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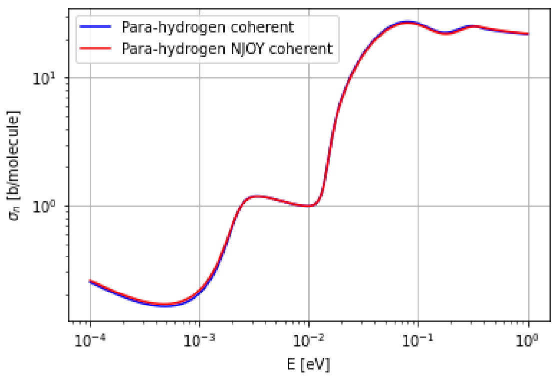
The challenge of slowing down neutrons the right way

The European Spallation Source ESS, which is currently under construction in Lund, Sweden, is a next-generation neutron research facility. Once completed, it will use neutrons to undertake a multitude of experiments, some of them carrying out fundamental research and others more practical in material science.

The production of neutrons in a spallation source requires an energetic proton beam which is accelerated by a linear particle accelerator to velocities close the speed of light. This beam is impacted into a target made of solid metal. Here, the neutrons are produced by a phenomenon called spallation: the protons are so fast that they break apart the nuclei of the target into smaller nuclei and, crucially, several free and very energetic neutrons. For many applications these neutrons are too fast and thus have to be slowed down to appropriate speeds. But how can you brake particles that move close to speed of light and have no electric charge which you could grab them by? You send them through a moderator. A moderator is a material that acts like a sticky ”syrup” on neutrons and slows them down to the speed of sound before they can escape again and then be used for experiments.

Moderators have been researched and used for decades in efforts to make nuclear energy a safe and reliable power source. Almost every nuclear power plant uses a very familiar moderator: water. However, even after passing through water, the neutrons, now called *thermal neutrons*, are still too energetic for a lot of material science applications. This is where current knowledge becomes sparser, since different, more rarely used moderators have to be employed, in case of the ESS liquid hydrogen. To design an efficient moderator, the slowing-down process is simulated with scattering software to obtain the *scattering kernel*, a quantity which describes how energy and momentum is deposited in the moderator when neutrons pass through it. So far, NJOY is the most-used program for this purpose, but as requirements to add more physical models to represent potential future moderating materials grow, limitations in NJOY have become apparent.

As a consequence, a new software called NCrystal, has been developed at the ESS with a more flexible design to make the simulation of different moderators easier. This Master thesis added the functionality of simulating liquid hydrogen, the cold moderator of the ESS. To achieve this, a number of physics models had to be included into the code which describe the interaction between neutrons and the molecules of liquid hydrogen. The final result which is easiest to cross-check against NJOY is the *total neutron scattering cross section* (see figure), which describes how much a neutron is slowed down by a material depending on the energy of the incident neutron. The results of the thesis show good agreement with existing literature and can thus be used in the future.



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Examensarbete 30 hp i Mai 2022
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