The Discovery of the Higgs Boson

New trends in Higgs Physics at LHC

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Taller de Altas Energias, Benasque 2013

Disclaimer

The Higgs boson

"The" refers to the one discovered

It is nevertheless the main question: which Higgs boson is it?

Menu “A la Carte…”

1.- Historical context

2.- Brief History of the Discovery

3.- How to read an exclusion or significance plot?

4.- Overview of channels and their results

5.- Couplings analysis

6.- Main quantum numbers

7.- Implications (Vacuum stability, SUSY)

8.- Electroweak precision data

9.- Searches for BSM Higgs (concise review)

10.- Total width through interferometry

11.- Future projects

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… in 2013 Entrance of the H^0 in the PDG!

Higgs Bosons — H^0 and $H^{\pm}$

A REVIEW GOES HERE – Check our WWW List of Reviews

NODE=S055
NODE=S055

CONTENTS:

NODE=S055CNT
NODE=S055CNT

NODE=S055CNT

H^0 (Higgs Boson)

NODE=S055210

The observed signal is called a Higgs Boson in the following, although its detailed properties and in particular the role that the new particle plays in the context of electroweak symmetry breaking need to be further clarified. The signal was discovered in searches for a Standard Model (SM)-like Higgs. See the following section for mass limits obtained from those searches.

NODE=S055210

H^0 MASS

NODE=S055HBM
NODE=S055HBM

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT	
125.9±0.4 OUR AVERAGE				
125.8±0.4±0.4	[1] CHATRCHYAN 13J	CMS	pp, 7 and 8 TeV	
126.0±0.4±0.4	[2] AAD 12AI	ATLS	pp, 7 and 8 TeV	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
126.2±0.6±0.2	[3] CHATRCHYAN 13J	CMS	pp, 7 and 8 TeV	OCCUR=2
125.3±0.4±0.5	[4] CHATRCHYAN 12N	CMS	pp, 7 and 8 TeV	

[1] Combined value from ZZ and $\gamma\gamma$ final states. NODE=S055HBM;LINKAGE=CA

[2] AAD 12AI obtain results based on 4.6–4.8 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.8–5.9 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.9 σ is observed at m_{H^0} = 126 GeV. See also AAD 12DA. NODE=S055HBM;LINKAGE=AA

[3] Result based on $ZZ \rightarrow 4\ell$ final states in 5.1 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 12.2 fb^{-1} at E_{cm} = 8 TeV. NODE=S055HBM;LINKAGE=CT

[4] CHATRCHYAN 12N obtain results based on 4.9–5.1 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.1–5.3 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.0 σ is observed at about m_{H^0} = 125 GeV. See also CHATRCHYAN 12BY. NODE=S055HBM;LINKAGE=CH

Inaugural entrance of the Higgs boson in the PDG particle listing !

$$H^0$$

2013 EPS-HEP Prize

European Physical Society
High Energy and Particle Physics Division

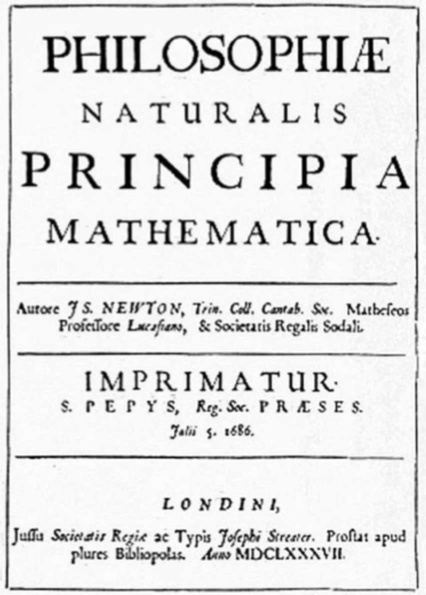
The 2013 High Energy and Particle Physics Prize, for an outstanding contribution to High Energy Physics, is awarded to the ATLAS and CMS collaborations, "for the discovery of a Higgs boson, as predicted by the Brout-Englert-Higgs mechanism", and to Michel Della Negra, Peter Jenni, and Tejinder Virdee, "for their pioneering and outstanding leadership rôles in the making of the ATLAS and CMS experiments".

HEP 2013
Stockholm
18-24 July 2013
(info@eps-hep2013.eu)

October 8, 2013…

?

Crowning of half a century of theoretical developments and Higgs Hunt ?


PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore J S. NEWTON, *Trin. Coll. Cantab. Soc.* Matheſeos
Profeſſore *Lucaſiano*, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,
Juſſu *Societatis Regiæ* ac Typis *Joſephi Streater.* Proſtat apud
plures Bibliopolas. *Anno* MDCLXXXVII.

Digression on the origin of Mass

- Gallilean and Newtonian concept of mass :

Inertial mass (F=ma) Gravitational mass (P=mg)

Single concept of mass

Conserved intrinsic property of matter where the total mass of a system is the sum of its constituents

- Einstein : Does the mass of a system depend of its energy content?

Mass = rest energy of a system or $m_0=E/c^2$

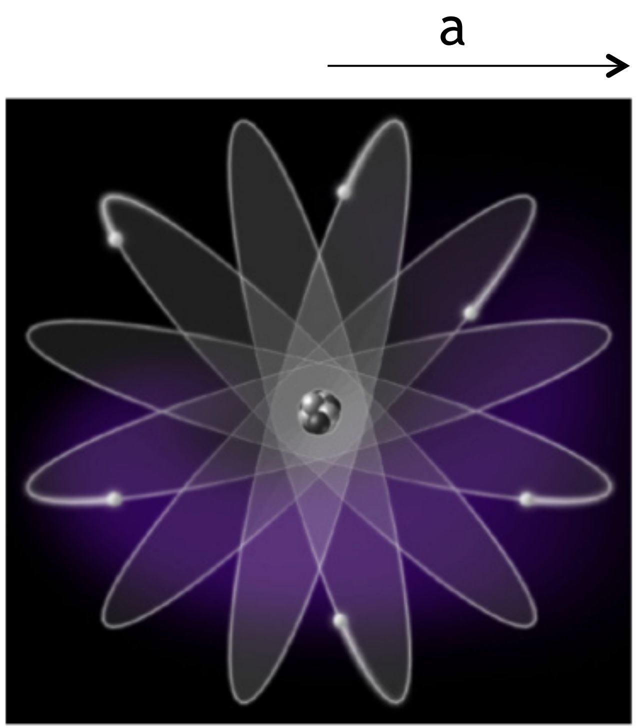
- Atomic level : binding energy ~O(10eV) which is ~10^{-8} of the mass
- Nuclear level : binding energy ~2% of the mass
- Nucleus parton level : binding energy ~98% of the mass

Most of the (luminous) mass in the universe comes from QCD confinement energy

The insight of the Higgs mechanism :

Understanding the origin of mass of gauge bosons and fermions

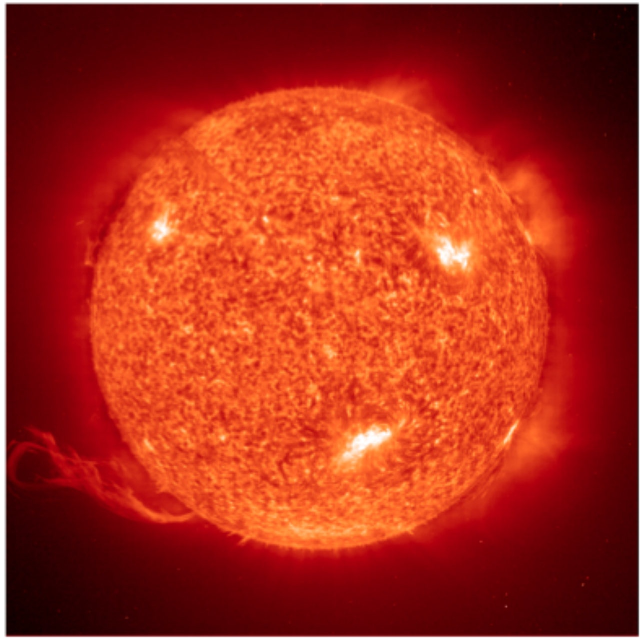
How Would it Be Without Elementary Particle Masses?



Electron mass (m_e = 511 keV)

Bohr Radius a = $1/(a_{EM}\ m_e)$ so :

If m_e = 0 : Then no atomic binding



W boson mass (m_W = 81 GeV)

$$G_F \sim (M_W)^{-2}$$

If no or lower W mass : shorter combustion time at lower temperature

Everything would be completely different!

1964

Five pages that changed the course of the Standard Theory of particles…

VOLUME 13, NUMBER 9 PHYSICAL REVIEW LETTERS 31 AUGUST 1964

BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

F. Englert and R. Brout
Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium
(Received 26 June 1964)

2 pages

BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

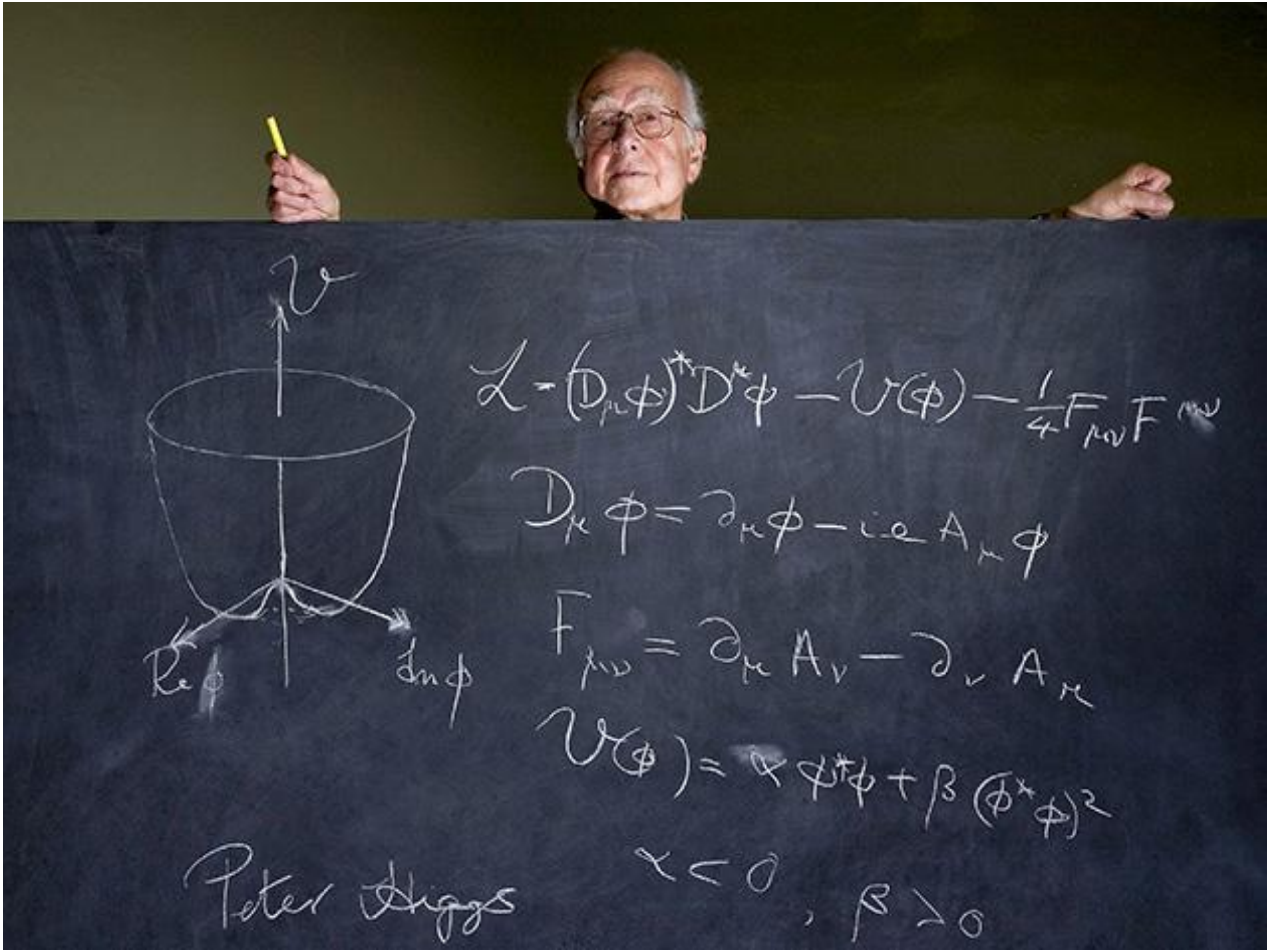
Peter W. Higgs
Tait Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland
(Received 31 August 1964)

1 page

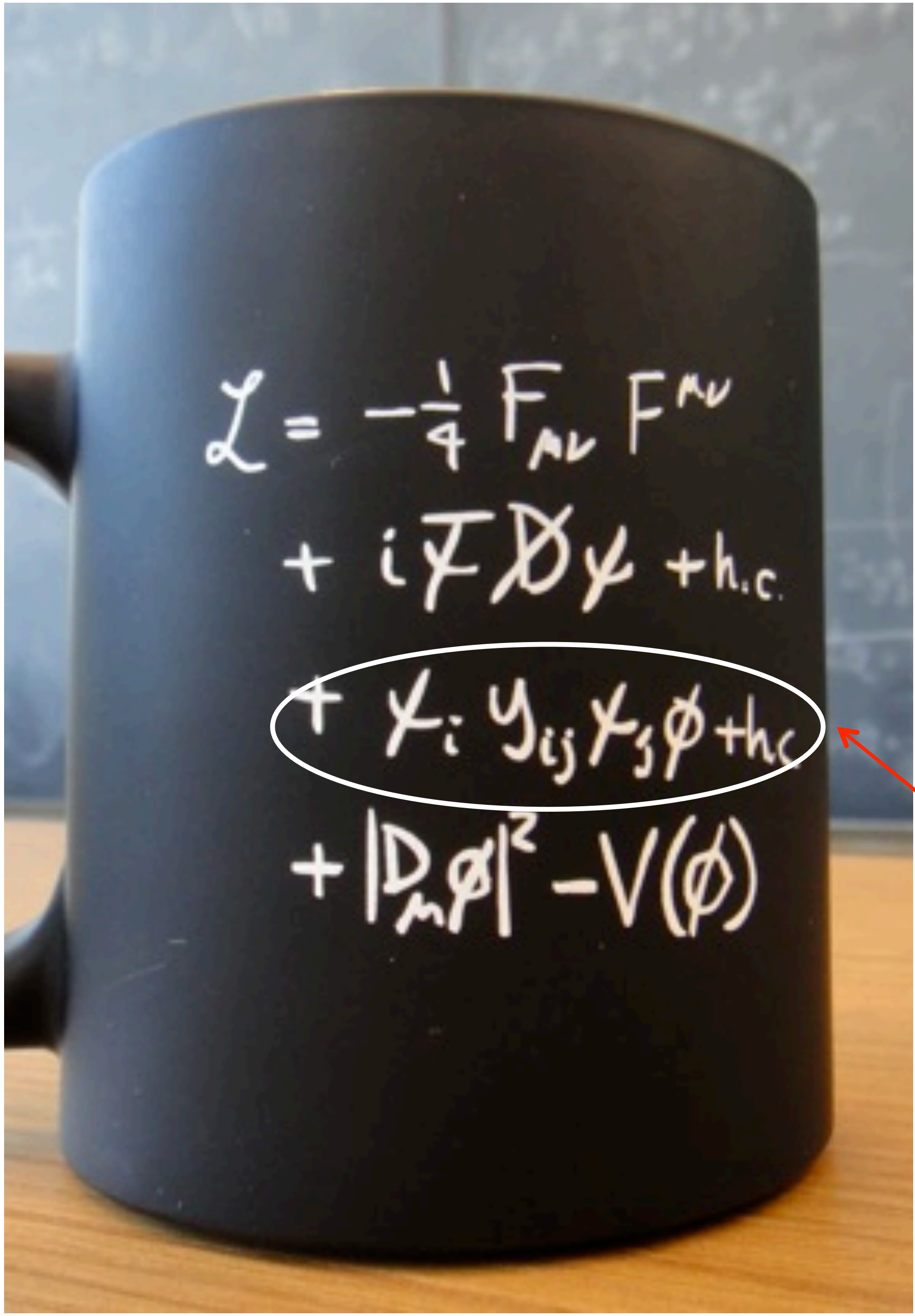
GLOBAL CONSERVATION LAWS AND MASSLESS PARTICLES*

G. S. Guralnik,† C. R. Hagen,‡ and T. W. B. Kibble
Department of Physics, Imperial College, London, England
(Received 12 October 1964)

2 pages



V
$\mathcal{L} = (D_\mu \phi)^* D^\mu \phi - V(\phi) - \frac{1}{4} F_{\mu\nu} F^{\mu\nu}$
$D_\mu \phi = \partial_\mu \phi - ie A_\mu \phi$
$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$
$V(\phi) = \alpha \phi^* \phi + \beta (\phi^* \phi)^2$
$\alpha < 0 , \beta > 0$
Re ϕ
Im ϕ
Peter Higgs

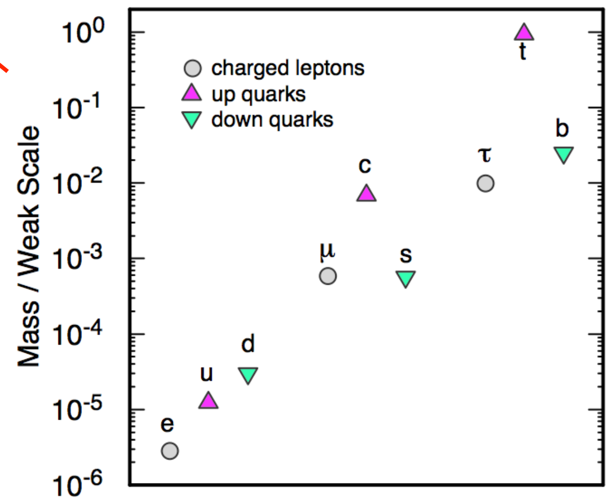


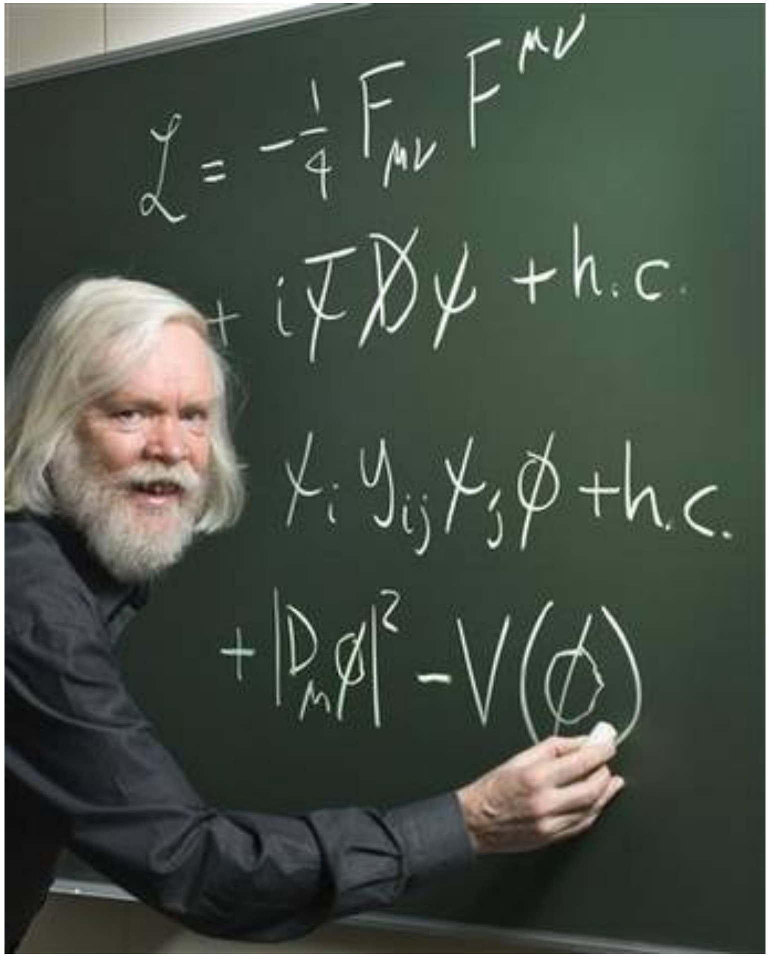
The BEH mechanism allows:

- Massive gauge bosons
- Massive fermions
- Renormalizability
- Unitarity

Splendid… but yet the least elegant part of the Standard Model

- No gauge principle
- Accounts for most free param.





1976

A PHENOMENOLOGICAL PROFILE OF THE HIGGS BOSON

John Ellis, Mary K. Gaillard *) and D.V. Nanopoulos +)
CERN -- Geneva

We should perhaps finish with an apology and a caution. We apologize to experimentalists for having no idea what is the mass of the Higgs boson, unlike the case with charm [3),4)] and for not being sure of its couplings to other particles, except that they are probably all very small. For these reasons we do not want to encourage big experimental searches for the Higgs boson, but we do feel that people performing experiments vulnerable to the Higgs boson should know how it may turn up.

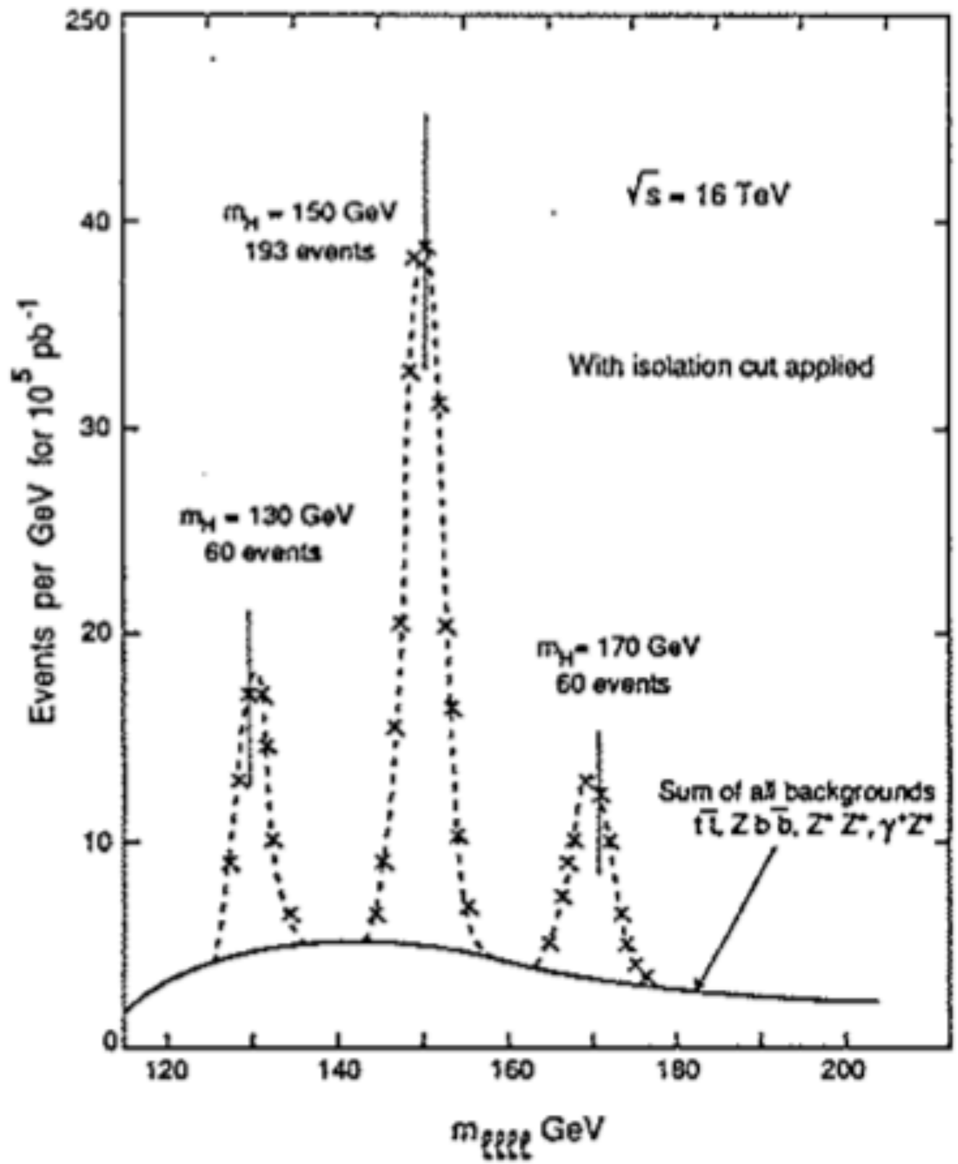
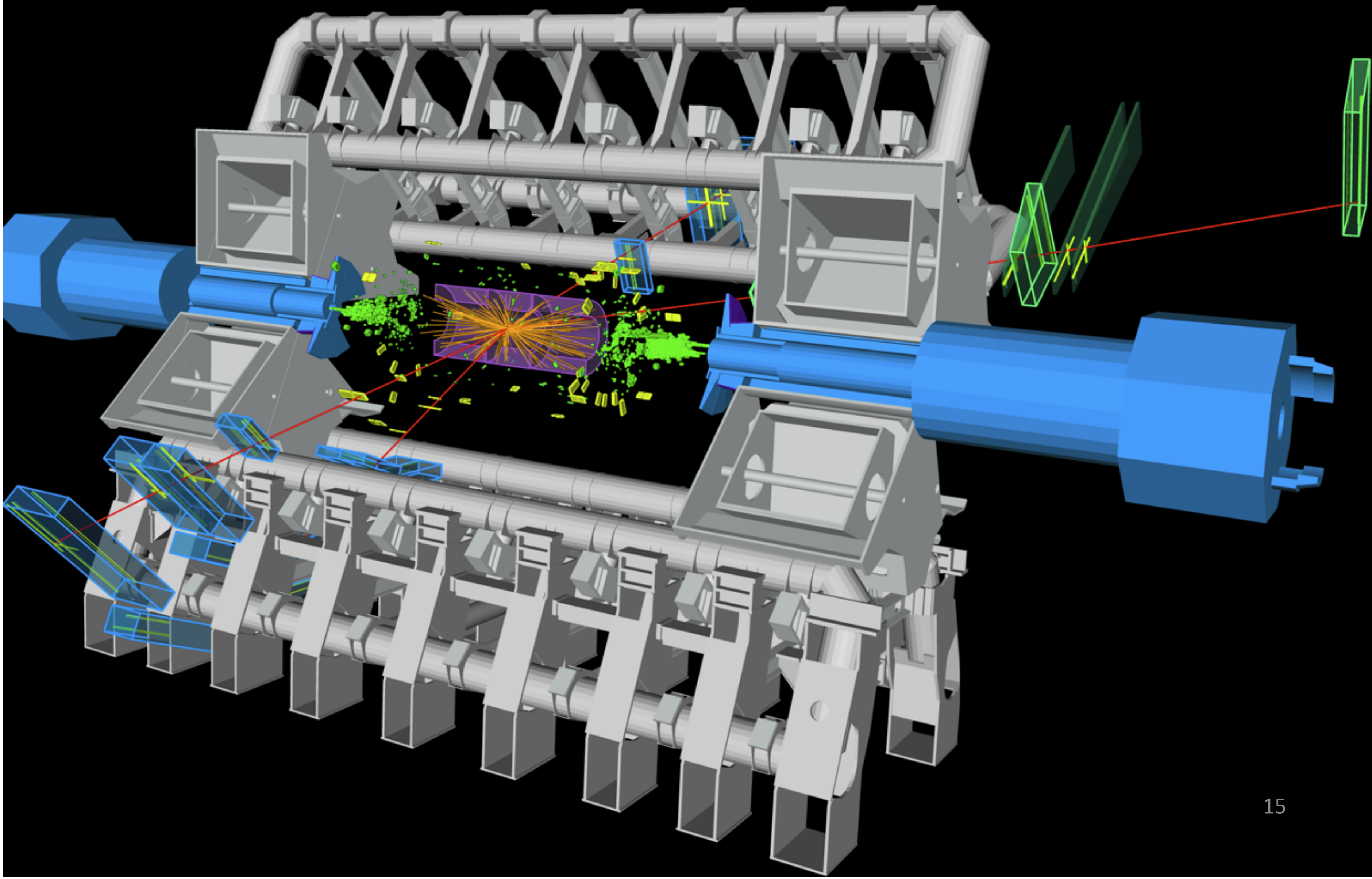


Fig. 10

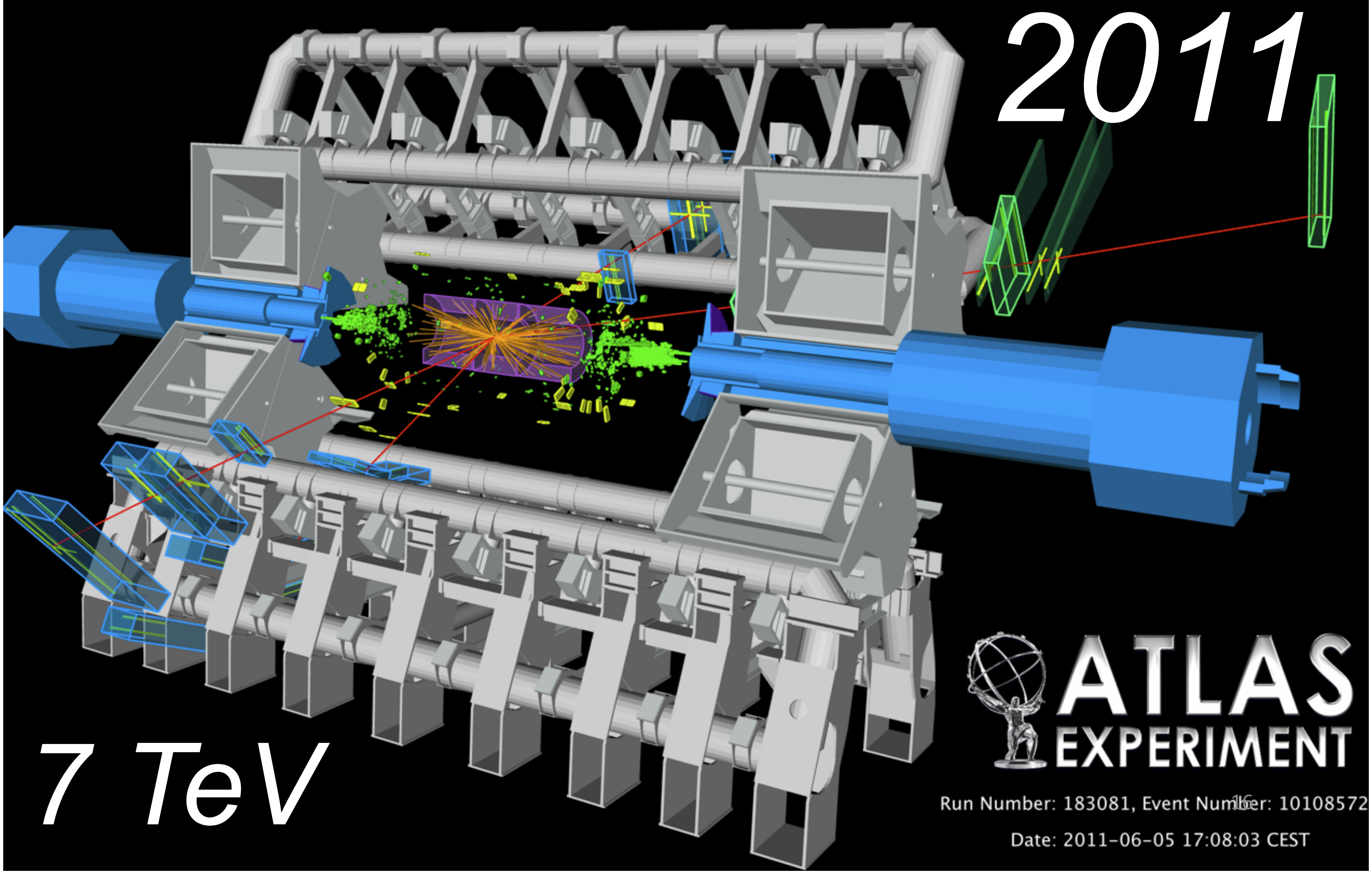
1990

Proceedings of LHC Workshop (Aachen, 1990): √s = 16 TeV, 100 fb^{-1}

20 Years, projecting, constructing and Simulating…

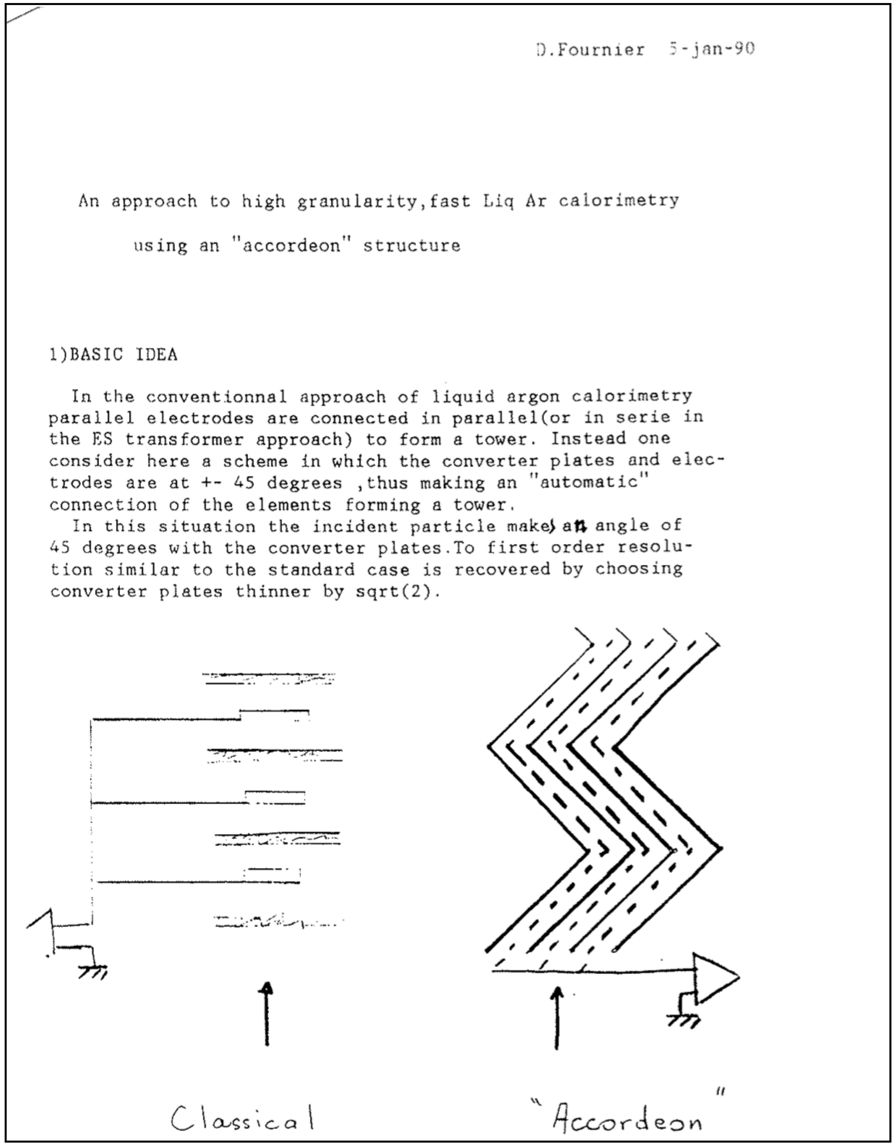


4 μ event … *Standard EW only or Higgs?*



ATLAS Electromagnetic Calorimeter

From RD3 to the LAr Calorimeter


D.Fournier 5-jan-90

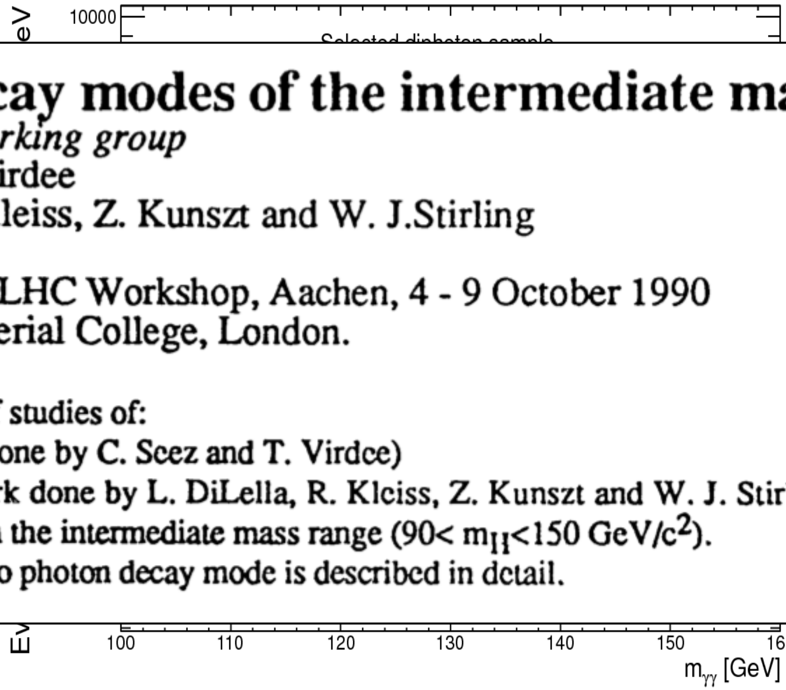
An approach to high granularity,fast Liq Ar calorimetry

using an "accordeon" structure

1)BASIC IDEA

In the conventionnal approach of liquid argon calorimetry parallel electrodes are connected in parallel(or in serie in the ES transformer approach) to form a tower. Instead one consider here a scheme in which the converter plates and electrodes are at +- 45 degrees ,thus making an "automatic" connection of the elements forming a tower.
In this situation the incident particle makes an angle of 45 degrees with the converter plates.To first order resolution similar to the standard case is recovered by choosing converter plates thinner by sqrt(2).

The Di-Photon Channel Historical Prospective



Photon decay modes of the intermediate mass Higgs
ECFA Higgs working group
C.Seez and T. Virdee
L. DiLella, R. Kleiss, Z. Kunszt and W. J.Stirling

Presented at the LHC Workshop, Aachen, 4 - 9 October 1990
by C. Seez, Imperial College, London.

A report is given of studies of:
(a) H -> $\gamma\gamma$ (work done by C. Seez and T. Virdee)
(b) W H -> $\gamma\gamma$ (work done by L. DiLella, R. Kleiss, Z. Kunszt and W. J. Stirling)
for Higgs bosons in the intermediate mass range (90< m_{H}<150 GeV/c^2).
The study of the two photon decay mode is described in detail.

1991 Analysis

First EAGLE (ATLAS) note

diphoton channel

16 TeV, 100 fb^{-1}

Moriond 2013 Analysis

ATLAS diphoton channel

7 - 8 TeV, ~25 fb^{-1}

L. Fayard
G. Unal
EAGLE Note
PHYSICS-NO-001
december 1991

July 4, 2012

… On the NY Times front Page!

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The SM Lagrangian after Breaking (See A. Casas)

$$\mathcal{L} = \frac{1}{2}\partial_\mu H \partial^\mu H - \frac{1}{2}\lambda v^2 H^2 - \lambda v H^3 - \frac{\lambda}{4} H^4$$

Massive scalar : The Higgs boson

$$+ \frac{1}{2}\left[\frac{g'^2 v^2}{4} B_\mu B^\mu - \frac{g g' v^2}{2} W^3_\mu B^\mu + \frac{g^2 v^2}{4} \vec{W}_\mu . \vec{W}^\mu\right]$$

Massive gauge bosons

$$+ \frac{1}{v}\left[\frac{g'^2 v^2}{4} B_\mu B^\mu H - \frac{g g' v^2}{2} W^3_\mu B^\mu H + \frac{g^2 v^2}{4} \vec{W}_\mu . \vec{W}^\mu H\right]$$

$$+ \frac{1}{2v^2}\left[\frac{g'^2 v^2}{4} B_\mu B^\mu H^2 - \frac{g g' v^2}{2} W^3_\mu B^\mu H^2 + \frac{g^2 v^2}{4} \vec{W}_\mu . \vec{W}^\mu H^2\right]$$

Gauge-Higgs interaction

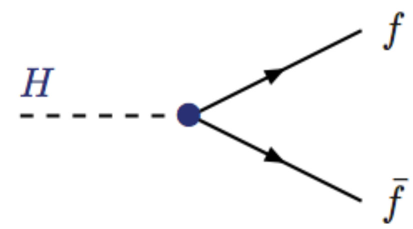
In order to derive the mass eigenstates :

Diagonalize the mass matrix $\frac{1}{4}\begin{pmatrix} g^2 v^2 & -g g' v^2 \\ -g g' v^2 & g'^2 v^2 \end{pmatrix} = \mathcal{M}^{-1}\begin{pmatrix} m_Z^2 & 0 \\ 0 & 0 \end{pmatrix}\mathcal{M}$

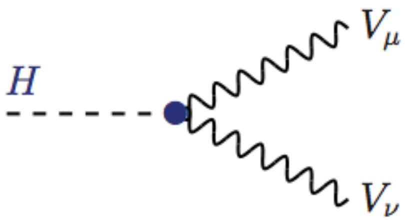
Where

$$\mathcal{M} = \begin{pmatrix} \cos\theta_W & -\sin\theta_W \\ \sin\theta_W & \cos\theta_W \end{pmatrix} \qquad \sin\theta_W = \frac{g'}{\sqrt{g^2 + g'^2}} \qquad \cos\theta_W = \frac{g}{\sqrt{g^2 + g'^2}}$$

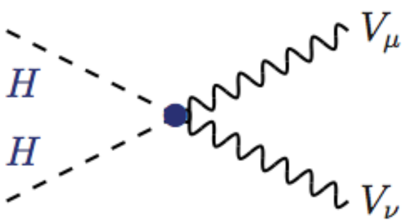
The Weinberg angle was actually first introduced by Glashow (1960)



$$g_{Hff} = m_f/v$$

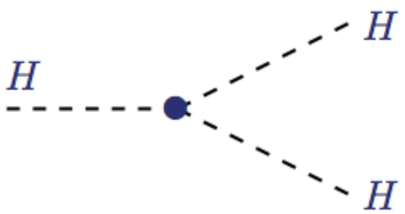


$$g_{HVV} = 2M_V^2/v$$

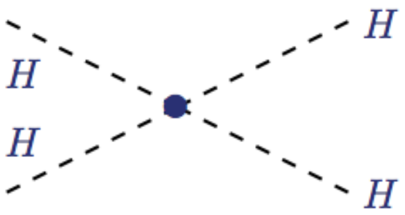


$$g_{HHVV} = 2M_V^2/v^2$$

Keep this in mind for the next lecture...



$$g_{HHH} = 3M_H^2/v$$



$$g_{HHHH} = 3M_H^2/v^2$$

Consequences of the Brout-Englert-Higgs Mechanism

1.- Two massive charged vector bosons :

$$m_W^2 = \frac{g^2 v^2}{4}$$

Corresponding to the observed charged currents

Thus v = 246 GeV

Given the known W mass and g coupling

2.- One massless vector boson : $m_\gamma = 0$

The photon correponding to the unbroken $U(1)_{EM}$

3.- One massive neutral vector boson Z :

$$m_Z^2 = (g^2 + g'^2)v^2/4$$

4.- One massive scalar particle : The Higgs boson

Whose mass is an unknown parameter

$$m_H^2 = \frac{4\lambda(v) m_W^2}{g^2}$$

Which of these consequences are actually predictions ?

1.- The theory was chosen in order to describe the weak interactions mediated by charged currents.

2.- The masslessness of the photon is a consequence of the choice of developing the Higgs field in the neutral and real part of the doublet.

3 & 4.- The appearance of massive Z and Higgs bosons are actually predictions of the model.

One additional very important prediction which was not explicitly stated in Weinberg's fundamental paper... although it was implicitly clear :

There is a relation between the ratio of the masses and that of the couplings of gauge bosons :

$$\frac{M_W}{M_Z} = \frac{g^2}{g^2 + g'^2} = \cos^2\theta_W$$

or

$$\rho \equiv \frac{m_W^2}{m_Z^2 \cos^2\theta_W} = 1$$

$$\rho = 1$$

$\text{Wilczek}_{\text{LEP celebration}}$: The Higgs mechanism is corroborated at 75%

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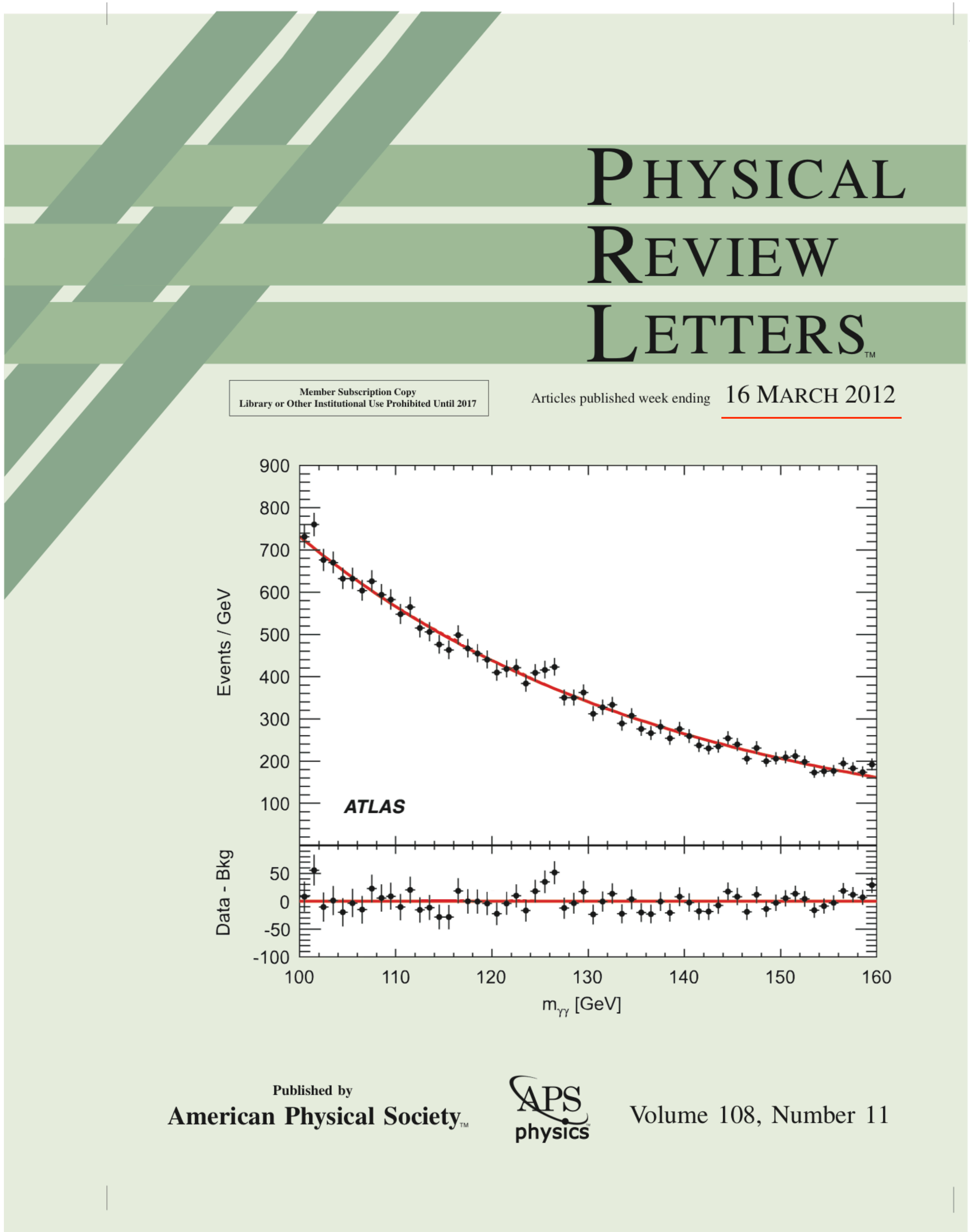


How to read Higgs Search Plots…

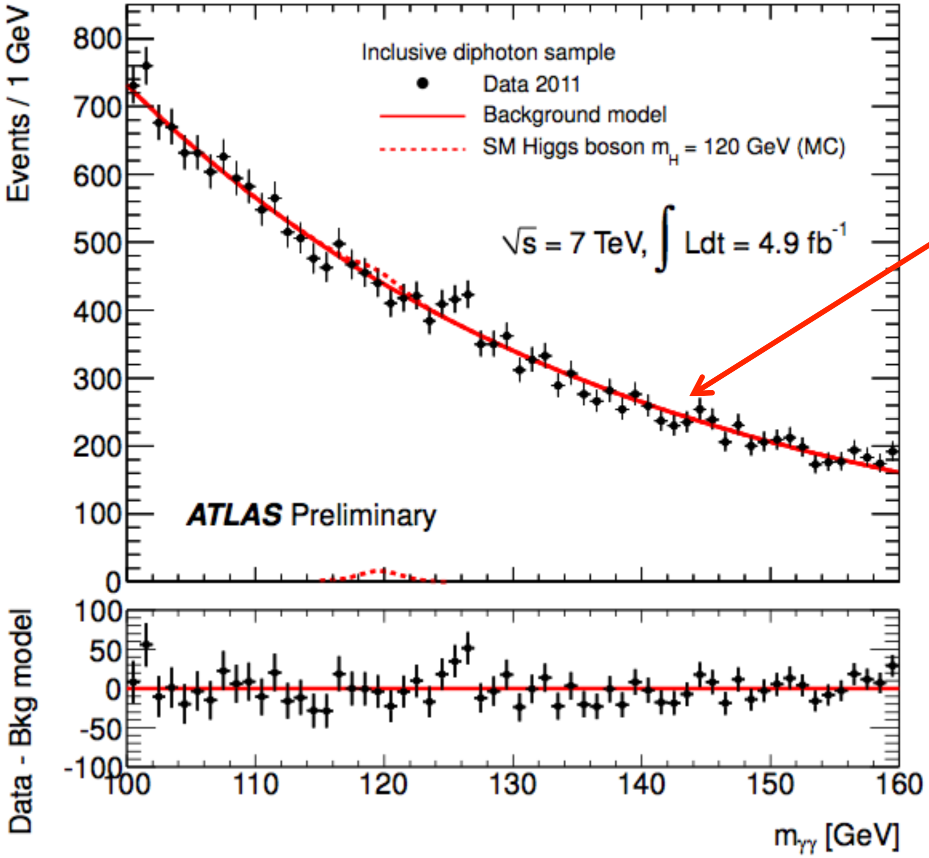
Starting from PRL Cover Plot

Statistical Interpretation

How to read Higgs Search Plots

Hypothesis testing using the

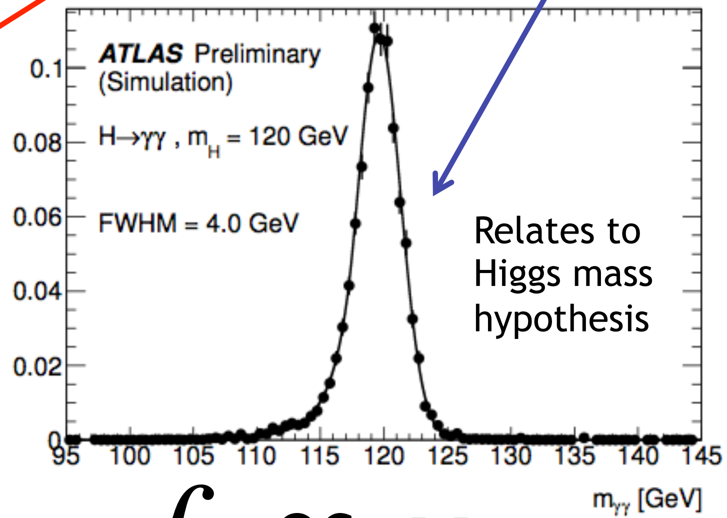
Profile likelihood ratio…



Likelihood Definition:

Simplified

$$L(\mu,\theta) = f_b \psi_b (M_{\gamma\gamma}) + f_s \psi_s (M_{\gamma\gamma})$$



Relates to Higgs mass hypothesis

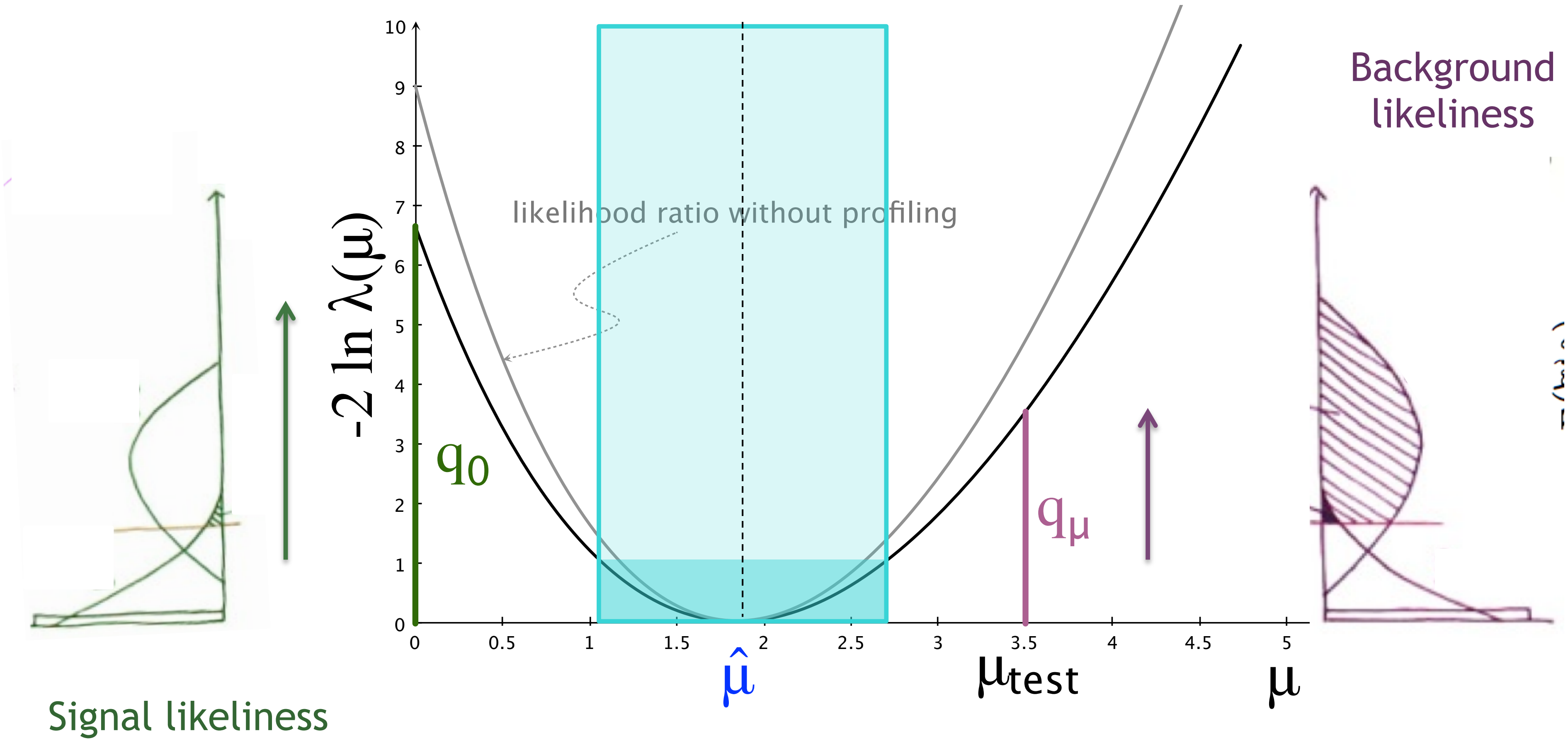
$$f_s \propto \mu$$

Global coherent factor

$$n_s = \mu \sigma Br L \varepsilon$$

How to Read Higgs Exclusion Limits Plots

$$\lambda_\mu = \lambda(\mu,\theta) = \frac{L(\mu,\hat{\hat{\theta}}(\mu))}{L(\hat{\mu},\hat{\theta})} \qquad q_\mu = -2\ln\lambda_\mu$$

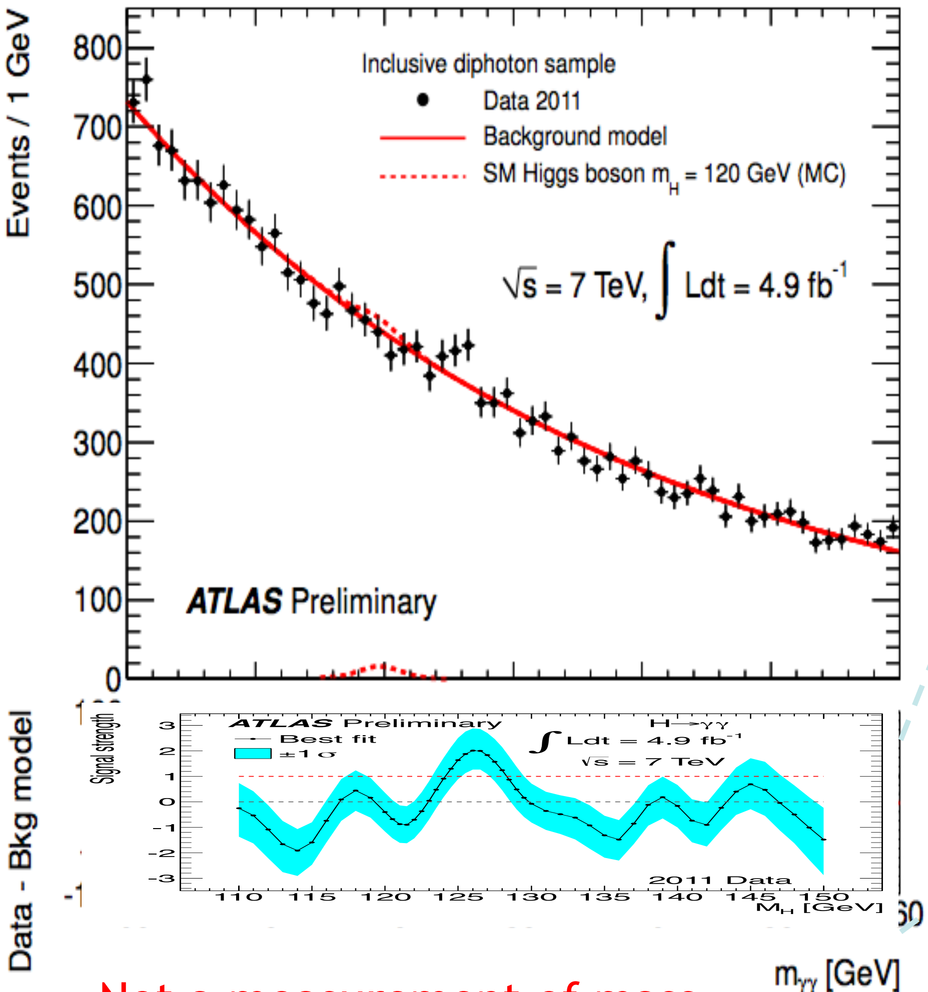


Statistical Interpretation

How to read Higgs Search Plots

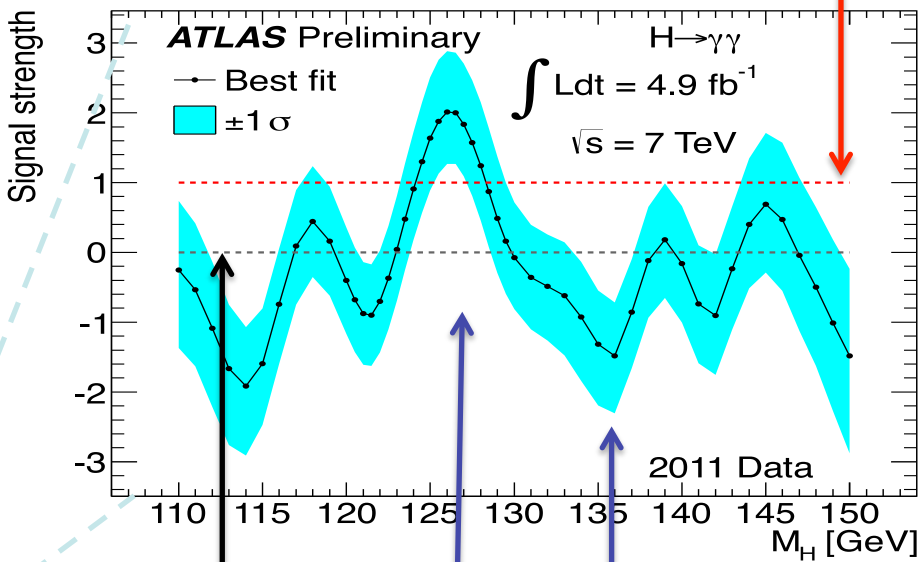
Hypothesis testing using the Profile likelihood ratio…

$\hat{\mu}$



Relate to Higgs mass hypothesis

Expected Signal



Expected Background

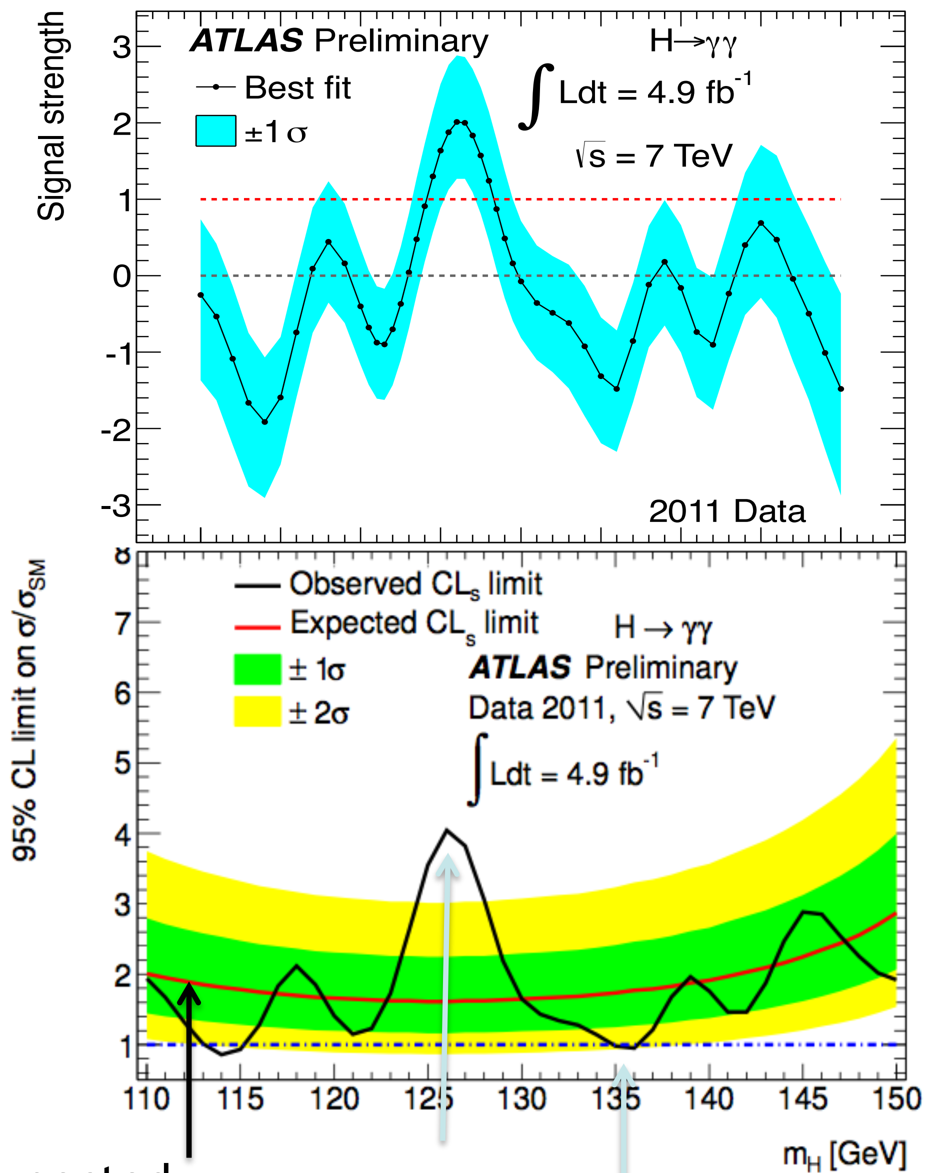
Excess

Deficit

Not a measurement of mass

Not a measurement of cross section

How to Read Higgs Exclusion Limits Plots



Expected Background

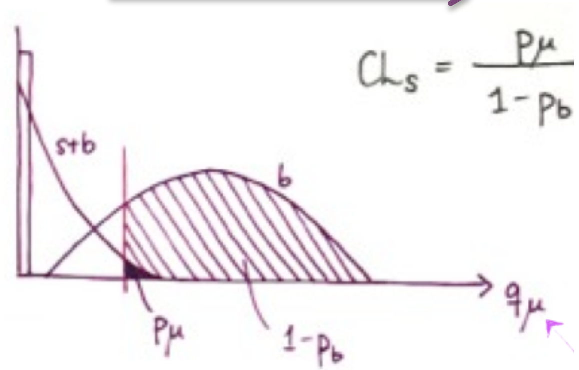
Excess

Deficit

$$\lambda_\mu = \lambda(\mu,\theta) = \frac{L(\mu,\hat{\hat{\theta}}(\mu))}{L(\hat{\mu},\hat{\theta})}$$

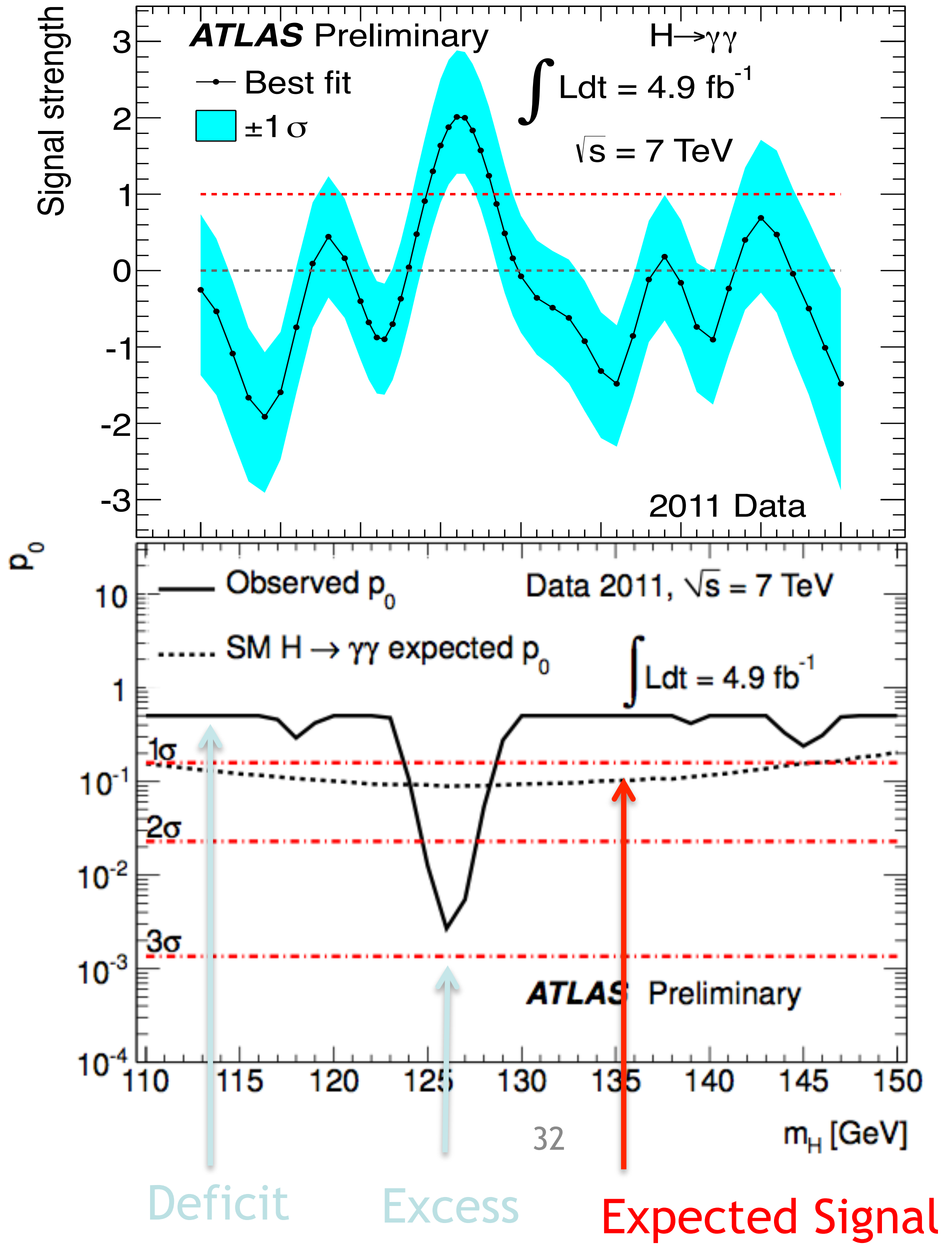
$$q_\mu = -2\ln\lambda_\mu$$

Background likeliness



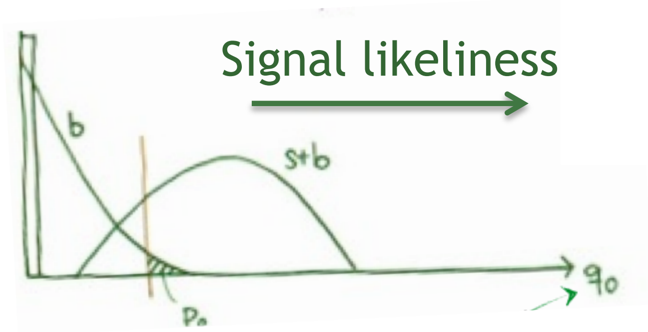
CL_{s+b} Probability that a signal-plus-background experiment be more background-like than observed

How to Read Higgs Observation Estimates



$$\lambda_0 = \lambda(0,\theta) = \frac{L(0,\hat{\hat{\theta}}(0))}{L(\hat{\mu},\hat{\theta})}$$

$$q_0 = -2\ln\lambda_0$$

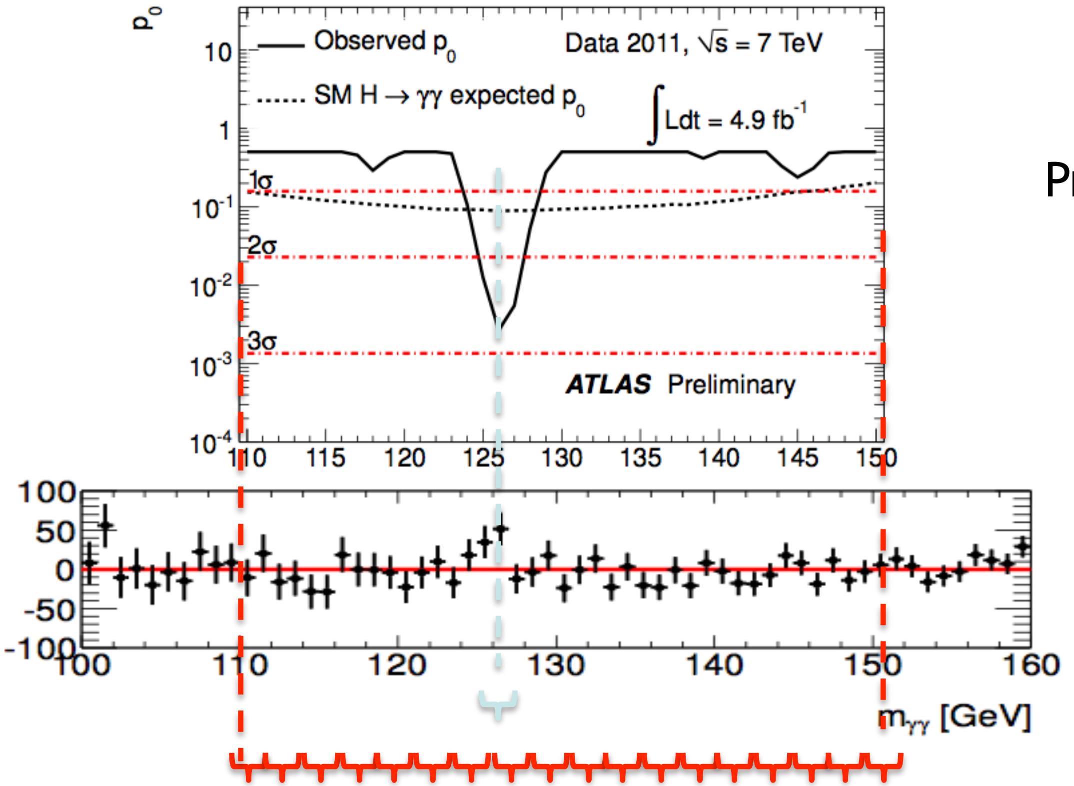


p_0 Probability that a background only experiment be more signal like than observed

Local vs. Global Probability

Look Elswhere Effect

(over)Simplified View



Probability of observing an excess at one specific mass (in absence of signal)…

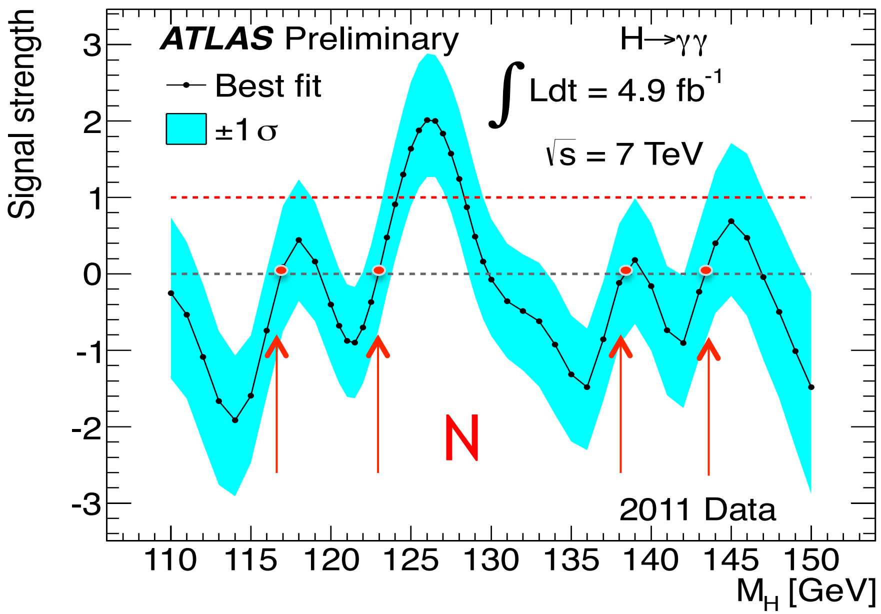
What is the probability of observing an excess at least as large as observed within a mass range ?

Trial factor ~ Number of possible independent outcomes within a mass range… (dependence on the significance)

Local vs. Global Probability

Look Elswhere Effect

Approximate Formula



Based on counting the numbers of up-crossings

Then applying the very simple following formula (Z is the local significance)

$$p_{global} = p_{local} + N \times e^{-\frac{Z^2}{2}}$$

Trial factor ~ Here the dependence is explicit…

E. Gross and O. Vitells, *Trial factors for the look elsewhere effect in high energy physics*, Eur. Phys. J. **C70** (2010) 525–530.

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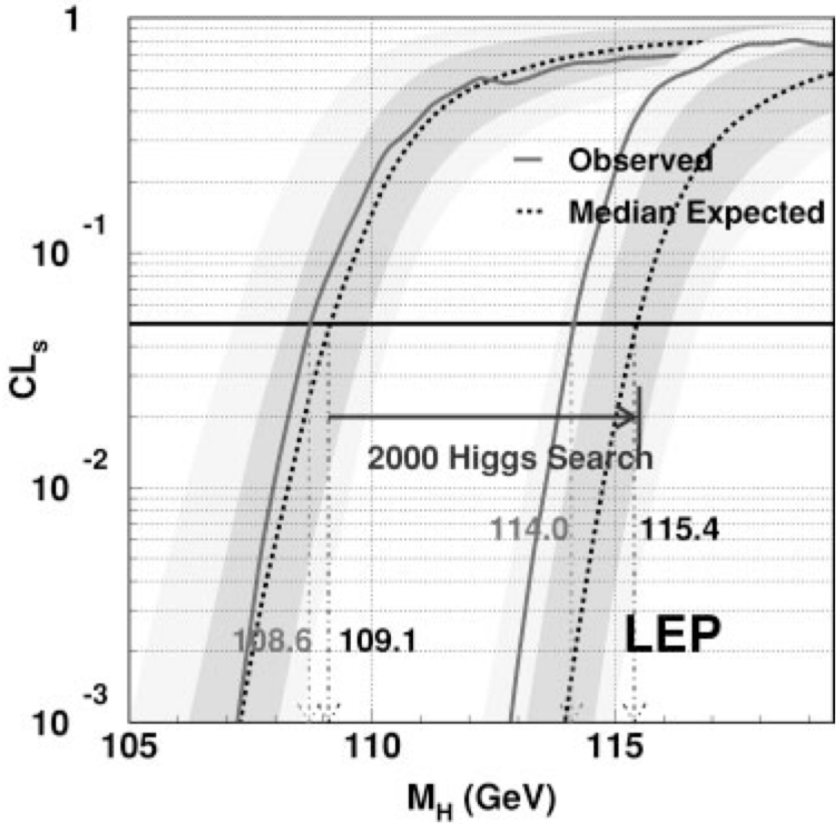
Other Higgs Programs

- LEP limits m_H > 114 GeV Absolute limit!
- In general reinterpretation of low mass searches

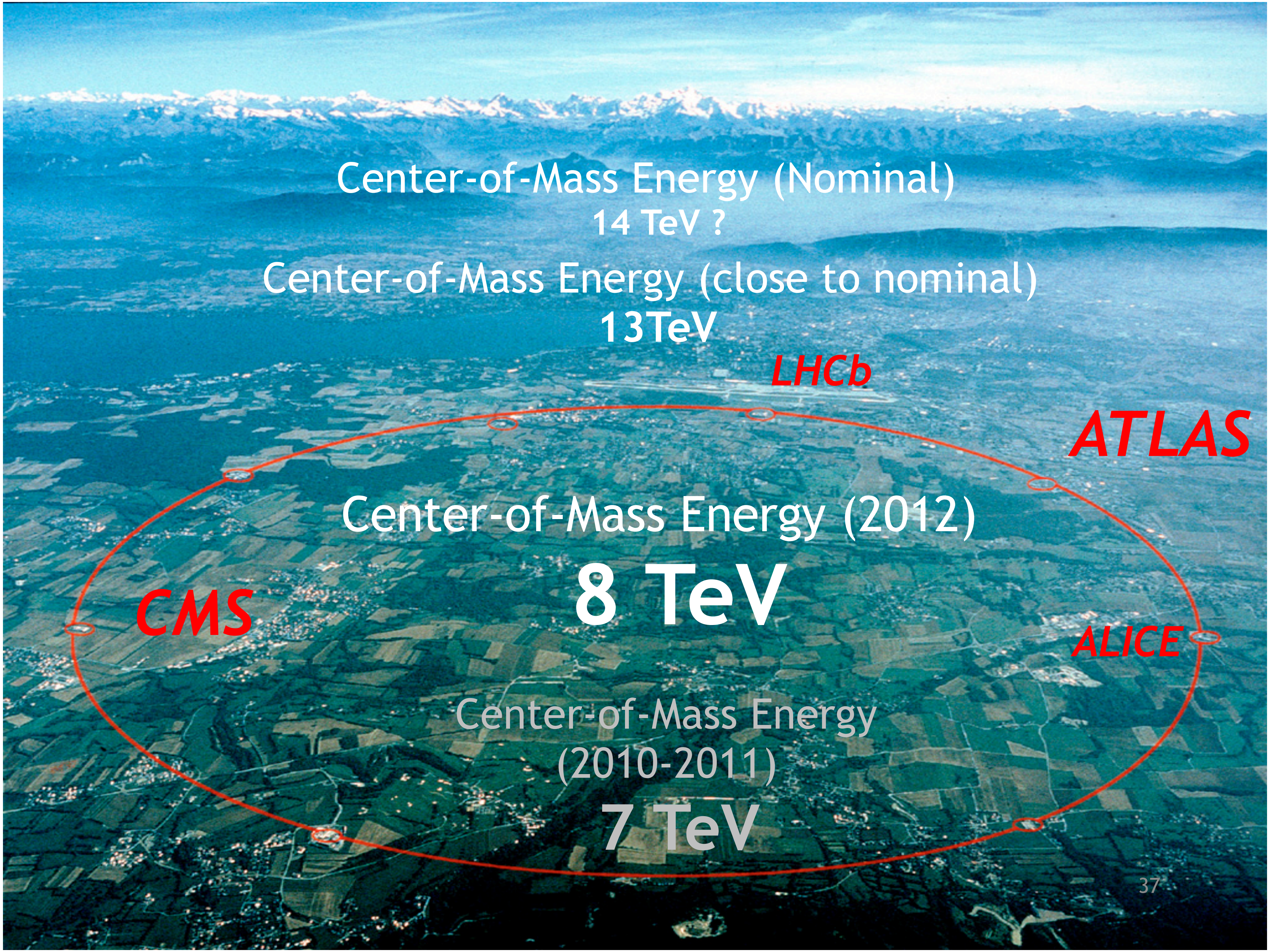
- PreLEP era
  - Absence of Higgs related effects in Nuclear Physics, neutron stars and neutron scattering experiments m_H>20 MeV
  - Kaon abd B-Meson decays limits m_H>5 GeV



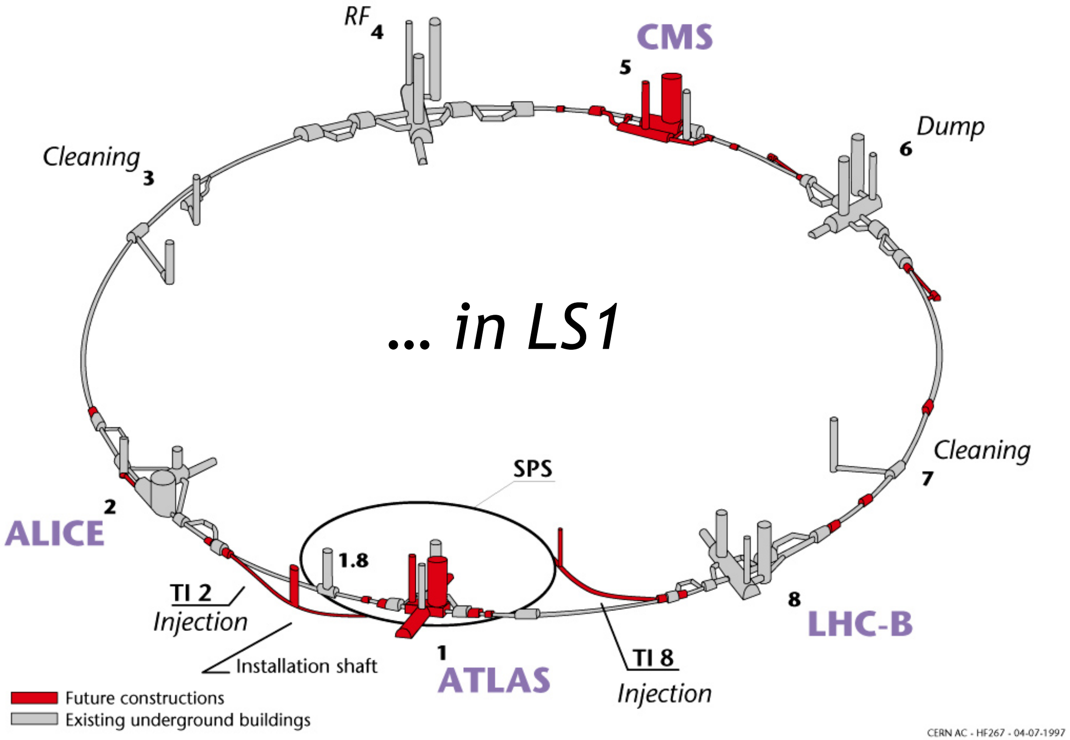
- LHCb
  - Standard Model H in bb
  - Higgs decays to long lived partices
  - (MSSM) Higgs to $\tau\tau$

- LHC diffractive Higgs production

- BaBar and Belle search for NMSSM a


Center-of-Mass Energy (Nominal)
14 TeV ?
Center-of-Mass Energy (close to nominal)
13TeV
LHCb
ATLAS
Center-of-Mass Energy (2012)
8 TeV
CMS
ALICE
Center-of-Mass Energy
(2010-2011)
7 TeV

Three Years of LHC operations at the Energy frontier



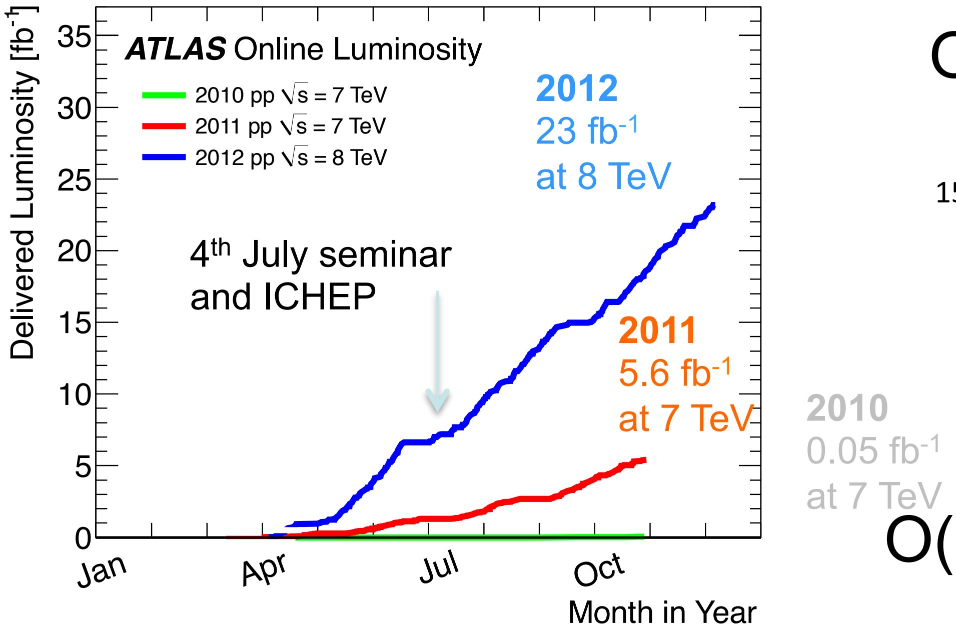
The LHC

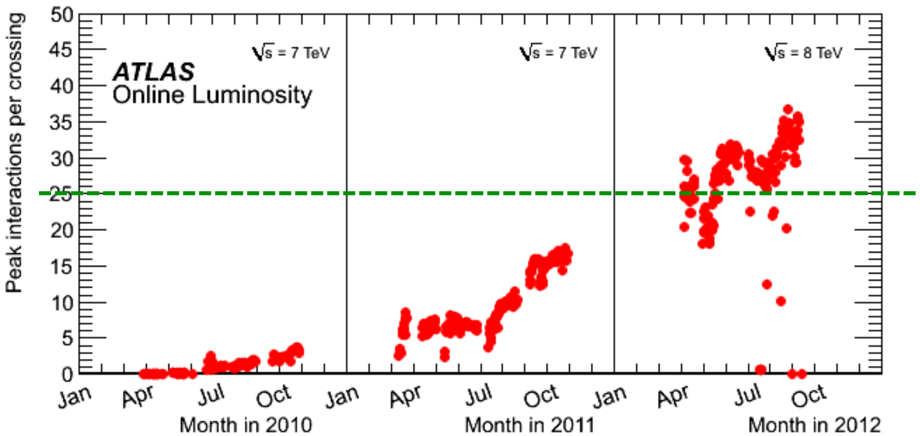
- Circumference 27 km
- Up to 175 m underground
- Total number of magnets 9 553
- Number of dipoles 1 232
- Operation temperature 1.9 K (Superfluid He)

$$\mathcal{L} = \frac{N_p^2 k_b f_{rev} \gamma}{4\pi \beta^* \epsilon_n} F$$

Parameter	2010	2011	2012	Nominal
C.O.M Energy	7 TeV	7 TeV	8 TeV	14 TeV
Bunch spacing / k	150 ns / 368	50 ns / 1380	50 ns /1380	25 ns /2808
ε (mm rad)	2.4-4	1.9-2.3	2.5	3.75
β* (m)	3.5	1.5-1	0.6	0.55
L ($cm^{-2}s^{-1}$)	$2x10^{32}$	$3.3x10^{33}$	$\sim 7x10^{33}$	10^{34}

The first LHC run



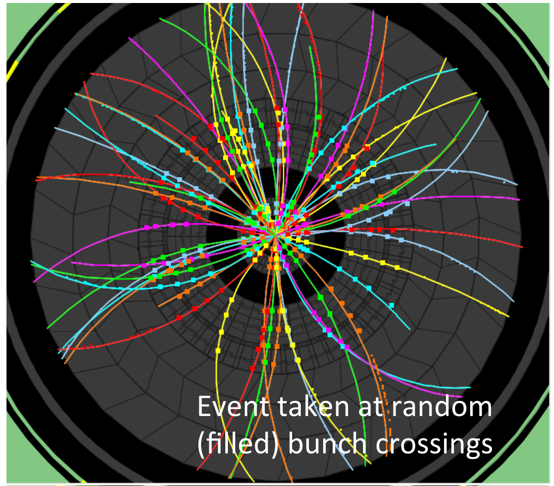


Design value (expected to be reached at $L=10^{34}$!)

2010

O(2) Pile-up events

150 ns inter-bunch spacing



2011

O(10) Pile-up events

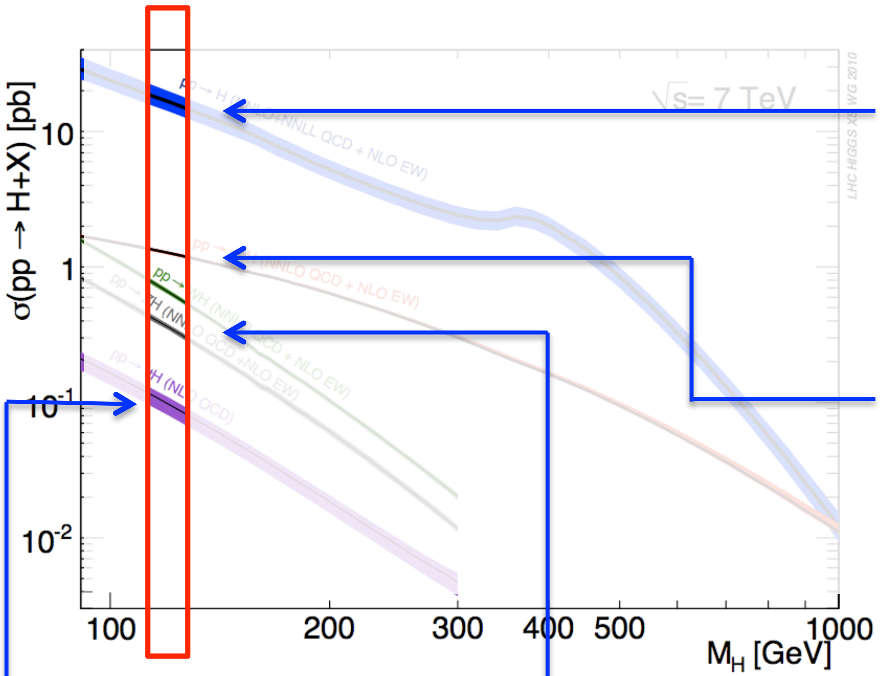
50 ns inter-bunch spacing

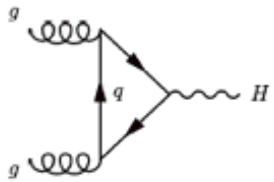
2012

O(20) Pile-up events

50 ns inter-bunch spacing

The Main Production Modes at the LHC

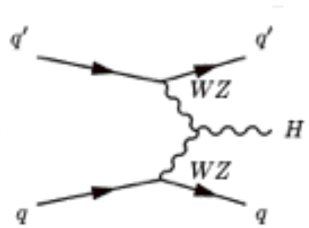




- Gluon fusion process :

Dominant process known at NNnLO TH uncertainty ~O(10%)

~0.5 M events produced!

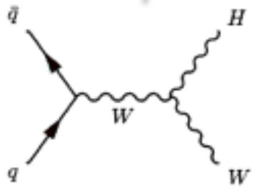


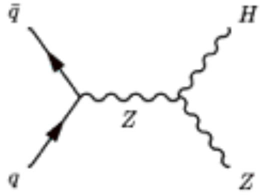
- Vector Boson Fusion :

known at NLO TH uncertainty ~O(5%)

Distinctive features with two forward jets and a large rapidity gap

~40 k events produced!



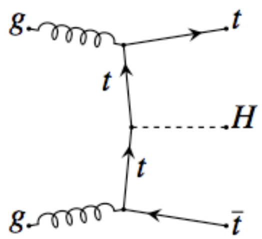


- W and Z Associated Production :

known at NNLO TH uncertainty ~O(5%)

Very distinctive feature with a Z or W decaying leptonically

~20 k events produced!



- Top Associated Production :

known at NLO TH uncertainty ~O(15%)

Quite distinctive but also quite crowded

~3 k events produced!

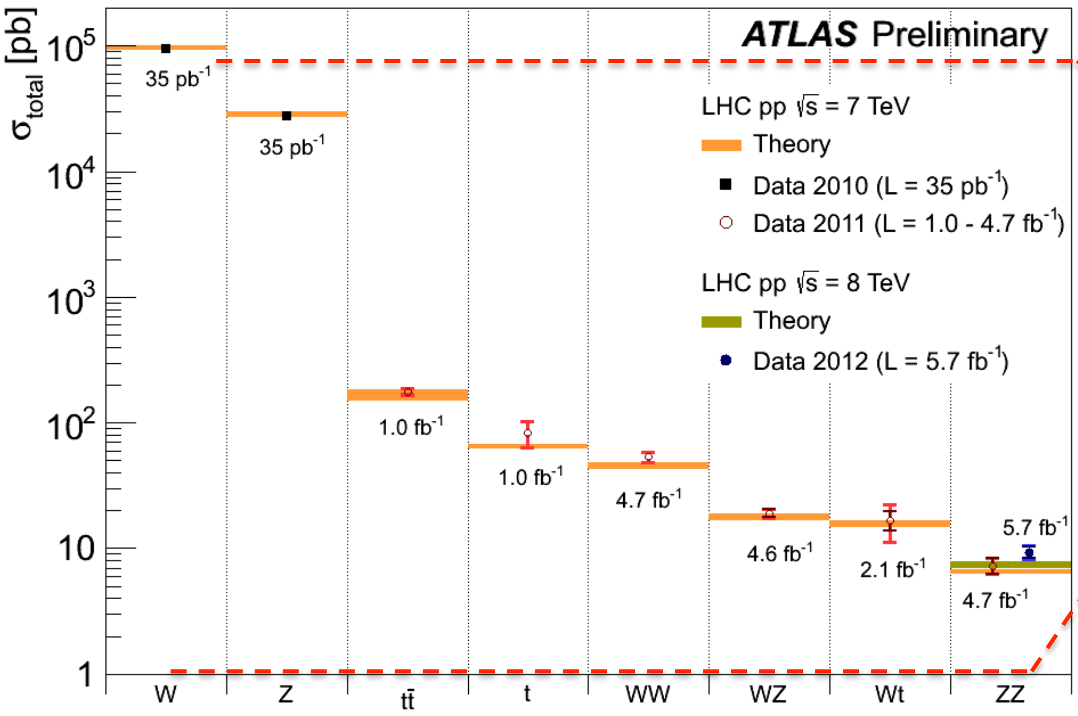
* TH uncertainty mostly from scale variation and PDFs, $\delta\sigma_{PDF-\alpha s}$~8-10% and $\delta\sigma_{Scale}$~ 7-8%

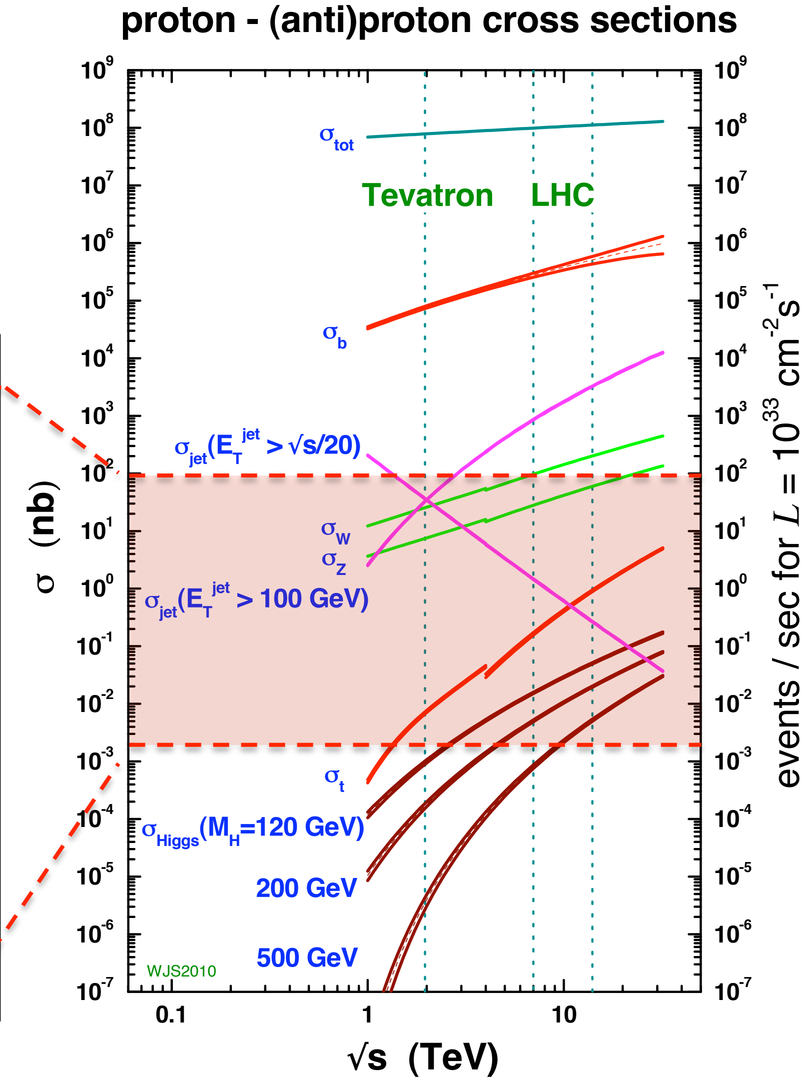
Overview of Cross Sections

Expected Standard Model and Higgs Productions

Theory and simulation "Next-to…" revolution :

- NNLO PDFs sets
- Calculations at unprecedented order in perturbation theory
- Parton Shower (and Matrix Element matching) improvements





Decay Modes

- Dominant decay mode b (57%)

Very large backgrounds, associated production W,Z H and Boost!

- The ττ channel (6.3%)

VBF, VH, but also ggF with new mass reconstruction techniques

- The γγ channel (0.2%)

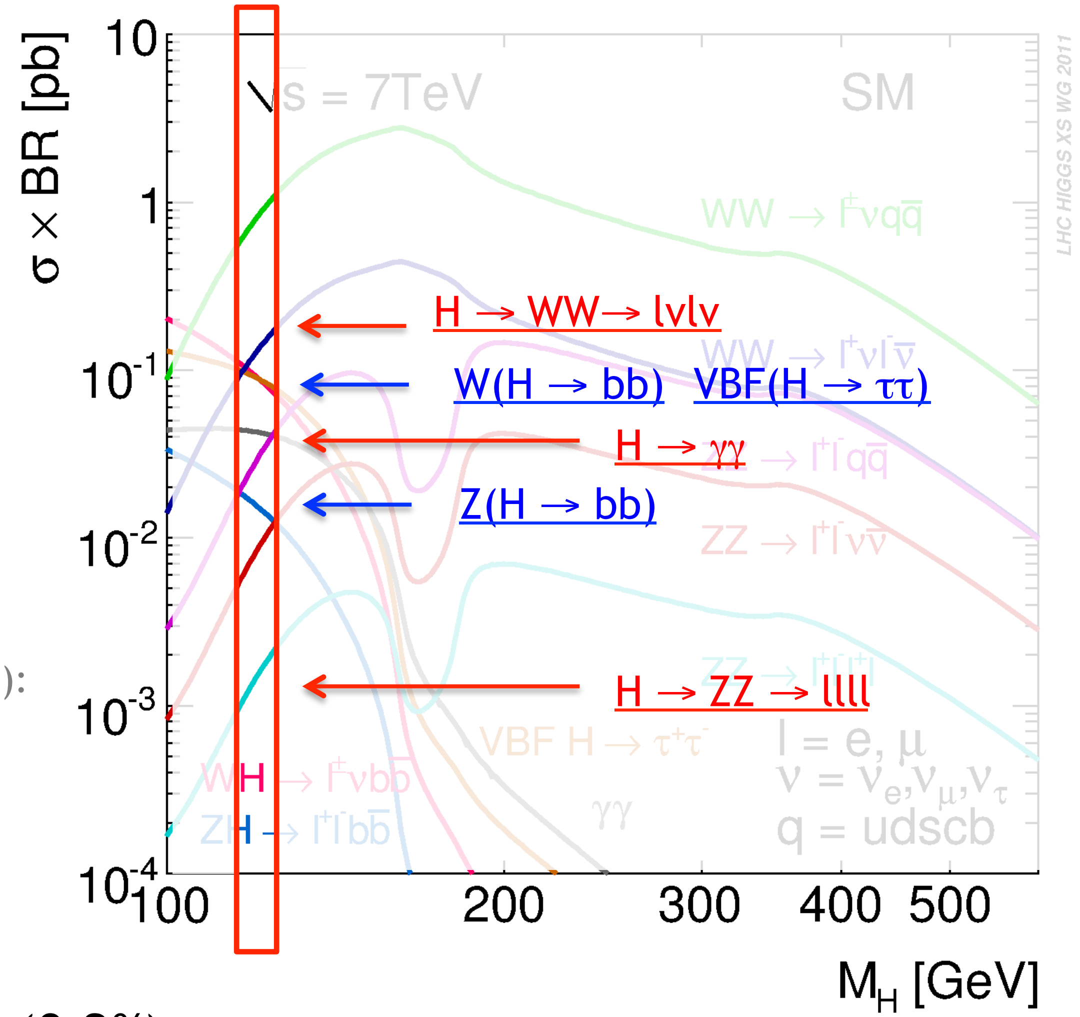
Discovery channel, high mass resolution (High stat, and backgrounds)

- The ZZ Channel (3%)

- Subsequent all leptons decays (low statistics): golden channel
- llqq and llvv sensitive mostly at high mass

- The WW Channel (22%)

- Subsequent lvlv very sensitive channel
- lvqq sensitive mostly at high mass



- The μμ channel (0.02%) and Zγ (0.2%)

Low statistics from the low branching in μμ or both the low branching and subsequent decay in leptons (Zγ)

- The cc channel (3%)

Very difficult

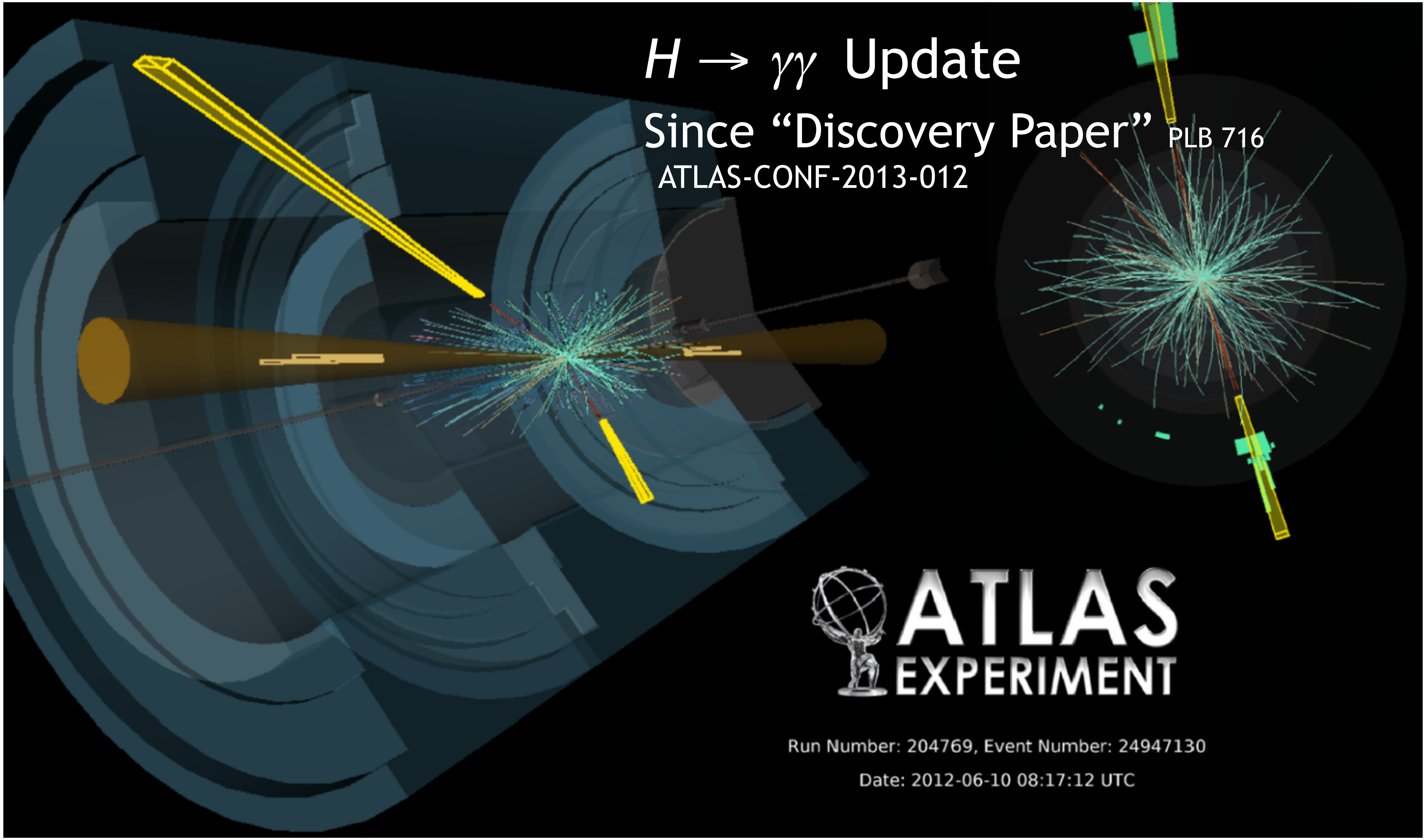
Channels investigated

Channel categories	ATLAS				CMS				TeVatron	
	ggF	VBF	VH	ttH	ggF	VBF	VH	ttH	VH	ggF
$\gamma\gamma$	✓	✓	✓	✓	✓	✓	✓	✓	(inclusive) ✓	
ZZ (llll)	✓	✓			✓	✓			✓	
WW ($l\nu l\nu$)	✓	✓	✓		✓	✓	✓		✓	✓
$\tau\tau$	✓	✓	✓		✓	✓	✓	✓	✓	
H (bb)			✓	✓		✓	✓	✓	✓	
$Z\gamma$	(inclusive) ✓				✓	✓				
$\mu\mu$	(inclusive) ✓									
Invisible			✓			✓	✓			

$H \rightarrow \gamma\gamma$ Update

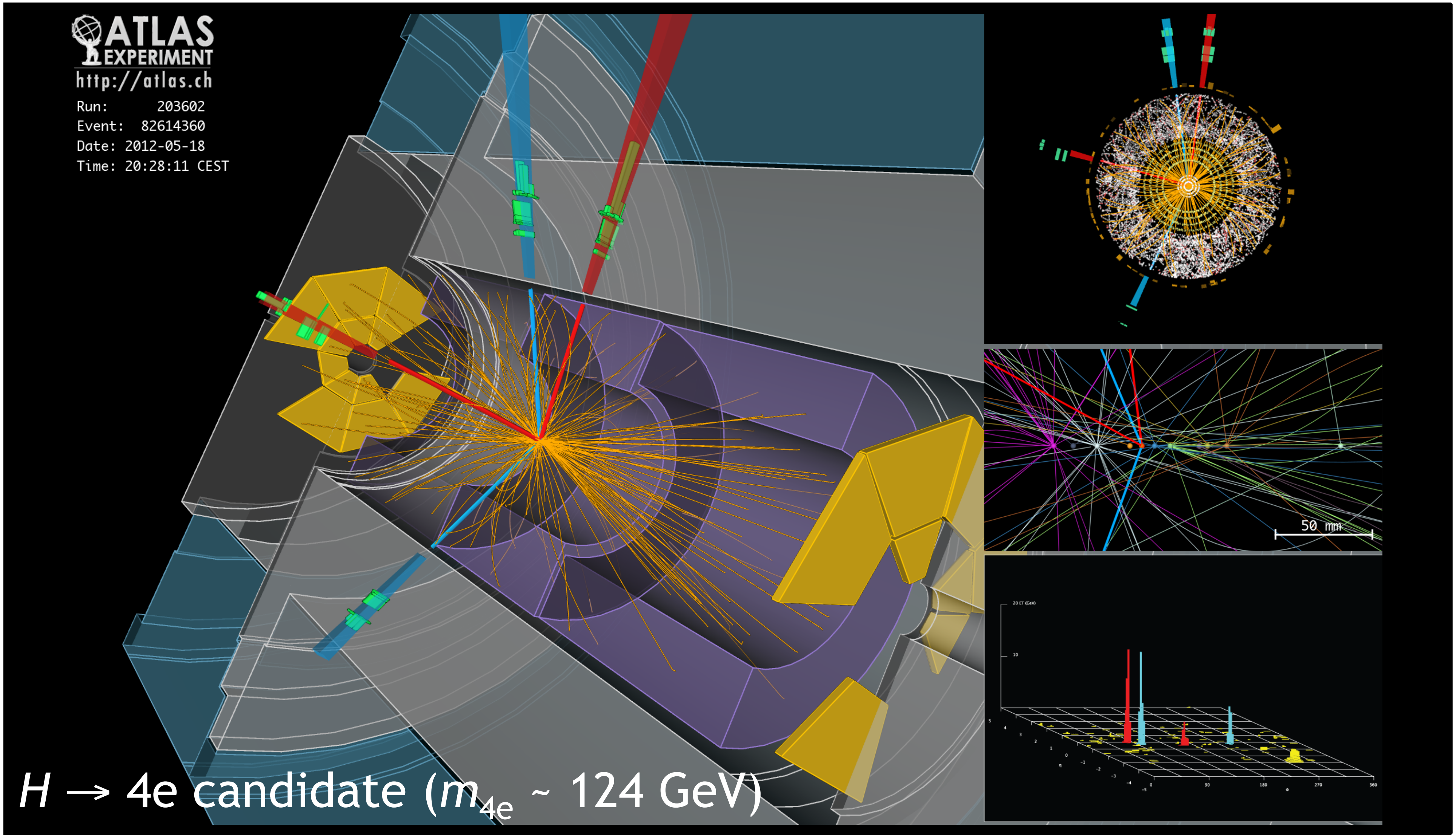
Since "Discovery Paper" PLB 716

ATLAS-CONF-2013-012



$\gamma\gamma$ channel basic facts sheet :

Signal ($SM_{126\ GeV}$)	Signal purity s/b	Main backgrounds	Production	7 & 8 TeV $\int L\,dt$
~450	2% - 60%	γγ,γj and jj	Hgg, VBF, VH	4.9 & 20.7 fb^{-1}



4l channel basic facts sheet :

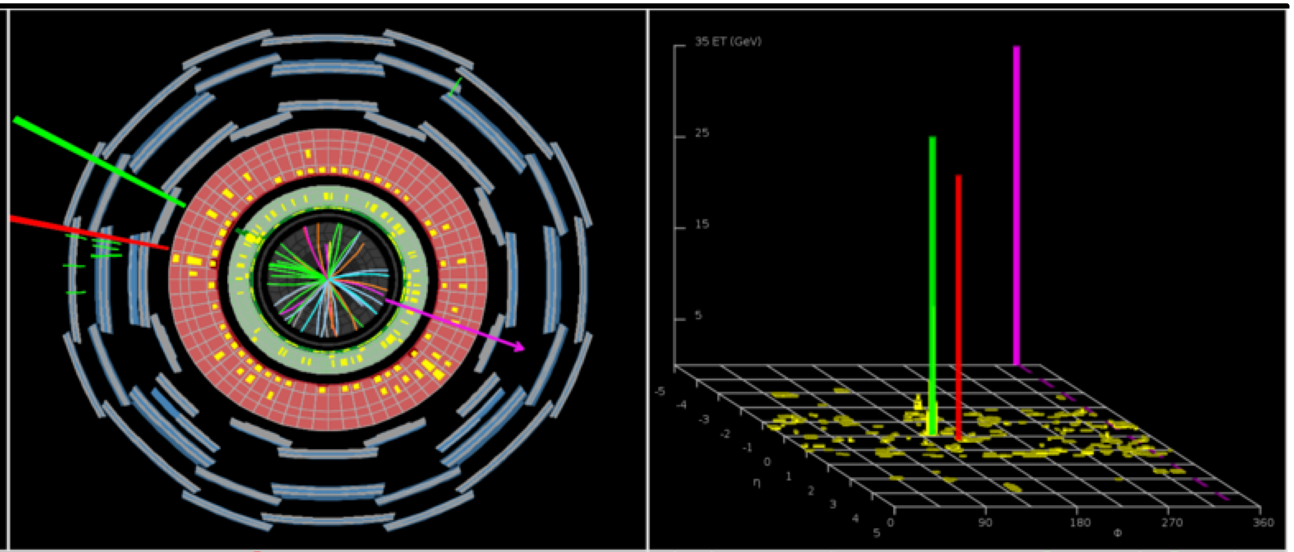
Signal	Signal Purity s/b	Main backgrounds	Production	7 & 8 TeV $\int L\,dt$
~16	~1.5	ZZ, Z+jets, top	ggH, VBF & VH	4.9 & 20.7 fb^{-1}

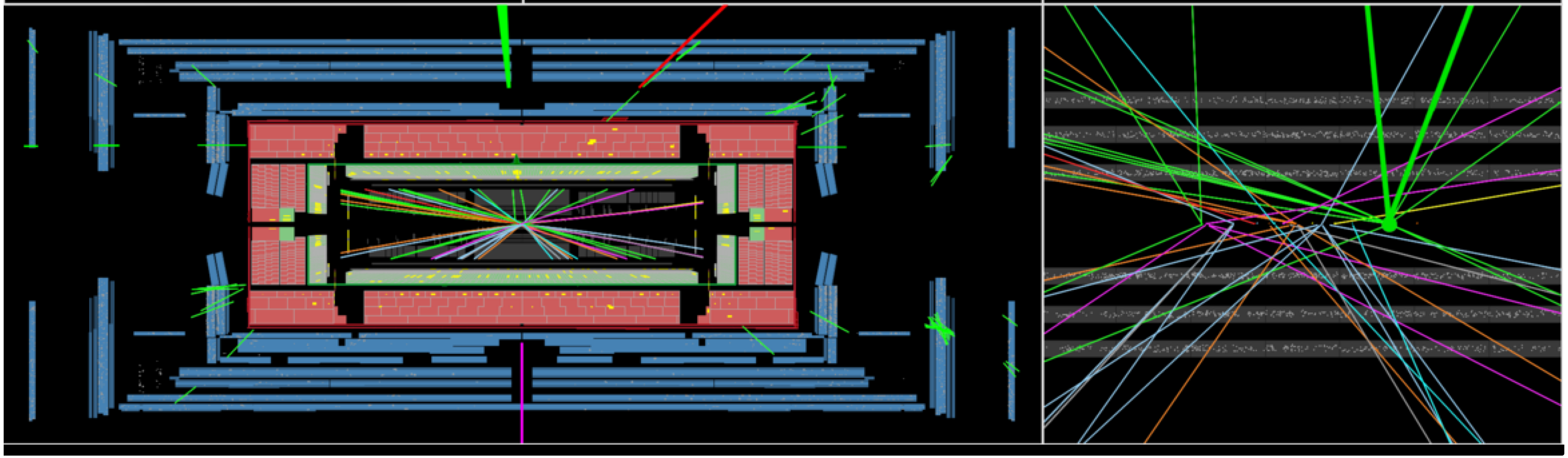
$H \rightarrow WW^{(*)}$

$ll + 2\nu$

0,1, 2 jet Channel

ATLAS-CONF-2013-030





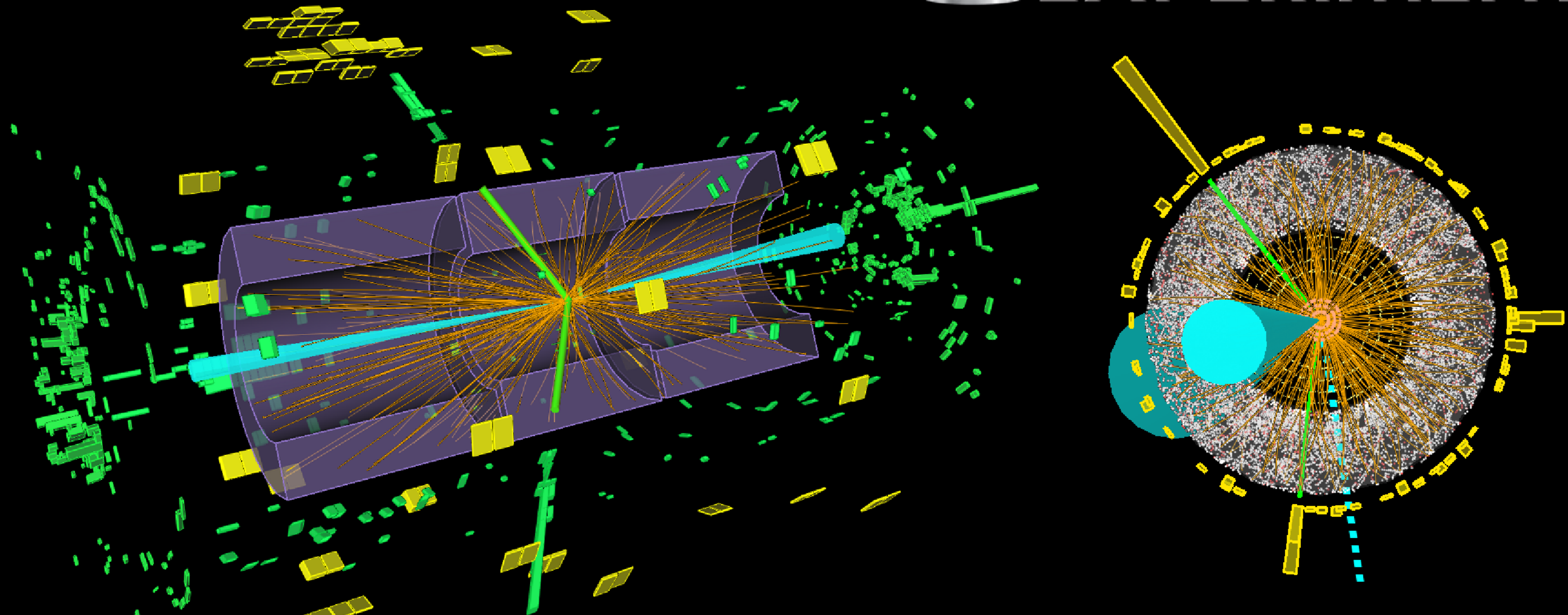
WW channel basic facts sheet :

Signal	Sig. Purity s/b	Main backgrounds	Production	7 & 8 TeV $\int L\,dt$
~250	~5%-40%	WW, W+jets, top, etc…	ggH & VBF	25fb^{-1}

$H \rightarrow \tau\tau$

Reoptimised 7+8 TeV analysis

ATLAS-CONF-2012-160



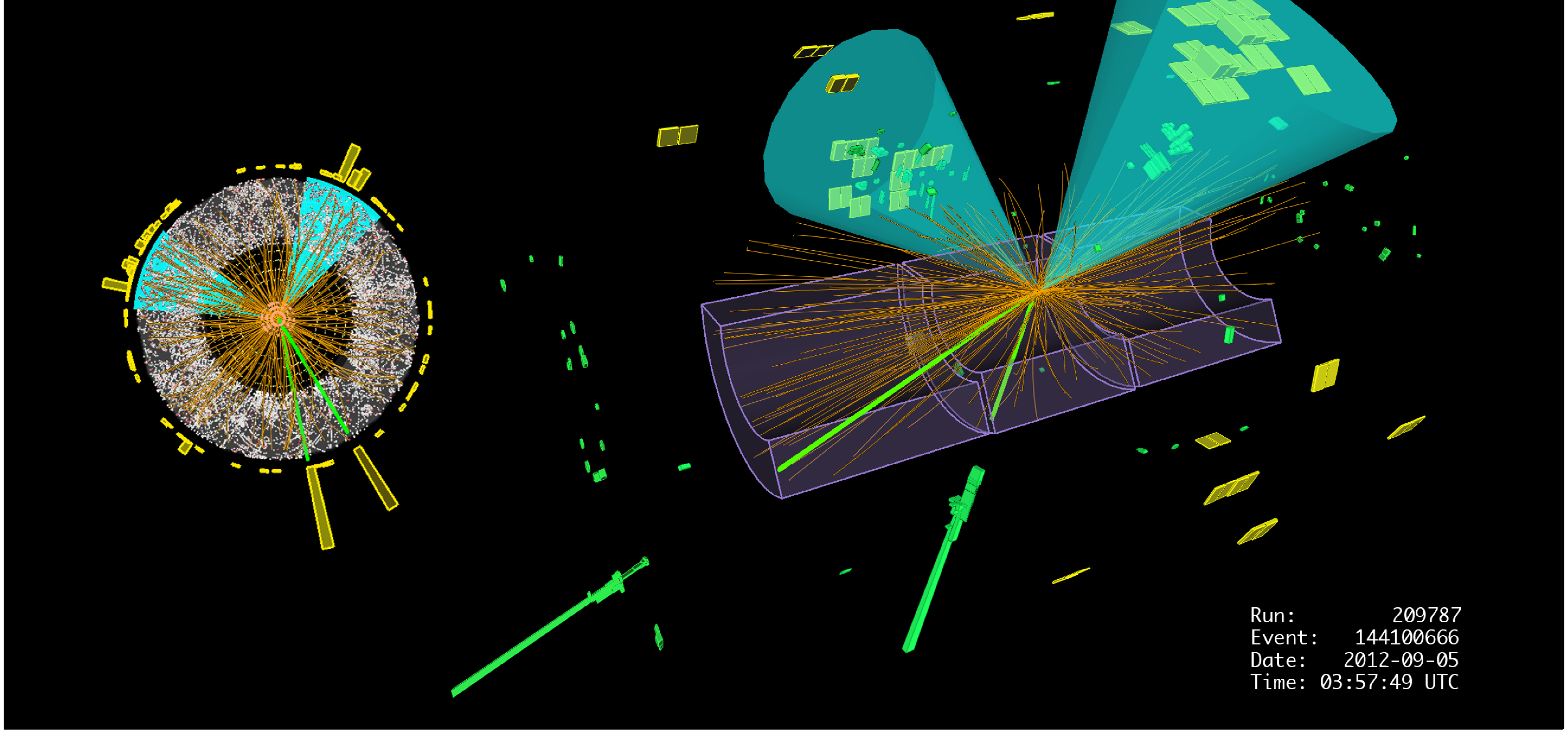
$H \rightarrow \tau_{had}\tau_{had}$ candidate in VBF channel (m_{MMC} = 131 GeV)

$\tau\tau$ channel basic facts sheet :

Signal (SM)	Signal purity s/b	Main backgrounds	Production	7 & 8 TeV $\int L\, dt$
~330	0.3% - 30%	ZZ, Z+jets, top	VBF, Hgg, VH	4.9 & 13 fb^{-1}

VH production with $H \rightarrow bb$

Combined and reoptimised 7+8 TeV analysis

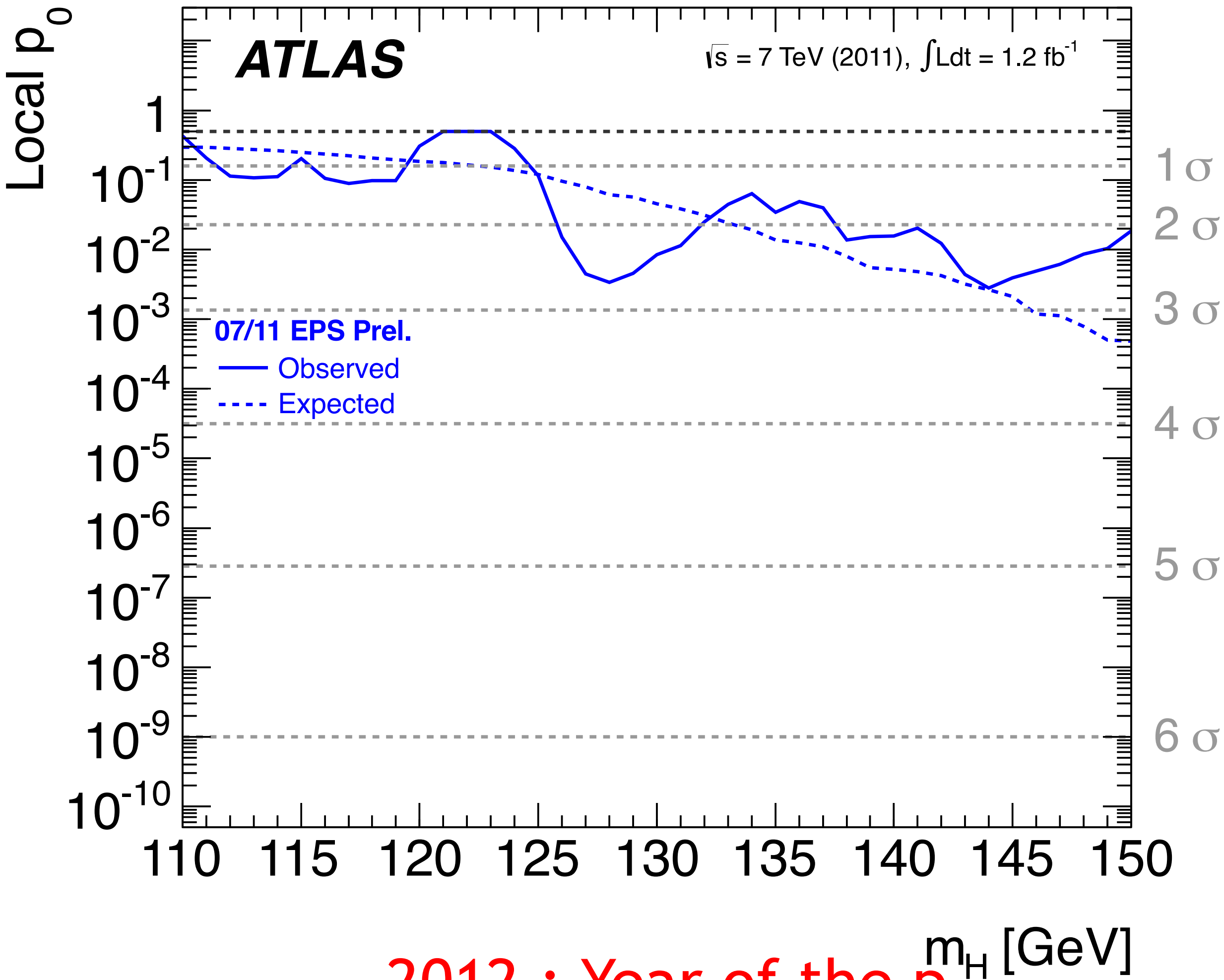


VH(bb) channel basic facts sheet :

Signal (SM)	Signal purity s/b	Main backgrounds	Production	7 & 8 TeV $\int L\,dt$
~50	~1% - 10%	Wbb,Zbb, top, etc…	VH	4.9 & 21 fb^{-1}

A Textbook Discovery!

Birth of a particle (different prospective)

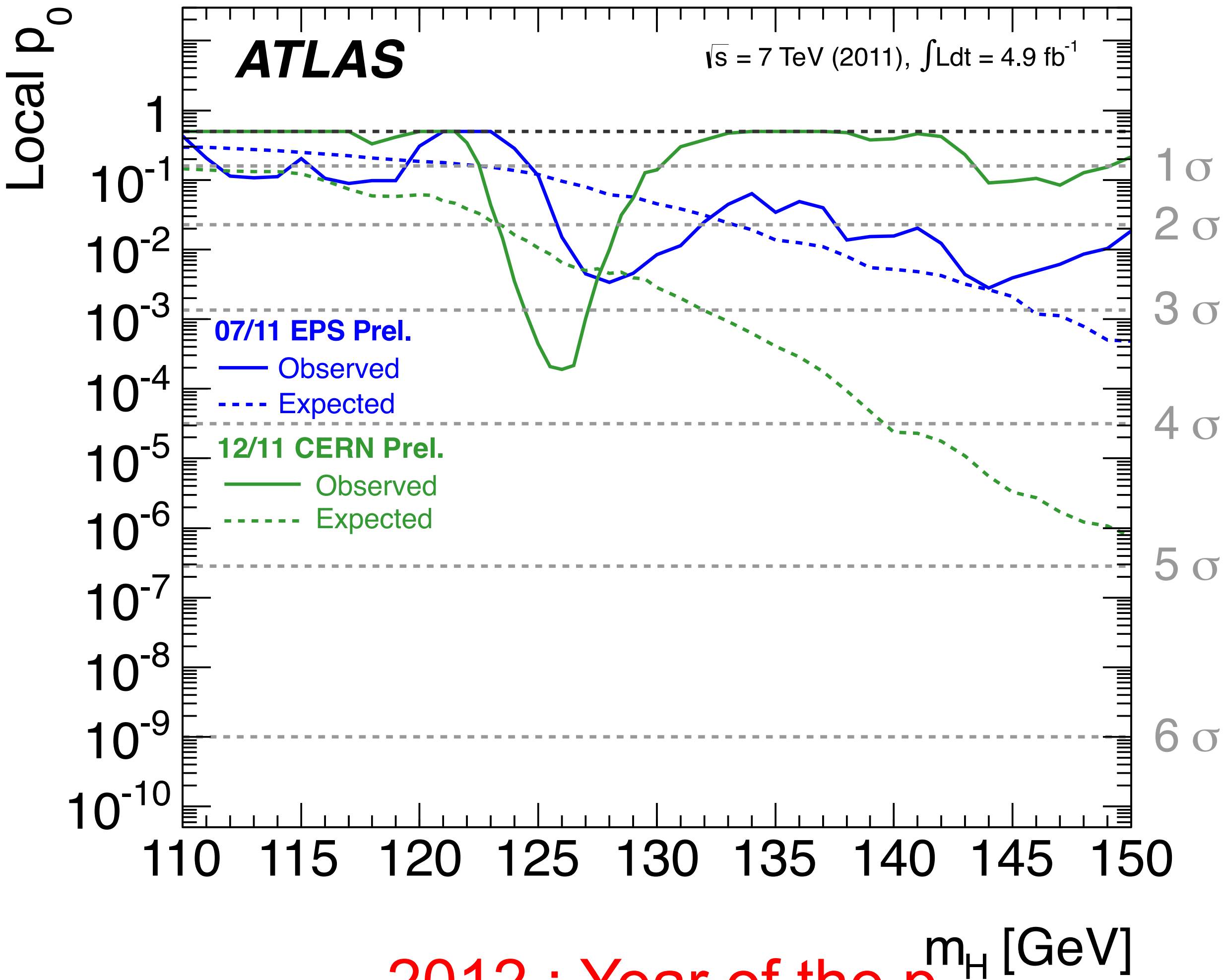


2012 : Year of the p_0

A Textbook Discovery!

Birth of a particle (different prospective)

CERN Council (December 2011)

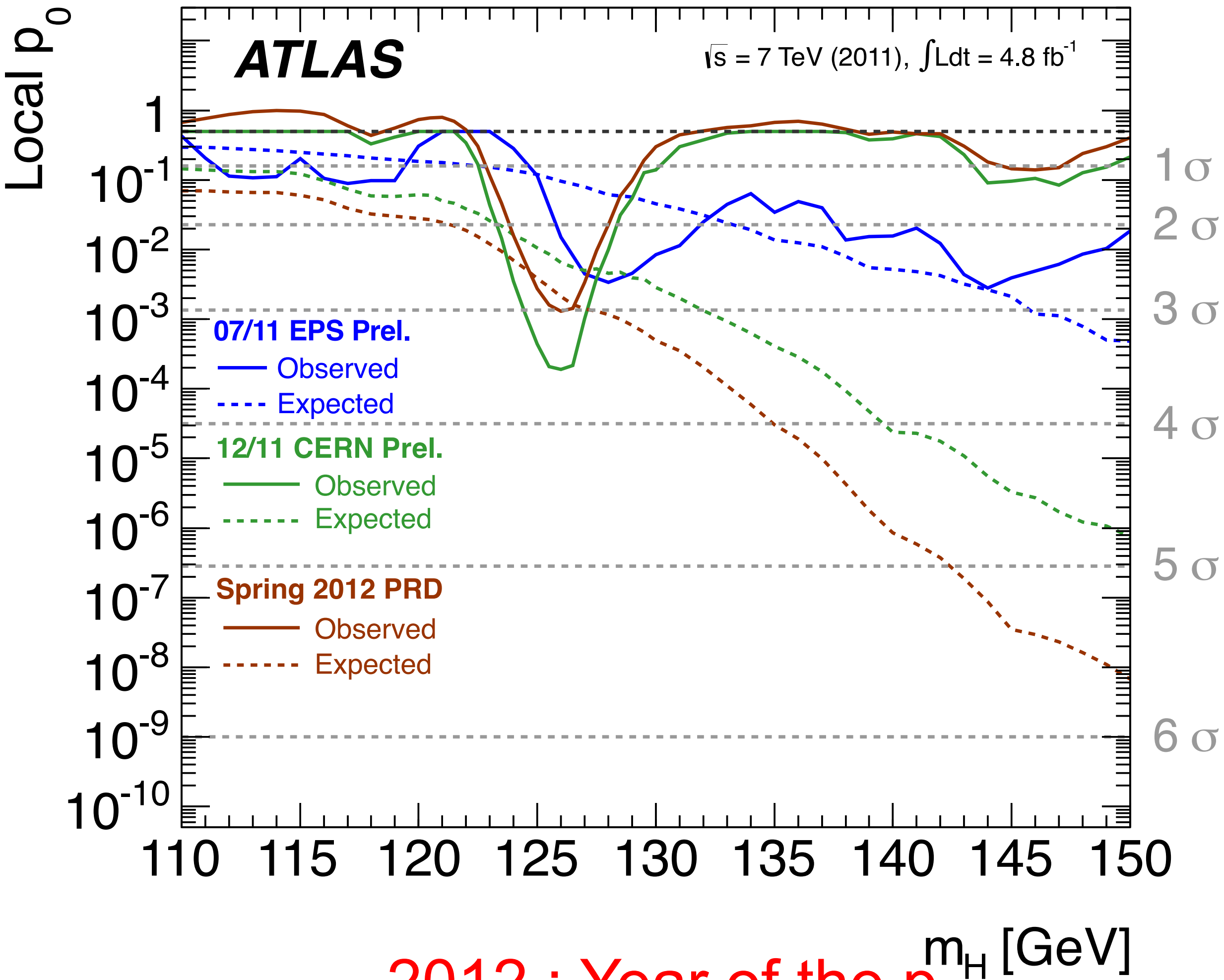


2012 : Year of the p_0

A Textbook Discovery!

Birth of a particle (different prospective)

Moriond (March 2012)

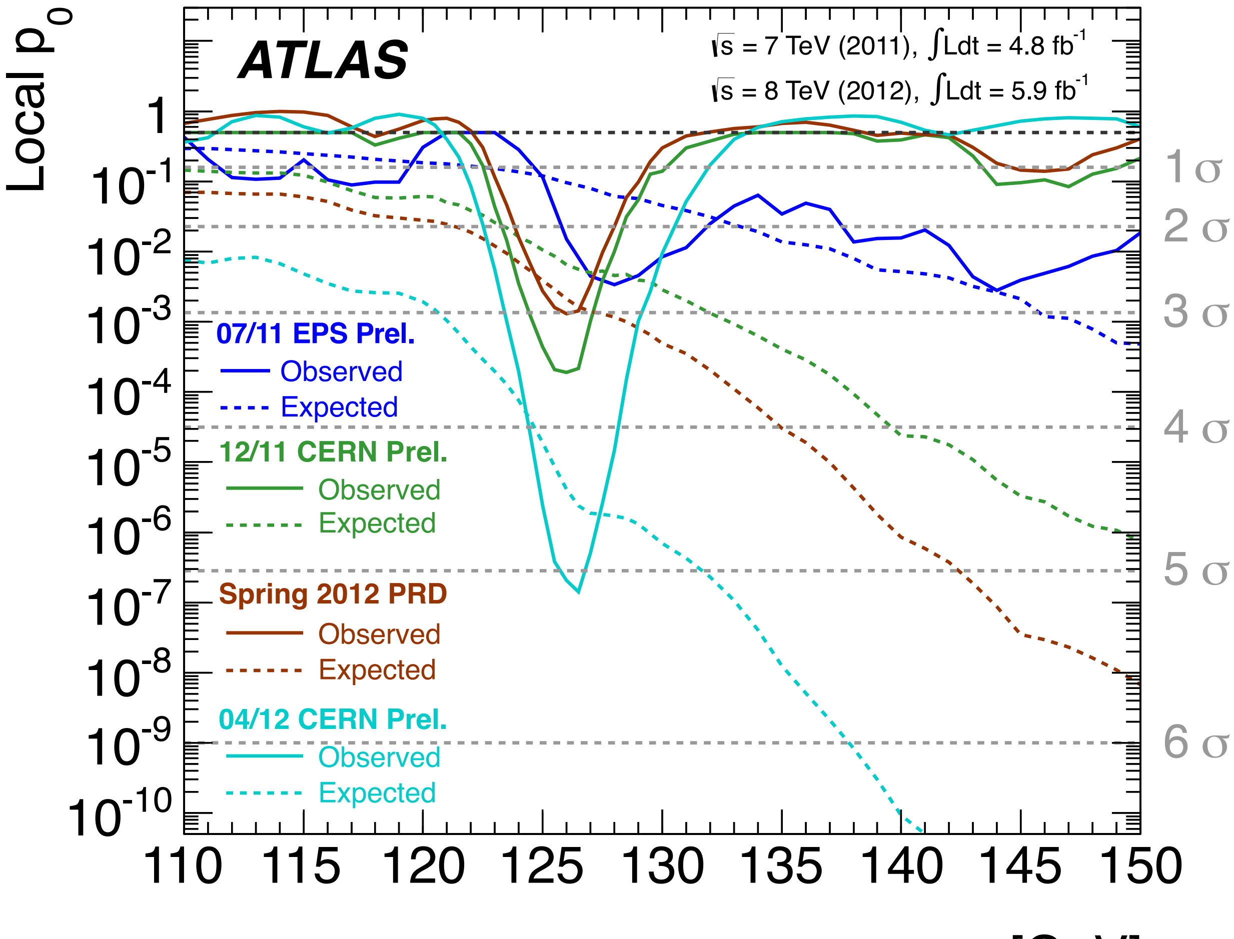


2012 : Year of the p_0

A Textbook Discovery!

Birth of a particle (different prospective)

ICHEP (July 2012)



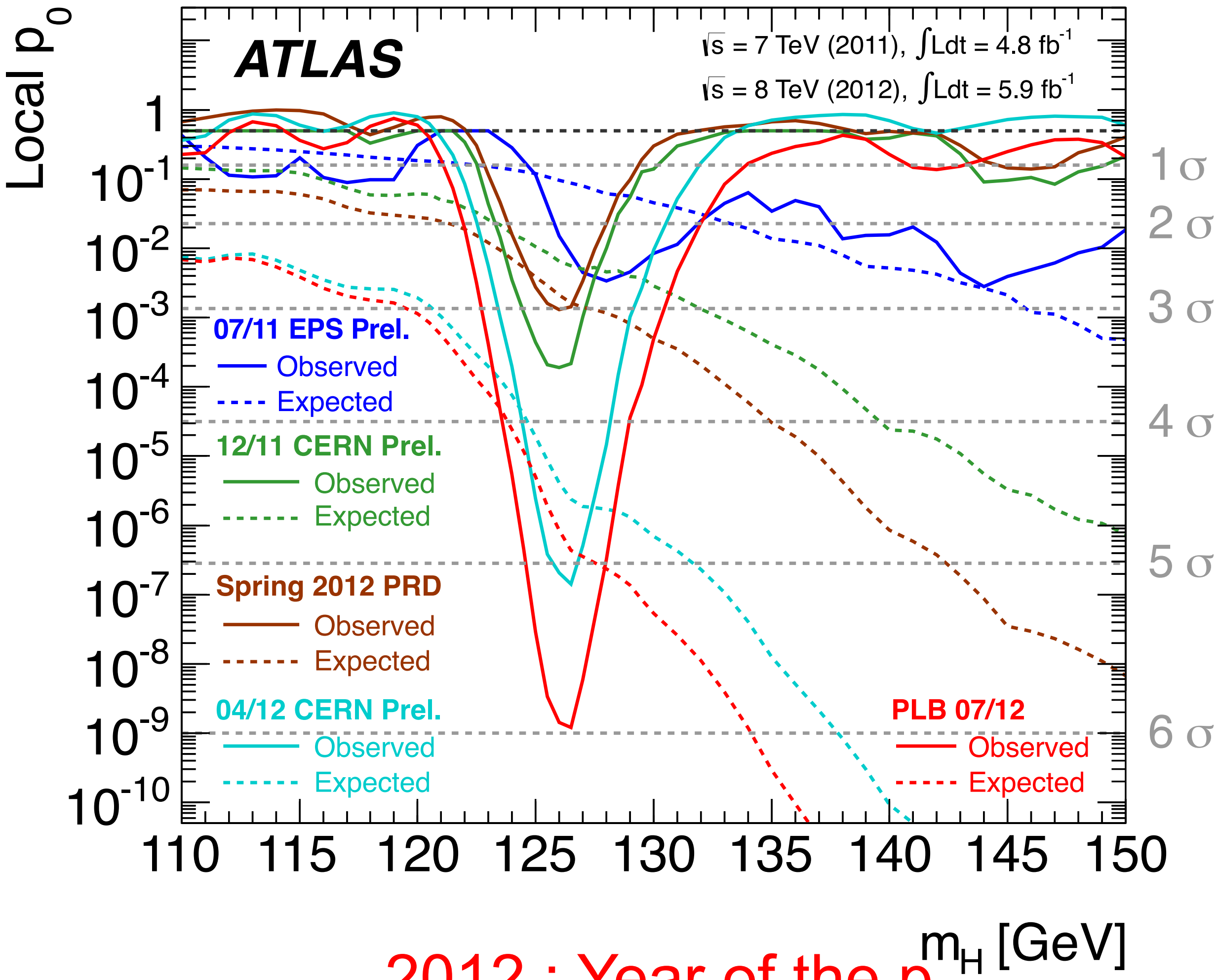
2012 : Year of the p_0

As a Layman : We have it!

A Textbook Discovery!

Birth of a particle (different prospective)

PLB (August 2012)



2012 : Year of the p_0

The Economist

The Discovery!

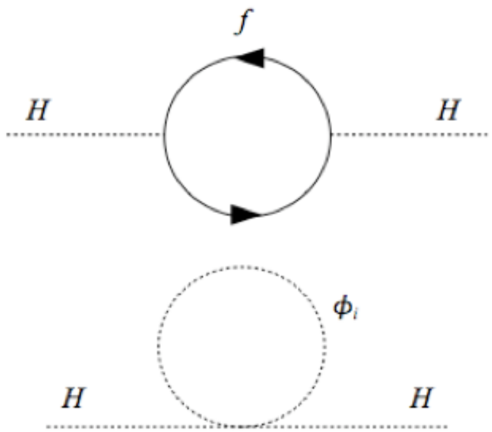
... in 2012

Backup Slides

Searching for SUSY with Tops

ATLAS-CONF-2012-166
ATLAS-CONF-2012-167

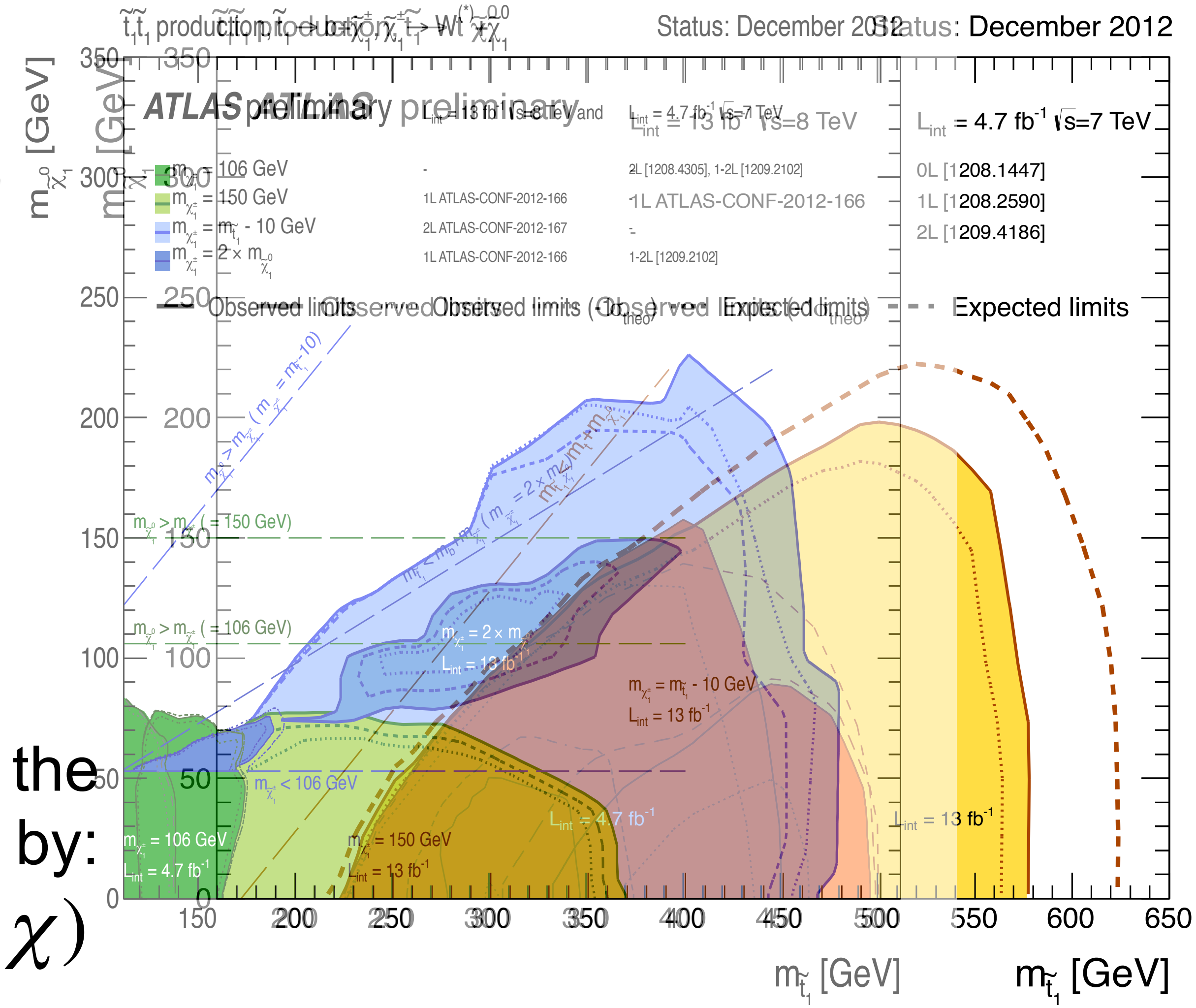
Seeking to Solve the Hierarchy Problem...



$$\tilde{t} \rightarrow t\chi$$

Complemented in the lower mass range by:

$$\tilde{t} \rightarrow b(\chi^{\pm} \rightarrow W^{\pm}\chi)$$



Significantly improved sensitivity at high stop masses with expected limits up to 620 GeV

Also, strongly enhanced sensitivity for lower mass stop decaying into *b* + chargino