Progress report of the ASACUSA Č H HFS experiment

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on behalf of the ASACUSA collaboration

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Lorentz symmetry is a cornerstone of modern physics
- Quantum Field Theory (QFT)
- Einstein’s theory of general relativity

Ongoing search for new theories
- Gravity not incorporated in QFT, dark matter, missing antimatter in universe...
- Many theories break Lorentz symmetry at some small level
- Finding Lorentz violating effects could lead to new physics

Standard Model Extension (SME) by Alan Kostelecky:
Parameterization of Lorentz-violating effects
- Allows for direct comparison of many experiments
- Compare groundstate hyperfine splitting (GS-HFS) in H + H: potential for highest sensitivity on absolute energy scale

Asacusa collaboration aims at measuring the GS-HFS of H
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Measurement principle

- Production of $\bar{H}$ in dedicated trap
- Trap emits beam of polarized LFS $\bar{H}$
- Induce spin-flips with microwave cavity: LFS become HFS
- Analyze spin states with sextupole
- Detector counts $\bar{H}$
H: GS-HFS known with a precision of $1.4 \times 10^{-12}$
- Only need to measure $\bar{H}$

$\bar{H}$: Recent measurement by ALPHA: $4 \times 10^{-4}$
- Trapping $\bar{H}$ with strong inhomogenic magnetic fields
- Get HFS by difference between $\pi_1$ and $\pi_2$ transitions
- Result is consistent with GS-HFS in H
- Not sensitive to CPT within the mSME

ASACUSA will measure HFS B-field free using $\bar{H}$-beam, measure transition directly
Experimental Setup

Mixing trap + spectroscopy beamline

Double-Cusp trap  Cavity  Sextupole  Detector
Mixing pbar and positrons

- Spectroscopy part: fully tested with hydrogen beamline
- Current work: optimizing $\bar{\text{H}}$ production
  (mixing $\bar{\text{p}}$ and $\text{e}^+$)

Optimization of mixing:
- Short setup: mount detector close to trap
- Fieldionizer before detector: ionizes and blocks $\bar{\text{H}}$ above a given n-state
- $\bar{\text{H}}$ with lower n-state are counted

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Mixing antiprotons and positrons

- Trapping of $\bar{p}$ and positrons
  - axially by MRE
  - radially by magnetic field
- prepare $\approx 60 \times 10^6$ e$^+$
- inject $\approx 3 \times 10^6 \bar{p}$
- pull up upstream potential barrier
- only neutral $\bar{H}$ can leave trap
Results: Measurement of n-state distribution

Time and quantum distribution of detected $\bar{H}$

- 43 mixing runs in total
- False positive rate: $0.0038 \text{ s}^{-1}$
- $n<14$ significance: $6 \sigma \quad \tau (n=14) \approx 50 \mu\text{s}$
What are the next steps?

- Optimize production of $\bar{\text{H}}$ in ground state
- Scan GS-HFS
  - Goal: $10^{-6}$ precision
  - 8000 $\bar{\text{H}}$ in ground state needed
- Proton size correction contributes in the order of $10^{-5}$
- Assuming QED obeys CPT:
  Determine Zemach and magnetic radii of antiproton
Thank you very much for your attention!

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