Latest Results from the ALPHA experiment and Upgrades for the Next Run

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Antihydrogen Laser PHysics Apparatus
http://alpha.web.cern.ch/

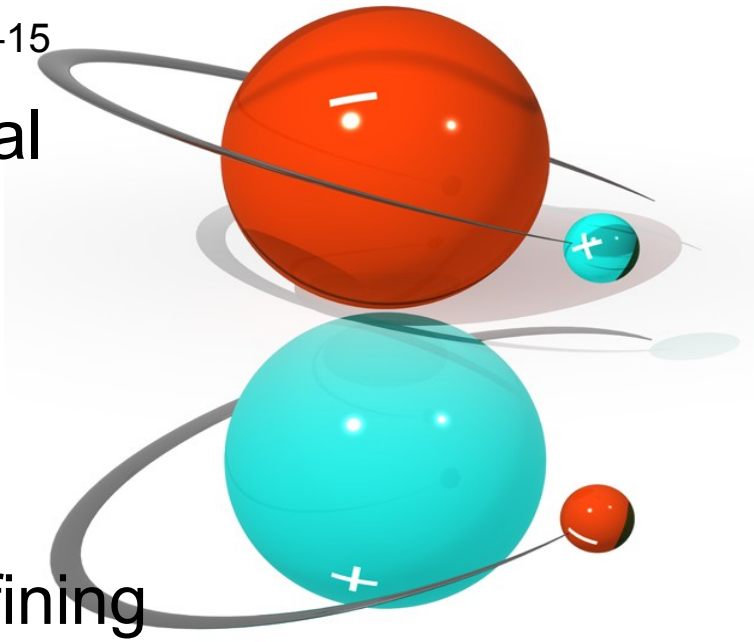
Overview

- Introduction
- ALPHA2 – Apparatus
- Highlights 2010 – present
- Present status & future

Overview of the experimental goal

- Ultimate long term goal 1S-2S antihydrogen atomic transition

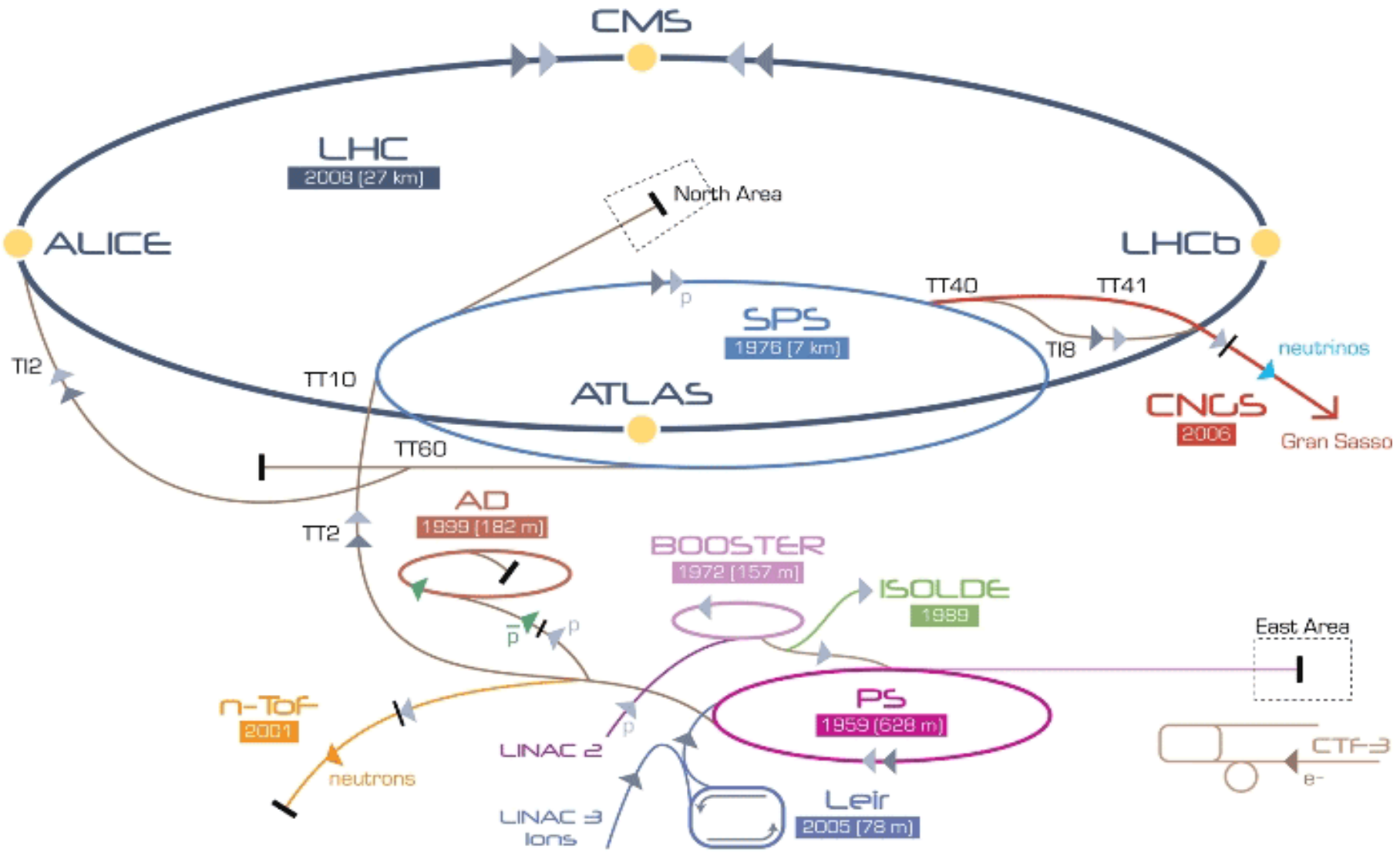
- Haench et al. Currently measured at 10^{-15} precision. One of the best studied physical systems



- => Low energy region test for the CPT -symmetry conservation

- Extreme experimental difficulties in confining the antihydrogen

- Need 0.5K stable atoms, starting point at the moment @ 5.3 MeV antiprotons



p (proton) ion neutrons p̄ (antiproton) proton/antiproton conversion neutrinos electron

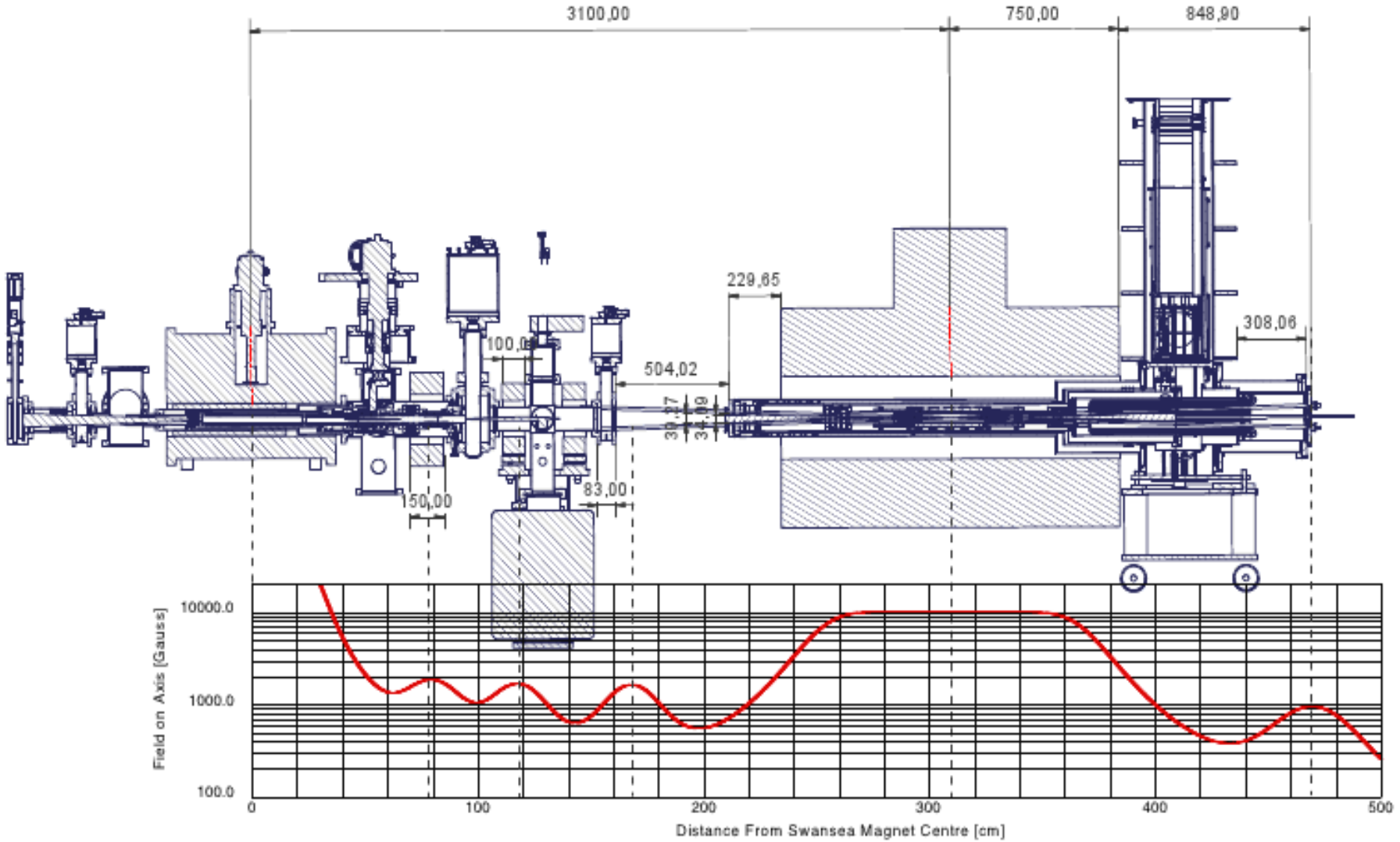
LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF-3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

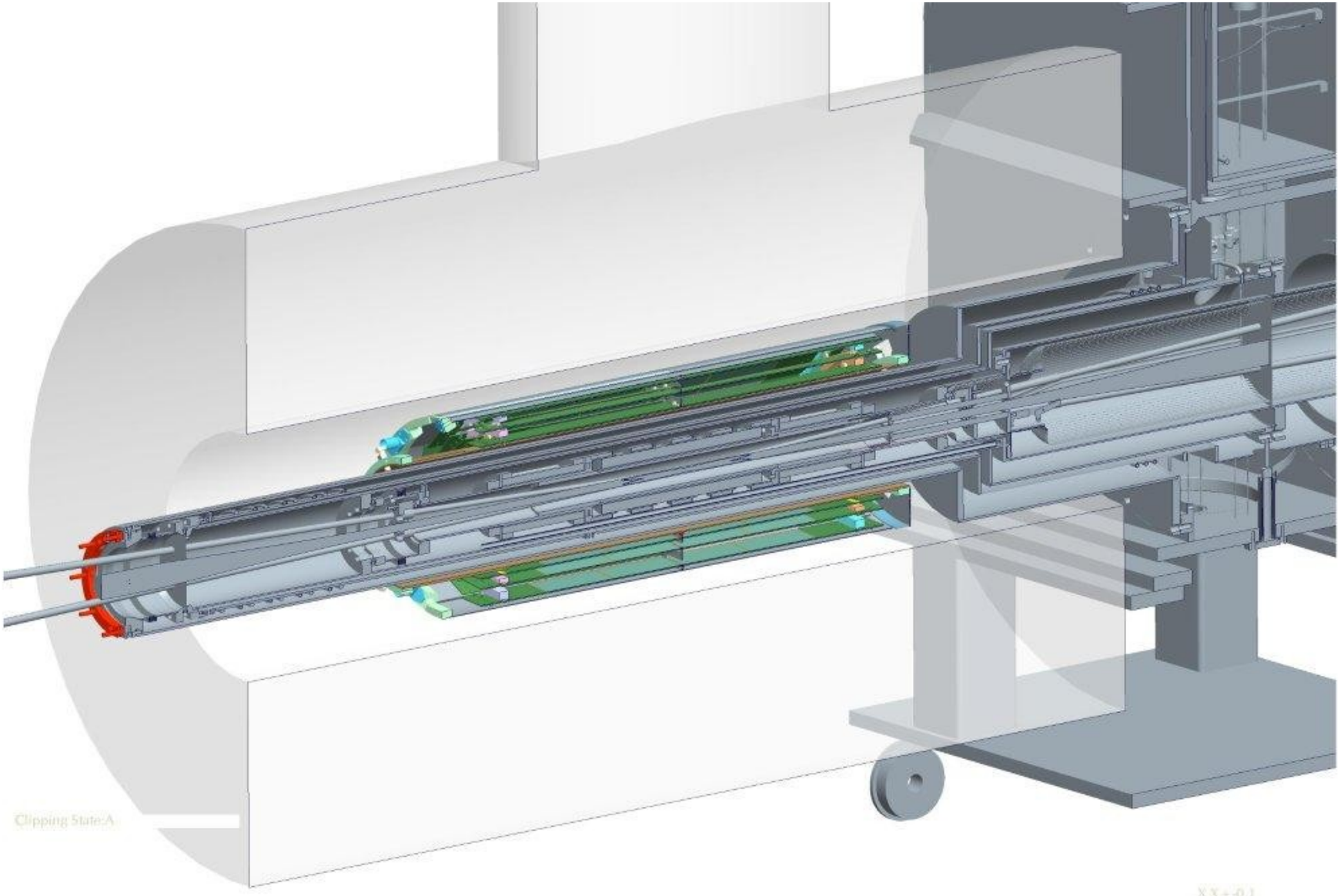
LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

Transfer magnets

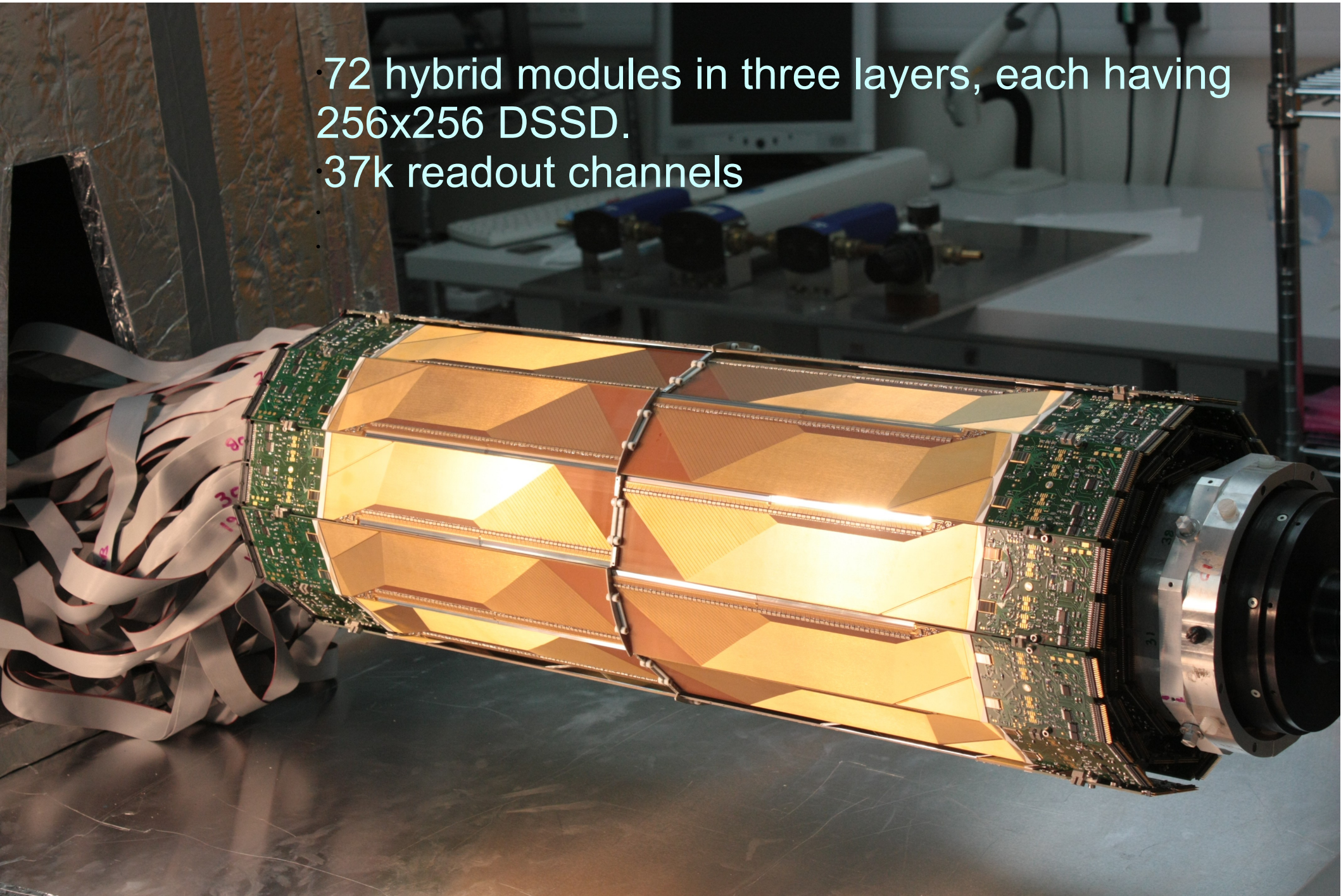
ALPHA - 2



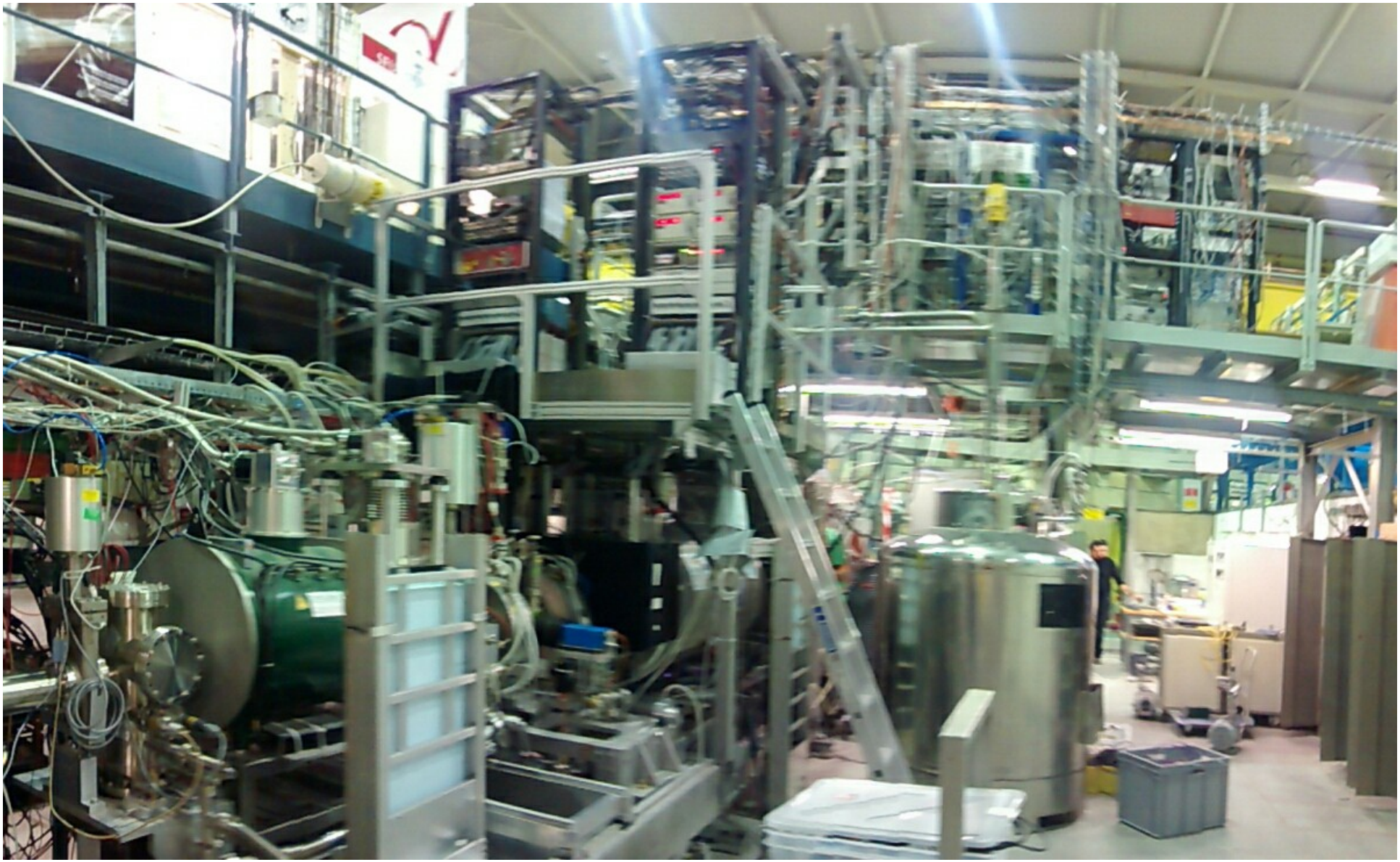
Neutral trap cut-through



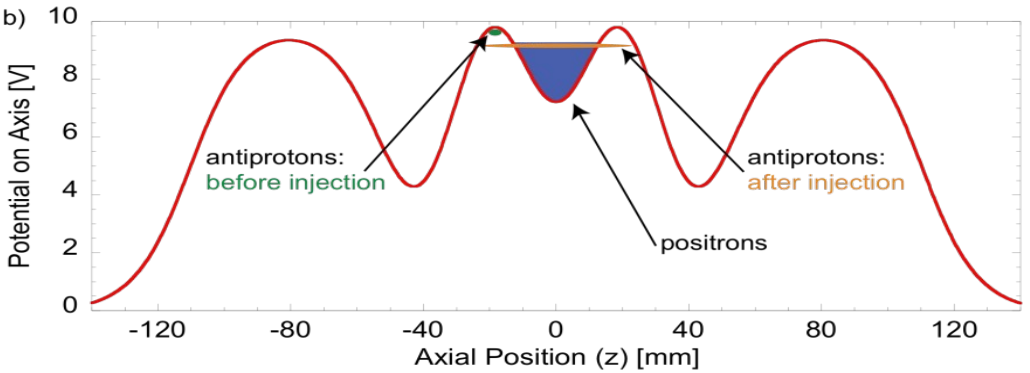
Silicon vertex detector upgrade for ALPHA-2



Zone layout



What to expect from trapping A-1



- Starting point is ~30000 antiprotons at about 100K and ~2M positrons at about 40K
- Mix these 1s by autoresonantly exciting the antiproton plasma
- As result, some 6000 antihydrogen atoms are created.
- In average less than one remains in the 0.5K neutral trap
- This cycle takes about 20mins

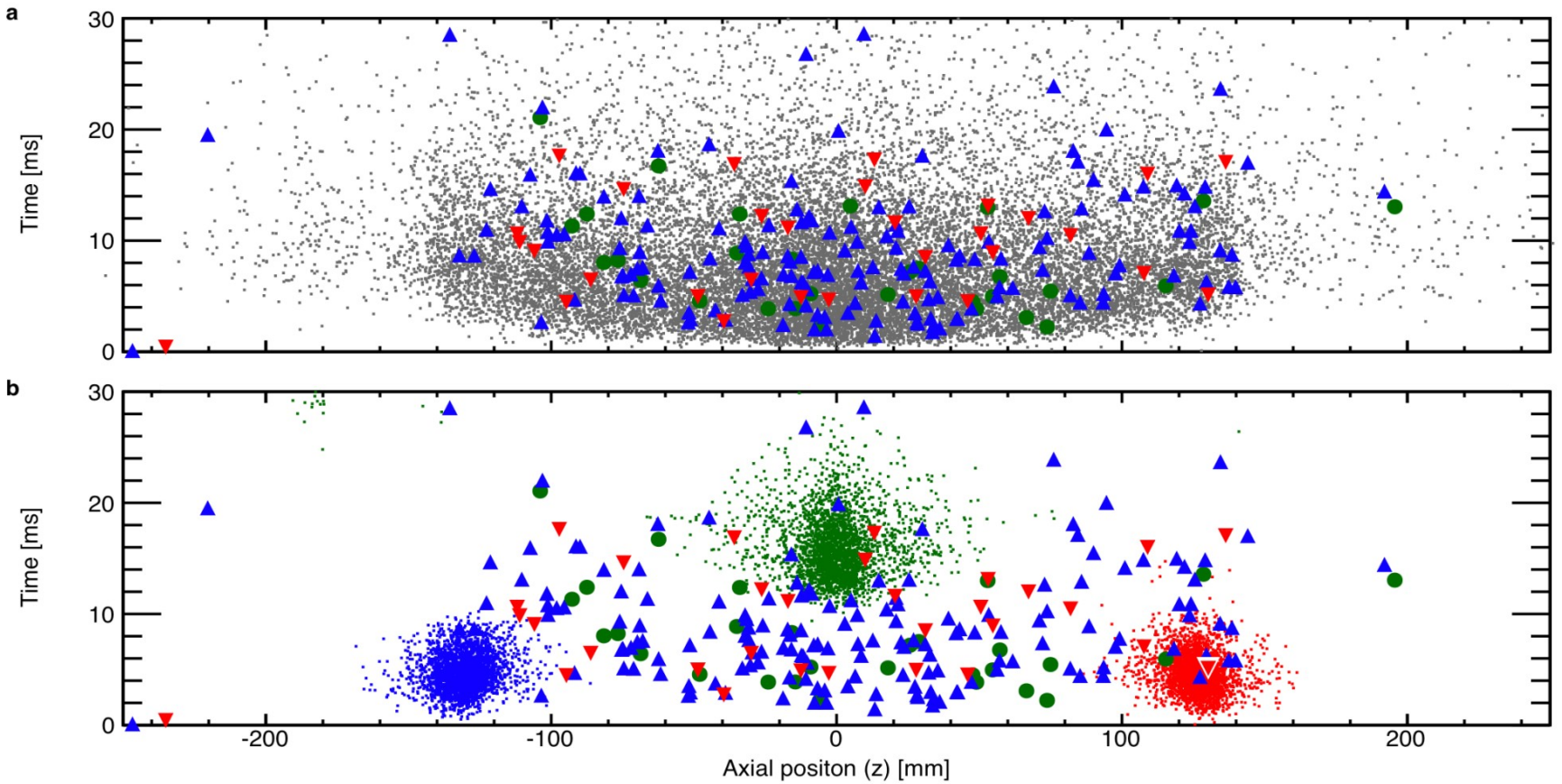
  => ALPHA-2 uppgrade
  - Separate catching and neutral trap region (catching region can operate independently)
  - APLHA-2 has four neutral traps (formed Hbar can be stored)
  - **A-2 Enabled access for lasers – precision measurements**

ALPHA highlights paving way for precision measurements

- 2010 Trapped Antihydrogen
- 2011 Confinement of Hbar for 1000 seconds
- 2012 Resonant quantum transitions in trapped antihydrogen atoms
- 2013 Description and first application of new technique to measure the gravitational mass of antihydrogen
- 2014 An experimental limit on the charge of antihydrogen

Trapping and proof of principle that the experiments can be performed with very low amount of antiparticles

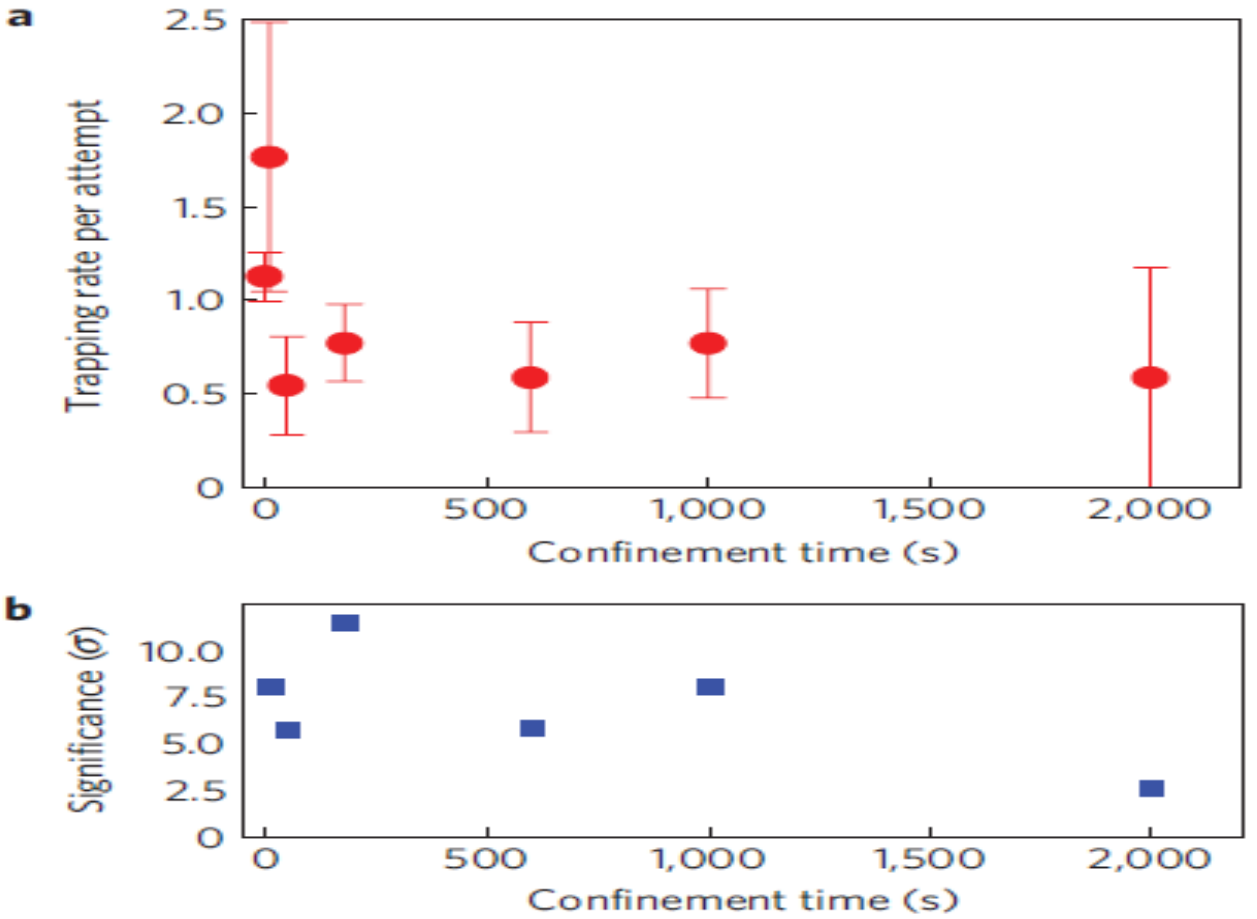
Trapped neutral antihydrogen



Trapped neutral antihydrogen, originally 39, identified using bias -fields and fast magnet shutdown

Doi:10.1038/nature09610

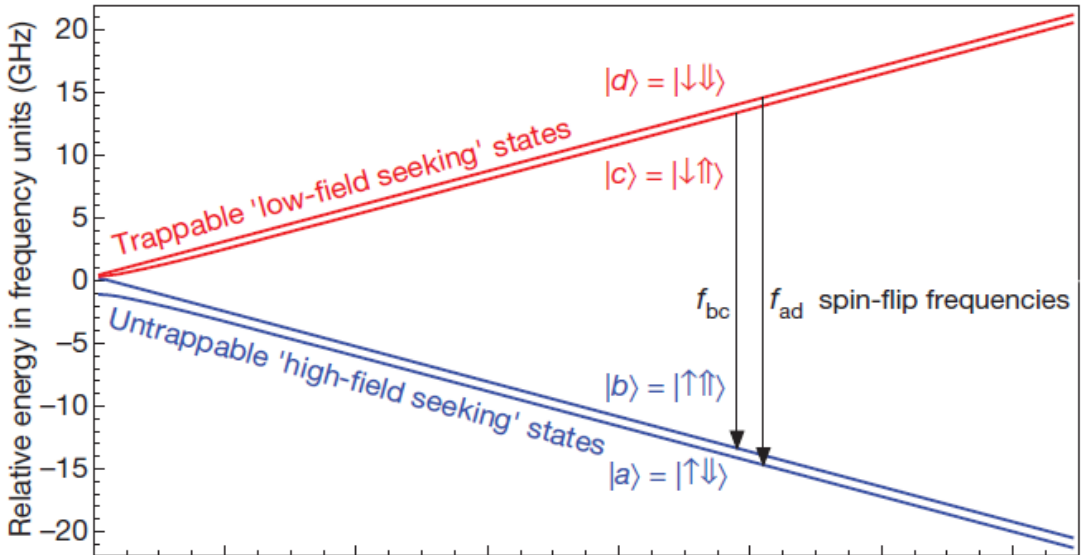
Long confinement

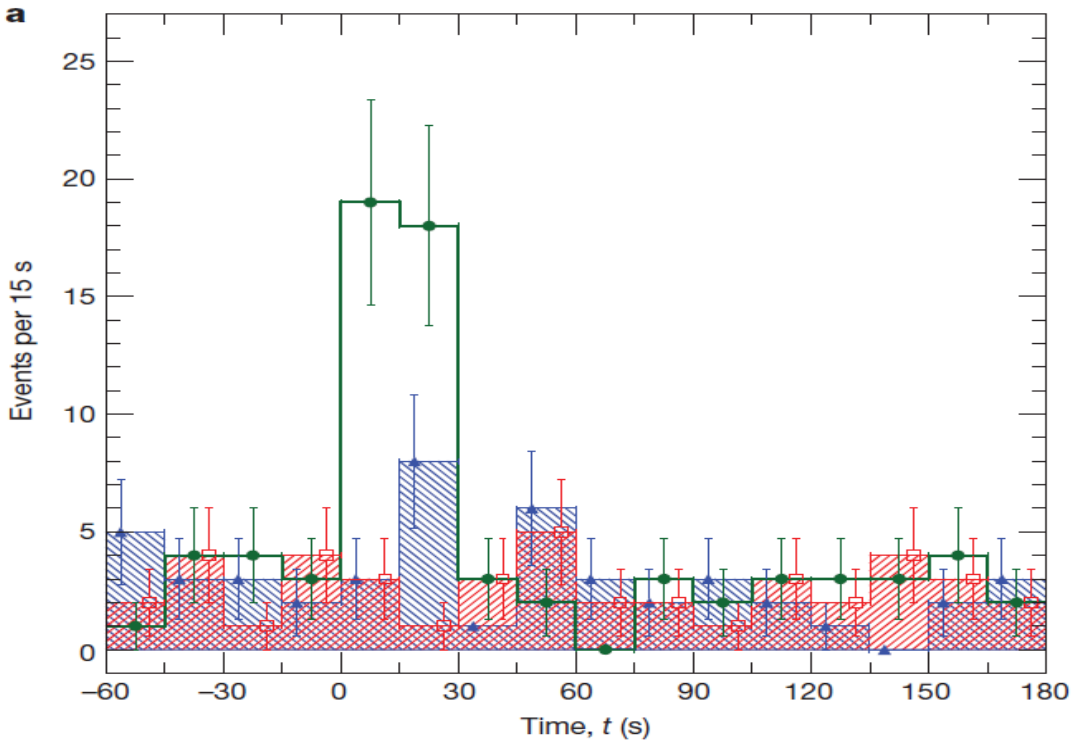


As trapping rates improved hold times before releasing the neutral trap were extended up to 2000s

Doi: 10.1038/NPHYS2025

μ-wave spectroscopy





Proof of principle for spectroscopic measurements.

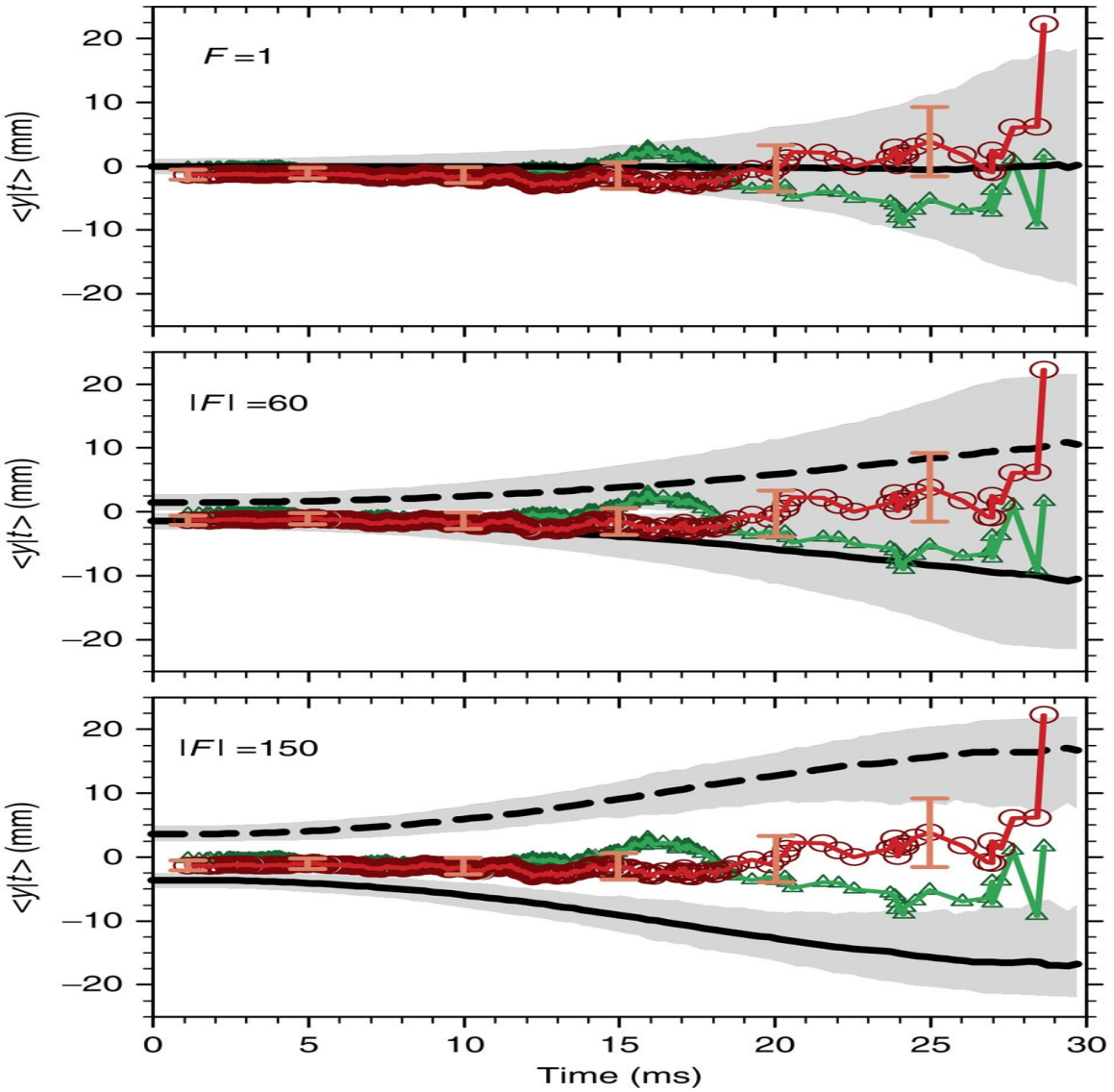
Antihydrogen spin-flip using microwaves.

Data taken as microwaves on/off, at off-resonance and with two different B-fields, datasets in 'appearance' and 'disappearance' -modes.

Result corresponds to a relative precision of about 4x10-3, compared with hydrogen.

Doi: 10.1038/nature10942

Gravitational measurements M_g/M_i



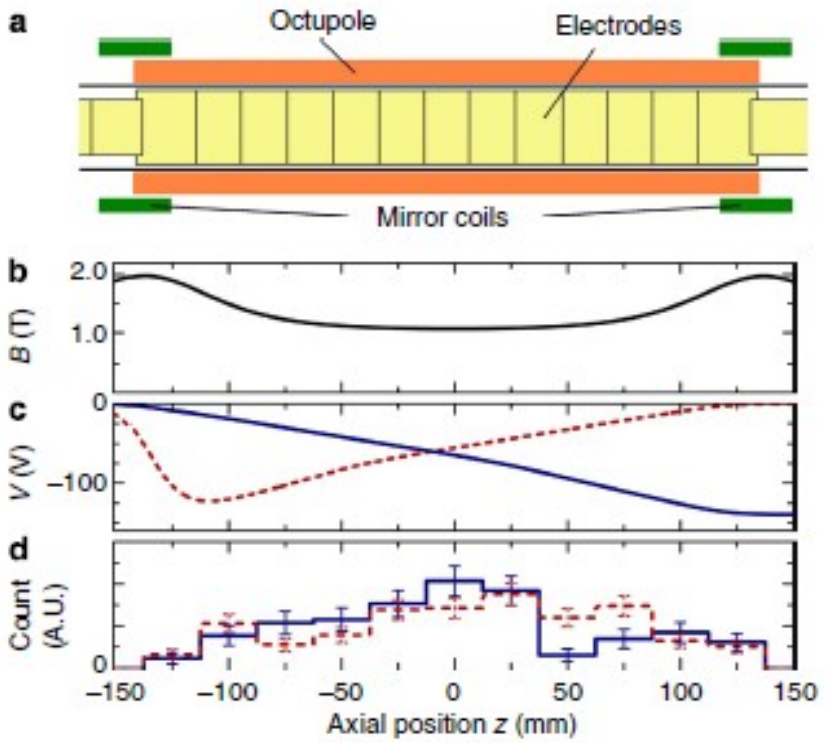
Proof of principle for a gravity measurement

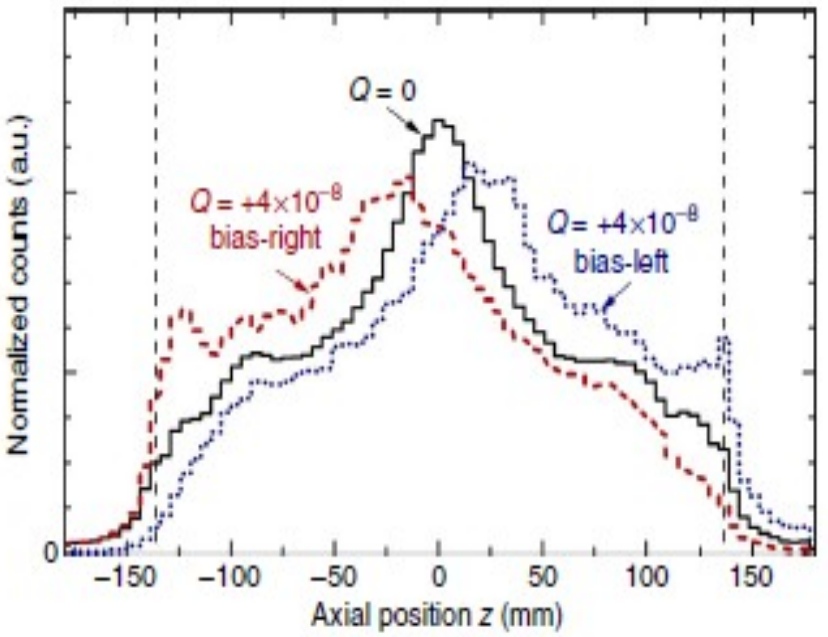
Retrospect analysis of annihilation data by using reverse cumulative average -method to calculate <y|t> - the vertical average of the annihilation position after the the neutral trap has been released.

This method sets an experimental limit for gravitational/inertial mass to be < 75.

Doi: 10.1038/ncomms2787

Antihydrogen charge



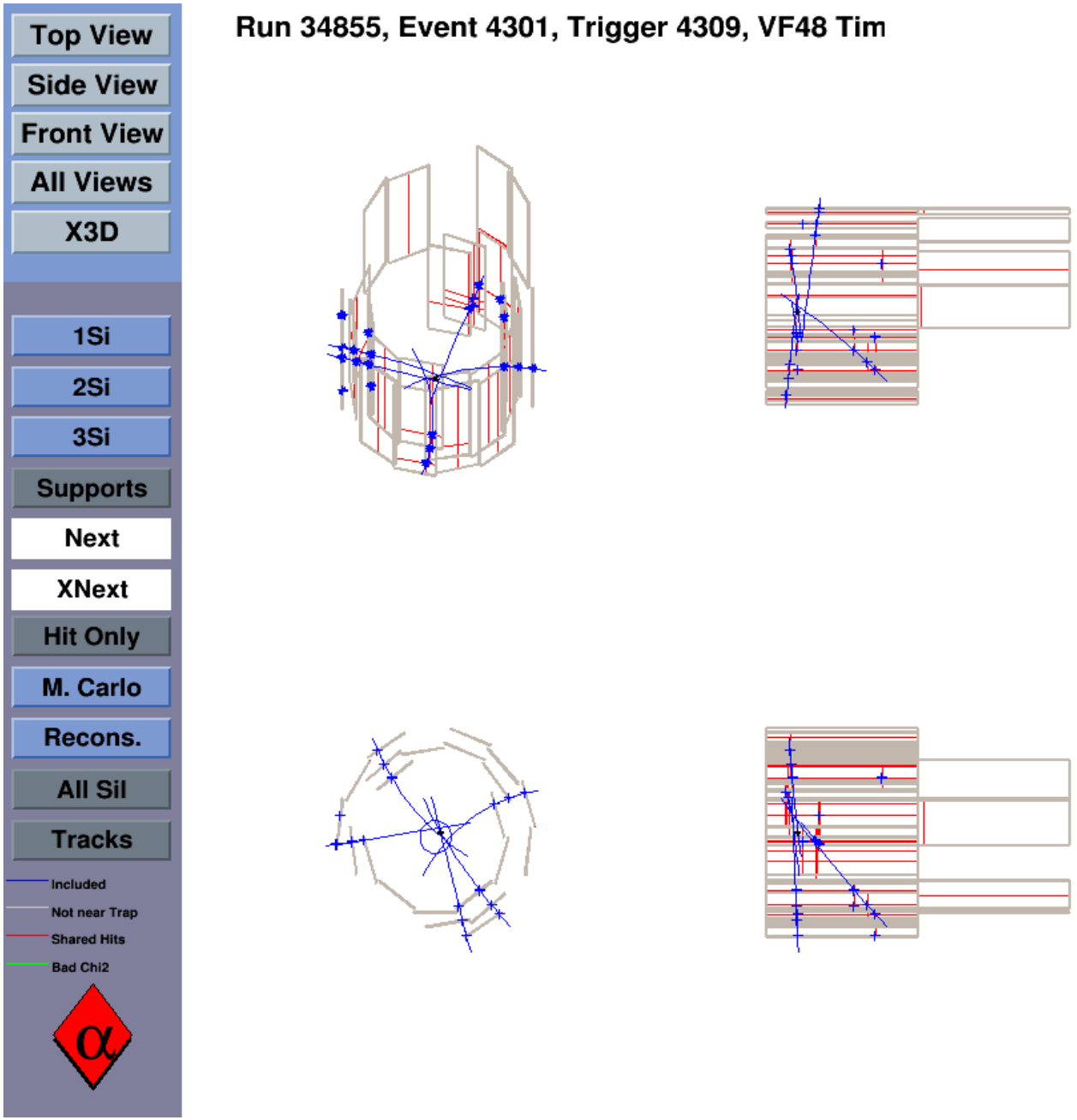


Retrospect analysis of data indicates antihydrogen is charge neutral with Q=(-1.3 ±1.1 ±0.4)x10-8 e charge.

DOI: 10.1038/ncomms4955

Last Saturday

First antiprotons observed in the neutral atom trap (16 of them).



2014 Strategy

- All principal components now operational
  - Laser access
  - Detector
  - Catching trap
  - Neutral trap cryostat
    - Some vacuum problems though
- With an enhancement cavity encompassing the trap at least 1W CW 243nm laser light will be available for probing the 1S-2S two photon transition => with this power excitation is predicted to occur within the antihydrogen trapping lifetime established in A-1

Conclusions

- Proof of principle –studies have been carried out
- Go through the learning curve to operate the new device (A-2)
- Established conditions sufficient, also hope to...
  - Improve trapping rate
  - Colder atoms (Laser cooling)

=> Spectroscopic measurements

Many thanks for your attention!