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# PARMTRACK, A Program To Track Particles In Fields With The Effects Of The Space Charge Forces And The Effects Of The Wakes.

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## ABSTRACT

The choice of implementing PARMELA original code (ref. 1 to 5) for accounting multi-bunches and wake fields is deliberate, because of its capacity in tracking particles according to a variety of external fields and with the effect of the space charge, even at low energy. Each super-particle is source of a delta wake potential, described from a double series of frequencies and loss factors supplied to the code. Then at regular intervals of time, the wake field forces are calculated for each particle from the position all the particles in front had when passing at same distance from origin. After the calculation of the forces, the dynamics is applied, from which results a new distribution. The effects of the wakes are introduced in the code in a way which is similar with those of the space charge. The conditions for obtaining precision from calculations with internal forces are carefully examined. Conclusions are valid for both effects. The difference between this code PARMTRACK and code MTRACK (ref. 15 to 17) lies in treating super-particles and not bunch slices, allowing for a redistribution of particles in all dimensions, even longitudinal with cross over of particles, and in having available all the facilities provided by PARMELA.
The code was written for being a decisive tool for the design of different components of the next generation of linear colliders (ref.6). Different results are shown for the CLIC structure with several bunches.

# INTRODUCTION

1. The minimum change has been made in the original code, PARMELA, to care for the action of the wake fields and to treat problems with several bunches. Beam is separated into bunches with identical initial population of super-particles holding the same charge.

   The 3 space coordinates, the associated momentum components, the kinetic energy and the phase, called by extension 'generalized' coordinates of the super-particles are modified along the successive steps of time, according to the description of the external fields, the self fields and of the wakes related with space coordinates and time.

   A list of frequencies and associated loss factors for a point like charge and for a limited number of modes is supplied to the program as for ancient codes (ref.10 to 13) and also in more recent ones, like MTRACK and DTRACK (ref. 14 to 16). In the present one, the precision is due to the 3D multiparticle treatment, when summing the forces due to the other particles and carefully following the dynamics for each particle. As for PARMELA, there is no tentative in refining the formulas in each step of the calculation: therefore the precision results also in choosing a step size small enough to have little influence on the results. A new input entry is proposed, which is more adapted for limited number of particles, and helps for the control of the precision.

2. Input - It is very similar to the one for PARMELA. In addition, the frequencies and loss factors associated to the longitudinal and transverse wakes are given on a separate input file.

3. Output - Statistical properties of the beam, such as the first and second order momenta of the coordinates, and the emittances are calculated when output is required.

   These outputs can be obtained under 2 different forms:

   - Printout of the statistical properties of the beam (rms values, emittances), each time the last particle has left the limit of an element (photograph of the beam at this given time).
   - Record of the generalized coordinates of the particles when crossing the limit of an element, for further treatment (statistics, plots) by an other program.

4. Examination of intermediate results such as the delta wake fields, and wake fields associated with a bunch, can be obtained by minor changes in the input. The most important parameters which can be printed or plotted are described further.

   In the first part of this paper, the precision of the results is discussed. In the second one, the different modes of input and output are described.

## 1. METHOD FOR CALCULATING THE WAKE FIELDS AND THEIR EFFECTS

### *1. 1 Wake field at a point*

The elements used for calculating the wake fields are read from a file, resulting from the application of another program (ref.17), such as KN7C (ref.18), or TRANSVRS (ref.19), or indirectly from MAFIA (ref.20),or ABCI(ref.21). In PARMTRACK, the wake field is 'reconstructed' by summing up over the modes the delta loss factors associated with the discrete series of frequencies and modulated by the respective positions of the influencing (index j) and influenced (index i) super-particles.

The expressions for the delta wake potentials are:

$$2 \Sigma k_{0n} \cos \omega_{0n} (t_j - t_i)$$

$$2 \Sigma k_{1n} (c/\omega_{1n} a^2) \sin \omega_{1n}(t_j - t_i)$$

where a is the iris radius, and $t_j - t_i$ measures the time elapsed between passage of particles j and i at the same place (ref. 7 to 9).

$\omega_{0n}$, $k_{0n}$ are the frequency and associated loss factor for the 'longitudinal' (m=0) mode, while $\omega_{1n}$, $k_{1n}$ are associated with the 'transverse' mode (m = 1). All other modes are neglected, as well as the longitudinal field due to the m = 1 mode.

Naturally, the fields due to all influencing particles are then summed as in all codes, such as MTRACK or DTRACK(ref.14 to 16). But, here, the distribution is renewed even longitudinally at each step of the calculation, hence the forces, because particles can change their speeds and cross over.

### *1.2 Action of the wakes*

Often, the action of the wake fields is shown according to a very schematic process: the leading particle, at a transverse distance from the structure axis, is ahead of the test particle by a longitudinal distance z. But since the transverse coordinate may change rapidly with z, and also because the leading particle may even be lost, the integration of the wake field effect along the path of the test particle requires the records of the transverse position of the leading particle when it was at the same longitudinal position as the test particle, and the record of the time separation. Also up to the point a leading particle is eventually lost, the wake field holds because structures are still ringing, but not further, if energy flow is slow compared to the time it takes for all bunches to pass.

Therefore, transverse position of the particles and time of passage are recorded for a discrete set of values of the distance to the origin, with as many points as needed for precise interpolations. This way of proceeding is the easier, if not the only possible one for implementing PARMELA.

## 2. EFFECTS OF THE SELF FORCE AND OF THE FORCE DUE TO THE WAKES AND VALIDITY OF THE RESULTS.

Because these forces result from the action of the other particles, they are calculated at a given time for all the particles. This is not so for the action of the external fields, where the particles can move independently.

This is a basic feature in PARMELA, recalled here because of its importance upon the precision of the results.

### *2.1 External field*

All particles are considered successively for a step in time. If during this step, a particle has to cross the limit of an element, a special smaller step is made for going to the crossing point and another one to complete the step in time.

By using these sub-intervals, the external fields, which may be different on the sides of the limit, are correctly taken into account for the record which is finally output.

### *2.2 Fields from the space charge effect and from the effects of the wake*

These fields are calculated with a 'frozen' distribution, in advance, for the n next steps of progression in the external fields. The action of these 'internal' fields is established by impulse approximation: the change in the components of the momentum is proportional to the components of the forces and to the interval n dt, as it is for the effects of the external forces in the successive intervals dt. But, for the action of the internal fields, the additional momentum is just superimposed with the components of the momentum, without a calculation of new space coordinates at that time.

Space coordinates, such as z, are modified by the additional momentum only when program returns to stepping really in time for the action of the external forces.

### *2.3 Validity of the result*

If n <> 1, the end of an elementary step, except the n th one, does not coincide with the end of the interval for calculating the internal forces. The part of the momentum due to the internal forces applied since their last calculation is not correctly evaluated: it were evaluated for interval n dt, and will be exact only at the end of this interval. Because of the error in the momentum at each elementary step except the last, the space coordinates are not so precise as for n = 1.

This holds for n<>1, but also for points at the z limits of an element, the only place where results are recorded. Even for n = 1, the change in momentum due to the internal force is then evaluated for the interval dt, while, for the external forces, the sub-interval to the z limit is taken into account for the record which is finally output.

Consequences are:

a/ Results are significant only after a time which is an integer multiple of n dt, i.e., by a photograph of the beam at this time.

b/ Statistics (and plots) based on recording the particles at a given distance from the origin (i.e., at limits of elements according to conventions in PARMELA) may be significantly wrong. This is because the intrinsic choice in having time steps, not z steps. The internal forces are not calculated at the time a particle goes through a limit, but at regular intervals of time, i.e., generally, before and after the limit.

The resulting error on the values of the momenta at z = constant varies with particle position and may be as high as the contribution in momentum due to the internal forces applied during interval n dt.

The plots of the momenta towards the phase of the particle illustrate this fact by an apparent grouping of the particles in separated subsets.

On Fig. 1 is shown the plot of yp = dy/ds (mrad) versus $\varphi$ (deg) for 35 particles of a gaussian bunch submitted to wake fields in a structure. The parameters are taken at z = 2.5 mm from the origin. On Fig. 2, the successive diagrams have been plotted at each 3.33 $10^{-11}$ s time interval. Each step provides another kick dy for the particles. It is shown how projections at z = 2.5 mm for yp are taken from the last evaluation before crossing, which explains the grouping.

Emittances evaluated from these distorted results are not correct.

***Remedies***

- It is possible to keep track, for each particle, with the help of a supplementary coordinate, of the last momentum change due to the internal forces, in order to apply this change further, when external forces are calculated and applied, and according to the time elapsed since internal forces were calculated. This could be easily implemented if enough memory is available.
- Unlike for what is obtained at z= constant, the output and the statistics obtained at a given time (photograph of the beam) are valid, provided that time of output is a multiple of n dt.
- The result at a distance z is right within the basic approximations used if internal forces are null in between this position and the last position where internal forces were calculated. Fig. 3 shows the yp versus phase plot for particles crossing a plane just at the exit of the wake field zone. It is compared with the same record, but after 2 cm more drift. For a calculation with space charge force, the interruption of the action of the force is not so easy to achieve. For pure wake fields forces, it is generally possible to have outputs at places where these conditions are fulfilled.

## 3. INPUT-OUTPUT AND AUXILIARY PROGRAMS

Here are mentioned the differences with PARMELA. The source for the transverse wake field can be given by

- a transverse shift of the beam at the source, as it exists in normal input for PARMELA (shifts in space coordinates or in the angles).
- a transverse shift of the structures along beam path (see below dxoff, dyoff).

### *3.1. FOR NORMAL RUNS*

***INPUT:***

'RUN' card : nbunch >=1, niwak=0

'INPUT' card : type 20, NP (number of particles per bunch: NP+1) dx , dxp , dy , dyp, are the bunch initial shifts.

'SCHEFF' card: beami= - overall number of electrons (as in PARMELA).

'WAKECERN' card : nb >=0, number of successive zones where wakefields may be found.
'wakefile': the name of the file holding the values for frequencies and loss factors for each wake field type (see 2.2).

'START' card: NSW >=1, same meaning as NSC for space charge: the wake field action will be evaluated each NSW multiple of the elementary time step.

***PRINTED OUTPUT:***

Statistical properties of the bunches.

In present version, this is done for all the bunches as a whole (i.e. ,the output directly obtained that way is meaningless if more than one bunch).

***RECORDED OUTPUT:***

The file contains the coordinates of the particles at the limits of successive elements.

***AUXILIARY PROGRAMS:***

(nearly unchanged from ref.22)

Command XPAW activates the interactive plotting of the recorded results. One has to specify the index number of the bunch to be examined.

Names and units of the quantities used are:

| x | xp | bgx | y | yp | bgy | z | bgz | phi | wz |
|---|---|---|---|---|---|---|---|---|---|
| mm | mrad | | mm | mrad | | cm | | deg | MeV |

Command XPRINT activates the calculation of the statistical properties of individual bunches from the recorded output and the printout of the results.

### *3.2 RUN FOR PLOTTING THE WAKE FIELDS*

INPUT cards:

'RUN' nbunch=1, niwak=1

'INPUT' type=20, NP >=1

There will be NP+1 particles in the gaussian bunch, generating the wake field. However, in this case, another NP+1 test particles will follow at regular distances, to witness the wake behind the bunch. By choice, these last NP+1 particles make no contribution to the wakes.

parameters $\alpha$, $\beta$, $\varepsilon$ (emittance)

The Twiss parameters are given for the NP+1 particles of the bunch.

'SCHEFF' card : beami = - the total number of electrons for the 2*(NP+1) superparticles.

'WAKECERN' nb= number of zones where there is a wake field

'START' NSC=0: the effect of space charge is thus discarded NSW $\geq$ 1

***RESULTS:***

The wake fields and the associated parameters are recorded when the reference particle (in PARMELA terminology) reaches the value 'cordmax' given with the input file 'wakefile'. The wake fields are recorded at the location of the NP+1 particles of the bunch, and of the other set of NP+1 test particles, which follow the bunch. Results are reported per pC of bunch charge.

By this way, the wake obtained with a given bunch length at the location of the last NP+1 test particles can be compared with the delta wake given by only 1 leading particle of 1 pC. To simulate the delta wake field, it is required to chose a very small longitudinal beam size, i.e. in the bunch longitudinal description, a small value for the product $\beta\,\varepsilon$.

As an example, this comparison is made on Fig. 4, for the longitudinal wake fields, and Fig. 5, for the transverse ones. On these figures, a is the radius of the structure (.002 m), p is the space period (.00333 m).

The fields in the first NP+1 particles of the bunch are also displayed, also per pC of the bunch charge.

***PRINTED OUTPUT:***

Usual output is suppressed

***RECORDED OUTPUT:***

The particles generalized coordinates, the wake fields and the associated parameters are recorded on the same file which is normally used for recording particle coordinates at the limits of the elements.

***AUXILIARY PROGRAMS***

[very similar to some PARMELA 'post processors', ref. 22].

Command XWAK is used to plot the wake fields and associated parameters at the location of the super particles.

The parameters which can be used for plots are:

x bgx wol y bgy wot z(mm) bgz dgbz dgby

but the names to be specified for running the auxiliary programs are limited to existing ones, so the specification should be used as follows:

x bgx y y yp yp bngz phi wz
wol,wot,dbgz,dgby are related to the wake field as described further (4.2)

### *3.3 RUN FOR PLOTTING THE WAKE FIELDS AT EACH STEP OF THE CALCULATION*

This helps studying the evolution of the wakes and their effects in time. The calculations are as in the general case. The wake fields and associated parameters will be recorded at the location of the super-particles at each step of the calculation of the wakes.

The results are printed within the usual printed output. The program stops after a total progression in phase which is given with the 'wakefile'.

INPUT cards:

'RUN' nbunch=1, niwak=-1 (nbunch=1 is not compulsory)

'INPUT' type = 20, NP ≥ 1

'START' NSC = 0, NSW = 1

*RESULTS:*

Command XLOC activates the plot of the results. After each successive interval for the calculation of the wakes the wake fields at the super-particles are recorded on the same record as for the normal printed output lines. Then, for using this file for plot, normal output lines should be discarded as required by the interactive program.

For each interval , as many times as there are particles , the following quantities, defined further in 4.2, are available for plots:

phase i z qdlq wol dgbz gbz wot dgby yp (mrad)

Fig. 2, discussed above, has been obtained by this option.

## INDEX OF TERMS USED IN PROGRAM AND OUTPUT.

### *4.1. Quantities read from file 'wakefile'*

There are nbw successive zones along the beam line where wake fields are described. nbw is given as parameter with card 'wakecern' (see 3.1 above). For each of these zones nc,

zmin(nc),zmax(nc),type(nc)

are the limits for the zone; type is the index reference with one of the wake field data record.

The wake field at the position of a particle depends on the coordinates of the other particles at the time they have passed at same distance z from the origin.

These coordinates are calculated from records at the discrete set of limits z given above. Then precision depends on the number of these limits.

nl is the index for the mode, nb is the index for the type of the wake-field.

nl is the index for the mode, nb is the index for the type of the wake-field.

xoff(nb), yoff(nb),

are the transverse displacements in m, if any, given for the structure type nb, for which wake fields are described. The other possible displacement is the one of the centroid of the initial bunch, as in the standard PARMELA input file.

nx,nr: maximum number of modes in the data list, selected number of modes for the calculations.

wfreql(nl,nb): frequency $\omega_l / 2\pi$, for longitudinal mode nl, zone nb, unit GHz. It is further multiplied by: $2\pi\ 10^9 / (3\ 10^8) = 20\pi / 3$

wkl(nl,nb): loss factor for mode nl, and zone nb, in V/pC per cell. It is further divided by the cell length, to have it per m, and multiplied by 2, to prepare the expression for the delta-wake.

wfreqt(nt,nb): frequency $\omega_t / 2\pi$, for transverse mode nt, zone nb, unit GHz. It is further multiplied by $20\pi / 3$.

wkt(nl,nb): loss factor for mode nl, and zone nb, in V/pC per cell, per m transverse shift of the exciting particle. It is further divided by the cell length, to have it per unit length. For preparing the calculation of the delta wake, it is also further multiplied by:

$2 * 3.\ 10^8 / (\omega_t\ a^2) = 0.3 / (\pi\ f_t\ a^2)$ where $\omega_t$ is in Hz, and $f_t$ in GHz.

### *4.2. Quantities read from the input data file, or used in the outputs:*

niwak (on 'RUN' card)

niwak=1: drives the calculation and the plot of the delta wake. The number of bunches should be 1. In this case, the number of super-particles is :2 (NP+1).

NP is the parameter given with the 'INPUT 20' card. The charge per super-particle is beami / (2 NP +2). Program is built such that in this case, only the first NP+1 super-particles are generating the wake. The following NP+1 are just test particles at the location of which the wakes and their effects are calculated.

deltaz: translation in distance of the time elapsed from the passage of the exciting particle at the place of the test particle.

wl: longitudinal wake in V per pC of the exciting charge, per m path in a structure, obtained by summing over the modes, for a given distance to the exciting super-particle.

wol(i): same quantity as for wl, but it is summed over the number of the exciting super-particles (in front). It is also multiplied by the cell length (to have the wake per cell), and divided by the number of the super-particles in the bunch (ibmax), to have it per pC of bunch charge.

Unlike wl, wol is not used for calculating the effects of the wakes.

wt: transverse wake, in V per pC of the exciting particle, per m path in structure, per m transverse shift of the exciting particle, obtained by summation over the modes, for a given distance to the exciting super-particle.

wot(i): same quantity as wt, but it is also summed over the number of exciting particles. It is further multiplied by the cell length (to have the wake per cell), by the iris radius (to ease the comparison with other results), and divided by the number of super-particles in the bunch, to have the wake per pC of bunch charge.

wot is not used for calculating the effects of the wakes.

dl: elementary path length, in m, of the test particle in the wake field per step of wake calculation. So, its maximum value corresponds to the time elapsed between 2 calculations of the wake field effect, i.e., a phase interval of

NSW * DW (deg)
with NSW given in card 'SCHEFF" and 'DW" in card 'START'

q : number of electron per super-particle = -beami / xnp
beami is given on card 'SCHEFF'.
xnp is the overall number of super-particles.

qdl : number of electrons per super-particle multiplied by the path length during a wakefield step.

This number is further multiplied by $1.6\ 10^{-16}$ for a change of units of the losses from V/pC into GV/electron, and further by:
$m_0 c^2 / e = 512\ 10^{-6}$ (in GeV), to be used for the action of field $E_i$ on momentum change :
$d(\beta_i\gamma) = E_i * dl / (m_0 c^2 / e)$

xtp(j,nc), ytp(j,nc): x and y transverse displacement (in cm)
of particle j when it was at the same z position as the particle i for which the wake field is calculated.

dxw = xtp(j,nc)/100 -dxoff(nb)
dyw = ytp(j,nc)/100 -dxoff(nb),
are the particle displacements (m) relative to the axis of the structures.

dgbx : wt qdl dxw
dgby : wt qdl dyw
dgbz : wl qdl,
are the changes in ($\beta\ \gamma$) i due to the action of the wake fields during a wake step.

cord(2,i) : new value for $\beta_x\gamma$

cord(4,i) : new value for $\beta_y\gamma$

cord(6,i) : new value for $\beta_z\gamma$

## 5. SOME RESULTS WITH CLIC STRUCTURE

Dynamics is calculated for CLIC structure for 2 bunches separated by 1 cm (360° with 30 GHz pulsing). In this application, the structure is interrupted after 10 cm and electrons are allowed to drift 5 cm further. An initial shift dy = 1 mm for all particles is the source of the transverse wake. The series of frequencies and associated loss factors have been calculated as reported in ref.(17).

Internal radius of the structure is 2 mm, which would stop most particles in 15 cm path. However, in this particular application, particles are not limited in their radial excursion and not discarded .

Characteristic input data:

The structure is passive (no energy gain)
kinetic energy: 60 MeV
charge per bunch: 20 nC
bunch length: 0.7 mm ($\sigma$)
x bunch size: 1 mm

### Results:

| | |
|---|---|
| y envelope for 100% particles | (Fig. 6) |
| yp versus phi at 15 cm | (Fig. 7) |
| y versus phi at 15 cm | (Fig. 8) |
| Kinetic energy versus $\varphi$ at 15 cm | (Fig. 9) |

For checking the results, let us calculate the beam loading ratio to the gain when using the structure for CLIC main beam.

The total kinetic energy interval is, for bunch 1: 4 MeV, as seen Fig.9.

Then, per m length and per nC, this interval is: 2 MeV.
The loss to gain ratio in CLIC is therefore:
$2 / 80 = 2.5\ 10^{-02}$ per nC

On Fig. 5, the apparent period for the transverse wake field is close to 8.8 mm, for one gaussian bunch with $\sigma \leq 1$ mm. This corresponds to the importance of the first of the modes for m = 1. Also the second maximum of the wake field is within a few % equal to the first one. Reporting this period on Fig.7, the influence of bunch 1 on bunch 2 is null at a distance of 0.88 cm from the first particle of bunch 1, and maximum 0.4 cm further. The variation is about the same as the one for bunch 1, but shifted by 0.88 cm.
Thus, field and resulting yp values on bunch 2 are the sum of fields or yp values on bunch 1, once shifted by 1 cm (the effect of the bunch upon itself is the same), and a second time shifted by 0.88 cm. This can be easily verified on Fig. 7.

The results on Fig. 6 to 8 show that the 1 mm initial beam offset is far too much for a bunch of 20 nC with $\sigma = 0.7$ mm: after 10 cm, an important part of bunch 1 is lost on the wall (a = 2 mm), and most of bunch 2. Fig. 10 to 12 can be compared with Fig. 7 to 9: the same total charge of 40 nC is distributed into 3 bunches instead of 2.

## 6. GAUSSIAN BUNCH: INPUT 20

In this mode of input, a gaussian distribution is provided for each of the 6 coordinates of the particles: (x,xp), (y,yp), ($\varphi$,dw/w). x and y are the transverse coordinates, xp and yp the derivatives with respect to the distance to origin, phi and dw/w are the phase and the relative spread in kinetic energy.

Correlation exist only between the coupled coordinates, such as x and xp. The Twiss parameters ($\alpha$, $\beta$, emittance $\varepsilon$) are given for each couple.

In PARMELA original code, a real random choice for each coordinate and associated angle (routine rannor) gives at each call 2 independent values $r_1$ and $r_2$ according to a normal distribution with unit sigma. These 2 values, and the other couples ($r_3$, $r_4$), ($r_5$, $r_6$) are selected or rejected with the condition:

$$r_1^2 + r_2^2 + r_3^2 + r_4^2 + r_5^2 + r_6^2 \leq cut^2$$

Thus are rejected the values which are too far in the distribution. These spherical coordinates are transformed into 6D ellipsoidal coordinates by linear relation using the Twiss parameters:

$$(\varepsilon / \gamma)^{1/2} \; (r_1 - \alpha r_2)$$

$$(\varepsilon \; \gamma)^{1/2} \; r_2$$

For any couple as (x,xp), $r_1^2 + r_2^2 \leq cut^2$ is then $cut^2$ transformed into:

$$\gamma x^2 + 2 \alpha x \, xp + \beta xp^2 = \varepsilon \leq cut^2$$

This method is convenient for a very large number of super-particles, but, for a small number of particles, it is more suitable to adopt a selection which is not really at random, but more regular. The super particles are placed at the centers of N equal charge intervals selected on the normal law curve, and the abscissa r for each of them is recorded. Total charge is supposed to be found between limits -rg and +rg, and corresponds to the sum of the probability density between these limits. The relative charge per interval is this sum divided by N. The successive values of r at the centers of the intervals are calculated by the inverse function of the cumulated relative charge intervals, by successive approximations.

It is worth to note that, because of the truncation, the rms. value of r is smaller than the initial value of sigma which is unity, and, because of the discretisation of the charge, the total extension in r and the rms. value are smaller than what a continuous distribution would give.

The set r represents N values selected in a normal distribution with cuts at ± rg. It is symmetric, regular, and the average is zero.

The distribution for the other dimensions in the ellipsoid can be obtained by the same transform as the one given above. If one chooses the same cut rg, the sets of values for r are all identical for all dimensions. However the values are randomly shuffled among the particles to avoid unwanted correlations. This is obtained by selecting another permutation of the indices for each new dimension.

## ACKNOWLEDGMENTS

We are grateful to G. Guignard for having encouraged the tentative to incorporate the effects of the wake fields in PARMELA and even suggested it, and for having discussed the results and provided comparisons with corresponding ouputs obtained from his programs MTRACK and DTRACK.

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**Figure 1**

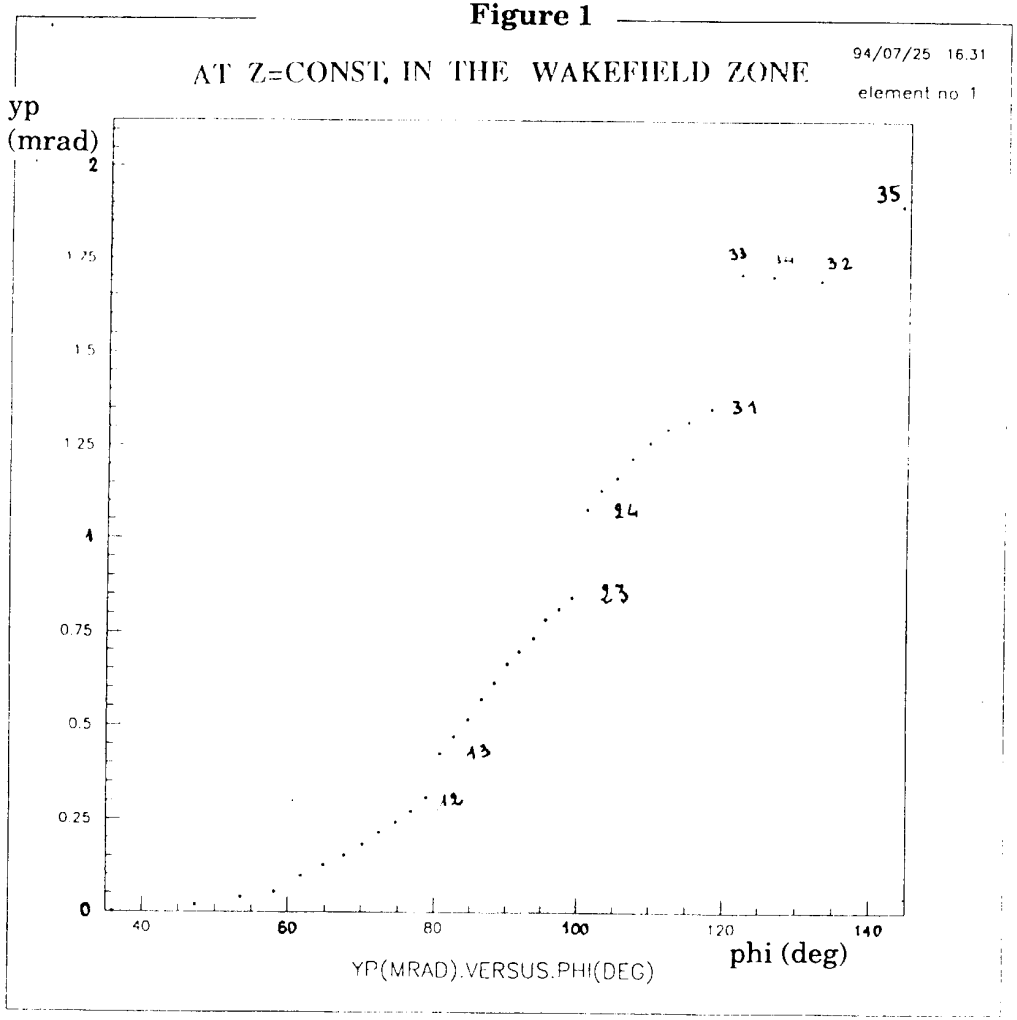
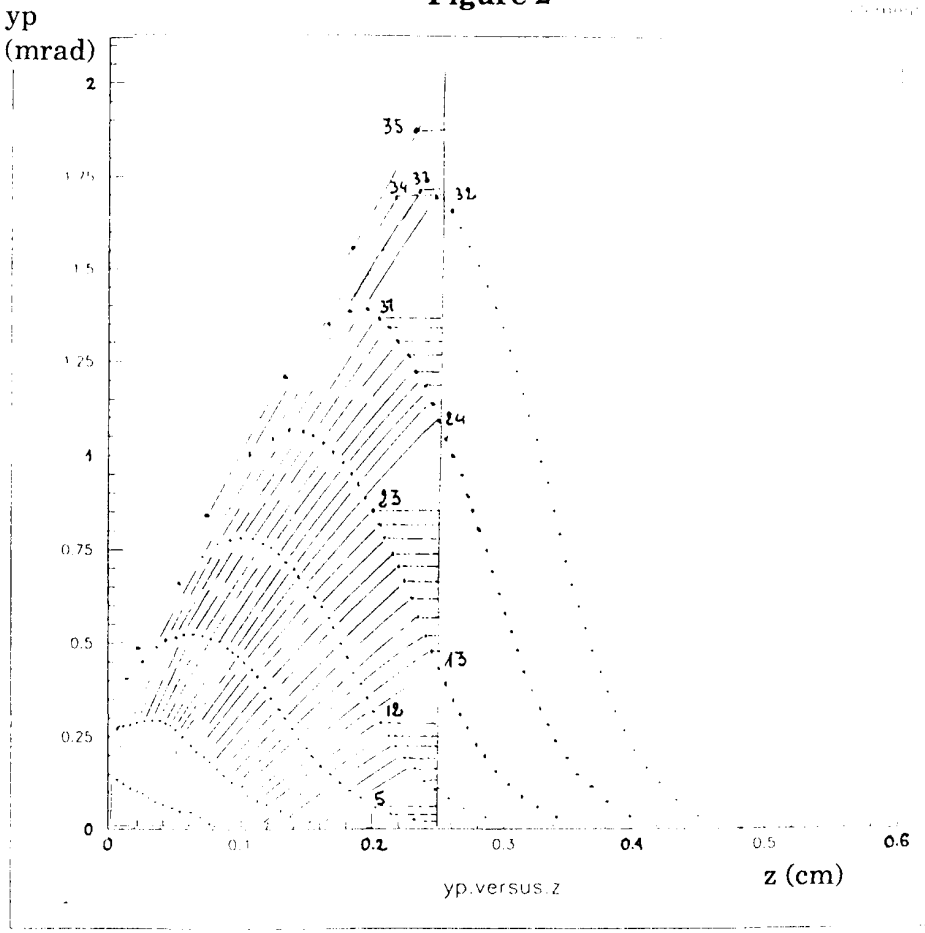
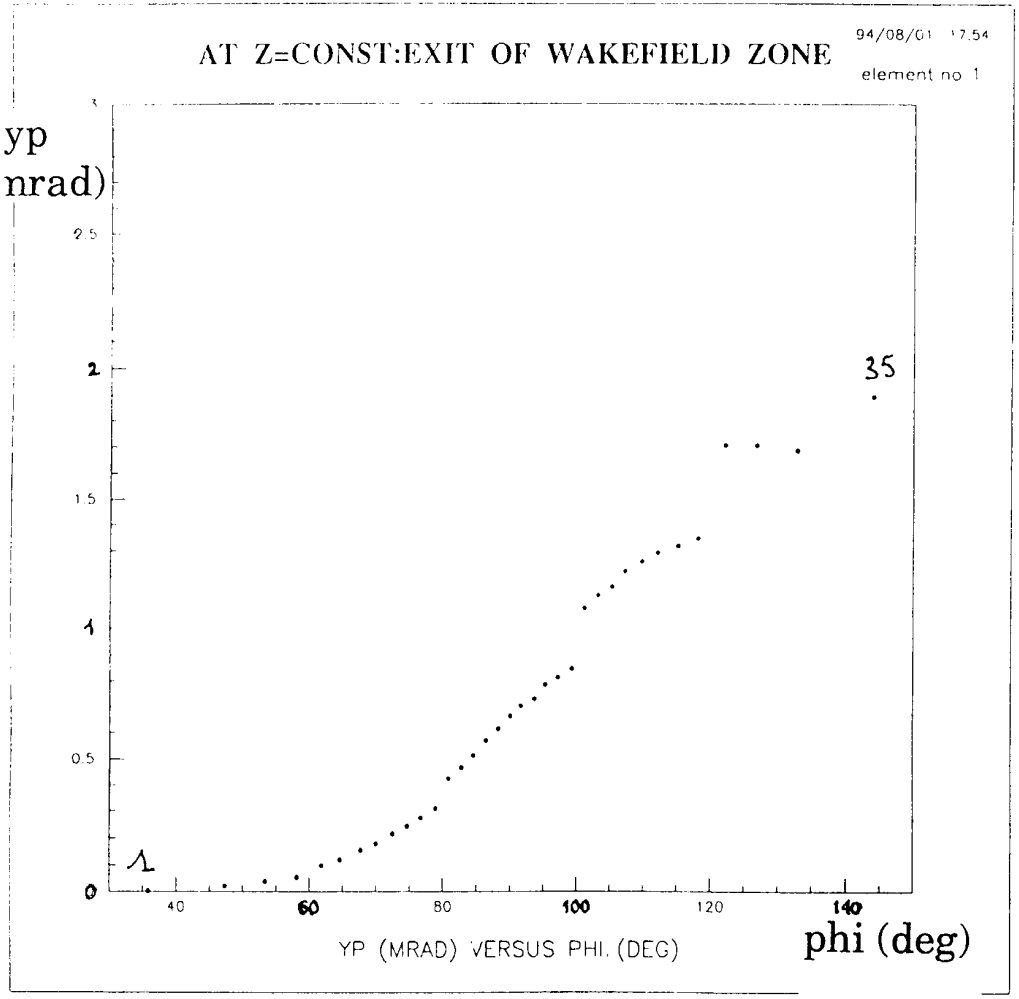
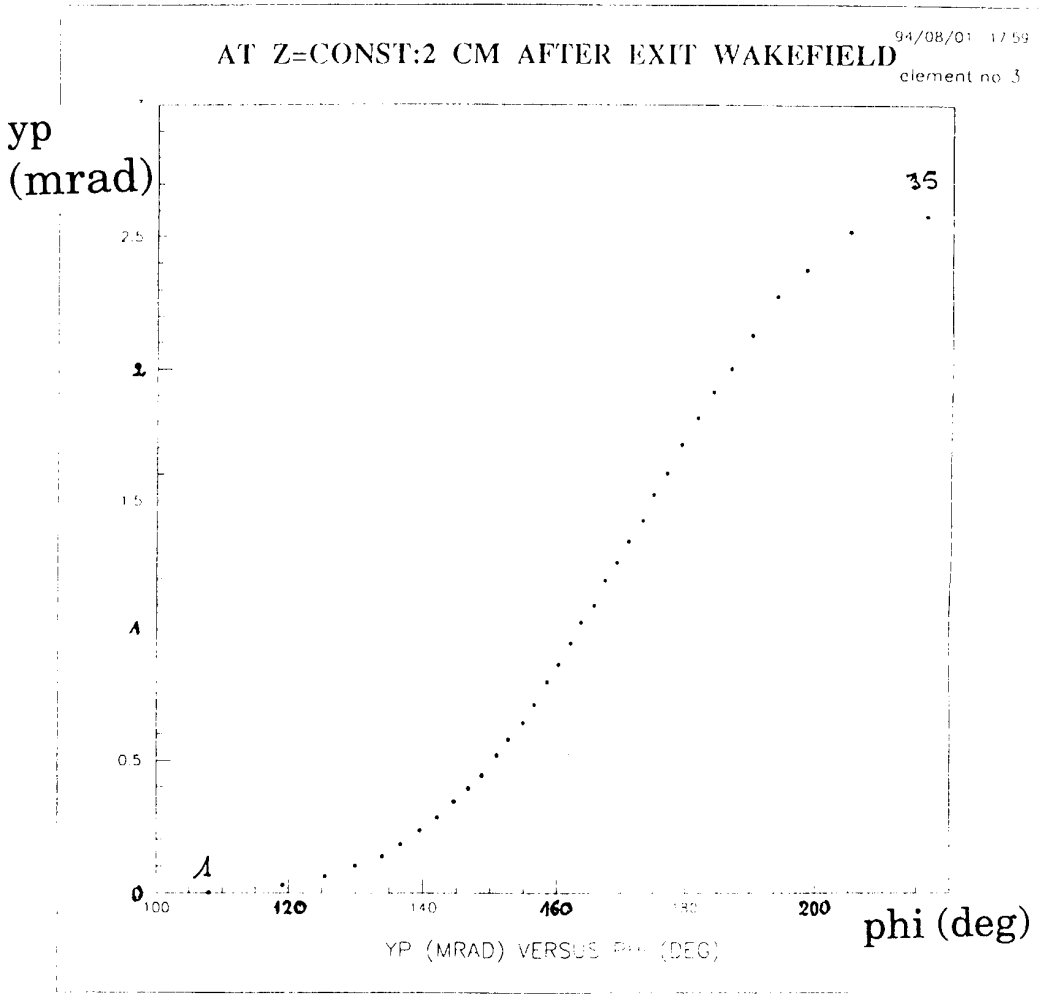



**Figure 2**

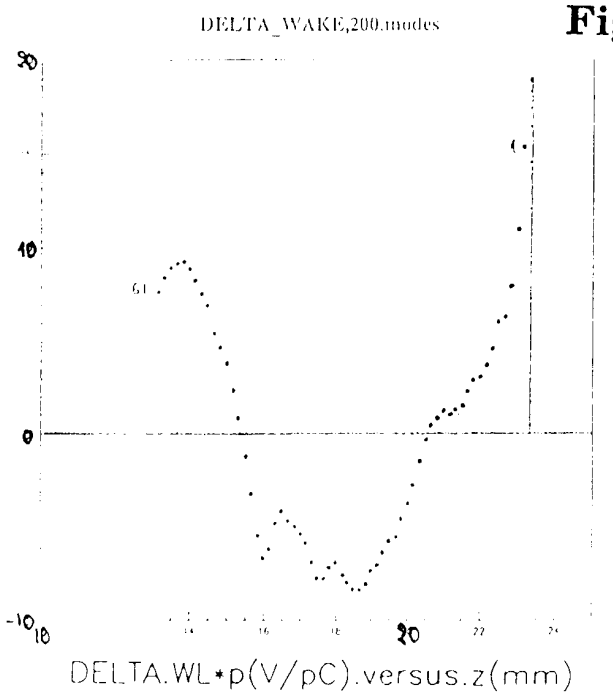


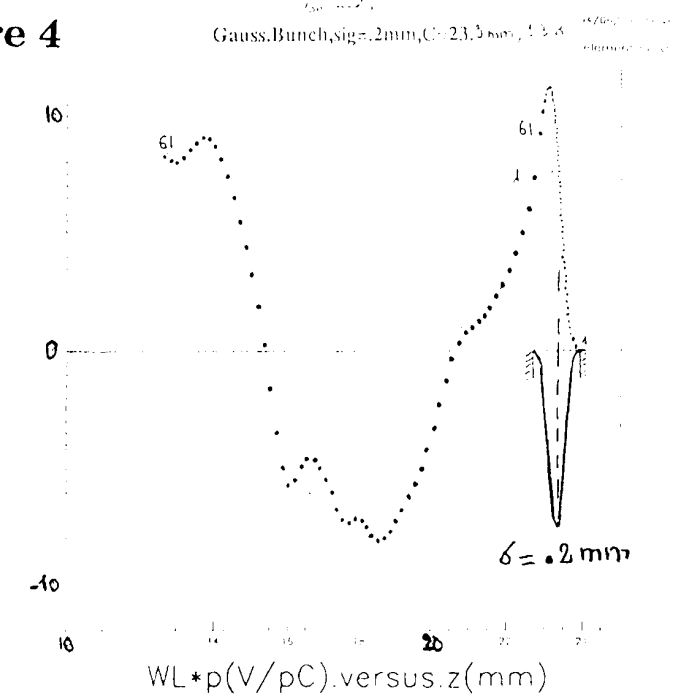
# Figure 3

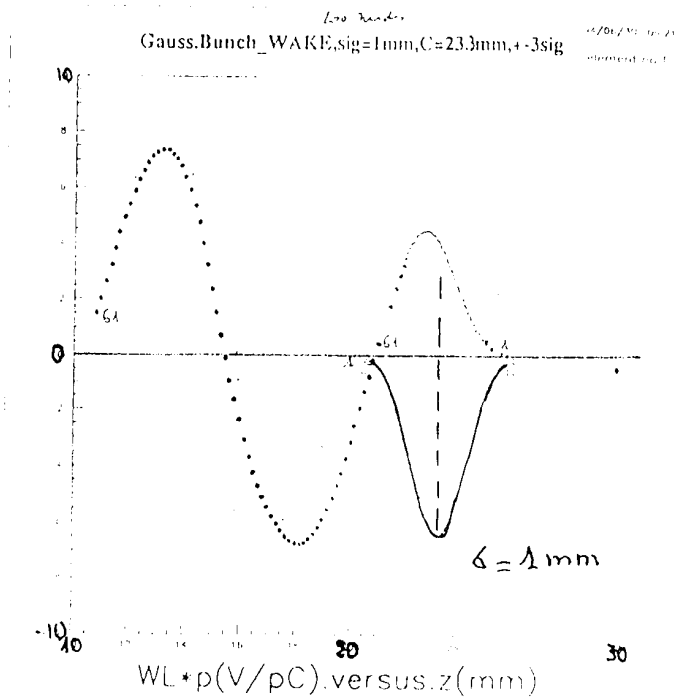

AT Z=CONST:EXIT OF WAKEFIELD ZONE
94/08/01 17.54
element no 1
yp
nrad)
2.5
2
1.5
1
0.5
0
35
40
60
80
100
120
140
YP (MRAD) VERSUS PHI (DEG)
phi (deg)


AT Z=CONST:2 CM AFTER EXIT WAKEFIELD
94/08/01 17.59
element no 3
yp
(mrad)
2.5
2
1.5
1
0.5
0
35
100
120
140
160
180
200
YP (MRAD) VERSUS PHI (DEG)
phi (deg)

# Figure 4


DELTA_WAKE,200.modes
30
10
0
-10
10
20
DELTA.WL*p(V/pC).versus.z(mm)


Gauss.Bunch,sig=.2mm,C=23.3mm
10
0
-10
10
20
δ = .2 mm
WL*p(V/pC).versus.z(mm)


Gauss.Bunch_WAKE,sig=1mm,C=23.3mm,+-3sig
10
0
-10
10
20
30
δ = 1 mm
WL*p(V/pC).versus.z(mm)

# Figure 5

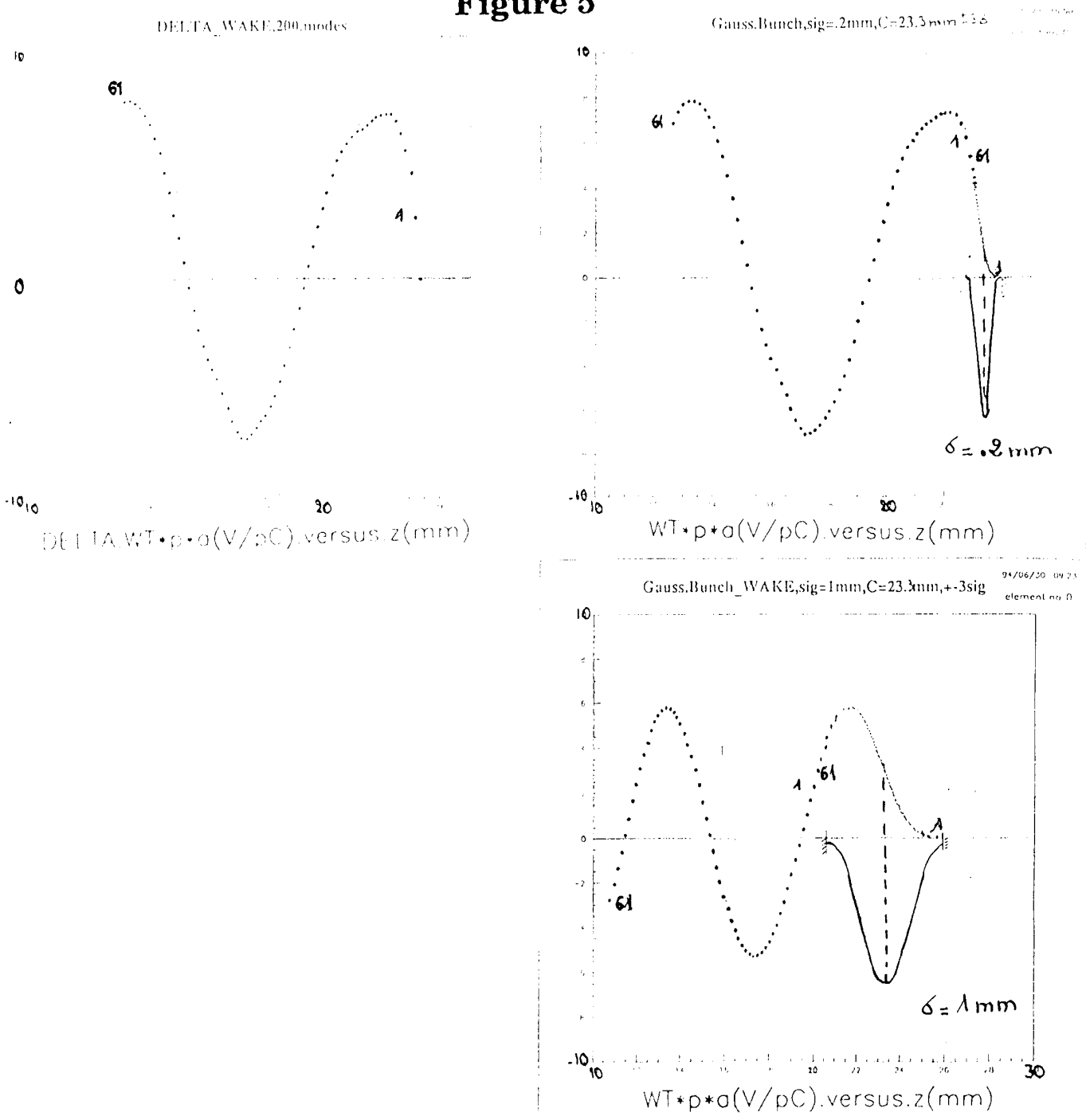
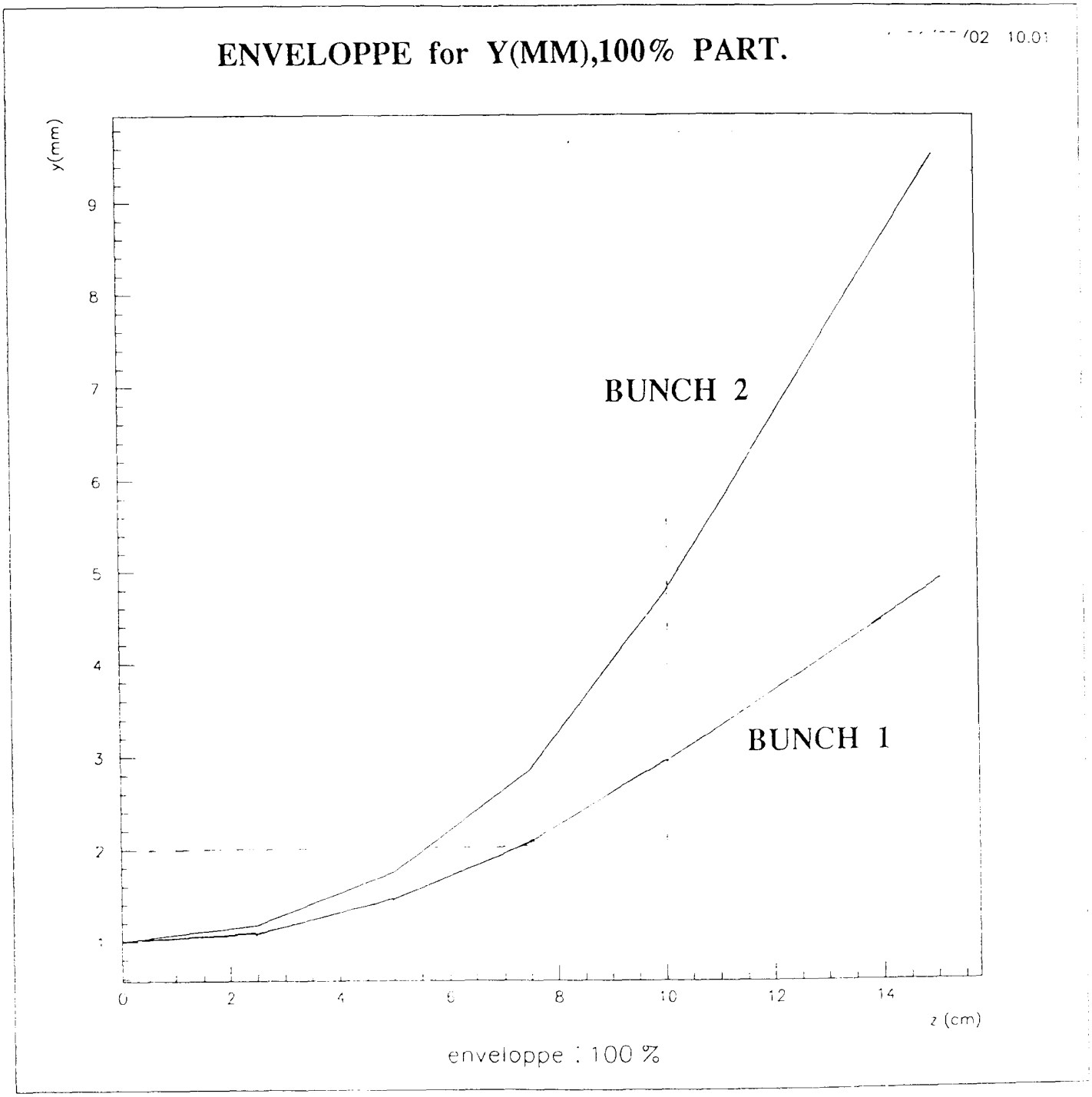
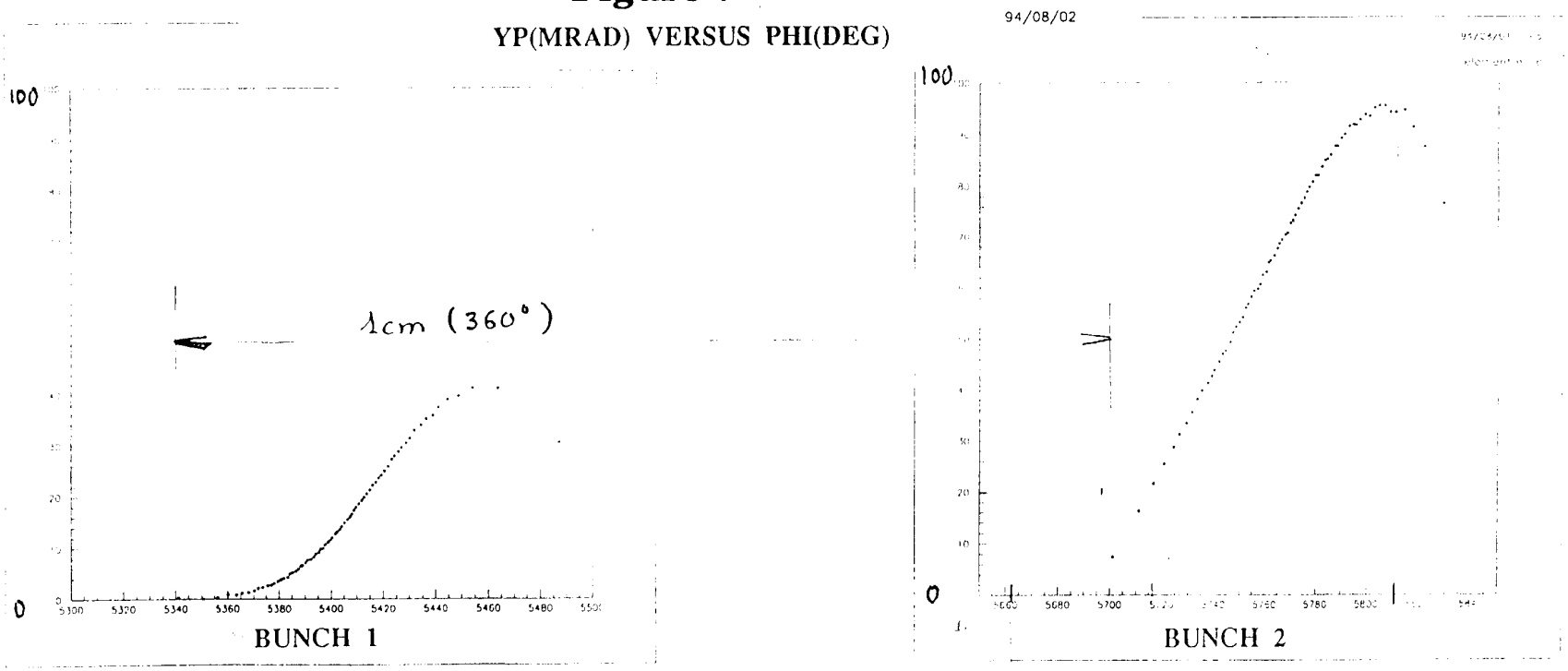

DELTA_WAKE,200modes
10
61
1
0
-10
10
20
DELTA WT*p*a(V/pC).versus.z(mm)
Gauss.Bunch,sig=.2mm,C=23.3mm
10
61
1
61
0
-10
10
20
σ = .2 mm
WT*p*a(V/pC).versus.z(mm)
Gauss.Bunch_WAKE,sig=1mm,C=23.3mm,+-3sig
10
61
1
61
1
0
-10
10
20
30
σ = 1 mm
WT*p*a(V/pC).versus.z(mm)

**Figure 6**


ENVELOPPE for Y(MM),100% PART.
y(mm)
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
z (cm)
BUNCH 2
BUNCH 1
enveloppe : 100 %

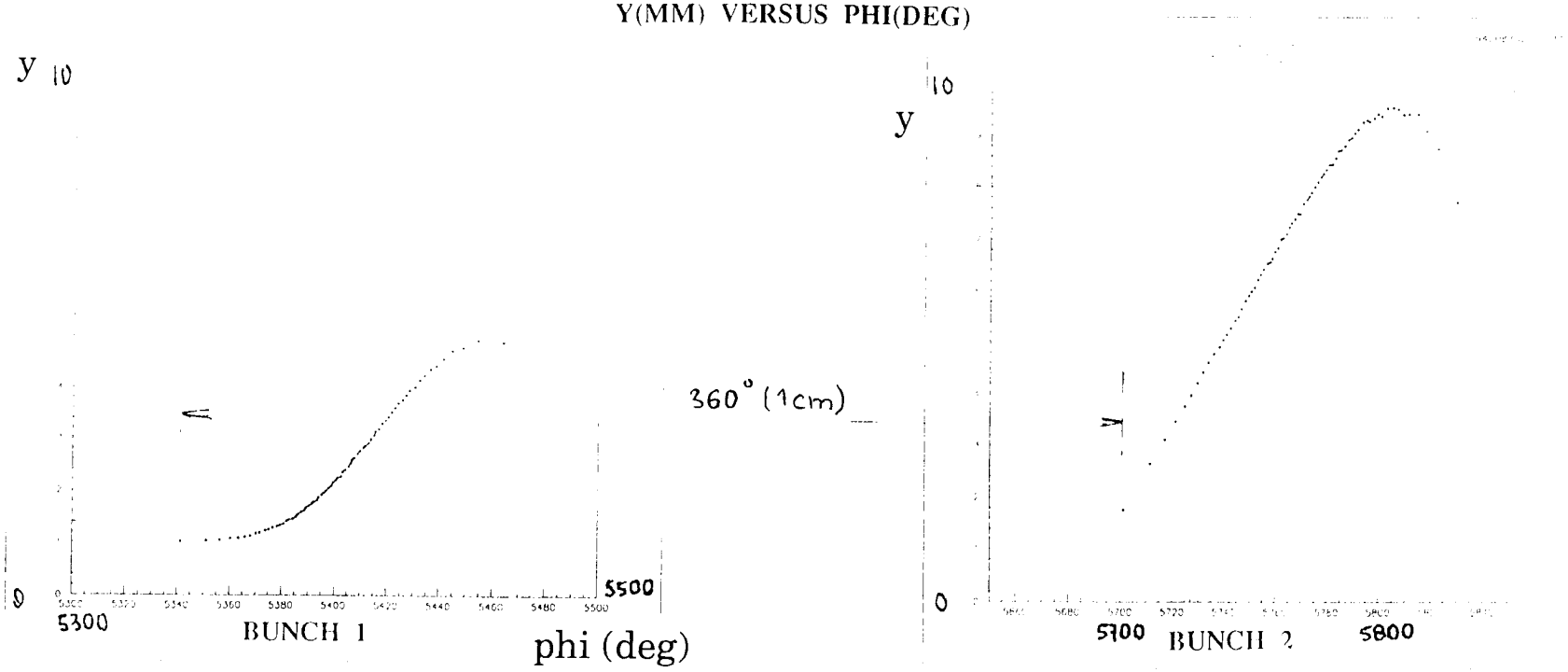
# Figure 7

YP(MRAD) VERSUS PHI(DEG)

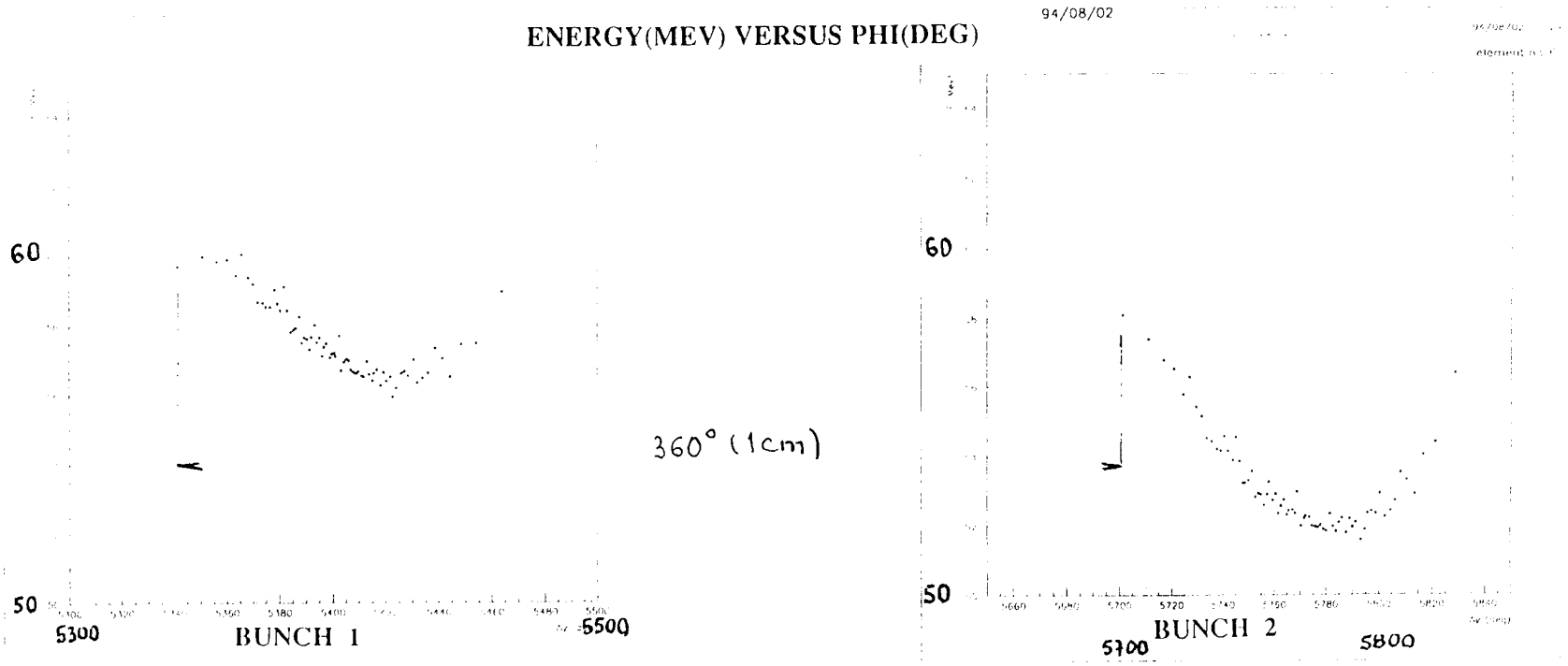


# Figure 8

Y(MM) VERSUS PHI(DEG)

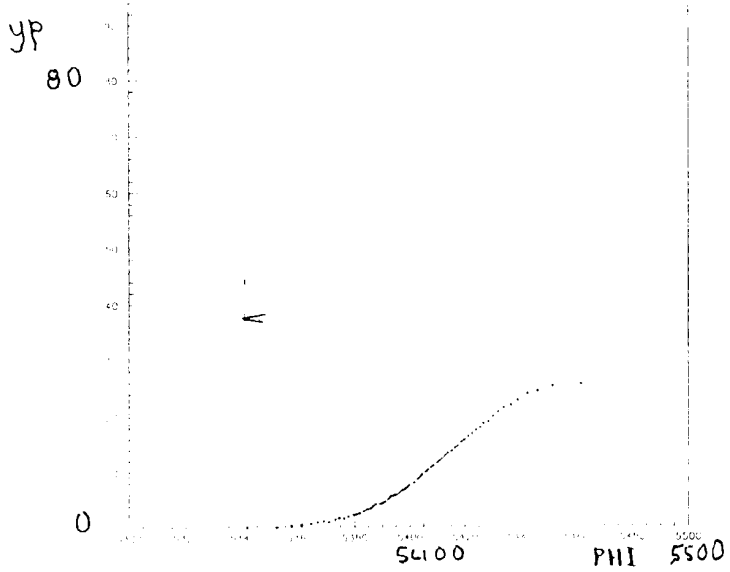


# Figure 9


ENERGY(MEV) VERSUS PHI(DEG)
94/08/02
60
50
5300
5500
BUNCH 1
360° (1cm)
60
50
5700
5800
BUNCH 2

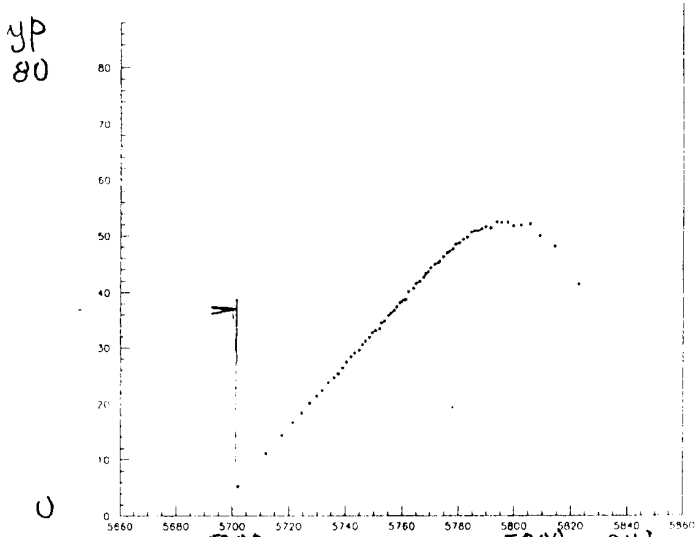
# Figure 10

YP(MRAD) VERSUS PHI(DEG)

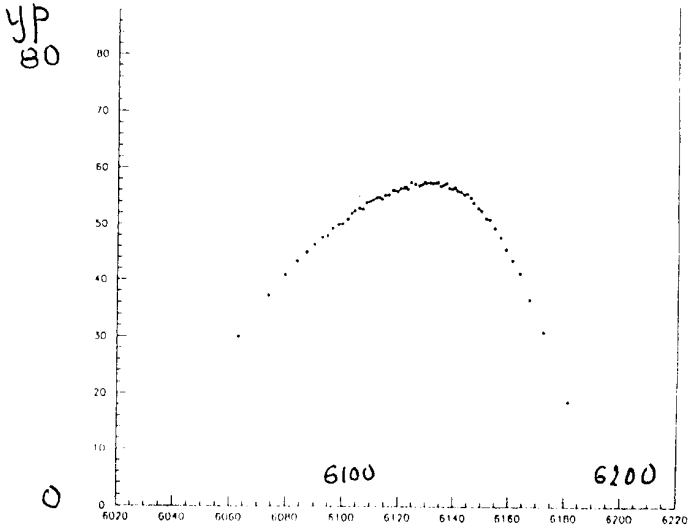



BUNCH 1 out of 3

360° (1 cm)



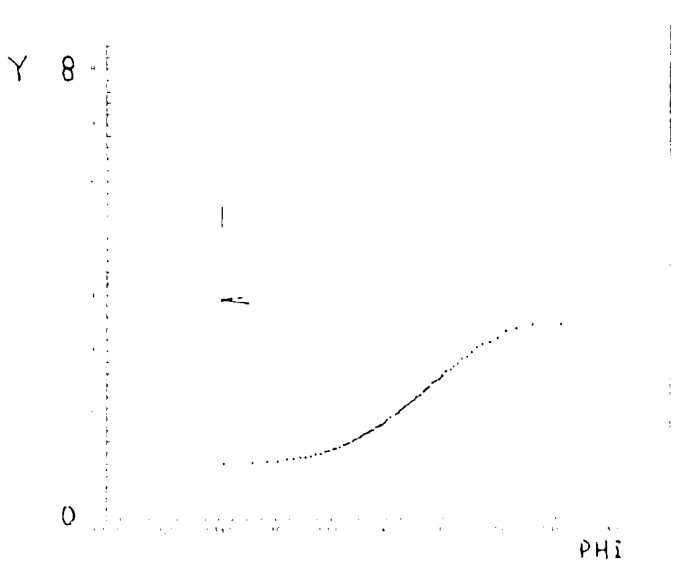

bunch2 out of 3




BUNCH 3 out of 3

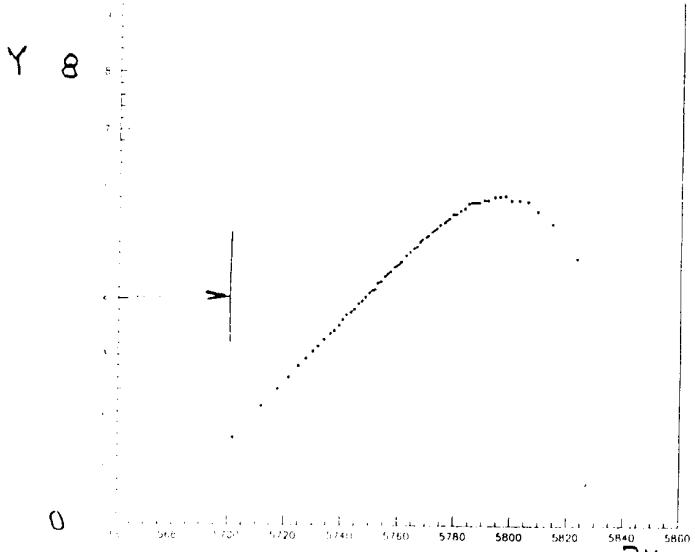
# Figure 11

Y(MM) VERSUS PHI(DEG)

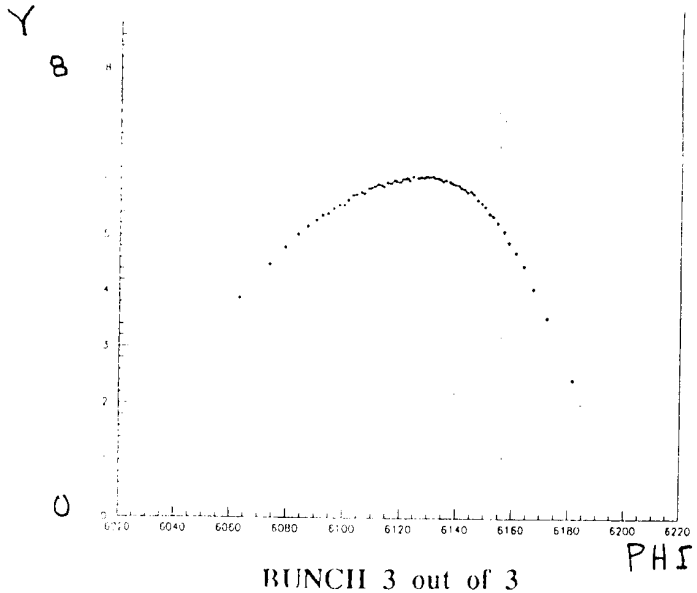



BUNCH 1 out of 3

360° (1cm)




bunch2 out of 3




BUNCH 3 out of 3

# Figure 12

ENERGY(MEV) VERSUS PHI(DEG)