First Ideas of a Medium Energy Electron Cooling System for COSY

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The existing electron cooler at COSY is a conventional device with energies up to 100 keV. At present, it is used at injection energy to prepare low-emittance proton or deuteron beams for external experiments or to increase the cooled beam intensity by stacking. Stochastic cooling is used to compensate emittance and momentum spread growth in internal experiments. Since the present stochastic cooling system is limited by its finite bandwidth to relatively low beam intensities (~10^{10} particles) and not too high target densities (~10^{14}atoms/cm^2), a future cooling device for high-luminosity experiments could be a Medium Energy Electron Cooling (MEEC) system. MEEC systems are being discussed since a few years:

- Traditional single-pass schemes with electrostatic acceleration up to the required energy. At Fermilab a 5 MeV system is under construction. First tests are underway [1].
- Multi-traversal schemes, where the same electron beam, stored in a solenoidal ring, is used many times for cooling before it is dumped and a fresh electron beam is produced. The electron beam is prepared at low energy and accelerated either externally by a linac or internally by a beam transformer [2]. Only little is known about such schemes and they are not proven experimentally anywhere.

The traditional single-pass system can provide electron beams with sufficiently low transverse and longitudinal temperatures, but HV problems, size and costs increase dramatically with electron energy. The multi-traversal scheme is more compact and probably less expensive. However, the electron beam quality is determined by the beam acceleration techniques and the electron motion in the cooling ring. So far, we are considering a system with a radio-frequency linac for beam acceleration. The layout of the considered COSY MEEC system is shown in Fig. 1.

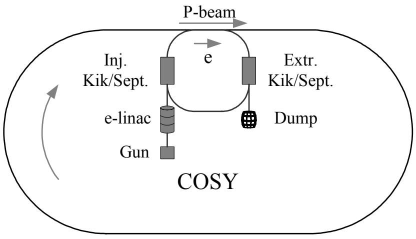

Fig. 1: Layout of a linac-based MEEC system

During the cooling process the ion beam temperature decreases while the electron temperature increases. The electrons have to be renewed after a significant temperature is reached. Simulations [3] show that cooling with a circulating e-beam may have the same cooling efficiency as a single-pass electron beam if the circulating time is short enough. To increase the electron thermo capacity, a long cooling ring and a high electron current are desirable, but space and electron current impose limitations. Basic parameters of a COSY MEEC system are:

Electron energy	0.5 ~ 1.5MeV
Circumference of cooling ring	20 m
Electron beam current	0.5 A
Electron energy spread	< 10^{-3}
Electron circulating time	< 100 ms

Designing an RF linac with low output energy and low energy spread (<10^{-3}) causes severe problems due to the sine shape of the RF fields and space-charge Coulomb effects. One possible way to overcome these problems is to use the fundamental and further RF harmonics to produce a relatively constant RF accelerating voltage [4]. Theoretically, a low energy spread (10^{-4}) is achieved with three harmonics (f, 3f, 5f), see Fig. 2.

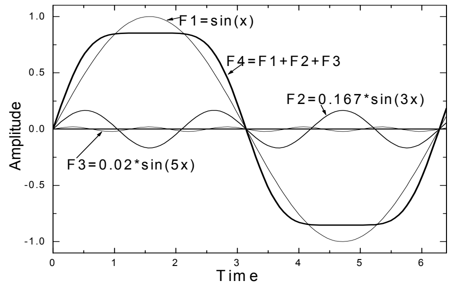

Fig. 2: Constant RF voltage

For efficiency reasons individual harmonic cavities are unavoidable leading to a large and complex system. Assume that the electron bunch density distribution is parabolic [4], the momentum spread is given by $\Delta p/p \propto f^3$. A low linac frequency f of 50 MHz is a reasonable compromise between cavity size and energy spread of the electron beam. Simulations have been carried out to study the linac beam dynamics. The average current of the linac during one RF period is 0.5 A and space charge effects become important. After optimization, the energy spread could be decreased to 4×10^{-4} assuming a gun voltage of 300 kV. The basic linac parameters are listed below:

Number of cavities	2 (main)+ 2 (harmonic)
Linac length (m)	4-5
Shunt impedance (MΩ/m)	≈ 3 (main cavity)
Power dissipation (kW)	≈ 400
Beam power (MW)	0.75
Duty cycle (%)	≈ 0.1

Studies on the so called LEPTA ring [5] have been undertaken at JINR, Dubna with parameters close to those desired for the COSY MEEC system. LEPTA is presently being setup to allow for first experiences. Our first results on both the linac and the magnetic ring indicate the feasibility of a linac-based MEEC system, but more profound studies are needed.

References:

[1] J. Leibfritz et al., Status of the FERMILAB Electron Cooling Project, Proc. EPAC 2002.

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[3] A. Sidorin et al., User Manual for BETACOOL.

[4] N.S. Dikansky et al., Large Linac-Based Electron Cooling Device, Proc. PAC 1997.

[5] I.N. Meshkov et al., Electron Cooling for Luminosity Preservation in an Experiment with Internal Target at COSY, to be published as Jül-report.

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