

# Visita virtual ao maior laboratório de física de partículas do mundo\*

\* baseado nos slides de F. Briard

*Começaremos a visita dentro de momentos  
Durante a apresentação desliguem o microfone e câmara, sff  
Tenham sempre aberta a janela de “chat”*

P. Ferreira da Silva (CERN)

# Um guia para esta visita

**Vou guiar-vos pelo mundo do CERN durante cerca de 40 min.**

- **Perguntem** à vontade, quando quiserem: por isso é que aqui estou
- **Perguntem** usando a janela de “chat” ou usando o microfone
- **Perguntem** mais ainda depois da apresentação durante o tempo de discussão
- Não sei se já referi mas, não tenham vergonha e **perguntem** 😊



## **Depois desta apresentação**

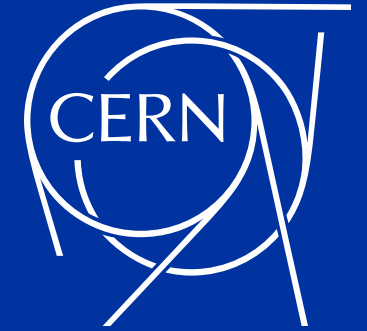
- Vão encontrar um questionário na página web que usaram para começar a vídeo-conferência
- Consultem os links que vos deixo e as páginas web do CERN
- E quem sabe... talvez nos encontremos pessoalmente no futuro quando vierem ao CERN

Como vim parar aqui?



# CERN: *O que é?*

# O que significa *CERN*?

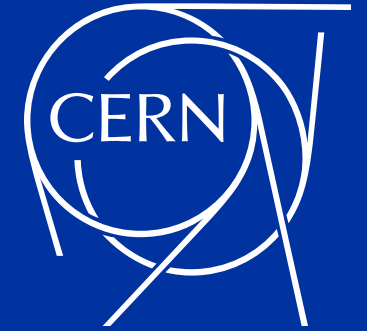


<b>C</b>	<b>C</b> onseil	<b>E</b> uropean
<b>E</b>	<b>E</b> uropéen pour la	<b>C</b> ouncil for
<b>R</b>	<b>R</b> echerche	<b>N</b> uclear
<b>N</b>	<b>N</b> ucléaire	<b>R</b> esearch



**1952** – o conselho é formado após uma proposta inicial de vários físicos europeus

# O que significa *CERN*?



<b>C</b>	<b>C</b> onseil	<b>E</b> uropean
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**1952** – o conselho é formado após uma proposta inicial de vários físicos europeus

**1954** – o conselho passa a laboratório, fundado por 12 países europeus



**Construção do CERN em Meyrin, perto da fronteira entre a Suíça e a França**

# Nuclear?



Laboratório europeu de física de partículas



# CERN: *Quem?*

# Estados membros

Orçamento (2020)

1,1 mil milhões EUR



-  Austria (1959)
-  Belgium (1953)
-  Bulgaria (1999)
-  Czech Republic (1993)
-  Denmark (1953)
-  Finland (1991)
-  France (1953)
-  Germany (1953)
-  Greece (1953)
-  Hungary (1992)
-  Israel (2014)
-  Italy (1953)
-  Netherlands (1953)
-  Norway (1953)
-  Poland (1991)
-  Portugal (1986)
-  Romania (2016)
-  Serbia (2019)
-  Slovakia (1993)
-  Spain (1961-1968, 1983-)

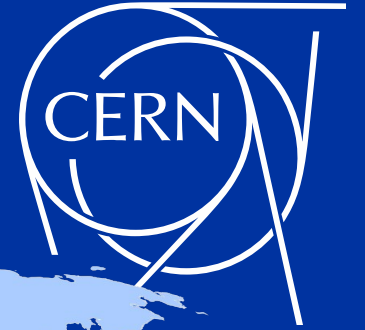
-  Sweden (1953)
-  Switzerland (1953)
-  United Kingdom (1953)

## Associated

-  Croatia (2019)
-  Cyprus (2016)
-  India (2017)
-  Lithuania (2018)
-  Pakistan (2015)
-  Slovenia (2017)
-  Turkey (2015)
-  Ukraine (2016)



# Uma colaboração à escala mundial



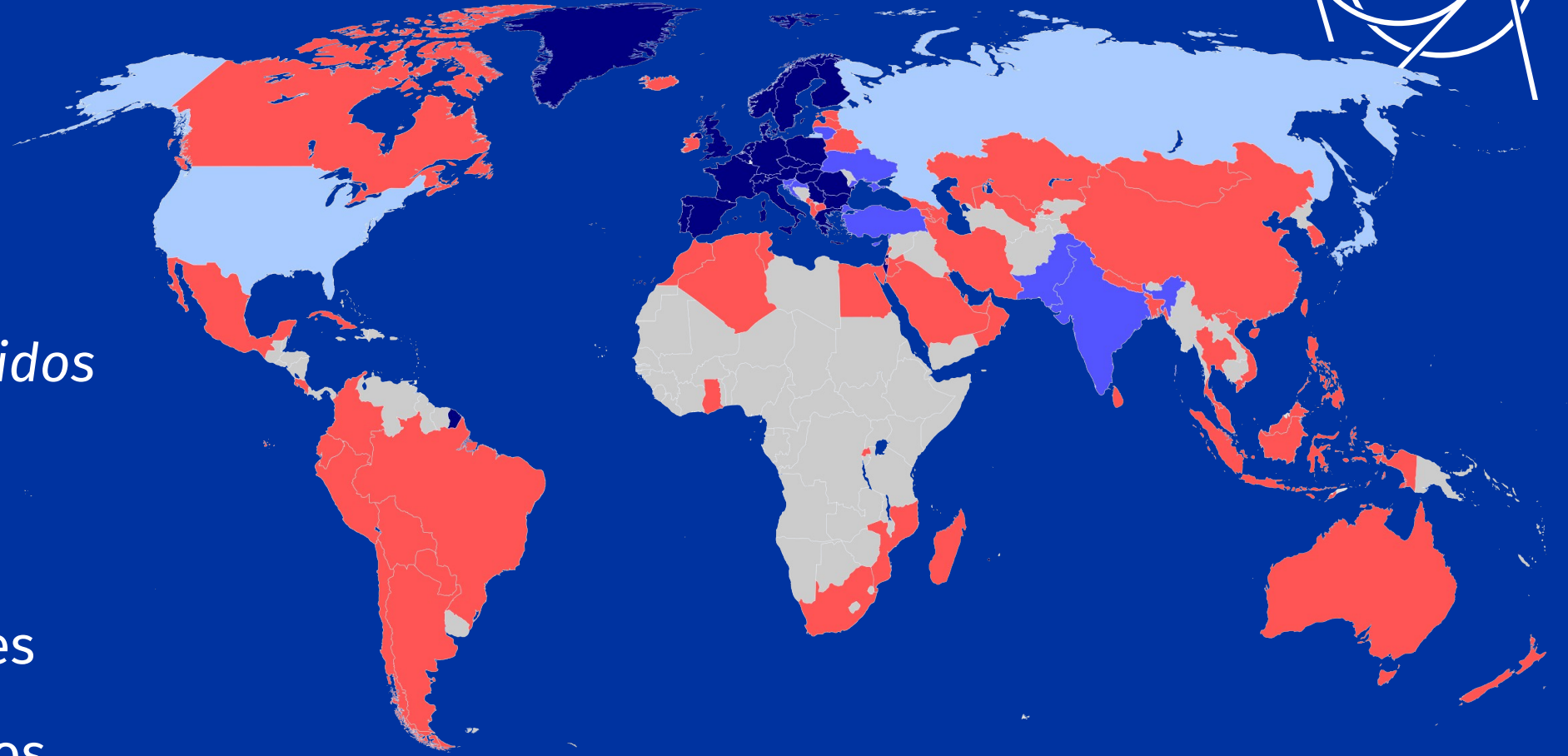
## *Países envolvidos*

23 membros

8 associados

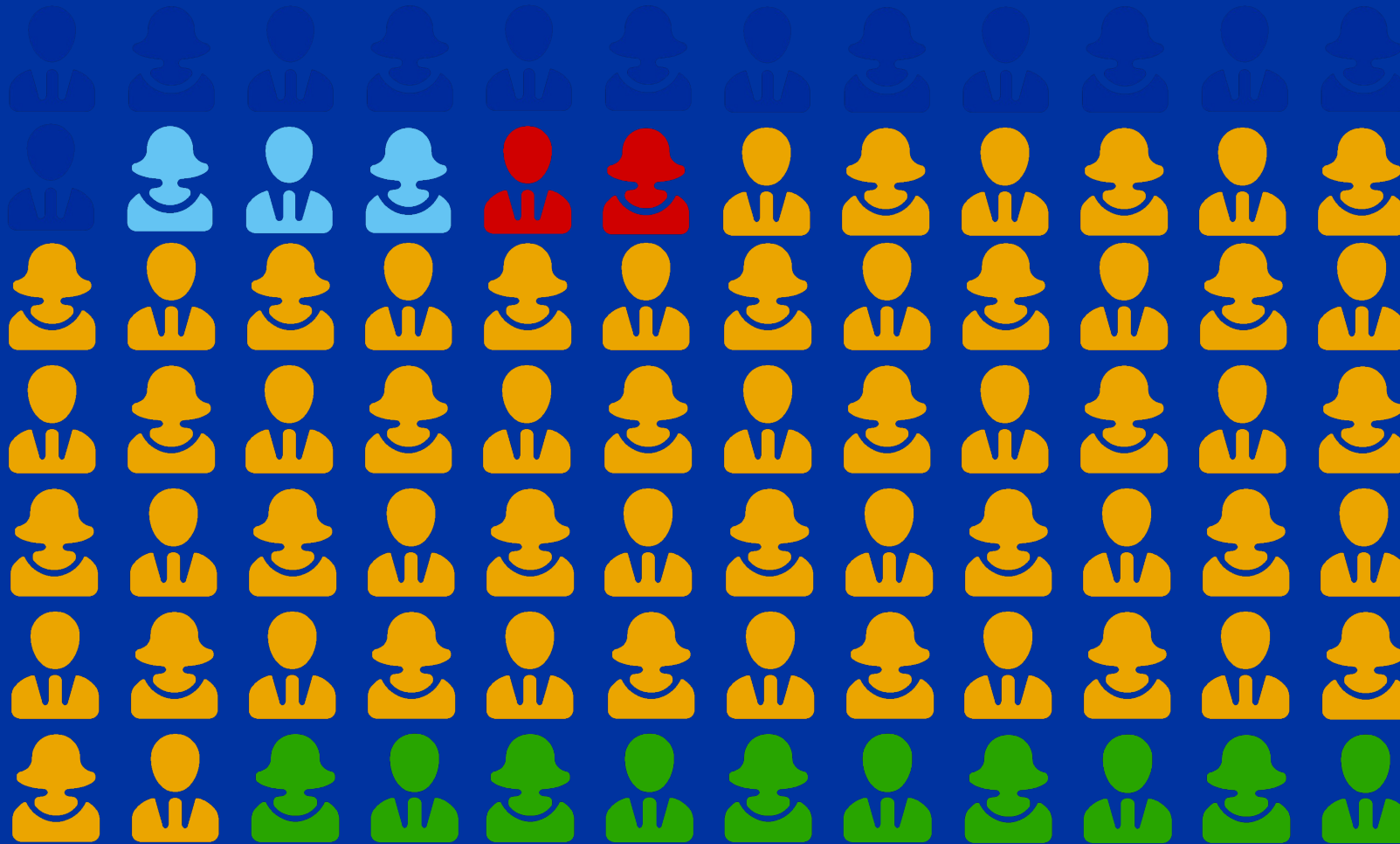
3 observadores

61 com acordos



# Quantas pessoas?

20 000!



2 600 funcionários

800 bolsеiros/  
aprendizes

550 estudantes

15 000 utilizadores

2 000 companhias  
externas

# **CERN:** *O que se faz?*

The background of the slide features a dark blue, almost black, space filled with numerous bright blue and cyan particle tracks. These tracks are curved and appear to be part of a larger, circular structure, possibly representing the Large Hadron Collider. The tracks are composed of many small, bright points, giving them a grainy, energetic appearance. The overall effect is one of high-tech scientific exploration.

## Levantar questões fundamentais



Levantar questões fundamentais  
**Contextualizar o problema**



Levantar questões fundamentais

Contextualizar o problema

**Sugerir uma hipótese**





Levantar questões fundamentais

Contextualizar o problema

Sugerir uma hipótese

**Experimentar a natureza**



Levantar questões fundamentais

Contextualizar o problema

Sugerir uma hipótese

Experimentar a natureza

**Analisar resultados das experiências**



Levantar questões fundamentais  
Contextualizar o problema  
Sugerir uma hipótese  
Experimentar a natureza  
Analisar resultados das experiências  
**Concluir**



Levantar questões fundamentais  
Contextualizar o problema  
Sugerir uma hipótese  
Experimentar a natureza  
Analisar resultados das experiência  
Concluir  
**Recomeçar tudo de novo :)**

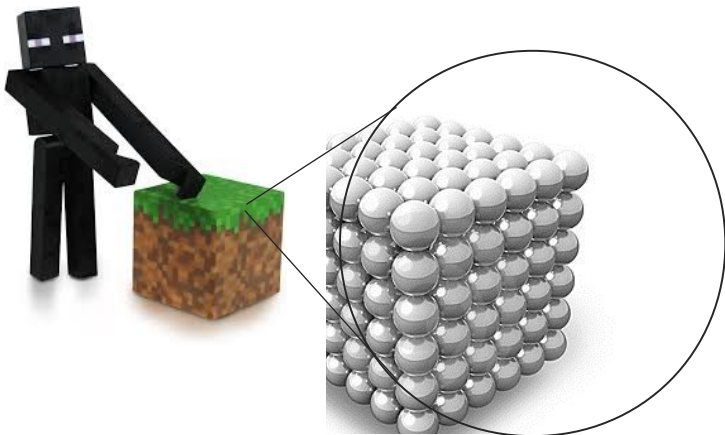


# O que constitui a matéria?



1 m

# O que constitui a matéria?



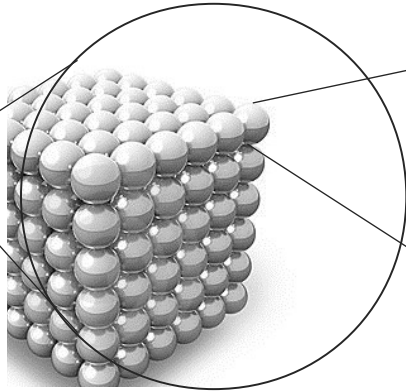
átomo

Séculos  
IV – V a.C.

1 m

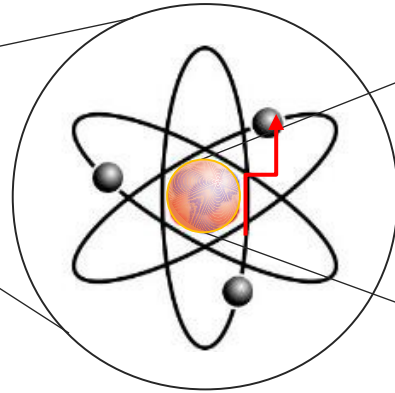
$10^{-10}$  m  
(Å)

# O que constitui a matéria?



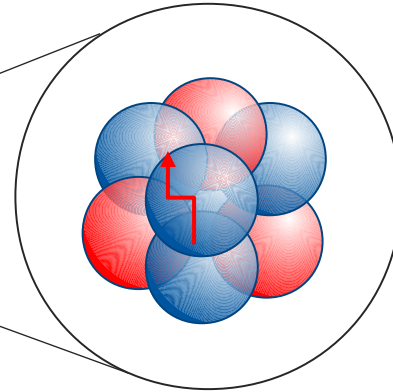
átomo

Séculos  
IV – V a.C.



electrão

Fim do  
séc. XIX



núcleo

protão

neutrão

Início do  
séc. XX

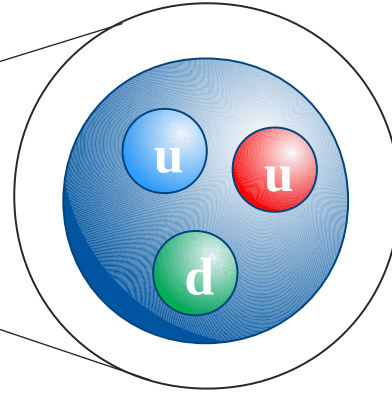
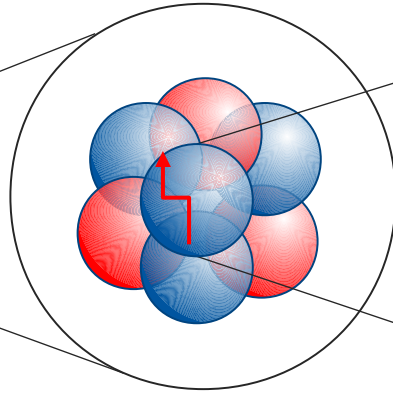
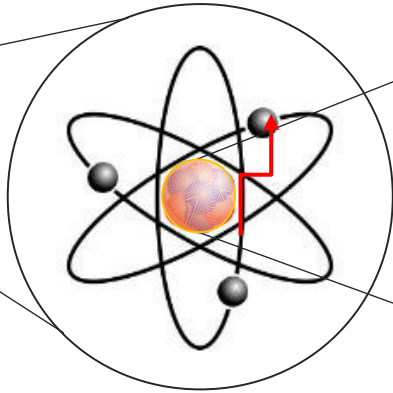
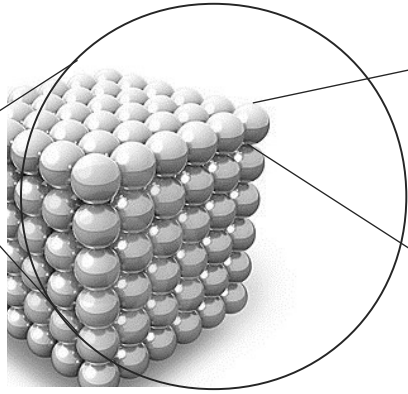
1 m

$10^{-10}$  m  
(Å)

$10^{-14}$  m  
(10 fm)

$10^{-15}$  m  
(1 fm)

# O que constitui a matéria?



átomo

electrão

núcleo

protão

neutrão

quark

Séculos  
IV – V a.C.

Fim do  
séc. XIX

Início do  
séc. XX

1960s

1 m

$10^{-10}$  m  
(Å)

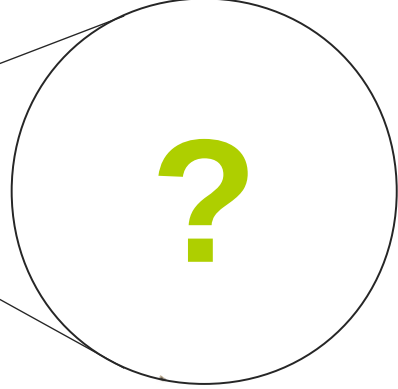
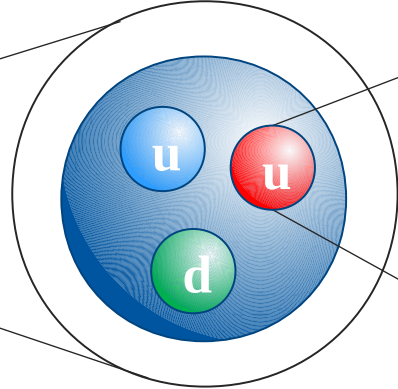
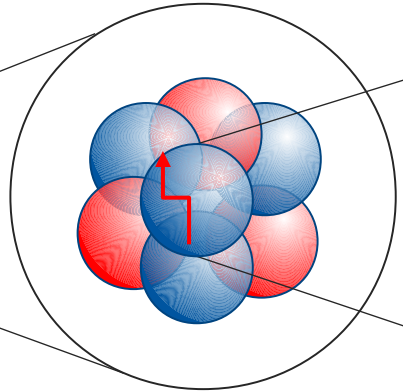
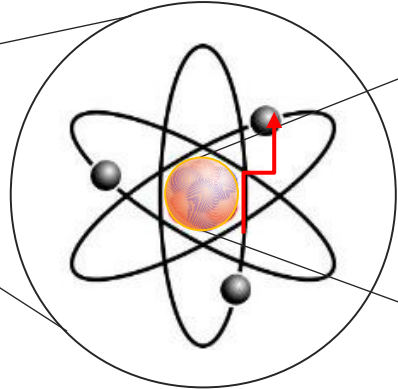
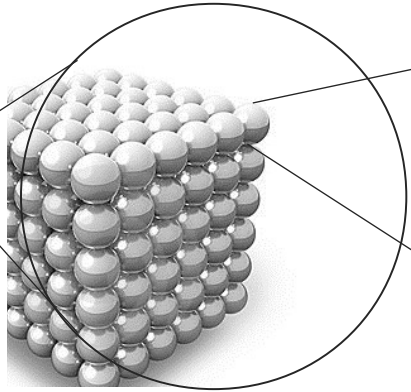
$10^{-14}$  m  
(10 fm)

$10^{-15}$  m  
(1 fm)

$10^{-16}$  m  
(0.1 fm)



# O que constitui a matéria?



átomo

electrão

núcleo

protão

neutrão

quark



Séculos  
IV – V a.C.

Fim do  
séc. XIX

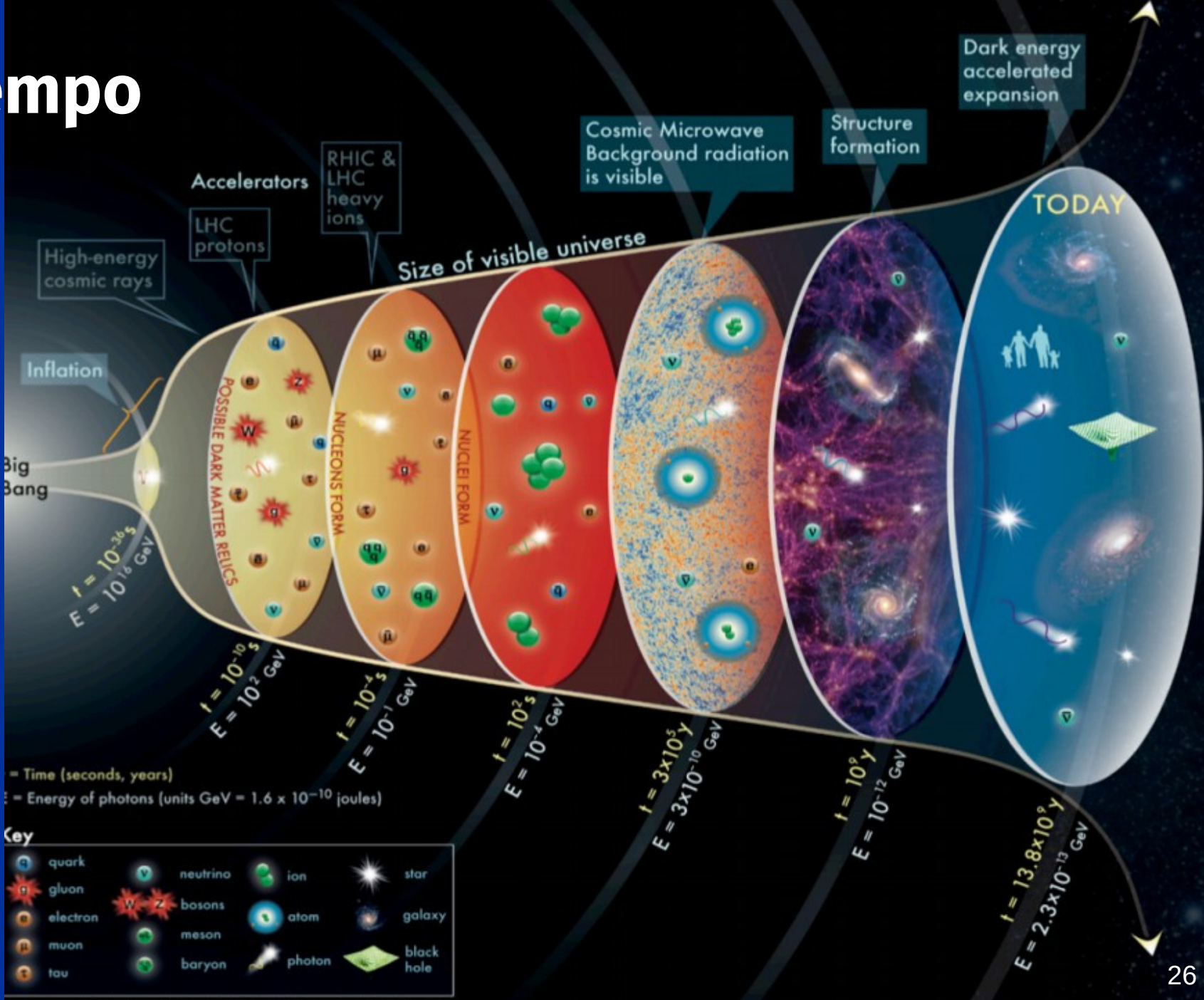
Início do  
séc. XX

1960s

2020



# Uma viagem no tempo



The concept for the above figure originated in a 1986 paper by Michael Turner.

# Testando as teorias

$$-dx^2 - dy^2 - dz^2$$

$\left( \frac{m}{\sqrt{1-u^2}}, \frac{m u_i}{\sqrt{1-u^2}} \right)$	$\frac{m u_i}{\sqrt{1-u^2}} \text{ Impuls}$
$\left( m + \frac{1}{2} m u^2, m u_i \right)$	$m \left( \frac{1}{\sqrt{1-u^2}} - 1 \right) \text{ Kin Energy}$

$$t' = \frac{t + v x}{\sqrt{1-v^2}} \quad \left| \quad x = \frac{x' + v t'}{\sqrt{1-v^2}} \quad y = y' \quad z = z' \right.$$

$$\sum \frac{1}{\sqrt{1-u^2}} = \frac{2}{\sqrt{1-u^2} \sqrt{1-v^2}}$$

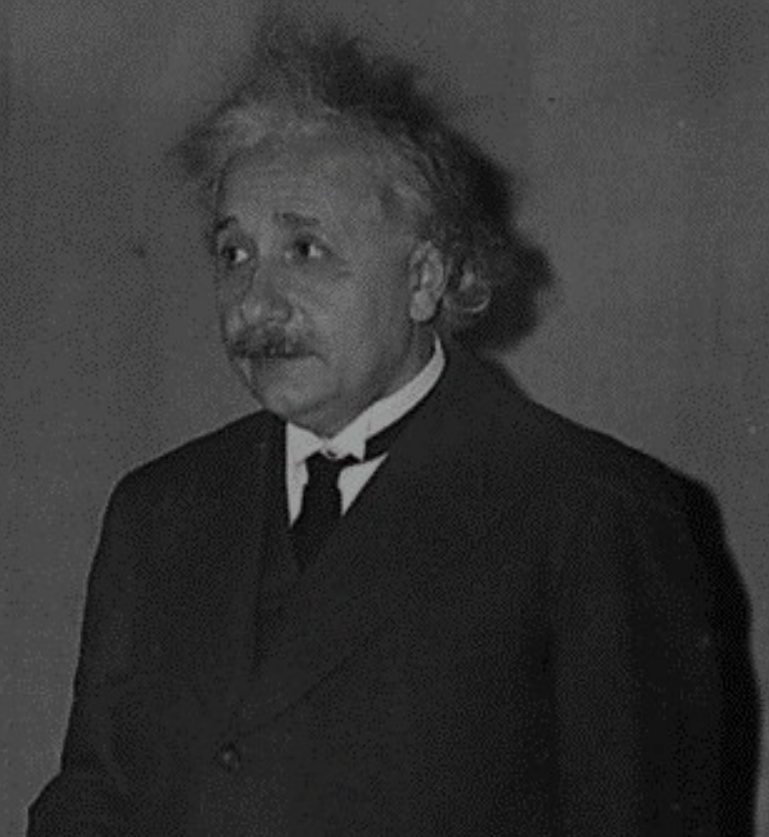
$$\sum \frac{u_i}{\sqrt{1-u^2}} = \frac{2v}{\sqrt{1-u^2} \sqrt{1-v^2}}$$

$$\text{Hyp. } \sum \vec{J}_v = \sum \vec{J}_v \text{ (cons)}$$

$$\sum \mathcal{E} = \sum \mathcal{E} \text{ (cons)}$$

$$\vec{J}_v = m \vec{u}_v \sqrt{1-u^2}$$

$$\mathcal{E} = \mathcal{E}_0 + m \mathcal{E}_f(u)$$















# O modelo padrão



# O modelo padrão

*Matéria ordinária*

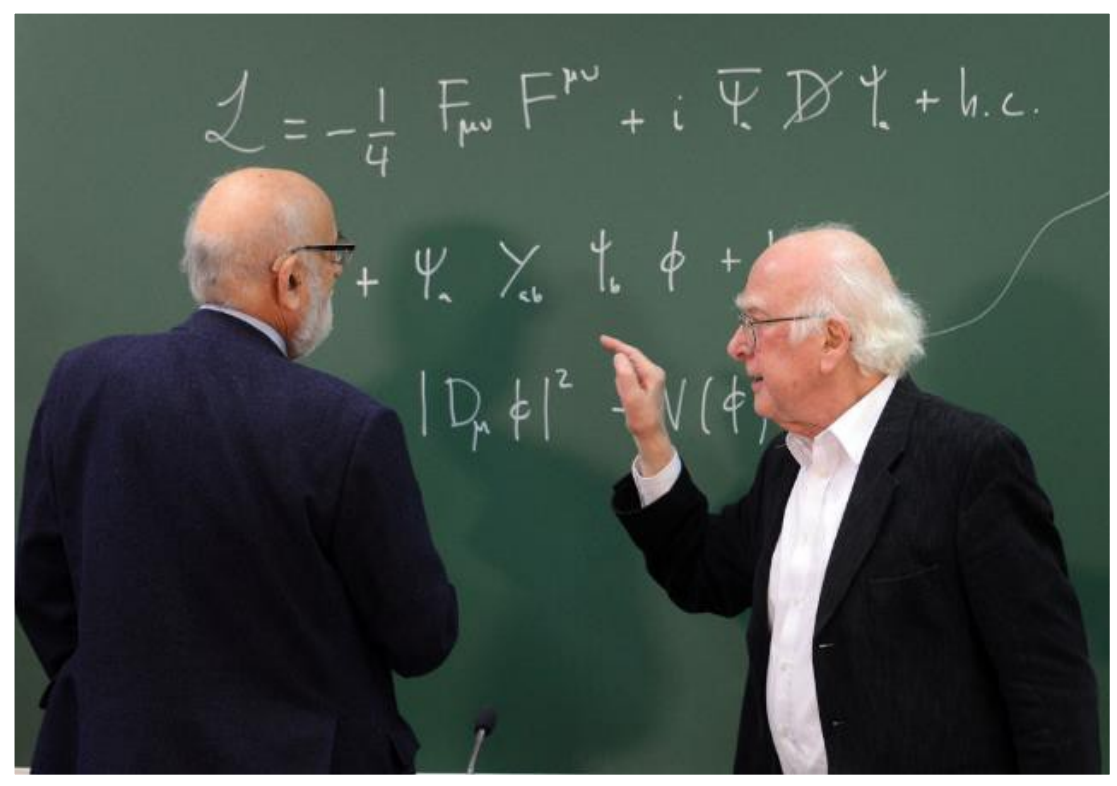
	LEPTONS				QUARKS			
<i>Matéria ordinária</i>	ELECTRON		ELECTRON NEUTRINO		UP		DOWN	
	MUON		MUON NEUTRINO		CHARM		STRANGE	
	TAU		TAU NEUTRINO		TOP		BOTTOM	



*4 forças*

 <p>GLUONS</p> <p><i>Strong force</i></p>	 <p>PHOTONS</p> <p><i>Electromagnetic force</i></p>	 <p>WEAK BOSONS</p> <p><i>Weak force</i></p>	 <p>GRAVITONS</p> <p><i>Gravity</i></p>
--	--	---	--

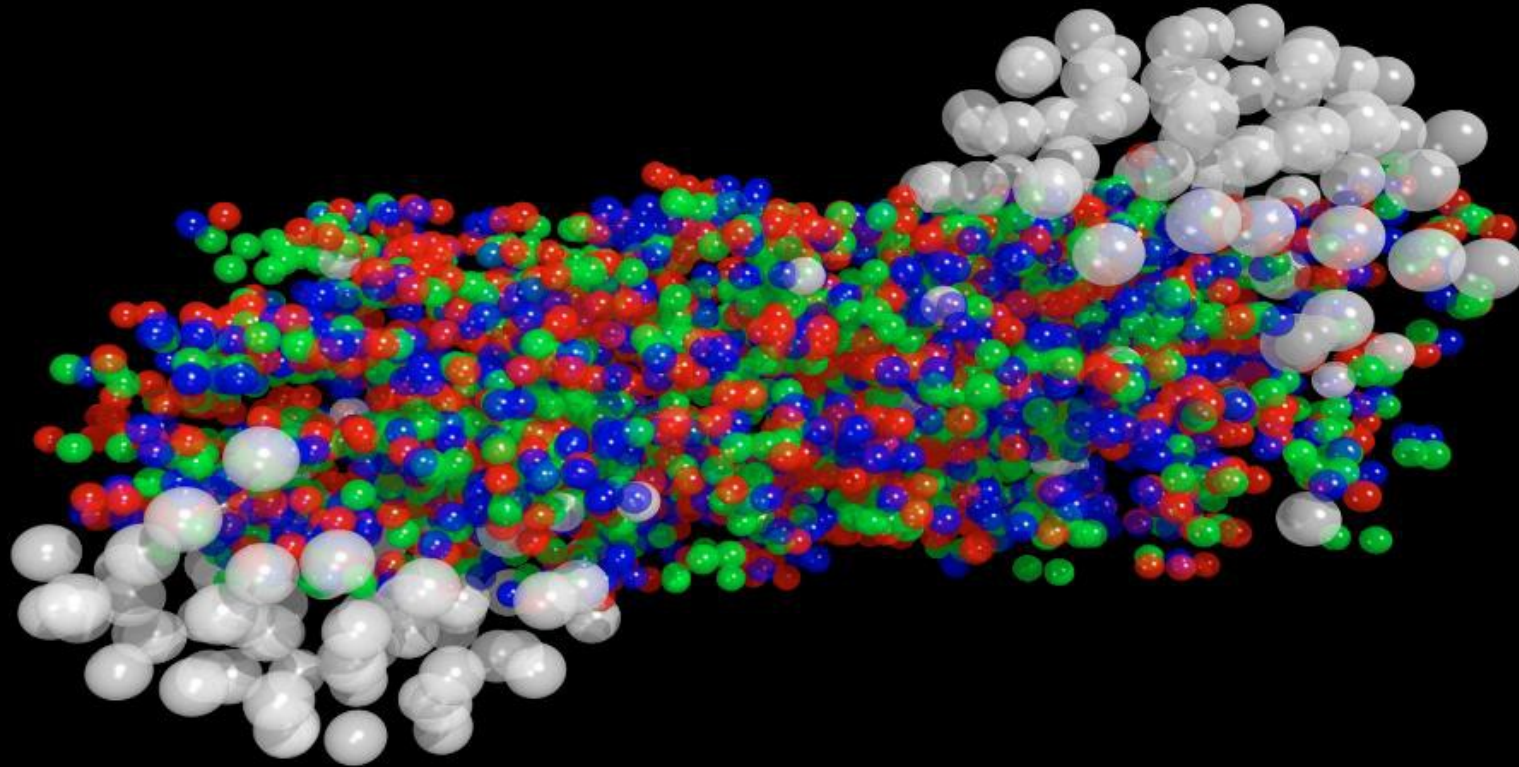
# Respondendo a questões fundamentais



Higgs

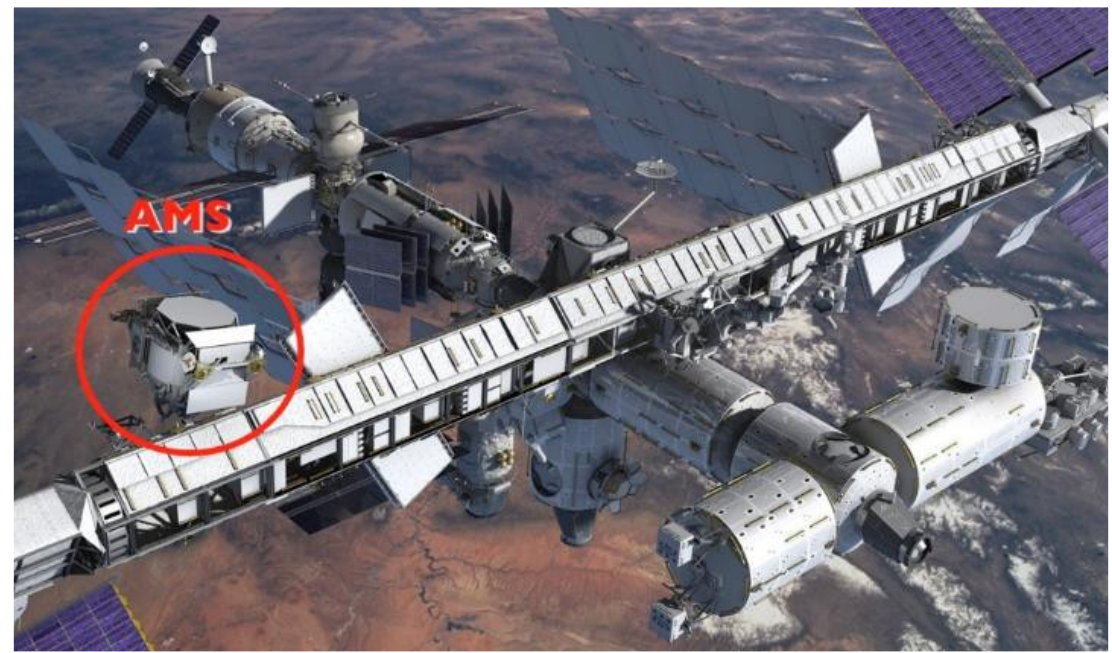
*O que estabiliza o Universo?*

# Respondendo a questões fundamentais



*Como se comporta a matéria a pressão/temperatura extremas?*

# Respondendo a questões fundamentais



*Onde está a anti-matéria ?*



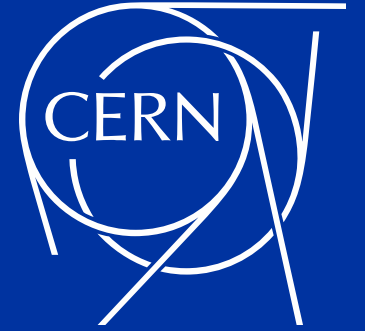
# Respondendo a questões fundamentais

*O que é a matéria escura?*

# CERN: Como funciona?

The background of the slide features a complex pattern of glowing blue and cyan particle tracks, resembling a particle detector's output. The tracks are dense and form a circular or spiral-like structure, with many small, bright points scattered throughout, suggesting a high-energy collision event.

# Acelerando e colidindo



$-\frac{\hbar^2}{2m} \frac{d^2\psi}{dx^2} + V\psi = E\psi$      $\Phi_e = \frac{L}{2\pi} \int \frac{1}{\lambda} = \frac{\lambda_1}{\lambda_2} = \frac{\lambda_2}{\lambda_1} \lambda_2$      $\Psi = NBS$   
 $U_{ef} = U_m$      $E = \hbar\omega$      $\Delta t = \frac{\Delta t'}{\sqrt{1-\frac{v^2}{c^2}}}$      $4\pi r^2$      $X_L = \frac{U_m}{I_m} = \omega L = 2\pi f L$      $F_g = \frac{\mu_1 \mu_2}{r^2}$   
 $\vec{B} = \mu_0 \frac{NI\sqrt{2}}{l}$      $v = \frac{nh}{2\pi r m_e}$      $\Phi_E = \frac{E_e}{\rho_0} = k \frac{Q}{r^2} \Phi$      $T = \frac{4n_1 n_2}{(n_2 + n_1)^2}$      $R_m = \frac{C}{T} k = \pm \sqrt{\frac{2m}{\hbar^2} (E - V_0)}$   
 $K = \rho^2 / 2m$      $m_0 = \frac{M_m}{N_A} = \frac{M_r \cdot 10^{-3}}{N_A}$      $m = N \cdot m_0 = \frac{Q}{v_e} \frac{M_m}{N_A}$      $E = \frac{E_c}{a} \int_{-a/L}^{+a/L} \sin(\omega t + \phi) dy$   
 $\lambda = \frac{h}{\sqrt{2eU m_e}}$      $R = \rho \frac{l}{S}$      $E = mc^2$      $\omega = 2\pi f$   
 $f_0 = \frac{1}{2\pi} \sqrt{\frac{g}{l}}$      $\psi(x) = \sqrt{2/L} \sin \frac{n\pi x}{L}$      $\beta = \frac{\Delta I_c}{\Delta I_B}$      $\phi_e = \frac{\Delta E}{\Delta t} \frac{\omega_1}{x} + \frac{\omega_2}{x'} = \frac{\omega_2 - \omega_1}{r}$   
 $\oint \vec{B} \cdot d\vec{l} = \mu_0 \iint_S \vec{J} \cdot d\vec{S}$      $\vec{S} = \frac{1}{\mu_0} (\vec{E} \times \vec{B})$      $\oint \vec{J} \cdot d\vec{S} = Q^*$   
 $v_k = \sqrt{\frac{3kT}{m_0}} = \sqrt{\frac{3kT N_A}{M_m}} = \sqrt{\frac{3R_m T}{M_r \cdot 10^{-3}}}$      $E = \hbar k^2 \cdot 1 \text{ pc} = \frac{1 \text{ AU}}{c}$      $R = \frac{U}{I}$      $\omega_2 = \omega_e I t$

$-\frac{\hbar^2}{2m} \frac{d^2\psi}{dx^2} + V\psi = E\psi$   
 $\Phi_e = \frac{L}{2\pi} \int \frac{1}{\lambda} = \frac{\lambda_1}{\lambda} = \frac{\lambda_2}{\lambda} S_2$   
 $U_{ef} = \frac{U_m}{E = \hbar\omega}$   
 $\vec{B} = \mu \frac{NI\sqrt{2}}{l}$   
 $k = \frac{p^2}{2m} m_0 = \frac{M_m}{N_A} = \frac{M_r \cdot 10^{-3}}{N_A}$   
 $\lambda = \frac{h}{\sqrt{2eUme}}$   
 $f_0 = \frac{1}{2\pi} \sqrt{\frac{g}{l}}$   
 $\oint \vec{B} d\vec{l} = \mu \iint_S \vec{J} d\vec{S}$   
 $v_k = \sqrt{\frac{3kT}{m_0}} = \sqrt{\frac{3kTN_A}{M_m}} = \sqrt{\frac{3R_m T}{M_r \cdot 10^{-3}}}$   
 $\Delta t = \frac{\Delta t'}{\sqrt{1 - \frac{v^2}{c^2}}}$   
 $U = \frac{W_{AB}}{|E_{PA} - E_{PB}|} = |\varphi_A - \varphi_B|$   
 $\varphi_E = \frac{F_e}{\rho_0} = k \frac{Q}{r^2} \varphi$   
 $m = N \cdot m_0 = \frac{Q}{v_e} \frac{M_m}{N_A}$   
 $E = \frac{E_c}{a} \int_{-a/L}^{+a/L} \sin(\omega t + \phi) dy$   
 $I = \frac{U_e}{R + R_i}$   
 $\frac{\sin \alpha}{\sin \beta} = \frac{v_1}{v_2} = \frac{m_2}{m_1}$   
 $\phi_e = \frac{\Delta E}{\Delta t}$   
 $\oint \vec{D} d\vec{S} = Q^*$   
 $X_L = \frac{U_m}{I_m} = \omega L = 2\pi f L$   
 $T = \frac{4n_1 n_2}{(n_2 + n_1)^2}$   
 $R_m = \frac{C}{T}$   
 $k = \pm \sqrt{\frac{2m}{\hbar^2} (E - V_0)}$   
 $\omega = 2\pi f$   
 $\beta = \frac{\Delta I_c}{\Delta I_B}$   
 $E_k = \frac{\hbar^2}{8mL^2} \hbar^2$   
 $\vec{S} = \frac{1}{\mu_0} (\vec{E} \times \vec{B})$   
 $E = \hbar k^2 \cdot 1 \text{ pc} = \frac{1 \text{ AU}}{c}$

# E = mc<sup>2</sup>

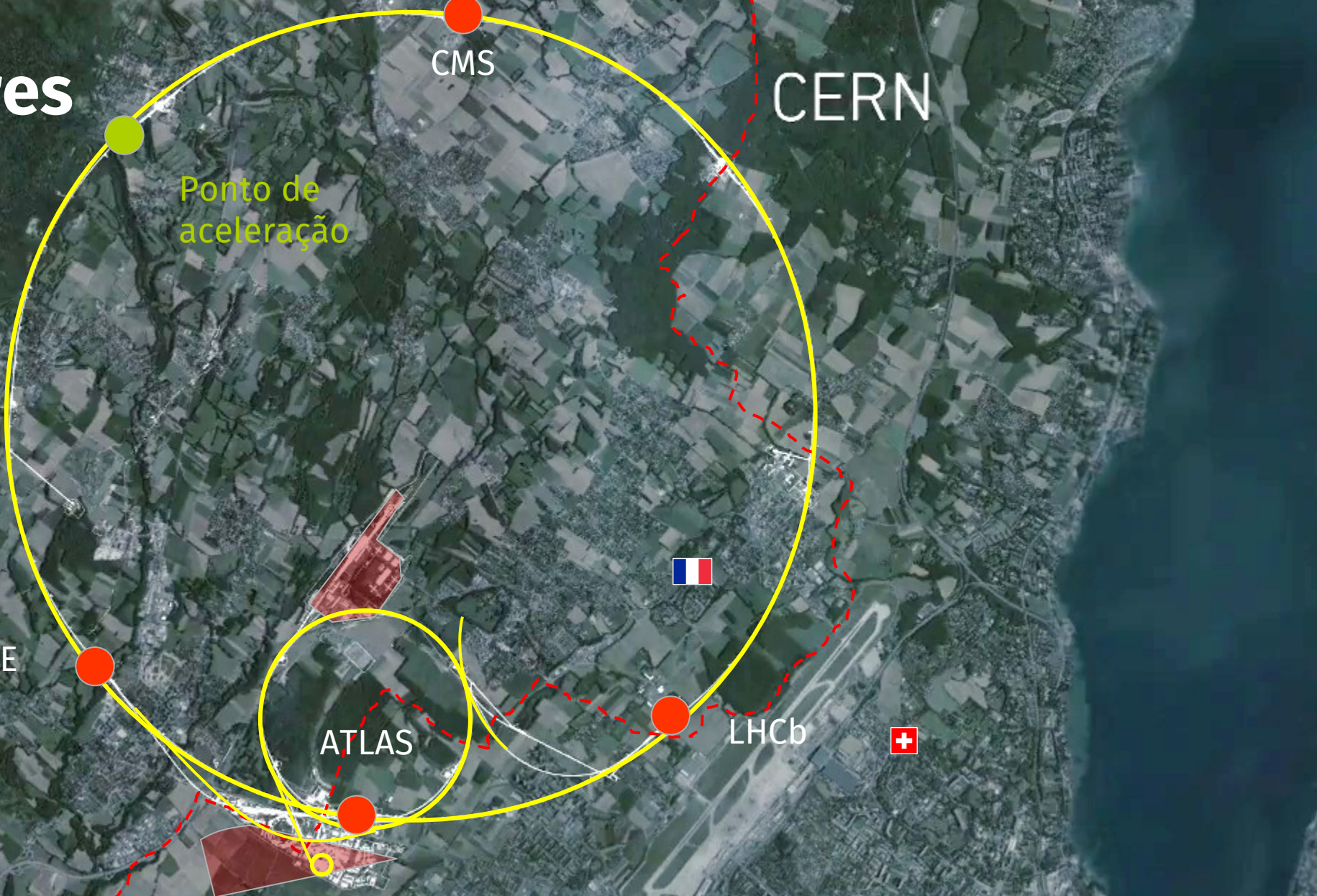
# A níveis de energia extraordinários

# 7 TeV



A energia equivalente a  
100'000'000'000'000'000'000'000 protões  
condensados num só

# Uma das maiores máquinas do mundo





# Os magnetes mais intensos

Dipólos de 15 metros, 8 Tesla  
Curvam partículas e núcleos  
a 99.999991% da velocidade da luz

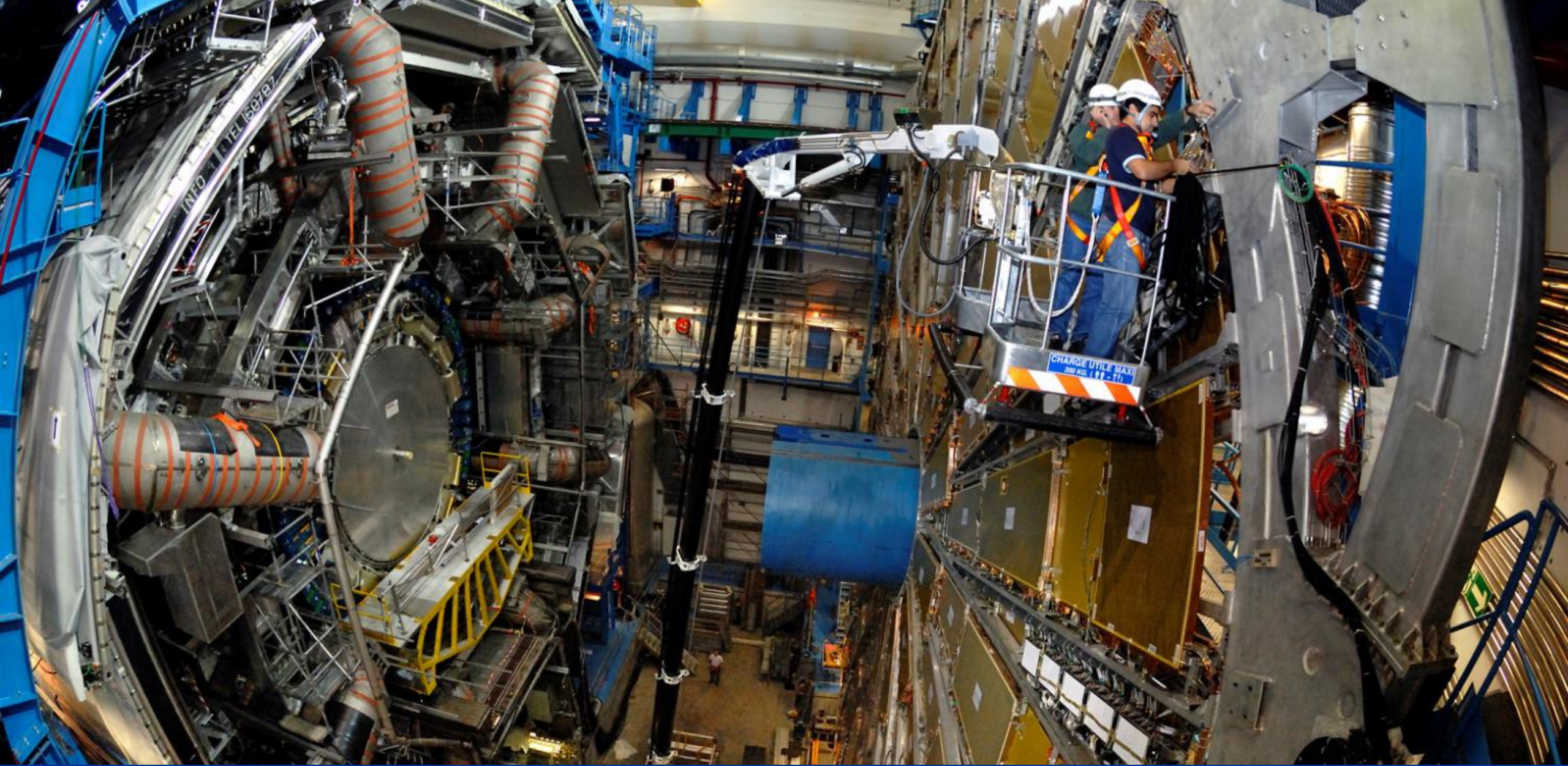




**Tão vazio quanto o espaço interestelar**  
 $10^{-10}$  –  $10^{-11}$  mbar

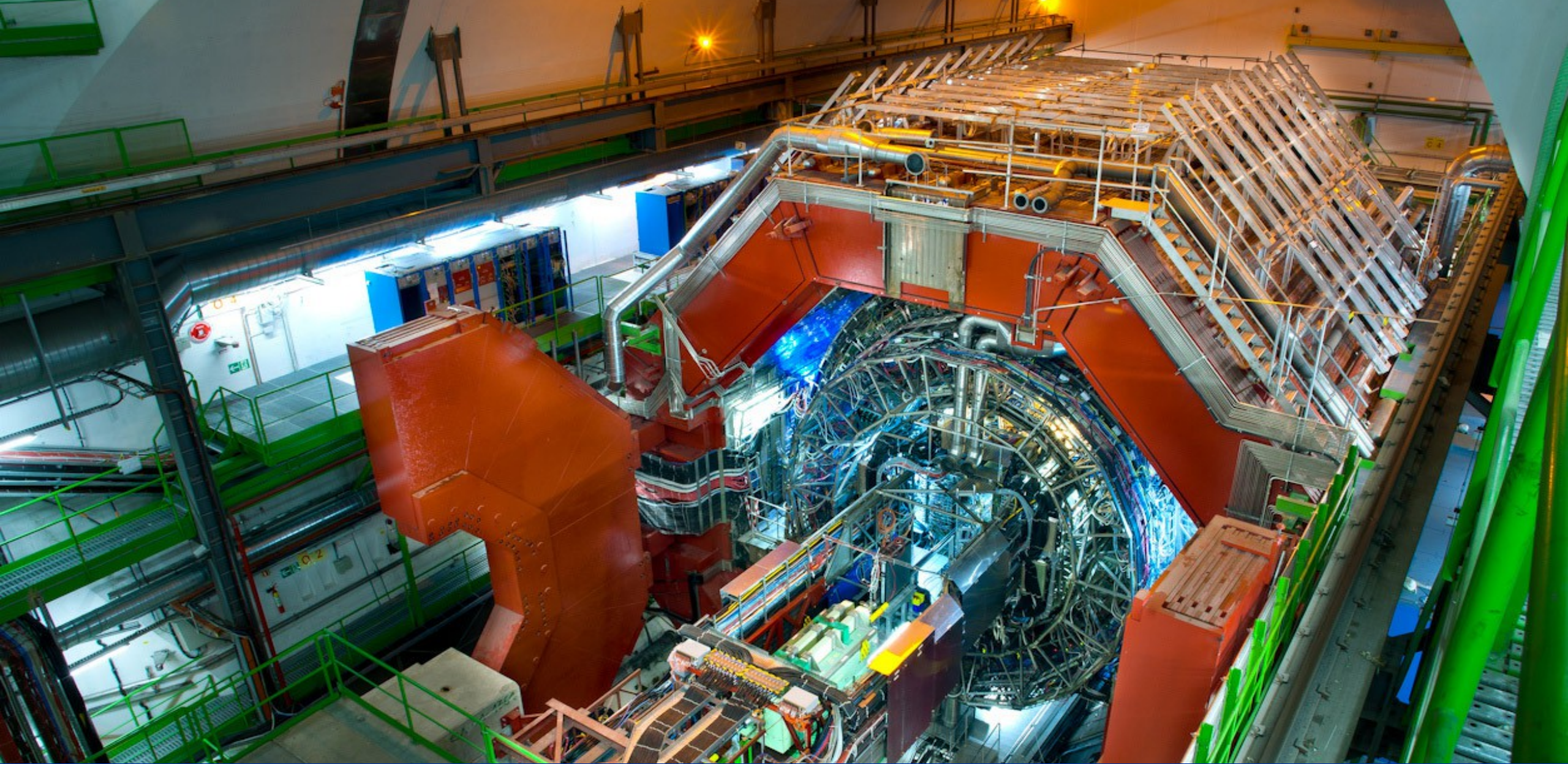


**Mais frio que o espaço interestelar**  
**-271,3° C = 1.9 K**



**ATLAS**



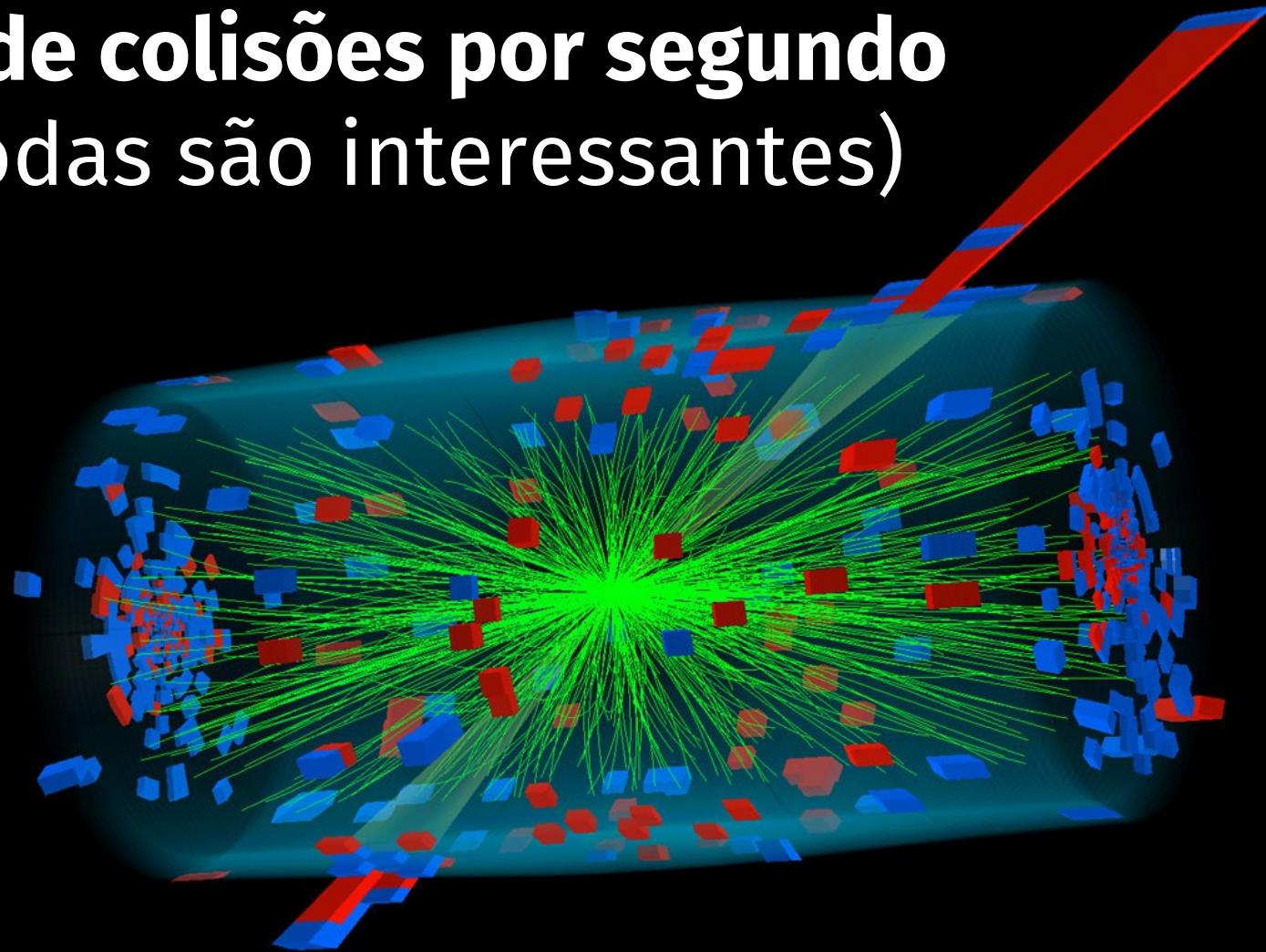


**ALICE**

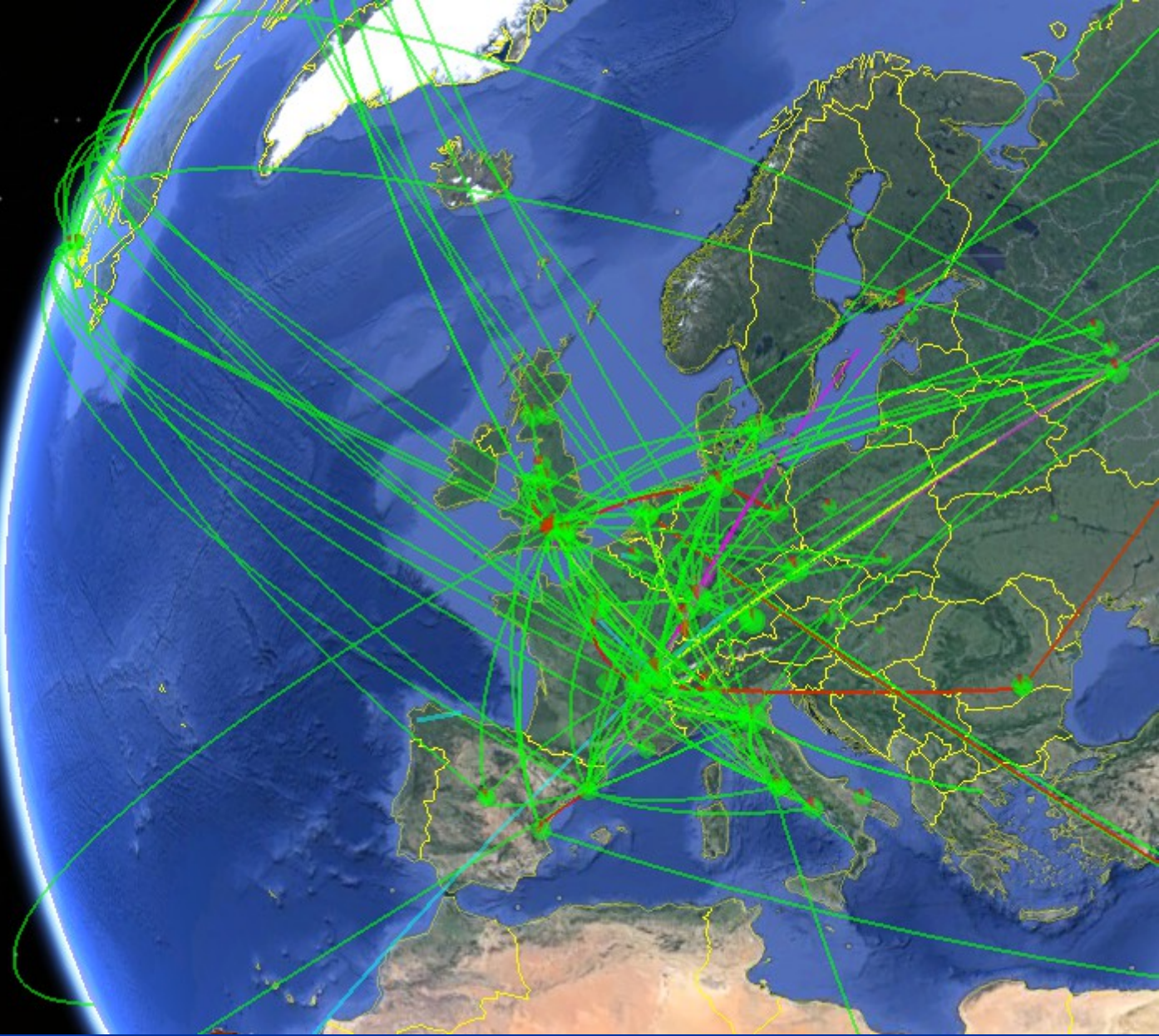


LHCb

**40 milhões de colisões por segundo**  
(mas nem todas são interessantes)



# Rede de computação à escala mundial



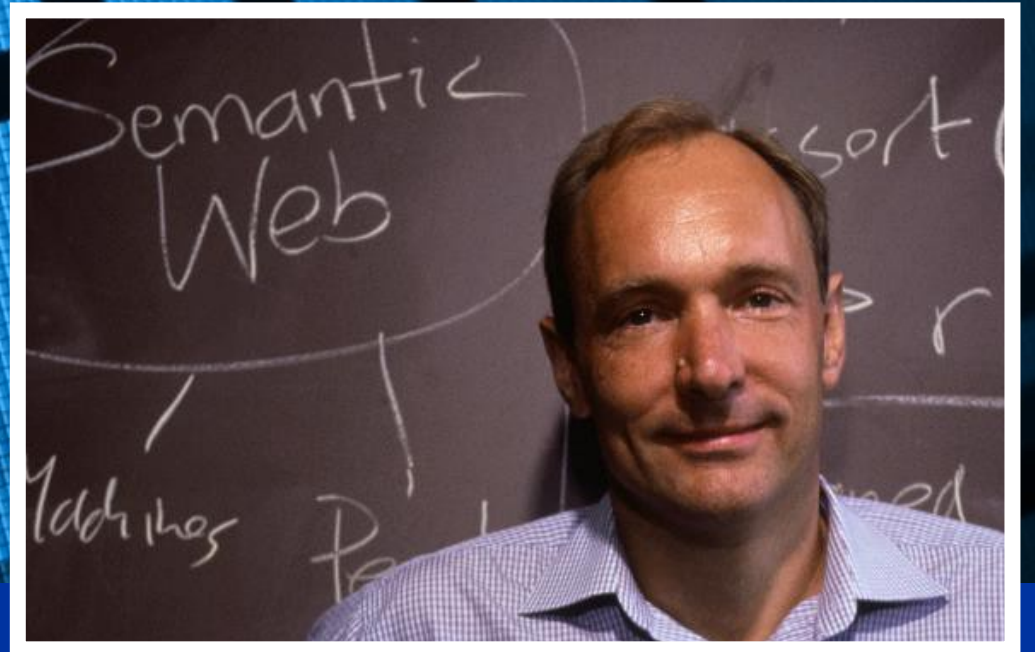


The background of the slide features a complex pattern of glowing blue and cyan particle tracks, resembling a particle detector's output. These tracks are composed of numerous small, bright points and thin lines, forming a dense, circular structure that suggests a high-energy collision event. The overall aesthetic is scientific and futuristic.

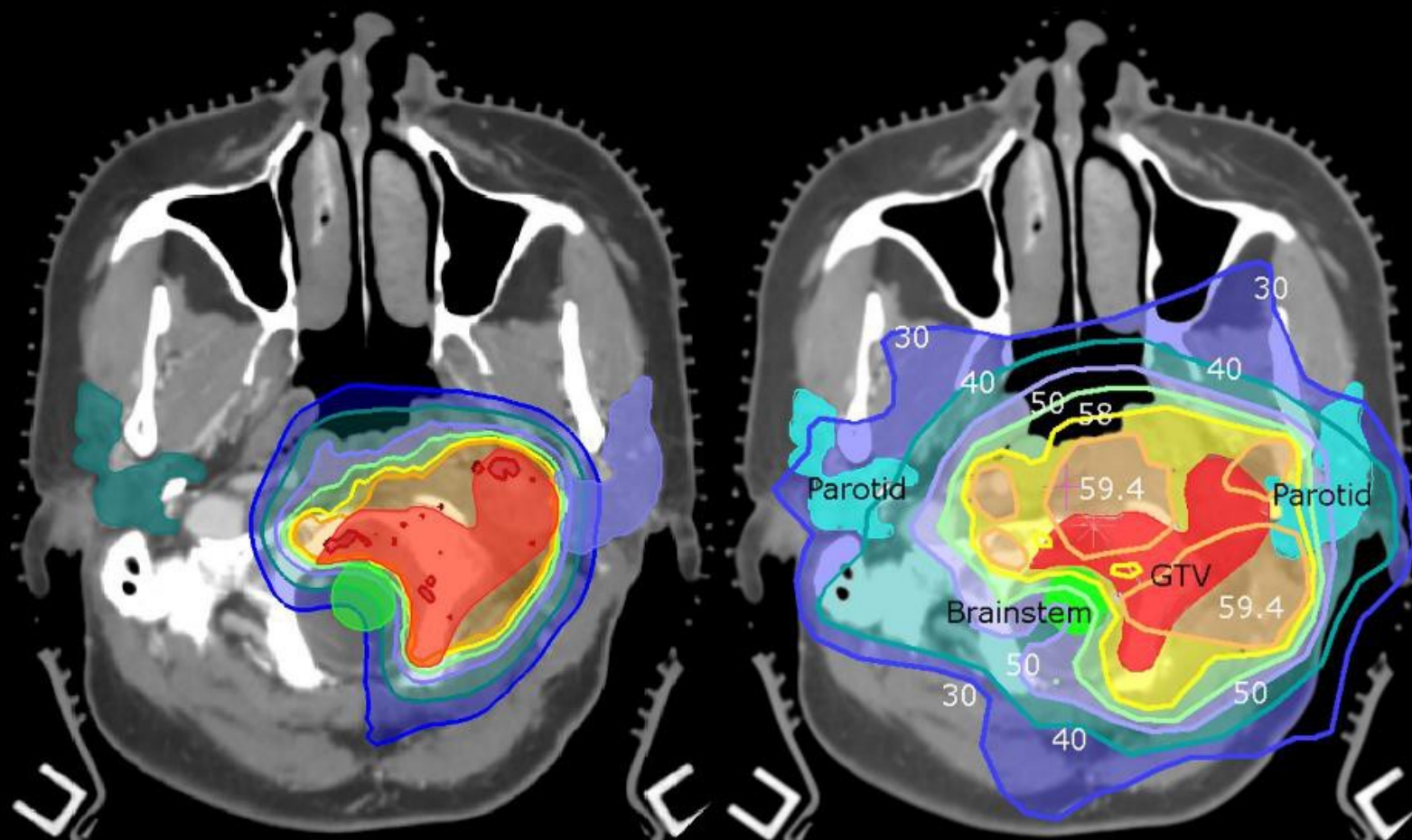
# CERN: OK, e então?

# World Wide Web

HTTP



# Aplicações médicas

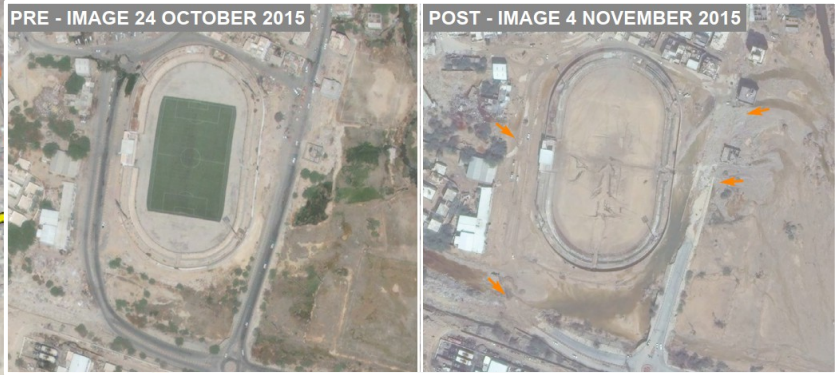


See inset for close-up view of affected roads around the Baradim Stadium in Mukalla City

Possible landslide caused by floods

PRE - IMAGE 24 OCTOBER 2015

POST - IMAGE 4 NOVEMBER 2015

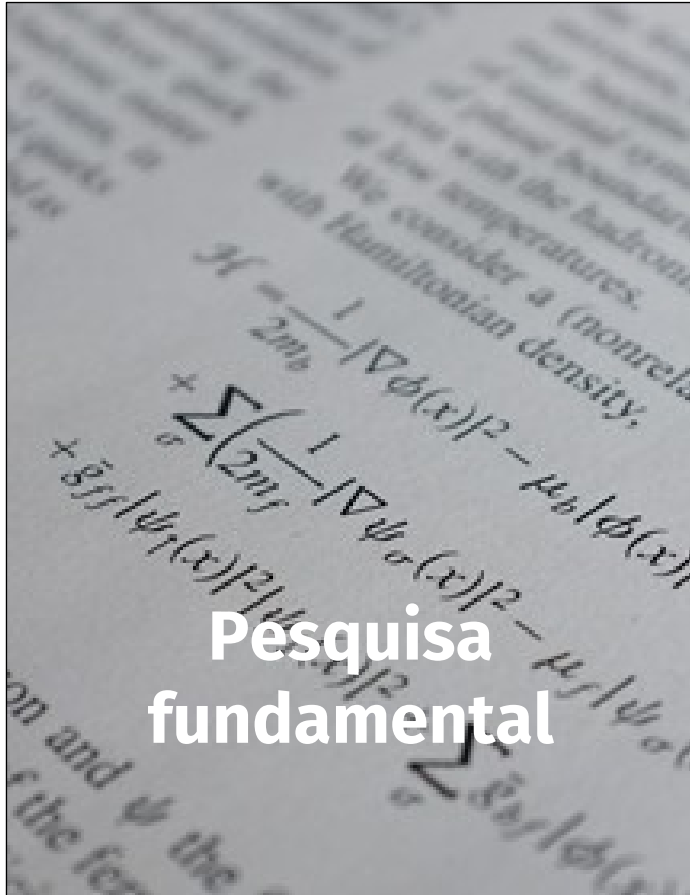


HADRAMAUT

ALMUKALLA

Missões  
humanitárias

# Em resumo...



# Obrigado pela vossa atenção!

Se ficaram curiosos:

[home.cern](http://home.cern)

[visit.cern](http://visit.cern)

[careers.cern](http://careers.cern)

... ou então escrevam-me: [psilva@cern.ch](mailto:psilva@cern.ch)

