Guide Sheet: **Mysteries of Matter**

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 4 min	**Safety** – *emergency exits* *Cryo liquids, magnetic fields and alternating current: DO NOT COME ON STAGE*	Safety slide	
	Introduction What is matter, State of matter (audience interactions)	(optional) states of matter slide	
	Introduce liquid nitrogen Temperature, nitrogen in air; *Safety: no jewellery/watch, goggles, gloves, long pants, closed shoes*	(optional) temperature scale slide	**00:05**
Phase transitions Liquid 5-10 min	**Boiling liquid nitrogen** Similarity between water and liquid nitrogen boiling	Liquid nitrogen in double-glass cylinder	
	Fog and freezing water Fog (condensed water vapour), ice (frozen water)	Liquid nitrogen into water	
Pressure Gas 5-10 min	**Balloon in liquid nitrogen** Air cools down and becomes a drop of liquid air	Balloon in liquid nitrogen	
	Liquid nitrogen in a bottle LN2 in a plastic bottle, balloon on top expanding. Close the bottle with a cap, see it pop off. *Connection: Pressure build-up can be a problem* *Safety: put the small dewar under the table*	Liquid nitrogen in a bottle – (1) expanding balloon and (2) popping bottle cap	
	[Optional] **Ping pong ball in liquid nitrogen** ping pong ball in LN2, put in plastic circle: spinning	(optional) Ping pong ball in liquid nitrogen	
Material change Solid 5-10 minutes	**Rubber tube in liquid nitrogen** Freeze rubber tube, break it with the hammer *Connection: cannot use the usual materials* *Safety: knot outside to prevent fountain effect, hit carefully*	Rubber tube in liquid nitrogen	
	Ring and ball apparatus When cooled down, the ball doesn't fit the ring anymore *Connection: LHC shrinks by 80m when cooled down*	Ring and ball apparatus	**00:30**
Material change Super-conductor 5-10 min	[Optional] **Eddy currents in copper tube** Drop [non-]magnetic balls through copper/plastic tube	(optional) Eddy currents	
		(Eddy currents slide)	
	Superconducting levitation Magnet levitating above the superconducting disc *Safety: be careful when handling magnets, do not touch directly the YBCO disc*	Levitating magnet	
		(optional) Superconductor slide	
	Superconducting levitating train Superconducting train levitating above a magnetic track	Superconducting levitating train	**00:35**
Plasma 5 minutes	**Plasma ball** Plasma is the most common state of matter in the Universe, really fast molecules/atoms, ionised matter	(optional) States of Matter + plasma slide	
		Plasma ball	**00:40**
	Fluorescent tube Bring closer to the plasma ball for it to light up	Fluorescent tube	**00:45**
Conclusion	**Wrap up and overview** Diff. states of matter, can be changed with temperature	Thank you slide	
"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. Take a **hand microphone** for the boiling experiment.
- 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 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 presentation on the **laptop**.
- Wait at the stage level while the audience is coming in and make sure no-one enters the stage area.
- 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

- Stow **the liquid nitrogen dewar under the table** and out of sight. If the dewar is running low, tell the person on duty/technicians to bring a new one.
- For cryogenic materials, empty the beakers with water back in the water can, put back the remaining liquid nitrogen of the small dewar into the big one and lay any wet items out to dry, so they are ready for the next performance. Absorbent tissues for drying materials are provided under the table if needed.
- **Clean up the table**: leave the area as clean as you found it.
- **Cover** the table and the Plasma Ball with the black cloth
- Ensure that **security bands** are well set around the stage.

Safety measures

PRESENTER

DO NOT PRESENT THE SHOW IF YOU ARE PREGNANT, HAVE A SENSITIVE MEDICAL DEVICE OR SUFFER FROM A HEART CONDITION

Strong permanent magnet

Be careful when handling the strong magnets. To avoid blunt injuries, keep a distance between the magnet and ferrous objects or sensitive electronics.

Liquid nitrogen

- **Remove** any watch and/or jewellery from hands. Wear **closed shoes and long pants.**
- Only handle the big liquid nitrogen dewar with **safety goggles AND gloves**.
- Never pour liquid nitrogen from the big dewar to the pot on the table – do it on the floor.
- Use **safety goggles at all times** when performing liquid nitrogen experiments.
- **Do not touch liquid nitrogen** or any materials that were in direct contact with liquid nitrogen with your bare hands. Do not put your face over the liquid nitrogen.
- When handling the rubber tube, make sure that there is a knot on the outer part of the tube to avoid the fountain effect.
- Once the **plastic bottle** cools down with liquid nitrogen, don't smash it on the table as it might crack.
- When doing the popping experiment with the plastic bottle, the **liquid nitrogen container must be placed under the table.**
- After you finish the liquid nitrogen experiments, **put the pot under the table, away from the public.** Similarly, move the big dewar under the table after the show.

Superconductors

- Be careful when handling the superconducting train and disc. Do not let the train fall as this could cause the YBCO ceramic to break.
- **Do not touch the YBCO ceramic directly**; use nitril gloves.

High voltage

- Don't touch the plasma ball if you have an active medical implant.
- Ensure that the fluorescent tube has black insulating tape on both ends before using it on the plasma ball.

Fragile materials

- Handle superconductors, magnets, and the fluorescent tube carefully.

AUDIENCE

- **Do not approach the stage** unless invited. Stay in the first row.
- **Do not touch** any equipment unless invited.

NO VOLUNTEER

In case of emergency, call the emergency services (fire department)

(+41 22 76) 74444

Show Overview

» **Duration:** 45 min + 15 min Q&A
Age group: 6+

AV support

Standard AV support	**Low AV support (weekend)**
• Cameras, screens and sound effects (optional) handled 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
• Sound always handled by (AV) technical team. • General lights handled by (AV) technical team (ask for it, if needed) (Or Streamdeck)	

Key messages

- Our world is made of matter.
- Matter can exist in various states (states of matter).
- We can use temperature changes to change the state of matter.
- Physics is fun! 😊

Common pre-conceptions

- Our world is made of matter.

Equipment

Safety gloves for cryogenics, safety goggles, liquid nitrogen, dewars (11L and 2L), double-glass cylinder, large and small glass beakers, watering can with water, balloons (long and normal), balloon pump, plastic bottle, bottle cap, wooden spoon, ping pong ball with a hole, plastic protector for ball, hammer, rubber tube with knot at the end, copper tube, plastic tube, copper plate, copper block, steel balls, magnetic balls, box for ball landing, magnets for superconductors, superconductor, polystyrene container, small plastic tweezers, plastic spacer (2x), magnetic track, DIY plastic train, plasma ball, fluorescent tube.

Example Script

Please use the **script below as an example**. You don't need to learn the script by heart, but 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.

Finally, enjoy the show! The audience responds really well to presenters that enjoy being on the stage with them. So, don't panic and have fun!

Introduction [slide: Welcome – chose the correct one (EN or bilingual)]

Welcome to Science Gateway and welcome to today's science show **Mysteries of Matter**. This show will take you on a journey into the world of matter. It will last **around 45 minutes** and will be **in [language(s)].** There will also be **some time for questions after the show.**

My name is [name], I am a [role at CERN] and today, I will explore the mysteries of matter with you (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 at the nearest emergency point. In addition, on the stage, we have some dangerous things, so please **do not come to the stage.** Thank you for your attention and we hope you enjoy this show about some of the coolest mysteries of matter.

So, let's start this science show on physics and magic … I mean matter; physics and matter! Are you ready?

States of matter

First, let's talk about matter. Does anyone know **what matter is**?

[Everything …?] [The stuff that everything is made of…?]

Yes, matter is the *stuff* that makes up **everything**. Everything we encounter in everyday life is made of matter. You, me, the seats in this auditorium, animals, plants, the air, rocks, stars… at a basic level, all these things are made of the same stuff. Matter. What makes things different from one another, is how the matter is arranged. And it's the structure of this matter that we study in detail here at CERN.

In science, we love putting things into categories according to their similarities. This is also true for matter. One of the ways to classify things is by the state of their matter. Does anyone know any states of matter?

[Solid, yes… liquid… and gas! Some people might mention plasma or other]

[optional slide: States of matter] Exactly, solid, liquid and gas are the three main states of matter that we are used to encountering in our everyday lives. Well done! But the state of matter is not fixed. **Matter can change state**. Take the example of water. When it flows from the tap, water is a liquid. But if we make it cold enough, it becomes… solid ice! Or if you want to cook some pasta, you heat up your liquid water, and it evaporates, it becomes a gas! So, if I heated water enough, we would hear the peculiar sound of water boiling. When water boils, it's turning from liquid to gas.

What have we changed in each of these cases?

[The water's temperature!]

[optional slide: Temperature scale] Exactly! And what is true for water in this case is true for every other substance: **by changing the temperature, we can change the state of matter**.

Today I'm going to show you a different liquid; a very special liquid, called **liquid nitrogen**. Do you know what nitrogen is?

[Some possible answers]

Nitrogen is the name of a chemical element. Elements are another way of classifying things. Other examples of elements are oxygen, carbon, helium and so on. Do you know where we usually find nitrogen?

[In the air / around us / audience might demonstrate with their hands]

That's right, **we usually find nitrogen around us as a gas**. The air around us is made of about 78% nitrogen and 20% oxygen. When we breath in and out, 80% of that gas is nitrogen, and it goes into our lungs and back out without going into our system.

So nitrogen is usually a gas, but if we cool it down and squeeze it together a lot, it becomes a liquid! Liquid nitrogen is a very cold liquid. It becomes a liquid at temperatures around **minus 200 degrees (-196°C)**.

This means that we need to treat it very carefully. **To make sure I am safe, I will remove all my rings and my watch**… so that I don't have anything metal on my hands. And I will put on protective **gloves and safety goggles**. Now that I am safe, I can pour some liquid nitrogen from this big container into a smaller container.

Have you seen liquid nitrogen before? What colour do you think it might be?

[Blue, red, transparent…]

Let's see. You need to watch carefully as I pour it out. Are you ready?

[Yes]

As you can see the liquid nitrogen is transparent, and it looks quite like boiling water. You can also see the fog or cloud forming around the liquid as I pour it. You can see that it is a liquid because I can pour it from one container into another.

Phase transitions - Liquids

I'm going to pour some liquid nitrogen into this glass container.

Take small container to table and pour some liquid nitrogen into the double-glass cylinder

The nitrogen looks like boiling water because it is **boiling** - just like water would if it was heated to 100 degrees, except in this case, the nitrogen is warming up from almost minus 200 degrees! You can hear it boiling if I use this microphone! You can also see what is happening above the liquid nitrogen, what do you see here?

[Fog / a cloud] [If audience members say steam, you can address this]

Yes, it looks like **fog**! This is not the nitrogen evaporating, but **water vapour in the air condensing**. The liquid nitrogen is extremely cold, so it is cooling down the air around it. As the cold liquid nitrogen gas rises, it cools down the water vapour in the air. This water vapour then changes state; it condenses from a gas into tiny droplets of liquid water, which we see as a fog – or a cloud.

We can try to make an even bigger cloud by introducing more water into the air. I will put some water into this beaker… and then I'm going to add some liquid nitrogen on top. What do you think will happen?

[Take some predictions from the audience…]

Let's see! Are you ready?

Pour liquid nitrogen into water in a beaker (can use watering can)

Wow, it forms a huge cloud! And, if we could see the surface better, we would also see that it's boiling. This is not water boiling, as it is much too cold; it is liquid nitrogen boiling on the surface of the water.

The water is at a much higher temperature than the liquid nitrogen, so it is warming up the liquid nitrogen and causing it to boil. At the same time, the liquid nitrogen is cooling down the water. What state of matter will water change to if the liquid nitrogen cools it down a lot?

[Solid]

Exactly, a solid. Solid water is **ice**. So, let's see if some ice has formed…

Get ice from water *(never with your bare hands, use the wooden spoon)*

Can you see it? It's solid ice! What is ice made of?

[Water]

Yes, ice is made of water. Both liquid water and ice are made of water molecules… **but the molecules are organised differently in the two states, and they don't move as much when they are very cold.**

Pressure - Gas

Okay, so we've now seen what happens if we cool down a liquid – it becomes a solid – the water changed into ice. We've also seen that if we warm up a liquid, it becomes a gas – the liquid nitrogen warmed up, boiled, and turned into a gas.

What happens if we cool down a gas? I'm going to trap some gas and then cool it down.

Inflate a long balloon *(or take one already inflated under the table)*

What's this?

[A balloon]

A balloon, that's right. What is inside a balloon?

[Air]

Yes, it's full of air. What state of matter is the air in?

[Gas / Gaseous]

Yes, air inside the balloon is a gas! But what do you think will happen if I put it into the liquid nitrogen?

[various suggestions from the audience – expand / explosion / nothing]

Well, let's see!

Push the balloon into the liquid nitrogen; use the wooden spoon to help it in if needed.

Hmm, where did the balloon go? Into the table? No, look!

Lift the pot of liquid nitrogen to show that there is no trick.

It's not a magic trick!... Hmm, interesting. So, the balloon is still in the liquid nitrogen. What do you think will happen to the balloon when I take it out?

[Take various suggestions, or suggest them]

Let's see...

Take the balloon out of the liquid nitrogen; *if there are parts that are too frozen, use your fingers to quickly warm those parts up. [Be careful].*

The balloon goes back to its original size and shape! So, what happened to the air in the balloon? Did it go out of the balloon then go back in it when we took it out of the container?

[No]

The balloon is closed, so that would be impossible. So, let's work out what happened. The balloon is full of air, which is a gas. Air is made of molecules. When these molecules are in gaseous form, they move around a lot, putting pressure on the walls of the balloon and keeping it expanded. **But when we cool the gas down in the liquid nitrogen, the air inside turns into a liquid**.

I will put the balloon in the liquid nitrogen again and this time, I will let you see what is happening. At first the air molecules are a gas, and they are taking up a lot of space inside the balloon. But as the air cools, **the air molecules get slower and slower, and they don't take up as much space anymore**. Eventually, when we cool it down enough, all of that air changes from a gas to a liquid and just takes up a tiny bit of space, a little drop in the bottom of the balloon.

Ok, so which one takes up more space? A liquid ? or a gas?

[Audience raises their hands]

Let's try this in a different way as well. I'm going to put a small amount of liquid nitrogen (about 1cm) in the bottom of this plastic bottle. Then I will put a balloon on top. If the gas takes up *more* space, then the balloon will expand. If the gas takes up less space, then the balloon will be sucked into the bottle. Are you ready?

Pour some liquid nitrogen into the bottle and put the balloon on the bottle. The balloon will expand quite rapidly. Remove it before it bursts/flies off.

What's happening to the balloon?

[It's expanding]

Yes, as the liquid nitrogen is warming up and changing from a liquid to a gas, it is taking up more space, so the balloon is expanding. **So apparently, the same amount of air in liquid form takes up much less room or volume than the equivalent gas**.

What about if I want to trap the nitrogen gas, and stop it from getting out of the plastic bottle? I'm going to try and keep it inside by closing the cap of the bottle!

Make sure that the bottle is close to you; the ***liquid nitrogen MUST be under the table when doing this experiment****.*

Cap on the bottle with liquid nitrogen. Cap flies off.

Wow, it pops right out!

Repeat the exercise several times, catching the cap as it's blown off each time.

The volume of the nitrogen increases as it goes from being a liquid to being a gas.

So now a quiz question for you: How much more space does the gas take? For example, if I poured out one litre of liquid nitrogen, and it all turned into gas… how many litres of gas would there be?

[100? 50? 500? Take some guesses from the audience]

The volume of the gas is actually **690 times** (almost 700 times) greater than the volume of the liquid!

This means that we need to be **really careful when we store liquid nitrogen**. The dewars that we use to store liquid nitrogen always have lids that can come off very easily. They not sealed tightly. If for some reason the liquid nitrogen heats up, becomes a gas and expands to take up more space, the lid will just fly off and release the gas, without an explosion.

Demonstrate by lifting the lid of the dewar

Material Changes - solid

So, we've seen the gas become liquid, and liquid become a gas… What about solids? If we cool down a solid, does it become… "more solid"?

Here I have an ordinary rubber tube. And if I place it on the table and hit it with this hammer…

Show the tube *(check that there is a knot at the end)****, its flexibility, hit it with a hammer.***

…it doesn't break. The tube is elastic and rubbery, so the hammer just bounces off it. But let's cool it down in the liquid nitrogen…

Put the rubber tube in liquid nitrogen, *make sure the knot is on the outside part of the tube!!*

What do you think will happen now?

[Take suggestions from the audience]

Well, we'll need to wait a bit to see that. Meanwhile, as this is cooking, the liquid nitrogen is boiling again – it does so every time it meets something warmer than itself. As soon as it stops boiling, our rubber tube is ready for the second part of the experiment. As I take it out, you can already hear that it sounds different. It doesn't sound as 'rubbery'.

Knock the tube on the side of the container – clanging sound

Ok, I'm going to hit it with the hammer again. Are you ready?

Take the tube out, put it on the cutting board, and smash GENTLY with a hammer. *Don't smash too much of it – we don't want to create too much waste with our experiments. Be extra careful if there are people on the front few rows.*

As the rubber tube cooled down, **it became more brittle,** and I was able to easily break it. But as it warms up and returns to room temperature, its rubbery properties will return. It's like the balloon from before. By changing the temperature, we can change the state of the matter in one direction, and back again! As you can see, we cannot use the materials we would use to transport water for example, when we want to transport our cryogenic liquids in our accelerators!

I have another fascinating experiment here. I have a ring and a ball. As you can see, the ball passes through the ring while they are both at room temperature. But what do you think will happen if I cool the ring down in liquid nitrogen?

[Take suggestions from the audience…]

Let's try it!

Ball and Ring: *Put the ring in the liquid nitrogen, then demonstrate that the ball no longer fits through the ring.*

The **ring has shrunk**! It is smaller than before. We can already see this effect with our small ring after just a few seconds in liquid nitrogen. Now, imagine what happens to our LHC accelerator, a 27-kilometer loop that we cool down to -270°C! How much do you think the accelerator shrinks?

[Pause for guesses – encourage higher/lower bids]

The answer is **80 meters**! So, we lose 80m from the 27km LHC machines when we cool them down and we really need to take that into consideration when we build the machines!

Material changes - superconductors

So far, we've seen some fairly ordinary things, materials from the everyday, that behave relatively "normally". Balloons, hammers, plastic bottles… nothing too exciting. We've seen that their properties can change quite dramatically when we change their temperature.

Well, some materials change their properties even more dramatically at different temperatures.

Look at this black disc. This is a "superconductor". It is made of **YBCO ceramics… Yttrium, Barium, Copper Oxide.**

Show the superconductor *– avoid touching it with your bare hands, use the plastic tweezers or nitril gloves*

Yttrium is found in red lasers and the red colour in TVs, Barium is used in medicine. At room temperature, it is not very interesting. Here I have a magnet, but if it put it near the superconductor *[demonstrate this]*, you can see that nothing happens. If I place the magnet on top of the superconductor, with a little plastic in between… nothing.

Nudge the magnet off the magnet with the tweezers.

Place the plastic separator on top of the superconductor, and the magnet on top of the separator.

But what happens if we cool it all down to a very low temperature?

Carefully pour some liquid nitrogen over the superconductor, plastic and magnet. *It takes 2 -3 minutes to work.*

[You can also add liquid nitrogen to the little train at this point, so that it starts to cool down, or wait until after this demonstration].

While it is cooling, tell the audience the following:

We use superconductors at CERN in our particle accelerators and particle detectors. These are huge machines that make up our physics experiments about the structure of matter. CERN superconductors aren't made of the same elements as this one, they are made of **Niobium Titanium** and look like a cable *(show prop)* and they are cooled to even lower temperatures. The LHC superconductors are cooled to around **-270° C, using liquid helium** instead of nitrogen, and we use a lot more liquid nitrogen for pre-cooling – around **20 million litres**, but it's the same idea.

Let's see if it's ready.

Test the magnet with the plastic tweezers. *If it's cold enough, the magnet should resist being moved. Otherwise, let it cool a bit longer – you may need to add more nitrogen.*

So, remember that at about 20 degrees, room temperature, the black ceramic and the magnet weren't very interested in each other. I could easily push the magnet, and it just fell off this little pile. But now I'm going to try and remove the plastic separator… let's see what happens…

Remove the plastic separator. The magnet stays in place! *Savour this moment, let the audience react – use the loop to show there really is nothing between the two. You can also spin the magnet if you want.*

Wow! Now that we've reached a very low temperature, the **superconductor has become sensitive to the magnetic field of the magnet**, which is now "**pinned**", so to speak, to the

superconductor. It takes some effort to remove the magnet, but I can remove it. But if I let it go from somewhere else, it will always return to exactly the same spot. Watch carefully.

Remove the magnet using the hammer, then put it back, or put another magnet – it returns to its original position. *Play with it a little while*

[optional slide: superconductors] The superconductor "remembers" the magnetic field that's been pinned to it. Isn't that spectacular? And don't forget, this is no magic trick. It's physics.

If you haven't yet cooled down the train, do that now.

At CERN we don't use superconductors in this way – we don't need to make things levitate, but we do use superconductors for their ability to carry currents without any losses, with zero resistance… In the same way they could help to revolutionise future transportation, through levitating trains.

Here I have another cool set-up. This time the superconductor is inside the train, which is sitting on top of a plastic separator and the whole track is made of magnets. So it is like the other demonstration, but upside down. And we cool the train down with some liquid nitrogen – and now we wait.

In just a few years, as of 2034 in Japan, we will have superconducting trains. These trains will use superconducting magnets to reduce the friction in their coils, allowing them to reach much higher velocities – amazing! Let's look at how a train like this works. Now, let's see if the train is ready…

Make the levitating train run along the track

Plasma

We've looked at the three main states of matter – solid, liquid, and gas. Do you think there are more? Does anyone know any other state of matter?

[Plasma]

[optional slide: states of matter + plasma] Exactly, plasma! Plasma is a very special state of matter. We can achieve it in two ways – **either we can heat a gas to a really high temperature, or we put the gas under a very high voltage.** In both cases, the molecules or atoms inside the gas get **ionised**. This means, that they lose an electron. Does everyone know what an electron is?

[Part of an atom]

Yes, an electron is one part of an atom. But under certain conditions, we can cause the electron to get separated from the atom. Of course, I wouldn't be talking about plasma if I wasn't able to show you plasma. Here I have a very special plasma ball! Are you ready to see it? First, I need to turn up the voltage to make the plasma, and then we need to all ask the awesome technical team in the back to make the room dark. But they have troubles hearing me sometimes, so let's do it together. When I count to three, everyone yells "dark". Ready? 1, 2, 3 – dark!

[Dark!]

Wow, can you see the plasma in the plasma ball? What can you see there? It's like lightning! In fact, the lightning that you see during a storm is plasma – how cool is that! We don't encounter much plasma in our everyday lives, but actually plasma is the **most common state of matter in the Universe** – the stars are also made of plasma! Let's try and make some experiments with plasma. First, let me see if I can control this plasma …

Put hands on the plasma, play around.

This experiment looks really cool, but what is really happening? Well, this glass ball is filled with gas (noble gas, usually argon or neon). **When we apply the high voltage, the electrons of the gas get separated from their atoms, creating a kind of 'soup'. Then the electrons are free to move.** They want to get to the ground, so they choose the easiest route to the ground. When I am not touching the ball, they have to travel through the gas, through the glass, down the plastic of the flight case and into the ground. But my body is a better conductor than those materials, so if I put my hand on the ball, they take the easier route, which is through my hand, through my body and into the ground. Luckily, the current in this ball is very, very, very low so this is one of the only examples of electrical currents not being dangerous.

This is really cool! But what happens if I put something *between* the plasma ball and my hand? Here I have a fluorescent tube, like we use in the lights. This lights up when a current (electrons) passes through it.

Do you know Star Wars? Do you remember the special swords they have in Star Wars?

[Lightsabers]

Yeah, lightsabers. Let's see what happens when I bring the fluorescent tube close to the plasma ball.

Play around with the fluorescent tube against the plasma ball. Put your hand at different places along the tube.

As I said, the electricity from the ball wants to reach the ground as soon as possible. So, the electrons travel through the ball, then through this tube, where they ionise even more atoms, the mercury vapor, which emits UV light, then the phosphor coating on the inside of the tube converts this UV light into visible light. My hand acts like a ground or an electrical sink in this setup. The part between the plasma ball and my hand is influenced by the electric field. My hand absorbs or blocks the field beyond that point — I am now part of the circuit path to ground - So the electric field strength drops significantly after my hand, and there is not enough energy to excite the gas further down the tube.

When you are ready, ask for the lights to be turned up (or ask the audience to do this) and then end the show…

We have now come to the end of our science show. I hope you all enjoyed learning more about the mysteries of matter and how we can change things from one state of matter to another, using temperature changes! Thank you for joining me on this adventure, and I hope you enjoy the rest of your time at CERN Science Gateway!

Additional things to show or tell

- **Leidenfrost effect** by pouring liquid nitrogen onto a surface. A phenomenon in which a liquid, close to a solid surface significantly hotter than the liquid's boiling point, produces an insulating vapor layer that keeps the liquid from boiling rapidly, creating "levitating" droplets.

- Sketches with **Genie:** pouring liquid nitrogen into the watering can, using the Genie with superconductors (swapping the magnet for the genie).

- **Ping pong ball:** submerge the ping pong ball in liquid nitrogen, wait for it to cool down, put in plastic circle to start spinning – talk about pressure

- **Volunteers showing states of matter** (only in front of the stage, away from all liquid nitrogen) I need 6 volunteers to help me! (pick them) Let's applaud them! You will each represent a molecule of water, which is a big science way of saying the smallest possible piece of water that's still water. You will start as ice, a solid. Link your arms together at the elbow. You are all very close to each other and cannot move independently. Now, we're going to raise the temperature a bit, coming up past zero degrees. As our ice melts, your arms slide out and you hold each other by the hand instead, for a nice round droplet. You are now a liquid. You are further away from each other and can move a little bit more freely, but you're still attached to each other a bit. And finally, let's boil you! Let go of each other's hands and run around! You have evaporated and you're a gas now! You are free from each other and move about as you wish! Thank you, you can go back to your places now.

- **Eddy currents**: to show the effect of eddy currents on magnets falling.
  Look here, I have a magnetic marble. (bring the head of the hammer towards the magnet and see it "jump" from the table) The marble is attracted by the iron in the hammer, so it's a magnet! Which is to say, it has a magnetic field around it, which certain other objects may interact, depending on the way the matter they're made of is arranged. Magnetism is so strong, it only takes a hammer to pick up this marble, while the entire Earth is influencing it in the opposite direction through gravity. So, it's not such a negligible force after all. Magnets on the fridge, and the one in front of me, don't usually move very much. They just sort of sit there. What we're interested in here, however, is what happens when a magnet moves. (prepare the plastic and copper tubes) Look what I have here. Plastic and copper tubes. Before testing the magnet, let's test an ordinary marble. See, the hammer doesn't attract this one (show that) it's an ordinary marble. If I hold this marble just above the end of the tube and let it go, what will happen? (wait for reply) It falls! Let's watch (let the marble fall through the plastic tube)
  Ordinary marble, plastic tube, so far so good, nothing very special. What a show. But if we're going to be good scientists here, we should test all the marbles and all the

tubes. So, what's next? Let's drop the ordinary marble down the copper tube this time. (repeat the exercise with the second tube. The marble falls normally)
OK, still not too exciting. But a magnet, well, that must be different (repeat with the magnet in the plastic tube. It falls normally)
Let's be rigorous if you really insist. I drop the magnet in the copper tube (do so – the magnet falls noticeably more slowly) Aha! Is it just me, or did it seem like that time, the marble fell more slowly than the others? Shall we try again to check? (repeat the exercise. The marble falls slowly) So, what happened there? [Eddy's current slide]
Well, the magnet's magnetic field, as it moves, "induces" an electric field in the copper, but not in the plastic. That's because copper is an electrical conductor. Think of the electric cables in your home, they're made of copper. And that electric field is moving too, which in turn induces a second magnetic field, but this time, the field is oriented in the opposite direction to the first, which opposes the movement of the marble. Look now at this plate made of copper. (show it) The ordinary marble just rolls along it as you'd expect. But the magnetic marble, watch, it gets slowed down (demonstrate this – be careful not to lose the marbles into the audience!) To summarize, there is an opposition between the induced magnetic field and the pull of Earth's gravity. Overall, it's gravity that wins out, so the magnet still falls or rolls, but more slowly than its non-magnetic cousin.