HBAR Technologies, LLC

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Commercial Production and Use of Antiprotons

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(on Sabbatical from Fermilab)

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Public Perception of Antimatter

- Star Trek, 1968 “What about Lazarus”

“If they touch, the entire universe will be annihilated”

- Star Trek, 1969 “Doomsday Machine”

“It cut up the planet with a force beam … an antiproton beam, absolutely pure antiproton”

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Public Perception (cont.)

- Star Trek, 1969
  "Obsession"

"The blast will tear away half of the planet's atmosphere"

- Star Trek: TNG, 1992
  "Time Loop"

"We are venting drive plasma … losing antimatter containment … core breach imminent … all hands abandon ship … kaboom"

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From Fiction to Reality

Technical History

- There have been studies on the use of antiprotons in the past. For example, the U.S. Air Force studied antimatter propulsion.
- There is an individual in the U.S. who claims that comets are in fact composed of antimatter (see www.matter-antimatter.com)
- Moving forward with a realistic and sincere commercialization plan requires that the scientific method be scrupulously applied.

Legal Reality

- There are people in the U.S. who make money by claiming ownership of ideas … intellectual property and trade secrets.
- Loma Linda holds the patent on synchrotrons.
- Penn State University hold the patent on portable Penning traps.
- A group of people are attempting to prevent this talk. They claim ownership of antiproton generation, storage, distribution, and most medical applications.

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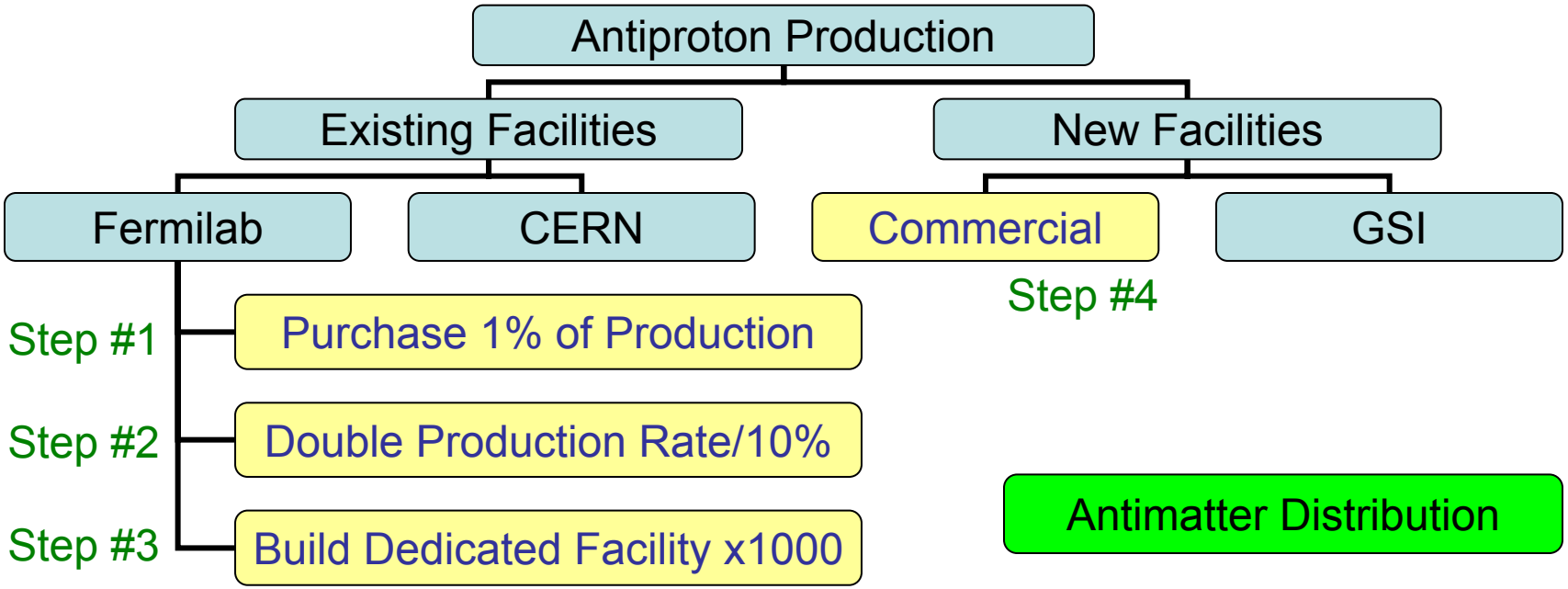
Antiproton Production



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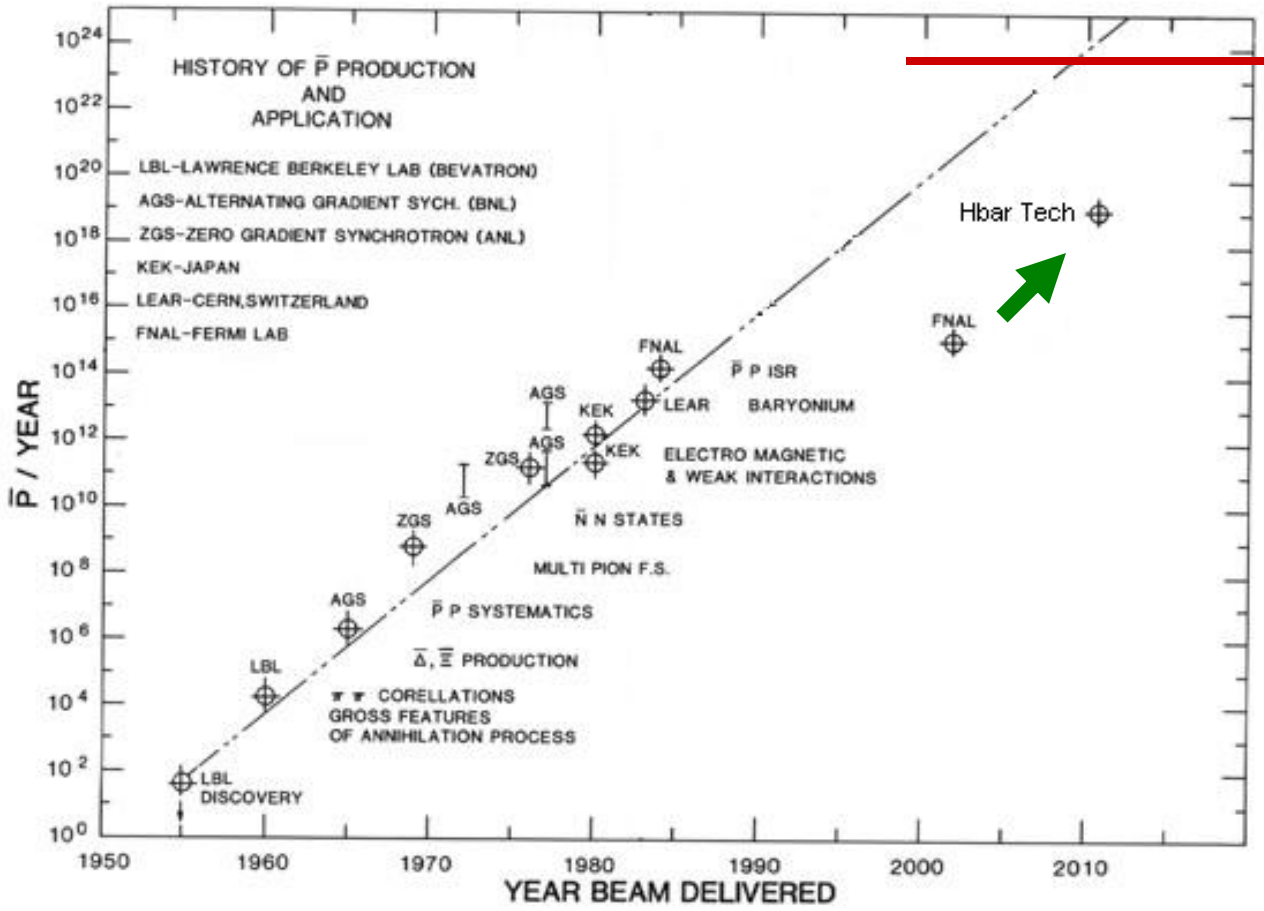
History of Antiproton Generation



Avogadro Number = 1 mole

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Antiproton Production @ Fermilab

- Present: 10^{11} antiprotons/hour for 4500 hours per year
- Present: 27.4 M$/year for purchase of all antiprotons
- Near Future: Agreement to purchase 1% of Fermilab production for an annual cost of 274 k$, plus cost of construction, utilities, and safety oversight of the Hbar Technologies research facility on the Fermilab site.
- Near Future: Fermilab and Hbar Technologies are working to double this antiproton production rate.
- 2-3 Years: As our appetite for antiprotons increases, we will negotiate for a higher fraction of antiprotons.

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Hbar Technologies Facility

The concept is to extract antiprotons out of the Main Injector, using the proton injection transfer line and associated kickers and Lambertson magnet.

A dedicated carrier pipe (0.6 m diameter) has been installed to carry the antiprotons up a transfer line to a near-future research facility.

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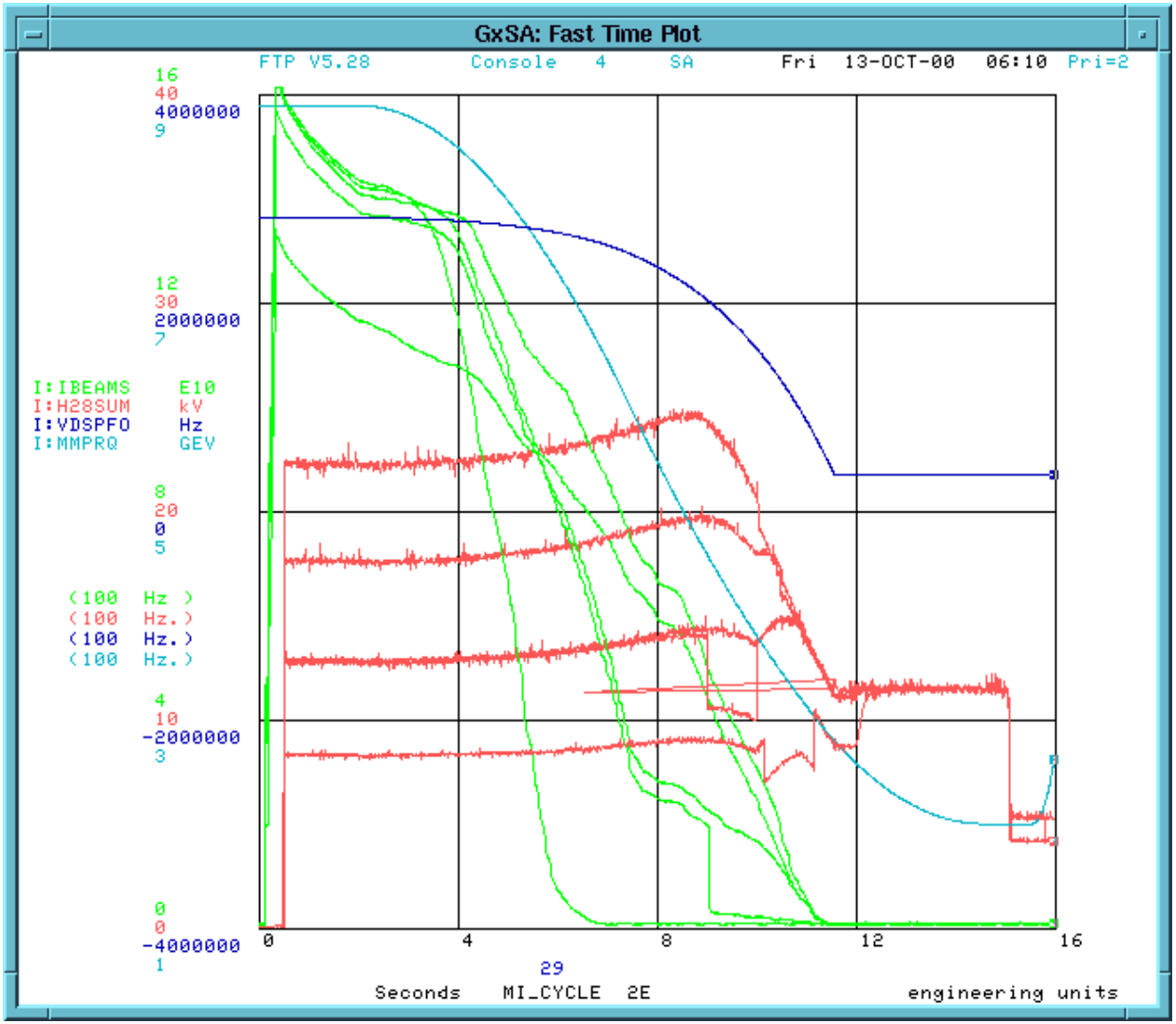
Fermilab Main Injector Deceleration

We will use the new Main Injector to decelerate antiprotons to as low as 250 MeV (0.73 GeV/c).

In October 2000 protons were decelerated in the Main Injector to 3 GeV/c with very little effort.

Beam Loss was due to insufficient RF bucket area.



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Dedicated Antiproton Production

1) Build a 120 GeV/c Stretcher Ring (500 bunches/spill)
2) Install a Thin Target (~100 passes/bunch)
   (N. Mokhov calculation x100)
3) Capture Antiprotons with a large acceptance optical system
4) Alternatively bunch rotate and decelerate into traps.

Picture of the Fermilab site just before construction of the Main Injector. Note that available land is plentiful for a dedicated 1-2 B$ antiproton facility.

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Antiproton Distribution

1) Lease the existing HiPAT trap from NASA.
2) Work with NASA to obtain required transportation permits.
3) Reduce the size of the support equipment and mass-produce next-generation traps after transportation tests.
4) Based on near-future results from CERN, develop a method to mass-produce antihydrogen.
5) Develop a portable antihydrogen bottle for transportation and distribution of antimatter.

Picture of the NASA HiPAT Penning trap This magnetic bottle was designed for the storage and transportation of 10^{12} antiprotons.

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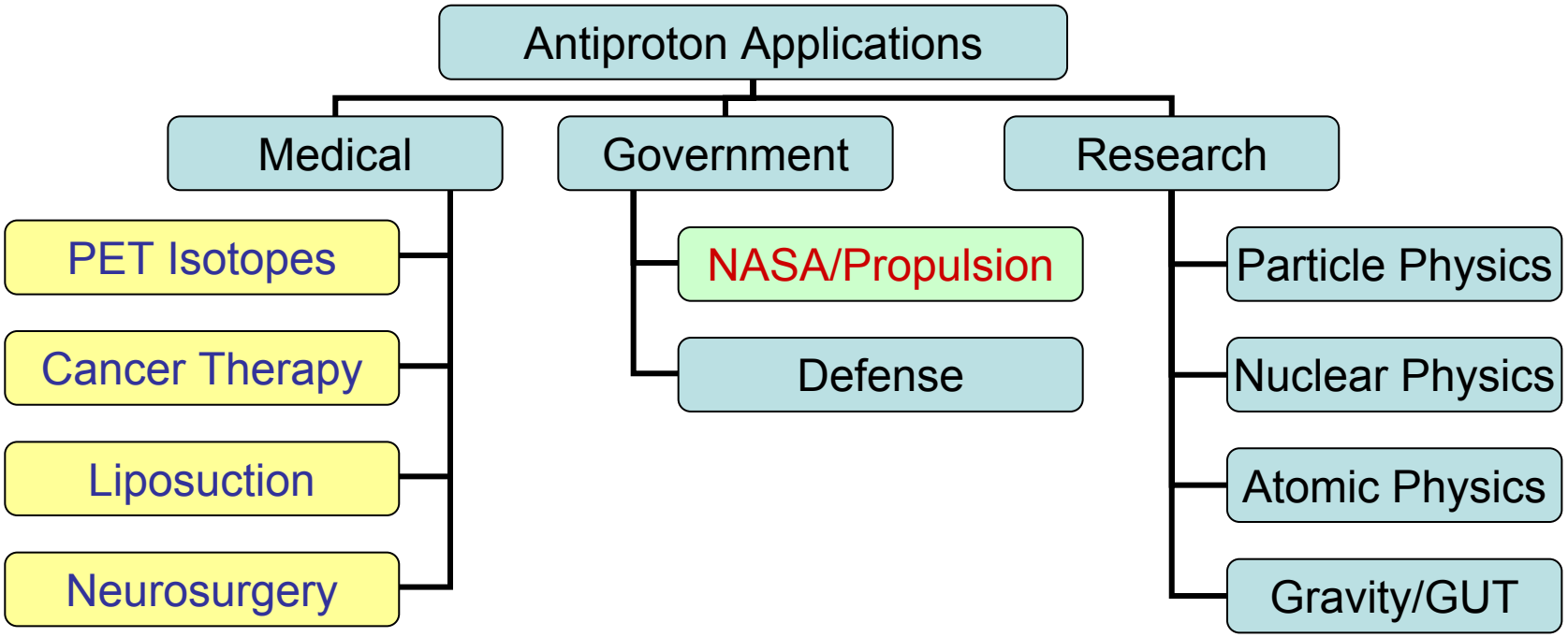
Antiproton Applications



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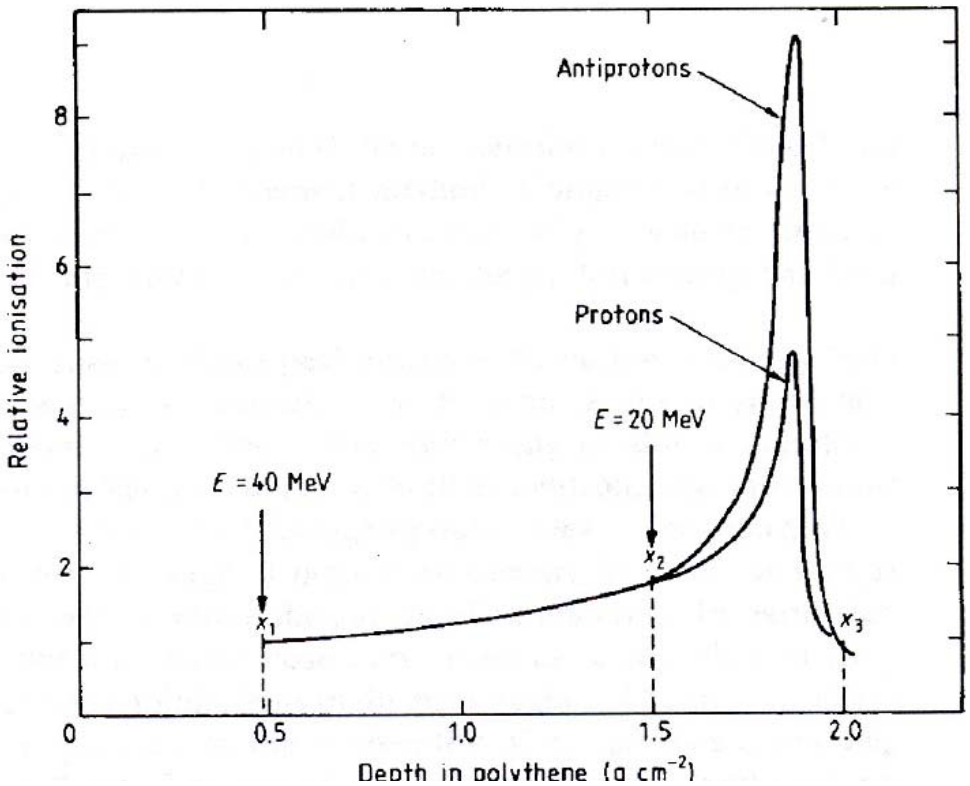
Antiproton Propagation

- Protons and antiprotons decelerate through material at the same rate.
- Most antiprotons annihilate at the end of their range through the material.
- Annihilation occurs against either a proton or neutron in an atomic nucleus, with approximately equal probability.



Sullivan, A.H., Phys. Med. Biol., Vol. 30, No. 12, pp. 1297-1303, 1985

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Antiproton Annihilation

- On average, the annihilation produces three 400 MeV charged pions and three gamma-rays (from neutral pion decay).
- On average, 1.25 pions are absorbed by the nucleus, causing the nucleus to recoil and fragment, carrying on average 150 MeV.
- For heavier elements, annihilation causes fission.
- In living tissue, neutron annihilation usually produces PET isotopes.

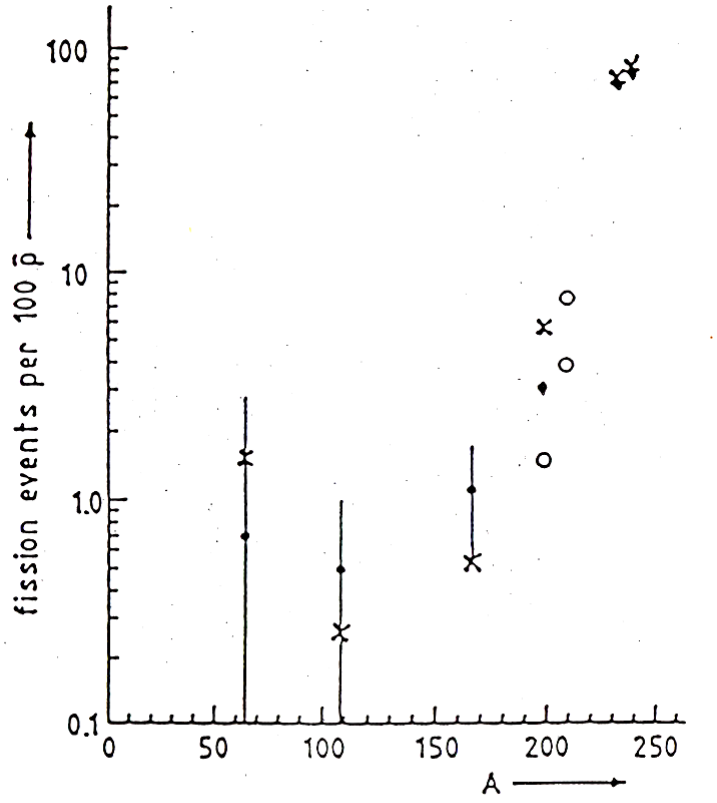

Fig. 3. Absolute fission probabilities for Cu, Ag, Ho, Au, ^{208}Pb, Bi, Th and U targets [6].

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Antiproton PET Isotope Generation

Isotope	Half Life (minutes)	Radiopharmaceutical	Diagnostic Use	Contamination (proton annihiltn)
C-11	20	C-11 methylspiperone	dopamine binding	C-12 to B-11
		C-11 acetate	cardiac metabolism	
		C-11 methionine	amino acid metabolism	
N-13	10	N-13 ammonia	cardiac blood flow	N-14 to C-13
O-15	2	O-15 water	brain blood flow	O-16 to N-15
F-18	110	F-18 (FDG) 2-deoxy-2 fluoro-D-glucose	glucose metabolism	F-18 to O-18

Hypothesis: 10^{10} antiprotons are needed per imaging session.

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Killing Cells with Antiprotons

- Antiproton annihilation generates heavy ions which deposit much more ionization energy in cells (High LET) as compared to x-rays or protons (Low LET).
- Low LET radiation is not very effective against dormant (non-reproducing) or hypoxic (oxygen starved) cells. For this reason treatments using low LET radiation requires weeks of exposures.
- Hypothesis: Because antiprotons are low LET entering the body, the amount of damage to healthy tissue is expected to be dramatically lower, and the number of treatments (fractions) is also expected to be much smaller.
- In the near future Hbar Technologies will be exposing a variety of cells and tissues to antiprotons to determine if this hypothesis is correct.

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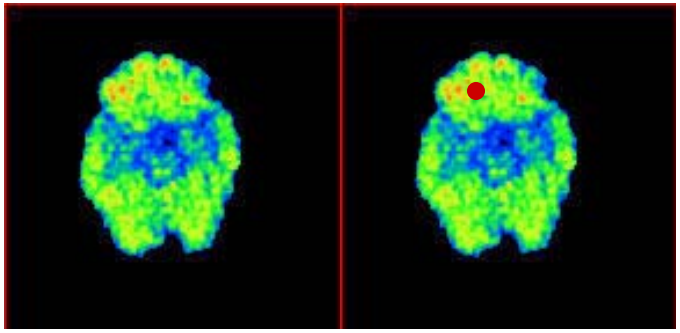
Antiproton Cancer Therapy



G. Krafft, GSI & S. Peggs, BNL

- As in the case of proton cancer therapy, a 250 MeV antiproton beam is needed.
- Because of the feature of 50% PET isotope generation it is proposed to treat patients positioned inside a PET scanner.
- Hypothesis: For a 10cc tumor, approximately 10^{10} antiprotons are required for full induction of apoptosis (programmed cell death).
- If one only targets patients who cannot be treated by conventional methods, the number of potential U.S. customers is 550,000/year.

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Antiproton Liposuction

From an economic point of view, Hollywood and the rest of southern California could probably consume the entire antiproton production capacity of the planet. What a waste!

- Traditional liposuction is a remarkably risky yet voluntary medical procedure which thousands of people undergo every year.
- An alternative method that is non-invasive, even if it involves radiation, is said to be preferable.
- Hypothesis: If antiprotons can kill cancer cells, why not other types of immortal cells such as fat (adipose) tissue?

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Antiproton Neurosurgery

- The economic impact of spinal injury and chronic back pain to the GNP of most industrialized nations is surprisingly large.
- An alternative non-invasive method of treatment for traditional surgery around the spinal column is desired by the medical community.
- Hypothesis: If antiprotons can kill cancer cells, why not other types of immortal cells such as cartilage and spinal disks?
- The market for this antiproton application could be larger than all other combined (with the exception of liposuction).

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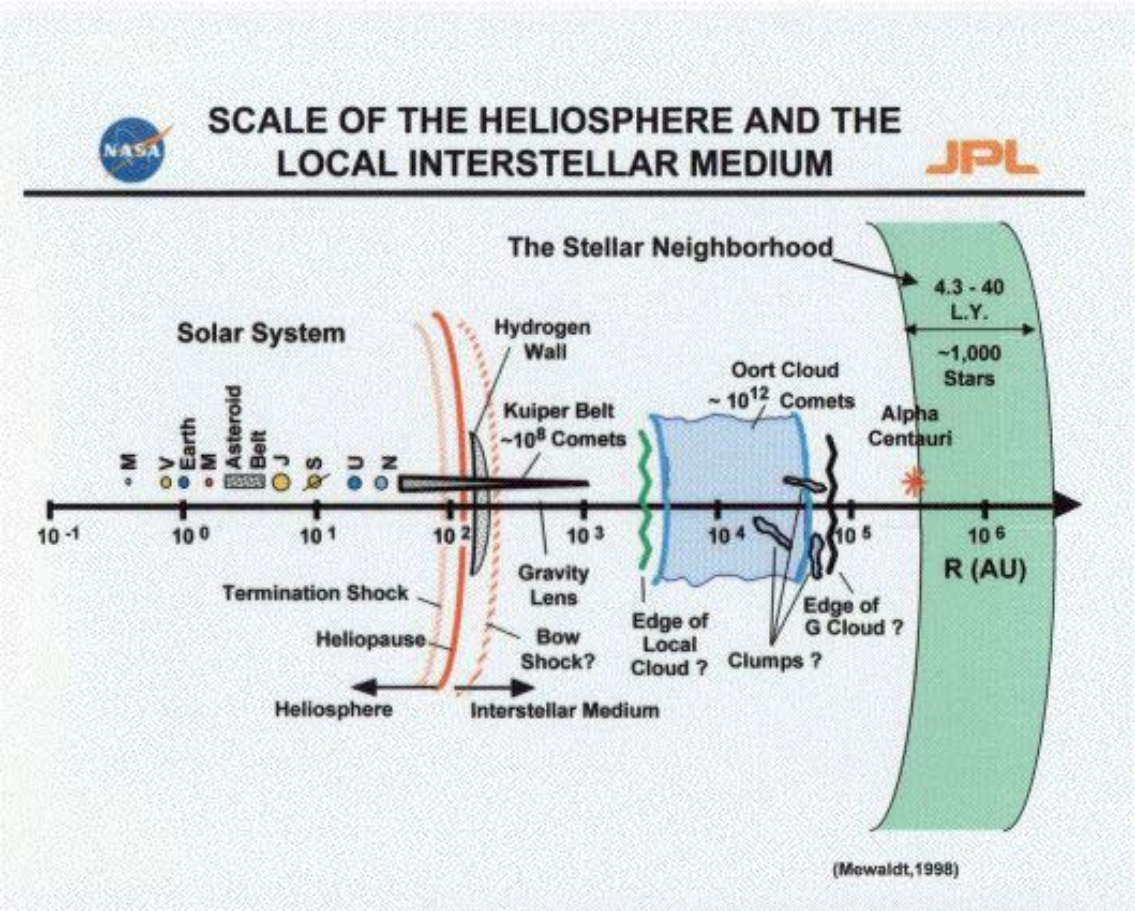
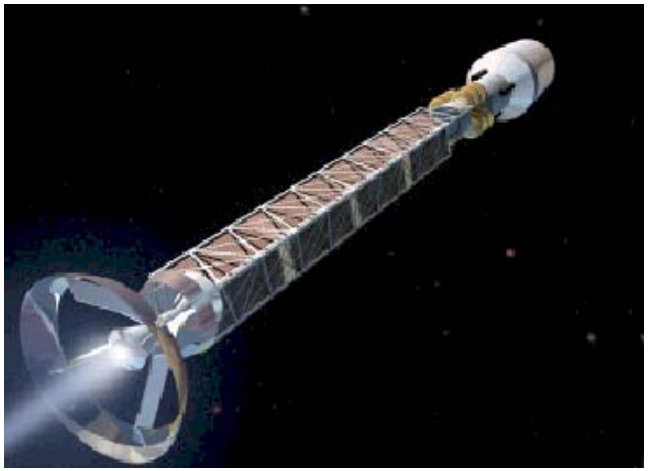
Antimatter for Propulsion





NASA has plans for a series of unmanned missions outside of the solar system starting in 20-30 years. With a requirement of reaching their destination in under 40 years, antimatter based propulsion is required.

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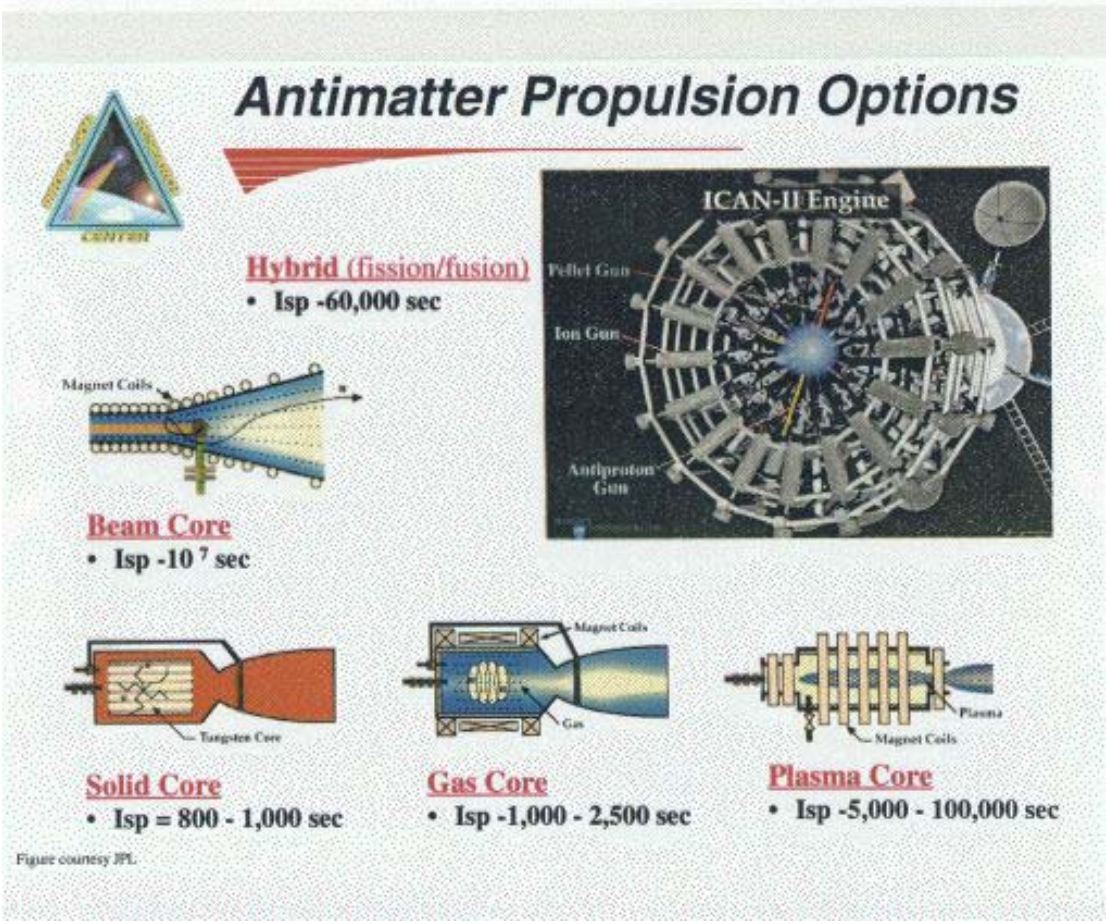
Antimatter Engine Concepts



- Isp is the number of seconds an amount of fuel can generate enough thrust to levitate itself against gravity (assuming no other mass, such as payload and the engine itself).
- Note that traditional chemical rockets has an Isp of 300 seconds, whereas some antimatter concepts have an Isp of over 30,000 seconds!

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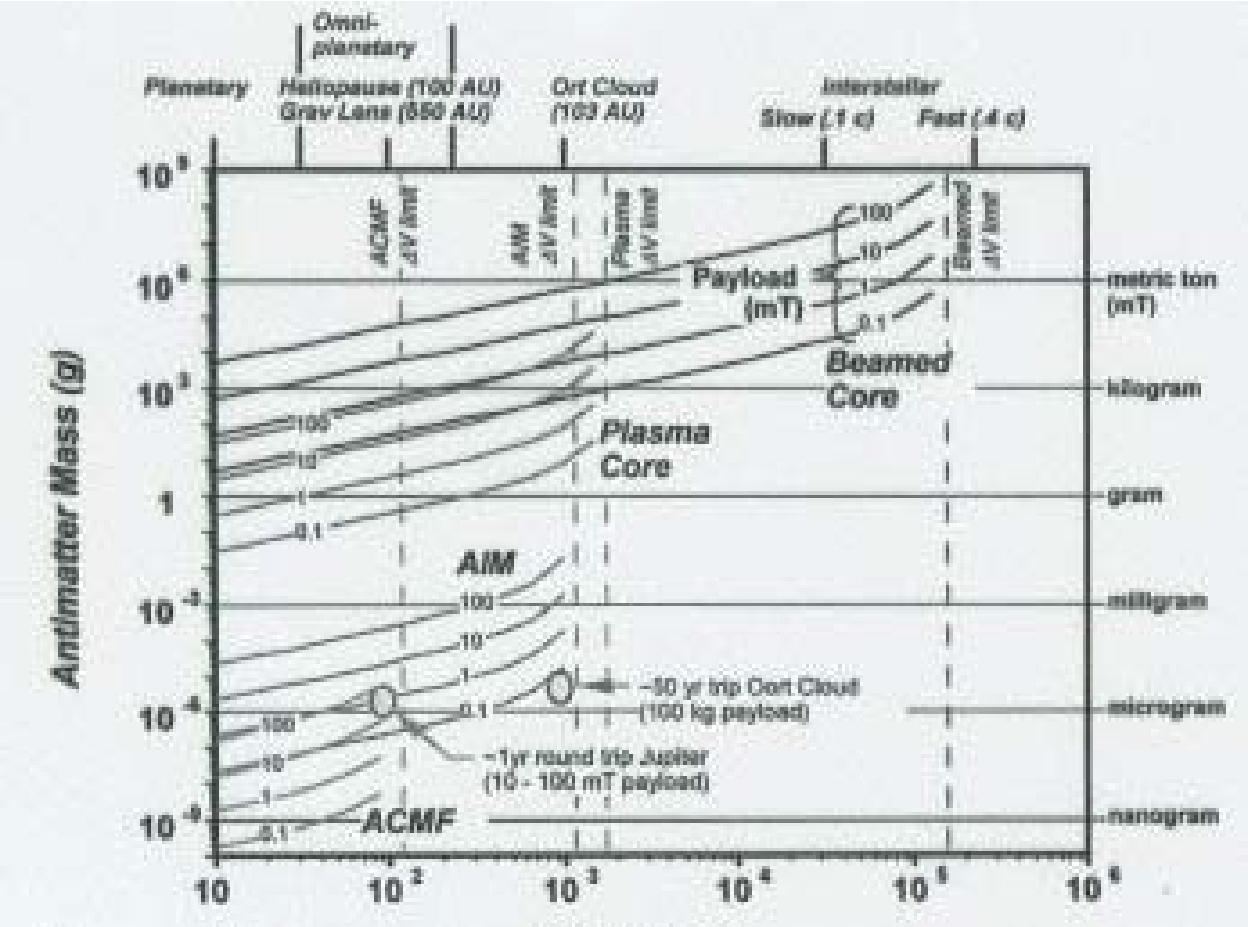
Antimatter Fuel Consumption



- Fermilab will produce about a nanogram of antimatter this year.
- With the dedicated Hbar Technologies production facility, it may be possible to achieve a few micrograms per year.
- Today we have enough to only perform engine R&D.

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Conclusions

- Rigorous scientific experimentation indicates that the production rate of antiprotons is now sufficient to at least perform proof-of-principle tests of commercial antiproton applications.
- It is imperative that these tests be performed in the next few years, as planet-wide antiproton production is scheduled to terminate before 2010 (unless the new GSI facility is approved). The cost to restart antiproton production in the future, only to perform these tests, would be too costly given the chance that none of these potential commercial applications may prove to be technically valid or economically feasible.

The Adventure has Only Begun!