Gleb Wataghin

R. A. Salmeron

Laboratoire de Physique Nucléaire des Hautes Energies
Ecole Polytechnique - 91128 Palaiseau Cedex - France

It is an honour and a pleasure to speak about Gleb Wataghin, the man who taught Brazilians the foundations of modern physics, how to learn it and how to do physics. The history of Gleb Wataghin in Brazil is a very nice and unusual history. There are not many similar examples of scientists who have had, by their own personal actions, such a strong influence on so many people of different generations in a country, which furthermore was not his own. The students of Gleb Wataghin and the students of his students spread out over different places, contributing to make Brazilian physics what it is today.

The description of Gleb Wataghin's work in Brazil would require much more than a lecture. We shall present a short summary, trying to show some aspects of his personality as a man, as a physicist and as a master.

The foundation of the University of São Paulo

Gleb Wataghin, Russian born who studied in Italy and became Italian, came from Torino to São Paulo in 1934. In oder to understand and properly evaluate his influence one must know a little about Brazilian schools for higher education at

---

Talk delivered at the commemoration of the centenary of Gleb Wataghin's birthday at the meeting which was at the same time the XI International Symposium on Very High Energy Cosmic Rays Interactions - named Gleb Wataghin Centennary Edition of the Symposium series - and the VI Gleb Wataghin School on High Energy Phenomenolgy, Universidade Estadual de Campinas, Campinas, São Paulo, Brazil, 17 - 21 July 2000.

that time. Brazil had only one university located at Rio de Janeiro, founded in 1920 by simply putting under a loose common administration the schools of Engineering, Medicine, Law, Dentistry and Pharmacy, but there was neither intellectual nor professional connection between them. Equivalent separated Schools without any interconnections existed in several places in Brazil.

The country had no special schools for the study of sciences of nature, human sciences or litterature. Persons became interested in mathematics, physics or chemistry usually by studying engeneering; those interested in biology studied medicine; the experts on litterature came mainly from the law schools, and so on. Scientists in nearly all fields, philosophers and writers acquired most of their professional education as self-taught persons. Very few had the opportunity to improve their education in Europe.

The University of São Paulo was founded in 1934. The schools for higher education existing in the city of São Paulo were grouped together under a common administration and, more important than this grouping of schools, a Faculty of Philosophy, Sciences and Letters was founded for the first time in the country. This Faculty had an enormous impact on the development of sciences in São Paulo, with subsequent influence on other universities which were founded later. Because of this influence the foundation of the University of São Paulo was the most important event in the history of Brazilian universities.

The founders of the university decided that eminent European professors should be invited to start teaching and research in different sciences. The organization of the invitations was given to the Brazilian mathematician Teodoro Ramos, who had worked for several years at the Sorbonne, in Paris, and had a good knowledge of the European scientific community. Ramos wrote one of the first books on vector analysis in french, while working in Paris. His influence on the organization of the new university was enormous, because he invited for sciences of nature, human sciences and mathematics persons of the highest level. For physics, he went to Rome to invite Enrico Fermi, who was then extremely busy with his famous experiments that became part of the history of physics. Fermi did not accept the invitation and recommended Gleb Wataghin, who was working at

Torino, whom, in Fermi's own words was one of the Italian theoreticians he trusted. Wataghin accepted the invitation to come to Brazil.

Wataghin the man

Wataghin's decision was a great chance to Brazil. Looking backwards at history, one sees that he was the right person to start physics in São Paulo, not only because of his scientific stature but also because of his human qualities. By starting physics in a country which had no tradition he had to face difficulties of different kinds: human, cultural, administratrive, financial. He solved them with energy, wisdom and tact.

Wataghin was a cheerful man with wide interest for things of life, enjoyed talking to people, loved physics and loved teaching, always available for long talks with students.

Many times, in the middle of a conversation about physics he started a dissertation on the contribution to science by « persons of deep thoughts », and expressed his personal admiration to many of his contemporary physicists. Such conversations stimulated the curiosity for science and respect for great scientists.

One of the main qualities of Wataghin as a master was his faith in young people. Always enthusiastic about their evolution, he used to say that young scientists in their continuous progress suddenly flourish « as a flower ».

The respect for his students and the level he wanted for the physics department of the new university can be appreciated by the choice of the physicists to whom he sent his students to work with, after they had worked with him for two or three years. He sent Marcello Damy de Souza Santos, experimental physicist, to work with Bragg in Cambridge; Souza Santos became one of the leaders of Brazilian physics, built a betatron and started accelerator physics, started nuclear energy research, put in operation the first nuclear reactor of the country and founded the Institute for Research on Nuclear Energy. Paulus Aulus Pompéia, experimental physicist, went to work with Compton, in Chicago; Pompéia became another leader, he was one of the main organizers of the Technological Institute for

Aeronautics, one of the most important engineering schools of the country. Mário Schenberg, theoretician, went to work with Fermi group in Rome. Sonia Ashauer went to work with Dirac, in Cambridge (unfortunately Ashauer died in Cambridge). Walter Schutzer (who also died young) worked with Wigner, in Princeton. Jayme Tiomno worked with Wheeler and Wigner, in Princeton. Paulo Leal Ferreira worked with the Rome group; he founded, with his brother Jorge, the Institute for Theoretical Physics in São Paulo, one of the most important in the country. Schenberg, Tiomno and Leal Ferreira are among the most important leaders of theretical physics in Brazil. Oscar Sala worked with Herb, in Wisconsin; one of the main leaders in nuclear physics in the country, he founded the Nuclear Physics Department in São Paulo, a well equipped laboratory with Van de Graaff accelerators. Another well known Wataghin's student who became a leader is Cesar Lattes, who worked with Powell in Bristol, but mainly under the influence of Giuseppe Occhialini; Lattes founded in Rio de Janeiro the Brazilian Centre for Physical Research and later started cosmic ray research at the University of Campinas.

Wataghin the physicist

Wataghin worked on theoretical and an on experimental physics, a quality which was extremely important for the beginning of physics in São Paulo, because he was able to train young physicists on both. He belonged to that last generation of the few physicists who knew all physics, and could deliver an impromptu lecture on practically any branch of physics of his time.

His wide knowledge was complemented by an unusual intuition on physical phenomena, which allowed him to predict sometimes long in advance the future of a line of research or of an experiment which had been started. We would like to quote two examples of his reactions in occasions he knew about new experiments being planned or new results which had been obtained. A first example is his reaction when he heard for the first time that Cern and Brookhaven had started experiments with neutrino beams. It took him just few minutes to realize that those experiments could change some of our concepts in physics; in fact, they gave the first evidence which led us to think seriously about the reality of QCD. A second example is his thought when he was told that muon pairs had been produced in hadron collisions. He concentrated for few minutes, then said that the muon pairs could come from gamma-rays, as electron pairs do, and asked the two questions: where would gamma-rays come from in hadron collisions ? should we investigate gamma-rays production in such collisions ? He was right, we know that the mechanism is production of a virtual gamma-ray in quark-antiquark annihilation, with subsequent decay into a muon pair, similar to the electron-positron annihilation in QED.

Theoretical Physics

Gleb Wataghin worked on several branches of theoretical physics:

- field theory, with emphasis on non-local field theory, on which he produced a pioneering paper in 1934, at the same time as Yukawa. He was interested on space-time structure of the theory and all his life he was convinced of the existence of a fundamental length in the interactions.
- statistics of particles at high temperature
- astrophysics (star composition)
- multiple production of mesons
- non-local theory of composite quark models.

Statistical model of meson production

We shall briefly describe, as an example of his works, Wataghin's statistical model of meson production in high energy collisions, which he developed in 1941-1942, before the discovery of the pion. As far as I know, this was the first statistical model of particle production.

Wataghin's physical insight can be appreciated by his own words in the description of his model:

« The purpose of the following remarks is to show some very simple features of the distribution of energy and momenta in a group of particles created in a high energy collision ... Let us examine the high energy collision of two nucleons in the frame of the centrum of masses... »

« Starting from the assumption that almost all energy lost is radiated in the form of a mesotron field and that the corresponding number of mesotrons is high, one can try to apply classical considerations to the collision, remembering that in this case the operators representing the mesotron field nearly commute. Then one can say that during the collision time Δt, which is obviously of the order of r_0/c, where r_0 is the range of nuclear forces, a wave packet is originated having the linear dimension r_0. The Fourier analysis of this packet contains terms corresponding to the period Δt. It follows from the above mentioned principle [1] that the avarage wave length of the produced mesotrons waves is also of the order of r_0 ... We find that in the most probable distribution the created mesotrons have, in the frame of the center of mass system, an energy $3mc^2$ (where m is the rest mass of a mesotron)...

The general conclusions are: for high energies ($\gamma >> 1$) the number n of the mesotrons and the (total) average energy of mesotrons are proportional to the square root of the primary energy (in the center of mass system). [2] »

Summarizing, Wataghin reached the two conclusions:

1) The average meson energy in the center of mass system of the collision should be $< E_{meson\ cm} > \approx 3$ m, where m is the meson mass, which we know to be true.
2) The multiplicity of the mesons production should vary as $(E_{cm})^{1/2}$ where E_{cm} is the collision energy in the center of mass system.

A third conclusion, which Wataghin did not explicitly mention is that the meson transverse momentum P_T should be limited. We know that this is true, in high energy collisions pions are produced with a transverse momentum which is limited to about 350 - 400 MeV/c, roughly 3 times the pion mass.

We would like to point out that Wataghin was one of the first to understand that collisions should be analysed in the center of mass system.

It is really astonishing that Wataghin reached these conclusions sixty years ago, at a time when high energy physics did not exist. We know today that the multiplicity varies as $\log E_{cm}$, a variation which is close to his prediction. The following table gives the ratio of the average multiplicity $< n >$ at a given momentum of the incident particle in the lab to the multiplity of a collision at 10 GeV/c, both with the $(E_{cm})^{1/2}$ and with the $\log E_{cm}$ variation.

$< n > / < n >$ at 10 GeV/c

P_{lab} GeV/c	$(E_{cm})^{1/2}$	$\log E_{cm}$
10	1	1
200	2.1	2.0
500	2.6	2.3
1000	3.1	2.5

Wataghin's prediction is very close to what we know today, even at 1000 GeV/c it is not so bad.

Research on cosmic rays

Wataghin soon realized that cosmic rays was an important field of research which could be properly done in Brazil at that time. Even if he was not an experimenter by training, he started an experimental group on cosmic rays, which within few years became internationally known. As examples of the success obtained by the São Paulo group we shall mention two results: the discovery of hadronic showers and the measurement of the proton-proton total cross section at high energies.

The discovery of hadronic showers

In 1940 Paulus. A. Pompéia, M. Damy de Souza Santos and G. Wataghin made an experiment which detected unexpected events: showers of particles that could go across many dozens of centimeters of lead [3]. Such showers could not be electromagnetic, since these are stopped within few centimeters of lead. They are therefore a new type of showers, which the authors called « penetrating showers ». They are in fact what we call today « hadronic showers », the groups of hadrons that are produced together in strong interactions. Hadronic showers are among the most important elements in high energy collisions. All large detectors used in particle physics must have a detector of hadronic showers.

This was an extremely exciting discovery, which had important consequences. Its importance is emphasized, for instance, by Heisenberg in his book on Cosmic Rays, which describes a theoretical and an experimental consequence.

The theoretical consequence was the attempts to answer the question: can many mesons be produced simultaneouly in a collision, or are mesons produced singly, only one per collision in many successive collisions ? The first mechanism, many mesons produced together, was called « multiple production », and its most illustrious defenders were Heisenberg and Wataghin. The second mechanism, in which only one meson would be produced in a collision and the shower would be the result of many successive collisions, was called « plural production », and its most prominent defender was Heitler. We know that the multiple production assumption was the right one, but we had to wait fifteen years - after the São Paulo experiment was done - to have the experimental proof of it, until mesons were produced in proton-proton collisions in a diffusion cloud chamber at the Brookhaven accelerator.

The experimental consequence we want to mention was the stimulus for the realization of another important experiment. Patrick Blackett, one of the most prestigious cosmic ray physicists, director of the Physics Department of the University of Manchester, influenced by the São Paulo experiment, after the Second World War suggested to G. Rochester and C. Butler to do an experiment on penetrating showers with a cloud chamber immersed in a magnetic field. The experiment was done and discovered a new kind of particles, unknown until then, which were called « V-particles », because their decay products made V-shaped tracks in the cloud chamber. Their name was changed later to « strange particles ». As is well know, this discovery produced a revolution in particle physics.

Proton-proton total cross section at high energies

In 1945, Oscar Sala and Gleb Wataghin did an experiment to study interactions of cosmic rays in paraffin, which is rich in hydrogen. They concluded tha the proton-proton total cross section at high energies should be 40 millibarns [4]. This is an astonishingly correct result, obtained nearly sixty years ago with a very simple experimental set-up. From accelerators experiments we know that at high energies this cross section varies by only about 10% around 40 millibarns.

Gleb Wataghin went back to Italy after working in São Paulo for 16 years. He did again a wonderful work at the University of Torino, with young theoretical and young experimental physicists, the latter participating actively in many experiments at the « golden age » of particle physics done with cosmic rays and working later in accelerators experiments.

This short summary of some of Gleb Wataghin's many activities and of some aspects of his personality is a modest tribute to a great man who, starting from nothing, had strong influence on an entire generation of scientists and shaped physics in Brazil.

References

1. The principle referred here had been postulated by Wataghin, who suggested the invariance of the physical laws with respect to a transformation of « observables » and « representatives » of a state in classical and quantum mechanics. Cf. G. Wataghin, Nature 393 (142) 1938; Comptes Rendues de l'Académie des Sciences, 358 (207) 1938 and 421 (207) 1938; Anais da Academia Brasileira de Ciências, July 1942.

2. G. Wataghin, « On the production of groups of mesotrons by high energy collisions », in Symposium on Cosmic Rays, Rio de Janeiro, 1941, Anais da Academia Brasileira de Ciências, p. 129, 1942.

Other references on statistical model are: G. Wataghin, « Statistical mechanics of processes observed in cosmic ray phenomena », Anais da Academia Brasileira de Ciências, 355 (15) 1943; G. Wataghin, « Statistical mechanics at extremely high temperatures », Phys. Rev. 149 (66) 1944; G. Wataghin, « On the multiple production of mesons », Phys. Rev. 975 (74) 1948.

3. P. A. Pompéia, M. D. Souza Santos and G. Wataghin, Phys. Rev. 61 (57) 1940; Phys. Rev.339 (57) 1940; Phys. Rev. 902 (59) 1941.

4. O. Sala and G. Wataghin, Phys. Rev. 5 (67) 1945.