

The background features a dark grey to black gradient with several overlapping circular elements. These include solid and dashed lines forming concentric circles, some with arrows indicating a clockwise direction. A large circular scale with numerical markings from 140 to 260 in increments of 10 is visible on the left side. The text is centered in a clean, white, sans-serif font.

WORKING GROUP 4  
USING CERN ANIMATIONS IN THE CLASSROOM  
FINAL PRESENTATION  
FOCUS AGE 13-16 YRS

# OVERVIEW

## Project 1:

- Writing a storyboard for a new animation to use with cloud chambers

## Project 2:

- 4 short lesson plans which use at least 1 animation per lesson to explain the main physics of CERN – approx. total teaching time 2.5 hours.

## Project 3:

- Developing a teaching resource to assist teachers using animations who have little particle physics knowledge to communicate the physics of CERN.

## Project 4:

- Animation storyboard developed to link CERN physics with real world applications.

# PROJECT 1 – STORYBOARD

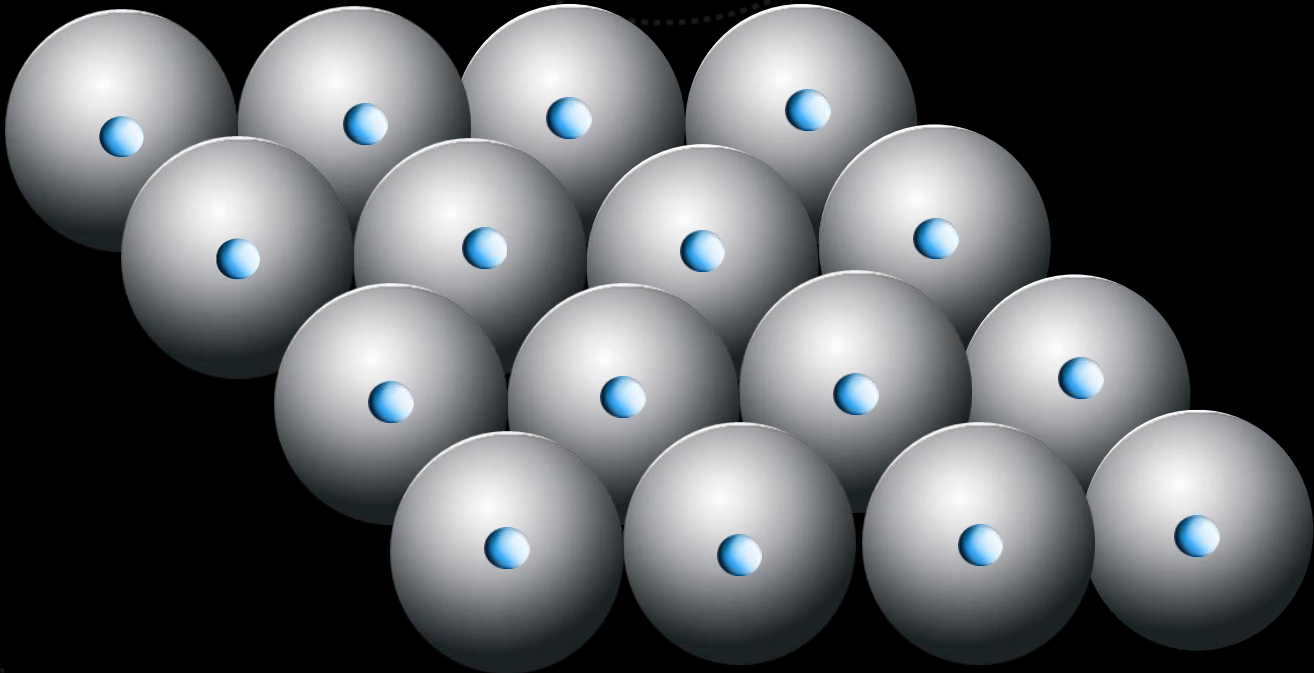
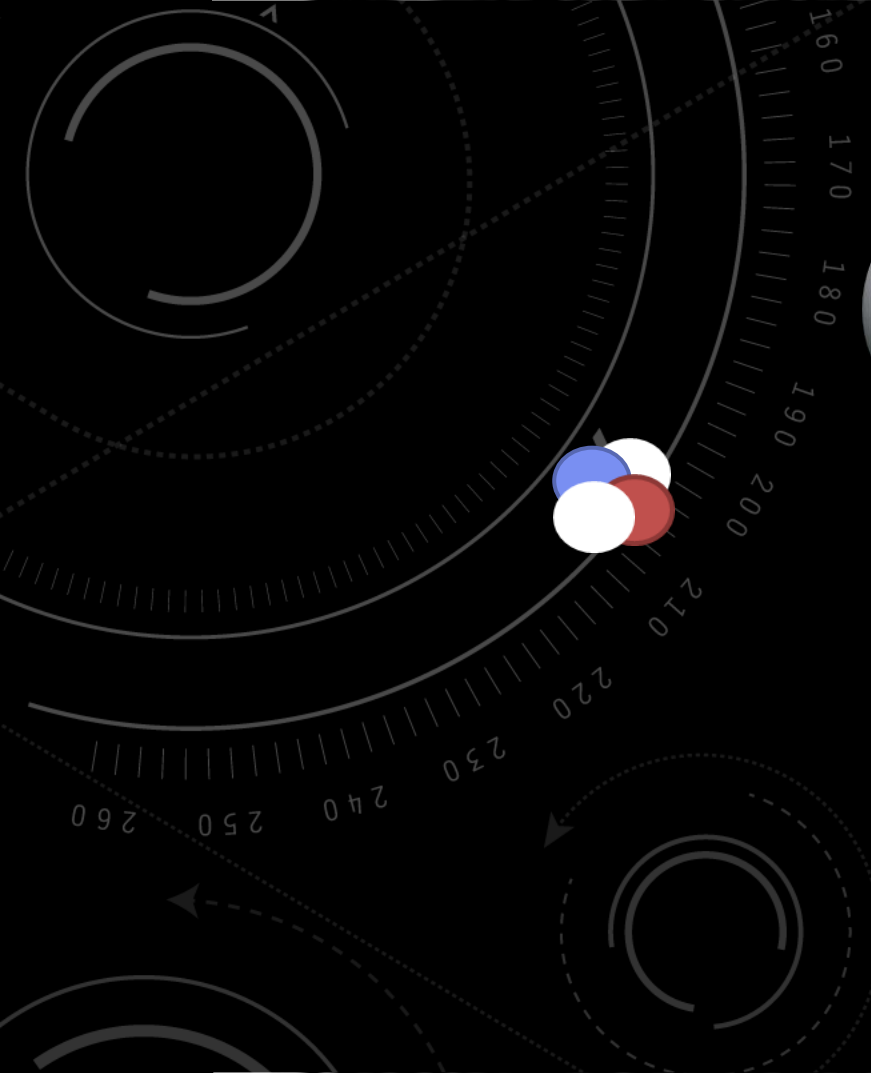
## PHIANKIT, SARAH, SARAH

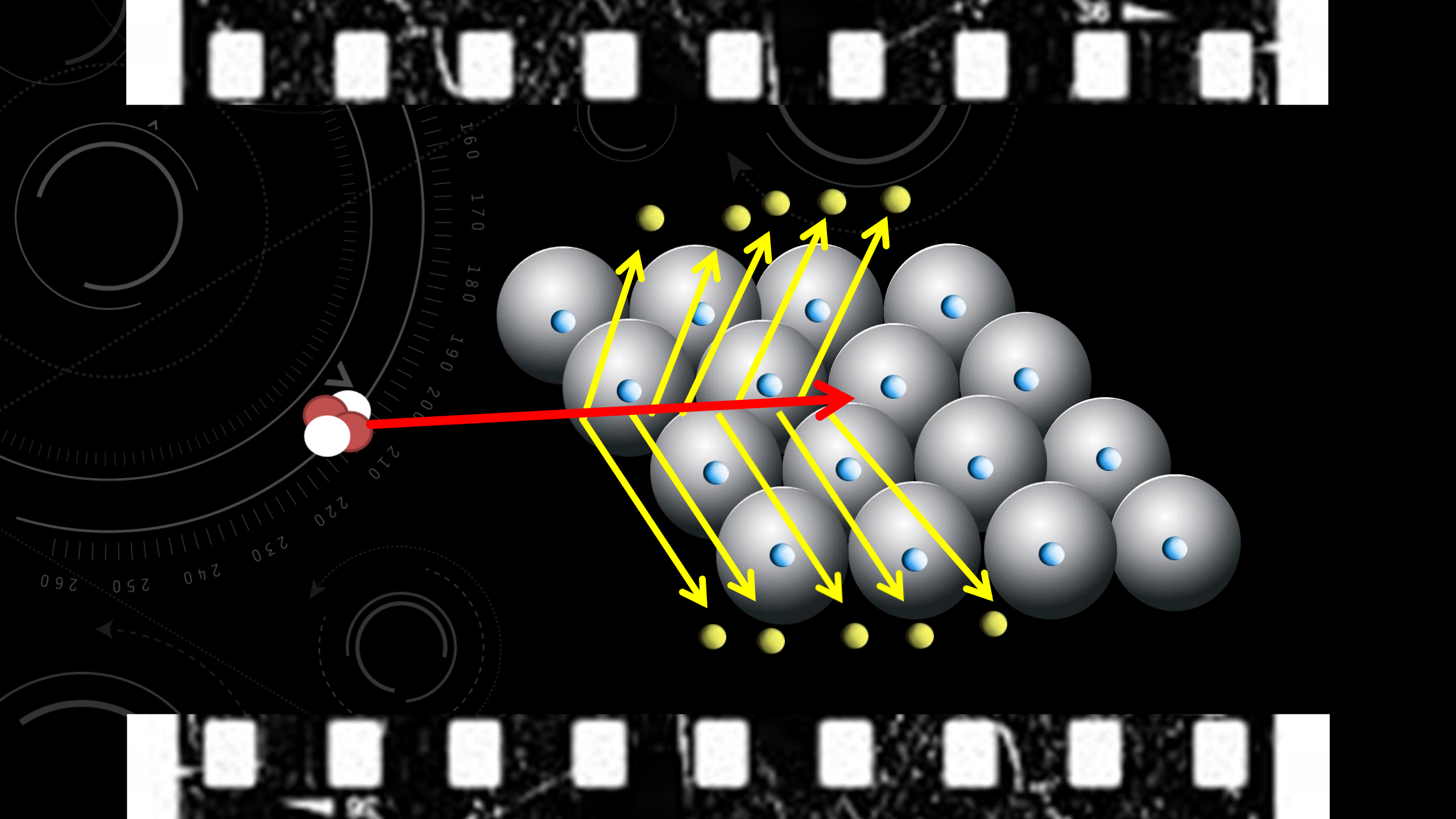


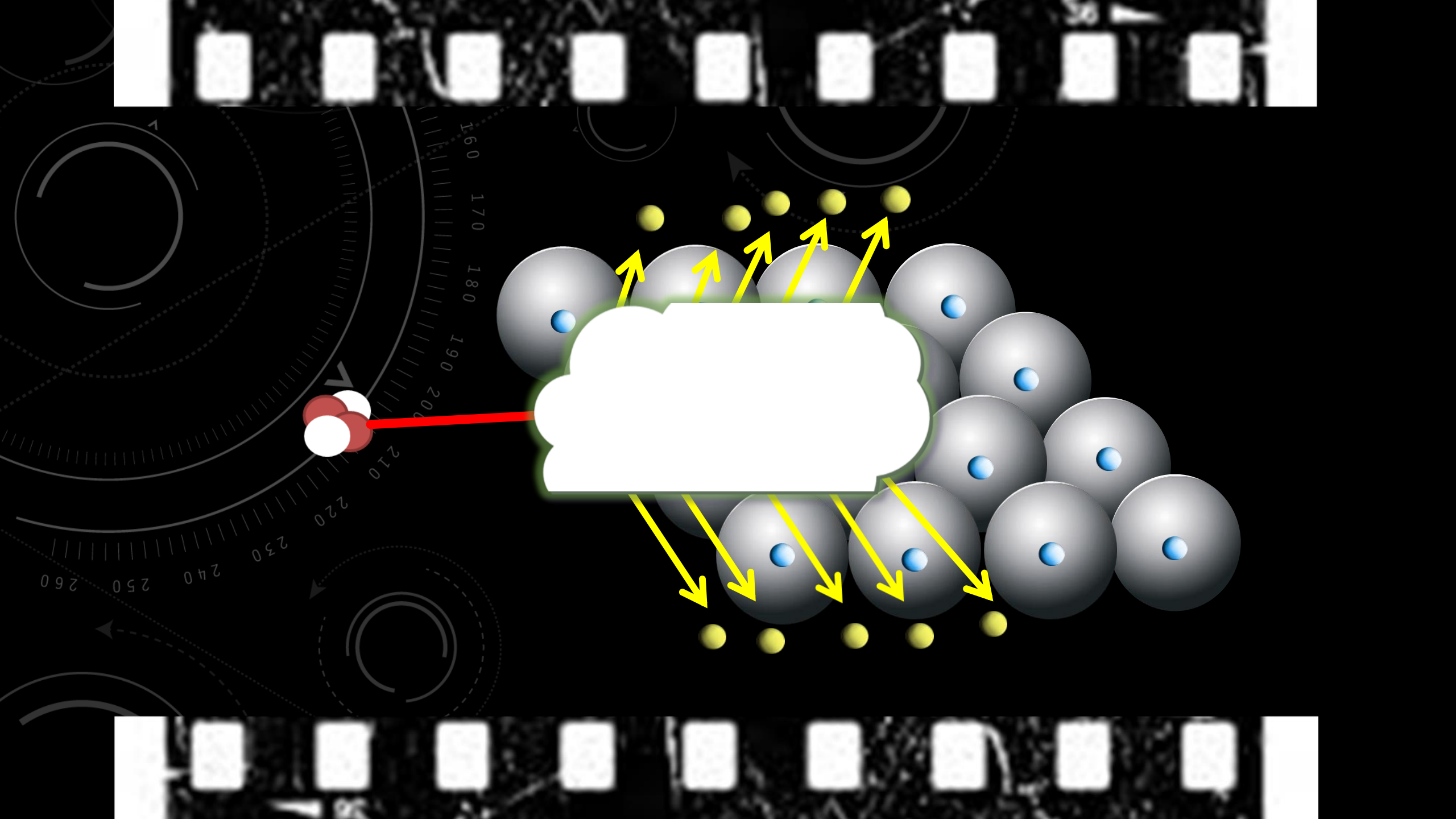
A photograph of a theater interior. The foreground is filled with rows of red seats. In the center, a large white screen displays the title 'THE CLOUD CHAMBER' in white, bold, sans-serif capital letters. The theater has a dark ceiling with several rows of small, warm-toned lights. The walls are a muted red color. On the right side of the image, there are faint, white, circular and linear patterns, possibly representing a technical or architectural diagram. On the left side, there are some faint, white, circular patterns and a small arrow pointing left.

# THE CLOUD CHAMBER



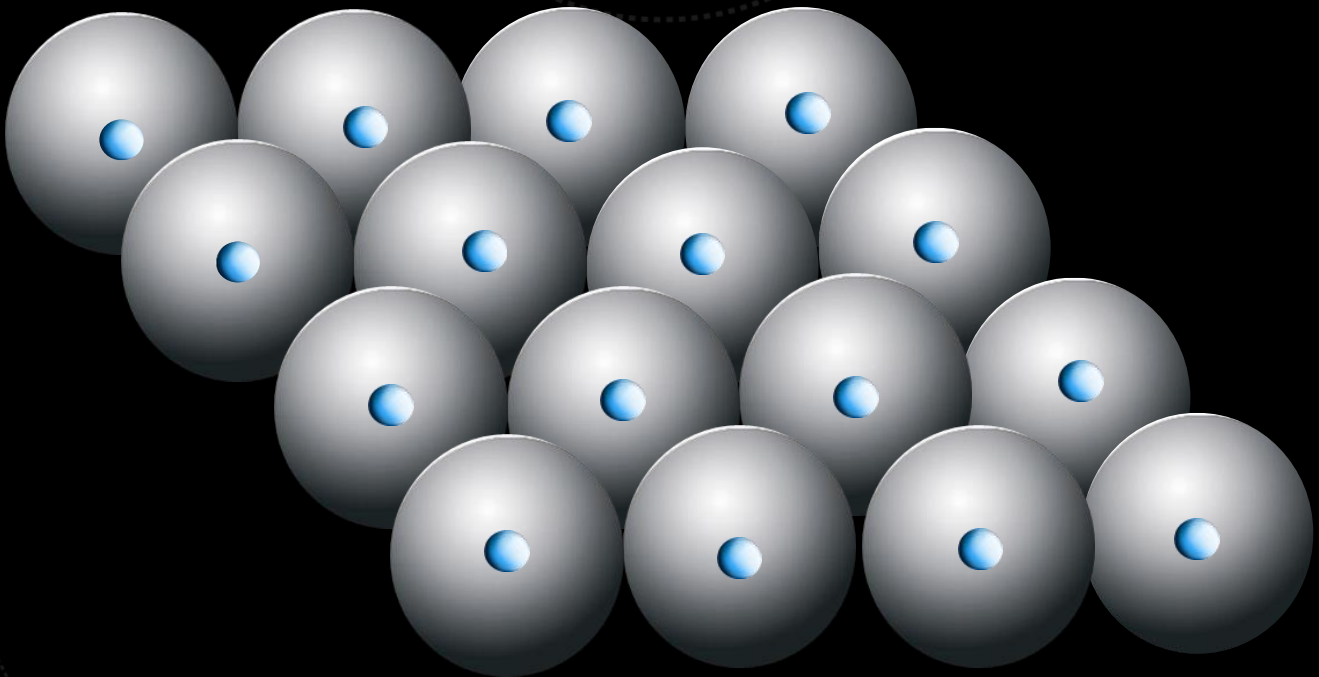


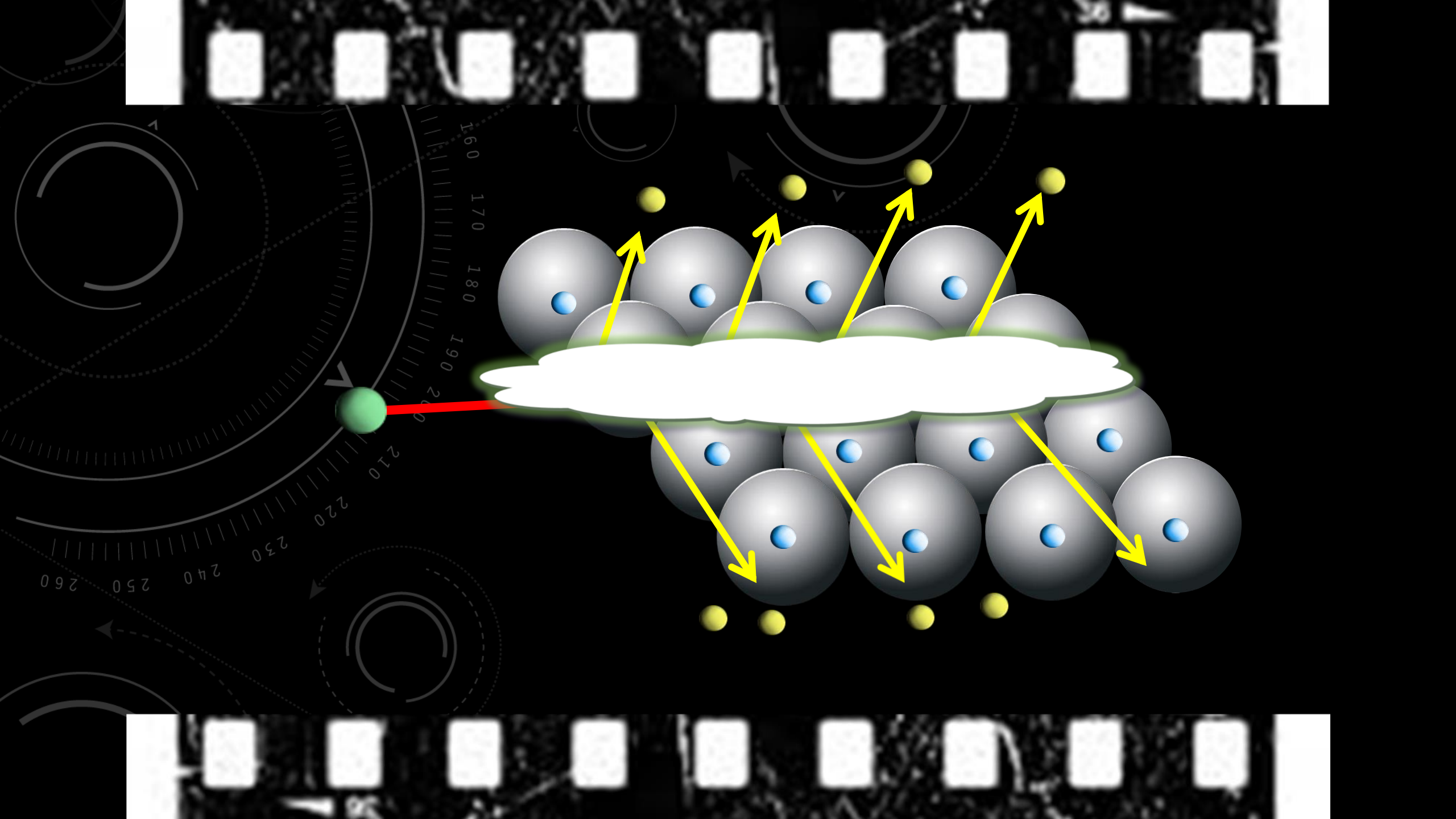




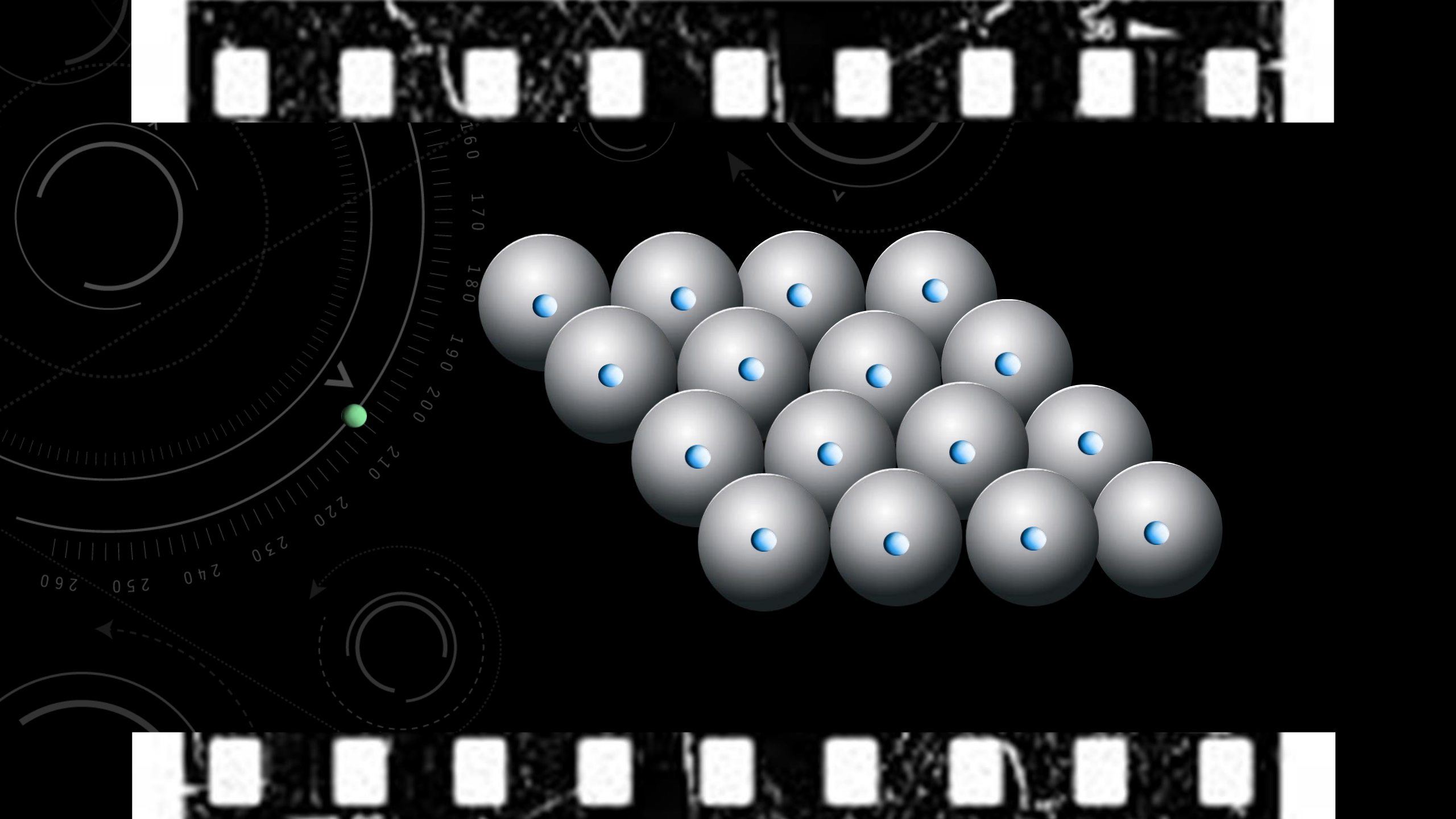


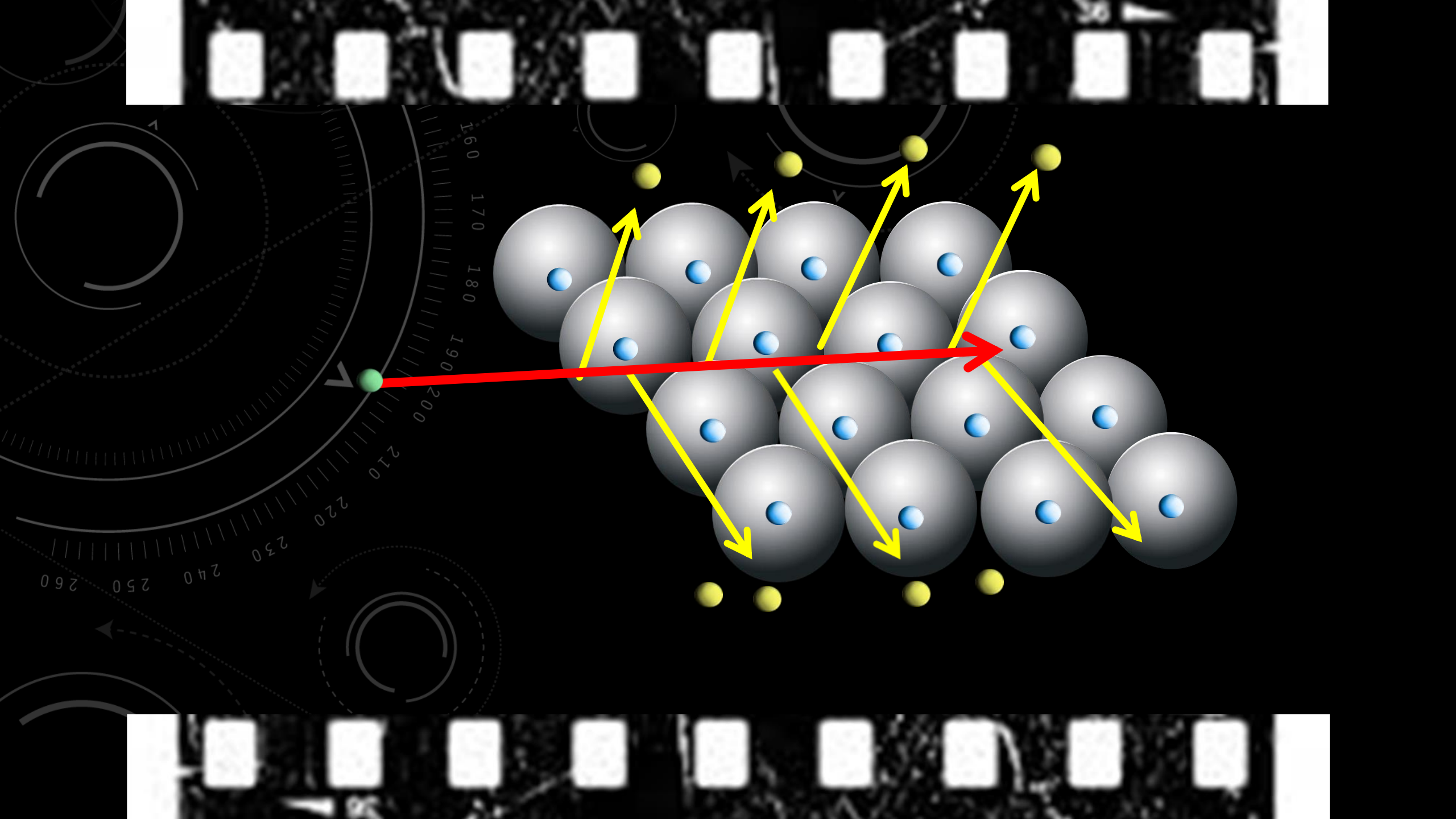


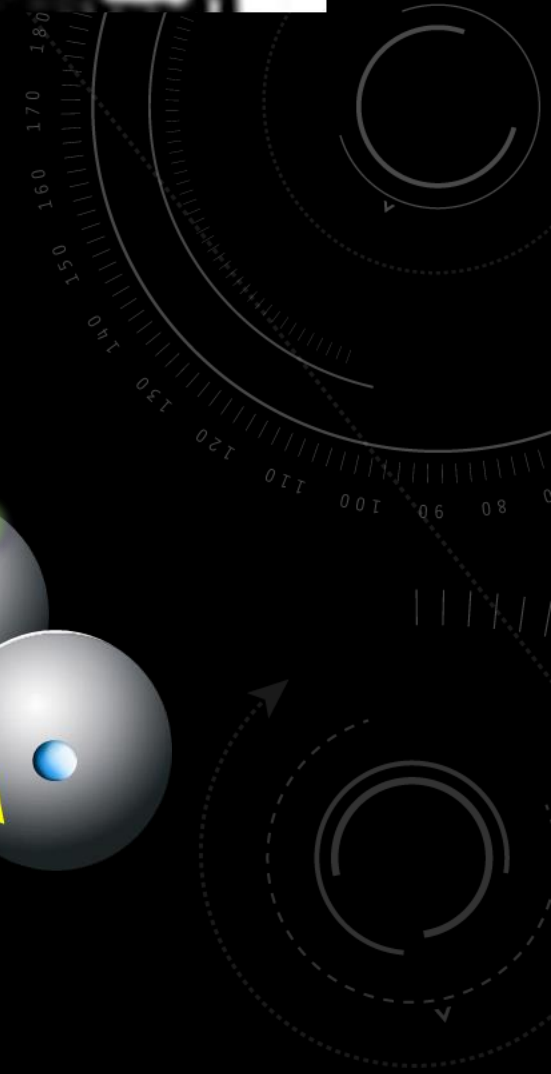
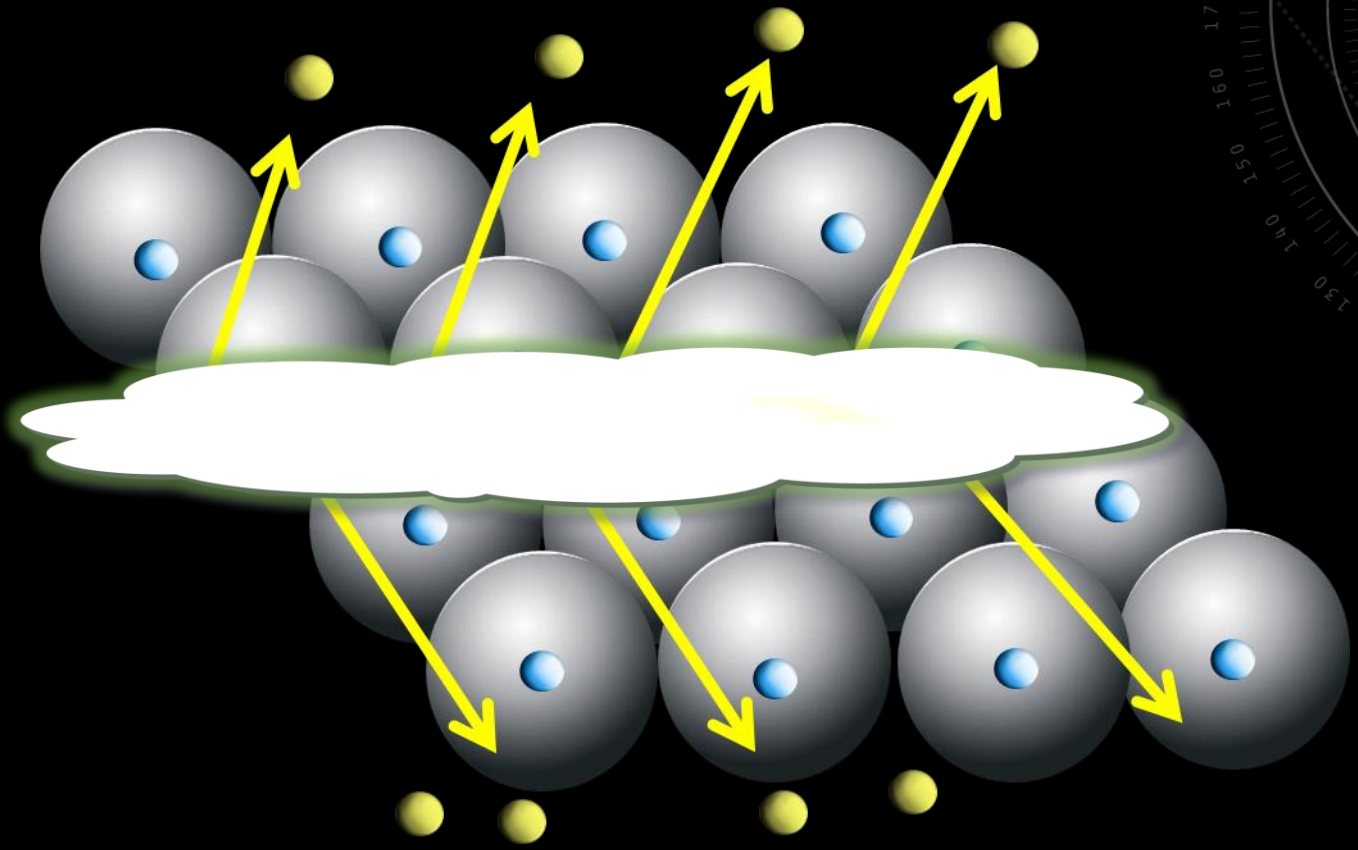


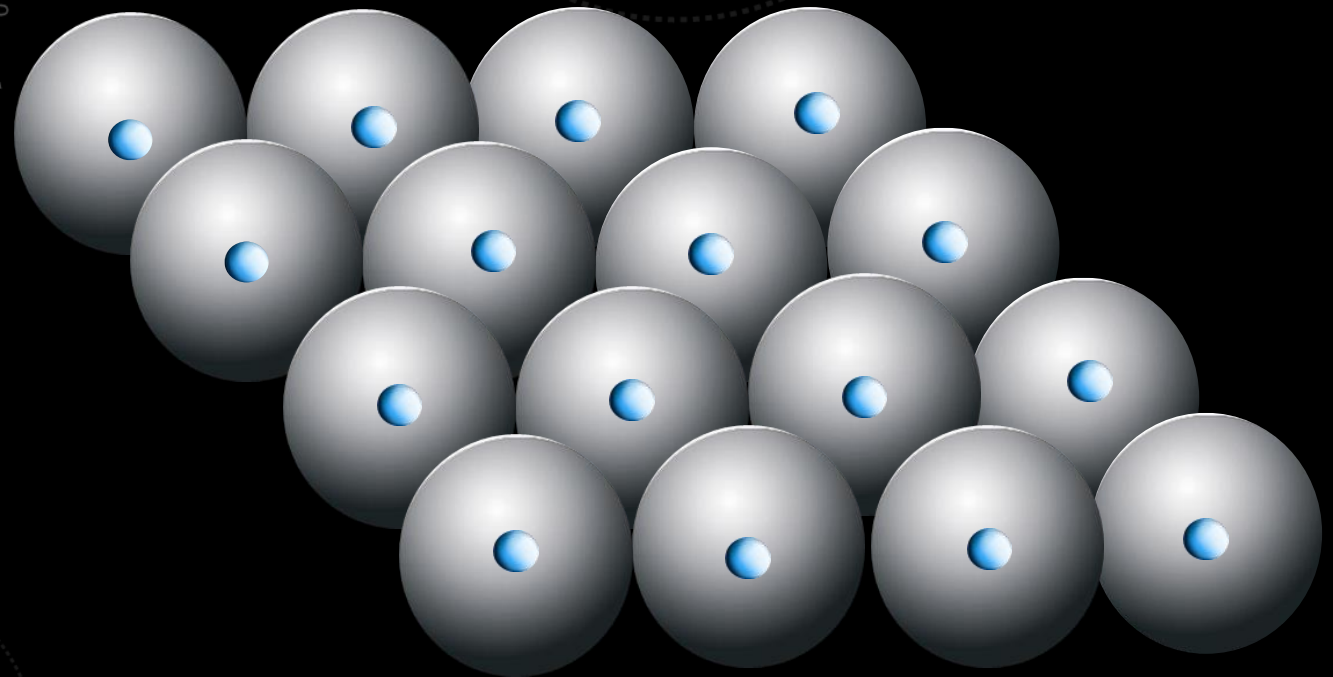




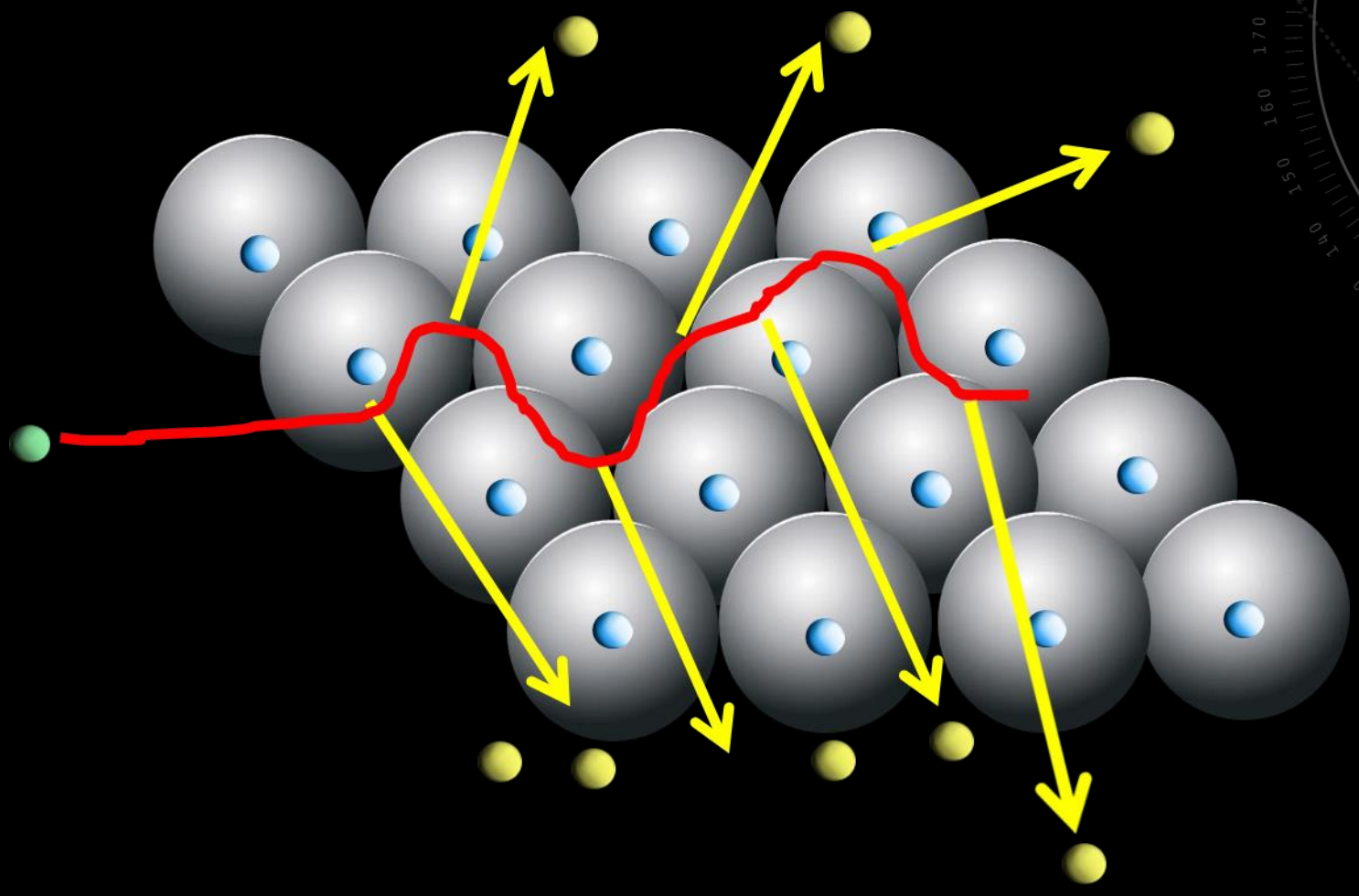


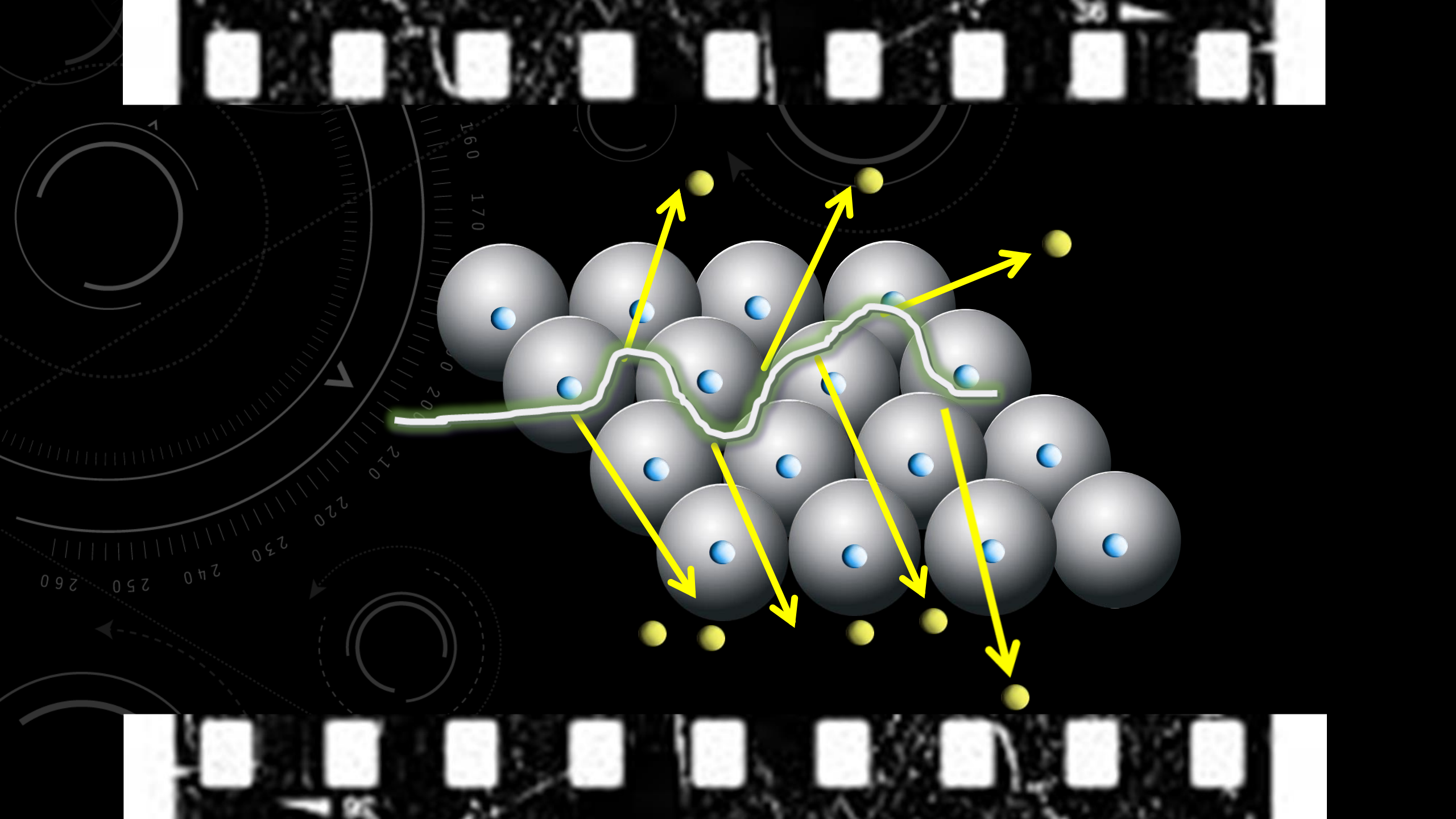














Alpha-Particle

Fast electron or muon

Slow electron

Thank you!!

The background features a dark grey to black gradient. On the right side, there is a large, semi-circular scale with numerical markings from 80 to 210. Several concentric circles and dashed lines are scattered across the page, some with arrows indicating a clockwise or counter-clockwise direction. The text is centered in the middle of the page.

PROJECT 2 LESSON PLANS  
ANA, ANA, ELEANOR

# SECTION 1: INTRODUCING CERN

AFTER COMPLETING THIS LESSON THE STUDENT WILL BE ABLE TO:

- EXPLAIN WHAT CERN IS WORKING TOWARDS AND WHY IT WAS CREATED
- IDENTIFY THE MEMBER STATES
- DESCRIBE THE COLLISION AND SOME OF THE DIFFICULTIES IN COLLIDING PROTONS

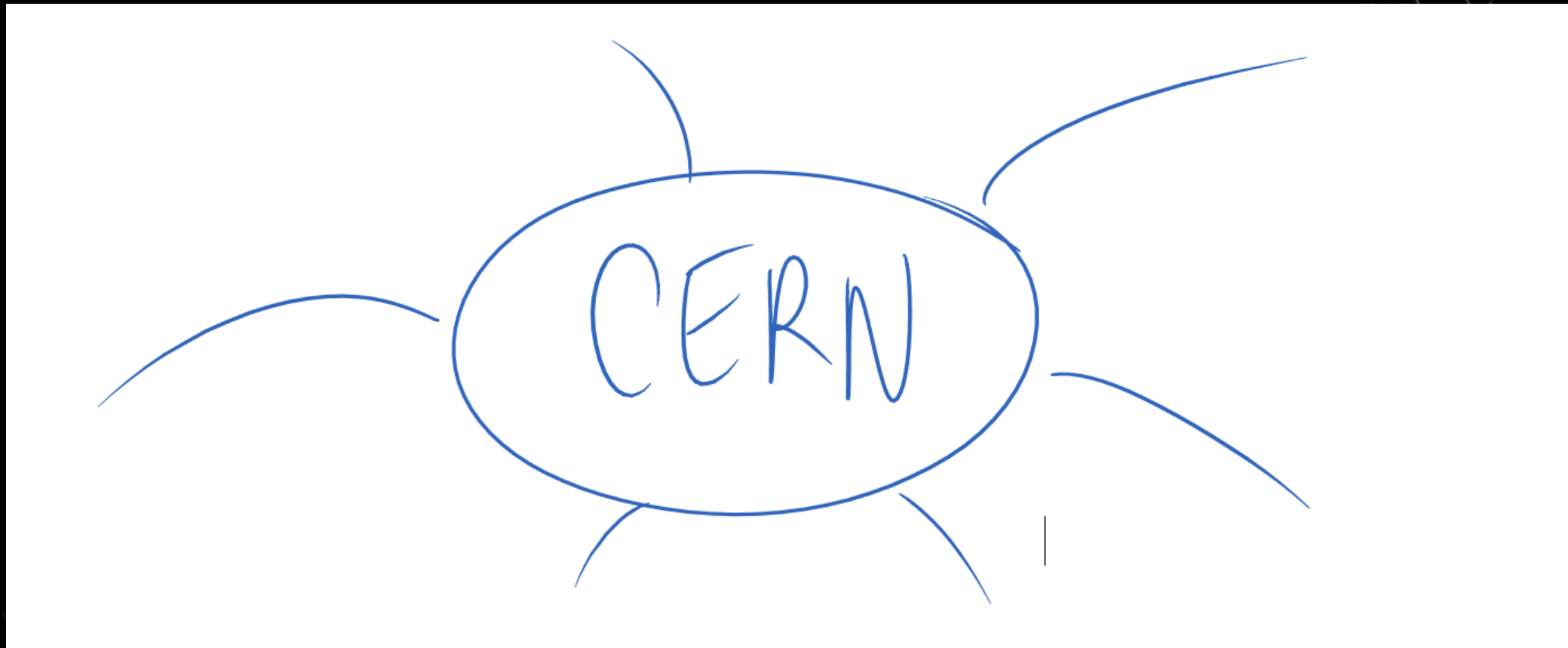
LEVEL

- ELEMENTARY

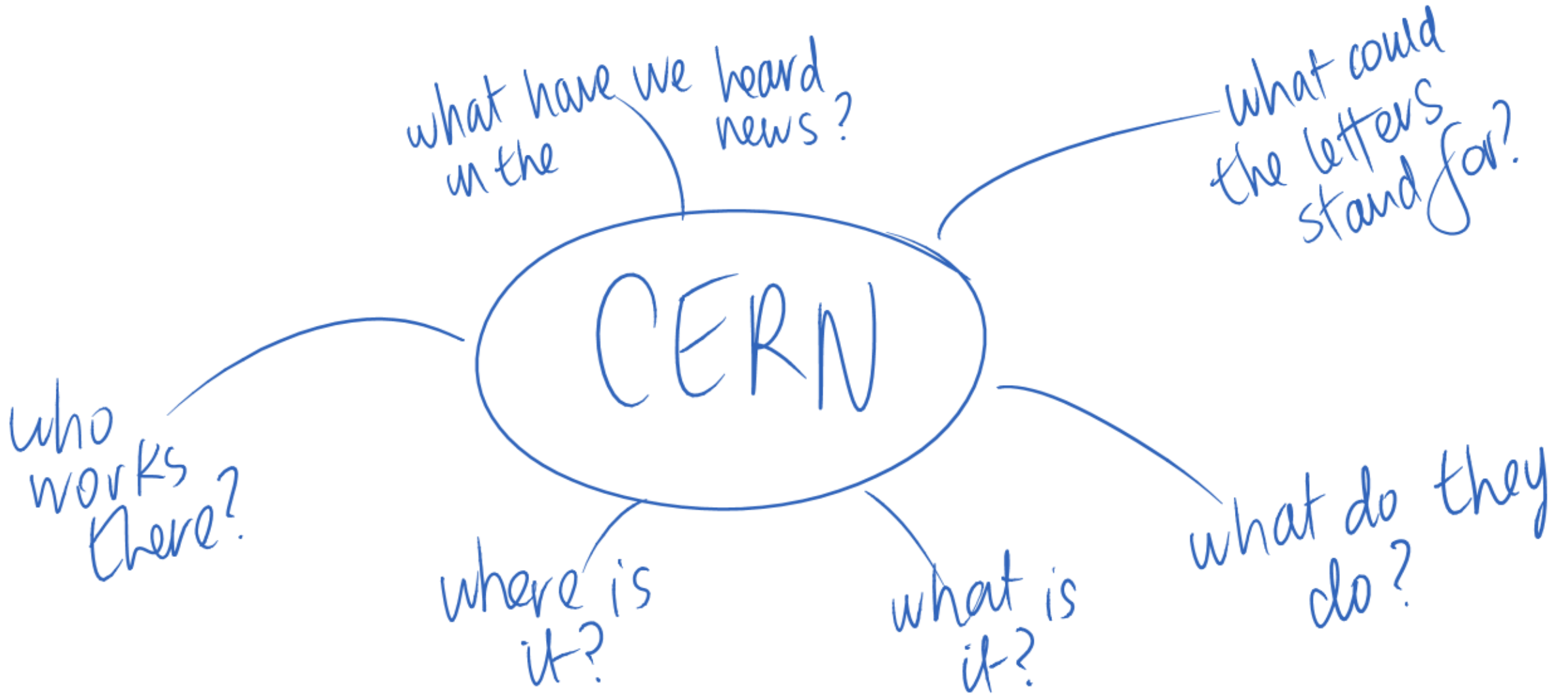
TIMING

- ONE CLASS SESSION
- ONE HOMEWORK ASSIGNMENT

# FIRST IDEAS



# SOME PROMPTS





## MEMBER STATES

Member states have special duties and privileges.

They make a contribution to the capital and operating costs of CERN's programmes, and are represented in the council, responsible for all important decisions about the organization and its activities.

# WHO IS A MEMBER?



# DISCUSSION POINT

Q1 What does CERN stand for?

## CERN

*Centre Européen pour la Recherche Nucléaire*

**European Centre for Nuclear Research**

### NEW KEYWORDS

Nucleus

Protons

Collision

Accelerator

Detector

European – Why Switzerland? How do the member states discuss ideas?

Is it useful to involve many countries? Advantages/Disadvantages?

Is there a similar organisation anywhere else?

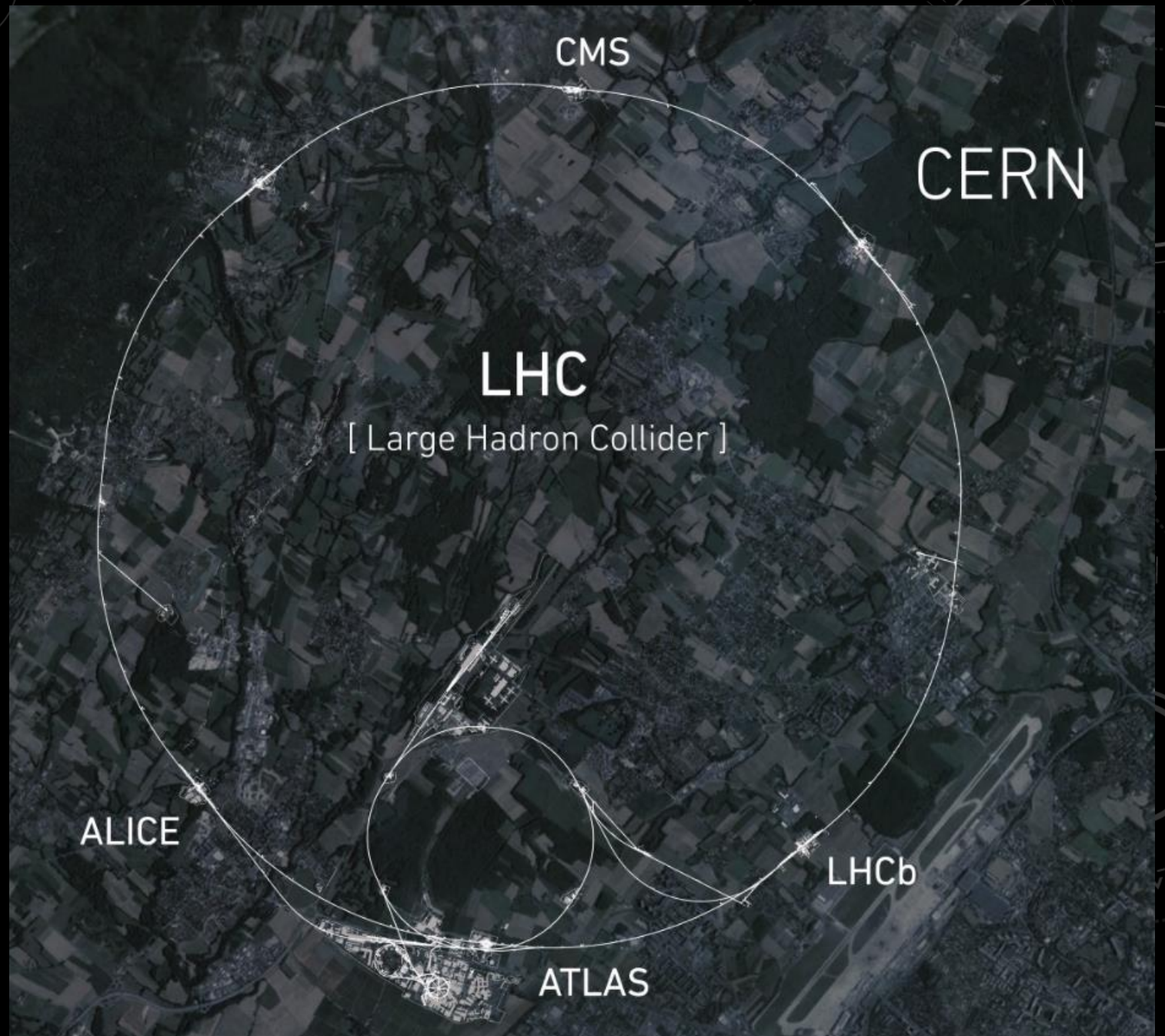
Nuclear – what does this mean? What is a nucleus?

Where is it? Can you see it? Is it related to you?

Should we know about it?

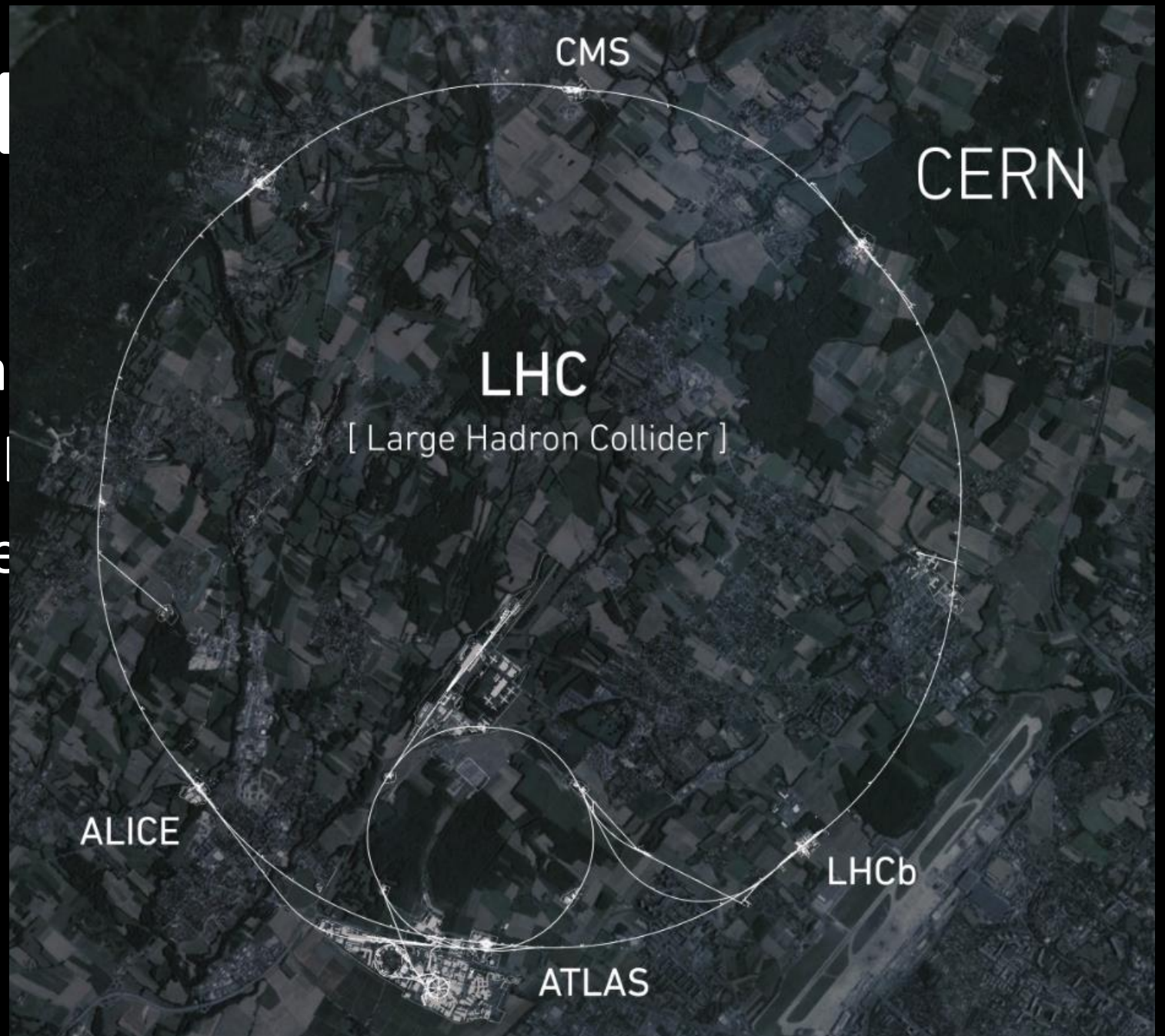
# ANIMATION

- <http://cern60.web.cern.ch/en/exhibitions/animations>

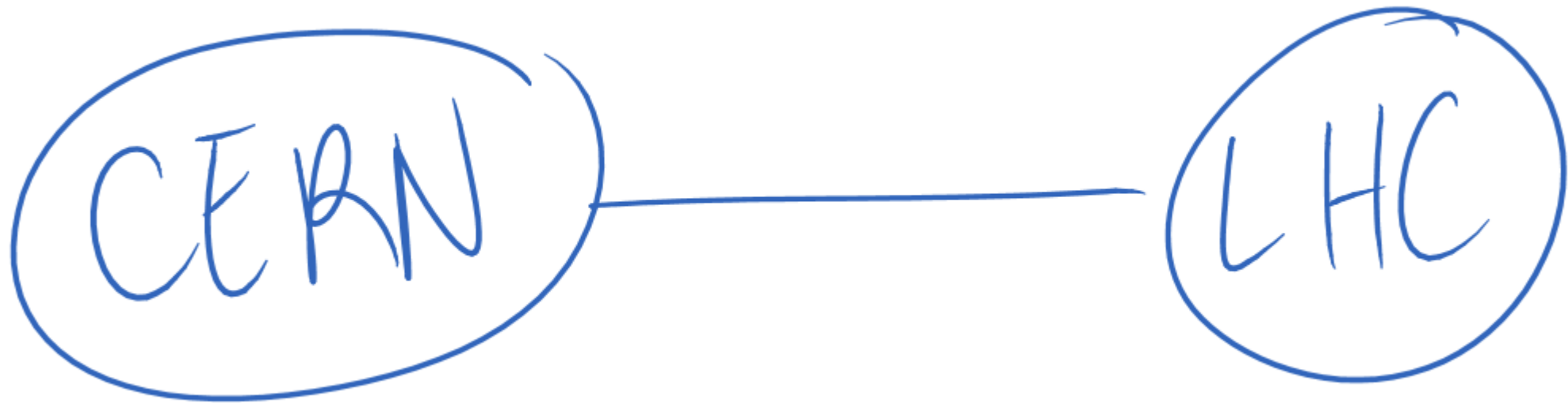


# SOME

- What did we notice a
- What is the little brigl
- Do they collide in one
- Why is this?
- What happens when



# QUICK REVIEW – WHAT ARE THEY?

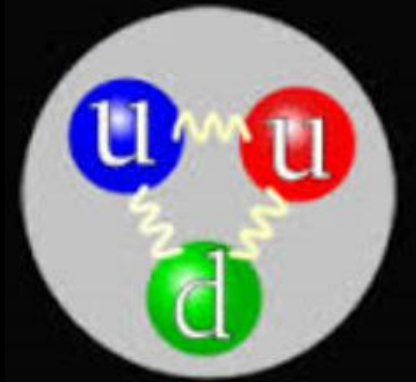


# LHC - LARGE HADRON COLLIDER

- The LHC collides hadrons 40 million times a second!
- The hadrons used are protons which are made up of 3 quarks.
- Is it easy to collide a beam so small?

**HADRON:** An atomic particle made up of quarks.

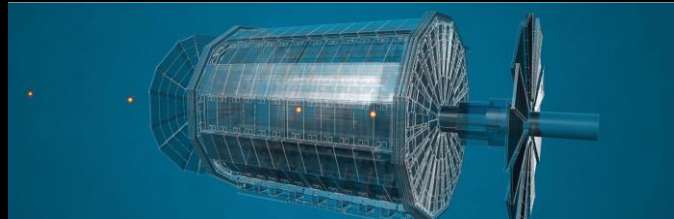
Proton Structure



# ACTIVITY: MAKE YOUR OWN COLLIDING BEAM!

## INSTRUCTIONS:

- Carefully pull out 1 hair and cut the hair to 2cm long.
- Hold the hair between fingers and try to collide with hair of partner.



- Is it easy to collide them?
- What techniques help?

## To Think About – Discussion Points

- If there is only half the particles in the same piece of hair what can we conclude about the space between them?
- Are the particles in the hair bigger/smaller than protons? Explain.
- Is it easy for the protons to collide?
- How many do you think collide each time?

Item	No. of particles (Average)
Hair (2cm)	18,000,000,000,000
Protons (Per Bunch)	40,000,000



# FURTHER RESEARCH – HOMEWORK TASK

- Q: How long is the LHC?
- Q: What is the shape of the LHC?
- Q: When was it founded and who came up with the idea?
- Q: Can you find another organisation which is a similar international collaboration for Science?

# SECTION 2: ACCELERATING PARTICLES.

AFTER COMPLETING THIS LESSON THE STUDENT WILL BE ABLE TO:

- KNOW THE EQUIVALENCE MASS-ENERGY.
- IDENTIFY CERN'S ACCELERATOR COMPLEX
- READ AND SUMMARIZE INFORMATION TO CREATE A TIME LINE.

LEVEL

- ELEMENTARY

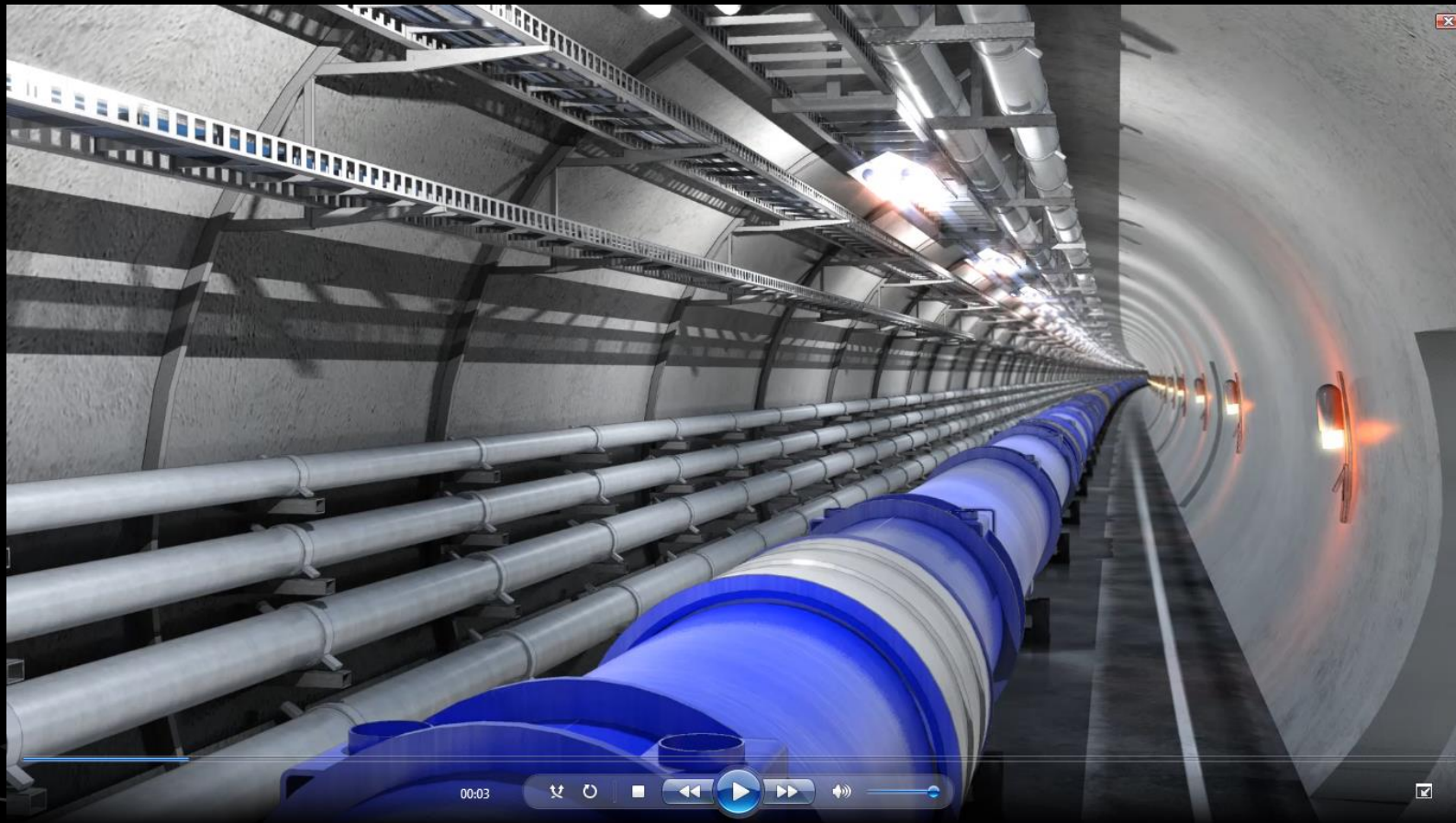
TIMING

- ONE CLASS SESSION
- ONE SELF-STUDY SESSION

# LET'S START WITH AN EASY ANALOGY



# PREVIOUS IDEAS



Why do we need to  
accelerate particles?

Because...

CMS collision.

From <http://cern60.web.cern.ch/en/cern-exhibitions-content>

LOOK AT THIS CLUE  
THE MOST FAMOUS EQUATION IN THE WORLD IS ...

$$E = mc^2$$

?

# DISCUSSION

E means...

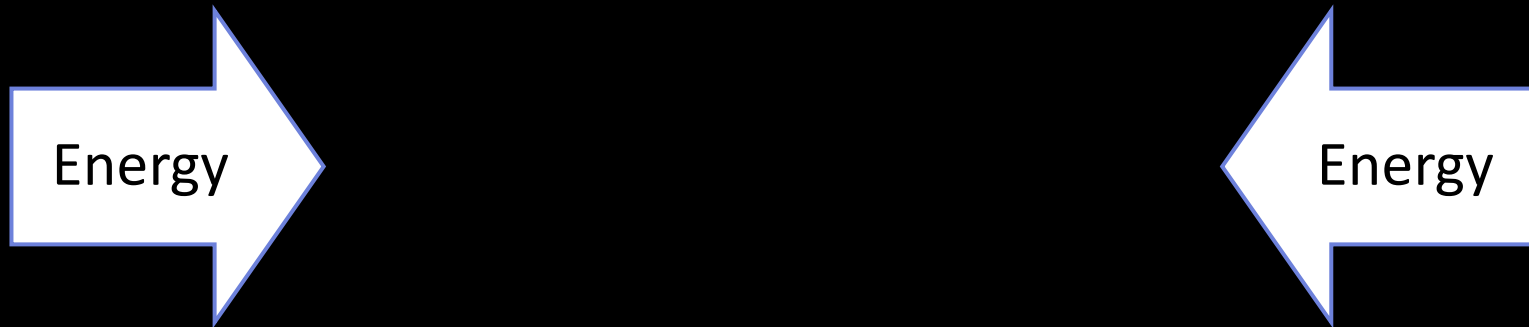
m means...

c means...

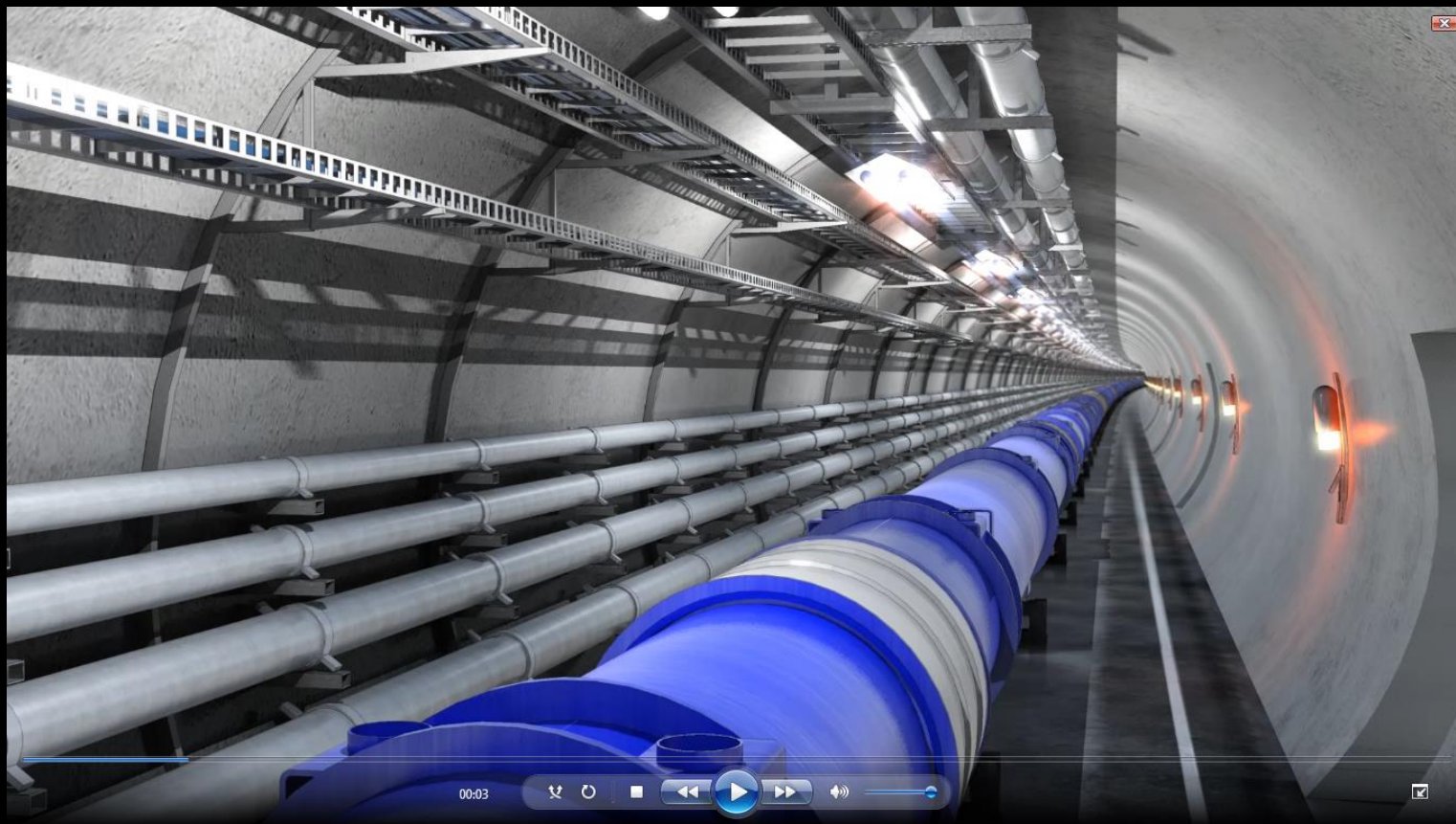
# EXPLANATION

In order to get enough energy to produce new particles, we should accelerate protons. They travel almost at the speed of light in opposite directions when the collision happens.

The more energy, the more mass and therefore the more particles we will produce.

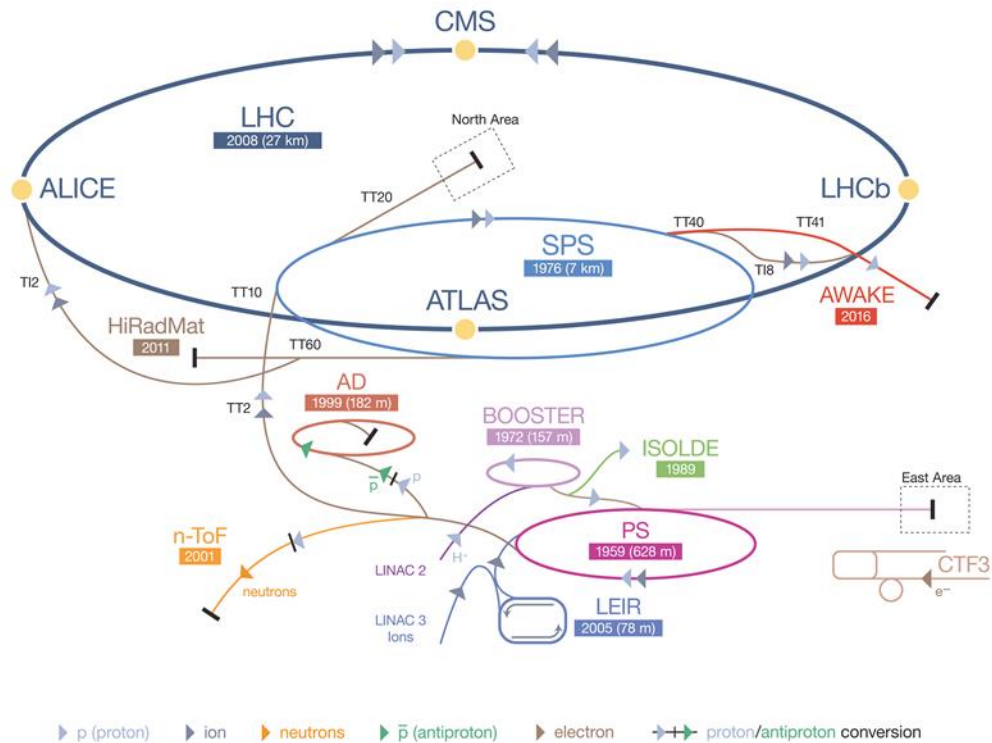


WATCH THE ANIMATION AGAIN





# CERN'S ACCELERATOR COMPLEX POSTER



LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility AWAKE Advanced WAKEfield Experiment ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring LINAC LInear ACcelerator n-ToF Neutrons Time Of Flight HiRadMat High-Radiation to Materials

A succession of accelerators boost particles to increasingly higher energies, before injecting the beam into the next machine in the sequence

The path taken by the particles is also a journey through the **history of CERN.**

# WEBQUEST ABOUT THE HISTORY OF CERN

- Using the information from the poster and from this website (<http://home.web.cern.ch/about>) discuss in class the following questions:
  1. When and why was CERN proposed?
  2. When CERN was founded and by whom?
  3. What is the name of the first accelerator? How long has it been running?
  4. When were antimatter particles detected for the first time?
  5. What was the detection method in the 1960's? Who proposed a new detection method? When?
  6. What happened in 1974-1976? What is the meaning of SPS?
  7. In 1988, a new accelerator was completed. What is it's name? Is it still running?
  8. When was the World Wide Web born?
  9. New experiments were approved between 1997-1998 at CERN. What are their names?
  10. The Globe of Science and Innovation was built in 2004 with what purpose?
  11. When did LHC start up? What are the two main results obtained recently?
  12. With this information you can create a time line of events in CERN from it's begining to the present day.



# SECTION 3: DETECTION

AFTER COMPLETING THIS LESSON THE STUDENT WILL BE ABLE TO:

- KNOW THE NAMES AND LOCATION OF THE DETECTORS IN LHC.
- UNDERSTAND HOW SCIENTISTS IDENTIFY PARTICLES.
- BE AWARE OF THE HUGE AMOUNT OF DATA PRODUCED.

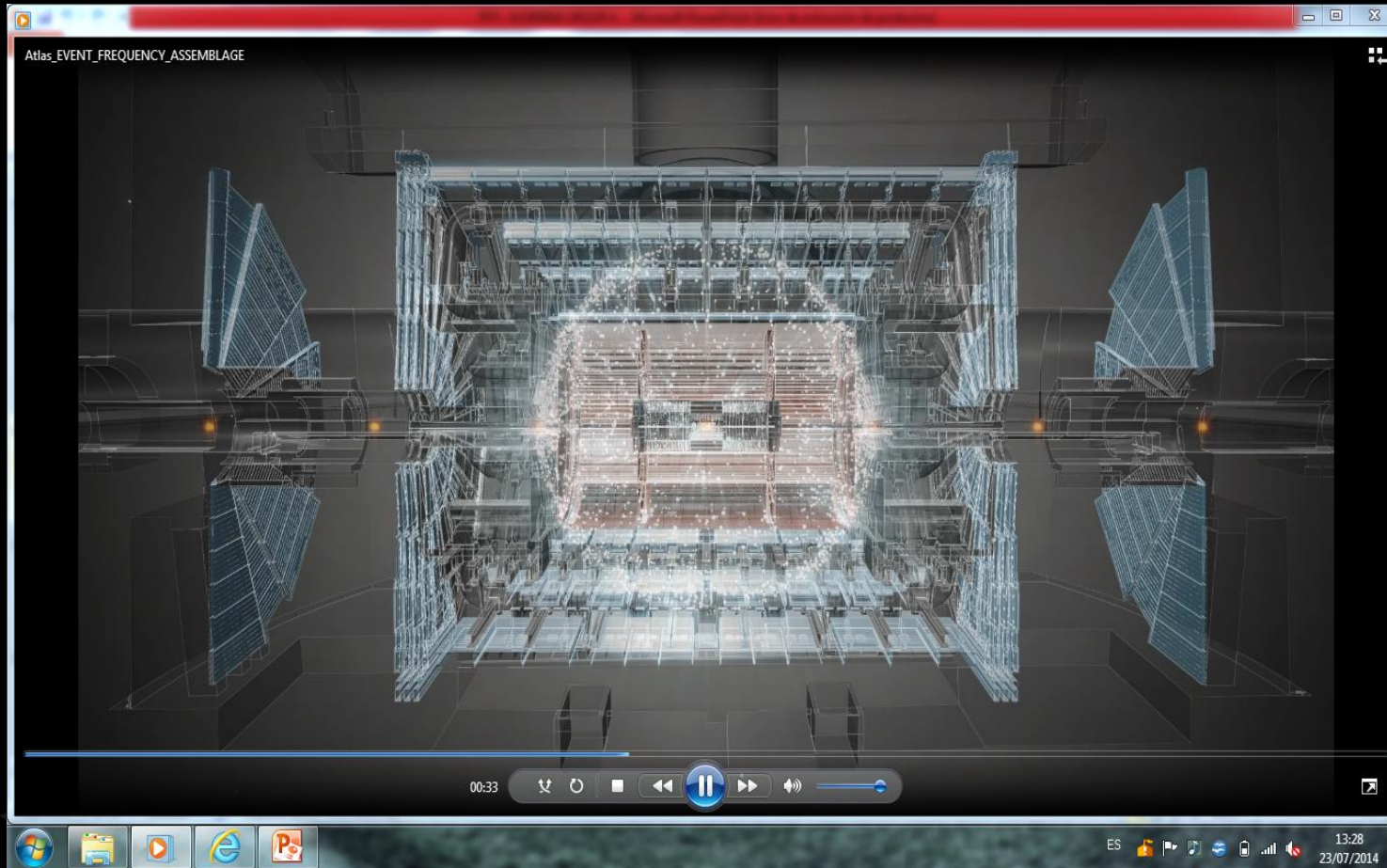
LEVEL

- ELEMENTARY

TIMING

- ONE CLASS SESSION

# PREVIOUS IDEAS



Describe what you see in this animation.

KEY WORDS: Collision, Energy, Particles, Detector, Frequency

ATLAS event

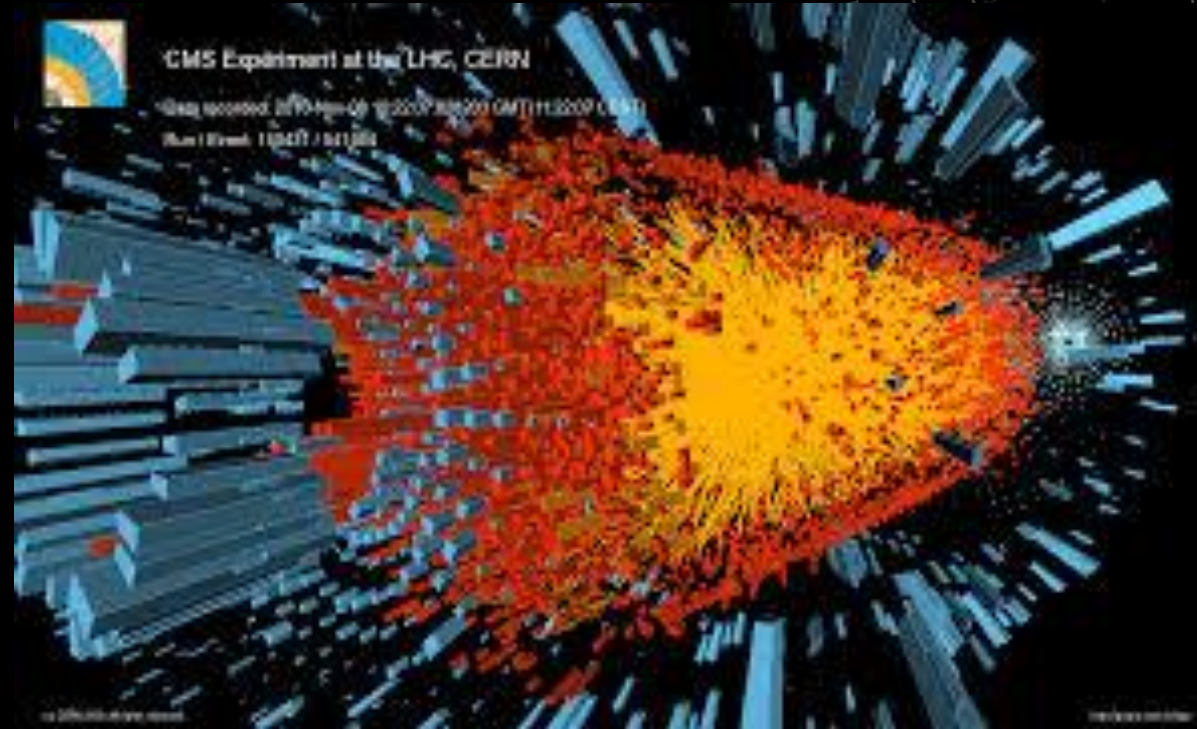
<http://cern60.web.cern.ch/en/exhibitions/atlas-event-frequency-assemblage>

# WHAT HAPPENS AFTER A COLLISION?

After each collision, many particles are created depending on the energy of the beam.

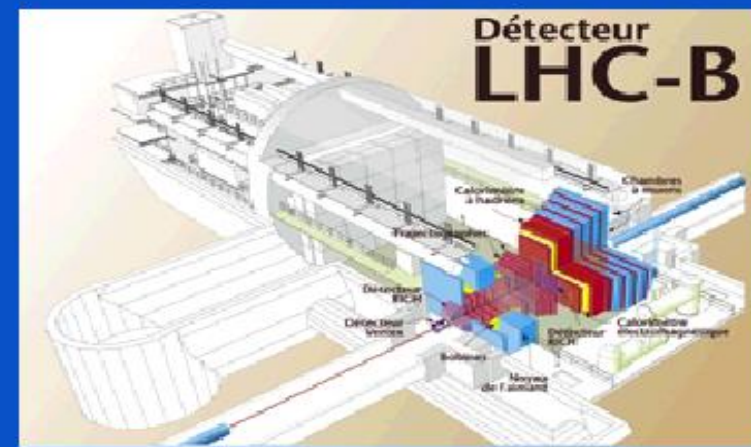
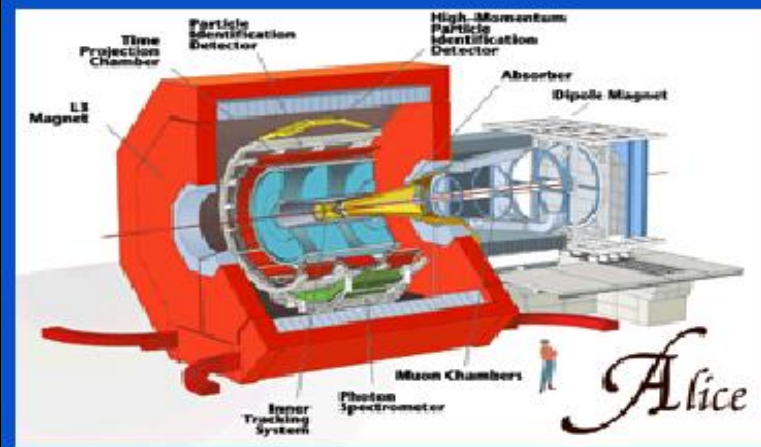
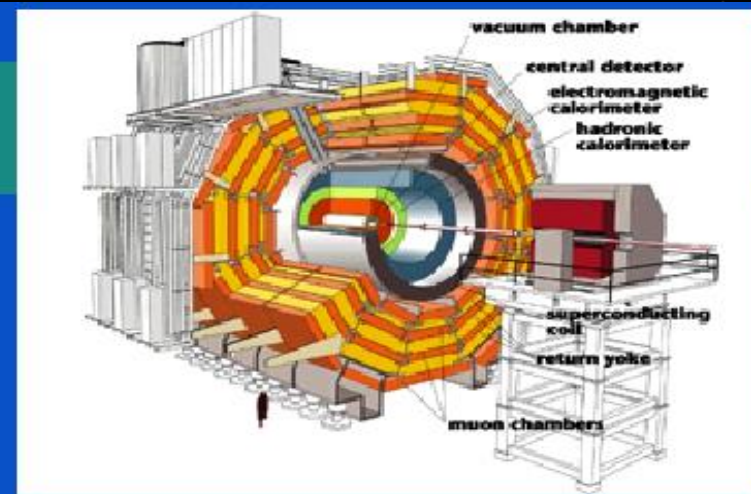
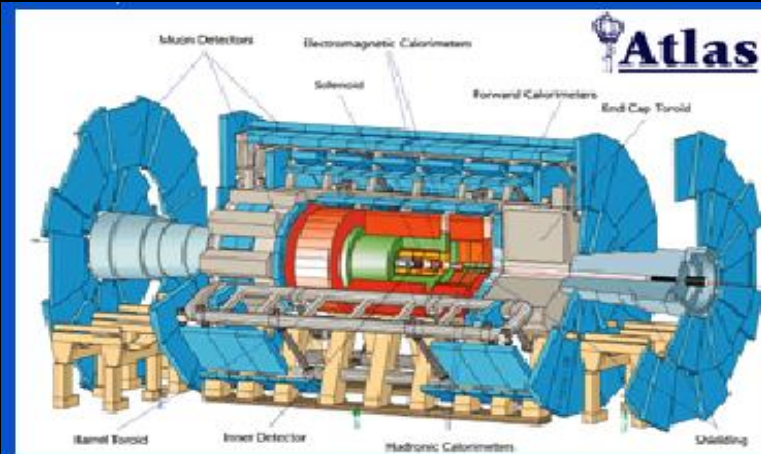
Detectors are used to trail, analyse and classify these particles.

Let's talk about detectors...

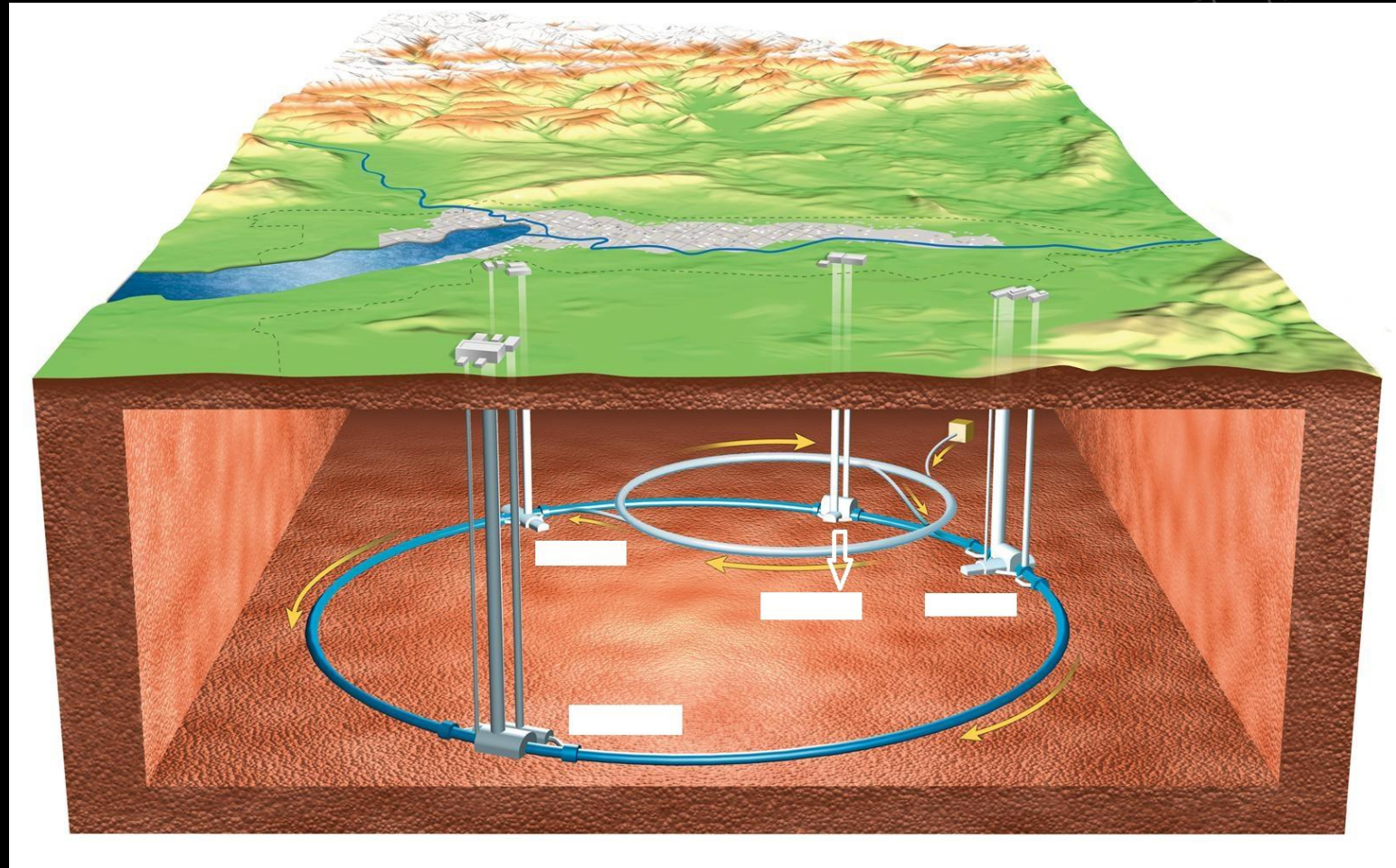
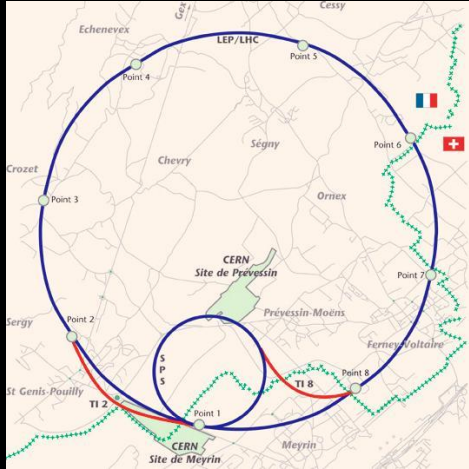




# LHC Experiments



# DO YOU KNOW WHERE THEY ARE SITUATED?



# HOW DETECTORS WORK?

Detectors are designed to find the identification mark of the particles i.e. the Particle ID!

Each particle has its own identity properties; just like animals or humans.

How do we identify them?



ANIMAL TRACKS



HUMAN FINGERPRINTS

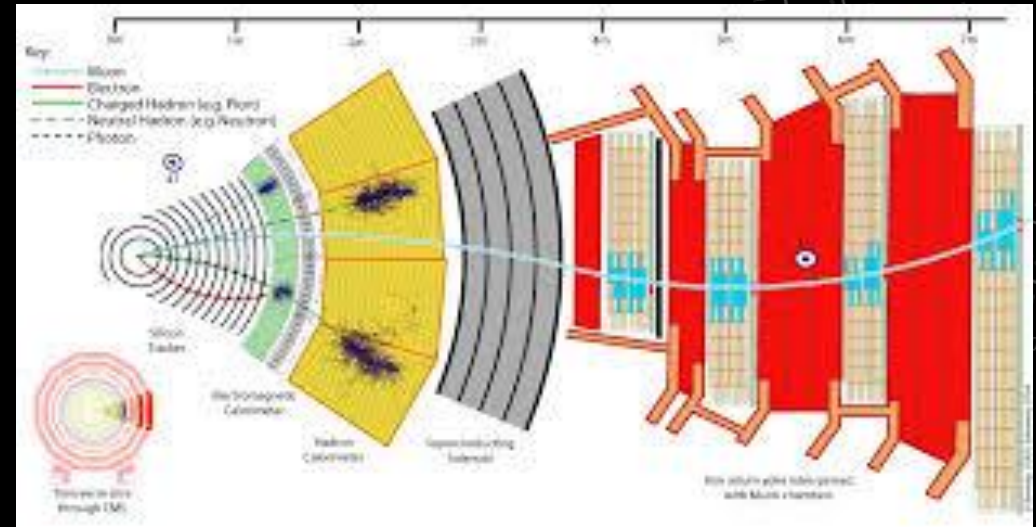


# HOW ARE THEY DESIGNED?

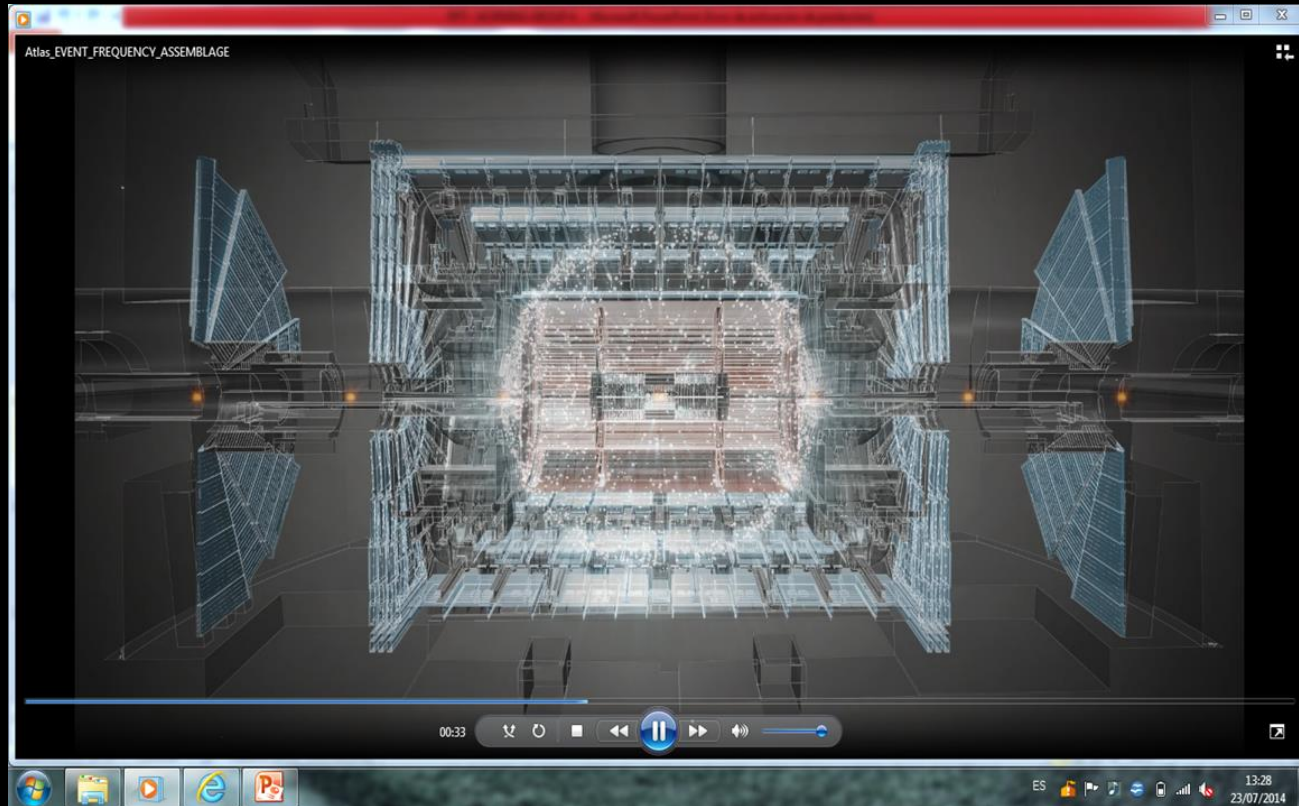
Detectors are made of several layers.

In some of the layers, the particles don't leave any tracks whereas in other regions they do.

Combining all the information from all the detectors involved, we may identify the particles.



# WATCH THE ANIMATION AGAIN AND ANSWER THE QUESTIONS



- What is a bunch?
- Which is the collision frequency?
- How many collisions will happen in one minute? And in one second?
- Discuss in class how you could analyse this data.

# SECTION 4: BEYOND COLLISION!

AFTER COMPLETING THIS LESSON THE STUDENT WILL BE ABLE TO:

- VISUALISE HOW THE PARTICLE TRACKS ARE CREATED FROM THE DETECTOR SIGNALS
- RECOGNISE THAT THE VOLUME OF DATA PRODUCED IN THE COLLISIONS REQUIRES NEW COMPUTING TECHNIQUES
- EXPLAIN HOW INTERNATIONAL COLLABORATION AND TECHNOLOGY IS CONTRIBUTING TO DATA ANALYSIS OF THE COLLISION OUTPUT.

LEVEL

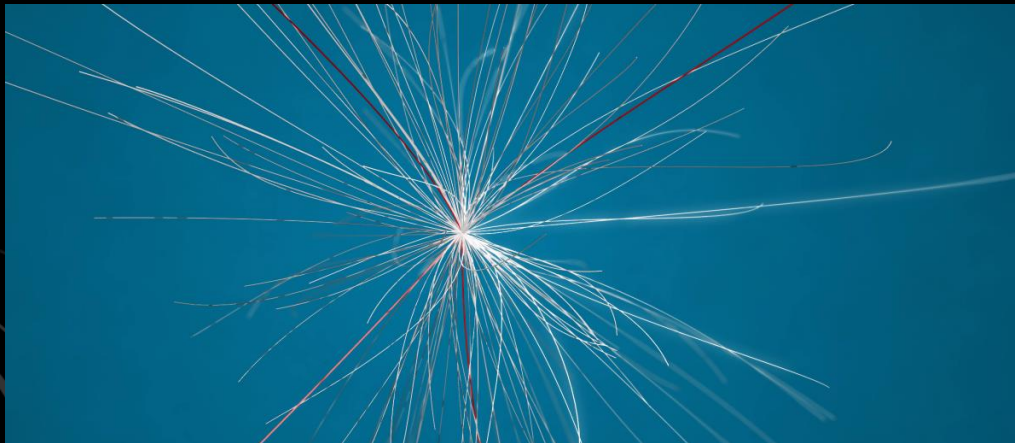
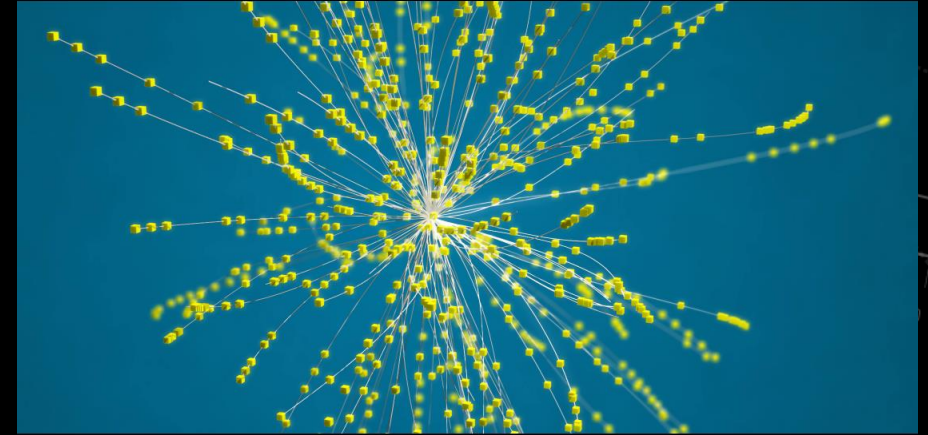
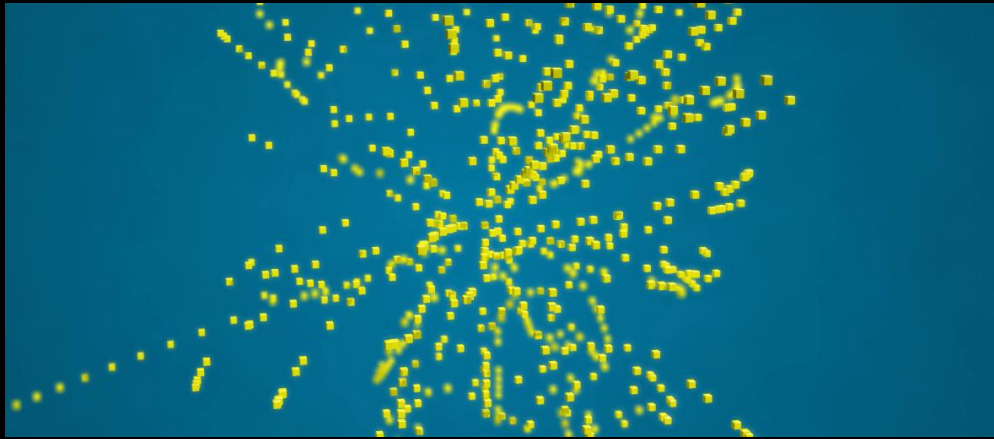
- INTERMEDIATE

TIMING

- HALF CLASS SESSION

- <http://cern60.web.cern.ch/en/exhibitions/animations-2>

# RECALL HOW THE DETECTOR CAPTURES THE INFORMATION



# NOT ALL PARTICLE TRACKS CAN BE SAVED!

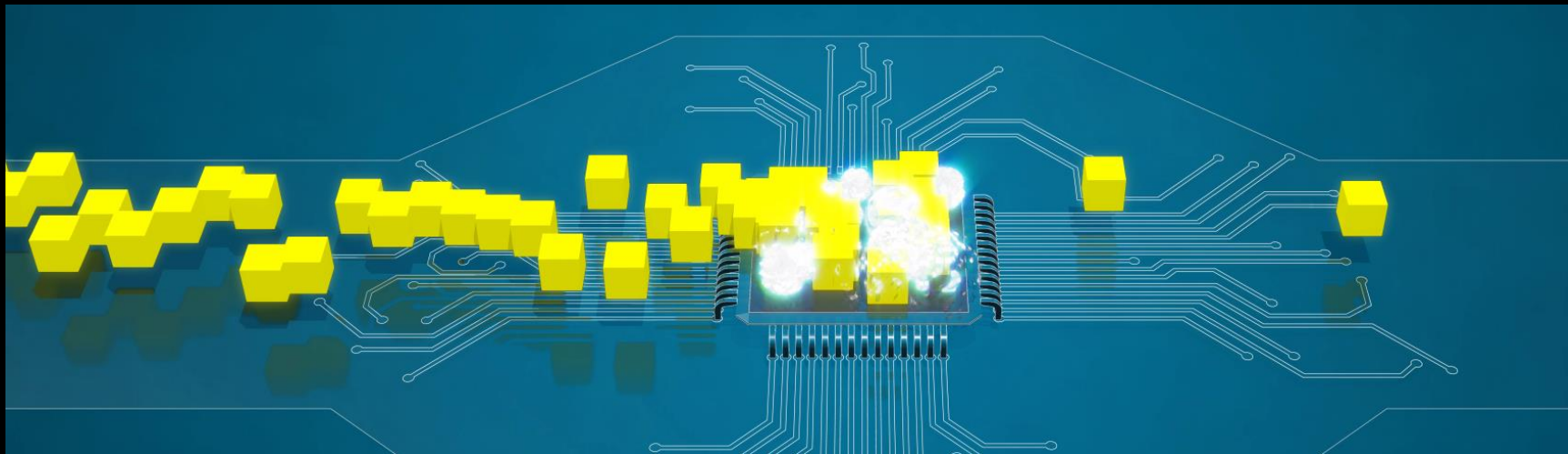
150 million sensors - Generating data 40 million times per second!

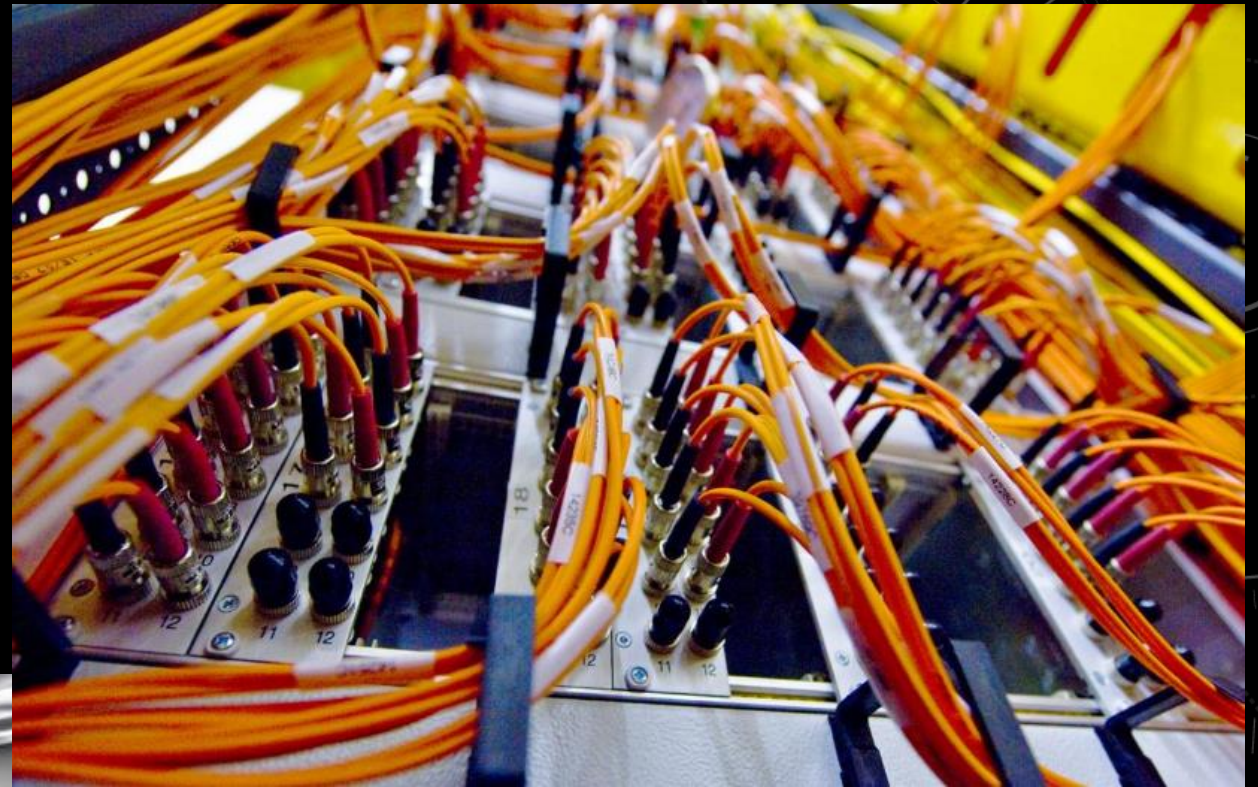
This is too much information coming too quickly!!!

**Trigger** Selects 100,000 per second which look 'interesting'.

**Filter** Selects 100 per second which contain the physics we want to study

Trigger animation

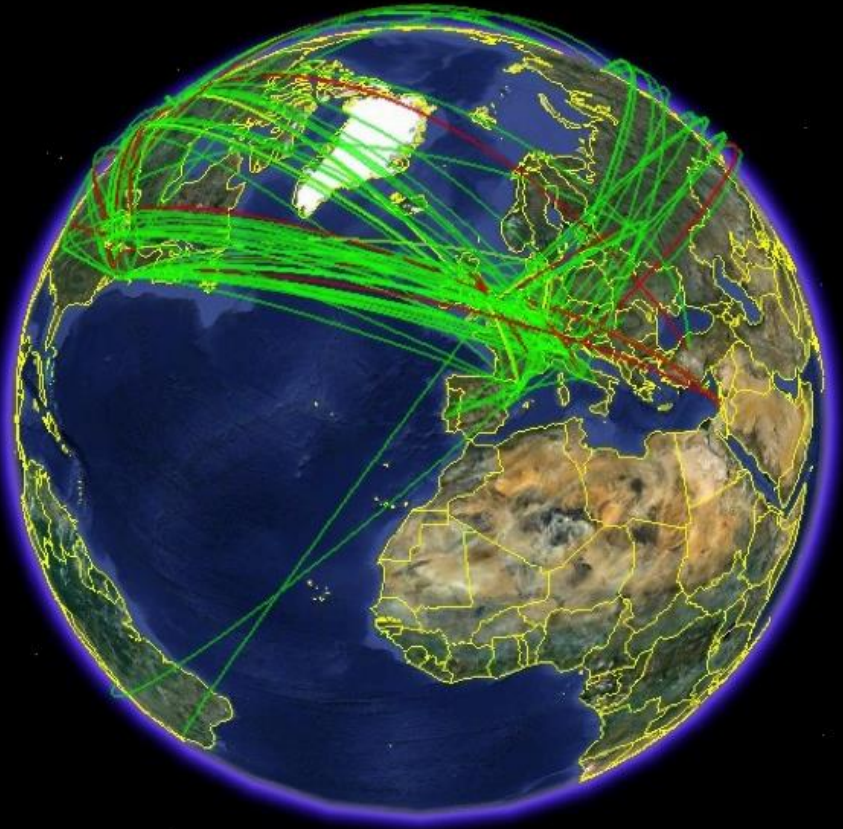




CERN still cannot manage  
all that data on it's own!  
What solutions can you  
think of to help process as  
much data as possible???

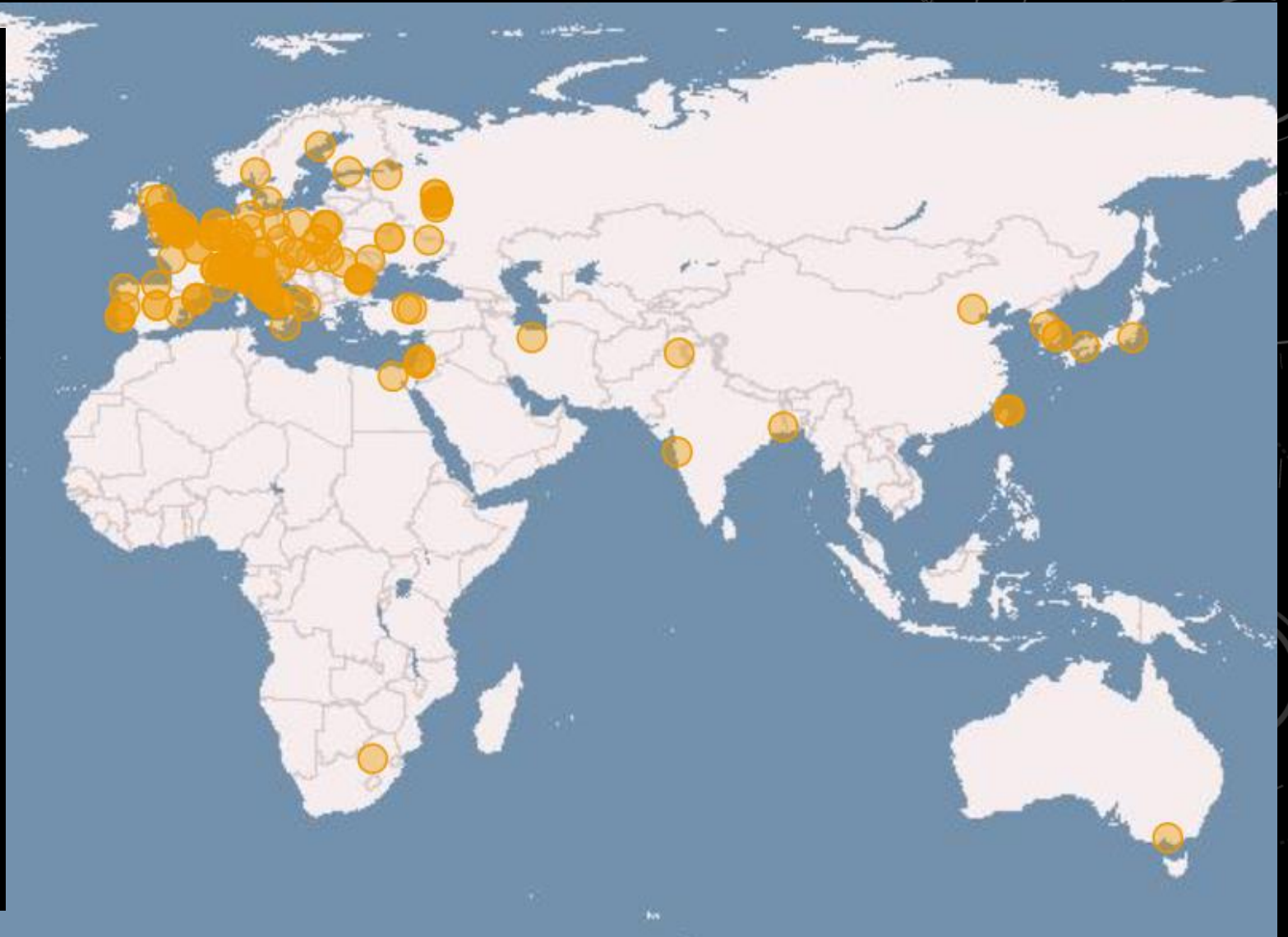
# THE WORLDWIDE LHC COMPUTING GRID

Running jobs: 246791  
Transfer rate: 13.98 GiB/sec



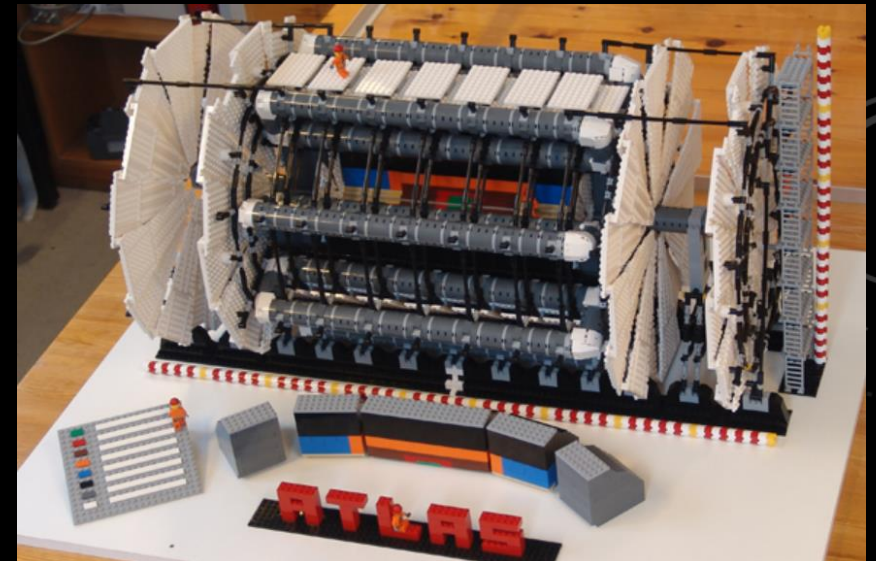
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
© 2012 Google  
US Dept of State Geographer  
© 2009 GeoBasis-DE/BKG

Google



# FINAL ACTIVITY – LEGO SEARCH!

- Use [google street view](#) to find the 3 of the many hidden Lego men in the LHC Computing Centre.
- Try looking on top of racks and servers – they won't be hanging in mid air!
- Take a screen shot once you have found them and save it as your homework assignment. Bonus points if you can name where you found it.
- Click [here](#) for a map to help you...






# PROJECT 3 – TEACHING NOTES

## NEASA, CHRISTOPHE, ROBERT

### 11 CMS Collisions -Teachers Resource




The Compact Muon Solenoid (CMS) is a general-purpose detector at the Large Hadron Collider (LHC). It is designed to investigate a wide range of physics, including the search for the Higgs boson, extra dimensions, and particles that could make up dark matter. Although it has the same scientific goals as the ATLAS experiment, it uses different technical solutions and a different magnet system design.

The CMS detector is built around a large solenoid magnet. This takes the form of a cylindrical coil of superconducting cable that generates a field of 4 tesla, about 100,000 times the magnetic field of the Earth. The field is confined by a steel "yoke" that forms the bulk of the detector's 12,500-tonne weight.

An unusual feature of the CMS detector is that instead of being built into like the other great detectors of the LHC experiment, it was constructed in 15 sections at ground level before being lowered into an underground cavern near CERN in France and reassembled. The complete detector is 31 metres long, 15 metres wide and 15 metres high.

The CMS experiment is one of the largest international scientific collaborations in history, involving 4500 particle physicists, engineers, technicians, students and support staff from 182 institutes in 41 countries (February 2014).




Detectors consist of layers of material that register the different properties of particles to catch and measure the energy and momenta of each one. CMS needs:



- a high performance system to detect and measure muons,
- a high resolution method to detect and measure electrons and photons (in electromagnetic calorimeters),
- a high quality central tracking system to give accurate momentum measurements, and
- a "hermetic" hadron calorimeter, designed to entirely surround the collision and prevent particles from escaping.

With these priorities in mind, the first essential item was a very strong magnet. The higher a charged particle's momentum, the less its path is curved in the magnetic field, so when we know its path we can measure its momentum. A strong magnet was therefore needed to allow us to accurately measure even the very high momentum particles, such as muons. A large magnet also allowed for a variety of other main detectors within the magnetic field, so instruments could be measured both inside the coil (by the tracking devices) and outside the coil (by the muon chambers).

### 10 Collimator -Teachers Resource



Designed at CERN but mostly produced by very specialised manufacturers in Europe, the LHC collimators are among the most complex elements of the accelerator. Their job is to control and safely dispose of the halo particles that are produced by unavoidable beam losses from the circulating beam core.




The LHC collimation system has been designed to ensure that beam losses in superconducting magnets remain below quench limits. In a collider, beam losses are caused by collimation at the interaction points, the interaction of the beam particles with residual gas, intra-beam scattering, beam instabilities and dynamics changes during the operation cycle (orbit drifts, optics changes, energy ramp, etc.). All these effects may vary over time, depending on various beam and machine parameters. Therefore, the collimation system must be very flexible and highly reliable. Each ring collimator of the LHC is programmed to follow the changes in energy and optics during the operation cycle of the machine. The jaws can move at a varying pace and can be controlled by the operator, who can also adjust their angle with respect to the beam trajectory. It is a very complex but very effective system, the state-of-the-art for hadron colliders.

The LHC employs the largest and most advanced cleaning system ever built for a particle accelerator.

Ideally, a storage ring like the LHC would never lose particles: the beam lifetime would be infinite. However, a number of processes will always lead to losses from the beam. The manipulations needed to prepare the beams for collision – such as injection, the energy ramp and "squaring" – all entail unavoidable beam losses, as do the all-important collisions for physics. These


### 10 Collimator -Teachers Resource



The Large Hadron Collider (LHC) is the world's largest and most powerful particle accelerator. It first started up on 10 September 2008, and remains the first addition to CERN's accelerator complex. The LHC consists of a 27-kilometre ring of superconducting magnets with a number of accelerating structures to boost the energy of the particles along the way.

Inside the accelerator, two high-energy particle beams travel at close to the speed of light before they are made to collide. The beams travel in opposite directions in separate beam pipes – two tubes kept at ultrahigh vacuum. They are pushed around the accelerator ring by a strong magnetic field maintained by superconducting electromagnets. The electromagnets are built from coils of superconducting cables that operate in a superconducting state, efficiently conducting electricity without resistance or loss of energy. This requires chilling the magnets to  $-271.3^{\circ}\text{C}$  – a temperature colder than outer space. For this reason, much of the accelerator is connected to a distribution system of liquid helium, which cools the magnets, as well as to other supply services.

The high luminosity performance of the LHC relies on strong, accelerating, and colliding beams with unprecedented intensities. The transverse energy density of the nominal beam is 1000 times higher than previously achieved in proton storage rings. The thickness of the stored beam suffices to quench a superconducting LHC magnet or even to destroy parts of the accelerators. Note that a 10<sup>17</sup> fraction of the nominal LHC beam will destroy Copper. The energy in the two LHC beams is sufficient to melt almost 1 ton of copper!



The collimation system is a vital part of the LHC project, protecting the accelerator against unavoidable regular and irregular beam loss.

The collimation system consists of a total of 118 devices, distributed in several places around the ring and in the transfer lines. Collimators are also installed close to the interaction points, where beams are optimised for collisions. By controlling the particle losses, the collimators protect the delicate elements of the machine, help reduce the total dose on the accelerator equipment and optimise the background for the experiments.

# PROJECT 4 – REAL WORLD APPLICATIONS

## ROBERT



# MEDICAL RESEARCH

Click [here](#)

# MEDICAL RESEARCH

ADAM Teachers Resource (Preview) - Microsoft Word non-commercial use

Print Preview

1 2 3 4 5 6 7

## ADAM medical app

### Teachers Resource

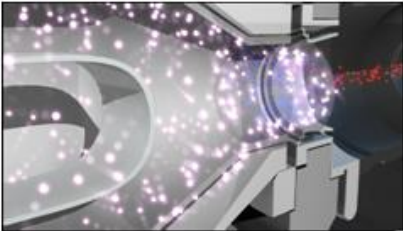
Keywords: Found at [http://www.adam-geneva.com/iam\\_180413.html](http://www.adam-geneva.com/iam_180413.html) The acronym is Application of Detectors and Accelerators to Medicine.

ADAM research activity is mainly focused on the construction and testing of linear accelerators (linacs) for medical purposes. ADAM has designed, built and tested the first unit of a linear accelerator for proton therapy and a small accelerator for IGRT. An auxiliary product engineered by the company is also a "collimator" for real-time monitoring of the exact dose delivered to the patient during a radiotherapy treatment.

**VIDEO** approx. 70 seconds in length.

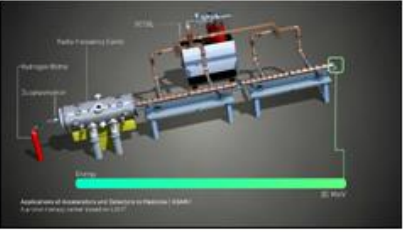
This video provides an animation of the ADAM medical device.

The opening scene starts from space to CERH, then to the duoplasma injector as seen in a previous video.

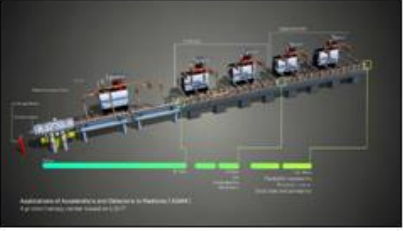


### SCTDL

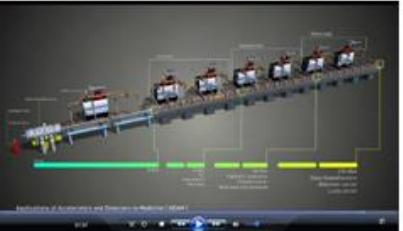
The SCTDL is the first accelerator that sends the protons to 200 MeV. Each Unit after the SCTDL boosts the protons to higher energies. The first Unit allows for a 700 MeV beam with sufficient energy to provide treatment to the eye, lip, and melanoma. UGRT stands for Ultra for Image Guided Hadron Therapy.



Adding a second Unit allows energies of up to 350 MeV and is useful in treatments of pediatric nasopharynx and prostate cancers.



After Unit 1 (with 200 MeV) and treated deep seated tumors and adenocarcinoma lung cancers.

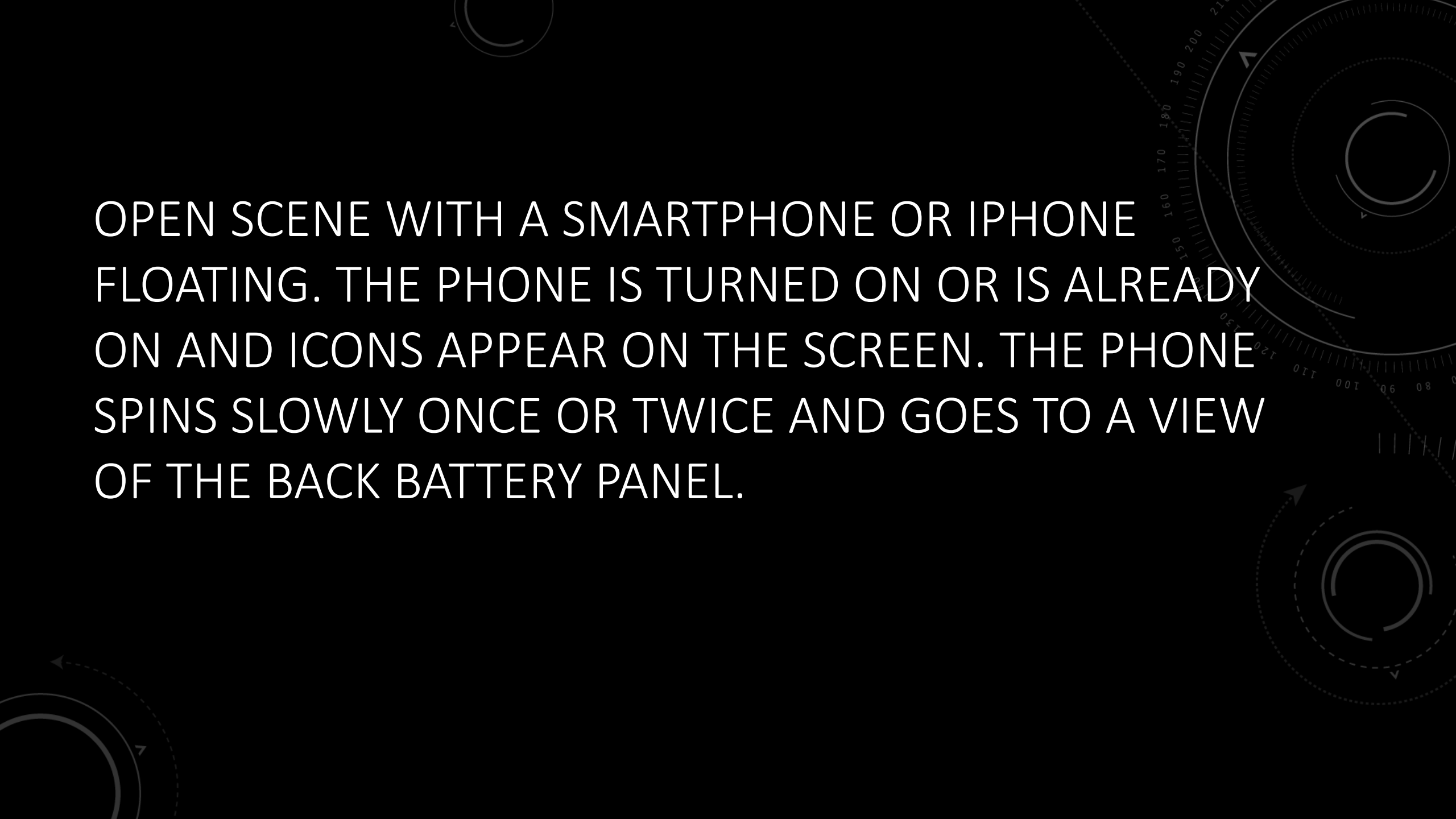


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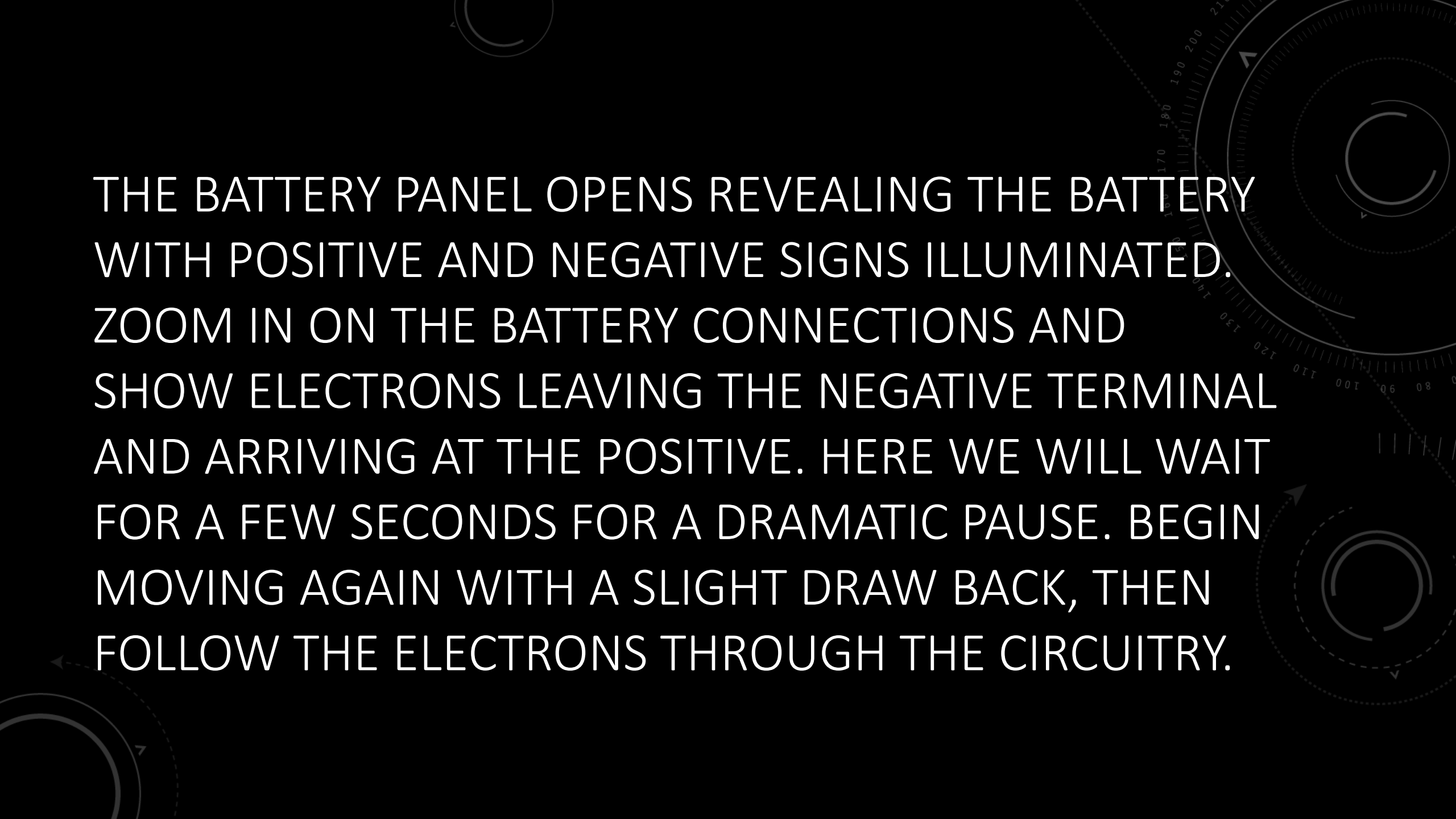
start 3 Windows Explorer Adam, Protonthera... WG4 HST 2014 Pres... ADAM Teachers Res... ADAM SCTDL and 3... 12:08 AM

# STORY BOARD OF REAL WORLD APPLICATIONS - SYNCHOTRON

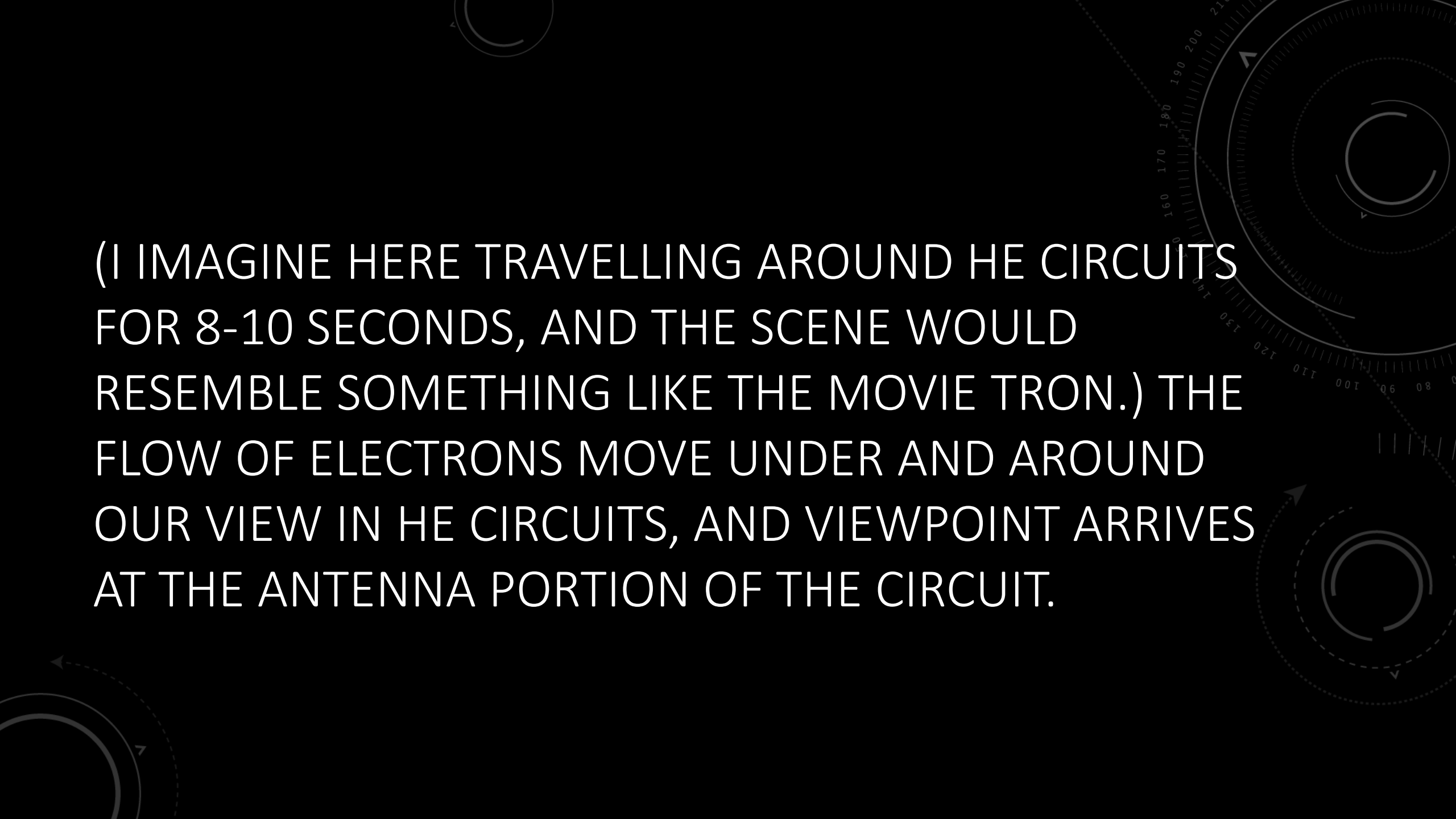


The background is dark with several faint, light-colored technical diagrams. On the right side, there are two large circular gauges or dials with numerical scales (0, 80, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210) and arrows. At the top center, there is a small circular diagram with a curved arrow. At the bottom left, there is another circular diagram with a curved arrow. The overall aesthetic is technical and futuristic.

OPEN SCENE WITH A SMARTPHONE OR IPHONE  
FLOATING. THE PHONE IS TURNED ON OR IS ALREADY  
ON AND ICONS APPEAR ON THE SCREEN. THE PHONE  
SPINS SLOWLY ONCE OR TWICE AND GOES TO A VIEW  
OF THE BACK BATTERY PANEL.

The background is dark with several faint, light-colored technical diagrams. On the right side, there are two large circular gauges with numerical scales (0 to 210) and arrows. On the left, there are smaller circular diagrams with arrows. The overall aesthetic is technical and scientific.

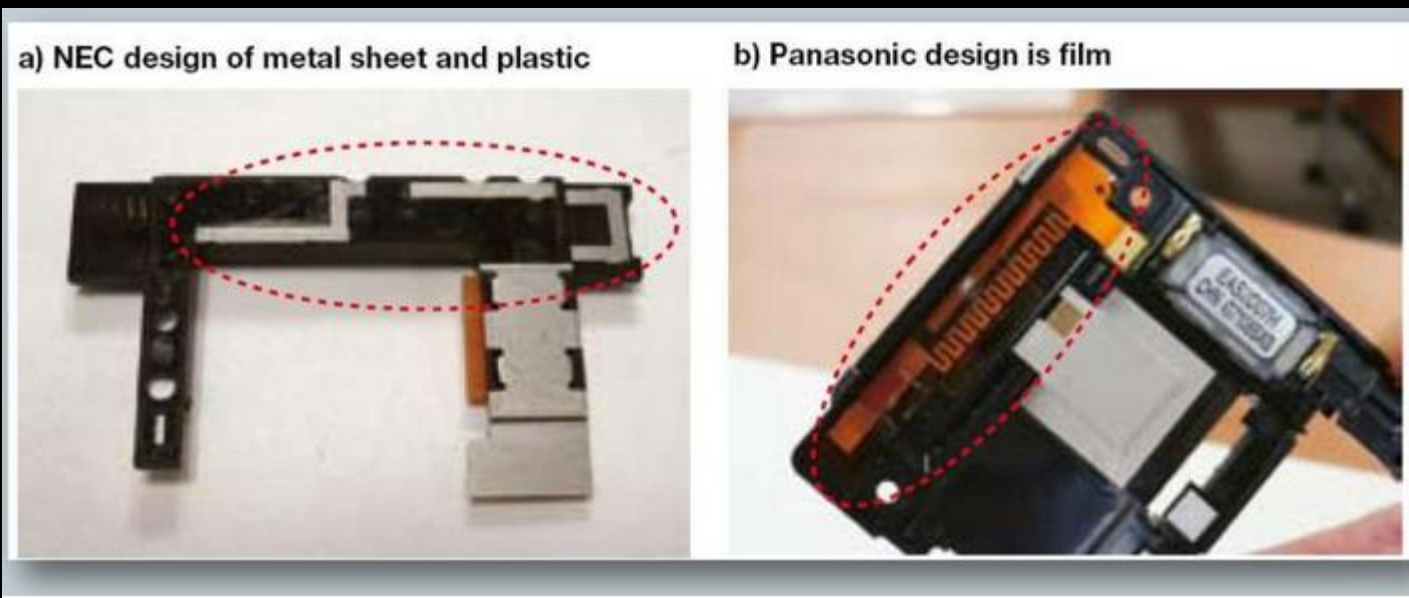
THE BATTERY PANEL OPENS REVEALING THE BATTERY WITH POSITIVE AND NEGATIVE SIGNS ILLUMINATED. ZOOM IN ON THE BATTERY CONNECTIONS AND SHOW ELECTRONS LEAVING THE NEGATIVE TERMINAL AND ARRIVING AT THE POSITIVE. HERE WE WILL WAIT FOR A FEW SECONDS FOR A DRAMATIC PAUSE. BEGIN MOVING AGAIN WITH A SLIGHT DRAW BACK, THEN FOLLOW THE ELECTRONS THROUGH THE CIRCUITRY.

The background is dark with several faint, light-colored technical diagrams. On the right side, there are concentric circles with radial lines and numerical labels (100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210) around the perimeter, resembling a scale or a circular gauge. There are also dashed lines and arrows indicating directions or paths. In the bottom left corner, there are more circular patterns with arrows. The overall aesthetic is technical and futuristic.

(I IMAGINE HERE TRAVELLING AROUND THE CIRCUITS FOR 8-10 SECONDS, AND THE SCENE WOULD RESEMBLE SOMETHING LIKE THE MOVIE TRON.) THE FLOW OF ELECTRONS MOVE UNDER AND AROUND OUR VIEW IN THE CIRCUITS, AND VIEWPOINT ARRIVES AT THE ANTENNA PORTION OF THE CIRCUIT.

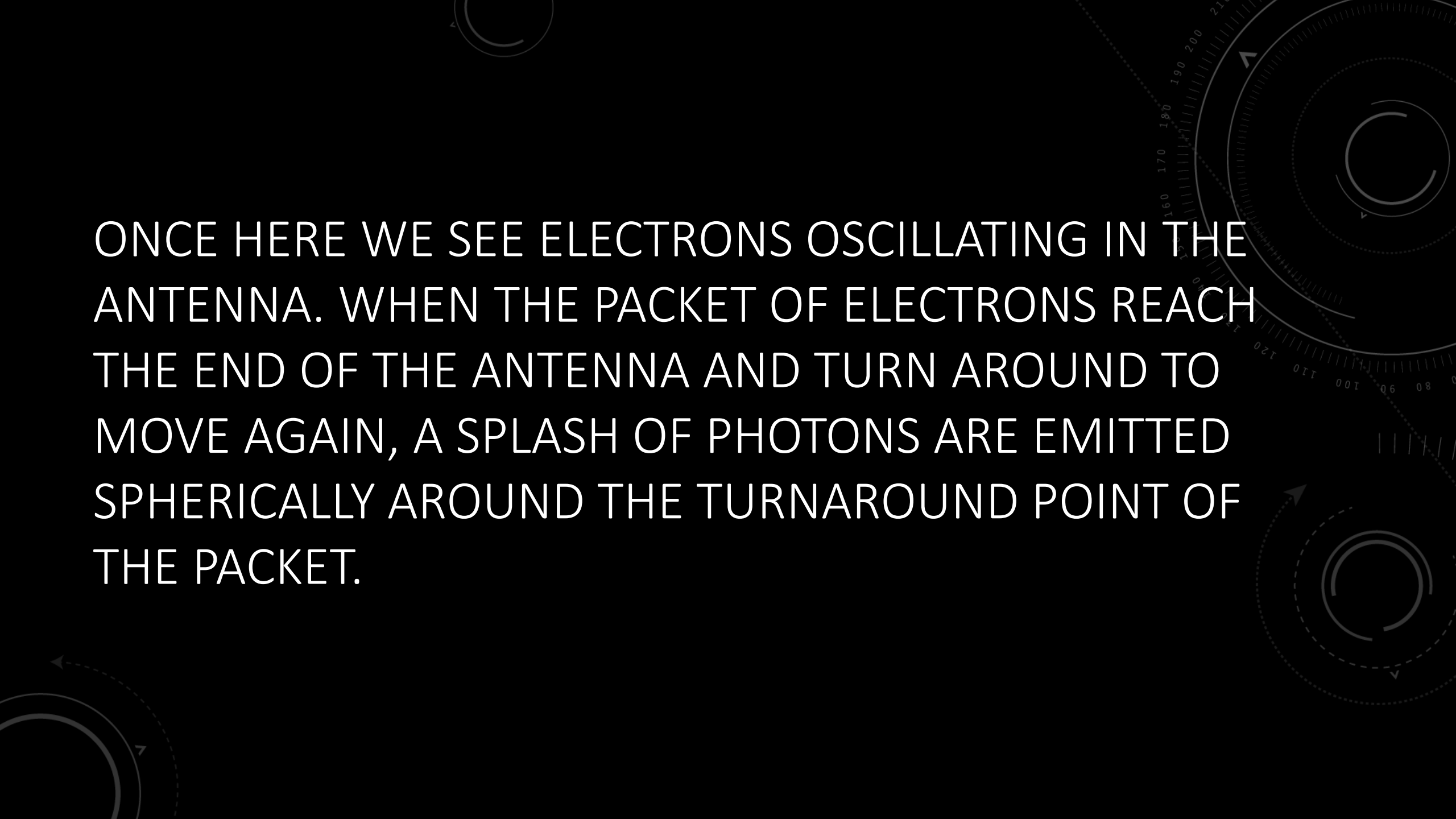


# METAL STRIP ANTENNA (NAVEEN KUMAR, SLIDESHARE)



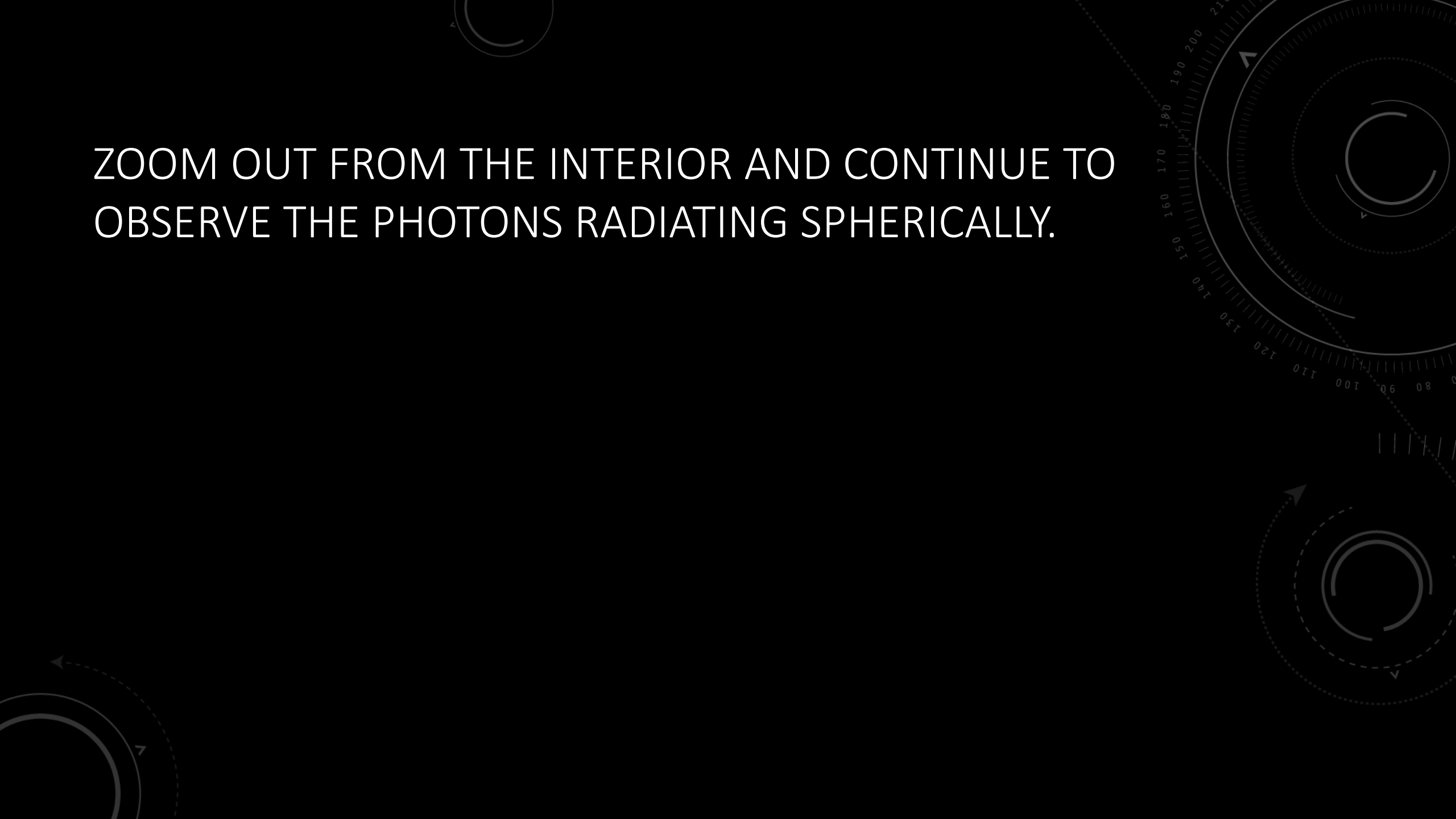
# TRON

<http://www.youtube.com/watch?v=oufRW8qDiTw>

The background is dark with several faint, light-colored technical diagrams. On the right side, there are concentric circles with radial lines and numerical labels (100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210) around the perimeter, resembling a circular scale or a cross-section of a sphere. There are also dashed lines and arrows indicating directions or paths. In the bottom left corner, there are more circular patterns with arrows, possibly representing a cross-section of a cylinder or a similar geometric shape.

ONCE HERE WE SEE ELECTRONS OSCILLATING IN THE ANTENNA. WHEN THE PACKET OF ELECTRONS REACH THE END OF THE ANTENNA AND TURN AROUND TO MOVE AGAIN, A SPLASH OF PHOTONS ARE EMITTED SPHERICALLY AROUND THE TURNAROUND POINT OF THE PACKET.

ZOOM OUT FROM THE INTERIOR AND CONTINUE TO  
OBSERVE THE PHOTONS RADIATING SPHERICALLY.



THANK YOU!  
QUESTIONS?

