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Status of Light Ion Approach to Inertial Confinement Fusion *

J. Pace VanDevender
Sandia National Laboratories

Introduction

Personnel at Sandia National Laboratories, the Naval Research Laboratory, Cornell University, and Los Alamos National Laboratory are developing cost effective beams of lithium ions to bridge the energy gap between lasers and underground nuclear explosions in the national Inertial Fusion Program.

We plan to probe the threshold for igniting thermonuclear fuel in the laboratory on the Particle Beam Fusion Accelerator II (PBFA II). We have met our April 1, 1989, milestone of 5 trillion watts per square centimeter power density on PBFA II. We wish to adapt the existing Hermes III accelerator at Sandia into a pre-prototype module of the DOE Laboratory Microfusion Facility for military applications in support of the DOE decision in the mid 90s on the best particle beam or laser for the facility. A German-American study concludes that our lithium ion approach offers the lowest cost option for fusion energy.

Ion beams are to bridge the gap between lasers and nuclear explosives as part of the US Inertial Fusion Program.

Lasers readily concentrate their energy in space and time to power inertial fusion experiments. Consequently, lasers have been and continue to be the best power source for exploratory experiments at low energy--energy far below that required for igniting thermonuclear fuel. The outstanding results on the NOVA and OMEGA lasers by personnel at the Lawrence Livermore National Laboratory and the University of Rochester, respectively, testify to the wisdom of this approach. However, the cost of today's lasers limits their available energy.

Underground nuclear explosives have far more energy than available from lasers; a very small fraction absorbed by an inertial fusion experiment is adequate for very energetic experiments. Excellent results by personnel from Lawrence Livermore National Laboratory and Los Alamos National Laboratory in the Halite-Centurion program have resolved many of the questions on the feasibility of inertial fusion. The expense of these experiments and the difficult diagnostics limit the frequency and utility of the underground source.

Nevertheless, the outstanding results from these experiments have justified devoting 86% of inertial fusion funding to these laser and nuclear-powered experiments. The remaining 14% has been devoted to developing a low cost technology with adequate, abundant energy to bridge the gap between lasers and nuclear explosives. This technology uses intense, cost-effective ion beams of hydrogen and lithium that will power large energy inertial fusion experiments for ignition and beyond in the laboratory. Since lithium and hydrogen have very low atomic masses, this approach is called the light ion approach.

The required energy ranges from 1.0 to 10.0 million Joules for ignition and high gain, respectively. Sandia has built three power sources with beam energies in this range for simulating the effects of Soviet nuclear weapons on American weapon systems and for experiments in inertial fusion and strategic defense. The largest is the Particle Beam Fusion Accelerator II or PBFA II.

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Ninety-five percent of the $25.8M funding for Inertial Fusion at Sandia supports the PBFA II experiments leading towards ignition.

PBFA II is being optimized to deliver 1 to 3 Megajoules of energy to an inertial fusion experiment to deduce the threshold for igniting thermonuclear fuel and--if that threshold is within range--to ignite fusion in the laboratory. Because of the promise of PBFA II, we are spending $23.5M, 95% of our funding, in FY89 on the PBFA II program. During the past year we have resolved the principal issues in each of the separate technologies required for PBFA II. We are now integrating them and progress has been rapid.

We have achieved our April 1, 1989, milestone of 5 trillion watts per square centimeter.

The key issue for this approach has been power concentration. Ten trillion to one hundred trillion watts per square centimeter are required for the experiments. In October 1988, our external review committee, chaired by Dr. Ron Davidson of MIT, challenged us with a milestone of 5 trillion watts per square centimeter (averaged over the area of the 3 mm radius baseline target) by April 1, 1988. It required increasing the power density by a factor of seven in the last six months. We met the milestone on March 20, 1989.

Because of this achievement and of the opportunity for further progress, we believe that we are on the correct path to making PBFA II a capable target driver at the 10 to 100 trillion watt per square centimeter power density required for the ignition class target experiments. We have already begun target experiments for diagnostic development. In FY90, our emphasis should shift from beam development to target physics experiments.

Sandia endorses the DOE plan preparing for a LMF driver decision.

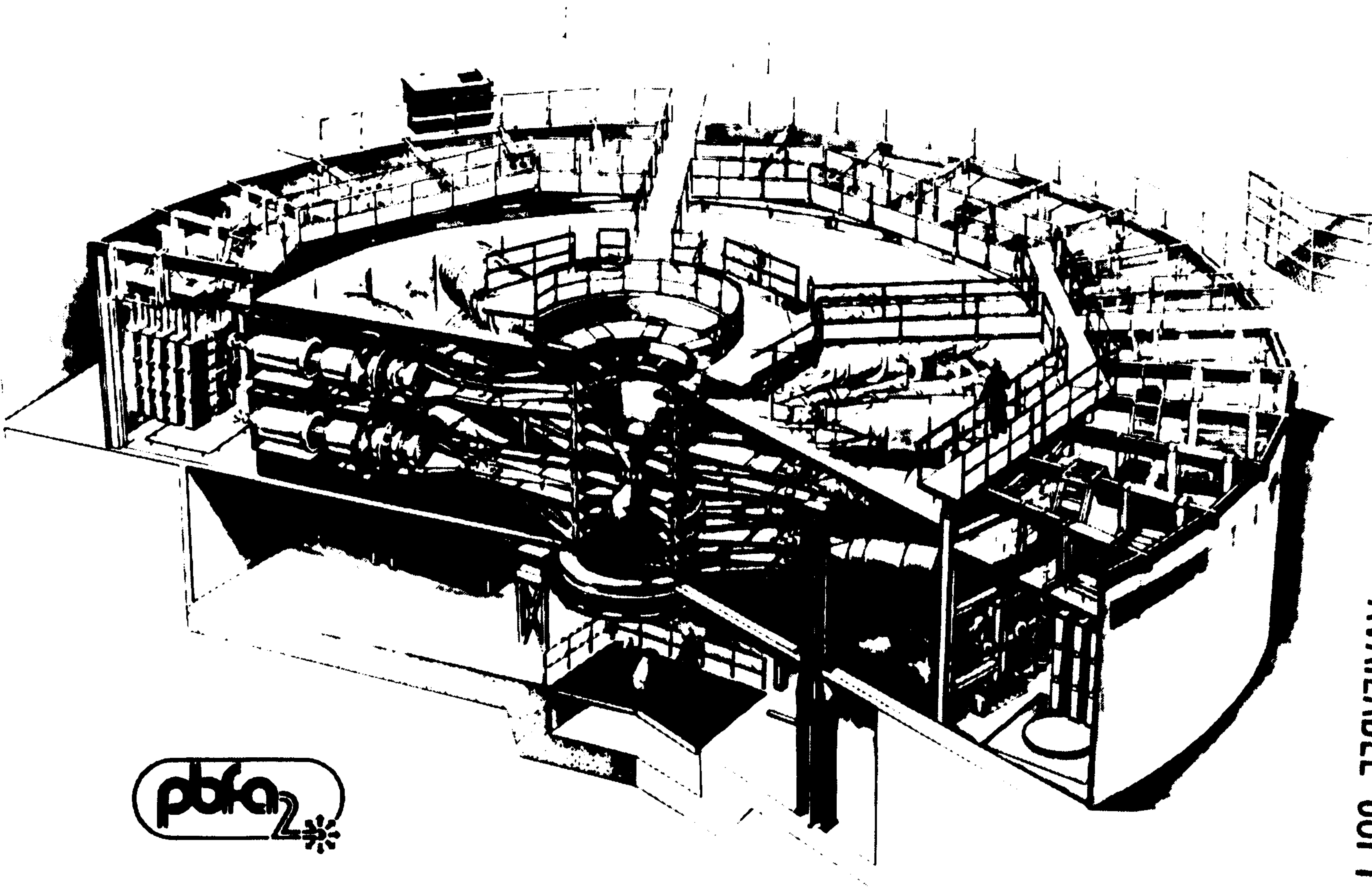
Although 95% of our funding enables the PBFA II experiments, the other 5% or $1.3M permits us to study the lithium ion option for the DOE Laboratory Microfusion Facility as the next major step for the national program. We have developed a conceptual design. Since it is a reasonable extension of the Hermes III accelerator technology at Sandia, we have a good basis for the cost estimate of $633M construction cost for a 23 million joule LMF--the lowest cost and the highest energy option being considered by DOE for the Laboratory Microfusion Facility.

Hermes III is a new and very reliable particle accelerator produced at Sandia National Laboratories after a successful technology development program with Sandia and Pulsed Sciences, Inc., of Titan Technologies, who were sponsored by the Defense Nuclear Agency.

The existence of Hermes III is a major boon to the lithium ion option for the Laboratory Microfusion Facility. Hermes III was built as the latest gamma ray simulator for the US weapons program. It is complete and reliably operates today as a cost center at Sandia. This year we discovered that it can be converted into a pre-prototype of the Laboratory Microfusion Facility module to develop the power generation, compression, transport, and focusing.

The light ion approach has the lowest projected cost for fusion energy production.

Although the Laboratory Microfusion Facility is primarily a military facility for simulating the effects of Soviet nuclear defenses against our strategic assets and for developing weapon physics, it is also a step to fusion energy. This year the Karlsruhe Center for Nuclear Research in the Federal Republic of Germany completed a study with the University of Wisconsin and others on the potential of this lithium ion approach for power production. They found that the high efficiency and low cost of this approach make it the lowest capital cost fusion option. The small size (330 MWe) for economical power production should make it relatively attractive to commercial power companies.



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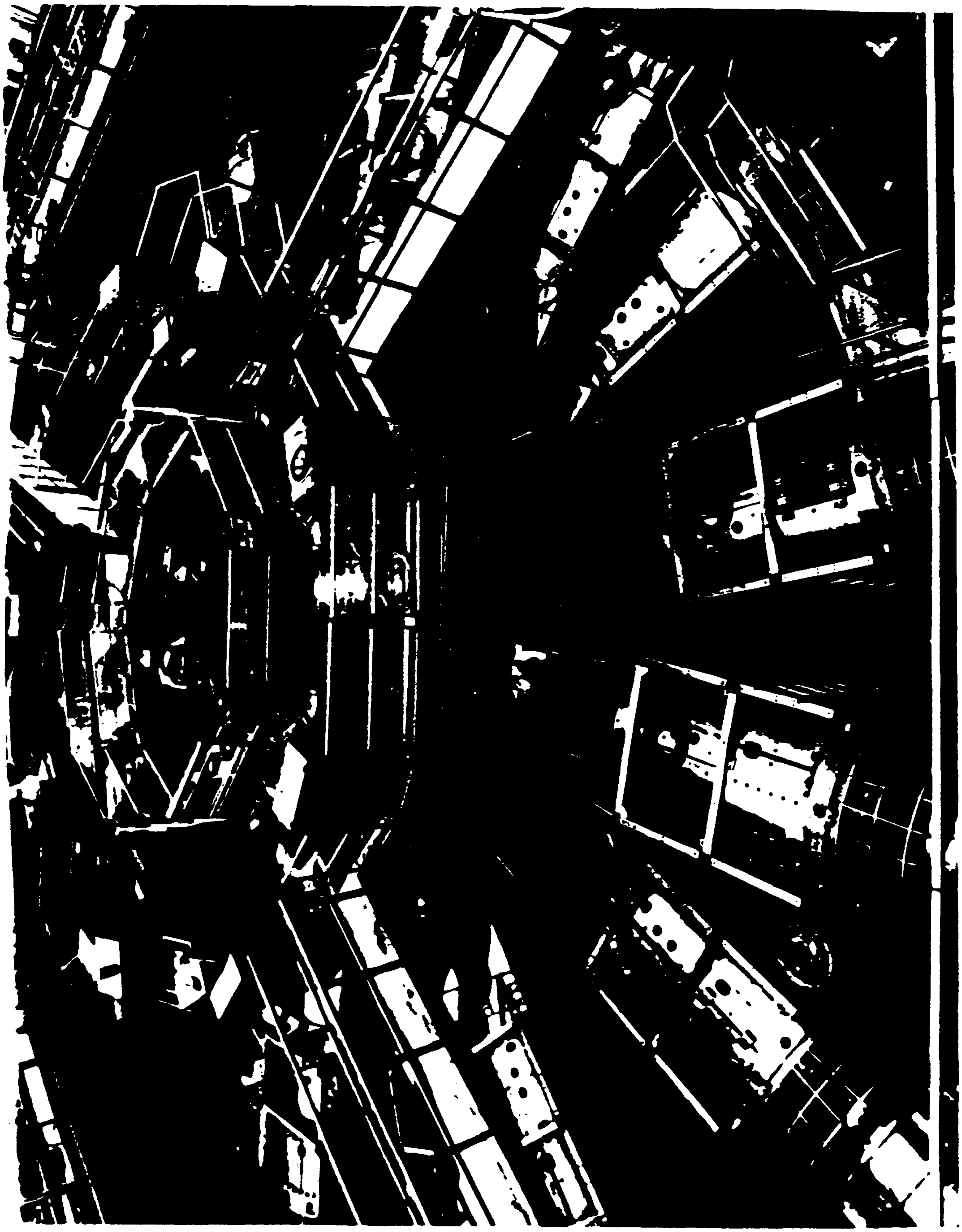
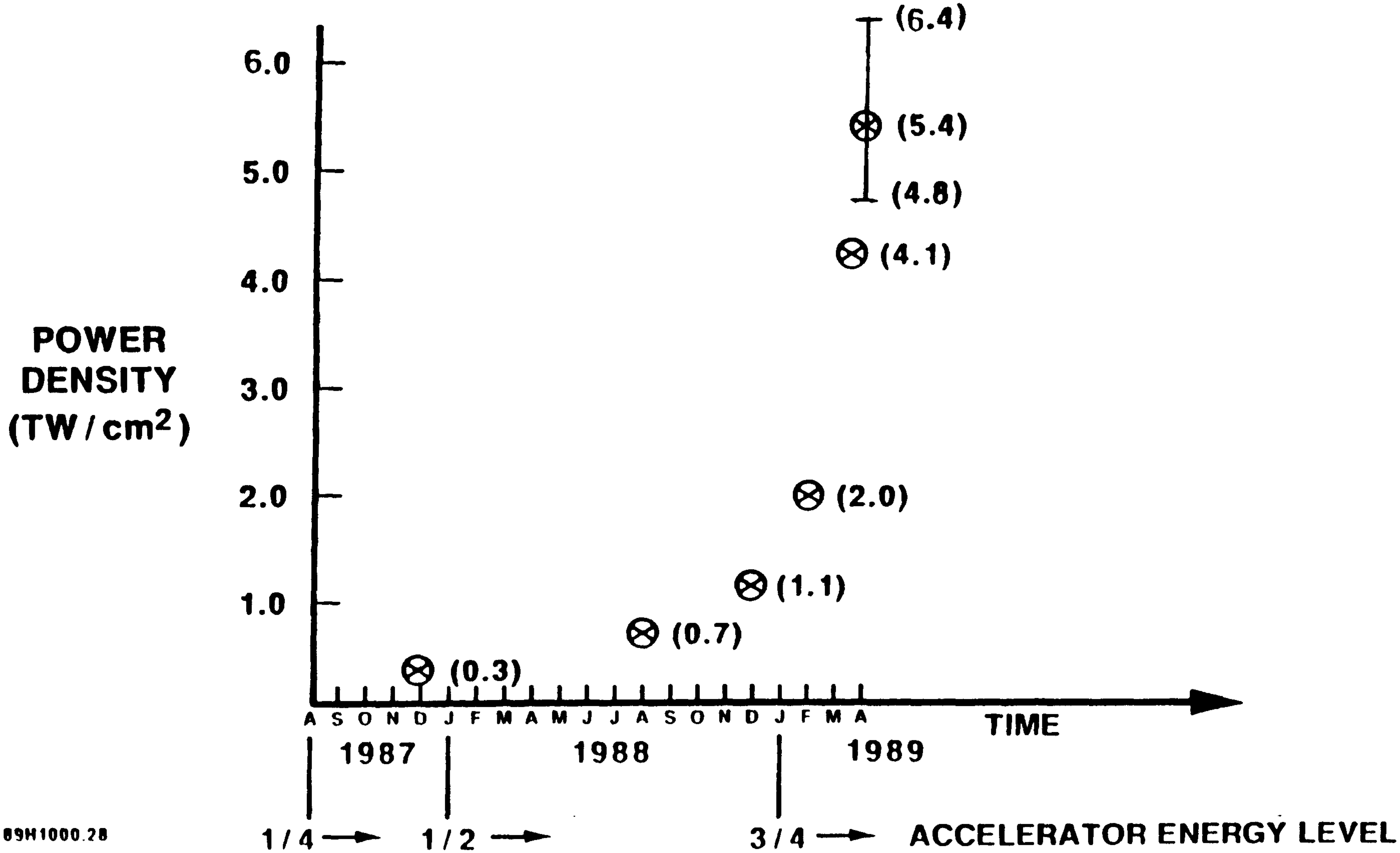


RECENT EXPERIMENTS SHOW INCREASING POWER DENSITY ON A 6-mm-DIAMETER SPHERICAL TARGET



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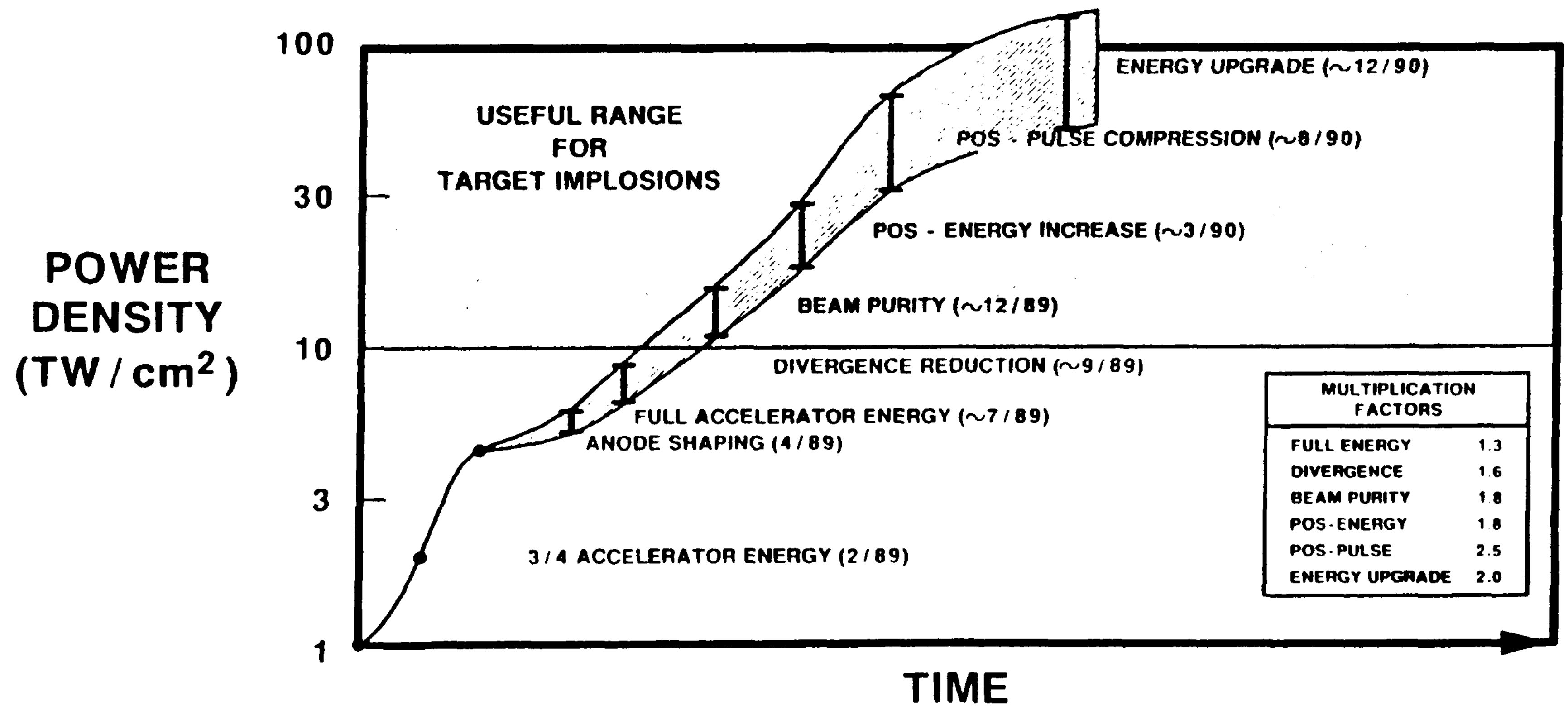
INTEGRATED EXPERIMENTS WILL MAKE PBFA II A POWERFUL DRIVER FOR TARGET IMPLOSIONS AT 10 - 100 TW/cm^2



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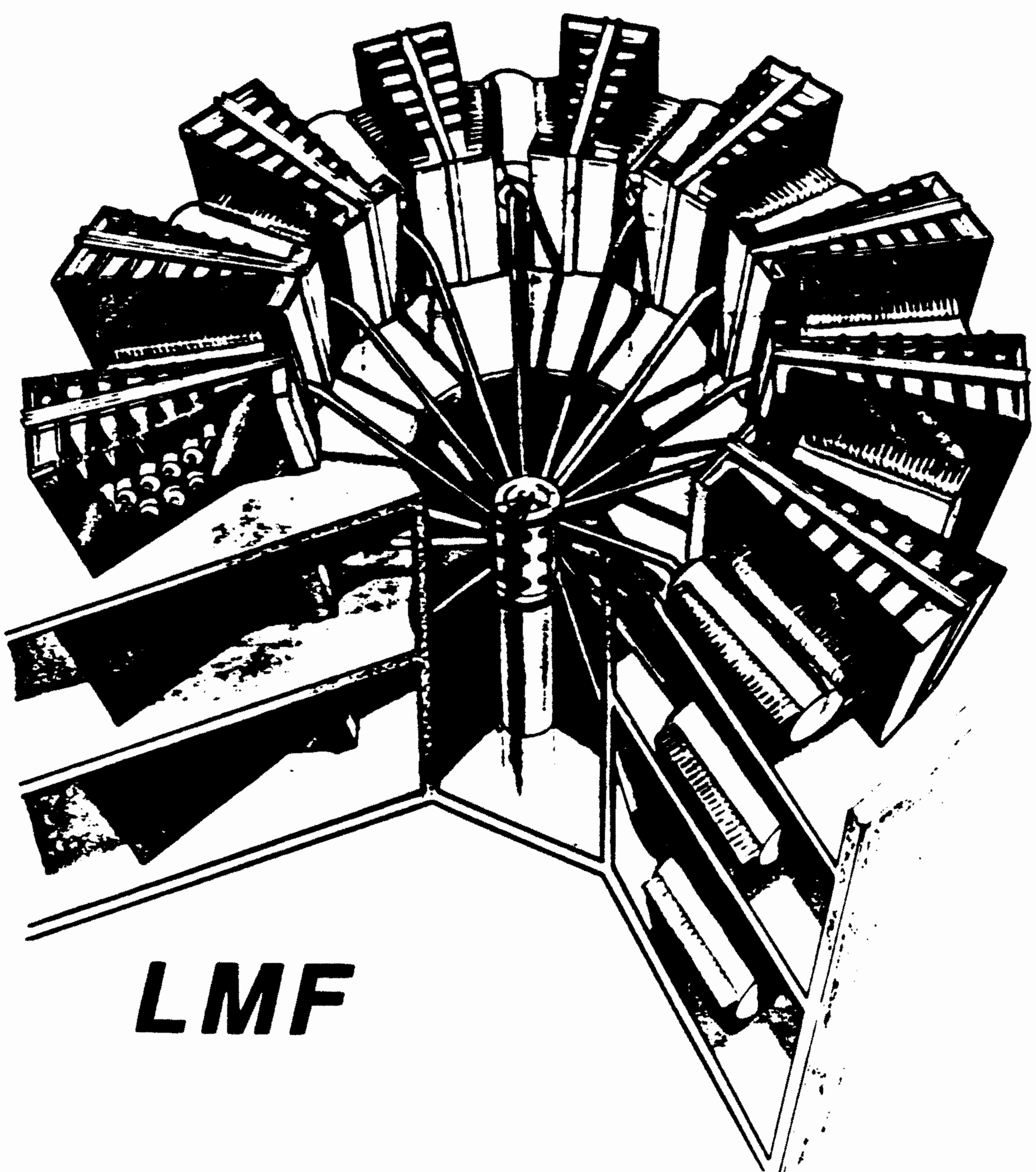
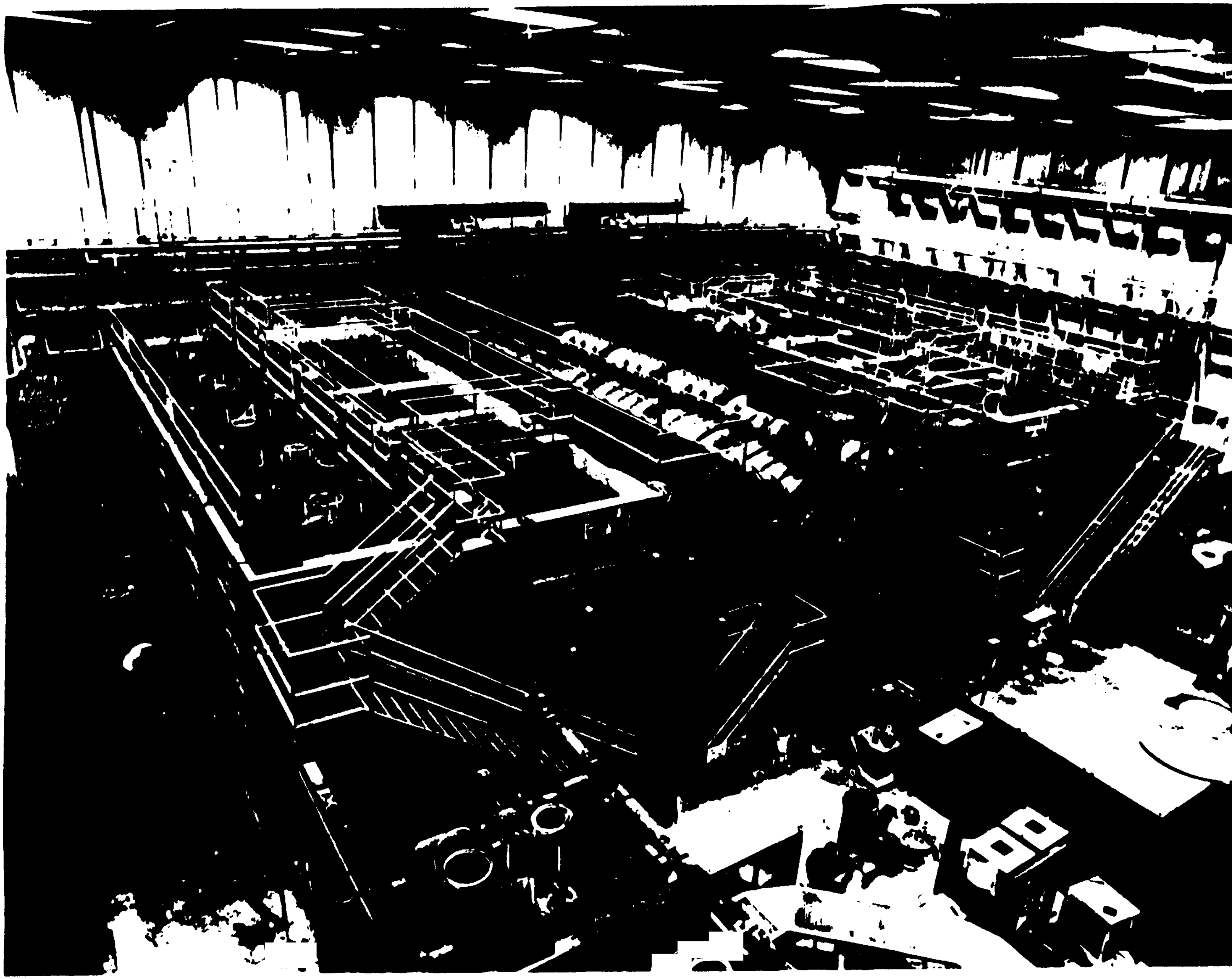
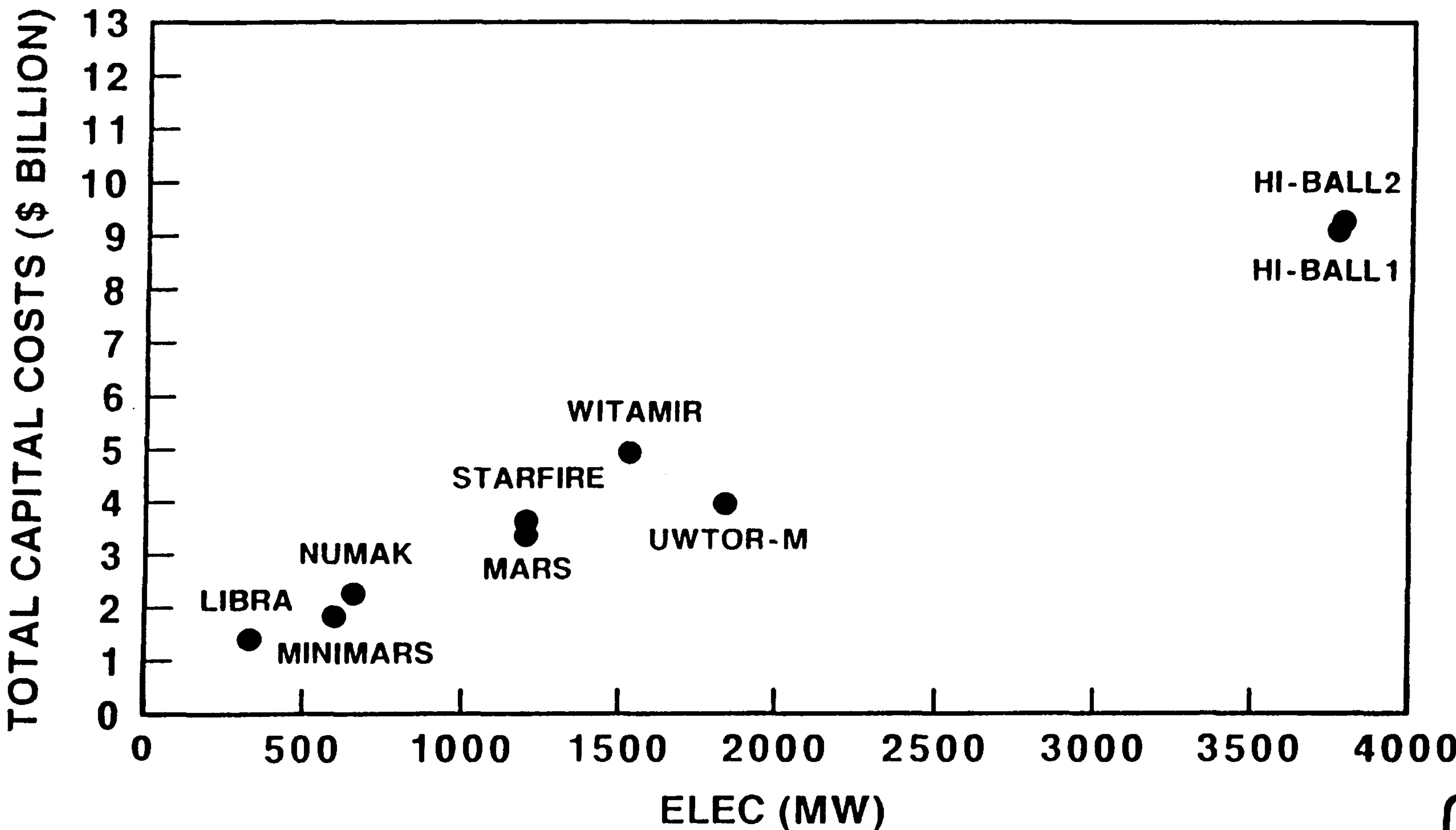


LMF



LIGHT ION DRIVEN INERTIAL FUSION HAS LOWEST CAPITAL COST



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