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OWL - A MONTE CARLO PHASE SPACE PROGRAMME

OWL is a Monte Carlo programme that calculates momentum, kinetic energy, and effective mass distribution for reactions having up to 10 outgoing particles. It has the advantage over numerical integration methods that many-body final states can be calculated in a reasonable time and the programme has a flexibility that allows matrix elements to be added easily. However, for three- or four-body final states it is slower (or less accurate) than existing numerical integration methods.

The heart of the programme is subroutine GENEV, which generates events uniformly in phase space by a Monte Carlo method. This subroutine does the same job as does subroutine GENPCM, which is used in programme FAKE. However, GENEV is considerably faster, using a method devised by E. Raubold (private communication), that uses the effective mass squared of the N-m (m = 1, N - 2) outgoing particles as the basic random variables, rather than the kinetic energy of the first N - 1 particles. In this report, I shall first describe the basic operation of the programme and then later some added features will be explained.

INPUT DATA

The data cards necessary for the programme are:

1. RANDOM NUMBER CARD. Format ($\bar{0}$12)
   For this any number that has no 8 or 9 will do.
2. GENERAL INFORMATION CARD. Format (2I5, F10.5, 2I5, F10.5).
   This card reads in the quantities called NTR, NEV, ETOT, MAT, MODE, FLOOR.
   NTR is the number of outgoing particles.
   NEV is the number of events to be generated.

ETOT is the total c.m. energy of the reaction.

MAT, MODE and FLOOR will be described later. They can be left blank.

3. MASS CARD. Format (7 F10.4)

   A card giving the masses of the NTR outgoing particles. Two cards are necessary if NTR > 7.

4. OUTPUT CARD. Format (5 F10.4)

   This card specifies what output is wanted. Each word gives the number of intervals into which the data is to be histogramed (maximum 100). If the first word is non-zero, a c.m. momentum distribution will be given for all particles. If the second word is non-zero, a kinetic energy distribution will be given for all particles. Likewise, the third word controls a two-body effective mass-squared distribution for all two-particle combinations; word four controls three-body effective mass distributions, and the fifth word controls four-body effective mass distributions.

OUTPUT

Each distribution is placed on a separate page headed by a mass. For momentum and energy distributions this mass is the mass of the particle being considered. For N-body effective masses it is the sum of masses of the N particles. The first column of the output gives the centre of the interval into which the data is being histogramed. The second column gives the height of the distribution in this interval, and the third column gives the accuracy with which this value is determined. When there is more than one particle or system of particles having the same mass, they are combined in the same distribution. The histogram is normalized to 100 times the number of times the mass occurs. Thus, for the reaction $\bar{p}\, p \rightarrow \pi^+\pi^+\pi^-\pi^-\pi^0$, the $\pi^\pm$ momentum histogram will be normalized to 400, the $\pi^\pm\pi^0$ effective mass-squared distribution will be normalized to 400, and the $\pi^\pm\pi^\pm$ effective mass distribution will be normalized to 600.

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STATISTICAL CONSIDERATIONS

The subroutine GENEV generates events which do not all have the same statistical weight. It is the normalized sum of the weights assigned to each event that is histogramed. This has two effects worth noting. First, the statistical accuracy of the sample is less than it would be if the events were equally weighted, and second, the quoted accuracy may be unrealistic if the number of events which contribute to the histogram is small.

SPEED OF THE PROGRAMME

The number of events that can be generated in one minute is about $40{,}000/(NTR)^2$. If the effective mass distributions are also calculated, the programme will be about a factor of two slower for five-body and a factor of four slower for ten-body events, Before printing the results the programme writes out the number of events per minute that have been generated, as well as the effective number of events per minute, a number that takes into account the non-uniform weight distribution.

MATRIX ELEMENTS

Subroutine MATRX is called by OWL immediately after the event is generated. It can multiply the weight assigned to the event by some number which can be a function of the c.m. momenta of the particles. If the word MAT is zero, MATRX is not used. If MAT is non-zero, it gives the number of matrix cards to be read in by the programme. Each of these cards has a format 7 F10.4. The second word is a code word, which can be between 1.0 and 13.0 and which specifies the type of matrix element that is to be used. The programme at present has the following matrix elements,

1. (Word 2 = 3.0) changes the Lorentz invariant phase space to non-Lorentz invariant phase space.
2. (Word 2 = 8.0) multiplies the weight by the c.m. momentum of one of the particles raised to some power. The particle is specified in word 3 (for example, the particle whose mass was second on the mass card is identified by a 2.0 at word 3). The power is given in word 4.

Numbers 9.0, 10.0, 11.0 and 12.0 all have to do with the effective mass (m) of a system of particles. These particles are specified in words 6 and 7. If word 6 is 2.0 and word 7 is 3.0, a two-body effective mass between the second and third particle is specified. If word 6 is 2.0 and word 7 is 5.0, then the four-body effective mass of particles 2, 3, 4 and 5 is specified.

3. (Word 2 = 9.0) This sets the weight to zero if M is not between the values given in words 3 and 4.

4. (Word 2 = 10.0) The weight is multiplied by a simple Breit-Wigner:

$$\frac{\Gamma^2/4}{\Gamma^2/4 + (M - M_0)^2}$$

where M_0 is given in word 3 and Γ in word 4.

5. (Word 2 = 11) The weight is multiplied by a general two-body Breit-Wigner:

$$\frac{\Gamma\Gamma_0}{\Gamma^2 + \frac{(M^2 - M_0{}^2)^2}{M_0{}^2}}$$

where M_0 is in word 3 and Γ_0 is in word 4 and

$$\Gamma = \frac{\Gamma_0 M_0}{M}\left(\frac{p}{p_0}\right)^{(2L+1)}$$

where L, the orbital angular momentum in the decay, is in word 5, p is the momentum of one of the decay particles and p_0 is the value of p when $M = M_0$.

ALTERNATIVE MODE OF OPERATION

It is possible to generate events using programme FAKE, have FAKE write a tape and have the tape read by OWL, which calculates the distributions. This may be useful because FAKE is more flexible than OWL (it can include angular distribution and it can generate resonances more efficiently). If MODE is non-zero, OWL expects to read a Fortran binary input tape which has some non-zero label in word 1, anything in words 2 to 5, the weight assigned to the event in word 6. Following this, there are 5 (3) words per track when MODE is positive (negative). When MODE is positive the words are the centre of mass p_x, p_y, p_z, E and p for the particle. When MODE is negative, the words are p, tan λ and φ in the laboratory system.

FLOOR

If FLOOR is zero (or negative) all events are used. If FLOOR is non-zero the programme eliminates (in an unbiased manner) events having a weight less than FLOOR. This feature may be useful if the weight distribution of the events is very non-uniform and time is being wasted by making calculations on events having very small relative weights. As FLOOR is increased the number of events generated per minute decreases, but the effective number of events per minute may increase. FLOOR cannot be used effectively until one finds out information about the actual weight distribution.