International Conference on History of the Neutrino

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Yesterday, we saw how deeply the way physicists' work changed during the interwar period, and how these changes were driven by a new role assigned to science by society. Today, we will address the next main topic. The topic of the Second World War, obviously. This Second World War is so much a pursuit of the first one, that it will of course point mostly towards the same directions.

One of the most impressive consequences was the tipping of the center of gravity for physics, from Germanic countries to the United States, over the course of ten years. The events we talked about yesterday had already laid out the field for the welcoming of a major part of international physics on the other side of the Atlantic. But the trigger was obviously the rise to power of the Nazis in Germany in 1933. Just among Jewish physicists, physicists with Jewish family, or left-wing political opponents, the Germanic countries saw in a few years a whole part of their scientific community fleeing central Europe. Schrödinger chose Ireland, Born the United Kingdom and Meitner Sweden. But for most of them, the United States had become the most natural destination. Among the most famous ones, we could name Einstein, Bohr, Fermi, Pauli, Bethe and Szilard. And most of them *stayed* in the United States once the war was over. Europe was then a devastated battleground, particularly Germany, who was placed under Allied administration. And more decisive, the economic domination of the United States became far stronger than it had become in the wake of the First War. For the second time in thirty years, the United States became the creditor of the European war effort, and decided to fund the reconstruction in exchange for massive import of American products. This was known as the *Marshall Plan*.

At the same time, the combination of the national scientific institutions of the interwar period with the abrupt conversion of countries to war economy, especially in the United Kingdom and the United States, led to an incredible intensification of the previous trends. Historians of science have called this new regime of science, completed with the Second World War, *Big Science. How Big?* Big in several meanings. First, because of a quantitative explosion. Of the number of scientists as well as the national spendings. Estimated research spendings for the United States were multiplied a thousandfold between 1935 and 1945. Second, because of the organization of scientific work in big laboratories mobilizing hundreds to thousands of researchers. And finally, because of the organization of this work around large instruments, like particle accelerators, large telescopes or computers.

Since the States were generously funding these activities, it was decided to fix practical goals to scientists, decided by a central administration, and to organize research in collaborative units, not unlike industrial organization. Around these practical goals that could help to win the war, multidisciplinary teams were established, with almost unlimited funds. All across the United States and the United Kingdom, scientists were *enlisted* like this, with the idea that scientific achievements could decide the outcome of the world conflict.

And in a way it did. The leading position acquired by Great Britain in the development of RADAR technologies during the conflict were of the highest importance for the Navy and the Air force. The field of *operations research* appeared, combining computation and mathematical analysis, to help solve the huge organizational issues of the war. Cybernetics and information theory arose from the study of communication problems and automatic guidance for air defense systems. And we have to mention the development of digital computers, for ballistic calculations or codebreaking. If you have seen the movie *The Imitation Game* about the work of Alan Turing during the war, you already know the importance cracking German intelligence codes had in defeating the German naval blockade of Great Britain.

And, above all, the bomb, obviously. I will not stay long on this well-known story. Just a few remarks on the importance of this episode for fundamental physics development. From the first publication on nuclear fission in 1939, to the Hiroshima bombing, only six years had passed. During this interval, the handful of nuclear physicists in the world informed of these works alerted their governments about the potential military use of this fundamental discovery. All open publication on this topic stopped. And in 1945, the most frightful weapon ever built by humankind killed 70,000 people instantly, and 200,000 more during the next five years, in one unique explosion. I think there is no need to stress more the importance took by fundamental physics in the twentieth century.

The team of Frédéric Joliot-Curie, in Paris, was probably the most advanced on this subject in 1939, but he preferred to stay in the occupied France and all their work stopped until the end of the war. Meanwhile, Robert Oppenheimer was charged by Roosevelt to be the scientific leader of the Manhattan Project. A large number of the most brilliant physicists, who had fled central Europe just some years ago, worked with him on the atomic bomb, with the assistance of more than one hundred and fifty thousand engineers, technicians and workers across the United States. The physicists' team founded the laboratory of Los Alamos – a kind of secret city built in the middle of nowhere in New Mexico – which basically became the prototype of modern fundamental physics laboratories. For the study of the nuclear detonation, it is there that the mathematician Stanislaw Ulam invented the Monte Carlo methods and proceeded to the first computer simulations.

For scientists, this *Big Science* meant a loss of their autonomy. They were no longer the ones to decide on their research priorities, instrument choices or colleagues. Concurrently, military power was not, for the first time, a demographic issue, but a scientific one. And if States could discipline and organize scientific research, this scientific issue could become itself an economic one. This situation led to a kind of historical mutual compromise between scientists and political power. This compromise was set out in the most famous and clearest way by Vannevar Bush, MIT researcher on computers and scientific advisor of then President Roosevelt, in a public report to the President of the United States published in 1945. Its title was *Science: The Endless Frontier.*

Bush was requesting the perpetuation of the national budgets without limit, like those they had known during the War, but argued for an ideal of autonomy for “pure science”. In exchange, society and political power could count on rapid return on investment, in terms of economic growth and military applications. With the example of nuclear physics in mind, fundamental physicists encountered no difficulty to convince military authorities to pay huge amounts to let them investigate whatever research lines they would like. *Something big and useful* would certainly come out of this one day or another!

Obviously this solution established itself thanks to the context of the Cold War, but I keep this part for my last talk tomorrow. Indeed, I have not talked at all about the USSR until now, which however was maybe the first country to enter in this *Big Science* regime, despite its economic weakness compared to the United States.

Thanks for your attention.