A Física do Infinitamente Pequeno

Masterclasses Internacionais de Física de Partículas
Universidade dos Açores – 29 de março de 2023

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Universidade de Coimbra / LIP

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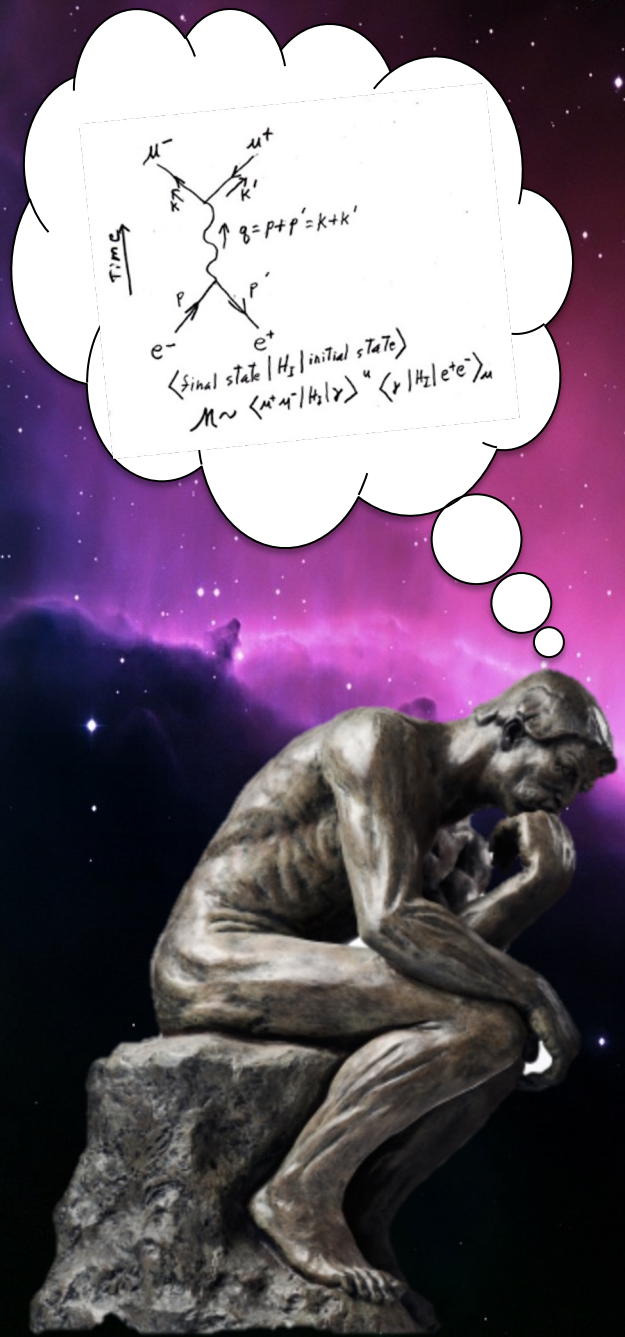

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  - Partículas e forças fundamentais
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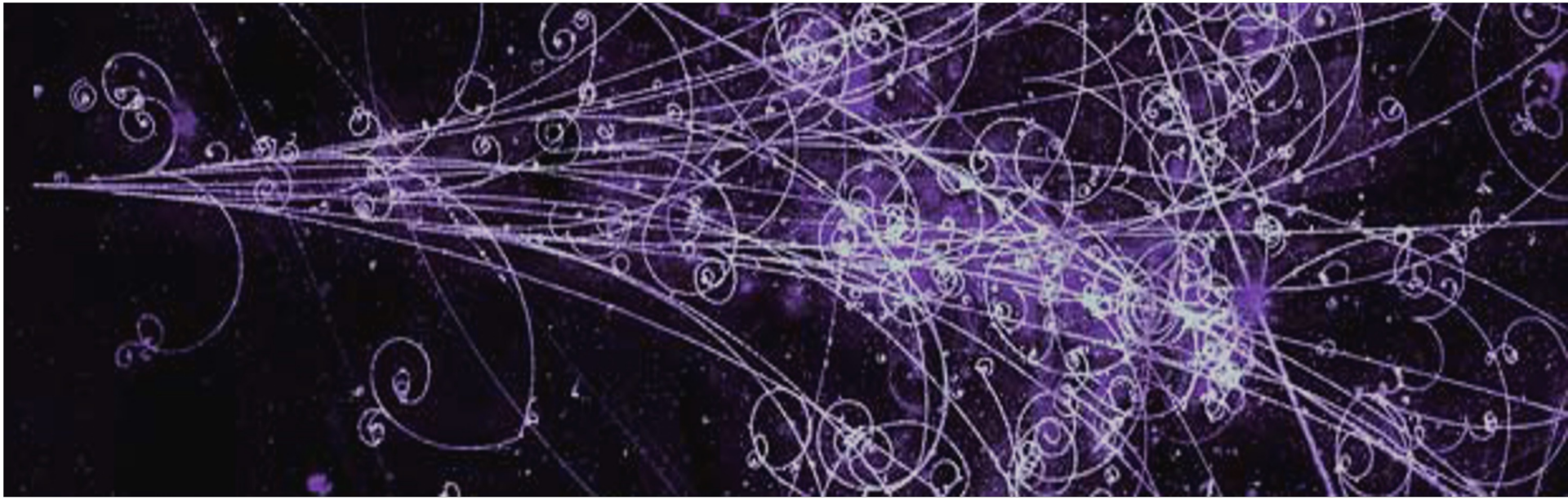
  - O que não sabemos?
- Benefícios para a sociedade
  - Terapia com radiação ionizante: partículas para a saúde

A física de partículas



De que são feitas as coisas???

Periodic Table of the Elements

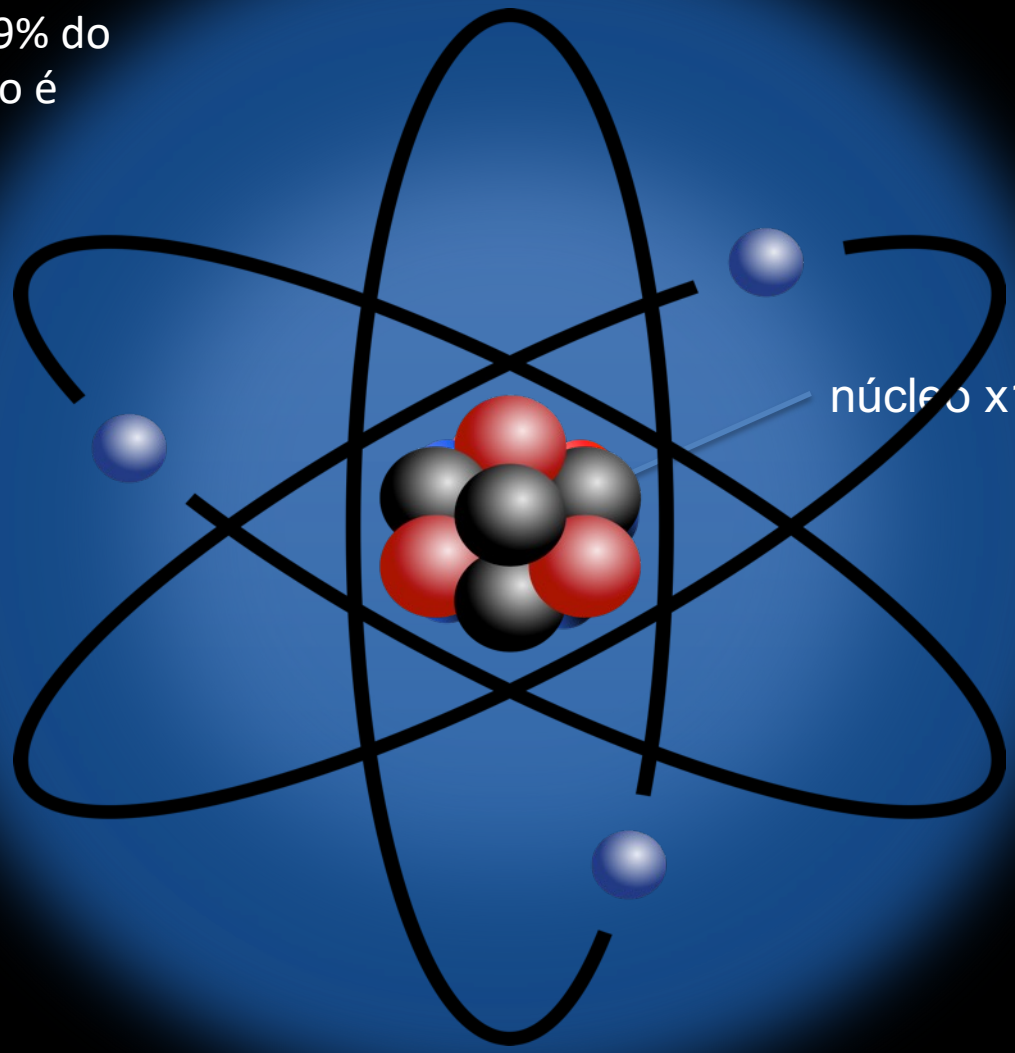
1 1IA 11A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.0079																	2 He Helium 4.00260
3 Li Lithium 6.941	4 Be Beryllium 9.01218											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797
11 Na Sodium 22.989768	12 Mg Magnesium 24.305											13 Al Aluminum 26.981539	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.64	33 As Arsenic 74.92159	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98.9072	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29
55 Cs Cesium 132.90543	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium [208.9824]	85 At Astatine 209.9871	86 Rn Radon 222.0176
87 Fr Francium 223.0197	88 Ra Radium 226.0254	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Uuq Ununquadium [289]	115 Uup Ununpentium unknown	116 Uuh Ununhexium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Lanthanide Series	57 La Lanthanum 138.9055	58 Ce Cerium 140.115	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.9655	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.0278	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium 237.0482	94 Pu Plutonium 244.0642	95 Am Americium 243.0614	96 Cm Curium 247.0703	97 Bk Berkelium 247.0703	98 Cf Californium 251.0796	99 Es Einsteinium [254]	100 Fm Fermium 257.0951	101 Md Mendelevium 258.1	102 No Nobelium 259.1009	103 Lr Lawrencium [262]

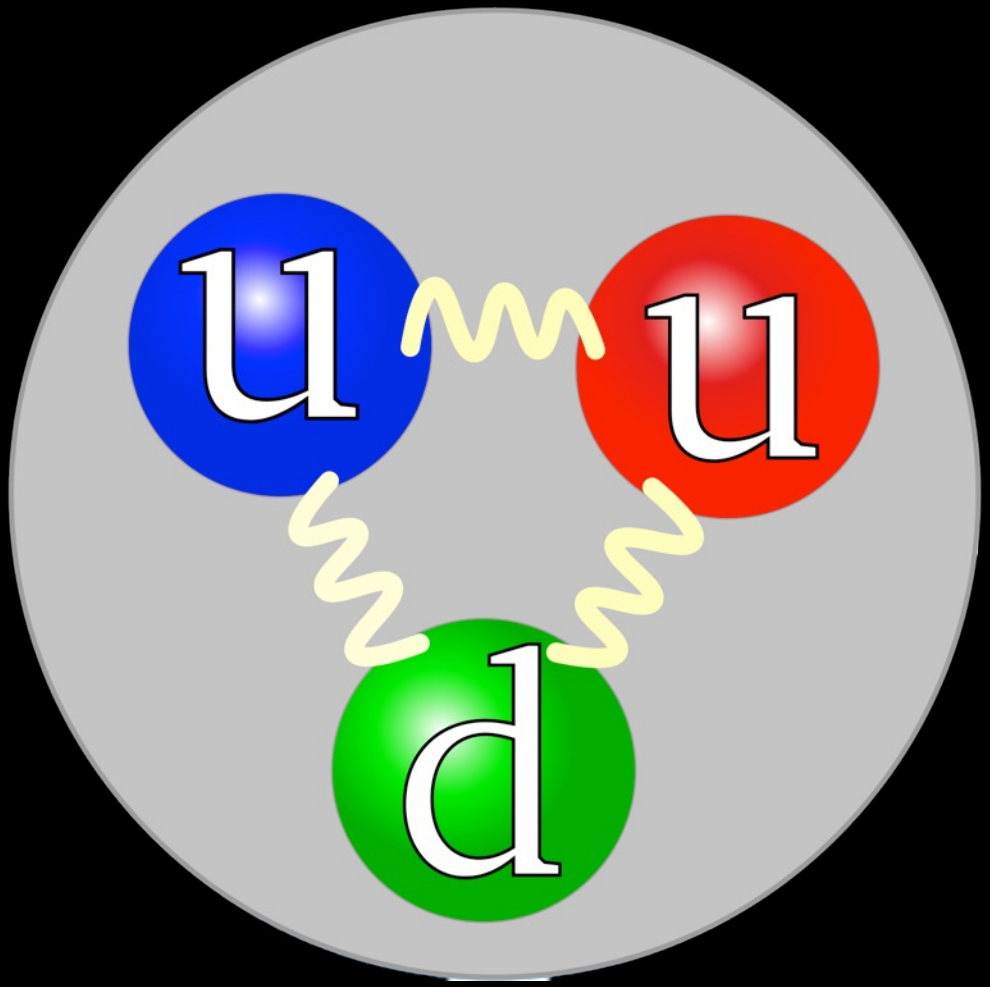
Alkali Metal | Alkaline Earth | Transition Metal | Basic Metal | Semimetals | Nonmetals | Halogens | Noble Gas | Lanthanides | Actinides

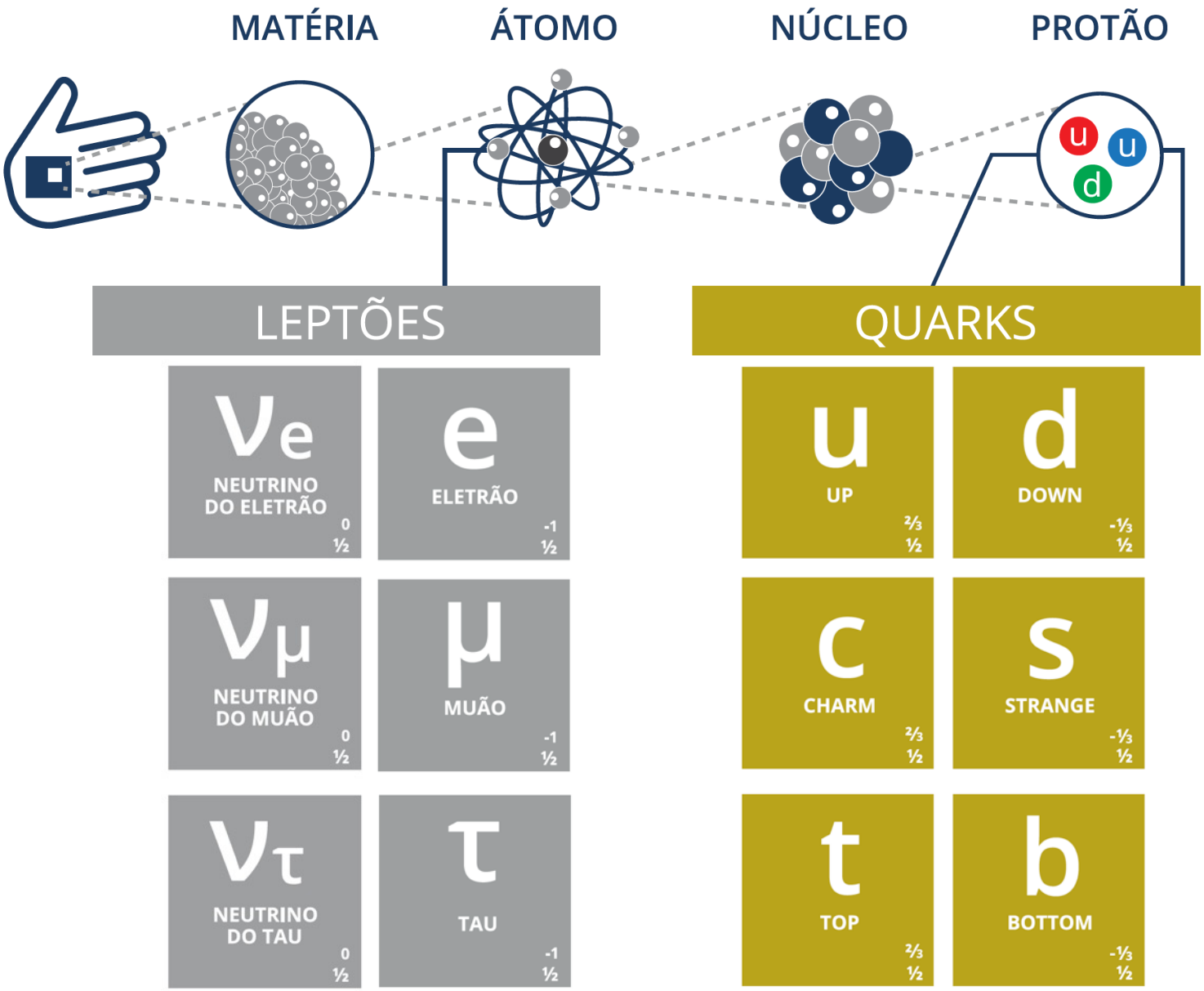
O átomo

99.999 999 999 9% do volume do átomo é vazio!



O protão no modelo dos quarks




MATÉRIA
ÁTOMO
NÚCLEO
PROTÃO
u
u
d
LEPTÕES
QUARKS
νe
NEUTRINO DO ELETRÃO
0
½
e
ELETRÃO
-1
½
u
UP
⅔
½
d
DOWN
-⅓
½
νμ
NEUTRINO DO MUÃO
0
½
μ
MUÃO
-1
½
c
CHARM
⅔
½
s
STRANGE
-⅓
½
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NEUTRINO DO TAU
0
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TAU
-1
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t
TOP
⅔
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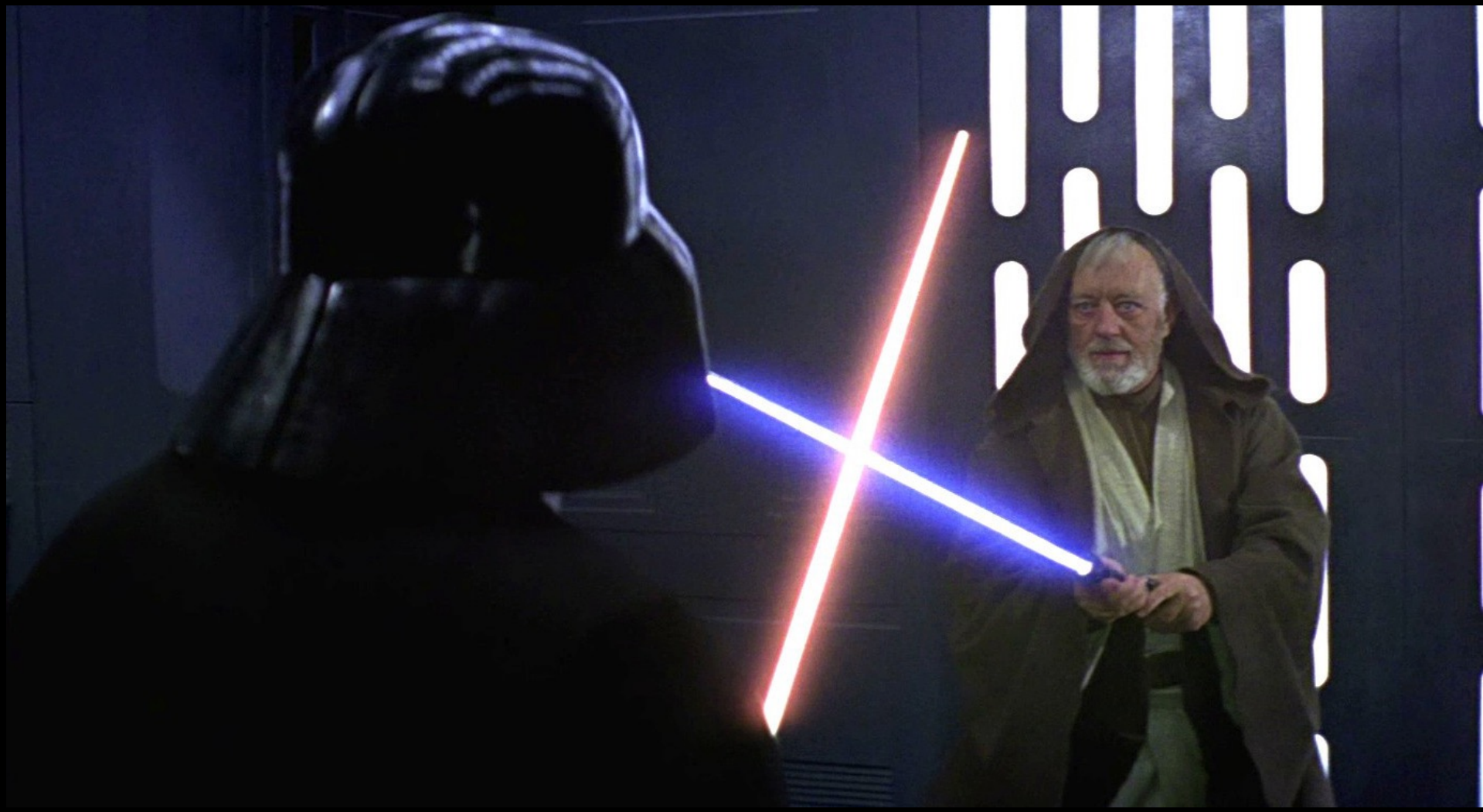
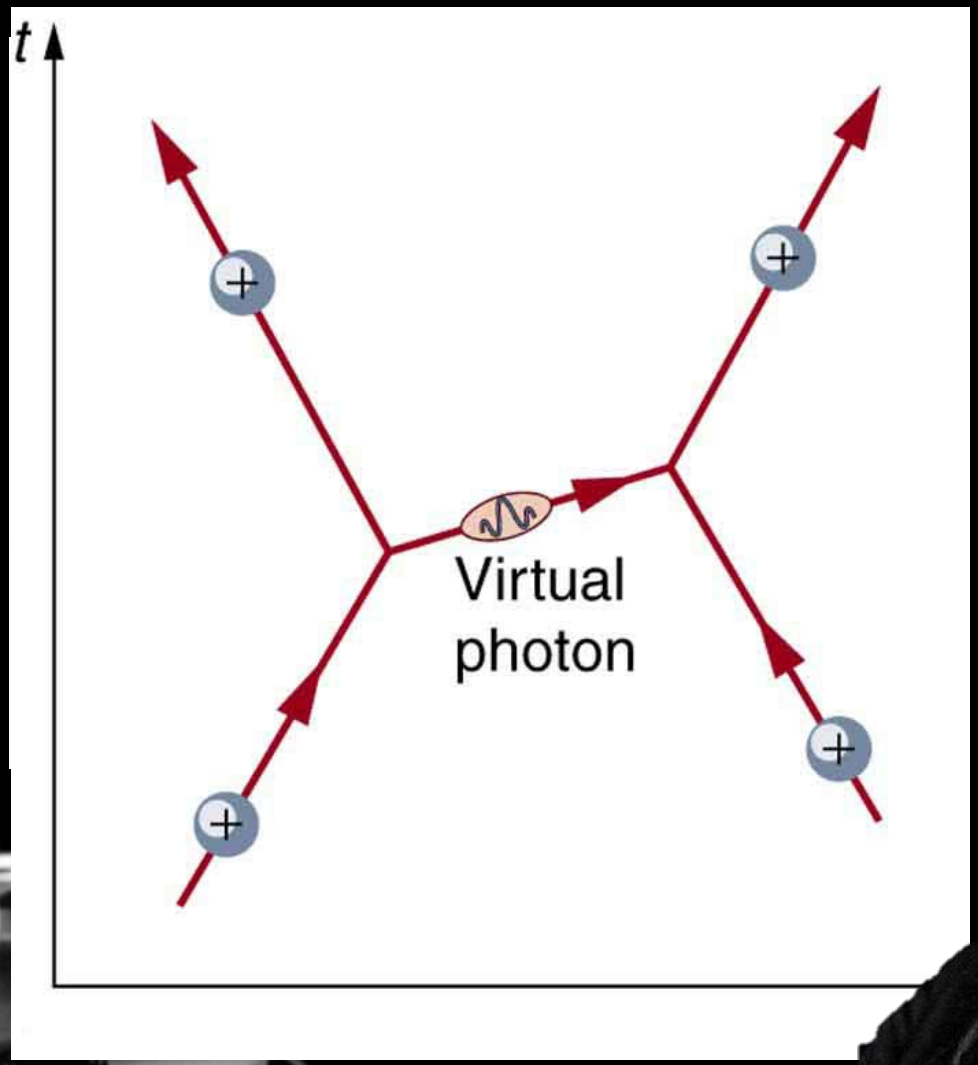
b
BOTTOM
-⅓
½

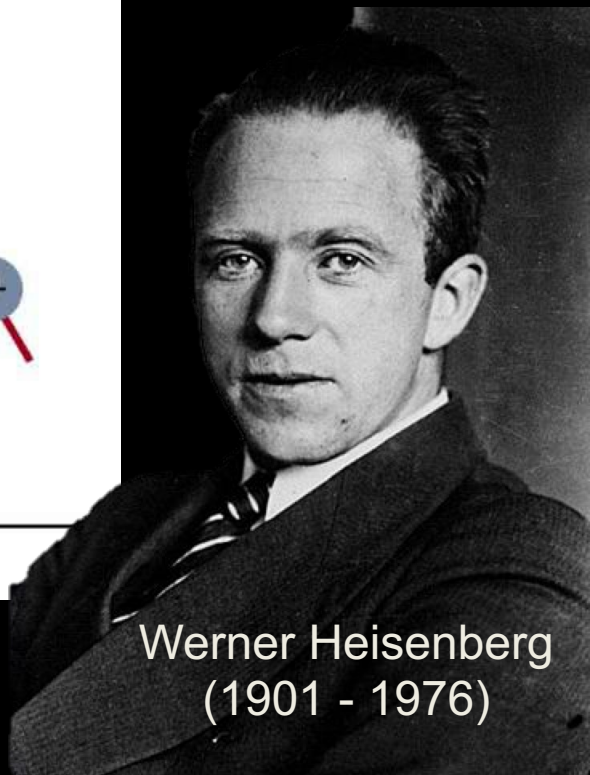
E as forças fundamentais?



$\Delta E.\Delta t = h/4\pi$

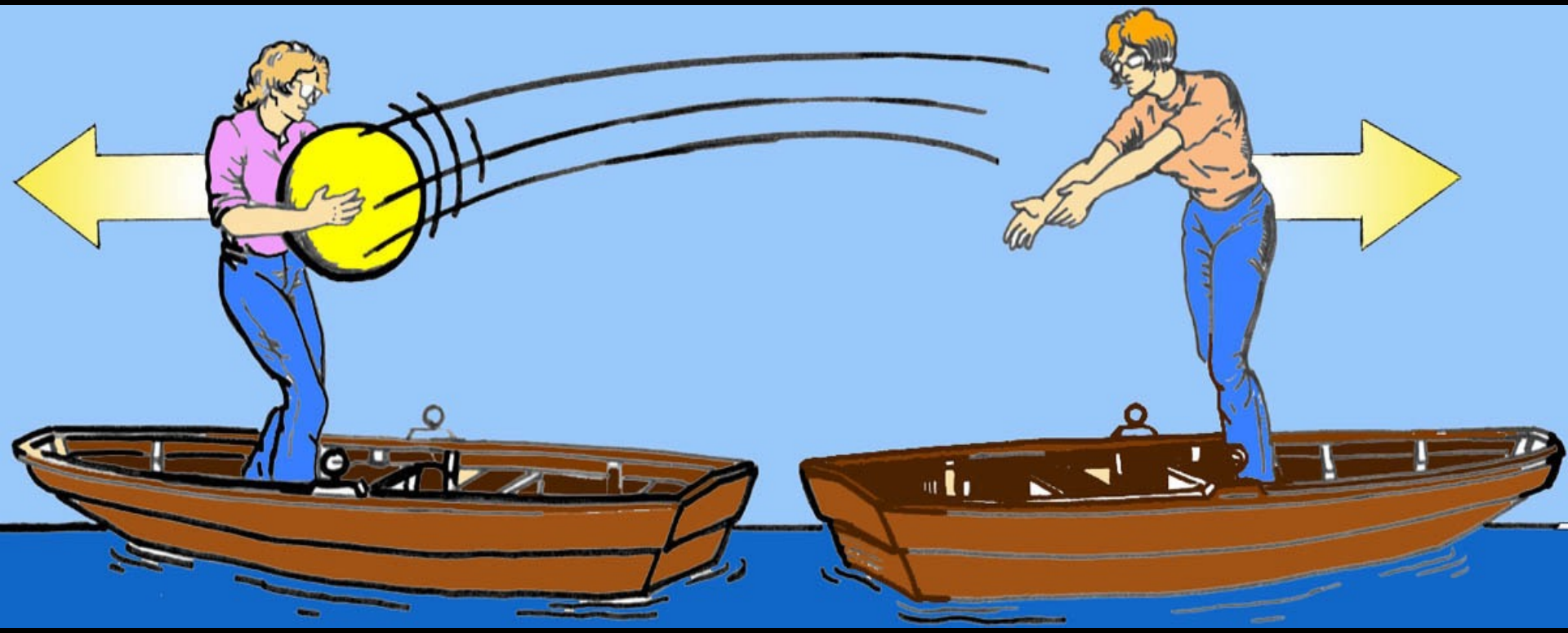
Richard Feynman
(1918 - 1988)

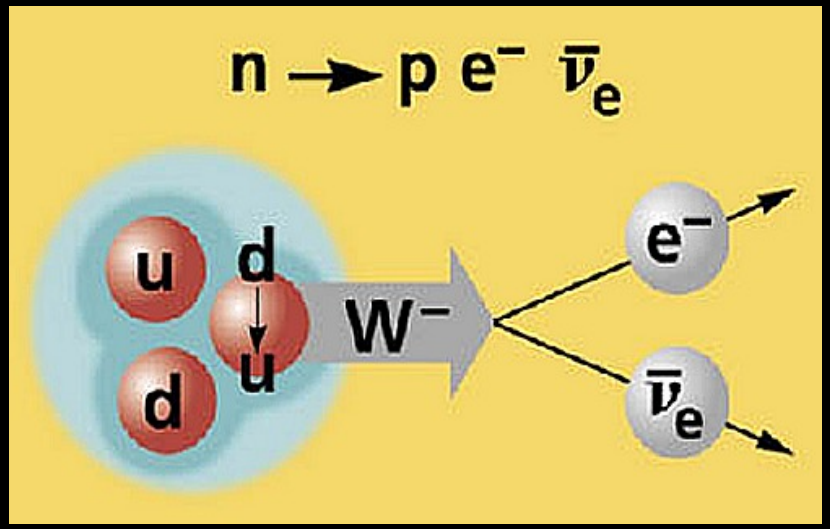


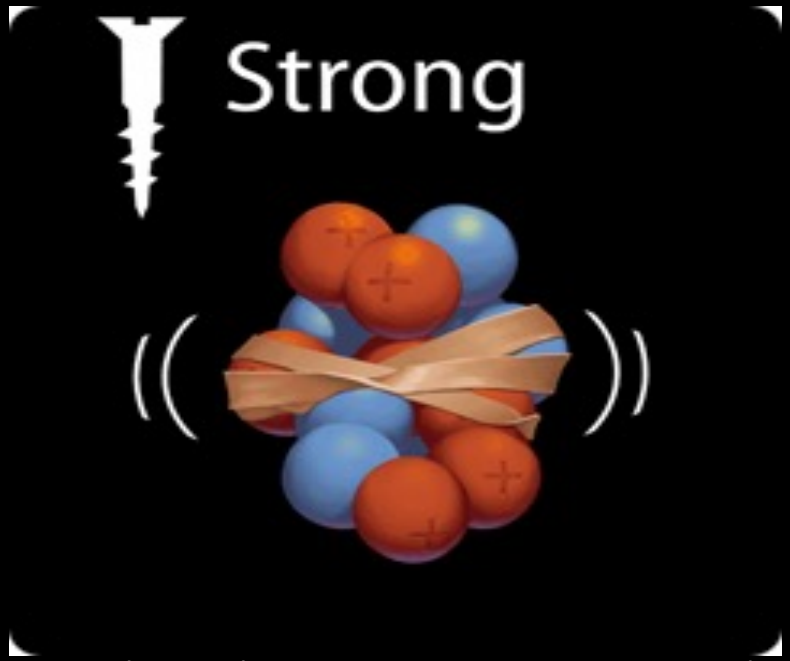


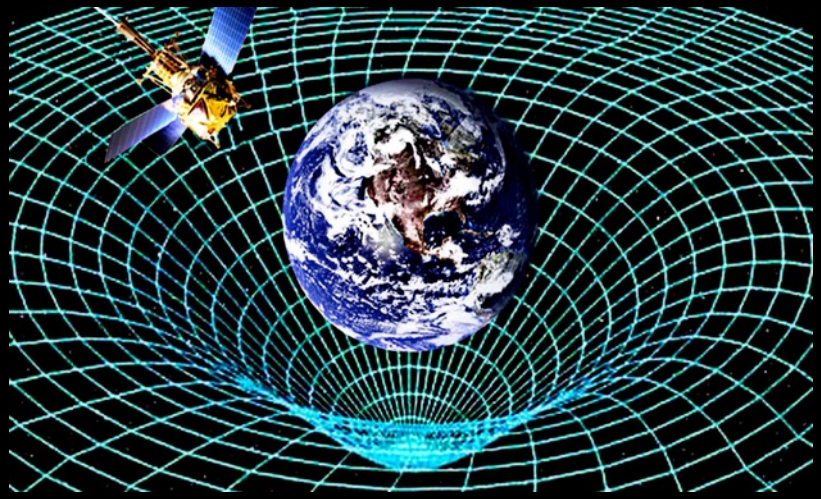
Werner Heisenberg
(1901 - 1976)

As forças fundamentais

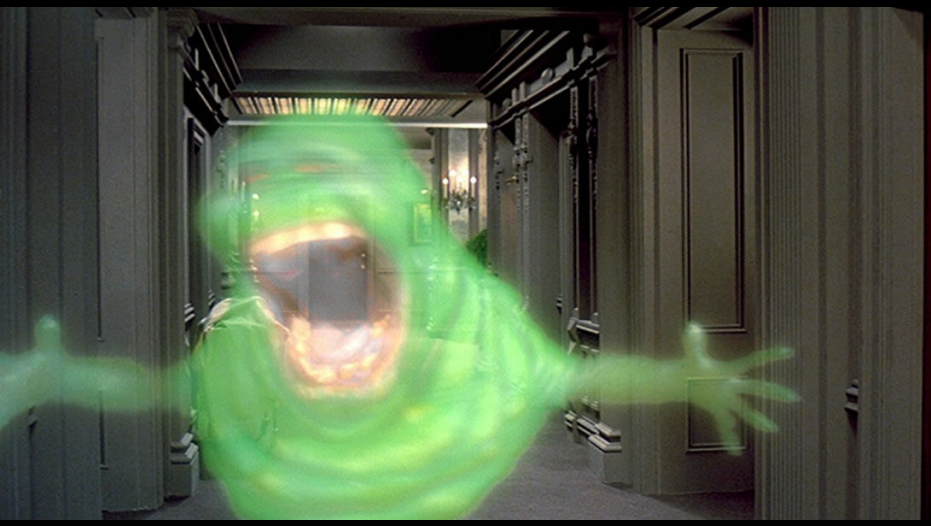



$n \rightarrow p\, e^- \bar{\nu}_e$
u
d
d
u
W^-
e^-
$\bar{\nu}_e$


Strong

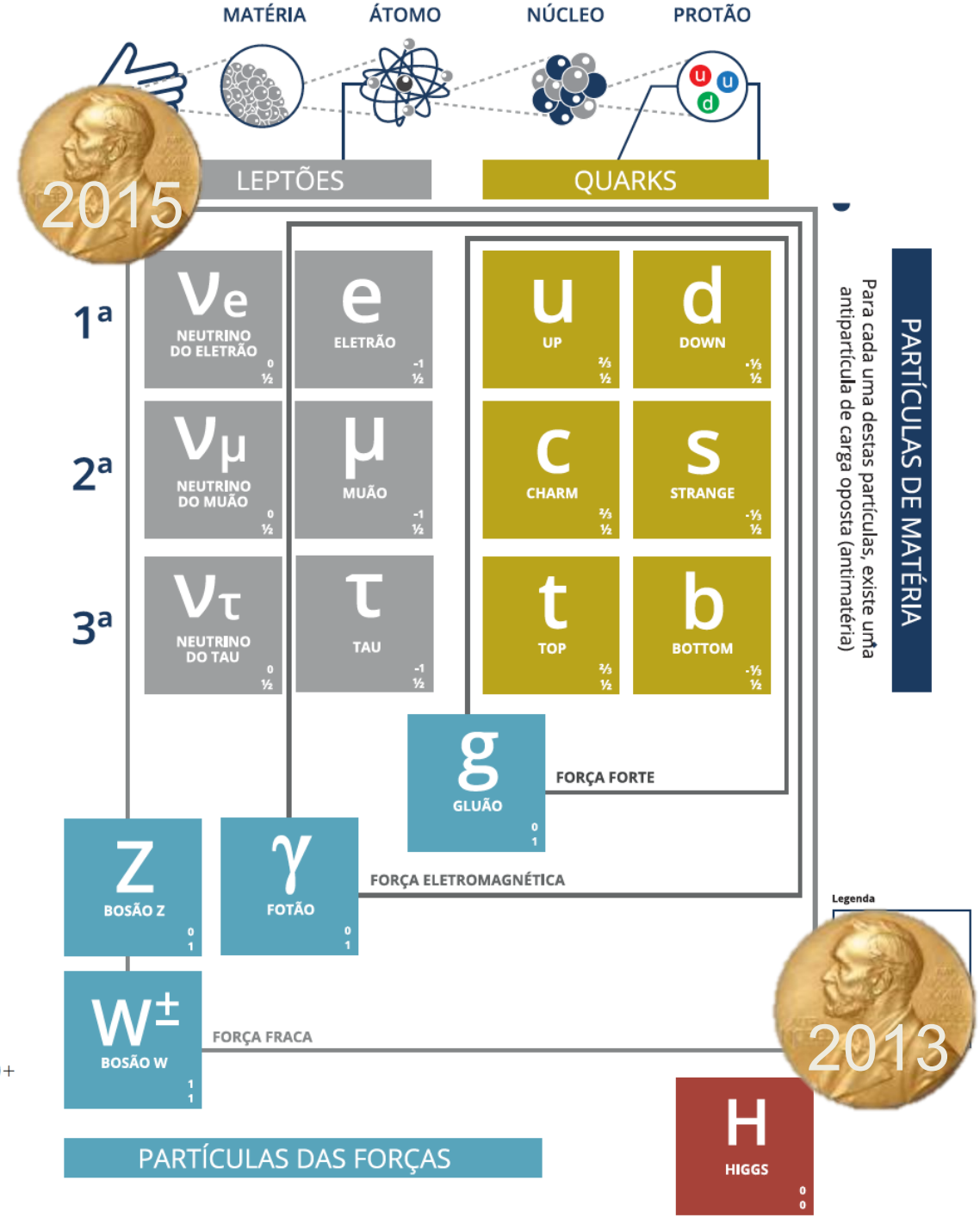


Teste intercalar:
O Que está errado nestas imagens?



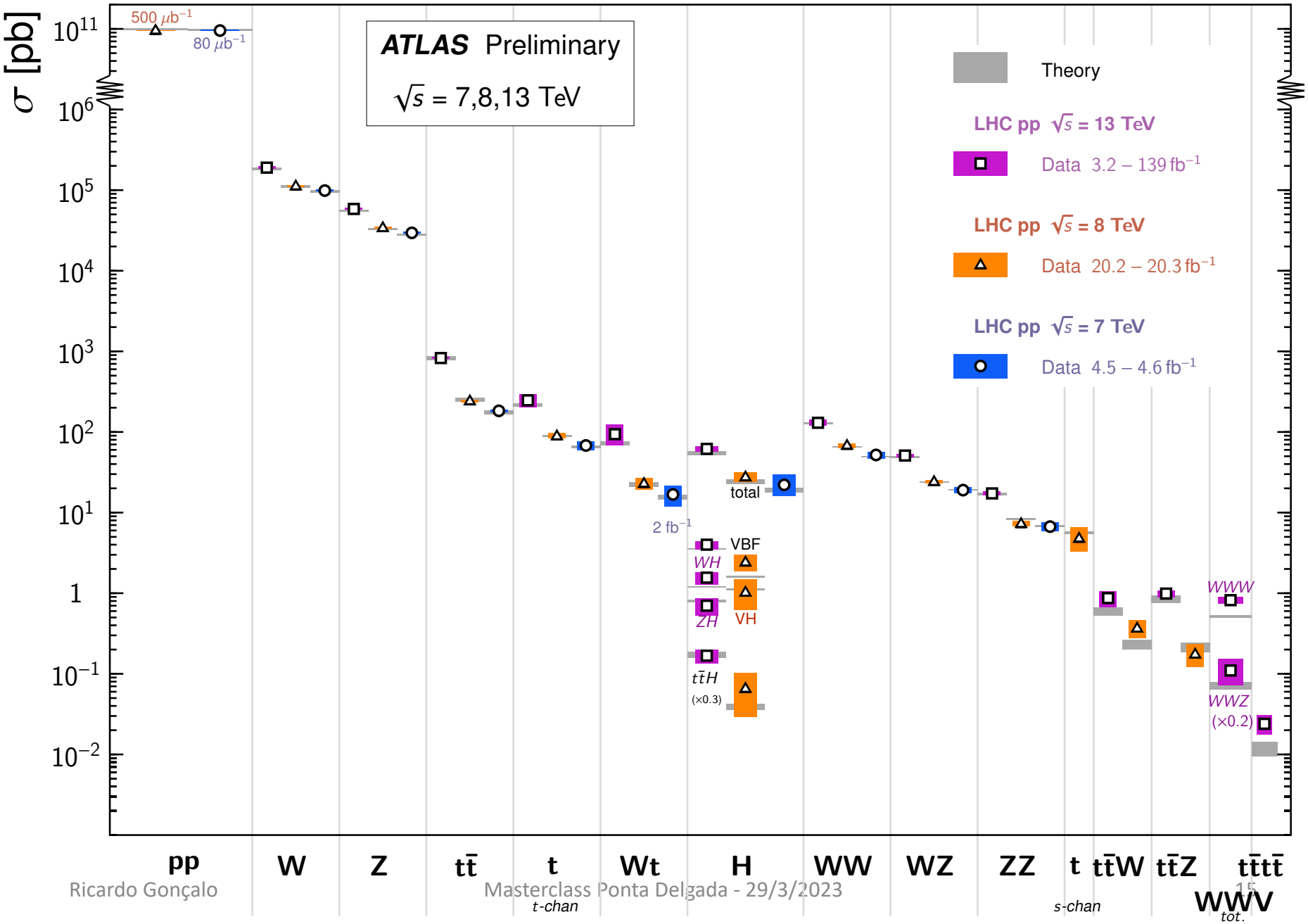
O Modelo Padrão da Física de Partículas

$$
\begin{aligned}
\mathcal{L}_{SM} = & -\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 - \partial_\nu W^+_\mu \partial_\nu W^-_\mu - \\
& 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 - 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) - \tfrac{1}{2}\partial_\mu H \partial_\mu H - 2M^2 \alpha_h H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - \tfrac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \\
& \beta_h \left(\tfrac{2M^2}{g^2} + \tfrac{2M}{g}H + \tfrac{1}{2}(H^2 + \phi^0\phi^0 + 2\phi^+\phi^-)\right) + \tfrac{2M^4}{g^2}\alpha_h - \\
& g\alpha_h M \left(H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-\right) - \\
& \tfrac{1}{8}g^2\alpha_h \left(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\right) - \\
& 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\left(W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)\right) + \\
& \tfrac{1}{2}g\left(W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) + W^-_\mu(H\partial_\mu\phi^+ - \phi^+\partial_\mu H)\right) + \tfrac{1}{2}g\tfrac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) + \\
& M\left(\tfrac{1}{c_w}Z^0_\mu\partial_\mu\phi^0 + W^+_\mu\partial_\mu\phi^- + W^-_\mu\partial_\mu\phi^+\right) - ig\tfrac{s_w^2}{c_w}MZ^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}{8}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^2 s_w^2 A_\mu A_\mu \phi^+\phi^- + \tfrac{1}{2}ig_s\lambda^a_{ij}(\bar{q}^\sigma_i\gamma^\mu q^\sigma_j)g^a_\mu - \bar{e}^\lambda(\gamma\partial + m^\lambda_e)e^\lambda - \bar{\nu}^\lambda(\gamma\partial + m^\lambda_\nu)\nu^\lambda - \bar{u}^\lambda_j(\gamma\partial + \\
& m^\lambda_u)u^\lambda_j - \bar{d}^\lambda_j(\gamma\partial + m^\lambda_d)d^\lambda_j + igs_w A_\mu\left(-(\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)\right) + \\
& \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{d}^\lambda_j\gamma^\mu(\tfrac{4}{3}s_w^2 - 1 - \gamma^5)d^\lambda_j) + \\
& (\bar{u}^\lambda_j\gamma^\mu(1 - \tfrac{8}{3}s_w^2 + \gamma^5)u^\lambda_j)\} + \tfrac{ig}{2\sqrt{2}}W^+_\mu\left((\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)U^{lep}{}_{\lambda\kappa}e^\kappa) + (\bar{u}^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)\right) + \\
& \tfrac{ig}{2\sqrt{2}}W^-_\mu\left((\bar{e}^\kappa U^{lep\dagger}{}_{\kappa\lambda}\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\kappa\lambda}\gamma^\mu(1+\gamma^5)u^\lambda_j)\right) + \\
& \tfrac{ig}{2M\sqrt{2}}\phi^+\left(-m^\kappa_e(\bar{\nu}^\lambda U^{lep}{}_{\lambda\kappa}(1-\gamma^5)e^\kappa) + m^\lambda_\nu(\bar{\nu}^\lambda U^{lep}{}_{\lambda\kappa}(1+\gamma^5)e^\kappa)\right) + \\
& \tfrac{ig}{2M\sqrt{2}}\phi^-\left(m^\lambda_e(\bar{e}^\lambda U^{lep\dagger}{}_{\lambda\kappa}(1+\gamma^5)\nu^\kappa) - m^\kappa_\nu(\bar{e}^\lambda U^{lep\dagger}{}_{\lambda\kappa}(1-\gamma^5)\nu^\kappa)\right) - \tfrac{g}{2}\tfrac{m^\lambda_\nu}{M}H(\bar{\nu}^\lambda\nu^\lambda) - \\
& \tfrac{g}{2}\tfrac{m^\lambda_e}{M}H(\bar{e}^\lambda e^\lambda) + \tfrac{ig}{2}\tfrac{m^\lambda_\nu}{M}\phi^0(\bar{\nu}^\lambda\gamma^5\nu^\lambda) - \tfrac{ig}{2}\tfrac{m^\lambda_e}{M}\phi^0(\bar{e}^\lambda\gamma^5 e^\lambda) - \tfrac{1}{4}\bar{\nu}_\lambda M^R_{\lambda\kappa}(1-\gamma_5)\hat{\nu}_\kappa - \\
& \tfrac{1}{4}\bar{\nu}_\lambda M^R_{\lambda\kappa}(1-\gamma_5)\hat{\nu}_\kappa + \tfrac{ig}{2M\sqrt{2}}\phi^+\left(-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)\right) + \\
& \tfrac{ig}{2M\sqrt{2}}\phi^-\left(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)\right) - \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{G}^a\partial^2 G^a + g_s f^{abc}\partial_\mu\bar{G}^a G^b g^c_\mu + \\
& \bar{X}^+(\partial^2 - M^2)X^+ + \bar{X}^-(\partial^2 - M^2)X^- + \bar{X}^0(\partial^2 - \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\left(\bar{X}^+ X^+ H + \bar{X}^- X^- H + \tfrac{1}{c_w^2}\bar{X}^0 X^0 H\right) + \tfrac{1-2c_w^2}{2c_w}igM\left(\bar{X}^+ X^0\phi^+ - \bar{X}^- X^0\phi^-\right) + \\
& \tfrac{1}{2c_w}igM\left(\bar{X}^0 X^-\phi^+ - \bar{X}^0 X^+\phi^-\right) + igMs_w\left(\bar{X}^0 X^-\phi^+ - \bar{X}^0 X^+\phi^-\right) + \\
& \tfrac{1}{2}igM\left(\bar{X}^+ X^+\phi^0 - \bar{X}^- X^-\phi^0\right).
\end{aligned}
$$



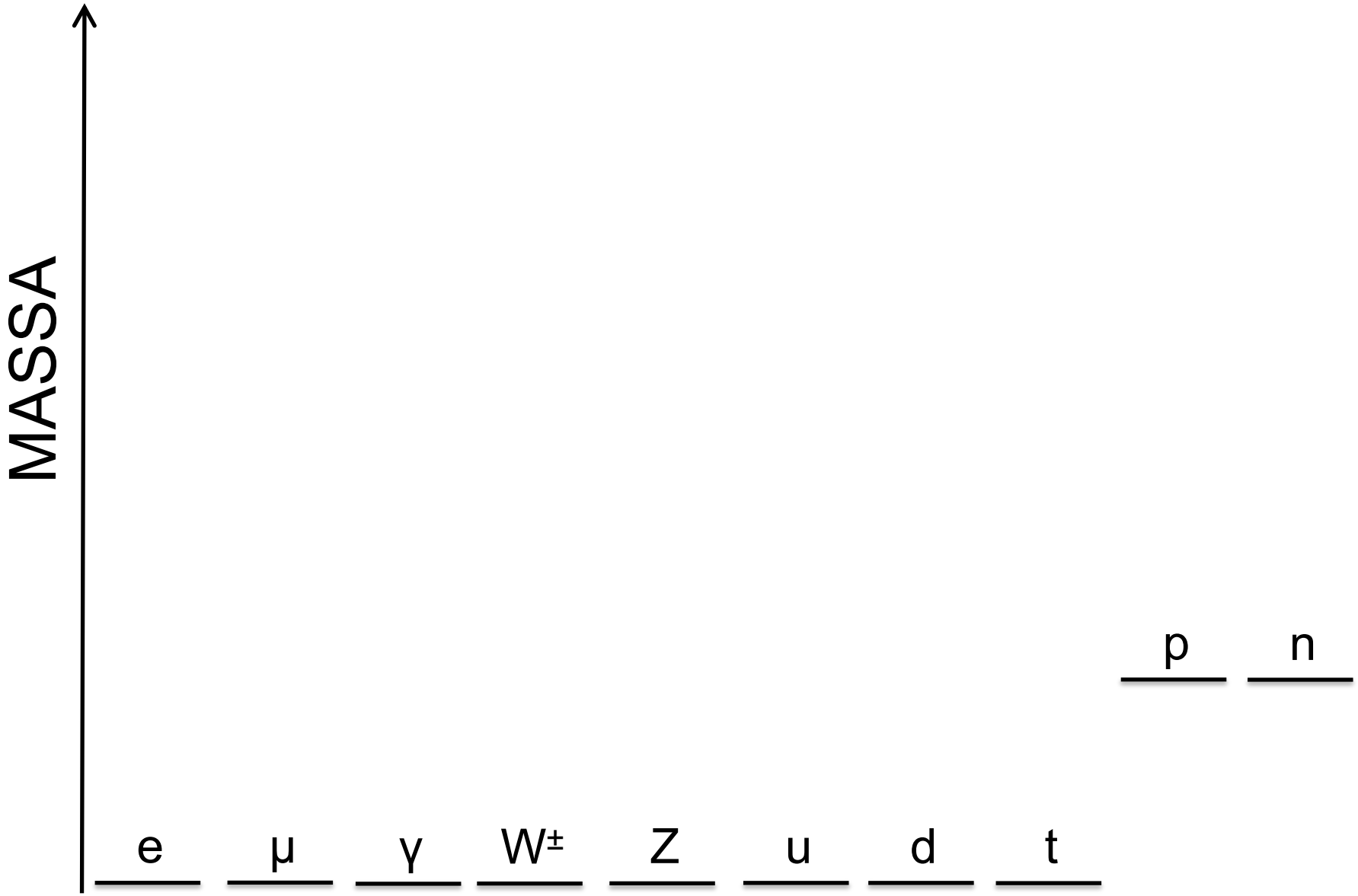
Standard Model Total Production Cross Section Measurements

Status: February 2022

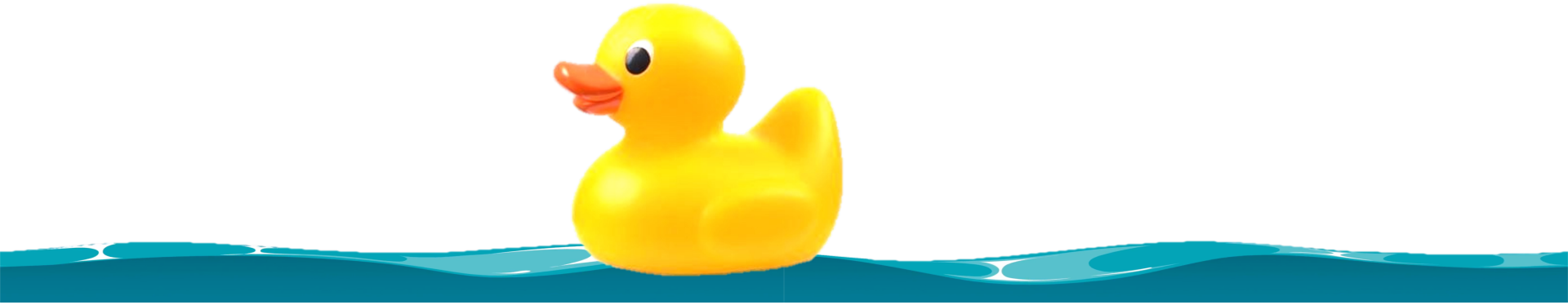


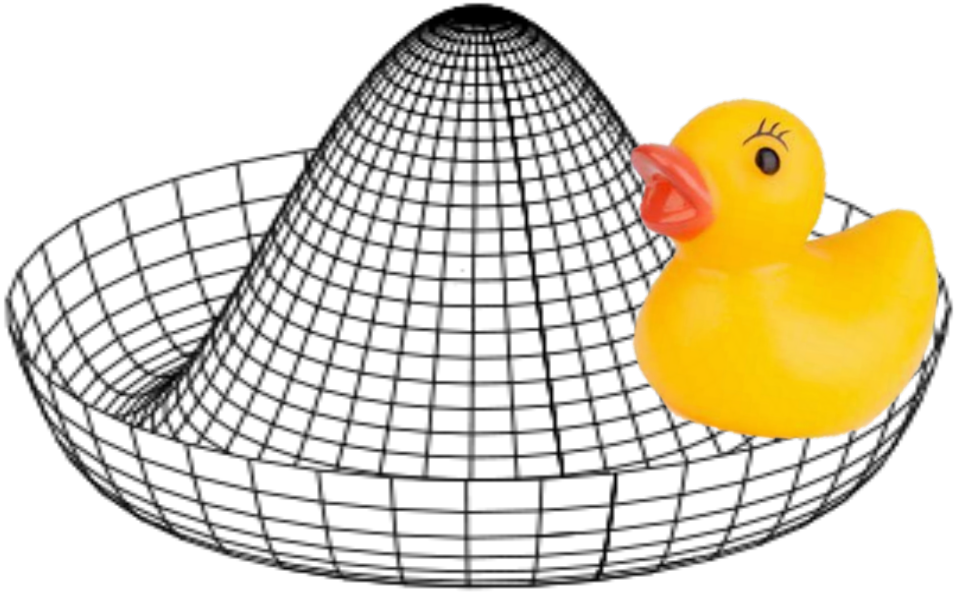
Agora os problemas...

Isto não devia funcionar!…

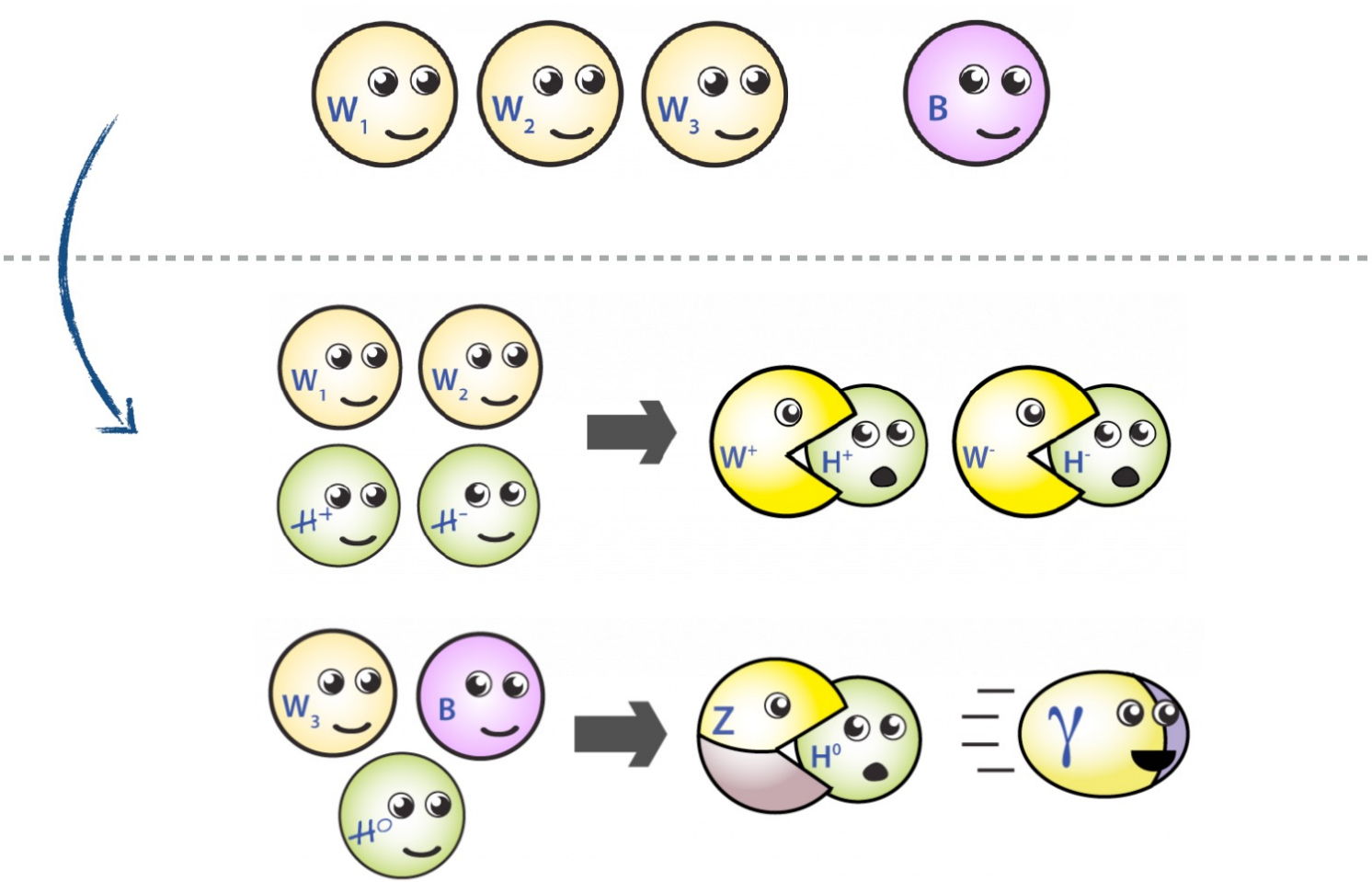


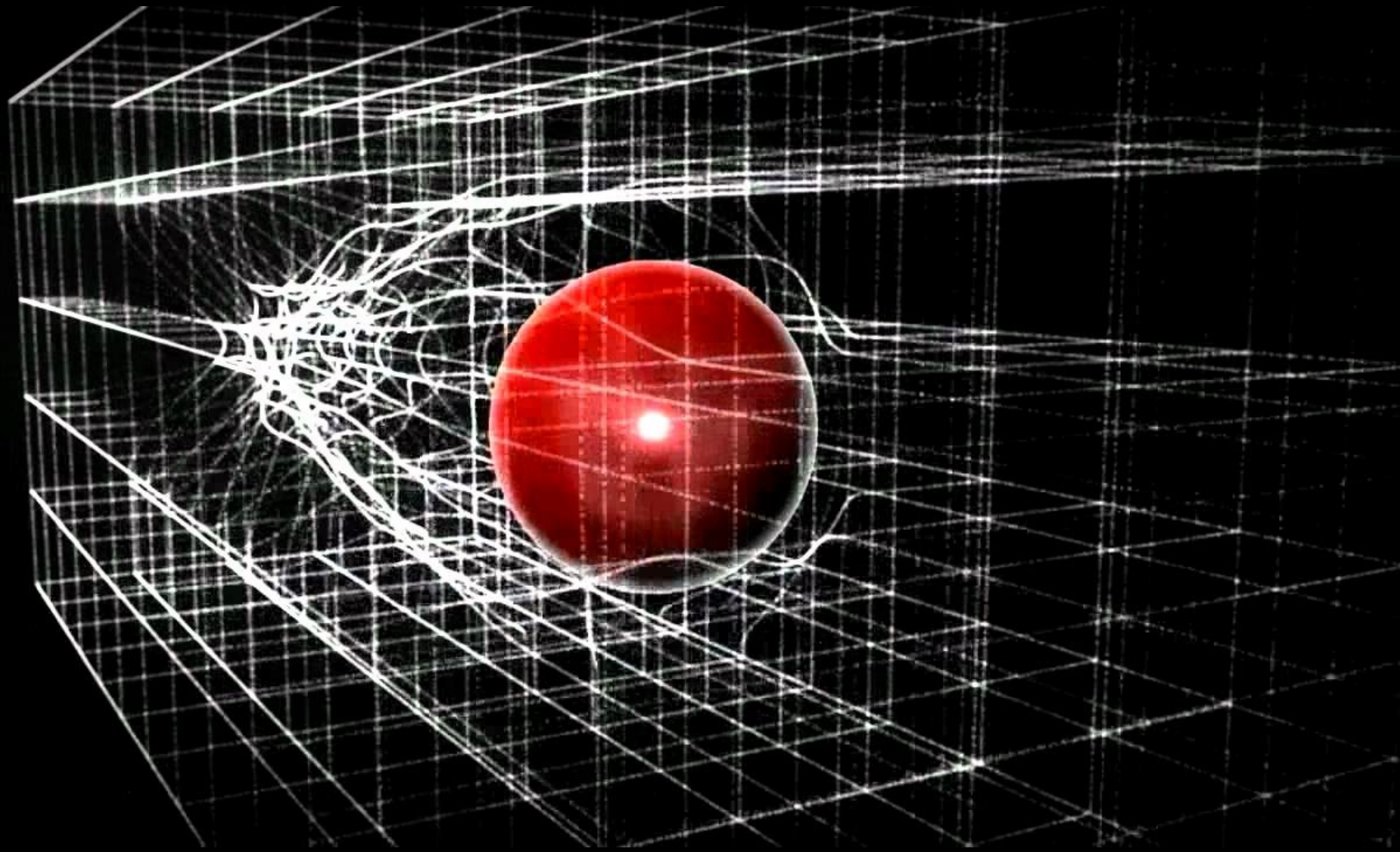
O Mecanismo de Higgs



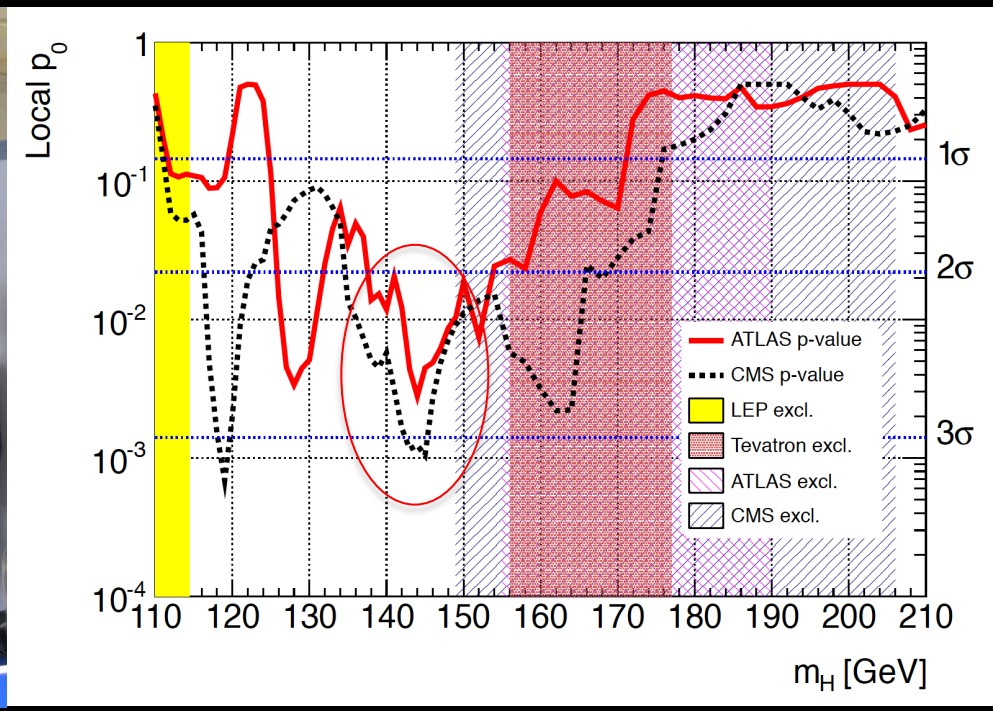


$$V(\phi) = \mu^2 \phi^\dagger \phi + \lambda (\phi^\dagger \phi)^2 \qquad \phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} \phi_1 + i\phi_2 \\ \phi_3 + i\phi 4 \end{pmatrix}$$


W1
W2
W3
B
W1
W2
H+
H-
W+
H+
W-
H-
W3
B
H0
Z
H0
γ

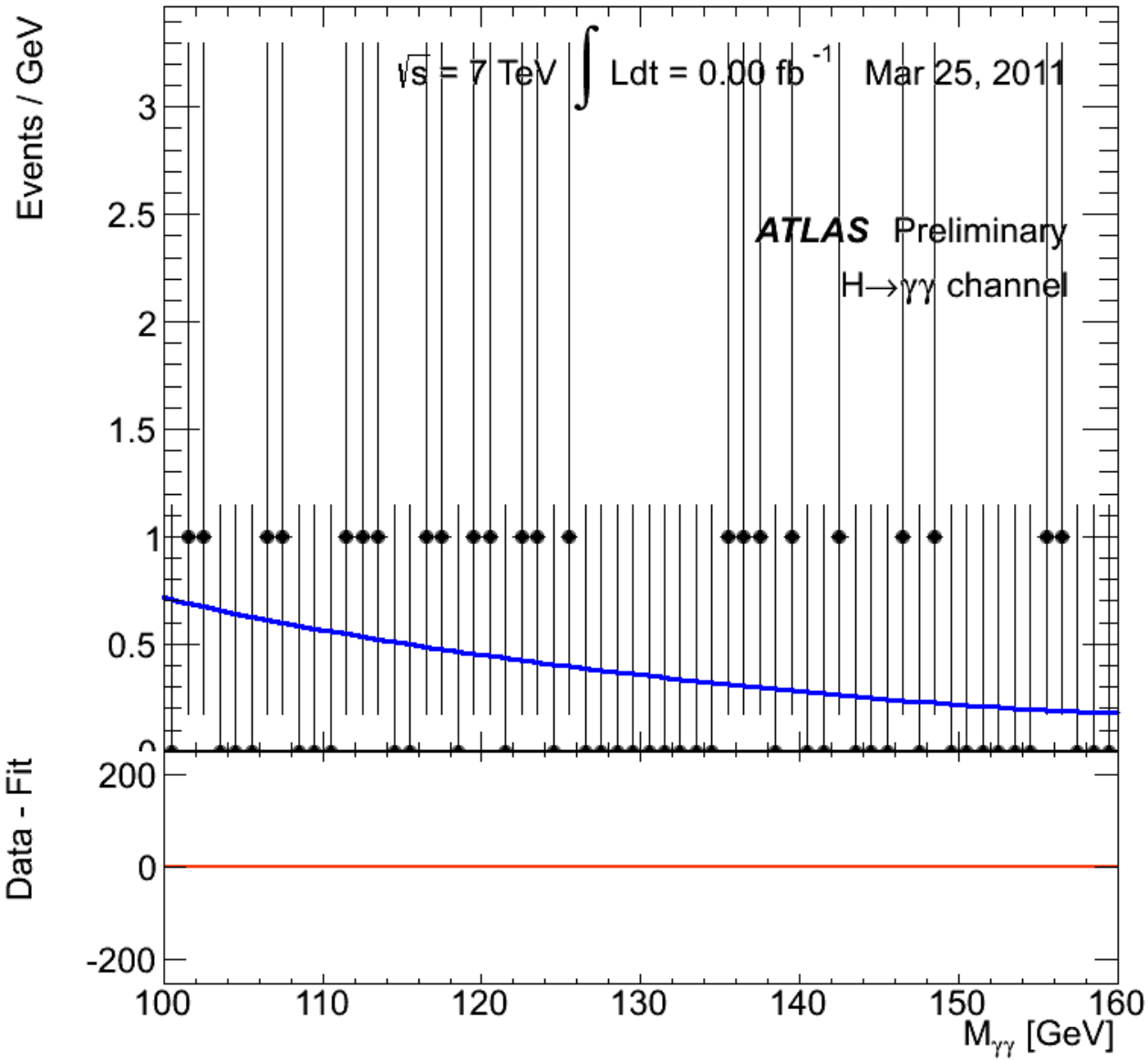


Nem sempre se acerta à primeira...



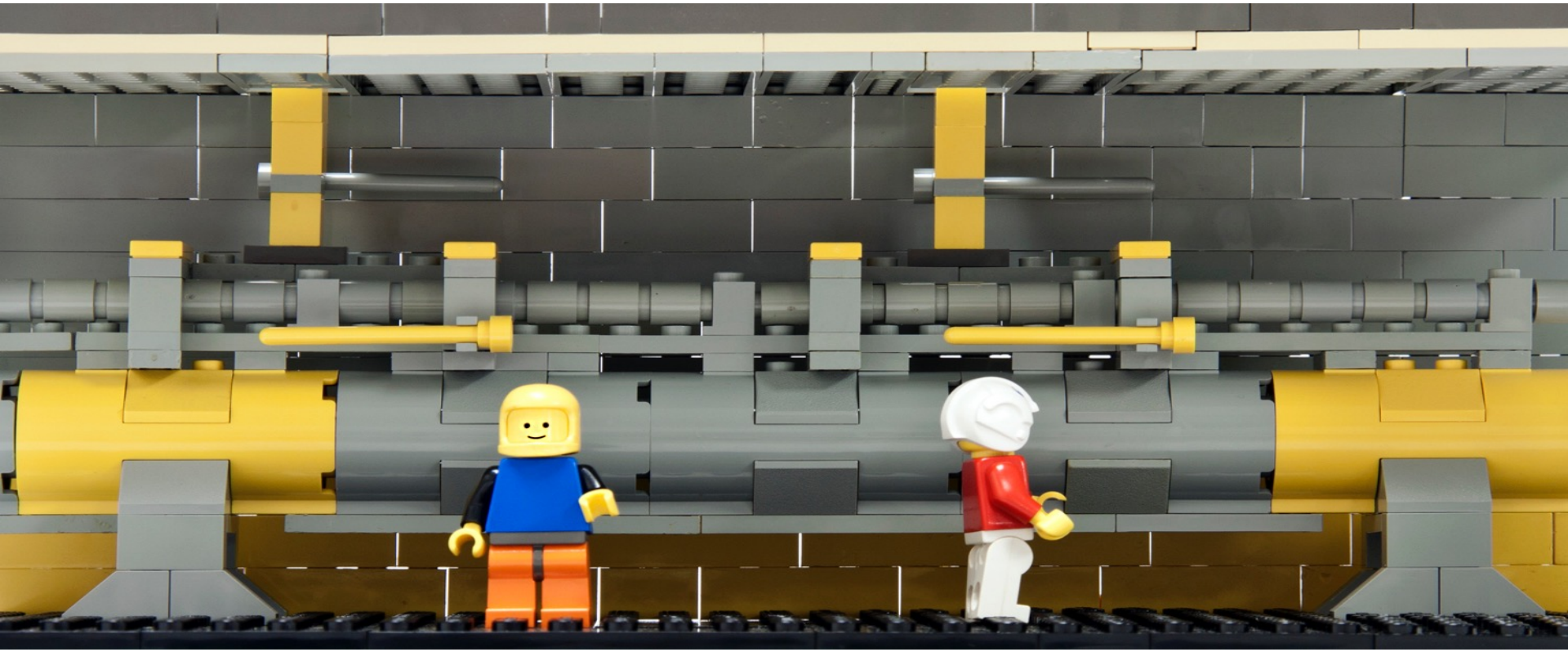
Conferência europeia de Física de Partículas (EPS-HEP) 2011

2012: Descoberta do bosão de Higgs: H->γγ

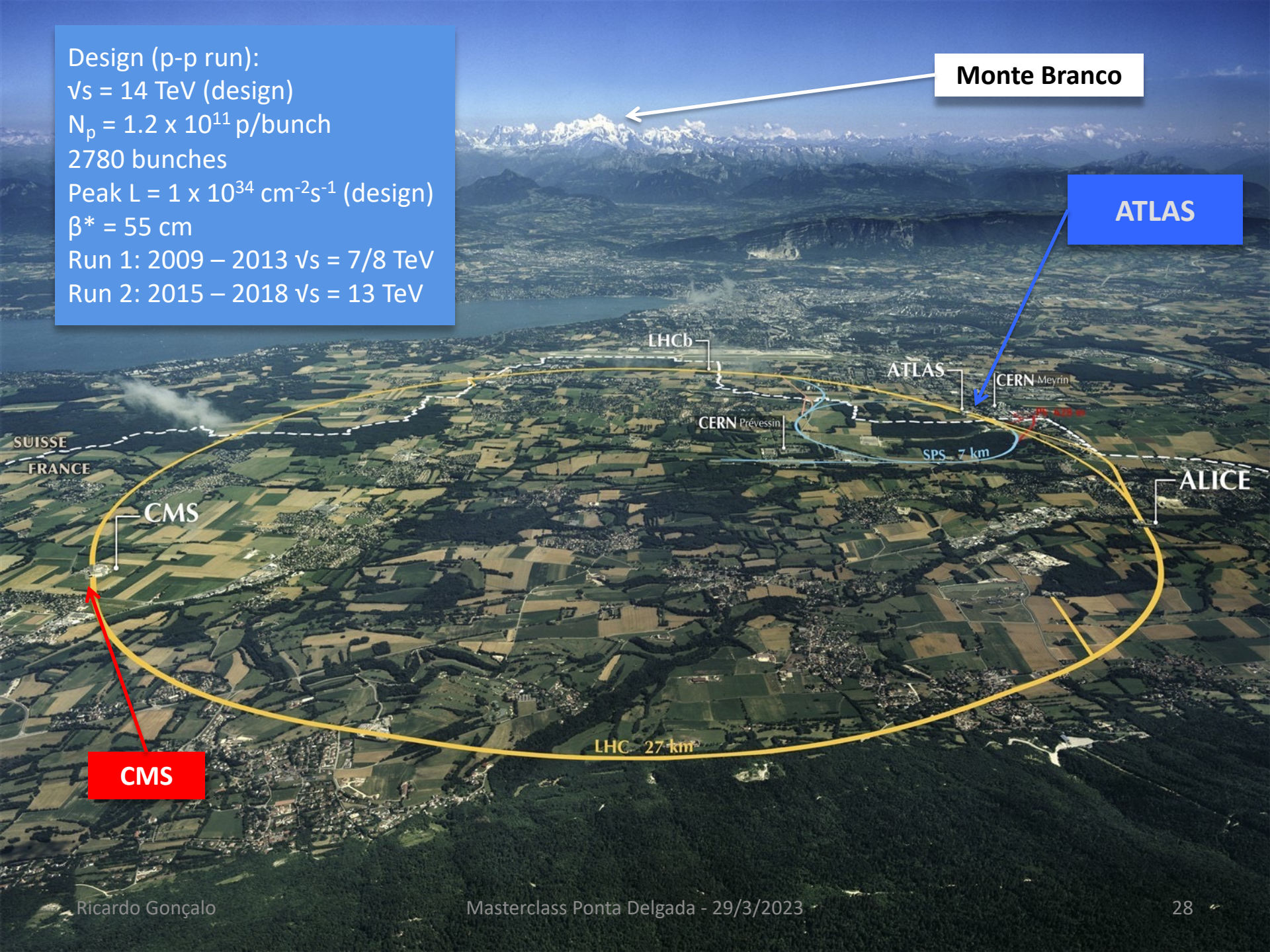


A Descoberta do bosão de Higgs

Experiências para ver o invisível



Design (p-p run):
√s = 14 TeV (design)
$N_p = 1.2 \times 10^{11}$ p/bunch
2780 bunches
Peak L = 1×10^{34} $cm^{-2}s^{-1}$ (design)
β* = 55 cm
Run 1: 2009 – 2013 √s = 7/8 TeV
Run 2: 2015 – 2018 √s = 13 TeV



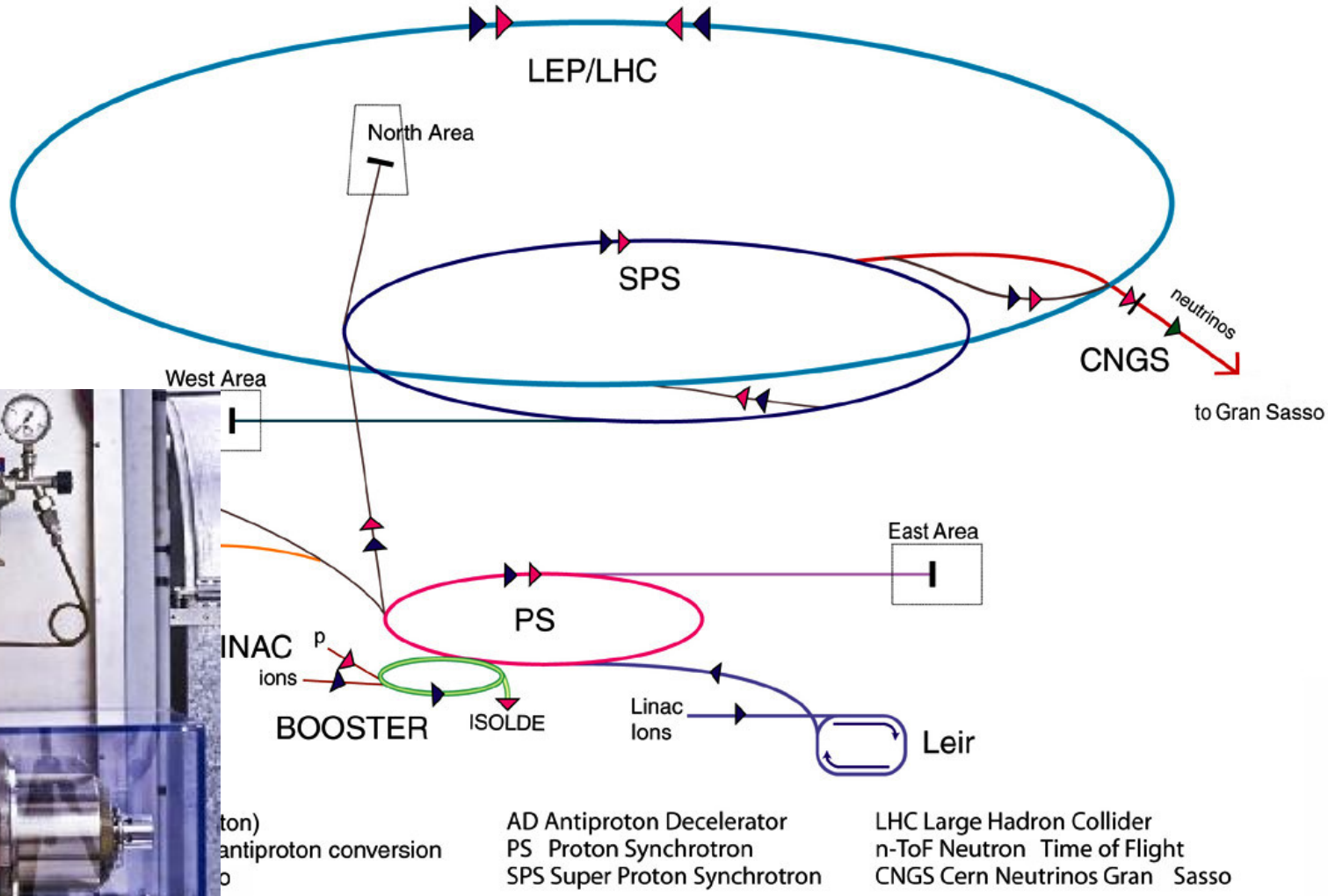
LINAC2 → **50 MeV**

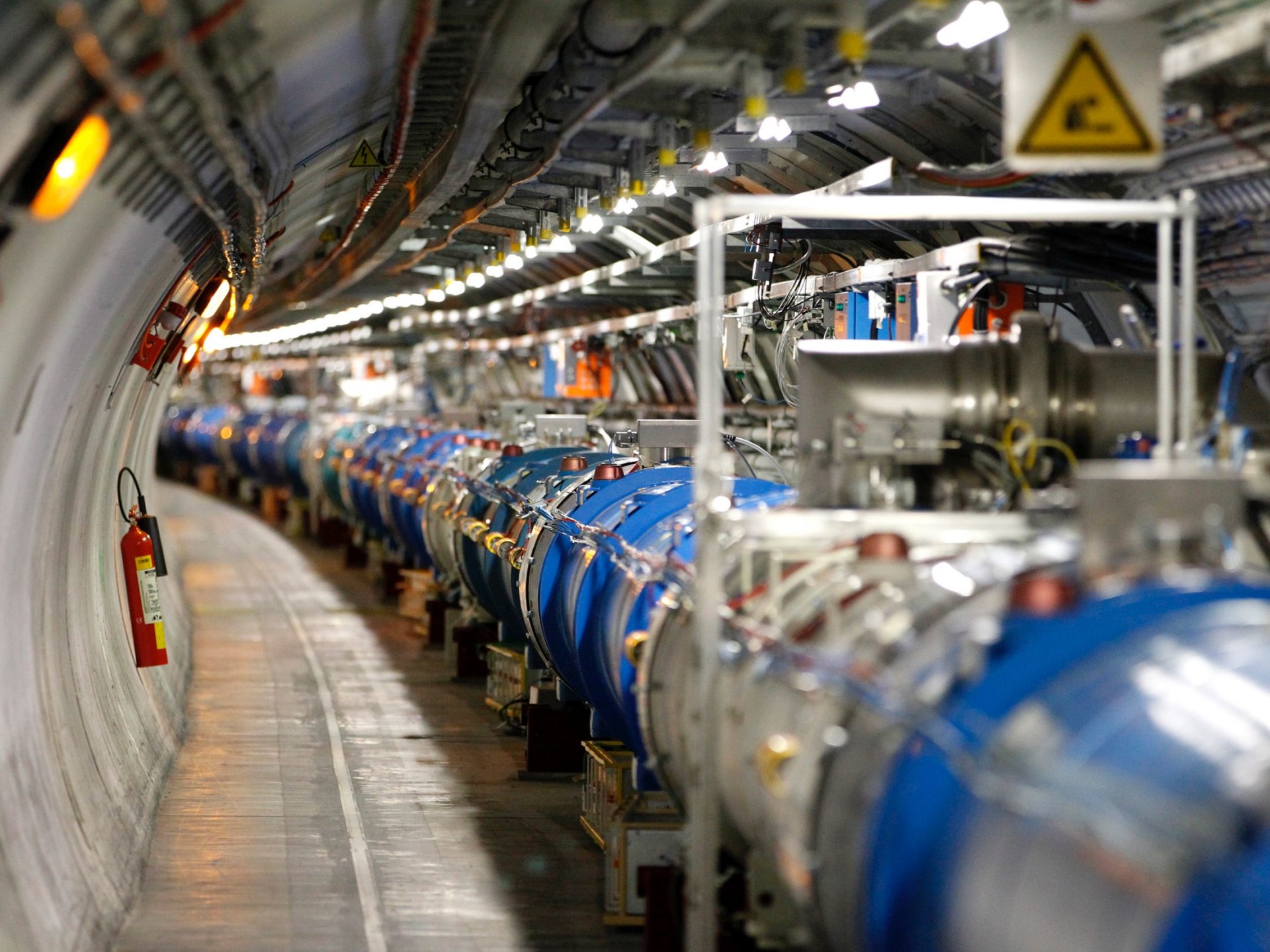
Booster → **1.4 GeV**

Proton Synchroton (PS) → **25 GeV**

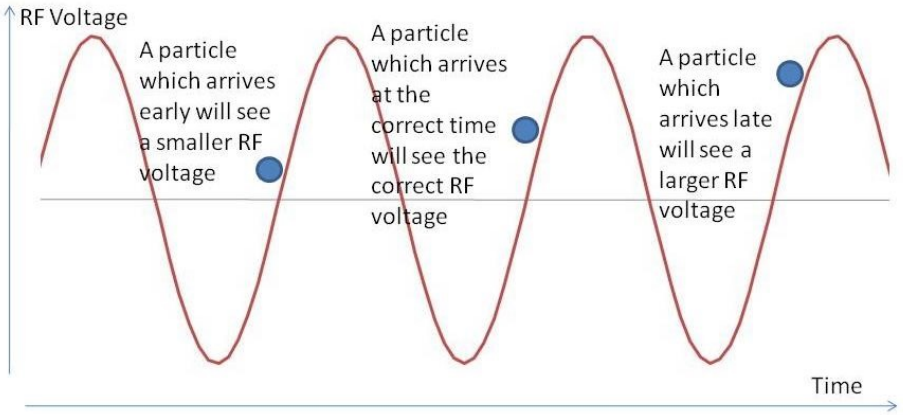
Super Proton Synchrotron (SPS) → **450 GeV**

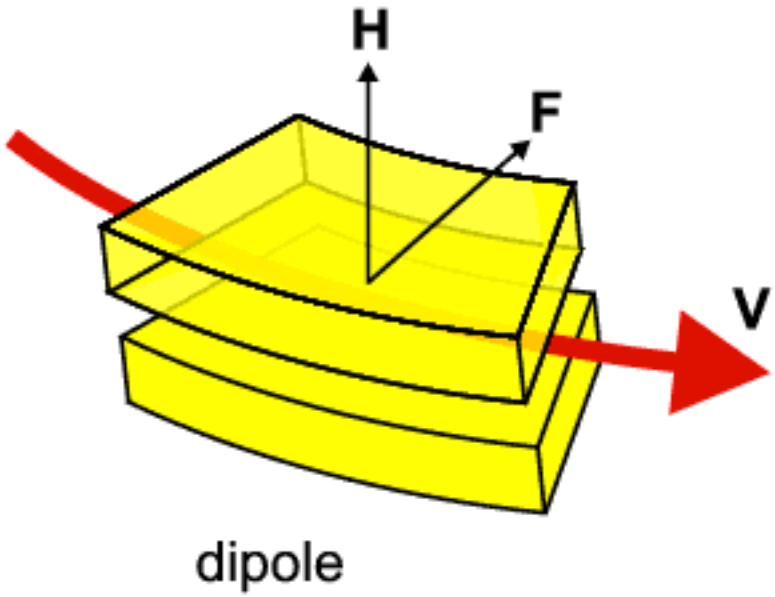
Large Hadron Collider (LHC)→ **7 TeV**

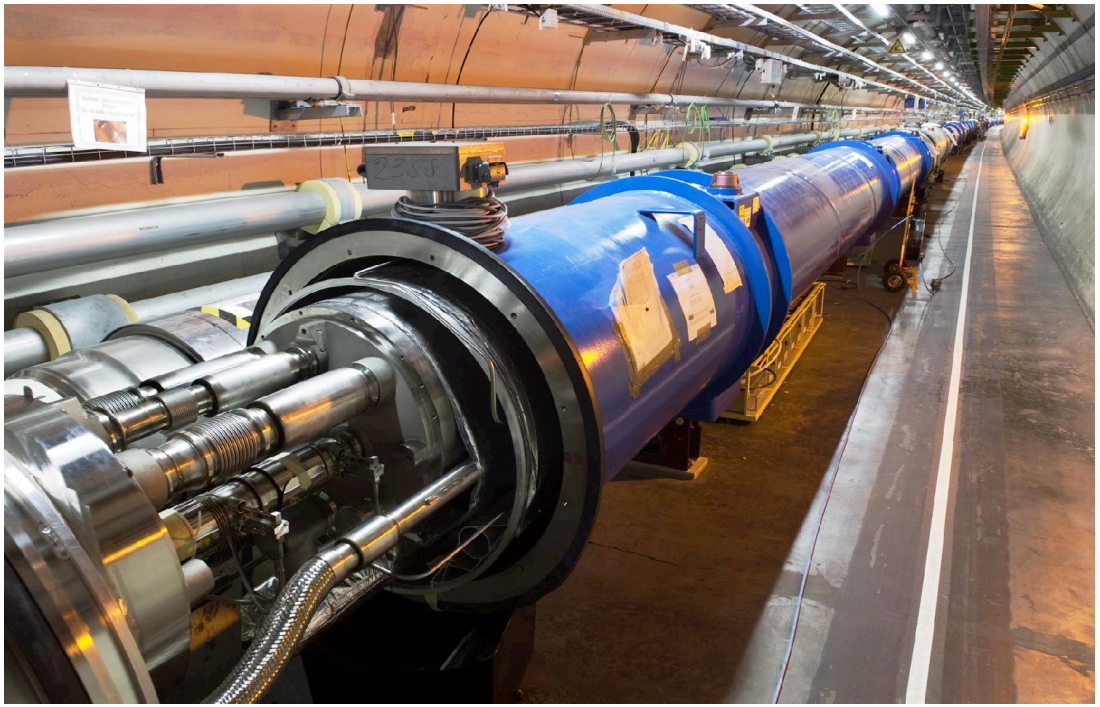




Beam accelleration

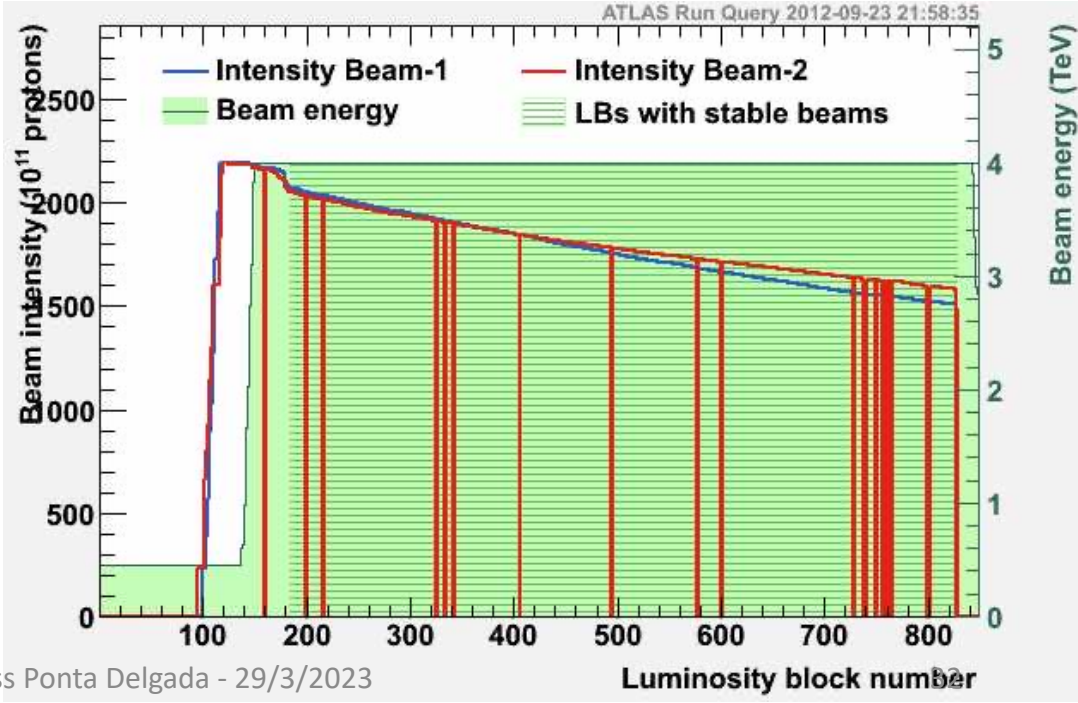




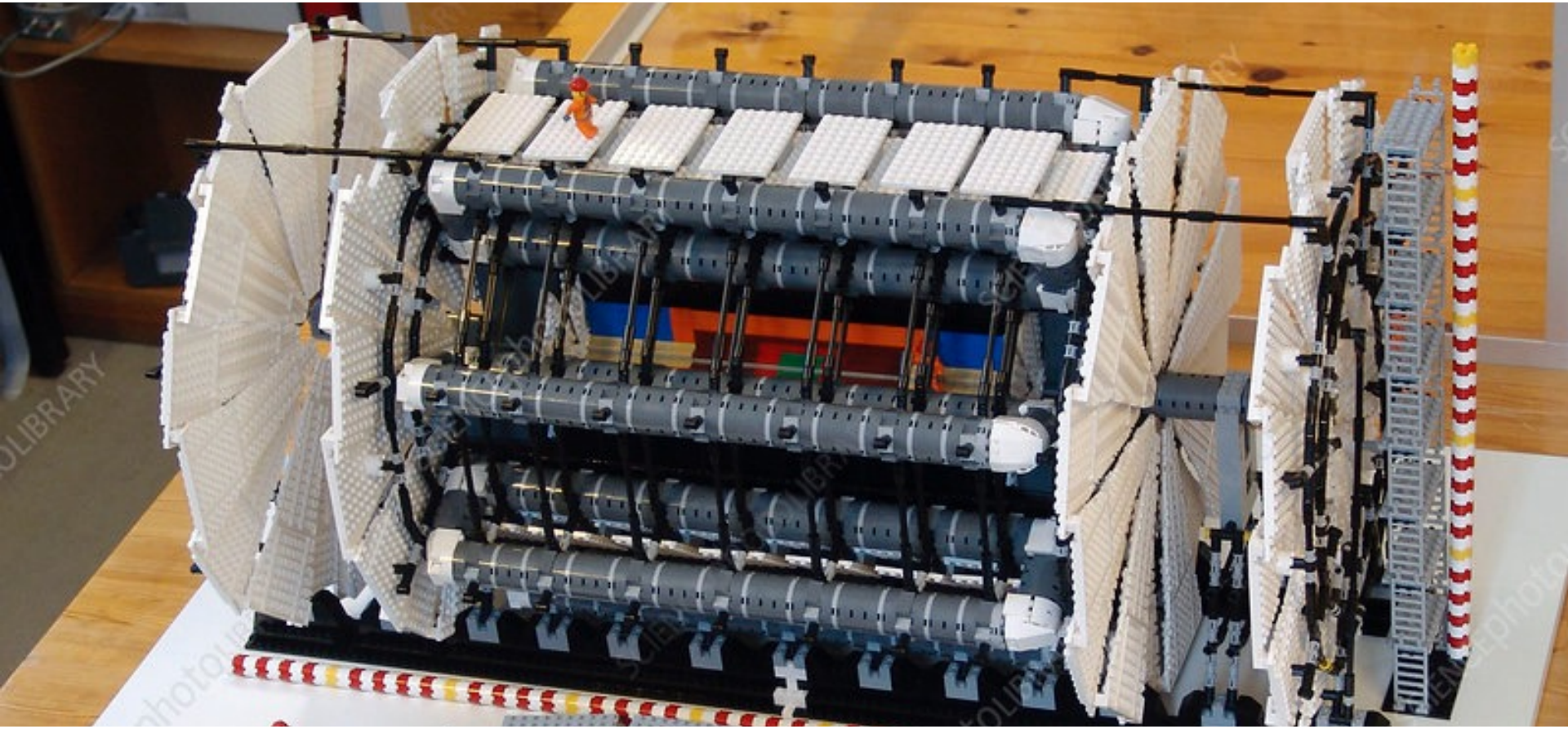


- Energia do feixe:
- 2802 bunches de 1.15×10^{11} protões
- 7TeV / protão (2015) = $7 \times 10^{12} \times 1.602 \times 10^{-19}$ J
- Dá 362 MJ por feixe…
- Igual à energia cinética de um porta-aviões de 20,000t a viajar a 11,7 nós (21.7 km/h)

- Tudo contido num feixe de ≈16µm
- Runs típicos duram cerca de 8 horas
- Intensidade diminui devido a perdas
- Depois voltamos a injectar novos feixes

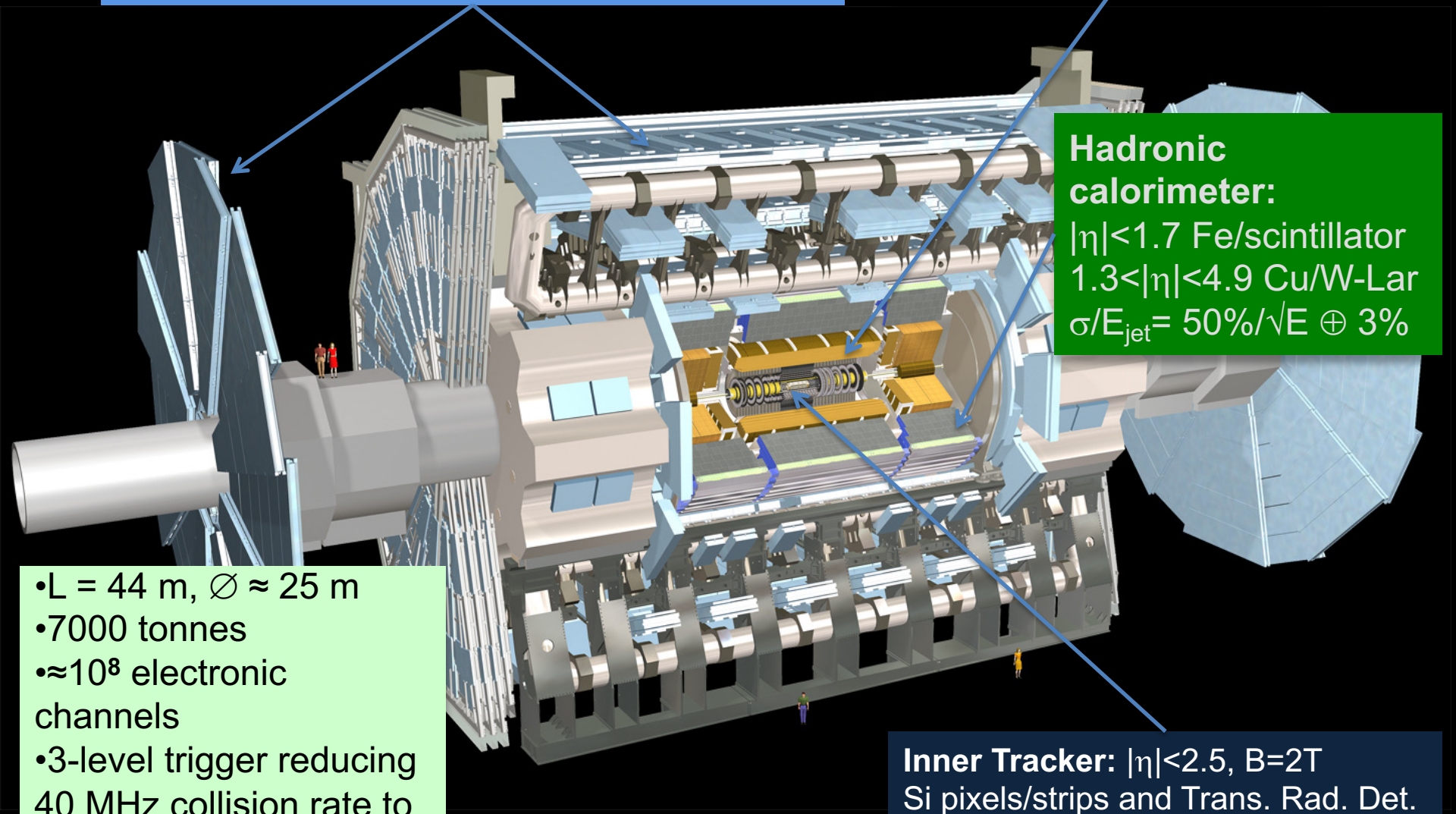


A Experiência ATLAS



Muon Spectrometer: $|\eta|<2.7$
Air-core toroids and gas-based muon chambers
$\sigma/p_T = 2\%$ @ 50GeV to 10% @ 1TeV (ID+MS)

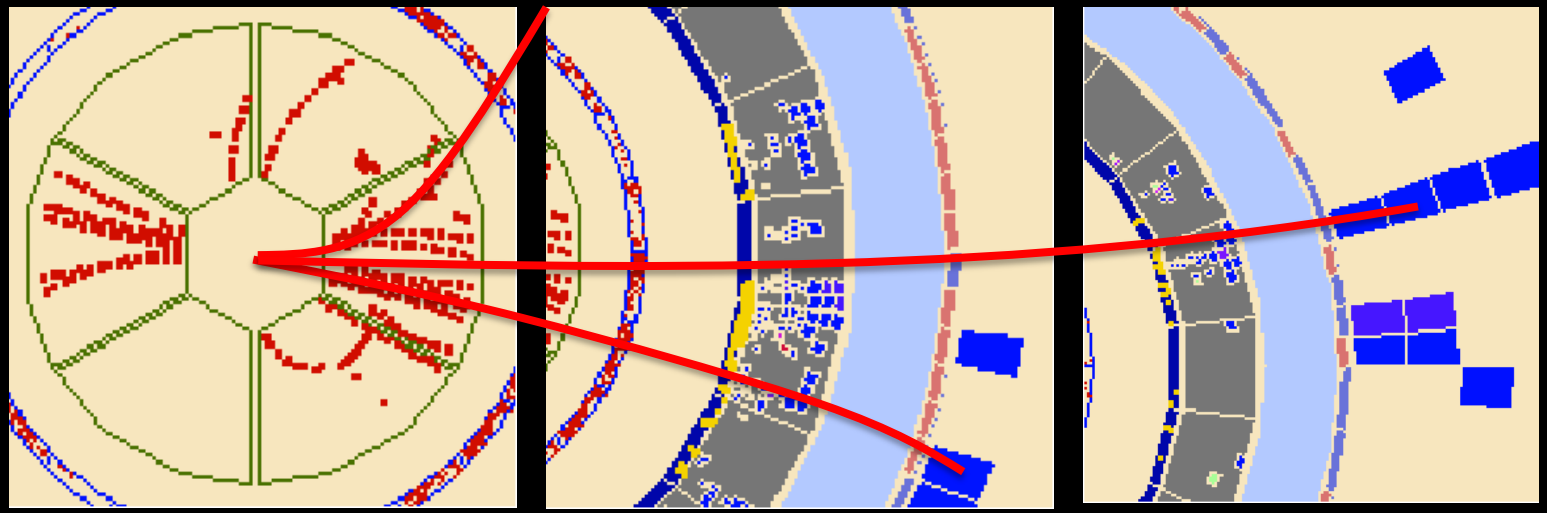
EM calorimeter: $|\eta|<3.2$
Pb-LAr Accordion
$\sigma/E = 10\%/\sqrt{E} \oplus 0.7\%$



Hadronic calorimeter:
$|\eta|<1.7$ Fe/scintillator
$1.3<|\eta|<4.9$ Cu/W-Lar
$\sigma/E_{jet} = 50\%/\sqrt{E} \oplus 3\%$

- L = 44 m, ∅ ≈ 25 m
- 7000 tonnes
- ≈10^8 electronic channels
- 3-level trigger reducing 40 MHz collision rate to 200 Hz of events to tape

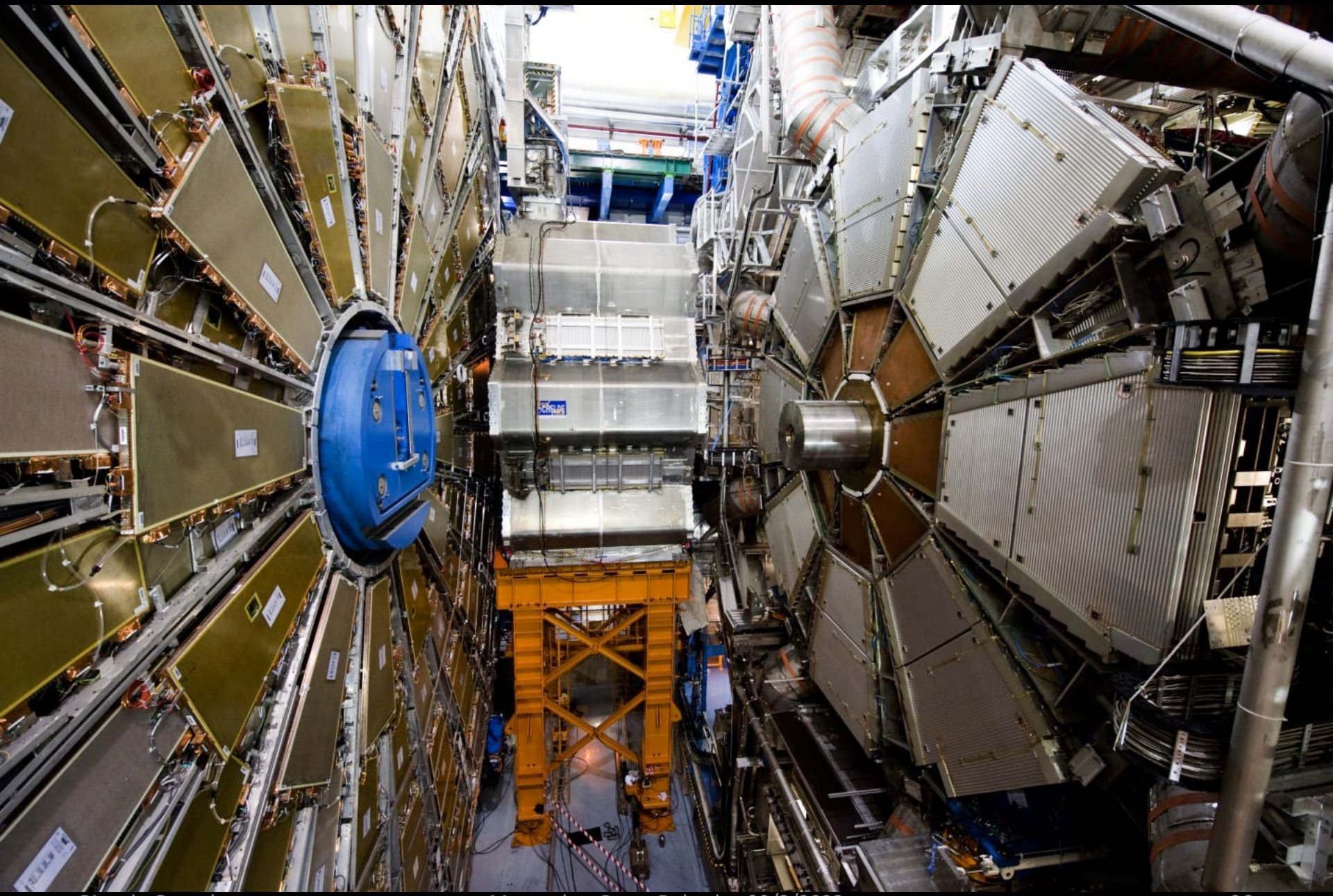
Inner Tracker: $|\eta|<2.5$, B=2T
Si pixels/strips and Trans. Rad. Det.
$\sigma/p_T = 0.05\%\ p_T\,(\text{GeV}) \oplus 1\%$

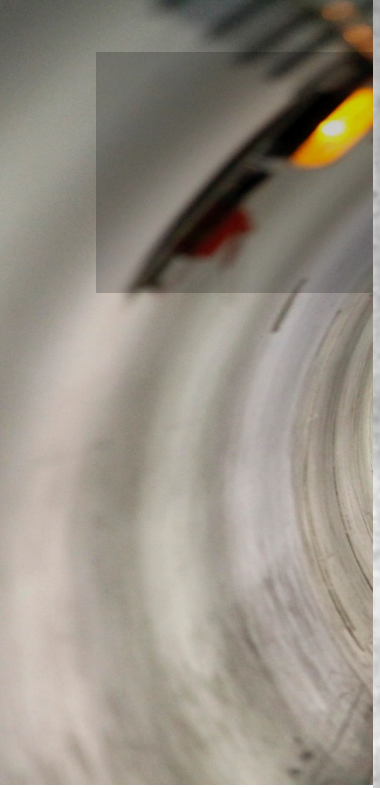


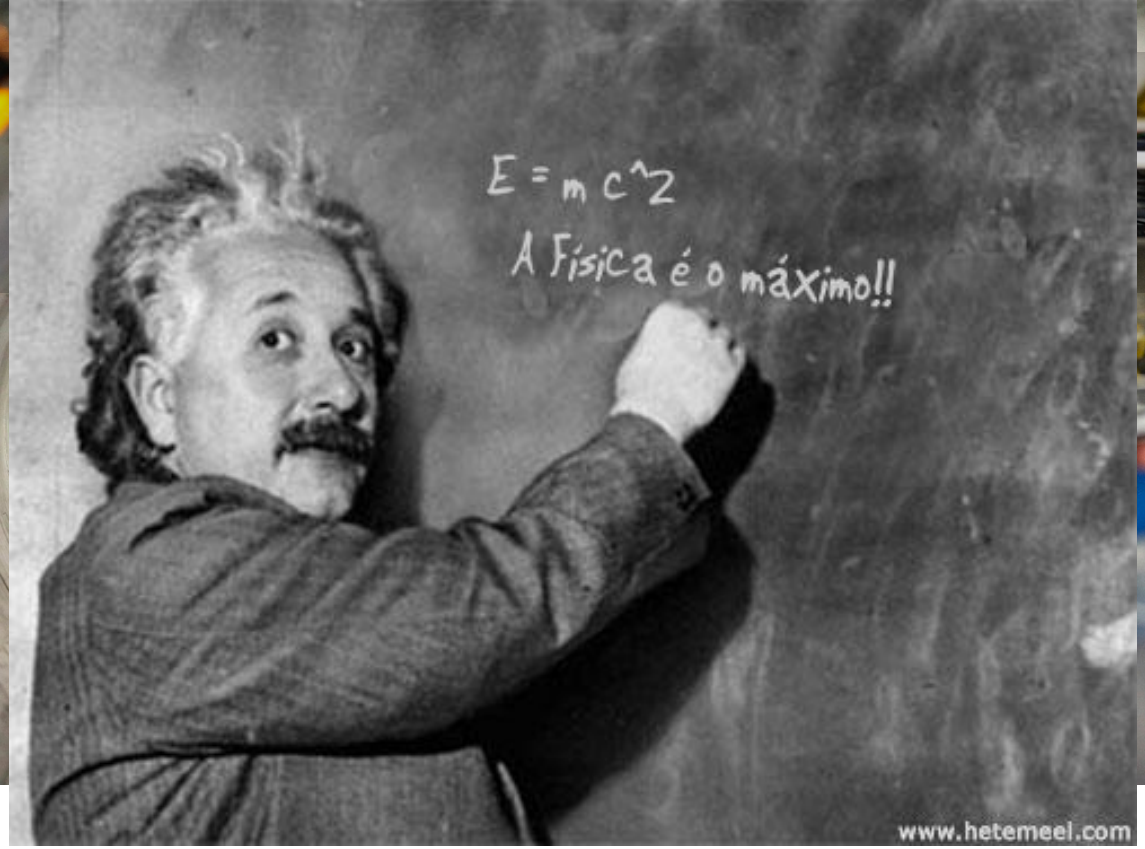
Detetor de Traços

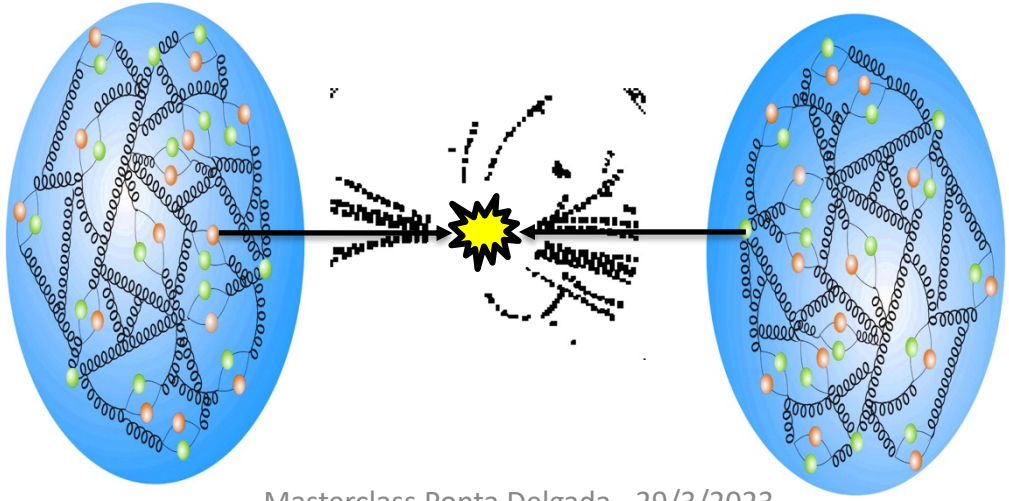
Calorímetro Eletromagnético

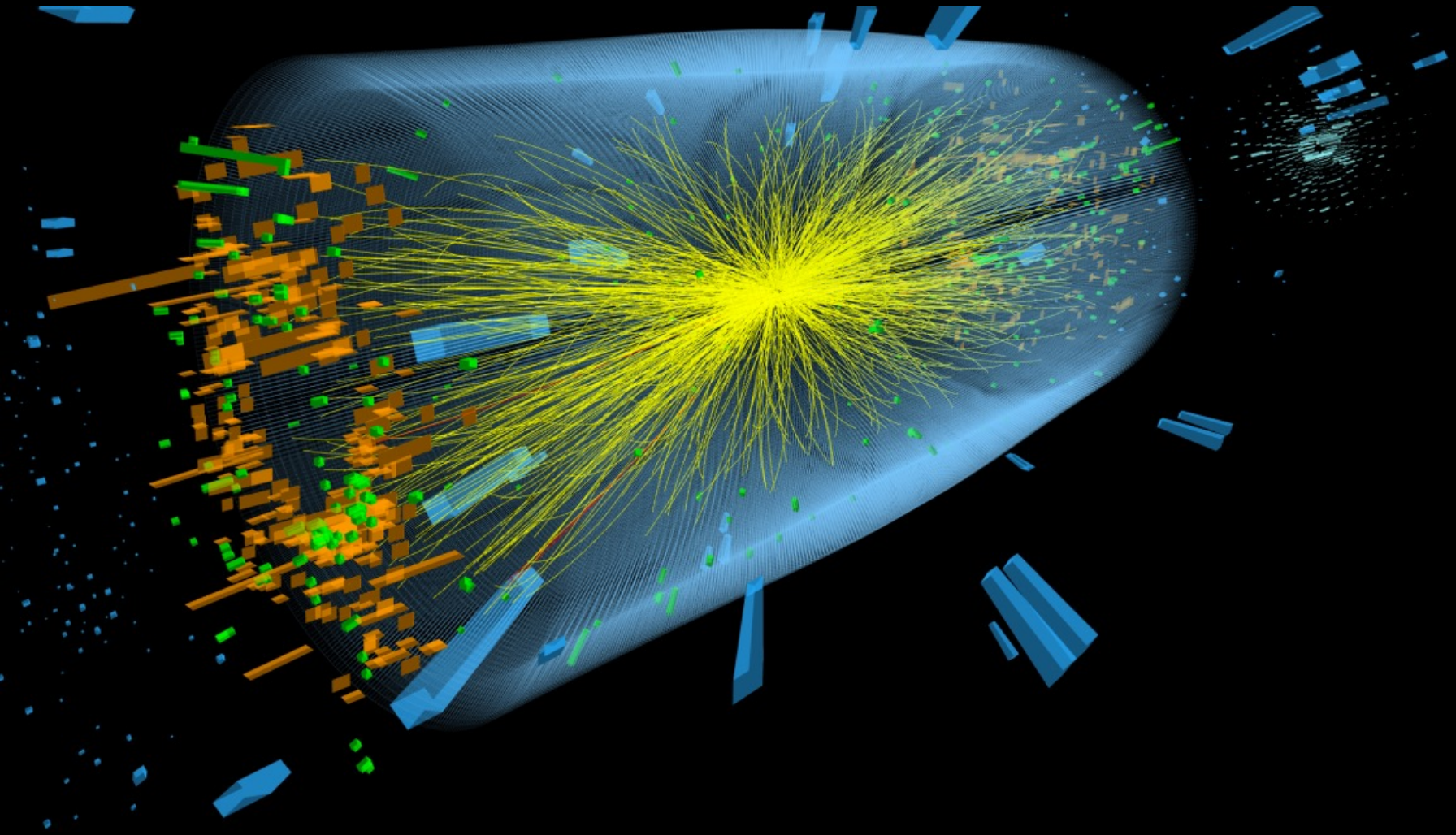
Calorímetro Hadrónico






E = m c^2
A Física é o máximo!!
www.hetemeel.com

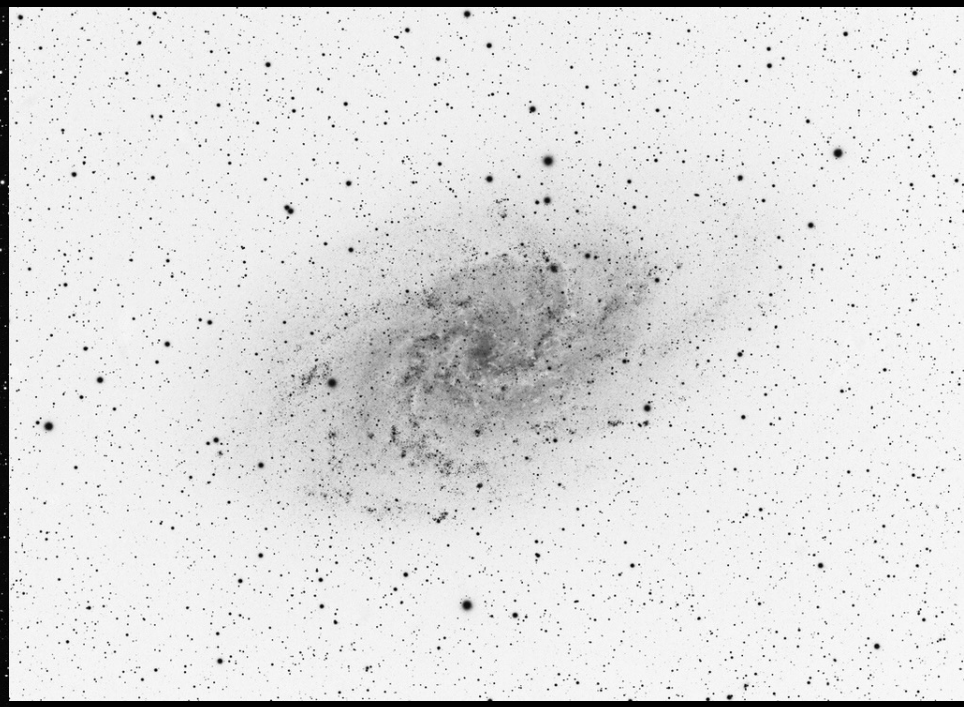




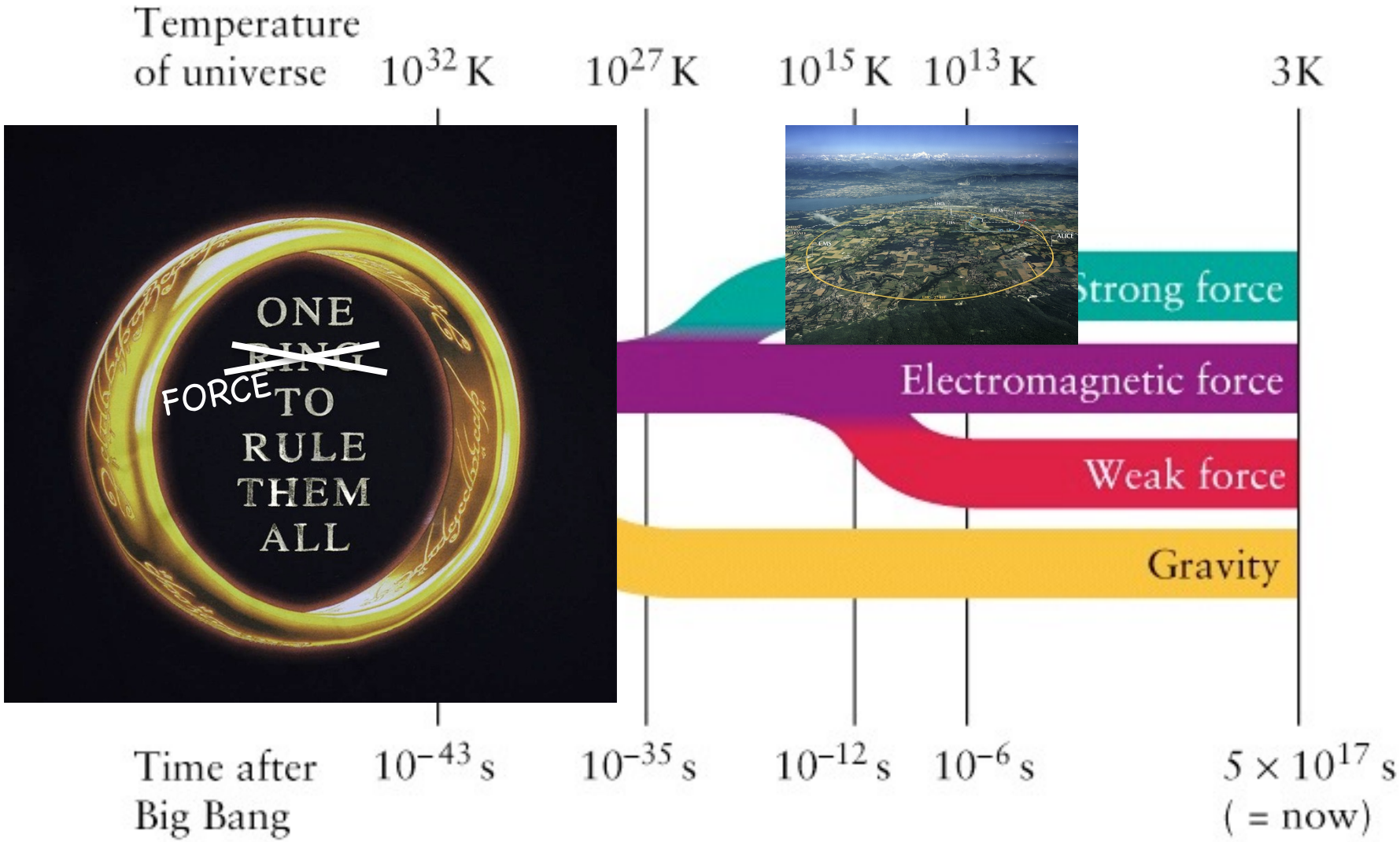
O que (ainda) não sabemos

"Há mais coisas no céu e na terra, Horácio, do que sonha a nossa filosofia??"

Para onde foi a antimatéria?

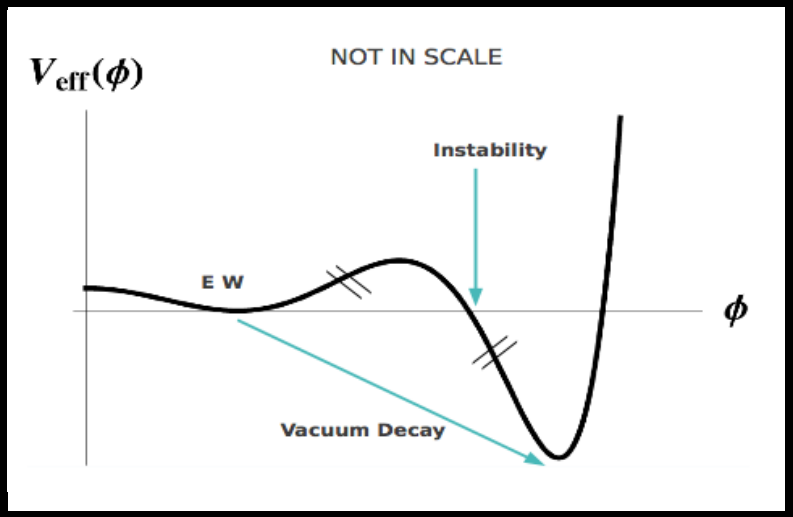


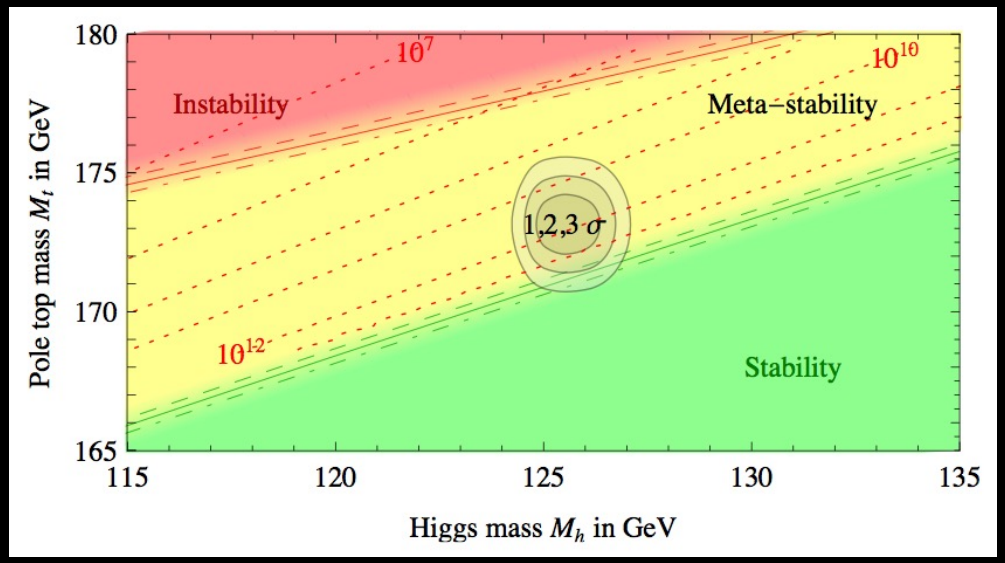
Uma força única?



Então e se o vácuo for instável?....

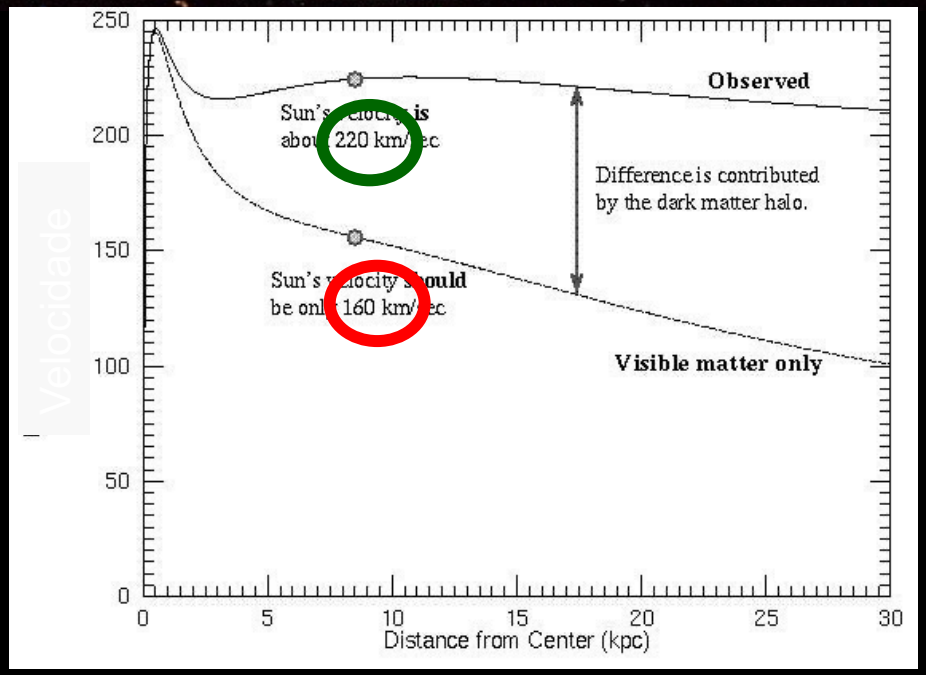
$$V^{1l}(\phi) = \frac{1}{2}m^2\phi^2 + \frac{\lambda}{24}\phi^4 + \frac{1}{64\pi^2}\left[\left(m^2+\frac{\lambda}{2}\phi^2\right)^2\left(\ln\left(\frac{m^2+\frac{\lambda}{2}\phi^2}{\mu^2}\right)-\frac{3}{2}\right)\right.$$
$$+3\left(m^2+\frac{\lambda}{6}\phi^2\right)^2\left(\ln\left(\frac{m^2+\frac{\lambda}{6}\phi^2}{\mu^2}\right)-\frac{3}{2}\right)+6\,\frac{{g_1}^4}{16}\phi^4\left(\ln\left(\frac{\frac{1}{4}{g_1}^2\phi^2}{\mu^2}\right)-\frac{5}{6}\right)$$
$$\left.+3\,\frac{\left({g_1}^2+{g_2}^2\right)^2}{16}\phi^4\left(\ln\left(\frac{\frac{1}{4}\left({g_1}^2+{g_2}^2\right)\phi^2}{\mu^2}\right)-\frac{5}{6}\right)-12\,h_t^4\phi^4\left(\ln\frac{g^2\phi^2}{\mu^2}-\frac{3}{2}\right)\right]$$





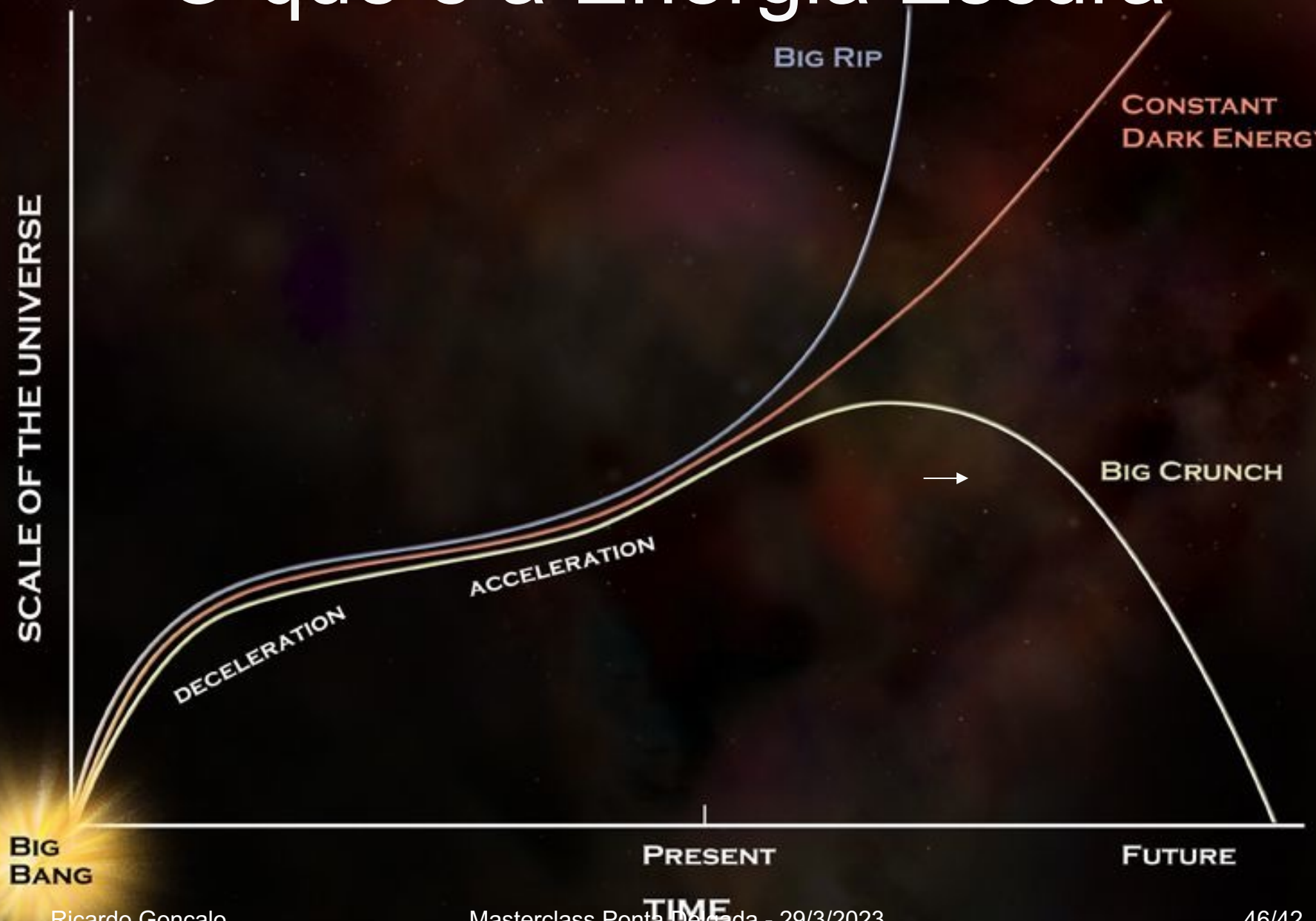
Perguntas que vieram do espaço

O Que é a Matéria Escura?



Nenhuma forma de matéria conhecida!

O que é a Energia Escura



Existem dimensões extra?

Origem da massa dos ν's

Novas interações?

Natureza dos ν's?

Teoria do sabor

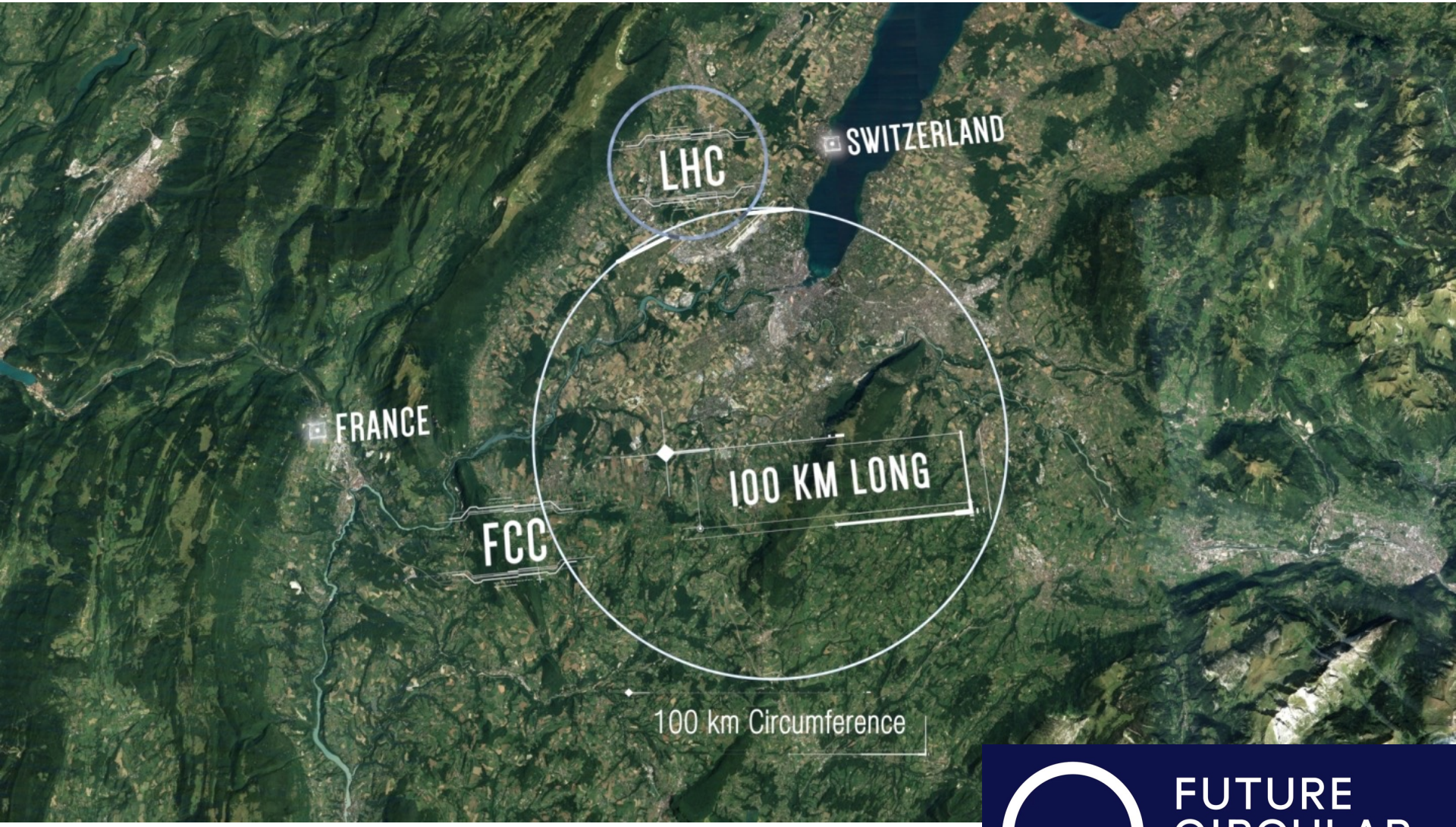
SUSY (supersimetria)

Gravidade

QCD (cromodinâmica quântica)

Mais bosões de Higgs?

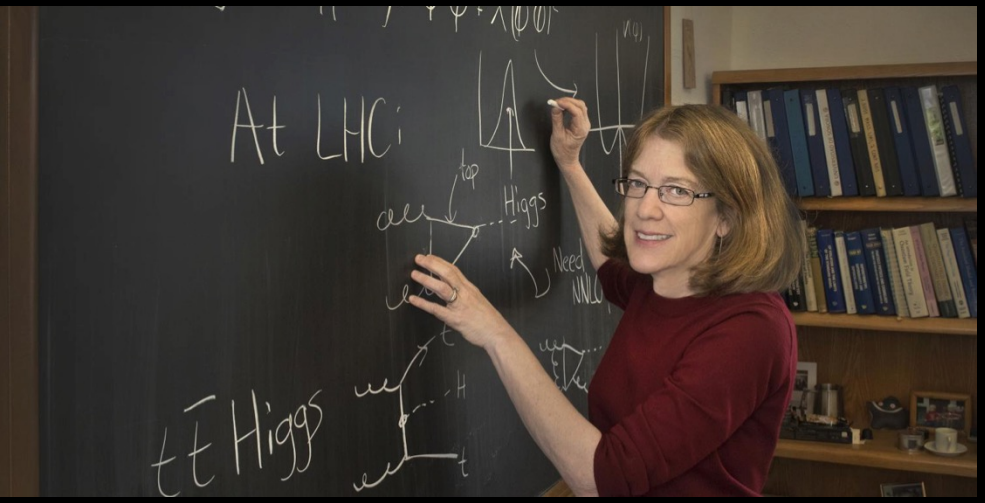
O Future Circular Collider - FCC

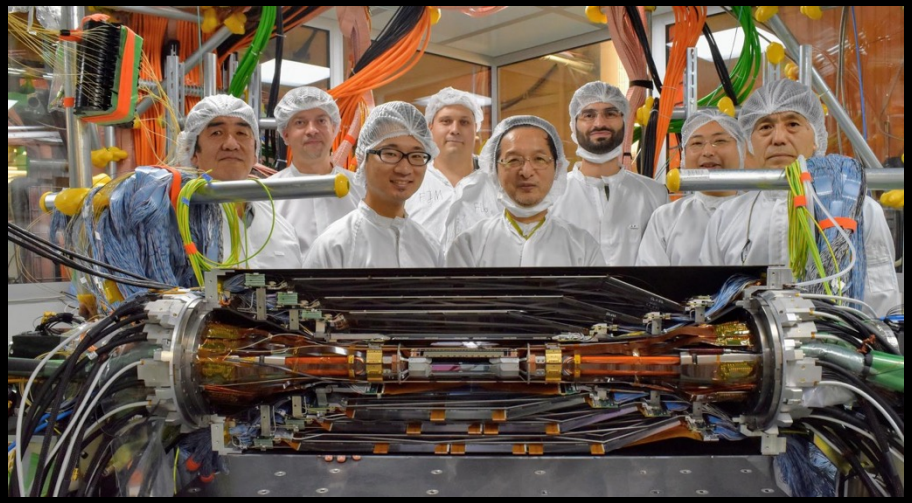


FUTURE CIRCULAR COLLIDER

Os Físicos de Partículas

Os caçadores de partículas

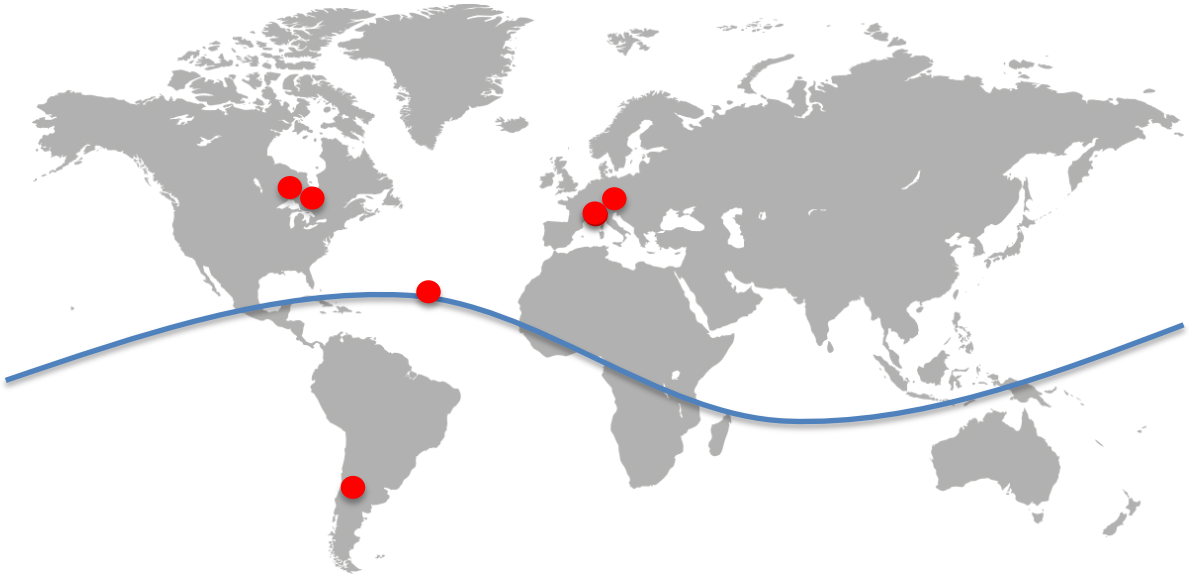




Física (Experimental) de Partículas em Portugal

- Lisboa, Coimbra, Minho
- 200 membros
- 90 doutorados
- 75 estudantes
- 25 engenheiros e administrativos

www.lip.pt



Perguntas?

Obrigado pelo vosso interesse!

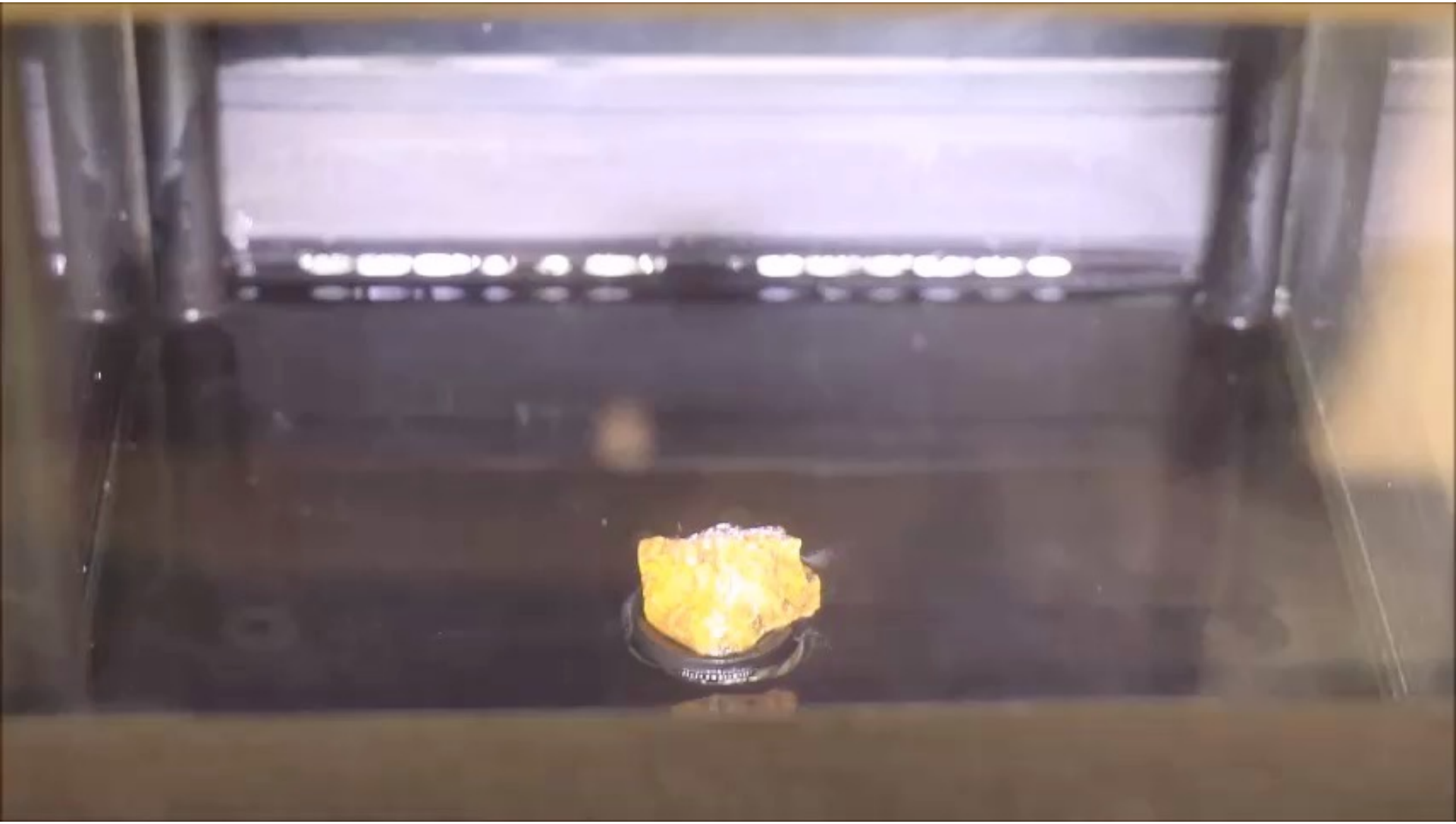
jgoncalo@lip.pt

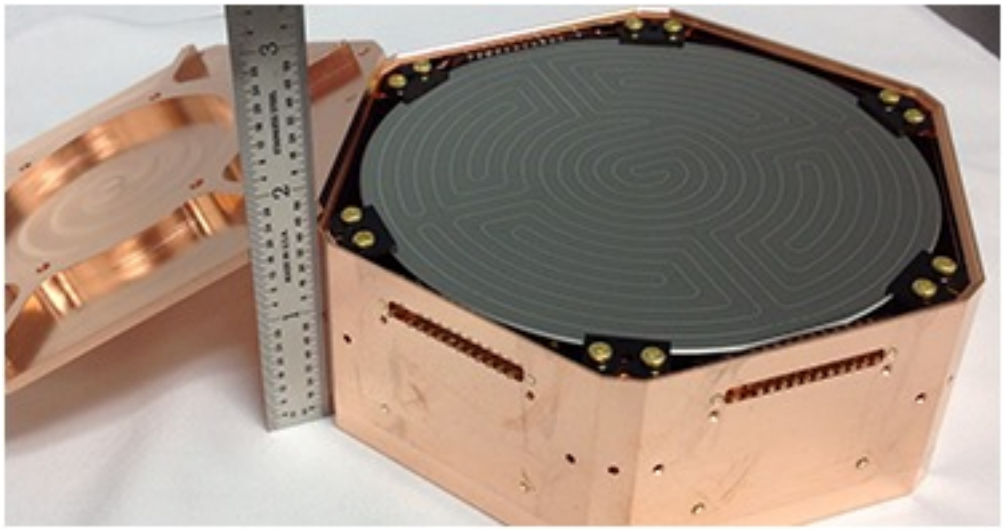
BACKUP Slides

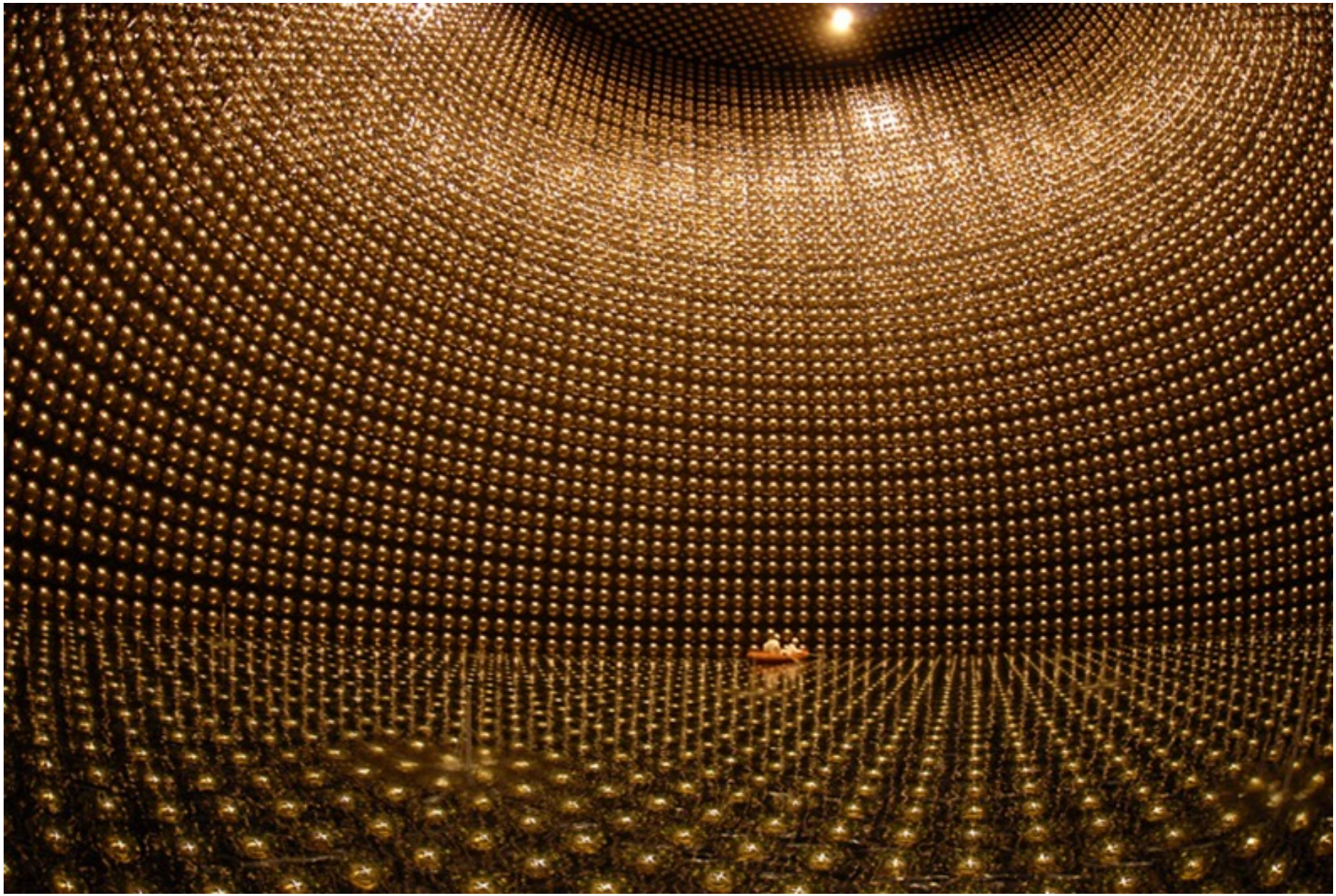
LIP

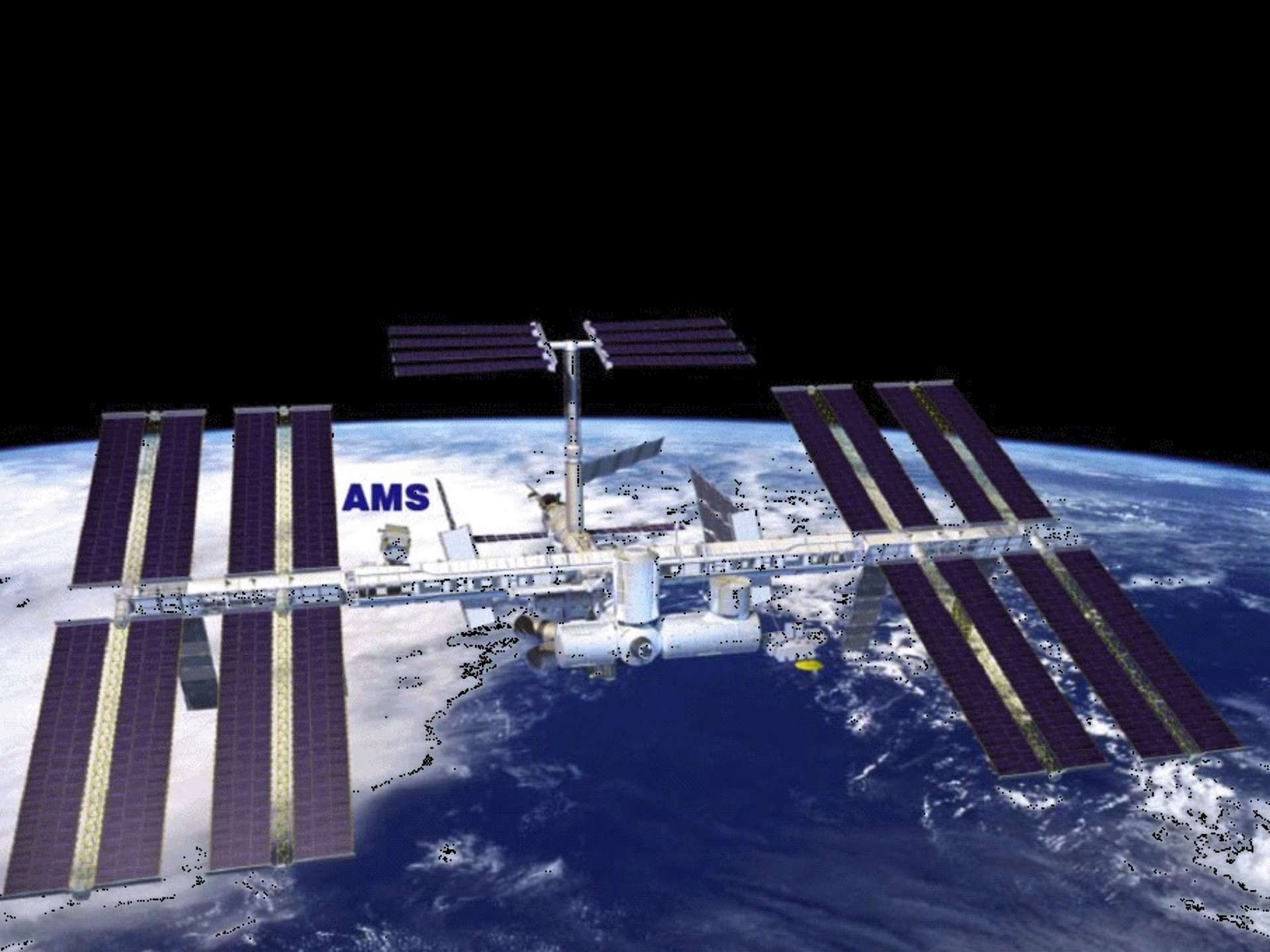
LET'S INSPIRE PEOPLE

Como ver partículas invisíveis

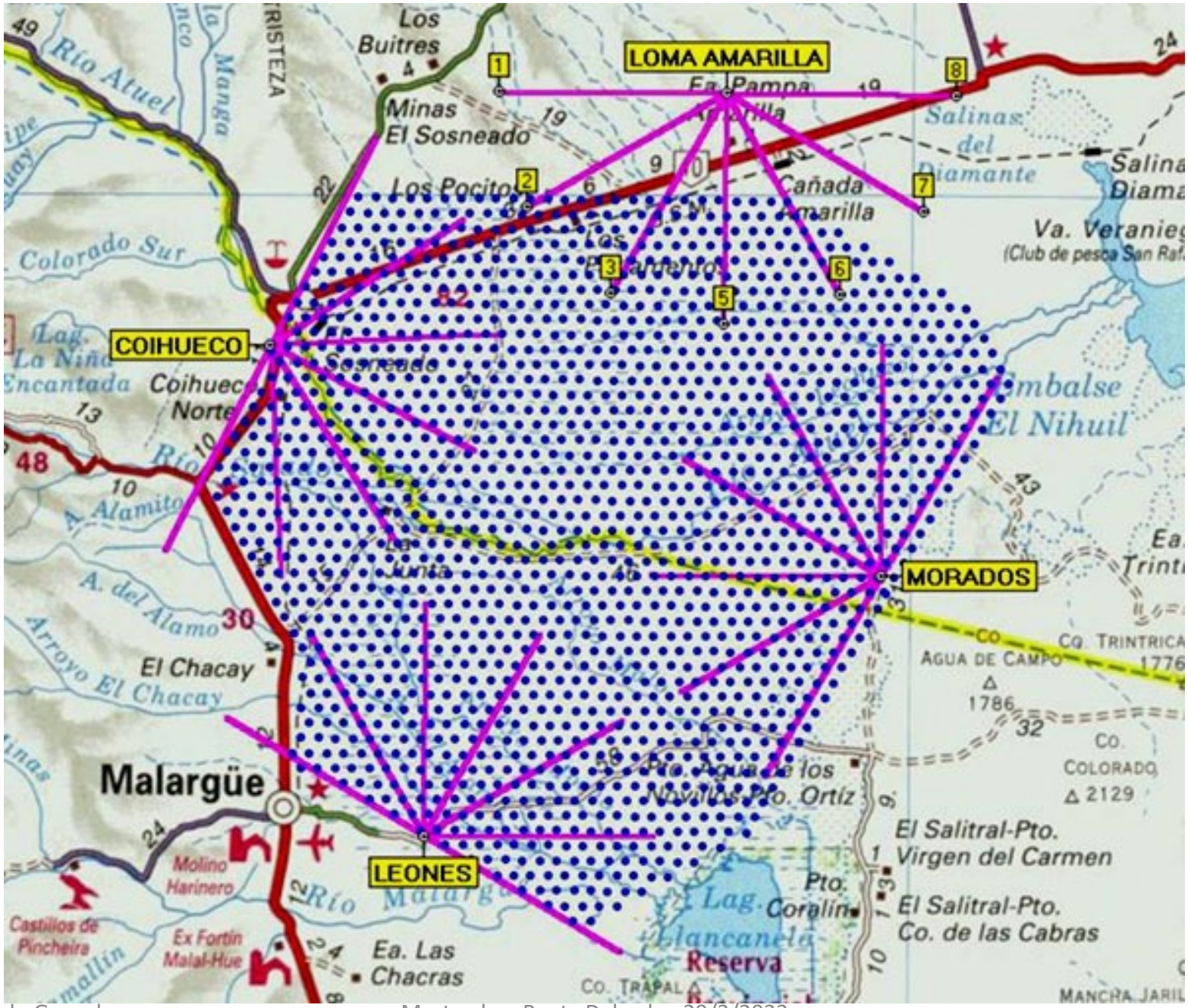


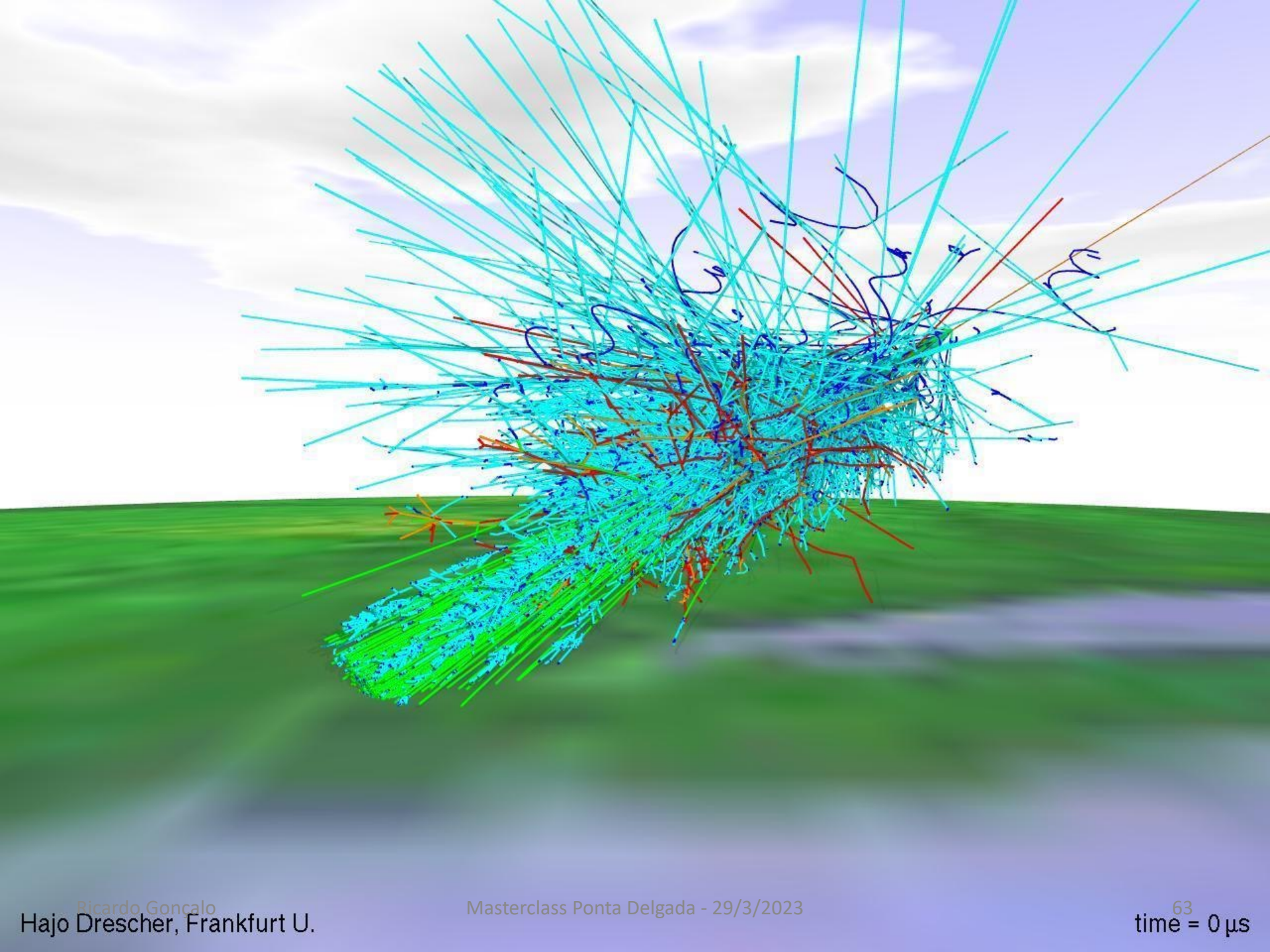




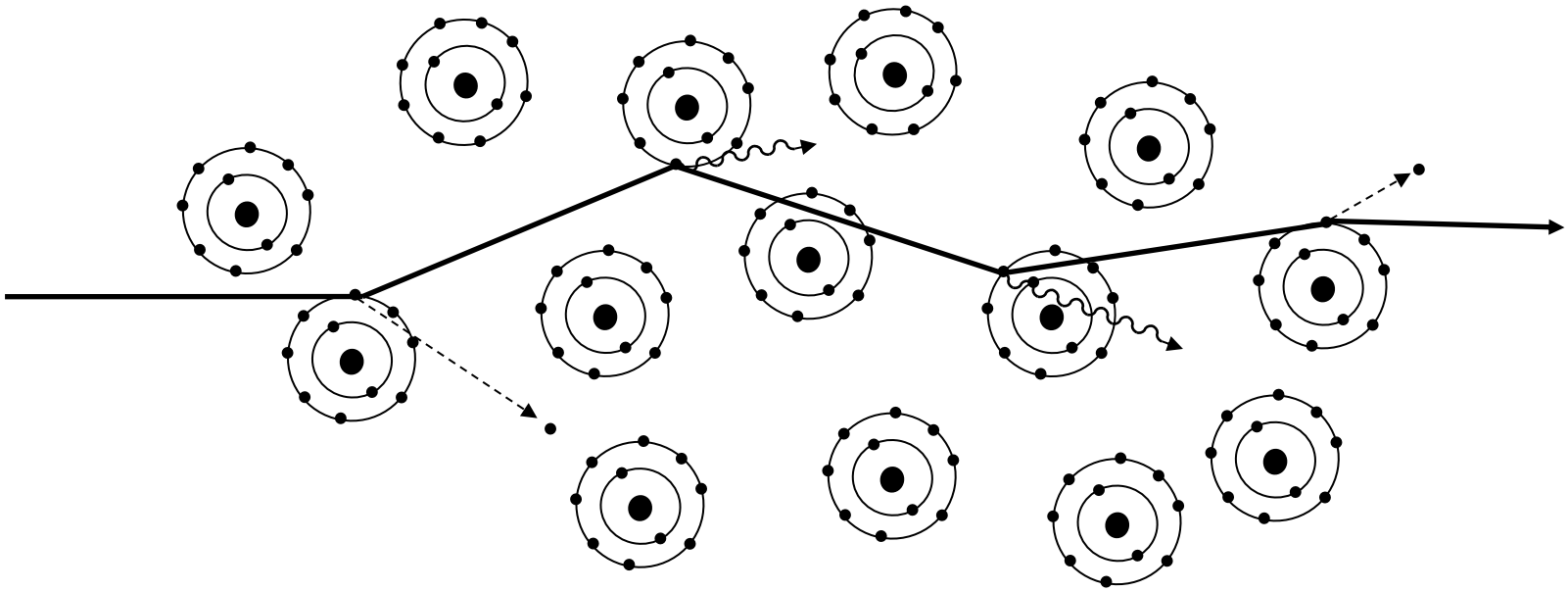

AMS


IceCube
South Pole Station
AMANDA
Skiway
Geographic
South Pole
Dark sector


LOMA AMARILLA
COIHUECO
MORADOS
LEONES
Malargüe
Los Buitres
Minas El Sosneado
Los Pocitos
Cañada Amarilla
Salinas del Diamante
Va. Veraniegu
(Club de pesca San Rafa
Colorado Sur
Lag. La Niña Encantada
Coihueco Norte
Sosneado
Embalse El Nihuil
Río Atuel
Río Malargüe
A. Alamito
A. del Alamo
Arroyo El Chacay
El Chacay
Ea. Trinta
Ea. Trinti
CO. TRINTRICA
AGUA DE CAMPO
1786
CO. COLORADO
2129
Pto. Aguada los Novillos Pto. Ortiz
El Salitral-Pto. Virgen del Carmen
El Salitral-Pto. Co. de las Cabras
Pto. Coralín
Lag. Llancanelo
Reserva
Ea. Las Chacras
CO. TRAPAL
MANCHA JARIL
Molino Harinero
Castillos de Pincheira
Ex Fortín Malal-Hue
Embalse El Nihuil


Hajo Drescher, Frankfurt U.
time = 0 µs

Mas como funciona?



Funcionamento de detetores

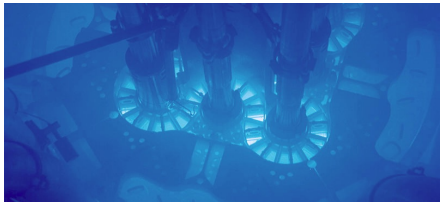
Para detetarmos uma partícula, ela tem de **interagir com o meio (o material do detetor)**

Essa energia é **amplificada** e transformada pelo detetor num **sinal elétrico**

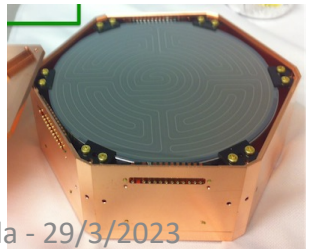
O Meio pode ser gasoso, líquido ou sólido

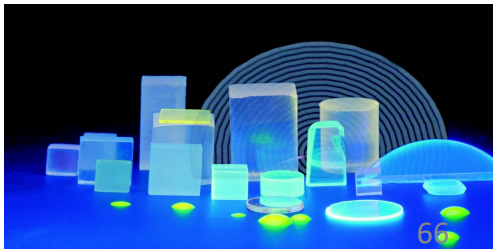
Gases
Gases nobres, misturas complexas, ...

Líquidos
líquidos cintiladores,
agua, Xénon, Árgon, etc



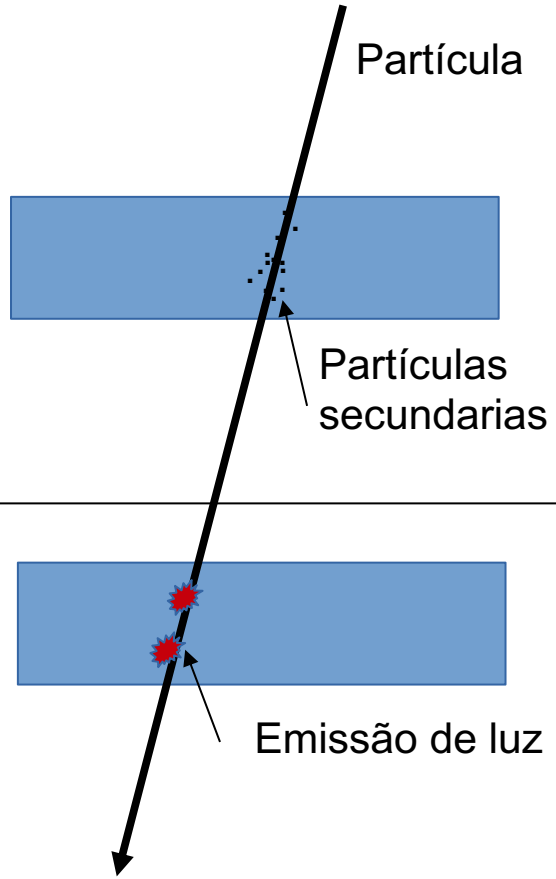
Sólidos
Semicondutores, plásticos cintiladores, etc





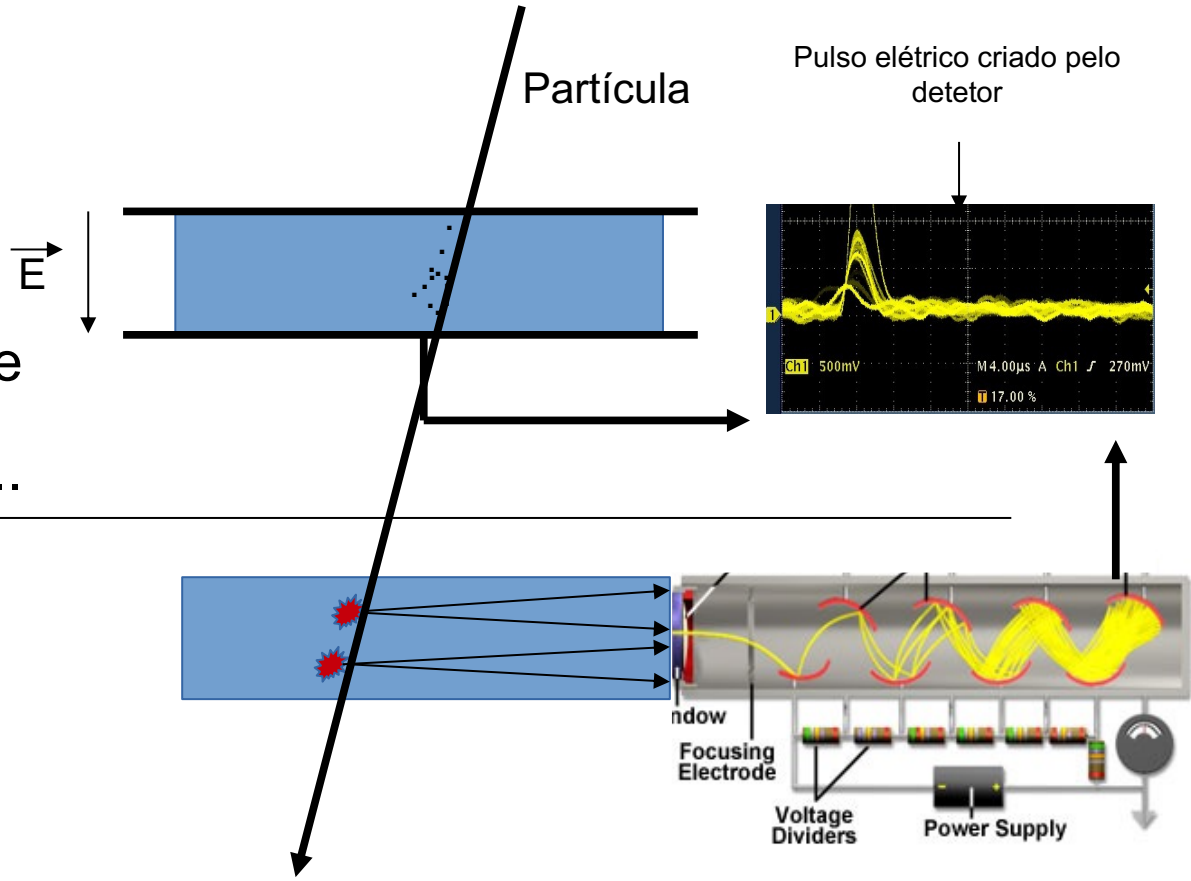
- **Produção de partículas secundarias**
  - Ionização, radiação de transição, dispersão elástica e inelástica, ...

- **Produção de luz**
  - Cintilação, luz Cherenkov, ...

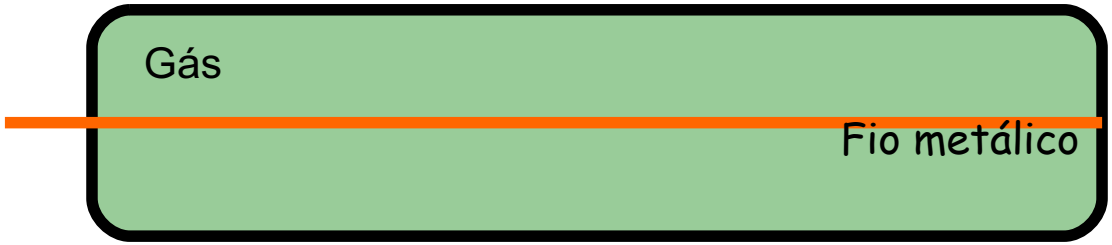


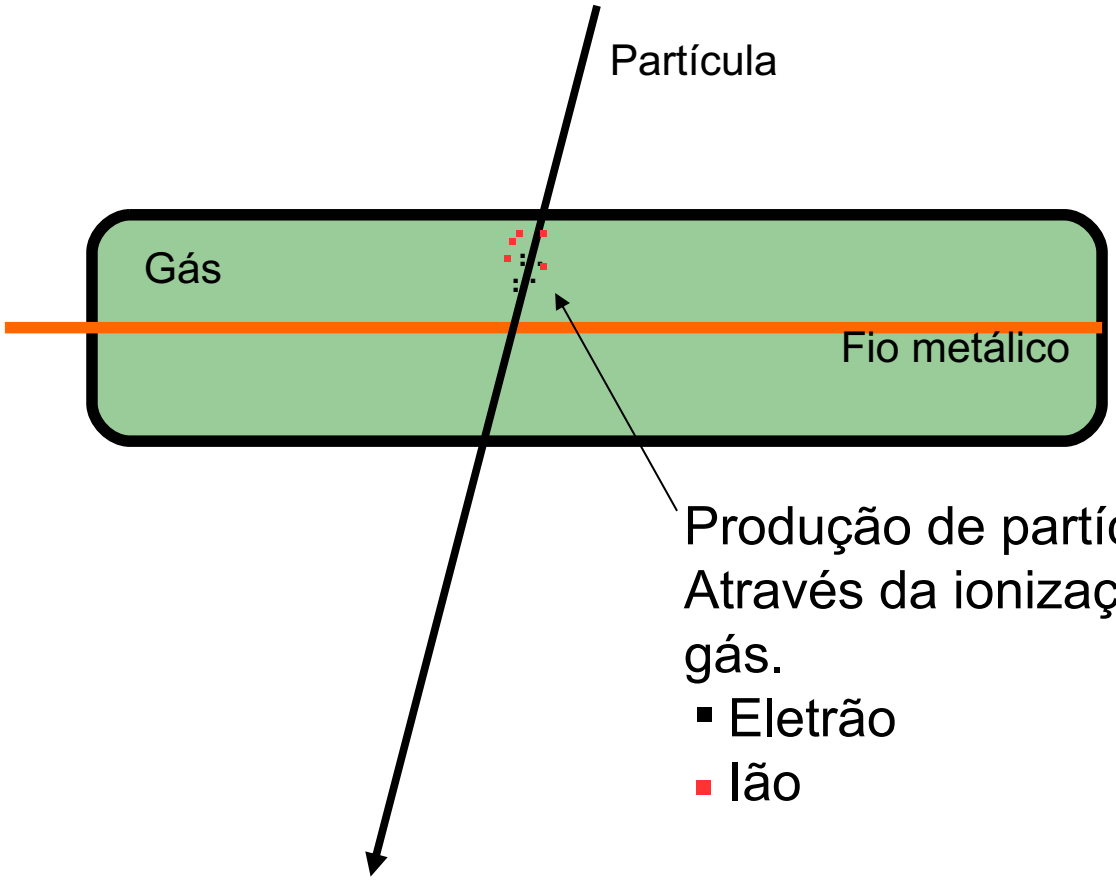
- **Produção de partículas secundarias**
  - Ionização, radiação de transição, dispersão elástica e inelástica, ...

- **Produção de luz**
  - Cintilação, luz Cherenkov, ...



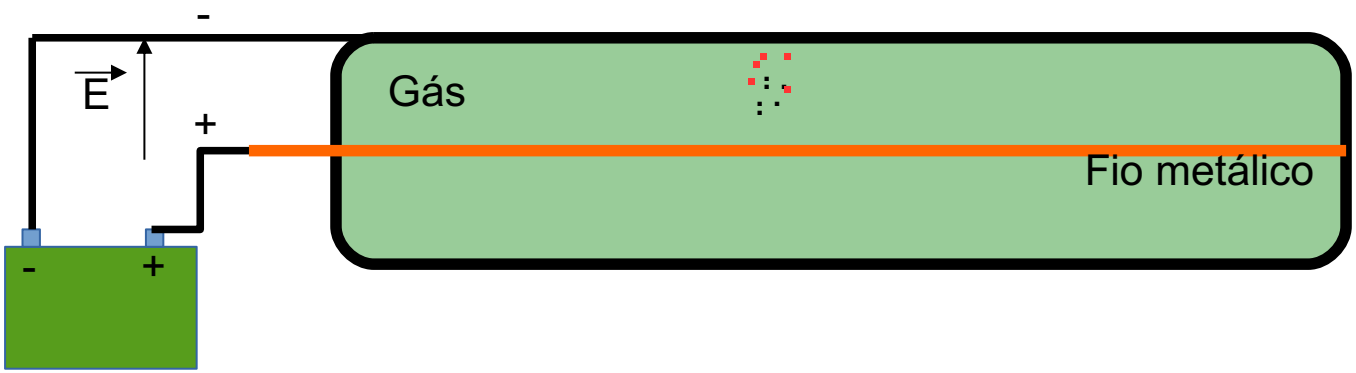

Bip! Bip!
Bip!

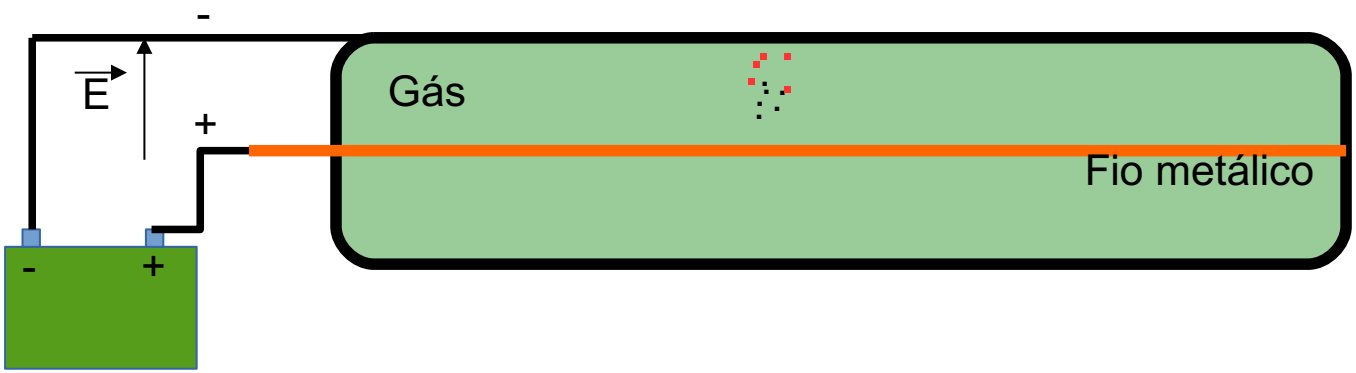

Gás
Fio metálico



Produção de partículas secundarias
Através da ionização dos átomos do gás.

- Eletrão
- Ião


-
E
+
Gás
Fio metálico
-
+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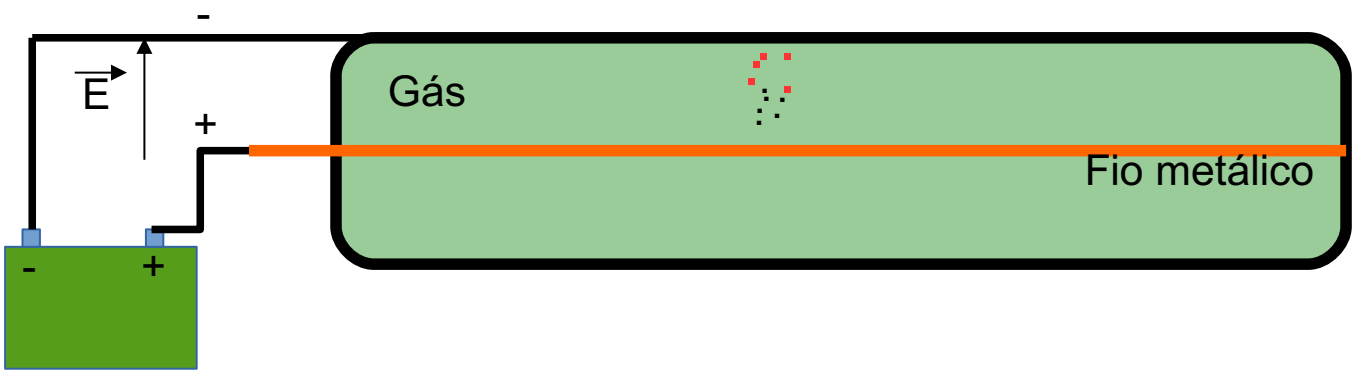
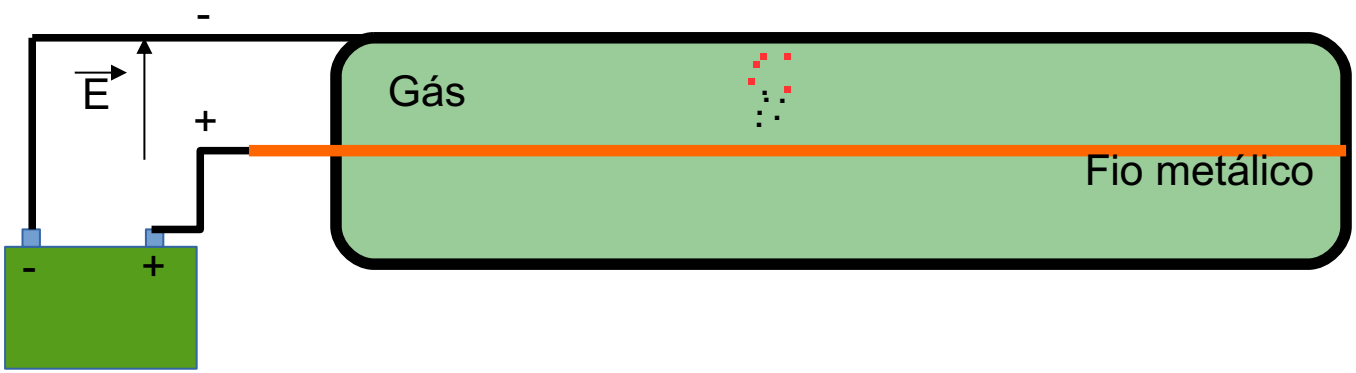

-
E
+
Gás
Fio metálico
-
+


-
E
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Gás
Fio metálico
-
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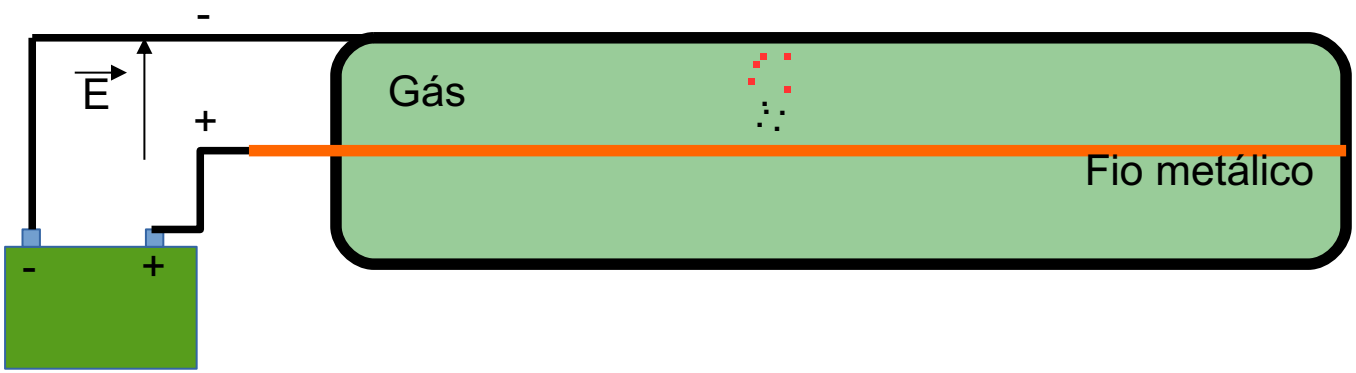
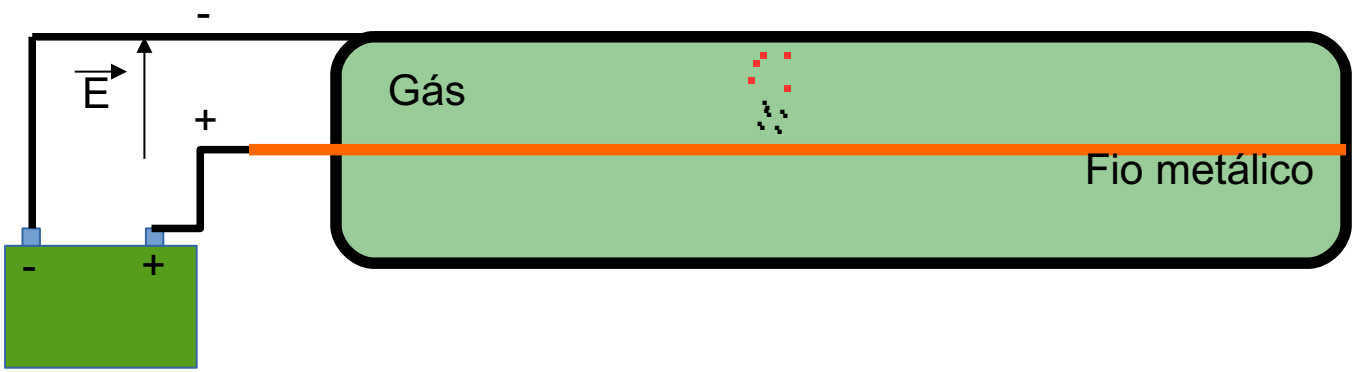
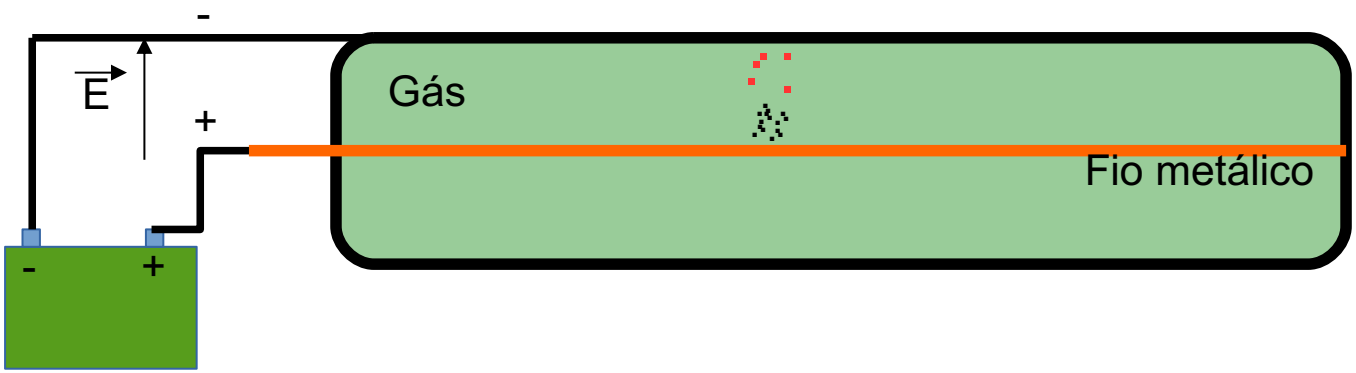
O **campo elétrico, E, dá energia aos eletrões** e iões **movendo-os** em direção ao fio e a parede respetivamente.

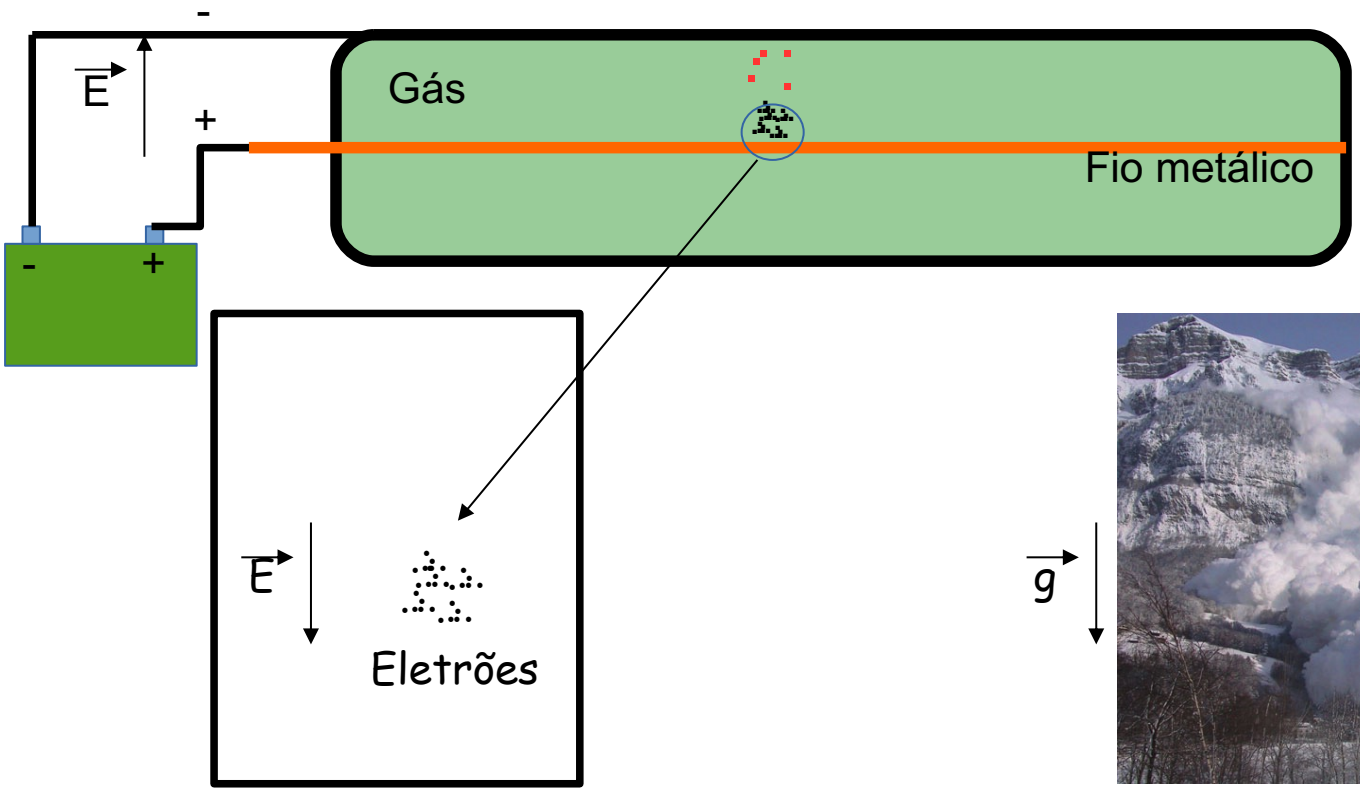


O **campo elétrico, E, dá energia aos eletrões** e iões **movendo-os** em direção ao fio e a parede respetivamente.

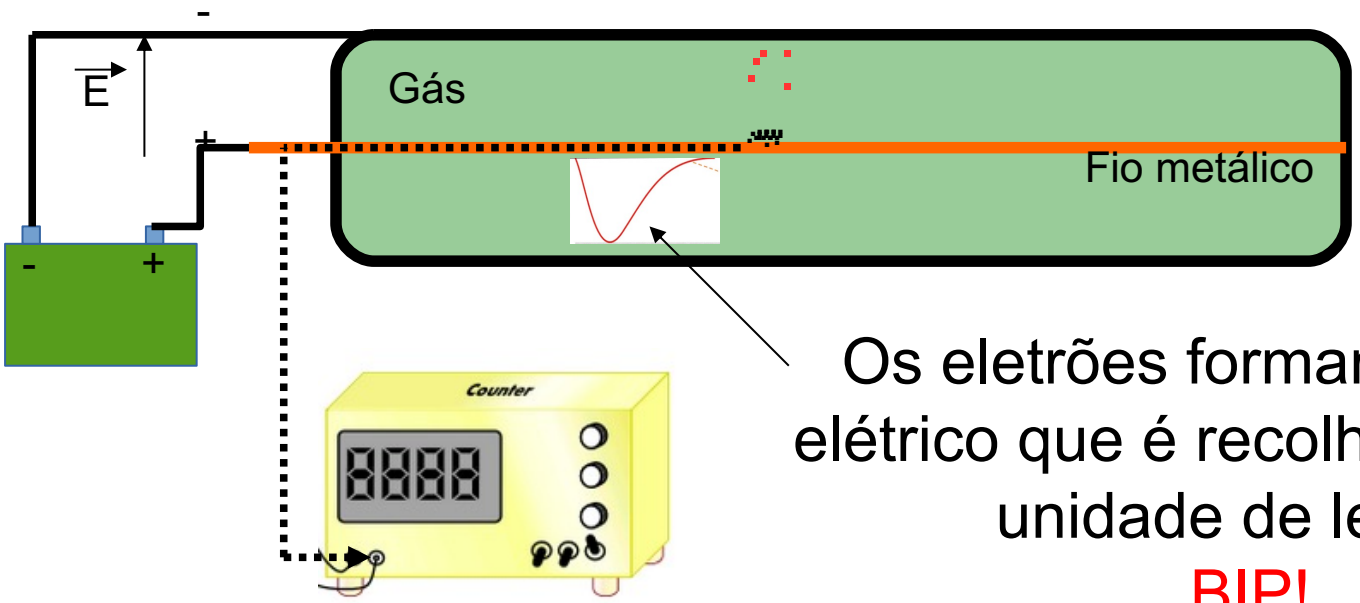


O **campo elétrico, E, dá energia aos eletrões** e iões **movendo-os** em direção ao fio e a parede respetivamente.



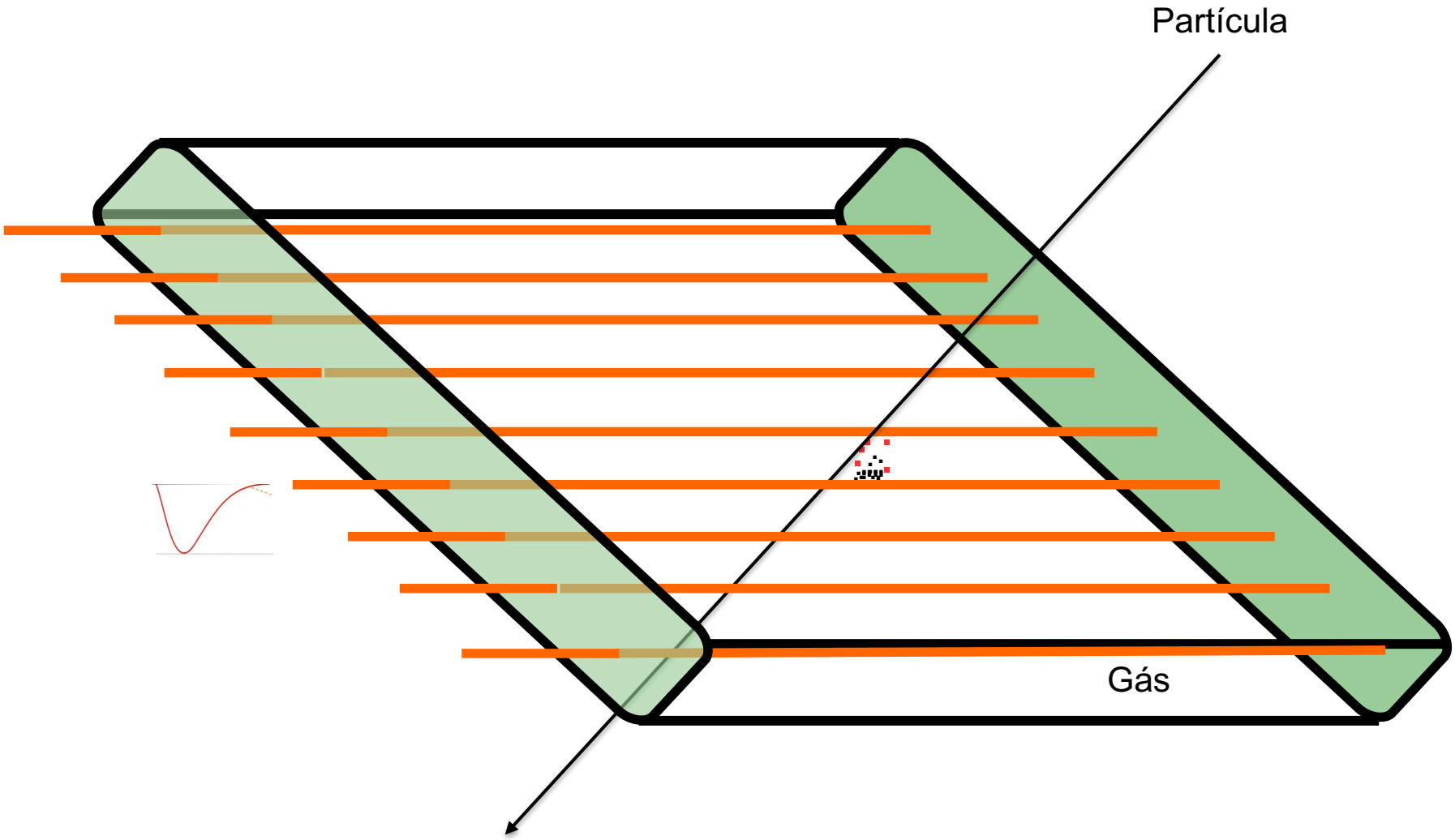

-
E
+
Gás
Fio metálico
-
+
E
Eletrões

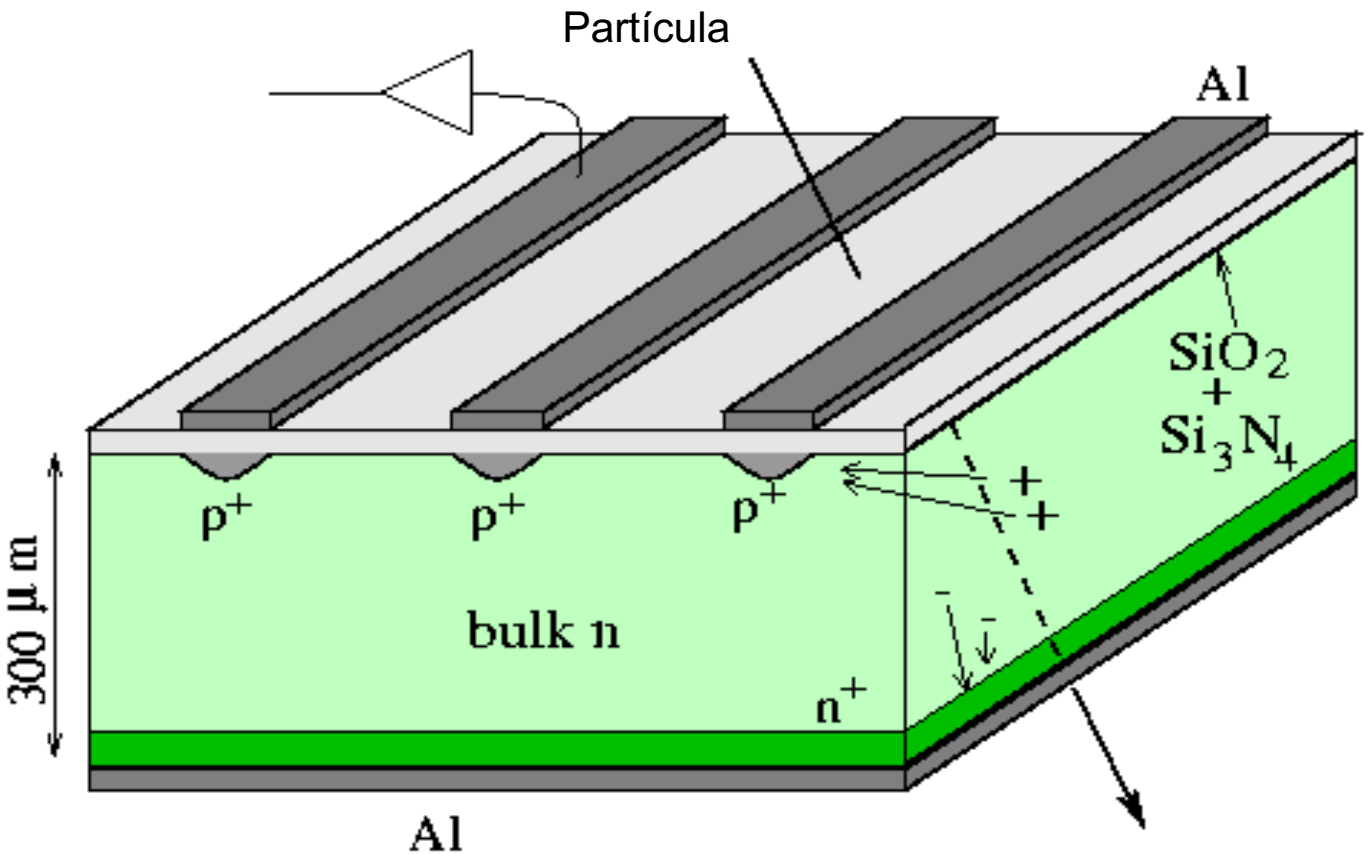

g
Neve

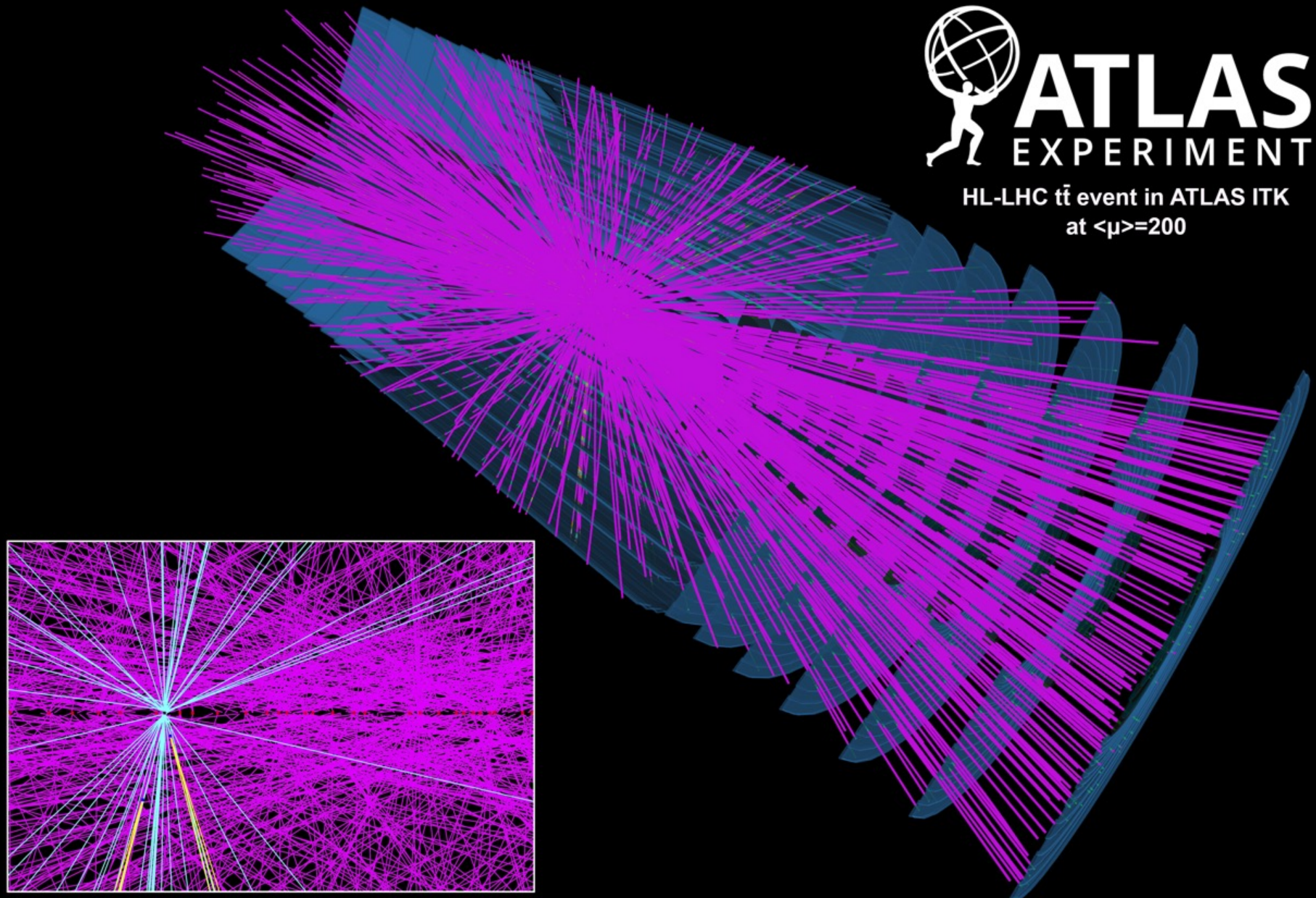


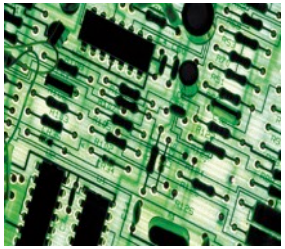
Os eletrões formam um sinal elétrico que é recolhido por uma unidade de leitura

BIP!

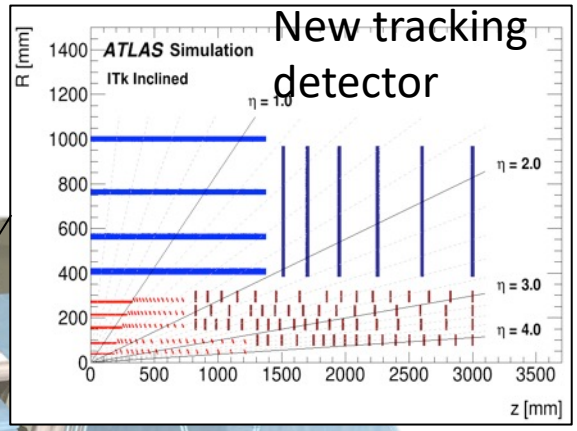

Partícula
Gás


Partícula
Al
SiO_2
+
Si_3N_4
p^+
p^+
p^+
bulk n
n^+
300 μm
Al

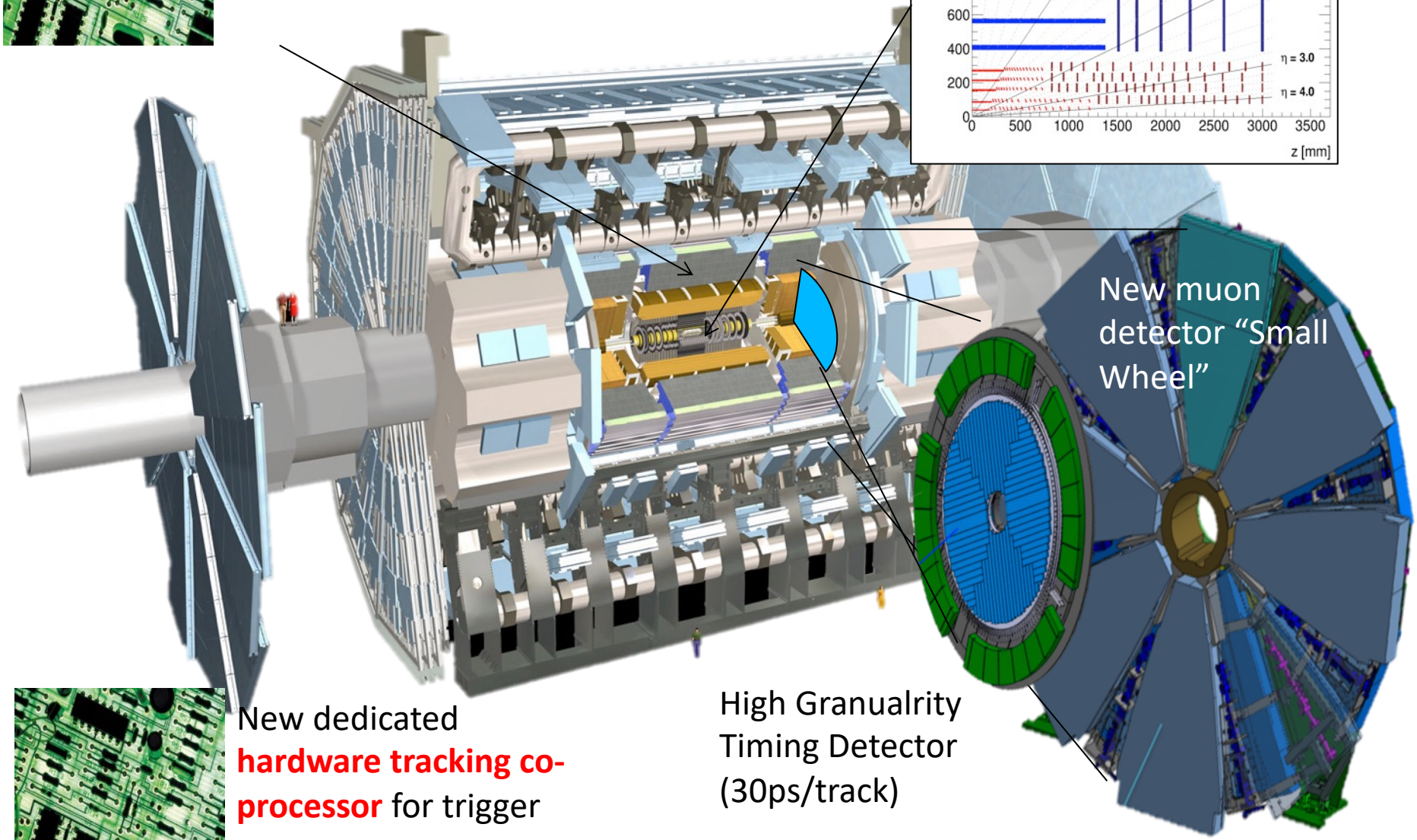

ATLAS
EXPERIMENT
HL-LHC $t\bar{t}$ event in ATLAS ITK
at <μ>=200



Calorimeter: new DAQ electronics, **HV sources** and gap scintillators



New tracking detector



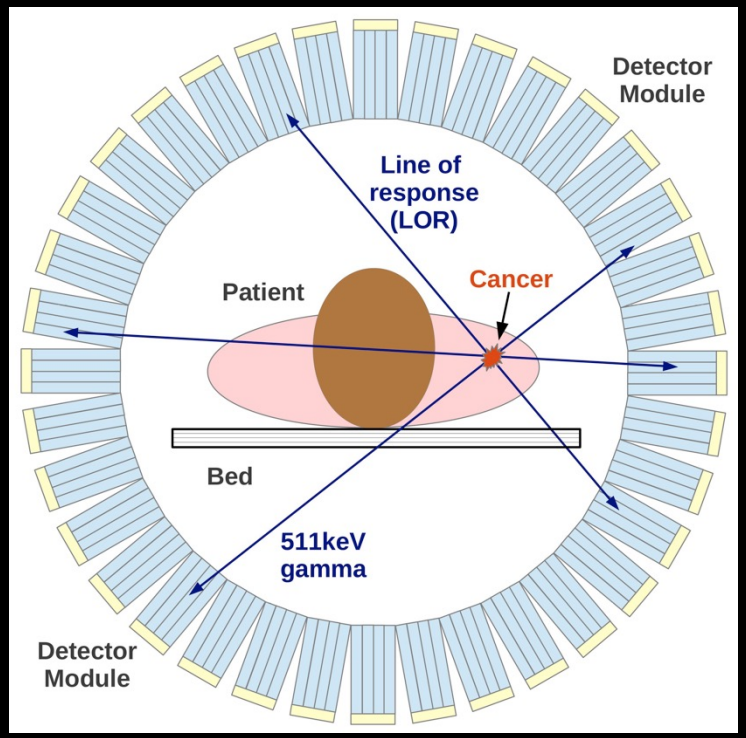
New muon detector "Small Wheel"

New dedicated **hardware tracking co-processor** for trigger

High Granualrity Timing Detector (30ps/track)

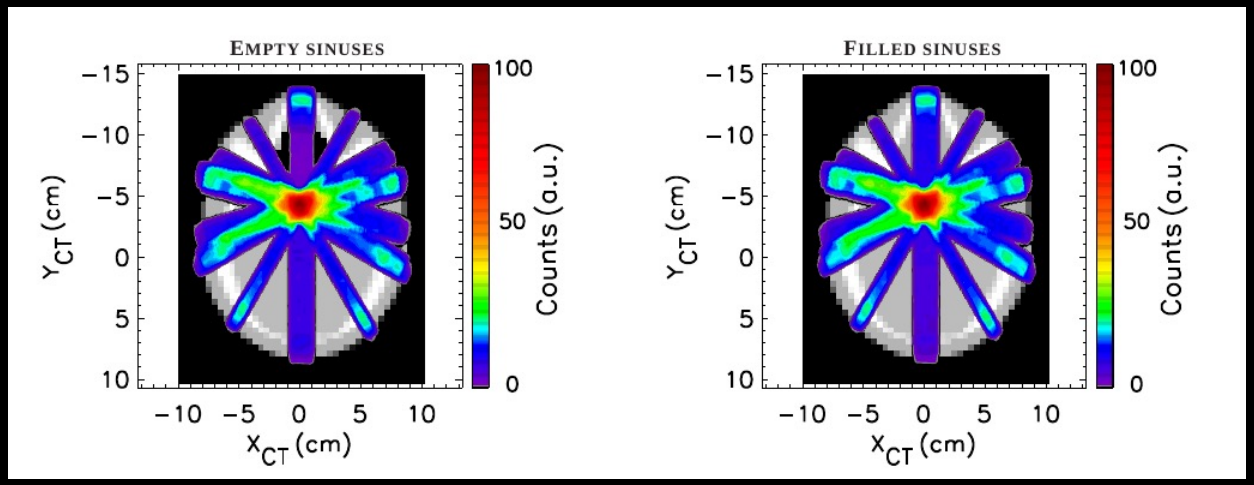
IMPACTO NA SOCIEDADE


Prototerapia
Computação na grid
Imagiologia médica
Radioterapia
Tomografia de muões (Pirâmide de Gizé)
Ciclo Solar
Exploração do espaço
World Wide Web



Tomografia de emissão de positrões (PET)

Terapia com feixes de protões



Exploração Espacial