Continued Search for Anti-Hydrogen at LEAR/CERN

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Like in 1993 [1] a measurement parasitically to the PS202-experiment at LEAR/CERN was done in order to observe anti-hydrogen ($\overline{\mathrm{H}}^0$) production. The underlying process is the creation of an electron–positron pair ($\mathrm{e}^+\mathrm{e}^-$) during the exchange of two photons emitted by the beam anti-proton ($\overline{\mathrm{p}}$) and a target proton (p) [2] [3].

$$\overline{\mathrm{p}}\,\mathrm{p} \;\rightarrow\; \overline{\mathrm{p}}\,\mathrm{p}\,\mathrm{e}^+\mathrm{e}^- \;\rightarrow\; (\overline{\mathrm{p}}\mathrm{e}^+)\,\mathrm{p}\,\mathrm{e}^-$$

The e^+ – if it has the appropriate velocity – can be captured by the $\overline{\mathrm{p}}$ thus forming an $\overline{\mathrm{H}}^0$-atom, which leaves the accelerator through a hole in the next bending magnet. Behind this dipol – still in vacuum – the $\overline{\mathrm{H}}^0$ ionizes in an 30μ Al foil. The e^+ is stopped in a subsequent silicon-counter ($700\,\mu\mathrm{m}, 1200\,\mathrm{mm}^2$) leaving all of its kinetic energy while the $\overline{\mathrm{p}}$ due to its high energy crosses this and all following detectors, namely a second silicon-counter ($500\,\mu$m, $1200\,\mathrm{mm}^2$) and the scintillation counters (BC-404, 5 mm, $100\,\mathrm{cm}^2$) for time-of-flight measurement, inducing signals proportional to the individual energy losses. The e^+ annihilates in the silicon and the two 512 keV photons (γ) are detected in a surrounding six-fold segmented NaI-detector.

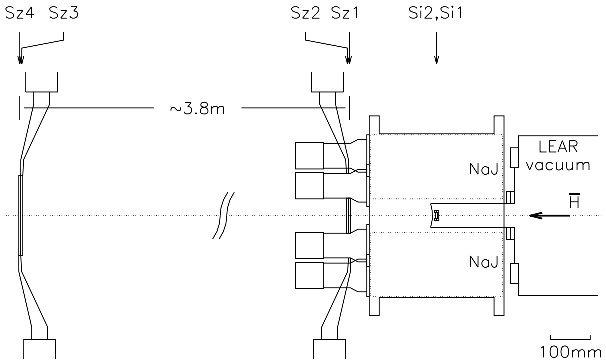

Figure 1: Experimental setup

The data analysis is based on following measured values: scintillator TDCs for time-of-flight and so velocity information from the $\mathrm{p}/\overline{\mathrm{p}}$, scintillator ADCs for velocity check via $(\mathrm{dE}/\mathrm{dx})_\mathrm{p}$, silicon ADC's for $(\mathrm{dE}/\mathrm{dx})_\mathrm{p} + \mathrm{T}_\mathrm{e}$ and $(\mathrm{dE}/\mathrm{dx})_\mathrm{p}$ resp. to ensure the existence of pe^- or $\overline{\mathrm{p}}\mathrm{e}^+$, and NaI ADCs for detection of the two e^+-annihilation γ's which then indicate at least the existence of the $\overline{\mathrm{p}}\mathrm{e}^+$-pair.

Data were taken during three weeks at different beam momenta: in steps of 20 from 1180 to 1280 MeV/c, in steps of 30 from 1315 to 1375 MeV/c, and at 1500, 1550 and 1800 MeV/c. The choice of these momenta was governed by the physics program of the PS202-experiment.

The time-of-flight spectrum in figure 2 consists of mainly two components: a peak at high velocity which is due to fast flying particles from $\overline{\mathrm{n}}$ induced reactions producing e.g. multiple pions, and a peak representing particles with velocities slightly slower than the beam itself. These particles are supposed to be p or $\overline{\mathrm{p}}$ mainly due to charge exchange reactions where a $\overline{\mathrm{n}}$ scatters at a n and a $\overline{\mathrm{p}}\mathrm{p}$-pair is produced. The other source of this type of events is the $\overline{\mathrm{H}}^0$-production.

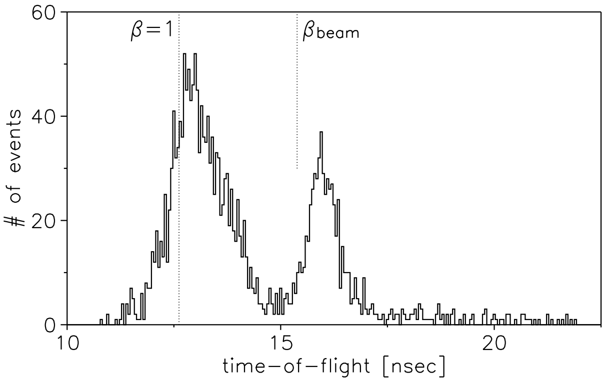

Figure 2: Time-of-flight spectrum at 1345 MeV/c

With the time-of-flight trigger 904,520 events were acquired. Applying several appropriate cuts with four standard deviations around the expected observables the following candidates remained: four events with a clean e^+-annihilation but no acceptable signals in the silicon counters, five events with a clean e^+-annihilation but time-of-flight and scintillator ADC values indicating multi pion events, and at least three events showing time-of-flight values in the expected range, consistent dE/dx measurements, silicon signals with the correct signal height for the $\overline{\mathrm{p}}\mathrm{e}^+$-pair from $\overline{\mathrm{H}}^0$, but no NaI-signature in opposite crystals which would indicate a e^+-annihilation doubtlessly. All six crystals would have to be summed up to fulfil the required $2 \times 512\,\mathrm{keV}$ signature. On the other hand, calibration measurements with a $^{22}\mathrm{Na}$-source have shown that the total efficiency, i.e. geometrical plus detection of the two γ's, is around 35 %.

In 1995 an improved setup will be installed which allows for particle identification using a magnetic separator system. Heavier nuclei will be used as a target to improve statistics since $\overline{\mathrm{H}}^0$-production cross section is proportional to $\mathrm{Z}^2_{\mathrm{target}}$.

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References:

[1] Annual Report 1993, Jül-2879 (1994) 75
[2] G.Baur, Phys.Lett. B 311 (1993) 343
[3] C.T.Munger et al., Phys.Rev. D49 (1994) 3228