

Table 1: The particles in the standard model of particle physics
Particle Data Group, 2022

Quarks	t	$172.69 \pm 0.30 \text{ GeV}$	$\bar{t}$	spin= $\frac{1}{2}$	$g = 2 \cdot 3 = 6$	
	b	$4.16\text{--}4.21 \text{ GeV}$	$\bar{b}$	3 colors		
	c	$1.27 \pm 0.02 \text{ GeV}$	$\bar{c}$			
	s	$90\text{--}102 \text{ MeV}$	$\bar{s}$			
	d	$4.50\text{--}5.15 \text{ MeV}$	$\bar{d}$			
	u	$1.90\text{--}2.65 \text{ MeV}$	$\bar{u}$			72
Gluons	8 massless bosons			spin=1	$g = 2$	16
Leptons	τ^-	$1776.86 \pm 0.12 \text{ MeV}$	τ^+	spin= $\frac{1}{2}$	$g = 2$	
	μ^-	105.658 MeV	μ^+			
	e^-	510.999 keV	e^+			12
	ν_τ	$< 1.1 \text{ eV}$	$\bar{\nu}_\tau$	spin= $\frac{1}{2}$	$g = 1$	
	ν_μ	$< 1.1 \text{ eV}$	$\bar{\nu}_\mu$			
	ν_e	$< 1.1 \text{ eV}$	$\bar{\nu}_e$			6
Electroweak gauge bosons	W^+	$80.377 \pm 0.012 \text{ GeV}$	W^-	spin=1	$g = 3$	
	Z^0	$91.1876 \pm 0.0021 \text{ GeV}$				
	γ	$0 \quad (< 1 \times 10^{-18} \text{ eV})$			$g = 2$	11
Higgs boson	H^0	$125.25 \pm 0.17 \text{ GeV}$		spin=0	$g = 1$	1
						$g_f = 72 + 12 + 6 = 90$
						$g_b = 16 + 11 + 1 = 28$
						$g_* = \frac{7}{8}g_f + g_b = 106.75$

Table 2: History of $g_*(T) \equiv 30\rho/(\pi^2 T^4)$

$T \sim 200 \text{ GeV}$	all present	106.75	
$T \sim 100 \text{ GeV}$	EW transition	(no effect)	
$T < 170 \text{ GeV}$	top annihilation	96.25	
$T < 80 \text{ GeV}$	$W^\pm, Z^0, H^0$	86.25	
$T < 4 \text{ GeV}$	bottom	75.75	
$T < 1 \text{ GeV}$	charm, τ^-	61.75	
$T \sim 150 \text{ MeV}$	QCD transition	17.25	(u,d,s,g $\rightarrow \pi^\pm, 0$, $47.5 \rightarrow 3$)
$T < 100 \text{ MeV}$	$\pi^\pm, \pi^0, \mu^-$	10.75	$e^\pm, \nu, \bar{\nu}, \gamma$ left
$T < 500 \text{ keV}$	e^- annihilation	(7.25)	$2 + 5.33(4/11)^{4/3} = 3.38$

Taulukko 1: Standardimallin hiukkaset

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Kvarkit	t	$172.69 \pm 0.30 \text{ GeV}$	$\bar{t}$	spin= $\frac{1}{2}$	$g = 2 \cdot 3 = 6$	
	b	$4.16\text{--}4.21 \text{ GeV}$	$\bar{b}$	3 väriä		
	c	$1.27 \pm 0.02 \text{ GeV}$	$\bar{c}$			
	s	$90\text{--}102 \text{ MeV}$	$\bar{s}$			
	d	$4.50\text{--}5.15 \text{ MeV}$	$\bar{d}$			
	u	$1.90\text{--}2.65 \text{ MeV}$	$\bar{u}$			72
Gluonit	8 massatonta bosonia			spin=1	$g = 2$	16
Leptonit	τ^-	$1776.86 \pm 0.12 \text{ MeV}$	τ^+	spin= $\frac{1}{2}$	$g = 2$	
	μ^-	105.658 MeV	μ^+			
	e^-	510.999 keV	e^+			12
	ν_τ	$< 1.1 \text{ eV}$	$\bar{\nu}_\tau$	spin= $\frac{1}{2}$	$g = 1$	
	ν_μ	$< 1.1 \text{ eV}$	$\bar{\nu}_\mu$			
	ν_e	$< 1.1 \text{ eV}$	$\bar{\nu}_e$			6
Sähköheikot mittabosonit	W^+	$80.377 \pm 0.012 \text{ GeV}$	W^-	spin=1	$g = 3$	
	Z^0	$91.1876 \pm 0.0021 \text{ GeV}$				
	γ	$0 \quad (< 1 \times 10^{-18} \text{ eV})$			$g = 2$	11
Higgsin bosoni	H^0	$125.25 \pm 0.17 \text{ GeV}$		spin=0	$g = 1$	1
						$g_f = 72 + 12 + 6 = 90$
						$g_b = 16 + 11 + 1 = 28$
						$g_* = \frac{7}{8}g_f + g_b = 106.75$

Taulukko 2: $g_*(T)$:n historia

$T \sim 200 \text{ GeV}$	kaikki	106.75	
$T \sim 100 \text{ GeV}$	EW-transitio	(ei vaikutusta)	
$T < 170 \text{ GeV}$	top-annihilaatio	96.25	
$T < 80 \text{ GeV}$	$W^\pm, Z^0, H^0$	86.25	
$T < 4 \text{ GeV}$	b-kvarkki	75.75	
$T < 1 \text{ GeV}$	lumo, τ^-	61.75	
$T \sim 150 \text{ MeV}$	QCD-transitio	17.25	(u,d,s,g $\rightarrow \pi^{\pm,0}$, $47.5 \rightarrow 3$)
$T < 100 \text{ MeV}$	$\pi^\pm, \pi^0, \mu^-$	10.75	$e^\pm, \nu, \bar{\nu}, \gamma$ jäljellä
$T < 500 \text{ keV}$	e^- -annihilaatio	(7.25)	$2 + 5.33(4/11)^{4/3} = 3.38$