Study about supercooling chambers

Why we want to come to CERN

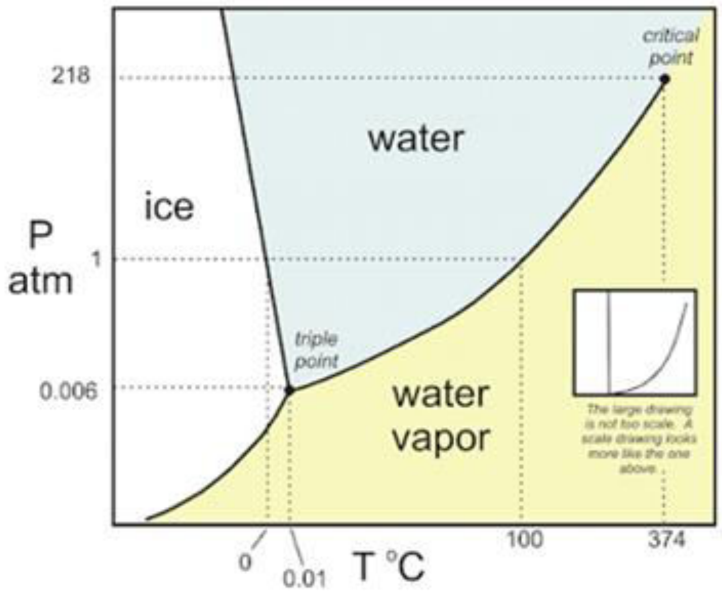
We are a group of seven pupils from Reims. When we heard about Beamline for schools' competition, we immediately knew that it was a great opportunity for us. Indeed, we are all science buffs, interested in physics and wanting to acquire new knowledge.

Going to CERN would be a great opportunity to make our experiment become true, meet physicists, and learn more about physical aspects not commonly taught at school. Moreover, our unique experiment would allow us to improve our knowledge in an exciting and uncommon way. This would also enable us to share our results and promote interest in physics in our school.

The idea: Creating a supercooling chamber

Usually, physicists use cloud chambers to see and analyse particle trails and study particle properties. We decided to revisit this process by creating a new kind of chamber using supercooling. We named it 'supercooling chamber'.

Supercooling is a state of certain elementary bodies. In this state, liquids such as water are under their fusion temperature, even if they are still liquid. Moreover, in this type of liquids, small crystals are formed and disappear constantly, due to the temperature being still too high. But a simple variation of energy in the supercooling liquid will create an instability and crystallize it.



Water triple point

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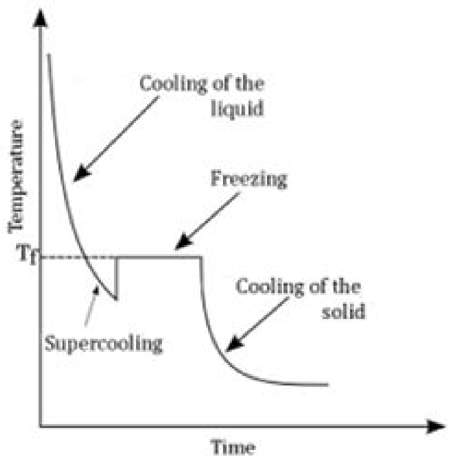
The idea is simple but exciting. We will build a tank of distilled water, cooled down by Pelletier elements, to put water in a supercooling state.

According to our calculations and hypothesis, if an accelerated particle passes through the supercooling liquid, its energy will lead to a crystallization of the water on its path (only above 0.2MeV, we have done all calculations here if you want: https://docs.google.com/document/d/1ikhWX5d_Bm57i9r1Aoca5P49sPlL_lRxFTlM1EKpTuU/edit?usp=sharing).

Thus, we can see the particles' trail (made of crystallized water), with detectors and do some analyses.

We will use the proton synchrotron to make different kinds of particles (protons, electrons, and antiparticles) with different momentums. Then, we will send these particles in our supercooling chamber, to collect a visual of their interactions with physical detectors. We will photograph and film the supercooling phenomenon with different detectors mention below. We will also determine, with measurements, what kind of particles went through the target, estimate their momentum, their speed, how they transmit their momentum and what the products of their collisions will be.

We will use a thermistor and an infrared sensor to measure the change of temperature that will trigger the reaction. Indeed, liquid water will have a temperature between -2 to -6°C, and will return to 0°C when it crystallizes. This change should be easy to observe.



Graphic indicating the state of water depending on time and temperature

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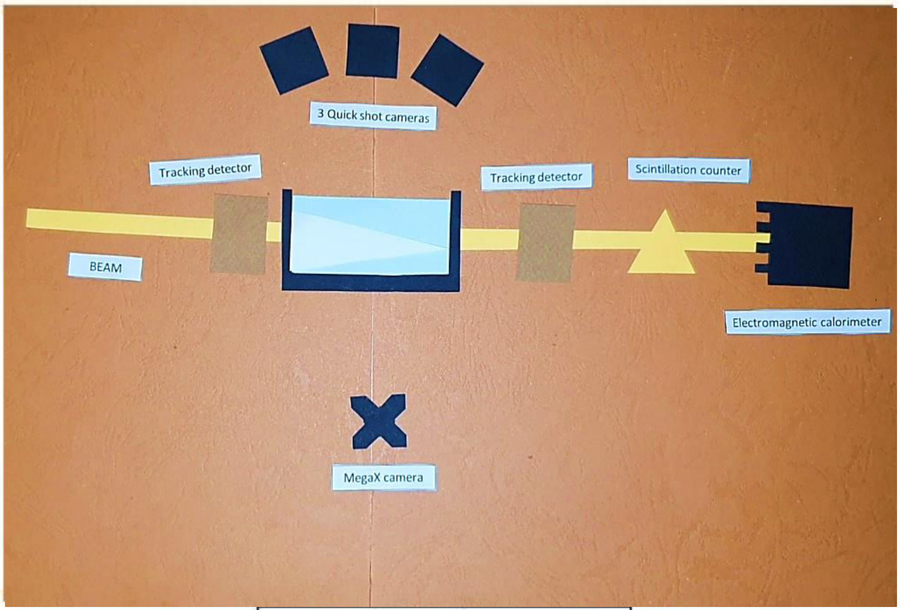
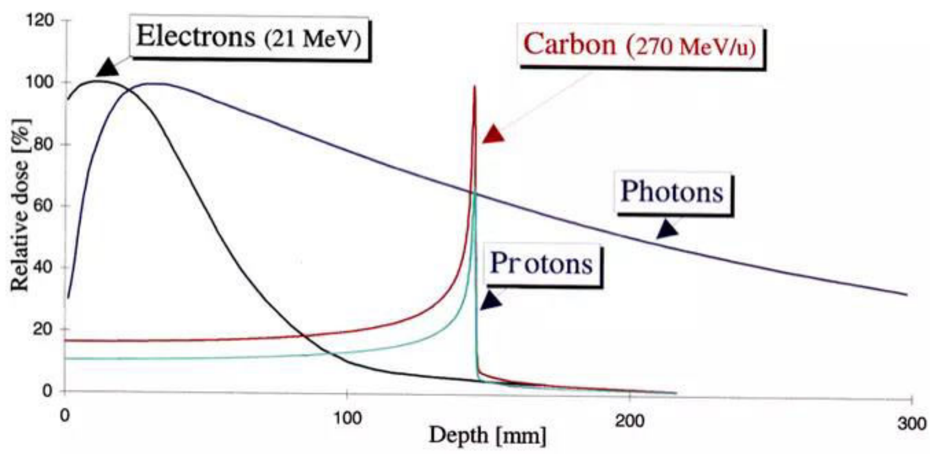
We plan to use three ultrarapid cameras to film the collision and the reaction.

At the end of the tank, we will put a scintillation counter to detect the passage of particles, as well as an electromagnetic calorimeter, a MegaX camera, and two tracking detectors, which will stay focus on the beam. Both estimate the energy transferred to the liquid, the number of particles, their position, and help to indicate the particle type, before and after the chamber.



Plan of our experimentation, made by ourselves

We expect different results depending on particle types. Indeed, for example protons and ions will transfer a small part of their energy at first, and then will lose all their remaining energy at the same time, it's called the Bragg Peak. We should observe an irregularity in crystallizations, indicating that it was protons or ions which came through. Electrons exchange their energy uniformly, and it will decrease continuously down to zero. Crystallizations should be uniform and straight for electrons. We can represent this phenomenon like this:



Graphic indicating percentages of radiative dose, depending on the depth materials and particles

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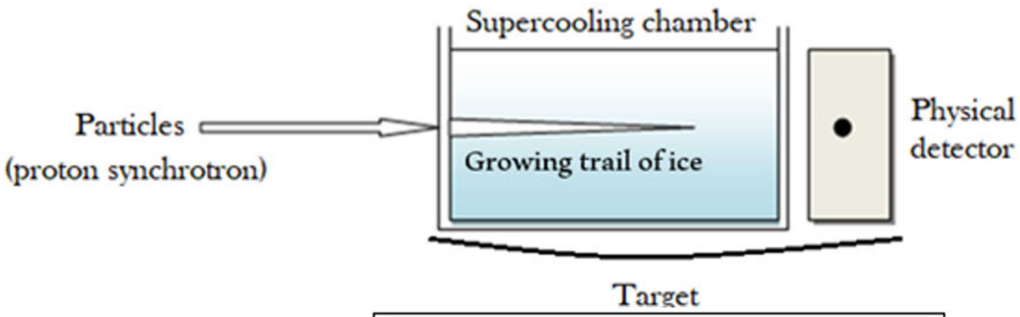
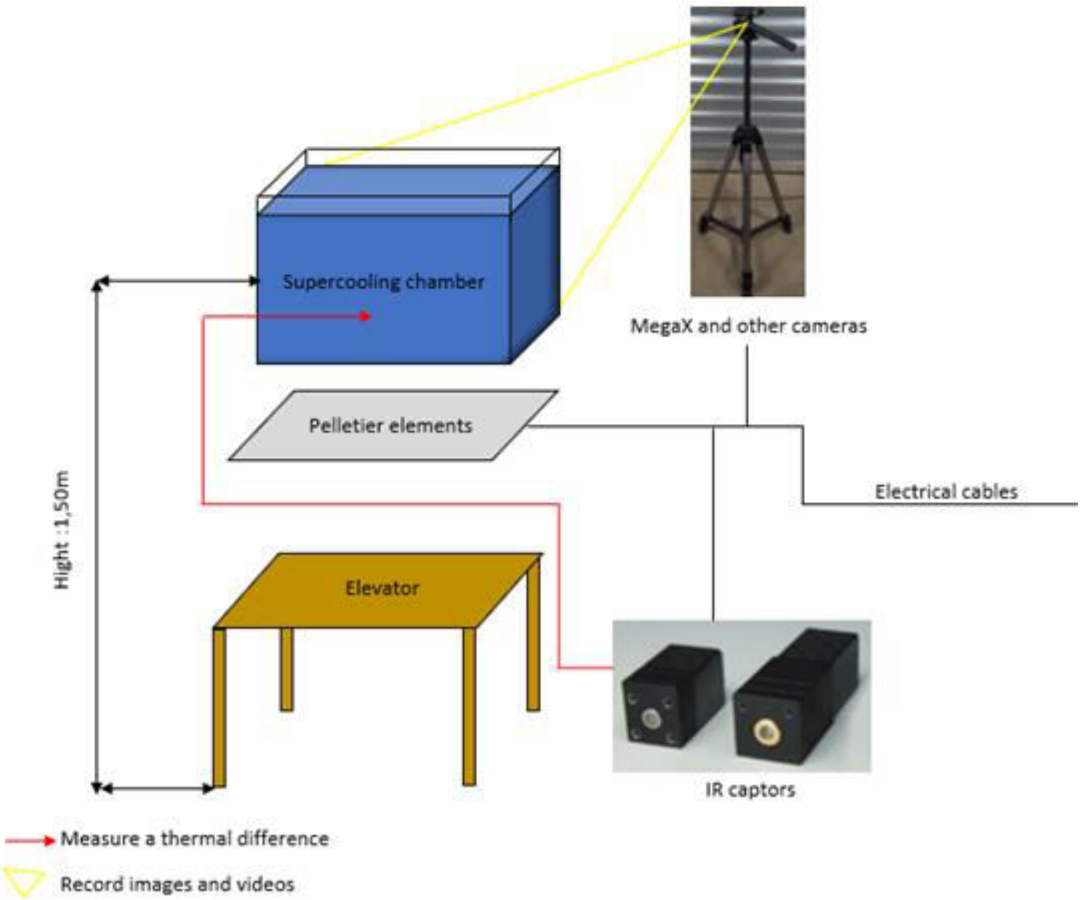
Moreover, we predict that antimatter should have a same type of reaction, with the chamber, than protons. It will interact with matter and give their whole energy at the same moment, but with more energy and less frequently. Using secondary beams is also possible but not the main objective.

We can summarize the experience with these diagrams:



Plan of supercooling phenomenon in a supercooling chamber, made by ourselves



Plan of our experimentation with the main material, made by ourselves

An extra step in our experiment, will be to try to find conditions where particles create a trail, which does not spread in the rest of the liquid. This may help us to capture the particle trail, and to conserve it for future analyses.

However, we must admit that some processes of our experiment are not very convenient. Firstly, we must wait from 1 hour to 2h45 to have water in its supercooling state. Nevertheless, we can solve this with a rotation of other tanks, previously prepared in a near freezer on site, which will reduce the wait time to about 15 to 30 minutes per experimentation. Also, our ideal tanks will have a measurement of 4x4x25cm (10x15x25 in the worst case), which is perfect for observations and a quick cooling down. Secondly, we expect the crystallization to be very quick. Here, we will need different cameras, detectors, to film the growing trails. Another question is whether the energy will be sufficient to trigger the crystallization. So, we calculated and did an analogy (you can see our experimentation here: https://www.youtube.com/watch?v=PjdeQGX1ZYA and our calculus here: https://docs.google.com/document/d/1fMEmv7yo0i6xBgbSnzH6qlbr9oTI4itwuNQTapIi44s/edit?usp=sharing), where a coin is dropped into a bottle of water, with the same energy level, and it crystallizes well. Our results indicate that the experiment is completely feasible.

What we hope to take away from this experience:

The results will hopefully be impressive and visual. We aim to establish and define specificities of this new kind of chamber, never made that way. We expect to obtain new results to help the research about the interaction of energetic particles in liquids. Our second objective is to produce an article, to describe our results, do statistics on supercooling chambers, and help physicists with a completely new tool. To finish, we want to obtain photographs to display them to the public, and promote physics in France, especially around us, for example in our high school.

What outreach activity or science education can we do in our community?

We have to say that we are very proud of our proposal. If we are chosen to make our project come true, we will be very pleased to share what we have learnt! Indeed, our first outreach activity would be in our school. As it has more than 1500 students, this will be a great opportunity to present specific physical aspects to all these teenagers, with science events, like conferences and an exhibition. We would explain how scientists work, what experiments we have done, what we have learnt, and we would also show photographs and videos. It will be a good way to promote science, for example by presenting the supercooling effect, thanks to a bottle of water, which is very impressive and not well known. Moreover, we are in a Lasalle school, which is part of a network of hundreds of schools located in 78 countries. So, this will be also important for us to do meetings, video conferences and talks with thousands of students, to transmit them our passion for science. We are sure that talking about unknown aspects of this discipline and presenting something we have achieved ourselves would be very worthwhile for the people we will talk to.