EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

VC/afm CERN/PS/89-57 (AR)

ASPECTS OF AUTOMATION AND APPLICATIONS IN THE CERN ANTIPROTON SOURCE

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Abstract

The Antiproton source is composed of 2 concentric accelerators and a production target zone. The Collector is a large-acceptance ring which acts as a buffer between the target and the Accumulator ring where the antiprotons are stored before being extracted. From the early days of the Accumulator (AA), various automatic procedures and tools had been introduced to assist in machine studies and diagnostics and to facilitate day-to-day operations for antiproton production and transfers to the CERN Collider. With the upgrade of the source in 1987 by the addition of the Collector ring (AC), the complexity of the source has at least doubled. New facilities have been added and the existing ones improved.

This paper exposes some of the applications, techniques and tools used for beam diagnostics, setting-up and routine operation of the antiproton source complex at CERN.

Paper presented at the International Conference on
Accelerator and Large Experimental Physics Control Systems
Vancouver, British Columbia, Canada
October 30 - November 3, 1989

Geneva, Switzerland
December 1989

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1. Introduction

The Antiproton source, its upgrade and the performance of the CERN Collider has been amply described elsewhere [1,2]. Considerable progress has been made in 1989 towards achieving a performance close to the design specifications for the upgrade [3]. While the complexity of operations has increased substantially, with the addition of the AC operating in conjunction with the AA, the same operating crew and interaction means have been used to carry out the routine operations. Relying mainly on experience gained from the operation of the single ring AA over the previous 7 years, several aspects have been streamlined and highly-automated methods and procedures have been introduced. Figure 1 shows the schematic layout of the two rings and the production target area. The controls system [4] had to be extended for the new source complex and this is described elsewhere [5].

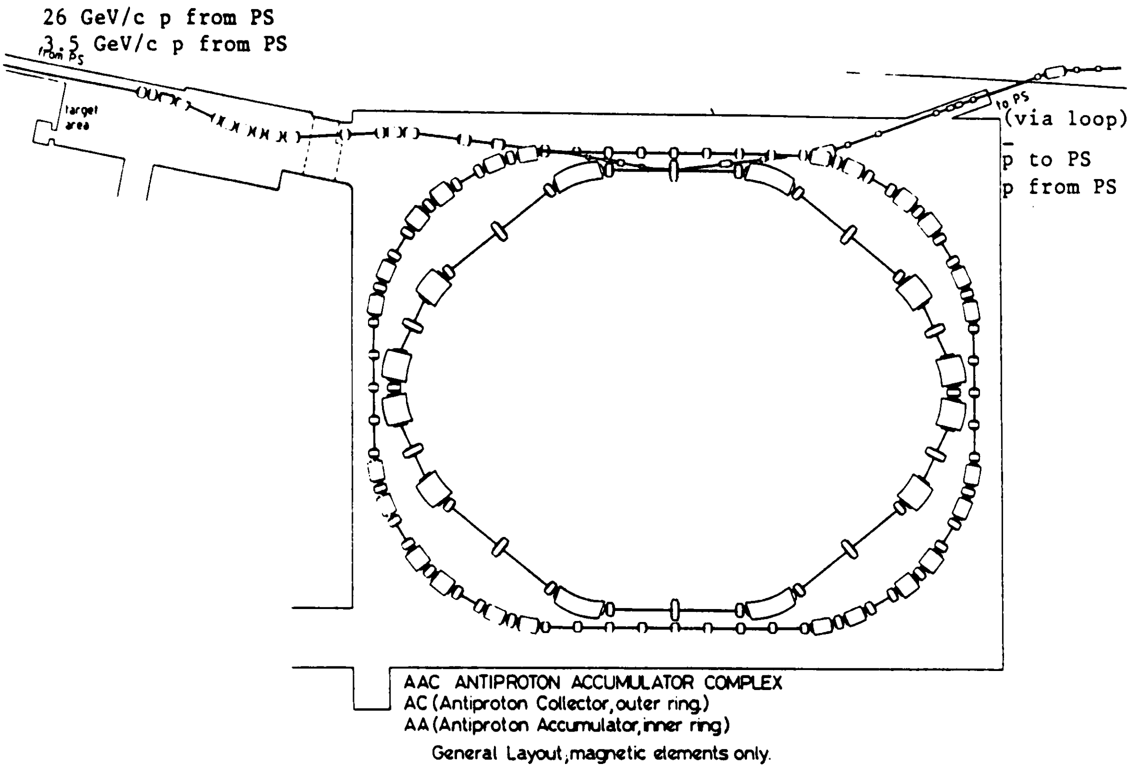


Fig. 1. Antiproton Accumulator Complex

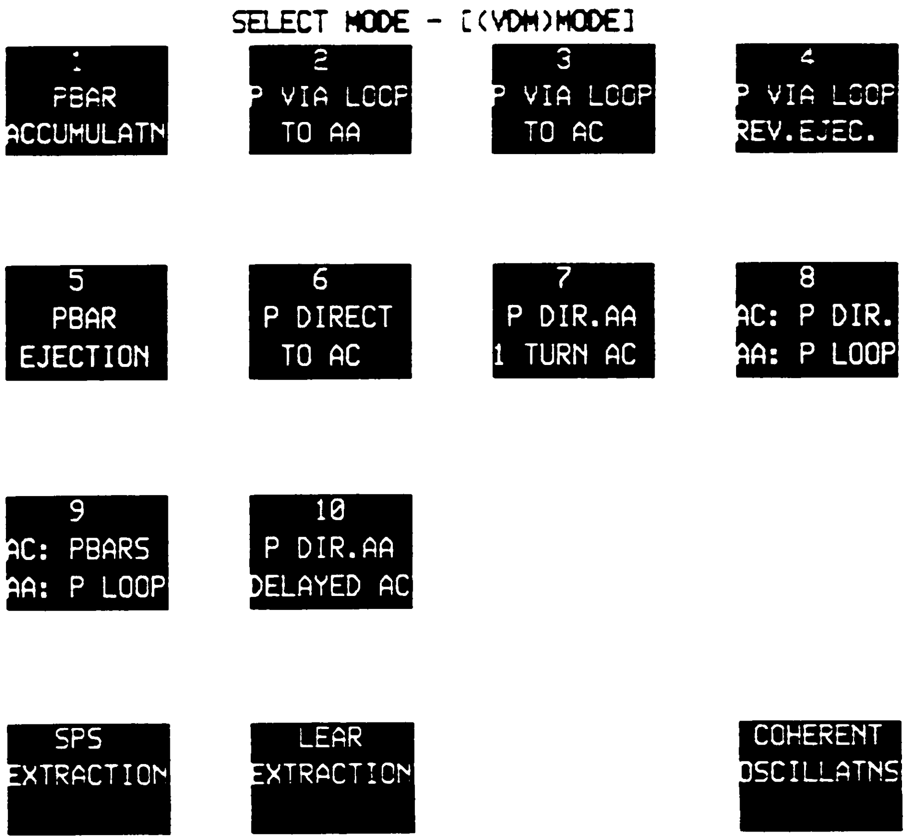


Fig. 2. Operational Modes in AAC

2. General Services and Basic Applications Programs

This class of applications software groups virtually all the basic elements necessary to control a particle accelerator remotely. While these are necessary and vital pre-requisites for the functioning of a complex of accelerators like the antiproton source, they only provide a base-level on which sophisticated applications may be built. They include the control of the most essential measurement devices (beam transformers, Schottky pickups, scintillation screens, and position pickups), magnet power supplies, vacuum system, radio-frequency equipment, timing and kicker magnet systems, stochastic cooling systems which include hundreds of relay switches and power amplifiers, and services such as the logging of data, statistics, alarms and so forth. The AA already had most of these applications functioning prior to the AC and the main task was to streamline and extend these and to use automation wherever possible, by means of higher-level applications software. It is only the latter which is considered below.

3. Operational Modes

The AA & AC (AAC) complex of 2 rings can exchange beam with the Proton Synchrotron (PS) from two different directions depending on the functionality required; the PS can supply test beams or beam for antiproton production; this leads to the AAC running under four almost mutually exclusive modes. Different combinations of these lead to as many as ten operational Modes as shown in the selection touch-panel in Fig. 2. Six of these are for proton test beams at 3.5 GeV/c which can feed the AAC directly through the target area or through the transfer line (via 'loop') from which the antiprotons are normally extracted. The AAC, unlike PS, does not operate in a pulse-to-pulse modulation mode and only one type of beam is exchanged per PS machine cycle. Only the necessary minimum timing information is exchanged with the PS and local operations which do not rely on beam exchange with the PS are performed asynchronously, leading to a fairly decoupled timing operation [6].

The automatic Mode selection chooses a series of timing files which are sent to hardware preset timers which, together with hardwired request handshakes, fore-warnings, fast timings and PS program line sequences, lead to the exchange of beam. As well as timings, the Mode selection also carries out the necessary checks and operations on power supplies, kicker magnets, magnet movements, rf and stochastic cooling systems.

4. Operations for Antiproton Production and Transfers

The production mode has its high level stacking statistics and performance verification programs which monitor antiproton progress from production target through the AC, the transfer line and into the AA, upto the stack core. However, the rf operations in both the rings are automatic and are triggered independently through the function generators loaded [7] with appropriate files by the Mode selection. This provides a fair degree of autonomous operation with essentially one beam-request timing controlling the whole production chain.

The antiproton transfer operations are more complex, with several requirements, constraints and client-machine needs [8]. The transfer process is entirely automated with the options shown in Fig. 3; the necessary measurement of Schottky scans and detailed manipulations are described in Ref. [9]. Prior to the transfers, the betatron tunes of the core of the stack and transverse emittances may be observed routinely as shown in Fig. 4.

5. Machine Experiment and Setting-up Modes with test beams

After machine shutdowns, or for experimental purposes, the AAC has to be adjusted and set-up using test proton beams. It is only in these modes that diagnostic equipment, such as position pickups work and closed orbits can be verified. A large degree of automation has helped enormously for all routine measurements and setting-up for studies or for production. The production mode is switched to only after all the correct setting-up work is terminated. The automated programs use combinations of beam instrumentation such as position and Schottky pickups, transverse beam scrapers, high and low sample-rate digitizers and beam blow-up by random noise together with several of the base-level application programs for on/off control of rf equipment, kicker magnets, timings and magnet current settings.

Figure 5 illustrates the displayed result from the automatic adjustment program which completely sets up the AA ring using test proton beams in a few minutes, this time being mainly governed by PS test beam cycles. The program requests the beam, measures orbits at the nominal central orbit and tunes at the stack orbit (after rf capture and displacement) and adjusts the trim supplies, central field and quadrupole strengths until standard vertical and horizontal tunes are obtained and the standard trim value arrived at, as defined in the closed-orbit program with correct

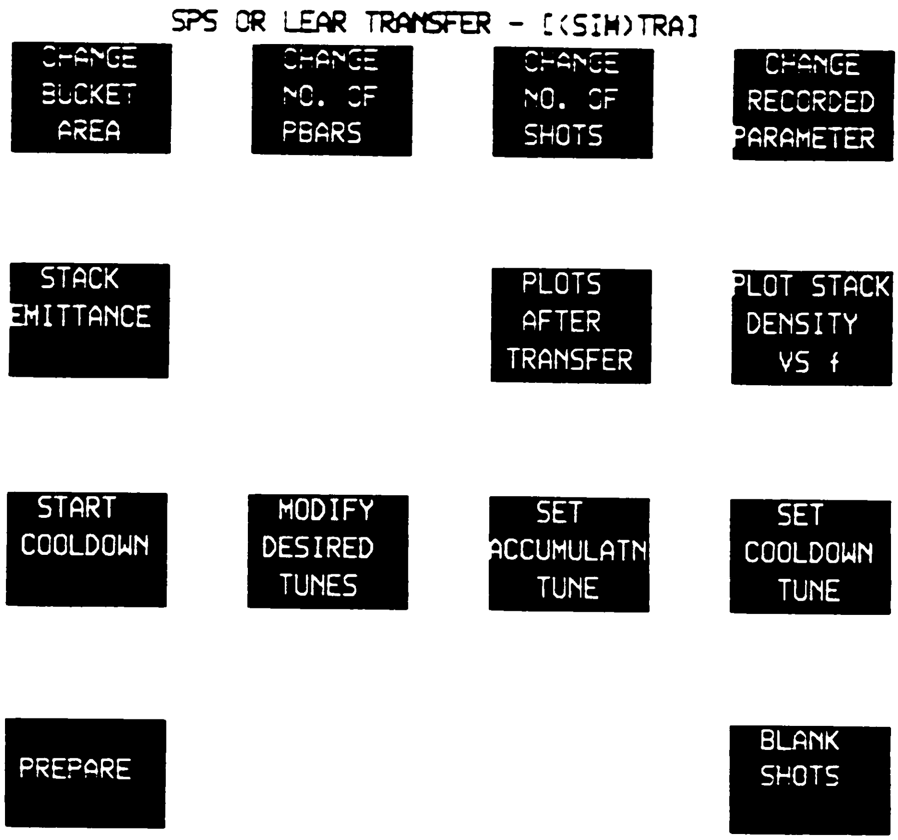


Fig. 3. Choices for Antiproton Transfers

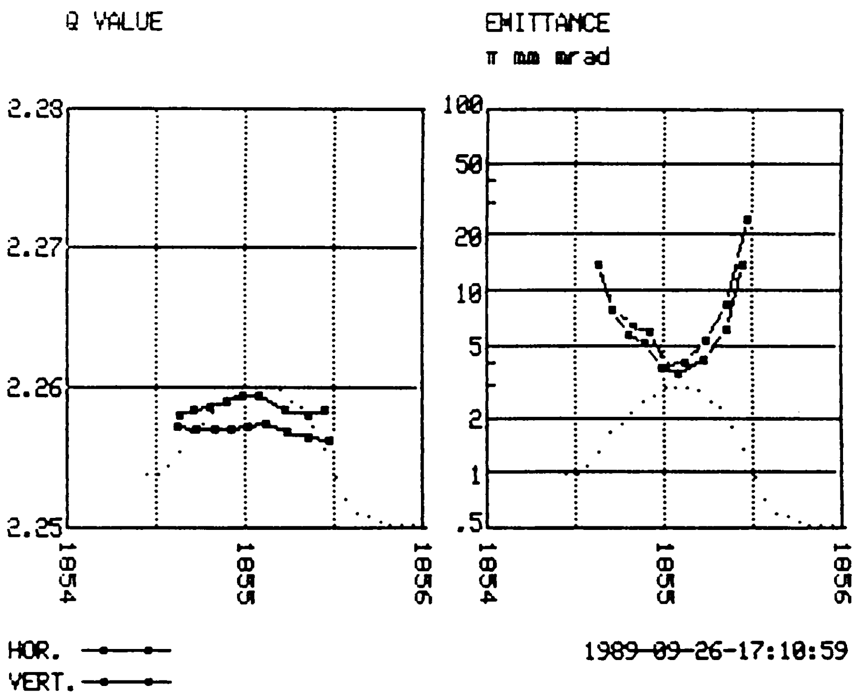


Fig. 4. Stack core Tunes and Emittances

AA ADJUSTMENT 1989-08-25-22:27

	REQUIRED	MEASURED
QH 1855.09	2.2555	2.2553
QV kHz	2.2598	2.2598
TRIM	0	0 mm
DP/P	0	0 E-3
COH.OSC. H	0	.4 mm
V	0	0 mm
COS COMP.L	0	0 deg

Coherent oscillations are adjusted with cooldown tunes. Accumulation tunes restored now.

RESULTING VALUES		SAVED IN
BENDING	1944.73 A	REFERENCE + FILE
TRIM	8.73 A	
QD	1058.59 A	
QF	1464.62 A	
SEPTUM	3878.39 A	REFERENCE + FILE
DVT8022	-1.46 A	
BTI8002	410.53 A	
EJ.KICKER	59.52 kV	
SYNC PH.	66.2 deg	FILE
+ INJ.	1845.83kHz	
INJ.EFFICIENCY	85 %	

The tunes have been adjusted to accumulation values on the stack orbit. These values are saved.

Fig. 5. Results from the Automatic Setting-up Program for AA

PROGRAMS FOR ME AND SETTING-UP - [SETUP-AA]

MEASURE Q	CLOSED ORBIT	INJECT AND DEPOSIT BEAM	SCRAPERS
ADJUST AA PARAMETERS	FIND VERTICAL OBSTRUCTNS		SEM-GRIDS
MEASURE ACCEPTANCE	SURVIVAL VS FREQUENCY	SURVIVAL VS TRIM	

Fig. 6. Choices for Machine Experiment and Setting-up Programs

central field. Using the fast and slow digitizers [10], the coherent injection oscillations are measured and then reduced both transversely and longitudinally. The energy matching between the PS and AA as given by the frequency at injection is also measured and stored for later use in transfer programs.

Figure 6 illustrates the choices available for some of the measurement programs for the AA ring. The AC ring has a similar set of programs for the relevant measurements and Modes. Figures 7 & 8 illustrate some typical results from the closed-orbit measurements and complete tune measurements across the aperture for the AA; the detailed techniques for measurements using Schottky signals are given in Ref. [11]. Figure 9 shows the result of another automated procedure to measure the transverse acceptance versus momentum for the AC ring. For each point of the plot, and for each plane, a complicated set of operations taking up to 3 minutes is carried out involving (a) injection of fresh test beam of sufficient quantity (b) transverse blow-up in that plane to ensure that the beam envelope touches the aperture, meticulous scraper displacement until the beam edge is found and (c) subsequent computations to obtain the transverse acceptance [12].

Finally, automatic obstruction search programs have been implemented using controlled radial bumps in the AA and motorised displacement jacks for quadrupoles.

6. <u>Conclusions</u>

Of all the CERN accelerators, the AAC complex is one of the most highly automated machines, especially for all the beam measurement, machine experiment and setting-up procedures necessary for this complex. One of the main reasons for being able to achieve and maintain this high degree of automation is the restricted number of intermediate levels (hardware or software) between the application programs and the equipment. The AAC touch-terminals [13] operate directly from the front-end computer connected to the CAMAC serial highway, which avoids any communications overheads or problems. Similarly, CAMAC modules access the hardware directly without any front-end microprocessors sitting in the same crate, which would otherwise introduce another intermediate level. Even the sophisticated GPIB devices like the spectrum analysers are connected directly, via a simple GPIB-CAMAC interface, thus avoiding the arbitration problems or complications of an intelligent module but, at the expense of an elaborate software equipment module.

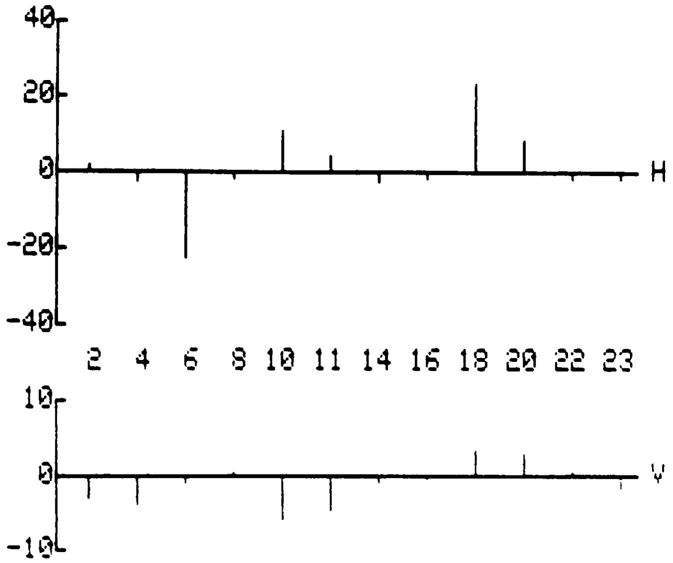
1989-09-23-12:37:17

	DP/P	FREQ.
FROM FREQ.MEAS.	.04E-3	1850.36
FROM PU AVERAGE	.15E-3	1850.34

TRIM, mm	
DESIRED	0
MEASURED	.1

Idc	1.2E10	
Ib	0	E10

P-U	H	V
BLG02	1.5	-3.0
QFW04	-3.0	-3.8
QFW06	-22.4	-1.1
QFW08	-1.9	.2
QFW10	10.6	-6.1
BLG11	4.0	-4.8
BLG14	-2.6	-1.0
QFW16	-1.8	-.4
QFW18	23.3	3.1
QFW20	8.4	2.6
QFW22	-2.2	.3
BLG23	-2.1	-1.9



LAST CALIB. 1989-08-24

Fig. 7. Results from the AA Closed Orbit Measurement

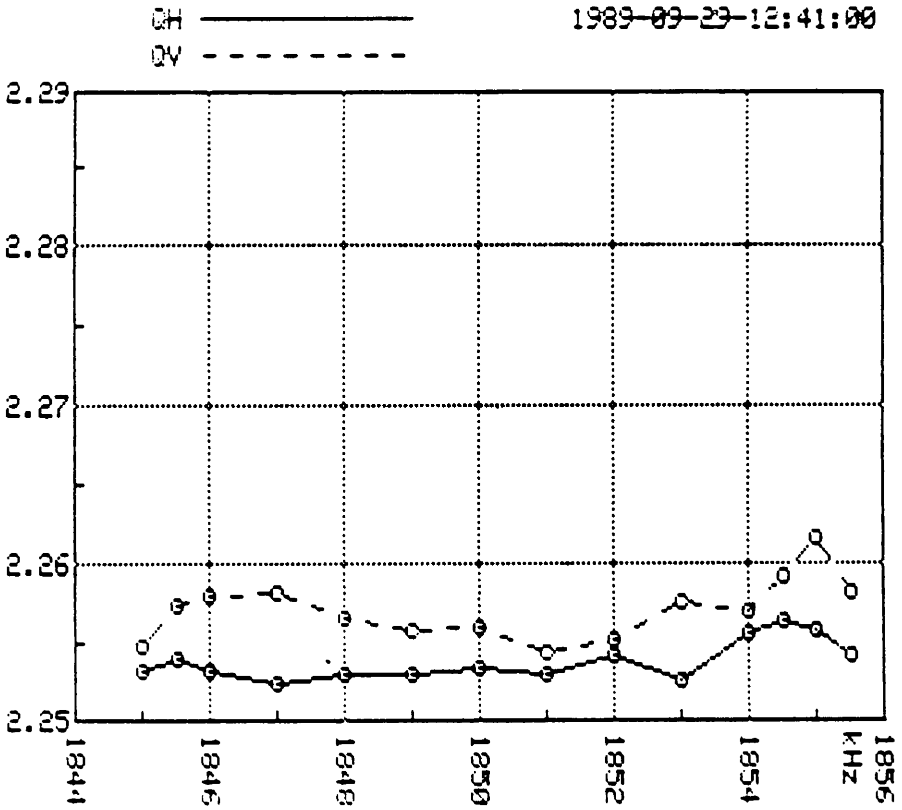
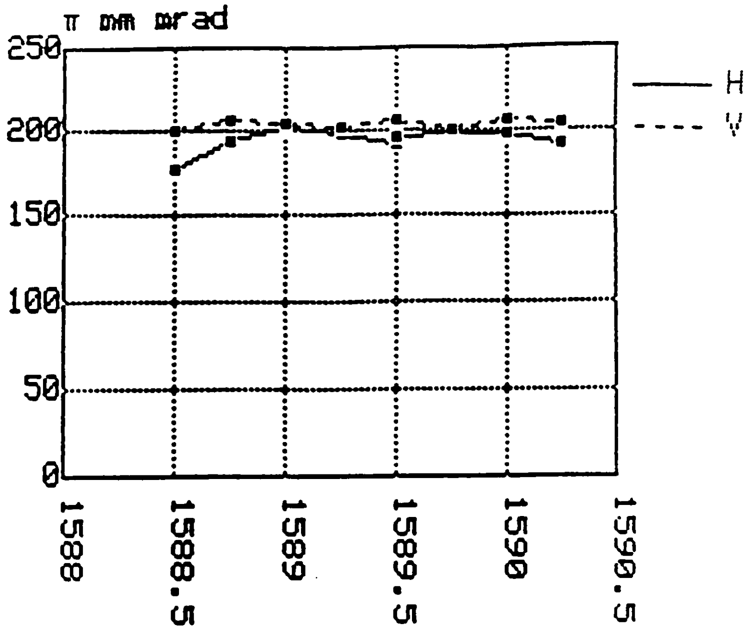


Fig. 8. Tunes Versus Momentum in AA Ring

AC ACCEPTANCE vs FREQUENCY 1989-08-25-23:43:

f_0 kHz	A_h/π mm mrad	A_v/π mm mrad
1588.5	177	199
1588.75	194	205
1589	201	203
1589.25	198	202
1589.5	191	205
1589.75	198	200
1590	197	206
1590.25	191	204
1589.5	195	



Acknowledgements

The high-level applications described here would not have been possible without the active support of many beam instrumentation experts and the necessary low-level hardware and software support provided by the Controls group. Particular mention should be made of Remy Dube and Michel Martini for all their efforts over the years in providing many sophisticated equipment software modules.

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