

Fluorescence Detection of Be⁺ and Antihydrogen in ALPHA-3

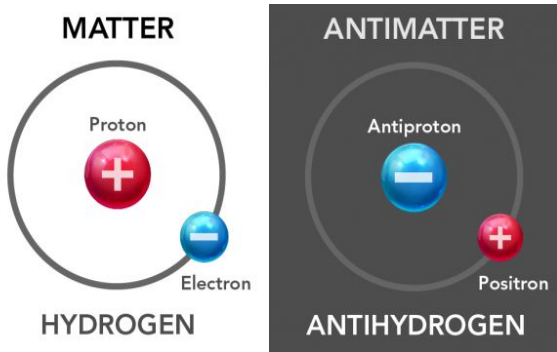
Shungo Fukaya

Supervisor: Dr. April Cridland



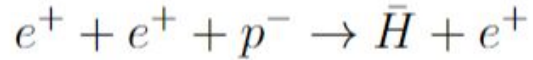
What does ALPHA do?

- Measure antihydrogen (\bar{H}) in the AD hall (antimatter factory)
- CPT invariance and matter/antimatter symmetry \rightarrow Hints to Baryon Asymmetry etc.
- Magnetically trap 20,000 antihydrogen everyday, lots of measurements
- Measure trapped cold atoms \rightarrow longer interaction time \rightarrow precision measurement !
- AMO physics



We want more antihydrogen

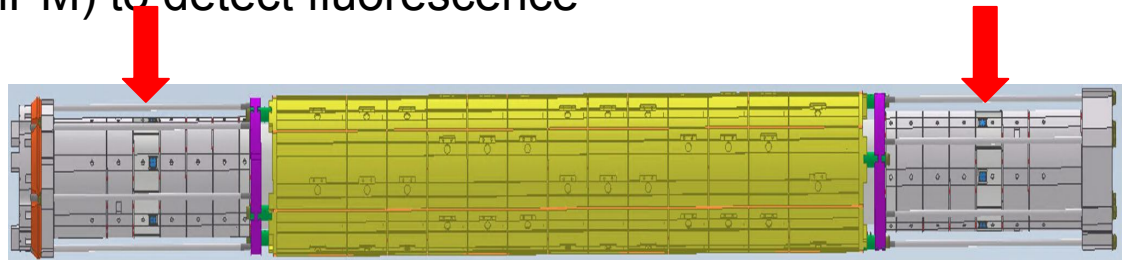
- Antihydrogen is formed by three-body reconfiguration process:



- This process is highly dependent on temperature:

$$\Gamma_{TBR} \sim n_e^2 T^{-\frac{9}{2}}$$

- To cool down e^+ , use sympathetic cooling with cold Beryllium ions (Be^+)
- Can't measure Be^+ temperature precisely in low temperatures
- Use Silicon Photomultipliers (SiPM) to detect fluorescence



My project: Estimate TDR of Be⁺ fluorescence

$$TDR = N * \gamma_s * PDE * \Omega$$

TDR: Total detection rate

N: Number of atoms

γ_s : Fluorescence rate

PDE: Photon detection efficiency

Ω : Solid angle towards SiPM

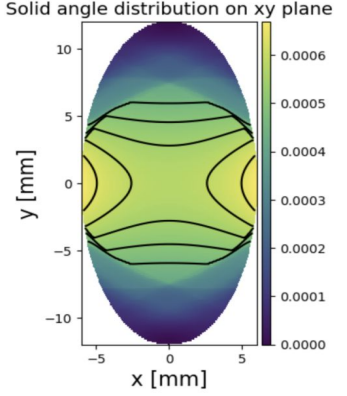
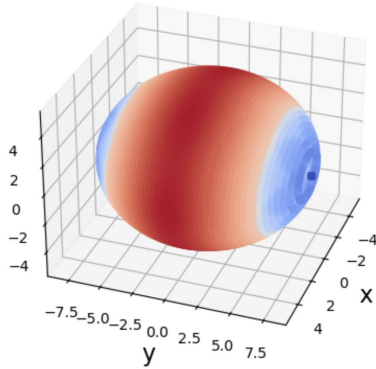
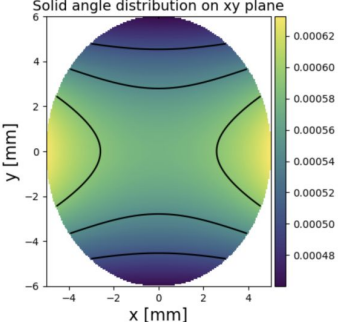
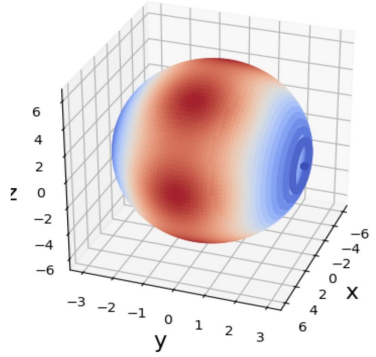
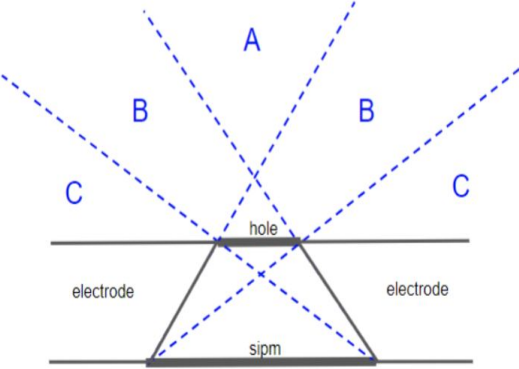
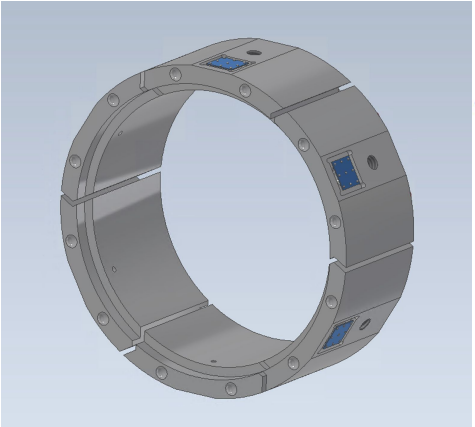
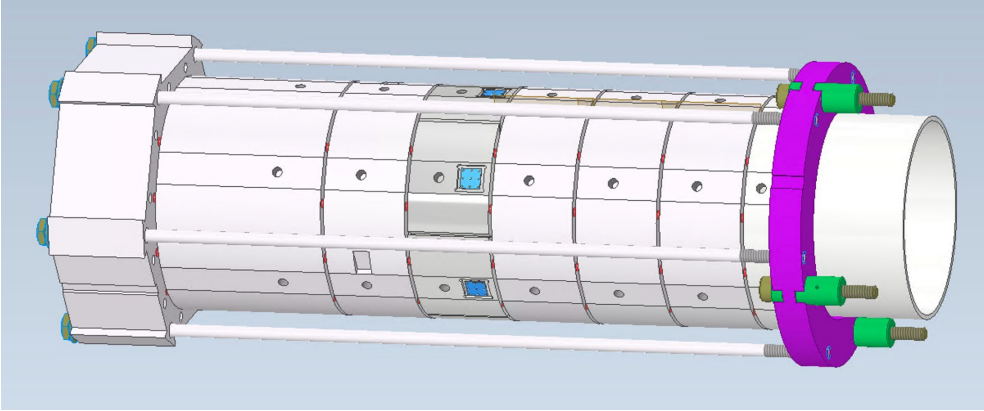
← already know

← want to estimate!

Project 1: Numerical calculation of solid angle

Project 2: Measurement of PDE under 4K temperature

Project 1: Solid angle calculation

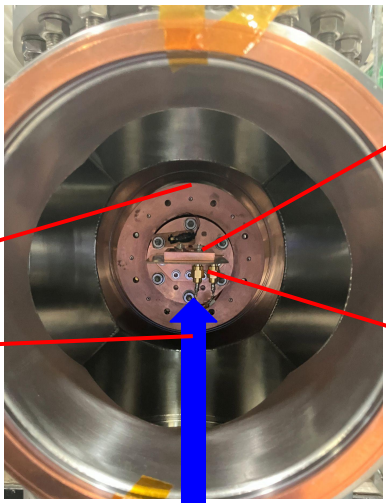


| Major Radius [mm] | Minor radius [mm] | Average Solid Angle [*1E-4] |
|-------------------|-------------------|-----------------------------|
| 3 | 3 | 5.36(1) |
| 5 | 3 | 5.23(1) |
| 8 | 3 | 4.78(1) |
| 3 | 5 | 5.44(1) |
| 5 | 5 | 5.24(1) |
| 8 | 5 | 4.74(1) |

Table 3: Average total solid angles in the unit of probability of ellipsoid plasmas for varied major and minor radius lengths. 5

Project 2: Measurement of PDE under 4K

- Set up test cryostat: 1E-8 mbar, 4 Kelvin
- Prepared SiPMs

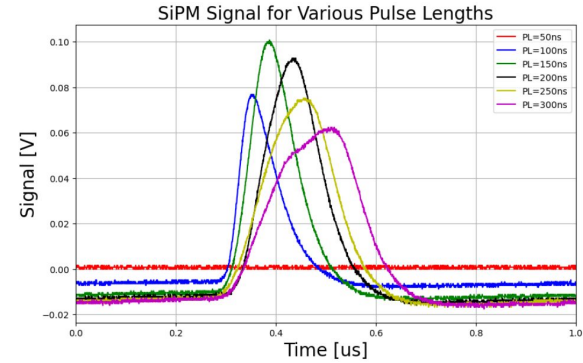
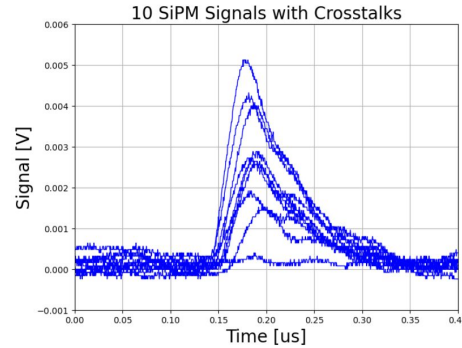


LED light

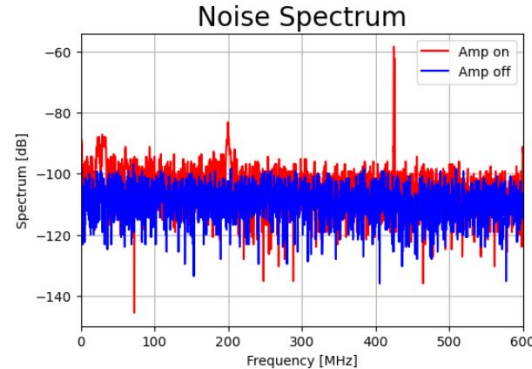


Project 2: Measurement of PDE under 4K

- Tested at room temperature



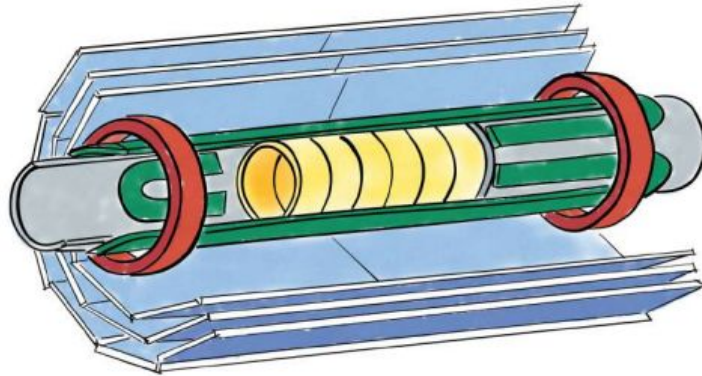
- Found noise source



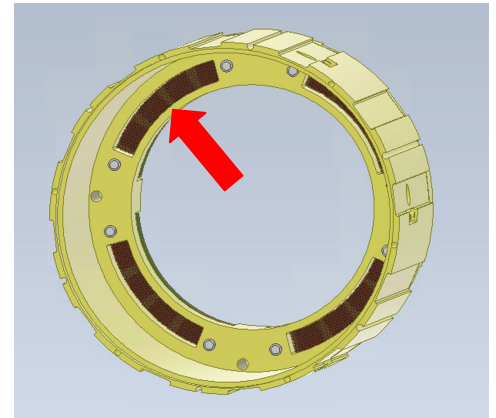
- PDE at 4K temperature – TBD

Measuring antihydrogen fluorescence in ALPHA-3 trap

- ALPHA-2 trap
- To determine resonant frequency, we count “how many atoms we lost”
 - destructive measurement !



- ALPHA-3 trap
- Measure fluorescence instead
 - non-destructive measurement !

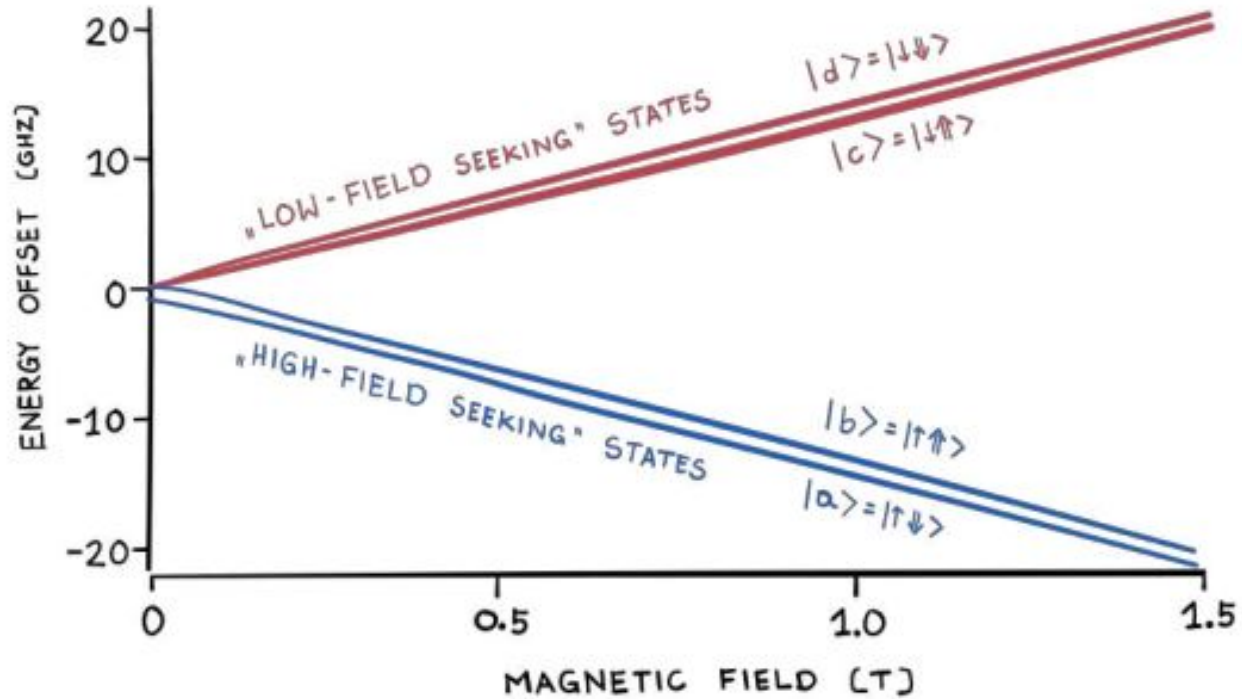


Conclusion & Future prospects of ALPHA-3

- Be⁺ temperature will be measured with SiPMs in ALPHA-3
 - Antihydrogen fluorescence will be measured with SiPMs in ALPHA-3
 - More antihydrogen will be produced
 - Non-destructive measurements will be done
- **More challenging experiments become possible!**



Appendix



Autobiography

Hi, my name is Shungo Fukaya and I just graduated from Northwestern University (USA) with a BS in applied math. I am currently working in the ALPHA team on the characterization of silicon photomultipliers (SiPMs) incorporated in our latest trap design that enables more efficient and precise measurements of antihydrogen atoms. After this summer program, I will start my PhD focusing on precision measurements of ultracold radioactive polar molecules at MIT.