

# ALPHA

## Antihydrogen Laser PHysics Apparatus

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On behalf of the ALPHA collaboration





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**University of Calgary,  
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**CERN**



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Center Negev, Israel**



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Sweden**



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Canada**



**TRIUMF,  
Canada**



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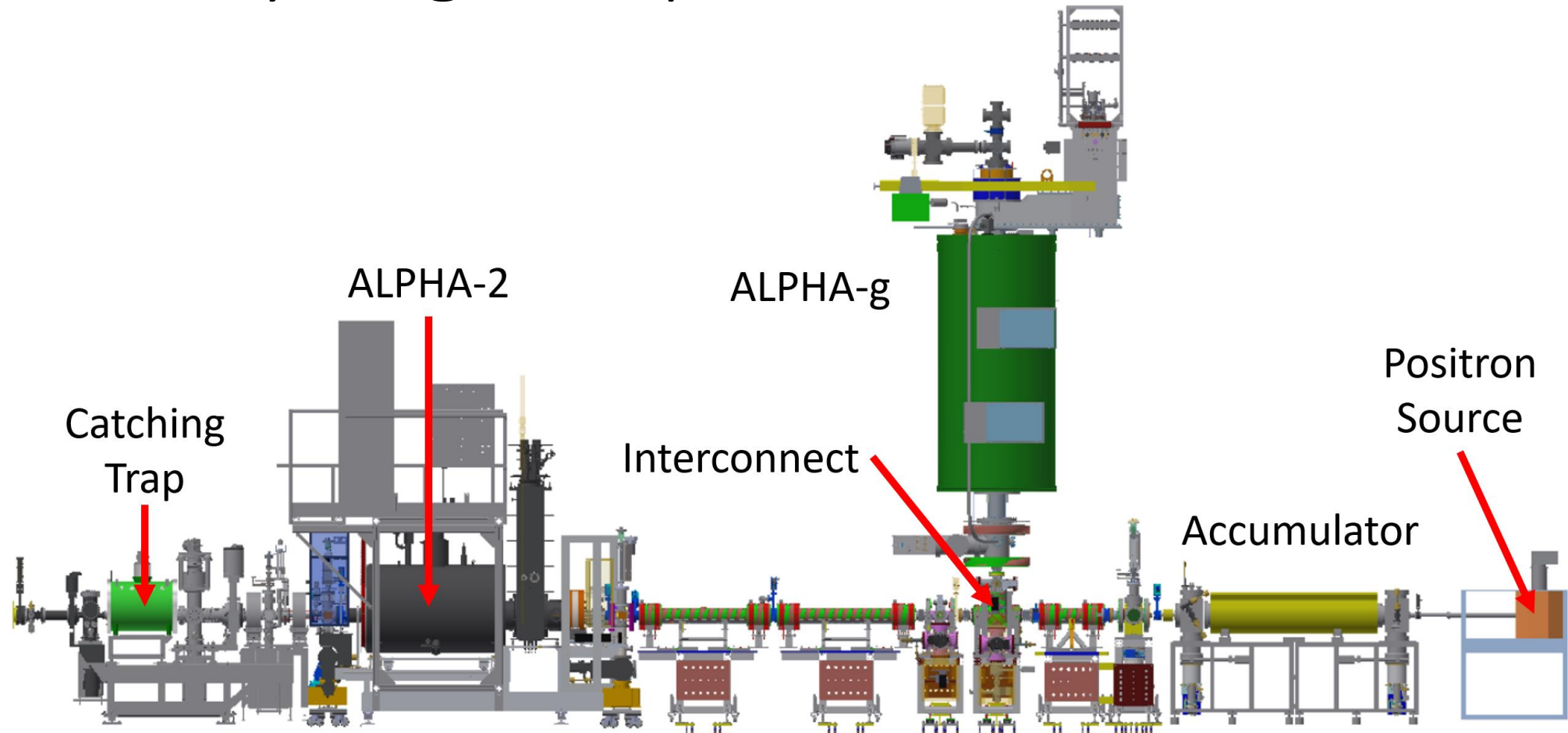


# Outline

- The ALPHA experiment at CERN
- ALPHA-2 achievements
- ALPHA-3 plans
- ALPHA-g status
- The ELENA decelerator

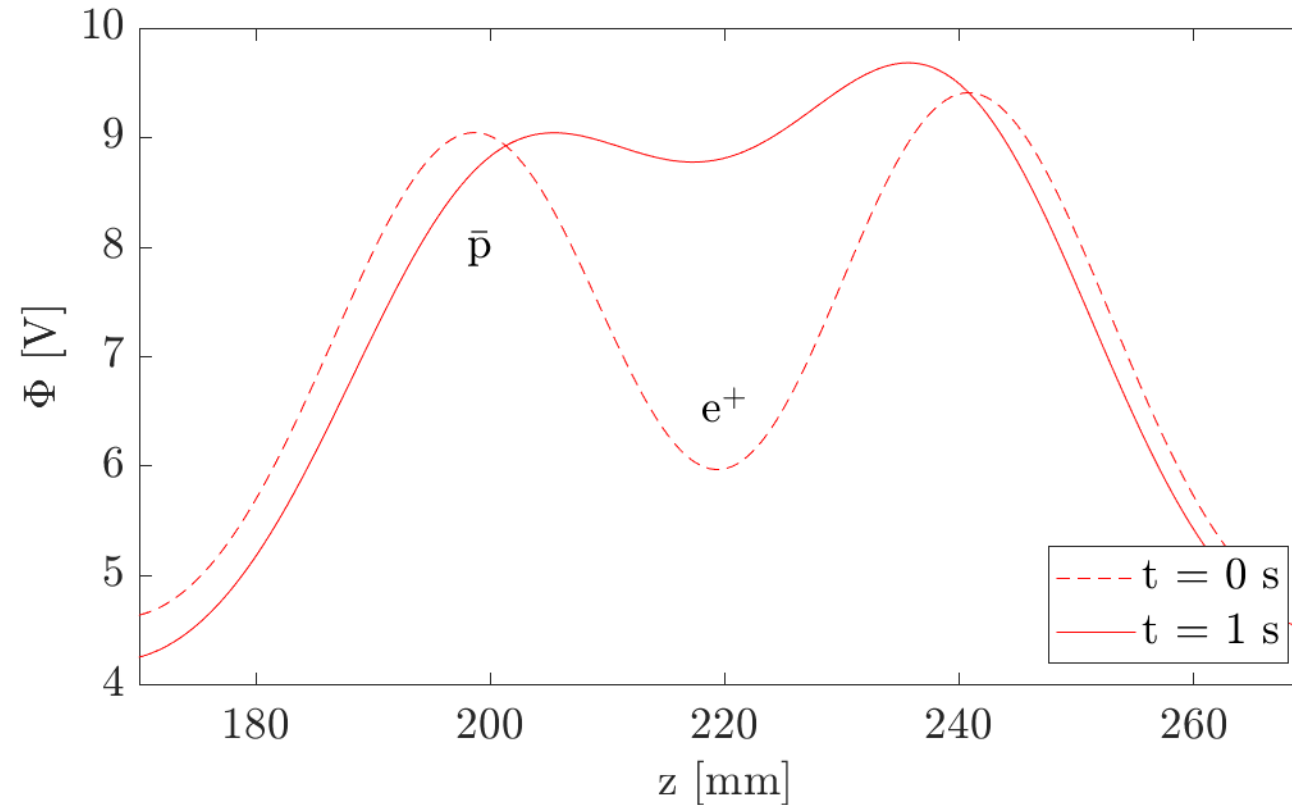


# An Antihydrogen Experiment

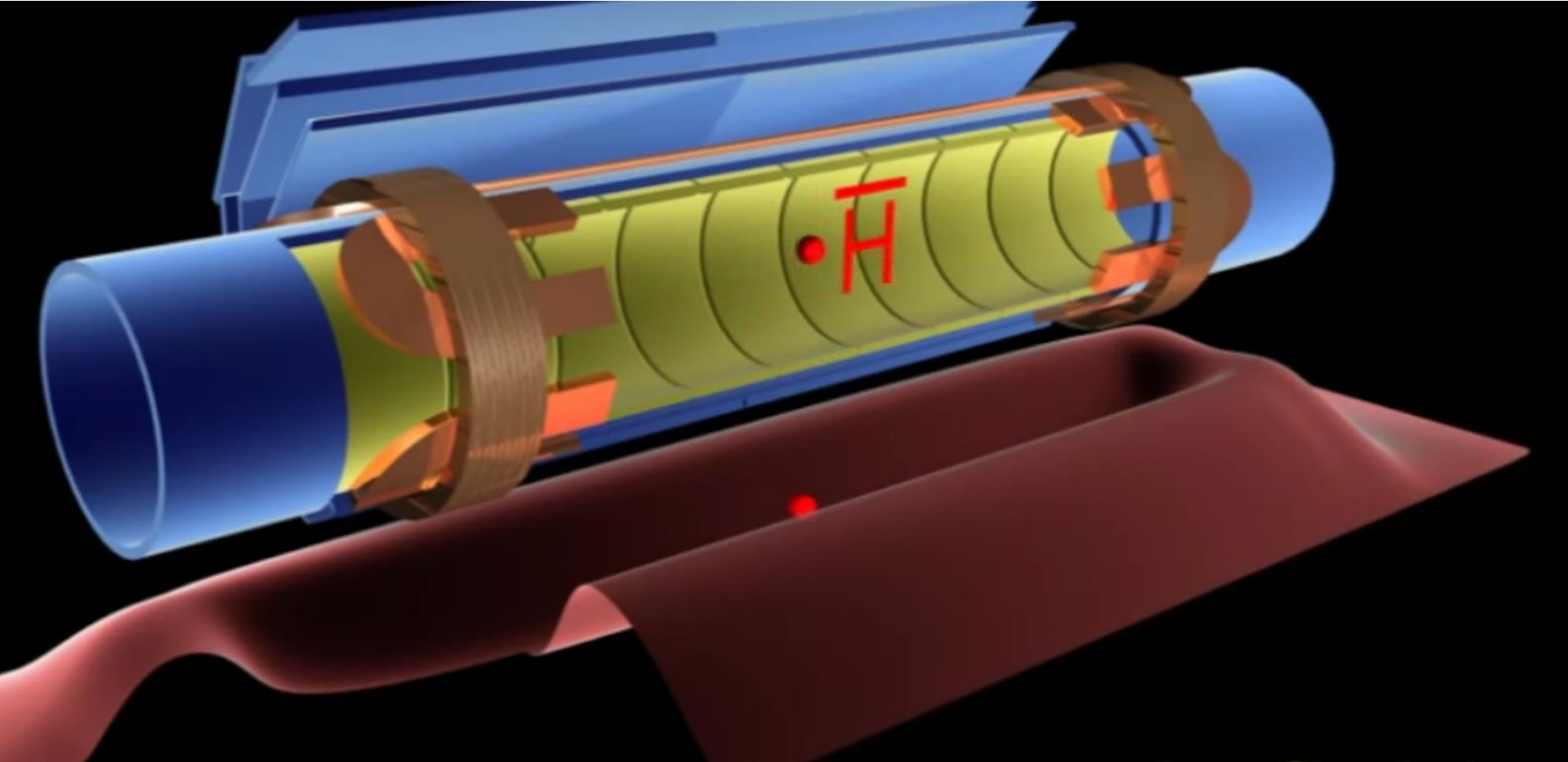


# Antihydrogen Formation

- Same for ALPHA-2 and ALPHA-g



# The Atom Trap



# Properties Already Measured

- $1S-2S$  ( $2.2 \cdot 10^{-12}$ )
- $1S-2P_{1/2}$  and  $2P_{3/2}$
- $1S$  hyperfine
- Charge neutrality
  
- Laser cooling, antihydrogen accumulation

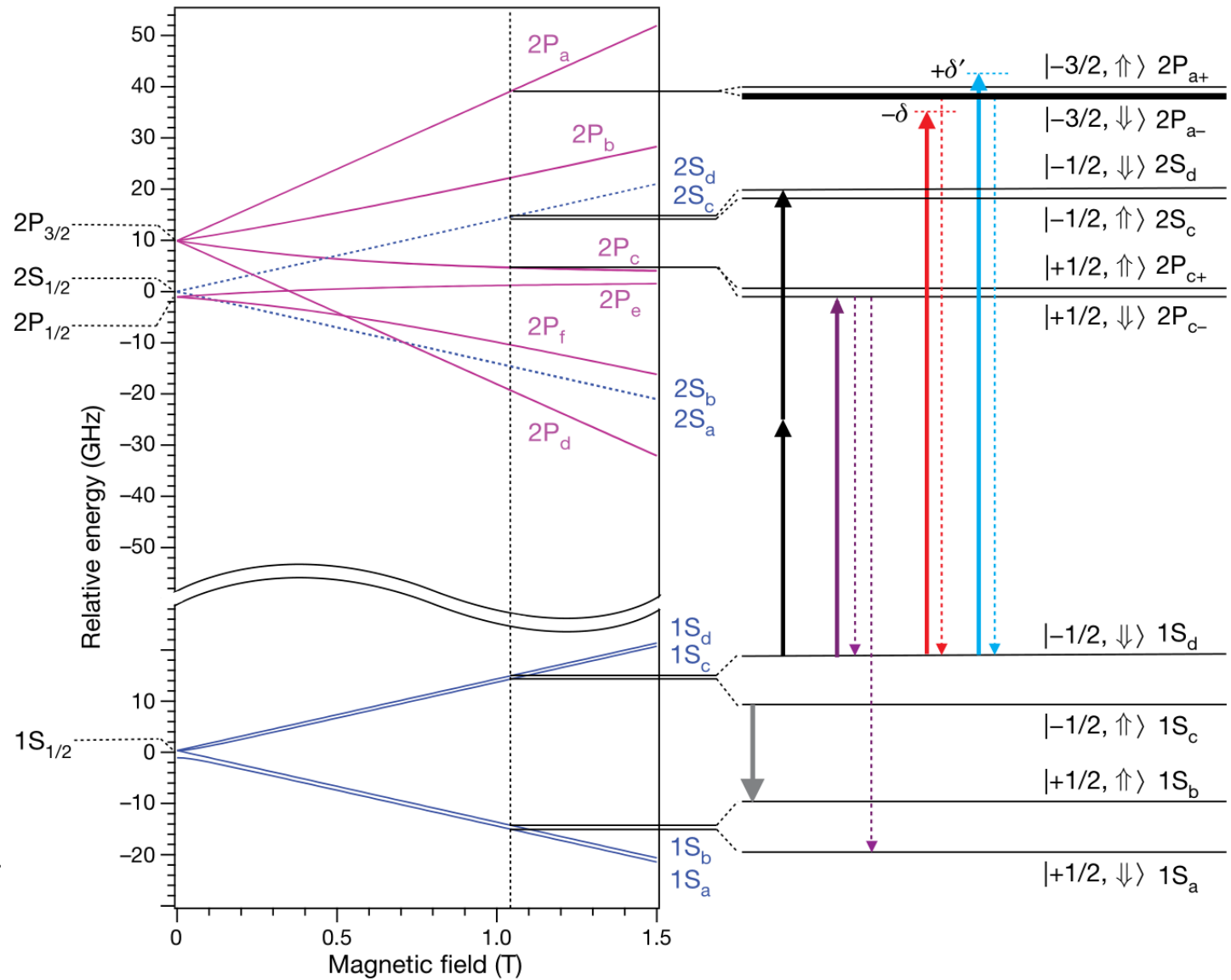
<https://alpha.web.cern.ch/publications>



# Laser Cooling



C. J. Baker et al. Laser cooling of antihydrogen atoms. Nature, 592(7852):35–42, mar 2021

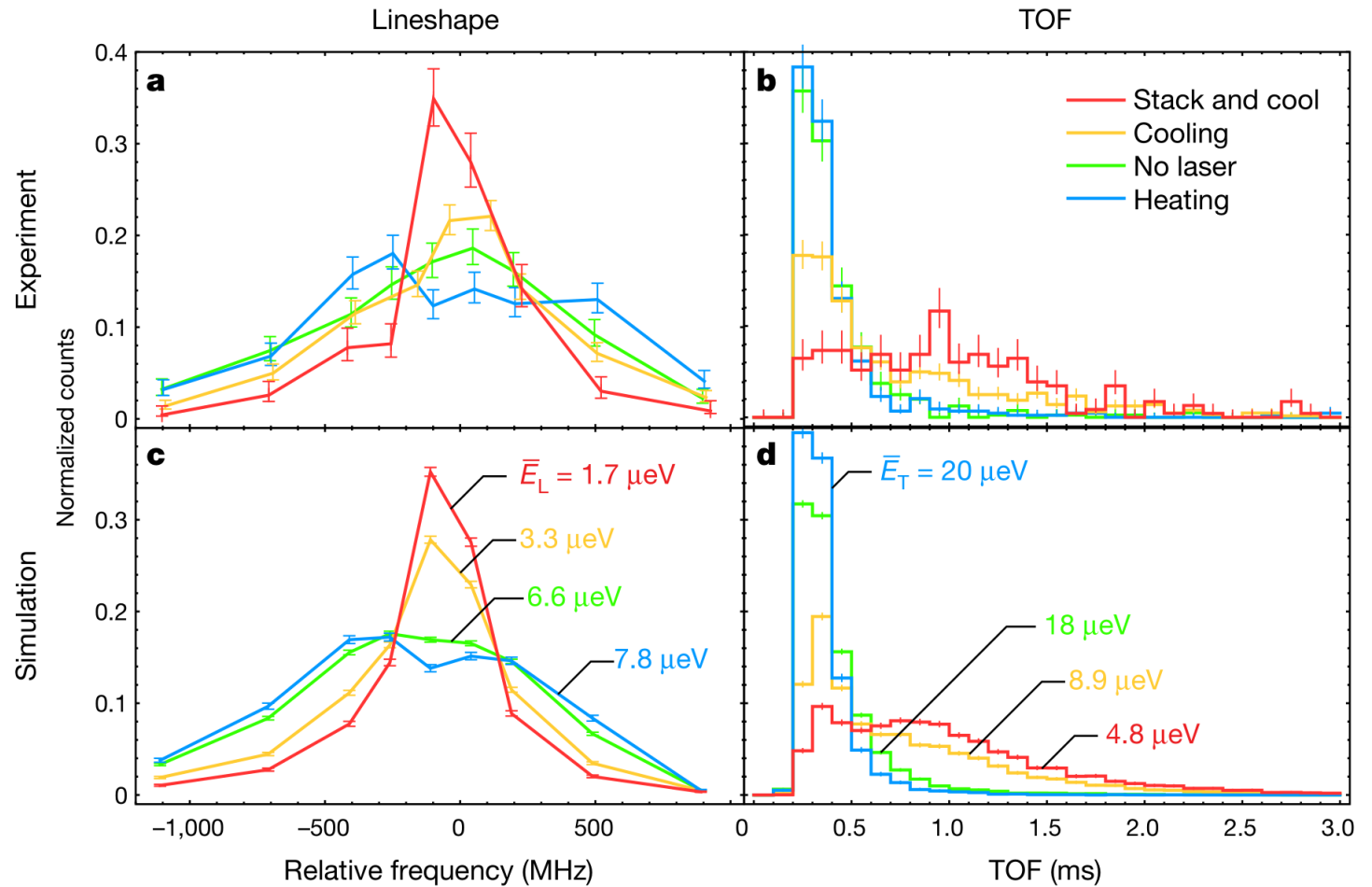




# Laser Cooling

- 1S-2S lineshape
- Time of flight

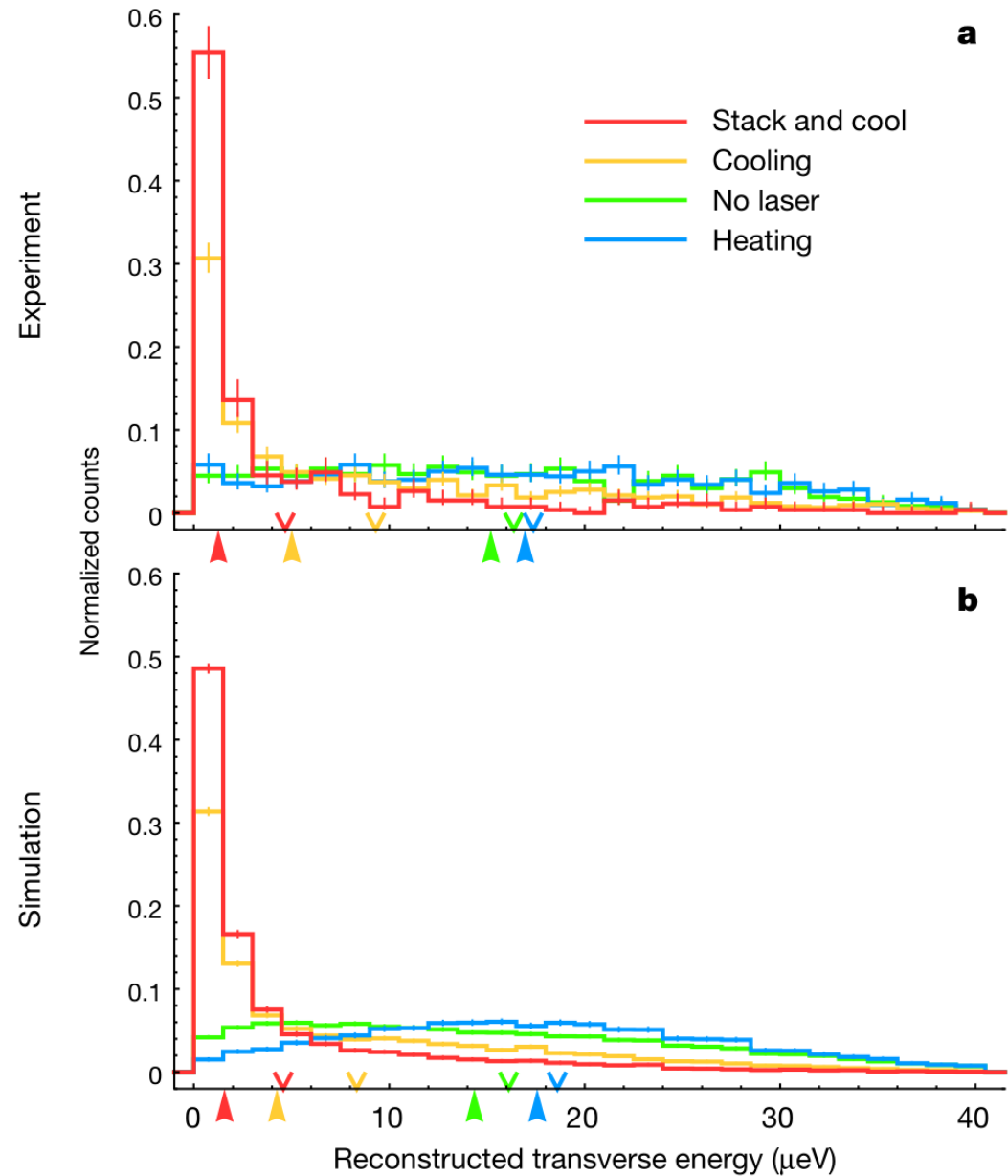
C. J. Baker et al. Laser cooling of antihydrogen atoms.  
Nature, 592(7852):35–42, mar 2021



# Laser Cooling

- Reconstructed transverse energies
- From 50 to 1  $\mu\text{eV}$

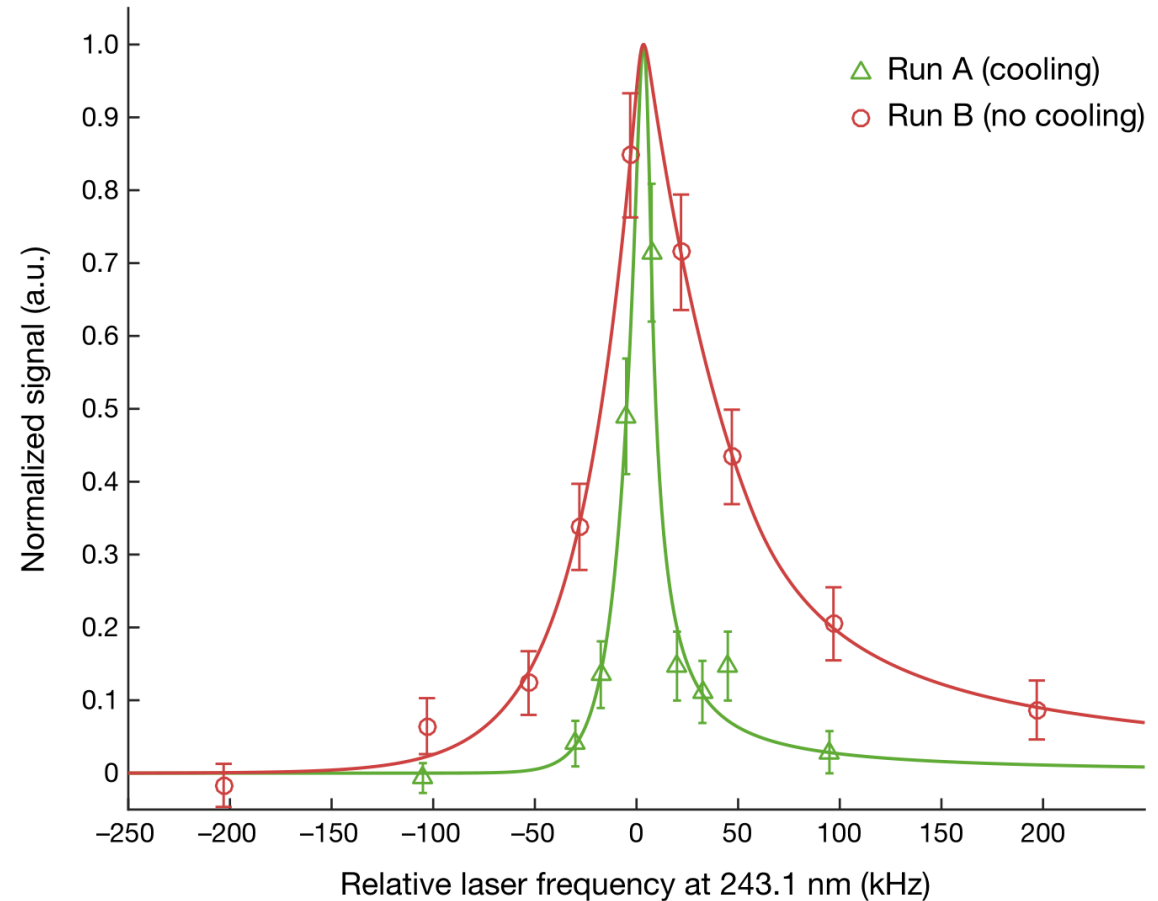
C. J. Baker et al. Laser cooling of antihydrogen atoms.  
Nature, 592(7852):35–42, mar 2021



# Laser Cooling

- 1S-2S transition
- 4 times as narrow

C. J. Baker et al. Laser cooling of antihydrogen atoms.  
Nature, 592(7852):35–42, mar 2021



# Beryllium Cooling

- Positrons currently 17 K
- Be<sup>+</sup> can be laser cooled
- Be/e<sup>+</sup> ratio of 1/10
- Effect saturates at 7 K
- 5x trappable antihydrogen

C. J. Baker et al. Sympathetic cooling of positrons to cryogenic temperatures for antihydrogen production. *Nature Communications*, 12(1), oct 2021

Jack Jones. Sympathetically Laser-Cooled Positron Plasmas for Antihydrogen Formation. PhD thesis, Swansea University, 2022



# ALPHA-3 Upgrade

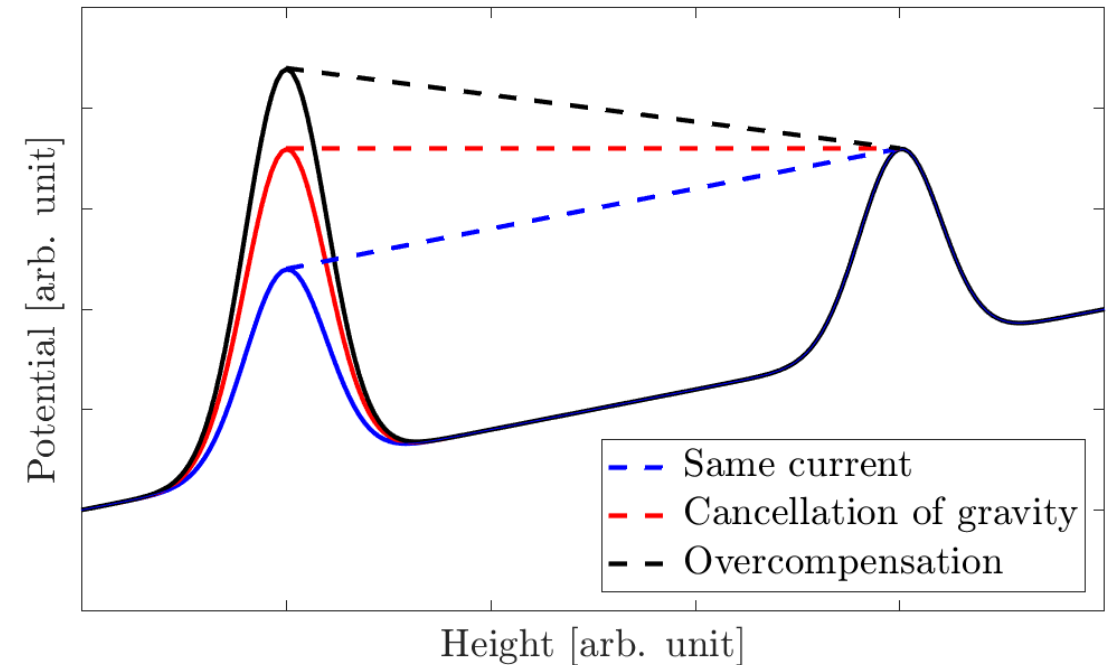
- Achieve hydrogen-like precision ( $4.2 \cdot 10^{-15}$ ) (or better)
- H MASER as ref. for frequency comb
- Cs fountain clock
- Sympathetic cooling with Be ions
- Laser cooling of antihydrogen



# ALPHA-g

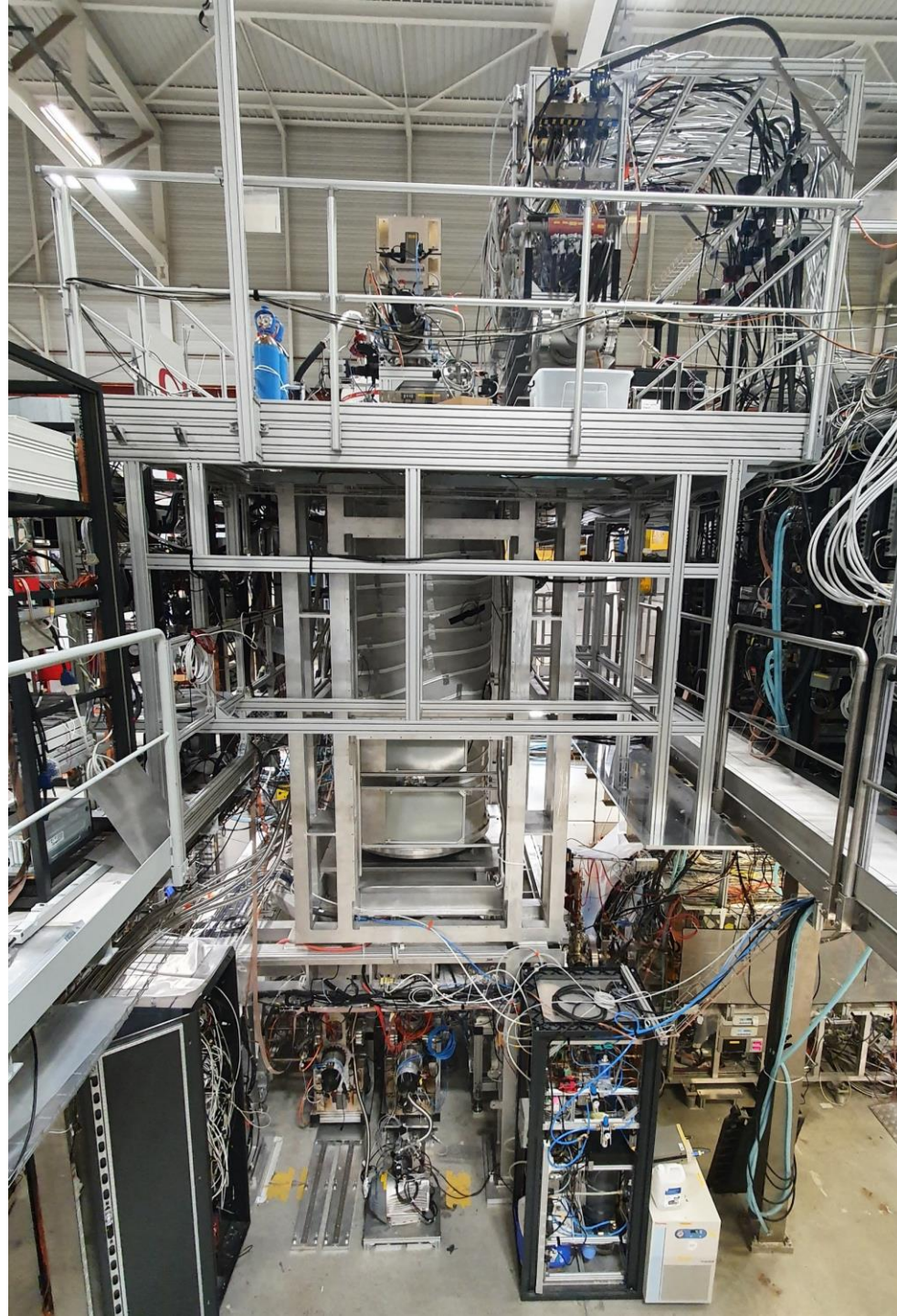
- Vertical atom trap
- An “anti-gravity” measurement
- Knowledge and control of B-fields
- Up/down and 1% measurement

J. S. Hangst et al. Addendum to the ALPHA proposal. 2016



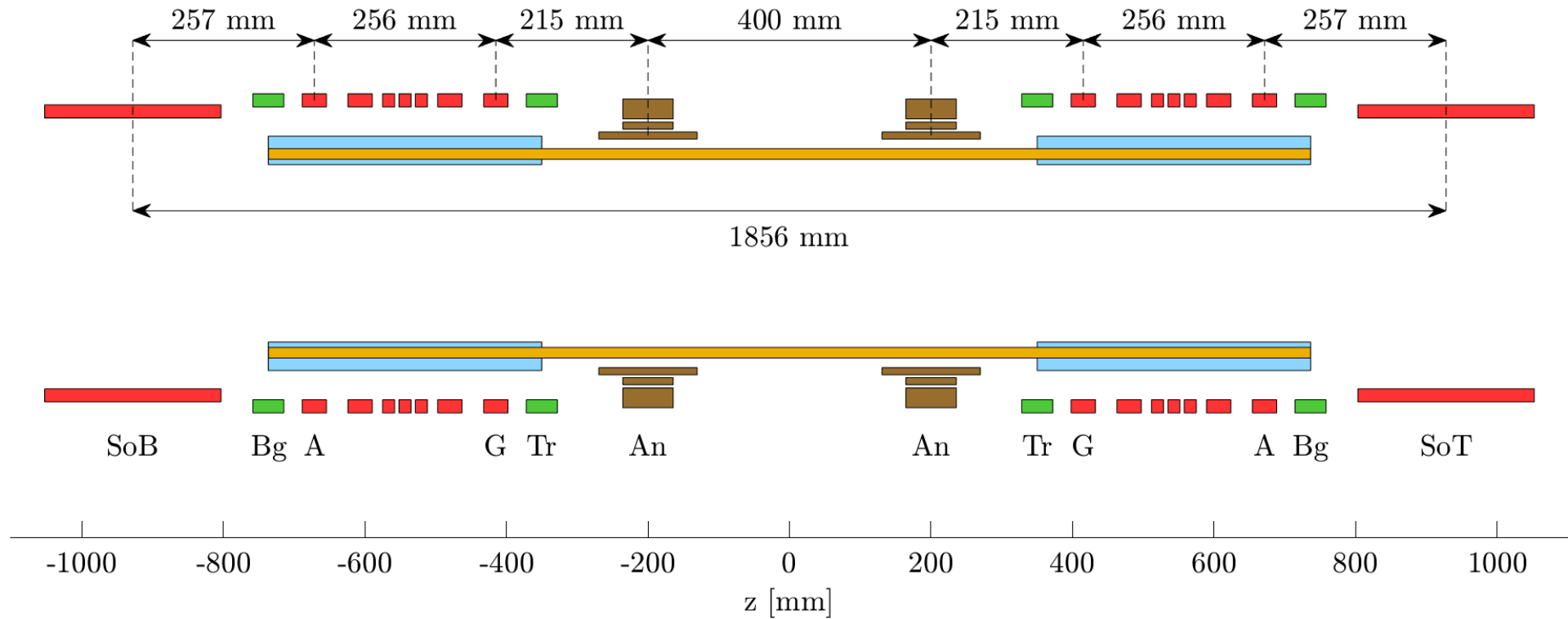


21/4 2022



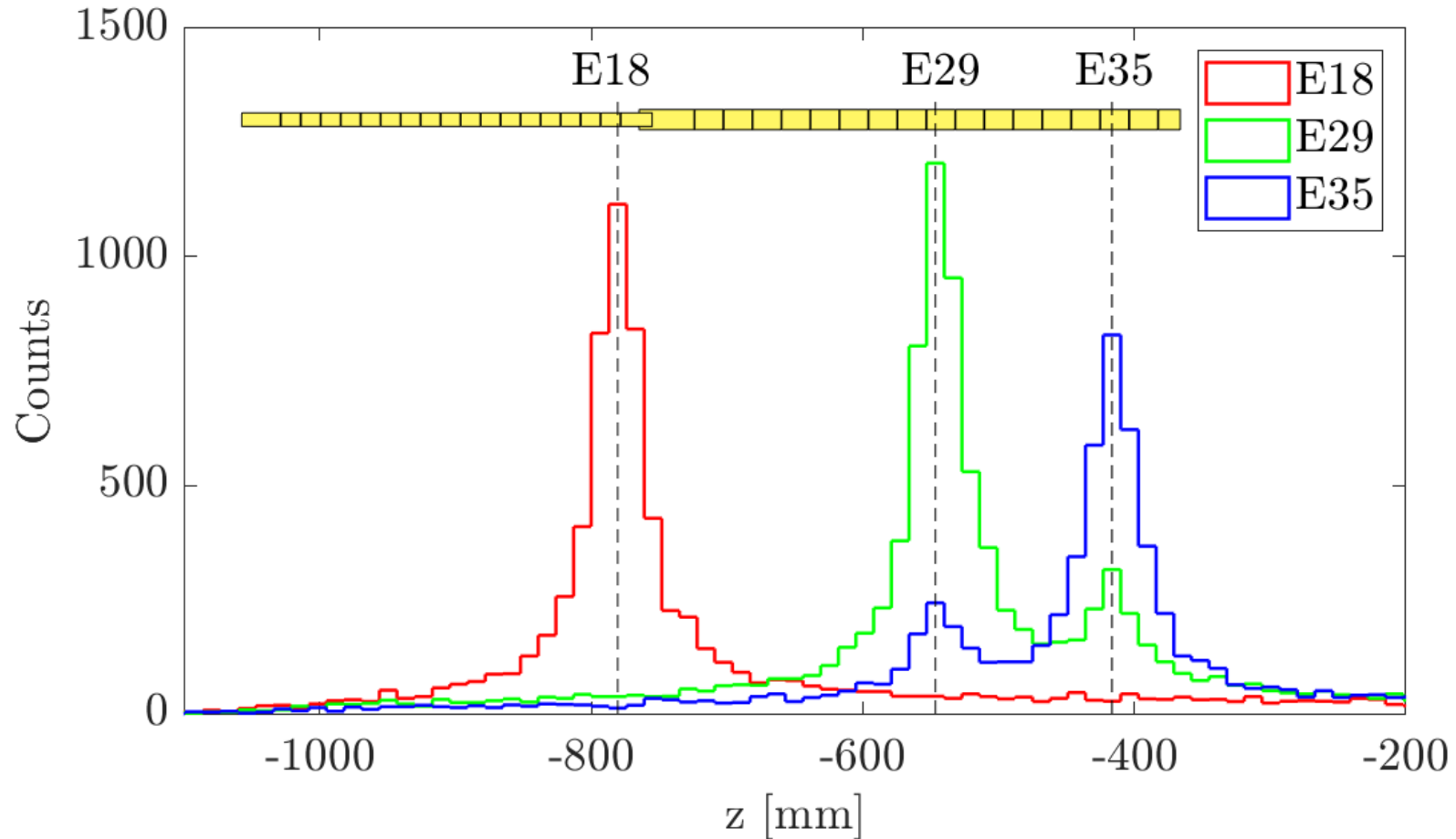
15

# ALPHA-g Magnet Layout



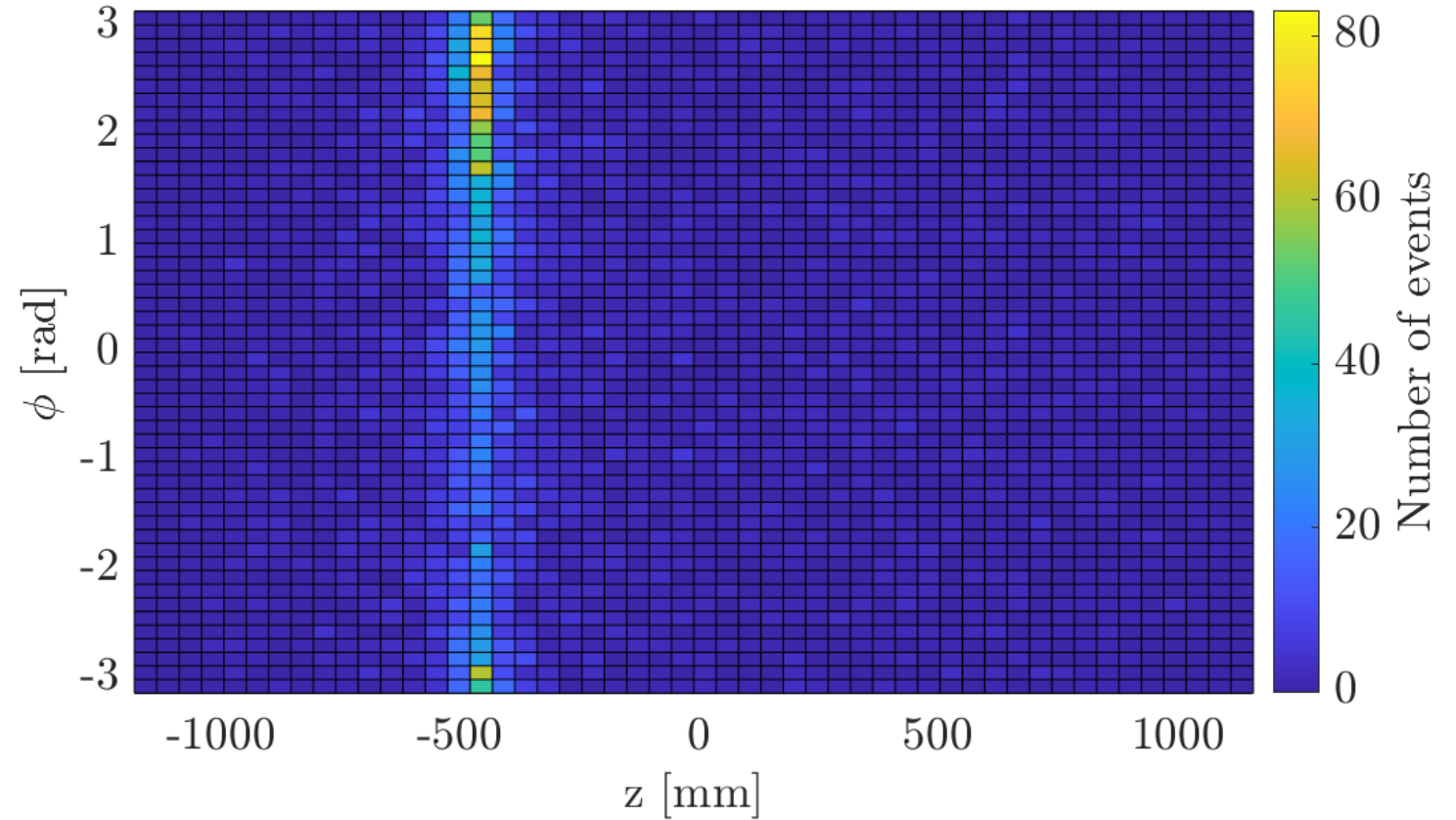


# Trapped Antiprotons 2018



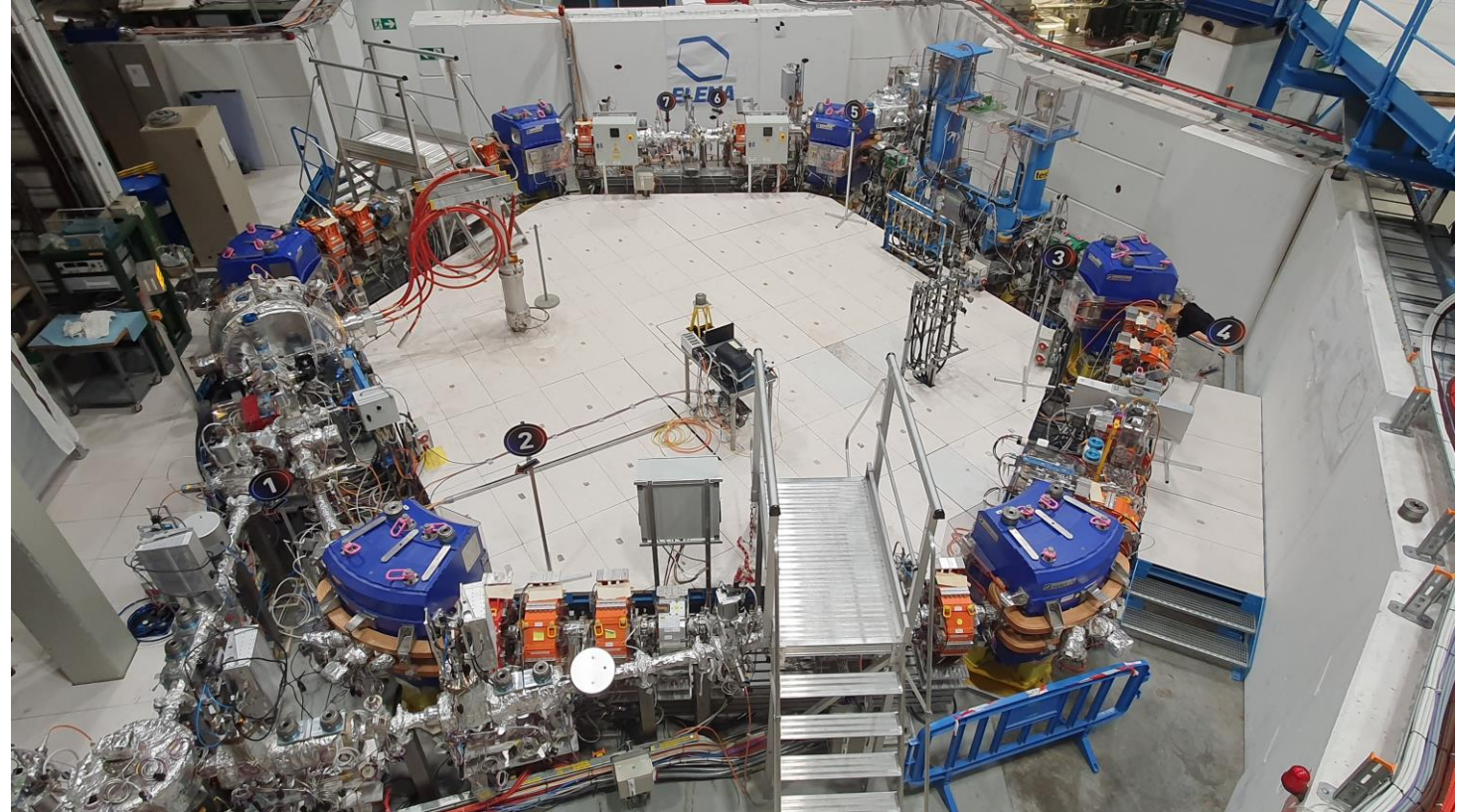
# The 2021 Run

- Better state
- Positron temperatures
- Mixing attempts
- Patch potentials
- Demonstrated ECR



# ELENA

- From 5.3 MeV to 100 keV
- $4.5 \cdot 10^6$  per bunch, 24/7
- Find the right foil



# Thank you

Get in touch:

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