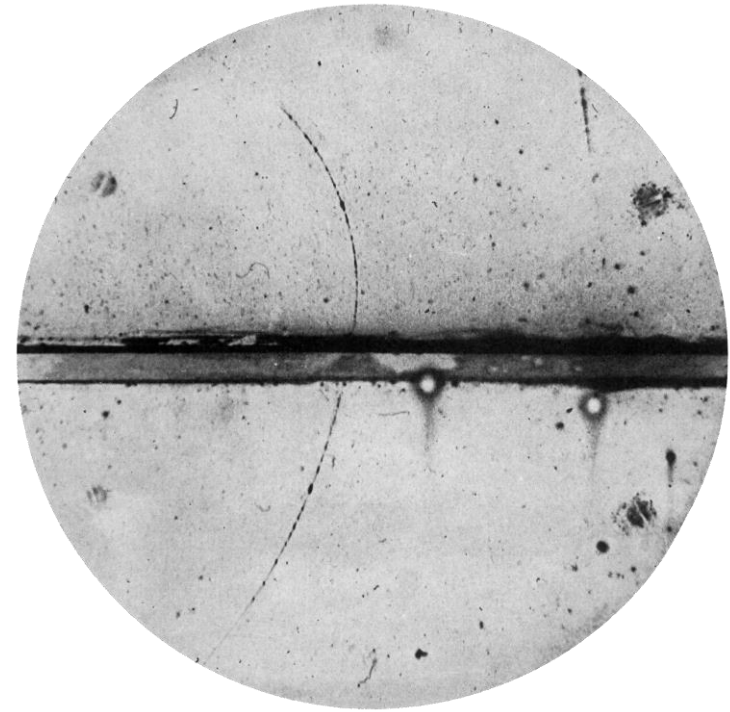


Antimatter research

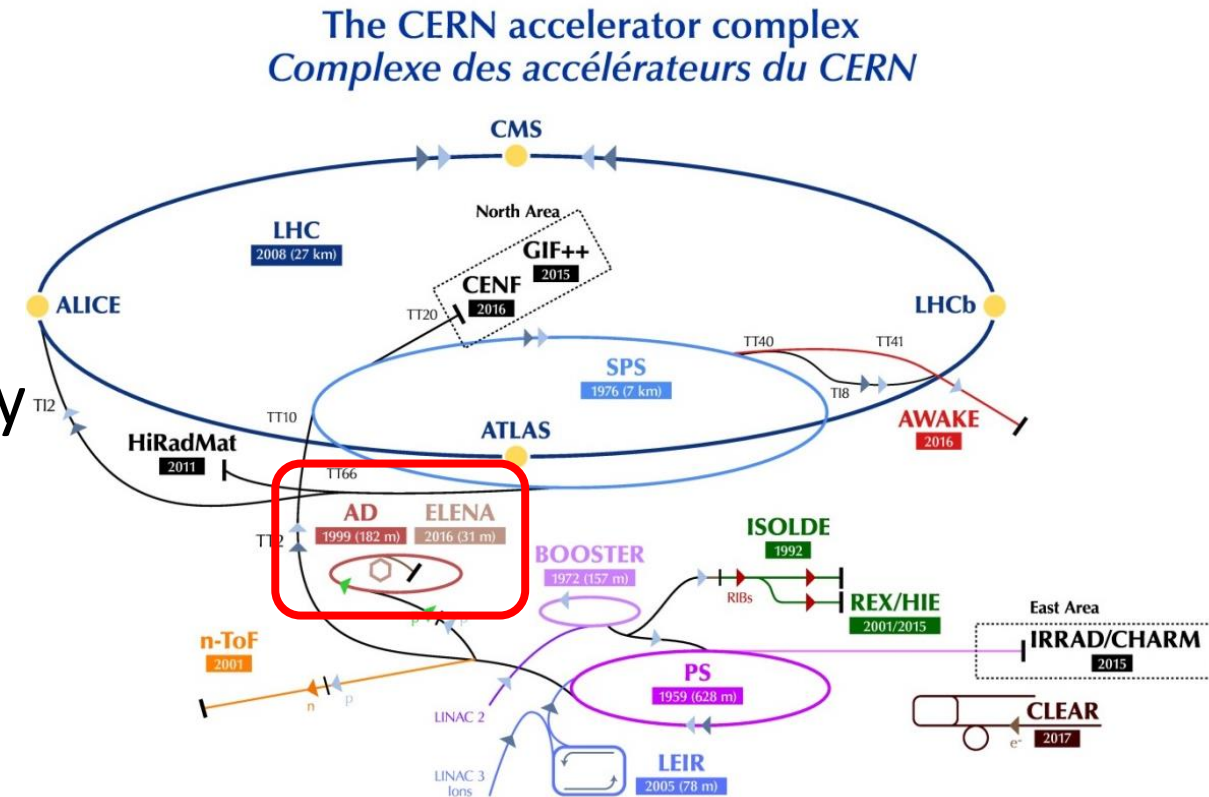
History

- Existence predicted by Dirac equation
- Positron discovered in 1932 by Carl D. Anderson
- Existence of antiproton confirmed in 1955
- Low Energy Anti-Proton Ring (LEAR) operated at CERN from 1982 to 1996
- At LEAR happened many studies on matter – antiproton interactions, proton/antiproton mass ratio and it's the first antihydrogen was created



CERN Antimatter Factory

- Antiproton Decelerator started operation in year 2000
- In 2016 ELENA (Extra Low Energy Antiproton) ring started operation
- Antimatter Factory is the only facility in the world that produces cold antiprotons
- Current experiments: AEGIS, ALPHA, ASACUSA, BASE, GBAR, PUMA



AEgIS

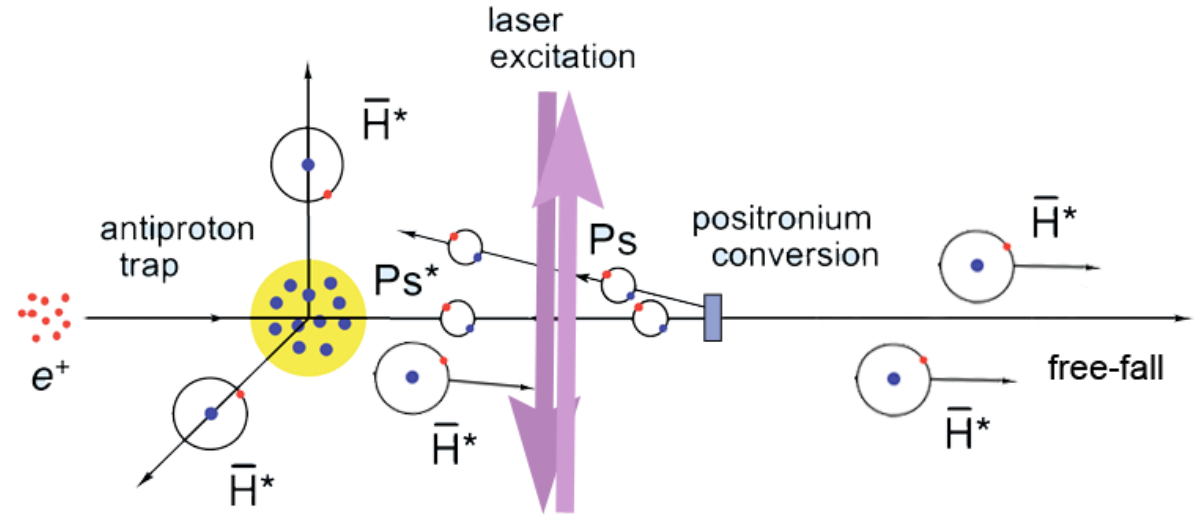
- Experiment where I'm working on my PhD
- Antimatter Experiment: gravity, Interferometry, Spectroscopy
- Main physics programs:

Antihydrogen free fall measurement

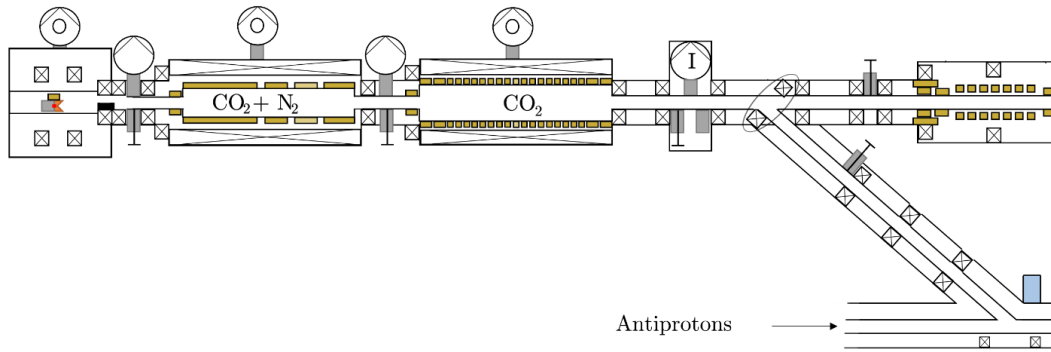
Positronium research

Antiprotonic atom program

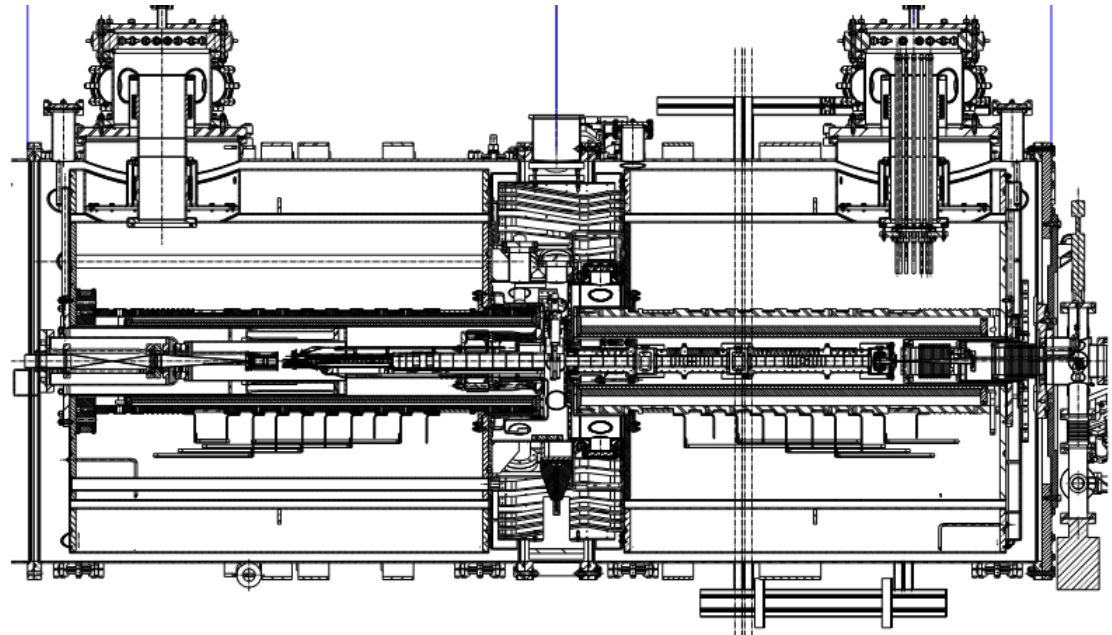
AEgIS



Positron system

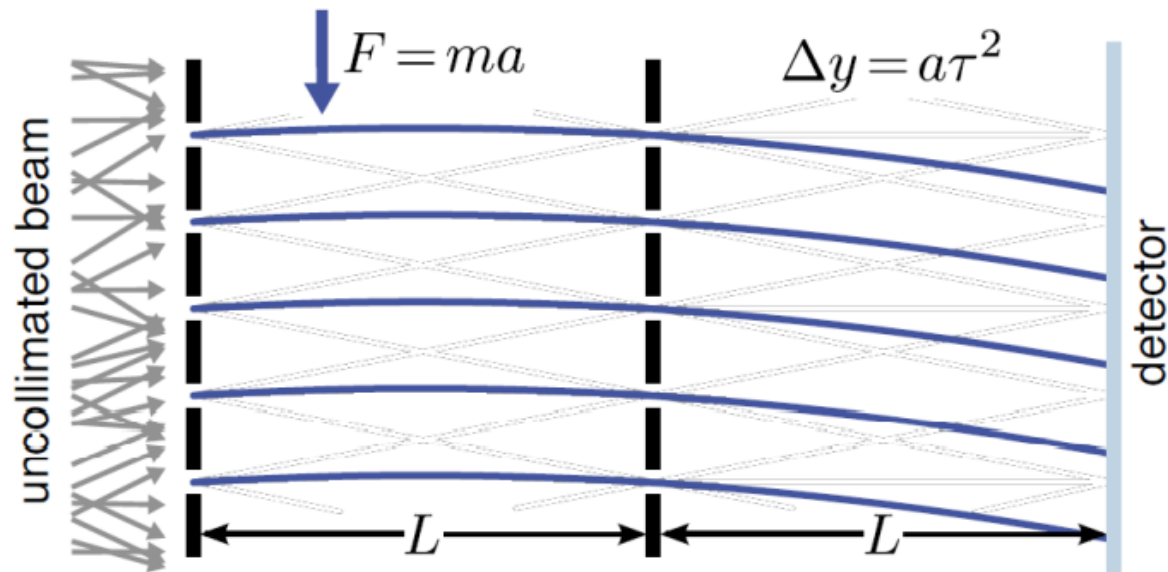


5T trap



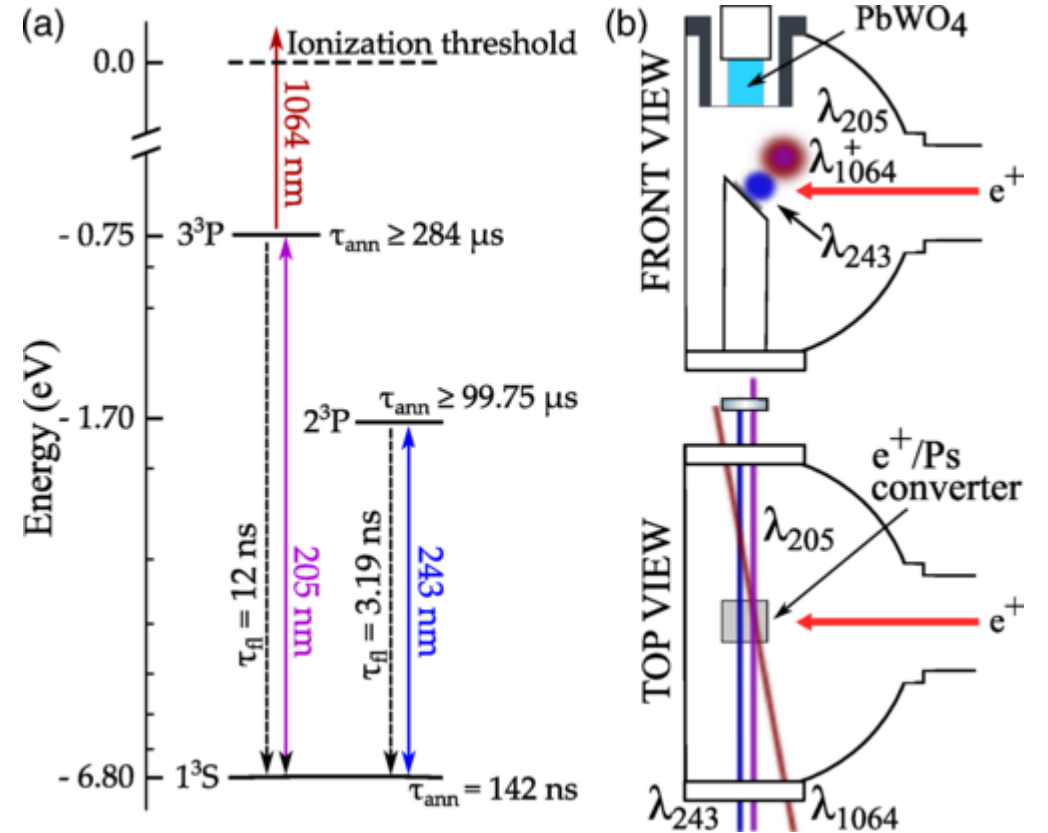
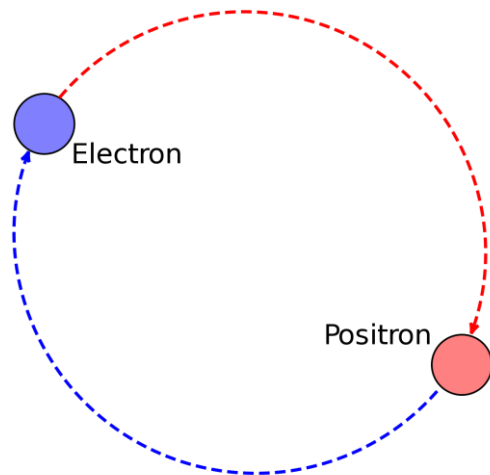
AEgIS gravity measurement

- Planned antihydrogen free fall measurement outside of a magnetic field using moiré deflectometer
- Current status: achieved pulsed formation of antihydrogen, working on beam formation and moiré deflectometer design



AEgIS positronium research

- Mostly focused on positronium spectroscopy
- Newest result: positronium laser cooling

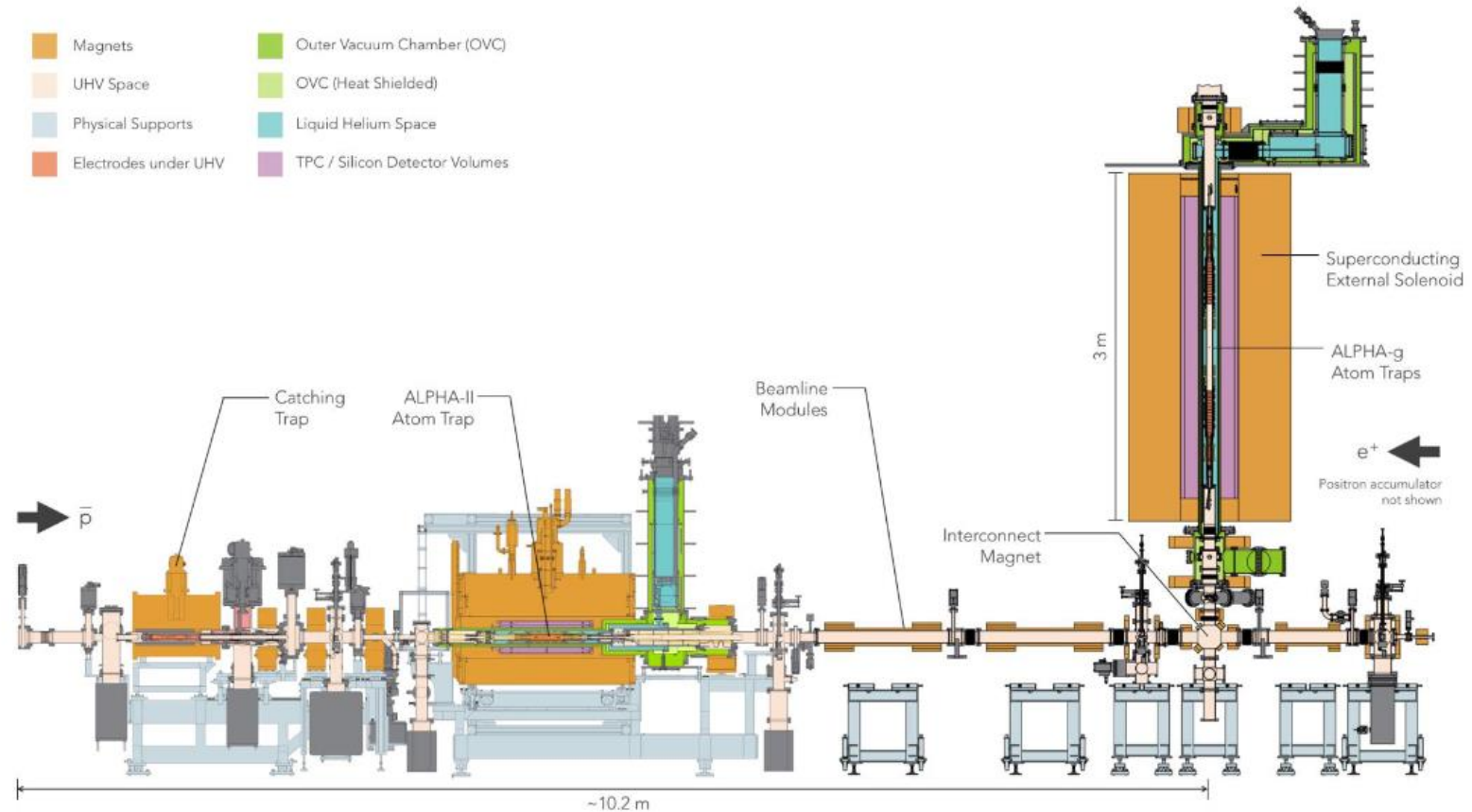


AEgIS antiprotonic atoms

- Bound system consisting of antiproton in orbit around a matter nucleus
- Current status: construction of a negative ion source, also did an opportunistic measurement with low pressure gas

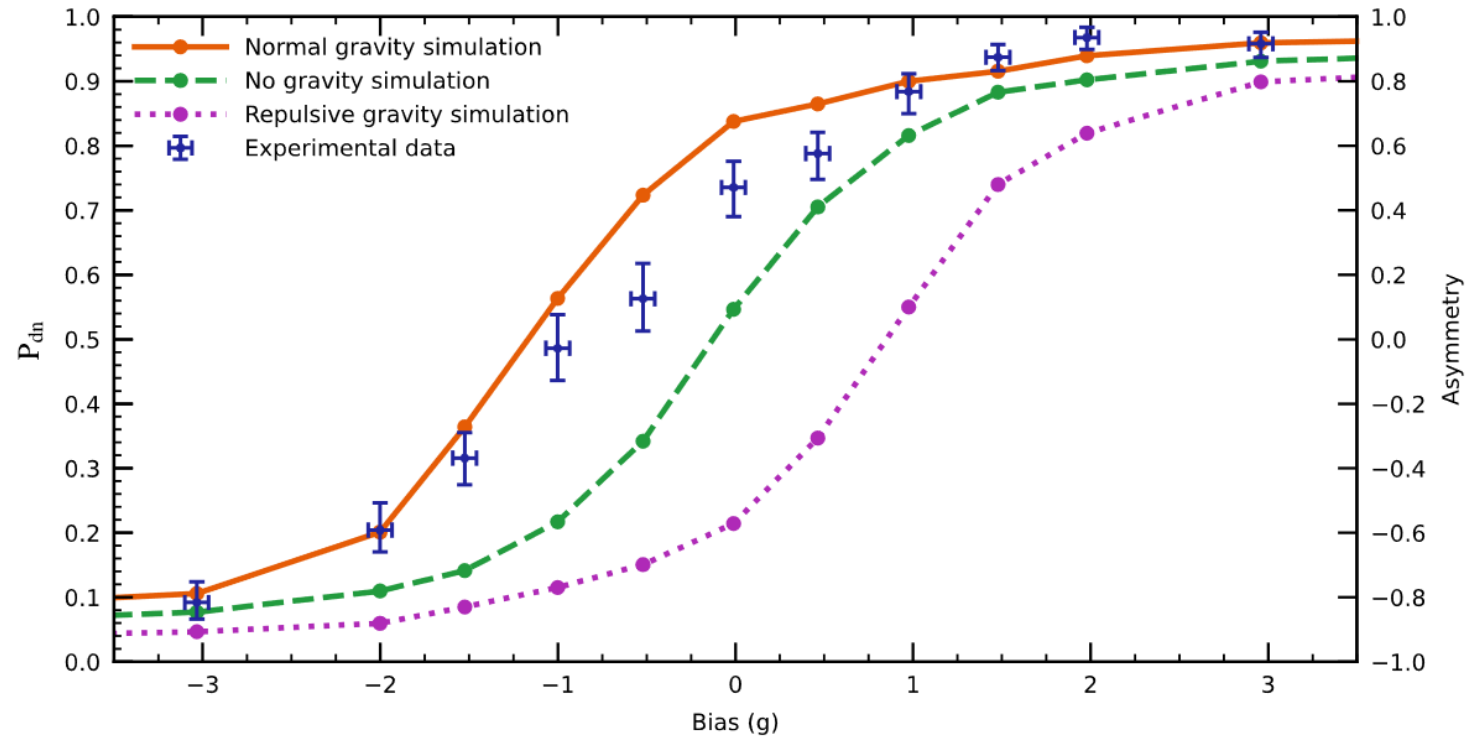
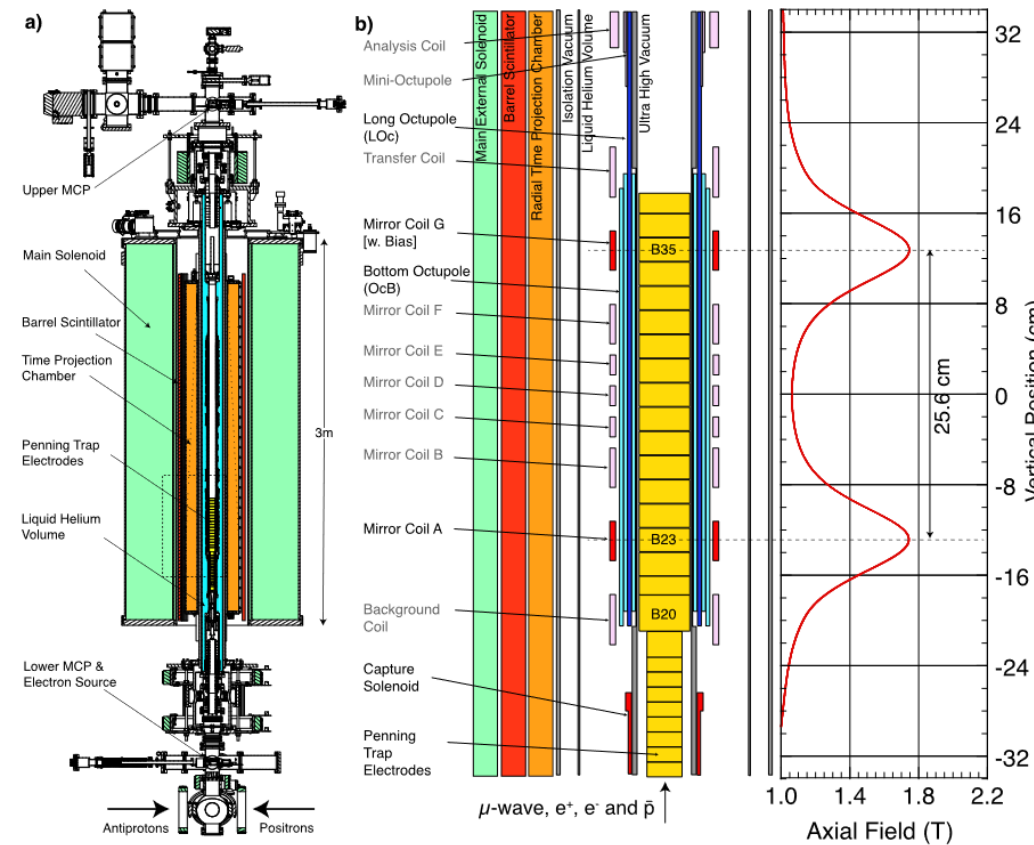
ALPHA

- Antihydrogen Laser Physics Apparatus
- Consists of ALPHA-2 (spectroscopy part) and ALPHA-g (free fall measurement part)
- Only experiment trapping antihydrogen



ALPHA gravity measurement

- Uses differential bias on the mirror coils



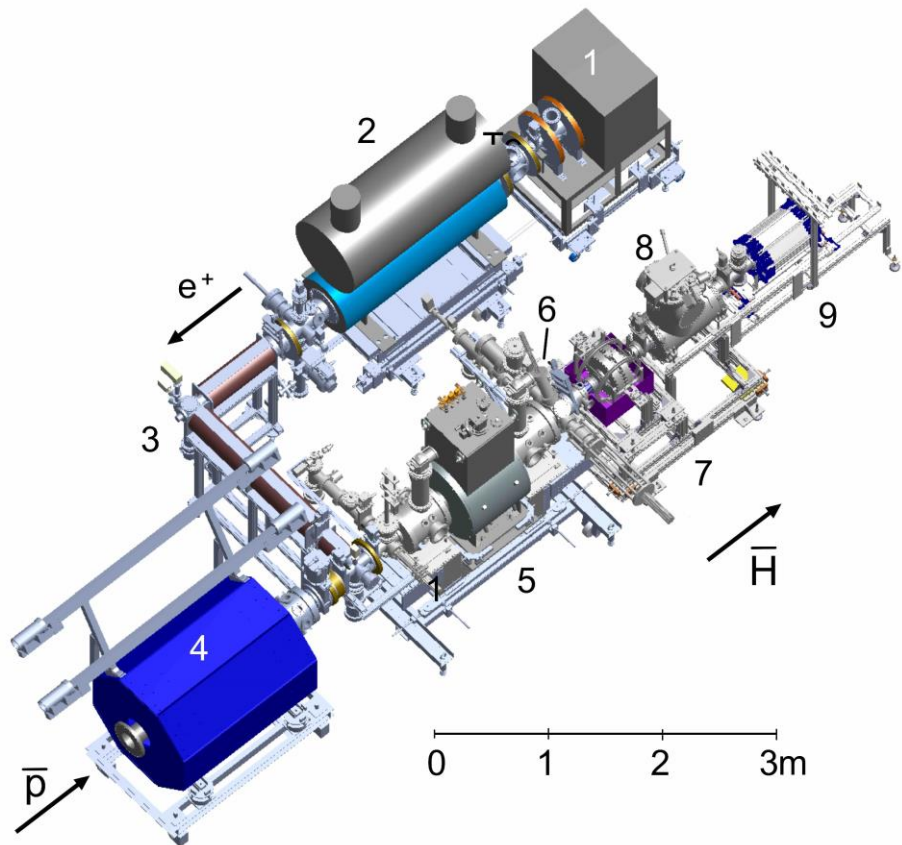
$a_{\bar{g}} = (0,75 \pm 0,13 \text{ (stat. + syst.)} \pm 0,16 \text{ (simulation)}) \cdot g$ where $g = 9,81 \text{ m/s}^2$

ALPHA spectroscopy

- Laser cooling of antihydrogen to 15mK
- 1S-2S transition measured to 10^{-8} precision
- 1S-2P transition measured to 16 parts per billion

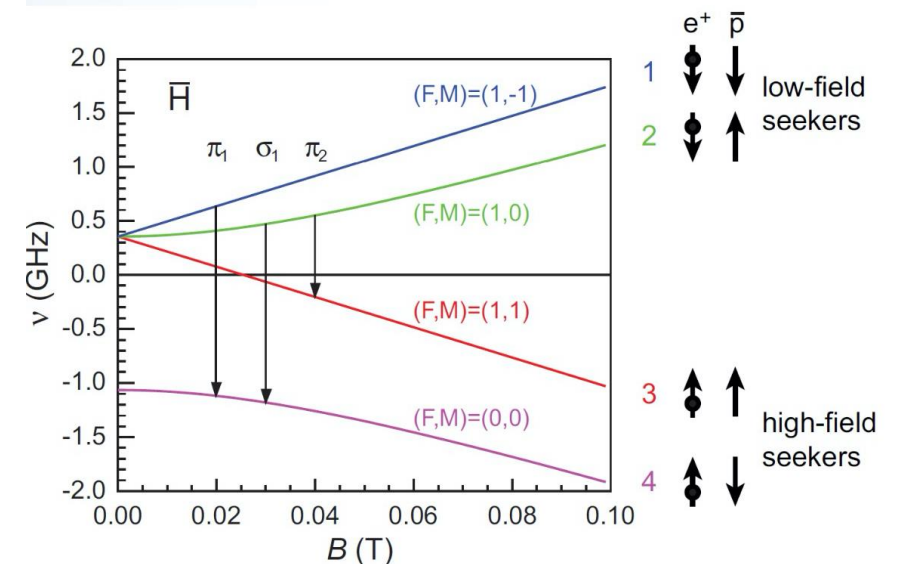
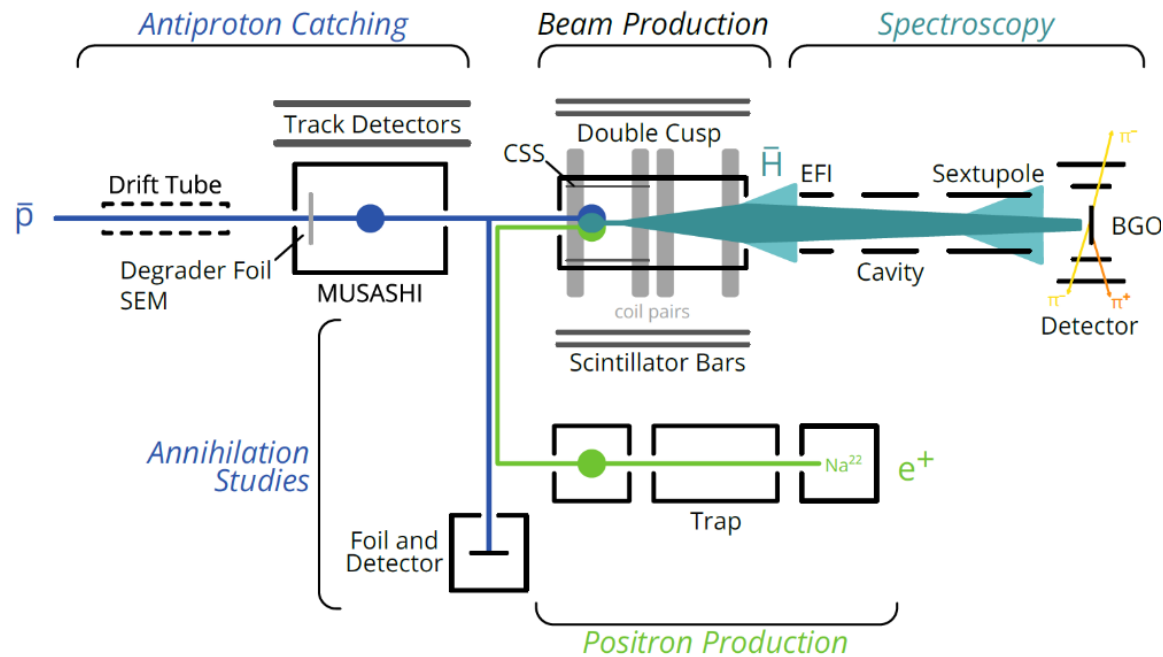
ASACUSA

- Atomic Spectroscopy And Collisions Using Slow Antiprotons
- Antihydrogen hyperfine spectroscopy and antiprotonic helium



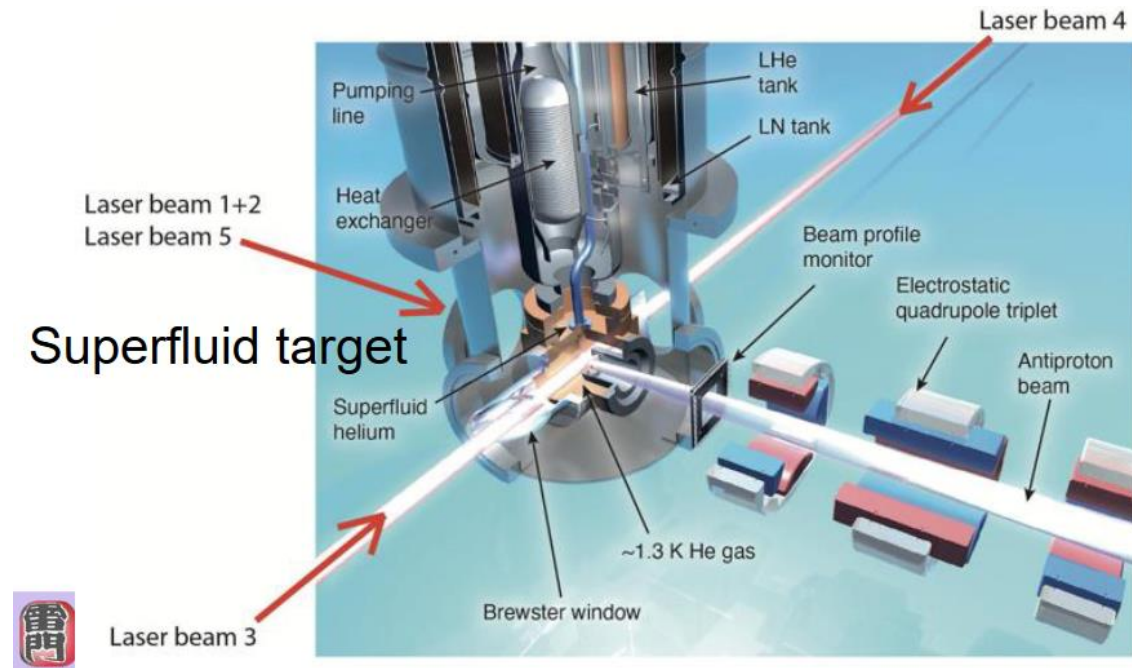
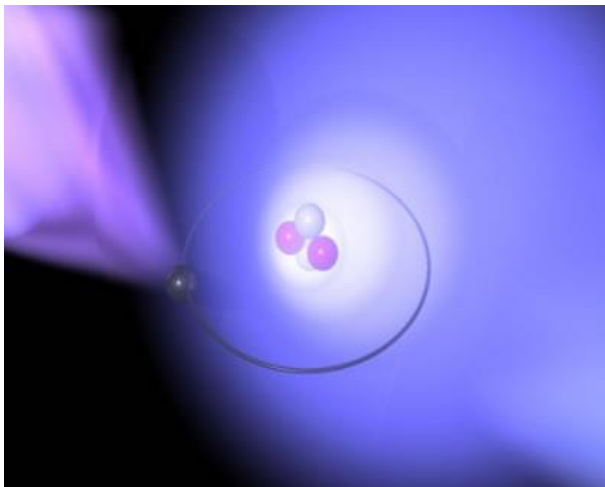
ASACUSA hyperfine spectroscopy

- Microwaves induce hyperfine transitions and a sextupole magnet is used for separating high field seekers from low field seekers



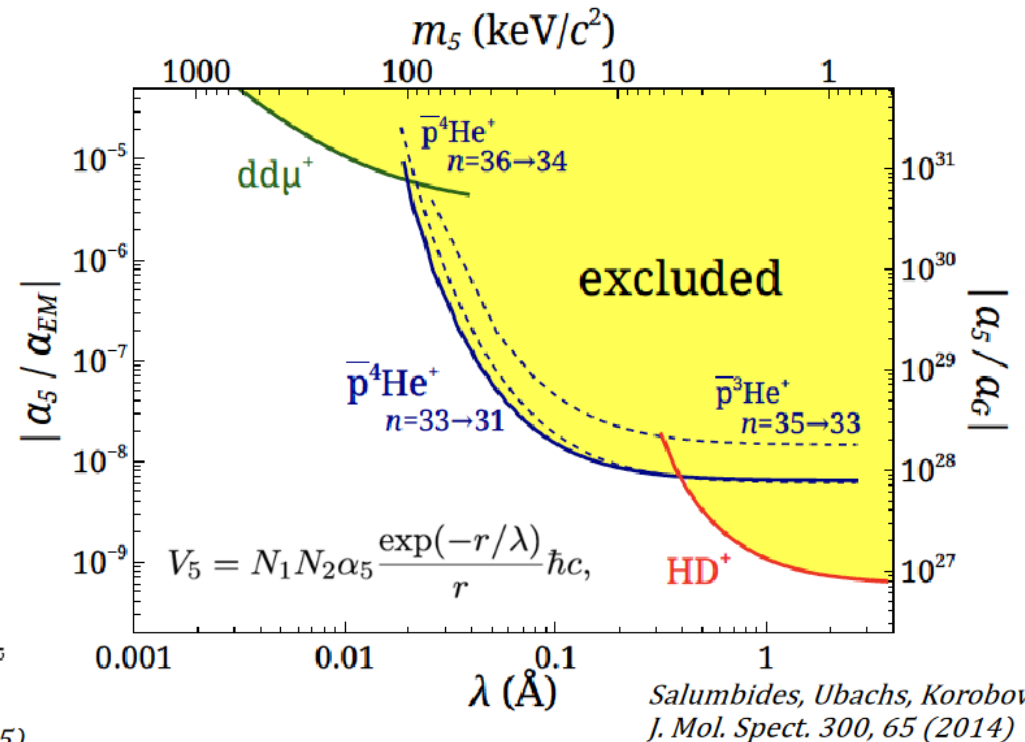
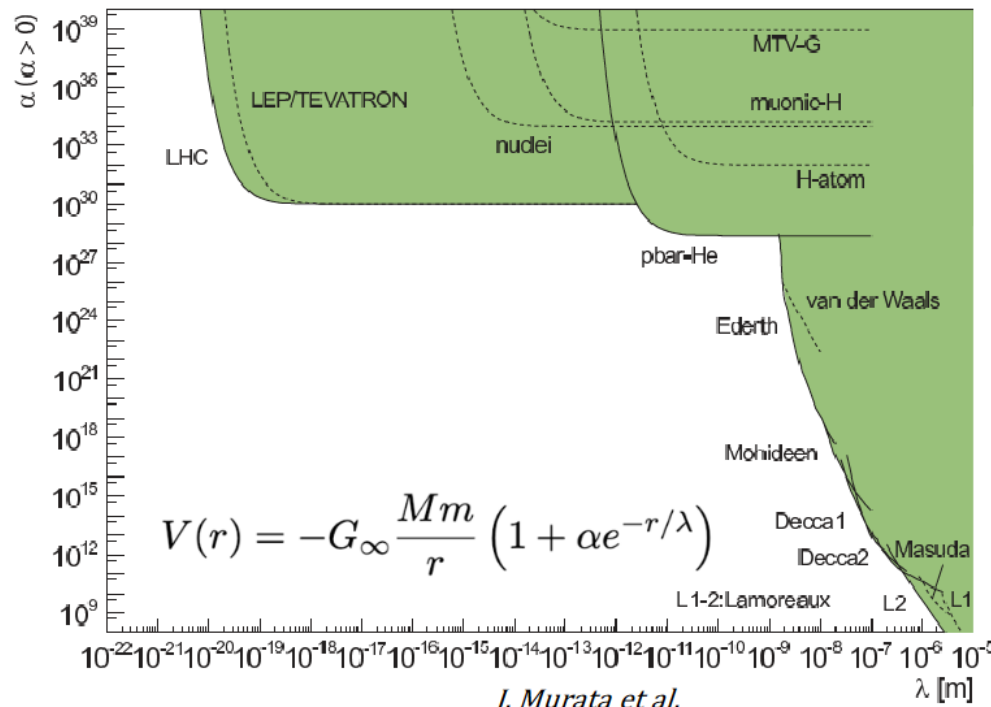
ASACUSA antiprotonic helium

- Antiproton and electron mass comparisons
- Tests of QED and CPT
- Longest lifetime ($4\mu\text{s}$) of any known matter – antimatter system



ASACUSA antiprotonic helium

Bounds on the 5th force at 10^{-11} to 10^{-9} m length scales

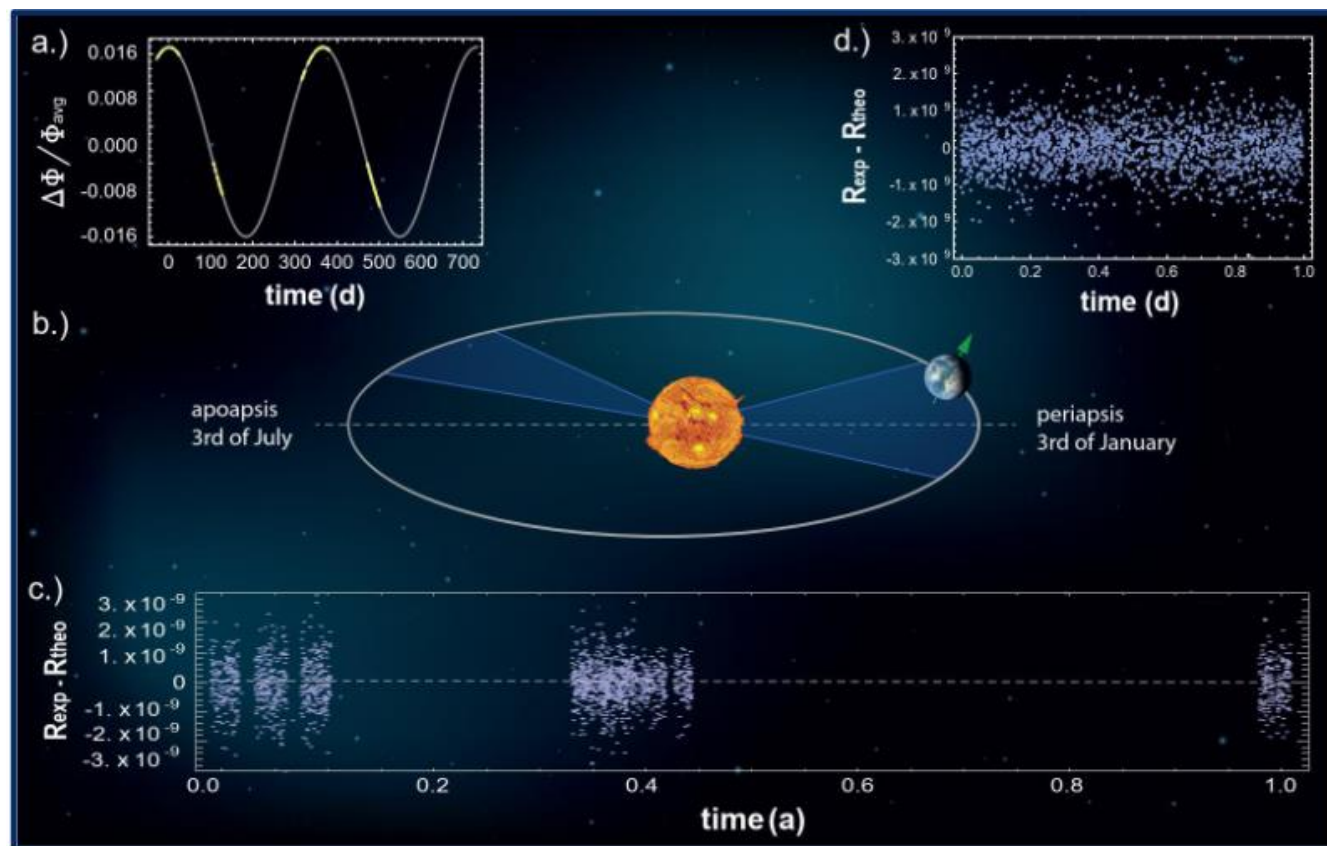
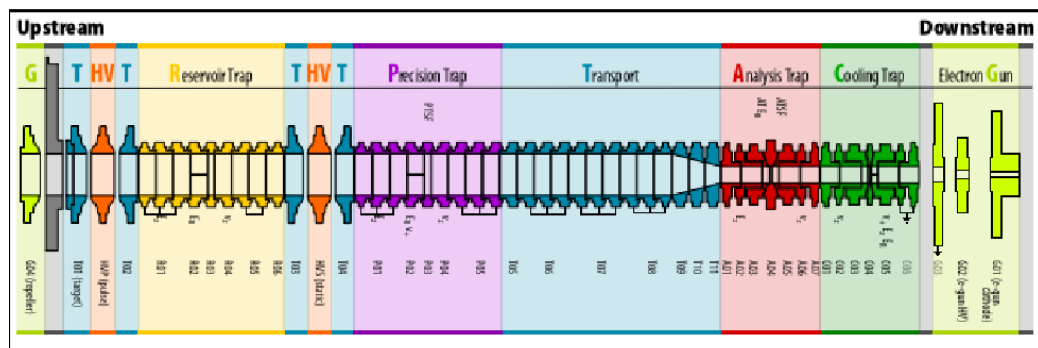


- Inverse square law of gravity has not been tested at length scales $< 100 \mu\text{m}$. Only upper limits that are many orders of magnitude larger than the Newtonian force exist.
- $\bar{p}\text{He}^+$ constrains Yukawa-like part of potential to $\alpha < 10^{28}$ times the Newtonian one.

BASE

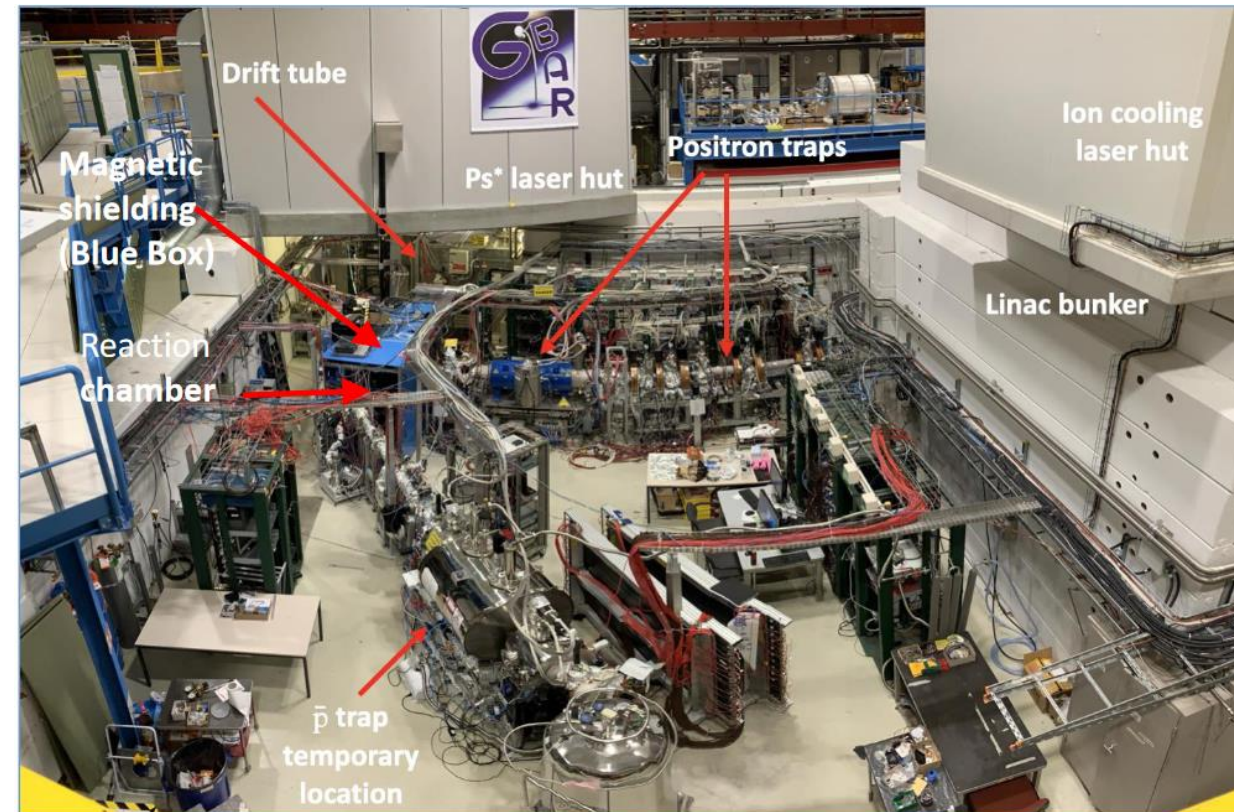
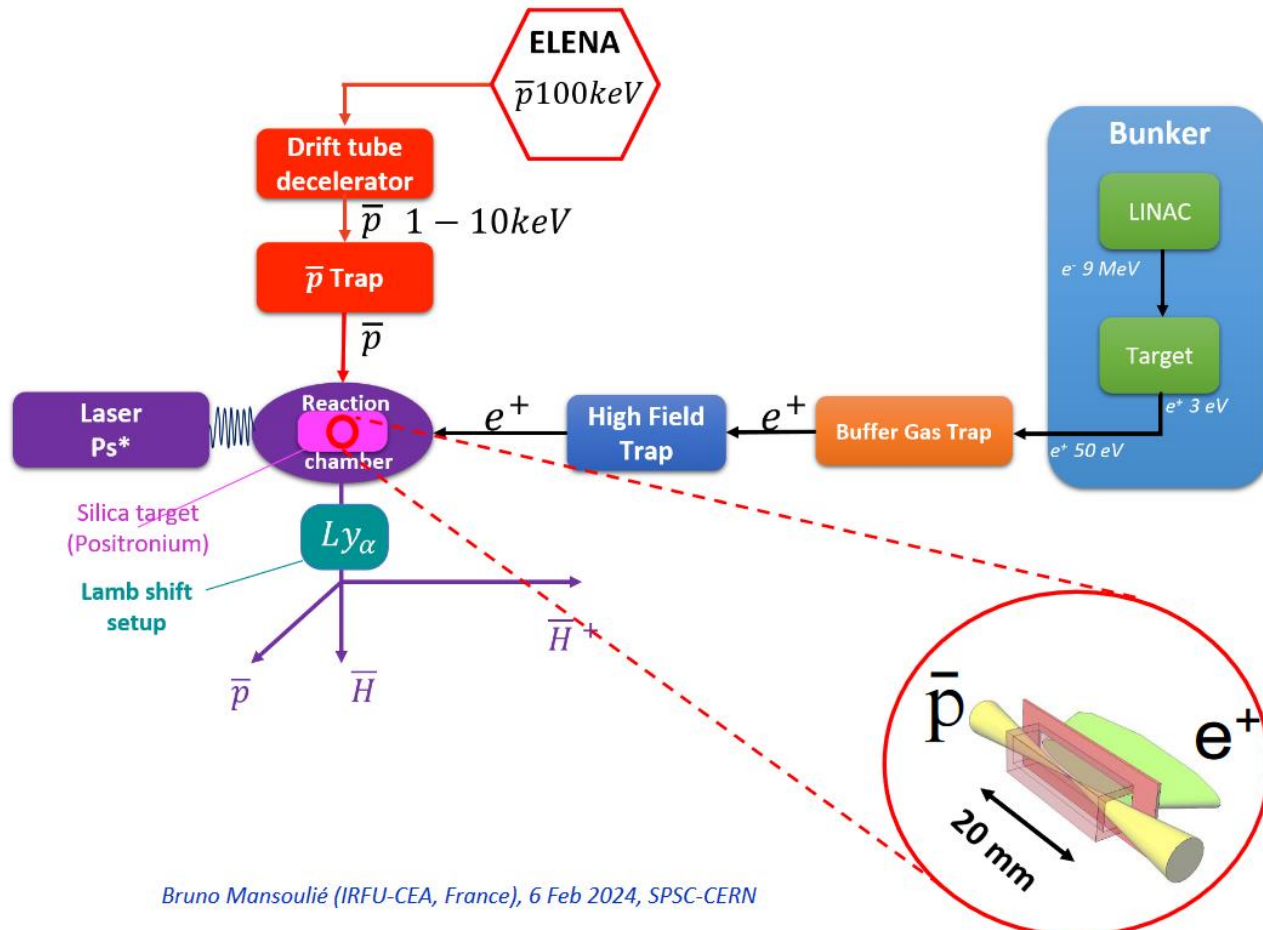
- Baryon Antibaryon Symmetry Experiment
- 16 parts per trillion precision achieved for proton/antiproton charge to mass ratio measurements
- Parts per billion accuracy on antiproton magnetic moment measurements
- BASE-STEP – ongoing work on a transportable trap

BASE



GBAR

- Gravitational Behaviour of Antihydrogen at Rest

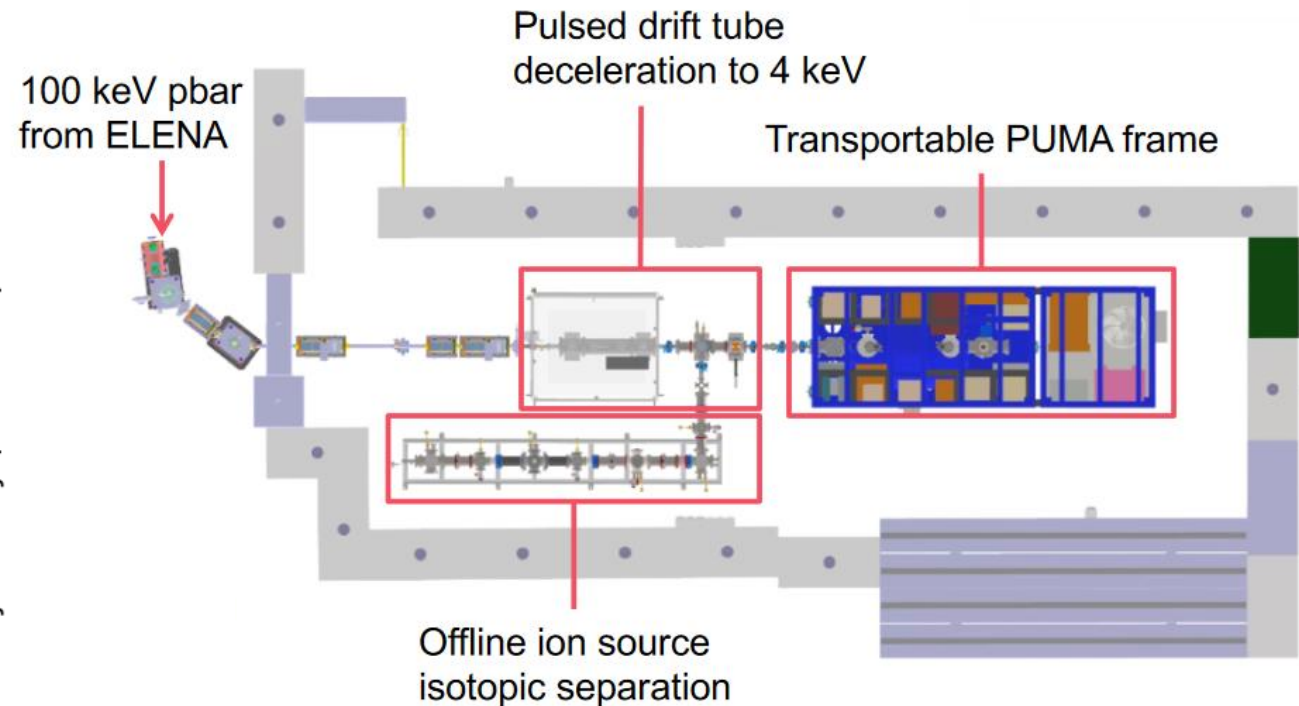
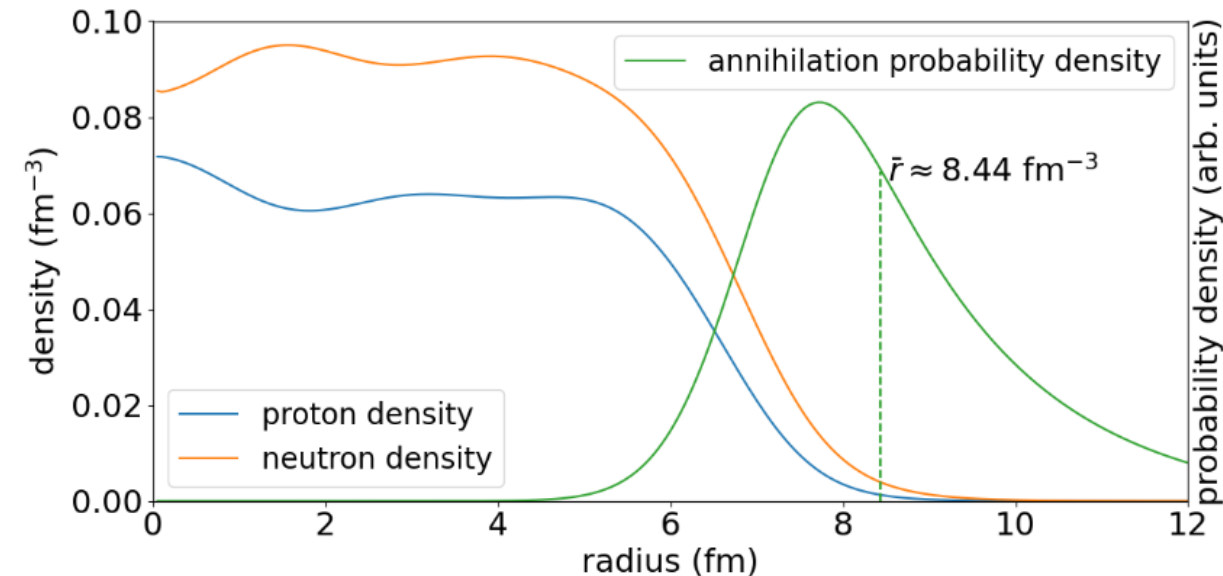


GBAR

- Ongoing work to measure antihydrogen Lamb shift and reaction rate
 $H + Ps \rightarrow H^- + e^+$ and $\bar{H} + Ps \rightarrow \bar{H}^+ + e^-$
- Future plans to make and cool \bar{H}^+ with laser cooled Be^+ ions to $10\mu\text{K}$ and observe the fall
- Possibility to study quantum reflections of antihydrogen

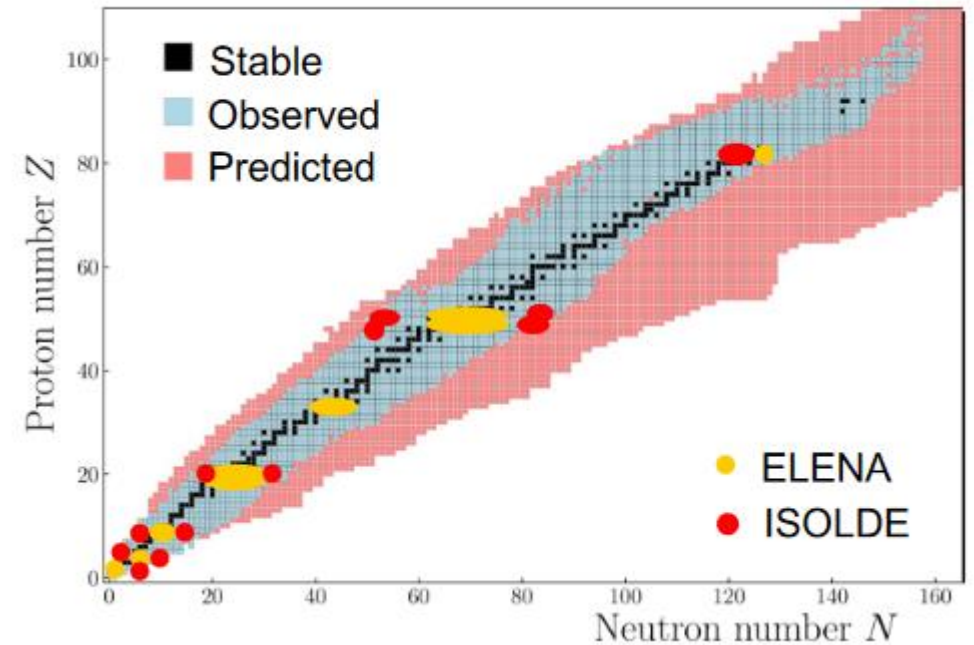
PUMA

- antiProton Unstable Matter Annihilation
- Trapping and bringing antiprotons to ISOLDE
- Measurements of neutron skin



PUMA

- Tracking pions and using machine learning
- Current status: assembly is in progress



Finished experiments

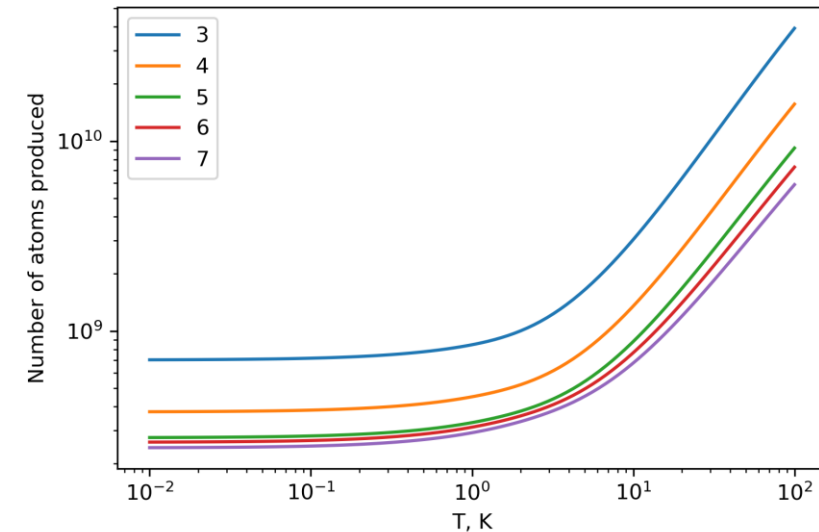
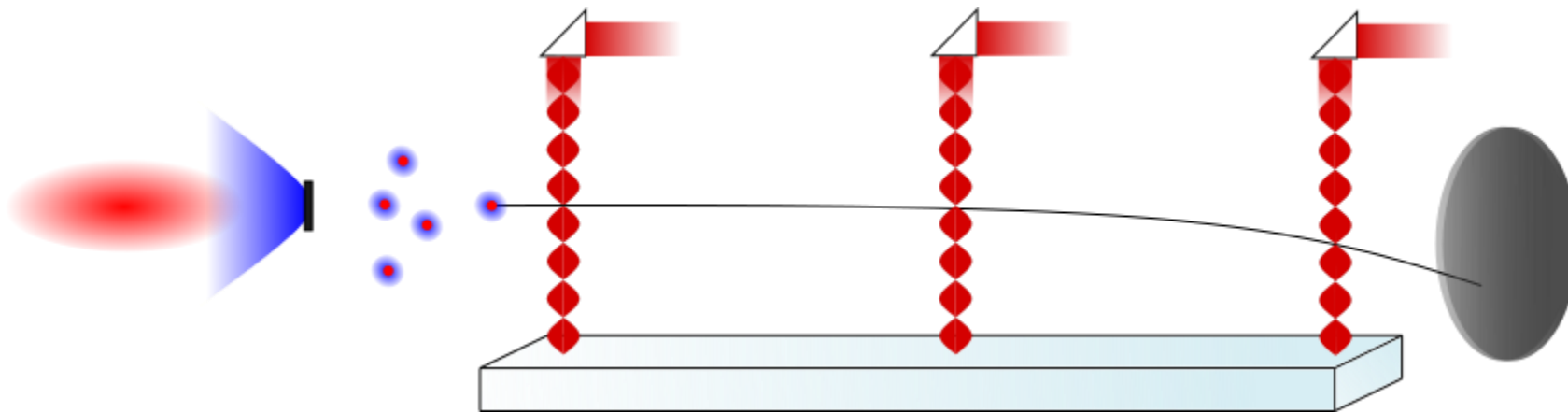
- ATHENA – made the first cold antihydrogen
- ACE – antiprotons for treatment of cancer, tests on cells, result: antiprotons are slightly better than protons for the treatment
- ATRAP – continuation of TRAP experiment, laser spectroscopy of antihydrogen and antiproton magnetic moment measurements

Future

- There are discussions on anti-deuteron studies
- Also, a proposal on hexaquark search

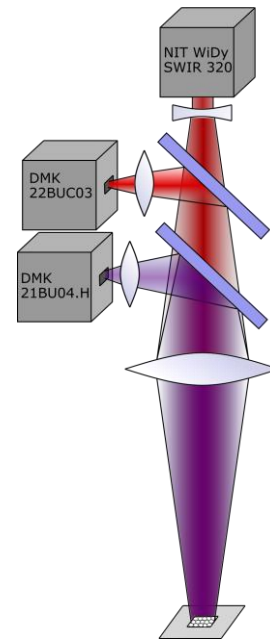
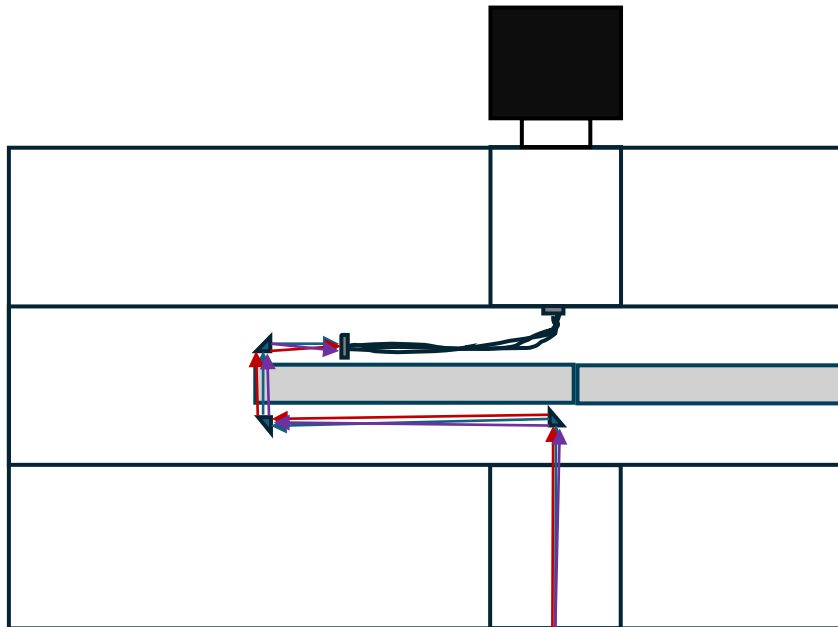
What I am doing

- The initial topic was “Construction of an optical interferometry and particle detector system for neutral anti-beam position measurements”
- Simulations proved it unfeasible



What I am doing

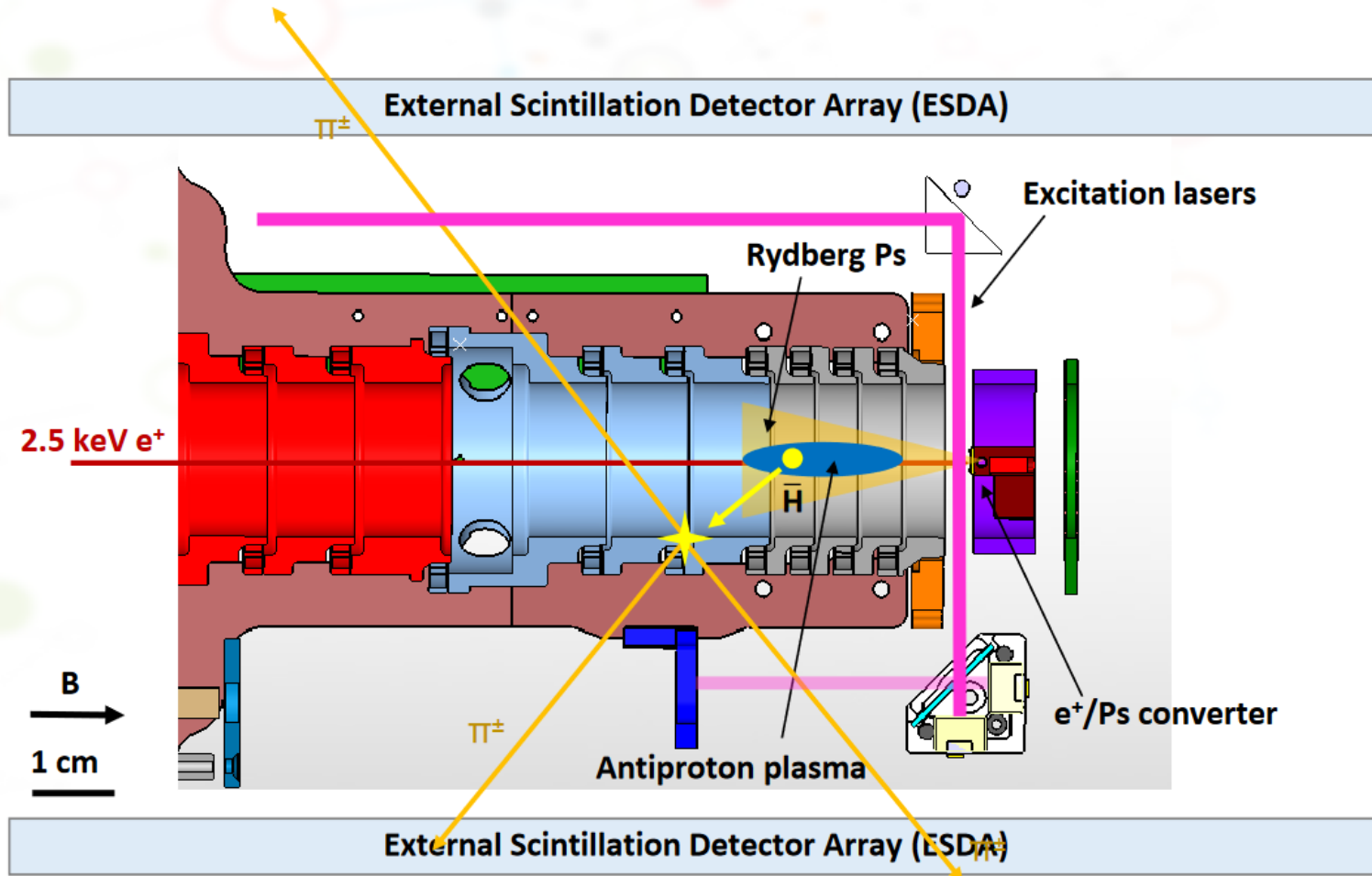
- New topic: positronium excitation to $n=30$ in magnetic field
- Other things I have been doing: developing system to image the fibre bundle, cryo shifts and helping with pretty much everything



Questions?

Thank you for listening!

More AEGIS



More AEgIS

