THE RUNNING OF GAUGINO MASSES, THE GAP AND THE SINGLE-PHOTON FINAL STATES IN THE SEARCH FOR THE SUPERWORLD

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Sometimes ago, in the middle eighties, I received a call from my friend and colleague, Nino Zichichi; he had decided to devote a great attention to the new theoretical set of discoveries called "supersymmetry".

He wanted to have my opinion in order to decide on the forthcoming Courses of the Subnuclear Physics School.

Not being my field of direct interest, I was not very enthusiastic for the simple reason that supersymmetry was lacking a direct impact with experiments.

Nino sent me his review paper [1] delivered at the EPS Conference in Geneva (1979) where he said: «*Unification of all forces needs first a supersymmetry. This can be broken later, thus generating the sequence of the various forces of nature as we observe them*».

This statement was based, as he has emphasized in many occasion, on a work with André Peterman.

Nino and his friend André, using the renormalization group equations, had realized that the problem of the convergence of the slopes (versus energy) of the three gauge-couplings, $\alpha_1\, \alpha_2\, \alpha_3$, could receive a new degree of freedom from supersymmetry.

At the time of the Geneva 1979 EPS Conference, the three gauge couplings, $\alpha_1\, \alpha_2\, \alpha_3$, were not converging in a point but in a sort of triangle. The new degree of freedom in the three slopes of the gauge couplings had as experimental impact the energy-threshold where to search for the first example of a superparticle.

Lot of problems needed to be clarified and Nino, a few months later, informed me that he wanted to devote the forthcoming Courses of the Erice Subnuclear Physics School to supersymmetry. He later send me the three volumes "Superworld I, II, III" of the Erice Schools (1986, 1987, 1988) [2].

These were just premises to what he told me in 1991, when, being engaged with is group in searching for the first experimental evidence of the Superworld in the 50 GeV mass range, the best theoretical prediction was giving as lower bound for the supersymmetry threshold the level of 21 TeV [3].

This prediction was based on the evolution of the gauge couplings ($\alpha_1\, \alpha_2\, \alpha_3$) computed neglecting the effects due to the evolution of the masses.

Once this effect is introduced, the energy threshold, for the detection of the first signal from the Superworld, is lowered by nearly three orders of magnitudes, more exactly a factor 700 [4].

The following Figure is taken from this paper [4] and illustrates the value of introducing the running of the gaugino masses in the determination of the supersymmetry breaking threshold.

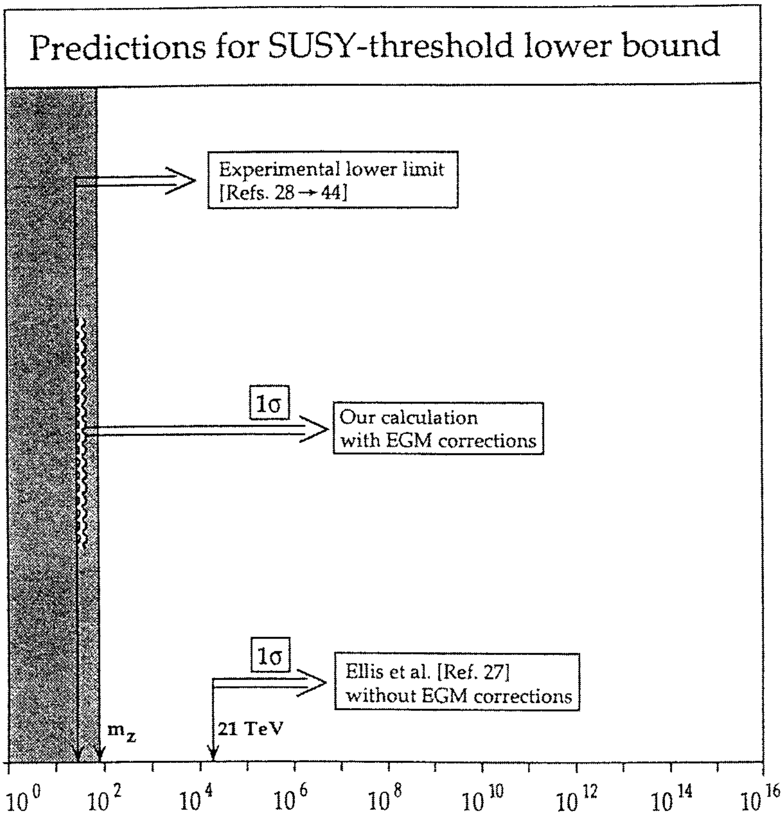

Figure published in Il Nuovo Cimento 106A, 581 (1992). Predictions for supersymmetry threshold lower bound, with and without corrections for the evolutions of the gaugino masses (EGM effect). The reference numbers are those specified in the original paper quoted above.

This result triggered a new revived interest in the search for the Superworld using the (e^+e^-) collider at CERN, LEP.

In fact other discouraging "theoretical" papers had been published, the most advertized one being that where the SUSY threshold was predicted to be above the TeV range [5].

As illustrated on the last five columns of the following Table, these "predictions" were neglecting, not only the EGM effect, but also many other "details".

These "details" illustrate how many important properties, of the Superworld physics to be described, had been neglected by many authors, including those whose claim was to "predict" the energy scale at which supersymmetry was expected to be broken. This Table has been presented by A. Zichichi in his "*Lezione Magistrale*" at the University of Turin, 21 May 2004. The numbers of the first column indicate the references quoted in his Lecture.

	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Authors	*Input data*	*Errors*	*EC*	M_{SUSY}	*CC*	*UC*	ΔT_L	M_X	ΔT_H	*EGM*
ACPZ [47, 49→54]	WA	± 2 σ	all possible solutions (24)	Yes	physical	Yes	Yes	Yes	Yes	Yes

Authors	*Input data*	*Errors*	*EC*	M_{SUSY}	*CC*	*UC*	ΔT_L	M_X	ΔT_H	*EGM*
AdBF [55]	only one experiment	± 1 σ	only one solution	Yes	Geometrical	No	No	No	No	No

① *WA* ≡ *World Average*
② *Errors* ≡ *Uncertainty taken from all data (World Average) or from a single experiment*
③ *EC* ≡ *Evolution of Couplings*
④ M_{SUSY} ≡ *Mass Scale assumed to represent the Supersymmetry Scale breaking*
⑤ *CC* ≡ *Convergence of Couplings*
⑥ *UC* ≡ *Unification of Couplings above* E_{GUT}
⑦ ΔT_L ≡ *Low Energy threshold*
⑧ M_X ≡ *Mass Scale at the breaking of the Grand Unified Theory to the SU(3)xSU(2)xU(1)*
⑨ ΔT_H ≡ *High Energy threshold*
⑩ *EGM* ≡ *Evolution of Gaugino Masses*

Let me say a few words on the five "details" reported in columns 6 to 10 of the Table above:

i) The unification of the gauge couplings (α_1 α_2 α_3) must continue above the energy level where they all converge (E_{GUT}); this condition is indicated as UC.

ii) The low energy threshold must be described by a spectrum, ΔT_L , and not using a sharp step at a given energy value.

iii) The mass scale (M_x) where the Grand Unified Theory (GUT) breaks into SU(3) × SU(2) × U(1) has to be investigated in terms of the experimental results in the low energy range, around the Fermi scale.

iv) The high energy threshold were the Grand Unified Theory breaks into the Standard Model (SU(3) × SU(2) × U(1)) cannot be a δ-function of the energy, but a spectrum. This spectrum, ΔT_H, has in fact consequences not only on the low energy threshold for supersymmetry breaking but also on the possible existence of a Gap between two basic energy scale: one is the energy level where all gauge couplings (α_1 α_2 α_3) converge, E_{GUT}, and the other is the energy level, E_{SU}, where the string theory predicts the unification of all forces (on the basis of the Newton gravitational coupling). The problem concerning the existence of the Gap [6] is another topic which Nino liked to discuss with his friends.

v) Finally, the evolution of the gaugino masses (EGM) which, as said before, has the effect of lowering the low energy supersymmetry threshold by nearly three orders of magnitude, must be duly taken into account.

I would like to mention another contribution by Nino which has been of remarkable value for the experimental search performed at CERN during more than a decade. It was Zichichi who actually called everybody's attention on the fact that also the "single-photon" final states had to be searched for as a basic signal for the Superworld [7].

In this note I have restricted my introduction to three effects which have attracted my interest, thanks to Nino's discussion on several occasions during many years, and in particular in 1979, and then in the years following 1991, when he decided to step in the field in order to avoid the general "theoretical" trend discouraging to search for superparticles below the TeV-mass-range.

The analysis of all experimental data and of all quantities having an effect on the experimental search for the Superworld is documented in the papers by A. Zichichi and collaborators reproduced in the present volume. This will be a guide not only for the forthcoming experiments in the new energy range opened by the CERN LHC Collider, but also for the future searches of the Superworld.

References

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