INTRODUCTION

My aim in this talk is to give a very brief and qualitative outline of string models (or dual-resonance models) and to indicate how vertex operators appear in such models. The basic idea is that the fundamental objects of the theory instead of being point-like, as they are in most other theories, are string-like.¹

String models are very tightly constrained and possess remarkable properties. They were originally discovered by virtue of these properties, and it was only realized later that they could be obtained from a simple string picture. The original intent was to apply them to hadronic physics, i.e., to sub-nuclear physics, whose domain of applicability involves distances of the order of magnitude of $10^{-13}$ cm. Physicists working in this regime have now largely abandoned the models, partly because an alternative theory ("quantum chromodynamics") has been found, but also because they possessed certain properties which rendered them inapplicable to hadronic physics. I may mention two such properties:

i) They turned out to be theories of gravity. Gravitational interactions are known to be completely negligible in hadronic physics.

ii) They only worked in unphysical numbers of space-time dimensions; twenty-six or ten. Polyakov² has recently proposed a new string model which may overcome these defects, and which may be equivalent to quantum chromodynamics. There will be talks on the Polyakov model later on in the conference; I shall not describe it today.

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² J. Lepowsky et al. (eds.), Vertex Operators in Mathematics and Physics © Springer-Verlag New York Inc. 1985
Physicists have recently been studying theories whose distances of applicability are very much smaller than $10^{-13}$ cm. Quantum gravity, which becomes important at about $10^{-32}$ cm, is now a subject of investigation. Among theories being studied are those of the Kaluza-Klein type, in which space-time has more than four dimensions, all but four of the dimensions forming a compact space of about $10^{-32}$ cm in diameter. The features of string models mentioned above are no longer defects; the gravitational properties of the theory are precisely what we require.\(^3\) In fact, string models are the only presently known theories of gravity which do not possess short-distance inconsistencies (they are the only theories which have a renormalizable perturbation series). Renewed attention is therefore being paid to string models.

There are two basic types of string theories. The first, the generalized Veneziano (G.V.) model, works in twenty-six dimensions, and has no degrees of freedom other than the position of the string. In the second model, the Neveu-Schwarz-Ramond (N.S.R.) model, which works in ten dimensions, there exist "spin" degrees of freedom distributed over the string. The N.S.R. model led to the concept of supersymmetry. Green and Schwarz\(^4\) have recently shown that the model is in fact a physical system with supersymmetry and supergravity properties. They and their collaborators are actively studying the model. It possesses a richer structure than the G.V. model, and has greater possibilities with regard to the elementary-particle problem. Unfortunately, due to limitations of time, I shall not be able to describe the N.S.R. model. My talk will be devoted to the simpler G.V. model.

As is usual when considering this type of problem, we shall divide it into several stages. We shall first consider the classical (i.e., unquantized) motion of a free, non-interacting string. Next we shall examine the corresponding quantum system which is still, from the physicists point of view, rather trivial, since strings do not interact. Finally we shall consider how we can allow the strings to interact in the simplest possible way, by joining and splitting. The vertex operator appears when we consider such interactions. We shall briefly examine ramifications and generalizations of the vertex