EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Note PS/LPI 87-30

July 1987

Calculating Emittances from Beam Profile Measurements

- Program,Data,Results

Alain Riche
CERN,PS,Geneva,Switzerland

Abstract

Many beam transport configurations are such that hand calculation of emittances from profile measurements is not practicable. A program is proposed,which entries may be sets of elements or matrices or Twiss parameters. Calculated results from some LPI beam measurements are presented.

1. Conditions of measurements and calculations.

a/ Nature of beam transport elements:
   drifts
   cavities with constant electric field
   quadrupoles as thin or thick lenses
   quadrupoles as thick lenses superimposed on accelerating cavities.

b/ Description of beam transport elements:
   The choice is given to describe an element by
      its beam transport matrix
      the Twiss parameters at both ends
      the set of items used in all classical programs.

A series of elements can be represented by a matrix or by Twiss parameters.

c/ Preparation of data

The set of data is shared by heading comments , a guiding frame to prepare any other set.

d/ Formalism.

First order matrix formalism is used,with simple or combined operators for the linacs description.

As well known,at least 3 observations are necessary for fixing the beam parameters in each plane.
It is possible to attach a weight to each observation of the beam width,accounting for the degree of confidence the user has in it.
Usefull considerations on the accuracy have been pointed out by S.Battisti(ref 2) about the necessary conditions for the measure--ments.

e/ The Cern computer library program "LINSQ" is used for least square fits.

f/ Beam observation.

Profiles were obtained from beam wire scanners or from scanning the video signal of the TV monitors used to get beam images when screens are introduced ,as J.P.Potier,J.P.Delahaye did (ref 1).

2. Short description of data set

Lines of comments must be present.

There are 2 paragraphs:

First : Number of points used. Horizontal or Vertical problem, Nb.of sigmas given, Signe of particle charge.
Currents in the quadrupoles,corresponding width profile in the H & V planes,weight. (dummy number for the width for the plane which is not selected).

Second:Description of the beam line,index for the description type, element after element ,or by matrices,or by Twiss parameters.

index	operator
-1	Quadrupole,thick lens
0	Quadrupole,thin lens
+1	Quadrupole,thick+acceleration.

lens with acceleration, 0:thin lens.

a quadrupole has a positive value for its gradient per ampere if it is H focusing for electrons.

+2	Matrix :2lines,each of 2 reals.
-2	Twiss parameters description : 2 lines with beta,alpha,mu (phase/2 PI) at each ends.
3	Drift with or without acceleration.

Remarks.

a/ Comments inserted within data help to set dthe description of the quadrupoles.By convention,the gradient per ampere is >0 for quadrupoles horizontally focusing electrons.

b/ Note that the quadrupoles for which the current varies are represented by a line with a dummy 0. current and 1 at the end.

c/ Units: Energy in Gev,Energy gain in Volt,Meter,Tesla.

d/ Use of Courant and Snyder parameter for unit cell strycture and corresponding beta function both periodic,(ref.4)

3. Examples .

a/LILV beam emittance,varying common current of QLB151 and QLB154,and observing WBS25.

b/Positron beam emittance,varying current of QNM36 and observing MTV30 screen.

```
' NB OF DATA SET FOR EMITTANCE CALCULATIONS'
 2
'Nb of exp. points ,1or2 :H or V ,Nb of sigmas measured, Part. sign'
5  1  1. -1
'Emitt. calculated for above nb of sigmas & also for population: '
0.80
'Ampere , H  Project.(M) , V Project.(m), Weight '
52.0  1.6E-3 .76E-3 1.
56.0  .85E-3 3.2E-4 1.
58.1  5.5E-4  5.5E-4 1.
60.0 3.0E-4  1.0E-3 1.0
64. 7.4E-4 0.  1.
'Title
 H plane first & last quadrupoles, at end oflinac V , 1 Amp., WBS25
'Nb of elements in the line,including drifts'
8
'-1:Lens, 0:Thin L., 1:Thick+Acc., 3:Drift acc?, 2:Matrix,-2Twiss'
-1
'Meters,DE(MeV),E(GeV), Gradient(TM-1A-1), Amp,0 or 1:Fix or Var.'
0.219 0. .2 6.12E-2 0.  1
3
0.061 0. 0. 0. 0. 0
-1
0.219 0. .2 -6.12E-2 55.4  0
3
0.061 0. 0. 0. 0. 0
-1
0.219 0. .2 -6.12E-2 55.4  0
3
0.061 0. 0. 0. 0. 0
-1
```

```
0.219 0. .2 6.12E-2 0.  1
3
1.677 0. 0. 0. 0. 0
'Part.sign +-1, Nb exp.points, lor2 :HorV, Nb of sigmas for 1/2 proj.
'
+1  6  2  4.
'Emitt. calculated for above nb of sigmas & also for population: '
0.80
0.8
'Ampere , H  Project.(M) , V Project.(m), Weight '
10. 0.   7.80E-3  0.5
40.0 0.  6.85-3  0.7
90.   0.  6.1E-3  0.9
120. 0.  6.15E-3 1.
180. 0.  7.2E-3   1.
210.  0. 8.65E-3   0.8
'Title       '
QNM36 V    positrons HIPMTV30
'Nb of elements in the line,including drifts'
4
'-1:Lens, 0:Thin L., 1:Thick+Acc., 3:Drift acc?, 2:Matrix,-2Twiss'
-1
'Meters,DE(MeV),E(GeV), Gradient(TM-1A-1), Amp,0 or 1:Fix or Var.'
0.300 0. .491 -1.75E-2 0.  1
3
0.668  7.  .493 0.      0. 0
3
0.304 0. 0. 0. 0. 0
-2
5.189  -0.194  0.031
2.261  -0.454 0.891
```

4. Some results.

Emittances are calculated for 80% of the beam population

Positrons

Varying	Monitor	Plane	Emittance	beta	alpha	ref
QNM36	WBS14	H	2.8e-6	7.2	-1.	(1)
QNM36	MTV30	H	6.4e-6	2.4	-.27	(2)
QNM36	MTV30	V	4.9e-6	2.9	.27	see fig.

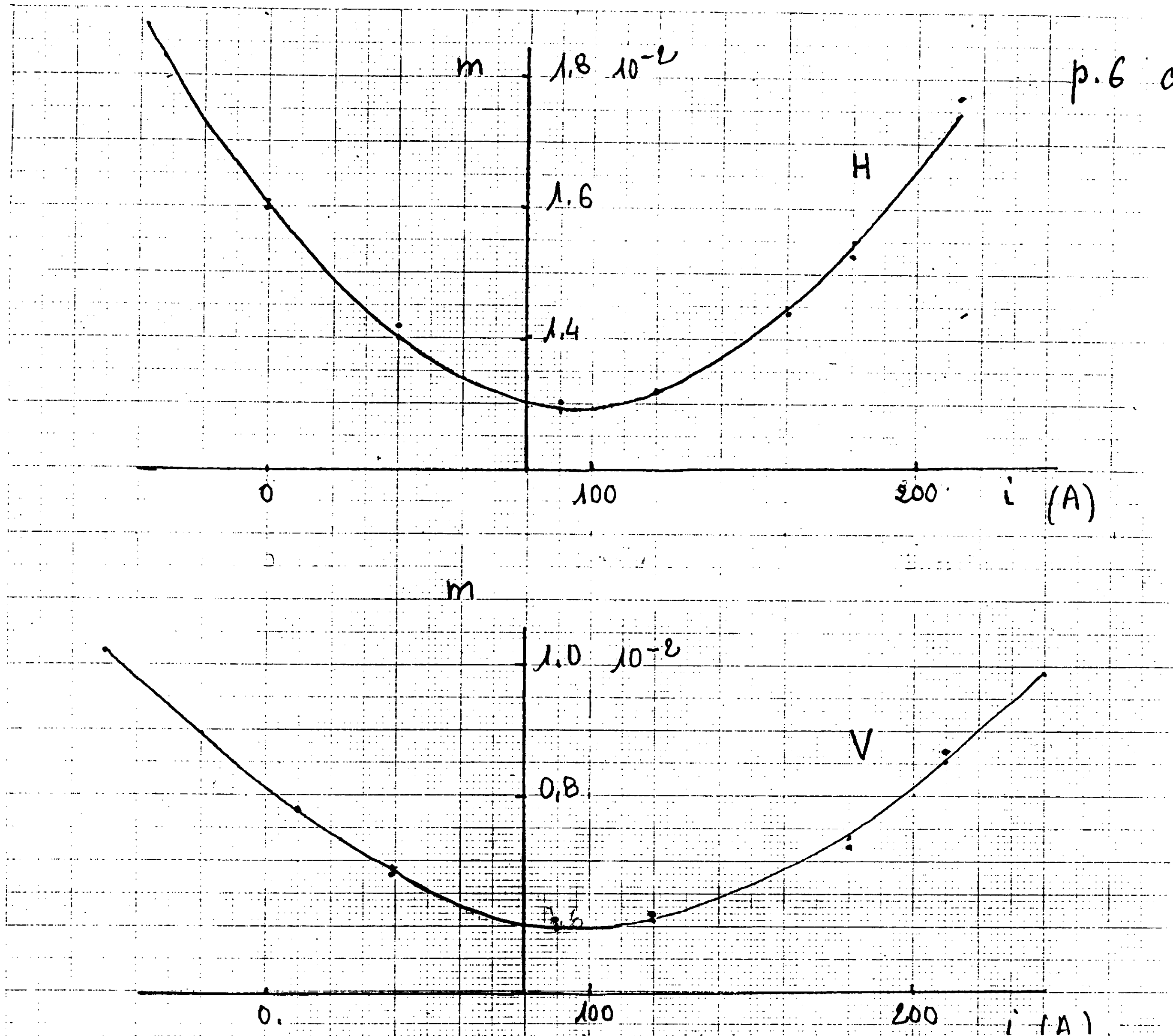
Electrons

Varying	Monitor	Plane	Emittance	beta	alpha	ref
QNM36	WBS00	H	0.2e-6	2.3	1.2	(3)
QNM36	WBS00	V	.22e-6	12.2	-3.9	
QLB152,3	WBS25	H	.23e-6	4.2	4.7	(4)
QLB151,4	WBS25	H	1.0E-6	20.	-1.5	(5)
QLB152,3	WBS25	H	2.3E-6	50.	-2.3	(6)
QLB152,3	WBS25	V	0.9E-6	16.	-8.7	(7)
QLB151,4	WBS25	V	.94E-6	22.	-4.3	(8)

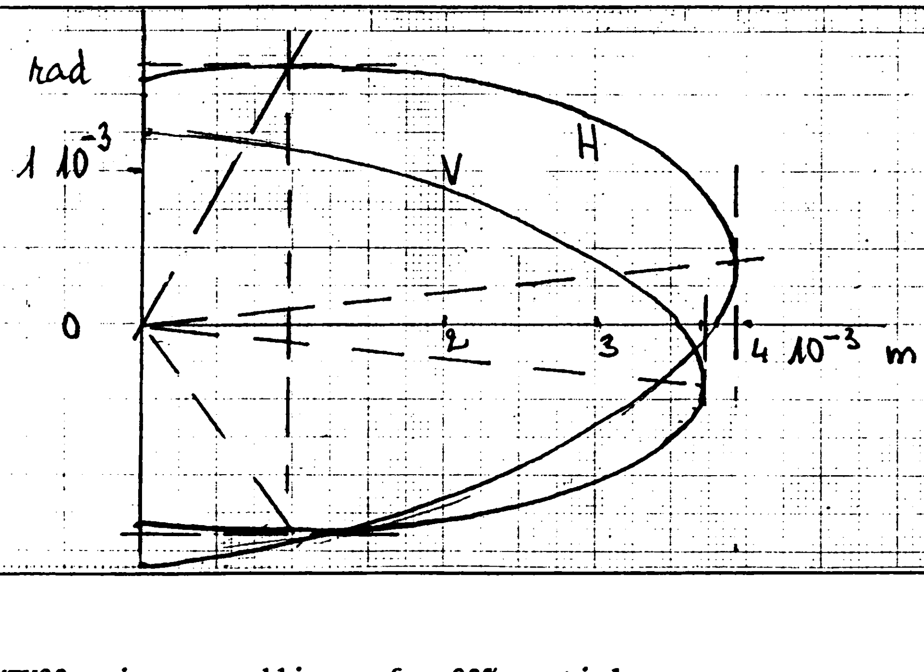
(1) Delahaye,Potier...LPI Log book 17.06.87
(2) Potier... LPI Log book 9.06.87
(3) Battisti... LPI Log book,28.11.86
(4) Potier,Priestnall,1/4/87, 1.5 A beam,12.5 Hz
(5) idem 1.0 A
(6) idem 0.5 A
(7) idem 1.0 A
(8) idem 0.5 A

5. Precision.

Varying the weights affects considerably the precision.
The e- beam measurements QNM36-WBS00 in vertical plane, are taken as data base. One solution is for uniform weight 1. In the others,weight is low for beam widths measured far from the minimum obtained when varying current in the quadrupoles. All such points are close to the asymptotic lines.
In this particular geometry,taking thin or thick lens model is not important.
Detailed results are presented in the appendix,with evidence of the difficulty for finding significant information from measurements.



QNM36-MTV30 profile measurement and fit (beam width:4 sigmas)



QNM36-MTV30 emittance ellipses for 80% particles.

6. Conclusion.

The interpretation of the beam profile measurements gives results which are less precise than generally expected.
Thus,the measurements for the positrons with WBS14 do not agree with those using MTV30.Part of the difference could be due to beam loss between screnn MTV30 and WBS14 positions or to differences in machine settings (gun,phases..) for the experiences.
Measurement of positrons in V plane,on WBS14 was unusable.

Corrresponding to the beam size variation observed on screen MTV30, the theoretical variation was represented on the same graph, as a result of nominal e+ beam parameters at LIL end.
Using this curve as data set and calculating back the beam parameters is a way to verify practically our formalism:

Varying	Monitor	Plane	Emittance	beta	alpha	ref
QNM36	MTV30	H	4.53e-6	4.04	-1.02	(2)
QNM36	MTV30	V	4.58e-6	4.62	1.14	(2)

References.

(1) LPI Log Book 1986-1987
(2) Mesure du Profil Transversal du faisceau de LIL et a l'injection dans EPA S.Battisti,PS/LPI/Note 83-14
(3) Mesure de l'ellipse d'emittance a la sortie de LILW A.Bellanger,S.Battisti,PS/LPI/Note 85-01
(4) TRANSPORT, K.L.Brown... CERN 80-04