DATA REQUIREMENTS AND HANDSHAKE FOR THE CERN ANTIPROTON TRANSFER OPERATIONS FROM THE AA AND PS TO CLIENT MACHINES

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Summary

The CERN Antiproton Accumulator(AA) fulfils its role as a p̄ source for all the diverse needs at CERN ranging from a few 10^9 p̄'s in a single bunch for the Low Energy Antiproton Ring(LEAR) every hour or so upto 10^{11} p̄'s in 3 bunches for the Super Proton Synchrotron(SPS) Collider operations every 24 hours. The geographically dispersed accelerators involve large distances and proper synchronisation is mandatory for successful transfer operations. While every transfer operation needs preparatory work on all the machines involved in the chain with and without verbal communication in-between operators and control centres, an essential element has been the data exchange over the computer network linking the various processors in the PS and SPS Collider complex. This paper attempts to show some of the specialised data requirements which arose for the p̄ transfer operations and the essential software linking of various processes in different computers leading to a complete transfer operation from the AA, via the transfer lines and PS, to the SPS Collider or LEAR. For the Collider runs, the pre- and post-countdown data synchronisation and interchange involves upto a dozen computers in the PS and SPS computer networks.

Antiproton Transfer Operations

p̄'s being very scarce, the process of transferring them to client machines is very delicate and the reliability of all the accelerators and transfer lines involved is of prime importance.

In the AA, once the stacking is stopped and the transverse emittances are reasonably small, the operator chooses the demanded intensity and longitudinal emittance required by the client machine. This is followed by an automatic sequence which measures the Schottky stack spectrum, carries out the necessary calculations and programs the r.f. system accordingly. The AA is then ready and awaits a PS ready timing trigger which puts the r.f. as well as the extraction system in the AA into action. In the PS, the 3.5 Gev/c bunches are injected counter-clockwise and accelerated or decelerated depending on the SPS or LEAR being the client and appropriate r.f., injection and extraction systems and lines activated. In all cases, it is the client machine which commands the ultimate timing trigger which permits a transfer.

The transfer operation is very intricate and can be time-consuming; for example, the initial fills at the beginning of a Collider run, the setting-up could take several hours while the SPS is adjusted using bunches of protons at 26 GeV/c prior to p̄ injection. Even before entering the crucial countdown phase for the transfer of three (in future, six) consecutive dense shots of a few 10^{10} p̄'s each, the whole sequence of operations in every machine in the chain is tested by a pilot pulse of antiprotons. The process is more reminiscent of a space program launch than a usual accelerator operation.

The transfer procedure is time sequential in that following a verbal communication of the desired number of p̄'s and shots between all three control rooms concerned, the AA prepares accordingly and obtains an estimation from the Schottky beam spectrum of the expected number of p̄'s per shot. In the PS, the necessary checks and procedures are carried out in parallel with the AA initial preparation. Finally, the AA Go-ahead to the Program-Line-Sequencer(PLS)(see below) is followed in quick succession by PS last verifications prior to the PS Go-ahead via a p̄-ready condition in the PLS. It is then upto the SPS or LEAR to take the shot(s) at their will.

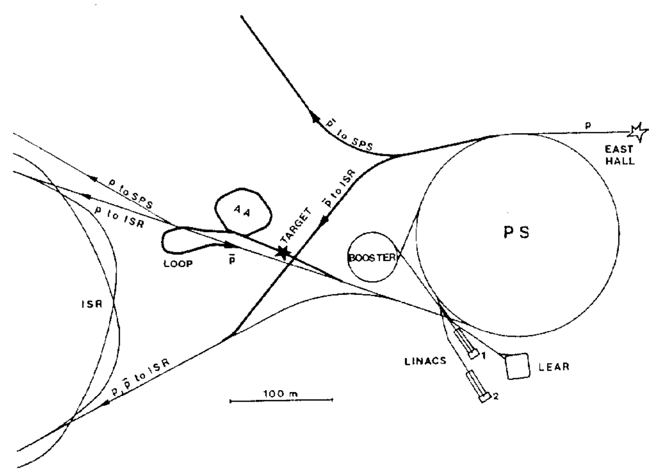

Fig. 1

The PS Complex and Controls environment

The PS Complex of accelerators and storage rings is shown in Fig.1 and full details of the functionality of the complex as a p̄-source are found elsewhere[1]. The Controls computer network consists of a hierarchical structure[2](fig.2) with each process controlled by its own computer and CAMAC Serial Highways dedicated to the particular process. A process in this context means a complete accelerator like the PS Booster or the AA Ring. While there is a very weak coupling between the so called processes, there is an elaborate software controlled structure linked with an equally complex timing system which enables the pulsed operation of the PS Complex. The PLS[3] thus ensures that all parameters which vary according to the beam transactions(send /receive beams) involved and the beam characteristics (intensity, bunch length, etc) do so correctly and at the right time.

The operator interface to the control processes is via several generalised consoles in the control room, each capable of handling any process in the Complex. Each console is run by a dedicated processor connected to the network.

The computers in the PS Complex communicate with each other over high speed serial links through a packet-switching, dedicated processor known as the message handling computer which is connected to another such processor functioning similarly for the SPS network.

General p̄ Transfer Philosophy

Since the first transfer operations in late 1981, the philosophy has been to keep the essential procedures in each accelerator in the chain as independent as possible. This has had advantages in many ways; it has also ensured that individual machines could be set up for transfers without the necessity of the whole chain being operational. It was also felt unreasonable to expect the p̄ source process(AA) to

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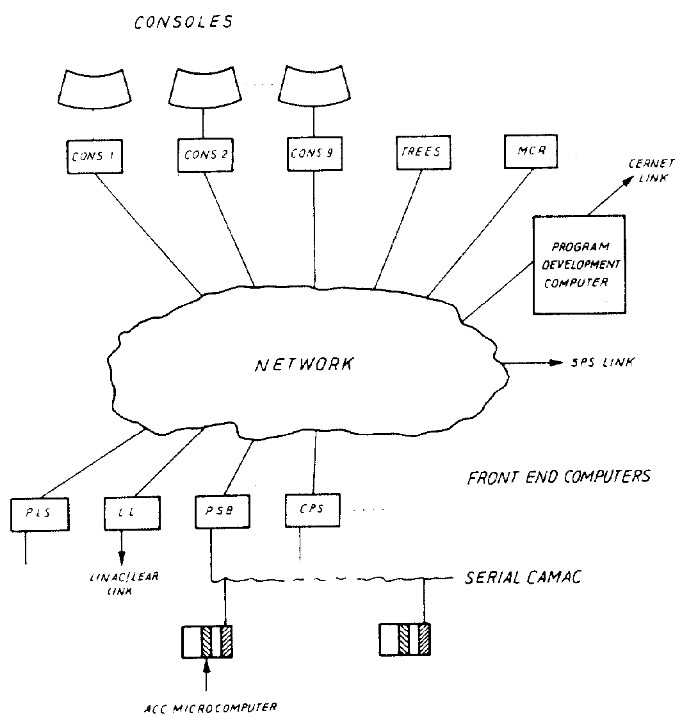

Fig.2 Computer Topology of PS Control System

control the complete sequence of events upto the SPS Collider level, which would have meant a very strong coupling of hardware and software over several computers and communication reliability would have come into play. In any case, the SPS Collider operation is complex enough to necessitate a multi-task, multi-processor control structure[4] running in the SPS network of computers.

In addition, while there is little distinction in software procedures in the AA to distinguish between a SPS or LEAR transfer, the pivotal machine PS plays completely different roles for these two cases. For all these and similar reasons, it was logical to permit only a weak software coupling between different procedures in different accelerators with any necessary linking software running only in the PS Main Control Room console computers so that not only the SPS/LEAR transfer distinctions be made but also the data handshake requirements be satsfied.

The general transfer philosophy from the PS complex therefore follows the schematic shown in Fig.3.

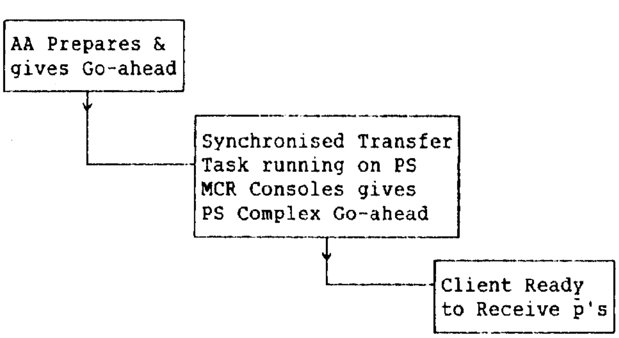

Fig. 3

Data Needs and Provision

Preparation in the AA: The AA Go-ahead for transfer is given together with (i) the "Prepared" number of $\bar{p}$'s and (ii) the number of $\bar{p}$'s expected in each of the single or triple shots programmed in the automatic transfer procedure. After the transfer takes place, the above values together with actual stack depletion values and ejection values are stored. The transverse emittances measured prior to the transfer are also stored.

Data Requirements in the SPS: The SPS sequence is initiated only after the AA Go-ahead and among other things, it may verify the programmed number of $\bar{p}$'s directly from the AA computer. In addition, the number of $\bar{p}$'s expected in each of the shots is available and specialised instrumentaion gain settings programmed automatically by the Sequencer.

After the transfer has taken place, the SPS also obtains all the transformer values in the whole chain including stack depletion. These values (24 for a triple shot transfer) are obtained in a single block created by the PS Transfer Task running on PS-MCR consoles.

Data Requirements in the PS & Transfer Lines: For dedicated instrumentation which measures the 4ns $\bar{p}$ bunch in the PS, it is necessary to program the intensity dependent gain automatically. Secondly, the beam transfer lines between the AA & PS and between the PS & SPS have beam position pick-ups and fast beam current transformers which also need to be programmed according to the expected intensity of the $\bar{p}$'s. Lastly, the PS radio-frequency gymnastics and bunch-matching to the SPS r.f. has control and measurement which both require the automatically programmed expected intensities.

The Antiproton Transfer Task in the PS

All the above needs in the PS and SPS and their time-critical application meant that a single task, not prone to any possible human error in control or instrumentation setting was necessary. The function of the Pbar-Kernel task which can run on any of the PS control room consoles is the following:

(The angle bracket<name> = computer involved)

(i) Verification of the programmed PLS conditions including the number of consecutive shots expected. <PLS>

(ii) Provision of expected number of $\bar{p}$'s per shot pre-countdown and all the transformer values in the chain as well as the Collider performance figures after the transfer. <AA>,<TT>,<CPS>,<SPS Network of Computers>

(iii) Control settings for pick-ups, transformers and measurement timings. <TT>,<CPS>

(iv) Control settings for r.f. Instrumentation and closed loop control. <CPS>

(v) Computer controlled Transfer Go-ahead or Abort. <PLS>

(vi) Synchronisation with appropriate PLS line and timing event within a cycle to acquire all beam current transformer values for multiple, consecutive shots, treatment and display. Typical displays are illustrated in Figs. 4 & 5. <PS-CONSOLE>

(vii) Storage of appropriate transfer values for replay or acquisition by client machines. <AA>

Remaining STK(e07): 21623 at 1984-11-17-16:02

PBAR TRANSFER AA-PS-SPS\LEAR TRANSFER NO: 1291

	1	2	3
AA STACK Loss(e07)	2812	2850	2755
AA Ejctn TFA2513	2730	2760	2670
TTL2 Loop Trnsfrmr	2636	2657	2571
TT2 before PS Inj	2534	2549	2459
PS Intrnl at C440	2443	2443	2394
PS Intrnl at C590	2443	2443	2394
PS Intrnl at C1190	2492	2443	2443
Ej58 TRA44 to SPS	2381	2415	2320
SPS TT70 Acquisitn	2472	2523	2441
SPS Injected(e07)	2228	2254	2165
SPS Stored	1879	1925	1846
TTL2 Loop/AA Loss	93%	93%	93%
EJ58 /TTL2	90%	90%	90%
EJ58 /AA Loss	84%	84%	84%
SPS Store/AA Loss	66%	67%	67%

EH: 2.34 EV: 1.33 HZ=160 AT 11-17-16:01

Fig.4 Triple-shot SPS Collider Transfer Dislpay in PS

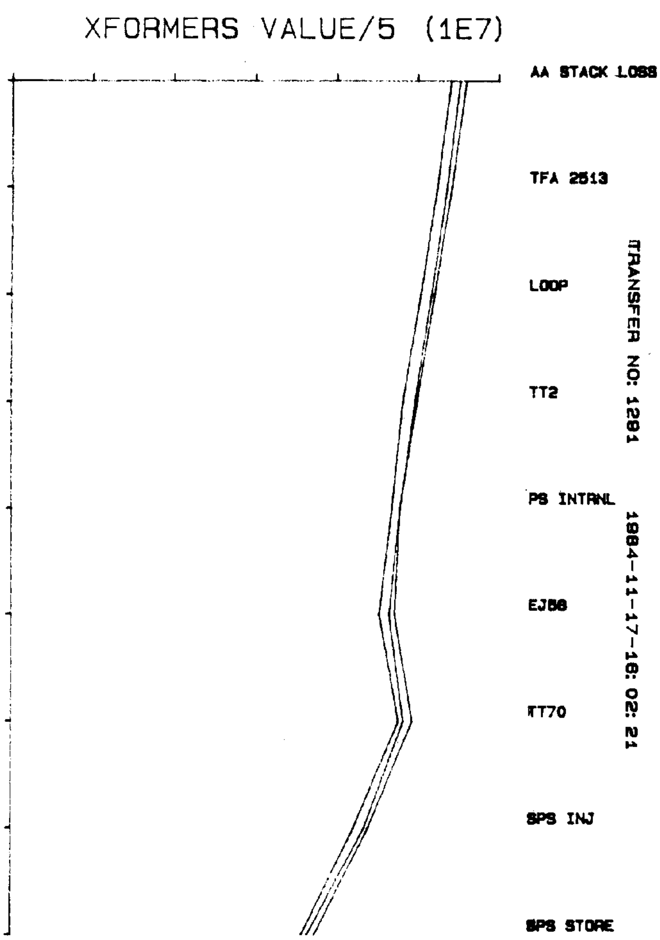

Fig.5 Graphical representation of Losses in the chain for a Triple-shot Transfer

Future Work

The Pbar-Kernel task has recently been incorporated in a general surveillance procedure[5] specially designed to give alarms and abort transfer countdown in the PS. This would enable a failsafe, single push button transfer operation in the PS control room with considerable savings in time and effort in pre-countdown checks and verifications.

Acknowledements

The help of S. van der Meer for the AA related aspects and the contributions of colleagues in the PS Operations and Controls groups as well as from the SPS Operations group, especially R. Lauckner, is gratefully acknowledged.

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