Guide Sheet: **Journey Through a Detector**

Overview and timing

Time	Task	Experiment/Slide	
Welcome (T0) 1 min	**Welcome** the audience, Introduce yourself and the show (title, language, duration) – (present translator)	Welcome slide English or bilingual	
Intro 10 min	**Safety** Outline safety instructions, using the evacuation plan	Safety slide	
	Introduction CERN Questions and introduction to Large Hadron Collider	LHC slide	
	Introduction: Interactions Detectors on our body, invisible particles, volunteer	Vortex cannon	
	Introduction: Incredible detectors Collisions happening 40 million times per second	Red/blue lights Collision speed slide	**00.10**
No later than 10 min into show: Particle detectors			
Tracker 10 min	**CMS overview: Size and layers** Dimension: 15x15x21m, 14,000 tons ~ 4,000 elephants	CMS Slide	
	Silicon detectors: IR light Remote control + camera; IR light has low energy and cannot by detected by our eyes	Tracker slide Remote control, camera Silicon detector prop	**00.15**
Checkpoint: If you're not here before 00.15, skip the pixel detector!			
	Silicon detectors: Pixel detector Background radiation is always present around us	Pixel detector, radioactive rock	
	Silicon detectors: Interaction Charged particles travel through the silicon detectors and free electrons from silicon atoms, creating electric signal that we can detect	"Ionisation" slide	**00.20**
No later than 20 min into show: Calorimeters			
Calori-meter 10 min	**Calorimeters: Scintillators** Scintillator vs. Plastic (plexi-glass); volunteer (**not a young child**); UV light has high energy Some things found in nature also fluoresce	Calorimeter slide Plastic, scintillator, cube scintillator, CMS led scintillator, tonic water	**00.25**
	Calorimeters: Photomultiplier Dominos; 15 repetitions = 32 768; volunteer	Dominoes Photomultiplier slide	**00.30**
Checkpoint: No later than 35 min into show: Muon system			
Muon detector 5 min	**Muon detector: Geiger-Muller counter** Muons are 200x heavier than electrons; check different substances with GM counter; volunteer	Muon detector slide Muon chamber prop GM counter, substances	**00.35**
Magnets 5 min	**Solenoid magnet** Curves the path of charged particles	Solenoid magnet slide Straight and curved paths slides	
		CRT TV with magnet	**00.40**
Checkpoint: If you're not here before 00.40, skip the tracks quiz and wrap-up!			
Final Summary 5 min	**Particle tracks quiz** Which particle left the track? Muon, Proton, Photon	Particle tracks quiz	
	Wrap-up: Overview What did we see/learn today? Include 3 key messages	Thank you slide	**00.45**
"Thank you, enjoy the exhibitions", individual Q&A possible in the first row (NOT ON STAGE)			

Show preparation

- Arrive at the auditorium at least **15 min before the show is due to start.**
- Say Hi to AV/Technical support, put on your microphone(s) and **check the sound** with them. Collect a hand-held microphone for the Geiger-Mueller counter.
- Check the **emergency exit route** at the stage level: do the doors open? is the path to leave the building clear? If not, report to the technical team.
- Remove the black cloth from the table (if present) and check the equipment. If anything is missing, check whether it is in the flight case or inform the person on duty or the technical team. If anything seems wrong with the equipment, inform the person on duty or the technical team.
- Set up the **laptop and presentation**. If using the weekend presentation, unhide the slide of blue/red colours.

If you are using it, prepare the **Pixel detector program**, check that it works and set it up on the stage screen (don't hesitate to ask the duty person if you struggle). To do this: connect the pixel detector to the computer and open the programme (first plug in the pixel detector, wait a few seconds, then open the program, otherwise it won't work. If you have a problem during the show, try to close the program and re-open it)

- Wait at the stage level while the audience enters the auditorium and make sure no-one approaches the stage or touches any equipment.
- If the show is translated, confirm final details with the translator.
- Any issues should be **communicated to the duty person or the technical team**, not the VTC.
- If you are performing the show during the weekend, you need to know how to use the Streamdeck with the Go Pros if the technicians have to leave for an emergency. You can find the explanations on Cernbox

End of the show

- **Clean up the table**: leave the area as clean as you found it, after your show.
- **Cover** the table and the CRT TV with the black cloths.
- Ensure that the **security bands** are in place around the stage.

Safety measures

PRESENTER
DO NOT USE THE CRT TV IF YOU ARE PREGNANT, HAVE A SENSITIVE MEDICAL DEVICE OR SUFFER FROM A HEART CONDITION
UV torch • **Wear UV goggles** when using UV torch. **CMS Scintillator** • **Do not touch the CMS led scintillator** with bare hands, keep it in the box **Weakly radioactive rock** • Keep the rock in its **plastic box**, do not touch directly. **CRT TV and Strong permanent magnet** • Do not wear metallic accessories • **Be careful when handing the TV**. Never remove the plastic casing at the back. **Turn it off** after the experiment. • **Put back the magnets in the box** provided after use • **Be careful when handling the strong magnet.** To avoid blunt injuries, keep a distance between the magnet and ferrous objects or sensitive electronics. Do not place the magnet directly on the screen as it scratches the screen – just hold it close to see the effect. In case of a safety issue on stage (e.g. fire), call for the technical team in the control room and evacuate the audience from the auditorium. The fire extinguisher is in the wall next to the emergency exit.
AUDIENCE
• **Do not approach the stage** unless invited. Stay in the first row. • **Do not touch** any equipment unless invited.
VOLUNTEERS
• Vortex cannon volunteer: **safety goggles** • Scintillator volunteer: **UV goggles**; strict instructions about holding the torch downwards, do not select a young child for this demonstration • Dominos volunteer - nothing • GM counter volunteer: remind them not to touch the powder with the GM counter
In case of an emergency, call the emergency services (fire brigade) ***(+41 22 76) 74444***

Show Overview

🕐 **Duration:** 45 min + 15 min Q&A
Age group: 12+

AV support

Standard AV support	**Low AV support (weekend)**
• Cameras and screens handled by AV team. • Red/blue light change done by AV team.	• If present, cameras handled by tech team • In case of emergency: Two GoPro cameras handled by the presenter using the Streamdeck to switch between laptop and camera view. Instructions • Red/blue light switch done on PowerPoint (**unhide slide 4**).
• Sound always provided by (AV) technical team. • General lights handled by (AV) technical team (ask for it if needed) (or Streamdeck)	

Key messages

- We detect the world around us through **interactions**.
- Modern particle detectors are made of **layers, each has a different function**.
- We use **deduction** to identify particles from the **tracks they leave behind**.

Equipment

Vortex cannon, safety goggles, remote control, silicon detector prop, pixel detector, radioactive rock, UV light, UV goggles, transparent scintillator, plexiglass, green cube scintillator, CMS led scintillator, tonic water, set of dominoes increasing in size, Muon chamber prop, Geiger-Mueller counter, on-stage microphone, substances in petri dishes (sugar, salt (NaCl and KCl), green chocolate-colouring powder, turmeric and graphite), [Jacob's ladder, graphite dust, syringe], CRT TV, magnets, laptop, clock

Example Script

Please use the **script below as an example**. You don't need to learn the script by heart. However, you should also not stray too far away from the storyline so that you don't lose your audience or extend the show.

Please, do your best to **stick to the timeline**. This will allow the audience to keep their attention on you and the show, and you will be left with enough time to answer their questions after the show.

Most importantly, enjoy the show! The audience responds really well to presenters who enjoy being on the stage with them. So, don't panic! ☺

Introduction [slide: Welcome – chose the correct one (EN or bilingual)]
Welcome to Science Gateway and welcome to today's science show **Journey Through a Detector**. This show will take you on a journey into the world of particle detectors. It will last around **45 minutes** and the whole show will be **in [language(s)]**. After the show, you will also have the opportunity to ask individual questions.

My name is [name], I am a [role at CERN] and today, I will take you on a journey through a particle detector (together with [name], who will translate this show).

[slide: Emergency exits] Before we start the show, I need to make a short safety announcement. In case of an emergency, this auditorium has **emergency exits** at the back, where you came in, and at the side(s) at the front of the room. After exiting the auditorium, please, follow the signs and meet us in front of the Globe. To reduce the risk of an accident, **please stay away from the stage** unless you are invited. This will make everyone's show more enjoyable. Thank you for your attention and we hope you enjoy this show about particle detectors at CERN.

Before we start with particle detectors, let's talk a bit about CERN. Does anyone know what CERN is?

[Maybe someone knows …]

CERN is the **biggest particle physics research laboratory in the world**, with more than 18,000 scientists, engineers, technicians and so on working together. Now, what do all these people do? Let's have a show of hands to see what you think. I'll read out a few statements and you raise your hand if you think this is what people at CERN do.
(1) Raise your hand if you think people at CERN produce antimatter and investigate its properties.
(2) Raise your hand if you think some people at CERN work in a hospital and develop medical devices.
(3) Raise your hand if you think people at CERN run the world's largest particle accelerator.

[Wait for audience to raise hands after each of these].

[slide: LHC animation] All of you are correct! At CERN, thousands of people are trying to learn what we are made of, how the universe began, and how the universe will continue to evolve by researching antimatter, medical applications, and much more! They are studying this with the help of the largest machine in the world: the **Large Hadron Collider**, or, as we call it, the **LHC**. The LHC is a **27km ring, hidden 100m underground**, and it accelerates particles up to almost the speed of light!

Once particles reach their final energy, they are directed towards each other and collided in the centre of one of four large detectors – **ALICE, ATLAS, CMS and LHCb**. Today, we will focus on exploring just one of these particle detectors – the **Compact Muon Solenoid**, or CMS detector.

But before we go down 100 m, let's first explore some detectors that we have here. Have any of you brought any detectors with you today?

[Maybe some hands …]

Well, maybe we should first discuss what detectors are. Does anyone know? What is a detector?

[Maybe someone knows …]

Detectors are instruments that help us **determine whether something is present or how much of something there is**. We all have detectors on our bodies – does anyone know of an example of a 'body' detector?

[Eyes, nose, ear …]

Yes, our bodies already have some very good detectors! For example, our eyes help us see amazing things. However, they can't detect everything – they can't detect things that are invisible. Can you think of something that is invisible? …that is all around us?

[Air …]

Exactly, air! But, if we can't see it, because it is invisible, how do we know that it's there? Well, here I have an experiment which will help to make the invisible (air) almost visible! I need my first **volunteer… perhaps someone with long hair or a long beard**.

[Volunteer…]

(volunteer name, applause …) Okay, [name], your job is very simple. You need to stand here … and now I will take an air cannon and shoot it at you. Okay?

[Yes.]

Make sure the volunteer is not standing too close to the air cannon as it can be a bit too strong (about 1m)

So this is your first lesson – never volunteer for something if you don't know what you'll have to do. As we take safety very seriously here at CERN, I want you to wear these **safety goggles**!

[Volunteer puts on safety goggles …]

Okay, are you ready? Yes? Then …

Vortex cannon experiment

Wow! Did you all see what happened? What happened?

[Maybe some answer …]

Exactly! [volunteer]'s hair moved! So, we still couldn't see the air, but we could see its effects on the hair. We can see the interaction between the air and the hair! This is how we can see, or better yet, **detect** the invisible… through **interactions**.
Thank you, [volunteer], you have helped us a lot!

[Volunteer returns to place]

So, everything we can detect, we detect through **interactions**. Even when we see things, we only see them because particles of light interact with our eyes. Does anyone know what particles of light are called?

[Maybe some answer …]

Exactly, **photons**. Our eyes are amazing at detecting photons. Not only do they detect photons, but they also detect the different energies photons have. We see different energies of photons as different colours.

For example, if we change the lights in the auditorium, what colour is this light?

Colour changes to red

Yes, red, and this one?

Colour changes to blue

Blue. The photons of red and blue light have different energies (the photons of blue light have more energy than the photons of red light) and your eyes detect this difference as different colours. See? Your eyes are great detectors! But they have some limitations. Let's do a demonstration. You will now be my photon detectors. I will split the audience into two halves – this half [indicate the half], I want you to clap when you see a red light. You only need to clap once, but make sure that you clap as soon as you see the light, so that you all clap together. This half [indicate the half], I want you to clap when you see a blue light. Again, try to clap as soon as you see the light.
Are you ready?

Clapping experiment [Take a bow – "thank you, thank you" "It's always nice to get a round of applause early in the show"]

Well, actually, I didn't do this just to get a round of applause. What you can see with this experiment is that our eyes struggle to detect very quick changes in the energy of light. Even at a slow pace it's difficult to be precise, but as it the changes get faster, it gets even trickier.

[slide: collision animation] In a particle detector this would be a problem. The particle detectors at CERN need to be extremely fast. For example, in the CMS particle detector, particle collisions happen **40 million times per second**! This means that new particles are created **every 25 nanoseconds**. And the detector needs to be able to detect all of the particles coming from each of those collisions.

[slide: CMS] So now, let's imagine we're going 100 m underground to see one of the four big detectors at CERN – the CMS detector. We chose this detector because of its pretty colours; but the technology and science that we will discuss today is similar in most other detectors as well.

CMS stands for **Compact Muon Solenoid** and it is really large: **15m wide, 15m high, and 21m long, and it weighs about 14,000 tons**. It is called "compact" because it is very heavy for its size. It is heavier than the Eifel tower (10'000 tons)! This *huge* machine is needed to study the *tiniest* particles that build up the Universe.

As you can see on the picture, the CMS detector is made of several different layers – each colour represents a different layer with different subdetectors. And each layer serves a different purpose. The best way to show you is to follow the path of a particle, as it travels outwards from the collision point at the centre of the detector through all the different layers of the detector.

Tracker [slide: tracker]

The very first, innermost, layer that this particle would encounter is called a tracker. This detector is similar to a photon detector that you might be carrying with you in your pocket. It's about this big (shows the size of a phone) and we use it to catch photos, I mean, photons … Do you have any idea what this could be?

[Phone …]

Exactly. Or more specifically a phone camera. Some phone cameras are better light detectors than our eyes and they can detect light that our eyes cannot see. Let's try it out.

Show the remote to the audience in the first row

You've probably seen the light at the front of the remote, right?

[Maybe some answer …]

But does it ever seem to work?

[No …]

These lights are invisible to our eyes. However, if we use our phone or a different camera, we can make the invisible ***press the button on the remote in front of the camera***… visible! Can you see the light now?

[Yes!]

You can also test your own phone, by pointing your camera at the rectangles on the ceiling, the ones with the little green lights. What do you see?

[red squares]

The technology used in such cameras is similar to the technology used in the innermost layer of the CMS detector – the tracker. I have an example of a tracker right here…

Show the silicon detector prop

Optional: I also have a pixel detector connected to the laptop over here.

Show the pixel detector – switch to the program

You see a little mark on the screen every time a particle hits the detector. We don't see these particles with our eyes, but when they interact with the detector, the detector detects them and sends a signal to the computer. Do you have any idea where these particles are coming from?

[Space!]

And does anyone know what kind of particles they could be?

[Maybe "electrons, protons, muons …"]

The particles that we detect, coming from space, are electrically charged particles, like electrons and muons. They are passing through the atmosphere, and our bodies all the time, but we don't feel them. Let's try the detector with something a little more radioactive. Here I have a rock, the same kind you could find when hiking. This rock emits more particles than those that we detect coming from space. So, what do you expect to see on the screen?

[More particle tracks…]

Put the rock above the Pixel detector

That sounds like a reasonable hypothesis. Let's see … Can you see the image change as the particles interact with the detector? These particles are now the ones coming from rock directly.

But how does this detector work? [slide: "ionisation"]

In a tracker, such as the one in our cameras and in the CMS detector, particles interact with the silicon in the detector. When elementary particles move through the silicon, they create a signal by interacting with electrons along their path and freeing them from the silicon atoms. The whole system is put in an electric field, so the electrons all flow to one side of the detector, due to this external electric field. This creates a small electric current – a signal, which can be read out by our computers.

If a particle has *interacted* with the tracker in the innermost layer of the CMS detector, then we know that it is electrically charged. **Only an electrically charged particle will leave a track in the first detector layer**. But that information alone is not enough. We need another layer to find out about the paths of electrically neutral particles and the energies of the particles. We can measure these in the second layer of the CMS detector – the calorimeter.

Calorimeter [slide: calorimeter]

The name calorimeter tells us that this layer is measuring **energy**. Maybe you noticed the word "calory" in "calorimeter", which we typically use to talk about how much energy a certain food item has. The calorimeter measures the energy of a particle.

The way the calorimeter works is that it uses a material called a **scintillator**. Scintillators are extremely common in particle physics research, and they are also used in medical research and in security scans at airports. While they can be made slightly differently, they all look very similar to what I have right here. We can use this scintillator to measure the energy of photons.

Present the two transparent glasses

One of these is a scintillator and the other is just a Plexiglas block. We're going to find out which one is the scintillator. To investigate this, I need a **volunteer** **[!Do not choose a young child!]**

[Volunteer, name, applause …]

First we can try shining a normal torch on these two blocks and see what happens. This is visible light.

The volunteer shines the torch on each block

Maybe we need to try it with a light that has more energy. Do you know what kind of light has more energy than visible light?

[Ultraviolet…]

Exactly. I have an ultraviolet torch right here. Ultraviolet light has a higher energy than visible light. It is invisible to human eyes, but it can cause damage, so we need to protect ourselves with these super cool sunglasses.

Put on a pair of glasses and give another pair to the volunteer

Let's try it out with the scintillator. Are you ready? Okay, 3, 2, 1 …

The volunteer shines the torch on each block

Wow, the scintillator glows! This phenomenon is called **scintillation**. The scintillator is able to change the incoming high-energy light into lower-energy light. Here, it changes the invisible ultraviolet light into visible blue light so we can see the block glowing.

We can observe a similar phenomenon in some everyday objects as well. For example, here I have a bottle of tonic water. Tonic water contains a molecule called quinine so it also glows blue under UV light – and if we had them here, we would also see that scorpions glow under UV light! In fact, that is how people search for them in desert areas – using UV light.

In the CMS detector, scintillators glow when certain particles **interact** with the calorimeter. How strongly the scintillators glow depends on how much energy the particle has when it enters the calorimeter; the more energy the particle has, the more the scintillator glows. However, there is a problem. We just shined billions of UV photons to see this scintillator glow. But in our detectors, we need to detect single particles, so **the light signal is very weak.** Too weak in fact for the computer to detect it. So, we need a way to amplify the signal, so that it is big enough to be detected. Let's demonstrate how we can **amplify a signal** with an experiment. I need another **volunteer** who can help me amplify the signal from the detector.

[Volunteer, name, applause …]

The problem is this. The only signal that we get from our detector was this tiny little domino [show the little blue domino]. Let's imagine our computer requires a signal that corresponds to this domino (show the big green domino)…Mmmh no, even bigger [take the big yellow domino from under the table]… Cern like to see things in big [take the big red domino under the table]. Here is the signal we need.

Let's see if we can use a series of dominoes to amplify the signal. You have a small but very important job. Your finger is now representing a photon entering the detector. Your photon finger will create a tiny signal, and the detector will (hopefully) amplify that signal until it creates a signal that is large enough for the computer to detect. Are you ready? Let's see if we can amplify the signal in 3, 2, 1…

Domino experiment

Wow, fantastic, great job! This experiment with dominos shows us how **photomultipliers** work. A photomultiplier is a technology that helps us to enhance electric signals. With the dominoes, the small domino knocked over a bigger domino, which knocked over a bigger domino, and so on.

[slide: photomultiplier] In CMS, a photon from the scintillator first enters the photomultiplier. When that happens, it knocks an electron from the top of the photomultiplier. This electron is then accelerated by an electric field into another electron, knocking it out of its place. Both electrons continue their journey, and soon they each knock out another electron, and then those 4 electrons each knock another electron and so on and so on… If we repeat this process, called an **electron avalanche**, just 15 times, we get **32,768** electrons from just one photon! That is certainly enough to trigger a signal.

And, again, the more energy the original particle has, the stronger the final signal will be. But how do we make sure we really measure the full energy of a particle? Calorimeters are designed to **completely stop particles** to ensure that every bit of their energy has been deposited into the detector.

Muon detector [slide: Muon detector]

But there are some particles that can pass through the calorimeters without being stopped. One particle that can pass through with little or no interaction is a **muon**. Does anyone know what muons are?

[Maybe someone? …]

Muons are like electrons but more massive, with the same negative electric charge but **200x the mass**. Muons can also tell us a lot more about what happened in the collision, so it's good to know as much about them as possible. Therefore, there is an entire layer of a detector dedicated for tracking them, called the muon detector. (We expect muons to be produced in the decay of a number of potential new particles; for instance, one of the clearest "signatures" of the Higgs Boson is its decay into four muons.)

At CMS, this muon system is similar to the most famous radiation detector. Does anyone have any idea what this is?

(Show the GM counter) [Maybe someone knows …]

This is a **Geiger Muller counter**. It is often used in movies when the characters are measuring radiation levels. Whenever a particle enters the detector, the detector makes a sound – a click for every detected particle.

Now, let's make an experiment. In front of me, I have some mystery substances. One of them is radioactive. Let's have a show of hands to hypothesise which of these substances looks like the most radioactive one.

[Show of hands for each of them …]

Now, science is about more than simply predicting – we need to test our hypothesis as well. Furthermore, radiation is not something that we can see with our eyes – we need to detect it through interactions with a particle detector. Now, I need a **volunteer** to help me use the Geiger counter to determine which substance is a bit more radioactive –don't worry though, all of these substances are safe.

[Volunteer, name, applause …]

Every time this detector detects a particle, you will hear a click; the more clicks, the more particles have entered the detector; the more particles, the more radiation! Now, when I turn it on, I'd like to first ask you to just wait a moment. ***(turn on the GM counter)*** We can already hear some clicks. Does anyone know where these particles are coming from?

[Space, cosmic rays.]

The particles causing these clicks are cosmic rays, coming from space. We already detected them before, with the pixel detector.
Now, I'd like you to use the probe of our detector to find which of these substances is more radioactive.

GM counter – *tell the volunteer not to dip the counter in the substances*

Perfect, do we all agree this is the most radioactive substance? You're right, it is! Thank you, [volunteer], you can now sit down.

This radioactive substance is called **potassium chloride or potassium salt.** Potassium is a slightly radioactive element, and it's also the reason bananas are slightly radioactive. But both bananas and potassium salt are perfectly safe to eat – and you can find them both in supermarkets. Most of the other substances are safe to eat as well (sodium salt, sugar, food colouring, turmeric). In fact the only inedible thing here is the grey dust. This is graphite dust.

The muon detector in the CMS detector works a bit like a Geiger counter, but it's specifically designed to detect muons. Here I have a real example of a muon chamber, or more precisely, a drift tube. In the CMS detector, thousands of these are arranged in concentric cylinders around the beam line. Each tube is a metal cylinder filled with gas, with a thin wire stretched through its center.

Show Muon chamber prop and light the wire with the torch

It is essentially two electrodes – the wire inside is one electrode and the whole metal cylinder around the outside, is another electrode. A high voltage is applied to the wire inside the tube, while the outside of the tube has an opposite charge. When a muon passes through the tube, it ionises the gas inside, knocking electrons off the gas atoms. These freed electrons "drift" towards the positively charged wire, guided by the electric field. When they reach the wire, the electrons are amplified (electron avalanche), creating a measurable pulse of electric charge. We can use this signal to work out where the muon crossed the drift tube, which helps us to reconstruct its path through the detector.

Solenoid Magnet [slide: Solenoid magnet]

Our journey has taken us through all the main detector layers of the CMS detector. We first looked at the tracker, then the calorimeter, and lastly the muon detector**. We know understand why it is called compact (C) – Muon (M) – but where does the S for "Solenoid" come from?**

It comes from the huge **solenoid magnet** in our detector. The solenoid magnet is not a detector in itself, but it plays a big role in helping us to detect particles. The function of this magnet is simple – it helps to **determine electric charge**.

[slide: straight and curved tracks slides] Without this magnet, all particles would travel in a straight line – that is the easiest path for particles to take. But by using a strong magnet, we can **curve the path of particles** with electric charge. As positively charged particles turn in one direction, and negatively charged particles turn in the other direction, we can identify the charge of each particle.

I'm going to show you something that will make some of you feel really old, if you remember this object, and some of you might be too young to know what it is!

Uncover the CRT TV

This is a really old TV. It is called a cathode ray tube TV, or CRT TV and it is also a particle accelerator! You can see the accelerator nicely if you open up a TV – but beware, opening a TV like this is something you should never do at home. The team that opened this TV are all trained professionals. Anyway, this particle accelerator is quite similar to what we use at CERN. First, by heating up/applying a high voltage to the material at the very back, we free electrons from this part, then, the electrons are accelerated towards the screen at the front. Finally, the electrons hit the screen, where they interact with the material and provide us with an image.

Here, we have also installed a magnet - this red thing on a stick ***(point out the magnet)***. This magnet is connected to the knob at the front, so when I turn the knob, the magnet moves closer to the beam of particles or away from the beam.

Now, let me turn the TV on … Wow, the image quality is not very good; you can see why new technology was developed. But you can probably still recognise the people on the screen. What do you think will happen if I turn the knob to bring the magnet closer to the electron beam in the CRT TV?

[The image will split/shift/change colour/brightness…]

Turn the knob/bring a magnet close and describe what we see *(don't touch the screen with the magnet!)*

So, when we bring a magnet close to the stream of electrically charged particles, they deflect, their path curves.

Particle tracks

[IF YOU HAVE THE TIME - slides: quiz]

Just like a detective, a particle physicist needs to use many different pieces of information about a particle to identify the particle. While the detector and computers can provide a lot of data, the final identification needs to be done by people. So, now it's over to you! We are going to see if you can use what you have learned today, along with the information from all the detector layers to identify three particles.

Guide the audience through each example, help them navigate the table but let them determine the particle: muon, proton and photon

Fantastic! Now you are ready to become a particle physicist at CERN! You can send us your CVs after the show.

[Thank you Slide]

Speaking of that - we're now at the end of the show. Today, we went on a journey through all the layers of a particle detector and discovered that each **layer serves a different purpose in particle detection**. We saw that for an 'invisible' particle to be detected it must **interact** with the layers of the detector and create a signal that we can detect. And finally, we used **deduction** to identify particles from the tracks that they leave behind. Basically, we spent an hour as particle physicists, congratulations everyone!

Thank you for joining me on this journey and I hope you enjoy the rest of your day at Science Gateway!