

It's a (Particle) zoo out there!

(A quick tour of the Standard Model of Particle Physics)

Alex Wright

Institute of Particle Physics and Queen's University

"Astronomy on Tap"

24 September 2020

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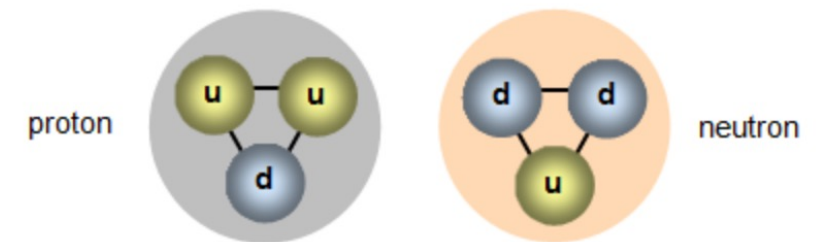
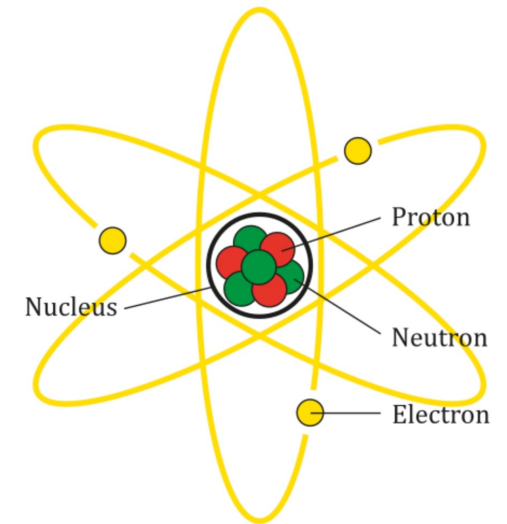
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The “Elementary” Particles

1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Cesium	56 Ba Barium		72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium		104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium



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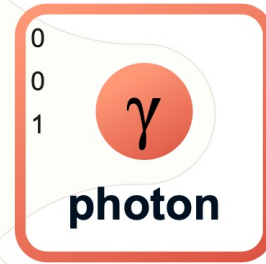
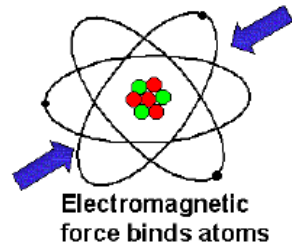


The Elementary Particles

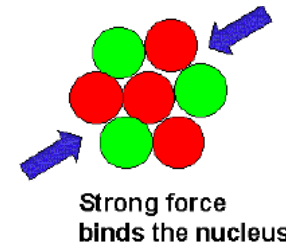
		three generations of matter (fermions)			interactions / force carriers (bosons)	
		I	II	III		
mass		$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	0	$\approx 124.97 \text{ GeV}/c^2$
charge		$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0	0
spin		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
		u up	c charm	t top	g gluon	H higgs
	QUARKS	$\approx 4.7 \text{ MeV}/c^2$	$\approx 96 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
		$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0	
		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
		d down	s strange	b bottom	γ photon	
	LEPTONS	$\approx 0.511 \text{ MeV}/c^2$	$\approx 105.66 \text{ MeV}/c^2$	$\approx 1.7768 \text{ GeV}/c^2$	$\approx 91.19 \text{ GeV}/c^2$	
		-1	-1	-1	0	
		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
		e electron	μ muon	τ tau	Z Z boson	
		$< 1.0 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 18.2 \text{ MeV}/c^2$	$\approx 80.39 \text{ GeV}/c^2$	
		0	0	0	± 1	
		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
		ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	
						GAUGE BOSONS VECTOR BOSONS
						SCALAR BOSONS

The Forces and Force Carriers

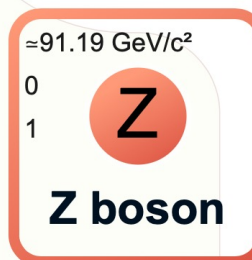
Electromagnetic Force



Strong Nuclear Force



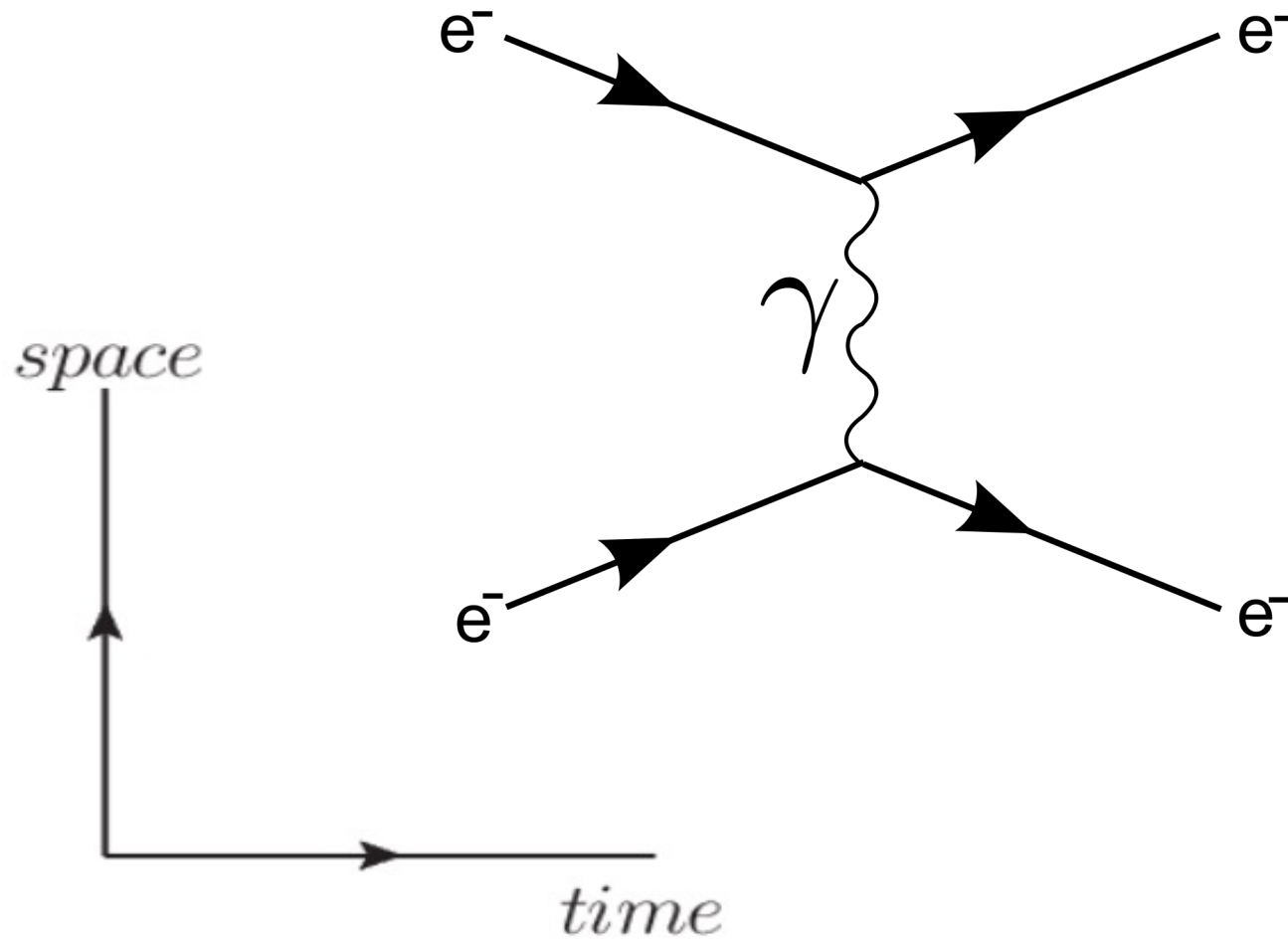
Weak Nuclear Force



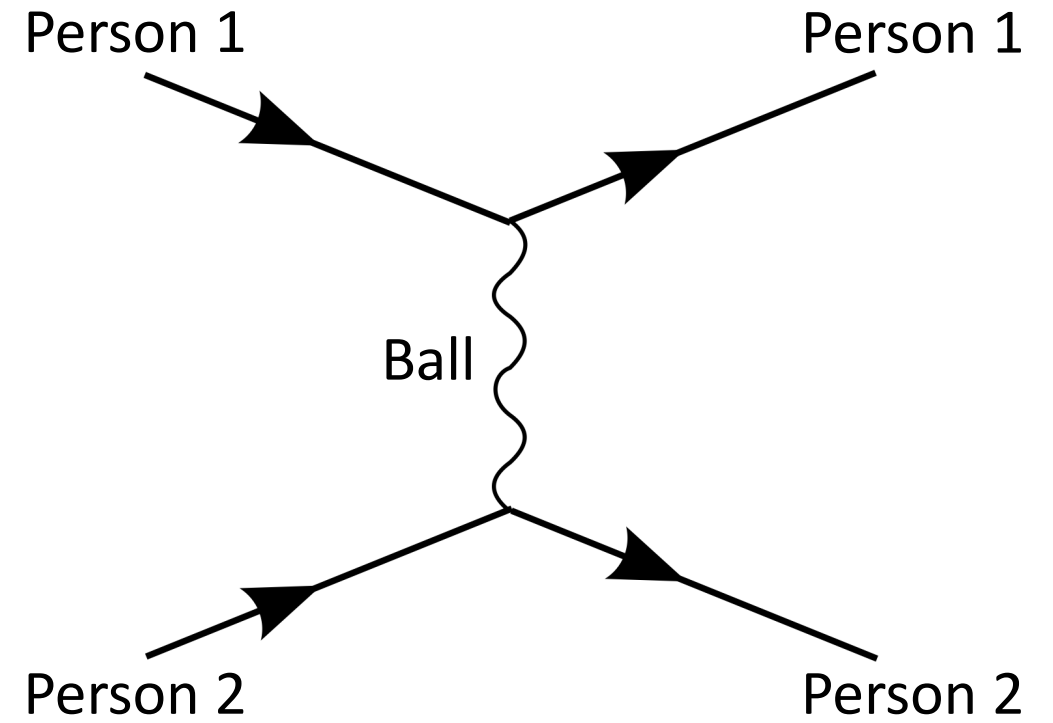
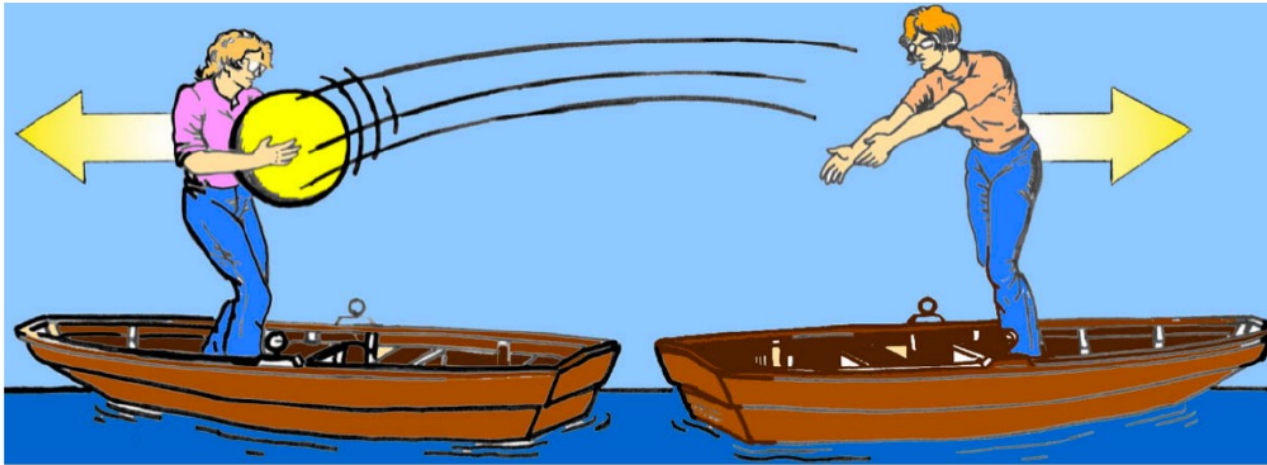
The Forces and Force Carriers

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		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
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		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
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		0	0	0	± 1	
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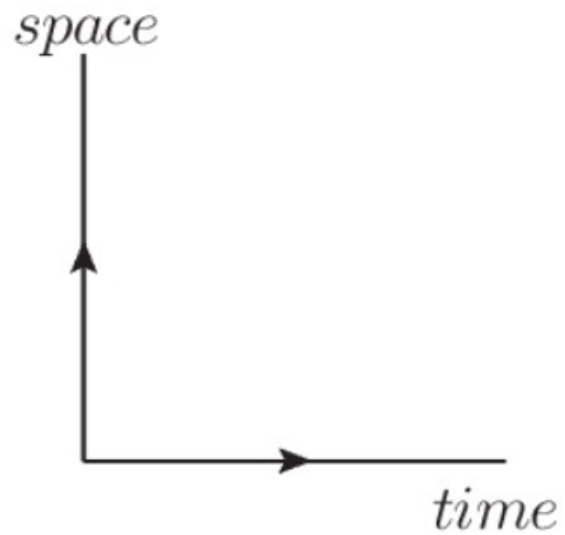
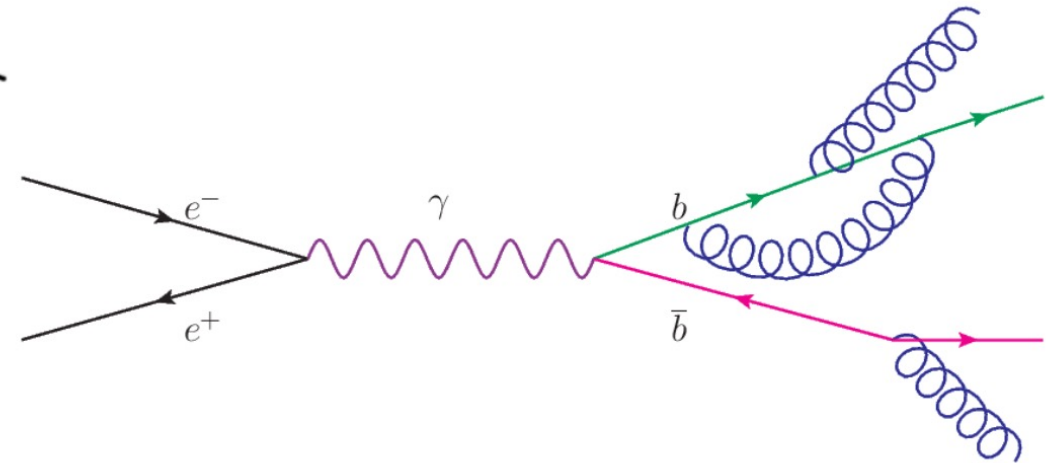
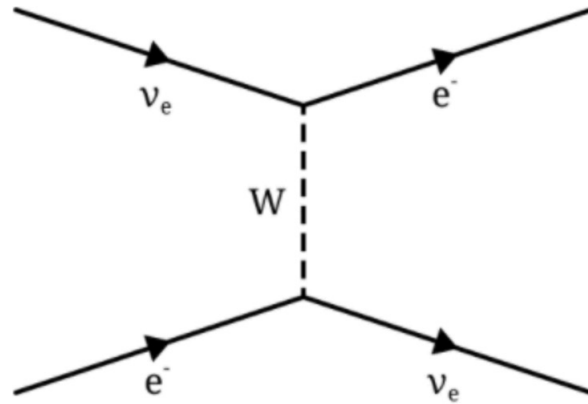
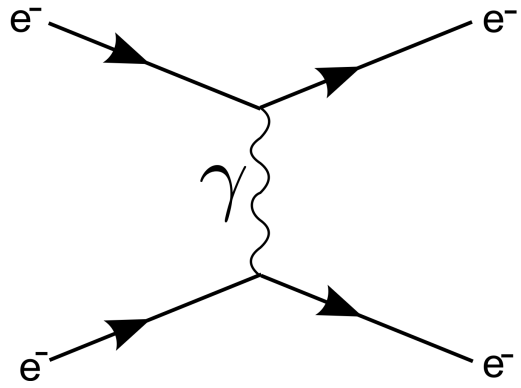
Forces from Particles



Forces from Particles



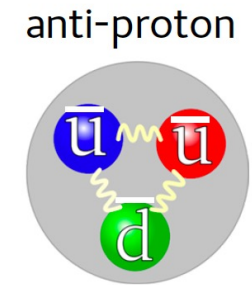
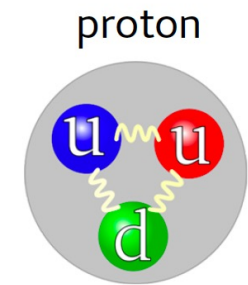
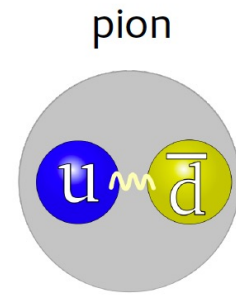
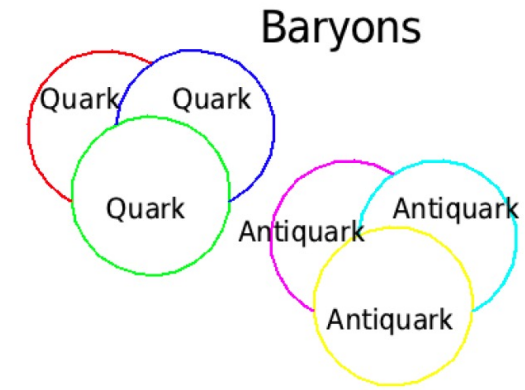
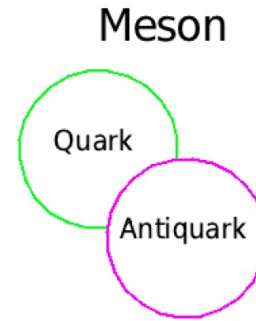
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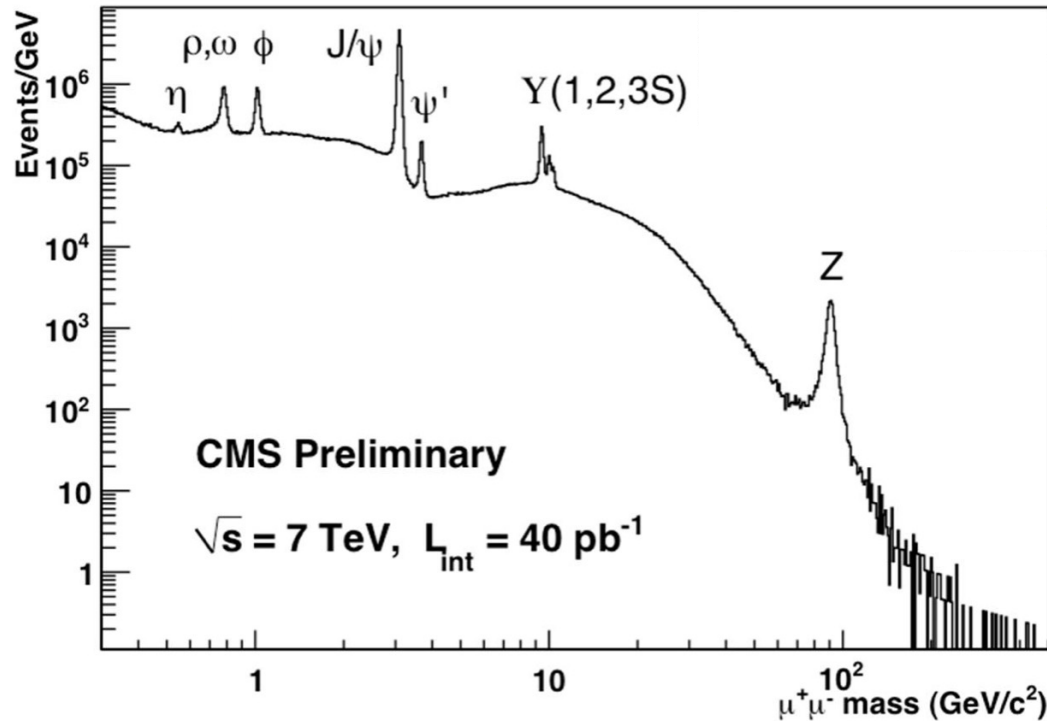
Quarks: The Gregarious Particles

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		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$

QUARKS



Quarks: The Gregarious Particles



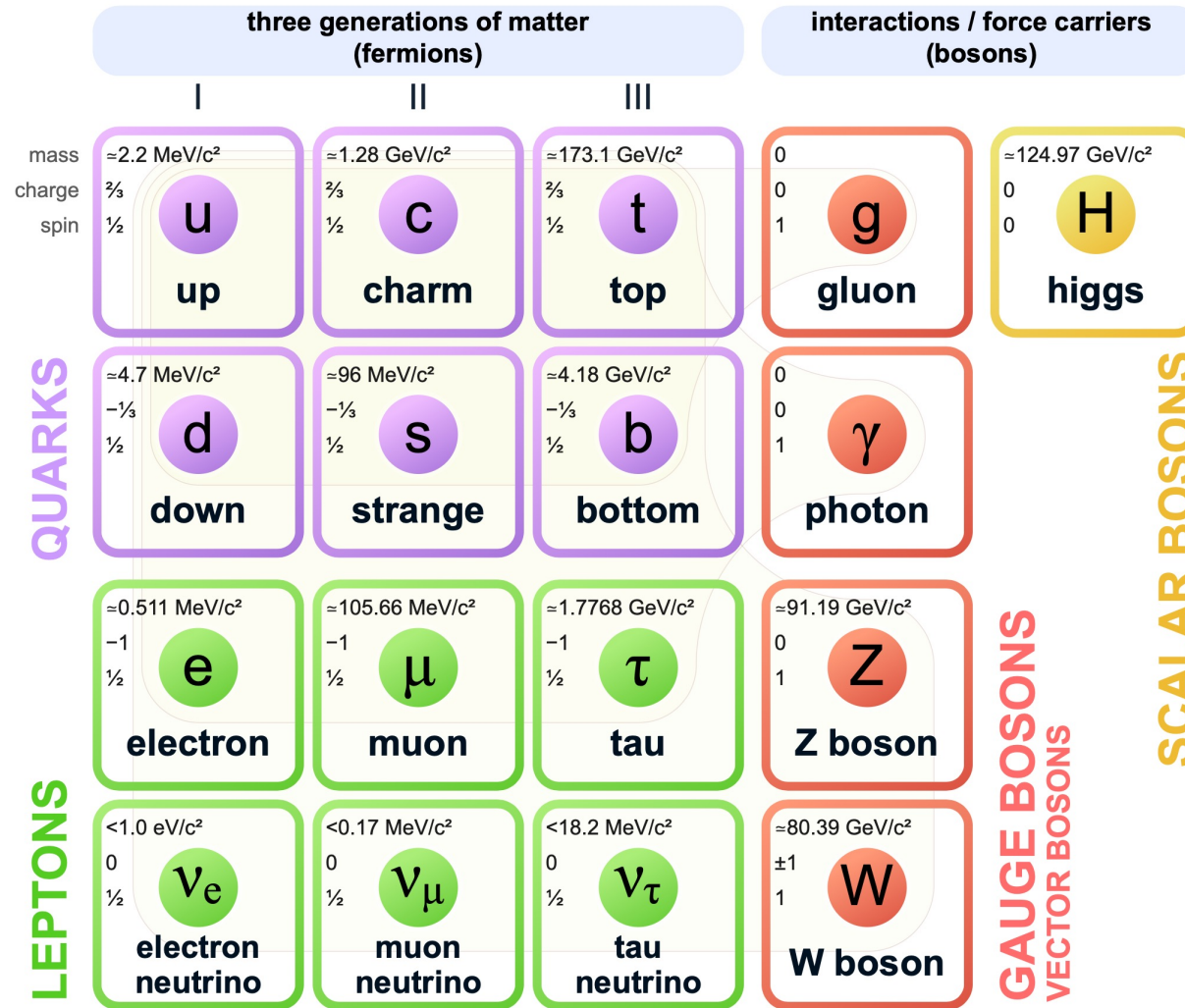
Meson Summary Table

LIGHT UNFLAVORED ($S=C=B=0$) $P(J^{PC})$		STRANGE ($S=\pm 1, C=B=0$) $P(J^{PC})$		CHARMED, STRANGE ($C=S=\pm 1$) $P(J^{PC})$		$c\bar{c}$ continued $P(J^{PC})$	
π^\pm	$1^-(0^-)$	$\pi_2(1670)$	$1^-(2^-)$	K^\pm	$1/2(0^-)$	D_s^\pm	$0(0^-)$
π^0	$1^-(0^+)$	$\rho(1680)$	$0^-(1^-)$	K_S^0	$1/2(0^-)$	D_s^0	$0(0^-)$
η	$0^+(0^-)$	$\rho(1690)$	$1^+(0^-)$	K_S^0	$1/2(0^-)$	$D_{s1}^0(2317)^\pm$	$0(0^+)$
$\eta(500)$	$0^+(0^+)$	$\rho(1700)$	$1^+(1^-)$	K_S^0	$1/2(0^-)$	$D_{s1}(2460)^\pm$	$0(1^+)$
$\eta(770)$	$1^+(1^-)$	$\rho(1700)$	$1^-(2^+)$	$K_S^0(700)$	$1/2(0^+)$	$D_{s1}(2536)^\pm$	$0(1^+)$
$\omega(782)$	$0^-(1^-)$	$\phi(1710)$	$0^+(0^+)$	$K^*(892)$	$1/2(1^-)$	$D_{s2}^*(2573)$	$0(2^+)$
$\eta'(958)$	$0^+(0^-)$	$\eta(1760)$	$0^+(0^+)$	$K_1^*(1270)$	$1/2(1^+)$	$D_{s1}^*(2700)^\pm$	$0(1^+)$
$\phi(980)$	$0^+(0^+)$	$\eta(1800)$	$1^-(0^-)$	$K_1^*(1400)$	$1/2(1^+)$	$D_{s1}^*(2860)^\pm$	$0(1^-)$
$\omega_0(980)$	$1^-(0^+)$	$\phi(1810)$	$0^+(2^+)$	$K^*(1410)$	$1/2(1^-)$	$D_{s1}(2860)^\pm$	$0(3^-)$
$\phi(1020)$	$0^-(1^-)$	$X(1835)$	$?^?(0^-)$	$K_S^*(1430)$	$1/2(0^+)$	$D_{s1}(3040)^\pm$	$0(1^?)$
$h_1(1170)$	$0^-(1^+)$	$\phi_3(1850)$	$0^-(3^-)$	$K_S^*(1430)$	$1/2(2^+)$		
$b_1(1235)$	$1^+(1^+)$	$\rho_2(1870)$	$0^+(2^-)$	$K(1460)$	$1/2(0^-)$	BOTTOM ($B=\pm 1$)	
$a_1(1260)$	$1^-(1^+)$	$\rho_2(1880)$	$1^-(2^-)$	$K_2(1580)$	$1/2(2^-)$	B^\pm	$1/2(0^-)$
$f_2(1270)$	$0^+(2^+)$	$\rho(1900)$	$1^+(1^-)$	$K(1630)$	$1/2(2^?)$	B^0	$1/2(0^-)$
$f_1(1285)$	$0^+(1^+)$	$f_2(1910)$	$0^+(2^+)$	$K_1(1650)$	$1/2(1^+)$	B^{\pm}/B^0 ADMIXTURE	$1/2(0^-)$
$\eta(1295)$	$0^+(0^-)$	$a_0(1950)$	$1^-(0^+)$	$K^*(1680)$	$1/2(1^-)$	$B^{\pm}/B^0/B_s^{\pm}/b$ -baryon ADMIXTURE	$1/2(0^-)$
$\pi(1300)$	$1^-(0^-)$	$f_2(1950)$	$0^+(2^+)$	$K_S(1770)$	$1/2(2^-)$	V_6 and V_6' CKM Matrix Elements	$1/2(0^-)$
$a_2(1320)$	$1^-(2^+)$	$a_4(1970)$	$1^-(4^+)$	$K_S^*(1780)$	$1/2(3^-)$	$R_{cc}(4240)$	$1^+(0^-)$
$f_0(1370)$	$0^+(0^+)$	$\rho_3(1990)$	$1^+(3^-)$	$K_S(1820)$	$1/2(2^-)$	$X(4250)^\pm$	$1^+(0^-)$
$\pi_3(1400)$	$1^-(1^-)$	$\rho_2(2005)$	$1^-(2^-)$	$K(1830)$	$1/2(0^-)$	B^*	$1/2(1^-)$
$\eta(1405)$	$0^+(0^-)$	$f_2(2010)$	$0^+(2^+)$	$K_2^*(1950)$	$1/2(0^+)$	$B_1(5721)^\pm$	$1/2(1^+)$
$h_1(1415)$	$0^-(1^+)$	$f_0(2020)$	$0^+(0^+)$	$K_2^*(1980)$	$1/2(2^+)$	$B_1(5721)^\pm$	$1/2(1^+)$
$a_1(1420)$	$1^-(1^+)$	$f_4(2050)$	$0^+(4^+)$	$K_1^*(2045)$	$1/2(4^+)$	$B_2^*(5732)$	$?^?(2^?)$
$f_1(1420)$	$0^+(1^+)$	$\rho_3(2100)$	$1^-(2^-)$	$K_2(2250)$	$1/2(2^-)$	$B_2^*(5747)^\pm$	$1/2(2^?)$
$f_2(1430)$	$0^+(2^+)$	$f_2(2150)$	$0^+(2^+)$	$K_3(2320)$	$1/2(3^+)$	$B_2(5840)^\pm$	$1/2(2^?)$
$a_0(1450)$	$1^-(0^+)$	$f_2(2150)$	$0^+(2^+)$	$K_3(2380)$	$1/2(5^-)$	$B_2(5840)^\pm$	$1/2(2^?)$
$\omega(1475)$	$1^+(1^-)$	$\phi(2170)$	$0^-(1^-)$	$K_4(2500)$	$1/2(4^-)$	$B_2(5970)^\pm$	$1/2(2^?)$
$f_0(1495)$	$0^+(0^+)$	$\phi(2200)$	$0^+(0^+)$	$K(3100)$	$?^?(2^?)$		
$f_2(1500)$	$0^+(2^+)$	$f_2(2220)$	$0^+(2^+)$	OTHER LIGHT ($C=\pm 1$)		BOTTOM, STRANGE ($B=\pm 1, S=\pm 1$)	
$f_1(1510)$	$0^+(1^+)$	$f_1(1510)$	$0^+(1^+)$	$\eta(2225)$	$0^+(0^-)$	D^*	$1/2(0^-)$
$f_2^*(1525)$	$0^+(2^+)$	$\eta(2225)$	$0^+(0^-)$	$\rho_3(2250)$	$1^+(3^-)$	D^0	$1/2(0^-)$
$f_1(1565)$	$0^+(1^+)$	$f_1(1565)$	$0^+(1^+)$	$\phi(2300)$	$0^+(2^+)$	B_c^0	$0(0^-)$
$\eta(1570)$	$1^-(1^-)$	$\phi(2300)$	$0^+(2^+)$	$\phi(2300)$	$0^+(4^+)$	$D^*(2007)^\pm$	$0(1^-)$
$h_1(1595)$	$0^-(1^+)$	$\phi(2300)$	$0^+(4^+)$	$\phi(2300)$	$0^+(4^+)$	$D^*(2010)^\pm$	$1/2(1^-)$
$\pi_3(1600)$	$1^-(1^-)$	$\phi(2330)$	$0^+(2^+)$	$D_S^*(2300)^\pm$	$1/2(0^+)$	$X(5568)^\pm$	$?^?(2^?)$
$a_1(1640)$	$1^-(1^+)$	$\phi(2340)$	$0^+(2^+)$	$D_S^*(2300)^\pm$	$1/2(1^+)$	$B_{c1}(5830)^\pm$	$0(1^+)$
$f_2(1640)$	$0^+(2^+)$	$\rho_3(2350)$	$1^+(5^-)$	$D_S(2300)^\pm$	$1/2(1^+)$	$B_{c1}(5840)^\pm$	$0(1^+)$
$\eta_2(1645)$	$0^+(2^+)$	$\phi(2510)$	$0^+(6^+)$	$D_s(2420)^\pm$	$1/2(1^+)$	$B_{c2}(5850)$	$?^?(2^?)$
$\omega(1650)$	$0^-(1^-)$			$D_s(2420)^\pm$	$1/2(2^?)$	BOTTOM, CHARMED ($B=C=\pm 1$)	
$\omega(1670)$	$0^-(3^-)$			$D_s(2460)^\pm$	$1/2(2^+)$	B_c^+	$0(0^-)$
				$D(2550)^\pm$	$1/2(2^?)$	$B_c(2S)^\pm$	$0(0^-)$
				$D_S^*(2460)^\pm$	$1/2(2^+)$	OTHER LIGHT ($C=\pm 1$)	
				$D(2600)$	$1/2(2^?)$	Further States	
				$D_S^*(2640)^\pm$	$1/2(2^?)$	$P_c(4312)^\pm$	*
				$D(2740)^\pm$	$1/2(2^?)$	$P_c(4380)^\pm$	*
				$D_S^*(2750)$	$1/2(3^-)$	$P_c(4440)^\pm$	*
				$D(3000)^\pm$	$1/2(2^?)$	$P_c(4457)^\pm$	*

Baryon Summary Table

p	$1/2^+$	****	$\Delta(1232)$	$3/2^+$	****	Σ^+	$1/2^+$	****	Ξ^0	$1/2^+$	****	Ξ^{++}	****
n	$1/2^+$	****	$\Delta(1600)$	$3/2^+$	****	Σ^0	$1/2^+$	****	Ξ^0	$1/2^+$	****	Ξ^{++}	****
$N(1440)$	$1/2^+$	****	$\Delta(1620)$	$1/2^+$	****	Σ^-	$1/2^+$	****	$\Xi(1530)$	$3/2^+$	****	Λ_b^0	$1/2^+$
$N(1520)$	$3/2^-$	****	$\Delta(1700)$	$3/2^-$	****	$\Sigma(1385)$	$3/2^+$	****	$\Xi(1620)$	*	$\Lambda_b(5912)^0$	$1/2^-$	
$N(1535)$	$1/2^-$	****	$\Delta(1750)$	$1/2^+$	*	$\Sigma(1580)$	$3/2^-$	*	$\Xi(1690)$	****	$\Lambda_b(5920)^0$	$3/2^-$	
$N(1650)$	$1/2^-$	****	$\Delta(1900)$	$1/2^-$	****	$\Sigma(1620)$	$1/2^-$	*	$\Xi(1820)$	$3/2^-$	****	$\Lambda_b(6146)^0$	$3/2^+$
$N(1675)$	$5/2^-$	****	$\Delta(1905)$	$5/2^+$	****	$\Sigma(1660)$	$1/2^+$	****	$\Xi(1950)$	****	$\Lambda_b(6152)^0$	$5/2^+$	
$N(1680)$	$5/2^+$	****	$\Delta(1910)$	$1/2^+$	****	$\Sigma(1670)$	$3/2^-$	****	$\Xi(2030)$	$\geq 3/2^+$	****	Σ_b	$3/2^+$
$N(1700)$	$3/2^-$	****	$\Delta(1920)$	$3/2^+$	****	$\Sigma(1750)$	$1/2^-$	****	$\Xi(2120)$	*	Σ_b^+	$3/2^+$	
$N(1710)$	$1/2^+$	****	$\Delta(1930)$	$5/2^-$	****	$\Sigma(1775)$	$5/2^-$	****	$\Xi(2250)$	*	$\Sigma_b(6097)^+$	****	
$N(1720)$	$3/2^+$	****	$\Delta(1940)$	$3/2^-$	**	$\Sigma(1780)$	$3/2^+$	**	$\Xi(2370)$	*	$\Xi_b^0(6097)^+$	****	
$N(1860)$	$5/2^+$	**	$\Delta(1950)$	$7/2^+$	****	$\Sigma(1880)$	$1/2^+$	**	$\Xi(2500)$	*	$\Xi_b^0(6975)^+$	$1/2^+$	
$N(1875)$	$3/2^-$	**	$\Delta(2000)$	$5/2^+$	**	$\Sigma(1900)$	$1/2^-$	**			$\Xi_b^0(6935)^+$	$1/2^+$	
$N(1880)$	$1/2^+$	****	$\Delta(2150)$	$1/2^-$	*	$\Sigma(1910)$	$3/2^-$	****	Ω^-	$3/2^+$	****		
$N(1895)$	$1/2^-$	****	$\Delta(2200)$	$7/2^-$	****	$\Sigma(1915)$	$5/2^+$	****	$\Omega(2012)^-$	$?$	****		
$N(1900)$	$3/2^+$	**	$\Delta(2300)$	$9/2^+$	**	$\Sigma(1940)$	$3/2^+$	*	$\Omega(2250)^-$	****			
$N(1990)$	$7/2^+$	**	$\Delta(2350)$	$5/2^-$	*	$\Sigma(2010)$	$3/2^-$	*	$\Omega(2380)^-$	**			
$N(2000)$	$5/2^+$	**	$\Delta(2390)$	$7/2^+$	**	$\Sigma(2030)$	$7/2^+$	****	$\Omega(2470)^-$	**			
$N(2040)$	$3/2^+$	*	$\Delta(2400)$	$9/2^-$	**	$\Sigma(2070)$	$5/2^+$	*			$P_c(4312)^\pm$	*	
$N(2060)$	$5/2^-$	****	$\Delta(2420)$	$11/2^+$	****	$\Sigma(2080)$	$3/2^+$	*			$P_c(4380)^\pm$	*	
$N(2100)$	$1/2^+$	****	$\Delta(2750)$	$13/2^-$	**	$\Sigma(2100)$	$7/2^-$	*			$P_c(4440)^\pm$	*	
$N(2120)$	$3/2^-$	****	$\Delta(2950)$	$15/2^+$	**	$\Sigma(2160)$	$1/2^+$	*			$P_c(4457)^\pm$	*	
$N(2190)$	$7/2^-$	****				$\Sigma(2230)$	$3/2^+$	*					
$N(2220)$	$9/2^+$	****	Λ	$1/2^+$	****	$\Sigma(2250)$	****				$\Lambda_c(2860)^+$	$3/2^+$	****
$N(2250)$	$9/2^-$	****	Λ	$1/2^-$	****	$\Sigma(2455)$	****				$\Lambda_c(2880)^+$	$5/2^+$	****
$N(2300)$	$1/2^+$	**	$\Lambda(1405)$	$1/2^-$	****	$\Sigma(2620)$	**				$\Lambda_c(2940)^+$	$3/2^-$	****
$N(2570)$	$5/2^-$	**	$\Lambda(1520)$	$3/2^-$	****	$\Sigma(3000)$	****				$\Sigma_c(2455)$	$1/2^+$	****
$N(2600)$	$11/2^-$	****	$\Lambda(1600)$	$1/2^+$	****	$\Sigma(3170)$	*				$\Sigma_c(2520)$	$3/2^+$	****
$N(2700)$	$13/2^+$	**	$\Lambda(1670)$	$1/2^-$	****						$\Sigma_c(2800)$	****	
			$\Lambda(1690)$	$3/2^-$	****						Ξ_c^+	$1/2^+$	****
			$\Lambda(1710)$	$1/2^+$	*						Ξ_c^0	$1/2^+$	****
			$\Lambda(1800)$	$1/2^-$	****						Ξ_c^+	$1/2^+$	****
			$\Lambda(1810)$	$1/2^+$	****						Ξ_c^0	$1/2^+$	****
			$\Lambda(1820)$	$5/2^+$	****						$\Xi_c(2645)$	$3/2^+$	****
			$\Lambda(1830)$	$5/2^-$	****						$\Xi_c(2790)$	$1/2^-$	****
			$\Lambda(1890)$	$3/2^+$	****						$\Xi_c(2815)$	$3/2^-$	****
			$\Lambda(2000)$	$1/2^-$	*						$\Xi_c(2930)$	****	
			$\Lambda(2050)$	$3/2^-$	*						$\Xi_c(2970)$	****	
			$\Lambda(2070)$	$3/2^+$	*						$\Xi_c(3055)$	****	
			$\Lambda(2080)$	$5/2^-$	*						$\Xi_c(3080)$	****	
			$\Lambda(2085)$	$7/2^+$	**						$\Xi_c(3123)$	*	
			$\Lambda(2100)$	$7/2^-$	****						Ω_c^0	$1/2^+$	****
			$\Lambda(2110)$	$5/2^+$	****						$\Omega_c(2770)^0$	$3/2^+$	****
			$\Lambda(2325)$	$3/2^-$	*						$\Omega_c(3000)^0$	****	
			$\Lambda(2350)$	$9/2^+$	****						$\Omega_c(3050)^0$	****	
			$\Lambda(2585)$	**							$\Omega_c(3065)^0$	****	
</													

The Elementary Particles



Neutrinos and Particle Oscillations

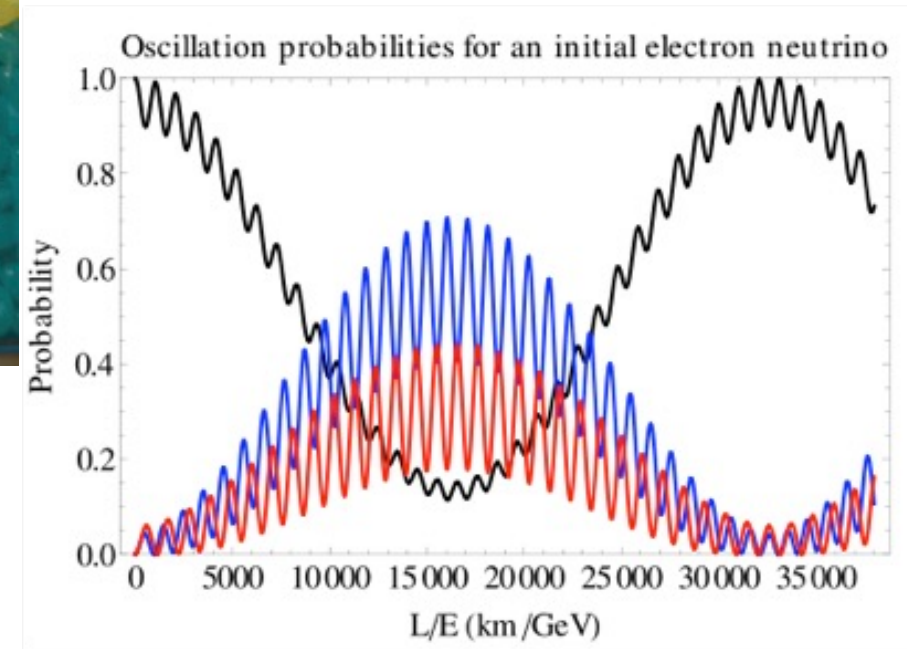
	three generations of matter (fermions)			interactions / force carriers (bosons)	
	I	II	III		
mass	=2.2 MeV/c ²	=1.28 GeV/c ²	=173.1 GeV/c ²	0	=124.97 GeV/c ²
charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0	0
spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
	u up	c charm	t top	g gluon	H higgs
	d down	s strange	b bottom	γ photon	
	e electron	μ muon	τ tau	Z Z boson	
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	

QUARKS (left side of table)

LEPTONS (left side of table)

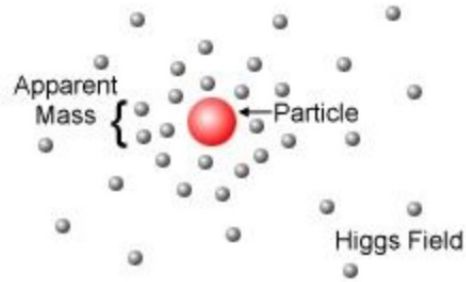
GAUGE BOSONS VECTOR BOSONS (right side of table)

SCALAR BOSONS (right side of table)

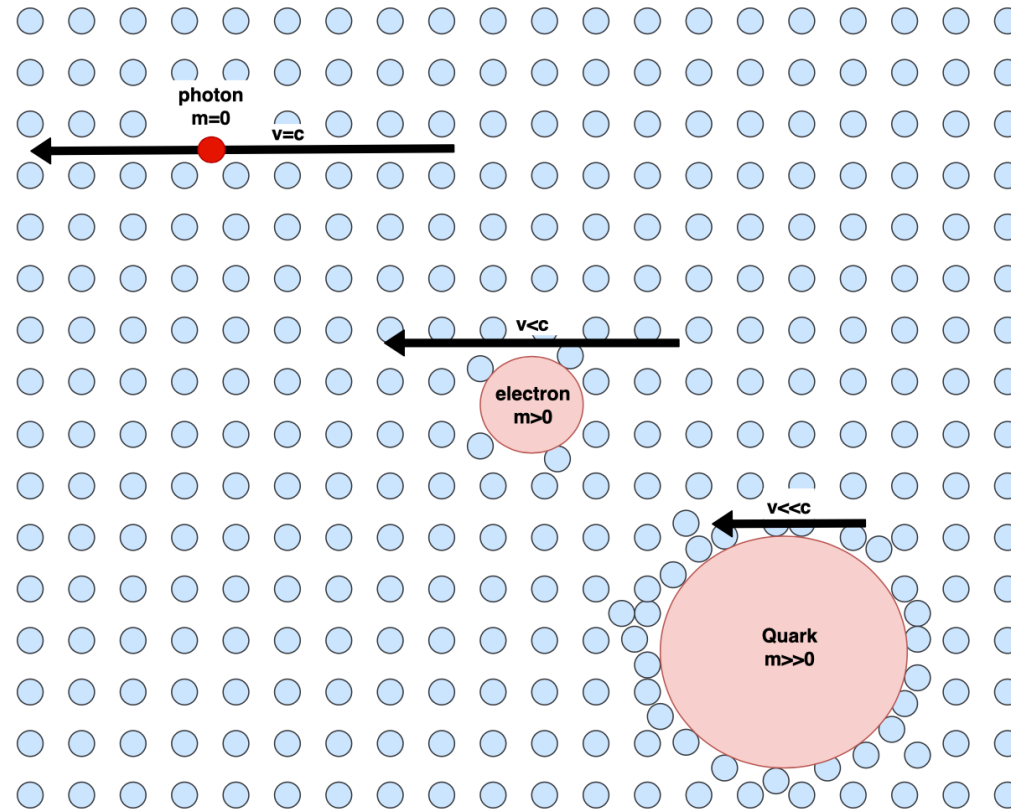
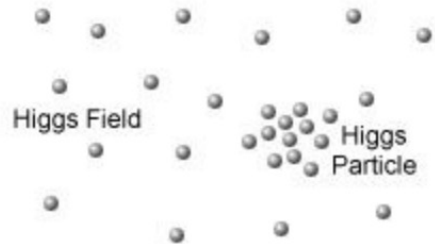


Particle Masses and the Higgs Field

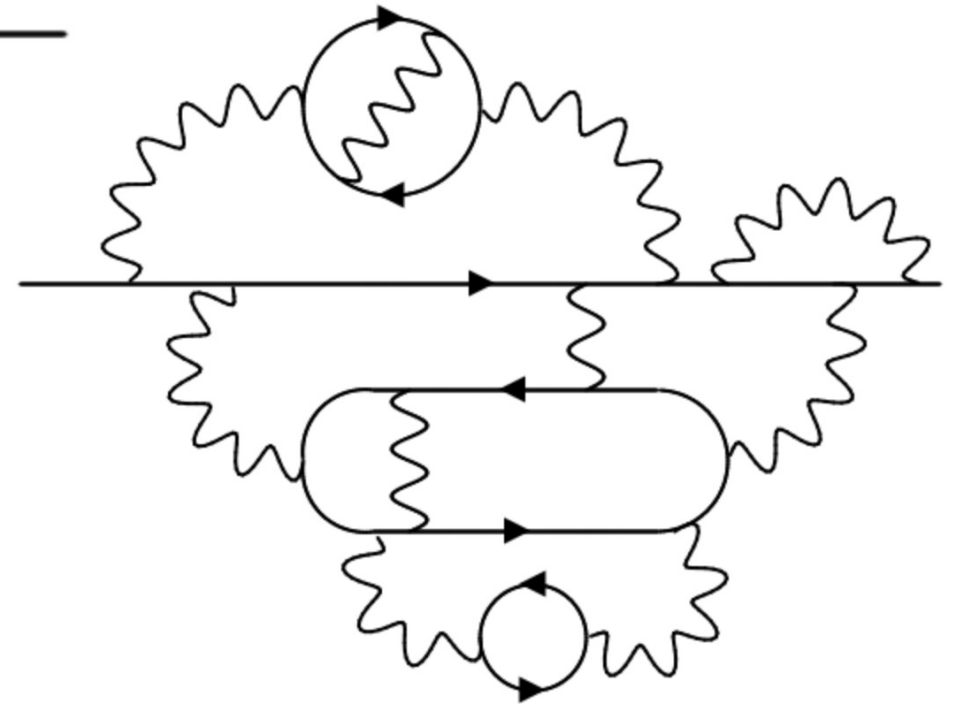
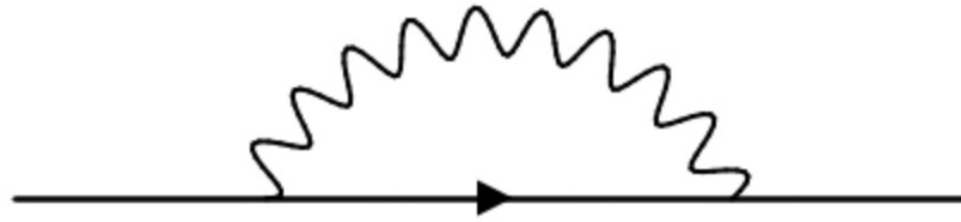
Higgs Mechanism



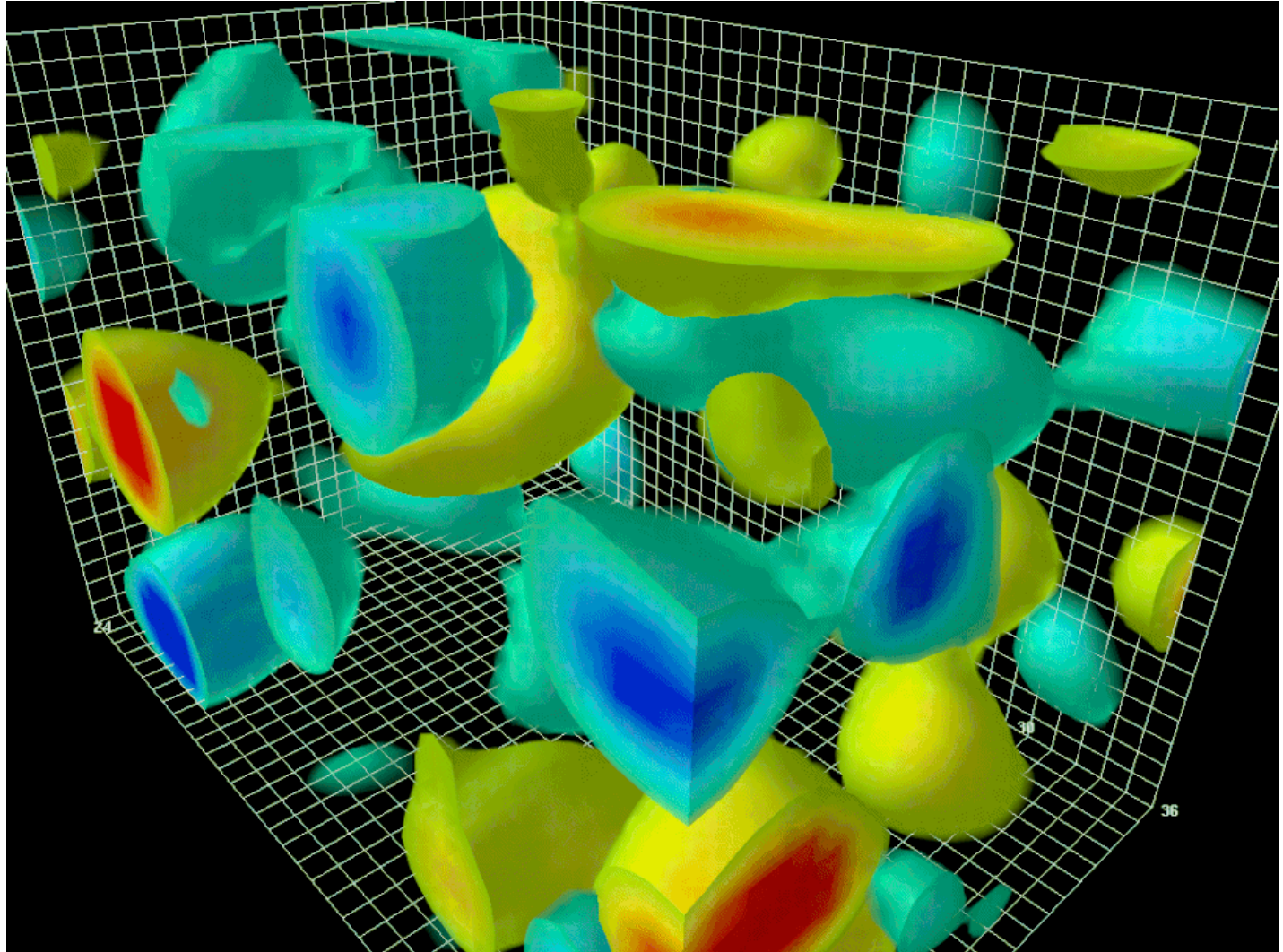
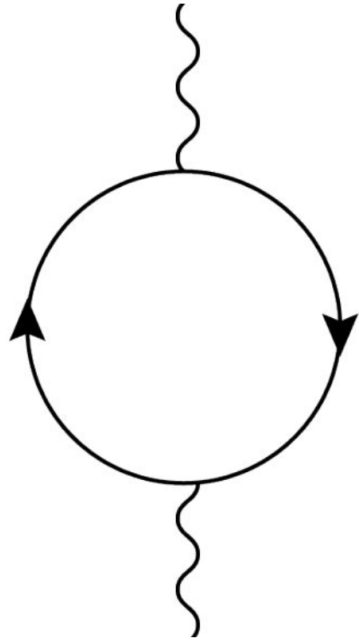
Higgs Particles



'Virtual' Particles



The “Empty” Vacuum



The Elementary Particles

		three generations of matter (elementary fermions)			three generations of antimatter (elementary antifermions)			interactions / force carriers (elementary bosons)	
		I	II	III	I	II	III		
mass		$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	0	$\approx 124.97 \text{ GeV}/c^2$
charge		$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	0	0
spin		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
		u up	c charm	t top	\bar{u} antiup	\bar{c} anticharm	\bar{t} antitop	g gluon	H higgs
	QUARKS	$\approx 4.7 \text{ MeV}/c^2$	$\approx 96 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	$\approx 4.7 \text{ MeV}/c^2$	$\approx 96 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
		$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	0	
		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
		d down	s strange	b bottom	\bar{d} antidown	\bar{s} antistrange	\bar{b} antibottom	γ photon	
		$\approx 0.511 \text{ MeV}/c^2$	$\approx 105.66 \text{ MeV}/c^2$	$\approx 1.7768 \text{ GeV}/c^2$	$\approx 0.511 \text{ MeV}/c^2$	$\approx 105.66 \text{ MeV}/c^2$	$\approx 1.7768 \text{ GeV}/c^2$	$\approx 91.19 \text{ GeV}/c^2$	
		-1	-1	-1	1	1	1	0	
		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
		e electron	μ muon	τ tau	e^+ positron	$\bar{\mu}$ antimuon	$\bar{\tau}$ antitau	Z Z ⁰ boson	
	LEPTONS	$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 18.2 \text{ MeV}/c^2$	$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 18.2 \text{ MeV}/c^2$	$\approx 80.39 \text{ GeV}/c^2$	$\approx 80.39 \text{ GeV}/c^2$
		0	0	0	0	0	0	1	-1
		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	1
		ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	$\bar{\nu}_e$ electron antineutrino	$\bar{\nu}_\mu$ muon antineutrino	$\bar{\nu}_\tau$ tau antineutrino	W⁺ W ⁺ boson	W⁻ W ⁻ boson

GAUGE BOSONS
VECTOR BOSONS

SCALAR BOSONS