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SUMMARY OF THE RESEARCH PROGRESS MEETING OF DECEMBER 13, 1952

Sergay Shewchuck

February 11, 1952

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Berkeley, California
SUMMARY OF THE RESEARCH PROGRESS MEETING OF DECEMBER 13, 1951

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February 11, 1952

I. Radiation from Electrons in the Synchrotron - D. L. Judd.

Schwinger* had made calculations of light emitted by radiation from electrons, which were of great interest in the development of electron accelerators such as the betatron and synchrotron. His conclusions are:

1. Radiated Energy = \frac{4\pi}{3} \times \frac{e^2}{R} \left( \frac{E}{m_0 c^2} \right)^4

\propto E^3 \text{ for a constant magnetic field since } R \propto E.

If \( E = 330 \text{ Mev}, \) and \( R = 1 \text{ meter} \)

\[ E = 1 \text{ kv/turn}, \text{ for the Berkeley synchrotron.} \]

For energies of order 1 Bev it is difficult to make up this loss.

2. Frequency distribution of emitted radiation:

\[ \frac{dP(\omega)}{d\omega} \propto \omega^{1/3} \text{ up to } \omega_c \]

\[ \omega_c = \omega_0 \left( \frac{E}{m_0 c^2} \right)^3; \text{ critical frequency } \omega_c; \omega_0 = \frac{c}{R}. \]

In other terms

\[ \frac{dP(\lambda)}{d\lambda} \text{ Parzen's correction} \]

\[ \lambda_c = \text{critical wave length; 250\AA for the Berkeley synchrotron.} \]
3. Nearly all the radiation is emitted in a narrow sheet in plane of orbit.

\[ \angle \approx \frac{\gamma m_0 c^2}{E} \]

angle \( \approx 0^\circ \) 6\(^{\circ}\) for the Berkeley synchrotron.

4. Classical calculation should be accurate for energies up to \( \sim 10^9 \) Mev in a \( 10^4 \) gauss field, so that quantum mechanical considerations are unimportant for presently attainable electron energies.

Parzen\(^*\) has questioned the fourth conclusion and has calculated a correction which chops out the short-wave end of the spectrum of the \( \frac{dP(\lambda)}{d\lambda} \) curve as shown on the figure. His cutoff frequency, rather than increasing as \( \omega_0 E^2 \), is independent of the particle energy in a fixed field. His spectrum correction factor is

\[ e^{-8\pi^2 \left( \frac{b}{\lambda} \right)^2} \]

where \( b^2 = \frac{\gamma \omega_0}{c} \).

\[ b \approx 260 \, \text{\AA} \] for \( 10^4 \) gauss.

This would result in radiated energy per turn rising as \( E^{1/3} \) rather than as \( E^3 \). However, errors have been found in the mathematics of Parzen's treatment. When corrected, the results do give the classical answer. Details are found in report UCRL-1599 by Judd, Lepore, Ruderman and Wolff.

Parzen's results contain two errors; one is purely mathematical, while the other is of some physical interest. His stationary state wave function are labelled by two quantum numbers \( n \) and \( \ell \). \( n \) determines the energy and radius, through

\[ R \approx b \sqrt{2n} \]

\[ E \approx 2 \pi \omega_0 n \]

\( n \) is about \( 10^{13} \) for the Berkeley machine. The other quantum number \( \ell \)
 determines the distance $R_c$ of the orbit center from an arbitrary coordinate origin:

$$R_c \approx b \sqrt{2\lambda - 1}$$

Each wave function is smeared out radially to breadth $\approx b$. Parzen considered only wave functions with $\lambda = 0$ (i.e. concentric orbits), basing this on an incorrect mathematical argument. One can show that $\Delta R \approx b^2 / \lambda$ when a quantum of wavelength $\lambda$ is emitted; thus the wave functions fail to overlap for $\lambda < b$, as sketched at (a) below. By considering other values of $\lambda$, however, one can get a good overlap, as at (b) below, and the exponential cutoff disappears.

The change $\Delta n$ in quantum number $n$ per photon emission is typically of the order of $10^8$ for synchrotrons like that at Berkeley, and Parzen's other error arose from neglecting terms like $(\Delta n)^2/n$ compared to unity.

For the Berkeley synchrotron about 70 quanta are emitted per turn, so that the line breadth is about 70 times the separation of the discrete line spectrum calculated by Schwinger for an electron forced to follow an exactly periodic orbit. Thus the actual spectrum is continuous.

II. Photodisintegration of the Deuteron – Seishi Kikuchi.

This talk was based on a paper for the December, 1951 Meeting of the American Physical Society at Berkeley. An abstract, UCRL-1552, is reproduced as follows:

"An analysis was made on proton tracks found in the photographic emulsion which had been exposed by S. White to secondary particles from a deuterium gas target bombarded by high-energy synchrotron gamma rays of maximum energy of about 320 Mev to investigate photomesons from deuterons. The energy spectra of protons at the emission angles of 45, 90, and 135 degrees were obtained. In each case it shows a fairly sharp cut off at the energies 190, 140, and 95 Mev, respectively. These energies correspond to the energy of the proton expected, if it were produced by the splitting of a deuteron into a proton and a neutron by the absorption of a photon of energy 320 Mev. The angular distribution of protons shows a fairly strong forward asymmetry. The cross section per photon for the photodisintegration increases steeply with the increasing photon energy above the meson threshold. The absolute value of the cross section is of the order of magnitude of the meson production cross section."


The talk was based largely on a thesis by the author published as report UCRL-1470, September 18, 1951; entitled "Detection of the Azimuthal Polarization of the Neutron-proton Interaction in the 150 Mev Energy Region". Also, the author commented on later developments of this work which were to be included in a paper for the December, 1951, meeting of the American Physical Society at Berkeley and which has been abstracted as report UCRL-1508.
A brief summary of report UCRL-1470 is as follows:

"Spin-dependent effects in n-p interaction were studied in a double scattering experiment using an initially unpolarized beam and unpolarized targets. A small part of the flux scattered and partly polarized by the first n-p interaction was used as the incident flux in the second n-p interaction. The azimuthal dependence of the second-scattered flux was measured at various given scattering angles by means of an azimuthal array of particle detectors. The results are interpreted as a direct confirmation of the existence of noncentral nucleon-nucleon interaction in the 150-Mev energy region."

Abstract report UCRL-1508 is as follows:

"In order to circumvent the accidental background in the double scattering experiment, the first scattering is performed inside the 184-inch cyclotron tank. LiD and LiH targets are compared in order to obtain the D-neutron contribution to the polarization due to the p-n interaction. The second scattering is performed as an orthodox n-p scattering experiment by paraffin-carbon difference, in the well-collimated neutron beam emerging outside the cyclotron shielding. Four scintillation counter telescopes are arranged in an azimuthal array observing the second scatterer. Each telescope consists of two photomultiplier-liquid phosphor units; these are operated from a pulsed H.V. source which is keyed in synchronism with the cyclotron beam pulse. Using selected 1P28 photomultipliers, the counter behavior is indistinguishable from normal D.C. operation, when using 100 microsecond keying pulses at 2 to 2.4 K.V. Five to ten volt signal pulses are obtained from incident protons, and these are mixed in a current-biased crystal diode coincidence circuit. The system shows an overall resolution time of 5 x 10^{-9} sec."