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A MONTE CARLO STUDY OF THE OBELIX TOF TRIGGER

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CONTENTS

1. Introduction

The Monte Carlo simulation of the Obelix TOF system has been performed considering for the apparatus :

° the exact geometry of all the components;
° the physical structure of each component (medium,density, etc.)
° the exact map of the magnetic field

The reaction process considered is the p-pbar annihilation

° at rest, in the centre of the target;
° in flight, uniformly distributed along the target

The annihilation products, only pions and kaons, can be generated according to:

° the 'single track' mode, at a fixed energy, from the flat spectrum or from the inclusive spectrum experimentally observed at rest in the p-pbar annihilation ;
° the 'phase space' mode, calculating the π multiplicities using the branching ratios (b.r.) from the model of Orfanidis and Rittenberg [(1)], the k multiplicies from some semiempirical formulae[(2)], and generating the momentum distribution of the particles, at a given multiplicity , with standard (FLOW -like) phase space methods.
The spectra generated in this way agree very well with the experimental ones for π and resonably well for k .
This treatment is valid up to pbar momenta of 5 GeV/c.

The annihilation products generated in the previous step are traced in the apparatus taking into account the following effects:

° Coulomb Multiple Scattering;
° Mean Energy Loss ;
° Decay;
° Curvature by the magnetic field .
° Jitter of the TOF electronics.

The results are presented in form of tables and histograms, and are,for each particular trigger configuration:

° kinematics ;
° TOF spectra ;
° hits correlations .

2. Geometry

The geometry considered in the program is shown in figs. 1a and 1b.

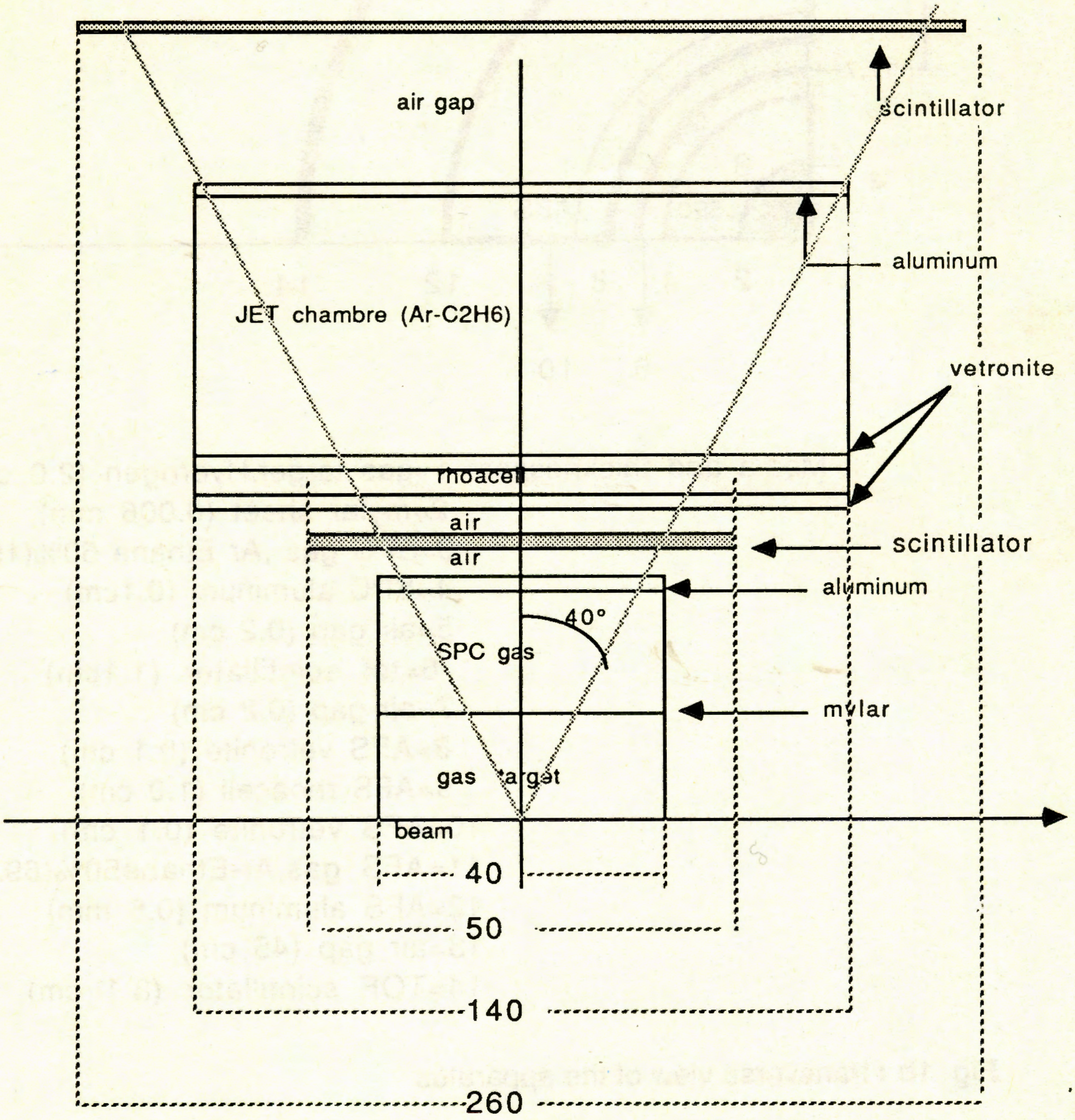
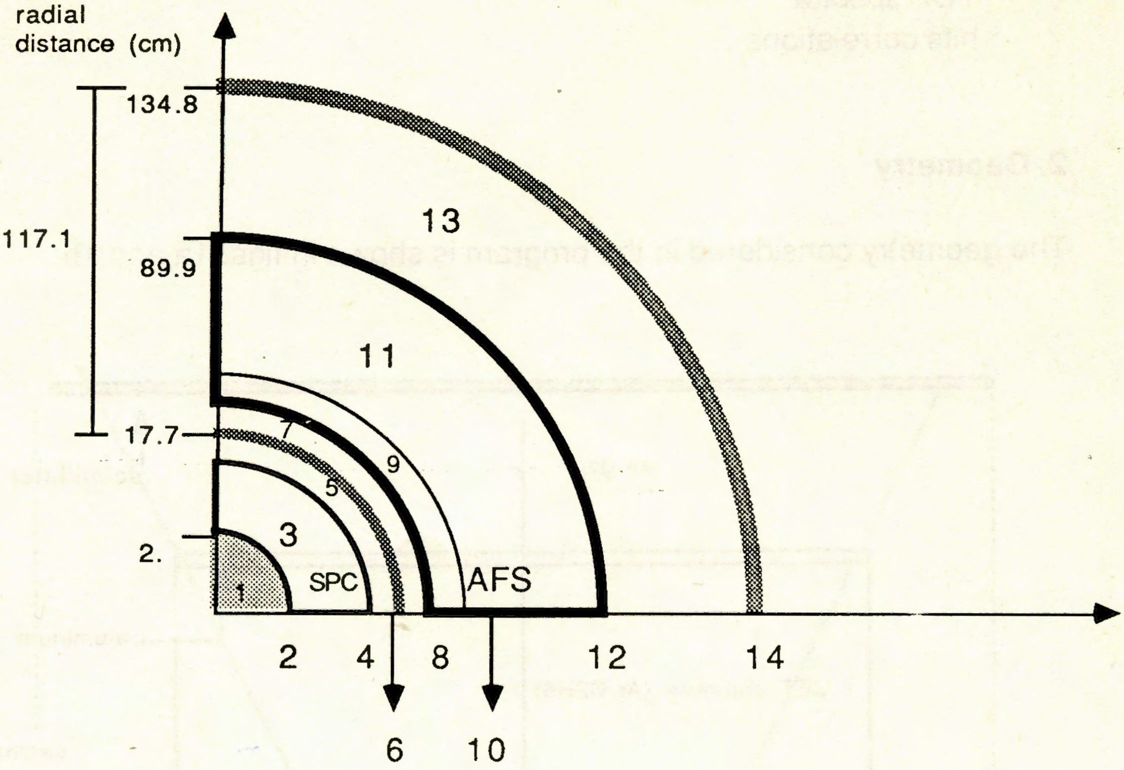


Fig.1a: longitudinal view of the apparatus; the measures are in cm.



Media and thicknesses: 1=gas target,Hydrogen (2.0 cm)
2=mylar sheet (0.006 mm)
3=SPC gas ,Ar Ethane 50%(15.5cm)
4=SPC aluminum (0.1cm)
5=air gap (0.2 cm)
6=tof scintillator (1.1cm)
7=air gap (0.2 cm)
8=AFS vetronite (0.1 cm)
9=AFS rhoacell (1.0 cm)
10=AFS vetronite (0.1 cm)
11=AFS gas,Ar-Ethane50%(69.5cm)
12=AFS aluminum (0.5 mm)
13=air gap (45 cm)
14=TOF scintillator (3.1 cm)

Fig. 1b : transverse view of the apparatus

On the basis of the above figures one can deduce the following general geometrical constraints for the TOF system:

° due to aluminum AFS exit surface (see fig. 1a) the acceptance angle of the TOF is 40°

° the distance travelled by a particle between the two scintillator barrels is :

minimum: 117 cm

Maximum: (117/cos(40°)) = 153 cm

° the effective longitudinal lenght of the outer TOF slabs is:

$\pm$ 117 tan(40°) = 98 cm

° the time jitter due to the geometry, for a relativistic particle (30 cm/ns), is:

$\pm$ (153 - 117)/30 $\approx$ $\pm$1.3 ns

° the solid angle fraction seen by the TOF is :

$[\, 4\pi - 4\pi(1-\cos(90°-40°))\,]/4\pi = \cos(50°) = 0.64$

3. Event generation and Kinematics

For the event generation two option are possible:

° the single track mode, which generates only one track (pion or kaon) per event. The momentun of these tracks is chosen at random from the flat spectrum or from the pion or kaon inclusive experimental spectrum taken from bubble chamber (BC) data.

° in the phase space mode, the procedure follows two steps:
- the annihilation channel is chosen at random using pion and kaon branching ratios deduced from some models (see below).
- Once the reaction type has been selected, the momentum of the outgoing mesons is generated according to the Lorentz Invariant Phase Space (LIPS) model.
  This step is performed by GEANT routines.

3.1 Pion branching ratios

The π multiplicities are calculated with the following formulae[1]:

$$\sigma_{n,l} = p_{n,l}\, P_n(s) \qquad (1)$$

$$p_{n,l} = \frac{2\,\alpha^{2l} \binom{n}{2l}}{(1+\alpha)^n + (1-\alpha)^n} \qquad (2)$$

$$P_n(s) = \frac{1}{\sqrt{(\pi M/2)}} \exp[-2(n-M)^2/M] \qquad (3)$$

Where σ is the π b.r. , n is the number of π, l is the number of negative π, s the total c.m. energy squared, α=1.5 and

$$M = 5.05\,(s/4m_p^2)^{1/3} \qquad (4)$$

where m_p is the proton mass.

This model is valid up to incident momenta of 5 GeV/c.
At rest we obtain the following values:

TABLE I

STATE	Experimental b.r.(BC) %		Model %	
$\pi^+\pi^-\pi^0$	6.9 ± 0.4		5.8	
$\pi^+\pi^-2\pi^0$	9.3 ± 3.0	35.4 ± 08	15.8	39.0
$\pi^+\pi^-3\pi^0$	23.3 ± 3.0		16.3	
$\pi^+\pi^-4\pi^0$	2.8 ± 0.7		6.9	
$2\pi^+2\pi^-$	6.9 ± 0.6		5.9	
$2\pi^+2\pi^-\pi^0$	19.6 ± 0.7		18.4	
$2\pi^+2\pi^-2\pi^0$	16.6 ± 1.0	20.8 ± 0.7	15.4	19.9
$2\pi^+2\pi^-3\pi^0$	4.2 ± 1.0		4.5	
$3\pi^+3\pi^-$	2.1 ± 0.2		2.3	
$3\pi^+3\pi^-\pi^0$	1.9 ± 0.2		2.0	

During the simulation the channels are chosen at random from these weights using a dicotomic search.

3.2 Kaon branching ratios

To calculate the kaon b.r. we use the empirical treatment of ref.(2), which gives reasonable results, considering also that these b.r. are not completely known and depends strongly on the atomic state of the target (liquid or gaseous).

The procedure is divided into the followings steps:

- the total probability of events containing kaons is calculated interpolating between experimental data:

$$P(k) = 0.067 + 0.0253\, P_{lab} \qquad (p_{lab} \text{ in GeV/c}) \qquad (5)$$

(at rest the experimental value is (0.0682 ± 0.0025), ref.(3).)

- the probability to have n pions associated to the $k\bar{k}$ kaon production is:

$$P(k\bar{k}\, n\pi) = \exp[-(n-x)^2/2s^2] \,/[\sqrt{(2\pi)}\, s] \qquad (6)$$

where $x = 2.21 + 0.00037\, p_{lab}$

$s = 0.77 + 0.00010\, p_{lab}$

The pion configuration is then calculated by charge conservation.

- the choice among the various kaon channels is made on the basis of fig 2, giving to each allowed kaon configuration at the same level equal probability [4].

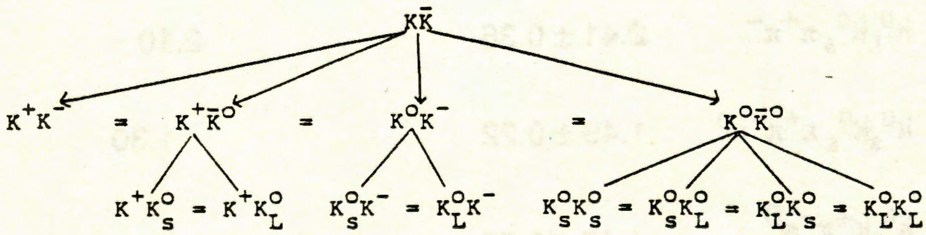


Fig.2: observable kaon channels from the associated $\bar{k}k$ production

As an example, we calculate with this method the weight of the channel $k^0_L k^- \pi^+ \pi^- \pi^+$ at rest.

° kaon production probability: 0.067 (from eq.5);

° probability to have 3 pions: 0.32 (from eq.6). Taking into account charge conservation,which allows also the configuration $\pi^+\pi^0\pi^0$, one obtains 0.32/2 = 0.16;

° probability of the configuration $k^0_L k^-$: 0.125 (from fig.2).

Hence, we have:

$$P(k^0_L k^- \pi^+ \pi^- \pi^+) = 0.067 \times 0.16 \times 0.125 = 1.34\ 10^{-3}$$

The comparison of this model with data is given in table II.

TABLE II

STATE	Exp (BC) $\times 10^{-3}$	Model $\times 10^{-3}$
k^+k^-	1.10 ± 0.10	0.30
$k^0_s k^0_L$ $k^0_s k^0_s$ $k^0_L k^0_L$	0.71 ± 0.10	0.30
$k^0_s k^0_s \pi^0$	0.73 ± 0.10	0.65
$k^0_s k^+ \pi^-$ $k^0_L k^+ \pi^-$ $k^0_s k^- \pi^+$ $k^0_L k^- \pi^+$	4.25 ± 0.55	2.60
$k^0_s k^0_s \pi^+ \pi^-$	2.01 ± 0.26	1.10
$k^0_L k^0_s \pi^+ \pi^-$	2.41 ± 0.36	2.10
$k^0_s k^0_s \pi^+ \pi^- \pi^0$	1.49 ± 0.22	1.30
$k^0_s k^+ \pi^- \pi^0$ $k^0_s k^- \pi^+ \pi^0$	4.47 ± 0.53	8.50

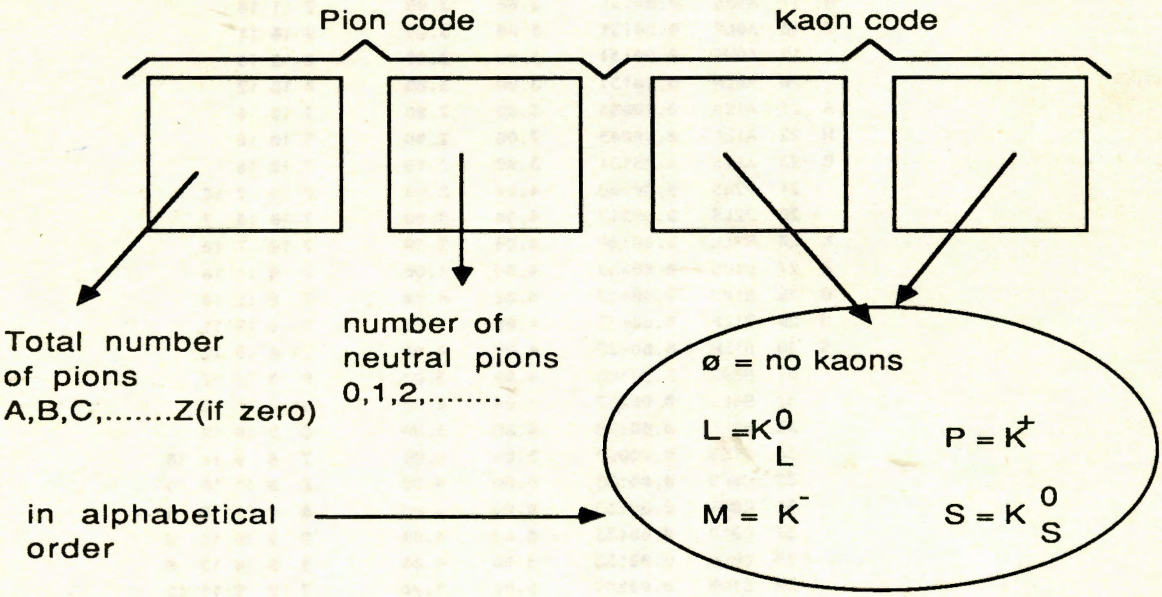
3.3 Generation and Kinematics

The program permits the selection of:
° one particular pion or kaon channel;
° all the pion channels;
° all the kaon channels;
° the complete kinematics, including the pion and kaon channels weighted as explained above.

The complete list of the reaction considered in the program is long; we report it in the TABLE III at the following page, where the internal matrix of the program is reproduced.

The explanation of the table is as follows:

° KEY = is the code of the reaction (see figure below):



For example, we have:

reaction $\pi^+\pi^-\pi^0\pi^0$ code = D 2 Ø Ø

reaction $\pi^+\pi^-k^+k^-$ code = B Ø M P , and so on.

° WEIGHT = is the b.r. calculated as explained above;

° NPART = the total number of particles of the reaction;

° HISTO = number of histograms (not important here);

° PARTICLE TYPES = they are reported in the last 7 columns of the table, with the code number following the GEANT convention.

TABLE III : reaction channels considered in the simulation.

		KEY	WEIGHT	NPART	HISTO	PARTICLE TYPES : PI0 = 7, PI+ = 8, PI- = 9, K0L = 10, K+ = 11, K- = 12, K0S = 16
	1	B000	0.00603	2.00	2.00	8 9
	2	C100	0.05721	3.00	3.00	7 8 9
P	3	D200	0.15474	4.00	3.00	7 8 9 7
I	4	E300	0.15979	5.00	3.00	7 8 9 7 7
O	5	F400	0.06710	6.00	3.00	7 8 9 7 7 7
N	6	G500	0.01192	7.00	3.00	7 8 9 7 7 7 7
S	7	D000	0.05803	4.00	2.00	8 9 8 9
	8	E100	0.17976	5.00	3.00	7 8 9 8 9
O	9	F200	0.15098	6.00	3.00	7 8 9 7 8 9
N	10	G300	0.04469	7.00	3.00	7 8 9 7 8 9 7
L	11	F000	0.02265	6.00	2.00	8 9 8 9 8 9
Y	12	G100	0.02011	7.00	3.00	7 8 9 8 9 8 9
	13	Z0MP	0.00029	2.00	2.00	11 12
P	14	Z0LS	0.00015	2.00	2.00	10 16
I	15	Z0SS	0.00007	2.00	1.00	16 16
O	16	Z0LL	0.00007	2.00	1.00	10 10
N	17	A0PS	0.00131	3.00	3.00	9 11 16
S	18	A0LP	0.00131	3.00	3.00	9 10 11
	19	A0MS	0.00131	3.00	3.00	8 12 16
	20	A0LM	0.00131	3.00	3.00	8 10 12
A	21	A1SS	0.00065	3.00	2.00	7 16 16
N	22	A1LL	0.00065	3.00	2.00	7 10 10
D	23	A1LS	0.00131	3.00	3.00	7 10 16
	24	B2SS	0.00108	4.00	2.00	7 16 7 16
	25	B2LS	0.00217	4.00	3.00	7 10 16 7
K	26	B2LL	0.00108	4.00	2.00	7 10 7 10
A	27	B1PS	0.00433	4.00	4.00	7 9 11 16
O	28	B1MS	0.00433	4.00	4.00	7 8 12 16
N	29	B1LP	0.00433	4.00	4.00	7 9 10 11
S	30	B1LM	0.00433	4.00	4.00	7 8 10 12
	31	B0SS	0.00108	4.00	3.00	8 9 16 16
	32	B0LS	0.00217	4.00	4.00	8 9 10 16
	33	B0LL	0.00108	4.00	3.00	8 9 10 10
	34	C1SS	0.00066	5.00	4.00	7 8 9 16 16
	35	C0PS	0.00133	5.00	4.00	8 9 11 16 9
	36	C0MS	0.00133	5.00	4.00	8 9 12 16 8
	37	C0LP	0.00133	5.00	4.00	8 9 10 11 9
	38	C0LM	0.00133	5.00	4.00	8 9 10 12 8
	39	C1MP	0.00266	5.00	5.00	7 8 9 11 12
	40	B0MP	0.00433	4.00	4.00	8 9 11 12
	41	A1MP	0.00262	3.00	3.00	11 12 7
	42	B2MP	0.00433	4.00	3.00	11 12 7 7
	43	C3MP	0.00266	5.00	3.00	11 12 7 7 7
	44	C3SS	0.00066	5.00	2.00	16 7 16 7 7
	45	C3LS	0.00133	5.00	3.00	16 10 7 7 7
	46	C1LS	0.00133	5.00	5.00	16 10 7 8 9
	47	C3LL	0.00066	5.00	2.00	10 7 10 7 7
	48	C1LL	0.00066	5.00	4.00	10 7 8 9 10
	49	C2PS	0.00133	5.00	4.00	11 16 7 9 7
	50	C2LP	0.00133	5.00	4.00	11 10 7 9 7
	51	C2MS	0.00133	5.00	4.00	12 16 8 7 7
	52	C2LM	0.00133	5.00	4.00	12 10 8 7 7

For example, the reaction E3ØØ (5 pions, 3 neutrals,no kaons), has a weight of 0.15979 , the reaction A1MP (one neutral pion, a kaon plus and a kaon minus), has a weight of 0.00262, etc..

The first 12 rows of the table refer to pure pion channels, the other ones to channels with kaons. At rest the 6.7% of the reactions contain kaons, the 5% charged kaons, in very good agreement with BC data(3).

The channel containing only π^0 has not been considered, because the pion decay in this case should not give any trigger in the TOF system.

The annihilation channels are chosen at random with a dicotomic search (following the weights of the table), then the type of the reaction selected is sent to the GEANT LIPS routines, which calculate the 4-momentum distribution of all the outgoing particles.

At this point the program starts with the tracking of all these particles.

4. Tracking

The reaction product are tracked in the Obelix apparatus (by GEANT) controlling continuosly the width of the tracking step in order to mantain a good accuracy. At every step the following quantities are computed:

° deflection angle due to multiple Coulomb scattering using the standard gaussian approximation .
This step is performed by GEANT routines (debugged)

° mean energy loss computed by the Bethe formula, with correction terms at low energy to take into account effective charge effects(6).
This is a user routine.

° decay (by GEANT routines);

° deflection by the magnetic field (by GEANT routines);

° jitter of the TOF electronics, by user routines.

In what follows we describe the calculations of mean energy loss and jitter, that are performed by user routines with specific methods, and are open to changes.

4.1 Mean energy loss calculation

The formulae used are taken from ref.(5) and are remarkably accurate also at low energy, as it is shown in figs.3a and 3b.

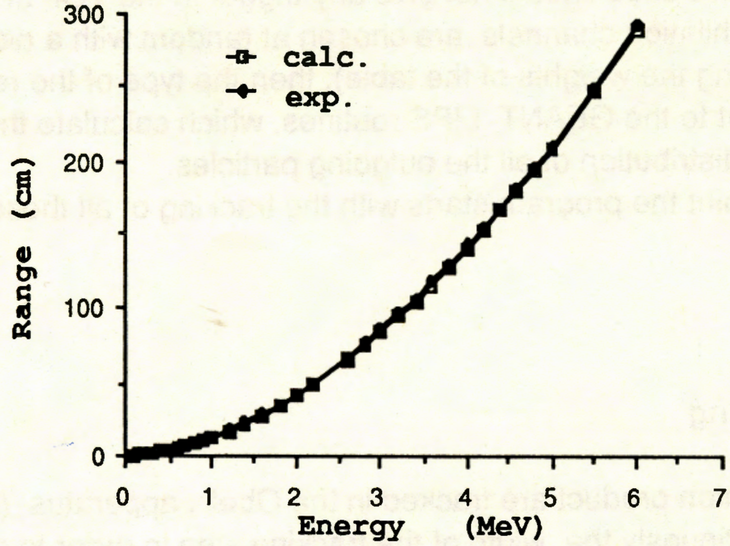


Fig.3a:calculated and experimentalranges versus energy for protons.

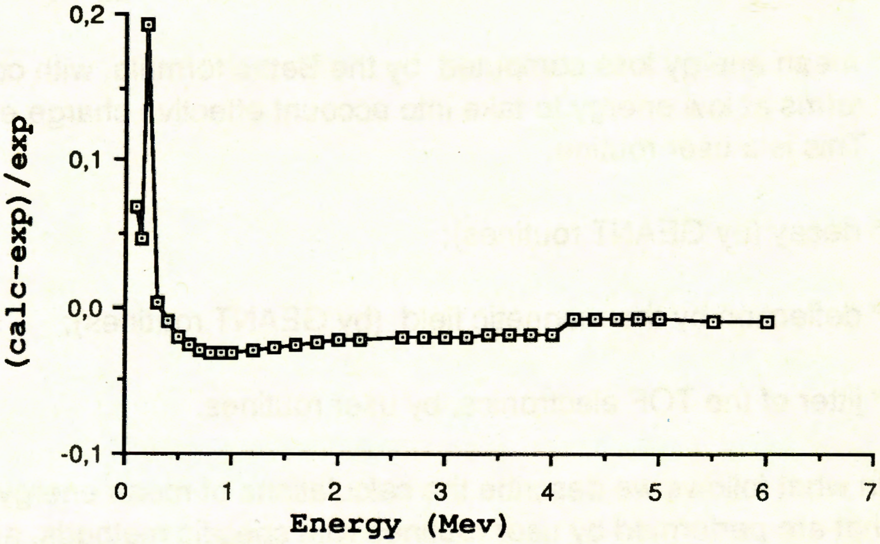


Fig.3b: relative difference between calculated and experimental[6] ranges for protons.

4.2 Electronic jitters

The following scheme represents a possible method for setting a TOF threshold (retarded coincidence) for the trigger.

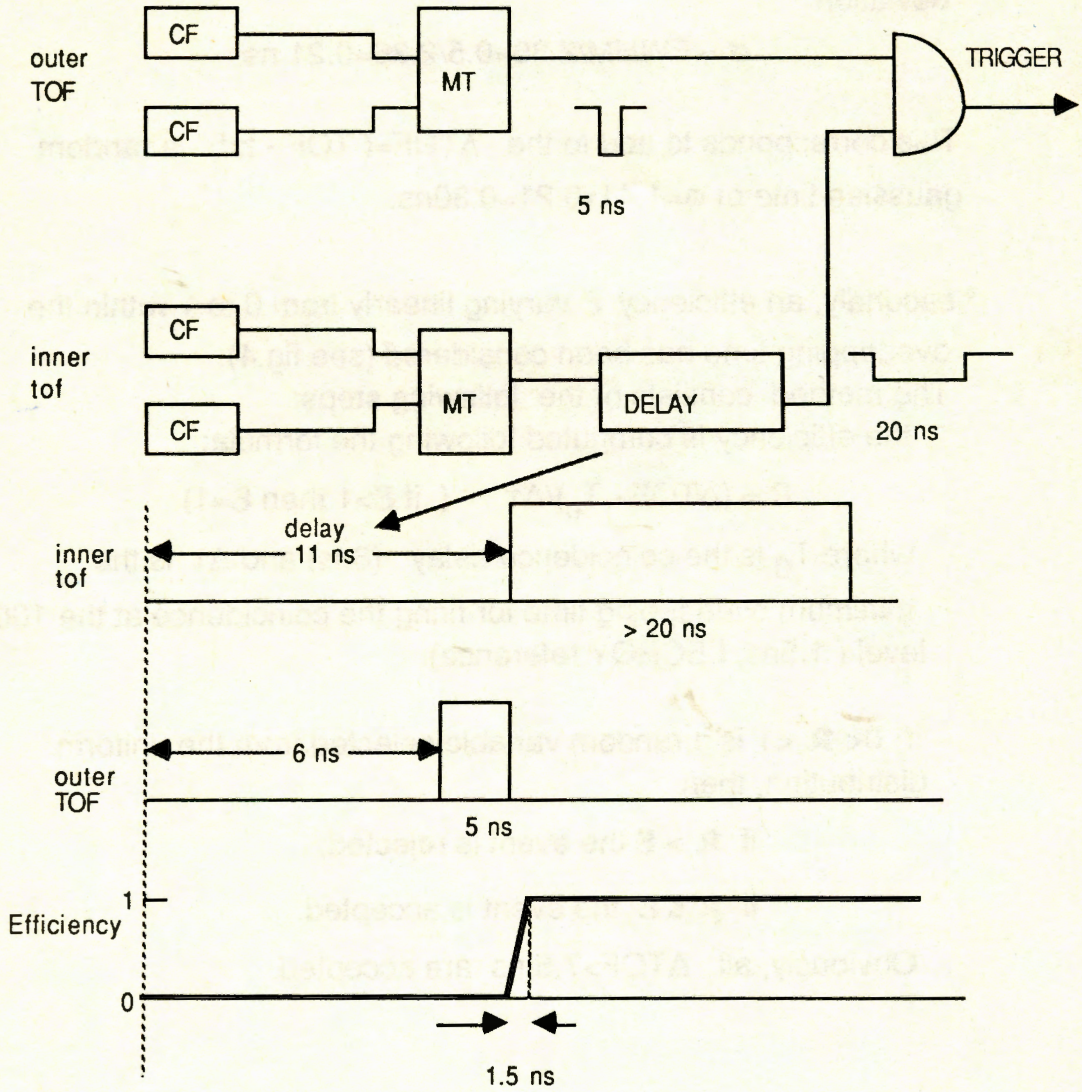


Fig 4 : retarded coincidence for setting a **6 ns** threshold in TOF. The minimum overlapping time for firing the (Lecroy) coincidence is about 1.5 ns,so that for 6<TOF<7.5 ns there is a loss of efficiency.CF= constant fraction disc.,MT= mean timer.

This scheme has been inserted in the simulation as follows:

° firstly, a jitter of FWHM=0.5 ns has been assigned to each MT. Hence, to the simulated inner tof (tof) and outer tof (TOF) two random gaussian times g_1 and g_2 are added:

$$tof \rightarrow tof+g_1$$

$$Tof \rightarrow Tof+g_2$$

where g_1 and g_2 are selected at random from a gaussian of standard deviation

$$\sigma = FWHM/2.36=0.5/2.36=0.21 \text{ ns}$$

This corresponds to add to the $\Delta TOF=(TOF - tof)$ a random gaussian time of $\sigma=1.41\times0.21=0.30$ns.

° secondly, an efficiency ε varying linearly from 0 to 1 within the overlapping time has been considered (see fig.4).
The method consists of the following steps:

- the efficiency is computed following the formula:

$$\varepsilon = (\Delta TOF - T_0)/\Delta\tau \qquad (\text{ if } \varepsilon>1 \text{ then } \varepsilon=1)$$

where T_0 is the coincidence delay (6ns) and $\Delta\tau$ is the minimum overlapping time for firing the coincidence at the 100% level (1.5ns, LECROY reference).

- if $0< \mathcal{R} <1$ is a random variable selected from the uniform distribution, then

if $\mathcal{R} > \varepsilon$ the event is rejected;

if $\mathcal{R} \leq \varepsilon$ the event is accepted.

Obviously, all $\Delta TOF>7.5$ ns are accepted.

5.Trigger Simulation

The first particle that hits the internal (external) barrel fires the electronics of the inner (outer) TOF.

In fig.5 some examples of all the possible trigger configurations are shown.

The situation is rather complicated, but we can simplify greatly our analysis considerig the *type of reaction selected by a given trigger, irrespective of the particular trigger configuration.*

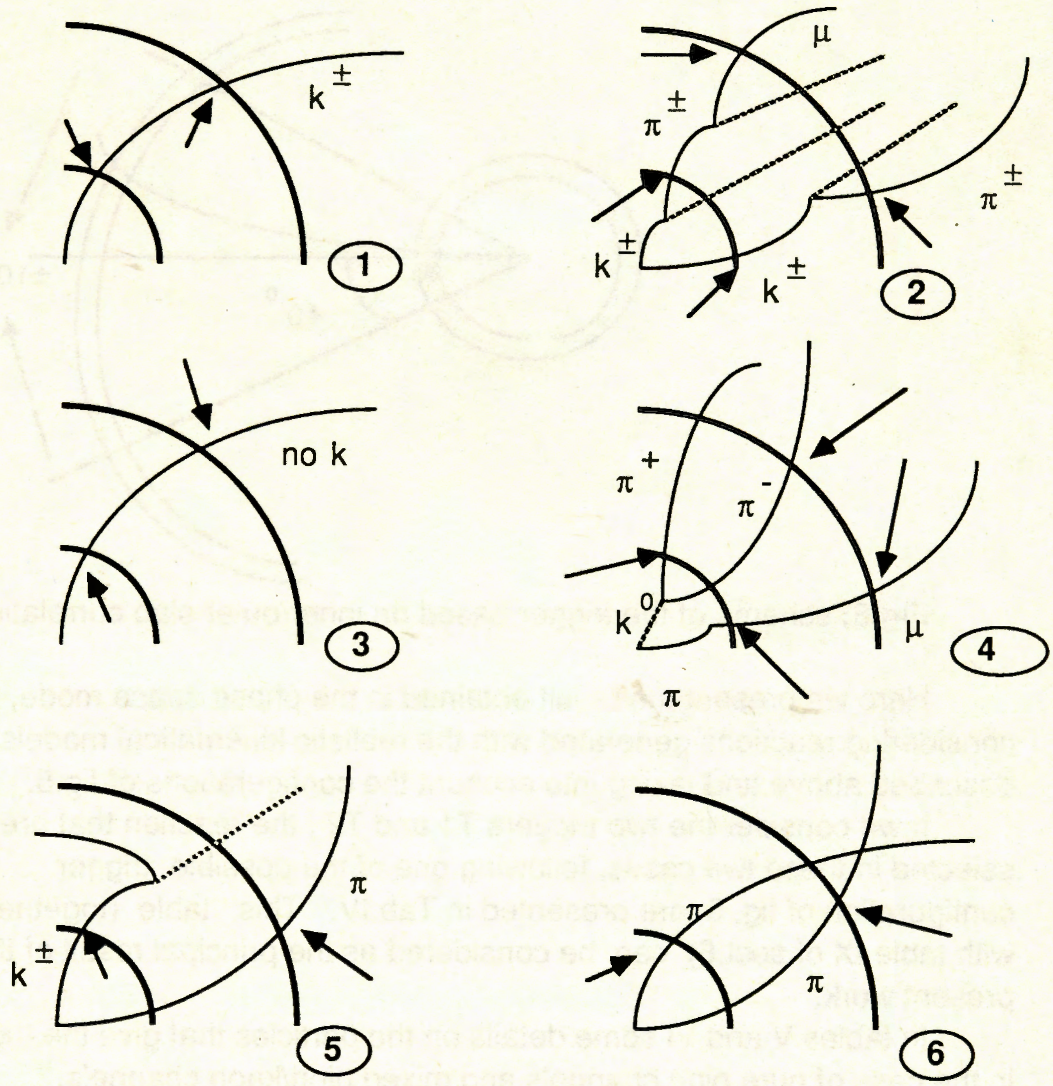


Fig.5: possible reaction configurations which give the TOF trigger. In the cases 1, 2, 3, 4 only one parent particle determines the trigger, in the cases 5, 6 two parent particles; these latter cases are named in the text as *spurious triggers* .

In this section we want to study the possible triggers which select with high efficiency the reactions containing charged kaons from the other ones.

This problem was partially studied in the single track mode in the addendum to the Obelix proposal, where a good method to select kaons from pions was shown to consists of two triggers:

T1) a 6 ns threshold in TOF;

T2) a 6 ns threshold in TOF and the correlation between the hitted internal slab and ± 10 external slabs (see fig 6).

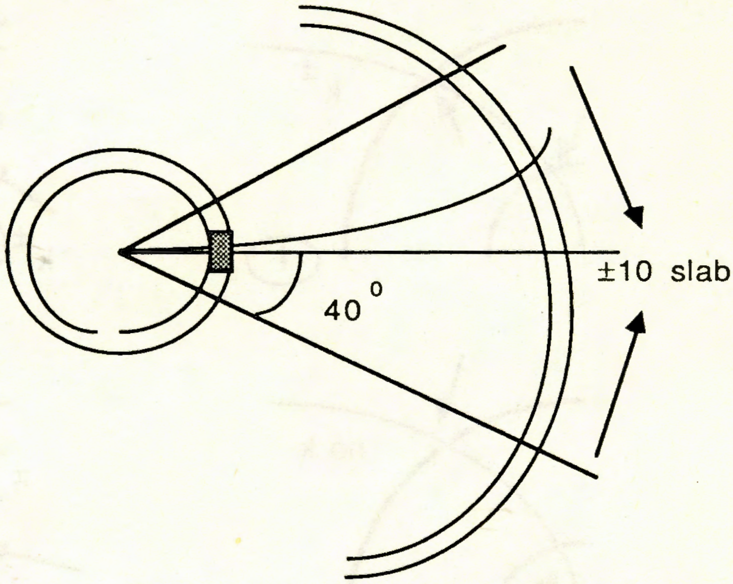


Fig.6: scheme of the trigger based on inner/outer slab correlation.

Here we present the result obtained in the phase space mode, that is considering reactions generated with the realistic kinematical models described above and taking into account the configurations of fig.5.

If we consider the two triggers T1 and T2 , the reaction that are selected in these two cases, following one of the possible trigger configuration of fig. 5, are presented in Tab.IV. This table (together with table IX of sect.6) can be considered as the principal result of the present work.

In tables V and VI some details on the particles that give the trigger in the case of pure pion channels and mixed pion/kaon channels, respectively, are given. Note that in the case of mixed channels also the pions give a non negligible contribution to the trigger efficiency. In effect, the momentum spectrum of the pions associated to the kaons is peaked at a lower value than in the pure pion case, so that also many pions pass the trigger, that selects mainly slow particles.

TABLE IV: triggers efficiencies on pion and kaon channels.

	reactions with π only	efficiency for π (%)	reactions with k	efficiency for k (%)	ratio reactions kaons/pions
generated	10000	--	10000	--	1
entered in TOF	8819	88.	7981	80.	0.905±0.006
selected TOF >6ns	309	3.1	1064	10.6	3.44±0.21
selected tof>6ns ±10 slab	41	0.4	506	5.1	12.34±1.4

TABLE V: tracks triggering the pure pion channels
The row "generated" refers to all the particles coming from the annihilation; the other rows refer to particles giving the trigger in the first barrel.

	π reactions	π^+	π^-	other particles (e^+,e^-,etc from π^0)
		<<<<<<<<<<<<<<<<<<<< (first barrel)>>>>>>>>>>>>>>>>>>>>>>		
generated	10000	15512	15512	19524
entered in TOF	8819	4355	4359	105
selected TOF >6ns	309	142	16	5
selected tof>6ns ±10 slab	41	22	18	1

TABLE VI : <u>tracks triggering the kaon channels</u>

The row "generated" refers to all the particles coming from the annihilation; the other rows refer to particles giving the trigger in the first barrel.

	k reactions	k^+	k^-	k^0_S	π^+	π^-	others (π^0,k^0_L)
		<<<<<<<<<<<<<<<<<<<<<< (first barrel)					>>>>>>>>>>>>>>>>>>>>>>>
generated	10000	4986	4965	5004	5359	5380	15799
entered in TOF	7981	837	894	1899	2110	2124	117
selected TOF >6ns	1064	291	292	83	189	196	13
selected tof>6ns ±10 slab	506	201	234	8	25	36	2

The following figs. 7-12 show the spectra of the triggering particles, compared with the corresponding annihilation (phase space) spectra.

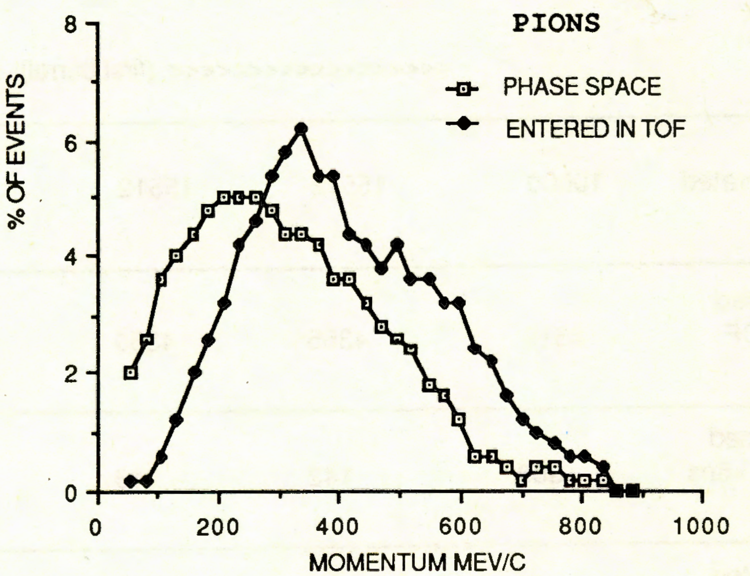


Fig. 7: momentum spectra of $\pi^{\pm}$ from phase space and triggering the TOF, normalized to the same area.

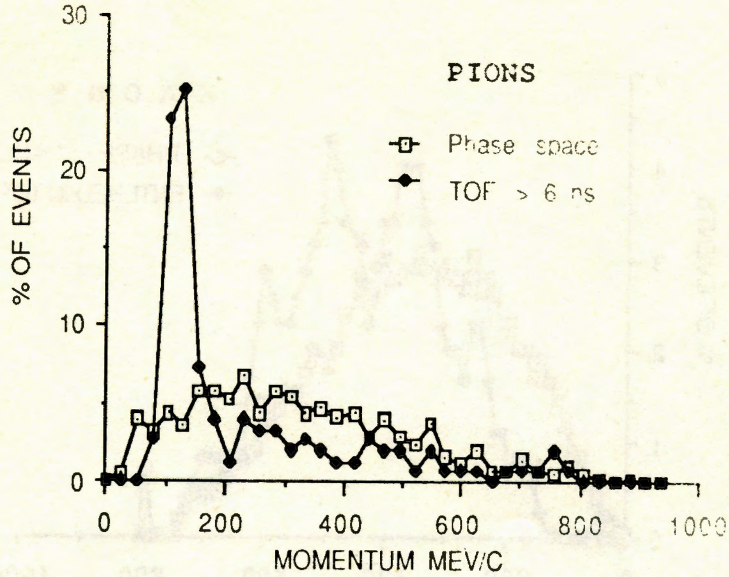


Fig. 8: momentum spectra of $\pi^{\pm}$ from phase space and triggering the TOF>6ns, normalized to the same area.

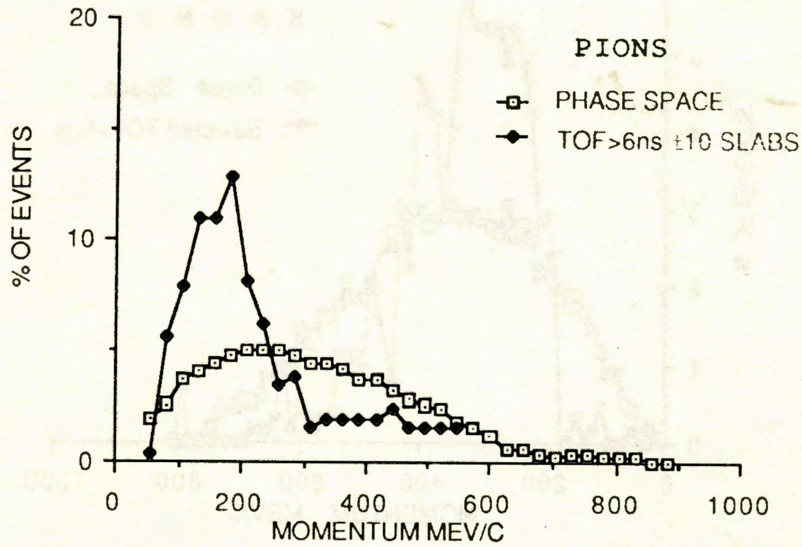


Fig. 9: momentum spectra of $\pi^{\pm}$ from phase space and triggering the TOF>6ns with ±10 slabs correlation, normalized to the same area.

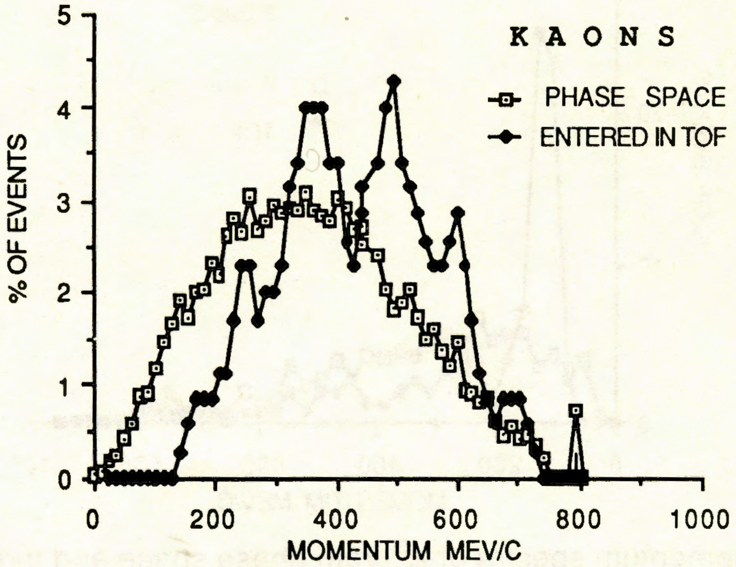


Fig. 10: momentum spectra of $K^{\pm}$ from phase space and triggering the TOF, normalized to the same area. The structure in the TOF spectrum is due to statistics.

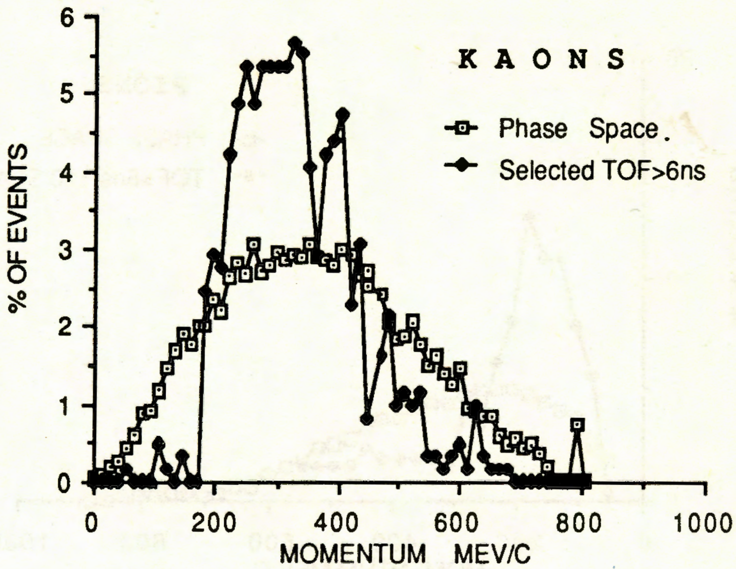


Fig. 11: momentum spectra of $K^{\pm}$ from phase space and triggering the TOF>6 ns, normalized to the same area. The structure in the TOF spectrum is due to statistics.

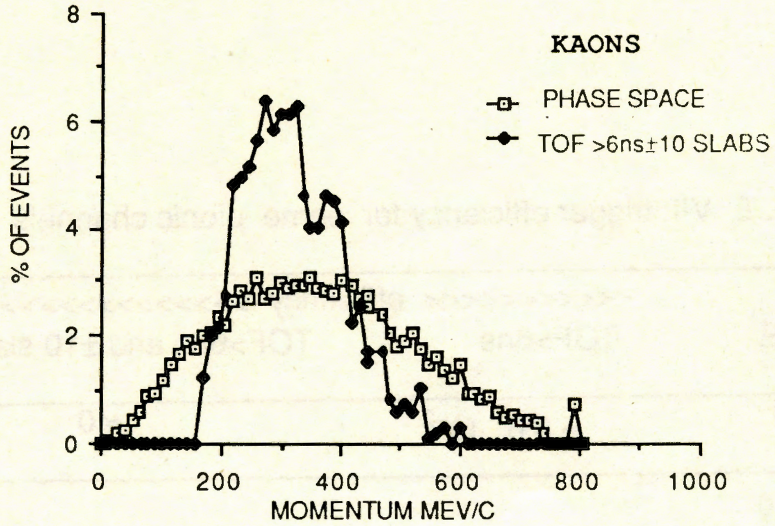


Fig.12: momentum spectra of $K^{\pm}$ from phase space and triggering the TOF>6ns with ±10 slabs correlation, normalized to the same area. The structure in the TOF spectrum is due to statistics.

As a comment on the above figures, it is important to note that the momentum cut introduced by the trigger refers only to the triggering particle, whereas the distorsions on the spectra of the reaction channel (momentum spectra of *all* the particles, effective masses) must be studied simulating the off line analysis taking into account the response of all the detectors. This will be the main task of the "physical Monte Carlo" which is in preparation. For what concerns the TOF trigger, in principle the upper and lower cuts on the momentum of the triggering particle should not introduce significant biases on the other annihilation products and, consequently, on the reaction spectra.

In tables VII and VIII the efficiencies on some typical channels are shown. As an example, we note that from tab. IV the overall efficiency of the TOF>6ns on the kaonic channels is 10.6%. From tab. VIII, we see that this efficiency is not constant over the channels; in effect, the efficiency on the 2-kaon 1-pion channel is 7.8%, whereas the efficiency on the 2-kaon 3-pion channels is ≈10%, slightly higher due to the slower kaon momenta and to the greater number of charged particles involved in this last case.

T A B L E VII: trigger efficiency for some pionic channels

STATE	<<<<<<<<<<< efficiency TOF>6ns	TOF>6ns and ±10 slabs >>>>>>>>>>>>>>>>>>>>
$\pi^+\pi^-\pi^0$	$\approx 0.6\ 10^{-2}$	≈ 0
$\pi^+\pi^-2\pi^0$		
$\pi^+\pi^-3\pi^0$	$3.7\ 10^{-2}$	$5\ 10^{-3}$
$\pi^+\pi^-4\pi^0$		
$2\pi^+2\pi^-$	$2.1\ 10^{-2}$	$2\ 10^{-3}$
$2\pi^+2\pi^-\pi^0$		
$2\pi^+2\pi^-2\pi^0$	$3.4\ 10^{-2}$	$5\ 10^{-3}$
$2\pi^+2\pi^-3\pi^0$		
$3\pi^+3\pi^-$	$2.3\ 10^{-2}$	$4\ 10^{-3}$
$3\pi^+3\pi^-\pi^0$		

T A B L E VIII: trigger efficiency on some kaon/pion channels

STATE	<<<<<<<<<<< efficiency	>>>>>>>>>>>>>>>>
	TOF>6ns	TOF>6ns and ±10 slabs
k^+k^-	≈ 0	≈ 0
$k^0_sk^0_L$		
$k^0_sk^0_s$	≈ 0	≈ 0
$k^0_Lk^0_L$		
$k^0_sk^+\pi^-$		
$k^0_Lk^+\pi^-$	7.8 10^{-2}	2 10^{-2}
$k^0_sk^-\pi^+$		
$k^0_Lk^-\pi^+$		
$k^0_sk^+\pi^-\pi^0$		
$k^0_sk^-\pi^+\pi^0$	6.4 10^{-2}	4 10^{-2}
$k^0_Lk^+\pi^-\pi^0$		
$k^0_Lk^-\pi^+\pi^0$		
$k^+k^-\pi^0$		
$k^+k^-\pi^0\pi^0$		
$k^+k^-\pi^+\pi^-$	19.3 10^{-2}	12 10^{-2}
$k^+k^-\pi^+\pi^-\pi^0$		
$k^+k^-\pi^0\pi^0\pi^0$		
$k^0_sk^+\pi^-\pi^+\pi^-$		
$k^0_sk^-\pi^+\pi^+\pi^-$	9.9 10^{-2}	2 10^{-2}
$k^0_Lk^+\pi^-\pi^+\pi^-$		
$k^0_Lk^-\pi^+\pi^+\pi^-$		

6. Conclusion on trigger simulation

From the analysis of the data reported above and of the complete outputs of the program, one can draw the following conclusions:

° efficiency in kaon/pion channels discrimination
from the efficiencies and the kaon/pion ratios (columns 2, 4 and 5 of Tab IV), and taking into account that at rest 93.3% of events contains pions only and 6.7% of events contain also kaons (5% charged ones), we obtain the results of table IX:

TABLE IX: trigger efficiency in kaon/pion channel discrimination

	% π reactions	% k reactions	counting rate per inc. antip.
ANNIHIL. (at rest)	93.3	6.7	1
TOF	93.8	6.2	0.87
TOF > 6 ns	80.2	19.8	$3.6\ 10^{-2}$
TOF > 6 ns ±10 slabs	50.4	49.6	$7.1\ 10^{-3}$

we see that the TOF increases slightly the π detection probability (due to the absorbing media between the scintillators), whereas the TOF> 6 ns and and the "TOF > 6 ns ±10 slabs " increase the efficiency to the 20% and 50% respectively.

° counting rates
from the 3-rd column of table IX we see that the counting rates decrease strongly increasing the selectivity of the trigger.
For instance, the rate of the "TOF>6 ns ± slabs" trigger is:

(6.7%) x (5.1%) = 0.342 % for kaons
(93.3%) x (0.4%) = 0.372 % for pions

Hence, we select kaons with a percentage of about 50%, with a total efficiency rate of (0.342 + 0.372)% = 0.714% ≈ $7\ 10^{-3}$ (see tab. IX).
With this efficiency rate, the data acquisition system is saturated

with a beam of ≈ $5\ 10^3$ antiprotons/s, which is well within the LEAR possibilities.

° <u>percentage of spurious triggers</u>

the percentage of the trigger due to two differents tracks of the same event (see fig.4), could be of some interest in planning the off line analysis. The results obtained with the simulation are reported in the following table.

TABLE X: percentage of spurious triggers

	% π reactions	% k reactions
TOF	8	30
TOF > 6 ns	58	37
TOF > 6 ns ±10 slabs	60	10

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APPENDIX

An example: the trigger on the E resonance.

Here we want to study whether the momentum cuts generated by the TOF on the triggering particle could affect the spectra of a certain reaction under study (see sect 5 and in particular the comments reported at pag.21).

As an example, we consider the candidate known as the E resonance (see fig. A1):

$E \dashrightarrow k^{\pm}\ [k^0]\ \pi^{\pm}$
mass = 1420 MeV   FWHM = 100 MeV

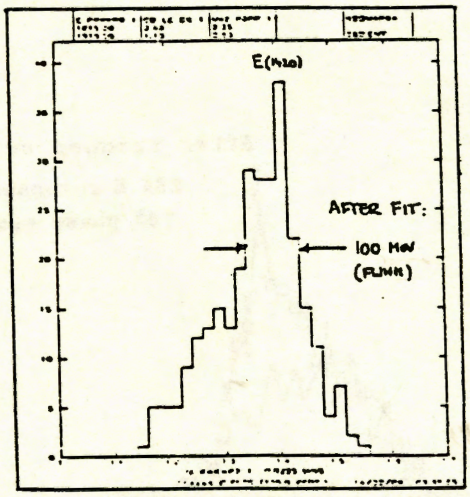

Fig. A1 : effective mass of the $k^+ k^- \pi^0$ system from the ASTERIX experiment.

In particular, we considered the reaction

$$(k^{\pm}\ k^0_s\ \pi^{\pm})\ \pi^0 \pi^0 \qquad (1)$$

with a 30% E resonance production and 70% phase space background, and studied the efficiency of the "TOF>6ns ± 10 slabs trigger".

Generating 10000 reactions, it results that 425 of them pass the trigger, in the way specified in the table A1.

The effective mass generated by kinematics in the simulation is shown in fig. A2 (input), that obtained from the triggered reactions is shown in fig. A3 (output).

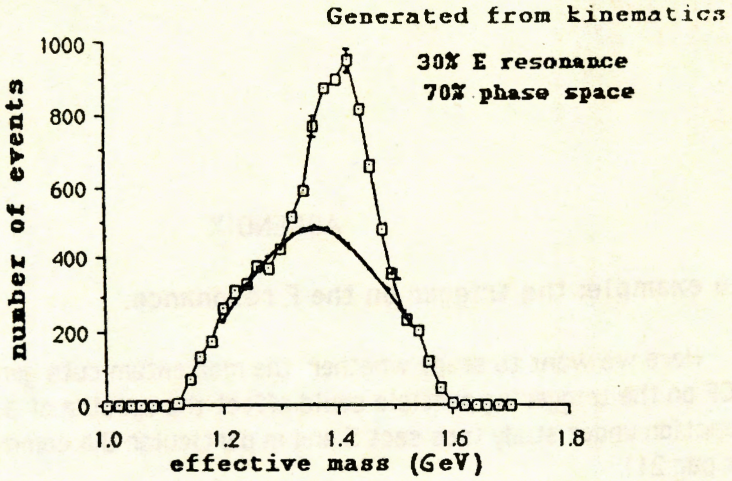

Fig.A2: effective mass of the system ($k^{\pm}$ k^0_s $\pi^{\pm}$) in the reaction ($k^{\pm}$ k^0_s $\pi^{\pm}$) π^0 π^0 with a 30% production of the E resonance. Mean= 1.384 GeV; st.d.=0.095 GeV.

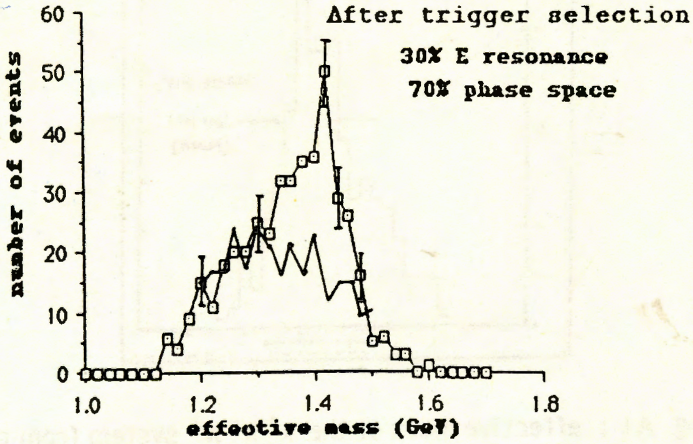

Fig.A3: the spectrum of fig A2 after the "Tof>6ns ± 10 slabs" trigger selection. Mean= 1.367 GeV; st.d.=0.091 GeV.

Table A1 : particles which gives the trigger in the ($k^{\pm}$ k^0_s $\pi^{\pm}$) π^0 π^0 channel. The efficiency of the trigger is about 4%.

Reactions generated	triggers	from k^+	from π^-	from k^0_s and π^0
10000	425	248	69	108

Considering the different statistics, the input histogram seems to be compatible with the output one. See also fig A4, where the two histograms, normalized to the same area, are compared.

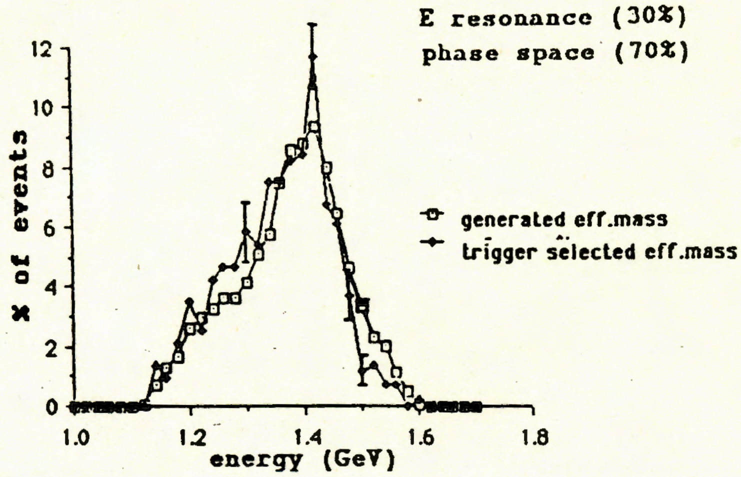

Fig A4: effective mass spectra of the reaction discussed in the text, with and without trigger selection.

However, the test on the means indicates that the trigger selected spectrum is sligthly depressed at the higher energies. Indeed, we have:

generated spectrum (true) mean:	1.384 GeV
standard deviation	0.095 GeV
selected spectrum mean (425 events):	1.367 GeV
standard deviation:	0.091 GeV

error on the mean : $0.095/\sqrt{425} = 0.0046$ GeV
standard variable= $(1.384-1.367)/0.0046 = 3.7$

We see that, after the trigger selection, the mean is lower than the true one of an amount higher than 3 standard deviations, which indicates a small distortion on high mass values. Nevertheless, the resonace peak appears clearly in the output spectrum.

As a last remark, we note that, with a counting rate of 35 antiproton/s, in 1 hour one collects 120000 triggers, and ≈60000 reactions containing kaons (see tab IX). Assuming that the reaction considered here has a branching ratio of $1.3 \; 10^{-3}$ on the total and of ≈2% on the kaon channels (see tab III), one has

$$60000 \times 0.02 \approx 1200 \text{ reaction per hour.}$$

Obviuosly, the arguments reported here are very preliminary, because the response of all the detectors has not been taken into account, and a careful analysis on the confidence levels for the unambiguous detection of the resonance in the output spectrum has not been performed.

All these tasks will be done with the "physical Monte Carlo.