Diagnostics and Data Analysis for the ETA-II Linear Induction Accelerator*

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Abstract

The ETA-II linear induction accelerator has pulse power and beam diagnostic sensors distributed throughout the system. The accelerator consists of an injector; 20 accelerator cells arranged in two ten cell blocks; and a transport section leading to an energy analyzer. In total there are approximately 120 beam diagnostic channels and 32 pulse power signals which are recorded on six Tektronix 7912AD oscilloscopes. The analysis, display, and interpretation of this data was done using systems for scientific visualization and a simple user interface. Results from several measurements will be presented showing how the diagnostics and system were utilized.

I. INTRODUCTION

The Experimental Test Accelerator--II (ETA-II) is the latest in a series of linear induction electron accelerators constructed and operated at the Lawrence Livermore National Laboratory (LLNL) [1-3]. We have developed computerized, digitized, data acquisition systems for capturing and recording the analog trace signals and TV images generated from our diagnostic sensors. Coupled to the data acquisition are the data analysis capabilities. In this report the current data analysis capabilities for trace data will be presented with emphasis on the choices made and the underlying motivation for these decisions. A similar system is used for TV image analysis.

II. DIAGNOSTIC SENSOR LAYOUT, SIGNALS

A schematic of the ETA-II 20 accelerating cell configuration is shown in figure 1. The machine employs solenoidal transport and is configured as an injector followed by two ten cell blocks. Separating each of these major components is a pair of beam position monitors, commonly referred to as beambugs, which measure the beam current I and x,y positions as functions of time into the beam pulse. There are additional beambugs in the transport beyond the second ten cell block. There are also voltage and current diagnostics on each adjacent pair of accelerating gaps.

The machine description consists of the machine parameters (the tune) and data from the beam bugs (bugwalks), the cell probes (cprobe walks), and any other functioning diagnostics. Walks are taken sequentially in Z using six channels of Tektronix 7912 digitizers. ETA-II operates at one pulse per second; in almost all cases shot to shot reproducibility is assumed in acquiring and analyzing the data. Overall, this is a diagnostic sparse, channel poor, shot rich environment. During operations large amounts of data can be rapidly accumulated. Ways must be found to rapidly and efficiently extract and present relevant information to the physicist.

III. GUIDING PRINCIPLES

The experimental results must be made available to the physicists in a timely and convenient manner. The system is set up to allow an intelligent person to operate it in the absence of an expert. The system works from data files; turnaround from data acquisition to data analysis is targeted to be five minutes. Since there is a large volume of data emphasis is placed on developing single page summaries of the relevant experimental results. Displays are designed to answer specific questions. Since all data analysis is fraught with danger, the raw data is displayed wherever possible, usually in a compacted form. Since printing of output over the network is often unreliable and cumbersome the system attempts to perform these functions for the physicist. Since physicists ultimately want paper and not gorgeous screen displays only black and white is used, color is not employed. Likewise, trendy scientific visualization techniques such as animation are not employed. Copious labelling is done (often making plots look cluttered) to provide the ability to identify data and analysis after the fact.

IV. THE HUMAN-MACHINE INTERFACE

The human-machine interface (HMI) screen, programmed in Interactive Data Language (IDL) running on networked VAX workstations, is shown in figure 2. This interface is inspired by the Macintosh graphical users interface (GUI); it is designed so a novice can analyze data without any typing. The upper quarter of the screen is devoted to information about the currently available data file and next file to be read. The remaining three quarters of the screen are devoted to a collection of buttons which are user selectable using the crosshairs and mouse in IDL. Buttons may be selected in any order, when they are selected a cross hatching appears. Multiple actions may be specified for sequential execution from the HMI. Buttons which cause immediate actions to take place are labelled with bold face type. The buttons are grouped in logical groupings with an indicated header. The user satisfaction with this approach has been very high. Data is typically analyzed within five minutes of its acquisition by whoever is in the control room at the time. This HMI works and earns the accolade, "user friendly".

A. File input, documentation, output

The buttons in the first column of the HMI deal with file input, data documentation, and graphical output to the printers. The first five selections under "Input file" allow the user to read in a new data file. The next two buttons under "File Info:" allow the user to print out the ASCII information contained in a single file or the file comments for a collection of files to locate relevant data. The final three buttons under "Output file:" specify if a plot file creation and destination.

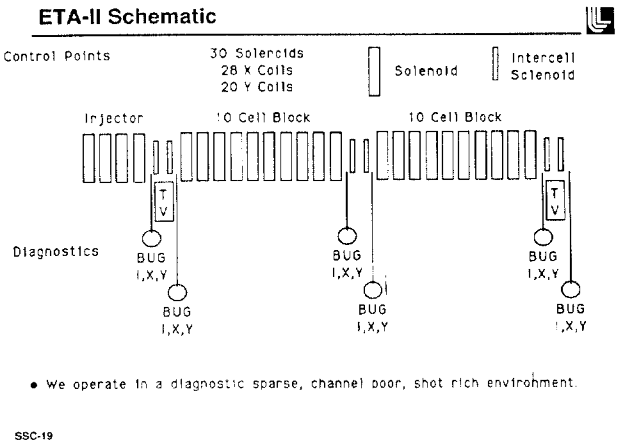

Figure 1. Schematic of the ETA-II configuration showing control and diagnostic points.

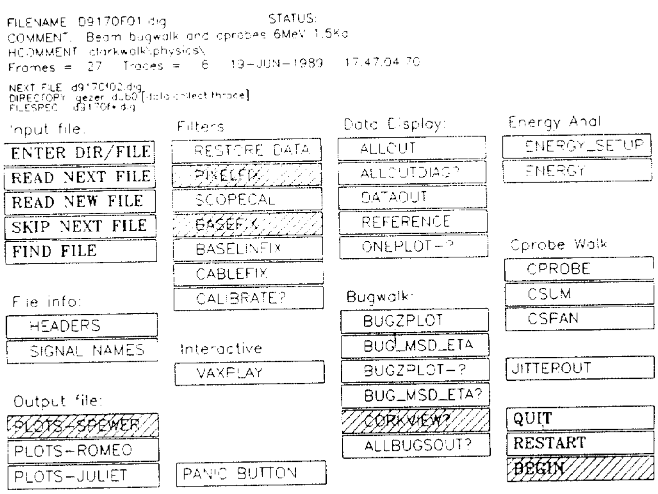

Figure 2. The Human-Machine Interface (HMI) showing data processing choices available to the user.

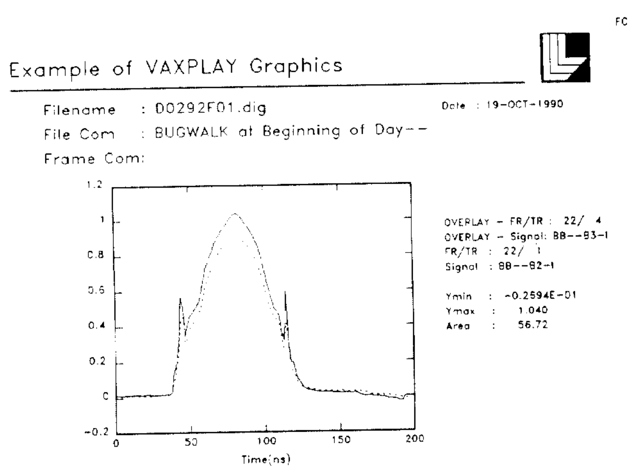

Figure 3. Example of the output of the interactive VAXPLAY data manipulation routines.

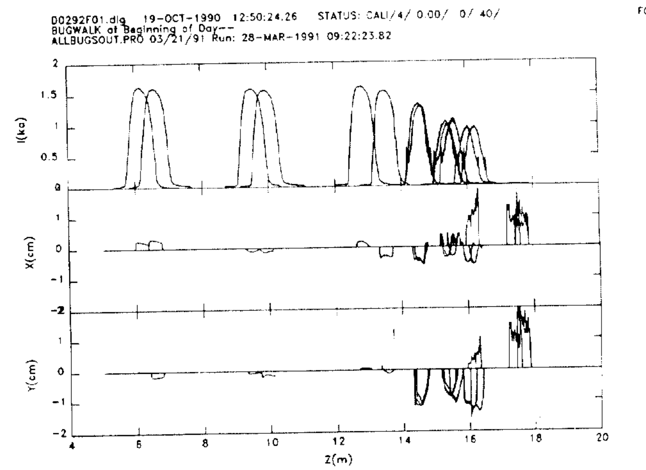

Figure 4. ALLBUGSOUT output for a bugwalk showing beam current and position for all data in a bugwalk.

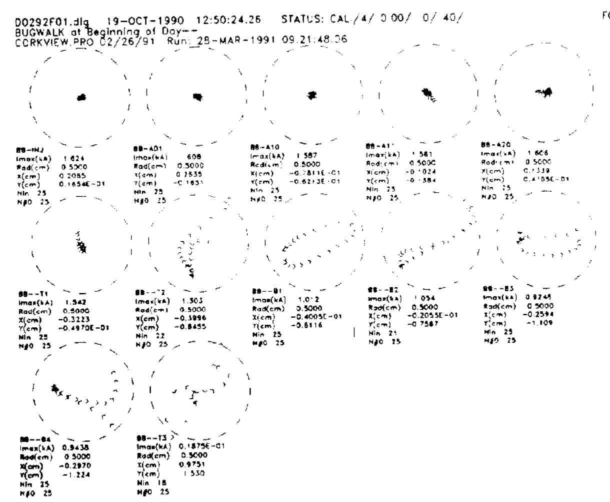

Figure 5. CORKVIEW output of beam position in x and y for all bugs in the bugwalk plotted in figure 4.

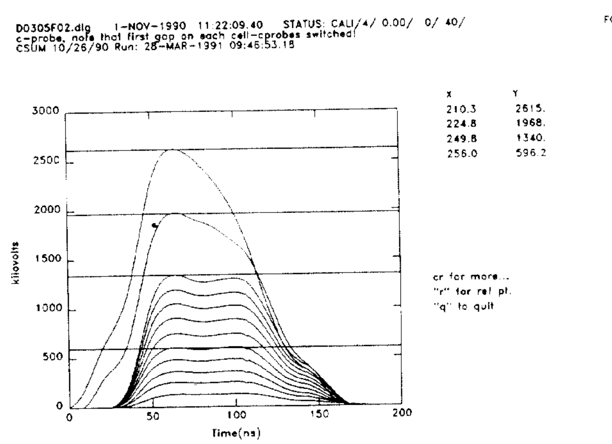

Figure 6. CSUM output of measured gap voltages showing voltages for the cell pairs and total accelerator voltage.

B. Filters

At the top of the second column the user can select filters to be applied globally to the data in the active file. PIXELFIX applies a median filter to the data to remove "bad pixels" from the data. BASEFIX and BASELINFIX apply baseline corrections to the data. The CABLEFIX filter corrects each signal for the frequency dependent cable transmission losses. CALIBRATE applies known calibration factors and algorithms to convert from the raw voltage signals to actual measured quantities. SCOPECAL uses reference channel data to determine the oscilloscope vertical gain calibrations and then to rescale the data. Several filters may be applied sequentially. When each filter is invoked it notes its actions on the file STATUS line.

C. Interactive Data Analysis

The next section is labelled, 'Interactive:'; with the button one can invoke the VAXPLAY data analysis tool. This allows one to interactively manipulate individual traces in a file using one and two letter commands. The usual manipulations such as scaling a trace, adding or subtracting traces, and plotting traces in a variety of ways are available. Under VAXPLAY the filters can be applied to individual traces. The most general data analysis capabilities reside in VAXPLAY; however the process can be slow and tedious. Hence analysis approaches are developed in VAXPLAY; then a specifically targeted data analysis routine may well be written. A sample of VAXPLAY output is shown in figure 3. VAXPLAY output is setup as a viewgraph with user specified title; this gimmick has proven quite useful.

D. Data Display

The options in the top of the third column under "Data Display:" are general purpose routines to display data in a generic fashion. These routines do not depend on the data source or format. ALLOUT will produce a full set of plots of all the data within a file; the plots are small (24 to a page). ALLOUTDIAG provides all the trace plots with printout of fundamental quantities such as mean and standard deviation. DATAOUT plots all the data on similar plots but places repeated shots on a single plot greatly compressing the data display. ONEPLOT allows one to extract a particular signal or set of signals an plot it on a user specified scale; REFERENCE extracts, plots, and analyzes the reference channel data contained in some files. Although the generic data display is useful and sometimes required, the users very quickly evolve into needing analysis tailored very specifically to the dataset and the relevant questions for that dataset.

E. Bugwalk: Data Analysis

The bugwalk data records the evolution of the time varying beam current and position in Z, the distance down the accelerator. Questions one might ask are, "Where is the current loss occurring?", "How is the corkscrew growing?", "How reproducible is the machine shot to shot?" The single page summary of a bugwalk shown in figure 4 from the ALLBUGSOUT option displays the data contained in 168 oscilloscope traces. The beam current and x,y positions are displayed in time at the various Z locations. One can see the pattern of the accelerator with the double beambugs at the ends of each cell block. Since for each bug four traces are overlayed one can see the shot to shot reproducibility is excellent. The onset of current loss is beyond the end of the accelerating section; the beam current also develops wings. Correspondingly, the beam x and y positions are now showing significant displacement and time dependent oscillations. To better view the corkscrew mode where the beam spirals around from head to tail in x and y a corkscrew plot has been developed as seen in figure 5. The x,y evolution of the beam is shown for successive beambugs down the accelerator and transport. This single page summary allows the experimentalist to quickly assess the Z growth of the corkscrew; it is easy to compare patterns from day to day.

Two other options are used in viewing beambug data. The BUGZPLOT plots single numbers parameterizations for the traces (e.g. peak current, charge, displacement) versus Z. This display is particularly useful when an instability is present; as in the study of the hose instability in beams propagating in gas. The BUG_MSD_ETA selection plots each beambug on a separate page for more detailed display.

F. Energy Measurements, C Probes

A program for analyzing the energy spectrometer data is available in the 'Energy Anal:" set of buttons. Energy analysis data appears in a companion paper [2]. The analysis of the Cprobe walks is done in the "Cprobe Walk:" section. The Cprobes are used to study the amplitude, shape, timing, and reproducibility of the applied accelerating voltage and current. With the CPROBE option the voltages from the successive diagnostics down the accelerator are plotted vertically staggered on a single plot to highlight cell to cell variations in the signals. CSPAN looks at the magnitudes of the signals from the two cellblocks. CSUM, figure 6, performs a running sum of the probes to compute the total beam kinetic energy.

V. SUMMARY

A data analysis capability has been developed which provides adequate power, flexibility, and rapid turnaround required for converting the massive amounts of data collected on all our experiments into an understanding of machine performance. The system has proven useful to users who are not proficient computer operators - a reasonably user friendly environment has been achieved. This system contributed significantly to the success of the recent experimental run.

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REFERENCES

[1] W. Turner et. al.,"Control of Energy Sweep and Transverse Beam Motion in Induction Linacs," these proceedings.

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[3] W. E. Nexsen et. al., 'Reduction of Energy Sweep on the ETA-II Beam,' these proceedings.