

STUDY OF THE FEASIBILITY OF DECREASING THE EMITTANCE
OF THE SSC BEAM THROUGH THE USE
OF ELECTRON COOLING IN THE SSC MEDIUM ENERGY BOOSTER

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A collaboration has been formed, and funding received by the Texas National Research Laboratory Commission, to study the feasibility of decreasing the emittance of the proton beams in the Superconducting Super Collider (SSC) by electron cooling the proton beams at their injection momentum of 12 GeV/c in the SSC Medium Energy Booster (MEB). The ultimate goal is to reduce the emittance of the proton beams that will collide at 20 TeV in the SSC by about a factor of two. If this can indeed be done, then the SSC luminosity (the number of physics events per second) will also be increased as much as by a factor of 2, despite a decrease in duty factor. Consequently, this relatively inexpensive device may be able to increase the performance of the SSC by a factor of two. The research done on this device shall also benefit IUCF in the future, since a similar device could be installed in LISS; consequently, we are also receiving support from Indiana University for this research.

The SSC luminosity is inversely proportional to the emittance of the two proton beams. Consequently, a smaller beam emittance will increase the SSC luminosity; in addition, a reduced beam emittance in the MEB will also lead to a reduced beam size in this machine as well as all the following accelerators; the smaller beam size will increase the tolerances for closed orbit error errors and for higher order multipoles in the magnets, and allows for easier transition crossing in the MEB.

The design¹ SSC rms normalized emittance is $1\pi\mu\text{m}$. This is a consequence of the $0.6\pi\mu\text{m}$ emittance of the beam injected into the LEB and the near perfect adiabatic transmission through the SSC complex of accelerators. Beam parameters for the SSC system of accelerators are shown below in Table I. The emittance appears to be limited primarily by the Lasslett space charge tune shift in the LEB at injection, and consequently can probably not be reduced, even with electron cooling. However, after acceleration in the

LEB, the limits placed upon the proton beam emittance are relaxed. We estimate that the normalized emittance of the beam injected into the MEB can be reduced by a factor of about 5 over the emittance of the beam injected into the LEB, and that this can be accomplished by electron cooling the proton beam at the injection energy in the MEB. However, for a variety of reasons, our goal is to reduce the emittance by a factor of two only.

The cooling time for the 12 GeV/c protons will be about 50 s. Although the MEB cycle time is 3 s (much smaller than the cooling time), the following machine (HEB) has a relatively long cycle time, 120 s. Consequently, precooling the 3 batches of beam in the MEB before acceleration and loading into the HEB would increase the total SSC filling time by less than a factor of two; the higher luminosity in the SSC would more than compensate for this decrease in duty factor.

In addition to increasing the SSC luminosity, a smaller beam emittance will increase the available machine aperture, and make transition crossing in the MEB easier. It is therefore worth studying the possible improvement of the beam emittance in the MEB using electron cooling. A complete 5 MeV electron cooling system would cost about 7 M\$. We are receiving about 5% of this amount over three years for a feasibility study of this possibility, its impact on the SSC design, and for an attack upon the principle technical obstacles which need to be solved in order to make such an idea viable.

Table I. Beam Parameters for the SSC accelerator complex.

Accelerator	LEB	MEB	HEB	SSC	Units
Injection Momentum	1.46	12	200	2,000	GeV/c
Final Momentum	12	200	2,000	20,000	GeV/c
Circumference	0.54	3.96	10.89	87.12	km
Harmonic Number	108	792	2,178	17,424	
Normalized rms emittance @ 10^{10} particles/bunch	0.6	0.7	0.8	1.0	($\pi\mu\text{m}$)
Normalized rms emittance @ 5×10^{10} particles/bunch	4	4	4	4	($\pi\mu\text{m}$)
Cycle Time	0.1	3	120		s

The project is composed of two principal parts: (1) a detailed study culminating in a design report for an electron cooling system for the SSC Medium Energy Booster (MEB); and (2) an experimental effort to overcome the primary technical problem which needs to be solved in order to build such a system: successful "recirculation" of a low transverse temperature, high density, nonmagnetically confined electron beam. Funding for the first year of studies is \$265,620. During this period we shall complete the design study and begin work on the test electron recirculation system. During the second year of funding, we will complete the assembly of the test system at the National Electrostatics Corp. in Middleton, WI, and during the following year we will perform our recirculation tests.

This research is supported by the Texas National Research Laboratory Commission under grant RGFY9158.

1. Helen T. Edwards, "SSC Design Status," *Particle Accelerators* **26**, 151 (1990).