Barbara Curli

Italy, Euratom and Early Research on Controlled Thermonuclear Fusion (1957-1962)*

ITER, the international controlled thermonuclear fusion project, is the world's largest fusion experiment and the most important European research project, apparently "one of the largest and most expensive science projects ever",[1] and also a very controversial one. The European Union (with Switzerland) participates for around 46 per cent of total costs and the other six partners (Japan, China, Korea, the Russian federation, India and the United States) for around 9 per cent each. The ITER device, "approximately three times as heavy as the Eiffel Tower", is a tokamak currently under construction at Cadarache, in the South of France.[2] Italian research and Italian industry extensively participate in the ITER project,[3] which is also intended as an industrial policy tool to support research and development in advanced technology on a European scale.[4] The

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1 W. Patrick McCray, "'Globalization with Hardware': ITER's Fusion of Technology, Policy, and Politics", *History and Technology* 26, no. 4 (December 2010): 283-312.

2 Fusion for Energy, *Annual Report 2014*, http://www.fusionforenergy.europa.eu/mediacorner/annualreport.aspx, last accessed April 19, 2016.

3 Aldo Pizzuto, "La partecipazione italiana al programma internazionale per la fusione", *Italian ITER Business Forum*, Milan, June 26, 2014, http://www.iibf2014.enea.it/, last accessed April 19, 2016; Paolo Acunzo, "La partecipazione delle industrie italiane al progetto ITER/Fusion for Energy", paper presented at the conference *ITER: un'opportunità per le aziende piemontesi*, Turin, November 16, 2015**,** http://www.confindustria.piemonte.it/convegni-ed-eventi/2444-iter-un-opportunita-per-le-aziende-piemontesi-torino-16-novembre-2015, last accessed April 19, 2016.

4 European Commission, Directorate general for Research, Fusion Energy Research, *Fusion and Industry together for the Future* (Luxembourg: Office for Official Publications of the European Communities, 2009).

Frascati Tokamak Upgrade (FTU), one of the seven tokamaks currently operating in Europe, which developed from a first generation prototype, the Frascati Tokamak (FT), set in operation in 1977, is located in the Frascati National Laboratories of the Comitato Nazionale per la ricerca e lo sviluppo dell'Energia Nucleare e delle Energie Alternative (ENEA), the national agency for new technology and energy. Italian industry (e.g. Ansaldo) also has a long tradition of presence in nuclear fusion and industrial application.[5]

Both European collaboration in controlled thermonuclear fusion research and Italian involvement in this field have in fact a long history, which goes back to the early days of the European Community, but has been underexplored so far. This chapter is intended as a preliminary contribution to the historical reconstruction of the early steps of European cooperation in nuclear fusion, with particular emphasis on Italian participation.[6] This chapter is part of a larger research project on the history of European research in nuclear fusion: here, we will limit ourselves to outlining the historical background leading to the first association contract between Euratom and the Comitato Nazionale per le Ricerche Nucleari (CNRN), then Comitato Nazionale per l'Energia Nucleare (CNEN), to support the early Italian effort in the field.

The History of Controlled Thermonuclear Fusion: Some Methodological Remarks

Historiography on fusion is still scarce, and mainly concerns the American case.[7] Limited access to archives, on nuclear energy in general, and on nuclear fusion in particular, partly explains the difficulties to be encountered in any scholarly reconstruction of fusion history. Most available literature deals with fusion either in the framework of future energy prospects,[8] or is limited to popular science books,[9] even to futurology.[10]

5 ENEA, *1960-2010: 50 anni di ricerca sulla fusione in Italia*, ed. Paola Batistoni (Frascati: ENEA-Edizioni Scientifiche, 2010).

6 We adopt here "fusion" as a simplified term for "controlled thermonuclear fusion", which would be the correct expression.

7 Joan Lisa Bromberg, *Fusion: Science, Politics, and the Invention of a New Energy Source* (Cambridge, MA: MIT Press, 1982).

8 *Fusion*, ch. 12, in Richard Muller, *Energy for Future Presidents: The Science behind the Headlines* (London: Norton, 2012), 199-218.

9 Garry McCracken and Peter E. Stott, *Fusion: The Energy of the Universe* (Oxford: Elsevier, 2005, 2nd ed. 2013); Charles Seife, *Sun in a Bottle: The Strange History of Fusion and the Science of Wishful Thinking* (New York: Viking, 2008); Robin Herman, *Fusion: The Search for Endless Energy* (Cambridge: Cambridge University Press, 1990).

10 Michio Kaku, *Physics of the Future: How Science Will Shape Human Destiny and Our Daily Lives by the Year 2100* (New York: Doubleday, 2011).

A series of books written by experts and protagonists are rich and informative, though they rarely escape some rhetorical, even lyrical, tone, related to the symbolic nature of fusion energy.[11] Apart from obvious questions arising from current events (the ITER project), which in themselves would indeed justify intellectual curiosity on the historical background of European fusion, there are several additional reasons for a historical research on the subject.

The first concerns the specificity of the European experience. Research on thermonuclear fusion had military origins (fusion being the principle on which the H bomb is based) and early ideas developed in American and British laboratories during and immediately after World War II. Research was then boosted in the early 1950s as a consequence of the announcement of the first Soviet atomic bomb in 1949, soon setting up a competition between the United States, the United Kingdom and the Soviet Union on which one would be the first nation to achieve nuclear fusion.

In Europe, where no single country would be able to carry out alone an effort in the field, research on nuclear fusion developed from the very beginning in the Community framework of Euratom. All national research evolved under Euratom's heading: in this respect, nuclear fusion is probably the only example of a truly "common" European policy and of a sector almost completely *euratomisé*, to use Jules Guéron's expression. This does not mean that there are no national programs. The Europeanization of techno-scientific research is not to be seen in contrast to national interests, but rather as also the pursuit "of one's interest by other means", that is, by Europeanizing all or part of national efforts.[12]

The history of fusion may indeed contribute to improve our understanding of Euratom's historical experience: usually (though undeservedly) portrayed as a "failure" in the history of European integration – especially if compared to its more successful Rome twin, the European Economic Community (EEC) – Euratom is in fact a still relatively underexplored subject, in particular with regard to the ways its activities were redefined as a consequence of the merger of the executives in 1967.[13] To write a history of fusion is

11 T. Kenneth Fowler, *The Fusion Quest* (Baltimore: Johns Hopkins University Press, 1997); Paul-Henri Rebut, *L'énergie des étoiles. La fusion nucléaire contrôlée* (Paris: Odile Jacob, 1999); Paul Reuss, *L'épopée de l'énergie nucléaire. Une histoire scientifique et industrielle* (Paris: EDP Sciences, 2007); Guy Laval, *L'énergie bleue. Histoire de la fusion nucléaire* (Paris: Odile Jacob, 2007).

12 John Krige, "The Politics of European Scientific Cooperation", in *Companion to Science in the Twentieth Century*, ed. John Krige and Dominique Pestre (1997, Amsterdam-Abingdon: Routledge, 2003), 897-919, quote 900.

13 Olivier Pirotte, *Trente ans d'expérience Euratom. La naissance d'une Europe nucléaire* (Bruxelles: Bruylant, 1988); Michel Dumoulin, Pierre Guillen, and Maurice Vaïsse, sous la direction de, *L'énergie nucléaire en Europe. Des origines à Euratom. Actes des journées d'études de Louvain-la-Neuve, des 18 et 19 novembre 1991* (Berne: Peter Lang, 1994); Gunnar Skogmar, *The United States and the Nuclear Dimension of European Integration* (Houndmills, Basingstoke, Hampshire-New York: Palgrave Macmillan, 2004).

thus to also write a history of the ways Euratom has been transformed overtime, and to look at the political, economic, and cultural dynamics underlying the "Europeanization" of scientific and technological collaboration.[14] As John Krige wrote, Euratom represented a new level of the postwar relationship between the state and *big science* in Western Europe, and its history depicts "the emergence of a new structure and a potent source of funding and of legitimation for expensive fields of scientific research and technical development". Krige lists nuclear fusion (referring to JET, the Joint European Torus) among the seven main fields of techno-scientific cooperation "to be situated at the heart of the process of European economic and political integration".[15]

Euratom's experience in controlled thermonuclear fusion should however also be assessed within the larger context of the role of *big science* in postwar international institutionalism. Euratom is a regional framework, whose activity is constantly in relation to other multilateral institutions in charge of nuclear energy development and control. The fusion experience is thus another example of hybridization and intersection among multiple international institutional levels – European Organization for Nuclear Research (CERN), Organisation for European Economic Co-operation (OECE), International Atomic Energy Agency (IAEA) etc. – and is also related to the important role played by the international Geneva conferences on the pacific uses of atomic energy (in particular that of 1958), and in the specific case of fusion by the international conferences on Fusion and Plasma Theory. Although constantly interacting, however, each of these levels retains its own specificity, both politically and institutionally (as in the case of early cooperation between Euratom and CERN on nuclear fusion, as subsequently analyzed).

Fusion, moreover, played a peculiar role in the technological and scientific Cold War. Although a highly "politicized" sector, though unlikely to yield economic or strategic-military-industrial returns if not in the very long term, research on fusion turned out to be particularly suited to "science diplomacy" practices and to be used as a foreign policy tool across the iron curtain. This role was somehow eased by the undisputed Soviet leadership in the field. According to the Report released in 1966 by the US Atomic Energy Commission (USAEC) on the status of fusion research in the world, as far as manpower involved in the sector the Soviet Union "leads the world": "their effort is twice the US effort. In plasma theory the Soviets are preeminent and at this time their effort in theory is about four times the US effort. In number and variety of major experimental devices the Soviets also lead the world".[16] As will be seen in the next paragraph, starting from the

14 Luca Guzzetti, *A Brief History of European Union Research Policy* (Luxembourg: European Commission, Directorate-General XII Science, Research, Development, 1995).

15 Krige, "The Politics", 897.

16 USAEC, *AEC and Action Paper on Controlled Thermonuclear Research*, June 1966, III-32, http://fire.pppl.gov/US_AEC_Fusion_Policy_1966.pdf, last accessed April 19, 2016.

decision to declassify information announced by the major nuclear powers (the United States, the United Kingdom and the Soviet Union) at the II Geneva conference in 1958, fusion was indeed a scientific field always bearing a "symbolic" value of collaboration which at times helped to cross the rigid logic of the Cold War divide, thereby setting up a long tradition of Euro-Soviet-American cooperation lasting to some extent until today. There is therefore an evident political dimension in the history of fusion that may have affected in different ways decision-making on national and international projects and gone beyond purely scientific considerations.

As a matter of fact, when looking at the history of nuclear fusion one is struck by the continuous exchange among European, American and Soviet laboratories already in the late 1950s and onward. A further element of interest in studying nuclear fusion in a historical perspective is thus to trace the development of a truly transnational (even across the iron curtain) epistemic community of scientists, technicians, technocrats, managers, promoters of science and of techno-scientific policies. At the national level, given the relevant involvement of the state in financing and control, fusion soon appeared as yet another very politicized field of scientific research, subject to bureaucratic management and rivalries, while at the same time "wedded to an ethic of progress and excellence".[17] At the European level, fusion raises a number of additional methodological questions, e.g. whether it is possible to detect a specificity, that is, whether Euratom's regional institutional dimension might have contributed to some peculiar form of "identity" of the European fusion community. The historical experience of the fusion community is thus to be assessed as a contribution to both the social history of nuclear energy, and the history of European integration.[18]

Given the high cost of investment, fusion research developed as a typically public-financed sector, both at a national and at a European level. A study of European fusion history may thus help us to deepen our understanding of the political decision-making processes leading to the investment in research and development on a Community scale and of the rhetoric supporting the development of a 'European public hand' in strategic sectors. In particular, it may help to assess the role of an emerging "fonction publique européenne" in techno-scientific cooperation. In the case of fusion, for example, one should acknowledge the fundamental role played by Donato Palumbo (1921-2011),

17 Steven Goldberg, "Controlling Basic Science: The Case of Nuclear Fusion", *Georgetown Law Journal* 68 (1979-80): 683-725, see 700.

18 Edgar Grande and Anke Peschke, "Transnational Cooperation and Policy Networks in European Science Policy-Making", *Research Policy* 28 (1999): 43-61; Olof Hallonsten, "Continuity and Change in the Politics of European Scientific Collaboration", *Journal of Contemporary European Research* 8, no. 3 (2012): 300-19; Laurence Jourdain, *Recherche scientifique et construction européenne. Enjeux et usages nationaux d'une politique communautaire* (Paris: L'Harmattan, 1995).

an Italian physicist and "a fusion visionary",[19] who from 1958 was in charge of the European Fusion Programme and for many years was its head and key figure. He carried out with unanimously recognized competence and dedication the *contrats d'association*, a new formula whereby Euratom would finance, develop, coordinate and supervise national fusion programs. When Palumbo retired in 1986, 13 contracts were in operation. Both archival documentation and oral sources confirm the key coordinating and stimulating role played by Palumbo,[20] who would himself confess "my total dedication to the European Fusion Programme throughout my 28 years in Brussels".[21]

Finally, a study of fusion is a study of the role played historically by Italian research in the nuclear field and on Italy's position in European techno-scientific cooperation and integration. It provides a further viewpoint from which to explore the relationship between Italy and Euratom, and – more broadly – to assess the patterns of Italian techno-scientific modernization, and its limits.[22] It is also a contribution to a still relatively little known aspect in the history of relations between Italy and France in the nuclear field.

Euratom and the Origins of the European Research Programme on Controlled Thermonuclear Fusion

The possibility of producing energy using the fusion of the isotopes of hydrogen had been first discussed during the war by scientists engaged in the Manhattan Project, and pursued early on in the United Kingdom by George Thompson, professor of physics at the Imperial College in London, and Moses Blackman, who in 1946 produced the first classified patented scheme to confine a plasma using a "pinch effect". To their effort was added that of Peter Thonemann, an Australian physicist working in Oxford, and of James Tuck, a British physicist who participated in the Manhattan Project, and after the war would be called back to Los Alamos to join the team assembled by Edward Teller to launch the program for a hydrogen bomb. The UK Atomic Energy Authority (UKAEA), and the British top nuclear establishment, in particular Sir John Cockroft and Lord Cherwell, thus became convinced that a British program on nuclear fusion

19 Jean Jacquinot, "Donato Palumbo (1921-2011), a Fusion Visionary", *ITER Newsline* 201 (December 2001), http://www.iter.org/newsline/201/977, last accessed April 19, 2016.

20 Harry Bruhns, "In Ricordo di Donato Palumbo (1921-2011)", *Il Nuovo Saggiatore* http://static.sif.it/SIF/resources/public/files/ricordo/palumbo.pdf, last accessed April 19, 2016.

21 Donato Palumbo, "The Work of the European Commission in Promoting Fusion Research in Europe", *Plasma Physics and Controlled Fusion* 29 (1987): 1465-73.

22 Barbara Curli, "L'esperienza dell'Euratom e l'Italia. Storiografia e prospettive di ricerca", in *L'Italia nella costruzione europea. Un bilancio storico (1957-2007)*, ed. Pietro Craveri and Antonio Varsori (Milano: FrancoAngeli, 2009), 211-29.

was needed, as it was indeed launched in 1951, to be developed in the Culham and Harwell laboratories.[23]

The US program was officially launched in 1951 as a classified program, the so-called Sherwood Project, financed and supervised by the USAEC, and carried out in four laboratories: Princeton (directed by Lyman Spitzer Jr.); the Los Alamos Scientific Lab (LASL), directed by James L. Tuck; the Livermore branch of the University of California's Radiation Lab, directed by Herbert York and Richard F. Post; and the Thermonuclear Group of the Oak Ridge National Laboratory; in addition to research carried out in several US universities.[24] Generous funding by the USAEC, which in the mid-1960s provided 23 million dollars out of a total national fusion budget of 40 million dollars (Defense providing an additional 10 and NASA another 5),[25] was intended to support nuclear fusion research, "because of its potential social benefits, and of its close association with the hydrogen bomb project", and in order to maintain "American leadership in nuclear technologies to ensure that the nation had a sound platform in both civilian and military applications".[26] Research on nuclear fusion was thus from the very beginning characterized by the "intermingling of science and politics".[27]

By the mid-1950s, then, although still strictly classified, fusion research was very much at the forefront of the international nuclear discourse and of Cold War techno-scientific and prestige competition, and very well embodying the optimistic ideology of those "années folles"– as Bernard Goldschmidt defined them – of nuclear fervor.[28]

Moreover, the origin of the European Fusion Programme should be assessed in the framework of the international competition between the United States, the United Kingdom and the Soviet Union, and in view of the International Conference on the Peaceful Uses of Atomic Energy held in Geneva in September 1958, where important announcements about nuclear fusion were anticipated. Already in April 1956, during a visit to England by Nikita Khrushchev – the first visit to the West by a Soviet leader – the Soviet physicist Igor Kurchatov (the father of the Soviet atomic bomb, and, with Andrei Sacharov, of the Soviet H bomb), who was a member of Khrushchev's delega-

23 On the British program see also R. S. Pease, "The UK Fusion Programme", *Plasma Physics and Controlled Fusion* 29 (1987): 1439-47.

24 On the origins of the US controlled thermonuclear fusion program see Bromberg, *Fusion*; Stephen O. Dean, "Historical Perspective on the United States Fusion Program", paper presented at American Nuclear Society 16th Topical Meeting on the Technology of Fusion Energy, Madison, WI, September 14-16, 2004, http://fire.pppl.gov/Dean_US_fusion_TOFE_2004.pdf, last accessed April 19, 2016.

25 USAEC, *AEC and Action Paper.*

26 John Krige, "The First Twenty Years of Nuclear Fusion Research", unpublished manuscript.

27 Bromberg, *Fusion*, 2.

28 Bertrand Goldschmidt, *L'aventure atomique. Ses aspects politiques et techniques* (Paris: Fayard, 1962).

tion, gave a very open and in-depth speech at Harwell on questions related to fusion.[29] The speech anticipated the declassification of information related to fusion, which was announced by the United States, the United Kingdom and the Soviet Union at the 1958 Geneva conference. It was evident that such a decision was intended to use international scientific cooperation also as a foreign policy and détente tool.[30]

All these features contributed to the insertion of nuclear fusion among the priorities set by the Treaty establishing the European Atomic Energy Community (Euratom), signed on March 25, 1957. During the negotiations leading to the Treaty, fusion had already been defined "une tache de première urgence".[31] It was listed in Annexe I of the Treaty as a field of research to be carried out by the Commission according to article 4 of the Treaty. Under the heading *Physics applied to nuclear energy,* point e) foresaw "the study of fusion, with particular reference to the behaviour of an ionized plasma under the action of electromagnetic forces and to the thermodynamics of extremely high temperatures".

In order to outline the strategic actions of the new Community, on September 11, 1957 Euratom's Comité intérimaire entrusted a group of experts with the task of establishing a first research program. The group of experts met for the first time in Paris on December 3, 1957 (Amaldi and Felice Ippolito were the Italian members).[32] On that occasion a *Note* presented by the French Delegation was adopted as a basis for discussion. According to the *Note*, which had been prepared by the French Commissariat à l'énérgie atomique (CEA), "le mandat donné au groupe d'experts qui se réunit le 3 décembre 1957 est d'étudier les possibilités d'entreprendre certains travaux préparatoires à l'exécution du programme de recherches d'Euratom. Il semble que l'on puisse, dans ce cadre, examiner les questions suivantes, en vue de s'adresser à la future Commission les recommandations appropriées". Among the priorities listed by the *Note*, were high flux reactors, research prototypes, and nuclear fusion. The aim would be to outline a kind of inventory of activities under way in member countries at that time, in each of these three fields, while waiting for the operational start up of the joint research centre (JRC): "Les premiers travaux de ces groupes d'études devraient permettre de passer commande d'études à faire sous contrat que le Centre commun ne peut espérer faire

29 Igor V. Kurchatov, "The Possibility of Producing Thermonuclear Reactions in a Gaseous Discharge", speech given at Harwell, April 25, 1956, published in *Nucleonics*, June 1956, http://fire.pppl.gov/kurchatov_1956.pdf, last accessed April 19, 2016.

30 United Nations, *Peaceful Uses of Atomic Energy: Fifty Years of Magnetic Confinement Fusion Research, 1958-2008* (Vienna: IAEA, 2008).

31 Groupe de l'Euratom, Rapport du Groupe ad hoc, *Programme et Budget de Recherche*, 3 Janvier 1957, Archivio Edoardo Amaldi, archivio del Dipartimento di Fisica, Università "La Sapienza", Roma (hereafter AAm), sezione Dipartimento di Fisica (hereafter SADF), 175, 2, 1.

32 On Amaldi and Ippolito see forward.

lui-même avant un certain temps". The reason for the insertion of fusion among these priorities was mainly political: according to the French *Note*, "Il convient de se hâter sur les travaux sur la fusion car Américains, Anglais et Russes ont annoncé que ce sera un des principaux sujets de la Conférence de Genève".[33]

Declassification then opened up a new phase in fusion research history and favored the start of the European program within the Euratom framework. No single European country at the time was able to carry out an exclusively national effort, thus there was no competition between a national and a European program, nor questions related to industrial applications (as in the case of fission); and a common program would allow to relieve the costs of research that no single member country would be able to bear individually, in particular in a field still at a very preliminary stage and with very long-term expected experimental results. Fusion seemed thus an ideal field of European co-operation, and one that would strengthen Europe's techno-scientific "identity", rooted in the golden age of faith in the capability of science and technology to orient unlimited progress and social change.[34]

The Group of Experts' Report accepted almost entirely the content of the French *Note* and proposed that the Commission adopted the three above-mentioned fields (high flux reactors, research prototypes, and nuclear fusion), as the first programs to be pursued by Euratom, in addition to the establishment of the JRC. In relation to fusion, the Report underlined:

> la fusion nucléaire constitue le type même de recherche à long terme où un travail en commun est particulièrement souhaitable. Les experts ont été unanymes à reconnaître l'urgence d'une action commune dans ce domaine ou anglo-saxons et russes ont consenti d'importants investissements et semblent attendre des résultats positifs. Les travaux de ce troisième Groupe devraient permettre de confier des contrats de recherche à des laboratoires, publics ou privés, sans attendre la constitution du Centre.[35]

33 *Note de la Délégation française sur les activités de recherche d'Euratom*, Paris le 28 novembre 1957, Archives historiques du Commissariat à l'Energie Atomique, Fontenay-aux-Roses, France (hereafter AHCEA), Archives du Haut-Commissaire à l'énergie atomique (hereafter HC), F5.17.11.

34 On these cultural, discursive features of Euratom's early history, see Barbara Curli, "Nuclear Europe: Technoscientific Modernity and European Integration in the Discourse on Euratom", in *Discourses and Counter-Discourses on Europe: From the Enlightenment to the European Union*, ed. Manuela Ceretta and Barbara Curli (London: Routledge, 2016, forthcoming).

35 Comité intérimaire pour le Marché commun et l'Euratom, *Rapport du Groupe de la Recherche nucléaire*, 4 décembre 1957, AHCEA, HC, F5.17.11.

The Euratom-CERN Joint Work Study Group, 1958-1959

Almost simultaneously, an attempt was made to establish a Euratom-CERN Joint Work Study Group for Fusion Research. The initiative apparently came from François De Rose, the man responsible for Atomic questions at the Quai d'Orsay, who had been the French representative at the IAEA and just appointed (1958) President of the CERN Council. De Rose had approached the President of the Euratom Commission Louis Armand and the director of Research and Education Jules Guéron, again in view of the Geneva conference.[36] On May 31, 1958 a first meeting between Guéron, Cornelis J. Bakker, the director-general of CERN, and John B. Adams, director of the protosynchroton division of CERN, laid the following terms of reference for the agenda of the Joint Study Group:

> to note and evaluate plasma physics research programmes aimed at fusion at present being conducted or planned in Europe and in other countries; to consider and make suggestions for coordinated European fusion programmes; to consider and make suggestions of the means by which such programmes could be carried out either by existing national research centres or by the creation of a European centre; to consider and estimate other research programmes that could be undertaken by small centres and university departments; to consider and make suggestions for the training of suitable staff for the above programmes in universities and other centres.[37]

During the meeting it was agreed that members of the Group "should be European scientists engaged in fusion research work who could be considered as experts in this field and whose advice is particularly valuable to the study group's work". The Italian scientists invited were Bruno Brunelli and Enrico Persico. Euratom would contribute two thirds of the estimated expenses, and CERN one third. Euratom's contribution would however not exceed 75,000 Sw. Frs for 1958.[38]

Participation in the Joint Study Group was inserted in Euratom's first Research Program laid down on June 19, 1958, as complementary to the strengthening of fusion research in national centers: "cependant, le sujet est si neuf que l'on doit aider plusieurs équipes, même petites et modestement outillées, et qu'il convient d'encourager des recherches annexes. Il y a donc lieu de prévoir, avant même la fin de l'étude CERN-Eurat-

36 Krige, "The First Twenty Years".

37 Euratom-CERN Joint Study for Fusion Research, *Minutes of Meeting held at CERN to discuss the possibility of setting up a joint study group to consider European fusion research programmes*, June 2, 1958, AAm, SADF, 190, 1, 1.

38 Euratom-CERN Joint Study for Fusion Research, *Minutes of Meeting*, June 2, 1958, AAm, SADF.

om, d'assez important contrats avec un ou deux centres puissants, et de plus nombreux contrats d'études auxiliaires".[39]

This line was confirmed by Euratom's Technical and Scientific Committee, chaired by Amaldi, during a meeting when Francis Perrin, member of the Committee and Haut Commissaire of the French CEA, "souligne l'importance de la fusion contrôlée et les espoirs qu'elle suscite, mais insiste sur les difficultés techniques et économiques auxquelles on se heurte aujourd'hui. Il estime qu'il y a là un objectif intéressant, quoique lointain, pour lequel Euratom pourrait être chef de file".[40]

The joint Euratom-CERN project would soon, however, meet the opposition of some members of CERN that were not members of Euratom. In addition to Great Britain, which at the time was the most advanced European country in nuclear fusion, tied to the United States by a series of nuclear special relationship agreements, the project met the opposition of Switzerland and Sweden, two neutral countries particularly sensitive to questions which might worry public opinion. Nuclear fusion could be related in the public mind to the H bomb and this raised also worries about the image of CERN, especially in that early start-up phase. CERN explicitly excluded any research which could bear any commercial or military return. Some members of CERN thus resented the project "as an unacceptable redefinition of CERN's identity".[41]

Finally, in June 1958 the CERN Council rejected the proposal of a joint CERN-Euratom study group. The failure of this initiative showed the difficulties in combining the efforts of two very different organizations with respect to membership, aims and structures.

At the same June 1958 meeting, the Council of CERN decided instead to set up its own Study Group to which representatives from European and other countries working in the field should be invited, and whose task would be to evaluate the research programs at present in progress or in preparation.[42]

In July 1958 Bakker informed Guéron that

> unfortunately, the objections to our joint proposal raised by some of our CERN Member States, who are not members of Euratom, were still maintained. The Council noted with appreciation the offer of Euratom to co-operate in an evaluation of plasma physics research programmes, but finally decided that, for the time being, CERN should conduct its own study. However, CERN proposes to invite

39 Euratom, la Commission, Division Recherche n° 95, *Programme de recherches*, Bruxelles, 19 juin 1958, AAm, SADF, 190, 1, 1.

40 Euratom, la Commission, Comité scientifique et technique, *Projet de compte-rendu de la réunion du 7 juillet 1958*, Bruxelles, 18 juillet 1958, AAm, SADF, 190, 1, 1.

41 Krige, "The First Twenty Years", 30.

42 European Organisation for Nuclear Research, *Annual Report 1958* (Geneva: CERN, 1959).

> Euratom and other organizations which might show an interest in the matter to send observers to the study group.[43]

The CERN Study Group held three meetings. In the letter of invitation to Persico to join the Group, Adams explained that the purpose of the first meeting was "to establish a list of the research programmes in the USA, USSR and Europe, the state of the work and the results obtained".[44] All European laboratories working in the field of fusion research, as well as CERN, Euratom and the OECE, were asked to send representatives.

The first meeting was held on September 25-26, 1958, shortly after the Atoms for Peace conference in Geneva. Nearly all the members of the Study Group had taken part themselves in the conference, and the meeting was devoted to "trying to assimilate the information released" at the conference.[45]

During the second meeting on December 11-12, 1958 various papers and reports were discussed, on specific research and experiments carried out in the members' laboratories, and a comparison was made with the work being undertaken in the United States and the Soviet Union. "The Study Group, having this time more or less assimilated the vast amount of published literature in the field of fusion research and having reviewed, in the light of this knowledge, their own fusion programmes" were able to begin to discuss the general problem of fusion work in Europe.

The aim of the third meeting, held on March 5 and 6, 1959, was to prepare a final report to be submitted to the CERN Council and to "define the nature of the work to be done in the near future". According to the report,

> the fundamental physics, on which all devices and projects depend, has proved to be much more intractable than was originally estimated. It is therefore clear that the major task before anyone in fusion work in the near future is to accelerate the understanding of the physics of plasma. However, such a conclusion does not imply that large scale experimental work should be abandoned, nor does it mean a slowing down of fusion activities. A properly balanced programme must allow for the study of fusion problems, theoretical, experimental and technological, on as broad a front as is economically possible …. A European fusion programme should aim at encouraging this diverse activity at all levels and by whatever means that are appropriate.

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43 Letter by Cornelis J. Bakker, Director-General of CERN to Jules Guéron, July 3, 1958, AAm, SADF, 175, 2, 2.

44 Letter by John B. Adams to Enrico Persico, "CERN Study Group on Fusion Problems", July 31, 1958, Archivio Enrico Persico, Dipartimento di Fisica, Università "La Sapienza", Roma (hereafter AEP), 16/73.

45 An account of the three meetings is in the Final Report, see *European Fusion Research: Report of the CERN Study Group on Fusion Problems*, 2nd draft, March 24, 1959, AEP, 16/73, from where subsequent quotes are taken.

A comparison was then made between the European effort (the largest laboratories in Britain, France and Germany) and the US effort in terms of scientific staff (210 versus 288) and operating costs (6.7 million dollars versus 28.7). Although the number of staff was comparable, costs were "but a small fraction of those of the USA".

However, the report continued, "the staffing problem in fusion research is not fundamentally different from the problem of finding staff for the other branches of physics. There is undoubtedly a serious shortage of physicists in Europe, and plasma physics and fusion research can only take a fraction of these people". Education and training should be supported in European universities, and the "exchange of staff working on fusion problems between the various laboratories" encouraged. "Now that there are no longer any questions of security or classification in fusion work, the problem is only one of arranging that European staff can move freely between the laboratories", as it was "already an established tradition" in several laboratories and "an accepted way of life in high energy physics".

The study group also considered the possibility of establishing a "European" laboratory for fusion problems, not meant to replace the national laboratories, but "in addition to those already existing". The several pros and cons were weighed and it was concluded that for the time being, "unless it can be demonstrated that a European laboratory is needed in order to build larger facilities than can be built by national groups, the many other advantages of such a centre may prove insufficient to overcome the difficulties in its creation and maintenance". The matter was therefore left for a later review.

Euratom, however, was playing a new role in the European research scenario, and its relation to CERN needed to be assessed,

> The part being played by Euratom in the fusion work was discussed by the Study Group. Euratom represents six of the twelve member states of CERN and unfortunately does not contain the most currently active member state in the work of fusion, namely Britain. The policy of Euratom on fusion is to encourage the growth of large centres in its member states by placing contracts for fusion work. … Their general policy, therefore, is to concentrate the fusion work in order to counteract the dispersion tendency.

The system was similar to the American one. However, whereas in the United States the AEC formed "a backbone to the whole venture", in Europe this raised the question of supervising fusion activities, as there was "no such common organization although the large national centers can be compared with the AEC laboratories in the States".

The Report of the Study Group was presented at the thirteenth session of the CERN Council in May 1959. It recommended against the establishment of a common European fusion research laboratory, but proposed the continuation of a loose association for

information and the exchange of ideas. The CERN Council approved this report and agreed that CERN for the time being should sponsor the Study Group until the end of the year, a period which was subsequently extended at the December session until the end of 1960.[46] The Group, under the continuous stimulus of Adams, would continue to hold scientific meetings until 1964 in several places and laboratories, widely attended by the European fusion community of the time.

The Euratom-CEA Association Contract

In September 1958, probably also as a consequence of the failure of the joint CERN-Euratom undertaking, the Euratom Commission put Palumbo in charge of the launching of a Community fusion program. Palumbo was well aware of the difficulties that a common fusion facility would raise (as it had been discussed on a more general European level during the CERN meetings), even if established in the new JRC in the process of being instituted. Rather, as anticipated also by Euratom's Scientific and Technical Committee, it was thought preferable to set up a network of contracts of association between Euratom and the national centers that were dealing with fusion research: the Community would coordinate and supervise the financial and scientific effort in the field. As Palumbo himself later recollected, "we should try to provoke collaboration within the six Member States, based on mutual confidence and co-responsibility", "In the course of this, I encountered some considerable difficulties and even hostility, not only from within the Commission but also from some of the potential partners. However, a Coherent European Fusion Programme was finally constituted".[47]

The new network of contracts of association would constitute the framework within which all fusion research in Europe would be developed, and would remain so for many years. The structure was partly modeled on that of the Sherwood Project, where the Sherwood Committee financed and coordinated research in American fusion laboratories.[48]

On December 23, 1959 the Commission met the representatives of the national nuclear authorities of the member states, with Palumbo and Guéron, in order to set the priorities of the new Community and outline the first five-year plan. During the meet-

46 European Organisation for Nuclear Research, *Annual Report 1959* (Geneva: CERN, 1960).
47 Palumbo, "The Work".
48 Bromberg, *Fusion*.

ing the importance of fusion was restated, and the first association contract on nuclear fusion signed with the French CEA was announced.[49]

The contract was located in Fontenay-aux-Roses (FAR) and was managed by a Comité de gestion (CdG), that met every three months and was made up of two representatives of Euratom (Palumbo and Ellerkmann, while Guéron attended the first meetings); two representatives of the CEA (Jacques Yvon, director of the Physique et Piles atomiques section of the CEA, and Jean-Pierre Goure), and Georges Vendryes, chief of the Département de Recherche Physique of the CEA, who was named chief of the Groupe de recherche of the association.[50] The chairman of the CdG was alternatively (on a yearly basis) either Palumbo or Yvon. The initial budget (350 million [old] francs) was 75 per cent at Euratom's expense and 25 per cent CEA. In 1959 there were 61 personnel involved in the contract (including 2 women); in 1961 the number had already increased to 150, one third of whom were Euratom employees.

Early activities were mainly devoted to an exchange of researchers with other laboratories, in particular in the United States and in the United Kingdom. Furthermore, in 1959, during the first negotiations for British entry in the Community, the United Kingdom-Euratom agreement was signed, which foresaw cooperation in nuclear fusion.[51] Fusion soon became an important part of the CEA activities at FAR, and very quickly developed to the extent that a complete reorganization was carried out in 1962, also involving a change in the terms of the contract with Euratom (participation became Euratom 54 per cent, CEA 46 per cent). The Service de phisique of the CEA Centre of Saclay was also included in the contract, with regard to studies on plasma behavior that could be related to controlled fusion.[52] In 1962 there were 127 personnel (including 6 women) – 84 from CEA and 43 from Euratom.

49 Commission Euratom, *Compte rendu sommaire de la réunion du 15 décembre 1959 à Val Duchesse*, AHCEA, HC, F5.17.11. Italy was represented by Ippolito, Forcella and Naschi of CNEN, France by Perrin, Goldschmidt and Yvon of the Cea; for Germany Wolfgang Filkelnburg and Dietmar Fuchs.

50 The Groupe de recherche included a Service de recherches sur la fusion, whose Chef de Service was Hubert and his alternate Prévot. Hubert would then become director at the Direction Recherche et Enseignement of Euratom. On this early French fusion community see Anatole Abragam, *De la physique avant toute chose* (Paris: Odile Jacob, 1987).

51 Mauro Elli, *Politica estera ed ingegneria nucleare. I rapporti del Regno Unito con l'Euratom (1957-1963)* (Milano: Unicopli Editore, 2007).

52 On fusion research carried out by the CEA in those early years see M. Trocheris, "Controlled Thermonuclear Fusion Research Conducted by the French Commissariat à l'energie atomique", in *Peaceful Uses of Atomic Energy*. Proceedings of the fourth international conference, United Nations-IAEA, Geneva, September 6-16, 1971, vol. 7; Trocheris, "The History and Future of the French Fusion Programme", *Plasma Physics and Controlled Fusion* 29 (1987): 1425-27.

The Laboratorio Gas Ionizzati and Early Italian Research on Nuclear Fusion

The launching of research on fusion in Italy can be dated back to May 1957 when Persico, professor in the Department of Physics of the University of Rome and one of Enrico Fermi's "ragazzi di via Panisperna", created a research group on ionized gasses bringing together some researchers (Bruno Brunelli, Franca Magistrelli, Alberto De Angelis) already active in research on sources of radio frequency ions at the Istituto di Fisica superiore. In June 1957, Persico and Amaldi[53] attended the international congress on ionized gasses in Venice, where they exchanged views and information on plasma and high temperature production. Immediately after the congress, and again in September 1957, Bruno Brunelli visited several laboratories abroad (namely, the Imperial College in London, Saclay, CERN, Amsterdam, the Clarendon Laboratory in Oxford, and Aachen),[54] while Persico and Amaldi were making contacts with eminent scientists in the field of fusion research. They organized exchanges and seminars in Rome, inviting, among others, Franco Rasetti, who was in the United States at Johns Hopkins University, and came to Rome in 1959 for a series of seminars on plasma spectroscopy; and George Linhart, from CERN, who gave a series of seminars on plasma physics, then edited by Franca Magistrelli and Ugo Ascoli. On September 20, 1957 Ippolito, Secretary General of CNRN, asked for a first draft budget and anticipated an amount of 10 million lire to provide the group with a more institutional framework.[55]

On October 18, 1957 the formal decree was signed that established the Laboratorio Gas Ionizzati (LGI), which consisted of a theoretical and an experimental group.[56]

53 One the most distinguished Italian scientists, Edoardo Amaldi came from the group of "ragazzi di via Panisperna" led by Enrico Fermi. The main figure behind the reconstruction of postwar Italian physics, he was director of the Department of Physics in Rome, President from 1960 to 1965 of the Istituto Nazionale di Fisica Nucleare and member of the Board of CNRN, then CNEN. He served as chairman of Euratom's Scientific and Technical Committee and as secretary general of CERN from 1952 to 1955. On Amaldi, see Carlo Rubbia, *Edoardo Amaldi. Scientific Stateman* (Geneva: CERN, 1991), http://cds.cern.ch/record/228364/files/CERN-91-09.pdf, last accessed April 19, 2016; Fernando Ferroni, ed., *The Legacy of Edoardo Amaldi in Science and Society*, Atti del Convegno (Bologna: Società italiana di fisica, 2010); Lodovica Clavarino, *Scienza e politica nell'era nucleare. La scelta pacifista di Edoardo Amaldi* (Roma: Carocci, 2014).

54 Bruno Brunelli, *Relazione sulle visite ai laboratori stranieri di ricerca sui plasmi ad alta temperatura*, n.d., AEP, 15/72.

55 On this early phase see also Luisa Bonolis and Franca Magistrelli, "La nascita e gli sviluppi della ricerca sui plasma e sulla fusione nucleare in Italia", *Analysis* 3-4 (2010): 27-44; Bruno Brunelli, "The History and Future of the Italian Fusion Programme", *Plasma Physics and Controlled Fusion* 29 (1987): 1429-38, and on the general background of Italian research in physics at the time, Claudio Villi, *La fisica nucleare fondamentale in Italia* (Padova: Cleup, 1976).

56 CNRN, Laboratori Gas ionizzati, *Resoconti organizzativi e scientifici*, n.d. (but December 1957), AAm, SADF, 198, 1, 4. The group was composed of Persico and Amaldi as scientific supervisors, Brunelli, Magistrelli, Ascoli, De Angelis, Segre, and A. Bernardini (lab technician).

In January 1958 a preliminary five-year research plan was outlined, with an estimated budget of 550 million lire.[57]

In 1960 the LGI, under the direction of Brunelli, was moved to Frascati, where the Laboratori Nazionali had just been constructed in order to host the Electrosincrotron. In 1960 CNRN changed its name to Comitato Nazionale per l'Energia Nucleare (CNEN). Its active and dynamic Secretary-General Ippolito provided the necessary financial and "political" support for the LGI's early steps, as yet another tile in the framework of the Italian nuclear program, that was intended as a project of modernization of national scientific research and nuclear industrial application.[58] As Brunelli himself recalled, "fortunately, in those years we had Felice Ippolito, who very quickly met our demands".[59] The LGI was subsequently joined by John Allen, from Harwell, and George Linhart, Charles Maisonnier and Heinz Knopfel, from CERN.

The launching of the Italian fusion program was also embedded in the optimistic climate following the Geneva Conference of 1958, as seen above. A long Report by Felice Ippolito on the conclusions reached by the conference and on the Italian position is worth dwelling upon. Is also worth remembering that at the Geneva conference Italy presented a joint study with the World Bank – the Energia Nucleare Sud Italia (ENSI) Project – for the construction of a nuclear plant in Southern Italy, which would become the Garigliano nuclear power plant, and which put Italy in all the international media regarding nuclear developments.[60] The Italian participation, although limited, had given a qualified and "favorable impression", showing that Italy, "although a late-comer, intends to make up for lost time".[61] Although mainly devoted to the prospects of nuclear fission, the Conference had been dominated by the declassification of information on nuclear fusion:

> Noteworthy results have been reached in this field by the United States, England, and the USSR, and by some minor countries, like France. During the sessions the

57 CNRN, *Programma di ricerche sul plasma*, Com RF/04/58, January 1958, AAm, SADF, 198, 1, 4.

58 On the launching of the Italian nuclear project in the second half of the 1950s and the role of Felice Ippolito, see Barbara Curli, *Il progetto nucleare italiano, 1952-1964. Conversazioni con Felice Ippolito* (Soveria Mannelli: Rubbettino, 2000).

59 See the interviews with Bruno Brunelli and Sergio Segre in *Energia, ambiente, innovazione, dal Cnrn all'Enea*, ed. Giovanni Paoloni (Roma-Bari: Laterza, 1992), 246-47. In this same volume see also Claudio Cigognetti, "I laboratori nazionali di Frascati, 1957-1982", 209-18. On this early phase see also Fernando Amman and Romano Toschi, "I Laboratori Nazionali di Frascati del Comitato Nazionale Ricerche Nucleari", *Ingegneria nucleare* II, no. 4 (1959): 175-85.

60 On the Ensi Project see Barbara Curli, "Energia nucleare per il Mezzogiorno. L'Italia e la Banca Mondiale, 1955-1959", *Studi Storici* 37, no. 1 (1996): 317-51.

61 *Relazione preliminare sulla II Conferenza di Ginevra sugli usi pacifici dell'energia nucleare*, settembre 1958 (unsigned, but written from Geneva by Felice Ippolito), AAm, SADF, 160, 2, from where subsequent quotes are taken.

> programs that the major powers intended to pursue in this research field have been discussed, which was particularly useful for specialists in other countries in order to coordinate programs and avoid duplication and waste of manpower and means.

However, it was evident that "practical industrial applications [are] still very far ahead and even the first step, that is, to produce a controlled fusion in a laboratory, [is] far away". Great powers devoted "enormous means" to fusion, but "the most eminent scientists attending the Conference agreed that these studies are still at a 'university stage'". And this was probably the reason why the Russian delegates had been so "open" on the issue, but very tight on all other matters (nuclear plants, uranium and thorium supplies on Soviet territory, etc.).

The Association Contract CNEN-Euratom

The association contract between the LGI and Euratom (Contratto di ricerca Euratom-CNRN [then CNEN]-Laboratorio Gas Ionizzati) was signed in January 1960. It originated as a sub-contract of the CEA contract, until 1962, when the CEA withdrew and the Italian contract became independent. Documentation shows that the idea of associating the LGI to the French contract may have been first put forward by Brunelli, who in a letter to Persico wrote: "I have told Hubert and Palumbo about the sub-contract …. They suggested that we should advance a formal request, that will be read at the next Comité de gestion to be held in early September".[62] The issue was then followed up by Amaldi with Guéron in Brussels. Guéron guaranteed that Palumbo and Vendryes were taking care of it.[63]

The first meeting of the association was held in July 1960 in Rome at the Physics Department. The Comitato di gestione (CdG) of the Italian contract was constituted by Amaldi, President of the Istituto Nazionale di Fisica Nucleare, as representative of CNRN (that in August 1960 would become CNEN, where Amaldi was a member of the Board); Palumbo as representative of Euratom; and Brunelli, as chief of the Research Group. Until 1962 a representative of the CEA would take part in the meetings: it was alternatively Michel Trocheris, of the Service de Physique théorique and chief of the Controlled fusion Department at the CEA, and Vendryes.

Even after 1962, when the CEA withdrew from the association, either Trocheris or Vendryes continued to attend the meetings in Frascati, and Brunelli those at Fontenay-aux-Roses. At times Giovanni Naschi, director of the Segreteria tecnica of CNEN, and

62 Letter from Bruno Brunelli to Enrico Persico, August 24, 1959, AEP, 15/72.

63 Letter from Jules Guéron to Edoardo Amaldi, September 16, 1959, AEP, 7/20.

in charge of its financial management, was present at the meetings. In 1965 Amaldi left the CdG because of other obligations, and was substituted by Sebastiano Sciuti.[64]

The Guidelines (*Regolamento*) of the CdG were modeled on the French one. The financial effort of the Italian contract was distributed as follows: Euratom 60 per cent, CNEN 40 per cent, for a total amount of around 270 million lire for 1963.

The Group was made up of 57 people. The group's only woman, Franca Magistrelli, remembers those years as "the most intense and productive years of my professional life".[65] Brunelli recalls "the great enthusiasm" of that period.[66]

In this early phase, research in Frascati developed along two main directions: the so-called Program A (directed by John Allen, originally from Harwell, then in Frascati as Euratom's employee) on "Cariddi", the "Hot Ice" experiment, etc.; and Program B (directed by Linhart) on MIRAPI (MInimum RAdius PInch) and MAFIN (MAgnetic Field INtensification, whose implementation required the construction of the Colleferro bunker).

Great importance was attributed to training and education, as particularly endorsed by Amaldi, and to developing ties with the University of Rome and other Italian universities, e.g. through the creation of graduate fellowships. A new generation of fusion experts would develop through a continuous exchange with laboratories abroad, in Europe, the United States and the Soviet Union. New figures were created in the Euratom framework, such as the *stagiaire qualifié d'Euratom*, who was allowed to train in European laboratories. The CdG also dealt with the organization of meetings and conferences; decisions on papers to be submitted to international conferences, etc. By the mid 1960s, a European fusion community had been established, in particular thanks to Euratom's financial effort and Palumbo's coordinating role.

After the first two years of operation (the association contract was originally intended to last for two years and six months), a CNEN internal document made a first assessment of the status of research on fusion in Italy and of the relationship with Euratom. Euratom had appreciated the work carried out by LGI and had proposed not only the renewal of the association as from July 1, 1962, but also the strengthening of the program, for a total amount of 3 billion lire on a three year period, of which 40 per cent at the expense of CNEN.[67]

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64 Reconstruction of the activity of the CdG is based on the Minutes of Meetings, in Archivi Enea Frascati, Contratto di ricerca Euratom-CNRN (Laboratorio Gas Ionizzati), poi Contratto di ricerca Euratom-CNEN (Laboratorio Gas Ionizzati), *Comitato di gestione, 1960-1968*.

65 On Franca Magistrellli, see "Franca Magistrelli", in *Maestri e allievi della fisica italiana nel Novecento*, ed. Luisa Bonolis (Pavia: Goliardica Pavese, 2008), 307-32, quote 318.

66 Brunelli, "The History", 1430.

67 CNEN, *Contratto di associazione CNEN-Euratom nel campo della fusione nucleare controllata*, GEN/24/62, ottobre 1962, AAm, SADF, 260.

Conclusion

The second phase of the association contract – that we are not dealing with here – would soon face a series of difficulties and shortcomings, related to the progressive bureaucratization of Euratom and its early "crisis", that would reflect itself in the drastic financial cut to the Community's second five-year plan, and to the crisis of the JRC at Ispra.[68] Cuts to the fusion program would be a direct consequence of these general changes (although they were less relevant than those affecting fission), before a wider reorientation of Euratom's activities took place as a consequence of the Merger of the executives in 1967. This would somehow affect all fusion programs in the various centers where association contracts were in operation – in addition to Fontenay-aux-Roses and Frascati, in the meantime Euratom had supported the launching of fusion programs in the German centers of Garching (the Max Planck Institut für Plasma Physik, where a contract had been signed with Euratom in 1961), and Jülich (in 1962); the Dutch centre of Fundamental Research on Matter (FOM, 1962) and the Belgian Ecole Royale Militaire in Brussels (1969).

Within this general framework, in the second half of the 1960s several difficulties would also affect national nuclear programs, including fusion programs, because of general economic and monetary troubles, the reconsideration of national fission programs (e.g. the French shift to light water reactors); and social and political unrest in 1968. In the Italian case, in particular, the crisis of the Frascati centre took place within the framework of the more general crisis of the Italian nuclear program, as a consequence of the "caso Ippolito" and the demise of CNEN;[69] and as a consequence of the events of 1968 and the resulting political and trade union unrest, which practically crippled activities in the Frascati Centre.[70]

This situation would soon require a re-launching of the European fusion program as a whole, which would only take place following the "tokamak revolution" announced at the Third Conference on Plasma Physics and Controlled Nuclear Fusion held at Novosibirsk in 1968, when Soviet scientists reported about the superiority of the toroidal configuration for magnetic confinement. A new phase of European fusion history would then be set into motion.

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68 On the crisis of Euratom and the difficult launching pf the second five-year plan, see Felice Ippolito, *Un progetto incompiuto. La ricerca comune europea, 1958-1988* (Bari: Dedalo, 1989).

69 On the "caso Ippolito", Curli, *Il progetto nucleare*; Curli, "Il caso Ippolito", in *Scienziati d'Italia. 150 anni di ricerca e innovazione*, ed. Marco Cattaneo (Torino: Codice Edizioni, 2011), 83-100.

70 On this critical passage at the Frascati Centre, see Giovanni Battimelli, ed., *L'Istituto Nazionale di Fisica Nucleare. Storia di una comunità di ricerca* (Roma: Laterza, 2002).