

Femto Fysica

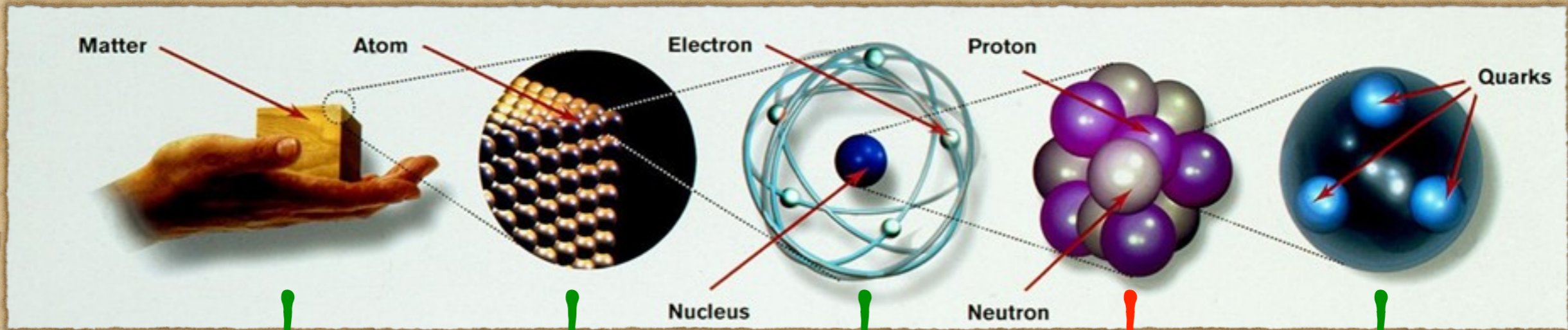
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NNV Profielwerkstukreis 2021

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Wát voor fysica... ?



5cm

(10^{-2} m)

1Å

(10^{-10} m)

0.01pm

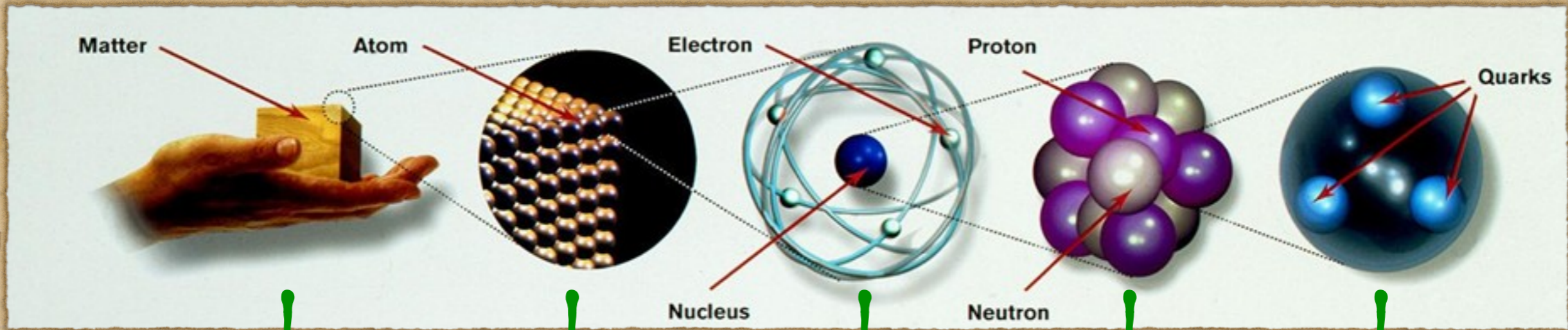
(10^{-14} m)

1am

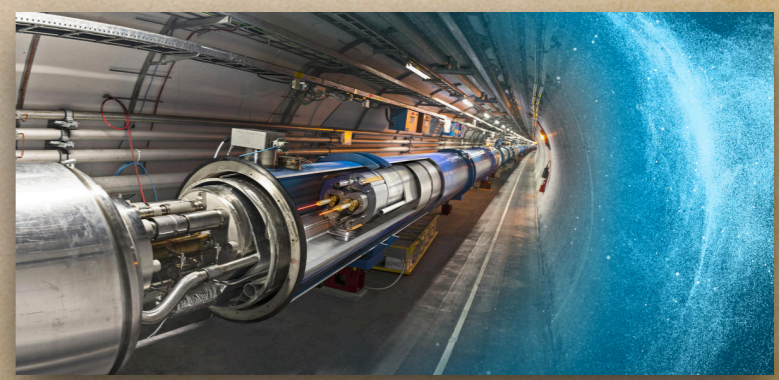
(10^{-18} m)

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

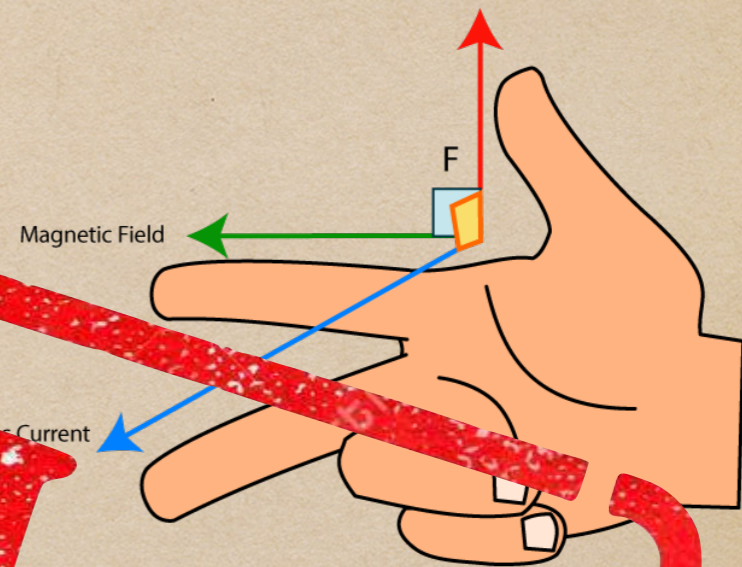
9593 magneten

1~2 **miljard** botsingen / s

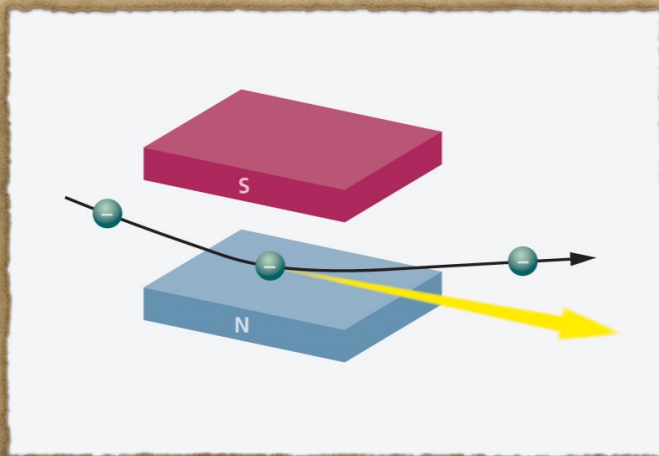
Versnellers

Magneten?

FAWI



Lorentz kracht loodrecht op bewegingsrichting



Effect van magneet is in 'foute' richting

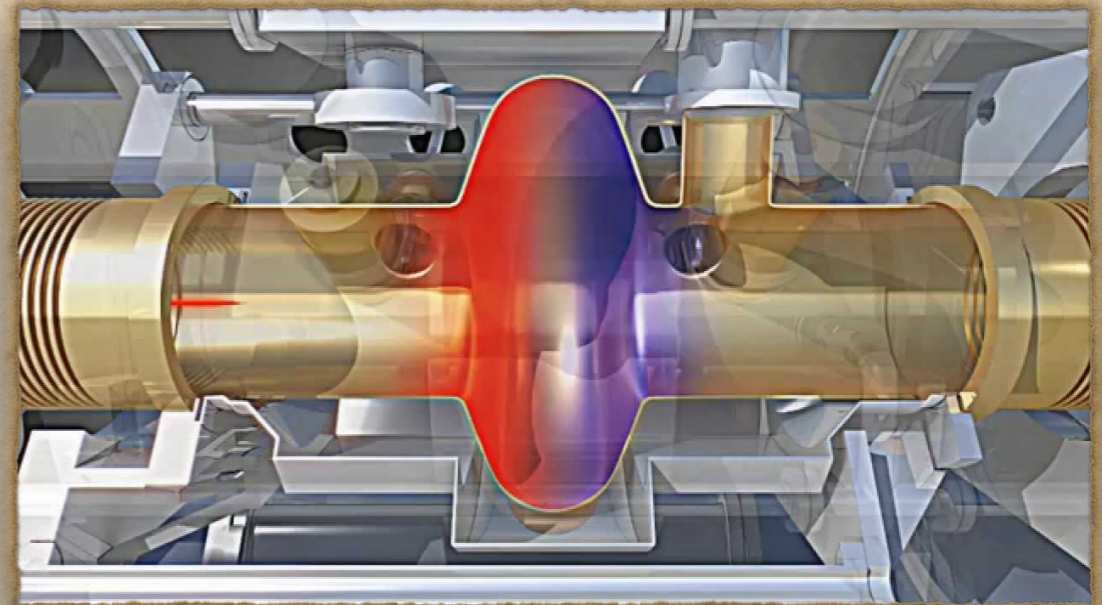
Vergelijk met schommel
langs zijkant te duwen



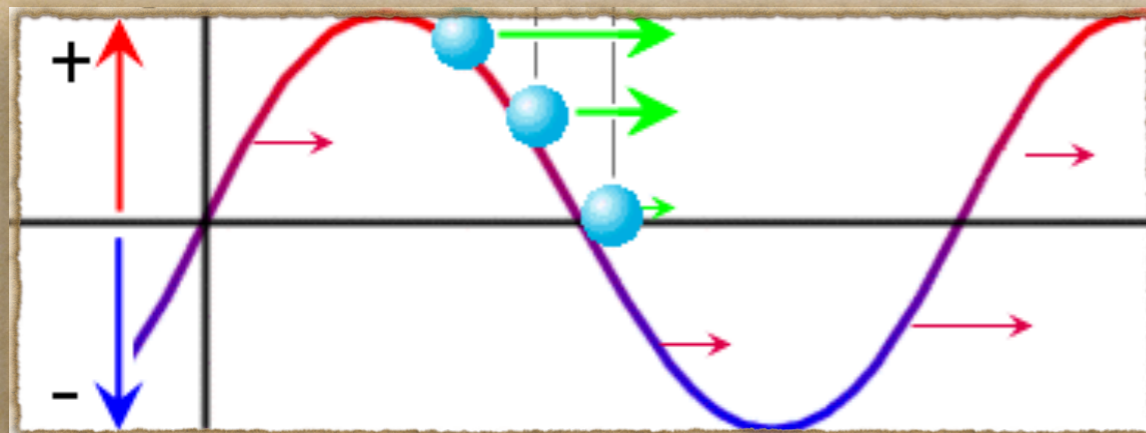
Versnellers

Elektrisch veld: **caviteiten**

Kracht is **longitudinaal**



Credit: CERN



Credit: JLAB

Veld moet op het juiste moment positief zijn.

Goede timing is cruciaal

Maar..

Maar..

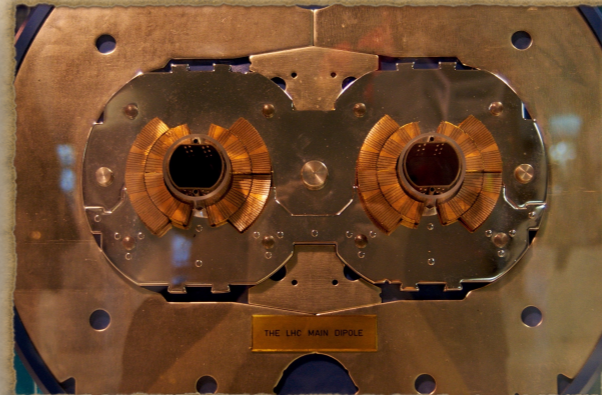
De LHC heeft 9600 magneten!

Waarom dan..?

Magneten

dipool:

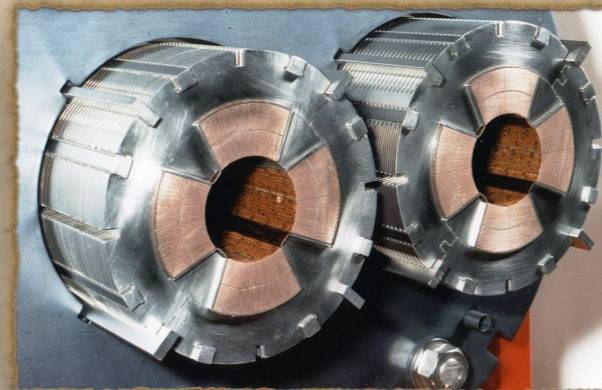
afbuiging



Credit: CERN

quadrupool:

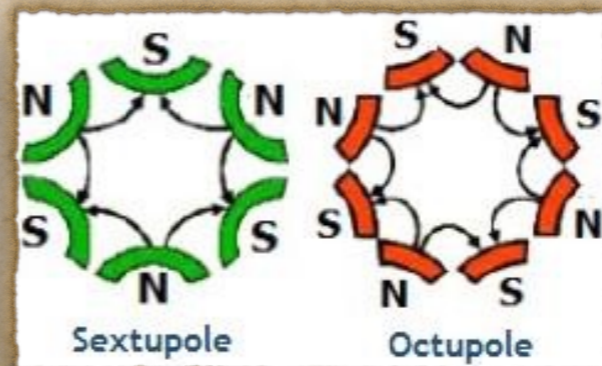
focusering



Credit: CERN

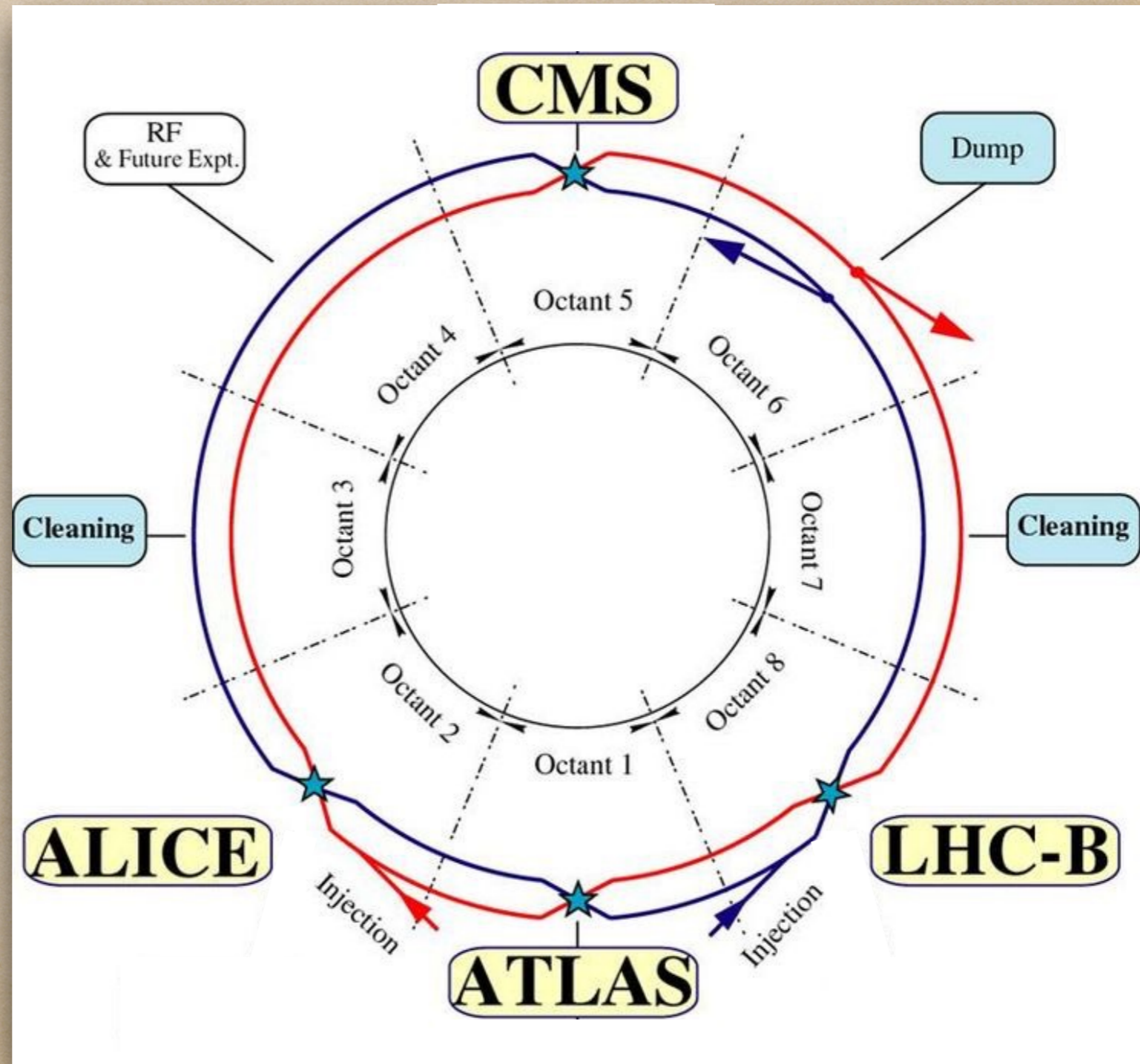
hogere ordes:

vanalles anders

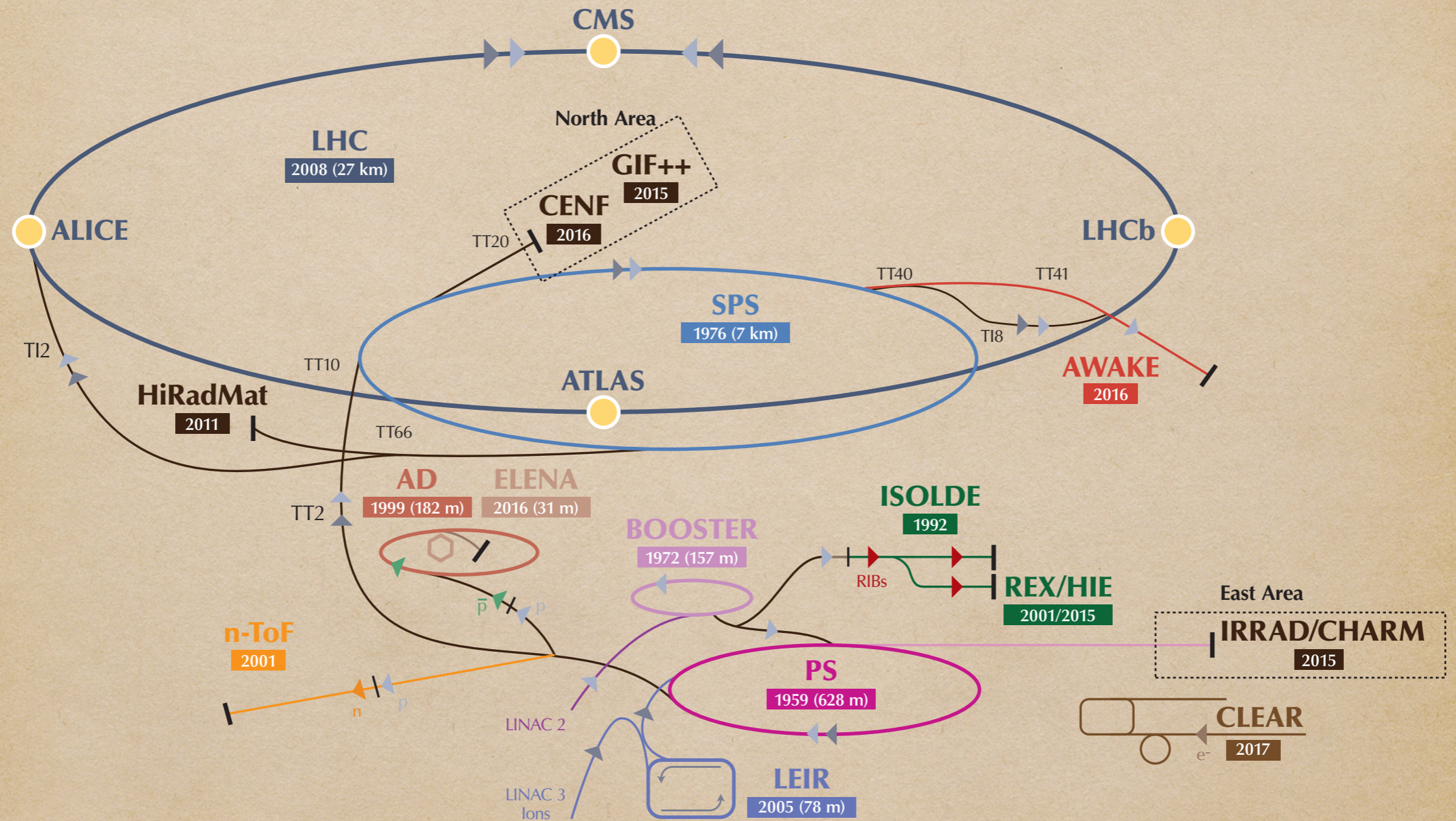


De Large Hadron Collider

Detectoren
Versnelling
Beam dump
Beam cleaning



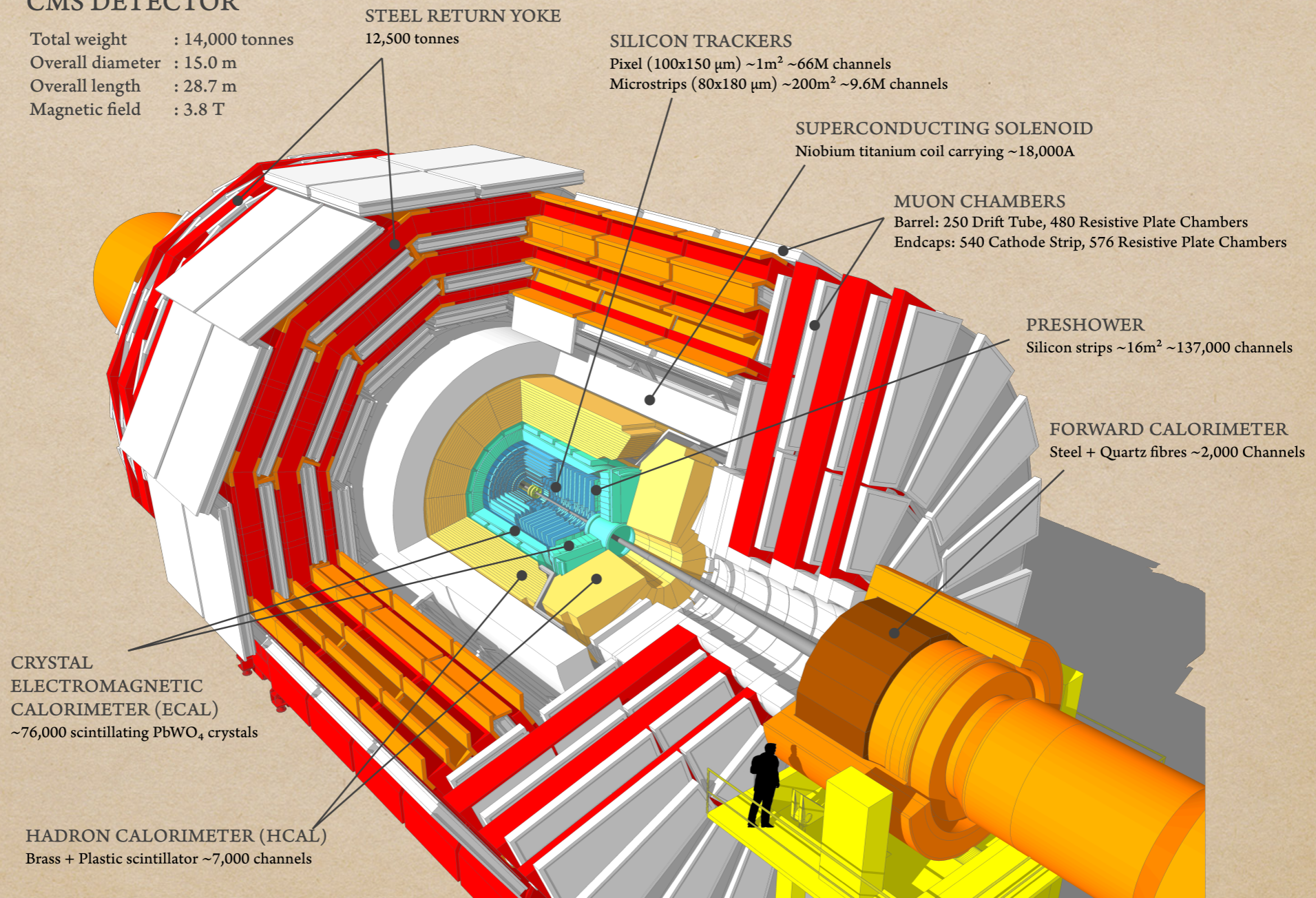
Het Versnellercomplex



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

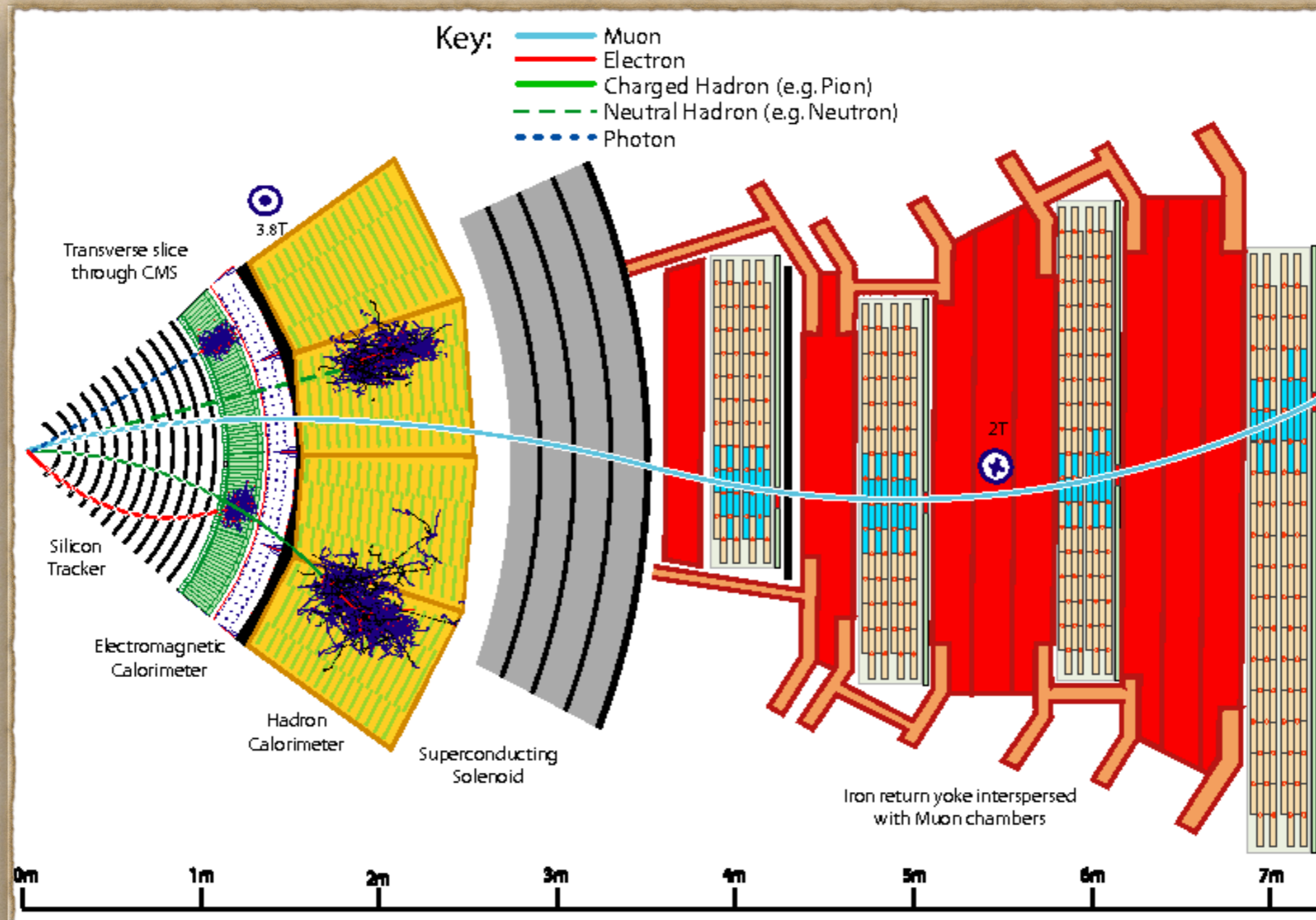
PRESHOWER
Silicon strips $\sim 16\text{m}^2 \sim 137,000$ channels

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

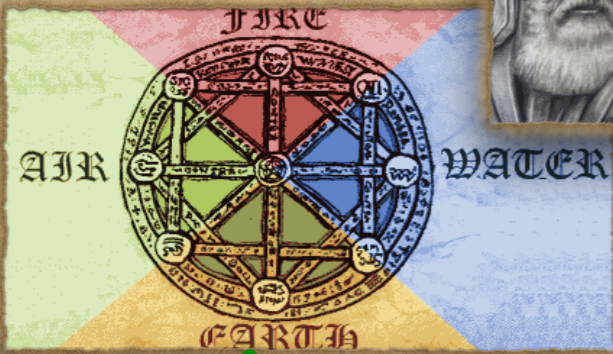
**Waarvan zijn
we gemaakt?**

**Waarvan is het heelal
gemaakt?**

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

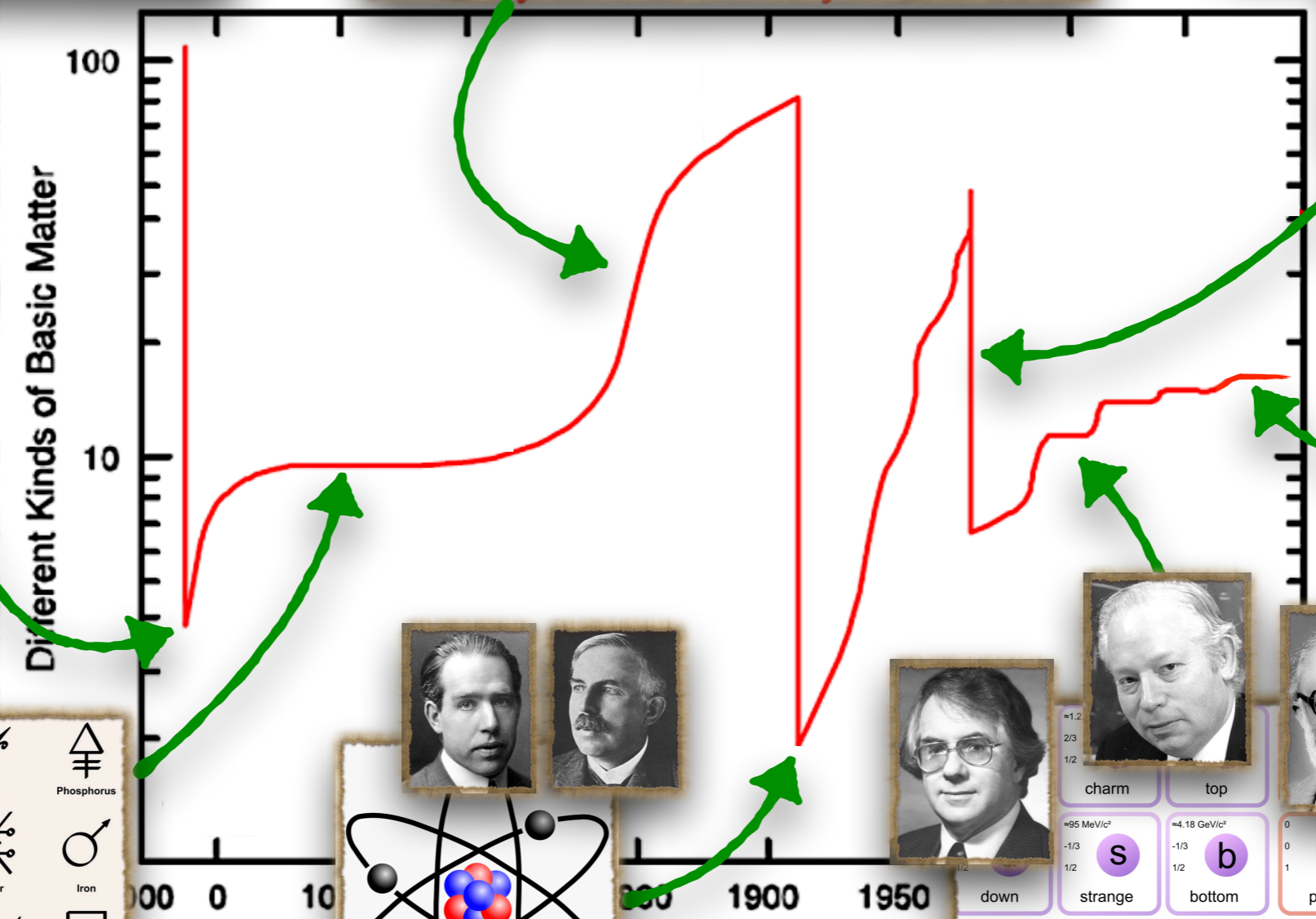
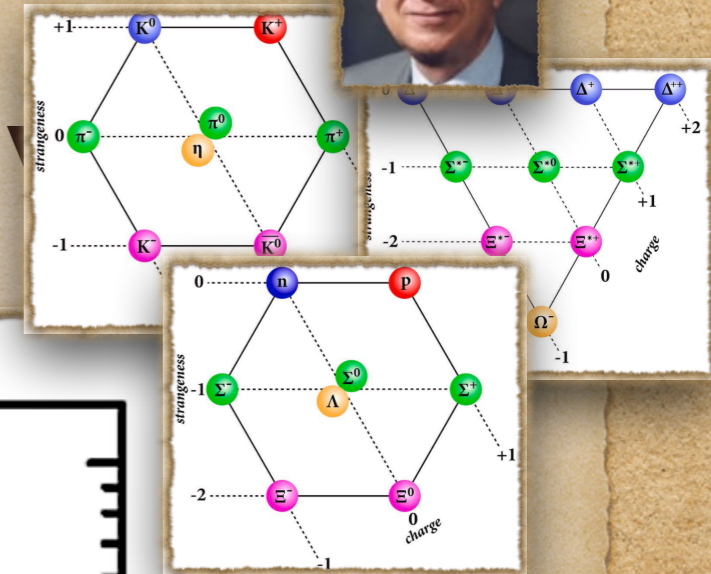
... ?





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	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr				
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe				
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn				
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og				
lanthanoid series 6 Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu actinoid series 7 Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr																						

en



v/c^2
H
Higgs boson

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



$\approx 0.511 \text{ MeV}/c^2$ -1 1/2 e electron	$105.7 \text{ MeV}/c^2$ -1 1/2 μ muon	$1.777 \text{ GeV}/c^2$ -1 1/2 τ tau	$91.2 \text{ GeV}/c^2$ 0 1 Z Z boson
$< 2.2 \text{ eV}/c^2$ 0 1/2 ν_e electron neutrino	$< 0.17 \text{ MeV}/c^2$ 0 1/2 ν_μ muon neutrino	$< 15.5 \text{ MeV}/c^2$ 0 1/2 ν_τ tau neutrino	$80.4 \text{ GeV}/c^2$ ± 1 1 W W boson

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

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]

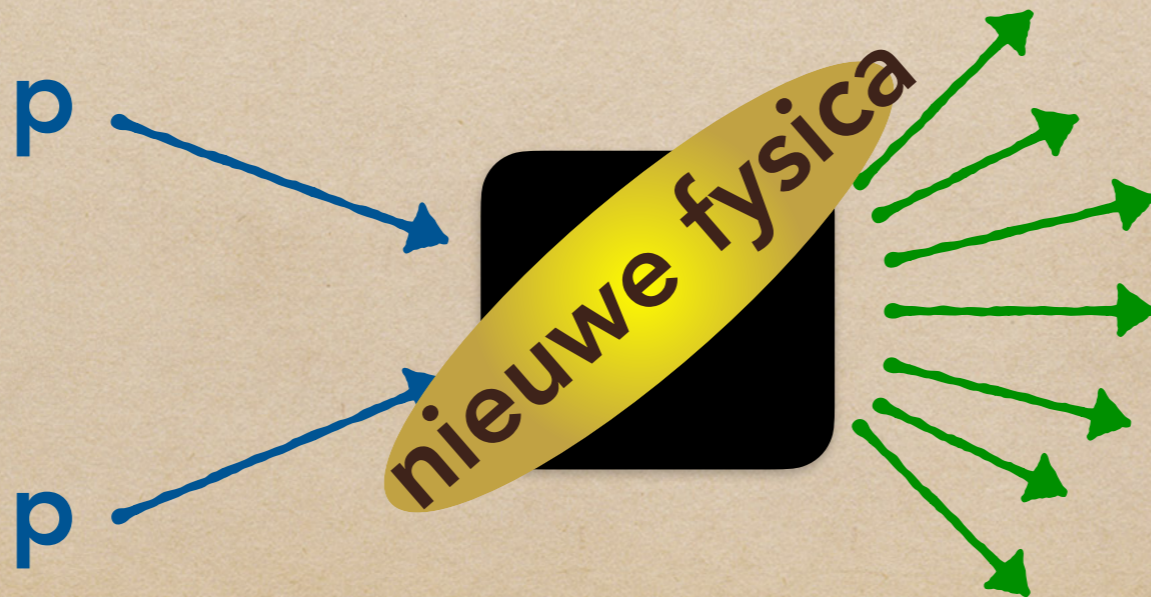
THAT'S NOT A SENTENCE. YOU JUST SAID 'RADIO—
—AND THOSE ARE THE FOUR FUNDAMENTAL FORCES!



Hoe werkt deeltjesfysica?

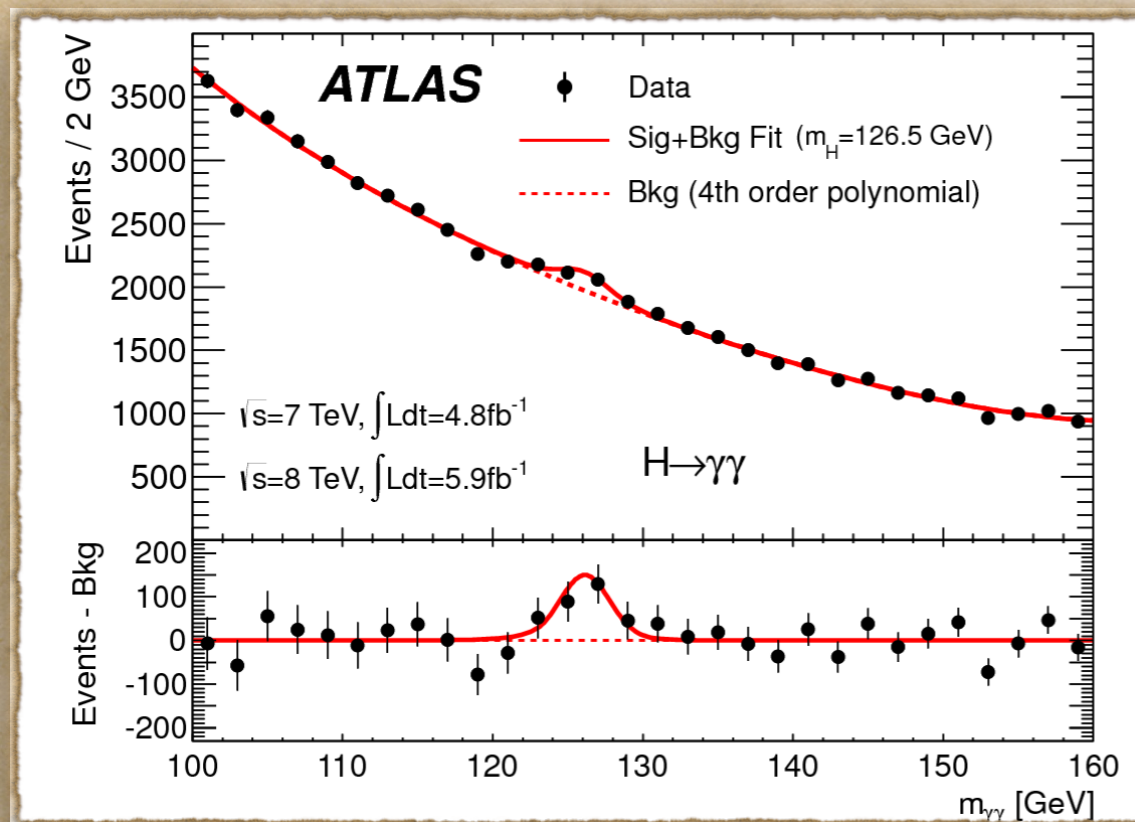
Black-Box mechanisme:

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

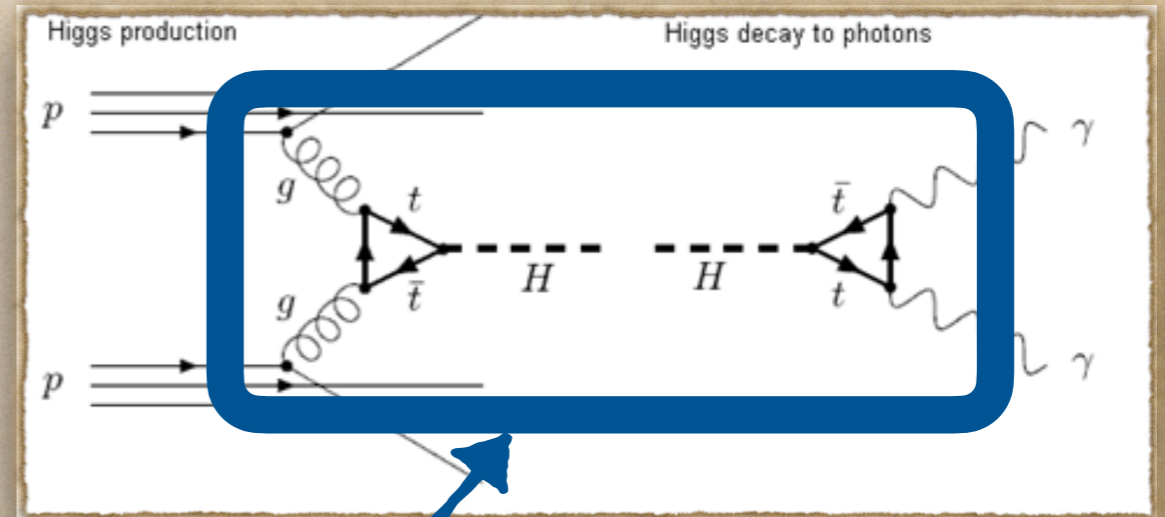


Statistiek!

Higgsdeeltje is gevonden!



Voorbeeld interactie

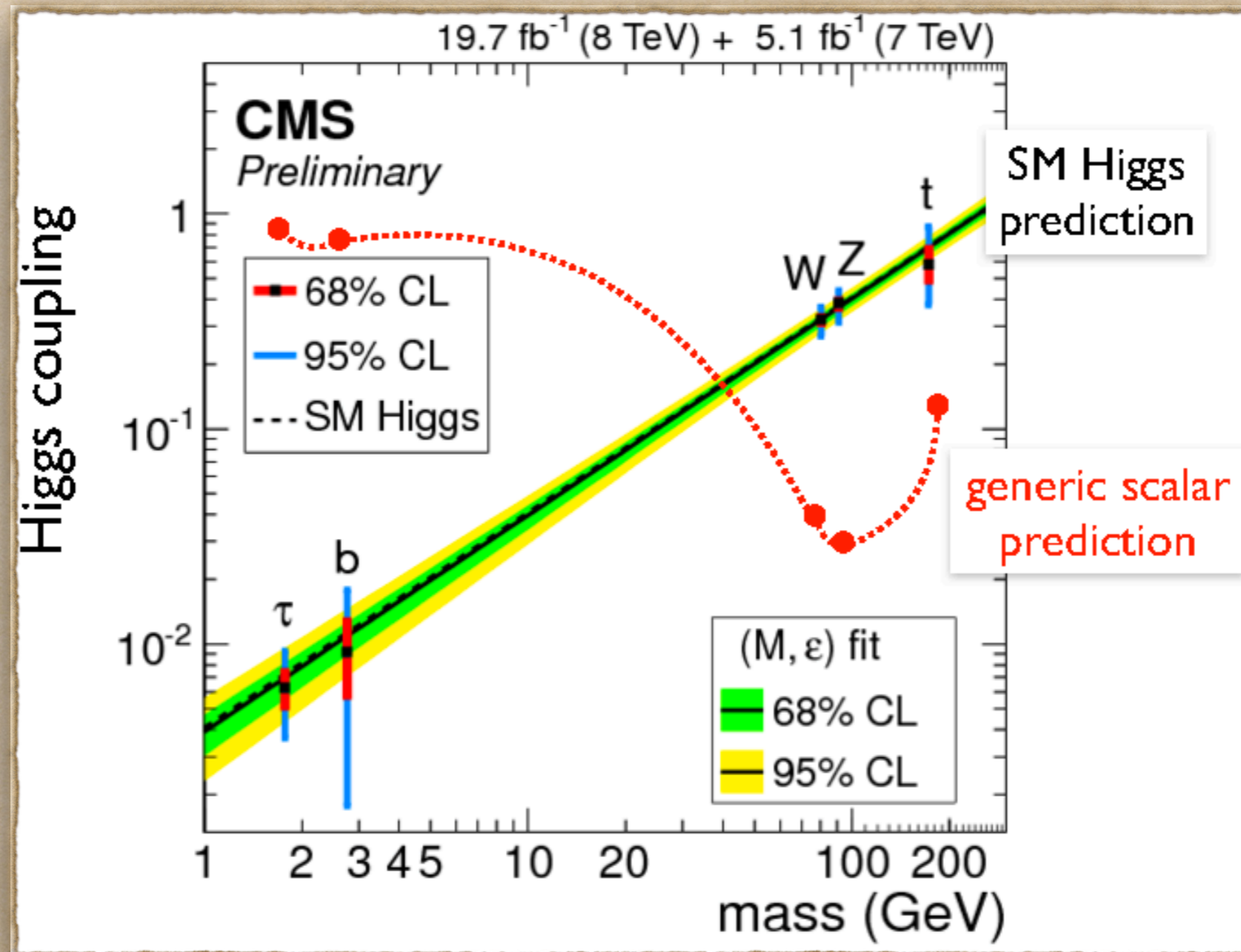


Black Box:

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

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

Het beweegt zoals een Higgs...



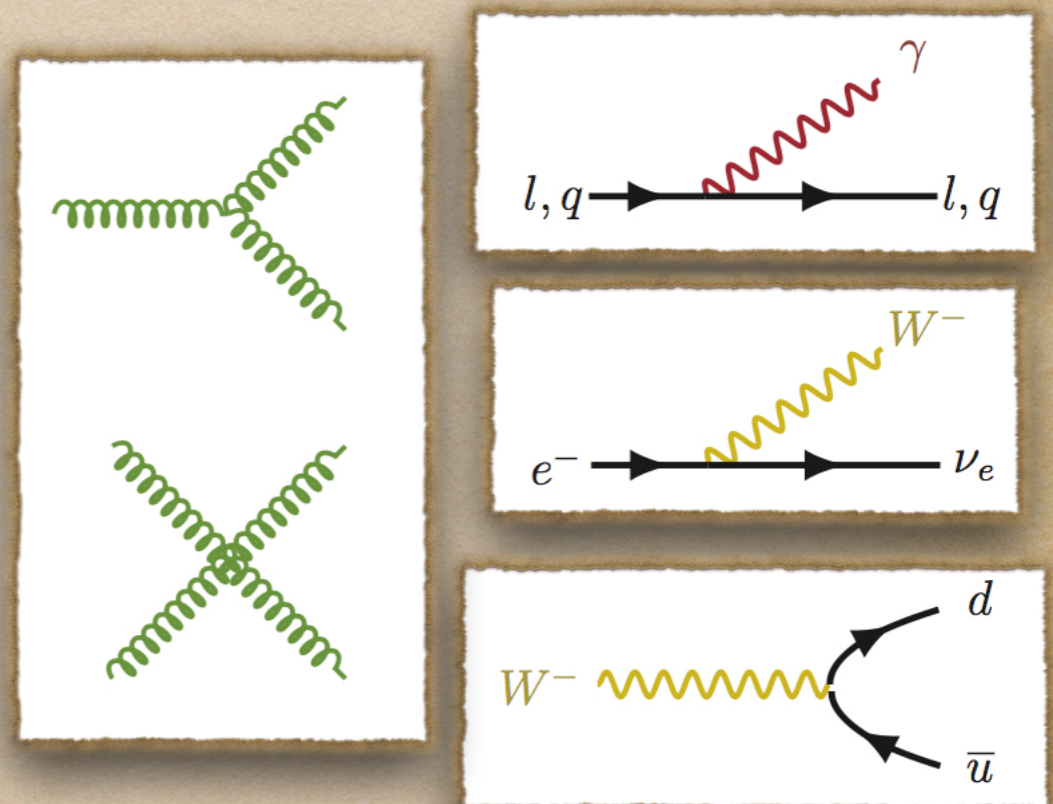
Binnenin de Black Box

Feynman diagrammen

Notatie

quark, lepton	
antiquark, antilepton	
photon	
gluon	
zwak boson	

Interactie

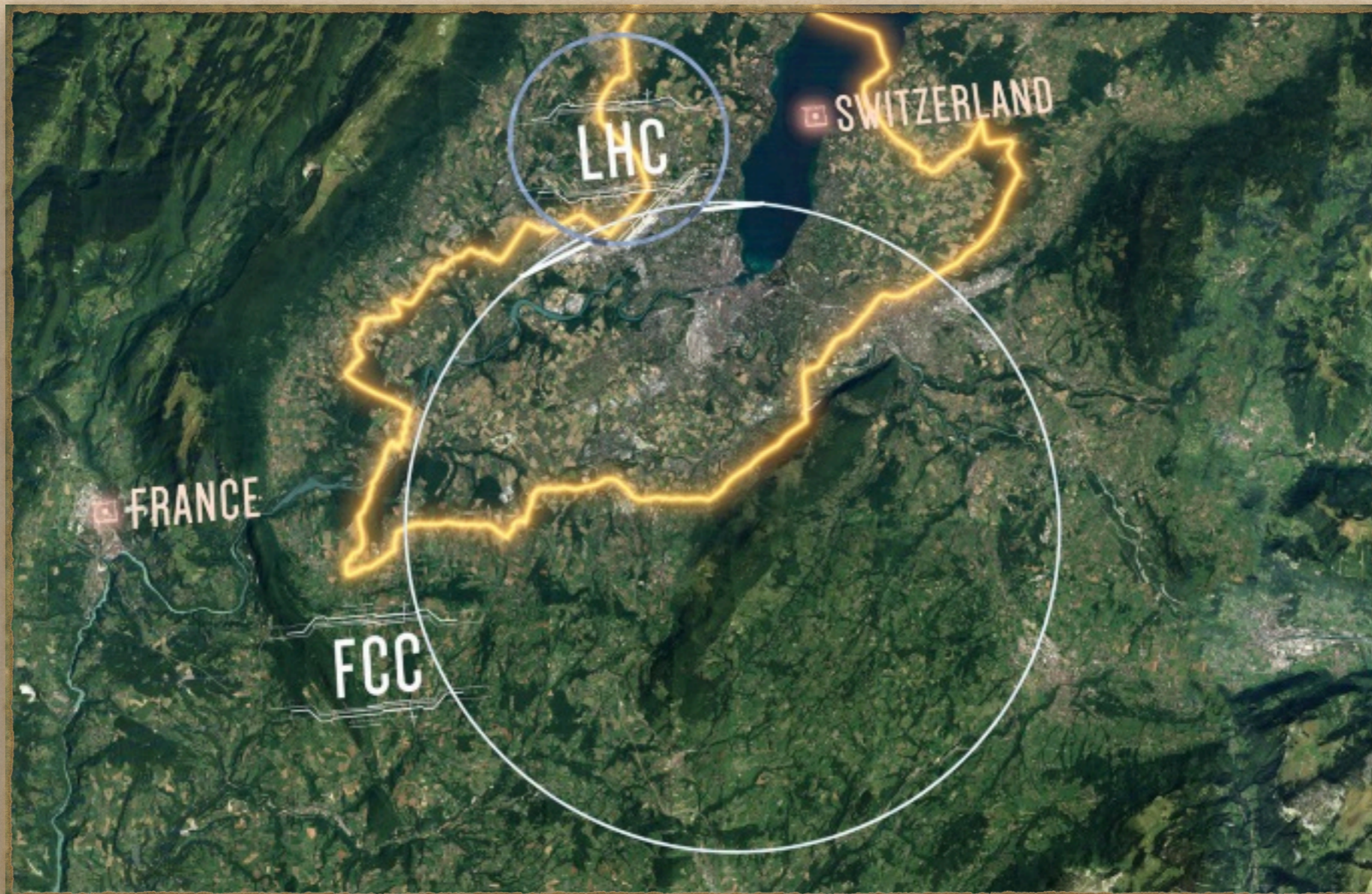


5

De Toekomst

Verbreiding van de zoektocht...

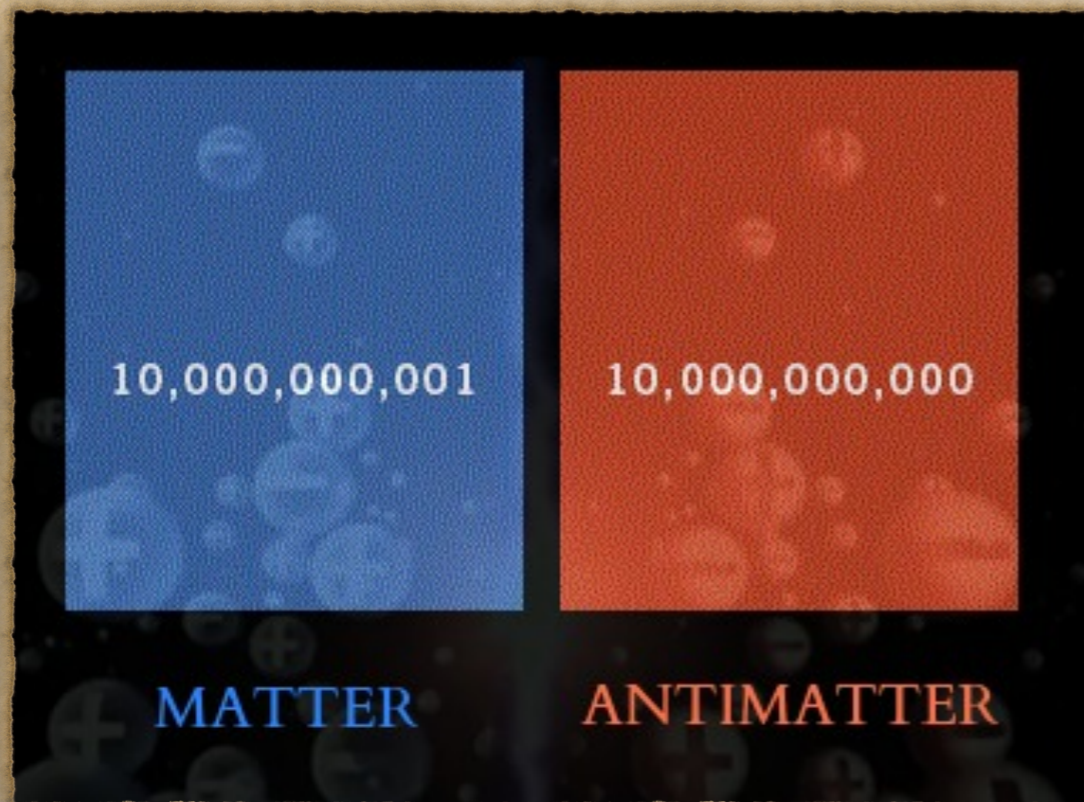
groter, breder, beter



(Anti)Materie Asymmetrie



(Anti)Materie Asymmetrie

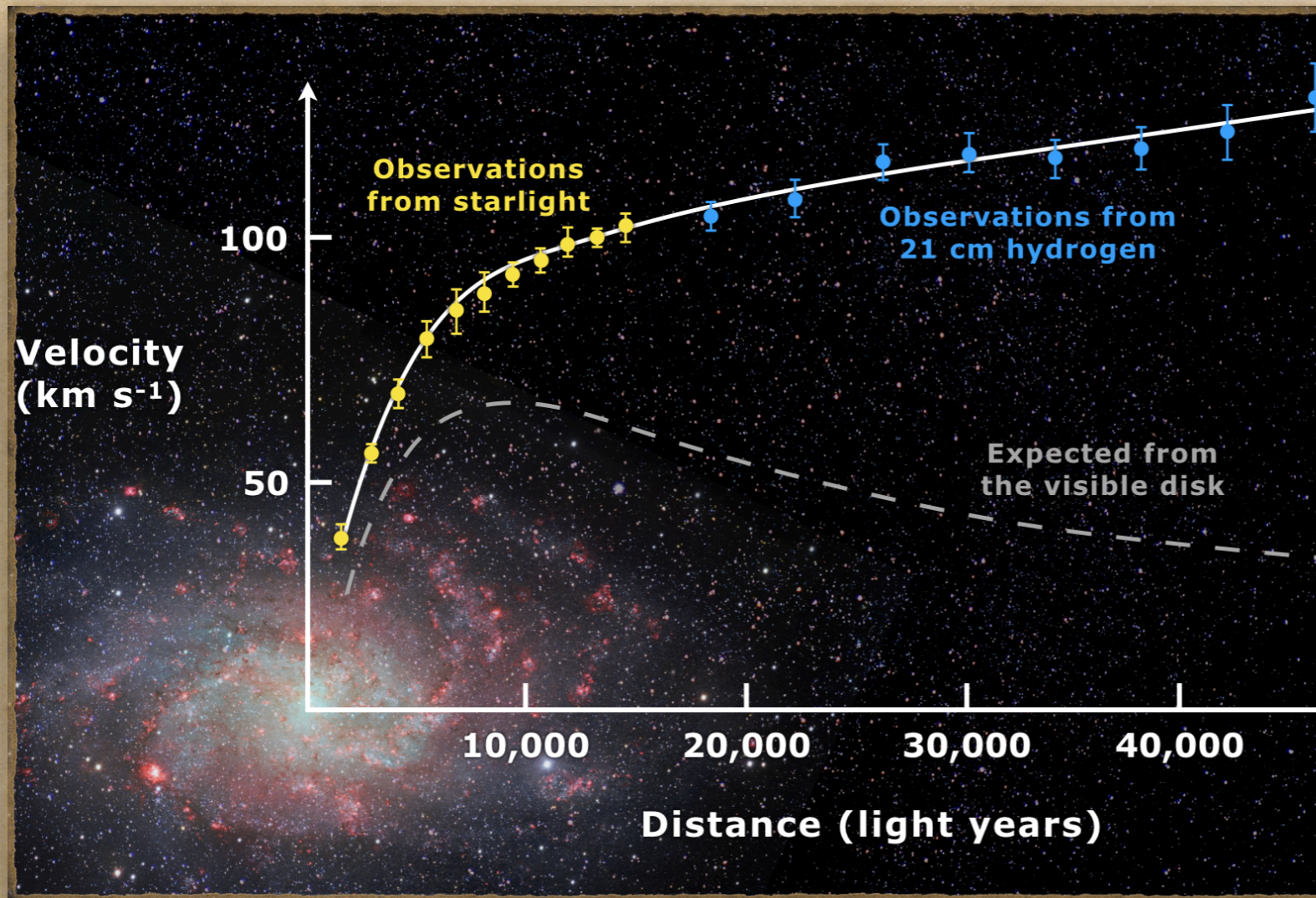


Ergens ver weg verborgen?

Asymmetrisch gecreëerd?

Asymmetrisch verval?

Donkere Materie



~~zwarte gaten?~~

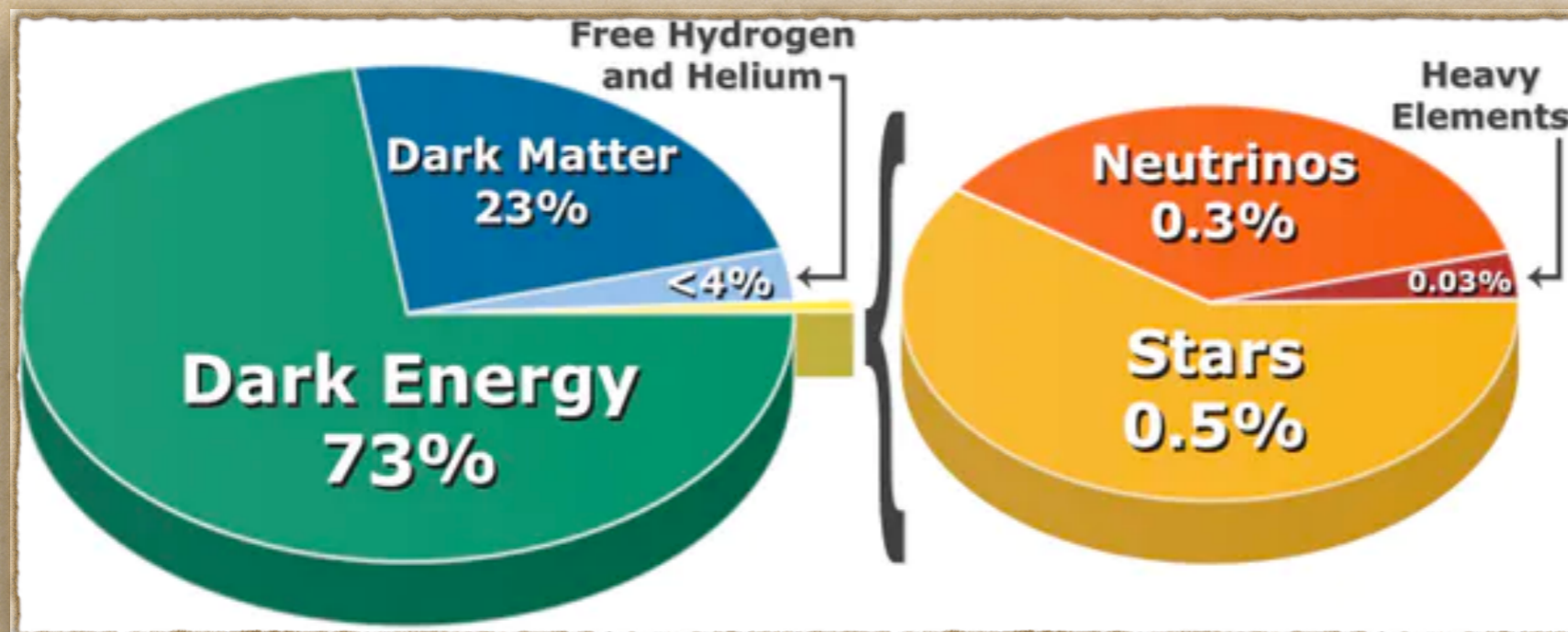
WIMPs?

steriele neutrinos?

Werkt zwaartekracht anders op grote schaal?

Donkere Energie

Variabel-energie veld?

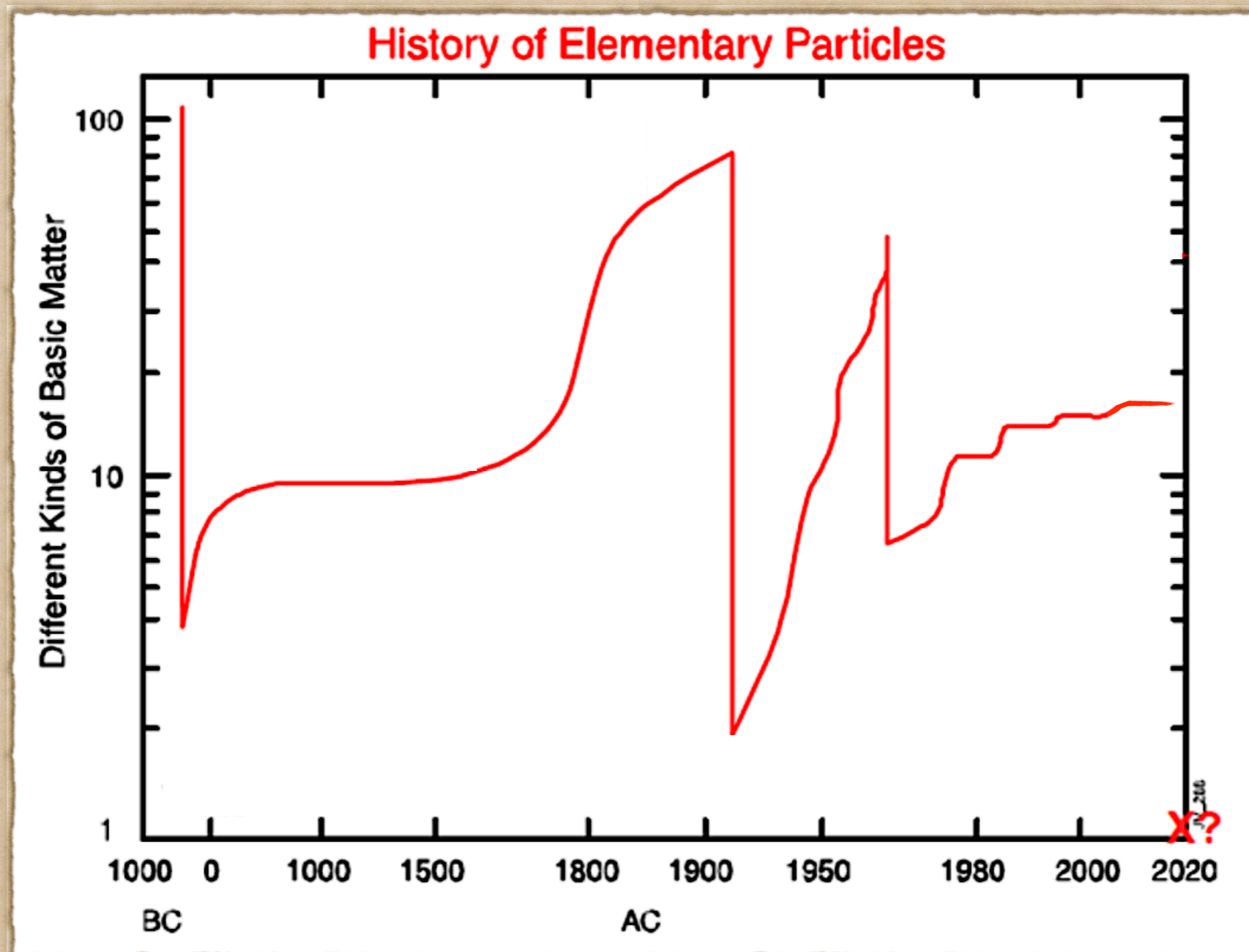


Werkt zwaartekracht anders op grote schaal?

Fundamentele eigenschap van tijdruimte?

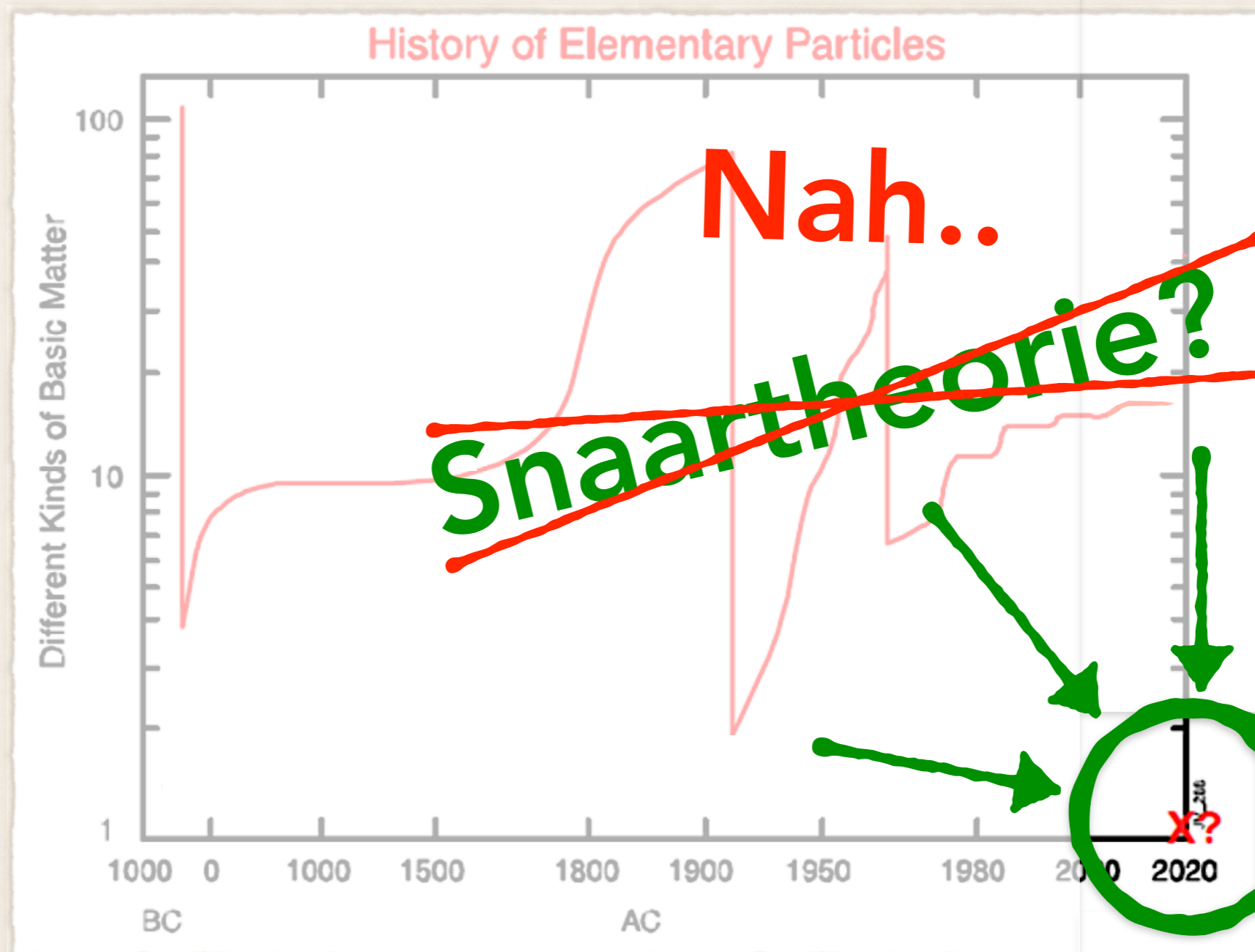
Oh en nog iets..

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