Chapter 15
Reminscenses of Rolf Hagedorn

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Abstract This is a personal recollection of the influence that Rolf Hagedorn had on the launch of the CERN heavy-ion program and on the physics choices made by my colleagues and myself in that context.

15.1 Many Years Ago

In 1964, as a CERN Fellow I started doing research on hadron physics, using at first bubble chambers and then electronic detectors. Like many other Fellows I was able to benefit from the vigorous CERN academic training program and from its teachers, all of whom were excellent physicists. There I met Rolf Hagedorn for the first time and enjoyed his lectures as well as his "Yellow Reports". His lectures were deep and clear. His reasoning was precise and very rigorous, yet he was patient with us and had a sense of humor. For example, once at the beginning of a lecture, he told us about a competition between ethologists of various nationalities for the best essay about "the elephant". While all the others described some facet of the elephant‘s personality, such as its character, its mental and physical capabilities as well as its elegance or its love-life, the German competitor‘s essay was entitled: "On the definition of the elephant". Hagedorn then continued: "at the end of this lecture, you will not have the slightest doubt about my nationality!" . Fifteen years later, during a discussion on a possible heavy ion experiment, I reminded him of the elephant's joke; he smiled and forgave a somewhat imprecise definition of mine.

In the 1960s, Hagedorn developed a statistical approach to describe particle production which led to the concept of a finite limiting temperature for hadronic matter—the Hagedorn temperature—and to the formulation of the statistical bootstrap model [1] in which the exponentially rising hadron mass spectrum occurred naturally. This major discovery, however, had to wait a few years before being fully appreciated, since at the time there was no fundamental theory of the strong interaction—and no consensus on how to construct one.

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The first clear formulation of the theory that we know today as QCD appeared in 1973. Two years later Cabibbo and Parisi [2] were the first to take up the challenge of the Hagedorn's limiting temperature and pointed out that it could be a critical temperature, at which hadronic matter could turn into a new state of unbound quarks and gluons. Such a possibility raised considerable interest since head-on collisions of high energy nuclei appeared then as a way to obtain such a new state in the laboratory, albeit for a very short time. It was discussed in several meetings (Erice 1978, Bielefeld 1980) and workshops (LBL Berkeley 1979, GSI Darmstadt 1980).

By 1980, Hagedorn and his close collaborator Johann Rafelski introduced a finite size for hadrons in the Statistical Bootstrap Model, and were able to show that the limiting temperature marked indeed a phase transition from hadronic matter to a quark-gluon plasma phase (QGP) [3]. At the same time Rafelski was the first, together with Hagedorn, to suggest that an excess of strangeness in the hadronic fireball from a nucleus-nucleus collision would be a natural signature of the formation of a de-confined phase [4]. His idea was then explored and developed with Berndt Müller[5]. The key prediction was that the onset of QGP should enhance, with respect to the case of proton-proton collisions, the final state abundance of the rare multistrange hadrons on account of the relatively higher phase space density of strangeness in the plasma. Detailed predictions—such as an increase of strange baryon and antibaryon enhancements with their strangeness content—were later published in a Physics Reports [6]. These predictions prompted many people, myself included, to start thinking of the possibility of detecting the decay of strange and multistrange hadrons amongst the large number of tracks produced in high energy heavy ion collisions.

15.2 The Heavy Ion Era at CERN Begins

In 1980, the time was ripe for action! A Letter of Intent [7] to study Ne-Pb reactions at the CERN Proton-Synchrotron, was submitted by a GSI-LBL Collaboration. This initiative triggered a long and eventually successful approval process [8], that resulted in a new CERN program involving ion beams at the CERN-SPS, at energies much larger therefore than those initially envisaged. However, a few years went by before the ion beams from the SPS became available!

Maurice Jacob, head of the CERN Theory Division from 1982 to 1988 and a strong supporter of ion beam experiments at CERN, played an important role in orchestrating interest among, particle and nuclear physics groups to work together in this new field. In preparation of the possible SPS program, Maurice organized, together with Torleif Ericson, Helmut Satz and Bill Willis, the Quark Matter meeting in Bielefeld 10–14 May 1982. All key participants from both sides of the Atlantic attended and the meeting prepared in six working groups the future CERN experiments. More on this topic is reported in Chap. 29.

At the time, CERN's top priority was to build LEP with a constant yearly budget. At the initiative of Robert Klapisch, nominated in 1981 Director of Research for all

Fig. 15.1 Hadronic collisions family picture October 1988: the first report from WA85 experiment on strange antibaryon production was presented by Emanuele Quercigh at the Tucson *Hadronic Matter in Collision* workshop, October 1988; This picture was taken on this occasion. Those appearing in the book are in bold, all from *left*: *back row*: **M. Danos, M. Gaździcki**, J. Whitmore, **E. Quercigh**, F. Navach, G. Zinoviev, M. Kalelkar, T. Awes, B. Barrett, D. Lodwick, R. Hwa, W. Geist; *middle row*: D. Slansky, I. Sarcevic, S. Stampke, M. Tannenbaum, **R. Glauber**, R. Thews (covered), M. Shupe, **H. Gutbrod**, D. Harley, **M. Gorenstein**, K.B. Luk, **B. Muller**, J. Sunier, S. Oh, **W. Greiner, M. Jacob**, T. Carey, S. Frenkel; *front row*: A.R. White, H. Eggers, T. Tranh Van, K. Goulianos, E. Friedlander, C. Quigg, I. Derado, **P. Carruthers**, W. Walker, J. Pancheri, **J. Rafelski** (who activated photo self timer), J. Rutherford, **L. Van Hove**, W. Busza, P. Stevenson, **P. Koch**, C. Chiu. Rolf Hagedorn was invited but could not come for personal reasons. *Photo: Johann Rafelski*

Non-LEP activities, a Workshop on the Future of Fixed Target Physics at CERN was held in December 1982: a group “Nuclear Beams and Targets” was convened by Bill Willis and summarized by Mike Albrow [9]. While initially the idea to use the PS energy range was explored, the greater opportunity both in terms of experimental capability as well as higher energy offered by CERN SPS became evident. Hence, the SPS community began to take an active interest in heavy-ion physics.

As a result in 1983, a collaboration between CERN, the GSI nuclear-physics laboratory in Darmstadt and the US Lawrence Berkeley Laboratory, started a pilot program at CERN to accelerate in the SPS oxygen nuclei and then sulfur nuclei, up to energies of 200 GeV per nucleon. These beams arrived in 1986 and 1987 respectively (Fig. 15.1). Following an upgrade of the accelerator complex by a collaboration between researchers from CERN, the Czech Republic, France, Germany, India, Italy, Sweden and Switzerland, a fully fledged CERN-SPS program with lead beams—up to 158 GeV per nucleon—arrived in 1994 (Fig. 15.2).

The concrete possibility of nuclear beams at the CERN-SPS, raised much interest and several experimental proposals were submitted to the CERN Committee. Two of them, NA35 and WA80, being the direct descendants of the 1980 Letter of Intent. The atmosphere was one of enthusiasm despite the severe budgetary constraint,

Fig. 15.2 Divonne 1994: during presentation of CERN DG Chris Llewellyn-Smith at Hagedorn's 75th birthday: front row from *left to right* E.L. Feinberg, J. Rafelski (leaning *forward*), to *right* recessed the leaders of Omega Prime Spectrometer Experiments: E. Quercigh, F. Antinori, K. Safarik; *second row*: R. Bock, R. Hagedorn (*behind* Rafelski). *Credit: CERN Image 199406-068-024*

which did not permit any large investment in the building of new detectors. Experiments had then to be assembled by recycling existing detectors and magnets. For an overview of the CERN heavy-ion experiments active from 1986 to 2006, see for example [10], while the four experiments on which I shall focus here (WA85, WA94, WA97, NA57) are summarized in [11] (and references therein).

15.3 Experiments WA85–WA94–WA97–NA57

My collaborators and I decided to use the Omega Prime Spectrometer [12] which we had already used for hadron spectroscopy. However, in order to analyze events of unprecedentedly high track multiplicity we had to upgrade its Multi-Wire Proportional Chambers. These could only handle up to about fifteen tracks per event and not hundreds as expected for experiments with high energy sulfur beams. Thus we modified all of them into the so-called "butterfly chambers", only sensitive to particles emitted in a restricted phase space region at central rapidity. Later, to cope with the even larger event multiplicities expected in lead-beam experiments, we built the first telescope of silicon pixel detectors. This development began in the framework of the CERN-LAA RD program and continued in the CERN RD19 project [13]. Such a telescope allowed us to determine the space points on a track directly and, because of its high granularity, it could be placed near the target, thus easing the detection of the short-lived strange baryons.

Of course, the beginnings were not simple. Apart from the delicate hardware modifications needed and people's fear that these could permanently damage the Omega chambers, there were several open physics questions. We needed to guess what the events from high energy nucleus-nucleus interactions would look like. What, also, would the multiplicities of the secondaries be? And how would these be distributed in phase space? Furthermore, how could we recognize the existence of a QGP during the interaction and how valid would an enhancement of strange-particle production be as a diagnostic tool for QGP? Which effects could distort the measurement and simulate a phase transition?

At that point we went for advice to Hagedorn, who had studied those subjects [14]. He patiently discussed these matters with us and gave much useful advice. For the questions about strangeness, however, Hagedorn suggested that we contact directly Johann Rafelski who, he said, would be delighted to discuss that issue with us! This echoed the advice we got from Léon Van Hove, a former CERN director general, also a strong supporter of the new research program. Indeed, Johann was delighted and this was the start of a long and friendly collaboration.

Our first two experiments, WA85 and WA94, took data at 200 A GeV in a sulfur beam, using the "'butterfly chambers". They were followed by two lead-beam experiments WA97 and NA57. The latter was a North-Area experiment with a new spectrometer and a new spokesperson: Federico Antinori. Both the latter two experiments made use of the Silicon Pixel telescope as their main tracking device.

The experiments confirmed our hopes. We found that the abundances of multistrange baryons and anti-baryons produced in heavy-ion collisions were indeed enhanced [15]. Moreover, these enhancements increased with the strangeness content of the produced baryon [15, 16]. For example, in central lead-lead collisions, the rare Ω^- particles carrying three units of strangeness were enhanced by a factor twenty! A behavior expected to ensue from the appearance of a deconfined phase during the interaction [6]. Similar results were subsequently obtained by many other experiments. These results constituted one of the main pieces of evidence for the formation of a new state of matter at the CERN-SPS energies, which CERN announced in a press release in February 2000. More on this topic is reported in Chap. 33.

Another interesting finding, suggesting a thermal production for s and $\bar{s}$ quarks [17] was the similarity of the slopes of the transverse mass spectra between strange baryons and corresponding antibaryons [18]. An observation which did indeed please Hagedorn! With this last example, I conclude my brief review of the influence that Rolf Hagedorn, together with his disciples and continuators, had on the CERN heavy-ion program and on our physics choices.

15.4 The Other Hagedorn

There is, however, another aspect of Hagedorn's activity which should not go unmentioned, namely his involvement in the defense of human rights. I here cite only the case of Yuri Orlov, a founder of the Moscow group set up to monitor the Helsinki Accords, who was arrested in 1978. Hagedorn, together with several other physicists working at CERN, took up his case and founded the Yuri Orlov

Committee to campaign on the matter. This the Committee did consistently, even directly approaching the governments of all CERN member states. Finally, during the Gorbachev years, Orlov was able to leave the Soviet Union for the United States and, in 1991 spent one year at CERN as a guest professor. As many of us know, however, Hagedorn's involvement in Orlov's defence was only one example of his readiness to help people whom he felt to be unfairly discriminated against!

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