GICOSY Tutorial 1

Helmut Weick, 02.06.2024

Fitting a quadrupole triplet

Needs: gicosy.x (executable program)

gicosybatch (shell script to run gicosy and convert oputput)

meta2ps (graphics converter program to postscript)

GIOSFF.DAT, GICOSYFF.DAT (information on fringe fields)
Input: quad-triplet.dat

output: GICOSYOUT.DAT (ascii output)

gicosyplot.ps (postscript graphics)

run from shell:

```
/u/weick/gicosy> ./gicosybatch quad-triplet.dat
 ************** GICOSY VERSION 2.8 (02-Feb-20), UNI GIESSEN, GSI **************
 Reading input
 Analysing input
           0  WARNINGS IN INPUT
           0  ERRORS IN INPUT

           0  WARNINGS IN EXECUTION
           0  ERRORS IN EXECUTION


  Graphic plot of system


 ***********************    E N D   O F   G I C O S Y    *********************
*** Transform GICOSY Meta File to Postscript
/u/weick/gicosy>
```

Text input structure:

```
; after semikolon rest is comment, line must end with ";"
;
;---------- max. 72 valid characters per line------------------------|
;23456789012345678901234567890123456789012345678901234567890123456789012
;         1         2         3         4         5         6         7
```

Command syntax:

```
MAGNETIC QUADRUPOLE 1.00  3.2  0.01 ;   full command followed by several parameters
M Q  1.00 3.2 0.01 ;                    but only first two letters are counted
```

Header (title and more comments):

```
S N quadrupole triplet ;
; as tutorial, Helmut Weick 02.06.2024
```

Arithmetic expressions (variables, calculations, …)

```
A = 0.3 ;
B = SQRT(2) ;
C = (A + B^2) * PI$ ;
```

PI$ = 3.14159 …, special variables of GICOSY have $ at the end.

End of calculation

```
END ;            end of calculation
```

All commands with all parameters in full command reference on WWW

Settings for calculations:

```
O C N M L N ;     output mode momentum and path length
C M 1 ;           calculation mode fixed equations
F T H ;           type of fringe field table
C O 2 ;           calculation order
O O 1 ;           output order
```

Output coordinates in momentum (M), path length (L), not scaled (N).
momentum is good for magnetic systems,

mode fixed equations (faster than numerical integration)

calculate up to 2nd order,
but write output only up to first order to avoid too long text

Beam definition:

```
R P 1008 12 6 ; ions with E = 1008 MeV, mass = 12u, charge = 6+
;
P X 0.001 0.010 ; initial phase space 1 mm x 10 mrad in x
P Y 0.002 0.005 ; initial phase space 2 mm x  5 mrad in y
D P 0.0 0.01 ;    deviation in momentum is 1%
```

from this the magnetic rigidity is computed

start with upright phase space (parallelogram) in x and y

set relative momentum variation of beam

Start System:

```
S S ;                start system
```

after beam definition here the geometry and computation starts

Geometry of quadrupole triplet:

```
  MQ1 = 0.05 ;   asign values to variables
  MQ2 = 0.05 ;
  MQ3 = 0.05 ;
;
D L 2.0 ;        free drift length
M Q 0.5 MQ1 0.1 ; magnetic quadrupole
D L 0.5 ;
M Q 0.5 MQ2 0.1 ;
D L 0.5 ;
M Q 0.5 MQ3 0.1 ;
D L 2.0 ;
```

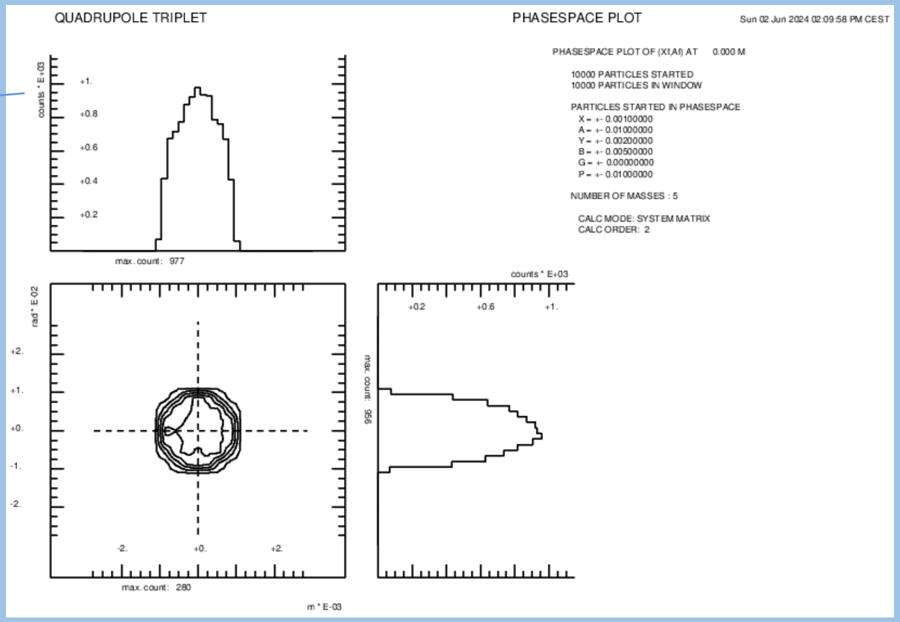
quad strength in variables for later modification

quadrupoles of 0.5m length
with distances inbetween

Grapics output:

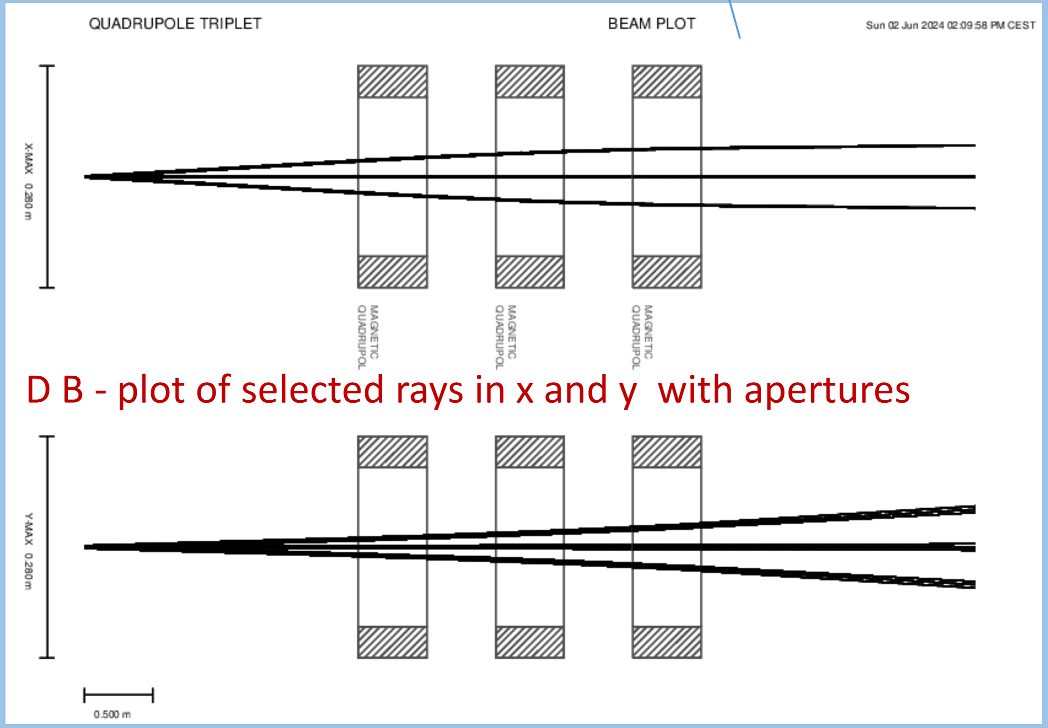
```
D H E (X,A) 10000  0.003 0.03 5 ;
```

two dimensioal plot, here phase space X, A, filled by 10 000 ions
ober the area of 3mm x 30 mrad, with 5 steps of momentum deviation

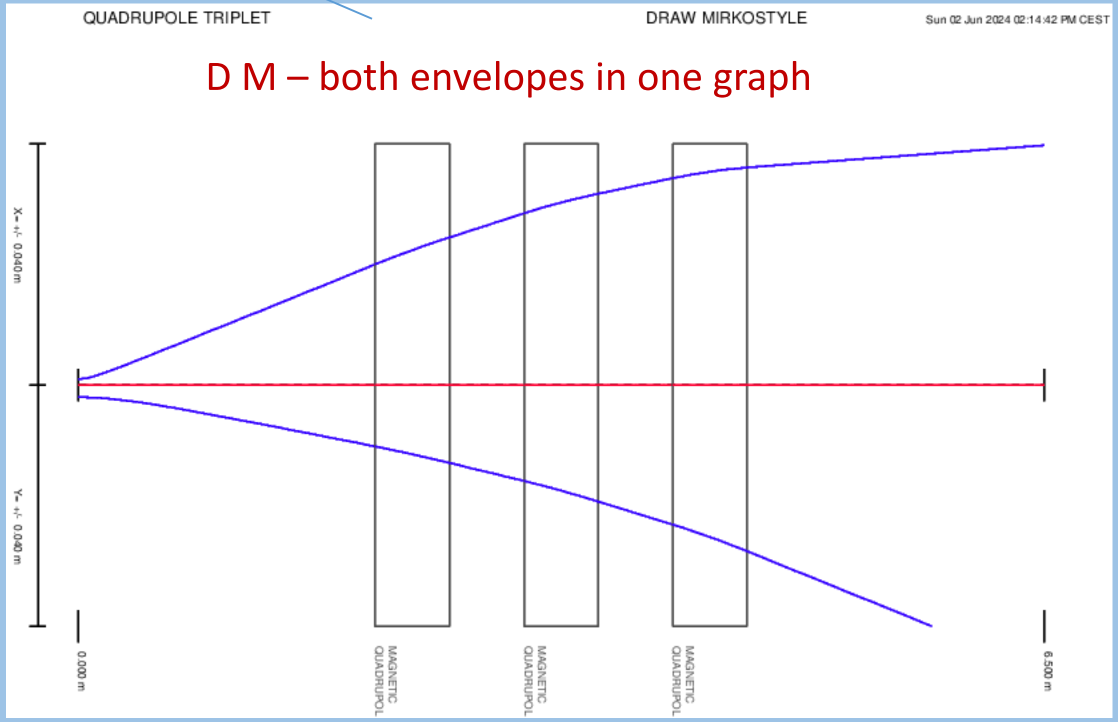



```
D B 0.14 0.14 100 3 3 1 3 3 3 1 ;  draw beam (many rays)
D S 0.14 10 100 3 3 1 3 1 1 ;      draw system with rays (top view)
D E 0.12 200. 20 (TXB$) ;          draw expression, beta function
D M 0.04 0.04 100 1 1000 ;         draw envelopes in MIRKO style
```

Plots of beam along the optial axis



D B - plot of selected rays in x and y with apertures



D M – both envelopes in one graph

Fitting: make it point-to-point focusing

```
  F B MQ1 MQ2 MQ3 ;
```

Define variables to modify (use after variable definition)

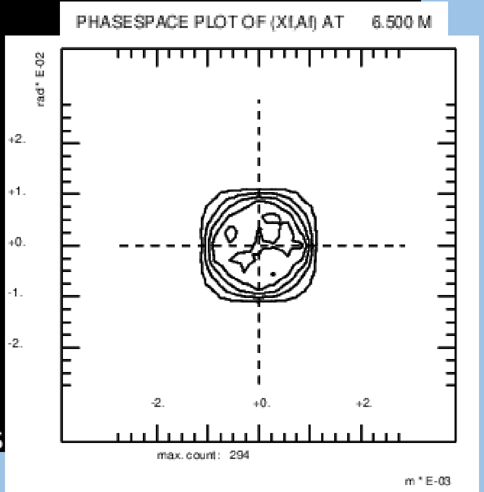
```
    MIN = [X,A]^2 + [Y,B]^2 + ([X,X]+1)^2 ;
F V MIN ;
F E 1.E-6 1000 6 ;
  P S 'MQ1 = ',MQ1 ;
  P S 'MQ2 = ',MQ2 ;
  P S 'MQ3 = ',MQ3 ;
```

Define variables to minimize, imaging in x and y, x magnification = -1
add in squares to have each single contzribution at zero
mumerically numbers differ a lot, weight factiors can help

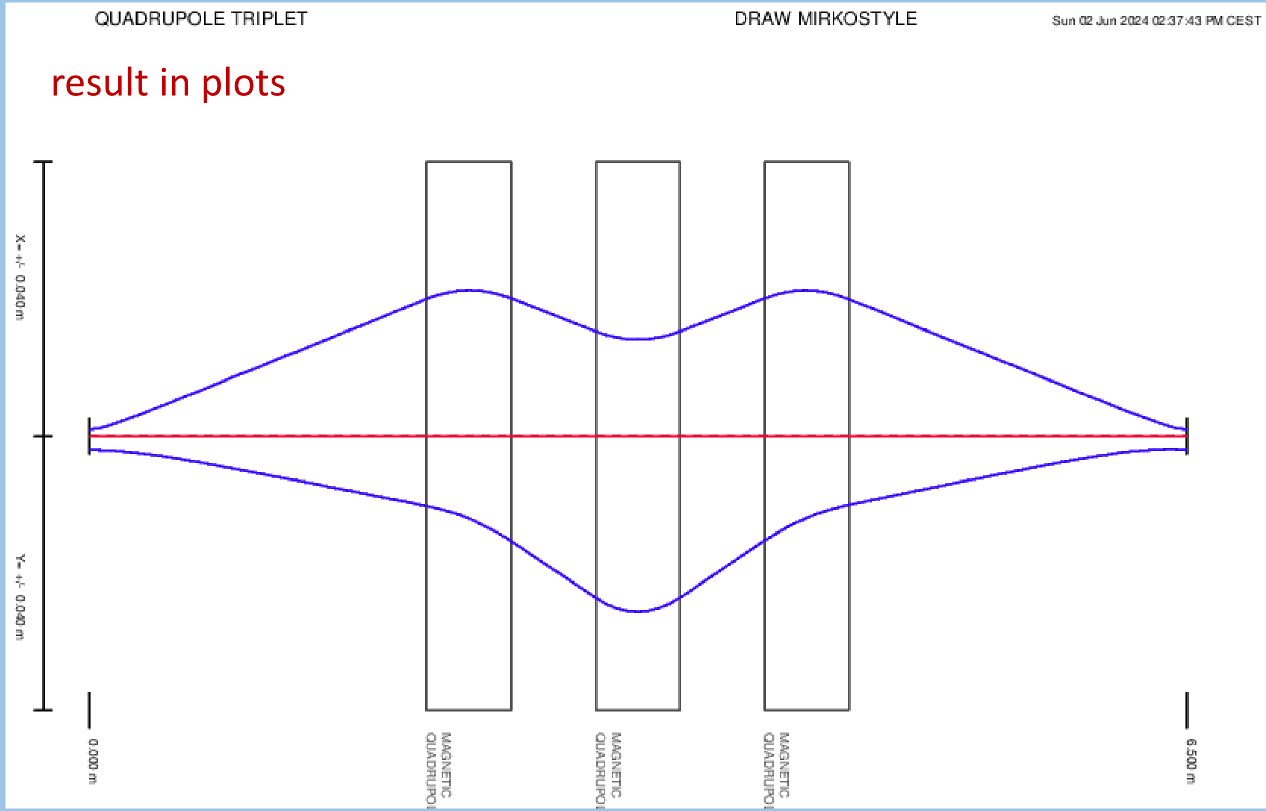
Fit end when steps in MIN<1e-6, max 1000 iterations, method #6

add direct screen output to see result of quadrupole values

```
/u/weick/gicosy> ./gicosybatch quad-triplet.dat
 ************** GICOSY VERSION 2.8 (02-Feb-20), UNI GIESSEN, GSI **************
 Reading input
 Analysing input
  ###      INFO:  FIT IS ACTIV
             0  WARNINGS IN INPUT
             0  ERRORS IN INPUT
 FIT FINISHED,           275  ITERATIONS
 MQ1 =  5.069424054E-01
 MQ2 = -7.149795004E-01
 MQ3 =  5.068998663E-01

             0  WARNINGS IN EXECUTION
             0  ERRORS IN EXECUTION


  Graphic plot of system

  Graphic plot of beam

  Graphic plot of expression

  MIRKO style envelope plot

 ************************    E N D   O F   G I C O S
```



result in plots



Understanding the text output:

```
***************************   E N D   I N P U T   ***************************

**********************   L I S T   O F   E R R O R S   **********************

          0  WARNINGS IN INPUT
          0  ERRORS IN INPUT

***  GICOSY VERSION 2.8 (02-Feb-2020) ***   DATE XX.XX.XXX    TIME YY:YY:YY **
******************************************************************************
**                                                                          **
**                    QUADRUPOLE TRIPLET                                    **
**                                                                          **
******************************************************************************

 MAGN.RIGIDITY =  2.697929811E+00 TESLAMETER     ENERGY= 1.008000000E+03 MEV
 ELEC.RIGIDITY =  3.221033198E+02 MEGAVOLT       CHARGE= 6.000000000E+00 UNITS
 VELOCITY      =  1.193890658E+08 METERS/SEC     MASS  = 1.200000000E+01 AMU

 X - DIRECTION   X0.... =  1.000000000E-03 M    ALPHA =  0.000000000E+00
                 SIN(A0)=  1.000000000E-02      BETA  =  1.000000000E-01 M
                 LX.... =  0.000000000E+00 M    EPS   =  1.000000000E-05 M

 Y - DIRECTION   Y0.... =  2.000000000E-03 M    ALPHA =  0.000000000E+00
                 SIN(B0)=  5.000000000E-03      BETA  =  4.000000000E-01 M
                 LY.... =  0.000000000E+00 M    EPS   =  1.000000000E-05 M
```

first the input is repeated

in case of errors check above where exactly ?

computation has started

beam definition and parameters, e.g. magnetic rigidity = 2.6979 Tm

```
*****************************   R E S U L T S   ******************************

******************************************************************************
        GRAPHIC PLOT OF PHASESPACE AT      0.000 M
******************************************************************************
 ----------------------------------------------------------------------------
                          U1 = 0.000000000E+00 M     V1 = 0.000000000E+00 M
 DRIFT LENGTH = 2.000000000E+00 M                     W  = 0.000000000E+00 DEG
                          U2 = 2.000000000E+00 M     V2 = 0.000000000E+00 M
 ----------------------------------------------------------------------------
 MAGN QUAD  PATH-LENGTH  = 5.000000000E-01 M  FL.DENSITY= 5.069424054E-01 T
 MAGN QUAD  APERT.RADIUS = 1.000000000E-01 M
 ----------------------------------------------------------------------------
```

Plot positions are marked

geometry is written in detail

Understanding the text output:

output at this position

```
NON SYMPL. SYSTEM TRANSFER MATRIX AT PATH-LENGTH L= 6.500000000E+00 M
**********************************************************************
                X              A              Y              B              L
 ------------------------------------------------------------------------------
 0         0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00 -2.533571E-15
 ------------------------------------------------------------------------------
 1 X      -1.000158E+00 -2.069520E-01  0.000000E+00  0.000000E+00  0.000000E+00
 2 A      -4.044937E-04 -9.999254E-01  0.000000E+00  0.000000E+00  0.000000E+00
 3 Y       0.000000E+00  0.000000E+00 -9.998225E-01 -7.303219E-01  0.000000E+00
 4 B       0.000000E+00  0.000000E+00  3.858187E-04 -9.998957E-01  0.000000E+00
 5 G       0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  5.469137E+00
 6 P       0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00 -5.469137E+00
```

Beam transfer matrix transposed compared to usual to fit better in screen including higher orders

(X,X) (A,X) (Y,X) (B,X) …
(X,A) (A,A) (A,Y) (B,Y) …

here (X,A) ~ 0, (Y,B) ~ 0, (X,X) ~ -1

In mode momentum dispersive variable is called P (=$\Delta p/p$).
In case of electric fields a second dispersive coordinate is needed, G = $\Delta m/m$, now all these coefficients are zero.

```
P F 'Hello, the system variable (X,X)=',[X,X] ;
```

output can also be written to file GICOSYOUT.DAT (P F).

→
```
Hello, the system variable (X,X)=-1.000158310E+00
```

Helmut Weick, 02.06.2024

GICOSY Tutorial 2

Helmut Weick, 02.06.2024

Adding Fringe fields

In larger aperture systems the fact that fields cannot drop from full value to zero is important.
A realistic distribution could be calculated numerically. However, for standard optical elements the shapes are very similar and a scaling with the aperture size is possible.
In GICOSY two options are available:
CM1 – precalculated fringing field integrals (fast)
CM2 and CM3 numerical integration through field parametrized by Enge function

For CM1 the precalculated integrals are written in GIOSFF.DAT,
for CM2/3 the Enge coeffecients are in GICOSYFF.DAT

The values for the first three entries in GIOSFF.DAT and GICOSYFF.DAT correspond.

Often using any old fringe field is already much better then neglecting the effect.