



Lyman- α Laser Cooling for Precision Spectroscopy of Antihydrogen

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The Canadian Astroparticle Summer Student Talk Competition 2026

Supervised by Professor Takamasa Momose

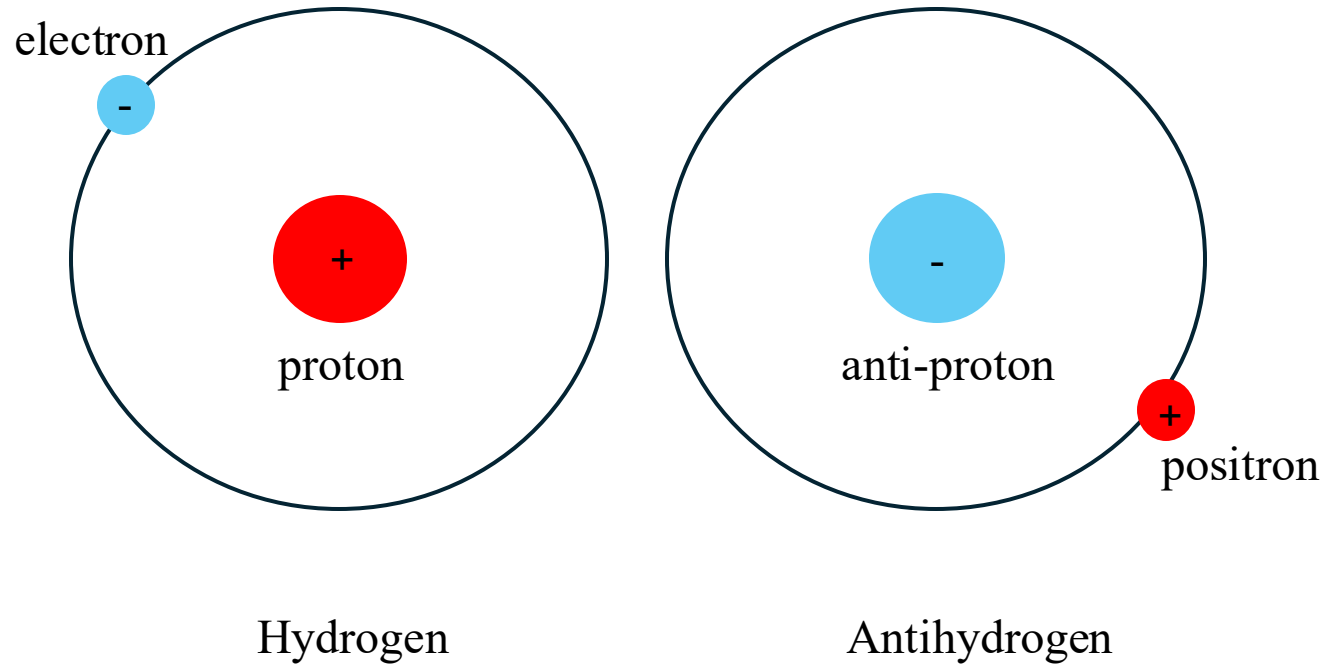
The Antihydrogen Laser Physics Apparatus (ALPHA) Collaboration

- Located at CERN antiproton decelerator (AD)
- Produces and traps antihydrogen
- Conducts spectroscopy and gravity experiments on antihydrogen



Why study antimatter?

- Antimatter is the counterpart of matter with the exact same properties except opposite charge
- The amount of matter and antimatter in the universe is unbalanced – why?

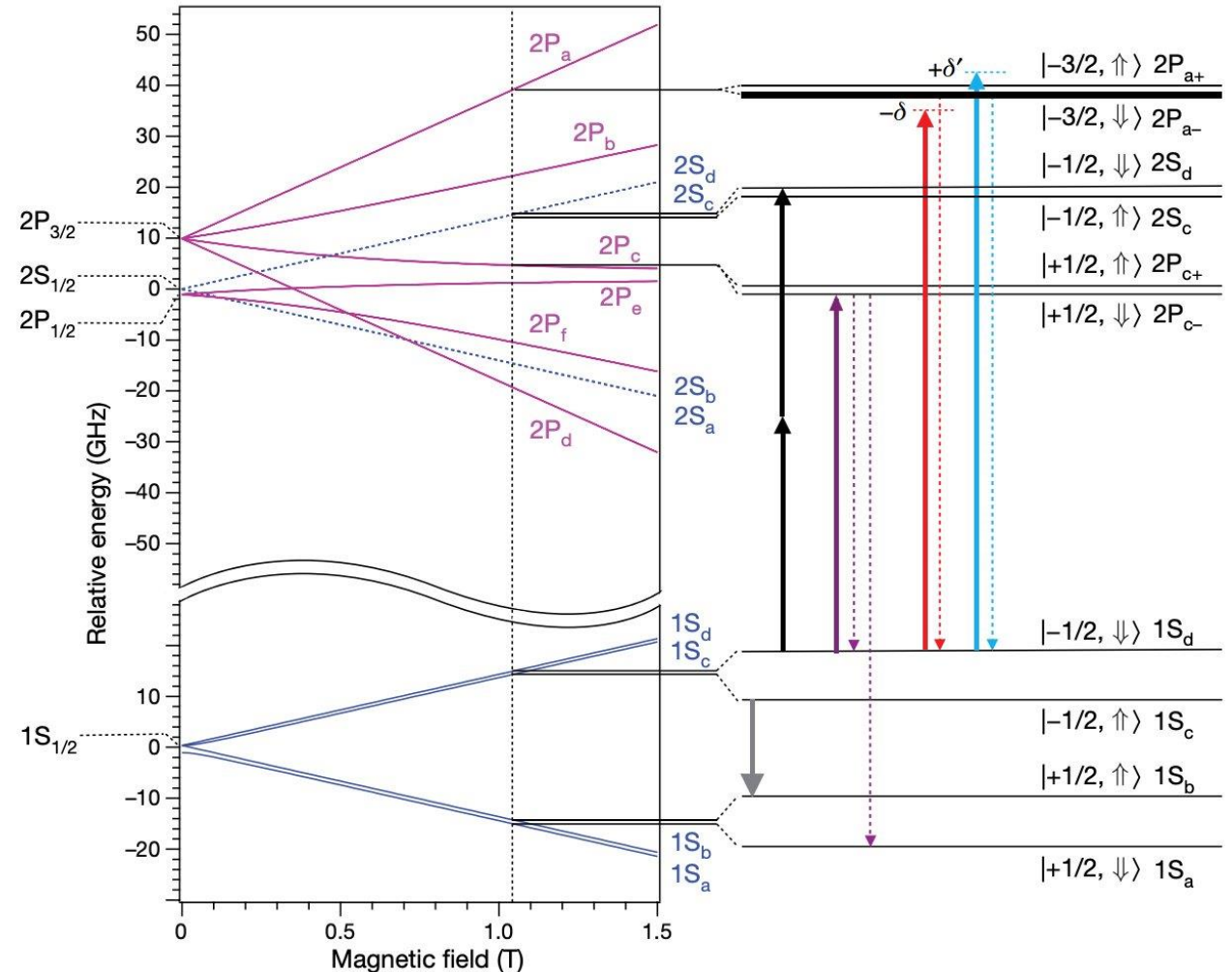


Why study antihydrogen?

- The 1s-2s transition
 - Extremely narrow
 - Measured in hydrogen to incredibly high precision

$$H : 10^{-15}$$

$$\bar{H} : 2 \cdot 10^{-12}$$



Baker, C.J., Bertsche, W., Capra, A. *et al.* Laser cooling of antihydrogen atoms. *Nature* **592**, 35–42 (2021). <https://doi.org/10.1038/s41586-021-03289-6>

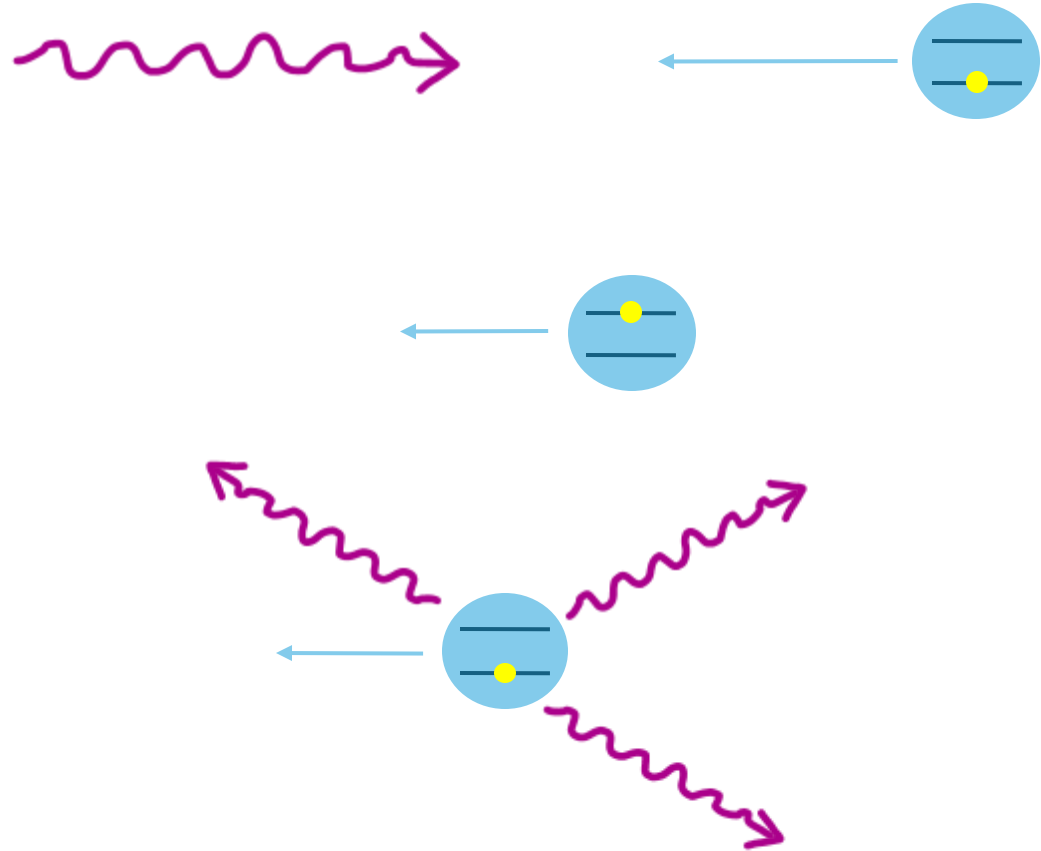
Limitations of 1s-2s measurement

- Doppler shifts
- Transit-time effects

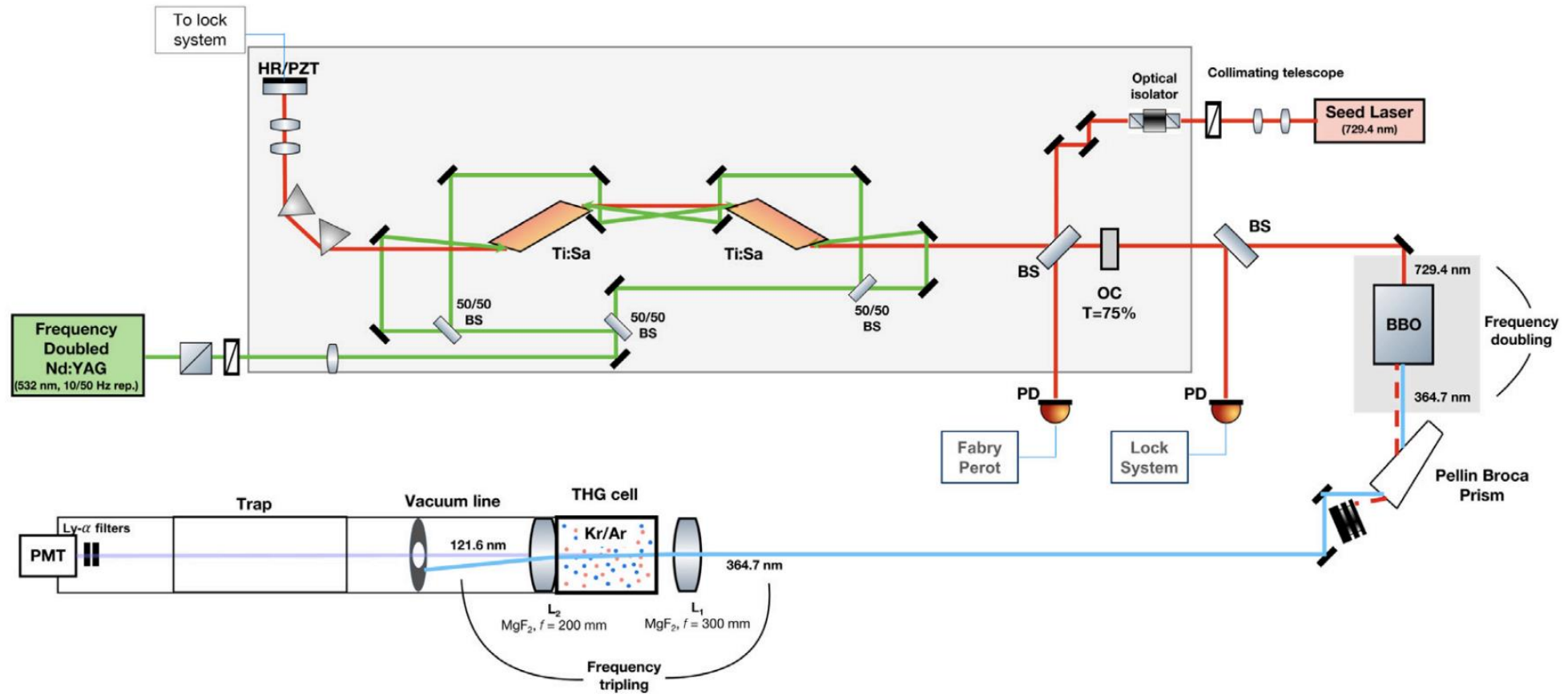
Faster atoms $\rightarrow$ broader resonance $\rightarrow$ lower precision

Laser cooling

- Doppler cooling using red-detuned light (lower frequency)
- Lowers kinetic energy of the atoms $\rightarrow$ lowers temperature

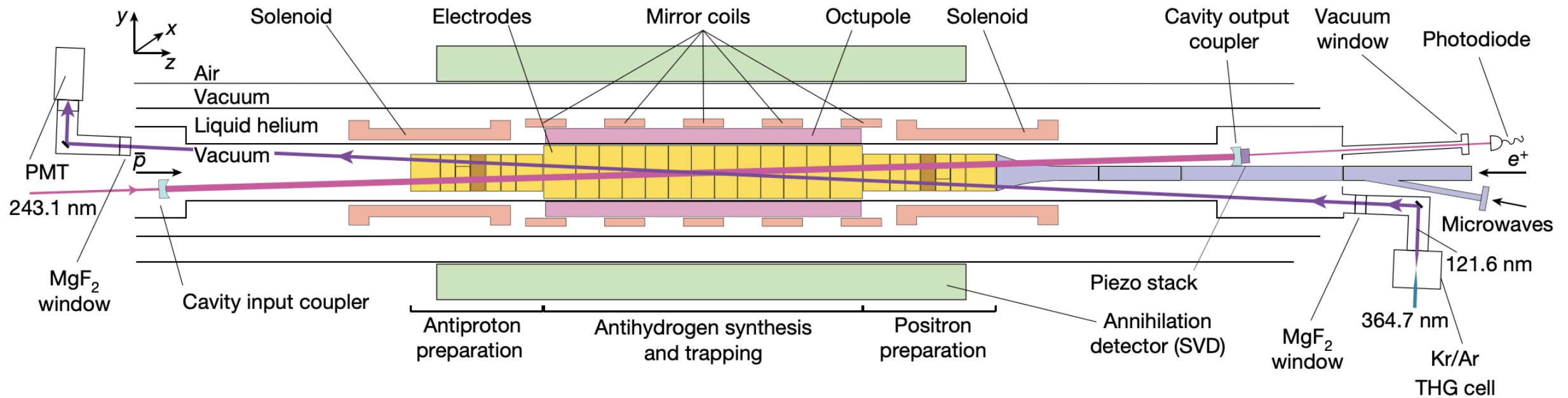


121nm light generation



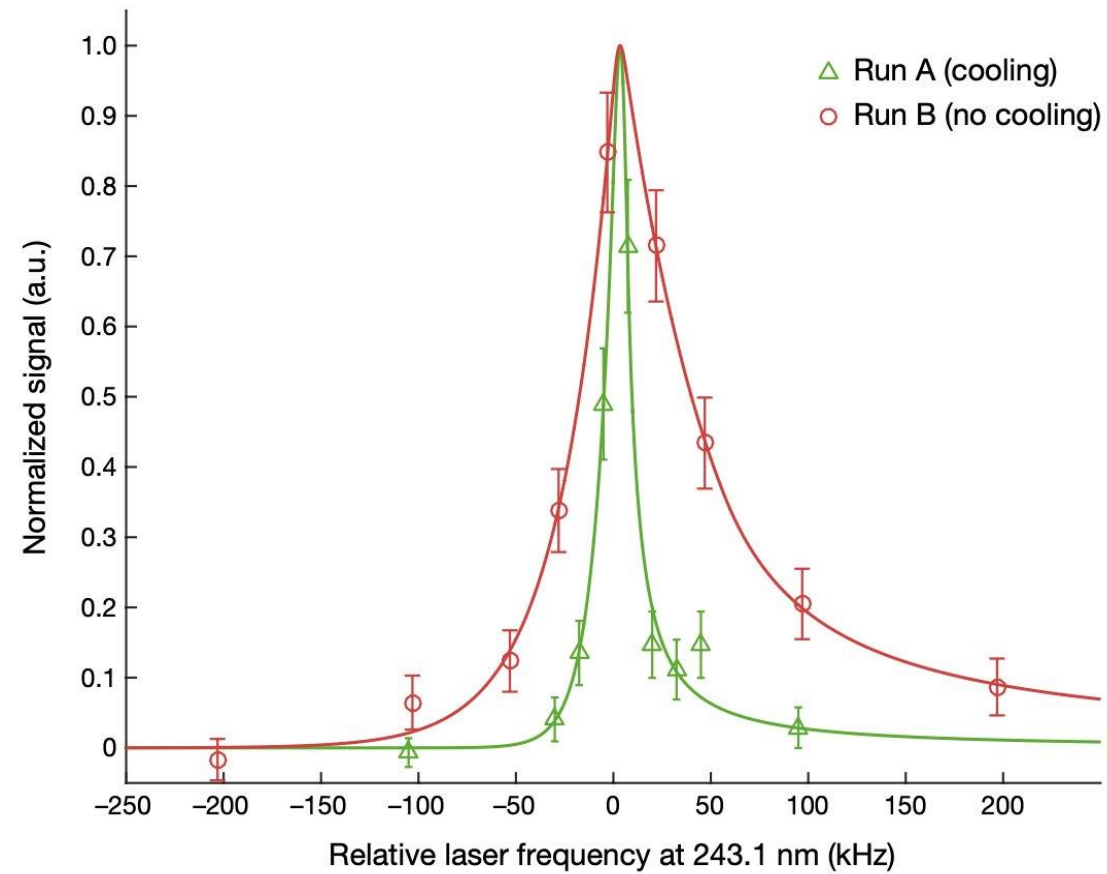
Akbari, R. ; Alves, B. X.R. ; Baker, C. J. et al. / **The ALPHA-2 apparatus - facilitating experimentation with trapped antihydrogen**. In: Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. 2025 ; Vol. 1072.

Laser cooling antihydrogen in ALPHA-3



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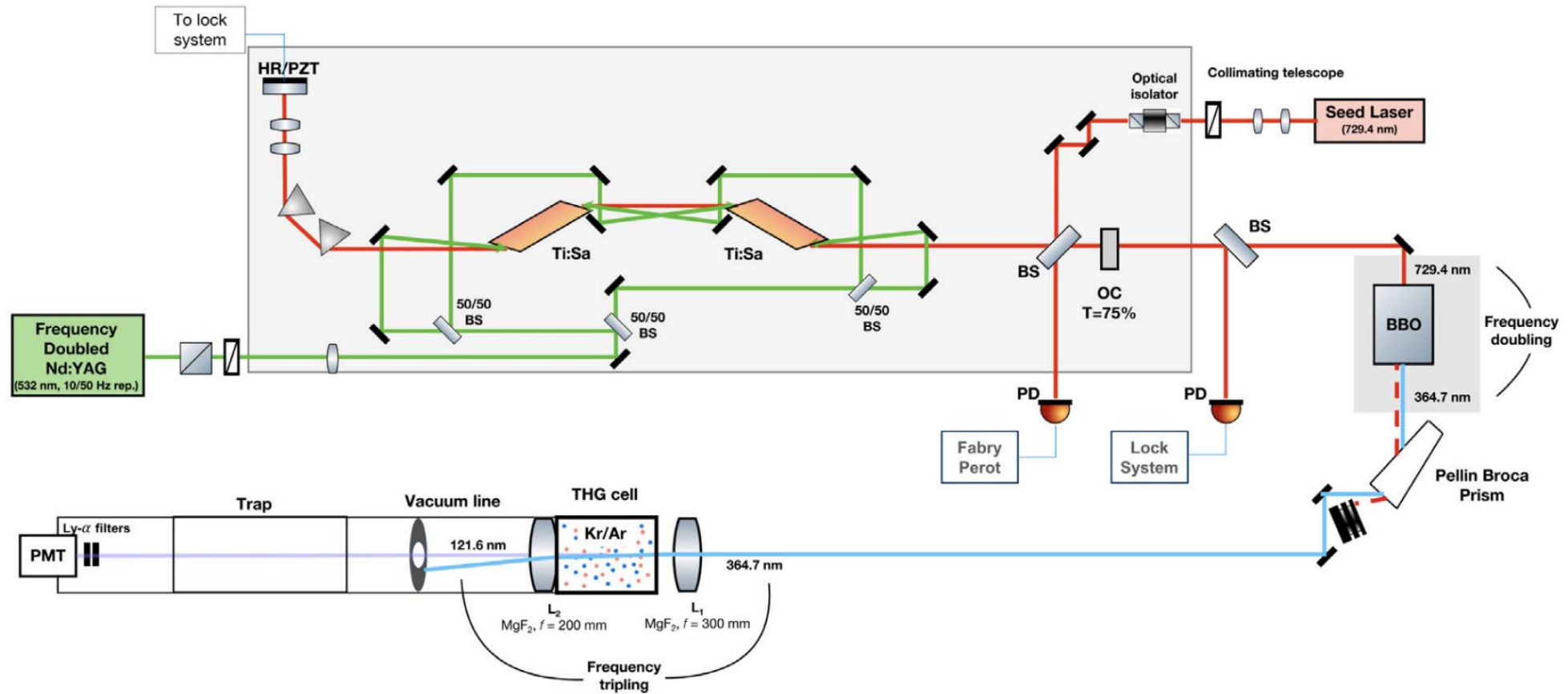
Summary



Baker, C.J., Bertsche, W., Capra, A. *et al.* Laser cooling of antihydrogen atoms. *Nature* **592**, 35–42 (2021). <https://doi.org/10.1038/s41586-021-03289-6>

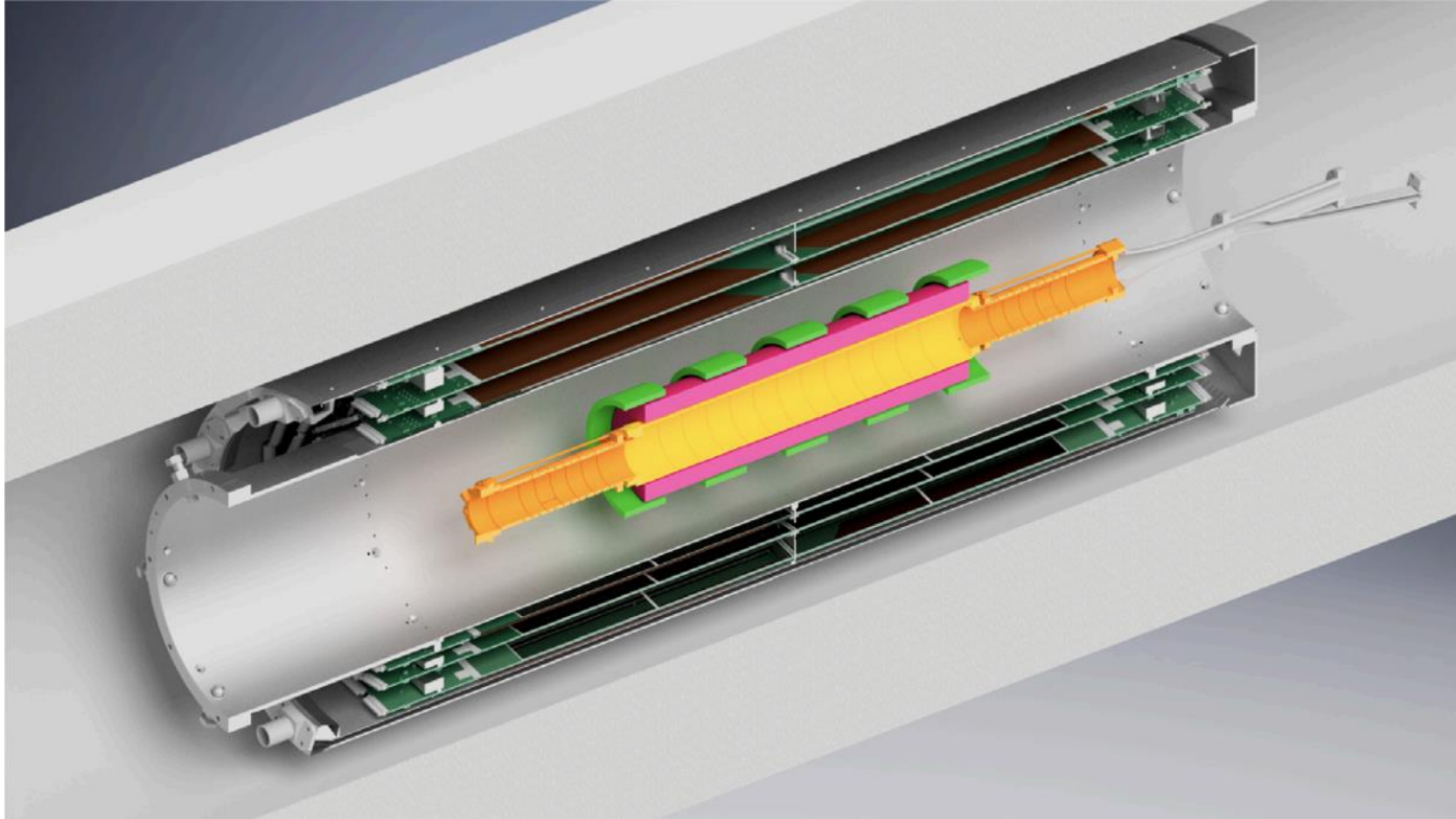
Supplementary slides

121nm light generation



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Silicon vertex detector

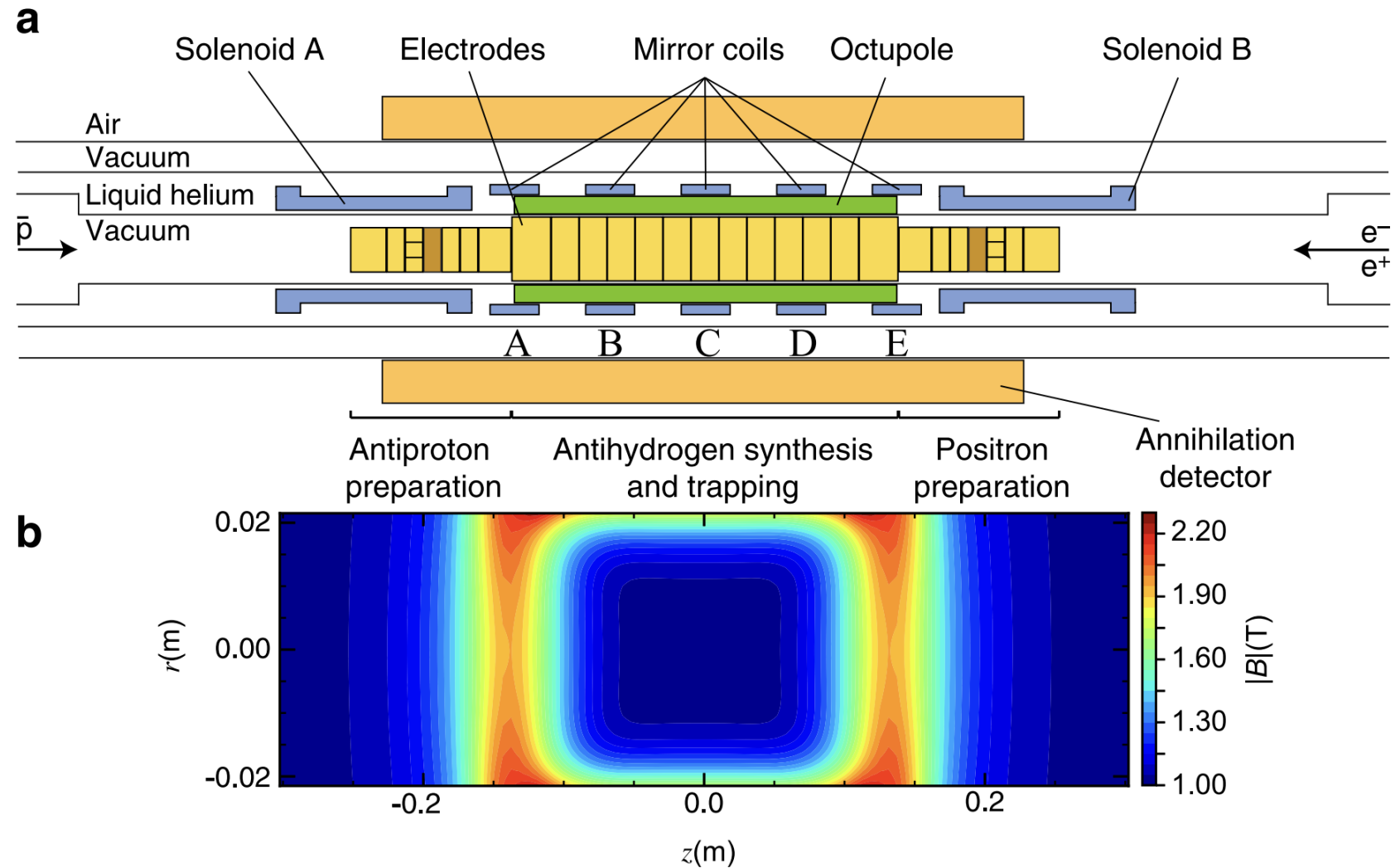


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Trapping antihydrogen

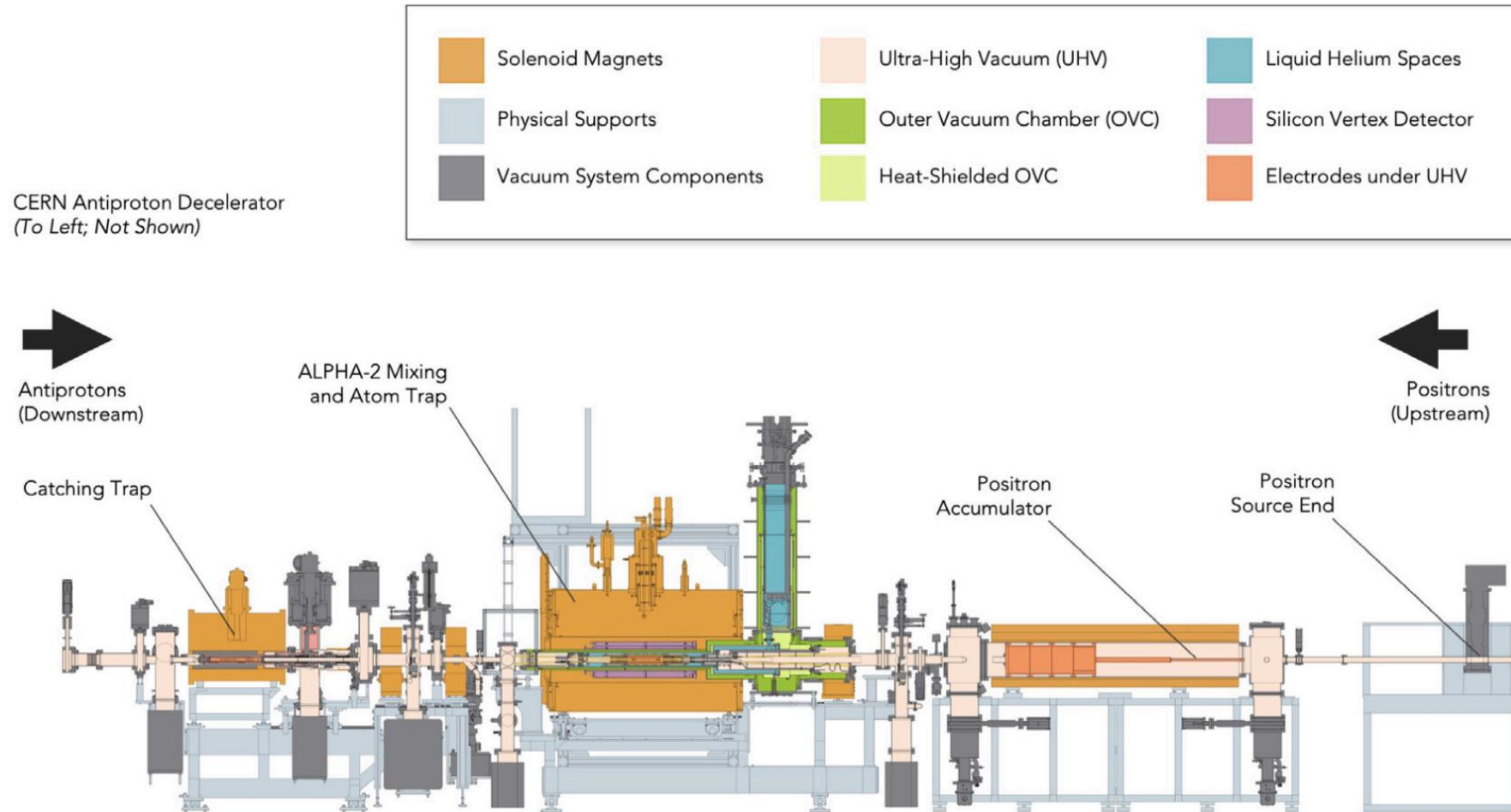
(a) shows a schematic of the atom and mixing trap apparatus, while (b) shows the corresponding magnetic field structure.

$$U = -\vec{\mu} \cdot \vec{B}$$



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Making antihydrogen



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