Research in Theoretical Physics*
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Abstract

We propose the continuation of the research under this grant. We propose to extend the search for signatures of "*new physics*" to new processes. In particular, we want to investigate extensions of the the search to hadronic reactions. The appearance of anomalous terms in the matrix elements of $SU(3)_{color}$ currents, indicating the presence of "*new physics*" in the quark sector of the Standard Model, can be studied by following the jet evolution and hadronization. The effect is expected to be rather large in top quark initial state gluon Bremsstrahlung, thus colliders are a good testing ground for the presence of "*new physics*" even at Tevatron energies. We continue the study of astro-particle physics. We propose to investigate further the structure of extensive air showers associated with point sources in the sky. We propose to study neutrino production in the Milky Way: this will enable us both to estimate the background of neutrino telescopes and to search for the presence of baryonic dark matter in the galactic halo.

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1 Introduction

This Proposal accompanies an Annual Progress Report (Report # DE-FG-85ER402211-7); instead of duplicating references already quoted there, we shall refer to that report as AR. The research proposed here is a continuation of the one reported on in AR. Consequently, the structure of this Proposal parallels the structure of that document. In the next Section we discuss the extension of our previous research on anomalous terms in current matrix elements. Section 3 contains the description of the proposed research on astro-particle physics. A brief Section 4 contains remarks about research proposed on other topics; time permitting, we want to carry out on them. However, the main thrust of the research is the one described in Sections 2 and 3.

Let us recall the motivation of the research we are proposing. Currently, the Standard Model of elementary particle interactions is in an excellent agreement with the experimental data; there are a few minor disagreements and there have been some in the past. So far, however, all those proved to be either statistical fluctuations or effects caused by systematic errors. The overall agreement between theory and experiment is excellent. Nevertheless, it is believed that that the Standard Model is not the last word in particle theory. It contains 19 parameters for three generations of quarks and leptons, the Higgs sector requires fine tuning, it gives no explanation of why there are three generations, etc.

Unfortunately, theories going beyond the Standard Model either have not been phenomenologically successful (as the grand unified theory based upon $SU(5)$) or they contain an even larger number of unknown parameters than the Standard Model itself (e.g. a grand unified theory based upon $SO(10)$ and a Higgs sector containing elementary scalar fields). It is reasonable therefore at this point to concentrate upon phenomenological searches of signals for physics not described within the framework of the Standard Model. The parametrization of the effects of such a "new physics" should be consistent with what we know about the theory at present. Presumably, we have not yet reached the energies at which the new phenomena become easily visible. Therefore, one can parametrize the matrix elements of the various processes in terms of a "low energy" phenomenology. The gauge structure of the theory severely restricts the possible parametrizations: neglecting a small contribution from longitudinal components of axial currents, in effect, the "new physics" can manifest itself only in the presence of Pauli terms in the current matrix elements, cf. AR and references quoted there. The rest of this Proposal is written taking into account these restrictions. Presumably, further restrictions on the "new physics" will come when we shall understand the symmetry breaking within the Standard Model somewhat better. As it is, we just parametrize the *physical* current matrix elements, i.e. those coupled to the g , W , Z , and γ . (Here and in what follows, 'g' stands for the $SU(3)_{color}$ gauge quantum, the gluon.)

2 New Physics in the Quark Sector

Given the fact that the $SU(3)_{color}$ currents are pure vector and the gauge symmetry is unbroken, the parametrization of “new physics” in this sector of the Standard Model is unambiguous. There is one Pauli term which is expected to be of the order of Λ^{-2} , essentially independent of the quark mass; Λ standing for the characteristic scale of the “new physics”. The complication is, of course, confinement. The price to pay for the simplicity of an unbroken gauge theory is that it is confining. Hence, there is no *direct* way of observing the presence of the Pauli terms in the current matrix elements: one has to follow through the quarks in the hadronization process. We envision two complementary ways of doing that. One is an approximate analytical method, following the jet evolution by means of the time-honored Altarelli-Parisi equations and then treating hadronization by means of some standard routine, e.g. LUND. This method has the advantage that one has practically total control over the “hard” part of the process. The jet evolution can be understood in intuitive terms. It is expected that the Pauli terms in the $SU(3)$ octet currents contribute corrections to the standard hadronization process which are of the order Λ_{QCD}/Λ , which is almost certainly small. As a consequence, the (soft) hadronization needs no modification.

Alternatively, one can follow through the entire process of jet evolution and hadronization by means of modifying available Monte Carlo routines. This approach is certainly more accurate, but less intuitive. Given the fact that one is facing a rather complicated situation — since the non-perturbative aspects of QCD are not very well understood — both approaches are necessary in order to understand the effect of a possible “new physics” on processes measured below its characteristic energy. The situation is somewhat similar to the approach we took to the development of “anomalous” air showers in astro-particle physics. There, we developed a similar strategy, by first studying results in a simplified but intuitive analytical model before implementing the full scale Monte Carlo simulation. The qualitatively correct, but inaccurate results of the analytical approach serve as a check on the Monte Carlo results. The accompanying AR contains sufficient details in order to elucidate this issue.

Stephen Mrenna and C.P. Yuan discovered that “initial state Bremsstrahlung” of gluons has a high rate in decays of the t -quark; see AR for the appropriate reference. This is a very interesting process, since t should be well identifiable by means of its decay products. Consequently, one has a good control over a process $t \rightarrow g + 't'$, where ‘ t' ’ stands for a tagged set of t decay products. In this process, one will be able to follow through the jet evolution and hadronization in considerable detail, so that the presence of color octet Pauli terms can be effectively tested for.

3 Astro-Particle Physics

3.1 Anomalous Extensive Air Showers

We discussed the question of anomalous extensive air showers in AR. In essence, the issue is the following. If the phenomena of muon rich showers and the absorption anomaly associated with point sources in the sky are both real, then there is some observational hint that there exist phenomena at relatively low energies (of the order of $\sqrt{s} \approx 2$ TeV) which transcend the framework of the Standard Model. In AR we described a series of calculations designed to explore this possibility. The argument is the following. Assuming that the above mentioned phenomena are real, there must exist other observable properties of these extensive air showers (EAS) which differ from the normal, proton or γ induced ones. We performed computations both in the framework of a simplified analytical model and carried out Monte Carlo simulations. The Monte Carlo simulation yielded a detailed description of the new phenomena and confirmed the suspicion that a number of the observed properties of the anomalous EAS differ from the normal ones. The simulation was, however, carried out under some simplifying assumptions, in order to save computing time. Since the results are encouraging, we now propose to run the full scale simulation, taking into account the spectral properties of the source and varying the properties of the first interaction. This is necessary in order to understand the influence of various properties of the initial interaction (multiplicity distribution, p_T distribution, etc. on the shower development. Armed with the results of this simulation, we shall be able to initiate a detailed comparison with currently available data and data to be obtained from future detectors. This is a painstakingly slow process, due to the low fluxes involved and of the episodic nature of the sources. Nevertheless, as we have repeatedly emphasized, currently (and in the near future) these are the only high energy lepton beams available.

3.2 Neutrino Production in the Milky Way

This research is aimed at determining the amount and distribution of neutrinos (mostly ν_μ) in our Milky Way. Neutrinos are produced by the cosmic radiation either confined to our galaxy or of extragalactic origin as it interacts with matter. This is of importance from two points of view.

- There are plans to build neutrino telescopes both in the United States and abroad. While most of these are designed with astronomical purposes in mind, the data collected by them can be used for purposes of astro-particle physics. The neutrinos produced by cosmic rays in the Milky Way constitute a background in the search for point sources.
- By scanning the angular distribution of the neutrinos incident upon a detector, one should be able to detect baryonic dark matter (if there is any) in the galactic halo.

In the course of the planned research, one has to use the known energy spectrum of the primary cosmic radiation and to make some plausible assumption about its chemical composition. Further, one has to extrapolate accelerator-based hadronic interaction cross sections, multiplicity and rapidity distributions to higher energies. Although *any* extrapolation is a dangerous one, in practice, the outcome of the computation is not very sensitive to it. This is due to the fact that the necessary hadronic input is known up to about $\sqrt{s} = 1800\text{GeV}$ from Tevatron measurements and older data. The spectrum of the primary cosmic radiation falls with energy, roughly as $s^{-\alpha}$, with $\alpha \approx 3$. Thus the energy region where the uncertainties become substantial, enters with a small weight.

In principle, one would have to consider the entire transport problem of the secondaries in the galaxy, which is a very complicated calculation. Preliminary estimates, however, indicate that given the matter density in our galaxy (about 1 proton per cm^3), the transport process will be dominated by the decay of the secondaries and hence, their angular and energy distribution is easy to calculate.

4 Other Planned Research

In this section we briefly mention some topics we are planning to investigate, assuming that the research described in the previous two sections progresses at the rate expected.

1. In the Proposal submitted last year we described a planned investigation of the possible role played by group deformations in describing broken symmetries. Due to unexpected technical difficulties with the subject and a somewhat slower than expected pace of the main research subject, this topic has not been completed. We are planning to continue the research, certainly up to a point at which it can be decided whether group deformations can play a role in physics outside the realm of completely integrable systems.
2. In a recent paper (J. Lukiersky *et al.*, Phys. Letters B264, 331 (1991)) discuss the mathematics of the deformation of the Poincaré group. This is not of a mathematical interest only. In fact, in various contexts (most recently, in connection with some alleged internal inconsistencies in the data collected on SN 1987A) there have been discussions whether the special theory of relativity is valid at short distances. Most models of transcending the special theory of relativity, however, have been contrived if not outright internally inconsistent. The only known exception is the deformation described by Lukiersky and collaborators. It contains one parameter of dimension energy, which, in a sense is the characteristic energy at which the special theory of relativity fails; in addition, it is a mathematically consistent and known structure. We are planning to explore at least some of the consequences of this structure. Some of the obvious questions arising are: can one place a lower limit on the characteristic energy from existing data, can one construct a consistent quantum theory covariant under a deformed group, etc.
3. There are persistent reports on the observation of γ bursts, the latest one being the data from GRO. We want to work out some suggestion about the possibility of

observing the areas of the sky by VHE and UHE detectors. If this is feasible and the same sources emit in the VHE and UHE region, the number of point sources observed could be enormously increased.

5 Summary

The research described in this Proposal is largely a continuation of the research we have been engaged in for the past few years. Progress in astro-particle physics is necessarily slower than in other areas of particle physics. For this reason, we consider the completion of the research described in Sec.2 very important: it will permit us to analyze accelerator based data in the search for post-Standard-Model physics.

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