# X-SECTIONS on the RISE

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In the spring of 1973 the world high-energy community received a firm but unexpected message from the ISR (CERN): the total cross-sections of $pp$-collisions at $\sqrt{s} = 23\div$ 63 GeV grow with energy [1]. Moreover in the corresponding publication of the collaboration led by the outstanding Italian physicist Ugo Amaldi it was stated that within error bars this growth is compatible with $\sim (log\sqrt{s})^2$.

This finding had a predecessor. In late 60-ies a statistically significant growth of the $K^+p$ total cross-section was discovered (by the group led by the eminent Russian experimentalist Yu.D. Prokoshkin) at the that-time most powerful accelerator in Serpukhov [2]. However physicists were not much disturbed by this news, and many considered this as a kind of transitory phenomenon due to "exotic" quantum numbers of the $K^+p$-system.

Three years later the rise was undoubtfully identified in the "normal" $pp$-collisions. Why the discovery was so exciting this time?

By the beginning of 70-ies there was a strong belief that the bulk of hadronic cross-sections is described by Regge poles among which the principal rôle was played by the leading trajectory, the Pomeron. Pomeron dominance of high-energy behaviour corresponds in its simplest incarnation to asymptotically constant total cross-sections.

Much earlier, in 1939 (and then repeatedly in 1952), the great German physicist, Werner Heisenberg, predicted theoretically [3] that total cross-sections should grow at very high energies just as $(logs)^2$.

Was he glorified in 1973 when such a growth was finally observed at CERN? Remarkable fact: Heisenberg's 1952 paper was cited in some experimental publications on the "ISR effect" but was not even mentioned in papers by prominent theoreticians Froissart, Martin and Cheng and Wu, where $(logs)^2$ — behaviour was discussed. What could be a reason for such an evidently unfair treatment?

Next year after publication in 1952 of the second Heisenberg's paper with more detailed derivation of growing cross-sections readers of a Soviet academic journal [4] could read an article contained a criticism of the Heisenberg's result with a didactic résumée : *"...the neglect of the uncertainty relations which takes place in the paper [1]* [Heisenberg's paper in question, my remark] *is inadmissible"*. The author of the famous uncertainty relations himself violated them! What a blunder!

This criticism was strongly backed by the famous Russian theorist Landau, just finished his own, hydrodynamical, model of high-energy collisions. Heisenberg did not gave an immediate and clear opinion on this criticism and left the field to concentrate himself on a new underlying theory of elementary particles, "non-linear spinor field theory".

Later, however, Heisenberg, taking part in the discussion of a talk by the known Soviet physicist D. Blokhintsev (at the 1956 CERN Symposium on High Energy Accelerators and Pion Physics) agreed vaguely that semiclassical consideration of inelasticity he made in his 1952 paper "cannot be justified from quantum theory", though he expressed an opinion that even a correct quantum theoretical calculation would lead to the results obtained classically. By the way the Blokhintsev's talk contained a crushing criticism of Landau hydrodynamical model.

Naturally, many physicists considered the question closed, and the idea that total cross-sections asymptotically achieve some constant values, defined by their "sizes", became dominant for many years. This belief, quantified by the famous Pomeranchuk pole, the Pomeron, with intercept at 1, was so overwhelming that when U. Amaldi gave a seminar at CERN in March 1973 devoted to the discovery of the growth of the $pp$ total cross-sections one very prominent theorist argued that the result was wrong because "everybody knew that cross-sections should be asymptotically constant because of the Pomeron". In general, high-energy community reconciled with growing cross-sections not without significant reluctance. Such was a psychological inertia caused by many reasons: symplicity of the Pomeron-pole model, authority of its advocates etc.

Already in 50-ies in spite of impressing successes of quantum electrodynamics, culminated in the renormalized perturbation theory, it became clear that strong interaction should be treated in a completely different way. One of the basic components of the new approach was the idea of Heisenberg [5] (1943) that what really matters is the preparation of colliding particles and subsequent measurement of the products of their reaction. All the rest is unobservable metaphysics. Formally the idea was quantified by the $S$-matrix containing infinite number of amplitudes of all processes allowed by the conservation laws. Realization of this program in the framework of the "axiomatic approach" naturally led to the study of analyticity properties of $S$-matrix elements as functions of kinematical variables extended to complex values. At quite abstract assumptions one could infer very interesting consequences for physical amplitudes.

In 1961 at the conference in La Jolla, French theoretician Marcel Froissart [6] reported that in the framework of such a general approach one may assert that at high energies total cross-sections cannot grow faster than $(logs)^2$. Exactly the behaviour predicted by Heisenberg! Nonetheless Froissart did not cite him. Froissart's result was very quickly recognized as a paramount theoretical discovery. Five years ago, Froissart's compatriot, André Martin [7], managed to prove the logarithmic bound on more general grounds than Froissart and with more rigour.

Since then this bound is called *"Froissart-Martin upper bound"*.

In 1969-70 two American theorists, H.Cheng and T.T. Wu, drew attention of the physics community by a series of paper, published mostly in Physical Review [8], where they, after a laborous asymptotic summation of awfully cumbersome Feynman diagrams, obtained explicitely (not as a bound!) the Heisenberg asymptotics, i.e. $(logs)^2$ behaviour of the total cross-section in the framework of "massive" electrodynamics. And again, Heisenberg was not even mentioned.

As we already said above, two years later, the growth of the total $pp$ cross-sections compatible with $(logs)^2$ was discovered at CERN-ISR. Since then the growth was confirmed at FNAL, later, at higher energies, again at CERN, and again at FNAL, at the highest energies (1,8 TeV) ever achieved in laboratory. We also have to remember that the growth of generic strong-interaction cross-sections $(pp, \bar{p}p, Kp, \pi p)$ as a natural phenomenon was unambiguously discovered at Serpukhov accelerator. Recently the growth was observed in $\gamma p$-interactions at HERA.

What about Heisenberg in all this story?

First of all, the criticism of his paper, mentioned above, was based on quite doubtful assumptions, and cannot be considered well sounded or even valid. For example the critics of Heisenberg put as undoubtful the argument that the "interaction time", wich they arbitrarily identified with a "time uncertainty", is defined by the Lorentz – contracted longitudinal size of the nucleon. This assumption sharply contrasts with later views which argue in favour of fixed longitudinal size of the nucleon [9], or growing with energy interaction time [10].

Certainly the model in the framework of which Heisenberg predicted $(logs)^2$ behaviour of the total cross-sections looks to the modern reader a little bit naive, but formally, its essential ingredients are the same, as in more rigorous proofs by Froissart and Martin. This by no means underestimates the significance of the Froissart – Martin result and we have to pay them our full tribute for their great contribution into our present understanding[1] of basic features of high-energy behaviour.

[1] Certainly the term "understanding" does not refer to the present state of affairs in the strong interactions theory which still lacks even a regular calculation procedure nothing to say about the real understanding of reaction mechanisms.

But at the same time it would be absolutely incorrect and unfair to keep further an "omerta" on the Heisenberg's pioneering breakthrough, where he clearly (though not in a general, model-independent way) predicted $(logs)^2$ growth of the strong-interaction cross-sections.

In the history of physics on can easily find cases when important results were inferred whith help of concepts and axiliary mechanisms which were later changed for more correct, but "wrong provenance" of thes results was never considered as a reason to bury in oblivion their creators.

And every participant of this "$(logs)^2 - saga$": Heisenberg, Froissart, Martin and Cheng and Wu, played his specific and historically significant rôle. One also has to be aware of the fact that our full understanding of the growing cross-sections in terms of the modern theory of strong interactions, QCD, is still absent.

In conclusion it worth to make the following citation from the last Heisenberg's book [11], published in 1977: "*...theoretical studies led, more than 20 years ago, to the assumption that in the high-energy range the value of the total cross-section for hadron collisions must grow proportionally to the square of logarithm of energy.*

*... This guess was confirmed in recent experiments at storage rings of the proton synchrotron in Geneva and at the accelerator in Batavia."*

*W. Heisenberg, 1977.*

This citation shows that Heisenberg (just on the eve of his physical disappearing) considered his 1952 paper as a correct and valuable prediction, succesfully confirmed experimentally. We do not see any reason not to join him in this judgement.

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