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ACCELERATOR DEPARTMENT
Informal Report

MASTER

SOME SPECULATIONS ON COLLIDING BEAMS OF 200 GeV PROTONS
AND 15 GeV ELECTRON-200 GeV PROTONS

Chen Ning Yang

January 31, 1972

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INTERSECTING STORAGE ACCELERATOR NOTES

Some Speculations on Colliding Beams of 200 GeV-200 GeV

Protons and 15 GeV Electron-200 GeV Protons

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As late as 12 months ago, there was considerable skepticism on the part of many physicists about our ability to overcome possible experimental difficulties with colliding beam machines like the ISR at CERN. Experience since last summer has helped to dissipate such fears. The ISR turns out to be a beautiful machine and is generating a unique excitement among the physicists at CERN.

Also during the last few years, it has become clear that with the energies available at the ISR and the 200 GeV machine we shall be really entering into the era of precision discussions of very high energy phenomena. In broad perspective we might say that in the early 1960's hadron physics was dominated by the studies of resonances. Resonance phenomena was of overriding importance in collisions up to AGS energies, and it was natural that they should receive the physicists' attention for many years. The trend was, however, already changing in the late '60's when extrapola-

tions of experimental and theoretical ideas led to definite frameworks with which to view high energy phenomena beyond the resonances, into what was sometimes called the asymptotic region. The preliminary experimental results obtained at the ISR testifies to the usefulness of such frameworks. Undoubtedly in the next few years this topic will be studied in great quantitative detail. In particular, one particle distributions, two particle correlations, complex multiplicity correlations and fluctuations etc. will all receive much attention. The correlation and fluctuation studies, though difficult, are of special interest since they serve to differentiate between different theoretical models that have so far been advanced.

In other words, the ISR and the Batavia machines will be giving us a first look on the qualitative nature of very high energy collisions and also some quantitative aspects, all within the framework of some already existing theoretical ideas. Are these ideas correct? Which one of these ideas (such as the parton model, the multiperipheral model, and the hypothesis of limiting fragmentation, etc.) is in better agreement with experimental reality? These are questions that we are all anxiously waiting to have answered.

But, what lies beyond these studies?

It could be, of course, that the ISR and the Batavia machines will produce results totally different from any of the existing theoretical frame-

works. But, that is extremely unlikely judging from the preliminary results of the ISR. I suspect a much more likely event is that the limiting behavior of high energy collisions will be largely verified, except for small fractional power dependence on E_{incoming} and/or dependence like $\log E_{\text{incoming}}$. That such subtle and slow dependence of various parameters may exist has been discussed theoretically already for a long time. The recent extensive work of H. Cheng and T. T. Wu on the high energy limit of Feynman diagrams gives strong emphasis to this possibility. To discuss and resolve such possible sophisticated dependencies, it will be necessary to go to much higher energies and make precision measurements on various parameters. Colliding beam proton-proton machines with high luminosity of the type envisaged in the BNL proposal are ideally suited for this purpose.

It should be emphasized that the resolution of these subtle questions is of great importance. Interest in such questions is not of a pedantic nature. For in such asymptotic behavior, one hopes to learn the fundamental interaction and the complex manifestations of such interactions through very high order processes in actual experiments. One also hopes in the process to learn the mathematical techniques to handle the problem which is emerging very clearly as the fundamental theoretical problem of hadron physics: how to deal with a strongly coupled infinite-degrees-of-freedom system. Without the proper orientation provided by experiments on how to

approach this fundamental problem, we may never be able to unravel the physics of the structure of hadrons and nuclei.

Everything that I said in the previous paragraphs, of course, applies also to a high energy colliding beam electron-proton machine. There is a slight advantage for this type of machine: the electromagnetic interaction of the electron is known. In experimental terms, this means that the identification of the outgoing electron as a fragment of the incoming electron is unambiguous. But, this argument should not be used to advance the view that the colliding electron-proton machine could be a substitute for a colliding beam proton-proton machine. Hadron-hadron collisions could not be understood without colliding beam hadron-hadron machines.

I do not believe, however, that a colliding beam proton-antiproton machine would prove to be of any great use. At very high energies, pp and $p\bar{p}$ collisions would be very similar to each other with the proper changes of particle identification along the antiproton direction.

I shall not discuss the possibilities of producing heavy new particles such as quarks or intermediate bosons with the proposed higher energy intersecting storage ring. Nor will I discuss the tests of quantum electrodynamics and experiments on weak interactions that will be possible with the proposed machines.