La fisica teorica delle particelle elementari

Quali i prossimi passi?

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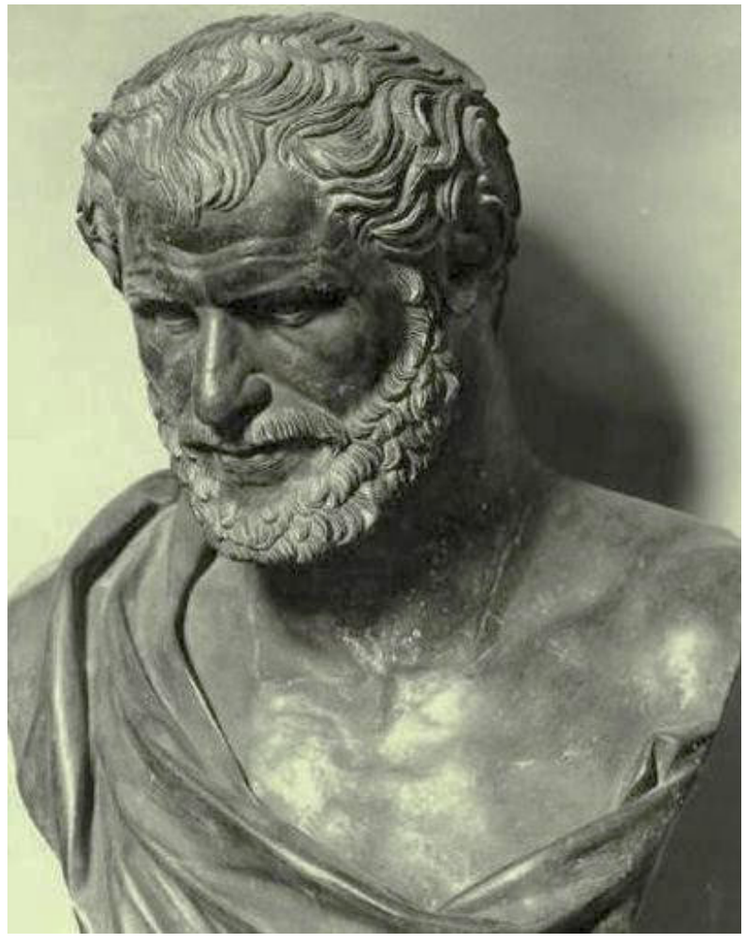
Trieste, 15 Ottobre 2020

Quali sono i mattoni fondamentali del nostro Universo?

Quali i primi passi?

Democrito

400 a.C.



Da Wikipedia, l'enciclopedia libera.

L'**atomismo** è una teoria filosofica che presuppone una pluralità di costituenti fondamentali all'origine della materia fisica

Newton

XVII secolo

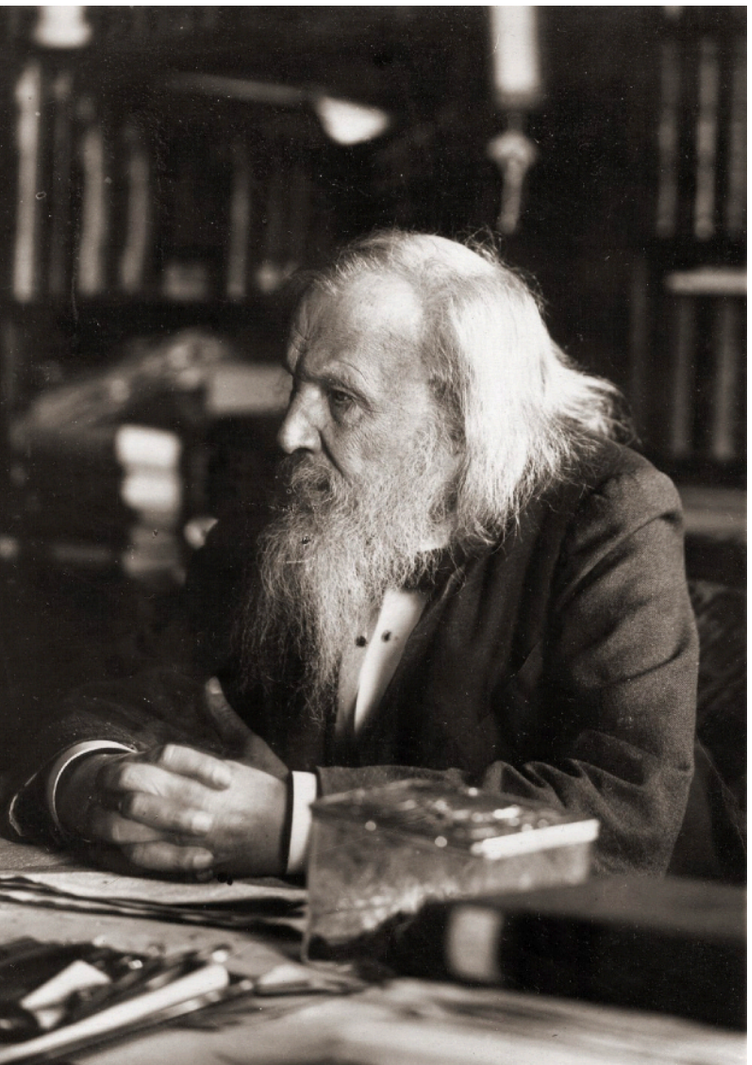
Pensava che la materia fosse composta da particelle

Dalton

XIX secolo

Nel 1808, John Dalton per primo cercò di descrivere l'atomo.

Probabilmente Dalton immaginò l'atomo
come una microscopica sfera completamente
piena e indivisibile.



Mendeleev

XIX secolo

Inventò la tavola periodica degli elementi nel 1869.

Tavola Periodica

gruppo 1 — gruppo 18

	IA	gruppo 2	gruppo 3	gruppo 4	gruppo 5	gruppo 6	gruppo 7	gruppo 8	gruppo 9	gruppo 10	gruppo 11	gruppo 12	gruppo 13	gruppo 14	gruppo 15	gruppo 16	*Alogeni* gruppo 17	VIIIA
		IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	
periodo 1	idrogeno 1 13.99K **H** 1312 0.07 1.008 2.2 Atm ±1 1s¹																	elio 2 0.95K **He** 2372 0.145 4.003 – Atm – 1s²
periodo 2	litio 3 453.65K **Li** 513 0.534 6.941 0.98 Lit +1 [He]2s¹	berillio 4 1560K **Be** 899 1.85 9.012 1.57 Lit +2 [He]2s²											boro 5 2349K **B** 801 2.08 10.81 2.04 Lit +3 [He]2s²2p¹	carbonio 6 3915K **C** 1086 1.8-2.1 12.01 2.55 Atm +2±4 [He]2s²2p²	azoto 7 63.15K **N** 1402 0.808 14.01 3.04 Atm +2±3+4+5 [He]2s²2p³	ossigeno 8 54.36K **O** 1314 1.141 16 3.44 Lit -2 [He]2s²2p⁴	fluoro 9 53.48K **F** 1681 1.505 19 3.98 Lit -1 [He]2s²2p⁵	neon 10 24.56K **Ne** 2081 1.207 20.18 – Atm – [He]2s²2p⁶
periodo 3	sodio 11 370.94K **Na** 496 0.968 22.99 0.93 Lit +1 [Ne]3s¹	magnesio 12 923K **Mg** 737.7 1.738 24.31 1.31 Lit +2 [Ne]3s²											alluminio 13 933.47K **Al** 578 2.7 26.98 1.61 Lit +3 [Ne]3s²3p¹	silicio 14 1687K **Si** 786 2.329 28.09 1.9 Lit +2±4 [Ne]3s²3p²	fosforo 15 317.3K **P** 1012 1.8-2.6 30.97 2.19 Lit ±3+5 [Ne]3s²3p³	zolfo 16 388.36K **S** 1000 2.7 32.07 2.58 Cal -2+4+6 [Ne]3s²3p⁴	cloro 17 171.6K **Cl** 1251 1.562 35.45 3.16 Lit ±1+3+5+7 [Ne]3s²3p⁵	argon 18 83.81K **Ar** 1521 1.395 39.95 – Atm – [Ne]3s²3p⁶
periodo 4	potassio 19 336.7K **K** 419 0.862 39.1 0.82 Lit +1 [Ar]4s¹	calcio 20 1115K **Ca** 590 1.55 40.08 1 Lit +2 [Ar]4s²	scandio 21 1814K **Sc** 631 2.985 44.96 1.36 Lit +3 [Ar]3d¹4s²	titanio 22 1941K **Ti** 658 4.506 47.87 1.54 Lit +2+3+4 [Ar]3d²4s²	vanadio 23 2183K **V** 651 6 50.94 1.63 Lit +2+3+4+5 [Ar]3d³4s²	cromo 24 2180K **Cr** 653 7.19 52 1.66 Lit +2+3+4+6 [Ar]3d⁵4s¹	manganese 25 1519K **Mn** 717 7.21 54.94 1.55 Sid +2+3+4+6+7 [Ar]3d⁵4s²	ferro 26 1811K **Fe** 759 7.874 55.85 1.83 Sid +2+3+6 [Ar]3d⁶4s²	cobalto 27 1768K **Co** 758 8.9 58.93 1.88 Sid +2+3 [Ar]3d⁷4s²	nichel 28 1728K **Ni** 737 8.908 58.69 1.91 Sid +2+3 [Ar]3d⁸4s²	rame 29 1357.77K **Cu** 745 8.96 63.55 1.9 Cal +1+2 [Ar]3d¹⁰4s¹	zinco 30 692.68K **Zn** 906 7.14 65.37 1.65 Cal +2 [Ar]3d¹⁰4s²	gallio 31 302.914K **Ga** 579 5.91 69.72 1.81 Cal +3 [Ar]3d¹⁰4s²4p¹	germanio 32 1211.40K **Ge** 762 5.323 72.64 2.01 Cal +2+4 [Ar]3d¹⁰4s²4p²	arsenico 33 887K **As** 947 5.727 74.92 2.18 Cal ±3+5 [Ar]3d¹⁰4s²4p³	selenio 34 494K **Se** 941 4.81 78.96 2.55 Cal -2+4+6 [Ar]3d¹⁰4s²4p⁴	bromo 35 265.8K **Br** 1140 3.102 79.91 2.96 Lit ±1+3+5 [Ar]3d¹⁰4s²4p⁵	kripton 36 115.78K **Kr** 1351 2.413 83.8 3 Atm – [Ar]3d¹⁰4s²4p⁶
periodo 5	rubidio 37 312.45K **Rb** 403 1.532 85.47 0.82 Lit +1 [Kr]5s¹	stronzio 38 1050K **Sr** 549 2.64 87.62 0.95 Lit +2 [Kr]5s²	ittrio 39 1799K **Y** 616 4.472 88.91 1.22 Lit +3 [Kr]4d¹5s²	zirconio 40 2128K **Zr** 660 6.52 91.22 1.33 Lit +4 [Kr]4d²5s²	niobio 41 2750K **Nb** 664 8.57 92.91 1.6 Lit +3+5 [Kr]4d⁴5s¹	molibdeno 42 2896K **Mo** 685 10.28 95.94 2.16 Sid +1+2+3+4+5+6 [Kr]4d⁵5s¹	tecnezio 43 2430K **Tc** 702 11 [98,91] 1.9 Lit +4+5+6+7 [Kr]4d⁵5s²	rutenio 44 2607K **Ru** 711 12.45 101.1 2.2 Sid +2+3+4+5+6+7 [Kr]4d⁷5s¹	rodio 45 2237K **Rh** 720 12.41 102.9 2.28 Sid +3 [Kr]4d⁸5s¹	palladio 46 1828K **Pd** 805 12.02 106.4 2.2 Sid +2+4 [Kr]4d¹⁰	argento 47 1234.93K **Ag** 731 10.49 107.9 1.93 Cal +1 [Kr]4d¹⁰5s¹	cadmio 48 594.22K **Cd** 868 8.65 112.4 1.69 Cal +2 [Kr]4d¹⁰5s²	indio 49 429.75K **In** 558 7.31 114.8 1.78 Cal +3 [Kr]4d¹⁰5s²5p¹	stagno 50 505.08K **Sn** 709 7.365 118.7 1.96 Cal +2+4 [Kr]4d¹⁰5s²5p²	antimonio 51 903.78K **Sb** 834 6.697 121.8 2.05 Cal ±3+5 [Kr]4d¹⁰5s²5p³	tellurio 52 722.66K **Te** 869 6.24 127.6 2.1 Cal -2+4+6 [Kr]4d¹⁰5s²5p⁴	iodio 53 386.85K **I** 1008 4.933 126.9 2.66 Lit ±1+5+7 [Kr]4d¹⁰5s²5p⁵	xenon 54 161.40K **Xe** 1351 2.942 131.3 2.6 Atm – [Kr]4d¹⁰5s²5p⁶
periodo 6	cesio 55 301.7K **Cs** 376 1.93 132.9 0.79 Lit +1 [Xe]6s¹	bario 56 1000K **Ba** 503 3.51 137.3 0.89 Lit +2 [Xe]6s²	Lantanidi	afnio 72 2506K **Hf** 642 13.31 178.5 1.3 Lit +4 [Xe]4f¹⁴5d²6s²	tantalio 73 3290K **Ta** 761 16.69 180.9 1.5 Lit +5 [Xe]4f¹⁴5d³6s²	tungsteno 74 3695K **W** 770 19.25 183.8 2.56 Sid +2+3+4+5+6 [Xe]4f¹⁴5d⁴6s²	renio 75 3459K **Re** 760 21.02 186.2 1.9 Sid +4+6+7 [Xe]4f¹⁴5d⁵6s²	osmio 76 3306K **Os** 839 22.59 190.2 2.2 Sid +2+3+4+6+8 [Xe]4f¹⁴5d⁶6s²	iridio 77 2719K **Ir** 878 22.56 192.2 2.2 Sid +3+4 [Xe]4f¹⁴5d⁷6s²	platino 78 2041.4K **Pt** 868 21.45 195.1 2.28 Sid +2+4 [Xe]4f¹⁴5d⁹6s¹	oro 79 1337.33K **Au** 890 19.3 197 2.54 Sid +1+3 [Xe]4f¹⁴5d¹⁰6s¹	mercurio 80 234.32K **Hg** 1007 13.53 200.6 1.9 Cal +1+2 [Xe]4f¹⁴5d¹⁰6s²	tallio 81 577K **Tl** 589 11.85 204.4 2.04 Cal +1+3 [Xe]4f¹⁴5d¹⁰6s²6p¹	piombo 82 600.61K **Pb** 716 11.34 207.2 2.33 Cal +2+4 [Xe]4f¹⁴5d¹⁰6s²6p²	bismuto 83 544.7K **Bi** 703 9.78 209 2.02 Cal +3+5 [Xe]4f¹⁴5d¹⁰6s²6p³	polonio 84 527K **Po** 812 9.196 [209] 2 Cal +2+4+6 [Xe]4f¹⁴5d¹⁰6s²6p⁴	astato 85 575K **At** 930 6.35 [210] 2.2 Lit ±1+3+5+7 [Xe]4f¹⁴5d¹⁰6s²6p⁵	radon 86 202K **Rn** 1351 4.4 [222] 2.2 Atm – [Xe]4f¹⁴5d¹⁰6s²6p⁶
periodo 7	francio 87 ?300K **Fr** 393 1.87 [223] 0.7 Lit +1 [Rn]7s¹	radio 88 1233K **Ra** 509 5.5 [226] 0.9 Lit +2 [Rn]7s²	Attinidi	rutherfordio 104 ?2400K **Rf** ?579.9 ?23.2 [261] – Syn ? +4 [Rn]5f¹⁴6d²7s²	dubnio 105 – **Db** ?664.8 ?29.3 [262] – Syn ? +5 [Rn]5f¹⁴6d³7s²	seaborgio 106 – **Sg** ?757.4 ?35 [266] – Syn ? +6 [Rn]5f¹⁴6d⁴7s²	bohrio 107 – **Bh** ?742.9 ?37.1 [264] – Syn ? +7 [Rn]5f¹⁴6d⁵7s²	hassio 108 – **Hs** ?733.3 ?40.7 [265] – Syn ? +8 [Rn]5f¹⁴6d⁶7s²	meitnerio 109 – **Mt** ?800.8 ?37.4 [268] – Syn ? +1+3+4+6 [Rn]5f¹⁴6d⁷7s²	darmstadtio 110 – **Ds** ?955.2 ?34.8 [271] – Syn ? +2+4+8 [Rn]5f¹⁴6d⁹7s²	roentgenio 111 – **Rg** ?1022 ?28.7 [272] – Syn ? +3 [Rn]5f¹⁴6d¹⁰7s²	copernicio 112 – **Cn** ?1155 ?23.7 [285] – Syn ? +1+2+4 [Rn]5f¹⁴6d¹⁰7s²	nihonio 113 ?700K **Nh** ?704.9 ?16 [284] – Syn ? +1+3 [Rn]5f¹⁴6d¹⁰7s²7p¹	flerovio 114 ?340K **Fl** ?823.9 ?14 [289] – Syn ? +2 [Rn]5f¹⁴6d¹⁰7s²7p²	moscovio 115 ?670K **Mc** ?704.9 ?13.5 [288] – Syn ? +1+3 [Rn]5f¹⁴6d¹⁰7s²7p³	livermorio 116 ?637K **Lv** ?723.6 ?12.9 [292] – Syn ? +2+4 [Rn]5f¹⁴6d¹⁰7s²7p⁴	tennesso 117 ?623K **Ts** ?742.9 ?7.1 [310] – Syn ? +1+3 [Rn]5f¹⁴6d¹⁰7s²7p⁵	oganesson 118 ?350K **Og** ?839.4 ?5.1 [314] – Syn ? +2+4 [Rn]5f¹⁴6d¹⁰7s²7p⁶
periodo 8	ununennium 119 – **Uue** ?463.1 ?3 ?[315] ?0.93 ? ?(+1) [Uuo]8s¹	unbinilium 120 ?953K **Ubn** ?578.9 ?7 ?[320] – ? ?(+2+4) [Uuo]8s²																

Lantanidi	lantanio 57 1193K **La** 538 6.162 138.9 1.1 Lit +3 [Xe]5d¹6s²	cerio 58 1068K **Ce** 528 6.77 140.1 1.12 Lit +3+4 [Xe]4f¹5d¹6s²	praseodimio 59 1208K **Pr** 523 6.77 140.9 1.13 Lit +3 [Xe]4f³6s²	neodimio 60 1297K **Nd** 530 7.01 144.2 1.14 Lit +3 [Xe]4f⁴6s²	promezio 61 1315K **Pm** 523 7.26 [145] ?1.13 Lit +3 [Xe]4f⁵6s²	samario 62 1345K **Sm** 543 7.52 150.4 1.17 Lit +2+3 [Xe]4f⁶6s²	europio 63 1099K **Eu** 547 5.264 152 1.2 Lit +2+3 [Xe]4f⁷6s²	gadolinio 64 1585K **Gd** 592 7.9 157.3 1.2 Lit +3 [Xe]4f⁷5d¹6s²	terbio 65 1629K **Tb** 564 8.23 158.9 1.2 Lit +3 [Xe]4f⁹6s²	disprosio 66 1680K **Dy** 572 8.54 162.5 1.22 Lit +3 [Xe]4f¹⁰6s²	olmio 67 1734K **Ho** 581 8.79 164.9 1.23 Lit +3 [Xe]4f¹¹6s²	erbio 68 1802K **Er** 589 9.066 167.3 1.24 Lit +3 [Xe]4f¹²6s²	tulio 69 1818K **Tm** 596 9.32 168.9 1.25 Lit +2+3 [Xe]4f¹³6s²	itterbio 70 1097K **Yb** 603 6.9 173 1.1 Lit +2+3 [Xe]4f¹⁴6s²	lutezio 71 1925K **Lu** 524 9.841 175 1.27 Lit +3 [Xe]4f¹⁴5d¹6s²	Lantanidi
Attinidi	attinio 89 1500K **Ac** 499 10 [227] 1.1 Lit +3 [Rn]6d¹7s²	torio 90 2023K **Th** 587 11.72 232 1.3 Lit +4 [Rn]6d²7s²	protoattinio 91 1841K **Pa** 568 15.37 231 1.5 Lit +4+5 [Rn]5f²6d¹7s²	uranio 92 1405.3K **U** 584 19.1 238 1.38 Lit +3+4+5+6 [Rn]5f³6d¹7s²	nettunio 93 912K **Np** 597 20.45 [237] 1.36 Lit +3+4+5+6 [Rn]5f⁴6d¹7s²	plutonio 94 912.5K **Pu** 585 19.81 [244] 1.28 Lit +3+4+5+6 [Rn]5f⁶7s²	americio 95 1449K **Am** 579 12 [243] 1.3 Syn +3+4+5+6 [Rn]5f⁷7s²	curio 96 1613K **Cm** 581 13.51 [247] 1.3 Syn +3 [Rn]5f⁷6d¹7s²	berkelio 97 1259K **Bk** 601 13.25 [247] 1.3 Syn +3+4 [Rn]5f⁹7s²	californio 98 1173K **Cf** 581 15.1 [251] ?1.3 Syn ? +3 [Rn]5f¹⁰7s²	einsteinio 99 1133K **Es** 619 8.84 [252] ?1.3 Syn ? +3 [Rn]5f¹¹7s²	fermio 100 ?1800K **Fm** 627 – [257] ?1.3 Syn ? +3 [Rn]5f¹²7s²	mendelevio 101 ?1100K **Md** 637 – [258] ?1.3 Syn ? +2+3 [Rn]5f¹³7s²	nobelio 102 ?1100K **No** 641 – [259] ?1.3 Syn ? +2+3 [Rn]5f¹⁴7s²	laurenzio 103 ?1900K **Lr** 478.6 – [262] – Syn ? +3 [Rn]5f¹⁴6d¹7s²	Attinidi

blocco - s (con He) | *blocco - f* | *blocco - d* | *blocco - p* (senza He)

Metalli

Metalli alcalini	Metalli alcalino terrosi
probabili	probabili

Attinidi	REE (Lantanidi)

REE = Terre Rare

Metalli di transizione	
REE	Metalli preziosi
probabili	

Post-metalli di transizione
probabili

Metalloidi

probabili

Nonmetalli

Poliatomici	Diatomici	Gas nobili

elettroni per livello — numero atomico (Z) — simbolo — peso atomico standard (A) — classificazione Goldschmidt

elemento: 1 | 1111K | **X** | 111 | 1111 | 1.1 | Atm | ±1 | 1s¹

nome — punto di fusione (K) — energia di prima ionizzazione (kj/mol) — densità (g/cm³) — elettronegatività — proprietà degli ossidi — stato d'ossidazione — configurazione elettronica

X solido — **X** liquido — **X** gassoso — **X** non conosciuto

fortemente acido — mediamente acido — debolmente acido — neutro — debolmente basico — mediamente basico — fortemente basico — anfotero

peso atomico elemento stabile — **[peso atomico]** elemento instabile o radioattivo

elemento naturale — **elemento** sintetico

Lit litofilo — **Cal** calcofilo — **Sid** siderofilo — **Atm** atmofilo — ***Syn*** sintetico

Antonio Ciccolella 2017

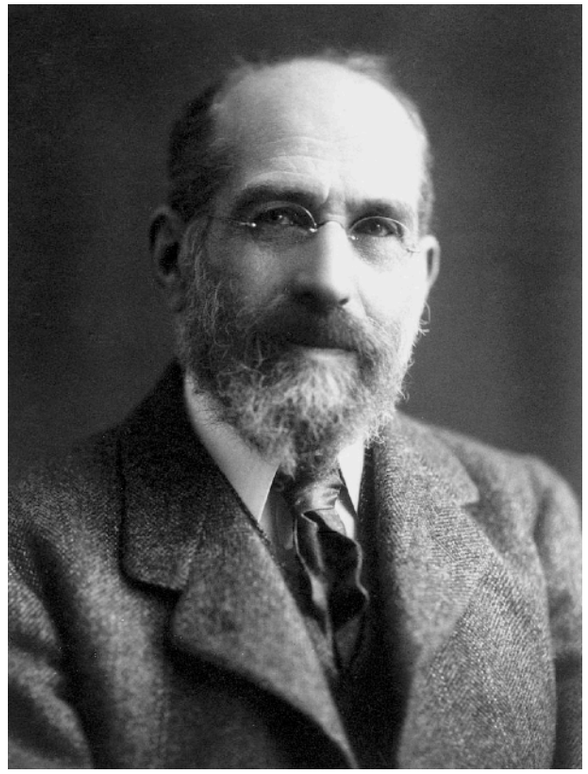
XIX e XX secolo

Thomson

Nato vicino a Manchester nel 1856

Professore a Cambridge dal 1884

Scoprì l’elettrone nel 1897

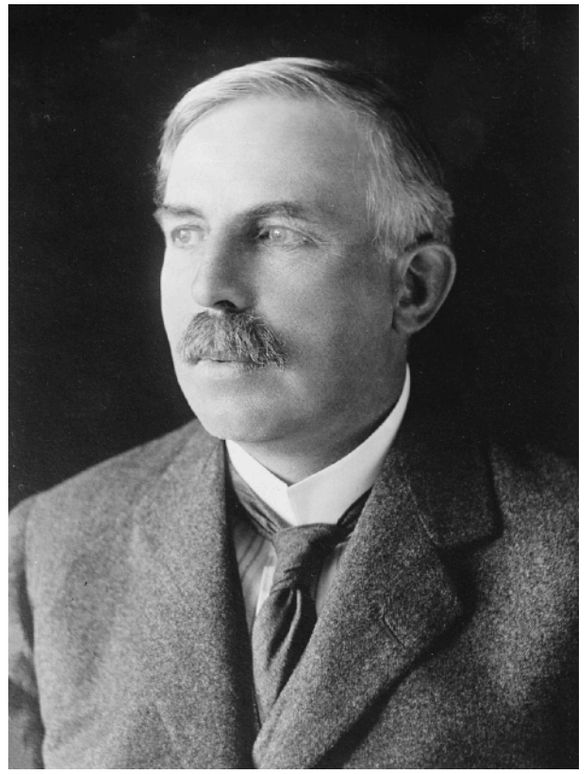


Schuster

Nato a Francoforte nel 1851

Professore a Manchester dal 1888 al 1907

Rischiò di scoprire l’elettrone per primo

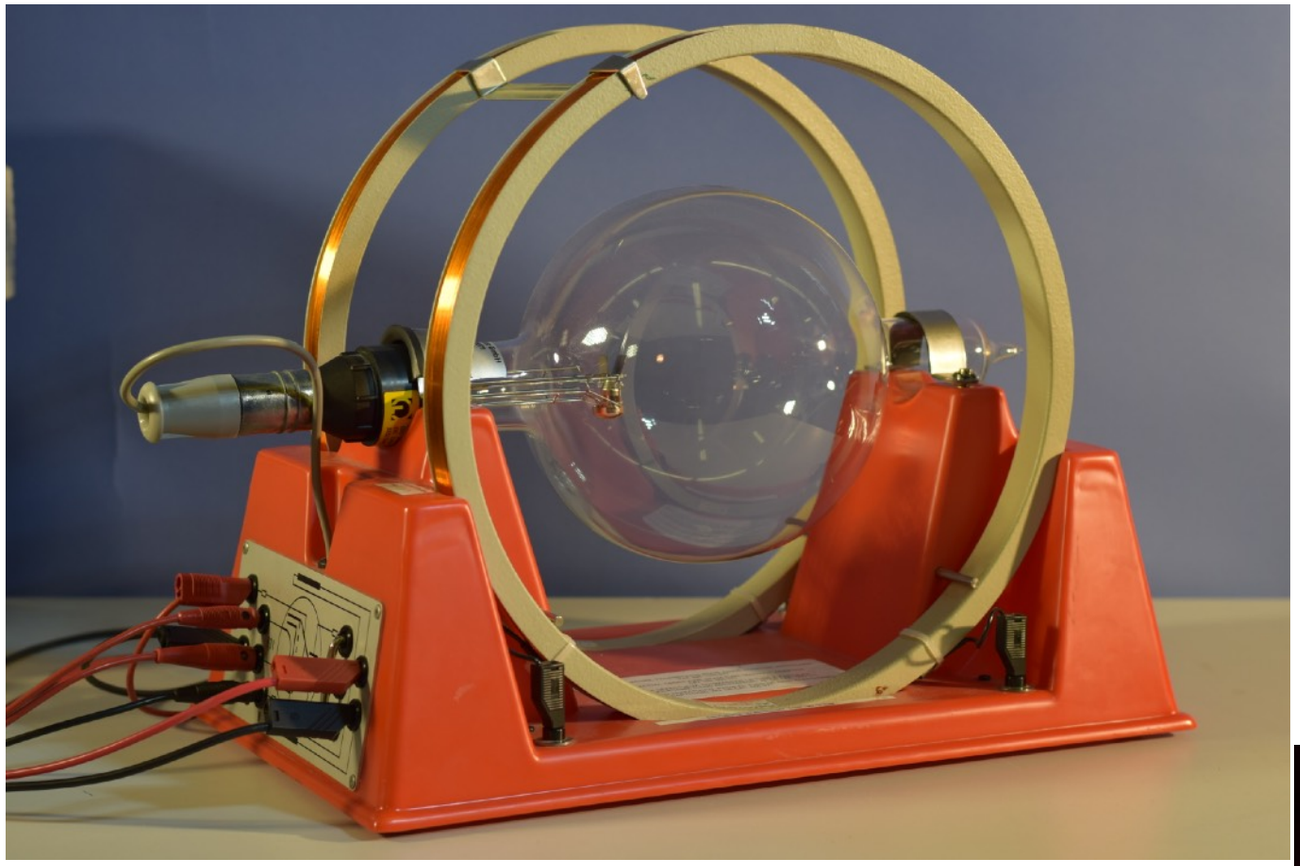


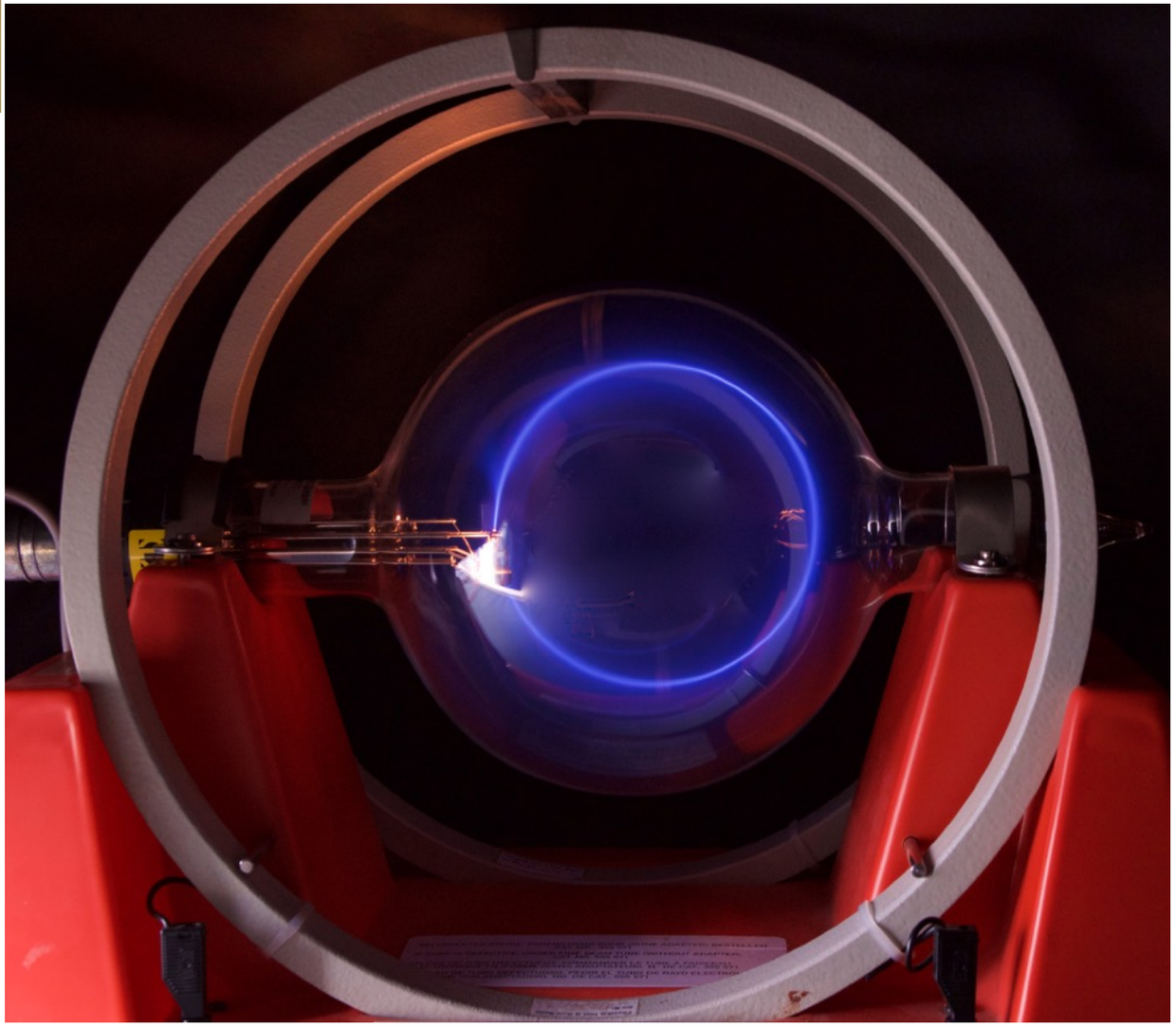
Rutherford

Nato in Nuova Zelanda nel 1871

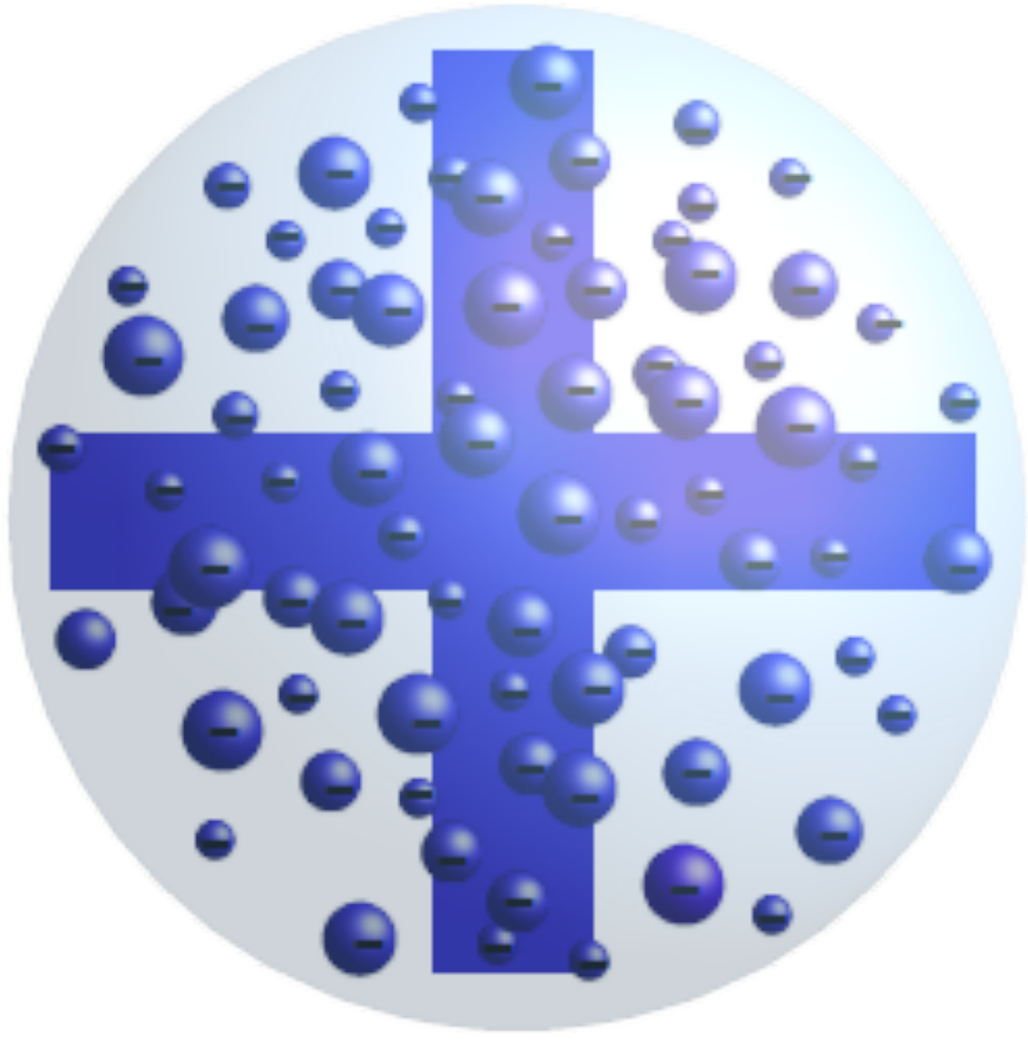
Studente di Thomson a Cambridge

Professore a Manchester dal 1907

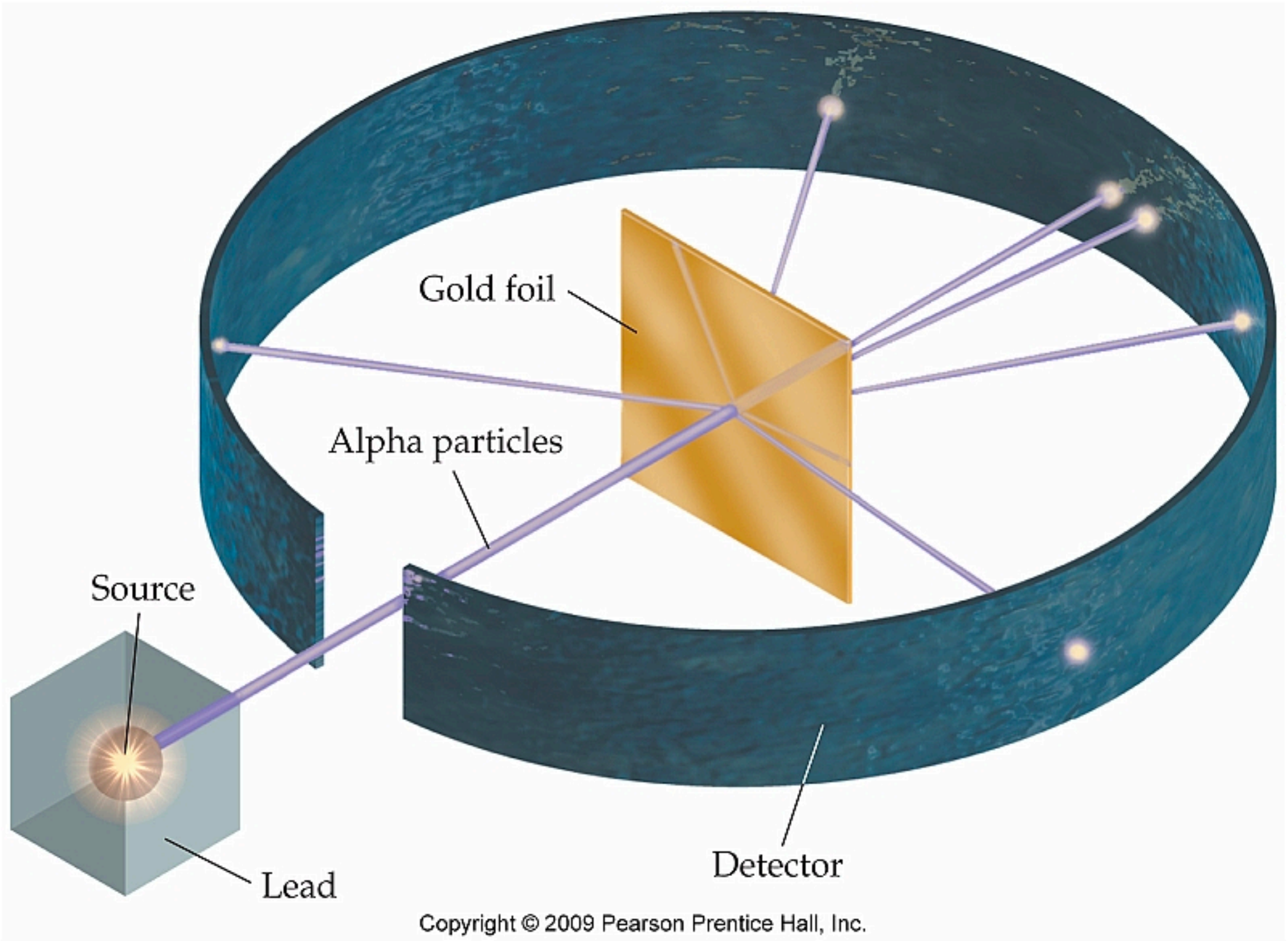




Modello dell'atomo di Thomson

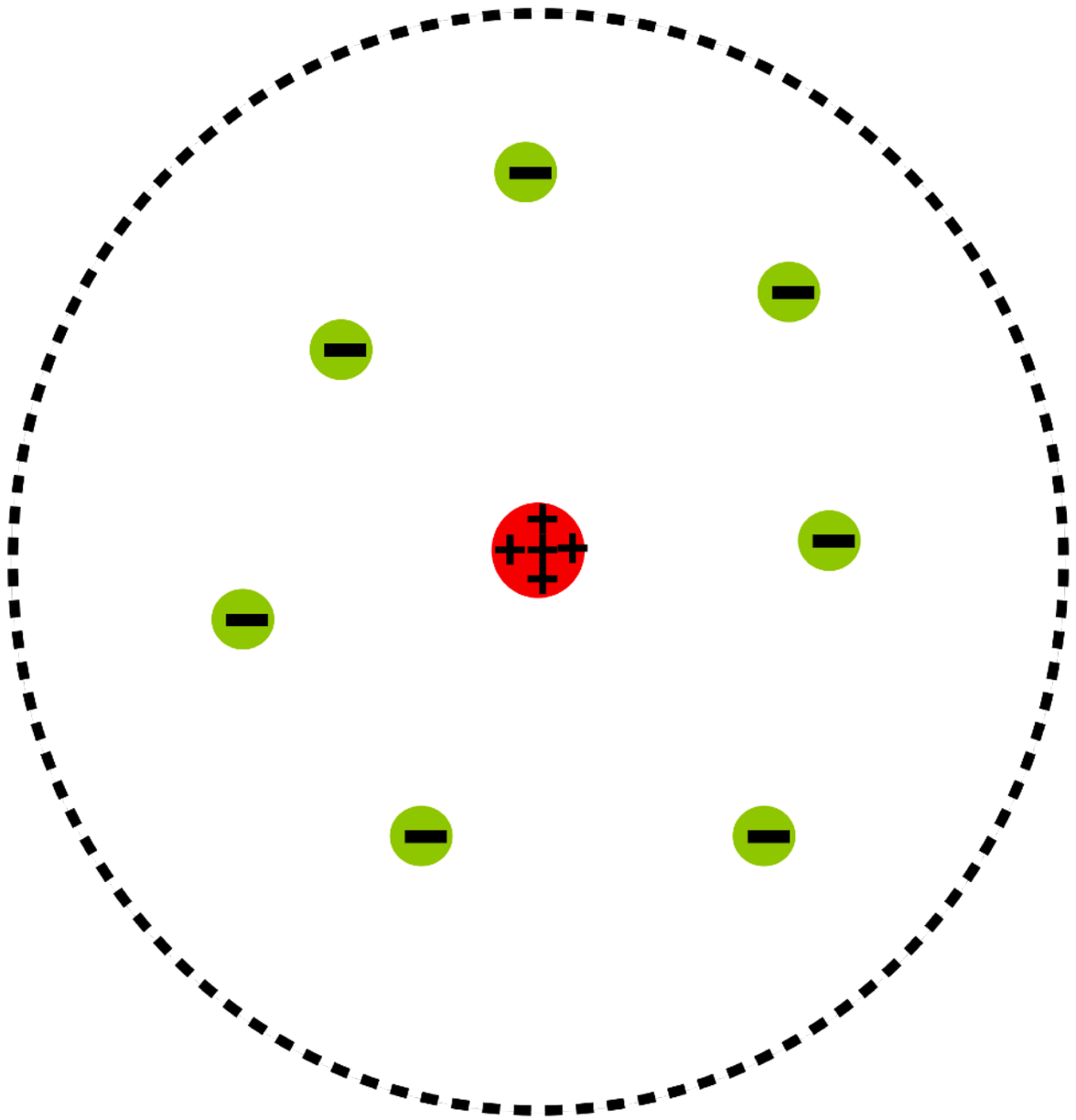


Esperimento di Rutherford (1911)

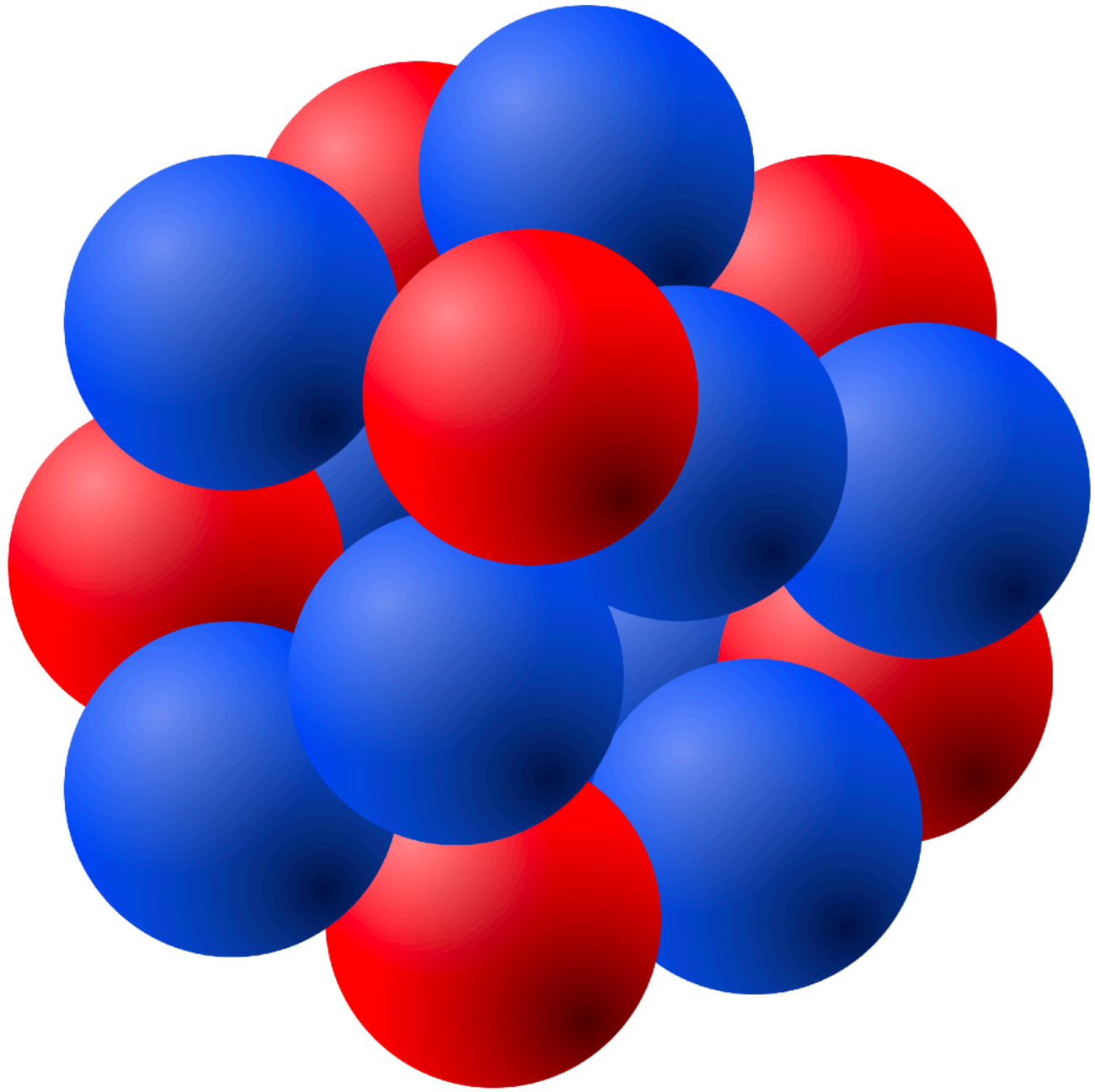


https://www.youtube.com/watch?v=5pZj0u_XMbc&ab_channel=BackstageScience

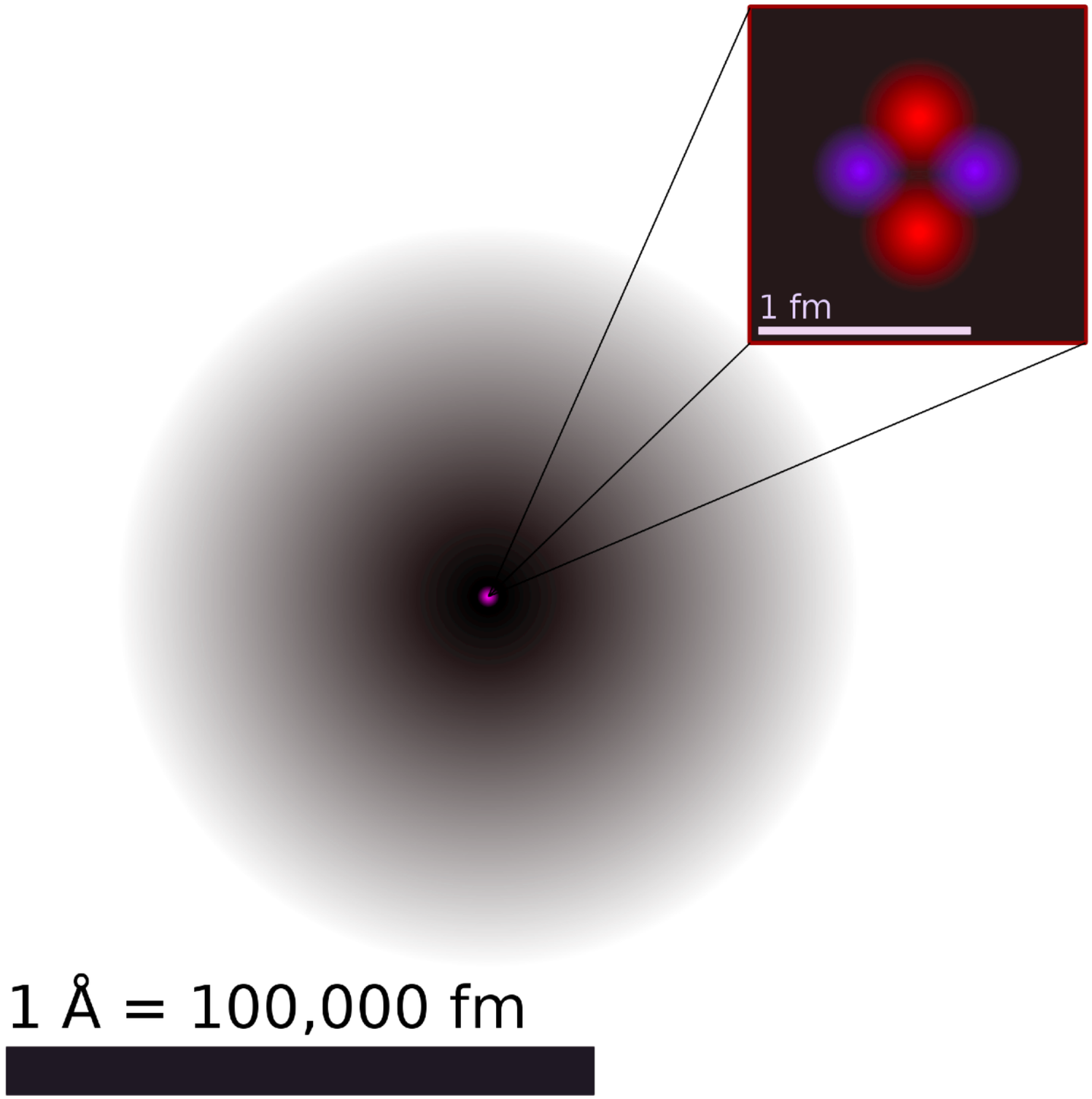
Modello dell'atomo di Rutherford



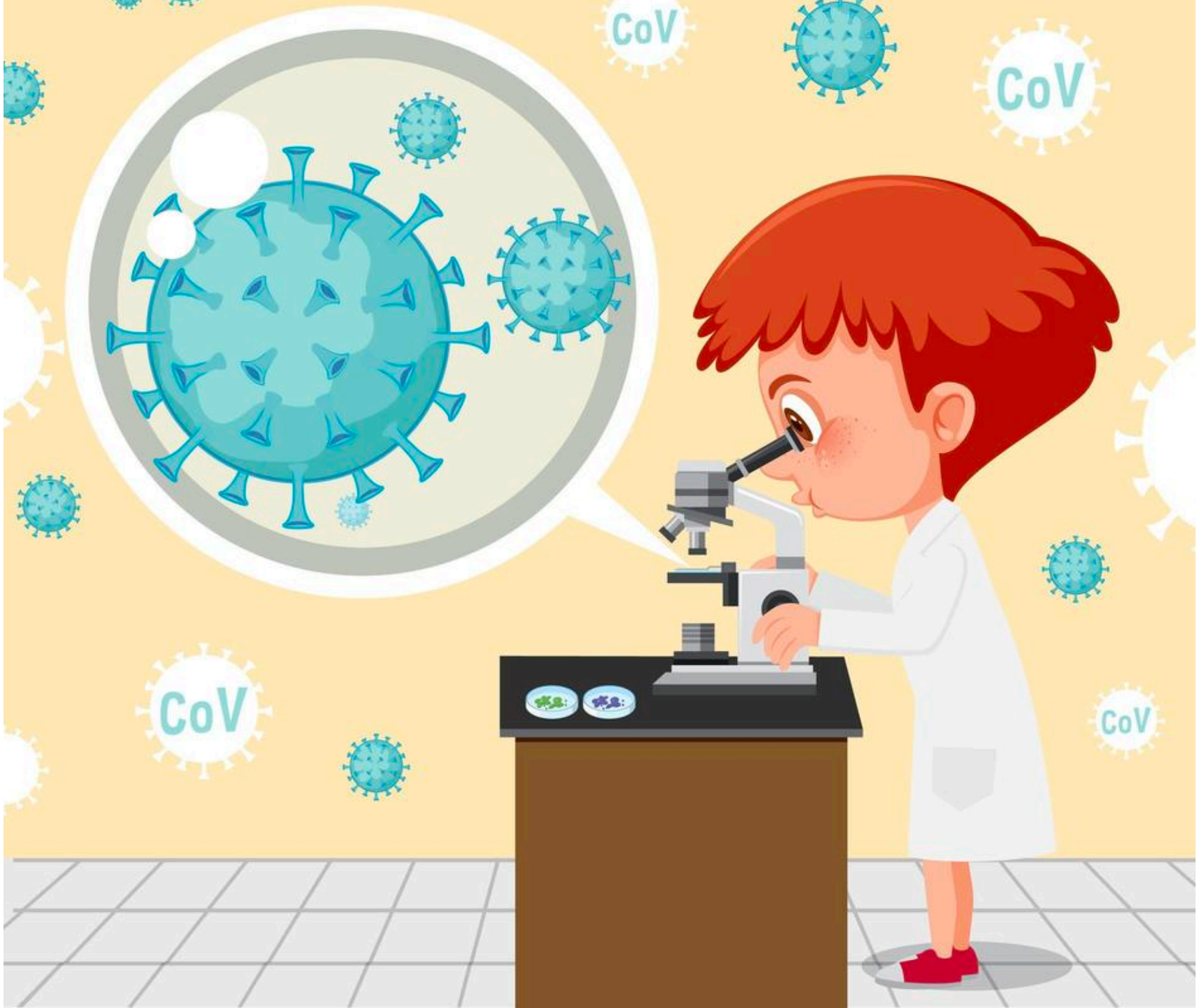
Modello del nucleo dell'atomo



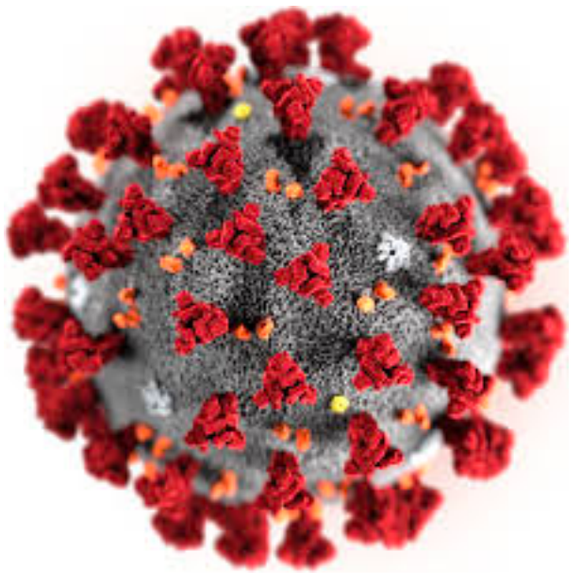
Modello attuale dell'atomo



CORONAVIRUS : CoV



Lunghezza d'onda luce visibile 0,00005 cm

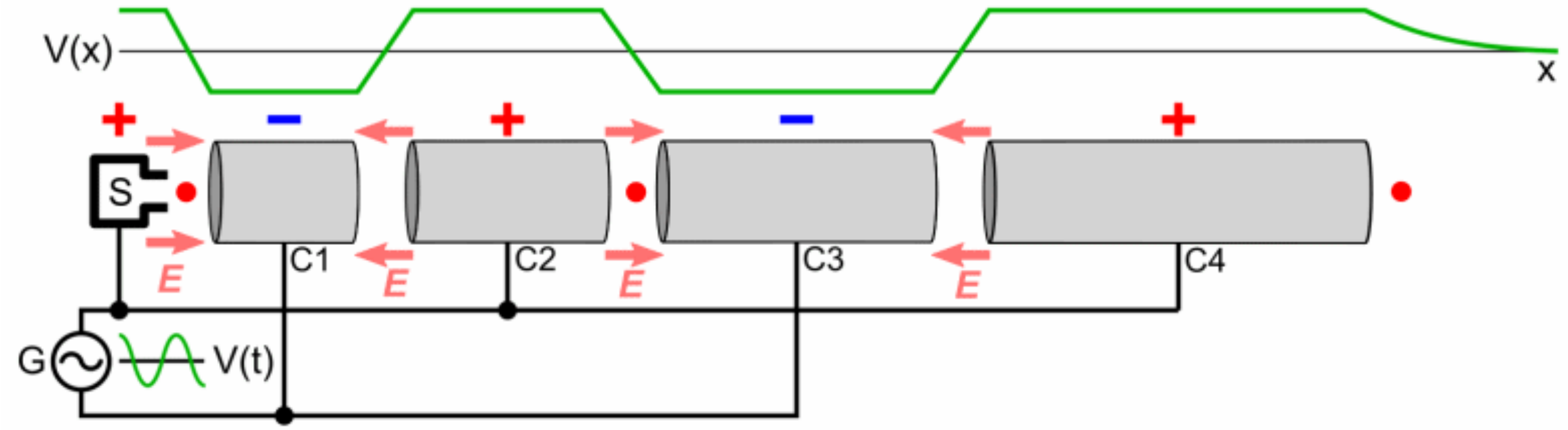


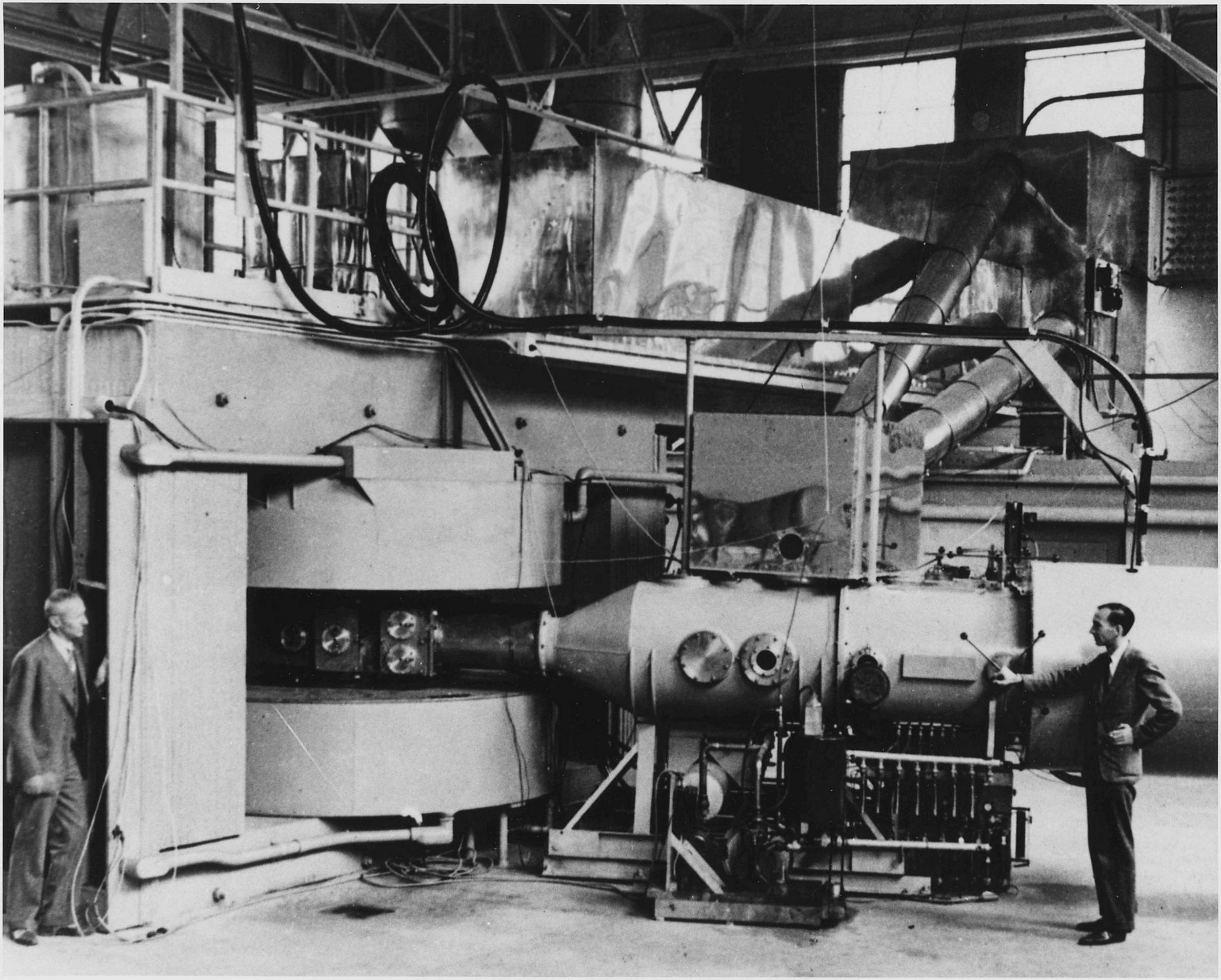
0,00001 cm 10^{-5} cm

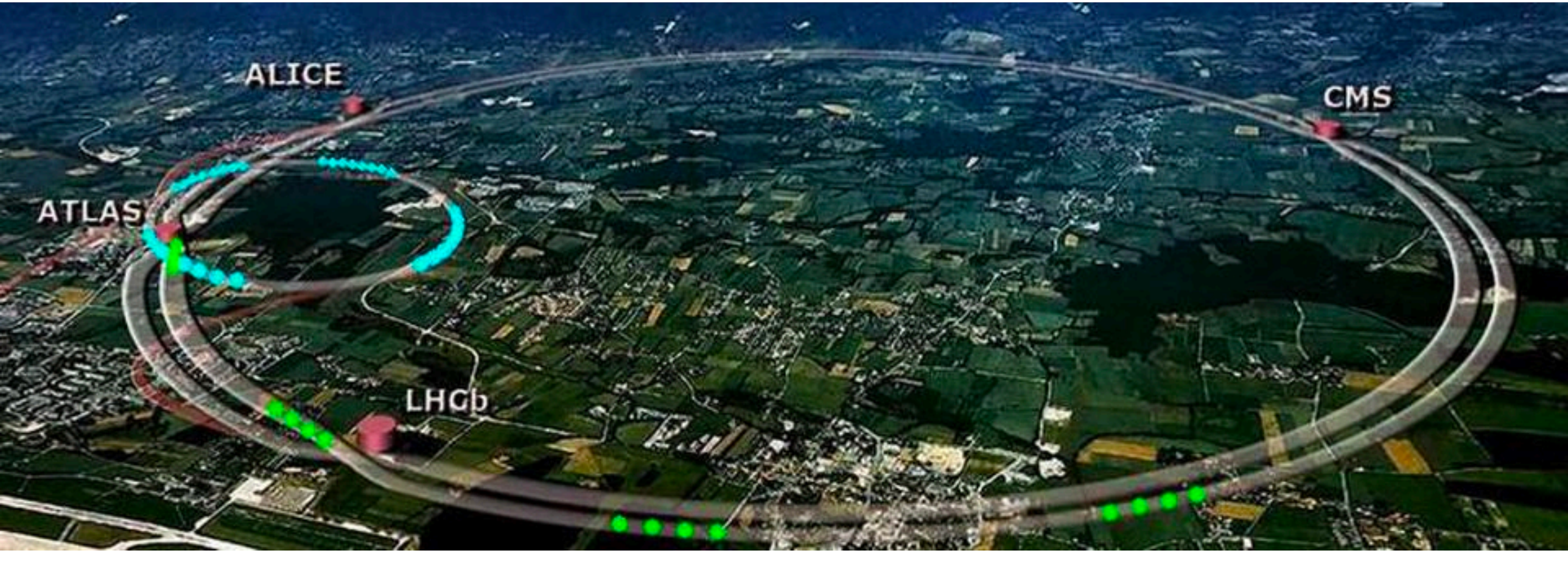
. 0,00000001 cm 10^{-8} cm

0,0000000000001 cm 10^{-13} cm

Acceleratori di particelle





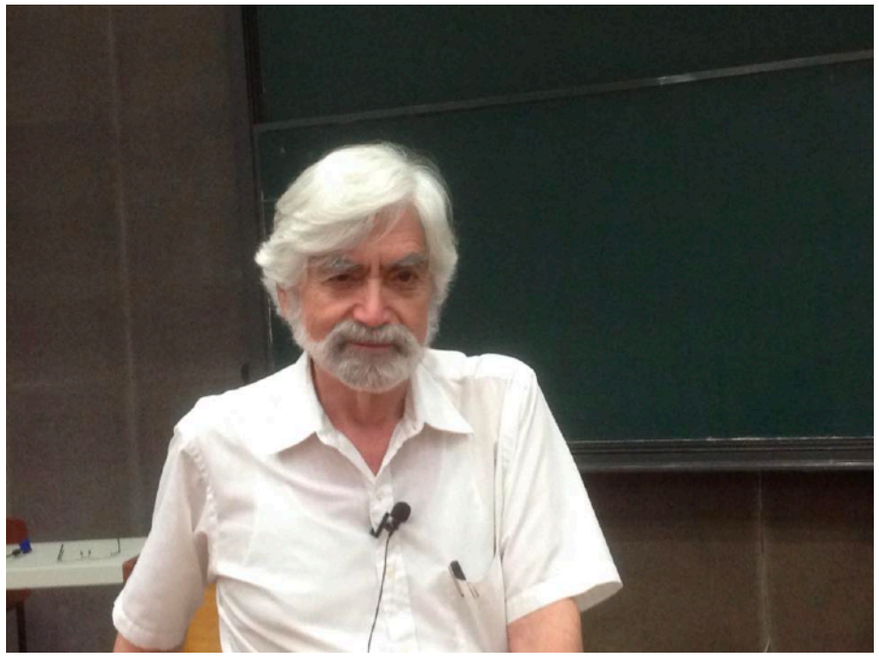

ALICE
CMS
ATLAS
LHCb

Uno zoo di particelle

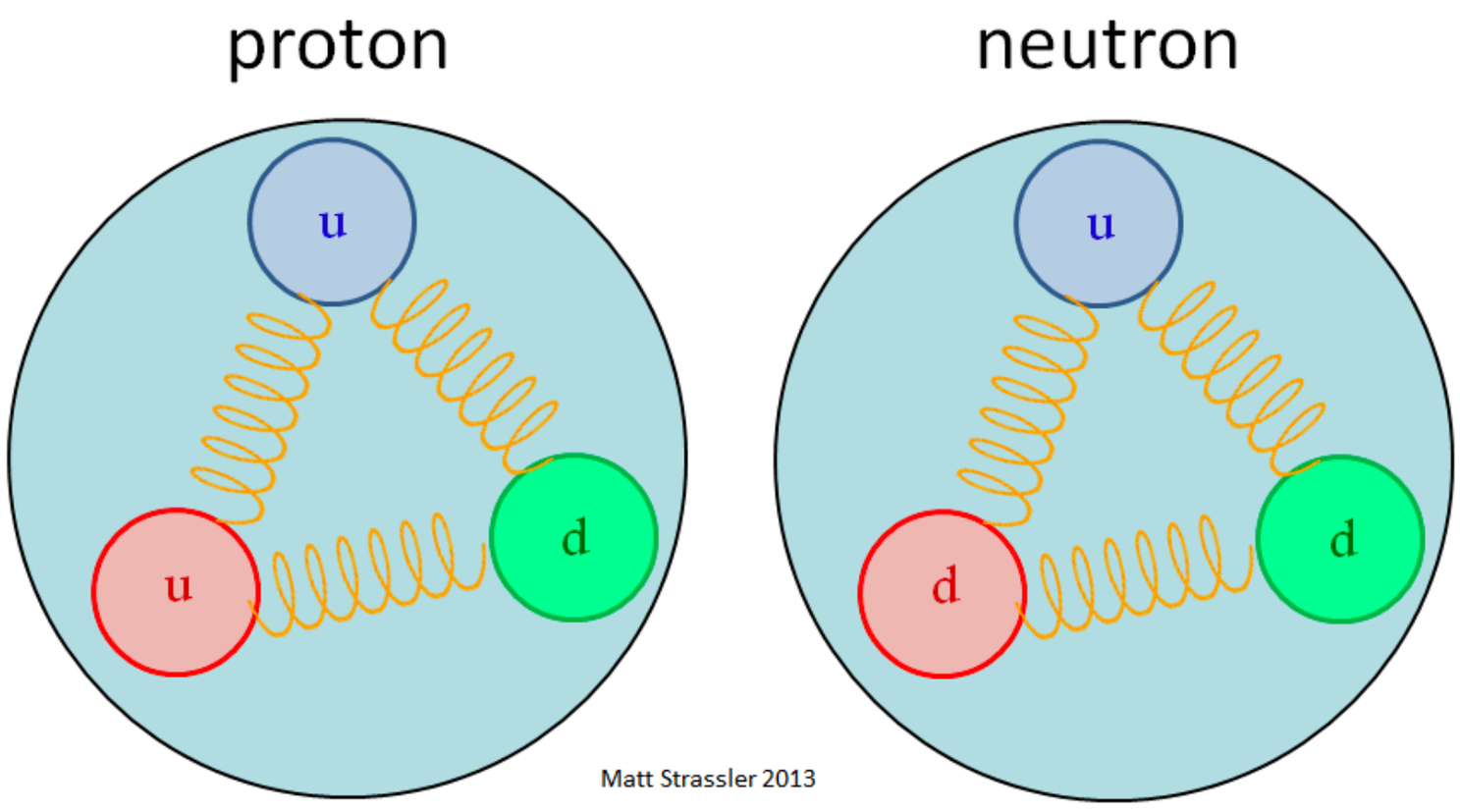
Pioni, kaoni, mesoni e barioni vari

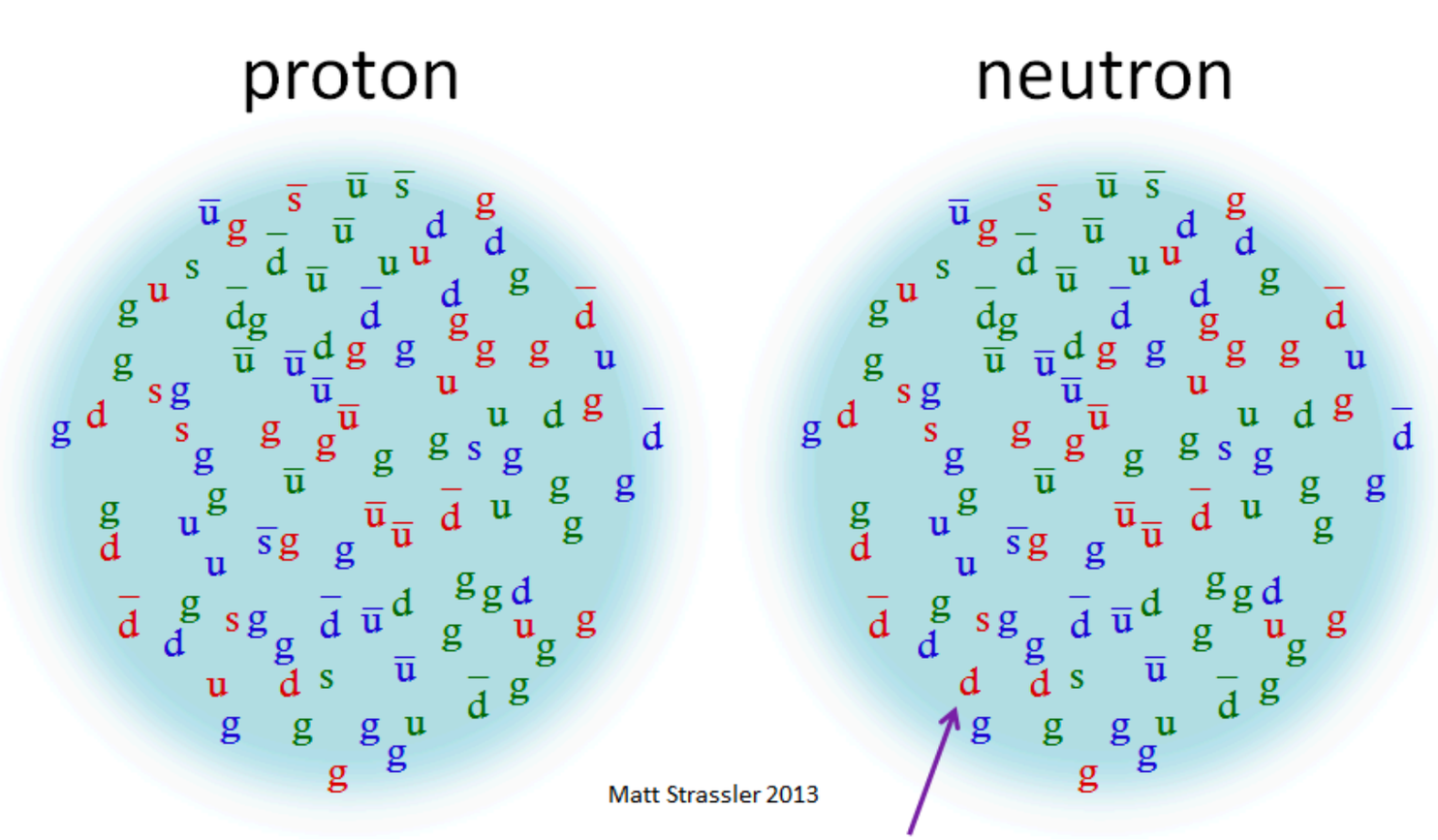
Il modello dei quark - 1964

Gell-Mann

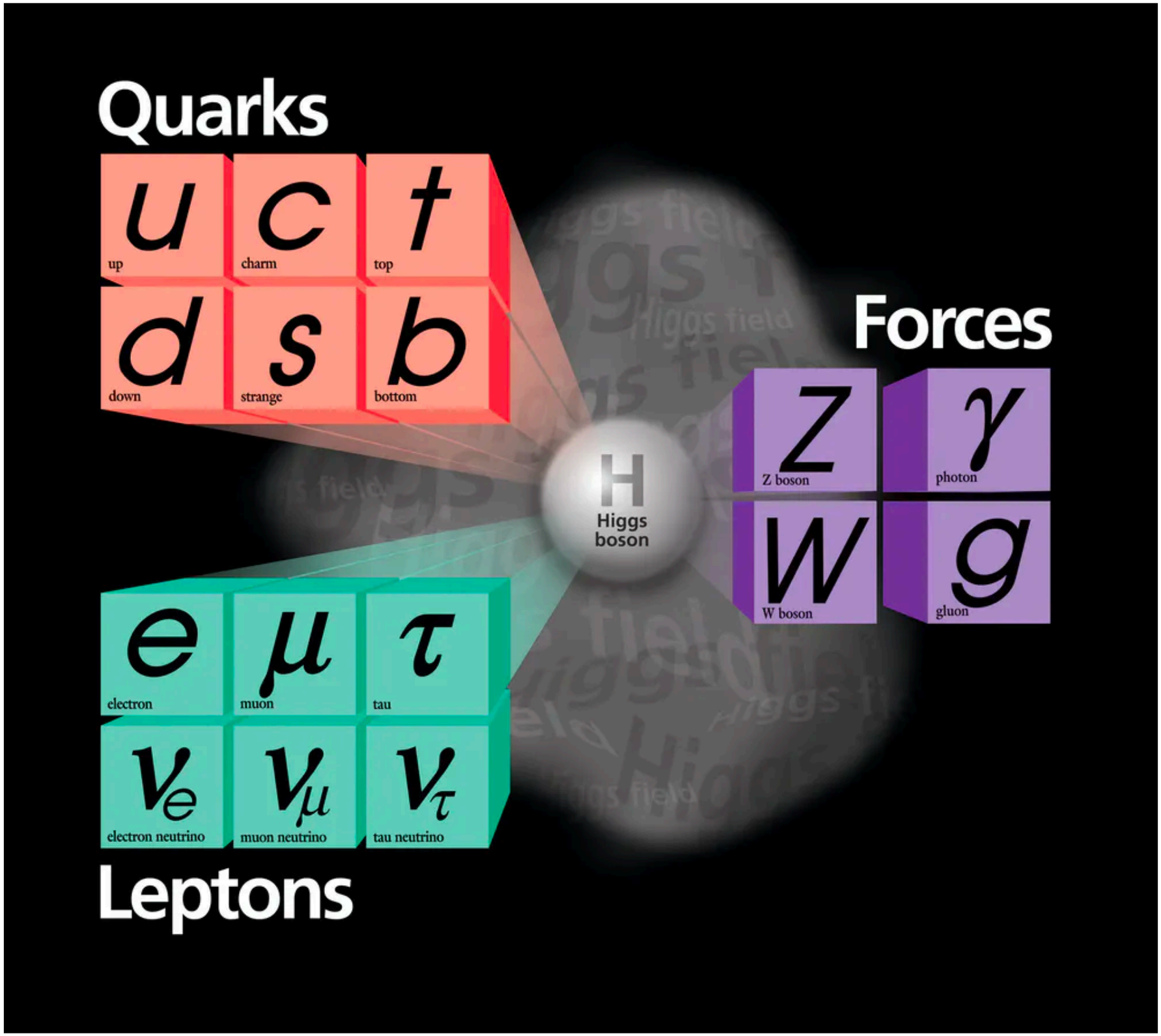


Zweig

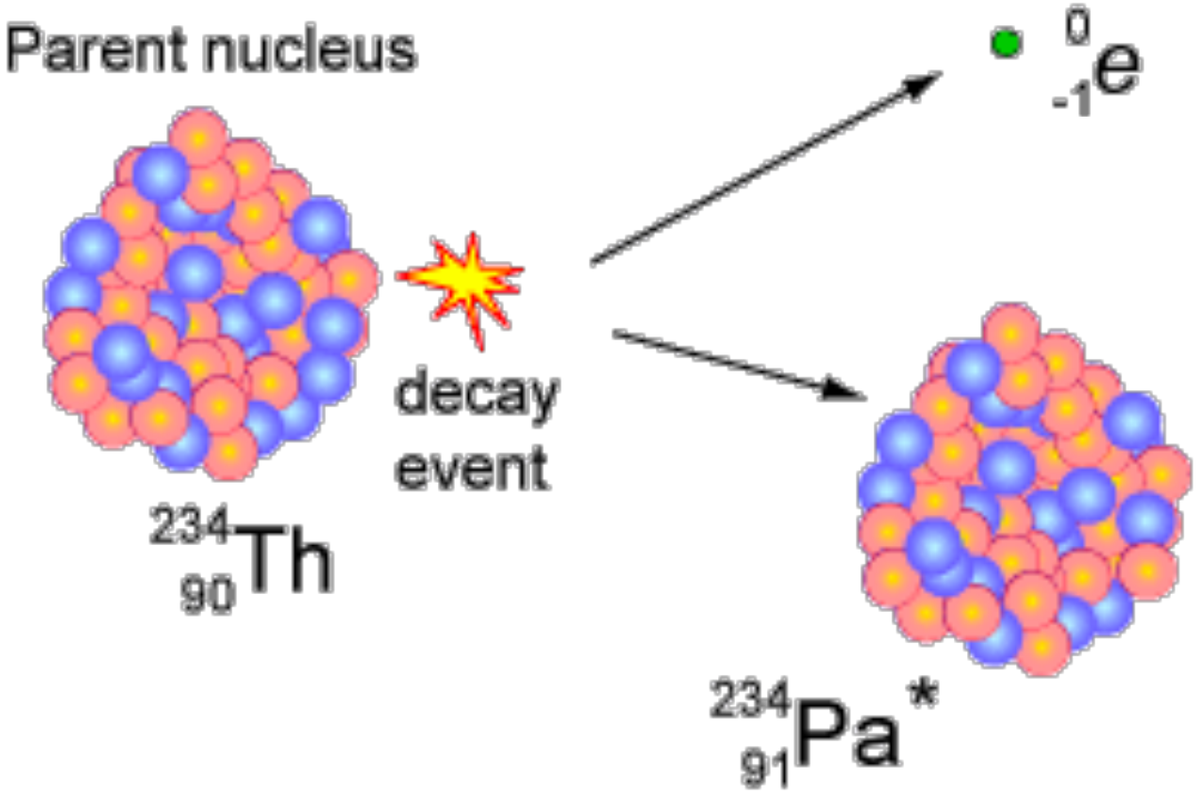

proton
neutron
u
u
d
u
d
d
Matt Strassler 2013


proton
neutron
Matt Strassler 2013

Il Modello Standard

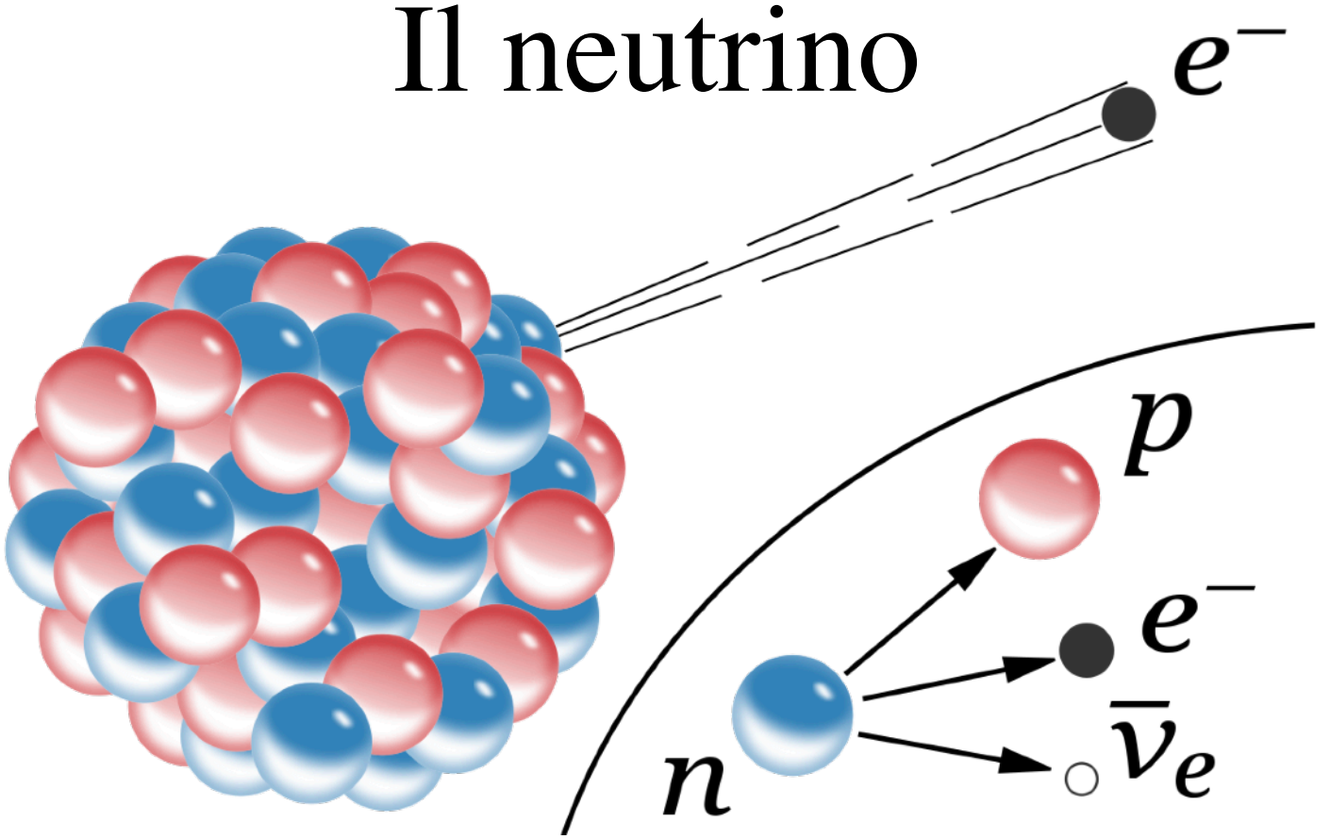


Radioattività



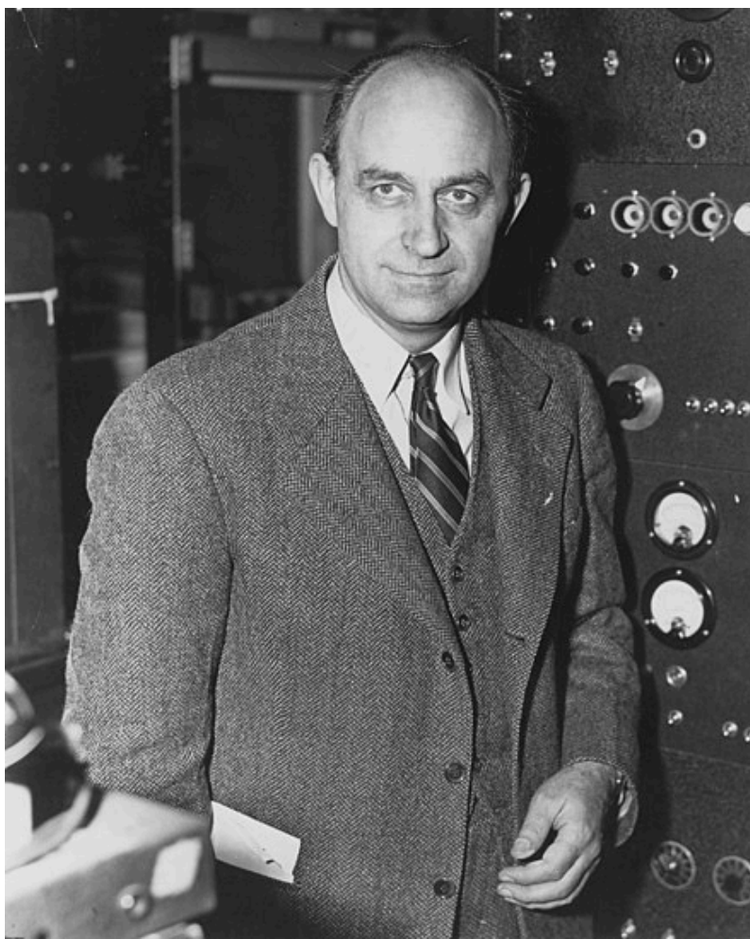
Marie Curie

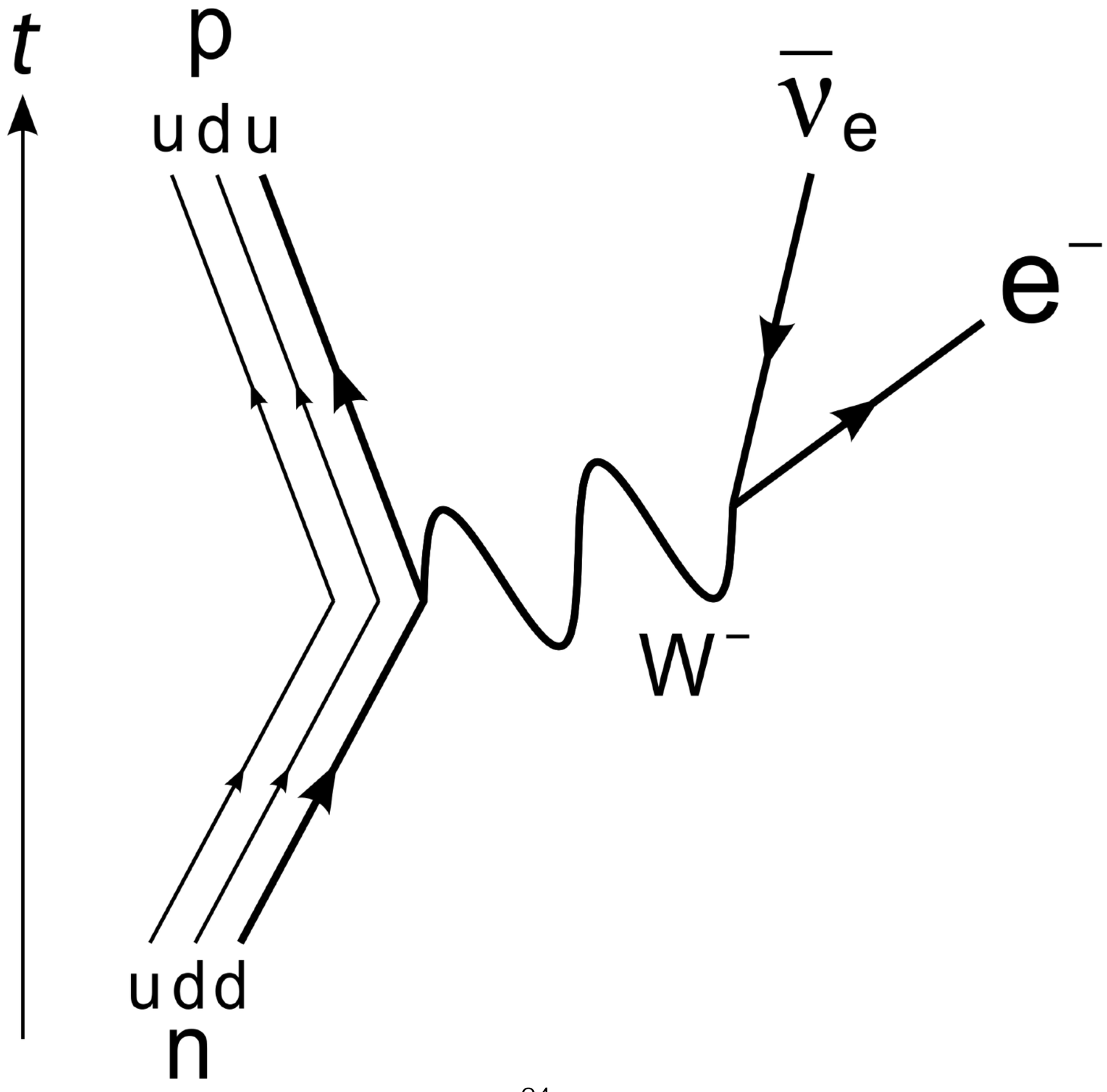
Il neutrino



Pauli

Fermi

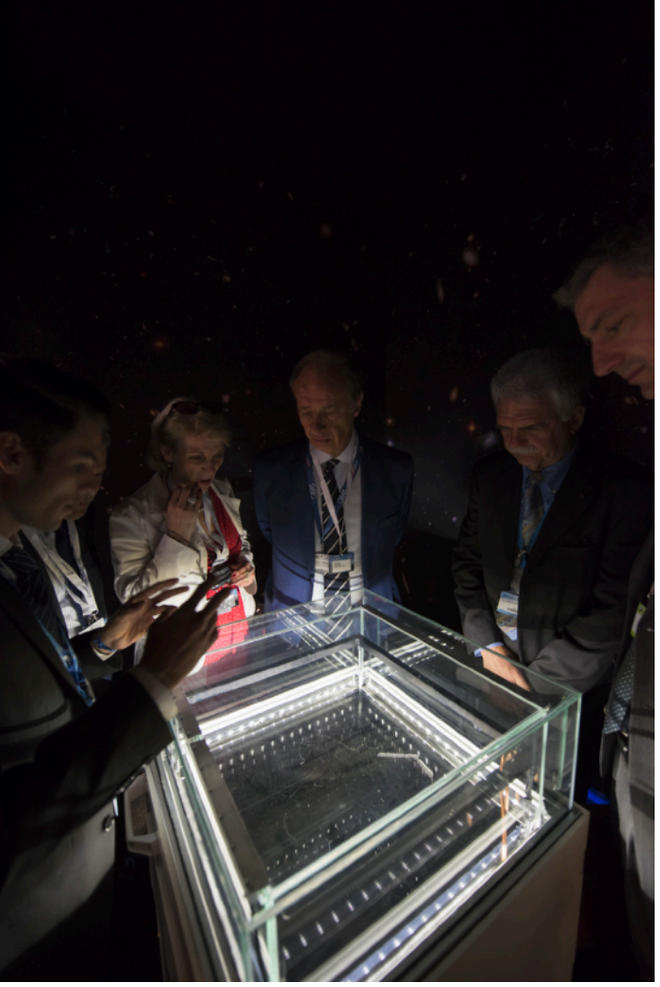



t
p
u d u
$\bar{\nu}_e$
e^-
W^-
u d d
n

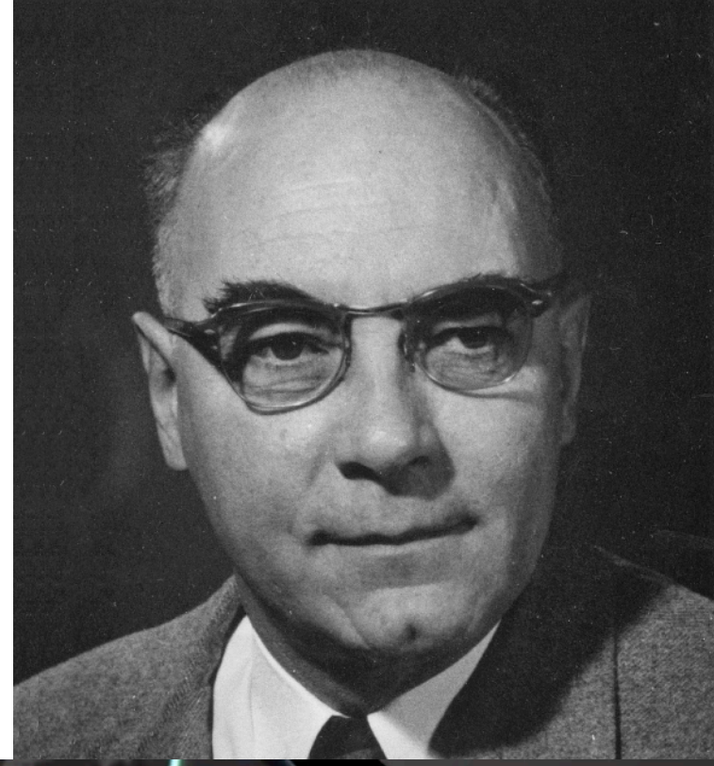
Glashow

Salam

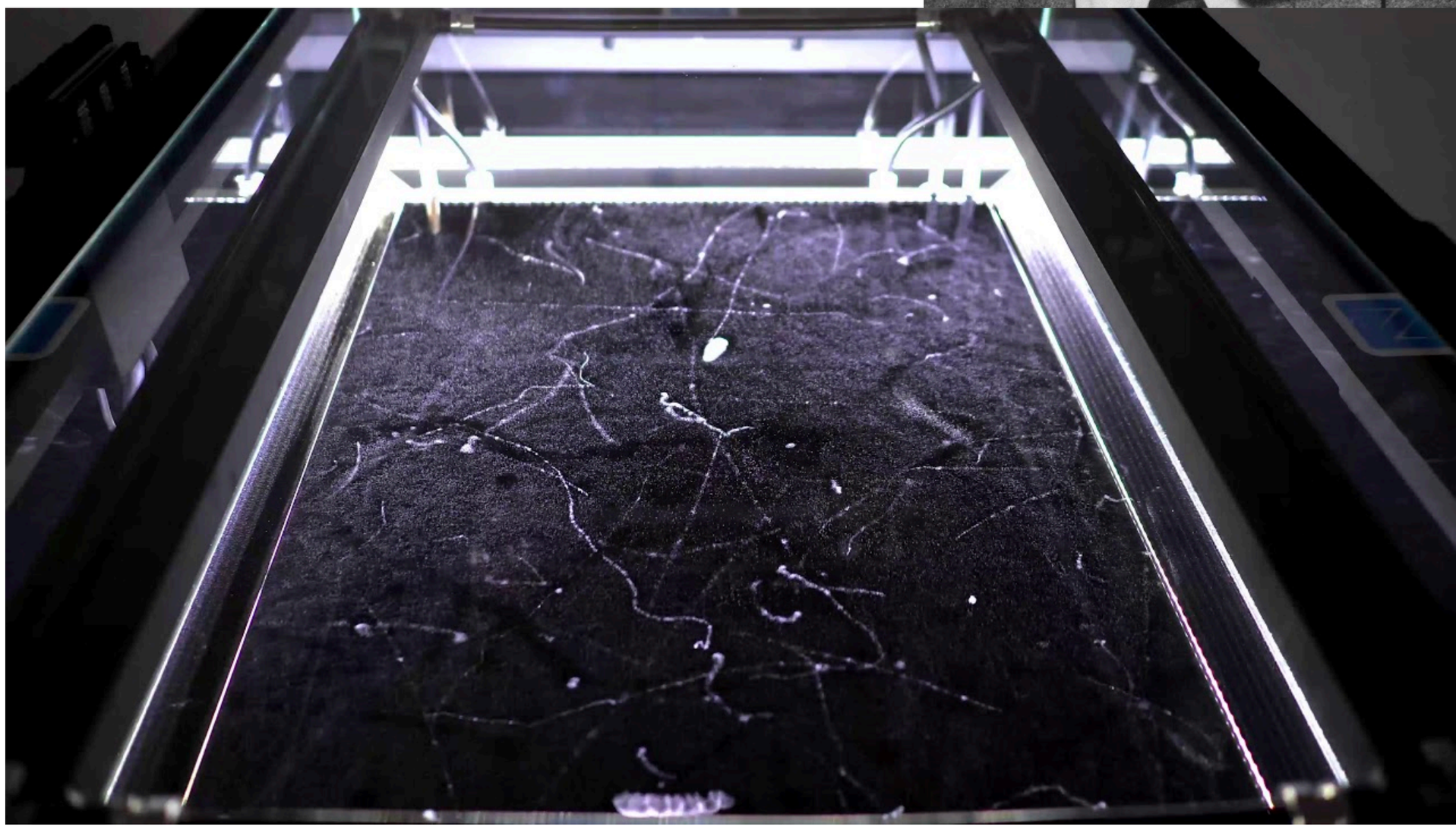
Weinberg

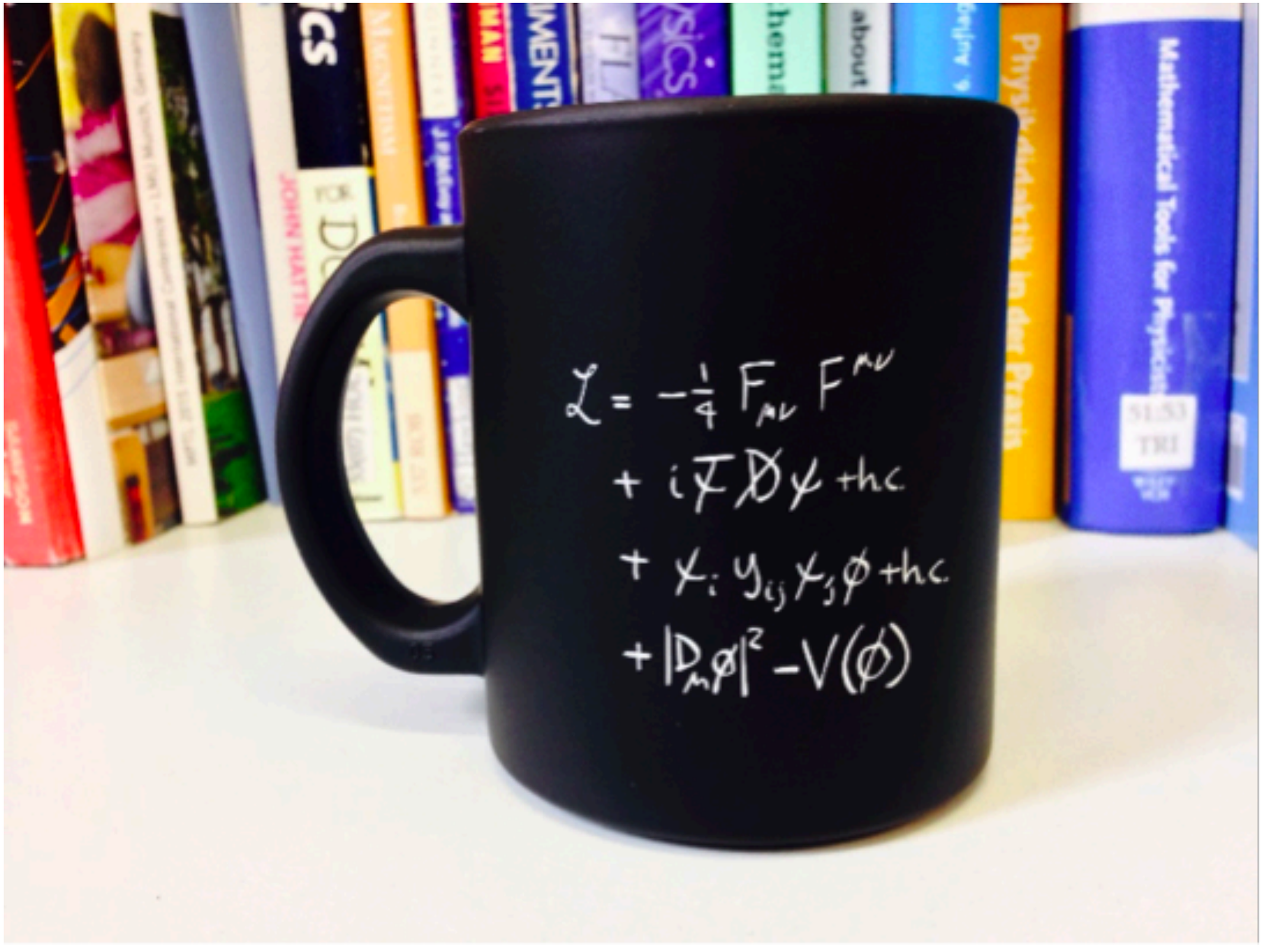


Il muone

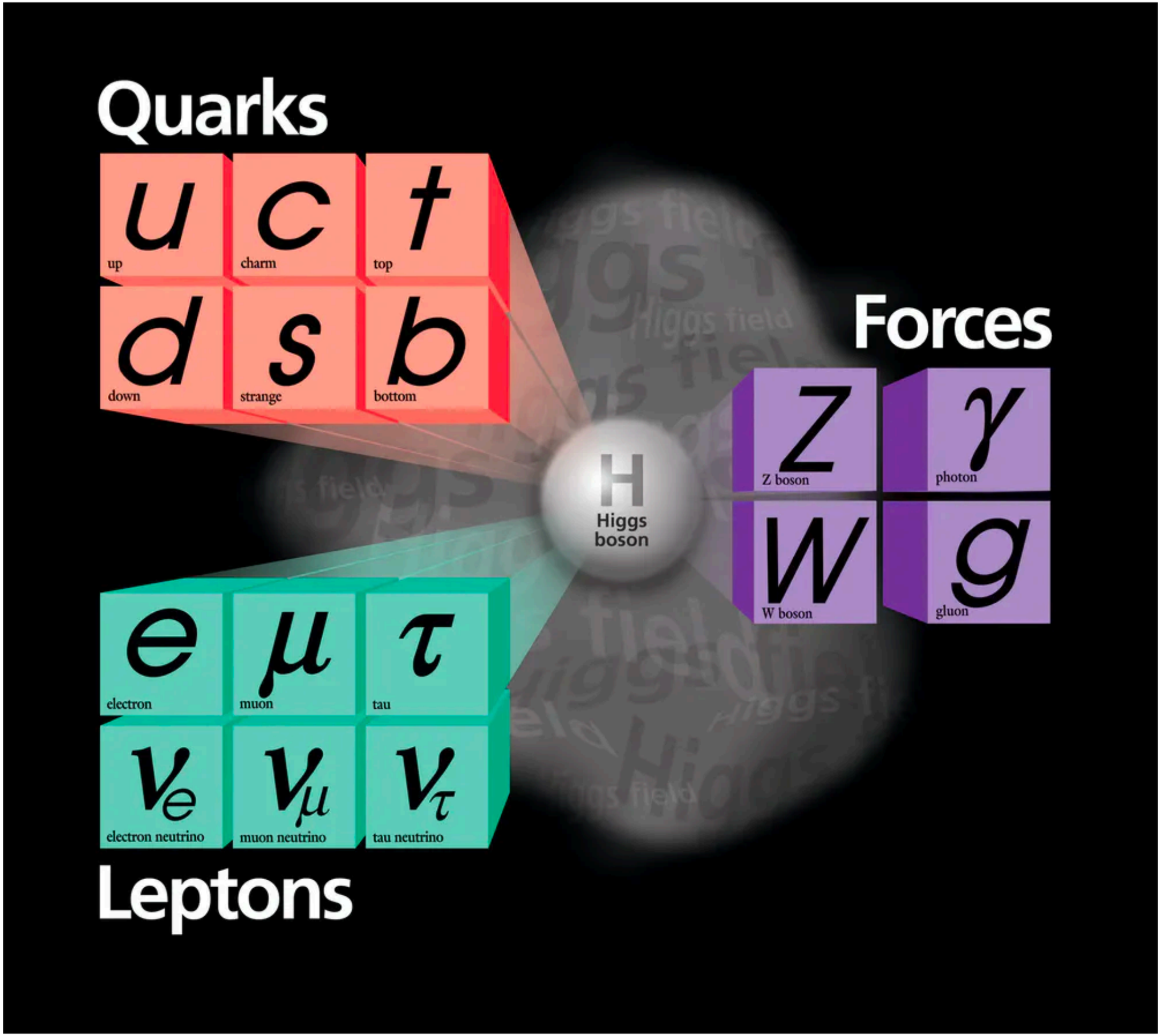


Anderson




$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$
$+ i\bar{\psi} \not{D} \psi + h.c.$
$+ \chi_i y_{ij} \chi_j \phi + h.c.$
$+ |D_\mu \phi|^2 - V(\phi)$

WHAT PART OF
DO YOU NOT
UNDERSTAND?


Quarks
u
up
c
charm
t
top
d
down
s
strange
b
bottom
Forces
Z
Z boson
γ
photon
W
W boson
g
gluon
H
Higgs boson
e
electron
μ
muon
τ
tau
νe
electron neutrino
νμ
muon neutrino
ντ
tau neutrino
Leptons

Kibble Englert

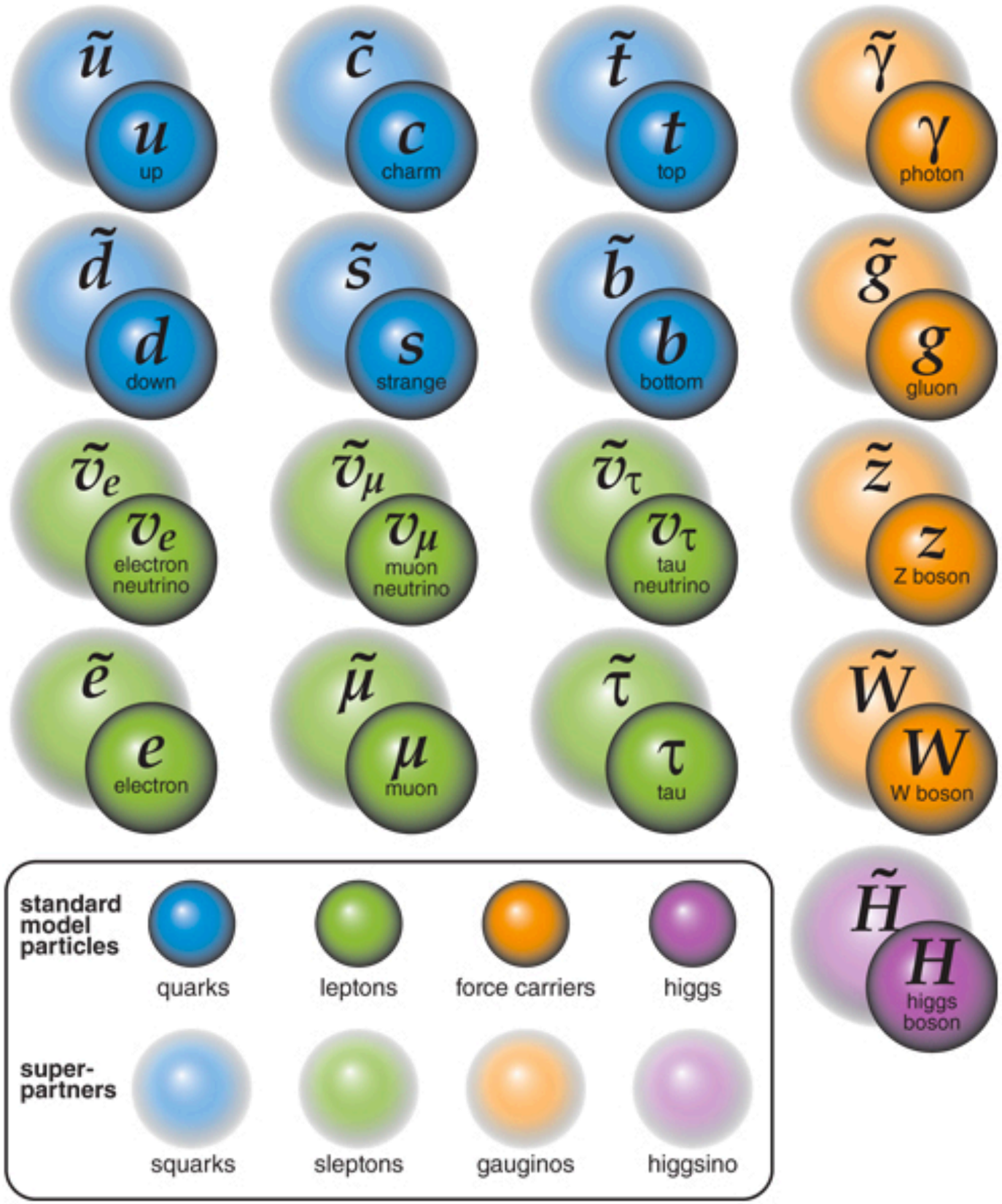
Guralnik Brout

Hagen

Higgs

Il Modello Standard rappresenta lo stato dell'arte della fisica teorica delle particelle. Descrive le interazioni elettrodeboli e forti tra le particelle elementari.

Quali i prossimi passi?


$\tilde{u}$ u up
$\tilde{c}$ c charm
$\tilde{t}$ t top
$\tilde{\gamma}$ γ photon
$\tilde{d}$ d down
$\tilde{s}$ s strange
$\tilde{b}$ b bottom
$\tilde{g}$ g gluon
$\tilde{\upsilon}_e$ υ_e electron neutrino
$\tilde{\upsilon}_\mu$ υ_μ muon neutrino
$\tilde{\upsilon}_\tau$ υ_τ tau neutrino
$\tilde{z}$ z Z boson
$\tilde{e}$ e electron
$\tilde{\mu}$ μ muon
$\tilde{\tau}$ τ tau
$\tilde{W}$ W W boson
standard model particles
quarks
leptons
force carriers
higgs
super-partners
squarks
sleptons
gauginos
higgsino
$\tilde{H}$ H higgs boson

La fisica delle particelle si confronta con una moltitudine di misure sperimentali non solo negli acceleratori, ma anche in astrofisica e cosmologia.

Planck

Xenon

Il futuro della fisica teorica è la fisica sperimentale