Antihydrogen formation using a slow merge mixing scheme in ASACUSA's Cusp trap

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Introduction

The ASACUSA collaboration at CERN aims to perform measurements of the hyperfine structure of antihydrogen ($\bar{\text{H}}$).

To produce $\bar{\text{H}}$ using the 3-body recombination process, we slowly merged a positron (e^+) and an antiproton ($\bar{p}$) plasma in a Penning-Malmberg trap with a cusped magnetic field.

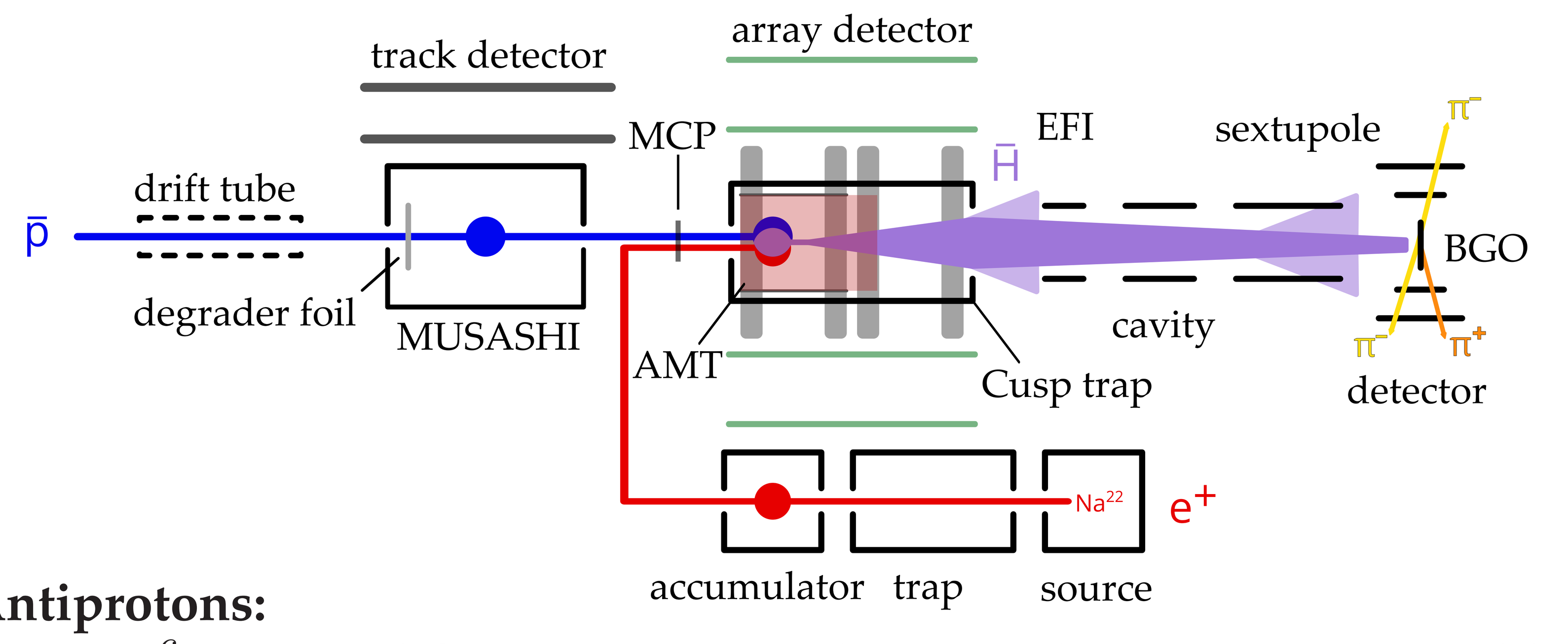
$$\bar{p} + e^+ + e^+ = \bar{\text{H}} + e^+$$

Main focus for the production of $\bar{\text{H}}$ in the ground state:

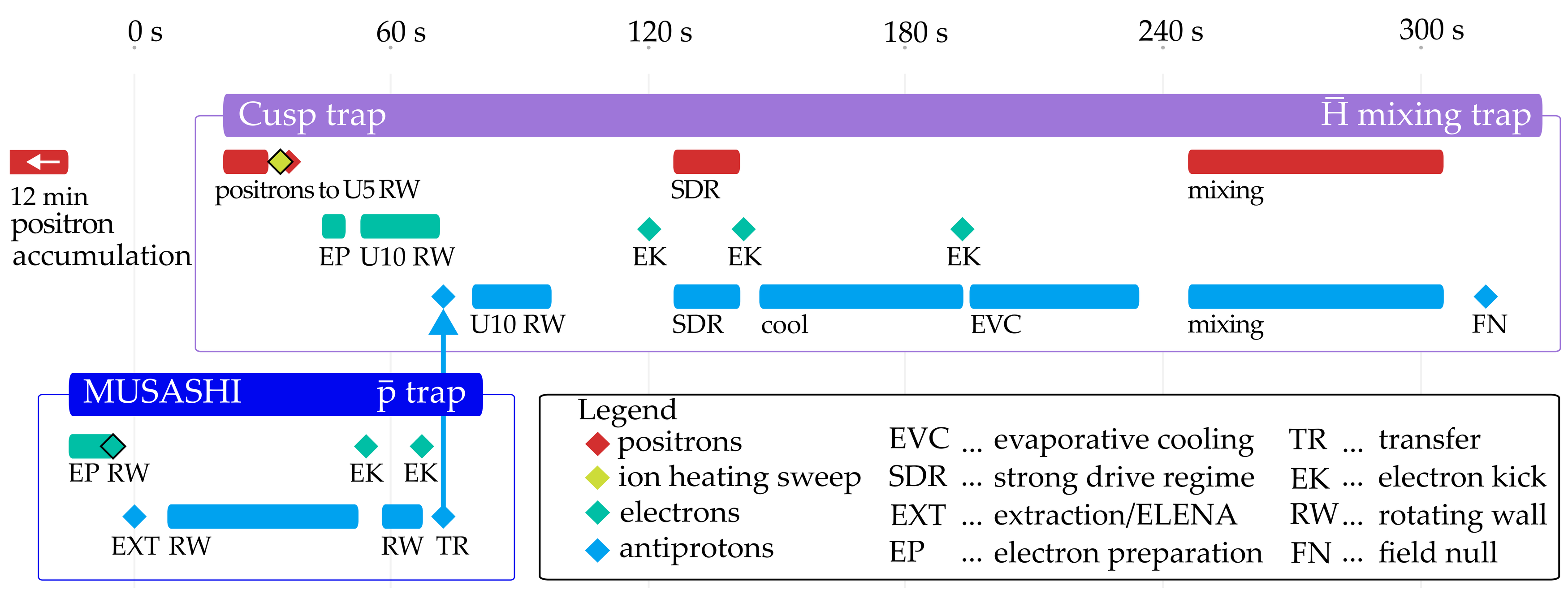
- the number of e^+ and $\bar{p}$
- the temperature of the plasma
- the spatial overlap of the plasma

We adjusted the rate at which the potential wells were merged from 0.1 s to 60 s and interrupted the mixing process at different stages to measure the space charge and temperature of the remaining plasma.

Experimental set-up



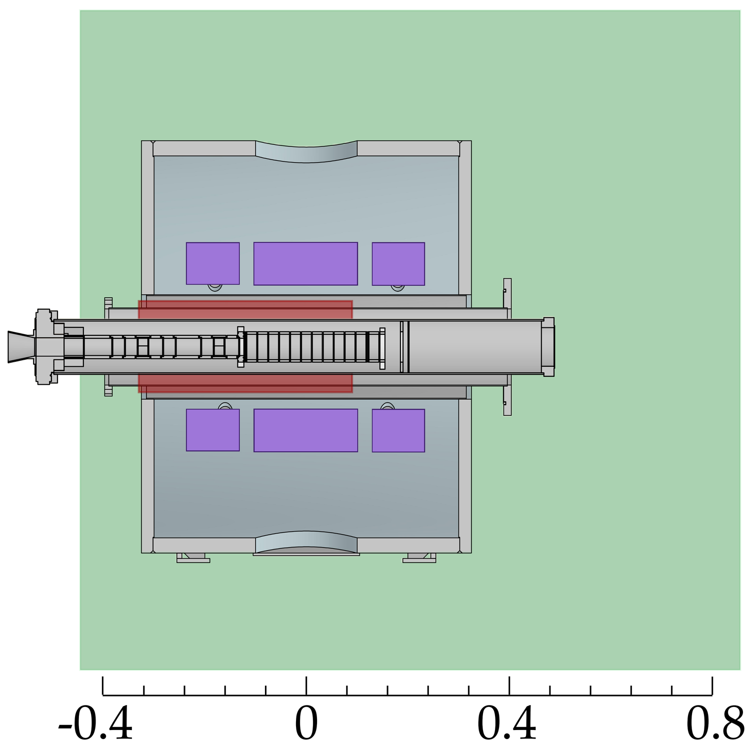
- **Antiprotons:** $\sim 7 \times 10^6$ extracted from ELENA at about 100 keV, are accelerated by a drift tube to 120 keV and trapped and cooled in the Penning-Malmberg trap MUSASHI.
- **Positrons:** produced by a Na^{22} source, trapped using a rare gas moderator and a buffer gas trap. Roughly every second the e^+ are then pulsed to the accumulator. Transfer of the "stacked" e^+ to the Cusp is done roughly every minute.

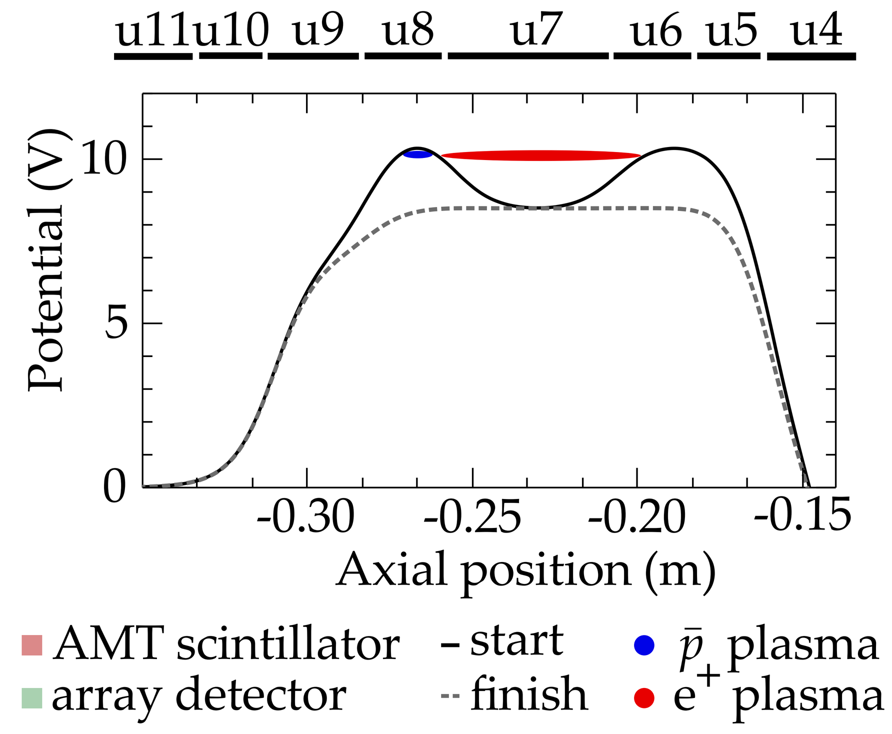


The $\bar{p}$ are trapped, cooled and compressed with e^- in MUSASHI, transferred into the Cusp trap, where this process is then repeated. The e^+ are re-compressed in the SDR with a 200 kHz frequency and only cyclotron cooled. Properties of the plasma before mixing:

Species	N (10^6)	ϕ (V)	T (K)	R (mm)	n (cm^{-3})	λ_D (mm)
e^+	4.0	1.6	25	0.4	1.6×10^8	0.03
$\bar{p}$	0.5	0.4	100	0.8	2.0×10^7	0.15

Results

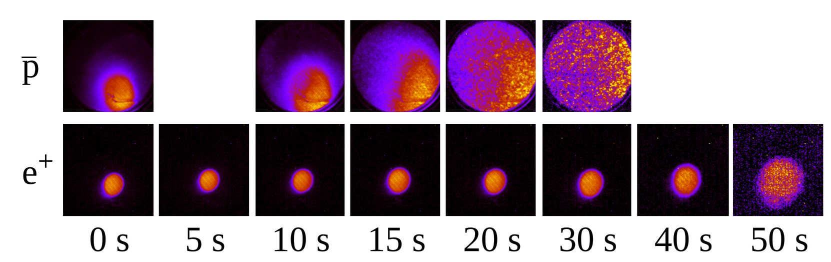


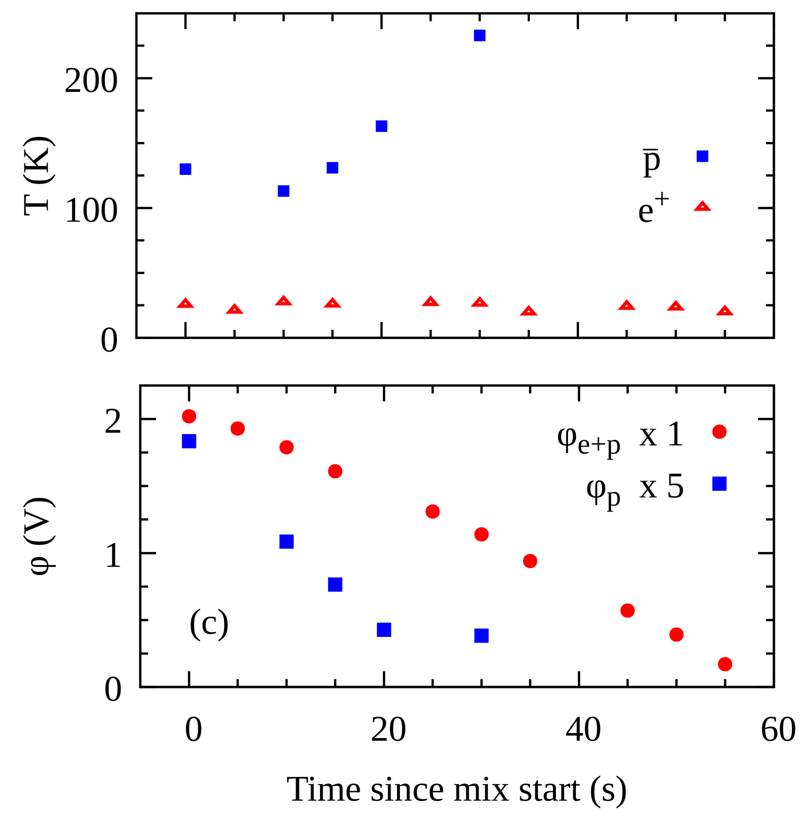


The well is morphed linearly from the nested potential to the mixing well (dotted line). The position of the annihilations during this process was determined using the array detector. The number of annihilations was estimated by comparing the AMT count rate in 2- and 3-coincidence mode. Temperature, number of particles, and radial profile was determined using a single stage MCP upstream of the Cusp trap.

Time dependence

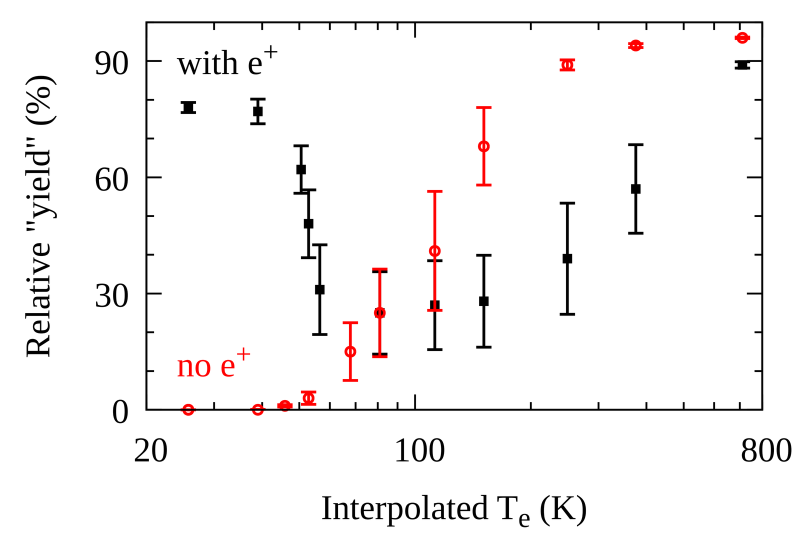
- slower mixing gave us higher total count rates
- for mixing slower than 1 s, there were two plateaus in the count rate
- the dependence of the space charge (ϕ) against time implies that the second lower plateau in the count rate stems from the depletion of the $\bar{p}$

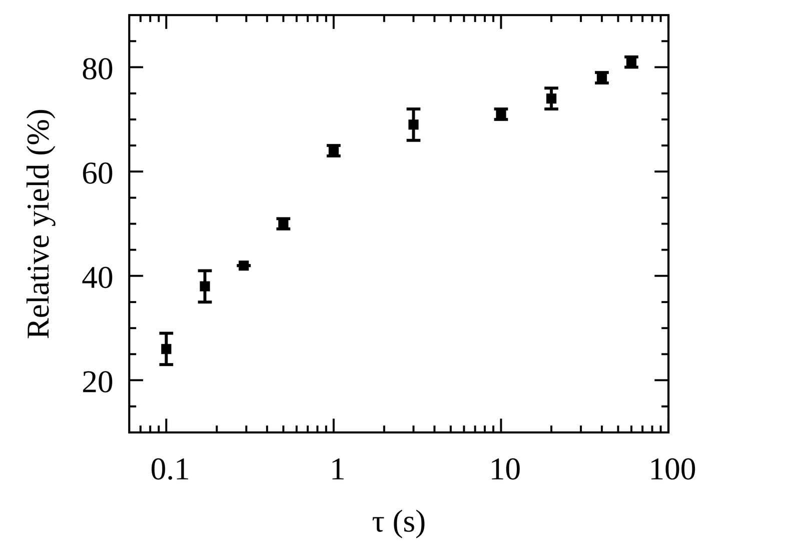




Temperature dependence

- heating the plasma with white noise on the split electrodes
- $\bar{\text{H}}$ yield dropped with increased temperature
- when heating $\bar{p}$ without e^+, the $\bar{p}$ leave at lower heating power





Summary and Outlook

- The slow merge mixing scheme produces $\bar{\text{H}}$ with high conversion efficiency. The efficiency is higher the slower we merge the plasma.
- In this scheme, the particles begin with low axial kinetic energy. No $\bar{\text{H}}$ was detected at the BGO downstream of the mixing trap. We will explore other mixing schemes to produce more beam-like atoms.

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MORE INFORMATION

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