

COMO VER PARTÍCULAS INVISÍVEIS!

Masterclasses Internacionais de Física de Partículas
Universidade de Coimbra – 25 de março de 2023

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Universidade de Coimbra / LIP

A UTILIDADE DA FÍSICA ☺













Parece que desta foi...

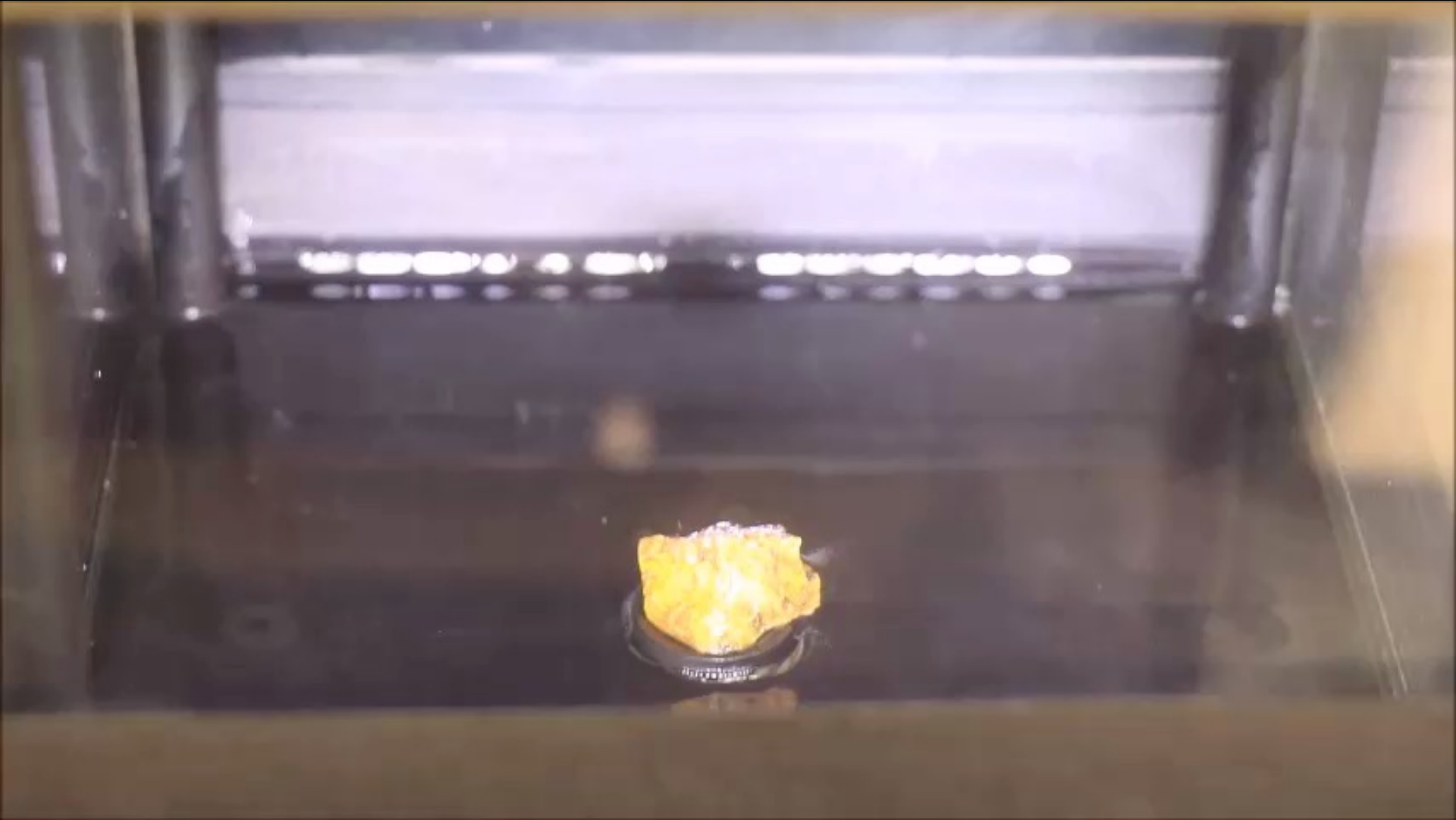
$$a P > A p$$

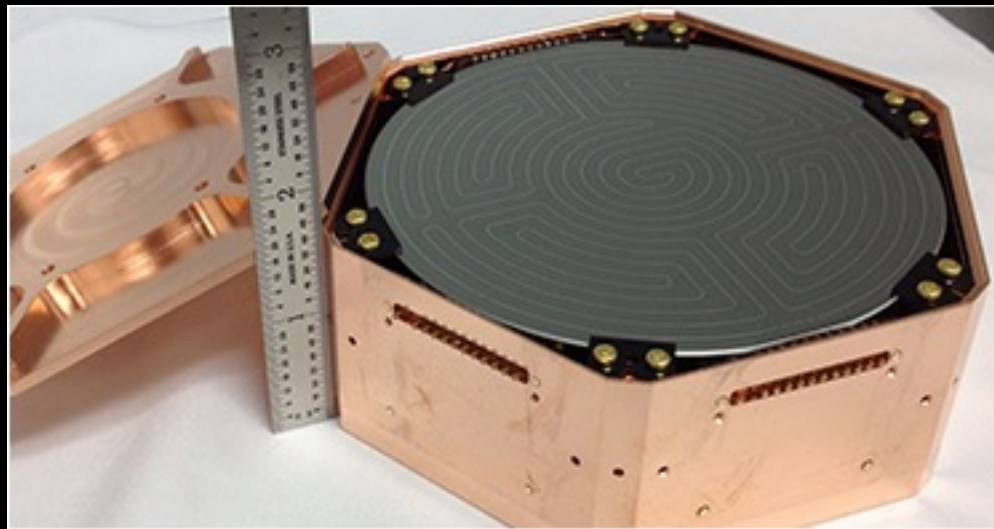
Moral da história: A Física tem um papel crucial no dia-a-dia!



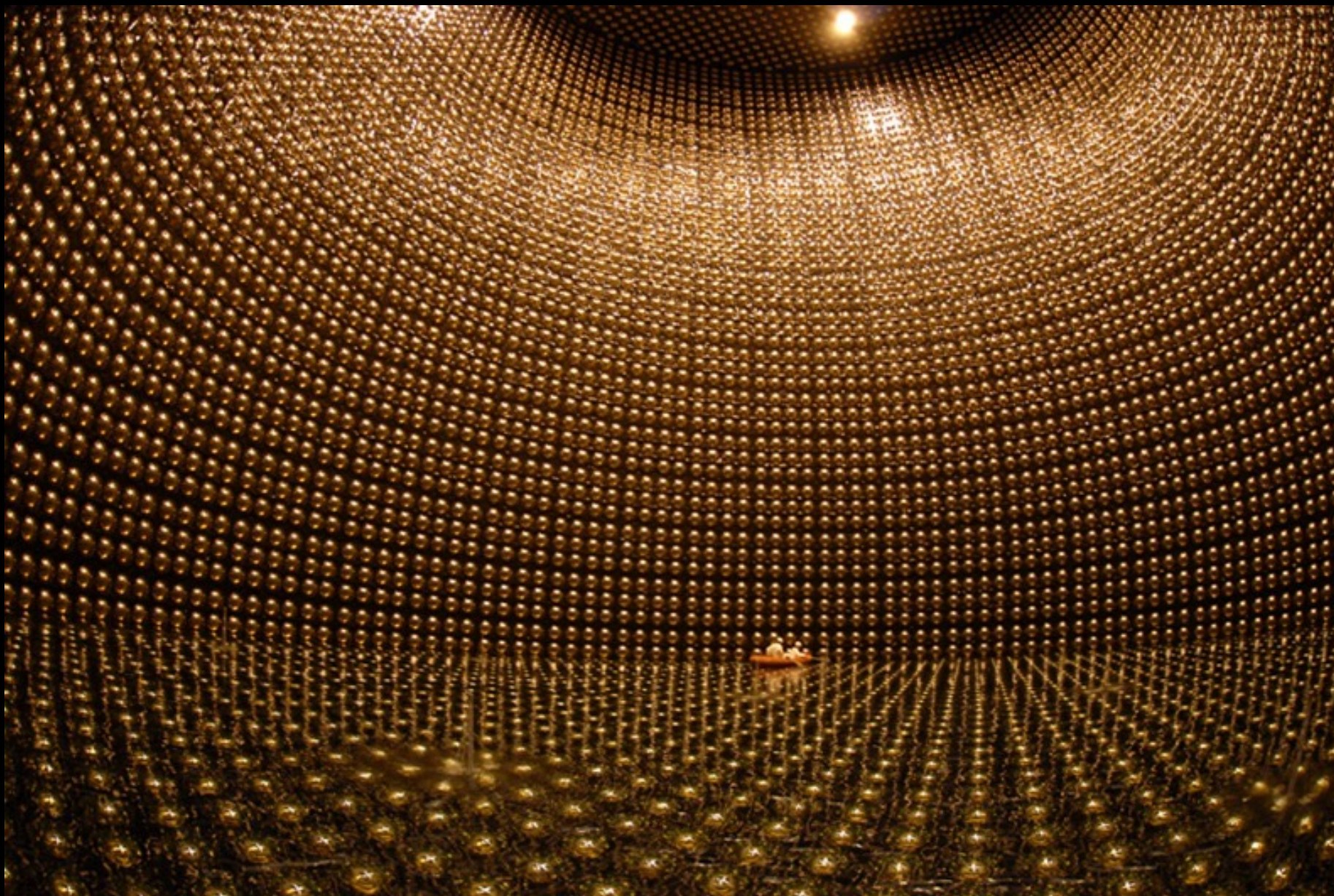
COMO VER PARTÍCULAS INVISÍVEIS

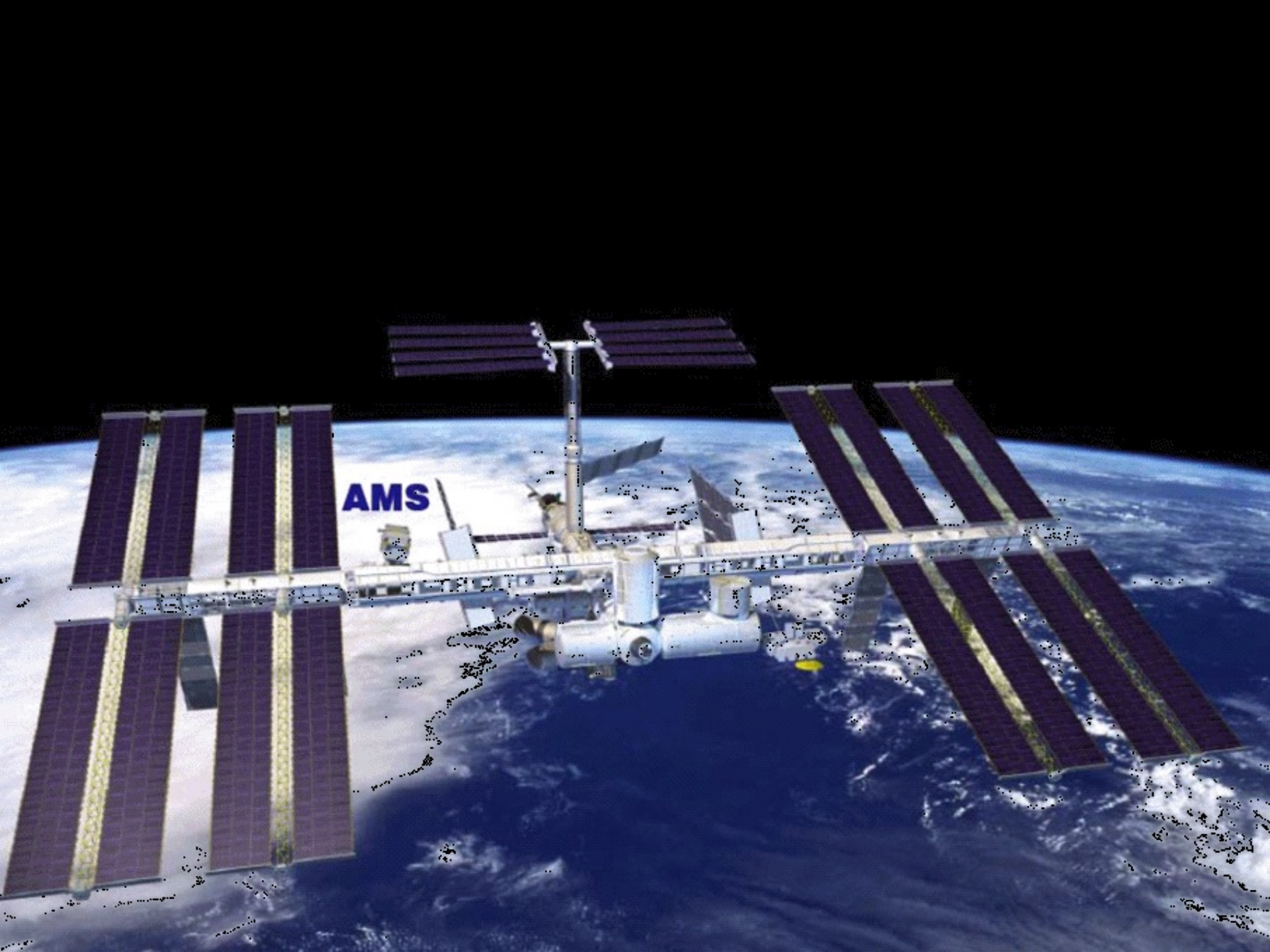




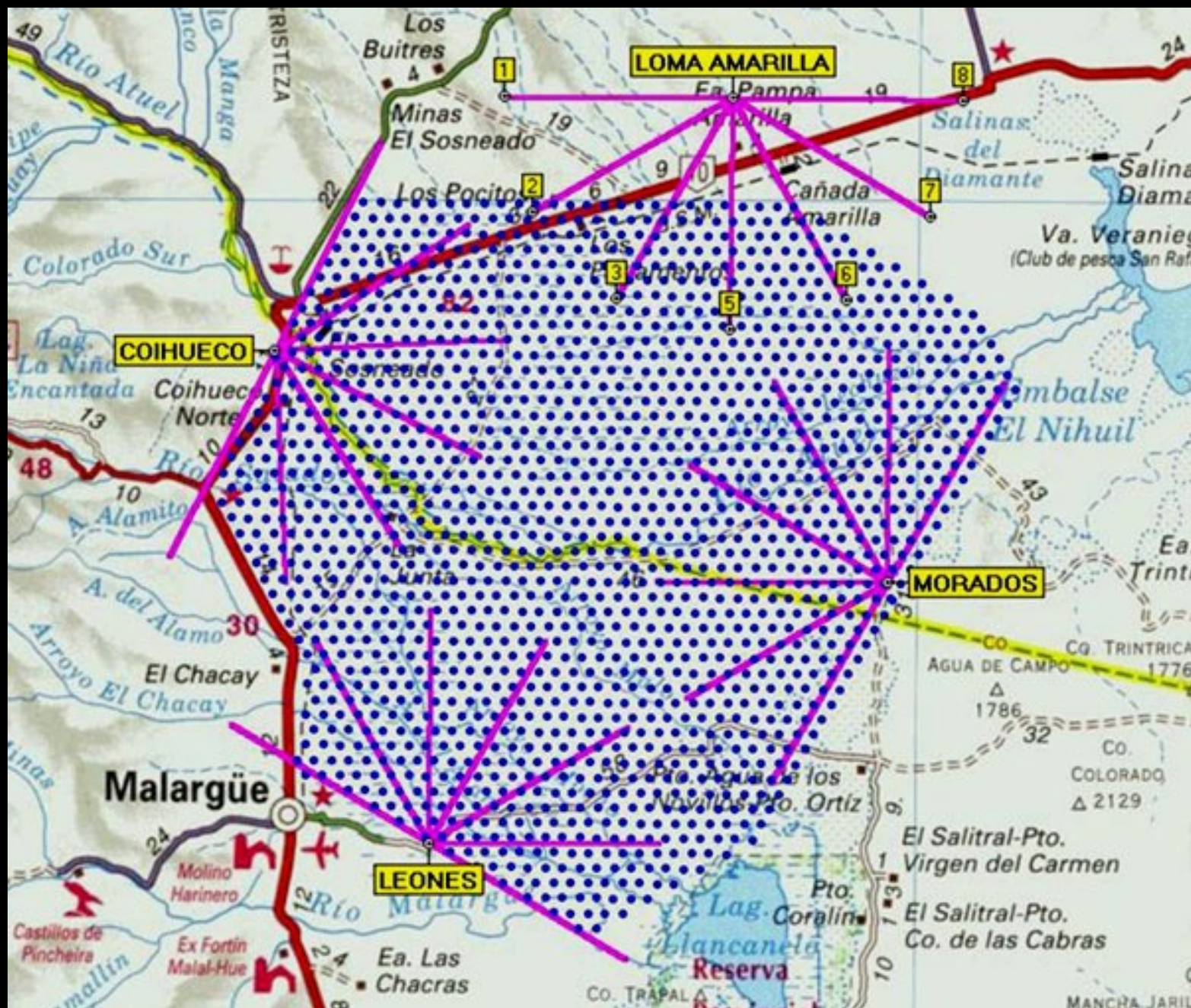


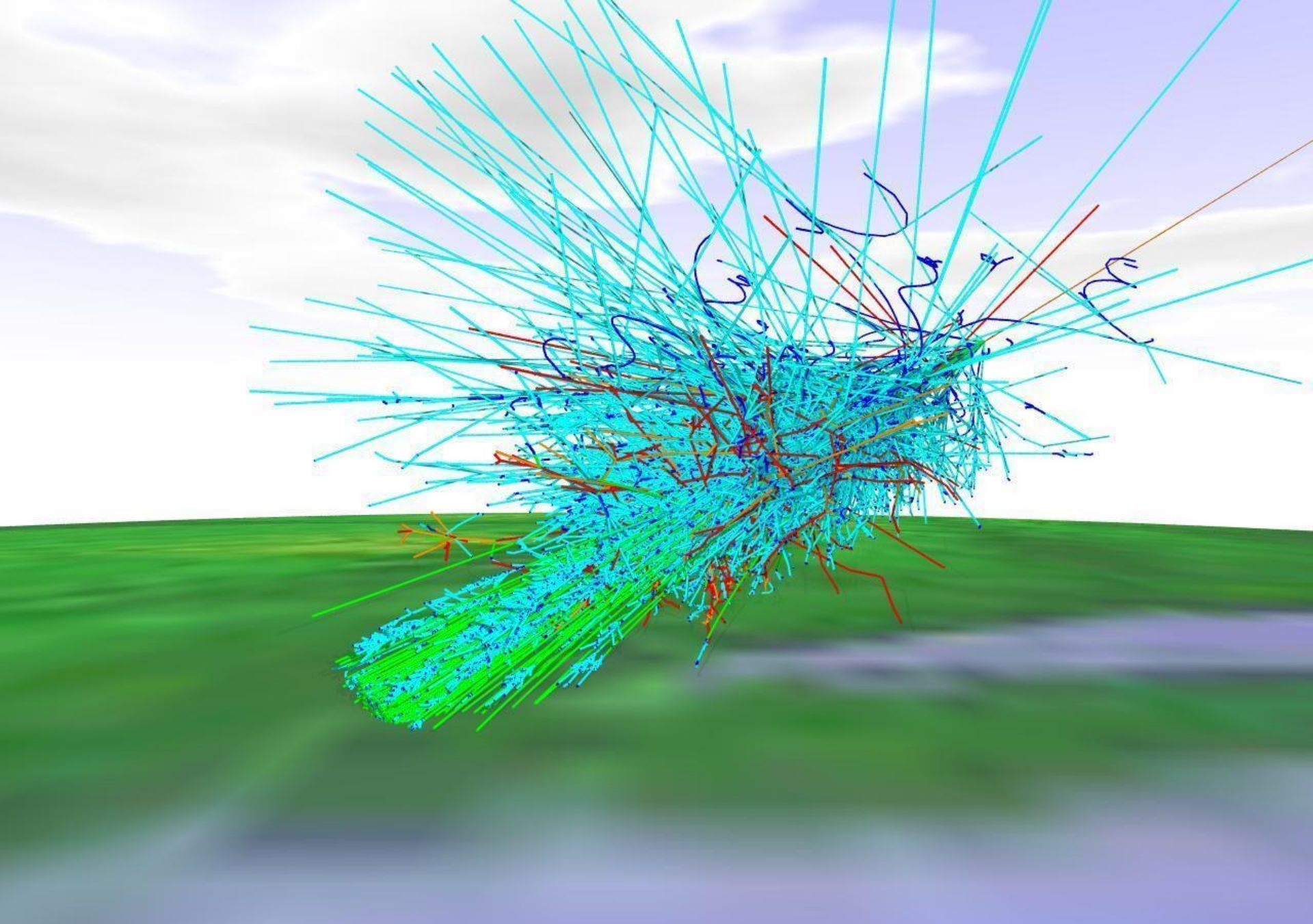






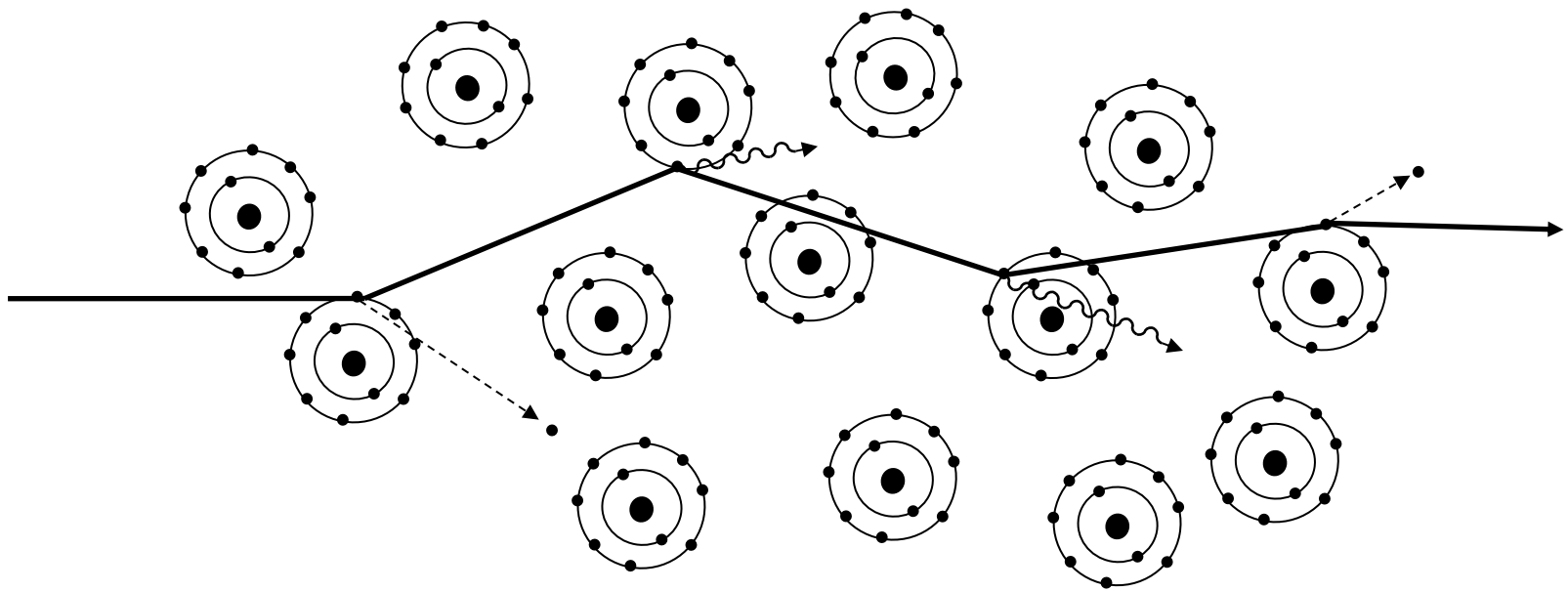






MAS COMO FUNCIONA?





Funcionamento de detetores

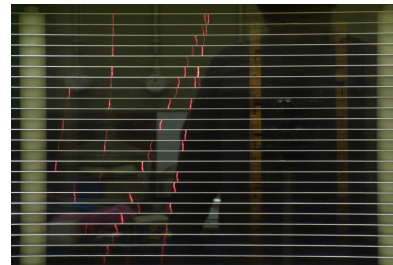
Para detetarmos uma partícula, ela tem de **interagir com o meio (o material do detetor)**

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

O Meio pode ser gasoso, líquido ou sólido

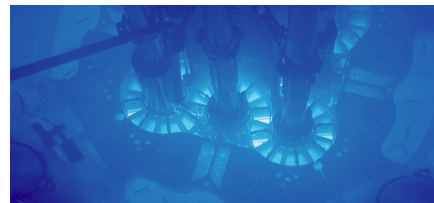
Gases

Gases nobres, misturas complexas, ...



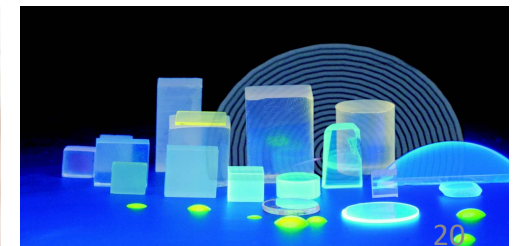
Líquidos

líquidos cintiladores,
água, Xénon, Árgon, etc



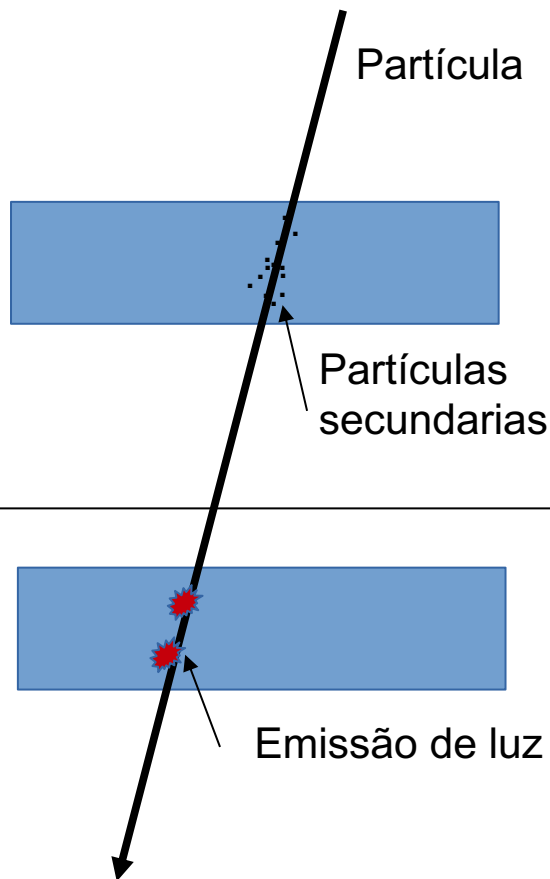
Sólidos

Semicondutores, plásticos cintiladores, etc



- **Produção de partículas secundárias**

- Ionização, radiação de transição, dispersão elástica e inelástica, ...



- **Produção de luz**

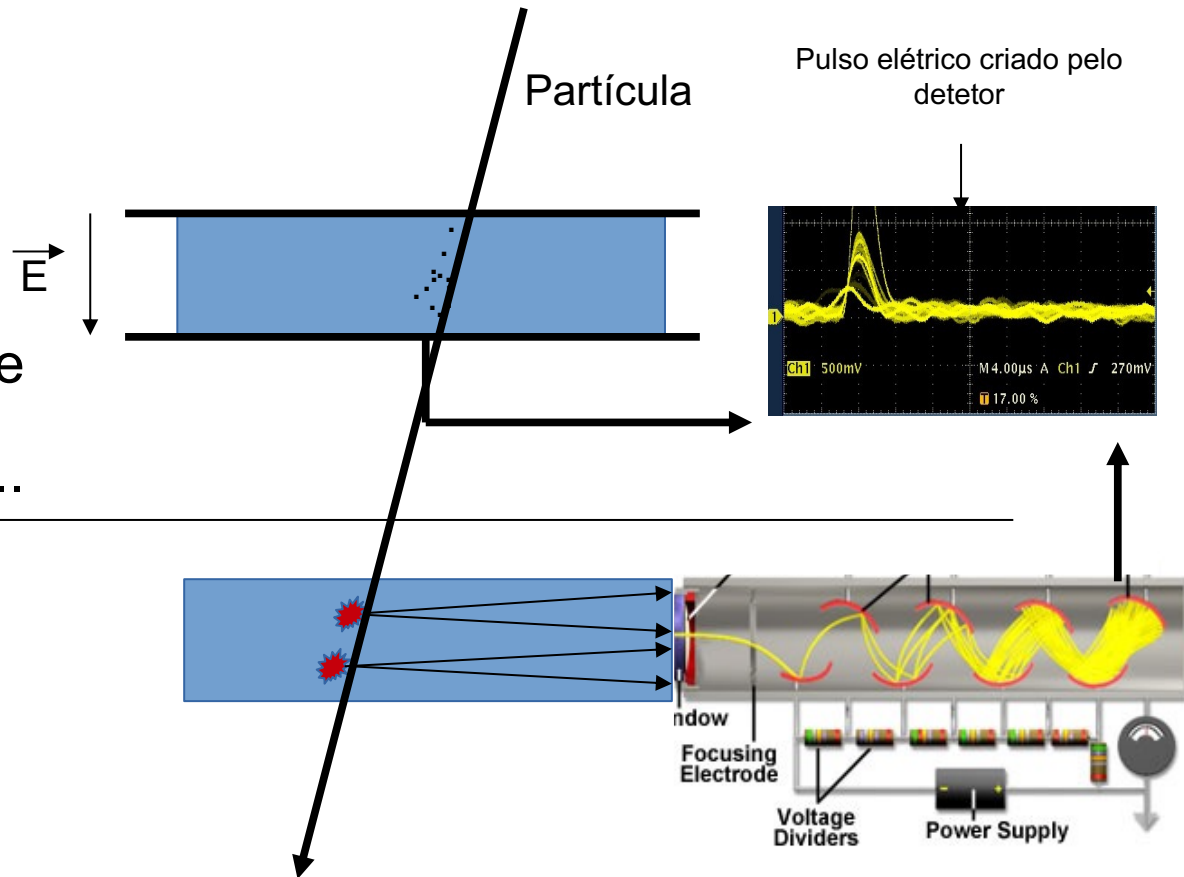
- Cintilação, luz Cherenkov, ...

- **Produção de partículas secundárias**

- Ionização, radiação de transição, dispersão elástica e inelástica, ...

- **Produção de luz**

- Cintilação, luz Cherenkov, ...

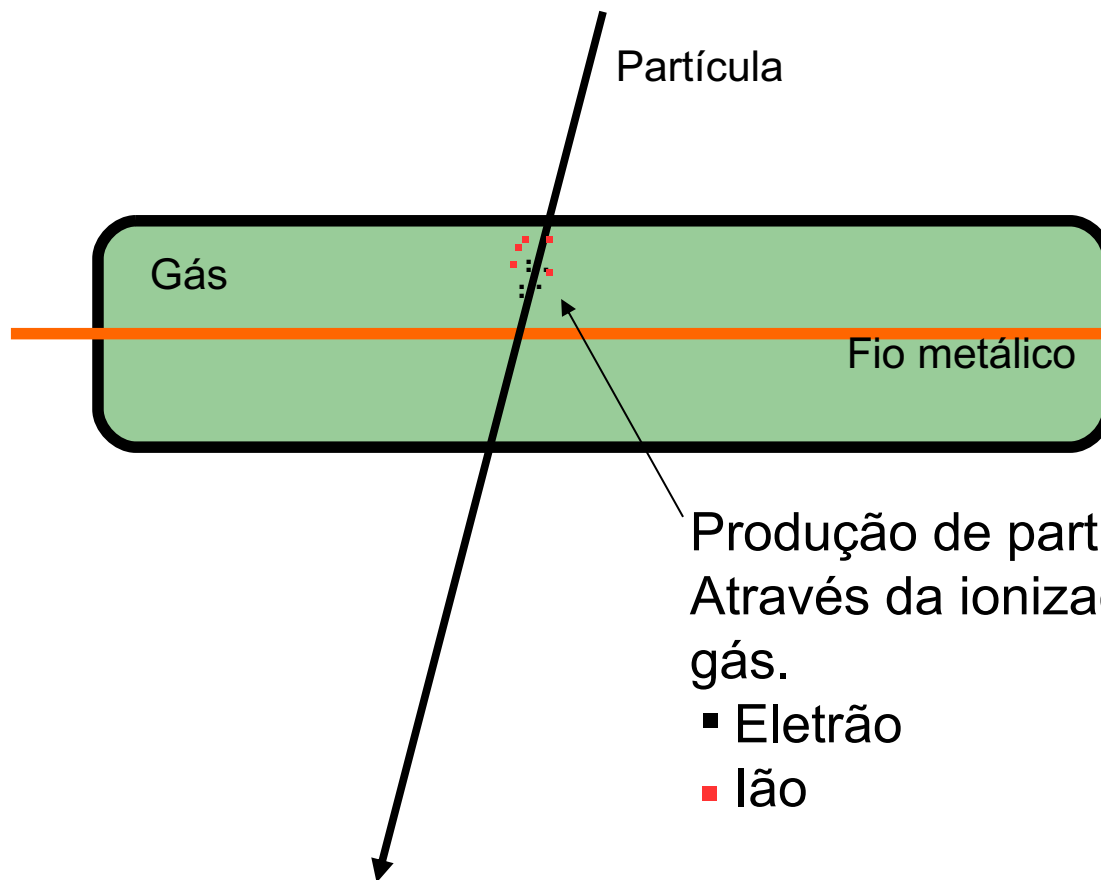


Exemplo: contador de Geiger-Müller



Gás

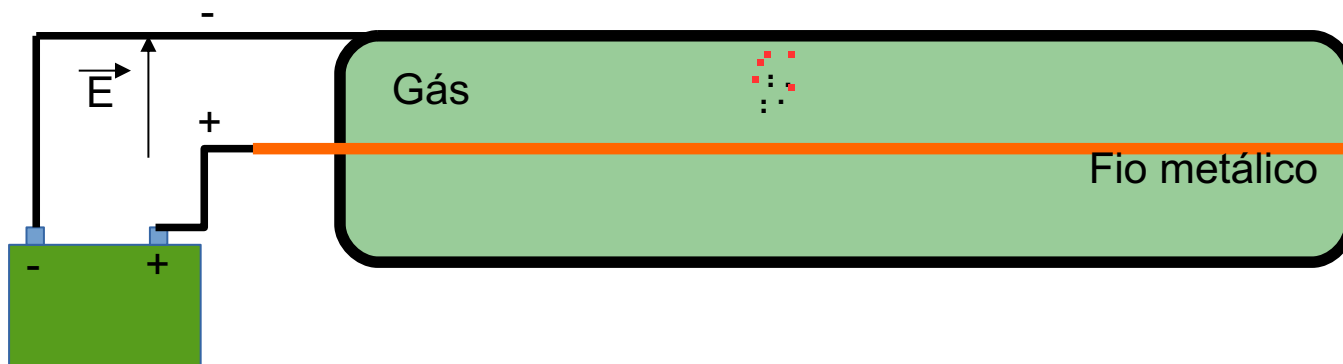
Fio metálico

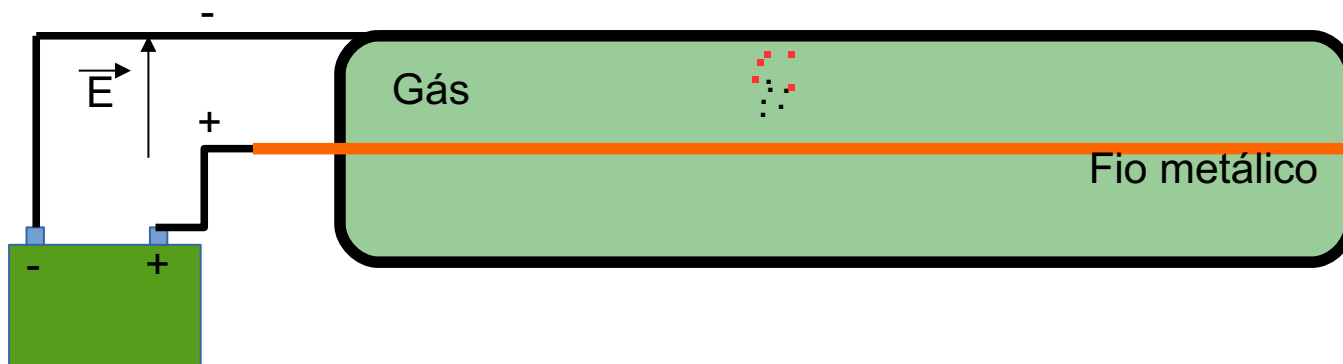


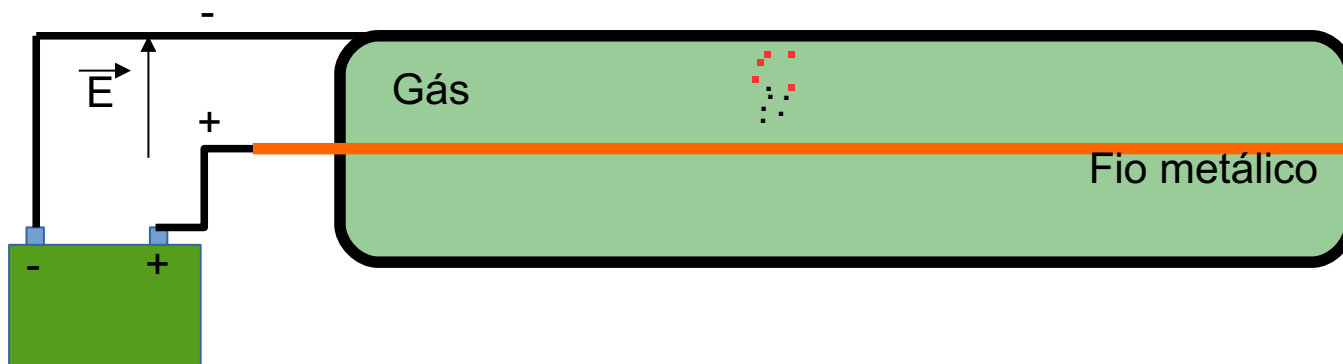
Produção de partículas secundárias
Através da ionização dos átomos do
gás.

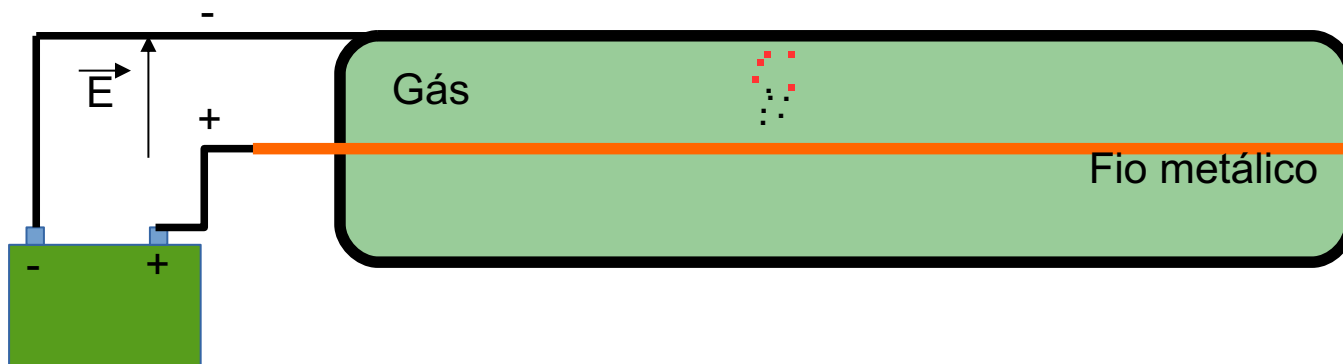
▪ Eletrão

▪ Íon

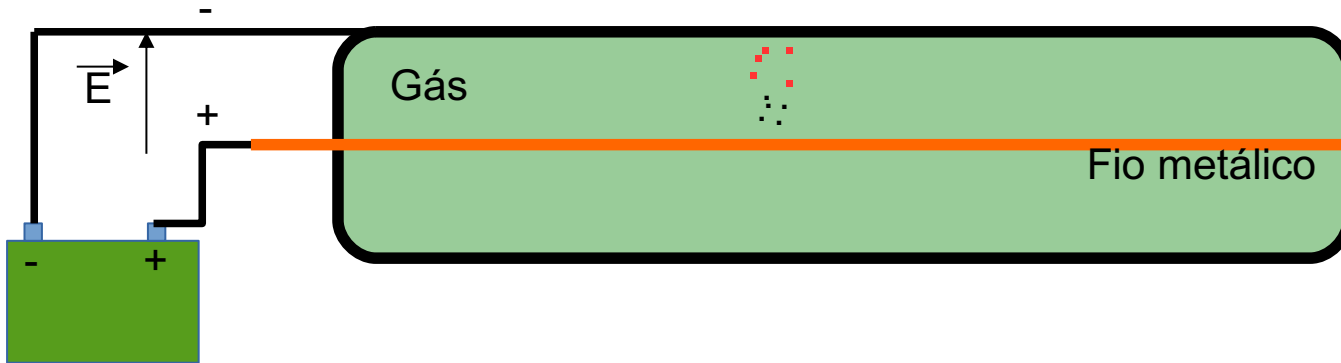




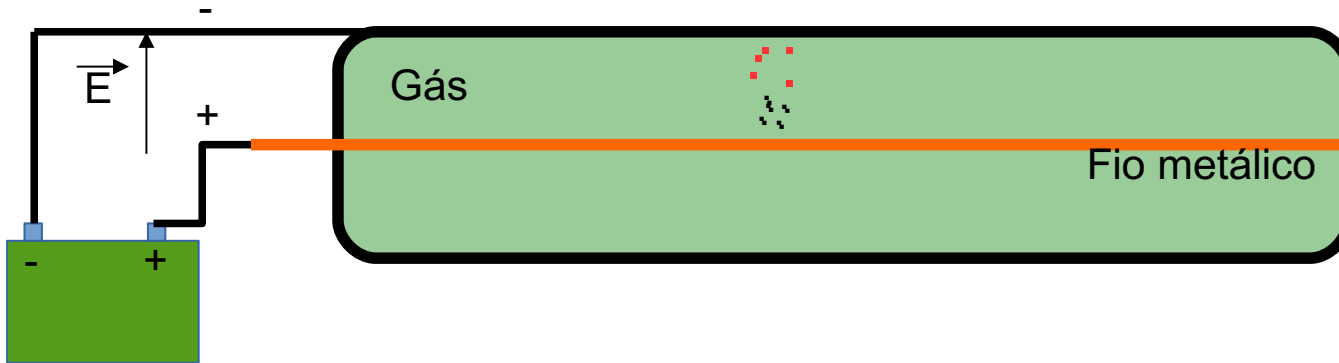




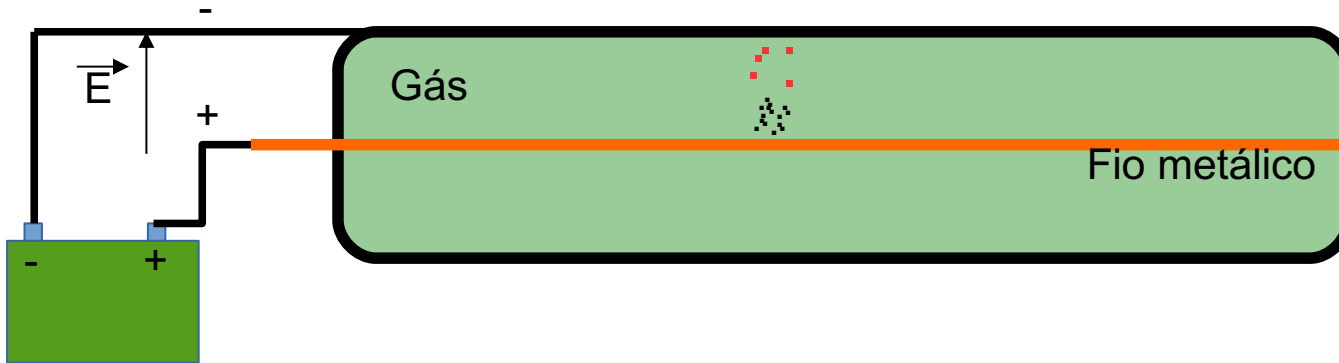
O **campo elétrico, E** , dá energia **aos elétrons** e iões **movendo-os** em direção ao fio e a parede respetivamente.

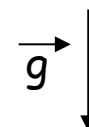
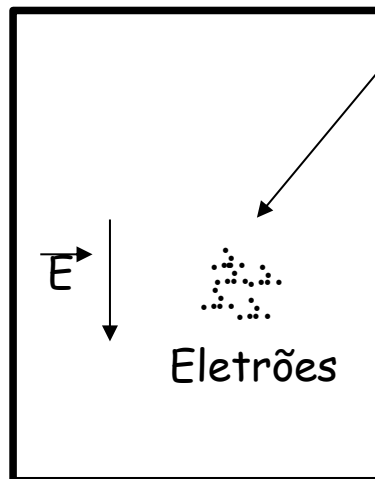
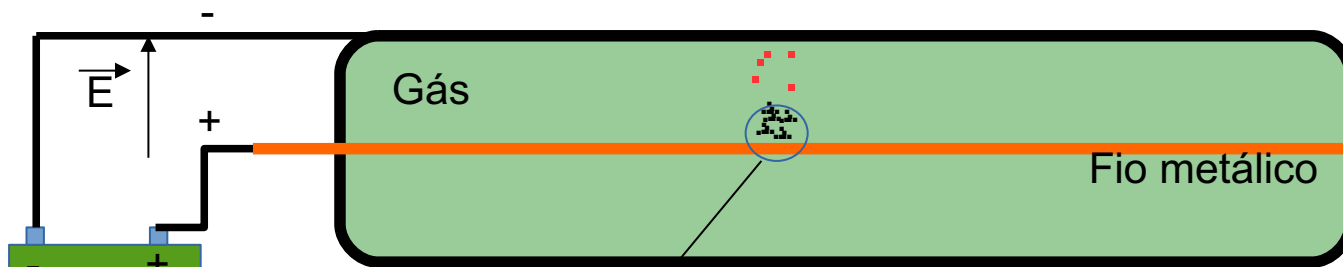


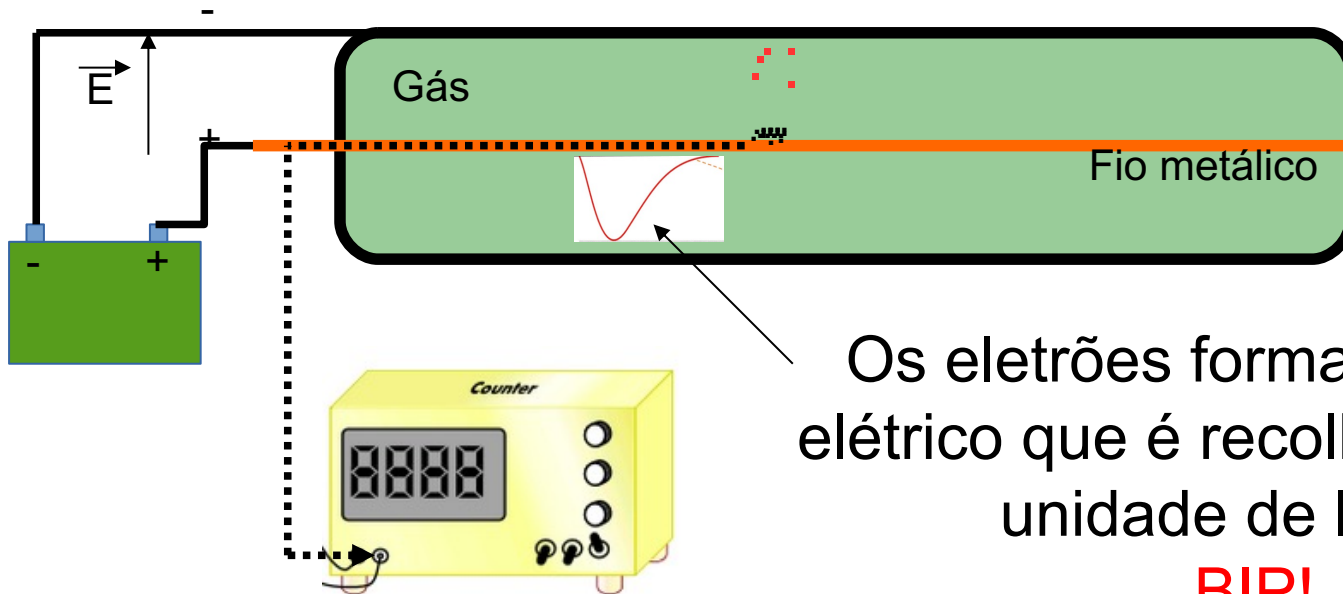
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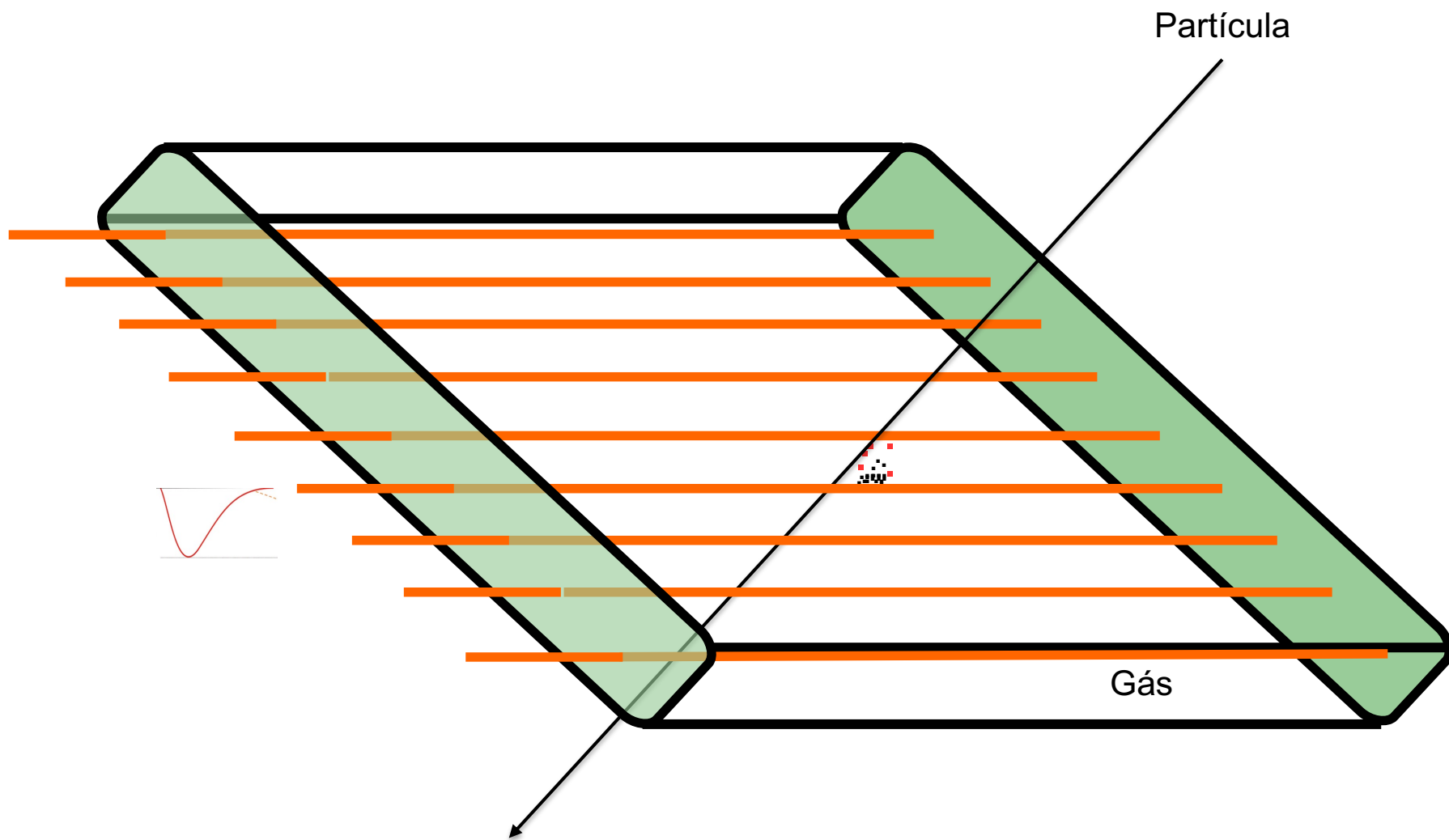


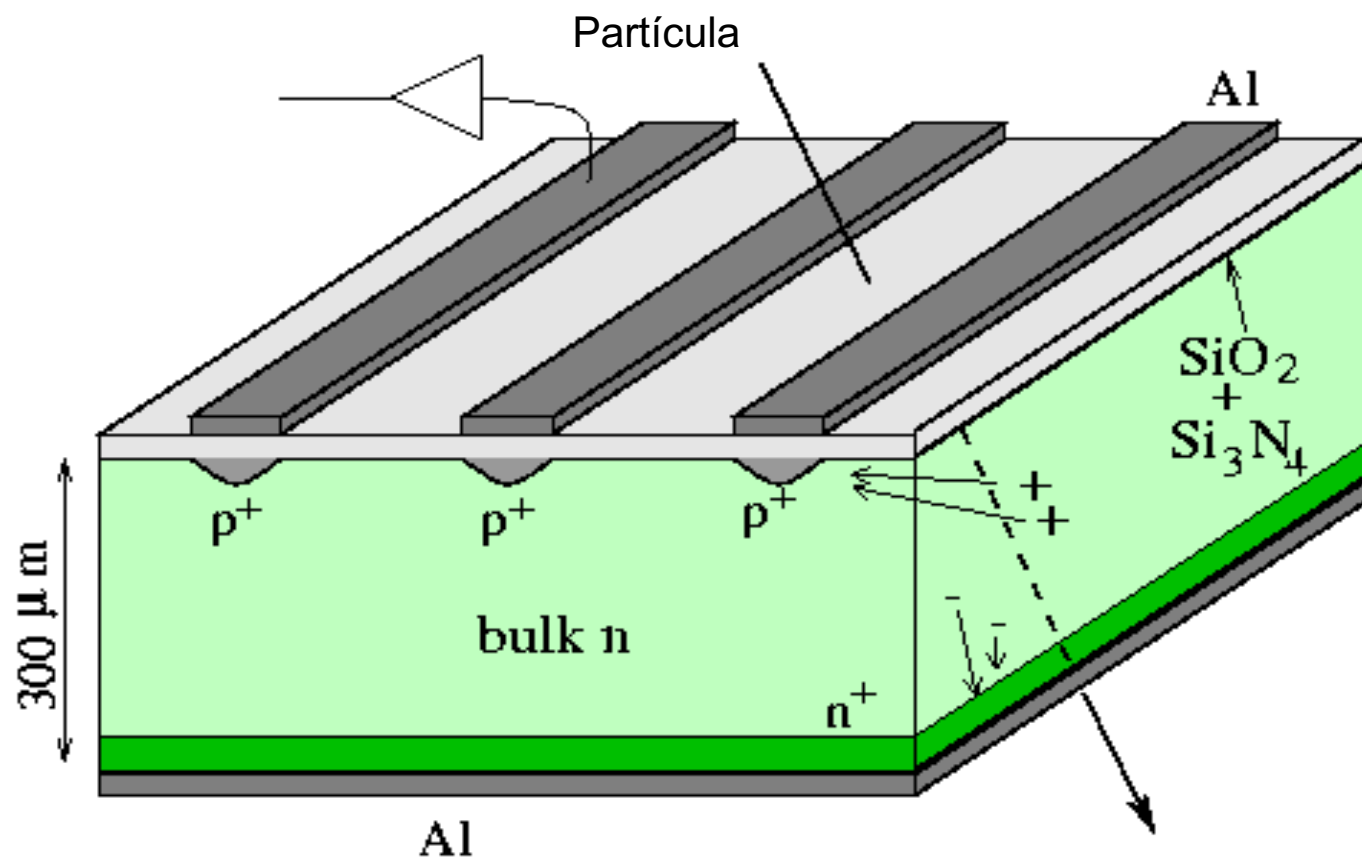




Os eletrões formam um sinal elétrico que é recolhido por uma unidade de leitura

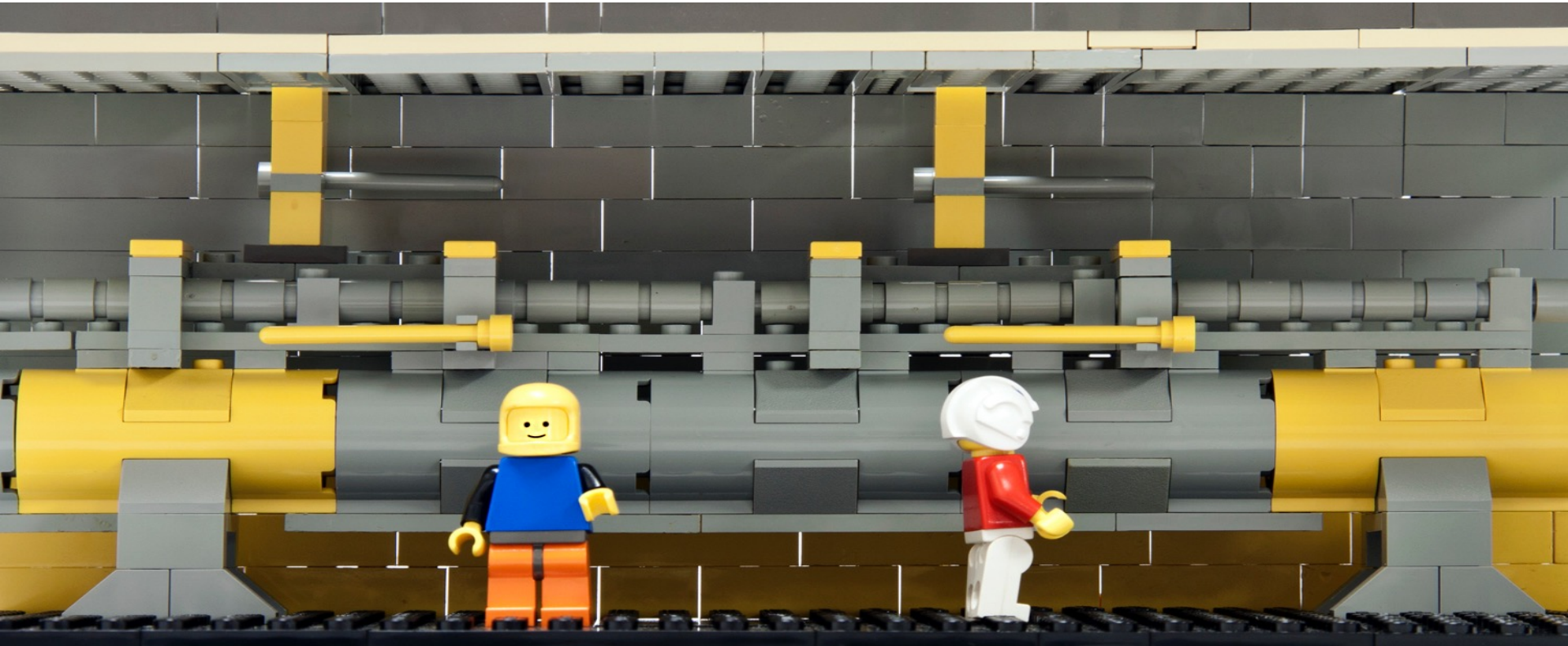
BIP!



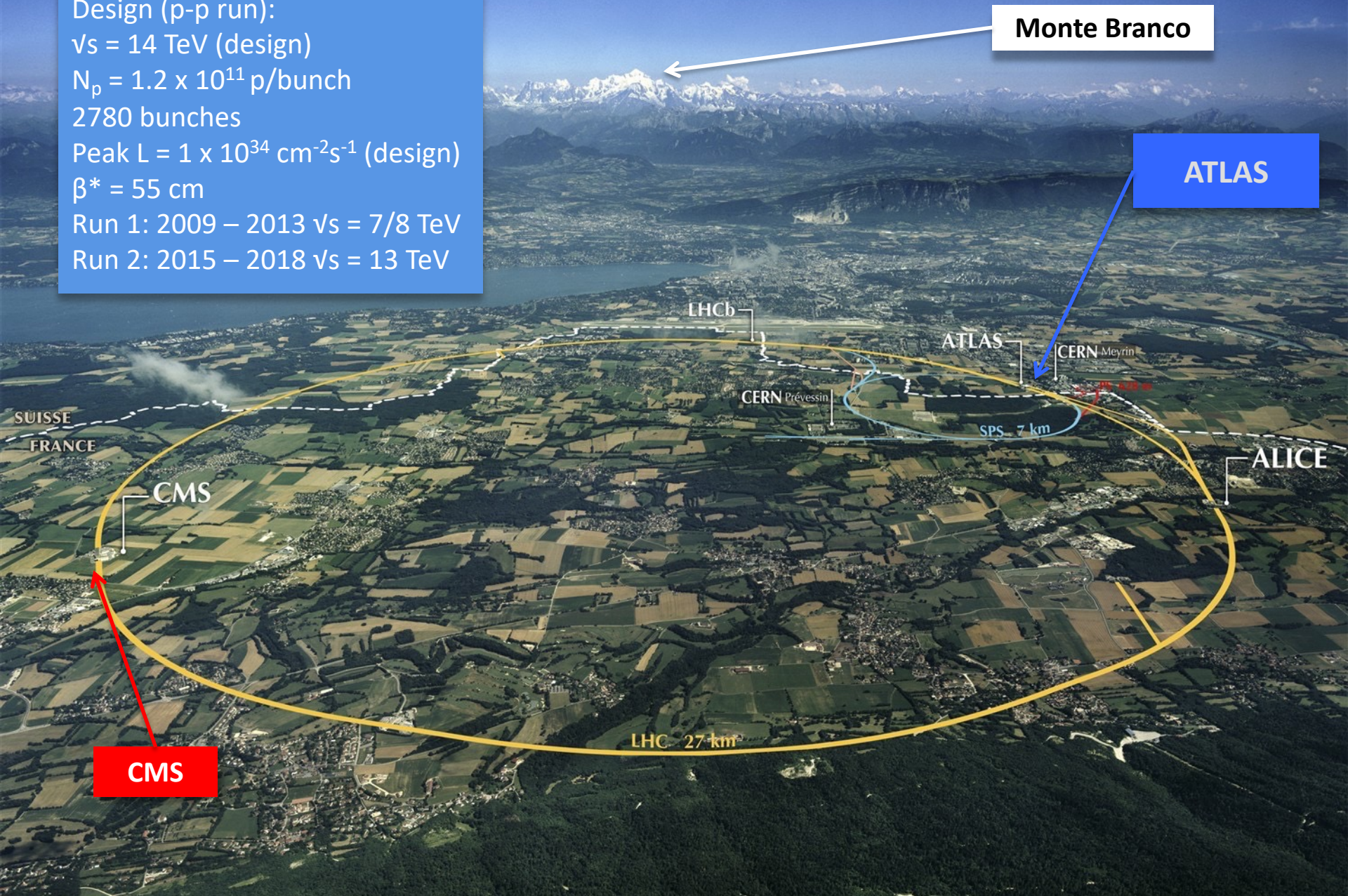




O ACELERADOR LHC DO CERN



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



Monte Branco

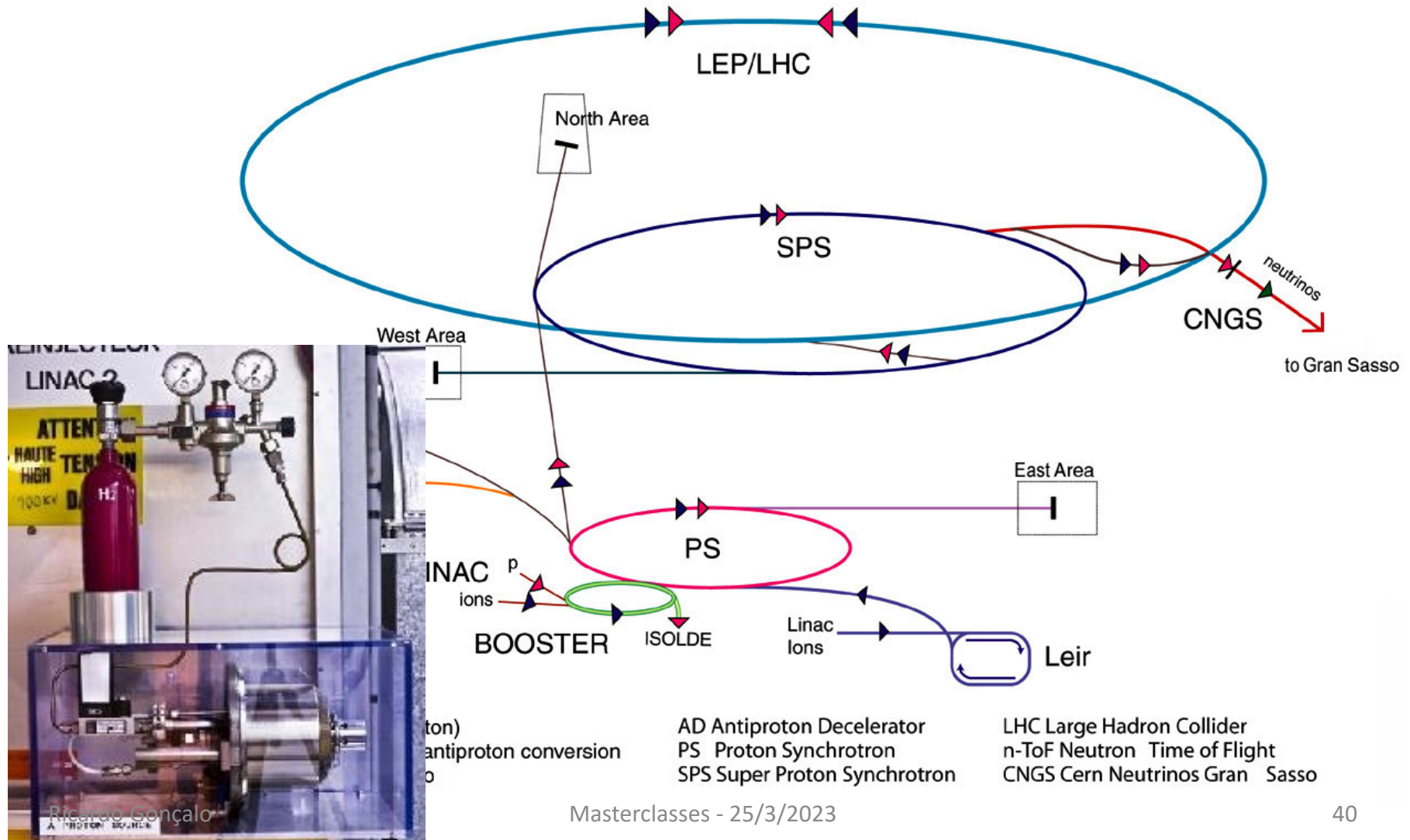
ATLAS

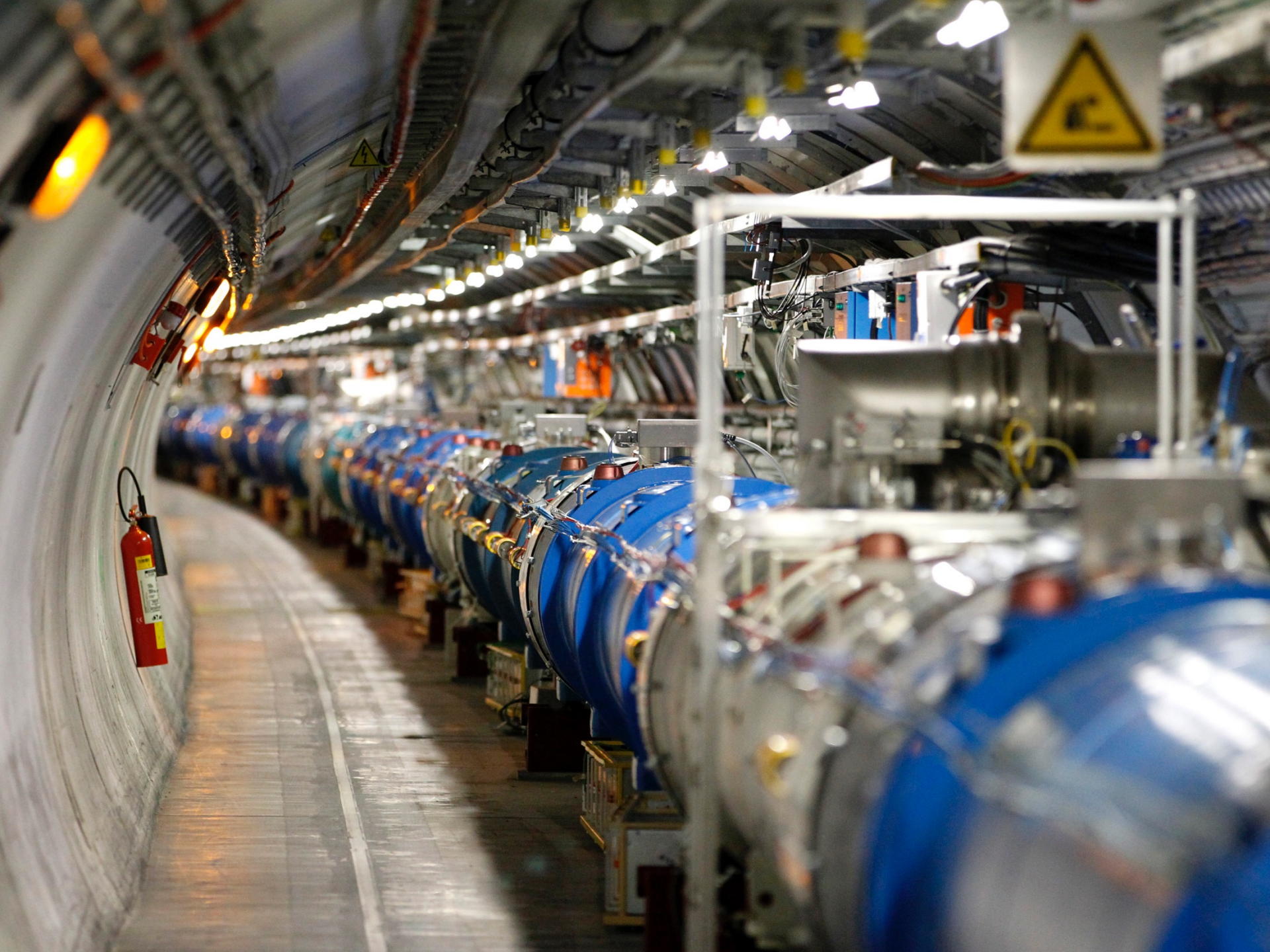
ALICE

CMS

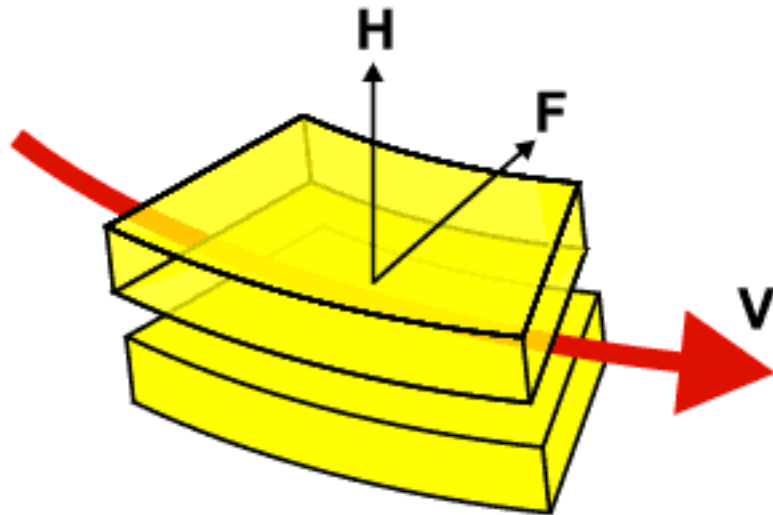
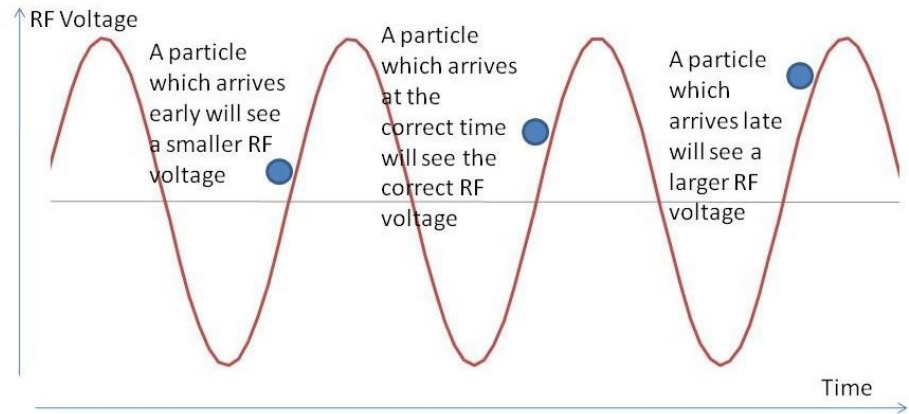
LINAC2 → **50 MeV**
Booster → **1.4 GeV**

Proton Synchrotron (PS) → **25 GeV**
Super Proton Synchrotron (SPS) → **450 GeV**
Large Hadron Collider (LHC) → **7 TeV**

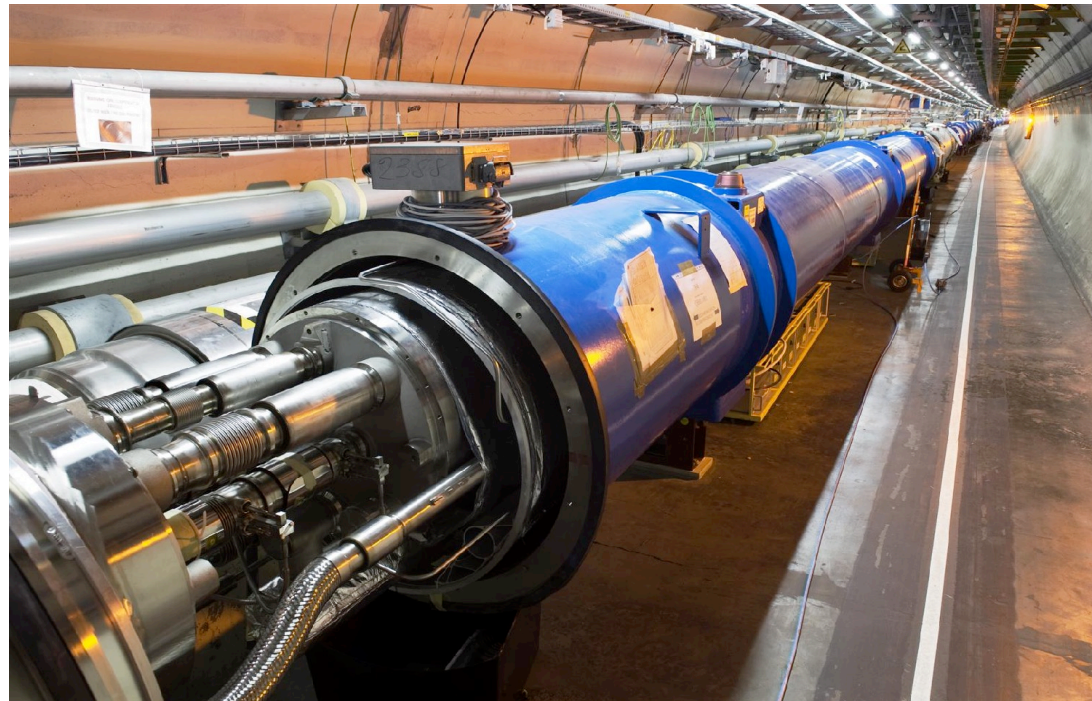




Beam acceleration



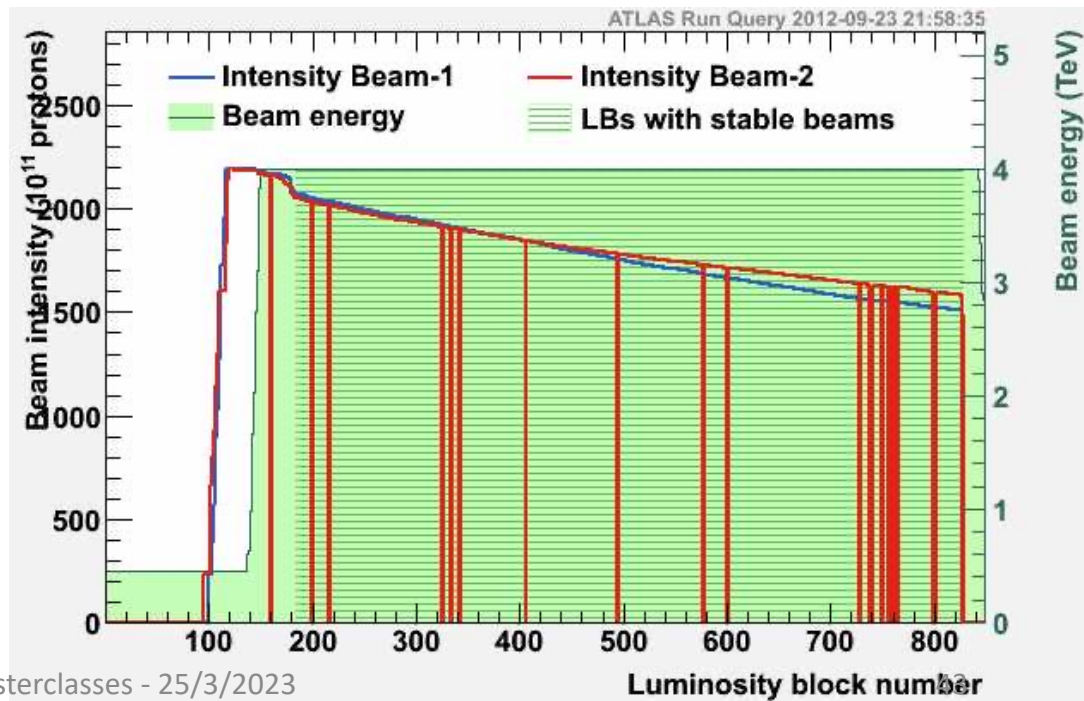
dipole



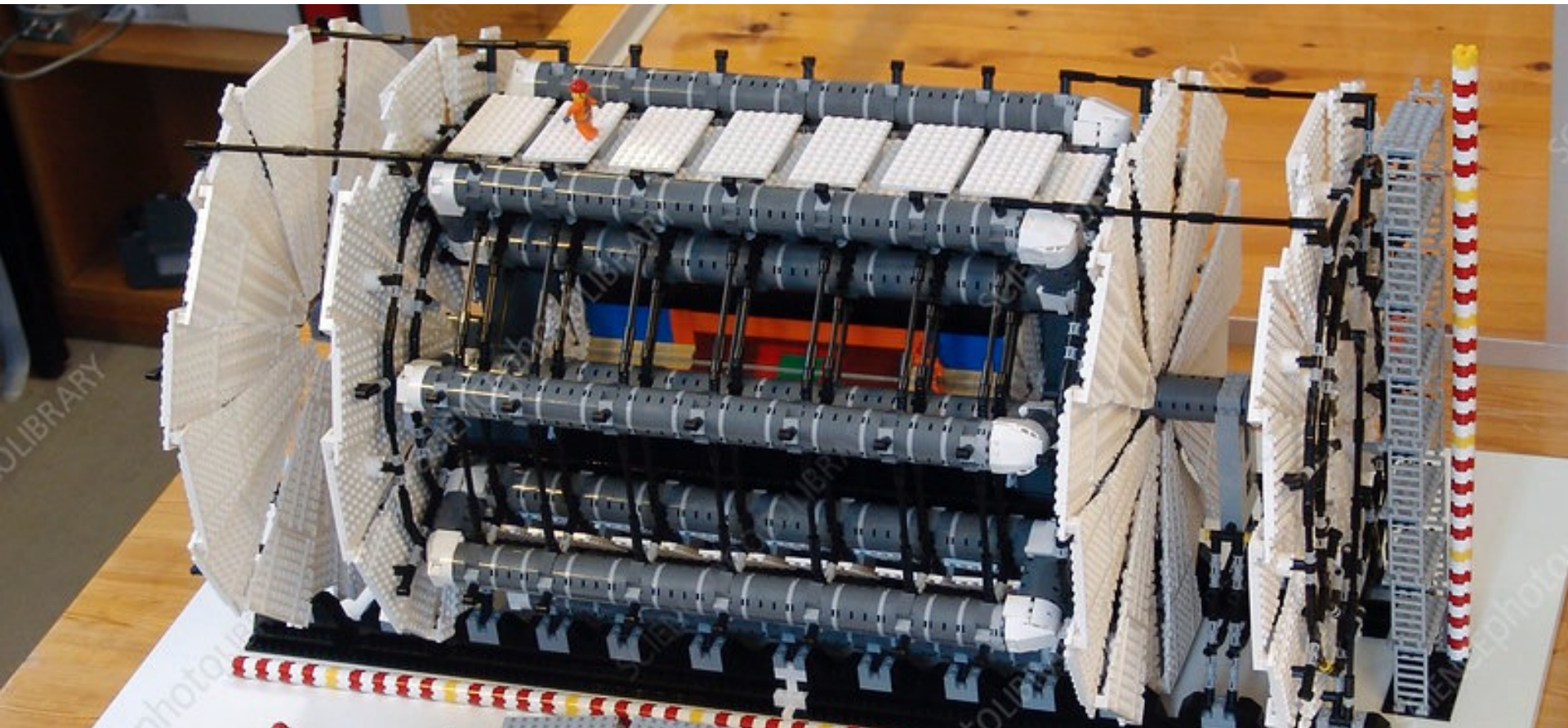


- Energia do feixe:
- 2802 bunches de 1.15×10^{11} prótons
- 7TeV / próton (2015) = $7 \times 10^{12} \times 1.602 \times 10^{-19}$ J
- Dá 362 MJ por feixe...
- Igual à energia cinética de um porta-aviões de 20,000t a viajar a 11,7 nós (21.7 km/h)

- Tudo contido num feixe de $\approx 16\mu\text{m}$
- 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
 $\sigma/p_T = 2\% @ 50\text{GeV}$ to $10\% @ 1\text{TeV}$ (ID+MS)

EM calorimeter: $|\eta| < 3.2$

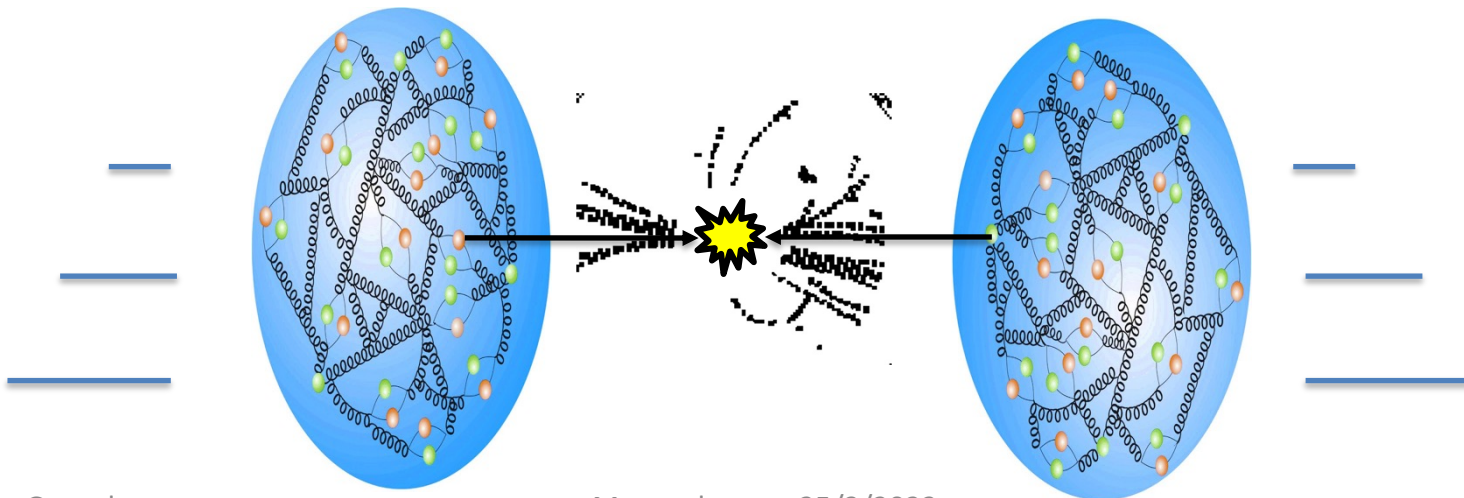
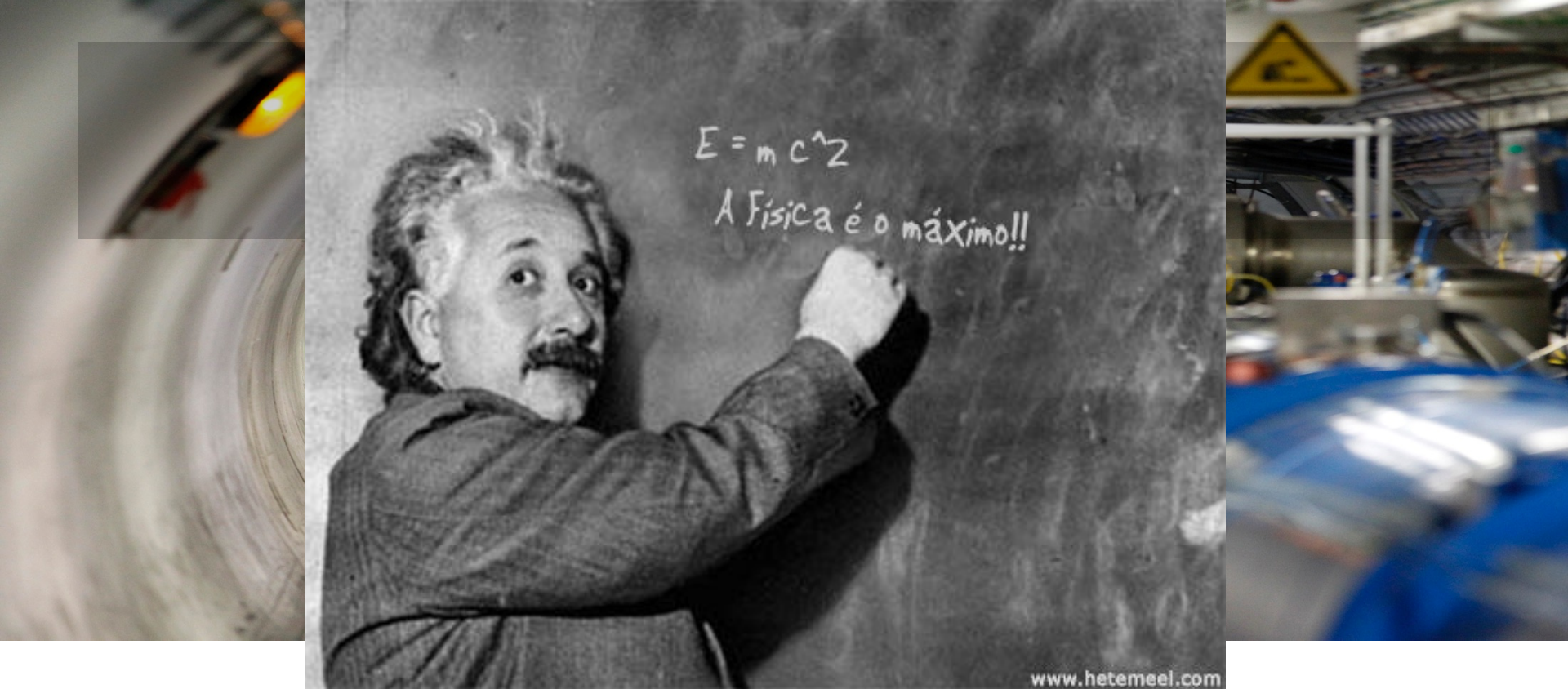
Pb-LAr Accordion
 $\sigma/E = 10\%/\sqrt{E} \oplus 0.7\%$

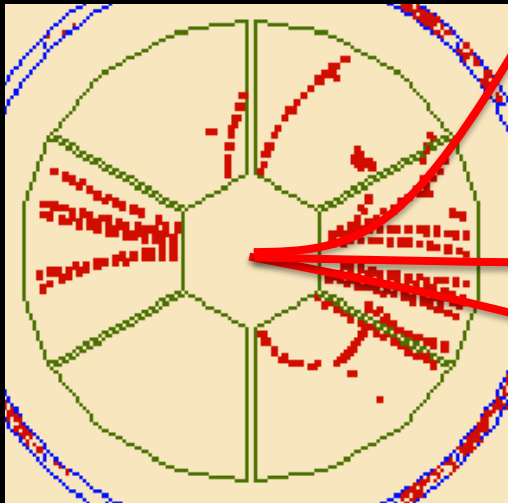
Hadronic calorimeter:

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

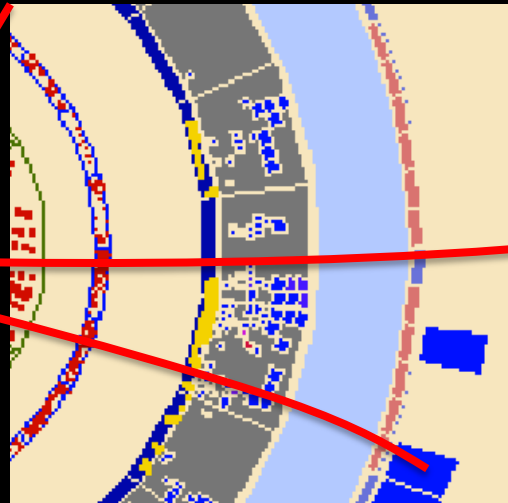
Inner Tracker: $|\eta| < 2.5$, $B=2\text{T}$
Si pixels/strips and Trans. Rad. Det.
 $\sigma/p_T = 0.05\% p_T (\text{GeV}) \oplus 1\%$

- $L = 44 \text{ m}$, $\varnothing \approx 25 \text{ m}$
- 7000 tonnes
- $\approx 10^8$ electronic channels
- 3-level trigger reducing 40 MHz collision rate to 200 Hz of events to tape

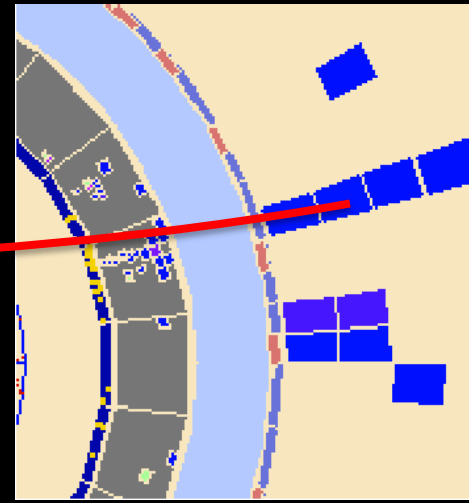




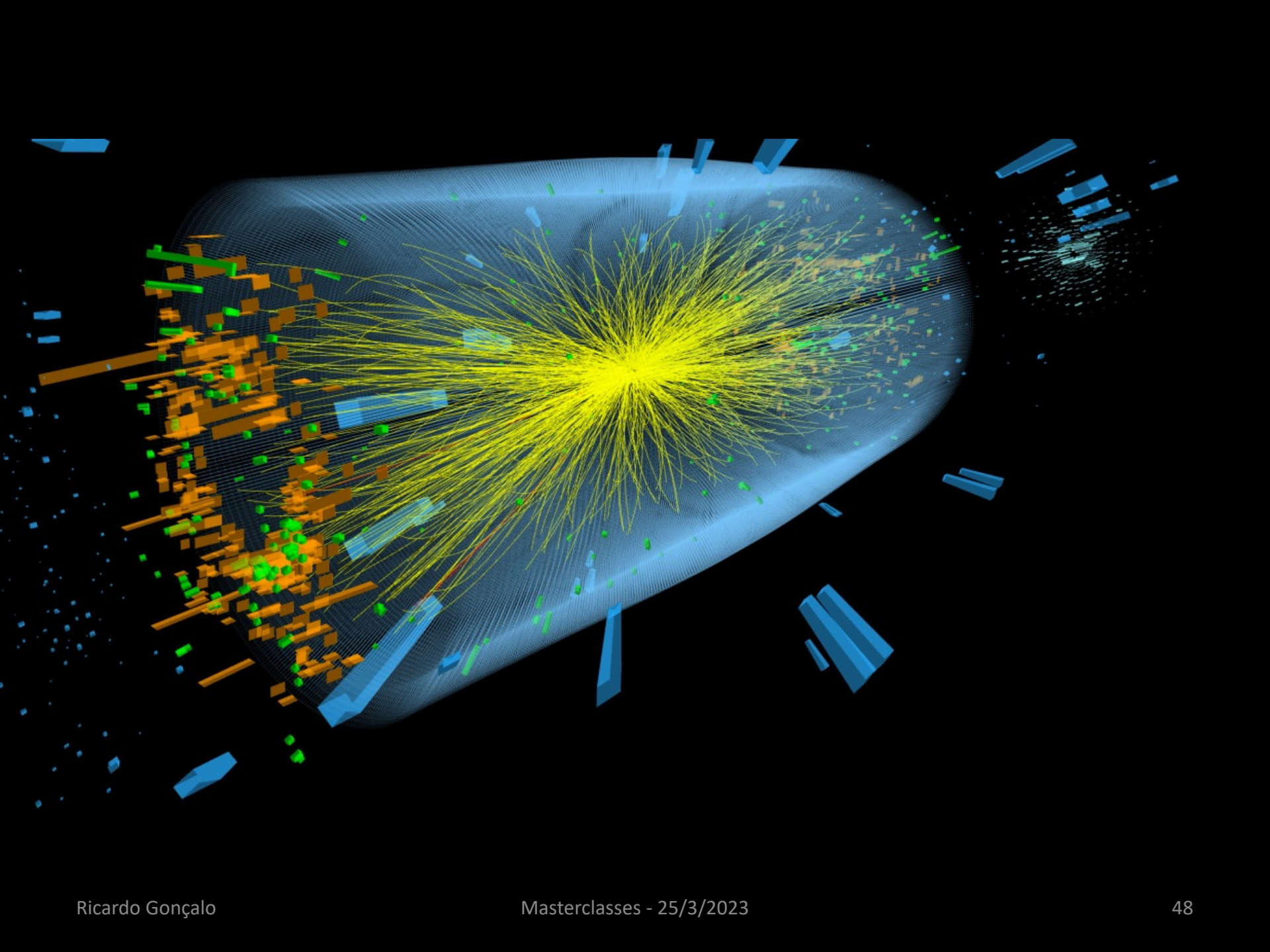
Detetor de Traços



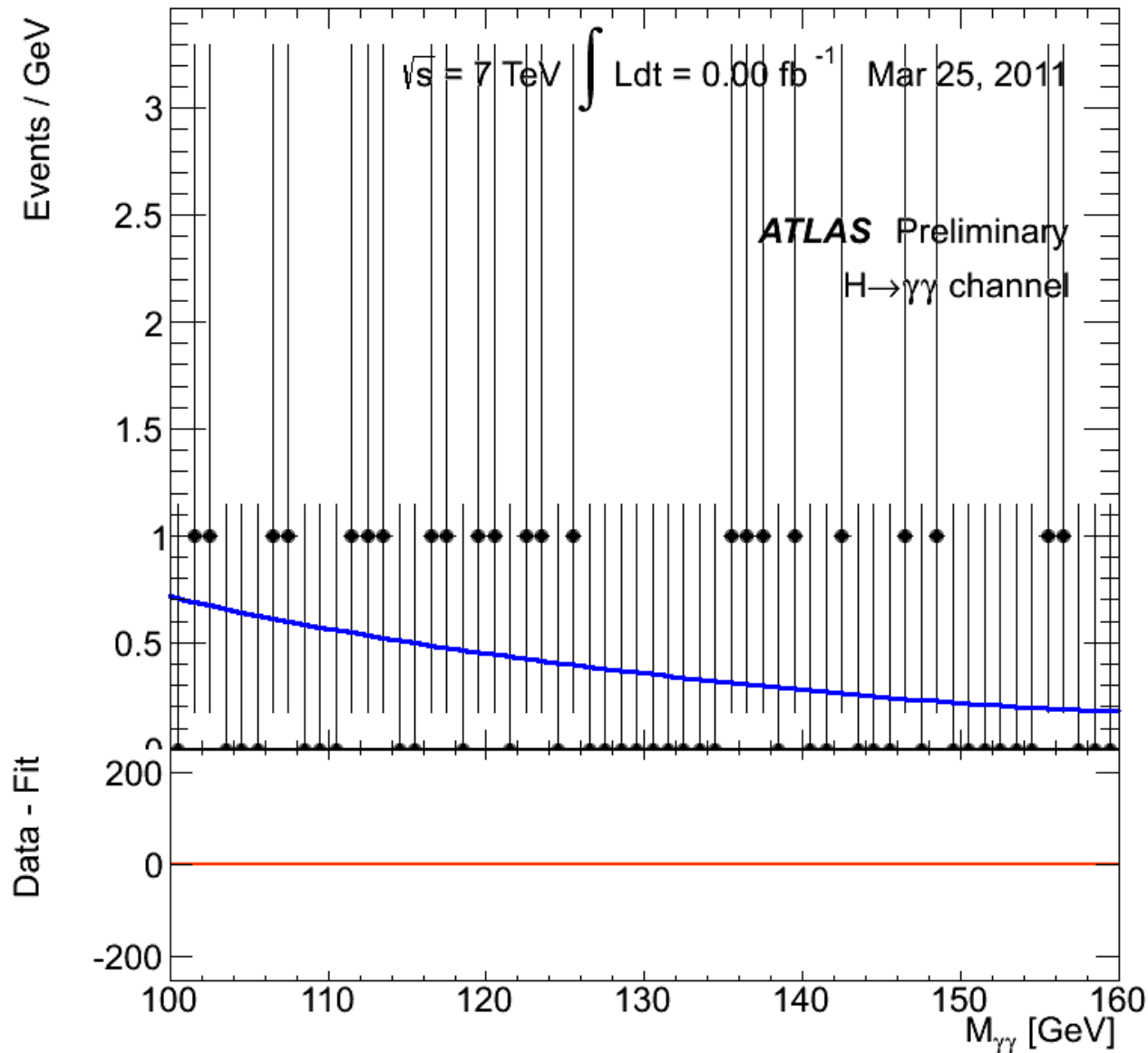
Calorímetro
Eletromagnético



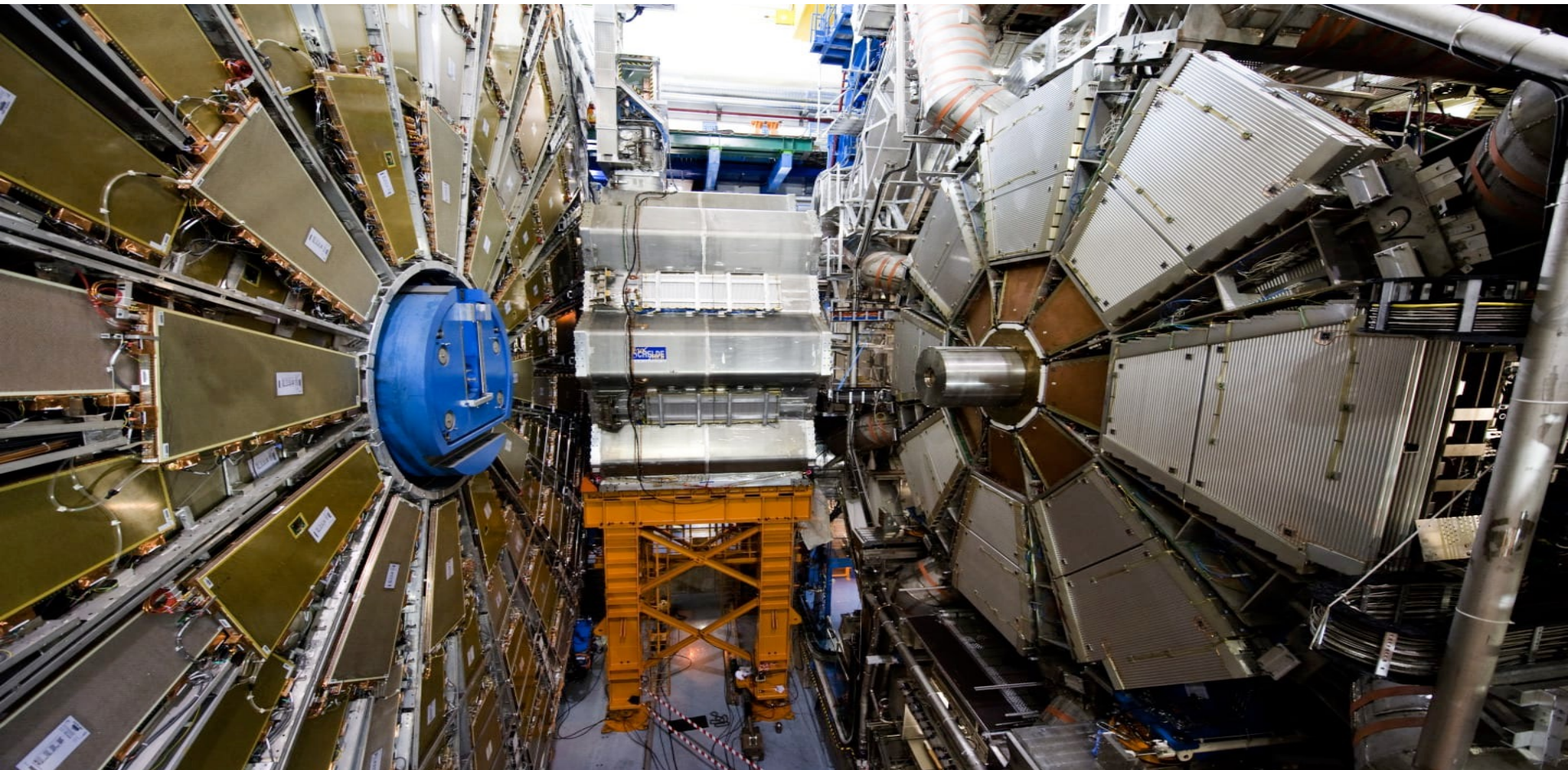
Calorímetro
Hadrónico



2012: Descoberta do bóson de Higgs: $H \rightarrow \gamma\gamma$

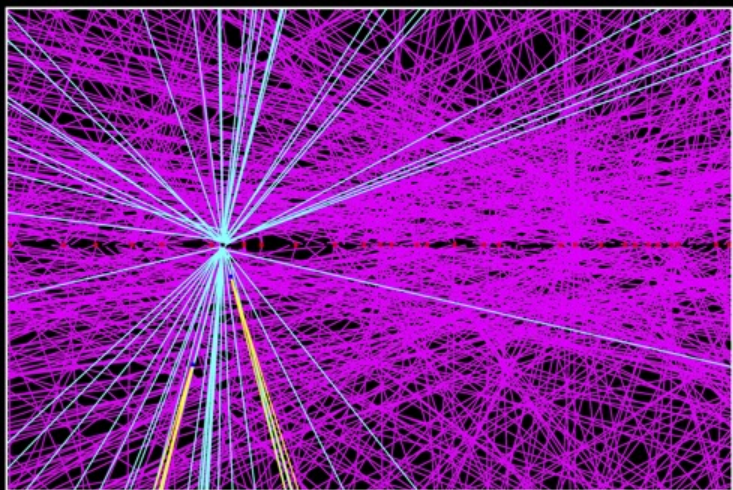
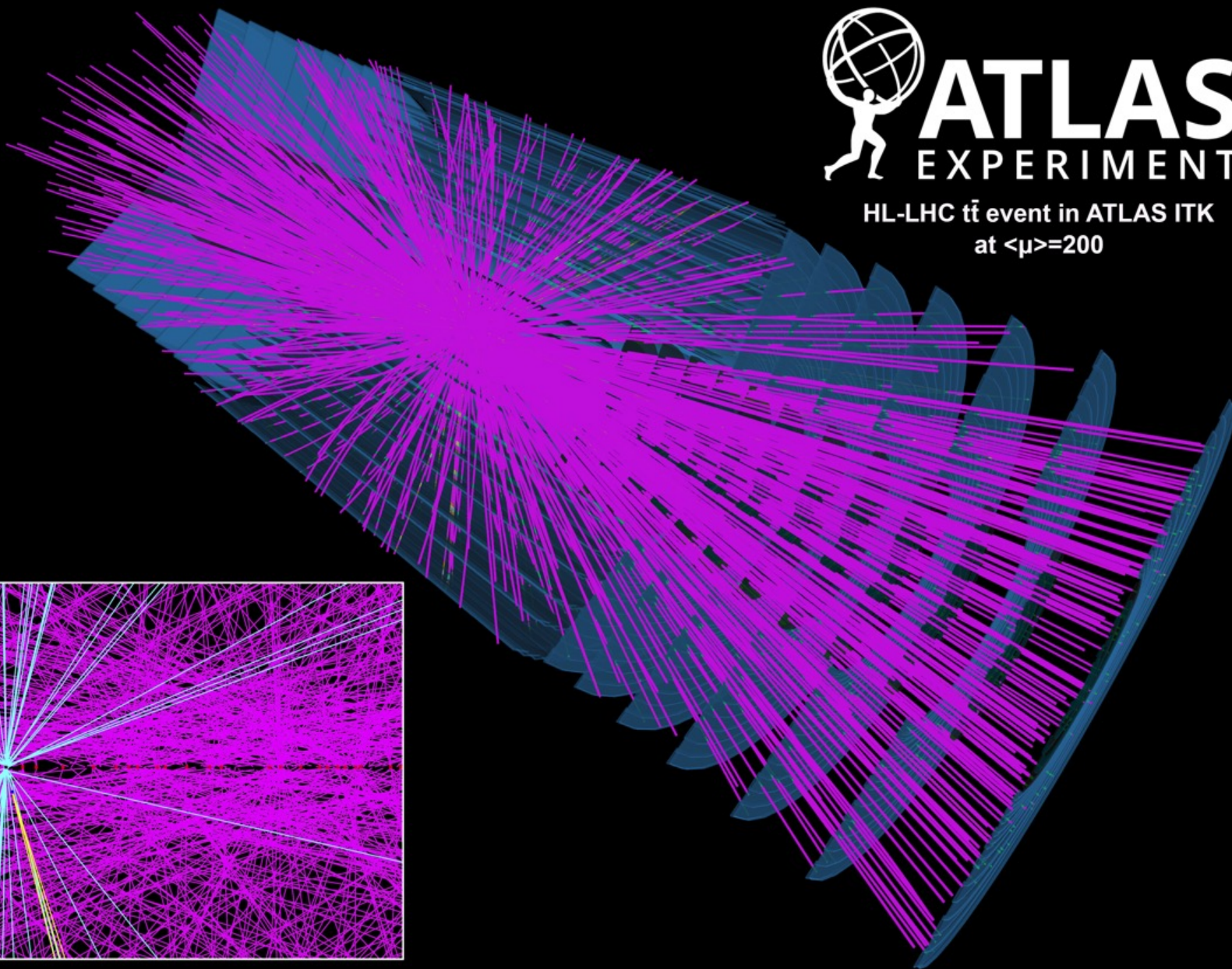


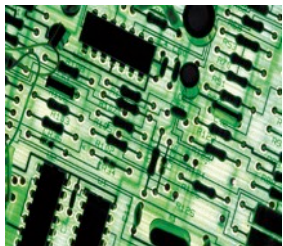
O FUTURO DO LHC



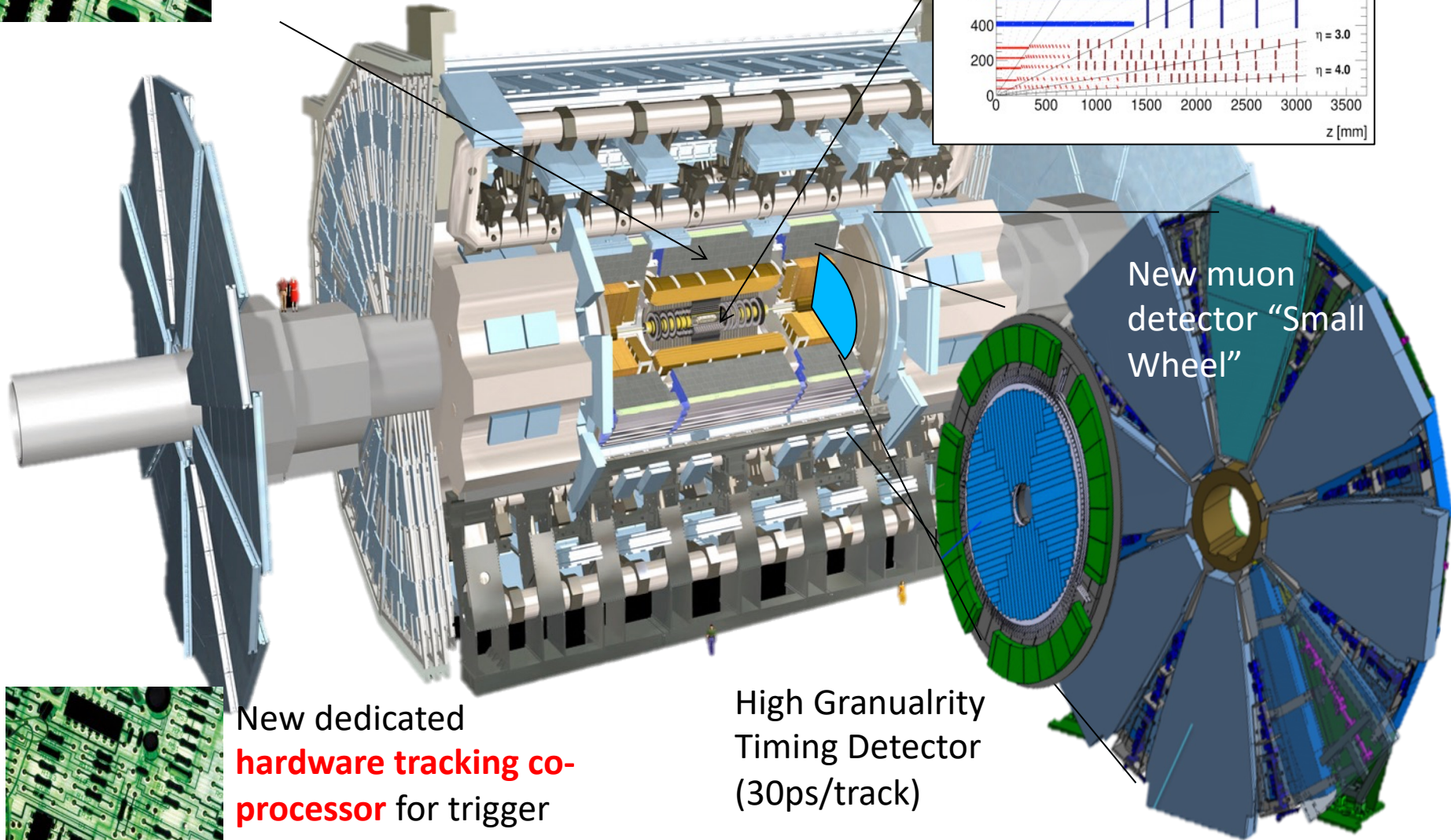
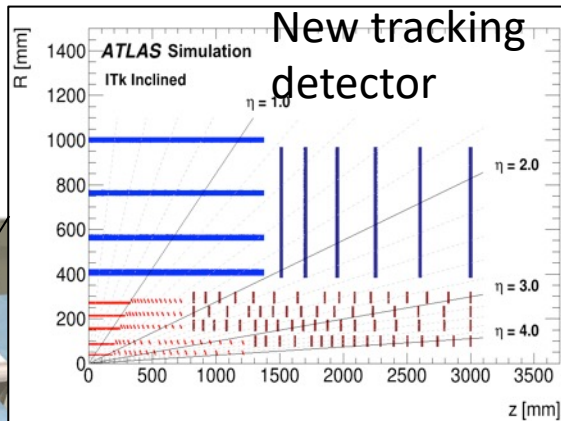


HL-LHC $t\bar{t}$ event in ATLAS ITK
at $\langle\mu\rangle=200$





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



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

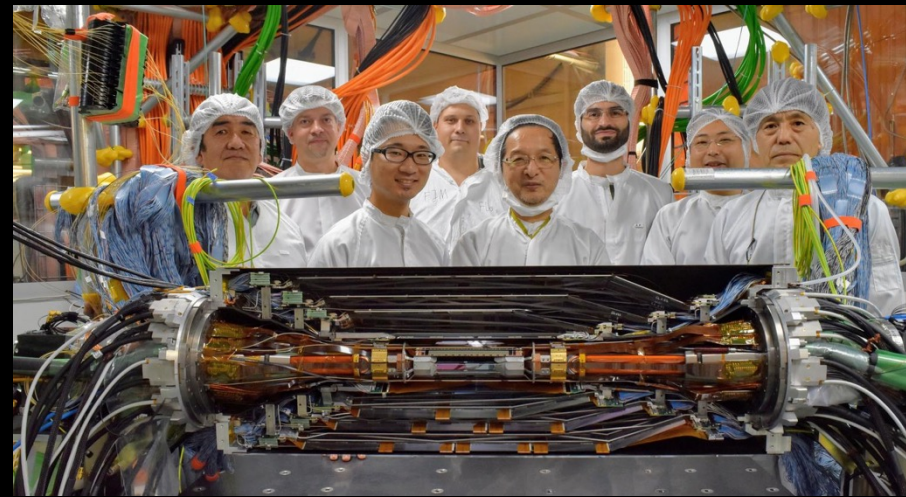
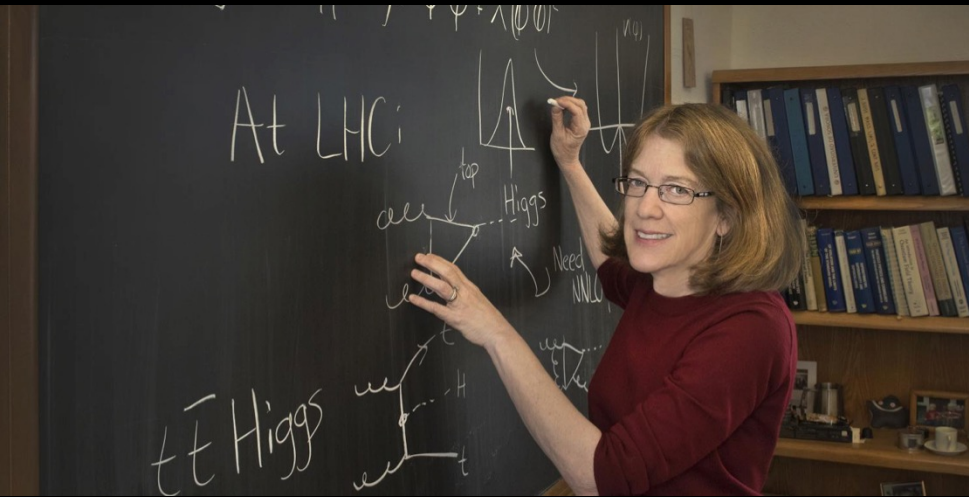
High Granualrity Timing Detector (30ps/track)

Os FÍSICOS DE PARTÍCULAS





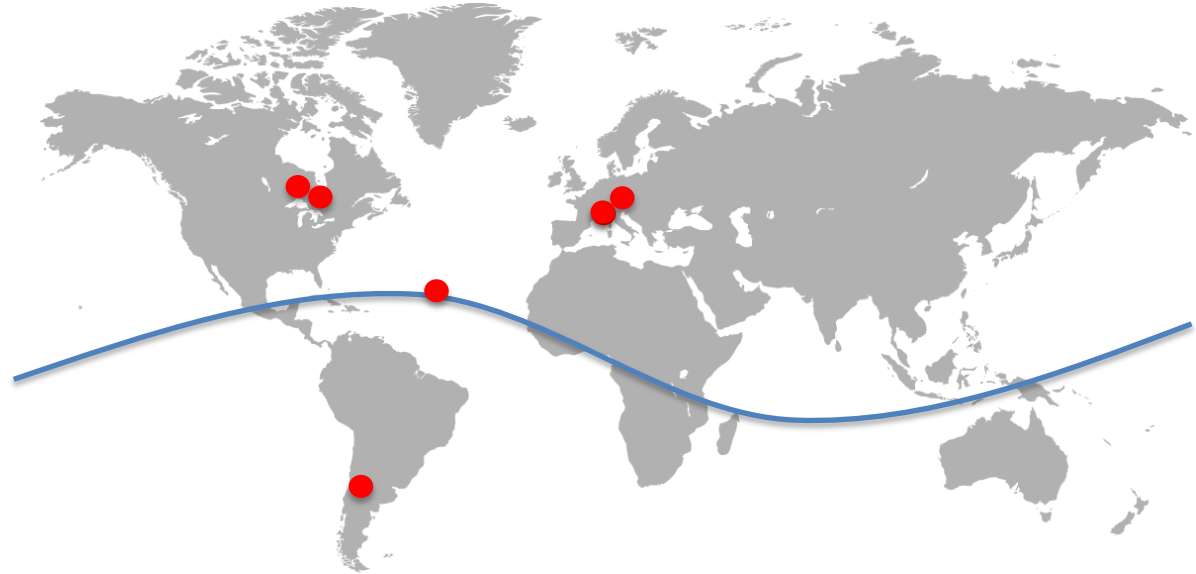
Os caçadores de partículas de hoje



Física (Experimental) de Partículas em Portugal

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

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IMPACTO NA SOCIEDADE



Impacto na Sociedade

Prototerapia

Computação
na grid

Imagiologia médica

Radioterapia

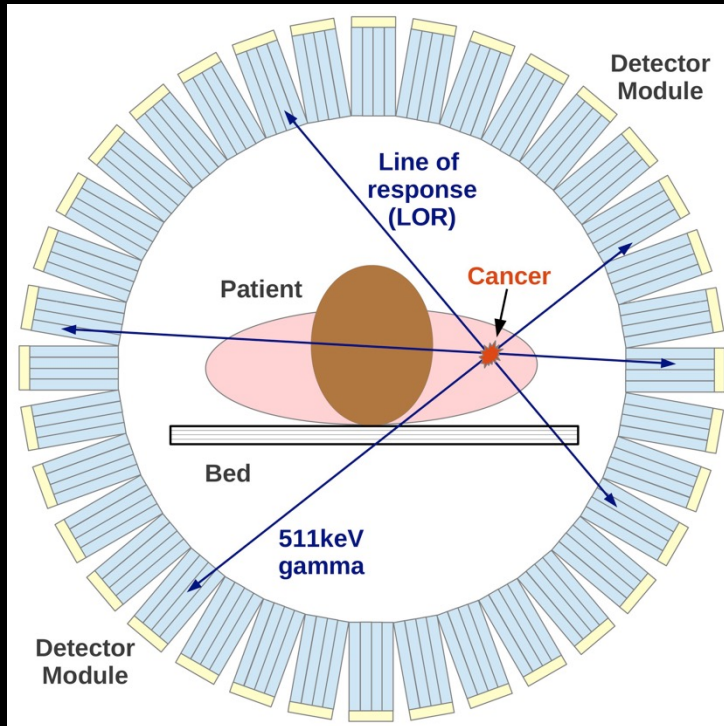
Tomografia de muões
(Pirâmide de Gizé)

Ciclo Solar

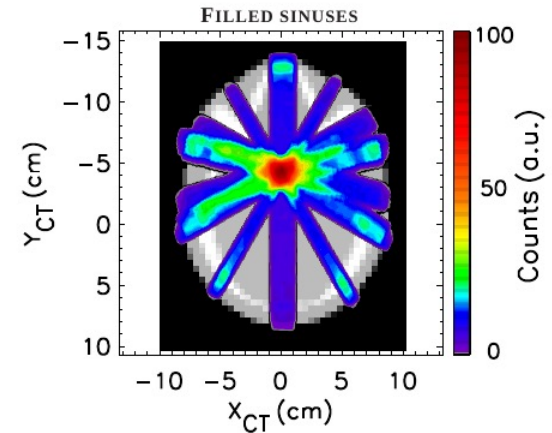
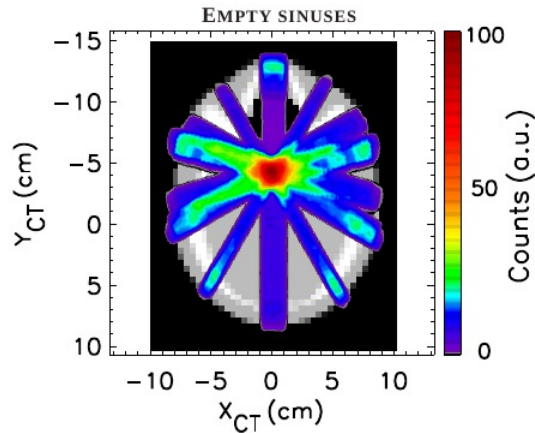
Exploração do espaço

World Wide Web

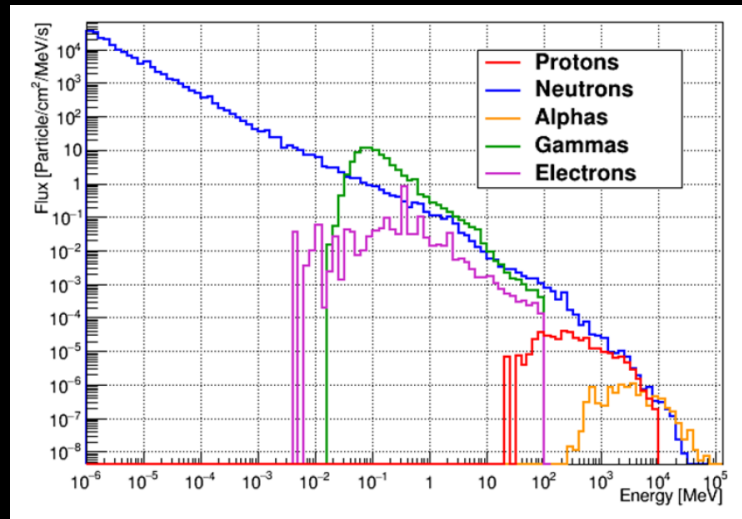
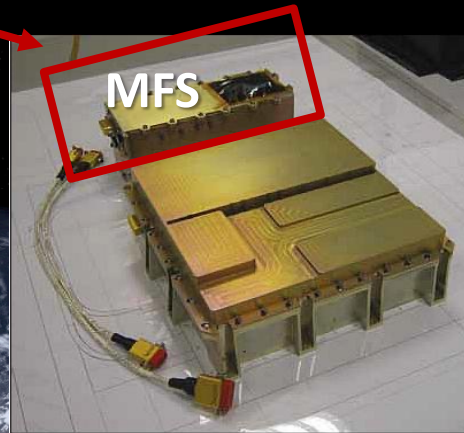
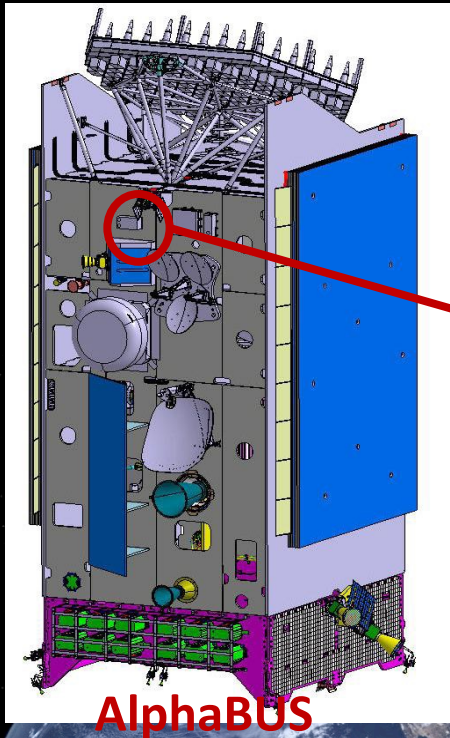
Tomografia de emissão de positrões (PET)



Terapia com feixes de prótons



Exploração Espacial



Perguntas?

Obrigado
pelo vosso
interesse!

jgoncalo@lip.pt

Ricardo Gonçalves

Mas



Bonus slides

