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Summary talk: Field Theory

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We present some remarks on the works reported at the section of particles and fields of the XXI Brazilian National Meeting on Particles and Fields.

The national meetings on Particles and Fields have occurred since 1979. The first meeting was took place in Cambuquira, Minas Gerais, and, as it was written in the proceedings, "it appeared as an answer to the increasing need for interactions between physicists working in such areas". That meeting had the participation of one hundred physicists, one third being graduated Ph. D. students. A large spectrum of interests was covered in the published communications (Solitons, 1/N expansions, bosonization, symmetries dynamically broken, Bethe-Salpeter and so on)

Before that meeting, most probably in 75/76, I recall J. A. Swieca being surprised with the absence of Brazilian physicists working on supersymmetry. As a matter of fact, only in the III meeting supersymmetry appeared explicitly, in a presentation by Elcio Abdalla and proceeded more intensely from the IV meeting onwards, with Victor Rivelles. At that time, there was great interest in two dimensional theories, which was naturally due to the great influence of the works of J. A. Swieca. At the second meeting I gave a lecture on the CP^n model and nonlocal charges.

In the present meeting, there was a notorious increase in the number or participants (around 300), as well as in the number of contributions. Furthermore, we should notice the large amount of presented posters which were absolutely scarce in the first meetings.

Within these twenty years, Brazilian physics has evolved rapidly in terms of quantity. The interests have also somehow changed. Works on 2+1 dimensional field theories, problems on the quantization of constrained systems with or without supersymmetry are natural part of the contributions. Modern subjects as the ADS-conformal theory correspondence and noncommutative spaces have begun to appear.

For the present meeting I tried to classify the contributions in two blocks: Formal aspects and Applications. Of course, this separation is not well defined, involving a certain degree of subjectivity.

1. Properties: Formal Aspects. Here, I grouped works in which basic aspects of quantization are investigated: the BRST symmetry and the Batalin-Vilkowski methods.

The presented contributions range from issues such as dimensional reduction in supersymmetric theories, supersymmetric Yang-Mills that until this day offer challenges for a proper understanding, dynamical mass generation and bound states.

As far as constrained systems are concerned, there have been discussions on the quantization of a particle constrained to move on the surface of a D dimensional sphere (C. Wotzasek and C. Neves). This is an old problem which has been taken into consideration by many physicists. In Brazil, we had works from the UFRJ group (J. Barcelos Neto, R. Amorim, C. Wotzasek and C. Neves), Elcio Abdalla and R. Banerjee and from H. O. Girotti. In other words, it is a high interest topic. The basic issue here is transforming a second class system into a first class one. A parentheses for the terminology; first and second class belong to the classification of constraints introduced by P. A. M. Dirac. The Poisson parentheses involving a first class constraint weakly vanishes, i. e., it is proportional to the other constraints. Those constraints which have non-vanishing Poisson parenthesis among themselves are called second class ones. There is a difficulty with second class constraints arising from the fact that their Poisson parentheses in general contain products of the canonical variables and so become ambiguous at the quantum level. In this context, people have proposed schemes to convert second into first class constraints. One aspect that has to be considered with regard to this constraint transmutation is when the problem reappears elsewhere, as, for instance, within the application of the Gupta–Bleuler method to construct a physical sub-space.

In 1992, H. O. Girotti, A. J. da Silva, myself and the then doctorate students R. S. Mendes and J. R. S. Nascimento, investigated the existence of bound states constituted from particles of equal charges, in 2+1 dimensions. We had noticed that in various circumstances the Chern-Simons (CS) term plays an stabilizing role. In the Thirring model it enables an increasing in the region free from tachions, in quantum electrodynamics it gives a mass to the gauge field, avoiding the occurrence of infrared divergences, and so on. In our study of 2+1 dimensional quantum electrodynamics the CS term, which is crucial to avoid the just mentioned divergences, does not initially exist but it is generated by radiative corrections. The corresponding nonrelativistic potential was obtained through the analysis of the two body Möller scattering. The binding energies that we obtained, measured in Kelvins, were near the critical temperatures found in the superconductor ceramics. In our meeting, O. M. del Cima presented a model in which the mass for the gauge field comes through the Higgs mechanism. This is a complementary possibility to ours since it needs an auxiliary scalar field to be implemented. Anyway, it is interesting to know that bound states can be formed even without the presence of a CS field.

Another basic subject covered in our gathering is related to the dynamical mass generation for gauge fields, in four dimensions. Various schemes are known to generate mass for gauge fields. In two dimensions we have Schwinger mechanism, the gauge field becoming massive, thanks to the chiral anomaly. Actually, the Maxwell equations clearly shows that. As we know, in three dimension we have the CS term providing a topological mass for the gauge field. In four dimensions, the situation is more complicated. In principle we would only have the Higgs scheme, but as the Higgs particle has not been found there is still a search going on to find a dynamical breaking of the symmetry without the elementary Higgs (by the way, I recall that R. Shellard had been working actively in this subject during his doctorate with J. Cornwall). There is also the proposal of using antisymmetrical fields in the so-called BF formalism. In the Abelian version of the model, the Lagrangian consists of the usual Maxwell term, a kinetic term of the antisymmetrical field and a topological term,

$$\mathcal{L} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} - \frac{1}{12}H_{\mu\nu\rho}H^{\mu\nu\rho} + \frac{1}{2}m\epsilon^{\mu\nu\rho\lambda}F_{\mu\nu}B_{\rho\lambda} \quad (1)$$

where, as C. Almeida explained, $H_{\mu\nu\rho} = \partial_\mu B_{\rho\lambda} + \partial_\nu B_{\rho\mu} + \partial_\rho B_{\mu\nu}$. The field equations show that both gauge fields are massive. In this respect, a 1997 result, due to M. Henneaux, S. Sorella and co., proving the failure of the scheme in the non Abelian situation, should be remembered. Similar analysis was performed by the group of Ceará when studying analogous theories in 2+1 dimensions.

There is, evidently, an intrinsic interest in this kind of development which points towards a better understanding of the foundations of the field theory. Within this context a 1996 contribution of Barcelos must be mentioned.

In our gathering the BF model was considered in at least two situations: as previously pointed out, it was regarded by the group of Ceará as a means of furnishing topological theories in 2+1 dimensions, through a process of dimensional reduction. In another presentation, by the CBPF group (J. Helayel-Neto and co), a dimensional reduction from four to three dimensions was made. A supersymmetrical model with $N = 1$ containing the BF term was analyzed in order to obtain a MCS theory with an additional magnetic coupling and with a $N = 2$ extended supersymmetry. Prior to that, it was verified, by de La Plata group among others, the existence of an association between the extended supersymmetry with $N = 2$ of the Higgs Abelian model and the appearance of Bogomol'nyi equations. These are first order equations and its soliton solutions saturate a lower limit for the energy. On the other hand, in a MCS gauge theory with magnetic coupling and with a specific quadratic potential it was show that Bogomol'nyi type of self-dual equation may exist. It was then conjectured that, also in this situation, there should exist a relationship between the self-duality limit and the $N = 2$ supersymetry of the model. It is clear that this topic arises interests in several groups (UFRJ, CPBR, UERJ and Ceará)

An interesting proposal for the quantization of a relativistic particle under the influence of an external electromagnetic background was presented by D. Gitman. The scheme, which surmounts the known difficulties of the first quantization for a relativstic system, leads to a description of both particle and antiparticle and, for weak fields, correctly reproduces the one particle sector of the quantum field theory.

2. Applications. The main applications found in this meeting were about the Casimir effect. This effect, which was proposed more than fifty years ago, is due to vacuum fluctuations in limited regions of the space. The intensity and the signal of the resulting force depend on the geometry and the spin being, in the bosonic case, attraction of parallel plates. The effect has been studied for a great number of geometries and the finite conductivity of the plates has also been perturbatively incorporated. This was explained in a seminar of Mostepanenko. Many situations were actually analyzed by the groups of UFRJ (C. Farina, M. V. Cougo-Pinto, A. C. Tort and collaborators). Temperature effects on the Casimir energy, for the case of a cavity having perfect conducting walls and also for parallel plates in scalar electrodynamics with diverse boundary conditions were considered.

An interesting thread is being developed by a group from Paraíba (D. Bazeia, F. A. Brito, J. R. S. Nascimento and R. Freire), focusing on the subject of defects in field theories. Spontaneous breaking of symmetry in theories with two degenerated vacuums allow for soliton solutions connecting these vacuums. The wall is the region where the soliton energy is concentrated. Situations where another field is nonvanishing in the middle of the wall may lead to the formation of another topological structure, the wall inside the first wall. Those solutions are present in supersymmetric theories. BPS solutions, in particular, are present if the supersymmetry is extended. Also, junctions can be formed if the model possesses more than two vacuum one wall ending at another wall. These studies may have implications to both cosmology and condensed matter, as D. Bazeia argued.

Renormalization group studies, adequate to the analysis of critical phenomena, were presented by a CBPF group (A. Malbouisson, Nogueira C. Calan and N. Svaiter). They considered the Ginzburg–Landau-CS model (i. e. scalar Maxwell–CS quantum electrodynamics with a ϕ^4 self interaction). In a one loop calculation and for a certain range of the parameters of the model, they showed that there exists a tricritical point in addition to another one infrared stable. Besides that, gauge invariance was analyzed and verified to be under control in spite of the sharp cutoff used. It would be interesting to compare the scaling properties with that obtained by a São Paulo group (de Albuquerque, da Silva and M. Gomes) which in a two loop calculation arrived at somewhat different results.

Temperature effects in theories with a CS term were presented by A. Das. At finite temperature, the non Abelian CS model presents a problem whose proper solution till today has not been found: due to gauge invariance, the coefficient of the non Abelian CS term must be quantized. However, as the temperature increases nothing seems to prevent continuos changes in that coefficient. Das described a 0+1 model where the problem can be discussed in extenso. Following the ideas in this simplified model, for particular situations, it was possible to demonstrate the compatibility of the perturbation at non zero temperature and the quantization of the CS coefficient in 2+1 dimensions. He also reported some more recent investigation on the subject, done together with J. Frenkel and F. Brandt.

At São Paulo, we have interest in the Aharonov–Bohm effect as obtained by a nonrelativistic reduction process starting from a relativistic theory. That was related in da Silva's talk. Whenever a CS model is considered, a natural issue is about the renormalization scheme to be employed since, due to the Levi-Civita symbol, dimensional regularization is not convenient. To circumvent such problem, in our discussion of 2+1 models we also employed a soft version of the BPHZ scheme.

Another, more recent interest at São Paulo is on noncommutative theories, as it was explained by V. Rivelles. Noncommutative theories had some of its motivation on a certain limit of superstrings models. Perhaps because of that origin, they were expected to be consistent. However, due to a sui generis ultraviolet/infrared mixing each situation should be investigated separately. In this respect, supersymmetric theories have a better chance of surviving.

I would like to end this talk by quoting J. A. Swieca's words in his work "Solitons and Confinement". More than twenty years ago, Swieca wrote: "After almost half a century of existence the main question about quantum field theory seems still to be: what does it really describe? and not yet: does it provide a good description of the nature?" After the success of the standard model many basic questions are without answers. Therefore, even today this citation remains pungently real.