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Correlation Plot Facility in the SLC Control System*

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Abstract

The Correlation Plot facility is a powerful interactive tool for data acquisition and analysis throughout the SLC. This generalized interface alows the user to perform a range of operations or machine physics experiments without the need for any specialized analysis software.

The user may step one or more independent parameters, such as magnet or feedback setpoints, while measuring or calculating up to 160 other parameters. Measured variables include all analog signals available to the control system, as well as calculated parameters such as beam size, luminosity, or emittance. Various fitting algorithms and display options are provided.

A software-callable interface has been provided so that a host of applications can call this package for analysis and display. Such applications regularly phase klystrons, measure emittance and dispersion, minimize beam size, and maintain beam collisions at the interaction point.

INTRODUCTION

Early in the development of the SLC, a generalized tool was written to acquire online data, and perform analysis and display functions across a wide range of information for many users. Rather than develop similar pieces of code for each combination of data, the Correlation Plot facility was designed generically to handle all of the data types available, and be extensible to other types that might evolve.

Due to the initial success of this implementation, a software-callable interface was added, so that other packages could make use of these fitting, plotting, and display facilities. This approach avoided redundant developments and provides a more consistent user interface for other parts of the control system.

ORGANIZATION

The main elements of the Correlation Plot faciltiy are:

- A general control package which can step through setpoints of magnets, klystrons, feedback loops, timing parameters, and other device points of interest.
- A general data acquisition facility that can acquire data from a variety of sources, including high level parameters derived from analysis of klystron fast time plots and wire scans.
- A range of curve fitting algorithms, including average, linear, polynomial, sinusoidal, Gaussian, and specialized beam-deflection curves.
- A general plotting package to display the acquired and fitted data. The sampled data may be plotted against the step variable, any of the sampled quantities, or the step number.
- A generic optimization feature allowing users to create a correlation plot to vary a step variable; obtain sampled data for each point, fit a parabola to the data, and implement the value of the step variable that results in the fitted minimum.

INTERFACES

Touch Panel

The Correlation Plot facility is an integral part of the SLC Control Program SCP [4]. The primary user interface utilizes a touch panel or cursor keys, although a mouse and trackball have been added as part of a newer X-window SCP. The main panel provides buttons for specifying the step and sample variables, selecting the range of the step variable, and setting other acquisition parameters. A generalized input parser interprets the input in a context-sensitive manner, where the meaning of each token depends on the valid tokens already accumulated. At any point, a list of the valid responses may be requested as a guide to the user.

From the touch panel or keyboard, the user may initiate data acquisition, terminate acquisition, or temporarily pause during an acquisition sequence. After data is acquired, display panels allow selection of fit and plot options. The user may request displayed or printed plots, as well as tabular formats. It is possible to specifically include or exclude selected data points, and have the facility recalculate the fit parameters.

An auxiliary output panel allows extended use of the system. Thus users may save data to disk files in various formats for offline analysis. Alternatively, users can reload previously stored command strings, or variables and data files, for further online analysis and display.

Callable Routines

All of the actions that are accessible via the operator interface are also available to software control. This makes it very easy to develop a layered application, using well-established building blocks. Callable functions support setting up variables and data acquisition options, and automatically acquiring desired data. Applications may obtain acquired data, perform a fit and retrieve the fit parameters, or provide for a variety of displays and plots. Some applications acquire data through specialized protocols, and then use the Correlation Plots for fitting and display functions.

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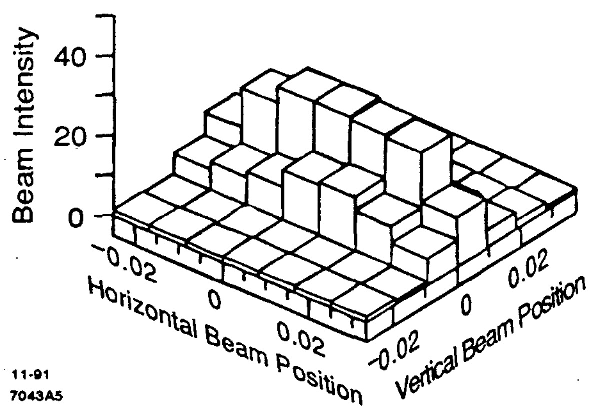

Figure 1. Beam aperture is studied by measuring beam intensity while varying horizontal and vertical position.

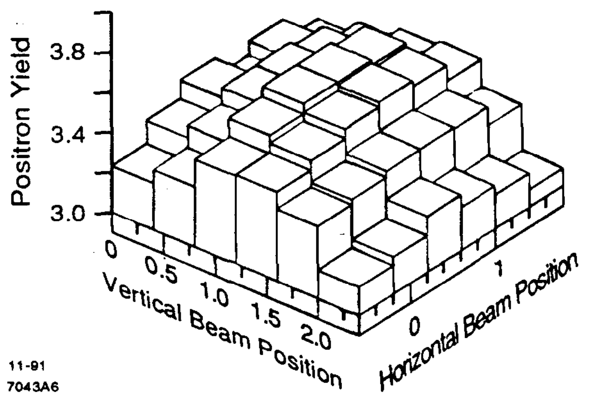

Figure 2. Optimization of beam position on the positron target.

CAPABILITIES

Monitoring

Correlation plot support is provided to measure or calculate a wide variety of data. Up to 160 variables may be sampled within a single acquisition sequence, and up to 100 data points are saved for each. At the current time, measured parameters include beam-related data from position monitors or toroids, and analog values from devices such as klystrons, magnets, thermocouples, and vacuum pumps, etc. For klystrons, in addition to simple analog values, the user may sample values derived from an analysis of the 64-pulse Fast Time Plot, such as phase and amplitude jitter, energy gain of the station, or perveance. This makes it possible to quickly scan the energy gain as a function of klystron phase to find the optimum setting, or to map out buncher jitter as a function of phase-shifter setting in the SLC injector.

Other calculated quantities available include energy, energy spread, particle yield, and beam position or deflection angle at the interaction point. Residual dispersion at the collision point may be measured noninvasively by correlating position and angle at the impact point with energy fluctuations. In addition, interfaces to other applications allow sampling of various derived quantities, such as beam states calculated by feedback and beam sizes, emittance and skew parameters determined from wire scans, beam scans, or profile monitor digitization. These quantities are used in a wide variety of beam optimization procedures.

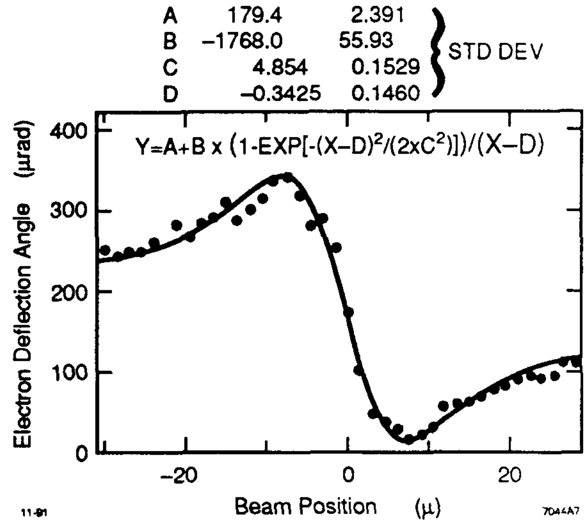

Figure 3. Beam-beam deflection fit at the interaction point.

Control

The user may elect to use either one or two step variables. Most of the variables available to software control have been implemented. Examples include:

- Setpoints of magnets or other analog control devices;
- Klystron setpoints, including amplitude, phase, and timing;
- Timing delays for any triggered device;
- Combinations of devices through the Multiknob facility;
- Setpoints of feedback loops stabilizing the beam [3,1];
- Time.

For many experiments, the Time step variable provides a simple delay between samples, in order to study the time structure of variations in normal running. Users can study correlations between sampled variables without modifying any control parameters. Most of the time, only one step variable is used, so a third has not been considered necessary. When two step variables are used, they define a grid of values, and the second is stepped through the whole range for each setting of the first. Figures 1 and 2 are examples of plots with two step variables.

Data Reduction

To aid in the analysis of the data, a variety of fitting routines may be selected. The selection of fitting algorithms may be accomplished through the user interface (touch panel) or by application software. Figure 3 shows the special beam-beam deflection fit used for optimizing collisions and estimating beam cross section at the interaction point.

APPLICATIONS

Various software applications used in the SLC have been built upon capabilities of the Correlation Plot facility. These analysis and control applications include the following:

1. Multivariate correlation plots make it possible to visualize a wealth of data in a focused and informative way. Figure 1 is a plot from a beam aperture study in which multistep variables are used to study beam intensity in three-dimensional space. Figure 2 is an optimization study of beam position on the positron target, where

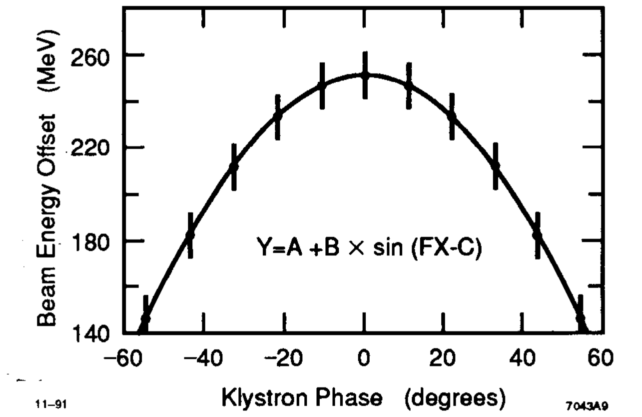

Figure 4. An automated procedure optimizes phases of the 240 SLC klystrons.

feedback setpoints are used to control horizontal and vertical beam position, and the application calculates positron yield at each combination of setpoints.

2. Data collection and optimization applications that calculate optimized values for klystron or magnet settings are common. Figure 4 displays the fitted beam energy offset for a single klystron, where an automated procedure steps through the devices, measuring beam energy as a function of phase in order to determine the optimum setting. Figure 5 displays a parabolic fit of beam width squared, from digitized profile monitor data as a function of quadrupole magnet strength.

CONCLUSIONS

The Correlation Plot facility has proven to be an extremely powerful tool for the analysis of accelerator functionality, device commissioning, and for building software applications. The flexibility provided by the different types of variables that may be controlled and monitored has allowed operators and physicists to rapidly design and execute a vast assortment of experiments without any new or specialized software. In fact, the Correlation Plots are used so extensively that most experimental data presented comes from this facility, and it is extremely rare that data needs to be plotted offline. Even for complicated experiments where further analysis is required, the Correlation Plots provide the data acquisition and online validation. The Correlation Plots facility has made an essential and invaluable contribution to the SLC development.

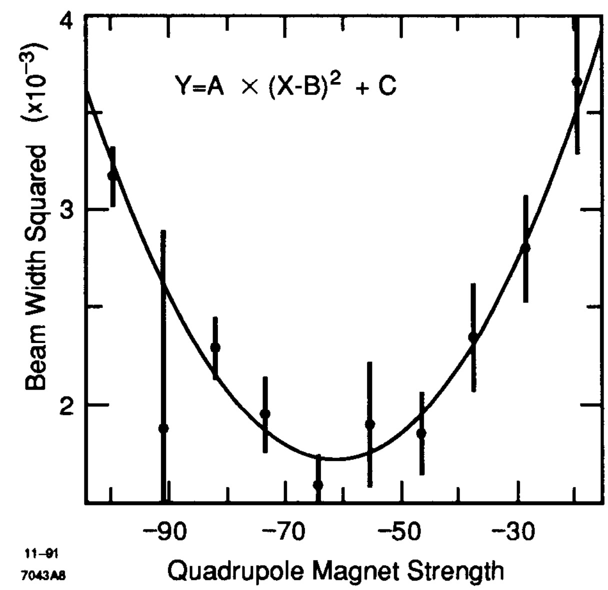

Figure 5. Beam emittance is calculated by varying a quadrupole setting and fitting a parabola to the estimated beam width squared.

ACKNOWLEDGMENTS

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