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Energy Recovery Linac: Beam Dump

A. Hershcovitch

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Collider Accelerator Department
Brookhaven National Laboratory

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A. Hershcovitch

Collider-Accelerator Department
Brookhaven National Laboratory
Upton, NY 11973

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Ady Hershcovitch

In this note the ERL beam dump system is described.

Introduction

As its name suggests, the beam dump is where electron bunches end up while depositing energy unrecovered by the ERL. The process of removing unrecovered energy must not have any adverse effects on the ERL system like outgassing or backstreaming electrons. Electron beam dumps are widely used in various applications ranging from radiation generating devices like klystrons and traveling wave tubes to EBIS sources and electron beam coolers, as well as to large machines that include LINACs and electron colliders. Energy of discarded electrons range from a few electron volts to 10's of GeV.

This beam dump has a couple of unique issues that determine the design concept: cascade showers and seals that can withstand high radiation dosage.

Physics Issues: Cascading & Radiation

Most electron beam dumps are basically energy disposal devices. Just like in proton or heavy ion beam dumps, particles are stopped in solid materials, which are cooled (usually by water). For electrons with energies that exceed 1.022 MeV, there is the phenomenon of cascading that must be dealt with. These electrons, when passing through solid material generate gamma rays, which in turn produce electron - positron pairs. The positrons annihilate and generate more gamma rays that produce more electron – positron pairs, thus resulting in cascade showers.

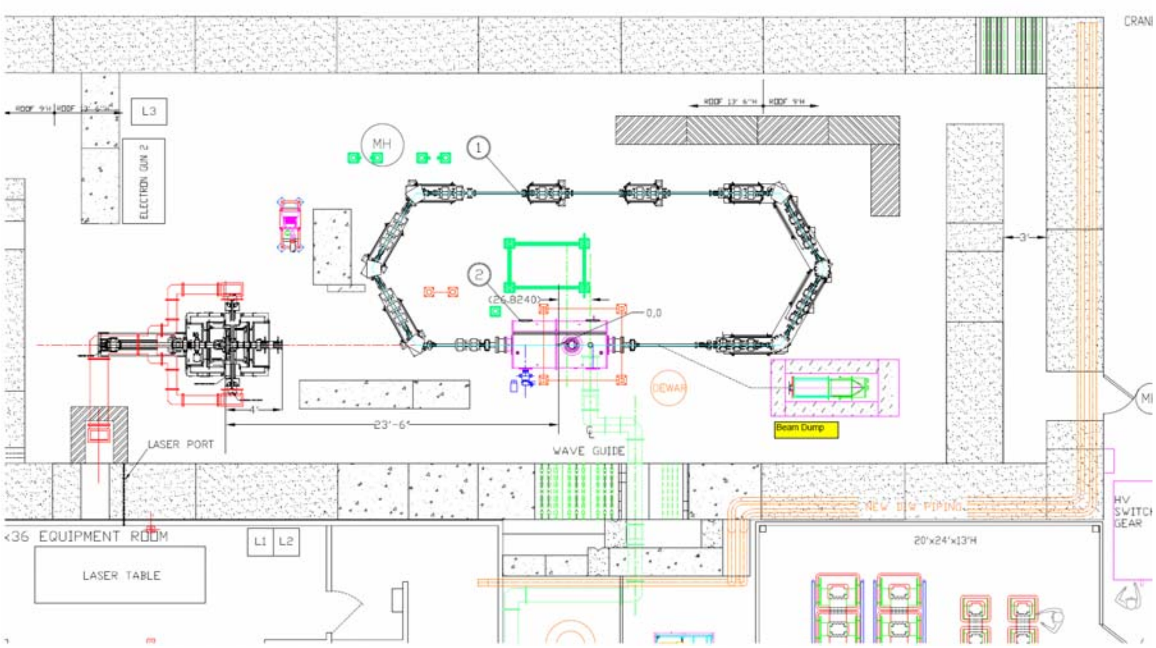
Angular dependence of cascade showers on beam energy is rather strong. The higher the energy, the less the angular spread. In the energy range of 30 – 40 GeV (like at SLAC), cascade showers are directed forward in the direction of beam propagation and have practically no energy spread. Beam dumps in this energy range are long solid tubes of water cooled low Z materials. They are easy to design and fabricate since there is low power per unit length of dissipation.

In the energy range of 1.022 MeV to 10 MeV, cascade showers spread laterally. Therefore, deposited electron beams must be spread out to power levels of below 500 W/cm^2 to prevent burning holes. But, this level of power density removal requires very challenging cooling techniques. Therefore, spreading beam deposition to below 100 W/cm^2 is preferable.

Commercially available beam dumps, which are extensively utilized in radiation generating devices like klystrons and traveling wave tubes, use good elastomers, like Buna-N, for seals. However, even the best elastomer fails after receiving a radiation dose of 10^8 Rad. Even though this is an enormous dose, it was soon realized that at full ERL power, a Buna-N seal will absorbs such a dose in about 5 hours. Therefore, all seals between flanges must be either metallic, or the flanges should be welded. Hence any commercially available beam dump will need to be modified.

ERL Layout and Beam Dump Location

Below is a figure showing the ERL layout and the beam dump location. The beam dump, which is shown in green and blue, is enclosed in shielding at the lower right corner inside the main ERL shielding in the figure below.

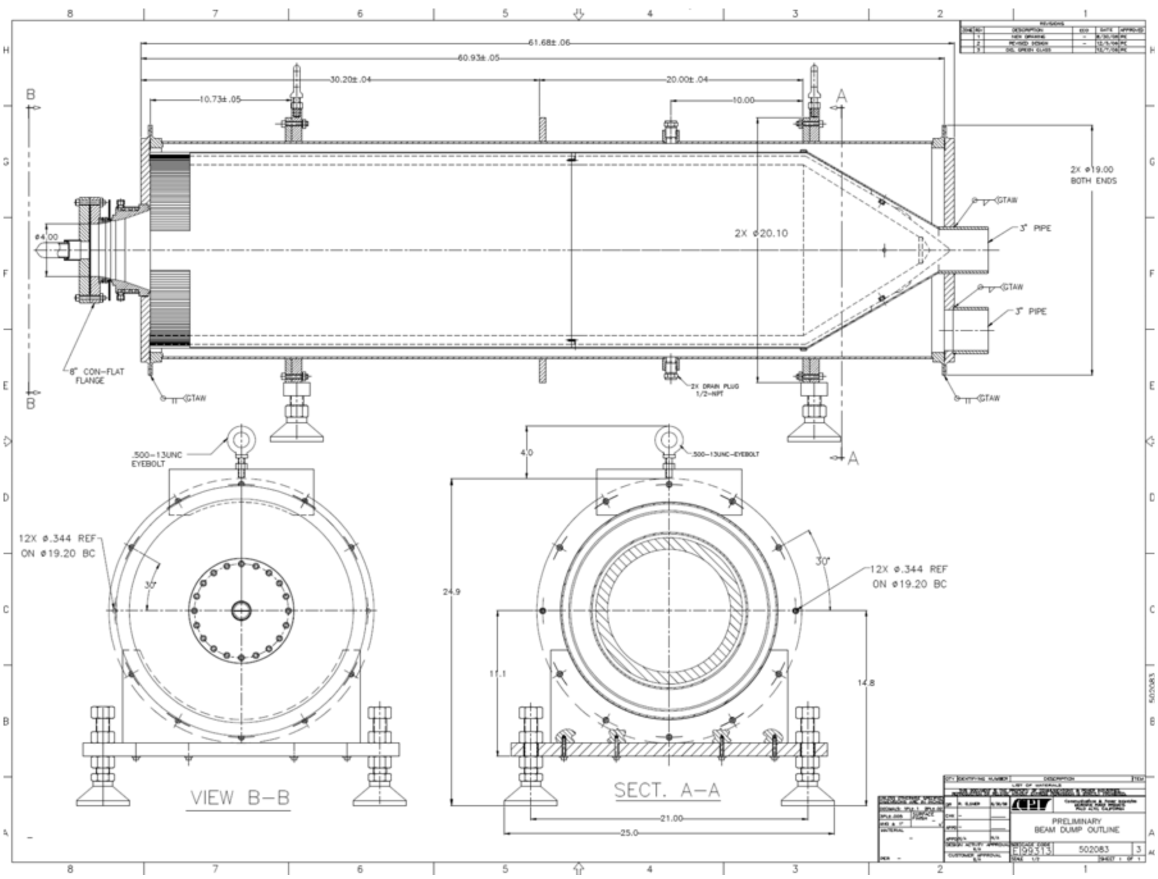


The Beam Dump

Decision was made to basically purchase a commercially available beam dump modified to the ERL special needs. The beam dump design is based on a similar 1 MW ERL klystron electron gun beam dump from CPI, which was purchased a few years ago. However, that and other similar commercially available MW beam dumps were designed to remove 10's of Ampere beams with energies of 10's of KeV. Therefore, upon entry into the beam dump, the electron beams spread out due to their high space charge and relatively low energies.

However for the ERL parameters, the beam dump has to address the issues of cascade showers, forced magnetic beam spreading due to low space charge at high energy, and issues associated with extremely high radiation doses. Therefore, a beam modified beam dump was designed and a purchased order was sent to CPI. Beam spreading is to be done magnetically to address the first two issues. And, all elastomer seals are to be replaced by metallic seals, or flanges are to be welded.

Below is a drawing of the ERL beam dump. Under present design, the beam will be spread on the surface of a water-cooled, cylindrically shaped copper electron beam dump. Dimensions of this beam dump are roughly 62” in length and 19” in diameter. Spreading the beam over this large area is to insure that local boiling of the cooling water does not occur. The beam will be spread over this large surface area by magnetic field coils.



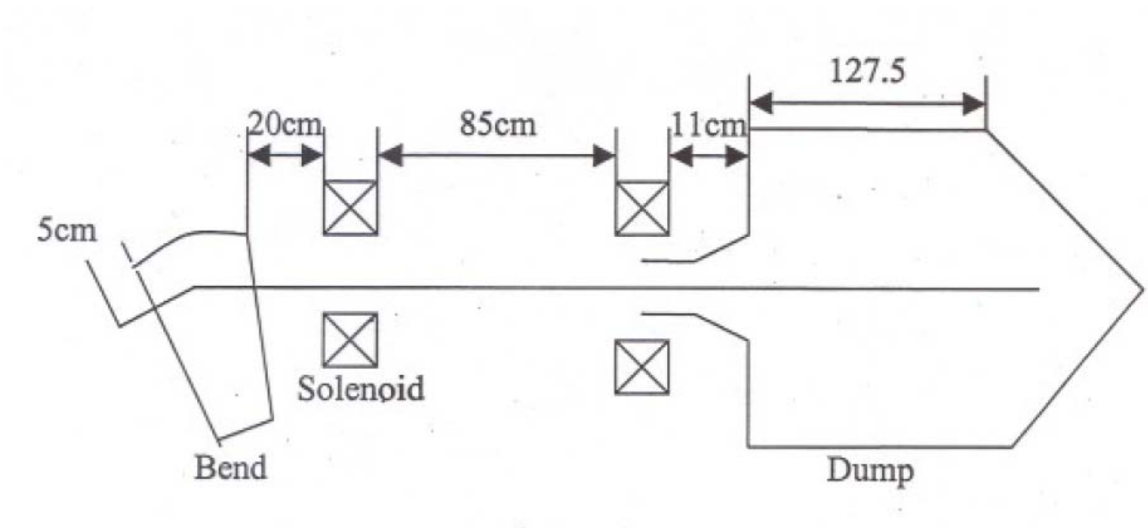
The inner structure (collecting the electron beam) is made of copper, while the outer structure is made of stainless steel.

Elastomers seals, which are replaced by welding flanges, have a 1” lip in order to facilitate easy opening, even though it is very unlikely that such a need will arise. To mitigate debris and outgassing streaming back into the rest of the ERL system, the inner copper walls of the beam dump are to be conditioned at low power without cooling; backscattering, secondary electrons etc. are not an issue due to the fact that the electron beams striking the inner copper walls have multi-MeV, and thus penetrate deeply into the walls.

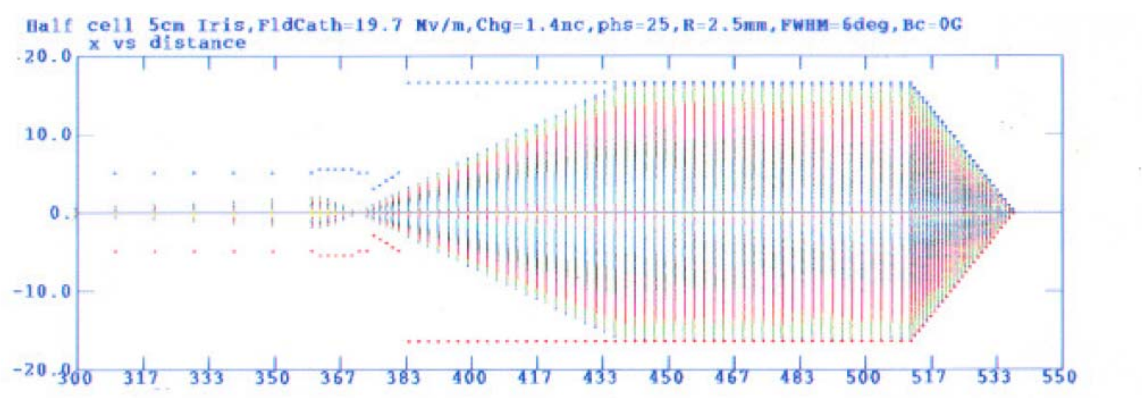
The beam dump is designed to have the capability for removing 1 MW of unrecovered electron beam power with beam energy of 5 MeV. Similar design with identical heat removing capability was successfully tested at 1.6 MW.

Spreading magnets' parameters are:
Bending dipole:
30 degree, R=60 cm
Spreader:
Focusing solenoid:
L= 10 cm, B= 2.7 kG

Bending and spreading magnets layout are shown below (not to scale)

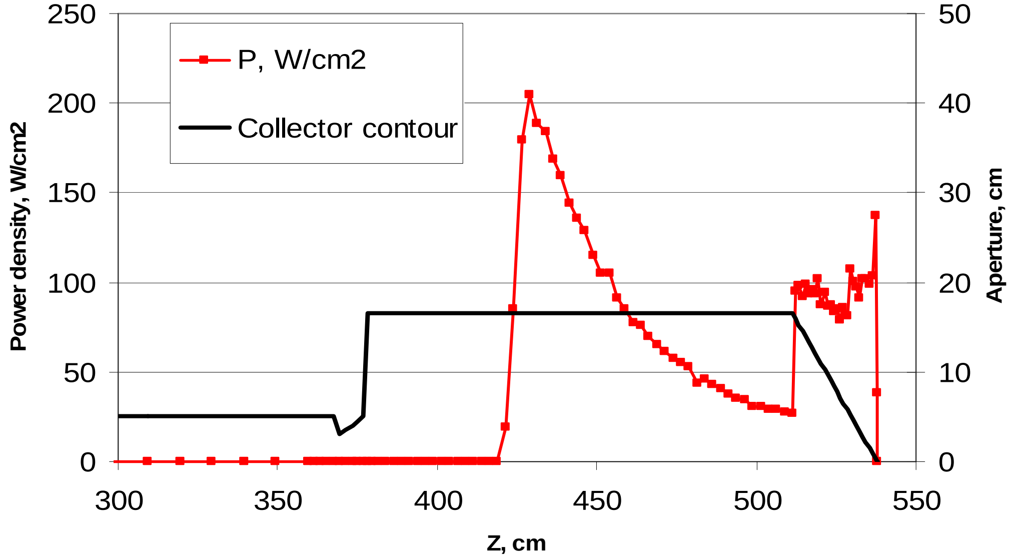


Simulations for spreading of an electron beam with the following parameters: charge per bunch = 1.4 nC; KE= 2MeV, I = 0.4 A, P = 1 MW is shown below.



Particles trajectories in collector

Heat load simulations as well as power density distribution indicate that electron beam power distribution is well below the safe limit. Basically, the beam dump should meet all ERL requirements. Shown in the figure below is the power density distribution.



Status

Beam dump design is complete. Purchase order was sent to CPI. Delivery date is set for March 26, 2010.

Acknowledgements

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