

Femto Fysica

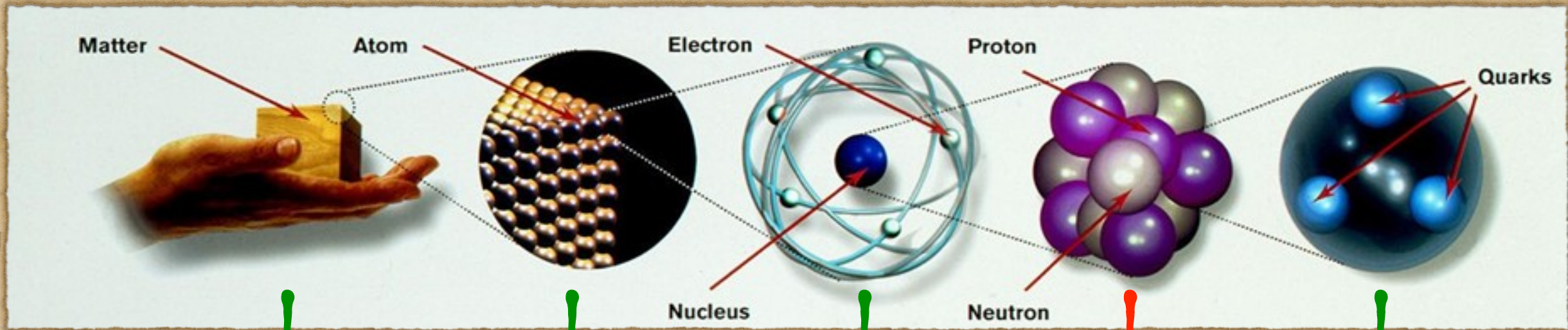
Frederik Van der Veken

BE HSSIP 2021 - Virtuele Ontdekkingsdag

frederikvanderveken@gmail.com

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Wát voor fysica... ?



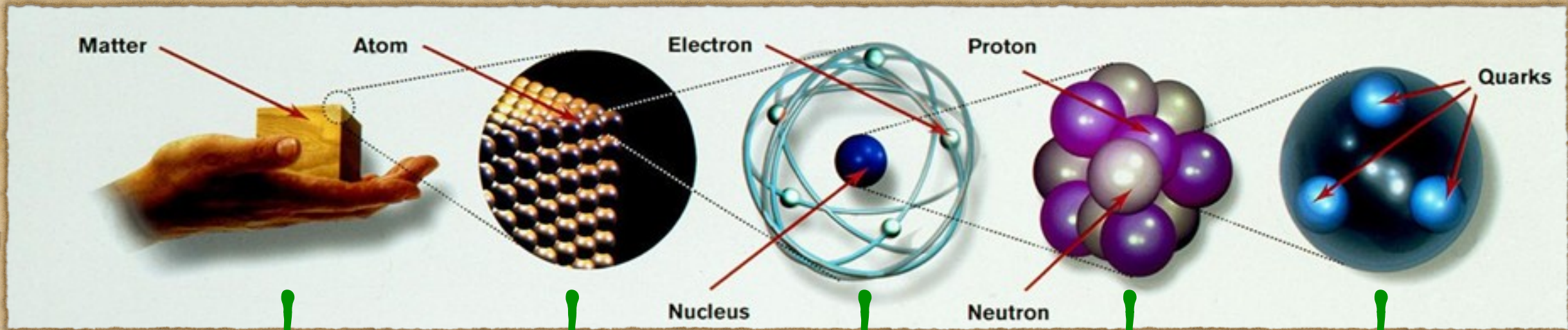
5cm
(10^{-2} m)

1Å
(10^{-10} m)

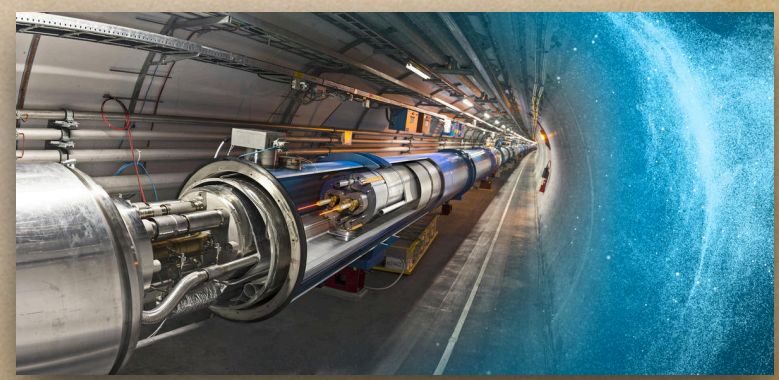
0.01pm
(10^{-14} m)

1am
(10^{-18} m)

Femto!
(10^{-15} m)



Credit: CERN



Credit: CERN

enorme machines
bereiken hoge energie
door protonen te versnellen
(met femtometer grootte)
en gebruiken deze
in de zoektocht naar mini deeltjes

2

Enorme Machines

Deeltjesversnellers

Versnelling: verhoog de energie van de deeltjes

Botsing: knal twee deeltjes op elkaar om extreme energie vrij te geven

Detectie: observeer de resulterende (nieuwe?) deeltjes

~~**Inzicht:** analyseer de resultaten, om de diepe mysteries van het leven te ontrafelen~~

→ Mensen, geen machines (maar dit is aan het veranderen...)

Deeltjesversnellers

Tekstboekvoorbeeld: de **Large Hadron Collider**



26.659 km

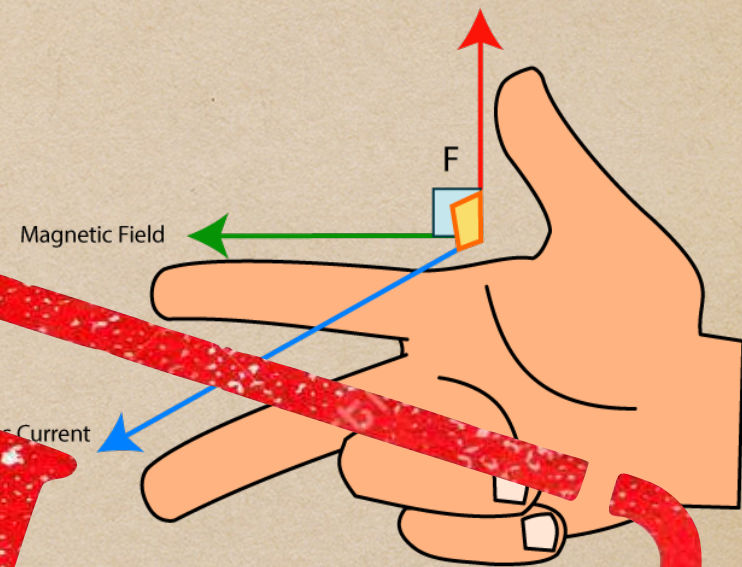
9593 magneten

1~2 **miljard** botsingen / s

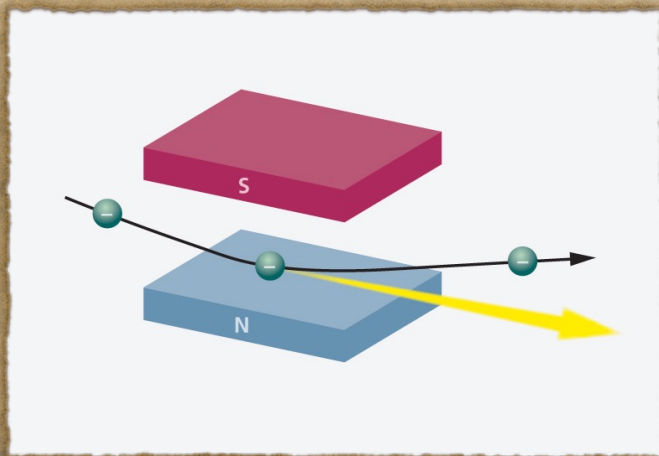
Versnellers

Magneten?

FAAII



Lorentz kracht loodrecht op bewegingsrichting



Effect van magneet is in 'foute' richting

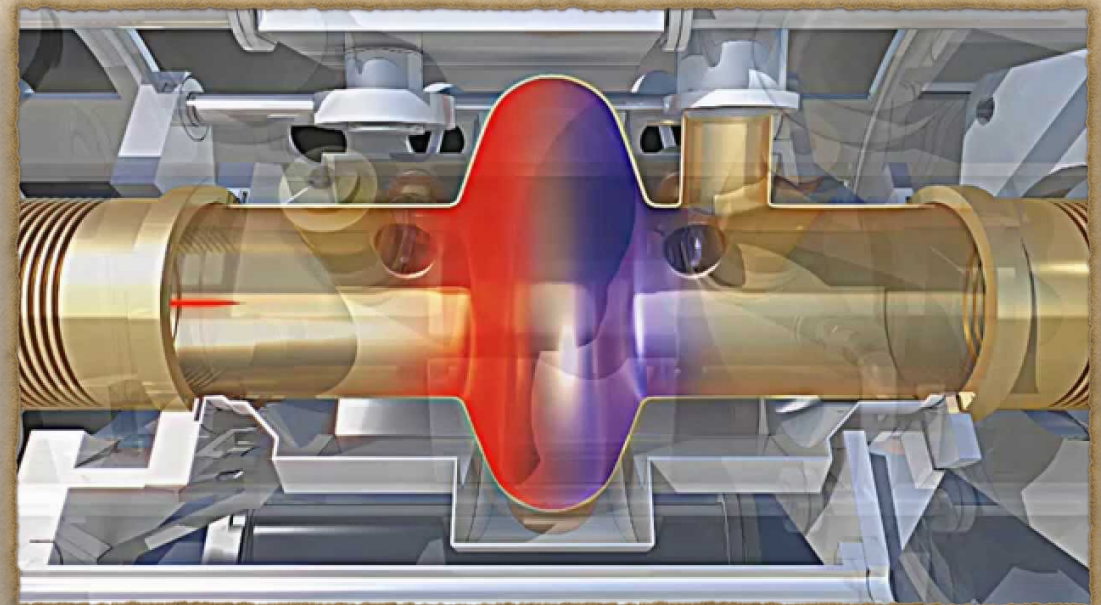
Vergelijk met schommel
langs zijkant te duwen



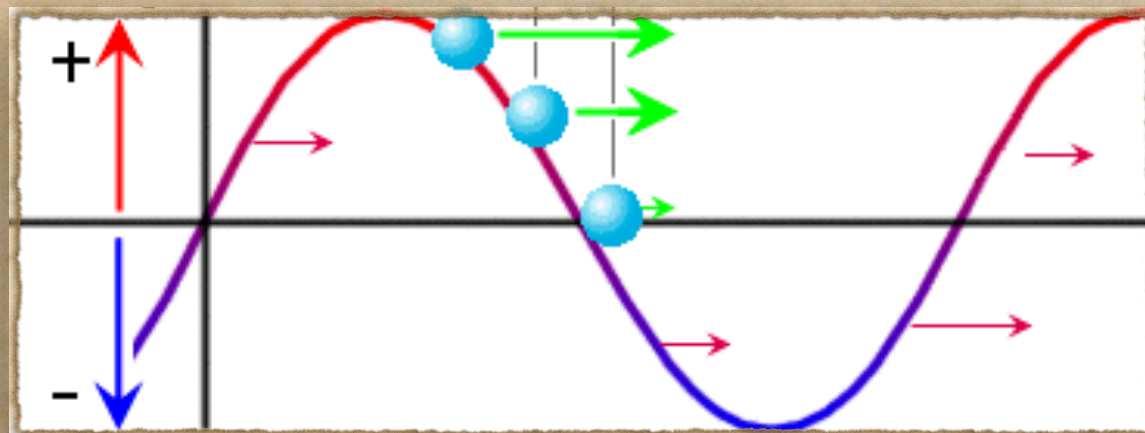
Versnellers

Elektrisch veld: **caviteiten**

Kracht is **longitudinaal**



Credit: CERN



Credit: JLAB

Veld moet op het juiste moment positief zijn.

Goede timing is cruciaal

Maar..

Maar..

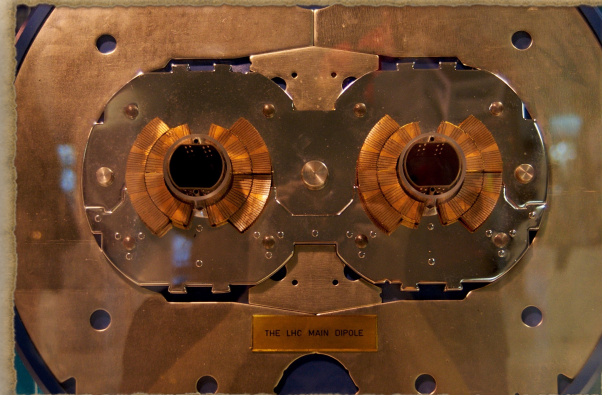
De LHC heeft 9600 magneten!

Waarom dan..?

Magneten

dipool:

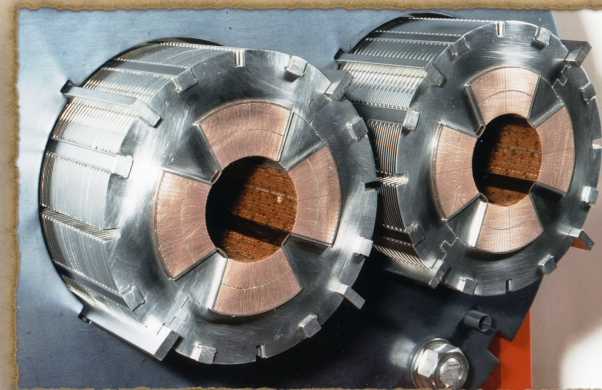
afbuiging



Credit: CERN

quadrupool:

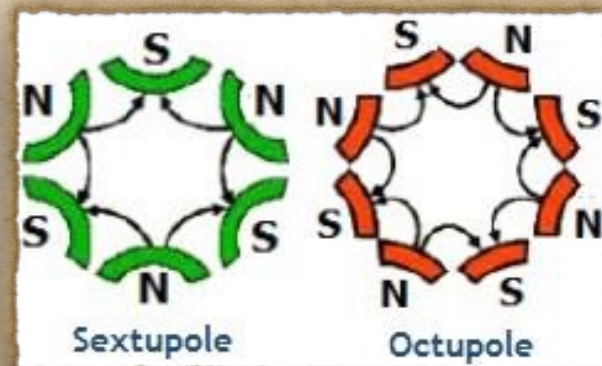
focusering



Credit: CERN

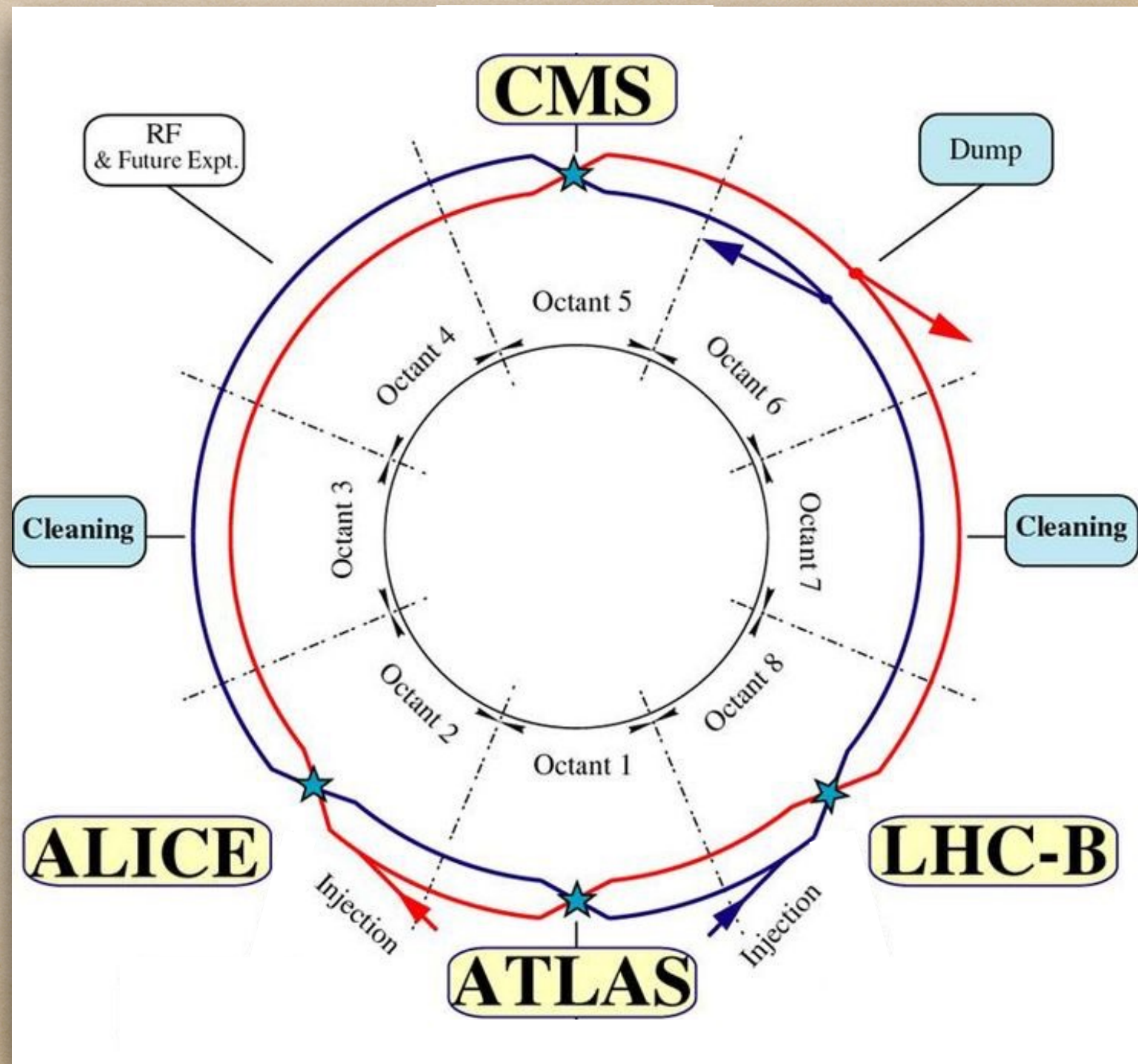
hogere ordes:

vanalles anders

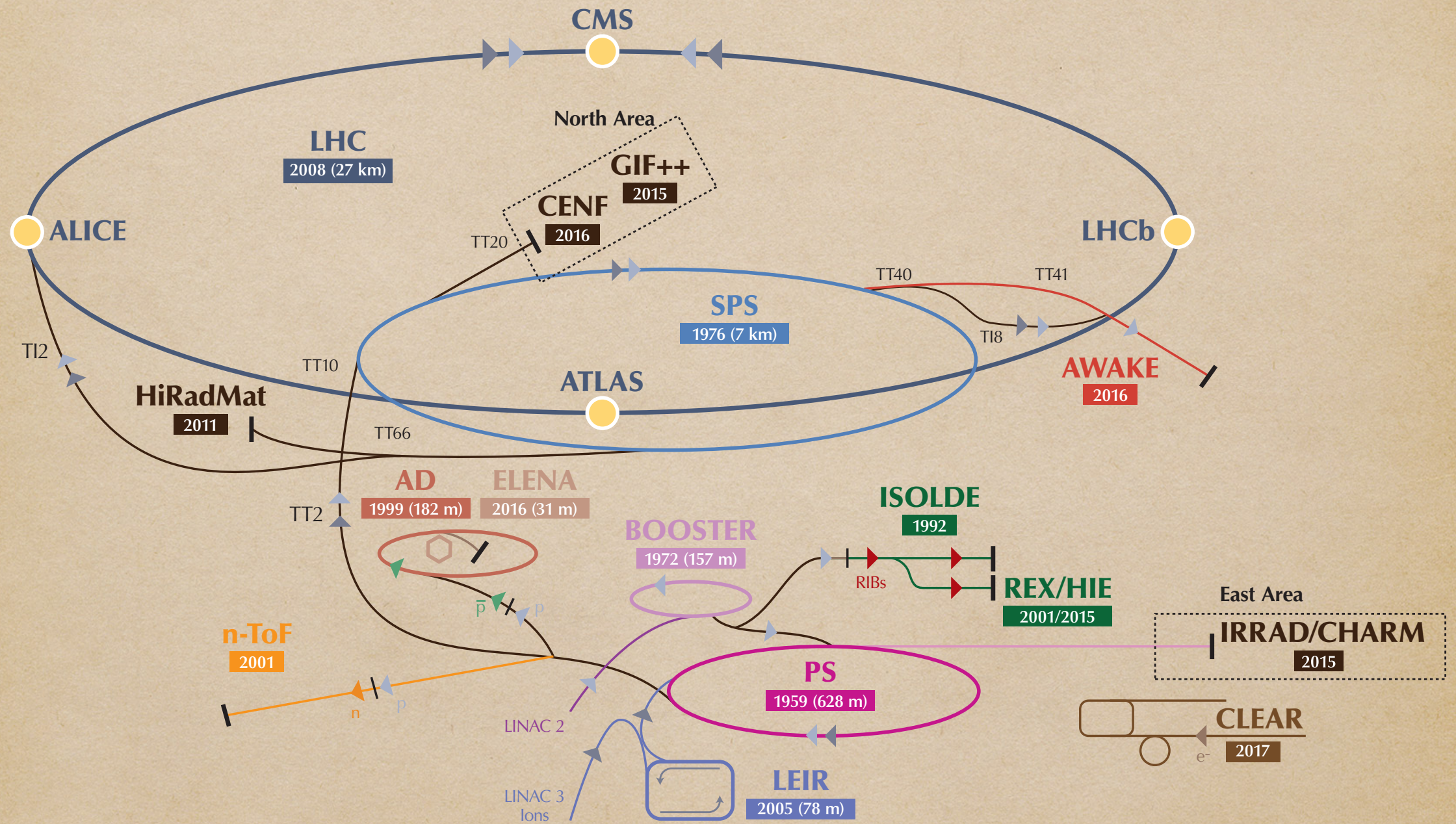


De Large Hadron Collider

Detectoren
Versnelling
Beam dump
Beam cleaning



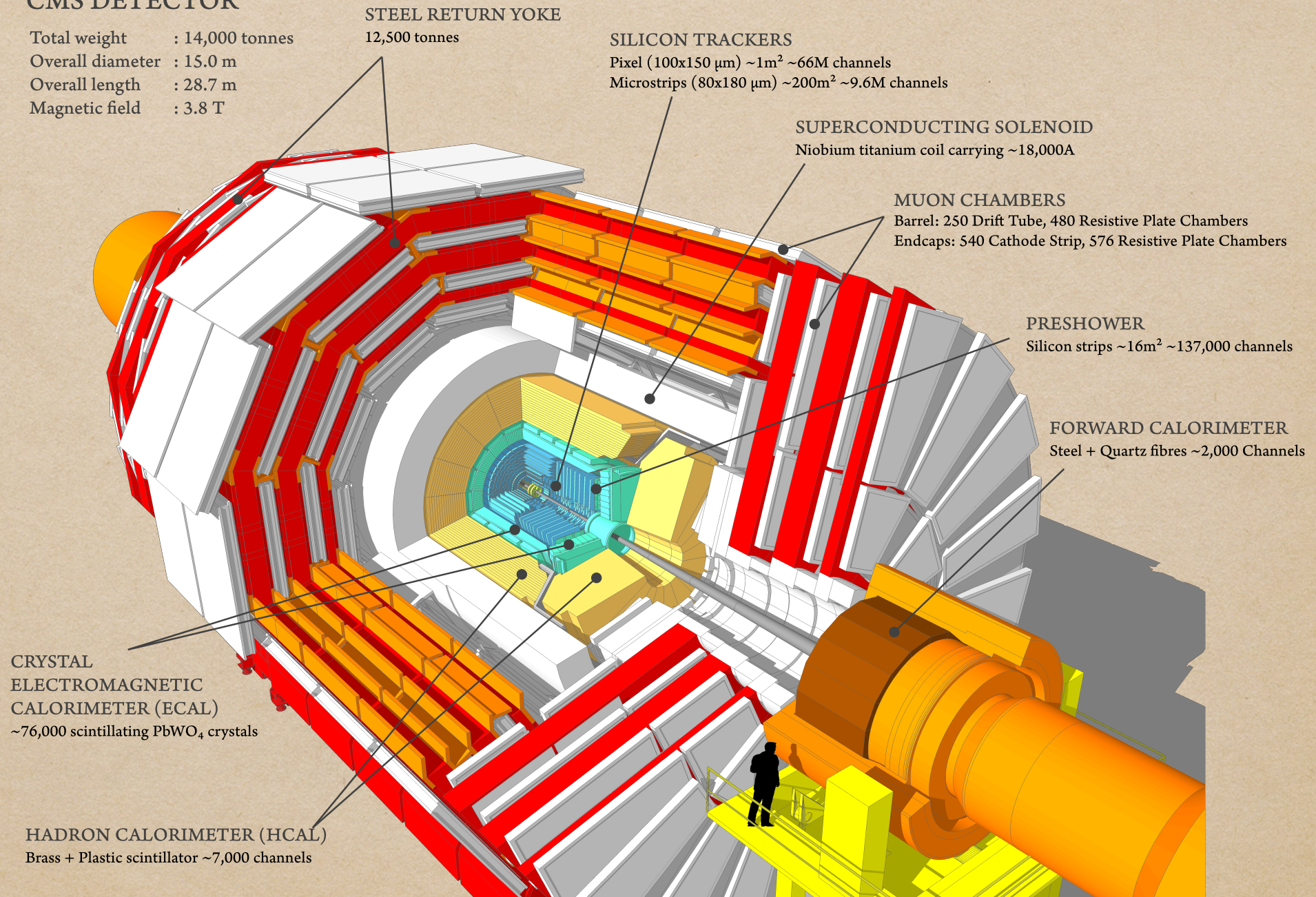
Het Versnellercomplex



Detectoren

CMS DETECTOR

Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T



STEEL RETURN YOKE
12,500 tonnes

SILICON TRACKERS
Pixel (100x150 μm) $\sim 1\text{m}^2 \sim 66\text{M}$ channels
Microstrips (80x180 μm) $\sim 200\text{m}^2 \sim 9.6\text{M}$ channels

SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying $\sim 18,000\text{A}$

MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 540 Cathode Strip, 576 Resistive Plate Chambers

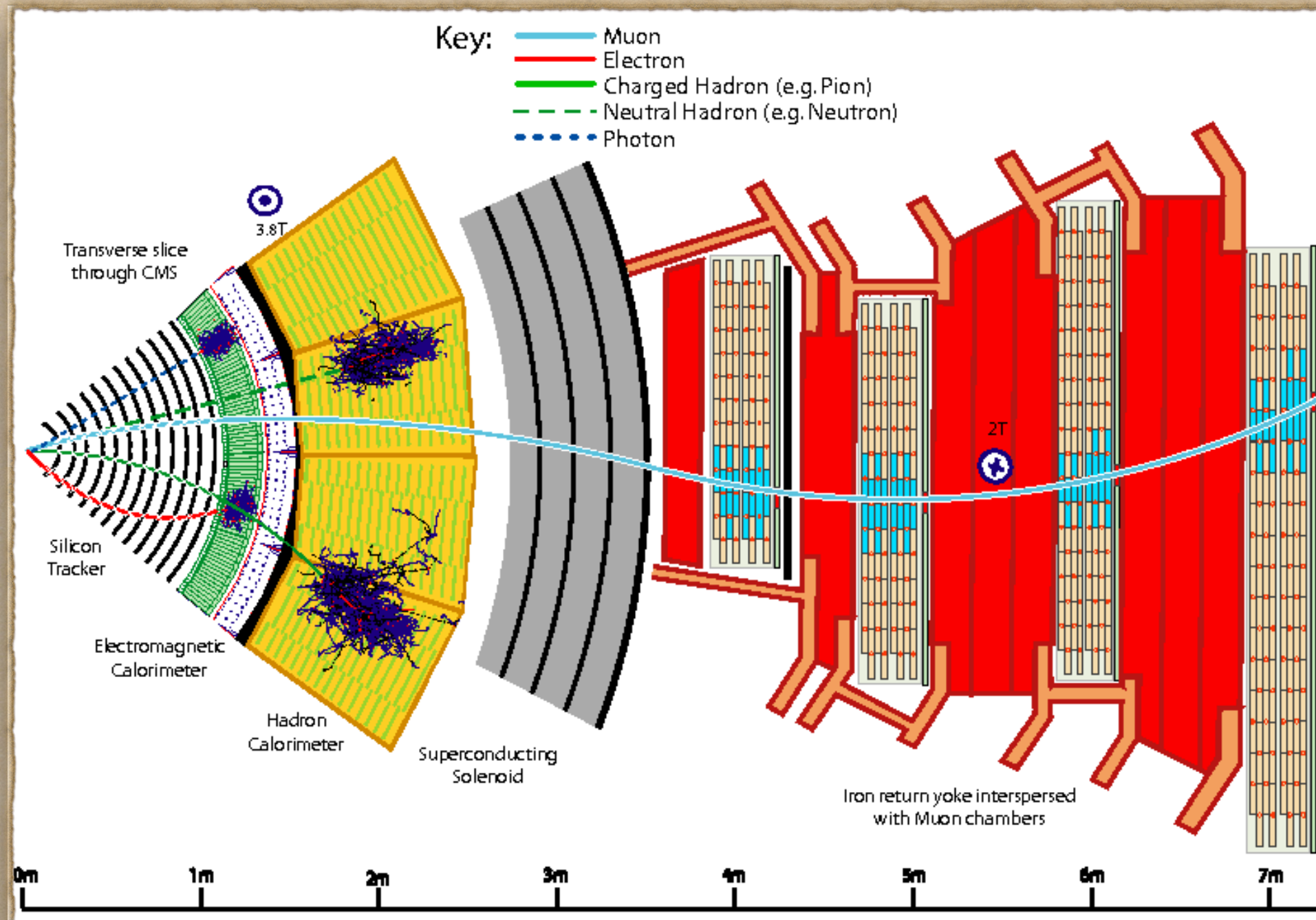
PRESHOWER
Silicon strips $\sim 16\text{m}^2 \sim 137,000$ channels

FORWARD CALORIMETER
Steel + Quartz fibres $\sim 2,000$ Channels

CRYSTAL
ELECTROMAGNETIC
CALORIMETER (ECAL)
 $\sim 76,000$ scintillating PbWO_4 crystals

HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator $\sim 7,000$ channels

Detectoren



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Mini Deeltjes

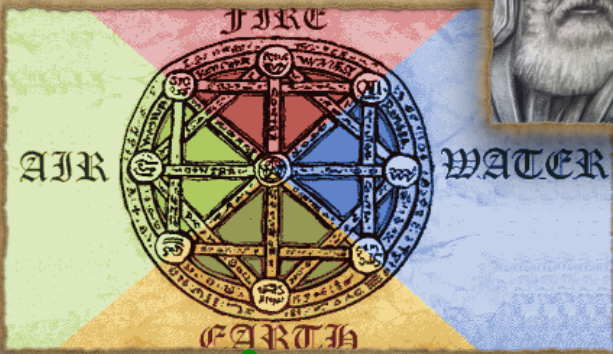
**Waarvan zijn
we gemaakt?**

**Waarvan is het heelal
gemaakt?**

**Hoe komt het dat alles
gewoon ... “werkt”?**

... ?

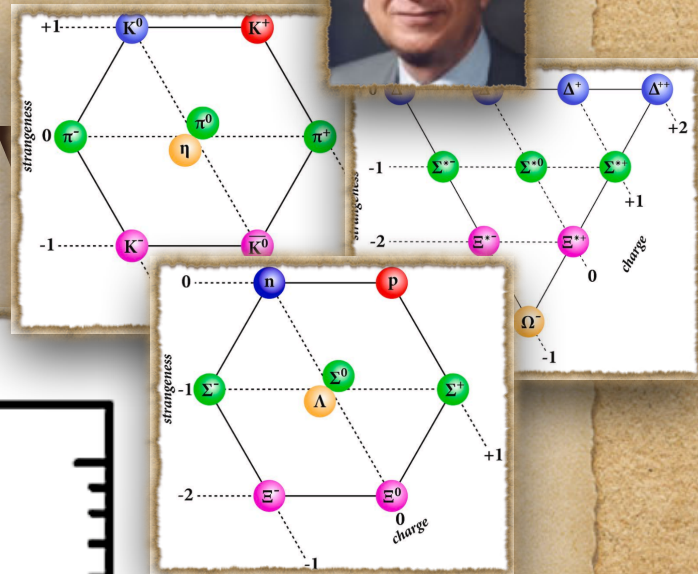
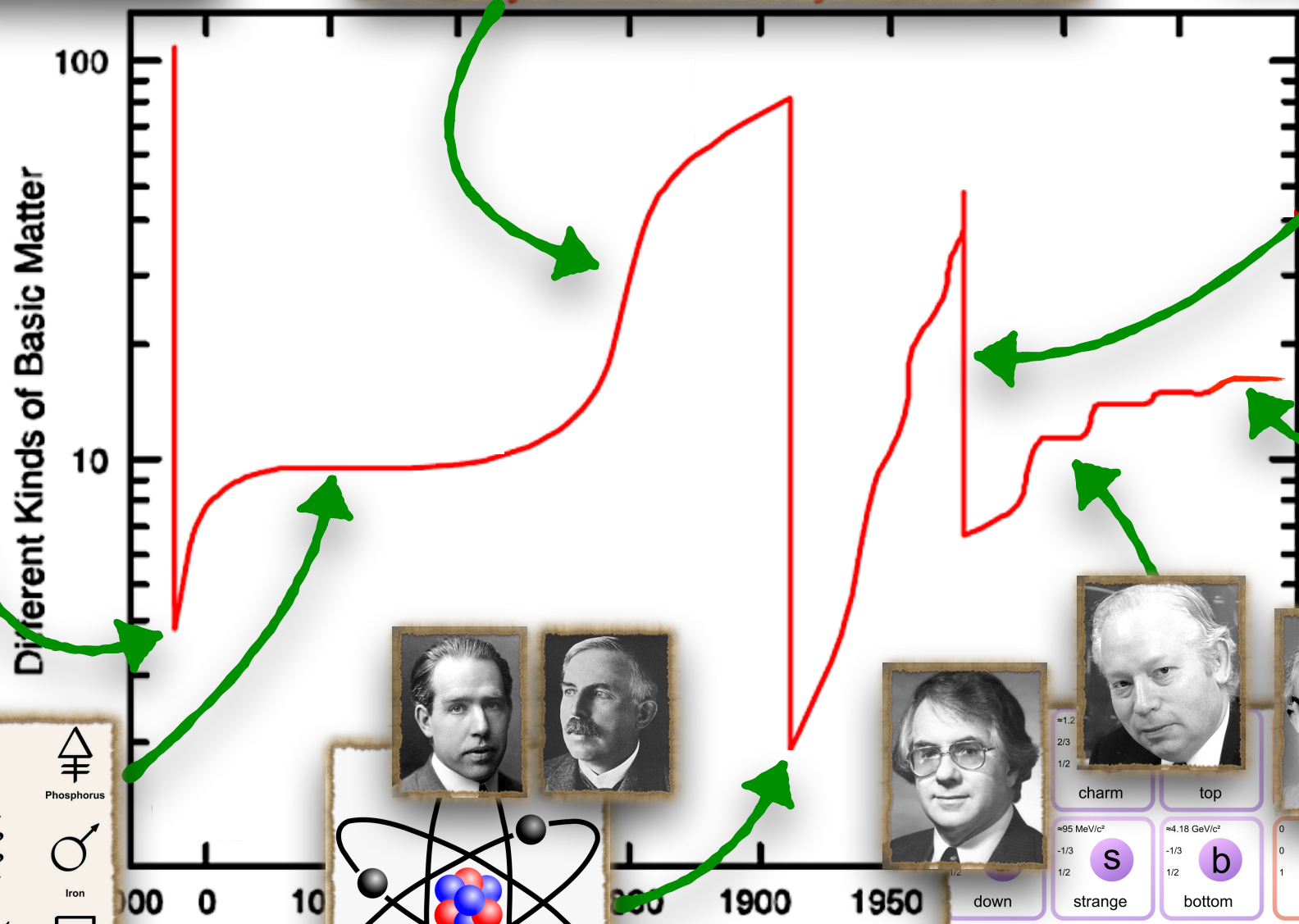




group																	18					
1*																	2					
1	H																	He				
2	Li	Be															B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar				
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36				
	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr				
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54				
	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe				
6	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86				
	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn				
7	87	88	89	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118				
	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og				
lanthanoid series 6 actinoid series 7																						

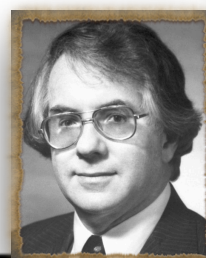
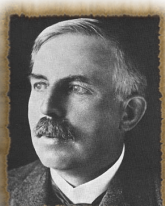
en

ni



v/c^2
H
Higgs boson

Antimony	Bismuth	Gold	Phosphorus
Lead	Mercury	Copper	Iron
Sulfur	Tin	Silver	Potassium
Zinc	Platinum	Magnesium	Arsenic



charm	top	γ photon
$\approx 95 \text{ MeV}/c^2$ s strange	$\approx 4.18 \text{ GeV}/c^2$ b bottom	Z Z boson
0.511 MeV/c^2 e electron	105.7 MeV/c^2 μ muon	1.777 GeV/c^2 τ tau
$< 2.2 \text{ eV}/c^2$ ν_e electron neutrino	$< 0.17 \text{ MeV}/c^2$ ν_μ muon neutrino	$< 15.5 \text{ MeV}/c^2$ ν_τ tau neutrino
		80.4 GeV/c^2 W W boson

[/arxiv.org/abs/1311.1769](https://arxiv.org/abs/1311.1769)

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deeltjes



Different Kinds of Basic Matter



Antimony	Bismuth	Gold	Phosphorus
Lead	Mercury	Copper	Iron
Sulfur	Tin	Silver	Potassium
Zinc	Platinum	Magnesium	Arsenic

v/c^2

H

Higgs boson

charm top

down strange bottom photon

electron neutrino muon neutrino tau neutrino Z boson W boson

Het Standaard Model

	mass →	charge →	spin →				
QUARKS	$\approx 2.3 \text{ MeV}/c^2$	$2/3$	$1/2$	u	up	$\approx 1.275 \text{ GeV}/c^2$	$2/3$
				c	charm		
				t	top	$\approx 173.07 \text{ GeV}/c^2$	$2/3$
				d	down	$\approx 4.8 \text{ MeV}/c^2$	$-1/3$
				s	strange	$\approx 95 \text{ MeV}/c^2$	$-1/3$
				b	bottom	$\approx 4.18 \text{ GeV}/c^2$	$-1/3$
LEPTONS				g	gluon	0	0
				γ	photon	0	0
				Z	Z boson	0	1
	$0.511 \text{ MeV}/c^2$	-1	$1/2$	e	electron	$105.7 \text{ MeV}/c^2$	-1
				μ	muon	$1.777 \text{ GeV}/c^2$	-1
				τ	tau	$91.2 \text{ GeV}/c^2$	-1
LEPTONS	$< 2.2 \text{ eV}/c^2$	0	$1/2$	ν_e	electron neutrino	$< 0.17 \text{ MeV}/c^2$	0
				ν_μ	muon neutrino	$< 15.5 \text{ MeV}/c^2$	0
				ν_τ	tau neutrino	$80.4 \text{ GeV}/c^2$	± 1
				W	W boson		1
			H	Higgs boson	$\approx 126 \text{ GeV}/c^2$	0	0

GAUGE BOSONS

4

Hoge Energie

Hoge-Energiefysica

THERE ARE FOUR FUNDAMENTAL FORCES BETWEEN PARTICLES:
(1) GRAVITY, WHICH OBEYS THIS INVERSE SQUARE LAW:

$$F_{\text{gravity}} = G \frac{m_1 m_2}{d^2}$$



OK...

(2) ELECTROMAGNETISM, WHICH OBEYS THIS INVERSE-SQUARE LAW:

$$F_{\text{static}} = k_e \frac{q_1 q_2}{d^2}$$

AND ALSO MAXWELL'S EQUATIONS



ALSO WHAT?

(3) THE STRONG NUCLEAR FORCE, WHICH OBEYS, UH...

...WELL, UMM...

...IT HOLDS PROTONS AND NEUTRONS TOGETHER.



I SEE.

IT'S STRONG.

AND (4) THE WEAK FORCE. IT [MUMBLE MUMBLE] RADIOACTIVE DECAY [MUMBLE MUMBLE]

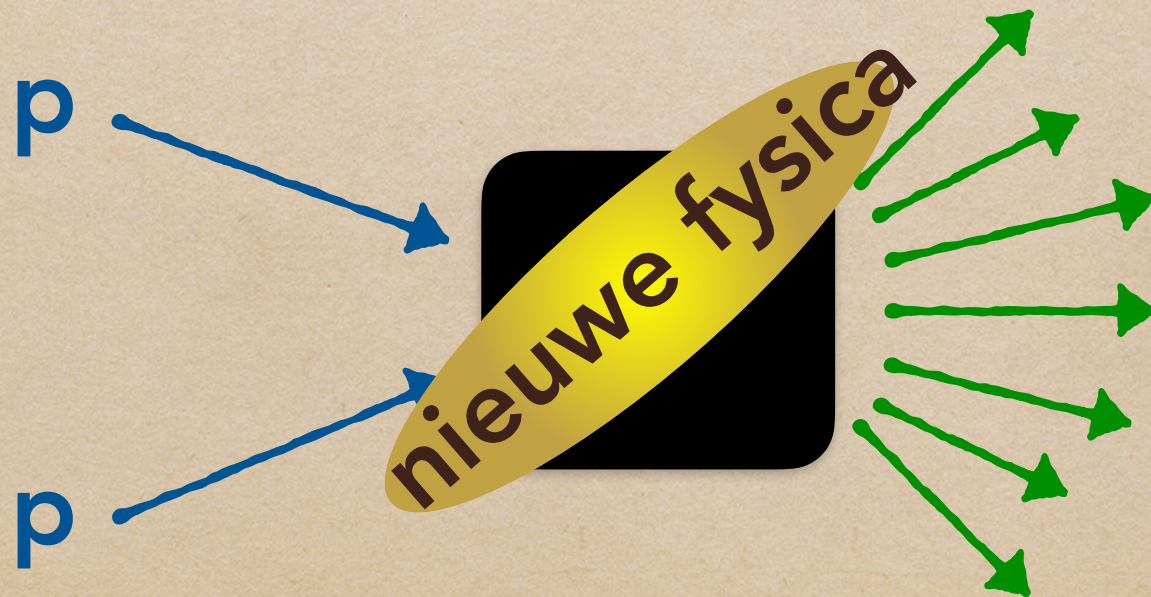
THAT'S NOT A SENTENCE. YOU JUST SAID 'RADIO—
—AND THOSE ARE THE FOUR FUNDAMENTAL FORCES!



Hoe werkt deeltjesfysica?

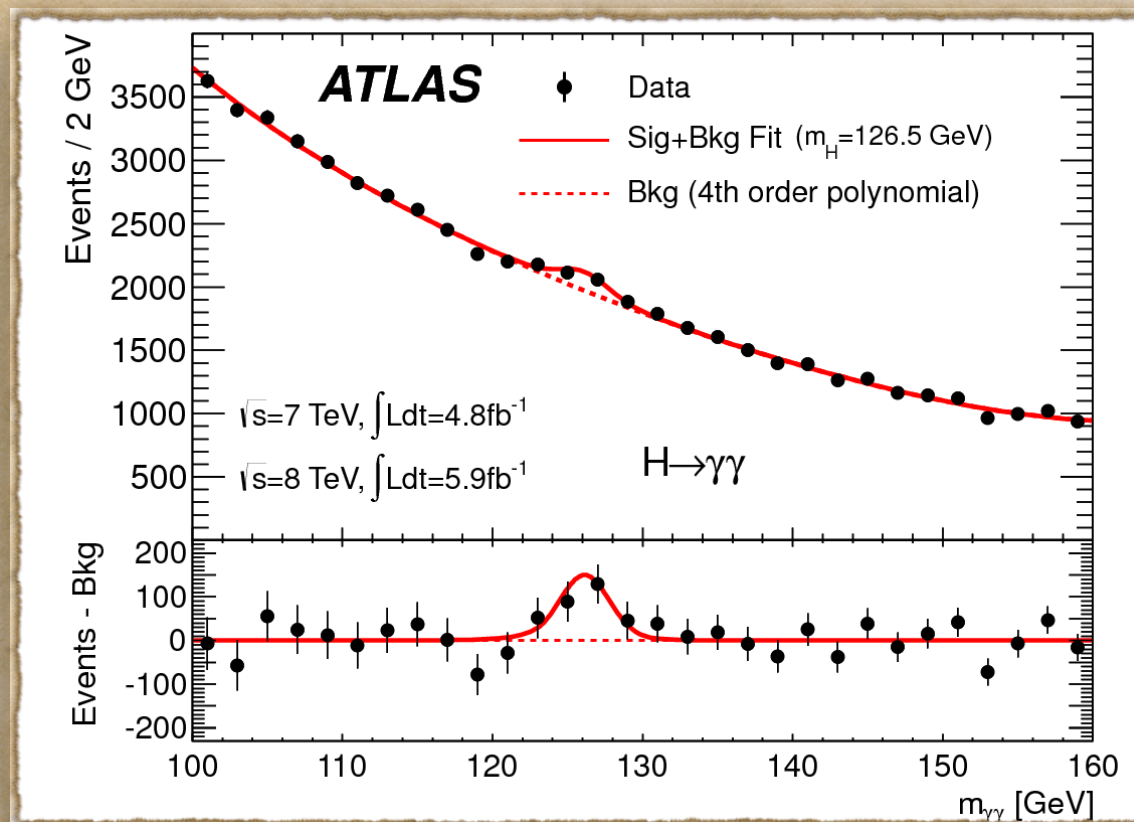
Black-Box mechanisme:

- we weten wat we er insteken
- we meten wat er uitkomt
- we gebruiken statistiek om af te leiden wat er onderweg gebeurd is

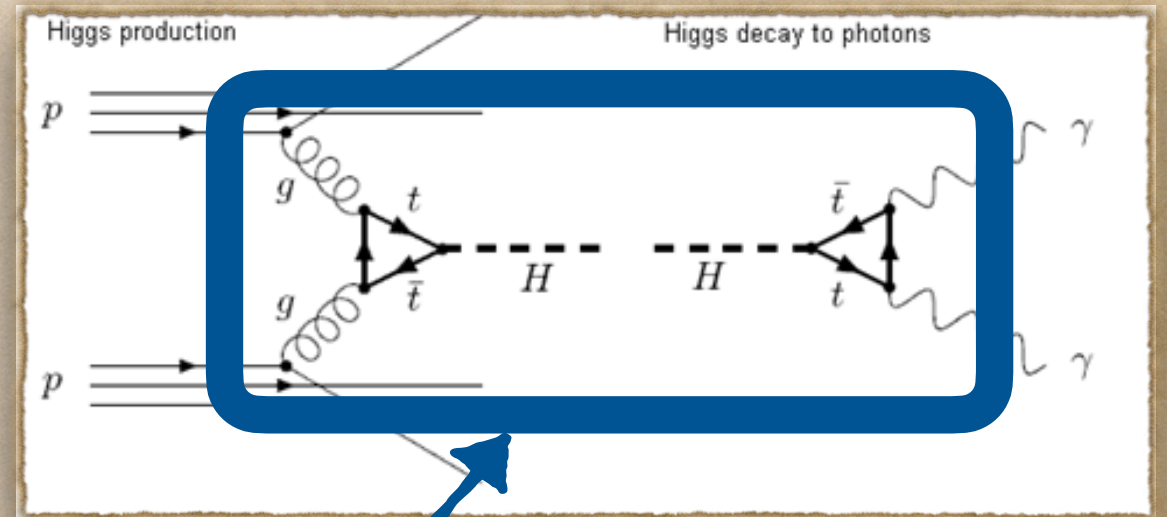


Statistiek!

Higgsdeeltje is gevonden!



Voorbeeld interactie

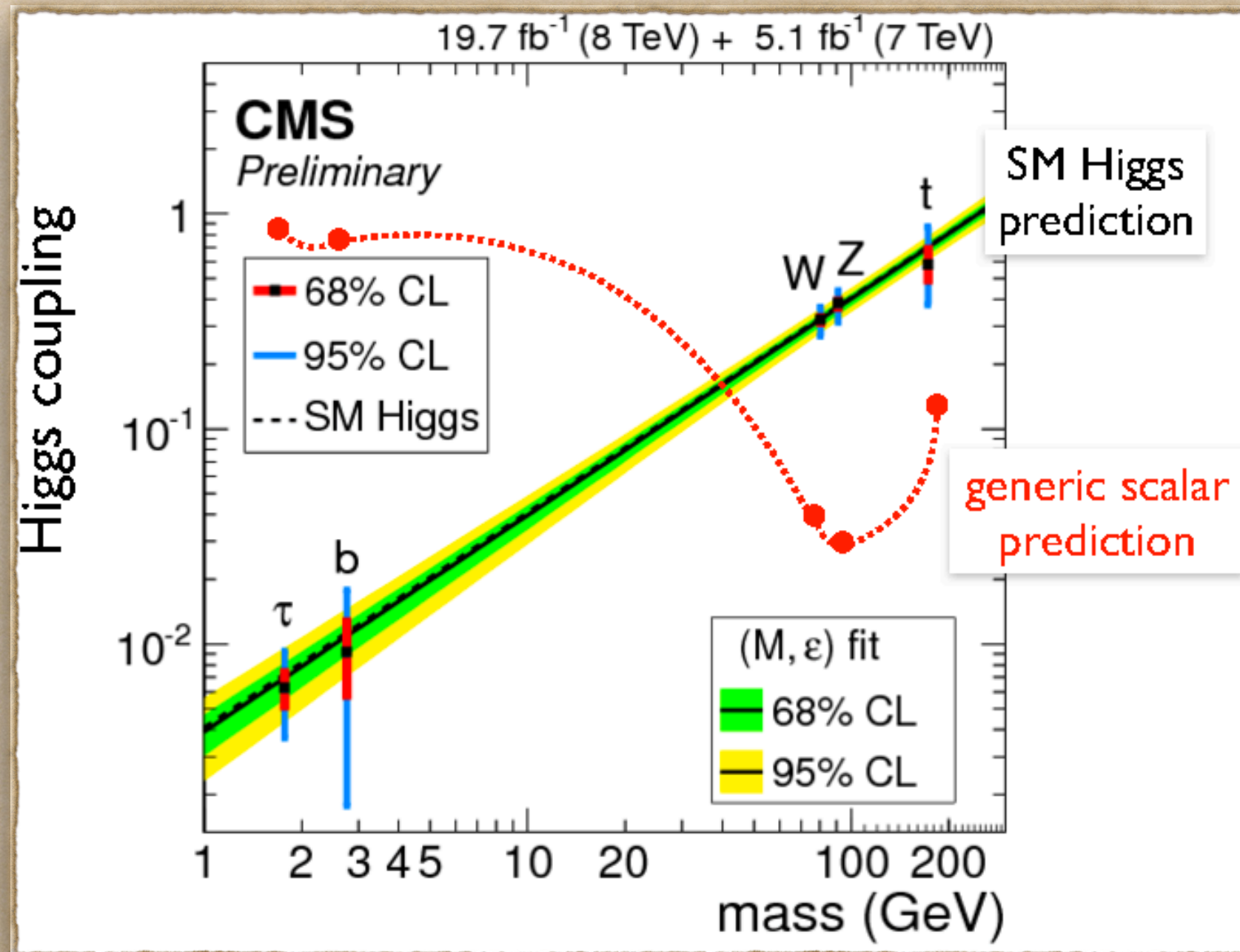


Black Box:

Kan om het even wat zijn (Higgs, photon, gluon,)

Gebruik **statistiek** en **waarschijnlijkheid** om een schatting te maken

Het beweegt zoals een Higgs...



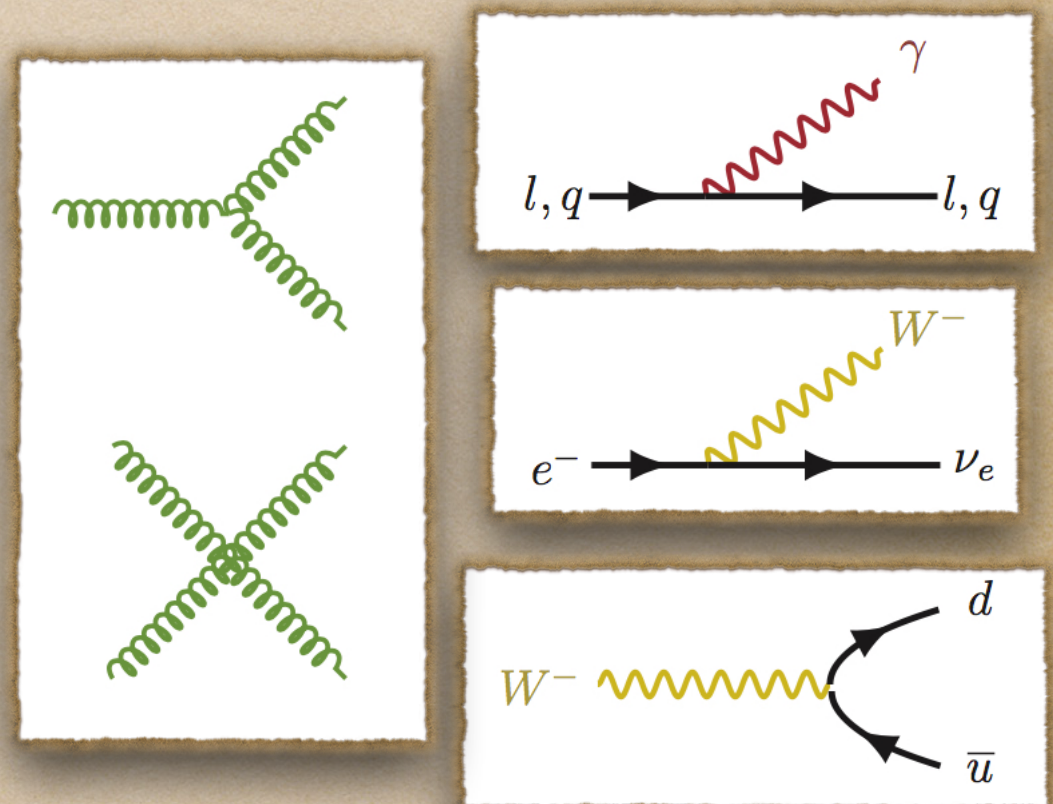
Binnenin de Black Box

Feynman diagrammen

Notatie

quark, lepton	
antiquark, antilepton	
photon	
gluon	
zwak boson	

Interactie

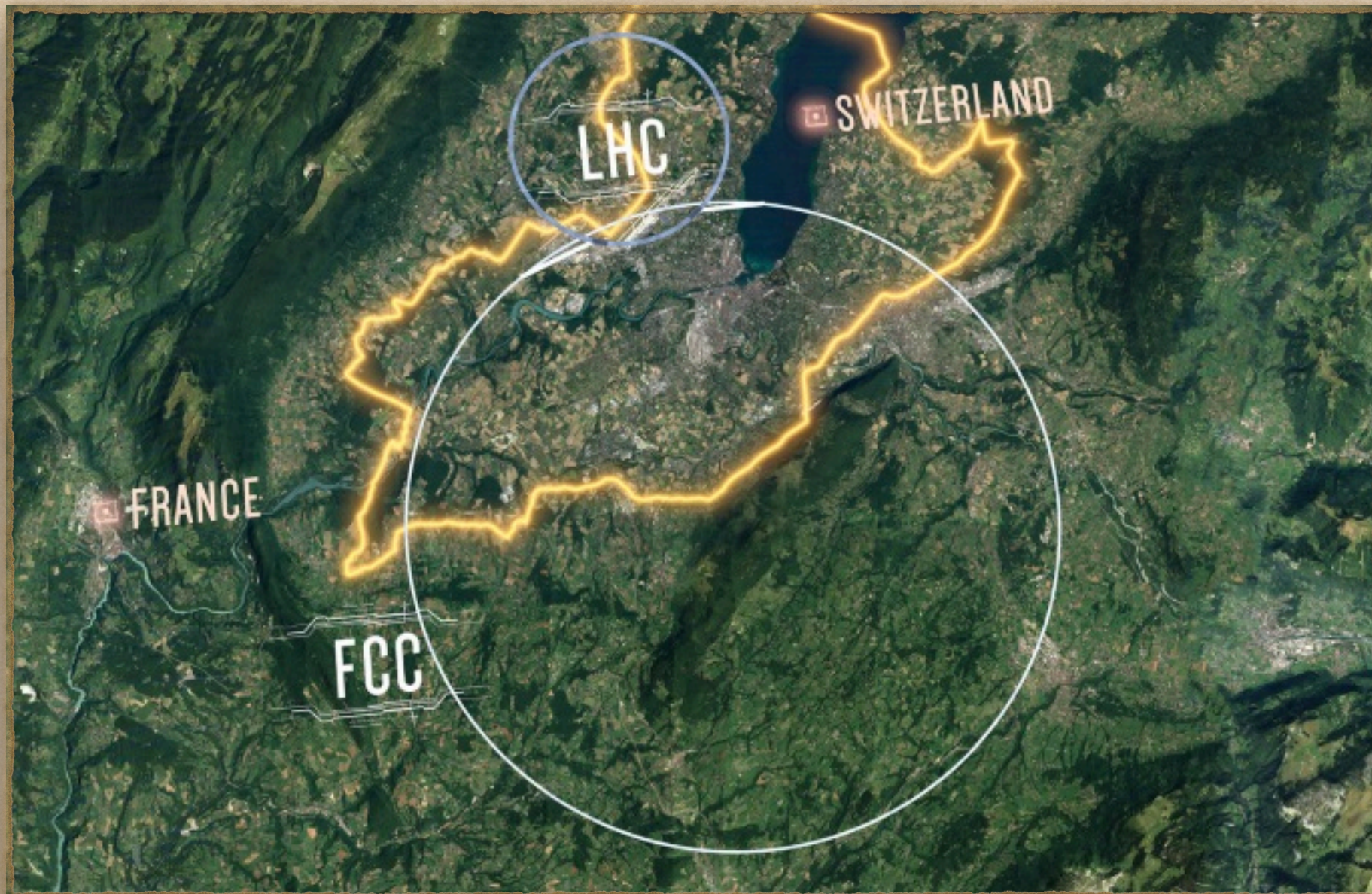


5

De Toekomst

Verbreiding van de zoektocht...

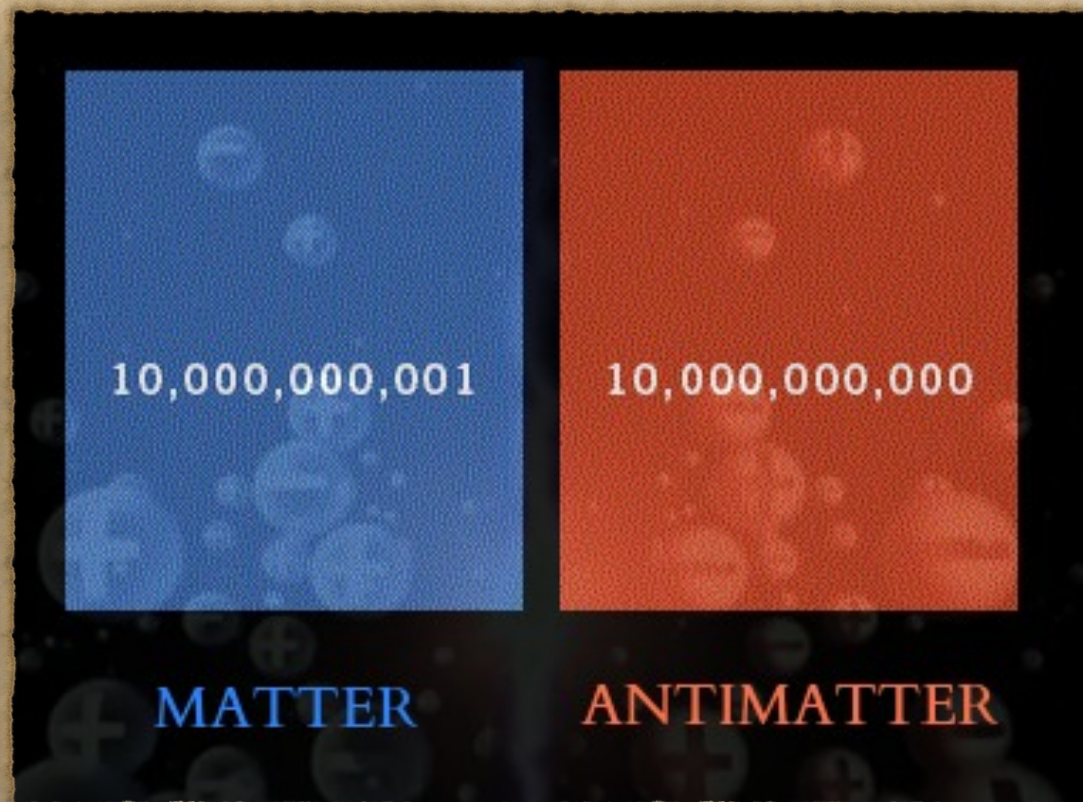
groter, breder, beter



(Anti)Materie Asymmetrie



(Anti)Materie Asymmetrie

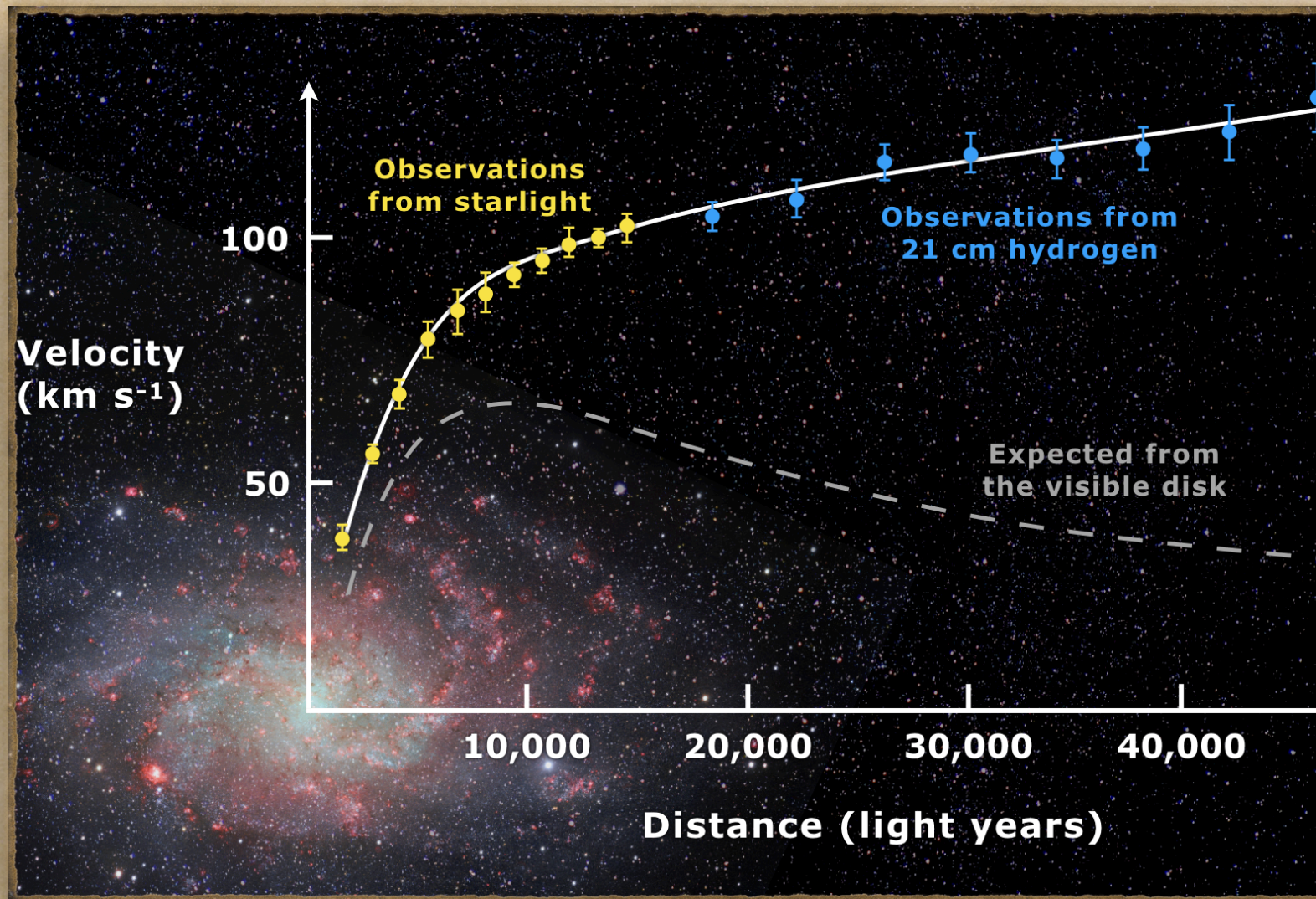


Ergens ver weg verborgen?

Asymmetrisch gecreëerd?

Asymmetrisch verval?

Donkere Materie



~~zwarte gaten?~~

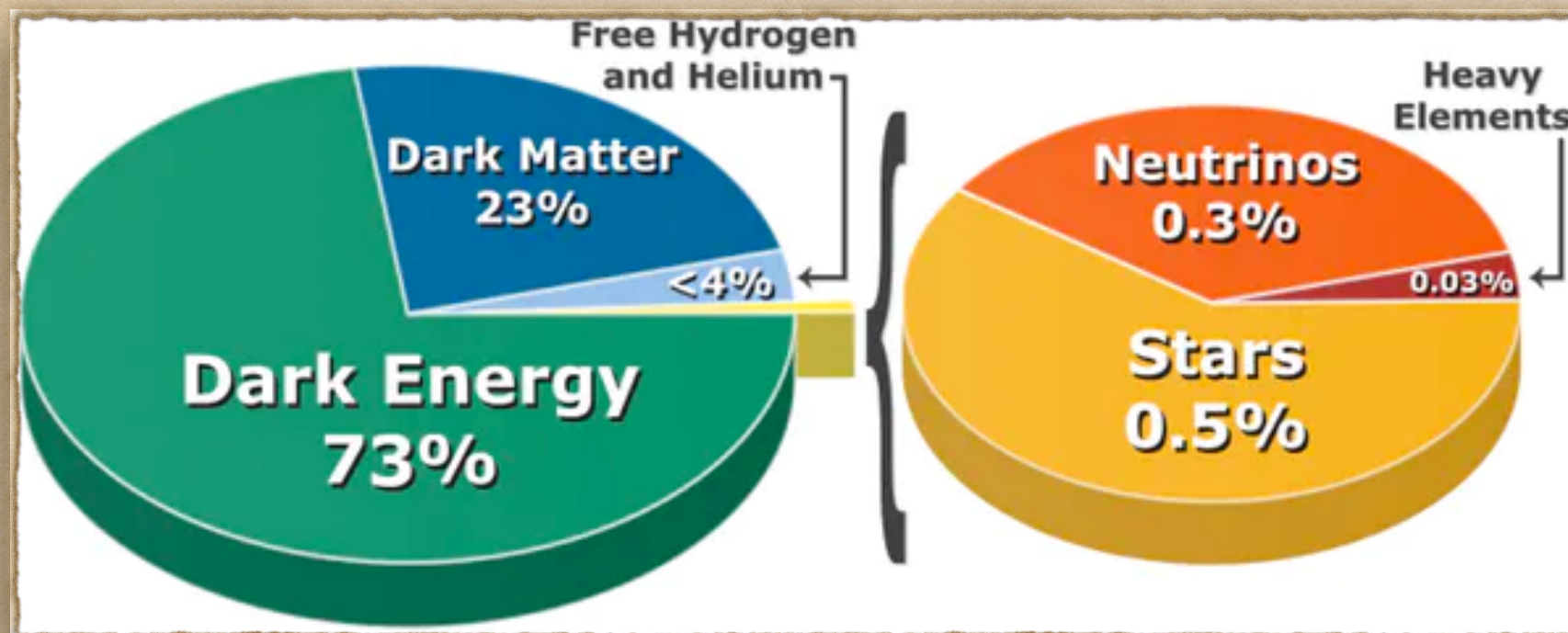
WIMPs?

steriele neutrinos?

Werkt zwaartekracht anders op grote schaal?

Donkere Energie

Variabel-energie veld?

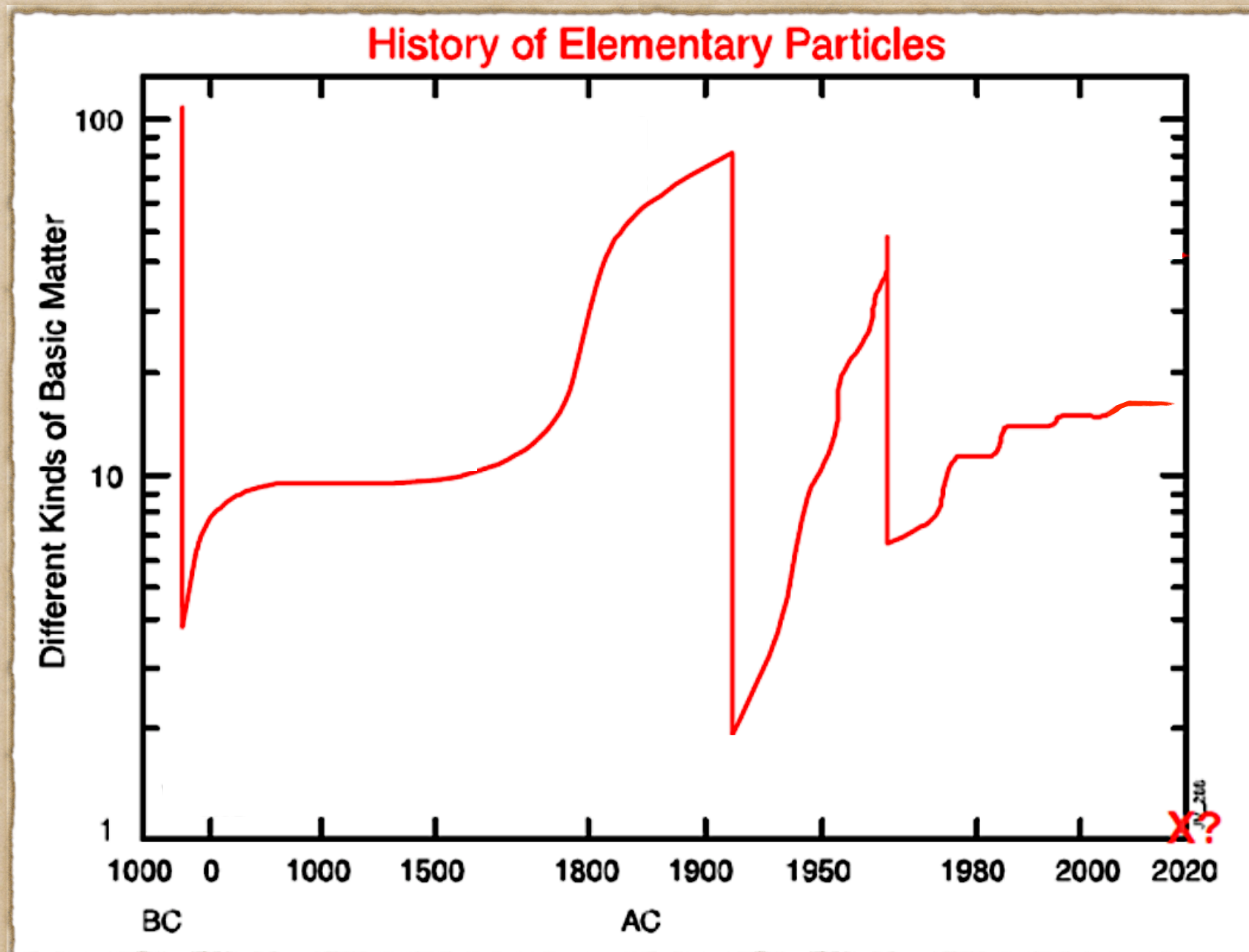


Werkt zwaartekracht anders op grote schaal?

Fundamentele eigenschap van tijdruimte?

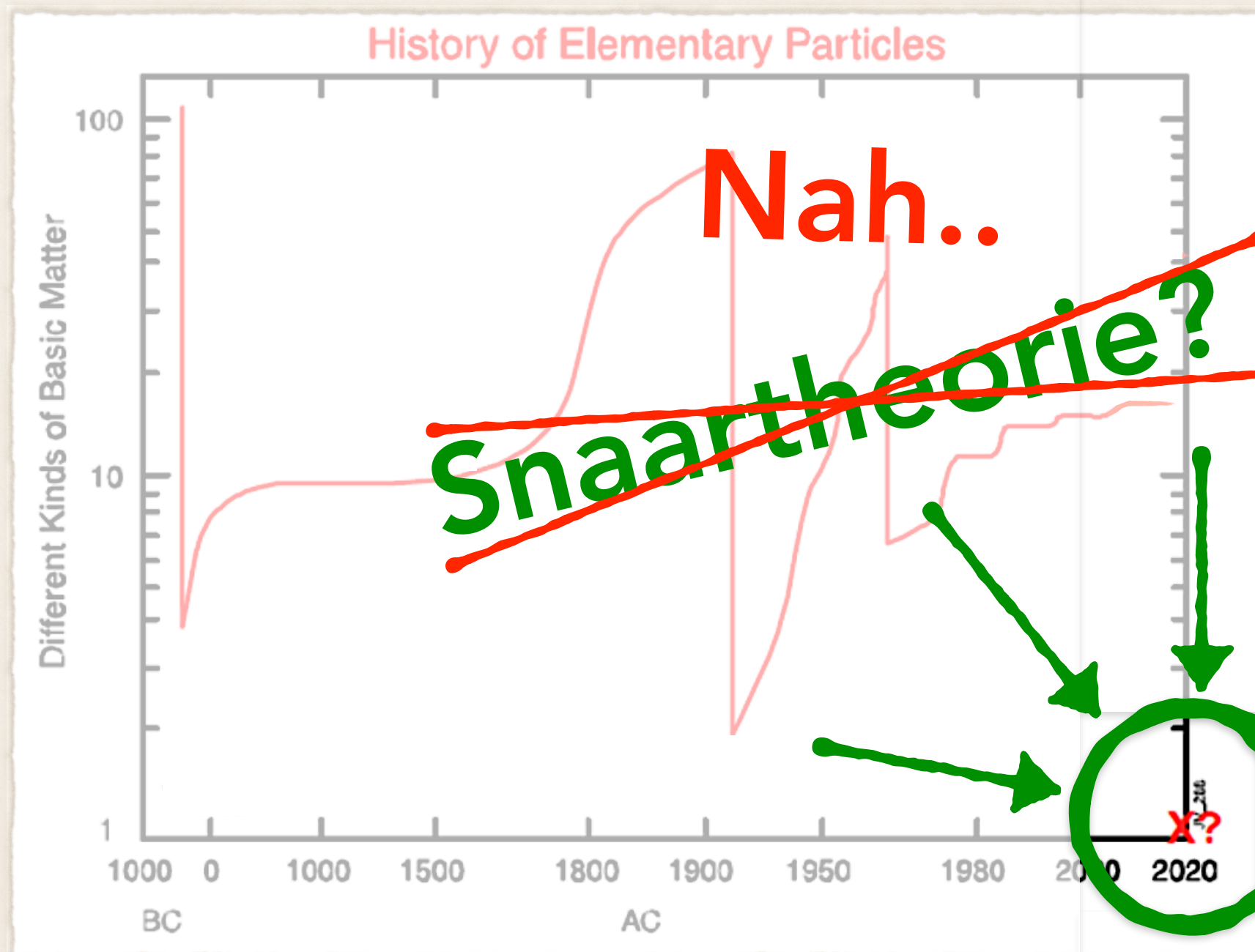
Oh en nog iets..

Bouwstenen van het universum



Credit: <http://arxiv.org/abs/1311.1769>

Basic Bricks of the Universe



Credit: <http://arxiv.org/abs/1311.1769>

Dit zijn vragen die nog steeds openstaan..

Klaar om verkend te worden...

Dankjewel voor je aandacht!

Vragen?

=> frederikvanderveken@gmail.com