AEgIS upgrades and Phase 2 developments

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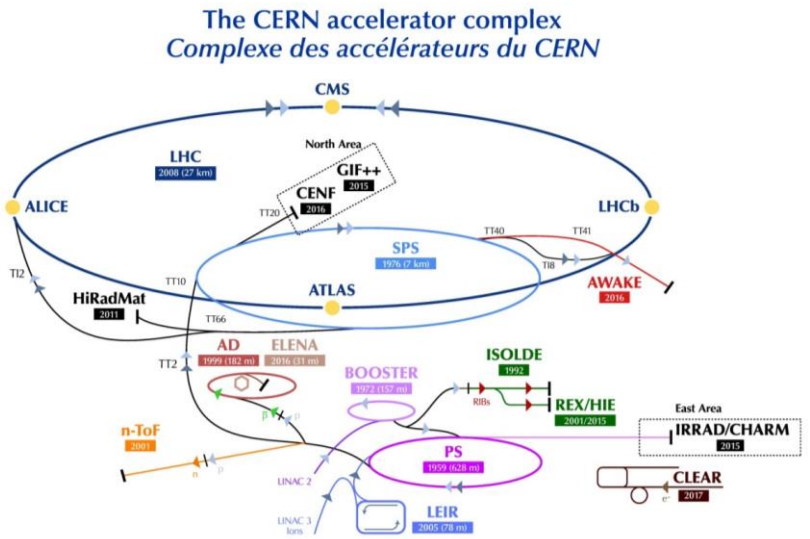
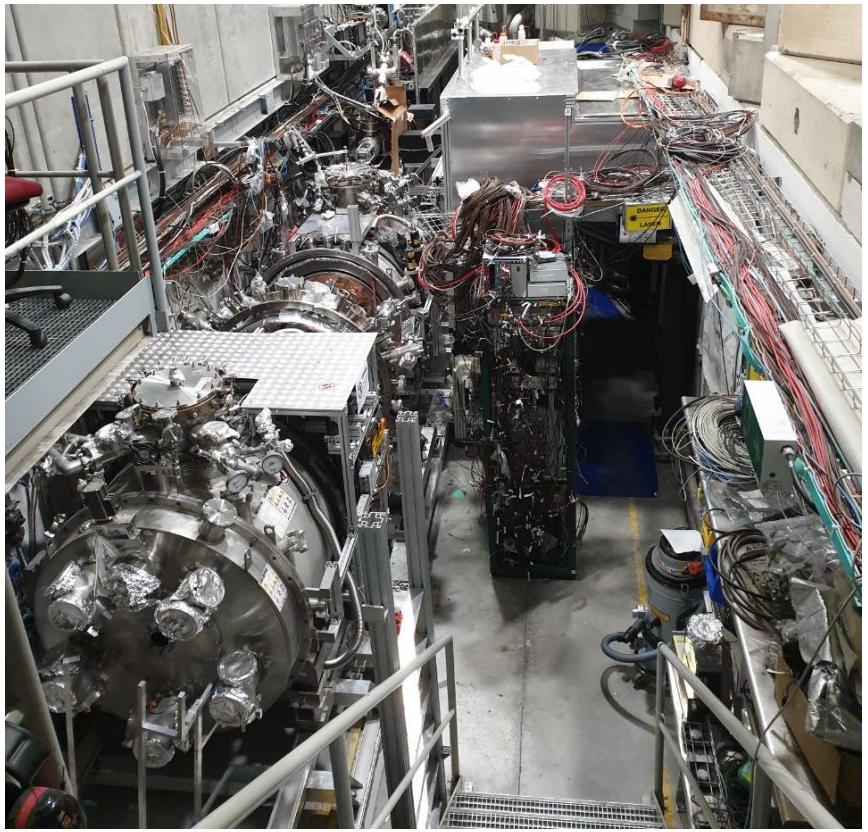
On behalf of AEgIS collaboration

Introduction to AEgIS

- Antimatter Experiment: gravity, Interferometry, Spectroscopy
- Located at CERN AD complex
- Aim of collaboration is to test Weak Equivalence Principle or the universality of free fall for antimatter containing neutral systems

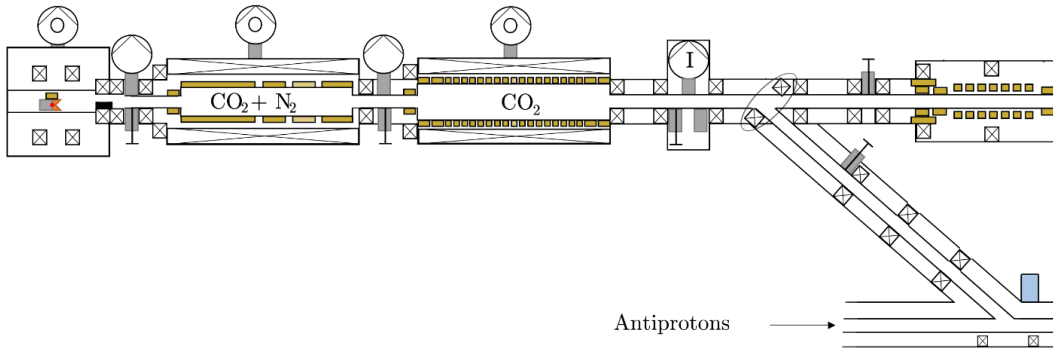




The experiment

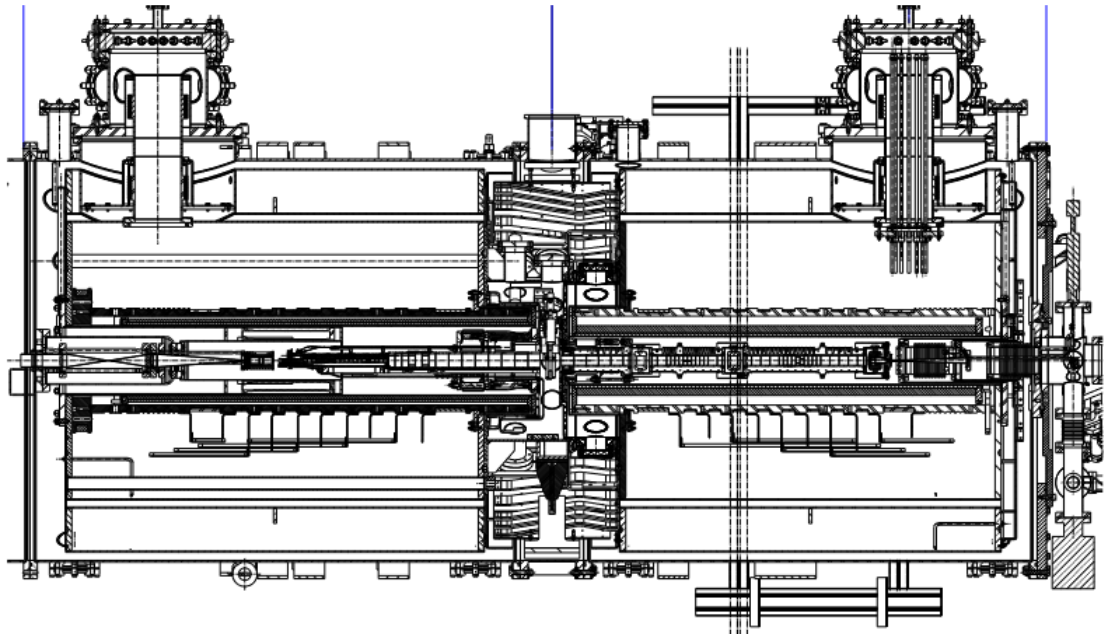
- Antiprotons are delivered from ELENA (previously from AD), then in AEgIS they are trapped and cooled
- Positrons are produced from ^{22}Na

Positron system



5T trap

1T trap



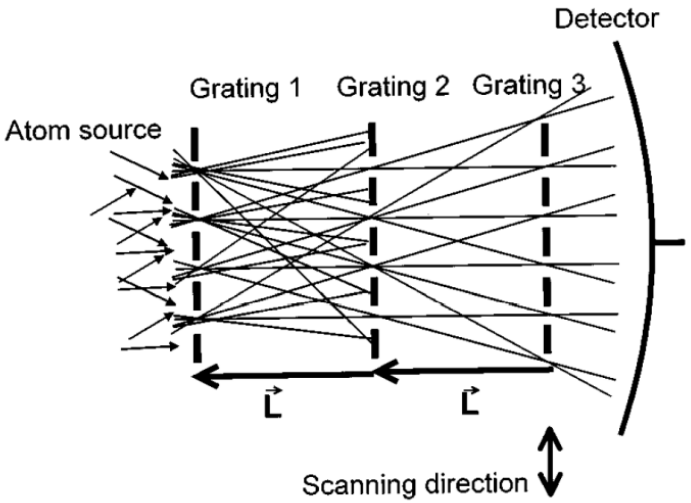
Antihydrogen production

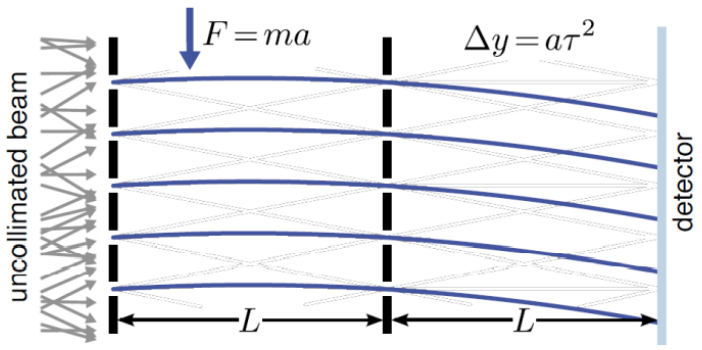
- Charge exchange reaction of Rydberg positronium and antiproton
- Allows for pulsed formation

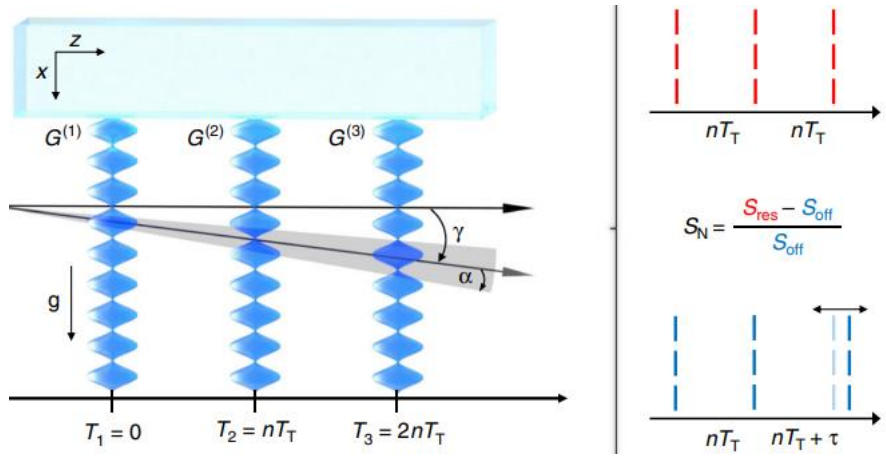
$$\mathrm{Ps}^{*} + \bar{\mathrm{p}} \rightarrow \bar{\mathrm{H}}^{*} + \mathrm{e}^{-}$$

Free fall measurements

- Moire deflectometer
- Optical Talbot-Lau time domain interferometer

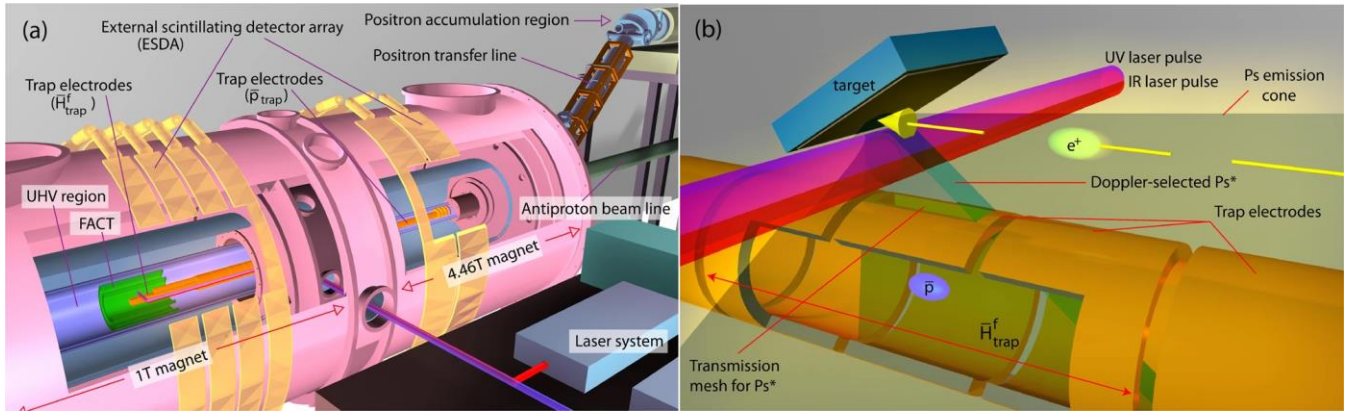


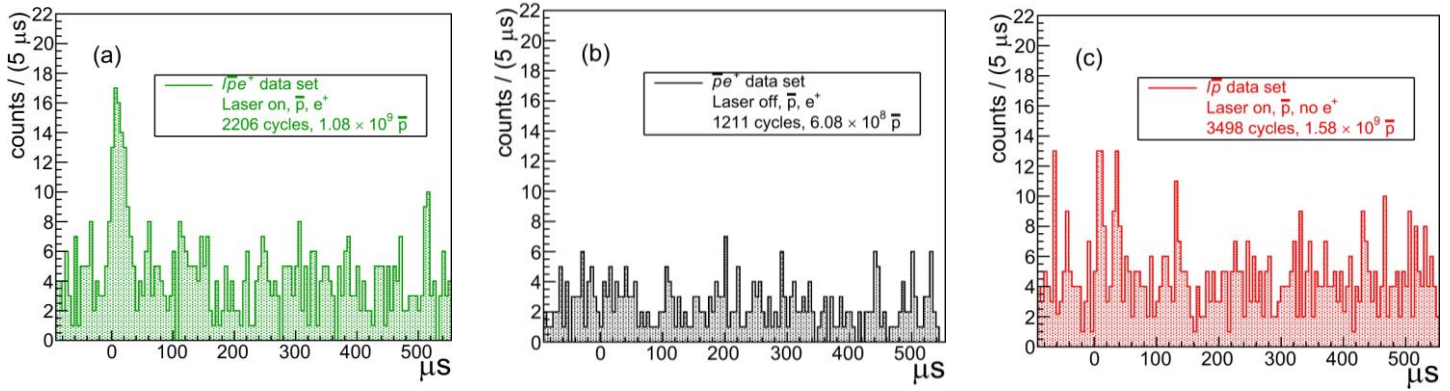




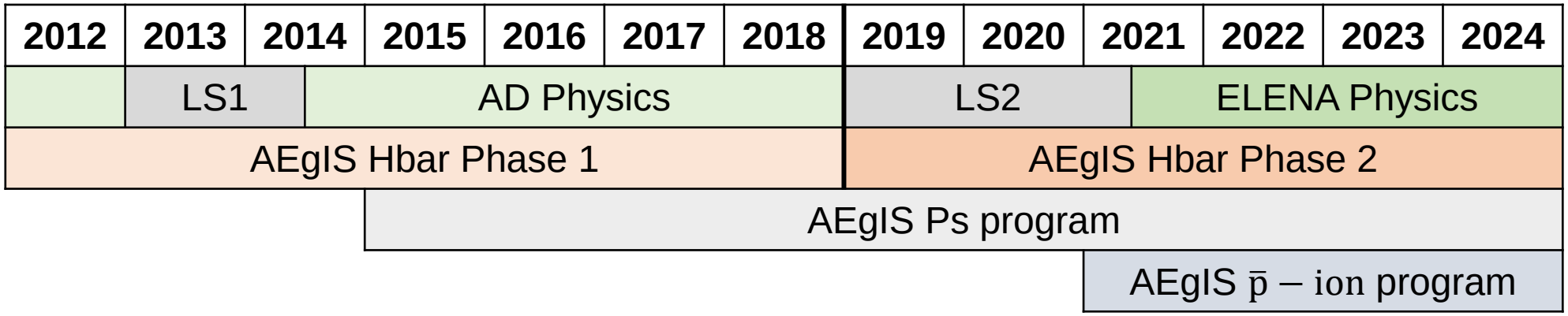
Phase 1

- AEgIS Phase 1 was a feasibility study of a pulsed antihydrogen source. It ended in 2018 with the formation of cold antihydrogen atoms in the trap.





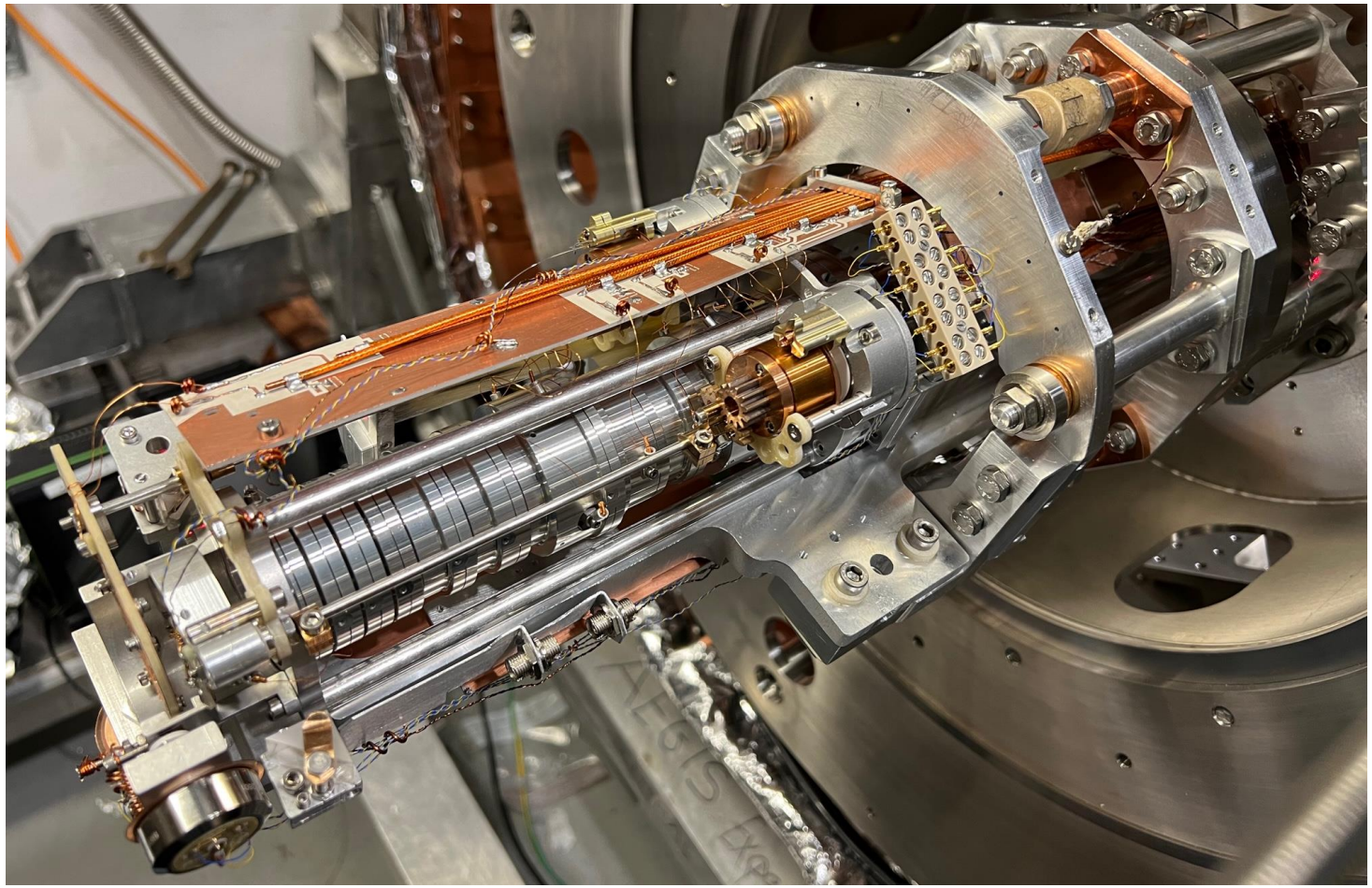
Timeline


2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
LS1
AD Physics
LS2
ELENA Physics
AEgIS Hbar Phase 1
AEgIS Hbar Phase 2
AEgIS Ps program
AEgIS $\bar{p}$ – ion program

Upgrades

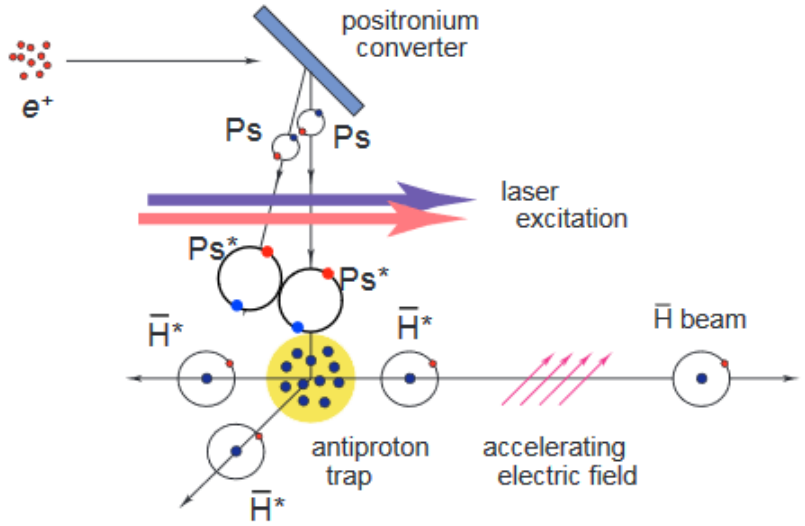
New trap

- Longer interaction with positronium
- Better diagnostics
- Positronium target baking during operation

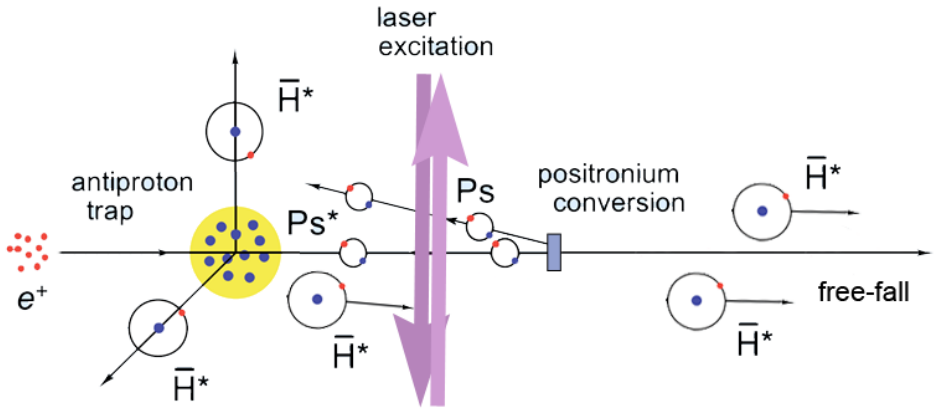


Antihydrogen production improvement

- Used in Phase 1



- Used in Phase 2



ARTIQ/Sinara control system

- Nanosecond precision over extended periods of time
- Based on Python

```python
from artiq.experiment import *
from artiq.coredevice.kasli_i2c import port_mapping

class test_HV_amps_trigger(EnvExperiment):

    def build(self):
        self.setattr_device("core")
        self.setattr_device("fastino0")
        self.setattr_device("ttl_hvamp1_sw0")
        self.setattr_device("ttl0")
        self.setattr_device("dio_mcx_dir_switch")
        self.setattr_device("i2c_switch0")

        self.dio_mmcx_i2c_port_1 = port_mapping["EEM0"]
        self.voltage = 0.05

    @kernel
    def set_dio_outputs1(self):
        self.i2c_switch0.set(self.dio_mmcx_i2c_port_1)
        self.dio_mcx_dir_switch.set(0b00000101)
        self.core.break_realtime()
        self.ttl0.input()
        self.core.break_realtime()

    @kernel
    def waitingtrigger(self):
        t_gate = self.ttl0.gate_rising(200*s)
        t_trig = self.ttl0.timestamp_mu(t_gate)
        if t_trig != -1:
            at_mu(t_trig)
            self.core.break_realtime()
            self.fastino0.set_dac(8, self.voltage)

    @kernel
    def run(self):
        self.core.reset()
        self.fastino0.init()
        self.ttl_hvamp1_sw0.on()
        self.core.break_realtime()
        self.set_dio_outputs1()
        self.waitingtrigger()
```

TALOS

- Total Automation of Labview Operation for Science
- Allows 24/7 unsupervised data taking
- Founding pillars:
  - Distributed system
  - “Everything is a microservice”

Future plans

- Produce 1000 times more antiprotons than in 2018
- Formation of antihydrogen beam
- Free fall measurement for antihydrogen
- Antiprotonic atom program

Thanks for attention!

Questions?