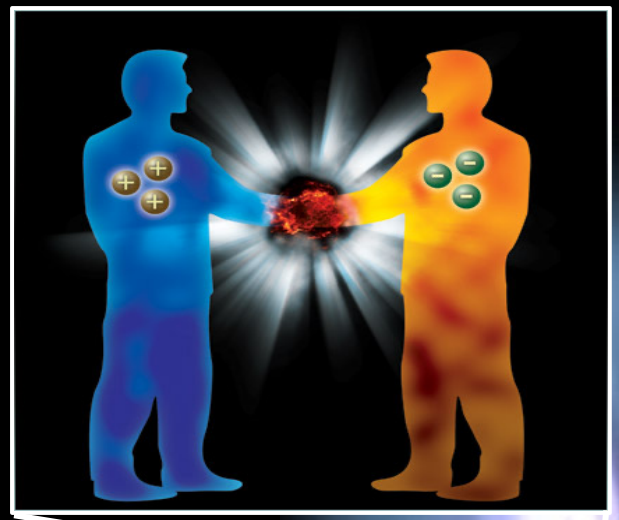
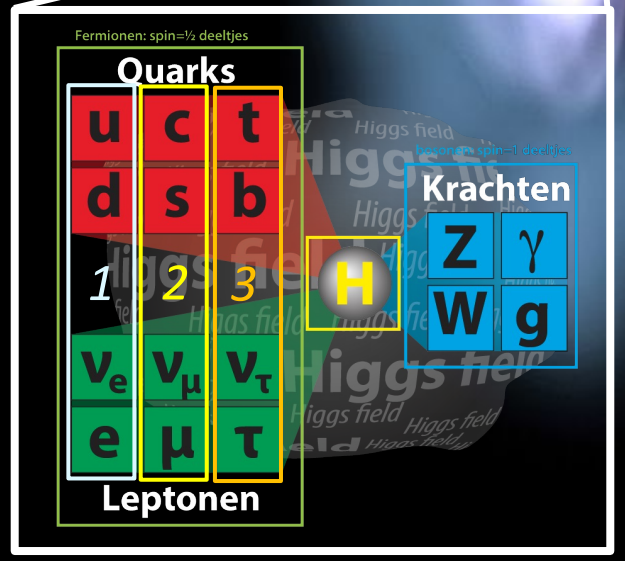
Waarom bestaat er iets in plaats van niets?

Nikhef TechnoBorrel, 1-5-2023

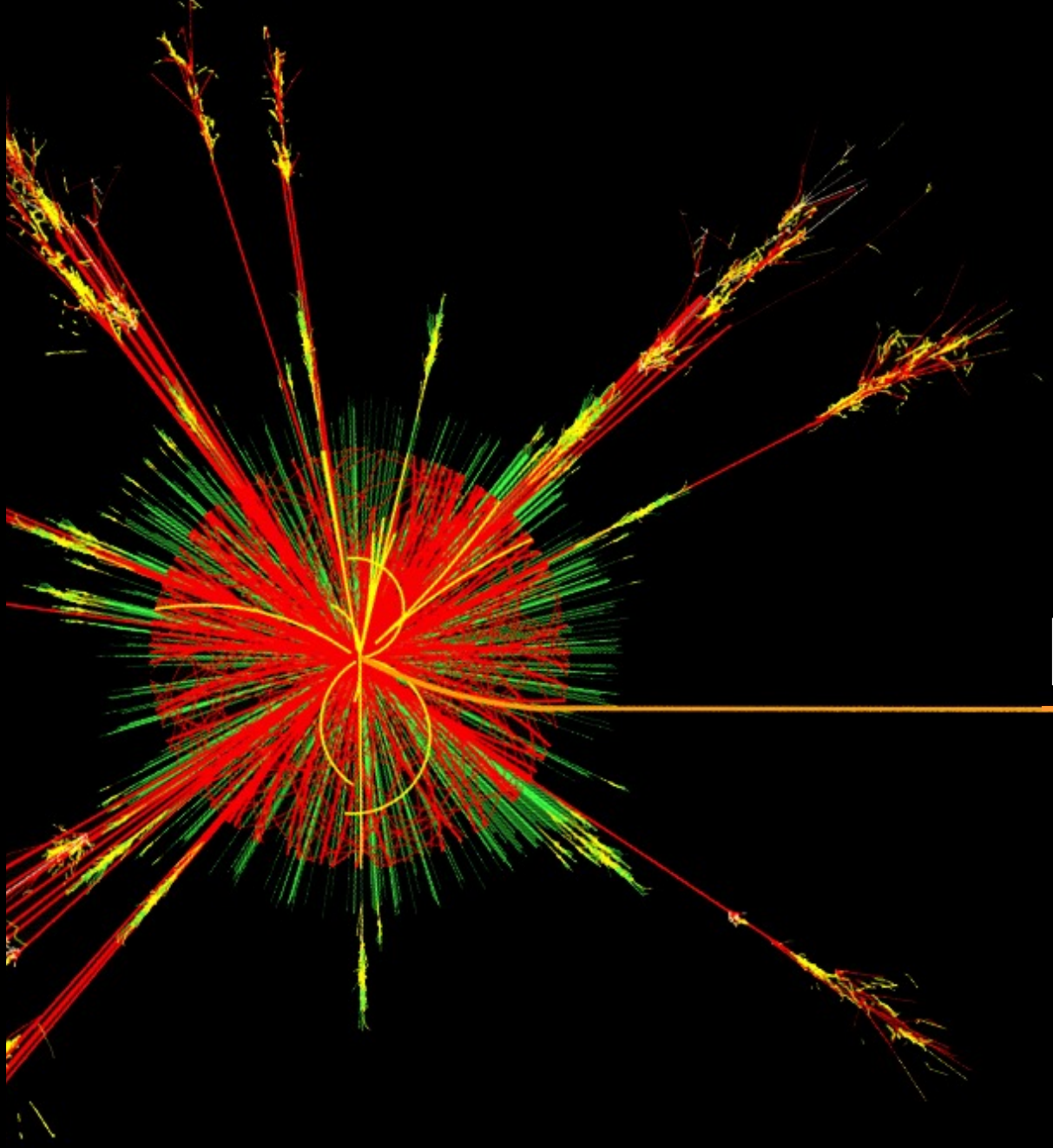
"Over Beauty-deeltjes, antimaterie en een nieuwe natuurkracht"

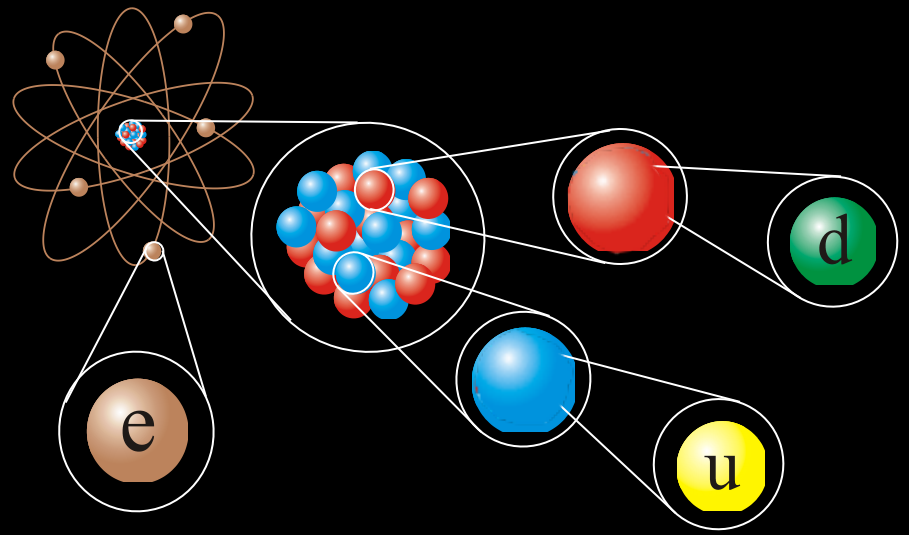
Hoe is de antimaterie verdwenen in het universum?





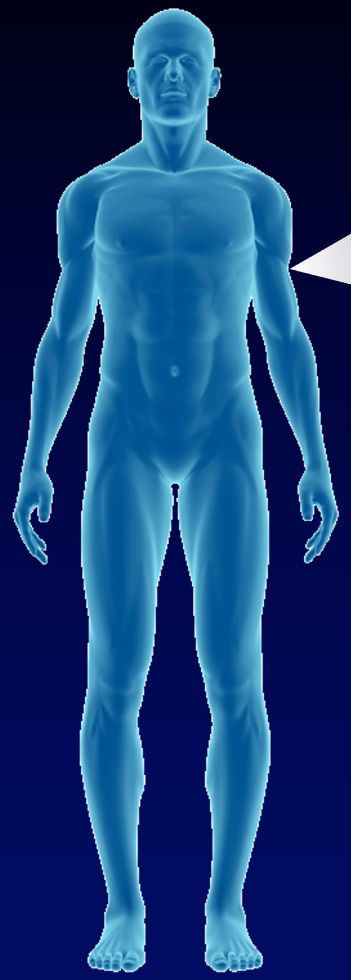
Flavor puzzle: waarom bestaan er drie generaties identieke deeltjes?



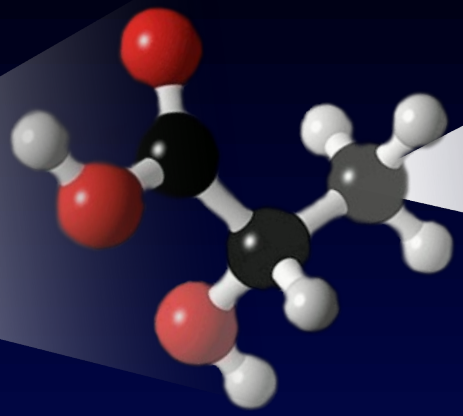


Materie en Antimaterie

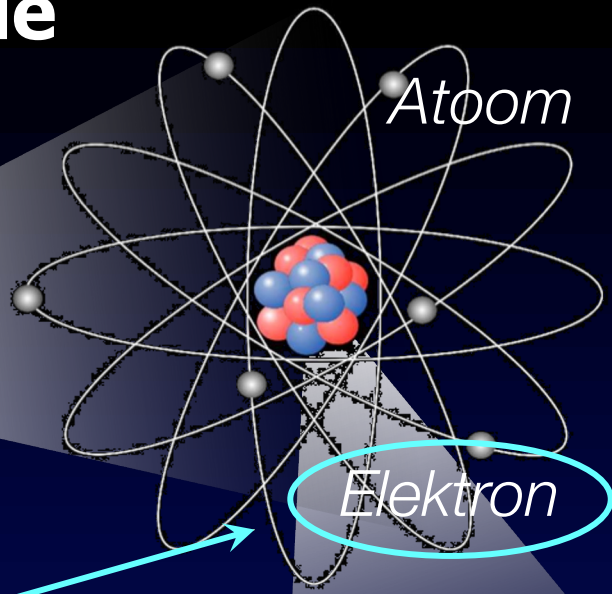
Bouwstenen van materie



Molecuul



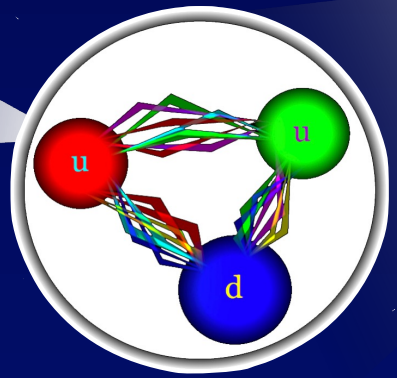
Atoom

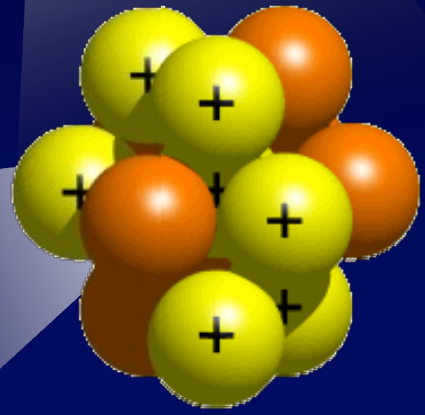


Elektron

Quark

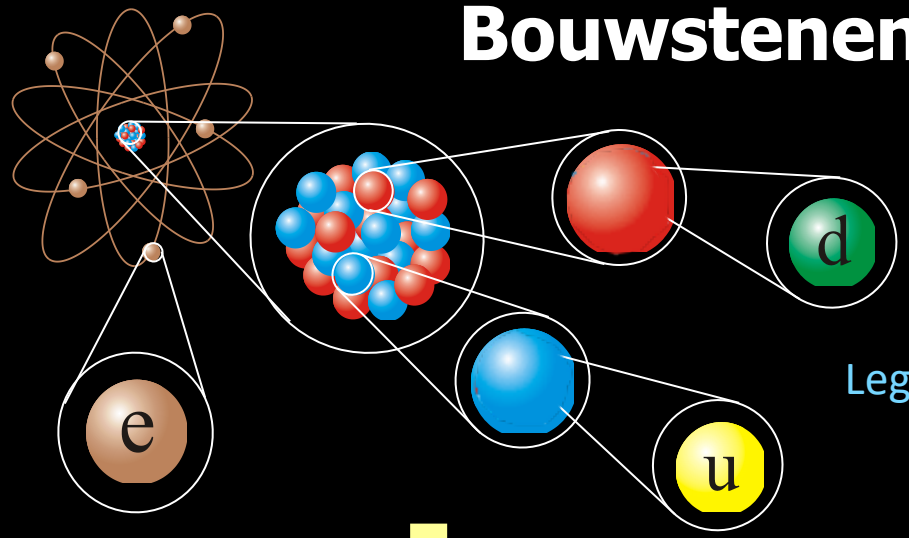
Proton/Neutron





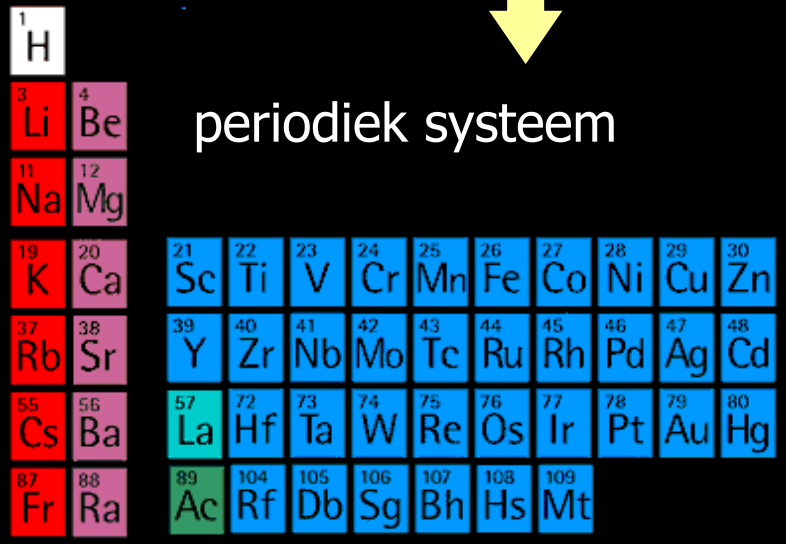
Atoomkern

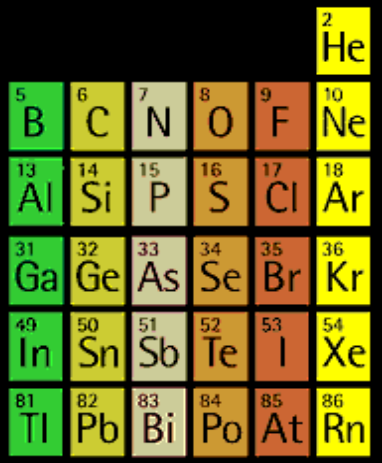
Bouwstenen van materie

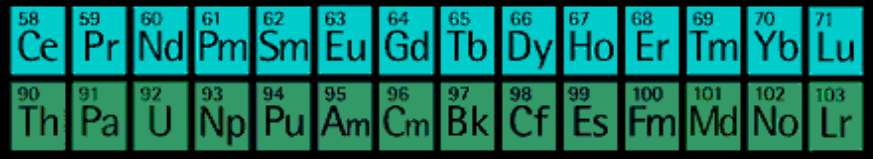


Lego blokken van de natuur

periodiek systeem

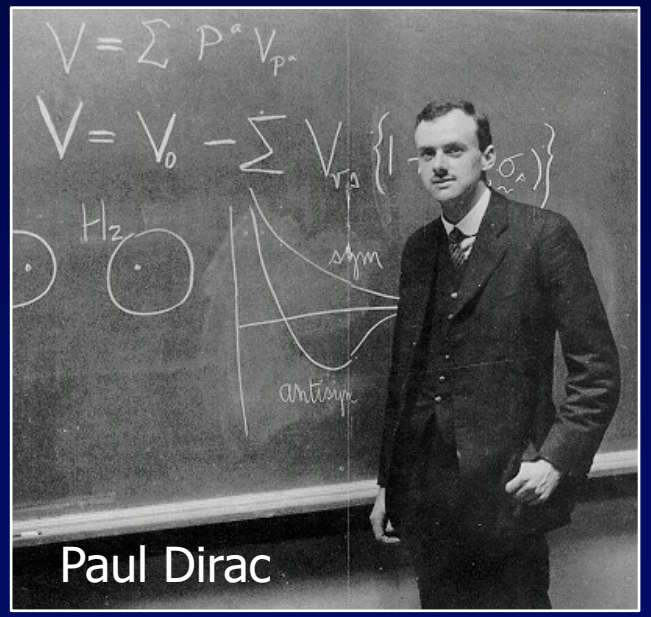






Paul Dirac en antimaterie

- 1928:
  - Dirac's relativistische quantum theorie
  - Voorspelling: *voor elk type deeltje bestaat er een identiek anti-deeltje!*
- 1932:
  - Anderson ontdekt het anti-elektron

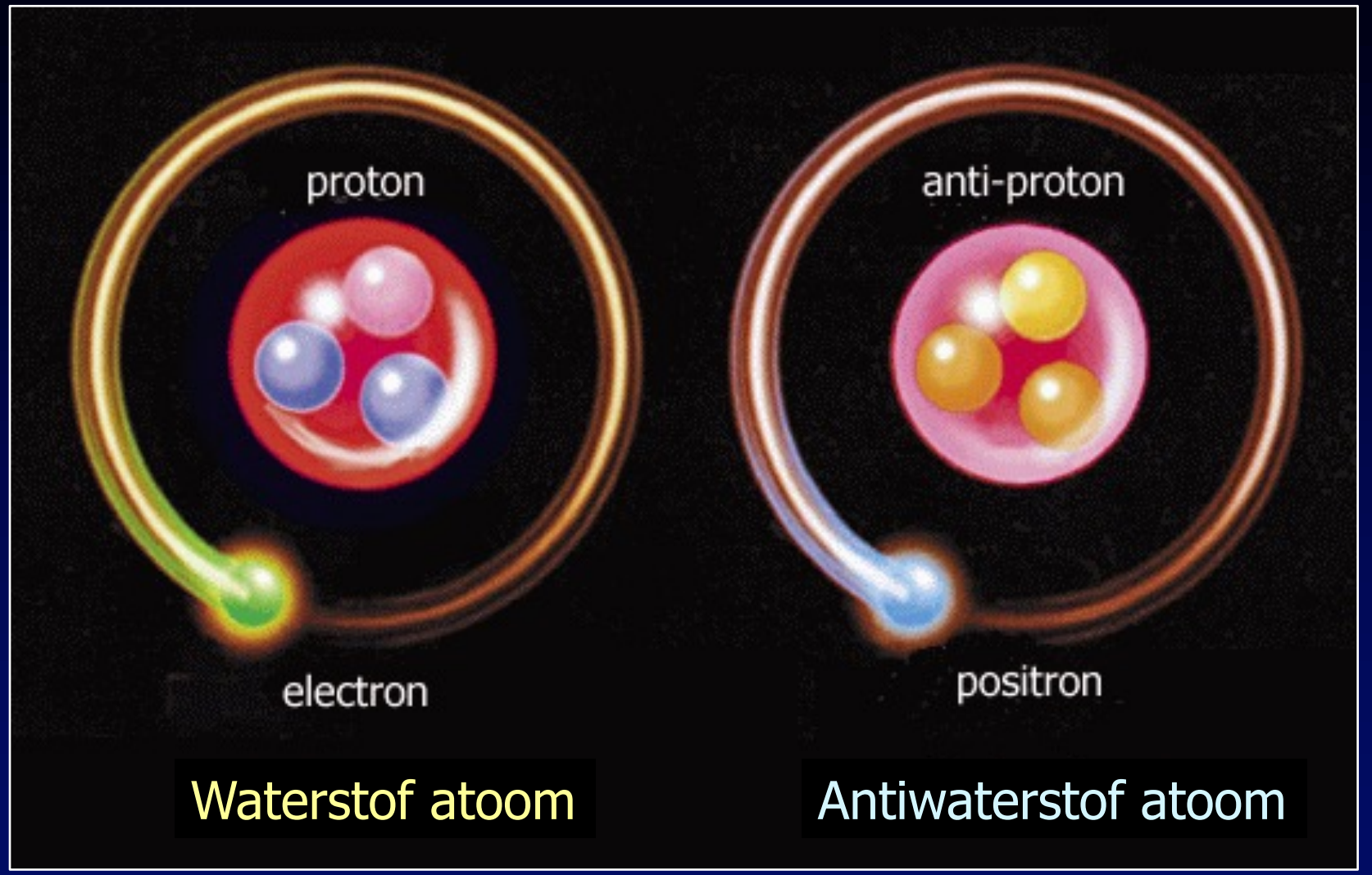

Paul Dirac


Carl Anderson

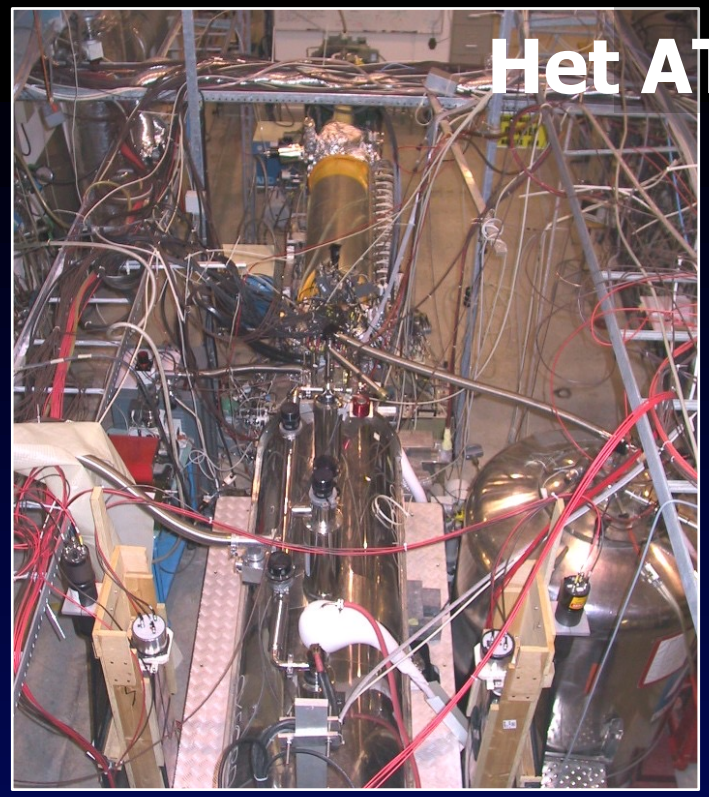

Dirac

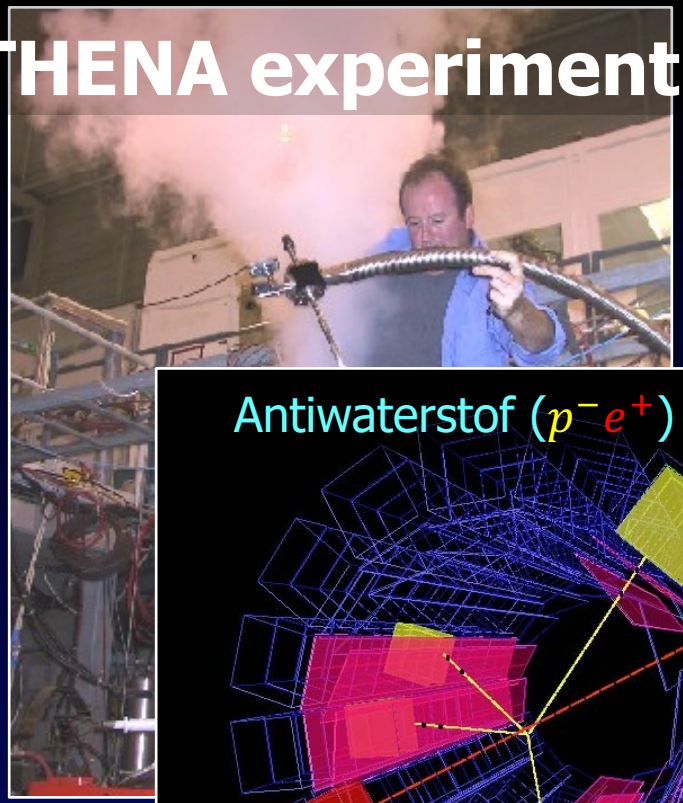
AntiDirac

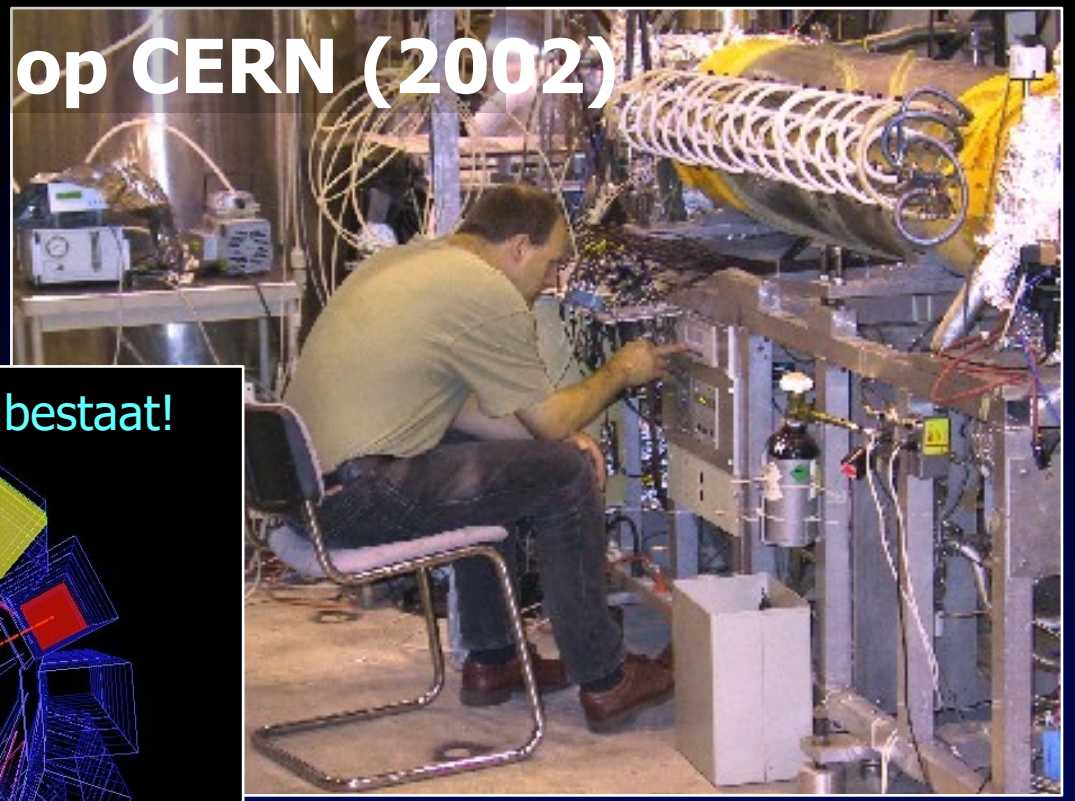
Antimaterie

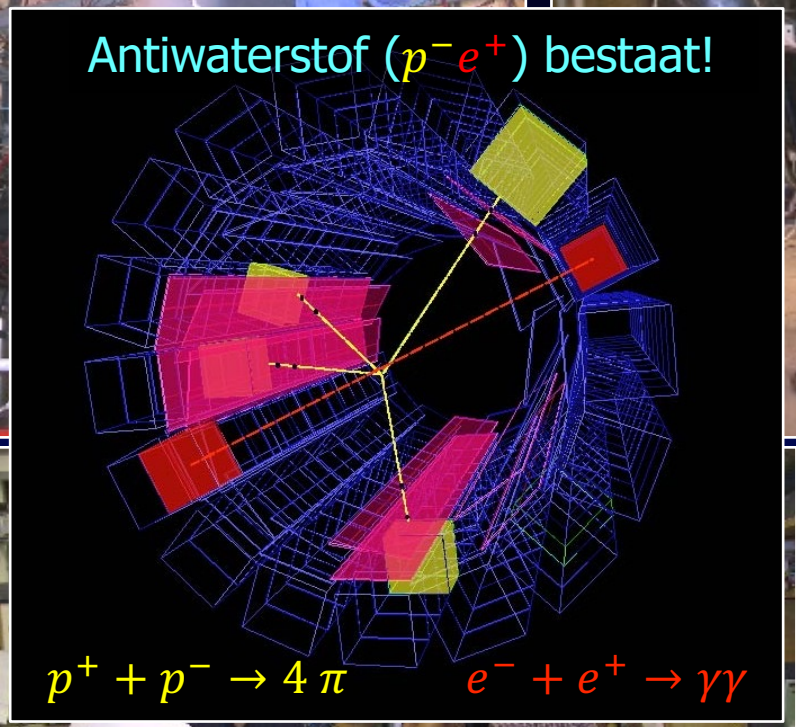


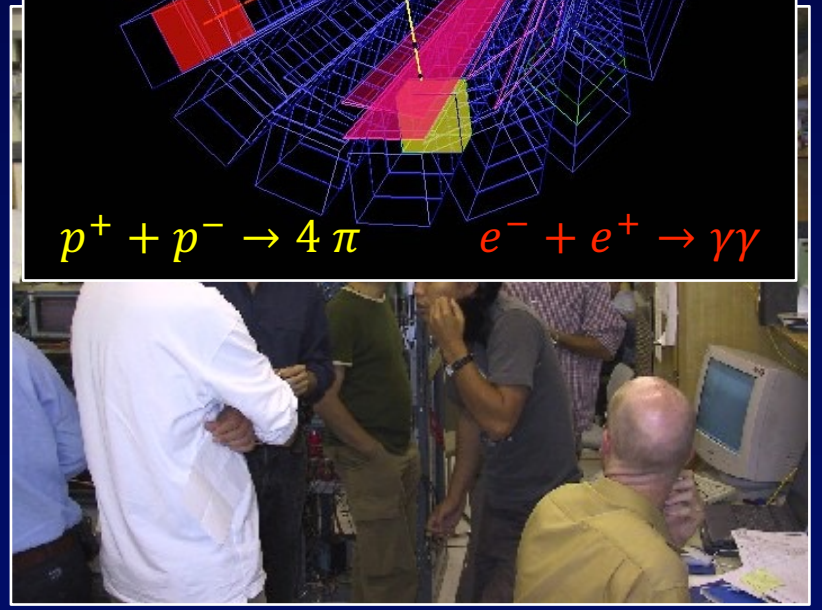
Het ATHENA experiment op CERN (2002)



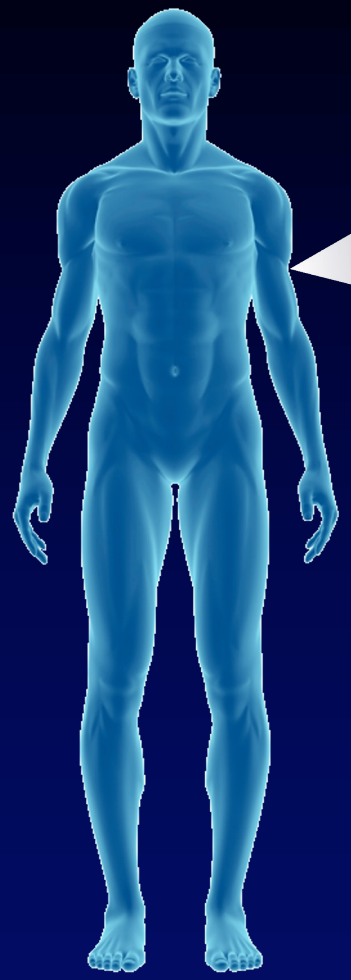






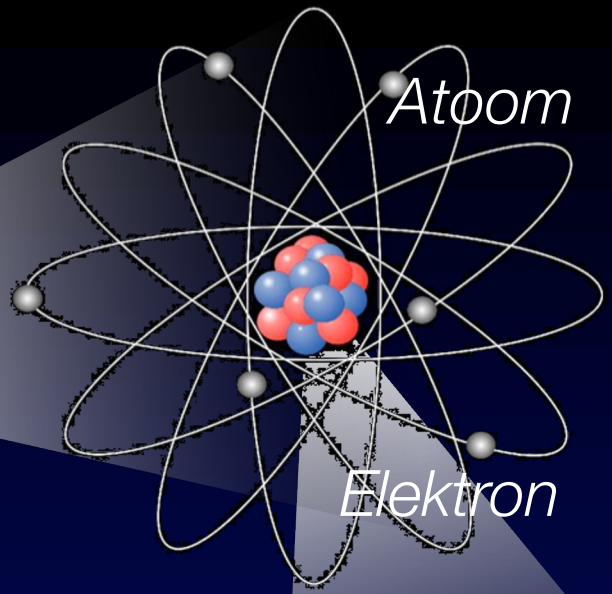


Een wereld van materie en …



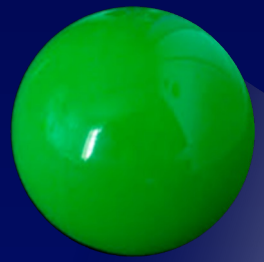
Molecuul

Atoom

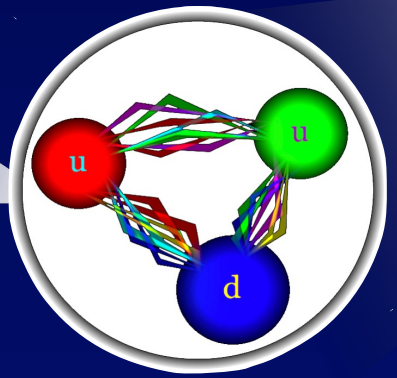


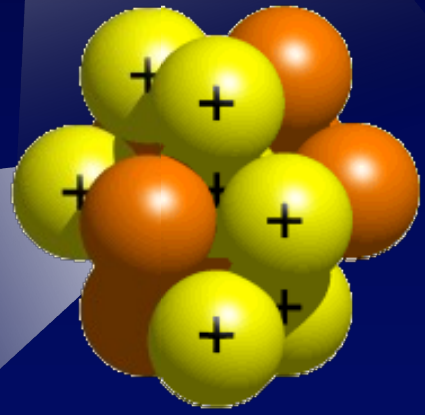
Elektron

Quark



Proton/Neutron



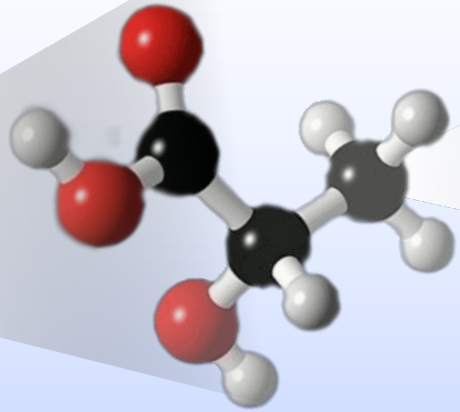


Atoom kern

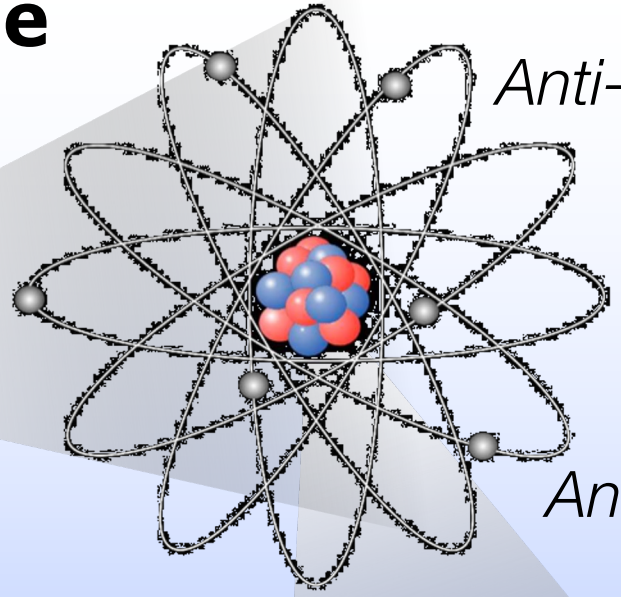
… een wereld van antimaterie

Identieke anti-wereld

Anti-Molecuul



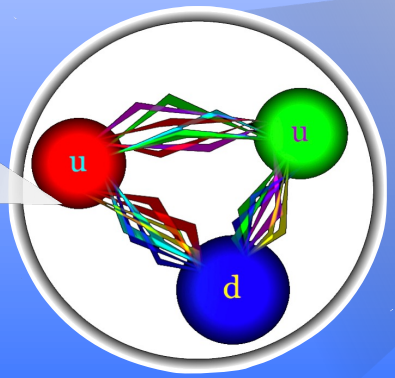
Anti-Atoom

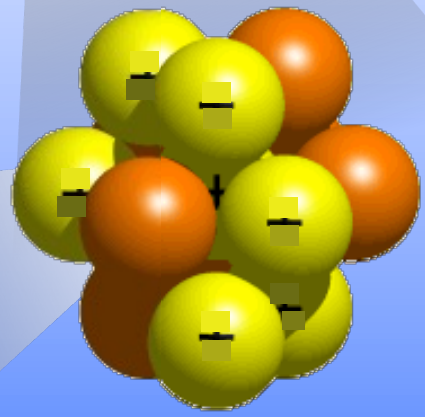


Anti-elektron

Anti-Quark

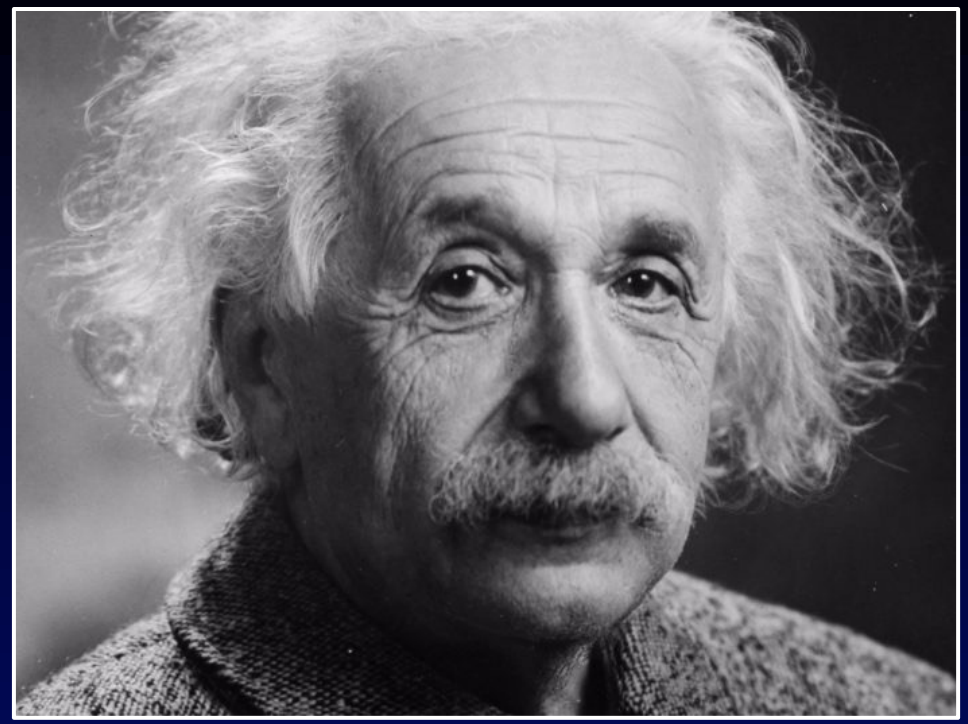
Anti-Proton / anti-Neutron

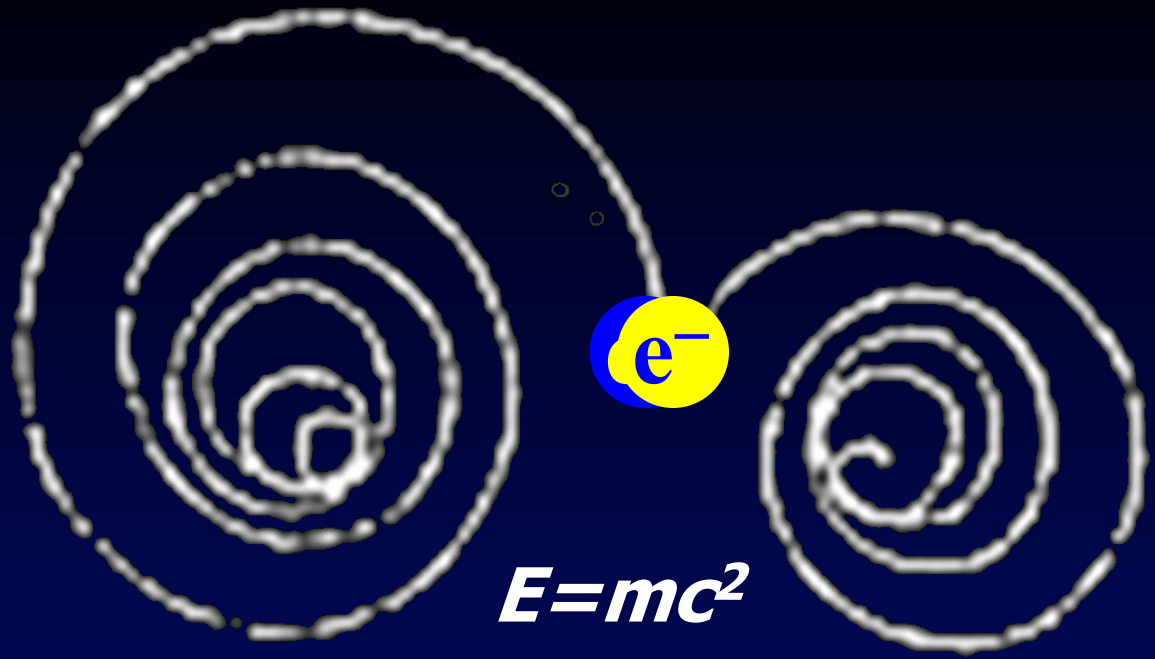




Anti-atoomkern

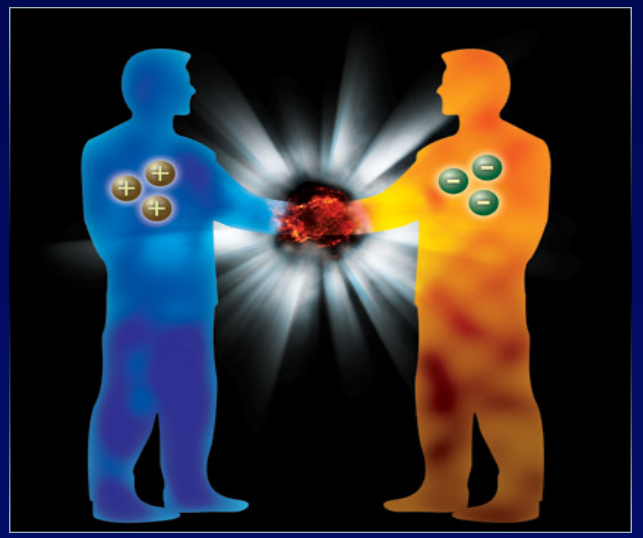
Albert Einstein: Energie = materie + antimaterie



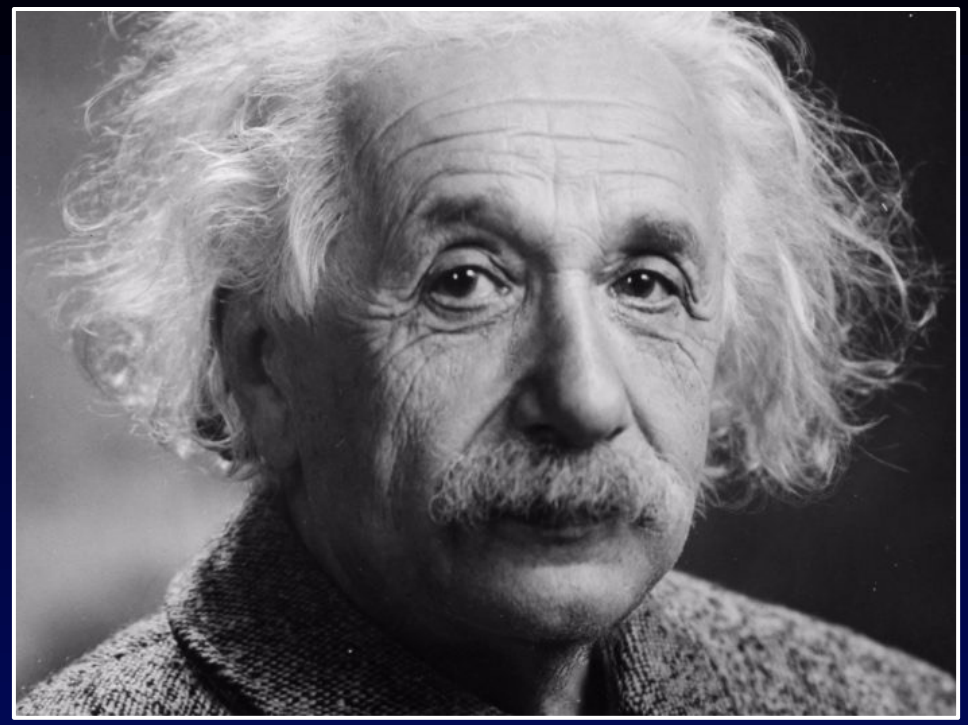


<u>Creatie:</u>
Energie → materie + antimaterie : → e^+ e^-

<u>Annihilatie:</u>
materie + antimaterie → energie : e^+ e^- →



Albert Einstein: Energie = materie + antimaterie

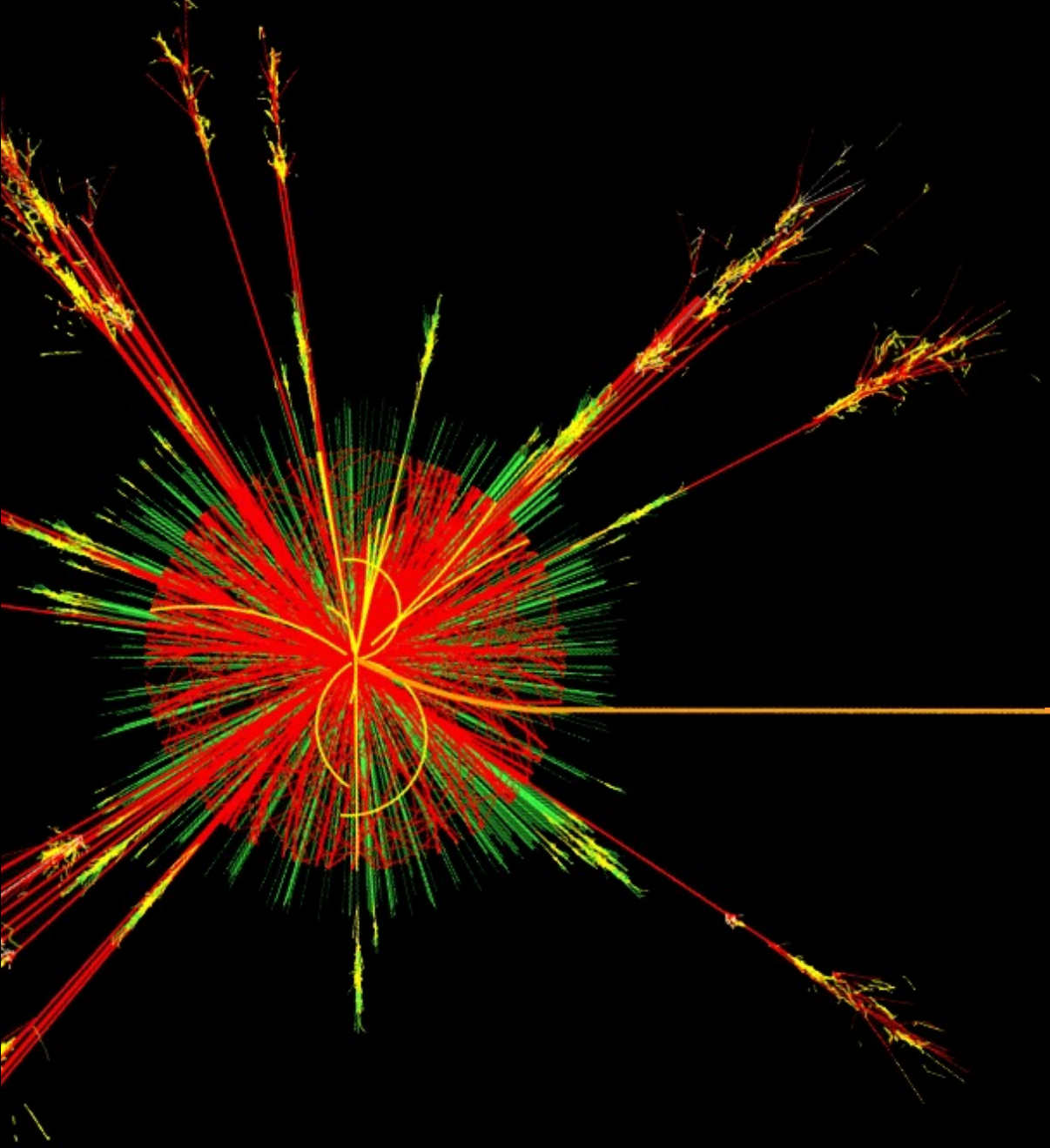


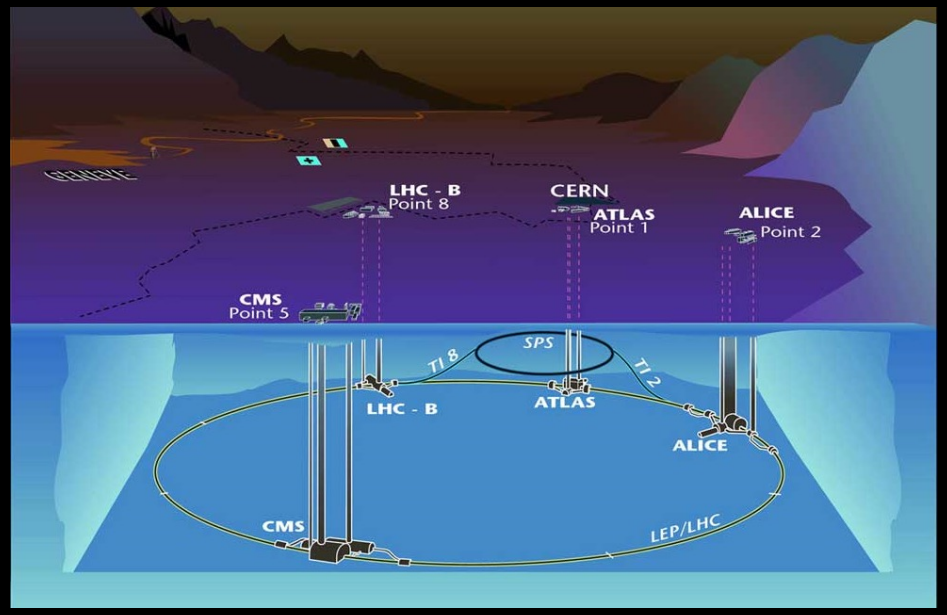
<u>Creatie:</u>
Energie → materie + antimaterie :  →

<u>Annihilatie:</u>
materie + antimaterie → energie : e^+ e^-

Vroege Universum: waar is de antimaterie heen?

*Inderdaad: Waarom **is** er eigenlijk iets in plaats van niets?!*

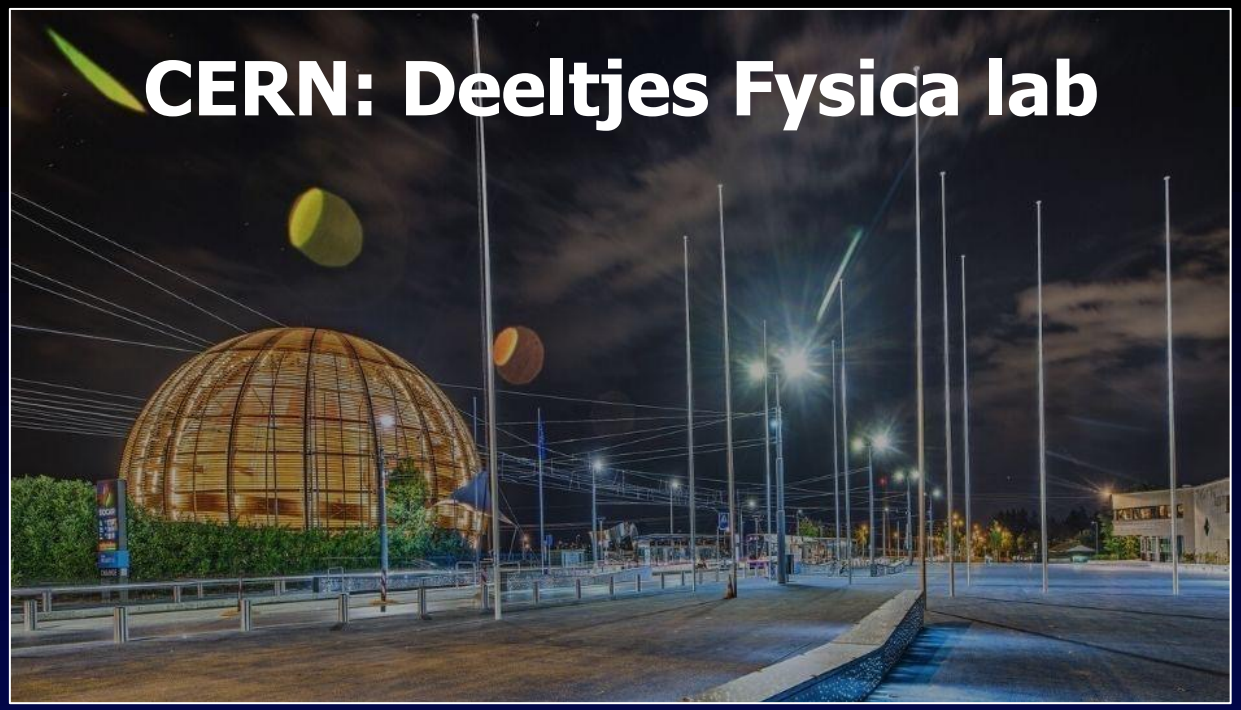


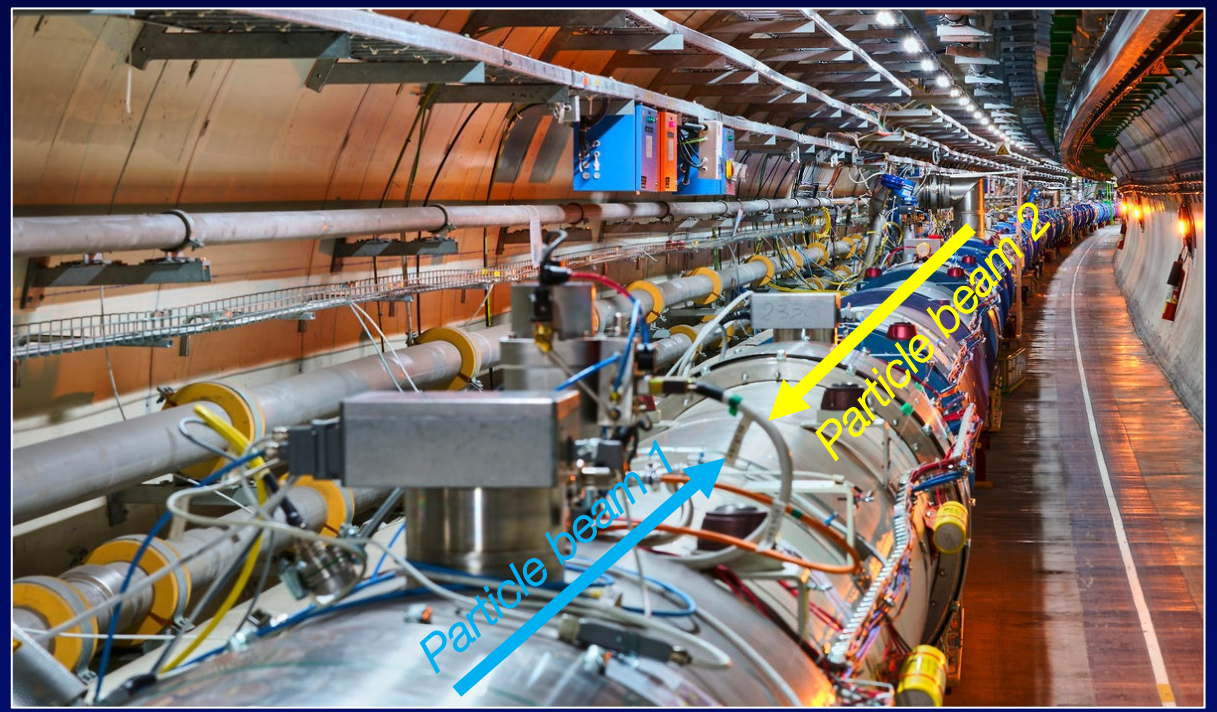

GENEVE
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC

CERN

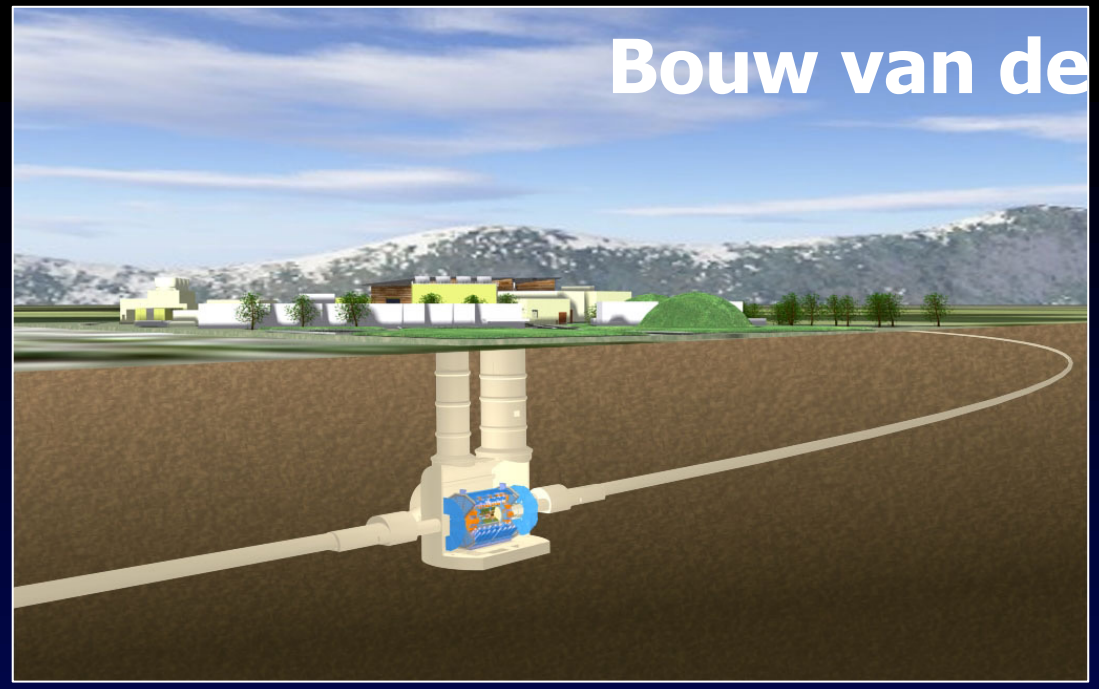

Member States (Dates of Accession)
AUSTRIA (1959)
BELGIUM (1953)
BULGARIA (1999)
CZECH FR (1993)
DENMARK (1953)
FINLAND (1991)
FRANCE (1953)
GERMANY (1953)
GREECE (1953)
HUNGARY (1992)
ITALY (1953)
NETHERLANDS (1953)
NORWAY (1953)
POLAND (1991)
PORTUGAL (1986)
SLOVAK FR (1993)
SPAIN (1/1961-12/1968-1/1983)
SWEDEN (1953)
SWITZERLAND (1953)
UNITED KINGDOM (1953)

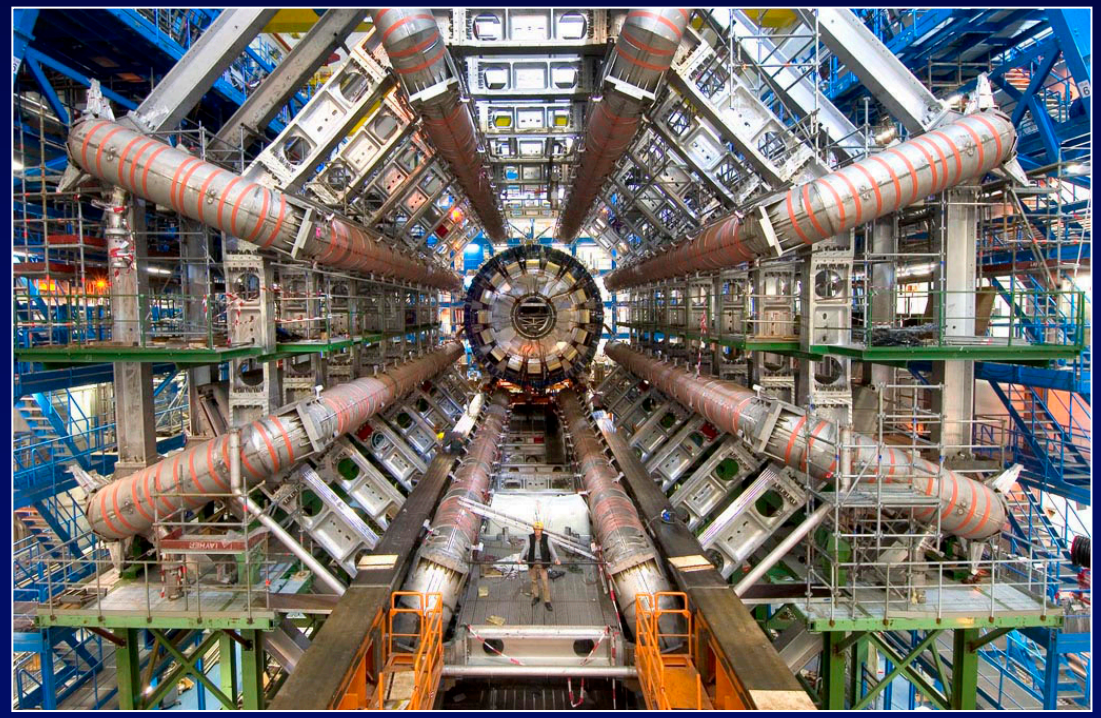
CERN: Deeltjes Fysica lab

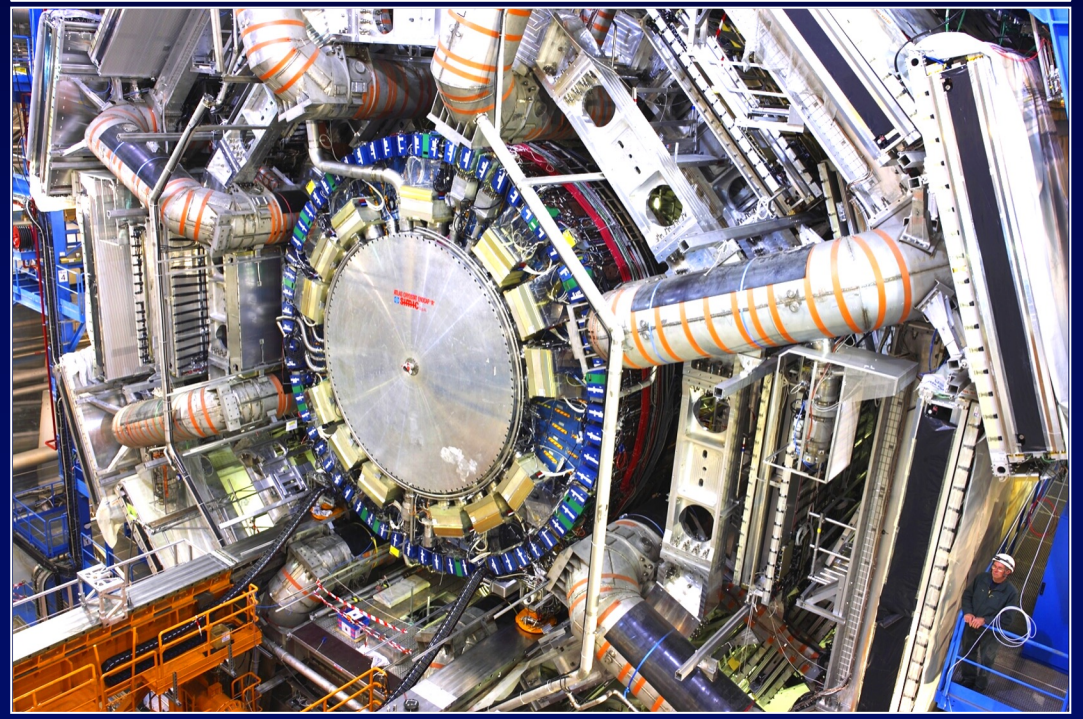




Bouw van de Atlas detector





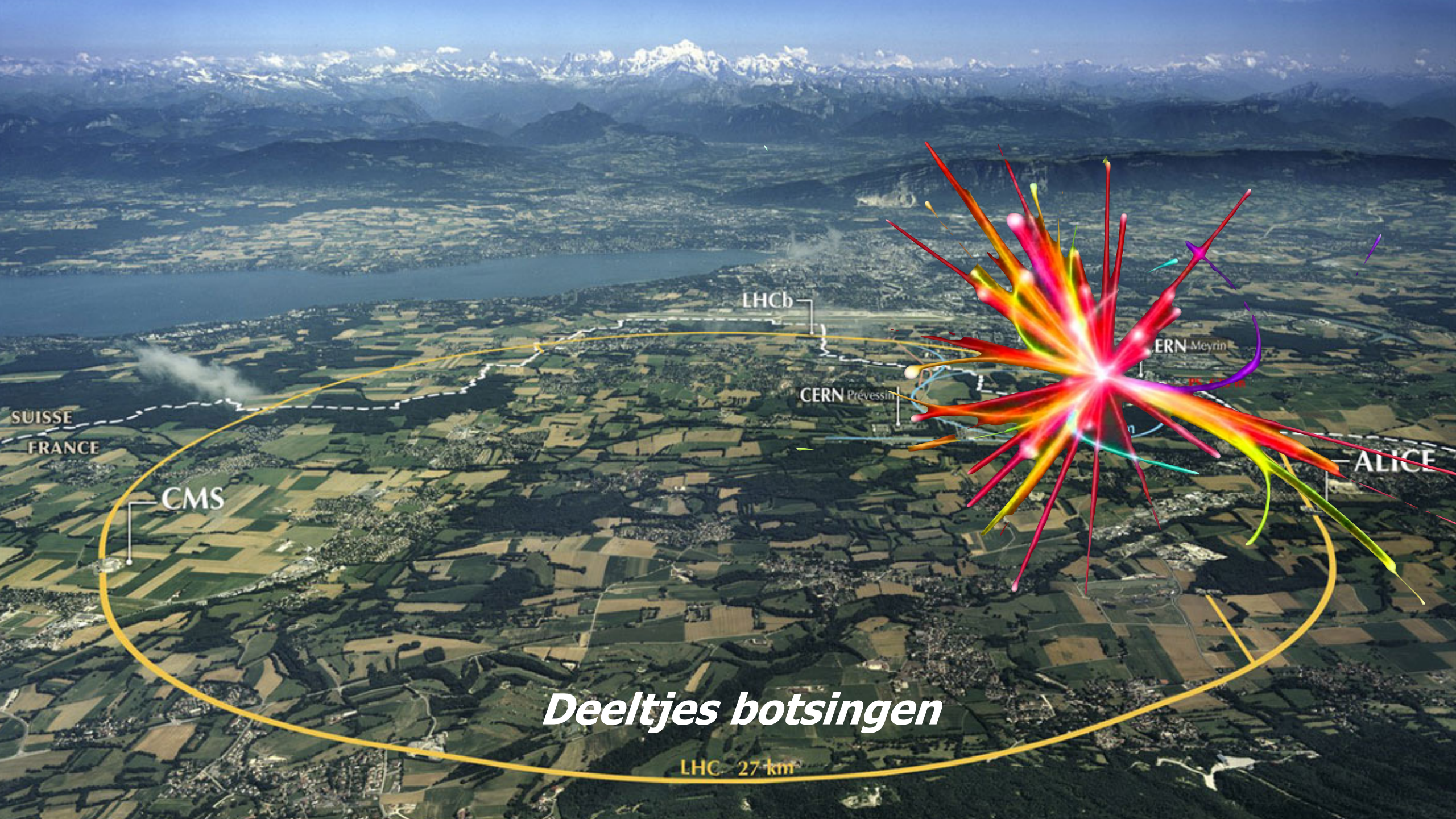


Het Atlas Experiment

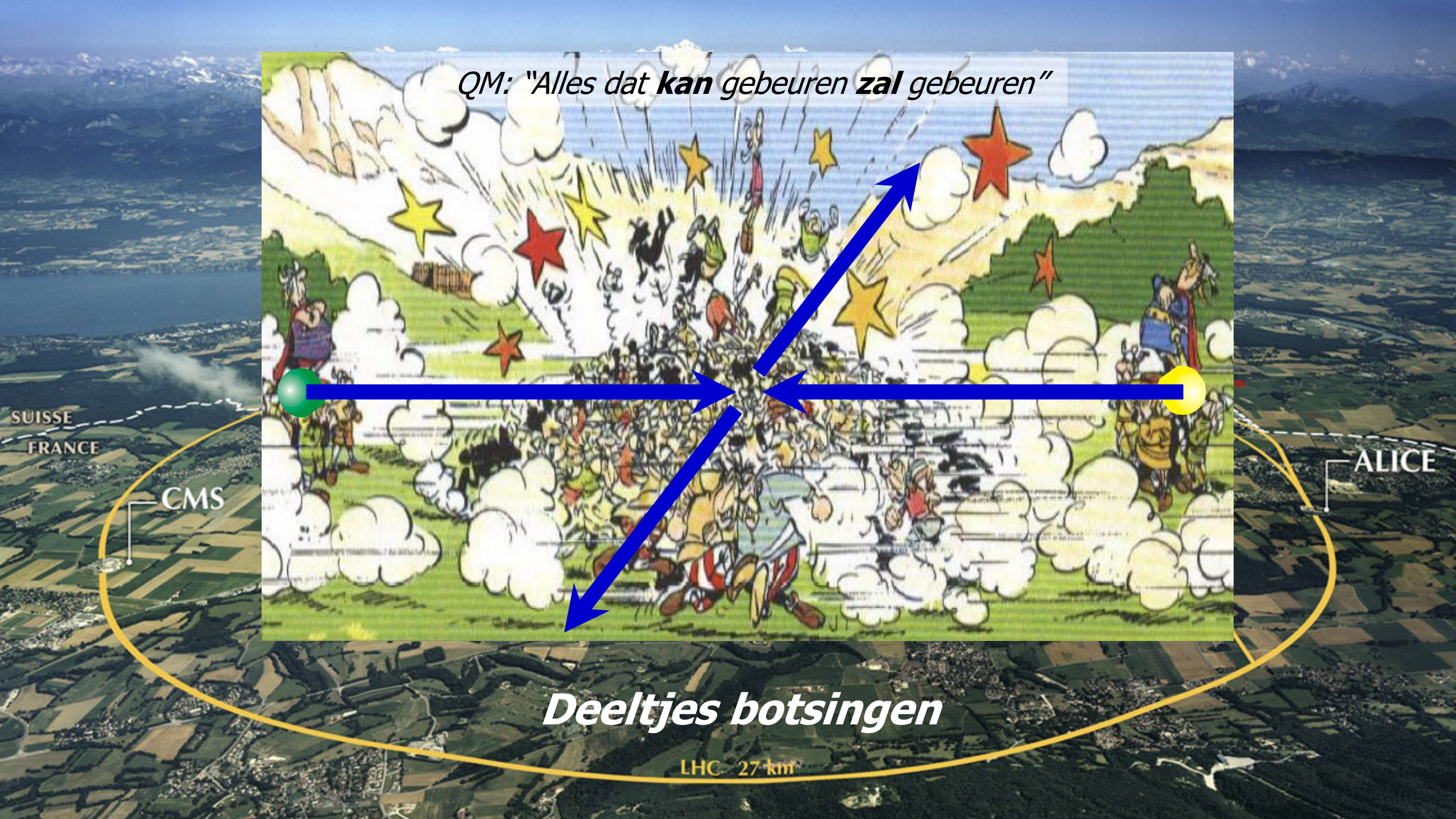
Het grootste fototoestel op aarde

- *45 m x 25 m*
- *3000 fysici*

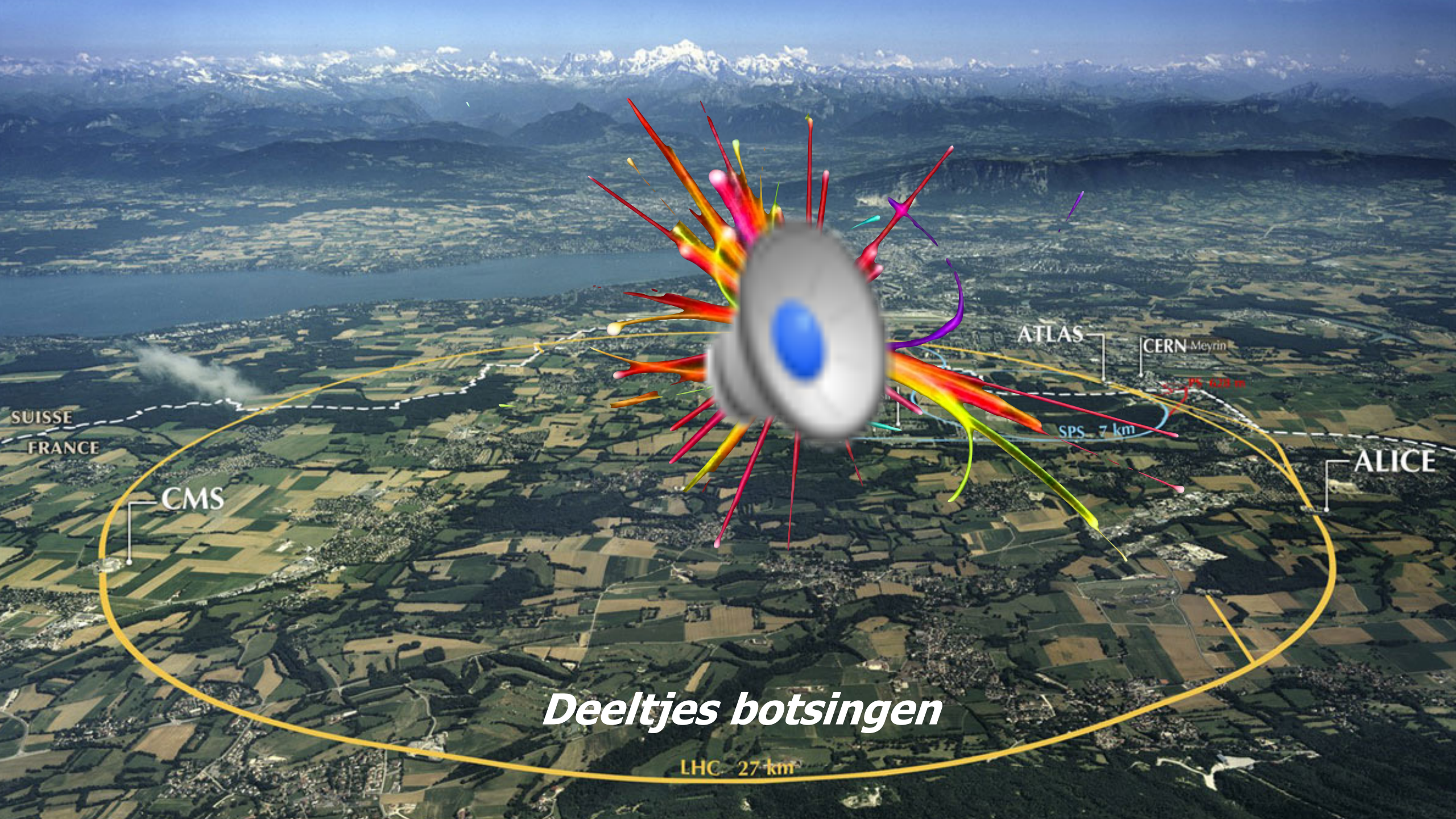
80 MegaPixel “camera”: 40.000.000 foto’s per seconde



Deeltjes botsingen



Deeltjes botsingen



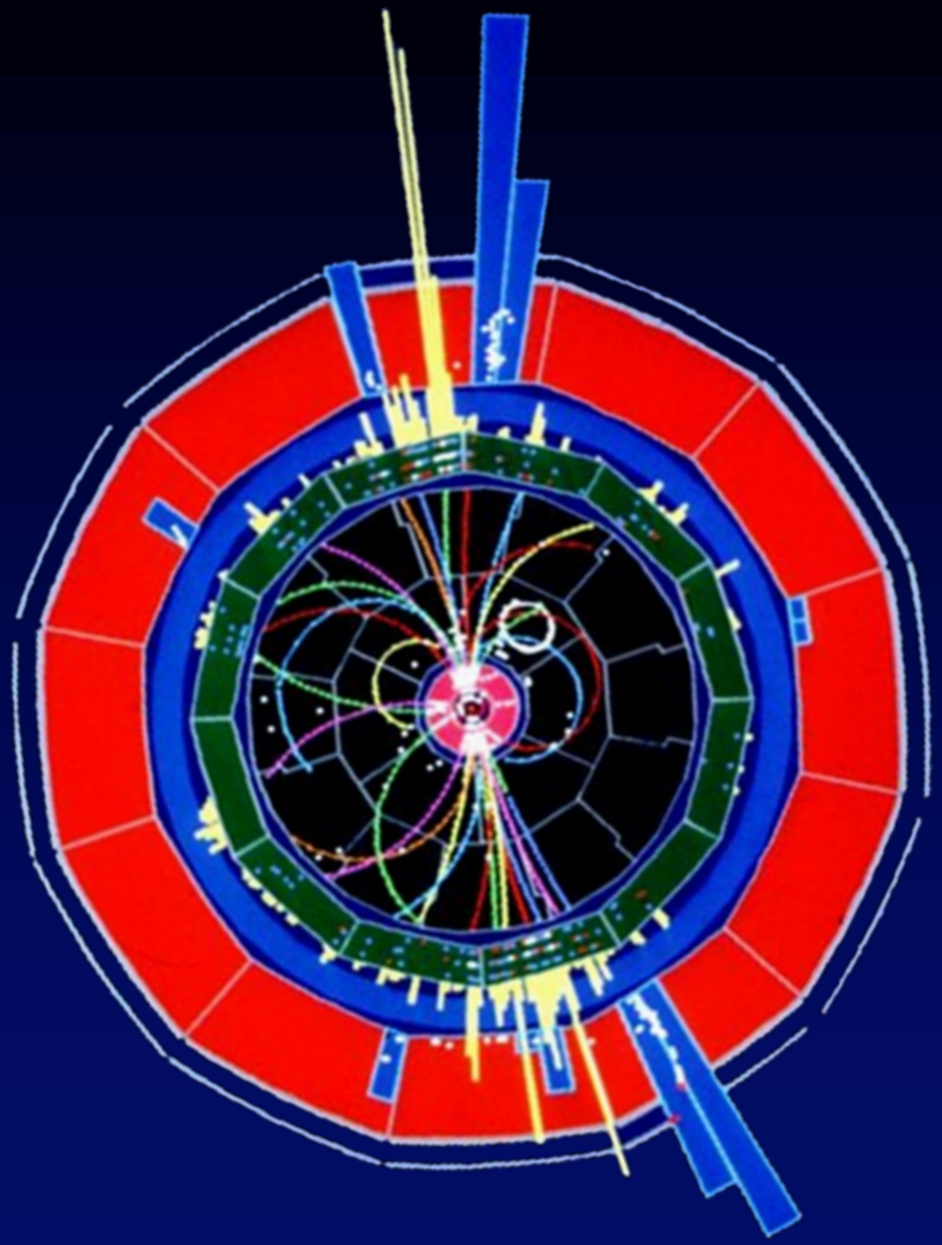
Deeltjes botsingen

De Elementaire Deeltjes

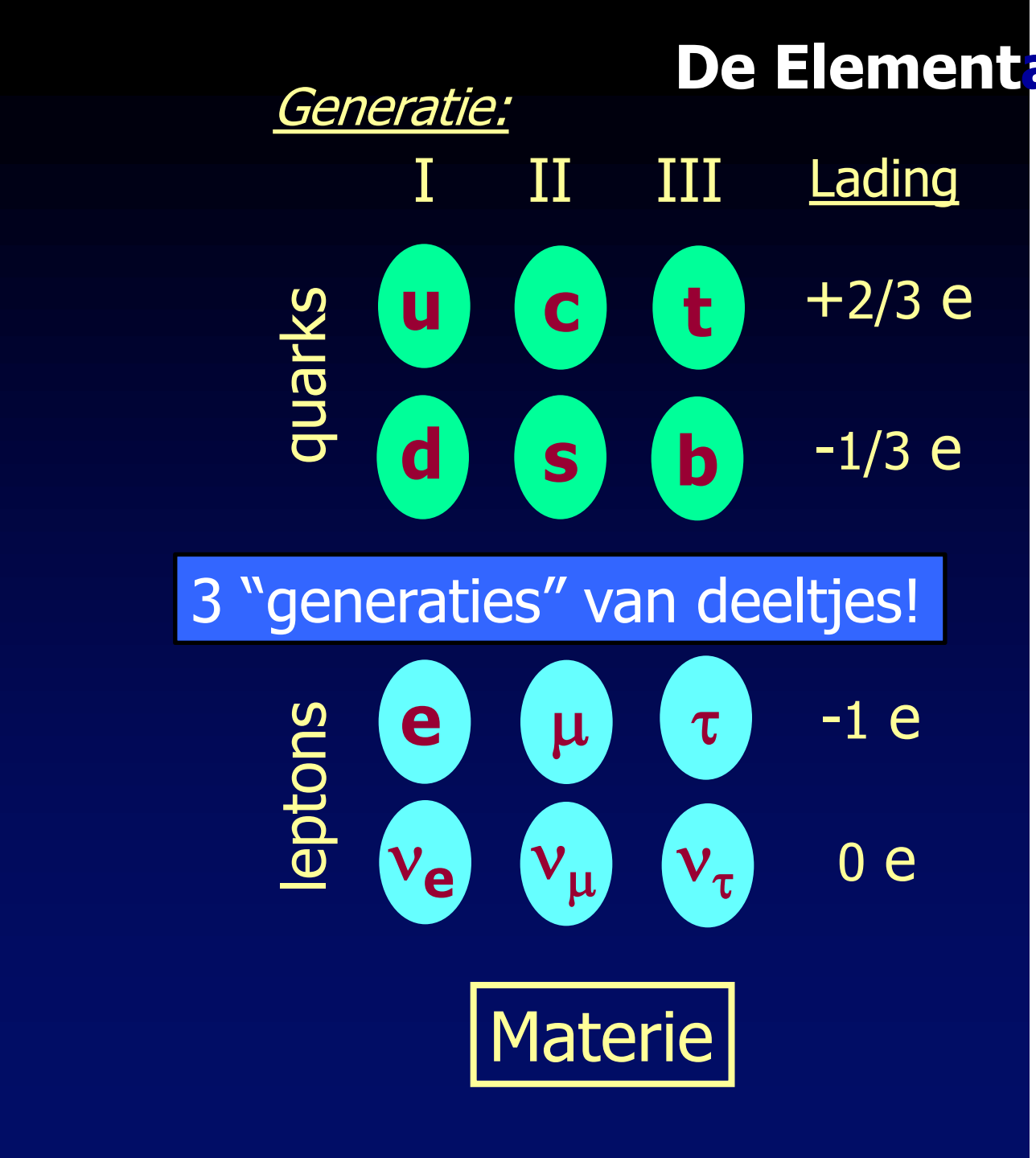
Generatie:	I	II	III	Lading
quarks	u	c (1976)	t (1995)	+2/3 e
	d	s (1947)	b (1978)	-1/3 e
leptons	e (1895)	μ (1936)	τ (1973)	-1 e
	ν_e (1956)	ν_μ (1963)	ν_τ (2000)	0 e

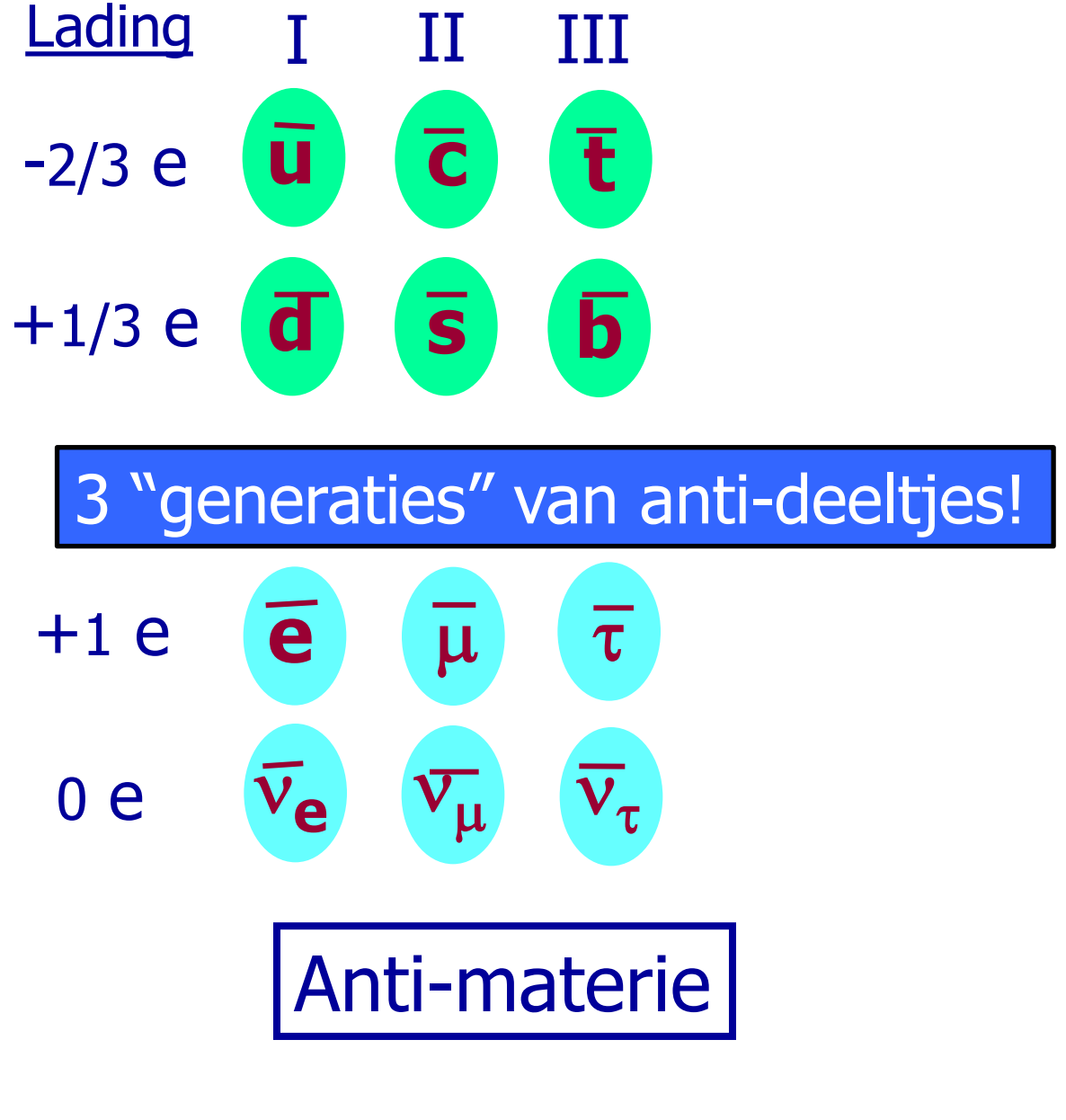
3 “generaties” van deeltjes!

Materie



De Elementaire Deeltjes





De Elementaire Deeltjes

Generatie:

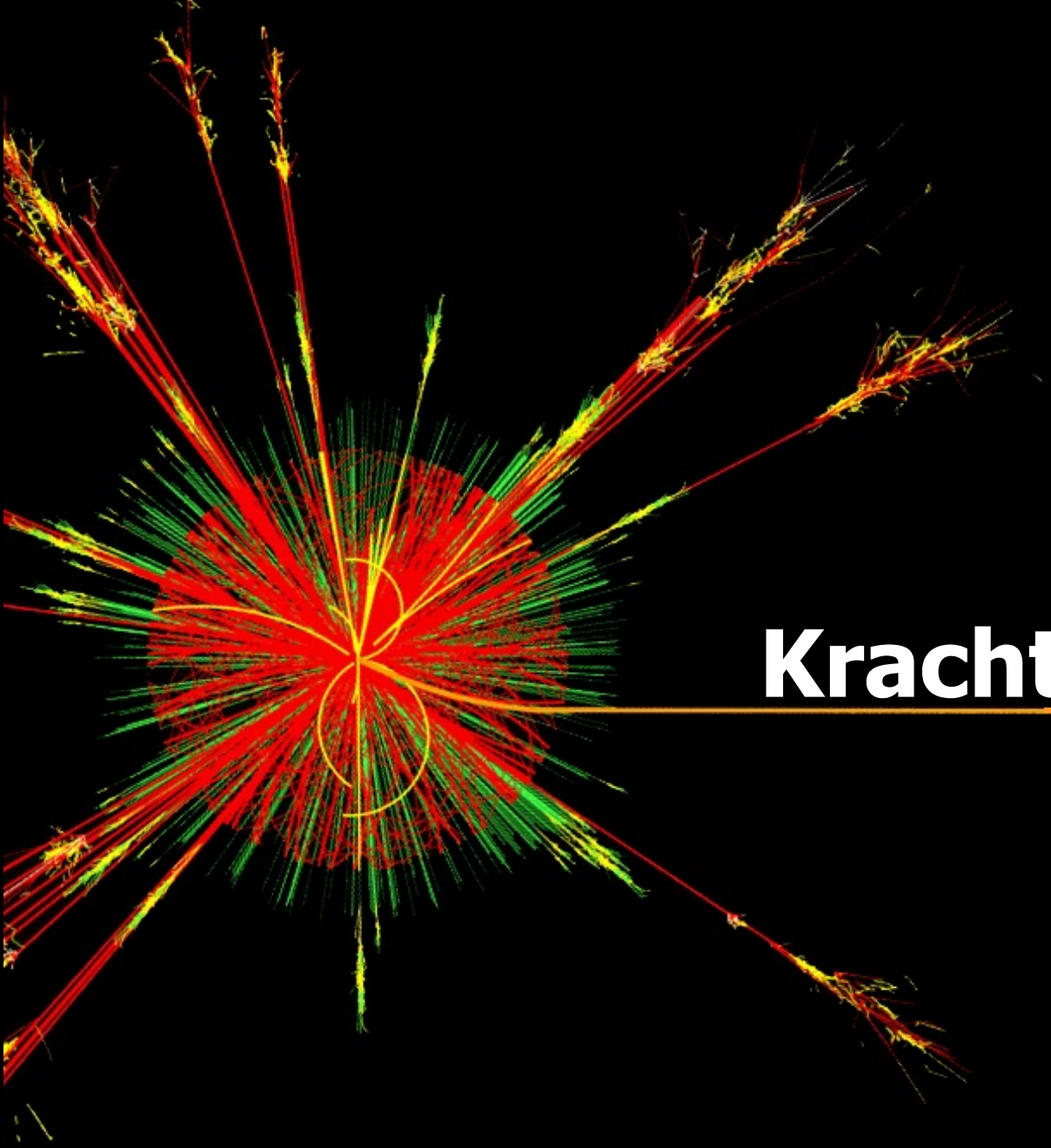
	I	II	III	Lading
quarks	u	c	t	+2/3 e
	d	s	b	-1/3 e
leptons	e	μ	τ	-1 e
	ν_e	ν_μ	ν_τ	0 e

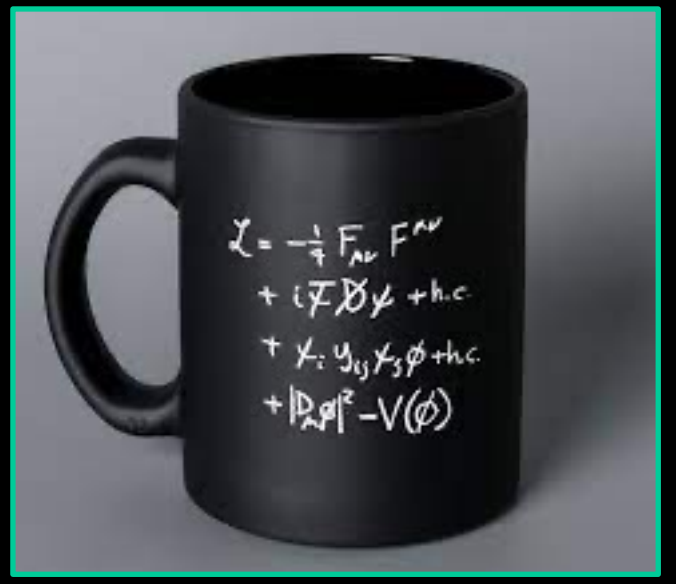
Materie

Lading	I	II	III
-2/3 e	$\bar{u}$	$\bar{c}$	$\bar{t}$
+1/3 e	$\bar{d}$	$\bar{s}$	$\bar{b}$
+1 e	$\bar{e}$	$\bar{\mu}$	$\bar{\tau}$
0 e	$\bar{\nu}_e$	$\bar{\nu}_\mu$	$\bar{\nu}_\tau$

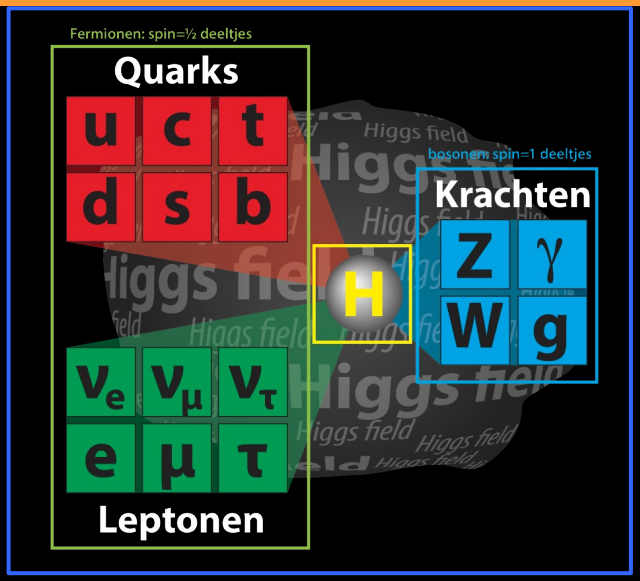
Anti-materie

Waarom 3 “generaties” van deeltjes?





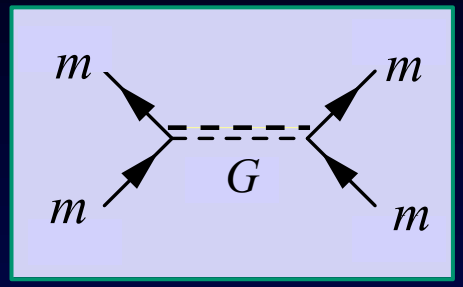
Krachten: “Standaard Model”



Vier fundamentele natuurkrachten

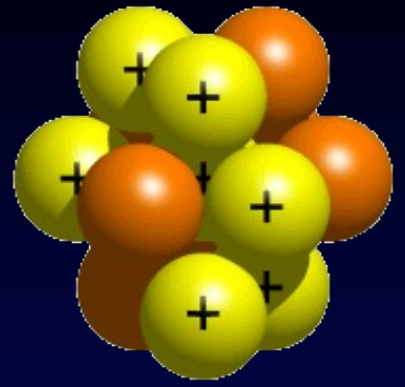
Zwaartekracht:

Quantum
Graviton exchange?



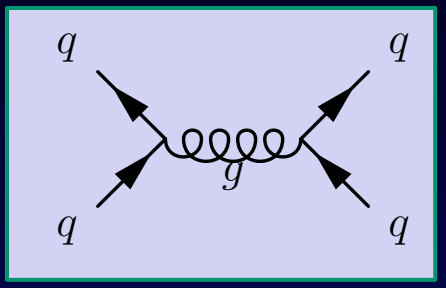
Werkt op alle deeltjes met massa

Sterke kernkracht:



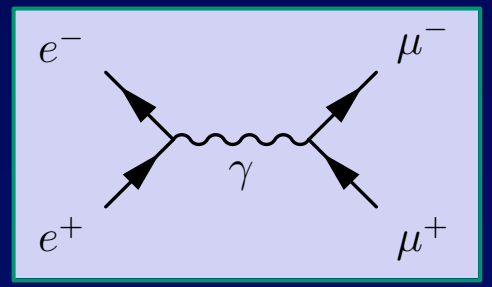
Werkt op alle quarks

Quantum
gluon exchange:



Elektromagnetisme:

Quantum
photon exchange:

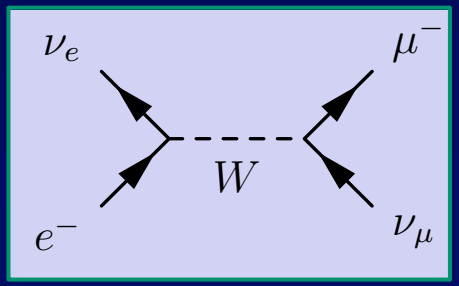


Werkt op alle elektrisch geladen deeltjes

Zwakke kernkracht:

Werkt op alle deeltjes

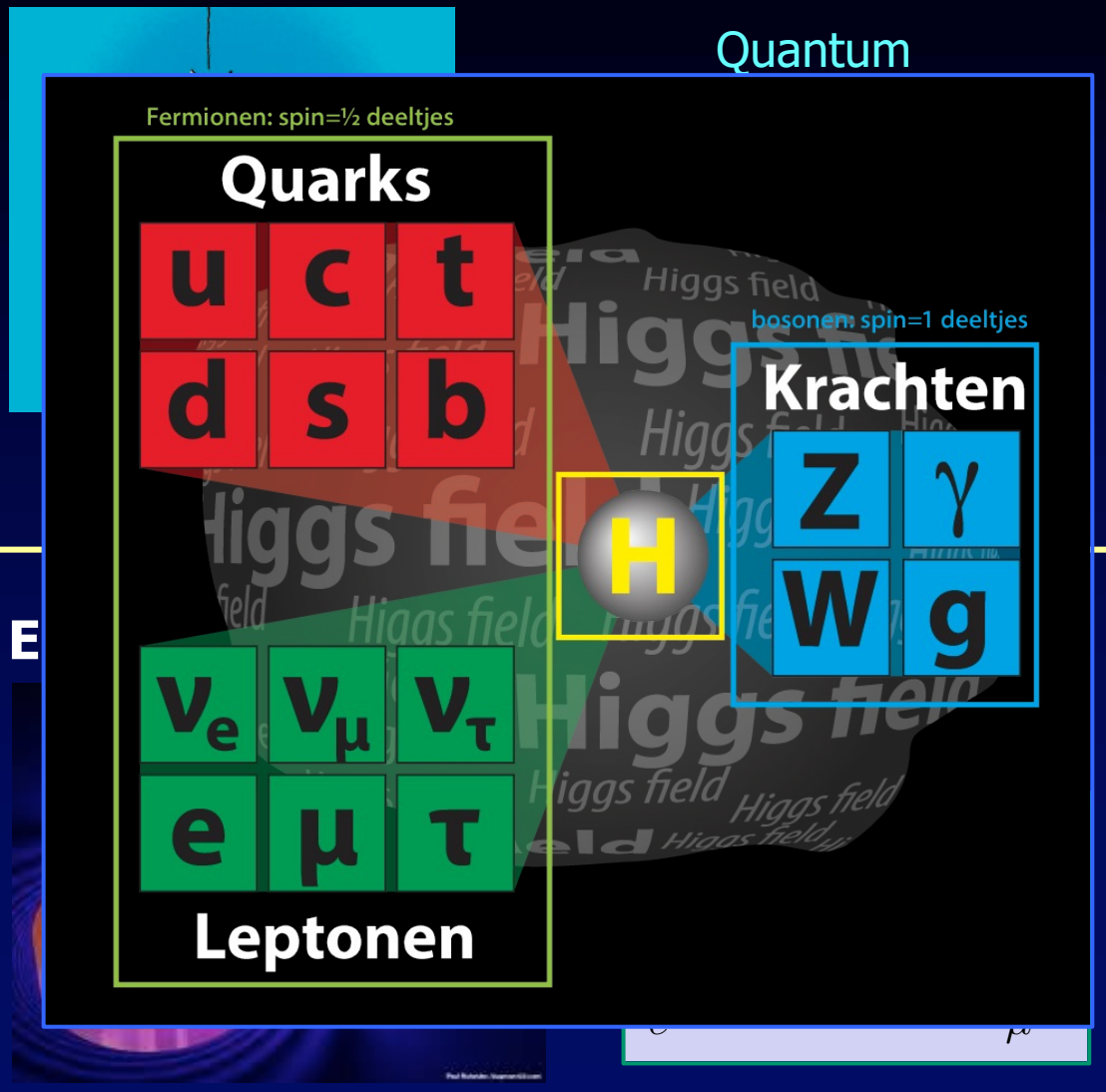
Quantum
W, Z exchange:



Vier fundamentele natuurkrachten

Zwaartekracht:

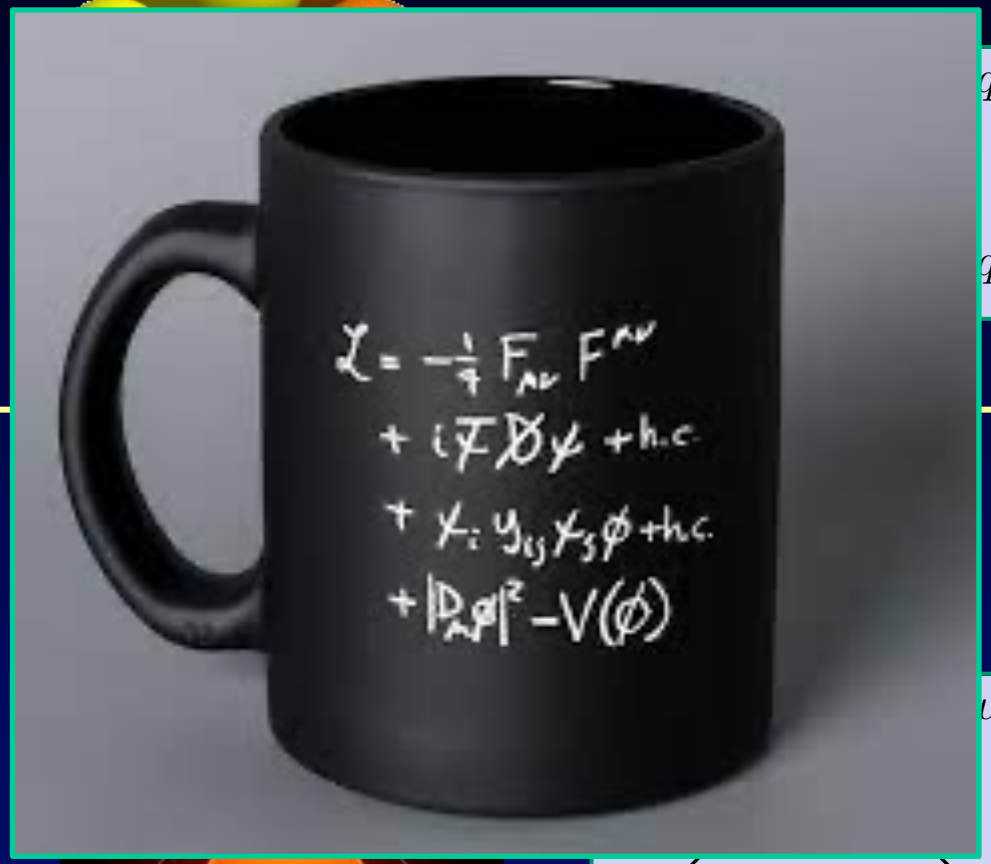
Quantum



Werkt op alle elektrisch geladen deeltjes

Sterke kernkracht:

Quantum
gluon exchange:

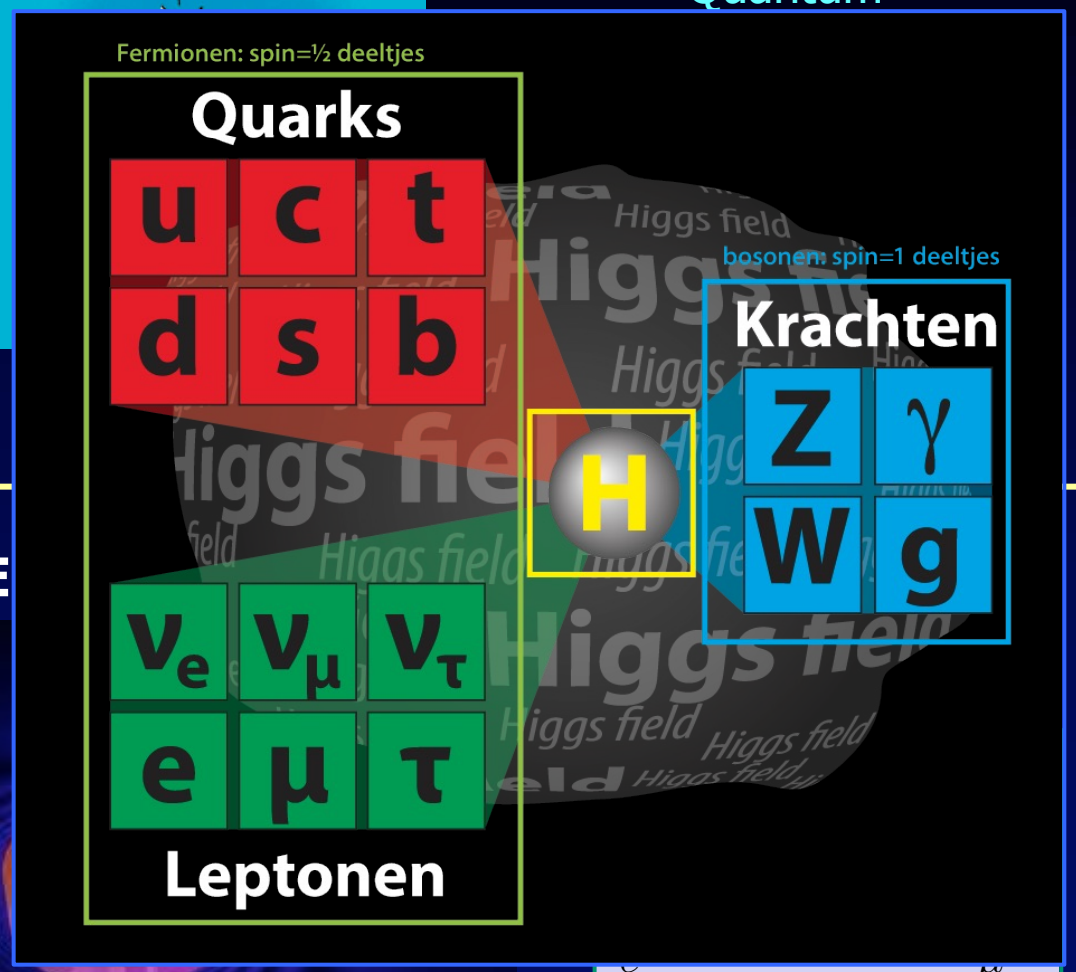


Werkt op alle deeltjes

Vier fundamentele natuurkrachten

Zwaartekracht:

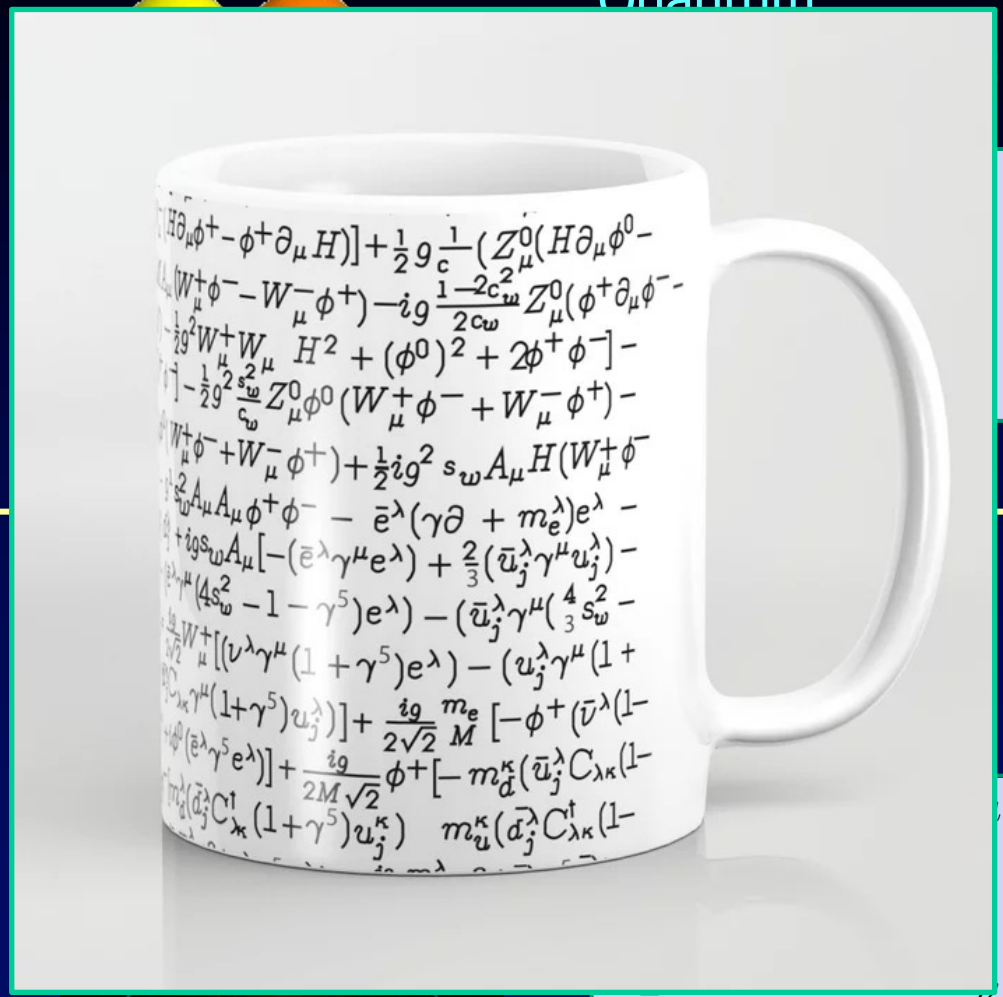
Quantum



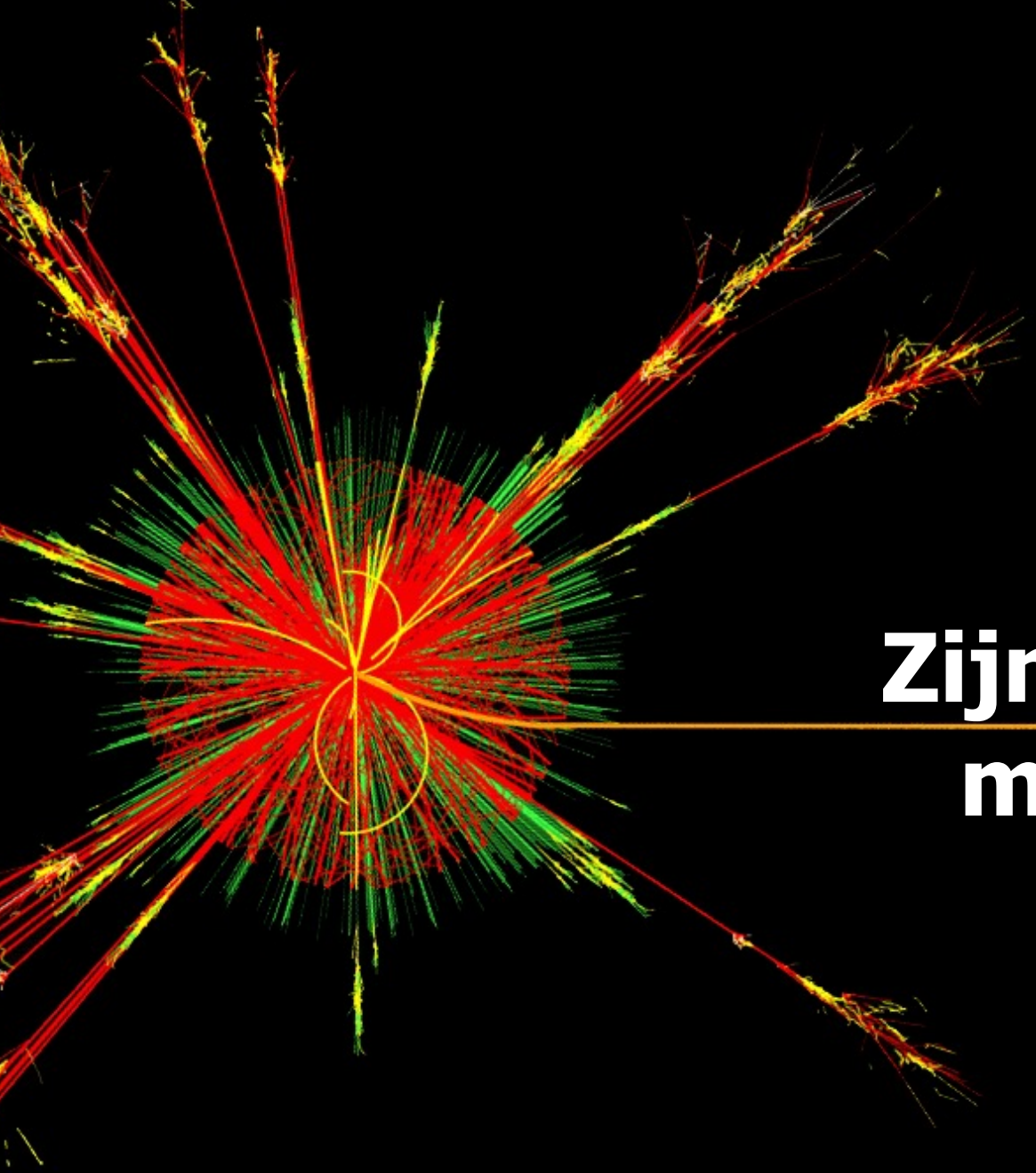
Werkt op alle elektrisch geladen deeltjes

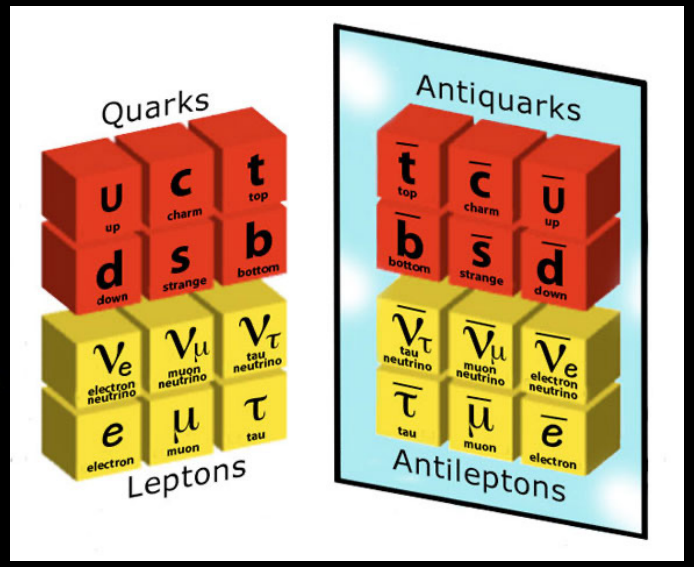
Sterke kernkracht:

Quantum



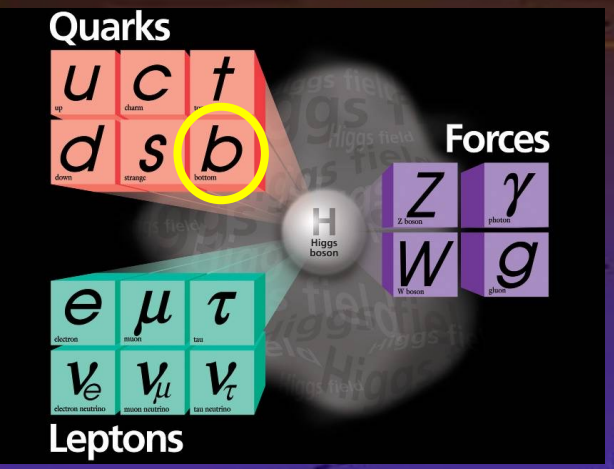
Werkt op alle deeltjes

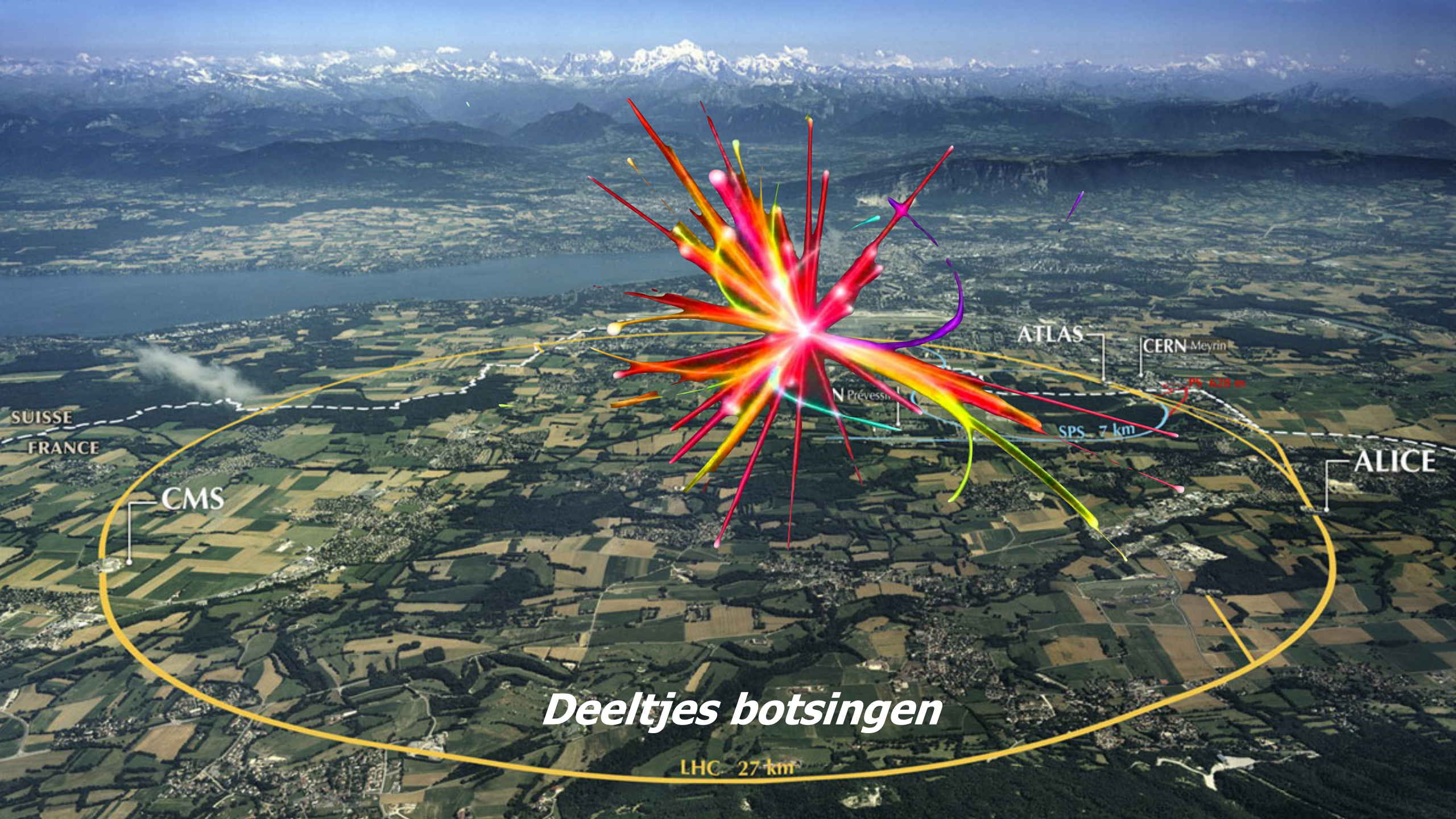




Zijn krachten identiek voor materie and antimaterie?

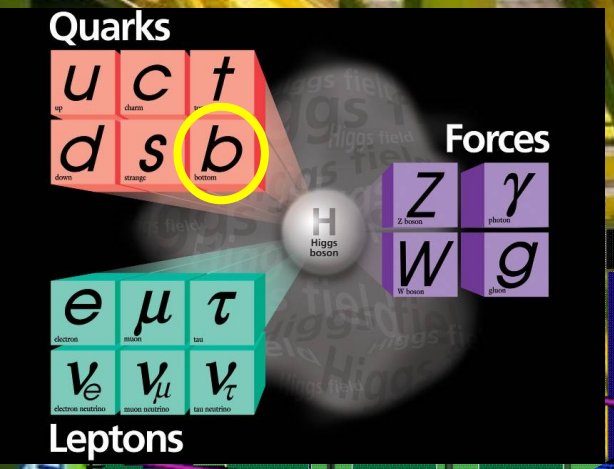
LHCB experiment: vervallen van B deeltjes





Deeltjes botsingen

LHCb Detector: B-particles



Zoom in op botsingspunt

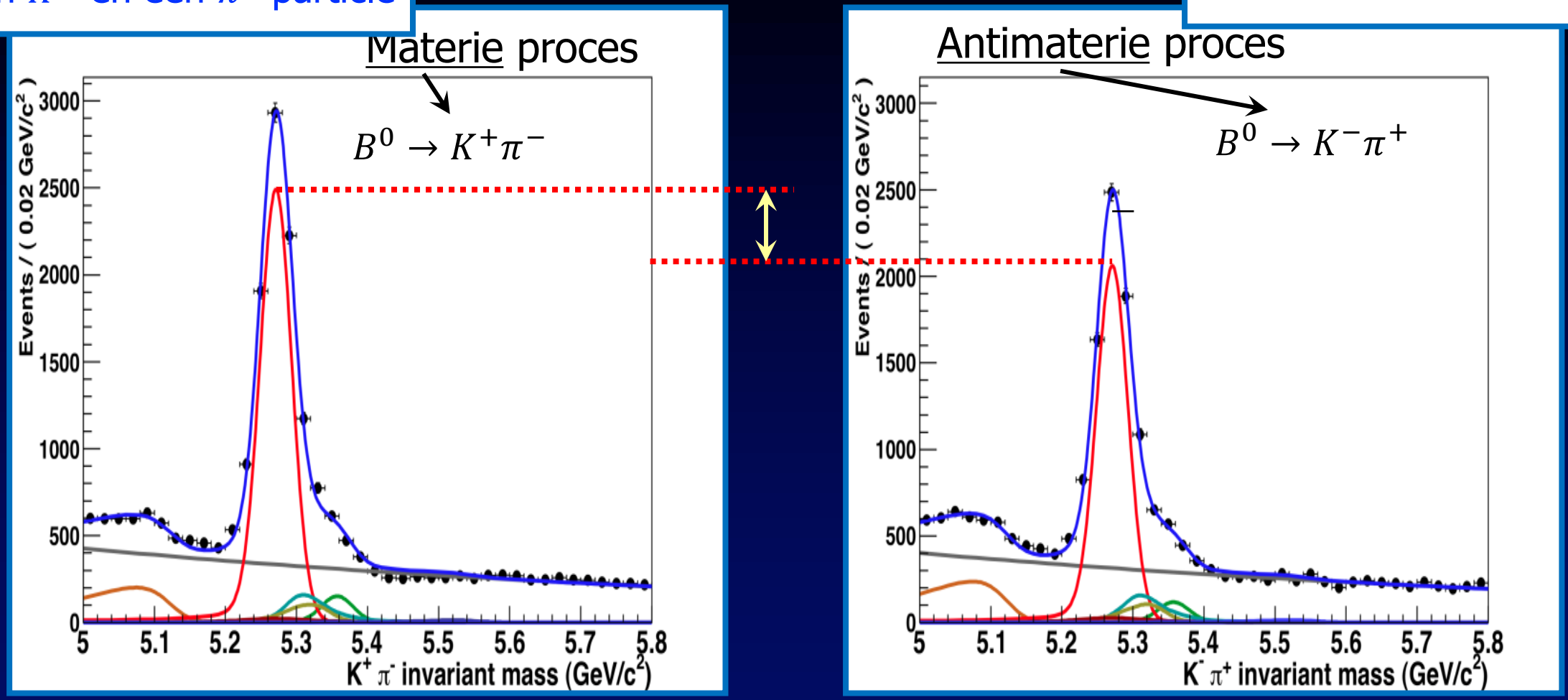
Reconstrueer miljoenen B-deeltjes vervallen en selecteer interesante gevallen.
Is materie anders dan antimaterie?

23 sep 2010 19:49:24
Run 79646 Event 143858637

B-vervalsproces: materie vs antimaterie

B deeltje verval naar een K^+ en een π^- particle

anti-B deeltje verval naar een K^-en een π^+ deeltje



Materie vervalsproces anders dan antimaterie versie!

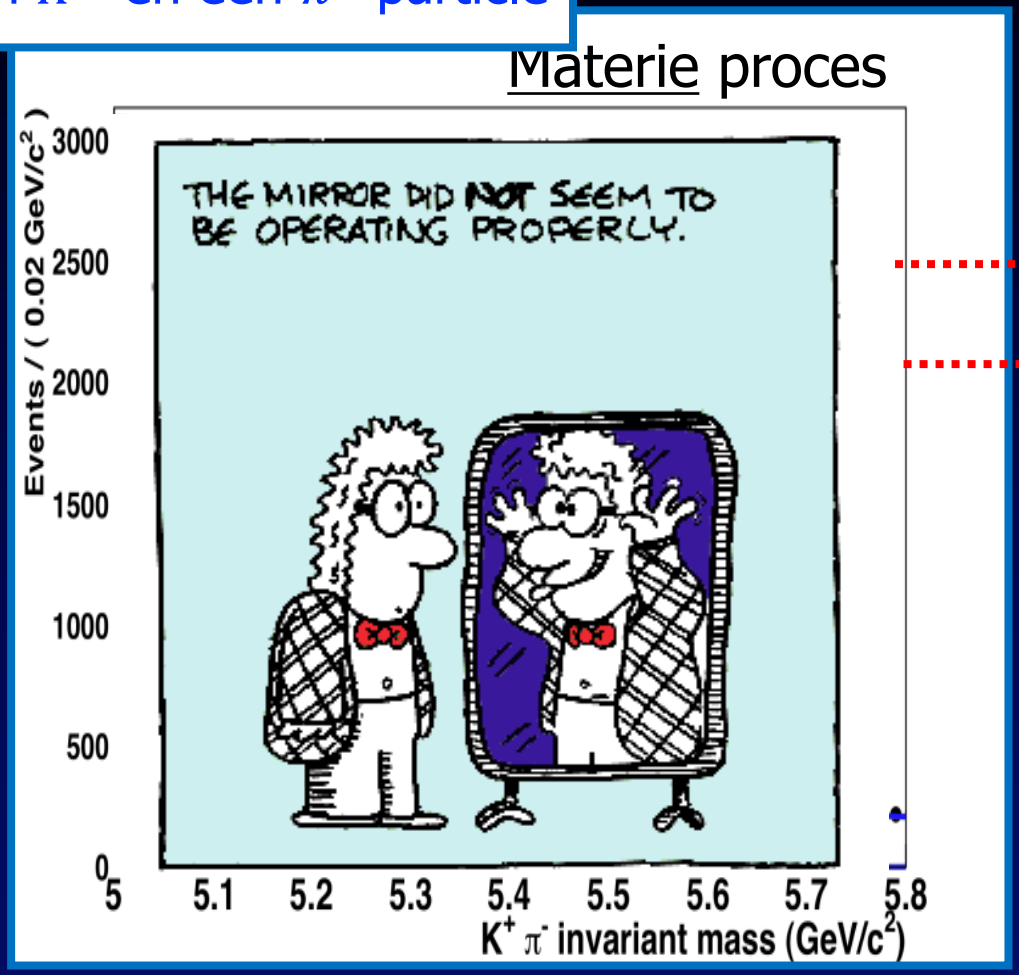
Quantum krachten tussen deeltjes en anti-deeltjes niet geheel identiek!

B-vervalsproces: materie vs antimaterie

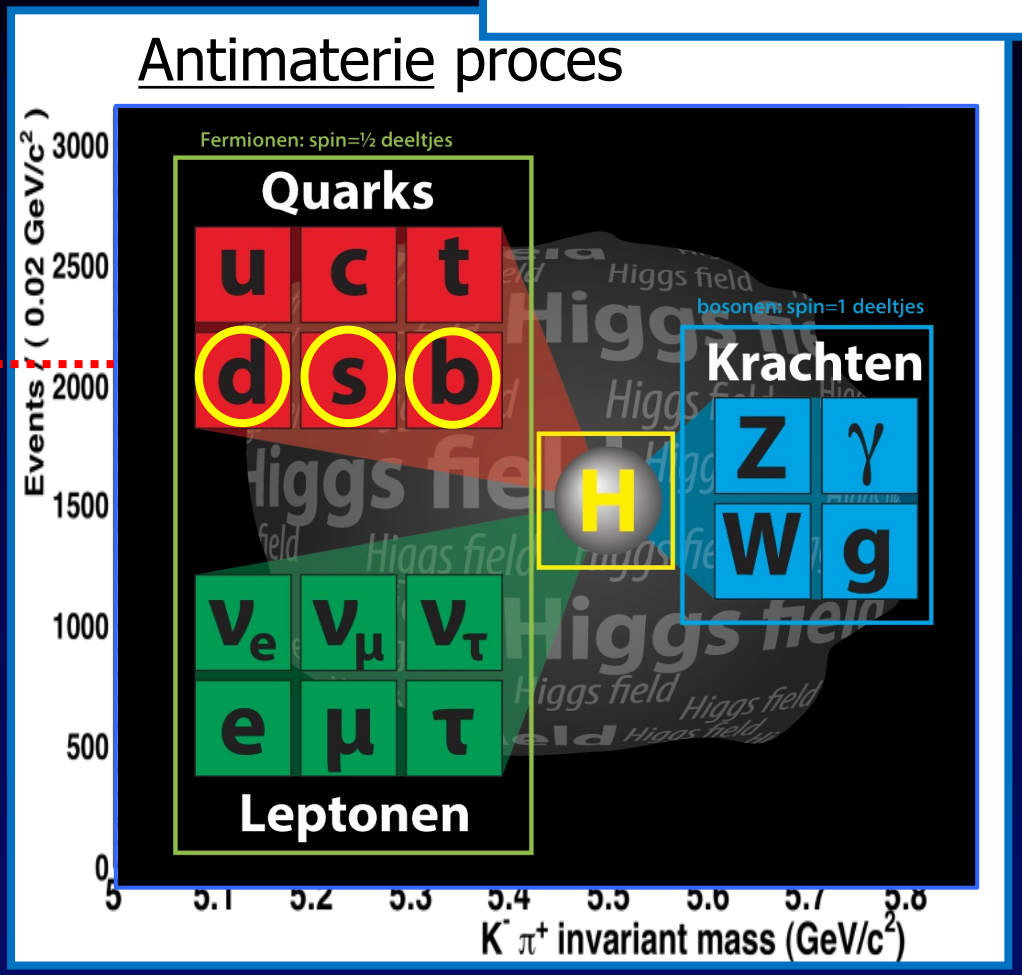
B deeltje verval naar een K^+ en een π^- particle

anti-B deeltje verval naar een K^-en een π^+ deeltje

Materie proces



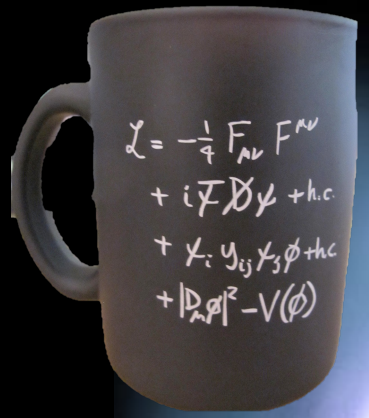
Antimaterie proces



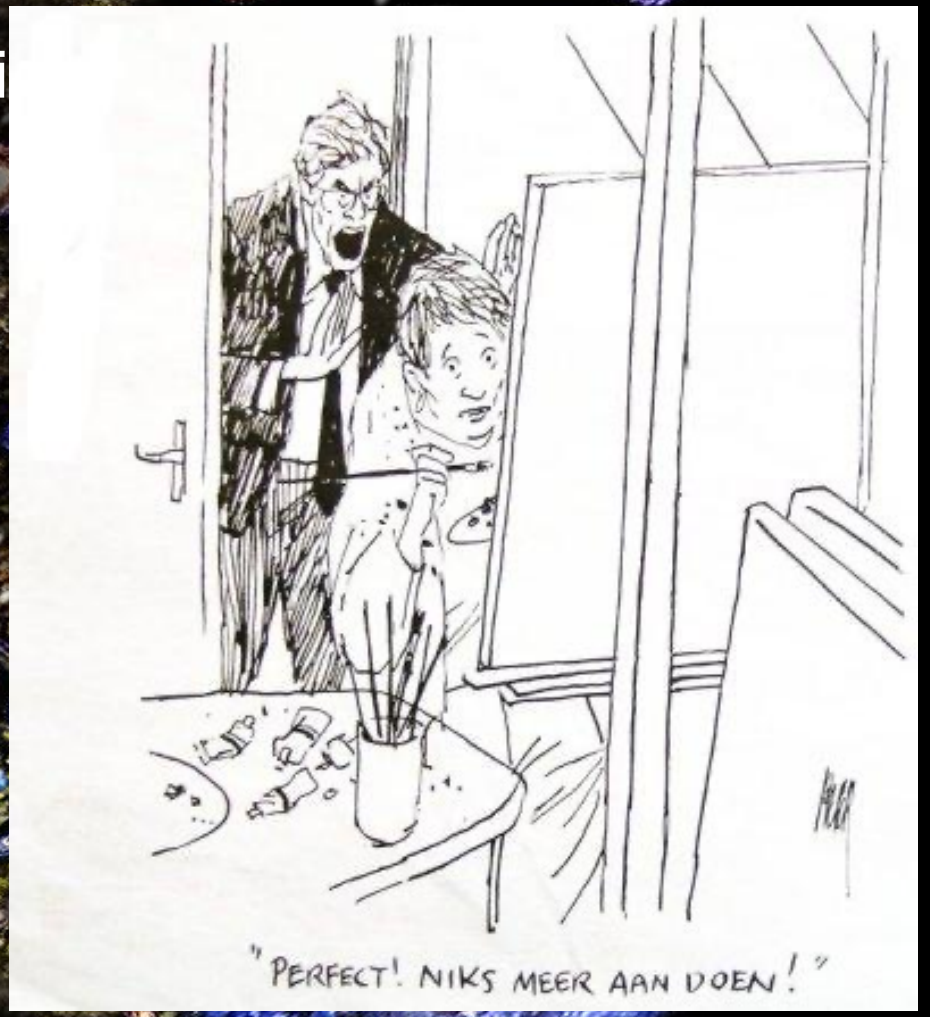
The materie – antimaterie symmetrie is verbroken

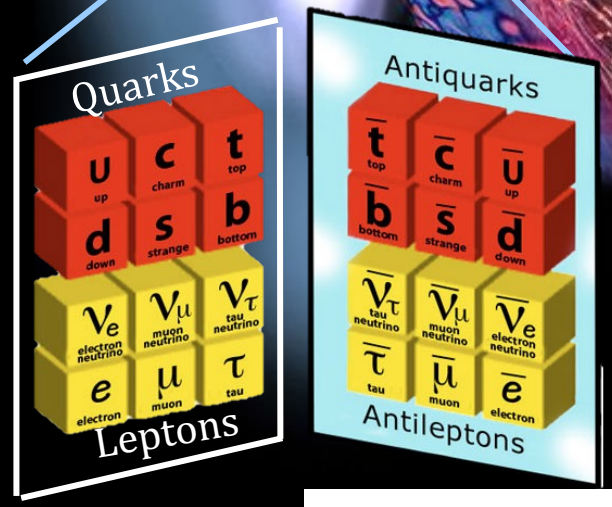
Dit gebeurt ***alleen*** als er tenminste ***drie generaties*** deeltjes bestaan!!!

Vroege Universum: waar is de antimaterie heen?



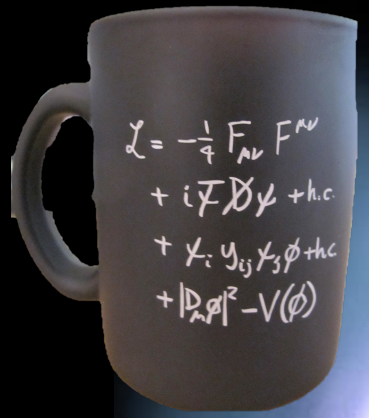
- → Asymmetrie in kracht
- → Beetje meer materie dan antimateri
- → Rest annihileert
- → Materie universum blijft over





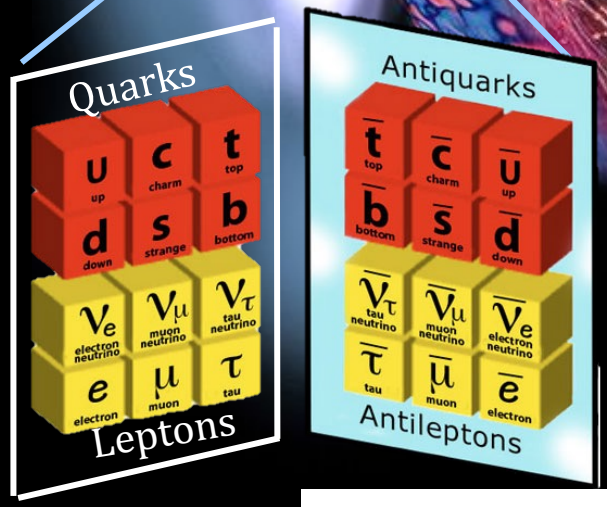
50.000001% | 49.999999%

Vroege Universum: waar is de antimaterie heen?

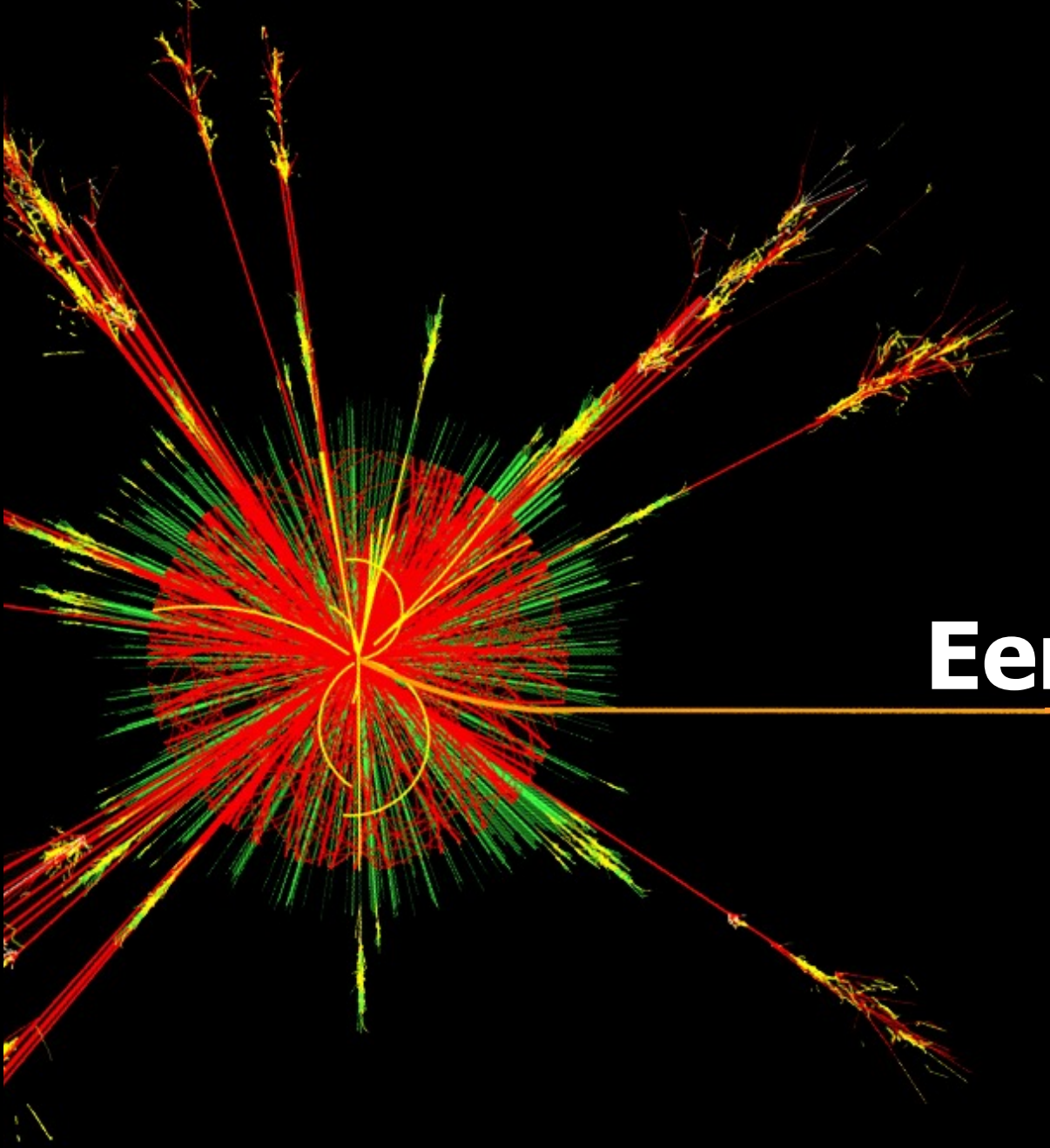


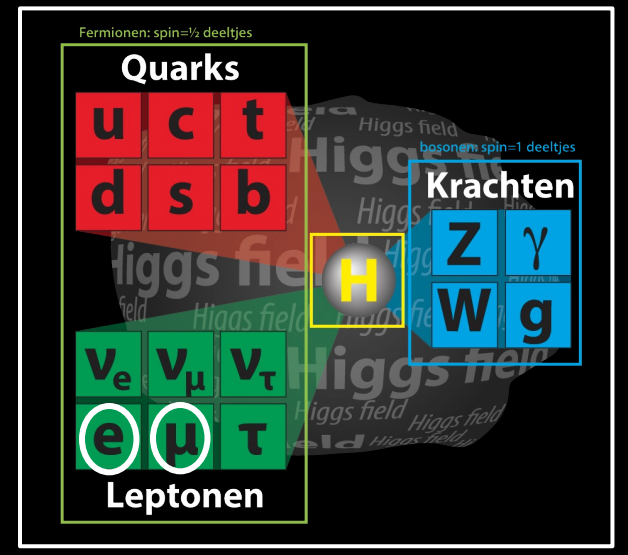
- → Asymmetrie in kracht
- → Beetje meer materie dan antimateri
- → Rest annihileert
- → Materie universum blijft over

Helaas: het werkt niet!
Asymmetrie is *niet groot genoeg.*
Verklaring vereist nieuwe kracht!

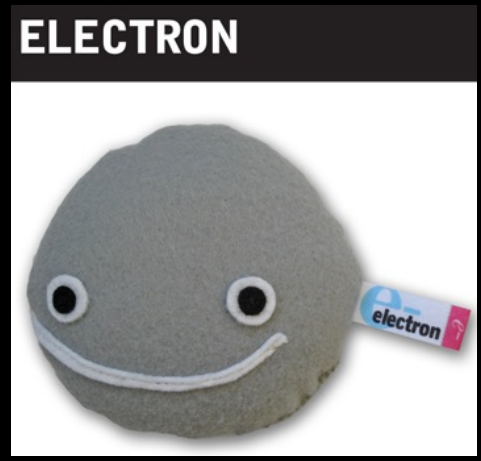


50.000001% | 49.999999%

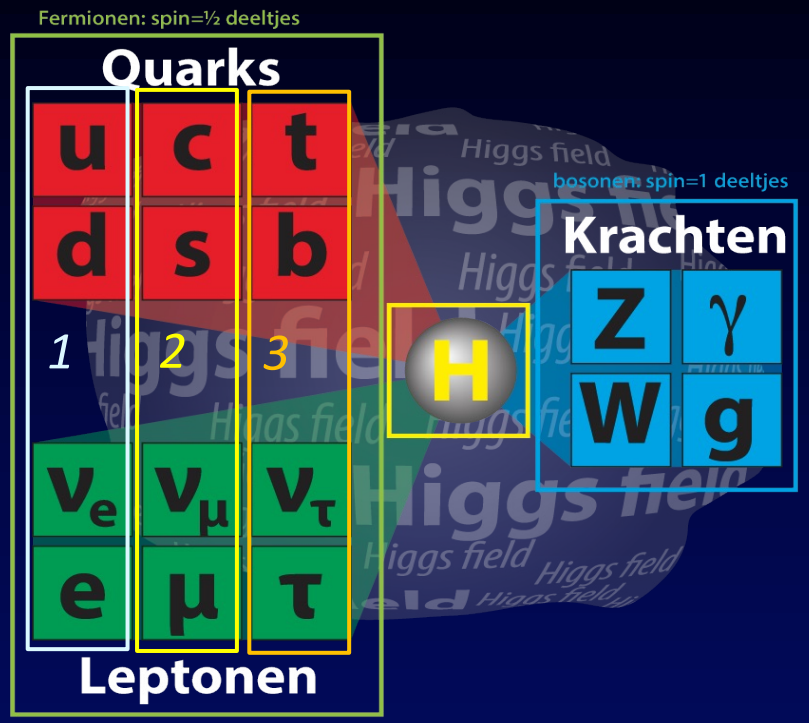


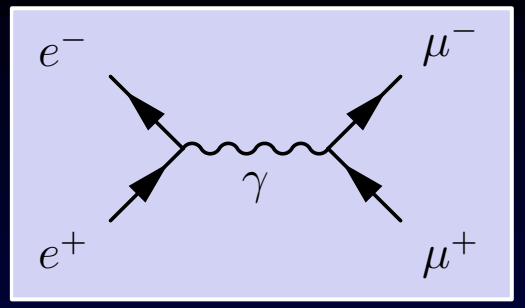


Een nieuwe natuurkracht?

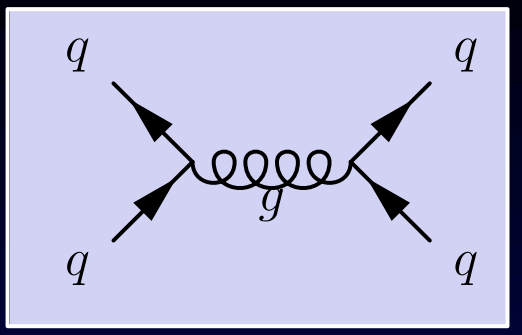


Standaardmodel: Universaliteit van de Krachten

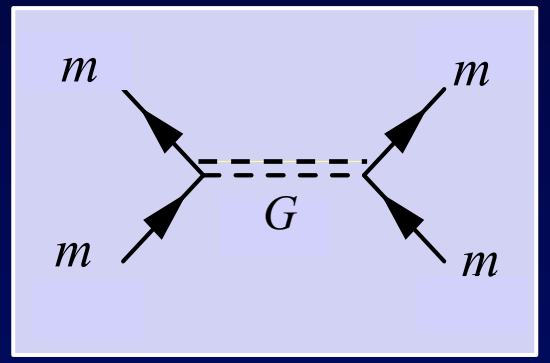




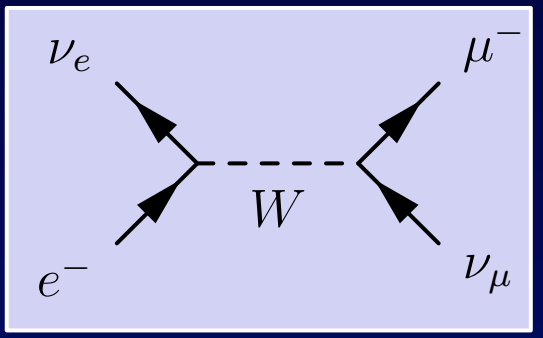
Elektromagnetisme



Sterke kernkracht



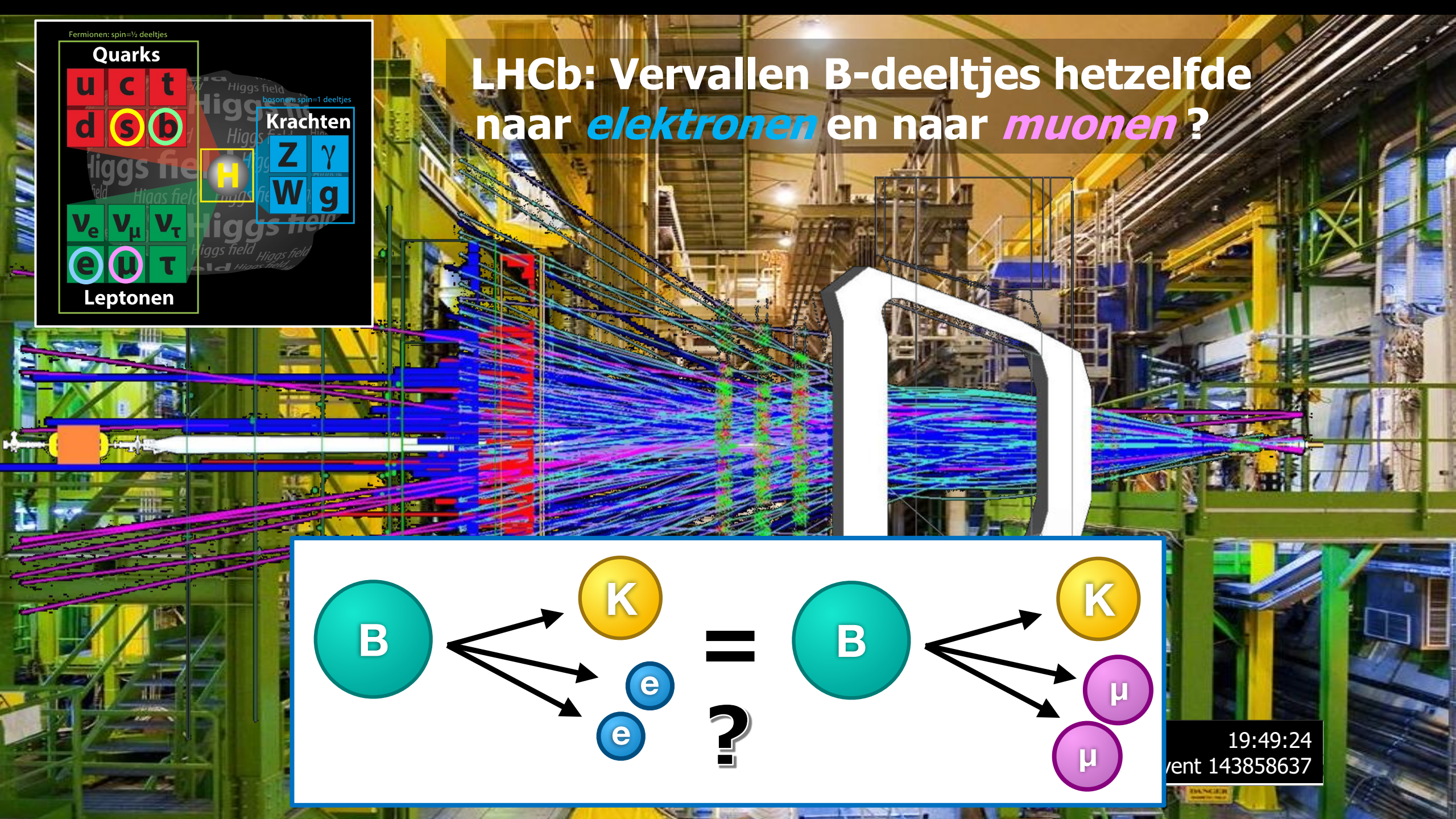
Zwaartekracht



Zwakke kernkracht

Krachten zijn identiek voor deeltjes van 1e, 2e en 3e generatie.

➔ "Universaliteit"


Fermionen: spin=½ deeltjes
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LHCb: Vervallen B-deeltjes hetzelfde naar elektronen en naar muonen ?
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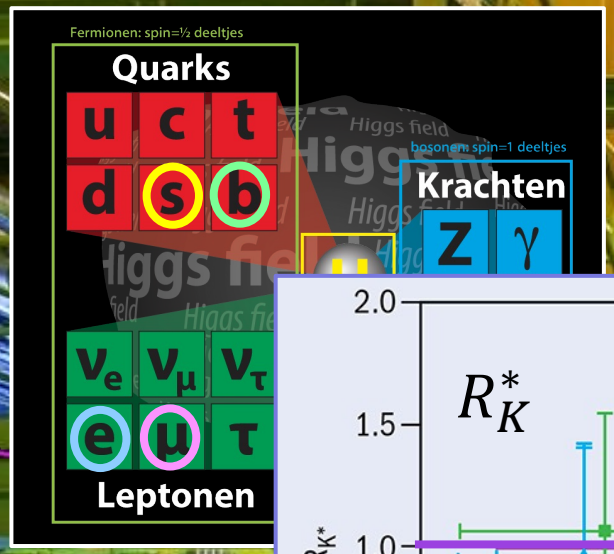
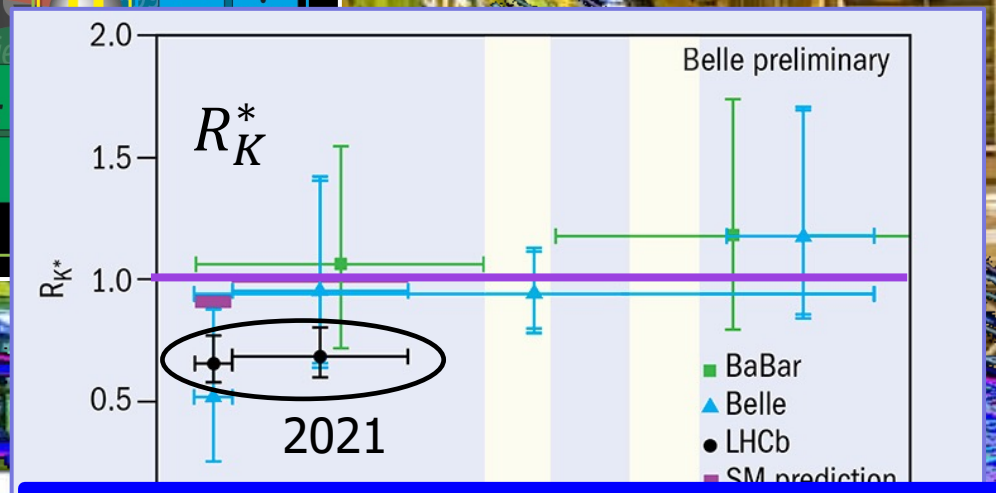
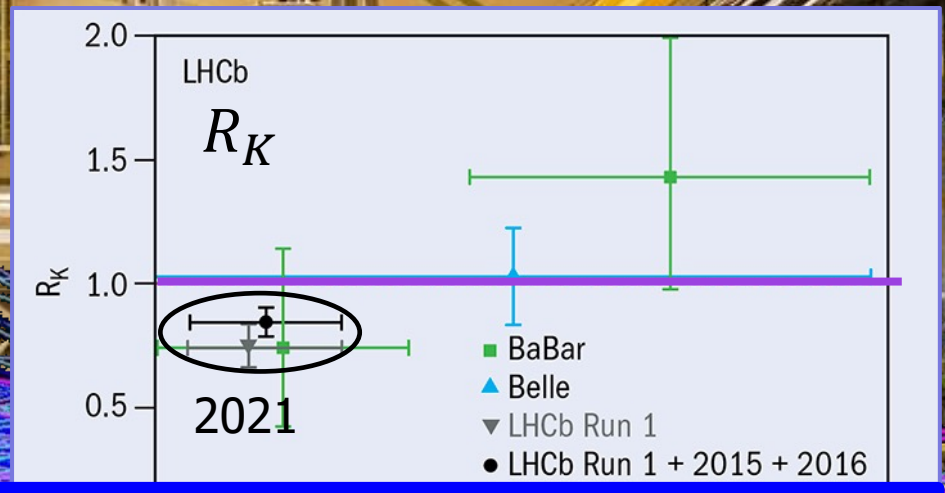
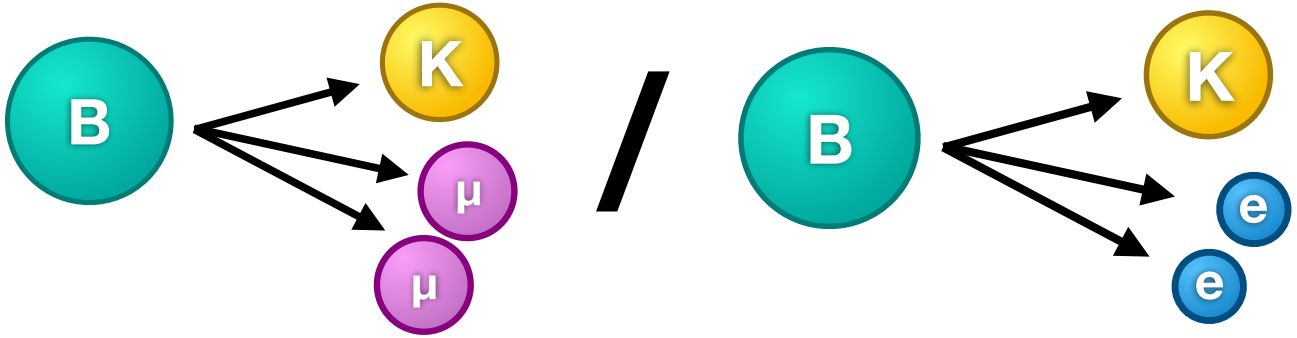


LHCb: Vervallen B-deeltjes hetzelfde naar *elektronen* en naar *muonen* ?





R niet precies gelijk aan 1??
➔ Verschillende kracht voor elektronen and muonen?!



49:24
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23 Maart 2021: Krantenkoppen… “voorzichtige opwinding”

Menu nrc

Voorzichtige opwinding onder fysici: deeltje gedraagt zich vreemd

Deeltjesfysica Het muon, het zware broertje van het elektron, gedraagt zich niet altijd als verwacht. Dat kán duiden op een barstje in het standaardmodel.

Margriet van der Heijden 23 maart 2021 Leestijd 3 minuten

Cern experiment hints at new force of nature - *Guardian*

Experts reveal ‘cautious excitement’ over unstable particles that fail to decay as standard model suggests

Zijn we een nieuwe natuurkracht met muonen aan het ontdekken?!

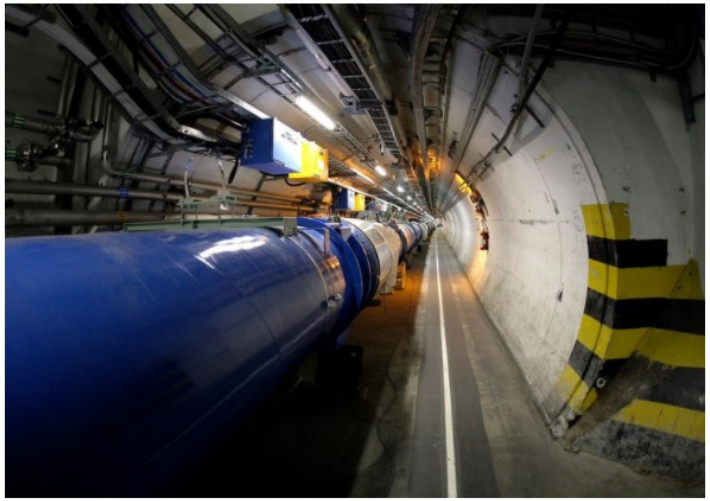
deVolkskrant

NIEUWS

Natuurkundigen van Cern vinden aanwijzing die ons begrip van de werkelijkheid op zijn kop kan zetten

Een gloednieuw deeltje, een nog onbekende natuurkracht… fysici bij onderzoeksinstituut Cern zien ijkheid op z’n nd. ‘Dit is

George van Hal 23 maart 2021, 9:00



De tunnel van deeltjesversneller LHC bij Cern, Genève. In de blauwe buis zwiepen deeltjes met bijna de lichtsnelheid rond tot ze op elkaar knallen. Tussen de brokstukken van die botsing zoeken fysici naar aanwijzingen voor hoe de wereld op het kleinste niveau werkt. Beeld AP

TELEGRAAF.NL

Experts zijn nieuwe natuurkracht op het spoor: ’We trilden helemaal’

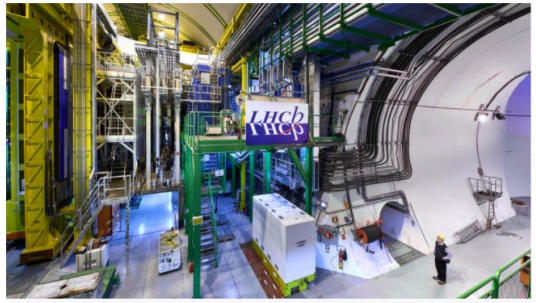
Na de vondst van het Higgs-deeltje, negen jaar geleden, klinken er nu opnieuw opgetogen …

NEWS / LIFE

CERN data on ‘beauty quarks’ behaviour may rewrite physics as we know it

24 MAR 2021

Beauty quarks or B mesons particles are not decaying as they should and while the findings may warrant “cautious excitement”, more research needs to be done, scientists say.



FILE PHOTO: A view of the Large Hadron Collider at CERN, near Geneva, Switzerland. (CERN)

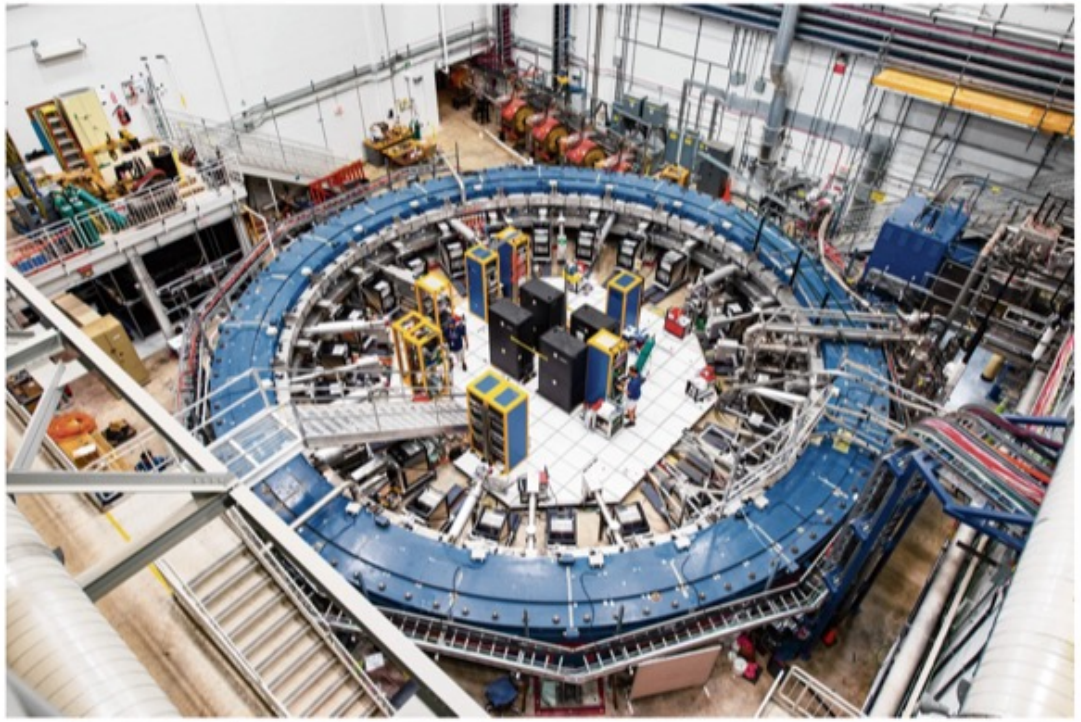
Twee weken later in Fermilab … muon magnetisch moment?!

Menu nrc

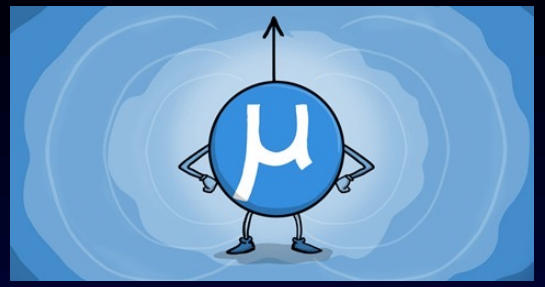
Opnieuw barstje in standaardmodel van deeltjesfysica

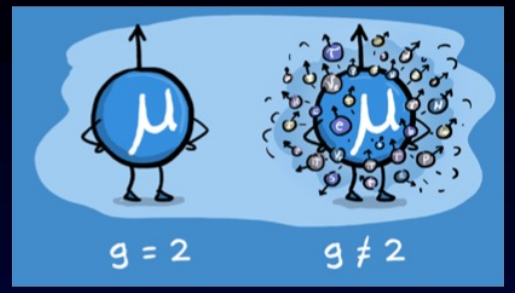
Natuurkunde Gaat het standaardmodel van de deeltjesfysica breken? Resultaten uit een Amerikaans experiment leiden tot opwinding.

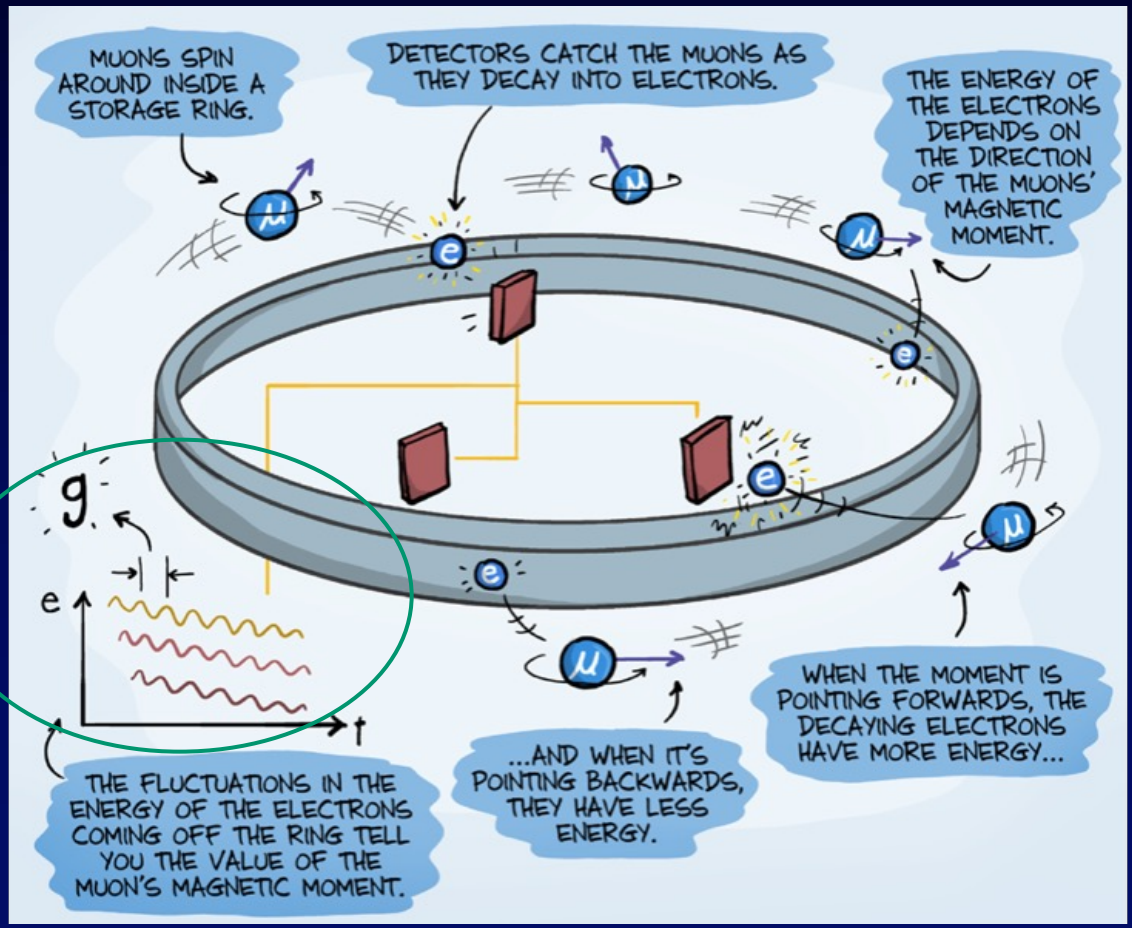
Dorine Schenk 7 april 2021 Leestijd 3 minuten



De Muon g-2-ring in het Fermilab in de buurt van Chicago. Het experiment wordt uitgevoerd bij een temperatuur van -268 graden Celsius.
Foto Reidar Hahn/Fermilab

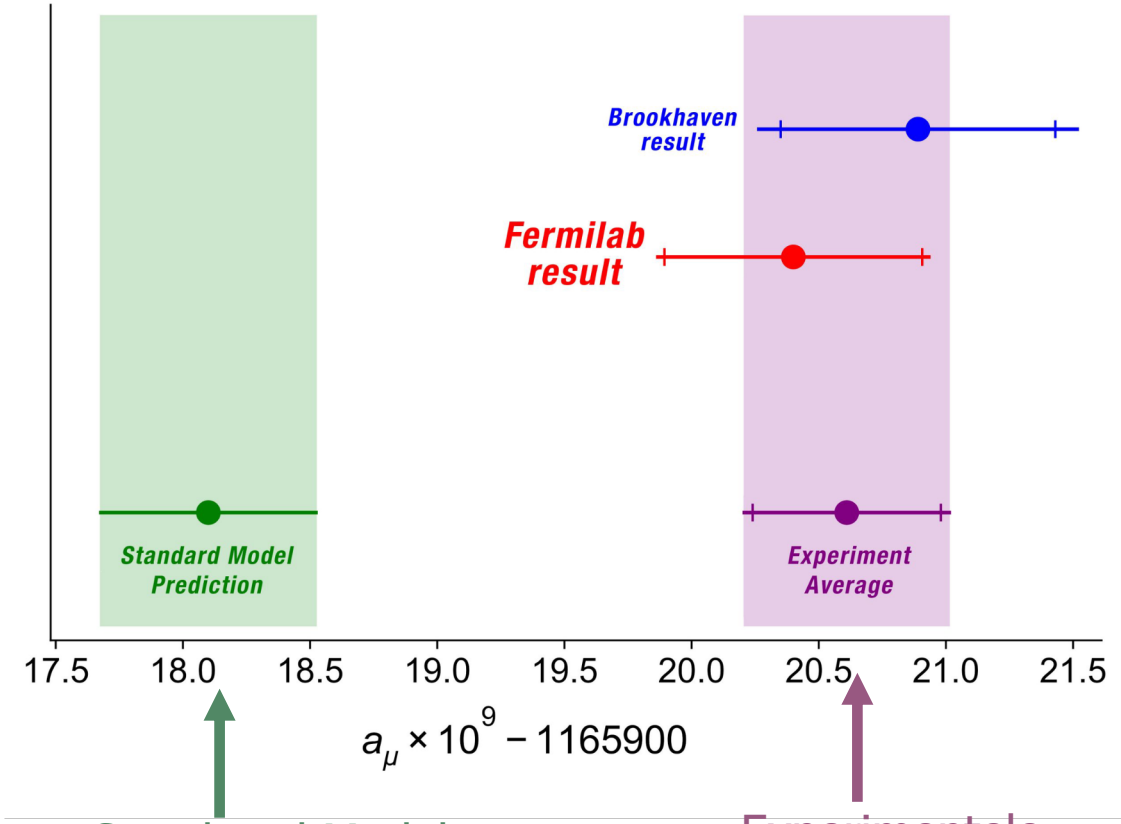






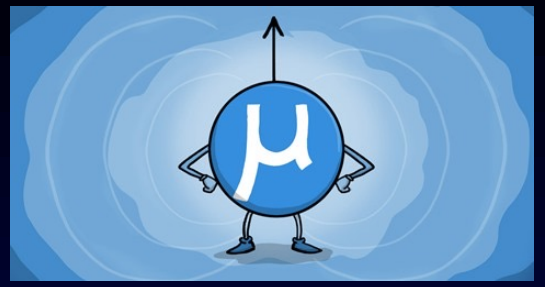
Twee weken later in Fermilab … muon magnetisch moment?!

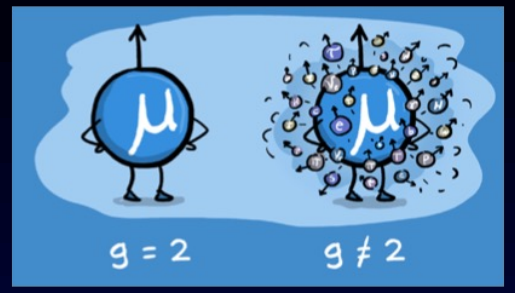
Het Standaardmodel lijkt niet te voldoen
➔ Een nieuwe quantum kracht nodig?!

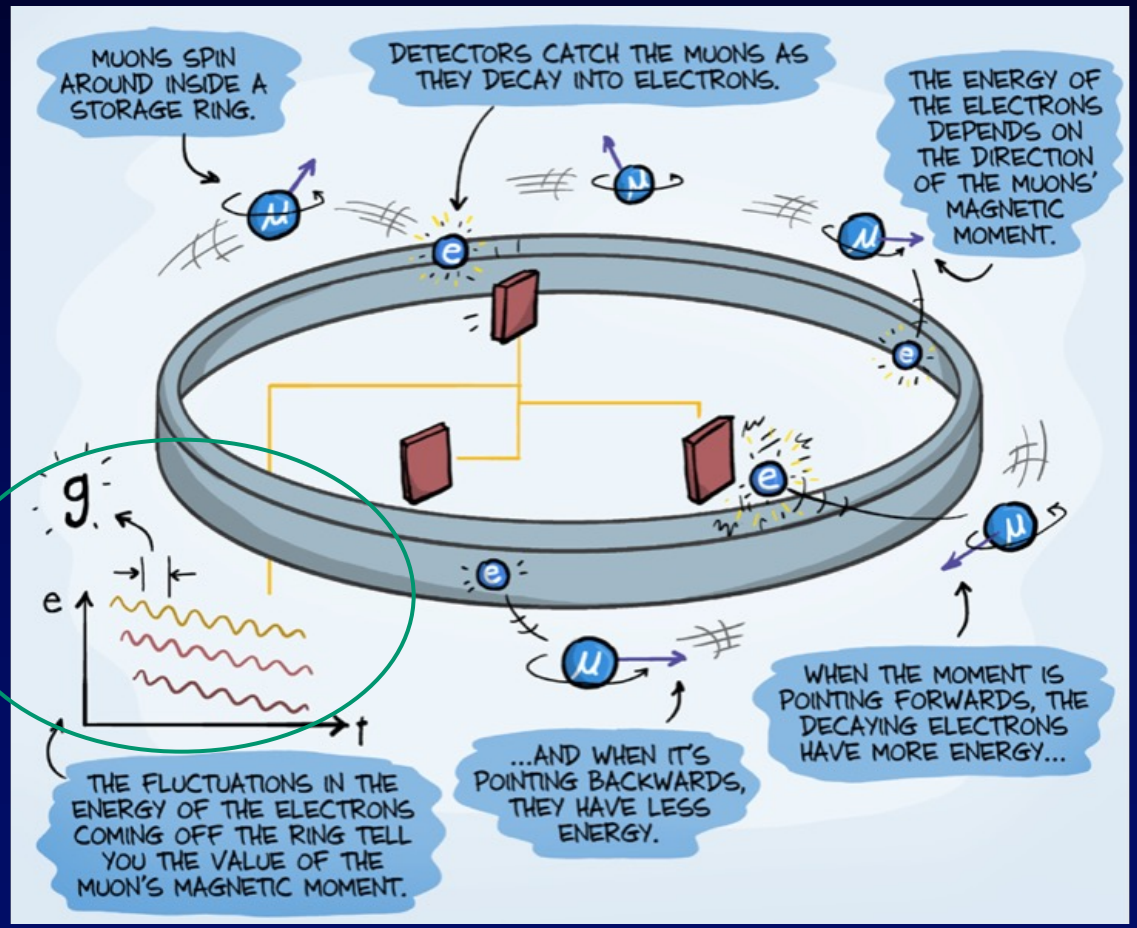


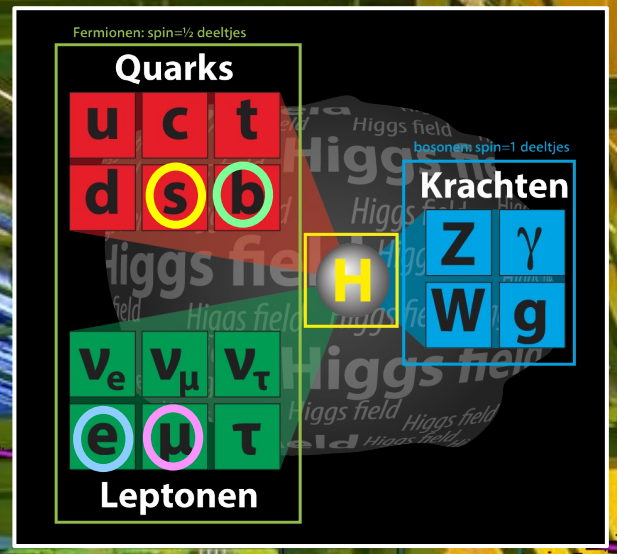
Standaard Model voorspelling

Experimentele meting

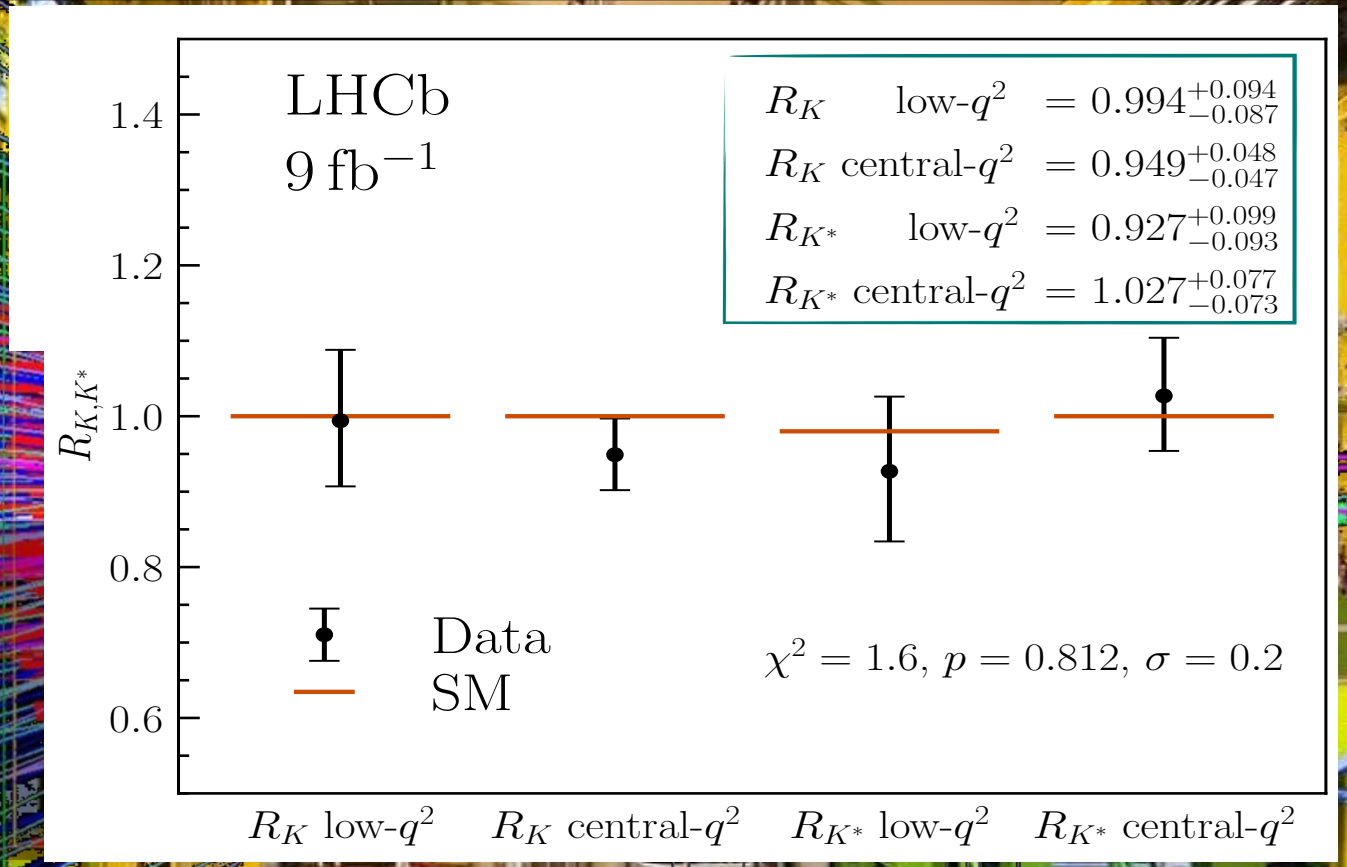




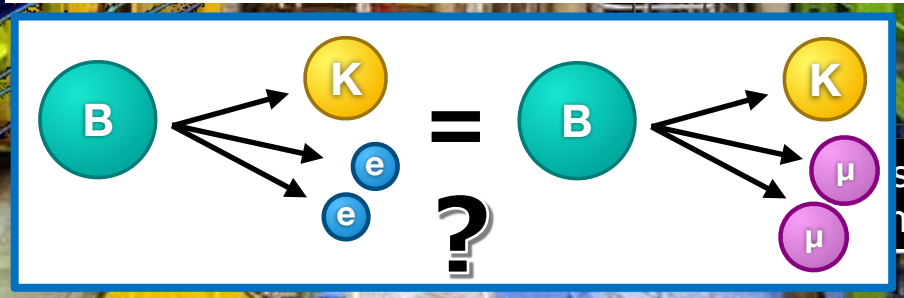


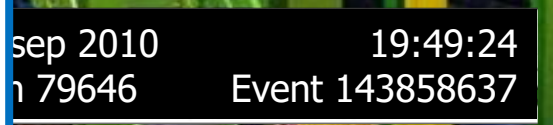


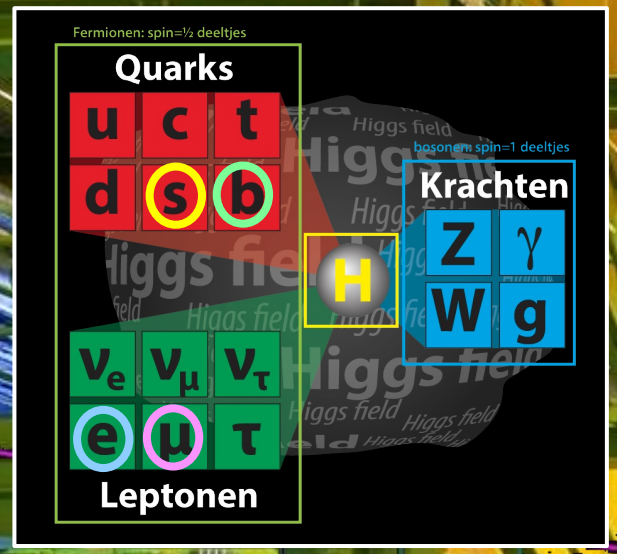
LHCb: Vervallen B-deeltjes hetzelfde naar *elektronen* en naar *muonen* ?



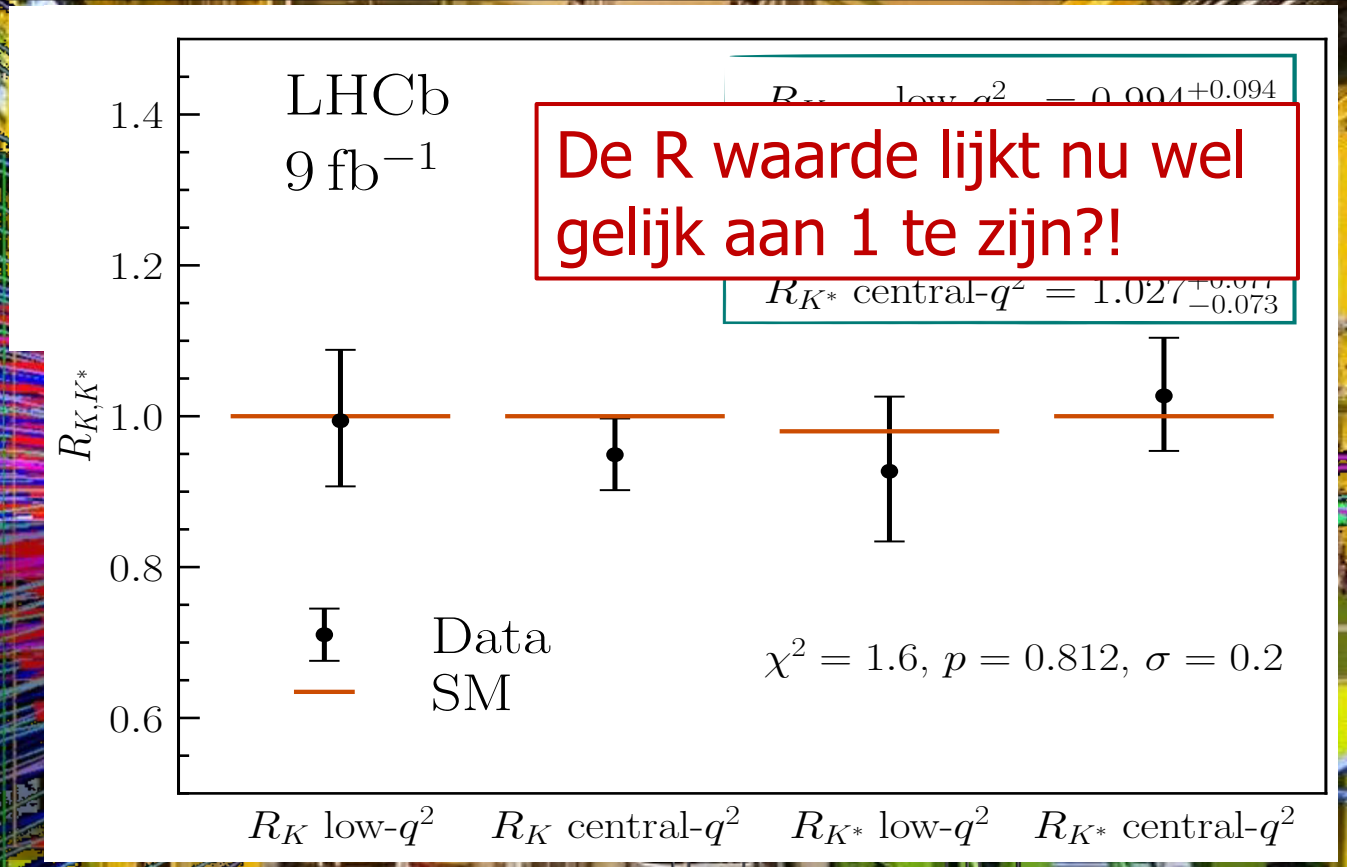
December 2022: verbeterde meting van de elektronen...



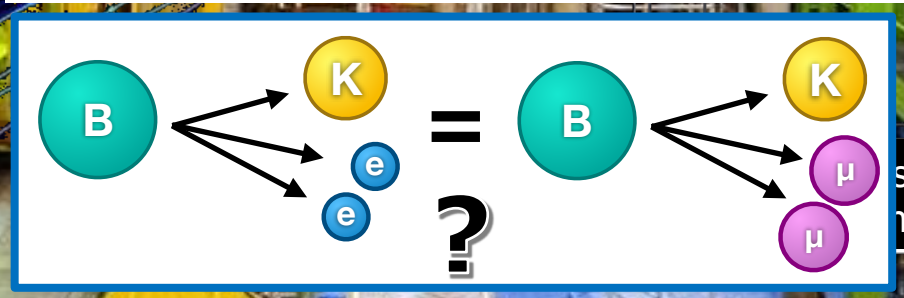




LHCb: Vervallen B-deeltjes hetzelfde naar *elektronen* en naar *muonen* ?

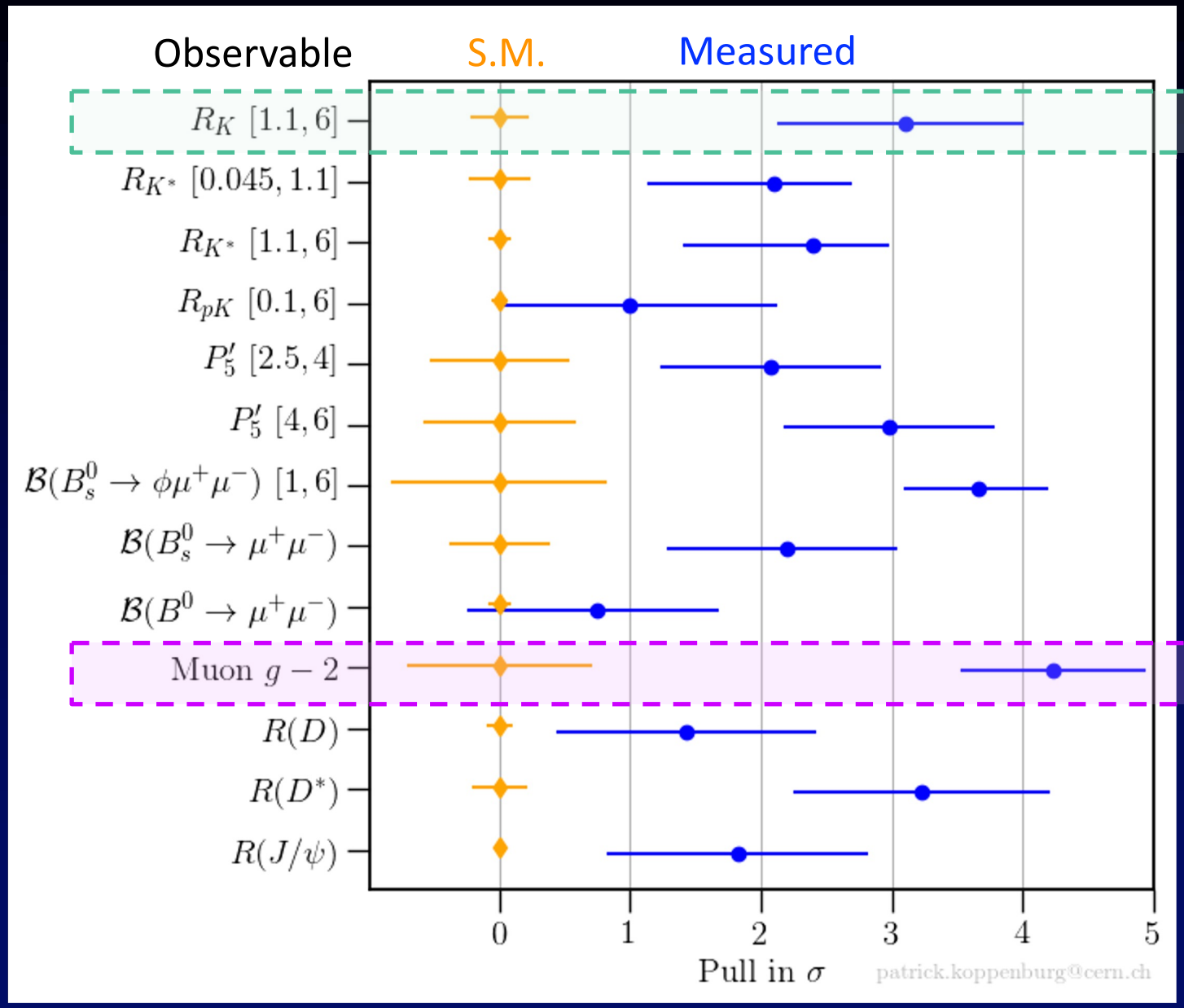


December 2022: verbeterde meting van de elektronen…



sep 2010 19:49:24
n 79646 Event 143858637

Maar bij het *muon* kloppen steeds meer metingen niet!



LHCb resultaat

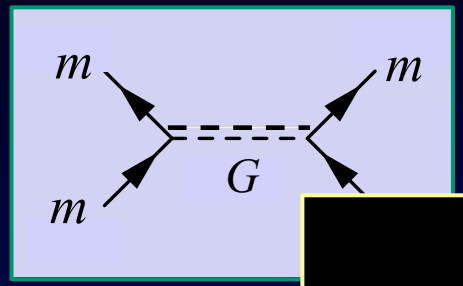
Fermilab g-2 resultaat

De puzzel wordt steeds dieper.

Vier(?) fundamentele natuurkrachten

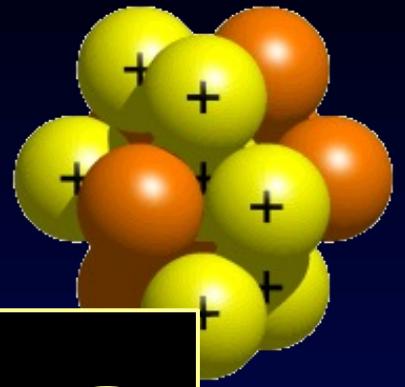
Zwaartekracht:

Quantum
Graviton exchange?



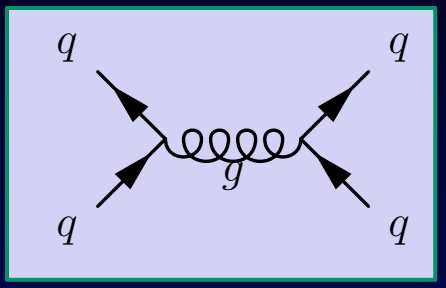
Werkt op alle deeltjes met massa

Sterke kernkracht:



alle quarks

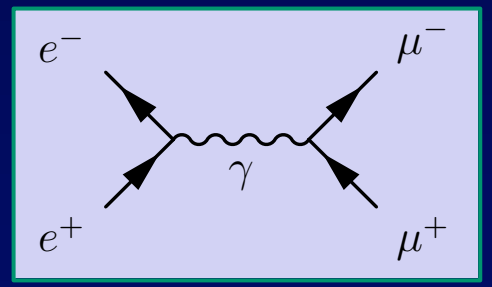
Quantum
gluon exchange:



+ ??? Vijfde kracht?

Elektromagnetisme:

Quantum
photon exc

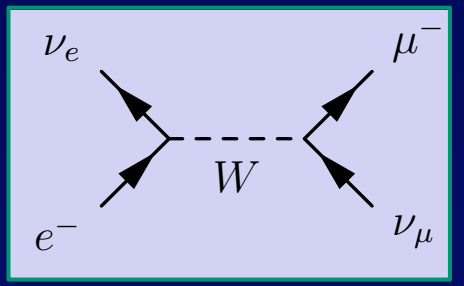


Werkt op alle elektrisch geladen deeltjes

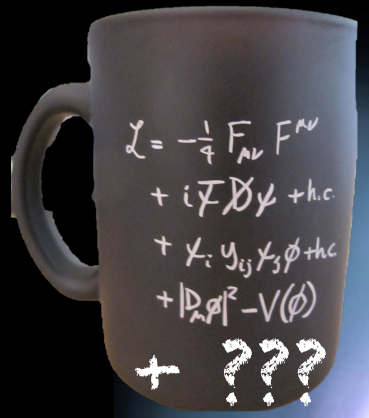
kernkracht:

Werkt op alle deeltjes

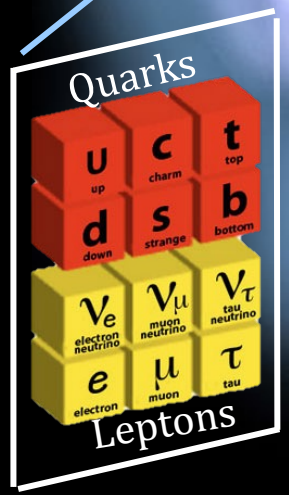
Quantum
W, Z exchange:

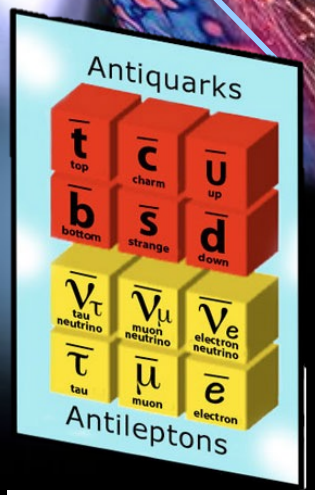


Conclusie: Hoe is de antimaterie verdwenen in het universum?



Door een vijfde kracht in de Big Bang?!



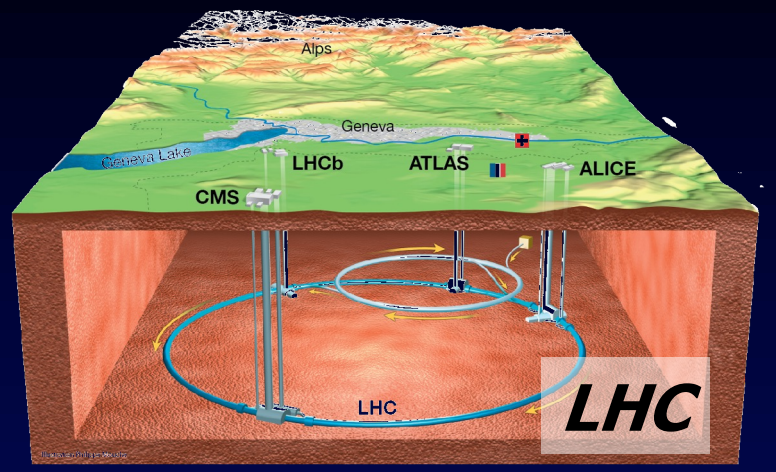


50.000001%

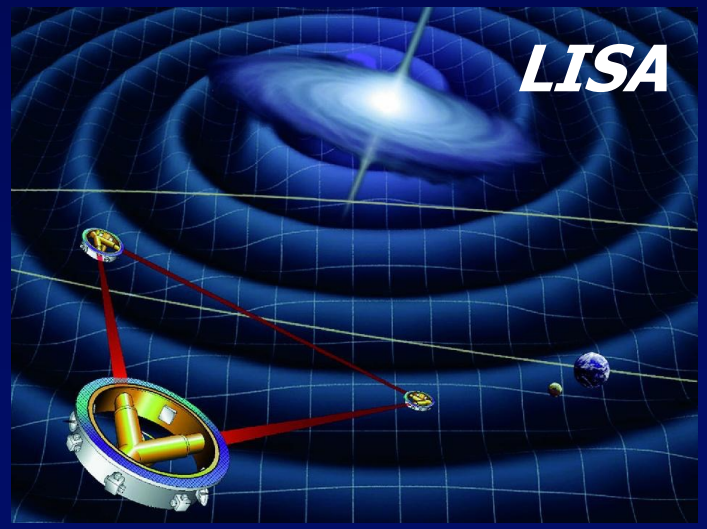
49.999999%

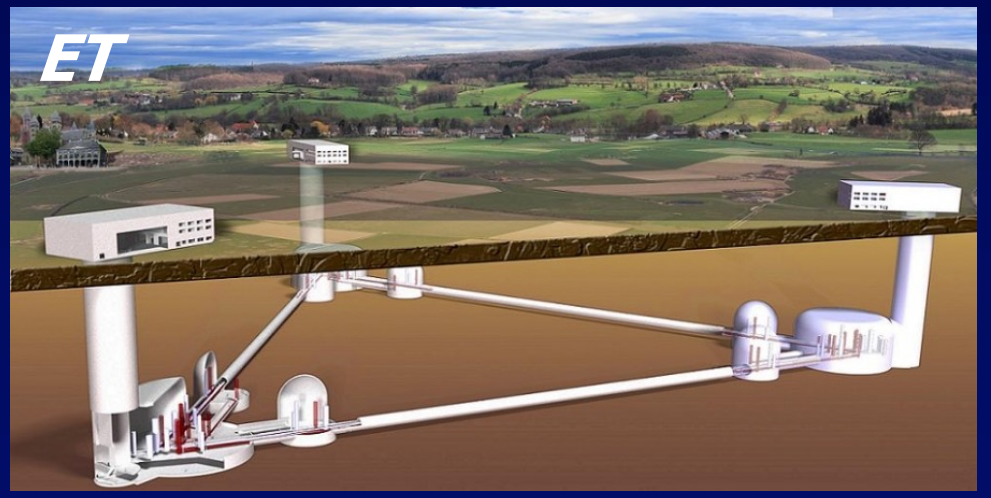
Toekomst: “Cirkels en Driehoeken”

Deeltjesversnellers: fysica van de Big Bang …



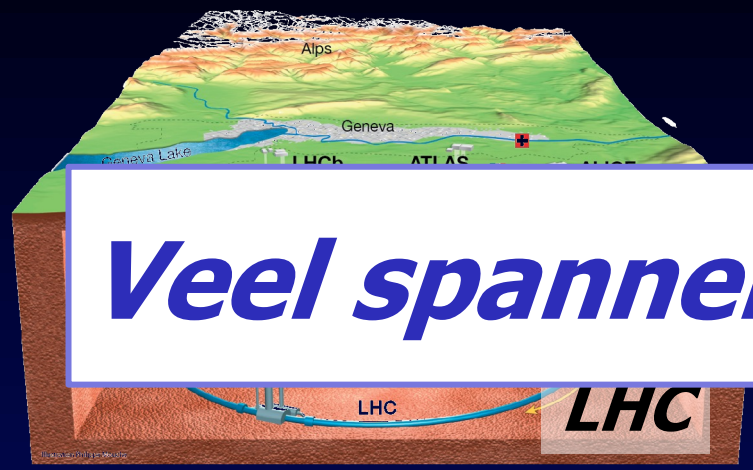
Gravitatie-detectoren: luisteren naar de Big Bang…





Toekomst: “Cirkels en Driehoeken”

Deeltjesversnellers: fysica van de Big Bang …

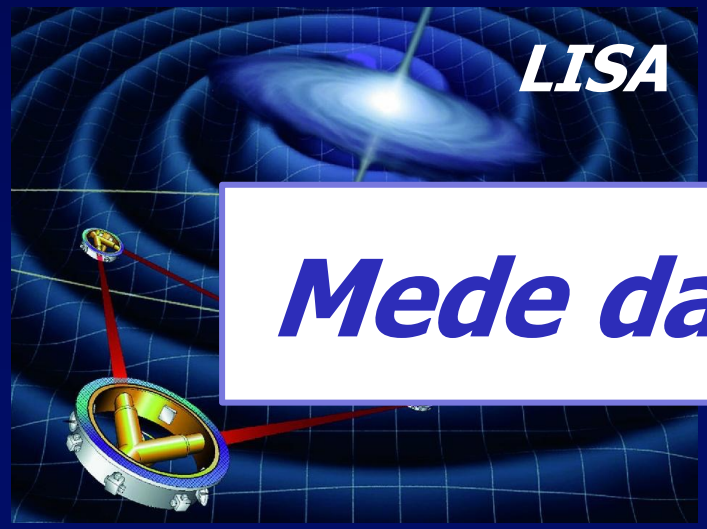


LHC

FCC

Veel spannend onderzoek onderweg

Gravitatie-detectoren: luisteren naar de Big Bang…

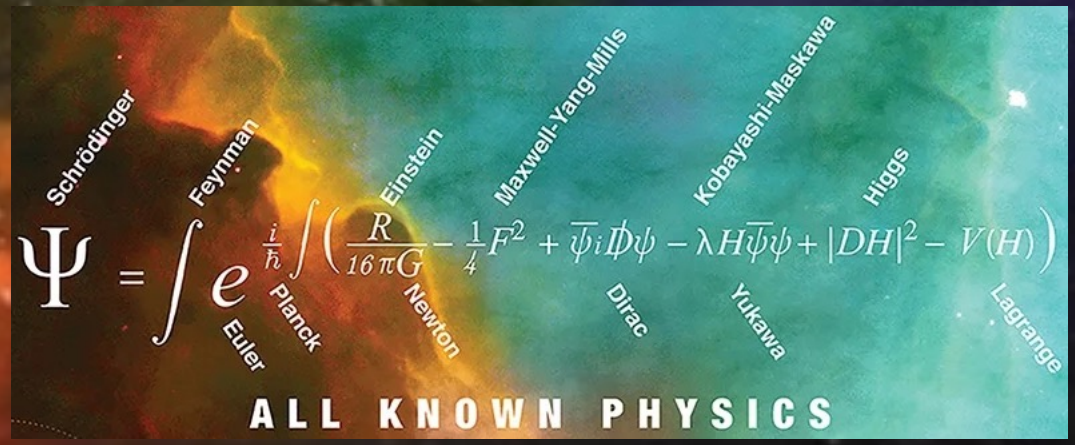


LISA

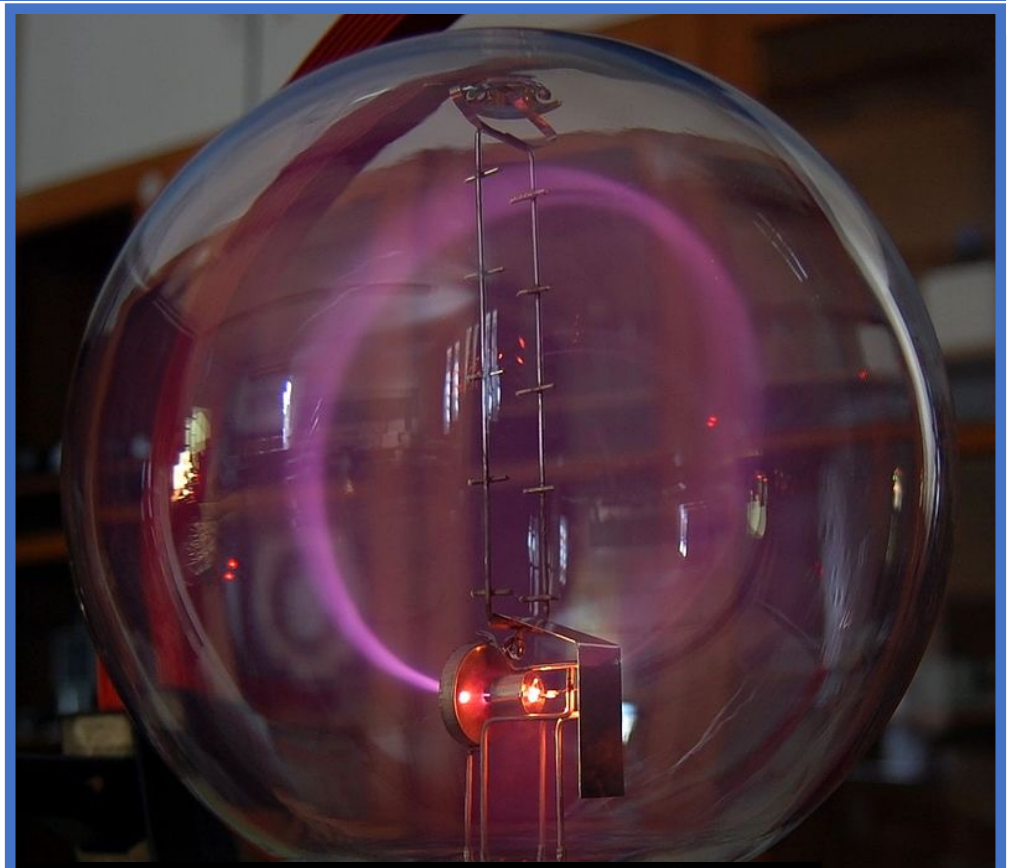
ET

Mede dankzij Nikhef Techno’s!

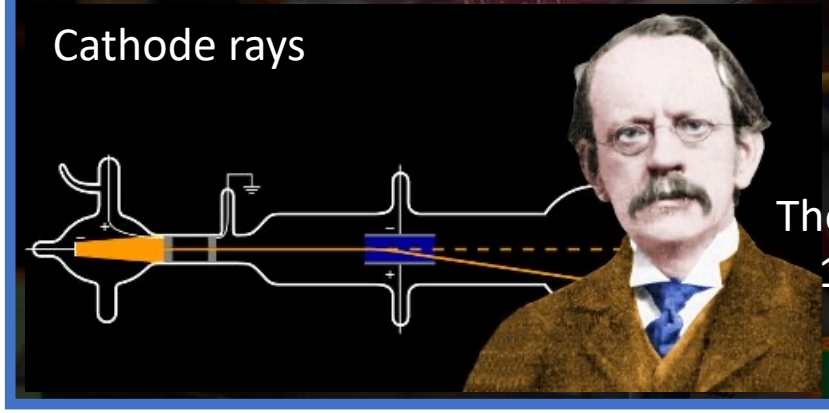
4 Forces of the Universe



Elektron



Cathode rays

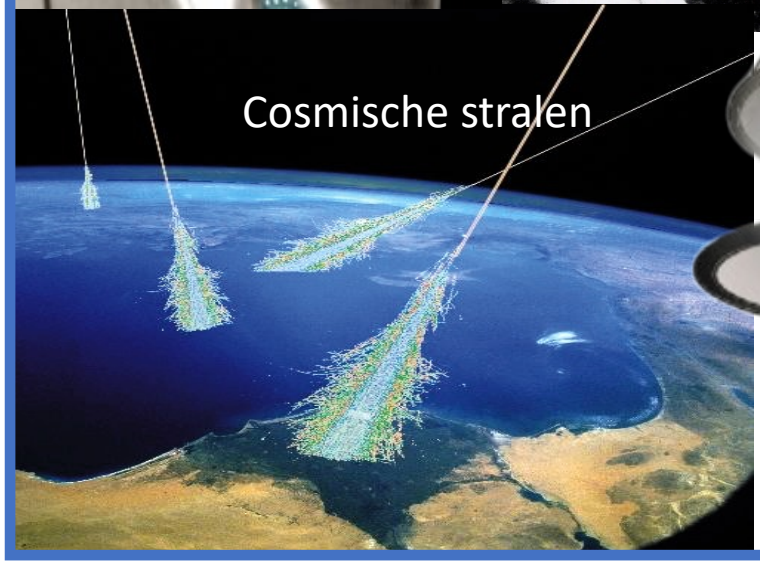


Thomson
1879

Muon

Anderson
1936

Isidor Rabi:
“Who ordered that?”



Cosmische stralen

23 maart 2021: Nikhef en LHCb/CERN publieke website

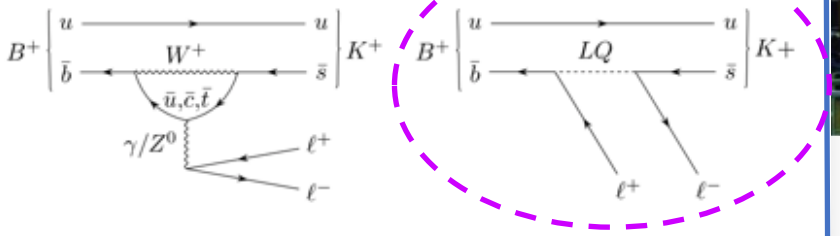
http://lhcb-public.web.cern.ch :

23 March 2021: Strengthened hints for a violation of lepton universality in B decays.

Update of R_K measurement

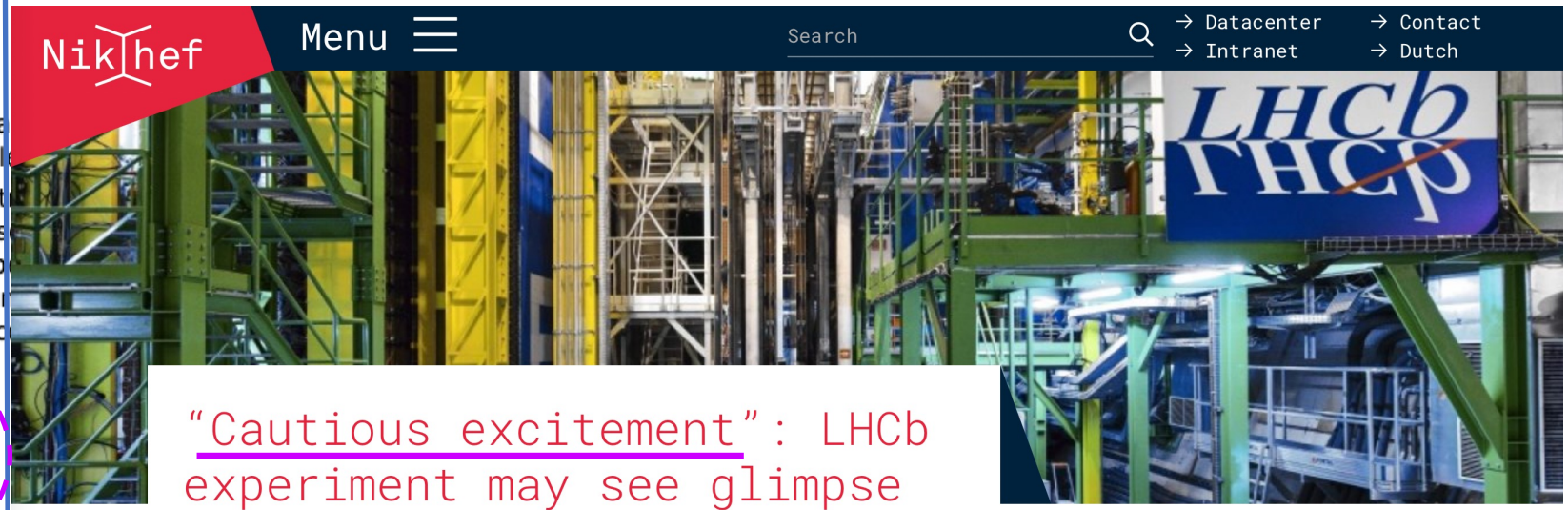
$$R_K = 0.846^{+0.044}_{-0.041}$$

Today at the Rencontres de Moriond EW conference and at a
measurement of the ratio R_K, an important test of a princip
universality". This principle states that the Standard Model t
identically, except for differences due to their different mass
indicate evidence for the breaking of lepton universality in b
deviations. "Evidence" is the term often used in the commu
the 5 standard deviation level at which an "observation" is c



Standard Model and can be affected by the existence of new
at the Large Hadron Collider. The left graph shows Standard
shows a possible new physics contribution to the decay with
bosons, could have different interaction strengths with the c

https://www.nikhef.nl/news/ :



"Cautious excitement": LHCb experiment may see glimpse of new physics

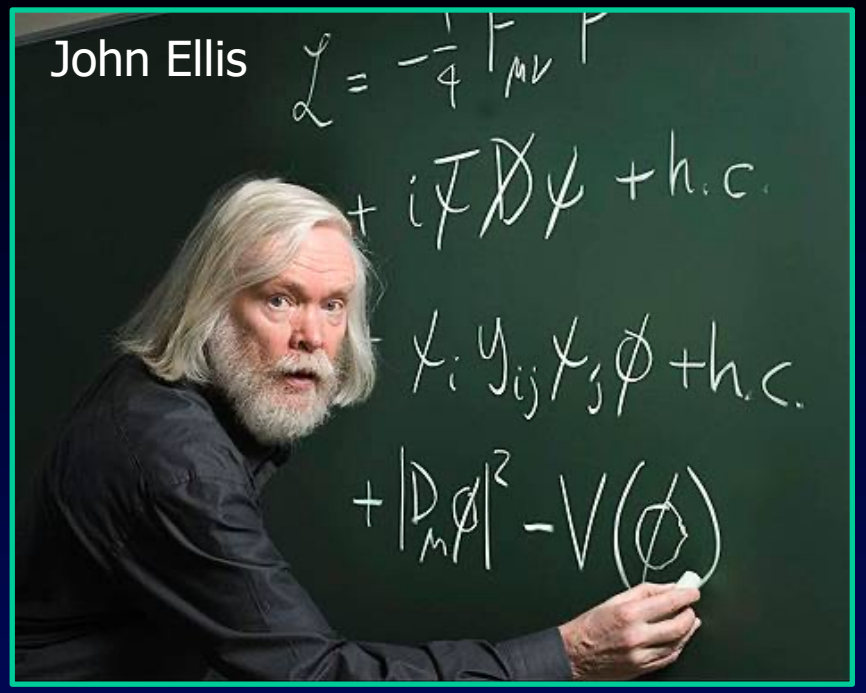
HOME → NEWS → "CAUTIOUS EXCITEME…

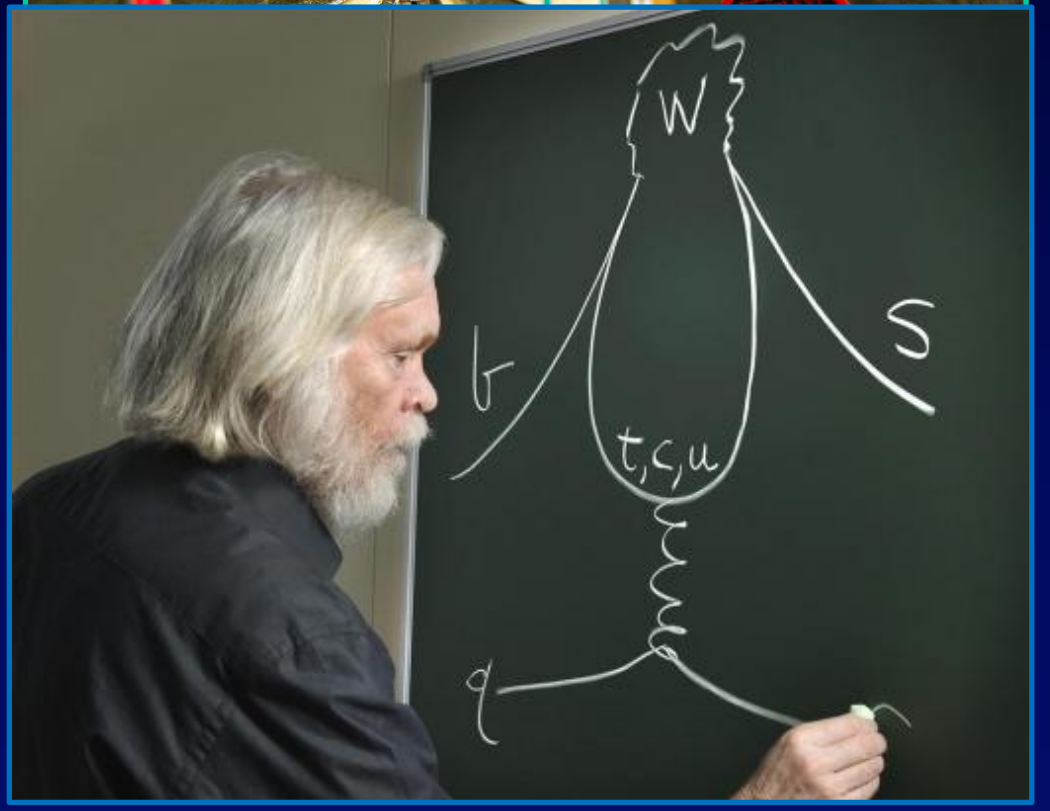
23 March 2021

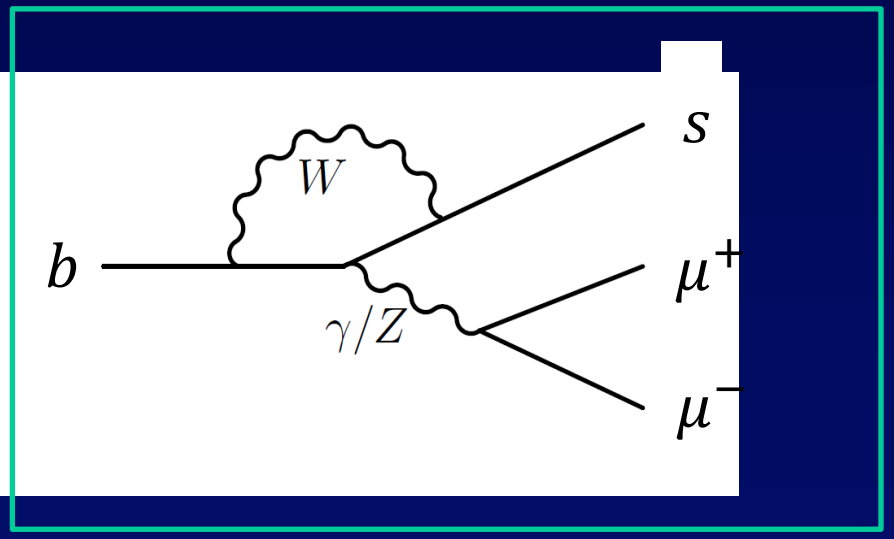
The LHCb experiment at CERN might be seeing a glimpse of new physics. The experiment has found a serious indication in its measurements that electrons and their heavier counterparts muons respond not exactly identical to forces.

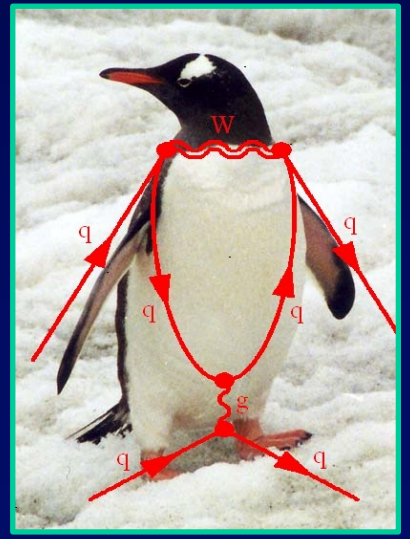
Particle Physics slang: "New Physics" = particles of fields beyond the Standard Model

A story on darts and penguins









Penguins in de Big Bang theory…