NEW LINAC THREE PHASE PLANES PULSED EMITTANCE MEASUREMENT

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Summary

To measure the new linac beam, a single pulse emittance system was developed which measures the beam pulse-to-pulse in the 3 planes.

Introduction

Within the framework of the building of the CERN new linac, it has been decided that the 50-MeV beam would join the old linac-booster beam line in BH3 allowing for the use of the old measurement lines to verify the matching to the booster (emittance line) and to adjust the debunchers (spectrometer line),(Fig. 1).

To test the new linac without involving the operation of the other machines, a complete 3-phase plane measurement system (H-horizontal, V-vertical and L-longitudinal) has been developed. The L plane measurement, handled in the same way as the H and V measurements, allows us to study specially the beam transfer to the booster by using the program TRANSPORT.

The single pulse measurement principle has been kept. The old lines can be used with the new system via a simple switch. This system can be matched by an interaction process to any characteristics of the linac beam.

Phase Planes Measurement Principle

Transverse plane (H horizontal, V vertical)

Upstream of a variable slit (0.5 to 2 mm), two pulsed magnets of the window-frame type, are powered in series and in opposite phase by a sine shaped pulse (T=72 μs). The part of the sine wave between $5\pi/6$ and $7\pi/6$ is used to sweep the beam. See Fig. 2.

In this way, a linear time-beam position relation is obtained. Changing the kicker current changes the diameter unit U_d. Between the slit and a set of 24 collectors, two pulsed quadrupoles maintain two conditions:

1. that each collector represents a given angular unit U_a at the diameter slit;
2. that no particles are lost in the measurement line before the collector.

Figure 3 shows the curves of the quadrupole current versus the desired angular unit U_a.

Finally, during the sweeping of the beam, the 24 collectors measure the beam density distribution as a function of the diameter.

Measurement of the longitudinal L plane (phase versus energy)

In order to have the same handling of the 3 phase planes, it is necessary that the information given by the 24 collectors for the L plane be identical to that coming from the H and V planes. Each collector covers an extension $\Delta\phi_1$ in rf phase and receives a current as function of the various energies contained in the beam, during the sweeping of the first kicker magnet, K1V (Fig. 4).

The first spectrometer magnet works in a classical way (Fig. 4). At the A_1 exit a kicker magnet identical to those of the H-V lines sweeps the beam to be analyzed across the Z_2 slit, which thus accepts the various energies ΔE_1, ΔE_2, ΔE_n sequentially. Z_2 is the object-slit of a second spectrometer magnet with the 24 collectors at the image point. An rf cavity tuned to the linac frequency works as a rotating lens in the $\Delta\phi\Delta E$-plane transforming the phase dispersion $\Delta\phi$ into an energy dispersion $\Delta E_\phi = C\cdot\Delta\phi$, analysed by the second spectrometer magnet.

The final transverse position Z_3 of a particle is a function of its energy at the output of the rf cavity :

$$Z_3 = f(E_o+\Delta E+\Delta E_\phi),$$

E_o is the mean energy of the beam which defines the central trajectory in the spectrometers, $\Delta E = f(t)$ is the linac beam energy dispersion, which becomes a function of time after the Z_2 slit. In order that Z_3 be only a function of ΔE_ϕ (and hence of $\Delta\phi$), a second kicker magnet (K2V) powered in series with the first one cancels the effect of the function $\Delta E = f(t)$.

When varying the kicker intensity, a variable energy axis unit U_E is obtained. In varying the effective voltage in the rf cavity, one can vary the phase unit U_ϕ.

A_1 and A_2 have a deflection angle of 54,3°, the length of the mean trajectory being 1.2 m.

Collectors

Secondary emission collectors are used, transparent to the 50-MeV beam. There are 24 nickel ribbons, 1.5-mm wide, with a thickness of about 4 μ; each ribbon is separated from the other by 0.3 mm. The front and back sides are screened by a 4 μ aluminium sheet, biased to + 200 V and placed at 5 mm distance. In order to avoid mechanical movements, two such collectors (for H and V phase planes) are placed one after the other, in a sandwich arrangement (screen - H collector - screen- V collector - screen).

Analog Signals Treatment

After having been amplified on the spot, the analog signal of the 24 collectors is transferred to the equipment gallery where a single set of electronics treat the information (Fig. 5).

Figure 6 gives the general layout of the system with the old and new lines. Each signal enters a comparator (IM319). At the output, the unit signal enters a shift register, with a series input and a parallel output triggered by a 2-MHz clock. Each signal is cut into 24 parts (measurement duration 12 µs). In due course, the shift register is read and the information is transferred in series via CAMAC to the computer which puts into its memory a matrix of 24x24 bits representative of the phase plane. The parameters of an ellipse, "the nearest to the measured surface", which, at 50 MeV, is almost elliptical, is calculated by the program.

In parallel with the comparator, each collector is linked to two circuits which are unlocked by a square pulse. One of these circuits gives an output signal proportional to the input signal and is gated on during the 12 µs measurement, while the other one gives a signal proportional to the current contained in the measured emittance and is gated by the output signal of the comparator. After integration of the 24 channels, two signals are obtained : one V_t, proportional to the total current and the other V_p, proportional to the current contained in the emittance delimited by a chosen equi-density line.

Operation of the Lines

Starting the operation

The lines are controlled via the consoles of the new linac, which allow access directly to either one of the three phase planes, or the 3 synoptics of these planes, which display the technological state of the lines (see Fig. 7 for the L plane synoptic). Calling one of the lines directly, one obtains, pulse-to-pulse, on a color TV display, the shape of the emittance and in addition calculated values as I_o - total current of the beam ; E - measured emittance ; PMAX - maximum abscissa of the measured ellipse ; WMAX - maximum ordinate of the measured ellipse ; E_o - emittance containing 63% of the beam (from calculated V_p, V_t and E); I_o/E_o - quality factor of the beam ; PMEAN and WMEAN – position of the ellipse center (Fig. 8).

The touch button "Change Unit" gives access to a new page, which allows the settings of the various parameters of the line to be changed.

Settings of the line

These settings have two aims :

1. that the whole measured beam arrives on the collector set
2. that one achieves the best measurement accuracy.

Five parameters are adjustable with acquisitions pulse-to-pulse on the display unit (Fig. 8):

1) U_d. The diameter unit can be varied from 1 to 3 mm for the H, V planes and from 7.5 to 15° for the L plane.
2) U_a or U_E. Variation from 0.15 to 0.5 mrad for U_a (H and V planes) and from 30 to 90 keV for U_E (L plane).
3) Threshold. Variable from 1% to 100% of beam density.
4) Delay. From 0 to 200 µs to vary the measurement momentum within the linac pulse.
5) Gains. From 0 to 7 as function of the total current to be measured (from 10 to 200 mA).

A program written by J. Stovall and modified by P. Mead raises the threshold voltage from 0 to 100% in steps of 5%, reads the numerical results for each pulse and allows in 20 pulses to get the repartition of current densities. One example of this program (Ref. Autostep) is shown in Fig. 9.

Calibration

Before putting the lines in operation it was necessary to check the accuracy of the different measurement parameters.

Transverse planes H and V

A given change of current in BH1 produces a certain change of the mean angle of the beam, and therefore a specific change of position at the measurement slit. In this way it was possible to calibrate the U_D and U_A.

Some measurements were done with a defined beam as a function of the slit width to know the space-charge effect in the line between slit and collectors. These tests confirmed the calculations that for the range of slit widths used, the global effect is smaller than 5% in the beam angular distribution.

Longitudinal plane

- Setting of the rf cavity :

The setting of the rf cavity phase must be such that with and without rf the center of the beam on the display does not change.

To check the calibration of the U_ϕ the rf phase in the cavity was changed by 30°, which moved the mean position of the beam on the display ; knowing the sensitivity of the second spectrometer it was possible to measure the exact U_ϕ.

A Typical Measurement

Figures 10a, b, c, show a typical result in the three phase planes for $E=2E_o$. By variation of the threshold the curves of Fig. 11 were obtained and by integration the exact value of E_o was found.

CONCLUSIONS

This system has now been used for one year. The final aim is to collect, in one pulse, the values of the densities for the 24x24 matrix by using a fast A/D converter and to have, what the "Autostep REF program" gives us now in 15 pulses, in a pulse-to-pulse way.

Acknowledgements

I wish to acknowledge our indebtedness to my colleagues in the PS and visitors for their essential contributions to this measurement system.

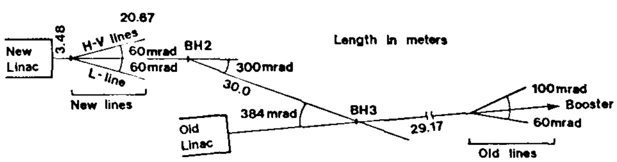

Fig. 1 Layout of the High Energy Beam Transport (HEBT) line

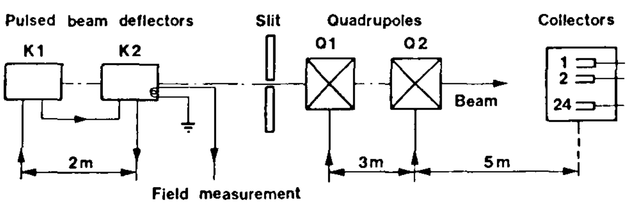

Fig. 2 Layout of the apparatus for the transverse phase planes measurement

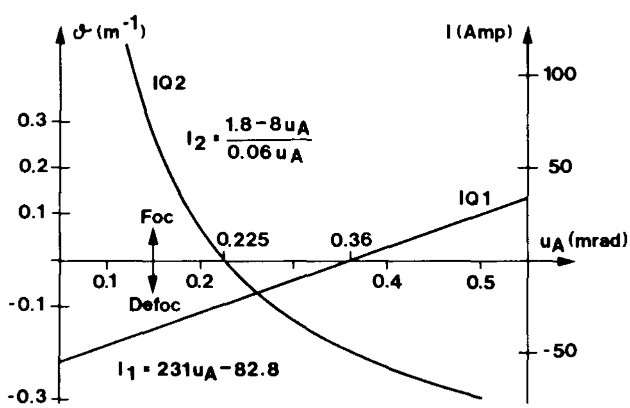

Fig. 3 Beam focusing of the transverse emittance line (measured plane)

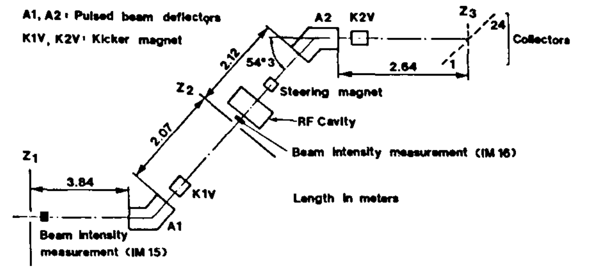

Fig. 4 Layout of the apparatus for longitudinal phase plane measurement

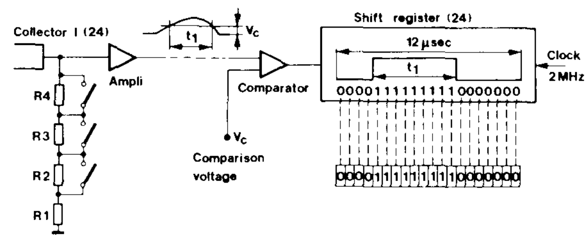

Fig. 5

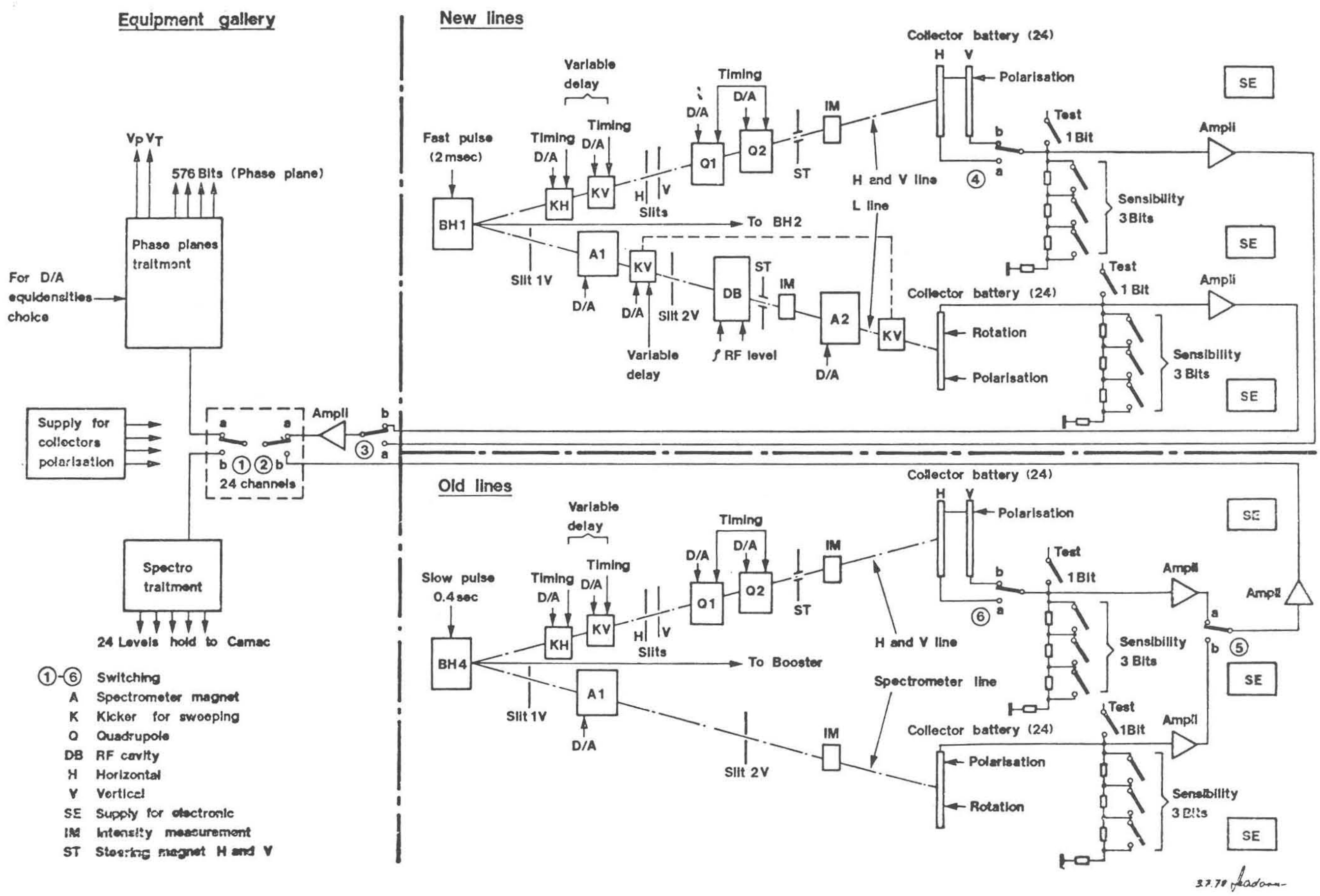

Fig. 6 General layout of the measurement lines
(at 50 MeV)

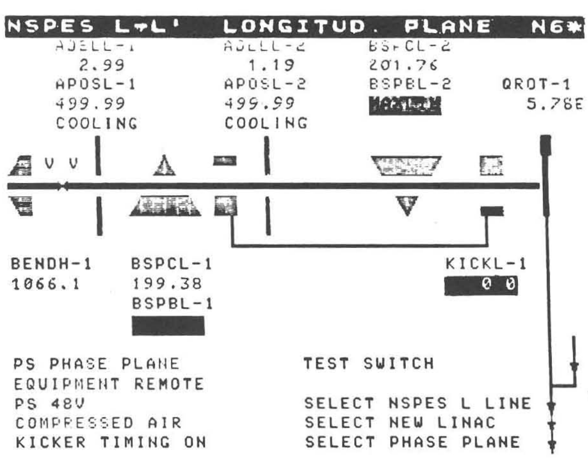

Fig. 7 Longitudinal Plane Synoptic

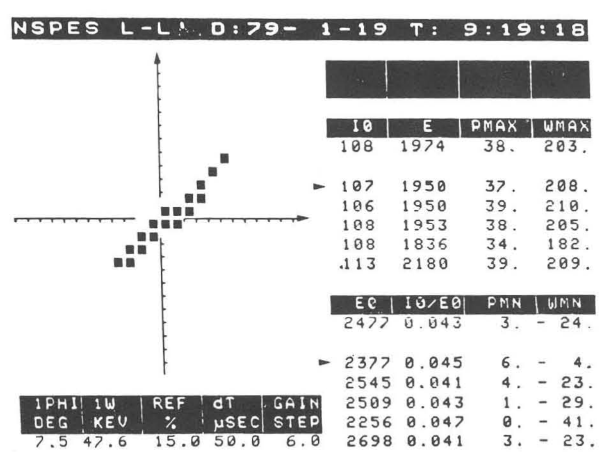

Fig. 8

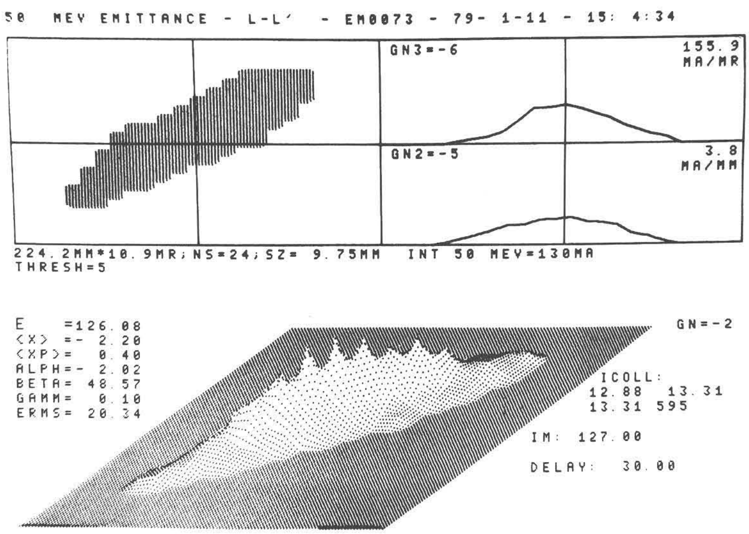

Fig. 9 Example of AUTO-STEP PROGRAM

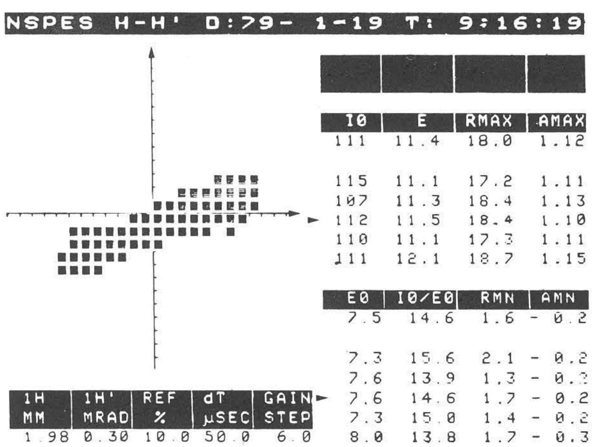

Fig. 10a

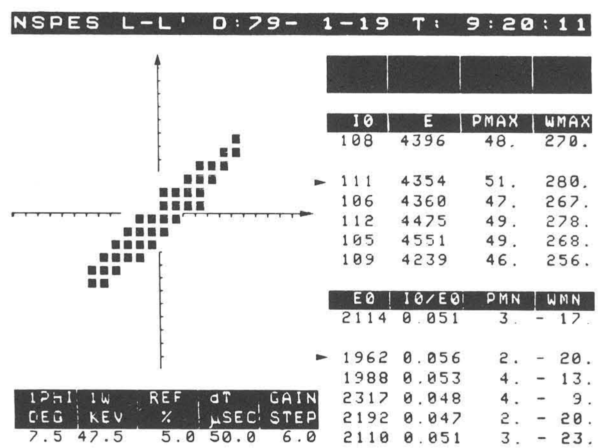

Fig. 10c

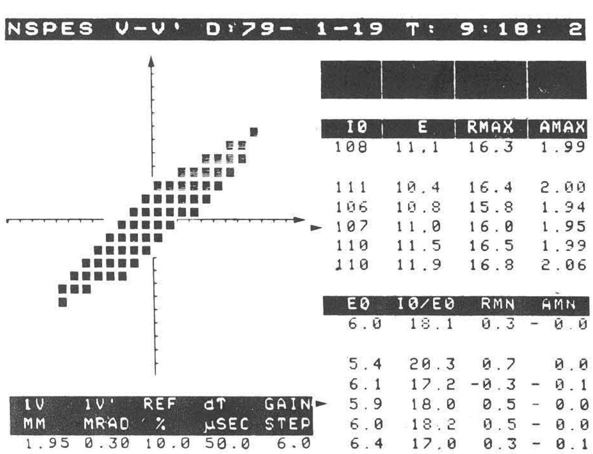

Fig. 10b

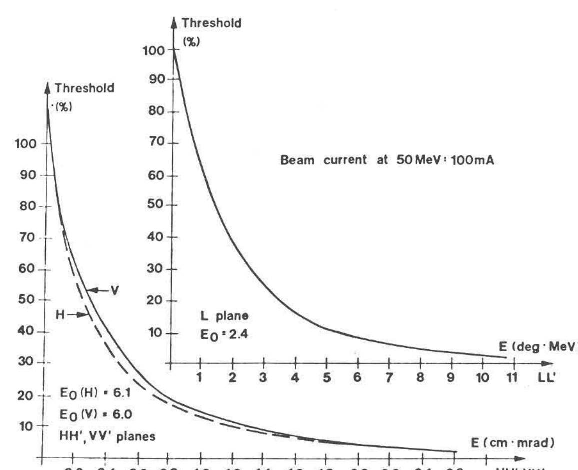

Fig. 11 Emittances as a function of threshold in the three phase planes