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The Theory of High Energy Collision Processes

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MASTER

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Summary of Progress (Jan.–Dec. 1991)

During the past year, we have made progress in the following directions:

1. By far the greatest effort has been directed at a better understanding of the Standard Model of Glashow, Weinberg, and Salam. The aim is to determine theoretically some of the parameters involved. For the motivation, the approaches used, and the results obtained so far, please see long-range project (A) in the Section "Detailed Description of the Projects" (pages 5–7). Briefly, two relations between the fermion and boson masses have been found. They can be solved for the only two masses not yet measured experimentally, namely those of the top quark and the Higgs. It is gratifying to find that the resulting mass of the top quark, obtained on the basis of purely theoretical reasoning, is indeed in the range favored by existing phenomenology. This work is being carried out by Newton (Research Fellow), Osland (former Research Fellow), and Wu.

2. Experimental data from the Fermilab Tevatron Collider have confirmed very well the predictions of the impact picture [1]. This is to be contrasted with the discrepancy on the ratio of the real and imaginary parts of the forward $p\bar{p}$ elastic scattering amplitude between the theoretical prediction and the data from the CERN $p\bar{p}$ Collider. For this reason, CERN has decided to devote about six weeks of running time to repeat this measurement in November and December of 1991. In anticipation of this additional data, a more detailed study of the real part of the amplitude has been carried out [3]. A review of of pp and $p\bar{p}$ elastic scattering has also been published [4]. See also the long-range project (C), pages 8–10.

3. The doctoral thesis of Newton has been published [2], and the corresponding problem in six dimensions turns out to be much easier [9]. This six-dimensional problem is interesting because ϕ_6^3 is renormalizable but not super renormalizable. Newton has been studying the even more interesting case of ϕ^4 theory in four

dimensions. This is a much more ambitious program in the sense that all Feynman diagrams are considered, not just the ladder diagrams. See also the medium-range project (g), pages 17, 18.

4. Two of the papers submitted for publication by Dodelson (Research Fellow until last July) have appeared [6], [7], and a third one is expected to appear soon. He has also studied, to one loop, the finite-temperature effective potential for a self-interacting theory with a conserved charge [8]. The regime of very high temperatures is especially interesting, showing explicitly the effects of the conserved charge. For the limit of low densities, some of the well-known results can be easily reproduced, but as yet the method used may not be powerful enough to give other known results.

5. Freeman (student) has gone much beyond his result of last year [5] in several directions. First, he has found a large class of separable potentials that share the same properties, previously found by Grossman and Wu, as the Fermi pseudopotential when arranged in a large circle [15]. The Fermi pseudopotential is a limiting case within this class. Secondly, he has derived approximate coupled integral equations for a large array of dipoles arranged around a smooth curve.

6. Earlier this year, the ALEPH Collaboration at LEP found a possible excess of $\tau^+\tau^-V$ events in Z decay. Assuming that this is not a fluctuation, we have studied some of the implication of this possible excess [10].

7. Previously the study of beamstrahlung has been limited mostly to the emission of a single photon. The method of Feynman diagrams has now been applied to the case of multiple emission of photons [11], [13]. The result is somewhat different from that previously expected. This has been reported at the 1991 Joint International Lepton-Photon Symposium and Europhysics Conference on High Energy Physics [16]. Quite unexpectedly, some physicists interested in the foundation of quantum mechanics find the beamstrahlung calculation interesting because a microscopic quantity (L_e) is much larger than a macroscopic quantity (bunch length)

[12]. See also the medium-range project (d), pages 13, 14.

8. The three-body quantum-mechanical system of three unit charges, $++-$ or $+--$, interacting through their Coulomb interaction sometimes has bound states and sometimes does not, depending on their relative mass. Since the results in the literature are rather fragmented, it may be interesting to find a more unified treatment. This has been carried out [14].

Papers Published During the Last Year:

1. Experimental Confirmation of the Impact-Picture Predictions for $\bar{p}p$ Elastic Scattering at FNAL Collider (C. Bourrely, J. Soffer, and T. T. Wu), Phys. Letts. B. **252**, 287 (1990).
2. High-Energy, Large-Momentum-Transfer Processes: The N-Rung Ladder Diagram of ϕ^3 Theory (C. Newton and T. T. Wu), J. Math. Phys. **32**, 1619 (1991).
3. Real Part of the $\bar{p}p$ Elastic Scattering Amplitude at $\sqrt{s} = 546$ GeV (C. Bourrely, J. Soffer, and T. T. Wu), Mod. Phys. Lett. A **6**, 2973 (1991).
4. Proton-Proton and Proton-Antiproton Elastic Scattering at High Energies —Theory, Phenomenology, and Experiment (T. T. Wu), pp. 314–324 in *Beyond the Standard Model II*, K. Milton, R. Kantowski, and M. A. Samuel, Eds., Proceedings of the International Conference on High Energy Physics, Norman, OK, 1–3 November 1990, World Scientific Publ. Co., Singapore (1991).
5. The Pseudodipole as the Limit of a Resonant Cylindrical Dipole (D. Kent Freeman), J. Math. Phys. **32**, 1961 (1991).
6. Neutrino–Two Photon Vertex (S. Dodelson and G. Feinberg), Phys. Rev. D **43**, 913 (1991).
7. Relativistic Bose Gas (J. Bernstein and S. Dodelson), Phys. Rev. Lett. **66**, 683 (1991).
8. Phase Structure and the Effective Potential at Fixed Charge (K. M. Benson, J. Bernstein, and S. Dodelson), Phys. Rev. D **44**, 2480 (1991).

The Following Papers Have Been Submitted for Publication:

9. The Asymptotics of ϕ^3 Ladder Diagrams in Six Dimensions: High Energy and Large Momentum Transfer (R. Gastmans, W. Troost, and T. T. Wu), accepted in Nucl. Phys. B (1991).
10. Excess of $\tau^+\tau^-V$ Events in Z Decays: A Naive Look (R. Gastmans, W. Troost, and T. T. Wu), accepted in Phys. Lett. B (1991).
11. Radiated Energy Loss Due to Beamstrahlung in High-Energy Electron-Positron Linear Colliders (M. Jacob, T. T. Wu, and G. Zobernig), accepted in Zeitschrift f. Physik C—Particles and Fields (1991).
12. Macroscopic Lack of Localization in Quantum Radiative Processes (M. Jacob and T. T. Wu), submitted to Phys. Lett. A (1991).
13. Multi-Photon Radiation in Beamstrahlung (M. Jacob and T. T. Wu), accepted in Nucl. Phys. B (1991).
14. Stability of Three Unit-Charge Systems (A. Martin, J.-M. Richard, and T. T. Wu), submitted to J. Chem. Phys. (1991).
15. Generalization of the Pseudopotential to an Interaction with Nonzero Range (D. K. Freeman), submitted to J. Math. Phys. (1991).
16. Beamstrahlung: A Status Report with Recent Results (M. Jacob and T. T. Wu), presented at the 1991 Joint International Lepton-Photon Symposium and Europhysics Conference on High Energy Physics, Geneva, Switzerland, July 25–August 1, 1991.

Doctoral Dissertation Completed During the Last Year:

17. High-Energy, Large-Momentum-Transfer Processes: Ladder Diagrams in ϕ^3 Theory (C. Newton), Ph.D. Thesis, Harvard University, November 1990.

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