PS/AR Note 94-01 (Min.)

SAP-08

13 January 1994

Minutes of the Forum of

Symbolic Computing for Accelerator Physics

held on Friday 16 December 1993

Present: B. Autin (Chairman), M. Bouthéon, G. de Rijk, W. Fischer, S. Hancock, J. Jowett (Deputy), M. Martini (Secretary), D. Manglunki, S. Maury, T. Risselada, F. Schmidt, J.C. Schnuriger, A. Verdier, E. Wildner, V. Ziemann.

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1 Contributions to CHEP94 conference: B. Autin

The CHEP94 (Computing for High-Energy Physics) conference is open to all activities connected to High-Energy Physics: Detectors, accelerators, controls ...
Topics for this conference will be discussed in the next SAP Forum.

2 Implementation of a steering program in the PS Control System: M. Martini

Program in directory: `g:\home\m\martinim\steering.ma`.

A method for the corrections of beam trajectories in the transport lines has been implemented in the present PS control system. The method is based on the measurement of beam profiles at three different SEMgrids installed in the transfer line, from which the beam positions at the monitor locations are derived. The beam positions are then corrected using steering magnets by means of the MICADO strategy.
The method corrects the trajectory using a small number of magnets with an iterative method based on least squares theory. It selects the "best magnet" that yields a good correction. The residual trajectory is then re-analyzed and the next "best magnet" is selected. The iterations proceed until the residual trajectory is sufficiently small.
MICADO algorithm has been coded in *Mathematica*. It is called through *MathLink* connection by a control application written in *C*, linked to the standard emittance measurement software installed in the PS control system.

A correction, with two dipoles, of the beam trajectory at SEMgrid locations in the PS to SPS transfer line (TT2) is shown in the attached slides.

3 Representation of coupled motions on KAM tori: D. Manglunki

Program in directory: `g:\home\d\django\acc_phys \kamtorus.ma`.

Ideas about representations of the motion (x, x', y, y') of a dynamical system on a 4-dimensional phase-space torus are presented. Each of the two generating circles of the torus is the projection of the 4-dimensional phase-space on either the (x, x') or the (y, y') phase-plane.
Included in the notebook is a function which returns the form of a magnetic field of arbitrary order and skewness.

See the attached slide.

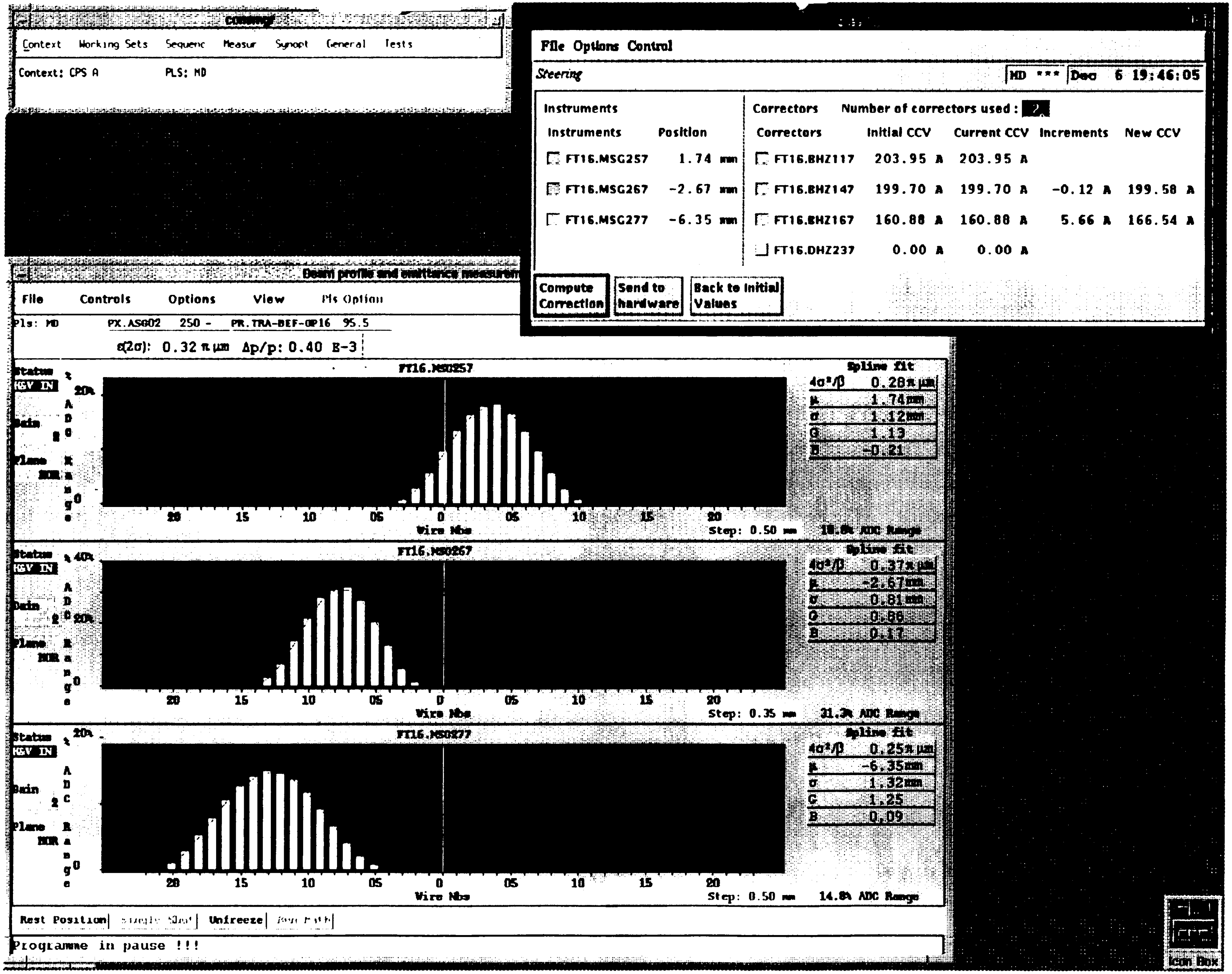
The next meeting will be held on:

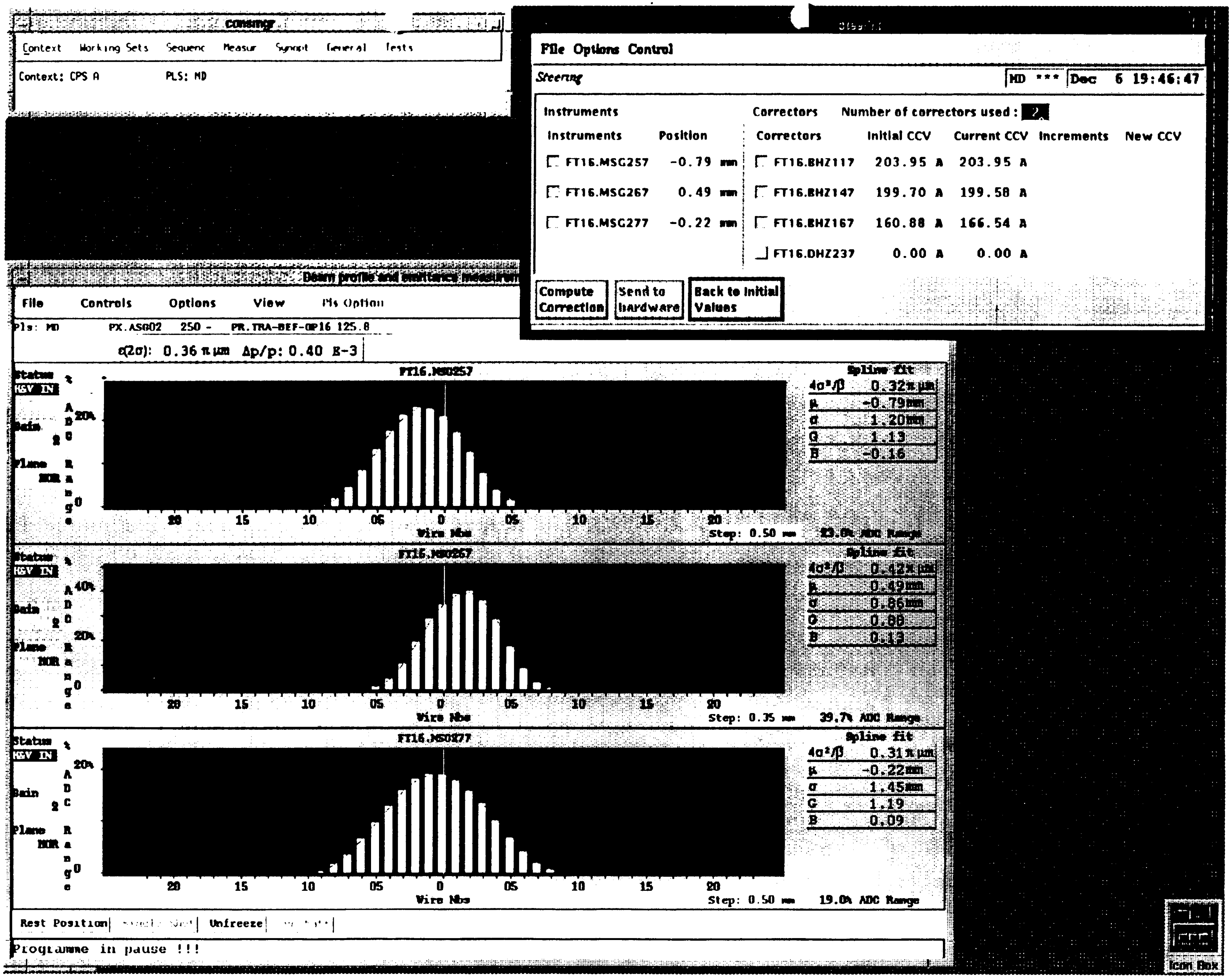
Friday 28 January at 16.00 hr in the PS Auditorium - Meyrin, Bldg 6, 2-024

M. Martini

Distribution list

AT, MT, PS and SL Division Leaders and Deputies.
AT, MT, PS and SL Group Leaders and Associates.
SAP list.


Context Working Sets Sequenc Measur Synopt General Tests
Context: CPS A PLS: MD
File Options Control
Steering
MD *** Dec 6 19:46:05
Instruments
Instruments Position
FT16.MSG257 1.74 mm
FT16.MSG267 -2.67 mm
FT16.MSG277 -6.35 mm
Correctors Number of correctors used : 2
Correctors Initial CCV Current CCV Increments New CCV
FT16.BHZ117 203.95 A 203.95 A
FT16.BHZ147 199.70 A 199.70 A -0.12 A 199.58 A
FT16.BHZ167 160.88 A 160.88 A 5.66 A 166.54 A
FT16.DHZ237 0.00 A 0.00 A
Compute Correction
Send to hardware
Back to Initial Values
File Controls Options View
Pls: MD PX.ASG02 250 - PR.TRA-BEF-OP16 95.5
ε(2σ): 0.32 π µm Δp/p: 0.40 E-3
FT16.MSG257
Spline fit
4σ²/β 0.28π µm
µ 1.74mm
σ 1.12mm
Step: 0.50 mm
Wire Nbs
FT16.MSG267
Spline fit
Step: 0.35 mm
31.3% ADC Range
Wire Nbs
FT16.MSG277
Spline fit
4σ²/β 0.25π µm
µ -6.35mm
σ 1.32mm
C 1.25
B 0.09
Step: 0.50 mm
14.8% ADC Range
Wire Nbs
Rest Position
Unfreeze
Programme in pause !!!
Icon Box


consmgr
Context Working Sets Sequenc Measur Synopt General Tests
Context: CPS A PLS: MD
File Options Control
Steering
MD *** Dec 6 19:46:47
Instruments
Correctors
Number of correctors used : 2
Instruments Position
Correctors Initial CCV Current CCV Increments New CCV
FT16.MSG257 -0.79 mm
FT16.MSG267 0.49 mm
FT16.MSG277 -0.22 mm
FT16.BHZ117 203.95 A 203.95 A
FT16.BHZ147 199.70 A 199.58 A
FT16.BHZ167 160.88 A 166.54 A
FT16.DHZ237 0.00 A 0.00 A
Compute Correction
Send to hardware
Back to Initial Values
File Controls Options View
Pls: MD PX.ASG02 250 - PR.TRA-BEF-OP16 125.8
ε(2σ): 0.36 π µm Δp/p: 0.40 E-3
FT16.MSG257
Spline fit
4σ²/β 0.32π µm
µ -0.79mm
σ 1.20mm
G 1.13
B -0.16
Wire Nbs
Step: 0.50 mm
FT16.MSG267
Spline fit
Wire Nbs
Step: 0.35 mm
39.7% ADC Range
FT16.MSG277
Spline fit
4σ²/β 0.31π µm
µ -0.22mm
σ 1.45mm
G 1.19
B 0.09
Wire Nbs
Step: 0.50 mm
19.0% ADC Range
Status
HSV IN
Gain
Plane
HOR
ADC Range
Rest Position
Unfreeze
Programme in pause !!!
Icon Box

EUROPEAN LABORATORY FOR PARTICLE PHYSICS

16 December 1993

Beam Steering in PS Transfer Lines

M. Arruat, B. Autin, M. Martini

THE BEST CORRECTOR METHOD

The method[1] uses a small number of magnets with an iterative process based on "least squares" theory. It is applicable to the corrections of beam trajectories in transfer lines.

- Let u_i the beam trajectory positions observed at n monitors: $U = (u_i)_{i=1\ldots n}$ (*trajectory vector*).
- This trajectory may be corrected by k dipolar correctors selected out of m available: $\Delta\varphi^{(k)} = (\delta\varphi_i)_{i\in\{i_1\ldots i_k\}}$ (*kick vector*).
- The trajectory distortion δu_i at the i-th monitor due to a unit kick at the j-th corrector is

$$a_{ij} = \sqrt{\beta_i\beta_j}\,\sin(\mu_i - \mu_j)$$

Let $A = (a_{ij})_{j=1\ldots m}^{i=1\ldots n}$ (*correction matrix*).

1st iteration:

The strategy starts using a single corrector chosen among m magnets.

- The correcting kicks are $(i = 1\ldots m)$

$$\Delta\varphi_{(i)}^{(1)} = -\left(A_i^{(1)t}A_i^{(1)}\right)^{-1} A_i^{(1)t}U$$

the $n\times 1$-matrix $A_i^{(1)}$ being the i-th column of A.

[1]B. Autin, Y. Marti, Closed Orbit Correction of A.G. Machines using a small Number of Magnets, CERN ISR-MA/73-17.

- The norm of the *residual vector* $R_i^{(1)} = U + A_i^{(1)} \Delta\varphi_{(i)}^{(1)}$ is

$$|R_i^{(1)}|^2 = U^t U + \Delta\varphi_i^{(1)\,t} A_i^{(1)\,t} U$$

- The best corrector (with index i_1) is the one which minimizes the norm of the m residual vectors

$$|R_{i_1}^{(1)}| = \min_i \left(|R_i^{(1)}| \right)$$

k-th iteration:

The k-th iteration requires k correctors, the first $k-1$ magnets (with indices $i_1 \ldots i_{k-1}$) are those retained at the previous iterations.

- The correcting kicks are ($i = 1 \ldots m$, $i \neq i_1 \ldots i \neq i_{k-1}$)

$$\Delta\varphi_i^{(k)} = -\left(A_i^{(k)\,t} A_i^{(k)} \right)^{-1} A_i^{(k)\,t} U$$

  the $n \times k$-matrix $A_i^{(k)}$ being obtained by concatenation of $A_{i_{k-1}}^{(k-1)}$ with the i-th column of A.

- The norm of the residual vector $R_i^{(k)}$ is

$$|R_i^{(k)}|^2 = U^t U + \Delta\varphi_i^{(k)\,t} A_i^{(k)\,t} U$$

- The k-th best corrector (with index i_k) is the one which minimizes the norm of the $m - k + 1$ residual vectors

$$|R_{i_k}^{(k)}| = \min_i \left(|R_i^{(k)}| \right)$$

The iterative computation is stopped when a small enough value of $|R_{i_k}^{(k)}|$ is achieved: The selected corrector indices are $\{i_1 \ldots i_k\}$.

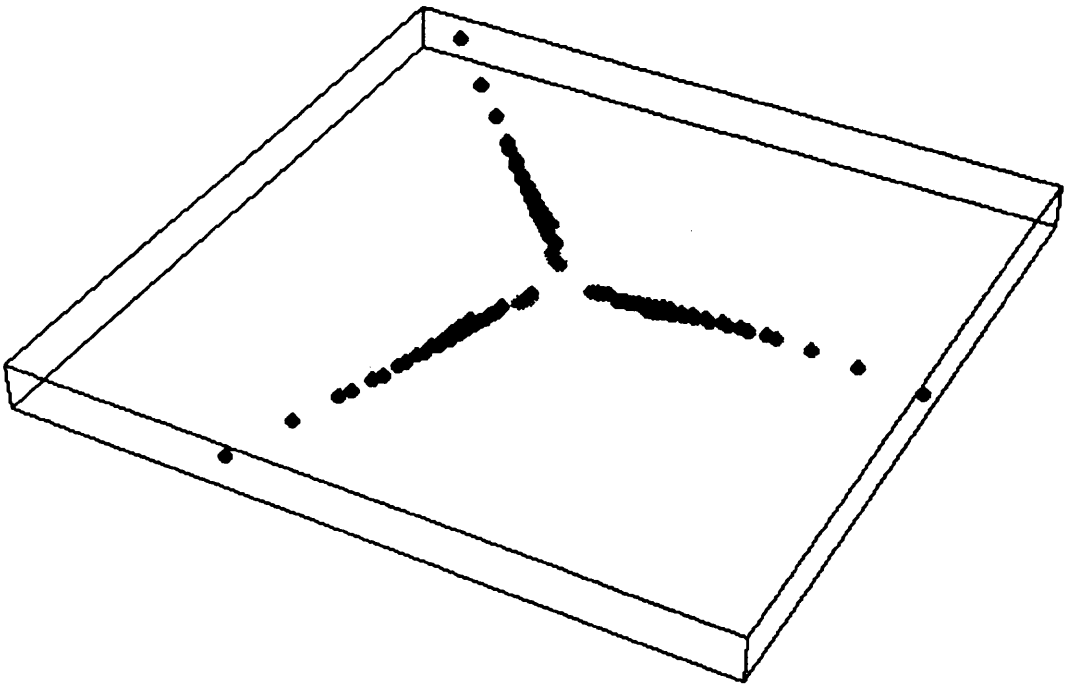
```
Openning a Link          :MLOpen()

Writing data to a link   :MLPutFunction();   /*putting composite expression*/
                          MLPutInteger();    /*putting number*/
                          MLPutIntegerList();/*putting lists of numbers*/
                          MLPutRealList();   /*putting lists of reals*/
                          MLEndPacket();     /*mark the end of an outgoing expression*/

    Example : Steering Application
                         MLPutFunction(lp, "Micado", 5);
                         MLPutInteger(lp, Plane);
                         MLPutIntegerList(lp, InstrumentsIdx, (long )count);
                         MLPutRealList(lp, Position, (long )count);
                         MLPutIntegerList(lp, CorrectorsIdx, (long )count);
                         MLPutInteger(lp, correctorsCount);
                         MLEndPacket(lp);


Waiting for new data     :MLReady()          /*Specifie If data are ready to be read*/
                                             /*from link immediatly*/


Packet type returned     :RETURNPKT          /*result of calculation*/


Data type codes returned :switch (MLGetNext()) {
                              case MLTKSYM:   /*Mathematica symbol*/
                                ...
                              case MLTKSTR:   /*Mathematica string*/
                                ...
                              case MLTKINT:   /*integer*/
                                ...
                              case MLTKREAL:  /*real number*/
                                ...
                              case MLTKFUNC:  /*Mathematica composite expression*/
                                ...
                              case MLTKERROR: /*Error*/
                                ...
                          }

    Example : Steering Application

                          case MLTKFUNC:
                                  if (MLCheckFunction(lp, "List", &count)) {
                                    switch(MLGetType(lp)) {
                                      case MLTKINT :
                                          for(i=1; i<=count; i++)
 /*Correctors selected by MICADO*/            MLGetInteger(lp, ptrListInt++);
                                        break;
                                      case MLTKREAL :
                                          for(i=1; i<=count; i++)
 /*CCV increment for this correctors*/        MLGetReal(lp, ptrListReal++);
                                        break;
                                    }
                                  }


 Close MathLink           :MLPutFunction();   /*Send "Exit" function*/
                           MLClose();         /*disconnect the Link*/
```

?KAMTrajectories

KAMTrajectories[map, x0, nturns] returns a 3D plot of the nturns iterations of the map on the initial conditions x0. x0 is a list of n quadruplets {x,x',y,y'}

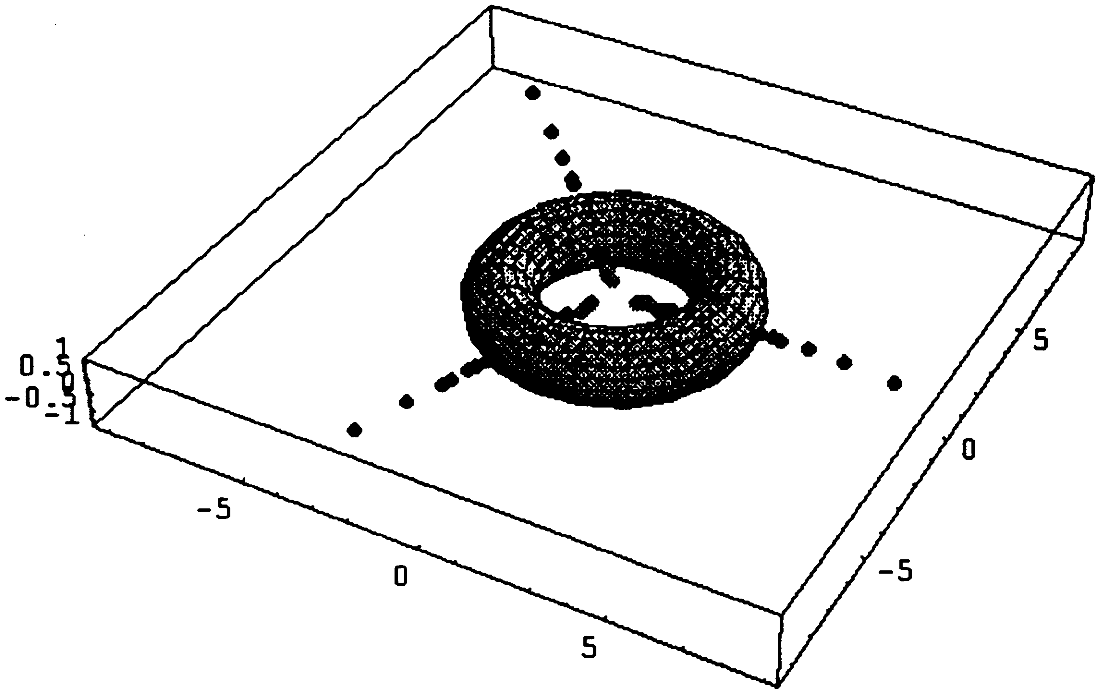
In the next line, oneturn *is the operator that transforms the 4-vector* {x,x',y,y'} *turn after turn. It includes a rotation in phase space, plus a non-linear element.*

KAMTrajectories[oneturnx,s0,nturn];



Here zk *has been defined as a plain torus. The previous plot is shown again, with the torus superimposed.*

Show[{zk,%}]



D. Manglunki
16/12/93