THE CERN COLLIDER AFTER ACOL

Eifionydd Jones
CERN, 1211 Geneva 23, Switzerland

Abstract

The CERN (SPS) collider and ACOL have been minutely described in many previous publications[1-2]. This conference paper concentrates on an overview of the latest, end 1988, performance and limitations of the whole CERN hadron collider complex since the ACOL upgrade was instigated. The details relating to the individual machines are described in greater depth elsewhere in this conference[3-4].

The post ACOL design goals for the collider are a peak luminosity of $4*10^{30}$ $cm^{-2}.sec^{-1}$ along with a luminosity lifetime appreciably greater than ten hours. In order to achieve this the antiproton production rate must approach $6*10^{10}$ pbars/H with an accumulated peak beam of $1*10^{12}$ circulating antiprotons. During 1988, the collider got to within two thirds of its full promise.

Some of the problems preventing the attainment of the design goals are described along with the prescribed solutions for 1989.

Antiproton Accumumulator Complex

The CERN 50 MeV linac, the 1 GeV (pre-ACOL 800 MeV) booster[5], the 26 GeV proton synchrotron, together produce $1.4*10^{13}$ protons per 2.4 sec within the specified density in phase space. The design goal is not far away at $2*10^{13}$ and the remarkable agility employed by our RF and beam gymnastics to achieve it is described elsewhere in this conference[6-7]. These proton producing machines along with the antiproton target area, the collecting and accumulating rings, make up the antiproton accumulator complex.

The 26 GeV protons are brought to bear on the pbar production target, not yet at full repetition rate, but only once every 4.8 sec. The stochastic cooling systems of the antiproton collector (AC) ring are not powerfull enough to handle the full repetition rate. Nevertheless, the cooling systems in this ring are well able, at half repetition rate, to reduce the dimensions of the pbar injected beam to the values required for efficient transfer to the antiproton accumulator (AA) ring. Therein cooling and acummulation continues until the collider is ready to receive the next batch of pbars. This generally occurs once a day when the cooled stack approaches 6 to $8*10^{11}$ pbars. In order to attain such large stacks an instability based on the interaction of the pbars and ions, produced by ionisation of the residual gas molecules of the $3*10^{-11}$ Torr vacuum, had first to be overcome. This instability is discussed elsewhere in this conference in detail[8-9]. The effect is similar to the beam-beam effect in colliders except that the non-linear resonances responsible for the pbar losses are driven by the ions trapped in the circulating beam. The method used to suppress it is based upon a modification of the ion cloud trapped in the potential well of the beam. To achieve this the stack is shaken transversely at a frequency corresponding to the lowest betatron side-band.

The best performance of the antiproton accumulator complex up to the end of 1988 is summarised below.

Table 1

	ACOL Goals	Performance 1988
Protons/pulse	$2*10^{13}$	$1.4*10^{13}$
Pbars/pulse (AC)	$1*10^{8}$	$0.85*10^{8}$
Pbars/pulse (AA)	$4*10^{7}$	$5.4*10^{7}$
Pulse cycle time	2.3s	4.8s
Stacking Rate	$6*10^{10}$/H	$4.1*10^{10}$/H
AA Stack intensity	$1*10^{12}$	$0.85*10^{12}$

The pre- and post- ACOL operational performance is illustrated in Figure 1.

The annual shutdown took place in the first two months of 1989. During which time improvements were carried out to the target area where a new larger diameter (36mm) Lithium collector lens and transformer, built in collaboration with our colleagues from the Soviet Institute for Nuclear Physics at Novosibirsk, were installed. A new pulsed supply should enable the lens when powered at 1.3 Mega-Amp to improve the pbar yield from the target by around 40%.

Some major changes to the collector ring cooling pickups during the shutdown, essentially additional cryogenics to reduce the temperature of the antennae support beams from 115 K to 30 K, should make more power available for faster stochastic cooling. The amplifiers of this system have also been added to, as have those of the accumulator ring pre-cooling. Attempts to reduce hardware and common mode coupling in the stack core cooling system were also carried out.

A considerable amount of work to improve the more classical radio-frequency systems of both AC and AA rings should result in more efficient beam handling and operational reliability. Overall the shutdown work will bring the 1989 pbar accumulator complex very near to the ACOL design goals.

The SPS Collider

The collider is filled, first with six bunches of protons and then with six bunches of antiprotons both via the PS machine at 26 GeV/c, and its energy increased to 315 GeV. Collisions occur at the detectors and the beams are forced to avoid each other elsewhere by electrostatic separation. This helps to reduce the beam-beam tune shift which is still a serious problem and does indeed contribute to reducing the luminosity and its lifetime. Nevertheless the maximum luminosity achieved approaches $2.5*10^{30}$ $cm^{-2}.sec^{-1}$ with a lifetime of 7 to 8 hours at the beggining of the coast. Each proton bunch contains about $1*10^{11}$ particles and each antiproton bunch about half this number. The transverse emittances for protons and antiprotons are respectively around 12 and 6π mm mrad (normalised). Hence both beams have about the same density in phase space and this appears to be the optimum for beam-beam effects. At the 26 GeV/c injection energy the tune spread due to space charge forces generally is considerable and great care has to be taken in setting up the tunes to avoid all the lower order non-linear resonances up to at least 7th order[10]. The other effect which tends to dilute the luminosity occurs during the first few milliseconds

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after injection into the 200 MHz buckets: beam losses occur which appear to be associated with a microwave instability. All told and essentially due to above mentioned effects, the efficiency of tranfer from AA-PS-SPS is between 50 to 70% with particles lost mostly between 26 and 50 GeV/c. Very little emittance blow up occurs.

The resulting performance is summarized in the figure illustrating the accumulated integrated luminosity versus weeks of operation during 1988. A total integrated luminosity of 3372 nb-1 was attained. The same figure contains the FERMILAB collider performance over the same period for comparison.

The following table gives the best collider performance for 1988.

Table 2

	CERN 88	CERN 85	FNAL 88
Peak luminosity (10^{30} $cm^{-2}.sec^{-1}$)	2.4	0.4	2.1
Maximum Integrated Luminosity/shot (nb-1)	70.6	23	105
Maximum Integrated Luminosity/day (nb-1)	81	18	
Maxaximum Integrated Luminosity/week (nb-1)	486	77	449

Improvements are planned for 1989. Most will depend upon the availability of antiprotons in ever greater numbers. However, the operational availability of a new 100 MHz RF system to be used at injection to lenghthen the bunches should reduce the space charge forces and should help to reduce the capture losses at injection. It is also planned to ameliorate the beam-beam effect by improving the separation of the beams with the addition of a second electrostatic separator.

These changes to the collider are expected to result in improving the peak luminosity and the lifetime so that the design goals can be reached in 1989.

Acknowledgements

The performance described above of the CERN collider, are the results of the dedication of almost every member of the staffs of the synchrotron and technical and administrative support divisions of CERN. The efforts of the ACOL project staff and the operating crews of the machines involved are particularly appreciated. An interesting and fundamental physics result such as the snaring of the top quark would be greatly appreciated.

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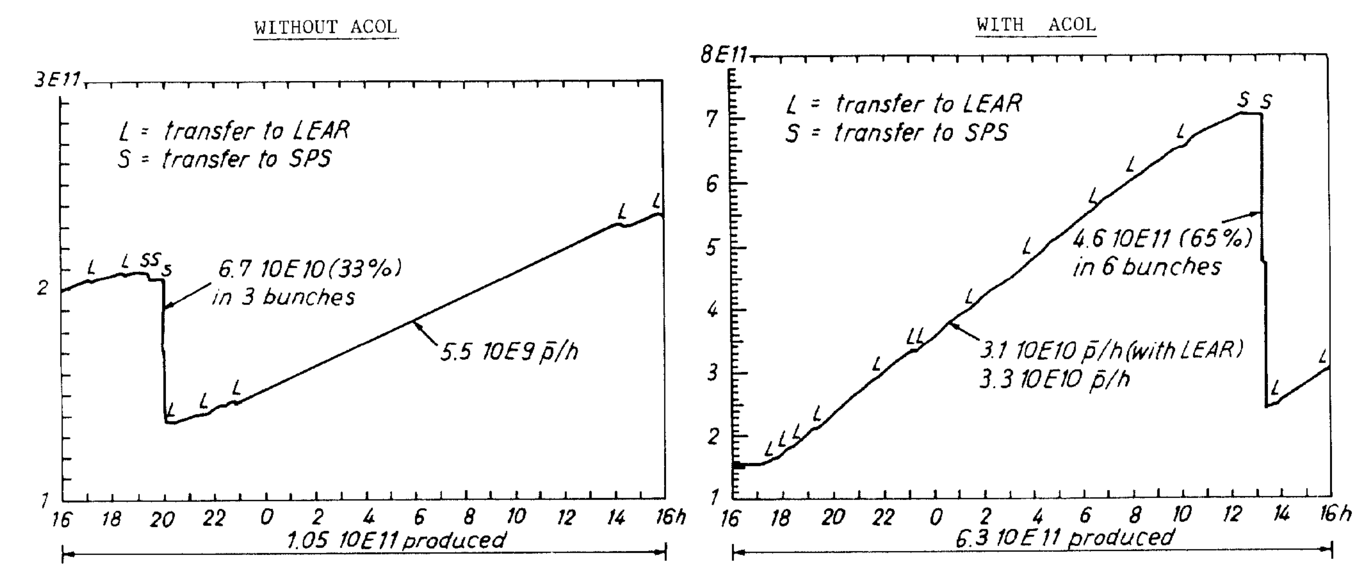

Figure 1 : AA stack evolution over 24 hours.

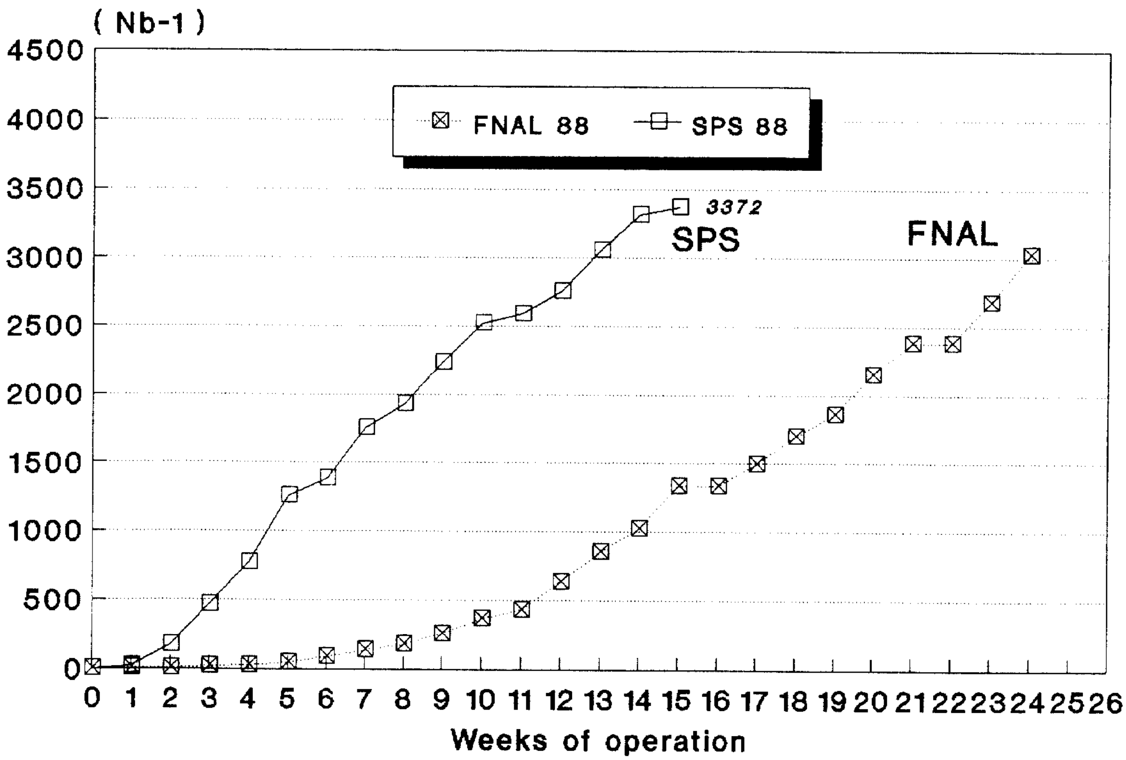

Figure 2 : (1988) Integrated Luminosity - SPS - FNAL