NEW LINAC THREE PHASE PLANES PULSED EMITTANCE MEASUREMENT

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Paper presented at the
Linear Accelerator Conference
10-14-September 1979, Montauk, New York, U.S.A.
Abstract

To measure the new linac beam, we developed a single pulse emittance system in the three phase planes which measures the beam pulse to pulse.

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.

Phase Planes Measurement Principle

Transversal plane (H horizontal, V vertical)

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

In this way, a linear time-beam position relation is obtained. If we change the kicker current, we change the diameter unit \( U_d \). Between the slit and a set of 24 collectors, two pulsed quadrupoles maintain two conditions:
1. Make that each collector represents a given angular unit \( U \) at the diameter slit.
2. Make that no particles are lost in the measurement line before the collector.

Finally, during the sweeping of the beam, the 24 collectors get 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 of the L plane be identical to that coming from the H and V planes. Each collector covers an extension \( \Delta \phi \) 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, KV (Fig. 4).
The first spectrometer magnet works in a classical way (Fig. 4). At the A1 exit a kicker magnet identical to those of the H V lines sweeps the beam to be analysed in front of the Z2 slit, which thus accepts the various energies $\Delta E_1$, $\Delta E_2$, $\Delta E_{in}$ sequentially. Z2 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 $\Delta \delta$-$\Delta E$-plane transforming the phase dispersion $\Delta \delta$ into an energy dispersion $\Delta E_0=C \Delta \delta$, 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:

$$Z_3 = f(E_0 + \Delta E + \Delta E_0),$$

$E_0$ 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 Z2 slit. In order that $Z_3$ become only a function of $\Delta E_0$ (and hence of $\delta$), we put a second kicker magnet powered in series with the first one and which cancels the effect of the function $\Delta E=f(t)$.

When varying the kicker intensity, we obtain a variable energy axis unit $U$, and in varying the effective voltage in the RF cavity one can vary the phase unit $U_0$.

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

Collectors

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

Fig. 5

Fig. 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 has then in memory a matrix of 24x24=576 bits representative of the phase plane. With the help of a program we calculate the parameters of an ellipse "the nearest to the measured surface", which, at 50 MeV, is almost elliptical.

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 unlocked during the 12us measurement, while the other one gives a signal proportional to the current contained in the measured emittance and is unlocked 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 equidensity line.

**Lines Operation**

**Starting the operation**
Access to the lines is obtained via the consoles of the new linac, which allow to call either directly 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). If one calls directly one of

![NSPES L-L'] LONGITUD. PLANE NEW

- **NSPES L-L'**
  - **LONGITUD. PLANE NEW**
  - **KICKL-1**
  - **TEST SWITCH**
  - **SELECT NSPES L LINE**
  - **SELECT NEW LINAC**
  - **SELECT PHASE PLANE**

The lines, one obtains, pulse to pulse, on a colour TV display the shape of the emittance and in addition calculated values as \( I_0 \): total current of the beam; \( E \): measured emittance; \( P_{MAX} \): maximum abscissa of the measured ellipse; \( W_{MAX} \): maximum ordinate of the measured ellipse; \( E_0 \): emittance containing 63% of the beam (from calculated \( V_e \), \( V_p \) and \( E \)); \( I_0/E_0 \): quality factor of the beam; \( P_{MEAN} \) and \( W_{MEAN} \): position of the ellipse centre (Fig. 8).

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

**Settings of the line**
These settings have two aims:

1. that the whole measured beam arrives on the collector set;
2. that one benefits from the best accuracy of the measurement.

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

- \( V_d \): The diameter unit can be varied from 1 to 3mm for the H, V planes and from 7.5 to 150 for the L plane.
- \( U_e \) or \( E_e \): Variation from 0.15 to 0.5 mrad for \( U_e \) (H and V planes) and from 30 to 90 keV for \( E_e \) (L plane).
- Threshold. Variable from 1% to 100% of beam density.
- Delay. From 0 to 200 us to vary the measurement momentum within the linac pulse.
- 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% by 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.

![Fig 9 Example of AUTO-STEP PROGRAM](image-url)
Calibration

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

Transverse planes H and V

To a certain change of current in BH corresponds a certain change of the mean angle of the beam, and therefore a certain change of position at the measurement slit. In this way it was possible to calibrate the U_H and U_V.

We did some measurements with a given beam as a function of the slit width to know the space charge effect in the line between slit and collector. These tests confirmed the calculations that for the range of slit widths that we use, the global effect is smaller than 5% in the beam angle 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 U_v we changed the RF phase in the cavity by 30°, which changed the mean position of the beam on the display; knowing the sensitivity of the second spectrometer it was possible to measure the exact U_v.

One typical measurement

Figures 10a, b, c, show a typical result in the three phase planes for E=2E_0. By variation of the threshold we get the curves of Fig. 11 and by integration the exact value of E_o.

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.