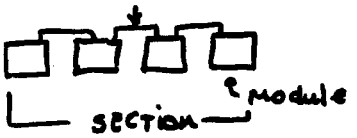
PRELIMINARY LIST of

BEAM DIAGNOSTICS REQUIREMENTS

(O.T.T.O.T.H.) Implications



1. Steer Beam Through Linac with minimal Scraping
   → B.P.M.'s @ β_{max} with a corresponding correction at prev. β_{max}.

2. Monitor / correct quad mis-tune
   → a) Wire monitors at consecutive β_{min} for beating
   b) BPMs throughout to measure phase advance
   Design: 60° per FODO (120° per Section)
   1 BPM per section per plane ⇒ 3 meas. / 2.π

3. Emittance Measurements: Transition section & 400 MeV.
   → "several" wires in transition section; (2 is easy)
   "several" During first "few" accelerating sections;
   "Two at the end, in the last section.
   Three in 400 MeV line

   2 @ S1 & S2 only.

4. Commisioning:
   a. Initial Quad tune
      → Same as 3 above
   b. "Δt" Startup procedure
      → BPMs between sections / Buttons?

5. Fast transverse effects (due to RF dipole?)
   → 1 BPM per section.

→ Bunch length measurement : 50 cm pickups, or novel method described in literature.

Symbol	Device	Length [cm]
B	beam position monitor	3.00
Q	standard quadrupole	8.00
Q′	DTL quadrupole	16.46
S	steering trim magnet	6.00
T	toroid current monitor	3.10
V	vacuum gate valve	4.90
W	wire scanner	5.0

Available for devices $3\beta\lambda/2 - 9.92$ cm.

$\beta_{max} \sim 10$ m

$\beta_{min} \sim 1.8$ m

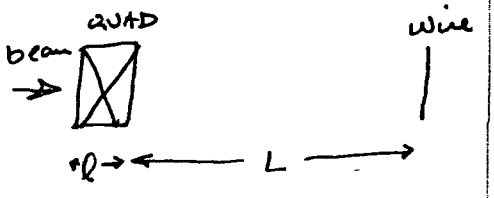
* = MODIFIED

(W) = Probably Not Needed

Module /Sect.	Grad. [MV/m]	KE_{out} [MeV]	L_{rf} [m]	L_{sep} [m]	Devices (upstream)	D_Q [m]	P_{Cu} [MW]	P_{beam} [MW]	$\Delta\psi_{x,y}$ [deg]	$\Delta\psi_z$ [deg]
0										
1	4.95	116.5	0.4254	0.3927	Q′/2 B V	0.0000	0.28	0.00		
2	3.16	116.5	0.2552	0.9751	Q	0.2613	0.07	0.00		
			0.0000	1.5748	W Q B S T B S Q/2	0.1900				
			0.6806	2.9426			0.35	0.00		
			3.6232				0.35			
1	8.04				W*					
1		125.1	1.3814	0.1418	Q/2 ~~W~~ V	0.0000	1.72	0.43		
2		133.8	1.4215	0.2628	T Q W	0.1168	1.73	0.44	77	109
3		142.8	1.4606	0.2703	B Q S	0.1201	1.75	0.45		
4		152.1	1.4987	0.2775	B Q S	0.1234	1.77	0.46	78	106
			5.7622	0.9524			6.97	1.78		
			6.7146				8.75			
2	7.82									
1		161.2	1.5353	0.2846	V Q ~~W~~ W*	0.1265	1.69	0.46		
2		170.6	1.5704	0.2912	T Q W	0.1295	1.70	0.47	80	103
3		180.2	1.6046	0.2978	B Q 7S/6	0.1323	1.72	0.48		
4		190.0	1.6380	0.3041	B Q 7S/6	0.1352	1.73	0.49	80	101
			6.3483	1.1777			6.84	1.90		
			7.5260				8.74			
3	7.63									
1		199.7	1.6700	0.3102	V Q ~~W~~ B S*	0.1379	1.67	0.48		
2		209.5	1.7008	0.3161	T Q (W)	0.1405	1.68	0.49	81	98
3		219.6	1.7308	0.3218	~~B~~ Q ~~7S/6~~ (W)	0.1430	1.70	0.50		
4		229.8	1.7600	0.3273	B Q 7S/6	0.1455	1.71	0.51	81	96
			6.8616	1.2754			6.76	1.98		
			8.1370				8.74			
4	7.46									
1		239.8	1.7881	0.3327	V Q ~~W~~ B S	0.1479	1.64	0.51		
2		250.1	1.8151	0.3379	T Q (W)	0.1502	1.67	0.51	81	94
3		260.5	1.8414	0.3428	~~B~~ Q ~~4S/3~~ (W)	0.1524	1.68	0.52		
4		271.1	1.8670	0.3477	B Q 4S/3	0.1546	1.69	0.53	80	92
			7.3116	1.3611			6.68	2.07		
			8.6727				8.75			
5	7.32									
1		281.5	1.8917	0.3524	V Q ~~W~~ BS	0.1567	1.64	0.52		
2		292.1	1.9155	0.3570	T Q (W)	0.1587	1.65	0.53	80	90
3		302.8	1.9386	0.3614	~~B~~ Q ~~4S/3~~ (W)	0.1606	1.67	0.53		
4		313.6	1.9612	0.3657	B Q 4S/3	0.1625	1.67	0.54	79	89
			7.7070	1.4365			6.63	2.12		
			9.1435				8.75			
6	7.18									
1		324.4	1.9829	0.3698	V Q ~~W~~ BS	0.1644	1.62	0.54		
2		335.2	2.0039	0.3738	T Q (W)	0.1662	1.64	0.54	79	87
3		346.1	2.0244	0.3777	~~B~~ Q ~~3S/2~~ (W)	0.1679	1.64	0.55		
4		357.1	2.0443	0.3815	B Q 3S/2	0.1696	1.66	0.55	78	85
			8.0555	1.5028			6.56	2.18		
			9.5583				8.74			
7	7.07									
1		368.0	2.0635	0.3852	V Q ~~W~~ B S	0.1712	1.61	0.55		
2		379.1	2.0821	0.3887	T Q W	0.1728	1.63	0.55	77	84
3		390.2	2.1002	0.3921	~~B~~ Q ~~3S/2~~ W	0.1743	1.63	0.56		
4		401.5	2.1179	0.3955	B Q 3S/2	0.1758	1.65	0.56	76	82
			8.3637	1.5615			6.52	2.22		
			9.9252				8.74			
Grand Total			**51.0905**	**12.2100**			**47.31**	**14.25**		
			63.3005				**61.56**			

May 12, 87

Quad : $\begin{pmatrix} 1 & 0 \\ k\ell & 1 \end{pmatrix}$



Drift : $\begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix}$

$$\begin{pmatrix} x \\ x' \end{pmatrix}_f = \underbrace{\begin{pmatrix} 1 & L^* \\ 0 & 1 \end{pmatrix}\begin{pmatrix} 1 & 0 \\ k\ell & 1 \end{pmatrix}}_{\underset{\sim}{M}^\circ} \begin{pmatrix} x \\ x' \end{pmatrix}_i \qquad L^* = L + \ell/2$$

$$\underset{\sim}{M}^\circ = \begin{pmatrix} 1 + k\ell L & L \\ k\ell & 1 \end{pmatrix}$$

go to $\begin{pmatrix} \beta \\ \alpha \\ \gamma \end{pmatrix}$ space

$$\underset{\sim}{M} = \begin{pmatrix} (1+k\ell L)^2 & -2(1+k\ell L)L & L^2 \\ -k\ell(1+k\ell L) & 1+2Lk\ell & -L \\ (k\ell)^2 & -2L & 1 \end{pmatrix}$$

$$\begin{pmatrix} \beta \\ \alpha \\ \gamma \end{pmatrix}_f = \underset{\sim}{M} \begin{pmatrix} \beta \\ \alpha \\ \gamma \end{pmatrix}_i$$

$$\boxed{\begin{gathered} \beta_f = (1+k\ell L)^2 \beta_i - 2L(1+k\ell L)\alpha_i + L^2 \gamma_i \\ \text{note: } \gamma = (1-\alpha^2)/\beta \\ \sigma_x^2 = \beta_f \epsilon \end{gathered}}$$

May 12, 87

RESULTS

Vertical: (Note that σ_N is determined by forcing the following:

$$\chi^2/\mathrm{DOF} = 1.$$

where $\chi^2 \equiv \Sigma(f(x) - d)^2/\sigma^2$)

$\beta_V = 0.88 \pm .08$ m

$\alpha = 0.619 \pm .007$

$\epsilon = 6.5 \pm 1.1$ mm mrad

$\boxed{\epsilon_N = 4.2 \pm .7 \ \pi \text{ mm mrad}}$ (RMS)

$\Rightarrow \sigma_V \approx 0.8$ mm

Horizontal:

$\beta_H = 2.02 \pm .11$ m

$\alpha = -0.53 \pm .02$

$\epsilon = 1.56 \pm .04$ mm mrad

$\boxed{\epsilon_N = 1.02 \pm .03 \ \pi \text{ mm mrad}}$ (RMS)

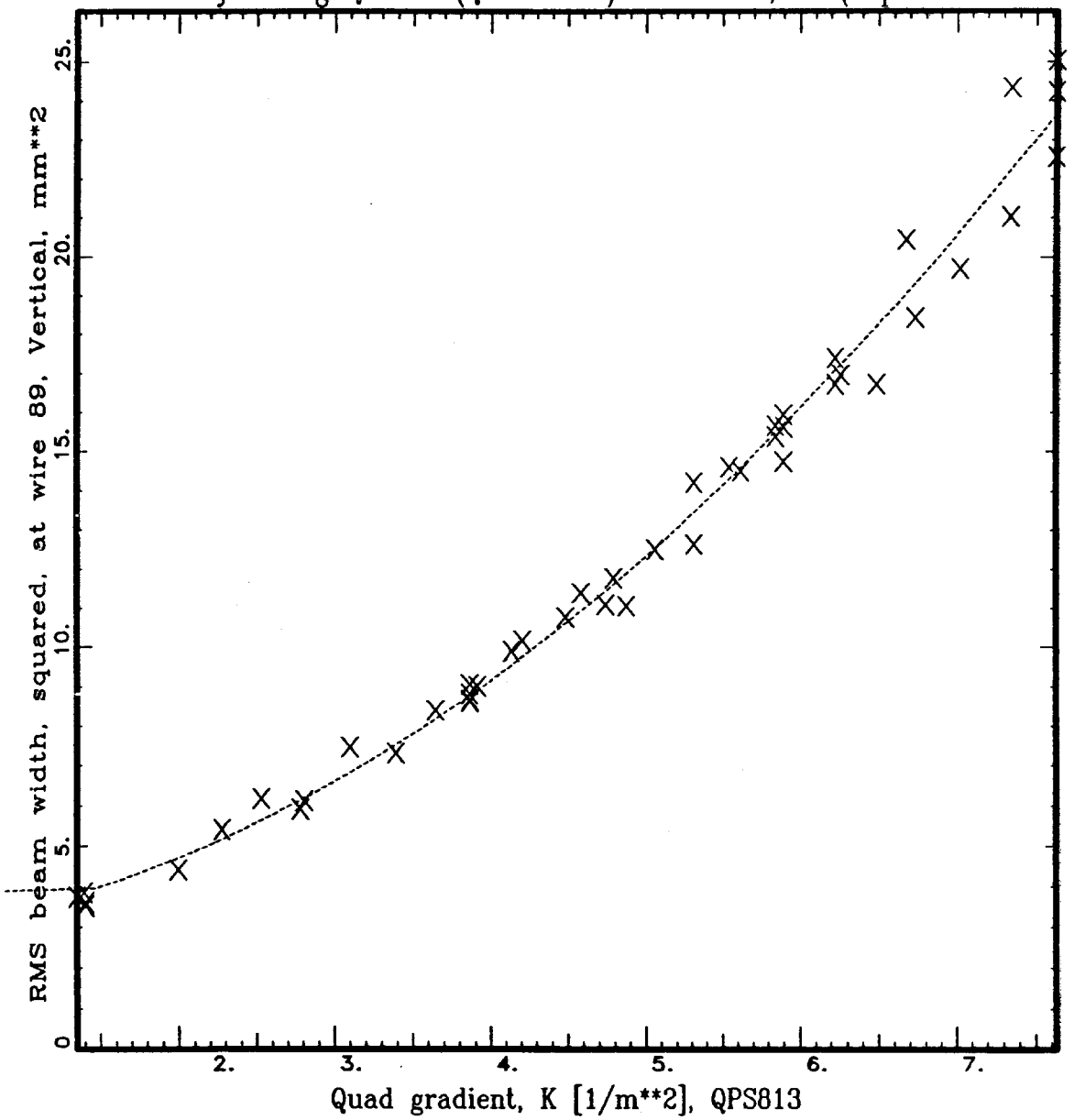
Hmmm?

$\Rightarrow \sigma_H \approx 0.5$ mm

Alpha, beta, gamma, emit @ QPS812: 0.6188 0.8848 0.6974, 0.645666E+01 [m,1/m,mm-mrad]
Normalized emittances: RMS= 4.190, 90%= 6.914, 95%= 8.213 pi-mm-mrad

[MCCRORY.MINUIT]ONEWIREMIT_5.DAT

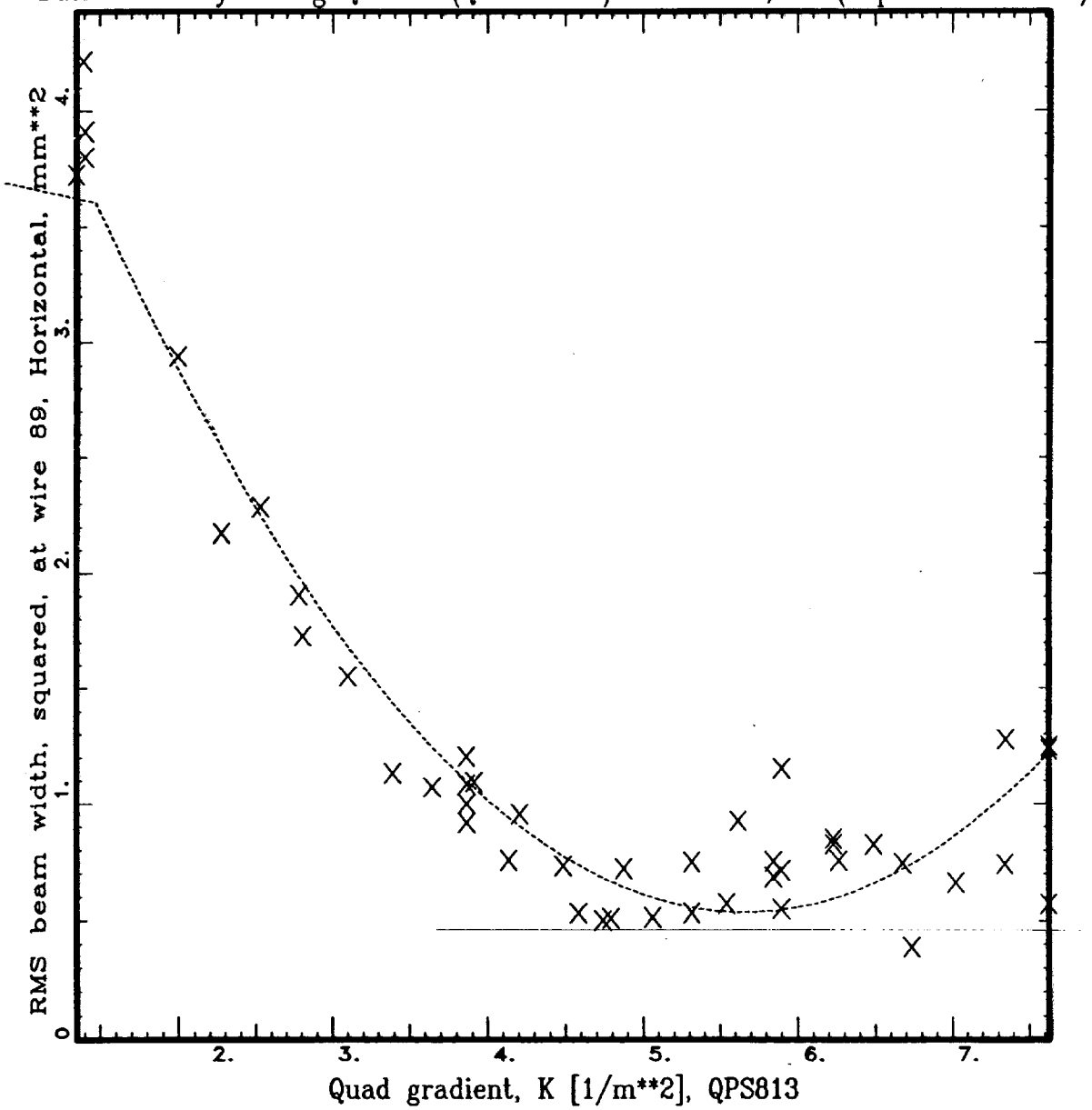
Data taken by tuning QPS812 (QPS813 off) on Dec 22, 88 (2 points removed)



Alpha, beta, gamma, emit @ QPS812: -0.5320 2.0216 0.3547, 0.156436E+01 [m,1/m,mm-mrad]
Normalized emittances: RMS= 1.015, 90%= 1.675, 95%= 1.990 pi-mm-mrad

[MCCRORY.MINUIT]ONEWIREMIT_5.DAT

Data taken by tuning QPS812 (QPS813 off) on Dec 22, 88 (2 points removed)



correlations in the fit, β vs. ε

```
SET PRIN            0
**********
***  1 ***SET PRIN     0.00000E+00
**********
_$1$DUA5:[MCCRORY]FITEMIT.LOG;22

MINIMIZE
**********
***  2 ***MINIMIZE
**********
```

VERTICAL

```
MIGRAD MINIMIZATION HAS CONVERGED.

FCN=   49.78020      FROM MIGRAD     STATUS=CONVERGE
                     STRATEGY= 1     ERROR DEF=     1

INT EXT  PARAMETER
NO. NO.    NAME          VALUE           ERROR
  1  1   BETA          0.88483        0.78732E-01    0.
  2  2   ALPHA         0.61882        0.71541E-02    0.
  3  3   EMIT           6.4567         1.0524       -0.
     4   x-zero        0.00000E+00    constant
     5   x-one         0.00000E+00    constant
     6   drift          1.1690        constant
     7   sigma         0.80000        constant
CONTOUR              1          3
**********
***  3 ***CONTOUR       1.0000        3.0000
**********
Y-AXIS: PARAMETER   3:   EMIT
   8.477      4446ADH      *
   8.309      54447AEI     *
   8.140      744447BFJ    *
   7.972      A643348BFJ   *
   7.804      C9632248CFJ  *
   7.635      FC8522258CG  *
   7.467      IFB8422258CG*
   7.299       IEB7422259CG
   7.130        HEA7322258CGJ
   6.962         HDA7321158CFJ
   6.793          HDA7311158BFI
   6.625           HDA7311147BEI
   6.457      ******HDA7411147AEH******
   6.288             HEB7411369DGJ
   6.120              HEB8511258CFI
   5.952               IFC8521147AEH
   5.783                IFC9631112369CFI
   5.615                 JGDA74222258BE
   5.446                  *HEB963222369
   5.278                  * IGDA7422224
   5.110                  *   HEB963222
   4.941                  *    IGDA8522
   4.773                  *      IFCA74
   4.604                  *        JHEC9
   4.436                  *          JHE
          I               I            I
      0.7274                        1.042
                  0.8848
     X-AXIS: PARAMETER  1:   BETA       ONE COLUMN=
FUNCTION VALUES: F(I)=   49.78     +   1.000     *I
EXIT
**********
***  4 ***EXIT
**********
```

```
-0.1528E-05  0.3267E-08  0.5340E-06
COVARIANCE MATRIX NOT POSITIVE-DEFINITE.
MATRIX FORCED POS-DEF BY ADDING 0.10015E-02 TO DIAGONAL
EIGENVALUES OF SECOND-DERIVATIVE MATRIX:
-0.3103E-04  0.6037E-05  0.9908E-03
COVARIANCE MATRIX NOT POSITIVE-DEFINITE.
MATRIX FORCED POS-DEF BY ADDING 0.10310E-02 TO DIAGONAL

MIGRAD MINIMIZATION HAS CONVERGED.
_$1$DUA5:[MCCRORY]FITEMIT.LOG;22                                  12-MAY-1989 10:4
```

HORIZONTAL

```
FCN=   38.27830      FROM MIGRAD     STATUS=CONVERGED  CALLS=  190 EDM=  0.24E-07
                     STRATEGY= 1     ERROR DEF=     1.0000

INT EXT  PARAMETER                                          STEP         FIRST
NO. NO.    NAME          VALUE           ERROR             SIZE       DERIVATIVE
  1  1   BETA          2.0216         0.11151        0.14408E-05   -0.60119E-01
  2  2   ALPHA        -0.53195        0.15632E-01   -0.10570E-03   -0.36577E-02
  3  3   EMIT           1.5644        0.38298E-01   -0.77864E-05   -0.17035E-01
     4   x-zero        0.00000E+00    constant
     5   x-one         0.00000E+00    constant
     6   drift          1.1690        constant
     7   sigma         0.50000        constant
CONTOUR              1          3
**********
***  3 ***CONTOUR       1.0000        3.0000
**********
Y-AXIS: PARAMETER   3:   EMIT
   1.638      33        2222222
   1.632     33       222 *   222
   1.626     3      222   *     222
   1.620     3     22     *       22
   1.613          22      *        22
   1.607         22       *         22
   1.601         2      111111       2
   1.595        22     11 *  11      22
   1.589        2      11  *   11      2
   1.583       22     11   *    11     2
   1.577       2     11    *     1
   1.570       2     1     *     1
   1.564      22****1***********1******
   1.558      2     1      *     1
   1.552      2     1      *     1
   1.546      2     1      *    11
   1.540      2     11     *    11      2
   1.534      2      111  * 111        2
   1.528      22       111111         22
   1.521       2          *          22
   1.515       22         *         22
   1.509        22        *        22
   1.503         22       *      222
   1.497          222     *  2222
   1.491            2222222222
          I            I            I
      1.799                     2.245
                  2.022
     X-AXIS: PARAMETER  1:   BETA       ONE COLUMN=  0.1784E-01
FUNCTION VALUES: F(I)=   38.28     +   1.000     *I**2
EXIT
**********
***  4 ***EXIT
**********
```