



# A virtual tour of the antimatter factory at CERN

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Guide: *Mario Campanelli*

Aug 3<sup>rd</sup> 2021

# What are we going to visit today ?



**Antiprotons from PS**

Energy: 3.5 GeV

**AD  
Antiproton Decelerator**

Start: 2000

Length: 182 m

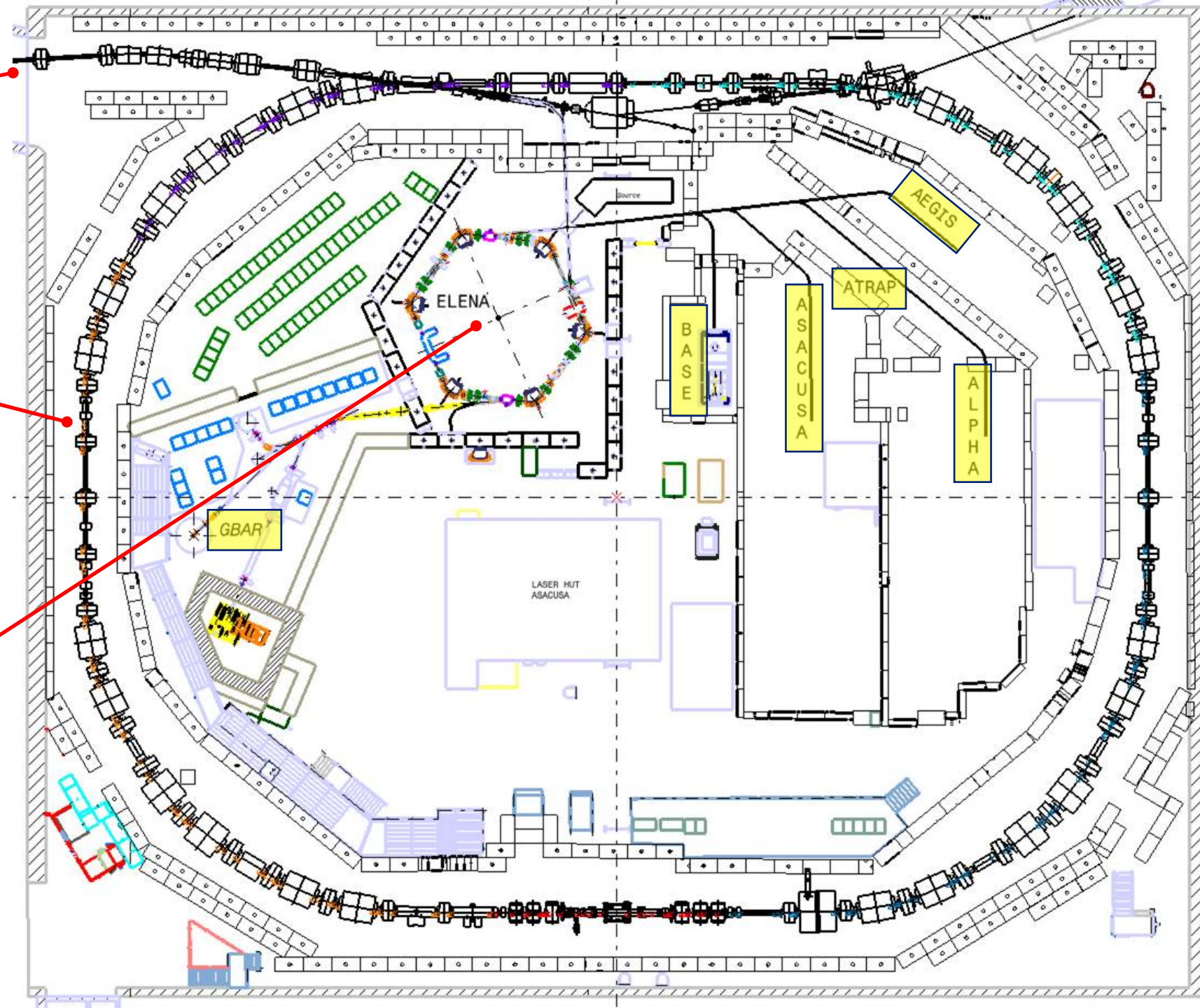
Energy: 5.3 MeV

**ELENA  
Extra Low  
Energy Antiproton**

Start: 2021

Length: 30 m

Energy: 0.1 MeV



# Antimatter?

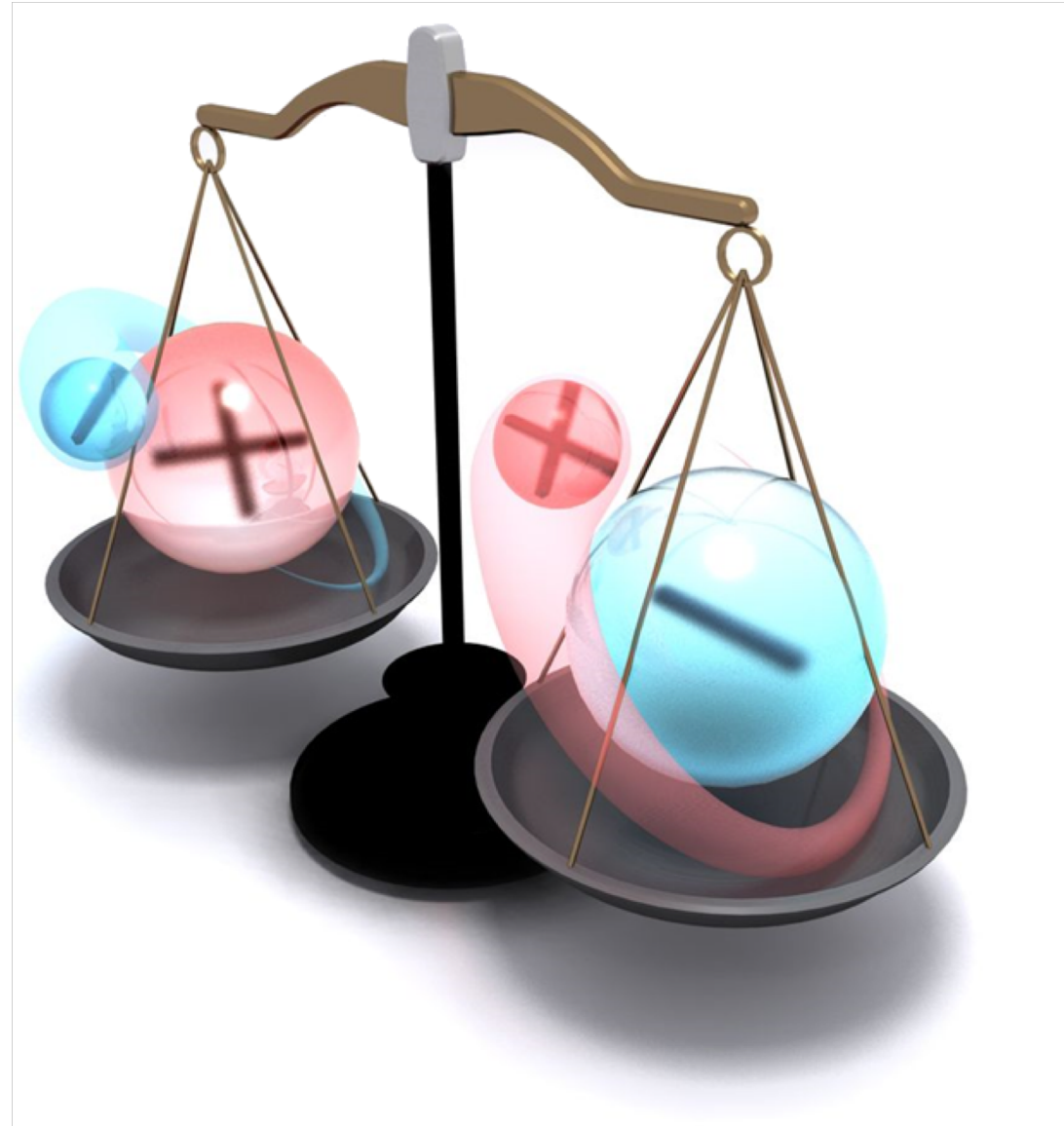
$$V = \sum P^a V_{P^a}$$

**Paul Dirac**

*The quantum theory of the electron, January 1928*

**Nobel Prize in Physics, 1933**

# Antimatter?



# Antimatter?

electron

-

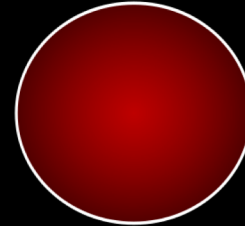
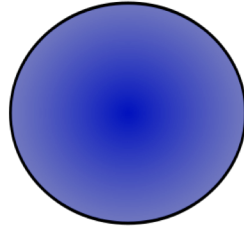


+

positron

proton

+

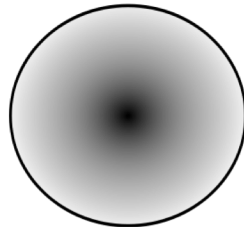


-

antiproton

neutron

n



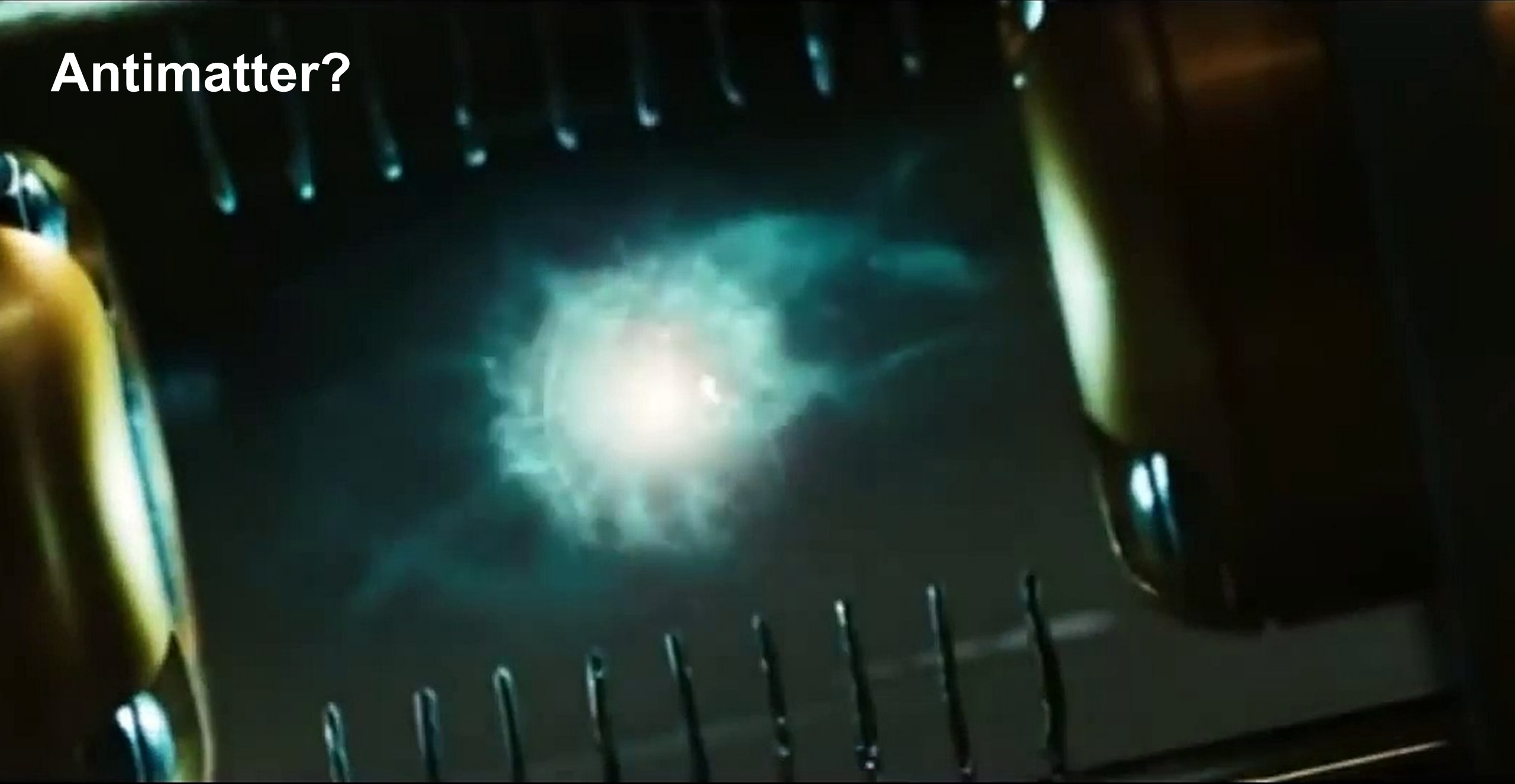
n

antineutron

# The Big Bang

$$E = mc^2$$

# Antimatter?





Where has all the antimatter gone?

**Lost and Found**



# How do we address this question at CERN?



How do we address this question at CERN?

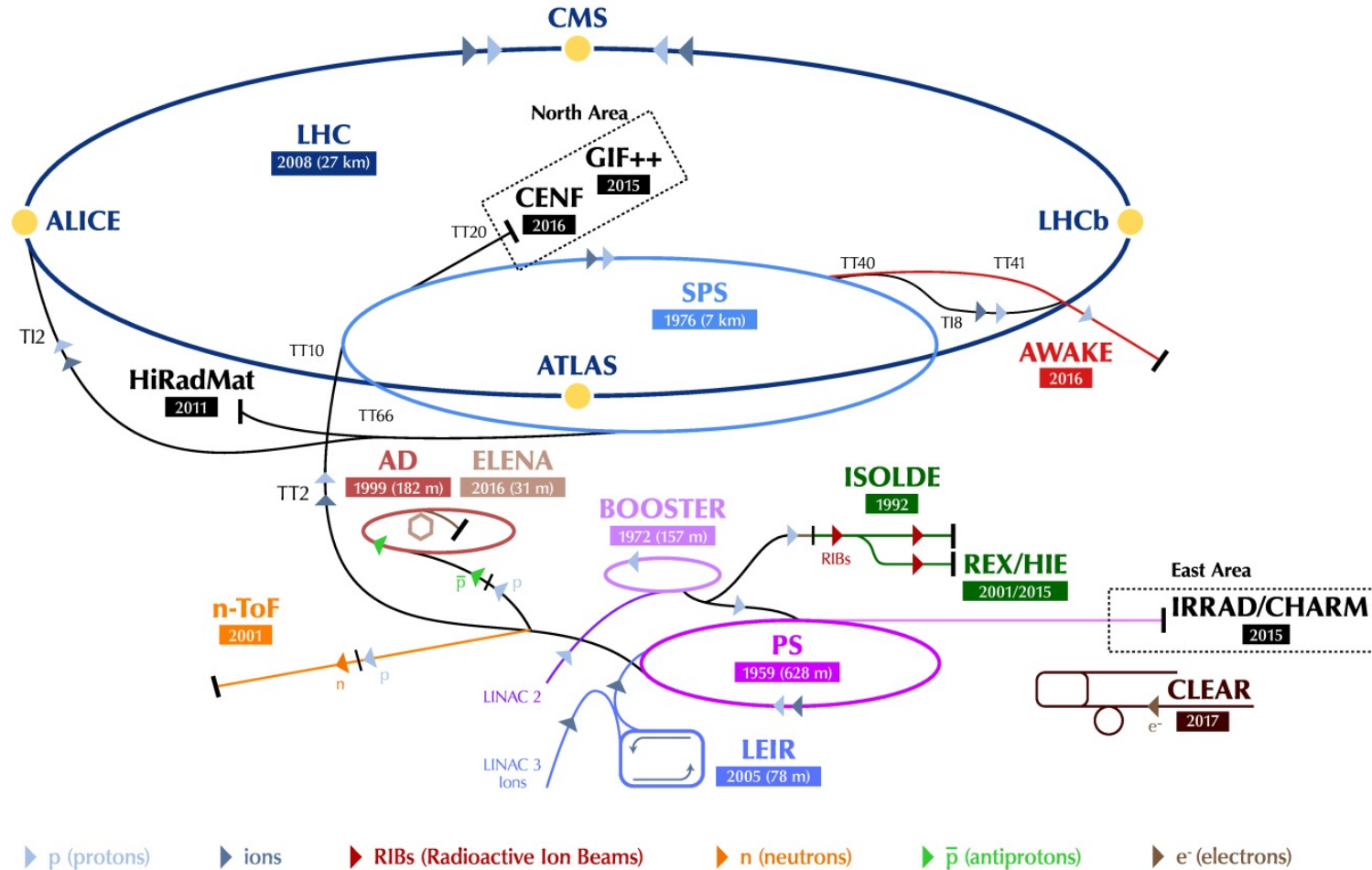


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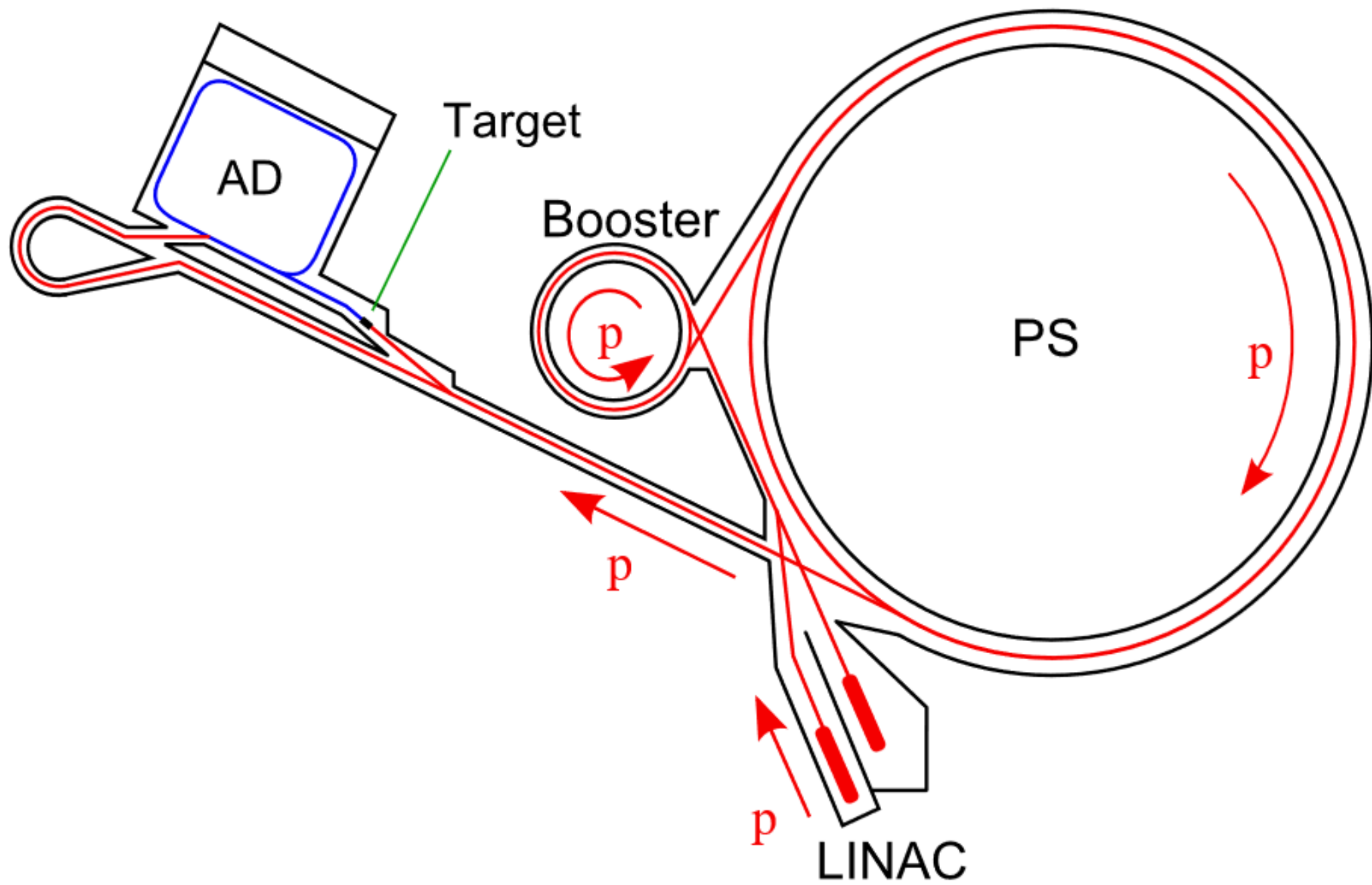


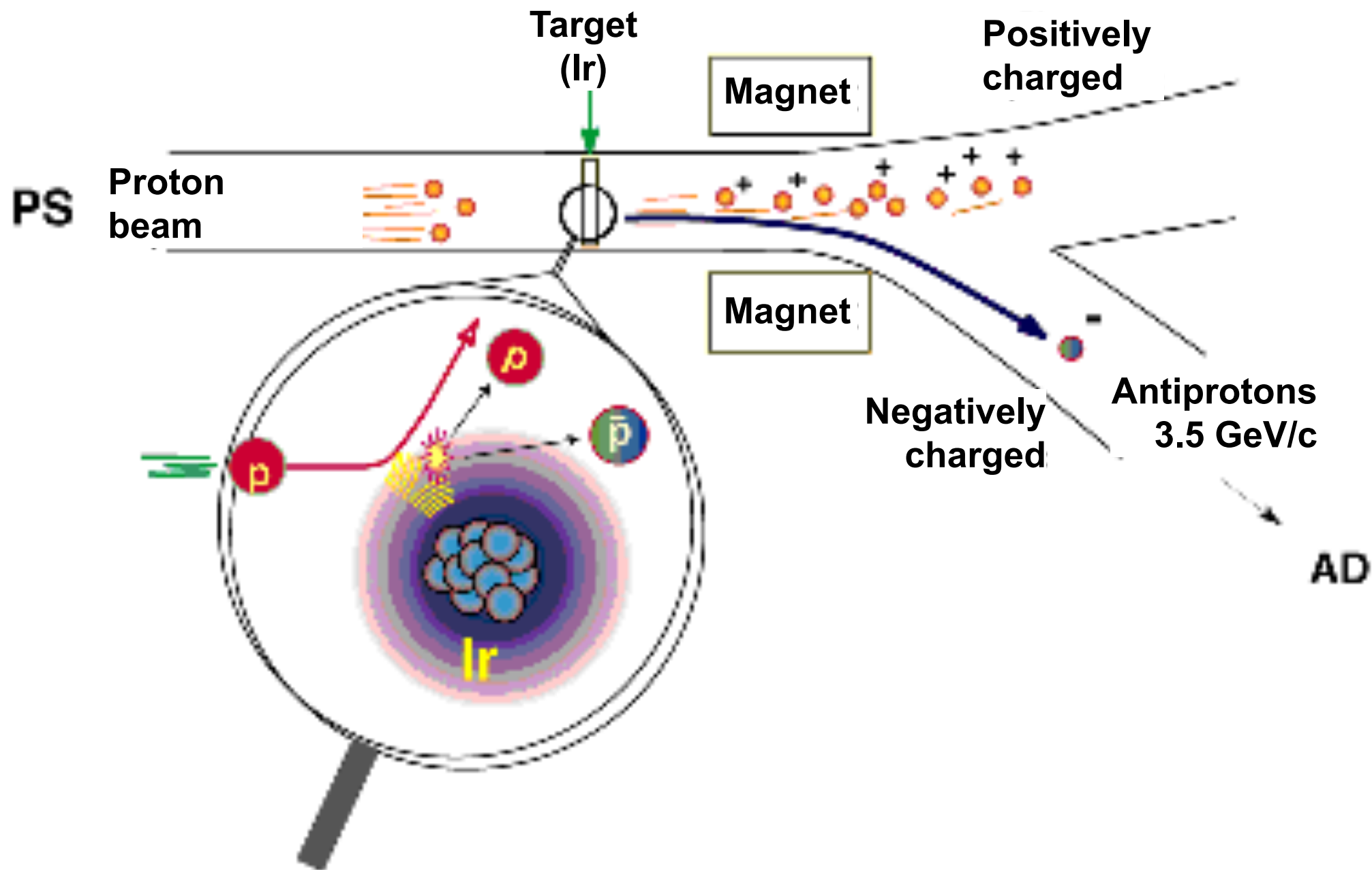
# The CERN accelerator complex

## 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





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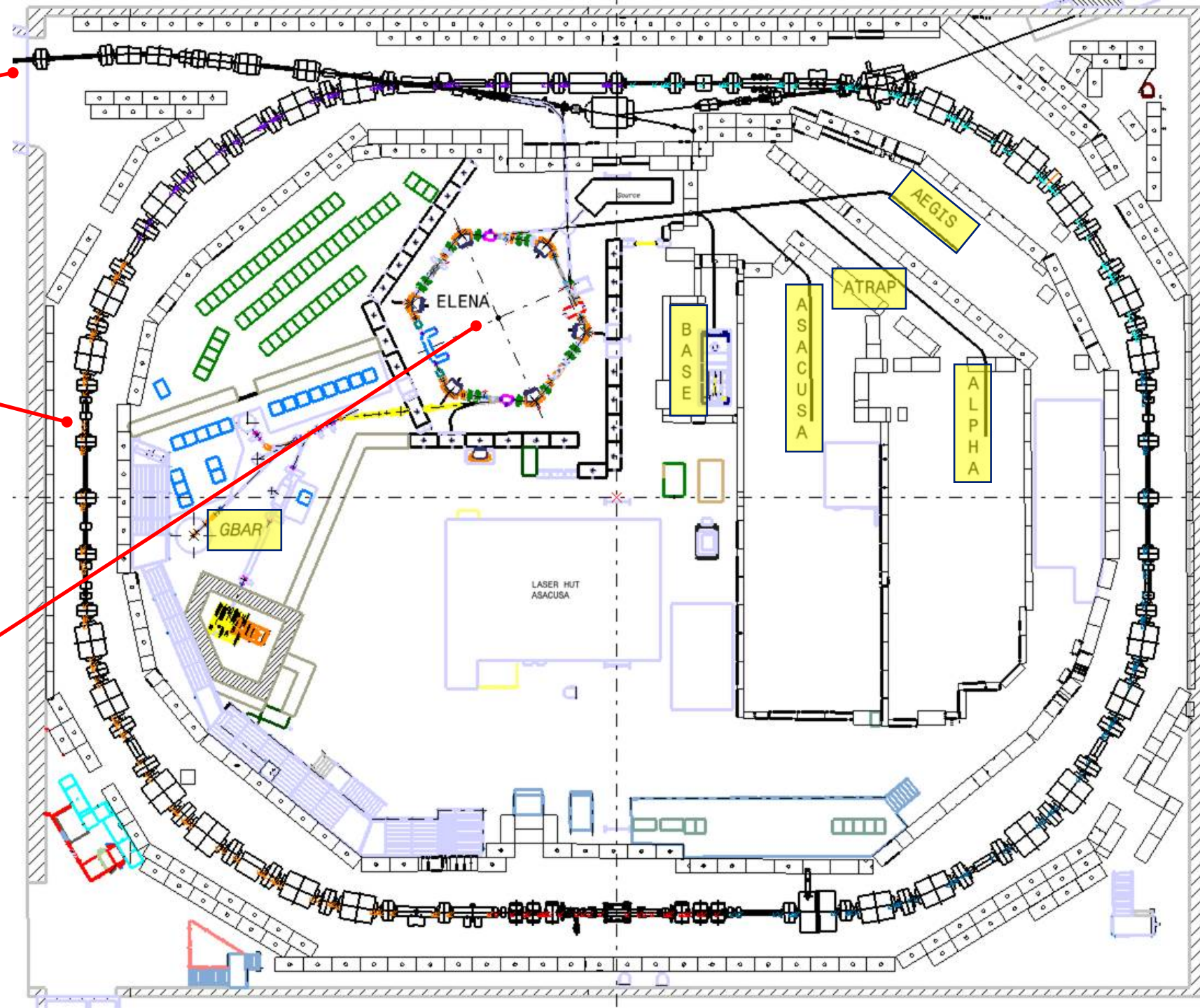
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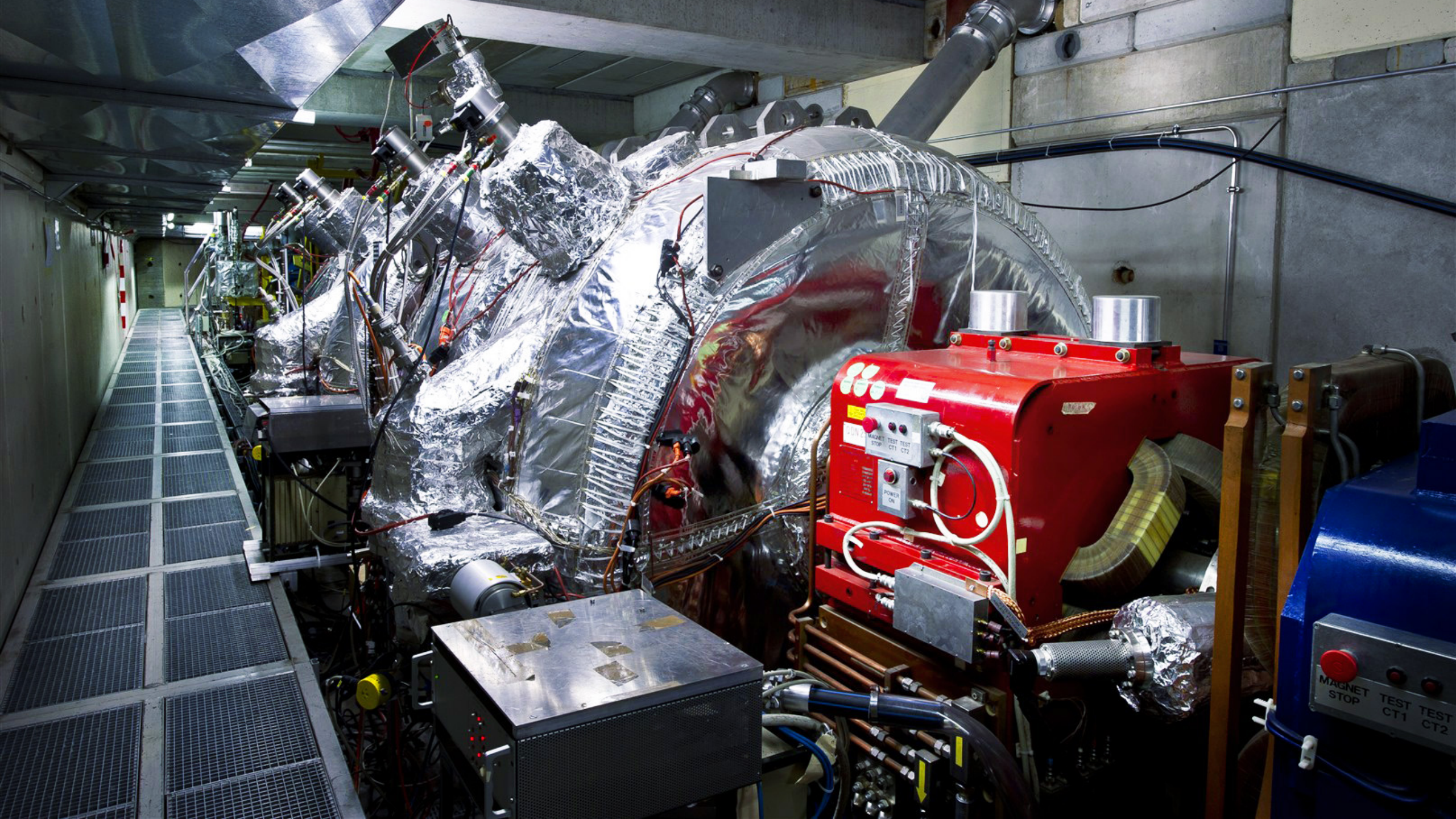
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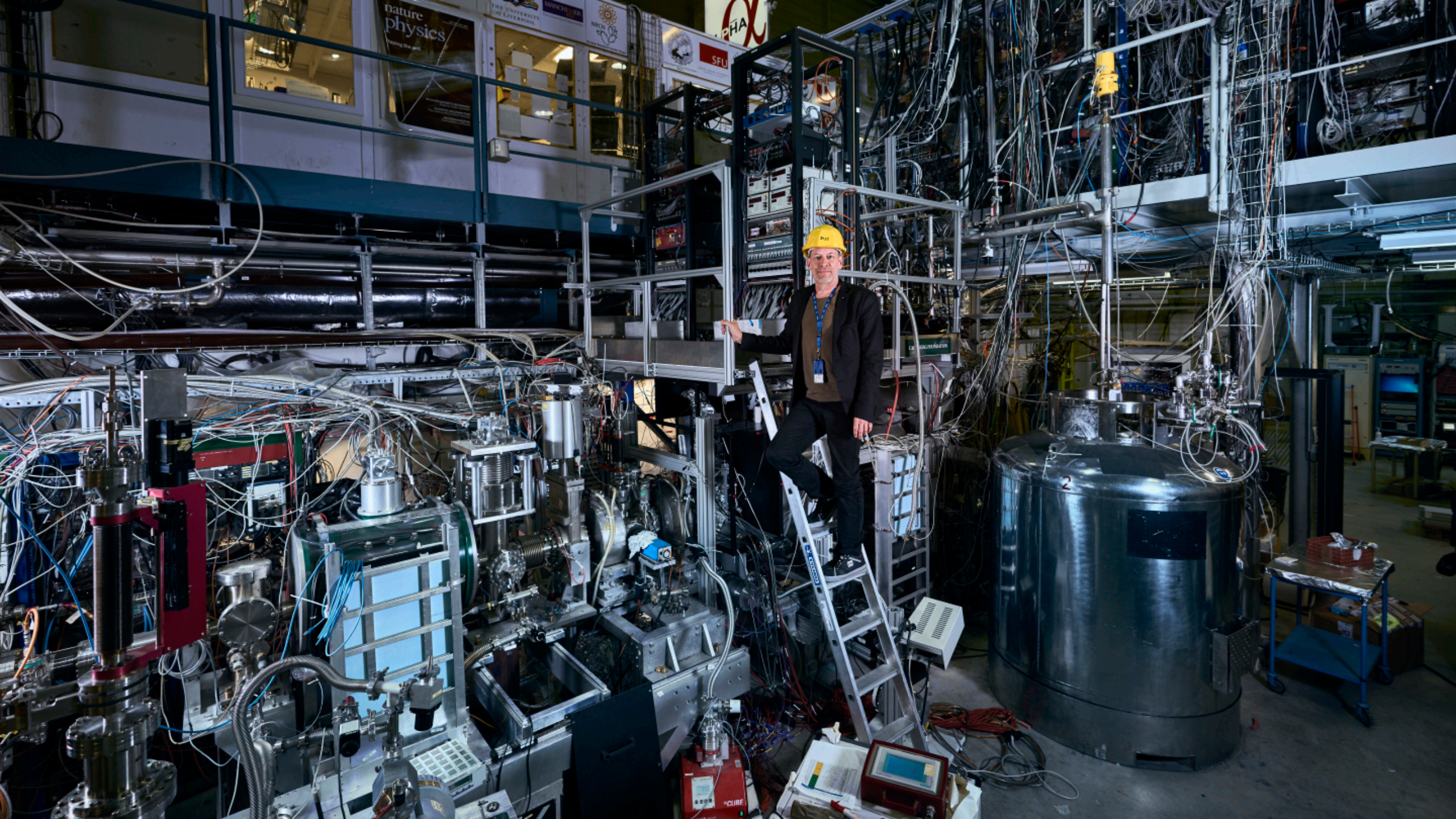
ASACUSA  
Atomic Spectroscopy And Collisions Using Slow Antiprotons

HARVARD ATRAP

ASACUSA  
Atomic Spectroscopy And Collisions Using Slow Antiprotons

H4  
H2

de visie  
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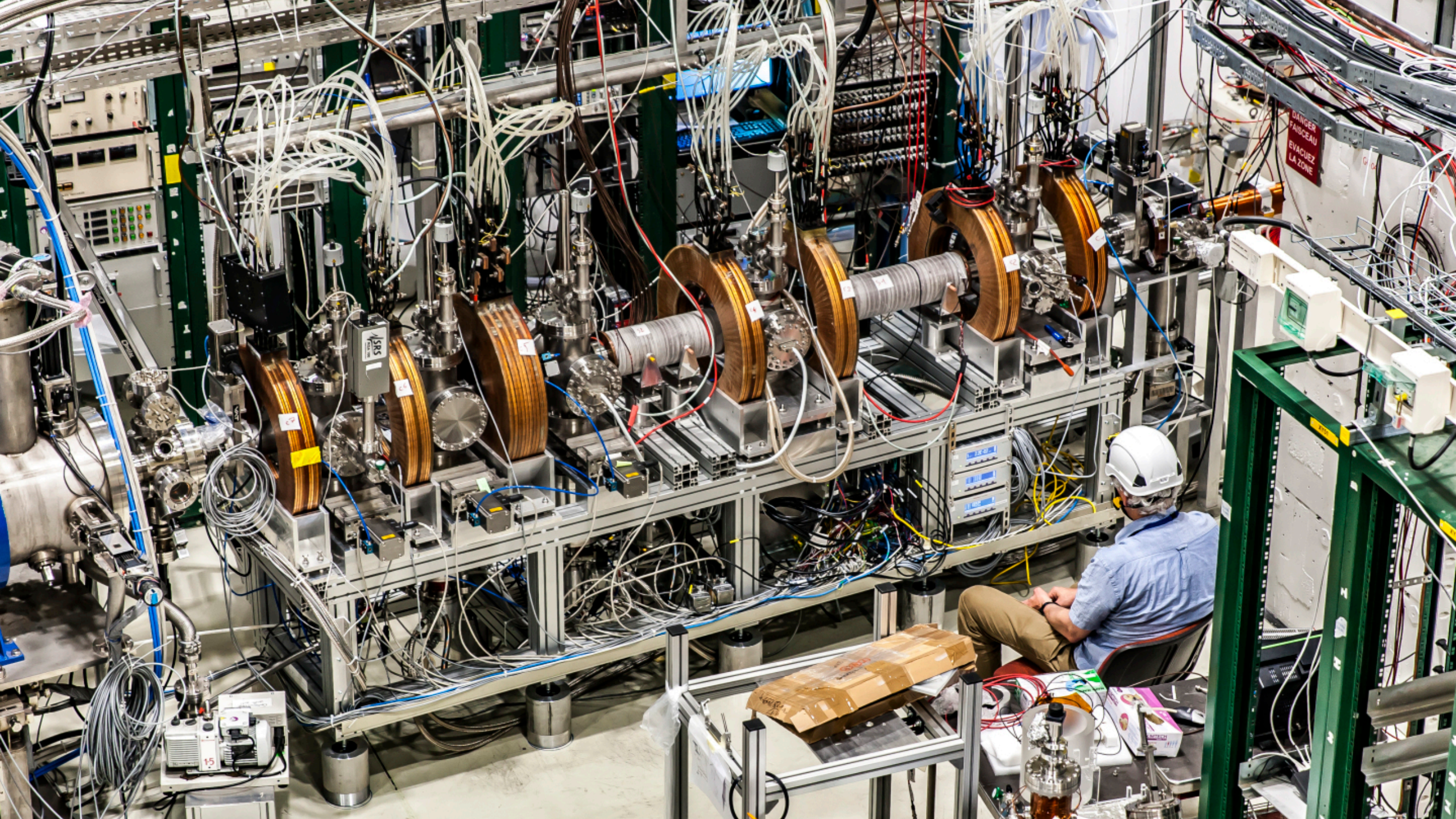


nature  
physics

THE UNIVERSITY OF LIVERPOOL

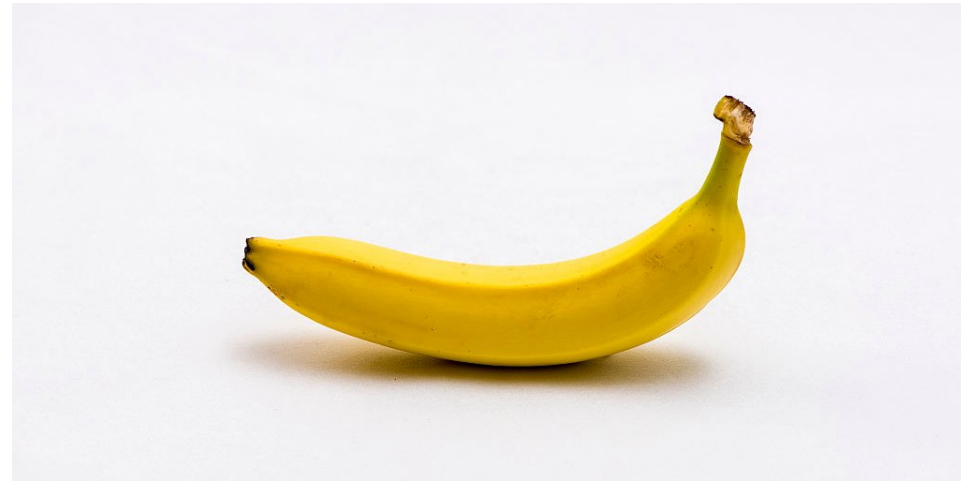
PHAX  
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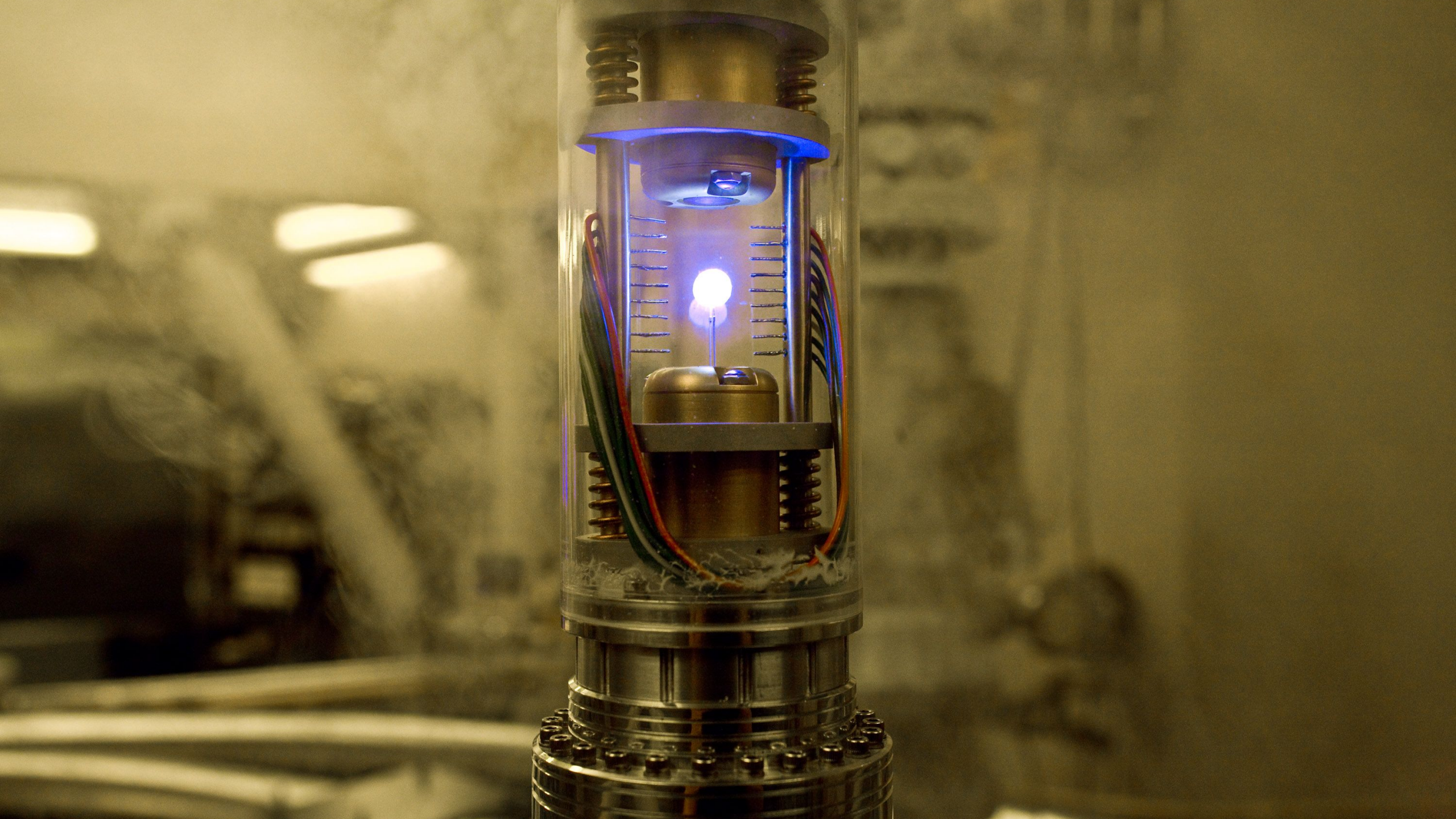
CUBE



# 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



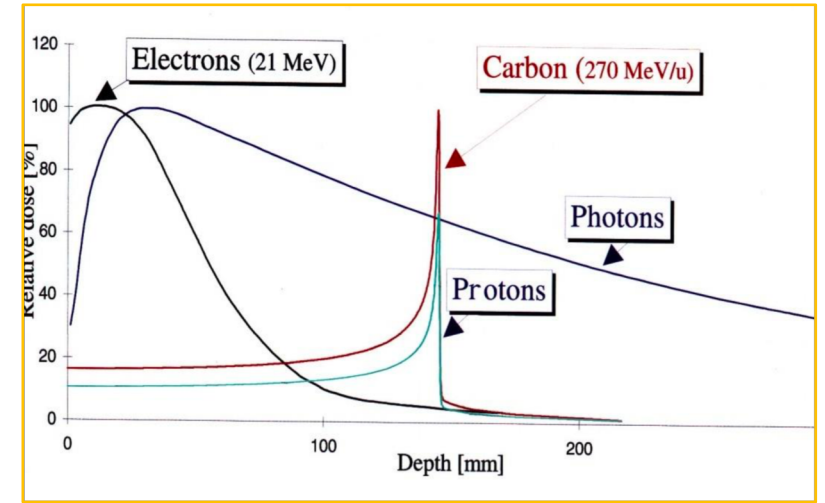




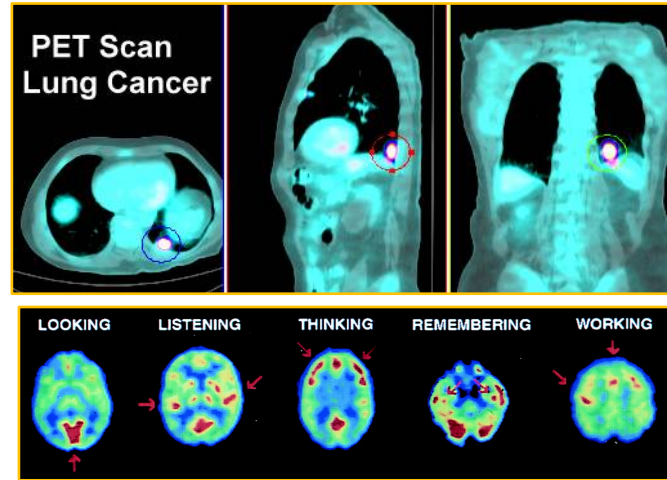
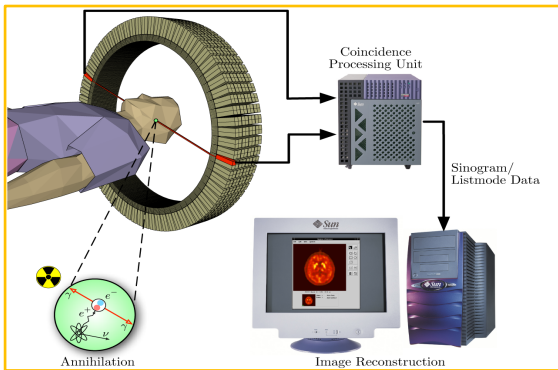


# Practical use...

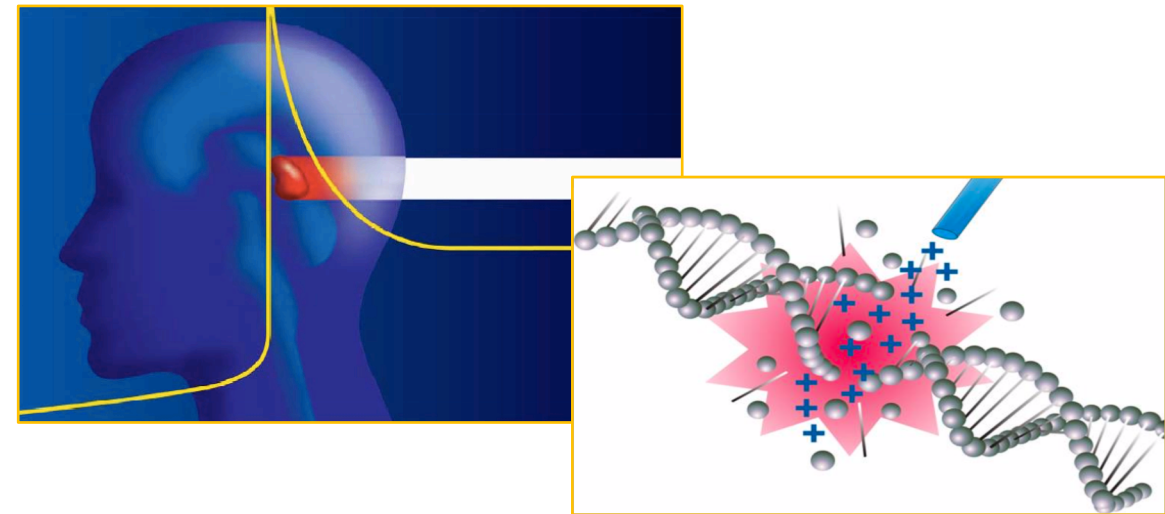
1g of antimatter contains 90 TJ of energy (~21 kT of TNT)  
(enough to power a car 1000 times around the world) but  
producing 1g of antimatter at CERN at current production rate  
would take **1 billion years**  
would cost **2 000 000 000 000 000 €**



## PET (Positron Emission Tomography)



## Hadron Therapy (antiprotons)

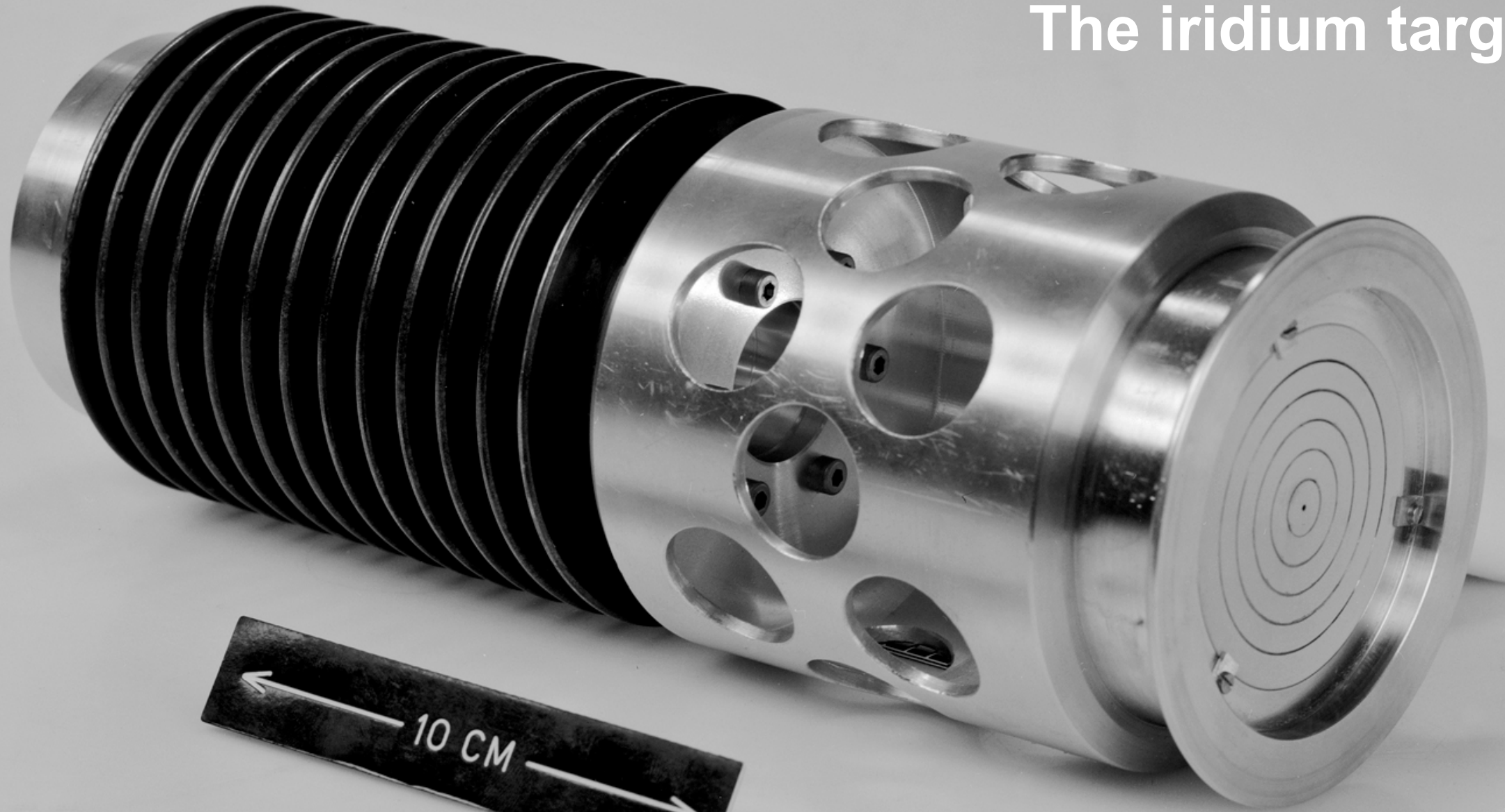


# Additional slides

# The experiments

	ALPHA	ATRAP	ASACUSA	BASE	AEGIS	GBAR
Approved	2005	1997	1997	2013	2008	2012
Data Taking	2006	2002	2002	2014	<i>Soon</i>	<i>Soon</i>
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 antihydrogen ( <i>spectroscopy</i> )	Compare hydrogen and antihydrogen ( <i>spectroscopy</i> )	Compare the <i>hyperfine structure</i> of hydrogen and antihydrogen	Compare the <i>magnetic moments</i> 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?

$$x^2 = 4$$

$$x = ?$$

