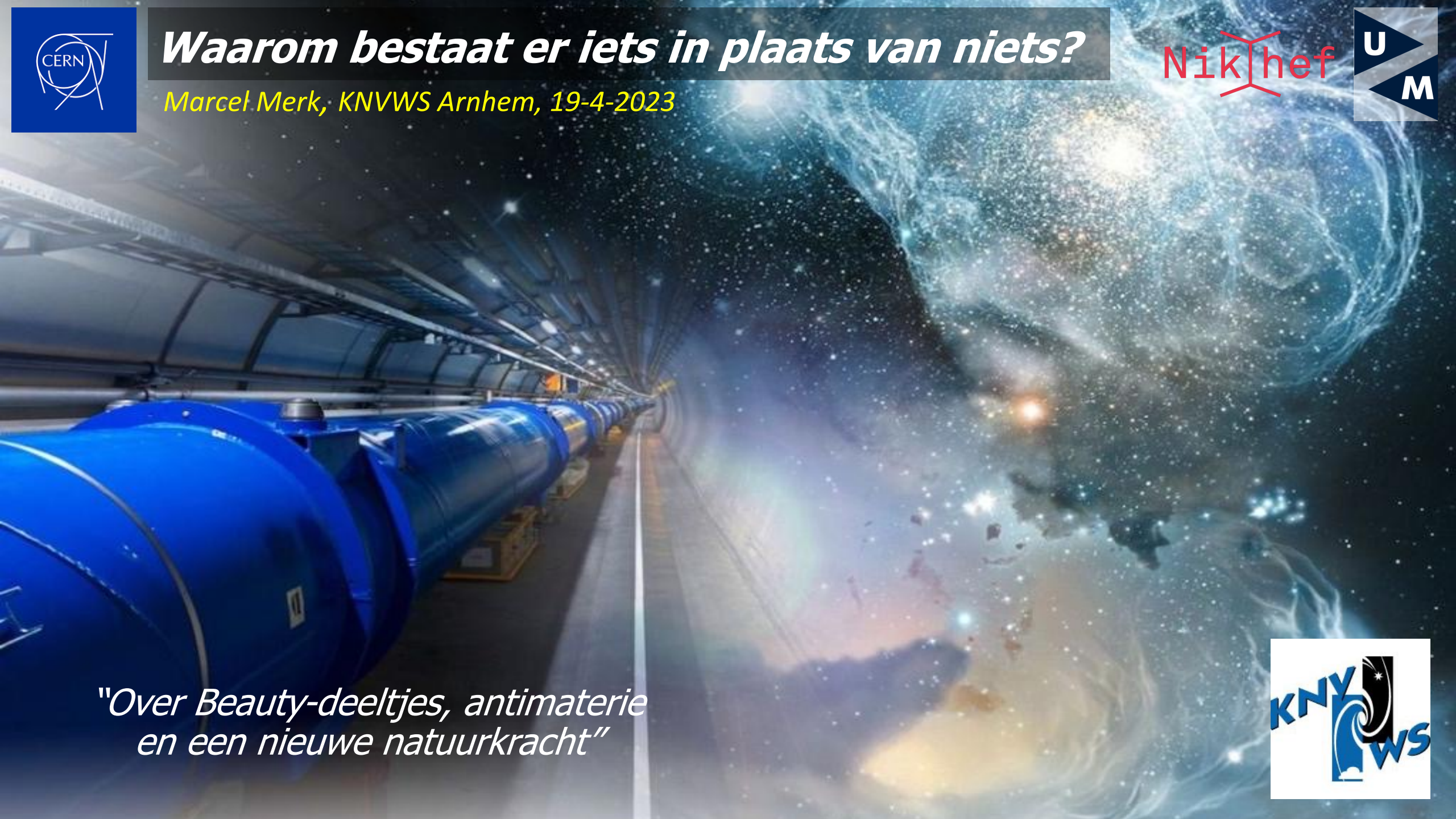
Waarom bestaat er iets in plaats van niets?

Marcel Merk, KNVWS Arnhem, 19-4-2023



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

Waarom bestaat er iets in plaats van niets?

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Inhoud:

1: Materie en antimaterie

2: Antimaterie en de Big Bang

3: Deeltjes en CERN

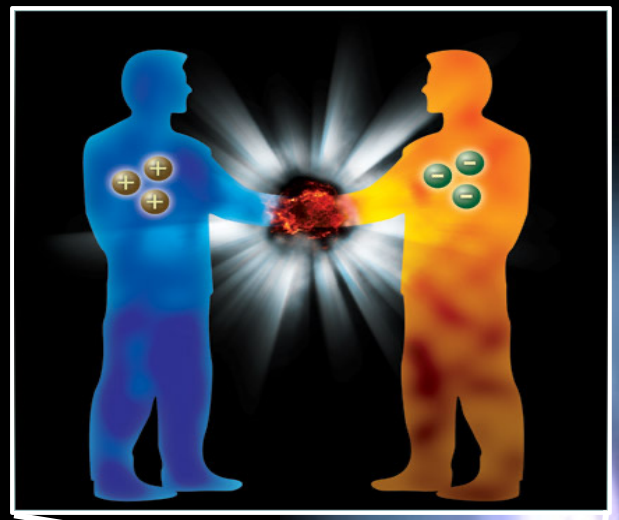
4: Krachten: het Standaard Model

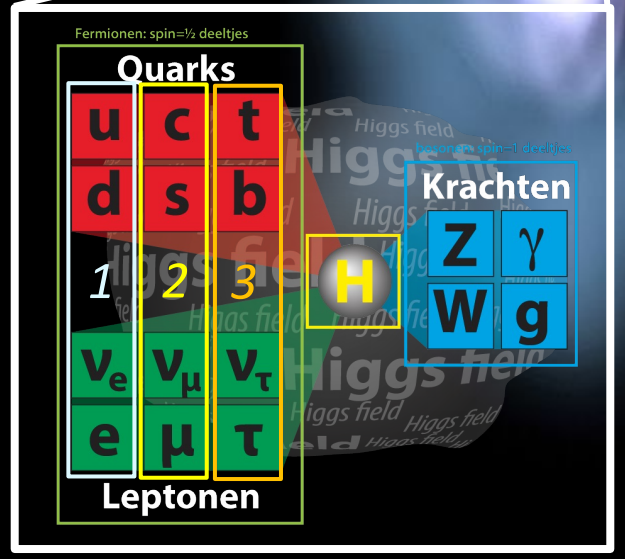
5: Symmetrie in materie en antimaterie?

6: Een nieuwe natuurkracht?

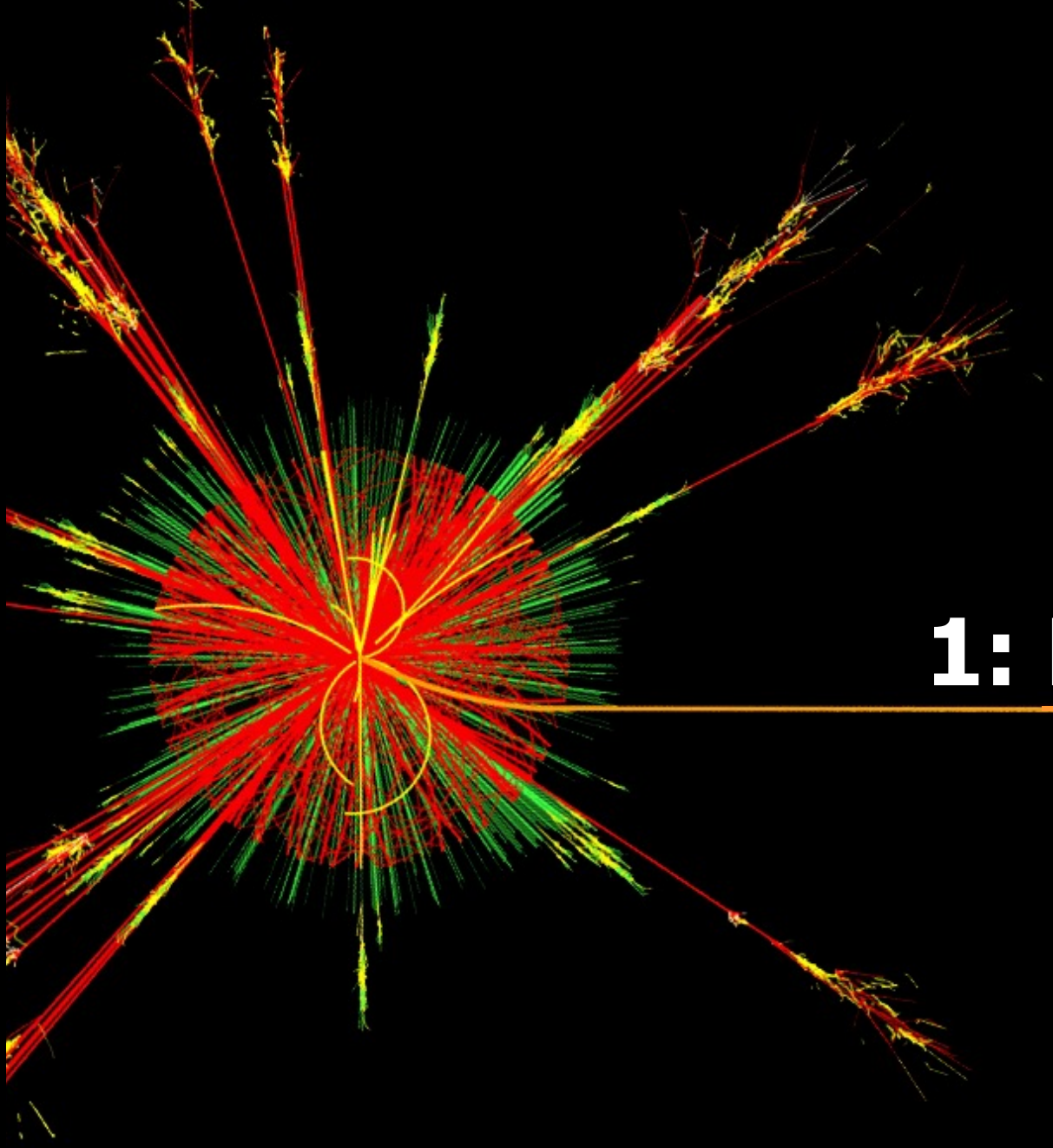
"Over Beauty-deeltjes, antimaterie en een nieuwe natuurkracht"

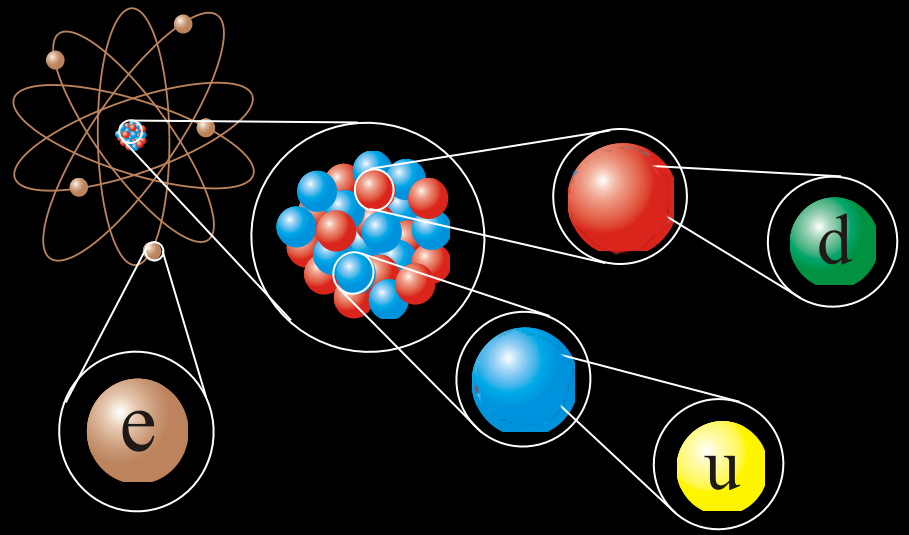
Hoe is de antimaterie verdwenen in het universum?





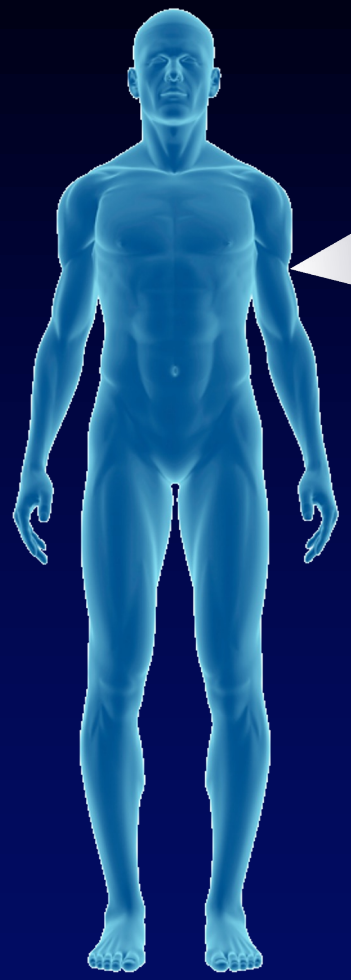
Flavor puzzle: waarom bestaan er drie generaties identieke deeltjes?





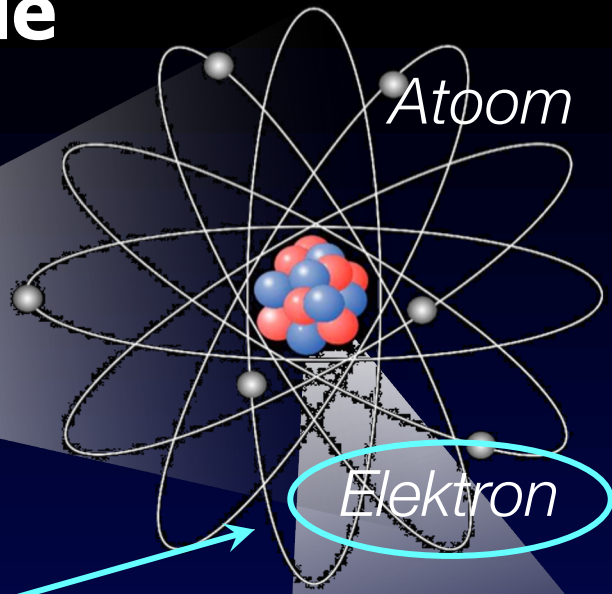
1: Materie en Antimaterie

Bouwstenen van materie



Molecuul

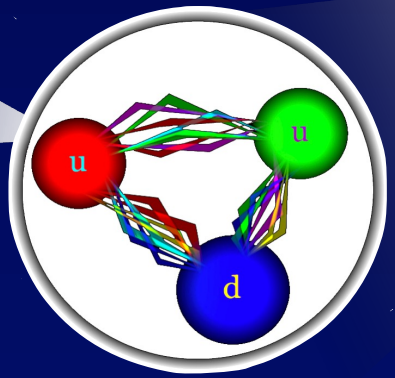
Atoom

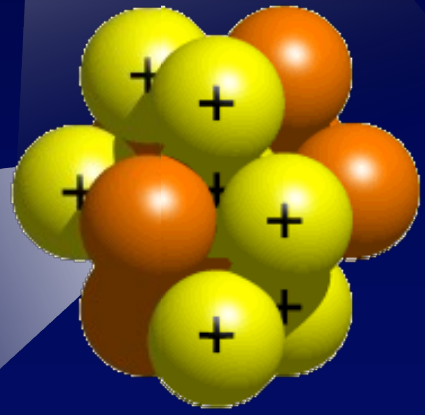


Elektron

Quark

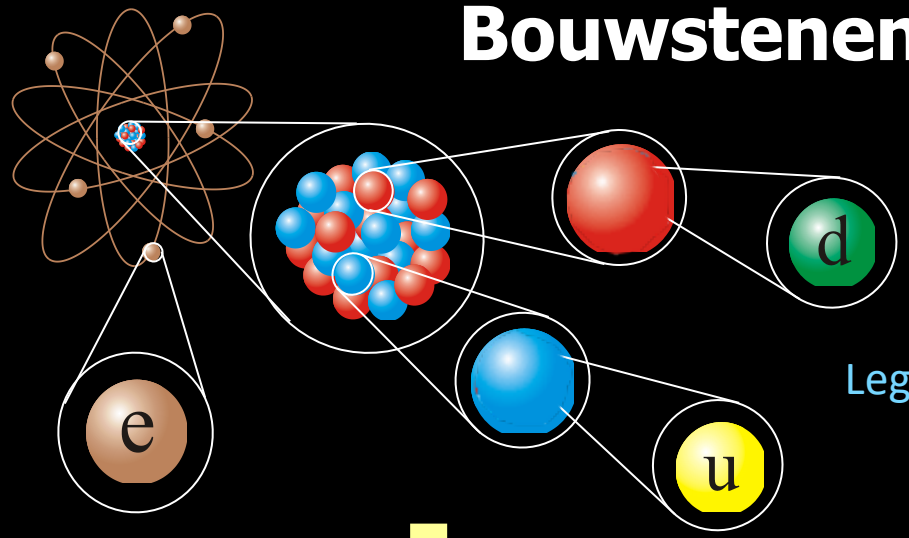
Proton/Neutron





Atoomkern

Bouwstenen van materie



Lego blokken van de natuur

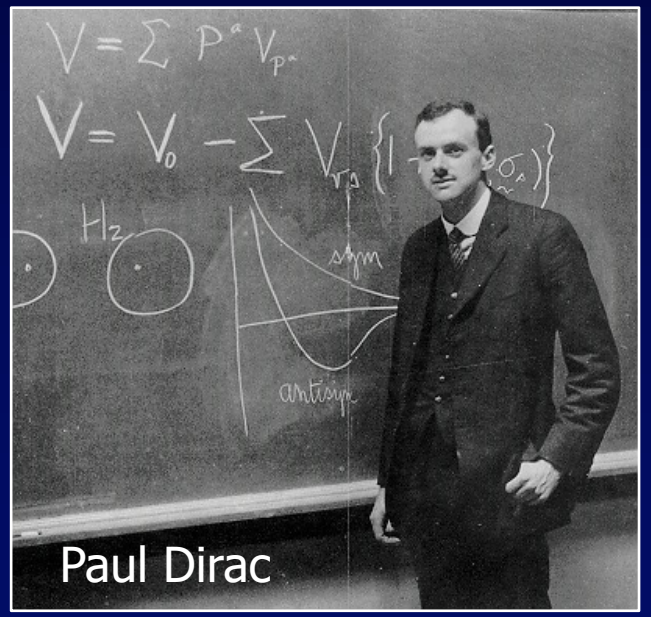
periodiek systeem

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt									

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

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

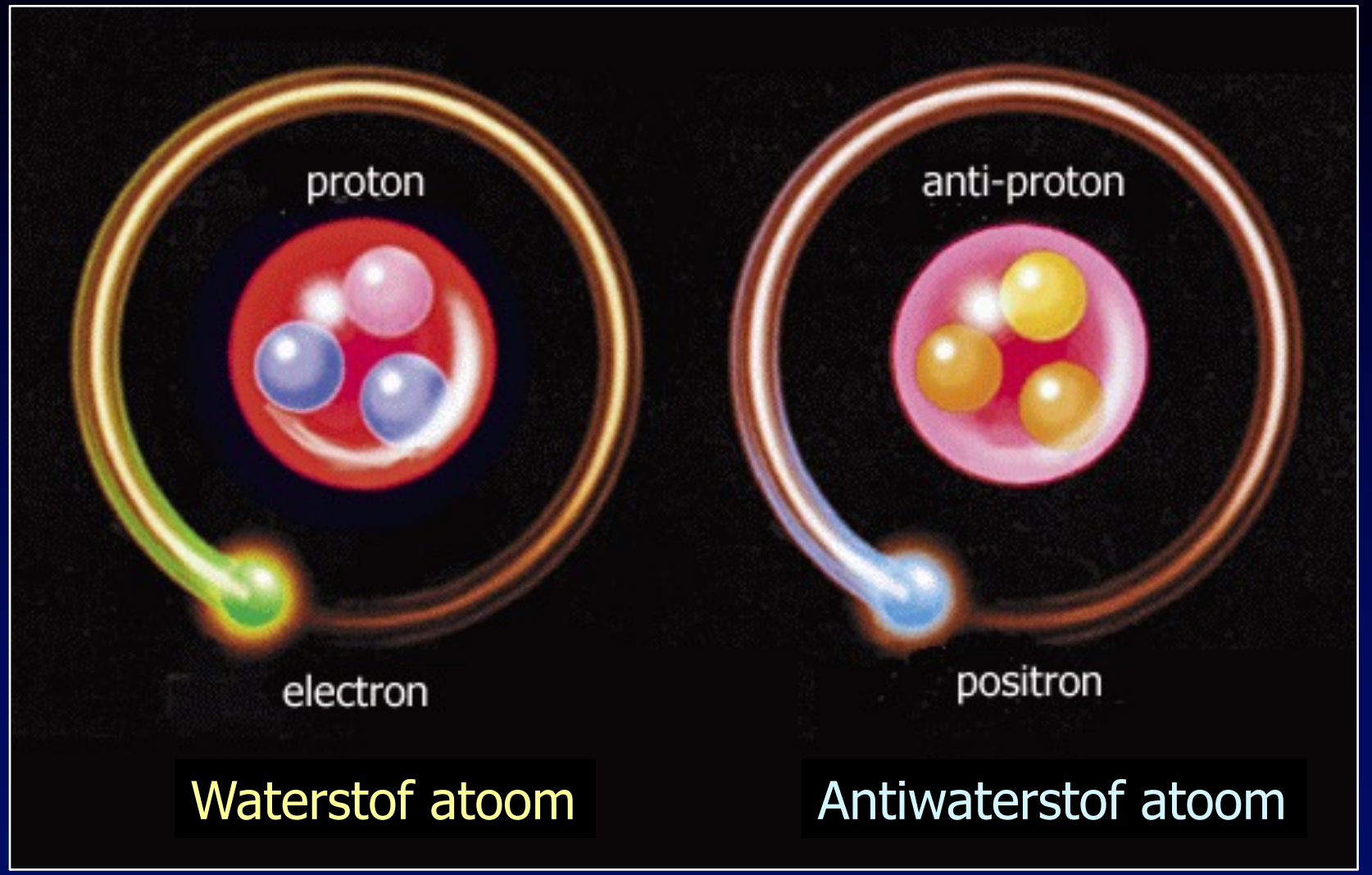

Paul Dirac


Carl Anderson

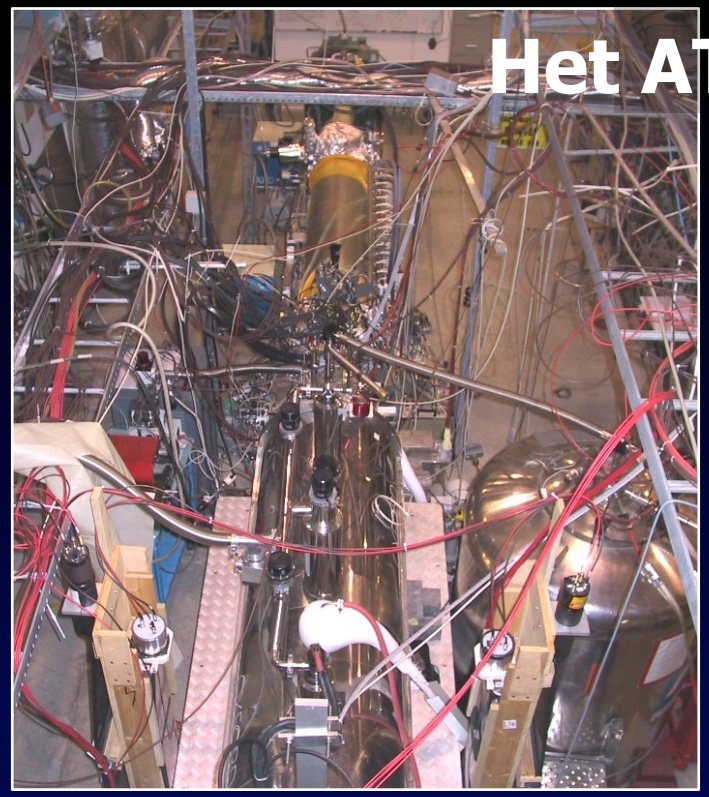

Dirac

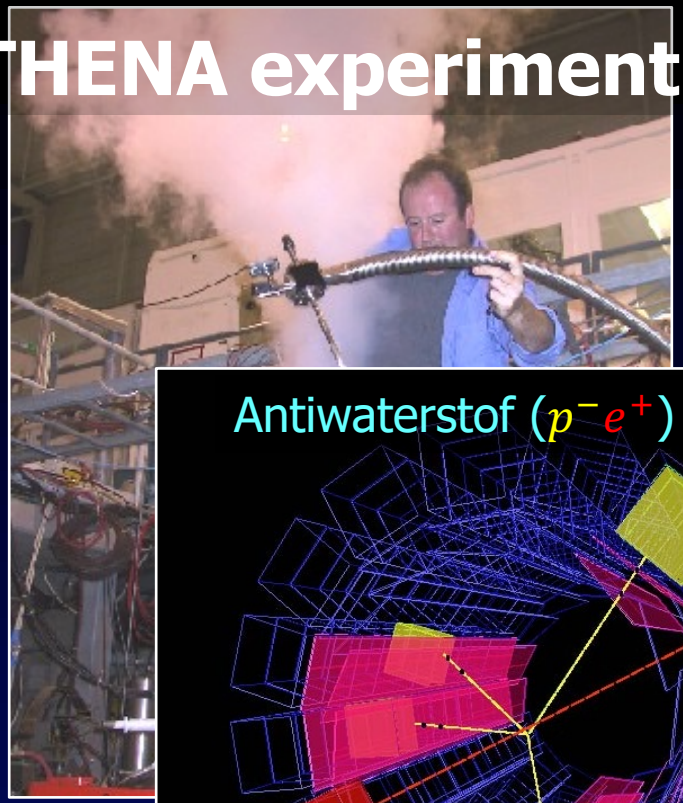
AntiDirac

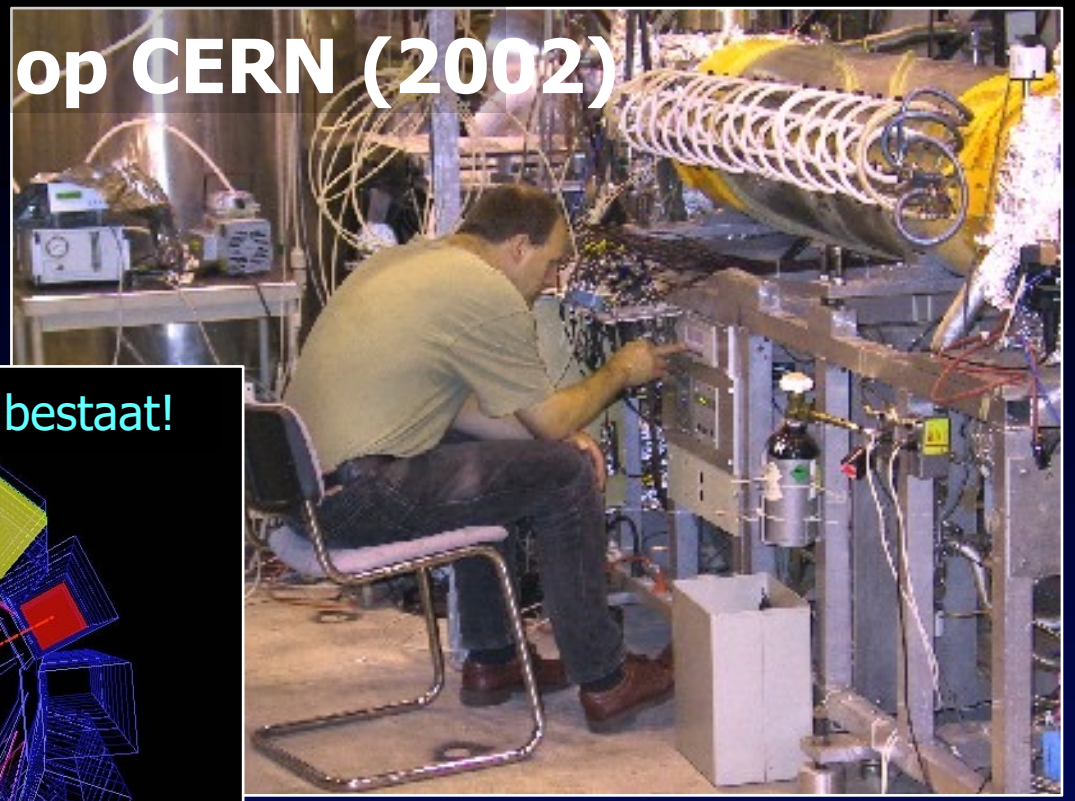
Antimaterie



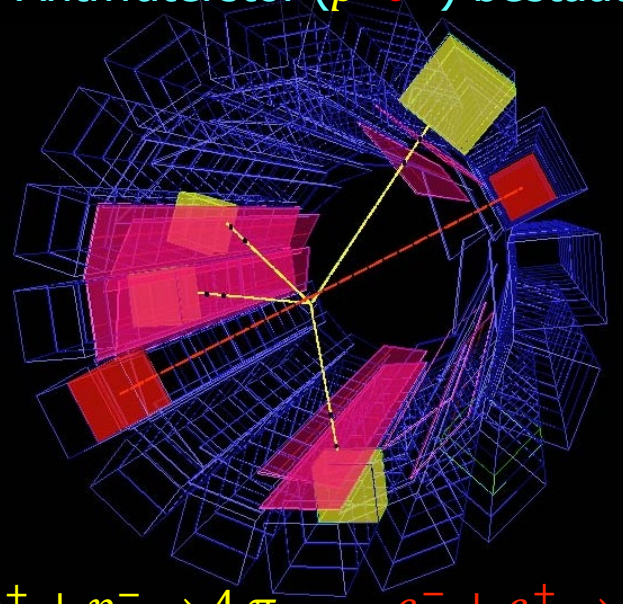
Het ATHENA experiment op CERN (2002)



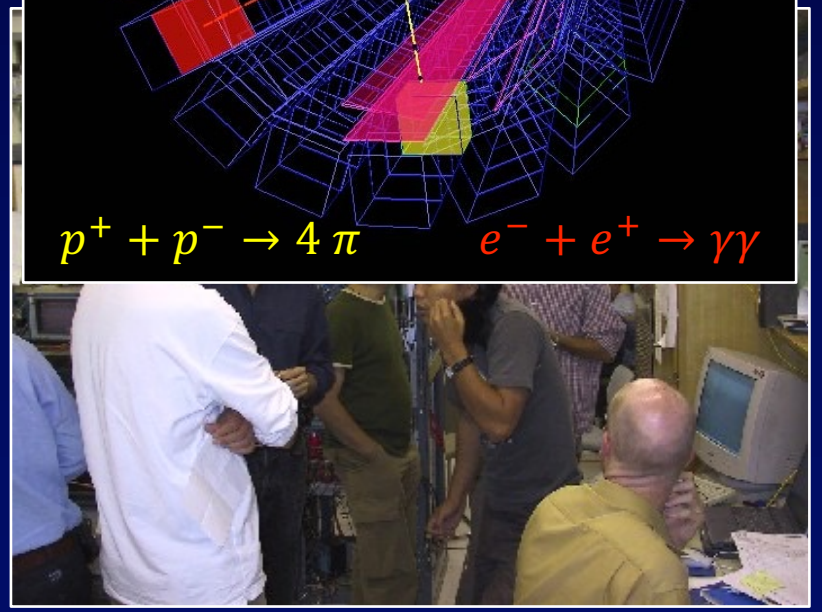




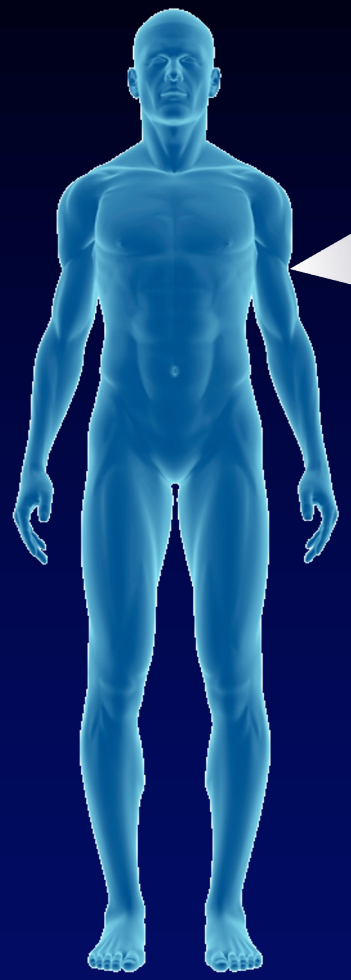
Antiwaterstof ($p^- e^+$) bestaat!



$p^+ + p^- \rightarrow 4\,\pi$ $\quad e^- + e^+ \rightarrow \gamma\gamma$

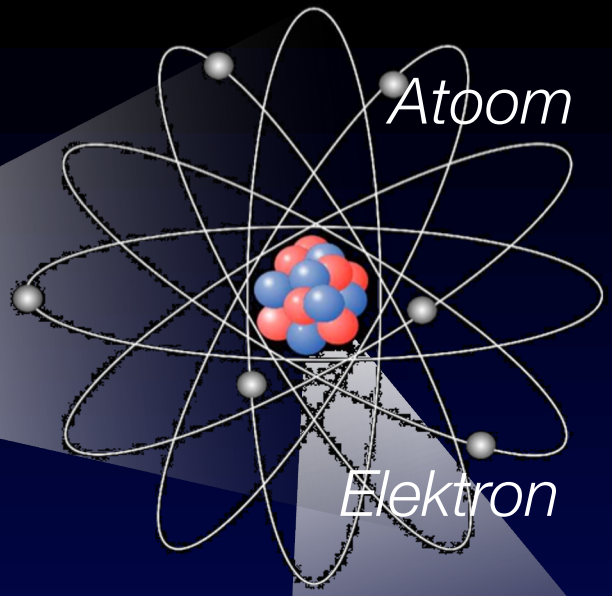


Een wereld van materie en …



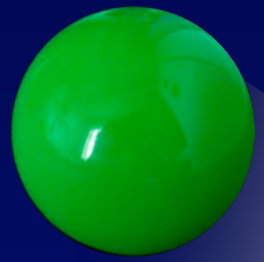
Molecuul

Atoom

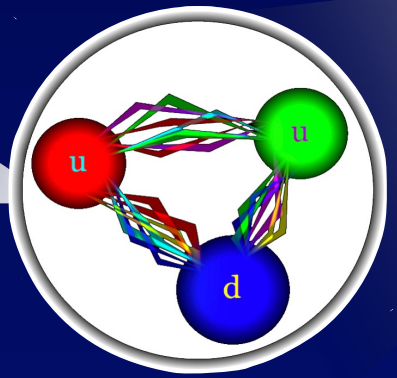


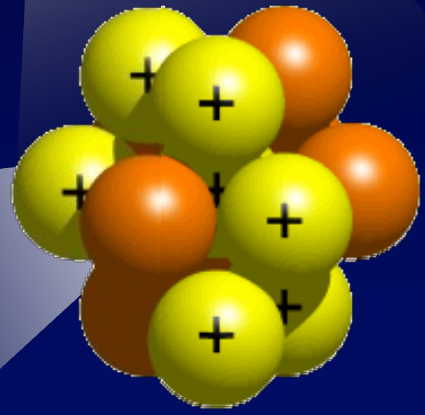
Elektron

Quark



Proton/Neutron



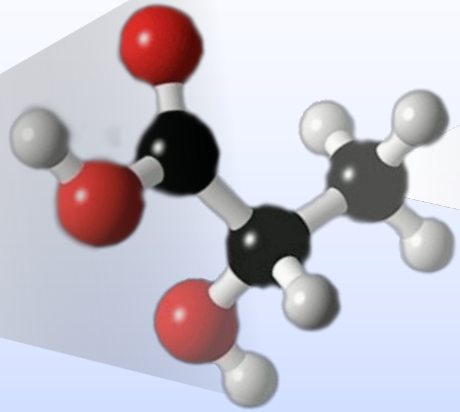


Atoom kern

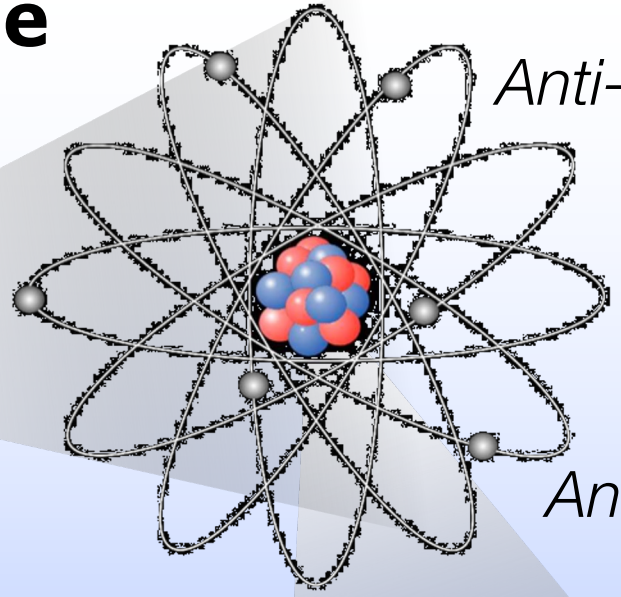
… een wereld van antimaterie

Identieke anti-wereld

Anti-Molecuul



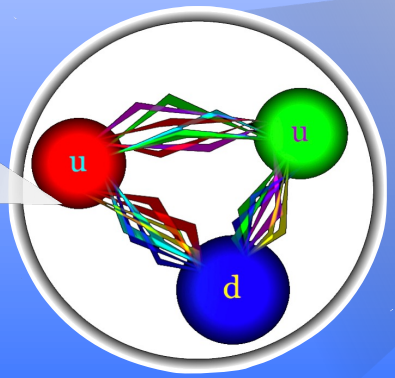
Anti-Atoom

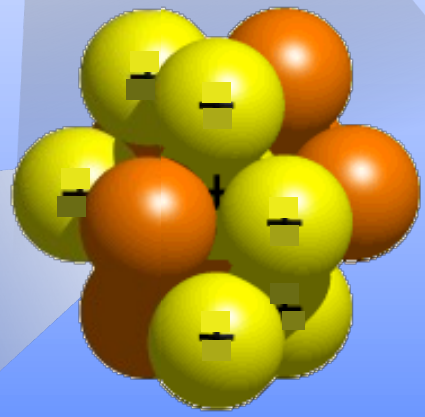


Anti-elektron

Anti-Quark

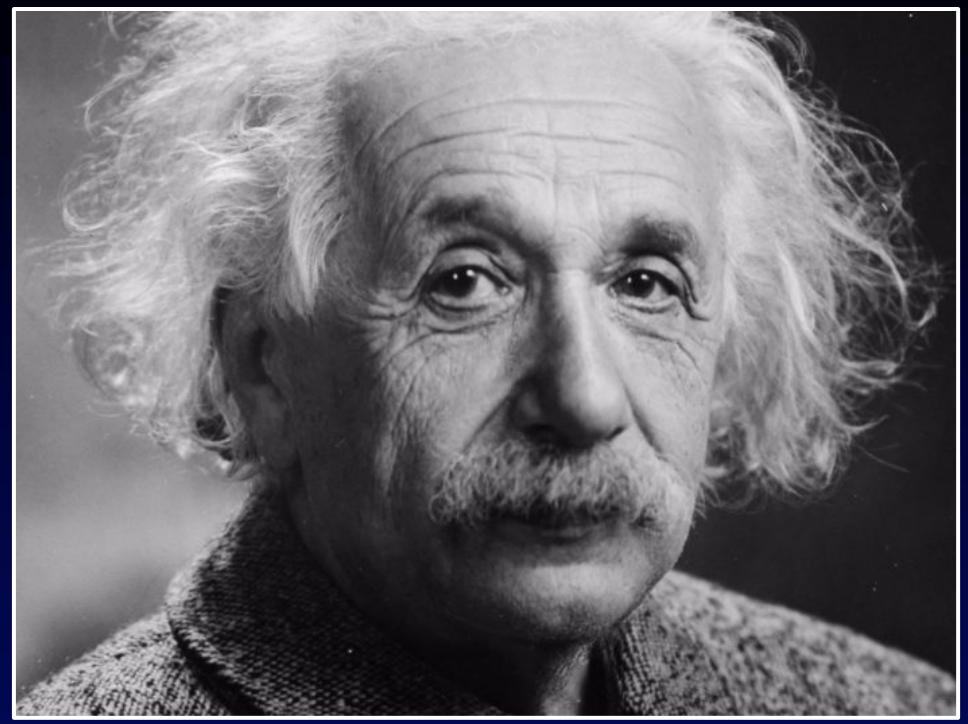
Anti-Proton / anti-Neutron

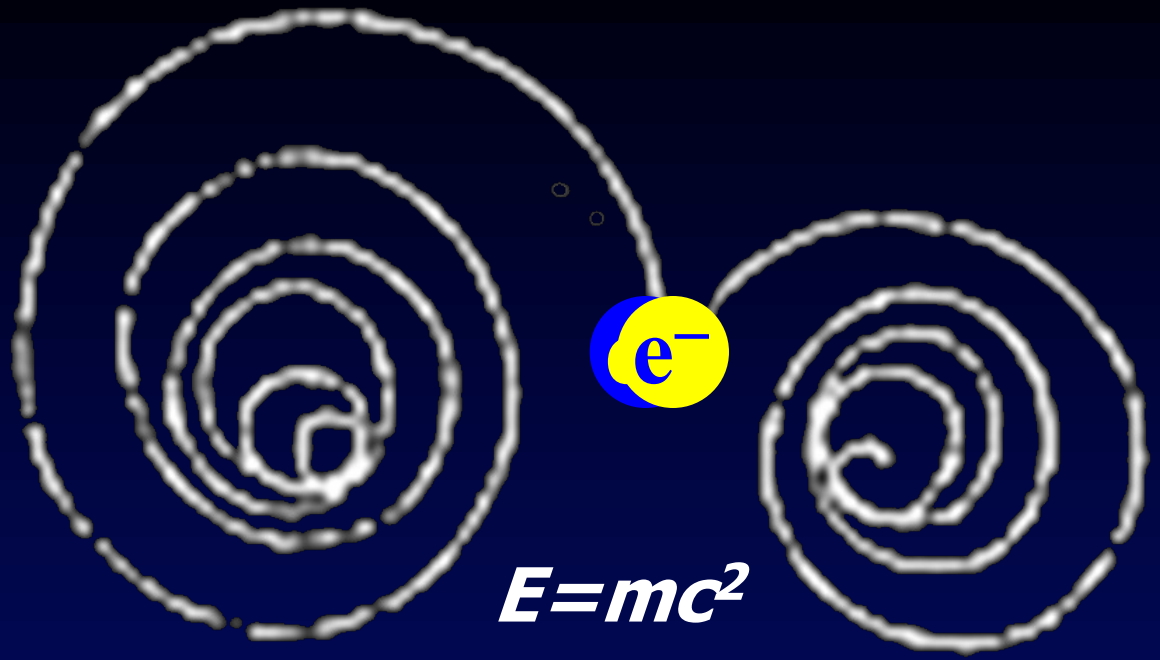




Anti-atoomkern

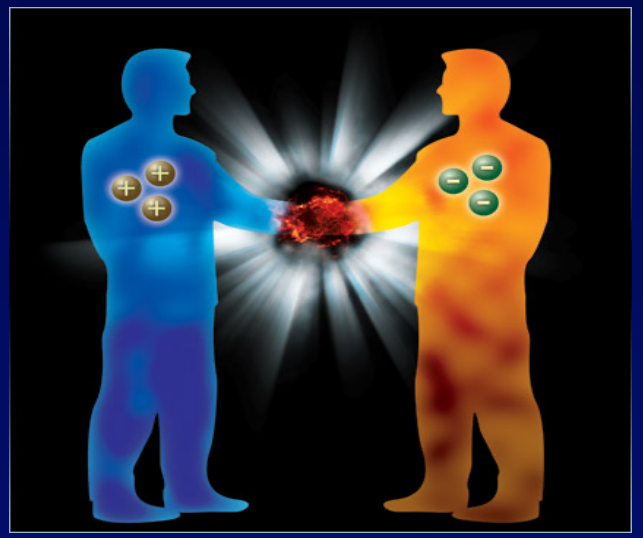
Albert Einstein: Energie = materie + antimaterie



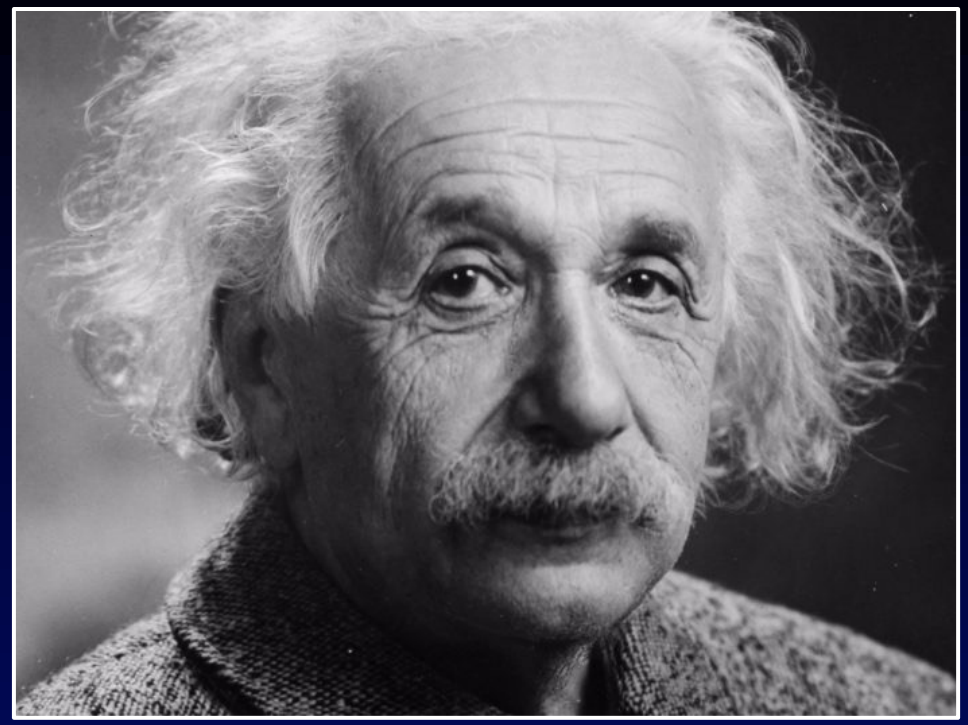


<u>Creatie:</u>
Energie → materie + antimaterie : → e^+ e^-

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



Albert Einstein: Energie = materie + antimaterie



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

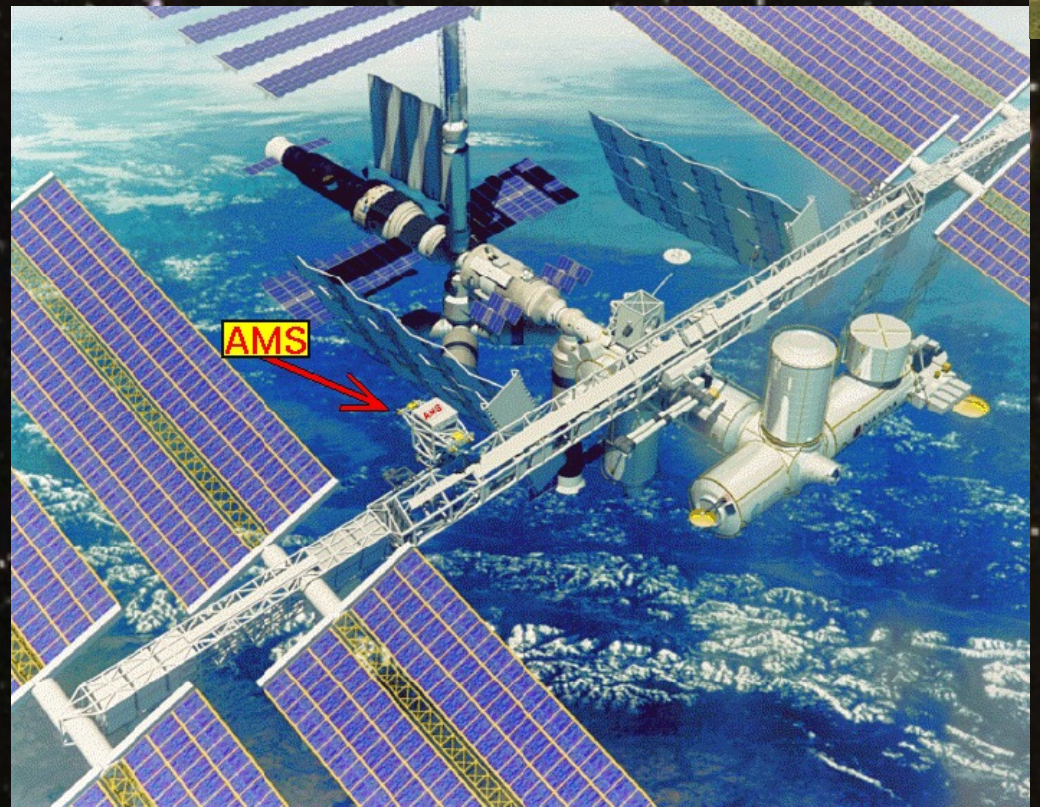
<u>Annihilatie:</u>
materie + antimaterie → energie : e^+ e^-

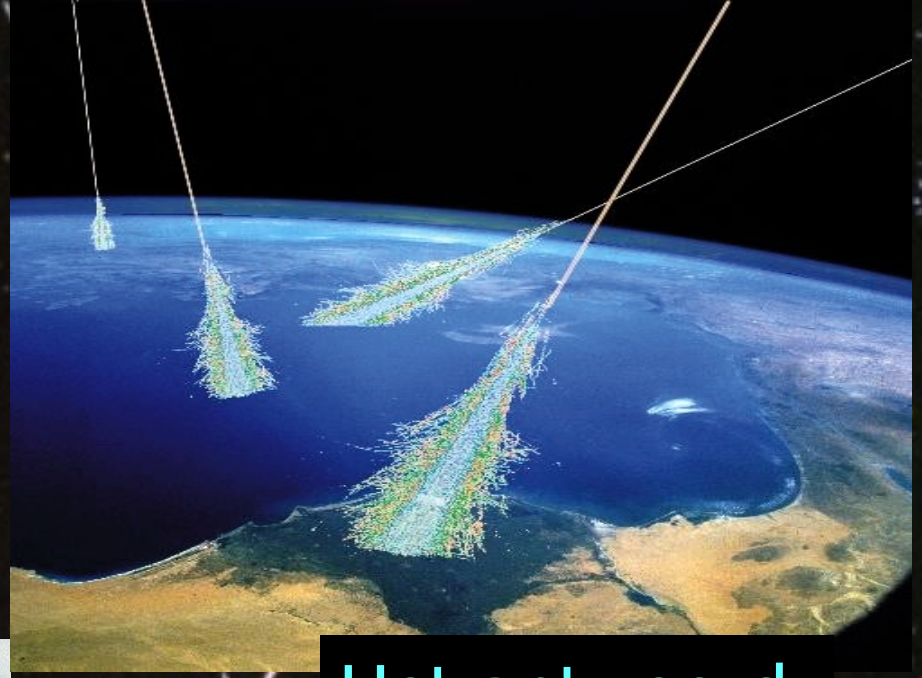
Is er antimaterie in de natuur?

- Komt het voor op Aarde?

- Nee, we zouden het onmiddelijk zien:
  - "Annihilatie"

- Is er antimaterie in kosmische straling?
  - Het AMS experiment





Het antwoord:

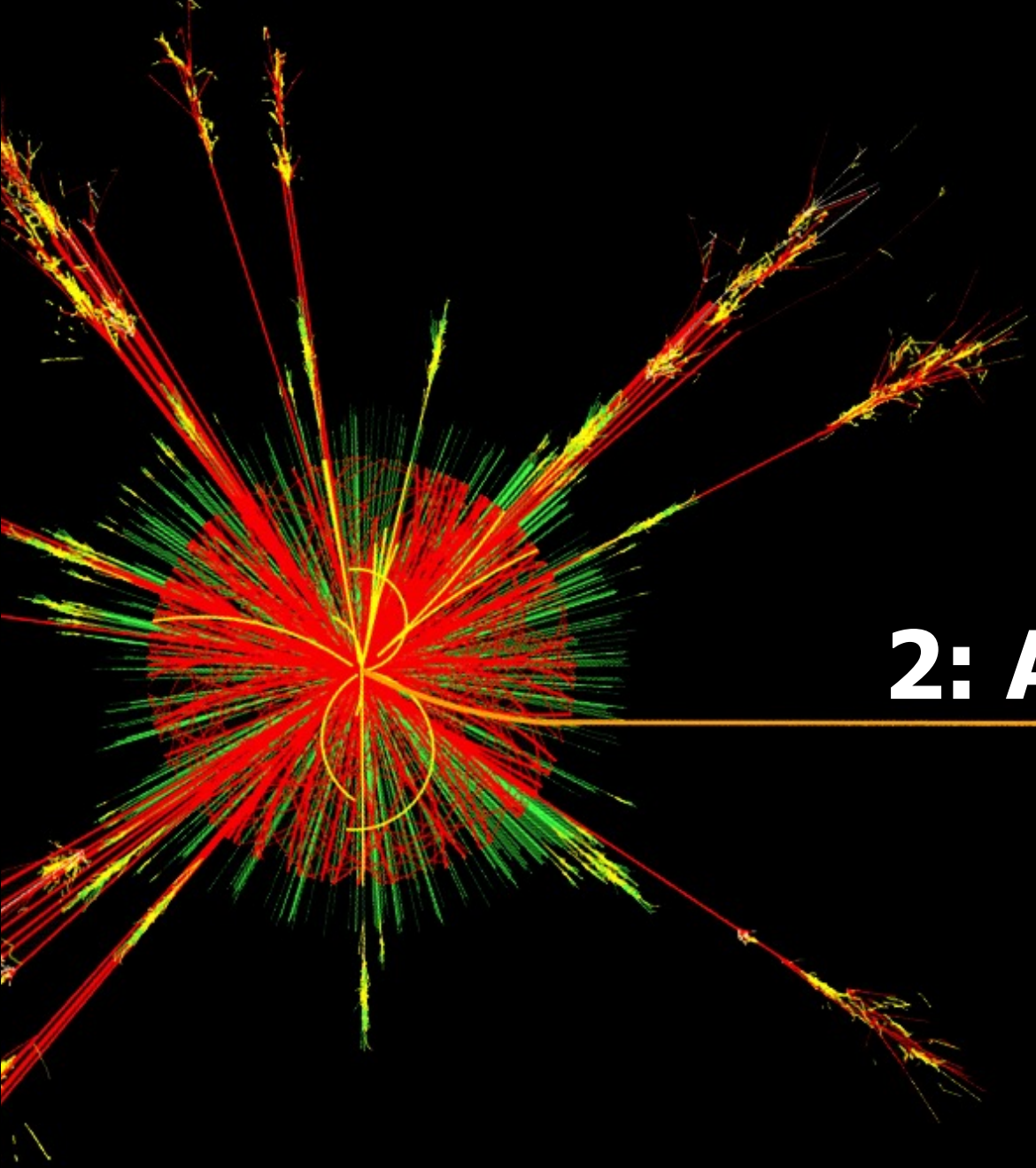
Zijn er antimaterie sterrenstelsels?

Nee!

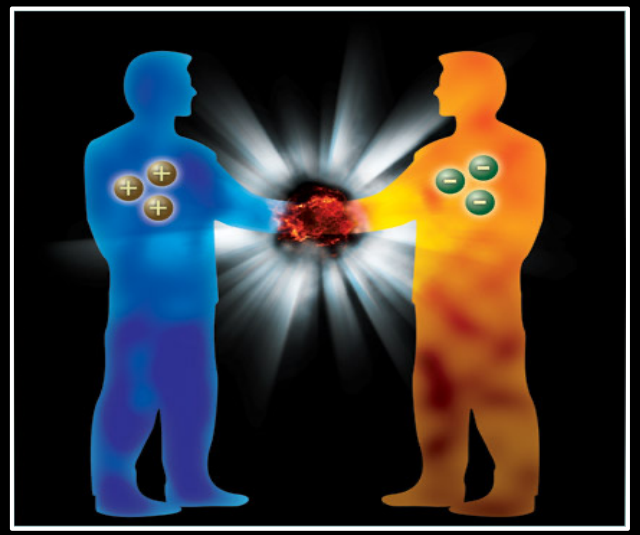
(materie + anti-materie =
Intense gamma stralen)

Vroege Universum: waar is de antimaterie heen?

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



2: Antimaterie en Big Bang

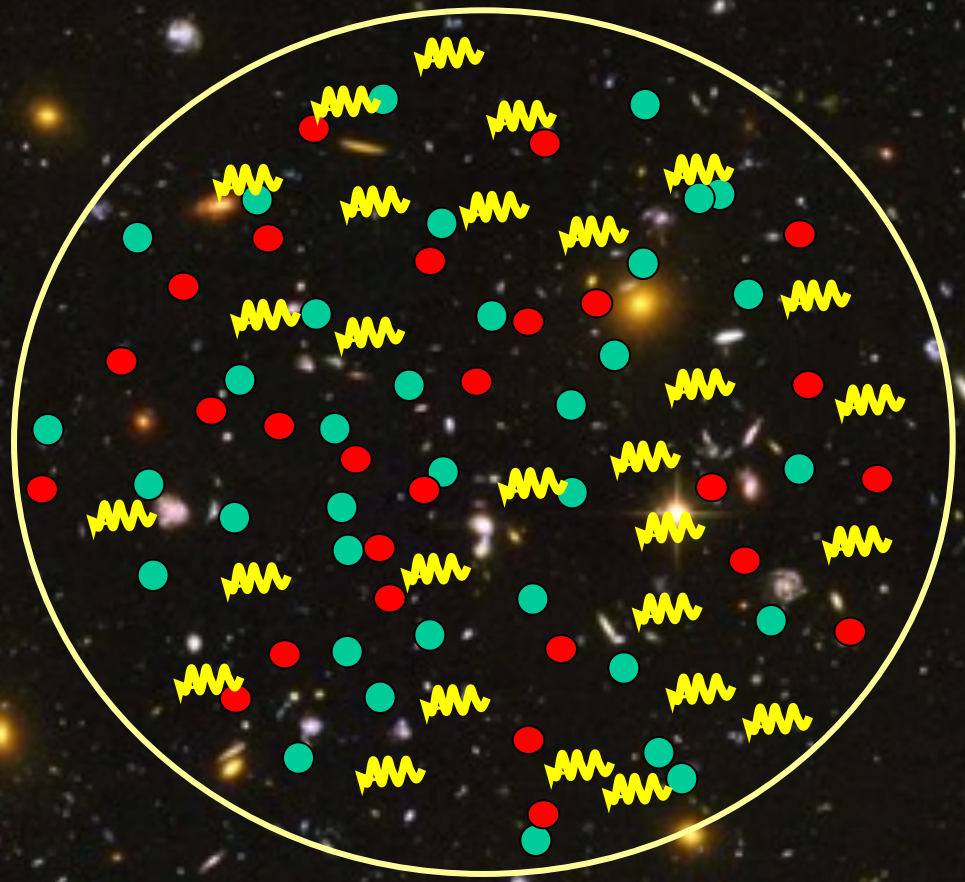


Terug naar de Oerknal

Veronderstelling: Er ontstaat materie en antimaterie!

Het vroege hete heelal

Tijd=0.00000000001 seconde



($E=mc^2$)

Stel:

- *materie:* 1000000001
- *antimaterie:* 1000000000
- licht

Dus: "ietsiepietsie" meer materie deeltjes
dan antimaterie deeltjes

Het afgekoelde heelal

Tijd ~1 seconde

materie

antimaterie

licht

Na afkoelen heffen ● en ● elkaar op

Er blijft over: veel licht en een beetje materie

Verhouding : 100000000 : 1

→ Ons huidige heelal….

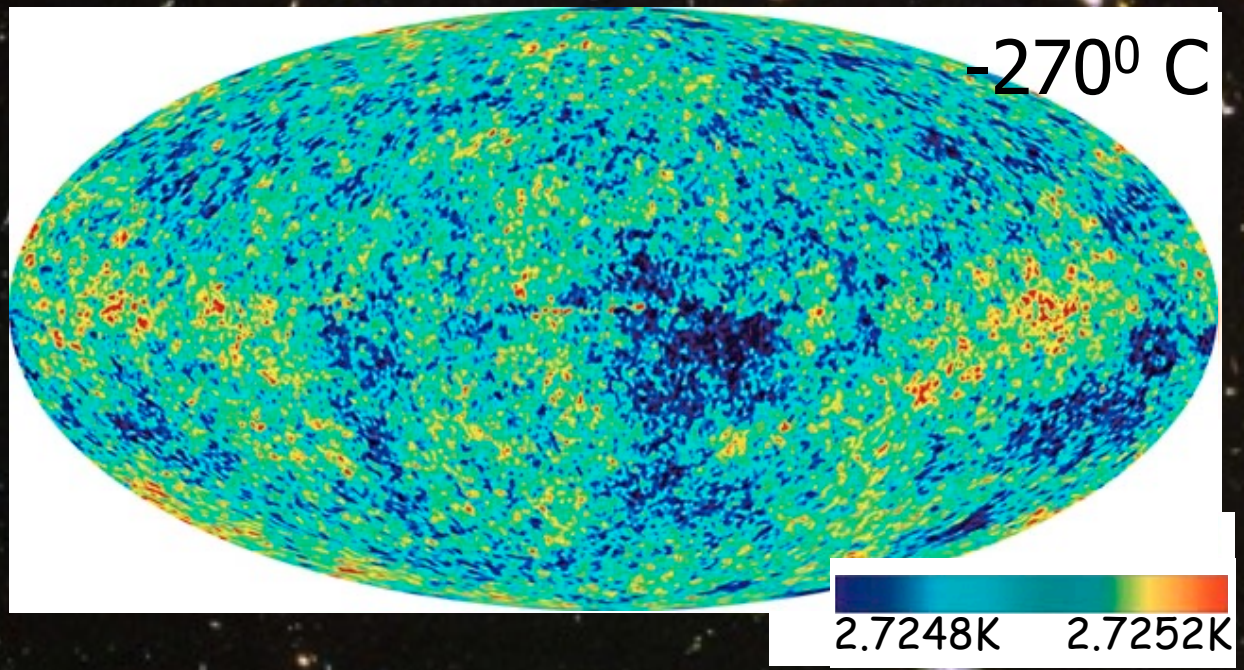
Kosmische achtergrond straling

1964: Penzias en Wilson ontdekken: “achtergrond licht” (fotonen)

Restant van de oerknal

Een temperatuur kaart ...

van het heelal



Voor elk materie deeltje zijn er miljard fotonen

Het heelal zoals we het nu zien

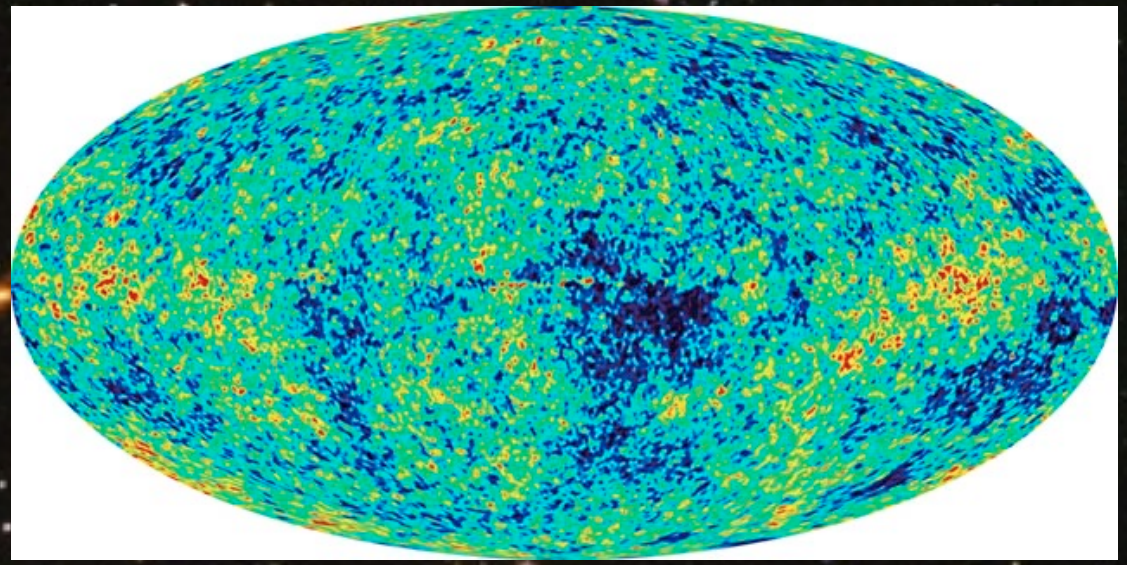
- Waargenomen Nagloeilicht:

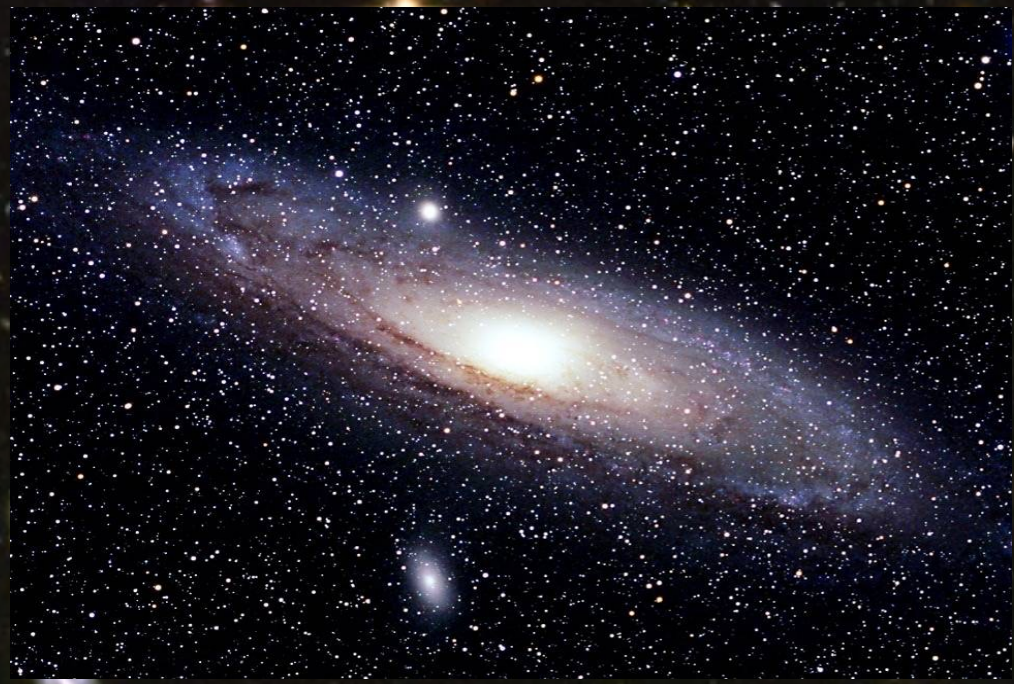
  "veel"
  (1000000000)

  +

- Resterende materie:

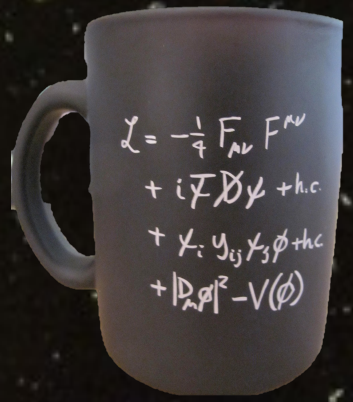
  "weinig"
  (1)





Hoe verdween antimaterie in de Big Bang?

Natuurwetten



?

Big Bang

Klein overschot

49.999999% anti-materie

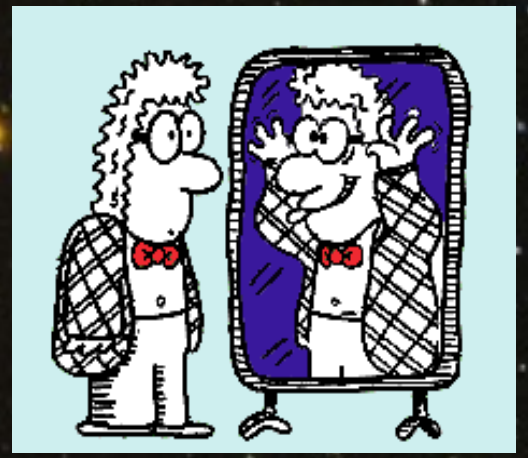
50.000001% materie

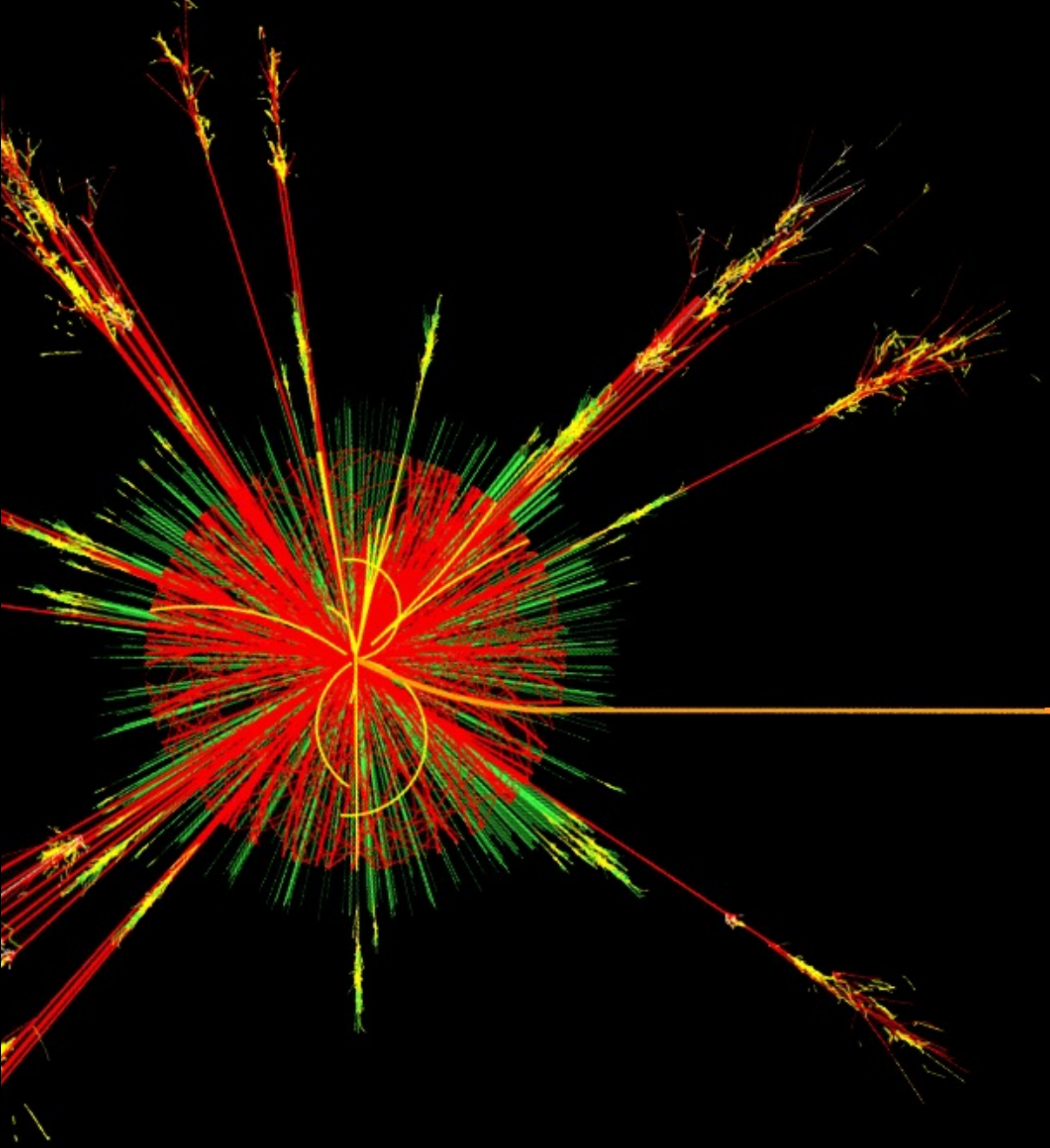
Domineert

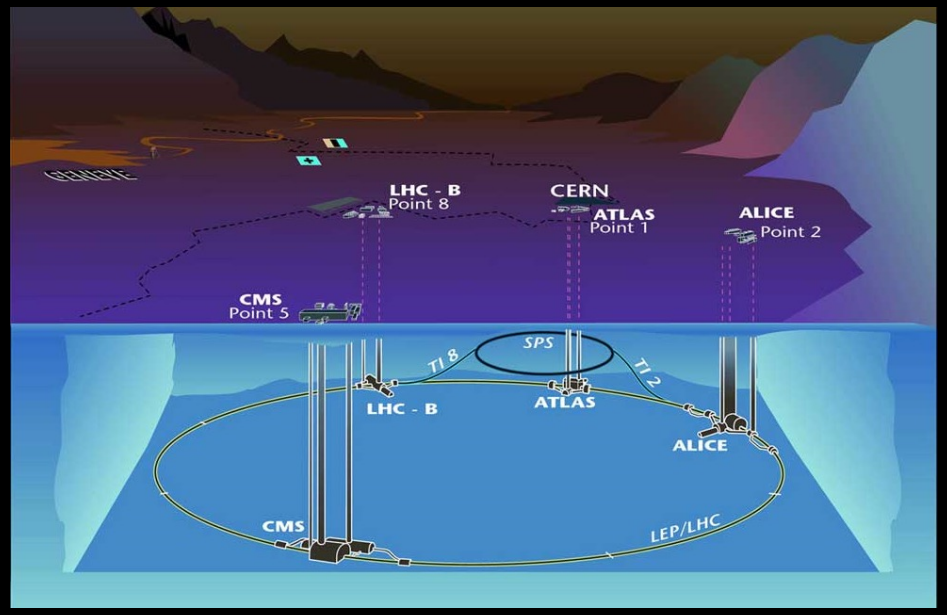
0.000001% materie

(+99.999999% straling)

Antimaterie niet het exacte spiegelbeeld van materie?

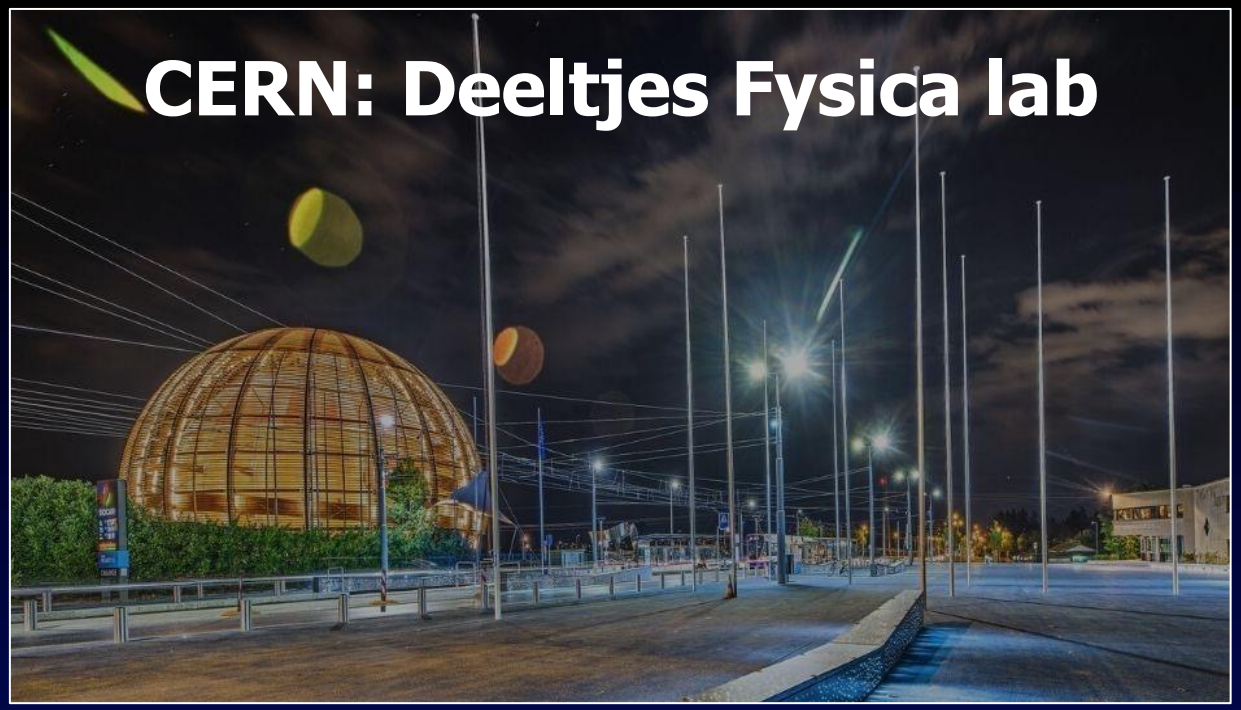


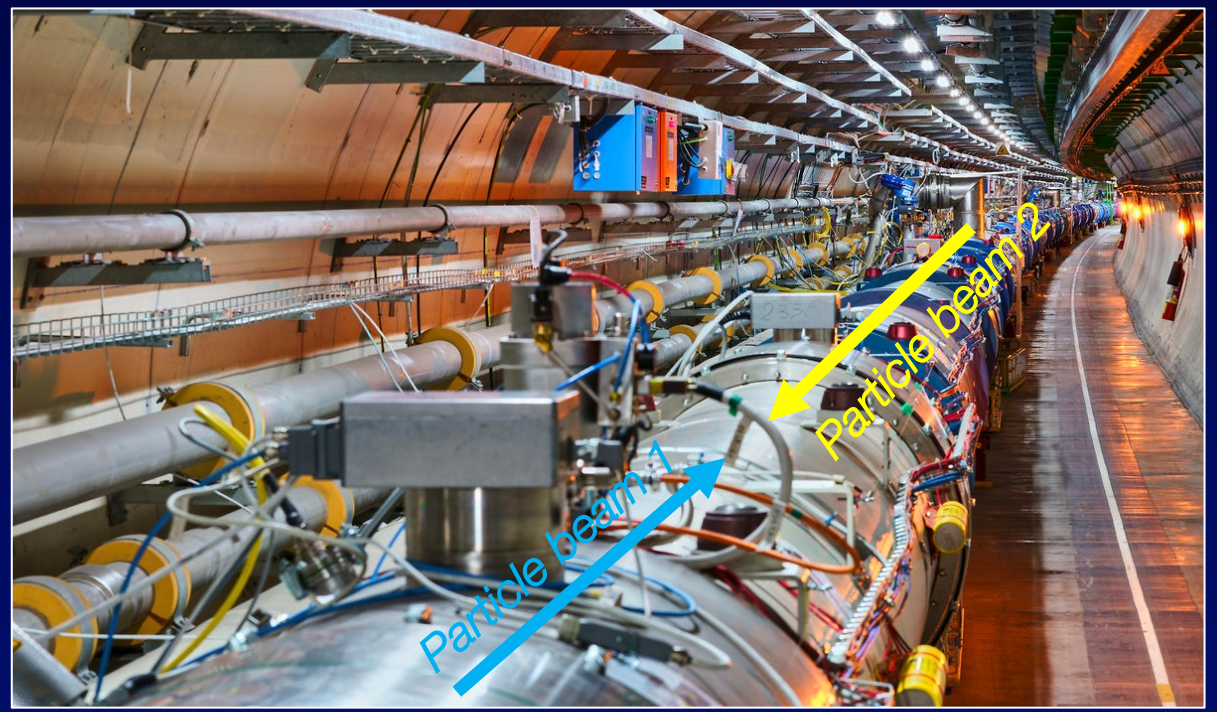




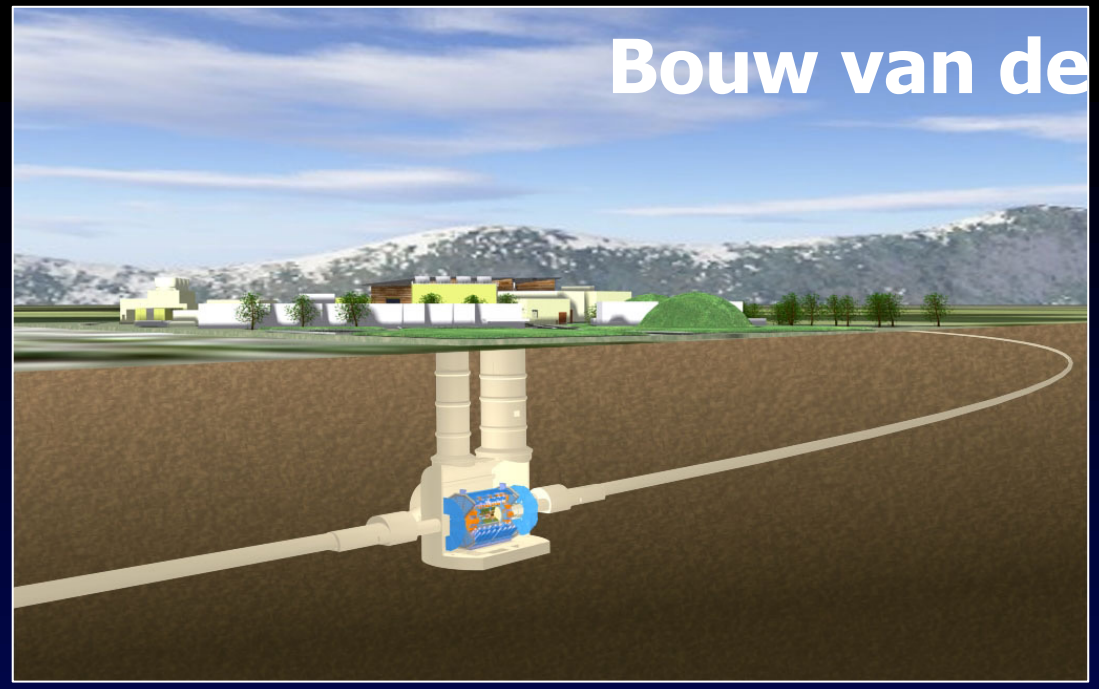
3: Deeltjes & CERN

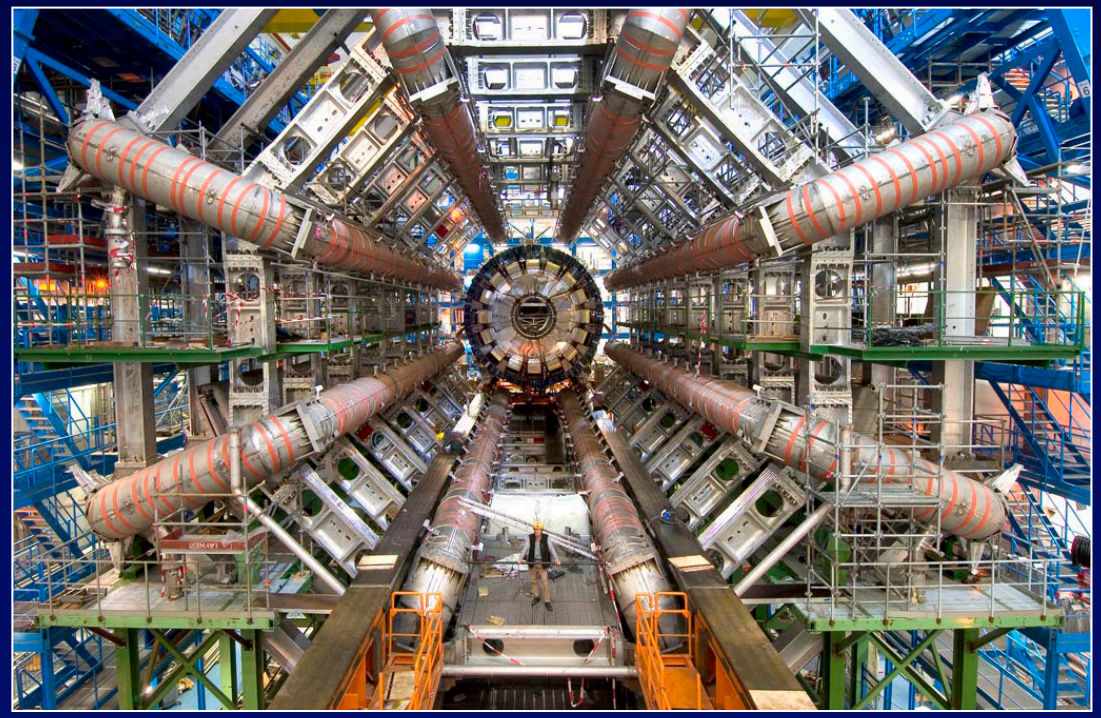
CERN: Deeltjes Fysica lab

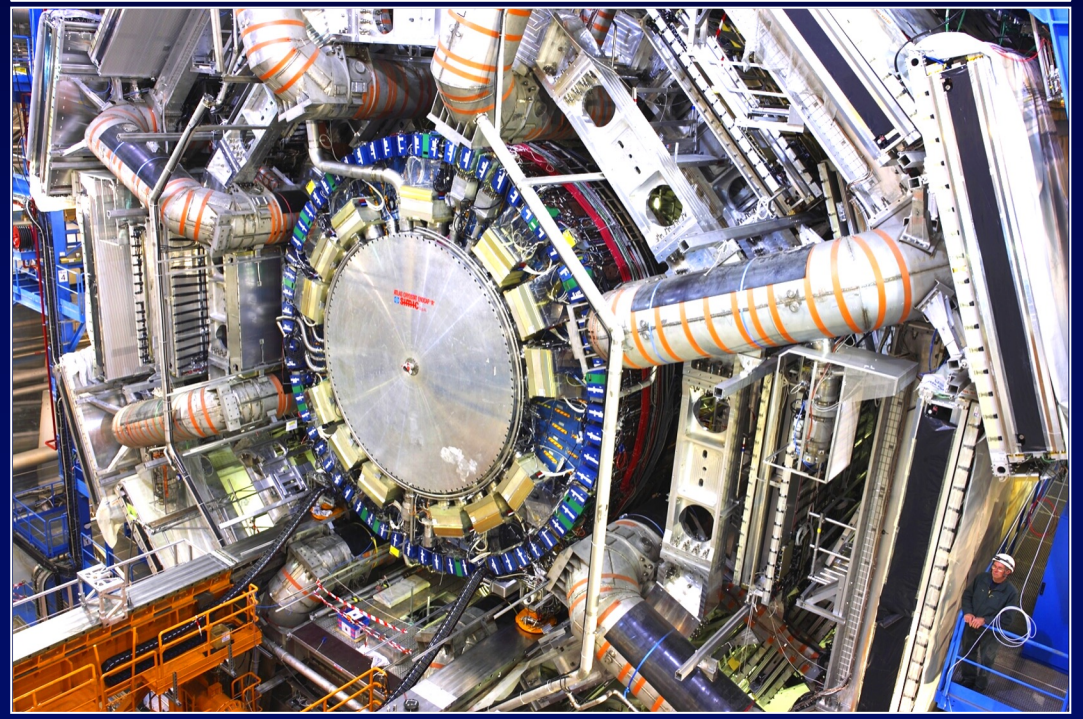




Bouw van de Atlas detector





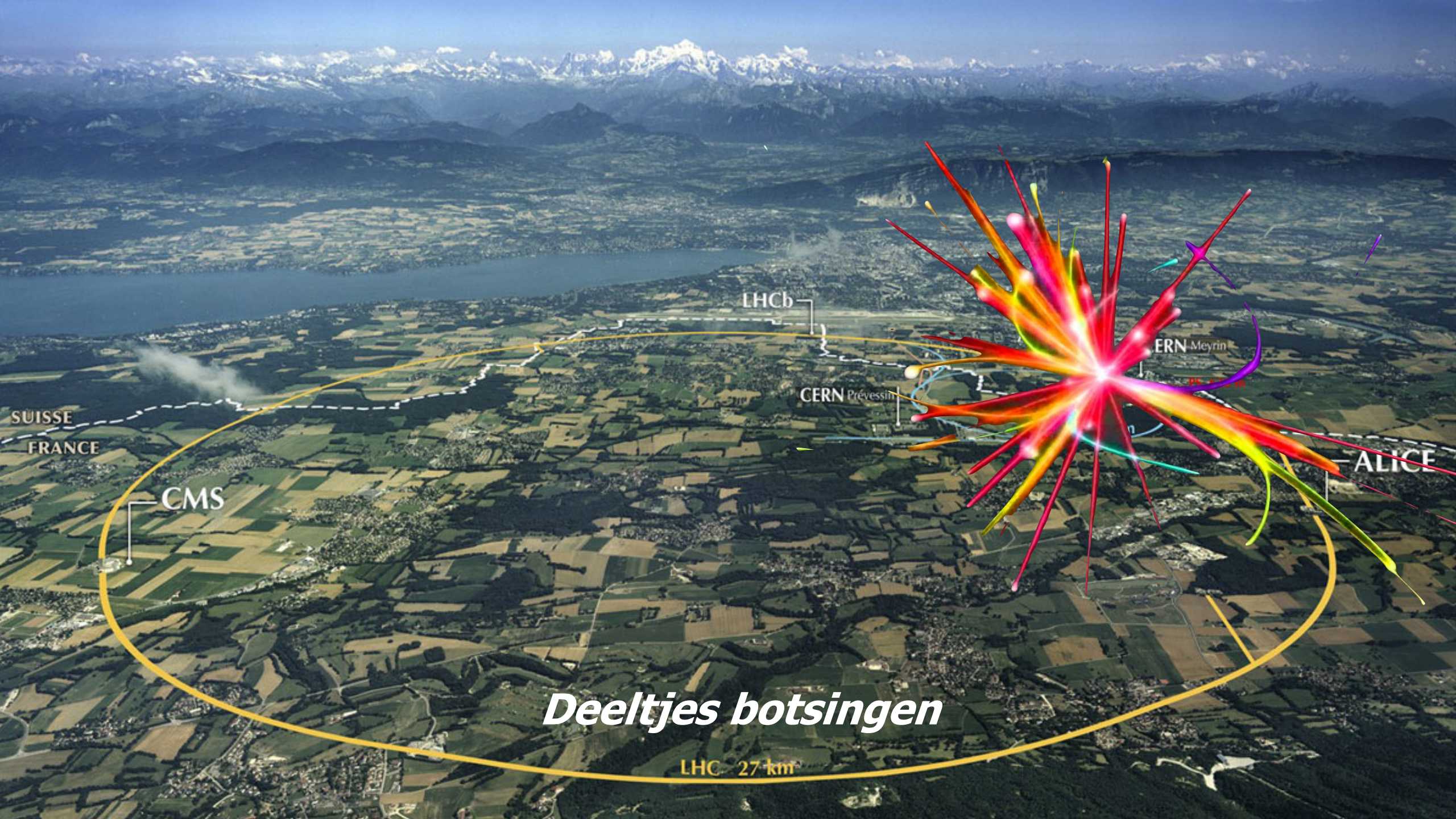


Het Atlas Experiment

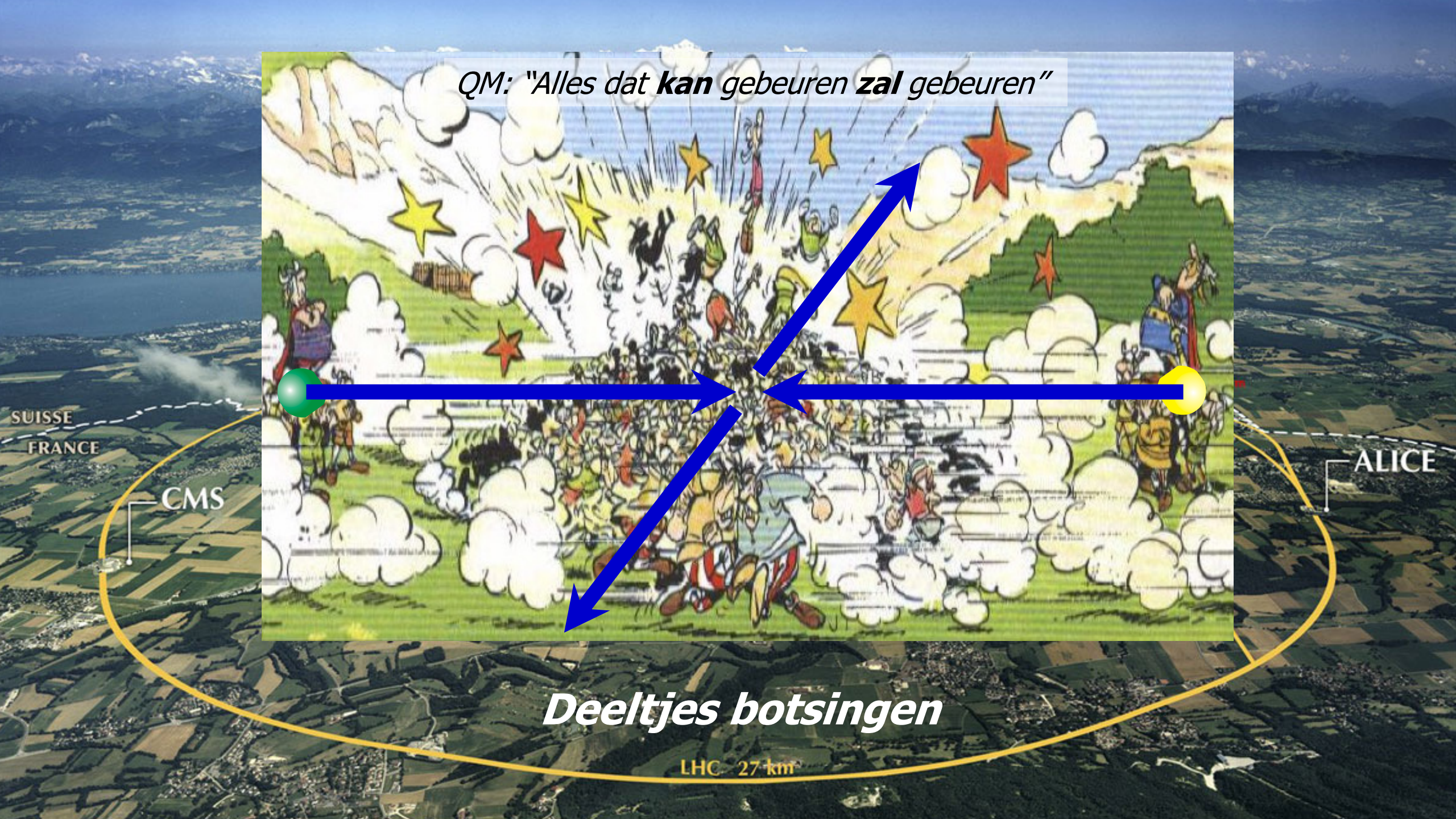
Het grootste fototoestel op aarde

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

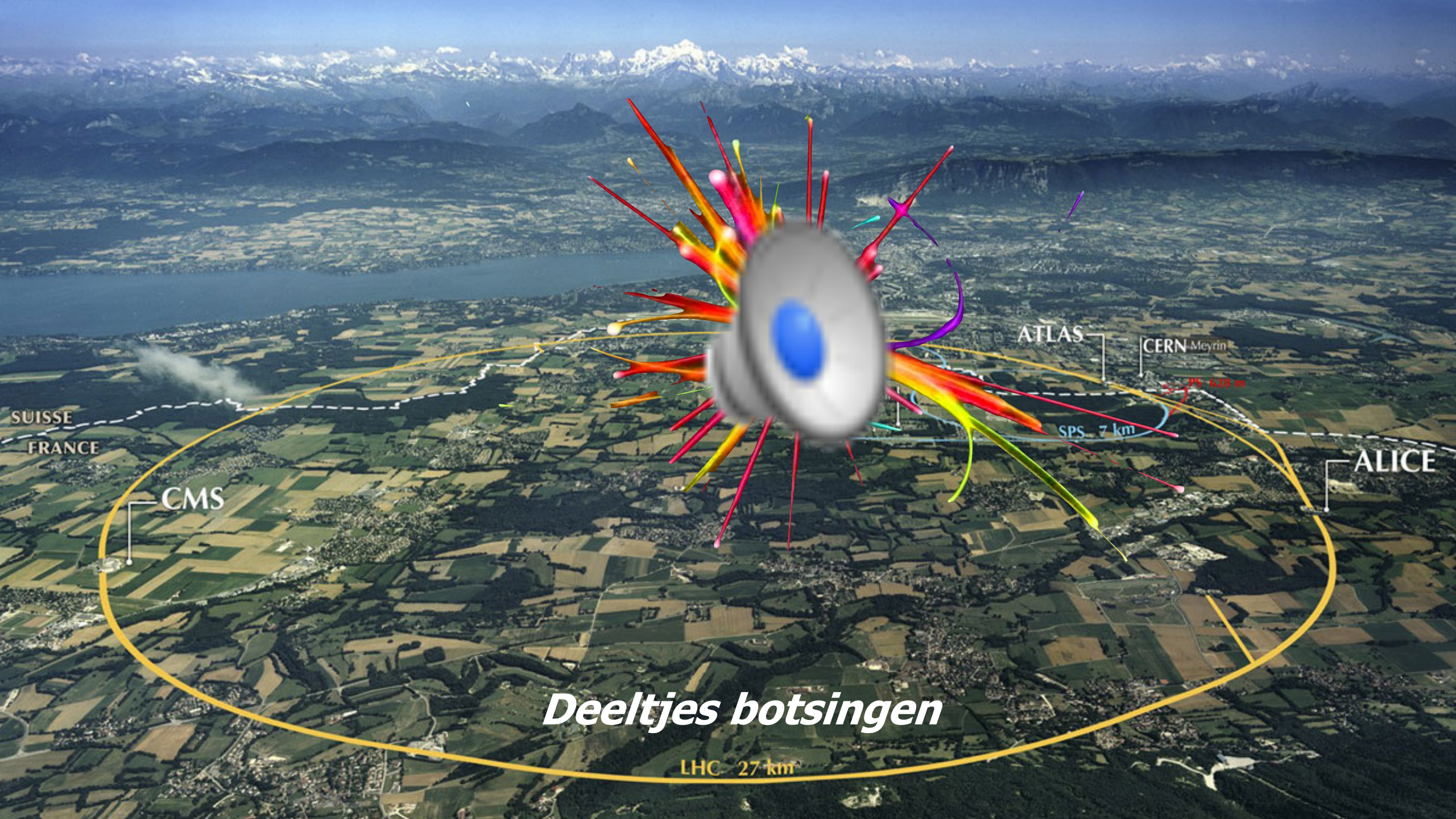
80 MegaPixel “camera”: 40.000.000 foto’s per seconde



Deeltjes botsingen



Deeltjes botsingen



Deeltjes botsingen

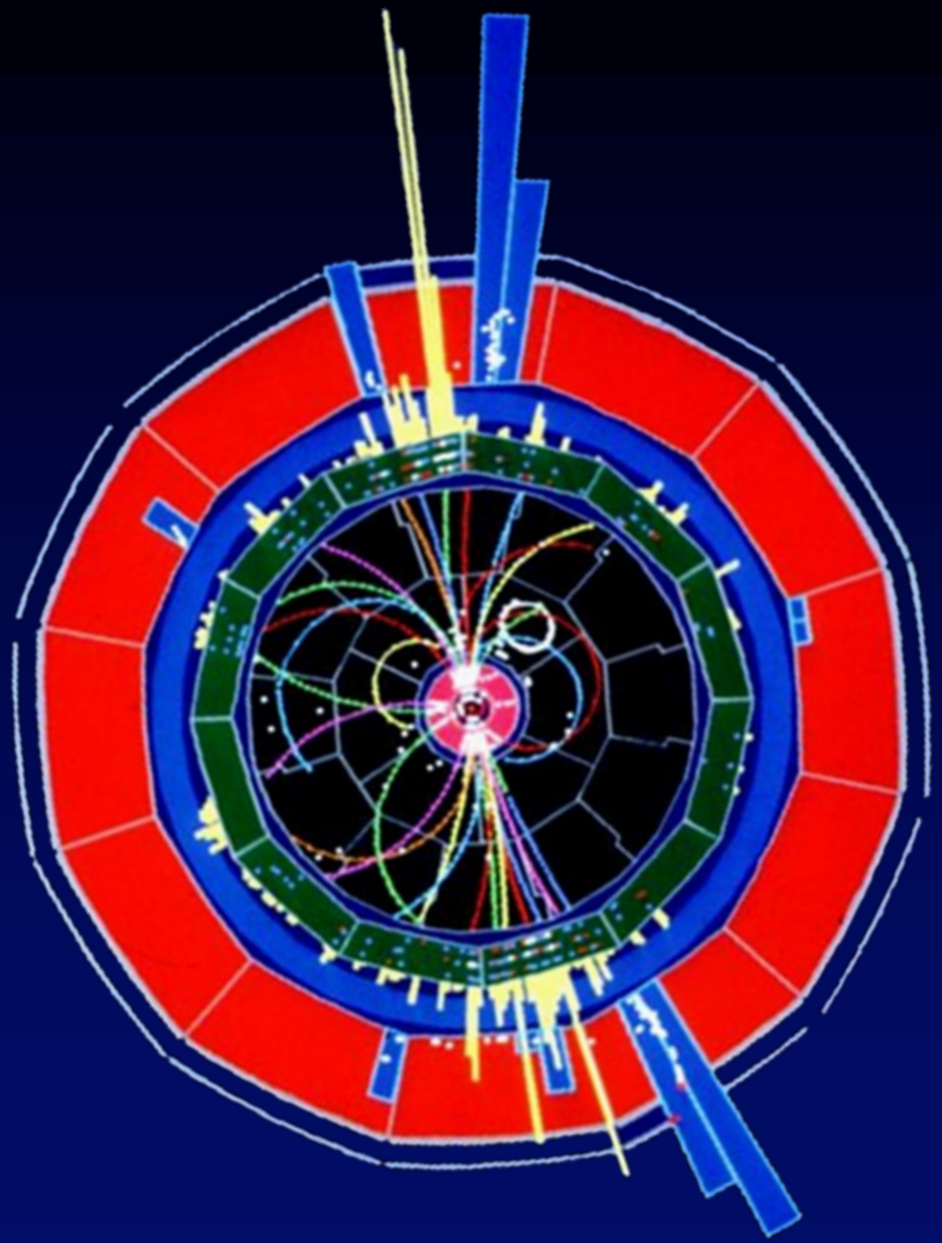
De Elementaire Deeltjes

Generatie:	I	II	III	Lading
quarks	u	c (1976)	t (1995)	+2/3 e
	d	s (1947)	b (1978)	-1/3 e

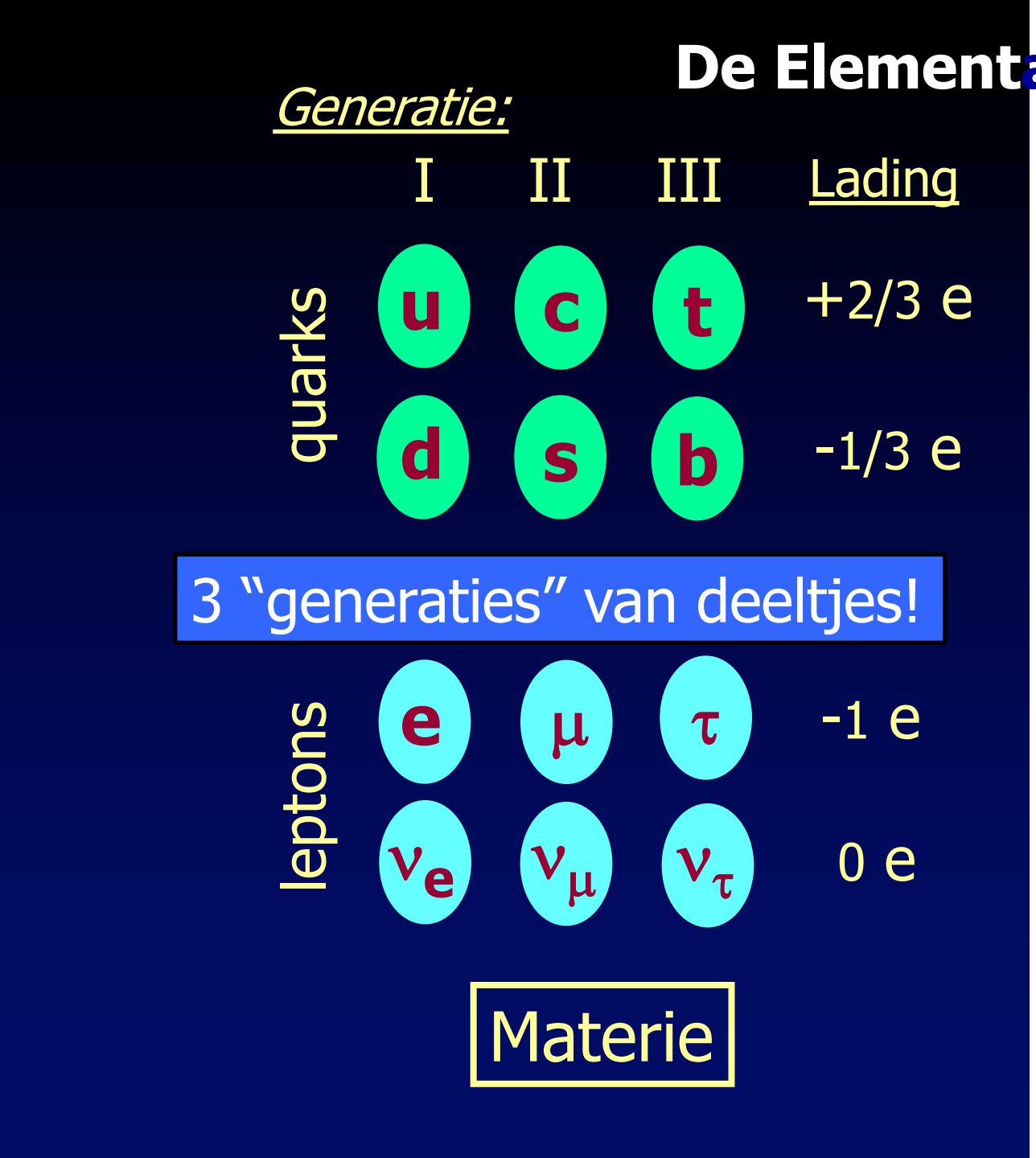
3 "generaties" van deeltjes!

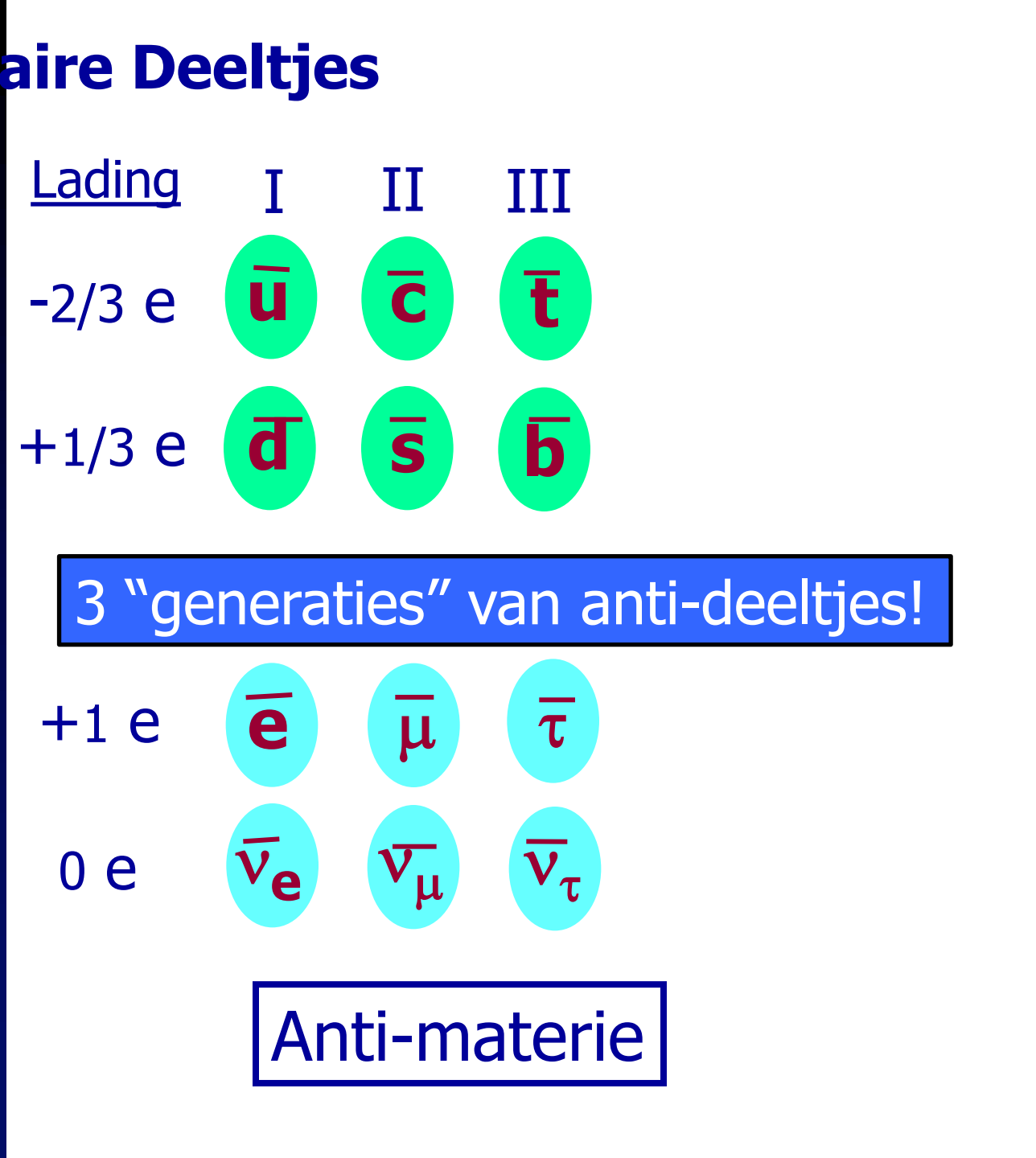
leptons	e (1895)	μ (1936)	τ (1973)	-1 e
	ν_e (1956)	ν_μ (1963)	ν_τ (2000)	0 e

Materie



De Elementaire Deeltjes





De Elementaire Deeltjes

Generatie:	I	II	III	Lading	Lading	I	II	III
quarks	u	c	t	+2/3 e	-2/3 e	$\bar{u}$	$\bar{c}$	$\bar{t}$
	d	s	b	-1/3 e	+1/3 e	$\bar{d}$	$\bar{s}$	$\bar{b}$

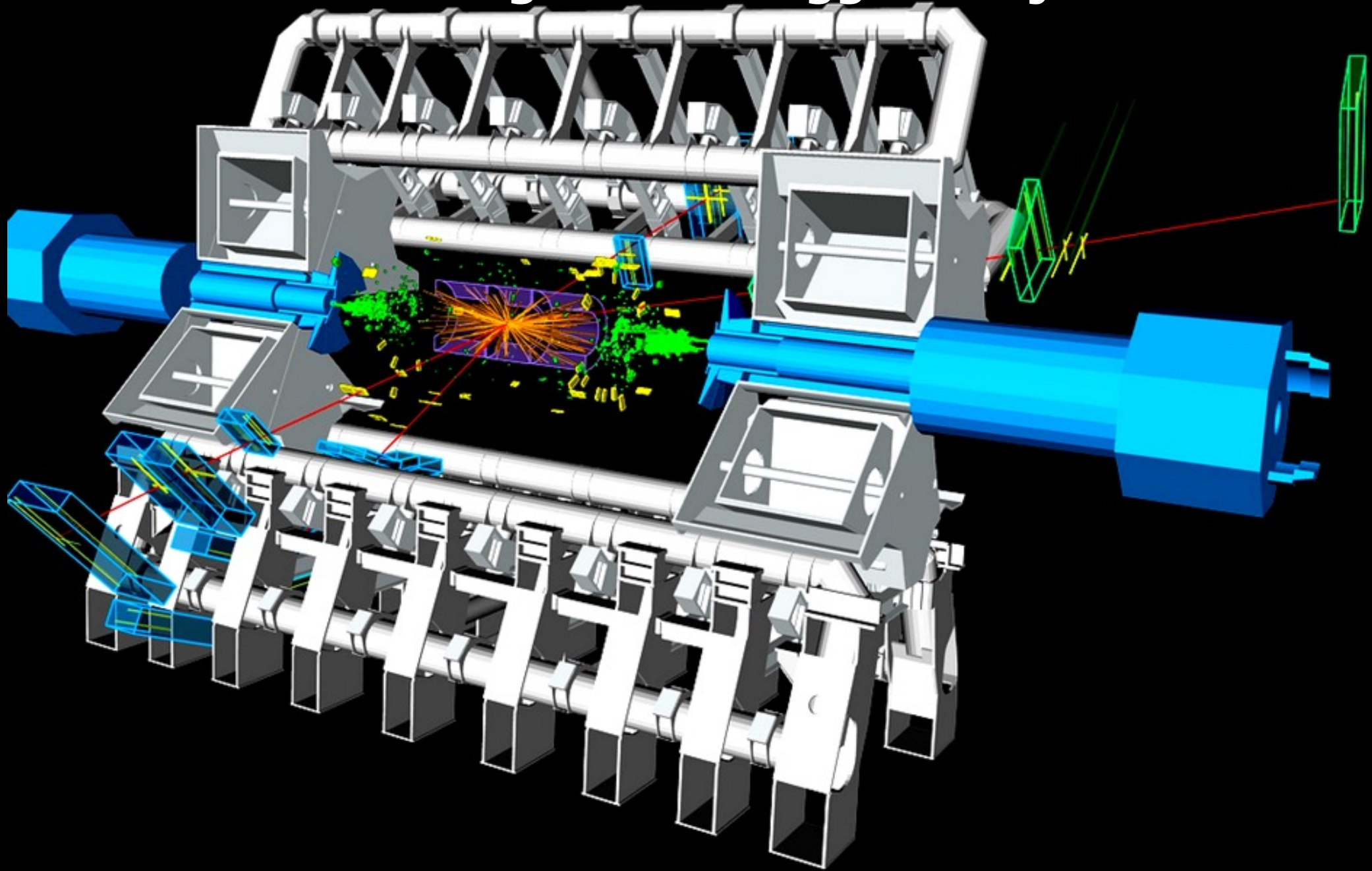
"Flavor puzzle": Waarom bestaan er **3** generaties van deeltjes??

leptons	e	μ	τ	-1 e	+1 e	$\bar{e}$	$\bar{\mu}$	$\bar{\tau}$
	ν_e	ν_μ	ν_τ	0 e	0 e	$\bar{\nu}_e$	$\bar{\nu}_\mu$	$\bar{\nu}_\tau$

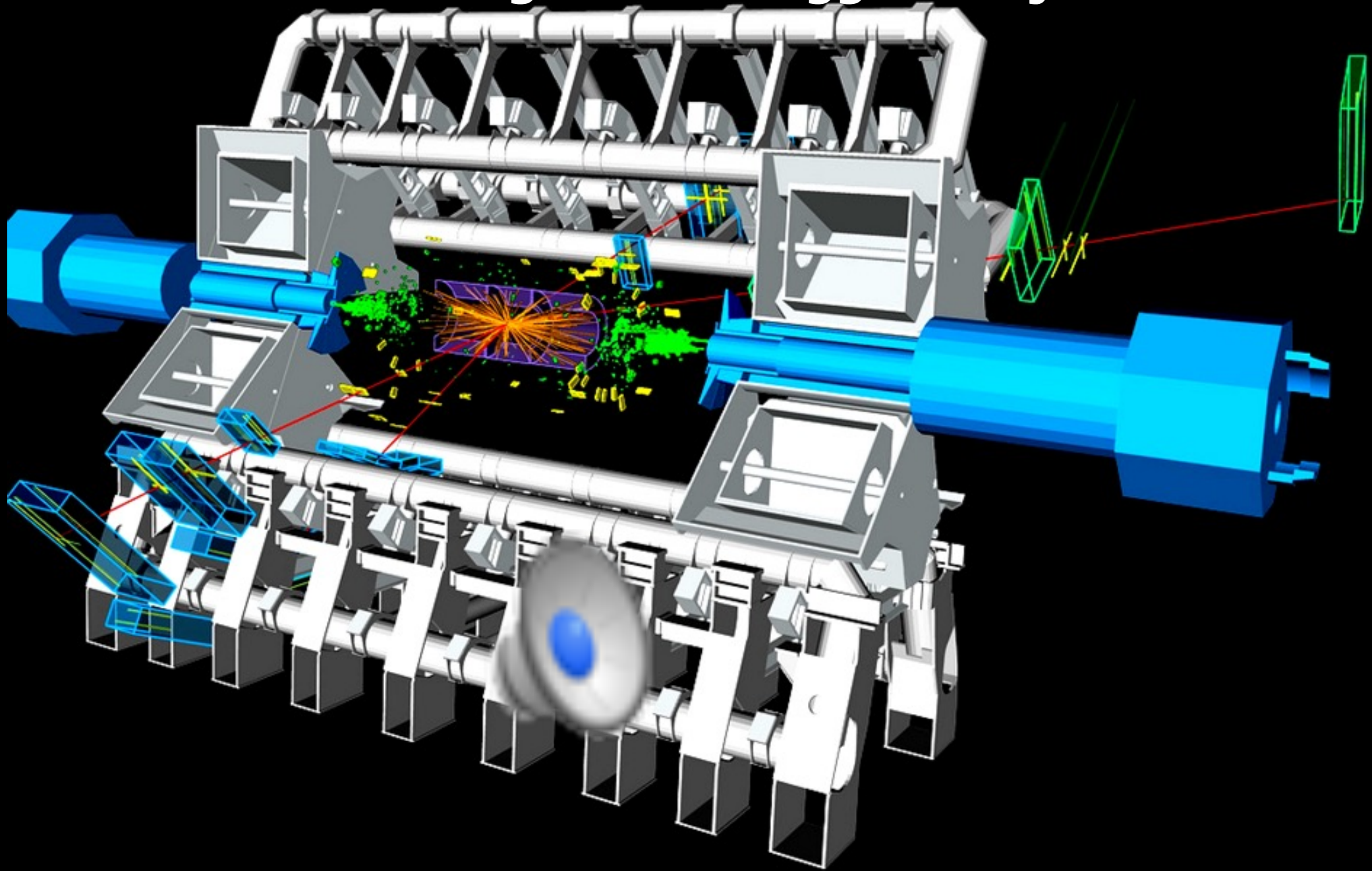
Materie

Anti-materie

Ontdekking van het Higgs deeltje

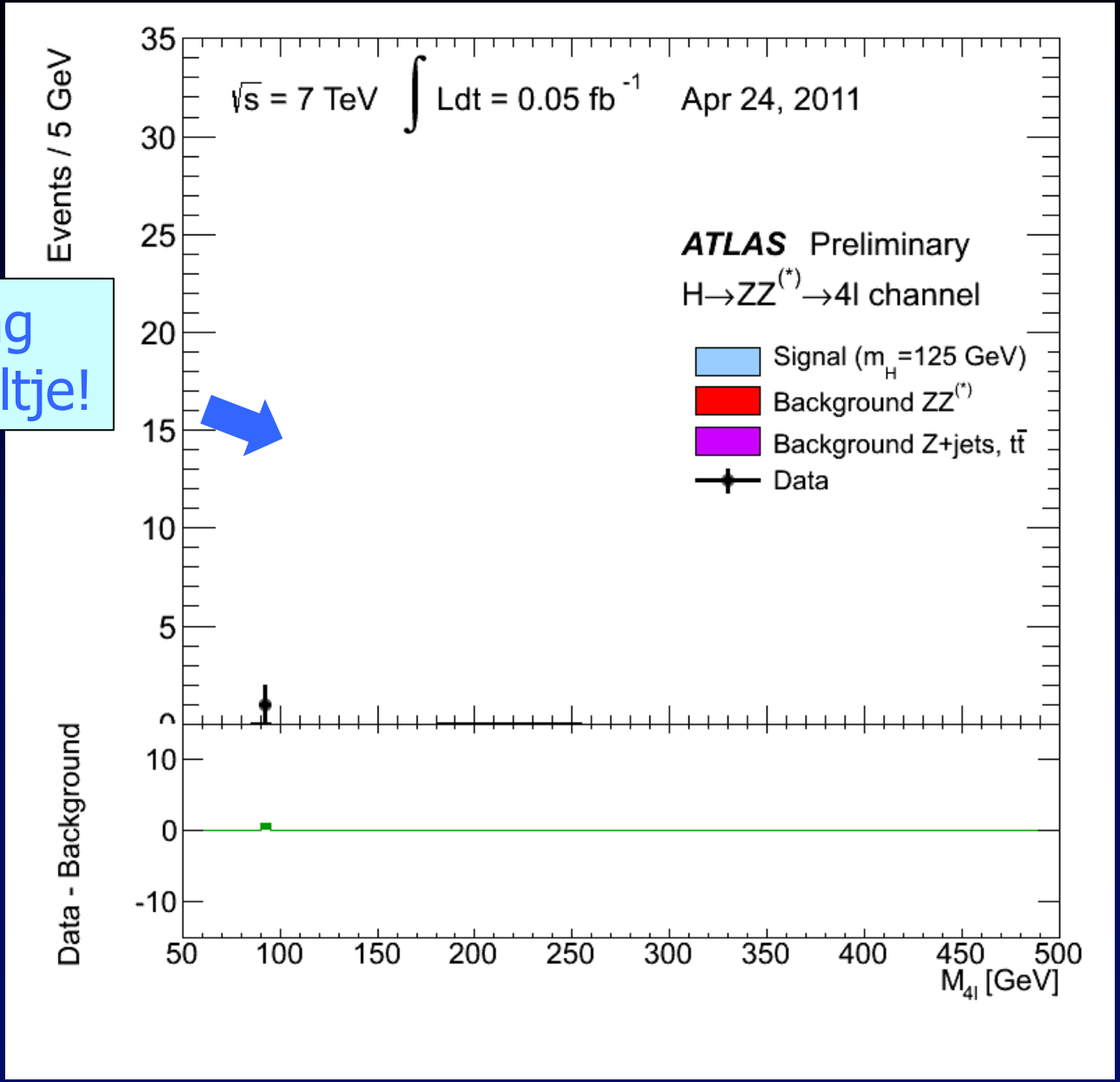


Ontdekking van het Higgs deeltje

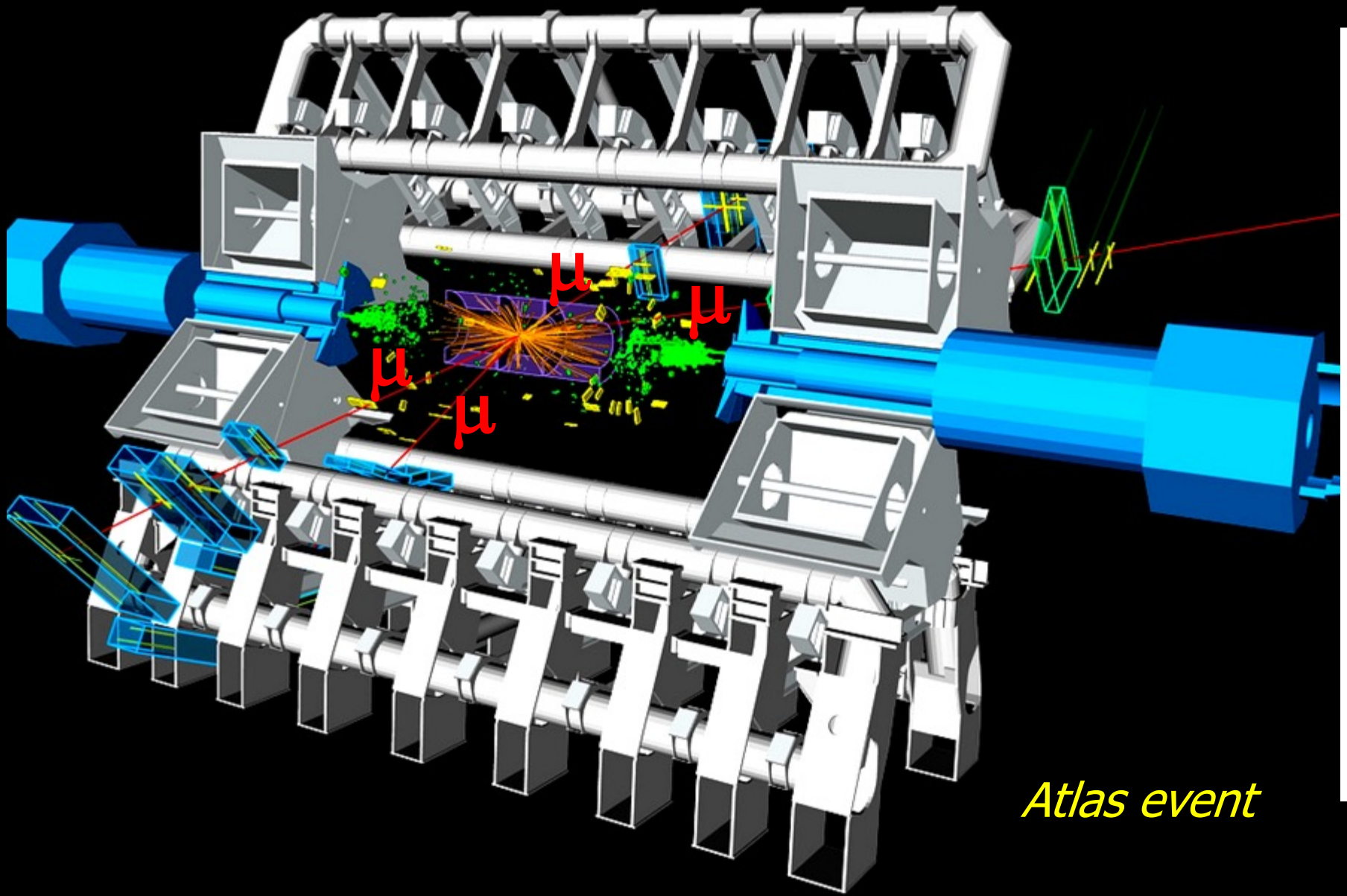


Higgs: data verzamelen en Theorie testen

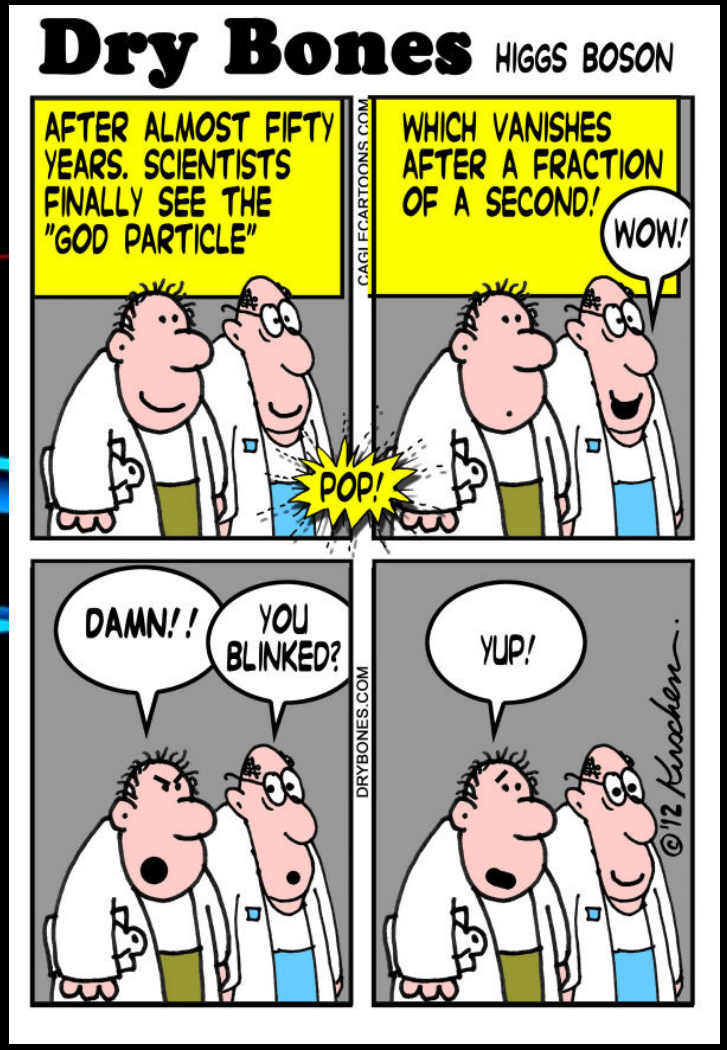
Ontdekking Higgs deeltje!



$pp \rightarrow Higgs \rightarrow ZZ \rightarrow \mu\mu\mu\mu$



Atlas event



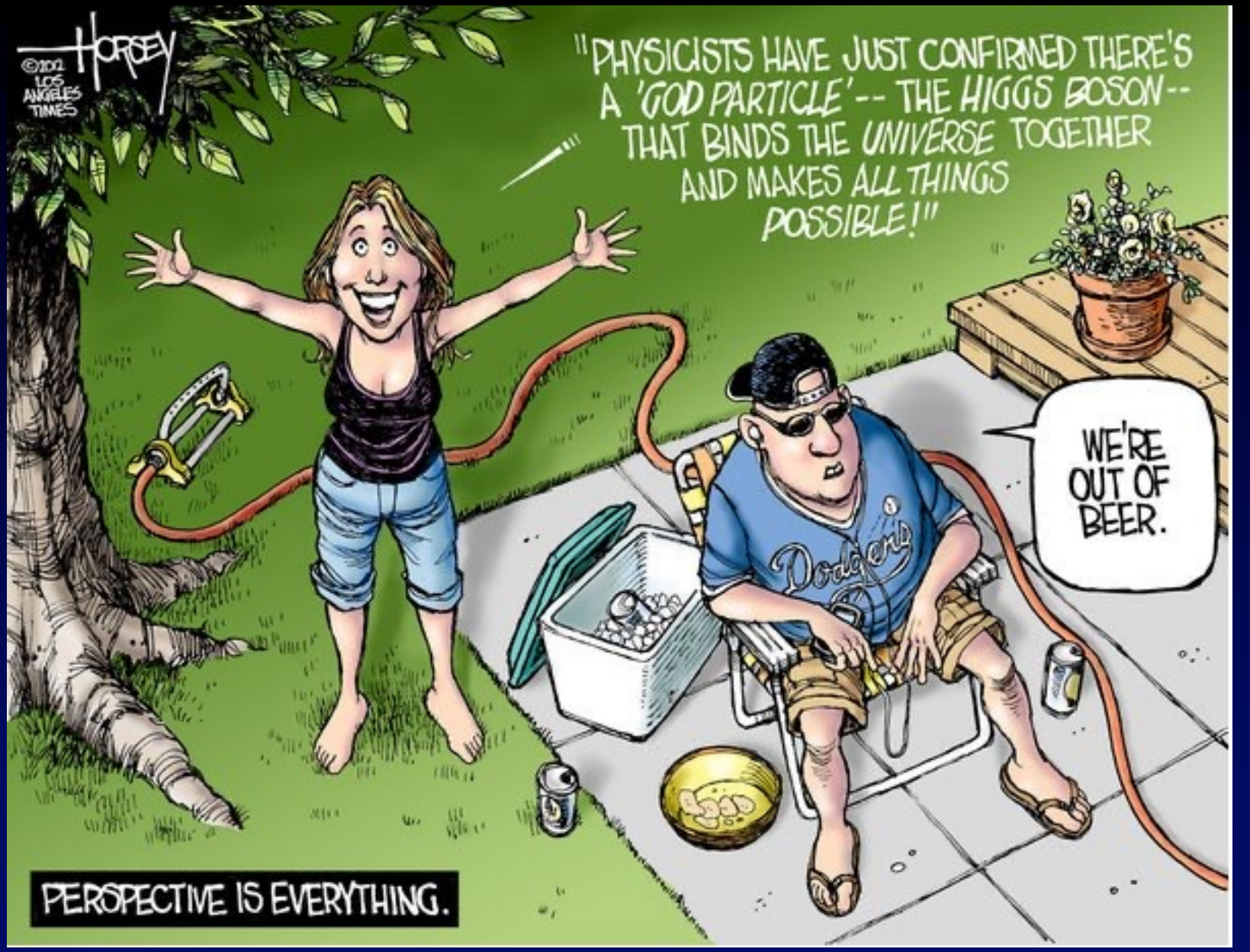
4 July 2012

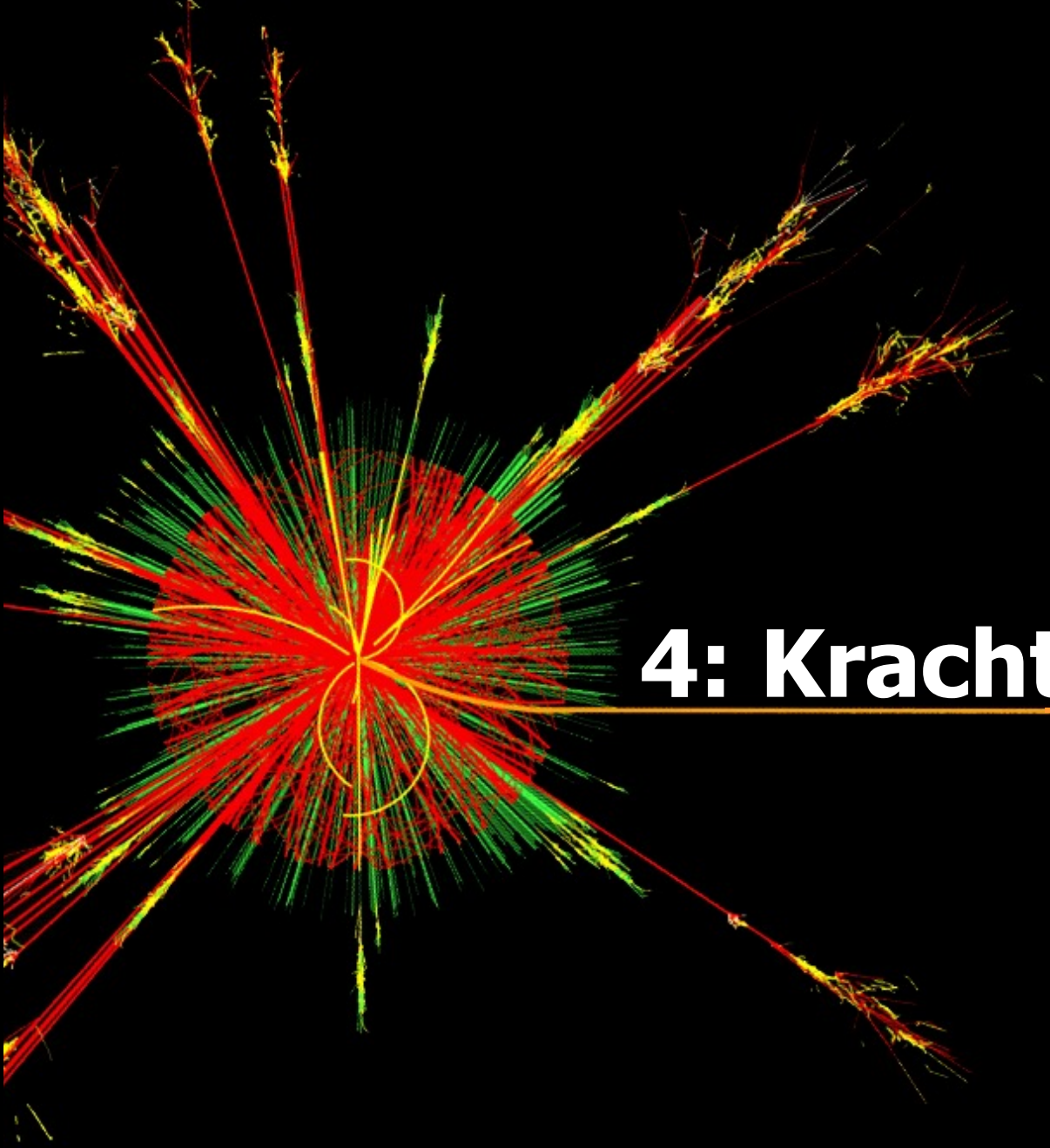
Bekendmaking Higgs ontdekking

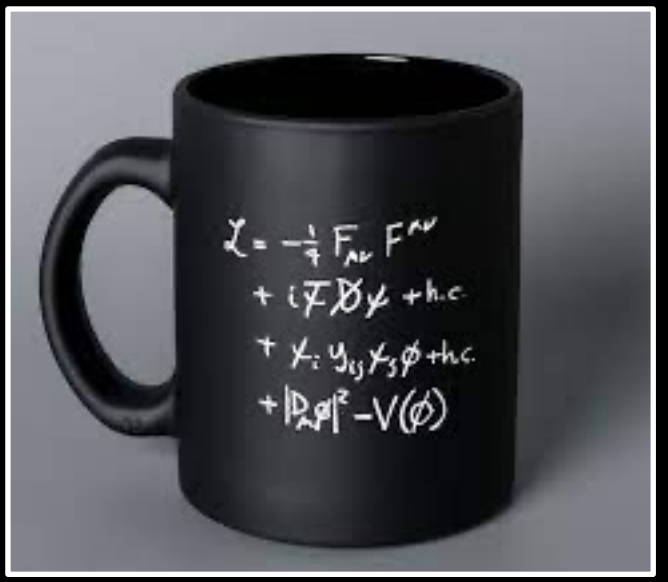
2013 Nobel prijs in Natuurkunde

Robert Brout

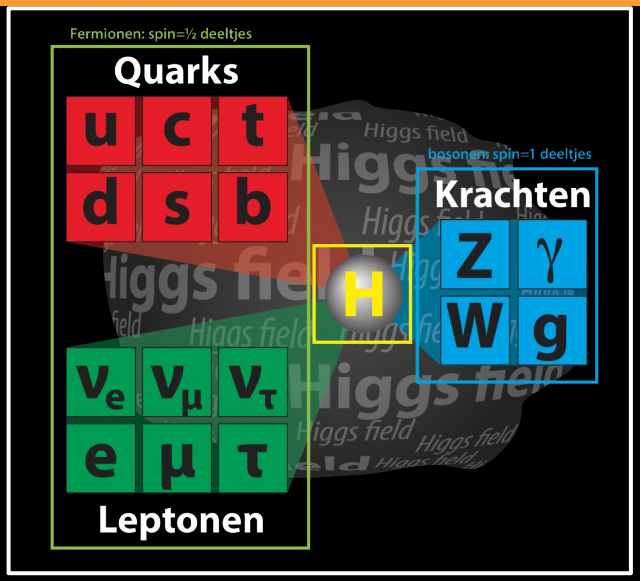
Francois Englert Peter Higgs


HORSEY
©2012 LOS ANGELES TIMES
"PHYSICISTS HAVE JUST CONFIRMED THERE'S A 'GOD PARTICLE' -- THE HIGGS BOSON -- THAT BINDS THE UNIVERSE TOGETHER AND MAKES ALL THINGS POSSIBLE!"
WE'RE OUT OF BEER.
PERSPECTIVE IS EVERYTHING.

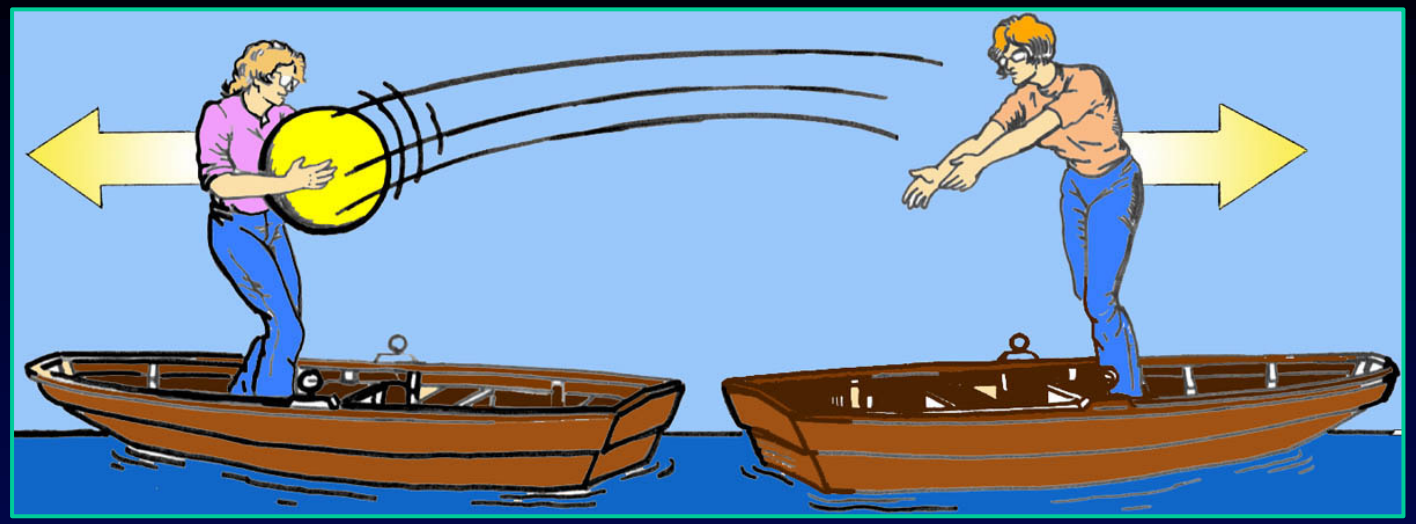




4: Krachten: “Standaard Model”

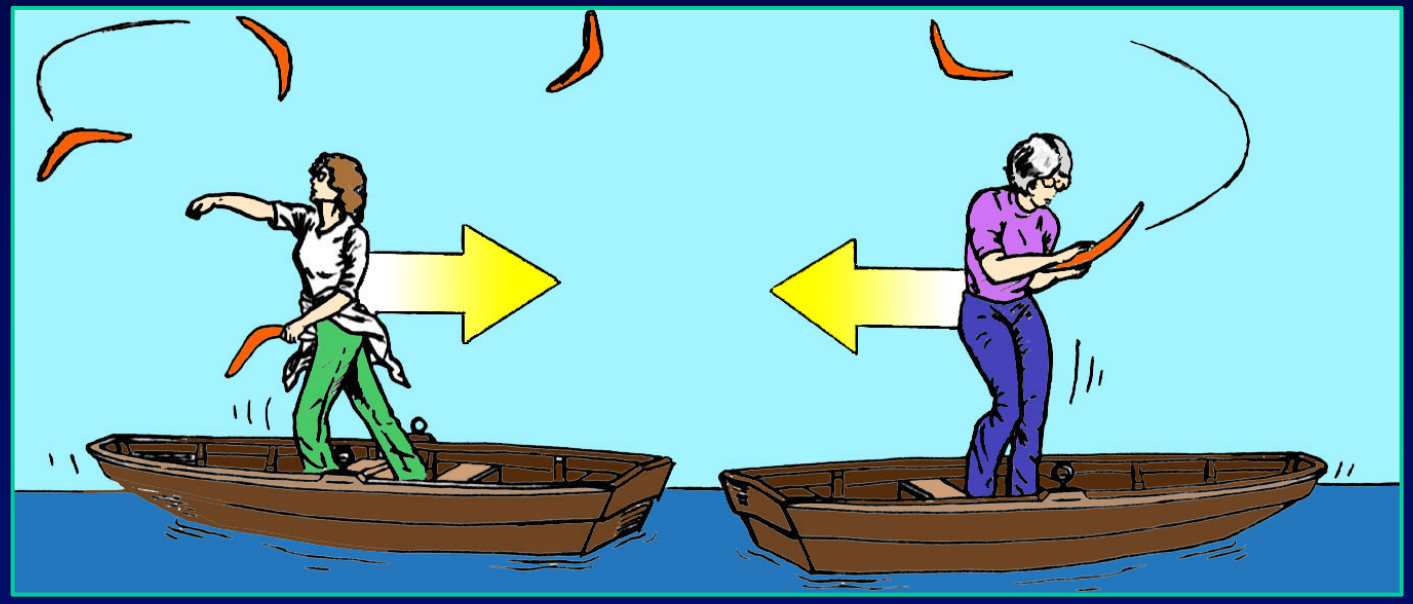


Krachten in Quantum Mechanica: deeltjesuitwisseling



"Afstotende kracht"

Er is geen
"aktie op afstand"

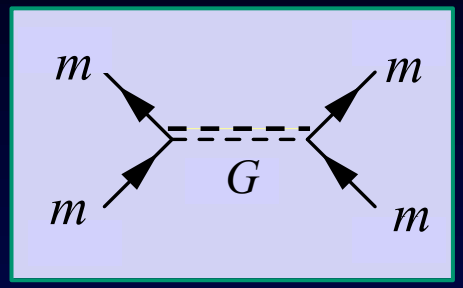


"Aantrekkende kracht"

Vier fundamentele natuurkrachten

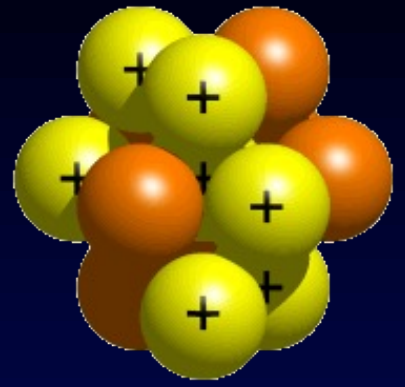
Zwaartekracht:

Quantum
Graviton exchange?



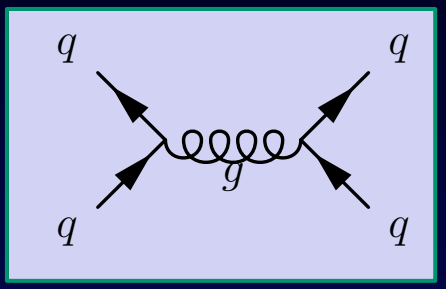
Werkt op alle deeltjes met massa

Sterke kernkracht:



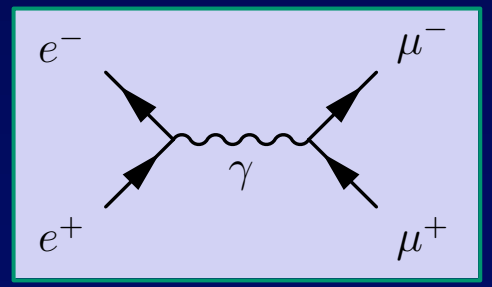
Werkt op alle quarks

Quantum
gluon exchange:



Elektromagnetisme:

Quantum
photon exchange:

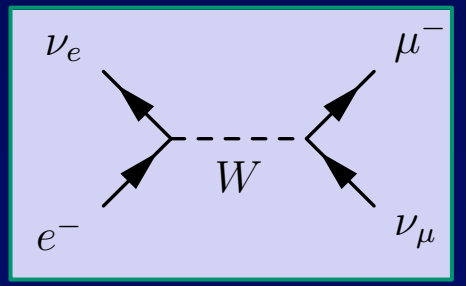


Werkt op alle elektrisch geladen deeltjes

Zwakke kernkracht:

Werkt op alle deeltjes

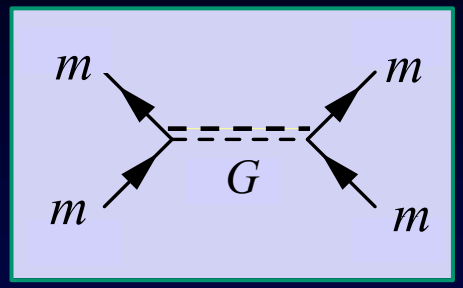
Quantum
W, Z exchange:



Vier fundamentele natuurkrachten

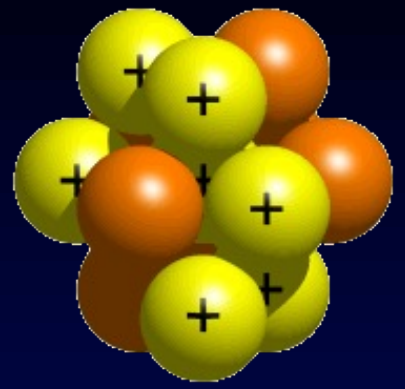
Zwaartekracht:

Quantum
Graviton exchange?



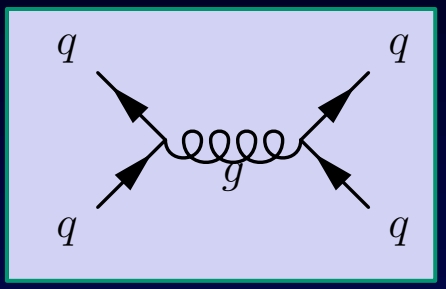
Werkt op alle deeltjes met massa

Sterke kernkracht:



Werkt op alle quarks

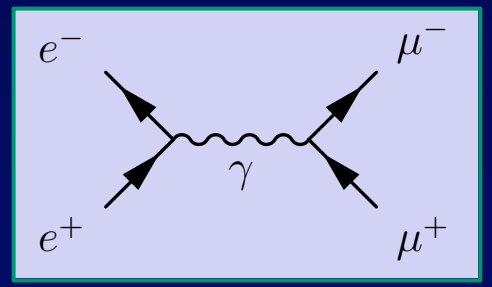
Quantum
gluon exchange:



Ele e:

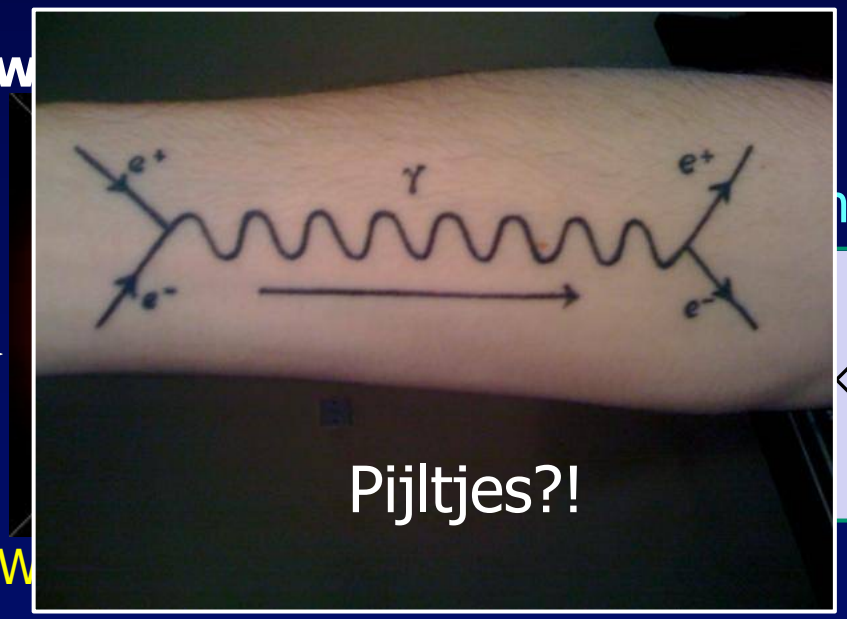
Richard Feynman

Quantum
photon exchange:



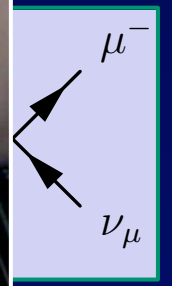
We n geladen deeltjes

Zw



Pijltjes?!

nge:

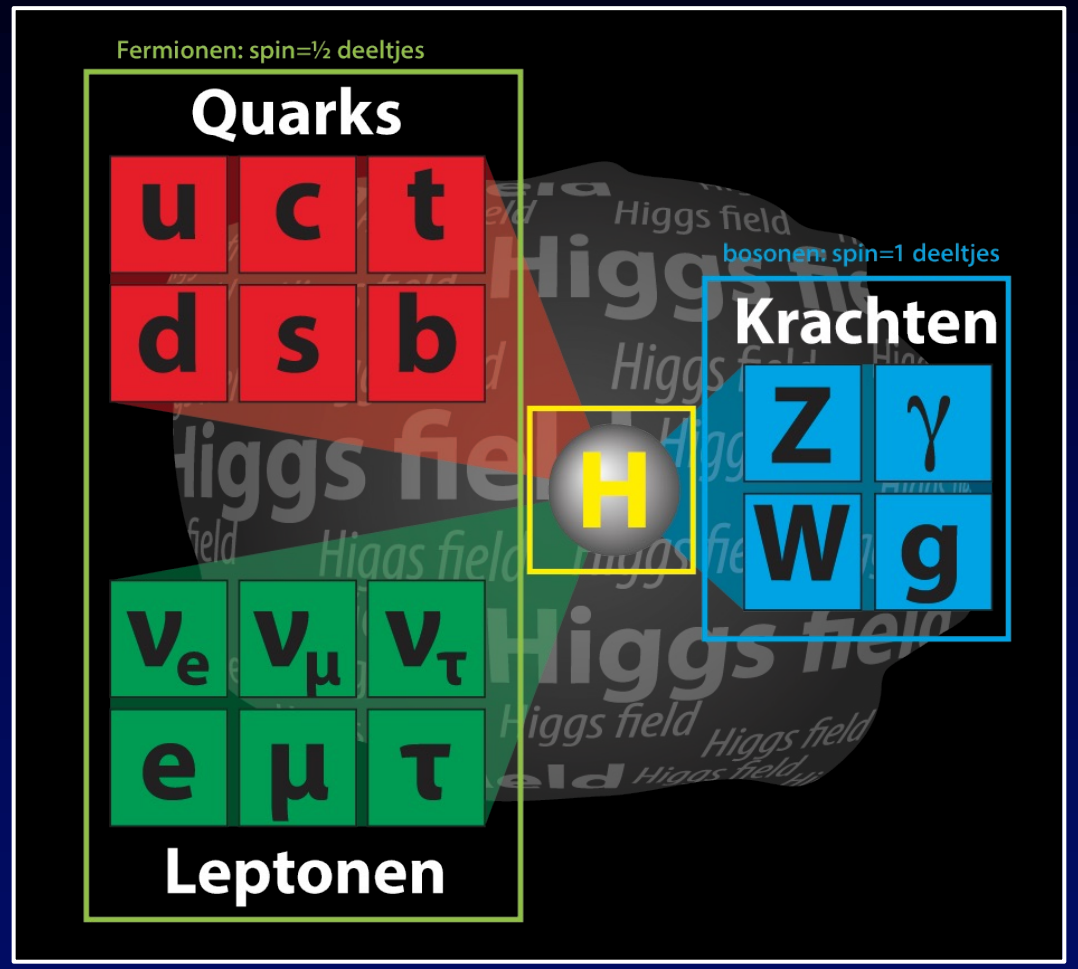


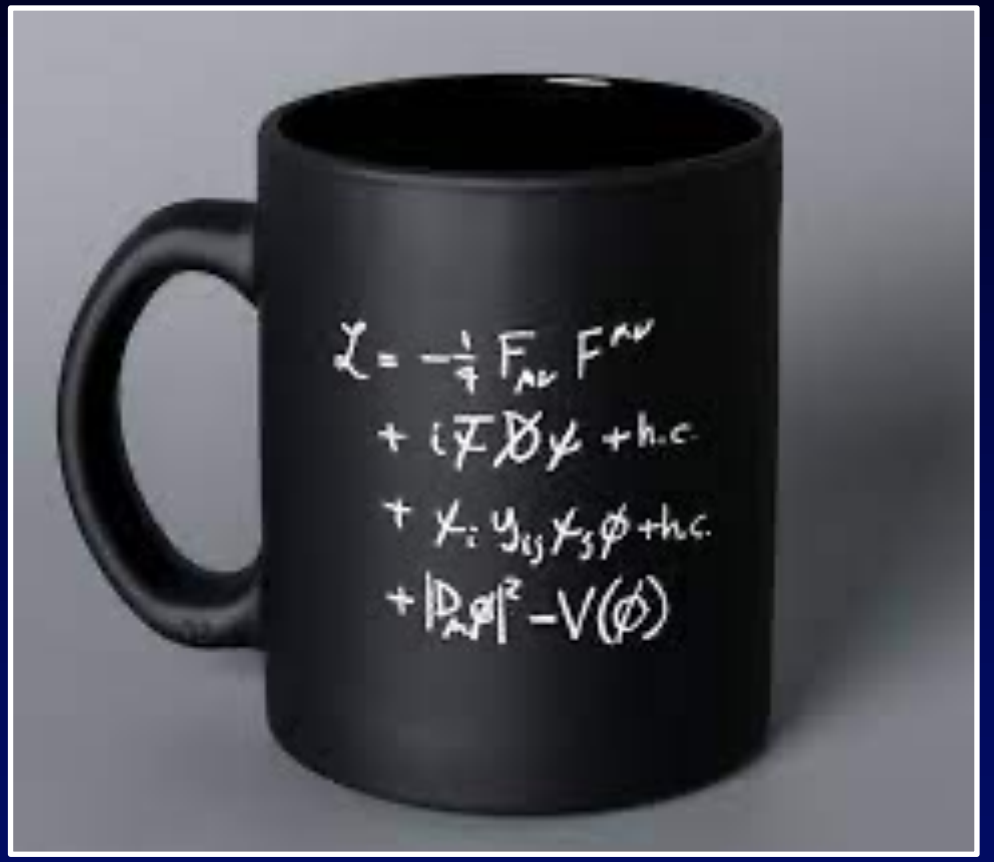
W

Hoe Sterk zijn de Krachten?

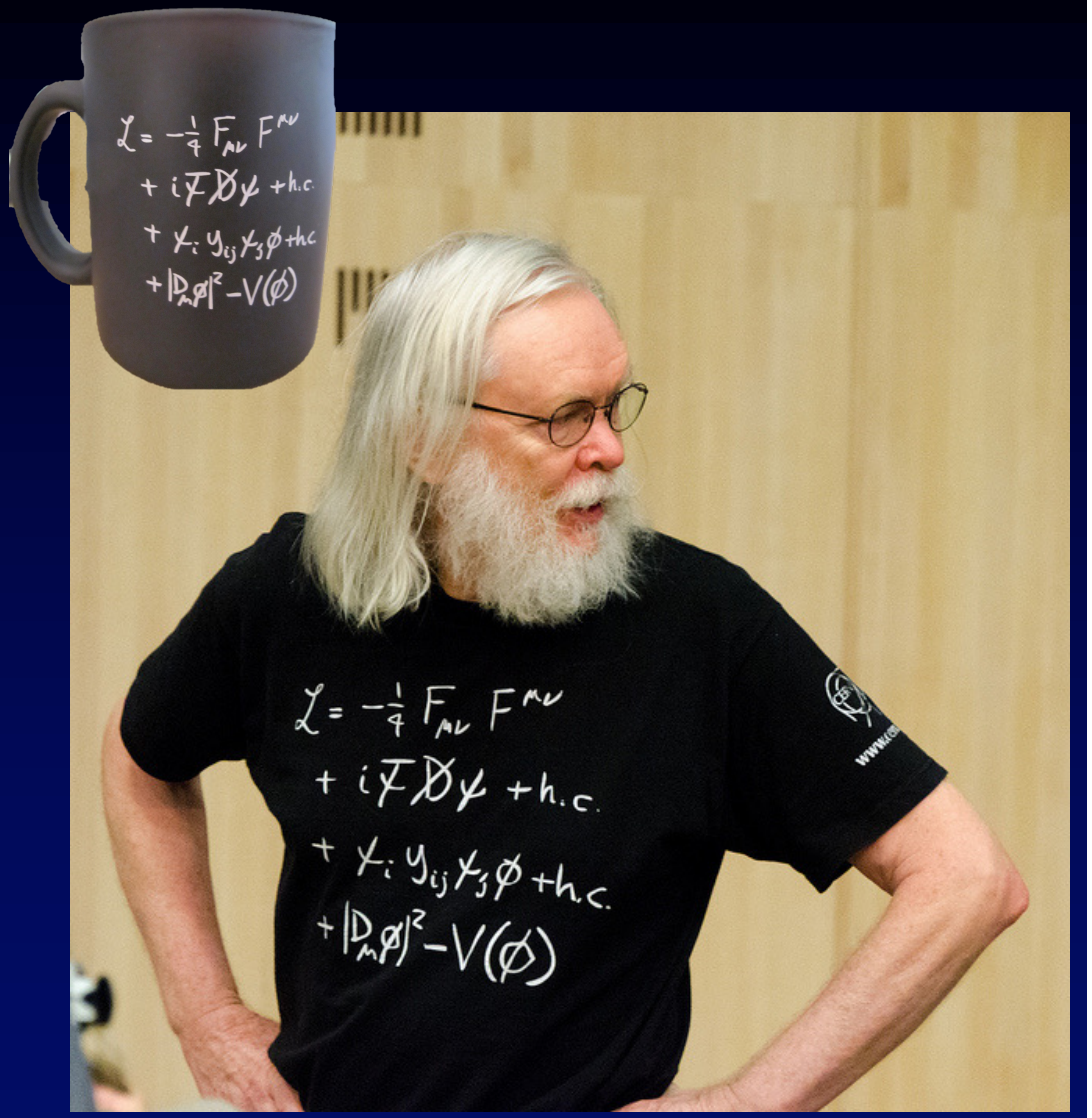
	Gravity	Weak (Electroweak)	Electromagnetic	Strong
Carried By	Graviton (not yet observed)	W^+ W^- Z^0	Photon	Gluon
Acts on	All	Quarks and Leptons	Quarks and Charged Leptons and W^+ W^-	Quarks and Gluons
Strength	0.00000000000000000000000000000001	0.0001	1	60

Het Standaardmodel: Deeltjes en Krachten



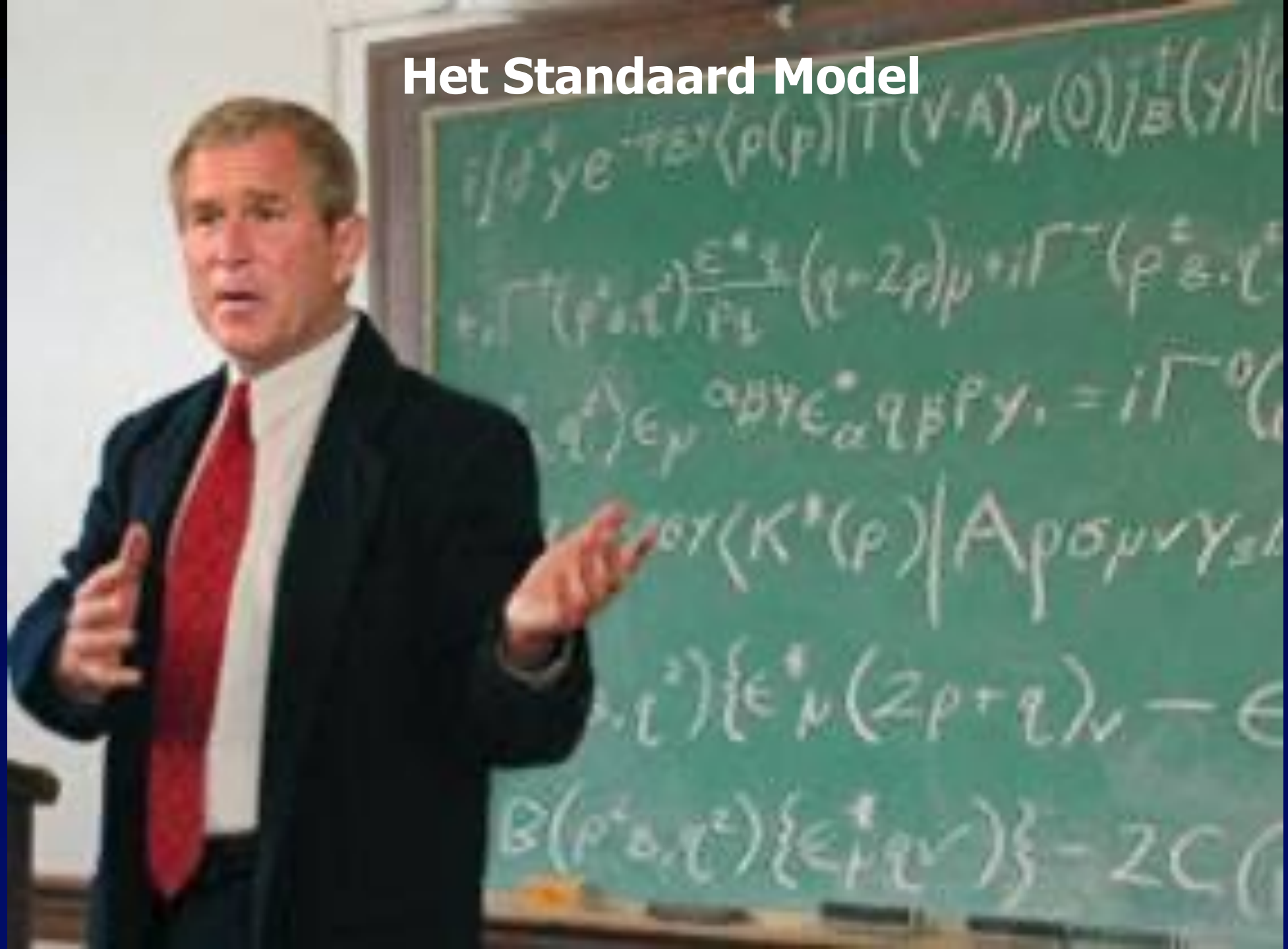


Standaard Model: Theorie



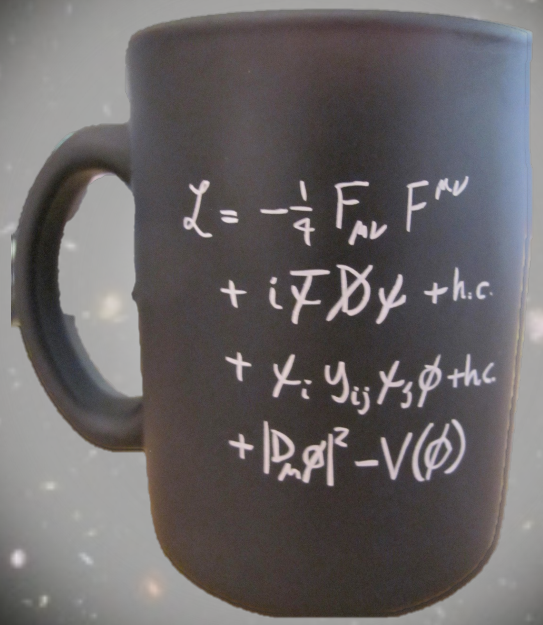
$$-\tfrac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \tfrac{1}{4}g_s^2 f^{abc} f^{ade} g^b_\mu g^c_\nu g^d_\mu g^e_\nu +$$
$$\tfrac{1}{2} i g_s^2 (\bar{q}^\sigma_i \gamma^\mu q^\sigma_j) g^a_\mu + \bar{G}^a \partial^2 G^a + g_s f^{abc} \partial_\mu \bar{G}^a G^b g^c_\mu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu -$$
$$M^2 W^+_\mu W^-_\mu - \tfrac{1}{2}\partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \tfrac{1}{2c_w^2} M^2 Z^0_\mu Z^0_\mu - \tfrac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu$$
$$\tfrac{1}{2} m_h^2 H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - M^2 \phi^+ \phi^- - \tfrac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \tfrac{1}{2c_w^2} M$$
$$\tfrac{2M}{g} H + \tfrac{1}{2}(H^2 + \phi^0\phi^0 + 2\phi^+\phi^-)] + \tfrac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu$$
$$W^+_\nu W^-_\mu) - Z^0_\nu (W^+_\mu \partial_\nu W^-_\mu - W^-_\mu \partial_\nu W^+_\mu) + Z^0_\mu (W$$
$$W^-_\nu \partial_\nu W^+_\mu)] - igs_w[\partial_\nu A_\mu (W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu$$
$$W^-_\mu \partial_\nu W^+_\mu) + A_\mu (W^+_\nu \partial_\nu W^-_\mu - W^-_\nu \partial_\nu W^+_\mu)] - \tfrac{1}{2} g^2 W^+_\mu$$
$$\tfrac{1}{2} g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2 c_w^2 (Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu$$
$$g^2 s_w^2 (A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w [A_\mu Z$$
$$W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2$$
$$\tfrac{1}{8} g^2 \alpha_h [H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi$$
$$gMW^+_\mu W^-_\mu H - \tfrac{1}{2} g \tfrac{M}{c_w^2} Z^0_\mu Z^0_\mu H - \tfrac{1}{2} ig[W^+_\mu (\phi^0 \partial_\mu \phi^- -$$
$$W^-_\mu (\phi^0 \partial_\mu \phi^+ - \phi^+ \partial_\mu \phi^0)] + \tfrac{1}{2} g[W^+_\mu (H\partial_\mu \phi^- - \phi^- \partial_\mu H) -$$
$$\phi^+ \partial_\mu H)] + \tfrac{1}{2} g \tfrac{1}{c_w} (Z^0_\mu (H\partial_\mu \phi^0 - \phi^0 \partial_\mu H) - ig \tfrac{s_w^2}{c_w} M Z^0_\mu (W^+_\mu$$
$$igs_w M A_\mu (W^+_\mu \phi^- - W^-_\mu \phi^+) - ig \tfrac{1-2c_w^2}{2c_w} Z^0_\mu (\phi^+ \partial_\mu \phi^- -$$
$$igs_w A_\mu (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) - \tfrac{1}{4} g^2 W^+_\mu W^-_\mu [H^2 + (\phi^0$$
$$\tfrac{1}{4} g^2 \tfrac{1}{c_w^2} Z^0_\mu Z^0_\mu [H^2 + (\phi^0)^2 + 2(2s_w^2 - 1)^2 \phi^+\phi^-] - \tfrac{1}{2} g^2 \tfrac{s_w^2}{c_w}$$
$$W^-_\mu \phi^|) - \tfrac{1}{2} ig^2 \tfrac{s_w^2}{c_w} Z^0_\mu H (W^|_\mu \phi^- - W^-_\mu \phi^|) + \tfrac{1}{2} g^2 s_w A_$$
$$W^-_\mu \phi^+) + \tfrac{1}{2} ig^2 s_w A_\mu H (W^+_\mu \phi^- - W^-_\mu \phi^+) - g^2 \tfrac{s_w}{c_w} (2c_w^2 -$$
$$g^1 s_w^2 A_\mu A_\mu \phi^+ \phi^- - \bar{e}^\lambda (\gamma\partial + m_e^\lambda) e^\lambda - \bar{\nu}^\lambda \gamma\partial \nu^\lambda - \bar{u}^\lambda_j (\gamma\partial + m$$
$$m^\lambda_d) d^\lambda_j + igs_w A_\mu [-(\bar{e}^\lambda \gamma e^\lambda) + \tfrac{2}{3}(\bar{u}^\lambda_j \gamma u^\lambda_j) - \tfrac{1}{3}(\bar{d}^\lambda_j \gamma d^\lambda_j)] +$$
$$\gamma^5) \nu^\lambda) + (\bar{e}^\lambda \gamma^\mu (4s_w^2 - 1 - \gamma^5) e^\lambda) + (\bar{u}^\lambda_j \gamma^\mu (\tfrac{4}{3} s_w^2 - 1$$
$$(\bar{d}^\lambda_j \gamma^\mu (1 - \tfrac{8}{3} s_w^2 - \gamma^5) d^\lambda_j)] + \tfrac{ig}{2\sqrt{2}} W^+_\mu [(\bar{\nu}^\lambda \gamma^\mu (1 + \gamma^5) e^\lambda$$
$$\gamma^5) C_{\lambda\kappa} d^\kappa_j)] + \tfrac{ig}{2\sqrt{2}} W^-_\mu [(\bar{e}^\lambda \gamma^\mu (1 + \gamma^5) \nu^\lambda) + (\bar{d}^\kappa_j C^|_{\lambda\kappa} \gamma^\mu ($$
$$\tfrac{ig}{2\sqrt{2}} \tfrac{m^\lambda_e}{M} [-\phi^+ (\bar{\nu}^\lambda (1 - \gamma^5) e^\lambda) + \phi^- (\bar{e}^\lambda (1 + \gamma^5) \nu^\lambda)] - \tfrac{g}{2}$$
$$i\phi^0 (\bar{e}^\lambda \gamma^5 e^\lambda)] + \tfrac{ig}{2M\sqrt{2}} \phi^+ [-m^\kappa_d (\bar{u}^\lambda_j C_{\lambda\kappa} (1 - \gamma^5) d^\kappa_j) + m$$
$$\gamma^5) d^\kappa_j] + \tfrac{ig}{2M\sqrt{2}} \phi^- [m^\lambda_d (\bar{d}^\lambda_j C^\dagger_{\lambda\kappa} (1 + \gamma^5) u^\kappa_j) - m^\kappa_u (\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}$$
$$\tfrac{g}{2} \tfrac{m^\lambda_u}{M} H (\bar{u}^\lambda_j u^\lambda_j) - \tfrac{g}{2} \tfrac{m^\lambda_d}{M} H (\bar{d}^\lambda_j d^\lambda_j) + \tfrac{ig}{2} \tfrac{m^\lambda_u}{M} \phi^0 (\bar{u}^\lambda_j \gamma^5 u^\lambda_j) - \tfrac{ig}{2}$$
$$\bar{X}^+ (\partial^2 - M^2) X^+ + \bar{X}^- (\partial^2 - M^2) X^- + \bar{X}^0 (\partial^2 - \tfrac{M^2}{c_w^2}$$
$$igc_w W^+_\mu (\partial_\mu \bar{X}^0 X^- - \partial_\mu \bar{X}^+ X^0) + igs_w W^+_\mu (\partial_\mu \bar{Y} X^-$$
$$igc_w W^-_\mu (\partial_\mu \bar{X}^- X^0 - \partial_\mu \bar{X}^0 X^+) + igs_w W^-_\mu (\partial_\mu \bar{X}^- Y$$
$$igc_w Z^0_\mu (\partial_\mu \bar{X}^| X^| - \partial_\mu \bar{X}^- X^-) + igs_w A_\mu (\partial_\mu \bar{X}^| X^| -$$
$$\tfrac{1}{2} gM [\bar{X}^+ X^+ H + \bar{X}^- X^- H + \tfrac{1}{c_w^2} \bar{X}^0 X^0 H] + \tfrac{1-2c_w^2}{2c_w} ig$$
$$\bar{X}^- X^0 \phi^-] + \tfrac{1}{2c_w} igM [\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-] + igMs_w [\bar{X}^0 X^- \phi^+ -$$
$$\bar{X}^0 X^+ \phi^-] + \tfrac{1}{2} igM [\bar{X}^+ X^+ \phi^0 - \bar{X}^- X^- \phi^0]$$

Het Standaard Model

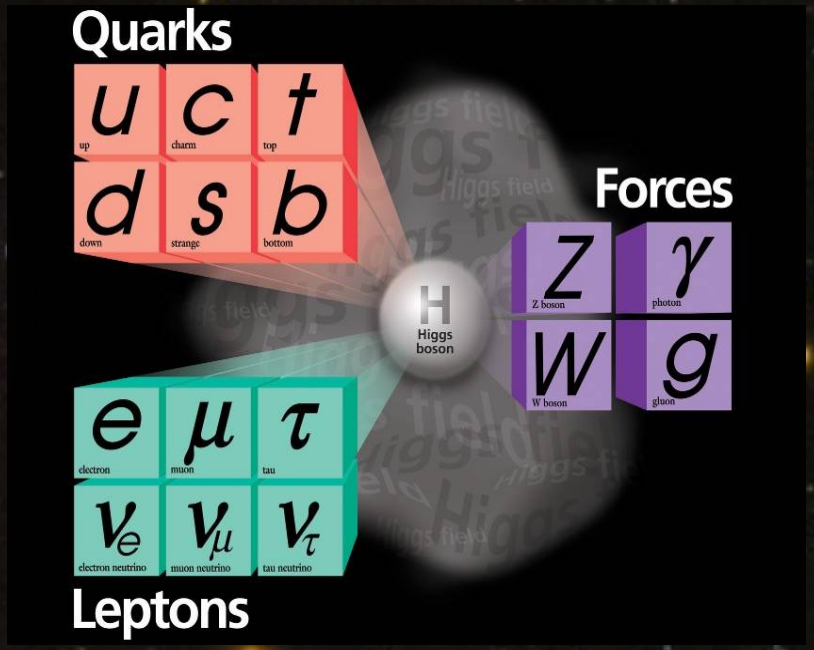


Het Standaard Model

"De formule"

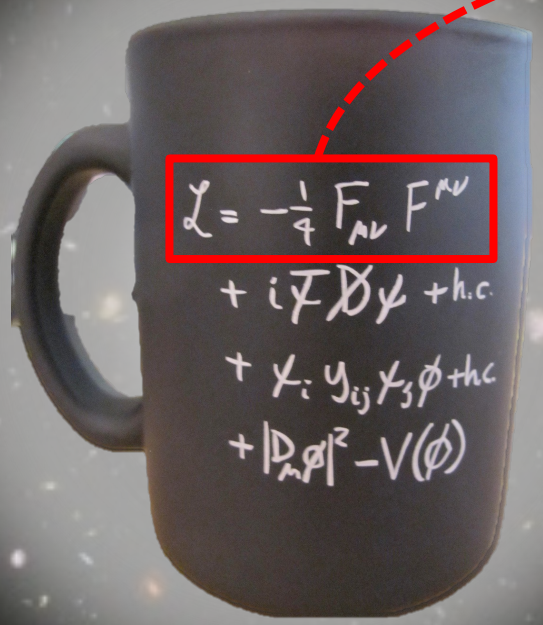


"De bouwstenen van de natuur"

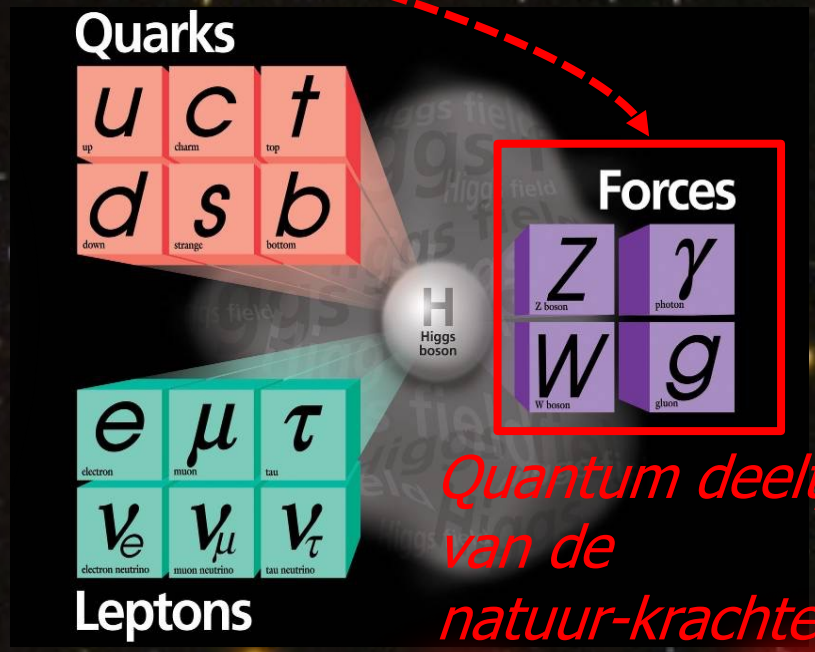


Het Standaard Model

"De formule"



"De bouwstenen van de natuur"

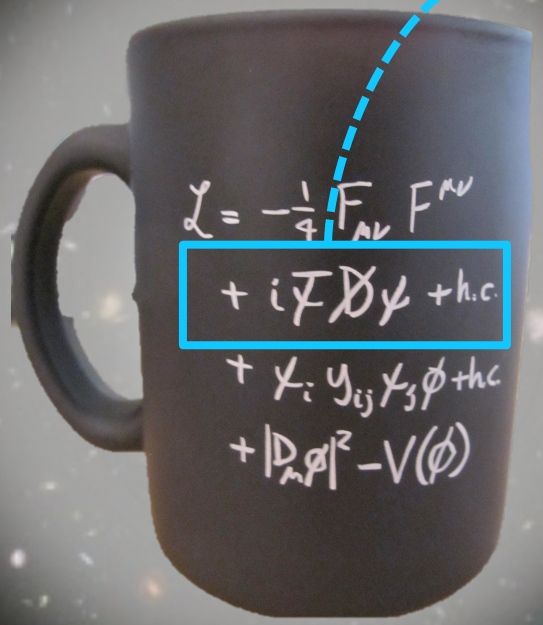


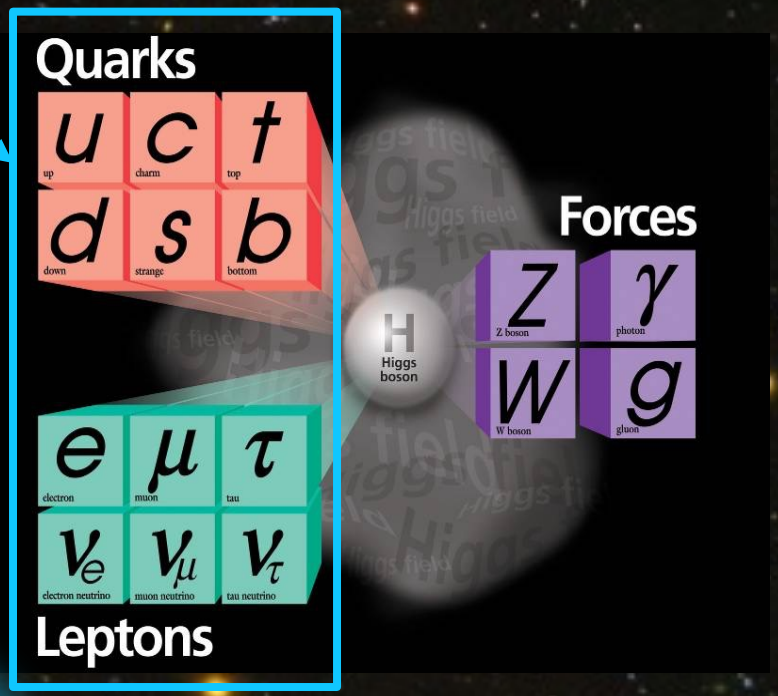
Quantum deeltjes van de natuur-krachten

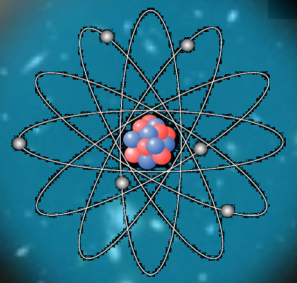
Het Standaard Model

"De formule"

"De bouwstenen van de natuur"



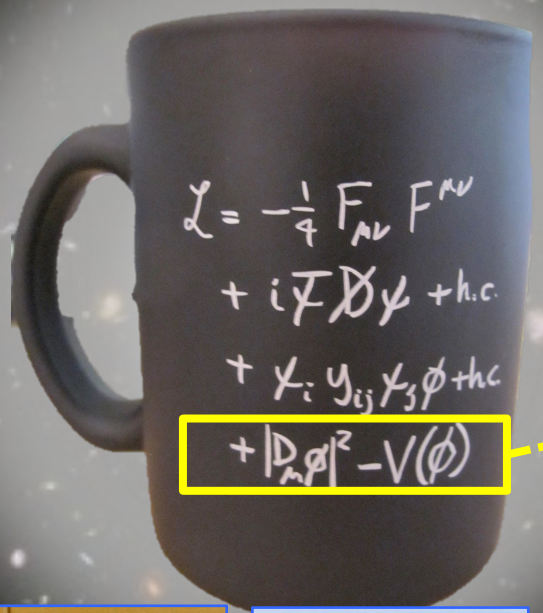




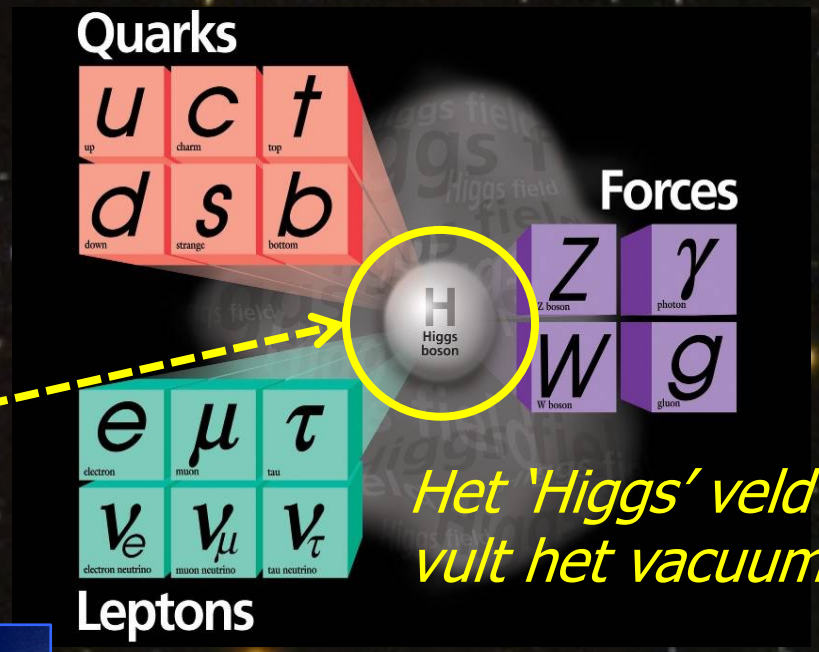
Bouwstenen van materie

Het Standaard Model

"De formule"

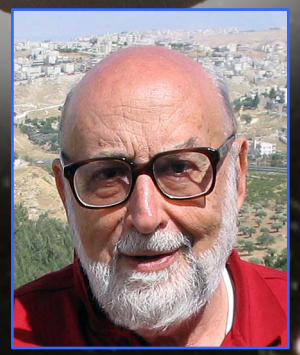


"De bouwstenen van de natuur"



Het 'Higgs' veld vult het vacuum

Brout



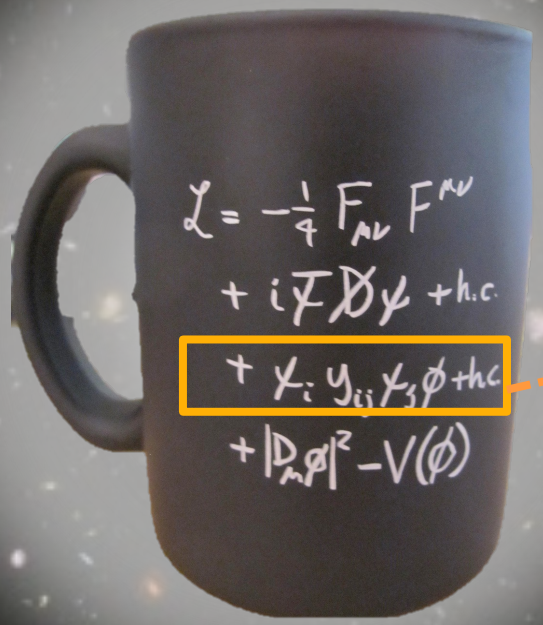
Englert

Higgs

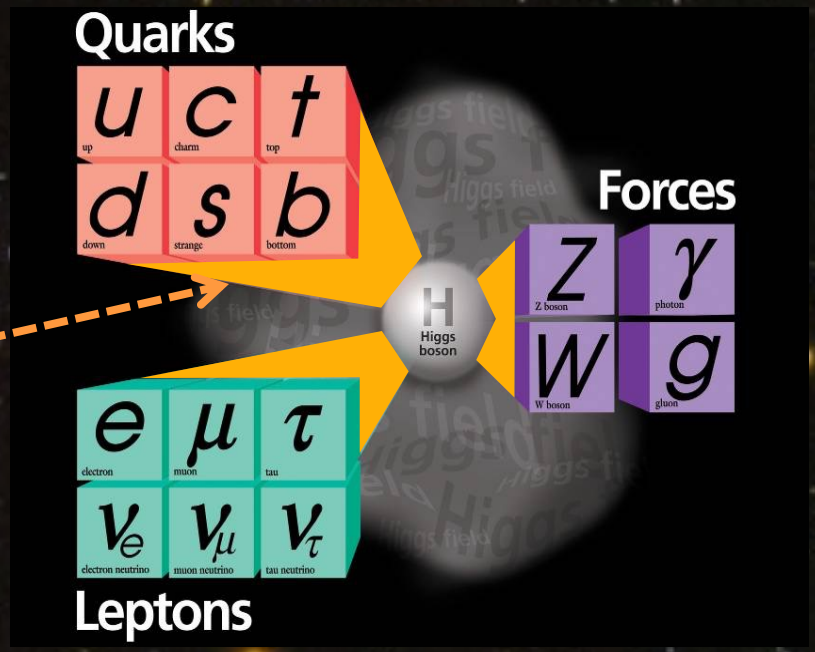
1964:
Standaard Model voorspelling:
lege ruimte is niet leeg!

Het Standaard Model

"De formule"



"De bouwstenen van de natuur"



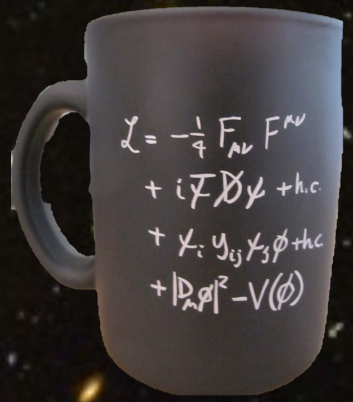
Massa wordt veroorzaakt door het Higgs veld!

Kobayashi

Maskawa

1972:
*Met **3 kopieën deeltjes** is asymmetrie tussen materie en antimaterie mogelijk!*

Hoe verdween antimaterie in de Big Bang?



Big Bang

Klein overschot

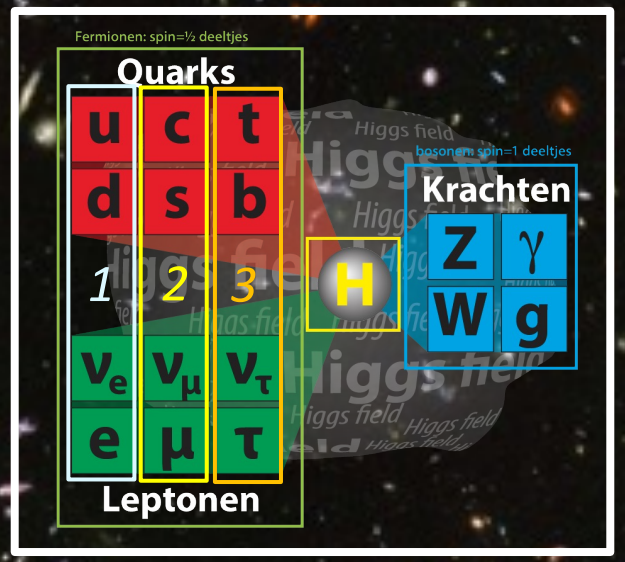
49.999999% anti-materie

50.000001% materie

Domineert

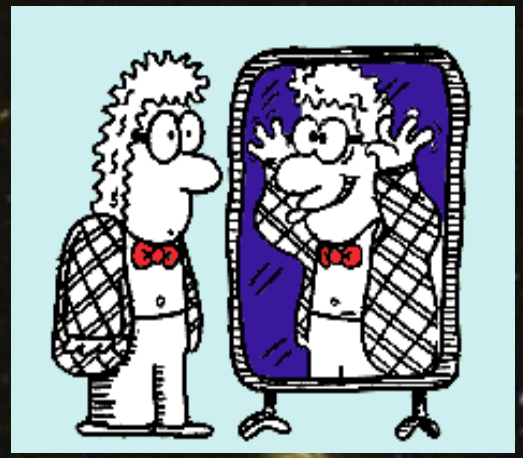
0.000001% materie

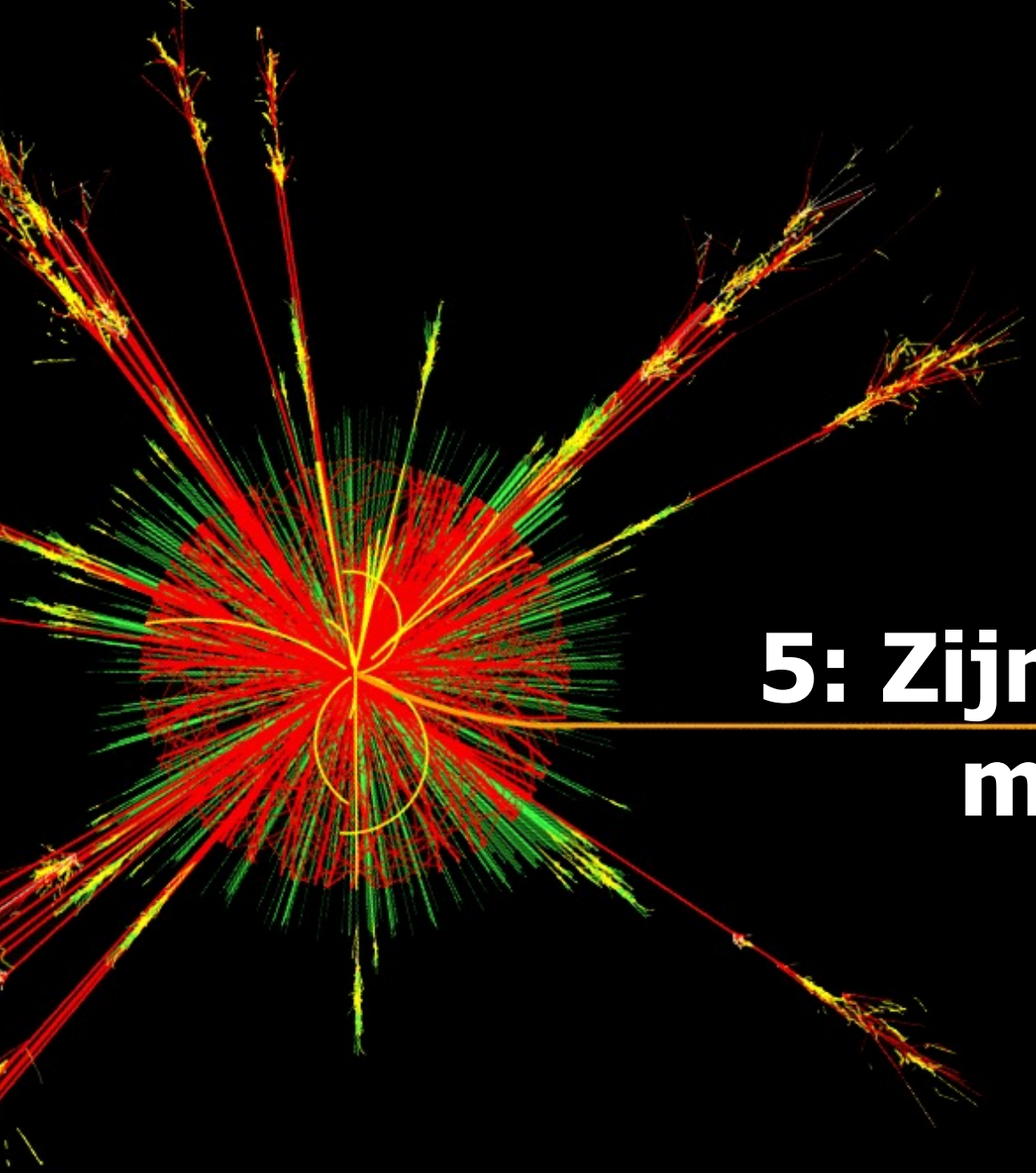
(+99.999999% straling)

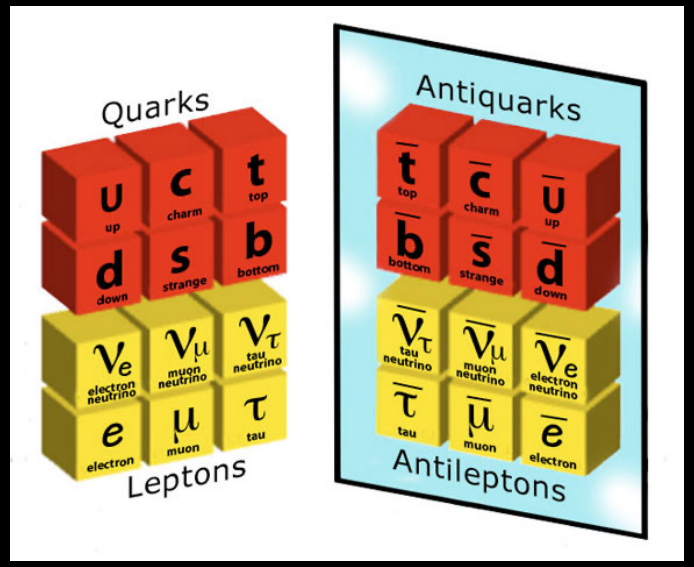


Antimaterie niet het exacte spiegelbeeld van materie?

In de theorie zijn hiervoor drie generaties van deeltjes nodig!

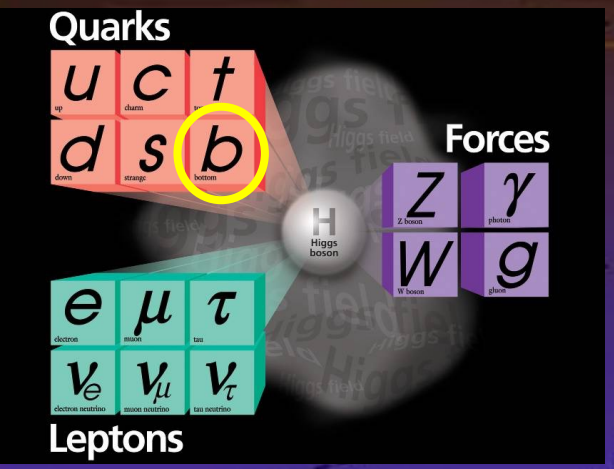




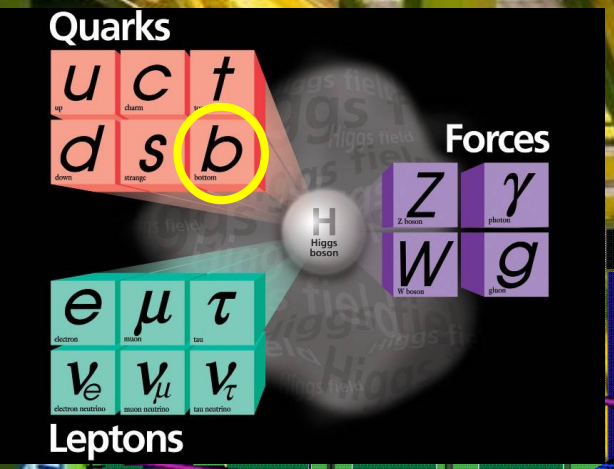


5: Zijn krachten identiek voor materie and antimaterie?

LHCB experiment: vervallen van B deeltjes



LHCb Detector: B-deeltjes



Zoom in op botsingspunt

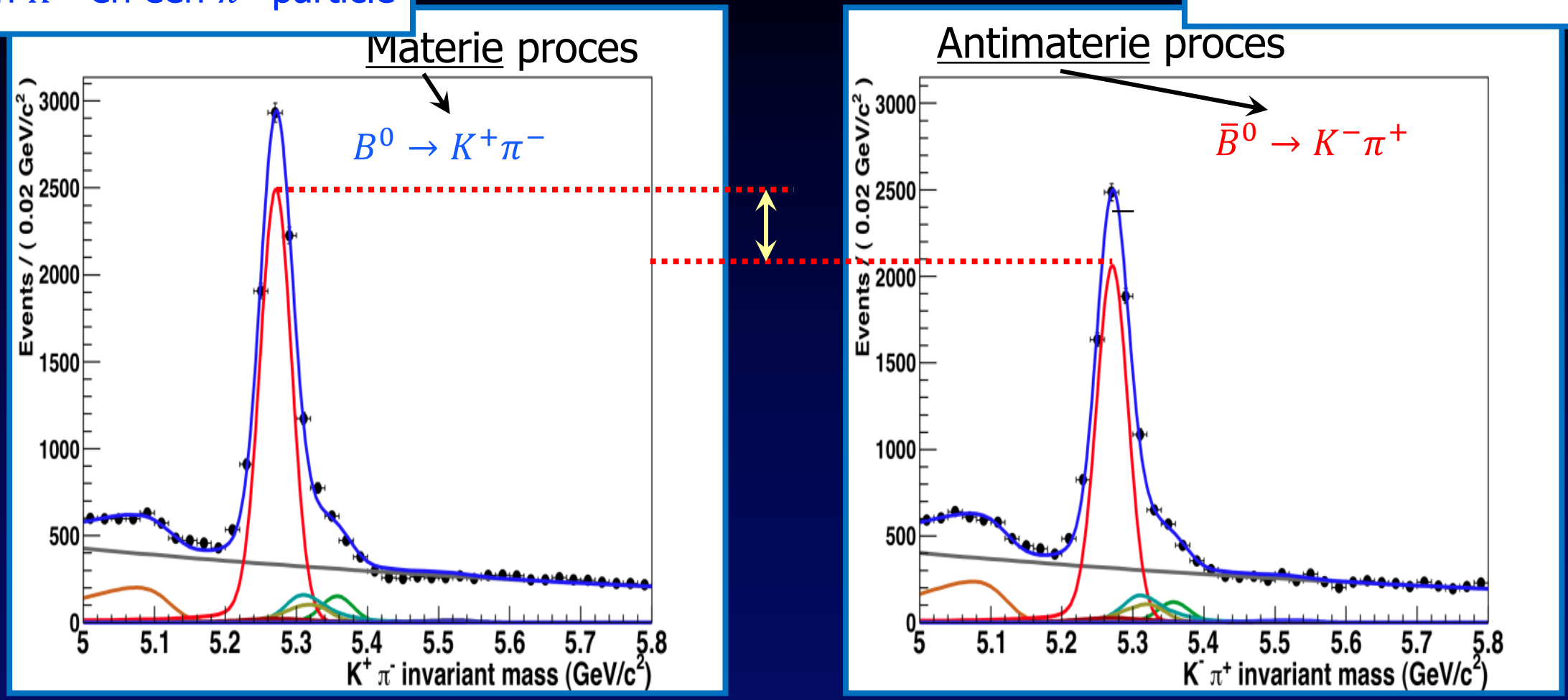
Reconstrueer miljoenen B-deeltjes vervallen en selecteer interessante gevallen.
Gaat verval anders bij materie dan bij antimaterie?

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



Asymmetrie: Materie vervalsproces anders dan antimaterie versie!

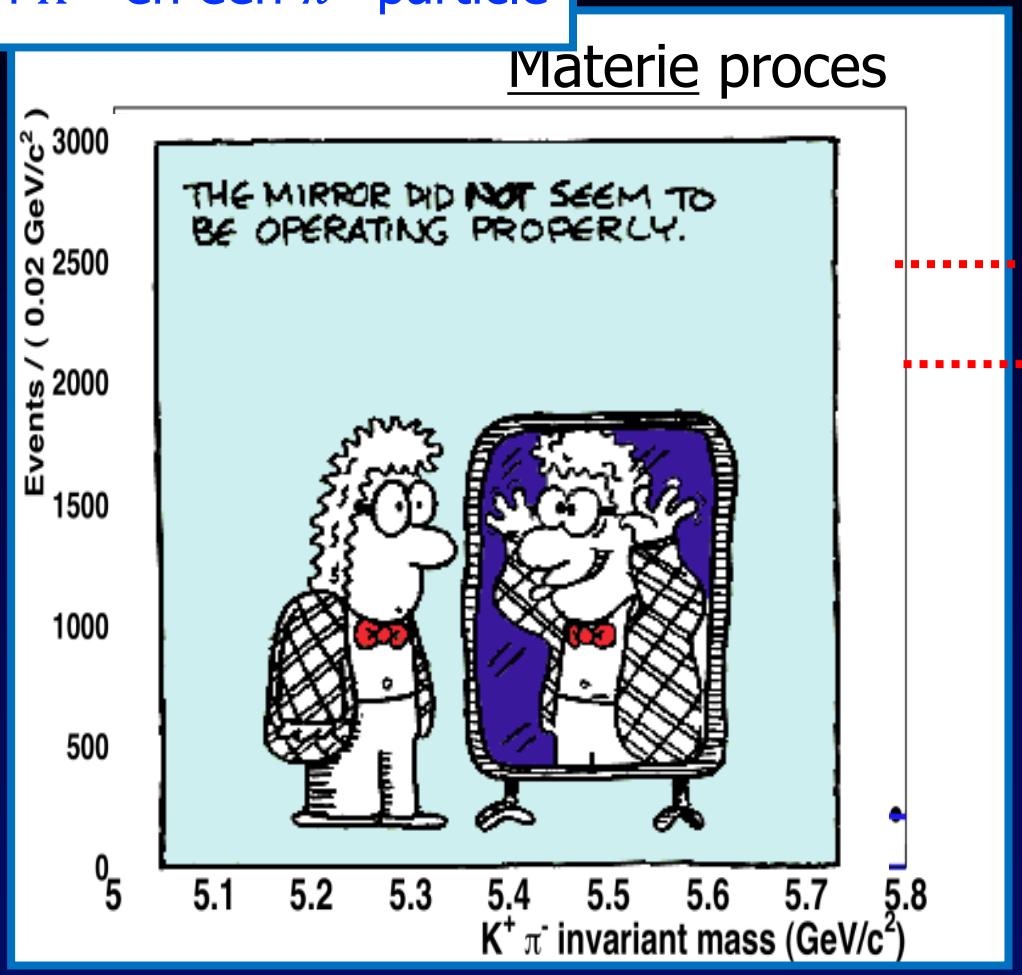
Quantum krachten tussen deeltjes en anti-deeltjes ***niet altijd identiek!***

B-vervalsproces: materie vs antimaterie

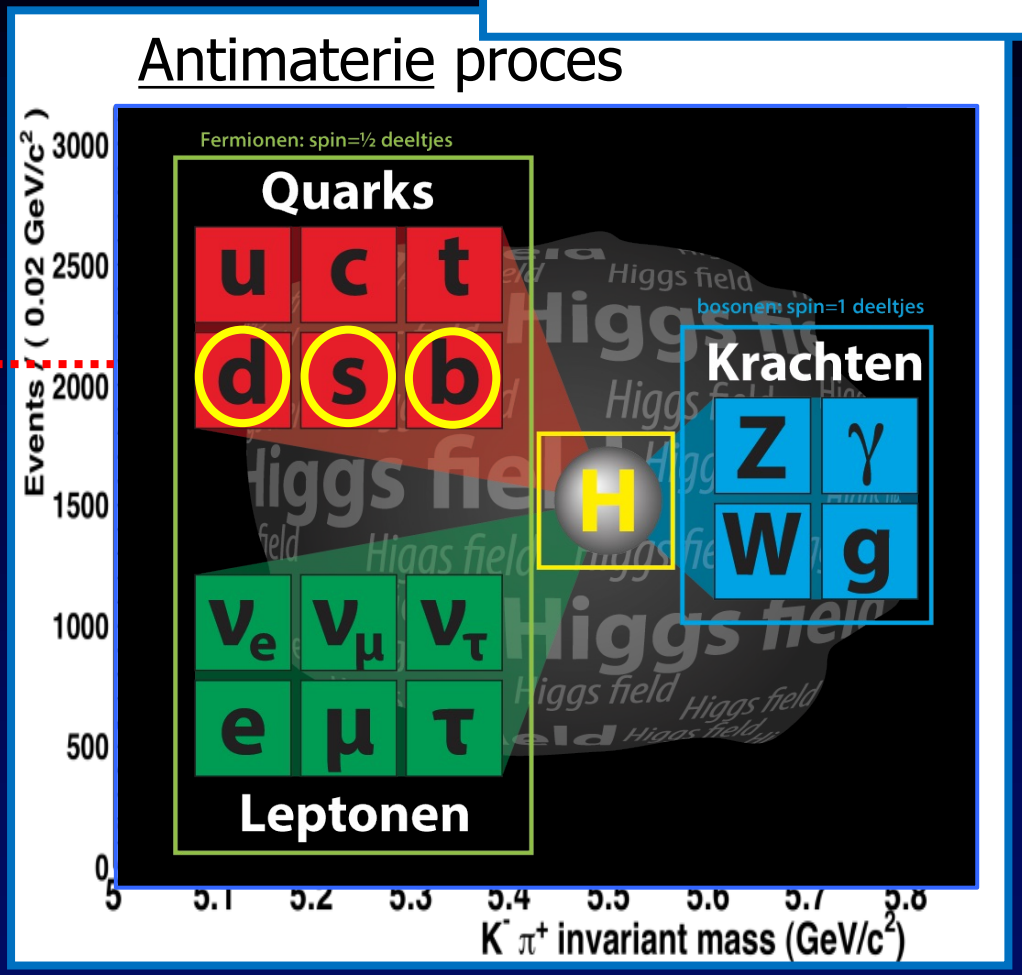
B deeltje verval naar een K^+ en een π^- particle

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

Materie proces



Antimaterie proces



The materie – antimaterie symmetrie is verbroken

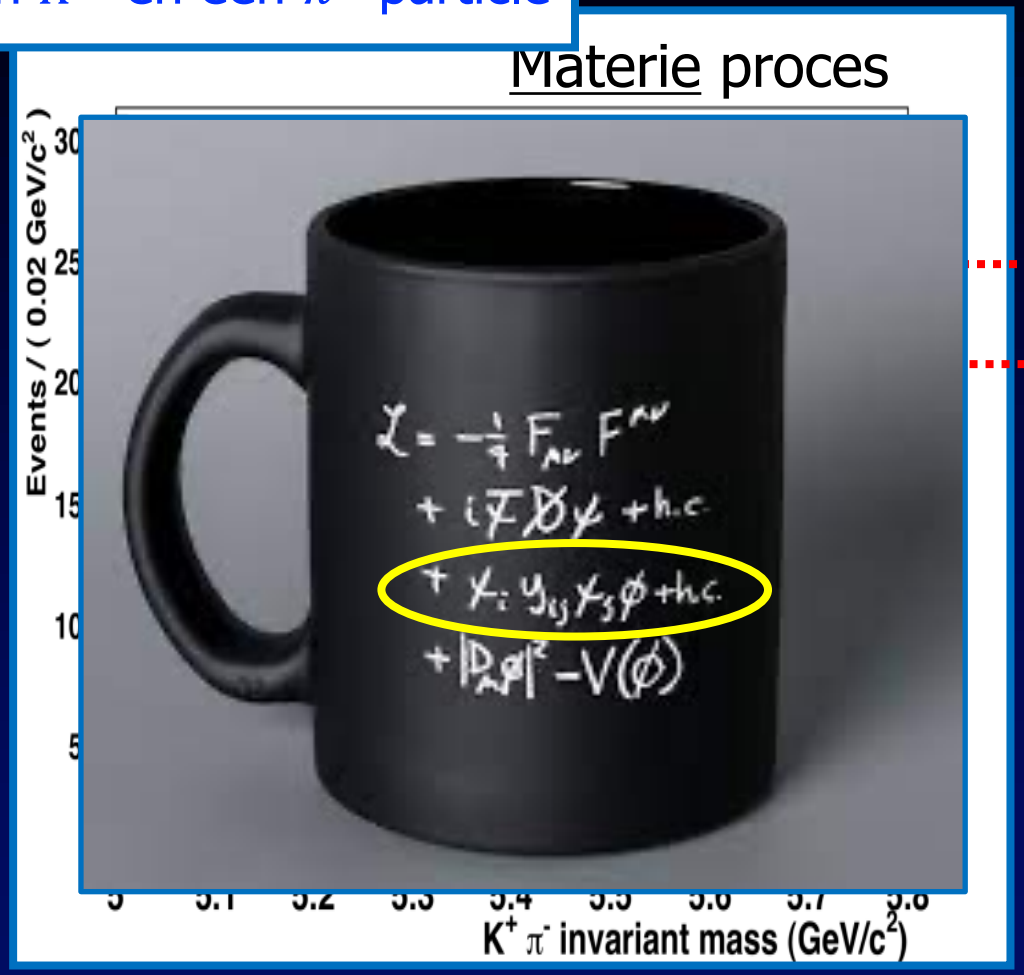
Dit gebeurt ***alleen*** als er tenminste ***drie generaties*** deeltjes bestaan!!!

B-vervalsproces: materie vs antimaterie

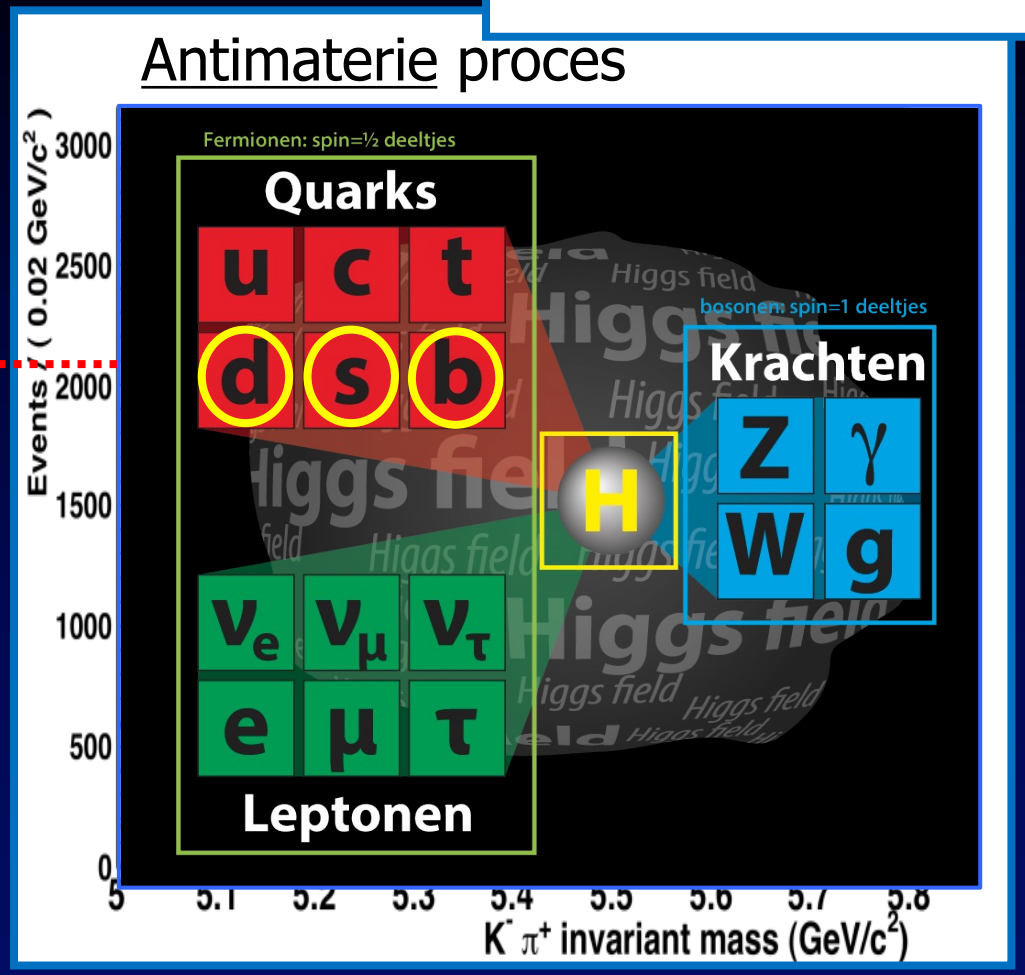
B deeltje verval naar een K^+ en een π^- particle

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

Materie proces



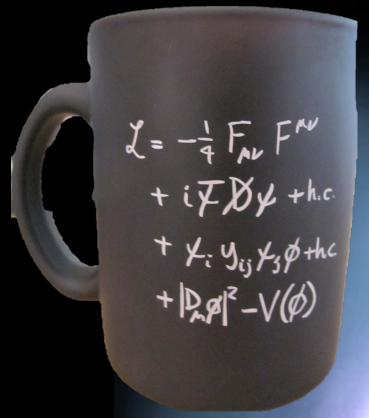
Antimaterie proces



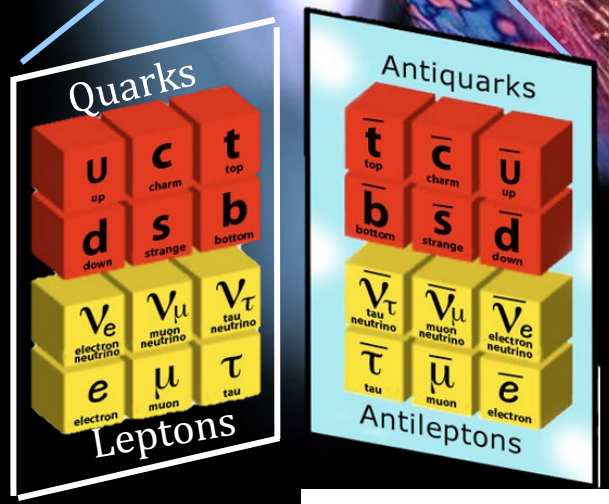
The materie – antimaterie symmetrie is verbroken

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

Vroege Universum: waar is de antimaterie heen?

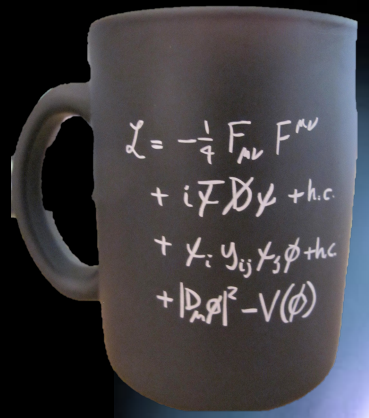


- → Asymmetrie in kracht
- → Beetje meer materie dan antimaterie
- → Rest annihileert
- → Materie universum blijft over

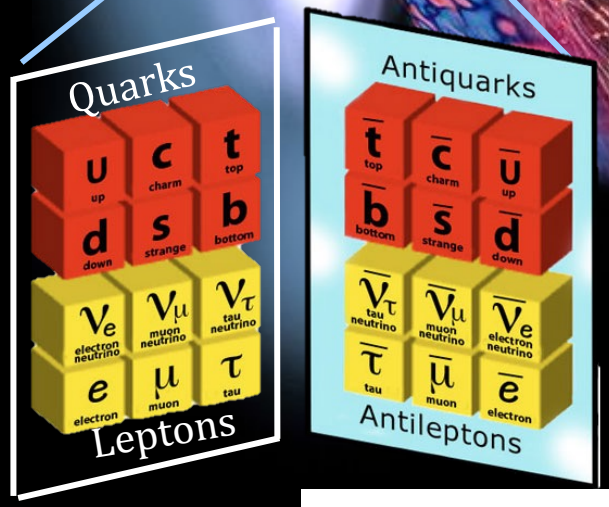


50.000001% | 49.999999%

Vroege Universum: waar is de antimaterie heen?

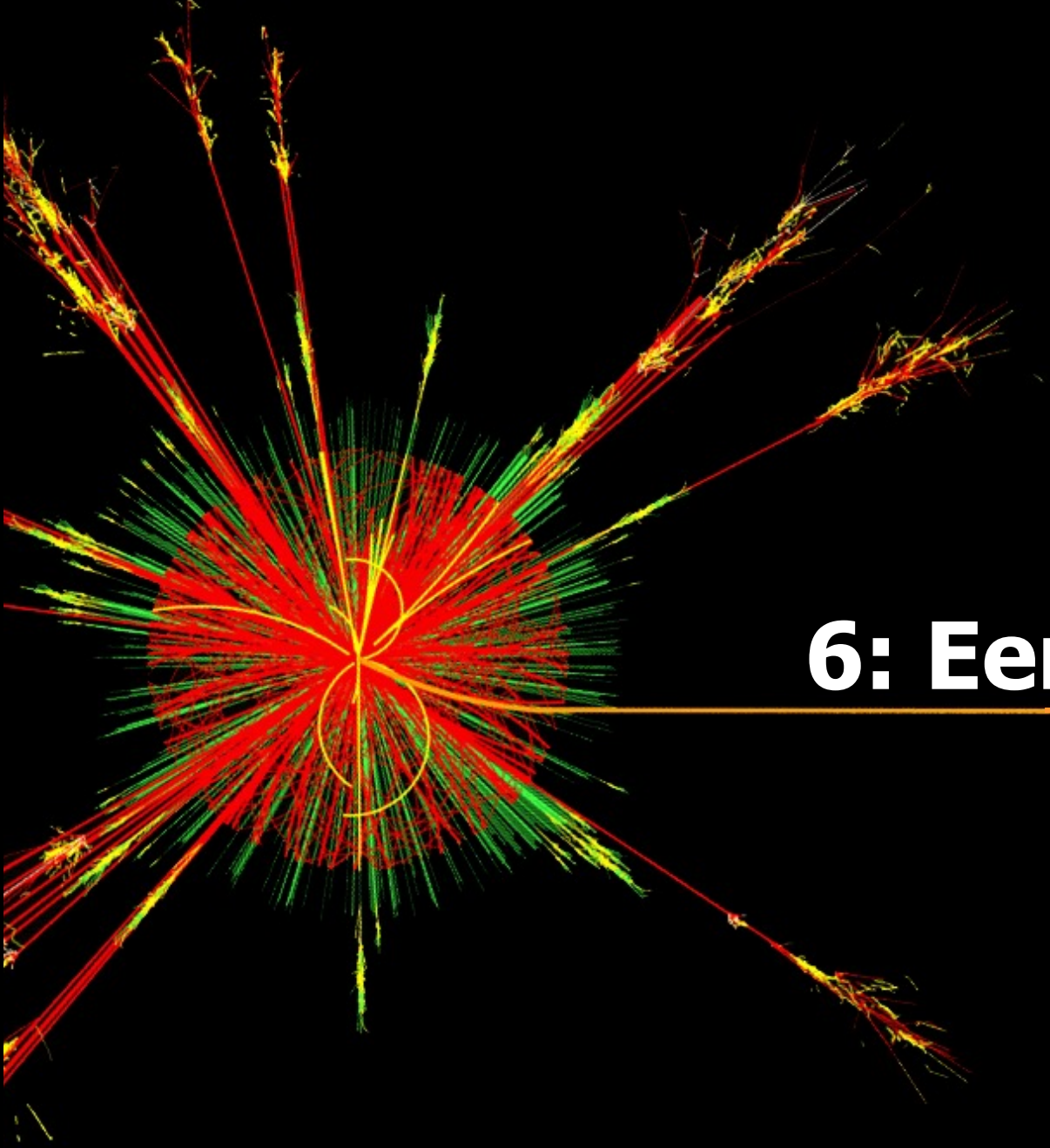


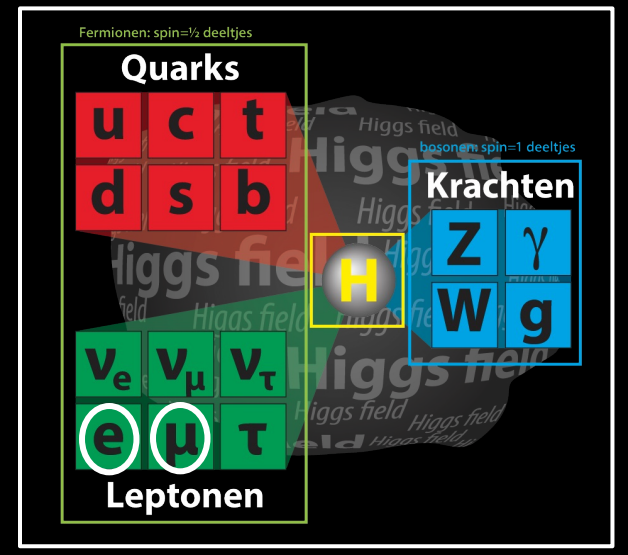
Helaas: het werkt niet!
Asymmetrie is niet groot genoeg.
Verklaring vereist nieuwe kracht of deeltjes!



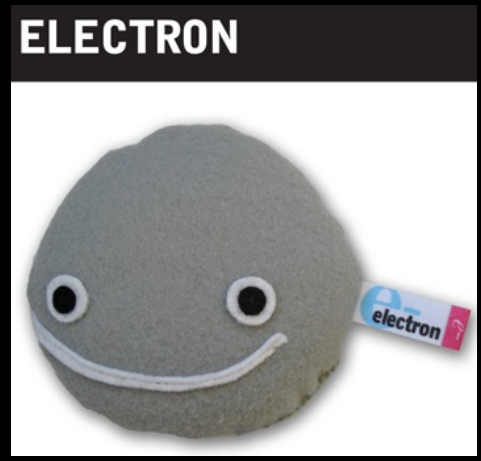
50.000001%

49.999999%

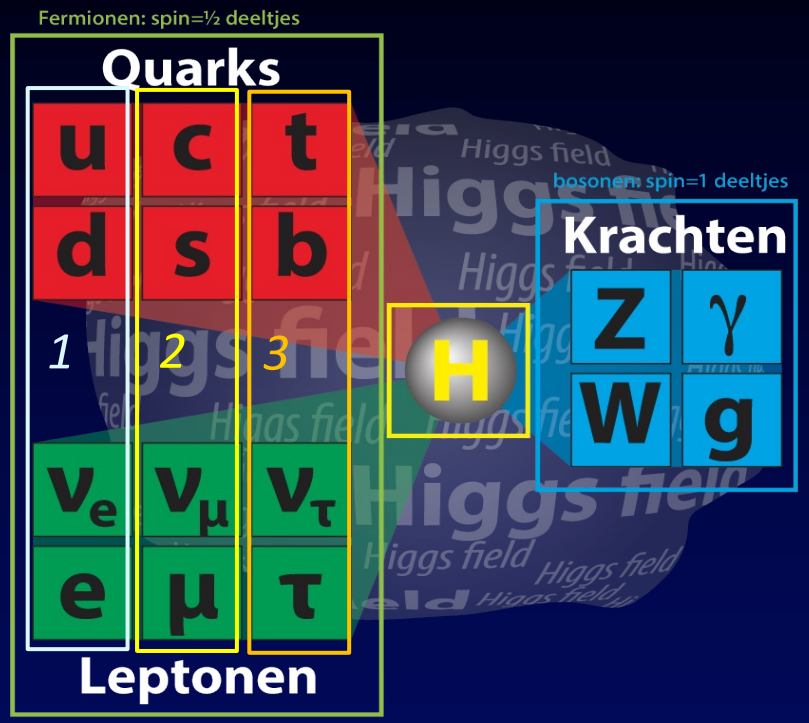


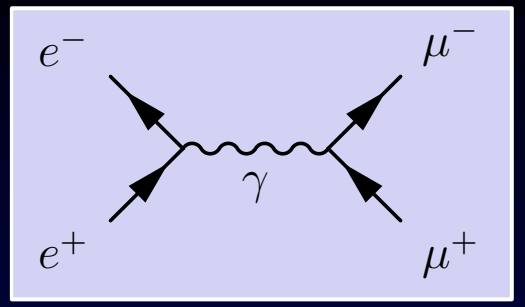


6: Een nieuwe natuurkracht?

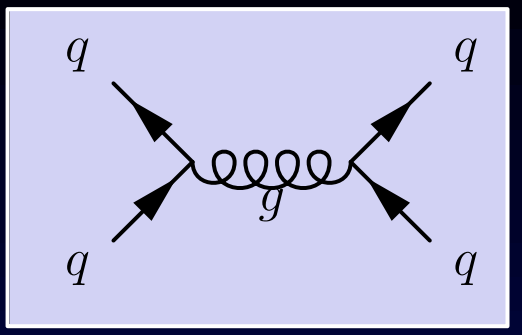


Standaardmodel: Universaliteit van de Krachten

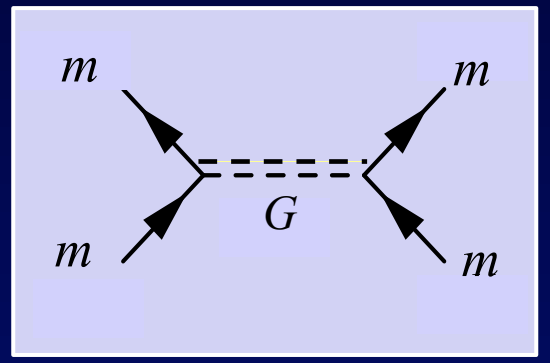




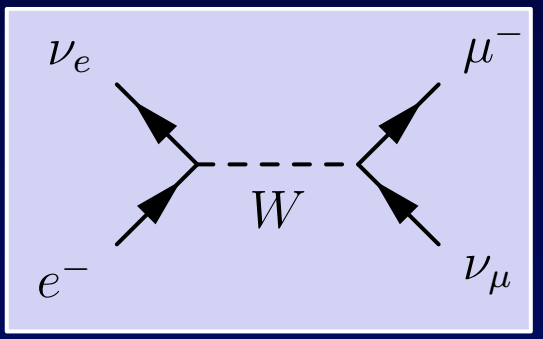
Elektromagnetisme



Sterke kernkracht



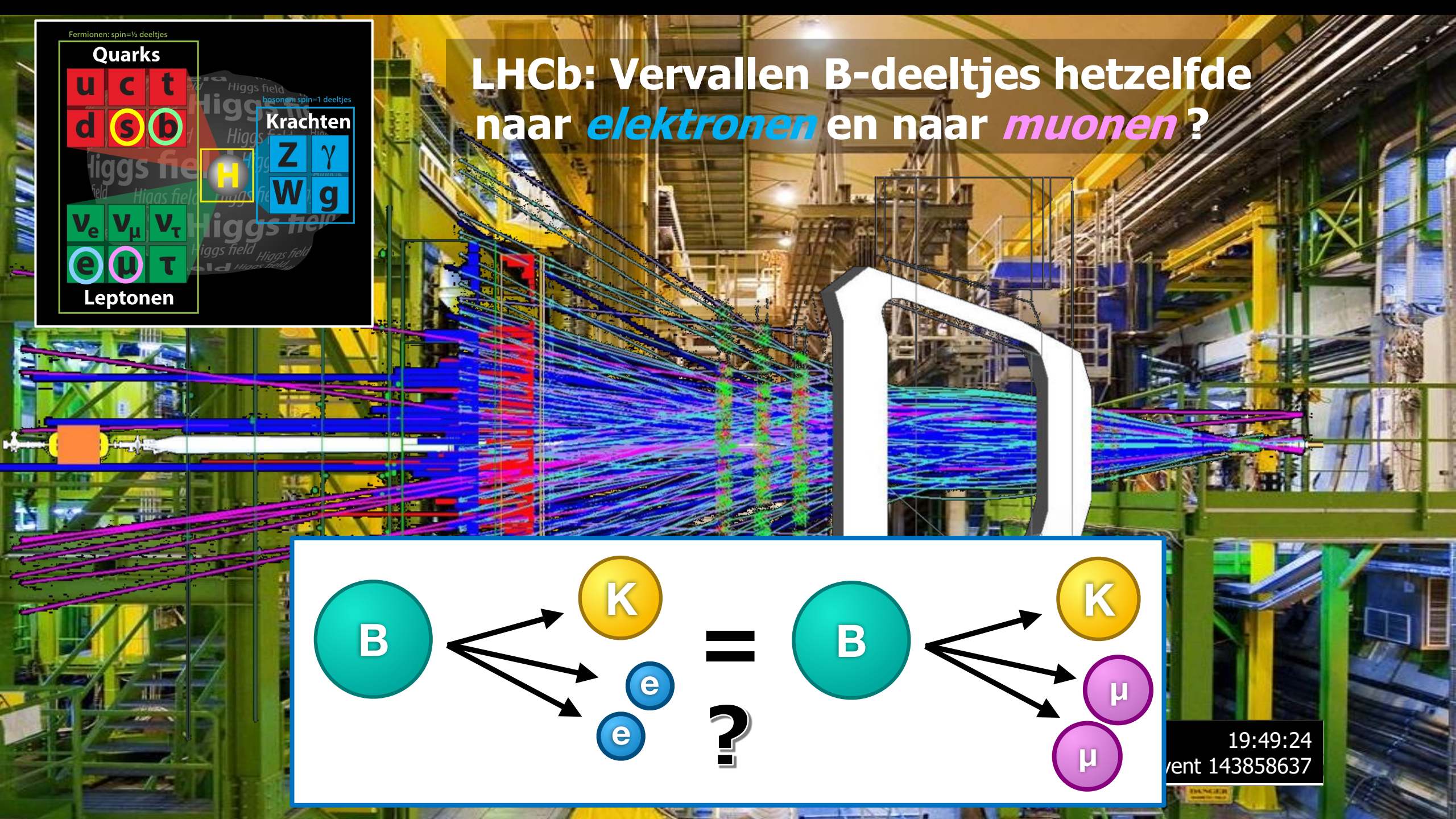
Zwaartekracht



Zwakke kernkracht

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

➔ "Universaliteit"


Fermionen: spin=½ deeltjes
Quarks
u c t
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Leptonen
ν_e ν_μ ν_τ
e μ τ
bosonen: spin=1 deeltjes
Krachten
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W g
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LHCb: Vervallen B-deeltjes hetzelfde naar elektronen en naar muonen ?
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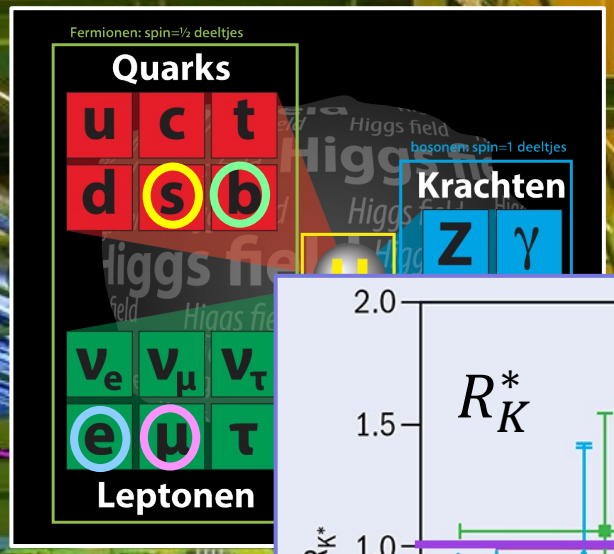
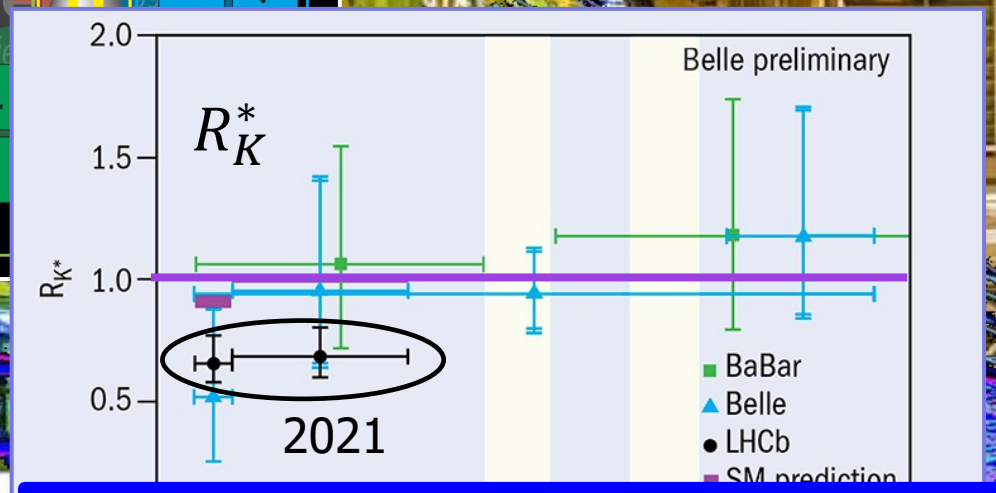
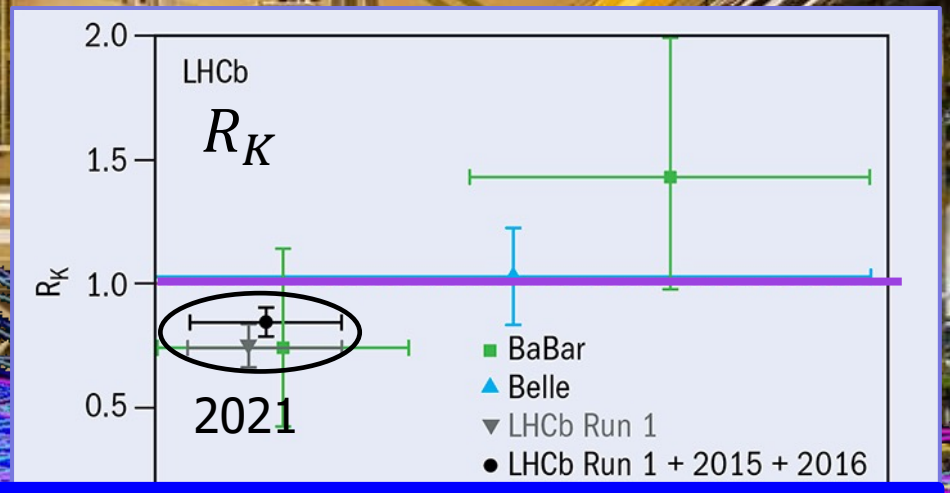
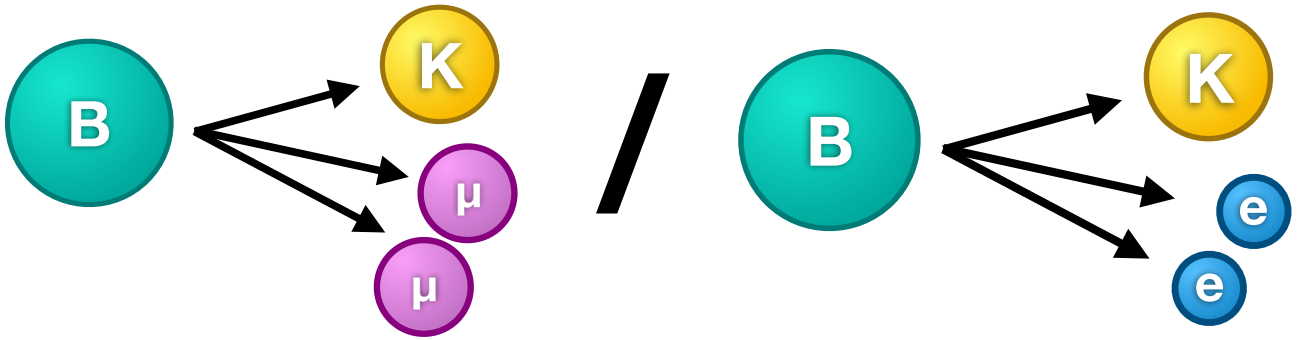
LHCb: Vervallen B-deeltjes hetzelfde naar *elektronen* en naar *muonen* ?







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



49:24
8637

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?!

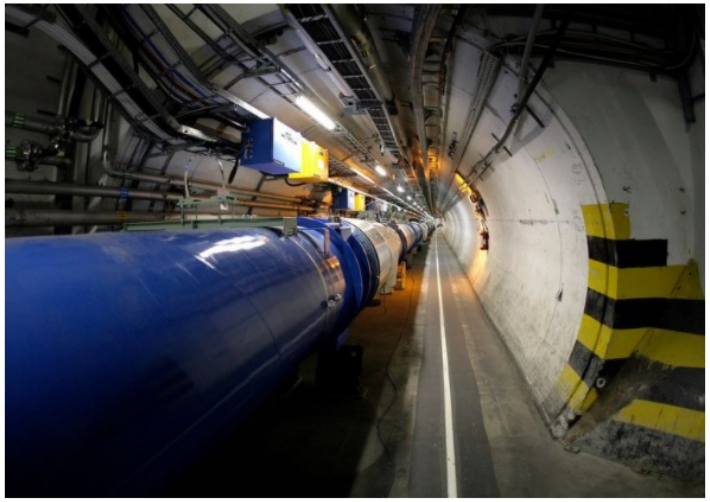
deVolkskrant

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’

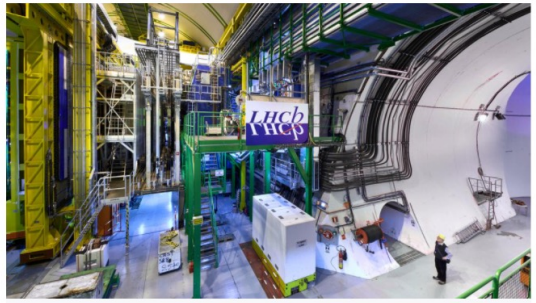
Na de vondst van het Higgs-deeltje, negen jaar geleden, klinken er nu opnieuw opgetogen …

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)

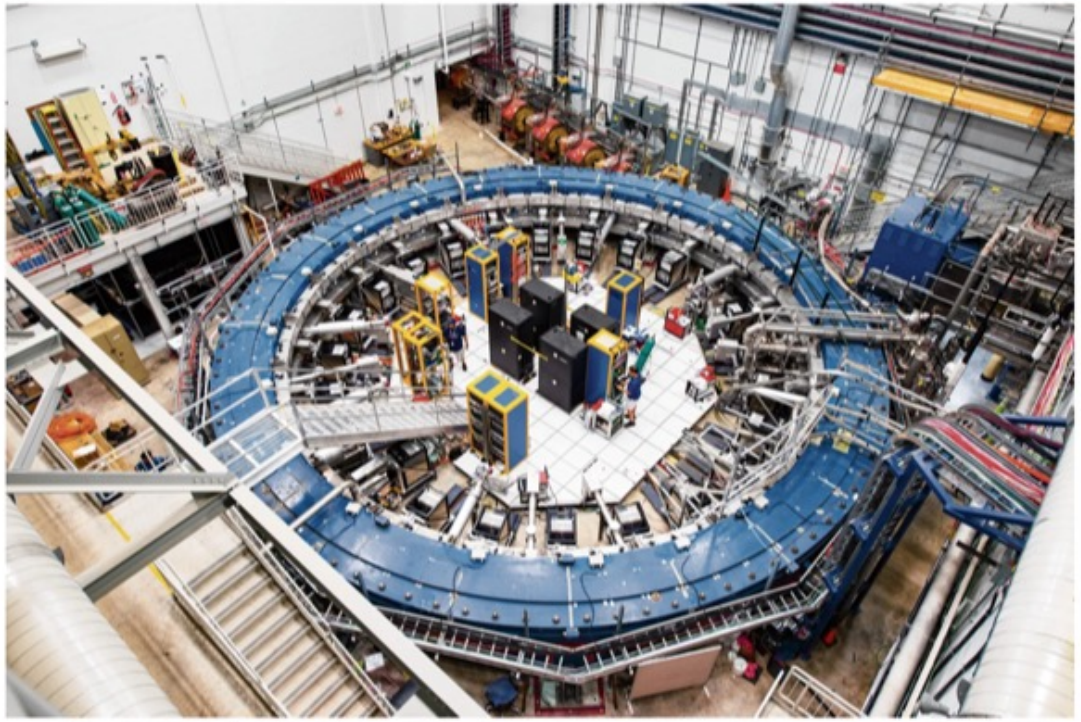
Twee weken later in Fermilab … muon magnetisch moment?!

Menu nrc

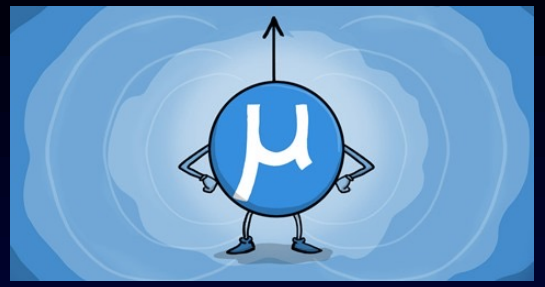
Opnieuw barstje in standaardmodel van deeltjesfysica

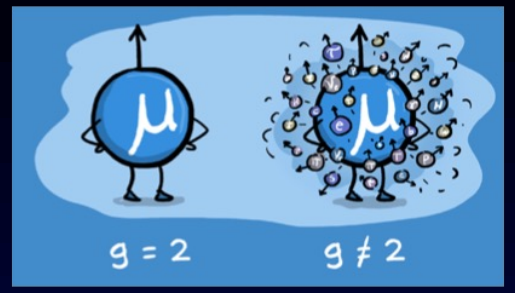
Natuurkunde Gaat het standaardmodel van de deeltjesfysica breken? Resultaten uit een Amerikaans experiment leiden tot opwinding.

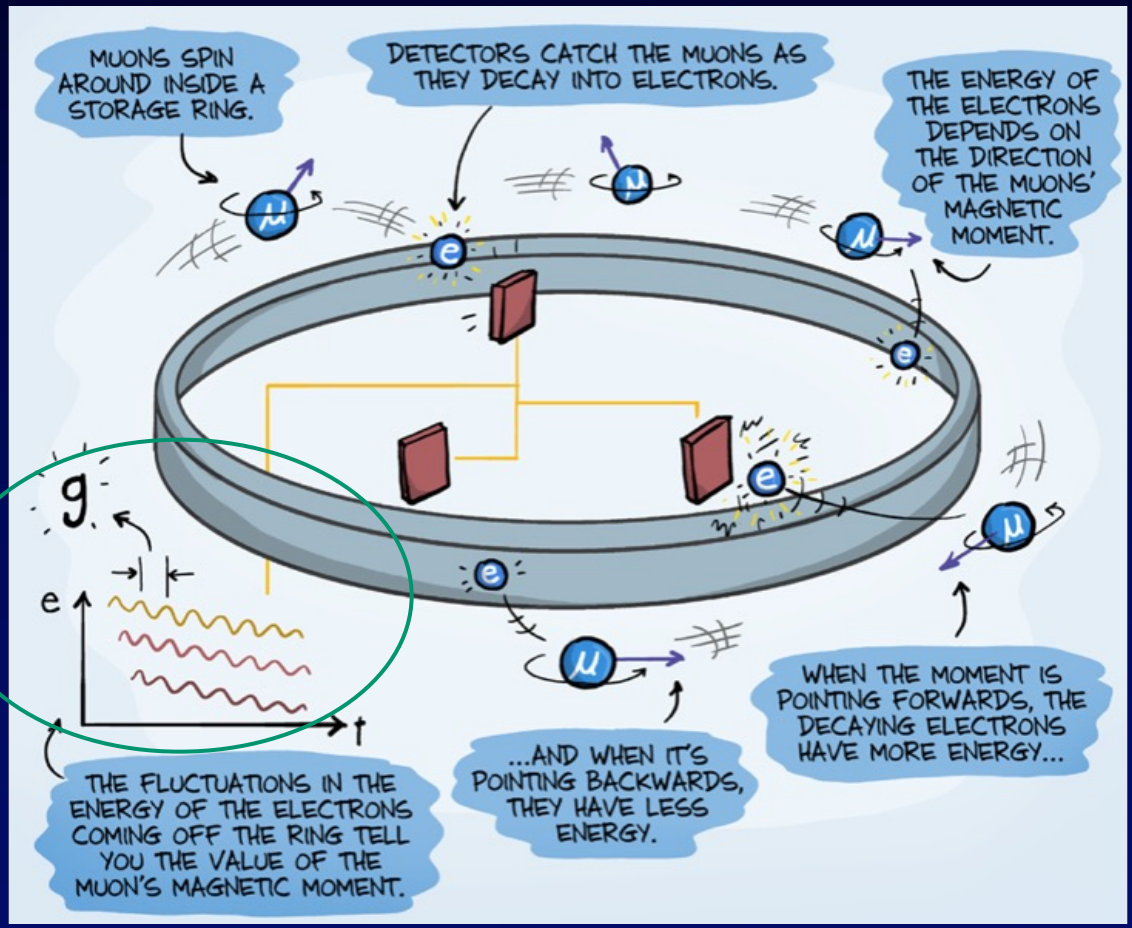
Dorine Schenk 7 april 2021 Leestijd 3 minuten



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

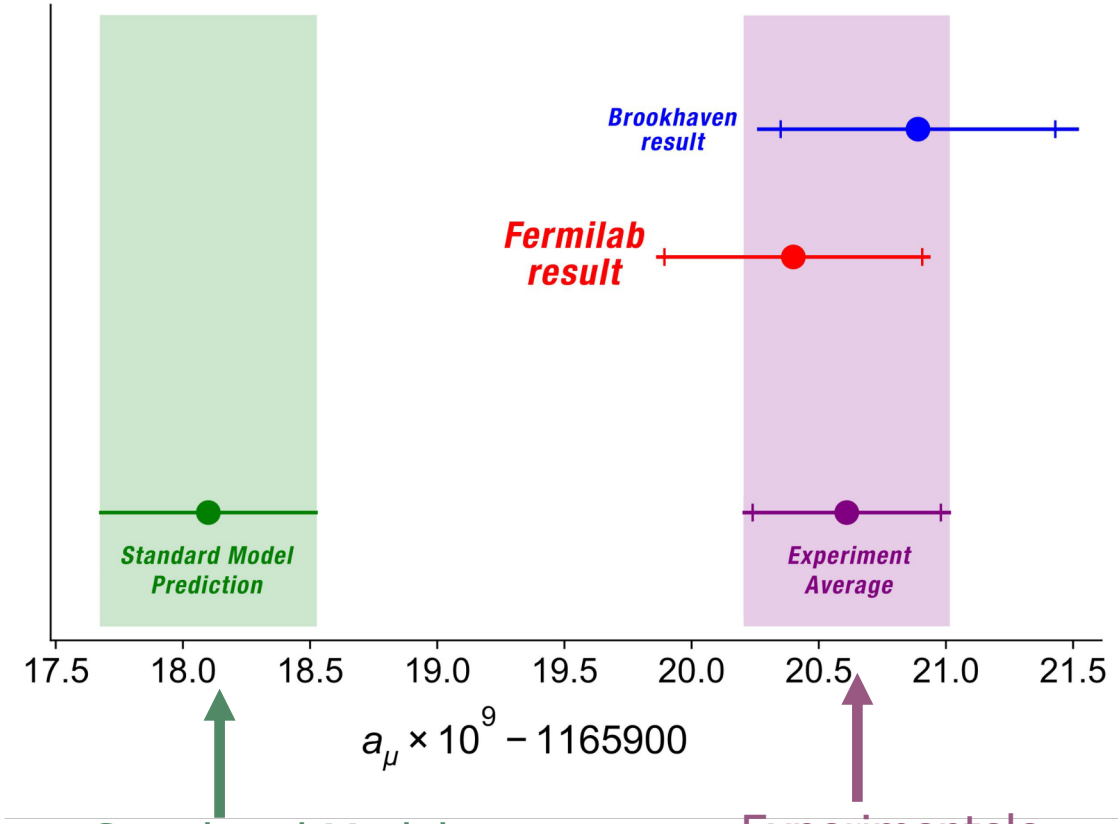






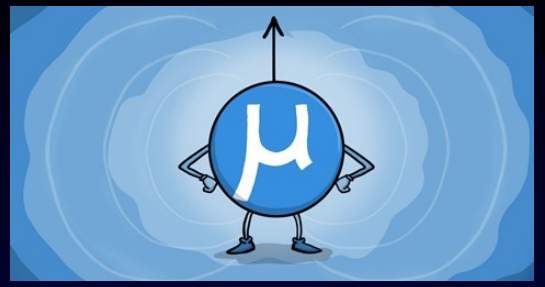
Twee weken later in Fermilab … muon magnetisch moment?!

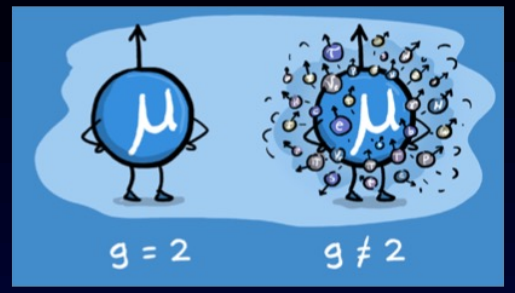
Het Standaardmodel lijkt niet te voldoen
➔ Een nieuwe quantum kracht nodig?!

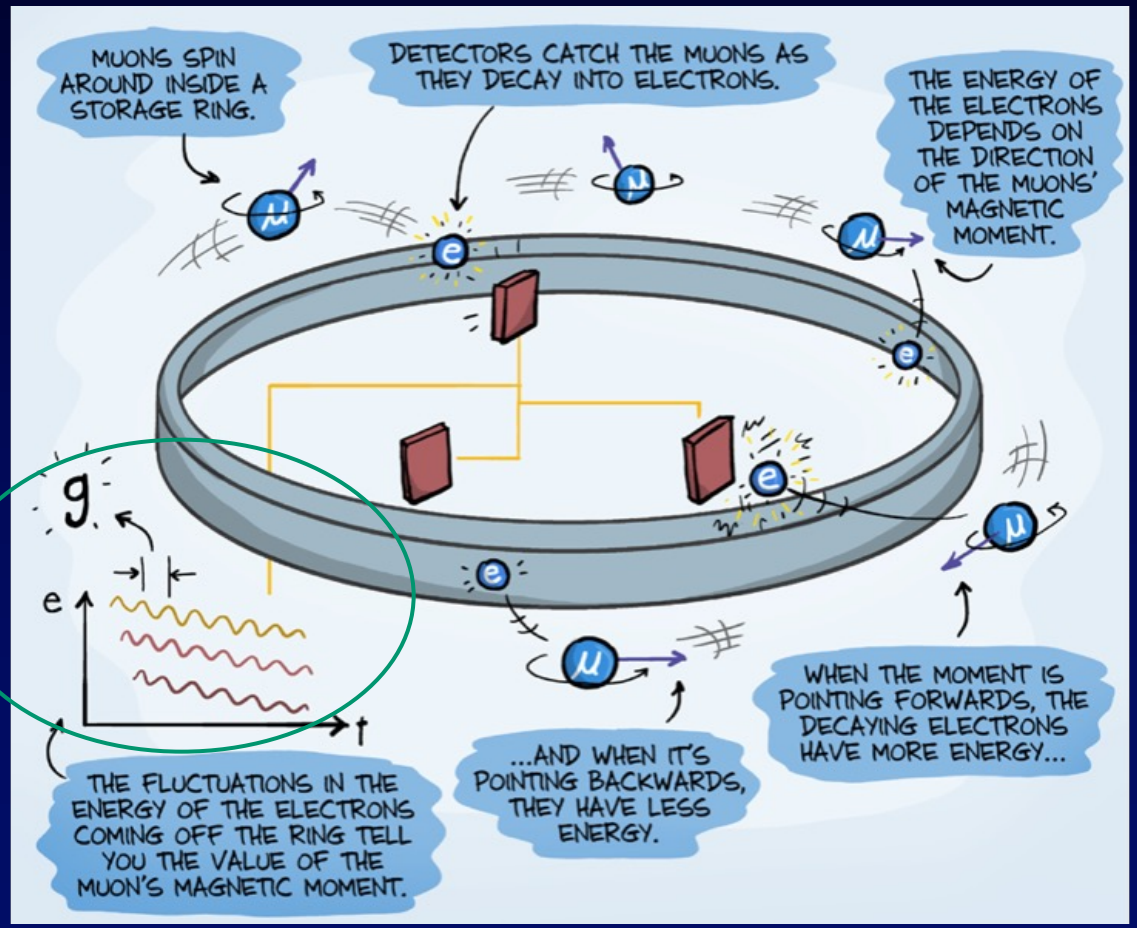


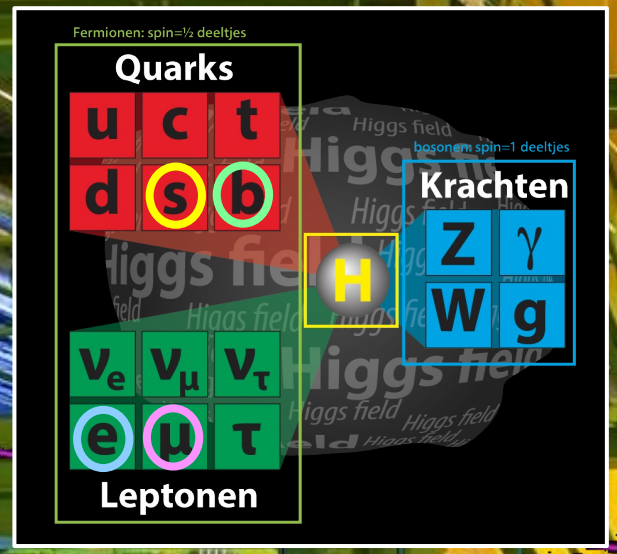
Standaard Model voorspelling

Experimentele meting

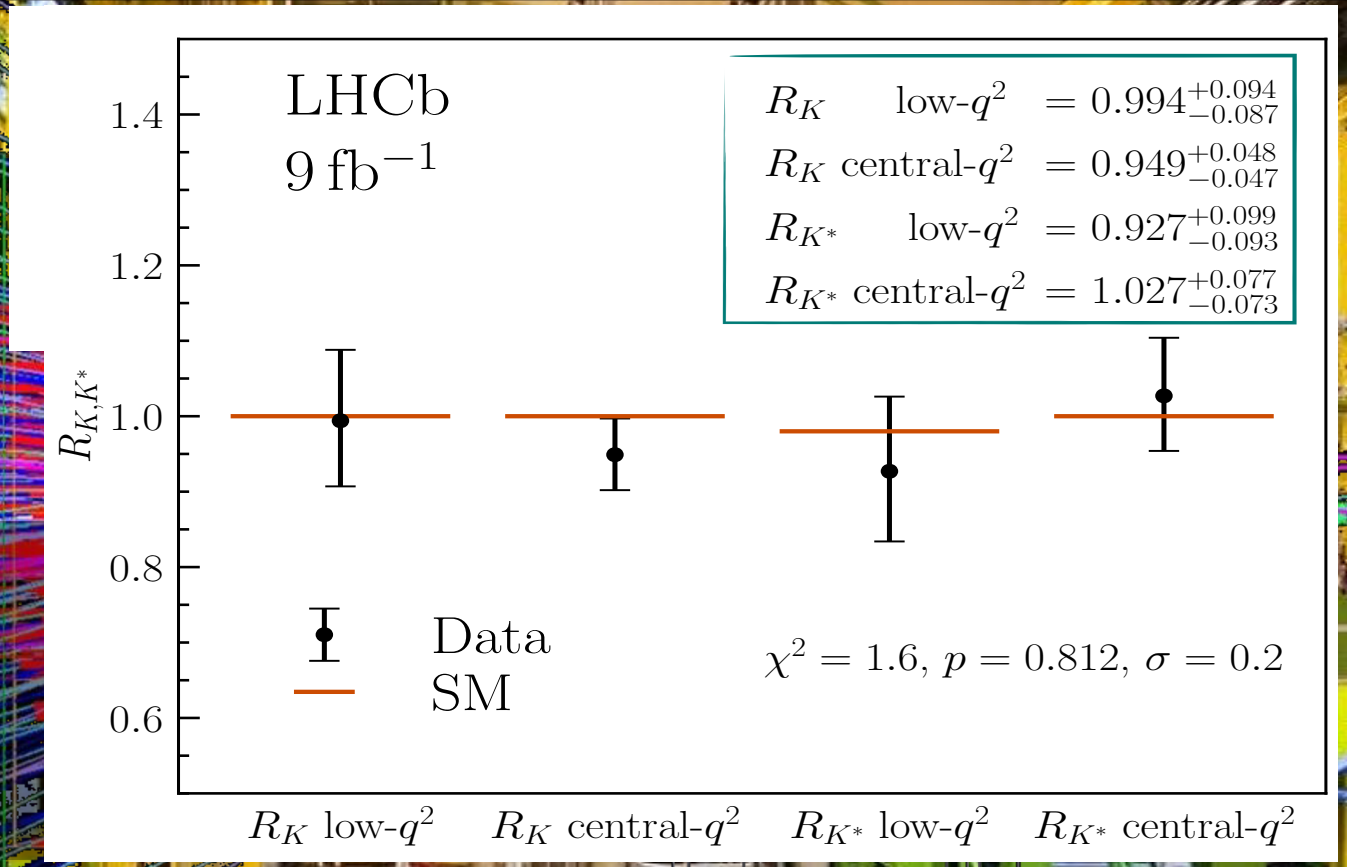




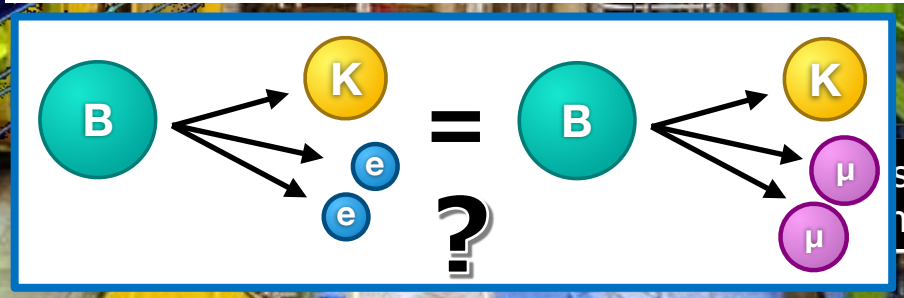


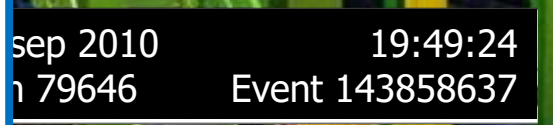


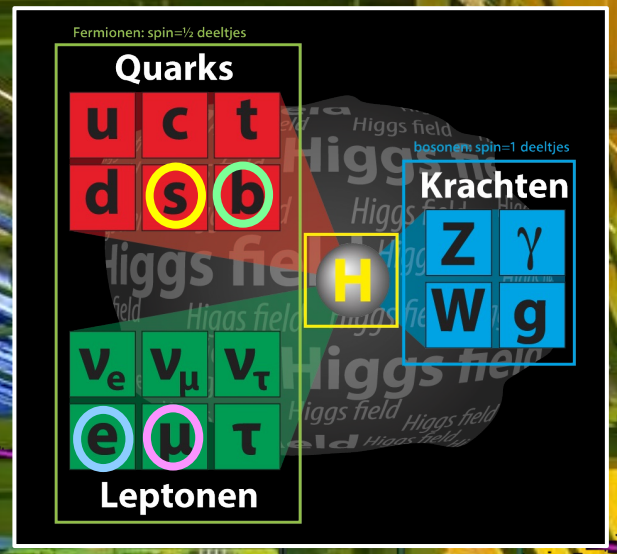
LHCb: Vervallen B-deeltjes hetzelfde naar *elektronen* en naar *muonen* ?



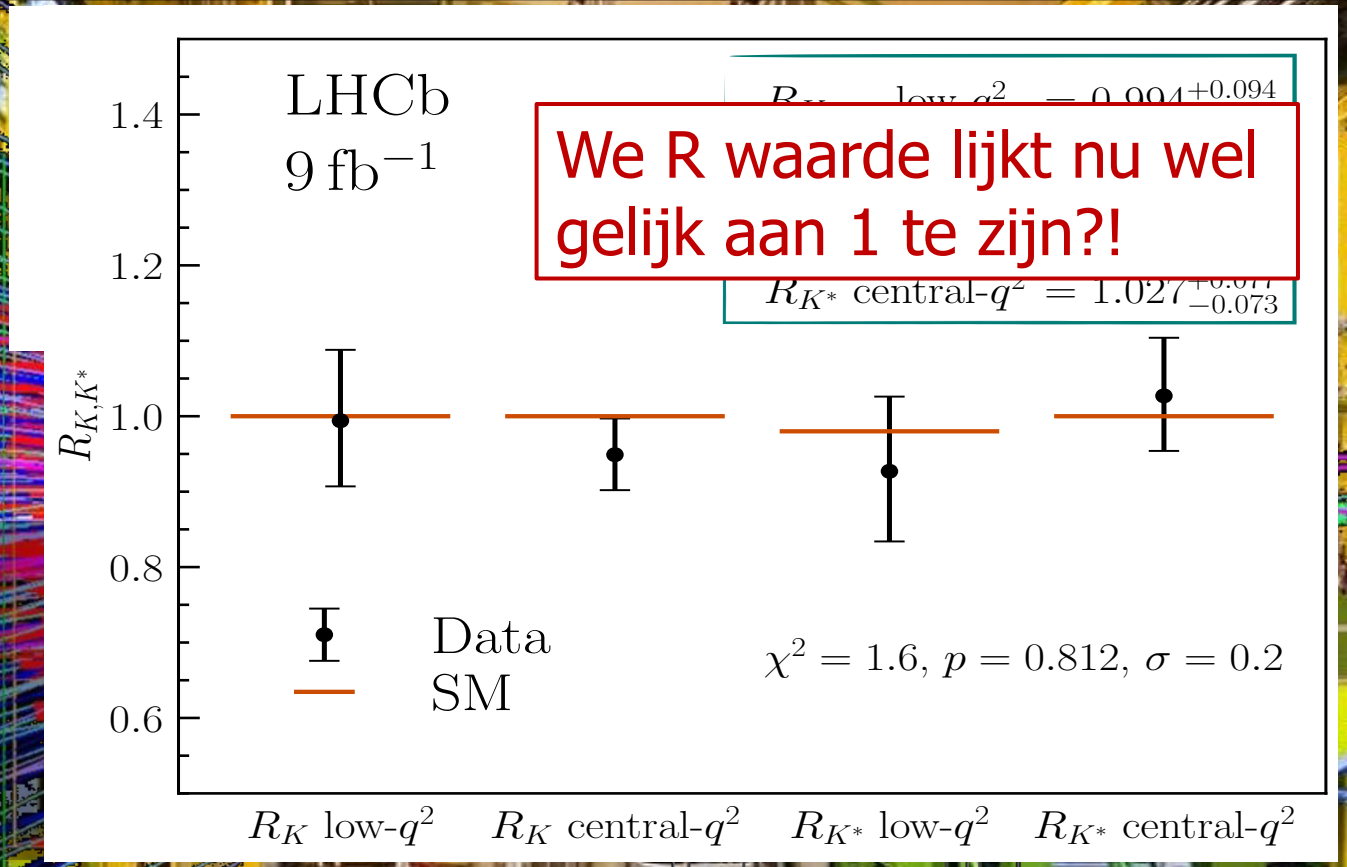
December 2022: verbeterde meting van de elektronen...



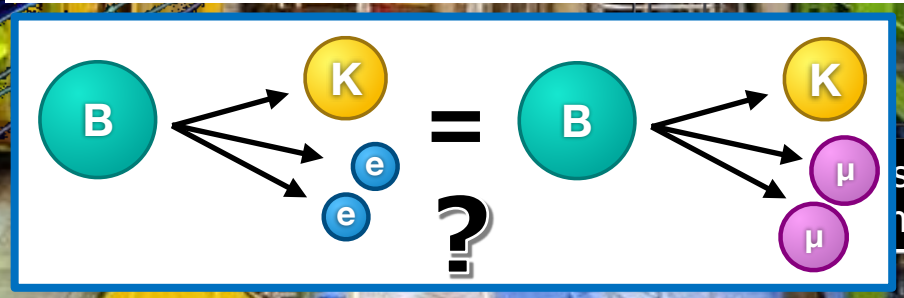




LHCb: Vervallen B-deeltjes hetzelfde naar *elektronen* en naar *muonen* ?

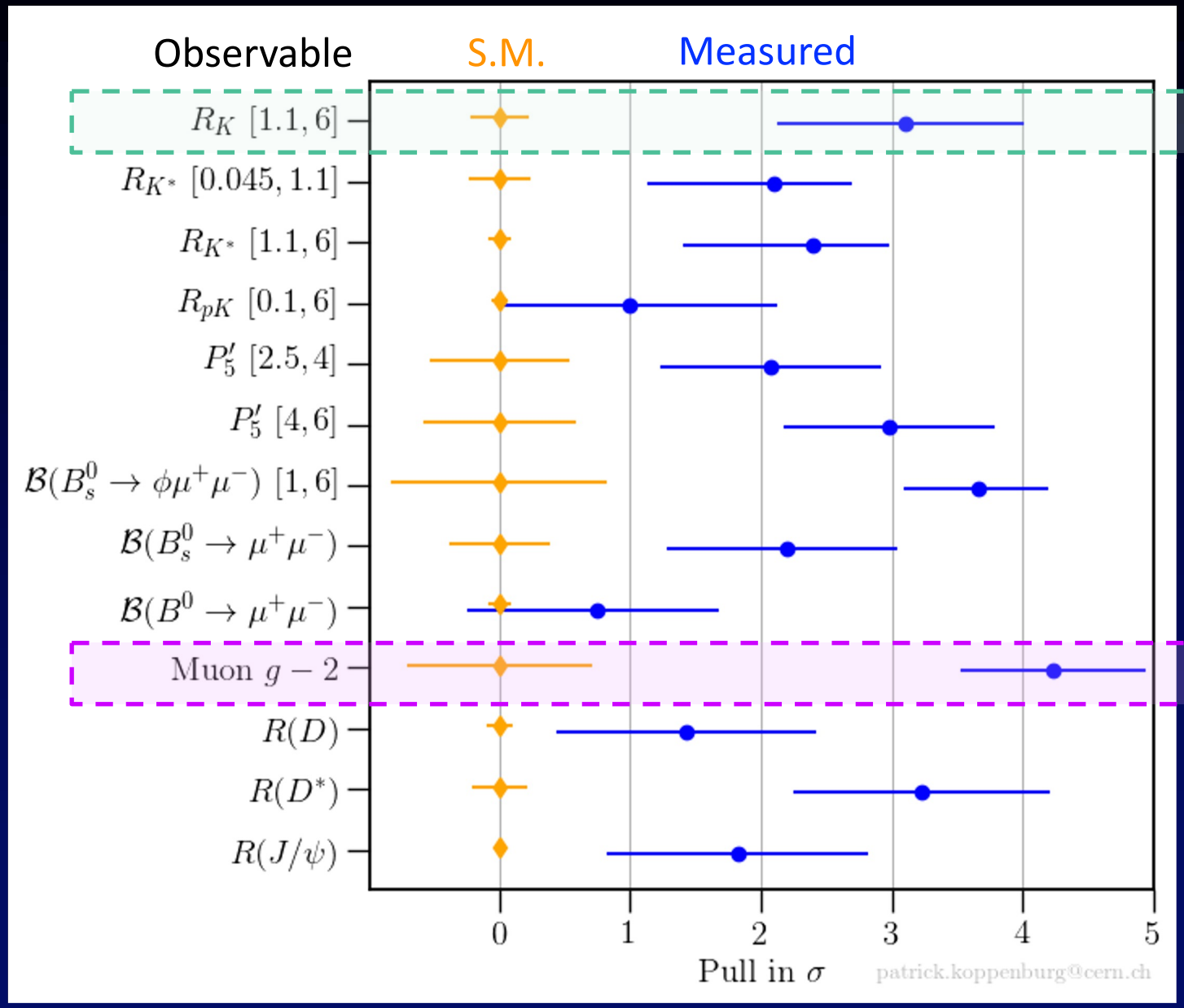


December 2022: verbeterde meting van de elektronen...



sep 2010 19:49:24
n 79646 Event 143858637

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



LHCb resultaat

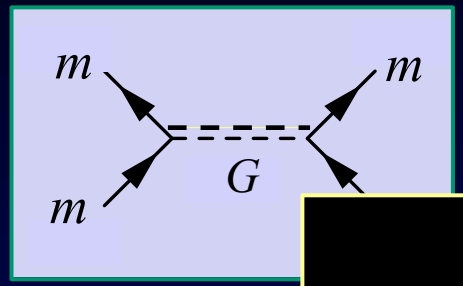
Fermilab g-2 resultaat

De puzzel wordt steeds dieper.

Vier(?) fundamentele natuurkrachten

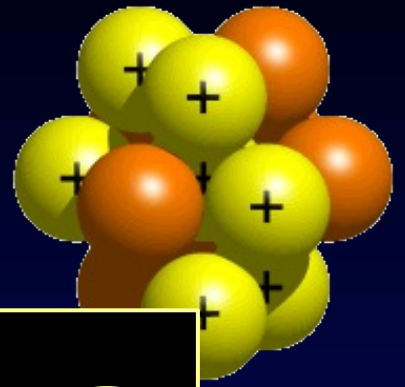
Zwaartekracht:

Quantum
Graviton exchange?



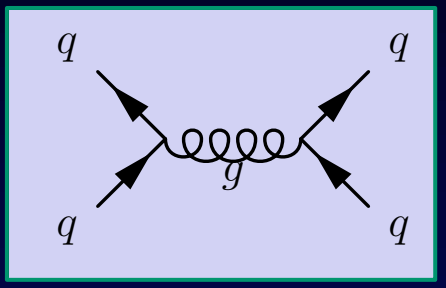
Werkt op alle deeltjes met massa

Sterke kernkracht:



alle quarks

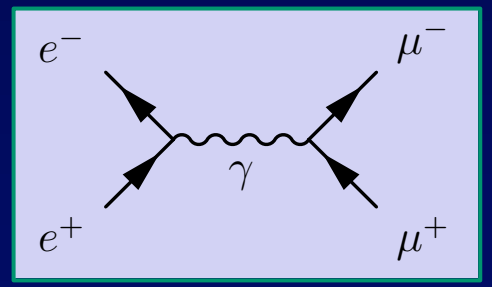
Quantum
gluon exchange:



+ ??? Vijfde kracht?

Elektromagnetisme:

Quantum
photon exc

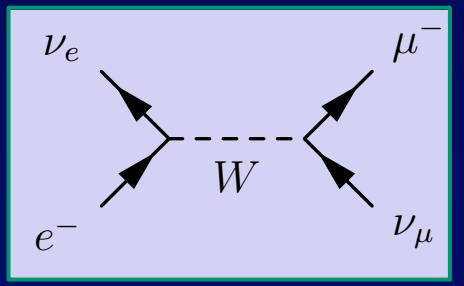


Werkt op alle elektrisch geladen deeltjes

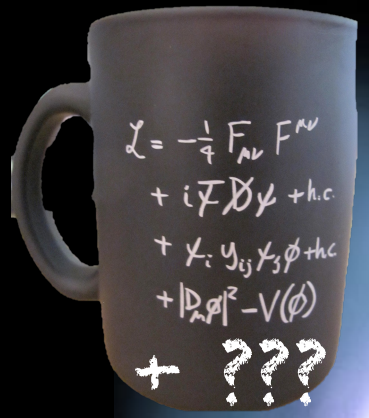
kernkracht:

Werkt op alle deeltjes

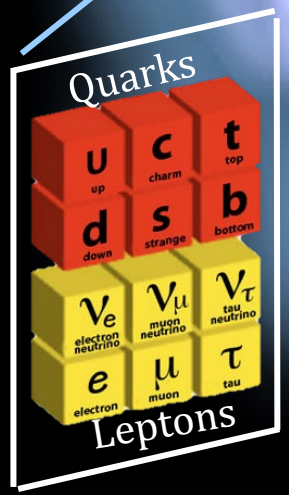
Quantum
W, Z exchange:



Conclusie: Hoe is de antimaterie verdwenen in het universum?



Door een vijfde kracht in de Big Bang?!

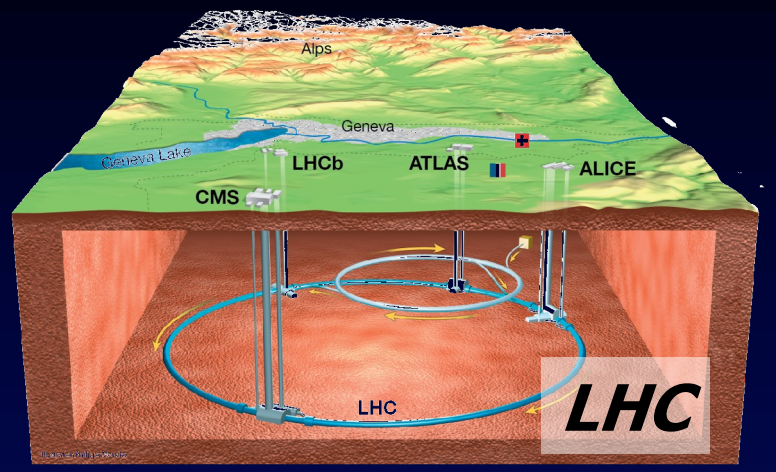


50.000001%

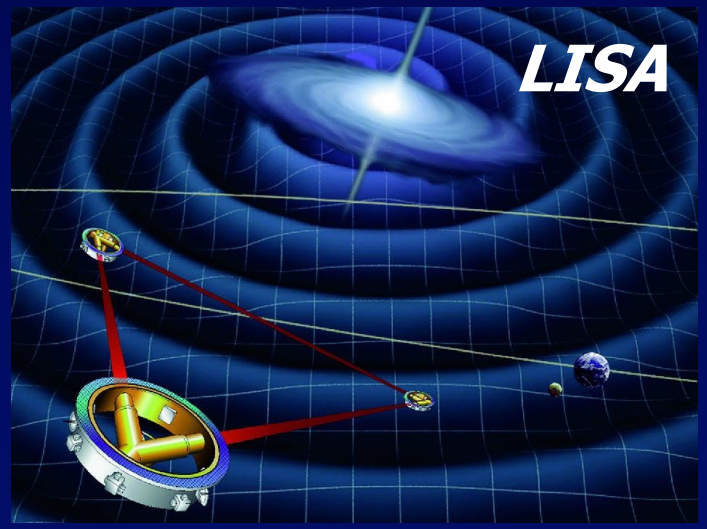
49.999999%

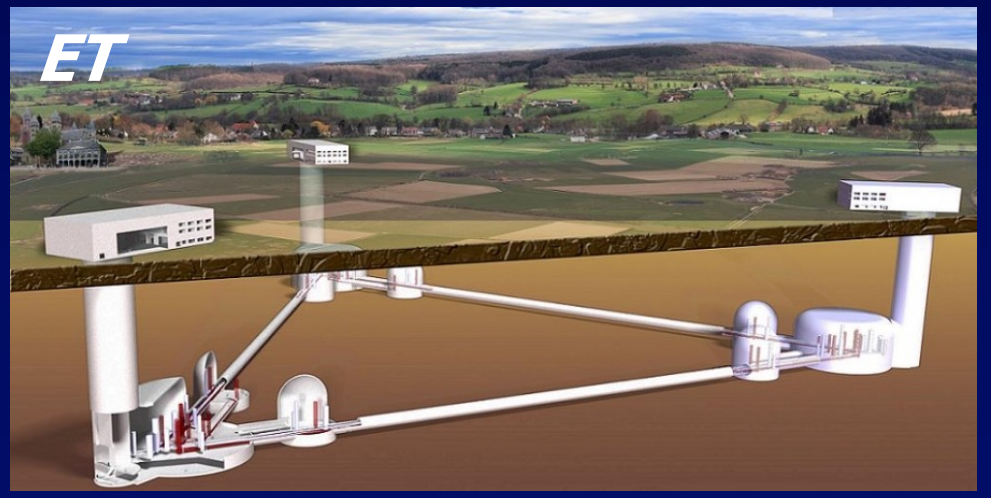
Toekomst: “Cirkels en Driehoeken”

Deeltjesversnellers: fysica van de Big Bang …



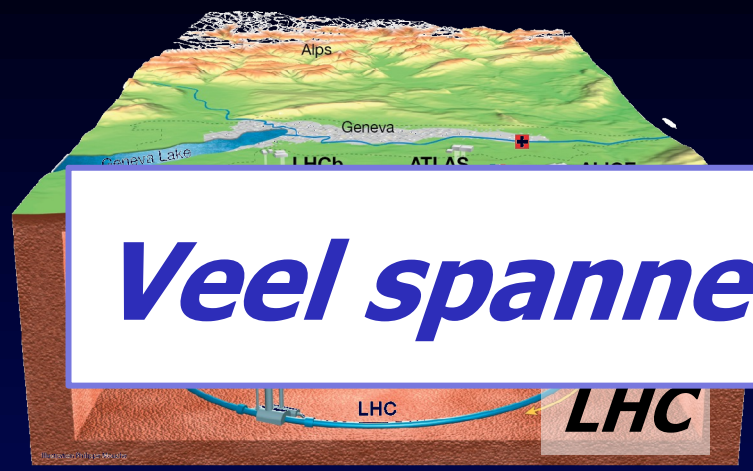
Gravitatie-detectoren: luisteren naar de Big Bang…





Toekomst: “Cirkels en Driehoeken”

Deeltjesversnellers: fysica van de Big Bang …

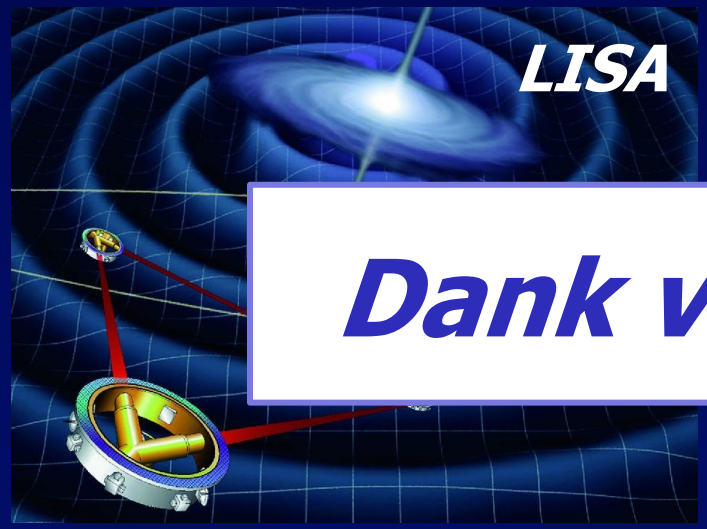


LHC

FCC

Veel spannend onderzoek onderweg

Gravitatie-detectoren: luisteren naar de Big Bang…



LISA

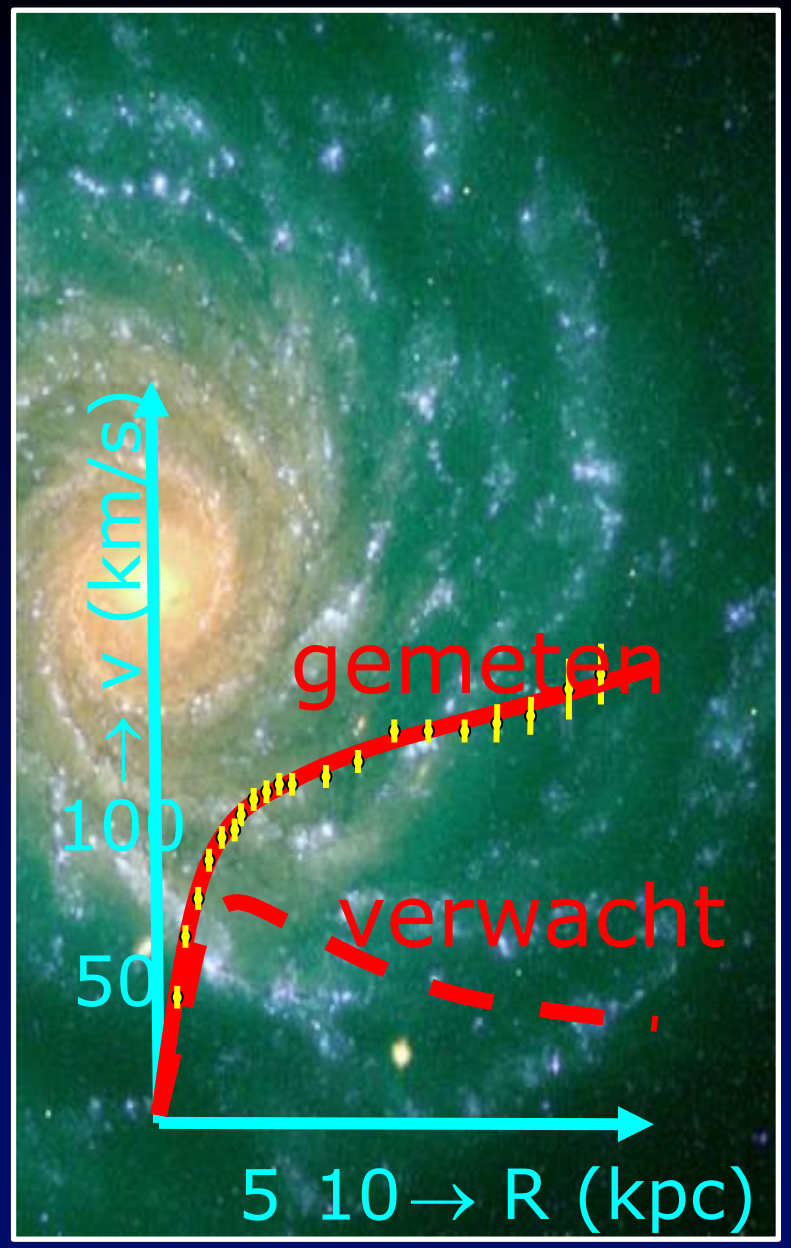
ET

Dank voor uw aandacht!

Donkere Materie

Zichtbare “baryonische” materie

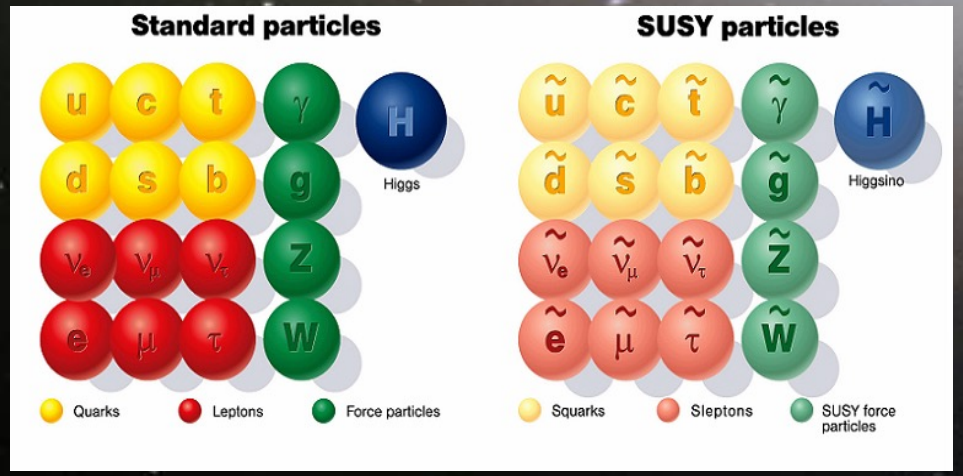
Spiraalarm rotatie en gravitationele lensen



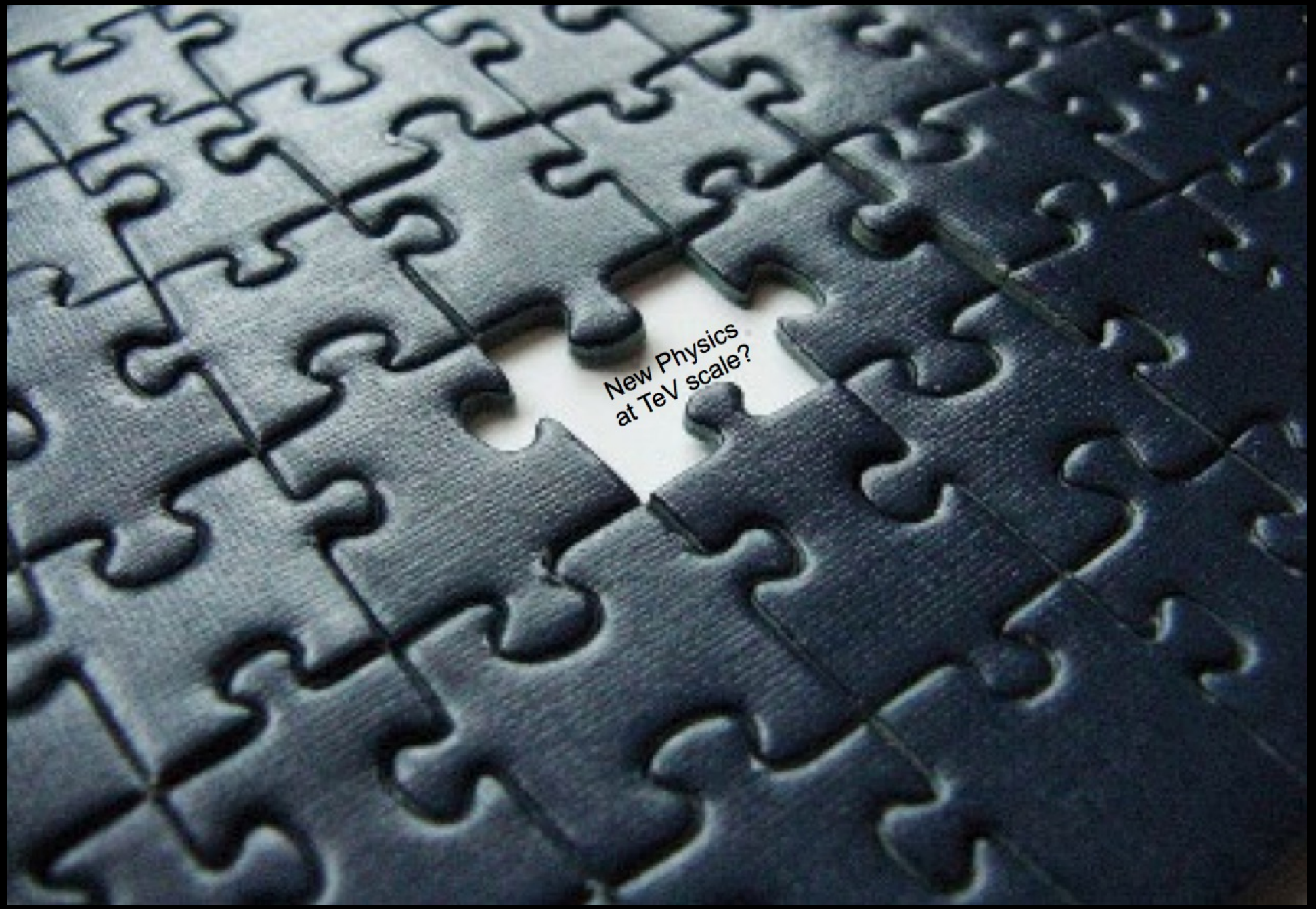
Donkere Materie

He H

donkere energie & donkere materie

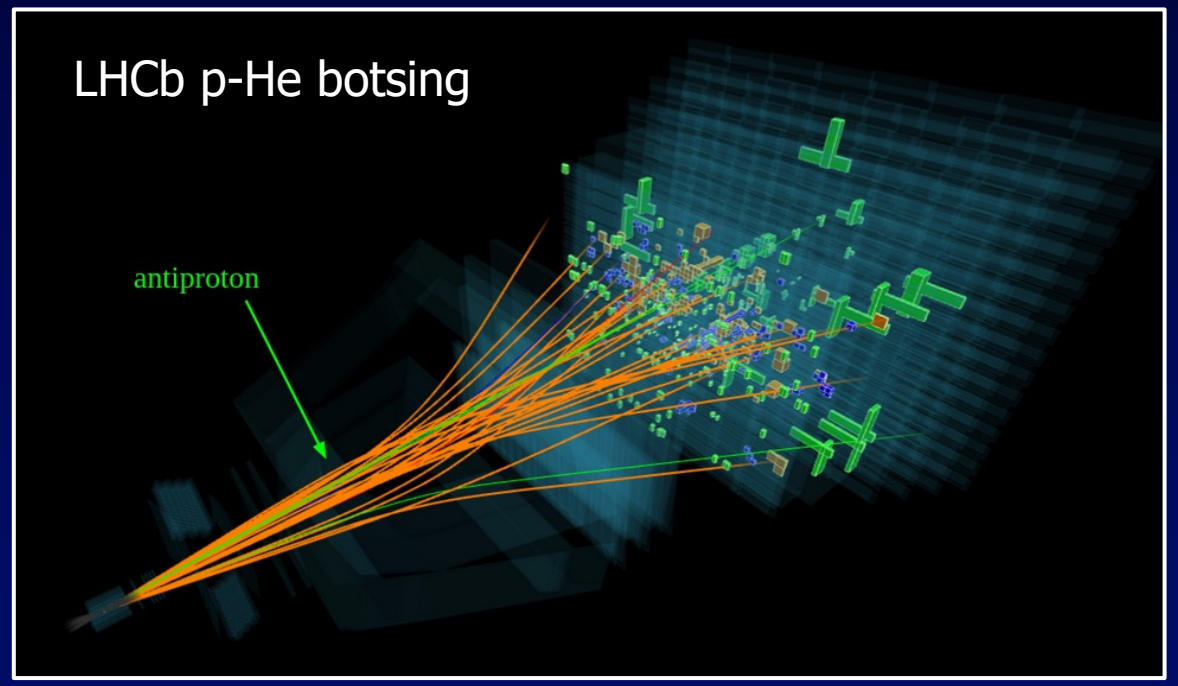


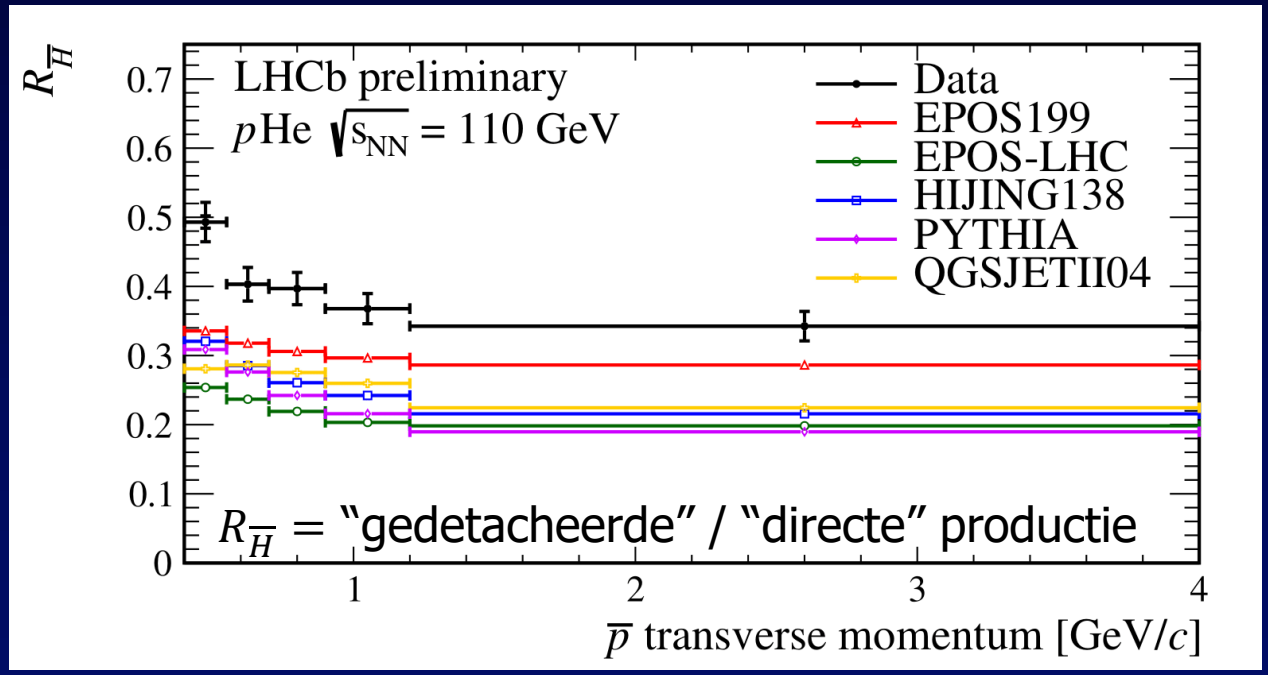
“The Dark Side rules the Universe”


New Physics
at TeV scale?

Antiproton productie (7 April, 2022)

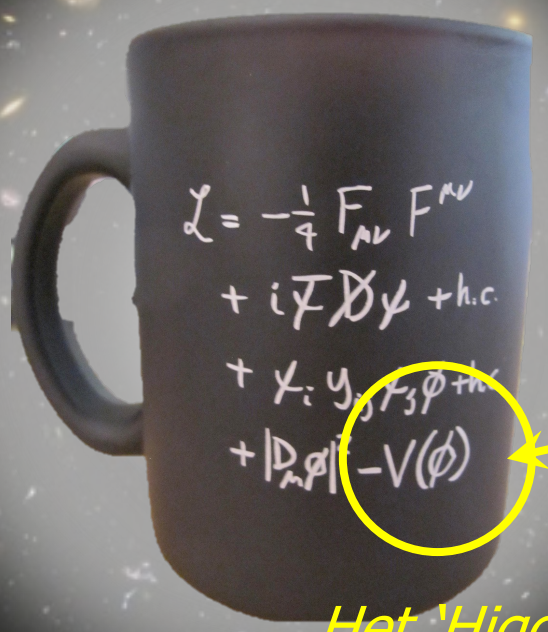
- AMS en Pamela experimenten meten antimaterie in de ruimte
- Antimaterie wordt ook gemaakt bij botsingen van protonen met gewone materie deeltjes (bv He)
  - De “gewone” antiproton ($\overline{H}$) productie is gemeten bij LHCb





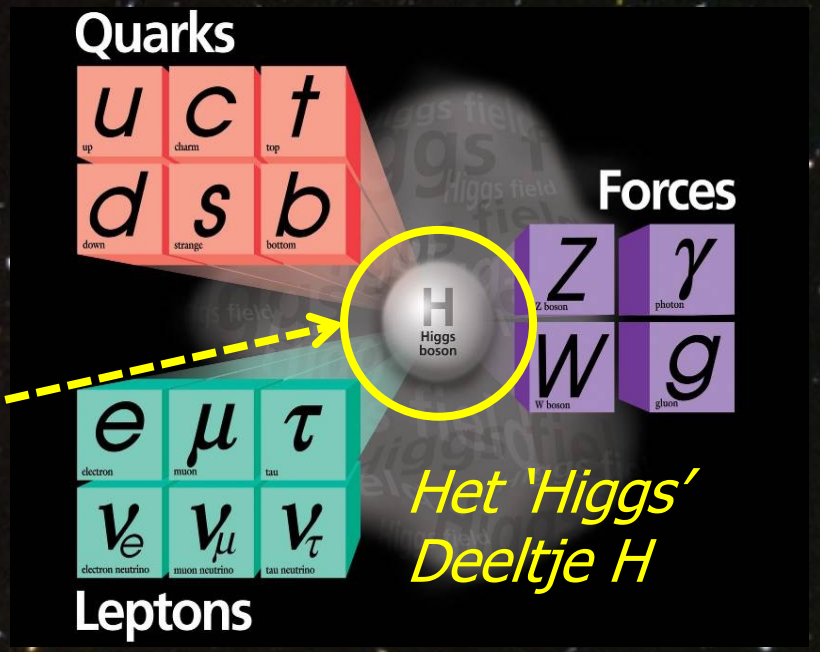
Het Standaard Model

"De formule"



Het 'Higgs' Veld ϕ

"De bouwstenen van de natuur"



Het 'Higgs' Deeltje H

Higgs Veld ϕ en Deeltje H

- Higgs veld ϕ is uniform, moeilijk waar te nemen.
- Higgs-boson deeltje H is "quantum-golf" van het veld.
- Massa ontstaat door interactie van materie deeltjes met het Higgs veld.

- Vergelijk:
  - Een foton is een kwantum van elektromagnetisch veld
  - Watergolf

$\phi \rightarrow H$

Higgs veld

Higgs deeltje
een "veld-kwantum"

Het Vacuum


..EUREKA..!!
..WE FINALLY FOUND NOTHING..!!!
CERN
HIGGS PARTICLE
SEARCH