

Antymateria ?

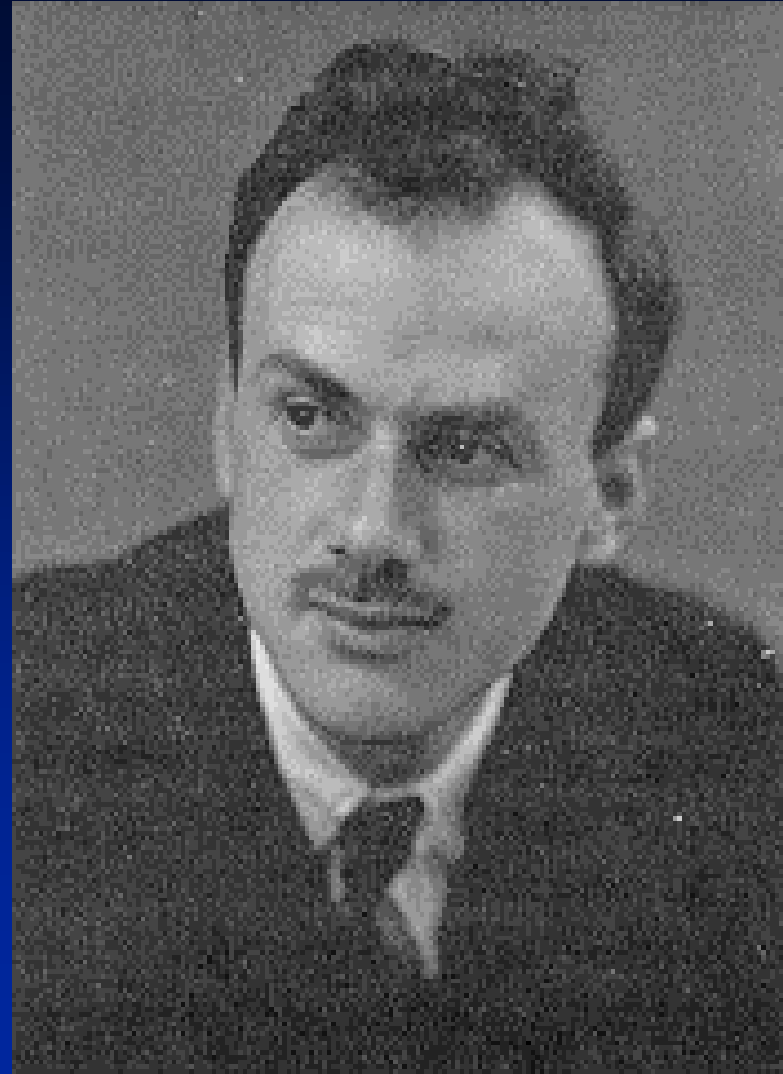
Po co nam to ?

Chronologia odkryć

- 1928-31 antyelektron (Dirac)
- 1932 pozyton (Anderson)
- 1955 antyproton (Segré i in.)
- 1956 antyneutron (Piccioni i in.)
- 1965 antydeuter (Lederman i in.)
- 1969 antyhelion-3 (Prokoshkin i in.)
- 1974 antytryt (Prokoshkin i in.)
- 1995 antywodór (Oelert i in)

Antyelektrony przewidziane teoretycznie

Paul Dirac w 1934 r.

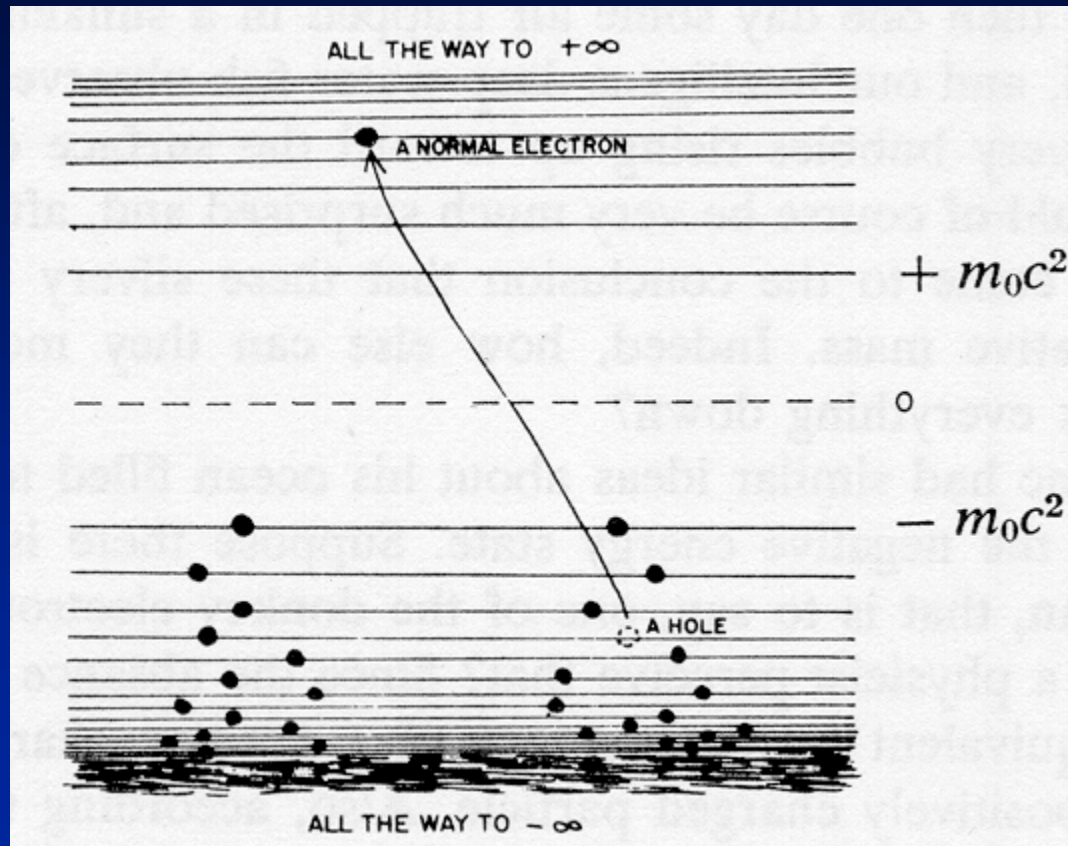


Dirac - Proc. Royal Society (1931)

A recent paper by the author may possibly be regarded as a small step according to this general scheme of advance. The mathematical formalism at that time involved a serious difficulty through its prediction of negative kinetic energy values for an electron. It was proposed to get over this difficulty, making use of Pauli's Exclusion Principle which does not allow more than one electron in any state, by saying that in the physical world almost all the negative-energy states are already occupied, so that our ordinary electrons of positive energy cannot fall into them. The question then arises as to the physical interpretation of the negative-energy states, which on this view really exist. We should expect the uniformly filled distribution of negative-energy states to be completely unobservable to us, but an unoccupied one of these states, being something exceptional, should make its presence felt as a kind of hole. It was shown that one of these holes would appear to us as a particle with a positive energy and a positive charge and it was suggested that this particle should be identified with a proton. Subsequent investigations, however, have shown that this particle necessarily has the same mass as an electron, and also that, if it collides with an electron, the two will have a chance of annihilating one another much too great to be consistent with the known stability of matter.

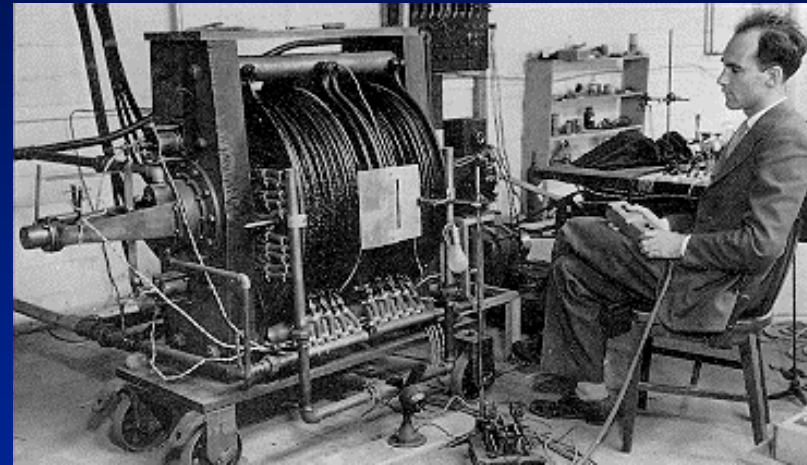
It thus appears that we must abandon the identification of the holes with protons and must find some other interpretation for them. Following Oppenheimer, we can assume that in the world as we know it, all, and not merely nearly all, of the negative-energy states for electrons are occupied. A hole, if there were one, would be a new kind of particle, unknown to experimental physics, having the same mass and opposite charge to an electron. We may call such a particle an anti-electron. We should not expect to find any of them in nature, on account of their rapid rate of recombination with electrons, but if they could be produced experimentally in high vacuum they would be quite stable and amenable to observation. An encounter between two hard γ -rays (of energy at least half a million volts) could lead to the creation simultaneously of an electron and anti-electron, the probability of occurrence of this process being of the same order of magnitude as that of the collision of the two γ -rays on the assumption that they are spheres of the same size as classical electrons. This probability is negligible, however, with the intensities of γ -rays at present available. The protons on the above view are quite unconnected with electrons. Presumably the protons will have their own negative-energy states, all of which normally are occupied, an unoccupied one appearing as an anti-proton. Theory at present is quite unable to suggest a reason why there should be any differences between electrons and protons

Diraca morze elektronów o ujemnej masie



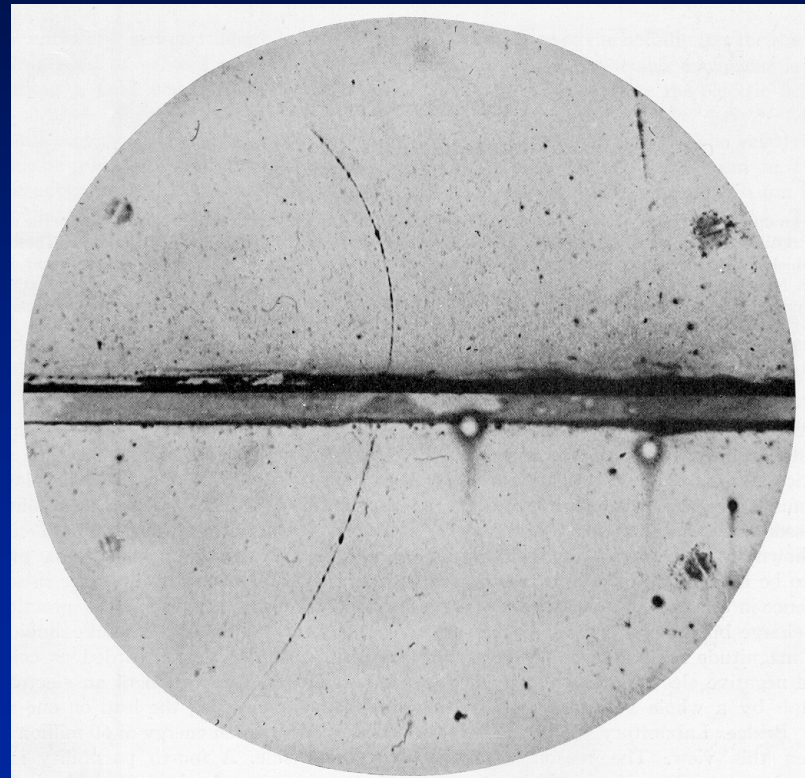
Odkrycie pozytonu (1932)

Carl D. Anderson
(ur. 1905), doktorant
Roberta Millikana w
Aeronautics Laboratory
w Caltech, badał
promienie kosmiczne
przy użyciu komory
Wilsona w polu
magnetycznym



Anderson 1932

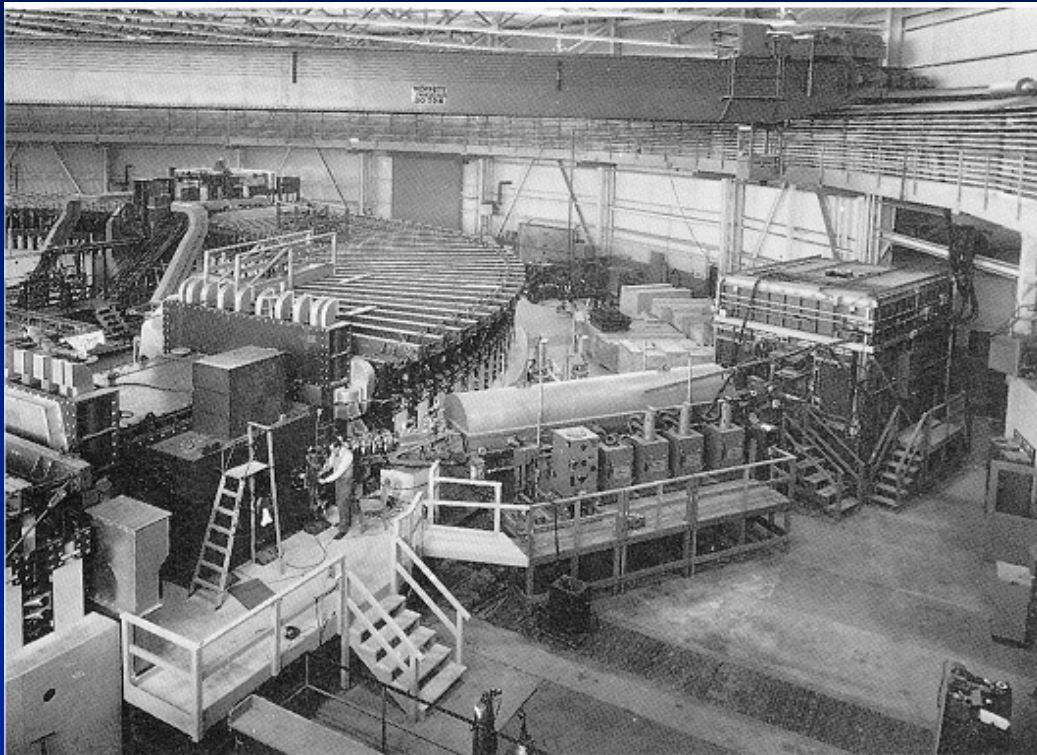
Pierwsza fotografia
toru pozytonu w
komorze Wilsona
zarejestrowana
przez Andersona
2 sierpnia 1932 roku



It has often been stated in the literature that the discovery of the positron was a consequence of its theoretical prediction by Dirac, but this is not true. The discovery of the positron was wholly accidental. Despite the fact that Dirac's relativistic theory of the electron was an adequate theory of the positron, and despite the fact that the existence of this theory was well known to nearly all physicists, it played no part whatsoever in the discovery of the positron.

Carl Anderson

Bevatron w Berkeley



Akcelerator protonów w Berkeley zaprojektowano tak, aby przekroczyć energię progową dla produkcji antyprotonów w reakcji

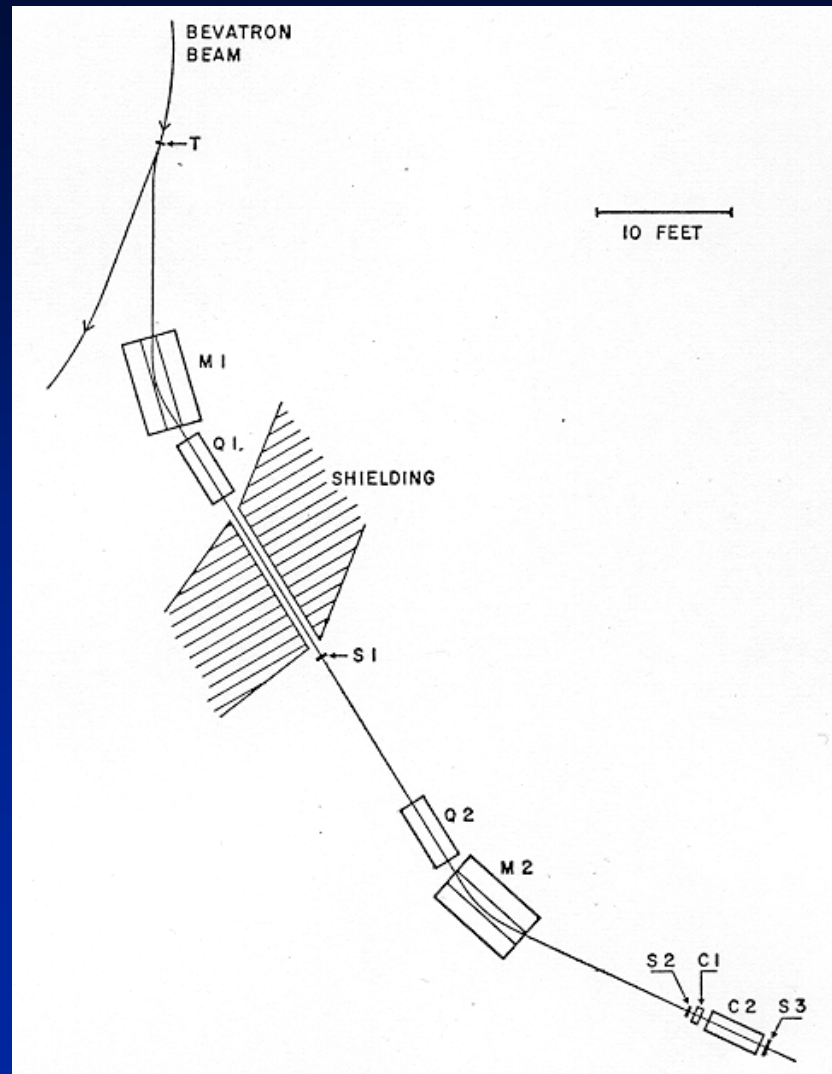
$$p + p = p + p + p + \bar{p}$$



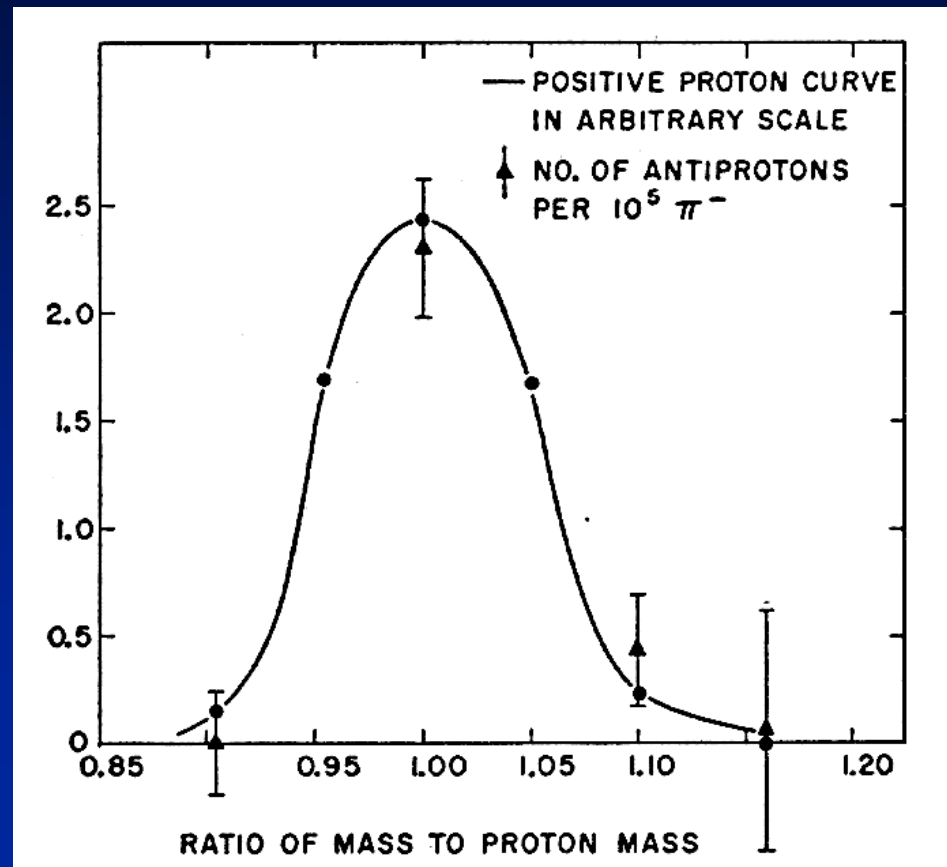
Odkrywcy
antyprotonu
(Lawrence
Radiation
Laboratory)

Emilio Segré
Clyde Wiegand
Edward Lofgren
Owen Chamberlain
Thomas Ypsylantis

Wiązka antyprotonów z Bevatronu



Wstępny pomiar masy antyprotonu



Observation of Antiprotons*

OWEN CHAMBERLAIN, EMILIO SEGRÈ, CLYDE WIEGAND,
AND THOMAS YPSILANTIS

*Radiation Laboratory, Department of Physics, University of
California, Berkeley, California*

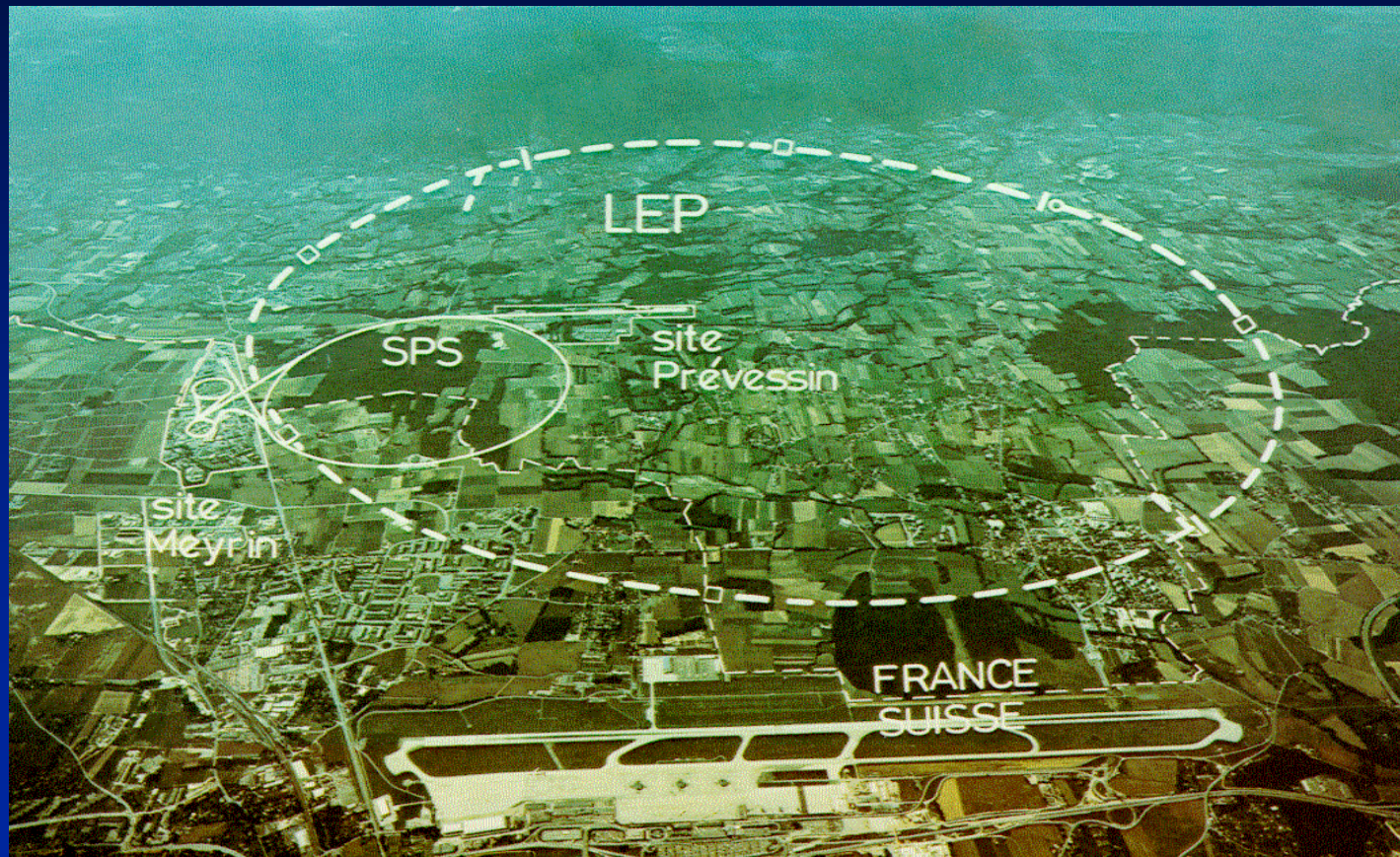
(Received October 24, 1955)

ONE of the striking features of Dirac's theory of the electron was the appearance of solutions to his equations which required the existence of an anti-particle, later identified as the positron.

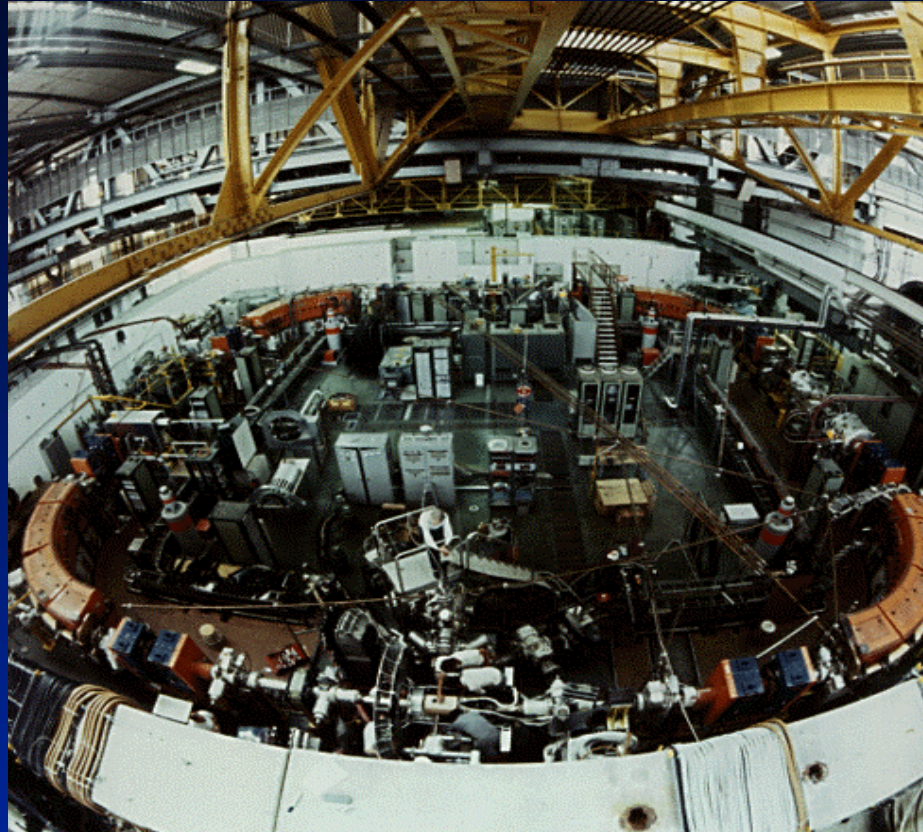
The extension of the Dirac theory to the proton requires the existence of an antiproton, a particle which bears to the proton the same relationship as the positron to the electron. However, until experimental proof of the existence of the antiproton was obtained, it might be questioned whether a proton is a Dirac particle in the same sense as is the electron. For instance, the anomalous magnetic moment of the proton indicates that the simple Dirac equation does not give a complete description of the proton.

The experimental demonstration of the existence of antiprotons was thus one of the objects considered in the planning of the Bevatron. The minimum laboratory kinetic energy for the formation of an antiproton in a nucleon-nucleon collision is 5.6 Bev. If the target nucleon is in a nucleus and has some momentum, the

Europejskie Laboratorium Fizyki Cząstek (CERN)

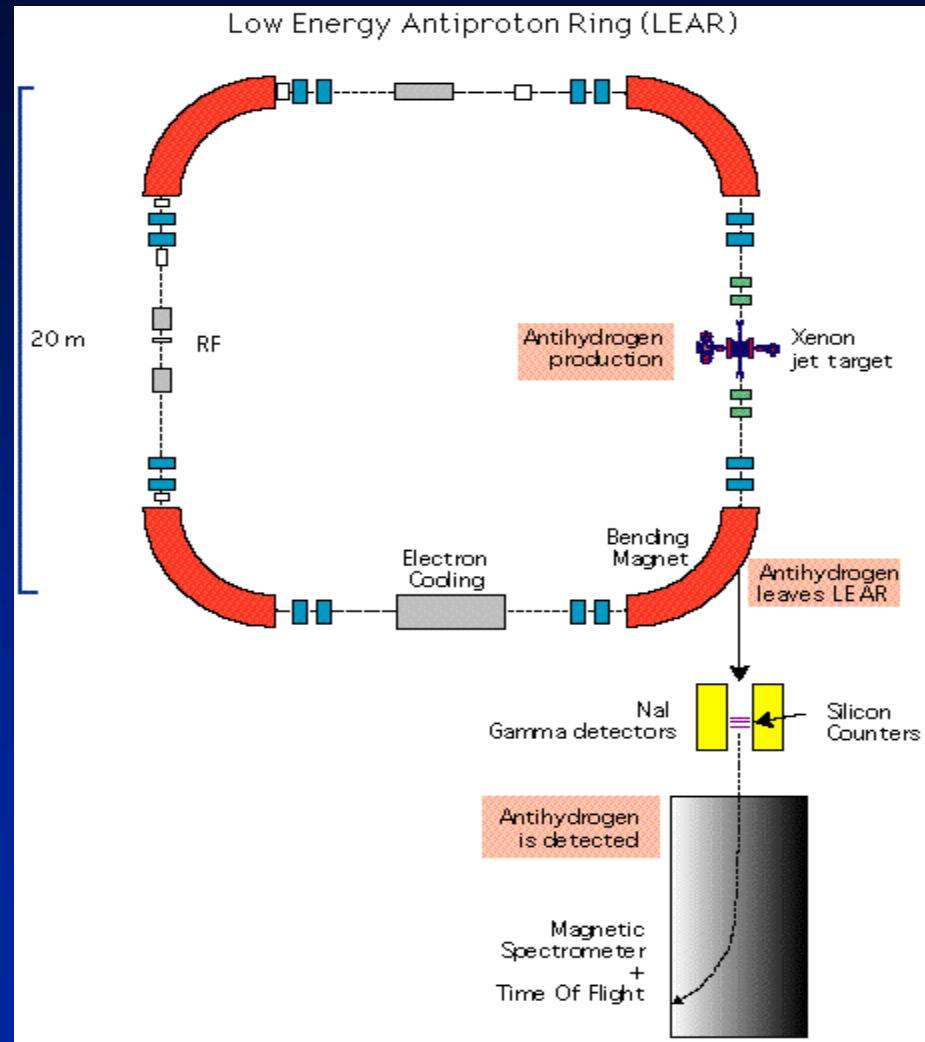


LEAR (Low Energy Antiproton Ring) w CERN



W pierścieniu akumulującym LEAR antyprotony wchodzące z pędem $0.6 \text{ GeV}/c$ są spowalniane do $100 \text{ MeV}/c$ (ok. 5 MeV energii kinetycznej)

Schemat pierścienia LEAR w CERN



Schemat procesu produkcji atomu antywodoru i jego rejestracji w eksperymencie w CERN

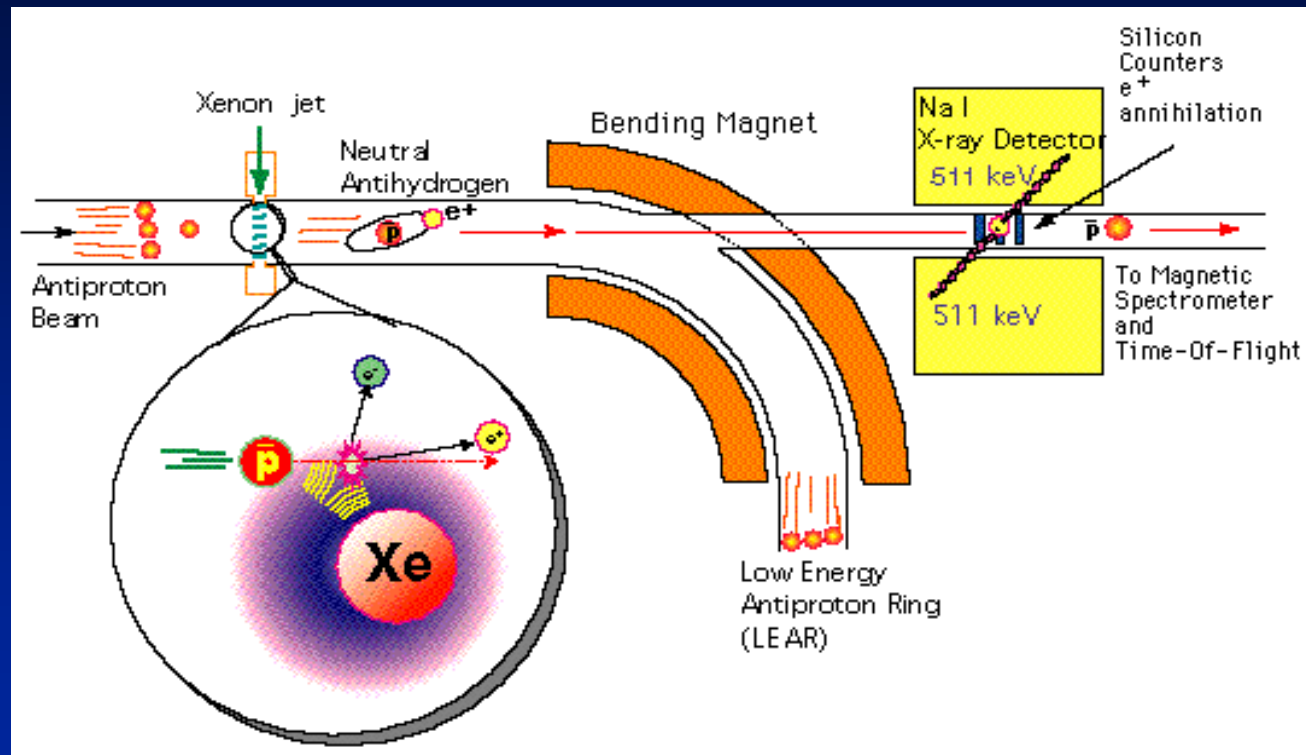
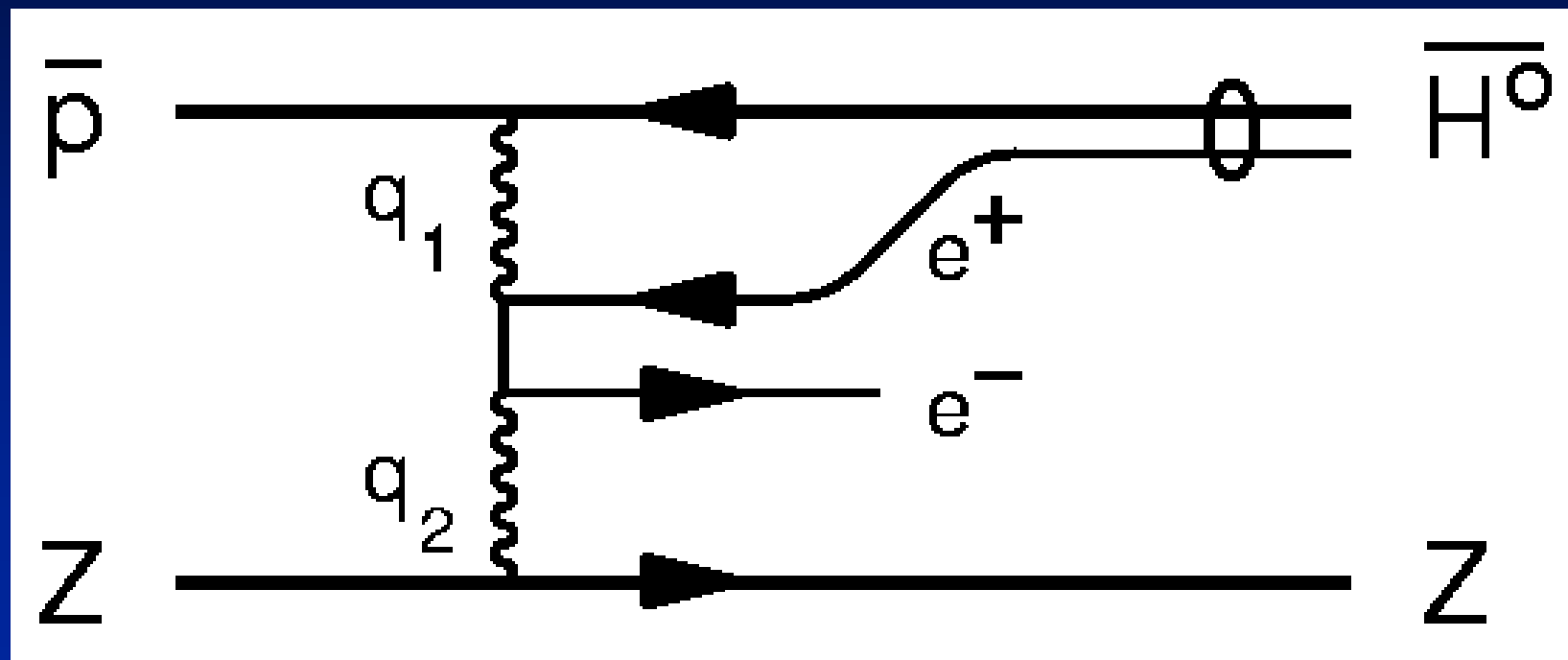
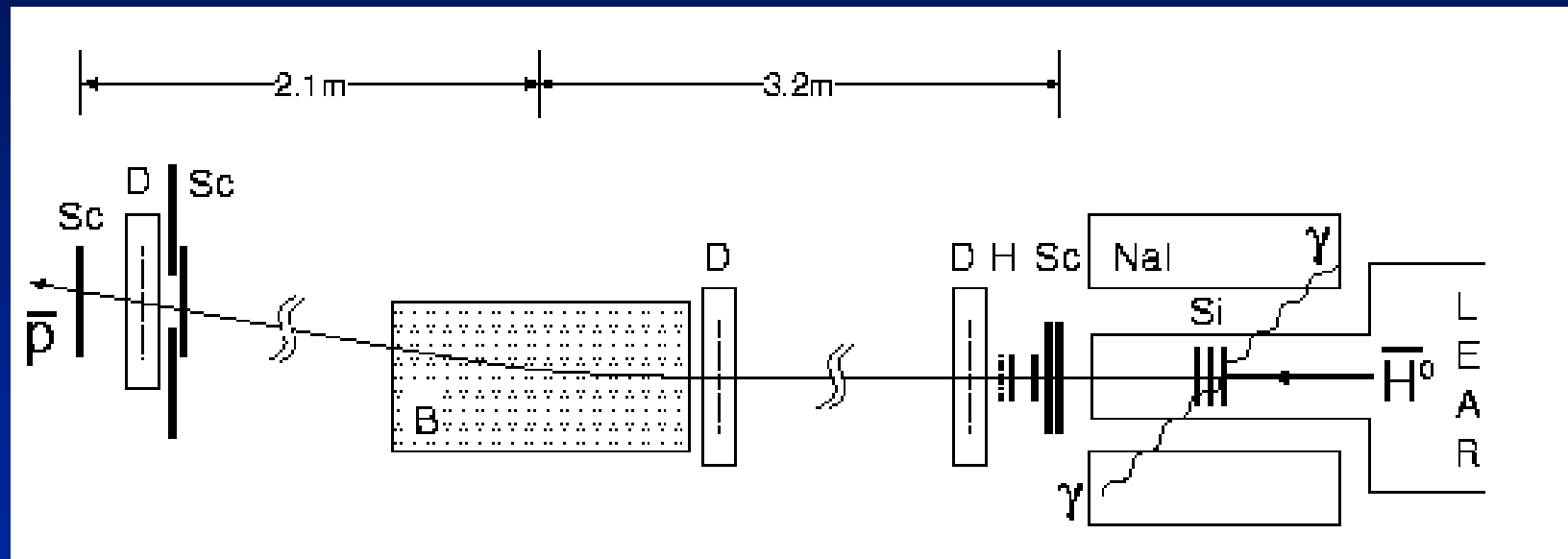


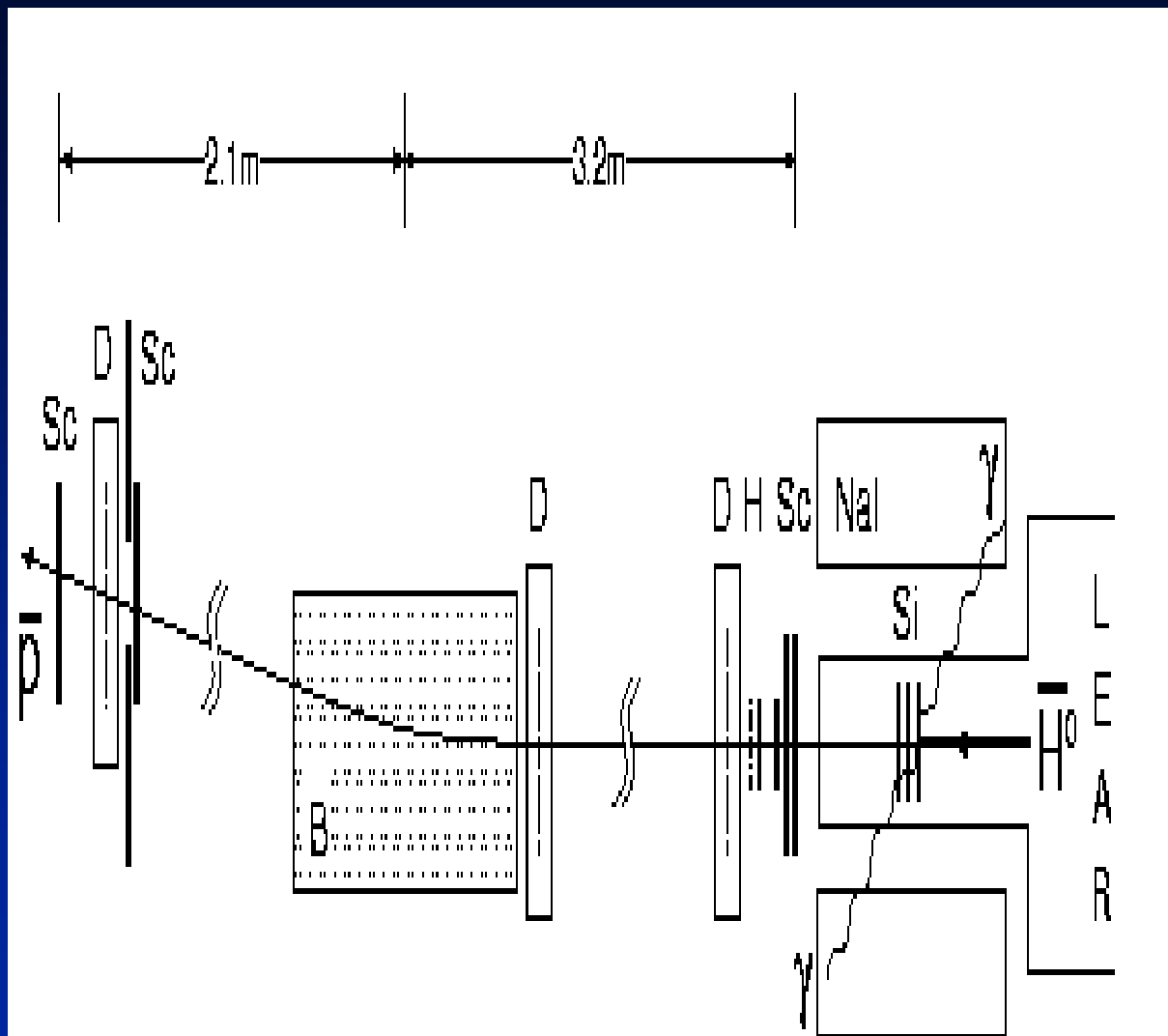
Diagram Feynmana opisujący powstawanie atomu antywodoru



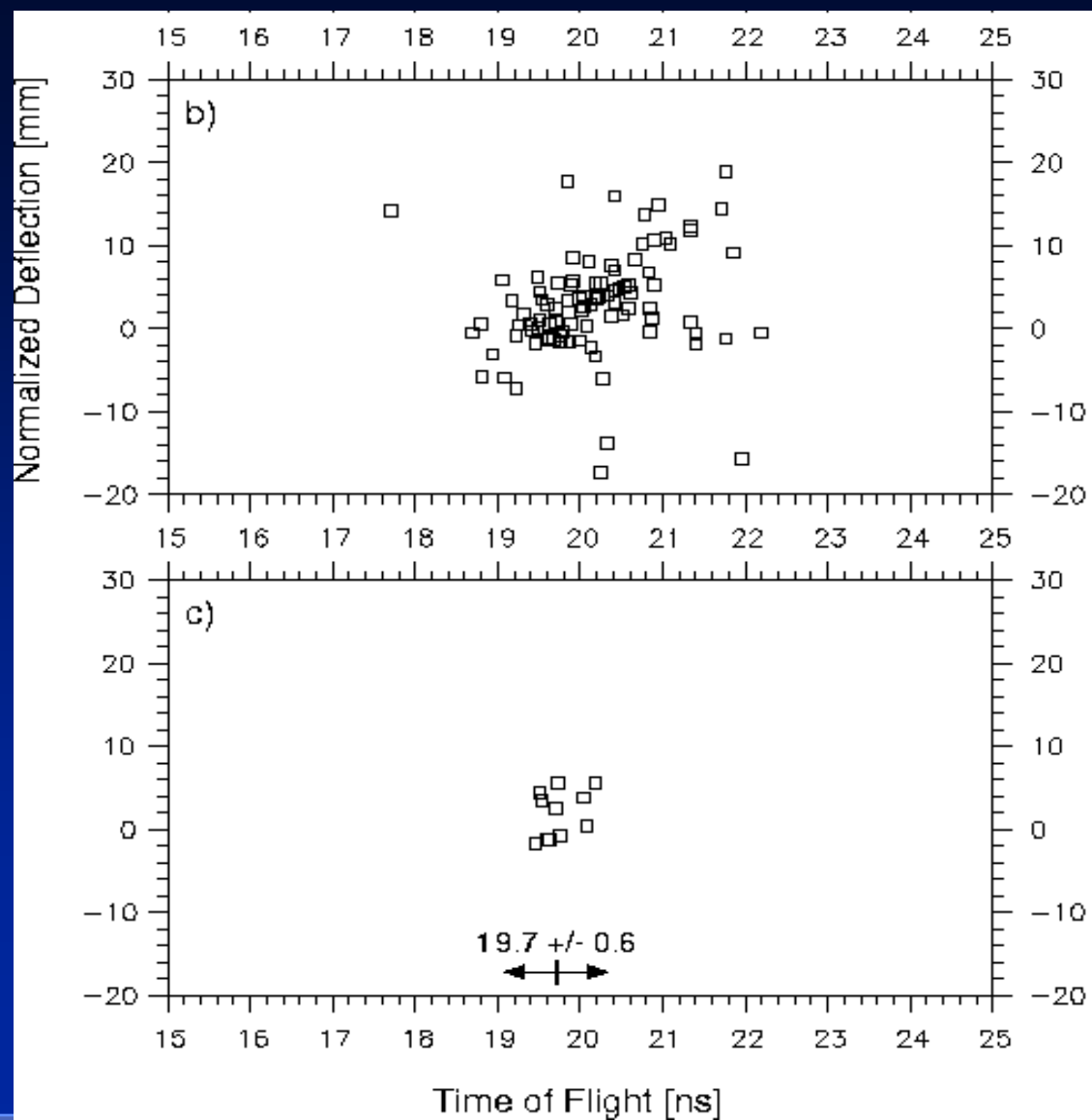
Układ do rejestracji atomów antywodoru w CERN



Zbadano łącznie około 300000 zdarzeń



Ostatecznie wybrano 11 przypadków antywodoru



Production of antihydrogen

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Received 8 December 1995; revised manuscript received 21 December 1995

Editor: L. Montanet

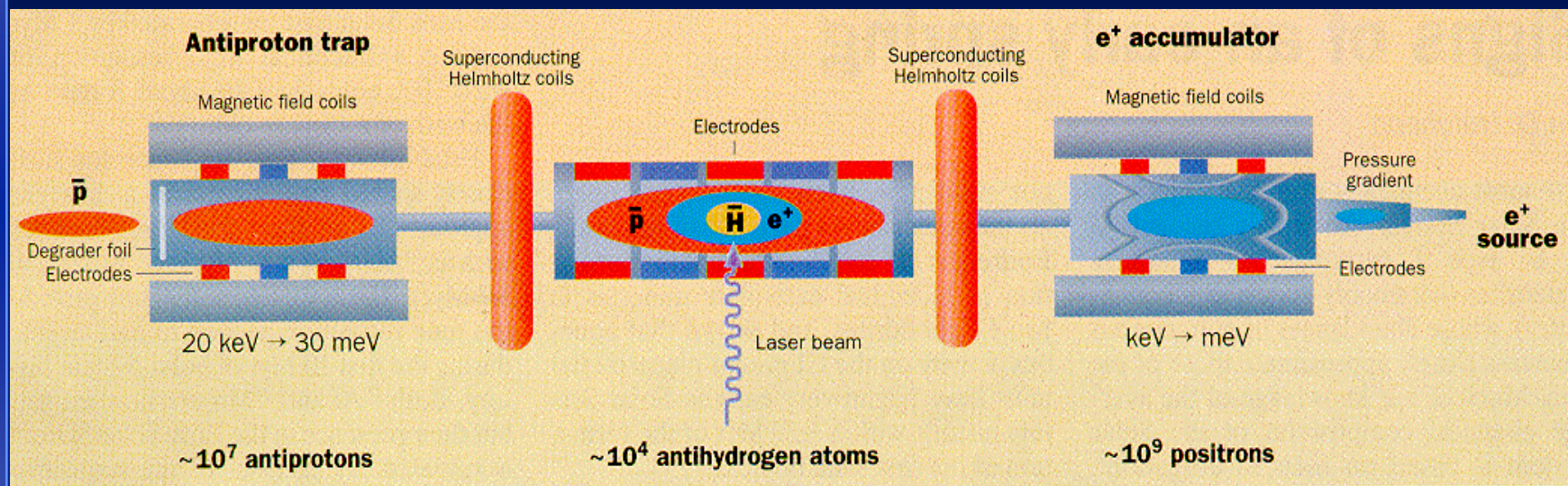
Abstract

Results are presented for a measurement for the production of the antihydrogen atom $\bar{H}^0 \equiv \bar{p}e^+$, the simplest atomic bound state of antimatter.

A method has been used by the PS210 collaboration at LEAR which assumes that the production of \bar{H}^0 is predominantly mediated by the e^+e^- -pair creation via the two-photon mechanism in the antiproton-nucleus interaction. Neutral \bar{H}^0 atoms are identified by a unique sequence of characteristics. In principle \bar{H}^0 is well suited for investigations of fundamental CPT violation studies under different forces, however, in our investigations we concentrate on the production of this antimatter object, since so far it has never been observed before.

The production of 11 antihydrogen atoms is reported including possibly 2 ± 1 background signals, the observed yield agrees with theoretical predictions.

Pułapka Penninga



- x, y, z Operacja P $-x, -y, -z$
- cząstka Operacja C antycząstka
- t Operacja T $-t$

$$|(S)\rangle \equiv \text{CPT} |(S)\rangle$$

Niektóre testy twierdzenia CPT

$$[q(e^+) + q(e^-)]/e < 4 \cdot 10^{-8}$$

$$[q(p^+) + q(p^-)]/e < 2 \cdot 10^{-5}$$

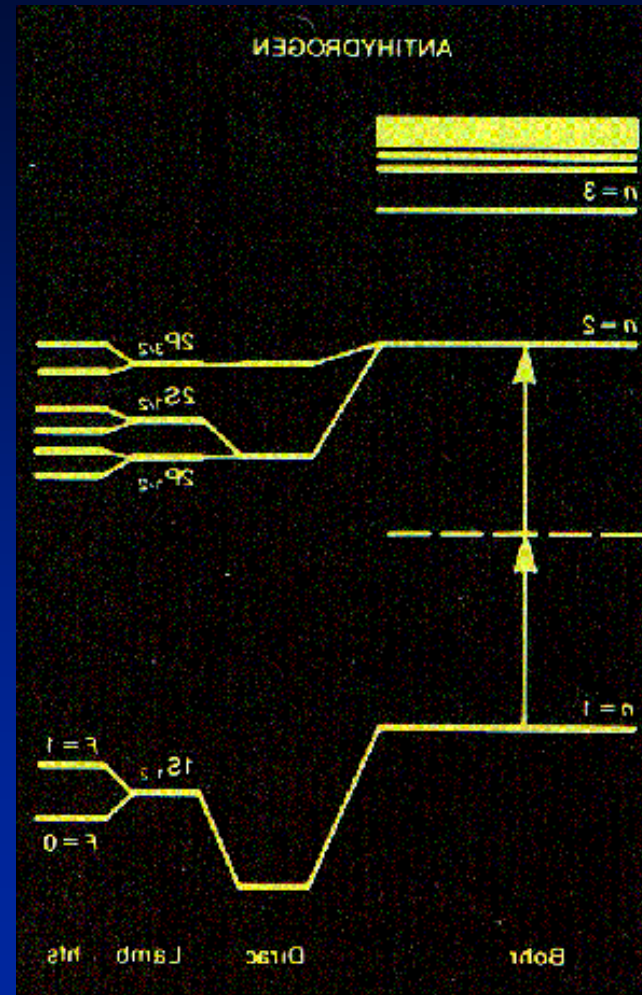
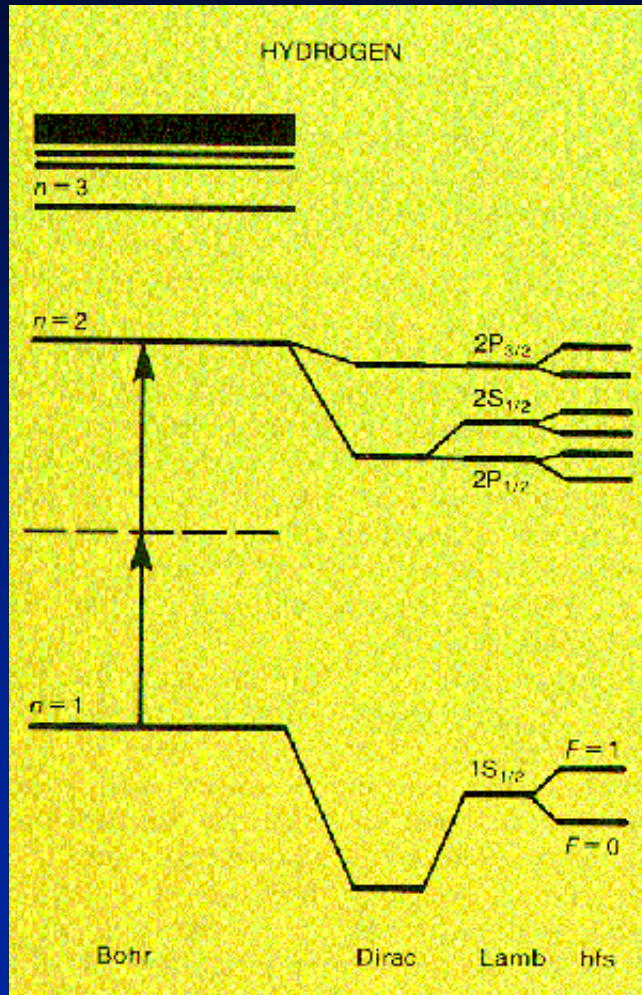
$$[m(e^+) - m(e^-)]/m_s < 4 \cdot 10^{-8}$$

$$[m(p^+) - m(p^-)]/m_s = (2 \pm 4) \cdot 10^{-8}$$

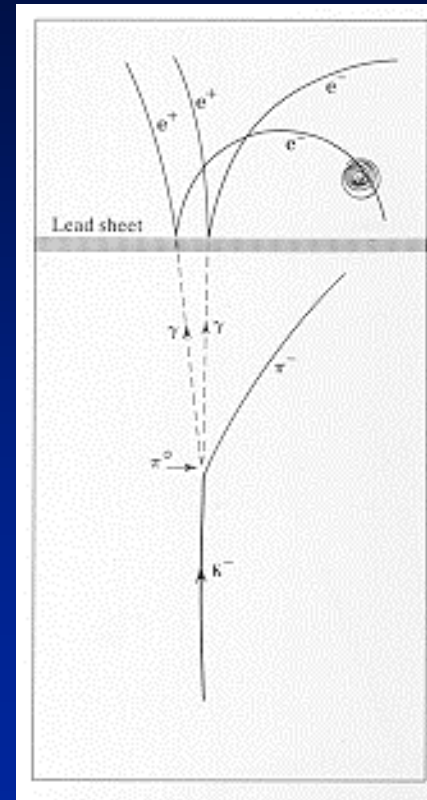
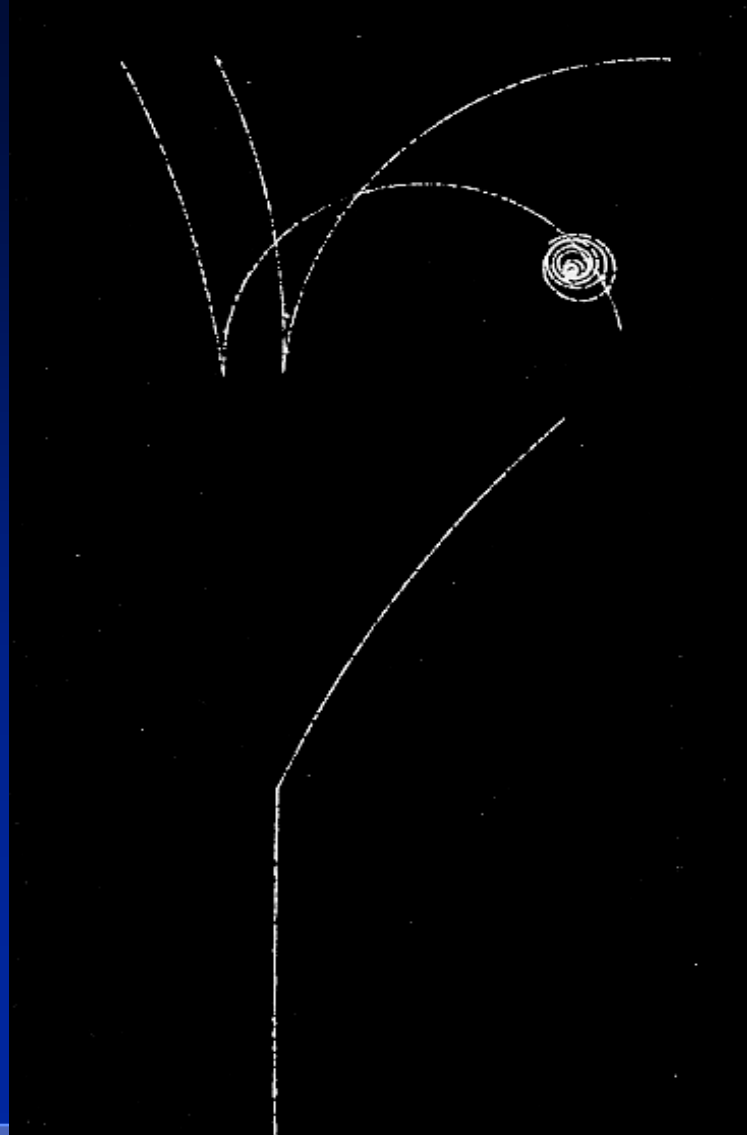
$$[m(n) - m(\bar{n})]/m_s = (9 \pm 5) \cdot 10^{-5}$$

$$(m(K^0) - m(\bar{K}^0)) < 10^{-18}$$

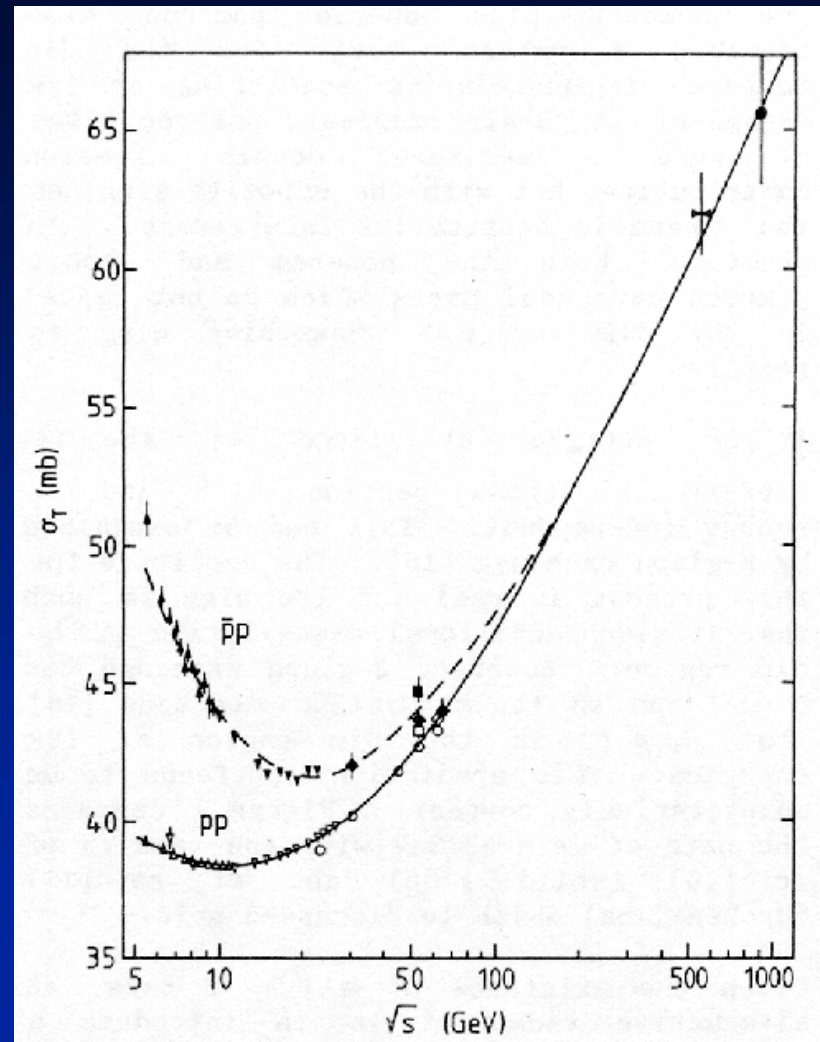
Poziomy energii wodoru i antywodoru



Pary elektron - pozyton



Przekroje czynne w funkcji energii zderzenia

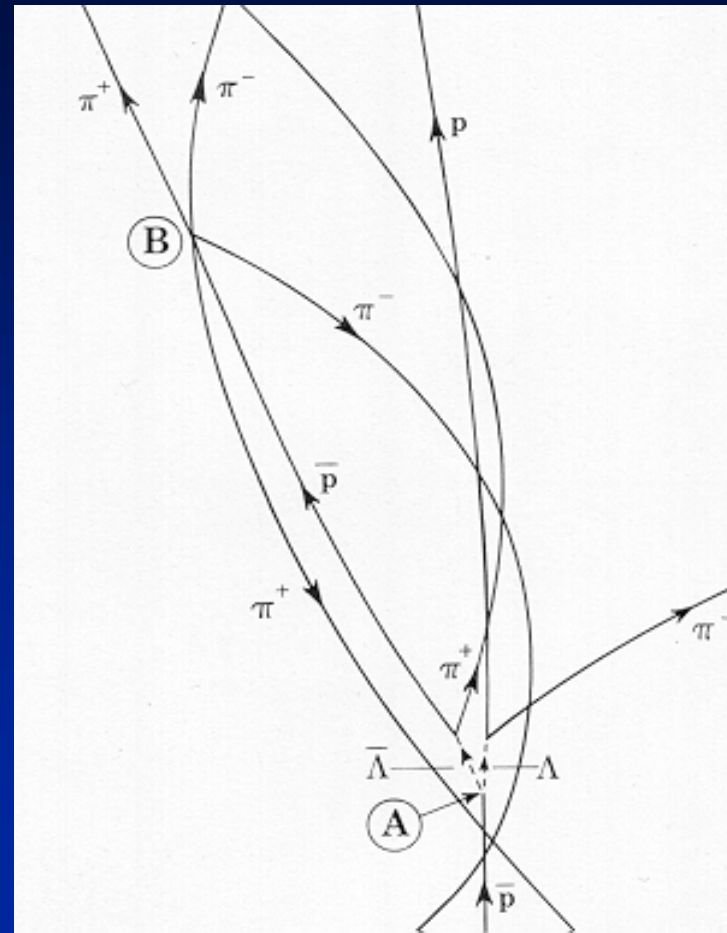
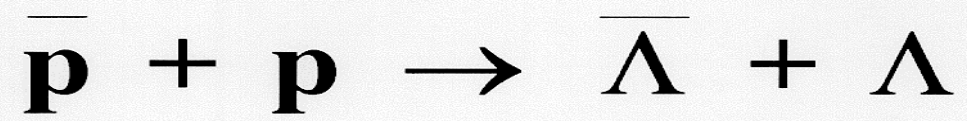


Gwiazdy z materii

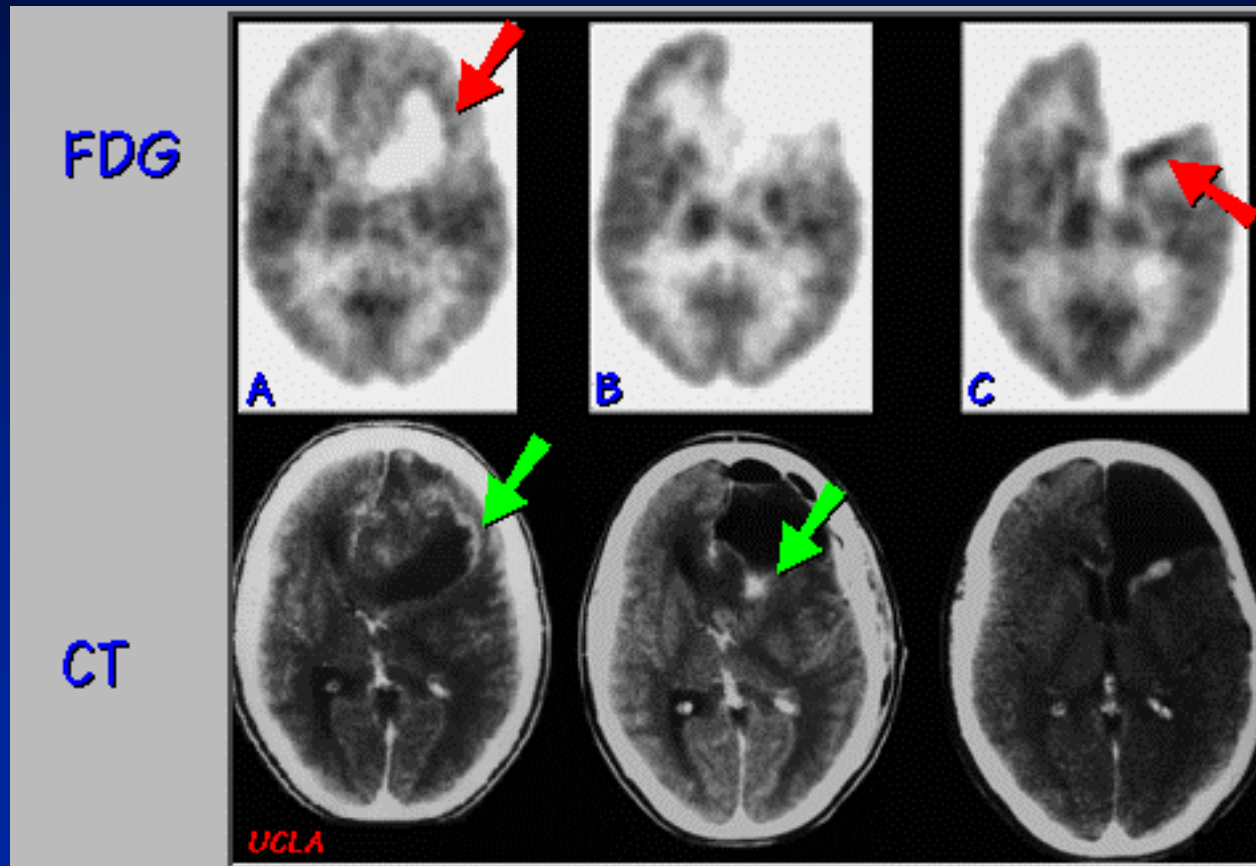


Gwiazdy z antymaterii

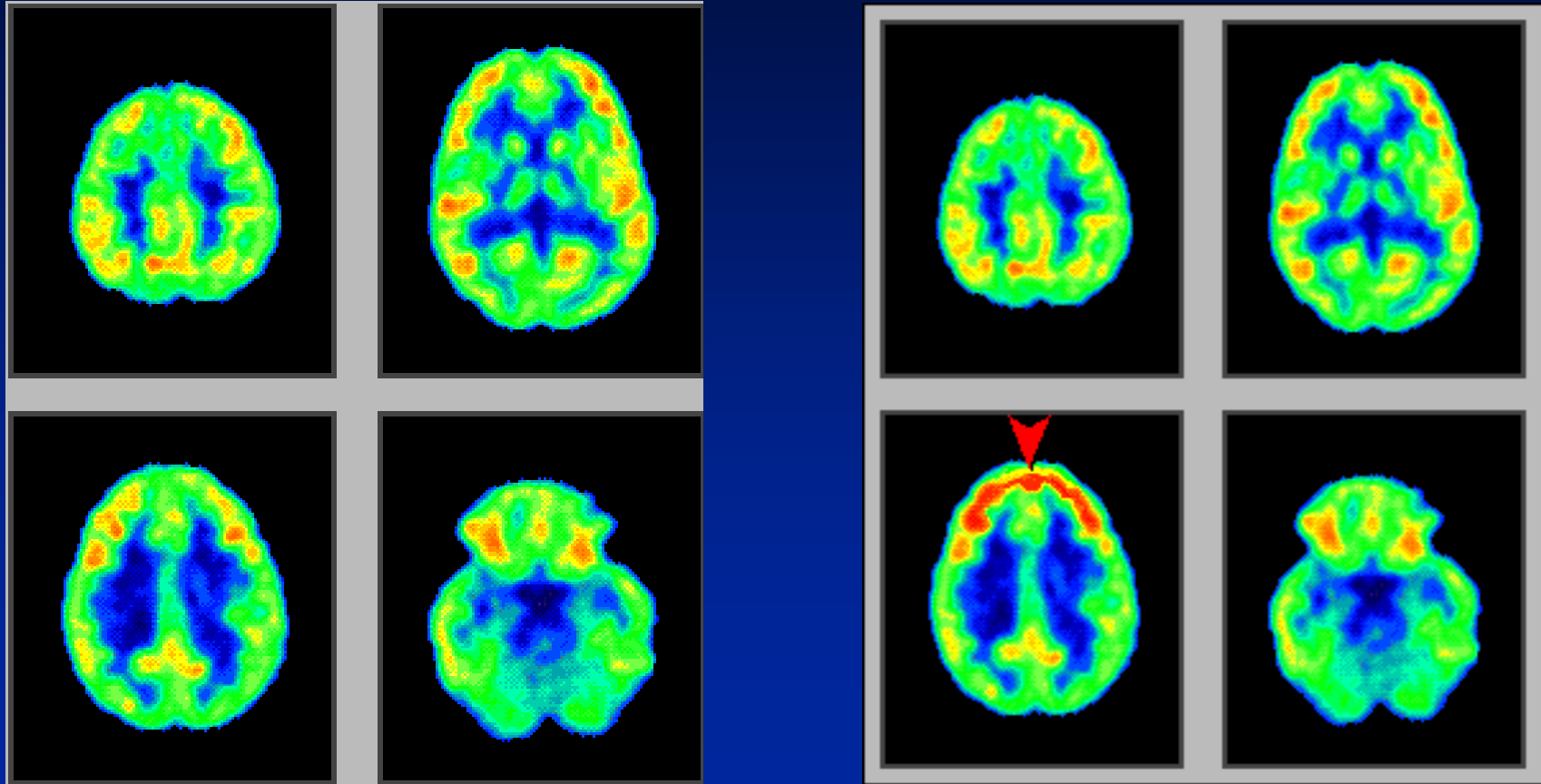




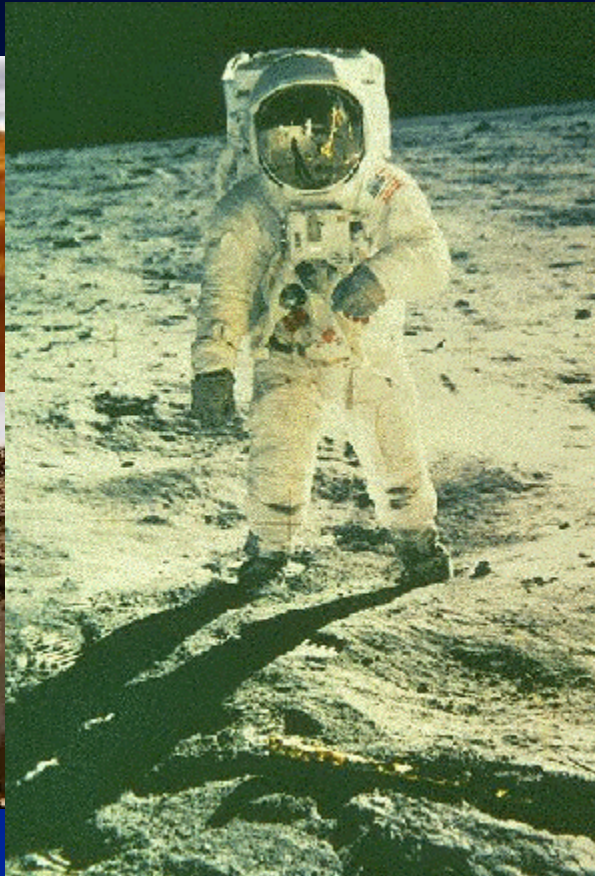
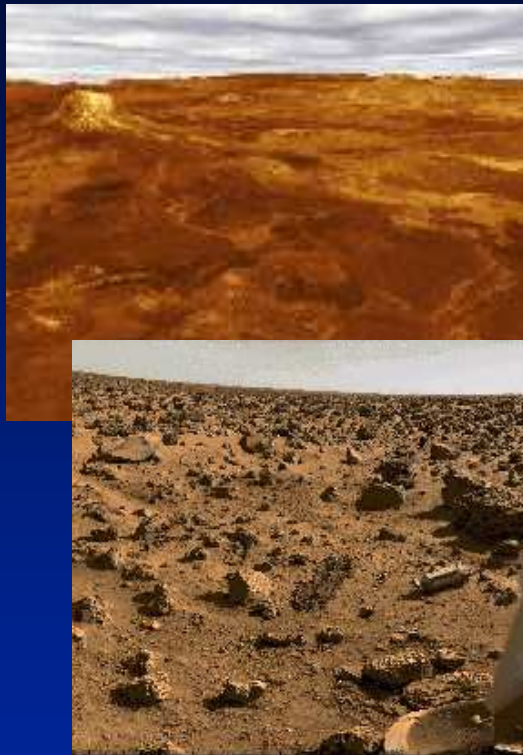
Wykrywanie guzów mózgu przez PET



Przykłady Emisyjnej Tomografii Pozytonowej [Positron Emission Tomography - PET]



Antymateria we wszechświecie



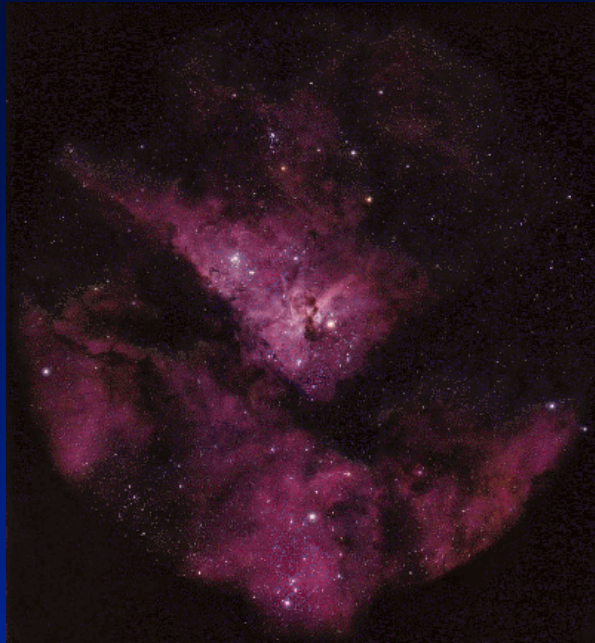
W Układzie Słonecznym mamy na pewno tylko planety z materii

Antymateria we wszechświecie

- W pierwotnym promieniowaniu kosmicznym docierającym do Ziemi przypada najwyżej 1 antyproton na 5000 protonów
- **Czy istnieją planety, gwiazdy i mgławice z antymaterii ?**



Antymateria we wszechświecie



Mgławice galaktyczne
są na pewno złożone
z materii

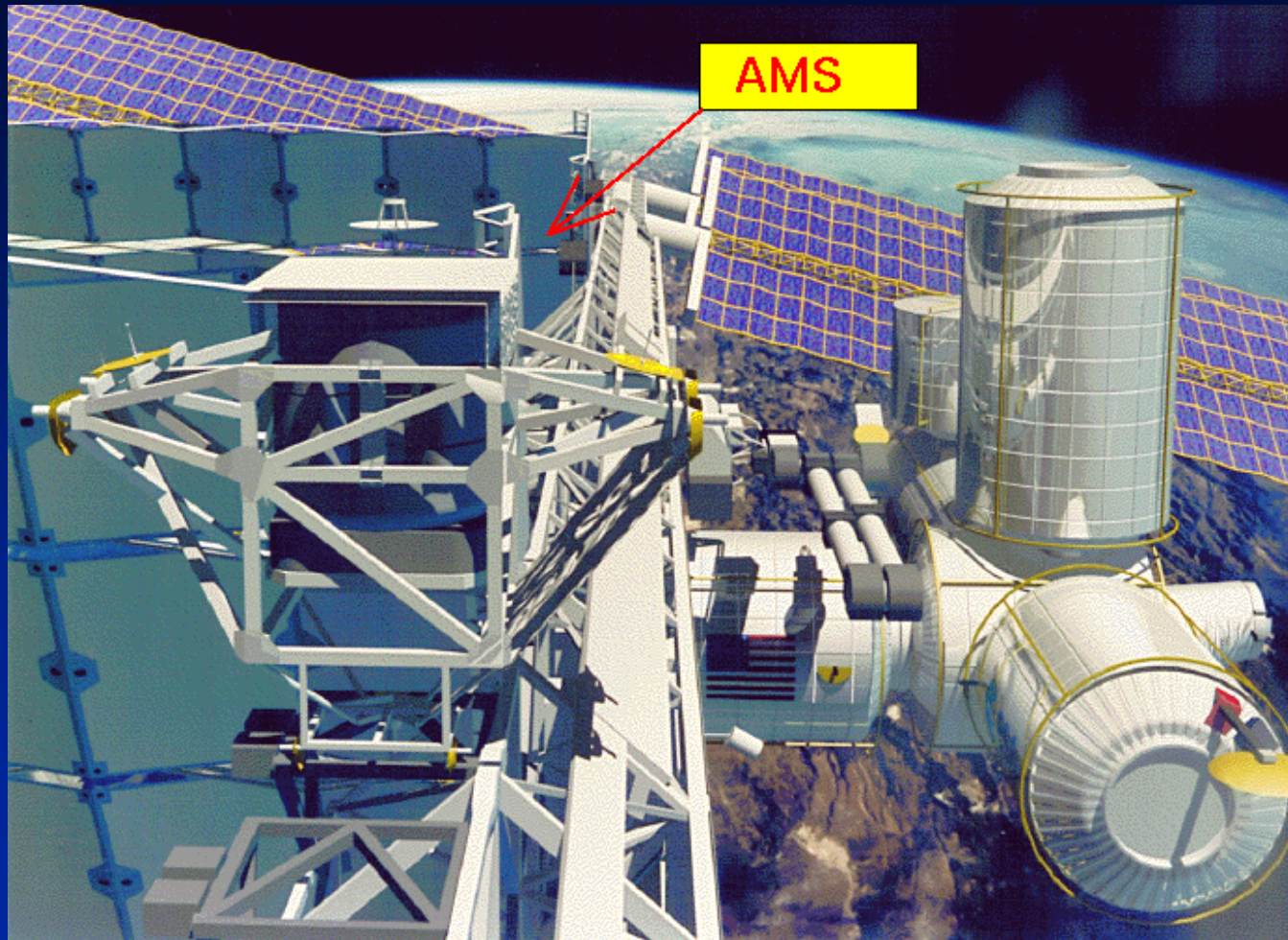


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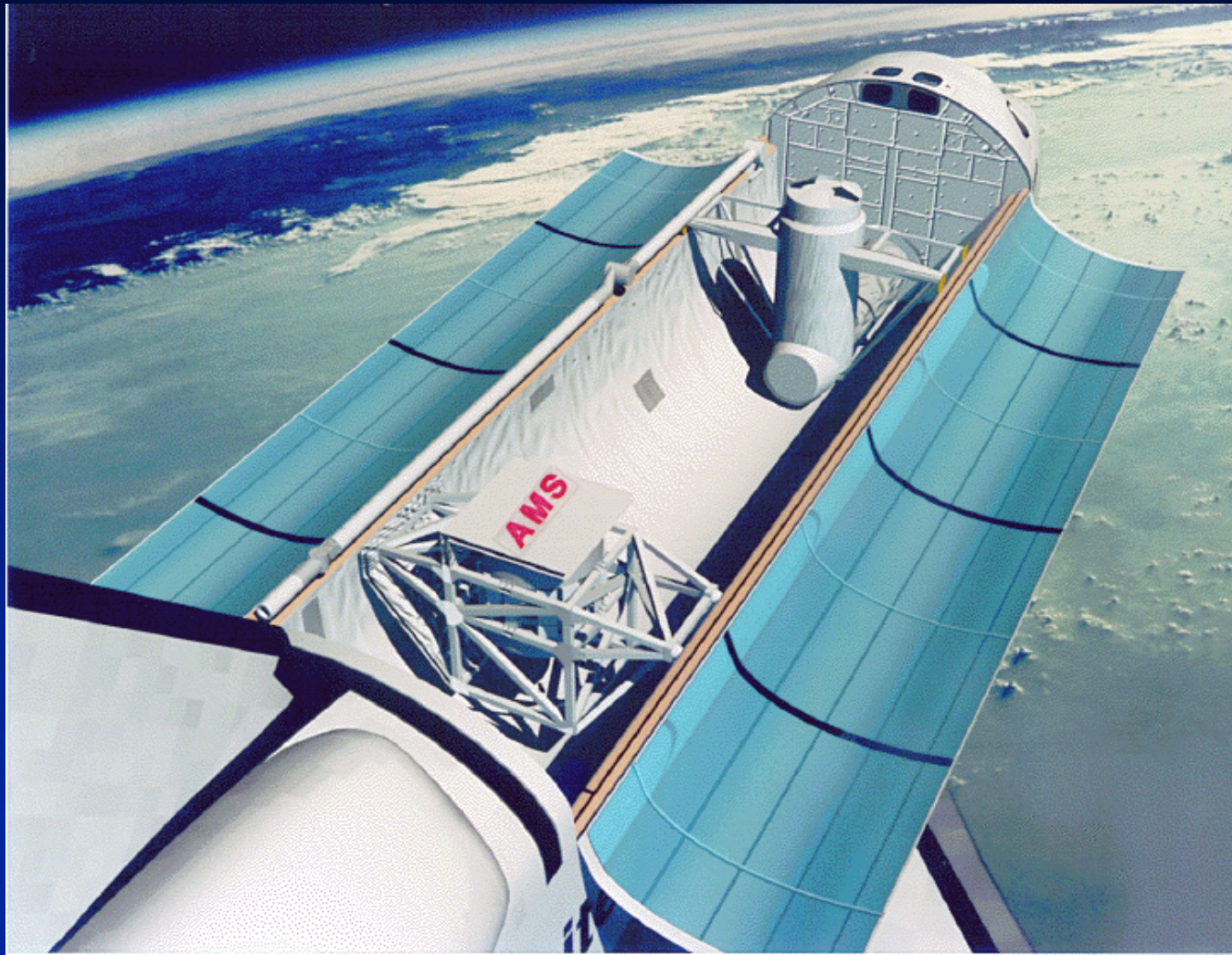
Eksperymenty dotyczące antymaterii w kosmosie

- **HEAT** (High Energy Antimatter Telescope)
- **IMAX** (Isotope Matter Antimatter Experiment)
- **MASS** (Matter Antimatter Superconducting Spectrometer)
- **AMS** (Alpha Magnetic Spectrometer)

Eksperyment AMS na International Space Station (2001)



AMS w luku Space Shuttle (Maj 1998)



Schemat AMS

