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COVARIANT PHASE SPACE FACTORS FOR REACTIONS INVOLVING FOUR TO SIX SECONDARY PARTICLES

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I. Introduction

This report describes a set of programs for computing covariant phase space factors using the IBM 650 computer. Originally the programs were written to investigate the K-production by $\bar{p}$-annihilation in terms of the statistical model. They were written with enough flexibility to permit their use on similar problems involving four to six secondary particles of another nature provided the particles can be ordered so that the last two particles in the successive integrals are identical. Removal of this restriction is being considered, nevertheless the programs now available may be used for some other reactions.

The programs are of two categories:

(1) HONE programs which give the momentum spectra of secondary particles.

(2) HOKO programs which give the distribution of angles between two secondary particles as predicted by momentum-energy conservation.

II General Formulation

We consider a reaction leading to n secondary particles

$$A + B \rightarrow m_1 + m_2 + m_3 + \ldots m_n \tag{1}$$

with total energy W_0, evaluated in the c. m. system of A and B.

(1) Momentum Spectrum for Particle m_1

The covariant phase factor integrated over the momentum coordinates is given by:[1]

$$F_n(W_0) = \underbrace{\int \cdots \int}_{n} \prod \frac{m_i \, d^3 \vec{p}_i}{E_i} \; \delta(\Sigma \vec{p}_i) \; \delta(W_0 - \Sigma E_i) \tag{2}$$

where $E_i = \sqrt{p_i^{\,2} + m_i^{\,2}}$ is the total energy of the secondary particle of mass, m_i: $c = 1$.

Integrating over $\vec{p}_1$ we get

$$F_n(W_0) = \int_1 \frac{m_1 \, d^3 \vec{p}_1}{E_1} \underbrace{\int \cdots \int}_{n-1} \prod_{i=2}^{n} \frac{m_i \, d^3 \vec{p}_i}{E_i} \; \delta(\vec{p}_1 + \sum_2^n \vec{p}_i) \; \delta(W_0 - E_1 - \sum_2^n E_i) \tag{3}$$

In view of the covariance property, the multiple integral can be evaluated in a particular Lorentz-frame, namely the c. m. system for the $n-1$ particles involved. The transformation thus made indicates that this integral is simply the phase space integral corresponding to a total energy, W_1, derived from W_0 by momentum-energy conservation:

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[1] Kalogeropoulos: Thesis, UCRL-8677.

$$W_1^{\,2} = (W_0 - E_1)^2 - \vec{p}_1^{\,2} = W_0^{\,2} + m_1^{\,2} - 2\,W_0\,E_1 \qquad (4)$$

This gives the recurrence formula

$$F_n(W_0) = \int_1 4\pi\, m_1\, p_1\, dE_1\, F_{n-1}\,(W_1) \qquad (5)$$

The range of integration is $m_1 \leq E_1 \leq \bar{E}_1$ where $\bar{E}_1$, the maximum total energy assumed by m_1 corresponds to

$$W_1 = m_2 + m_3 + \ldots m_n \qquad (6)$$

thus

$$\bar{E}_1 = \frac{W_o^{\,2} + m_1^{\,2} - (m_2 + m_3 + \ldots m_n)^2}{2W_0} \qquad (7)$$

These relations successively applied give finally

$$F_2(W_{n-2}) = \iint \frac{m_{n-1}\, d^3\vec{p}_{n-1}}{E_{n-1}}\ \frac{m_n\, d^3\vec{p}_n}{E_n}\ \delta(\vec{p}_{n-1} + \vec{p}_n)\ \delta(W_{n-2} - (E_{n-1} + E_n)\ ) \qquad (8)$$

We assume the last two particles identical

$m_{n-1} = m_n = m.$

then

$$F_2(W_{n-2}) = 2\pi \left[1 - \frac{4m^2}{W_{n-2}^{\,2}}\right]^{\frac{1}{2}} \qquad (9)$$

where $W_{n-2}^{\,2}$ is given by an expression analogous to (4)

i. e.

$$W_{n-2}^{2} = (W_{n-3} - E_{n-2})^2 - p_{n-2}^{2} = W_{n-3}^{2} + m_{n-2}^{2} - 2\, W_{n-3}\, E_{n-2} \tag{10}$$

By means of the recurrence relations, the covariant phase space integral becomes the (n-2)-tuple integral

$$F_n(W_0) = \prod_1^{n-2} (4\pi m_i) \int_{m_1}^{\bar{E}_1} \sqrt{E_1^{2} - m_1^{2}}\; dE_1 \int_{m_2}^{\bar{E}_2} \sqrt{E_2^{2} - m_2^{2}}\; dE_2 \cdots$$

$$\int_{m_{n-2}}^{\bar{E}_{n-2}} \sqrt{E_{n-2}^{2} - m_{n-2}^{2}}\; F_2\,(W_{n-2})\; dE_{n-2} \tag{11}$$

where the upper limits, given by expressions similar to (7), depend on the values assumed by the E's figuring in the precedent integrals.

The computation of the phase space factor, within a trivial numerical factor is achieved in two steps:

First, the HONE program compute

$$N_n(p_1) = \frac{p_1^{2}}{\sqrt{p_1^{2} + m_1^{2}}} \int_{m_2}^{\bar{E}_2} \sqrt{E_2^{2} - m_2^{2}}\; dE_2 \cdots\cdots \int_{m_{n-2}}^{\bar{E}_{n-2}} \sqrt{E_{n-2}^{2} - m_{n-2}^{2}}$$

$$f_2(W_{n-2})\; dE_{n-2} \tag{12}$$

for $0 \leq p \leq \bar{p}_1 = \sqrt{\bar{E}_1^{\,2} - m_1^{\,2}}$ with $f_2 = \frac{1}{2\pi} F_2$.

Second, an auxiliary program, FONE performs the integration

$$f_n(W_0) = \int_0^{\bar{p}_1} N_n(p_1)\, dp_1 \tag{13}$$

therefore

$$F_n(W_0) = \frac{1}{2}\,(4\pi)^{n-1}\,(m_1\, m_2\, m_3 \ldots m_n)\, f_n\,(W_0) \tag{14}$$

(2) Angular Correlation

In the absence of final state interactions among the secondary particles, the distribution of angle, θ, between a pair of particles, say m_1 and m_2 is subject only to the constraint imposed by the overall conservation of energy-momentum. The phase integral (2) for a given θ can be written as:

$$F_n(W_0, \theta) = \iint_D \frac{m_1\, d^3\vec{p}_1}{E_1} \cdot \frac{m_2\, d^3\vec{p}_2}{E_2}\, F_{n-2}\,(W^1) \tag{15}$$

Taking the z - axis along $\vec{p}_1$ we have

$$d^3\vec{p}_1 \cdot d^3\vec{p}_2 = 2\pi \sin\theta\, d\theta\, p_1^{\,2}\, dp_1\, d\Omega_1\, p_2^{\,2}\, dp_2\, d\Omega_2$$

The total energy left for the $n-2$ last particles is then

$$(W^1)^2 = (W_0 + E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2$$

$$= W_0^2 + m_1^2 + m_2^2 - 2W_0 (E_1 + E_2) + 2 (E_1 E_2 - \sqrt{E_1^2 - m_1^2} \sqrt{E_2^2 - m_2^2} \cos \theta) \tag{16}$$

Therefore

$$F(W_0, \theta) = (4\pi)^2 m_1 m_2 \int 2\pi d \cos \theta \iint_D \sqrt{E_1^2 - m_1^2} \sqrt{E_2^2 - m_2^2}$$

$$F_{n-2} (W^1) dE_1 dE_2 \tag{17}$$

The domain, D, is determined by

$$\begin{cases} m_1 \leq E_1 \leq \bar{E}_1 = \dfrac{W_0^2 + m_2^2 - (m_2 + m_3 \ldots\ldots m_n)^2}{2W_0} & (18) \\ m_2 \leq E_2 \leq \bar{E}_2 = \dfrac{W_o^2 + m_2^2 - (m_1 + m_3 + \ldots\ldots m_n)^2}{2W_0} & (19) \\ W^1 \geq (m_3 + m_4 \ldots\ldots m_n) & (20) \end{cases}$$

Ignoring the numerical factors, we obtain for the distribution in $x = \cos \theta$

$$\phi_{12} (W_0, x) = \iint_D \sqrt{E_1^2 - m_1^2} \sqrt{E_2^2 - m_2^2} \quad f_{n-2} (W^1) dE_1 dE_2 \tag{21}$$

where $f_{n-2} = \frac{1}{2\pi} F_{n-2}$ (22)

The HOKO programs perform the integrations to evaluate equation (21). Explicit formulations for the 4, 5, and 6 particle reactions together with decriptions of the corresponding programs is given in what follows.

Operating instructions for all HONE and HOKO programs are given in Appendix 1.

III SPECIFIC FORMULATION AND DESCRIPTION OF PROGRAMS

A) Four Particle Reaction $n = 4$

$$A + B \longrightarrow m_1 + m_2 + m_3 + m_4$$

1) HONE4 Momentum Spectrum $m_3 = m_4 = m$

$$N_4(p_1) = \frac{p_1^2}{\sqrt{p_1^2 + m_1^2}} \int_{m_2}^{\bar{E}_2} \sqrt{E_2^2 - m_2^2}\; dE_2\, f_2\,(W_2)$$

$$W_1^2 = W_0^2 + m_1^2 - 2W_0\, E_1 \qquad\qquad p_1 = \sqrt{E_1^2 - m_1^2}$$

$$W_2^2 = W_1^2 + m_2^2 - 2W_1E_2$$

$$\bar{E}_1 = \frac{W_0^2 + m_1^2 - (m_2 + 2m)^2}{2W_0} \qquad\qquad \bar{p}_1 = \sqrt{\bar{E}_1 - m_1^2}$$

$$\bar{E}_2 = \frac{W_1^2 + m_2^2 - (2m)^2}{2W_1} \qquad\qquad \Delta E_2 = \frac{\bar{E}_2 - m_2}{S}$$

$$f_2(W_2) = \left[1 - \frac{4m^2}{W_2^2}\right]^{\frac{1}{2}}$$

HONE 4 computes $N_4(p_1)$ for $0 \leq p_1 \leq \bar{p}_1$ in steps of Δp_1 from total energy, W_0, and particle masses, m_1, m_2, m using S integration steps. This information together with some identifying number, I is read in after loading program

Imput Data Card (1)

1st word W_0 machine language floating point

2nd word m_1 -do-

3rd word m_2 -do-

4th word 2m -do-

5th word =0= =0=

6th word S machine language floating point $(10 \leq S \leq 50)$

7th word I any number desired by user

8th word Δp_1 machine language floating point

For each such input card, the program punches a set of answer cards, one card for each p_1; $p_1 = 0, \Delta p_1, 2\Delta p_1 \ldots, \bar{p}_1$ in the following form:

Output Answer Card

1st word	W_0
2nd word	I
3rd word	=0=
4th word	p_1
5th word	E_1
6th word	$N_4(p_1)$
7th word	=0=
8th word	$\bar{p}_1$

2) <u>HOKO 4</u> <u>Angular Correlation</u>

In this program, the restriction $m_3 = m_4$ has been replaced by $m_3 \geq m_4$.

$$\phi_{12}(W_0, x) = \int_{m_1}^{\bar{E}_1} \int_{m_2}^{\bar{E}_2} \sqrt{E_1^2 - m_1^2} \sqrt{E_2^2 - m_2^2} \quad f_2(W') \, dE_2 \, dE_1$$

$$\bar{E}_1 = \frac{W_0^2 + m_1^2 - (m_2 + m_3 + m_4)^2}{2W_0} \qquad \Delta E_1 = \frac{\bar{E}_1 - m_1}{S}$$

$$\bar{E}_2 = \frac{W_0^2 + m_2^2 - (m_1 + m_3 + m_4)^2}{2W_0} \qquad \Delta E_2 = \frac{\bar{E}_2 - m_2}{S}$$

$$(W')^2 = W_0^2 + m_1^2 + m_2^2 - 2W_0 (E_1 + E_2) + 2(E_1 E_2 - \sqrt{E_1^2 - m_1^2} \sqrt{E_2^2 - m_2^2} \, x)$$

$$(W')^2 \geq (m_3 + m_4)^2$$

$$f_2(W') = \frac{\sqrt{\left[(W')^2 - (m_3 + m_4)^2\right] \left[(W')^2 - (m_3 - m_4)^2\right]}}{(W')^2 + (m_3^2 - m_4^2)}$$

For each reaction, one input data card is used, which specifies the total energy, masses of secondary particles, number of integration steps, S, identifying number, I, and the steps Δx, of $x = \cos\theta$, for which $\phi(W_0, x)$ is desired.

Input Data Card

1st word W_0

2nd word m_1

3rd word m

4th word	$m_3 + m_4$
5th word	$m_3 - m_4$
6th word	S
7th word	I
8th word	Δx

For each such input the program punches a set of answer cards, one card for each x, in steps of Δx, for $-1 \leq x \leq +1$.

Output Answer Cards

1st word	W_0
2nd word	I
3rd word	x
4th word	=0=
5th word	$\phi(W_0, x)$
6th word	=0=
7th word	=0=
8th word	S

B) Five Particle Reaction $n = 5$

$$A + B \longrightarrow m_1 + m_2 + m_3 + m_4 + m_5$$

$$m_4 = m_5 = m.$$

1) HONE 5 Momentum Spectrum

$$N_5(p_1) = \frac{p_1^{\,2}}{\sqrt{p_1^{\,2} + m_1^{\,2}}} \int_{m_2}^{\bar{E}_2} \sqrt{\bar{E}_2^{\,2} - m_2^{\,2}}\, dE_2 \int_{m_3}^{\bar{E}_3} \sqrt{E_3^{\,2} - m_3^{\,2}}\; f_2(W_3)\, dE_3$$

$$W_1^{\,2} = W_0^{\,2} + m_1 - 2W_0 E_1 \qquad\qquad p_1 = \sqrt{E_1^{\,2} - m_1^{\,2}}$$

$$W_2^{\,2} = W_1^{\,2} + m_2^{\,2} - 2W_1 E_2$$

$$W_3^{\,2} = W_2^{\,2} + m_3^{\,2} - 2W_2 E_3 \qquad\qquad W_3 \geqslant 2m$$

$$\bar{E}_1 = \frac{W_0^{\,2} + m_1^{\,2} - (m_2 + m_3 + 2m)^2}{2W_0} \qquad\qquad \bar{p}_1 = \sqrt{\bar{E}_1^{\,2} - m_1^{\,2}}$$

$$\bar{E}_2 = \frac{W_1^{\,2} + m_2^{\,2} - (m_3 + 2m)^2}{2W_1} \qquad\qquad \Delta E_2 = \frac{\bar{E}_2 - m_2}{S}$$

$$\bar{E}_3 = \frac{W_2^{\,2} + m_3^{\,2} - (2m)^2}{2W_2} \qquad\qquad \Delta E_3 = \frac{\bar{E}_3 - m_3}{S}$$

$$f_2(W_3) = \left[1 - \frac{4m^2}{W_3^{\,2}}\right]^{\frac{1}{2}}$$

HONE 5 computes $N_5(p_1)$ from the following

Input Data Card (1)

1st word	W_0	machine language floating point
2nd word	m_1	machine language floating point
3rd word	m_2	machine language floating point
4th word	m_3	machine language floating point

5th word	$2m$	machine language floating point	
6th word	S	machine language floating point	$10 \leq S \leq 50$
7th word	I	any identifying number	
8th word	Δp_1	machine language floating point	

Output Answer Cards

1st word	W_0
2nd word	I
3rd word	=0=
4th word	p_1
5th word	E_1
6th word	$N_5(p_1)$
7th word	=0=
8th word	$\bar{p}_1$

2) HOKO 5 Angular Correlation

$$\phi_{12}(W_0,x) = \int_{m_1}^{\bar{E}_1} \int_{m_2}^{\bar{E}_2} \sqrt{E_1^2 - m_1^2} \sqrt{E_2^2 - m_2^2} \, dE_1 \, dE_2 \int_{m_3}^{\bar{E}_3} \sqrt{E_3^2 - m_3^2} \, f_2(W'') \, dE_3$$

$$\bar{E}_1 = \frac{W_0^2 + m_1^2 - (m_2 + m_3 + 2m)^2}{2W_0}$$

$$\bar{E}_2 = \frac{W_0^2 + m_2^2 - (m_1 + m_3 + 2m)^2}{2W_0}$$

$$\bar{E}_3 = \frac{(W')^2 + m_3^2 - (2m)^2}{2W^1}$$

$$(W')^2 = W_0^2 + m_1^2 + m_2^2 - 2W_0 (E_1 + E_2) + 2 (E_1E_2 - \sqrt{E_1^2 - m_1^2}\sqrt{E_2^2 - m_2^2} \; x)$$

$$(W')^2 \geq (m_3 + 2m)^2$$

$$(W'')^2 \quad (W')^2 + m_3^2 - 2 \, W' E_3 \qquad\qquad W'' \geq 2m$$

$$f_2(W'') = \left[1 - \frac{4m^2}{(W'')^2} \right]^{\frac{1}{2}}$$

For each reaction, one input data card is used

Input Data Card

1st word	W_0
2nd word	m_1
3rd word	m_2
4th word	m_3
5th word	2m
6th word	S
7th word	I
8th word	Δx

For each such input the program punches a set of answer cards, one card for each x, $x = -1, \ -1 + \Delta x, \ldots +1$

Output Answer Cards

1st word	W_0
2nd word	I
3rd word	x
4th word	=0=
5th word	$\emptyset(W_0, x)$
6th word	=0=
7th word	=0=
8th word	S

C. Six Particle Reaction $n = 6$

$$A + B \longrightarrow m_1 + m_2 + m_3 + m_4 + m_5 + m_6$$

$$m_5 = m_6 = m$$

1) HONE 6 Momentum Spectrum

$$N_6\,(p_1) = \frac{p_1^{\,2}}{\sqrt{p_1^{\,2} + m_1^{\,2}}} \int_{m_2}^{\bar{E}_2} \sqrt{E_2^{\,2} - m_2^{\,2}}\; dE_2 \int_{m_3}^{\bar{E}_3} \sqrt{E_3^{\,2} - m_3^{\,2}}\; dE_3 \int_{m_4}^{\bar{E}_4} \sqrt{E_4^{\,2} - m_4^{\,2}}$$

$$f_2(W_4)\; dE_4$$

$$W_1{}^2 = W_0{}^2 + m_1{}^2 - 2W_0E_1 \qquad p_1 = \sqrt{E_1{}^2 - m_1{}^2}$$

$$W_2{}^2 = W_1{}^2 + m_2{}^2 - 2W_1 E_2$$

$$W_3{}^2 = W_2{}^2 + m_3{}^2 - 2W_2 E_3$$

$$W_4{}^2 = W_3{}^2 + m_4{}^2 - 2W_3 E_4 \qquad W_4 \geq 2m$$

$$\bar{E}_1 = \frac{W_0{}^2 + m_1{}^2 - (m_2 + m_3 + m_4 + 2m)^2}{2W_0} \qquad \bar{p}_1 = \sqrt{\bar{E}_1{}^2 - m_1{}^2}$$

$$\bar{E}_2 = \frac{W_1{}^2 + m_2{}^2 - (m_3 + m_4 + 2m)^2}{2W_1} \qquad \Delta E_2 = \frac{\bar{E}_2 - m_2}{S}$$

$$\bar{E}_3 = \frac{W_2{}^2 + m_3{}^2 - (m_4 + 2m)^2}{2W_2} \qquad \Delta E_3 = \frac{\bar{E}_3 - m_3}{S}$$

$$\bar{E}_4 = \frac{W_3{}^2 + m_4{}^2 - (2m)^2}{2W_3} \qquad \Delta E_4 = \frac{\bar{E}_4 - m_4}{S}$$

$$f_2(W_4) = \left[1 - \frac{4m^2}{W_4{}^2}\right]^{\frac{1}{2}}$$

In order to load the required information, <u>two</u> data cards are necessary for each reaction.

<u>First</u> Input Data Card

1st word S

2nd word I

3rd word Δp_1

4th to 8th words =0=

Second Input Data Card

1st word	W_0
2nd word	m_1
3rd word	m_2
4th word	m_3
5th word	m_4
6th word	2m
7,8th words	=0=

Output Answer Cards

1st word	W_0
2nd word	I
3rd word	=0=
4th word	p_1
5th word	E_1
6th word	$N_6(p_1)$
7th word	=0=
8th word	$\bar{p}_1$

2) HOKO 6 Angular Correlation

$$\phi_{12}(W_0, x) = \int_{m_1}^{\bar{E}_1} \int_{m_2}^{\bar{E}_2} \sqrt{E_1^2 - m_1^2} \sqrt{E_2^2 - m_2^2} \; dE_1 \, dE_2 \int_{m_3}^{\bar{E}_3} \sqrt{E_3^2 - m_3^2} \; dE_3 \int_{m_4}^{\bar{E}_4} \sqrt{E_4^2 - m_4^2}$$

$$f_2(W''') \, dE_4$$

$$\bar{E}_1 = \frac{W_0^2 + m_1^2 - (m_2 + m_3 + m_4 + 2m)^2}{2W_0} \qquad \Delta E_1 = \frac{\bar{E}_1 - m_1}{S}$$

$$\bar{E}_2 = \frac{W_0^2 + m_2^2 - (m_1 + m_3 + m_4 + 2m)^2}{2W_0} \qquad \Delta E_2 = \frac{\bar{E}_2 - m_2}{S}$$

$$\bar{E}_3 = \frac{(W')^2 + m_3^2 - (m4 + 2m)^2}{2W'} \qquad \Delta E_3 = \frac{\bar{E}_3 - m_3}{S}$$

$$\bar{E}_4 = \frac{(W'')^2 + m4^2 - (2m)^2}{2W''} \qquad \Delta E_4 = \frac{\bar{E}_4 - m_4}{S}$$

$$(W')^2 = W_0^2 + m_1^2 + m_2^2 - 2W_0 (E_1 + E_2) + 2(E_1 E_2 - \sqrt{E_1^2 - m_1^2} \sqrt{E_2^2 - m_2^2} \; x)$$

$$(W'')^2 = (W')^2 + m_3 - 2W' E_3$$

$$(W''')^2 = (W'')^2 + m_4 - 2W'' E_4 \qquad W''' \geq 2m$$

$$f_2(W''') = \left[1 - \frac{4m^2}{(W''')^2} \right]^{\frac{1}{2}}$$

Two data cards are required for each reaction

First Input Data Card

1st word	S
2nd word	I
3rd word	Δx
4th word to 8th words	=0=

Second Input Data Card

1st word	W_0
2nd word	m_1
3rd word	m_2
4th word	m_3
5th word	m_4
6th word	2m
7, 8th words	=0=

For each such pair of input data cards, the program punches a set of answer cards, one card for each x, $x = -1, \ -1 + \Delta x, \ldots\ldots, + 1$

Output Answer Cards

1st Word	W_0
2nd word	I
3rd word	x
4th word	=0=
5th word	ϕ (W_0,x

6th word $=0=$

7th word $=0=$

8th word S

D. Auxiliary Program FONE

A set of output answer cards from any HONE program constitute an input data deck for FONE. Such sets may be loaded successively. Caution - no blank cards. For each such set the program FONE punches one output card as follows:

1st word W_0

2nd word I

3rd word $=0=$

4th word Δp_1

5th word $=0=$

6th word $\int_0^{\bar{p}} N(p_1)\, dp_1$

7th word and 8th word $=0=$

Formula

$$f_n (W_0, p_1) = \int_0^{\bar{p}_1} N(p_1)\, dp_1$$

APPENDIX I

Operating Instructions for HOME and HOKO Programs

Standard drum clear and load punch routines are in the program decks. Place program deck followed by data cards in the read hopper. Several data cards may be processed successively. Have blank cards in punch input hopper.

A)	Console	70	1951	1951
	Address Selection	1000		
	Programmed	stop		
	Half Cycle	Run		
	Control	Run		
	Display	Program Register		
	Overflow	Stop		
	Error	Stop		

Press computer reset

Press program start

Press reader start

Press punch start

On end-of-file, press end-of-file

If the machine stops before processing all the data cards, the data for the reaction in which the stop occurred is invalid. Remaining data if valid may be processed by setting

B) Control Manual

Press computer reset

Press transfer

Control Run

Press start

The time required for these programs depends on S, and Δp_1 or Δx.

With S = 10, or 12, and $\Delta x = 0.2$ or with Δp_1 reasonably chosen time for each reaction under

HONE 4	less than 5 minutes
HONE 5	less than 25 minutes
HONE 6	less than 2 hours
HOKO 4	less than 25 minutes
HOKO 5	less than 2 hours
HOKO 6	less than 9 hours

If it is necessary to interupt the program while processing the data for a particular reaction, this processing may be resumed at that point if the following procedure is followed.

Set

C) Address selection 1800

Control Address stop

When machine stops, remove and save answer cards already obtained

Set Address	1961
Set Console	07 0001 0508
Set Control	Manual

Press computer reset

Press transfer

Set Control Run

Press Start

Press Punch Start

Remove cards from punch output deck. This memory dump contains all the necessary data for resuming the problem later. Remove the blank cards and the card which gives the contents of the index register. The remainder is saved as a supplementary deck.

To resume the problem, take the original program deck being used at time of interruption, remove the transfer card (last non-data card) replace it by the supplementary deck and a transfer card to 1800 and follow procedure A) above.

For successive processing of other data cards not already started, load these data cards immediately after the above supplemented program deck.

Operating Instructions for FONE Program

Standard drum clear and load punch routine are in the program deck. Place program followed by a set (or sets) of output cards from HONE. Several sets may be processed successively. Each set must be in the order punched, i. e. in ascending order of p., first card with $p_1 = 0$, last card with $p_1 = \bar{p}_1$ and there must be no blank cards. Have blank cards in punch unit input hopper.