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SEARCHING FOR ANTIPROTON DECAY AT THE FERMILAB ANTIPROTON ACCUMULATOR [1]

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Presented on behalf of the APEX Collaboration

Abstract

This paper describes an experimental search for antiproton decay at the Fermilab Antiproton Accumulator. The E868 (APEX) experimental setup is described. The APEX data is expected to be sensitive to antiproton decay if the antiproton lifetimes is less than a few times 100 000 years.

1 Introduction

There has been a considerable experimental effort devoted to the search for proton decay. As a result we know that the proton lifetime $\tau_p \geq O(10^{32})$ years. The CPT theorem requires that the proton and $\overline{p}$ lifetimes are equal. A search for $\overline{p}$ decay with a short lifetime ($\tau_{\overline{p}} < \tau_p$) tests the CPT theorem and the intrinsic stability of antimatter. Although we have no deep theoretical reason to suspect CPT violation we note that $\overline{p}$ decay with a short lifetime would provide a natural although unconventional explanation for baryogenesis.
In the past there have been a number of experimental searches for the decay of antiprotons stored in ion traps or storage rings. The most sensitive results to date are listed in Table 1.

[1]Presented at the International Europhysics Conference on High Energy Physics, Brussels, Belgium, 27 July - 2 August 1995

Table 1: Published experimental limits on lifetime / branching ratio for antiproton decay.

Experiment	Mode	τ/BR Limit	Reference
Ion Trap	inclusive	3.4 months	Galbrielse et al. [2]
T861	$\overline{p} \rightarrow e^-\gamma$	1848 years	Geer et al. [1]
	$\overline{p} \rightarrow e^-\pi^0$	554 years	Geer et al. [1]
	$\overline{p} \rightarrow e^-\eta$	171 years	Geer et al. [1]
	$\overline{p} \rightarrow e^-K^0_S$	29 years	Geer et al. [1]
	$\overline{p} \rightarrow e^-K^0_L$	9 years	Geer et al. [1]

In particular, the APEX test experiment (T861) at the Fermilab Antiproton Accumulator achieved a sensitivity of order 1000 years for some decay modes [1]. Experience gained in the T861 experiment was used to design an upgraded experiment (APEX) with the goal of improving on the T861 sensitivity by about a factor of 1000 and extending the search to include many additional possible decay modes. The APEX experiment was proposed in September 1992, approved in spring 1993, installed in March 1995, and took data between April and July 1995.

2 The APEX Experimental Setup

The APEX experiment took data at the Fermilab Antiproton Accumulator operating at 8.9 GeV/c with typical beam currents of 100 mA (corresponding to 10^{12} stored antiprotons). The detector, which was located downstream of a 15.9 m straight section in the 474 m circumference accumulator ring, was designed to search for two-body decay modes with an electron in the final state. The experimental setup (see Fig. 1) consists of:

(i) Decay tank. A 3.7 m long evacuated decay tank operated at 10^{-11} Torr. The downstream end of the tank is a 1 m diameter cylinder with a thin stainless steel window.

(ii) Veto counters. Upstream of the tank, 4 horizontal and 4 vertical scintillation counters are arranged around the beampipe in a 1×1 m^2 plane to veto tracks from upstream interactions.

(iii) Electromagnetic calorimeter. Lead-scintillator sampling calorimeter consisting of 144 rectangular modules arranged in a 13×13 array with the 6 modules at each of the 4

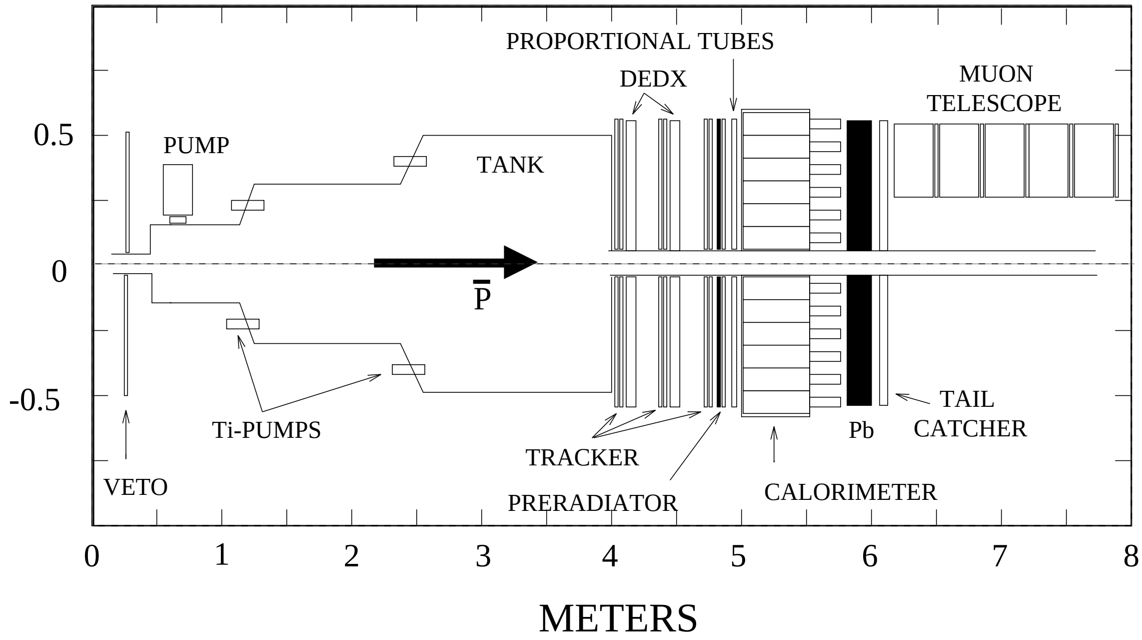

Figure 1: Schematic of the APEX detector.

corners missing, and the central module absent to enable passage of the beam pipe. The modules are 17.7 radiation lengths deep and have transverse dimensions of 10×10 cm^2. Further details can be found in ref. [3].

(iv) Scintillating fiber tracker. Between the tank window and the calorimeter there are three vertical and three horizontal planes of 2 mm scintillating fibers. Each plane consists of 768 fibers read out by 4 Hamamatsu multianode photomultipliers.

(v) dE/dx and preradiator counters. Between the tank window and the calorimeter there are three planes of scintillation counters. The first two planes are designed to measure the dE/dx of traversing charged particles, and determine how many charged particles are in the event. The third plane is downstream of a 2 radiation lengths thick lead radiator, and is designed to assist in electron-hadron discrimination. Each scintillator plane is constructed from four $1.3 \times 50 \times 100$ cm^3 counters read out at both ends. Two of the counters are hung vertically on either side of the beampipe, and two counters are hung horizontally, one above and one below the beampipe.

(vi) Proportional tubes. Downstream of the preradiator there are 56 horizontal and 56 vertical proportion tubes designed to provide position information for photon showers. The tubes have a 1×1 square inch cross-section.

(vii) Tail catcher to aid electron-hadron discrimination. Downstream of the calorimeter there is a 20 cm deep lead wall followed by horizontal and vertical planes of scintillation counters.

(viii) Muon telescope. Finally, downstream of the tail catcher a 30×30 cm^2 telescope provides muon identification within a limited acceptance. The telescope consists of 5 modules, each module having 30 cm of iron absorber followed by a scintillation counter.

3 Data Sample and Future Prospects

The APEX data sample is currently being analysed. A measure of the potential sensitivity of the experiment is given by the antiproton current in the accumulator integrated over the data taking time. The APEX data sample corresponds to 26 000 mA-hours. This means that if the $\overline{p}$ lifetime was 2×10^9 years then on average one $\overline{p}$ should have decayed somewhere in the accumulator during our data taking. To obtain the sensitivity of the data sample we need to know the overall efficiency of the experiment. The decay tank occupies about 1% of the accumulator ring. Other geometrical factors together with trigger and selection efficiencies are expected to result in an overall efficiency of about 0.1%. Hence the single event sensitivity of the data sample is expected to be of order 10^6 years.
The results of past $\overline{p}$ decay searches, present expectations, and future hopes are summarized in Fig. 2. In the future we can imagine a second generation experiment (APEX II) with a single event sensitivity of order 10^8 years, and a correspondingly improved background rejection. At present there are plans to upgrade the Fermilab antiproton accumulator that may or may not be compatible with a future APEX II. If APEX II proves to be practical then in a few years we might be able to find or exclude antiproton decay with lifetimes up to about 1% of the age of the universe !

Acknowledgments

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References

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[2] G. Galbrielse et al., Phys. Rev. Lett. 65, (1317) 1990.

[3] M. A. Hasan et al., Nucl. Instrum. Methods Phys. Res., Sect. A 295, 73 (1990).

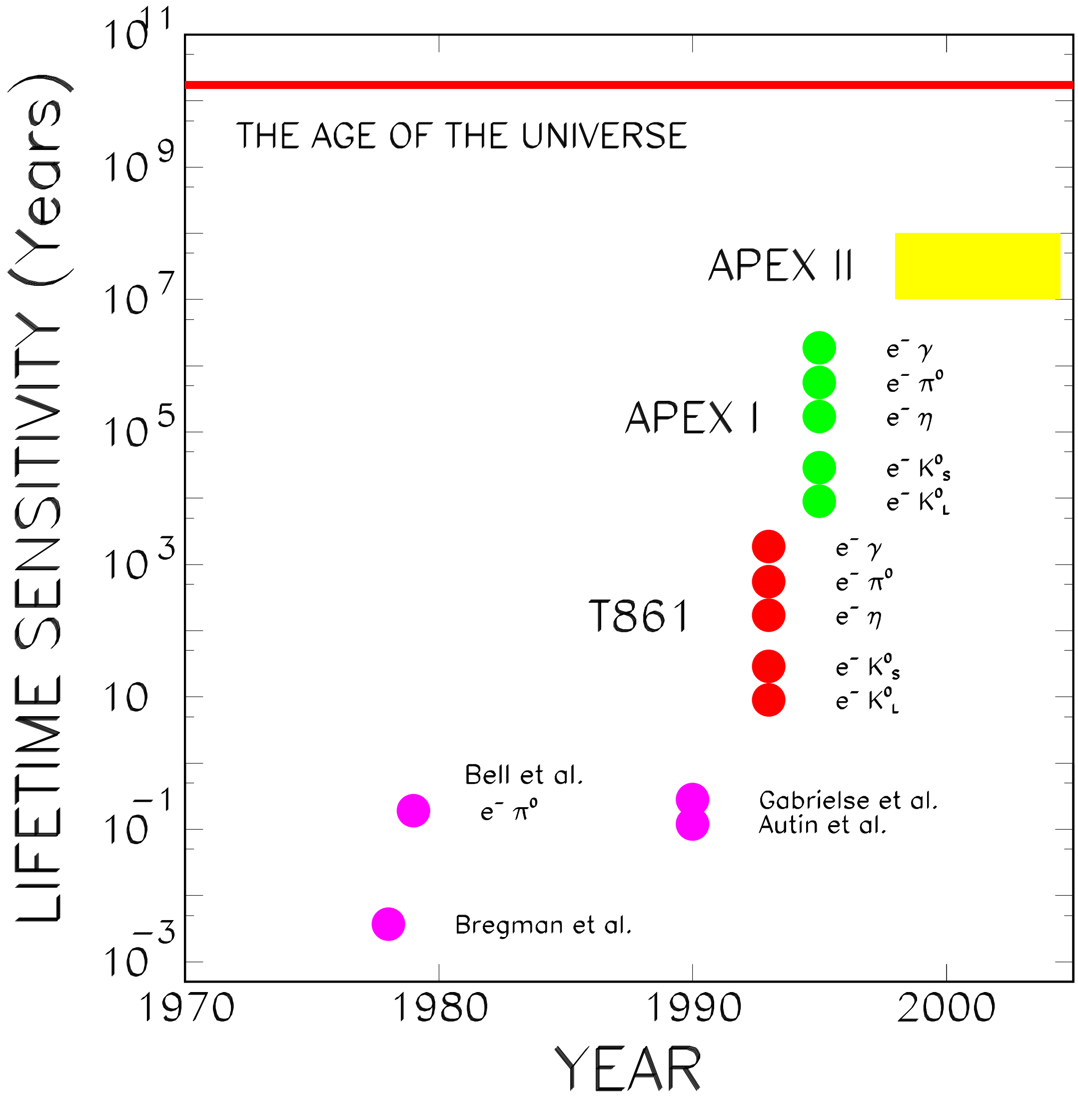

Figure 2: Past experimental results, present expectations (APEX), and future hopes (APEX II).