

2S-4P Spectroscopy of Antihydrogen and Centrifugal Separation of Be^+/e^+ Plasma

ALPHA Collaboration

Cheng Chiu

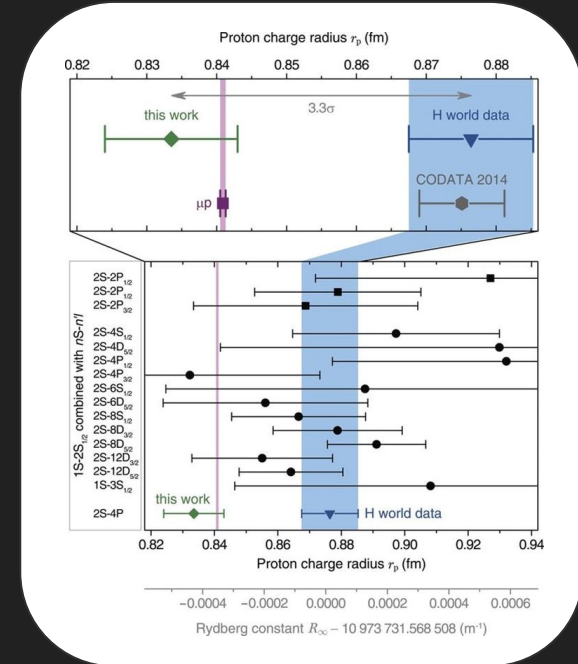
ALPHA

Motivation

- ❖ Test of CPT symmetry with trapped antihydrogen atoms
- ❖ The matter-antimatter asymmetry problem
 - Why do we exist?
- ❖ Measure proton/antiproton charge radius

Axel Beyer et al.

$$E_{nlj} = R_{\infty} \left(-\frac{1}{n^2} + f_{nlj} \left(\alpha, \frac{m_e}{m_p}, \dots \right) + \delta_{\ell 0} \frac{C_{NS}}{n^3} r_P^2 \right)$$



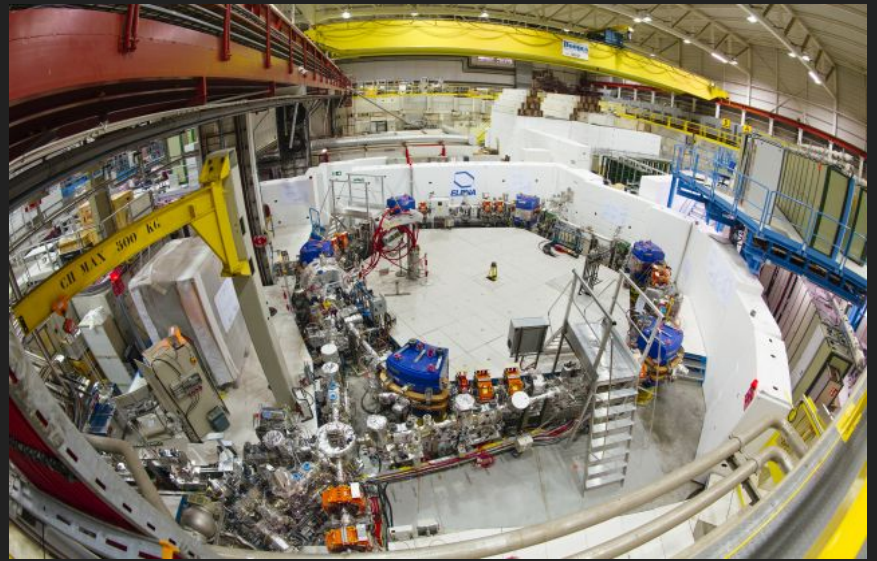
Apparatus

Antiproton Decelerator (AD)

Extra Low ENergy Antiproton ring (ELENA)

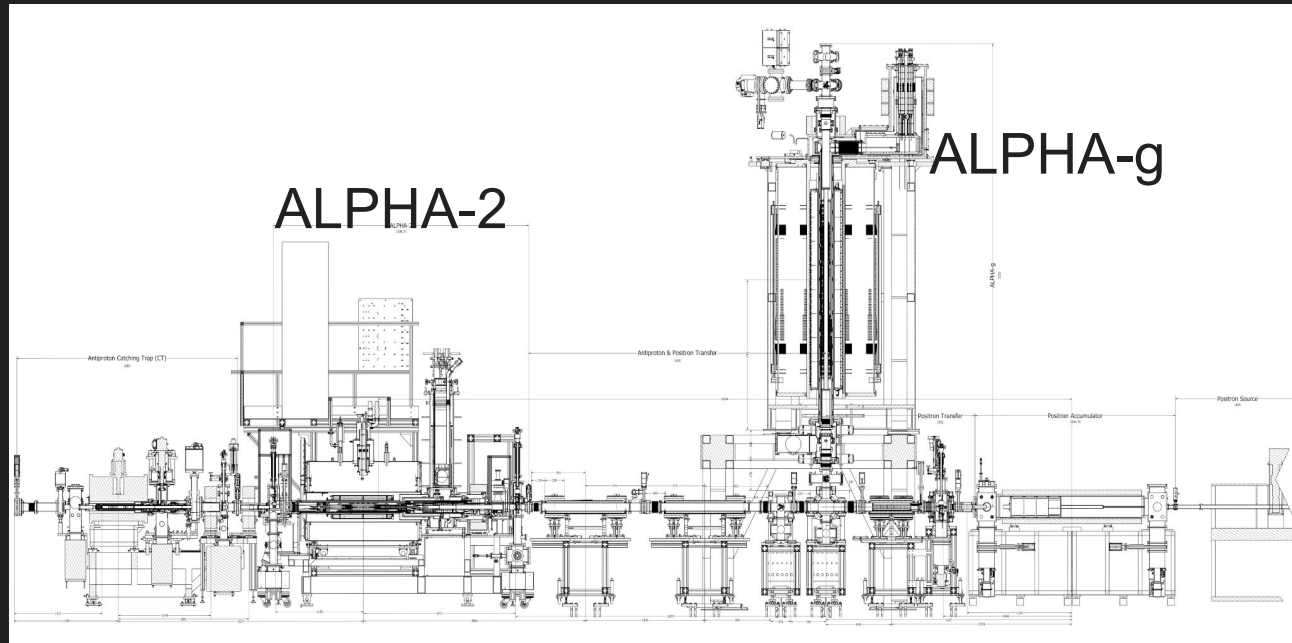
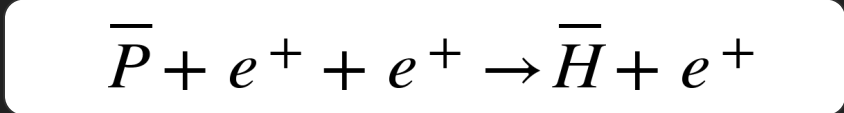


<https://cds.cern.ch/record/39385>



<https://home.cern/fr/node/4325>

Experiment Logistics

 \bar{p} e^+ 

Experiment Logistics Cont.

Produce and Store Antihydrogen

- ❖ Slow down antiproton beam
- ❖ Cool positron with beryllium
- ❖ Cool antiproton with electron
- ❖ Laser cool Antihydrogen

Do Measurement with it

- ❖ ALPHA-2
 - Spectroscopy (1S-2S, 2S-4P,...)
- ❖ ALPHA-G
 - Gravitational measurement

Detector

- ❖ Reconstruct annihilation vertex

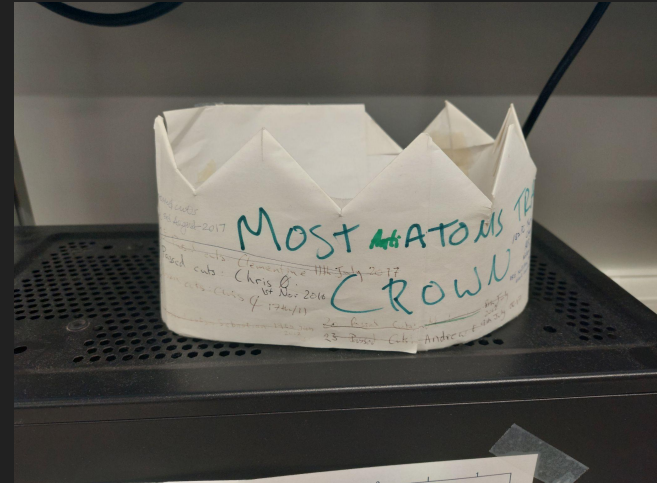
Shift Work

→ Regular work:

- ◆ Stacking
- ◆ Data-logging
- ◆ Cryogenics
- ◆ Thermal cycle (every ~2 weeks)
- ◆ ... anything that needs to be done

→ Currently Happening:

- ◆ 2S-4P Measurement
- ◆ Lyman-Alpha Measurement (1S-2P)
- ◆ Energy mixing experiment
- ◆ ALPHA-G upgrade installation



New pass cut record: 182 (X)

Now 186

2S-4P Measurement with 486nm Laser

2S-4Pa ($\sim 1 \mu W$) :

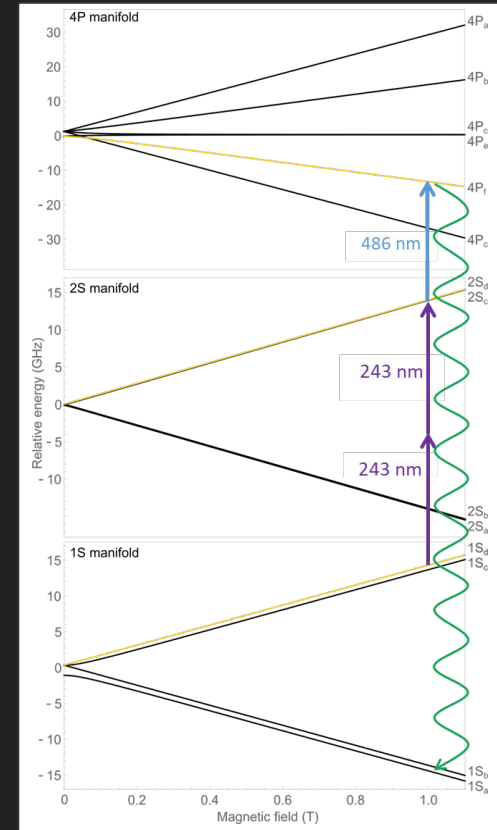
100% decay back to 1Sd trappable state

=> signal suppression on resonance

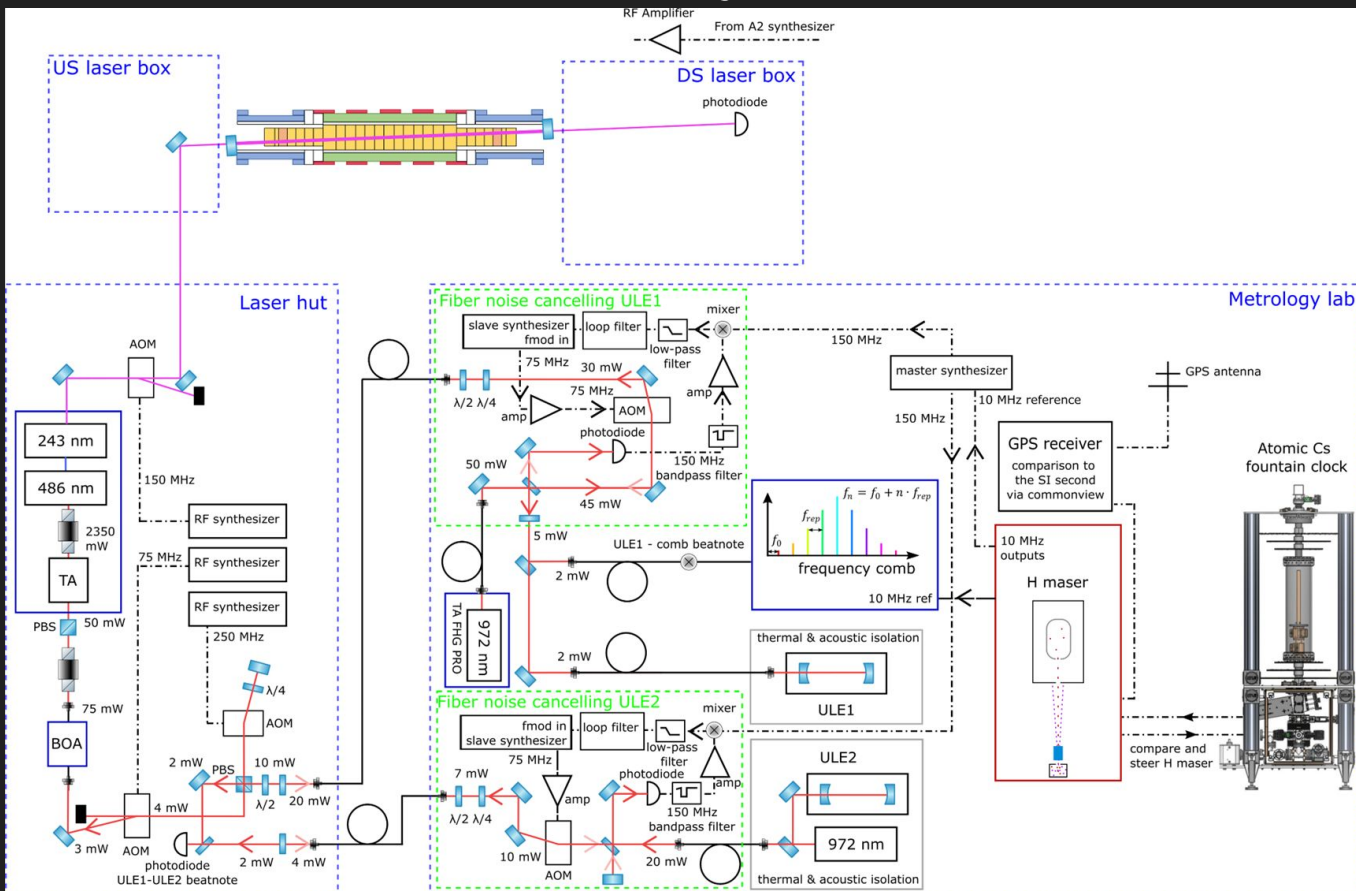
2S-4Pf ($\sim 100 \mu W$) :

$\sim 100\%$ decay into 1Sa untrappable state

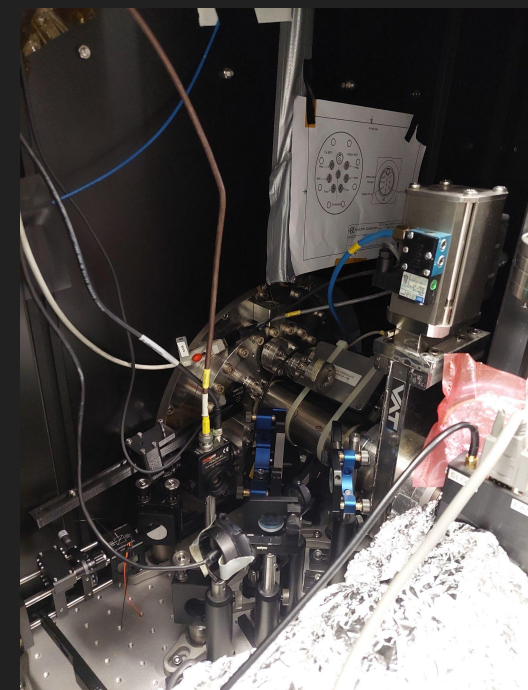
=> signal enhancement on resonance



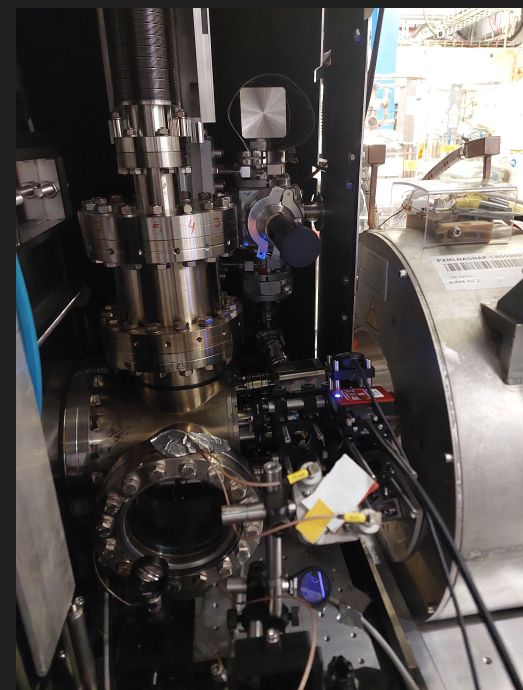
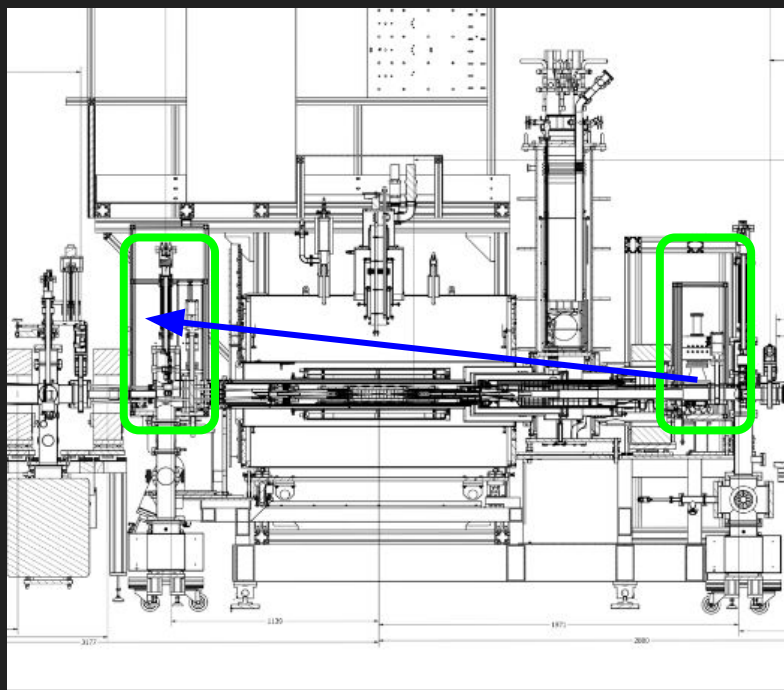
Laser System



486 nm Laser



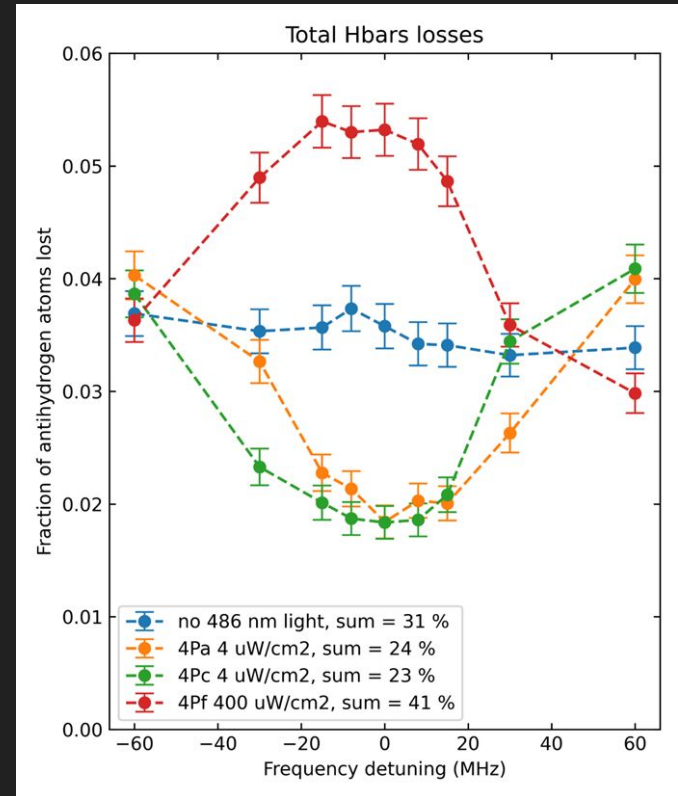
Upstream



Downstream

2S-4P Summary

- ❖ Procedures:
 - Optical design & alignment
 - Labview control
 - Connect to sequencer
 - Cooperation with Laser Cooling Team & Microwave Team
 - Run experiment (of course)

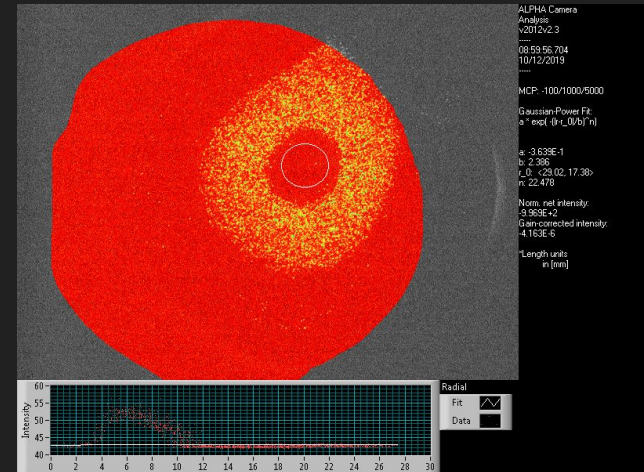


Centrifugal Separation of Be⁺/e⁺

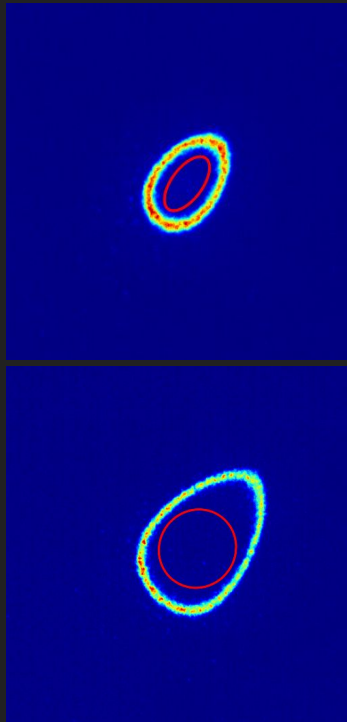
- ❑ Why: Cold position => more trappable antihydrogen
- ❑ How: sympathetic cooling of e⁺ with laser-cooled Be⁺
- ❑ Lower temperature => more centrifugal separation
- ❑ Implies no further cooling of e⁺

Goal:

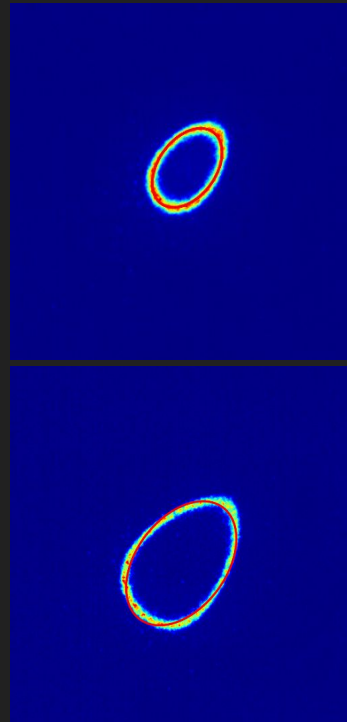
1. Model-to-Data Comparison
2. Feasibility Test of New Species for Cooling



Centrifugal Separation of Be⁺/e⁺ Analysis

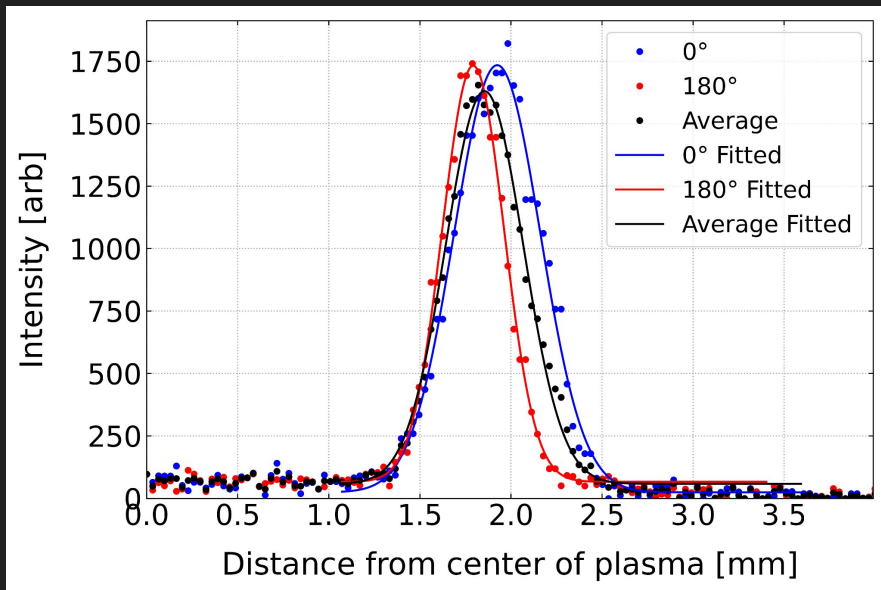


Old Fitting

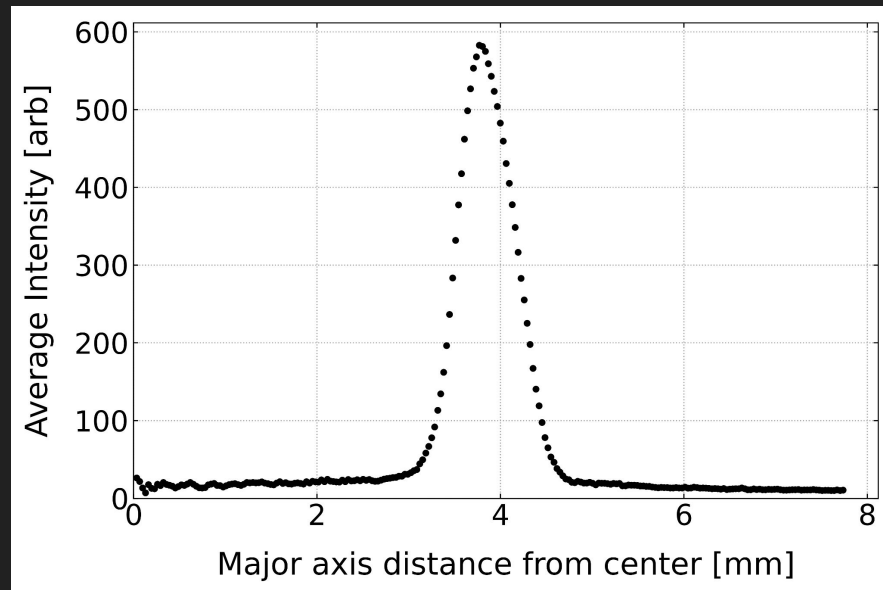


New Elliptical Fitting

Centrifugal Separation of Be⁺/e⁺ Analysis

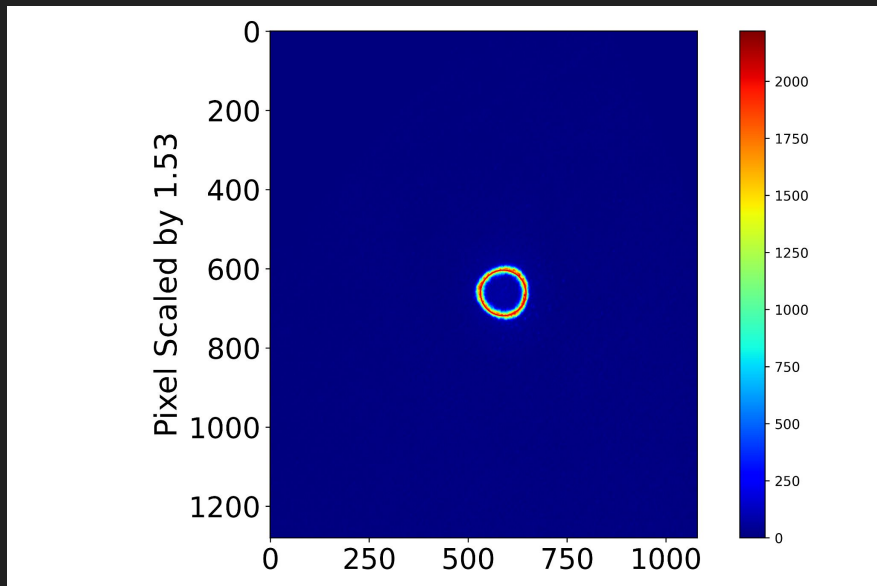


Along Major Axis

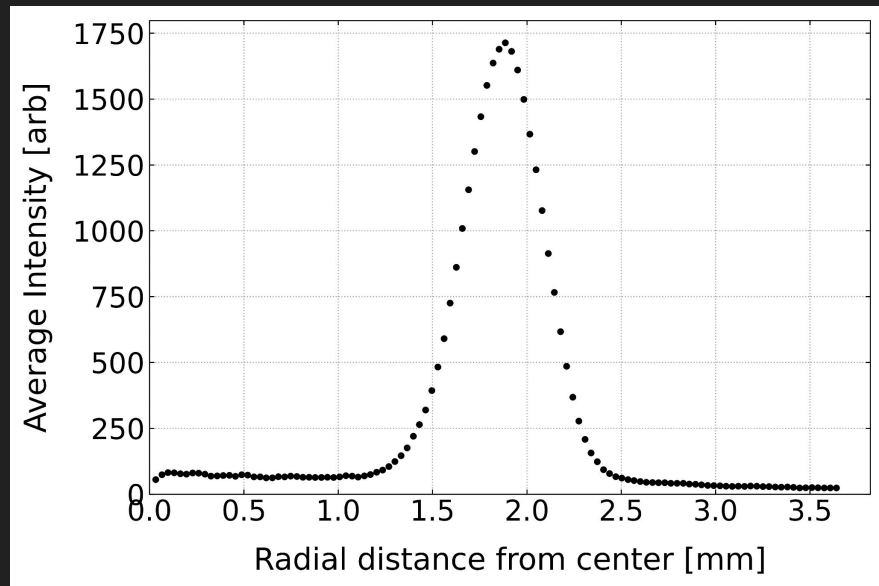


Elliptical Average

Centrifugal Separation of Be⁺/e⁺ Analysis

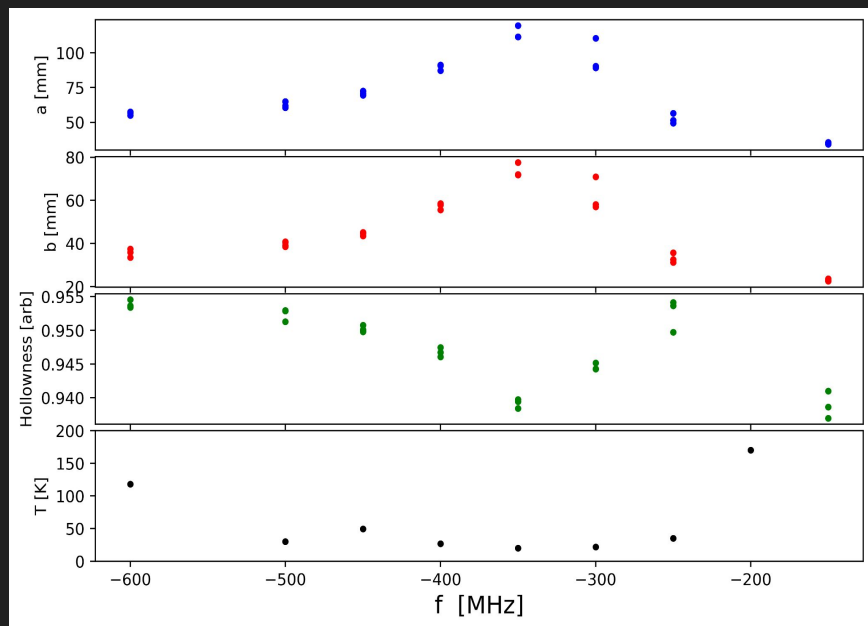


Circular Fitting after Transformation

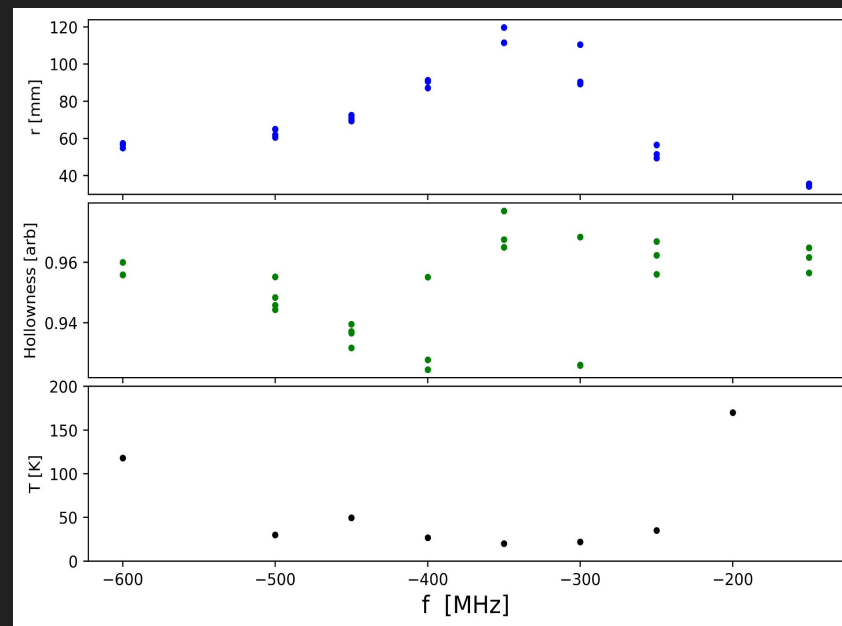


Circular Average

Centrifugal Separation of Be⁺/e⁺ Analysis

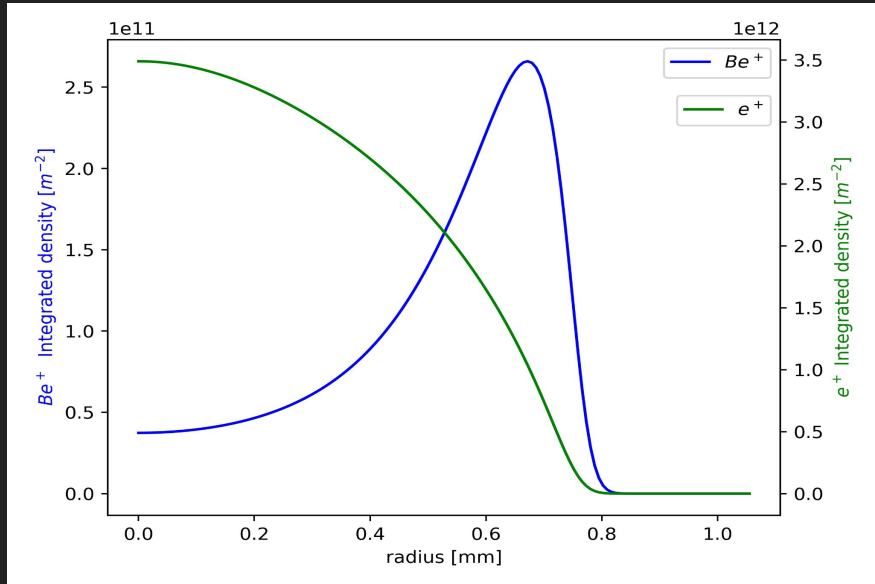


Elliptical Profile

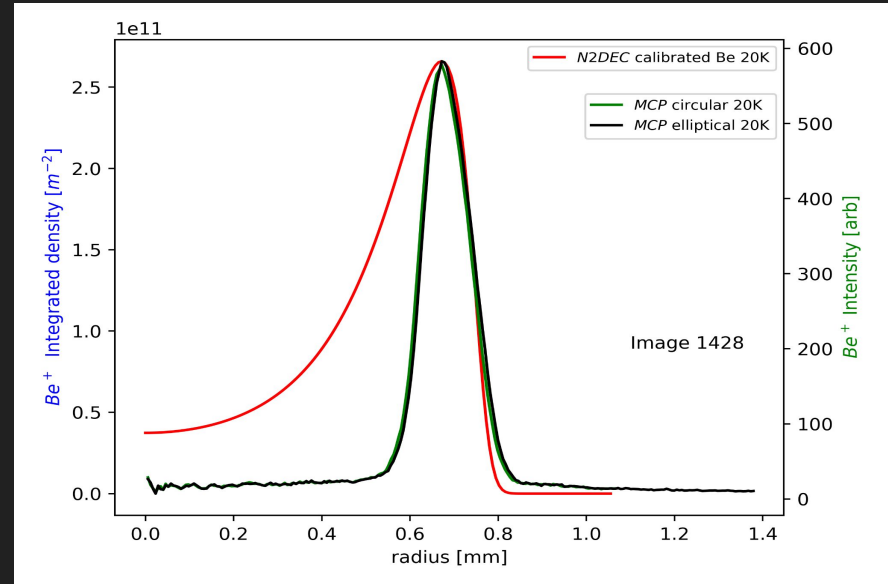


Circular Profile

Centrifugal Separation of Be⁺/e⁺ Simulation



Simulation



Comparison with data

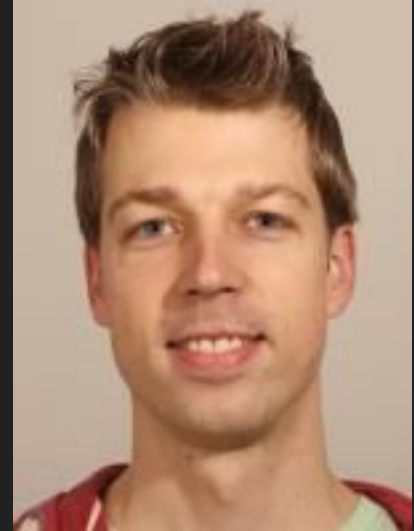
Mentors



Prof. Niels Madsen



Dr. Kurt Thompson

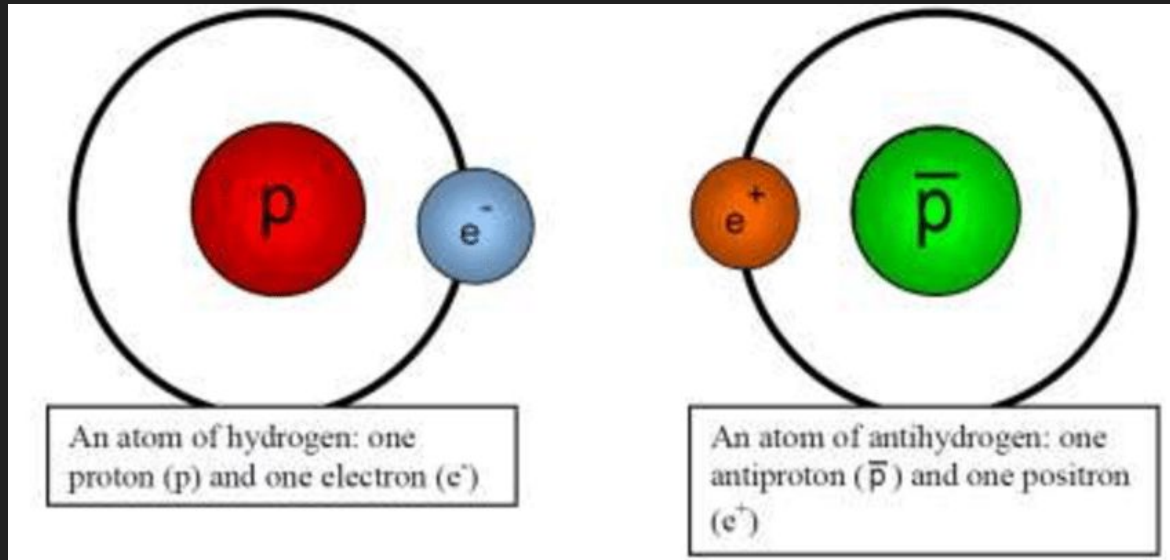


Dr. Janko Nauta



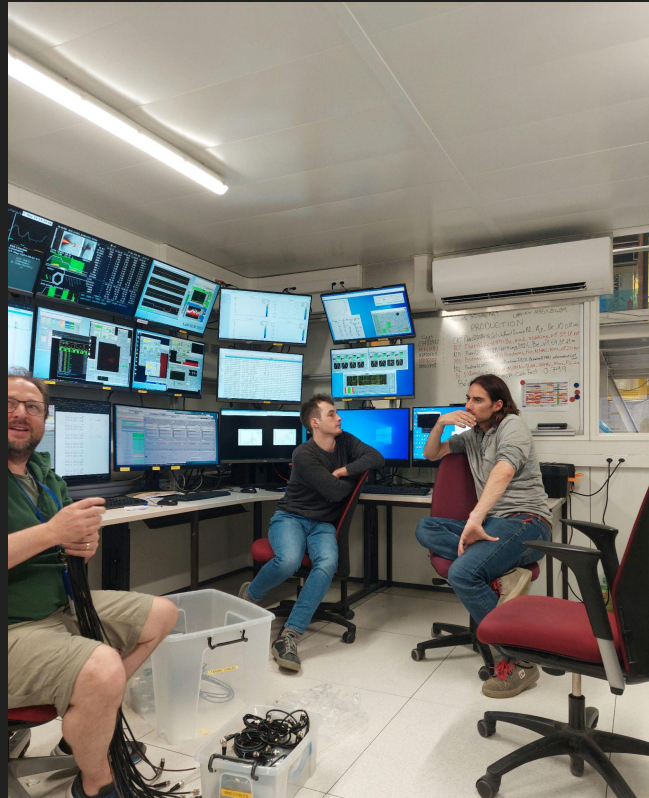
Purpose

Investigate any asymmetry between matter and antimatter, with antihydrogen

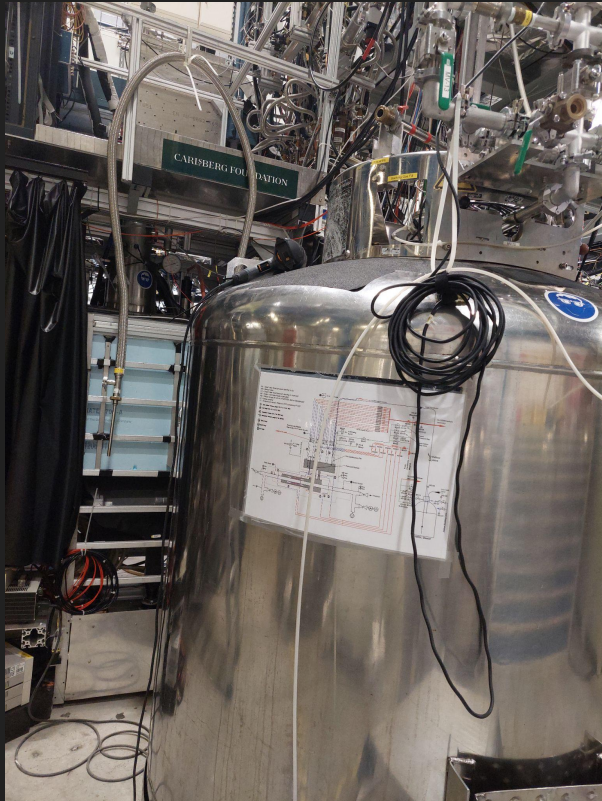


https://www.researchgate.net/figure/Description-of-hydrogen-and-antihydrogen-atom-2_fig1_343695668

Control Room



Shift Work



- Cryogenic Operation:
Liquid Helium / Nitrogen Transfer

Culture

