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LIMITATIONS ON STOCHASTIC COOLING AND THE ANTIPROTON OPTION FOR THE EHF

D. Möhl

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Scaling from existing and planned antiproton sources, it is concluded that -- due to inherent limitations of stochastic cooling -- Pbar accumulation at the EHF will be limited by cooling and not by production.

The situation is similar to ACOL and especially to that at the FNAL-source where acceptances have been chosen to match the yield to the cooling limit of, say, 1E8 Pbar/sec, obtainable with two rings and an impressive number of cooling systems with 2 or 4 GHz bandwidths.

More complex systems are required to handle larger fluxes and even most advanced sources discussed for multi TeV hadron colliders are limited to 1E9 Pbar/sec.

Important limitations are the bandwidth and the RF-power requirement of the cooling system. In this context a slow, high intensity synchrotron looks more adapted to Pbar production for accumulation than a fast cycling machine with the same number of protons per second.

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1. Introduction.

The European Hadron Facility is designed to provide 6E14 protons/sec at 30 GeV [1]. Taking a yield of 1E-5 antiprotons at 3.5 GeV per primary proton, this leads to almost 1E10 Pbars/sec.

The question then arrises, whether such fluxes can be cooled and accumulated using stochastic cooling. In the present note, this question will be addressed by scaling from existing and planned antiproton sources.

2. EXISTING ANTIPROTON SOURCES.

Both the new CERN- and the FERMILAB sources are designed to accumulate a maximum of almost 1E8 Pbars/sec. It is fair to say, that this limit is set by the cooling capability. The acceptances have then been chosen to match the production to the cooling limit.

Both the FNAL- and the upgraded CERN-facility use two rings with a circumference of about 500 m each and 160 m each respectively. The cost of construction is in the range of 100 to 200 Million Swiss Francs in both cases.

The complexity is well illustrated by the number of cooling systems: at least 10 in both designs with several hundreds of pick-up- and kicker units and an impressive number of amplifiers with low noise cryogenic input stages, amplification factors of 120 to 150 dB together with a bandwidth of several GHz.

For details the reader is referred to the design reports [2], [3]

3. ULTIMATE ANTIPROTON SOURCES.

The question of antiproton accumulation is of utmost importance in the design of a multi TeV hadron collider: a single Pbar-P main ring could be used, instead of a more expensive system with two proton rings, if cooled antiprotons can be provided at a sufficient rate, say 5E9/sec

Sources for this purpose were studied by G. Lambertson and C. Leemann [4], by A. Ruggiero [5], and by a group at a workshop on Pbar-options for the SSC [6]. Designs for up to 7E8 Pbars/sec were worked out and it was -- more or less generally-- agreed that because of the inherent limitations of cooling one cannot reasonably hope to prepare more than 1E9 Pbars/sec. On this basis both the SSC design group and the study group for a large European hadron collider decided in favour of the proton-proton version.

Designs for fluxes above 1E8/sec are more complex than the FNAL- and the upgraded CERN-sources. Systems of several 500 m rings for debunching and betatron precooling, betatron cooling, momentum precooling, accumulation and final stacking were considered in the context of the SSC-studies.

4. SOME LIMITATIONS.

We content ourselves to point to two limitations here: the bandwidth and the power limits of stochastic cooling. The former is discussed in more detail by van der Meer [7]. Going back to first principles of stochastic cooling he obtains a limiting stacking rate

$$dN/dt = (3/8)*[W/\ln(D)] < (1/20)*W$$

where W is the cooling system bandwith and D (typically at least 1E3) is the ratio of peak stack density to injected density.

This relation can be understood, noting that the initial cooling time constant can be written as :

$$1/Tau = (W/N)/a$$

Here 'a' is a 'design constant' ; $a >= 10$ in practical systems. Then for cooling of N particles a time equal to about 2Tau is needed In this form the relation is independend of stacking requierements.

It is not easy, to increase the bandwidth much beyond a few GHz : pick-up and kicker become inefficient when their transverse dimensions become comparable to the wavelength , secondly it is difficult in this situation to avoid microvave propagation back from kicker to pick up through the vacuum chamber. thirdly there are technological limits to the the broadband microwave powersystems needed.

The RF-power to drive the kicker systems increases strongly (typically in square) with the cooling speed. Both ACOL and the FNAL - source (with a repetion time of 2.6 and 2 sec respectively for Pbar-injection) work at levels of many 100 Watt per system. About 10 kW maximum were contemplated for the transverse cooling systems of the source for the SSC with a 1 sec injection cycle.

Scaling to the 80 msec repetion capability of the EHF, one arrives at hundreds of kilowatts. Regarding this together with the GHz bandwidth, one concludes that such cooling performances are unfeasible. A fraction of the EHF- cycles can then profitably be used to produce Pbars to be cooled. The remaining ones may be devoted to other uses.

In fact a slow machine with high intensity per pulse looks more apt than a fast synchrotron, to produce large Pbar-fluxes to be cooled. it has been proposed [8] therefore to use the stretcher ring of the EHF to store high intensity proton pulses for antiproton production.

5. CONCLUSIONS.

The yield of cooled Pbars to be exspected at the EHF is limited by cooling. A maximum flux of, say, 1E8/sec may be obtainable with systems comparable to the FNAL- and CERN-sources. To increase this rate by a sizesable factor one would need a considerably more complex system of cooling and accumulation rings.

No technology seems to exist or to be forseeable to cool more than about 1E9/sec except may be 'broote force concepts of duplication', where the yield increases at best linearly with the number of sources

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