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REPORTS ON RELATIVISTIC KINEMATICS FOR TWO-BODY INTERACTIONS

Owen Eldridge

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Introduction

As the precision of experiments involving elementary particles increases it becomes necessary to increase the accuracy of computation of their kinematic properties. For extreme accuracy, computer programs may be used to analyze each event, but for many purposes, such as the identification of the particles, accurately computed tables and graphs are useful. This report is a preliminary bibliography of these tables and graphs with information about the ranges of relevant parameters.

Methods of Computation

1. J. Blaton, On a Geometrical Interpretation of Energy and Momentum Conservation in Atomic Collisions and Disintegration Processes, Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd., **24**, no. 20 (1950).

A graphical method is given for solving relativistic two-body problems.

2. A program has been set up for the IBM model 650 data-processing machine at the University of California Radiation Laboratory at Livermore for the calculation of any elastic or inelastic two-body interactions. This program is known as Project KINE; it was prepared by Mr. Kent Curtis of the Theoretical Group.

Interactions of Strange Particles, Nucleons, and Mesons

1. John H. Malmberg and L. J. Koester Jr., Tables of Nuclear Reaction Kinematics at Relativistic Energies, Physics Department, University of Illinois, 1953.

   a. The reactions and kinetic energy ranges are.

      (1) $h\nu + p \rightarrow \pi^+ + n$, $h\nu = 154(1)310$ Mev,

      (2) $h\nu + p \rightarrow \pi + p$, $h\nu = 146(1)340$ Mev,

      (3) $h\nu + d \rightarrow \pi + d$, $h\nu = 141(1)340$ Mev,

      (4) $\pi^+ \rightarrow \mu^+ + \nu$ (in flight), $T_{\pi^+} = 10(10)130$ Mev,

      (5) $h\nu + d \rightarrow p + n$, $h\nu = 20(10)80$ Mev.
      80(20)400 Mev.

   b. The input data are:

      (1) the kinetic energy of the incident particle in the laboratory system;

      (2) the kinetic energy of one outgoing particle in the center-of-mass system;

      (3) the β of the center of mass.

   c. The output data for the outgoing particle are:

      (1) the center-of-mass angle;

      (2) the laboratory angle;

      (3) the solid-angle transformation;

      (4) the kinetic energy in the laboratory system.

2. H. L. Anderson and D. G. Wilson, Pion-Proton Scattering Tables, Institute for Nuclear Studies, University of Chicago, May, 1954.

   Scattering tables are calculated for the range of kinetic energies of the incident particle from 0(10)320 Mev.

3. J. A. Baker and J. Killeen, Pion-Proton Scattering Tables, UCRL-2843, Feb. 1955.

These tables give the following parameters when one of them and the kinetic energy of the incident pion are known:

a. The angle of the scattered pion, and the angle of the scattered proton, in the laboratory system.

b. The total energy of the scattered pion.

c. The angle of the scattered pion in the center-of-mass system and its cosine.

d. The ratio of the solid angle in the center-of-mass system to the solid angle in the laboratory system for the scattered pion.

The range of the kinetic energy of the incident pion is 300(50)6000 Mev; the angular increment is $\Delta\theta = 15^{\circ}$.

4. J. A. Baker and K. Curtis, Tables of K Meson Scattering, UCRL-3274, Jan. 1956.

The same information is given as in UCRL-2843. The ranges of the kinetic energy of the incident K-meson are:

10(10)200 Mev and 200(50)6000 Mev. The mass of the K meson is assumed to be 966 electron masses.

5. E. Pedretti, Kinematics of the Reaction $K + p \rightarrow \pi + \Sigma$ and of the Elastic Scattering $K + p \rightarrow K + p$, Nuovo Cimento 3, 956(1956).

a. The reactions and kinetic energy ranges are :

(1) $K + p \rightarrow \pi + \Sigma$, 60(20)160 Mev,

(2) $K + p \rightarrow K + p$, 10,25(25)150,200 Mev.

b. Graphs are plotted of :

(1) the angle of one outgoing particle in the center-of-mass system versus each angle in the laboratory system;

(2) the kinetic energy of each outgoing particle in the laboratory system versus its angle;

(3) for the outgoing Σ particle, its vange in G. 5 emulsion versus its angle in the laboratory system;

(4) the solid-angle transformation for the reaction $K + \quad \rightarrow K + p$.

6. Beverly H. Willis and Charles V. Stableford, High-Energy Particle Data, Vol. 1, UCRL-2426 (Rev.), Nov. 1956.

a. Plotted as functions of kinetic energy are the kinematic functions, β, $\gamma - 1$, p, $p\beta$, and $H\rho$, for the following particles:

(1) electrons (1 Kev to 10 Mev);

(2) μ mesons (100 Kev to 10 Bev);

(3) π mesons (100 Kev to 10 Bev);

(4) $K^{\pm}$ mesons (100 Kev to 10 Bev);

(5) Λ^0, Σ, Ξ^- Hyperons (100 Kev to 100 Bev);

(6) protons, deuterons, and alpha particles (100 Kev to 100 Bev).

b. The functions of the center-of-mass system $\bar{\beta}$, $\bar{\gamma} - 1$, $\bar{\eta} = \bar{\beta}\bar{\gamma}$, and total energy are plotted against kinetic energy in the laboratory system for the following two-body systems: $\gamma + p$, $e + p$, $\pi + p$, $K + p$, $p + p$, for kinetic energies from 10 Mev to 10 Bev.

7. Unpublished Tables:

a. Dr. J. M. Sellen, Jr. of Cornell University has calculated tables for:

(1) photoproduction of π^+ and π^0 from hydrogen;

(2) the photodisintegration of deuterium;

(3) π^0 production in deuterium.

The energy range is 400 to 1600 Mev.

b. Dr. L. B. Leipuner of Brookhaven National Laboratory has calculated tables for:

(1) θ^0, Λ^0, Σ^- decay,	pc = 0(0.1)2 Bev, $\Delta\bar{\theta} = 10^\circ$;
Σ^0 decay,	pc = 0(0.05)1.1 Bev, $\Delta\bar{\theta} = 5^\circ$;
$\pi^- + p \rightarrow \Lambda^0 + \theta^0$,	T_{π^-} = 1.1(0.05)2.0 Bev, $\Delta\bar{\theta} = 5^\circ$;
$\pi^- + p \rightarrow \Sigma^- + K^+$,	T_{π^-} = 1.1(0.05)2.0 Bev, $\Delta\bar{\theta} = 5^\circ$;
$\pi^- + p \rightarrow \pi^- + p$,	T_{π^-} = 0.75(0.05)1.1 Bev; $\Delta\bar{\theta} = 5^\circ$;
$\pi^- + p \rightarrow \Lambda^0 + \theta^0$,	T_{π^-} = Threshold(0.05)1.1 Bev, $\Delta\bar{\theta} = 5^\circ$;
$\pi^- + p = \Sigma^- + K^+$.	T_{π^-} = Threshold(0.02)1.1 Bev, $\Delta\bar{\theta} = 5^\circ$.

Here pc is the momentum of the decaying particle, T is kinetic energy, and $\Delta\bar{\theta}$ is the increment of the angle in the center-of-mass system. The computed quantities are T, pc, β and θ in the laboratory system for each produced particle.

Other Interactions

1. M. Wiener, Energy and Angle Distribution of the Photoprotons from Deuterium, National Bureau of Standards Circular 515, 1951.

In graphical form are presented:

a. In the laboratory system, proton energy versus photon energy.

b. The angle of proton emission versus photon energy.

c. The angle of proton emission versus proton energy.

d. The angle of proton emission versus the change in this angle when transforming from the center-of-mass to the laboratory system.

d. The solid-angle transformation for the emitted proton versus the angle of proton emission.

2. A. Nelms, Graphs of the Compton Energy-Angle Relationship and the Klein-Nishina Formula from 10 Kev to 500 Mev, National Bureau of Standards Circular 542, Aug. 1953.

Graphs are given for:

a. Scattered photon energy versus angle.

b. Recoil electron energy versus angle.

c. Photon wave length distribution.

d. Photon angular distribution.

e. Electron angular distribution.

f. Photon energy distribution.

g. Electron energy distribution.

h. The integral Klein-Nishina cross section per electron.

3. L. Blumberg and S. I. Schlesinger, Relativistic Tables of Energy and Angle Relationships for the $T(p,n)He^3$, $D(d,n)He^3$, and $T(d,n)He^4$ Reactions, AECU-3118, May 1956.

Tables are given relating the following parameters:

a. Kinetic energy of the incident particle.

b. The angle of emission of each particle in the laboratory system.

c. The kinetic energy in the laboratory system of each emitted particle.

d. The solid-angle transformation.

The kinetic energy range of the incident particle is 1.1 to 25 Mev.

Range-Energy Relations in Emulsion

1. Fay, Gottstein, and Kain, Numerical Tables of Relations Frequently Used in Nuclear Emulsion Work, Suppl. Nuovo cimento 11, 234(1954).

a. As a function of residual range in Ilford G.5 emulsion are plotted

(1) kinetic energy,

(2) $\sqrt{1-\beta^2}$,

(3) β ,

(4) pc,

(5) $p\beta$,

(6) the "cell-size" schemes for the mass determination of particles coming to rest in the emulsion, using the "constant-sagitta method" of measuring scattering.

b. The particles considered are: μ mesons, π mesons, τ mesons, protons, and hyperons.