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, U.S.A.

Data Acquisition.

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.

SDA is an acronym with dual meaning.

Originally it was introduced in the Controls department as **Sequenced Data Acquisition**. Sequenced Data Acquisition is **based on rules** and serves as the **main data source** for analysis. The significant terms in these rules are **event**, **device**, **collection** and **shot**. 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. The source of many of those events is the **Sequencer**. Data collected during the shot is stored in a relational database. Every collection has a type and 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. **Shots**, **Cases** and **Sets** are the main terms in SDA. They provide a **time frame** for analysis.

To provide a complete picture several shots of different types are combined. For example a complete ColliderShot always has a corresponding PbarTransferShot and/or RecyclerShot referring to pbars originating from the Accumulator or Recycler respectively.

Shot structure in SDA Viewer.

SDA Viewer version 4

File Data View Edit Help

get data | reload tree | open view | edit view | clear view | show Over (old)

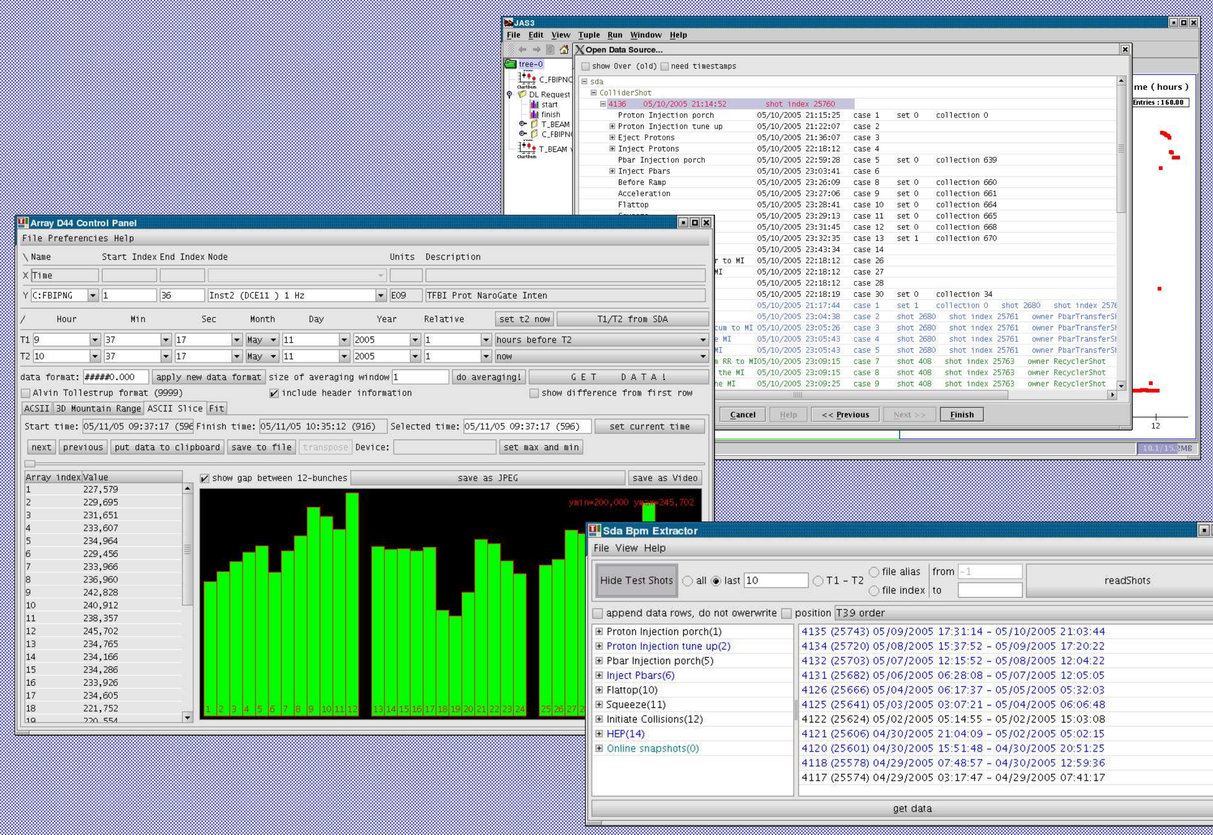
sda						
ColliderShot						
4135	05/09/2005 17:31:14	shot index 25743				
4134	05/08/2005 15:37:52	shot index 25720				
4132	05/07/2005 12:15:52	shot index 25703				
Proton Injection porch	05/07/2005 12:16:09	case 1	set 0	collection 0		
Proton Injection tune up	05/07/2005 12:25:43	case 2				
Eject Protons	05/07/2005 12:36:43	case 3				
Inject Protons	05/07/2005 13:25:12	case 4				
Pbar Injection porch	05/07/2005 13:54:27	case 5	set 0	collection 587		
Inject Pbars	05/07/2005 13:56:33	case 6				
Before Ramp	05/07/2005 14:18:56	case 8	set 0	collection 608		
Acceleration	05/07/2005 14:20:19	case 9	set 0	collection 609		
Flattop	05/07/2005 14:21:52	case 10	set 0	collection 612		
Squeeze	05/07/2005 14:22:56	case 11	set 0	collection 613		
Initiate Collisions	05/07/2005 14:25:39	case 12	set 0	collection 616		
Remove Halo	05/07/2005 14:26:29	case 13	set 1	collection 618		
HEP	05/07/2005 14:44:49	case 14				
Pause HEP	05/08/2005 12:02:28	case 15	set 0	collection 749		
Inject Protons: Booster to MI	05/07/2005 13:25:12	case 26				
Accelerate Protons in MI	05/07/2005 13:25:12	case 27				
Coalesce Protons	05/07/2005 13:25:12	case 28				
Abort	05/08/2005 12:03:17	case 29	set 1	collection 751		
Conditions	05/07/2005 13:33:07	case 30	set 0	collection 266		
Set up	05/07/2005 12:22:56	case 1	set 1	collection 0	shot 2667	shot index 25704
Unstack pbars	05/07/2005 13:57:59	case 2	shot 2667	shot index 25704	owner PbarTransferShot	
Transfer pbars from Accum to MI	05/07/2005 13:59:13	case 3	shot 2667	shot index 25704	owner PbarTransferShot	
Accelerate pbars in the MI	05/07/2005 13:59:30	case 4	shot 2667	shot index 25704	owner PbarTransferShot	
Coalesce Pbars in the MI	05/07/2005 13:59:30	case 5	shot 2667	shot index 25704	owner PbarTransferShot	
Pbar Transfer Shot from RR to MI	05/07/2005 14:03:02	case 7	shot 403	shot index 25706	owner RecyclerShot	
RR Accelerate Pbars in the MI	05/07/2005 14:03:02	case 8	shot 403	shot index 25706	owner RecyclerShot	
RR Coalesce Pbars in the MI	05/07/2005 14:03:12	case 9	shot 403	shot index 25706	owner RecyclerShot	
Set up	05/07/2005 12:56:41	case 10	set 0	collection 0	shot 403	shot index 25706
4131	05/06/2005 06:28:08	shot index 25682				
4126	05/04/2005 06:17:37	shot index 25666				
4125	05/03/2005 03:07:21	shot index 25641				

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. Data Loggers are a good source of detailed information for analysis, especially for **lifetimes** and **growth rates**.

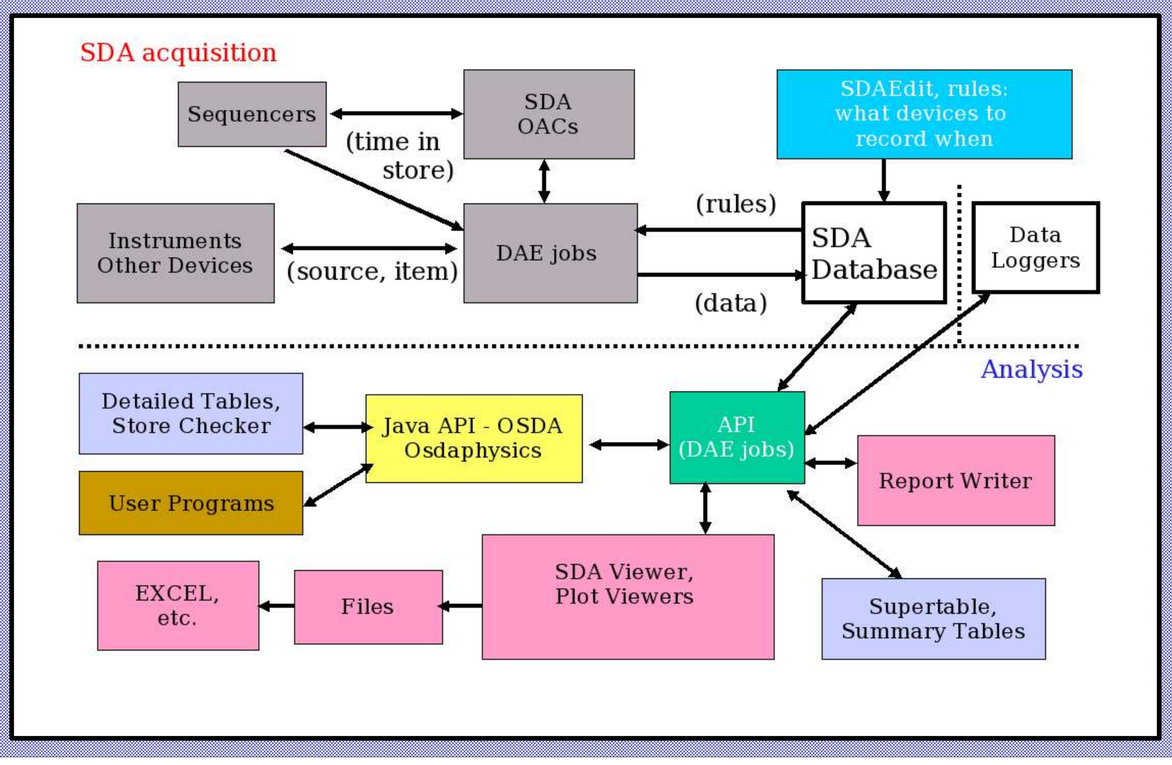
There is a rich set of tools for working with “raw data” (from Sequenced Data Acquisition and Data Loggers). We will name just a few of them:

SDA Edit (for editing the rules),
SDA Viewer (for browsing of scalars stored in the database),
Web D44 (for plotting and extracting Data Logger data),
Array Data Logger Plotter (for plotting and extracting Data Logger data for array devices)
SDA BPM Extractor (Beam Position Monitor readings), etc.

Java Analysis Studio (**JAS**) was recently incorporated into SDA tools. JAS SDA Viewer and Data Logger plugins were developed.



The overall diagram of SDA software.



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.

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Analysis.

SDA is an acronym with dual meaning.

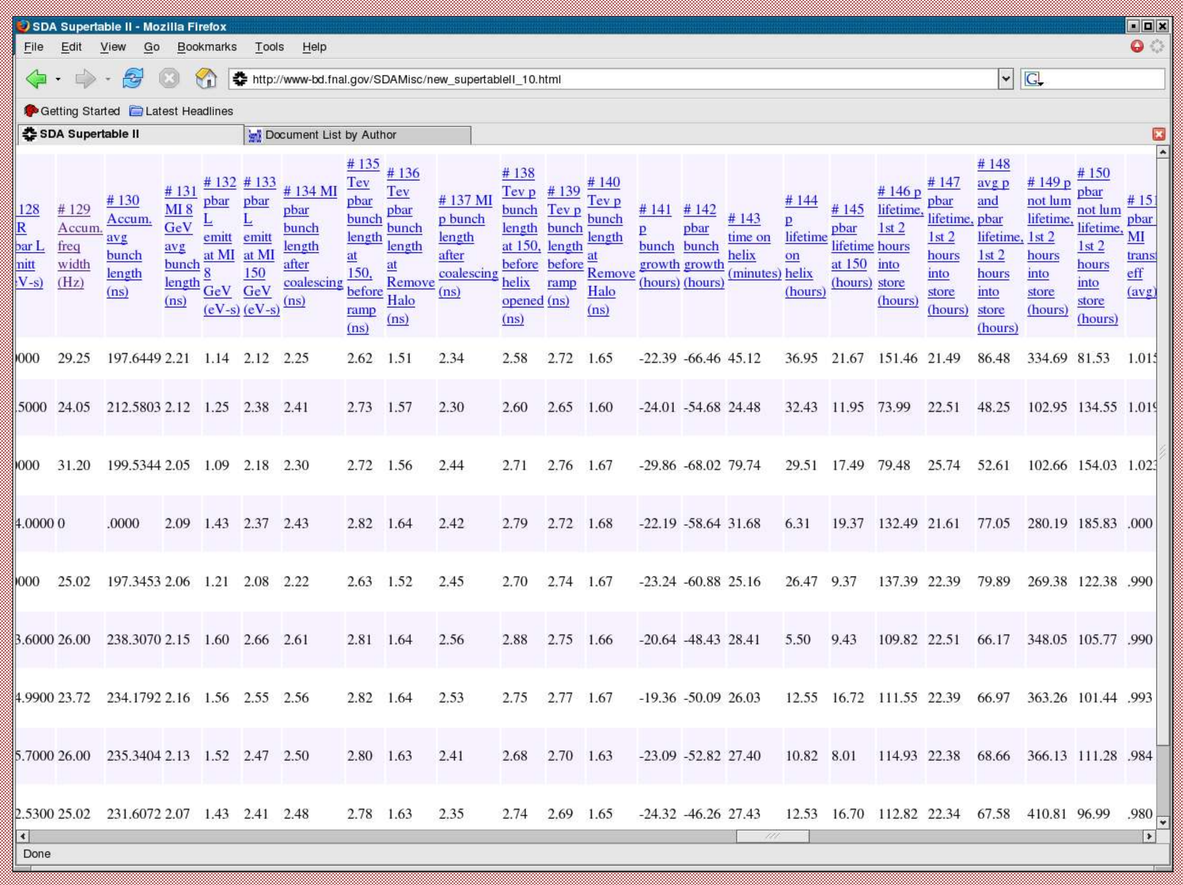
The Integration department uses it as **Shot Data Analysis** and this reading of the term became more popular. The data used in Shot Data Analysis comes from two sources: the **Sequenced Data Acquisition** and the **Data Loggers**. The **Supertable**, the **Summary** tables, the **Detailed** tables, automatically generated **JAS Plots** and numerous user analysis programs based on OSDA (Open SDA) and OSDA Physics packages or on Fermilab JAS plugins are Shot Data Analysis tools.

The Supertable.

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.

The Supertable allows us to study the evolution of accelerator parameters from shot to shot over a long period of time.

The availability and quality of the information in the Supertable depends on the beam quality as well as the functioning of many components: instrumentation, Data Acquisition, database, software tools, etc.



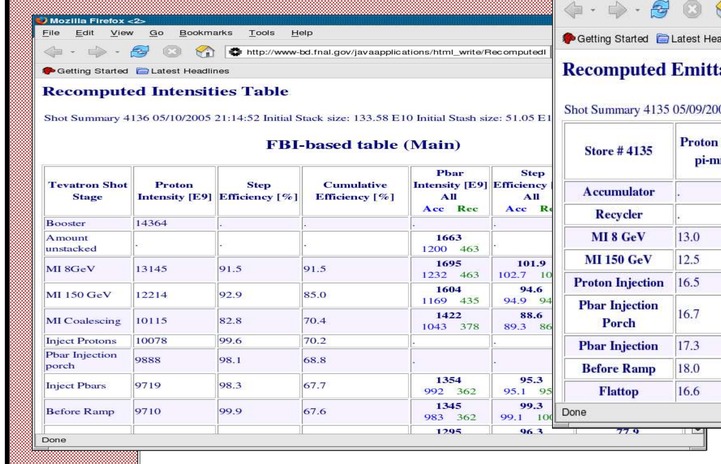
128 R bar L nitt V-s)	# 129 Accum. freq width (Hz)	# 130 Accum. avg bunch length (ns)	# 131 MI 8 GeV avg bunch length (ns)	# 132 pbar L emitt at MI 8 GeV (eV-s)	# 133 pbar L emitt at MI 150 GeV (eV-s)	# 134 MI pbar bunch length after coalescing (ns)	# 135 Tev pbar bunch length at 150, before ramp (ns)	# 136 Tev pbar bunch length at Remove Halo (ns)	# 137 MI p bunch length after coalescing (ns)	# 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)	# 148 avg p and pbar lifetime, 1st 2 hours into store (hours)	# 149 p not lum lifetime, 1st 2 hours into store (hours)	# 150 pbar not lum lifetime, 1st 2 hours into store (hours)	# 15 pbar MI trans eff (avg)
000	29.25	197.6449	2.21	1.14	2.12	2.25	2.62	1.51	2.34	2.58	2.72	1.65	-22.39	-66.46	45.12	36.95	21.67	151.46	21.49	86.48	334.69	81.53	1.015
5000	24.05	212.5803	2.12	1.25	2.38	2.41	2.73	1.57	2.30	2.60	2.65	1.60	-24.01	-54.68	24.48	32.43	11.95	73.99	22.51	48.25	102.95	134.55	1.019
000	31.20	199.5344	2.05	1.09	2.18	2.30	2.72	1.56	2.44	2.71	2.76	1.67	-29.86	-68.02	79.74	29.51	17.49	79.48	25.74	52.61	102.66	154.03	1.023
4.0000	0	.0000	2.09	1.43	2.37	2.43	2.82	1.64	2.42	2.79	2.72	1.68	-22.19	-58.64	31.68	6.31	19.37	132.49	21.61	77.05	280.19	185.83	.000
000	25.02	197.3453	2.06	1.21	2.08	2.22	2.63	1.52	2.45	2.70	2.74	1.67	-23.24	-60.88	25.16	26.47	9.37	137.39	22.39	79.89	269.38	122.38	.990
3.6000	26.00	238.3070	2.15	1.60	2.66	2.61	2.81	1.64	2.56	2.88	2.75	1.66	-20.64	-48.43	28.41	5.50	9.43	109.82	22.51	66.17	348.05	105.77	.990
4.9900	23.72	234.1792	2.16	1.56	2.55	2.56	2.82	1.64	2.53	2.75	2.77	1.67	-19.36	-50.09	26.03	12.55	16.72	111.55	22.39	66.97	363.26	101.44	.993
5.7000	26.00	235.3404	2.13	1.52	2.47	2.50	2.80	1.63	2.41	2.68	2.70	1.63	-23.09	-52.82	27.40	10.82	8.01	114.93	22.38	68.66	366.13	111.28	.984
2.5300	25.02	231.6072	2.07	1.43	2.41	2.48	2.78	1.63	2.35	2.74	2.69	1.65	-24.32	-46.26	27.43	12.53	16.70	112.82	22.34	67.58	410.81	96.99	.980

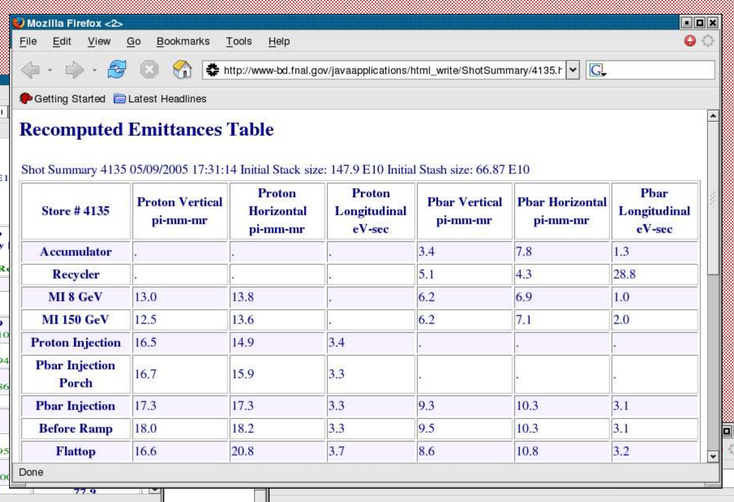
The Supertable is organized as **one line per shot** and it currently contains **224 columns**. Intensities, efficiencies and emittances are reported separately for pbars originating from the Accumulator and from the Recycler. The Supertable is computed three times during the shot: in the beginning of 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.

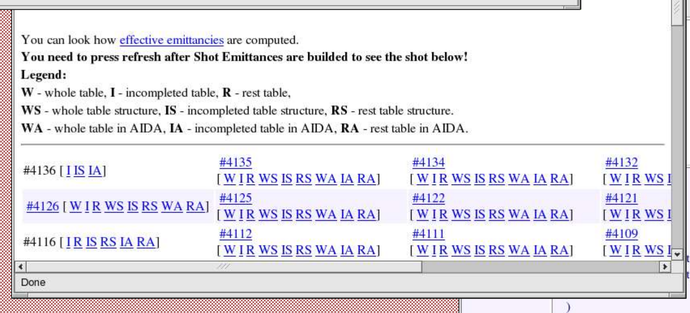
The Supertable is available in four formats: **HTML** table, **MS Excel** worksheet, **AIDA** (Abstract Interfaces for Data Analysis) file, and **CSV** (Comma Separated ASCII text). In the HTML format the column headers contain links to the descriptions of their content.

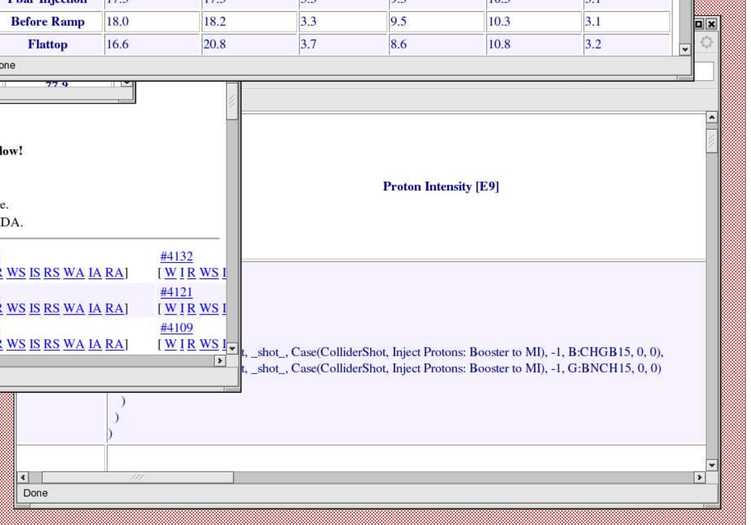
In order to make the Supertable information easily available to all interested parties, **Summary** tables, Views (excerpts from Supertable), and Detailed tables are provided. The Summary tables (the **Recomputed Emittances** and the **Recomputed Intensity**) provide concisely intensity, efficiency and emittance information throughout the acceleration chain separately for protons and pbars.

The 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 Summary tables are automatically sent to a **Web-based logbook**.



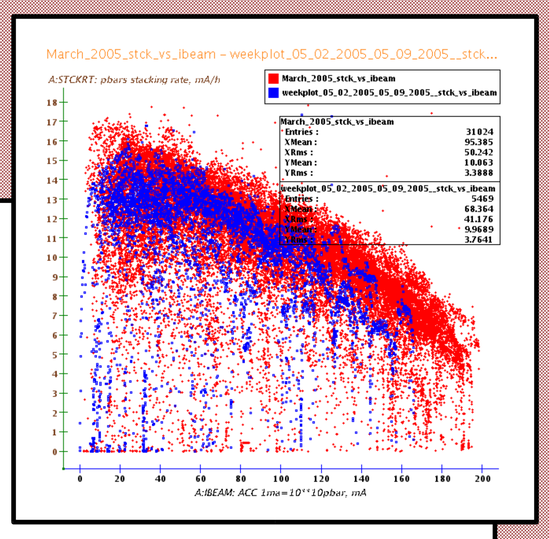






JAS Plots.

In addition, several sets of plots are generated using JAS libraries every day. 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. The data used to build the plots is available in AIDA and Excel formats.



On the picture:
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.