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SDA-BASED DIAGNOSTIC AND ANALYSIS TOOLS FOR COLLIDER RUN II*

T.B. Bolshakov#, P. Lebrun, S. Panacek,V. Papadimitriou, J. Slaughter, A. Xiao,

Fermilab, Batavia, IL 60510, U.S.A.

Abstract

Operating and improving the understanding of the Fermilab Accelerator Complex for the colliding beam experiments requires advanced software methods and tools. The Shot Data Analysis (SDA) has been developed to fulfill this need. Data from the Fermilab Accelerator Complex is stored in a relational database, and is served to programs and users via Web-based tools. Summary tables are systematically generated during and after a store. These tables (the Supertable, the Recomputed Emittances, the Recomputed Intensities and other tables) are discussed here.

DATA SOURCES FOR ANALYSIS

SDA is an acronym with dual meaning. Originally it was introduced in the Controls department as “Sequenced Data Acquisition” [1]. The Integration department uses it as “Shot Data Analysis” and this reading of the term became more popular. So, “Sequenced Data Acquisition” serves as the main source of data for “Shot Data Analysis”. The data used in Shot Data Analysis comes from two sources: 1) the Sequenced Data Acquisition and 2) the Data Loggers.

Sequenced Data Acquisition

Sequenced Data Acquisition is based on rules. The significant terms in these rules are “event”, “device”, “collection” and “shot”. This paper is not the best place to give a detailed description of the ACNET Device and Event Model. A brief introduction can be found in [2].

“Collection” is a set of devices collected on specified events. Events for every device are stored in the SDA configuration database. There are several types of collections. The type is determined by a set of rules for different devices.

A shot contains certain types of collections and event-based rules for starting and stopping the processing of those collections. Some types of collections are started several times – for example collections associated with proton and pbar injections. The source of many of those events is the Sequencer [3]. The Sequencer is a final state machine that describes operations needed to perform different Tevatron tasks.

Data collected during the shot is stored in a relational database. In this database every shot and every collection has a unique number (index). In addition, every collection has a type and a name associated with it, for example collection type 6 has the name “Inject Pbars”. Collections in one particular shot with the same type are called “Cases”. If a collection is repeated several times then the “Case” may have “Sets” - several instances of the same collection. For example “ColliderShot” always has 36 sets in the case “Inject Protons” and 9 sets in the case “Inject Pbars”. Those shots, cases and sets are the main terms in “Shot Data Analysis”. They define the structure of the shot as can be seen in Figure 1. The sequence of cases describes what actually took place during the particular shot. Cases and sets provide a time frame for analysis. Devices collected in cases and sets serve as the main data source. To provide a complete picture, several shots of different types are combined. For example a complete ColliderShot always has corresponding PbarTransferShot and/or RecyclerShot referring to pbars originating from the Accumulator or Recycler respectively.

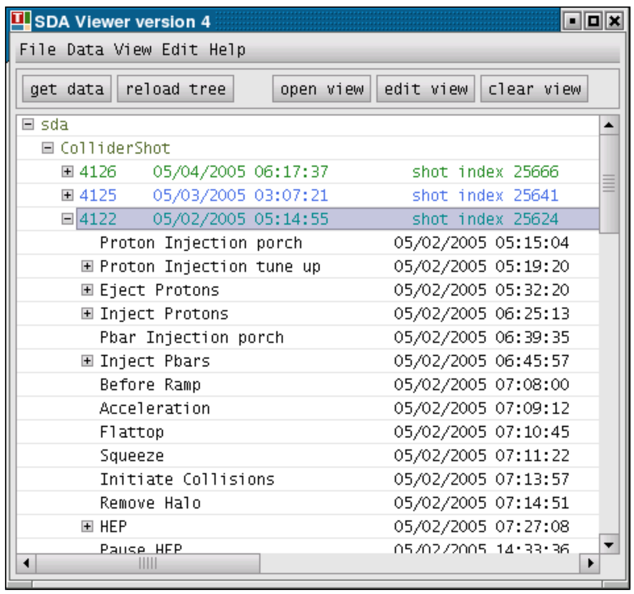

Figure 1: Shot structure in SDA Viewer.

Data Loggers

Another important data source for analysis is a group of Fermilab Data Loggers. Data Loggers store daily several Gb of pairs <time stamp, device value> on a distributed cluster of 70 machines. A good description of the Data Loggers can be found in [4]. Data Loggers are a good source of detailed information for analysis, especially for lifetimes and growth rates.

SDA Tools

There is a rich set of tools for working with “raw data” (from Sequenced Data Acquisition and Data Loggers).

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#tbolsh@fnal.gov

We will name just a few of them: SDA Edit (for editing the rules), SDA Viewer (for browsing of scalars stored in the database), SDA Plot Viewer (for browsing of blocks of time/value data in the Sequenced Data Acquisition database), SDA Reports (a Web-based tool for implementing simple expressions involving the scalars in the database), Vax D44 (for plotting of Data Logger data), Web D44 (for plotting and extracting Data Logger data), Array Data Logger Plotter (for plotting and extracting Data Logger data for array devices) etc. All of them can be found in Fermilab index pages [5]. JAS (Java Analysis Studio) plugins for obtaining SDA and Data Logger data were also developed.

The beam data analysis package is based on a "simplified" and convenient library called OSDA (Open SDA). This library also includes objects and methods for accessing Data Logger Data. It can work over HTTP (outside of the Accelerator Division firewall) or through a fast binary protocol (Java RMI). Requests for data are consolidated and partially cached to improve performance.

All the software for SDA and Data Loggers is written in Java using Object-Oriented design. In several distinct places "Functional Programming" (FP) approach is also used. The "Functors" Java library was designed for FP. The Functors package allows for writing self-documenting programs for computations, it helps in the consolidation of requests and simplifies complicated programming tasks.

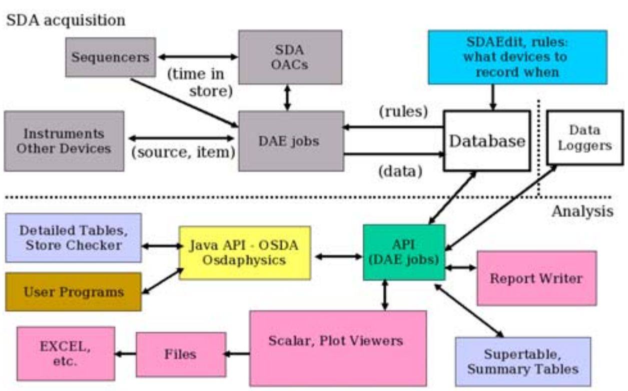

Figure 2: SDA data flow diagram.

The overall scheme of the SDA software can be found in Figure 2. As can be seen on the diagram, all low level tasks are performed by DAE (Data Acquisition Engine) by starting and stopping DAE Jobs [2]. The DAE Job is a basic Data Acquisition process that can be defined by four parameters: Source, Disposition, Item and Event. Source describes the data source, Disposition describes the Object where data have to be delivered, Item describes devices and device properties, and Event describes time and condition of the data collection. So, for example all Sequenced Data Acquisition DAE Jobs have "Accelerator" as Source and "SDA database" as Disposition. Items and Events are extracted from the rules. DAE Jobs, generated during analysis, have the "SDA database" as Source and the analysis program as Disposition. Data Logger DAE Jobs are specified in a similar way. The DAE Jobs architecture allows for writing a flexible, extendible and universal low-level API.

A cluster of Tomcat servlet engines is used for Web-based requests. Servlets are working as a bridge between DAE Jobs and HTTP-based APIs. Servlets and JSPs (Java Servlet Pages) provide the Web interface for final users. Several daemons monitor the state of the accelerator complex and compute the Supertable and Summary tables.

SUPERTABLE AND SUMMARY TABLES

The Supertable is the official document of the best available information for every shot. It is a systematic tabulation of intensities, efficiencies, transverse emittances and their growth rates, bunch lengths, and lifetimes. Measured instantaneous and integrated luminosities, proton and pbar losses, tunes, chromaticities, various comments about beam conditions and beam quality are also stored there. The Supertable includes as well several calculated quantities: hourglass factor, effective emittances, expected luminosity etc. The Supertable is calculated on a shot by shot basis and throughout the acceleration chain.

# 138 Tev p bunch length at 150, before helix opened (ns)	# 139 Tev p bunch length before ramp (ns)	# 140 Tev p bunch length at Remove Halo (ns)	# 141 p bunch growth (hours)	# 142 pbar bunch growth (hours)	# 143 time on helix (minutes)	# 144 p lifetime on helix (hours)	# 145 pbar lifetime at 150 (hours)	# 146 p lifetime, 1st 2 hours into store (hours)	# 147 pbar lifetime, 1st 2 hours into store (hours)
2.58	2.72	1.65	-22.39	-66.46	45.12	36.95	21.67	151.46	21.49
2.60	2.65	1.60	-24.01	-54.68	24.48	32.43	11.95	73.99	22.51
2.71	2.76	1.67	-29.86	-68.02	79.74	29.51	17.49	79.48	25.74
2.79	2.72	1.68	-22.19	-58.64	31.68	6.31	19.37	132.49	21.61
2.70	2.74	1.67	-23.24	-60.88	25.16	26.47	9.37	137.39	22.39
2.88	2.75	1.66	-20.64	-48.43	28.41	5.50	9.43	109.82	22.51

Figure 3: HTML format of the Supertable. Columns 138 to 147 are shown. The Column headers contain links to the descriptions of their content.

The computation of the Supertable requires algorithms which are not necessarily available at the Front-End because of limited capabilities and networking issues. In addition, offline computation is more flexible and can be performed later in case error or inconsistency was found in the algorithms. The Supertable allows us to study the evolution of accelerator parameters from shot to shot over a long period of time. Over the last three years new columns were added to the Supertable after every upgrade in the accelerator complex.

The Supertable is organized as one line per shot and it currently contains 224 columns. Intensities, efficiencies and emittances are reported separately for pbars originating from the Accumulator and from the Recycler. The Supertable is computed three times during the shot: in the beginning of the shot, three hours into the shot and in the end of the shot. This allows for tracking all quantities of interest as soon as they are available.

The Supertable is available in four formats: HTML table (see Figure 3), MS Excel worksheet, AIDA (Abstract Interfaces for Data Analysis) file, and CSV (Comma Separated ASCII text).

In order to make the Supertable information easily available to all interested parties, Summary tables, "Views" (excerpts from Supertable), and Detailed tables are provided. The Summary tables (the Recomputed Emittances and the Recomputed Intensity) provide concisely intensity, efficiency and emittance information throughout the acceleration chain separately for protons and pbars. The Detailed tables provide similar information for every bunch. Custom "Views" are subsets of Supertable columns (e.g. all data from Main Injector, or all the luminosities, or all the lifetimes, etc.)

The Recomputed Emittances and the Recomputed Intensities tables are self documenting. Every table for every shot is acompanied by an automatically generated description of calculations performed for every cell. The descriptions are saved together with the tables and are available for all the users. The Summary tables are automatically sent to a Web-based logbook.

The availability and quality of the information in these tables depends on the beam quality as well as the functioning of many components: instrumentation, Data Acquisition, database, software tools, etc. Therefore the tracing of possible problems involves collaboration from colleagues across various departments of the Accelerator Division.

JAVA ANALYSIS STUDIO.

Java Analysis Studio (JAS) is a general purpose, open-source data analysis tool with a number of useful features [6]. JAS was recently incorporated into SDA tools. SDA Viewer and Data Logger plugins were developed. The Supertable and Summary tables are now available in JAS native format (AIDA).

In addition, several sets of plots are generated using JAS libraries every day (see Figure 4). In those plots data for the last day/week/month are compared with the data of the "best month". Data Loggers serve as the main source of data for those plots. Right now 18 different types of plots are generated on a daily basis. The data used to build the plots is available in AIDA and Excel formats.

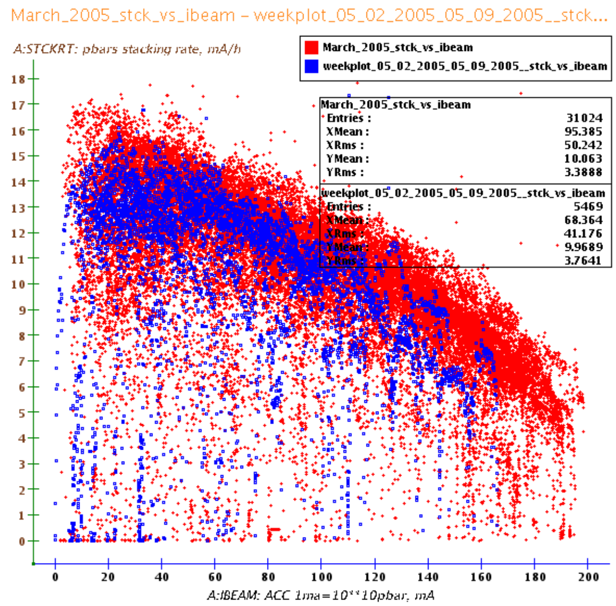

Figure 4: JAS Plot of Stacking Rate (A:STCKRT) vs. Stack size (A:IBEAM) in the Accumulator. The red points correspond to data collected during the entire month of March 2005. The blue points correspond to data collected during the first week of May 2005.

CONCLUSION.

A rich set of diagnostic tools was designed to support Fermilab Collider Run II. Those tools are implemented on several levels and include sophisticated data acquisition, low level data viewers, program API's, and analysis programs. Data acquisition and analysis are developed to look at every problem from several points of view. The Supertable and Summary tables provide a fast overview of current and past accelerator parameters. Such a hierarchical set of tools allows for fine tuning and troubleshooting of the machine and play a significant role in the overall accelerator performance.

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