Particles



WHAT QUANTITIES ARE WE DETECTING

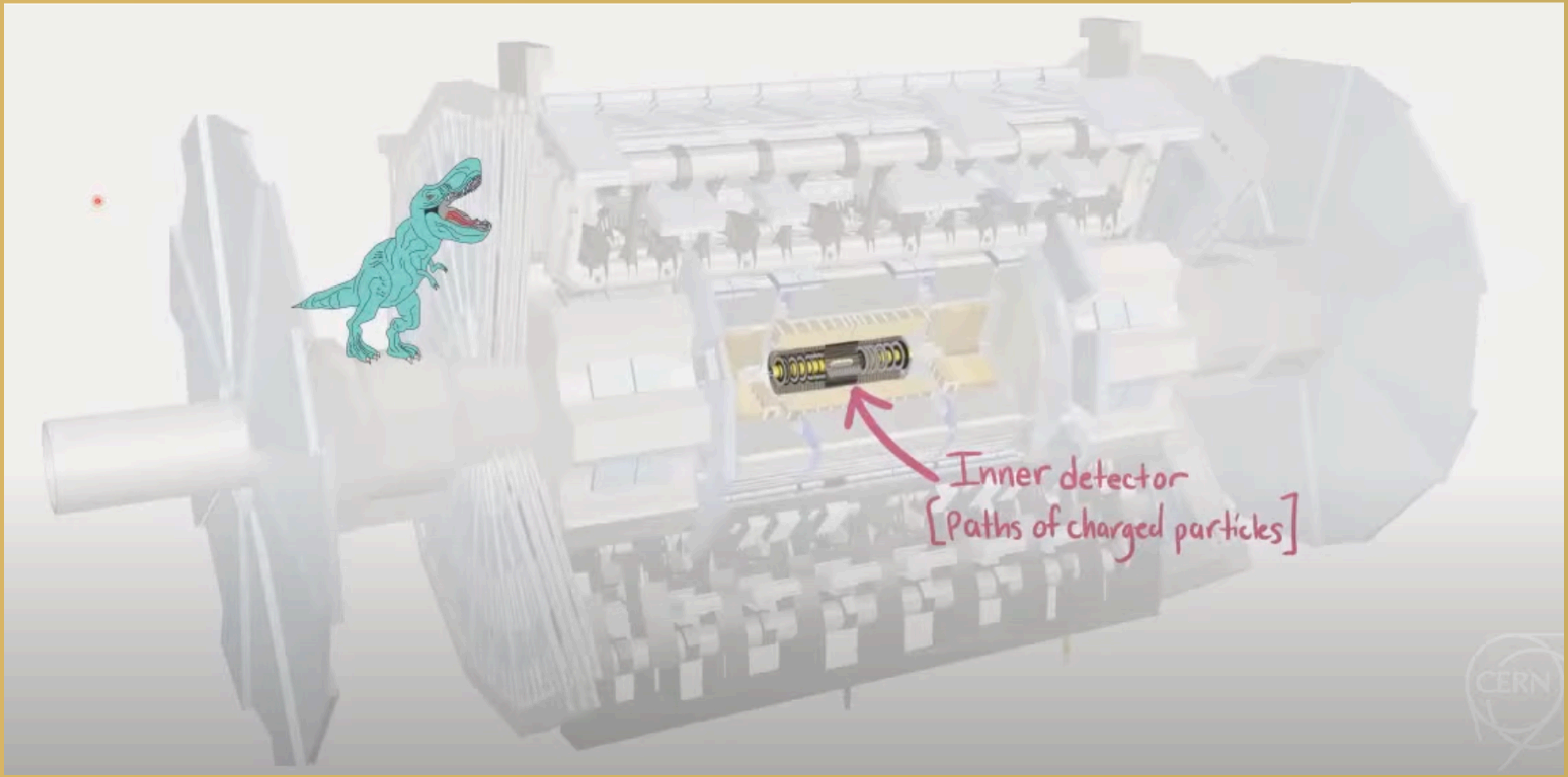
- Trajectory,
- Momentum,
- Energy,
- Charge

Prelude: Key concept



- As energetic charged particles go through material, they can liberate electrons from atoms of the material.
- Under an influence of an electric field, these electrons can move in a particular direction and can be collected.
- These electrons can then create an electric current that can that be detected.
- Where the current is coming from can tell us the location of the original particle
- The amount of current can tell us how many ionization electrons were liberated

IONIZATION



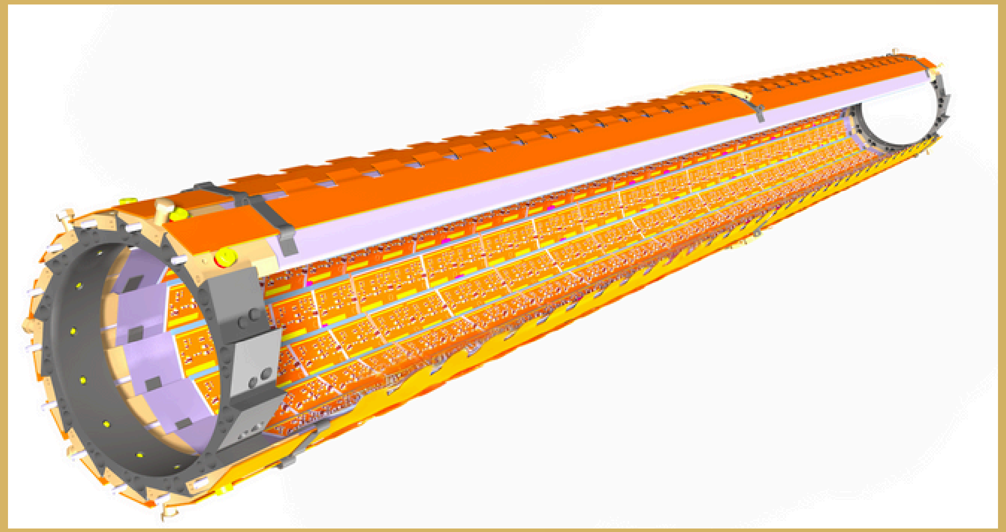
INNER DETECTOR

First part of ATLAS to see the decay products of the collisions

- The Inner Detector measures the direction, momentum, and charge of electrically-charged particles produced in each proton-proton collision.

Silicon Pixel Detectors & Silicon Strip Detectors

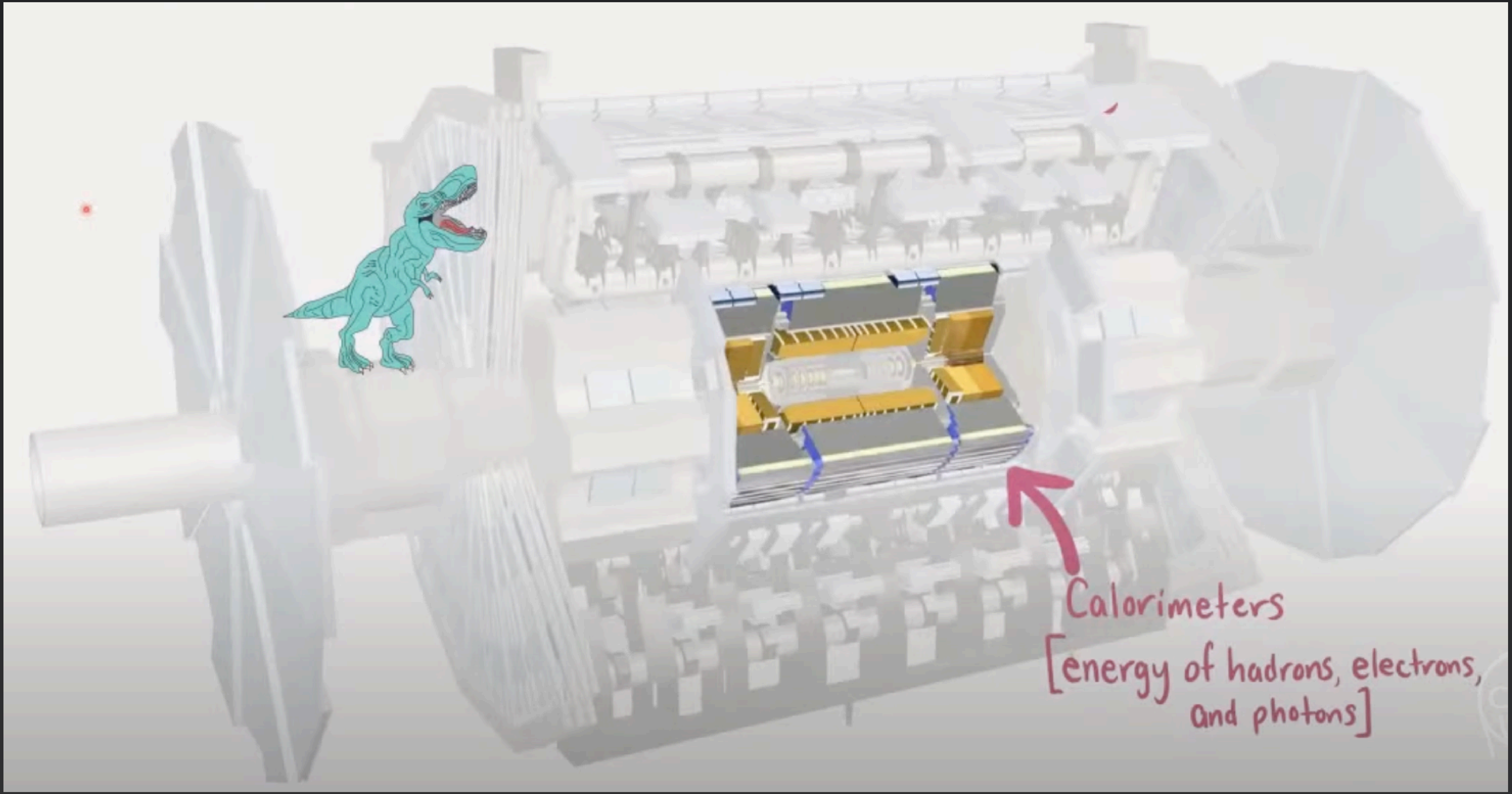
- Pixel Detector located 3.3 cm from LHC beam line
- Made of silicon pixels smaller than a grain of sand
- Contains over 92 million pixels
- Records energy deposits left by charged particles from collisions



Transition Radiation Tracker (TRT)

- The TRT is comprised of thousands of narrow straw tubes filled with gas.
- As charged particles pass through the straws, they ionize the gas inside. The ionization electrons are collected by a wire running through the center of each straw, which then measures the amount of charge and the time it took for the charge to drift to the wire, allowing the particle's trajectory to be reconstructed.
- Transition radiation helps detect high-speed electrons via their emitted radiation.

INNER DETECTOR



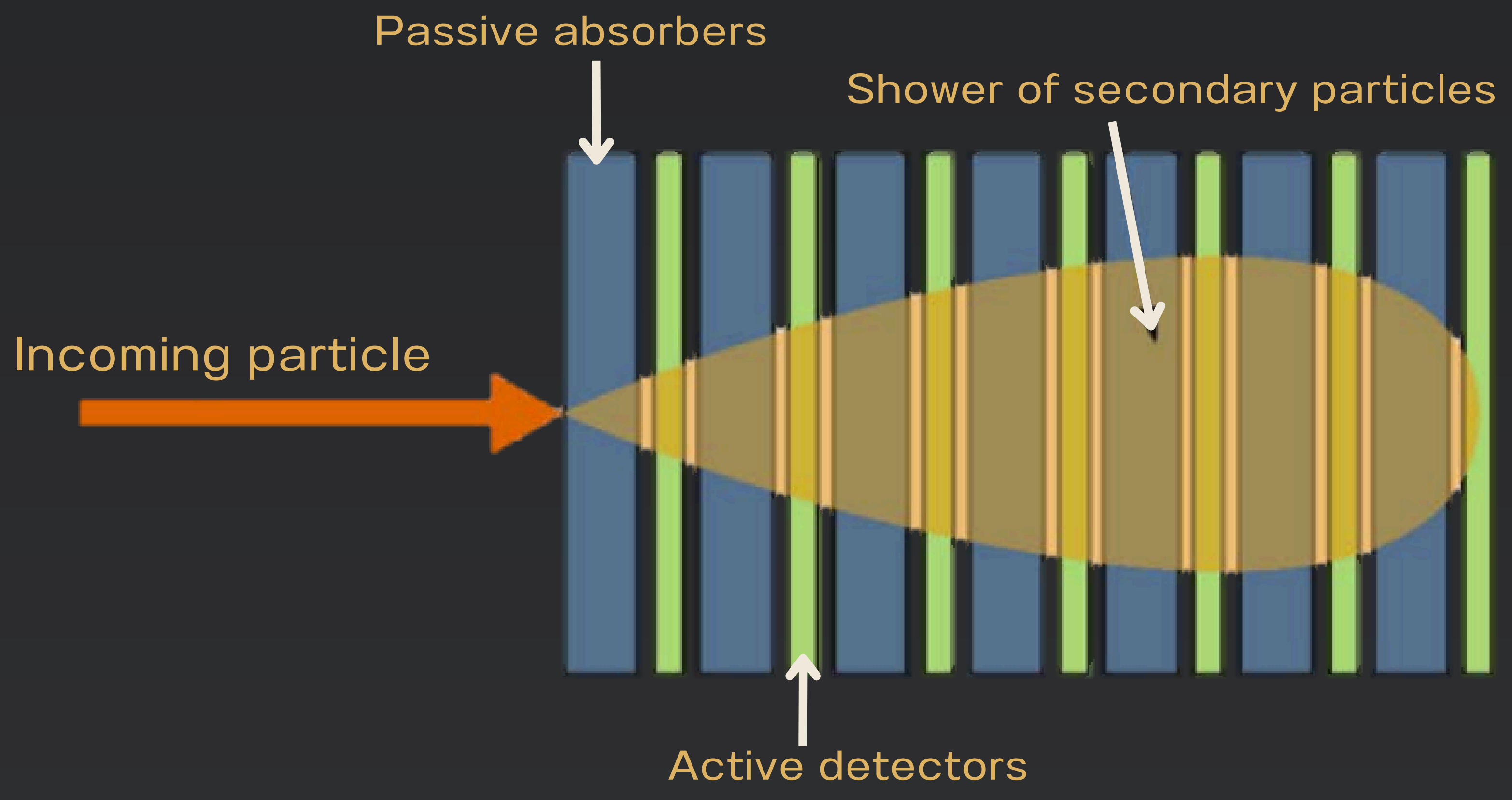
CALORIMETER

Measures the energy a particle loses as it passes through the detector

Two kinds: Electromagnetic calo — Measures energy of electrons and photons
Hadronic calo — Measures energy of hadrons

They are designed to absorb most of the particles coming from a collision, forcing them to deposit all of their energy and stop within the detector.

- ATLAS calorimeters consist of sandwiches of passive absorbers and active detectors.
- Incoming particles interact with the absorbers, converting them into new, lower energy particles.
- These new particles interact further with the absorbers, converting them into even lower energy particles.
- Cascade of reactions - particle shower!
- These particles ionize and are detected by the active material which sends an electric current proportional to the energy deposited
- By combining all of the detected currents, we can determine the energy of the original particle that hit the detector.



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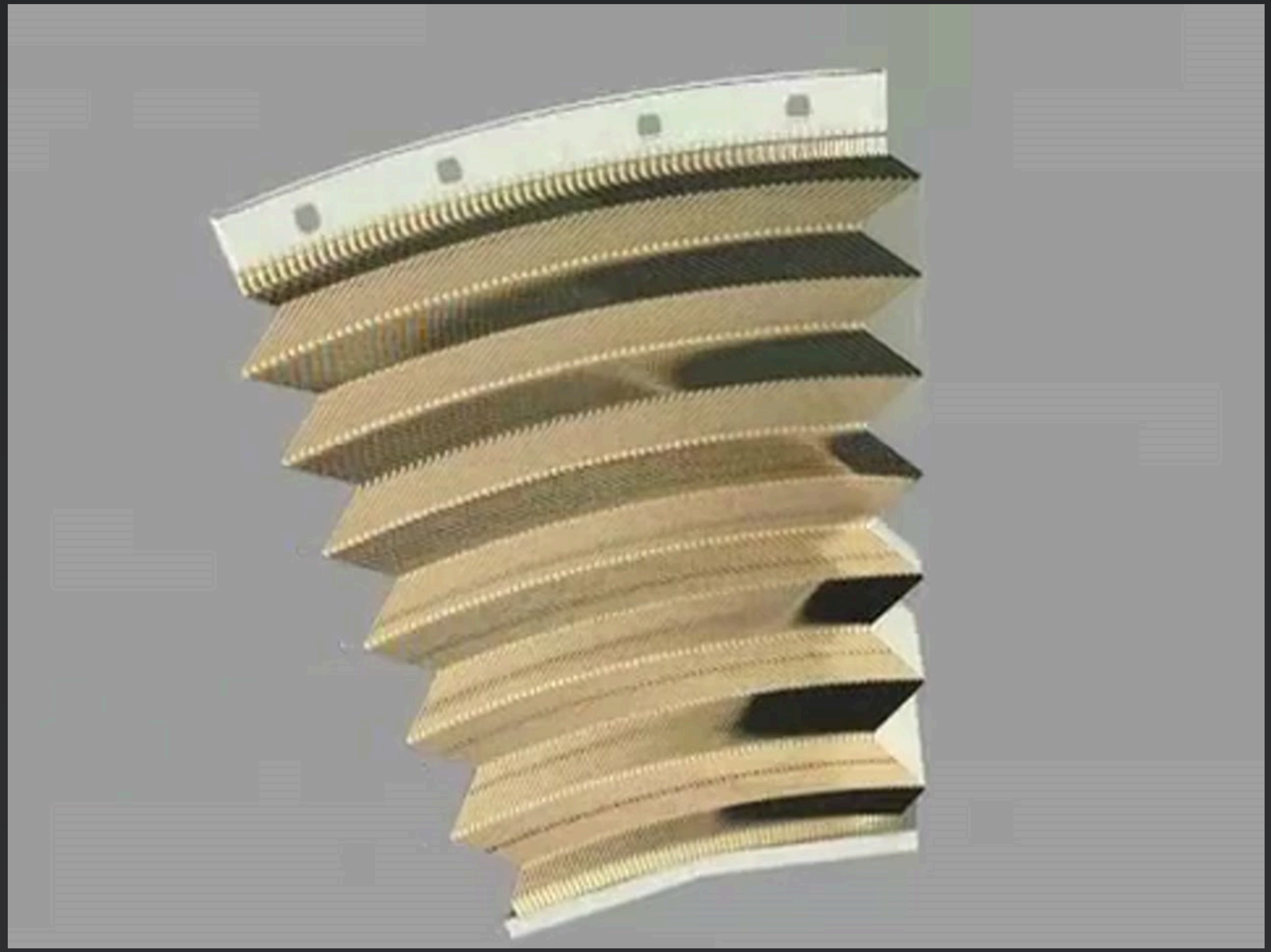
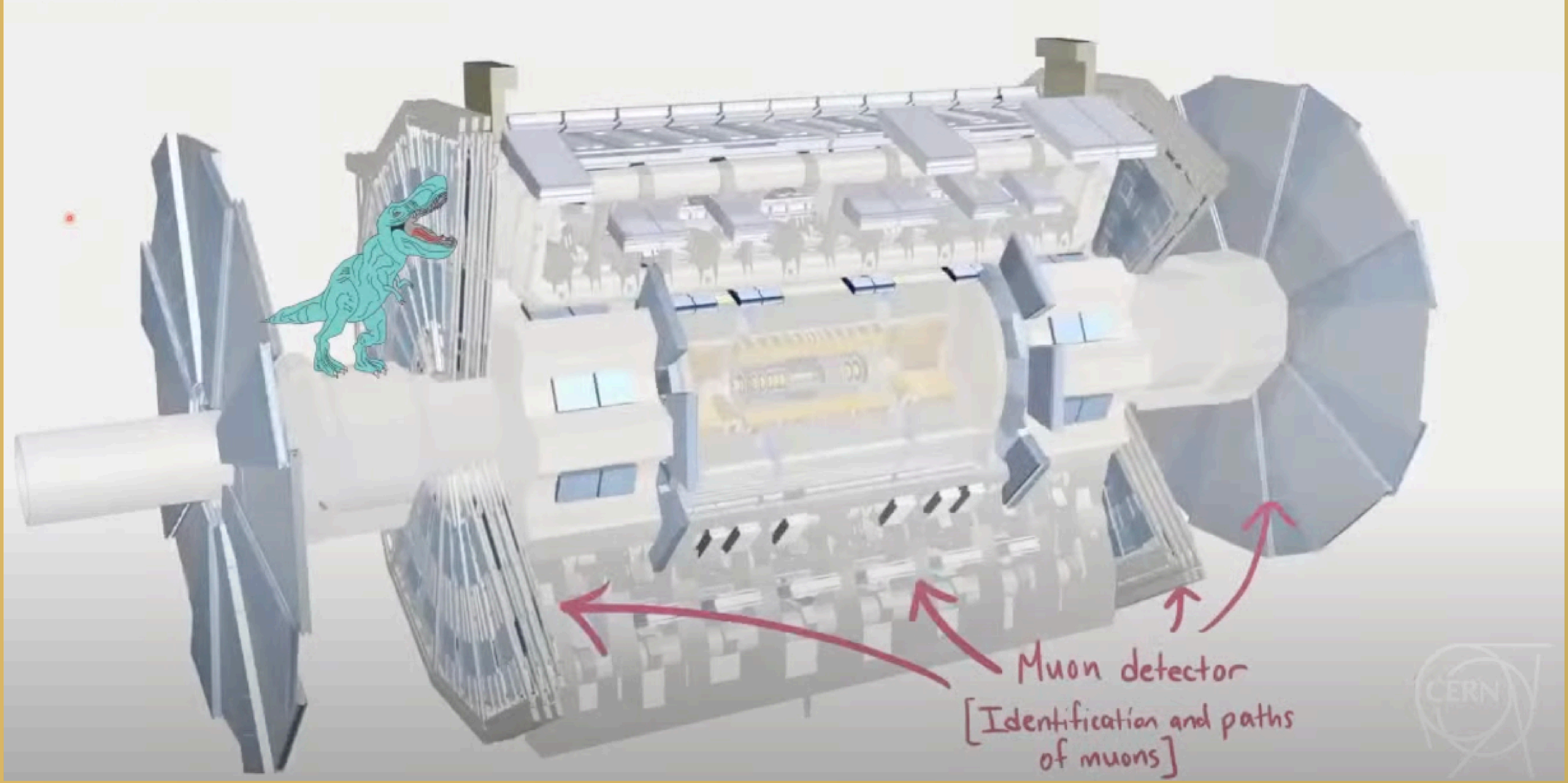


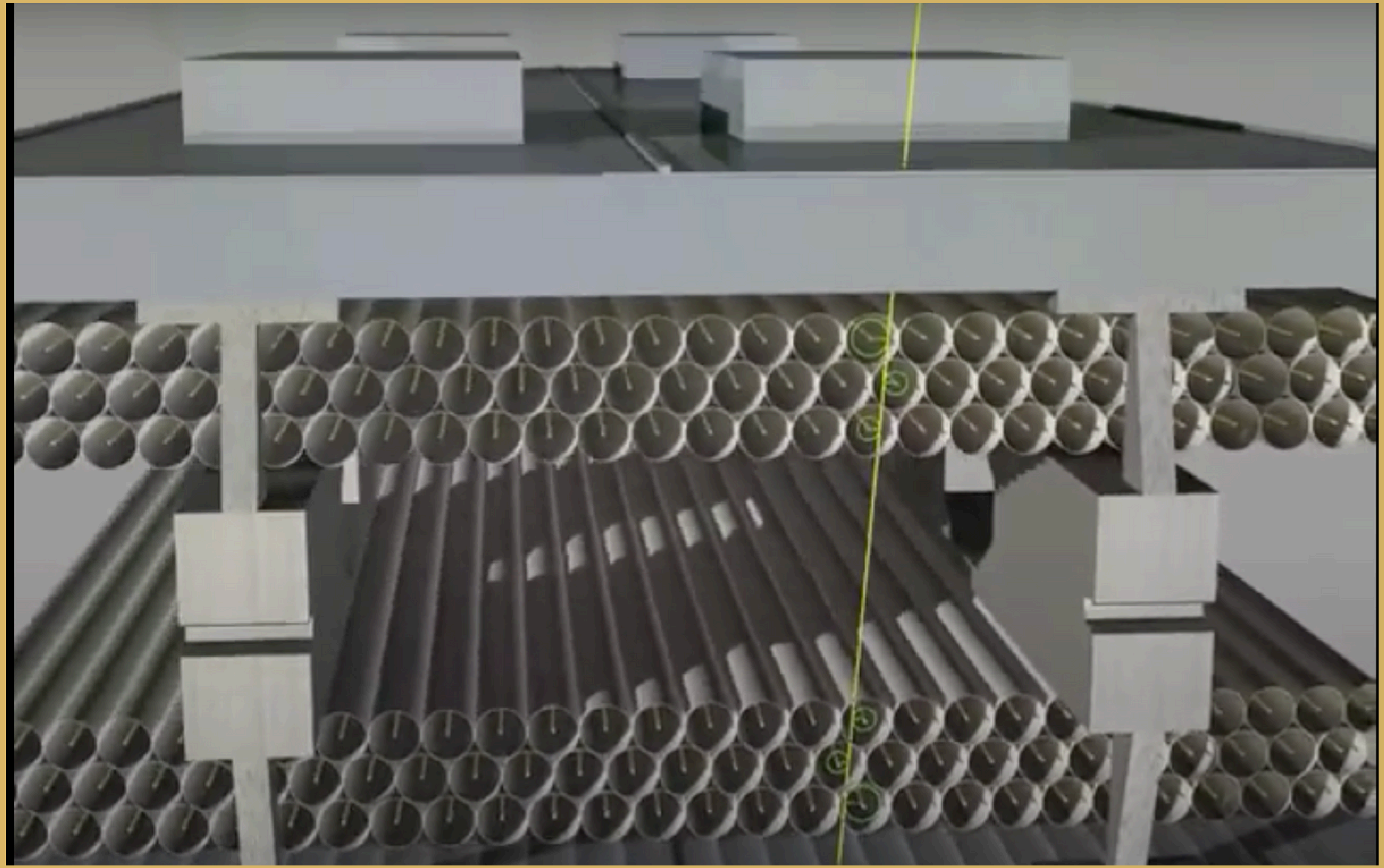
CALORIMETER



MUON SPECTROMETER

Muons are not stopped in the calorimeter and pass all the way to the outermost layers of the detector

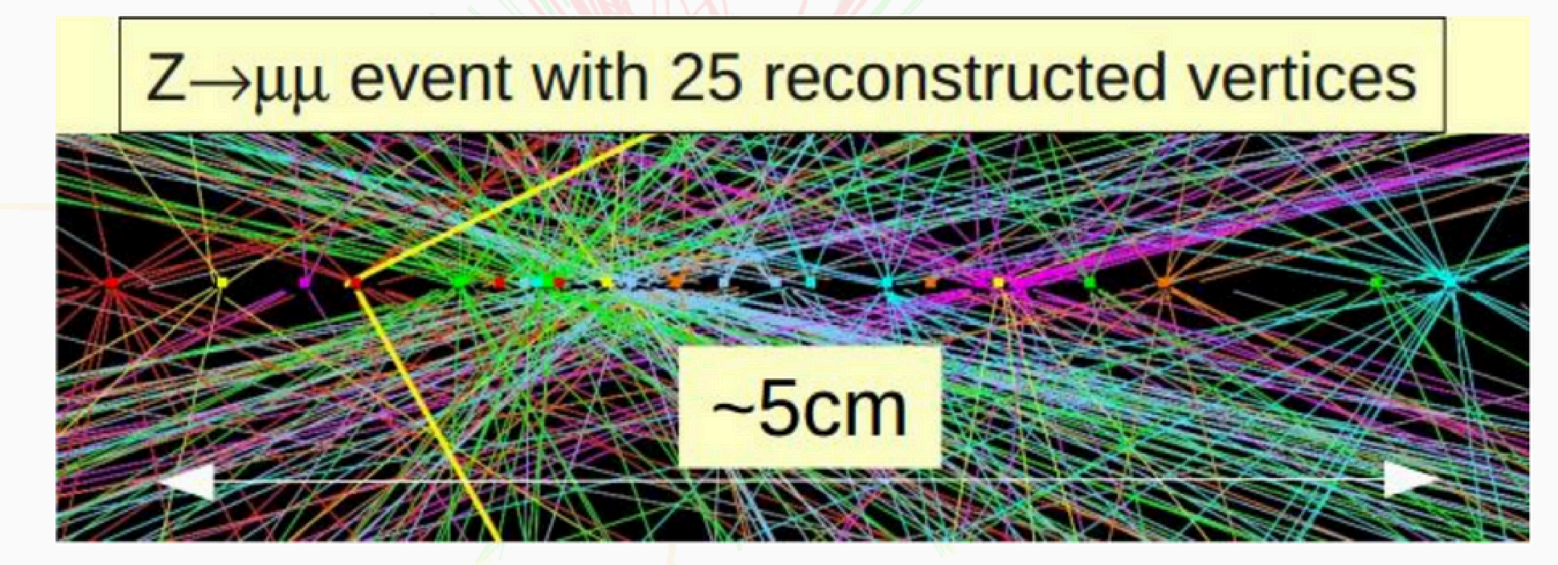
- The muon spectrometer identifies and measures the momenta of muons
- This part of the detector is huge! If spread out flat, it would cover the surface of several football fields



- One part of the muon chamber has small gas-filled tubes.
- Muons create charged ions and electrons in the tubes, which drift to the tube's sides and center.
- Measuring the drift time helps determine the muon's position.

MUON SPECTROMETER

We can detect a lot, but it's not that simple



It is busy!

- 1 billion collisions per second, surely we can't collect all of the data, all of the time? No we can't. We have to select which events we want to save.
- All detector systems feed into a central trigger system, that very (very) quickly (and roughly) analyzes the energies, and decides if this is an interesting physics event and worth keeping.

It is noisy!

- Recall there are several collisions happening at a bunch crossing.
- All of these will be picked up by the detector, but most of them are not "interesting" physics
- Usually only care about one of these, the most energetic collision.
- We can create filters post-detection to remove unnecessary low energy particles

It relies on collaboration and ingenuity!

- Having the detector output is just one part of the puzzle.
- Reconstructing the event from the output requires deep understanding and transfering knowledge from different teams.
- You will help us today!!

MISCELLANEOUS

THE TAKEAWAY SLIDE