

Guide preparation for **Seeing the Invisible**

🕒 **Duration:** approx. 45 mins

👥 **Age group:** suitable for all age groups

Introduction area	Experimental area
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Suggested structure & timings

Time	Task	Equipment
00:00 – 00:05 5 mins	Introduction to workshop: Introduce yourself + general info + goal + duck starter.	2 Ducks. Scales.
00:05 – 00:10 5 mins	Guide demo + instructions: show how to roll ping pong balls in and draw (part of) a model. “No eyes or hands; call a guide when you are done.”. Then reveal the obstacle and compare to your model. Show how to get the ball back by tilting the box.	1 detector box with green obstacle, ping pong ball.
Checkpoint 1: No later than 10mins in, participants move to experimental area.		
00:10 – 00:20 10 mins	Experimental Phase 1: Each group conduct experiments. When they are done, students call the guide to discuss and check their model. Then the guide swaps the green obstacle for a red one.	Boxes with green obstacles, ping pong balls, whiteboards, green obstacles.
00:20 – 00:30 10 mins	Experimental Phase 2: At first, groups only have ping pong balls to investigate the red obstacles. When they are done, you can them a bag of marbles and let them try again. Then, you can swap the red obstacle for a blue one.	+ marbles + red obstacles + blue obstacles
00:30 – 00:40 10 mins	Experimental Phase 3: 1x IR camera per group, students can walk around and explore freely.	IR cameras
Tidying up : each group erases the whiteboard, remove the current obstacle, puts the marbles in the bag, the ping pong balls in the box, and gives IR cameras back to the guide. The guide puts a green obstacle in each box and takes back the marbles and the advanced obstacles to the trolley.		
Checkpoint 2: No later than 40mins in, participants move to intro area.		
00:40 – 00:45 5 mins	Guide Explanation: Debrief. What we did today. Link to CERN and everyday life. Any questions?	

Set up of workshop

When you arrive in the labs, the equipment should already have been set up as follows: on the teacher trolley, a demo box with the easiest obstacle (a simple wall on the side). In addition, the trolley contains: more obstacles (green, red and blue), 6 bags with marbles and eight FLIR C5 infrared cameras.

On each table, there should be:

- A mystery box with a green obstacle covered by a metal plate,
- A box with 6 table tennis balls,
- A whiteboard and a whiteboard marker.

Suggested Script

Everything written in “ ” is a suggestion of the type of explanations that can be given, feel free to adapt as required.

Introduction area

Introduction to workshop (no more than 5mins)

➔ **Introduction of guide(s):** “Welcome to the Science Gateway Labs at CERN! My name is ..., I work at CERN ...” If possible, either a) explain why you think that science is fun, b) tell something cool about what you do at work, or c) share a story from early high school that motivated you to get a scientific work (ideally from when you were around 12, 13, 14 years old, so that the students can relate to your passion for science).

➔ **General info:** “In case of an alarm, you will leave your belongings here and follow us down the stairs, as you may have practiced at school. We will take you outside to the nearest assembly point. We ask you not to eat or drink in the experimental area - the area with the tables over there. Feel free to take pictures if you want.”

➔ **Goal of the workshop:** “During this workshop we will try to make the invisible visible. That is very similar to what the scientists at CERN are doing. They are looking for clever ways to determine invisible properties and make them visible so to speak. Scientists at CERN use big detectors to do this.”

➔ **Duck Starter:**

Theatrical/Mysterious “**I am going to show you something invisible today, are you ready?**”

You hold up 2 ducks and say “**spot the invisible difference!**” and you wait! Let audience make a few hypotheses and interact. You can reject things like ‘one has a tiny mark’ => refer back to: “there is a really big difference here!” You can prompt: “**I did say I was going to show you something invisible: spot the INVISIBLE difference!**”.

If somebody guesses that they have different masses/weights, “**how can you detect this difference?**”. Then: “I brought my monster detector along, let’s see what we can detect..” Place both ducks on either side and release at the same time so the scales tilt quickly to one side. – *big wow from the audience hopefully!* “...Correct! One is heavier than the other one, **they have a different mass, which is an invisible property.**”

“**Did you all bring your detectors with you today?** In case we weren’t allowed to use the monster detector”. In case no one knows what you mean, give them a hint by saying that their eyes and hands (just like many of their other senses, <https://www.sensorytrust.org.uk/blog/how-many-senses-do-we-have>) are detectors. Then hand out the ducks to a person and ask them again “**Detect the invisible difference using your hand-detectors**”, ducks can then be passed around so that everyone can feel the difference for themselves.

“Today you will be using a special type of **detector** to make invisible structures visible”.

Guide Demo + instructions (no more than 5mins)

“There is an invisible obstacle underneath here and it is your job to make it visible as precisely as possible! We will **not use our eyes or our hands** again as detectors to develop models for the next experiments. In physics and science, you cannot generally see with your eyes what you want to discover, but need **indirect** ways of measuring properties, so we are trying to make you experience authentic, similar to what it is like to be a real scientist!”

“We will only use this **ping pong ball** detector. It works the following way: You take a ball and let it roll down, to determine where the hole(s) are located and where plastic is in the way.”

Demo for 1 ball on the wall & 1 on the gap. Do this slowly & get everyone to be super silent so you can even hear the click (i.e. using ears as detectors!) when it hits the obstacle. Then show how to get the ball back by tilting the box. “If you have a guess what the structure looks like, then draw it on your **whiteboard**.” Show how to do: draw a line where the wall is. “But no cheating and no using other detectors like your eyes or your hands!”.

“Important: come up with your best model and **be as precise as you can be!** When you are done, call a guide to reveal the obstacle and to discuss your models, before trying new obstacles! Now you are allowed to use your eyes as detectors to double check.”

Then, reveal this obstacle by lifting cover. This helps students get a better idea for what they are looking for, i.e. a 2D structure with holes/walls. “How accurate was your model?” Make a comment on how it could have been improved if no good suggestions made about the scale / the precision of the gap width / etc...

“Any questions? Anything unclear?... Let’s go! Go sit at a table in teams of 4, then you can start”.

Experimental area

Experimental phase 1: green obstacles

Check students are doing it correctly, keep emphasizing that they need to be super precise. Encourage them to repeat experiments. “Is this model to scale? How sure are you the end of the gap is exactly there?” “The ball hits something and then comes out on a different lane – what could it mean?” When they are done, you can reveal the obstacle to let the student verify and compare it to the model. Then you can swap their green obstacle for a red one.

Experimental phase 2: red obstacles (first with ping pong balls, then with marbles)

When you give them a box with a red obstacle, students still only have ping pong balls at their disposal. They should thus not detect any small gap. When a group is done: “How sure are you? Would it be possible that this obstacle here is not a wall, even if the ping pong balls cannot pass through?”

To help them get to the solution, that we are after smaller resolution: “If we had used a bowling ball instead of a ping pong ball, then what would have happened?”. Right answer: the ball would not have rolled through the obstacle, because it has the wrong **size** and we wouldn’t have been able to determine the structure. “So if a bowling ball is too big, and therefore prevents us from finding out the structure of the obstacle, what can we use to make sure we draw the right structure? Right answer: We could use smaller balls!

“Yes, you’re lucky, **new detector technology** has been developed by R&D. In this bag, you will now have **marbles** at your disposal. Again, one volunteer of each group can come take some and then you can try it again with the marbles, to see if your model is still the best possible, or if you decide to develop a new, more precise model!”

OPTIONAL (for students that finish early): blue obstacles

Let the groups try and figure these obstacles out, then you can discuss with them about the relevance of the ping pong balls in this context and about the limitations of our detection system.

Experimental phase 3: IR cameras

“We have these special detectors called Infrared Cameras that make yet another invisible property visible: temperature! Sort of like another temperature detector that you might be familiar with: a thermometer! Why can’t we use our hands as detectors for temperature all the time?” It might be dangerous (too hot) or inappropriate (inaccessible) or too small ...

Instructions

1. **Emphasis on being careful.** Fragile & expensive detectors.
2. One person at a time.
3. With school groups: “pass the camera around” - everyone gets to have the camera at some point.

Suggested activities

1. Look at each other through the IR cameras.
2. Look at power cables / windows to spot hold/cold spots.
3. Write your name on the table in invisible writing (using friction of finger to write it).
4. Find materials that reflect infrared light.

Tidying up

Approx. 5-10 minutes before the end of the time: “I know we could probably spend a whole day experimenting, but the detectors now need to be shut down, so we can analyse and discuss the detector results we have obtained today. We will ask each team to:

- erase their whiteboard,
- remove the red/blue obstacle from the box and leave it just next to it,
- put the marbles back in the bag,
- put the ping pong balls back in the box, and
- bring us back the IR camera

... so that everything is ready for the next group. Then just come back here to the discussion area, so we can have a little meeting about what we learned through these experiments.”

In the meantime, you can put all the red/blue obstacles and the marbles back in the teacher trolley, and put a green one in each box.

Introduction area

Conclusion (5 mins)

➔What we did today:

1. **Invisible:** “What invisible properties have we seen today?” Mass, structure, temperature and others that they might have mentioned. Many properties we are interested in in science, such as mass, structure, energy, electric charge, magnetism, radiation (which unfortunately are mostly invisible to our senses) can only be observed indirectly.
2. **Detectors:** “What detectors did we use for each?” Refer to hands, senses, monster detector, special table tennis ball detectors, IR cameras, ...
3. **Resolution:** Importance of the resolution of the measuring devices. To observe anything, the size of the gap has to be comparable to the particle we are using to measure it. One can make a comparison with the limitation of the light microscope, for example, and allude to the fact that higher and higher energy is needed to make smaller and smaller structures 'visible'.

➔Link to CERN and everyday life:

- **CERN:** there is a link to CERN detectors, though they work based on different principles. Today was just an **illustration** of how we can make the invisible visible using a special ping pong ball marble detector, that you now have mastered to operate and optimise. The basic idea of CERN detectors is the same: Figure out a clever way of making something invisible visible and coming up with models of these invisible properties. In real life we use lots of different techniques and technologies to better understand and measure different invisible properties of particles, like mass, charge, energy and spin. “At the big LHC detectors we use for example gigantic magnets, in order to determine the electrical charge of a particle”. Here you may show a photo of a particle collision.
- **Everyday life:** you can show the picture with animal tracks. “Which animals were there?” Birds, a fox/wolf/dog... “You managed to guess which animals walked on the snow without even seeing them! You looked at the tracks and they gave you info. Well, that is also something that occurs at CERN: scientists look at particle tracks, and that allow them to guess which particle was there.”

➔**Questions:** “Are there any more questions about the experiments we did today? Are there more questions for me?”

THE END

A few tips and suggestions:

- 1) Make sure everyone can see your demo – you can put the box on one of the seats or on the floor and tell students to come closer if needed.
- 2) For younger audiences (age 5-7), it is generally easier to find the gaps instead of the walls. In your demo, start by drawing a complete wall, then erase parts of it when the ball passes through.
- 3) During the hands-on part: if you feel that the table-to-table interaction takes too much time, you can ask for everyone's attention and give instructions to the entire group instead. You can also let the participants handle more tasks by themselves (e.g. revealing the obstacle when they think they are done and then coming to you to ask for the next challenge (instead of you running from table to table), or even swapping out the obstacle for their table...).