

# A experiência ATLAS



14<sup>a</sup> Escola de Professores no CERN em Língua Portuguesa  
8 de Setembro de 2022

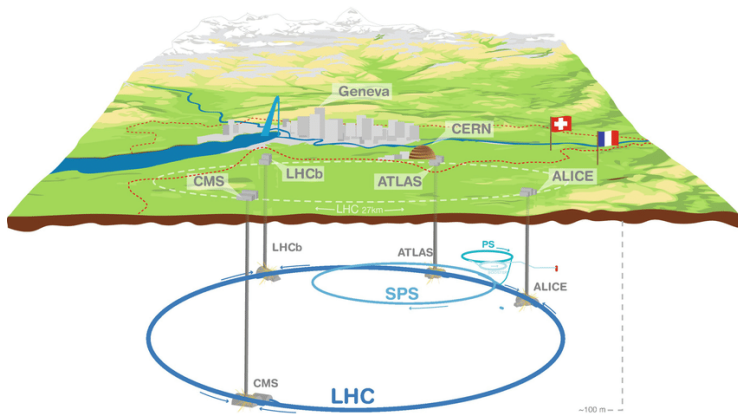
Ana Peixoto

Laboratoire de Physique Subatomique et de Cosmologie



# ATLAS: A Toroidal LHC Apparatus

Colaboração mundial





# ATLAS: A Toroidal LHC Apparatus

Colaboração mundial



2





## Ana Peixoto

- ▶ Nacionalidade portuguesa e natural do Alto Minho (Paredes de Coura)
- ▶ Pós-doutoranda desde 2021 na pesquisa da matéria escura no LPSC em Grenoble, França
- ▶ Membro da colaboração ATLAS desde 2015: Mestrado e doutoramento no LIP-Minho (em colaboração com a Universidade do Minho)

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# ATLAS: A Toroidal LHC Apparatus

Colaboração mundial



Status: June 2022

- Argentina
- Armenia
- Australia
- Austria
- Azerbaijan
- Belarus
- Brazil
- Canada
- Chile
- China
- Colombia
- Czech Republic
- Denmark
- France
- Georgia
- Germany
- Greece
- Israel
- Italy
- Japan
- Mongolia
- Morocco
- Netherlands
- Norway
- Palestine
- Philippines
- Poland
- Portugal
- Romania
- Russia
- Serbia
- Slovakia
- Slovenia
- South Africa
- Spain
- Sweden
- Switzerland
- Taiwan
- Türkiye
- UAE
- UK
- USA
- CERN
- JINR

## ATLAS Collaboration

181 institutions (244 institutes) from 42 countries



# ATLAS· A Toroidal LHC Apparatus

Colaboração mundial



- |                |                 |              |
|----------------|-----------------|--------------|
| Alghazestan    | India           | Romania      |
| Algeria        | Indonesia       | Russia       |
| Argentina      | Iran            | Rwanda       |
| Armenia        | Iraq            | Sao Marito   |
| Australia      | Ireland         | Saudi Arabia |
| Austria        | Israel          | Senegal      |
| Azerbaijan     | Italy           | Serbia       |
| Bahrain        | Japan           | Slovakia     |
| Bangladesh     | Kazakhstan      | Slovenia     |
| Belarus        | Kenya           | South Africa |
| Belgium        | Kyrgyzstan      | South Korea  |
| Burkina Faso   | Latvia          | Spain        |
| Brazil         | Lebanon         | Sri Lanka    |
| Bulgaria       | Lithuania       | Sweden       |
| Canada         | Madagascar      | Switzerland  |
| China          | Malawi          | Switzerland  |
| Colombia       | Malaysia        | Syria        |
| Croatia        | Malta           | Taiwan       |
| Cuba           | Mauritania      | Thailand     |
| Cyprus         | Mexico          | Turkey       |
| Czech Republic | Mongolia        | Turkmenistan |
| Denmark        | Morocco         | Ukraine      |
| Ecuador        | Norway          | UK           |
| Egypt          | Nepal           | Uganda       |
| Ethiopia       | Netherlands     | UK           |
| Finland        | New Zealand     | Uruguay      |
| France         | North Macedonia | USA          |
| Georgia        | Norway          | Uzbekistan   |
| Germany        | Pakistan        | Venezuela    |
| Ghana          | Pakistan        | Vietnam      |
| Greece         | Pakistan        | Yemen        |
| Guatemala      | Peru            | Zambia       |
| Hungary        | Philippines     | Zimbabwe     |
| Iceland        | Portugal        |              |

## ATLAS Collaboration member nationalities

Over 5900 members of 103 nationalities



# ATLAS: A Toroidal LHC Apparatus

Investigação em Língua Portuguesa



## Portugal:

~ 25 investigadores, ~ 15 estudantes, ~ 3 técnicos

LIP - Coimbra, Minho, Lisboa

FCUL, FCTUC, UM, CEFITEC/UNL, INESC, CFMC

Programa de treino de engenheiros no CERN

## Brasil:

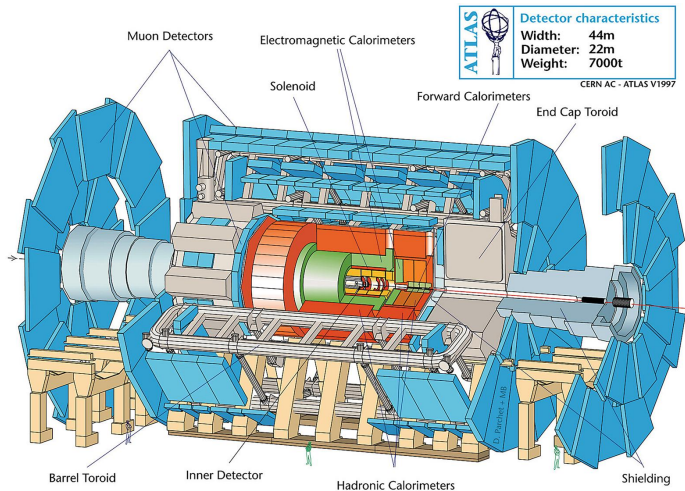
~ 50 colegas de várias instituições

UFRJ, UFJF, USP, UFSJ



# ATLAS: A Toroidal LHC Apparatus

O detector



# ATLAS: A Toroidal LHC Apparatus

O início de uma longa história



## Time line of the LHC project until the Higgs boson discovery

1984	Workshop on a Large Hadron Collider in the LEP tunnel, Lausanne.
1987	Workshop on Physics at Future Accelerators, La Thuile, Italy. The Rubbia "Long-Range Planning Committee" recommends the Large Hadron Collider as the right choice for CERN's future.
1990	European Committee for Future Accelerators (ECFA) LHC Workshop, Aachen (discussion of physics, technologies and designs for LHC experiments)
1992	General Meeting on LHC Physics and Detectors, Evian les Bains (4 general-purpose experiment designs presented along with their physics performance)
1993	Three Letters of Intent submitted to the CERN peer review committee LHCC. ATLAS and CMS selected to proceed to a detailed technical proposal.
1994	The LHC accelerator approved for construction
1996	ATLAS and CMS Technical Proposals approved.
1997	Formal approval for ATLAS and CMS to move to construction (materials cost ceiling of 475 MCHF)
1997	Construction commences (after approval of detailed engineering design of subdetectors (magnets, inner tracker, calorimeters, muon system, trigger and data acquisition))
2000	Assembly of experiments commences, LEP accelerator is closed down to make way for the LHC.
2008	LHC experiments ready for pp collisions. LHC starts operation. An incident stops LHC operation.
2009	LHC restarts operation, pp collisions recorded by LHC detectors
2010	LHC collides protons at high energy (centre of mass energy of 7 TeV)
2012	LHC operates at 8 TeV: discovery of a Higgs-like boson.

Peter Jenni

*It took a long time, and we already had a tunnel...*

# ATLAS: A Toroidal LHC Apparatus

O início de uma longa história





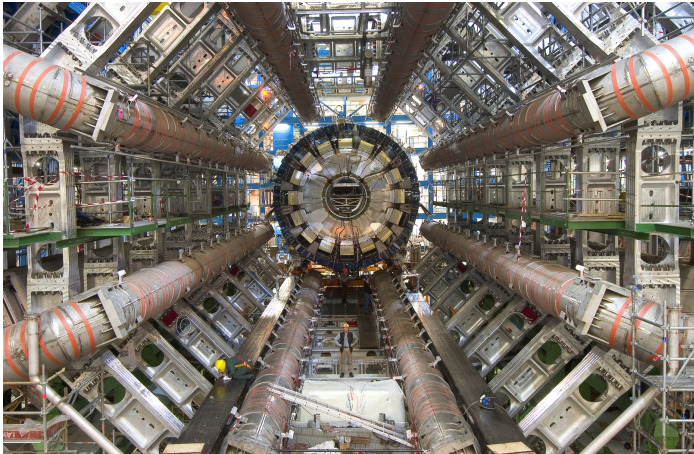
# ATLAS: A Toroidal LHC Apparatus

O início de uma longa história



# ATLAS: A Toroidal LHC Apparatus

O início de uma longa história



# ATLAS: A Toroidal LHC Apparatus

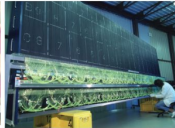
O progresso de um sub-detector



1993-1995 R&D-protótipos



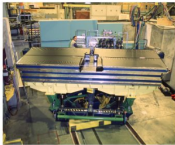
1996-2002: construção



1999-2002 Instrumentação



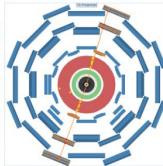
1999-2004: Electrónica



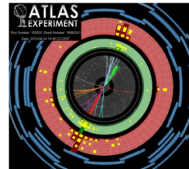
2002-2004: calibrações



2004-2006 Instalação



2007-2009 certificação  
(raios cósmicos)

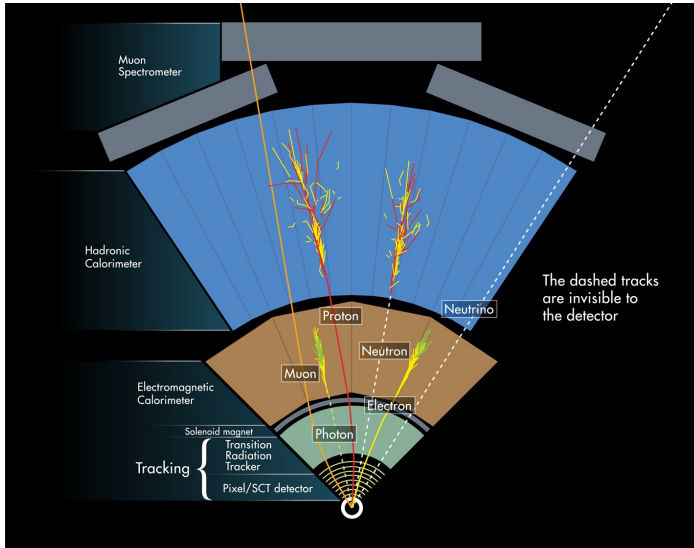


2009: aquisição/análise  
dados LHC

[Nuno Castro]

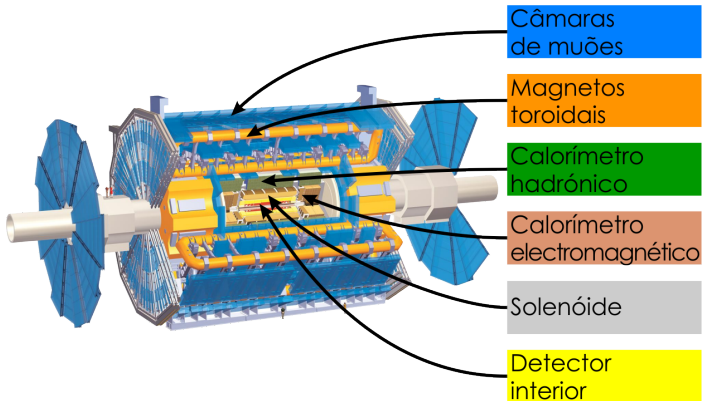
# ATLAS: A Toroidal LHC Apparatus

Funcionamento de um detector de partículas



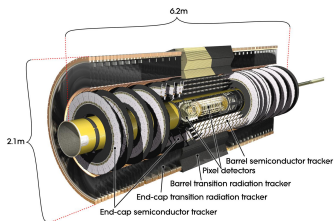
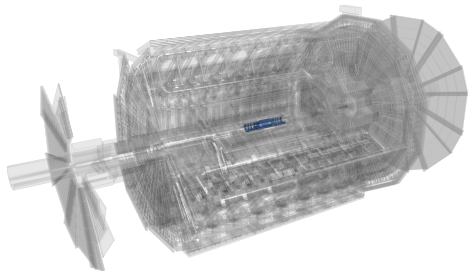
# ATLAS: A Toroidal LHC Apparatus

O detector



# ATLAS: A Toroidal LHC Apparatus

O detector interior



## Detector de Píxeis

92 milhões de píxeis de  $50 \times 400 \mu\text{m}^2$  e  $50 \times 250 \mu\text{m}^2$  em apenas  $1.9 \text{ m}^2$

## Traceador semiconductor

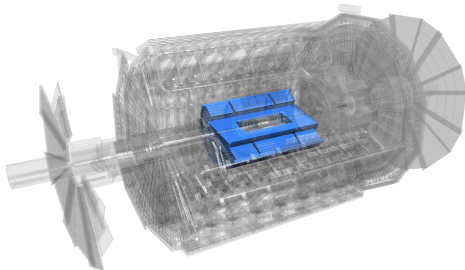
$60 \text{ m}^2$  de Silício distribuído por 4 camadas cilíndricas com *readout* a cada  $80 \mu\text{m}$

## Traceador de Radiação de Transição

350000 canais de *readout* compostos por tubos de  $4 \text{ mm}$  de diâmetro com um tubo de Tungstênio de  $0.03 \text{ mm}$  no seu centro com uma precisão na medida de partículas de  $0.17 \text{ mm}$

# ATLAS: A Toroidal LHC Apparatus

O calorímetro electromagnético



## Calorímetro de Árgon Líquido (LAr)

Objectivo de detectar electrões e fótons

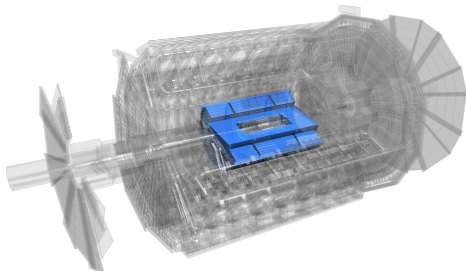
110000 canais electrónicos distribuídos por um comprimento de 6.4 m e uma espessura de 53 cm

Mantido a uma temperatura de cerca de -184 graus Celsius

Estrutura em forma de acordeão

# ATLAS: A Toroidal LHC Apparatus

O calorímetro hadrónico



## Calorímetro Hadrónico *Tile* (Azulejo)

Detecta partículas hadrónicas

Camadas de aço e plástico cintilantes num total de 420000 azulejos que pesam cerca de 2900 toneladas(!)

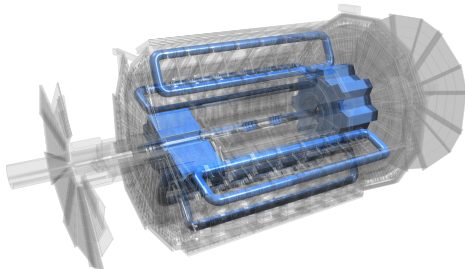
9500 tubos fotomultiplicadores





# ATLAS: A Toroidal LHC Apparatus

O sistema magnético



## Ímã do Solenóide Central

Permite a medida do momento das partículas carregadas electricamente

Campo magnético de 2 Tesla em apenas 4.5 cm de espessura (mas com um peso de 5 toneladas)

9 km de fio supercondutor com uma corrente de 7.73 kA

## Ímã Toroidal

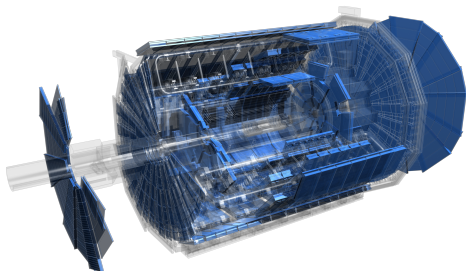
Maior ímã alguma vez construído tendo 56 km de fio supercondutor e pesando cerca de 830 toneladas

Campo magnético de 4 Tesla com uma temperatura de 4.7 K e uma corrente de 20.5 kA



# ATLAS: A Toroidal LHC Apparatus

As câmaras de muões



## **Câmaras de Fenda Fina (*Thin gap*)**

Medida das coordenadas das partículas no final do detector (440000 canais)

## **Câmaras de Placas Resistivas**

Medida das coordenadas das partículas na região central do detector (380000 canais)

## **Tubos de deriva monitorizados**

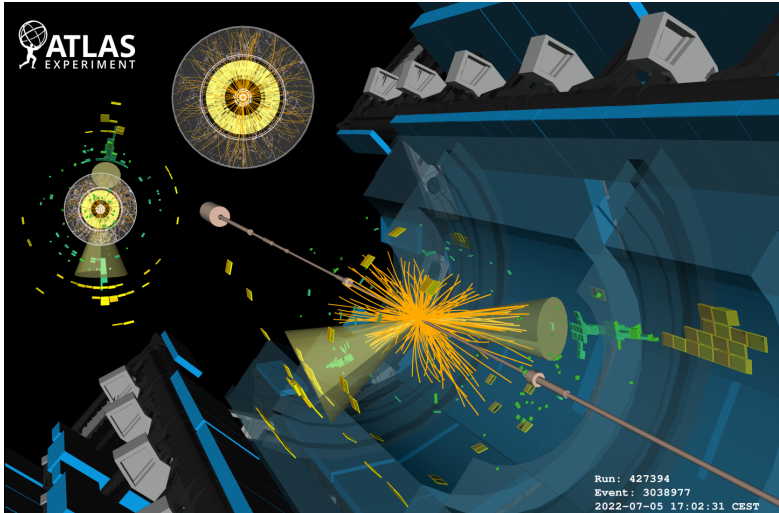
Medida da curvatura dos traços (354240 tubos com uma resolução de  $80 \mu\text{m}$ )

## **Câmaras de Tiras de Cátodos**

Medida de precisão das coordenadas no final do detector (70000 canais com uma resolução de  $60 \mu\text{m}$ )

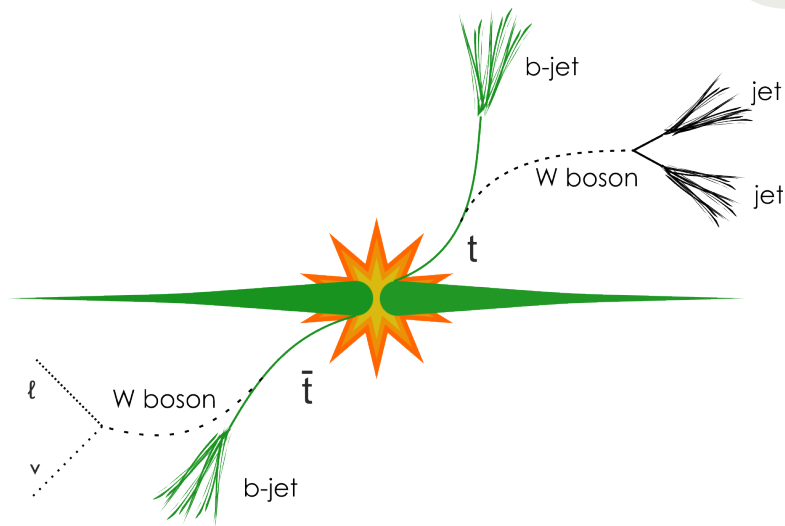
# ATLAS: A Toroidal LHC Apparatus

O resultado final



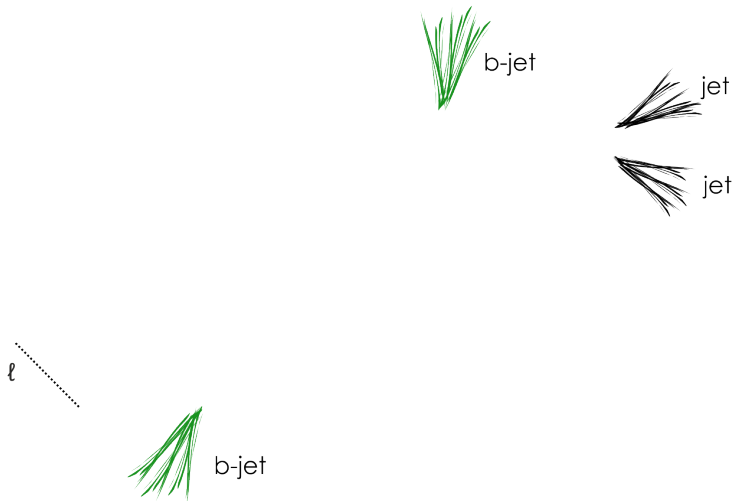
# ATLAS: A Toroidal LHC Apparatus

Deteção das partículas finais



# ATLAS: A Toroidal LHC Apparatus

Reconstrução do evento

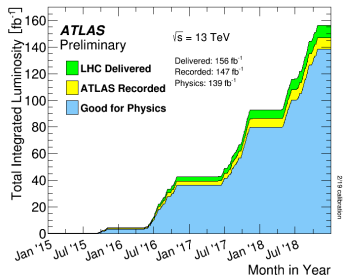
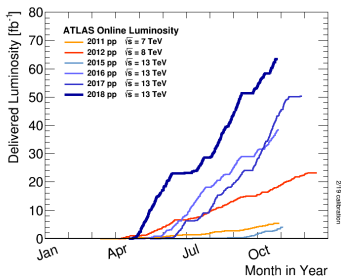


# ATLAS: A Toroidal LHC Apparatus

Aquisição de dados

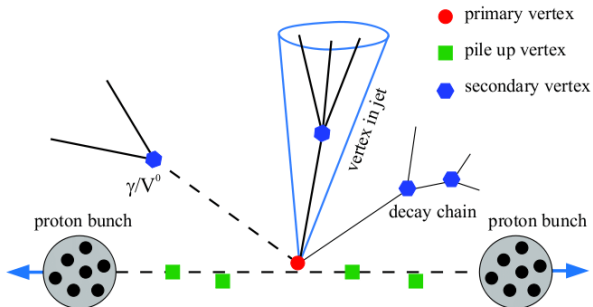


As experiências são cada vez mais eficazes a armazenar dados com qualidade





Mesmo que não haja apenas um acontecimento a cada colisão de prótons!

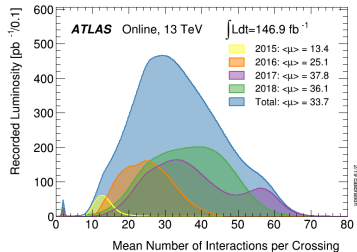
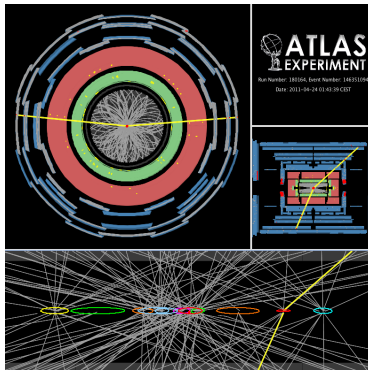


# ATLAS: A Toroidal LHC Apparatus

Aquisição de dados



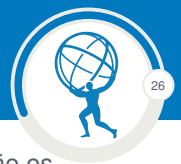
O número médio de interações por cruzamento de prótons é um parâmetro que pode ser controlado e depende do período de tomada de dados





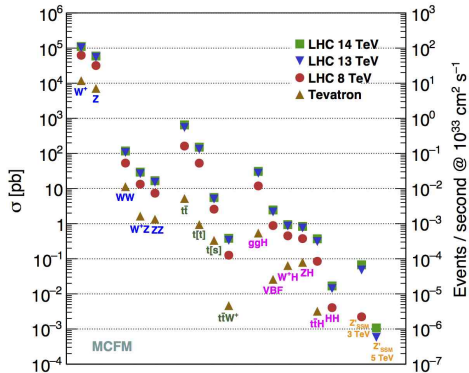
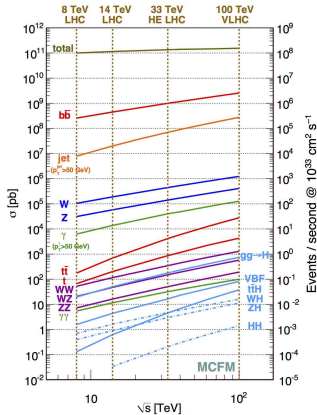
# ATLAS: A Toroidal LHC Apparatus

Escolha dos acontecimentos interessantes



26

E a verdade é que os processos mais prováveis nem sempre são os mais interessantes!



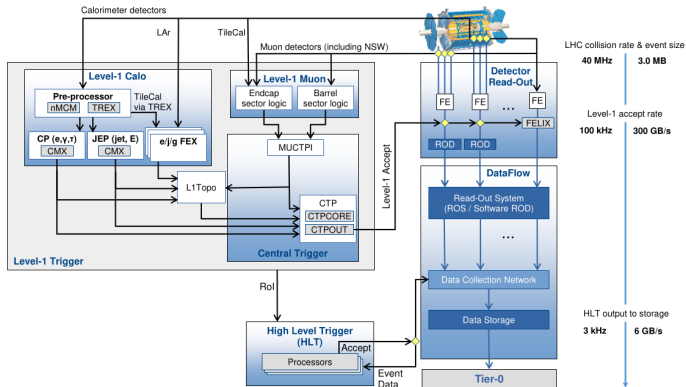


Com uma colisão de prótons (ou íons pesados) a cada 25 ns em que existem vários acontecimentos simultaneamente, torna-se impossível de armazenar todos os dados:

- ▶ Escolhas são necessárias!
- ▶ Tendo  $\sim 10$  ordens de grandeza de diferença entre a secção eficaz total do LHC e os processos mais interessantes, esta decisão tem de ser tomada considerando todos os cenários importantes - sendo resumida a cerca de 100 diferentes estados finais de física (do Modelo Padrão e não só!)

# ATLAS: A Toroidal LHC Apparatus

Escolha dos acontecimentos interessantes



# ATLAS: A Toroidal LHC Apparatus

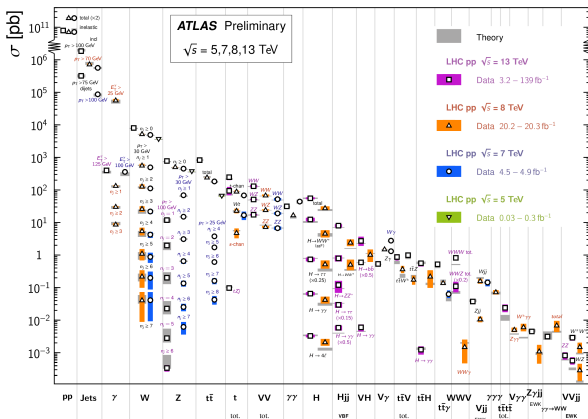
Teste ao Modelo Padrão



Com todos estes dados, podemos testar o Modelo Padrão comparando as medidas experimentais com as previsões teóricas

Standard Model Production Cross Section Measurements

Status: February 2022



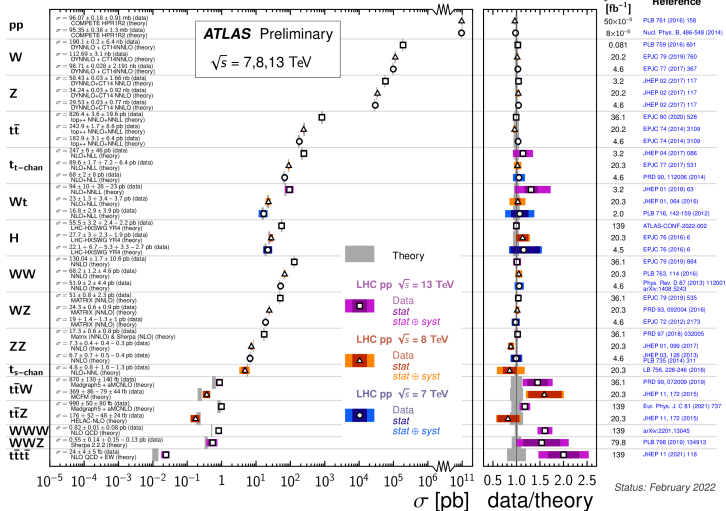
Até ao momento, o acordo é excelente!

# ATLAS: A Toroidal LHC Apparatus

Teste ao Modelo Padrão



## Standard Model Total Production Cross Section Measurements

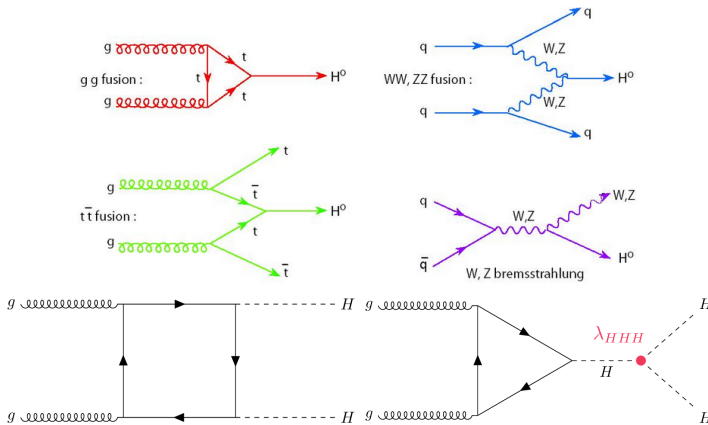


# ATLAS: A Toroidal LHC Apparatus

Propriedades do bóson de Higgs



O bóson de Higgs, a última partícula elementar a ser descoberta, pode ser produzida através de vários processos:



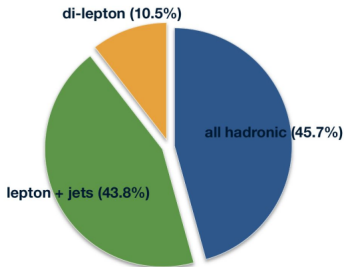
...permitindo o estudo das suas propriedades ao detalhe!

# ATLAS: A Toroidal LHC Apparatus

Propriedades do bosão de Higgs

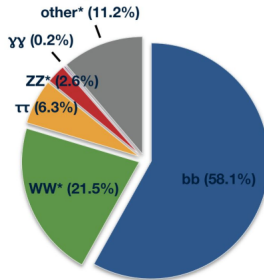


### ttbar decay BRs



- all hadronic (45.7%)
- lepton + jets (43.8%)
- di-lepton (10.5%)

### Higgs decay BRs



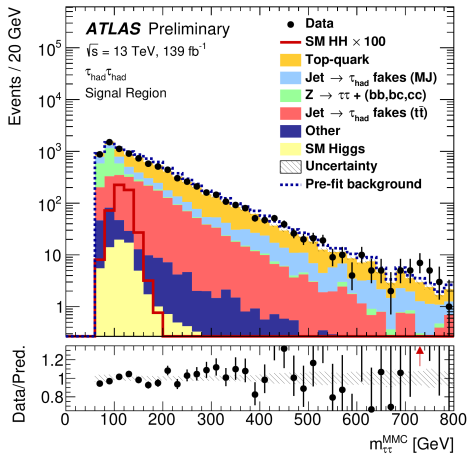
- bb (58.1%)
- WW\* (21.5%)
- $\tau\tau$  (6.3%)
- ZZ\* (2.6%)
- $\gamma\gamma$  (0.2%)
- other\* (11.2%)

smaller BR,  
higher purity  
(generally)



# ATLAS: A Toroidal LHC Apparatus

Propriedades do bosão de Higgs



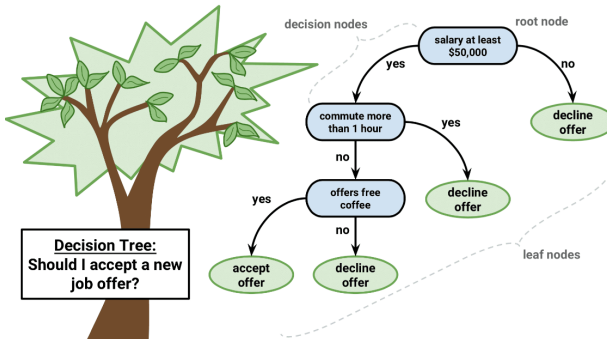


# ATLAS: A Toroidal LHC Apparatus

Propriedades do bóson de Higgs



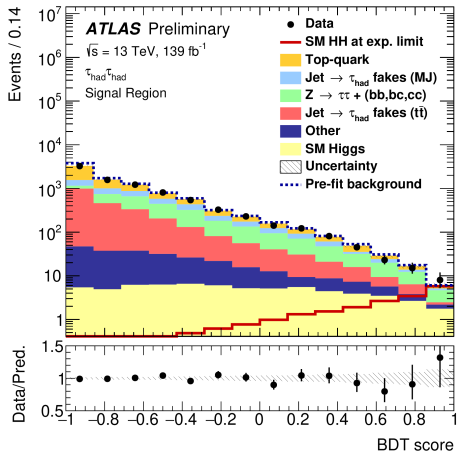
Neste tipo de tarefa, o uso da famosa *Machine Learning* torna-se uma útil ferramenta!



Tal pode ser feito através de *Boosted Decision Trees* e redes neurais, em que a complexidade das mesmas tem evoluído nos últimos anos

# ATLAS: A Toroidal LHC Apparatus

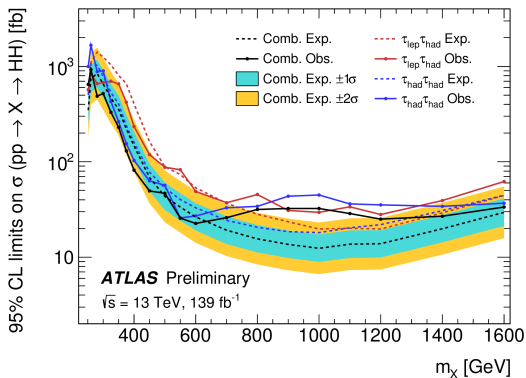
Propriedades do bosão de Higgs



Valores de BDT perto de 0 são caracterizados como fundo e valores perto de 1 como sinal - neste caso, a produção de dois bosões de Higgs



Após a otimização da nossa seleção de dados, é necessário comparar os nossos resultados esperados e obtidos com diferentes incertezas ( $\pm 1$  e  $2 \sigma$ )

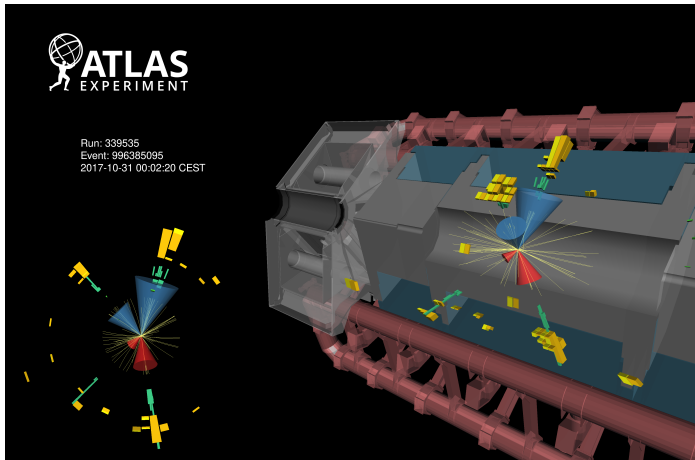


# ATLAS: A Toroidal LHC Apparatus

Propriedades do bosão de Higgs

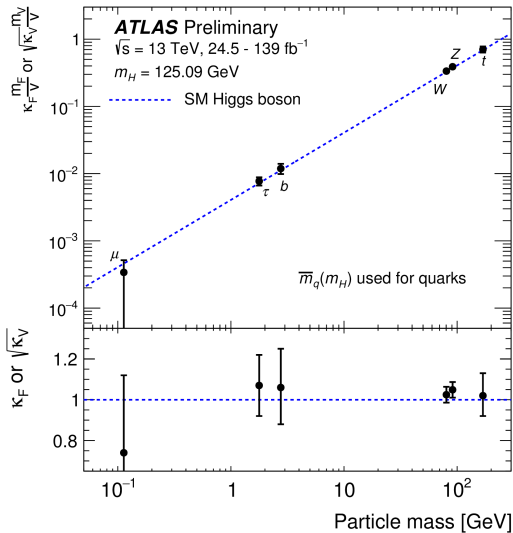


Podemos também visualizar um dos acontecimentos candidatos ao sinal!



# ATLAS: A Toroidal LHC Apparatus

Propriedades do bóson de Higgs



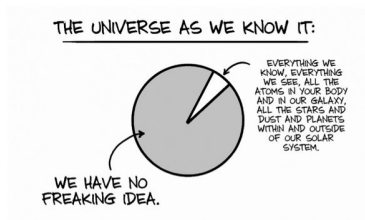
# ATLAS: A Toroidal LHC Apparatus

Para além do Modelo Padrão



Mas temos também de procurar pistas de fenómenos para além do Modelo Padrão! Porquê?

- ▶ Primeiro, porque é o nosso trabalho compreender tudo o que os nossos dados nos apresentam!
- ▶ Além disso, há imensas perguntas a responder!
  - ▶ Hierarquia da mass dos fermiões (e porquê três famílias?)
  - ▶ Assimetria entre a matéria e a anti-matéria
  - ▶ Origem da matéria escura
  - ▶ Entre outros...



# ATLAS: A Toroidal LHC Apparatus

Para além do Modelo Padrão



## ATLAS Heavy Particle Searches\* - 95% CL Upper Exclusion Limits

Status: July 2022

ATLAS Preliminary

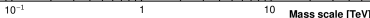
$$\int \mathcal{L} dt = (3.6 - 139) \text{ fb}^{-1}$$

$$\sqrt{s} = 8, 13 \text{ TeV}$$

Model	$\ell, \gamma$	Jets <sup>†</sup>	$E_{\text{miss}}^+$	$\int \mathcal{L} dt [\text{fb}^{-1}]$	Limit	Reference	
Extra dimensions	ADD $G_{\mu\nu} \rightarrow g/\gamma$	$0, e, \mu, \tau, \gamma$	1-4	Yes	139	$M_{\text{pl}} = 11.2 \text{ TeV}$ $M_{\text{S}} = 8.6 \text{ TeV}$ $M_{\text{A}} = 9.4 \text{ TeV}$ $M_{\text{H}} = 9.55 \text{ TeV}$	$n = 2$ 2107.10074 1910.04147 1512.02586
	ADD OBH	$2\gamma$	-	-	36.7		$n = 6$ 3102.02840
	ADD BH multijet	$2\gamma$	$\geq 3j$	-	3.6		$M_{\text{pl}} = 3 \text{ TeV}$ , rot BH 2102.13405 1939.02260
	RS1 $G_{\mu\nu} \rightarrow \gamma\gamma$	$2\gamma$	-	-	139	$G_{\mu\nu}$ mass $G_{\mu\nu}$ mass	$k/\Lambda_{\text{pl}} = 0.1$ $k/\Lambda_{\text{S}} = 1.0$ $k/\Lambda_{\text{H}} = 1.0$ 2004.14636
	Bulk RS $G_{\mu\nu} \rightarrow WW/ZZ$	$2\gamma$	-	-	36.1	$2.3 \text{ TeV}$ $2.0 \text{ TeV}$	$\Gamma/m = 15\%$ 1804.10823
	Bulk RS $G_{\mu\nu} \rightarrow WV \rightarrow \nu\mu q$	$1, e, \mu$	$2j/1j$	Yes	139	$3.8 \text{ TeV}$	1903.09776
	Bulk RS $g_{\text{KK}} \rightarrow t\bar{t}$	$1, e, \mu$	$\geq 1b, \geq 1A, 2j$	Yes	36.1		
	Bulk RS $g_{\text{KK}} \rightarrow t\bar{t}$	$1, e, \mu$	$\geq 2b, \geq 3j$	Yes	36.1		
	2UED / RPP	$2, e, \mu$	-	-	139	$1.6 \text{ TeV}$	$\text{Tan}(\beta), 2j, (A^{(1,2)} \rightarrow t\bar{t}) = 1$
	Gauge bosons	SSM $Z' \rightarrow \ell\ell$	$1, e, \mu$	-	-	139	$Z'$ mass $Z'$ mass
SSM $Z' \rightarrow \tau\tau$		$2\gamma$	-	-	36.1	$2.42 \text{ TeV}$	1805.05939
Leptophobic $Z' \rightarrow b\bar{b}$		$0, e, \mu$	$\geq 2b$	Yes	139	$Z'$ mass $Z'$ mass	2005.05138 1936.05609
Leptophobic $Z' \rightarrow t\bar{t}$		$0, e, \mu$	$\geq 1b, \geq 2j$	Yes	139	$Z'$ mass $Z'$ mass	2004.14636
SSM $W' \rightarrow \ell\nu$		$1, e, \mu$	-	-	139	$W'$ mass $W'$ mass	ATLAS-COANF-2021-025 ATLAS-COANF-2021-043
SSM $W' \rightarrow \nu\tau$		$1\tau$	-	-	139	$W'$ mass $W'$ mass	ATLAS-COANF-2022-005
SSM $W' \rightarrow b\bar{b}$		$1, e, \mu$	$\geq 1b, \geq 1j$	Yes	139	$W'$ mass $W'$ mass	$g_{\nu} = 3$ $g_{\nu\tau} = 1, g_{\tau} = 0$ 2207.00230
HVT $W' \rightarrow WZ \rightarrow \nu\mu q$ model B		$1, e, \mu$	$2j/1j$	Yes	139	$W'$ mass $W'$ mass	2207.00230
HVT $W' \rightarrow WZ \rightarrow \nu\tau$ model C		$3, e, \mu$	$2j$ (VBF)	Yes	139	$W'$ mass $W'$ mass	$m(N_{\mu}) = 0.5 \text{ TeV}$ , $\ell_{\mu} = g_{\mu}$ 1904.12679
HVT $W' \rightarrow WH \rightarrow \nu b\bar{b}$ model B		$1, e, \mu$	$1-2b, 1-1j$	Yes	139	$W'$ mass $W'$ mass	
HVT $Z' \rightarrow ZH \rightarrow \ell\ell + b\bar{b}$ model B	$0, e, \mu$	$1-2b, 1-1j$	Yes	139	$Z'$ mass $Z'$ mass		
LRSM $W_{\mu} \rightarrow \mu N_{\mu}$	$2\mu$	$1j$	-	80	$W_{\mu}$ mass		
CI	CI $q\bar{q}q$	$2, e, \mu$	-	-	37.0	A	$21.8 \text{ TeV}$ , $\eta_{\text{CI}}$ 1703.09127
	CI $\ell\ell q$	$2, e, \mu$	-	-	139	A	$35.8 \text{ TeV}$ 2008.12946
	CI $e\bar{e}e$	$2\mu$	$1b$	-	139	A	$g = -1$ 2105.13847
	CI $\mu\mu\bar{b}b$	$2\mu$	$1b$	-	139	A	$g = 1$ 2105.13847
CI $e\bar{e}t\bar{t}$	$\geq 1\mu, \geq 1b, \geq 1j$	-	-	36.1	A	$ c_{\mu}  = 4\pi$ 1811.02305	
DM	Axial-vector med. (Dirac DM)	$0, e, \mu, \tau, \gamma$	1-4	Yes	139	$\mu_{\text{DM}}$ $\mu_{\text{DM}}$	$g_{\nu} = 0.25, g_{\mu} = 1, m(\chi) = 1 \text{ GeV}$ 2102.10874
	Pseudo-scalar med. (Dirac DM)	$0, e, \mu, \tau, \gamma$	1-4	Yes	139	$\mu_{\text{DM}}$ $\mu_{\text{DM}}$	$g_{\nu} = 1, g_{\mu} = 1, m(\chi) = 1 \text{ GeV}$ 2102.10874
DM	Vector med. $Z'$ -2HDM (Dirac DM)	$0, e, \mu, \tau$	$2b$	Yes	139	$\mu_{\text{DM}}$ $\mu_{\text{DM}}$	$\tan\beta = 1, g_{\nu} = 0.5, m(\chi) = 100 \text{ GeV}$ 2108.13391
	Pseudo-scalar med. 2HDM-a	multi-channel	-	-	139	$\mu_{\text{DM}}$ $\mu_{\text{DM}}$	$\tan\beta = 1, g_{\nu} = 1, m(\chi) = 10 \text{ GeV}$ ATLAS-COANF-2021-036
LO	Scalar LQ 1 <sup>st</sup> gen	$2, e$	$\geq 2j$	Yes	139	LQ mass LQ mass	$\beta = 1$ 2006.05872
	Scalar LQ 2 <sup>nd</sup> gen	$2, \mu$	$\geq 2j$	Yes	139	LQ mass LQ mass	$\beta = 1$ 2106.05872
	Scalar LQ 3 <sup>rd</sup> gen	$1, \tau$	$2b$	Yes	139	LQ mass LQ mass	$\beta = 1$ 2106.07865
	Scalar LQ 3 <sup>rd</sup> gen	$0, e, \mu$	$\geq 2j, \geq 2b$	Yes	139	LQ mass LQ mass	$\beta = 1$ 2004.14060
	Scalar LQ 3 <sup>rd</sup> gen	$\geq 2, e, \mu, \tau$	$\geq 1b, \geq 1j$	Yes	139	LQ mass LQ mass	$\beta = 1$ 2101.11582
Scalar LQ 3 <sup>rd</sup> gen	$0, e, \mu, \tau$	$0, 1b, 2j$	Yes	139	LQ mass LQ mass	$\beta = 1$ 2101.10237	
Vector LQ 3 <sup>rd</sup> gen	$1\tau$	$2b$	Yes	139	LQ mass LQ mass	$\beta = 1$ 2108.07865	
Vector-like fermions	VLO $TT \rightarrow Zt + X$	$2e/2\mu/3e, \mu$	$\geq 1b, \geq 1j$	-	139	T mass B mass	SU(2) doublet SU(2) doublet ATLAS-COANF-2021-024
	VLO $BB \rightarrow WW, Z\gamma + X$	multi-channel	-	-	36.1	B mass B mass	1808.02343
	VLO $Te\bar{t} \rightarrow Te\bar{t} + X$	$2j$ (SS) $\geq 2\mu, \geq 1b, \geq 1j$	-	-	36.1	$L_{\mu}$ mass $L_{\mu}$ mass	$1807.11953$
	VLO $T \rightarrow H\tau, Z\tau$	$1, e, \mu$	$\geq 1b, \geq 3j$	Yes	139	T mass T mass	SU(2) singlet, $\tau = 0.5$ ATLAS-COANF-2021-040
	VLO $Y \rightarrow W\tau$	$1, e, \mu$	$\geq 1b, \geq 1j$	Yes	36.1	Y mass Y mass	$\beta = 1$ SU(2) doublet, $c_{\nu} = 0.3$ 1812.07343
VLO $B \rightarrow bb$	$1, e, \mu$	$\geq 1b, \geq 1j, \geq 1A$	Yes	139	B mass B mass	SU(2) doublet, $c_{\nu} = 0.3$ ATLAS-COANF-2021-014	
VLL $T^+ \rightarrow Z\tau/H\tau$	multi-channel	$\geq 1j$	Yes	139	T mass B mass	SU(2) doublet SU(2) doublet ATLAS-COANF-2022-044	
Exotic fermions	Exotic quark $q' \rightarrow q\bar{q}$	-	$2j$	-	139	$q'$ mass $q'$ mass	only $u'$ and $d'$ , $A = m(q')$ 1910.08447
	Exotic quark $q' \rightarrow q\gamma$	$1\gamma$	$1j$	-	36.7	$q'$ mass $q'$ mass	only $u'$ and $d'$ , $A = m(q')$ 1709.10440
	Exotic quark $q' \rightarrow qg$	-	$1b, 1j$	-	139	$q'$ mass $q'$ mass	1910.08447
	Exotic lepton $\ell'$	$3, e, \mu, \tau$	-	-	20.3	$\ell'$ mass $\ell'$ mass	$A = 3.0 \text{ TeV}$ 1411.2921
Exotic lepton $\nu'$	$3, e, \mu, \tau$	-	-	20.3	$\nu'$ mass $\nu'$ mass	$A = 1.6 \text{ TeV}$ 1411.2921	
Other	Type II Seesaw	$2, 3.4, e, \mu$	$\geq 2j$	Yes	139	$H^{\pm}$ mass $H^{\pm}$ mass	$m(W_{\mu}) = 4.1 \text{ TeV}$ , $g_{\nu} = g_{\mu}$ 2202.02039
	LRSM Magrana $\nu$	$2, \mu$	$2j$	Yes	36.1	$N_{\mu}$ mass $N_{\mu}$ mass	1809.11105
	Higgs triplet $H^{\pm} \rightarrow W^{\pm} W^{\pm}$	$2, 3.4, e, \mu$ (SS)	various	Yes	139	$H^{\pm}$ mass $H^{\pm}$ mass	$\beta = 1$ 2101.11891
	Higgs triplet $H^{\pm} \rightarrow \ell\ell$	$2, 3.4, e, \mu$ (SS)	-	-	139	$H^{\pm}$ mass $H^{\pm}$ mass	ATLAS-COANF-2022-010
	Higgs triplet $H^{\pm} \rightarrow \ell\tau$	$3, e, \mu, \tau$	-	-	20.3	$H^{\pm}$ mass $H^{\pm}$ mass	DV production, $\beta(H^{\pm} \rightarrow \tau\tau) = 1$ 1411.2921
	Multi-charged particles	-	-	-	139	multi-charged particles mass monopole mass	DV production, $ \ell  = 5_{\mu}$ ATLAS-COANF-2022-034 1905.10130
Magnetic monopoles	-	-	-	34.4	$\mu_{\text{DM}}$ $\mu_{\text{DM}}$	DV production, $ \ell  = L_{\mu}, \text{ sph } 1/2$	

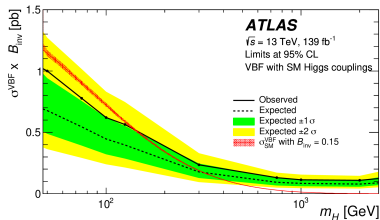
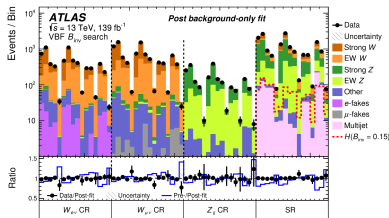
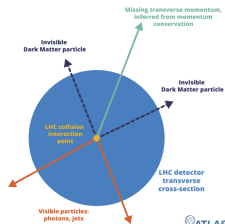
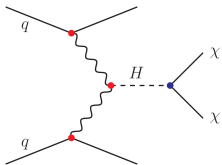
\*Only a selection of the available mass limits on new states or phenomena is shown.

† Small-radius (large-radius) jets are denoted by the letter (j) (J).



# ATLAS: A Toroidal LHC Apparatus

Para além do Modelo Padrão



Para mais detalhes, ver: [JHEP08\(2022\)104](https://arxiv.org/abs/2205.08137)

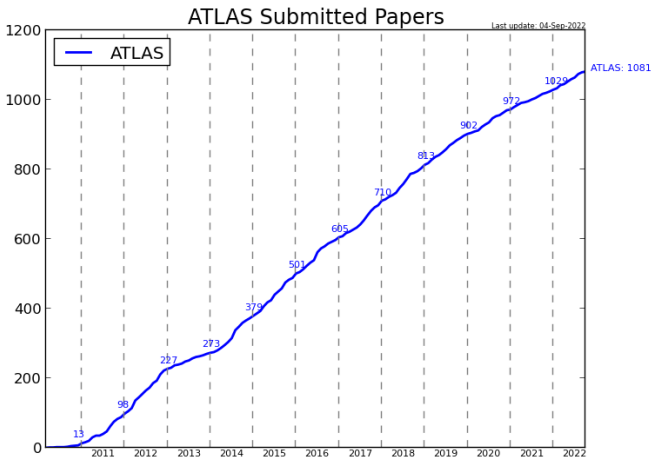


# ATLAS: A Toroidal LHC Apparatus

Resumo dos resultados de ATLAS

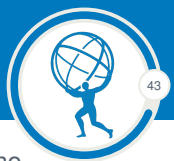


Impossível de resumir todos os resultados de ATLAS apenas numa apresentação!



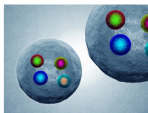
# ATLAS: A Toroidal LHC Apparatus

Resumo dos resultados de ATLAS



Para cada novo resultado importante, ATLAS publica um pequeno resumo com uma linguagem mais direccionada aos seus fãs não cientistas: <https://atlas.cern/Updates/Briefing>

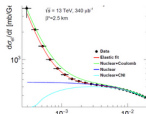
## Briefings



### ATLAS observes potential four-charm tetraquark

In a new analysis presented at the ICHEP 2022 conference, ATLAS physicists found evidence of a four-charm-quark excess. Like the LHCb Collaboration, ATLAS sees both the  $X(6900)$  particle and a broad structure at threshold.

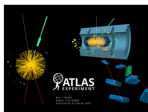
Physics Briefing | 9 July 2022



### ATLAS measures quantum interference when protons bounce off each other

In a new result presented at ICHEP 2022, ATLAS physicists set out to measure proton scattering at microradian angles and study this quantum interference.

Physics Briefing | 8 July 2022



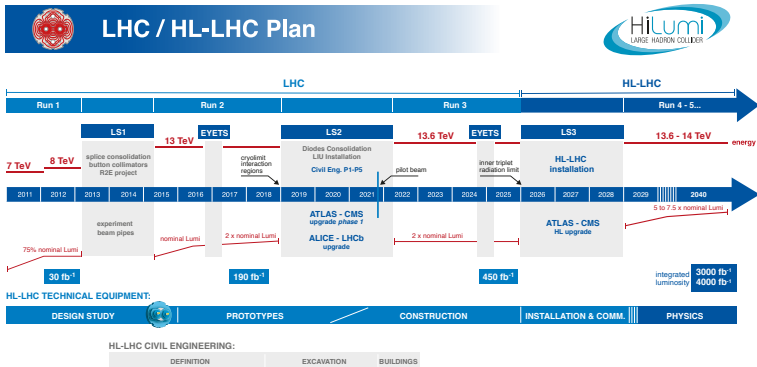
### ATLAS measures joint polarisation of W and Z bosons

In a new result presented at the ICHEP 2022 conference, ATLAS physicists have been able to observe events with both a W and Z boson simultaneously polarised longitudinally for the very first time.

Physics Briefing | 7 July 2022

# ATLAS: A Toroidal LHC Apparatus

O futuro de ATLAS e do LHC



*"Enquanto houver estrada pra andar... A gente vai continuar!"*

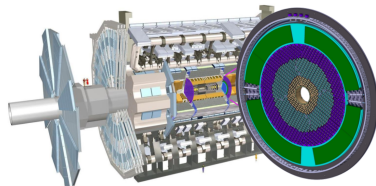
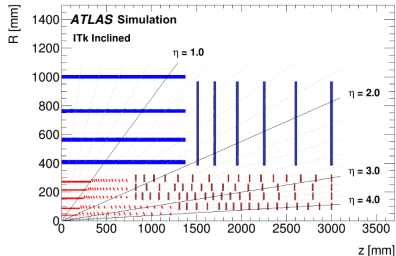
# ATLAS: A Toroidal LHC Apparatus

O futuro de ATLAS e do LHC



O HL-LHC desafia a electrónica de todo o detector, especialmente os sub-detectores mais expostos à radiação:

- ▶ Inner Tracker (ITk) Strips and Pixels
- ▶ LAr e TileCal
- ▶ High Granularity Timing Detector (HGTD)
- ▶ Muons
- ▶ Trigger e Data Acquisition



# ATLAS: A Toroidal LHC Apparatus

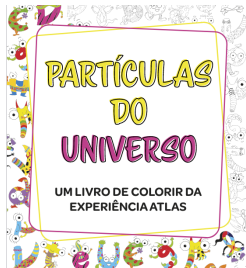
O que podemos fazer nas nossas escolas?



- 🔗 ATLAS Open Data
- 🔗 Livros de colorir em Língua Portuguesa
- 🔗 Masterclasses
- 🔗 Visitas virtuais (já apresentado pelo Denis Damazio)
- 🔗 Realidade Virtual

E muito mais em:

<https://atlas.cern/Resources>



How to rediscover the Higgs boson – ATLAS Open Data Tutorial

ATLAS Experiment



# Obrigada pela atenção!

Perguntas?

✉ [ana.peixoto@cern.ch](mailto:ana.peixoto@cern.ch)