



BNL-105200-2014-TECH

Booster Technical Note No. 156; BNL-105200-2014-IR

## CPLOT: AN APOLLO PLOTTING PROGRAM USING CALCOMP AND GPR

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January 1990

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USDOE Office of Science (SC)

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**C P L O T : A N A P O L L O P L O T T I N G P R O G R A M**  
**U S I N G C A L C O M P A N D G P R**

**A G S**  
**B O O S T E R T E C H N I C A L N O T E**  
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**A. LUCCIO**

**JANUARY 9, 1990**

**A C C E L E R A T O R D E V E L O P M E N T D E P A R T M E N T**  
**B R O O K H A V E N N A T I O N A L L A B O R A T O R Y**  
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# C P L O T : A N A P O L L O P L O T T I N G P R O G R A M U S I N G C A L C O M P A N D G P R

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## 1. Introduction

"cplot", a Fortran plotting program using "calcomp" and "gpr" has been developed to plot on the Apollo workstations line diagrams and any pattern of circles, rectangles, ellipses, etc. The program is currently being used to check the algorithms for the model based control of the AGS Booster.

calcomp is an old graphic package by California Computer Products, Inc., edited by R.G.Wittlock at Brookhaven<sup>1</sup>. gpr is one of graphic packages available on the Apollo workstations<sup>2</sup>. Agnes Abola of the AGS Control Group has created a user library on the AGS Apollo network and has put together calcomp and gpr, to form the basis on which cplot operates.

cplot is by no means a final product, but we find it already very useful as is.

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<sup>1</sup> Wittlock, R.G. "CALCOMP Language Reference Manual", Report BNL 23987, 1978

<sup>2</sup> "Domain Graphics Primitive Resource Call Reference", Apollo Computers Inc., Order No. 007194, Rev 02, 1987  
also: "Programming with Domain Graphics Primitives", Order No. 005808, Rev 01, 1987

## 2. Compile and bind cplot

The fortran-77 source for cplot is in Appendix A. cplot is compiled with the Domain fortran compiler. At the Aegis<sup>3</sup> prompt \$, type:

```
$ftn cplot
```

then, bind with calcomp and gpr as follows:

```
$bind cplot.bin -inlib [dir]/controls.userlib -inlib [dir]/calcomp.gplib -b cplot
```

where (at the present time. If it does not work, ask Agnes):

```
[dir] = /users/operations/com
```

---

<sup>3</sup>Aegis is an Apollo shell command language. See: "Domain System Call Reference", Apollo Computers Inc., Order No. 002547, Rev. 04, 1987.

### 3. Use of cplot. Parameter file

The input is the file "cplot.in" (App. B) containing the following:

```
temp      parameter file  
  
xx      }  
yy      data files (files containing the data to plot )  
....  
zz      }
```

where temp,xx, yy .... zz are any file names

The plot of Fig. 1 (a collection of distorted orbits in the Booster generated by MAD<sup>4</sup> for several random extractions of position and field errors in the magnets) uses the parameter file shown in App. C. This file is a namelist "plotp" input for cplot, containing the following:

title	(will appear on the top of the plot);
xx and yy	dimensions of the plot in screen inches;
xlabel and ylabel	axis labels;
xpmin, xpmax, ypmin, ypmax	minima and maxima of the values we want on each axis, in real coordinates;
isym	in calcomp, Ref <sup>1</sup> , page 3-27, a symbol code for the data point to draw. In the example, isym = 3 means a cross or a "+";
n_data_max	for a curve - self explanatory - to keep low the dimensions of the program;
max_plot	as above;
n_y	how many curves to plot from the same data file;
window	Apollo graphics window, in pixels. In the order: top edge from screen top, left edge from screen left, x-size, y-size.

---

<sup>4</sup> Iselin, F. Ch, and Niederer, J., "The MAD Program (Methodical Accelerator Design, Version 6, User's Reference Manual", Rept. CERN/LEP-TH/87-33, Geneva, April 1987

- Notes: (i) Each label, like the title and the axis labels must be terminated with a \$ sign.  
(ii) The axis are automatically numbered. To obtain nice numbers, xmin-xmax should be a nice multiple of xx. Likewise for ymax-ymin and yy.

For a good use of cplot you want to put bookkeeping informations in the title, to be printed on the graph. For this, the editing Aegis script "ctime" is used. ctime inserts date, time, run id and page # after the title, changing the parameter file into "temp".

Therefore, after cplot.in is prepared, to run the program, first type at the Aegis prompt \$:

```
$ctime [parameter_file] temp [run#] [page #]
```

then invoke cplot:

```
$cplot
```

#### 4. Data files. Data type.

A data file for cplot must have a keyletter representing a data type in row 1, column 1, to specify how to interpret the data which follow, and the keyletter "Q" after the last row of data, column 1. cplot ignores what is written in the remainder of the first row and after the Q. A file may contain many blocks of data, each initiated by a proper keyletter.

Keyletters are:

L

Data are for a solid line plot. The first column is x, the following columns are sets of y. cplot plots n\_ y curves of y vs. x. Example in App. D. At the present, only linear coordinate axis are implemented.

D

Dashed line plot.

X

Scatter plot of the y's vs. x. The symbol used is determined by isym.

R

Draw rectangles. Following calcomp, the data in each line are: the coords of the left lower corner, the x and y dimensions and the rotation angle in degrees. App. E shows the file to plot the Booster layout of Fig. 1.

C

Draw arcs. Data in each line are: the coords of the center, start and end radii (it draws also spirals), start and end angles. Example in App. F, a data file for Fig. 2.

P

Draws straight segments. In each line: start coords, length, angle (in deg) (App. D). If the lines are too long, the routine "inside" clips them, so they stay inside the frame. This is useful if we want to mess up with the window in the parameter file for zooming the plot.

T

Draws text anywhere on the screen. For each test string, a first line gives: the coordinates of the left lower corner of the first character, the height of the characters and the angle of the text string, and a second line gives the string (terminated by a \$). Example in App. G, a data file for Fig. 1.

E

Ellipses. A line represents: coords of the center, x and y axis, angle of rotation (in rad). The phase space ellipses in Fig. 3 (proton injection in the Booster) are obtained with this option.

## Appendix A . Fortran code for "cplot".

```
*****CPLOT.FTN*****
* //acn40d01/reality/luccio/graf
* A.Luccio BNL Sept-1988
* using CALCOMP and GPR
* Modif: Thursday, November 16, 1989 3:57:12 pm (EST)
*****program cplot

c%include '/sys/ins/base.ins.ftn'
c%include '/sys/ins/gpr.ins.ftn'

integer      nzch(10)
integer*2     stream_id,window(4),bitm_size(2)
&           ,b_scale(2),time(3)
character    yorn,data_type
character*64   xlabel,ylabel,zlabel(10),title
character*128  infile,ppar_file,xi_fname,anychar
logical       start,spline

namelist     /plotp/
&           xx,yy,xlabel,ylabel,zlabel,title,
&           xpmin,xpmax,ypmin,ymax,isym,
&           n_data_max,max_plot,n_y,window,
&           spline,interc

common       /plotp/
&           xx,yy,dxp,dyp,b_scale,
&           xpmin,xpmax,ypmin,ymax,isym,
&           xlabel,ylabel,zlabel,title,
&           nxch,nych,nzch,ntch,
&           nv,n_y,n_data_max,max_plot,spline

data        n_data_max,max_plot,window/10000,512,100,500,750,750/
data        stream_id/-1/
&           ,start,spline/.true.,.false./

open        (19,file='cplot.in')

*      write    (*,6000)
6000  format  ('Enter xxx.ppar file: ',$)
*      read    (*,'(a128)') ppar_file
read    (19,'(a128)') ppar_file
*      write    (*,'(a128)') ppar_file
open    (14,file=ppar_file)
read    (14,plotp)
close   (14)

dxp      = (xpmax-xpmin)/xx
dyp      = (ymax-ypmin)/yy
x_t      = 0.1*(xpmax-xpmin)/dxp
h_t      = (ymax-ypmin)/40/dyp
y_t      = 1.025*(ymax-ypmin)/dyp
*      bitm_size(1) = window(3)
*      bitm_size(2) = window(4)
c      b_scale(1)  = bitm_size(1)/xx
c      b_scale(2)  = bitm_size(2)/yy

do i = 1,64
  if (xlabel(i:i) .eq. '$')    nxch = i-1
  if (ylabel(i:i) .eq. '$')    nych = i-1
  if (title(i:i) .eq. '$')    ntch = i-1
  do j = 1,10
    if (zlabel(j)(i:i) .eq. '$') nzch(j) = i-1
  end do
end do
-----
100  continue
*      write    (*,6010)
6010  format  ('Enter xxx.pdat file: ',$)
*      read    (*,'(a128)') infile
```

## Appendix A . Fortran code for "cplot"(continue).

```

      read    (19,'(a128)',end=900) infile
*      write   ('','(a128)') infile
*      if (infile .eq. 'end') goto 900

      if (start) then
        call new_initialize_gpr (window)
        call calinit
        call erase
        call acquire
        call rect  (0.,0.,yy,xx,0.,isym)
        call symbol (x_t,y_t,h_t,title,0.,ntch)
        call release
      endif

      call gpr_$init
      &(gpr_$borrow,int2(1),bitm_size,int2(1),int4(1),status)

      open    (10,file=infile)
200    read    (10,'(a)') data_type
*      print   *,'(1)data_type= ',data_type
      call acquire
      if (data_type.eq.'L' .or.
&      data_type.eq.'X' .or.
&      data_type.eq. 'D')
&      call line_plot  (start,data_type,*100,*200)
      call layout_plot (start,data_type,*100,*200)

900    continue
*      pause
      close   (19)
      write   (*,6020)
6020    format ('Type any char to exit plot: ',\$)
      read   (*,'(a128)') anychar

      call erase
      call terminate_gpr

      end
c-----
c----- subroutine line_plot (start,data_type,*,*)
      parameter  (m=1002)
      integer    nzch(10)
      integer*2   l_scale,b_scale(2),bx(m),by(m)
      integer*4   status
      real       x(m),y(m),z(5,m)
      character  data_type
      character*64 xlabel,ylabel,zlabel(10),title
      logical    start,spline

      common     /plotp/
      &          xx,yy,dxp,dyp,b_scale,
      &          xpmn,xpmax,ypmn,ypmax,isym,
      &          xlabel,ylabel,zlabel,title,
      &          nxch,nych,nzch,ntch,
      &          nv,n_y,n_data_max,max_plot,spline

      lintyp = 0
      if (data_type .eq. 'X') lintyp = -1

100    i      = 1
      read   (10,*,err=104) x(i),(z(k,i), k=1,n_y)
      if (x(i).ge.xpmax) xpmax = x(i)
      if (x(i).le.xpmin) xpmin = x(i)
      do k = 1,n_y
        if (z(k,i).ge.ypmax) ypmax = z(k,i)
        if (z(k,i).le.ypmin) ypmin = z(k,i)
      end do
      i      = i +1
      if (i .gt. n_data_max) goto 104

```

## Appendix A . Fortran code for "cplot"(continue).

```

      goto 100
104    nv     = i-1
      n_skip = nv/max_plot +1
      j      = 0
      do 110 i = 1,nv,n_skip
         j      = j +1
         x(j)  = x(i)
c        bx(j)  = int2(b_scale(1)*(x(j)-xpmin))
      do 110 k = 1,n_y
         z(k,j) = z(k,i)
         nv     = j
         x(nv+1) = xpmin
         x(nv+2) = (xpmax-xpmin)/xx

      do 120   k = 1,n_y
         l_scale = int2(1 +10*(k-i))
         call gpr_Set_linestyle (gpr_Set_dotted,l_scale,status)
         do   i = 1,nv
            y(i)   = z(k,i)
            by(i)  = int2(yy-b_scale(2)*(y(i)-ypmin))
c           print *,k,i,bx(i),by(i)
         end do
         y(nv+1) = ypmmin
         y(nv+2) = (ypmax-ypmmin)/yy
         call rescale
         if (start) then
            call axis (0.,0., xlabel,-nxch,xx,0.,x(nv+1),x(nv+2))
            call axis (0.,0., ylabel,nych,yy,90.,y(nv+1),y(nv+2))
            start = .false.
         endif
         npts   = nv
         if (spline) npts = -nv
*          call fline (x,y,npts,1,lintyp,isym)
*          if ( (k/2).eq.(k/2.) .or.
*               if (
&             data_type .eq. 'D' ) then
              call dash1 (x,y,npts,1,lintyp,isym)
            else
              call line (x,y,npts,1,lintyp,isym)
            endif
            call gpr_Smove (bx(1),by(1),status)
c           call gpr_Set_polyline (bx,by,int2(nv),status)
120    continue

      call release

      backspace (10)
      read    (10,'(a)') data_type
      if (data_type .eq. 'Q') then
*       print '(2) data_type= ',data_type
      close   (10)
      return 1
      else
      backspace (10)
      return 2
      endif
      end
c-----
c----- subroutine layout_plot (start,data_type,*,*)
      integer      nzch(10)
      integer*2    b_scale(2)
      character   data_type
      character*64 xlabel,ylabel,zlabel(10),title,text
      logical      start,spline

      common      /plotp/
                     xx,yy,dxp,dyp,b_scale,

```

## Appendix A . Fortran code for "cplot"(continue).

```

&           xpmmin,xpmmax,ypmin,ypmax,isym,
&           xlabel,ylabel,zlabel,title,
&           nxch,nych,nzch,ntch,
&           nv,n_y,n_data_max,max_plot,spline

if (start) then
  call axis (0.,0.,xlabel,-nxch,xx,0.,xpmmin,dxp)
  call axis (0.,0.,ylabel,nych,yy,90.,ypmin,dyp)
  start = .false.
endif

call rescale

if (data_type .eq. 'R') goto 200
if (data_type .eq. 'C') goto 300
if (data_type .eq. 'P') goto 400
if (data_type .eq. 'T') goto 500
if (data_type .eq. 'E') goto 600
if (data_type .eq. 'Q') goto 900
c----- R: Rectangle
200 read (10,*,err=900) xrr,yrr,w,h,angle
      x_r      = (xrr -xpmmin)/dxp
      y_r      = (yrr -ypmin)/dyp
      hei_r    = h/dyp
      wid_r   = w/dxp
      ang_r   = angle
      call rect (x_r,y_r,hei_r,wid_r,ang_r,3)
      goto 200
c----- C: Circle
300 read (10,*,err=900) xcc,ycc,rcc1,rcc2,angle1,angle2
      x_c      = (xcc -xpmmin)/dxp
      y_c      = (ycc -ypmin)/dyp
      rad_c1   = rcc1/dyp
      rad_c2   = rcc2/dyp
      ang_c1   = angle1
      ang_c2   = angle2
      call circl (x_c,y_c,ang_c1,ang_c2,rad_c1,rad_c2,0.5)
      goto 300
c----- P: Polygon
400 read (10,*,err=900) xll,yll,sll,angle
      call inside (xll,yll,sll,angle,data_type)
      if (sll .eq. 0.) goto 400
      i_l      = i_l +1
      x_l      = (xll -xpmmin)/dxp
      y_l      = (yll -ypmin)/dyp
      s_len    = sll/dyp
      ang_l    = angle
      call poly (x_l,y_l,s_len,1.,ang_l)
      goto 400
c----- T: Text
500 read (10,*,err=900) xtt,ytt,htt,angle
*   print *, 'xt,yt,ht,angle= ',xtt,ytt,htt,angle
read (10,'(a64)') text
*   print *, 'text=' ,text
      i_t      = i_t +1
      x_t      = (xtt -xpmmin)/dxp
      y_t      = (ytt -ypmin)/dyp
      hei_t    = htt/dyp
      ang_t    = angle
      do i = 1,64
        if (text(i:i) .eq. '$') n_t = i-1
      end do
      call symbol (x_t,y_t,hei_t,text,ang_t,n_t)
      goto 500
c----- E: Ellipse
600 read (10,*,err=900) xc,yc,a,b,theta
      aa      = a*sqrt((cos(theta)/dxp)**2 +(sin(theta)/dyp)**2)
      bb      = b*sqrt((sin(theta)/dxp)**2 +(cos(theta)/dyp)**2)
      xxc    = (xc-xpmmin)/dxp
      yyc    = (yc-ypmin)/dyp
      angle   = atan2((dxp*tan(theta)),dyp)

```

## Appendix A , Fortran code for "cplot"(continue),

```

      dega      = angle*180/3.141592654
      xpage    = xxc +aa*cos(angle)
      ypage    = yyc +aa*sin(angle)
      call elips (xpage,ypage,aa,bb,dega,0.,360.,3)
      goto 600
c----- P: Polygon
900  call release
      backspace (10)
      read     (10,'(a)') data_type
      *      if (data_type .eq. 'Q') then
            print *, '(3) data_type= ',data_type
            close   (10)
            return  1
      else
            backspace (10)
            return  2
      endif
      end
c-----
c----- subroutine inside (xl,yl,s1,angle,data_type)
      integer      nzch(10)
      integer*2    b_scale(2)
      dimension    x(6),y(6),xc(2),yc(2)
      character*64 xlabel,label,zlabel(10)
      character    data_type
      logical      spline
      common       /plotp/
      &           xx,yy,dxp,dyp,b_scale,
      &           xpmmin,xpmmax,ypmmin,ypmmax,isym,
      &           xlabel,label,zlabel,title,
      &           nxch,nych,nzch,ntch,
      &           nv,n_y,n_data_max,max_plot,spline
      data        pie/3.14159265/
      if (data_type .eq. 'P') goto 100
100   theta    = angle*pie/180
      do 110 i  = 1,5,2
            x(i)    = xl
            x(i+1)  = xl +s1*cos(theta)
            y(i)    = yl
            y(i+1)  = yl +s1*sin(theta)
      if (x(1) .eq. x(2)) goto 130
            x(3)    = xpmmin
            x(4)    = xpmmax
      do 120 i  = 3,4
            y(i)    = y(1) +(x(i)-x(1))*tan(theta)
      130  if (y(1) .eq. y(2)) goto 150
            y(5)    = ypmmin
            y(6)    = ypmmax
      do 140 i  = 5,6
            x(i)    = x(1) +(y(i)-y(1))/tan(theta)
            xold   = 9999
            yold   = 9999
            j      = 1
      do 160 i  = 1,6
            if (j .gt. 2) goto 170
            if ( (x(i)-xpmmax)*(x(i)-xpmmin) .le. 0
      & .and. (y(i)-ypmmax)*(y(i)-ypmmin) .le. 0
      & .and. (x(i).ne.xold .or. y(i).ne.yold)) then
                  xc(j) = x(i)
                  yc(j) = y(i)
                  xold  = x(i)
                  yold  = y(i)
      170  continue
      600  end
      end

```

## Appendix A . Fortran code for "cplot"(continue).

```
      j      = j +1
160  endif
     continue

170  xl      = xc(1)
     yl      = yc(1)
     sl      = sqrt((xc(2)-xc(1))**2 +(yc(2)-yc(1))**2)
     if (j .le. 2) sl = 0
     angle   = 90
     if (xc(2).ne.xc(1)) then
       theta  = atan2( (yc(2)-yc(1)) , (xc(2)-xc(1)) )
       angle  = theta*180/pie
     endif
200  continue
     return
end
*****
```

Appendix B. Input to "cplot". File "cplot.in".

```
temp  
/users/luccio/plots/data/linear.pdat  
/users/luccio/plots/data/kick_layout.pdat  
/users/luccio/orbit/kick.pdat  
/users/luccio/orbit/orbit.a.pdat  
/users/luccio/orbit/orbit.w.pdat  
/users/luccio/orbit/orbit.z.pdat
```

---

Appendix C. Parameter file containing the namelist \$plotp. This file is transformed to "temp".

```
$plotp  
  title='BNL AGS BOOSTERS'  
  xx=9.  
  yy=7.  
  xlabel='s (m)$'  
  ylabel='x or y (mm)$'  
  xpmmin=-30.  
  xpmmax=240.  
  ypmmin=-15.  
  ypmmax=20.  
  isym=3,  
  n_data_max=1000  
  max_plot=512  
  n_y=2  
  window=0,100,900,750  
$
```

Appendix D. To plot a line graph. This makes a pair of curves for Fig. 1. The content of the first row, after "L" is ignored, as well as the informations after "Q".

L	s	xc	yc
	0.308	9.568	-1.004 MONV
	4.511	10.043	-0.105 MONH
	8.715	10.097	1.047 MONV
	12.919	10.459	0.835 MONH
	17.123	10.307	1.398 MONV
	21.326	10.133	0.226 MONH
	25.530	9.706	-1.039 MONV
	29.734	8.788	-1.027 MONH
	33.938	9.259	-2.101 MONV
	38.141	9.049	-0.808 MONH
	42.345	9.616	-0.149 MONV
	46.549	10.047	0.354 MONH
	50.753	10.247	1.179 MONV
	54.956	10.568	0.292 MONH
	59.160	10.504	-0.576 MONV
	63.364	10.980	-0.607 MONH
	67.568	10.414	-1.400 MONV
	71.771	10.552	-0.752 MONH
	75.975	13.940	-0.843 MONV
	80.179	21.633	-0.132 MONH
	84.383	14.783	0.240 MONV
	88.586	10.994	0.167 MONH
	92.790	10.254	0.357 MONV
	96.994	9.531	0.136 MONH
	101.198	9.435	0.068 MONV
	105.401	8.742	-0.079 MONH
	109.605	9.388	-0.475 MONV
	113.809	9.761	-0.560 MONH
	118.013	10.312	-1.183 MONV
	122.216	11.458	-0.550 MONH
	126.420	11.150	-0.469 MONV
	130.624	11.874	-0.064 MONH
	134.828	10.568	0.415 MONV
	139.031	9.783	0.076 MONH
	143.235	9.480	-0.557 MONV
	147.439	8.472	-0.542 MONH
	151.643	8.893	-0.909 MONV
	155.846	8.454	-0.298 MONH
	160.050	9.441	0.230 MONV
	164.254	10.076	0.662 MONH
	168.458	10.461	1.720 MONV
	172.661	11.410	1.079 MONH
	176.865	10.918	1.320 MONV
	181.069	10.837	0.125 MONH
	185.273	9.886	-1.223 MONV
	189.476	8.868	-1.254 MONH
	193.680	9.182	-2.470 MONV
	197.884	8.720	-1.087 MONH
Q	tunes	B_rho	
	4.731051	4.692142	2.148156
	beta_x_max=	13.49146	beta_y_max= 13.29091
	xcmax=	11.63300	xcmin= -1.546000
	ycmax=	1.720000	ycmin= -2.470000
	<xx>=	0.3966875	s(x)= 2.025079
	<y>=	-0.2153542	s(y)= 0.8719825

Appendix E (partial). To plot rectangles and segments. To plot the Booster layout of Fig. 1

<b>P</b>	-4.00000000 0.00000000 35.000000 0.00000000
	-4.00000000 -10.000000 35.000000 0.00000000
	0.00000000 -15.000000 35.000000 90.000000
<b>R</b>	-0.25187500 -12.000000 0.5037500 2.000000 0.0000000 QV
	3.95187500 -10.000000 0.5037500 2.000000 0.0000000 QH
	4.75562500 -11.500000 2.400000 3.000000 0.0000000 DH
	8.15562500 -12.000000 0.5037500 2.000000 0.0000000 QV
	8.95937500 -11.500000 2.400000 3.000000 0.0000000 DH
	12.35937500 -10.000000 0.5037500 2.000000 0.0000000 QF
	16.5631250 -12.000000 0.5037500 2.000000 0.0000000 QV
	17.36687500 -11.500000 2.400000 3.000000 0.0000000 DH
	20.76687500 -10.000000 0.5037500 2.000000 0.0000000 QH
	21.570625 -11.500000 2.400000 3.000000 0.0000000 DH
	24.9706250 -12.000000 0.5037500 2.000000 0.0000000 QV
	25.77437500 -11.500000 2.400000 3.000000 0.0000000 DH
	29.17437500 -10.000000 0.5037500 2.000000 0.0000000 QH
	29.9781250 -11.500000 2.400000 3.000000 0.0000000 DH
<b>P</b>	33.6300000 -15.00000 35.00000 90.00000
<b>R</b>	33.3781250 -12.00000 0.5037500 2.000000 0.0000000
	37.5818750 -10.00000 0.5037500 2.000000 0.0000000
	38.3856250 -11.50000 2.400000 3.000000 0.0000000
	41.7856250 -12.00000 0.5037500 2.000000 0.0000000
	42.5893750 -11.50000 2.400000 3.000000 0.0000000
	45.9893750 -10.00000 0.5037500 2.000000 0.0000000
	50.1931250 -12.00000 0.5037500 2.000000 0.0000000
	50.9968750 -11.50000 2.400000 3.000000 0.0000000
	54.3968750 -10.00000 0.5037500 2.000000 0.0000000
	55.2006250 -11.50000 2.400000 3.000000 0.0000000
	58.6006250 -12.00000 0.5037500 2.000000 0.0000000
	59.4043750 -11.50000 2.400000 3.000000 0.0000000
	62.8043750 -10.00000 0.5037500 2.000000 0.0000000
	63.6081250 -11.50000 2.400000 3.000000 0.0000000
<b>P</b>	67.2600000 -15.00000 35.00000 90.00000
<b>R</b>	67.0081250 -12.00000 0.5037500 2.000000 0.0000000
	71.2118750 -10.00000 0.5037500 2.000000 0.0000000
	72.0156250 -11.50000 2.400000 3.000000 0.0000000
	75.4156250 -12.00000 0.5037500 2.000000 0.0000000
	76.2193750 -11.50000 2.400000 3.000000 0.0000000
	79.6193750 -10.00000 0.5037500 2.000000 0.0000000
	83.8231250 -12.00000 0.5037500 2.000000 0.0000000
	84.6268750 -11.50000 2.400000 3.000000 0.0000000
	88.0268750 -10.00000 0.5037500 2.000000 0.0000000
	88.8306250 -11.50000 2.400000 3.000000 0.0000000
	92.2306250 -12.00000 0.5037500 2.000000 0.0000000
	93.0343750 -11.50000 2.400000 3.000000 0.0000000
	96.4343750 -10.00000 0.5037500 2.000000 0.0000000
	97.2381250 -11.50000 2.400000 3.000000 0.0000000
<b>P</b>	100.890000 -15.00000 35.00000 90.00000
<b>R</b>	100.638125 -12.00000 0.5037500 2.000000 0
	104.841875 -10.00000 0.5037500 2.000000 0
	105.645625 -11.50000 2.400000 3.000000 0
	109.045625 -12.00000 0.5037500 2.000000 0
	109.849375 -11.50000 2.400000 3.000000 0
	113.249375 -10.00000 0.5037500 2.000000 0
	117.453125 -12.00000 0.5037500 2.000000 0
	118.256875 -11.50000 2.400000 3.000000 0
	121.656875 -10 2.400000 3.000000 0
	122.460625 0.5037500 2.000000 0
	125.86 0.5037500 2.000000 0
	126 0.5037500 2.000000 0

**Appendix F.** To plot rectangles and circles. This is used for the "circular layout" of Fig. 2.  
The coordinates are obtained by trigonometry from the "linear layout".

R							
-0.2461051	31.61304	0.5000000	0.7500000	0.4460343	1	qd	
0.5414103	31.60936	2.400000	1.000000	-0.9812753	2	b	
3.909375	31.62327	0.5000000	0.7500000	-7.047342	3	qf	
4.659013	31.26881	2.400000	1.000000	-8.474651	4	b	
7.937262	30.60138	0.5000000	0.7500000	-14.54072	5	qd	
11.95404	29.53668	0.5000000	0.7500000	-22.03409	6	qf	
12.58652	29.00042	2.400000	1.000000	-23.46140	7	b	
15.58067	27.50796	0.5000000	0.7500000	-29.52746	8	qd	
16.26102	27.11133	2.400000	1.000000	-30.95478	9	b	
19.18549	25.44074	0.5000000	0.7500000	-37.02084	10	qf	
22.16414	22.54320	0.5000000	0.7500000	-44.51422	11	qd	
22.71878	21.98412	2.400000	1.000000	-45.94152	12	b	
25.11177	19.61411	0.5000000	0.7500000	-52.00759	13	qf	
25.39175	18.83358	2.400000	1.000000	-53.43490	14	b	
27.25479	16.01940	0.5000000	0.7500000	-59.55450	15	qd-----	
27.64536	15.33555	2.400000	1.000000	-60.98180	16	b	
29.34136	12.42574	0.5000000	0.7500000	-67.04787	17	qf	
29.40920	11.59931	2.400000	1.000000	-68.47518	18	b	
30.47028	8.426539	0.5000000	0.7500000	-74.54124	19	qd	
31.55657	4.415535	0.5000000	0.7500000	-82.03463	20	qf	
31.40839	3.599674	2.400000	1.000000	-83.46193	21	b	
31.61292	0.2604267	0.5000000	0.7500000	-89.52800	22	qd	
31.60960	-0.5270912	2.400000	1.000000	-90.95531	23	b	
31.62504	-3.895047	0.5000000	0.7500000	-97.02137	24	qf	
30.60498	-7.923398	0.5000000	0.7500000	-104.5147	25	qd	
30.39812	-8.683267	2.400000	1.000000	-105.9421	26	b	
29.54209	-11.94065	0.5000000	0.7500000	-112.0081	27	qf	
29.00612	-12.57338	2.400000	1.000000	-113.4354	28	b	
27.50045	-15.59390	0.5000000	0.7500000	-119.5550	29	qd-----	
27.10350	-16.27406	2.400000	1.000000	-120.9823	30	b	
25.43151	-19.19772	0.5000000	0.7500000	-127.0484	31	qf	
24.74971	-19.66969	2.400000	1.000000	-128.4757	32	b	
22.53253	-22.17498	0.5000000	0.7500000	-134.5418	33	~	
19.60202	-25.12121	0.5000000	0.7500000	-142.0351			
18.82136	-25.40081	2.400000	1.000000	-14~			
16.03175	-27.24753	0.5000000	0.7500000				-----
15.34807	-27.63841	2.400000	1.000000				line b #1
12.43903	-29.33573	0.5000000					q 2
8.440332	-30.46647	0.5000000					q 3
7.678844	-30.66725						q 4
4.429836	-31.5~						q 5
3.613896	-~						q 6
0.245??	-~						b #7
-0~	-~						b #8
							q 9
							b #10
							q 11
							b #12
							q 13
							q 14
							q 15
							q 16
							q 17
							q 18
C							
C	32.11400	0.0000000	32.11400	32.11400	0.0000000	360.0000	
P							
P	0.0000000	35.32540	70.65079	-90.00000			
	-30.59269	-17.66270	70.65079	30.00000			
	-30.59269	17.66270	70.65079	-30.00000			
	-56.19433	2.628707	40.00000	-59.61690	inj. line		
	-51.13654	-5.997922	12.02995	-52.11690		1 to 7	
	-43.74952	-15.49274	1.633728	-20.57690		7 to 8	
	-42.22002	-16.06694	2.234032	10.96310		8 to 10	
	-40.02676	-15.64207	5.656758	42.50310		10 to 12	
	-35.85637	-11.82020	14.00602	74.04310		12 to 19	
Q							
Q	//node_140cl/users/luccio/plots/data						
	Thursday, January 5, 1989	11:17:26 am (EDT)					

Appendix G (partial). To plot text. For Fig. 1

P	-4.00000000	0.0000000	35.00000	0.0000000
	-4.00000000	10.0000000	35.00000	0.0000000
T	-28.0000000	11.00000	0.5000000	0.0000000
HORIZONTALS	-28.0000000	1.00000	0.5000000	0.0000000
VERTICALS	15.0000000	-6.00000	0.5000000	0.0000000
A\$	4.00200000	10.00000	0.4000000	0.0000000
1\$	11.4090000	10.00000	0.4000000	0.0000000
2\$	20.8170000	10.00000	0.4000000	0.0000000
3\$	29.2240000	10.00000	0.4000000	0.0000000
4\$	49.0000000	-6.00000	0.5000000	0.0000000
B\$	37.4280000	10.00000	0.4000000	0.0000000
1\$	45.8360000	10.00000	0.4000000	0.0000000
2\$	54.2430000	10.00000	0.4000000	0.0000000
3\$	61.6510000	10.00000	0.4000000	0.0000000
4\$	83.0000000	-6.00000	0.5000000	0.0000000
C\$	70.8540000	10.00000	0.4000000	0.0000000
1\$	79.2620000	10.00000	0.4000000	0.0000000
2\$	87.6690000	10.00000	0.4000000	0.0000000
3\$	96.0770000	10.00000	0.4000000	0.0000000
4\$	115.0000000	-6.00000	0.5000000	0.0000000
D\$	104.281000	10.00000	0.4000000	0.0000000
1\$	111.688000	10.00000	0.4000000	0.0000000
2\$	120.596000	10.00000	0.4000000	0.0000000
3\$	129.503000	10.00000	0.4000000	0.0000000
4\$	150.000000	-6.00000	0.5000000	0.0000000
E\$	137.707000	10.00000	0.4000000	0.0000000
1\$	146.114000	10.00000	0.4000000	0.0000000
2\$	154.522000	10.00000	0.4000000	0.0000000
3\$	161.929000	10.00000	0.4000000	0.0000000
4\$	182.000000	-6.00000	0.5000000	0.0000000
F\$	171.133000	10.00000	0.4000000	0.0000000
1\$	179.541000	10.00000	0.4000000	0.0000000
2\$	187.948000	10.00000	0.4000000	0.0000000
3\$	196.351000	10.00000	0.4000000	0.0000000
4\$				

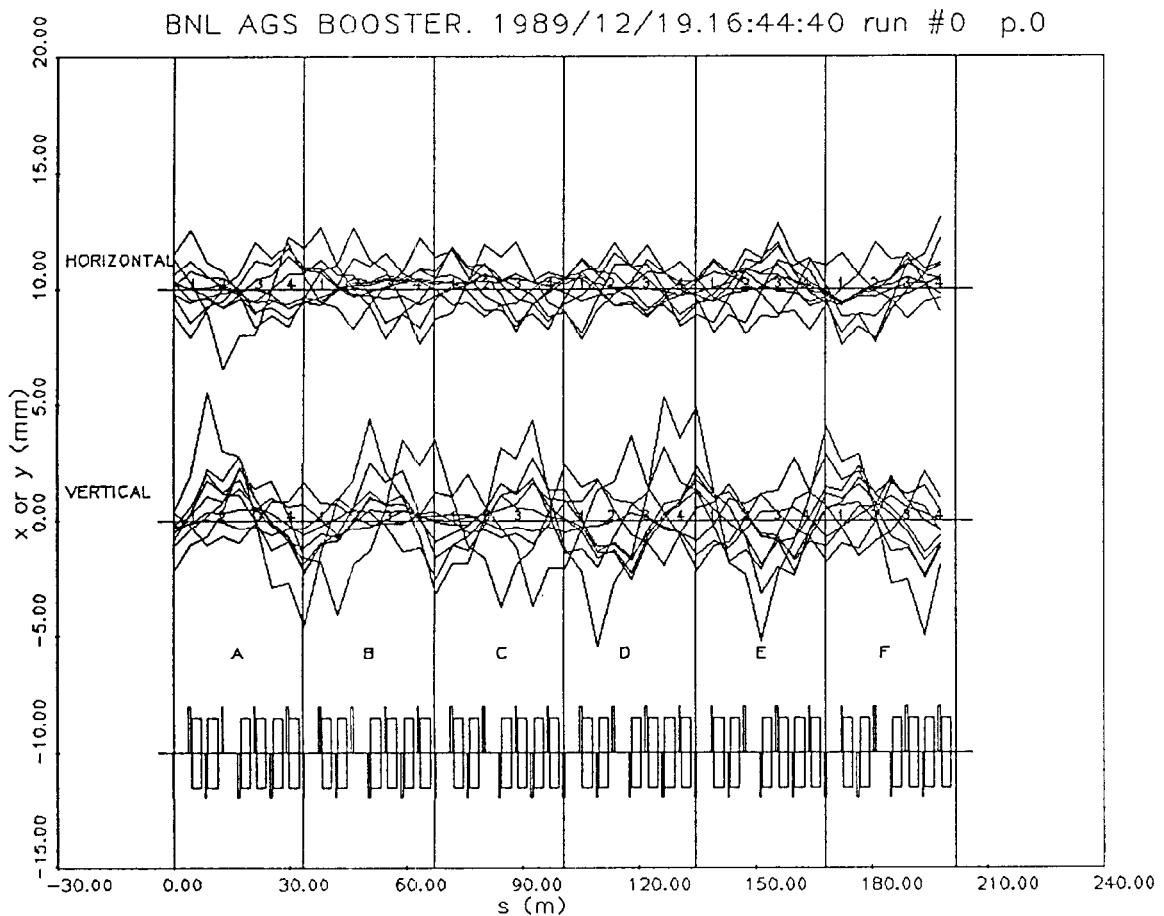


Fig. 1. A collection of distorted orbits in the Booster obtained by random extraction of errors of position, angle and field in the magnets.

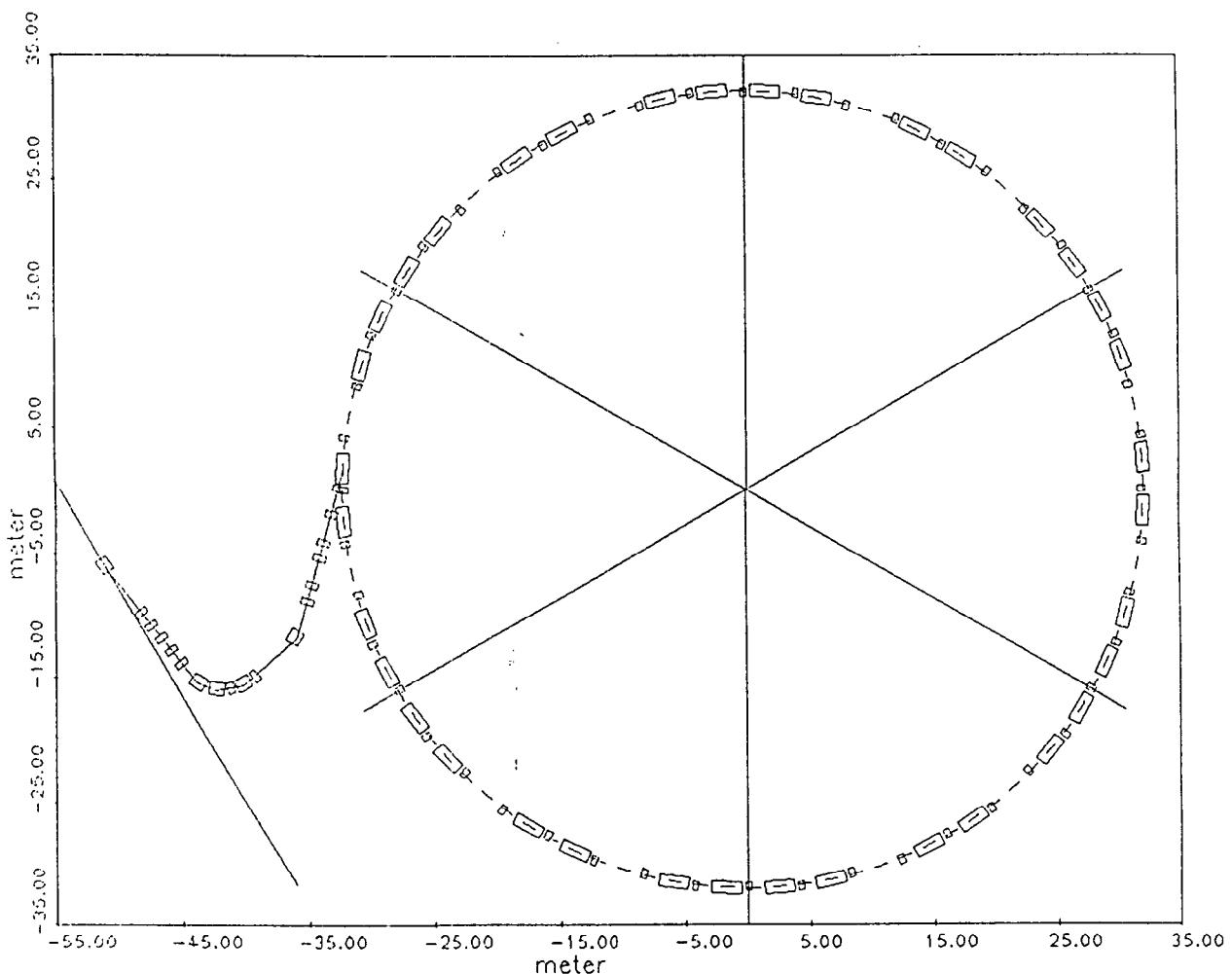


Fig. 2. "Circular layout" of the Booster and the proton injection line.

BOOSTER. 1989/05/12.11:11:26 run #1 p.26

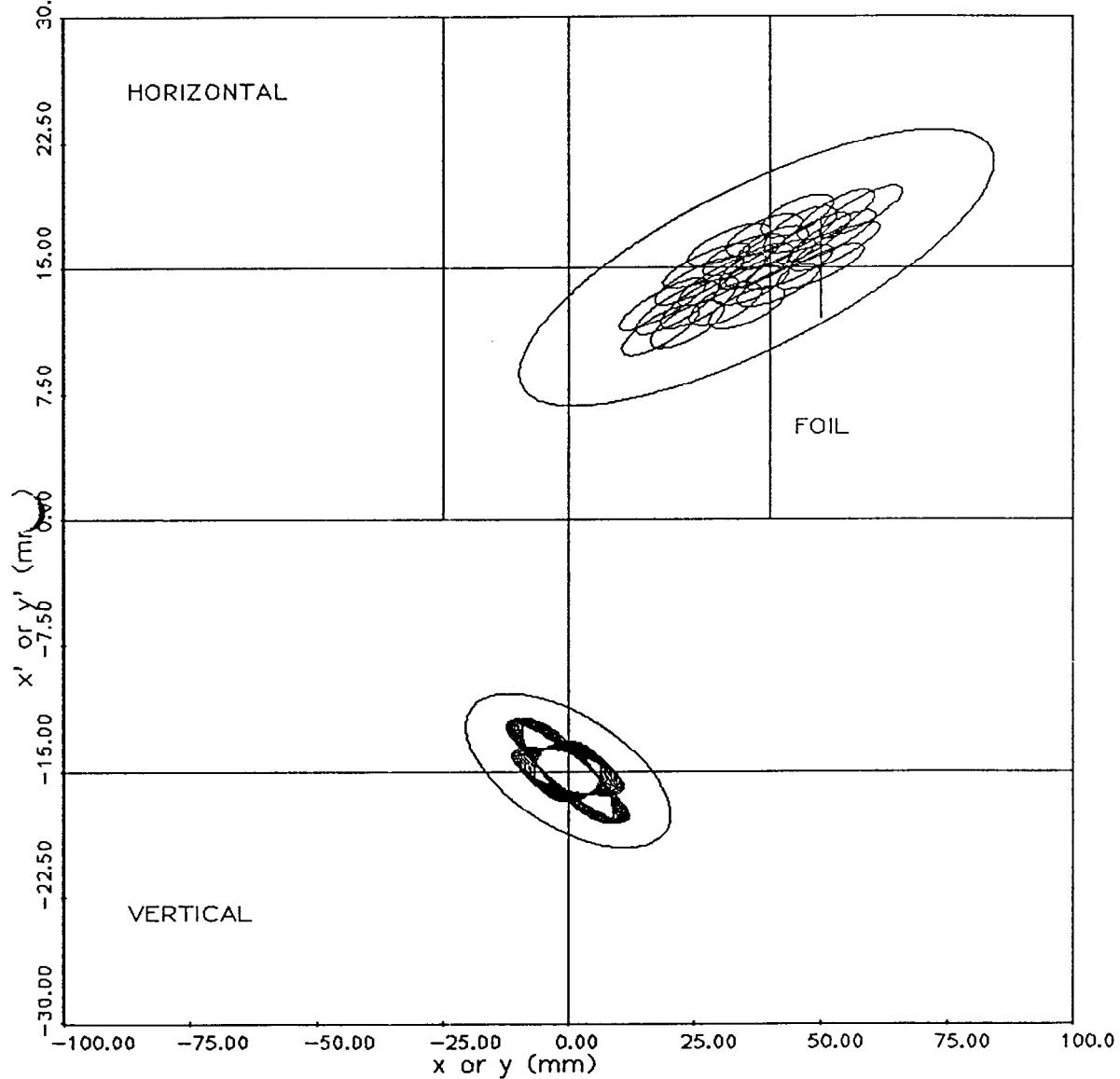


Fig. 3. Injection of protons in the Booster. The acceptance phase space ellipses and the injected proton emittances are shown.