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1 GeV リニアック検討資料

1 GeV LINAC DESIGN NOTE

題目 (TITLE) Modification of CCL focusing design

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概要 (ABSTRACT)

Three modifications are considered in the CCL focusing design; the first is the gradual increase of the length of short-tanks of the injection part of the CCL in order to achieve smooth variation of the beta function, the second is a change of the length of the quadrupole magnets in order to obtain a sufficient space between the end-plate of the CCL tank and the adjacent Q-magnets, the third is a change of the variation method of the phase advance in the CCL.

KEY WORDS:

Ion source, RFQ, DTL, CCL, Magnet, Monitor, Beam Dynamics,
Transport, Vacuum, Cooling
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Control, Operation, Radiation, Others

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Three modifications are considered in the CCL focusing design; the first is the gradual increase of the length of short-tanks of the injection part of the CCL in order to achieve smooth variation of the beta function, the second is a change of the length of the quadrupole magnets in order to obtain a sufficient space between the end-plate of the CCL tank and the adjacent Q-magnets, the third is a change of the variation method of the phase advance in the CCL.

1) Modification of the length of the short tanks

In the old-CCL-design, there are 16 short-tanks of about 110 cm in length, followed by normal-tanks of 210 cm. Therefore, there is an abrupt change in focusing parameters in the transition region, which badly affects the beam dynamics. For example, figure 1 shows the beta function of the CCL linac. A large change in the beta function can be seen near the Z of 30 m. Then, the modification was made so that the lengths of the short tanks gradually increase from 105 cm (No.1 tank) to 192 cm (No.24 tank). The beta function,shown in Fig.2, increases smoothly along the CCL. Table 1 shows the main parameters for two designs.

Table 1 Comparison of parameters of the old and new CCL linacs

	old design	new design	constant μ	
Length	303.0175	303.8307	303.8307	m
RF power	81.655	81.674	81.674	MW
Number of tank	152	152	152	
Number of cell	3568	3576	3576	
Max. phase slip	-57.47	-51.23	-51.23	degree
Acceptance				
x (90%)	2.93	2.83	2.81	πcm·mrad
y (90%)	2.63	2.68	2.69	πcm·mrad
longitudinal	87.57	100.74	100.74	MeV·deg
Emittance				
x (90%)	2.12	2.26	2.43	πcm·mrad
y (90%)	1.97	2.17	2.40	πcm·mrad
longitudinal	87.11	88.69	88.69	MeV·deg

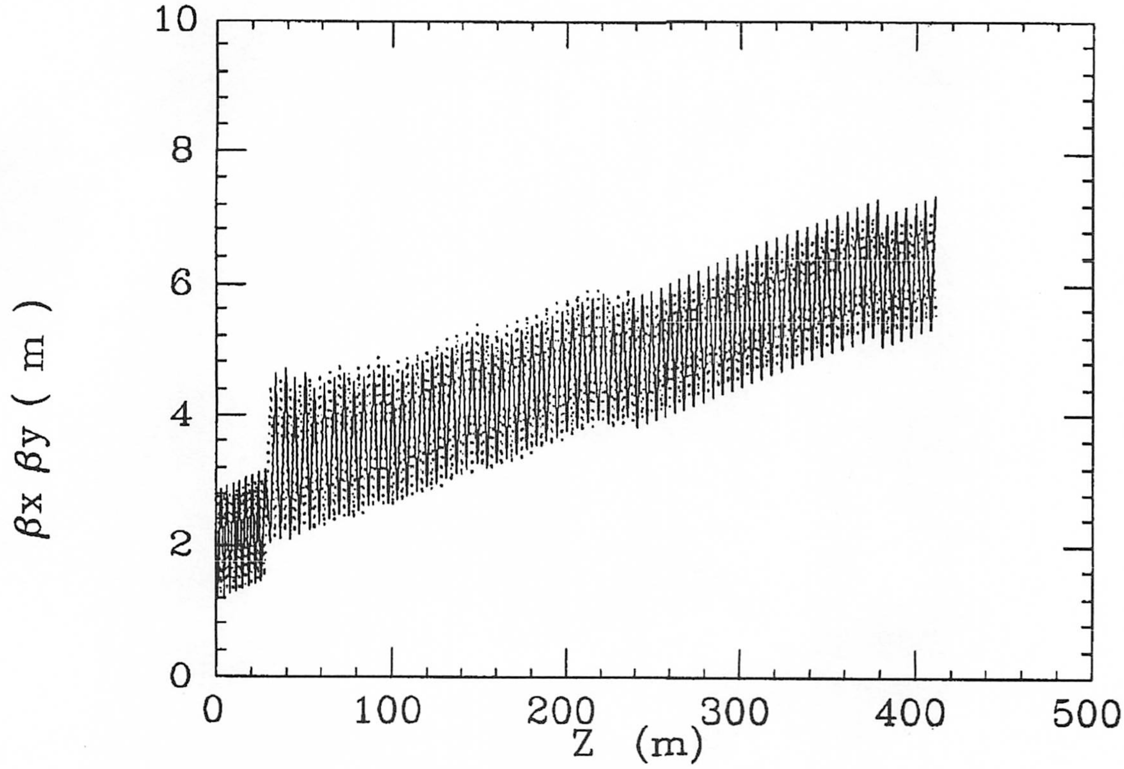

Fig.1 Beta function of the CCL linac for the old design.

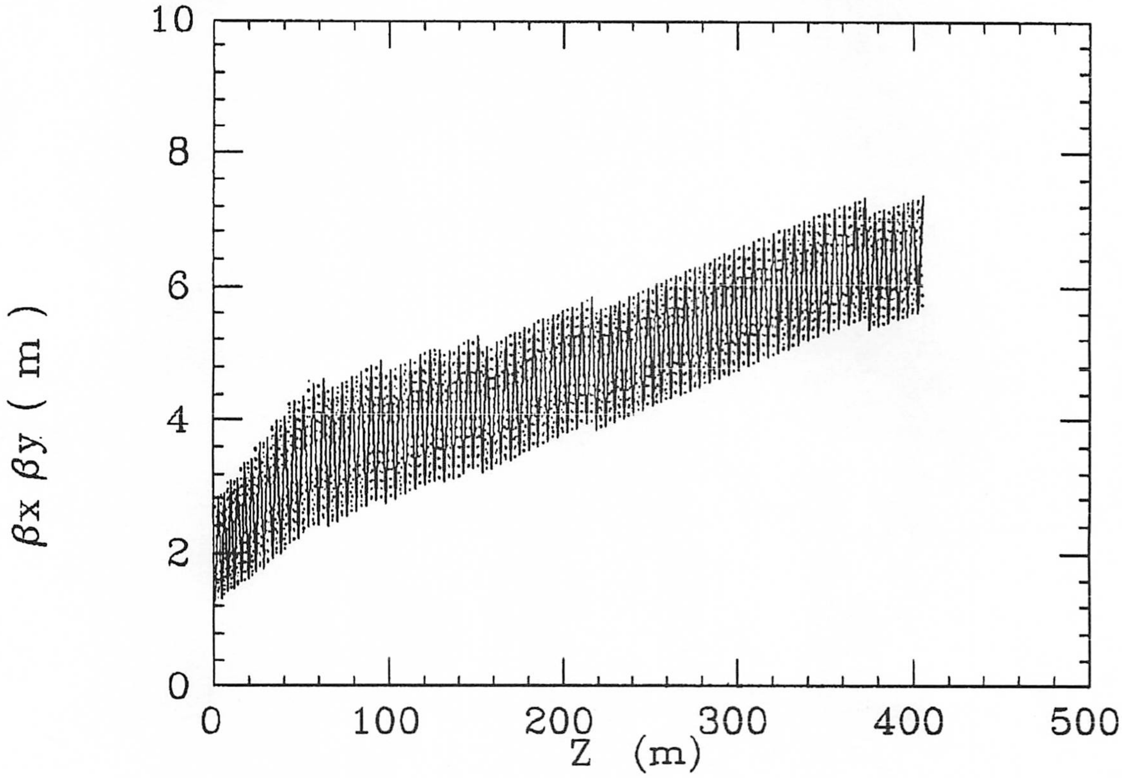

Fig.2 Beta function of the CCL linac for the new design.

2) Modification of the geometry of the focusing section

Figure 3 shows the configuration of the focusing section between adjacent two tanks. SPAC(5) and SPAC(11) represent quadrupole magnets, while SPACE(2,J) represents an accelerator tank. The length of SPAC(11) is always set to zero in FODO lattice. In the old design, SPF(J) and SPB(J) (the length between the quadrupole magnet and an end-plate of the tank) vary from 5.0 to 23.3 cm, which seems too narrow to install vacuum flanges and quadrupole magnets. Also, SPF(J) is equal to SPB(J) in the old design. Now, the modification was made in order to equalize the lengths of SPB(J) and SPF(J+1).

Optimization of the length of the Q-magnets(SPAC(5)) was done holding the SPACE(11,J) and SPAC(4) constant.

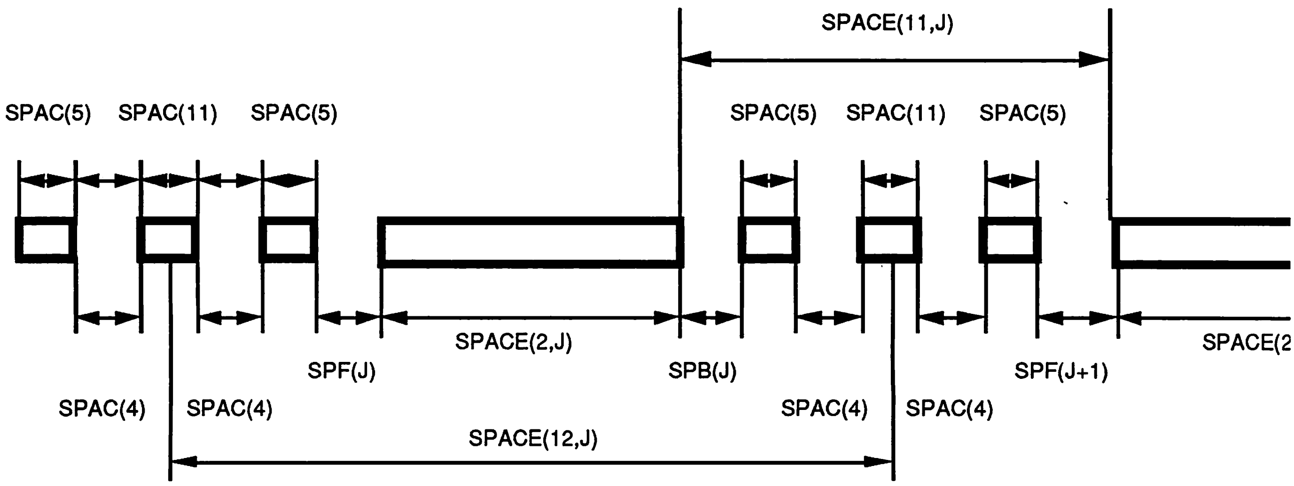

Fig. 3 Configuration of the focusing periods in the CCL.

Thus, the lengths of SPF(J) and SPB(J) change in the calculation. The field gradient, which is held constant in the linac, also varies in order to achieve the given-phase advance at the injection point. The results of calculation are shown in Figs.4 and 5. The acceptance and emittance do not depend upon the length of the magnets. On the other hand, the field gradient increases as the length of the magnet decreases.

The field gradient can be changed more than 50% of the nominal value in the future tuning study, and then the maximum surface field will be limited by the saturation effect of the material. Therefore, the length of the quadrupole magnet of 12.5 cm is chosen. The lengths of SPF(J) and SPB(J) vary from 8.9 to 15.5 cm.

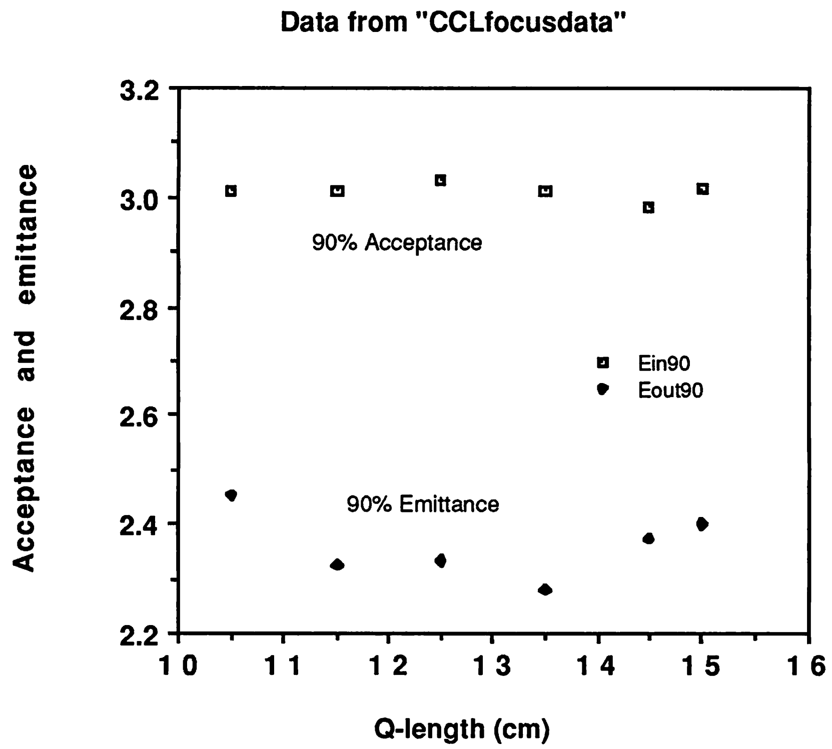

Fig. 4 Acceptances and emittance (πcm·mrad) vs. length of SPC(5).

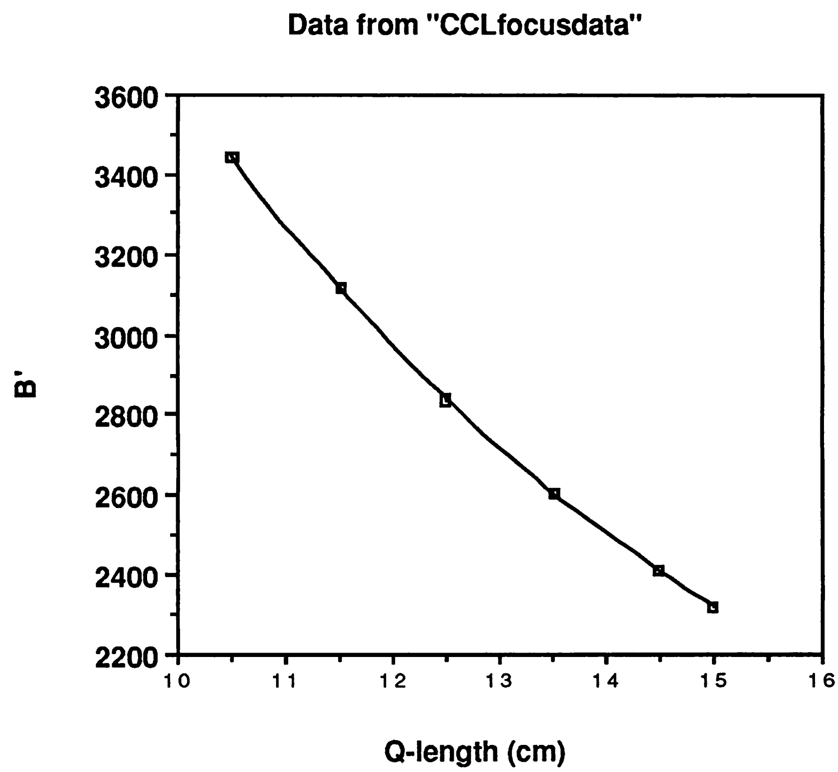

Fig.5 Quadrupole-field gradient (G/cm) vs. length of SPAC(5) for the phase advance of 60 degrees at the injection points.

3) Variation method of phase advance in the CCL

In the old design, the magnetic field gradient is held constant throughout the linac. Therefore, the phase advance decreases from 60 to 25 degrees for the field gradient of 2790 G/cm. The beta function increases as shown in Fig. 2, and then the beam radius is nearly held constant in the linac. The another criterion is to hold the phase advance constant in the linac. In this scheme, the field gradient increases from 2790 to 6104 G/cm in order to hold the phase advance of 60 degrees and the beta function is nearly constant in the linac as shown in Fig. 6. As a result, the beam radius decreases along the linac, which is preferable from the viewpoint of beam losses. Figure 7 shows the acceptances for both the constant-field gradient and the constant-phase advance designs. There is not large difference between them since the beam loss is found near the injection part of the CCL in this simulation and the local acceptance for a focusing period increases along the linac even in the constant-field design. Thus, the final focusing scheme should be determined by the consideration that how much margin, the radius-ratio of the beam and the beam-hole, is necessary in the acceleration of the beam under the many unsatisfactory conditions such as mismatches of magnitude and phase of the accelerating field, alignment errors, and many imperfection related to the beam.

Therefore, it takes further consideration to obtain the final design of the CCL focusing scheme, or it is enough to make a focusing system which easily produces the distribution of the quadrupole field between two extreme two cases mentioned above.

Table 1 also shows the results of the constant-phase advance (60 degrees) calculation. Figures 8 - 11 show the acceptances and corresponding emittances for two focusing schemes.

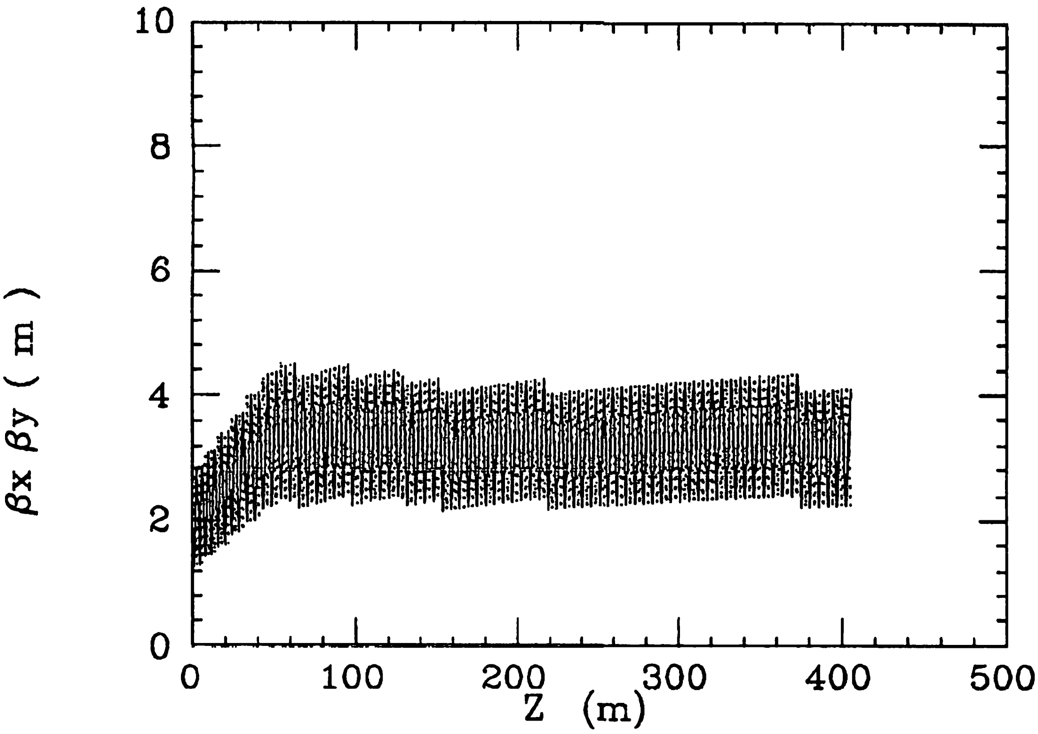

Fig.6 Beta function of the CCL linac for the constant-μ design.

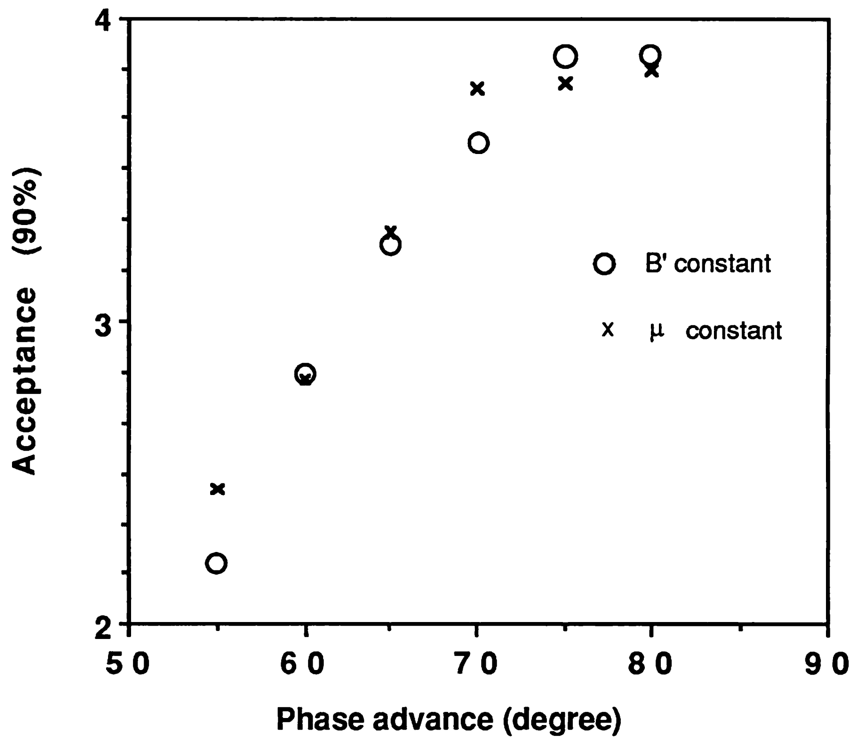

Fig.7 Comparison of acceptance between the constant-field gradient design and the constant-phase advance design. In the former case, the phase advance for the injection point is plotted.

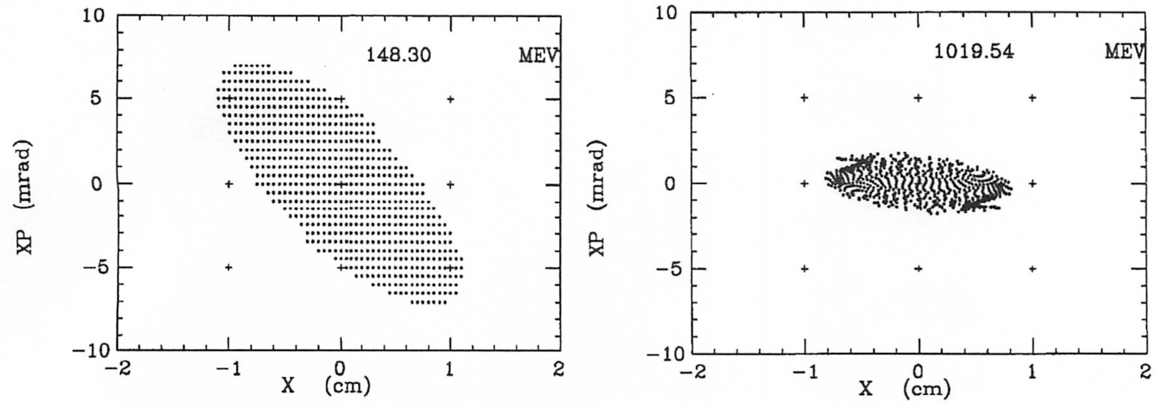

Fig. 8 Acceptance and emittance (x-x') for constant B' of 2790 G/cm.

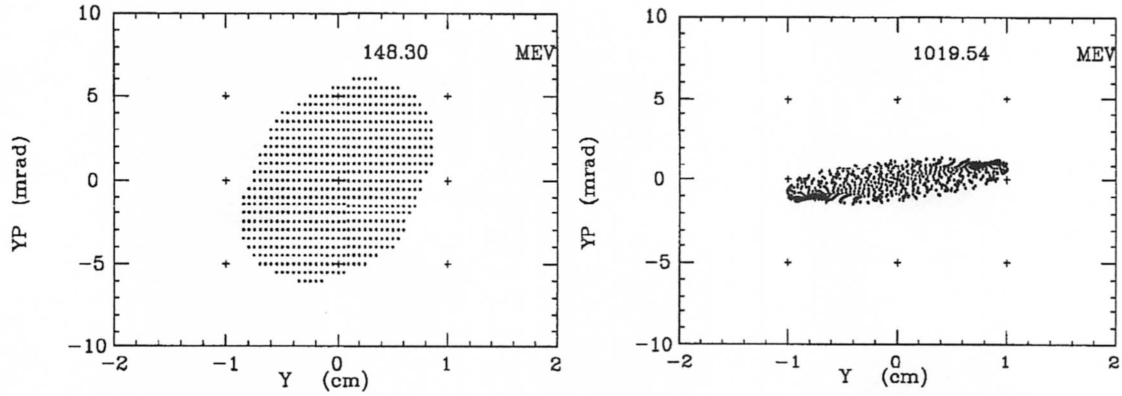

Fig. 9 Acceptance and emittance (y-y') for constant B' of 2790 G/cm.

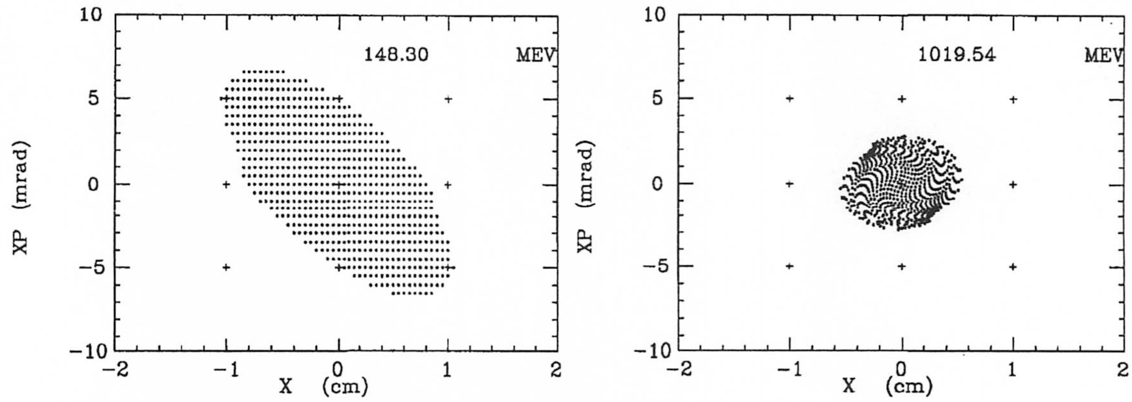

Fig. 10 Acceptance and emittance (x-x') for constant μ of 60 degrees.

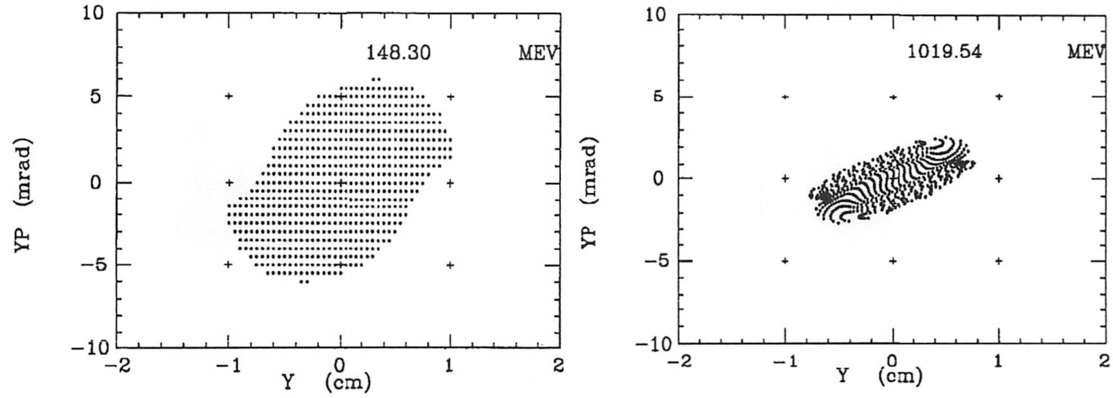

Fig. 11 Acceptance and emittance (y-y') for constant μ of 60 degrees.