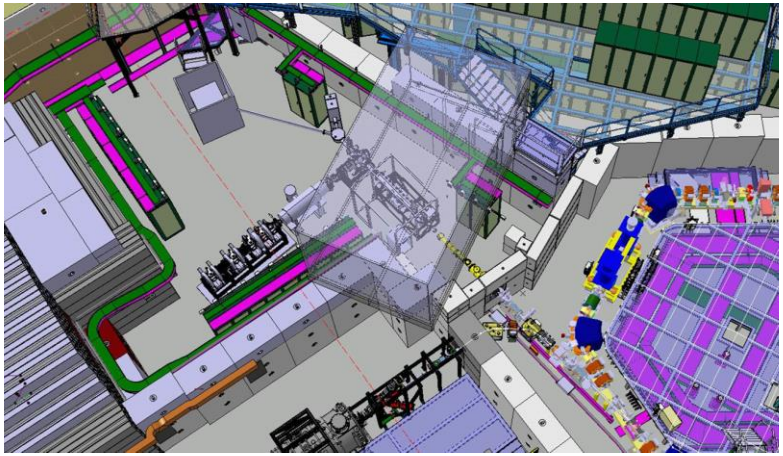
Laser Control for the Production of Excited Positronium in GBAR

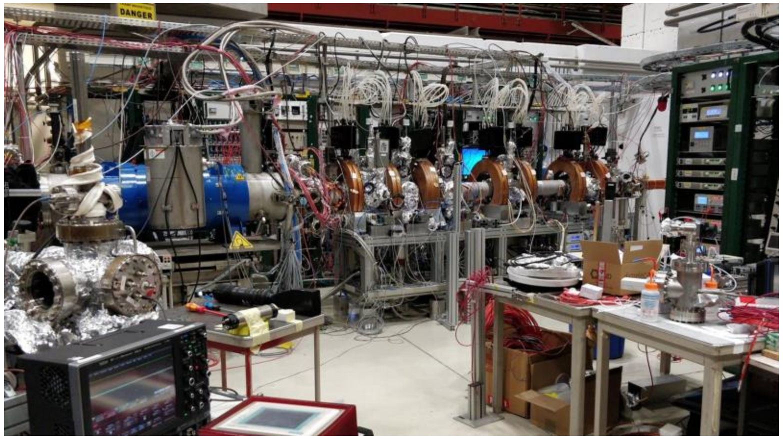
Eric Putney
15 August, 2019

GBAR - Grav. Behavior of Antihydrogen at Rest [1]

- Does antimatter fall just like matter?
  - Does it fall up or down?
  - Direct test of weak equivalence principle and baryon asymmetry.
- **Goal:** Produce positively charged antihydrogen ions.
  - Permits record cooling of antihydrogen to tens of μK.
  - More manipulatable than neutral antihydrogen.



A 3D diagram of the experiment and an image of the experimental zone.



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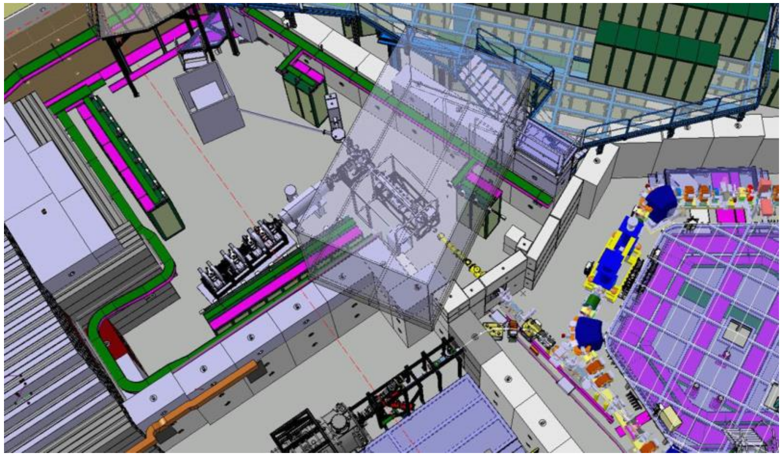

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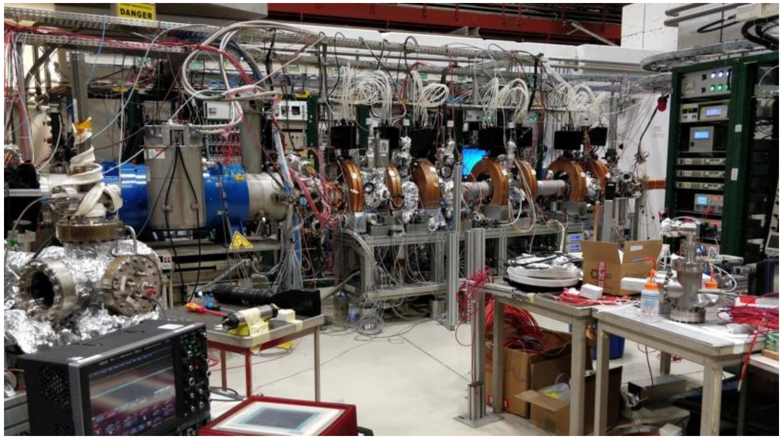
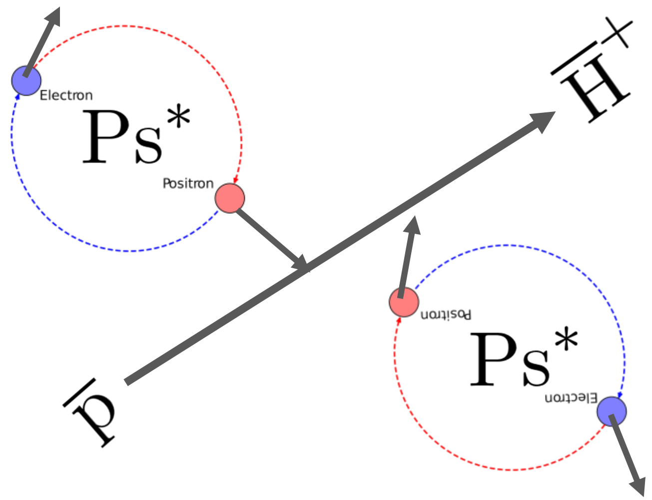


Making “H-Bar-Plus” via 2x Positron Capture

- Must produce positive antihydrogen via the “double-capture” of positrons from positronium.
- Excited positronium has a higher x-section than lone positrons or ground state positronium. [1]
- Must be excited shortly before capture.



A cartoon depiction of the double capture of positrons.

$$\bar{p} + \mathrm{Ps}^* \rightarrow \bar{\mathrm{H}}^* + e^-$$

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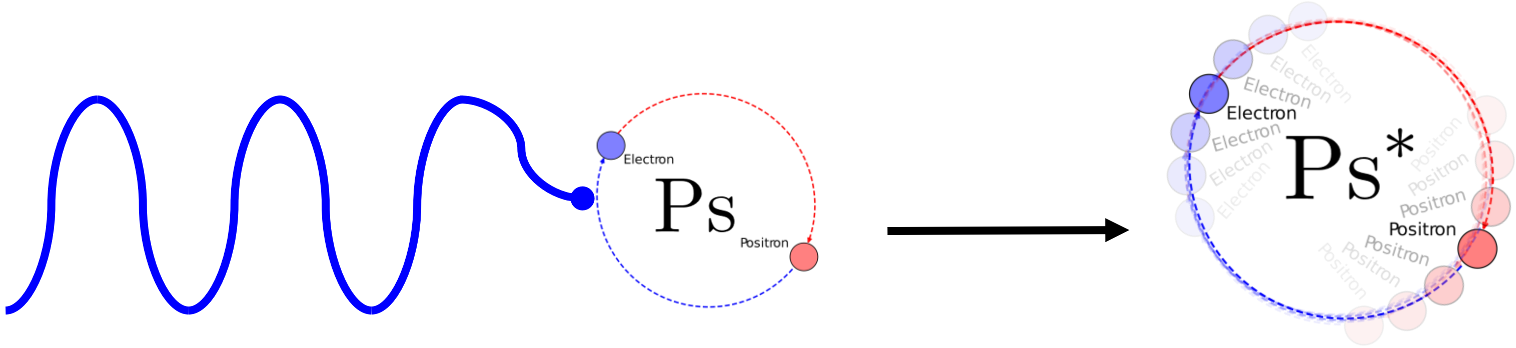
Preparing Excited Positronium

- ❑ Ortho-positronium (parallel spins, long lifetime ~142 ns) excited to the 3D state.
- ❑ Requires an intense light source to efficiently excite a large number of positronium.
- ❑ A pulsed laser precisely timed with the arrival of bunches of positronium provides this environment.



Positronium excited by 410 nm light from the ground state to the 3D state.

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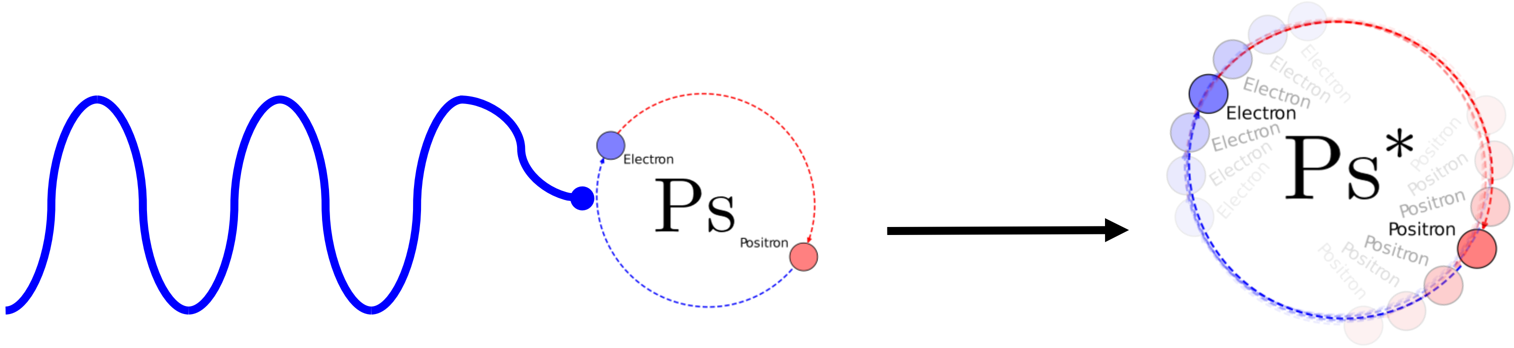

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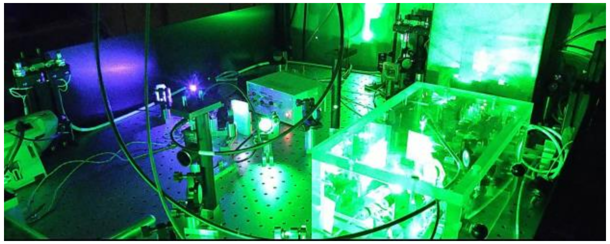
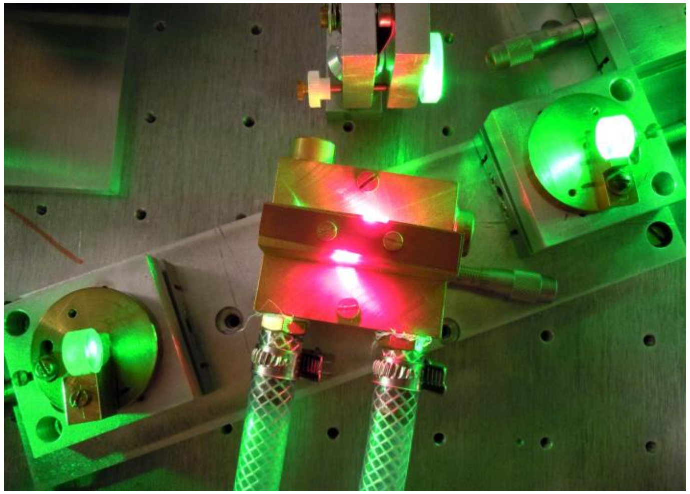
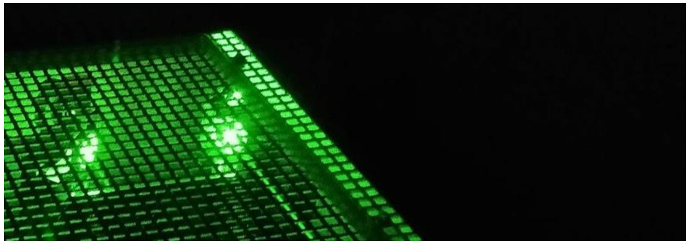
Project Overview - Laser Control + Prep

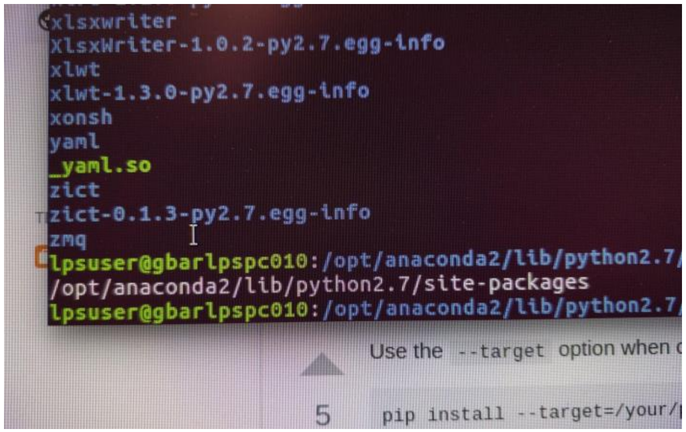
- ❑ Developed several Python libraries for remote systems control.
- ❑ Frequency calibration of the beam
- ❑ Tested and calibrated beam stabilization
- ❑ Set up pre-chamber optics.

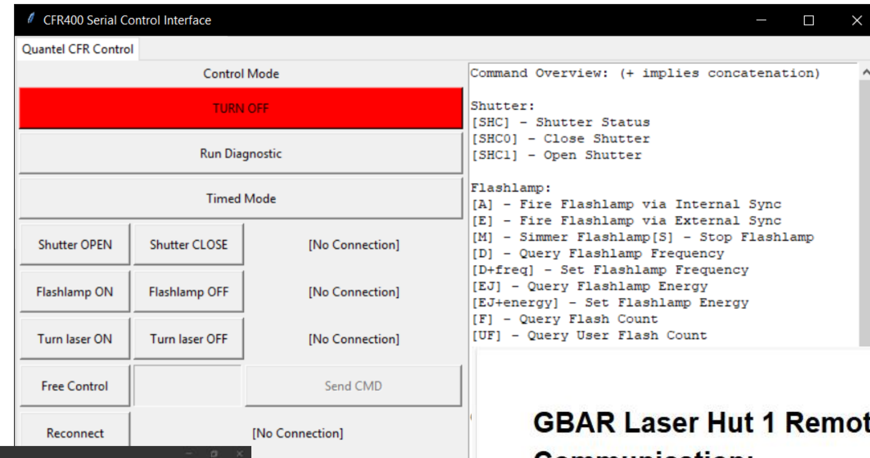


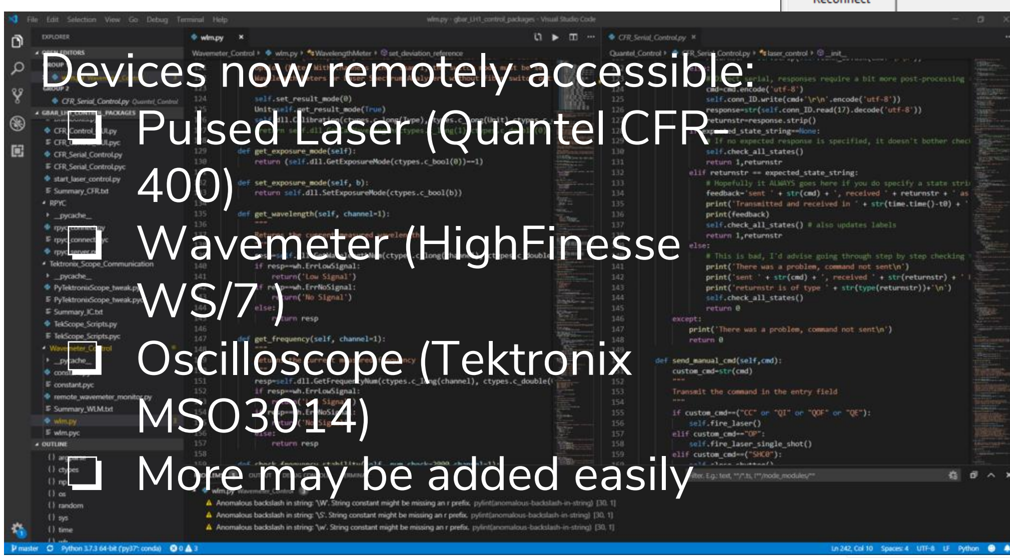




Remote Control of the Laser Hut

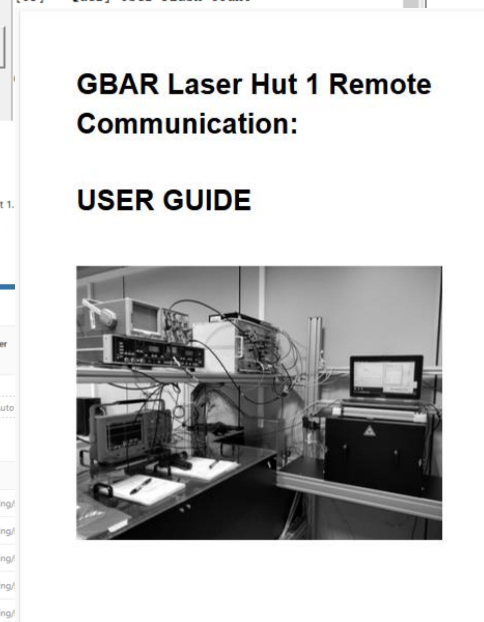






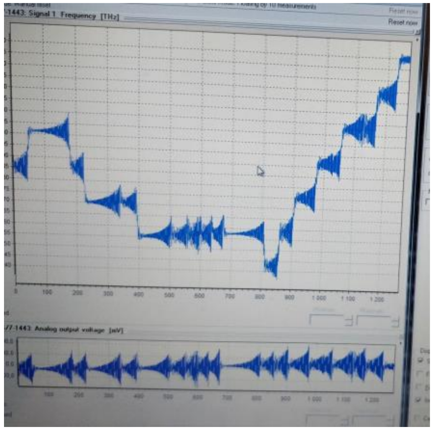
Devices now remotely accessible:

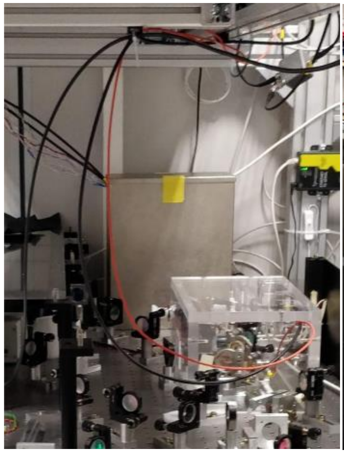
- ❑ Pulsed Laser (Quantel CFR-400)
- ❑ Wavemeter (HighFinesse WS/7)
- ❑ Oscilloscope (Tektronix MSO3014)
- ❑ More may be added easily

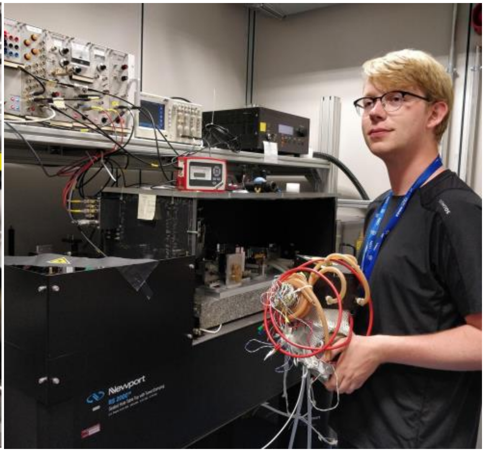


Frequency Calibration of CW IR Laser

- ❑ Monitored by a wavemeter (HighFinesse WS/7).
- ❑ Validated by comparing reported frequency to detected fluorescence of a cesium transition.
- ❑ Cesium transition could be used as an additional stabilizing mechanism.



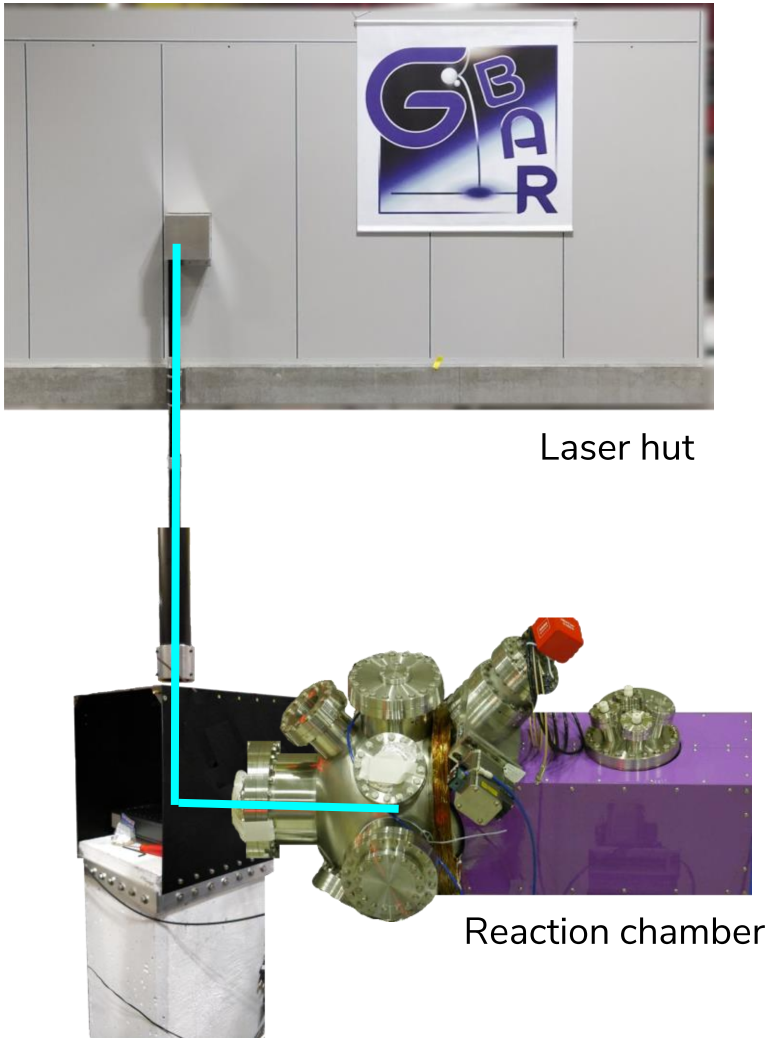




We monitor the frequency several ways, this is critical for efficient production of positronium.

Stabilization of Transported Beam

- Stable beam transport from the laser hut to the reaction chamber is needed.
- These are not co-moving, alignment is always changing.
- **Solution:**
  - Position-sensitive photodiodes know when the beam moves.
  - This error signal is sent to piezo-controlled mirrors that counters this movement.



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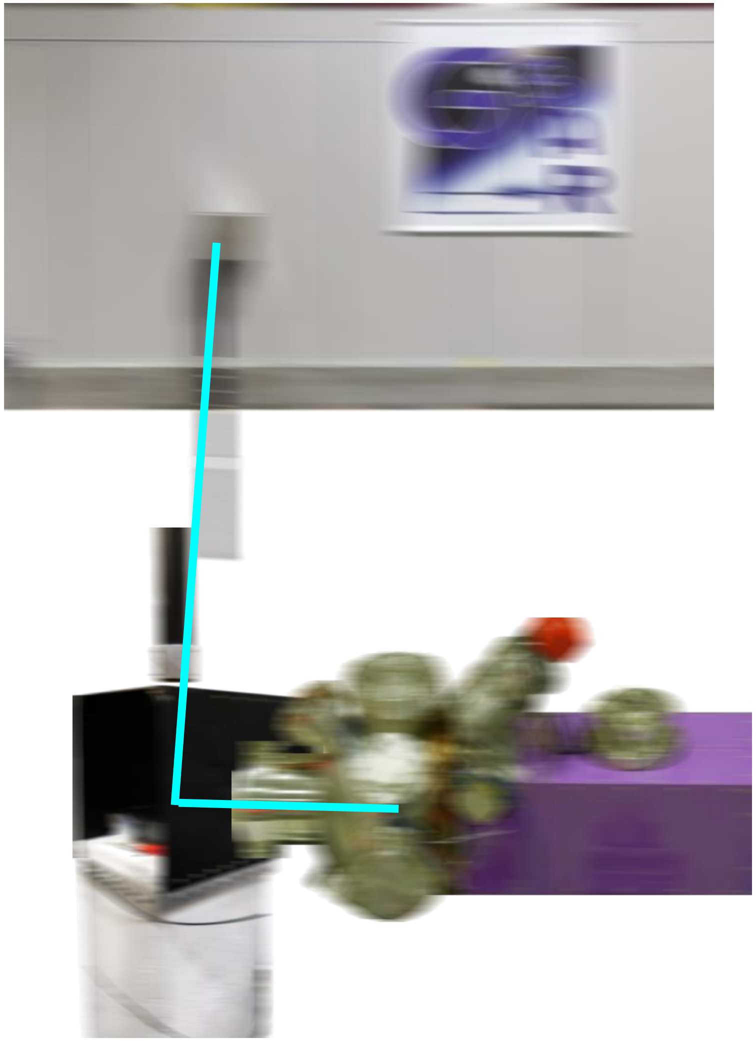
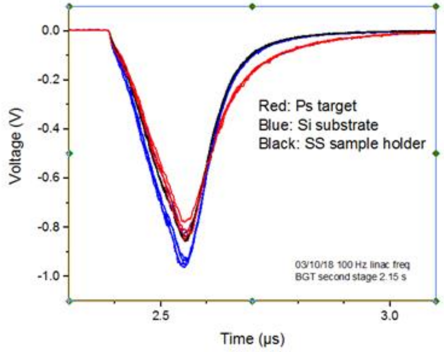
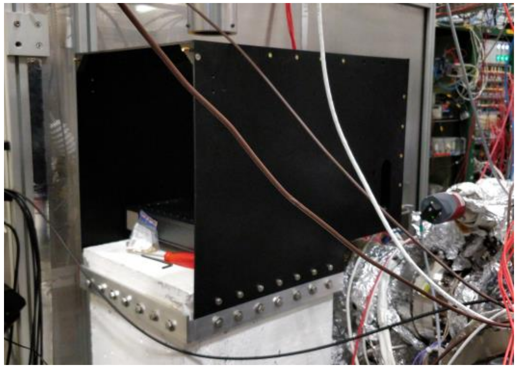


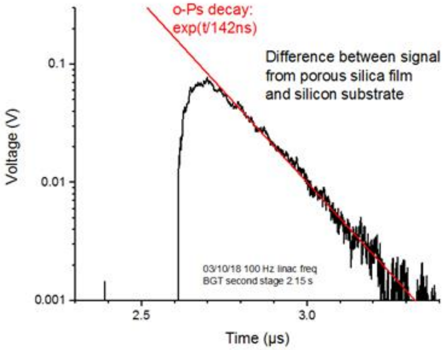
Pre-Reaction Chamber Optics

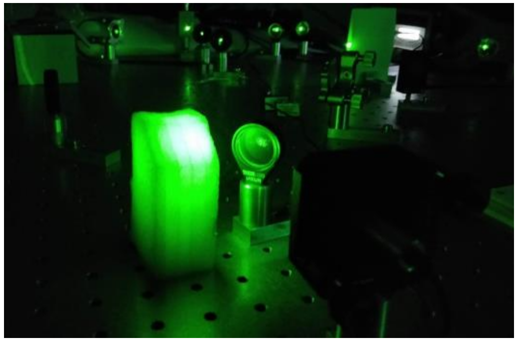
- ❑ Recently built the laser safety box for the experimental zone.
- ❑ Begin migrating optics from the test bench down to the experiment.
- ❑ Set up + calibrate the laser stabilization.
- ❑ Excite positronium!

Courtesy: Laszlo Liszkay









(Left) Detection of positronium annihilation signal, confirmed by lifetime analysis.

Adventures @ CERN and in Switzerland







GRAB DES
UNBEKANNTEN BERGSTEIGERS
LA TOMBE DE L'ALPINISTE INCONNU
GRAVE OF THE UNKNOWN CLIMBER
TOMBA DELLO
SCALATORE SCONOSCIUTO


PERREN










Michel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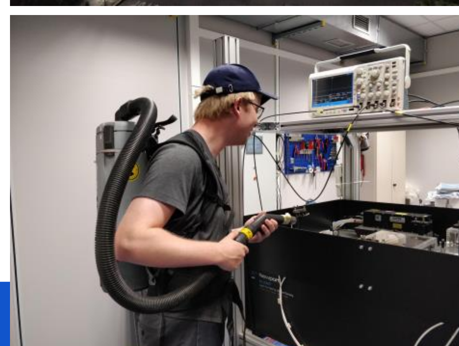







ANTIMATTER
FACTORY
ELENA

Thanks for listening!

Questions?

Special thanks to my advisor Dr. Comini & the GBAR team for their patience, guidance and friendliness!

Additional thanks to CERN for hosting us, the Univ. of Michigan for organizing this program, and the National Science Foundation for funding!

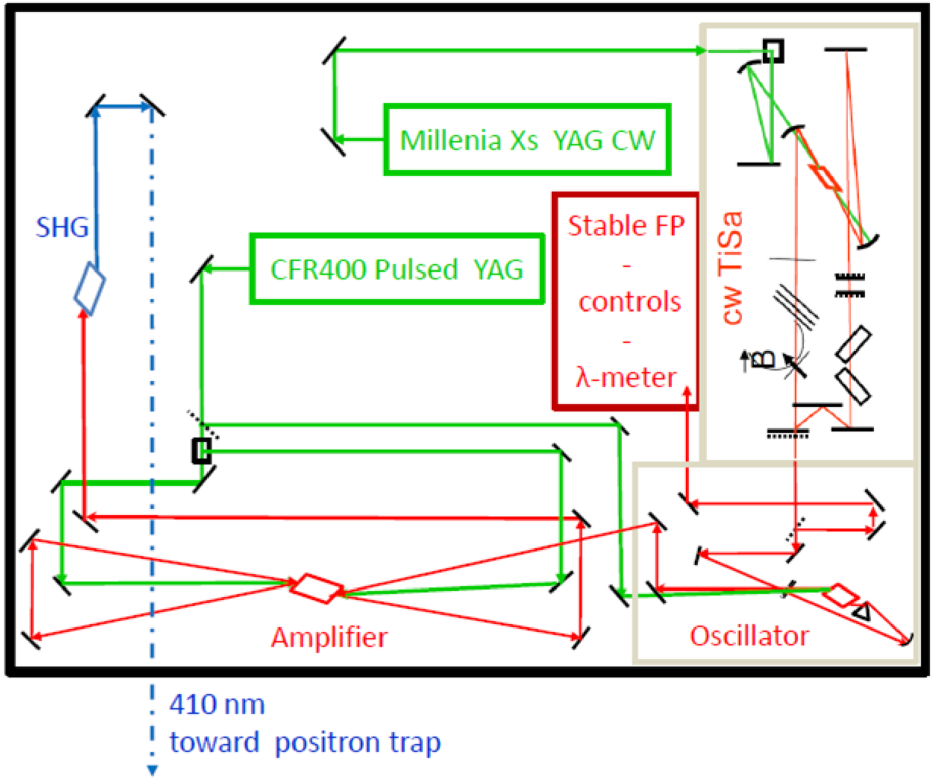
References

[1] CERN-SPSC-2011-029 / SPSC-P-342. Proposal to measure the Gravitational Behaviour of Antihydrogen at Rest

[2] Comini, Pauline. (2014). Étude de la formation d'antihydrogène neutre et ionisé dans les collisions antiproton-positronium - Study of the antihydrogen atom and ion formation in the collisions antiproton-positronium. 10.13140/2.1.4519.7605.

Bonus slide: Optics details

- Combination of pulsed + CW green light pumps Ti-Sa crystals.
- Ti-Sapphire crystal produces infrared light.
- Infrared light is frequency-doubled to pulses of blue light.



Block diagram of the pulsed 410 nm system. [2]

Bonus slide: Why positronium?

- ❑ Higher x-section than a positron beam.
- ❑ You can practice with normal matter under identical conditions! <u>Useful during LS2.</u>

Antimatter: Matter: