TRIUMF

M15 permanent magnet quads positioning

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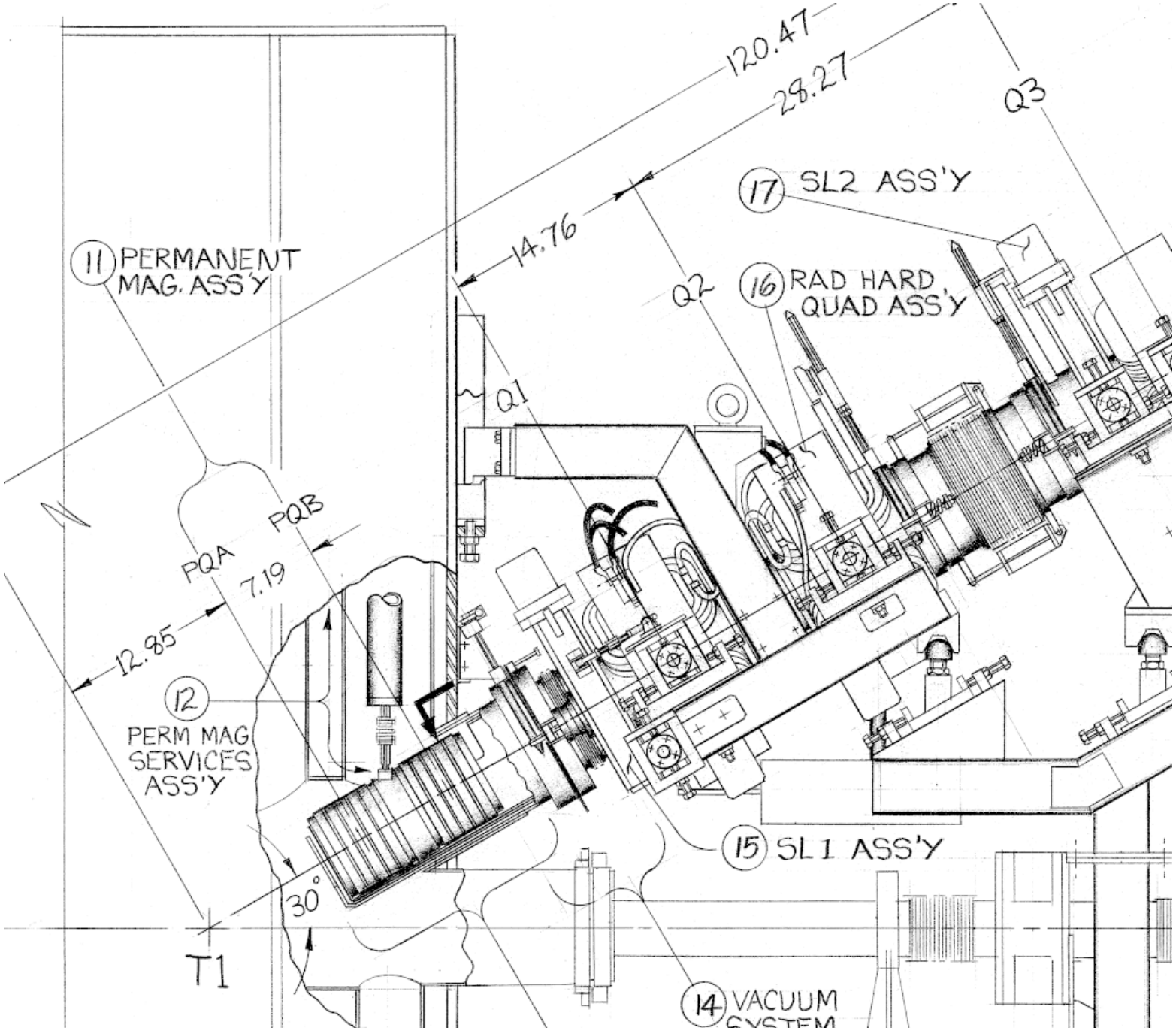
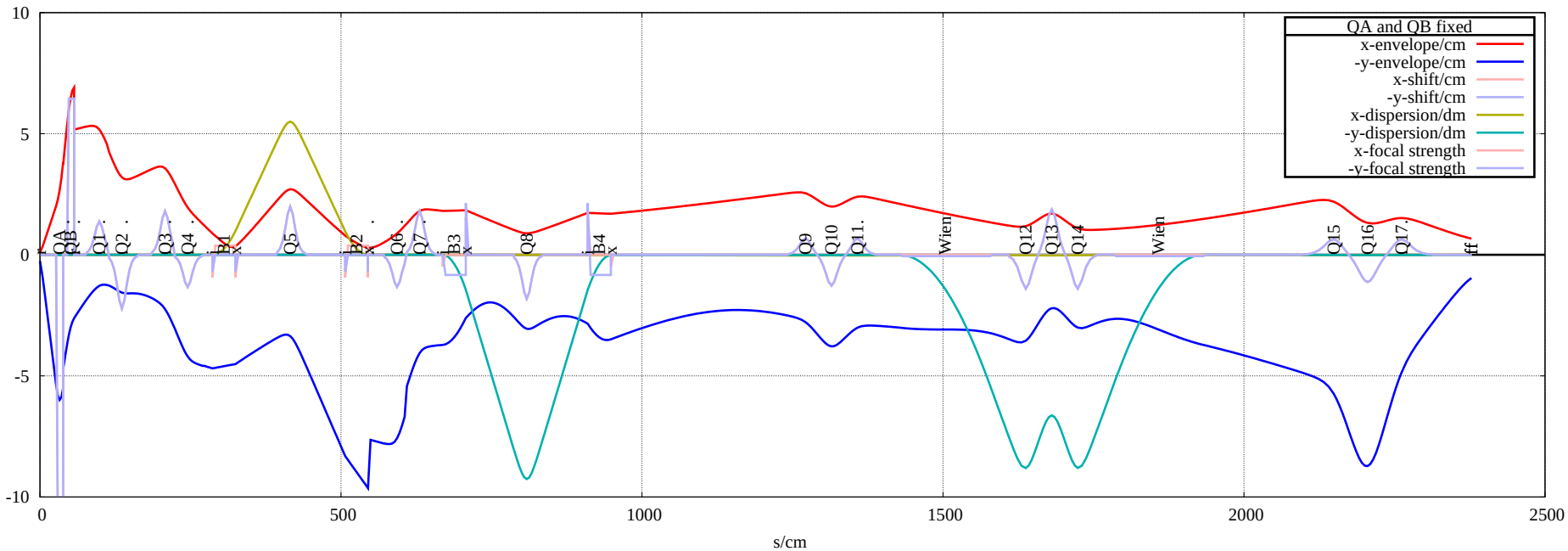
Beam Physics Note TRI-BN-23-01

Front-end layout (lengths in inches)



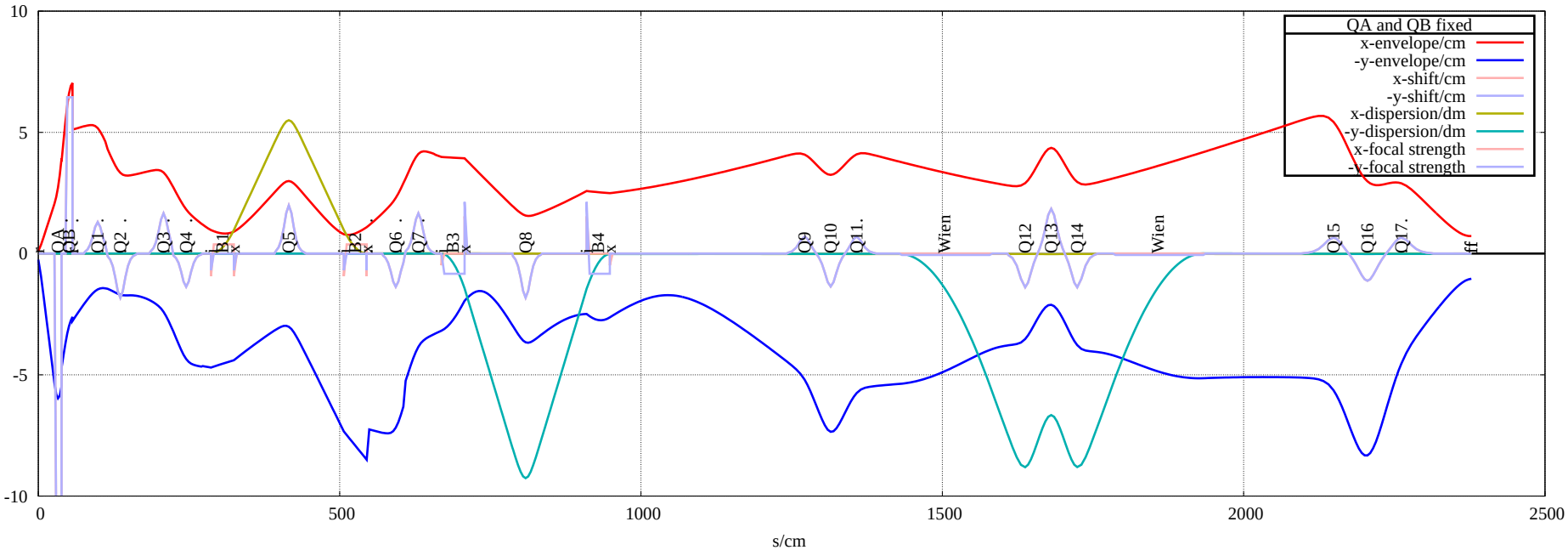
Basic tune

I used the given QA,QB specs, along with Jaap's original initial beam (halfsizes) 0.1 mm by 75 mrad in x (x direction is initially vertical) and 0.25 mm by 200 mrad in y. I quickly established that the QA,QB doublet will work well with the rest of M15 if QA is focusing in the y (horizontal) direction. The tune is developed to keep beam within the beam pipe and Q5, Q8, Q12-Q13-Q14 triplet adjusted to keep the beam doubly achromatic everywhere; lastly, a roughly 1.5 cm dia. spot at final focus.



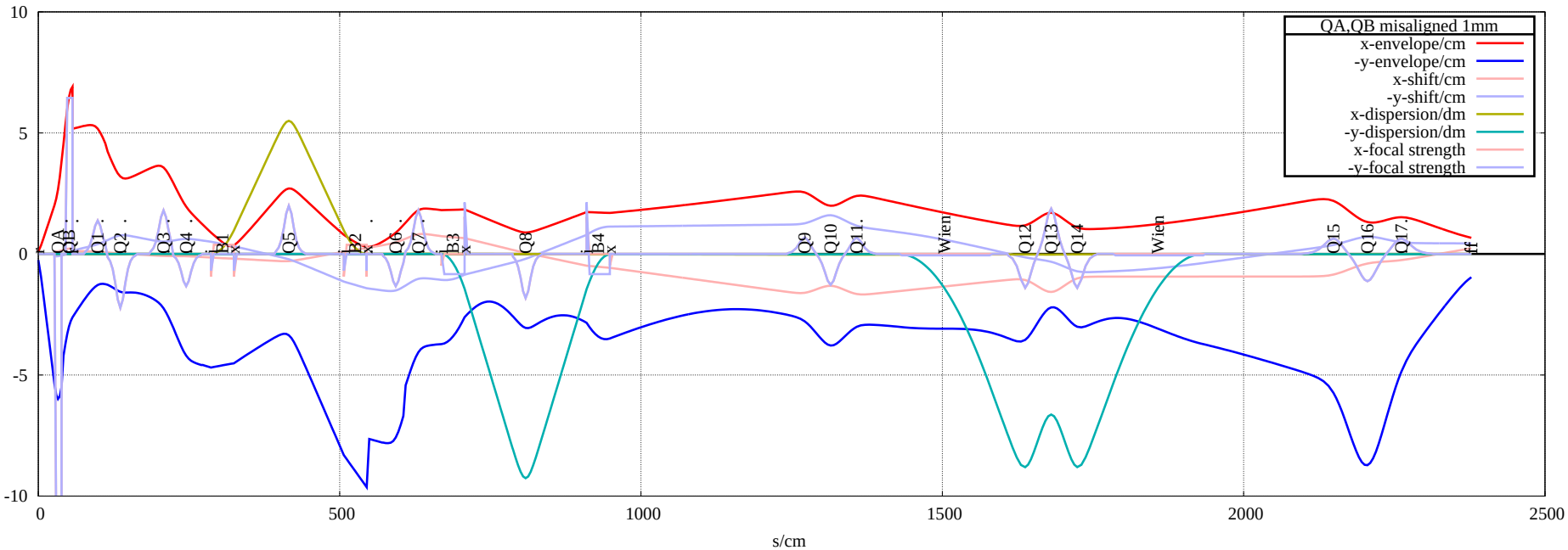
Note that the envelopes are cut by ‘slits’ sized to reflect vacuum chamber: x is cut at QB, and y is cut at the dipole B2. This shows that the chosen initial beam just barely fits into the 6-inch beam pipe. Quad strengths are fitted to minimize the cut and meet the fit constraints mentioned above.

Rotation: Rotating the doublet by 5° does not have very much effect, so one can conclude that the roll angle needs not be precise to a tolerance of less than a degree or so.



Misalignments:

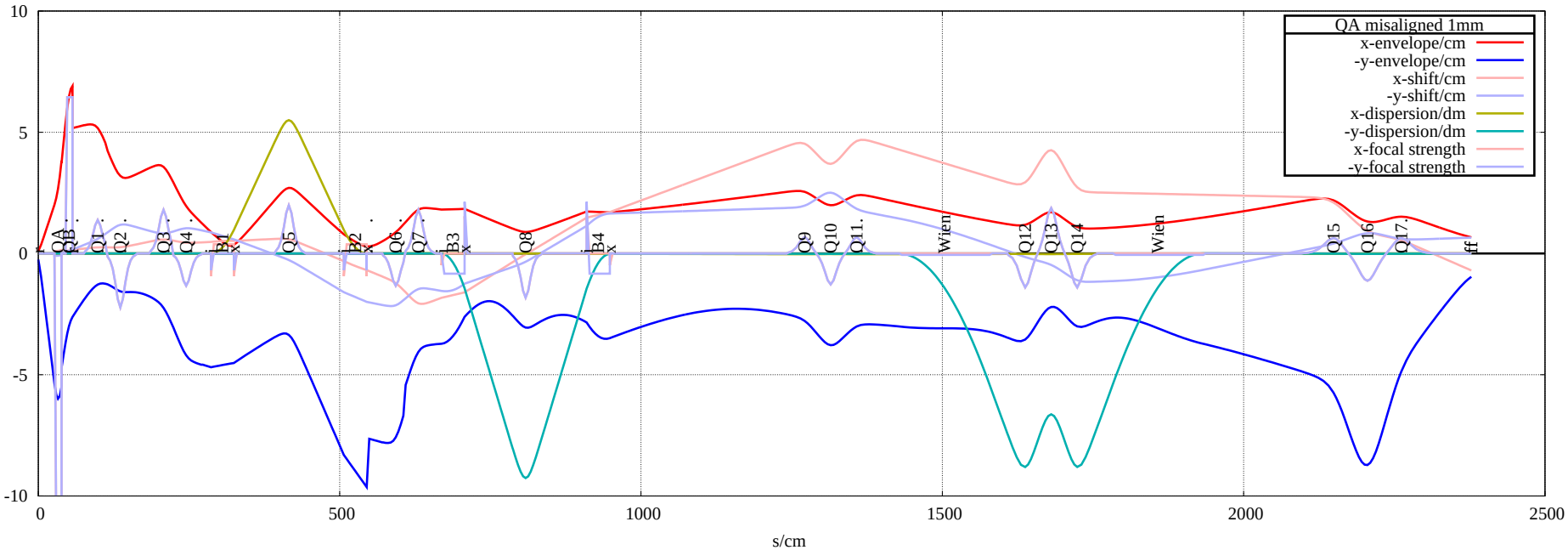
With the doublet displaced by 1 mm in both x and y, we see displacements comparable to the beam envelope size:



This is easy to understand: there is a magnification of order 10 between T1 and the rest of the beamline.

Misalignments...

Misaligning only QA and not QB is even worse:



I conclude that there have to be tight tolerances of order 0.1 mm, not only for the placement of the doublet with respect to the beamline centreline and T1, but importantly, the quadrupoles' axes have to be located and fiducialized to the same tolerance. This applies to the quadrupoles individually. The doublet assembly can have an alignment tolerance about 2 to 3 times more relaxed, as long as the tilt angle of the assembly not exceed 0.5 mrad (=0.1 mm/183 mm).

final thoughts

Dead reckoning alignment specs can be alleviated by having steering correctors. So one way to ease the requirement is by steering the spot on the T1 target. IOW, the axis defined by QA,QB meets T1 at a point, and the proton beam can be steered to that point.

In fact that is probably precisely how M15 has been optimized in the past when “target scans” are performed. I conjecture that it’s not a T1 ‘hot spot’ we are after, but simply the location on T1 that is in line with the PQs’ axis.

A minor additional steering issue is that muons exiting PQA/PQB doublet will be also off axis. There are no dedicated steerers in the M15 beamline to make the correction; some of the correction can be made using the benders, but some quads should be made steerable. That’s a separate study.

TRANSOPTR code SY.f

```
      SUBROUTINE TSYSTEM
      COMMON /BLOC1/szx,angx,szy,angy,
     +QA,QB,Q1,Q2,Q3,Q4,Q5,Q6,Q7,Q8,Q9,Q10,Q12,Q13,Q15,Q16
!
      common/RKKIND/IRK
      COMMON/PRINT/IPRINT,IT(8)
      COMMON/SCPARM/QSC,ISC,cmps
      if(Q6**2+Q7**2.eq.0.)then
         Q6s=Q4
         Q7s=Q3
      else
         Q6s=Q6
         Q7s=Q7
         endif
      cmps=5.
      IT(1)=1
      IT(2)=2
      IT(3)=1
      IT(4)=6
      IT(5)=3
      IT(6)=6
      apcon=4./3.141593
      wq =  1.
      ws=1.
      irk=0
c     some error in my file:
c     E-30403 has Q1Q2 2.1" closer to target.
      drerror=2.12*2.54
c 6Q6's Q1 thru Q8
      ap6=7.94
      pipe6=7.37
      a6=ap6*apcon
      efflen6=22.1
      conv6=0.001692*efflen6/ap6
      conv6r=0.000187*efflen6/ap6
      de6=-22.5/2.
c 7Q7's (yellow)
      ap7=9.84
      a7=ap7*apcon
      efflen7y=9.80*2.54
      conv7y=0.000628*efflen7y/ap7
      de7y=(-28.2)/2.
c 7Q7's (blue)
      efflen7=9.42*2.54
      conv7=0.000656*efflen7/ap7
      de7=(-28.2)/2.
c 12Q12's Q15-Q17
      ap12=15.56
      a12=ap12*apcon
      efflen12=34.52
      conv12=0.000818*efflen12/ap12
      de12=(-32.3)/2.
c
      betx=szx/angx
      emitx=szx*angx
      bety=szy/angy
      emity=szy*angy
c
c DIPOLES
      AK1=0.2875
      AK2=3.0
      fgap=15.875
      rho12=72.444
      rho34=49.000
c
      call cic(0.,betx,emitx,0.,bety,emity)
      call uxyz(0.,(-150.)/57.29578,2,dum1,dum2,dum3)
c     call fitarb(0.,1./emitx/emity,.01,1)
      shf=0.
      roll=0.
      call rotate(roll,'      r')
      call dr(26.787-shf,0,0)
      call genshift(.1,.0,.1,.0)
      call MQUAD(QA,5.24,11.708,wq,'QA  ')
      call slit4(5.24,5.24,ws,'.      .')
      call genshift(-.1,.0,-.1,.0)
      call dr(6.56,0,0)
      call MQUAD(QB,5.93,11.676,wq,'QB  ')
      call slit4(5.24,5.93,ws,'.      .')
      call rotate(-roll,'      r')
      call drift(35.962+shf-drerror-de6,'NARE')
      call MSQUAD(Q1*conv6r,a6,wq,'Q1  ')
      call slit4(pipe6,pipe6,ws,'.      .')
      call drift(15.-de6-de6,'NARE')
      call MSQUAD(-Q2*conv6r,a6,wq,'Q2  ')
      call slit4(pipe6,pipe6,ws,'.      .')
      call drift(43.8+drerror-de6-de6,'NARE')
      call MSQUAD(Q3*conv6,a6,wq,'Q3  ')
      call slit4(pipe6,pipe6,ws,'.      .')
      call drift(15.-de6-de6,'NARE')
      call MSQUAD(-Q4*conv6,a6,wq,'Q4  ')
      call slit4(pipe6,pipe6,ws,'.      .')
```

SY.f code cont'd

```
      call dr(30.-de6,0,0)
      call Ea(15.,rho12,30.,0.,AK1,AK2,fgap,0.,wq,0,0)
      call BEnd(rho12,30.,0.,'B1  ')
      call Ea(15.,rho12,30.,0.,AK1,AK2,fgap,0.,wq,0,0)
      call drift(80.-de6,'NARE')
      call MSQUAD(Q5*conv6,a6,wq,'Q5  ')
c      call slit4(pipe6,pipe6,ws,'.      .')
      call dr(80.-de6,0,0)
      call Ea(15.,rho12,30.,0.,AK1,AK2,fgap,0.,wq,0,0)
      call BEnd(rho12,30.,0.,'B2  ')
      call Ea(15.,rho12,30.,0.,AK1,AK2,fgap,0.,wq,0,0)
      call slit4(fgap/2.,fgap/2.,ws,'.      .')
      call dr(30.,0,0)
      call fit(2,1,6,0.,1.,1)
      call drift( 7.-de6,'NARE')
      call MSQUAD(-Q6s*conv6,a6,wq,'Q6  ')
      call slit4(pipe6,pipe6,ws,'.      .')
      call drift(15.-de6-de6,'NARE')
      call MSQUAD(Q7s*conv6,a6,wq,'Q7  ')
      call slit4(pipe6,pipe6,ws,'.      .')
      call dr(27.-de6,0,0)
      call yEa(0.,rho34,45.,0.,AK1,AK2,fgap,0.,wq,0,0)
      call yBEnd(rho34,45.,0.,'B3  ')
      call yEa(22.5,rho34,45.,0.,AK1,AK2,fgap,0.,wq,0,0)
      call dr(37.5,0,0)
      call dr(22.5,0,0)
      call dr(15.,0,0)
      call drift(15.-de6,'NARE')
      call MSQUAD(-Q8*conv6,a6,wq,'Q8  ')
c      call slit4(pipe6,pipe6,ws,'.      .')
      call dr(30.-de6,0,0)
      call dr(22.5,0,0)
      call dr(37.5,0,0)
      call yEa(22.5,rho34,45.,0.,AK1,AK2,fgap,0.,wq,0,0)
      call yBEnd(rho34,45.,0.,'B4  ')
      call yEa(0.,rho34,45.,0.,AK1,AK2,fgap,0.,wq,0,0)
      call dr(42.,0,0)
      call fit(2,3,6,0.,1.,1)
      call dr(112.56,0,0)
      call drift(154.49-de7y,'NARE')
c      call MSQUAD(Q9*conv7y,a7,wq,'Q9  ')
```

```
c      call drift(15.-de7y-de7y,'NARE')
      call MSQUADtrip(Q9*conv7y,-Q10*conv7y,15.-de7y-de7y,a7,wq,
     $     'Q9  ','Q10 ','Q11 ',50)
      call slit4(abs(a7),abs(a7),ws,'.      .')
c      call MSQUAD(-Q10*conv7y,a7,wq,'Q10 ')
c      call drift(15.-de7y-de7y,'NARE')
c      call MSQUAD(Q9*conv7y,a7,wq,'Q11 ')
      call dr(28.-de7y,0,0)
      call dr(28.32,0,0)
      call WFy(183.8,150.,0,0)
      call drift(45.-de7,'NARE')
c      call MSQUAD(Q12*conv7,a7,wq,'Q12 ')
c      call drift(15.-de7-de7,'NARE')
      call MSQUADtrip(Q12*conv7,-Q13*conv7,15.-de7-de7,a7,wq,
     $     'Q12 ','Q13 ','Q14 ',50)
c      call slit4(abs(a7),abs(a7),ws,'.      .')
c      call MSQUAD(-Q13*conv7,a7,wq,'Q13 ')
c      call drift(15.-de7-de7,'NARE')
c      call MSQUAD(Q12*conv7,a7,wq,'Q14 ')
      call dr(45.-de7,0,0)
      call WFy(183.8,150.,0,0)
      call dr(25.,0,0)
      call dr(25.,0,0)
      call drift(150.-de12,'NARE')
c      call MSQUAD(Q15*conv12,a12,wq,'Q15 ')
c      call drift(24.-de12-de12,'NARE')
      call MSQUADTRIP(Q15*conv12,-Q16*conv12,56.3,a12,wq,
     $     'Q15            ','Q16 ','Q17 ',50)
      call slit4(abs(a12),abs(a12),ws,'.      .')
c      call MSQUAD(-Q16*conv12,a12,wq,'Q16 ')
c      call drift(24.-de12-de12,'NARE')
c      call MSQUAD(Q15*conv12,a12,wq,'Q17 ')
      call drift(100.-de12,'ff  ')
      call fit(1,1,1,.7,3.*wq,1) !
      call fit(1,3,3,1.,3.*wq,1) !
      call fit(2,3,6,0.,1.,1) !
      call fit(2,4,6,0.,100.,1) !
      call vective(10)
      call print_transfer_matrix
      call drift(0.,'ff  ')
      return
      end
```

TRANSOPTR input DATA.DAT

```
 0.    28.86 0.  105.659  1. 0.
 -3 4  5.  3.e-4
 000 0.00 1. 1. 0. 0. 0.!251 is DE file 20021101
 .50 0.075   0.25  0.2   1.  0.03
    1.  1.    1. 1.     1. 1.    1. 1.
 0
 20
 .1     0.      1.      0       !sizex Jaap's is 0.2cm dia.
 0.075   0.001   1.      0       !anglex Jaap's is 150mrad dia.
 0.25    0.      1.      0       !sizey Jaap's is 0.5cm dia.
 0.2   0.001   1.      0       !angley Jaap's is 400mrad dia.
 -0.282    -10.  10. 0 ! M15:QA,kG DATA V: 1983 spec .538kG/cm
  0.184   -10.  10. 0 ! M15:QB,kG DATA V: 1983 spec .31kG/cm
  250.       0. 750. 1 ! M15:Q1,Amp DATA V
  400.0      0. 750. 1 ! M15:Q2,Amp DATA V
  37.65     0.  80. 1 ! M15:Q3,Amp DATA V
  24.73     0.  80. 1 ! M15:Q4,Amp DATA V
  41.10     0.  80. 0 ! M15:Q5,Amp DATA V
  0.      0.  80. 0 ! M15:Q6,Amp DATA V
  0.      0.  80. 0 ! M15:Q7,Amp DATA V
  37.60     0.  80. 0 ! M15:Q8,Amp DATA V
  52.87      0. 200. 1 ! M15:Q9,Amp DATA V
  98.86      0. 200. 1 ! M15:Q10,Amp DATA V
 -106.7   -200. 200. 1 ! M15:Q12,Amp DATA V
 -143.6   -200. 200. 1 ! M15:Q13,Amp DATA V
  66.41      0. 200. 1 ! M15:Q15,Amp DATA V
  112.9      0. 200. 1 ! M15:Q16,Amp DATA V
3.E-4  1000
010  1.00  0.9 10
```

TRIUMF

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