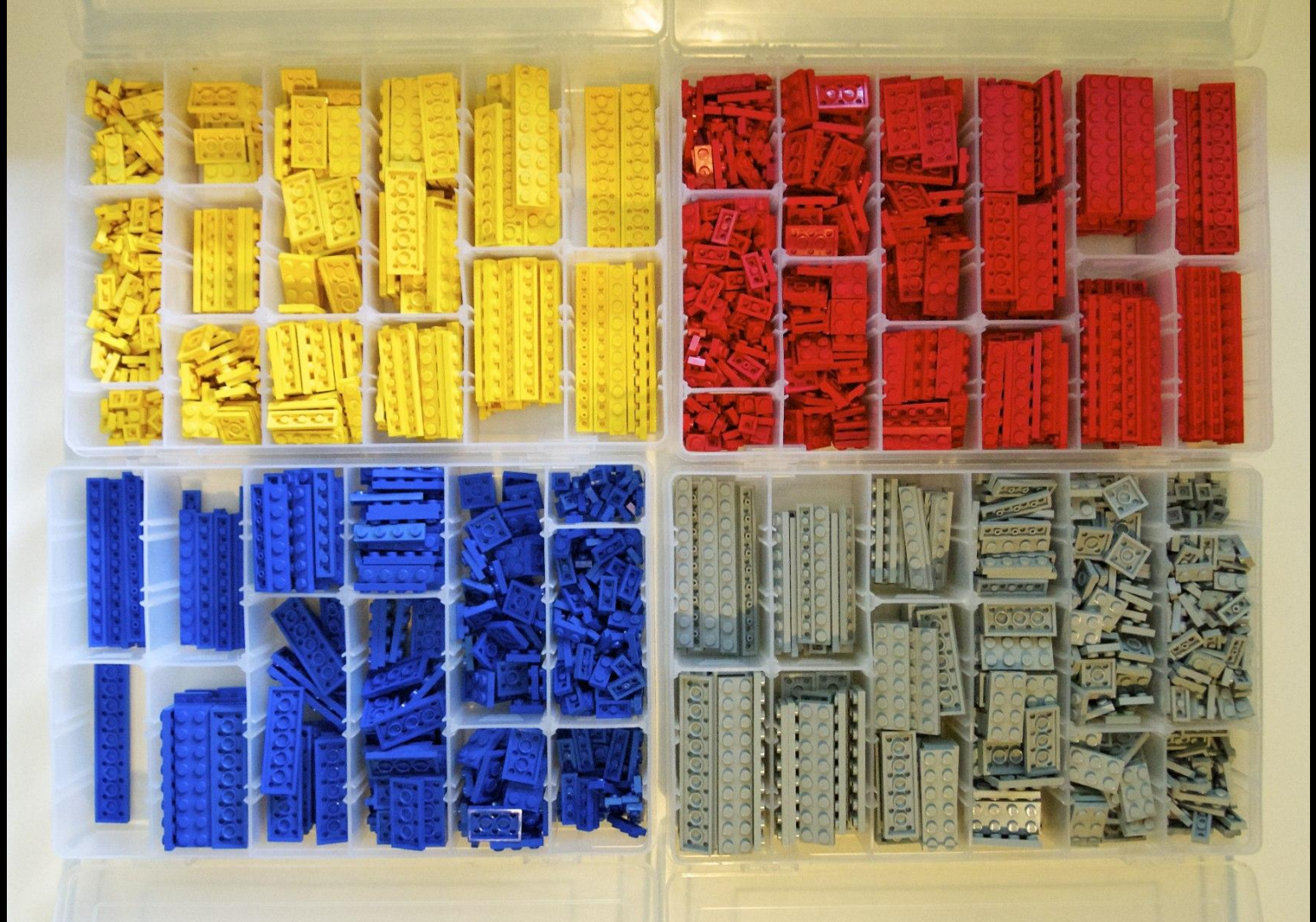
Einführung in die Teilchenphysik

Masterclass 2017

Simon Corrodi


HOTEL
HOTEL
30

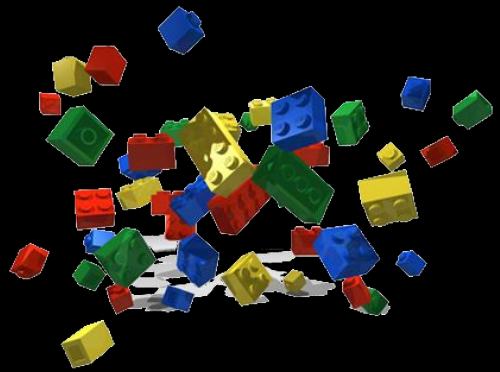


Aufeinanderschiessen

Theorie

Was wird geschehen?

Loch? Explosion?



Vergleichen

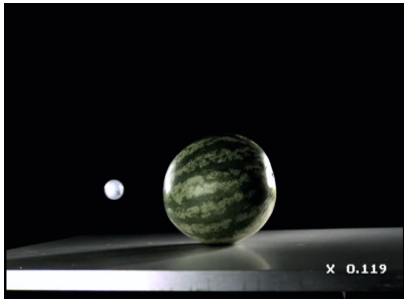
Übersicht

- Aufeinanderschiessen: Beschleuniger (nächste Präsentation)
- Theorie: Das Standard Modell
- Vergleichen: Detektoren (nächste Präsentation)

- Wie gut ist die gezeigte Analogie?
- Worum geht es heute?
- Ok. Und jetzt?

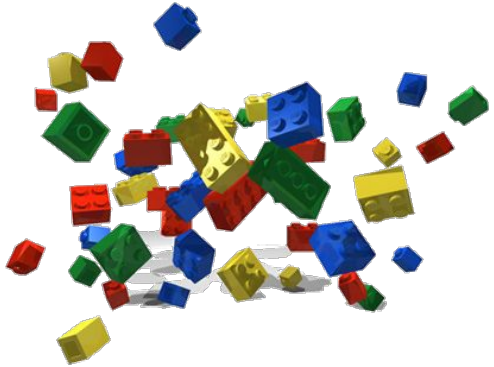
Aufeinanderschiessen

- Was? Teilchen….
- Wie? (nächster Vortrag)



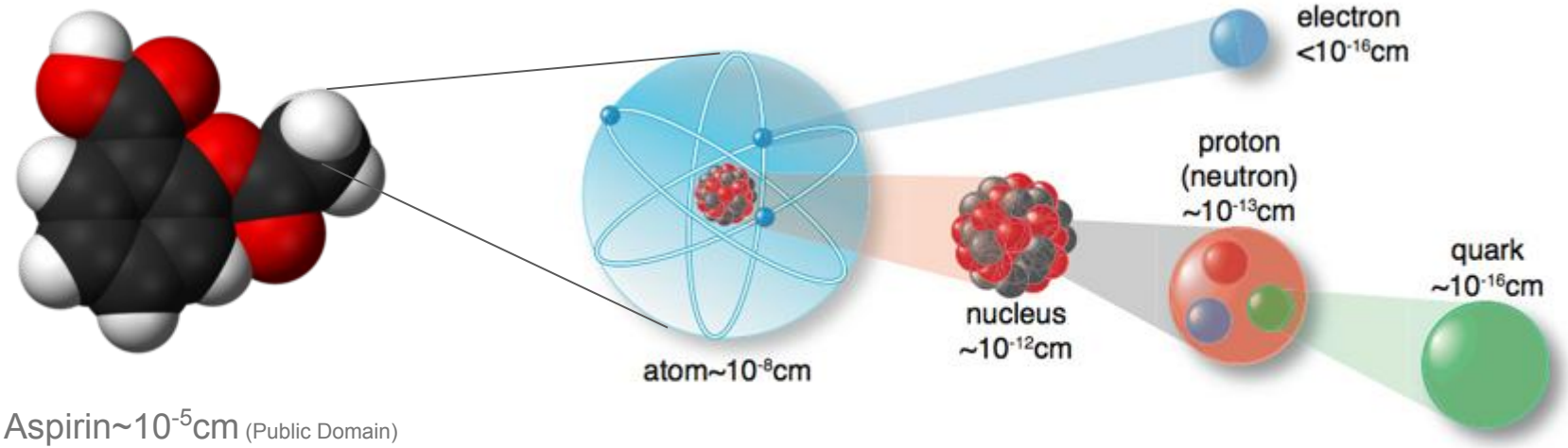
Theorie
Das Standard Modell

Woraus besteht Materie?



- ca. 600 v. Chr.: 4 Elemente
- heute?

Molekül Atom Nukleus **Elementarteilchen**



Aspirin~10^{-5}cm (Public Domain)

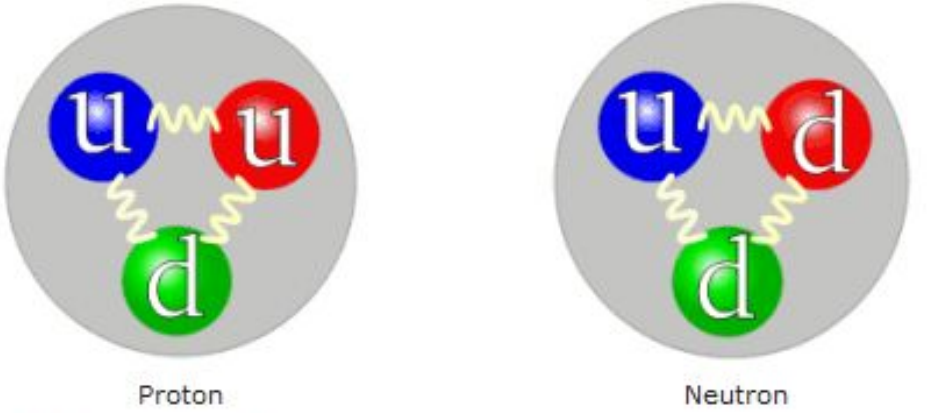
Woraus besteht Materie?

Frage: wie sieht man $<10^{-16}$cm?

Woraus besteht Materie?

Frage: wie sieht man <10^{-16}cm?

Antwort: de Broglie: E ~ 1/λ; hohe Energien

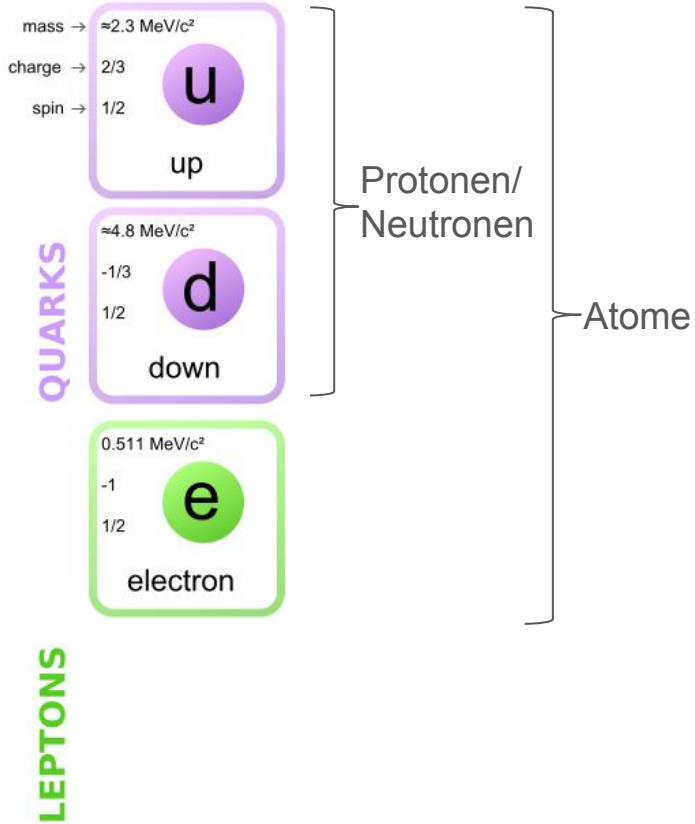


Quark composition of a proton and a neutron (diagrams from *Wikipedia*)

Quarks

- Elementarteilchen
- Ladung:
  - up: +2/3e
  - down: -1/3e
- 3 “Farben”
- nie “alleine”

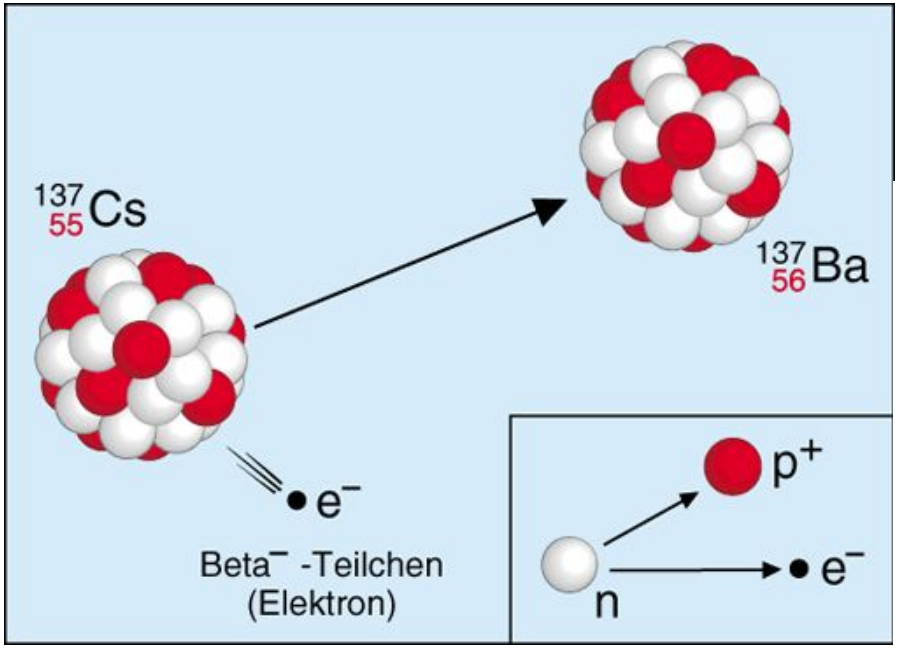
Standard Modell: Teilchen I



Bemerkung

1 MeV/c^2 = 1.78 x 10^{-30} kg

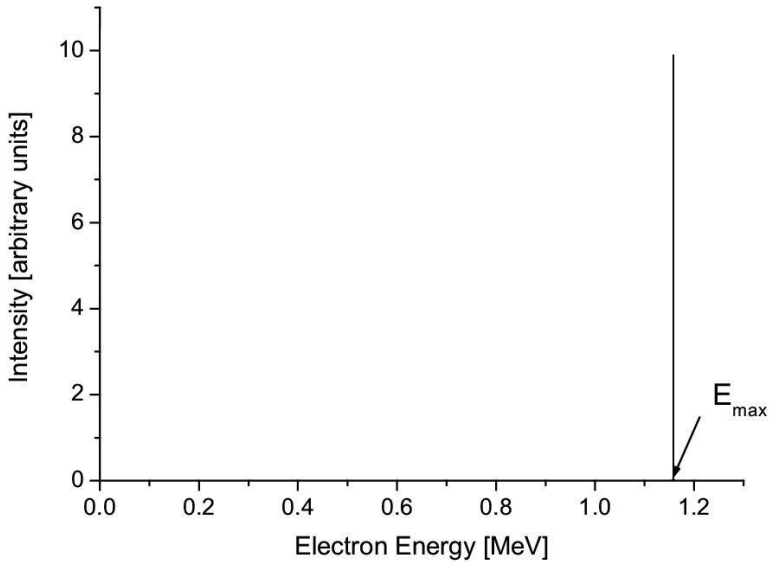
β^--Zerfall



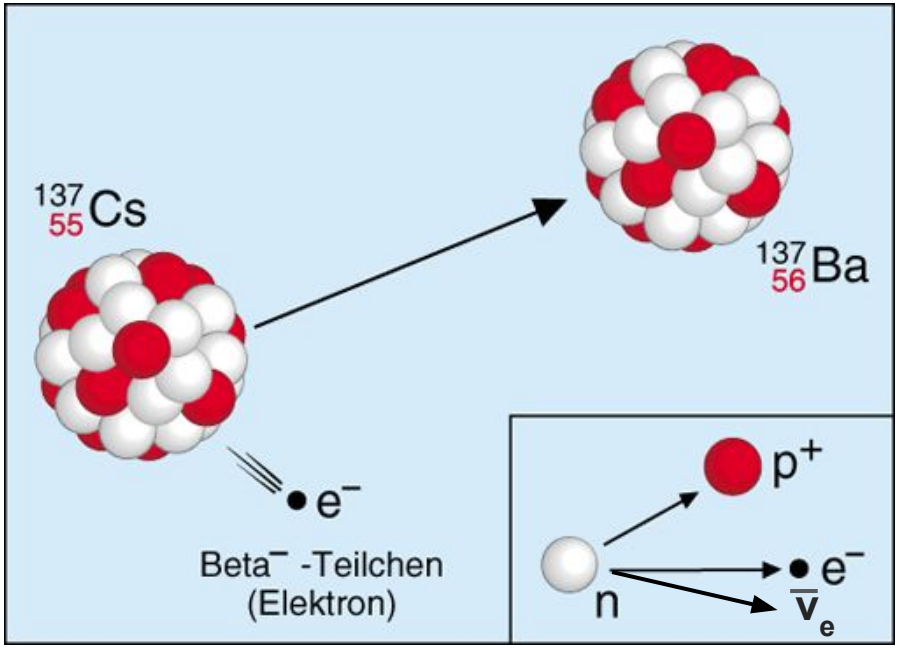
Neutron -> Proton + Elektron

$E_{kin} = m_{Cs} - (m_{Ba} + m_e)$: **konstnat**

2 Teilchen, Impulserhaltung: **“back-to-back”**



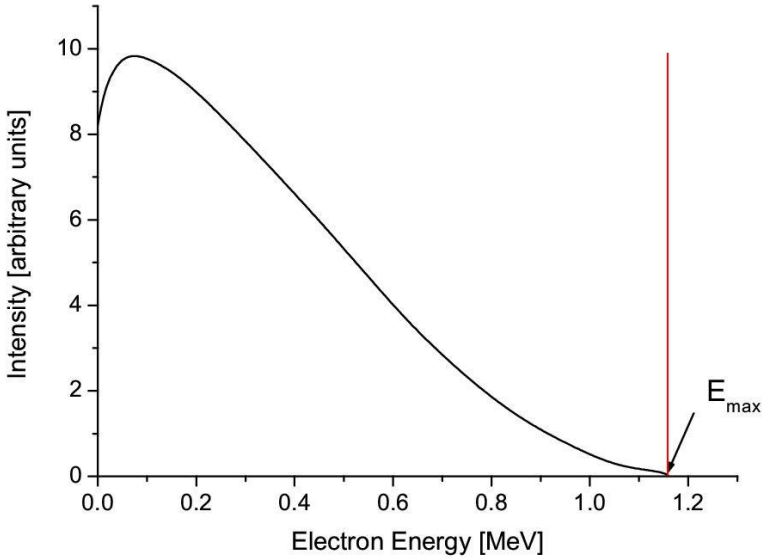
β^--Zerfall



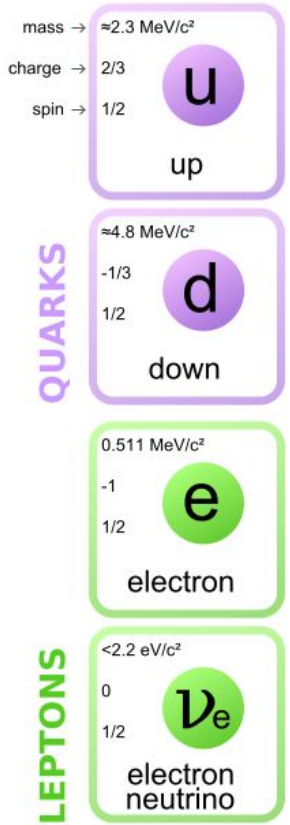
Neutron -> Proton + Elektron
+ *Neutrino*

$E_{kin} = m_{Cs} - (m_{Ba} + m_e)$: **konstnat**

~~2 Teilchen~~, Impulserhaltung: **~~"back-to-back"~~**



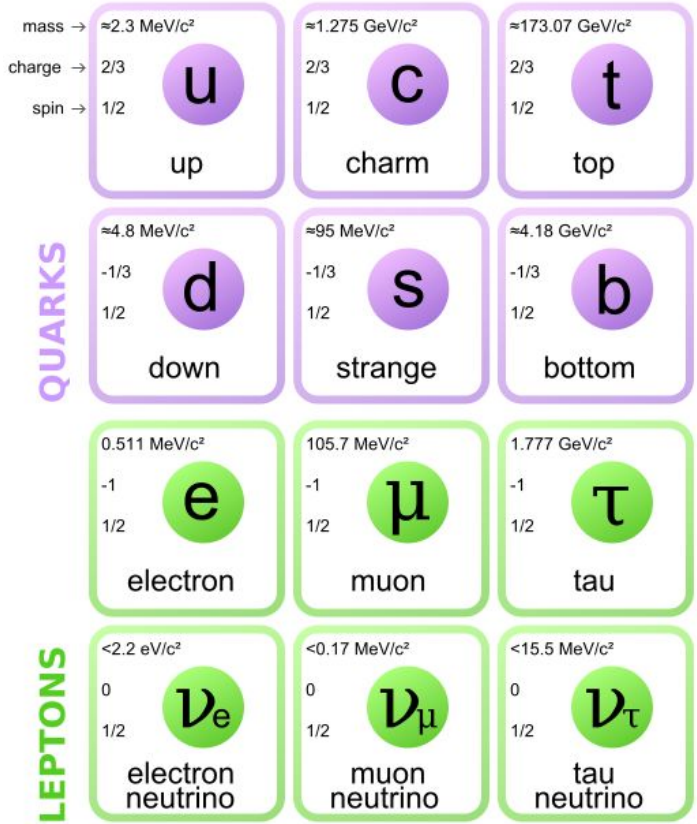
Standard Modell: Neutrinos



Neutrino

- Elementarteilchen
- Ladung: 0
- Masse: sehr klein
  nicht 0

Standard Modell: Familien



Frage:

Wieso sehen wir fast ausschliesslich u, d (Protonen, Neutronen) und e (Elektronen)?

Antwort:

a) Neutrino kaum Interaktion
b) Nicht stabil, Zerfall

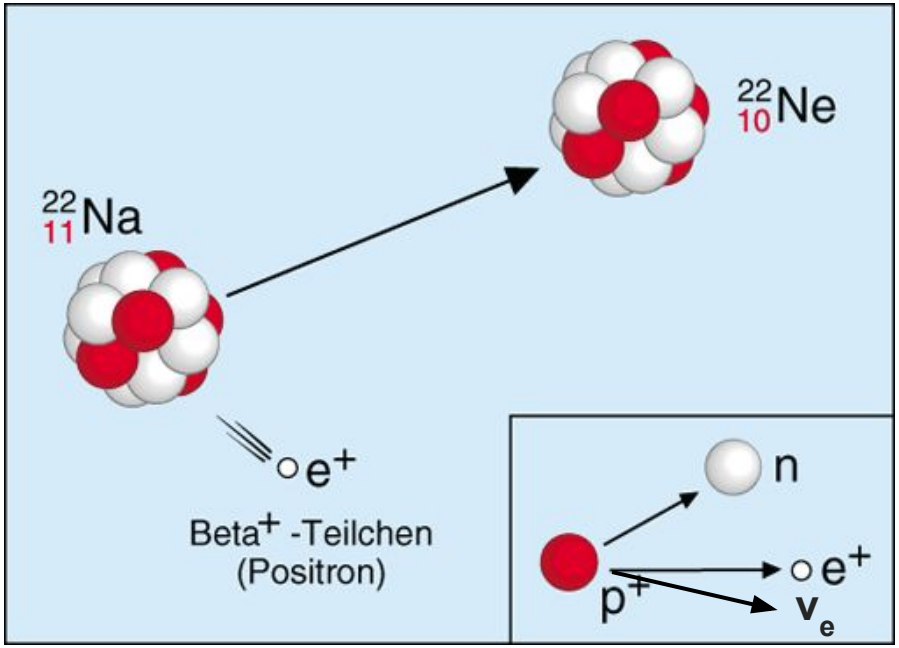
Frage:

Wieso gibt es 3 “Familien”

Antwort:

???

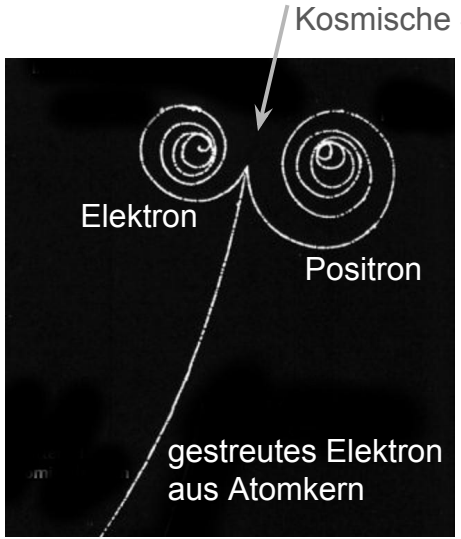
β^+-Zerfall



Proton -> Neutron + *Positron*
+ Neutrino

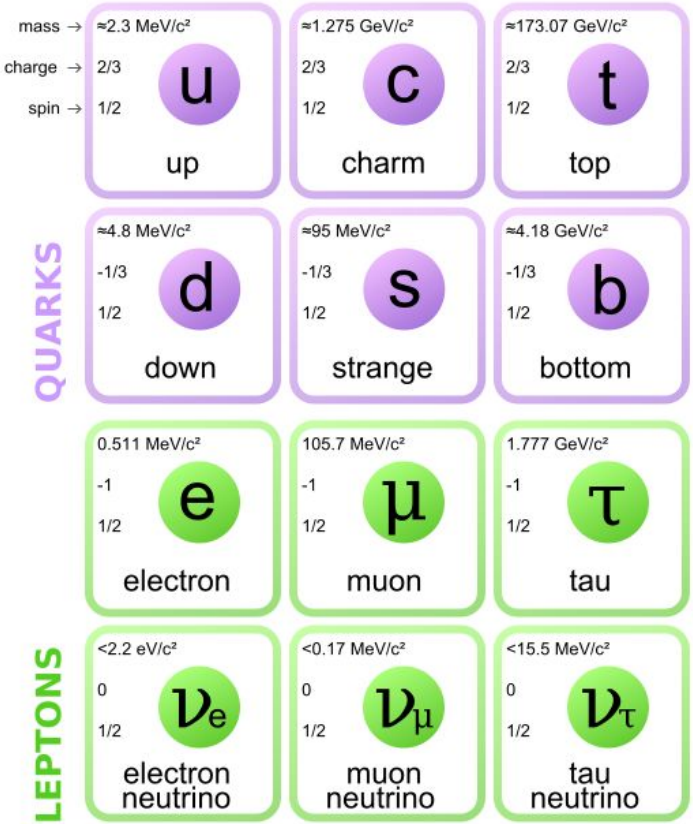
Positron (e^+) = Anti-Elektron ($\overline{e^-}$)

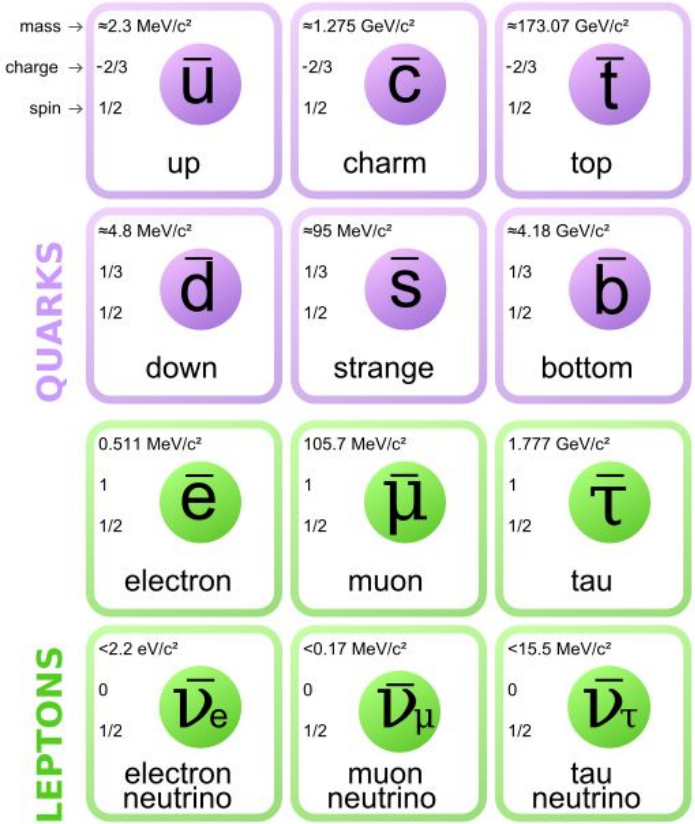
Lorentzkraft: $\mathbf{F}_L = q\mathbf{v} \times \mathbf{B}$



Blasenkammer e^+/e^- Paar

Standard Modell: Anti-Teilchen





Wie interagieren Teilchen? Kräfte

Gravitation (Schwerkraft)

Planetenbahnen, Gewichtkraft

- nur positiv
- Reichweite: ∞

Elektromagnetische Kraft

Licht, Elektrizität, Magnetismus,
Elektronen um den Kern -> Chemie

- positiv/negativ
- Reichweite: ∞

Schwache Wechselwirkung

Beta-Zerfall, Fusion (Sonne),
Leptonen <-> Quarks

- Reichweite: klein (~10^{-16}cm)

Starke Wechselwirkung

Zusammenhalt der Protonen/Neutronen,
Quarks <-> Quarks

- Reichweite: speziell

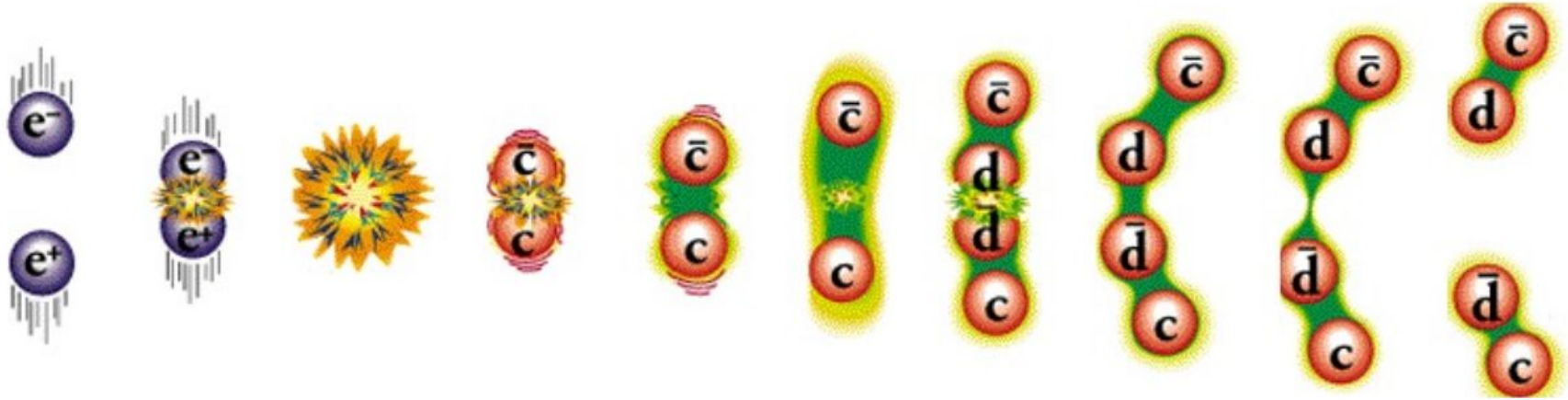
Starke Wechselwirkung

“bekannte Kräfte” (Elektromagnetisch, Gravitation)

$F \sim 1/r^2$

Starke Wechselwirkung

stärker je weiter die Teilchen auseinander, Vorstellung: Gummi-Band



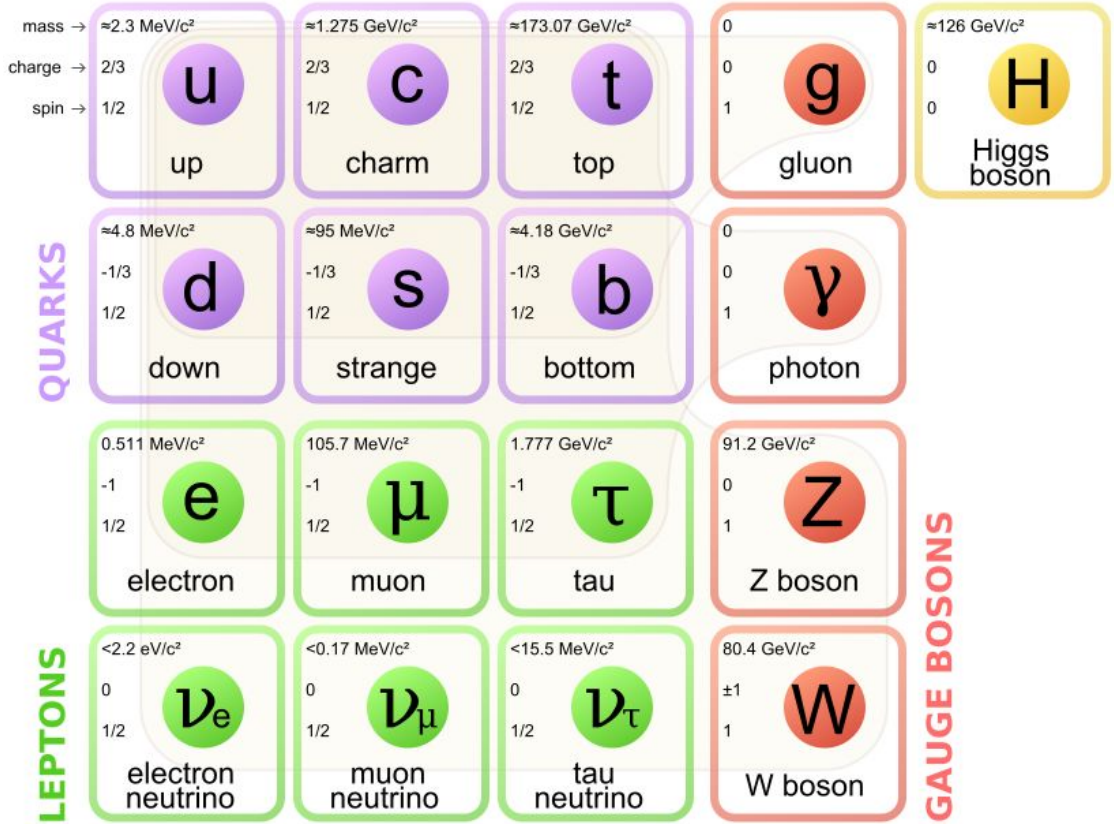
Grund weshalb es keine freien Quarks gibt

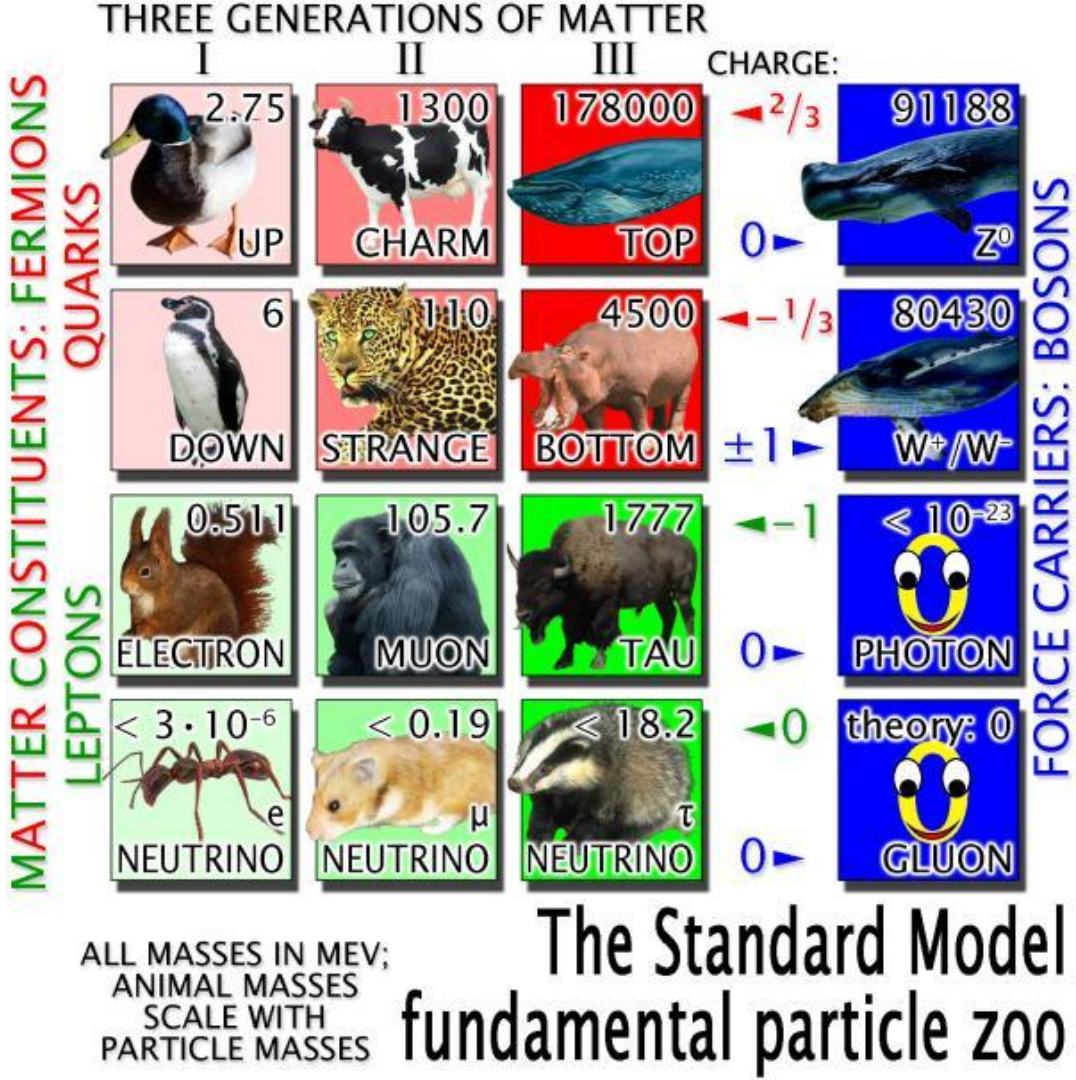
“Botenteilchen”: Bosonen

Wechselwirkungen werden durch “Botenteilchen” (Bosonen) vermittelt.

Wechselwirkung	**Teilchen (Boson)**	***Ladung***	***Relative Stärke***
Elektromagnetisch	Photon (γ)	*elektisch*	10^{-2}
Schwach	W^+, W^-, Z^0	*“schwach”*	10^{-15}
Stark	Gluon (g)	*Farbe*	*1*
Gravitation	Graviton?	*Masse*	10^{-41}

Standard Modell Teilchen





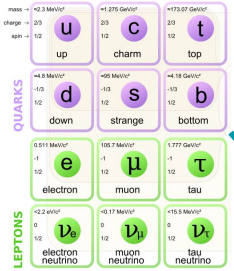
http://teoriasperturbativas.wikidot.com/blog:9

$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

$$+ i \bar{\chi} \not{D} \chi + \text{h.c.}$$

$$+ \chi_i y_{ij} \chi_j \phi + \text{h.c.}$$

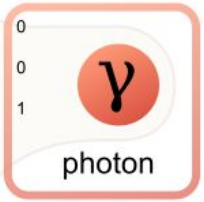
$$+ |D_\mu \phi|^2 - V(\phi)$$

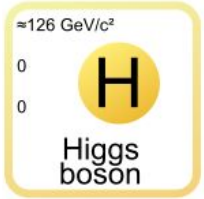


Elektroschwache Wechselwirkung

$$
\begin{aligned}
&1\quad -\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 - \\
&2\quad 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^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^-] - \\
&\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)^2 H^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} M Z^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^\lambda_e) e^\lambda - \bar{\nu}^\lambda \gamma \partial \nu^\lambda - \bar{u}^\lambda_j (\gamma\partial + m^\lambda_u) u^\lambda_j - \\
&3\quad \bar{d}^\lambda_j (\gamma\partial + m^\lambda_d) 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^\lambda_e}{M} [-\phi^+ (\bar{\nu}^\lambda (1-\gamma^5) e^\lambda) + \phi^- (\bar{e}^\lambda (1+\gamma^5) \nu^\lambda)] - \\
&4\quad \tfrac{g}{2}\tfrac{m^\lambda_e}{M} [H(\bar{e}^\lambda e^\lambda) + 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^\lambda_u (\bar{u}^\lambda_j C_{\lambda\kappa} (1+\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} (1- \\
&\gamma^5) u^\kappa_j] - \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}\tfrac{m^\lambda_d}{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 - \\
&5\quad \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{aligned}
$$

Starke Wechselwirkung





http://www.symmetrymagazine.org/article/the-deconstructed-standard-model-equation

Theory: Das Standard Modell

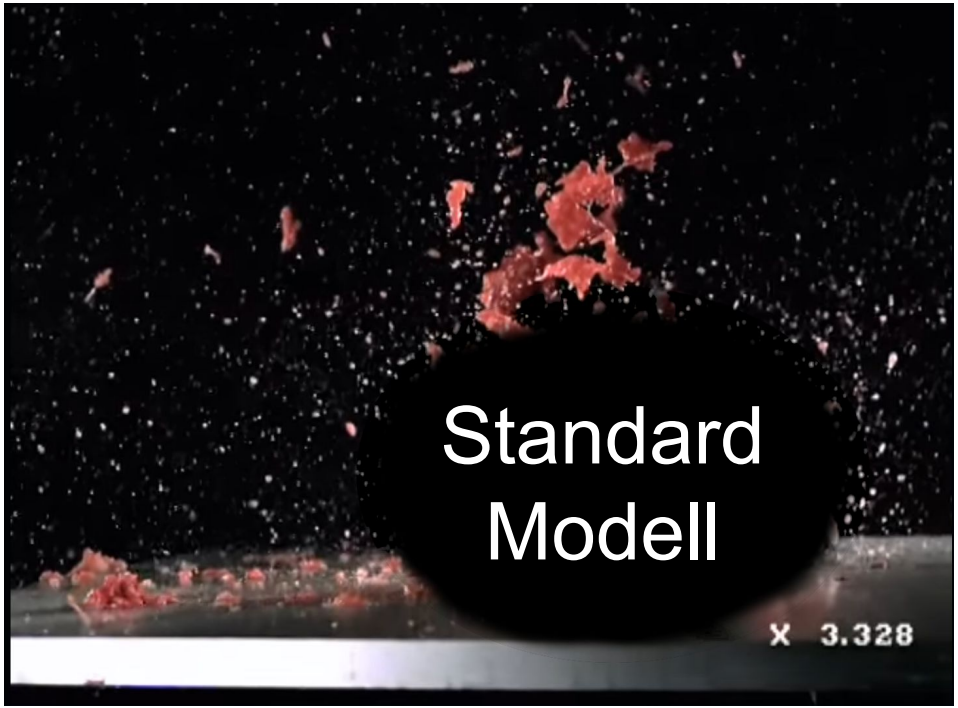
- Elementarteilchen
- Wechselwirkungen (ausser Gravitation)
- 26 freie Parameter (z.B. $m_{Higgs,}$ m_Z)

- kompatibel mit der speziellen Relativitätstheorie
- sehr gut getestet: Bsp $g_{Elektron}$

  Gemessen: $g_{Elektron}$ = -2.002319304361 82(52)

  Theorie: $g_{Elektron}$ = -2.0023193048(8)

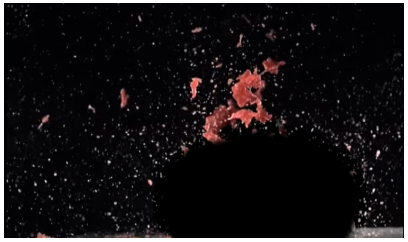
Theorie

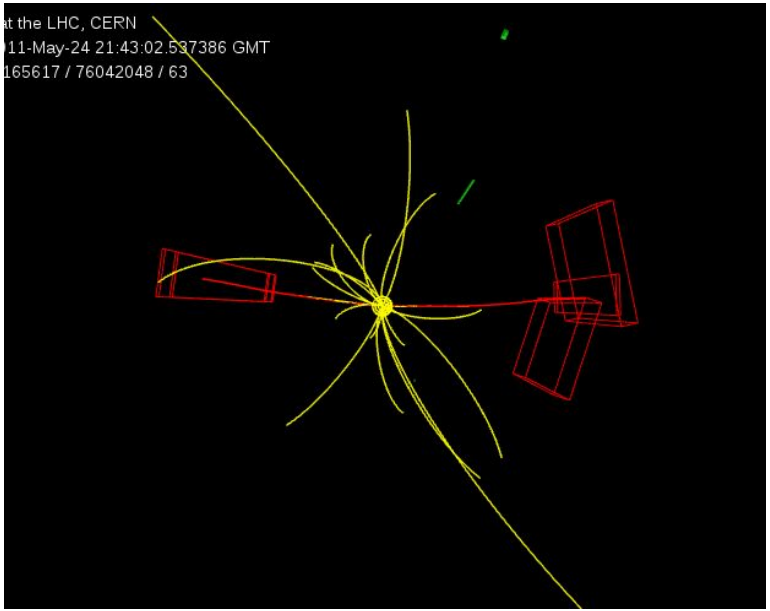


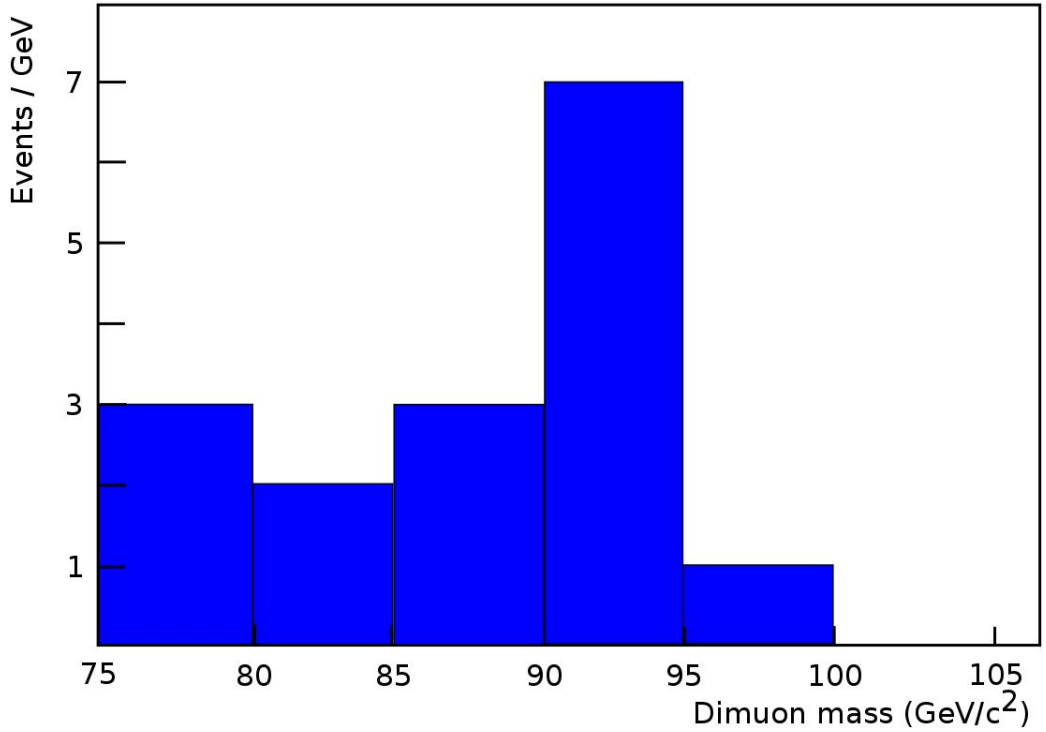
Vergleichen

Selektion: 2 muonen

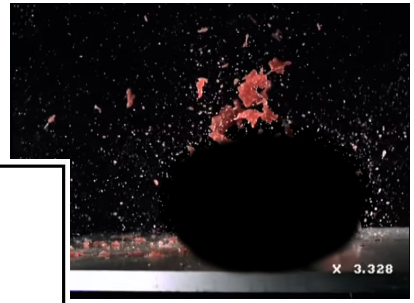
Grösse: Energie/Masse ($E=mc^2$)

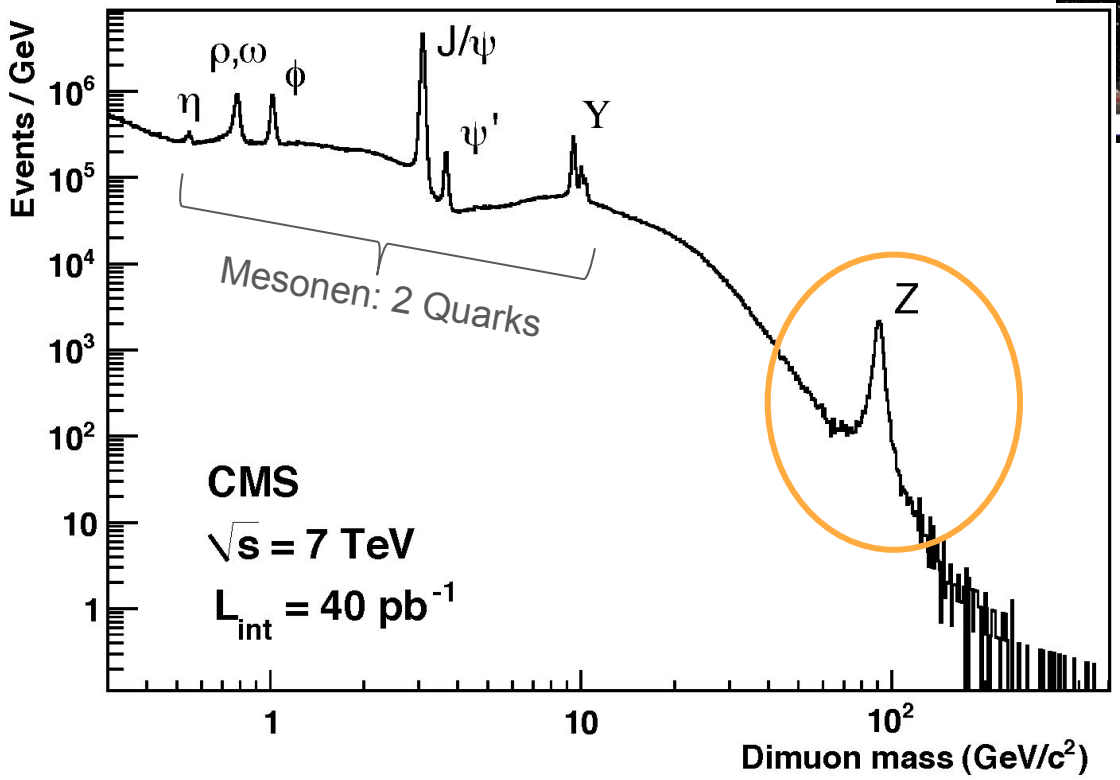




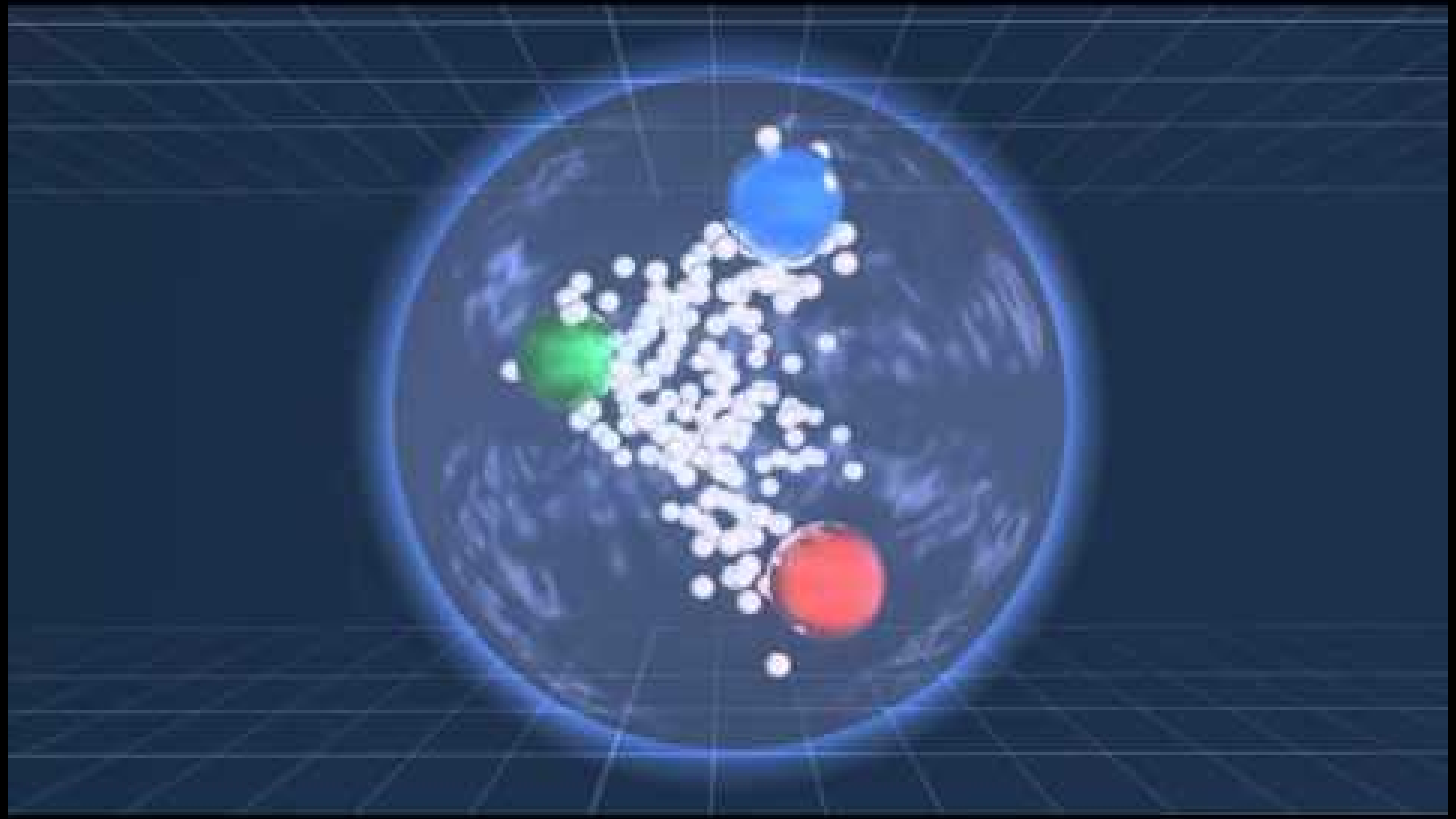


Vergleichen





Wie gut ist die
“Golfball - Melonen” Analogie?



Wie gut ist die Analogie?

Golfball <-> Melone

ganze Objekte kollidieren

Melone wird “zerrissen”, die Teile werden verteilt

relativ langsam

Proton <-> Proton

einzelne Quarks kollidieren

Quark/Anti-Quark erzeugen ein neues Objekt

Energy <-> Masse

Einstein: $E^2 = (mc^2)^2 + (pc)^2$

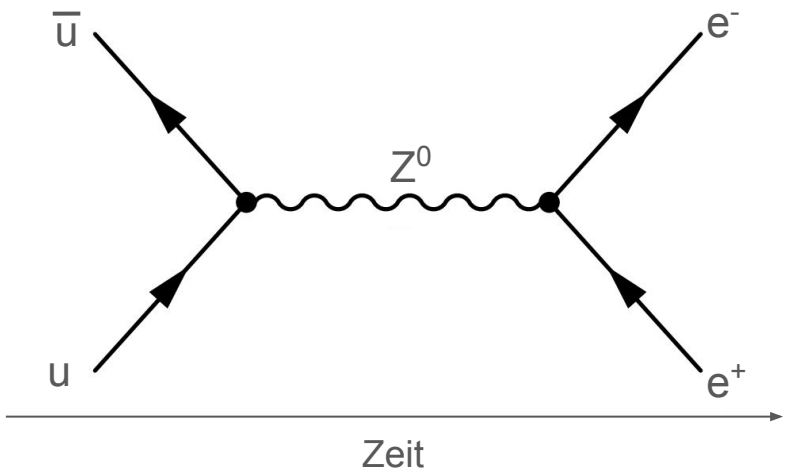
(m: Masse, p: Impuls, c: Lichtgeschwindigkeit)

sehr schnell -> viel Energie für neue Teilchen

Heute:
W- und Z-Bosonen
Standard Modell Test

Heute: W- und Z-Bosonen

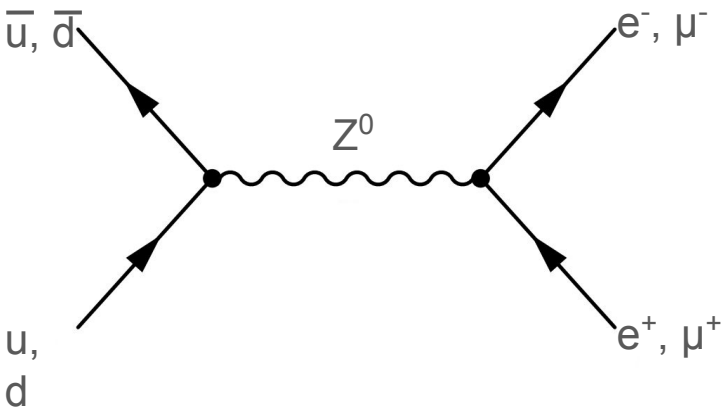
was kann passieren? was schauen wir uns an? was können wir testen?



- “von Links nach Rechts”
- Quark + Anti-Quark -> Z^0
- Z^0 zerfällt sofort in e^+/e^-

Z^0-Boson -> 2 Leptonen

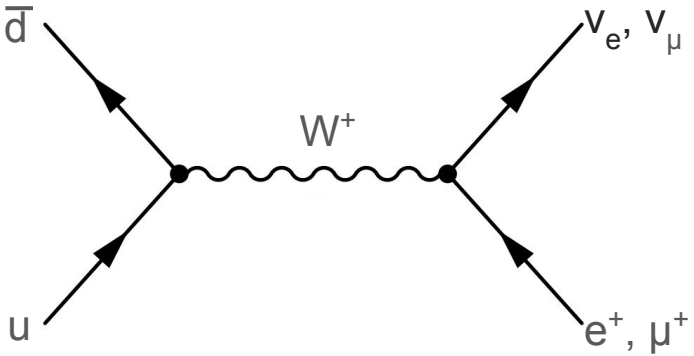
Z^0 zerfällt sofort: im Detektor sehen wir Leptonen (e/μ)



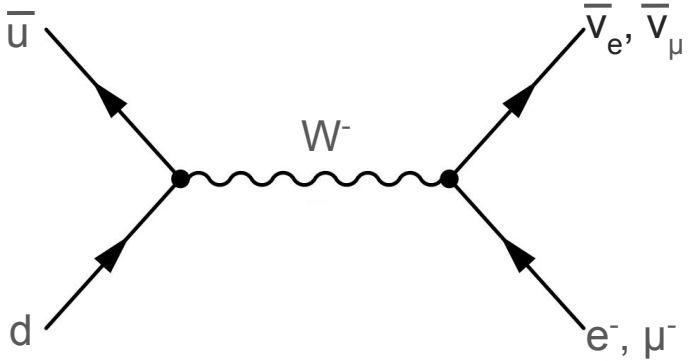
- Quark + Anti-Quark: Ladung 0
- Z^0: Ladung 0
- e^+/e^- oder μ^+/μ^-: Ladung 0

$W^{-/+}$-Boson -> 1 Lepton

$W^{+/-}$ zerfallen sofort, Neutrinos sind “unsichtbar” für den Detektor
im Detektor sehen wir Leptonen (e/μ)



- Up(2/3) + Anti-Down(1/3): Ladung +
- W^+: Ladung +
- e^+/ν_e oder μ^+/ν_μ: Ladung +



- Down(-1/3) + Anti-Up(-2/3): Ladung -
- W^-: Ladung -
- $e^-/\overline{\nu}_e$ oder $\mu^-/\overline{\nu}_\mu$: Ladung -

Heute: Was testen/messen wir?

Standard Modell Vorhersagen:

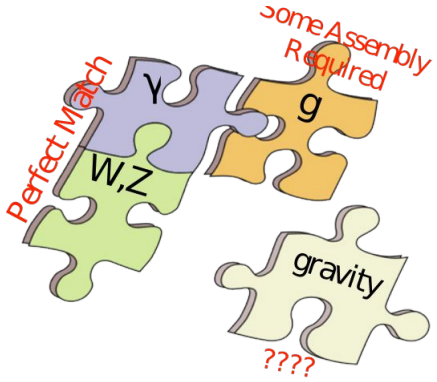
- Verhältnis von Zerfällen nach e und μ (W- und Z-Bosonen)
- Verhältnis von produzierten W^+ und W^-
- Verhältnis von produzierten Z^0 und $W^{+/-}$

Freier Parameter im Standard Modell:

- Masse Z^0

Ok. Und jetzt?

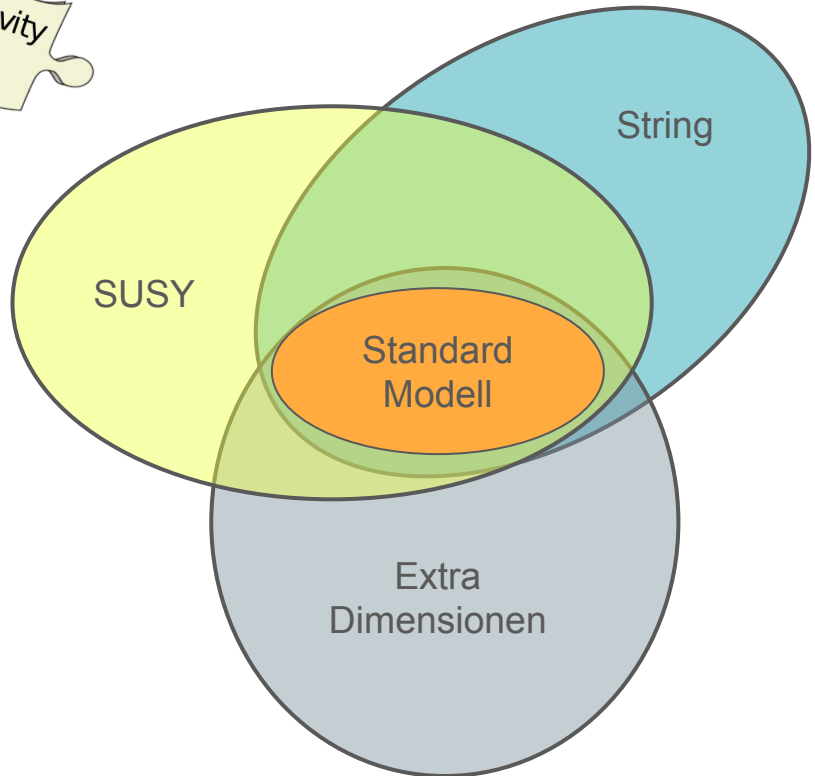
Ok. Und jetzt?



Fragen

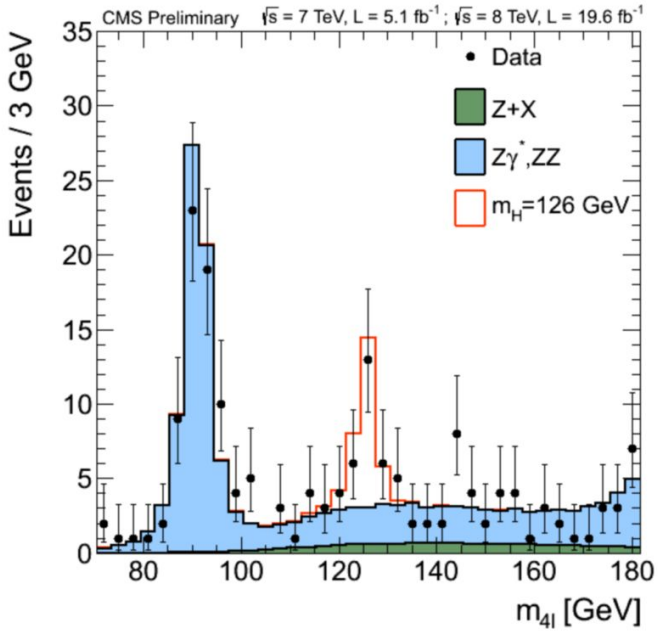
wie passt **Gravitation** ins Bild?
wieso 26 freie Parameter?
wieso sind diese so verschieden? (Naturalness)
wieso 3 Familien?
wieso gibt es mehr **Materie als Anti-Materie**?
wieso dehnt sich das Universum aus?
was ist **dunkle Materie**?
was ist dunkle Energie?
wie viele Dimensionen gibt es?
wieso ist “**fine-tuning**” notwendig?

viele neuen Theorien

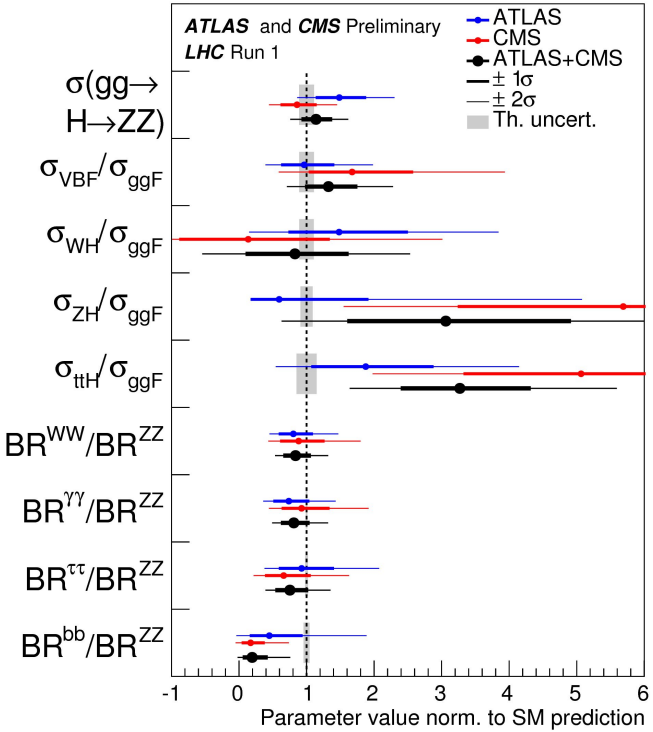


Ok. Und jetzt?

Direkt (neue Teilchen)



Indirekt (stimmt irgend etwas nicht?)



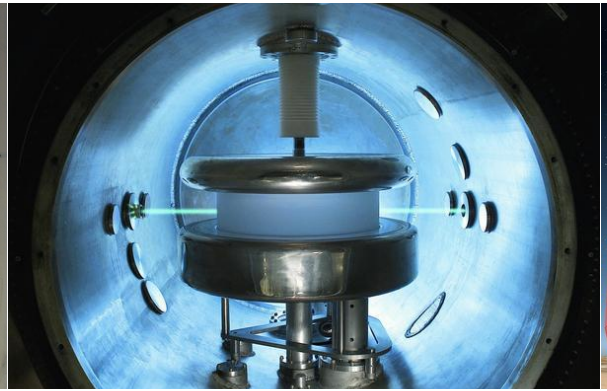
Ok. Und jetzt?

Hohe Energien (~13 TeV)

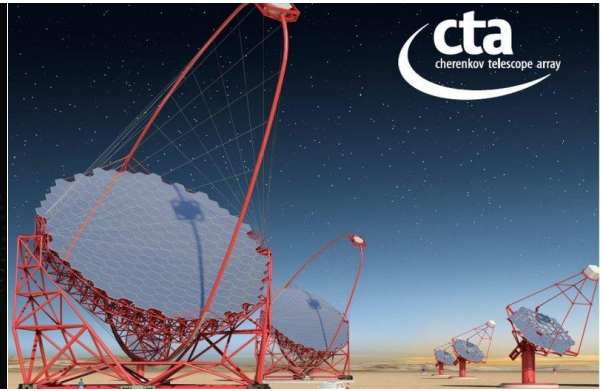
Hohe Intensitäten
(Präzision, ~MeV)

Kosmisch Strahlung

CERN: **Beschleuniger**
neue Teilchen?
(nächster Vortrag)



nEDM (PSI, Villigen)
stimmt was nicht?
elektrische Dipolmoment des Neutrons



CTA Teleskop
Cherenkov Telescope Array
Teilchen kosmischen Ursprungs

Fragen?

Bildnachweis

Golfball - Melone: https://youtu.be/fogo9NQ1g6A
CERN Tunnel: http://lhc-machine-outreach.web.cern.ch/lhc-machine-outreach/images/cern-photos/CE0085M.jpg
Molekül: http://www.pharma-select.net/s/cc_images/cache_2421886599.png (public domain)
Atom Grössen: http://www.ipp.phys.ethz.ch/outreach/particle-physics--a-brief-review.html
Standard Modell:
https://en.wikipedia.org/wiki/Standard_Model#/media/File:Standard_Model_of_Elementary_Particles.svg
Standard Modell Tiere:http://teoriasperturbativas.wdfiles.com/local--files/blog:9/SM.jpg
Quarks: https://upload.wikimedia.org/wikipedia/commons/thumb/9/92/Quark_structure_proton.svg/2000px-Quark_structure_proton.svg.png
Wellen Analogie: https://www.youtube.com/watch?v=RQ95WcCCI9w (Physikshow, Universität Bonn)
Radioactive Decays: https://www.euronuclear.org
Standard Modell Wandtafel: https://cds.cern.ch/record/1561145/files/Formula_image.jpg
Standard Modell: *http://www.symmetrymagazine.org/article/the-deconstructed-standard-model-equation*
Dimuon Spektrum: https://inspirehep.net/record/872180/files/denterria_dimuon_mass_spectrum_cms2010.png
SM Puzzle: “Tricks and Traps: Low Energy Searches for High Energy Physics”, Guy Ron.
Z-Produktion Video: www.cern.ch
Higgs Peak: http://sse.royalsociety.org/summer13/media/18946/cms-data_800.png
Standard Modell Testes: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-044/fig_07.png
nEDM: http://www.ipp.phys.ethz.ch/research/nedm-at-psi/_jcr_content/par/fullwidthimage/image.imageformat.lightbox.537890934.png

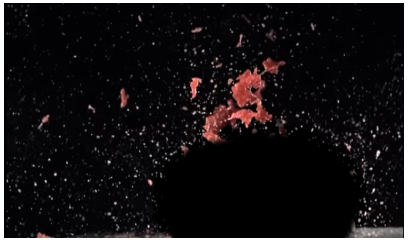

X 1.916

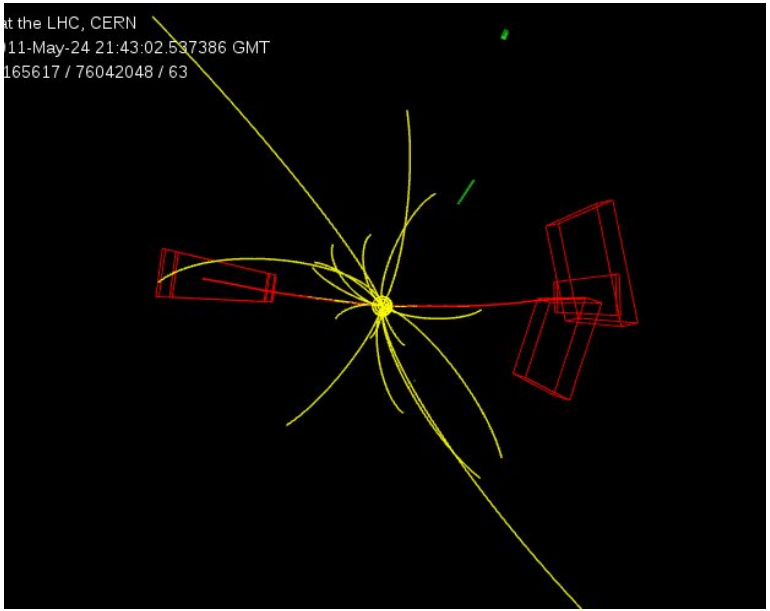
Erinnerung

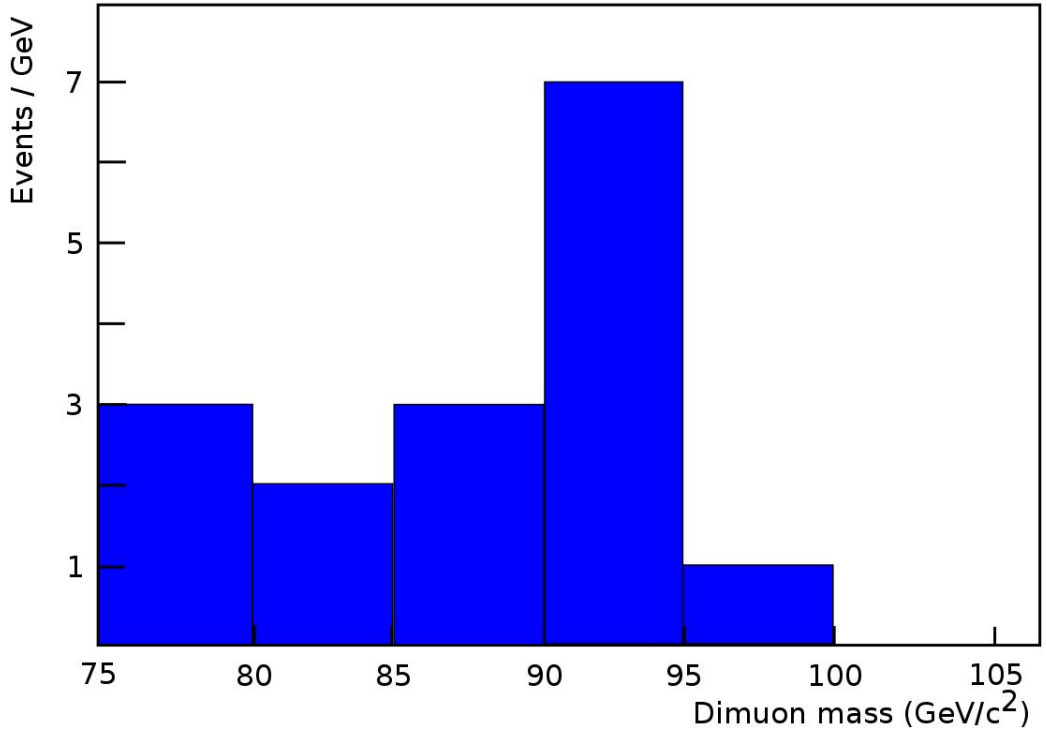
Vergleichen

Selektion: 2 Muonen

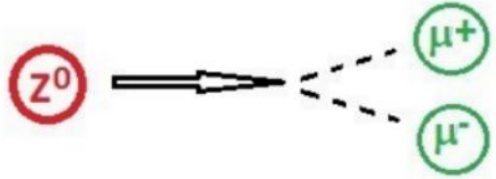
Grösse: Energie/Masse ($E=mc^2$)

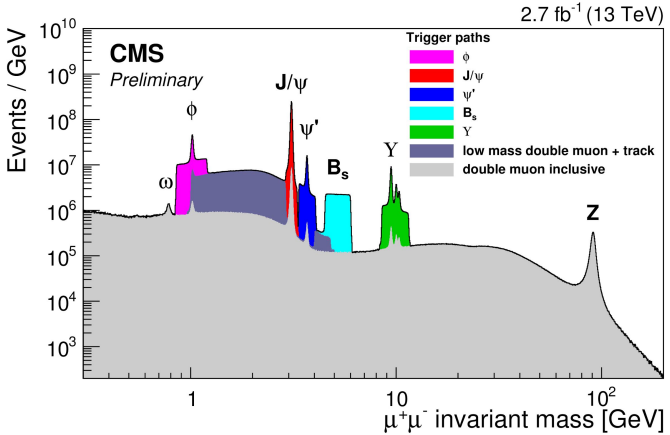






Heute: Daten


Z0
μ+
μ-


2.7 fb-1 (13 TeV)
CMS
Preliminary
Trigger paths
ϕ
J/ψ
ψ'
Bs
Υ
low mass double muon + track
double muon inclusive
Events / GeV
μ+μ- invariant mass [GeV]
ω
ϕ
J/ψ
ψ'
Bs
Υ
Z

Events / (2GeV/c²)

CERN-PH-EP-2012-218

Accepted by: Physics Letters B

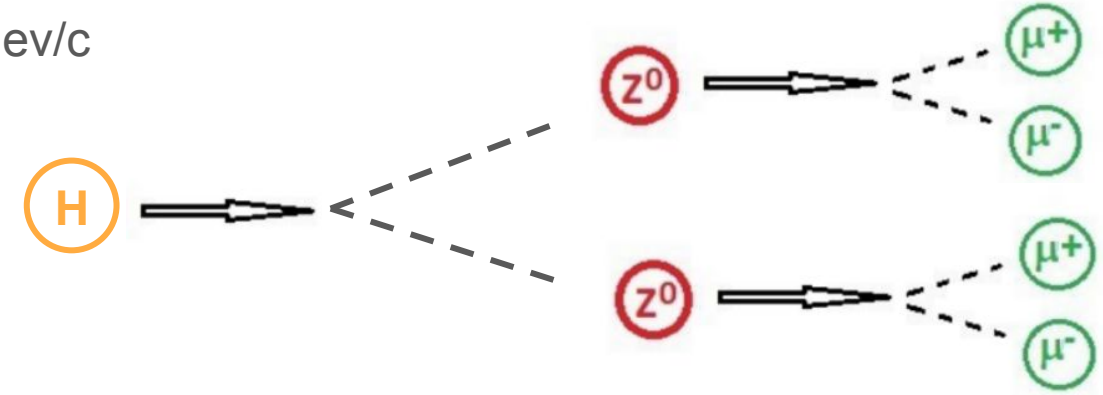
Observation of a New Particle in the Search for the Standard Model Higgs Boson with the ATLAS Detector at the LHC

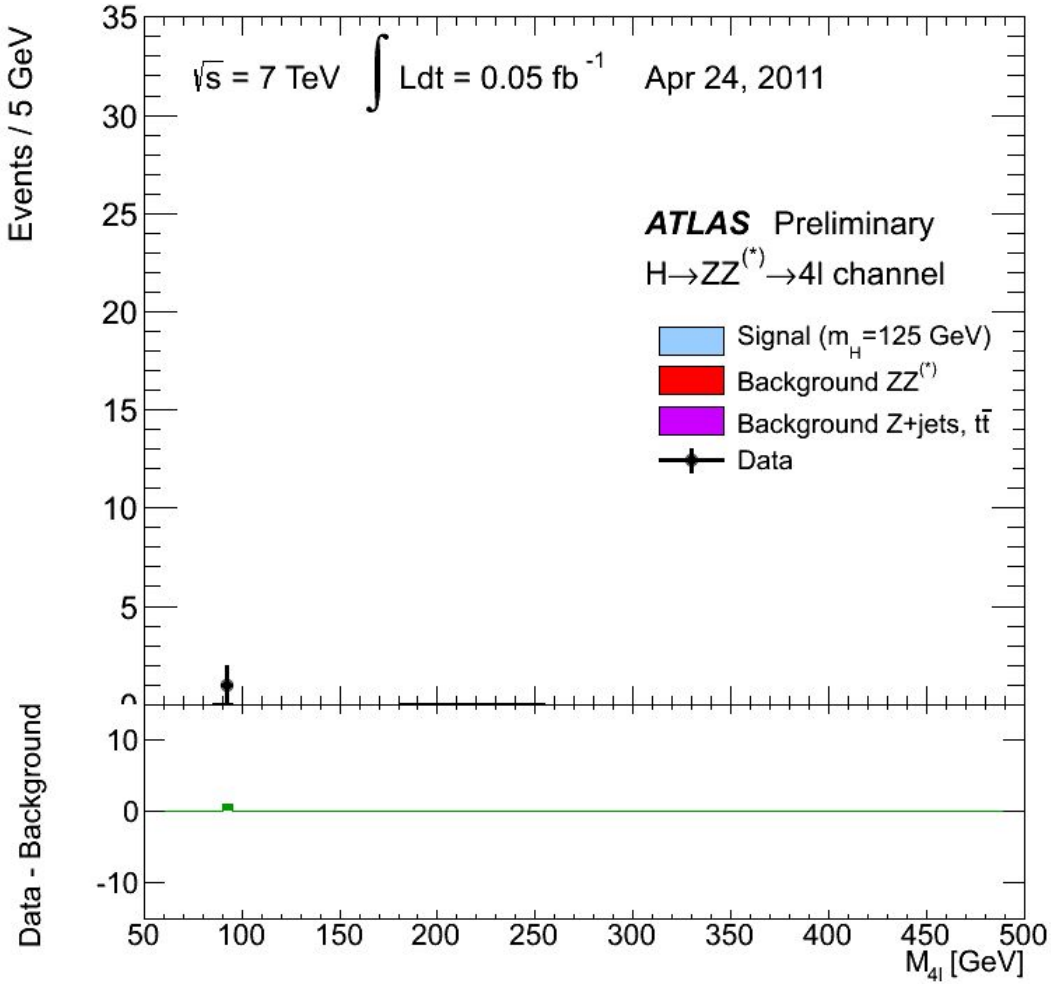
The ATLAS Collaboration

This paper is dedicated to the memory of our ATLAS colleagues who did not live to see the full impact and significance of their contributions to the experiment.

LHC: Higgs Boson

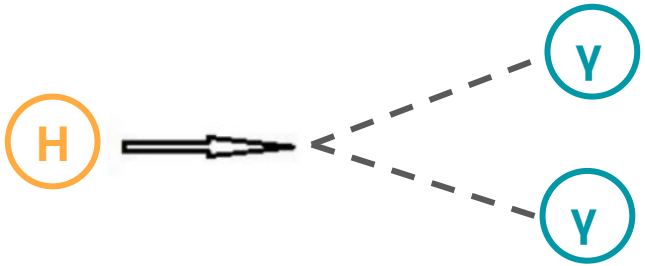
- 2 Muon Paare
- Jeweils +/-
- p = 25Gev/c
- …..




√s = 7 TeV ∫ Ldt = 0.05 fb -1 Apr 24, 2011
ATLAS Preliminary
H→ZZ(*)→4l channel
Signal (mH=125 GeV)
Background ZZ(*)
Background Z+jets, tt̄
Data
Events / 5 GeV
Data - Background
M4l [GeV]

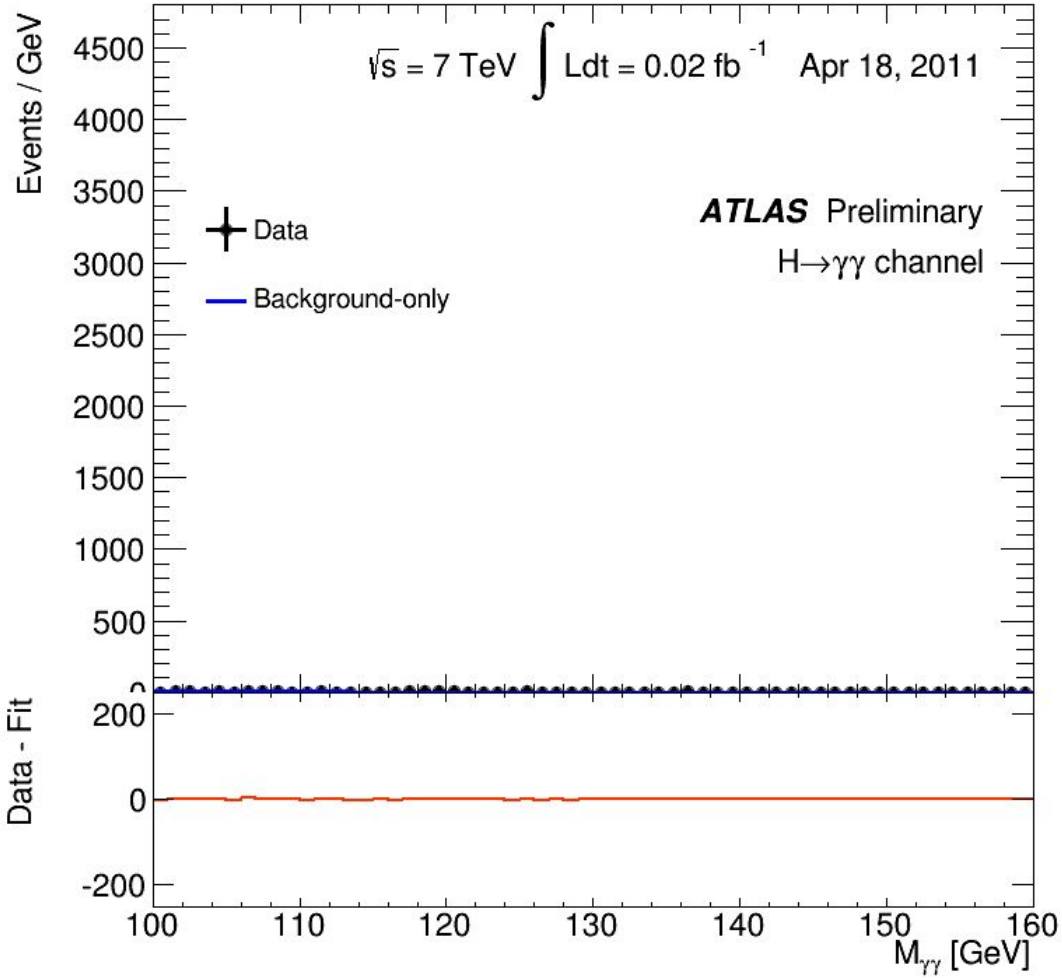
LHC: Higgs Boson

- 2 Photonen
- ….

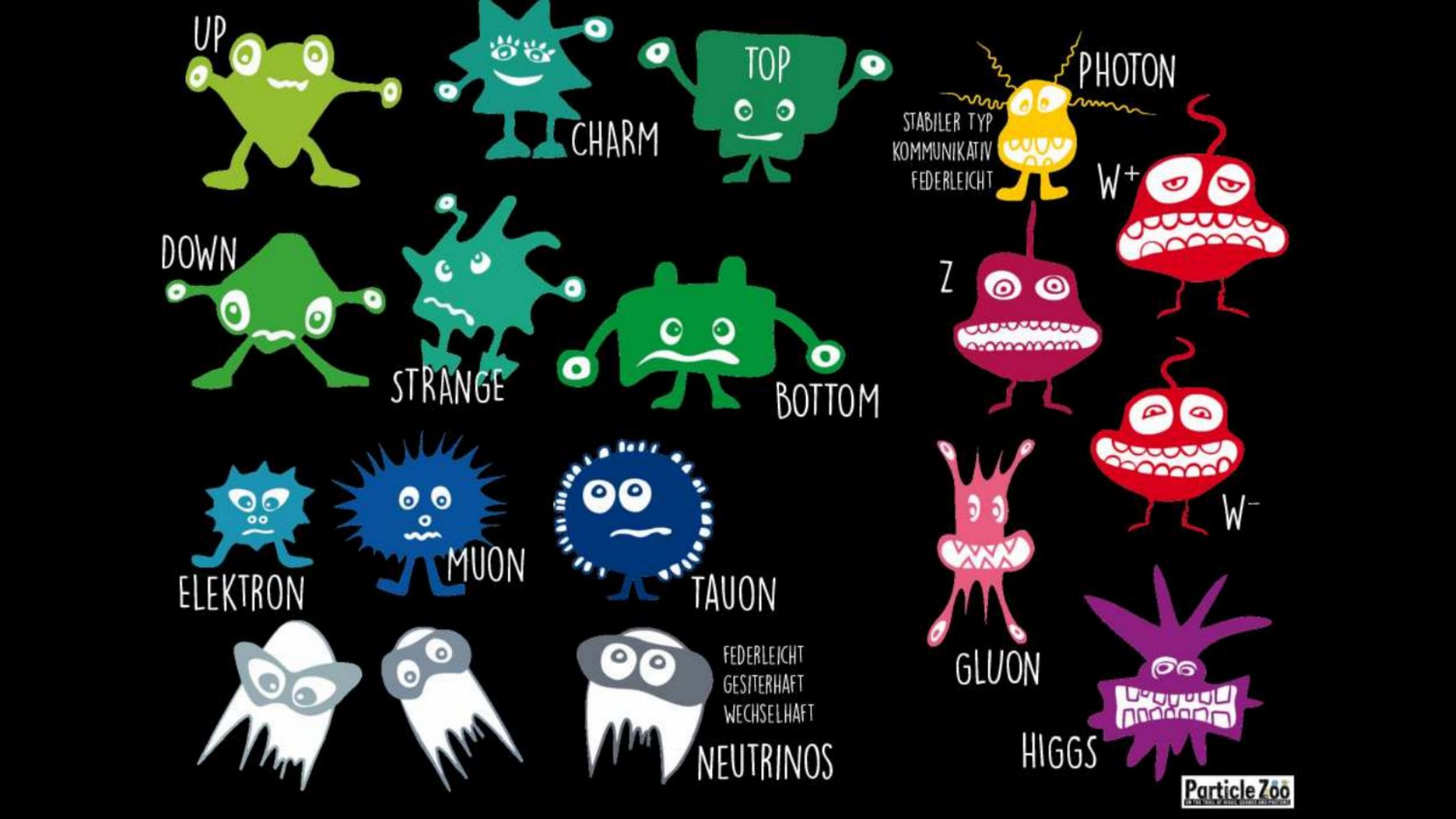


5.1. Event selection

The data used in this channel are selected using a diphoton trigger [96], which requires two clusters formed from energy depositions in the electromagnetic calorimeter. An E_{T} threshold of 20 GeV is applied to each cluster for the 7 TeV data, while for the 8 TeV data the thresholds are increased to 35 GeV on the leading (the highest E_{T}) cluster and to 25 GeV on the subleading (the next-highest E_{T}) cluster. In addition, loose


√s = 7 TeV ∫ Ldt = 0.02 fb -1 Apr 18, 2011
ATLAS Preliminary
H→γγ channel
Data
Background-only
Events / GeV
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Data - Fit
200
0
-200
100
110
120
130
140
150
160
Mγγ [GeV]

Fragen?


UP
CHARM
TOP
PHOTON
STABILER TYP
KOMMUNIKATIV
FEDERLEICHT
W+
DOWN
STRANGE
BOTTOM
Z
W−
ELEKTRON
MUON
TAUON
GLUON
FEDERLEICHT
GESITERHAFT
WECHSELHAFT
NEUTRINOS
HIGGS
ParticleZoo