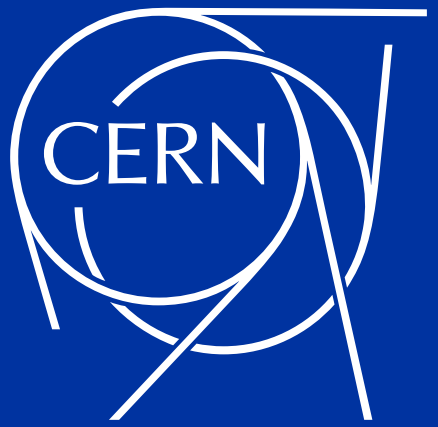


A virtual tour of the antimatter factory at CERN

Speaker: *Sonia Natale*
Guide: *Mario Campanelli*

Jan 14th 2022

What are we going to visit today ?

Antiprotons from PS

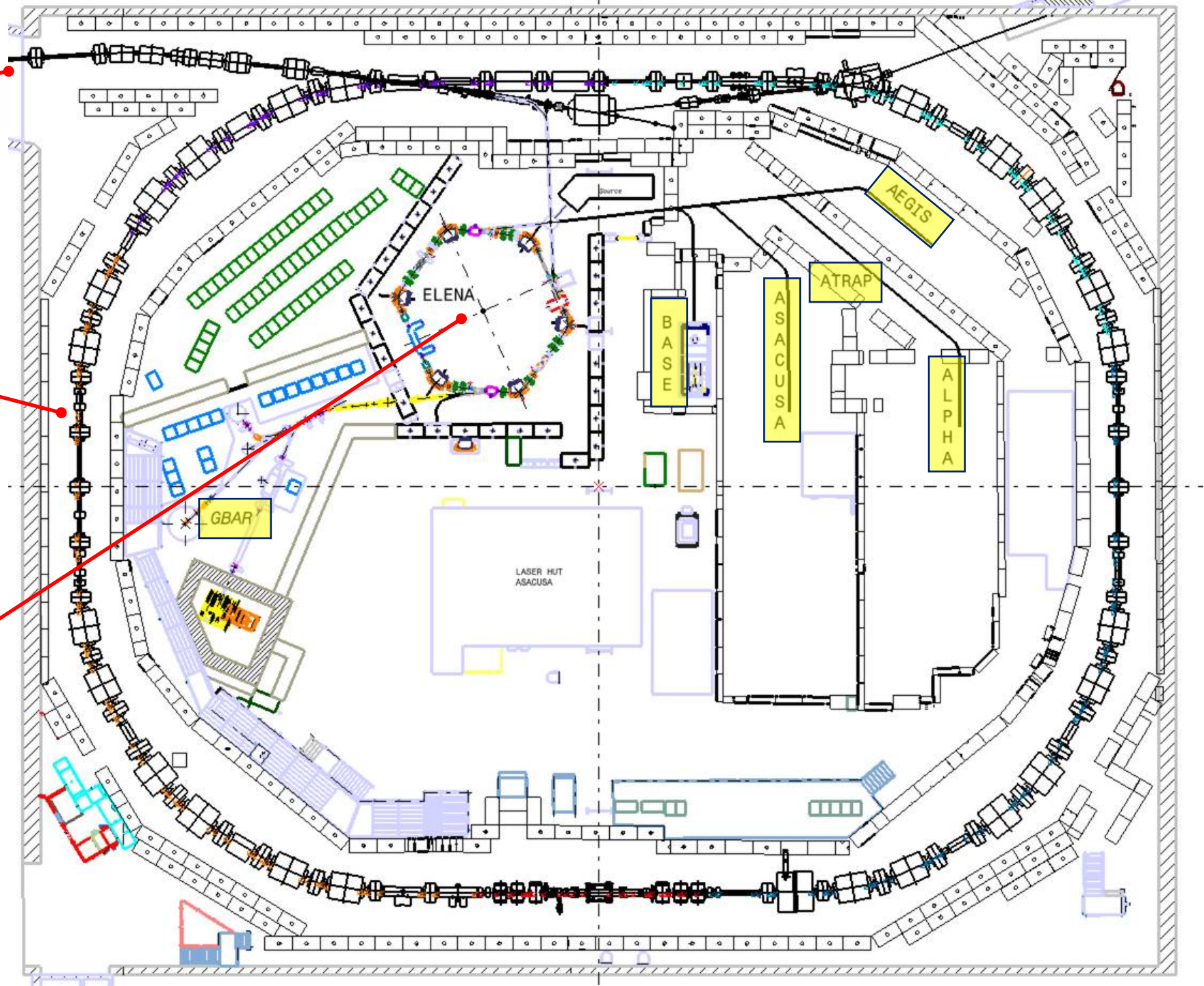
Energy: 3.5 GeV

AD
Antiproton Decelerator

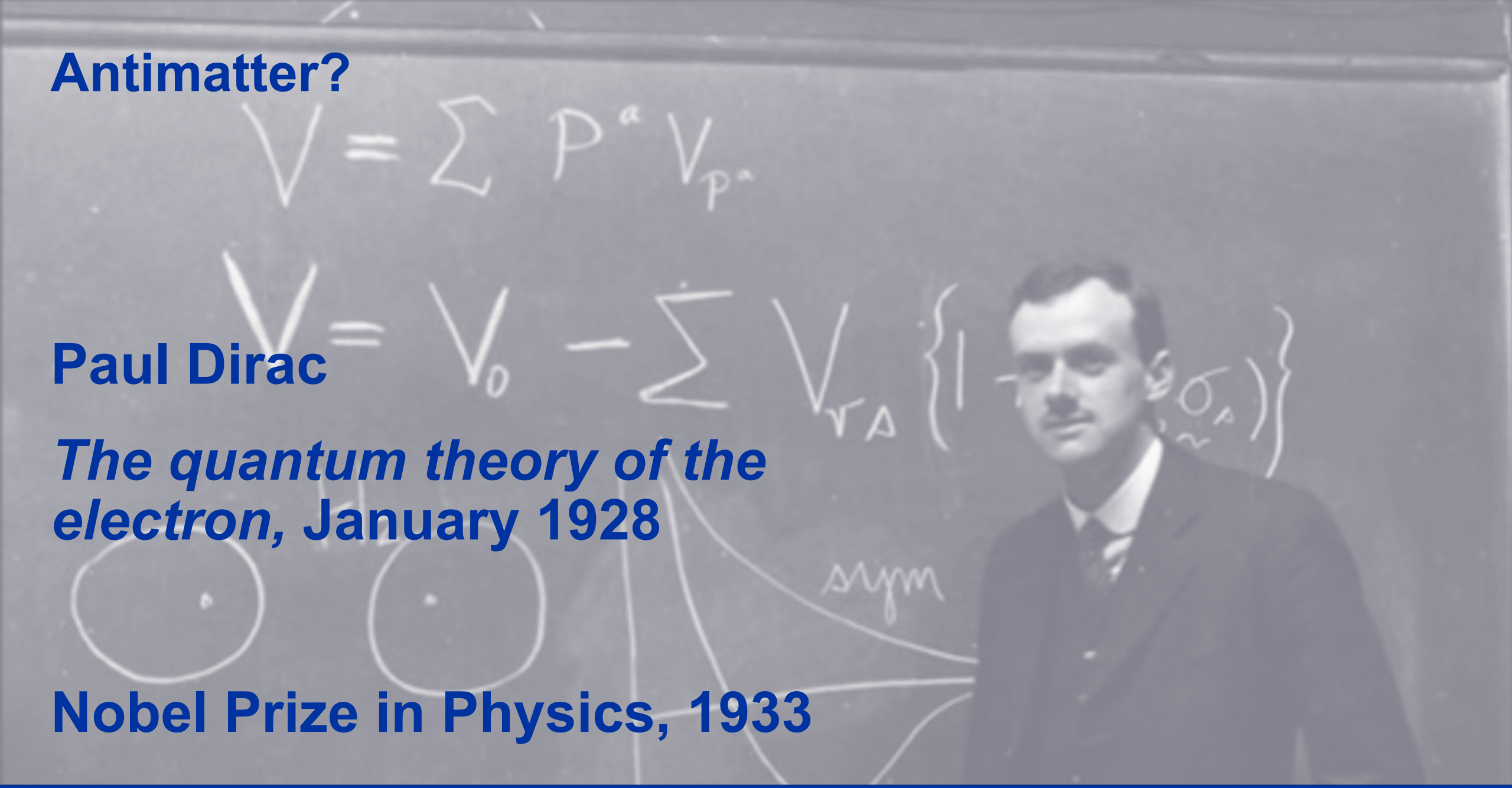
Start: 2000
Length: 182 m
Energy: 5.3 MeV

ELENA
Extra Low
ENergy Antiproton

Start: 2021
Length: 30 m
Energy: 0.1 MeV



Antimatter?



Paul Dirac

***The quantum theory of the electron*, January 1928**

Nobel Prize in Physics, 1933

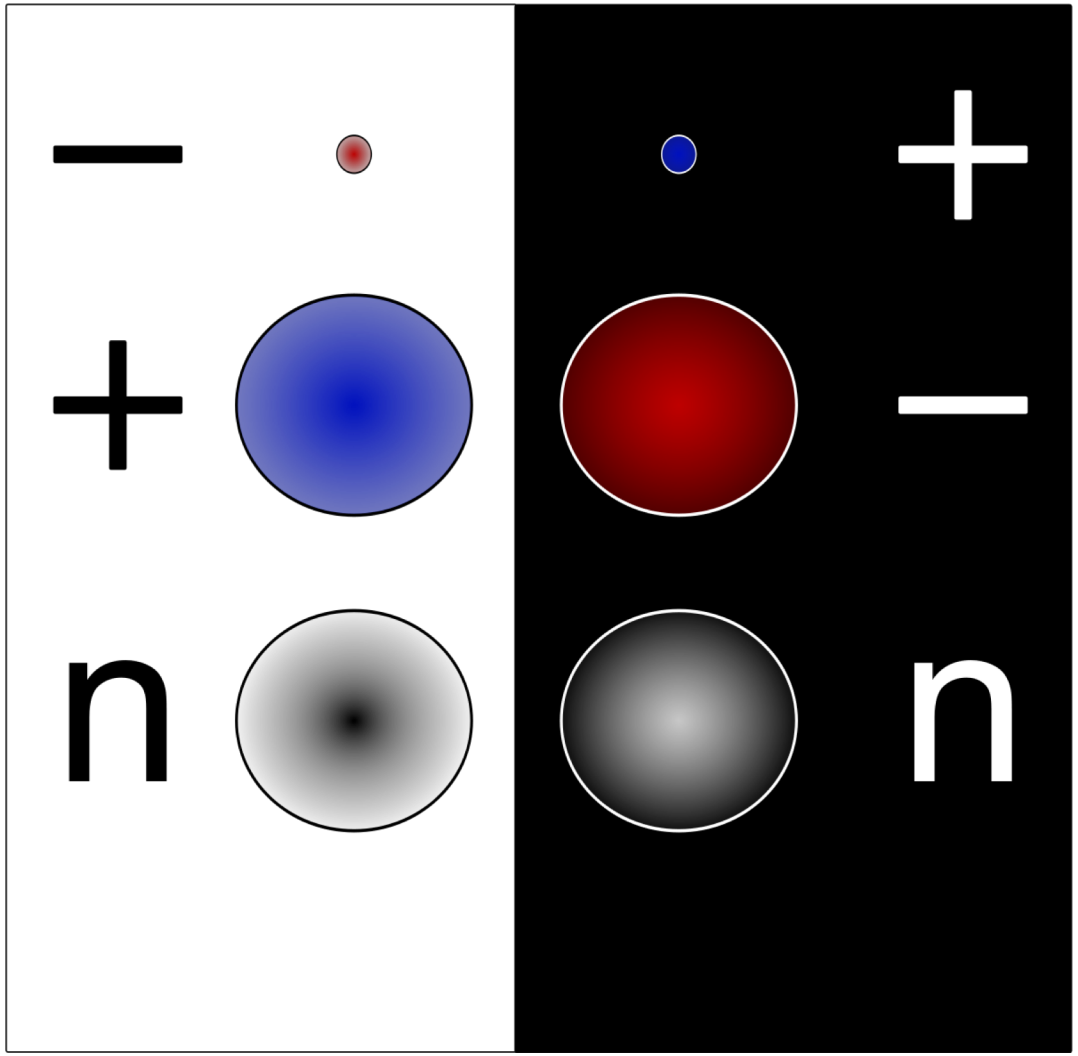
Antimatter?

Antimatter?

electron

proton

neutron

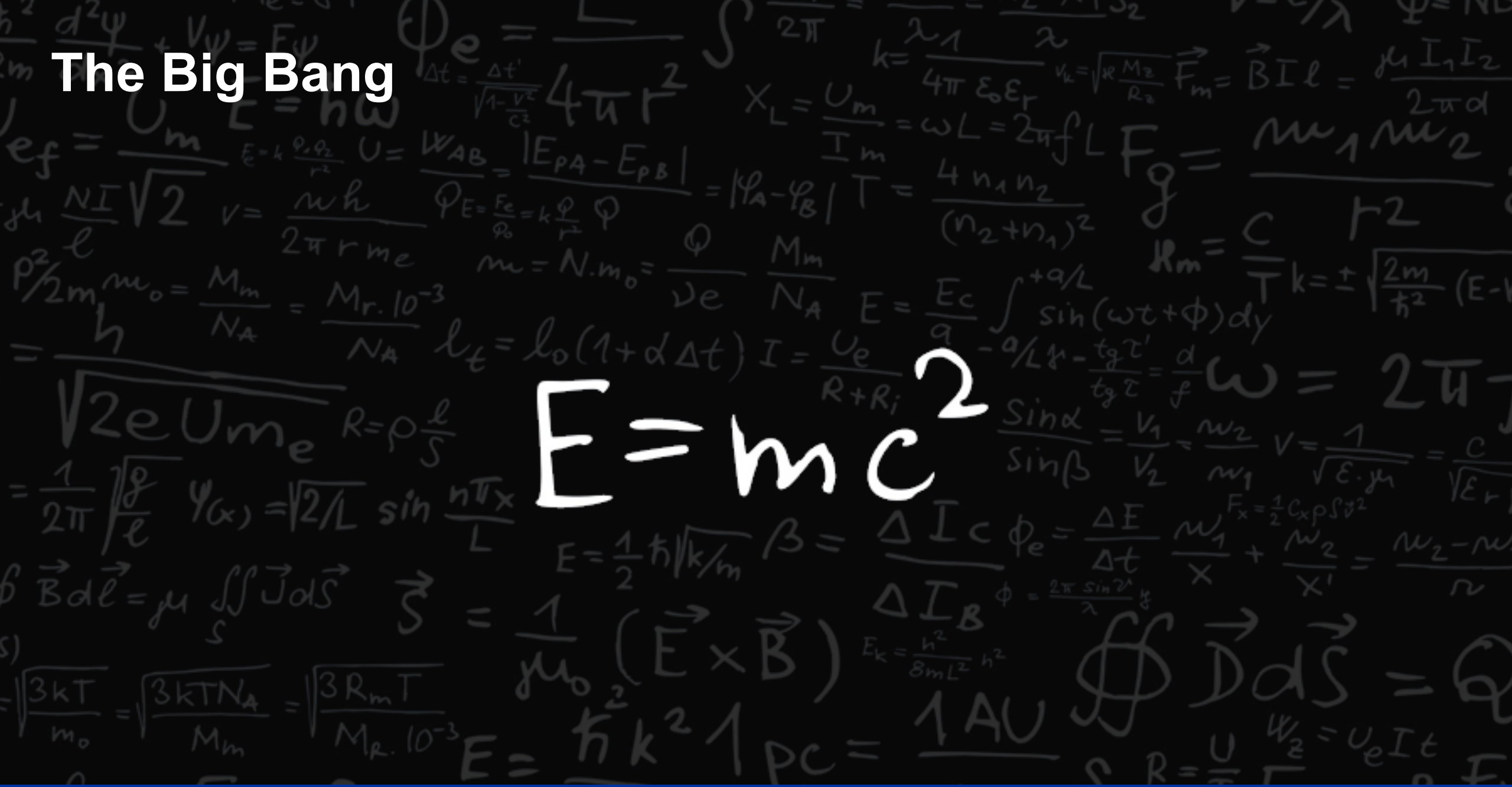


positron

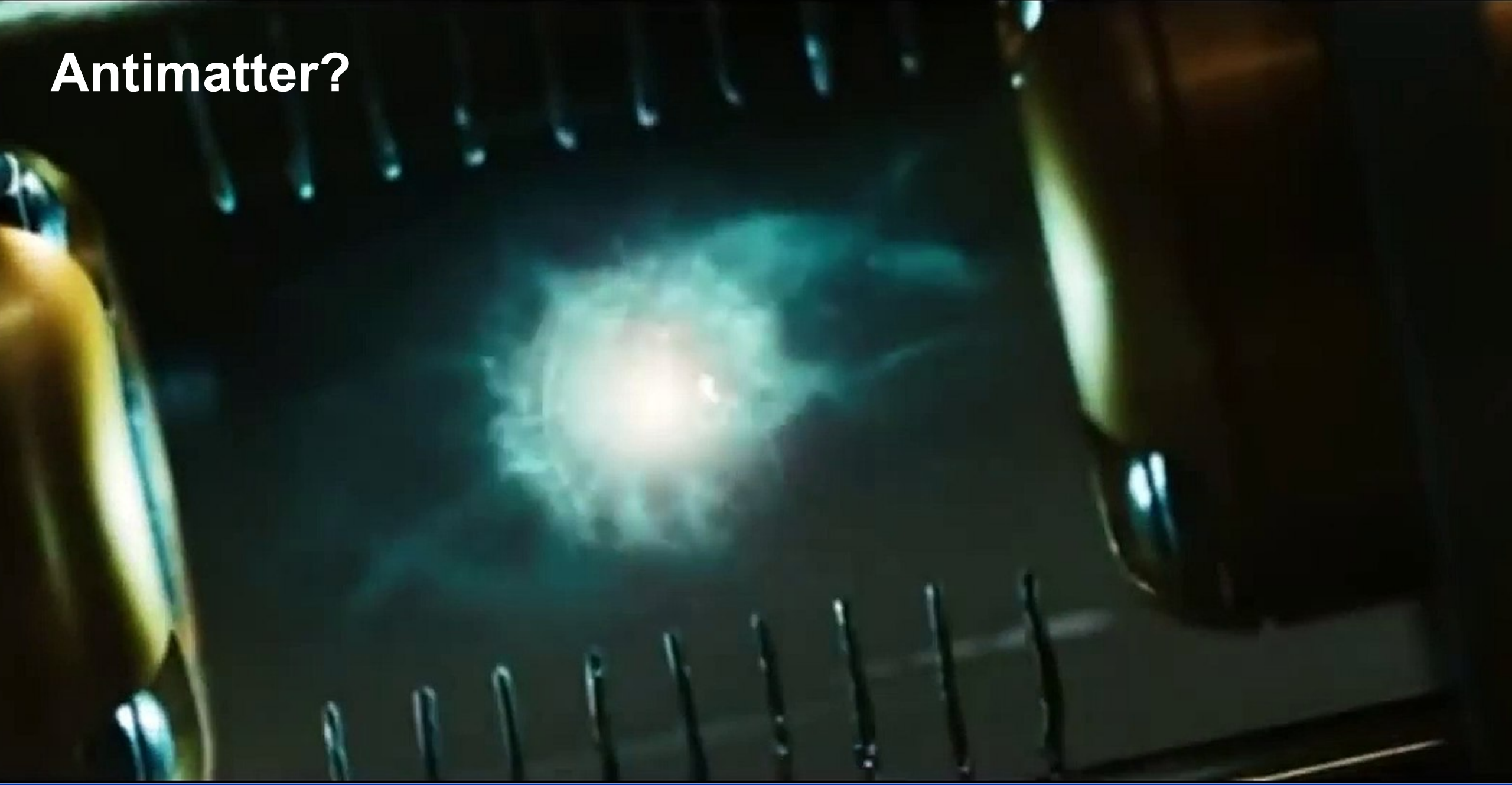
antiproton

antineutron

The Big Bang



Antimatter?



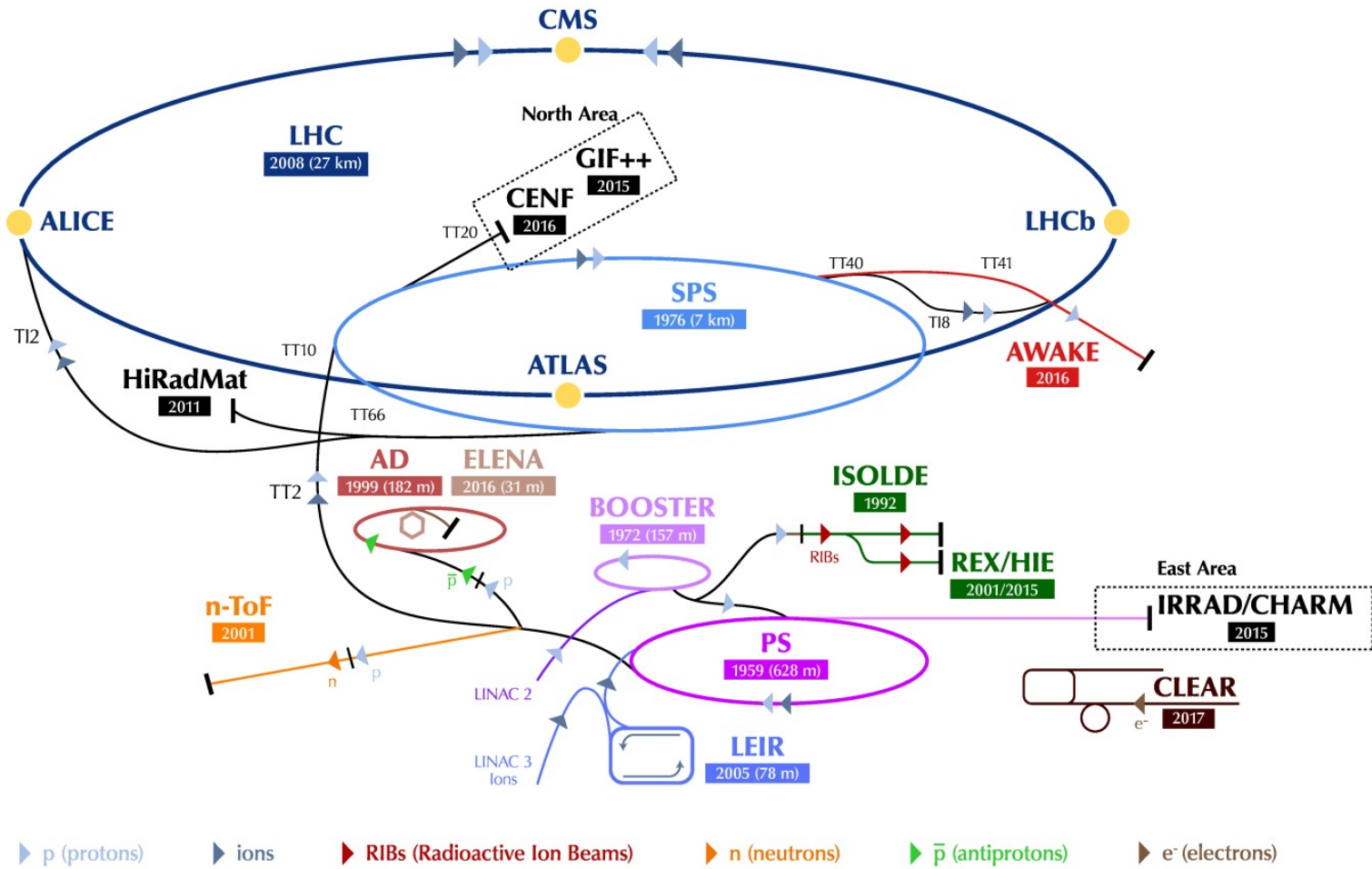
Where has all the antimatter gone?

How do we address this question at CERN?

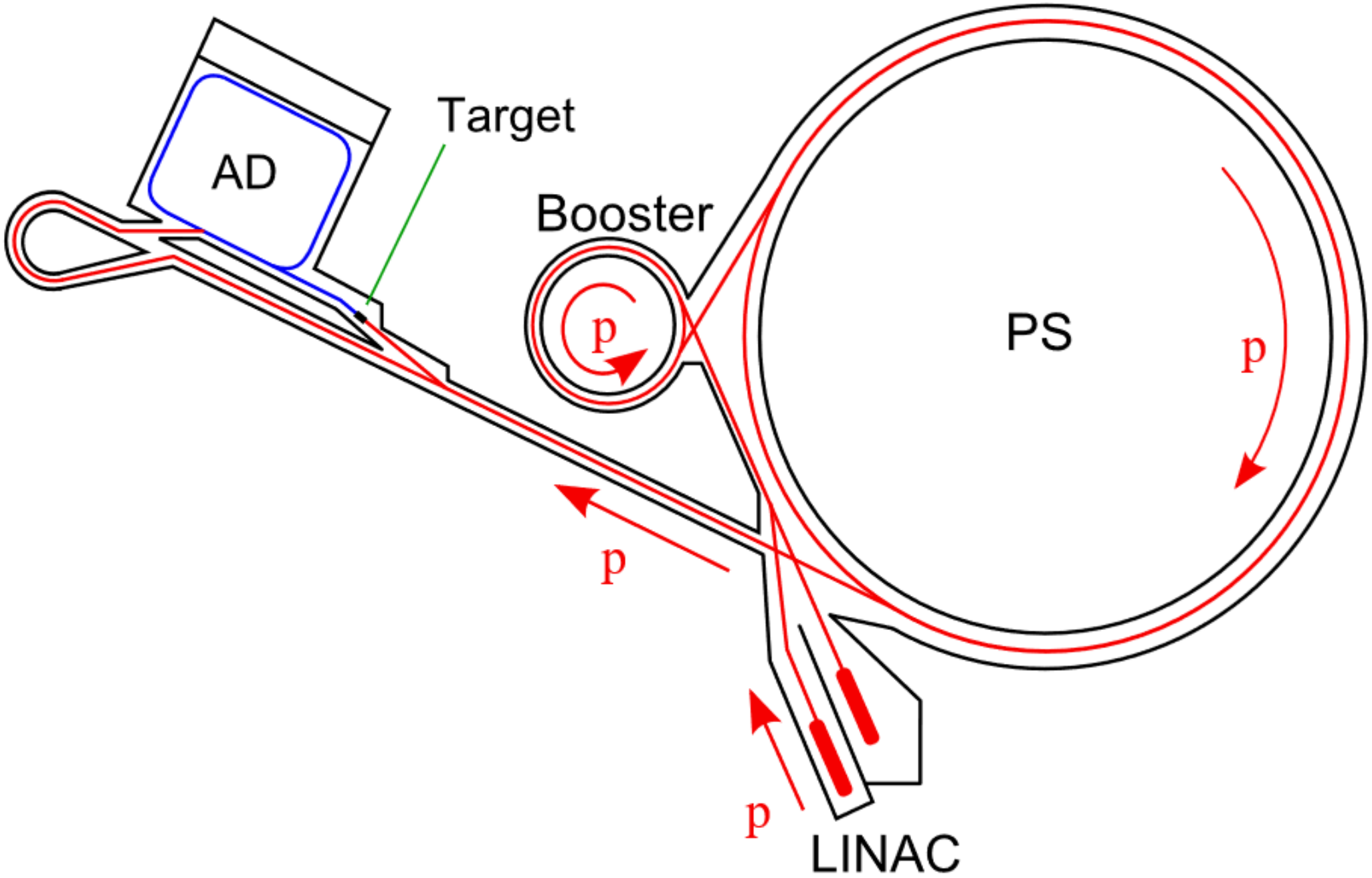
How do we address this question at CERN?

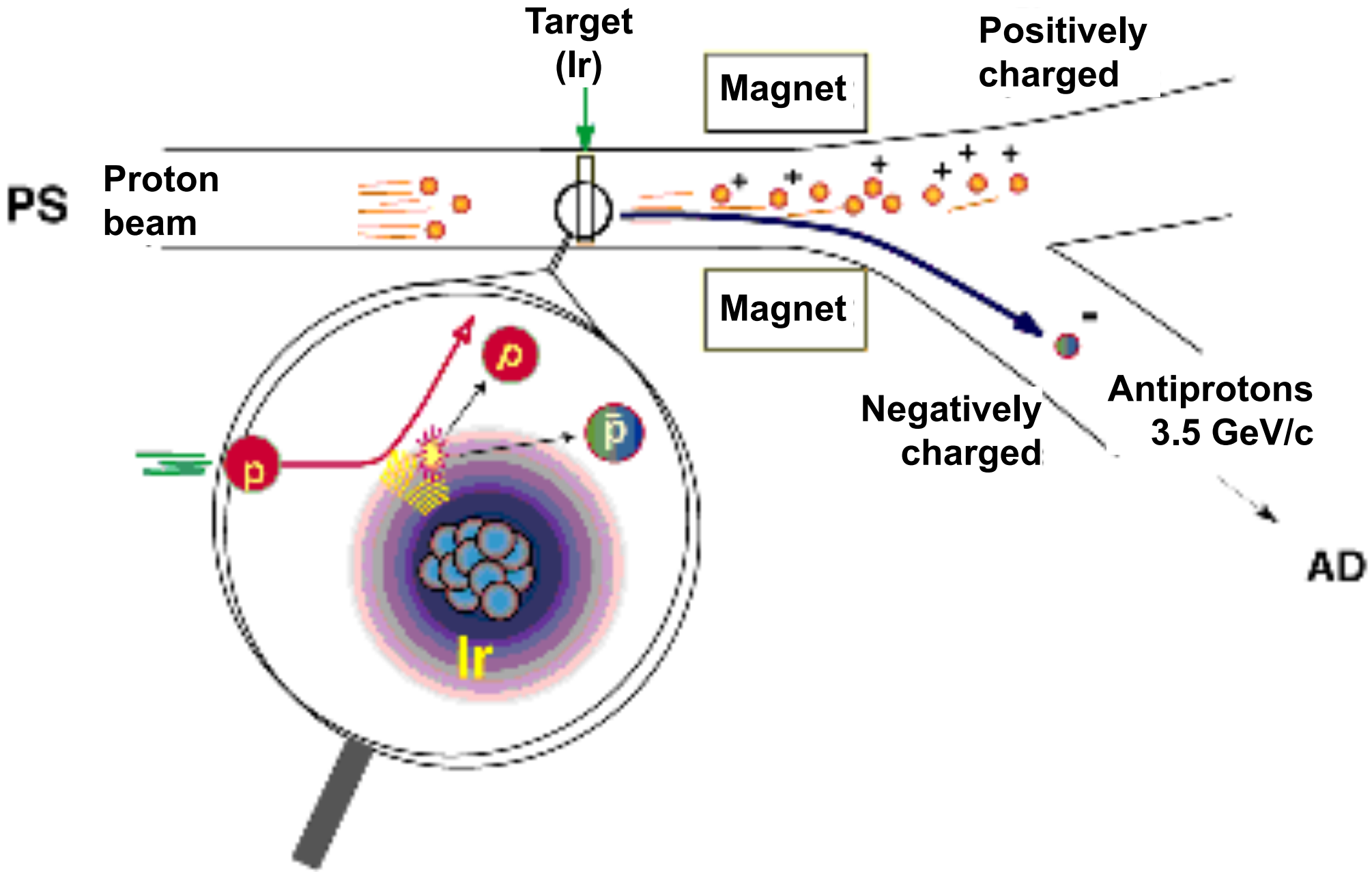
How do we address this question at CERN?

The CERN accelerator complex
Complexe des accélérateurs du CERN



LHC - Large Hadron Collider // **SPS** - Super Proton Synchrotron // **PS** - Proton Synchrotron // **AD** - Antiproton Decelerator // **CLEAR** - CERN Linear Electron Accelerator for Research // **AWAKE** - Advanced WAKefield Experiment // **ISOLDE** - Isotope Separator OnLine // **REX/HIE** - Radioactive EXperiment/High Intensity and Energy ISOLDE // **LEIR** - Low Energy Ion Ring // **LINAC** - LINear ACcelerator // **n-ToF** - Neutrons Time Of Flight // **HiRadMat** - High-Radiation to Materials // **CHARM** - Cern High energy AcceleRator Mixed field facility // **IRRAD** - proton IRRADiation facility // **GIF++** - Gamma Irradiation Facility // **CENF** - CErn Neutrino platForm


AD
Target
Booster
p
PS
p
p
p
LINAC


Target
(Ir)
Magnet
Positively
charged
PS
Proton
beam
Magnet
Negatively
charged
Antiprotons
3.5 GeV/c
AD
p
p
p̄
Ir

Antiprotons from PS

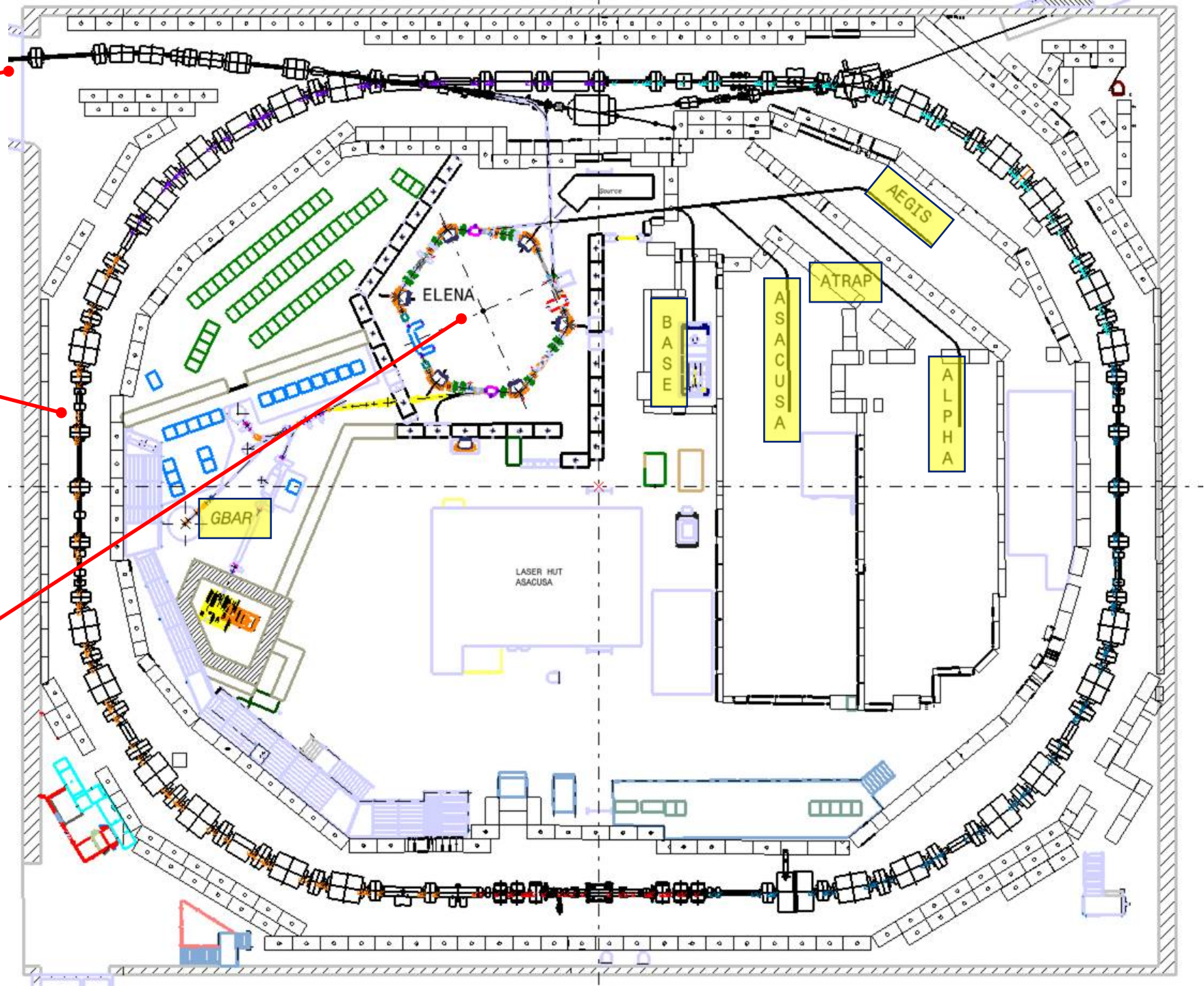
Energy: 3.5 GeV

AD
Antiproton Decelerator

Start: 2000
Length: 182 m
Energy: 5.3 MeV

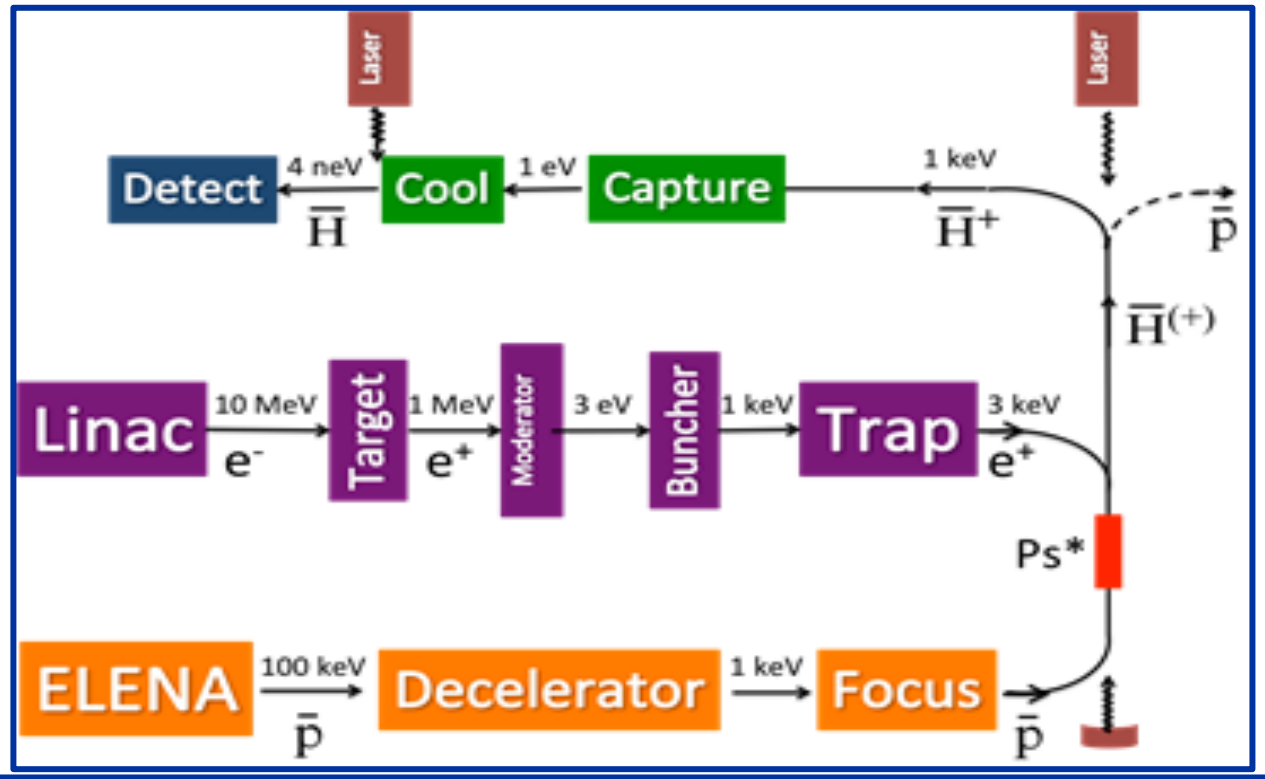
ELENA
Extra Low
ENergy Antiproton

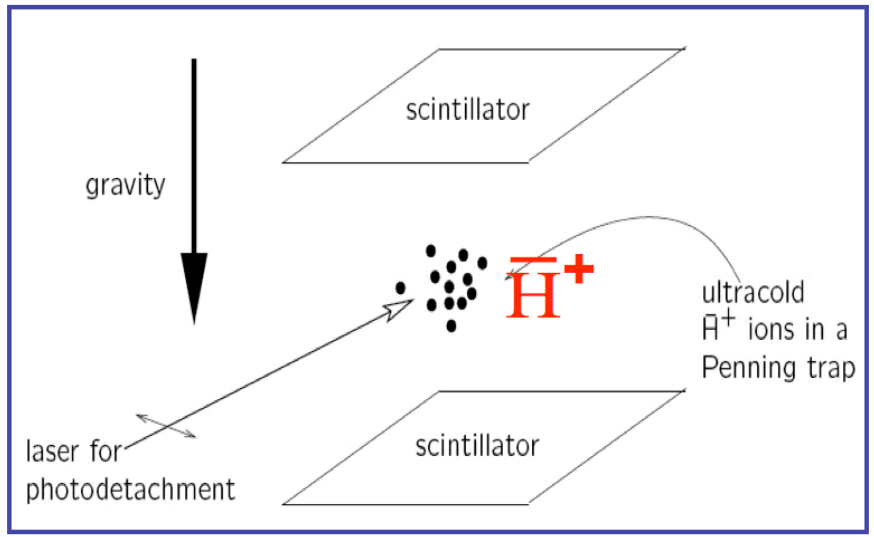
Start: 2021
Length: 30 m
Energy: 0.1 MeV



Gbar Experiment

- The GBAR experiment uses antiprotons supplied by the ELENA deceleration ring and positrons produced by a small linear accelerator to make antihydrogen ions, consisting of one antiproton and two positrons.
- Next, after trapping the antihydrogen ions and chilling them to an ultralow temperature (about 10 microkelvin), it uses laser light to strip them of one positron, turning them into neutral antiatoms.
- At this point, the neutral antiatoms will be released from the trap and allowed to fall from a height of 20 centimetres, during which the researchers will monitor their behaviour.

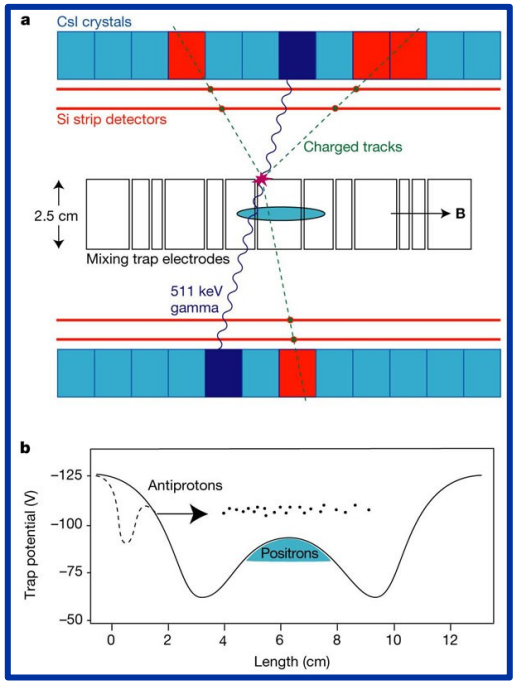




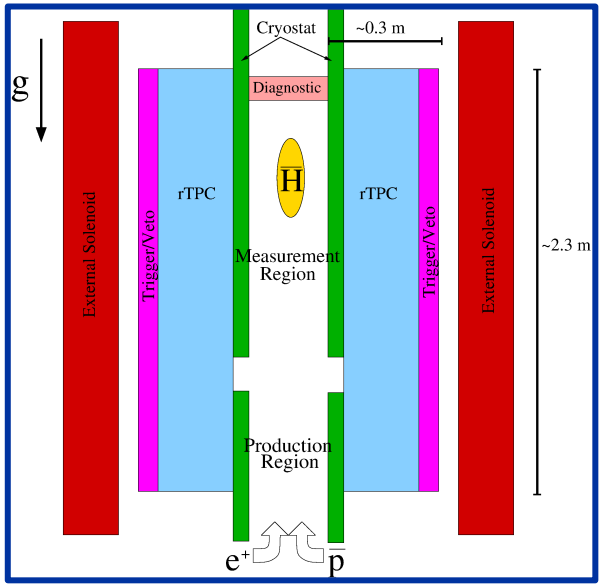
ALPHA and ALPHA-g Experiment

- ALPHA-g is very similar to the ALPHA experiment, which makes neutral antihydrogen atoms by taking antiprotons from the Antiproton Decelerator (AD) and binding them with positrons from a sodium-22 source.
- ALPHA then confines the resulting neutral antihydrogen atoms in a magnetic trap and shines laser light or microwaves onto them to measure their internal structure.

- The ALPHA-g experiment has the same type of apparatus for making and trapping antiatoms, except that it is oriented vertically. With this vertical set-up, researchers can precisely measure the vertical positions at which the antihydrogen atoms annihilate with normal matter once they switch off the trap's magnetic field and the atoms are under the sole influence of gravity. The values of these positions allows them to measure the effect of gravity on the antiatoms.



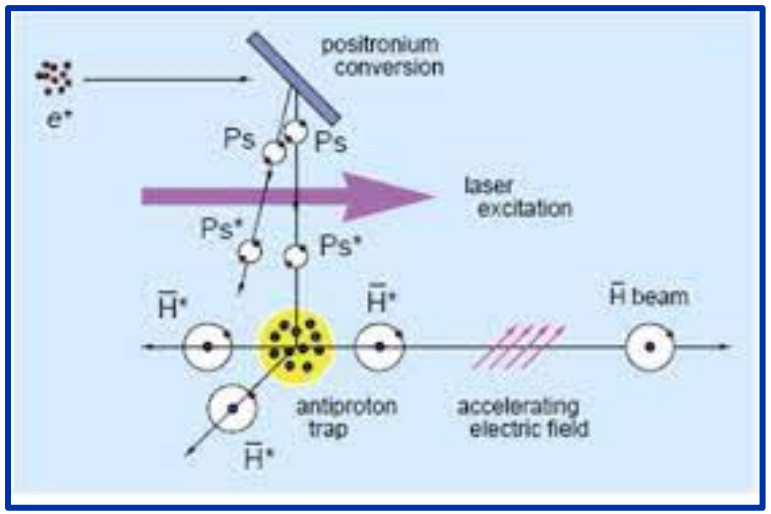
ALPHA

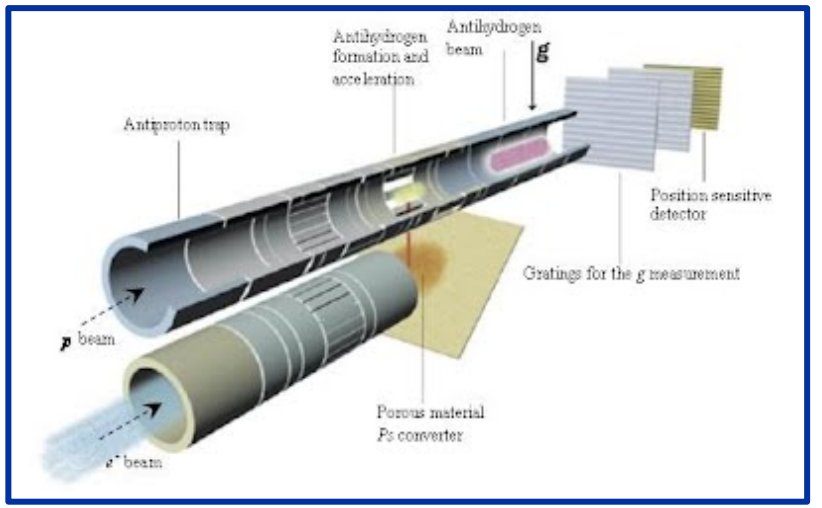


ALPHA-g

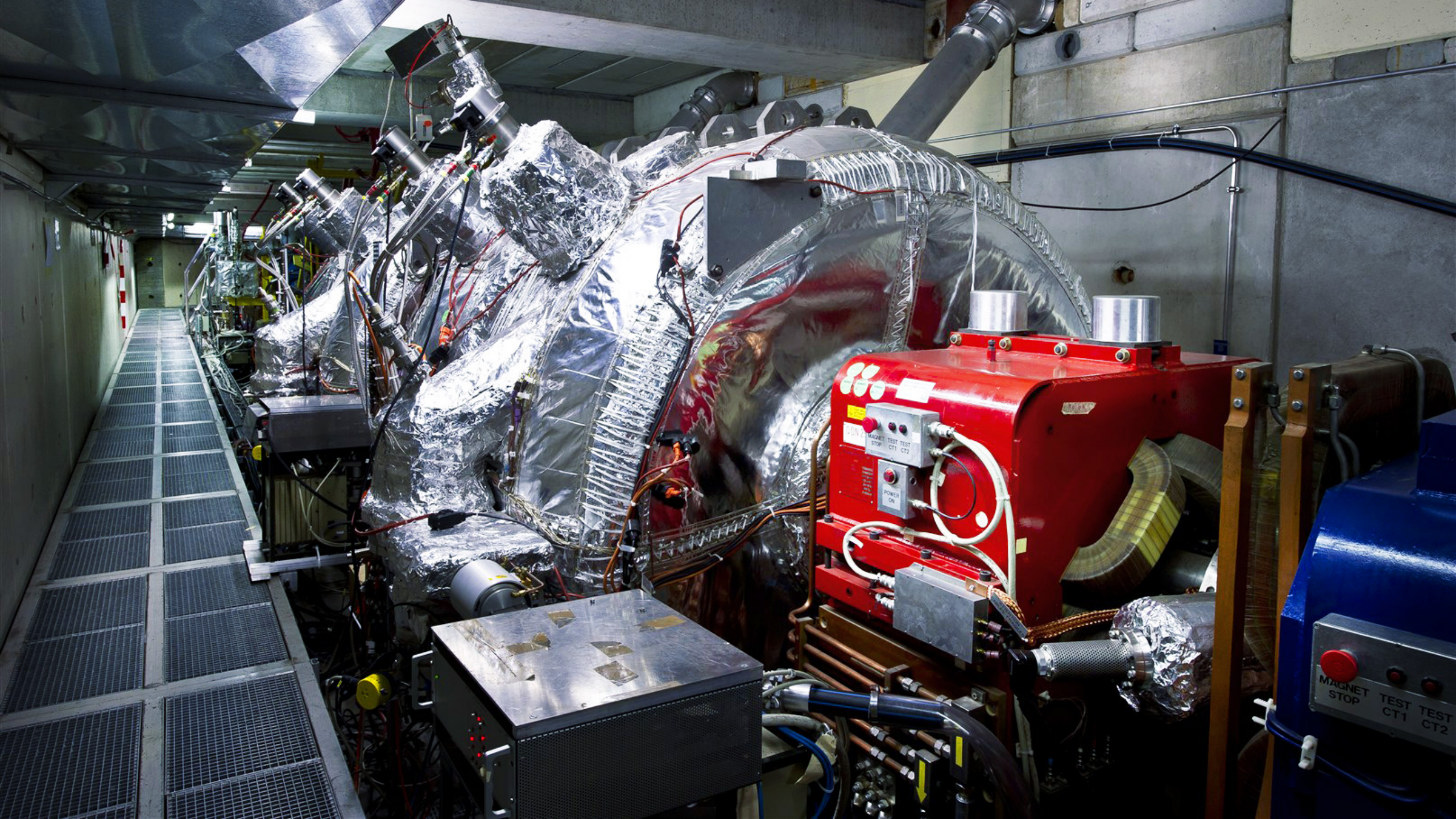
Experiment

- A system of gratings in the deflectometer splits the antihydrogen beam into parallel rays, forming a periodic pattern.
- From this pattern, the physicists can measure how much the antihydrogen beam drops during its horizontal flight.
- Combining this shift with the time each atom takes to fly and fall, the AEgIS team can then determine the strength of the gravitational force between Earth and the antihydrogen atoms.

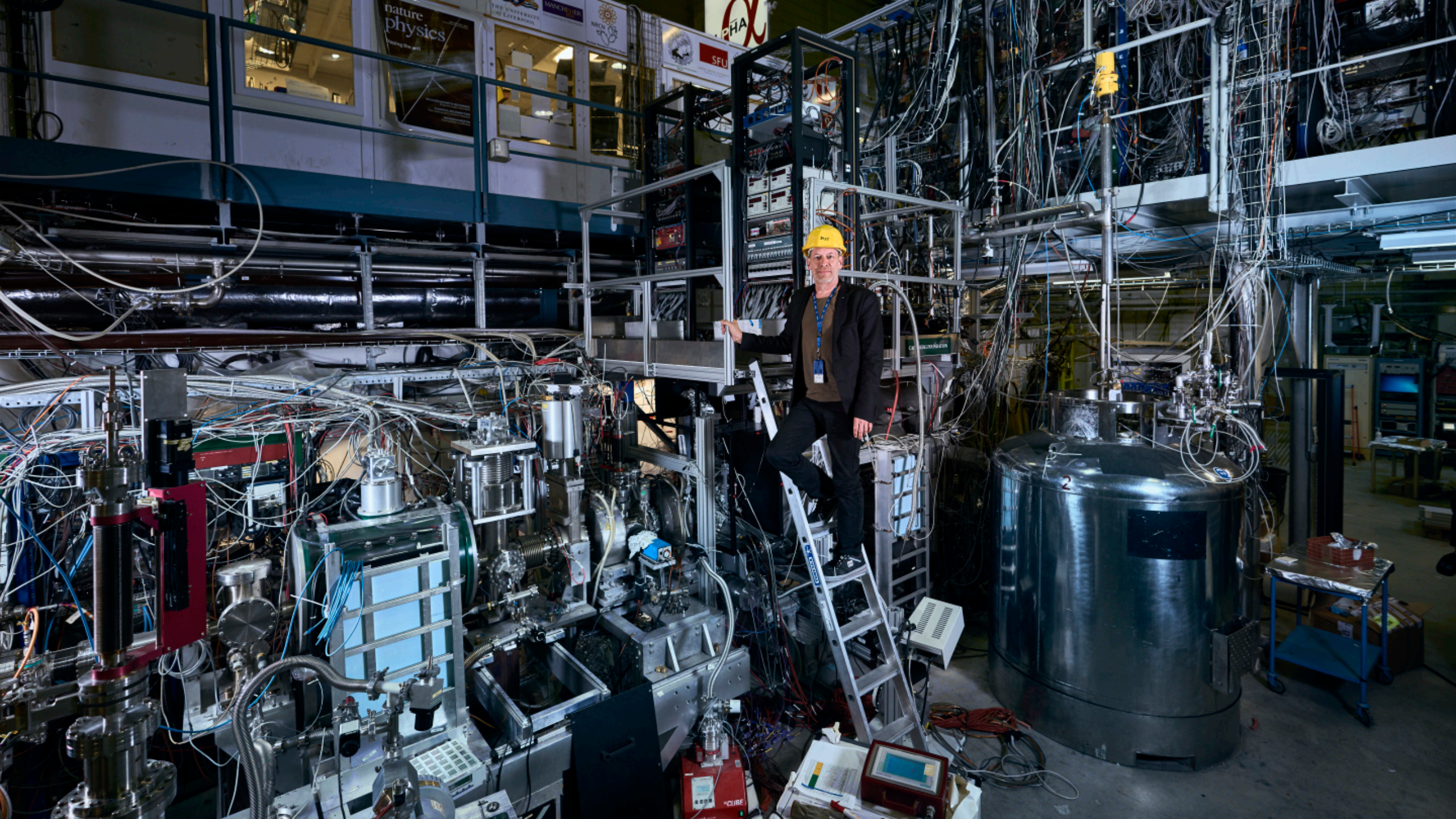


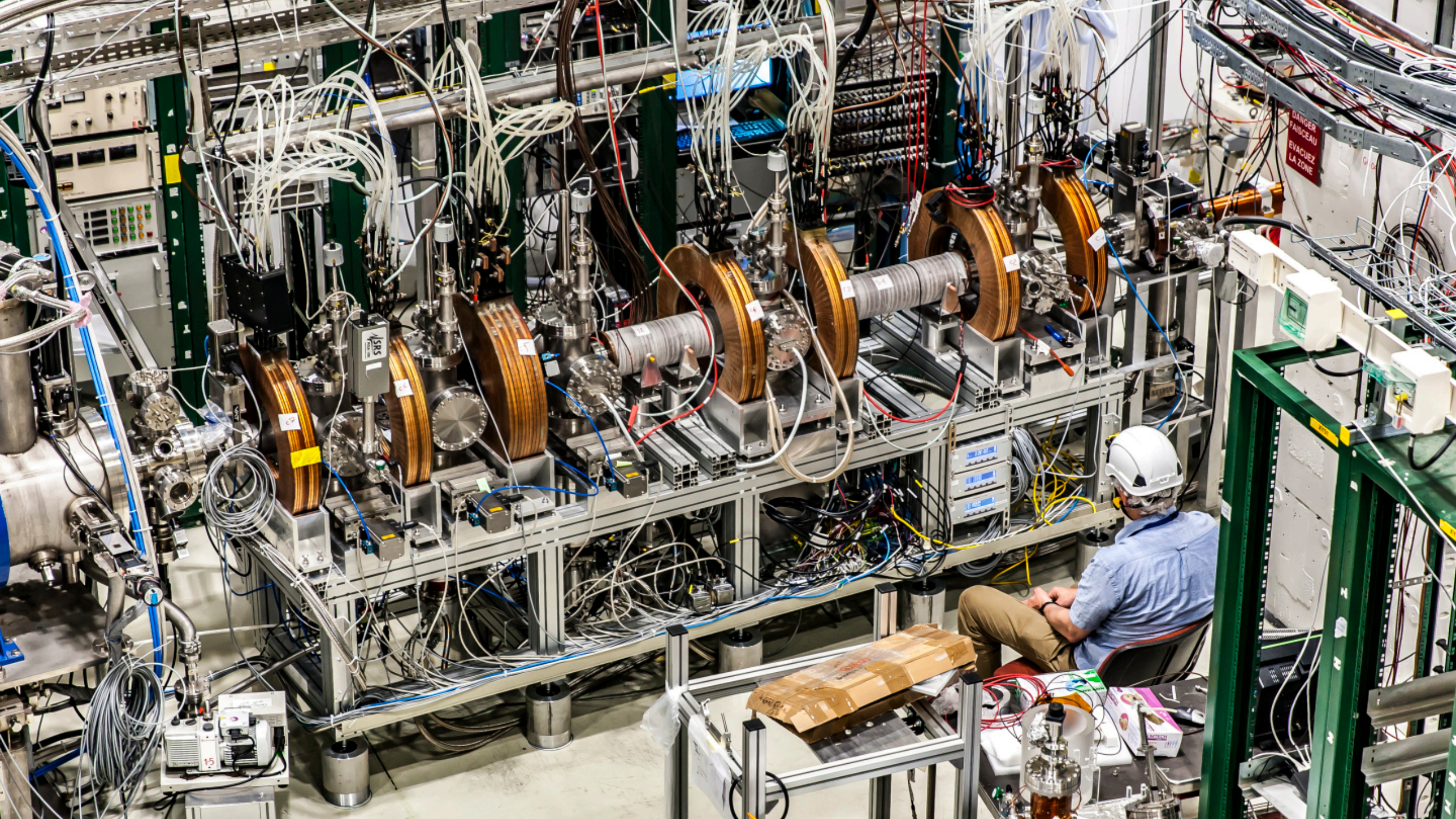


In 2018, AEgIS demonstrated the first pulsed production of antihydrogen atoms, by interacting pulse-produced positronium (an atom consisting of only an electron and a positron) with cold, trapped antiprotons.


MAGNET STOP
TEST CT1
TEST CT2
POWER ON


ASACUSA
HARVARD
ATRAP
ASACUSA
ASACUSA
H4
H2

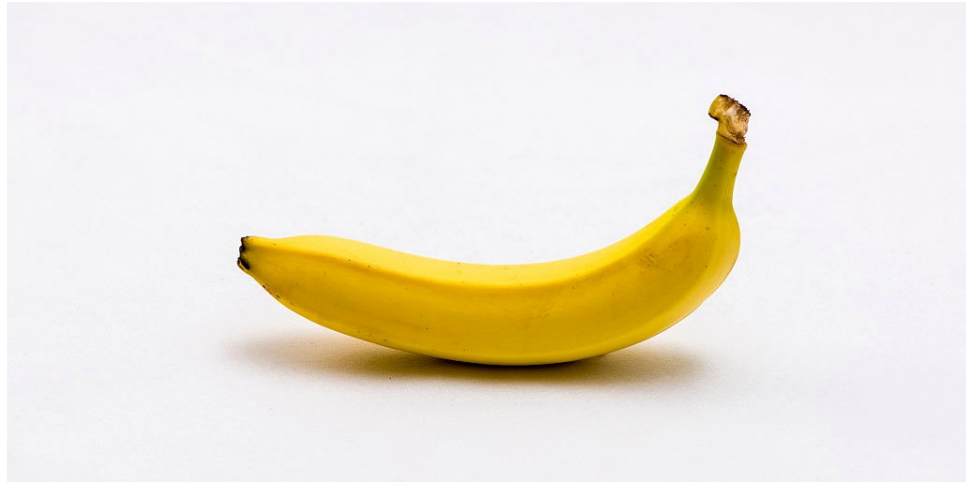

nature physics

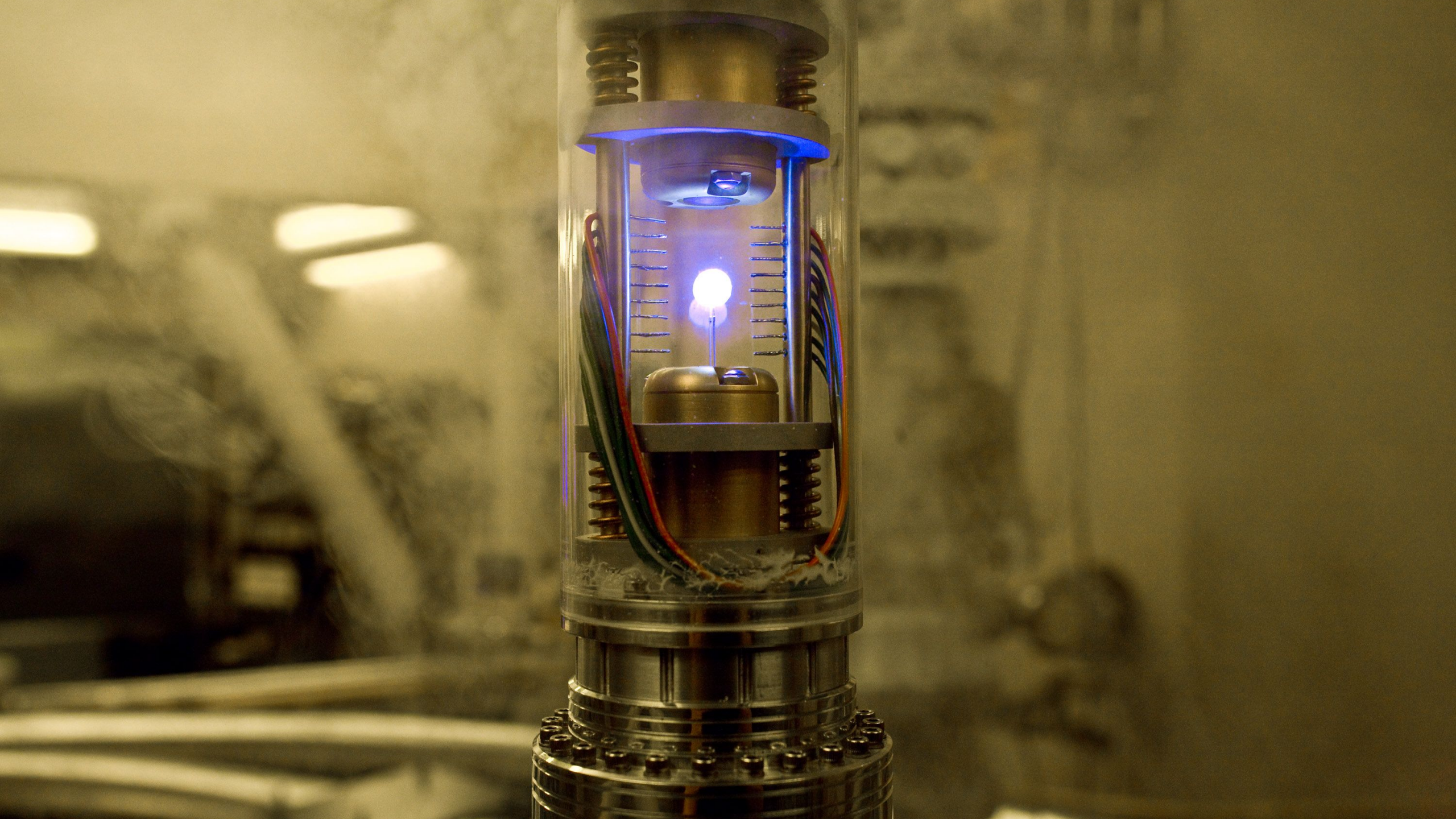

DANGER
FAISCEAU
EVACUEZ
LA ZONE

Natural antiparticles

- A person weighting 80 kg produces 180 e^+ per hour from the desintegration of Potassium-40, a natural isotope

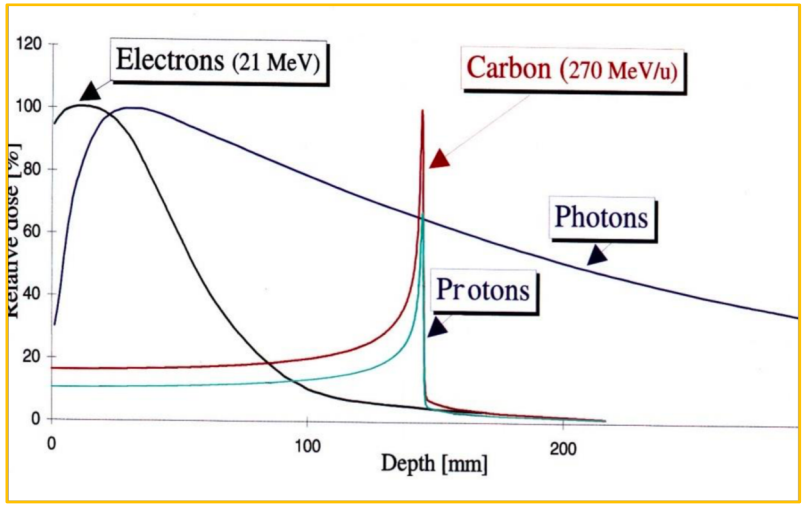
- A banana produces 10 e^+ per second



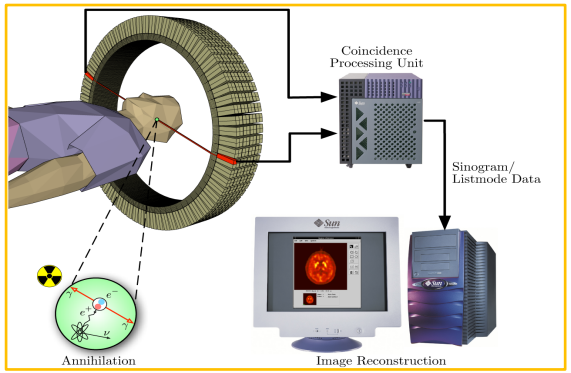


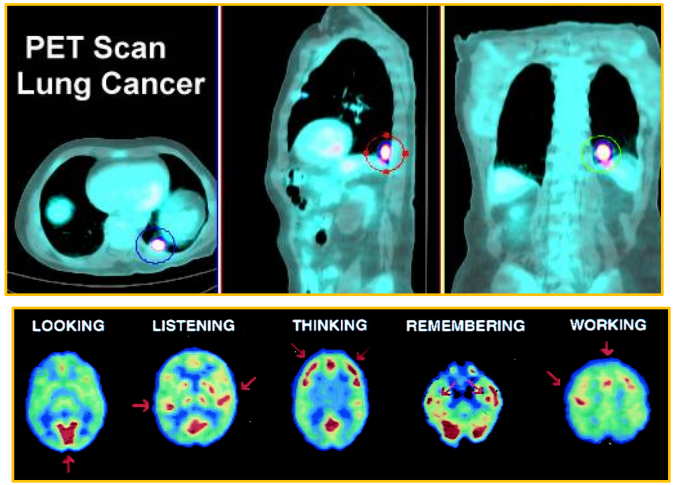
Practical use…

1g of antimatter contains 90 TJ of energy (~21 kT of TNT) (enough to power a car 1000 times around the world) but producing 1g of antimatter at CERN at current production rate would take1 billion years
would cost 2 000 000 000 000 000 €

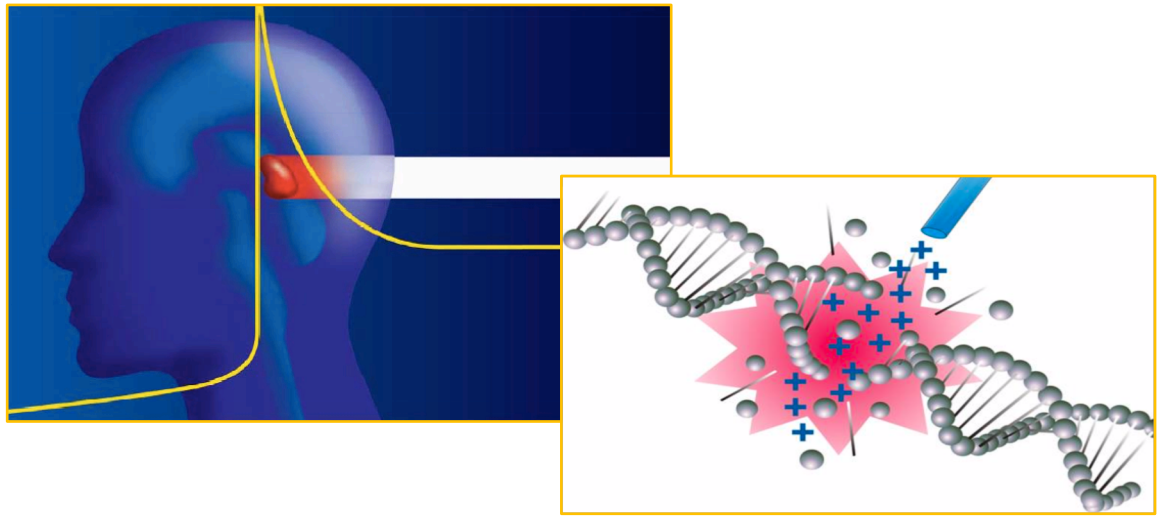


PET (Positron Emission Tomography)





Hadron Therapy (antiprotons)



Additional slides

The experiments

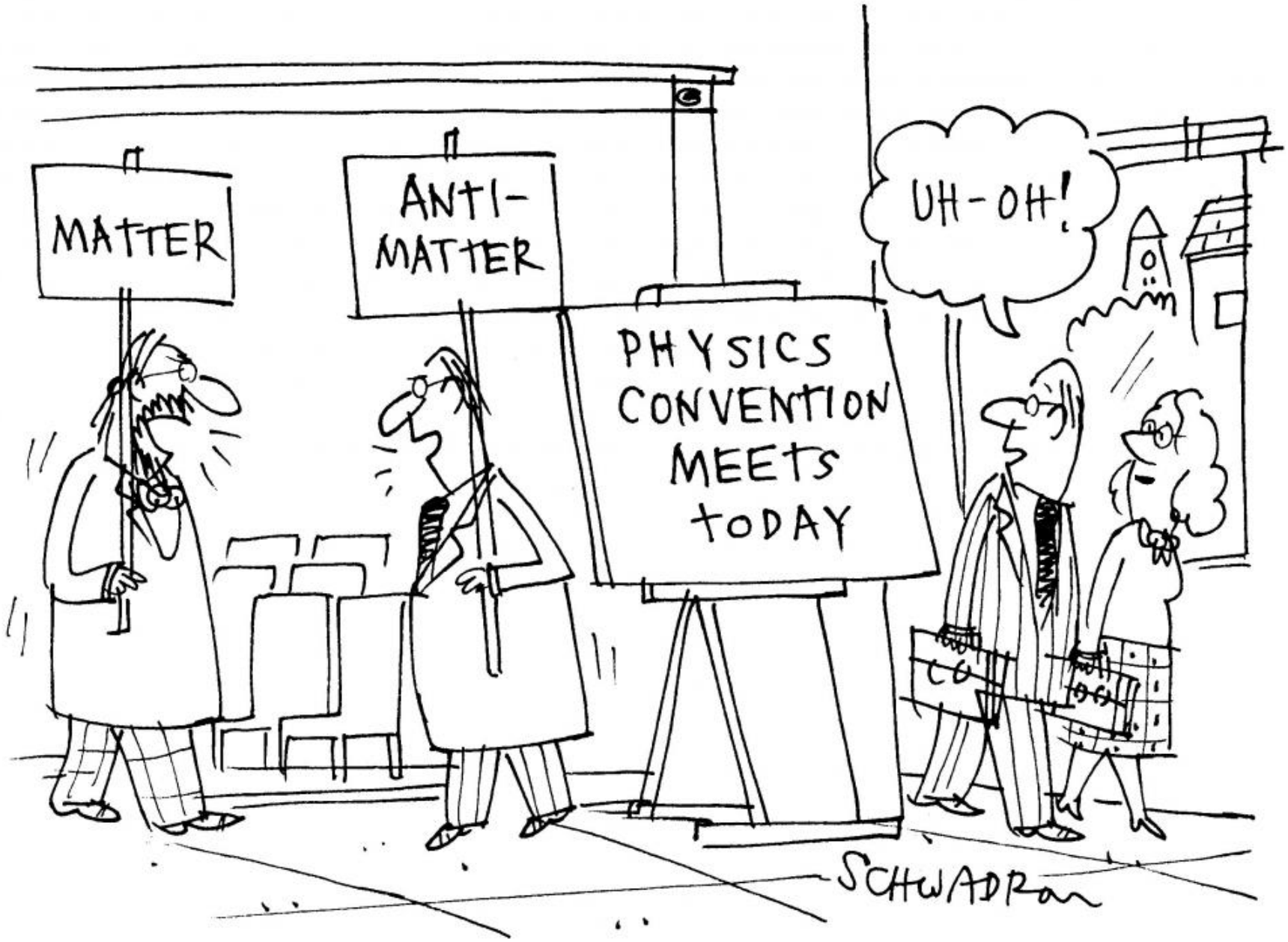
	ALPHA	ATRAP	ASACUSA	BASE	AEGIS	GBAR
Approved	2005	1997	1997	2013	2008	2012
Data Taking	2006	2002	2002	2014	*Soon*	*Soon*
Countries	8	4	8	3	11	9
Institutes	16	6	19	7	23	16
Researchers	57	31	51	41	113	87
Main goals	Compare hydrogen and antohydrogen (*spectroscopy)*	Compare hydrogen and antohydrogen (*spectroscopy)*	Compare the *hyperfine structure* of hydrogen and antihydrogen	Compare the *magnetic moments* of matter and antimatter.	Study effects of Earth's gravity on antimatter	Study effects of Earth's gravity on antimatter
Highlight	Jun 2011: trapped antiprotons for 16 minutes	Mar 2013: magnetic moment measurement	Nov 2016: measure the mass of antiproton	Jun 2014: first observations		

The iridium target

Antimatter?

$$x^2 = 4$$

$$x = ?$$


MATTER
ANTI-
MATTER
PHYSICS
CONVENTION
MEETS
TODAY
UH-OH!
SCHWADRON