EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
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CERN - PS DIVISION

PS/ PA/ Note 96-27 (PPC)

MINUTES OF THE PPC MEETING HELD ON 21ST JUNE, 1996

D. Manglunki

Geneva, Switzerland
28 June 1996

PS/PA Note 96-27 (PPC)

Minutes of the PPC meeting held on June 21st, 1996

Present: G.Arduini, R.Cappi (Chairman), K.Cornelis, R.Jung, D.Manglunki (Secretary), M.Martini, J.P.Riunaud, G.Roy, K.Schindl

Agenda: PS-SPS transfer of LHC beams:

- Identification of the problems
- Status of PS beam studies
- Common strategy: Who will do what? How and when?

Introduction (R.Cappi):

- As a reminder, specifications of the PS beam for LHC:
  - 84 bunches
  - total intensity $1.5\text{x}10^{13}$ protons per pulse
  - $\beta\gamma = 28.1$
  - $\varepsilon_x^* \approx \varepsilon_y^* \approx 3\ \mu\text{m}$ $(\beta\gamma\,\sigma^2_{x,y}/\beta_{x,y})$
  - $4\,\sigma_t \approx 4$ ns
  - $2\,\sigma_p/p \approx 2.5\text{x}10^{-3}$
  - bunch spacing = 25 ns

- Problem number one is the conservation of transverse emittances in the transfer from PS to SPS. The main causes for blow-up would be:
  - the stray field in the PS magnet downstream the extraction septum
  - mismatch
  - missteering

Status of the study of the stray field(M.Martini):

(see attached copy of poster and transparencies)

- The model that had been used up to now (localised multipole components, tracked with MAD) gave a computed geometric blow-up factor of more than 50%.
- The stray field has been measured on a laboratory magnet. The effect of shims (absent on the measured unit) has been added, and particles were tracked. The computed Twiss parameters are in better agreement with the measurements. (geometric blow-up less than 15%)
- Dispersion studies is the next step: reproduce on computer simulations the observed behaviour of the matching with respect to $\Delta p/p$

Discussion on common strategy

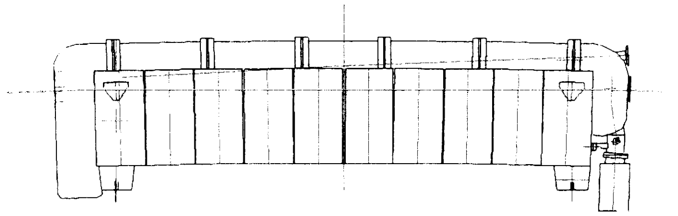
- The computed geometric blow-up is not to be neglected but is usually pessimistic.
- The measurements of the magnetic field on the PS magnets in the laboratory, and the computations have been performed with PFW currents that are different from the ones that are currently used in operation. They have to be refined with the proper currents.
- A correction scheme for matching with respect to $\Delta p/p$ has to be studied, possibly by the addition of sextupoles inTT2.
- The SPS semgrids that are currently used in TT10 are not adapted to the LHC beam. A new device based on Mylar/Aluminum screens, using transition radiation (surface effect) is being studied by SL/BI.
- Machine developments to compare the emittances of the circulating beam in PS and SPS, using wire scanners, will take place during the following weeks.

TRAJECTORY AND OPTICAL PARAMETERS IN A NON-LINEAR STRAY FIELD

D. Manglunki, M. Martini, CERN
I. Kirsten, Heidelberg University

Abstract

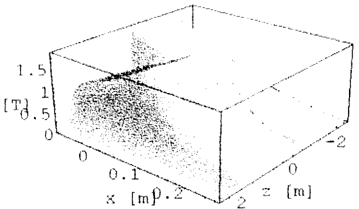
A new optics for the main CERN Proton Synchrotron magnet is modelled to allow a precise description of the ejected beams. For that purpose, field maps of the magnet have been measured for the various operational current settings. They include the central field, the end stray field and the lateral stray field. In order to get a functional form which can be inserted in the equations of motion for a charged particle in a magnetic field, the discrete field maps are converted into bi-dimensional polynomials of degree up to fourteen. These equations of motion can be written as a set of four first order differential equations which are solved simultaneously. Two of them are non-linear and describe the centroid motion, the other two are linear and apply to the betatron motion. The method has been validated by producing extraction conditions which have been verified experimentally with the 26 GeV/c beam for the future LHC.



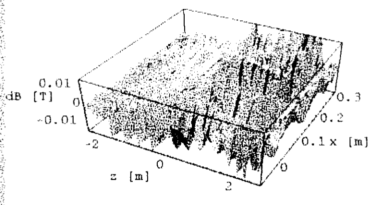
CERN PS magnet unit number 16, including the 26 GeV/c proton extraction channel

The CERN PS lattice consists of 10 super-periods made of 10 combined function magnets, eight 1.0 m and two 2.4 m long straight sections. Each magnet is composed of two half-units with gradient of opposite sign, separated by a central junction. The half-units are made of five blocks with small wedge gaps in between lined up on the central orbit.

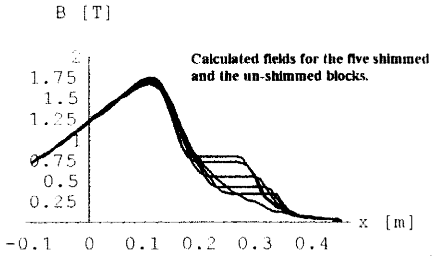
The necessity to extract 26 GeV/c protons in a 2.4 m straight section with little angle deflection (29 mrad) imposes the downstream half-unit adjacent to the ejection septum to be open to ease the fitting of the extraction pipe across the magnet aperture. The ejection trajectory in this region remains close to the central orbit and thus the aberrations in the magnetic fields are kept at a reasonable value. When traversing the subsequent F half-unit the ejection trajectory moves away from the central orbit and field aberrations become strongly non-linear: the beam experiences a field gradient with a reverse sign, yielding large horizontal betatron function values at the magnet end.
Reduction of the non-linear aberrations was done by shimming the F half-unit. Straight parallel shims have been mounted at different radial positions on the five blocks to shape a constant magnetic field over the ejected beam width.



Fitted field map



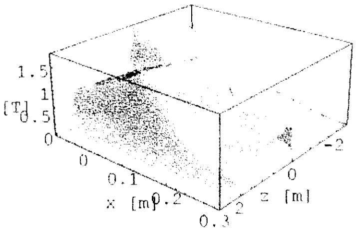
Difference between fitted and measured field



Calculated fields for the five shimmed and the un-shimmed blocks.

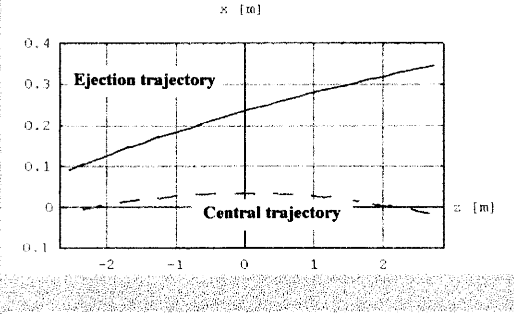
New magnetic measurements on operational CERN PS magnet working points were performed in 1992, including measurements of the central field, the end and lateral stray fields, and the field in the junction between the two half-units. Polynomials up to degree 14 in *x* and *z* have been retained to reach a good agreement with the measured field (accuracy within ±0.01 T). The fitting has been performed using the standard *Mathematica* fit function.

Magnetic measurements have been done on a laboratory magnet unit in the absence of shims, thus the measured field map has to be corrected to consider the shimming effect.

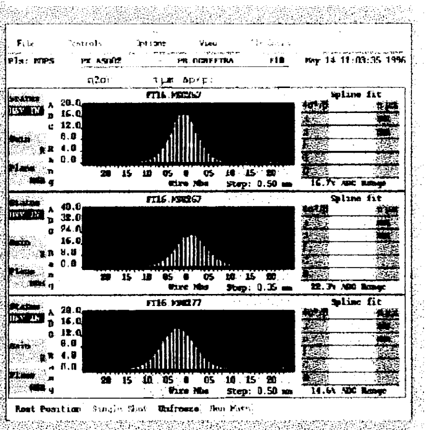


Fitted field map after considering the shims

Field calculations have been carried out on the five blocks equipped with shims using the two-dimensional Poisson program. Polynomial fittings up to degree 25 in *x* of Poisson output have been carried out to get a functional form of the computed field.



Ejection trajectory and transfer matrix computations have been performed using the built-in *Mathematica* numerical differential equation solver with initial conditions given by MAD: the beam centroid enters the field map with coordinates x=91.6 mm, ϕ=62.6 mrad, and exits the field map at x=345.0 mm, ϕ=36.4 mrad. For comparison the angle of the ejection pipe with respect to the z-axis in the F half-unit 16 is 43 mrad.



Transverse emittance matching in the TT2 channel are obtained from beam profiles measured at three SEM-grid detectors. Using the computed optics parameters, the mismatch derived from measurements was found to be less than 15% for the horizontal plane and less than 10% for the vertical plane. This is a fairly good result (the best achieved so far) considering that an error on optical parameters transforms into a large mismatch error.

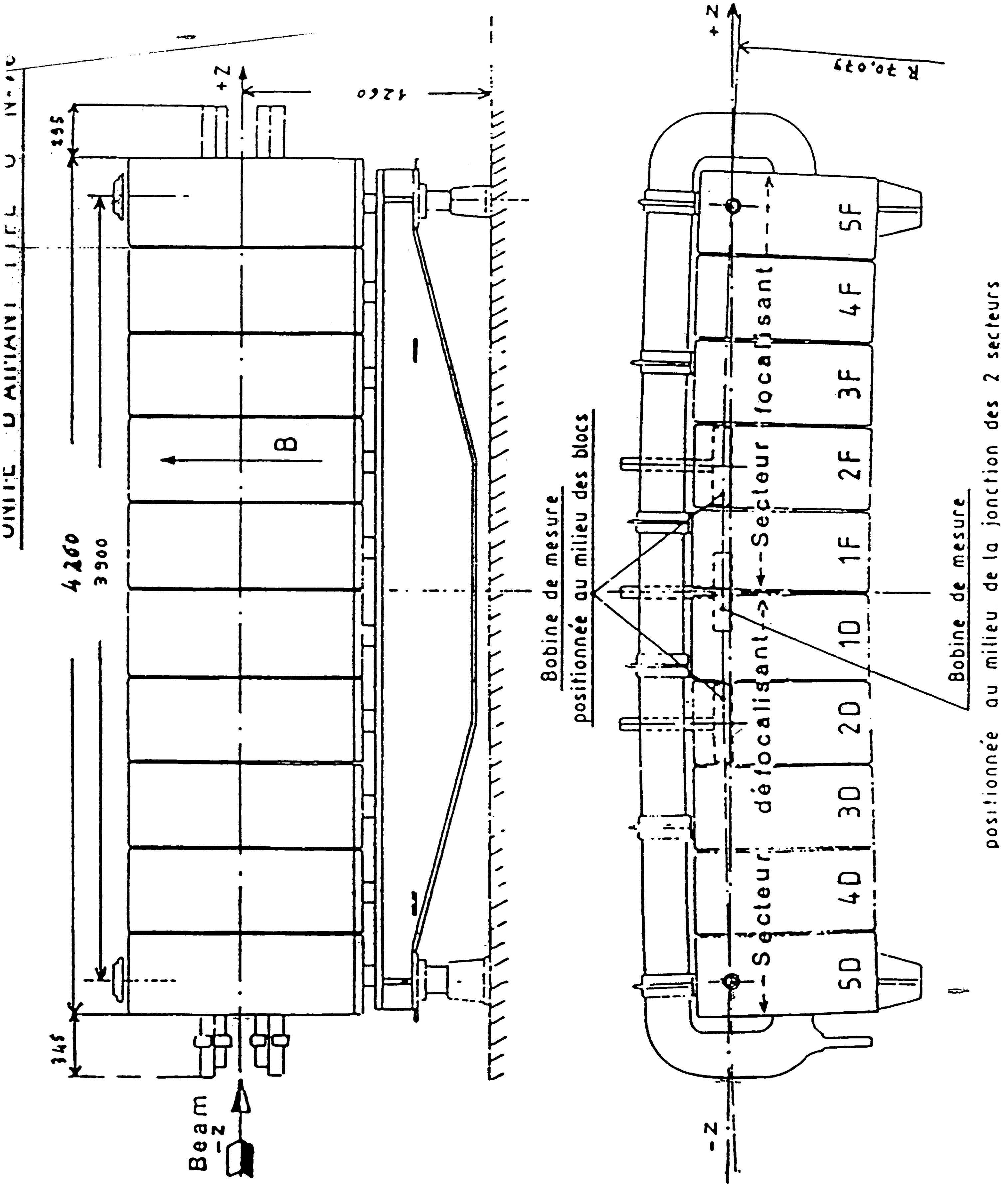
	β_x [m]	α_x	D_x [m]	D_x'	β_y[m]	α_y
Field map	31.25	-2.71	3.10	0.26	7.11	0.74
MAD	33.79	-3.37	3.25	0.32	6.13	0.85

Optics parameters (at stray field exit) derived from the transfer matrices

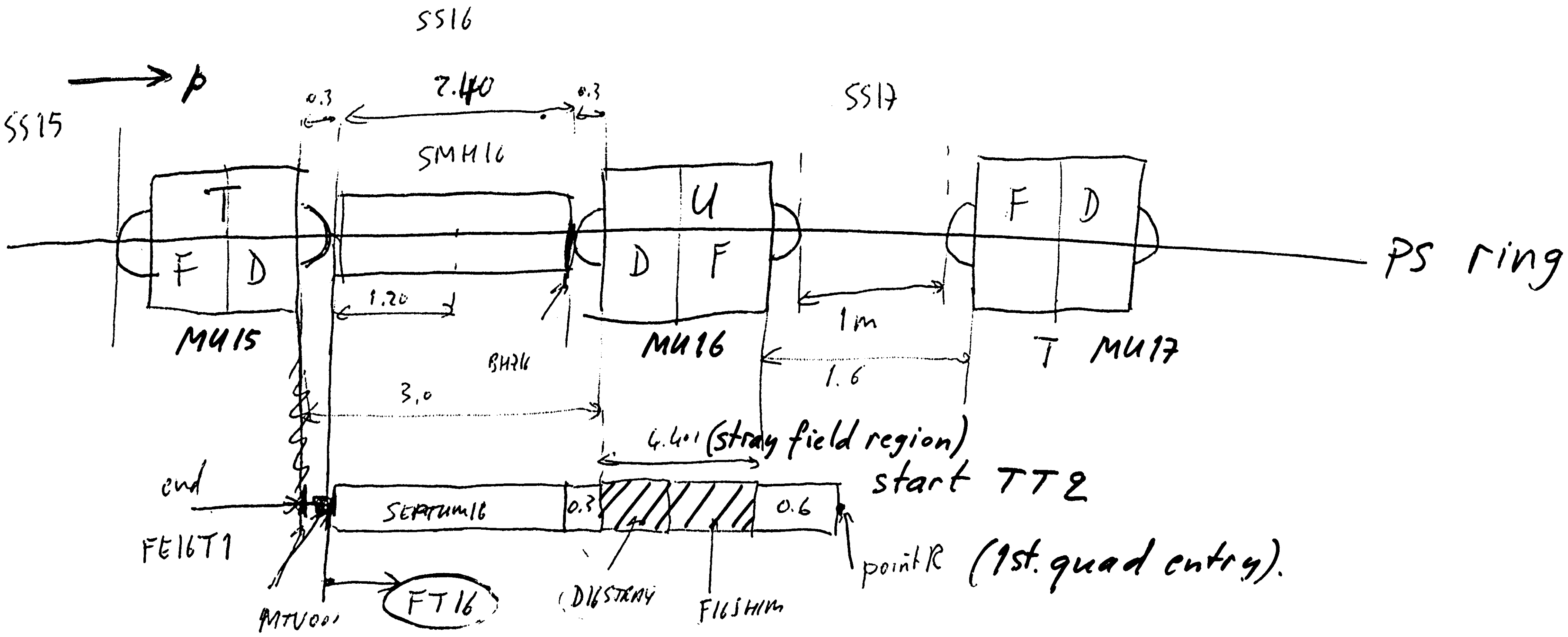
The optical parameters have been derived from the transfer matrix components and compared with previous models which consider the MAD stray field description as given by dipole, quadrupole and sextupole coefficients distributed over the magnet length.

The emittance measurement program shows a mismatch less than 15%

PS MAGNET


+Z
-Z
1260
295
4260
3900
345
B
Beam
R 70,079
5F
4F
3F
2F
1F
1D
2D
3D
4D
5D
Secteur focalisant
Secteur défocalisant
Bobine de mesure positionnée au milieu des blocs
Bobine de mesure positionnée au milieu de la jonction des 2 secteurs

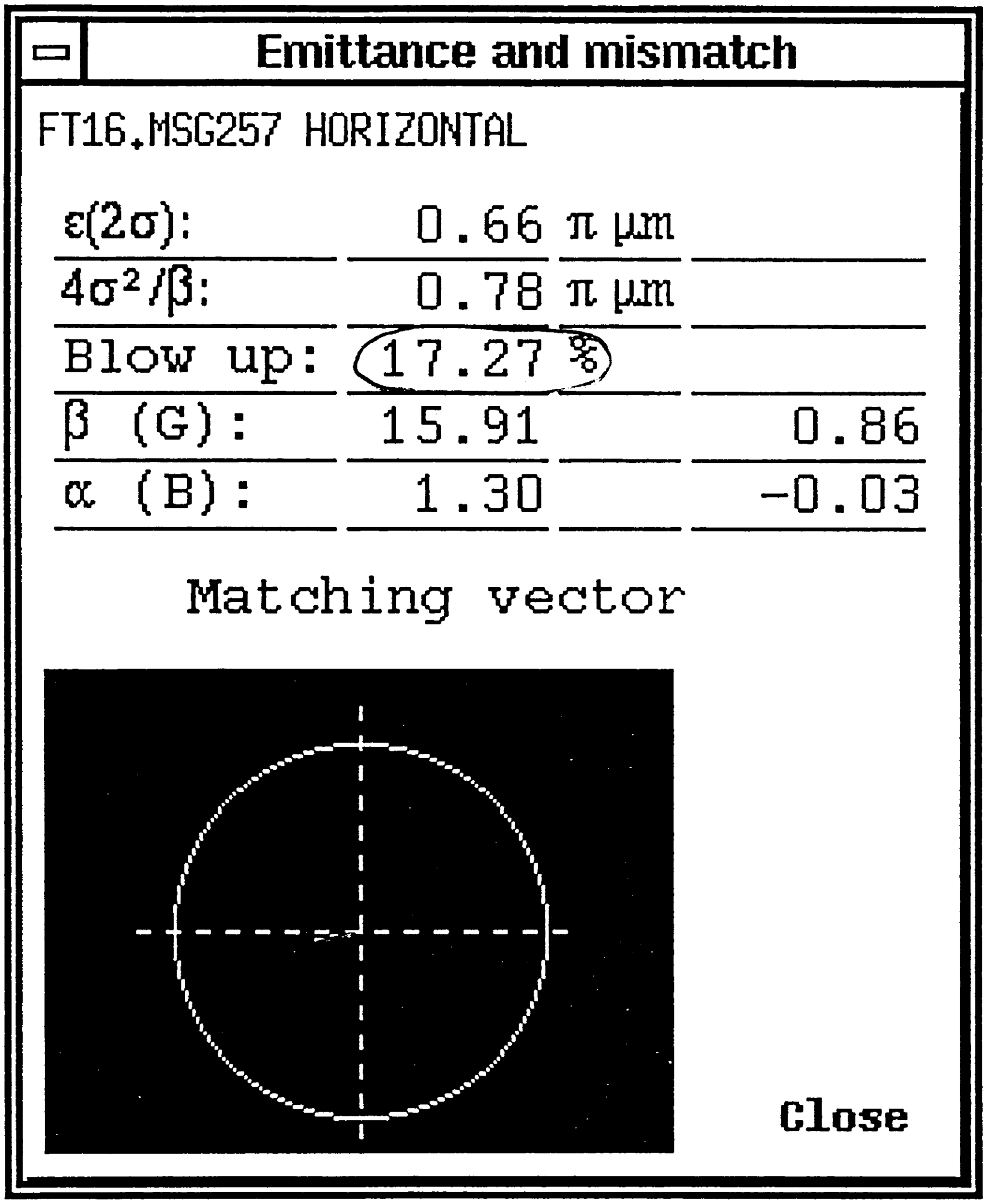
EJECTION 16
(PS → TT2)



MAD model

TRAJ model

Trajectory & transfer matrix computations through ejection magnet stray field
(see EPAC 96, I. Kirsten, D. Manglunki, M. Martini)



Emittance and mismatch

FT16.MSG257 HORIZONTAL

$\varepsilon(2\sigma)$:	0.66	π µm	
$4\sigma^2/\beta$:	0.78	π µm	
Blow up:	17.27	%	
β (G):	15.91		0.86
α (B):	1.30		-0.03

Matching vector

$$\frac{\Delta\varepsilon}{\varepsilon} = k\left(\frac{k}{2}+\sqrt{1+\frac{k^2}{4}}\right) \qquad k=\sqrt{\frac{(G-1)^2+B^2}{G}}$$

k is the matching vector
($k=0$ i.e $G=1$ and $B=0$ for perfect matching)

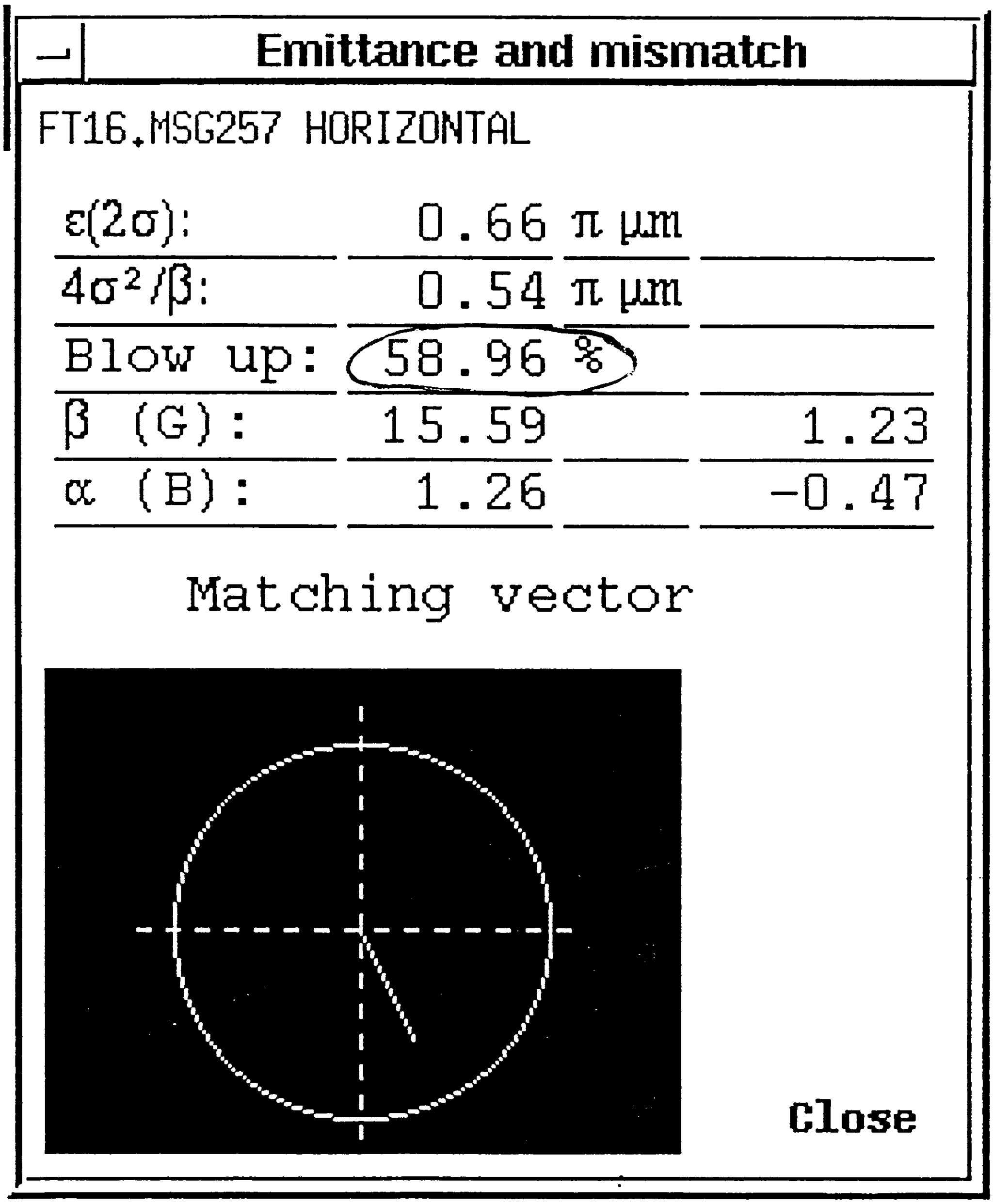
```
Linear lattice functions.    TWISS               line: TT2
Delta(p)/p:     0.000000     symm: F             super:   1
--------------------------------------------------------------------------------
     ELEMENT SEQUENCE       I                 H O R I Z O N T A L             I
pos.  element occ.     dist I   betax  alfax   mux    x(co)   px(co) Dx     Dpx  I
no.   name    no.      [m]  I   [m]    [1]     [2pi]  [mm]    [.001] [m]    [1]  I
--------------------------------------------------------------------------------
begin TT2        1      0.000   33.241 -3.358  13.568  0.000   0.000  3.034 0.296
   98 MSG257     1    162.011   19.130  2.007  14.709  0.000   0.000  1.752-0.256
  106 MSG267     1    180.471    7.544 -0.106  14.979  0.000   0.000 -0.991-0.145
  114 MSG277     1    198.931   32.398  0.929  15.117  0.000   0.000 -2.886 0.090
end   TT2        1    343.099    5.341 -0.056  16.345  0.000   0.000 -0.065 0.219
--------------------------------------------------------------------------------
total length =        343.099400          mux           =        16.344898
delta(s)     =          0.000000 mm       dmux          =        -6.818652
                                          betax(max)    =        99.923250
                                          Dx(max)       =         4.775940
                                          Dx(r.m.s.)    =         2.719416
--------------------------------------------------------------------------------
```

TRAJ MODEL

See EPAC96

(I. Kirsten, D. Manglunki, M. Martini)

MAD model



Emittance and mismatch

FT16.MSG257 HORIZONTAL

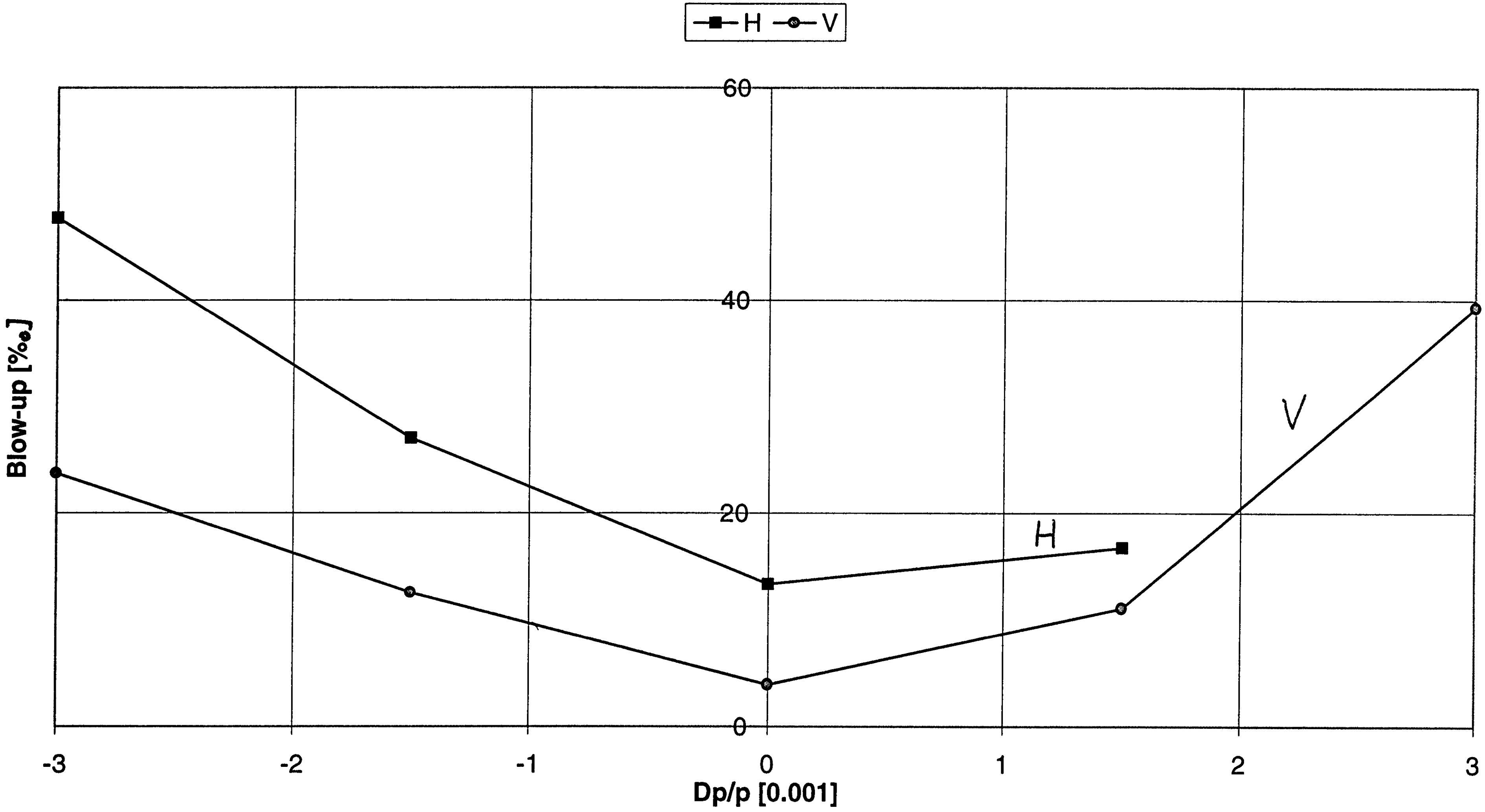
$\varepsilon(2\sigma)$:	0.66	π µm	
$4\sigma^2/\beta$:	0.54	π µm	
Blow up:	58.96	%	
β (G):	15.59		1.23
α (B):	1.26		-0.47

Matching vector

```
1TT2,FROM,POINT,R,TO,POINT,A
 Linear lattice functions.    TWISS               line: TT2
 Delta(p)/p:     0.000000     symm: F             super:   1
 ------------------------------------------------------------------------------------------
      ELEMENT SEQUENCE       I                H O R I Z O N T A L                       I
 pos.  element occ.     dist I   betax  alfax   mux     x(co)   px(co) Dx      Dpx   I
 no.   name    no.       [m] I    [m]    [1]    [2pi]   [mm]    [.001] [m]     [1]   I
 ------------------------------------------------------------------------------------------
 begin TT2        1     0.000   30.572 -2.633  13.569  0.000   0.000   3.046 0.238
    98 MSG257     1   162.011   13.609  1.142  14.774  0.000   0.000   0.612-0.185
   106 MSG267     1   180.471   10.850  0.225  14.993  0.000   0.000  -1.485-0.048
   114 MSG277     1   198.931   22.408  0.899  15.131  0.000   0.000  -2.311 0.130
 end   TT2        1   343.099    7.761 -0.445  16.407  0.000   0.000   0.703 0.203
 ------------------------------------------------------------------------------------------
 total length =        343.099400         mux           =        16.406534
 delta(s)     =          0.000000 mm      dmux          =        -4.695814
                                          betax(max)    =        65.477862
                                          Dx(max)       =         3.507183
                                          Dx(r.m.s.)    =         2.249668
 ------------------------------------------------------------------------------------------
```

MAD MODEL

Mismatch vs. momentum deviation



Distribution

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G.Roy	SL
K.Schindl	PS
D.J.Simon	PS