AIRIX ALIGNMENT AND HIGH CURRENT BEAM DIAGNOSTICS

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Abstract

The high performance required for the French Radiographic Hydrotest Facility is tightly connected to the quality of the electron beam. As part of the AIRIX program an Integrated Test Stand named PIVAIR is achieved at CESTA. Many tools have been developed to control and optimize the beam parameters. At first, we describe the alignment technique choosed for PIVAIR. Since AIRIX have essentially time dependant characteristics, all the beam diagnostics are time resolved. Emittance measurement which uses pepper-pot technique associated to a fast scintillator radiator and a gated camera, is described. Non destructive electric diagnostic of the beam position is discussed. We talk about beam profile recording from Cerenkov or Optical Transition Radiation (OTR) radiator. We bring up results of a high resolution energy spectrometer.

I. INTRODUCTION

In the AIRIX project a high current (3.5 kA) beam, generated by the PIVAIR injector at 4 MeV, is then accelerated up to 20 MeV by passing through the 64 cells of an Induction Accelerator. The high focus quality requires small emittance and low energy spread. Stability of the emittance along the accelerator needs in particular carefulness of the mechanical and magnetic alignment and a fine control of beam transport. The goal, to reduce chromatic effect, is to enclose all the magnetic axes of the cells in a 250 μm diameter cylinder with an angle spread lower than 500 μrad. For PIVAIR experiment, emittance measurement is done with pepper-pot technique. The results of this diagnostic, strongly disturbing, have to be analyzed carefully. Beam transport must be controled by non-destructive diagnostics. We use beam position monitor with B-loops to locate the centroid of charges. The objective, on PIVAIR experiment, is to analyze corkscrew, due to chromatic effect, and Beam-Break-Up generated by the accelerating gap in the cells. Radial charge density profile, which gives information about transport quality, is recorded using destructive diagnostic. The energy spread, second cause of chromatic aberrations, must be limited in the ± 1% range. Results of the PIVAIR injector and of the first cells are presented.

II. ALIGNMENT

The discrepancy between mechanical and magnetic axes in each cell is reduced by assembling technique of the different parts and the use of an homogenizer rings mechanically centred in the solenoid.

The aim of alignment procedure is to be able to control the mechanical stability of the accelerator beetween two experiments. In this case, beam axis can no more be used. We developed a prism technique described on the following picture:

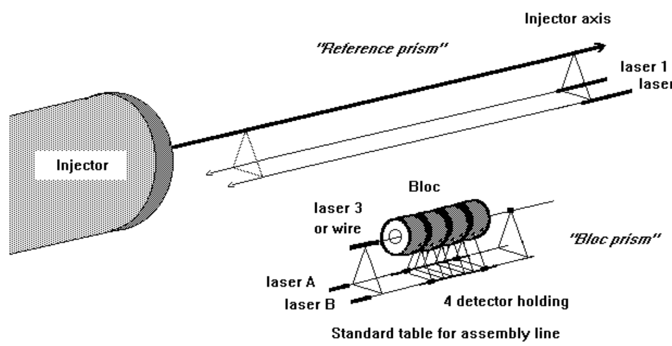

Figure 1: Alignment

Cells are put together on a standard table to be mechanically aligned using laser 3 of a three parallel laser system. The magnetic alignment may be controlled on this table with the stretched wire technique. The "Bloc prism" is defined using four laser (A & B) impacts on XY detector located under the first and fourth cell. The Bloc prism is aligned on "Reference prism" using laser 1 and 2 impacts.

We are currently studying a technique using Hydrostatic Leveling System [1] to control the stability of our reference prism system.

III. EMITTANCE

The emittance has been measured with the pepper-pot technique which was improved since reference [2].The new CESTA system consists of a 3 mm thick tantalum plate with an array of 1 mm diameter holes and decreasing spacing in the periphery of the mask. The beam is intercepted by this mask and drifted 337 mm to a Bicron 422 scintillator. The beamlet image is recorded with a gated camera (with gating down to 5 ns). This recording gives XY information at a fixed time, during a pulse duration of 60 ns.

The emittance analysis is performed by two techniques. The first is performed by summing the image intensities in "y" and measuring the beamlet widths at 10% of the maximum beamlet intensity. The width is then used to draw a phase space diagram. The area of this diagram is proportional to the emittance defined by the relation.

$$\varepsilon_{nx(90\%)} = \frac{\beta\gamma(area._x)}{\pi}$$

The second technique uses a parametric fit of the beamlets to a Gaussian finding the mean angle x'_c , and corrected angle x'. This fit is used to calculate the rms emittance using the following relations.

$$x^2 = \frac{\sum x_i^2 \sigma_i A_i}{\sum \sigma_i A_i}$$

$$x'^2 = \frac{\sum (x'^2_{\sigma i} + x'^2_{ci})\sigma_i A_i}{\sum \sigma_i A_i}$$

$$xx' = \frac{\sum x_i x'_{ci}}{\sum \sigma_i A_i}$$

$$\varepsilon_{nrms} = 4\beta\gamma\sqrt{\langle x^2\rangle\langle x'^2\rangle - \langle xx'\rangle^2}$$

Where x is the hole position, x'_σ is the beamlet angular width, x'_c is the mean angle, $\sigma_i A_i$ is the weight of each beamlet.

The two analysis are quite different and give similar results only for ideal beam $\varepsilon_{nrms} = \varepsilon_{n(100\%)}$. We made some experiments to evaluate error bars. Repetitivity from shot to shot gives only ± 2% error. Numerical analysis gives about ± 2% error. Correction for nonlinearity in camera recording is in progress. Space charge effect on the drifted beamlets is currently studied. Significant effects are due to pepper-pot mask. We have pointed out a changing of ε_{nrms} versus mask material. At present, it seems that ε_{nrms} increases when mask resistivity decreases.

Taking into account this remark, results on PIVAIR experiment are the followings:

PIVAIR	V (MV)	I (kA)	ε_{nrms} (π.mm.mrad)
Injector	3.8	3.5	1600
Accelerated	4.6	3.5	1600

No emittance increase was measured after four PIVAIR cells.

IV.BEAM POSITION

A. *Electrical Beam Position Monitor*

Beam transport along the accelerator is controlled by Beam Position Monitor using four loops influenced by the B_θ field generated by the beam. The object of our development is, in addition to guiding, to measure either corkscreew effect or Beam Break Up (B.B.U) effect. The aim is a range of operation of ± 5 mm round the accelerator axis, an accuracy of ± 0.1 mm and a sensitivity of ± 0.02 mm. The voltage pulse generated by each loop is proportional to the time derivative of current. Analysis of this signal depends on the effect. Beam positioning and corkscreew need only a 60 MHz bandwith active integrator. At present the 8 bit resolution of the digitizing recorder limits to ± 0.2 mm the accuracy on the absolute position of the beam centroid. Higher accuracy will be reached using Tektronix SCD 1000 scope. B.B.U effect numerical analysis, which needs at least 1 GHz bandwidth, is done by FFT computing. In this case ± 0.02 mm sensitivity is reached.

B. *Optical Beam Position Analyser*

Transverse beam profile is recorded using Cerenkov or OTR radiators and a gated camera. Numerical analysis includes centroid research and RMS dimensions of the beam.

V. SPECTROMETER

Measurement of absolute energy and energy spread is done using a home made magnetic spectrometer. The principle is based on a 180° deviation obtained with the help of an electromagnet. The magnetic field is measured by a Nuclear Magnetic Resonance probe giving an absolute accuracy around 10^{-5}. Two sheets of 100 optical fibers fit out the analyzing plan. Cerenkov radiation generated by electrons going through each fiber is guided to a streak camera for time analysis.

Picture 2 shows the time evolution of energy at the end of PIVAIR injector recorded with the high resolution sheet ($\Delta E/E$ = 0.1 % over a 0.1 E energy range)

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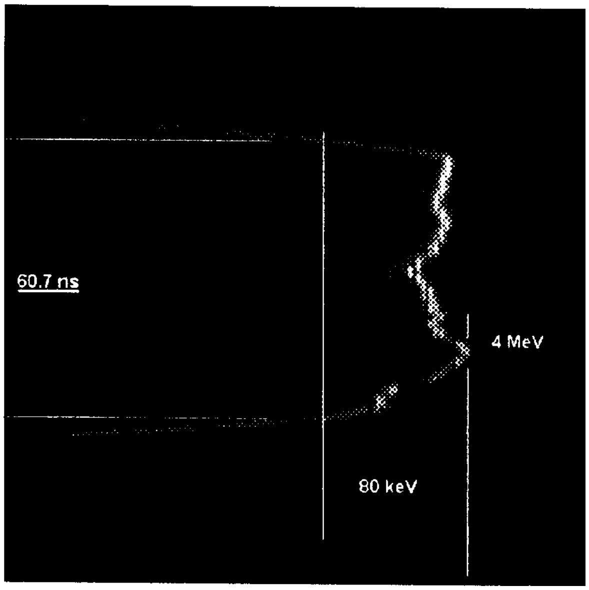

Figure 2 : Injector spectrum

The pictures 3 and 4 present measurements at the end of PIVAIR Accelerator. The second picture shows for comparison an other shoot recorded with the low resolution sheet ($\Delta E/E = 0.5\%$ over an energy range of 0.5 E).

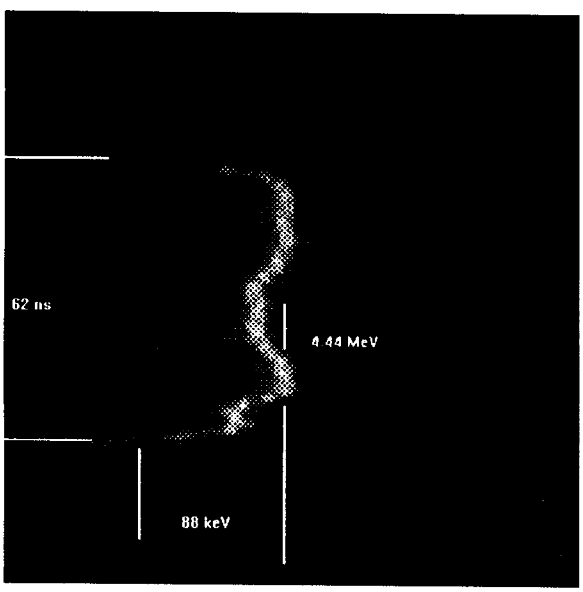

Figure 3 : High resolution at the end of four cells

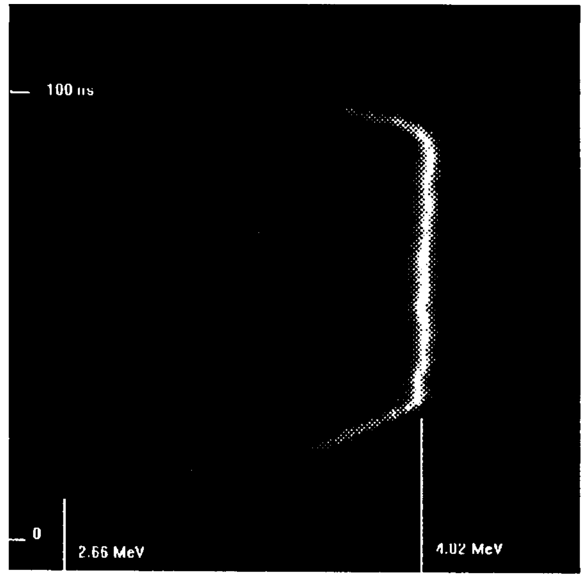

Figure 4 : Exemple of low resolution recording

VI CONCLUSIONS

These diagnostics appear directly connected with the development of the AIRIX program. They aim at analyzing some crucial parameters of the French Radiographic Hydrotest Facility.

VII REFERENCES

[1] Hydrostatic Leveling System developed by ESRF France

[2] Diagnostic development for high current electron accelerator at CESTA. J. de Mascureau & al Proceedings of 1993 IEEE Particle Accelerator Conference p 2115-2117