LHCb

Wat doen wij?

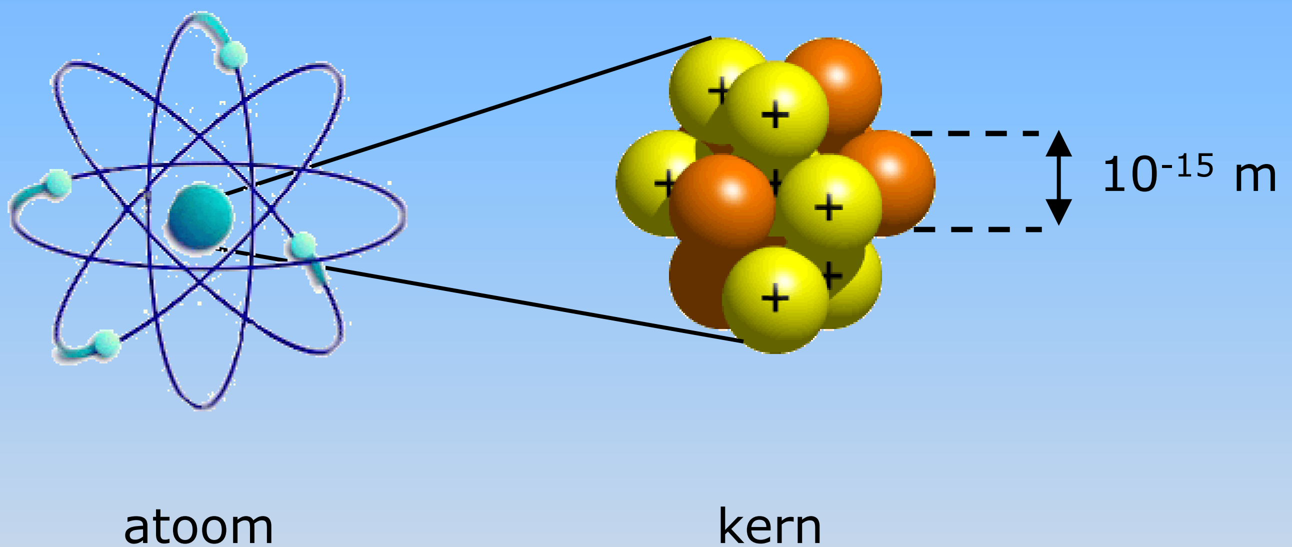
Niels Tuning voor ET - 8 januari 2013

LHCb

- Waarom deeltjesfysica?
- Waarom LHCb?
- Resultaten
- Upgrade

Deeltjesfysica

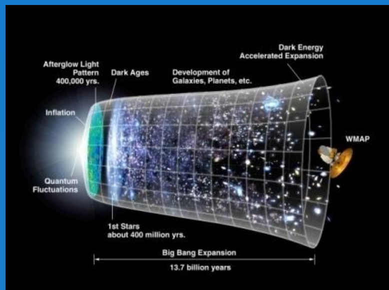
Bestudeert de natuur op afstanden < 10^{-15} m



Quantum theorie beschrijft alle metingen tot 10^{-18} m

(Ter vergelijk: 10^{+18} m = 100 lichtjaar)

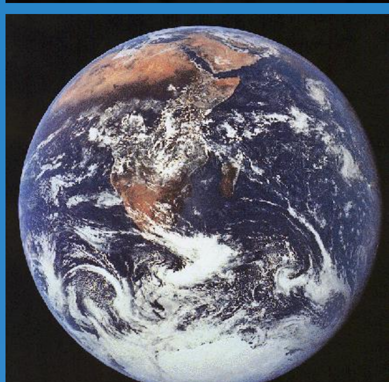
Machten van tien …



Heelal
10^{26} m

Melkweg
10^{21} m

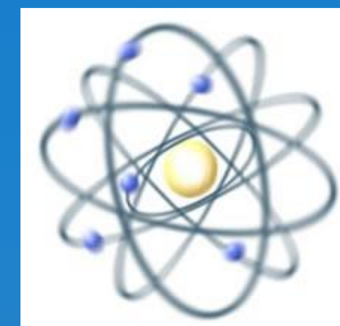
Zonnestelsel
10^{13} m



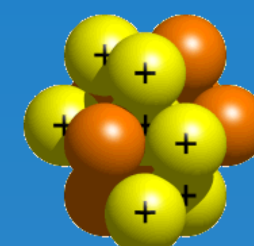
Aarde
10^{7} m

Spin
10^{-2} m

Atoom
10^{-10} m



Kern
10^{-15} m



Botsingen
10^{-18} m

Wat is het nut van dit onderzoek?

Fundamenteel onderzoek

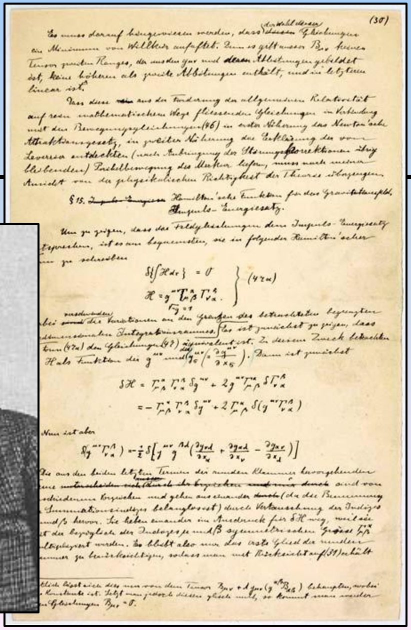
- Kan leiden tot verrassingen,
  - Soms zelfs nuttig…
  - Maar per definitie van te voren onbekend

"Oneindig veel toegepast onderzoek aan de kaars zou ons nooit het electrische licht hebben gebracht."

Wat is het nut van dit onderzoek?

Fundamenteel onderzoek

- Kan leiden tot verrassingen,
  - Soms zelfs nuttig…
  - Maar per definitie van te voren onbekend



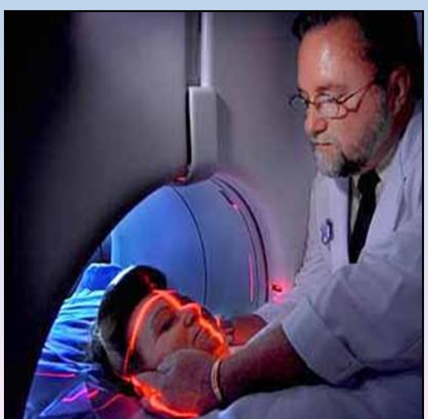
"Zonder relativiteits-theorie zit de GPS er 10km/dag naast!"

Wat is het nut van dit onderzoek?

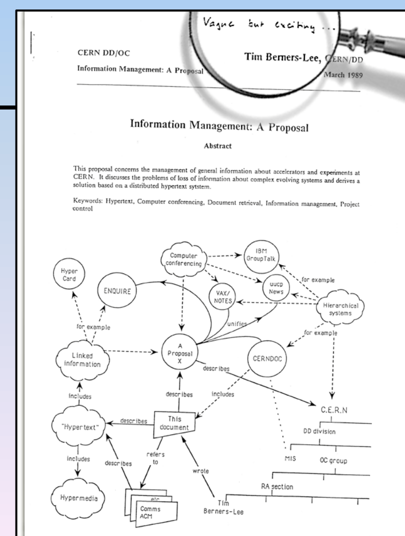
Fundamenteel onderzoek

- Heeft nuttige bij-effecten
  - Medische toepassingen
  - Internet
  - Opleiden van onderzoekers voor de maatschappij (Philips, ASML, etc, etc)

PET scan



www



Vague but exciting ...

CERN DD/OC

Information Management: A Proposal

Tim Berners-Lee, CERN/DD

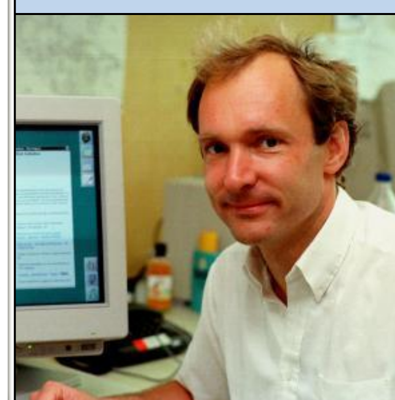
March 1989

Information Management: A Proposal

Abstract

This proposal concerns the management of general information about accelerators and experiments at CERN. It discusses the problems of loss of information about complex evolving systems and derives a solution based on a distributed hypertext sytstem.

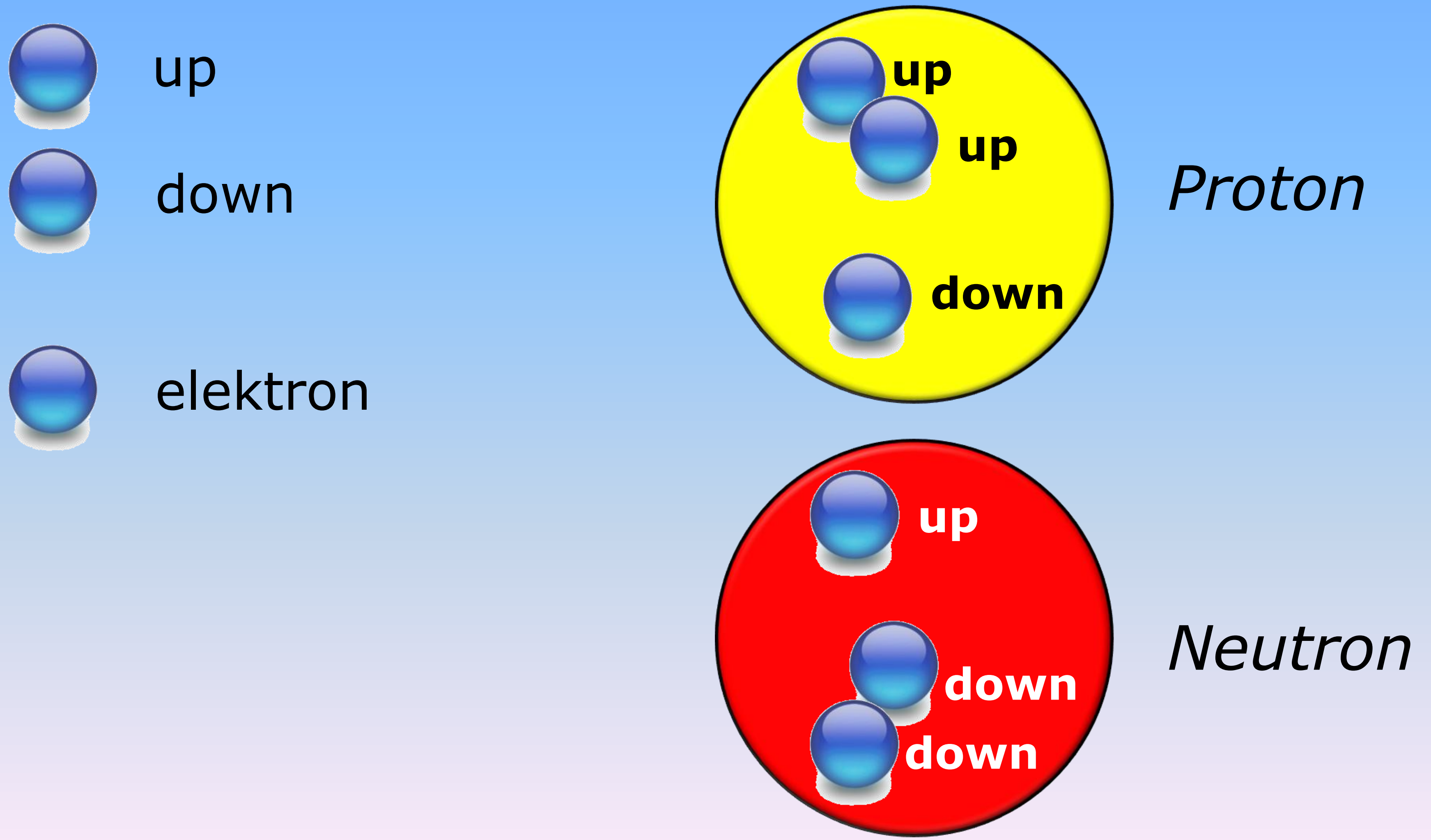
Keywords: Hypertext, Computer conferencing, Document retrieval, Information management, Project control



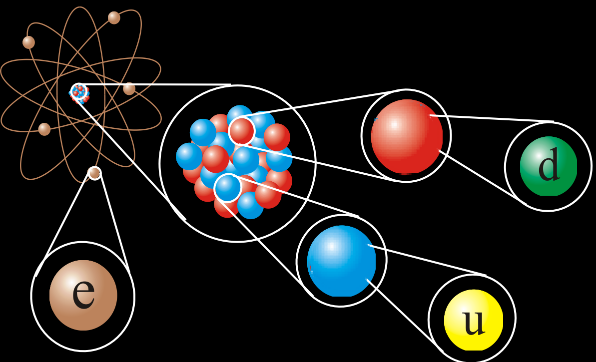
De stand van zaken in 2012

http:// pdg.lbl.gov

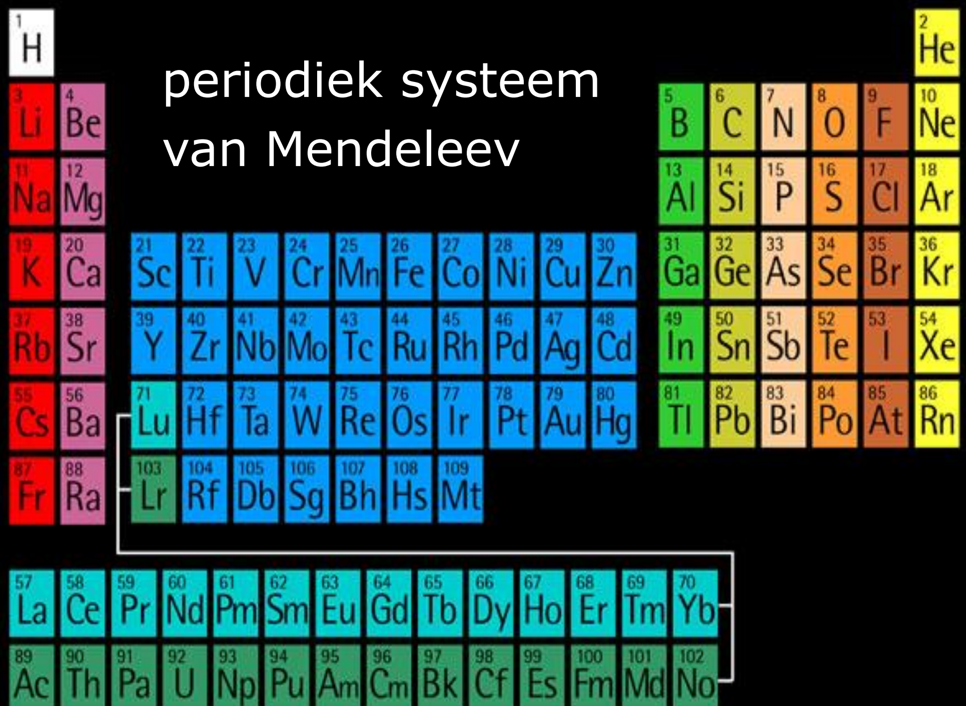
De elementaire deeltjes

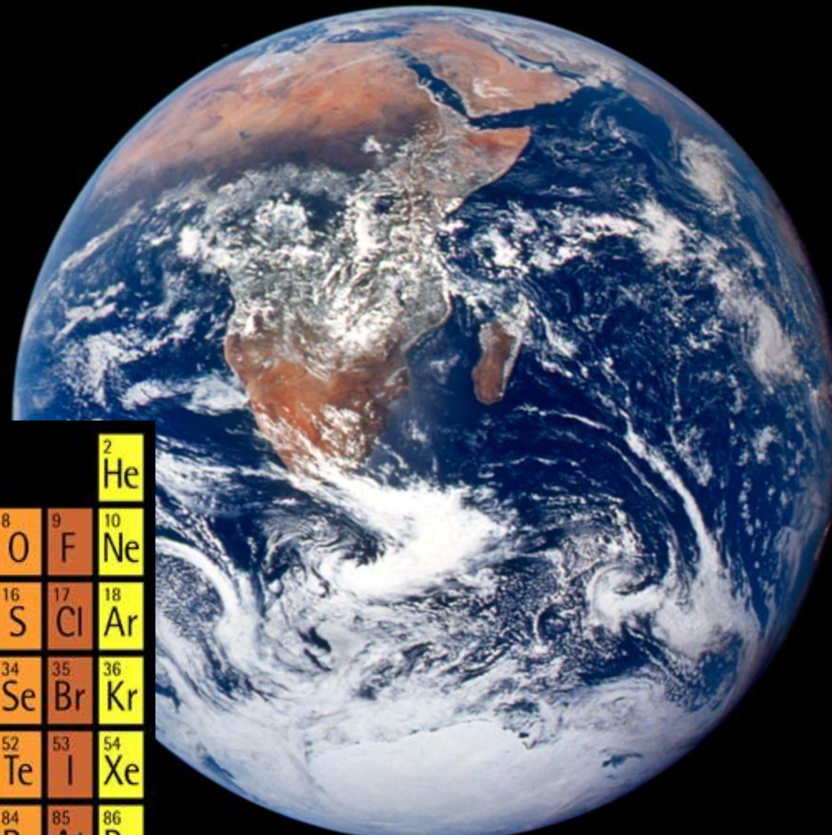


Wat kan je maken van deze 3 bouwstenen?



periodiek systeem van Mendeleev



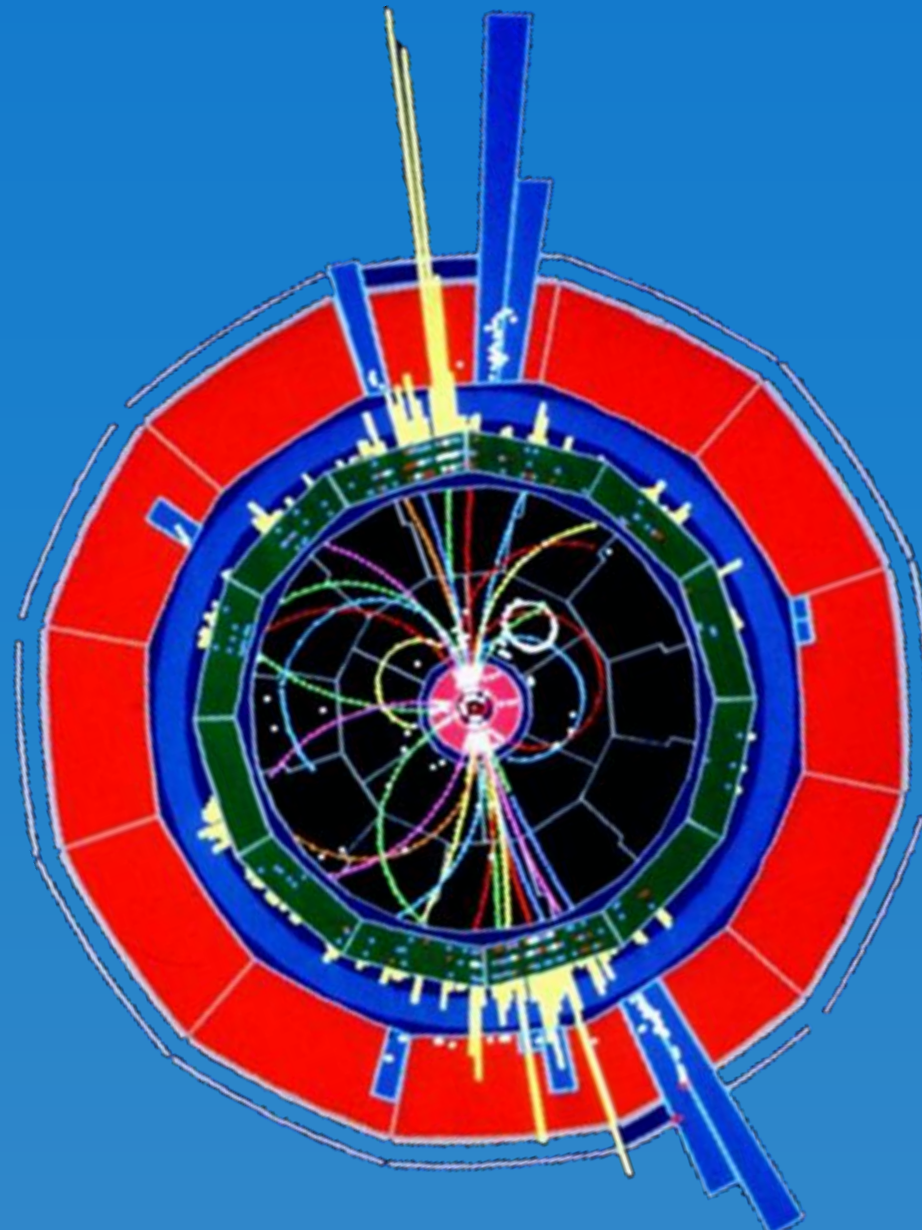


Alles!

De elementaire deeltjes

Niet één serie, maar drie!

	I	II	III
quarks	u	c (1976)	t (1995)
	d	s (1947)	b (1978)
leptons	e (1895)	μ (1936)	τ (1973)
	ν_e (1956)	ν_μ (1963)	ν_τ (2000)

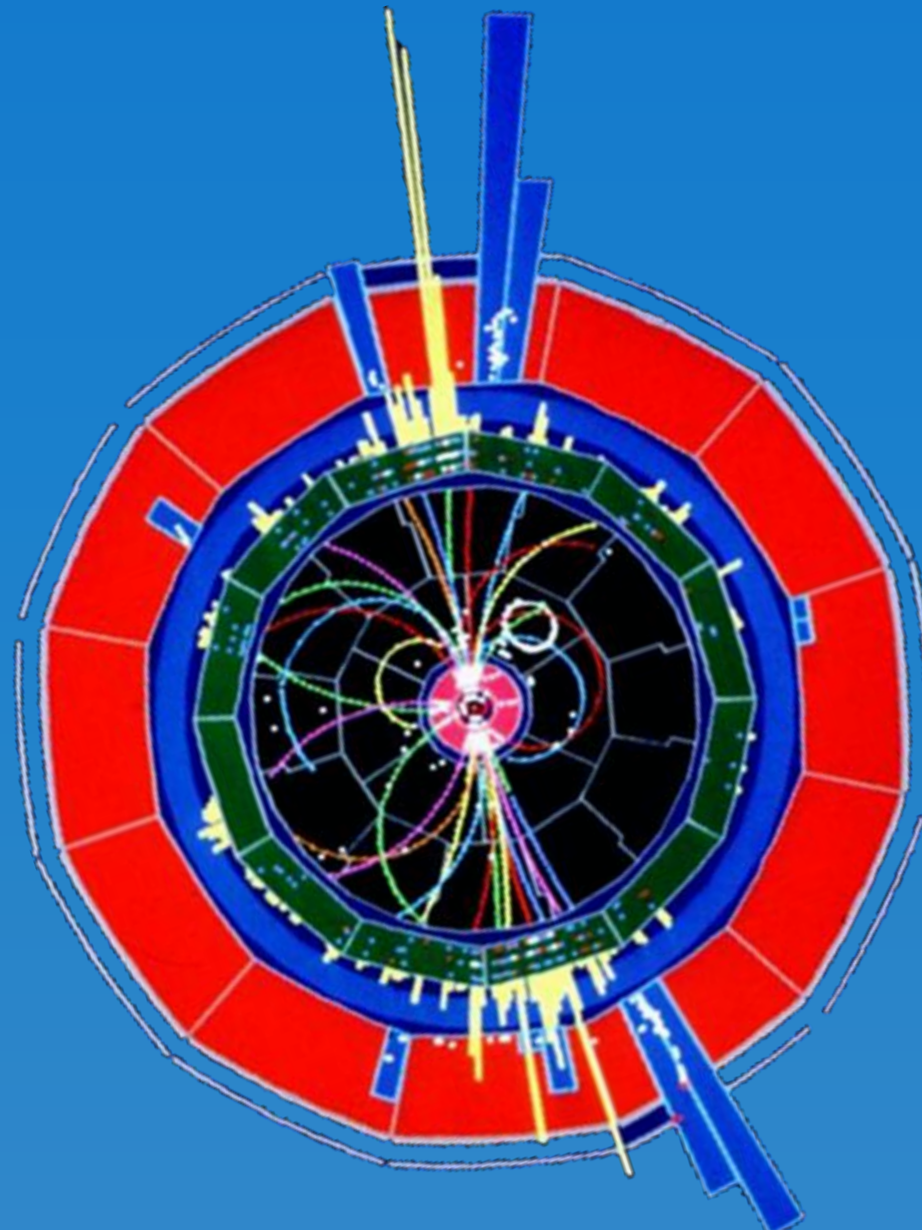


De elementaire deeltjes

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

Materie

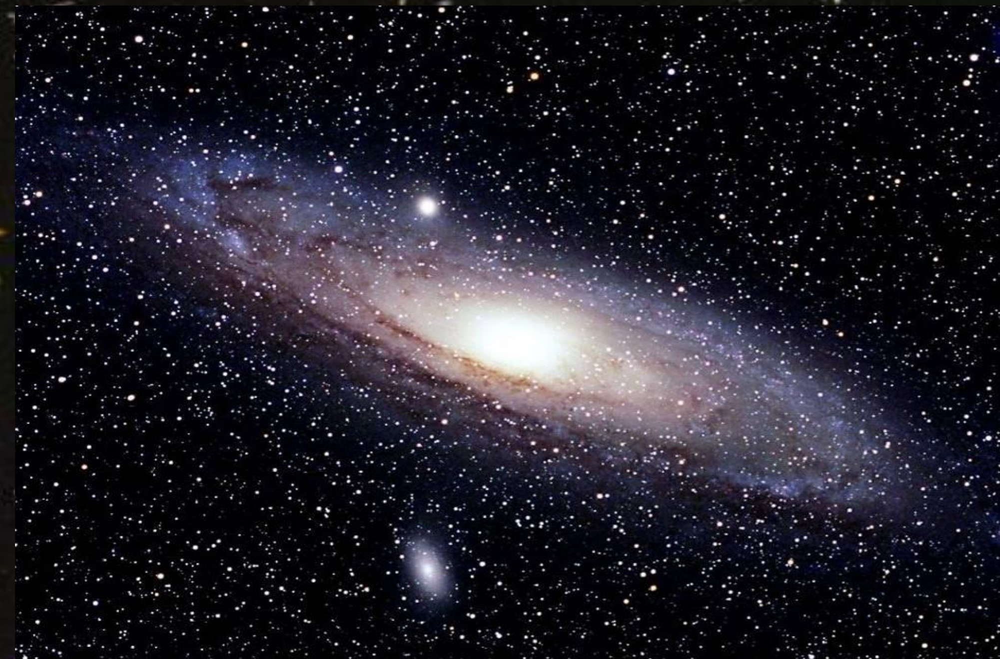


Is dit alles?

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

Materie

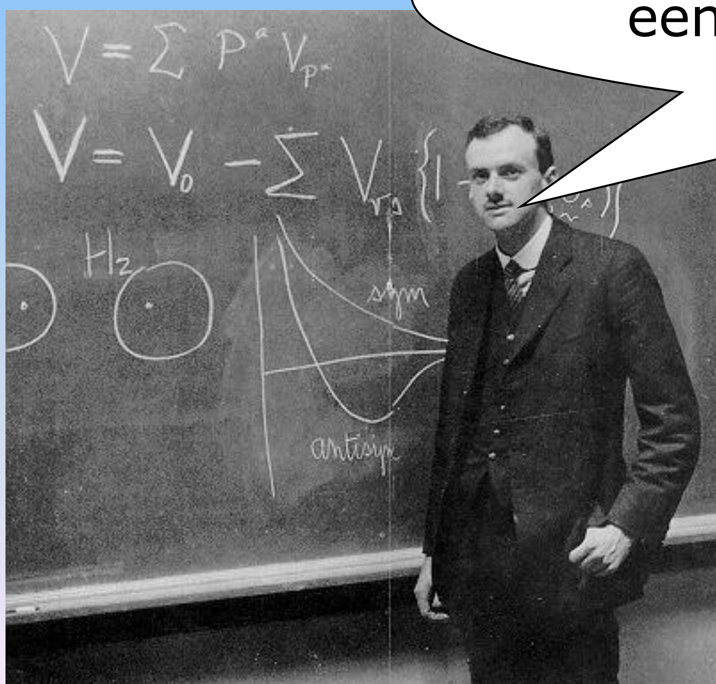


Anti-materie

Revoluties begin vorige eeuw:

- Relativiteitstheorie
- Quantum Mechanica

Paul Dirac (1928): relativistische quantum theorie!



Voor elk materiedeeltje bestaat een anti-materiedeeltje!

Anti-materie deeltje:

- Zelfde massa
- Tegenovergestelde lading

De elementaire deeltjes

	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

Materie

De elementaire deeltjes

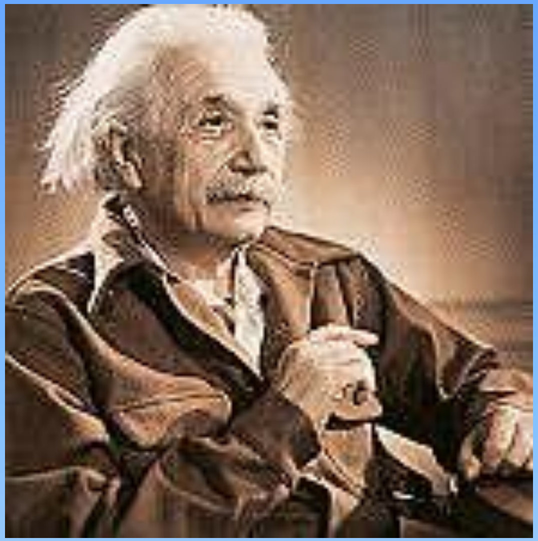
Materie

	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

Anti-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	$\bar{\nu}_e$	$\bar{\nu}_\mu$	$\bar{\nu}_\tau$

Hoe maak je anti-materie??

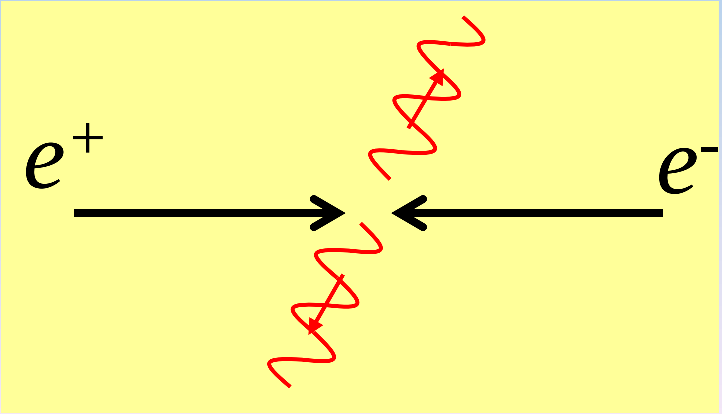


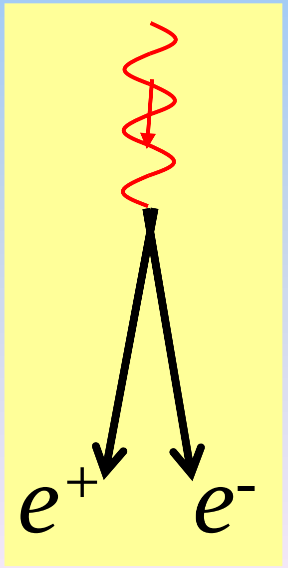
Albert Einstein:

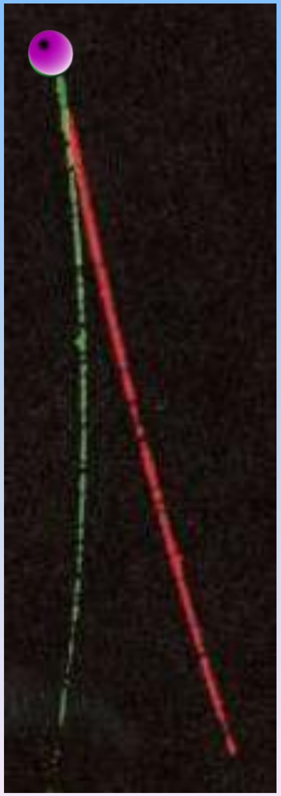
$E=mc^2$

materie + antimaterie = licht !

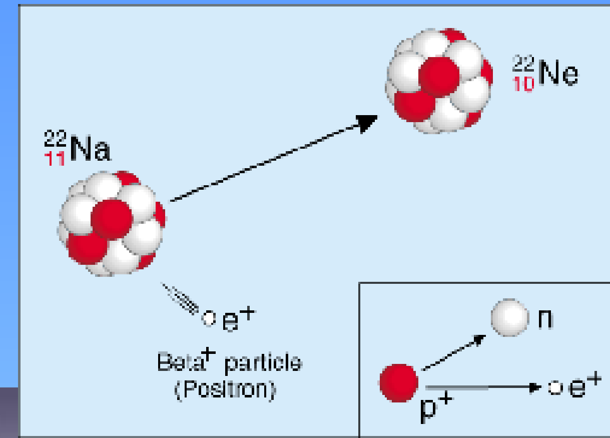
(en vice versa)

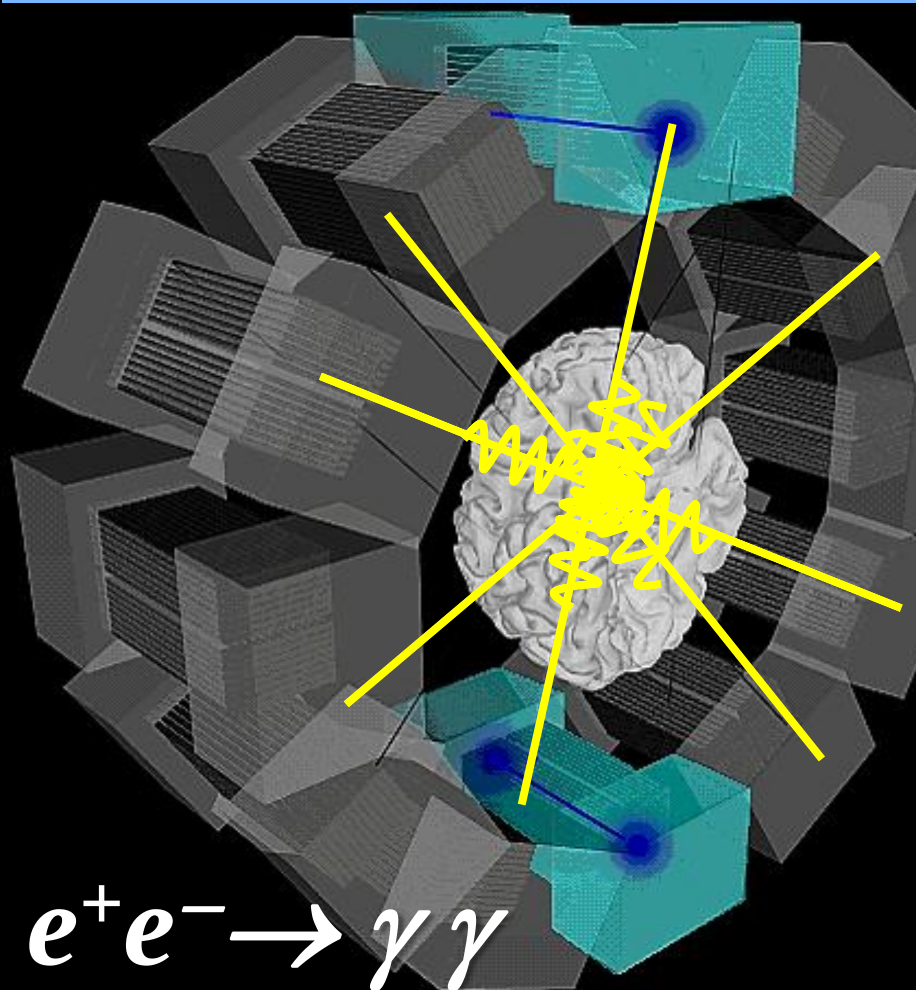


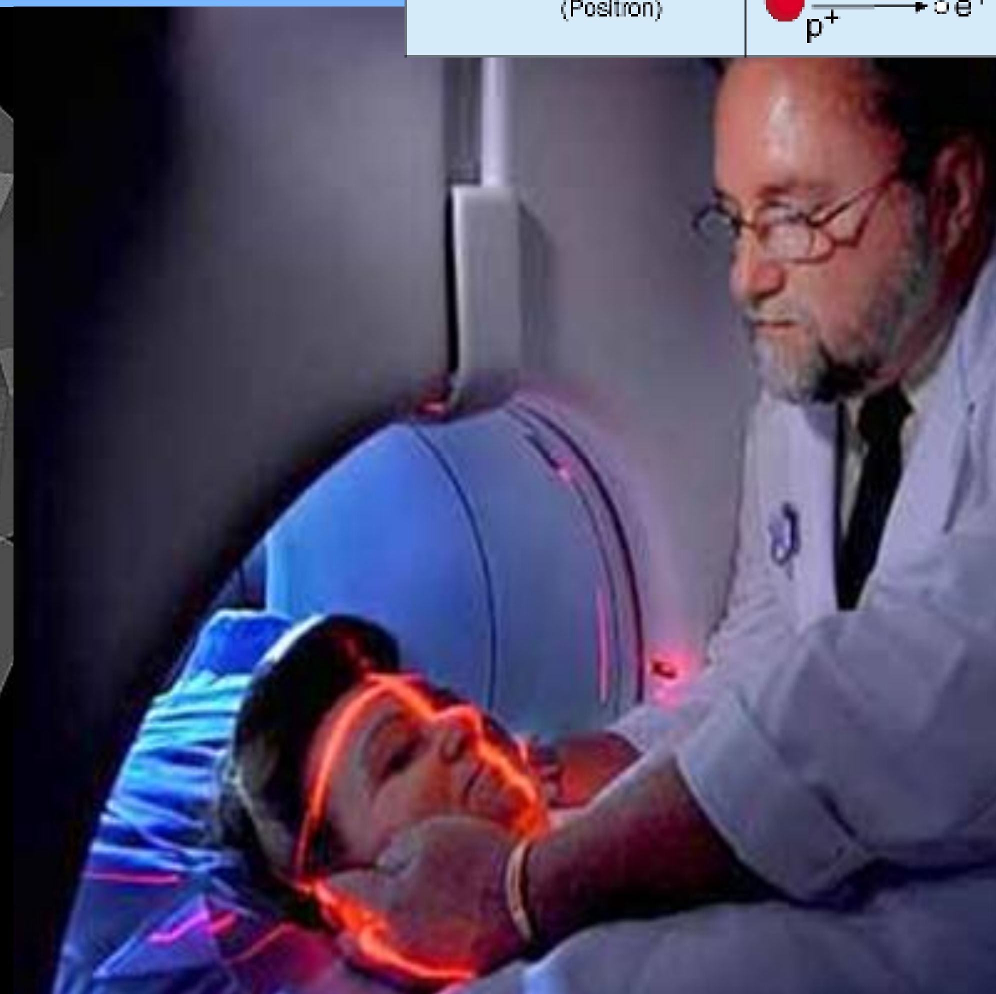




Anti-materie in ziekenhuizen: de PET-scan





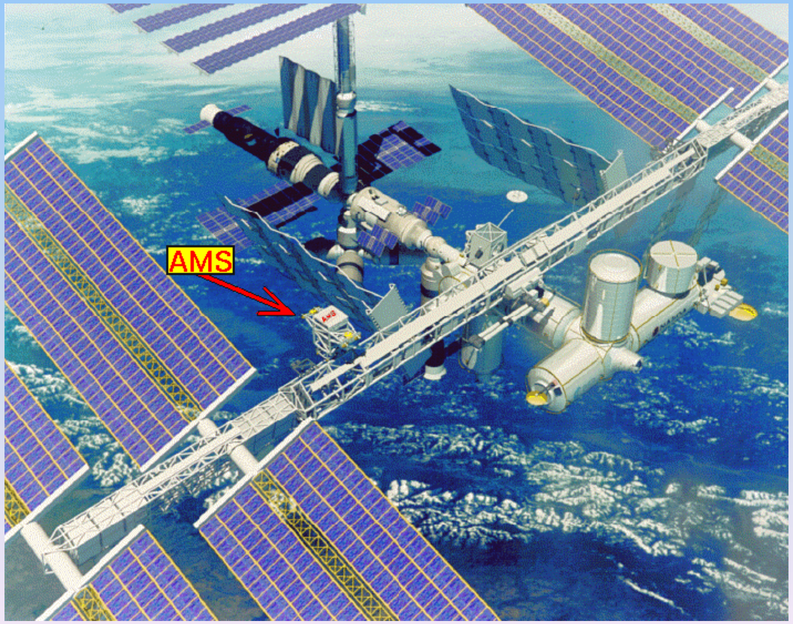


Wat snappen we nog niet:

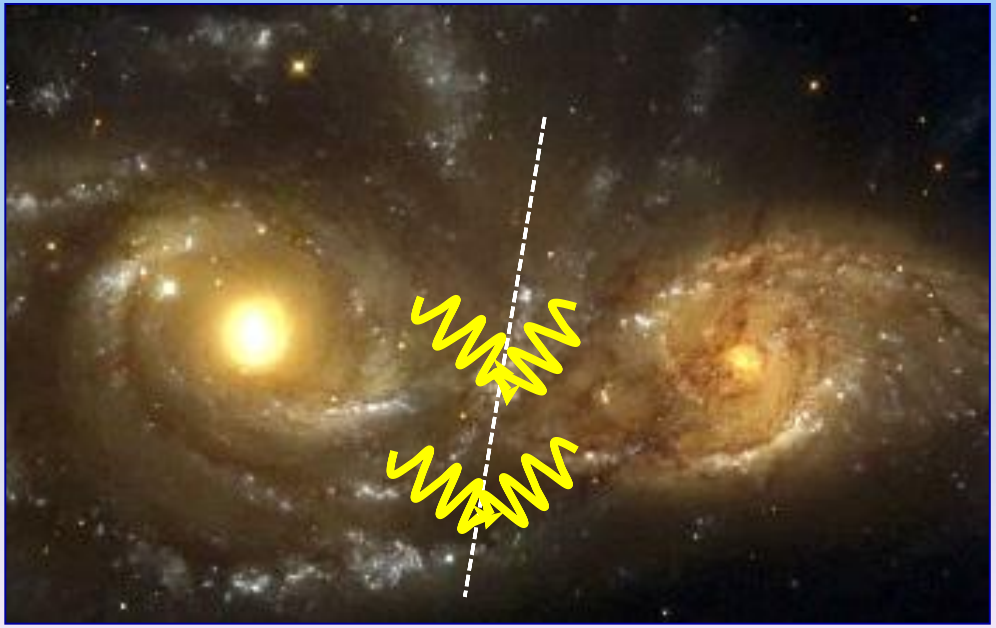
I. Wat snappen we nog niet? "*Anti-materie*"

Waar is de anti-materie gebleven?

Geen anti-materie met satellieten



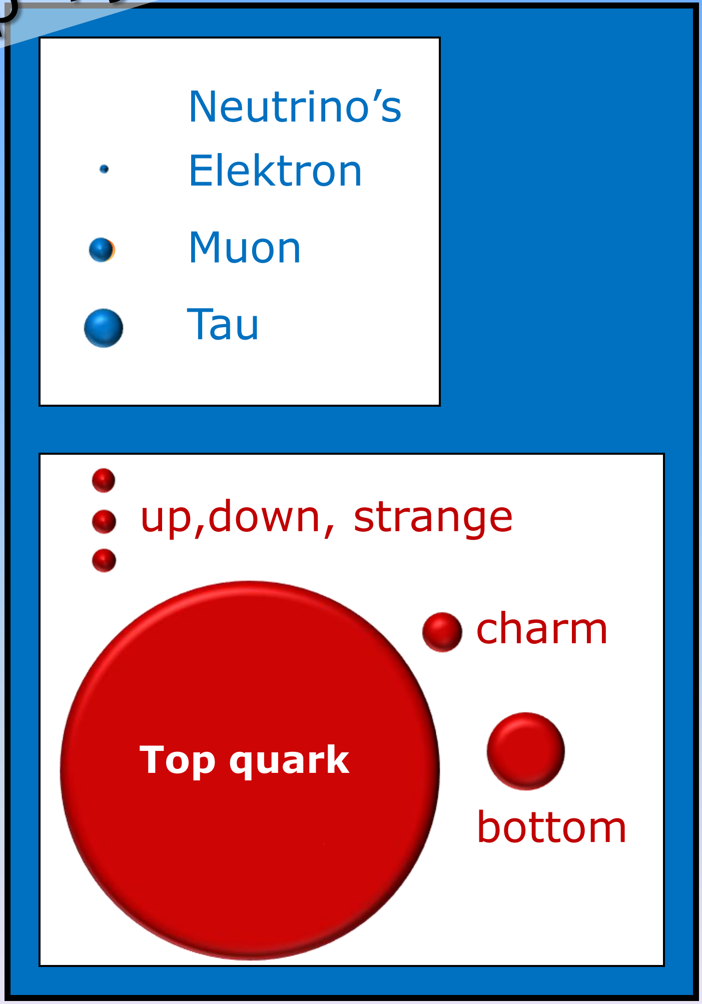
Geen anti-materie sterrenstelsels



II. Wat snappen we nog niet? *"Higgs"*

(Gedeeltelijk beantwoord op 4 juli 2012 !)

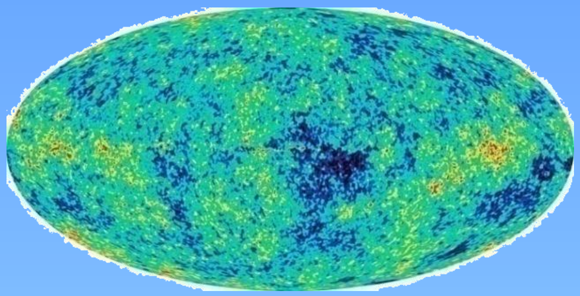
Massa van deeltjes



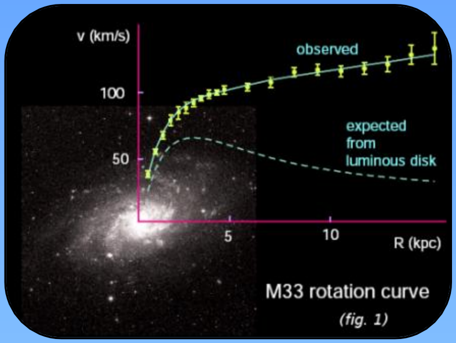
Bijzondere voorspelling:

Het Higgs boson:
zorgt ervoor dat deeltjes massa kunnen hebben in de theorie

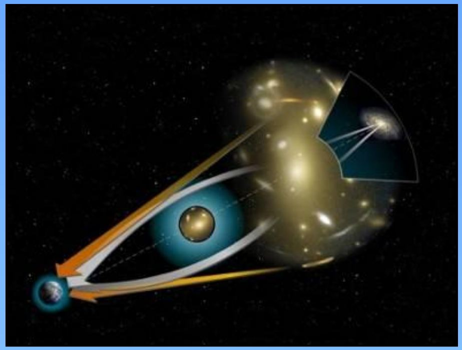
III. Wat snappen we nog niet? “*Donkere materie*”



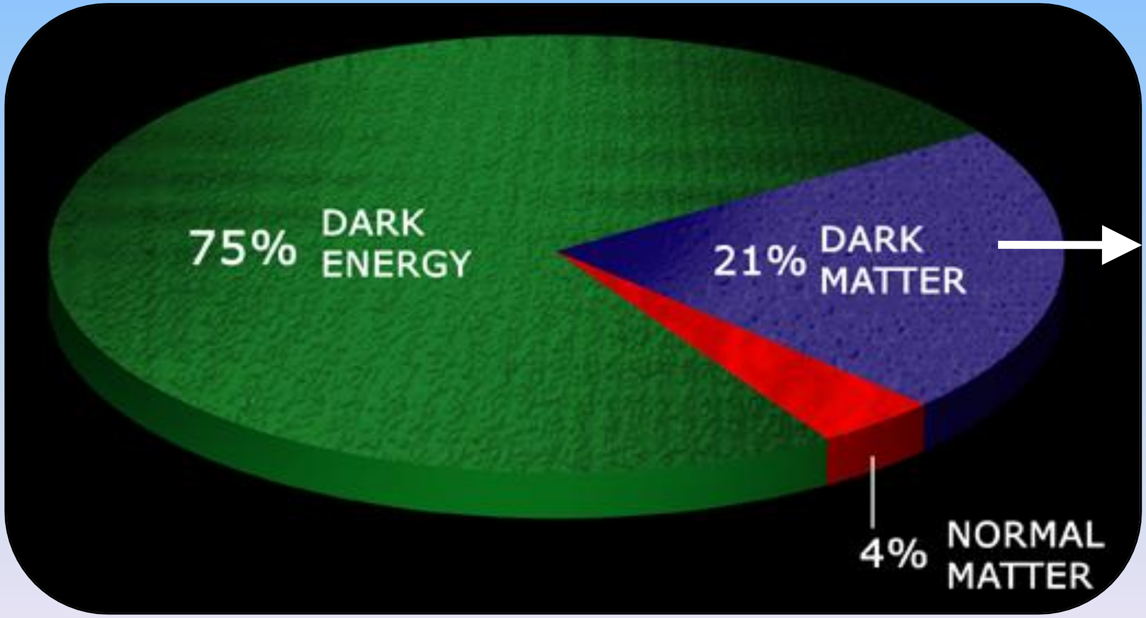
Temperatuurfluctuaties structuur van het heelal



Rotatie-curves



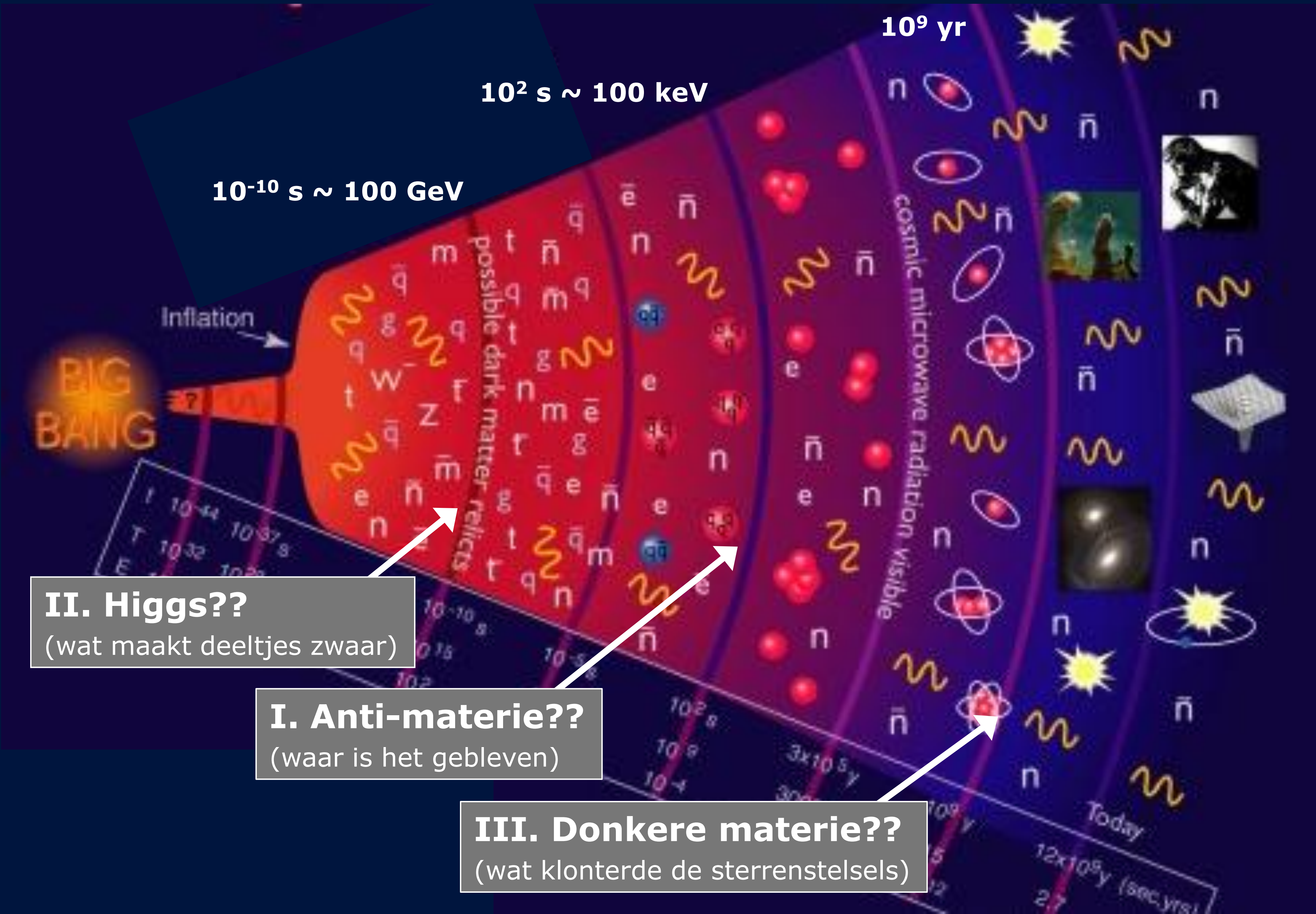
Gravitationele lens



Wat is de donkere materie ?

We hebben al die tijd maar 4% van het heelal bestudeerd!

Wat snappen we niet?   Drie Grote Vragen




Astronomie
Deeltjes fysica
Fundamenteel
(nieuwsgierigheid gedreven)
onderzoek

Klassiek botsen

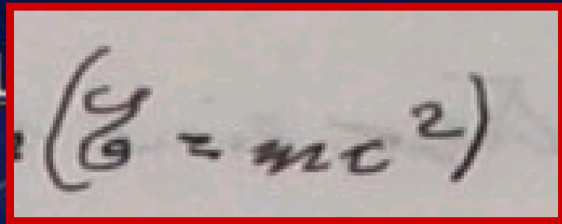
Quantummechanisch botsen

proton **proton**

Wat verwacht je ?

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

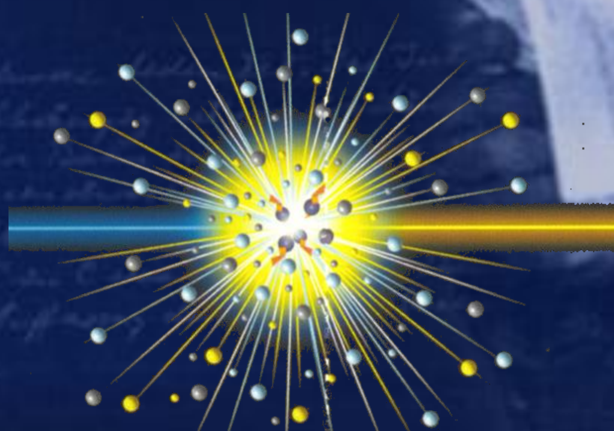
Al 40 jaar bestaan er precieze wiskundige voorspellingen!

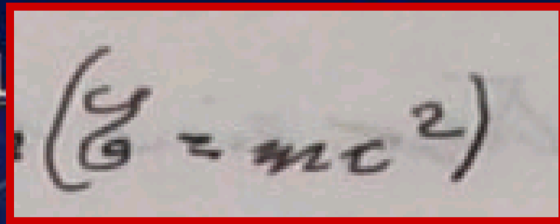


Hoe ontdekken we nieuwe deeltjes?

<u>Bij de LHC op Cern</u>:

1) Verander energie in materie!



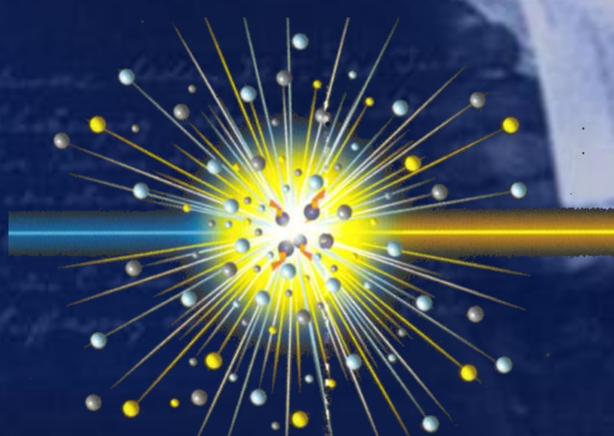


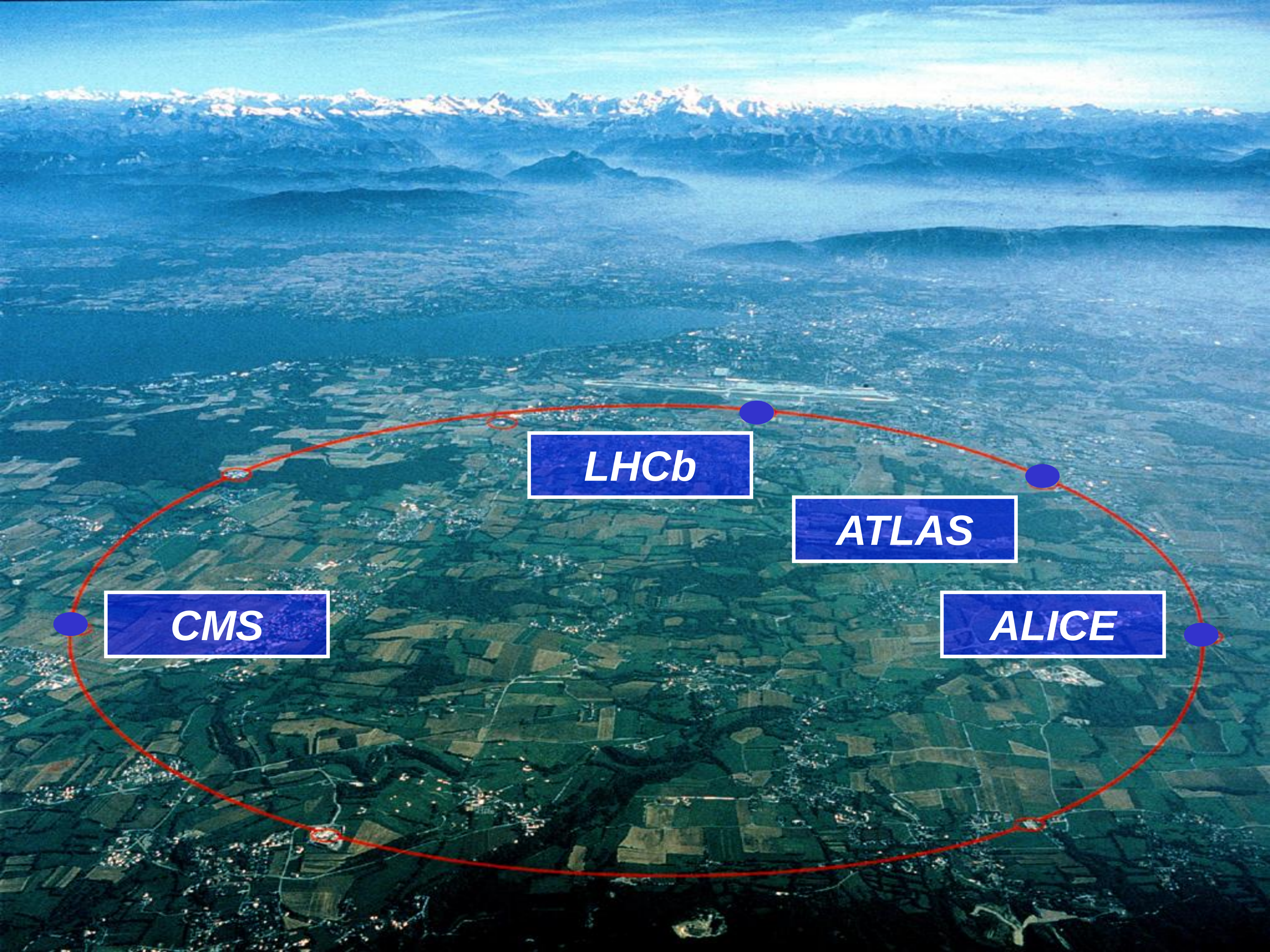
Hoe ontdekken we nieuwe deeltjes?

Bij de LHC op Cern:

1) Verander energie in materie!

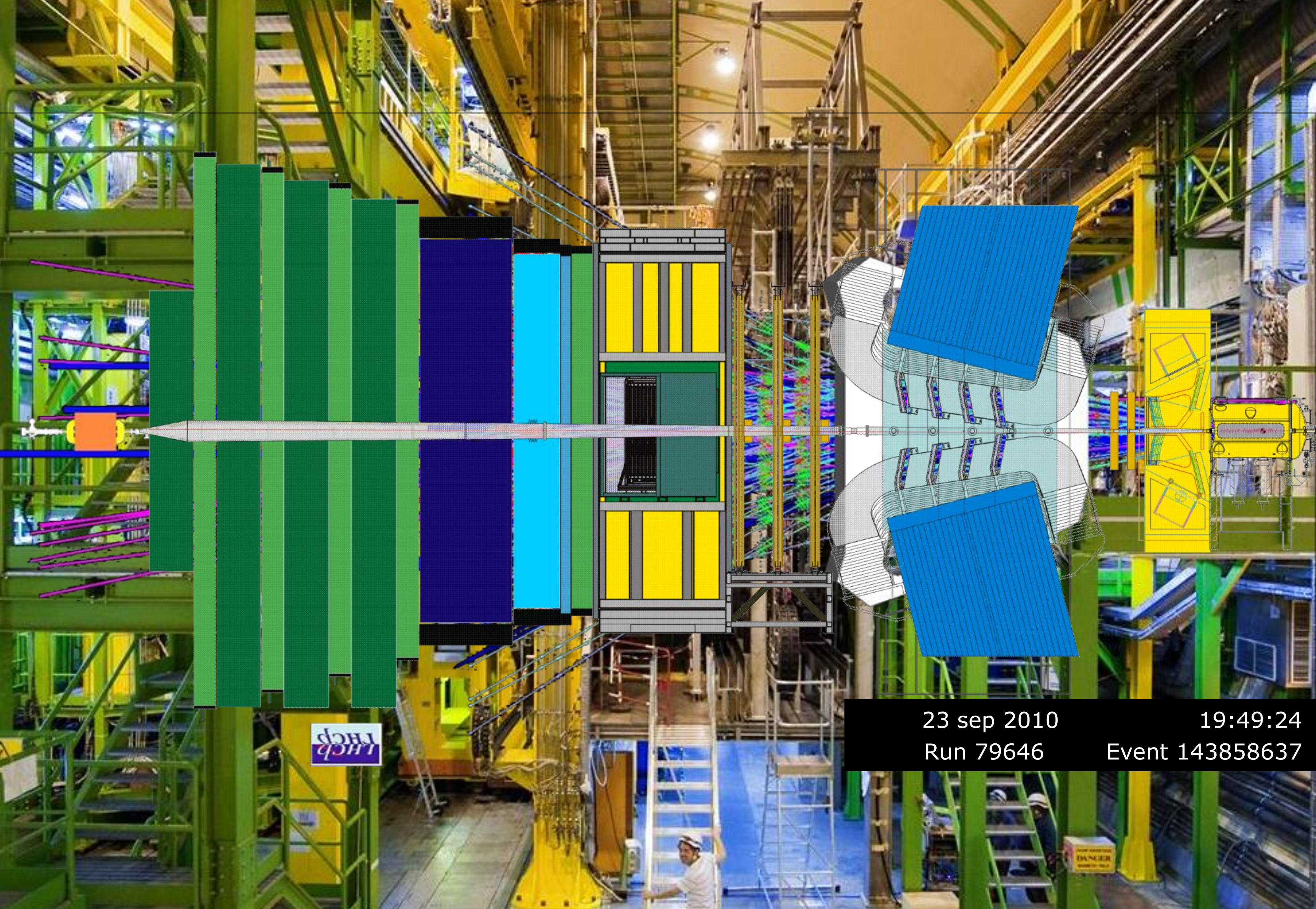
2) Nieuwe deeltjes veranderen voorspellingen

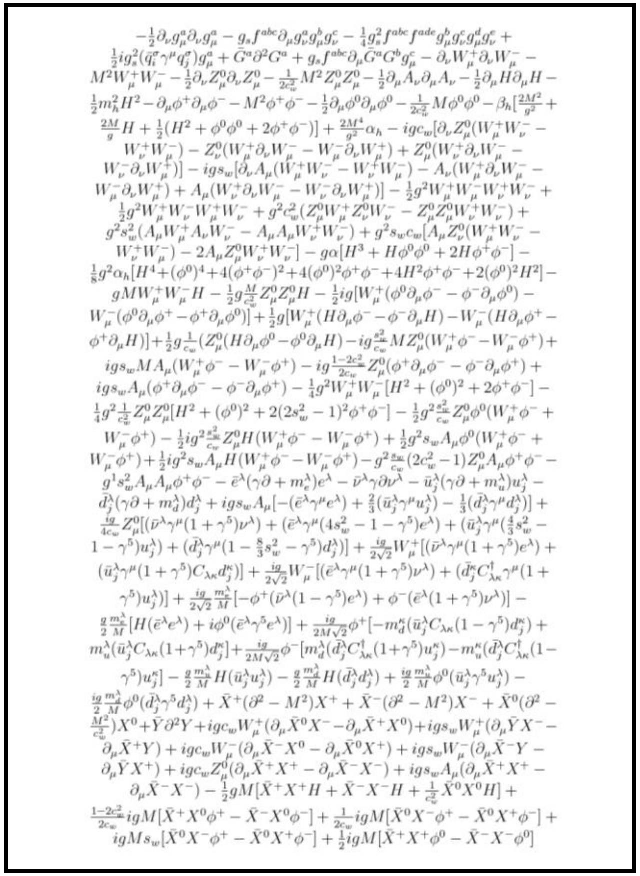



LHCb
ATLAS
CMS
ALICE


2) Nieuwe deeltjes veranderen voorspellingen
1) Verander energie in materie
LHCb
ATLAS

The LHCb Detector





$$
\begin{gathered}
-\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}ig_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}\partial_\mu H\partial_\mu H - \\
\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\phi^0\phi^0 - \beta_h[\tfrac{2M^2}{g^2} + \\
\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 Z^0_\mu(W^+_\mu W^-_\nu - \\
W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu - \\
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 - \\
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 W^-_\mu W^+_\nu W^-_\nu + \\
\tfrac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + \\
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^0_\nu(W^+_\mu W^-_\nu - \\
W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] - \\
\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^- + 2(\phi^0)^2H^2] - \\
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^- - \phi^-\partial_\mu\phi^0) - \\
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) - W^-_\mu(H\partial_\mu\phi^+ - \\
\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}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + \\
igs_w MA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\tfrac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \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)^2 + 2\phi^+\phi^-] - \\
\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}Z^0_\mu\phi^0(W^+_\mu\phi^- + \\
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_\mu\phi^0(W^+_\mu\phi^- + \\
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 - 1)Z^0_\mu A_\mu\phi^+\phi^- - \\
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_u^\lambda)u^\lambda_j - \\
\bar{d}^\lambda_j(\gamma\partial + m_d^\lambda)d^\lambda_j + igs_w A_\mu[-(\bar{e}^\lambda\gamma^\mu e^\lambda) + \tfrac{2}{3}(\bar{u}^\lambda_j\gamma^\mu u^\lambda_j) - \tfrac{1}{3}(\bar{d}^\lambda_j\gamma^\mu d^\lambda_j)] + \\
\tfrac{ig}{4c_w}Z^0_\mu[(\bar{\nu}^\lambda\gamma^\mu(1 + \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 - \gamma^5)u^\lambda_j) + (\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) + \\
(\bar{u}^\lambda_j\gamma^\mu(1 + \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^\dagger_{\lambda\kappa}\gamma^\mu(1 + \\
\gamma^5)u^\lambda_j)] + \tfrac{ig}{2\sqrt{2}}\tfrac{m_e^\lambda}{M}[-\phi^+(\bar{\nu}^\lambda(1 - \gamma^5)e^\lambda) + \phi^-(\bar{e}^\lambda(1 + \gamma^5)\nu^\lambda)] - \\
\tfrac{g}{2}\tfrac{m_e^\lambda}{M}[H(\bar{e}^\lambda e^\lambda) + i\phi^0(\bar{e}^\lambda\gamma^5 e^\lambda)] + \tfrac{ig}{2M\sqrt{2}}\phi^+[-m_d^\kappa(\bar{u}^\lambda_j C_{\lambda\kappa}(1 - \gamma^5)d^\kappa_j) + \\
m_u^\lambda(\bar{u}^\lambda_j C_{\lambda\kappa}(1 + \gamma^5)d^\kappa_j] + \tfrac{ig}{2M\sqrt{2}}\phi^-[m_d^\lambda(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1 + \gamma^5)u^\kappa_j) - m_u^\kappa(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1 - \\
\gamma^5)u^\kappa_j] - \tfrac{g}{2}\tfrac{m_u^\lambda}{M}H(\bar{u}^\lambda_j u^\lambda_j) - \tfrac{g}{2}\tfrac{m_d^\lambda}{M}H(\bar{d}^\lambda_j d^\lambda_j) + \tfrac{ig}{2}\tfrac{m_u^\lambda}{M}\phi^0(\bar{u}^\lambda_j\gamma^5 u^\lambda_j) - \\
\tfrac{ig}{2}\tfrac{m_d^\lambda}{M}\phi^0(\bar{d}^\lambda_j\gamma^5 d^\lambda_j) + \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})X^0 + \bar{Y}\partial^2 Y + 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^- - \\
\partial_\mu\bar{X}^+ Y) + 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 - \\
\partial_\mu\bar{Y}X^+) + igc_w Z^0_\mu(\partial_\mu\bar{X}^+ X^+ - \partial_\mu\bar{X}^- X^-) + igs_w A_\mu(\partial_\mu\bar{X}^+ X^+ - \\
\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}igM[\bar{X}^+ X^0\phi^+ - \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]
\end{gathered}
$$

Quantummechanisch botsen

LHCb in getallen

120,000 B events per sec

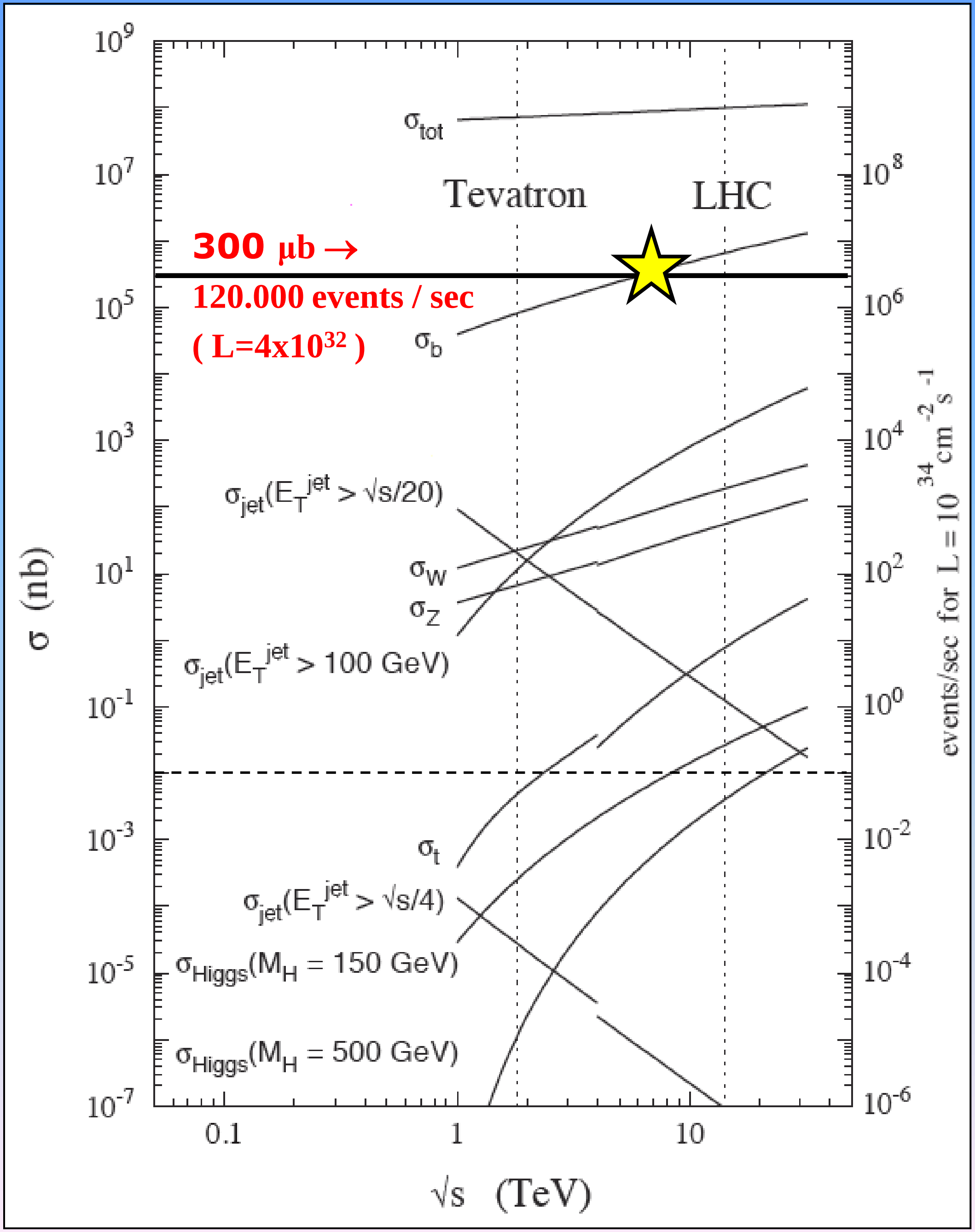
(ter vergelijk: in ATLAS : 1 Higgs in 100 sec)

10^{11} B events in 2011

(ter vergelijk: Babar heeft in totaal 10^9 B events)

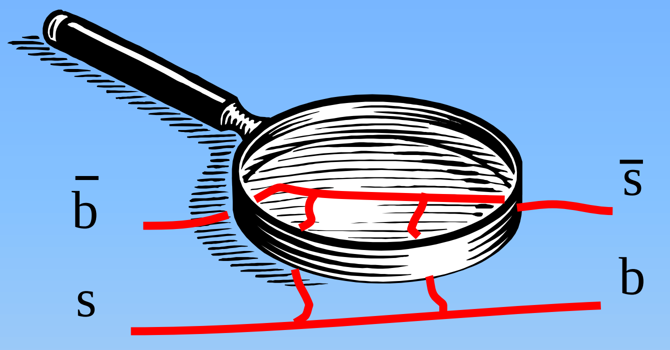
3 kHz naar tape

(ter vergelijk: ATLAS schrijft 200 Hz weg)

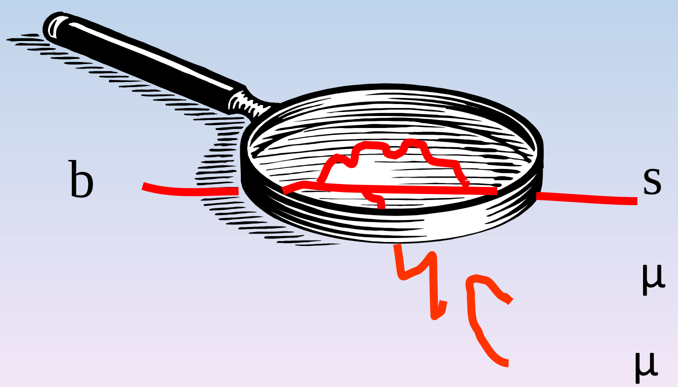


LHCb: bestuderen van *B* deeltje

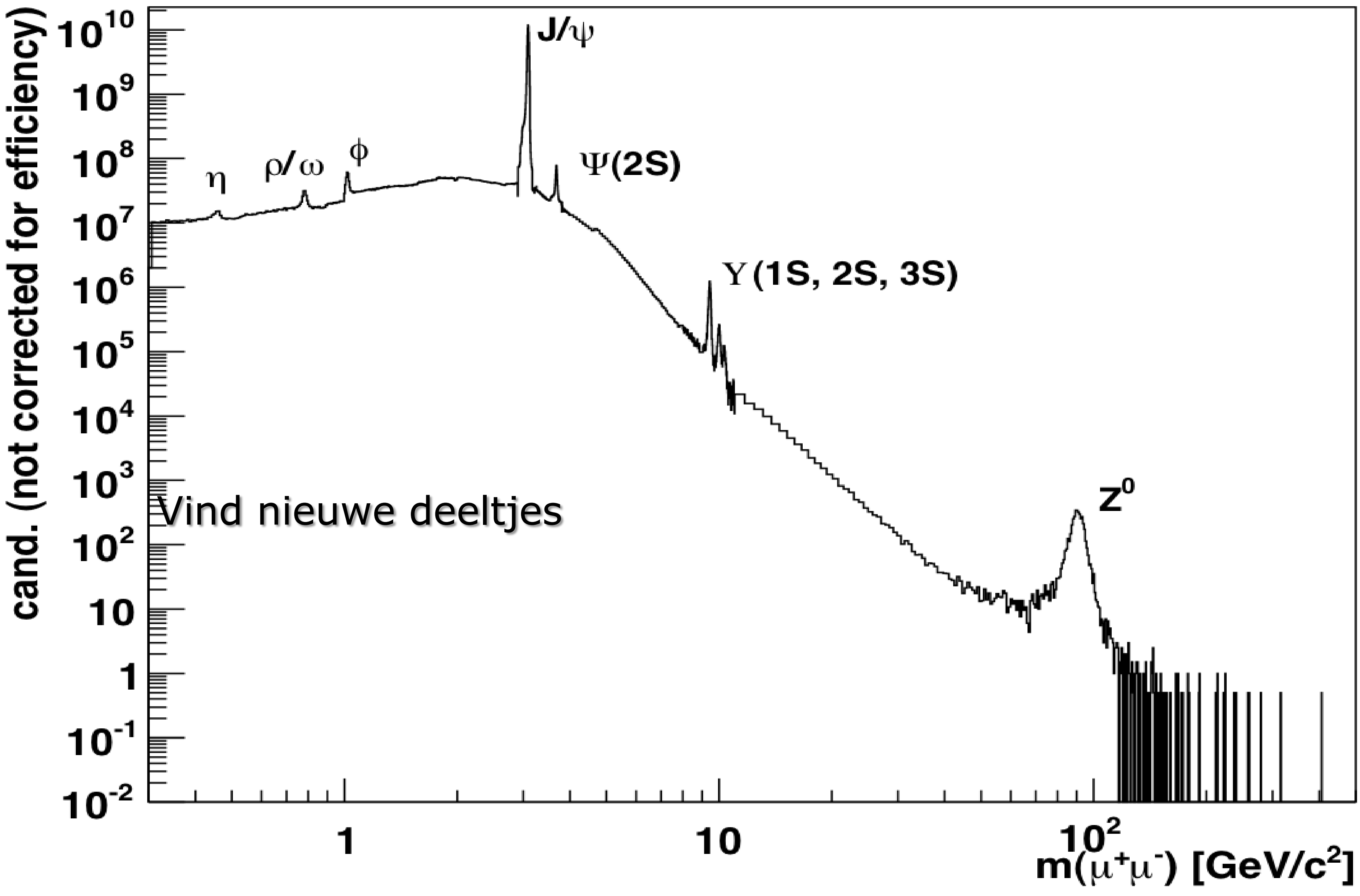
1) Vind verschillen tussen materie en anti-materie



2) Vind nieuwe deeltjes

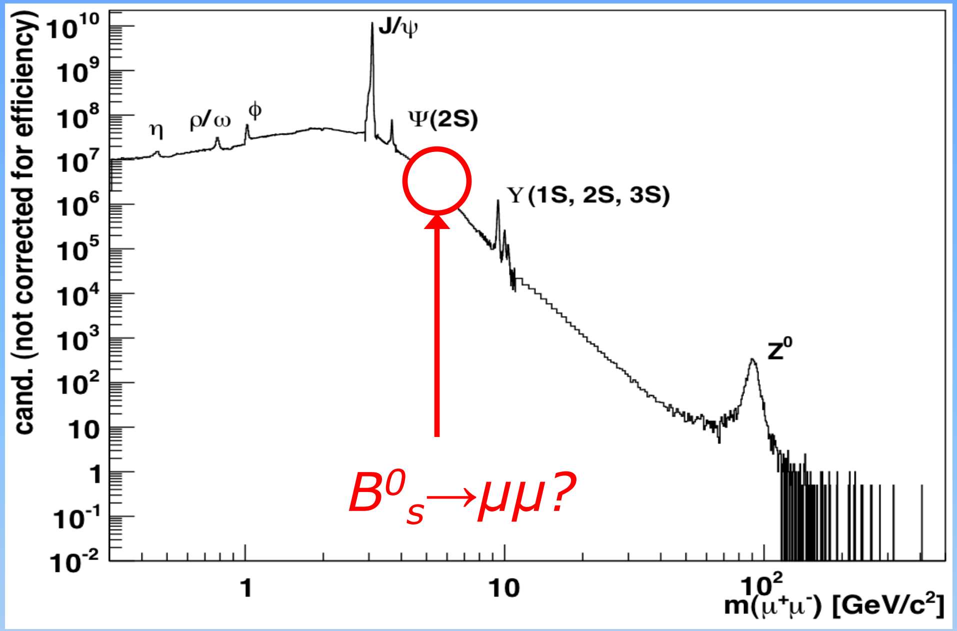


LHCb: bestuderen van *B* deeltje



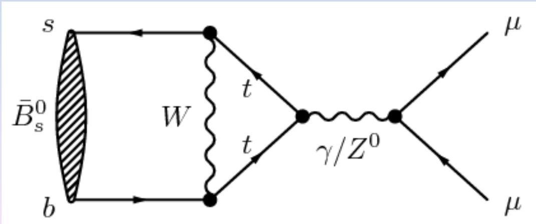
Vind nieuwe deeltjes

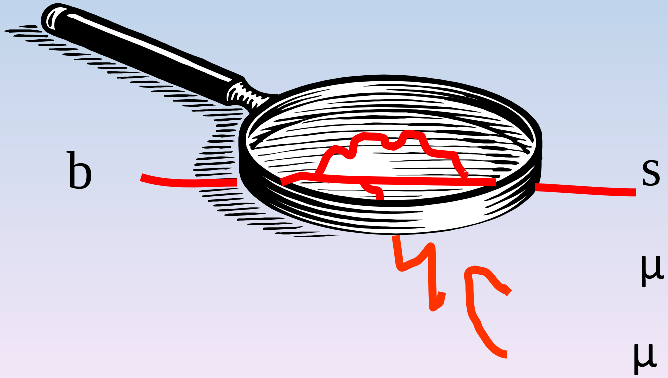
LHCb: bestuderen van *B* deeltje



2) Vind nieuwe deeltjes

$B^0_s \to \mu\mu$

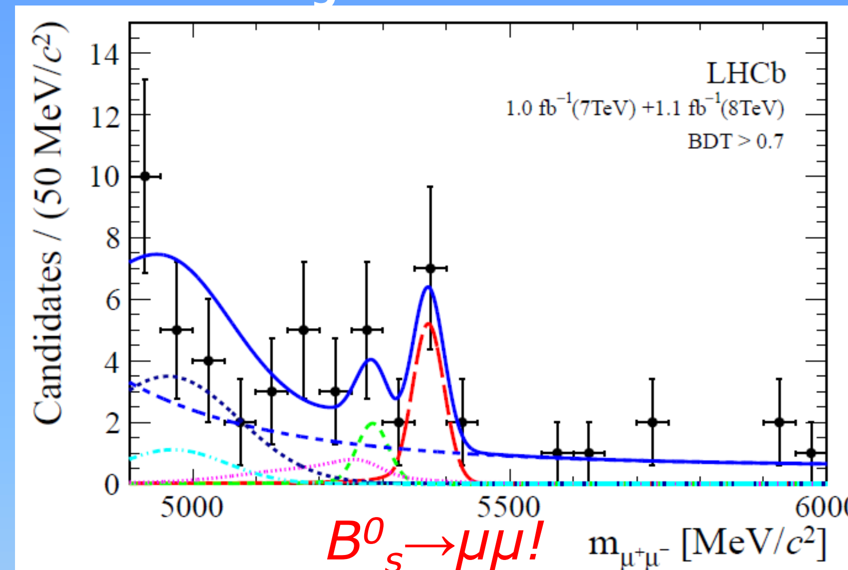




LHCb: bestuderen van *B* deeltje

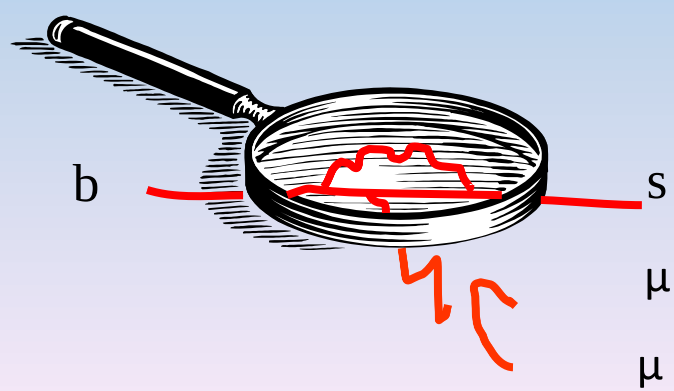
CERN-PH-EP-2012-335
08 November 2012

First evidence for the decay $B^0_s \to \mu^+\mu^-$

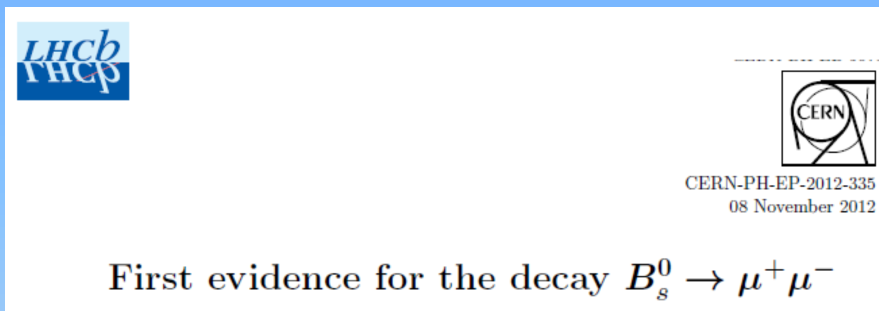


Slechts 3 op de miljard *B* deeltjes vervalt naar 2 muonen

Bestaan er nieuwe deeltjes?

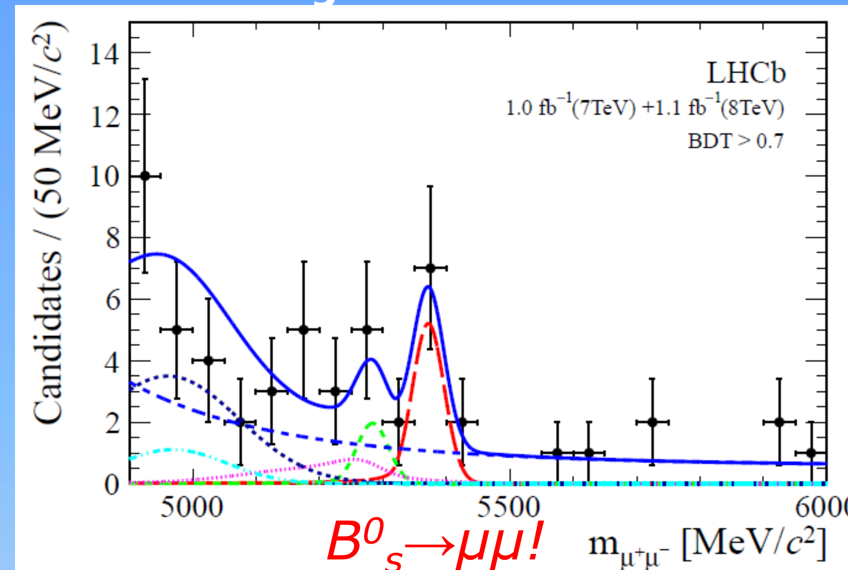


LHCb: bestuderen van *B* deeltje



CERN-PH-EP-2012-335
08 November 2012

First evidence for the decay $B_s^0 \to \mu^+\mu^-$



Gemeten:

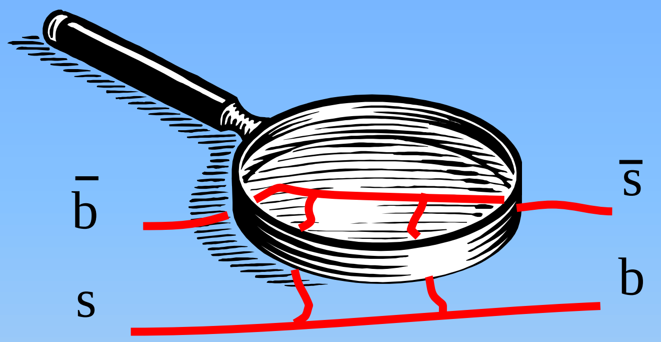
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.2\,^{+1.4}_{-1.2}(\text{stat})\,^{+0.5}_{-0.3}(\text{syst})) \times 10^{-9}$$

Voorspeld:

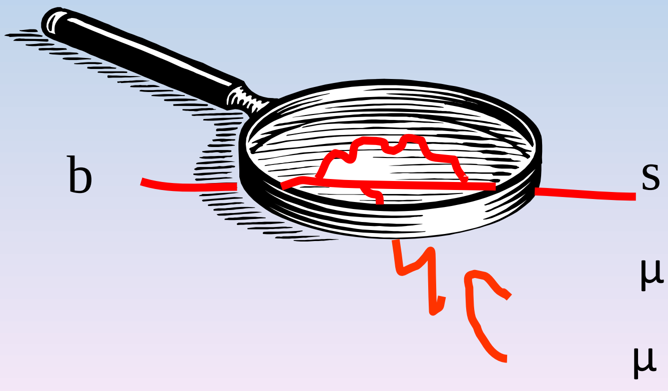
$$\text{BR}(B_s \to \mu^+\mu^-)_{\text{SM}}|_{y_s} = (3.5 \pm 0.2) \times 10^{-9}$$

LHCb: bestuderen van *B* deeltje

1) Vind verschillen tussen materie en anti-materie

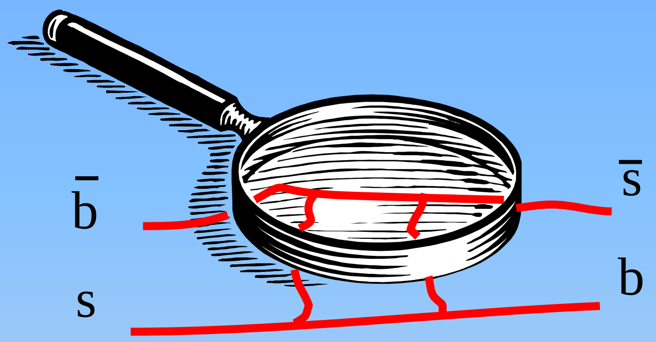


2) Vind nieuwe deeltjes



LHCb: bestuderen van *B* deeltje

Vind verschillen tussen materie en anti-materie



Highlights:

1) First evidence for the decay $B_s^0 \to \mu\mu$, arXiv:1211.2674
2) Observation of D^0-$\bar{D}^0$ Oscillations, arXiv 1211.1230
3) Measurement of the CP-violationg phase φ_s in $B_s^0 \to J/\psi\varphi$, arXiv:1112.3183, PRL 108 (2012)
4) Differential branching fractions and angular analysis of the decay $B^0 \to K^{*0}\mu\mu$, arXiv:1112.3515, PRL 108 (2012)
5) First Evidence of direct CP violation in charmless two-body decays of B_s^0 mesons, arXiv:1202.6251, PRL 108 (2012)

LHCb: bestuderen van *B* deeltje

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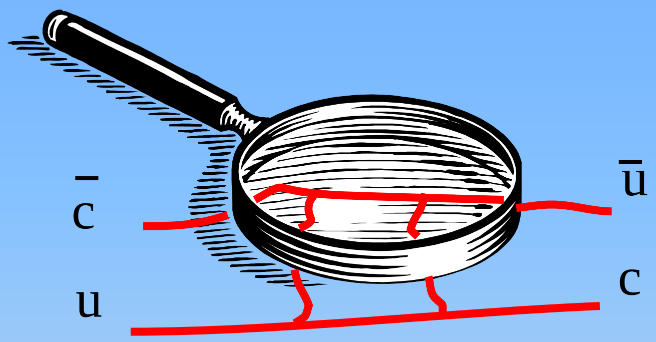

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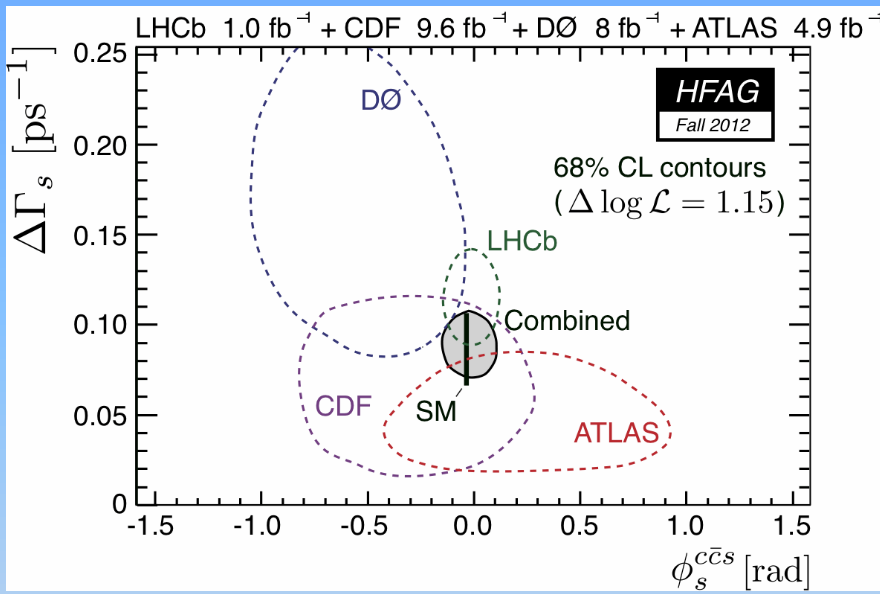

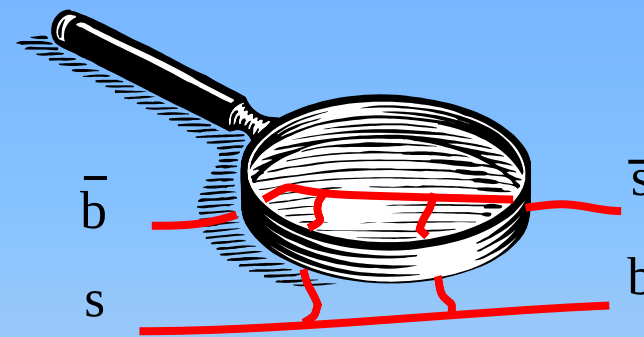

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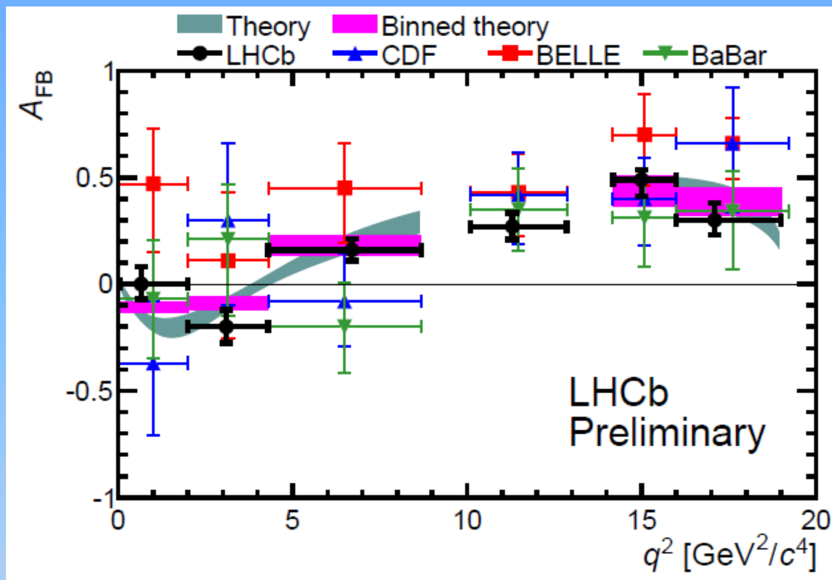

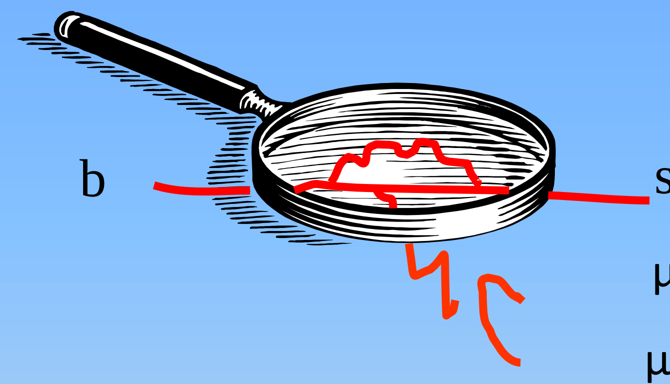

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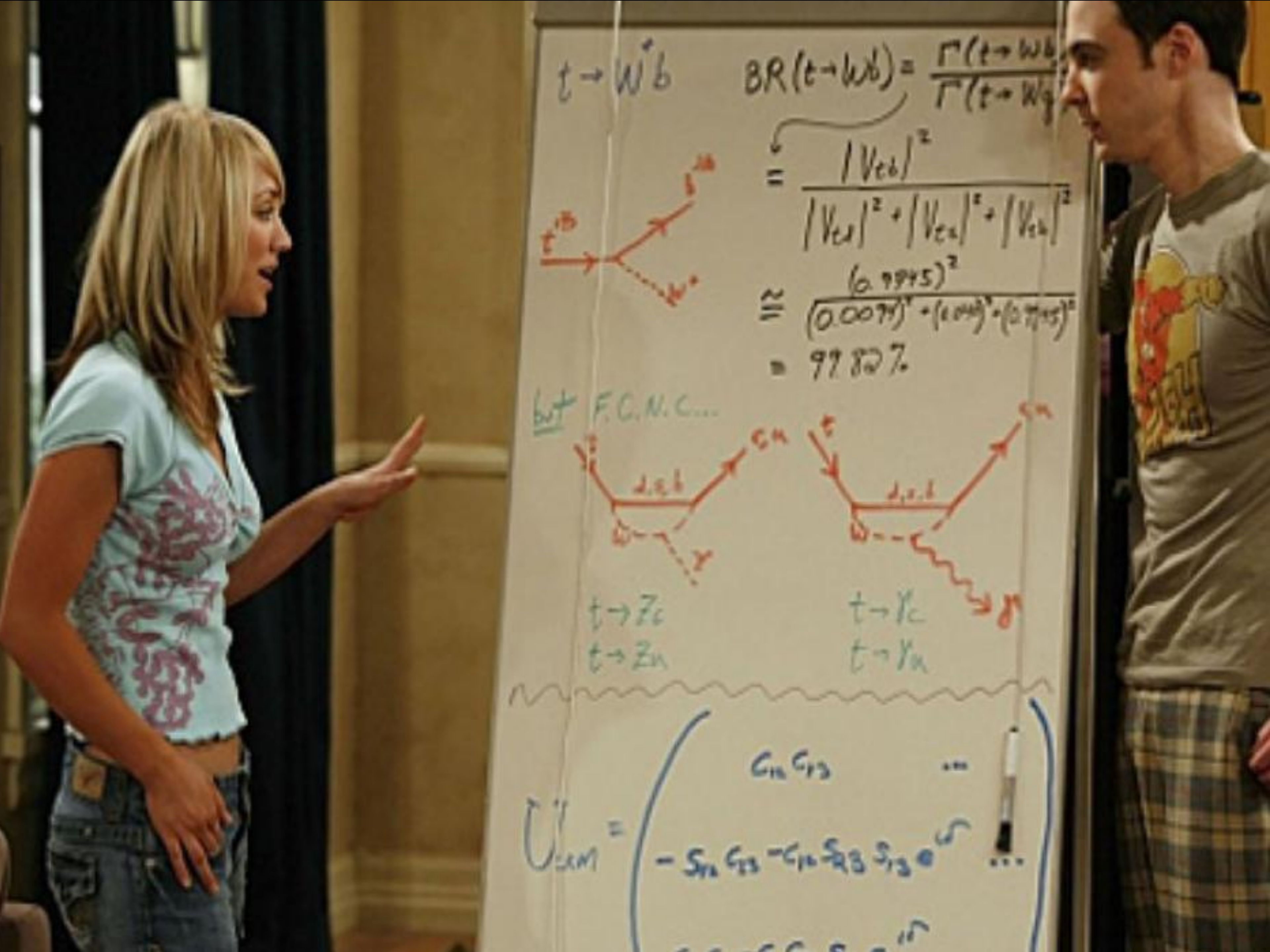
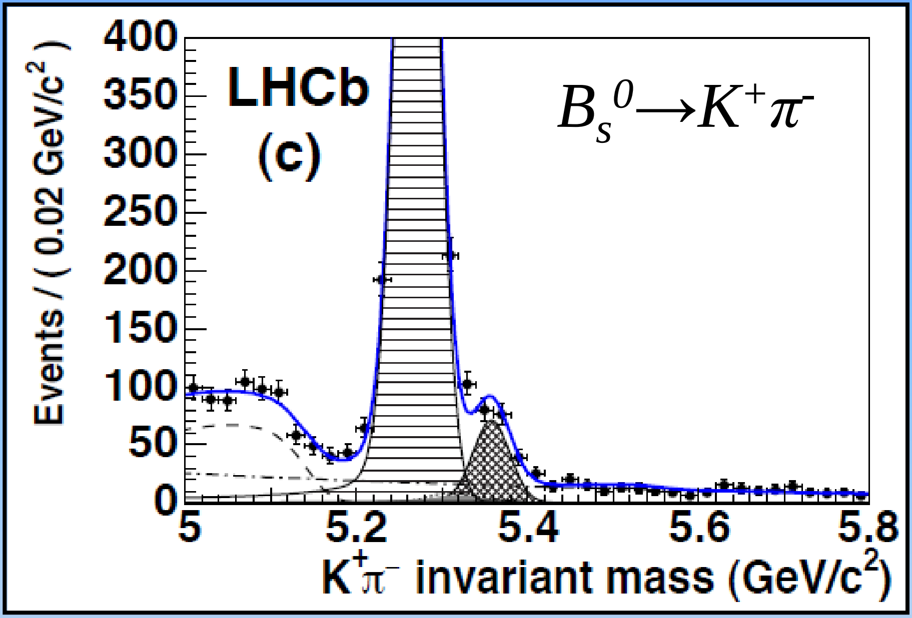
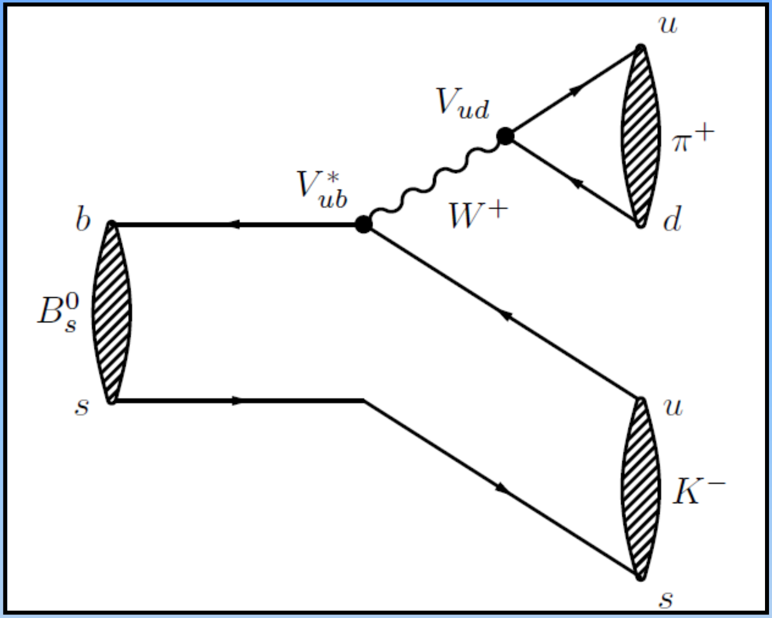


t → W+b
BR(t→Wb) =
= 99.82%
but F.C.N.C...
t → Zc
t → Zu
t → γc
t → γu

LHCb: bestuderen van *B* deeltje

Vind verschillen tussen materie en anti-materie





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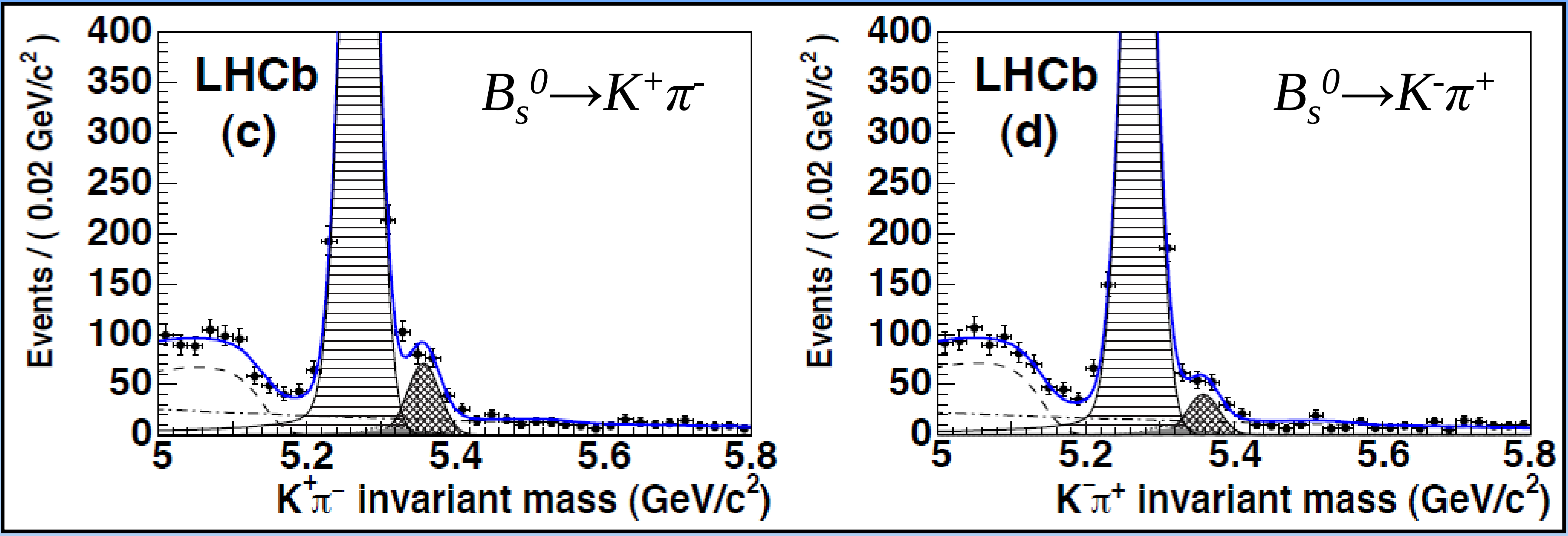
2) Observation of D^0-$\bar{D}^0$ Oscillations, arXiv 1211.1230
3) Measurement of the CP-violationg phase φ_s in $B_s^0 \to J/\psi\varphi$, arXiv:1112.3183, PRL 108 (2012)
4) Differential branching fractions and angular analysis of the decay $B^0 \to K^{*0}\mu\mu$, arXiv:1112.3515, PRL 108 (2012)
5) **First Evidence of direct CP violation in charmless two-body decays of B_s^0 mesons,** arXiv:1202.6251, **PRL 108 (2012)**

LHCb: bestuderen van *B* deeltje

Vind verschillen tussen materie en anti-materie



Highlights:

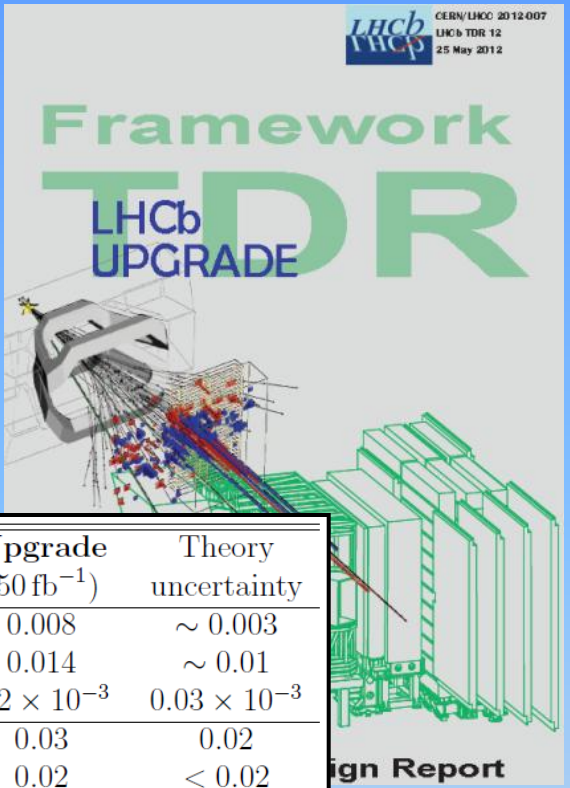
(ds) **1964**: CP schending met K^0		(Nobelprijs 1980)
(bd) **2000**: CP schending met B^0		(Nobelprijs 1998)
(bs) **2012**: CP schending met B^0_s		

5)First Evidence of direct CP violation in charmless two-body decays of B_s^0 mesons,

arXiv:1202.6251, **PRL 108 (2012)**

LHCb: Hoe verder?

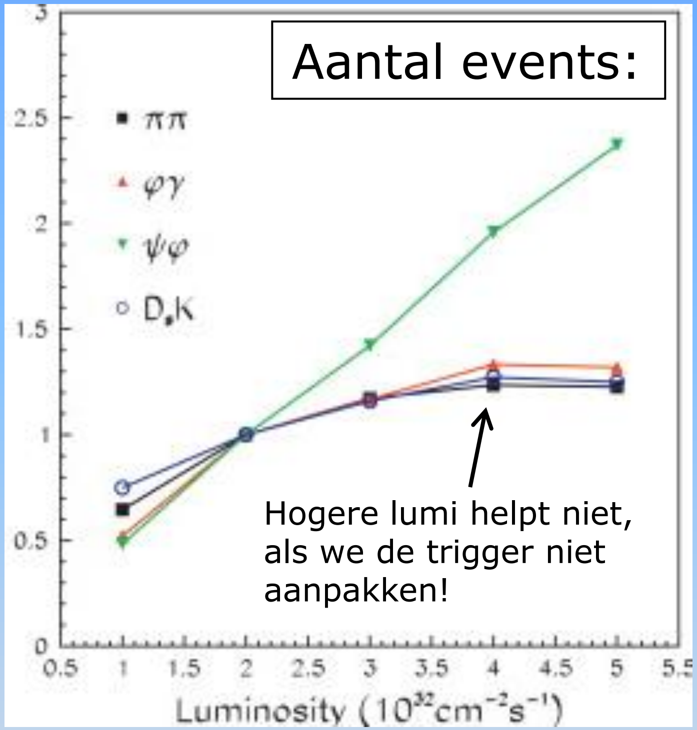
- **Preciezer! → Upgrade (2018)**



Type	Observable	Current precision	LHCb 2018	**Upgrade** ($50\,\mathrm{fb}^{-1}$)	Theory uncertainty
B_s^0 mixing	$2\beta_s\ (B_s^0 \to J/\psi\ \phi)$	0.10 [30]	0.025	0.008	~ 0.003
	$2\beta_s\ (B_s^0 \to J/\psi\ f_0(980))$	0.17 [32]	0.045	0.014	~ 0.01
	$a_{\rm sl}^s$	6.4×10^{-3} [63]	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguins	$2\beta_s^{\rm eff}(B_s^0 \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{\rm eff}(B_s^0 \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{\rm eff}(B^0 \to \phi K_S^0)$	0.17 [63]	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{\rm eff}(B_s^0 \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{\rm eff}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
Electroweak penguins	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,\mathrm{GeV}^2/c^4)$	0.08 [64]	0.025	0.008	0.02
	$s_0\ A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$	25 % [64]	6 %	2 %	7 %
	$A_{\rm I}(K\mu^+\mu^-; 1 < q^2 < 6\,\mathrm{GeV}^2/c^4)$	0.25 [9]	0.08	0.025	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 % [29]	8 %	2.5 %	~ 10 %
Higgs penguins	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	1.5×10^{-9} [4]	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	–	~ 100 %	~ 35 %	~ 5 %
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	~ 10–$12°$ [40, 41]	4°	0.9°	negligible
	$\gamma\ (B_s^0 \to D_s K)$	–	11°	2.0°	negligible
	$\beta\ (B^0 \to J/\psi\ K_S^0)$	0.8° [63]	0.6°	0.2°	negligible
Charm *CP* violation	A_Γ	2.3×10^{-3} [63]	0.40×10^{-3}	0.07×10^{-3}	–
	ΔA_{CP}	2.1×10^{-3} [8]	0.65×10^{-3}	0.12×10^{-3}	–

LHCb: Upgrade - Trigger

- Precisie meting → Meer luminositeit
- Meer luminositeit → ~~Hogere trigger rate~~
- Meer luminositeit → Hogere threshold
- Hogere threshold → ~~Minder events …~~



<u>Oplossing:</u>

Slimmere trigger → *alle* events naar CPU farm:

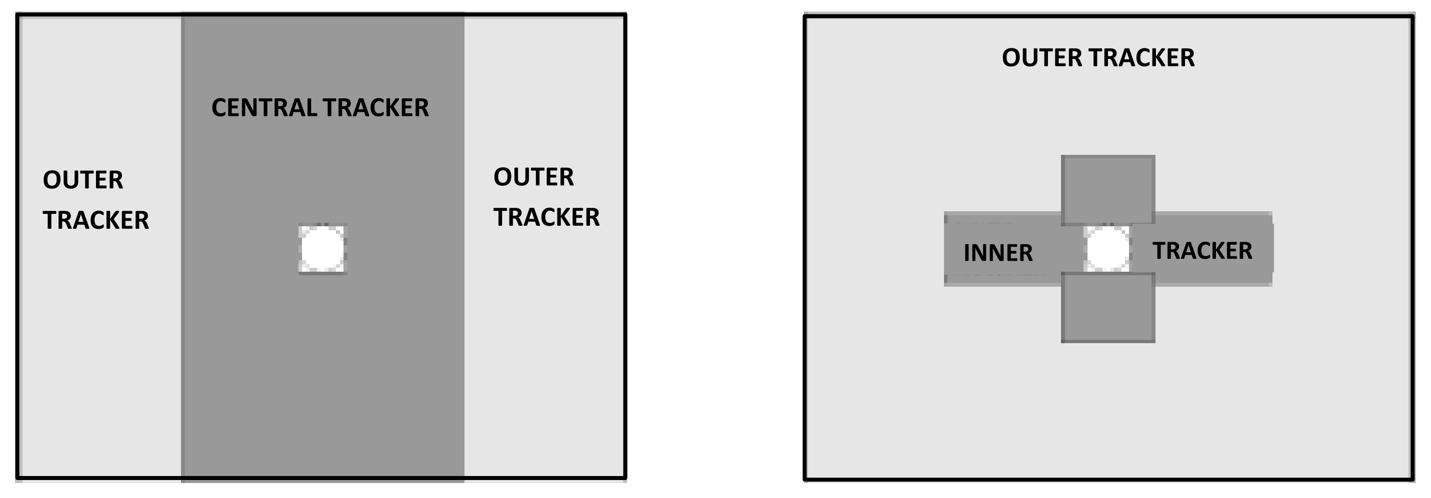
➢ Readout @40 MHz, niet 1 MHz …

LHCb: Upgrade - Detectors

- Precisie meting → Meer luminositeit
- Meer luminositeit → Hogere particle rate
- Hogere particle rate → Occupancy te hoog in de Outer Tracker

➢ 2 opties:

Beslissing in 2013



1) Inner Tracker wordt Scintil. Fiber, Outer Tracker wordt *minder*

2) Inner Tracker wordt groter, Outer Tracker wordt *kleiner*

LHCb zoekt naar nieuwe deeltjes om antwoorden te zoeken op grote vragen

II. Higgs??
(wat maakt deeltjes zwaar)

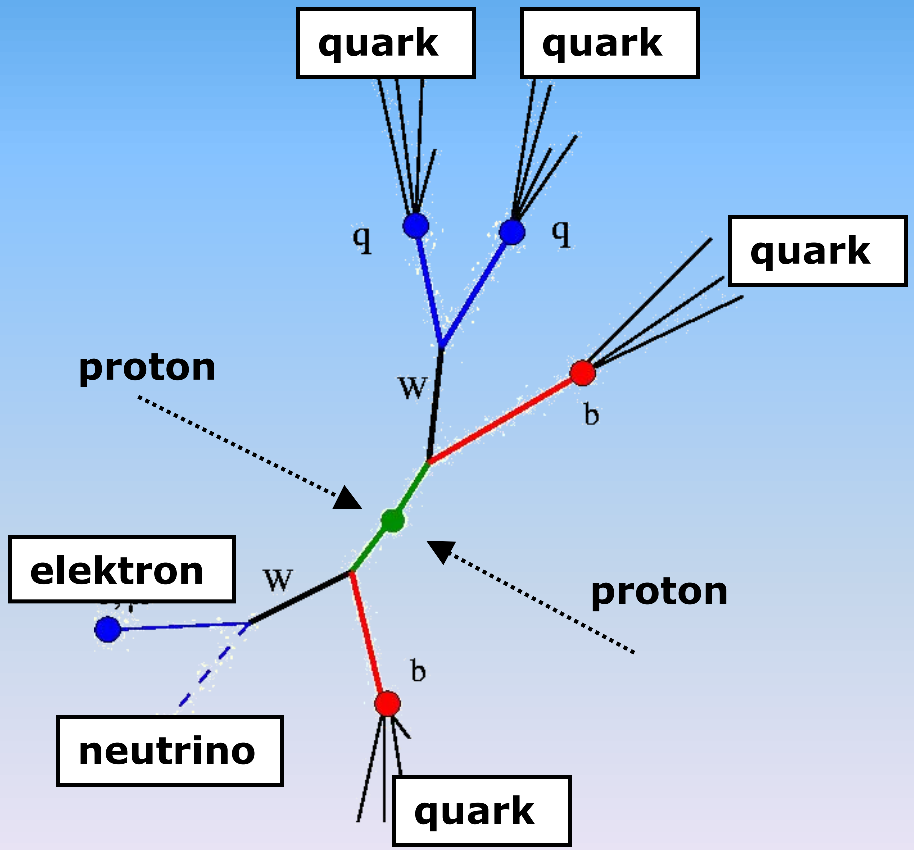
I. Anti-materie??
(waar is het gebleven)

III. Donkere materie??
(wat klonterde de sterrenstelsels)

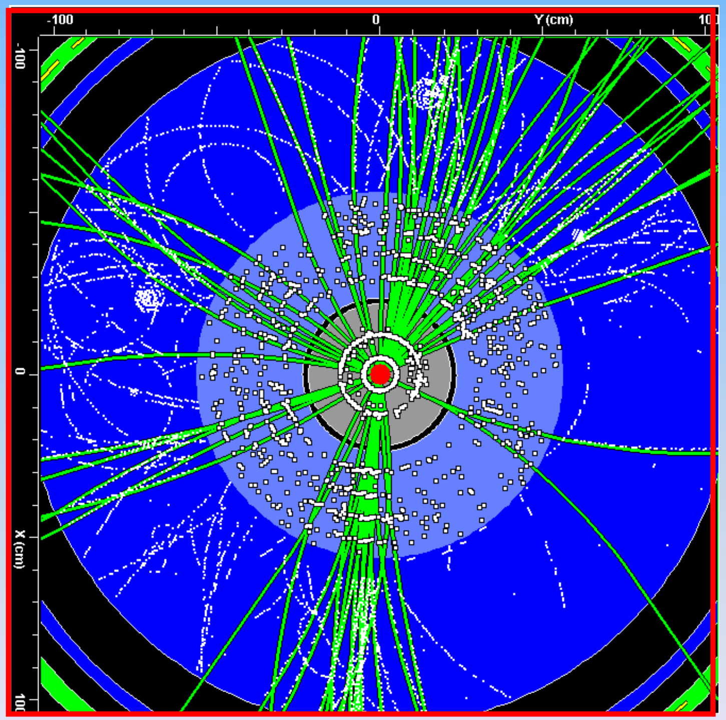
Backup

- Iets over de Higgs voor de liefhebber

Hoe zien die botsingen er nou uit ?

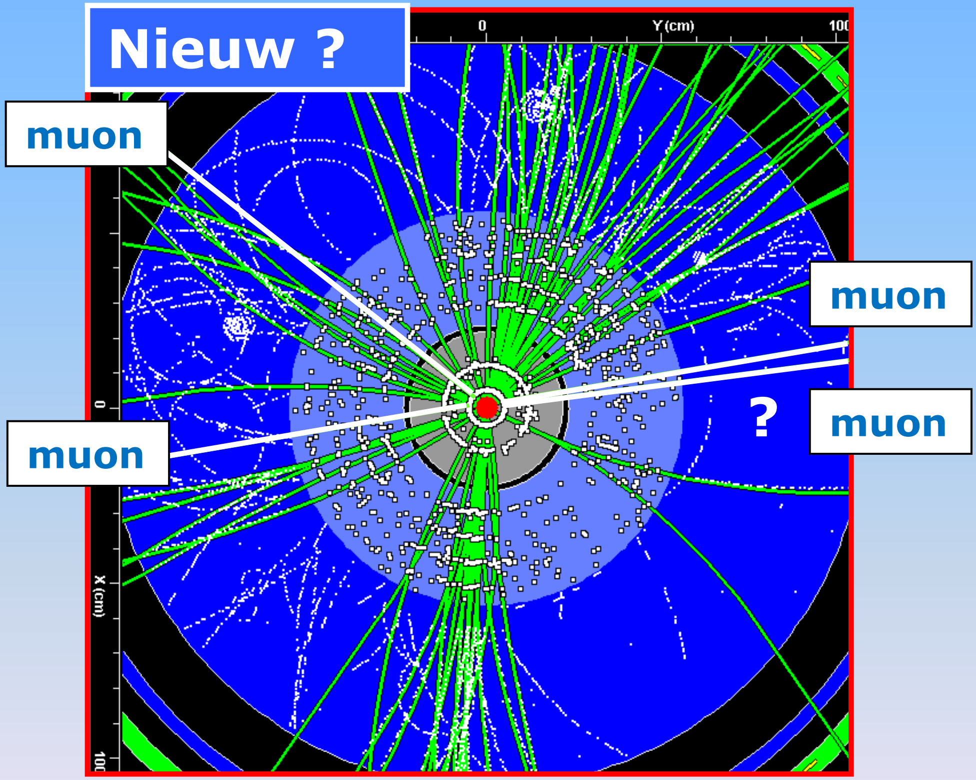


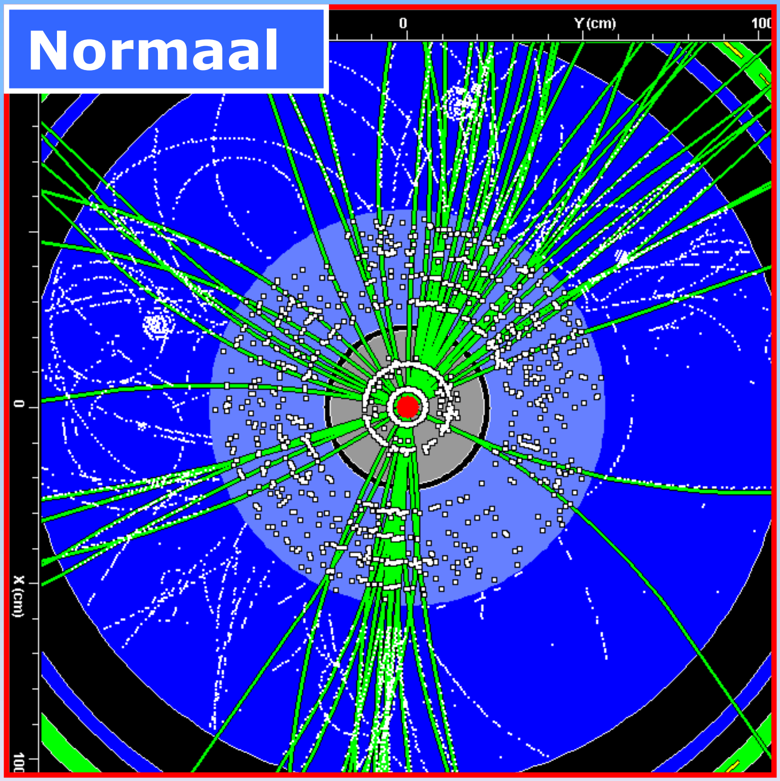
Simulatie top quark productie



Hoe ontdek je nou nieuwe dingen

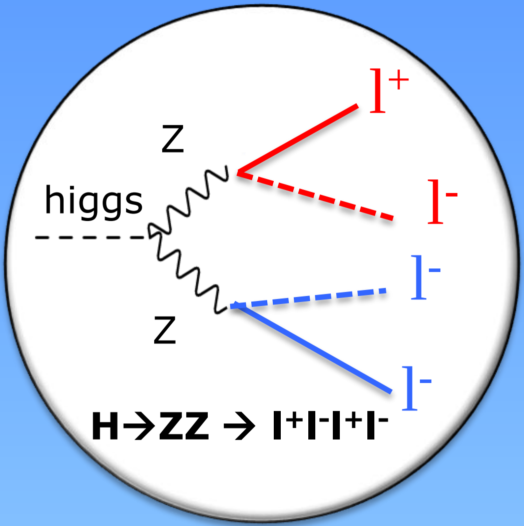
Nieuwe afstandschaal EN nieuwe detector





Higgs → ZZ → 4 leptonen

klein aantal schitterende botsingen



120.000 Higgs bosonen

⇩

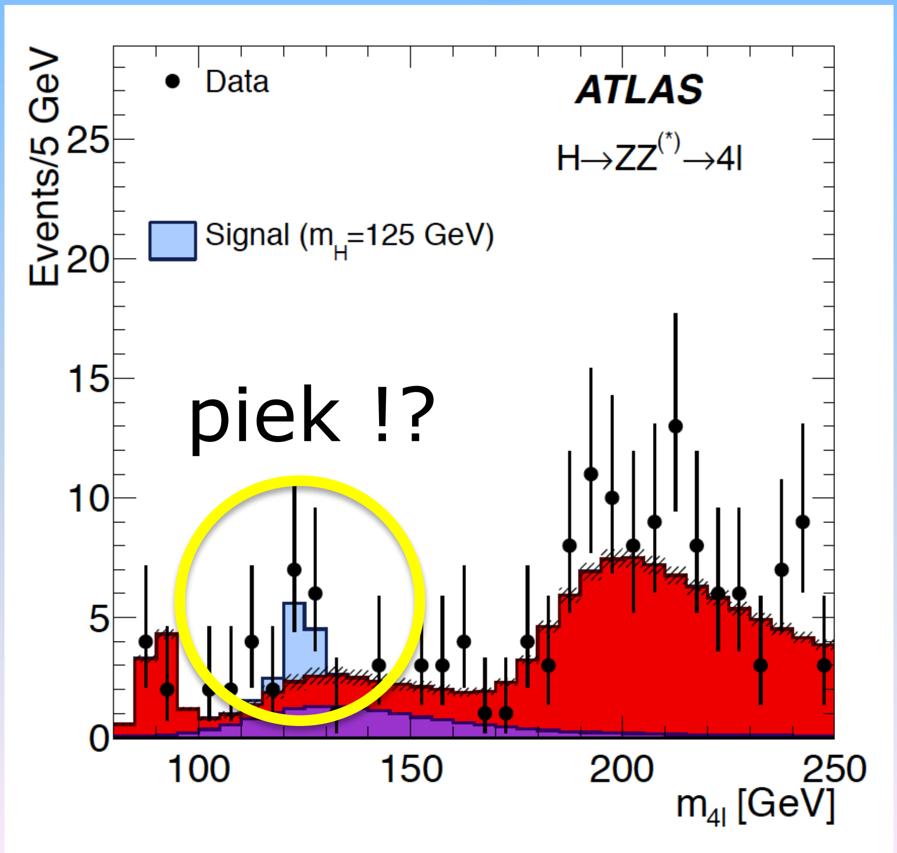
- Maar 1 op de 1000 Higgs bosonen vervalt naar 4 leptonen

- 50% kans dat ATLAS detector ze allemaal goed terugvindt

⇩

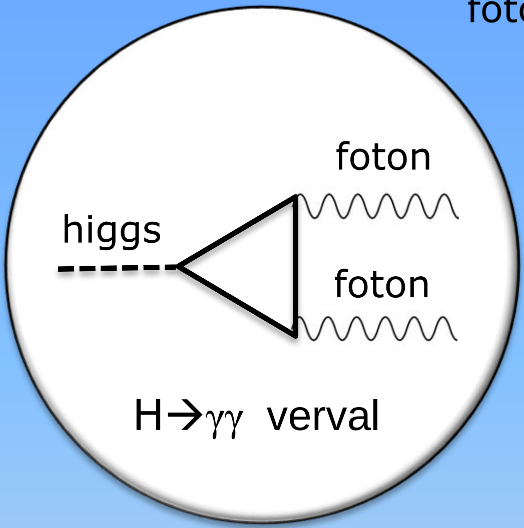
60 (Higgs → 4 lepton) events

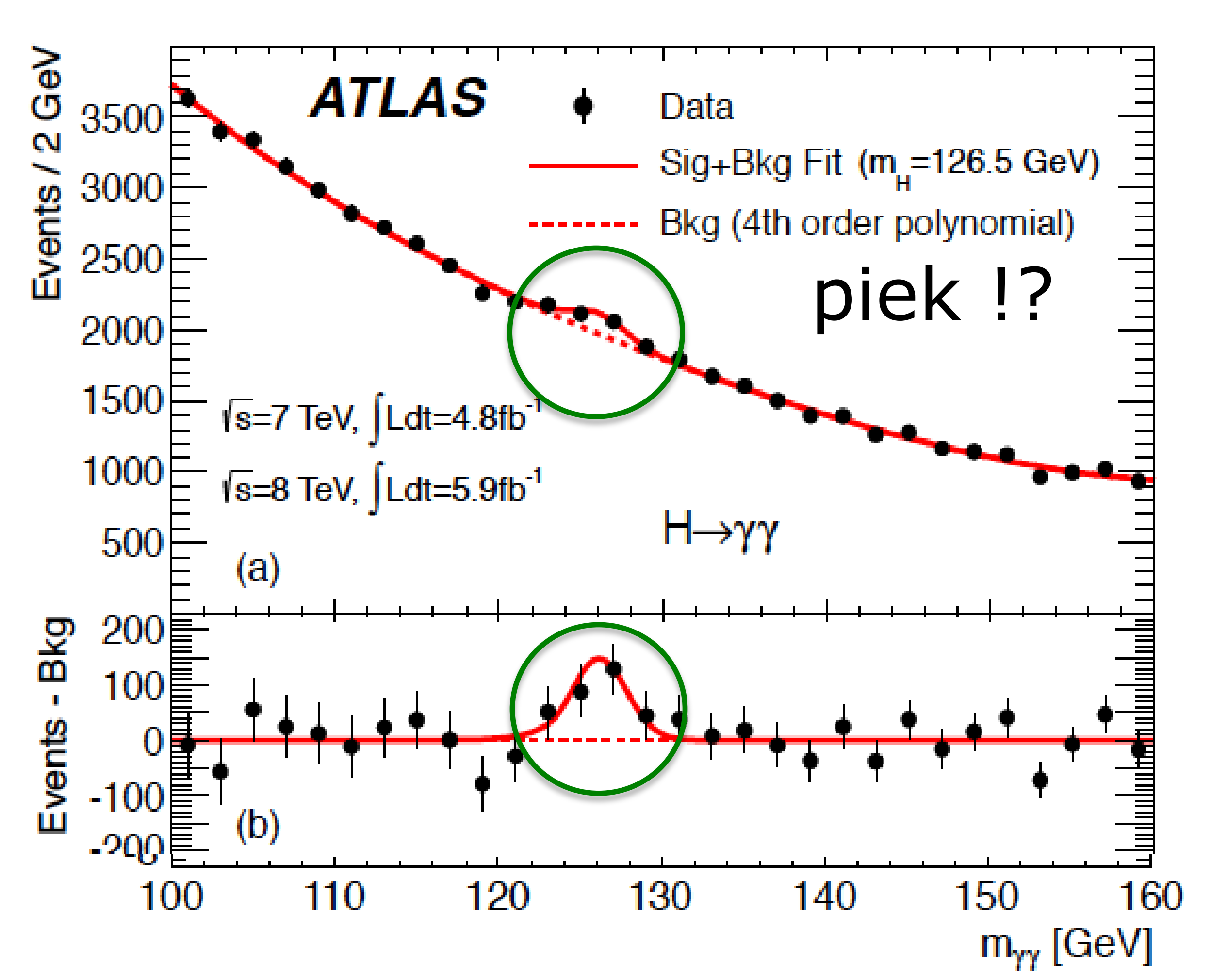
'overig'	52 events
Met Higgs	68 events



Higgs → 2 fotonen

foton

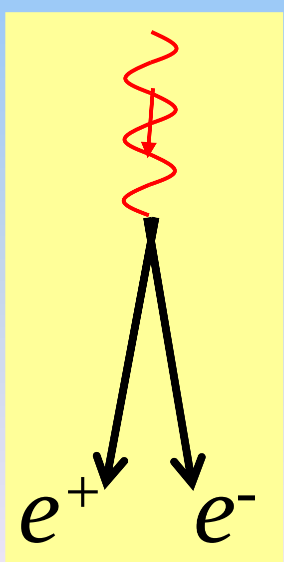




Higgs: Deeltje? Veld?

<u>Deeltje</u>

Foton (lichtdeeltje)

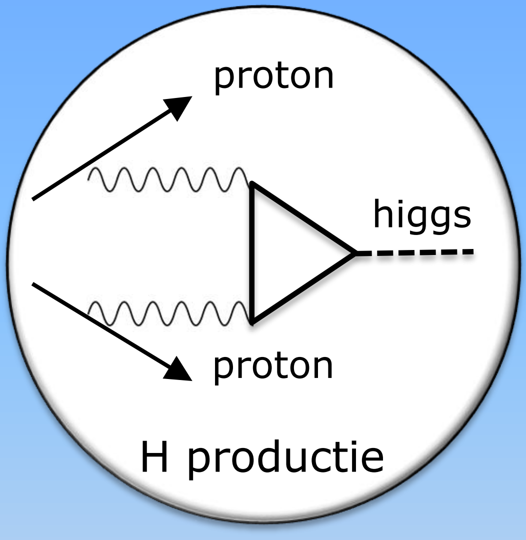


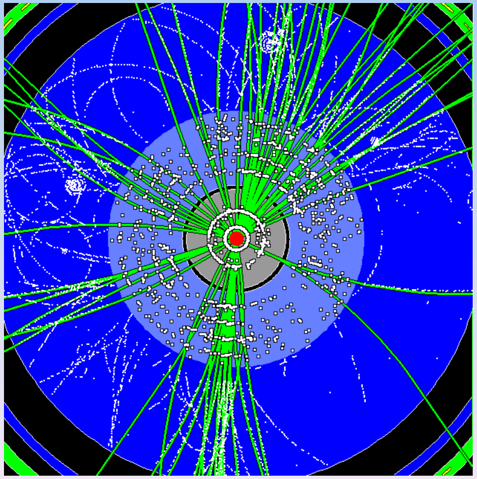
<u>Veld</u>

Elektrisch veld

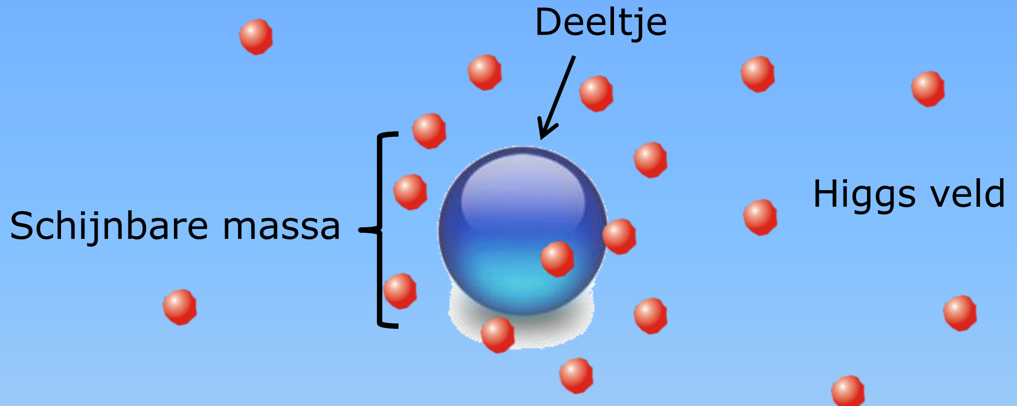
Waarom is de Higgs zo bijzonder?

Deeltje





Veld



Alsof de vis het water heeft ontdekt…