The International Linear Collider beam dumps

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The ILC beam dumps are a key part of the accelerator design. At Snowmass 2005, the current status of the beam dump designs was reviewed, and the options for the overall dump layout considered. This paper describes the available dump options for the baseline and the alternatives and considers issues for the dumps that require resolution.

1. INTRODUCTION

The ILC is a very complicated and expensive project. One aspect of key importance is the main beam dumps, which are required to safely dispose of the high power ILC beams. The work on such dumps was started at the SLC, albeit at much lower power, and continued as part of the TESLA project. However, much more work is needed to obtain satisfactory beam dumps for the ILC. We shall now review the baseline and alternative beam dump designs.

2. THE ILC DUMP REQUIREMENTS

The baseline layout of the ILC consists of two linacs, which then branch into two interaction regions. The current choices of crossing angle for the interactions regions are 20mrad and 2mrad. The requirement to dump the main beam after collision then leads us to two full power beam dumps for each interaction region. Furthermore, the need to dump the beam at the end of the linac for commissioning and fast extraction purposes adds two more full power beam dumps to the baseline design. Note, the 500 GeV machine average beam power is 11MW and that of the 1 TeV machine is 18MW; in this paper we always consider the dump being rated for the higher power.

There is also a need to dump the beamstrahlung photons generated during the beam-beam interaction at the interaction point. This photon power is around 1MW. For the 20mrad interaction region layout the photon beam dump is common for both charged beam and photons, while for the 2mrad layout the photon dump is separate.

Hence, there are separate beam dumps rated for full power for all beam lines including tune-up lines, or a total of six beam dumps in the baseline. The tune-up dumps are required to be sufficiently remote from the IP, so that the collider halls can be accessed for detector maintenance while the linac is being tuned, and full beam sent to the tune-up dump.

Technically, the elimination of two full power tune-up dumps should be possible. This will impact availability which may be partly mitigated by reduced power tune-up dumps (0.5MW). The cost savings need to be further evaluated and supported by detailed design [1].

3. THE BASELINE TECHNOLOGY - THE WATER DUMP

The water-based dump concept [2] is patterned after the design built in 1965 as the main dump for the SLAC Linac [3], where it is still in use. This dump was designed and built to work at 2.2MW, but in reality it was only used at powers up to 800kW. Figure 1 shows a picture of the SLAC dump. The baseline design for the ILC beam dump is based on a water dump with a vortex-like flow pattern and is rated for 18MW beam. The choice of a water dump for the baseline has many advantages: the water dump has been studied in detail for accelerator projects, the problems of the larger dump design have been noted, and the studies indicate there are no "show-stoppers". The water dump for the TESLA project was studied in detail at DESY [4], with input from several industrial companies.

The basic principle of a water dump is to present the incoming beam with a region of cold, pressurized water flowing transverse to the direction of the beam. The beam dissipates its energy into this water, which rapidly moves away. This presents the following portion of the incoming beam with fresh water. The heat is trejected through heat exchangers. At a depth sufficiently beyond shower maximum the beam's transverse size has increased to where solid materials like copper or tungsten plates can absorb the remaining power in the tail of the beam energy spectrum and thus help reduce the overall length of the dump. This is followed by a stage of solid material cooled by air natural convection and thermal radiation to ambient and many metres of shielding. The water is separated from the vacuum of the extraction line by a thin window - required to be thin enough to avoid the window absorbing excessive amounts of power. The window design is a key part of the overall dump design.

The water flow velocity is required to be sufficiently high to avoid volume boiling of the water at the tank operating pressure when the dump is accepting the larger spot sizes of the disrupted beam. The dump window is primarily cooled by forced convection to the water so that its temperature rise during the passage of the bunch train and the resultant thermal stress rise is less than its thermal stress limit. The spot size of the undisrupted beam must be sufficiently large to prevent window damage. This will be done through a combination of optical means, an increase in extraction line length after the last optical element, and sweeping the beam across the face of the window. Beam sweeping can also help prevent volume boiling of the water behind the window; if employed, the sweeping or rastering mechanism will need to be interlocked to the machine protection system. The water circuit consists of two closed loops and an external water circuit. The inner water loop is pressurized to 10bar and has a volume of around 18 cubic meters. The length of the dump, including all shielding, is about 25m longitudinally and about 15m transversely.

The control and transport of radioactive byproducts is of central importance to the dump design. Work is ongoing in this area. For example, isotropically produced neutrons contribute to the shielding thickness and careful computation of the neutron fluence is needed. For a deep-tunnel site the forward-peaked muons are stopped in approximately one km of earth. A shallow-tunnel site may require a small downward bend of the beam before it enters the dump. That would necessitate a separate dump for the beamstrahlung followed by the charged beam dump. The required R+D items for the baseline are a study of window survivability, and the corresponding computation of radiation damage, measured in displacements per atom (DPA), and the resultant change in pertinent material properties. A window replacement procedure, probably incorporating remote or robotic handling, and schedule can then be developed. A prototype of the window and a beam test are also necessary. The required test beam must give similar energy densities in the window as the full ILC machine. Furthermore, some studies of pressure wave formation and propagation may be necessary.

Another topic that requires study is the management of tritium gas and tritiated water in vapor form. In the closed loop radioactive water system they are contained and their low energy beta emission is easily shielded against, regardless of in what form they exist. If, however, radioactive water was spilled, say, on the tunnel floor and the various tritium containing molecules are evaporating, there will be significant issues how to contain it. On one hand, the low beta energy makes detection next to other more energetic isotopes difficult employing commonly used survey instruments. On the other, the long half life (t1/2=12.3 years) and the easy incorporation of the tritiated water molecule into biological systems presents major challenges. The required R&D work probably does not entail test beam time.

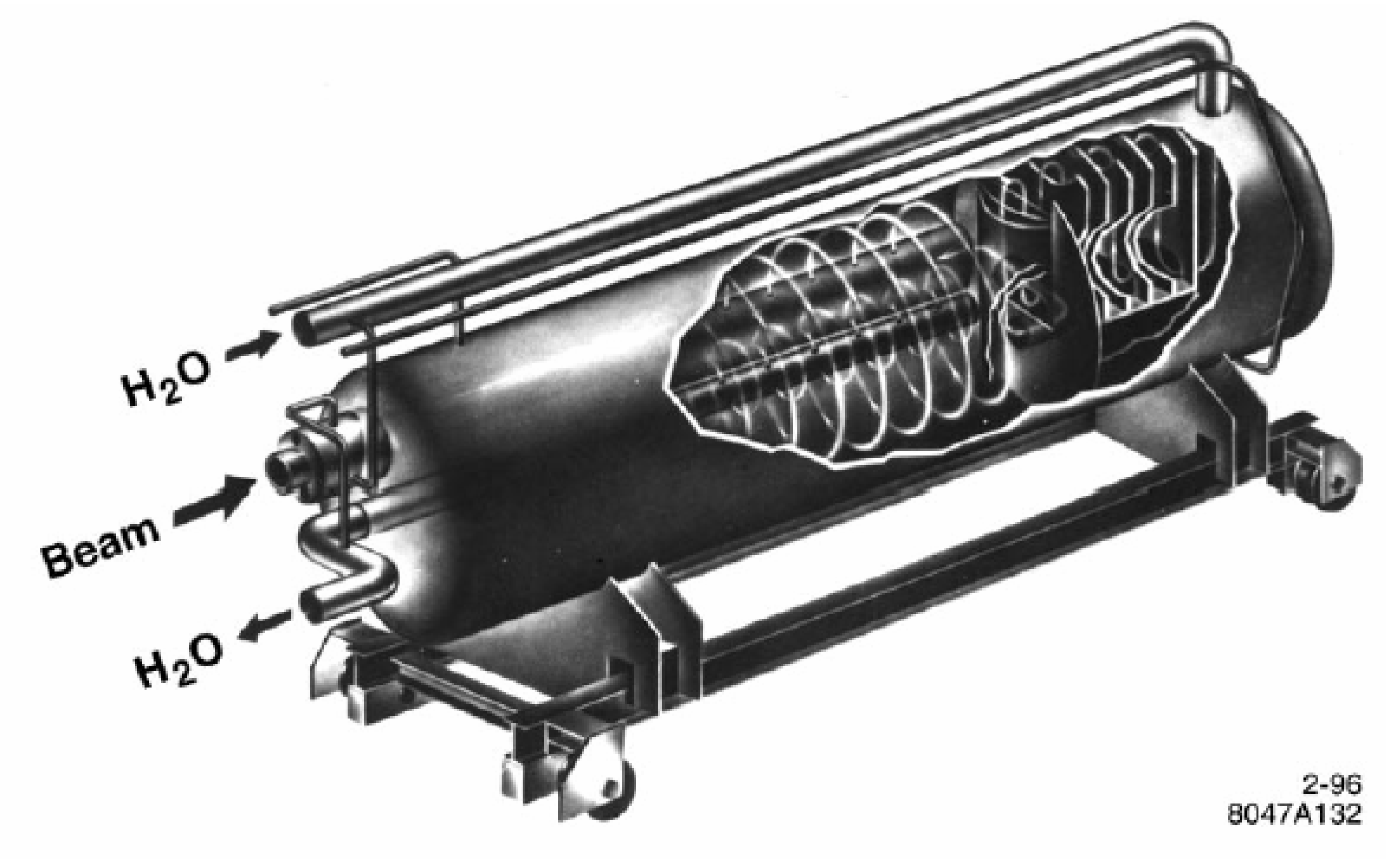

Figure 1: The water-based dump in use at SLAC [2]

4. THE ALTERNATIVE TECHNOLOGY - THE GAS DUMP

The noble gas dump is the alternative design for the ILC beam dump [5, 6]. This consists of about 1km of a noble gas (Ar looks the most promising) enclosed in a water cooled steel jacket. The gas core acts as a scattering target, blowing the beam up and distributing the energy into the surrounding iron. Considerable iron is required to successfully transport the heat to the outside water cooling. As in the water dump, the final layer of cooling is an outside air system

This gas dump design may ease some issues such as radiolysis and tritium production, and a gas profile can be exploited to produce a uniform energy deposition along the length of the dump. However, other issues arise such as particle beam heating of the gas and ionization effects. Further studies are needed to understand the feasibility and benefits of the gas dump. Another possibility is a gas/water hybrid dump, involving the use of a shorter gas dump as a passive beam expander, followed by a small water dump. This option also requires further study. Yet another possibility is a rotating solid dump immersed in water, or a dump based on some kind of liquid metal.

The required R+D items for the alternative design are studies of gas heating, including ionization effects, and a study of radiation and activation effects. A study of the gas dump windows and heat rejection from it are also required. A smaller scale prototype of the dump, and some test beam, would also be highly recommended.

5. CONCLUSION

In this paper, we discussed the baseline and alternative designs of the ILC beam dumps. The baseline is a high pressure water dump. Such a dump has been built before for the SLAC high power beam dump but operated at much lower power. This is a solid choice for the baseline, although much work is needed. The alternative choice is a gas-based dump. This looks promising, although many further studies and prototyping will be required.

References

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