

# Probing new physics at the LHC: searches for heavy top-like quarks with the ATLAS experiment

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Bellaterra, 28th of February, 2014

# Four questions, one dissertation

- ▶ Why? bother with “new physics”

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- ▶ **Where?** is all happening

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- ▶ **What?** are we looking at

# Four questions, one dissertation

- ▶ Why? bother with “new physics”
- ▶ Where? is all happening
- ▶ What? are we looking at
- ▶ How?

# Outline

Theoretical framework

The ATLAS experiment at the LHC

Monte Carlo simulation

Event reconstruction

Searches for vector-like top partner pairs in the single lepton channel

Search for  $T\bar{T}$  decaying to  $Wb + X$

Search for  $T\bar{T}$  decaying to  $Ht + X$

Final results

Conclusions and outlook

# Standard Model as an effective theory

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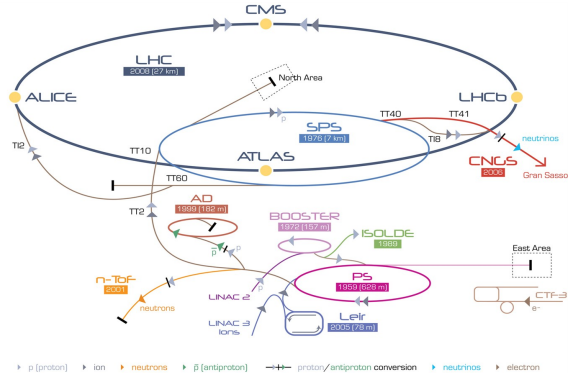
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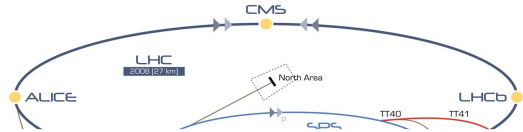


# The LHC complex



LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron  
 AD Antiproton Decelerator CTF-3 Clic Test Facility CNUS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice  
 LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-Tof Neutrons Time Of Flight

# The LHC complex



Parameter	designed	2012
Beam energy (TeV/c)	7	4
Beta function $\beta^*$ (m)	0.55	0.6
Max. No. bunches/beam	2808	1380
Max. No. protons/bunch	$1.15 \times 10^{11}$	$1.7 \times 10^{11}$
Bunch spacing (ns)	25	50
Peak luminosity ( $\text{cm}^{-2}\text{s}^{-1}$ )	$1 \times 10^{34}$	$7.7 \times 10^{33}$
Emittance $\varepsilon_n$ ( $\mu\text{rad}$ )	3.75	2.5
Max. $\langle \mu \rangle$	19	37

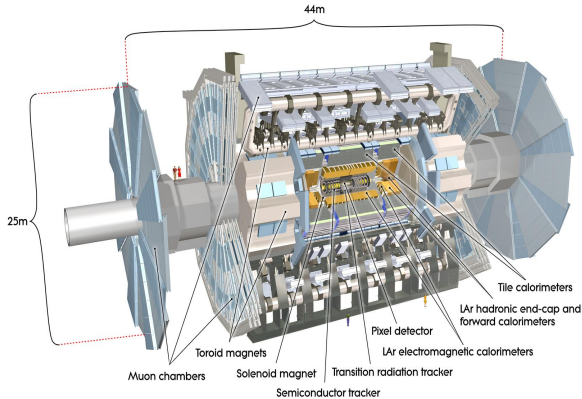
▶ p [proton]   ▶ ion   ▶ neutrons   ▶  $\bar{p}$  [antiproton]   ↔ proton/antiproton conversion   ▶ neutrinos   ▶ electron

LHC Large Hadron Collider   SPS Super Proton Synchrotron   PS Proton Synchrotron  
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# The ATLAS Detector

A general purpose experiment

- ▶ vertex detector and central tracker
- ▶ superconducting solenoid
- ▶ electromagnetic and hadronic calorimeters
- ▶ muon spectrometer
- ▶ superconducting toroids
- ▶ high hermeticity (full  $\phi$  and  $|\eta| < 5$ )

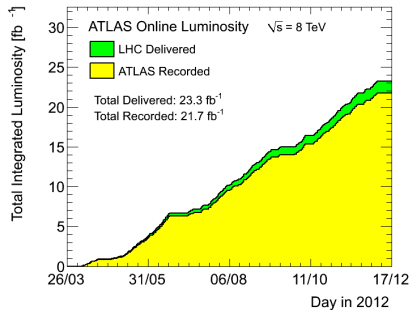


# The ATLAS Detector

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**In 2012  $21.7\text{fb}^{-1}$  collected at  $\sqrt{s} = 8\text{ TeV}$ !**



See [ATLAS public page](#)

Will present results obtained with  $14.3\text{fb}^{-1}$  of 2012 data

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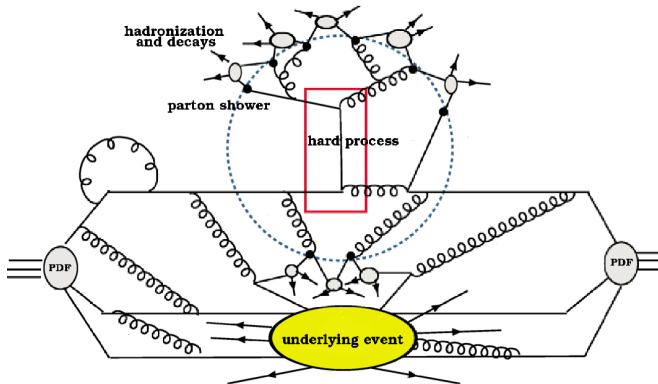
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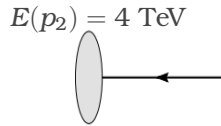
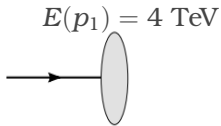
# Modelling of hadron collisions

want to do physics at hadron colliders?  
need a good understanding of incoming hadrons



# Modelling of hadron collisions

Drawings from [?]

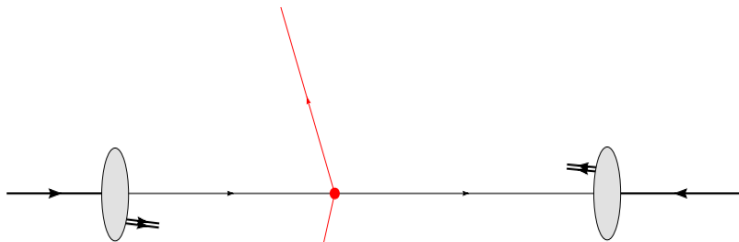


Quarks are distributed according to PDFs inside the proton



initial energy unknown

# Hard scattering of two partons

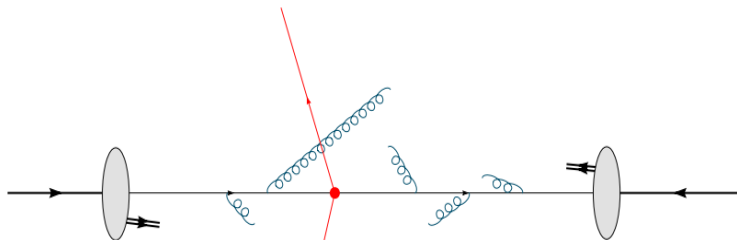


asymptotic freedom: high energy  $\longleftrightarrow$  low  $\alpha_S$

$\Downarrow$   
(fixed order) pQCD



# Parton showering

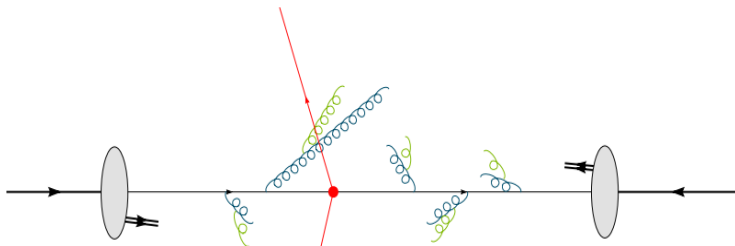


QCD emission:  $q \rightarrow gq$ ,  $g \rightarrow gg$ ,  $g \rightarrow q\bar{q}$



higher-order corrections

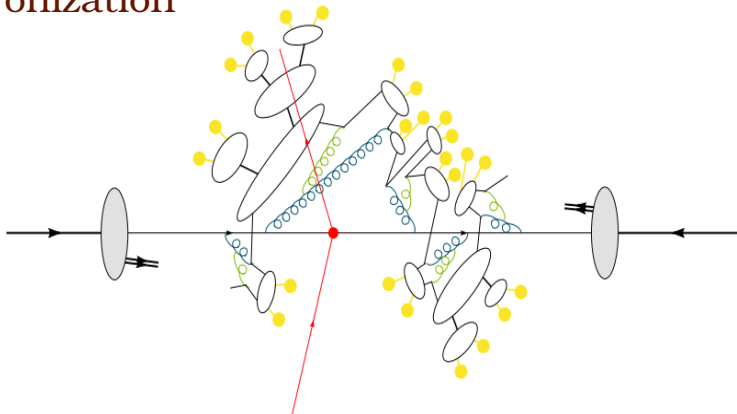
# Parton showering



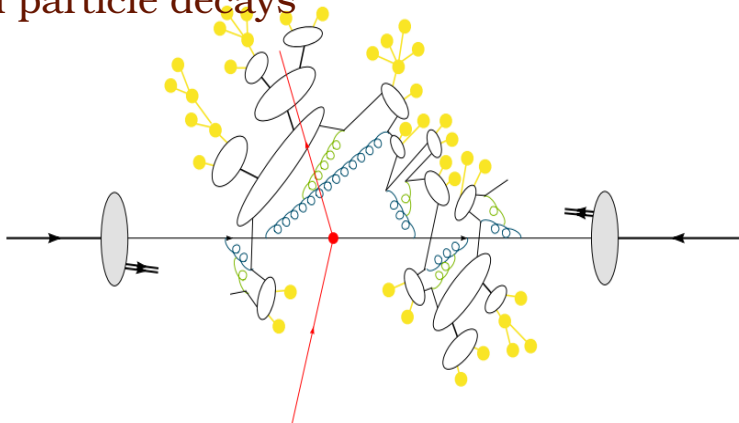
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⇓  
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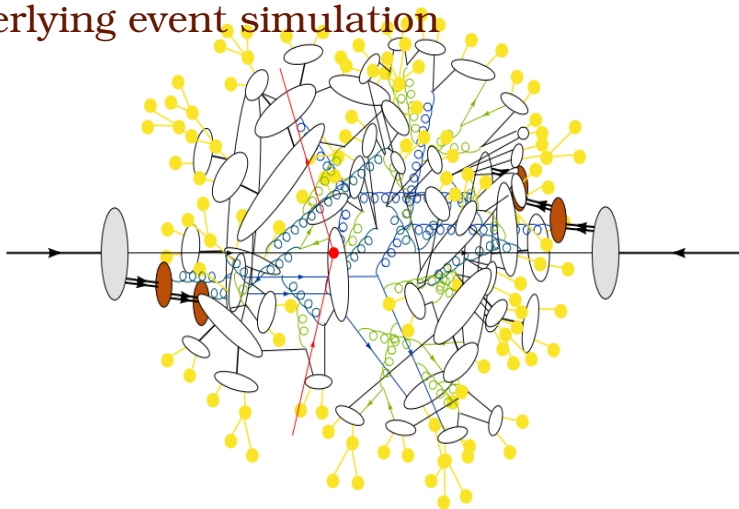
# Hadronization



# Final particle decays



# Underlying event simulation



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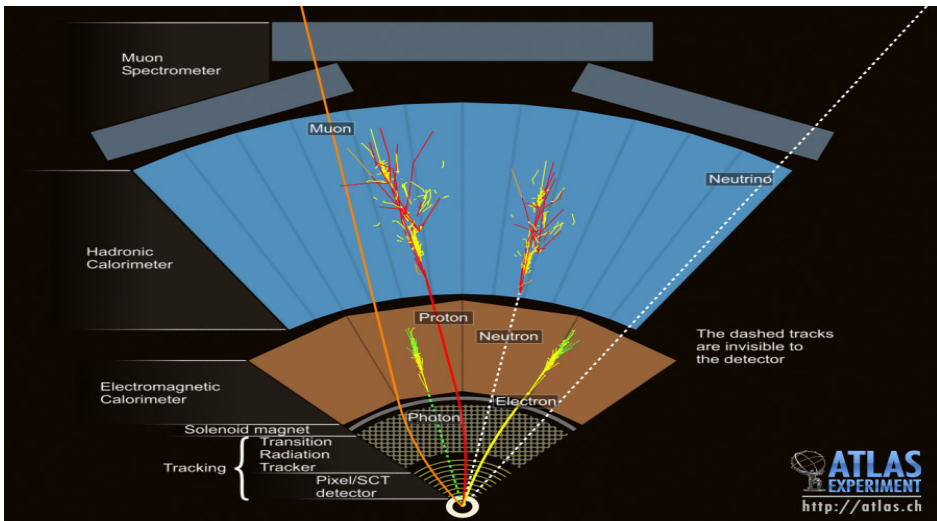
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# Physics objects puzzle



# One lepton



# Many jets

# Missing transverse energy

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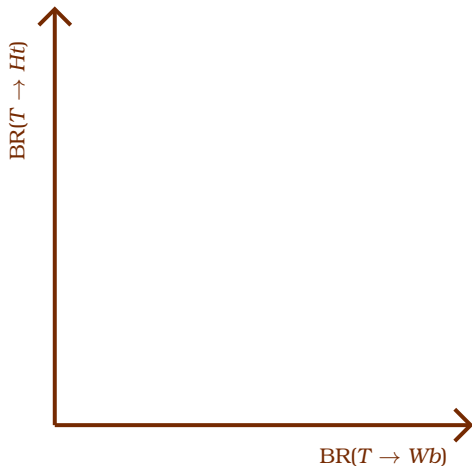
# One lepton

# Model Independent Strategy started Oct 2012 [?]

- Build a 2-dim plane to scan model mixing

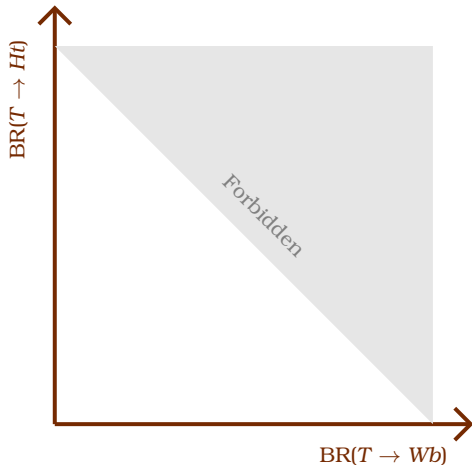


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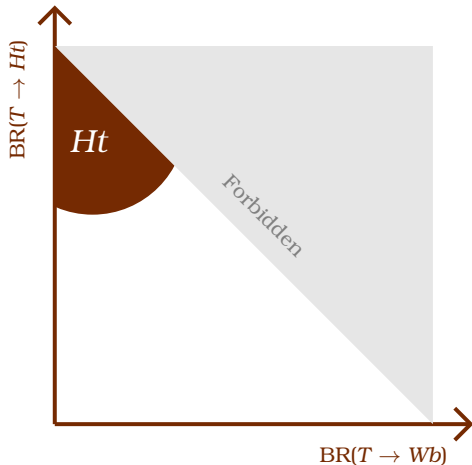
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- Build a 2-dim plane to scan model mixing
- Sum of BRs is 1<sup>(a)</sup>

$$^{(a)} BR(T \rightarrow Zt) = 1 - BR(T \rightarrow Ht) - BR(T \rightarrow Wb)$$

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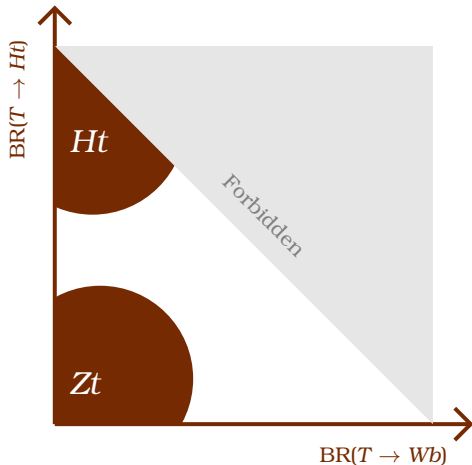


- Build a 2-dim plane to scan model mixing
- Sum of BRs is 1<sup>(a)</sup>
- Different analyses are sensitive to different areas

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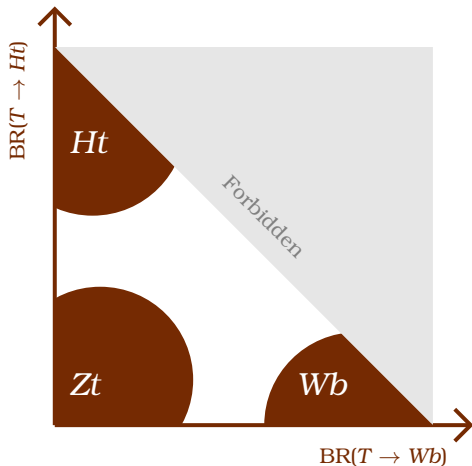
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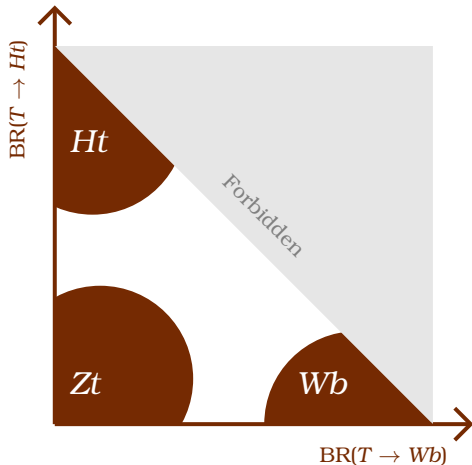
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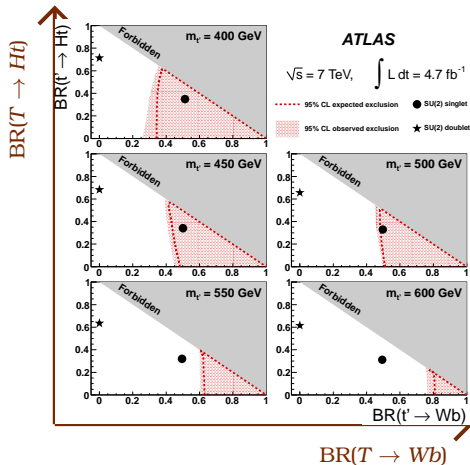
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- Set exclusion using  $CL_s$  technique [?, ?]

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- Build a 2-dim plane to scan model mixing
- Sum of BRs is 1<sup>(a)</sup>
- Different analyses are sensitive to different areas
- Set exclusion using  $CL_s$  technique [?, ?]
- Updating 7 TeV results

<sup>(a)</sup>  $BR(T \rightarrow Zt) = 1 - BR(T \rightarrow Ht) - BR(T \rightarrow Wb)$

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## **BACKUP SLIDES**

# LHC parameters

Parameter	designed	2010	2011	2012
Beam energy (TeV/c)	7	3.5	3.5	4
Beta function $\beta^*$ (m)	0.55	2.0/3.5	1.5/1.0	0.6
Max. No. bunches/beam	2808	368	1380	1380
Max. No. protons/bunch	$1.15 \times 10^{11}$	$1.2 \times 10^{11}$	$1.45 \times 10^{11}$	$1.7 \times 10^{11}$
Bunch spacing (ns)	25	150	75/50	50
Peak luminosity ( $\text{cm}^{-2}\text{s}^{-1}$ )	$1 \times 10^{34}$	$2.1 \times 10^{32}$	$3.7 \times 10^{33}$	$7.7 \times 10^{33}$
Emittance $\varepsilon_n$ ( $\mu\text{rad}$ )	3.75	2.0	2.4	2.5
Max. $\langle \mu \rangle$	19	4	17	37

**Table:** Overview of some parameters for the LHC performance comparing the design values with their time evolution during the first long run operation in 2010-2013 [?].