BNL-104698-2014-TECH

AGS/AD/Tech Note No. 280;BNL-104698-2014-IR

# STUDY OF A NEW EXTRACTION SCHEME

C. Steinbach

May 1987

Collider Accelerator Department

**Brookhaven National Laboratory**

**U.S. Department of Energy**

USDOE Office of Science (SC)

# DISCLAIMER

Accelerator Division
Alternating Gradient Synchrotron Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

Accelerator Division
Technical Note

**AGS/AD/Tech. Note No. 280**

STUDY OF A NEW EXTRACTION SCHEME

Charles Steinbach*

May 4, 1987

Recent measurements of the efficiency of the AGS slow extraction give a result of 97 ± 1%.[1] The increase in intensity expected from the future use of the Booster makes it desirable to improve this efficiency. This note presents the summary of studies on possible more efficient new extraction schemes for the AGS. All these results have been obtained using a program initially written for the HP 9845 desk computer, now available on IBM PC,[2], and described in Appendix I.

## Present Extraction

Figure 1 shows the phase plane at the electrostatic septum (ES) straight section (bump not taken into account).

When the four sextupoles are powered, extraction can start, driven by a negative slope of the flattop. This pushes the beam from its stable position slightly inside the machine, toward the resonance region near the center. For each energy, there is a set of three separatrices, forming a triangle within which particles are stable. The lower the energy, the larger the stable triangle. Resonance occurs near the central orbit, when the triangle reduces to zero.

At any time during extraction particles escape on all separatrices between the zero emittance triangle and the nominal emittance one, the corresponding energy being higher for the zero and lower for the nominal emittance.

For a $2\pi$ mm mrad emittance,

$$\frac{\Delta p}{p} \simeq 2 \times 10^{-4}.$$

*Visitor from CERN.

Particles move outward along each of the three separatrices, one after the other, at an increasing velocity in the horizontal phase plane. They eventually jump across the ES, and are kicked toward the outside. They now follow trajectories outside the separatrices, with a different velocity, so that after almost three revolutions they reach the thin septum magnet (TSM) at F5. The part of the beam being extracted has then become wider, and is separated from the circulating beam by a gap wide enough to accommodate the 0.8 mm septum at F5, as can be seen in Figure 2 showing the horizontal phase space in F5.

F5 gives the beam another kick to the outside, creating a hole at F10, wide enough to accept the 16 mm thick extraction magnet (EM), which deflects the beam to the outside into the extracted beam transfer line (Figure 3).

## New Possibilities

There are two ways to improve efficiency:

1. decrease the ES effective thickness (Ti-alloy wires being tested),[3]
2. increase the spiral pitch at the ES.

We will concentrate on this second approach.

We must obviously drop the idea of using the non-linear effect to create the gap at the thin septum magnet, and we choose to use the ES deflection directly.

Unfortunately, the hole one can create at the TSM is small and emittance dependent (two examples in Figures 4 and 5). The phase of the extracted beam at the EM is also a problem. Figures 6 and 7 show cases in which the extractor magnet comes too early or too late in betatron phase around the machine. It is also possible that straight sections may not be available, as in the case of Figure 7, which would require that the ES be located in A20 in order to keep the EM in F10.

We, therefore, propose to enhance the kick produced at ES with a quadrupole to increase the clearance at the TSM. An additional quad of equal strength and opposite polarity will roughly cancel the tune shift due to the first quad and can be used to help adjust the phase at the EM.

A further gain can be obtained from the quads, since they modulate the dispersion functions around the machine. If the dispersion function is increased at the ES and decreased at the TSM, then the holes at the TSM created by the ES kick at various energies tend to move closer together. A careful choice of the quad locations can give this result. This effect becomes stronger if the chromaticity is reduced, but the instantaneous $\Delta p/p$ is then increased.

Three tentative schemes are presented here, as examples, following these principles.

1. ES in A20, TSM in F5, and EM in F10 with quads in A5 and L5 normal chromaticity (Figures 8, 9, and 10).

2. Same as #1 with reduced chromaticity (Figures 11, 12, and 13).

3. ES in F20, TSM in K5, and EM in F10 with quads in F5 and H5, normal chromaticity (Figures 14, 15, and 16).

4. Same as #2 with reduced chromaticity and quad strength (Figures 17, 18, and 19).

Appendix II shows the main characteristics of these schemes together with those of the existing one, as calculated from the computer program. Standard present strengths of the ES and TSM have been used.

None of these can be implemented as such due to the unavailability of many straight sections. There are obviously other interesting schemes, but no real good one has been found until now that fits in the present machine without requiring straight sections which are necessary for other uses.

However, the A20 straight section will no longer be used when the AGS is injecting through the Booster. Schemes #1 and #2 would become possible. The second is particularly interesting as it offers small beam sizes for the circulating beam as well as in both magnetic septa for a 10 mm spiral pitch at the electrostatic septum. The clearances for both magnetic septa are large and relatively independent of emittance. It is an attractive and simple design with apparently good performances, which could potentially halve the losses at extraction.

At this stage, one can list some of the further questions to be answered before one can talk of implementing the scheme:

- Make sure the A20 straight section is really available, and so are A5 and L5 for the quadrupoles.
- A current of 600 A is assumed for the quadrupoles, as well as the sextupoles. Is this possible, or should special elements be designed? The chromaticity will have to be decreased too.
- It may not be impossible to find a sextupole arrangement using still available straight sections in 5, so that those in 13 would be freed for chromaticity corrections.
- The electrostatic septum gap and its voltage should be doubled, to increase the useful width and keep the field to its present value. Does this raise big problems?
- The instantaneous momentum dispersion is equal to about 8 x $10^{-4}$ for 1.5 $\pi$ mm-mrad (5 times bigger than at present for the same circulating beam emittance). Is this acceptable?
- The vertical phase optics should be checked.
- Last but not least, the next step should be a more realistic simulation with a sophisticated tracking program including the full machine non-linearities.

The author wishes to thank all the AGS people who have helped him in this work, one way or another, and particularly E. Bleser, C. Gardner, J.W. Glenn, D. Lowenstein, Th. Sluyters, A. Soukas, M. Tanaka, R. Thern, and W. van Asselt.

## References

1. M. Tanaka, Extraction Group Physics Note #001.
2. R. Thern, Private Communication.
3. L. Repeta, Private Communication.

mvh

APPENDIX I

COMPUTER PROGRAMME

The tracking programme, written in Basic, uses the interactive and plotting possibilities of the HP 9845 desk computer.

A set of data describes the machine. These are the values of the betatron wave number Q in both planes and the horizontal chromaticity for the bare machine.

The number of straight sections taken into account is limited to those where a relevant element is installed: septum, dipole, quadrupole or sextupole. The data describing each section of the bare machine are:

- the phase angle as counted from the last section $\Delta\varphi_i$ for both planes,
- the Twiss parameters $\alpha_i$, $\beta_i$ for both planes,
- the dispersion parameter $\alpha_{pi}$ and its derivative $\alpha'_{pi}$,
- the strength of the element located in the section,
- in the case of a septum, its radial position.

The elements are all considered as thin and placed in the centre of the straight section. The 2x2 matrix, referring to the closed orbit as origin, between two sections labelled 1 and 2 is [5,6]:

$$\begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix} = \begin{pmatrix} \sqrt{\frac{\beta_2}{\beta_1}}\,(\cos\Delta\varphi_2+\alpha_1\sin\Delta\varphi_2) & \sqrt{\beta_1\beta_2}\,\sin\Delta\varphi_2 \\ \frac{-1}{\sqrt{\beta_1\beta_2}}\left[(1+\alpha_1\alpha_2)\sin\Delta\varphi_2+(\alpha_2-\alpha_1)\cos\Delta\varphi_2\right] & \sqrt{\frac{\beta_1}{\beta_2}}\,(\cos\Delta\varphi_2-\alpha_2\sin\Delta\varphi_2) \end{pmatrix}$$

and the 3x3 matrix applying to the horizontal phase plane coordinates relative to the centre of the machine and to $\Delta p/p$ may be written [7]:

$$\begin{pmatrix} A_{11} & A_{12} & \alpha_{p_2}-A_{11}\alpha_{p_1}-A_{12}\alpha'_{p_1} \\ A_{21} & A_{22} & \alpha'_{p_2}-A_{21}\alpha'_{p_1}-A_{22}\alpha'_{p_1} \\ 0 & 0 & 1 \end{pmatrix}$$

A choice of actions allows the study of the extraction as defined by the programme data. Among the possibilities, let us point out:

- the program performs, on request, calculations of the β fonctions as perturbed by the quadrupole in both planes for all odd straight sections.
- A " mountain climbing " routine finds out the horizontal closed orbit and $\Delta p/p$ of particles just on resonance, which allows tracking of the extraction from the centre of the emittance.
- Starting from an initial particle that can be changed at any time, tracking is performed and followed continuously on the plot of any of the straight section phase plane.
- The beam emittance enclosed in any stable phase plane trajectory can be calculated on request.
- A final plot of the horizontal phase plane, almost normalized, can be obtained from any of the sections. It shows the separatrices for the two energies corresponding to the nominal emittance and its centre, and the part of the beam being extracted. This is the way the figures presented in this paper were obtained.

APPENDIX II

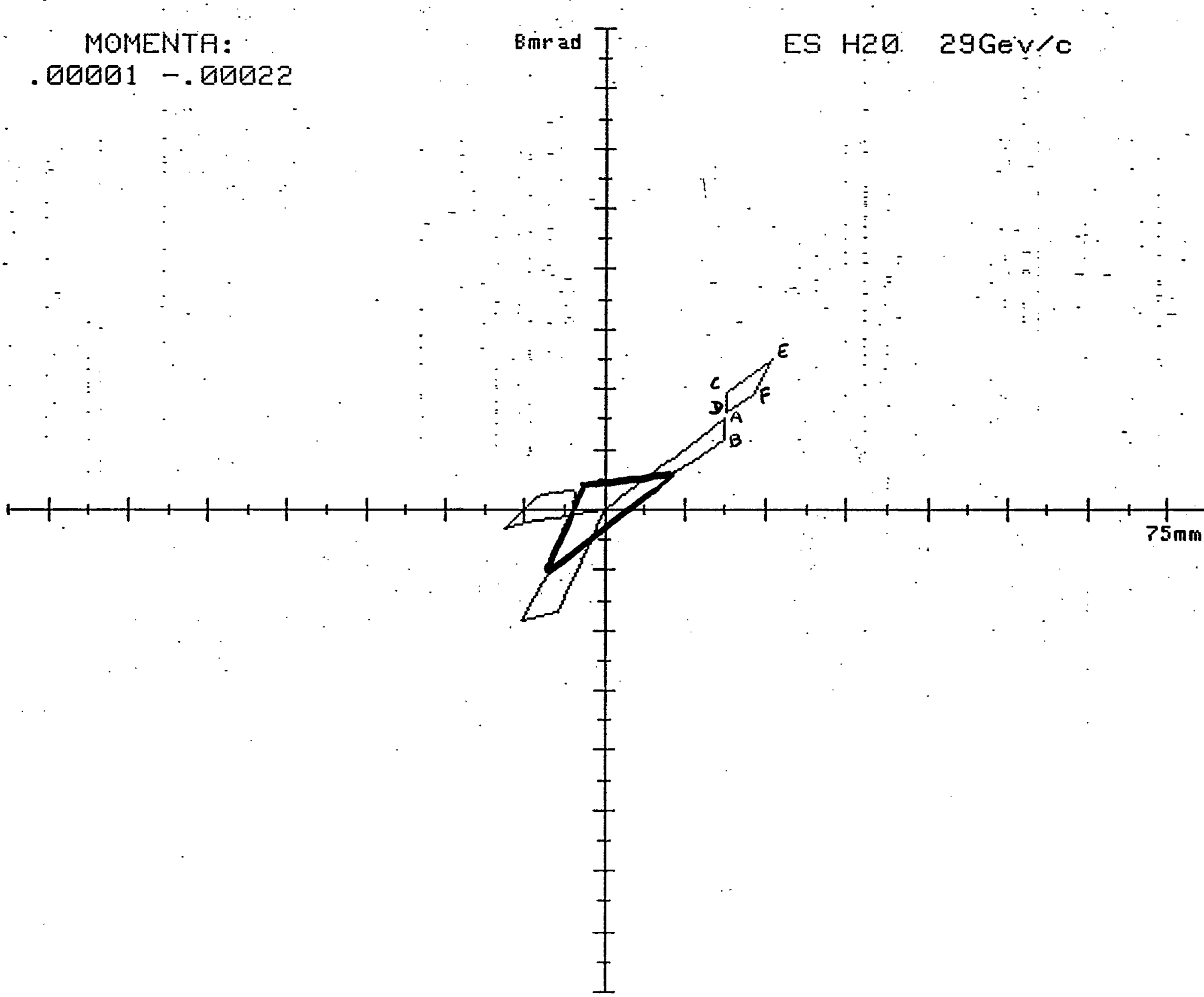
Compared Calculated Performances of Various Schemes

| Scheme | Spiral Pitch mm | Clearance at 1st Mag. Septum mm | Clearance at Extraction Mag. mm | Instantaneous $\Delta p/p$ | Beam Width at F10 mm | Corresponding Circulating Beam Emittance $\pi$ mm mrad |
|---|---|---|---|---|---|---|
| Present | 5.8 | 1.9 (1) | 16.9 | $2.3 \times 10^{-4}$ | 14 | 2.5 |
| #1 | 9.5 | 2.4 | 18.7 | $6 \times 10^{-4}$ | 10.4 | 2.5 |
| #2 | 10.9 | 3.9 | 18.9 | $12 \times 10^{-4}$ (2) | 11 | 2.5 |
| #3 | 10.4 | 4.3 | 23.0 | $2.3 \times 10^{-4}$ | 16 | 2.3 |
| #4 | 11.2 | 3.8 | 19.5 | $9 \times 10^{-4}$ | 20 | 2.8 |

(1) becomes 3.2 for a 1.5 $\pi$ mm mrad emittance.

(2) becomes $8 \times 10^{-4}$ for a 1.5 $\pi$ mm mrad emittance.

# Fig 1




Zero emittance momentum : .00001 APRIL 8 87
Nominal emittance momentum :-.00022 Emittance= 2.51 πmmmrad

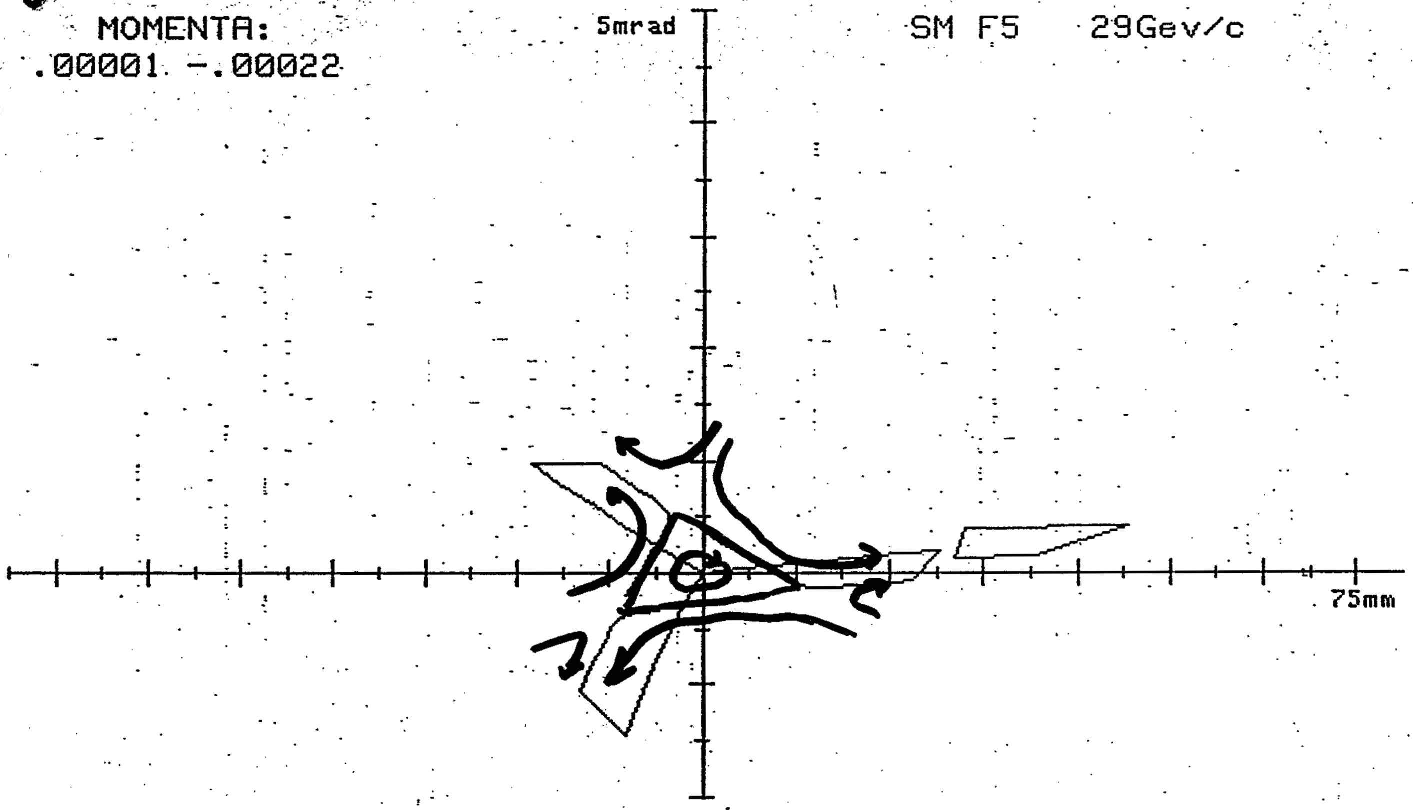
| | | | | | | |
|---|---|---|---|---|---|---|
| 15.00 | 15.00 | 15.10 | 15.10 | 20.82 | 18.31 | } coordinates of points A to F on figure |
| 1.51 | 1.18 | 1.94 | 1.61 | 2.49 | 1.92 | |

Starting point for zero emittance in electr.septum section : 3 ; .3
Starting point for nominal emittance in electr.septum section : 7.2 ; .39

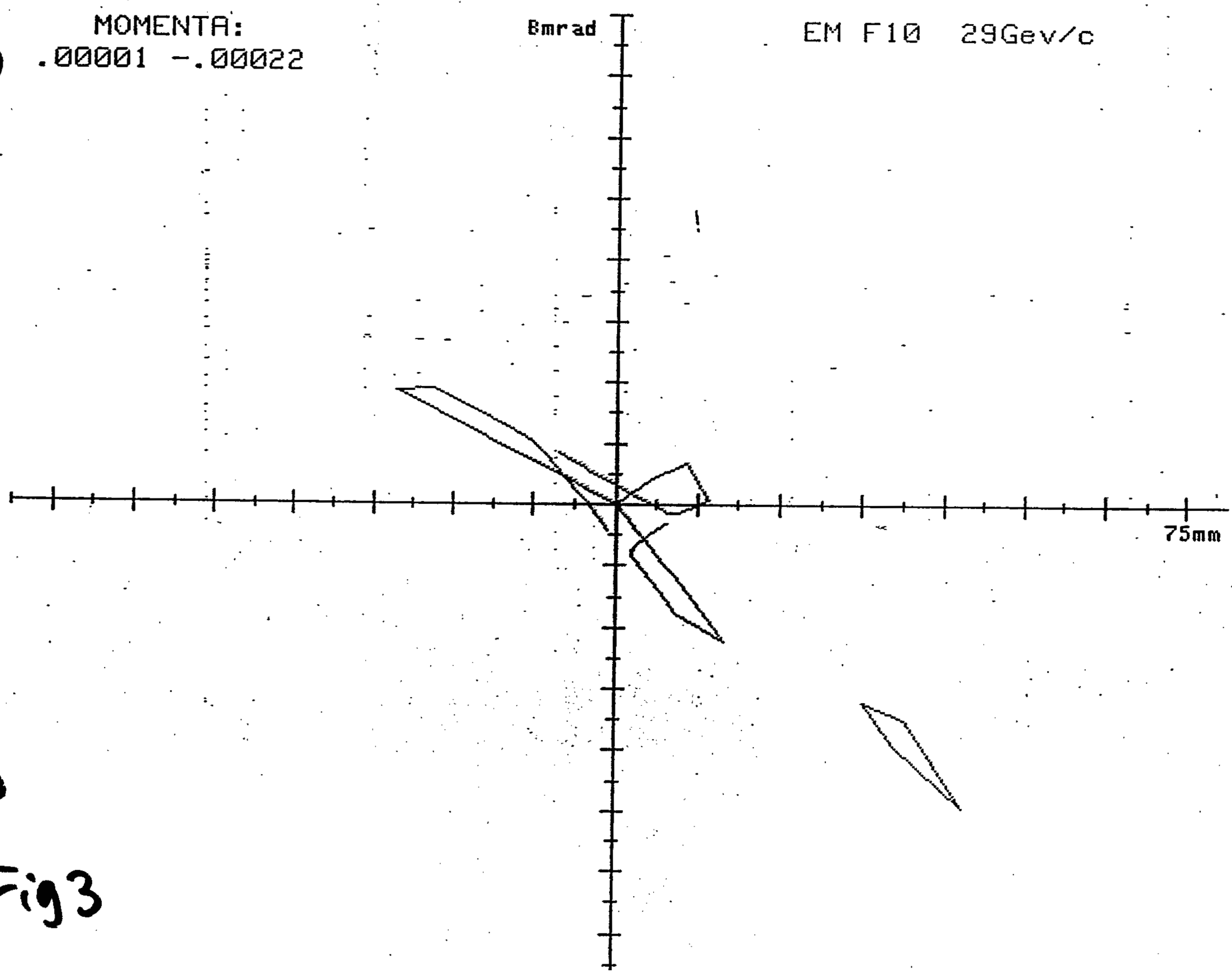
| ADAT1 (nb of relevant S.S.) | Energy | $\nu_0$ used for phase angles | vertical $\nu_0$ | actual bare machine $\nu_x$ | $\nu_y$ | Horizontal chromaticity | Vert. chrom. |
|---|---|---|---|---|---|---|---|
| 7 | 29 | 8.711 | 8.8 | 8.667 | 8.8 | -4.7 | 1 |

| | phase | Betax | Alfax | Xeq | DXeq | Betay | Alfay | ident. of element | element and S.S. | strength | width | position (for septa) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.912 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX C13 | -.00023 | 0 | 0 |
| 2 | 3.803 | 22.5 | 0.00 | 2121 | 0.0 | 10.1 | 0.00 | Sept | SM F5 | 1.08 | .76 | 15 |
| 3 | 3.975 | 15.4 | 1.32 | 1844 | -147.0 | 15.3 | -1.31 | Sept | EM F10 | 20 | 5 | 15 |
| 4 | 4.090 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX F13 | .00023 | 0 | 0 |
| 5 | 5.808 | 15.4 | -1.32 | 1844 | 147.0 | 15.3 | 1.31 | Elsp | ES H20 | .42 | .1 | 15 |
| 6 | 6.267 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX I13 | -.00023 | 0 | 0 |
| 7 | 8.445 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX L13 | .00023 | 0 | 0 |

Fig 2

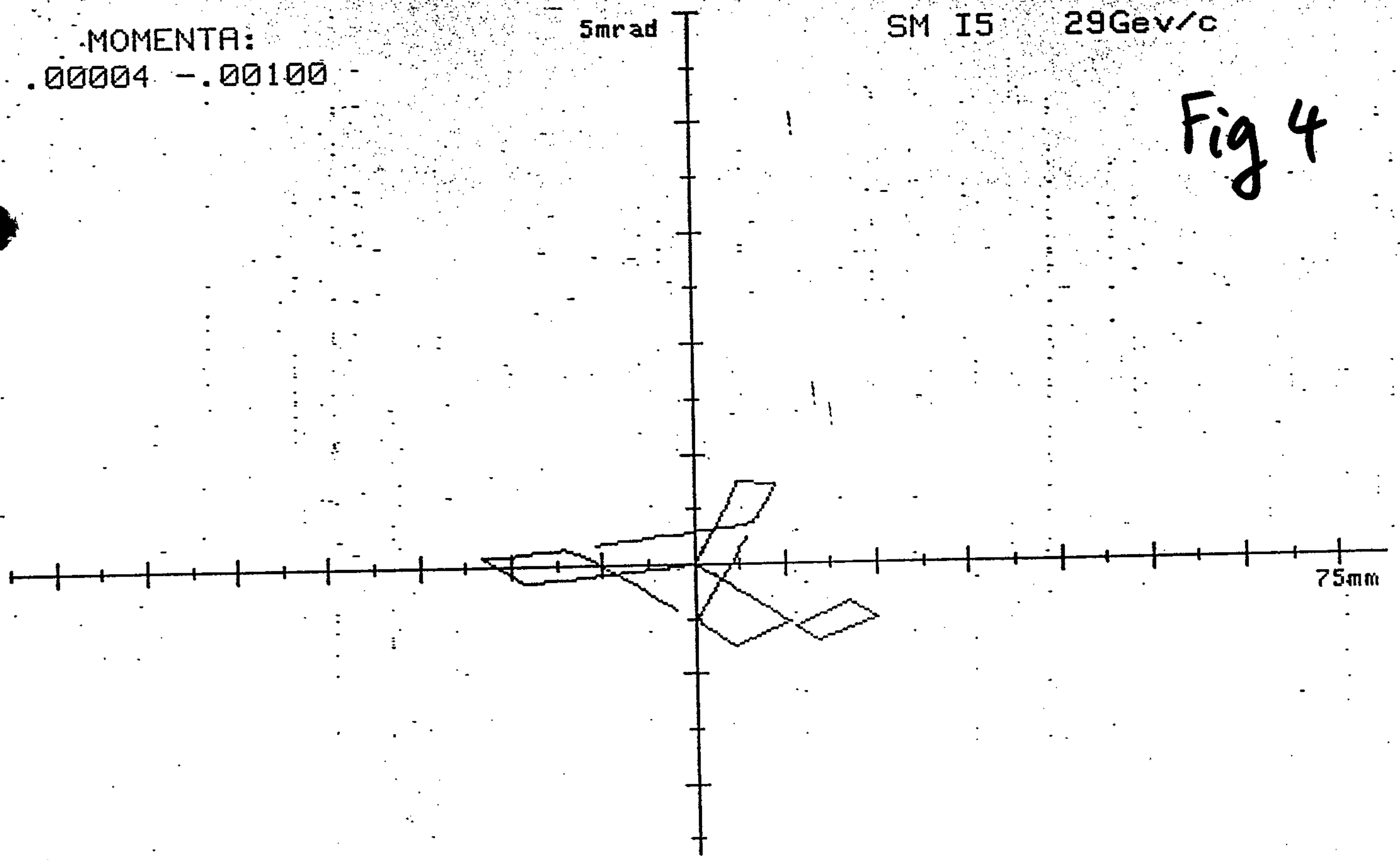


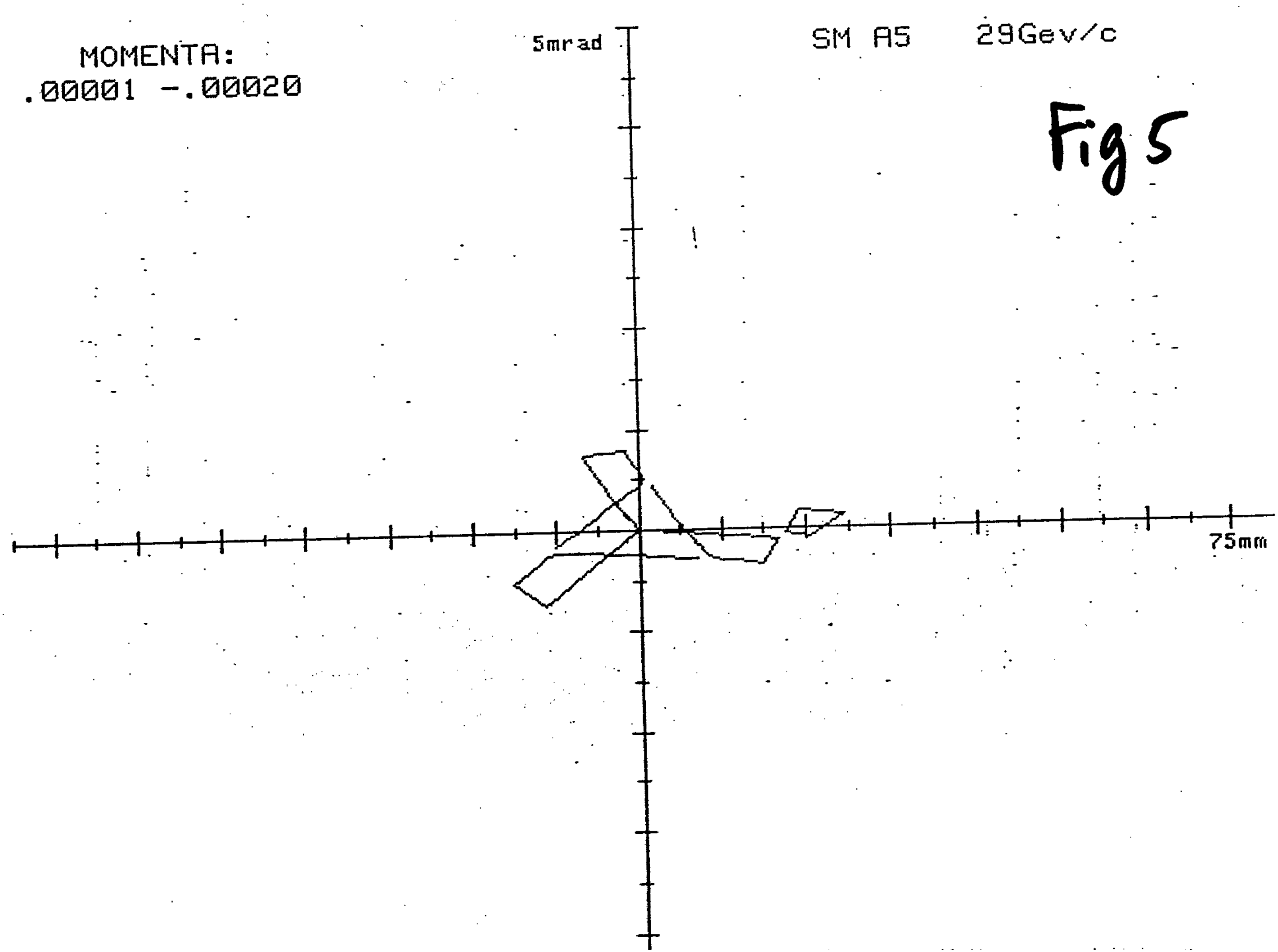
MOMENTA:
.00001 -.00022
5mrad
SM F5 29Gev/c
75mm

MOMENTA:
.00001 -.00022
8mrad
EM F10 29Gev/c
75mm


Fig 3


MOMENTA:
.00004 -.00100
5mrad
SM I5 29Gev/c
75mm
Fig 4


MOMENTA:
.00001 -.00020
5mrad
SM A5 29Gev/c
75mm
Fig 5

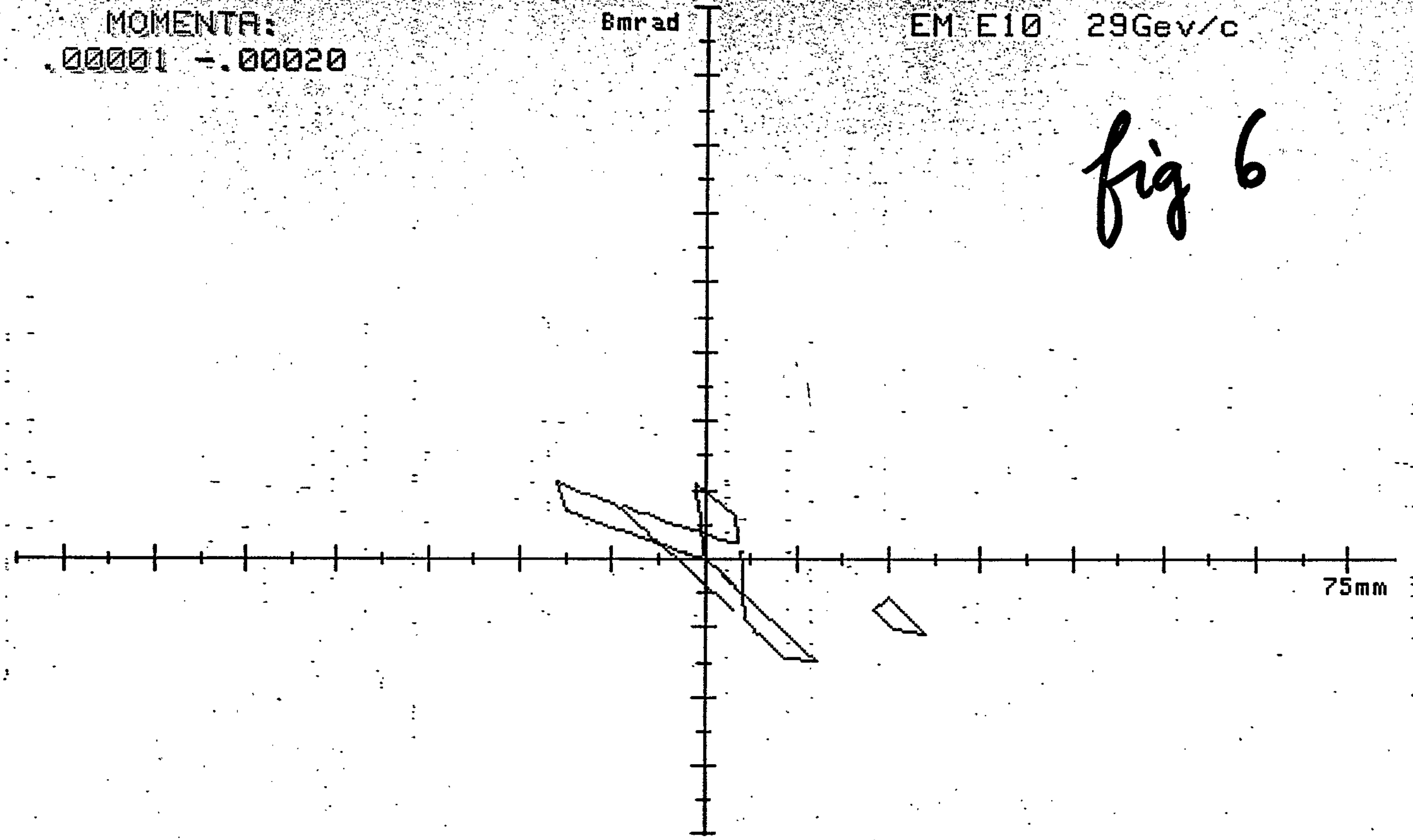

MOMENTA:
.00001 -.00020
Bmrad
EM E10 29Gev/c
75mm

fig 6

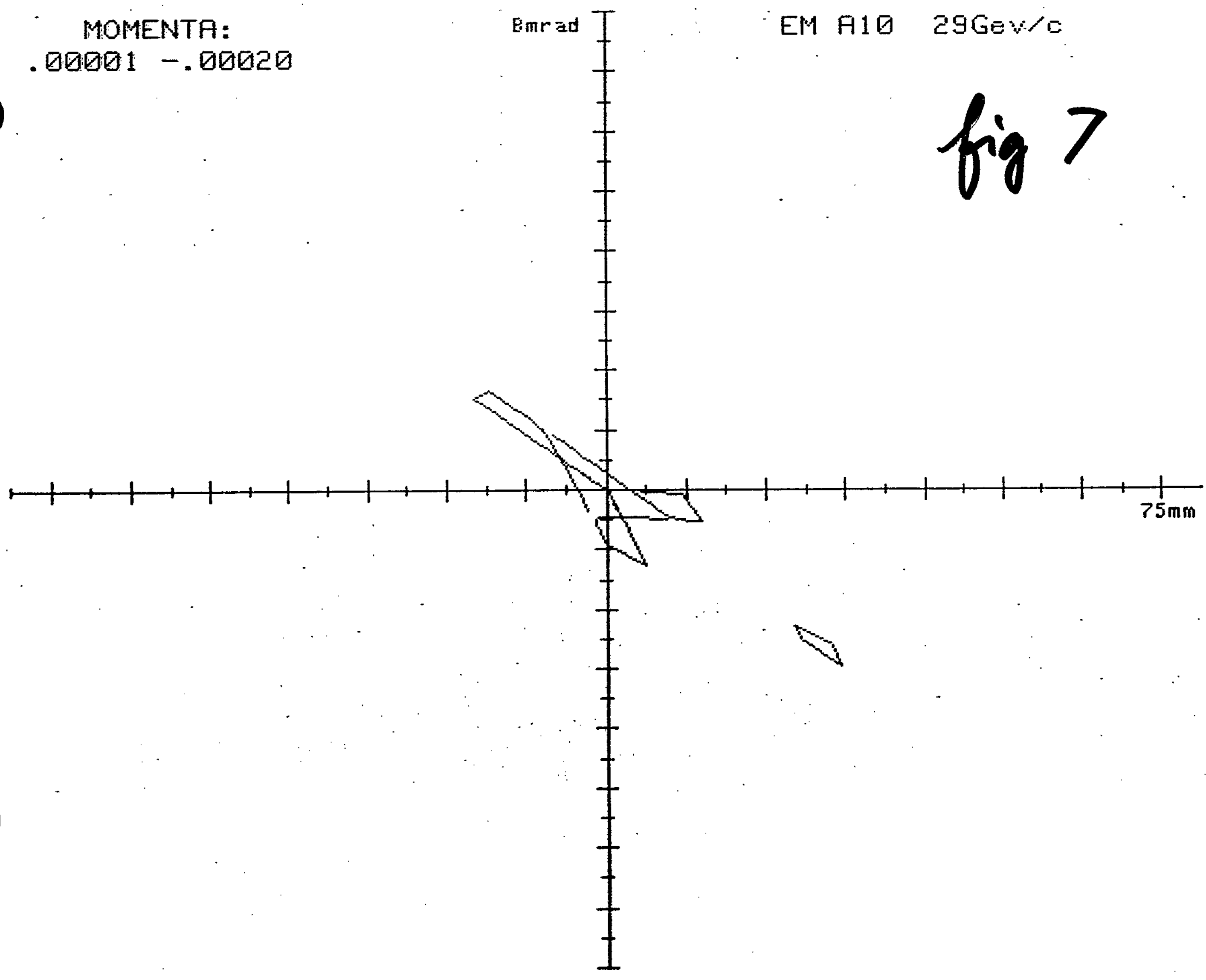

MOMENTA:
.00001 -.00020
Bmrad
EM A10 29Gev/c
75mm

fig 7

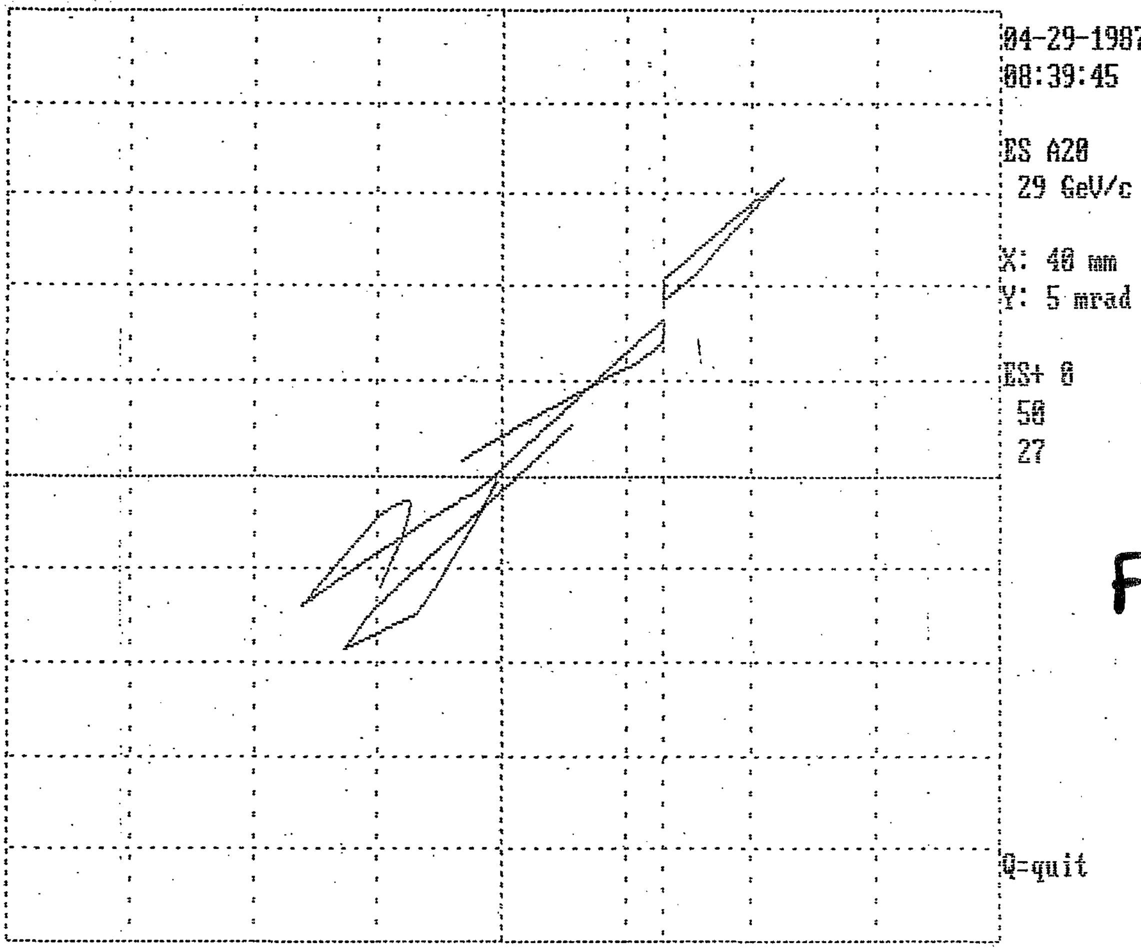



Fig 8

04-29-1987 08:40:19 Emittance= 2.4750 PI-mm-mrad
Zero emittance momentum : -0.0004000 Nom. emittance momentum : -0.0010000

| XY1 | XP1 | XY2 | XP2 | XY3 | XP3 | XYK1 | XPK1 | XYK2 | YPK |
|---|---|---|---|---|---|---|---|---|---|
| 13.000 | 13.000 | -16.096 | -9.720 | -6.795 | -12.644 | 13.050 | 13.050 | 22.511 | 15.34 |
| 1.640 | 1.404 | -1.402 | -0.429 | -1.495 | -1.856 | 2.066 | 1.829 | 3.191 | 2.09 |

Starting point for zero emittance at el. sept: 1.0000 0.2000 -0.0004000
Starting point for nom. emittance at el. sept: 8.0000 0.8000 -0.0010000
Calculated zero-emittance triple point : -0.6180 -0.0227 -0.0004226
Starting point for emittance calc at el. sept: 7.9000 0.8000 -0.0010000
bdat.prn from file

| N | P | Qh0 | Qv0 | Qh | Qv | Chromx | Chromy |
|---|---|---|---|---|---|---|---|
| 0 9 | 29.00 | 8.7110 | 8.8000 | 8.6660 | 8.8000 | -4.7000 | 1.0000 |

| I, | Psx, | Betax, | Alphax, | Xeq, | Dxeq, | Betay, | Alphay, | Type$, | Descr$, | | Param1, | Param2, | Param3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.173 | 22.47 | 0.000 | 2121 | 0 | 10.10 | 0.000 | Quad | Q | A5 | 0.03000 | 0.000 | 0.0 |
| 2 | 0.726 | 15.43 | -1.320 | 1844 | 147 | 15.26 | 1.310 | Elsp | ES | A20 | 0.42000 | 0.050 | 13.0 |
| 3 | 1.186 | 22.00 | 0.000 | 2115 | -3 | 10.38 | 0.000 | Sext | SX | B13 | -0.00040 | 0.000 | 0.0 |
| 4 | 1.912 | 22.00 | 0.000 | 2115 | -3 | 10.38 | 0.000 | Sext | SX | C13 | -0.00040 | 0.000 | 0.0 |
| 5 | 3.803 | 22.47 | 0.000 | 2121 | 0 | 10.10 | 0.000 | Sept | SM | F5 | 1.08000 | 0.760 | 0.0 |
| 6 | 3.975 | 15.43 | 1.320 | 1844 | -147 | 15.26 | -1.310 | Sept | EM | F10 | 20.00000 | 5.000 | 50.0 |
| 7 | 5.541 | 22.00 | 0.000 | 2115 | -3 | 10.38 | 0.000 | Sext | SX | H13 | -0.00040 | 0.000 | 0.0 |
| 8 | 6.267 | 22.00 | 0.000 | 2115 | -3 | 10.38 | 0.000 | Sext | SX | I13 | -0.00040 | 0.000 | 0.0 |
| 9 | 8.158 | 22.47 | 0.000 | 2121 | 0 | 10.10 | 0.000 | Quad | Q | L5 | -0.03000 | 0.000 | 0.0 |

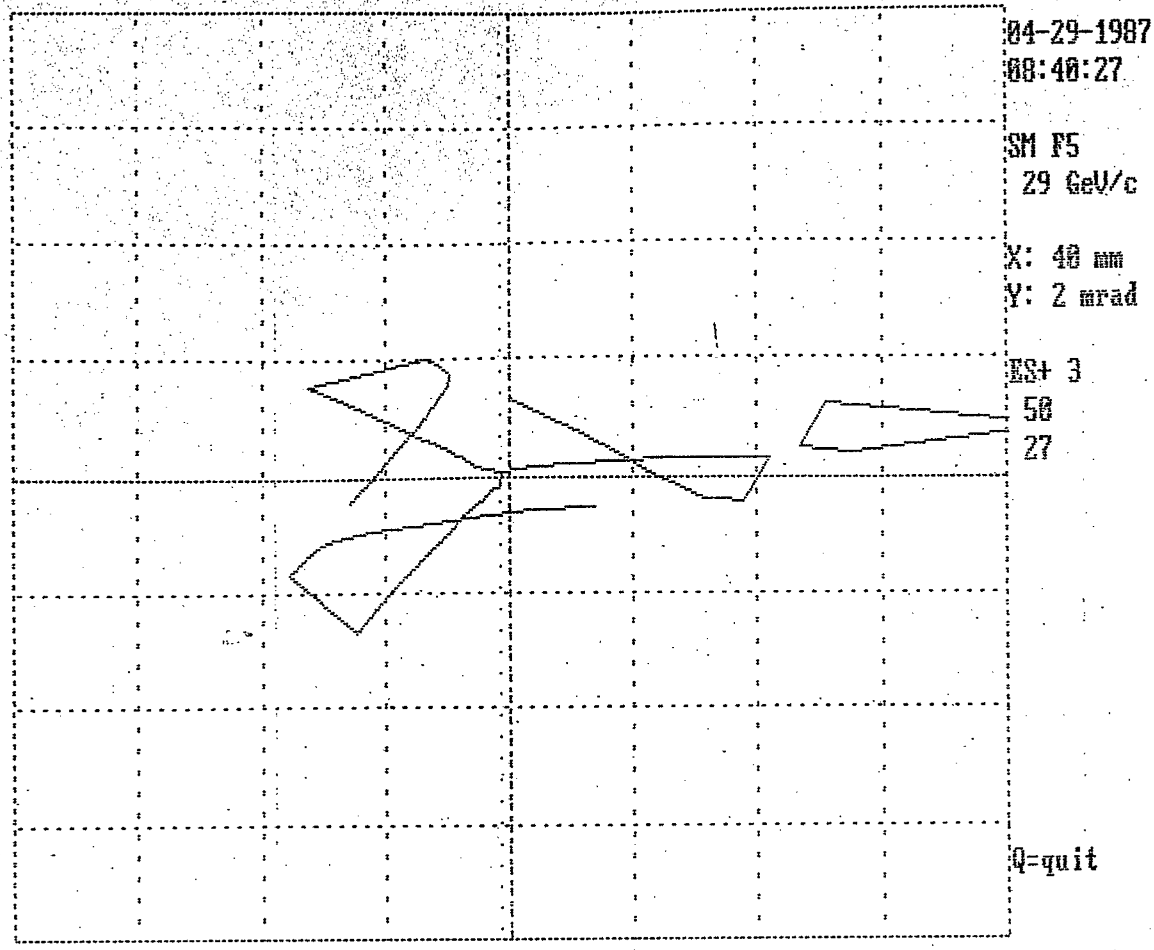

04-29-1987
08:40:27
SM F5
29 GeV/c
X: 40 mm
Y: 2 mrad
ES+ 3
50
27
Q=quit

Fig 9

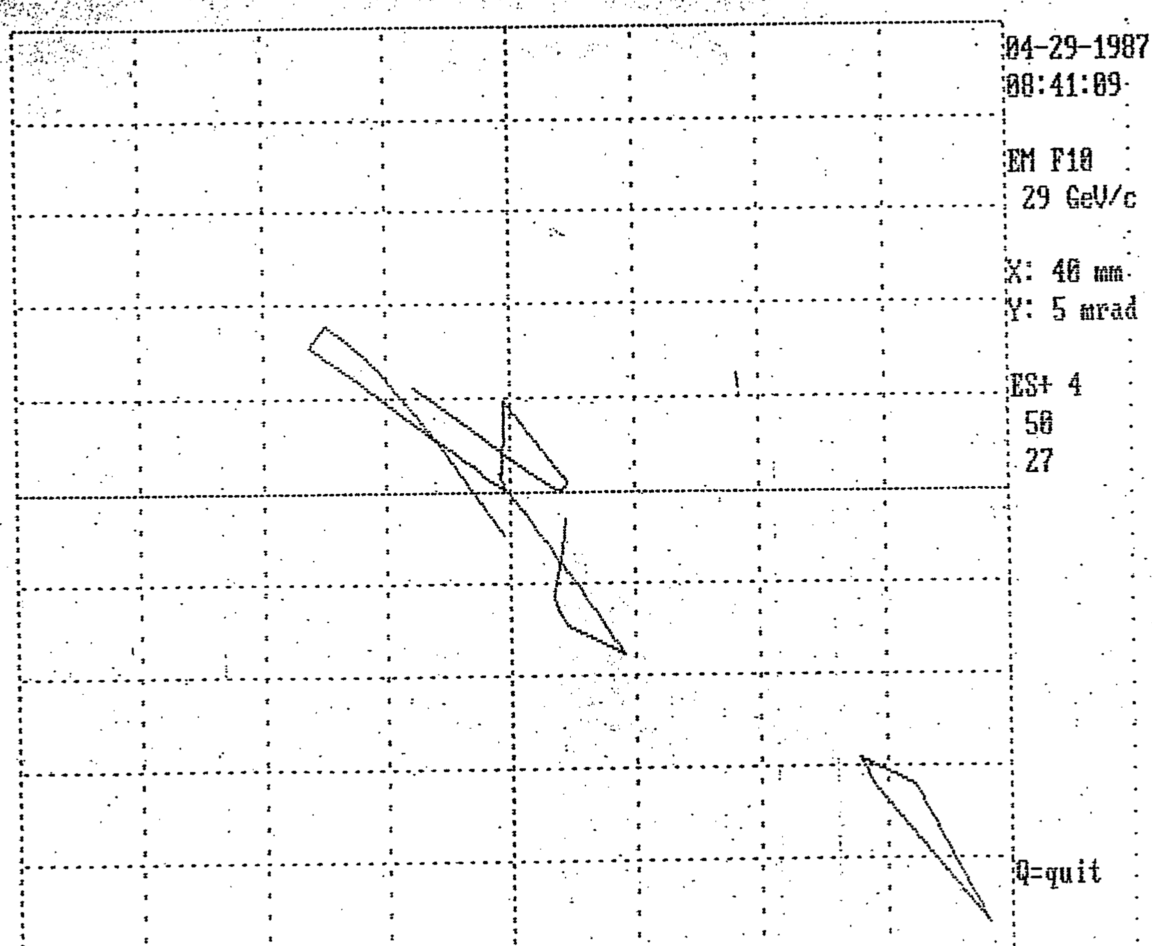

04-29-1987
08:41:09
EM F10
29 GeV/c
X: 40 mm
Y: 5 mrad
ES+ 4
50
27
Q=quit

Fig 10

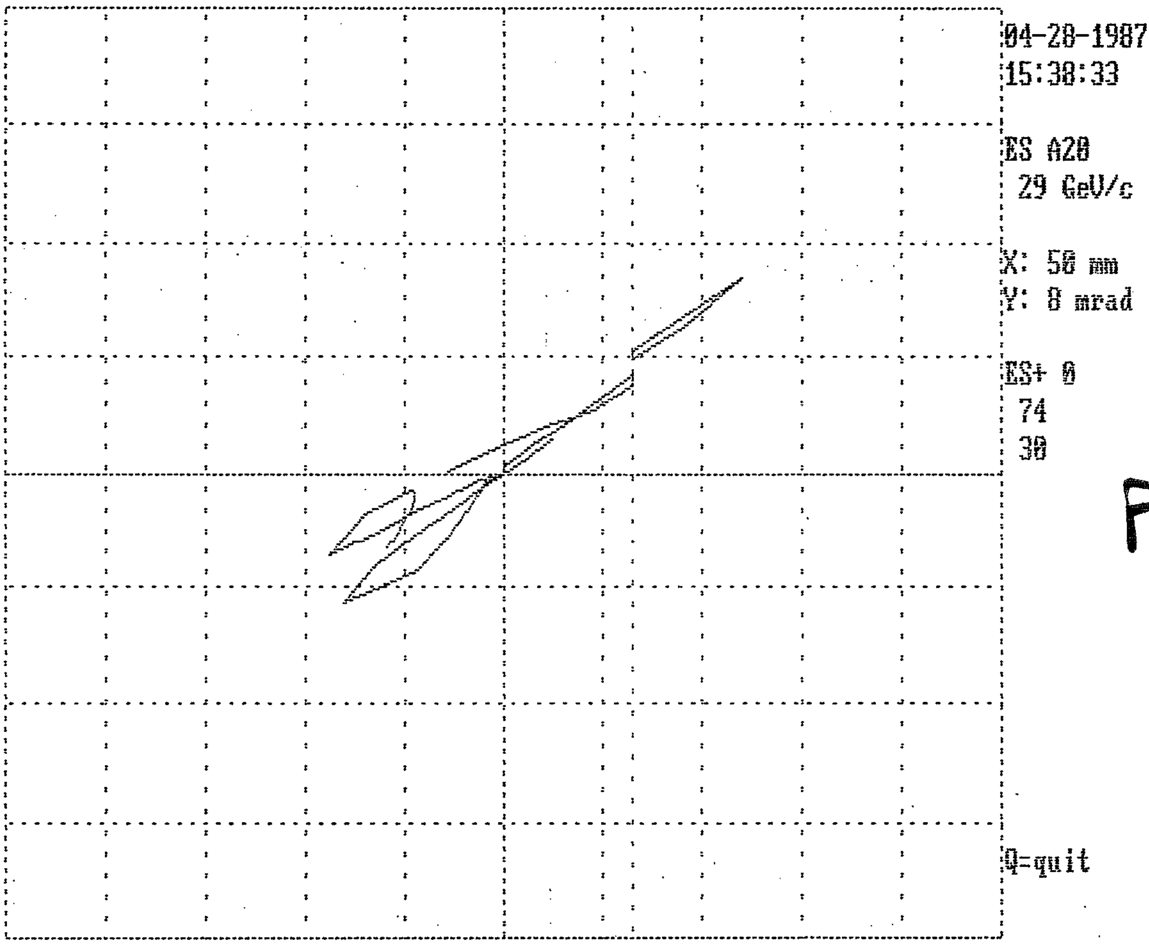



Fig 11

04-28-1987 15:39:11 Emittance= 2.5307 PI-mm-mrad
Zero emittance momentum : -0.0009000 Nom. emittance momentum : -0.0021000

| XY1 | XP1 | XY2 | XP2 | XY3 | XP3 | XYK1 | XPK1 | XYK2 | YPK2 |
|---|---|---|---|---|---|---|---|---|---|
| 13.000 | 13.000 | -17.578 | -13.946 | -8.715 | -16.084 | 13.050 | 13.050 | 23.922 | 18.127 |
| 1.677 | 1.513 | -1.474 | -0.709 | -1.711 | -2.259 | 2.103 | 1.938 | 3.387 | 2.518 |

| | | | |
|---|---|---|---|
| Starting point for zero emittance at el. sept: | 0.0000 | 0.1000 | -0.0009000 |
| Starting point for nom. emittance at el. sept: | 7.0000 | 0.8000 | -0.0021000 |
| Calculated zero-emittance triple point : | 0.0000 | 0.0000 | 0.0000000 |
| Starting point for emittance calc at el. sept: | 6.9000 | 0.8000 | -0.0021000 |

bdat.prn from file

| | N | P | Qh0 | Qv0 | Qh | Qv | Chromx | Chromy |
|---|---|---|---|---|---|---|---|---|
| 0 | 9 | 29.00 | 8.7110 | 8.8000 | 8.6660 | 8.8000 | -3.0000 | 1.0000 |

| I, | Psx, | Betax, | Alphax, | Xeq, | Dxeq, | Betay, | Alphay, | Type$, | Descr$, | Param1, | Param2, | Param3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.173 | 22.47 | 0.000 | 2121 | 0 | 10.10 | 0.000 | Quad | Q A5 | 0.03000 | 0.000 | 0.0 |
| 2 | 0.726 | 15.43 | -1.320 | 1844 | 147 | 15.26 | 1.310 | Elsp | ES A20 | 0.42000 | 0.050 | 13.0 |
| 3 | 1.186 | 22.00 | 0.000 | 2115 | -3 | 10.38 | 0.000 | Sext | SX B13 | -0.00040 | 0.000 | 0.0 |
| 4 | 1.912 | 22.00 | 0.000 | 2115 | -3 | 10.38 | 0.000 | Sext | SX C13 | -0.00040 | 0.000 | 0.0 |
| 5 | 3.803 | 22.47 | 0.000 | 2121 | 0 | 10.10 | 0.000 | Sept | SM F5 | 1.08000 | 0.760 | 0.0 |
| 6 | 3.975 | 15.43 | 1.320 | 1844 | -147 | 15.26 | -1.310 | Sept | EM F10 | 20.00000 | 5.000 | 50.0 |
| 7 | 5.541 | 22.00 | 0.000 | 2115 | -3 | 10.38 | 0.000 | Sext | SX H13 | -0.00040 | 0.000 | 0.0 |
| 8 | 6.267 | 22.00 | 0.000 | 2115 | -3 | 10.38 | 0.000 | Sext | SX I13 | -0.00040 | 0.000 | 0.0 |
| 9 | 8.158 | 22.47 | 0.000 | 2121 | 0 | 10.10 | 0.000 | Quad | Q L5 | -0.03000 | 0.000 | 0.0 |

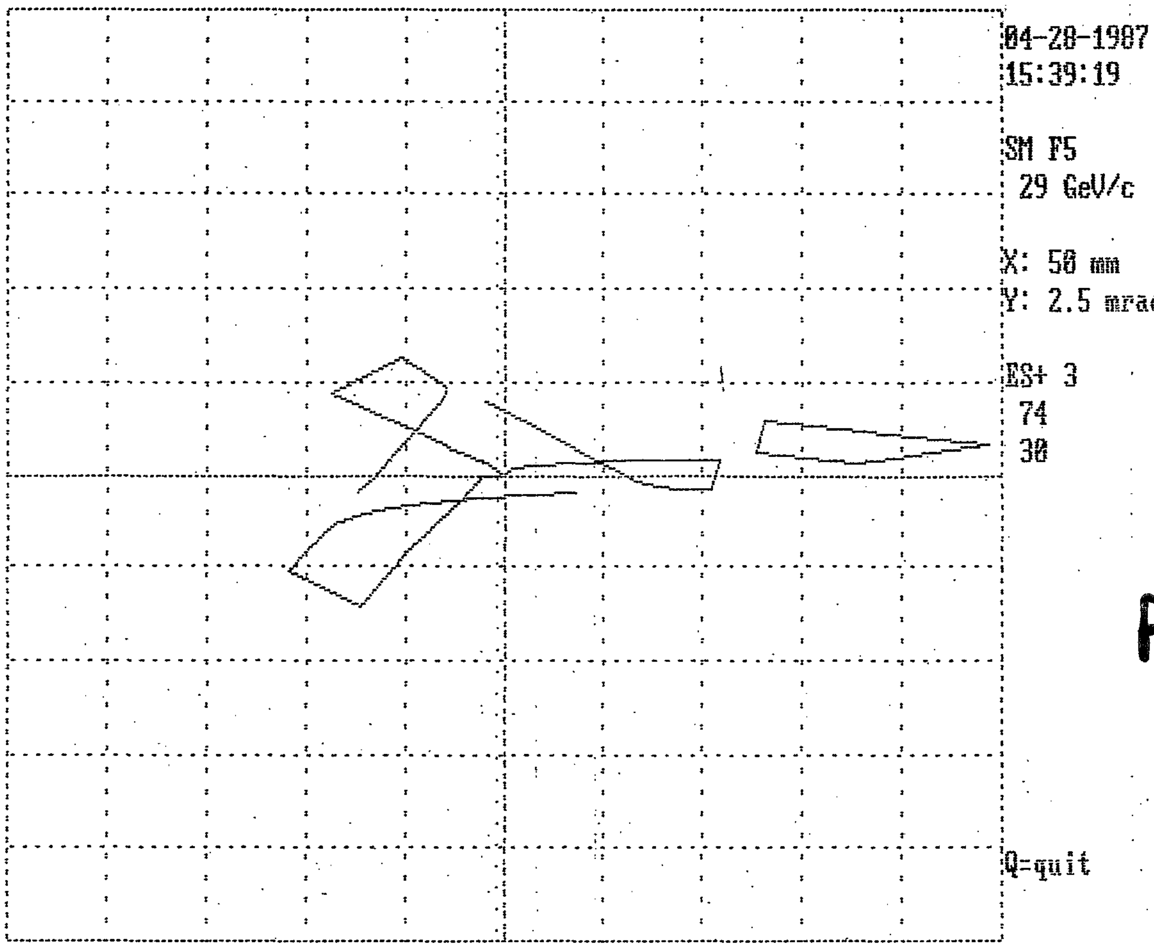

04-28-1987
15:39:19
SM F5
29 GeV/c
X: 50 mm
Y: 2.5 mrad
ES+ 3
74
30
Q=quit

Fig 12

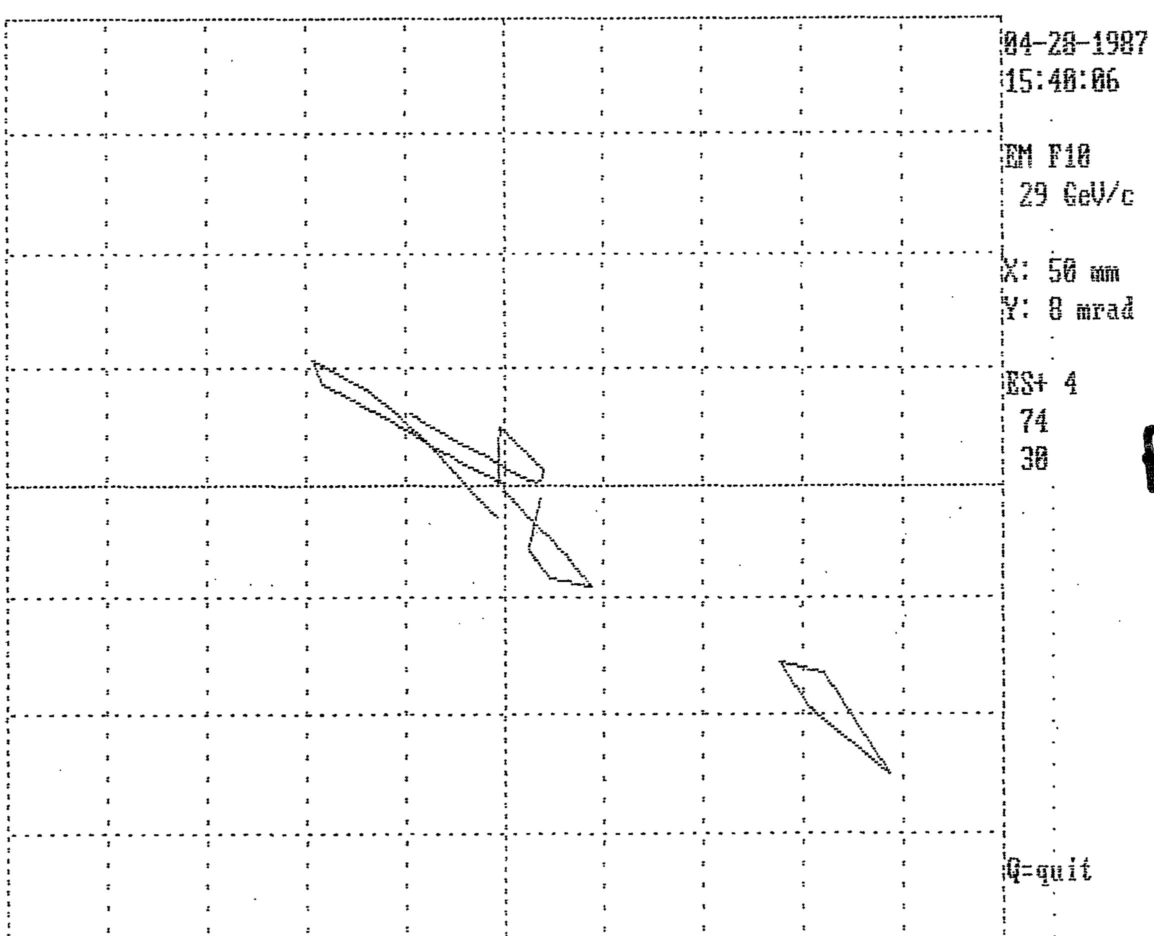

04-28-1987
15:40:06
EM F10
29 GeV/c
X: 50 mm
Y: 8 mrad
ES+ 4
74
30
Q=quit

Fig 13

MOMENTA:
-.00057 -.00080

ES F20 29Gev/c

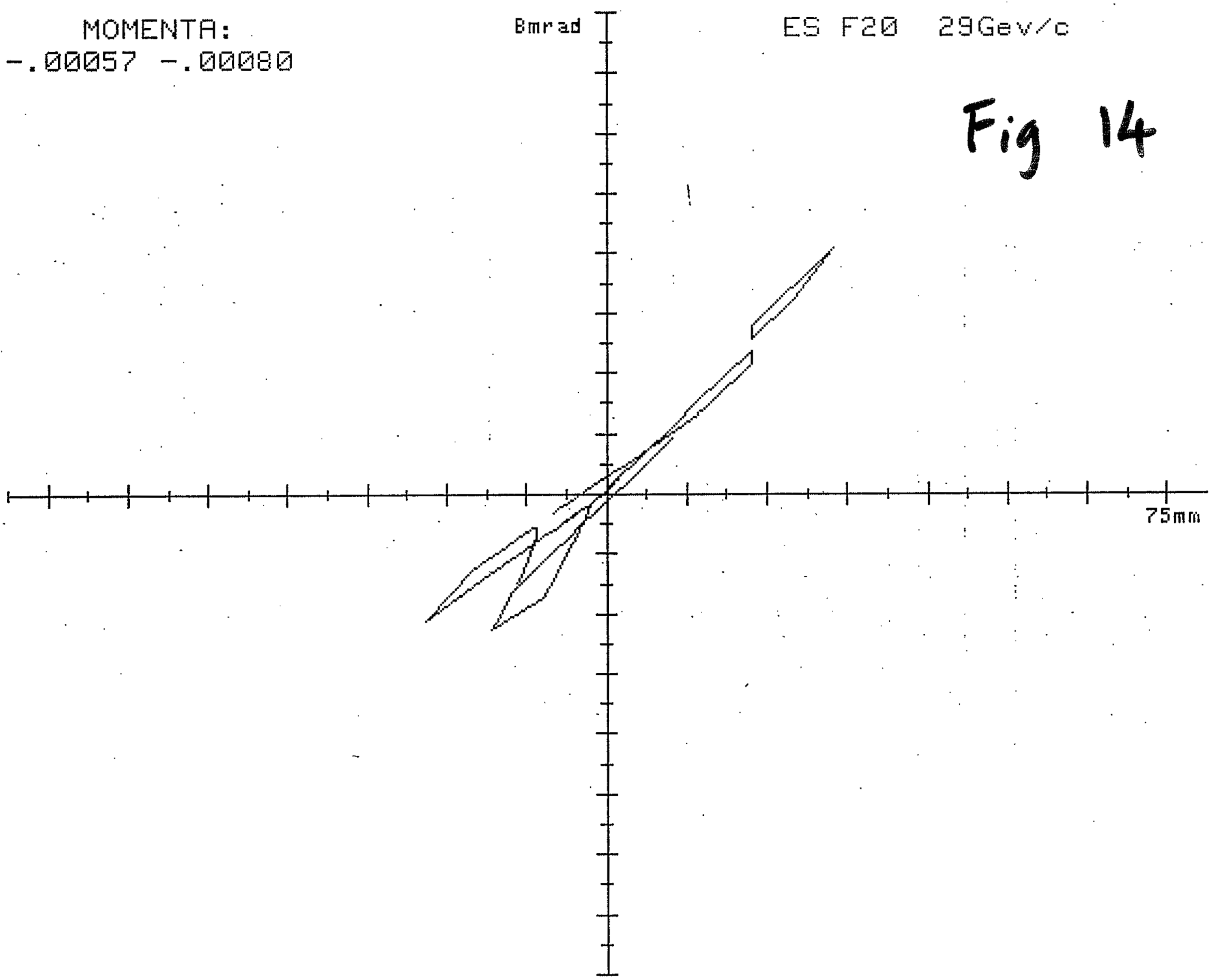



Fig 14

Zero emittance momentum :-.00057 14 APRIL 87
Nominal emittance momentum :-.00080 Emittance= 2.30 πmmmrad

| | | | | | |
|---|---|---|---|---|---|
| 18.00 | 18.00 | 18.10 | 18.10 | 28.38 | 23.15 |
| 2.35 | 2.13 | 2.78 | 2.57 | 4.07 | 3.20 |

Starting point for zero emittance in electr.septum section : 0 ; .07
Starting point for nominal emittance in electr.septum section : 9 ; 1

ADAT5:T14

9 29 8.711 8.8 8.667 8.8 -4.7 1

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .460 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX | A13 | -.00023 | 0 | 0 |
| 2 | 2.638 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX | D13 | .00023 | 0 | 0 |
| 3 | 3.803 | 22.5 | 0.00 | 2121 | 0.0 | 10.1 | 0.00 | Quad | Q | F5 | .04 | 0 | 0 |
| 4 | 3.975 | 15.4 | 1.32 | 1844 | -147.0 | 15.3 | -1.31 | Sept | EM | F10 | 20 | 5 | 15 |
| 5 | 4.356 | 15.4 | -1.32 | 1844 | 147.0 | 15.3 | 1.31 | Elsp | ES | F20 | .42 | .1 | 18 |
| 6 | 4.815 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX | G13 | -.00023 | 0 | 0 |
| 7 | 5.248 | 22.5 | 0.00 | 2121 | 0.0 | 10.1 | 0.00 | Quad | Q | H5 | -.04 | 0 | 0 |
| 8 | 6.993 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX | J13 | .00023 | 0 | 0 |
| 9 | 7.433 | 22.5 | 0.00 | 2121 | 0.0 | 10.1 | 0.00 | Sept | SM | K5 | 1.08 | .76 | 15 |

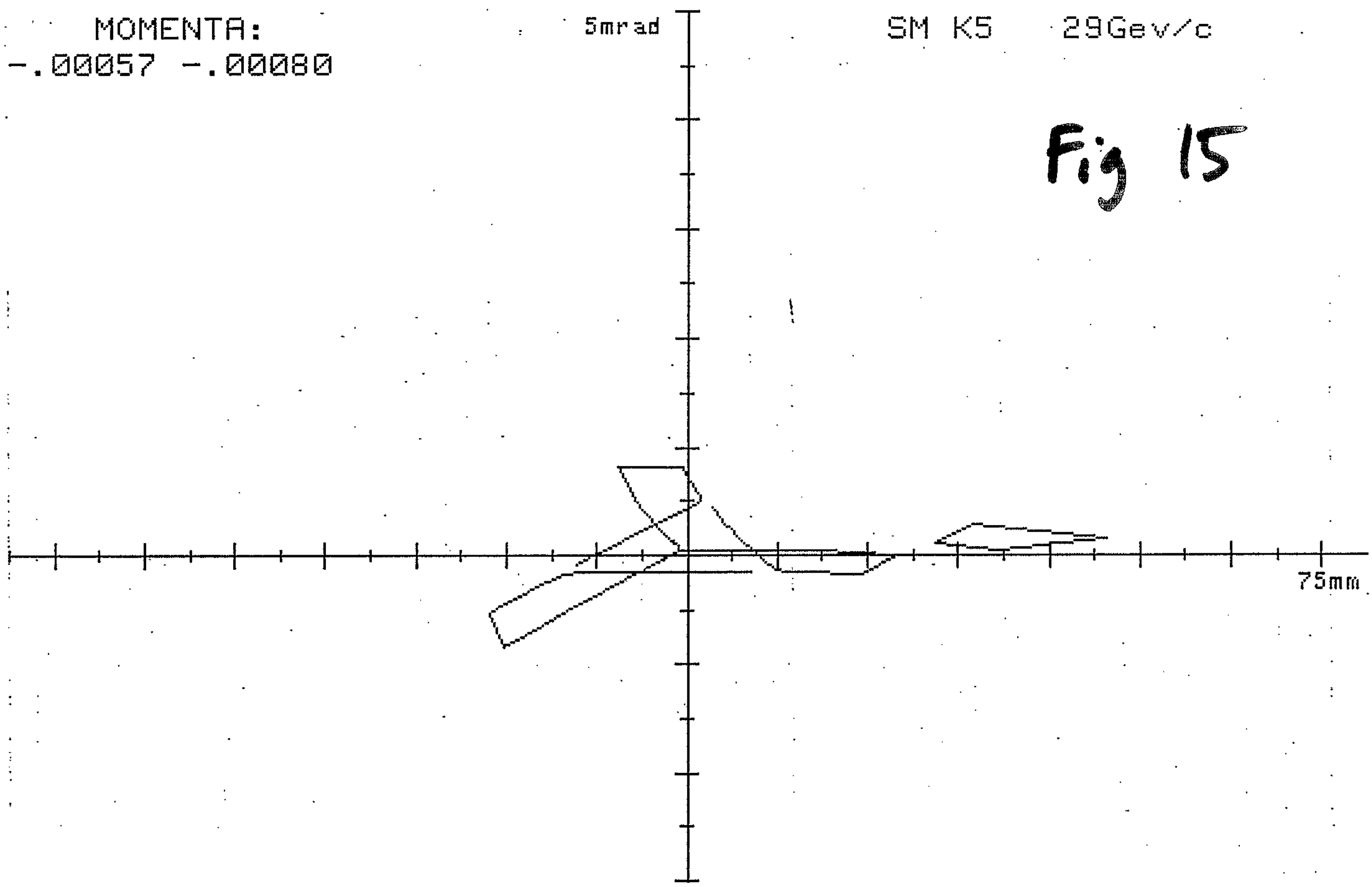

MOMENTA:
-.00057 -.00080
5mrad
SM K5 29Gev/c
75mm

Fig 15

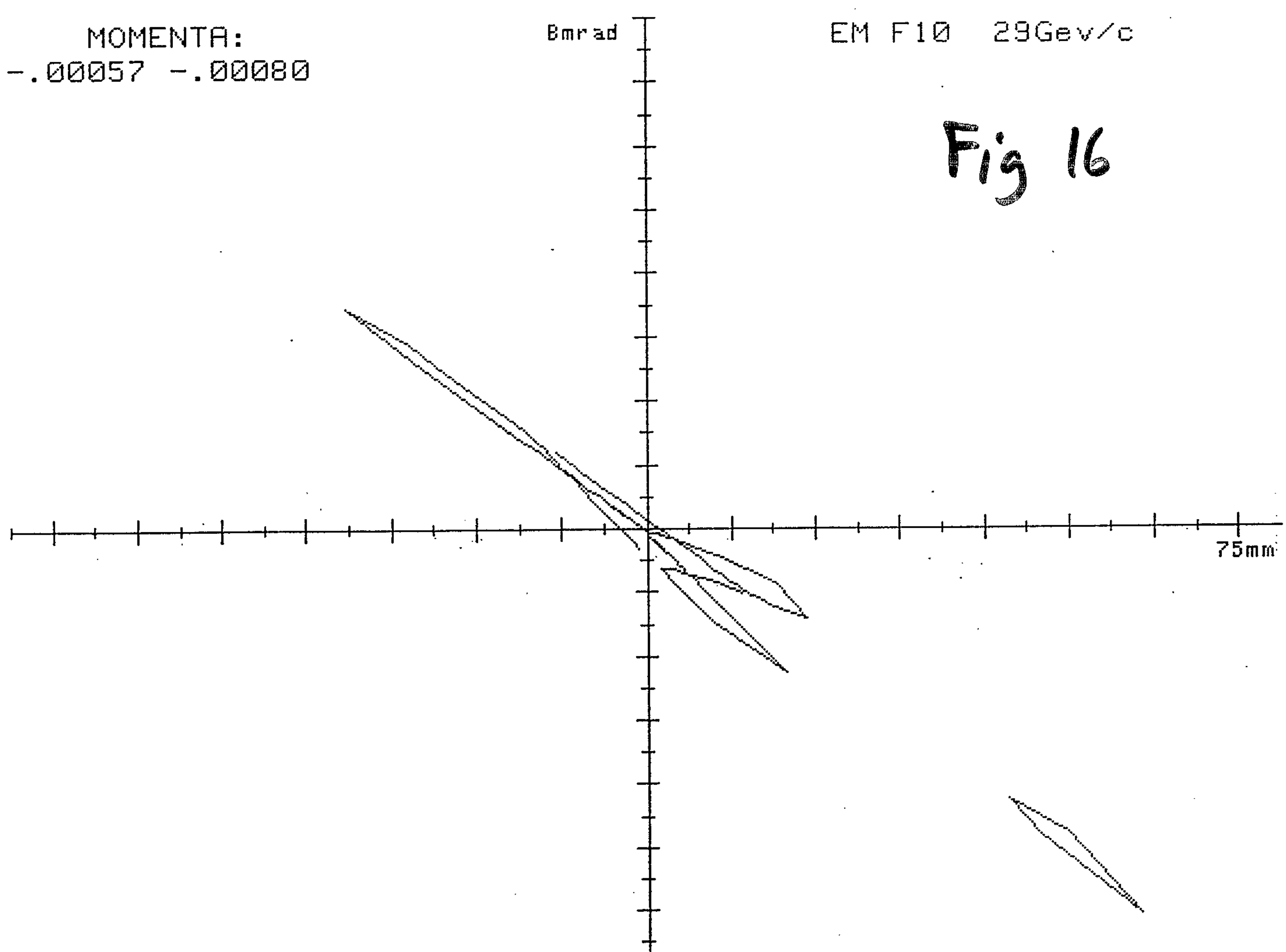

MOMENTA:
-.00057 -.00080
8mrad
EM F10 29Gev/c
75mm

Fig 16

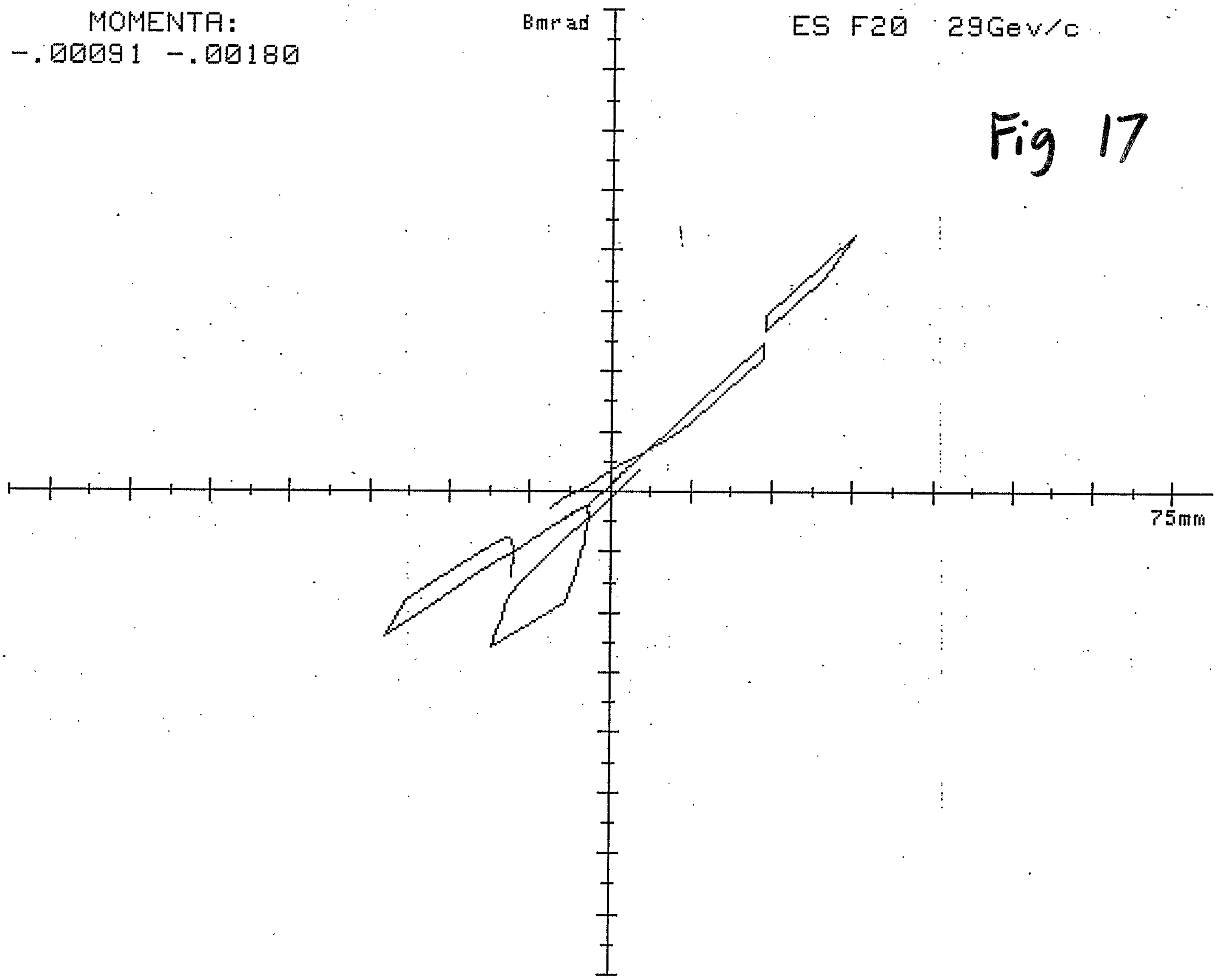



Fig 17

Zero emittance momentum :-.00091 15 APRIL 87
Nominal emittance momentum :-.00180 Emittance= 2.79 πmmmrad

| | | | | | |
|---|---|---|---|---|---|
| 19.00 | 19.00 | 19.10 | 19.10 | 30.23 | 26.43 |
| 2.48 | 2.24 | 2.91 | 2.67 | 4.27 | 3.55 |

Starting point for zero emittance in electr.septum section : 0 ; .1
Starting point for nominal emittance in electr.septum section : 4.9 ; .5

ADAT5:T14

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 29 | 8.711 | 8.8 | 8.667 | 8.8 | -2 | 1 | | | | | | |
| 1 | .460 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX | A13 | -.00023 | 0 | 0 |
| 2 | 1.186 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX | B13 | -.00023 | 0 | 0 |
| 3 | 3.803 | 22.5 | 0.00 | 2121 | 0.0 | 10.1 | 0.00 | Quad | Q | F5 | .025 | 0 | 0 |
| 4 | 3.975 | 15.4 | 1.32 | 1844 | -147.0 | 15.3 | -1.31 | Sept | EM | F10 | 20 | 5 | 15 |
| 5 | 4.356 | 15.4 | -1.32 | 1844 | 147.0 | 15.3 | 1.31 | Elsp | ES | F20 | .42 | .1 | 19 |
| 6 | 4.815 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX | G13 | -.00023 | 0 | 0 |
| 7 | 5.248 | 22.5 | 0.00 | 2121 | 0.0 | 10.1 | 0.00 | Quad | Q | H5 | -.025 | 0 | 0 |
| 8 | 5.541 | 22.0 | 0.00 | 2115 | -2.5 | 10.4 | 0.00 | Sext | SX | H13 | -.00023 | 0 | 0 |
| 9 | 7.433 | 22.5 | 0.00 | 2121 | 0.0 | 10.1 | 0.00 | Sept | SM | K5 | 1.08 | .76 | 15 |

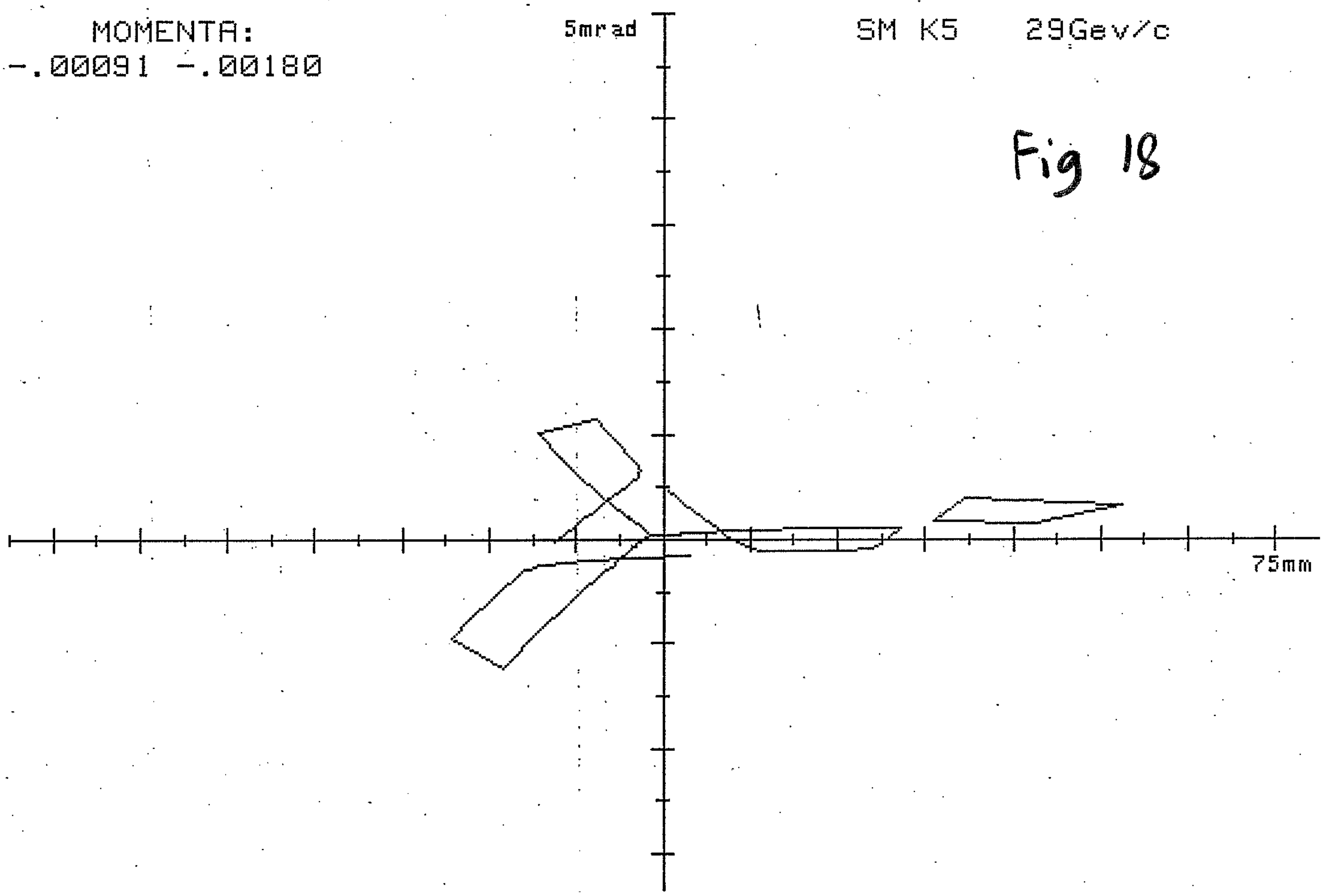

MOMENTA:
-.00091 -.00180
5mrad
SM K5 29Gev/c
75mm

Fig 18

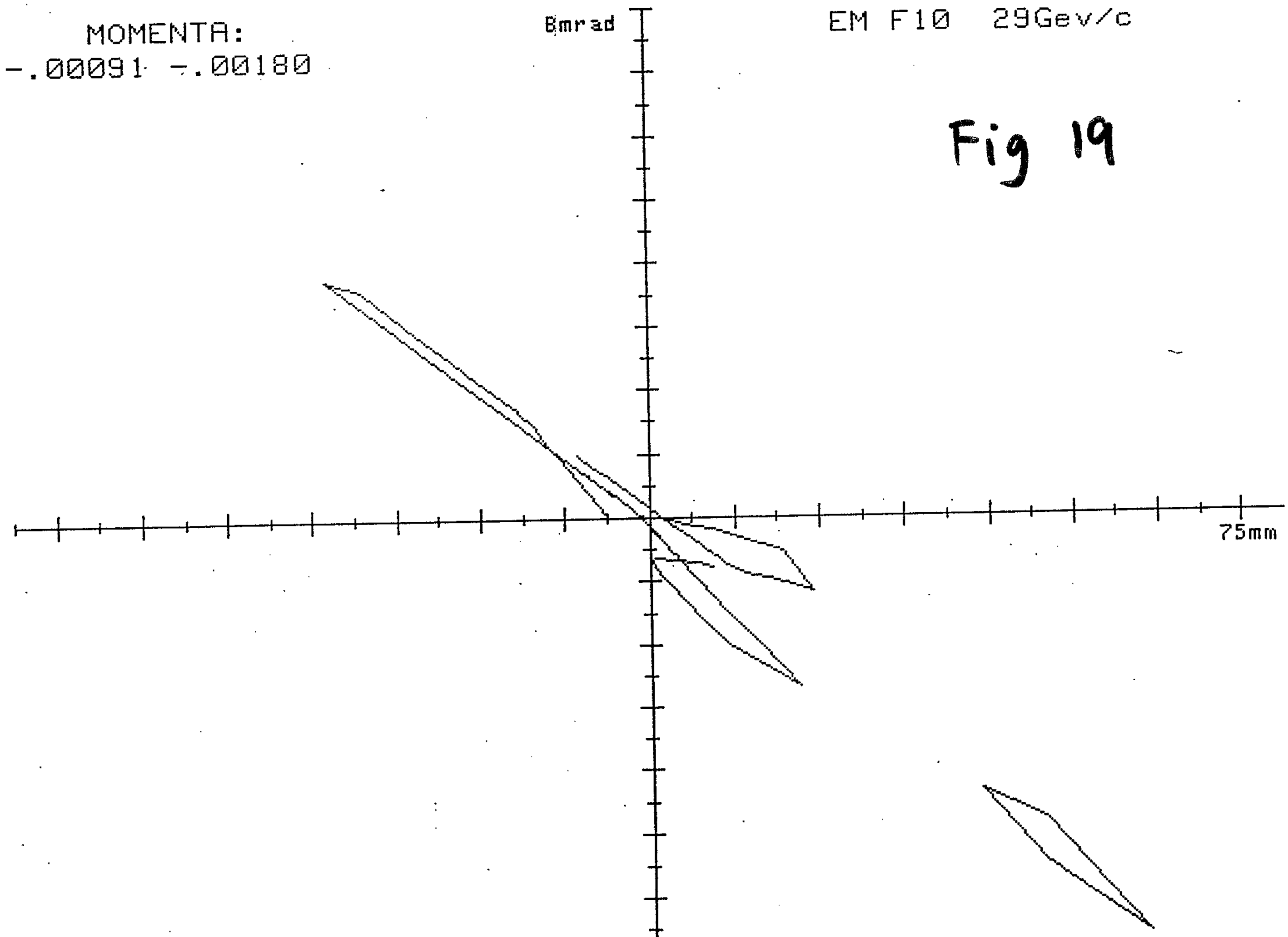

MOMENTA:
-.00091 -.00180
8mrad
EM F10 29Gev/c
75mm

Fig 19

```
AAAAAAAAAA    4444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444    AAAAAAAAAA
AAAAAAAAAA    4444444444444444444444444  Digital Equipment Corporation - VAX/VMS Version V4.4  4444444444444444444444444    AAAAAAAAAA
AAAAAAAAAA    4444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444    AAAAAAAAAA

                                          SSSS   TTTTT  EEEEE   III   N   N  BBBB    AAA    CCCC  H   H
                                         S         T    E        I    N   N  B   B  A   A  C      H   H
                                         S         T    E        I    NN  N  B   B  A   A  C      H   H
                                          SSS      T    EEEE     I    N N N  BBBB   A   A  C      HHHHH
                                             S     T    E        I    N  NN  B   B  AAAAA  C      H   H
                                             S     T    E        I    N   N  B   B  A   A  C      H   H
                                         SSSS      T    EEEEE   III   N   N  BBBB   A   A   CCCC  H   H

                                                 MM      MM    AAAAAA      IIIIII    LL
                                                 MM      MM    AAAAAA      IIIIII    LL
                                                 MMMM  MMMM  AA      AA      II      LL
                                                 MMMM  MMMM  AA      AA      II      LL
                                                 MM  MM  MM  AA      AA      II      LL
                                                 MM  MM  MM  AA      AA      II      LL
                                                 MM      MM  AA      AA      II      LL
                                                 MM      MM  AA      AA      II      LL
                                                 MM      MM  AAAAAAAAAA      II      LL
                                                 MM      MM  AAAAAAAAAA      II      LL
                                                 MM      MM  AA      AA      II      LL
                                                 MM      MM  AA      AA      II      LL
                                                 MM      MM  AA      AA    IIIIII    LLLLLLLLLL
                                                 MM      MM  AA      AA    IIIIII    LLLLLLLLLL

                                                       LL            IIIIII      SSSSSSSS      ;;;;
                                                       LL            IIIIII      SSSSSSSS      ;;;;
                                                       LL              II      SS              ;;;;
                                                       LL              II      SS              ;;;;
                                                       LL              II      SS
                                                       LL              II      SS
                                                       LL              II        SSSSSS        ;;;;
                                                       LL              II        SSSSSS        ;;;;
                                                       LL              II              SS      ;;;;
                                                       LL              II              SS      ;;;;
                                               ....    LL              II              SS        ;;
                                               ....    LL              II              SS        ;;
                                               ....    LLLLLLLLLL    IIIIII    SSSSSSSS        ;;
                                               ....    LLLLLLLLLL    IIIIII    SSSSSSSS        ;;
```

File _DUA1:[]MAIL.LIS; (15046,43,0), last revised on 23-APR-1987 08:04, is a 3 block sequential file owned by UIC [BITNET,STEINBACH]. The records are variable length with implied (CR) carriage control. The longest record is 71 bytes.

Job MAIL (1859) queued to LZ911Q on 23-APR-1987 08:04 by user STEINBACH, UIC [BITNET,STEINBACH], under account BITNET at priority 100, started on printer _LTA8: on 23-APR-1987 08:05 from queue LZ911Q.

AAAAAAAAAA    4444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444    AAAAAAAAAA
AAAAAAAAAA    4444444444444444444444444  Digital Equipment Corporation - VAX/VMS Version V4.4  4444444444444444444444444    AAAAAAAAAA
AAAAAAAAAA    4444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444444    AAAAAAAAAA