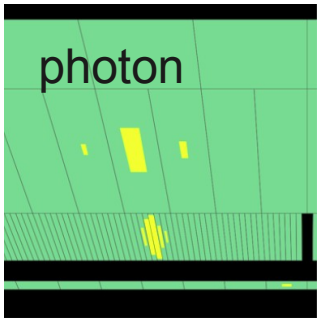
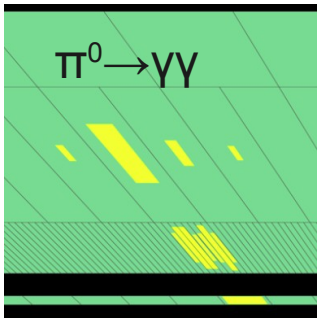


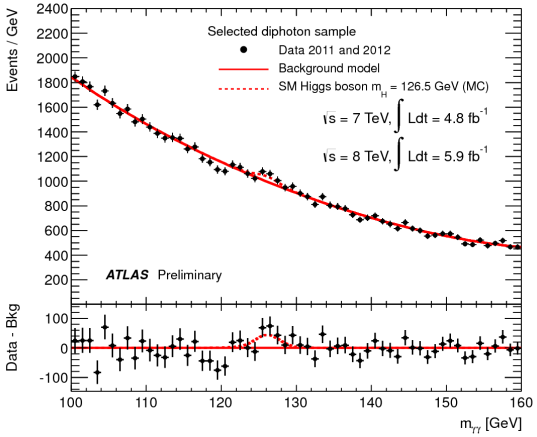


Le Higgs dans ATLAS, derniers résultats

Laboratoire d'Annecy-le-Vieux de Physique des Particules

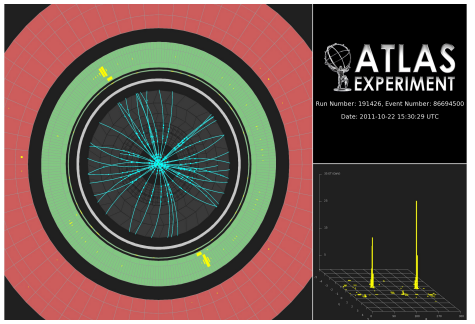
Elisabeth Petit

pour le groupe ATLAS du LAPP

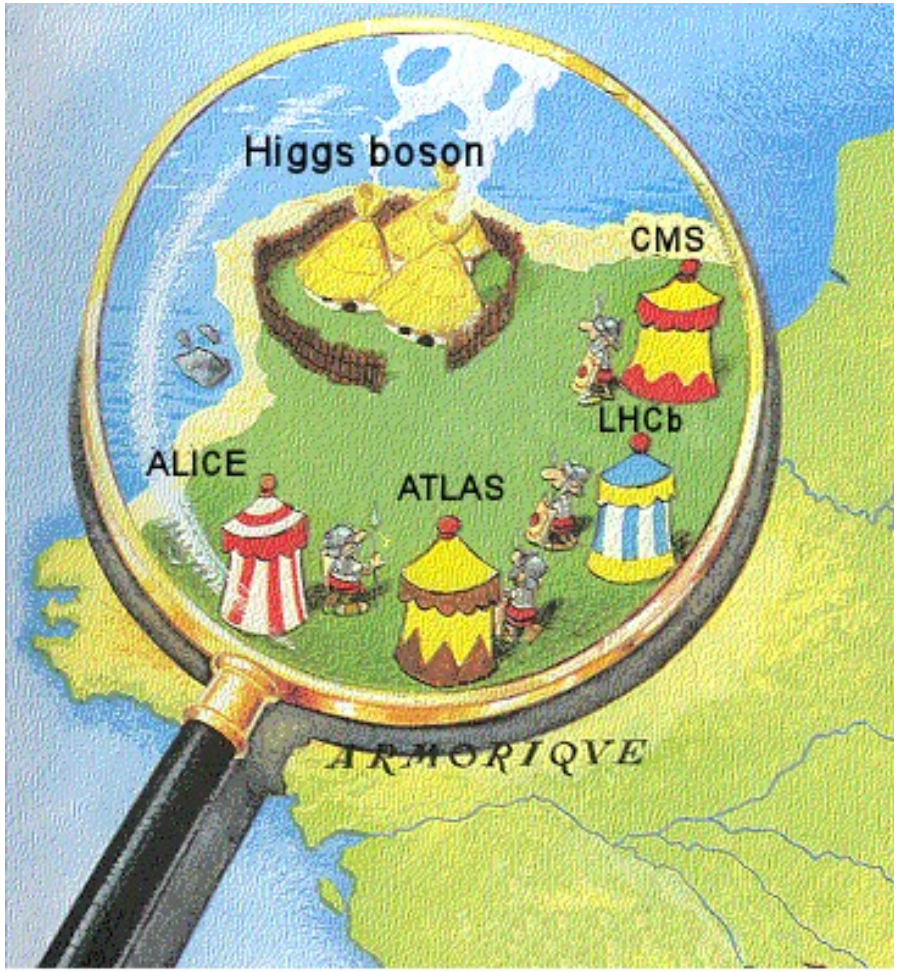


séminaire LAPP

10 of Juillet 2012

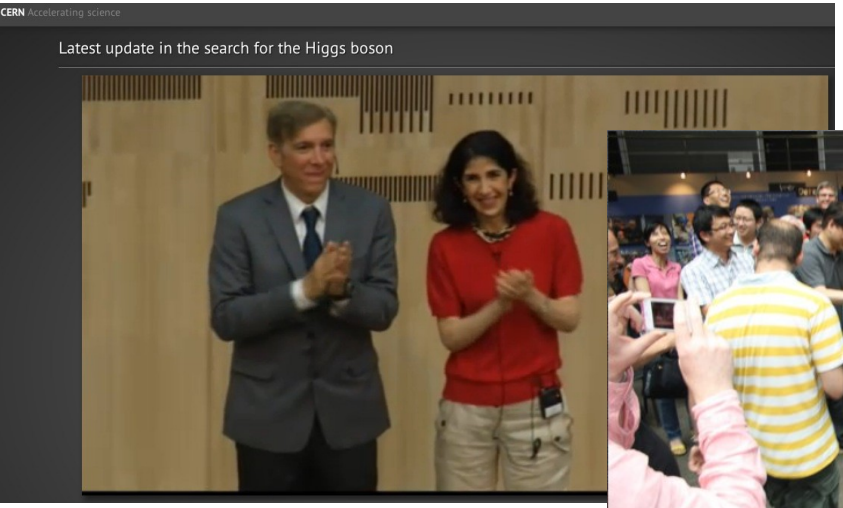


Introduction



- Nous sommes le 4 juillet 2012 après Jésus-Christ ; tout le Modèle Standard a été découvert...
  Tout ? Non ! Car une particule résiste encore et toujours à l'envahisseur.
  Et la vie n'est pas facile pour les garnisons de physiciens des camps retranchés de ALICE, ATLAS, CMS et LHCb.

Le 4 juillet : 'Higgstérie' au CERN

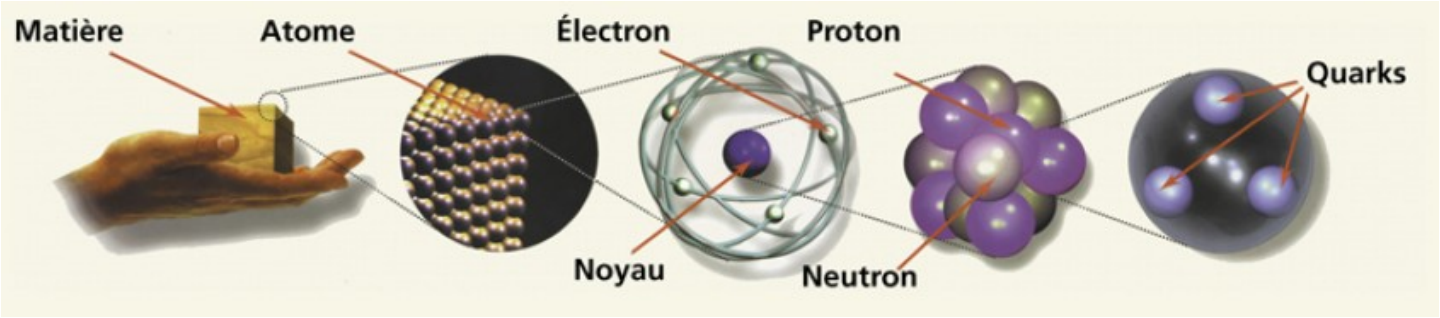


Plan

- Le boson de Higgs : quoi, pourquoi, comment ?
- Le boson de Higgs au LAPP
- Recherche du boson de Higgs dans le canal $H \rightarrow \gamma\gamma$
- Recherche du boson de Higgs dans le canal $H \rightarrow 4\ell$
- Combinaison des résultats

Le boson de Higgs

Le Modèle Standard



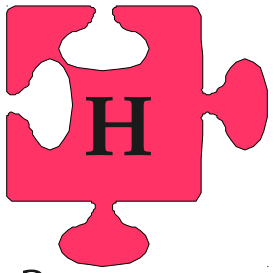
♦ 12 particules élementaires

quarks	u up	c charm	t top
	d down	s strange	b bottom
leptons	e electron	μ muon	τ tau
	ν_e neutrino electronique	ν_μ neutrino muonique	ν_τ neutrino tauique

bosons
γ photon
W bosons W±
Z boson Z
g gluon

♦ 4 interactions fondamentales

- électromagnétisme
- interaction faible
- interaction forte
- gravitation



♦ + boson de Higgs ?

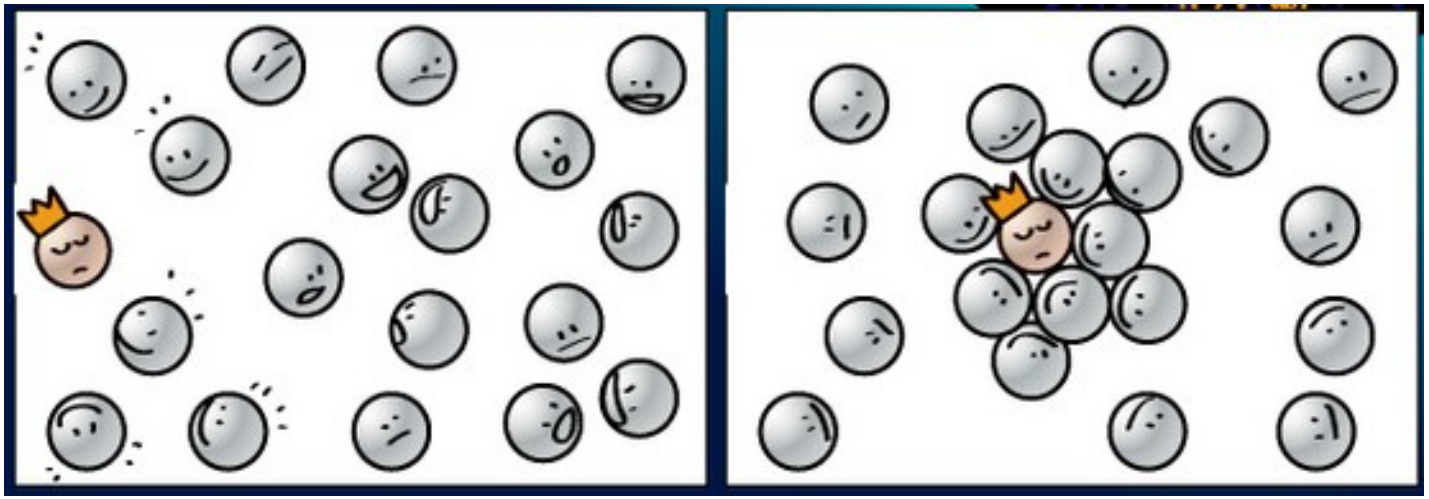
Pourquoi le boson de Higgs

- Mécanisme de Higgs:

  (ou de Englert-Brout-Higgs-Guralnik-Hagen-Kibble)

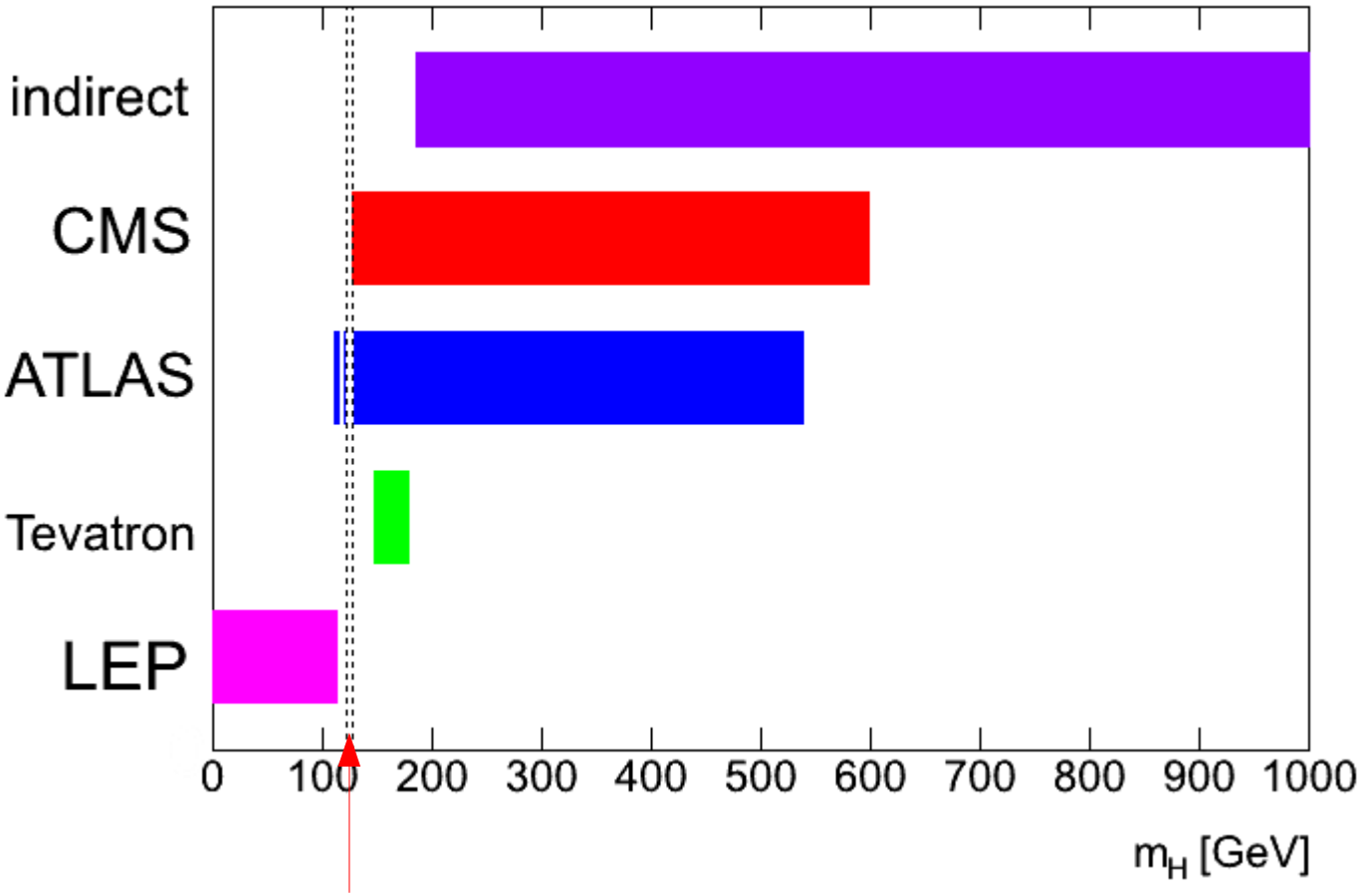
  - postulé en 1964
  - donne masse bosons W et Z, et aux fermions (quarks, électrons, etc)
  - prévoit existence d'un nouveau boson

- Analogie : le cocktail



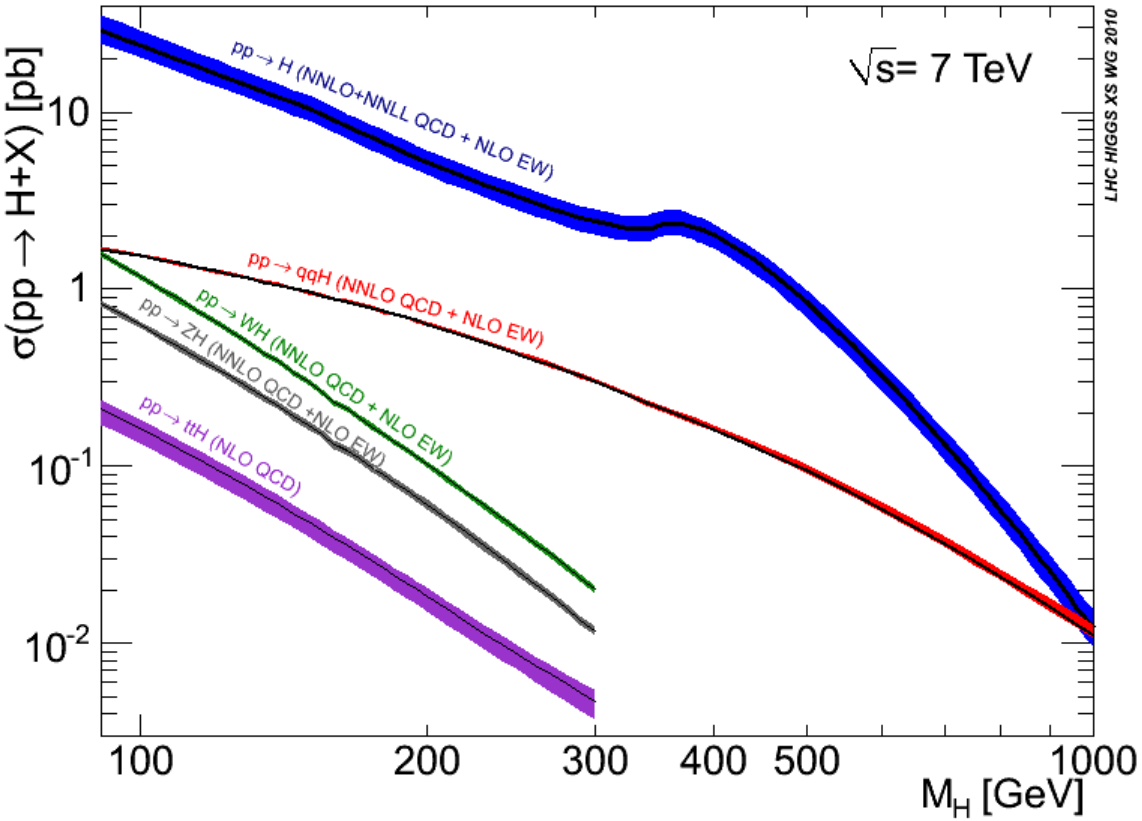
Recherche suivant masse

- Boson de Higgs donne la masse aux particules mais on ne peut pas prévoir la sienne !
- Recherche pour masses entre 100 GeV et 1 TeV
- Masses exclues avant le 4 juillet 2012 :



Production au LHC (1)

- Section efficace ⇔ taux de production

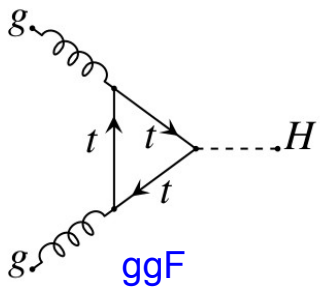


$\sigma(m_H = 125\ \text{GeV}, \sqrt{s} = 7\ \text{TeV}) = 17.5\ \text{pb}$

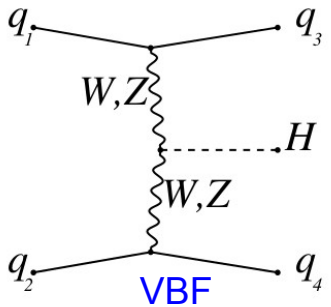
$\sigma(m_H = 125\ \text{GeV}, \sqrt{s} = 8\ \text{TeV}) = 22.3\ \text{pb}$

Actuellement :

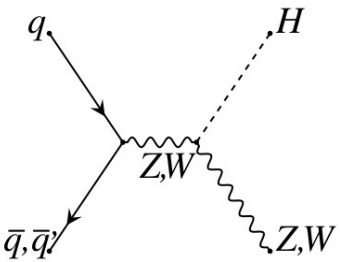
- ~1 boson de Higgs toutes les 10 s
- 50 bosons W /s
- 1 million di-jet /s



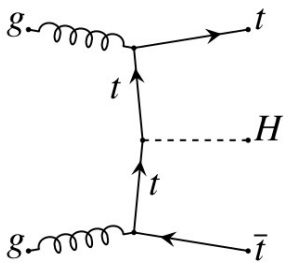
ggF
87.5%



VBF
6.7%



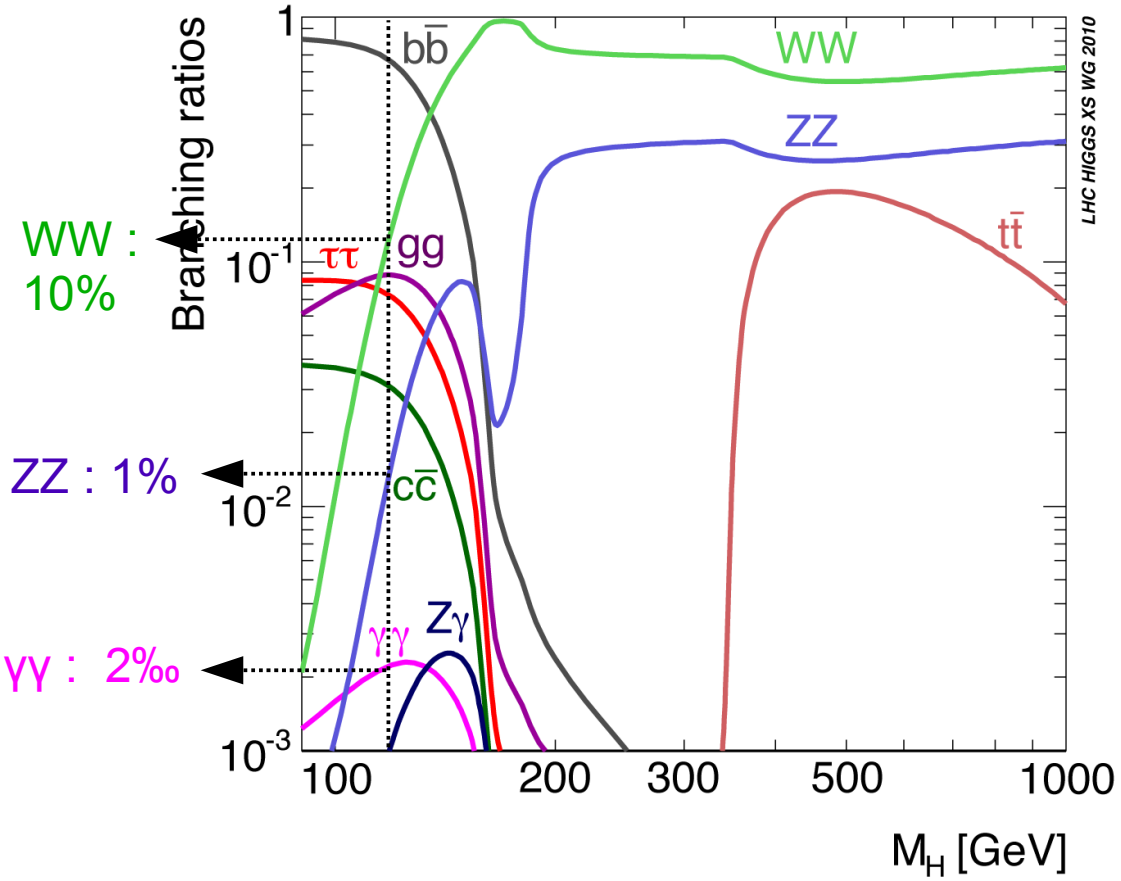
ZH, WH
5.3%



ttH
0.5%

Production au LHC (2)

- On n'observe pas directement le boson de Higgs, mais ses produits de désintégration
- Rapport d'embranchement = fraction d'événements dans un état final

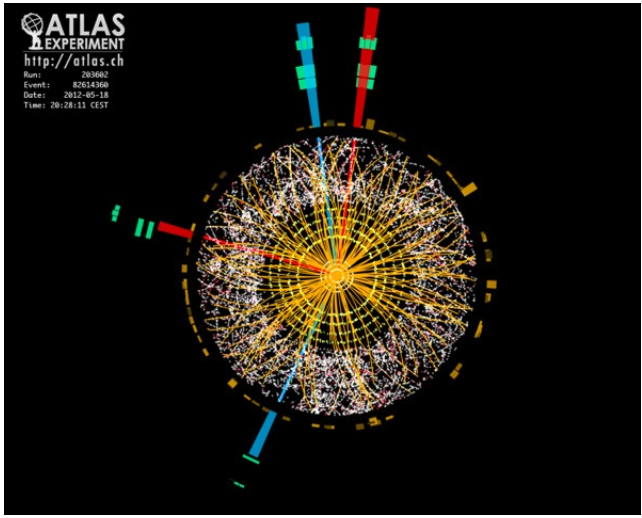


Actuellement :

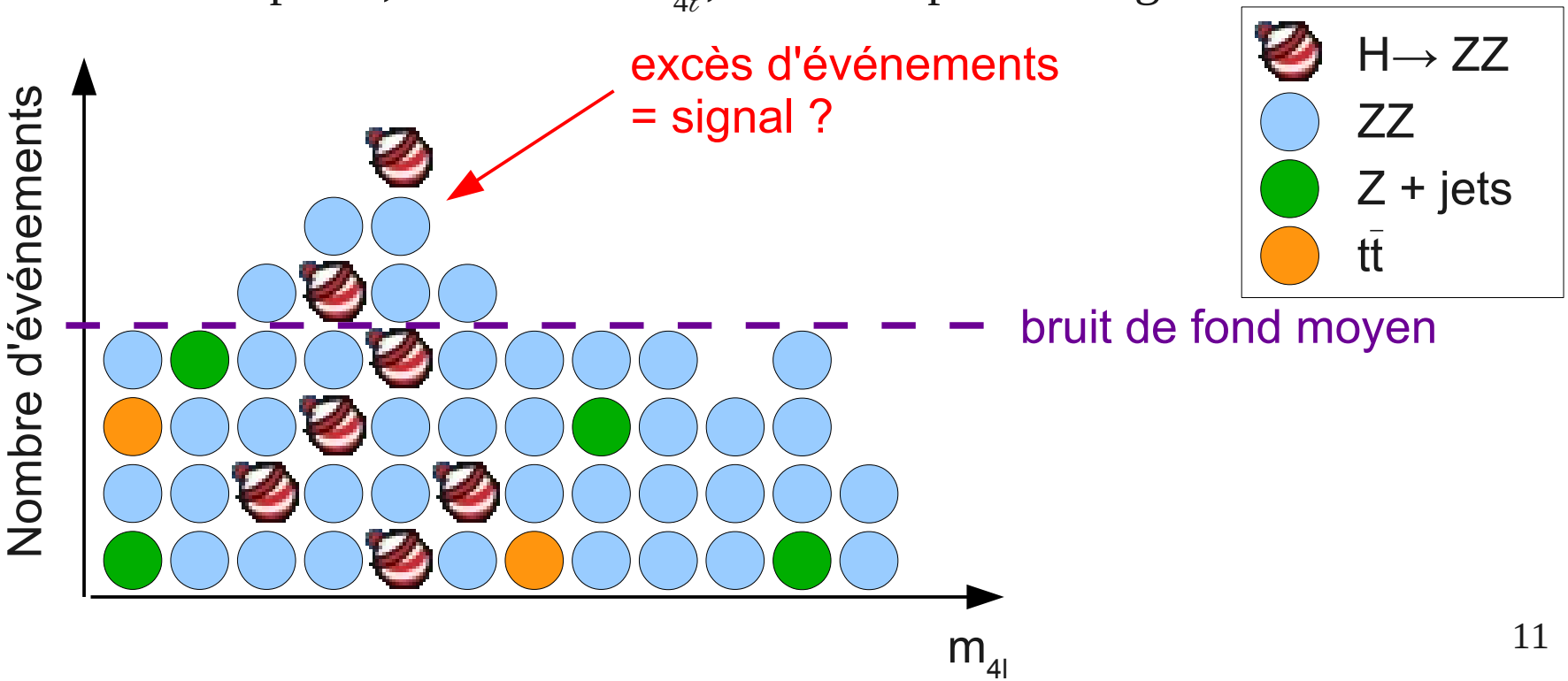
- 1 Higgs toutes les 10 s
- 1 H → γγ toutes les 1.5 h
- 1 H → ZZ toutes les 10 minutes
  - 1 H → 4ℓ toutes les 3 heures

Comment on le recherche (1)

- Exemple : signal = H → ZZ → $\ell^+\ell^-\ell^+\ell^-$
- Autres particules qui vont avoir état final semblable = bruit de fond
  - irréductible : production de 2 bosons Z
  - réductible : Z + jets, $t\bar{t}$, etc

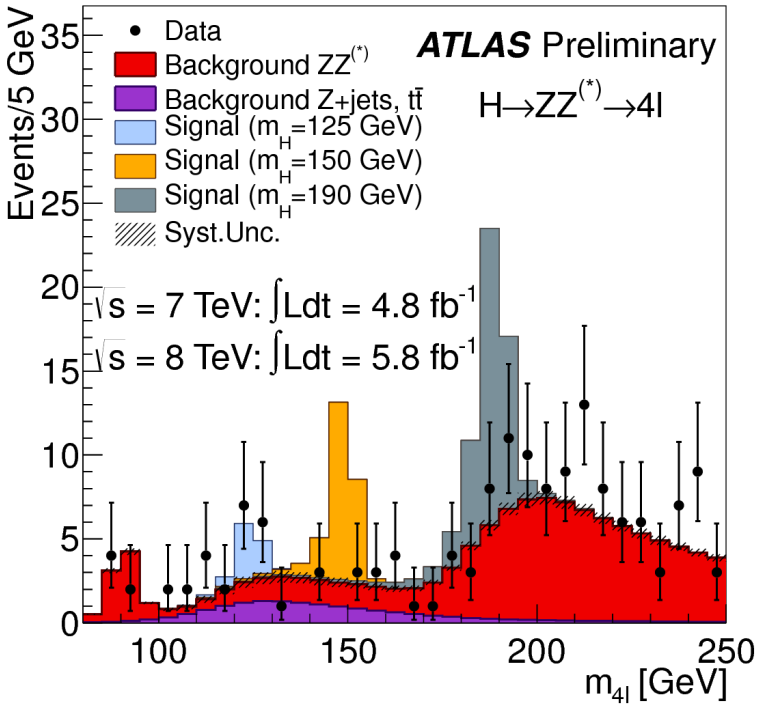


- A partir des 4 leptons, on calcule $m_{4\ell}$, et on remplit l'histogramme



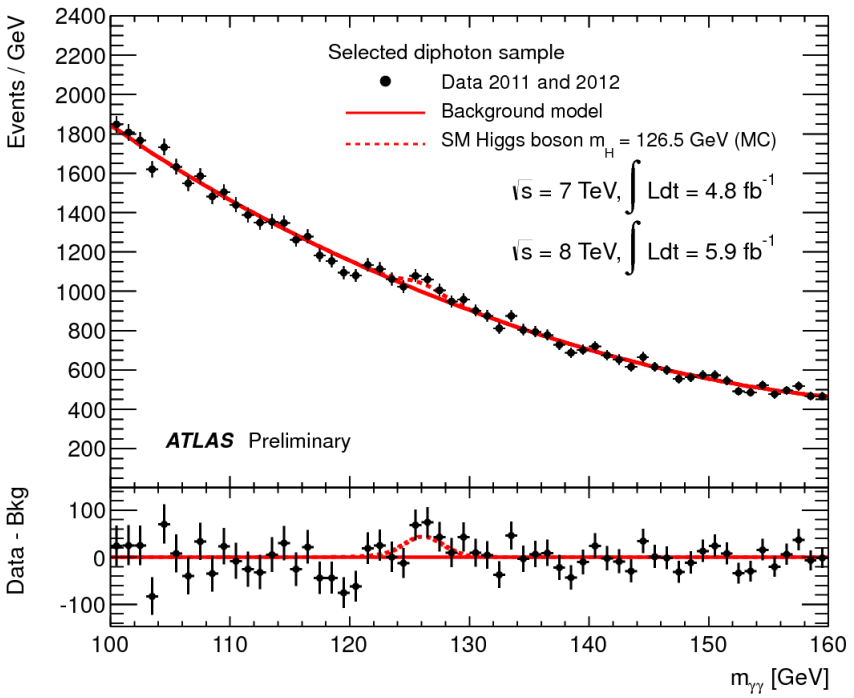
Comment on le cherche (2)

- Les histogrammes en vrai:
- $H \rightarrow ZZ \rightarrow 4\ell$:



➔ Très peu d'événements attendus

- $H \rightarrow \gamma\gamma$:



➔ Très petit signal par rapport au bruit de fond

ATLAS et boson de Higgs au LAPP (1)

Equipe actuelle

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Yildizkaya Tamer	1633	tamer.yildizkaya@lapp.in2p3.fr	Mécanique	HL-LHC

- physique
- mécanique
- électronique
- informatique
- administration

ATLAS et boson de Higgs au LAPP (2)

- Thèses au LAPP:

Thèses en Cours

Nom	Directeur	Sujet de la thèse	Date de soutenance prévue
Houry Keoshkerian	Emmanuel Sauvan	Recherche de signaux de nouvelle physique à plusieurs électrons auprès du LHC	2014
Maud Schwoerer	Jessica Lévêque / Isabelle Wingerter	Recherche de signatures inclusives contenant deux photons dans le détecteur ATLAS	2013
Dimitra Tsionou	Lucia Di Ciaccio / Stathes Paganis	mesure de la section efficace de production du W	2012
Ludovica Agerio-Bella	Tetiana Berger-Hryn'ova / Lucia Di Ciaccio	Recherche de nouveaux états physiques dans le spectre de di-électrons à haute masse avec l'expérience ATLAS	2012
Louis Hélary	Nicolas Berger / Isabelle Wingerter	Recherche de technicouleur avec l'expérience ATLAS; mise en route du calorimètre électromagnétique	09.12.2011
Kieu Oanh Thi Doan	Théodore Todorov	Mesure de la section efficace différentielle de production du boson Z	2012

Thèses Soutenues

Mathieu Aurousseau	30 septembre 2010	Recherche du Higgs en 2 photons: préparation de l'analyse avec les premières données. Mise en route du calorimètre électromagnétique: étude des muons cosmiques.	2010
Olivier Arnaez	5 juillet 2010	Etude de la production du Z à 14 TeV dans le centre de masse dans l'expérience ATLAS. Mise en route du calorimètre électromagnétique	lien
Thibault Guillemin	30 juin 2009	Préparation à la mesure de la section efficace de production inclusive du boson W en électron-neutrino dans l'expérience ATLAS au LHC	pdf
Jean-François Marchand	3 juin 2009	Etude de la recherche du boson de Higgs en deux photons dans l'expérience ATLAS au LHC et calibration du calorimètre à Argon liquide	pdf
Michele Consonni	15 juillet 2008	Recherche du boson de Higgs dans les cascades de désintégration de particules supersymétriques avec le détecteur ATLAS au LHC.	pdf
Mohamed Aharrouche	11 décembre 2006	Etude des performances en faisceau-test d'une tranche des calorimètres centraux d'ATLAS. Mesure de l'asymétrie avant-arrière des Z produits au LHC dans le mode de désintégration e+e-.	pdf
Fabien Tarrade	18 septembre 2006	Etalonnage du calorimètre électromagnétique tonneau. Identification des leptons taus et recherche d'un boson de Higgs dans le canal qqH->qq tau tau dans l'expérience ATLAS au LHC.	pdf
Damien Prieur	14 avril 2005	Etalonnage du calorimètre électromagnétique d'ATLAS. Reconstruction des événements avec des photons non pointants dans le cadre d'un modèle supersymétrique GMSB.	pdf
Olivier Gaumer	13 décembre 2004	Analyse de l'uniformité des modules de série du calorimètre électromagnétique tonneau d'ATLAS. Recherche de bosons supplémentaires neutres	pdf
Christophe Le Maner	27 juin 2003	Etude de la reponse du calorimètre électromagnétique et recherche d'un boson de Higgs de 300 GeV/c2 dans le canal qqH -> qqWW -> qqlvujj dans l'expérience ATLAS au LHC	pdf
Lionel Neukermans	22 mai 2002	Etalonnage du calorimètre électromagnétique d'ATLAS. Recherche du boson de Higgs dans ses désintégrations invisibles	pdf
Nicolas Massol	19 avril 2000	Conception et mise au point de la procédure de qualification du calorimètre électromagnétique à argon liquide d'ATLAS	pdf
Jean-Marie Bussat	5 juin 1998	Conception d'un dispositif d'acquisition rapide de grande dynamique : application à la lecture du calorimètre de l'expérience ATLAS	pdf
Guillaume Eynard	6 mai 1998	Étude de la production associée du boson de Higgs, HW, Httbar, HZ --> 2gamma + e+-/mu+- + X avec le détecteur ATLAS, auprès du LHC	pdf
Serge Nicoleau	16 avril 1997	Désintegration du boson de Higgs en électrons et photons : optimisation et étalonnage du calorimètre électromagnétique d'ATLAS	
Olivier Linossier	8 avril 1997	Recherche du boson de Higgs de masse intermédiaire (120-180 GeV) dans le canal H0 --> ZZ* --> 4 leptons sur ATLAS et test d'un prototype de calorimètre électromagnétique	
Valérie Hermel	20 septembre 1996	contribution à la conception et à la réalisation d'un circuit spécifique de codage des informations issues du calorimètre d'une expérience auprès du LHC.	
Frédéric Rival	22 juin 1994	Construction d'un prototype de calorimètre hadronique pour le futur collisionneur à haute énergie LHC du CERN.	
Mario Stipcevic	19 mai 1994	Étude d'un prototype de calorimètre hadronique à argon liquide pour une expérience auprès du LHC: comportement en faisceau et optimisation de la résolution à l'aide d'une méthode de pondération	

Aubert Bernard, Ballansat Jacques, Barate Robert, Baud Jean-Philippe, Baudin Patrick, Beeldens Yannick, Bouedo Thierry, Cailles Michel, Colas Jacques, Corageoud Francois, Delebecque Pierre, Dromby Gérard, Dubois Jean-Marc, Ghez Philippe, Girard Claude, Michel Gouanère, Ionescu Gelu, Jeremie Andrea, Journet Laurent,Lieunard Bruno, Monteiro Ino, Nappa Jean-Marc, Panazol Jean-Luc ,Perrodo Pascal, Sauvage Gilles, Tassan Jean, Zitoun Robert, Zolnierowski

Sebastien, Pierre-Yves, Nicolas D, Renaud, Nicolas L, Nicolas M, Fatima, Guy, Julie

Alain, Fatih, Sabine

Stéphane

Jessica

David, Ludovica, Nicolas, Tetiana, Marco, Lucia, Oanh, Corinne, Stéphane, Mayuko, Houry, Rémi, Jessica, Vincenzo, Elisabeth, Helenka, Emmanuel, Maud, Théodore, Dimitra, Isabelle

Nos anges gardiens :
Lionel, contrats
Claudine, LAr
Myriam, stagiaires
Cécile, budgets
Marie-Claude, missions
Nathalie, missions
Brigitte, missions
Chantal,) pour tout

image : http://www.lhc-france.fr

Comment chercher le H→γγ avec ATLAS

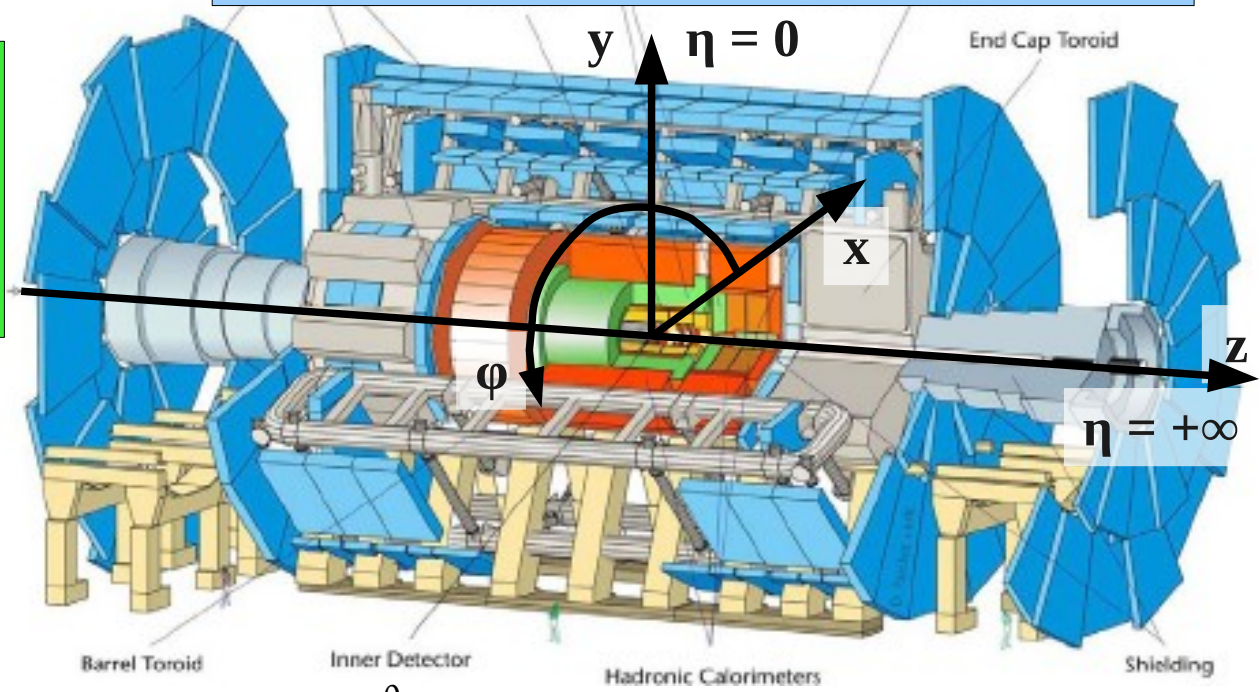
The ATLAS experiment

Inner detector (2 T)
$|\eta| < 2.5$
Si Pixel et SCT, TRT
tracks, vertex
$\sigma/p_T \sim 0.05\% \; p_T$ (GeV) $\oplus$ 1%

Electromagnetic calorimeter
$|\eta| < 3.2$
Pb + LAr
electrons, photons, trigger
$\sigma/E \sim 10\%/\sqrt{E}$ (GeV) $\oplus$ 0.7%

Hadronic calorimeter
$|\eta| < 4.9$
Fe/Tile (central)
Cu/W + LAr (forward)
jets, E_T^{miss}, trigger
$\sigma/E \sim 50\%/\sqrt{E}$ (GeV) $\oplus$ 3%

Muon spectrometer (0.5 T)
$|\eta| < 2.7$
gas chamber in toroidal magnetic field
tracks, trigger
$\sigma/p_T < 10\%$ up to 1 TeV



$$\eta = -\ln\left(\tan\left(\frac{\theta}{2}\right)\right)$$

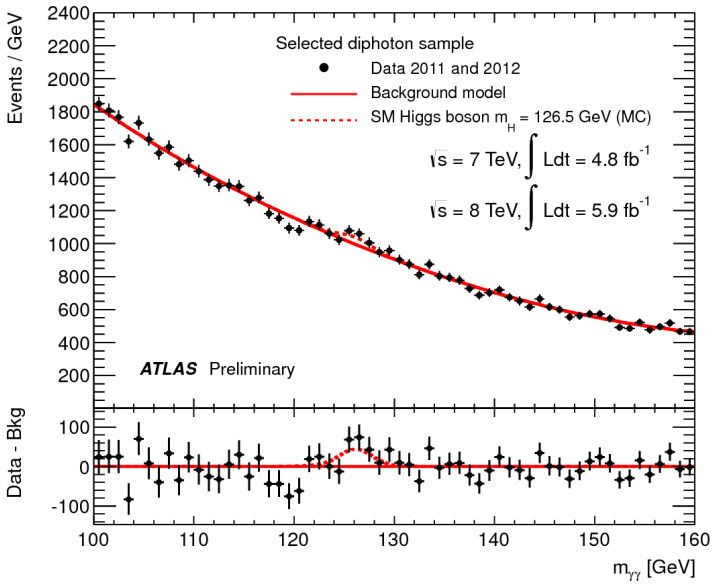
- > 96% operating channels
- > 90% of data used for physics

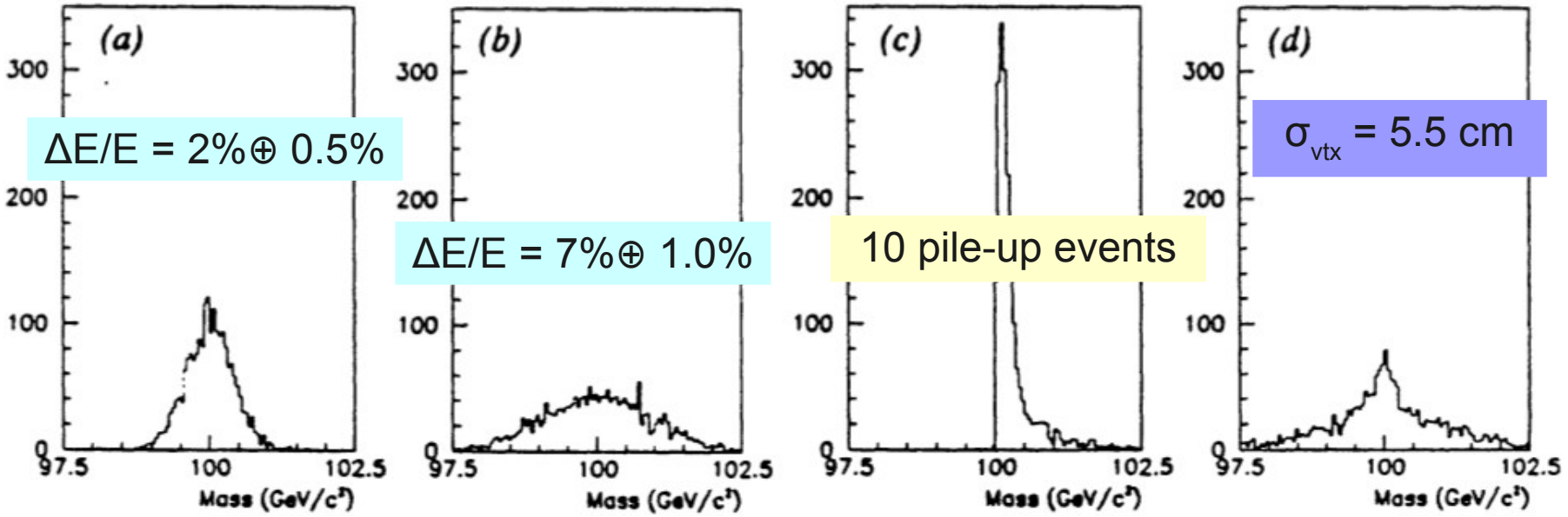
➔ Very good behaviour of all sub-detector

38 countries
~ 3000 members

Calorimeter constraints for H→γγ search

- Invariant mass: $m_{\gamma\gamma}^2 = 2\,E_1\,E_2\,(1-\cos\Delta\varphi(\gamma_1;\gamma_2))$
- Energy: 1% precision needed
  ⇒ EM calo resolution cst term < 1%
- Angular separation: better than 5 mrad
  ⇒ vertex precision < 1.5 cm



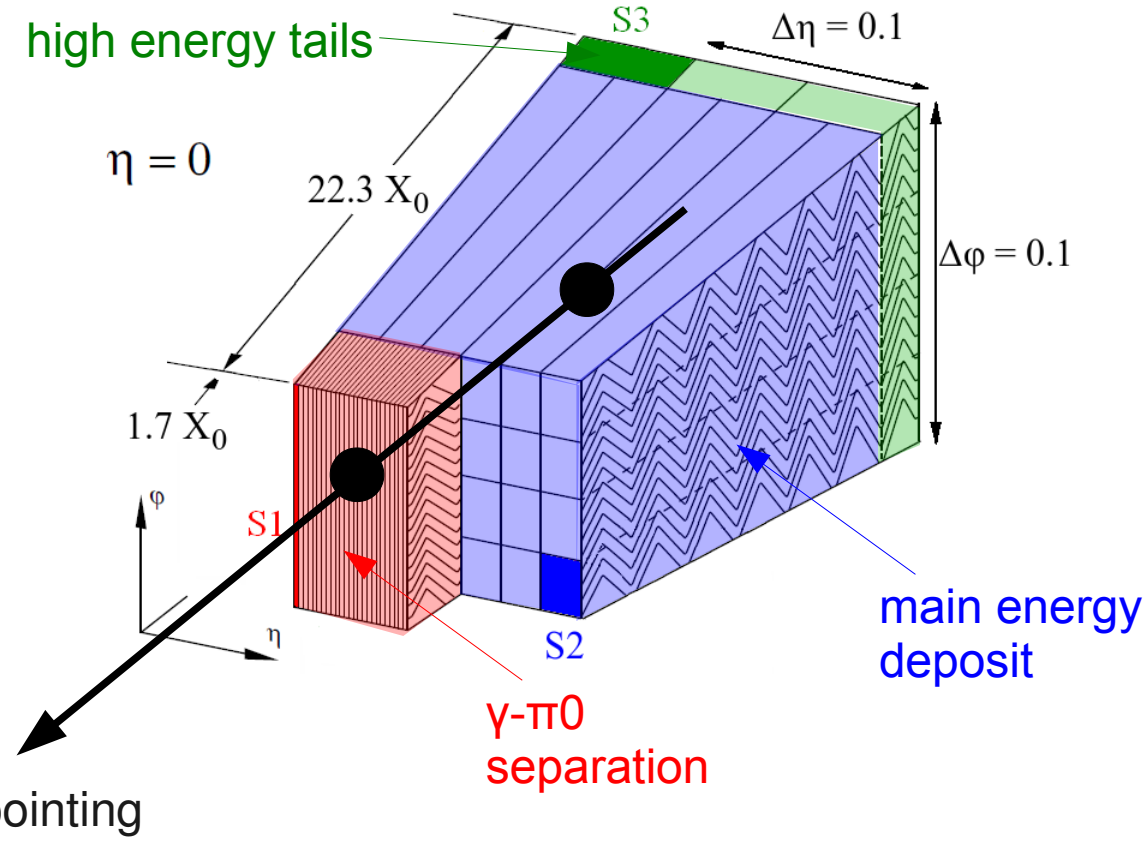


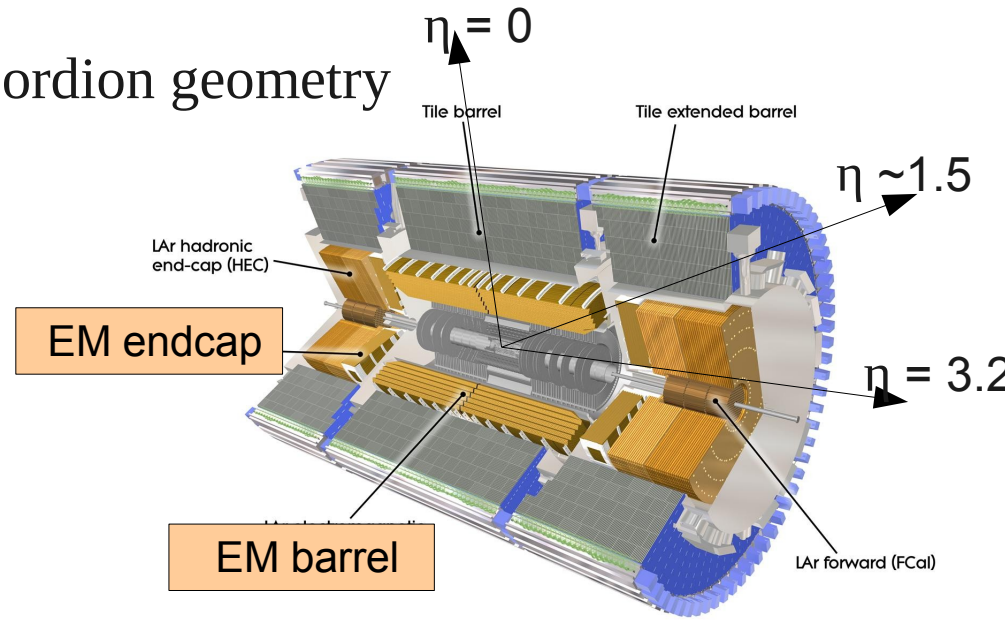
Large Hadron Collider Workshop, Aachen, Germany, 1990

- Good photon identification and large jet rejection

EM calorimeter

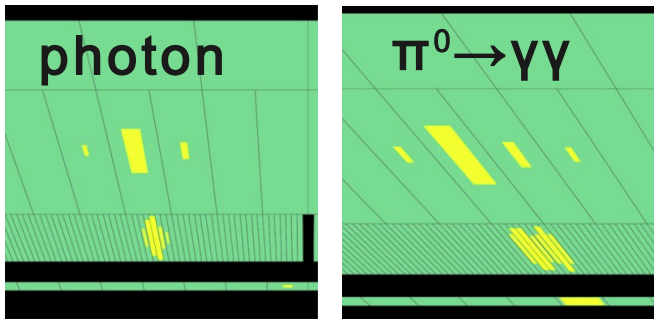
- Sampling calorimeter: Pb-LAr with accordion geometry
  - fast read-out
  - hermiticity in φ
  - high granularity (~160000 cells)
  - segmented laterally and longitudinally





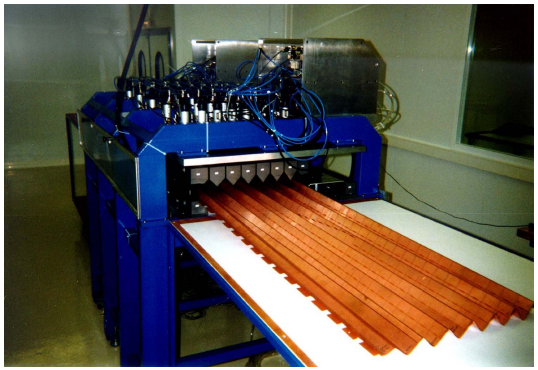
- Expected resolution:

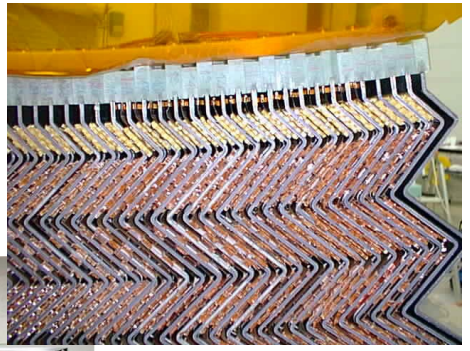
$$\frac{\sigma_E}{E} = \frac{10\,\%}{\sqrt{E}} \oplus 0.7\,\%$$



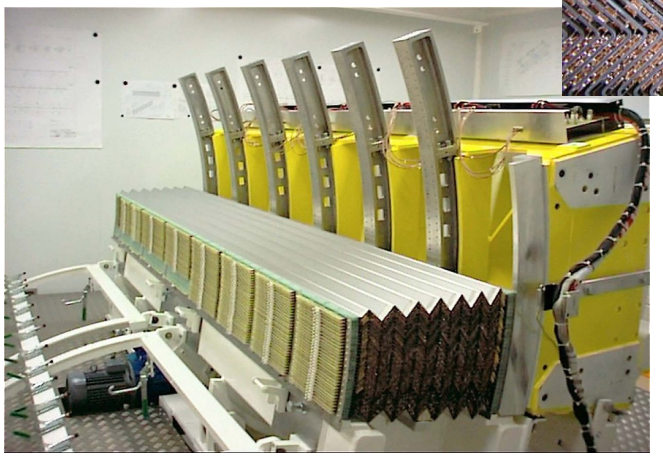
Le revers de la médaille...

- Pliage des électrodes : machine du LAPP





- Assemblage des modules
  - ~1/3 assemblés et testés au LAPP



- Cablâge

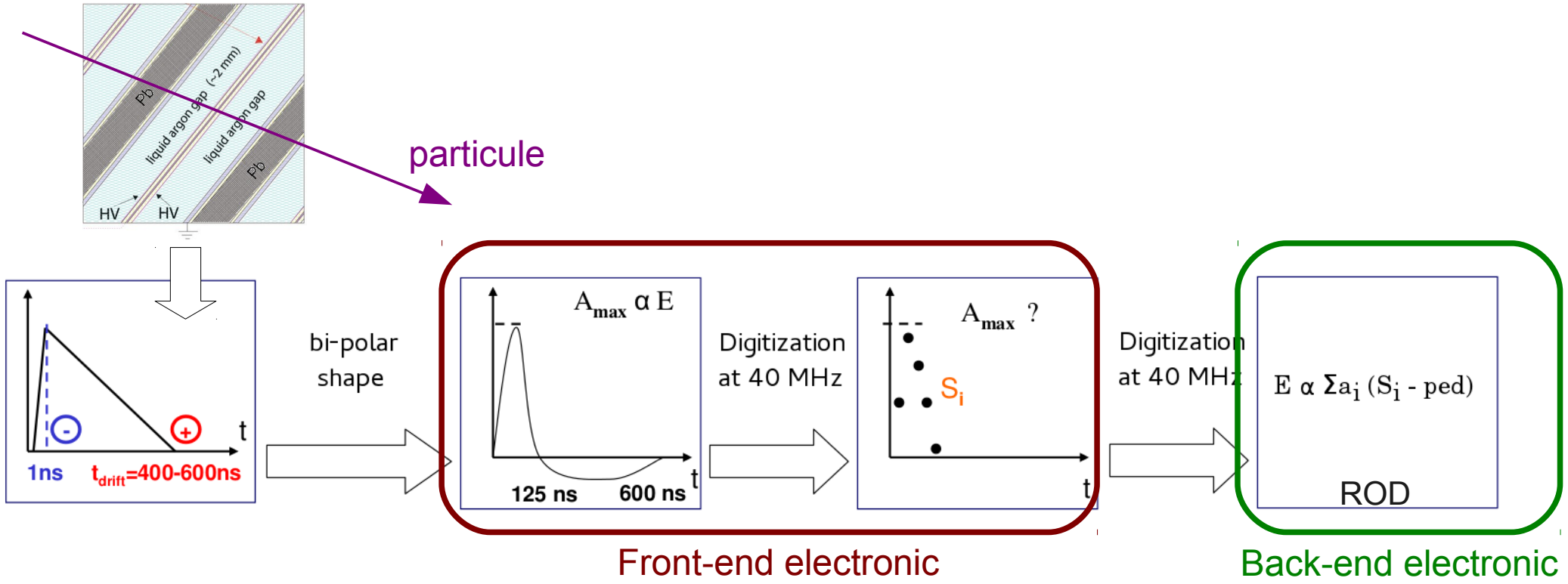
ATLAS note
ATL-AB-EN-0014

Cabling procedure for the ATLAS electromagnetic barrel calorimeter modules

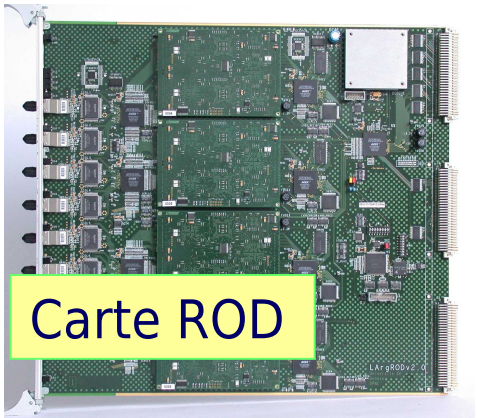
Written by : P. Perrodo[1].
Have contributed to this work: M. Cailles[1], M. Chalifour[2], P. Cornebise[3], A. Girard[1], P. Imbert[3], A. Jeremie[1], B. Mansoulié[2], N. Massol[1], H. Przysiezniak[1], G. Sauvage[1], J. Schwindling[2] and J. Tassan[1].
Updated from the experience on the wheel M

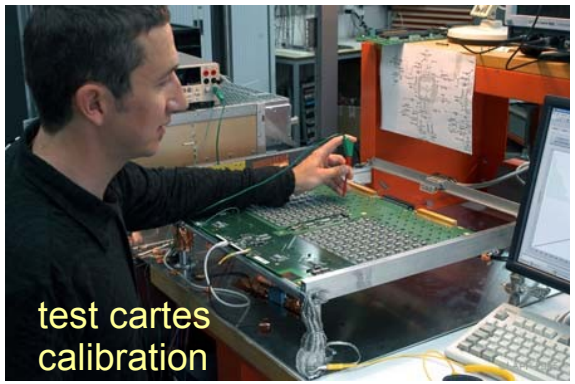
May 29, 2002

Reconstruction de l'énergie dans le calorimètre



- Cartes calibration, ROD
- Soft acquisition et contrôle des cartes + code DSP

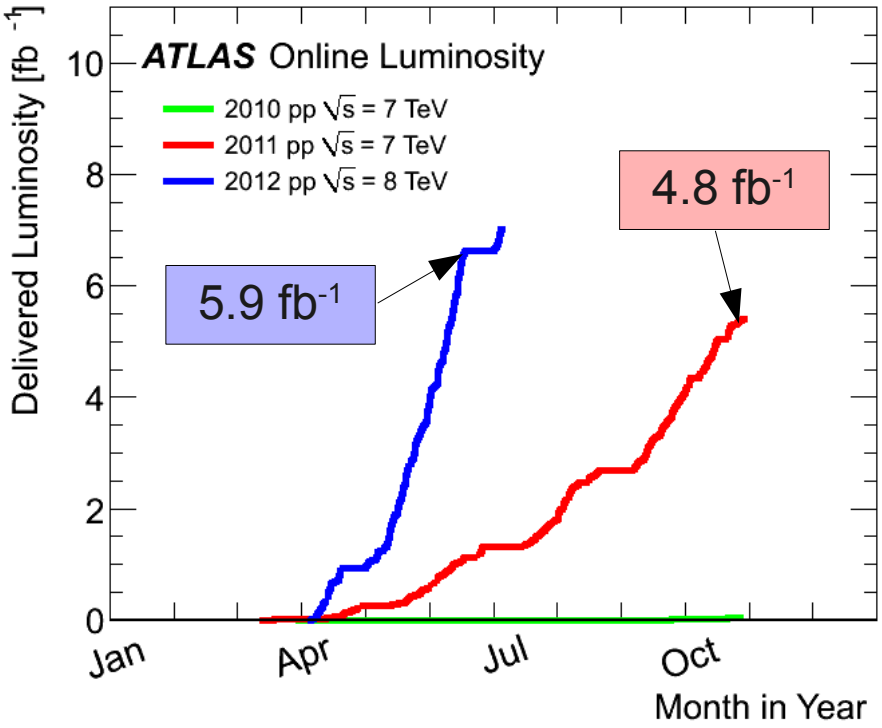


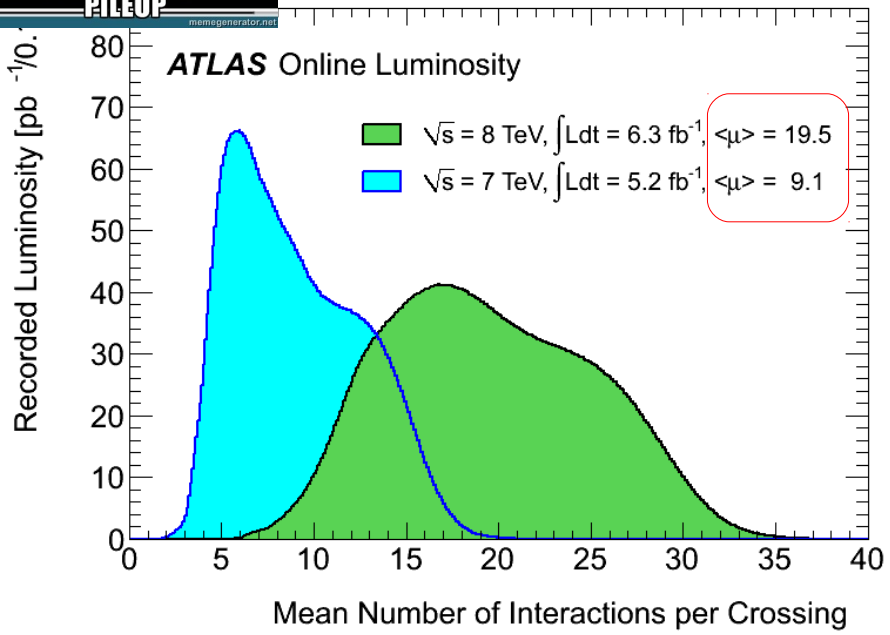


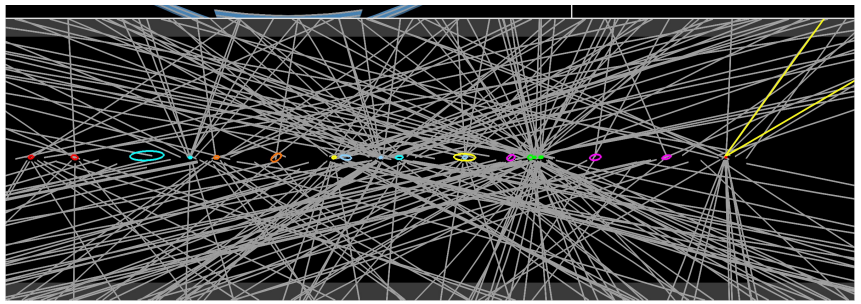
H→γγ

Luminosity & pile-up

- Total luminosity 2011 + 2012: 10.7 fb^{-1}



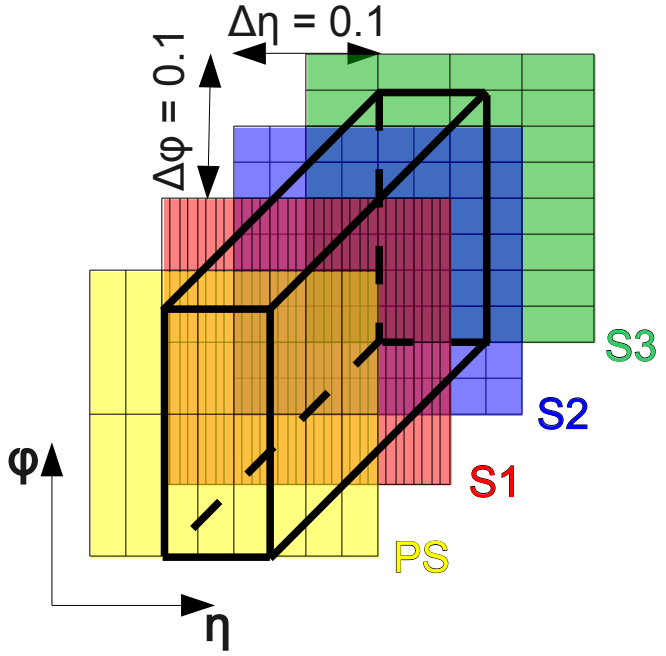




Z→μμ + 20 pile-up events

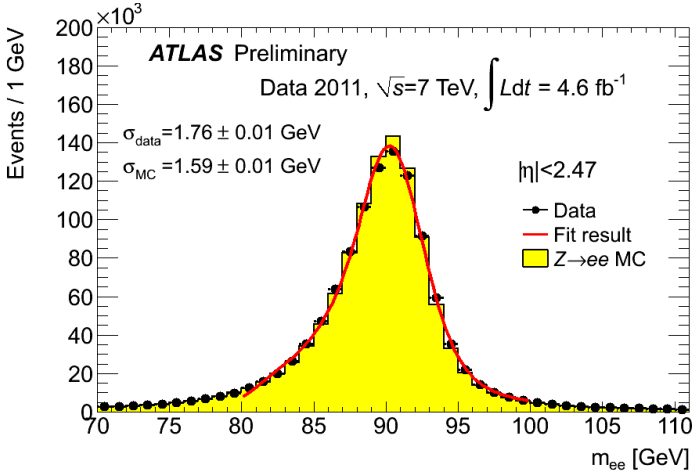
Photons: energy

- Cluster reconstruction
  - $\Delta\eta x\Delta\varphi = 0.075x0.175$ = 3x5/3x7 cells, in the barrel
  - $\Delta\eta x\Delta\varphi = 0.125x0.125$ = 5x5 cells, in the end-caps
  - $E_{amas} \approx E_{PS}+E_1+E_2+E_3$



- Energy resolution $m_{\gamma\gamma}^2 = 2\,E_1\,E_2\,(1-\cos\Delta\varphi(\gamma_1;\gamma_2))$
  - measured from $Z \rightarrow ee$ peak resolution

$$\begin{cases} c = 1\% \text{ barrel} \\ c = 1.2\text{-}2.5\% \text{ endcap} \end{cases} \qquad \frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus c$$



$\Rightarrow$ 12% uncertainty on $m_{\gamma\gamma}$ resolution

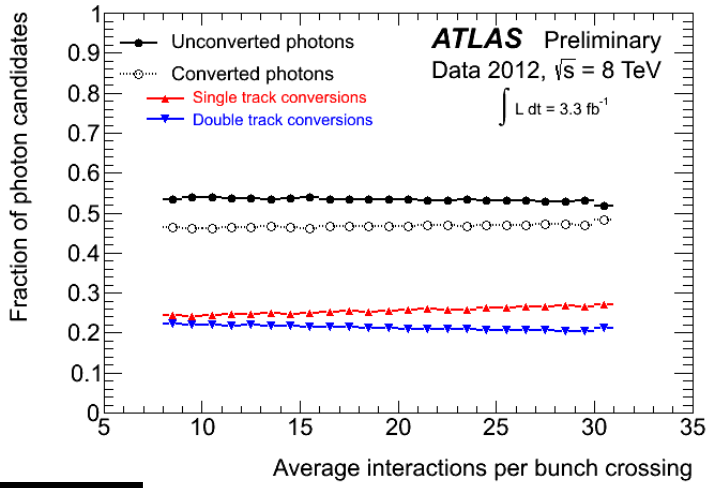
- Electron energy scale extrapolated to photon with MC

$\Rightarrow$ 6% uncertainty on $m_{\gamma\gamma}$ resolution

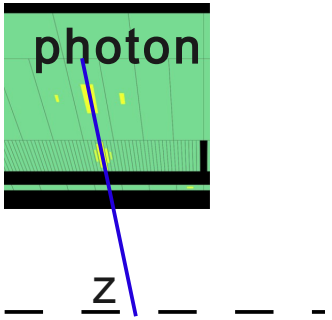
Photon: tracking and pointing

- ~ half of photons converted before calo
  - stable with pile-up

$$m_{\gamma\gamma}^2 = 2 E_1 E_2 (1-\cos\Delta\varphi(\gamma_1;\gamma_2))$$



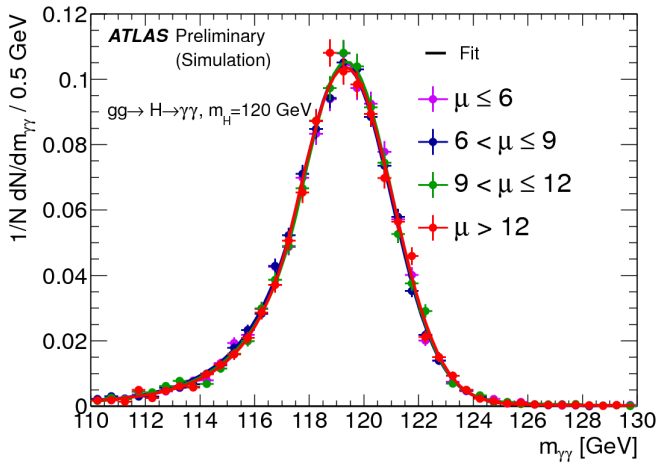
- Unconverted photons
  - photon direction from calorimeter longitudinal segmentation



- Converted photons
  - position of conversion vertex (Si hits)

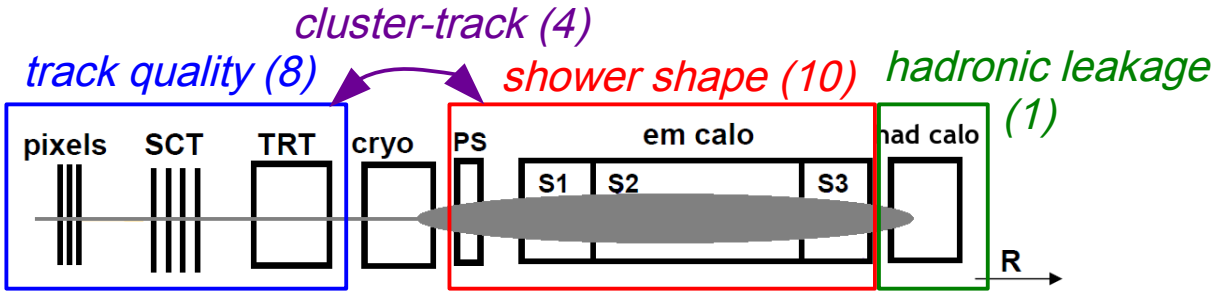
➔ Primary vertex measured to ~1.5 cm

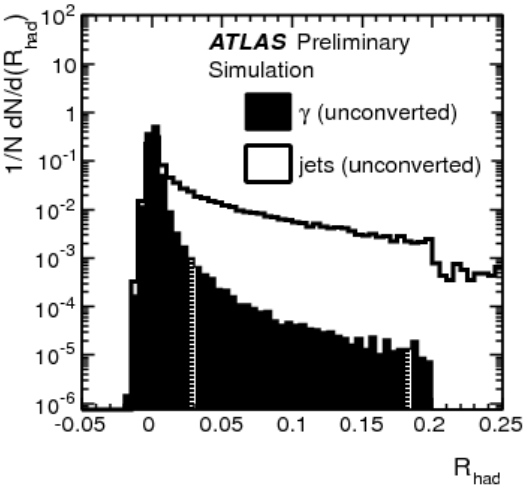
➔ Insensitive to pile-up



Photons: identification

- Identification : info from calo + tracks

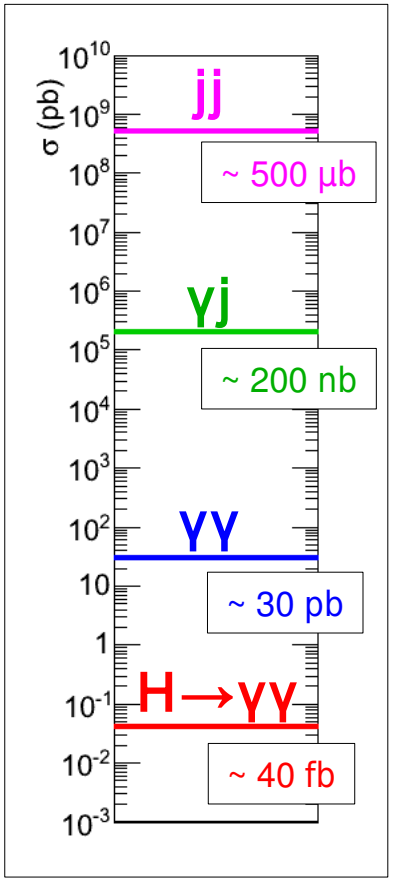




- Two methods used:
  - √s = 7 TeV: Neural-network

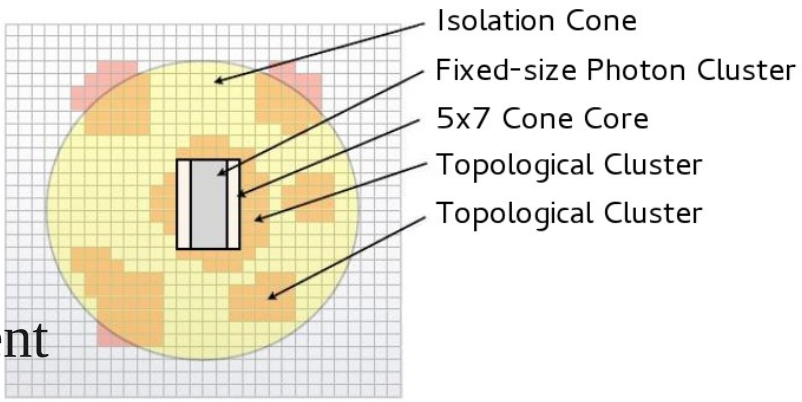
    uncertainty: ~4%/photon ⇒ 8.4%/event
  - √s = 8 TeV: rectanguler cuts, optimised against pile-up
    uncertainty: 5/7% barrel/end-cap ⇒ 10.8%/event

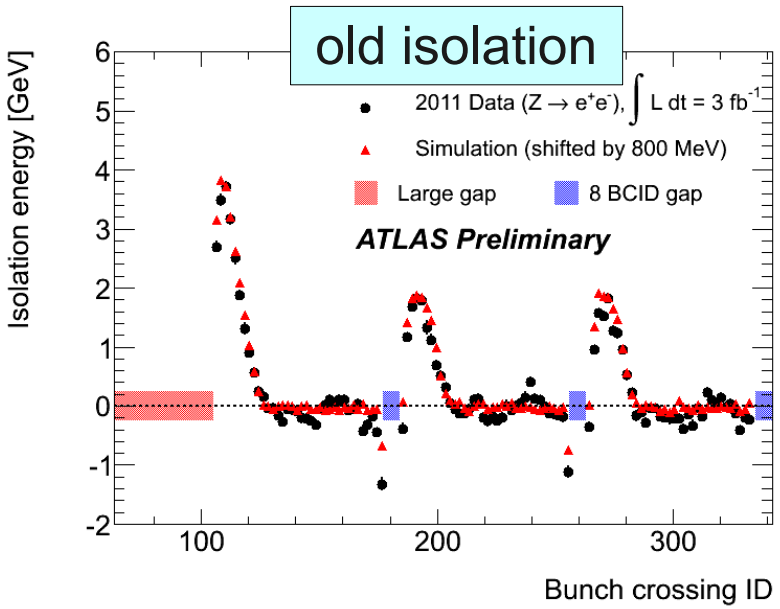
- efficiency: 85% to >95%
  - rejection ~5000

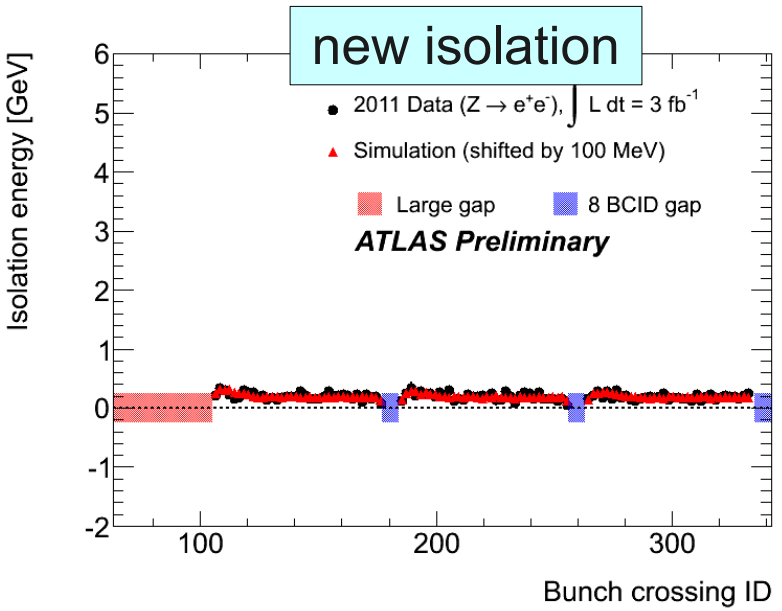


Photon: isolation

- Computed from positive-energy topological clusters in calorimeter with $\Delta R < 0.4$
- Corrected for pileup and underlying event by subtracting ambient energy density event-by-event



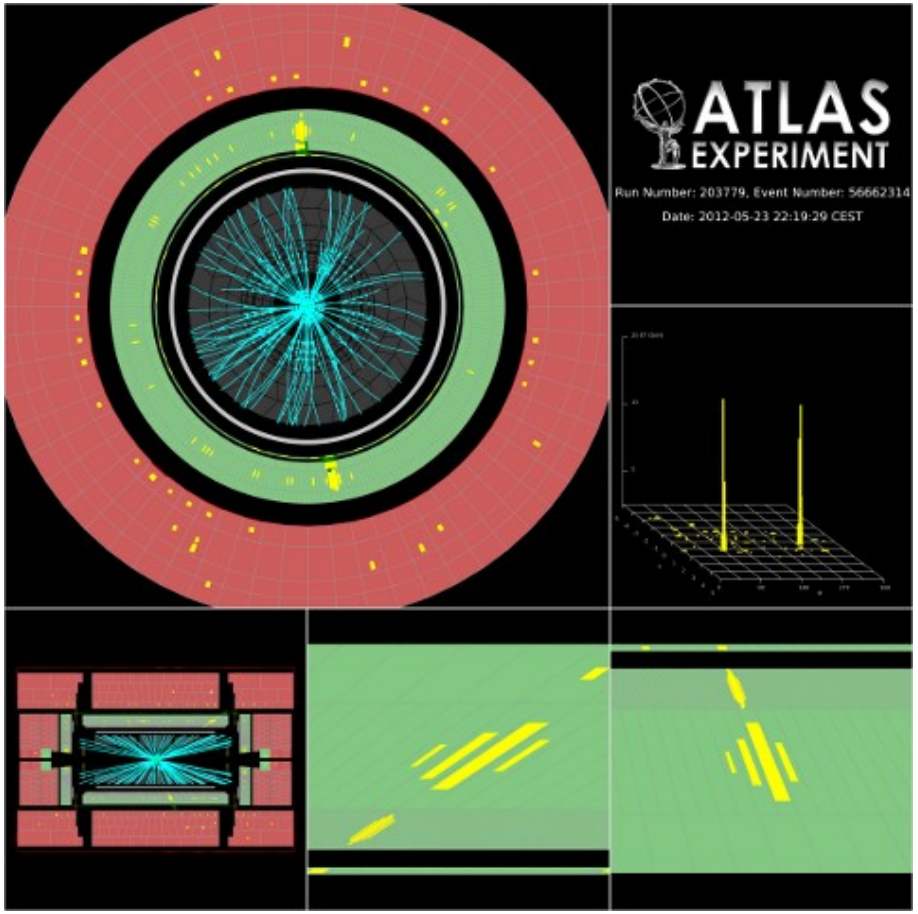




- Good stability with position of colliding bunches in train → robust with pileup
- Uncertainty on signal yied: 0.4-0.5%

Event selection (1)

- Cuts
  - 2 photons with $|\eta| < 2.37$, not in crack
  - $p_T^{\text{leading}} > 40$ GeV, $p_T^{\text{subleading}} > 30$ GeV
  - *tight* identification
  - isolated
  - $100 < m_{\gamma\gamma} < 160$ GeV



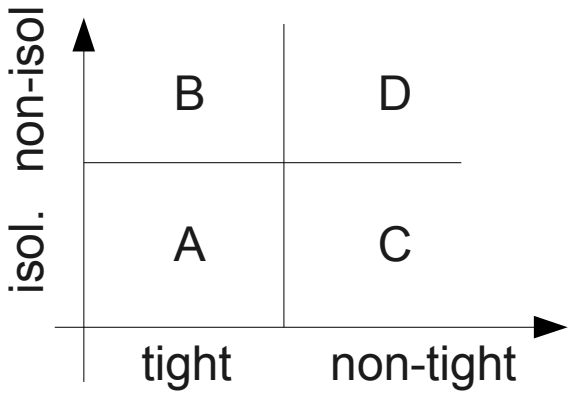
- Acceptance on signal:
  - 30-40%

- Expected and selected events:

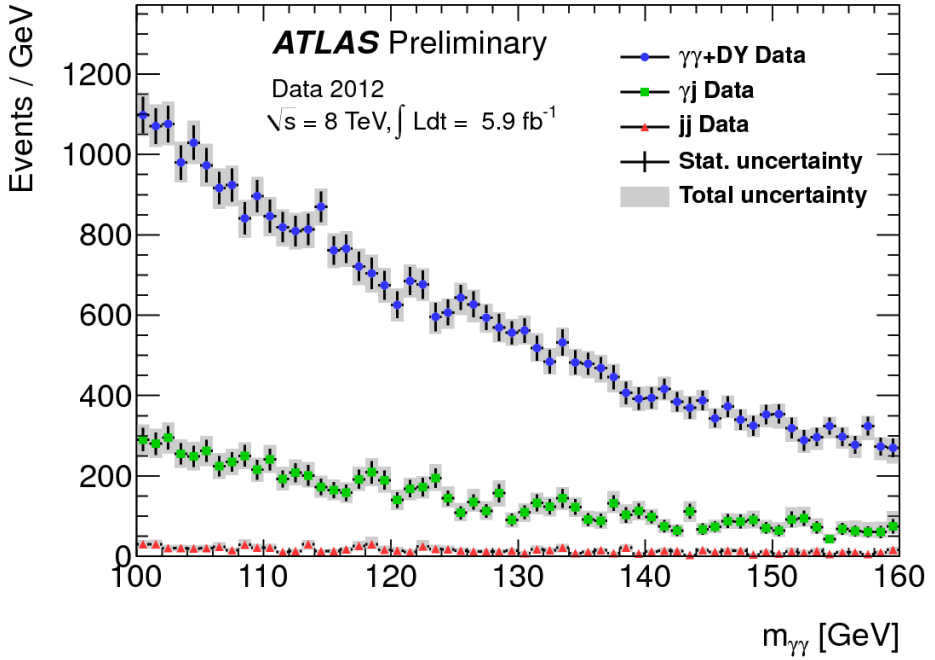
	ggF	VBF	WH	ZH	ttH	total	data
√s = 7 TeV	70.9	5.8	2.4	1.3	0.3	80.8	23788
√s = 8 TeV	100.3	8.3	3.2	1.8	0.5	113.1	35271

Event selection (2)

- Background decomposition
  - *irreducible*: γγ from QCD processes
  - *reducible*: γj or jj with mis-identified jet



- Data-driven decomposition
  - 2x2D side-band method
    - generalisation of ABCD method for two candidates
  - check performance of photon identification
  - validation of description of background modelling



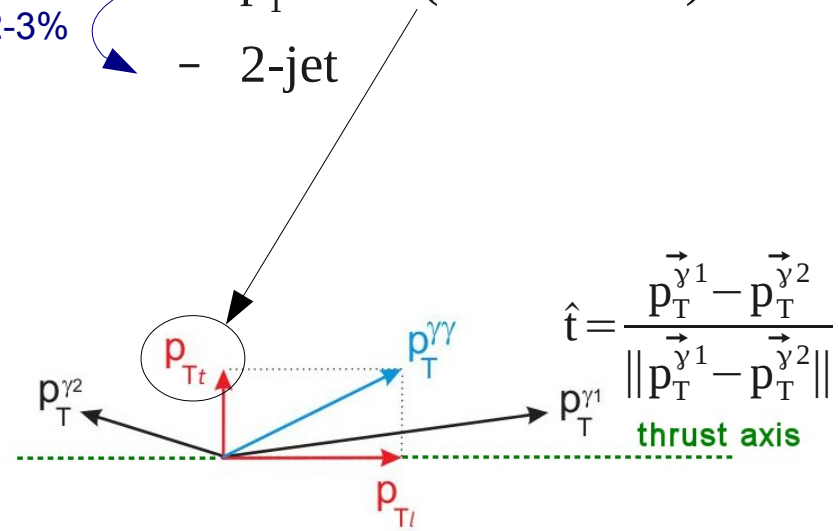
- Results:

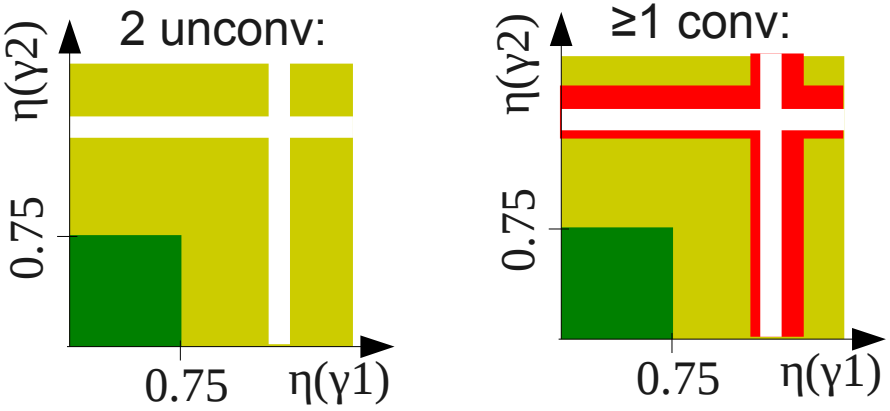
	γγ	γj	jj
√s = 7 TeV	80%	19%	1.8%
√s = 8 TeV	75%	22%	2.6%

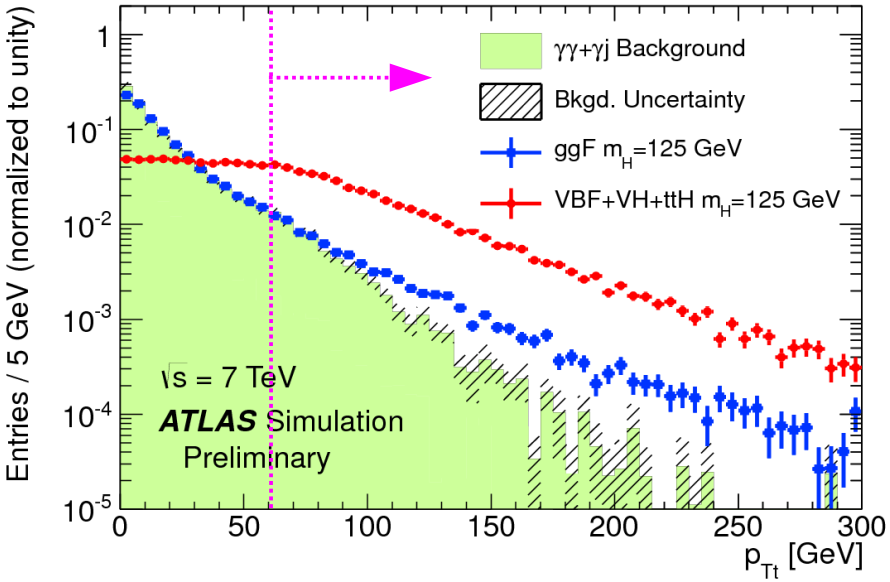
Study in categories (1)

- To enhance sensitivity: data sample split in categories, with different $m_{\gamma\gamma}$ resolutions and different S/B

- 10 categories:
  - converted/unconverted photons (+15%)
  - 3 eta regions (+5-10%)
  - $p_T$thrust (60 GeV cut)
  - 2-jet (+2-3%)

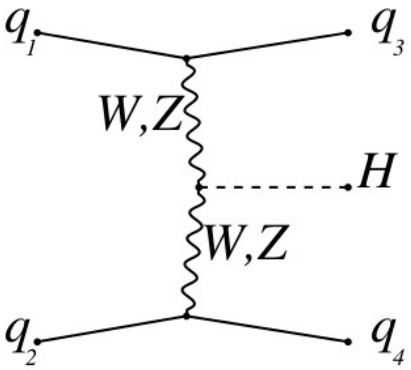


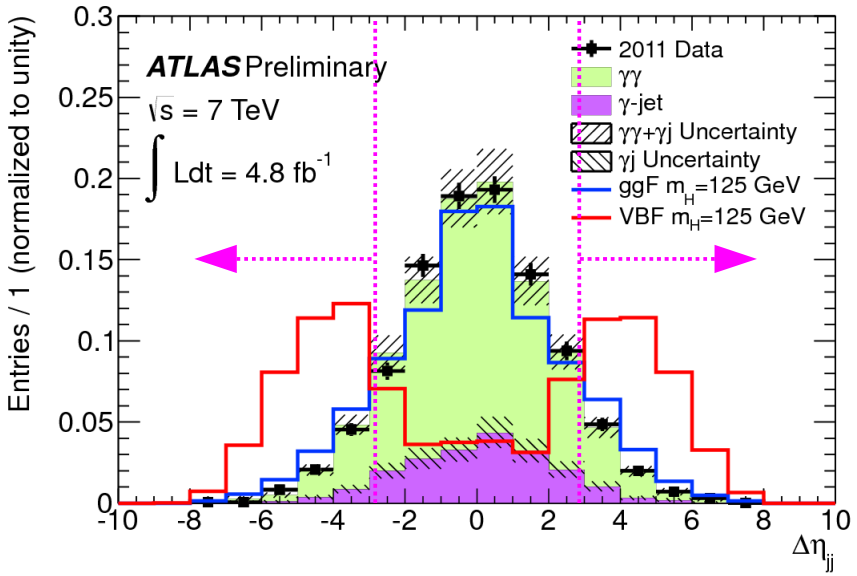


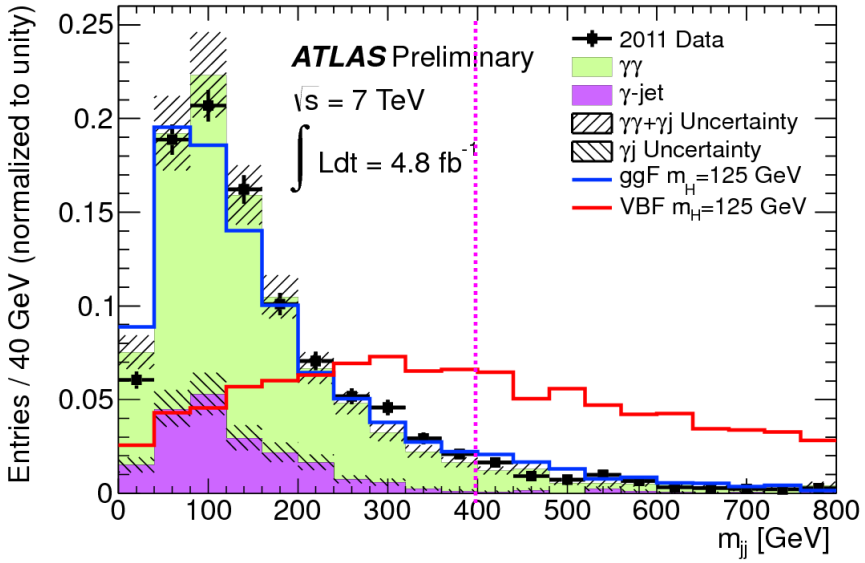


Study in categories (2)

- Category for enriched VBF signature:
  - 2 jets with p_T > (30)25 GeV and |η| < 4.5
  - |Δη| > 2.8
  - m_{jj} > 400 GeV
  - |Δφ(γγ:jj)| > 2.6





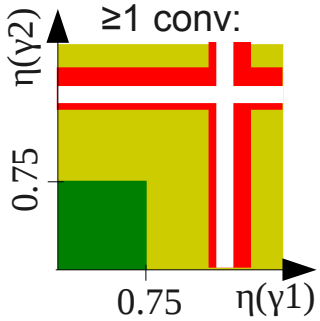


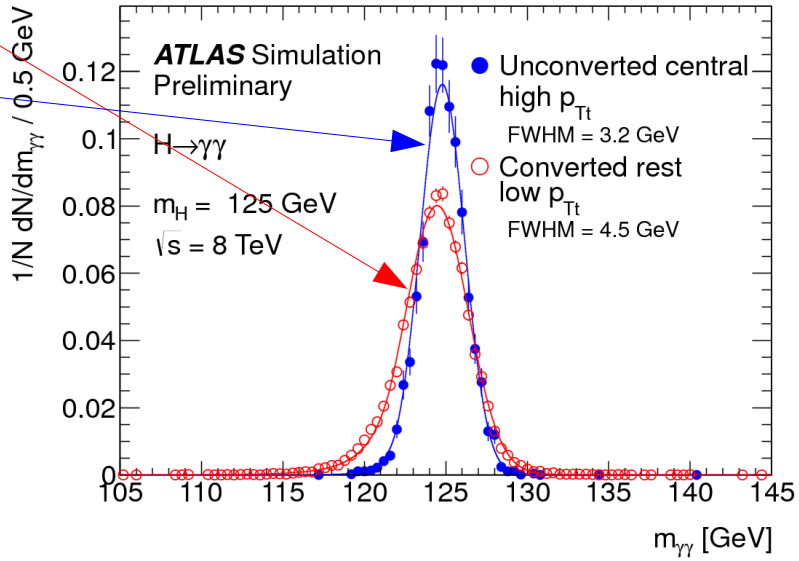
- 29%/24% efficiency on VBF Higgs boson at √s = 7/8 TeV
  - ~70% VBF, 30% ggF

Study in categories (3)

- Resolution and S/B in window that would contain 90% of the signal:
  - $\sqrt{s}$ = 8 TeV, m_H = 126.5 GeV

			resolution (GeV)	S / B
inclusive			1.63	0,030
low pTt	unconv	low eta	1.45	0,060
		high eta	1.57	0,025
	conv	low eta	1.67	0,042
		high eta	1.93	0,018
	conv	crack eta	2.65	0,014
high pTt	unconv	low eta	1.37	0,164
		high eta	1.51	0,071
	conv	low eta	1.50	0,150
		high eta	1.68	0,057
2-jets			1.57	0,217





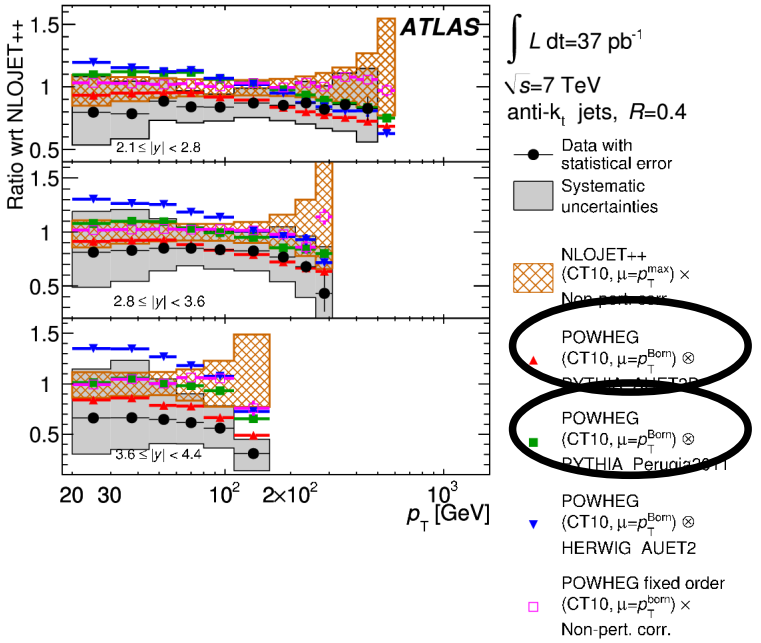
Systematic errors related to jets (1)

- Introduction of 2-jet category ⇒ new systematics uncertainties

m_H = 120 GeV	QCD scale	PDF + α_S
ggF	+11.9% -7.9%	+7.8% -7.2%

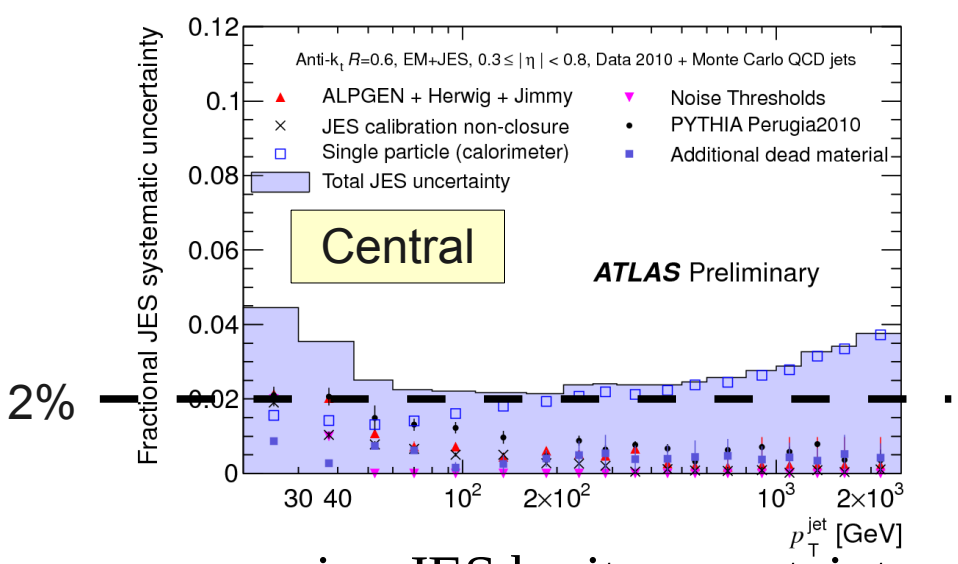
- QCD scale uncertainty
  - baseline: "Handbook of LHC Higgs Cross Sections"
  - ggF: computed at NNLO ⇒ 1st jet at NLO ⇒ 2nd jets at LO ⇒ 70% error
  - use of MCFM: γγ+2 jets at NLO ⇒ 25% error for 2-jet bin
- Underlying Event modelling
  - comparison of 2 two pythia tunes: AUET2B and Perugia2011
  - different description of forward jets
  - example: Measurement of inclusive jet and dijet production in pp collisions at s√ = 7 TeV using the ATLAS detector
  - 30% uncertainty for ggF
  - 6% uncertainty for VBF

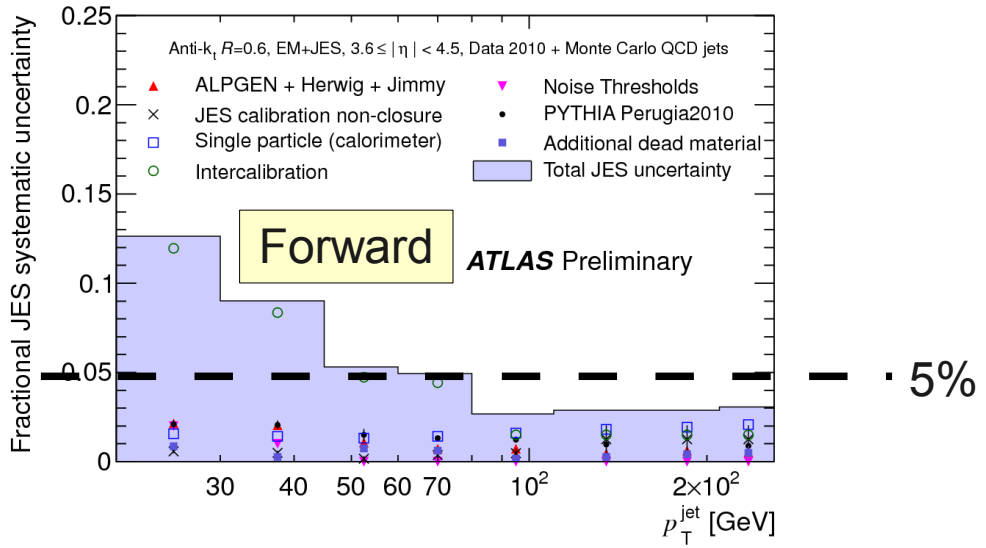
CERN-PH-EP-2011-192



Systematic errors related to jets (2)

- Jet Energy Resolution: negligible
- Jet Energy Scale uncertainties



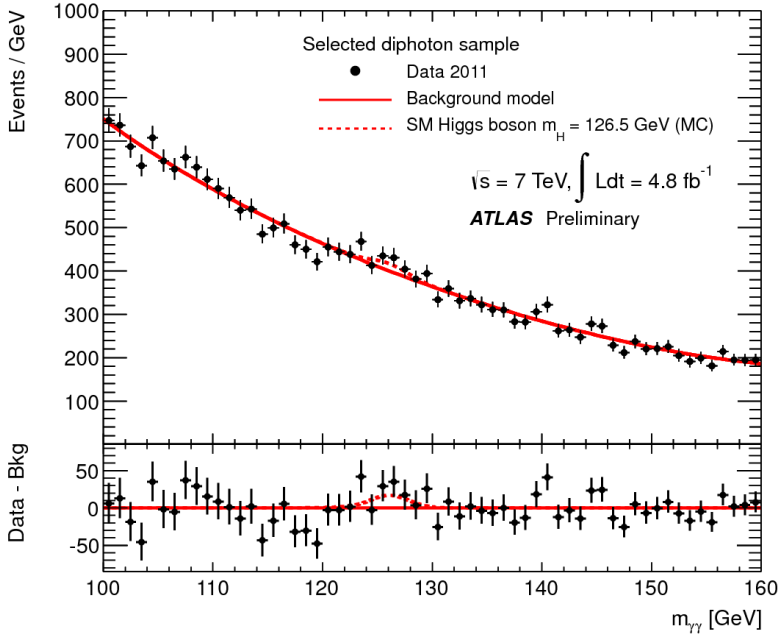


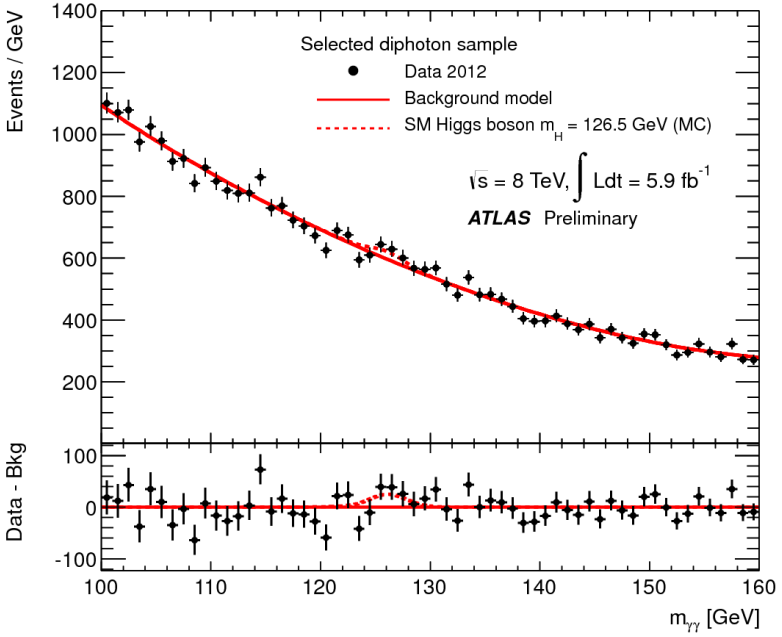
- varying JES by its uncertainty
- uncertainties separated for
  - low pTt, high pTt and 2-jet categories
  - ggF, VBF, others
- up to 19% in 2-jet bin, <5% in other categories

Summary of systematic errors

- Systematic uncertainties /category and /production process
- Largest systematic errors:

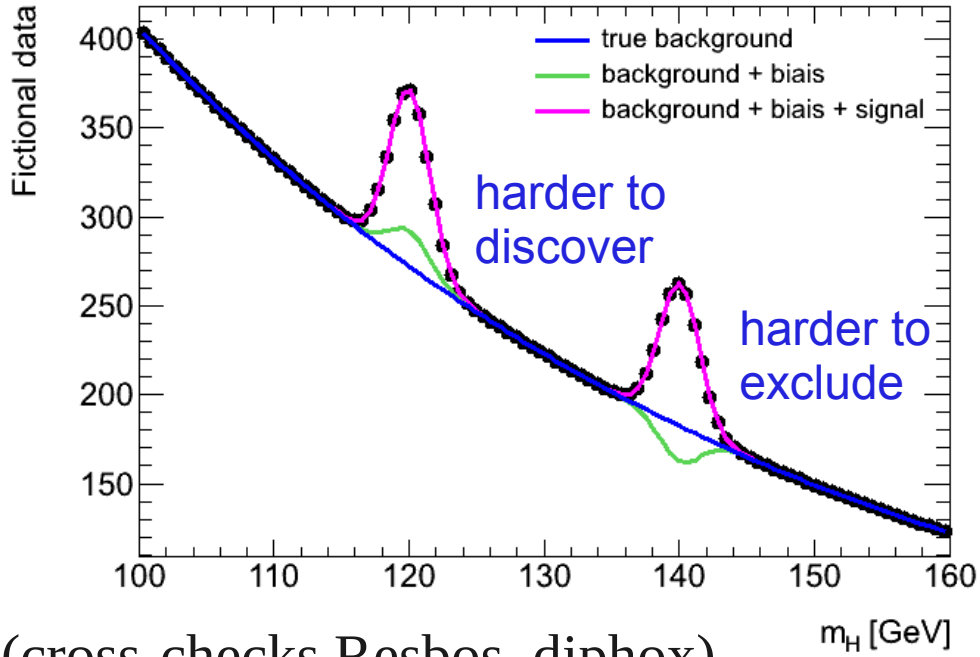
		7 TeV	8 TeV
Signal event yield	photon ID	8.4%	10.8%
	theory gg → H + 2jets	up to 25%	
	Underlying Event (2-jet)	6-30%	
Category migration	Jet energy scale	ggF:19%	
		VBF : 8%	
Mass Resolution	calo energy resolution	12%	
	photon energy calibration	6%	





Background fits (1)

- Bkgd parametrized by analytic function for each category
  - exponential
  - 4^{th} order Bernstein polynomial
  - $\exp(a*x+b*x^2)$



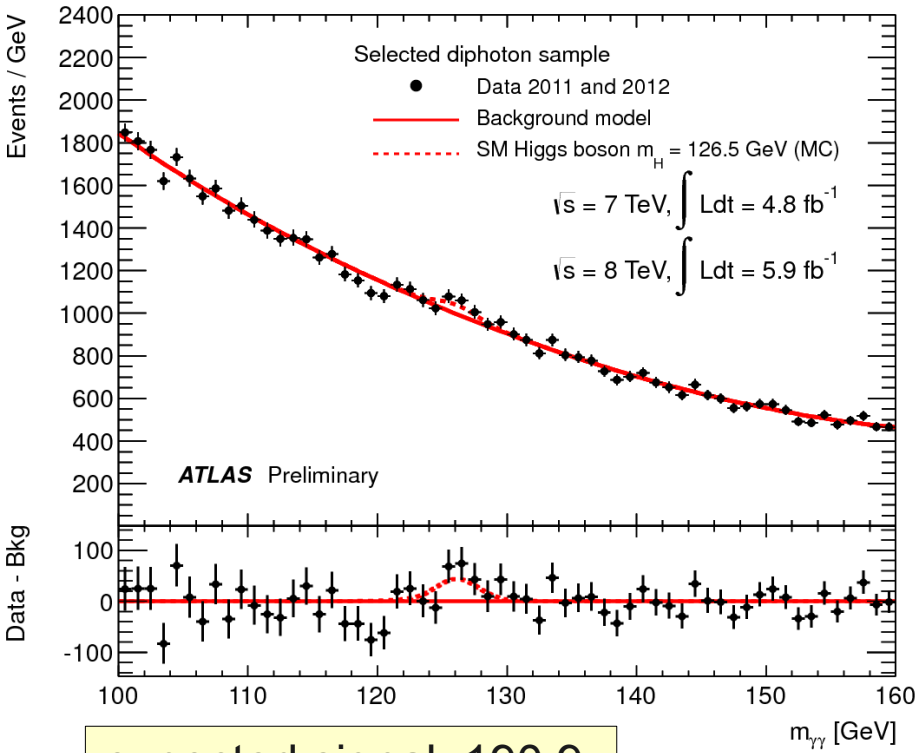
- Bias checked with Bkgd MC Sherpa (cross-checks Resbos, diphox)
  - bias = number of event when fitting 'bkgd+signal' fit on bkgd only MC
- MC bkgd shapes compared to data-driven decomposition in each category

➔ Uncertainty on signal normalisation

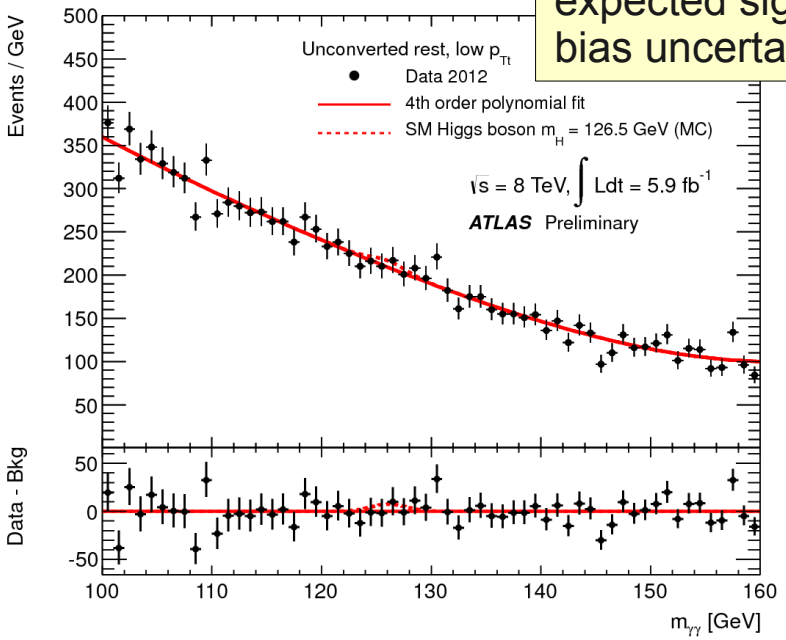
  - inclusive: 7.3 events at $\sqrt{s}$ = 7 TeV, 10.6 events at $\sqrt{s}$ = 8 TeV

Background fit (2)

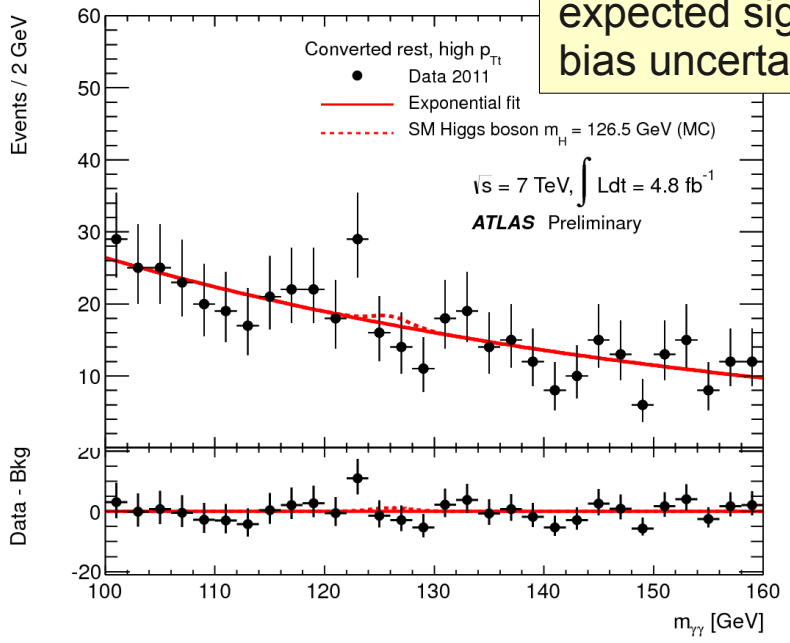
- Examples:



expected signal: 190.9
bias uncertainty: 17.9



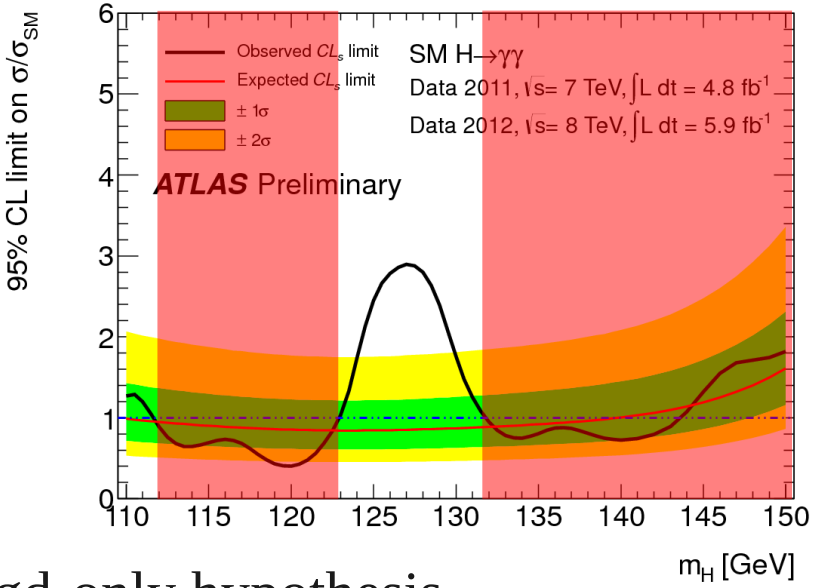
expected signal: 31.4
bias uncertainty: 3.3



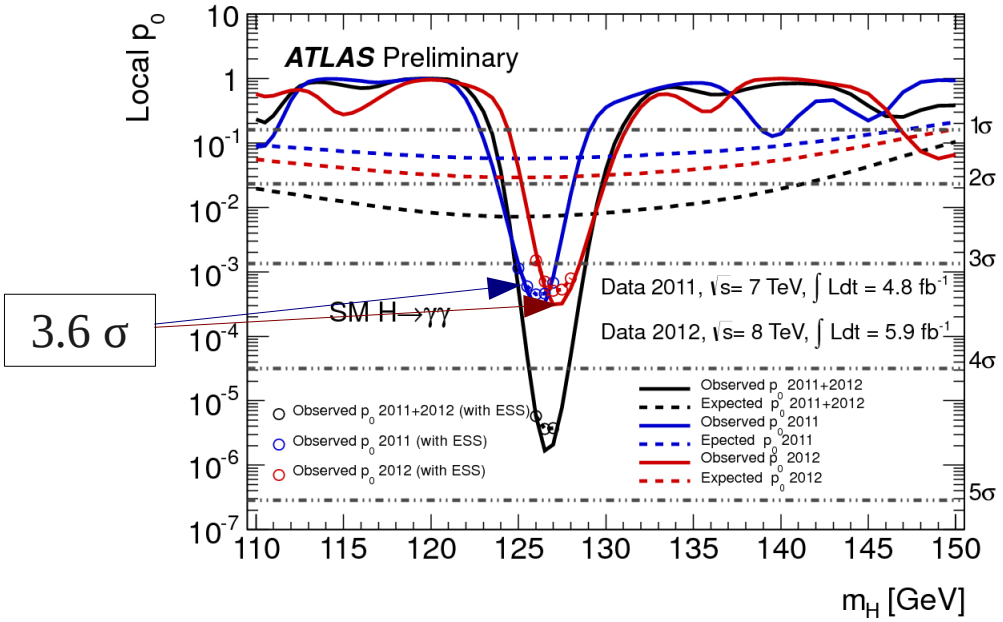
expected signal:2.7
bias uncertainty: 0.5

Results (1)

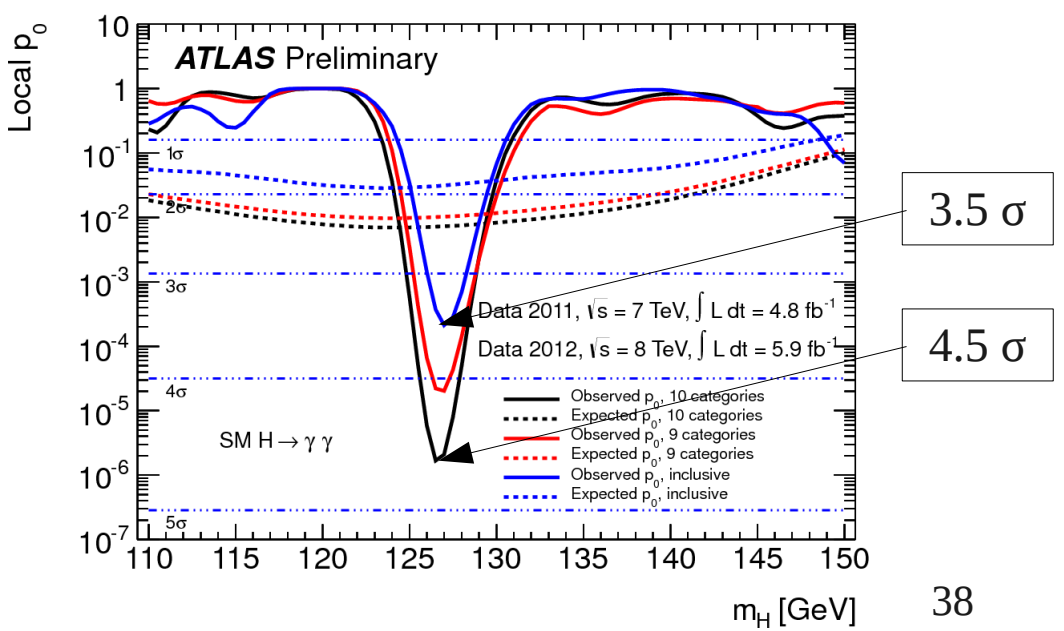
- Exclusion @95% CL:
  - expected: 0.8 to 1.6 SM
  - excluded: (112-122.5) and (132-143) GeV



- p_0 = compatibility of selected events with bkgd-only hypothesis
  - min: 2.10^{-6} at 126.5 GeV



3.6 σ

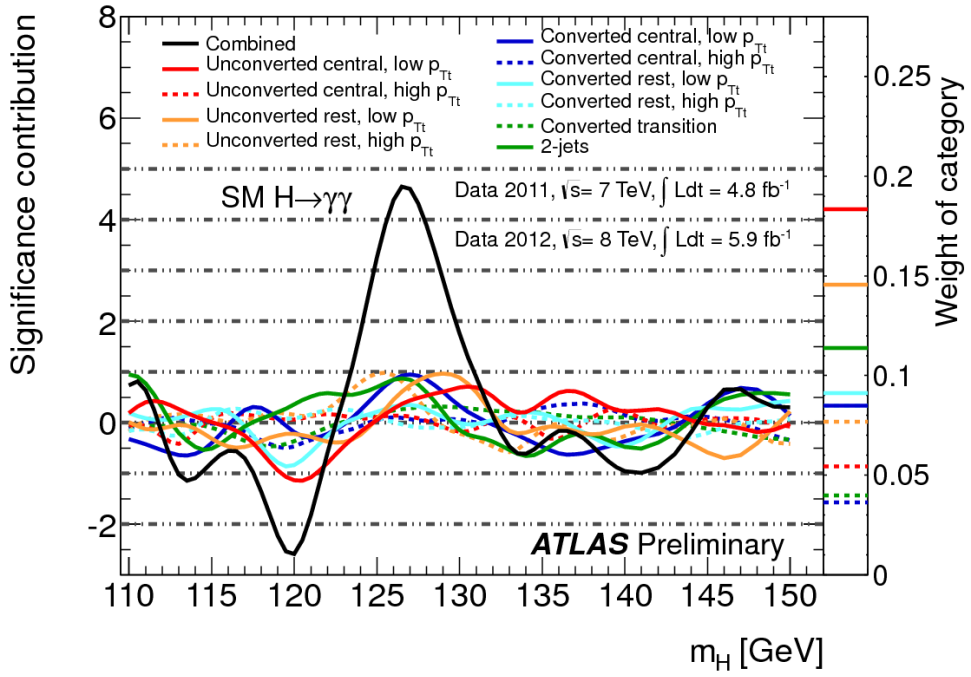


3.5 σ

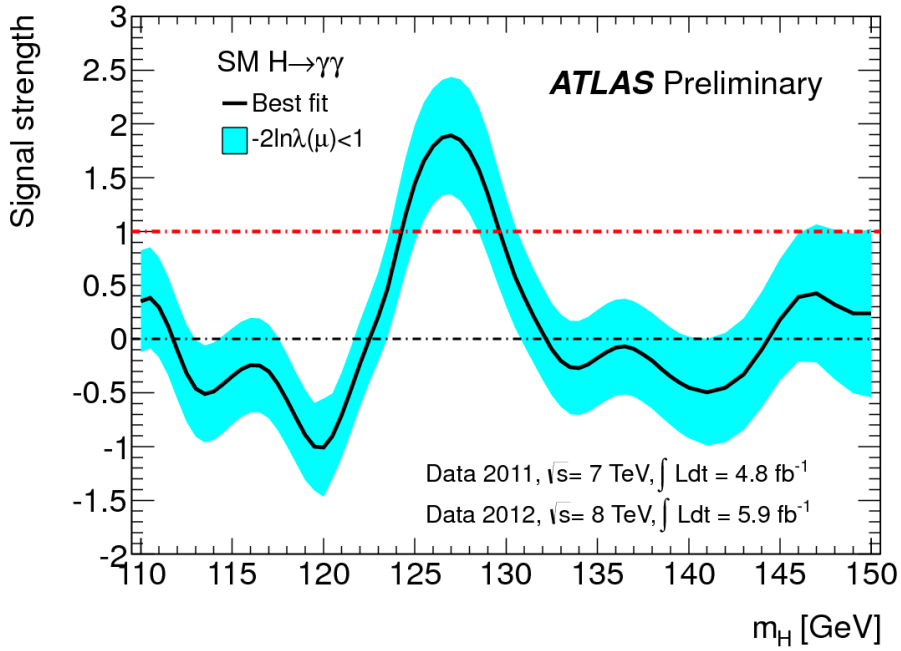
4.5 σ

Results (2)

- Max significance :
  - 4.5 σ (local)
  - expected: 2.5 σ
  - 3.6 σ (global)
  - *CMS: 4.1σ (local)*



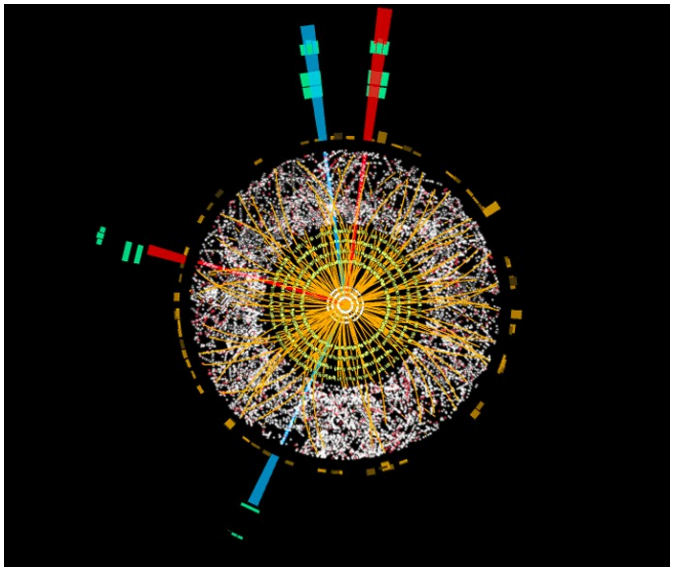
- Fitted signal strength:
  - $\mu = \frac{\sigma}{\sigma_{\text{SM Higgs}}}$
  - μ = 1.9 ± 0.5 at 126.5 GeV
  - *CMS: μ = 1.6 ± 0.4 at 125 GeV*



$$\mathrm{H} \rightarrow \mathrm{ZZ} \rightarrow \ell\ell\ell\ell$$

Event selection

- Two same-flavor opposite-sign di-leptons (e/μ)
- $p_T^{1,2,3,4} > 20, 15, 10, 7$ GeV (6 GeV for μ)
- 50 GeV < m_{12} < 106 GeV
- 17.5 - 50 <m_{34}<115 GeV
  - all same-flavor opposite-sign pairs m_{ll}>5 GeV
  - ΔR(l,l′) > 0.10(0.20) for all same(different)-flavor

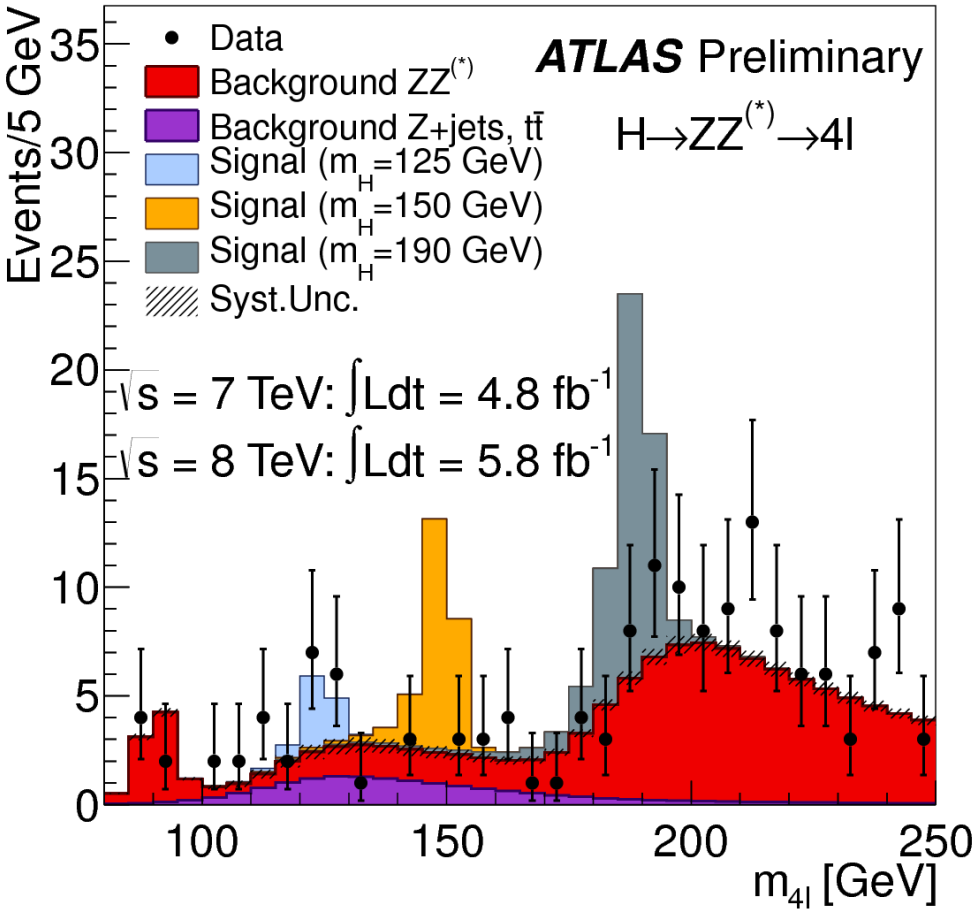


- Number of events in 80 < m_{4l} < 600 GeV:

	√s = 7 TeV	√s = 8 TeV
obs	88	142
exp	71 ± 5	109 ± 7

H→4 leptons

- Invariant mass:



- ZZ bkgd shape from MC, norm. with data
- Z+jets, Zbb̄, tt̄ : data-driven

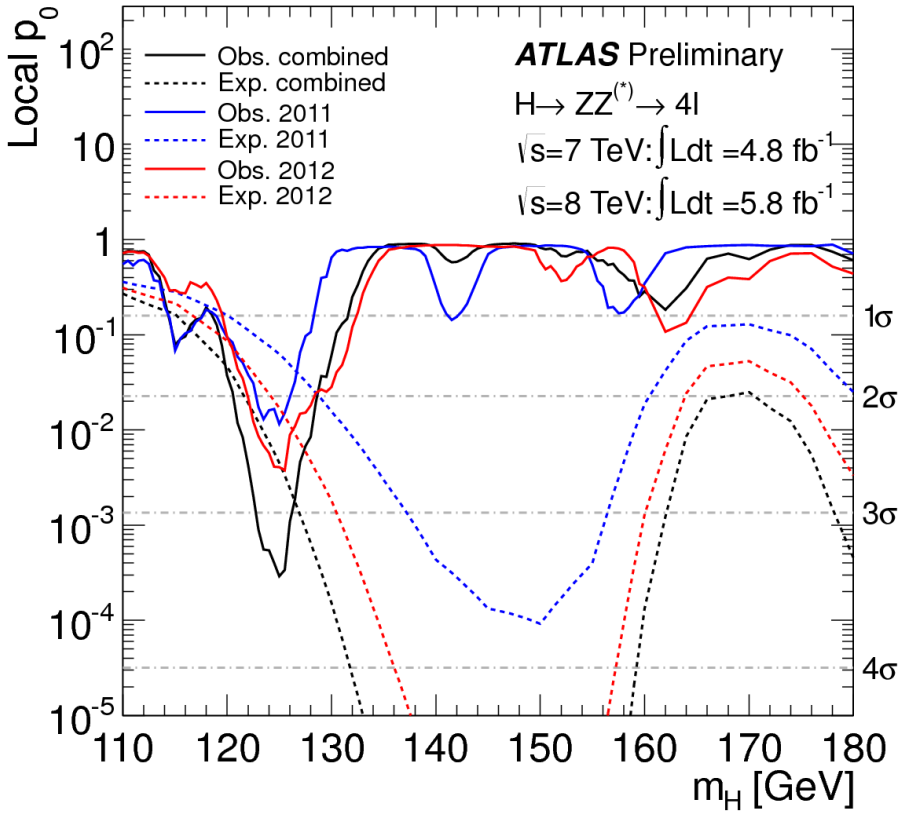
- Events in $m_{4\ell}$ region 125 ± 5 GeV:

	√s = 7 TeV	√s = 8 TeV	total
exp. bkgd	2.1 ± 0.3	2.9 ± 0.4	5.1 ± 0.8
exp. signal	2.0 ± 0.3	3.3 ± 0.5	5.3 ± 0.8
observed	4	9	13

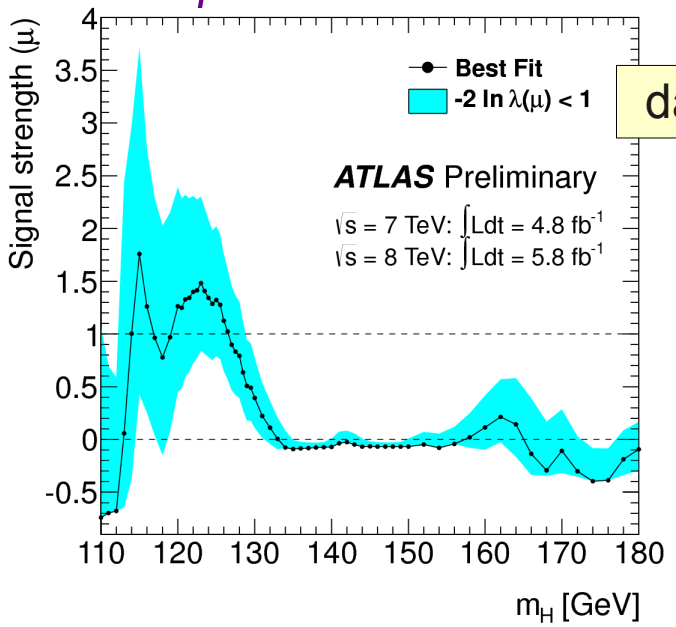
- Expected S/B at 125 GeV:
  - 4μ ~ 1.6
  - 2e2μ ~ 1.0
  - 4e ~ 0.8

Results

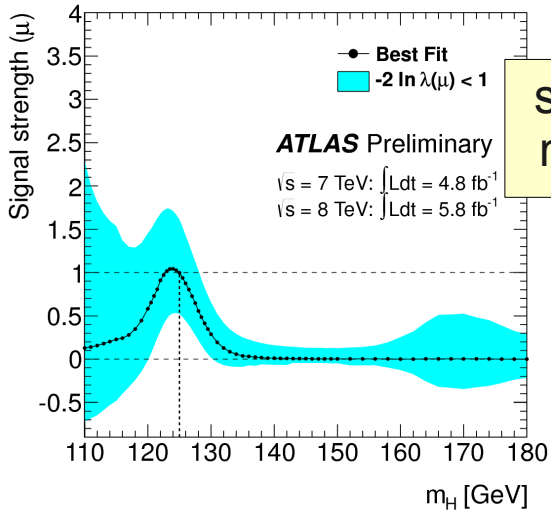
- p_0 value:
  - **3.4 σ** (local)
  - expected: 2.6 σ
  - 2.5 σ (global)
  - *CMS: 3.2σ (local)*



- Fitted signal strength:
  - $\mu = 1.3 \pm 0.6$ at 125 GeV
  - *CMS: $\mu = 0.7 \pm 0.4$ at 125.6 GeV*



data



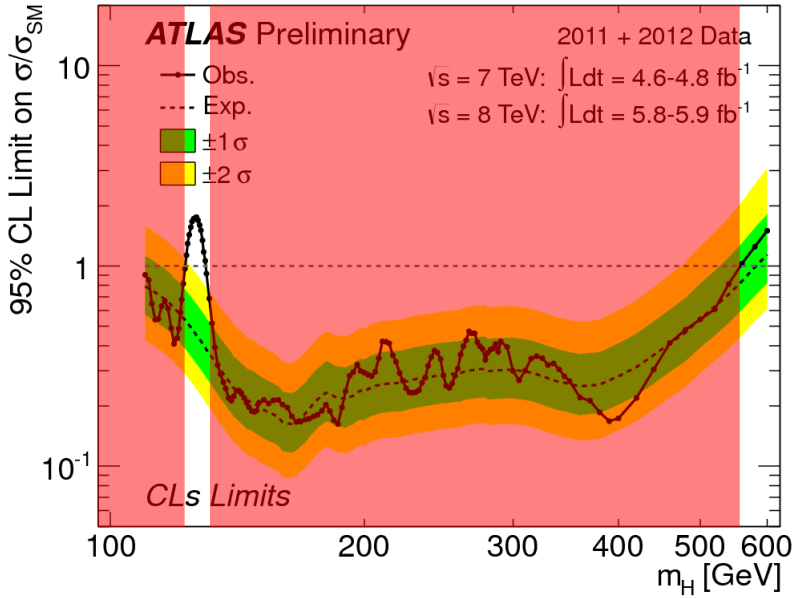
signal injection
m_H = 125 GeV

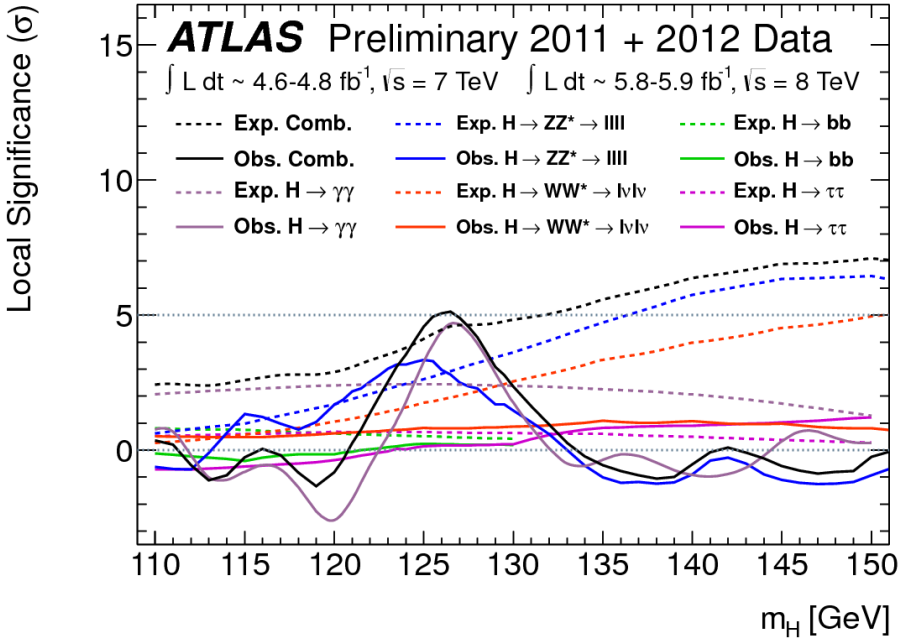
Combinaison of results

Results (1)

- $H \to \gamma\gamma$, $H \to 4\ell$: 2011 + 2012 datasets (10.7 fb^{-1})
- full 2011 dataset (up to 4.9 fb^{-1})
  - $H \to WW(*) \to l\nu l\nu$, $H \to WW \to l\nu qq$
  - $H \to ZZ \to ll\nu\nu$, $H \to ZZ \to llqq$
  - $H \to \tau\tau$
  - $WH \to l\nu bb$, $ZH \to llbb$, $ZH \to \nu\nu bb$
- Exclusion at 95% CL:
  - 110-122.6 GeV
  - 129.7-558 GeV
- Significance:
  - max at 126.5 GeV: **5σ**

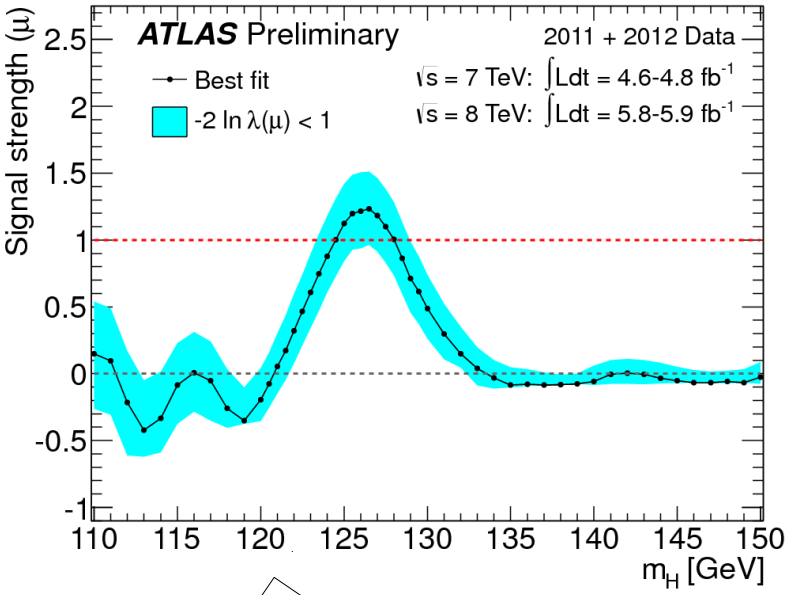
    (expected: 4.6σ)
  - *CMS: 4.9σ ~ 125 GeV, expected 5.9σ*

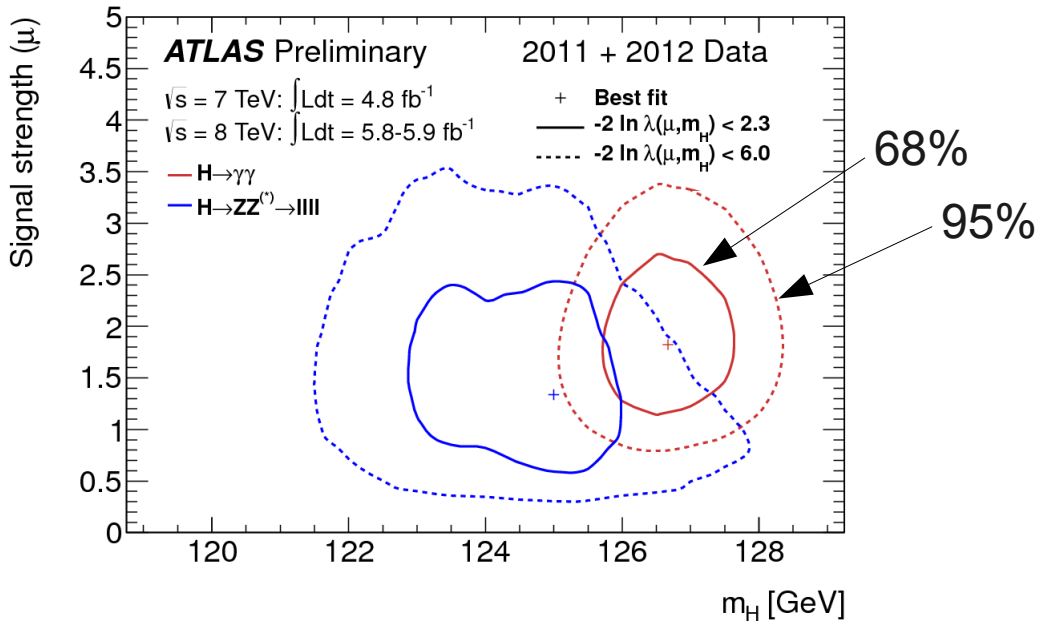


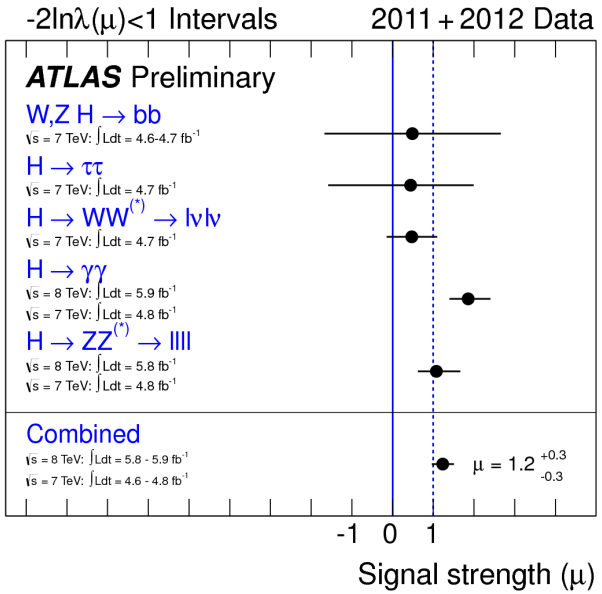


Results (2)

- Fitted signal strength:
  - $\mu = 1.2 \pm 0.3$ at 126.5 GeV
  - in agreement with SM Higgs boson within stat. uncertainties
  - *CMS: $\mu = 0.8 \pm 0.2 \sim 125$ GeV*
- Likelihood contour
  - 2D likelihood fit to signal mass and strength

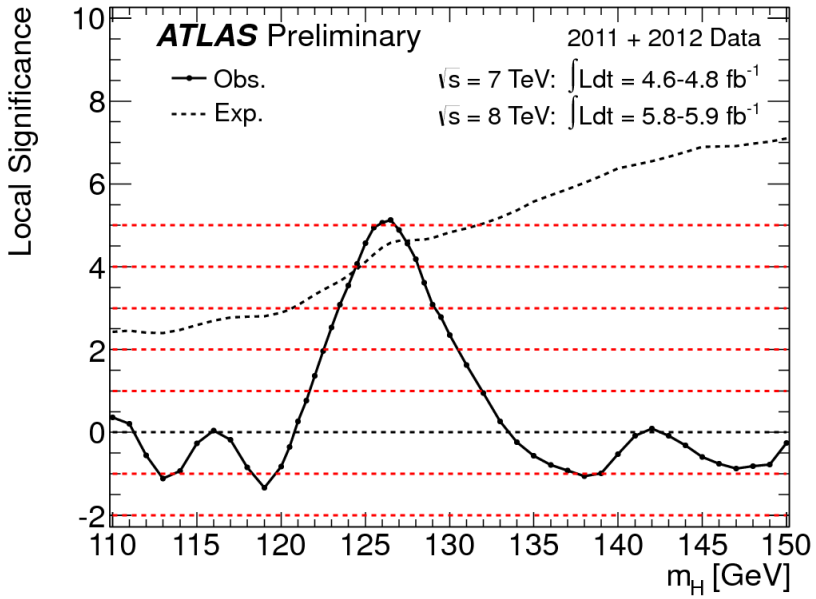


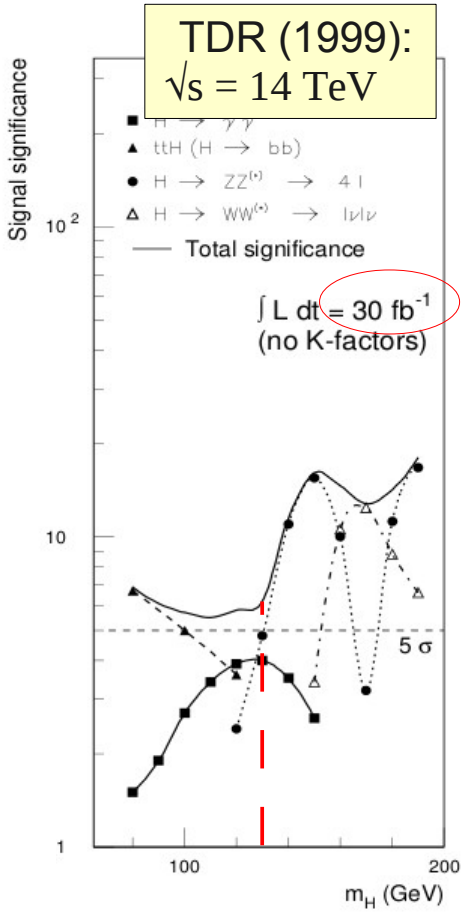




Conclusion

- up to 10.7 fb^{-1} of data analysed, $\sqrt{s}$ = 7, 8 TeV
- Observation of a new particle compatible with a Higgs boson
- Local combined significance: 5.0 σ
  - expected: 4.6 σ
  - H → γγ: 4.5 σ
  - H → 4ℓ: 3.4 σ
- Fitted signal strength: μ = 1.2 ± 0.3 at 126.5 GeV





Is this the end?

- No ! This is just the beginning
- Need to check:
  - if spin 0
  - if Higgs boson
  - if SM Higgs boson
- Properties measurements
  - cross-sections
  - branching ratios
  - couplings
  - ...

need of high luminosity and high statistics

Back-up slides

"Take a look at this everyone - it just could be the signature we've been looking for!"

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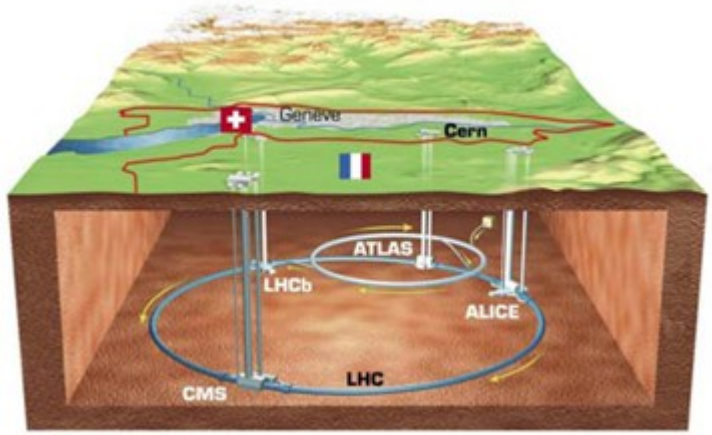
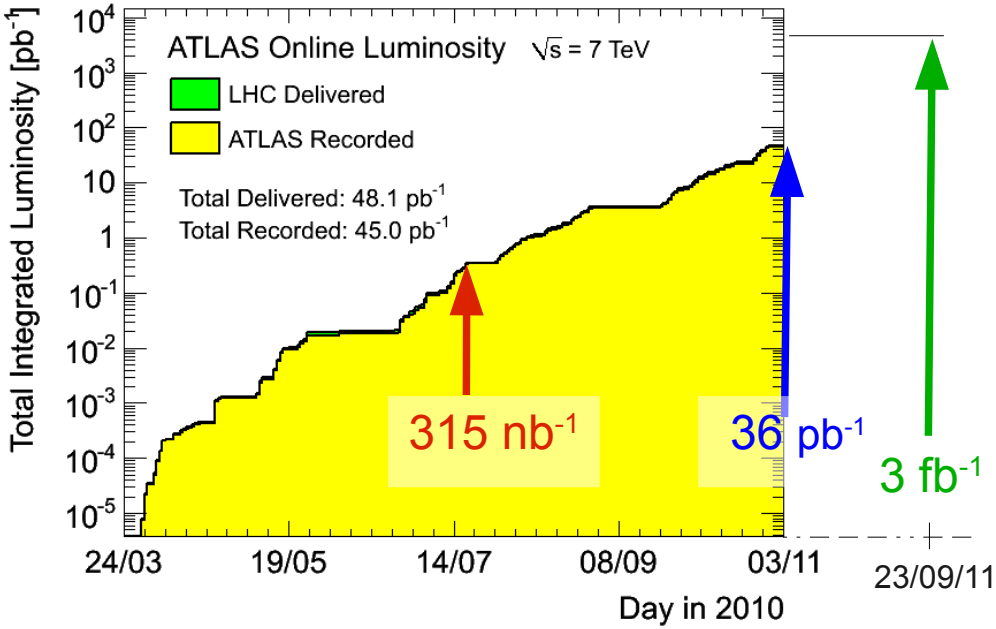
Le LHC



- Large Hadron Collider
  - accélérateur de protons de 27 km
  - 1232 aimants supraconducteurs
  - 4 expériences principales
- Histoire :
  - approuvé en 1994
  - installation démarrée en 2000
  - premiers faisceaux en 2008
  - premières collisions fin 2009

- Paramètres :

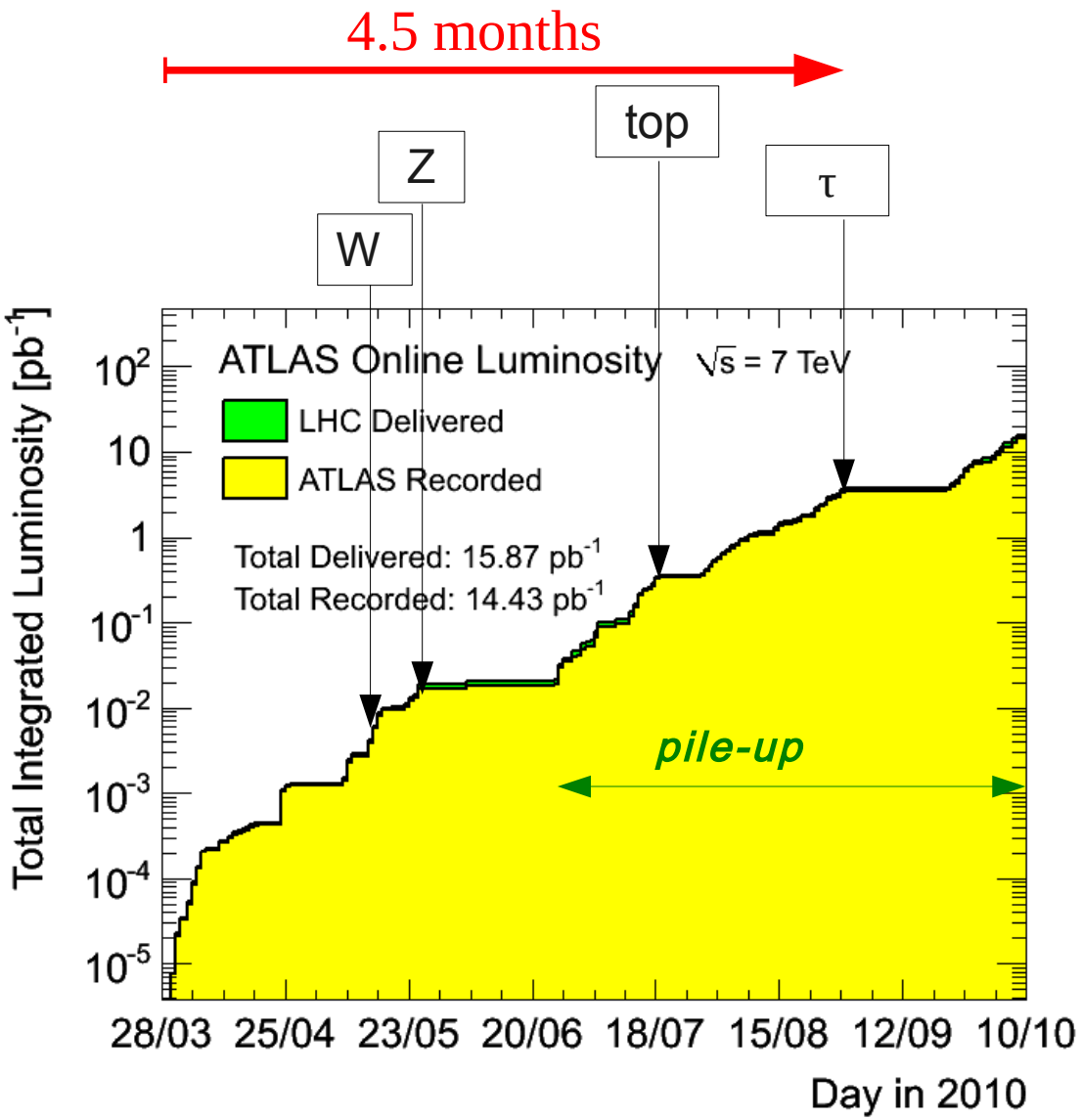
	2009	2010	2011	nominal
$\sqrt{s}$ (TeV)	0.9-2.4	7	7	14
L_{max} ($cm^2.s^{-1}$)	-	2.10^{32}	3.10^{33}	10^{34}
L_{int} /an	12 μb^{-1}	45 pb^{-1}	3 fb^{-1}	100 fb^{-1}



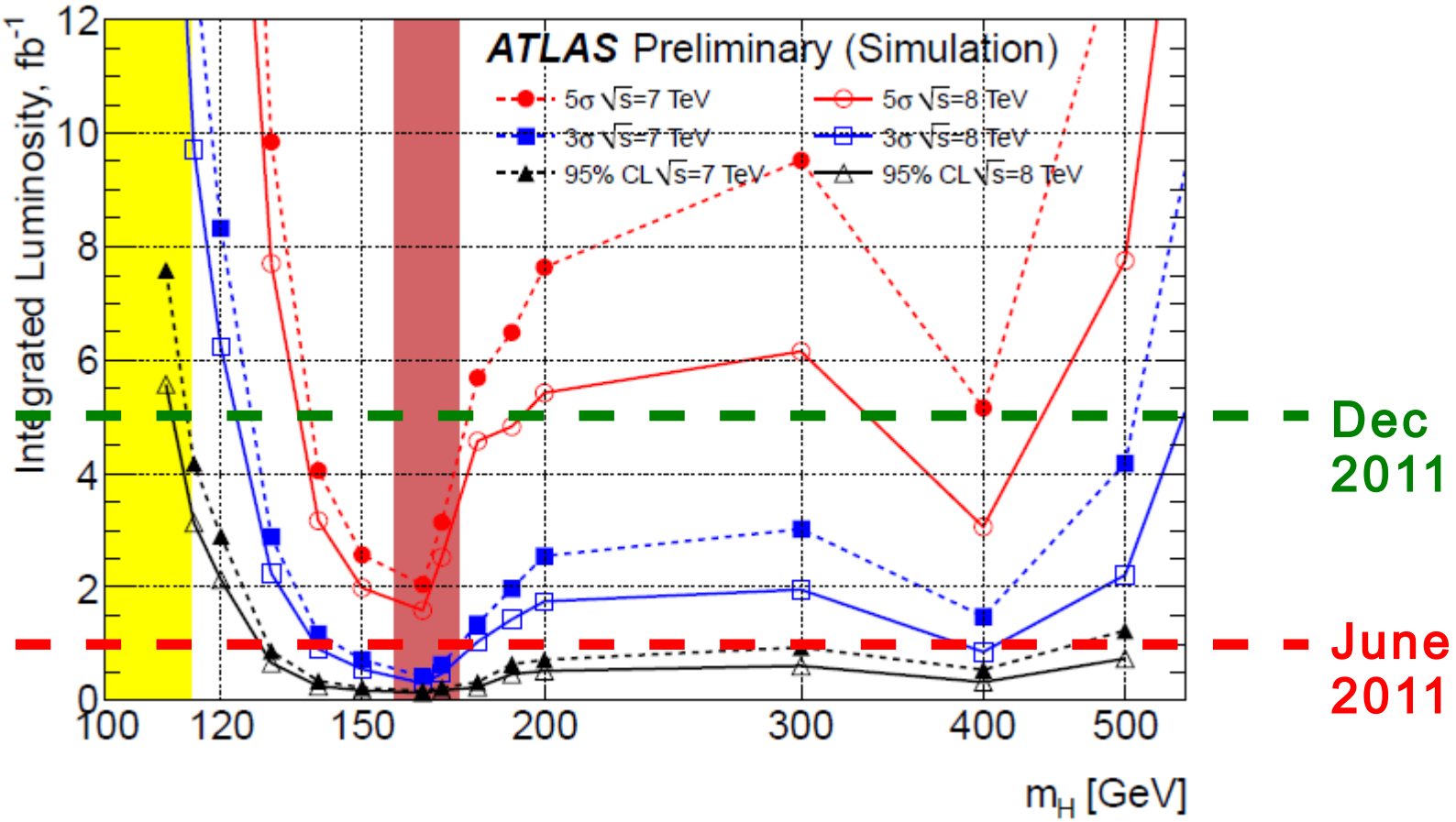
First months of LHC running at 7 TeV

- SM discovery:
  - electron: 1897
  - muon: 1936
  - ν_μ: ~1950
  - ν_e: 1956
  - quarks: 1968-1995
  - tau: 1975
  - W,Z : 1983-1984
  - ν_τ: 2000
  - Higgs: 2012

~100 years



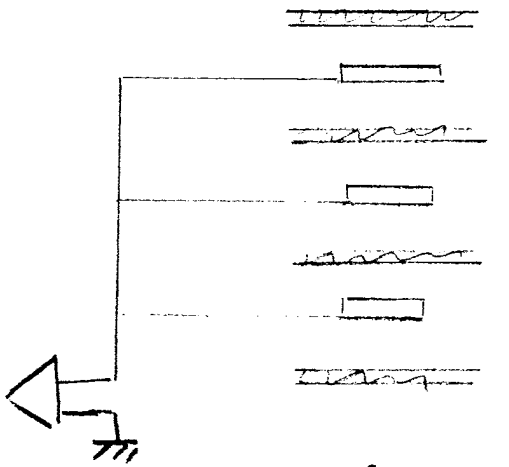
Higgs sensitivity with ATLAS

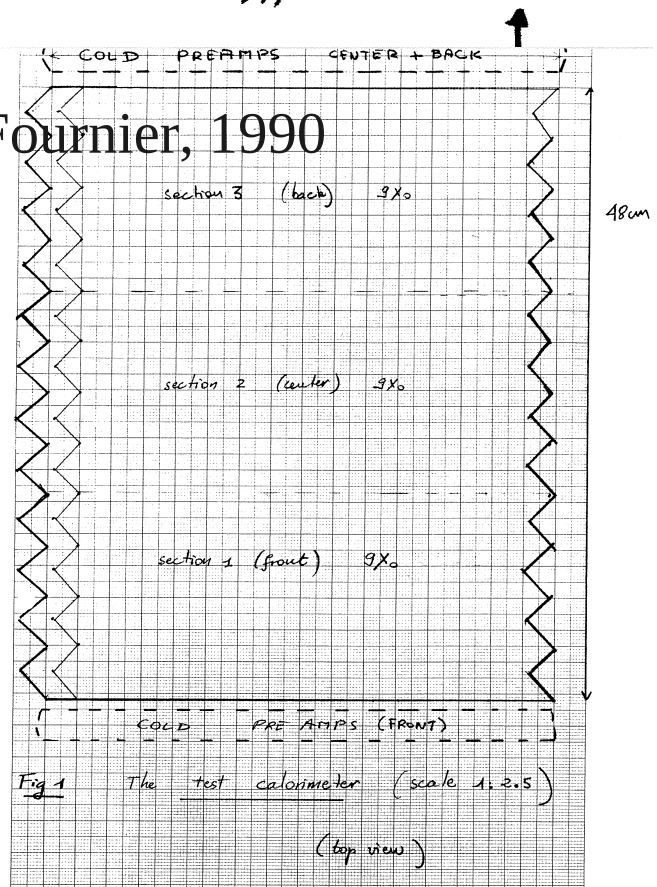


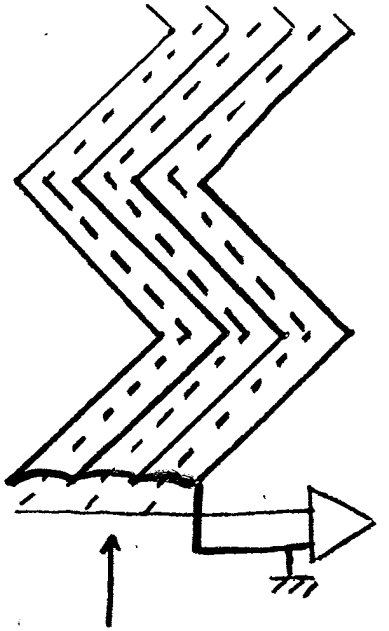
- 95% exclusion with 1 fb^{-1}: 130-460 GeV
- 3σ discovery with 5 fb^{-1}: 120-500 GeV

Le calorimètre à argon liquide: premières idées

- Rapide
- hermétique
- segmenté
-
- premier papier de D. Fournier, 1990







ATLAS et boson de Higgs au LAPP (2)

— physique
— mécanique
— électronique
— informatique

♦ lappwiki.in2p3.fr/twiki/bin/view/AtlasLapp/LeGroupe

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Zitoun Robert			physicien	Retraité
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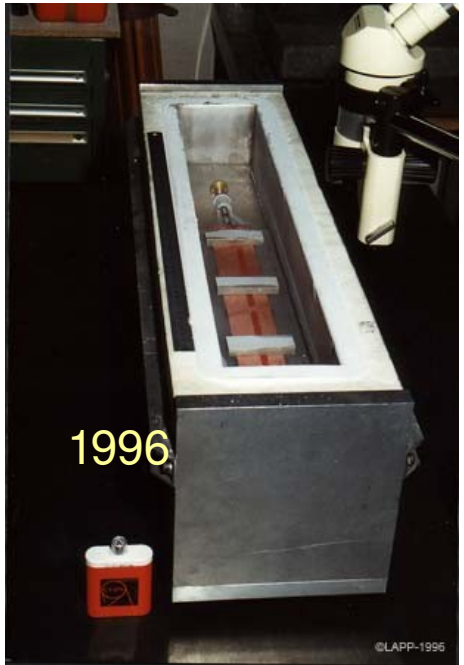
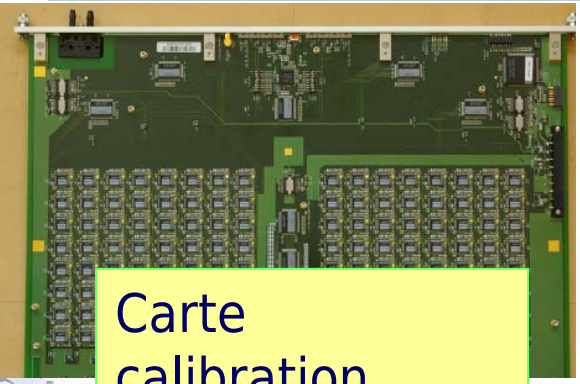
Tests à froid

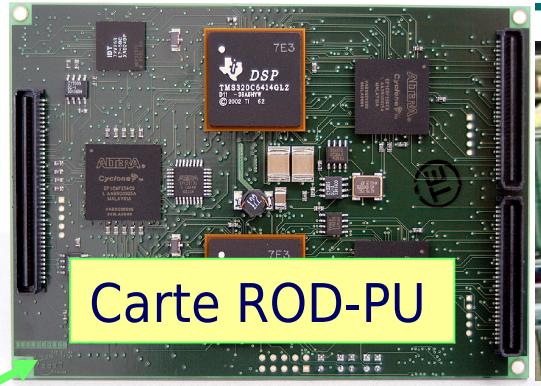
- Fabrication des modules en série
- 2000-2003
- Tests à froid de 28 modules tonneau
- Quatre iront en tests en faisceau
- Suivi de la production



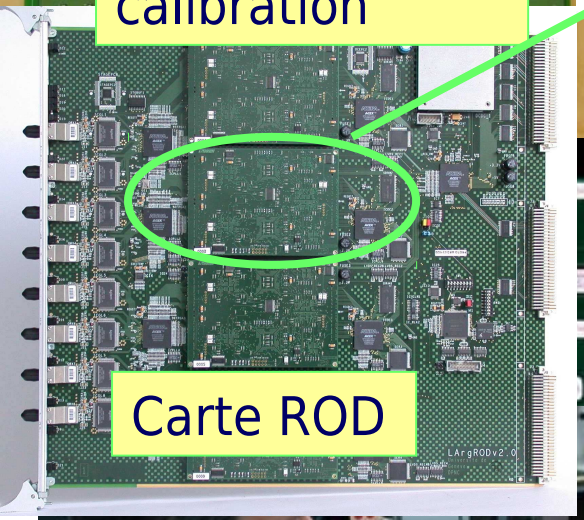
Insertion de la roue dans le cryostat

Electronique

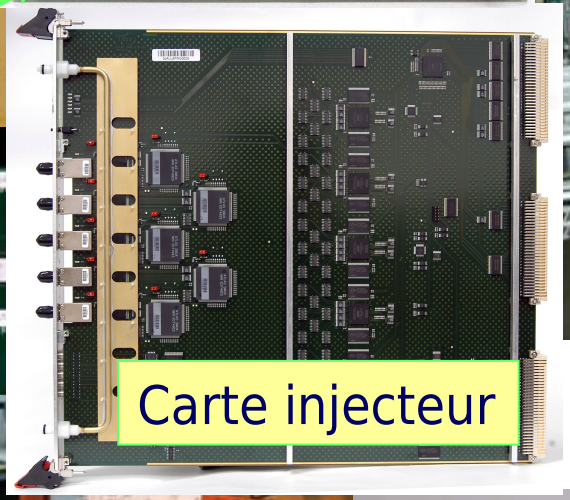

Carte calibration

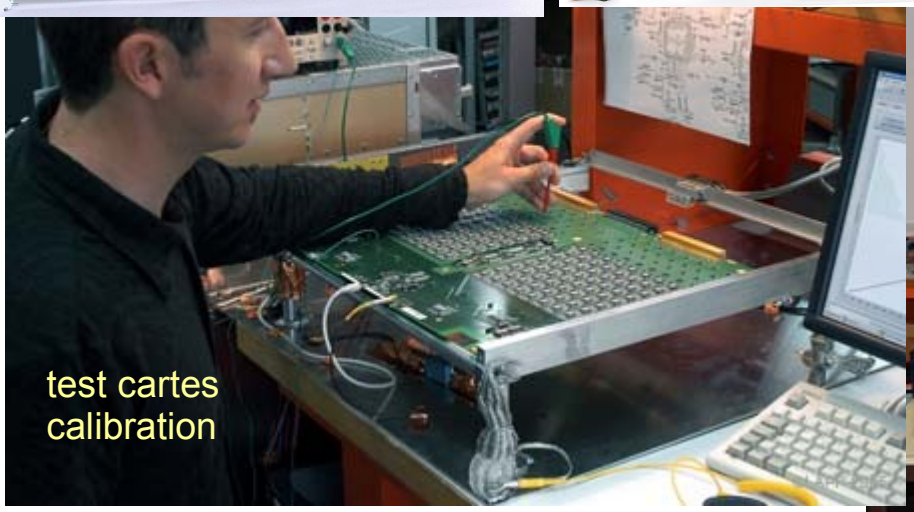


Carte ROD-PU



Carte ROD

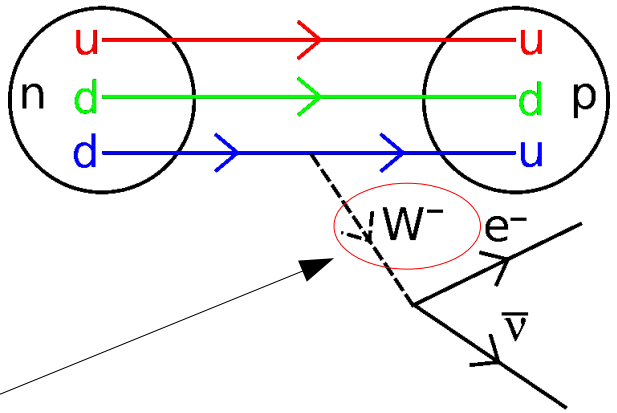

Carte injecteur


test cartes calibration

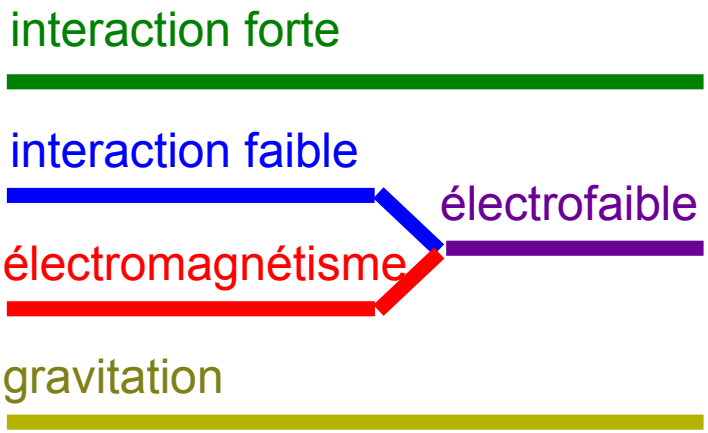
Force électrofaible

- Interaction faible
  - désintégrations nucléaires
  - fusion (ex : soleil)
- Exemple:

$$\begin{cases} {}^{14}C \rightarrow {}^{14}N + e^- + \bar{\nu}_e \\ n \rightarrow p + e^- + \bar{\nu}_e \\ udd \rightarrow uud + e^- + \bar{\nu}_e \end{cases}$$



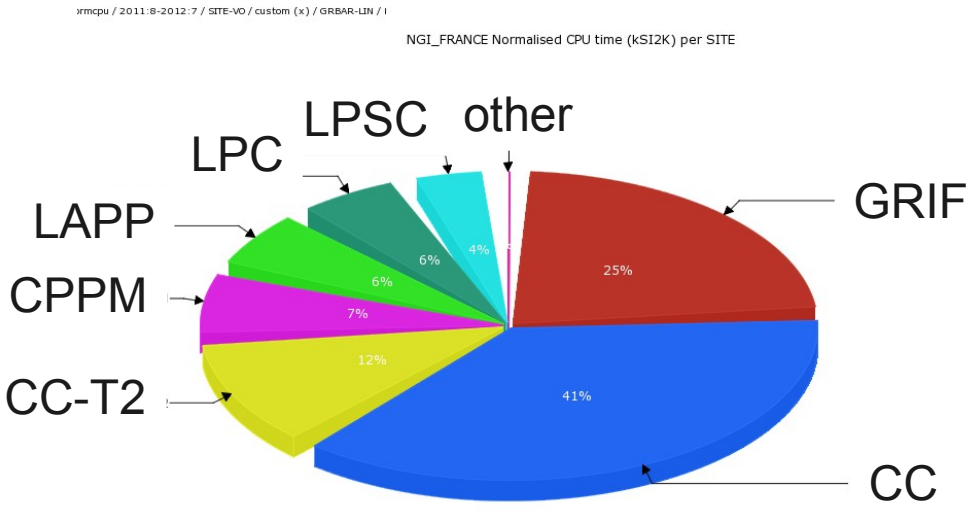
- 2 bosons de jauge massifs : W et Z

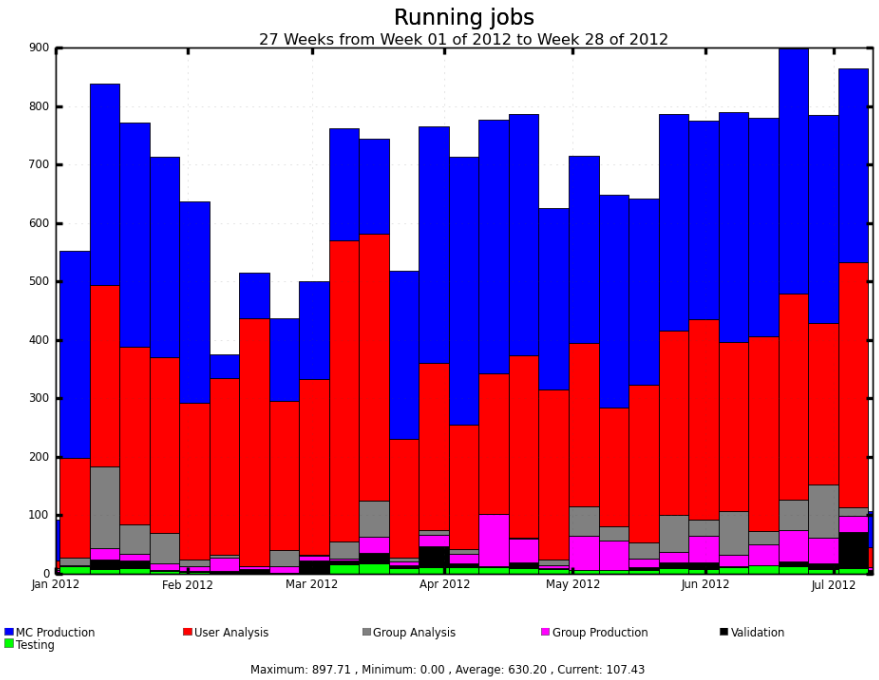


- fin années 60 : force électro-faible
  - unification forces électromagnétique et faible
  - problème : les bosons W et Z ont une masse nulle dans cette théorie!

Computing

- ATLAS jobs on world-wide Grid
  - MC production
  - user and group analysis
  - at CERN, 10 Tier1-s, ~ 70 Tier-2

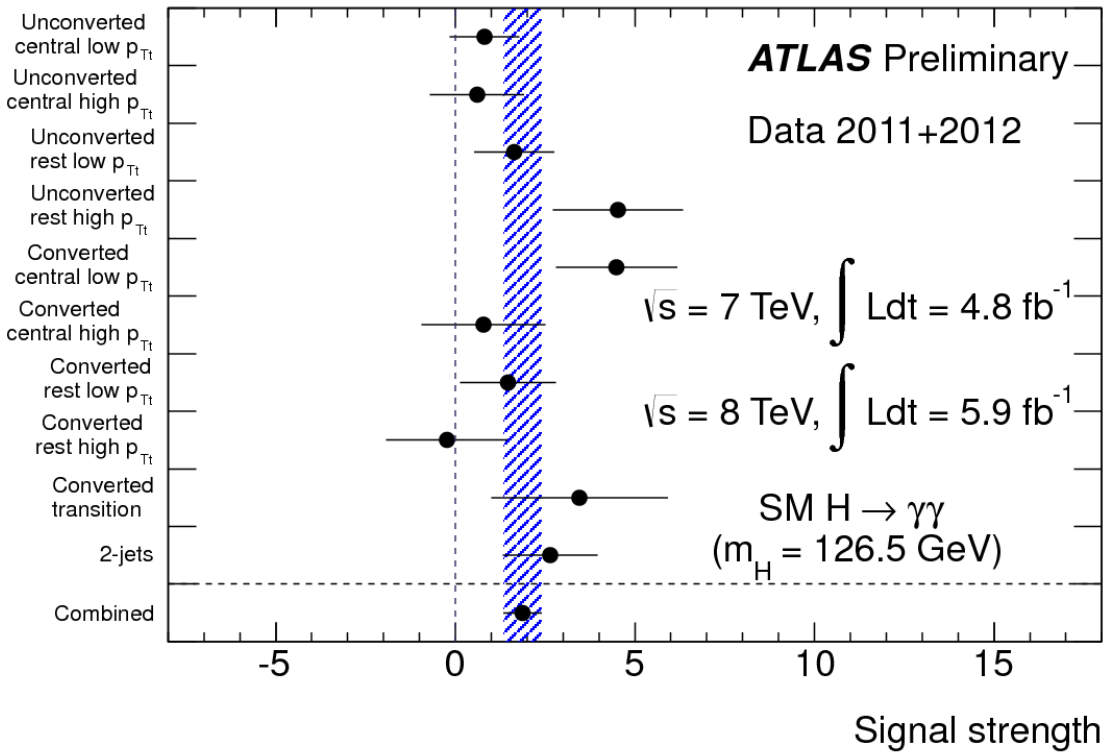


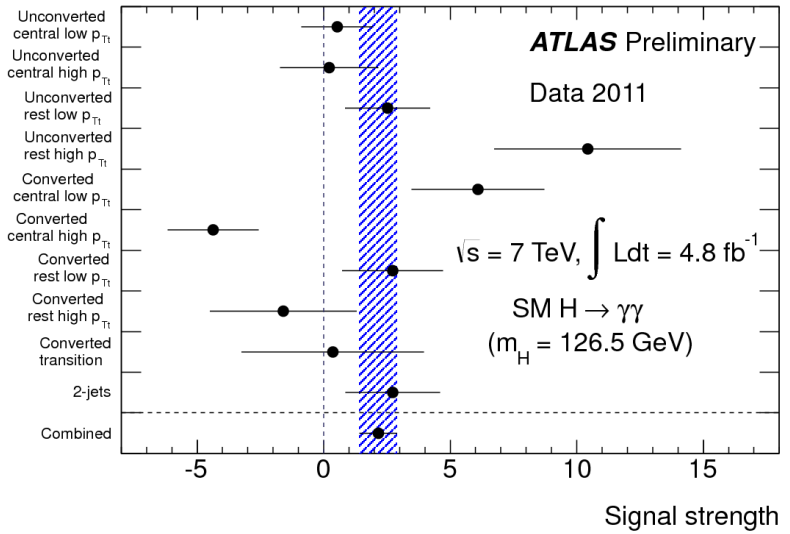


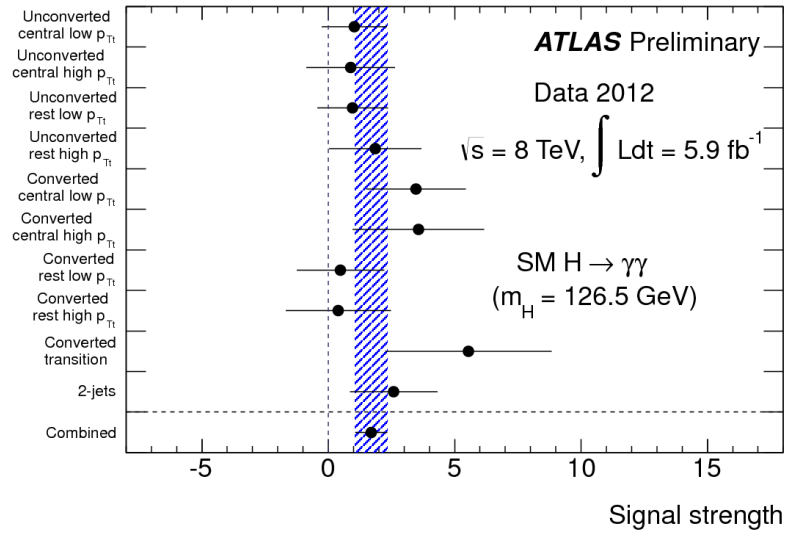
- One Tier-2 at LAPP
  - ~600 jobs /sem
  - ~half Monte-Carlo production, half user analysis

H→γγ, signal strengh

- Compute μ / category:

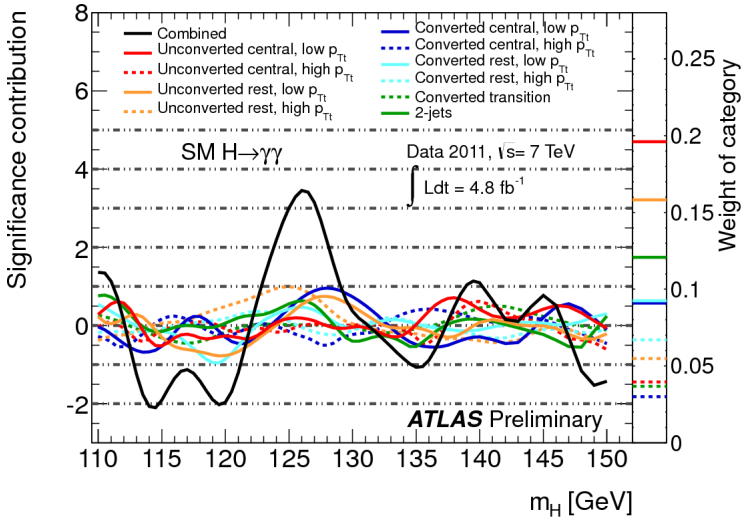


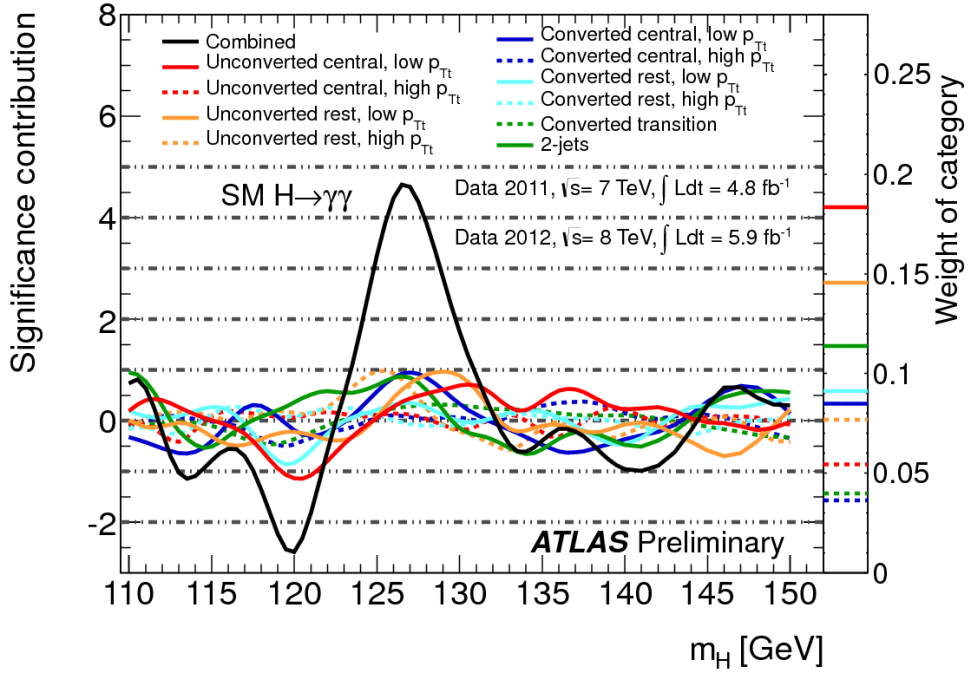


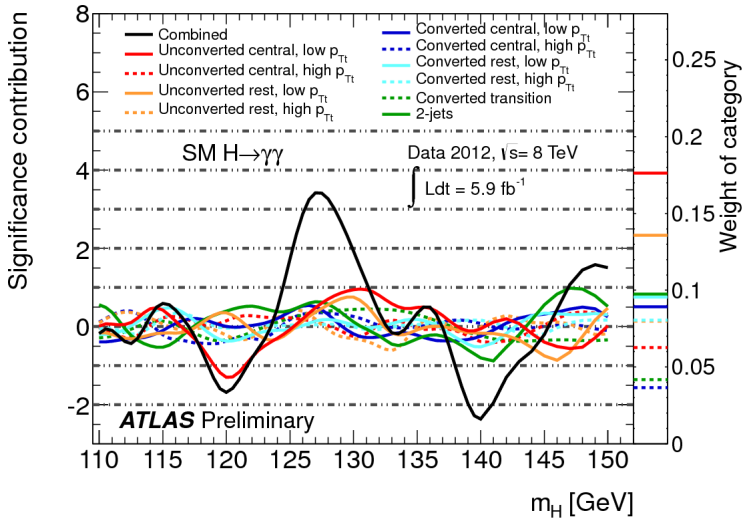


H→γγ, local significance

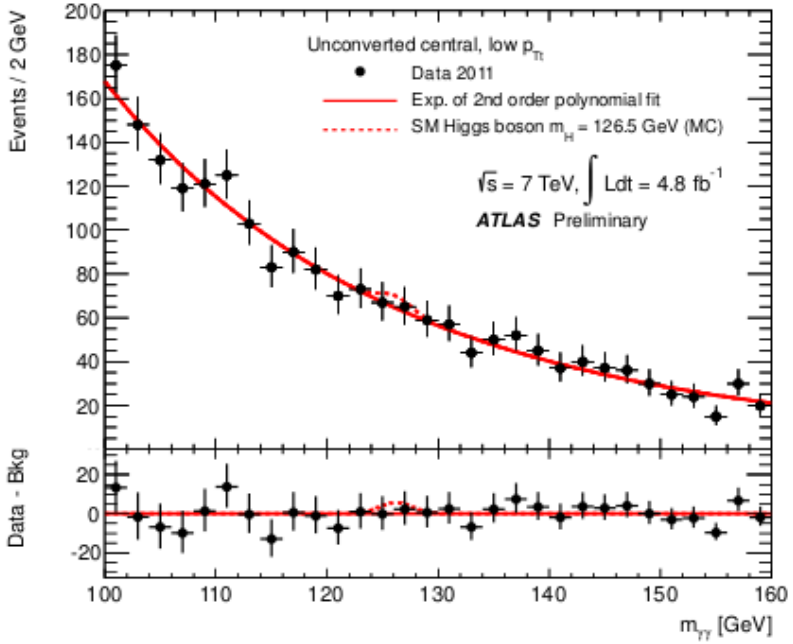
- weights w_i: expected contribution from each individual category for a SM Higgs boson
  - $w_i = \sigma^2/\sigma_i^2$, σ_i, σ = expected statistical uncertainties on the signal strength per category i and for the combined analysis
  - weighted significances $Z'_i = \mathrm{sqrt}(w_i)Z_i$.

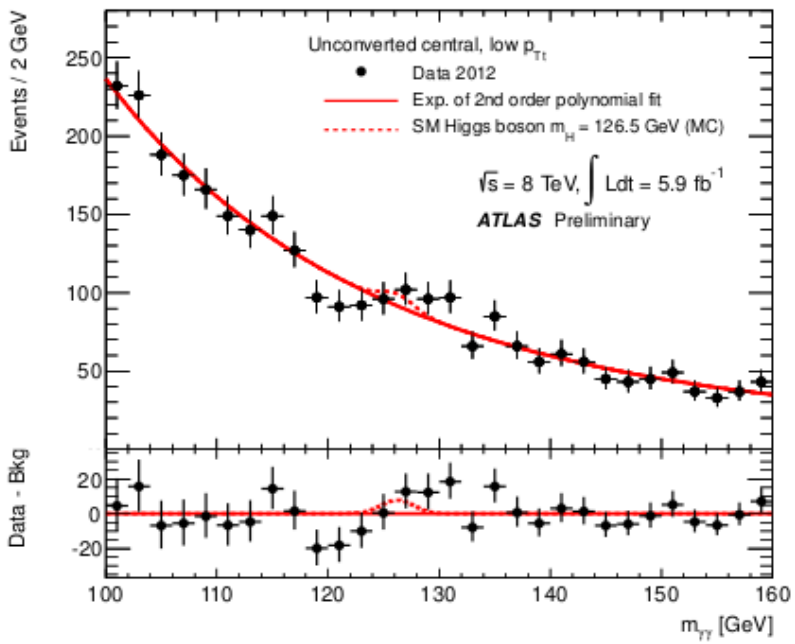


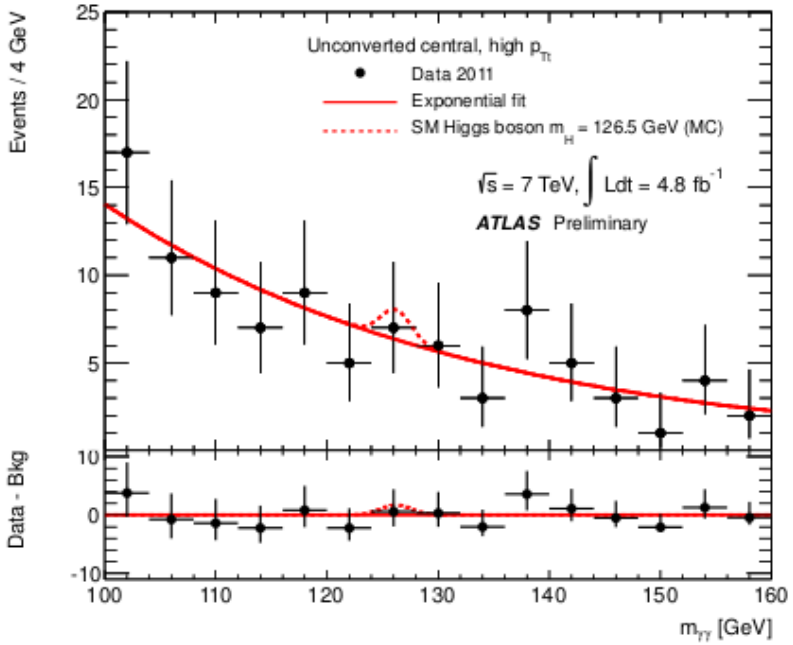


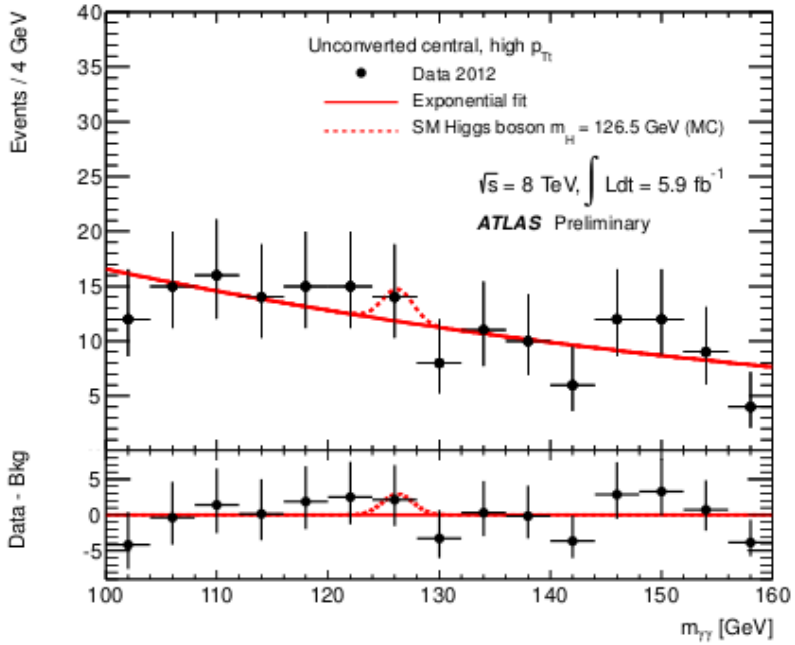


H→γγ, $m_{\gamma\gamma}$ /category (1)

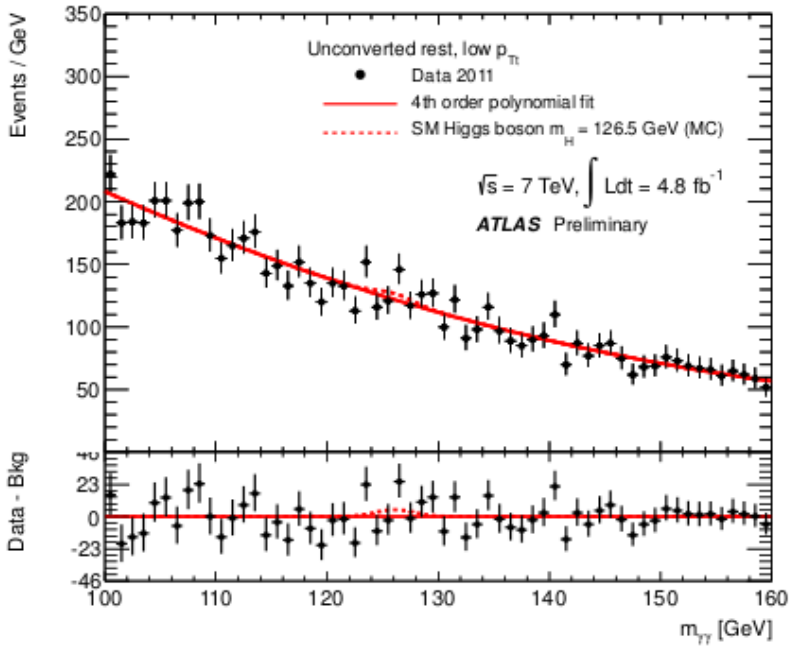


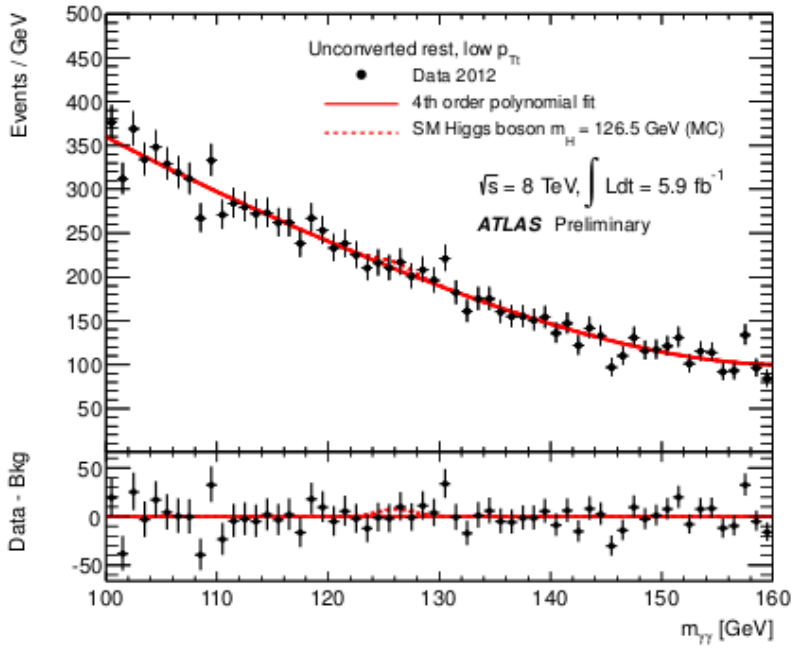


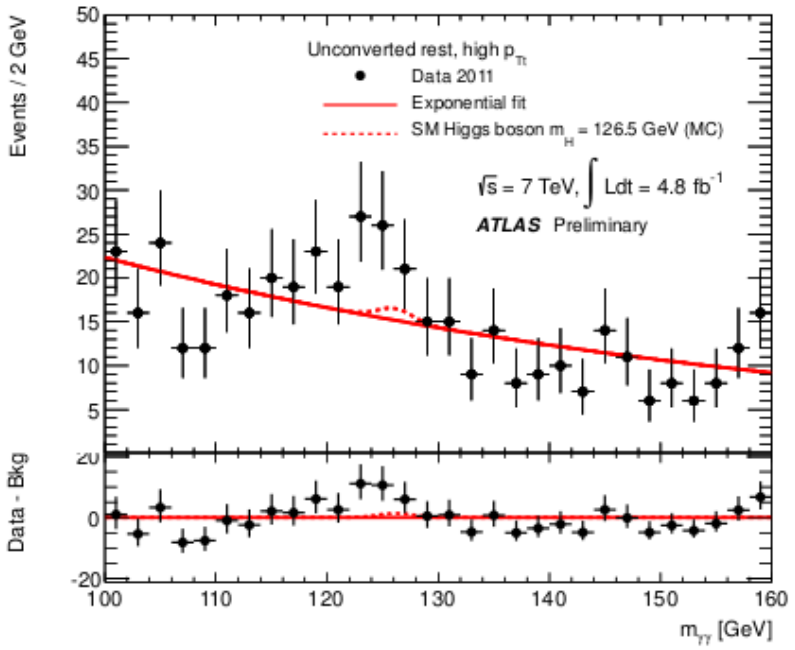


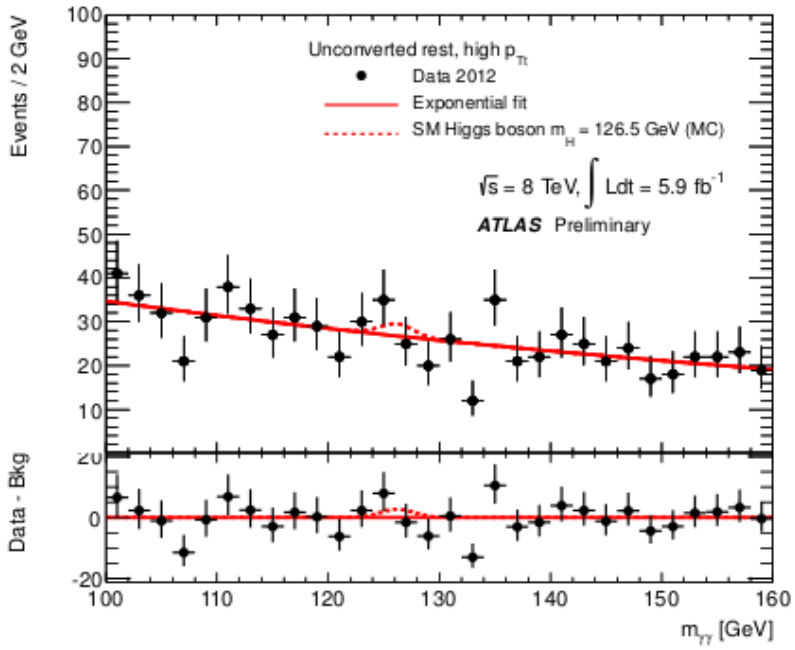


H→γγ, $m_{\gamma\gamma}$ /category (2)

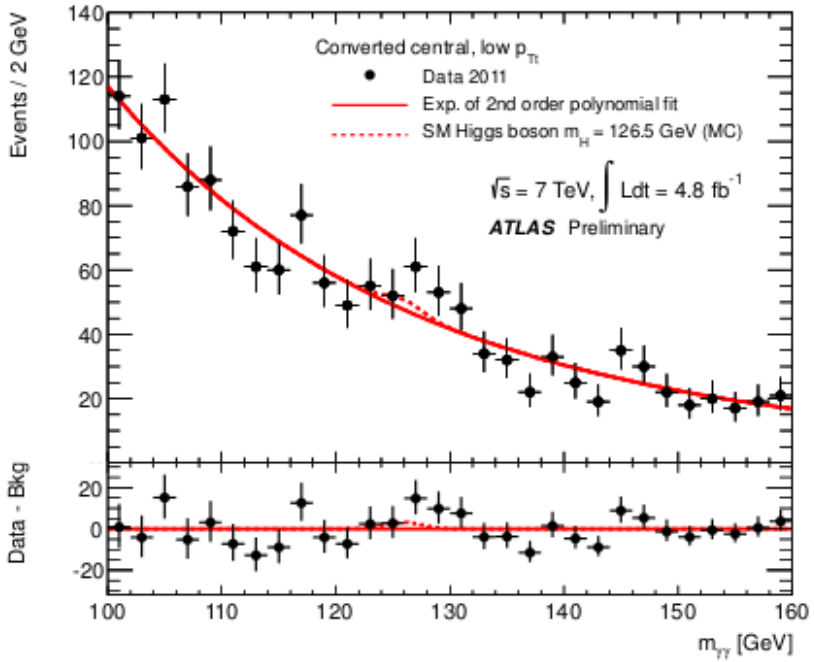


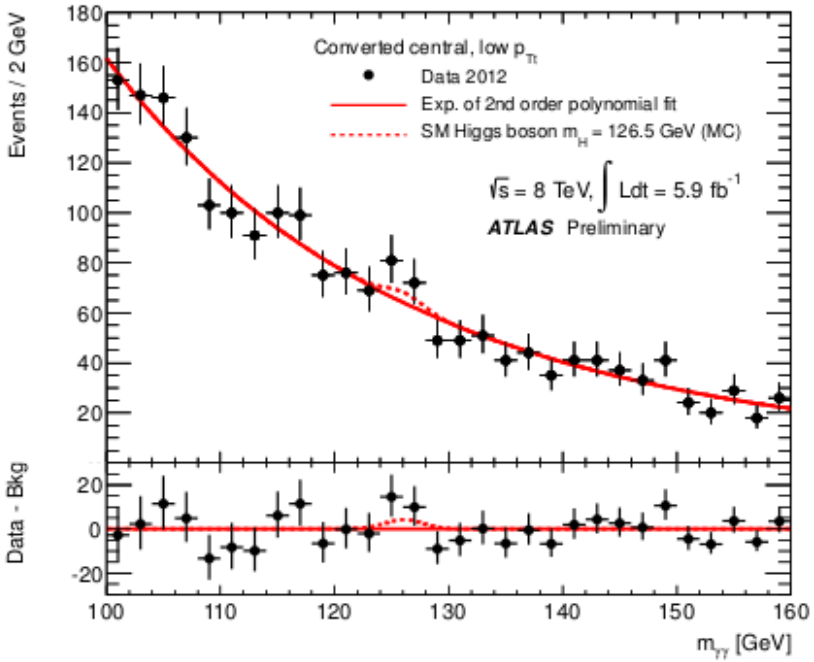


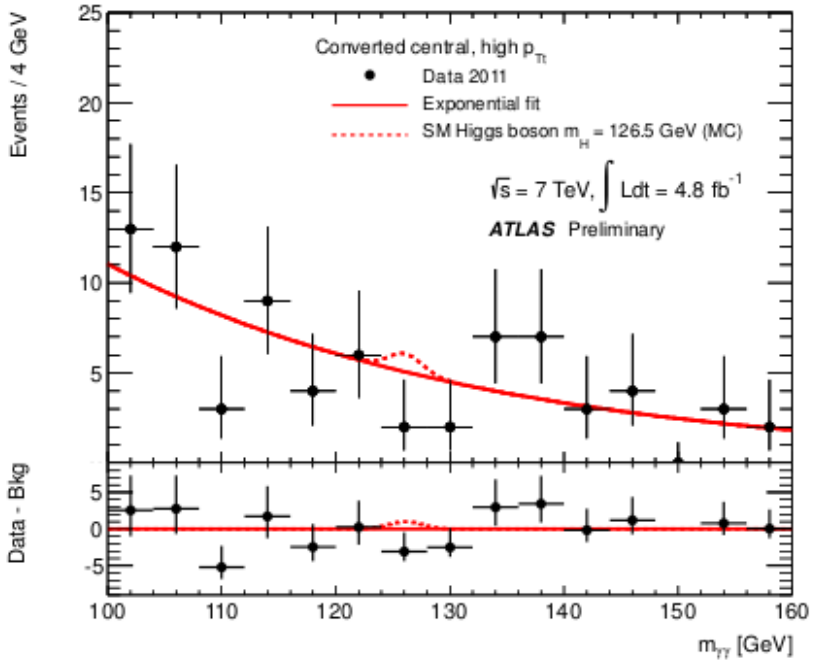


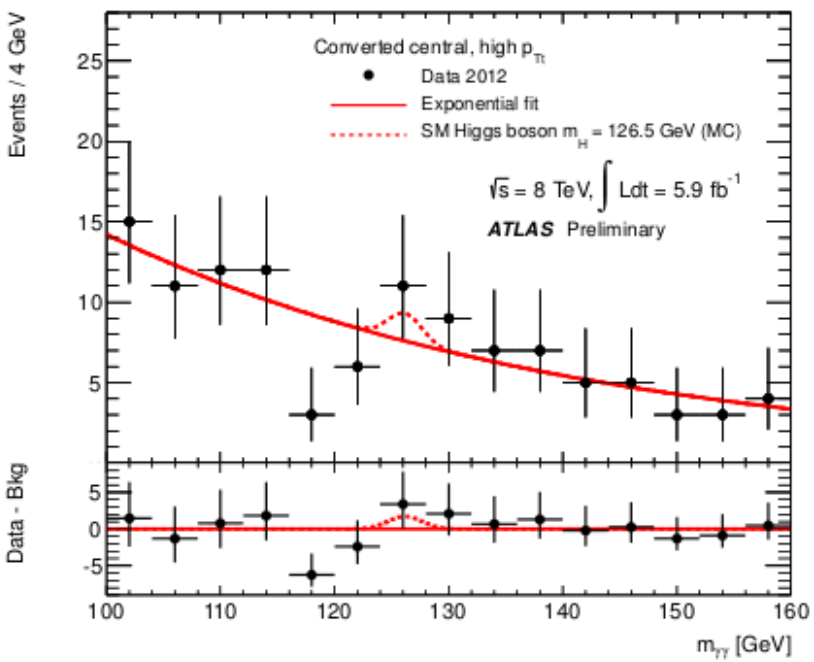


H→γγ, $m_{\gamma\gamma}$ /category (3)

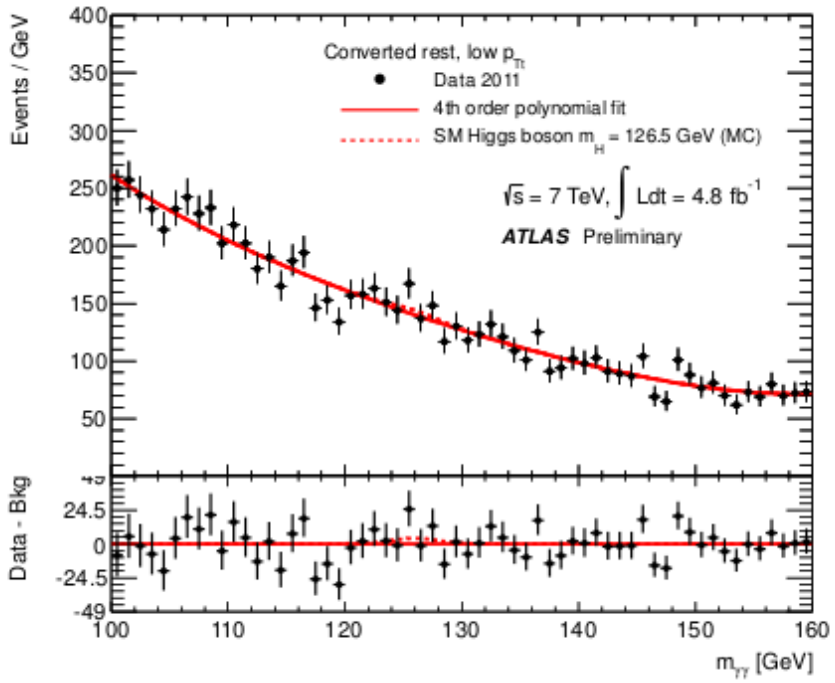


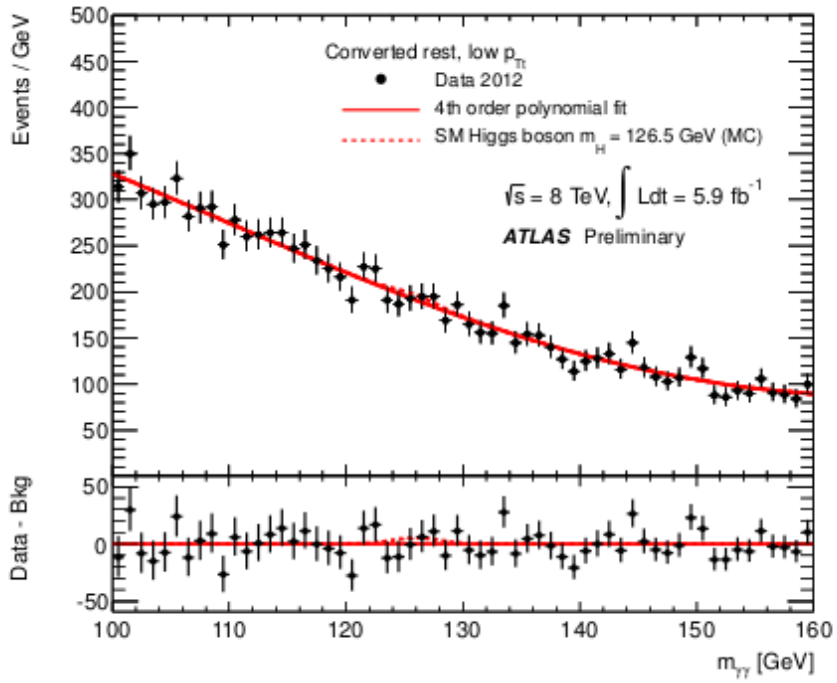


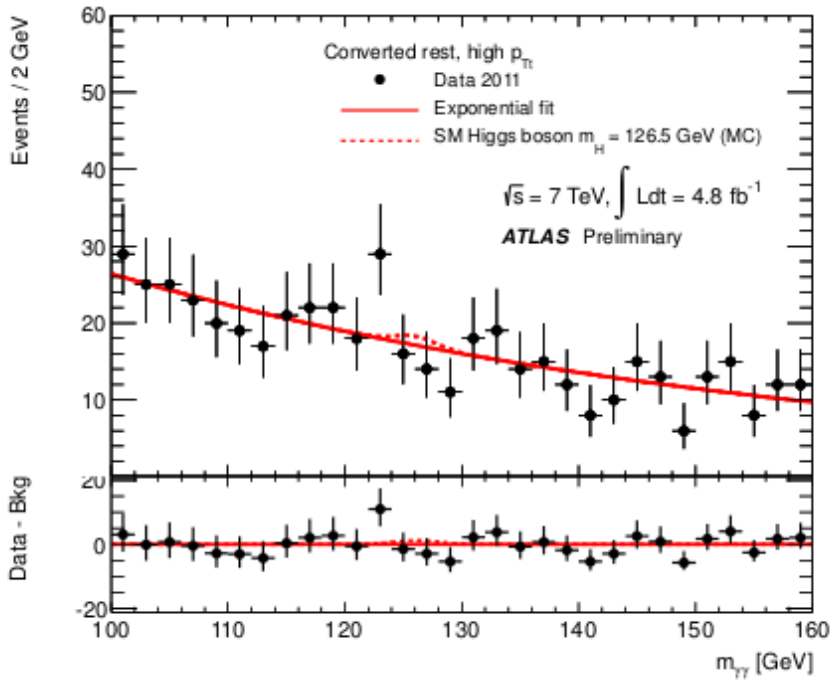


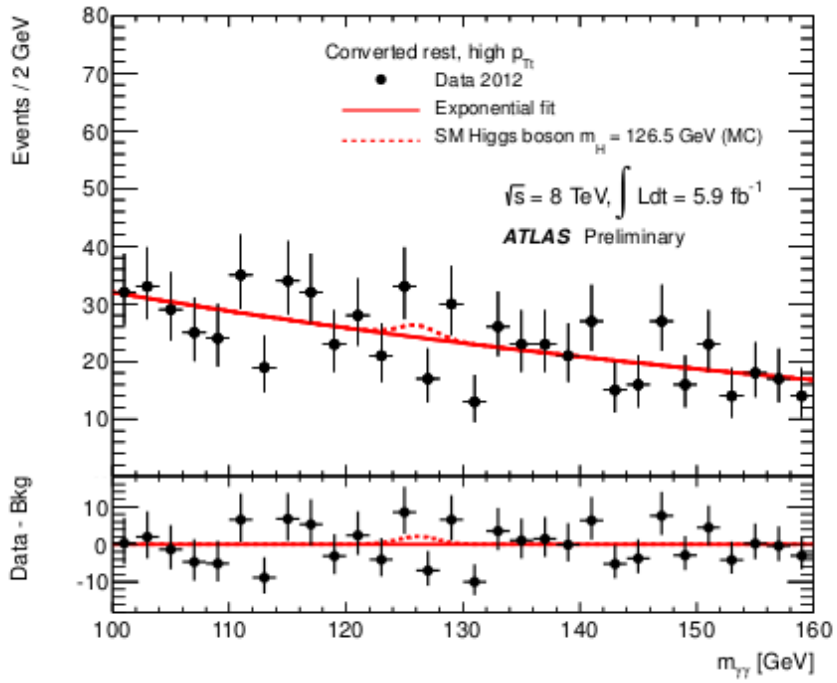


H→γγ, $m_{\gamma\gamma}$ /category (4)

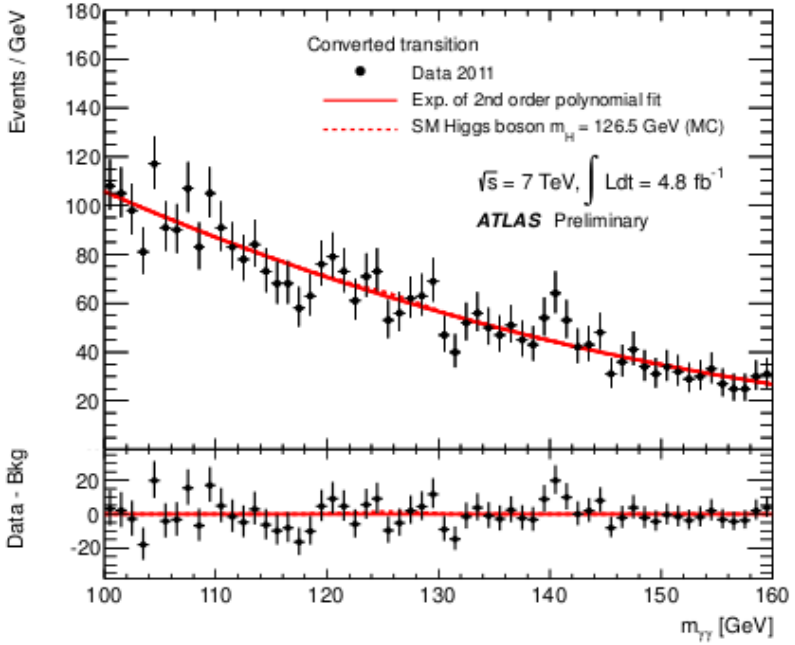


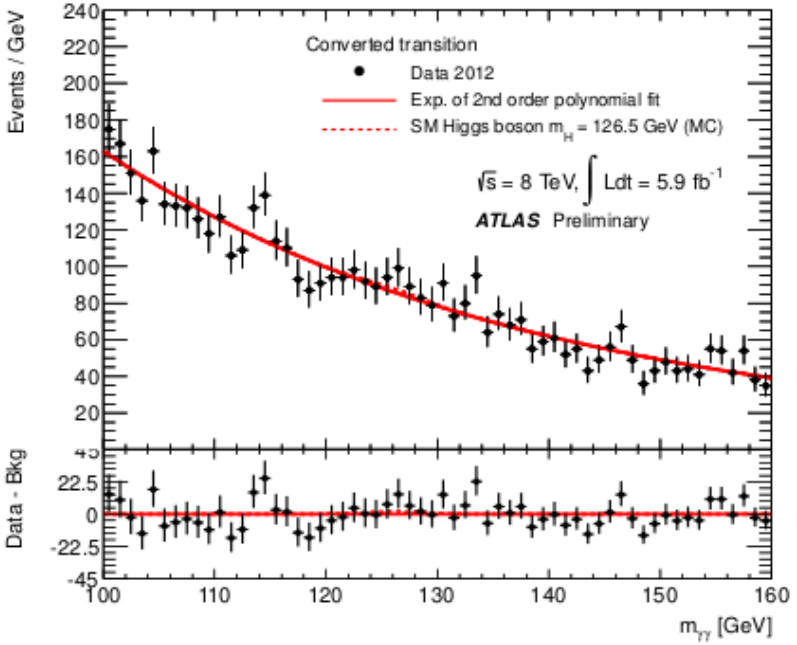


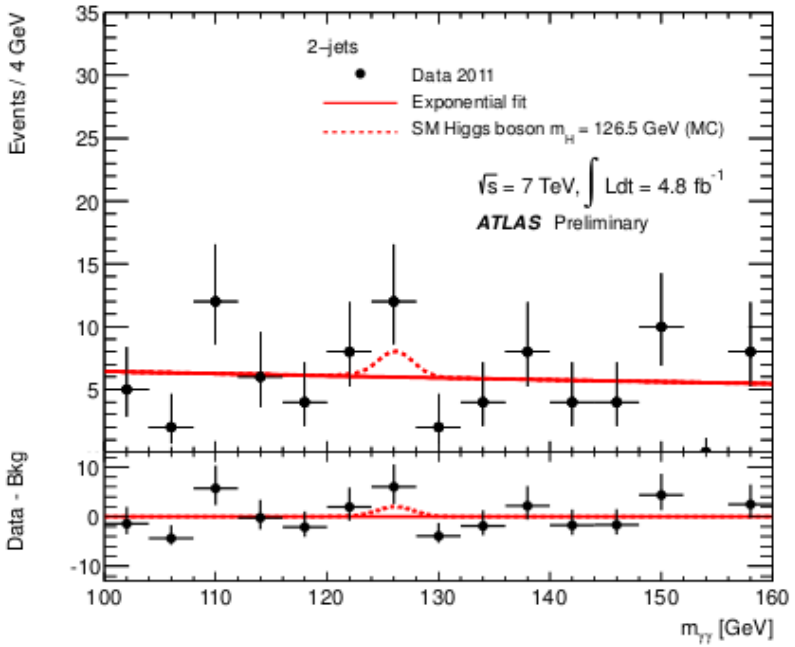


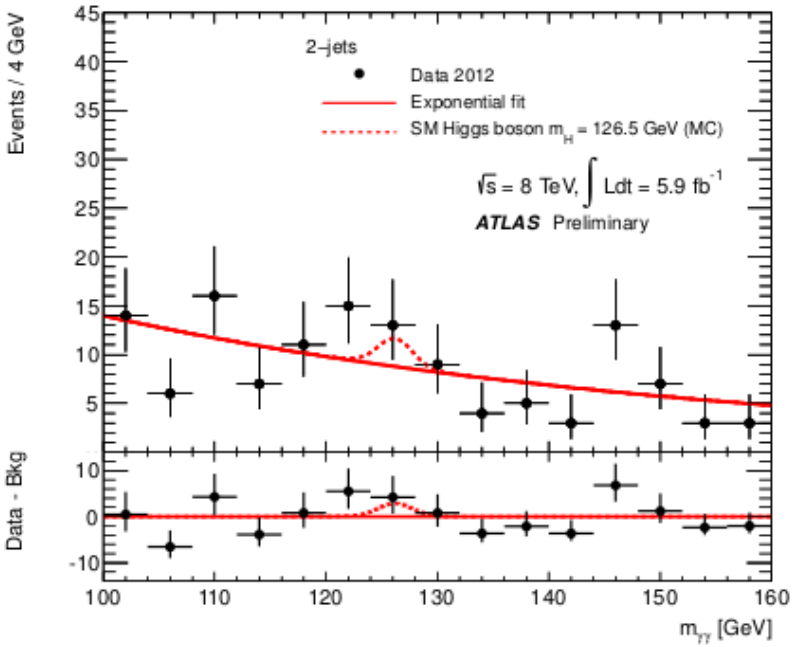


H→γγ, $m_{\gamma\gamma}$ /category (5)



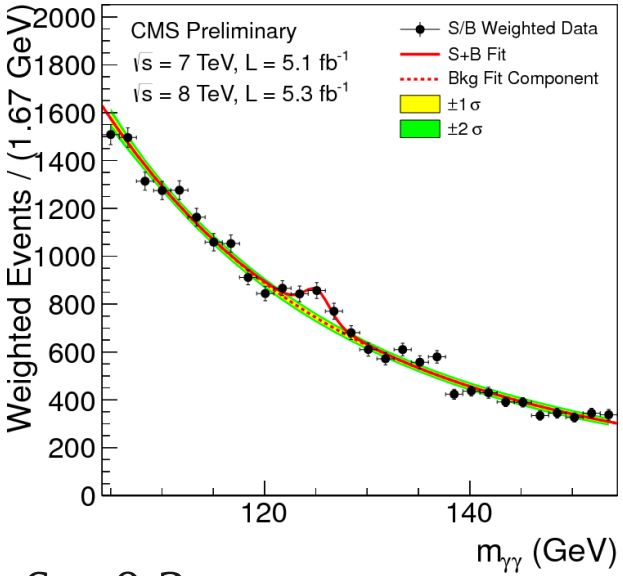


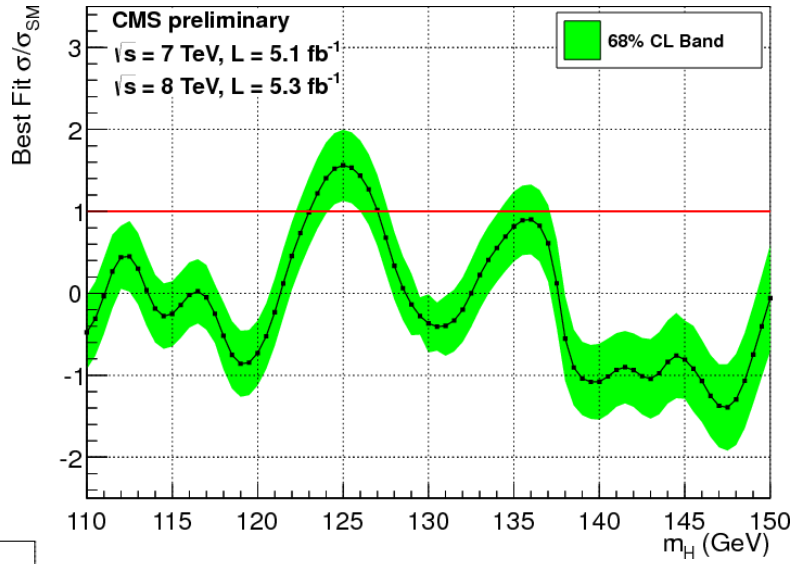




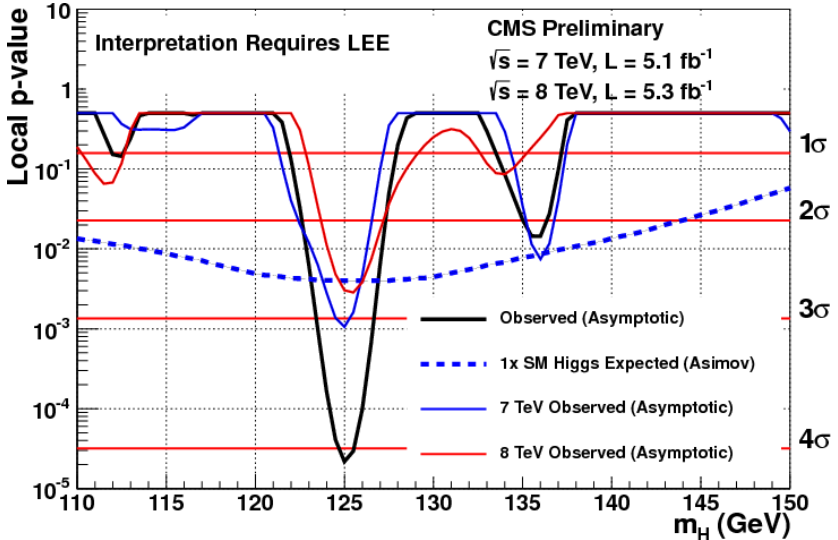
CMS, H->γγ

- For the mass fit MVA and combined datasets, result of summing the data and the signal plus background fits weighted by the ratio of signal to background in each event class



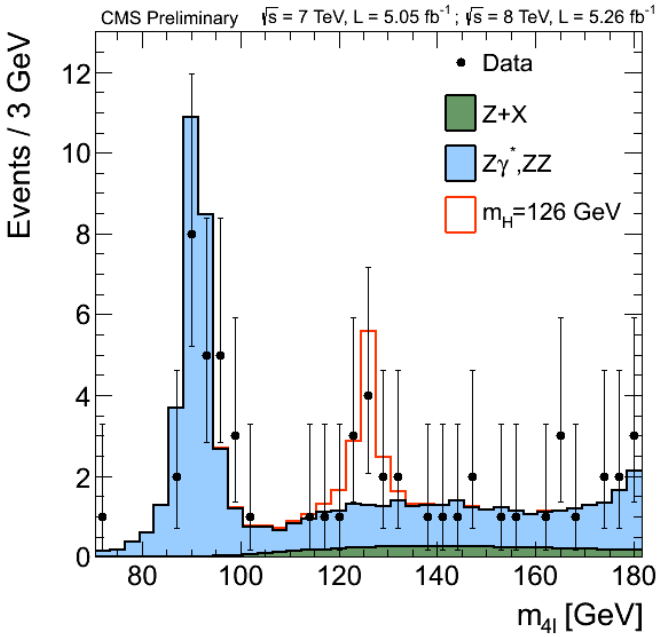


- Best signal fit: μ = 1.6 ± 0.3
- Significance:
  - local: 4.1σ
  - global: 3.2σ

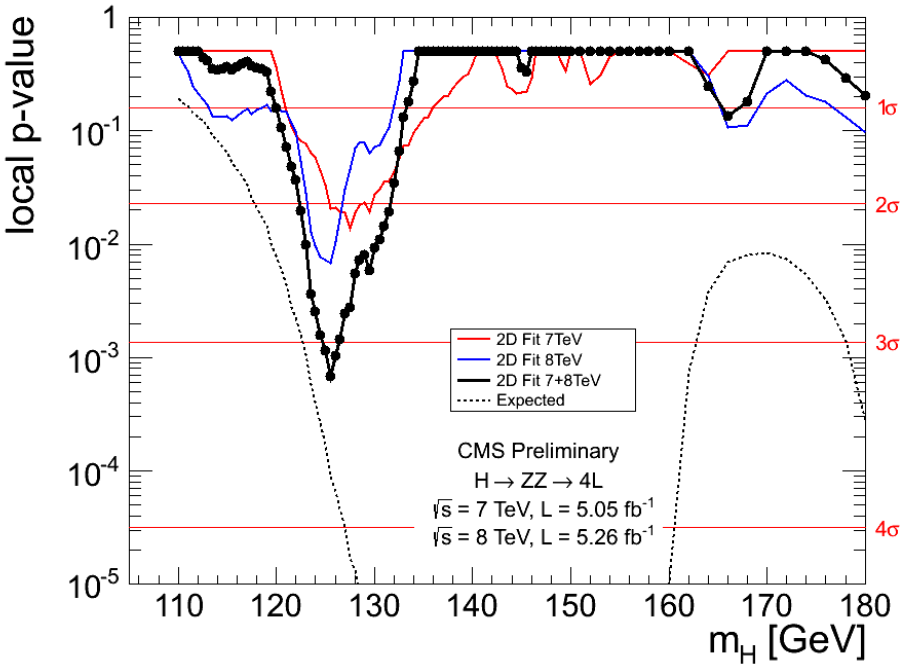


CMS, H->4l

- Invariant mass m_{4l}
  - in [100-800] GeV:
  - 164 events expected
  - 172 events observed

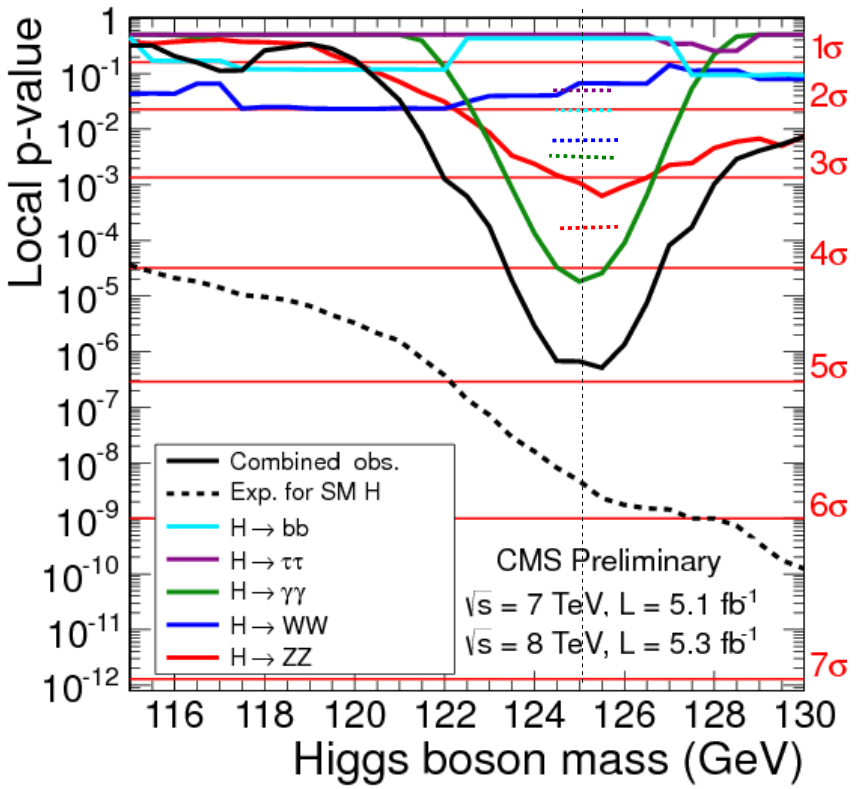


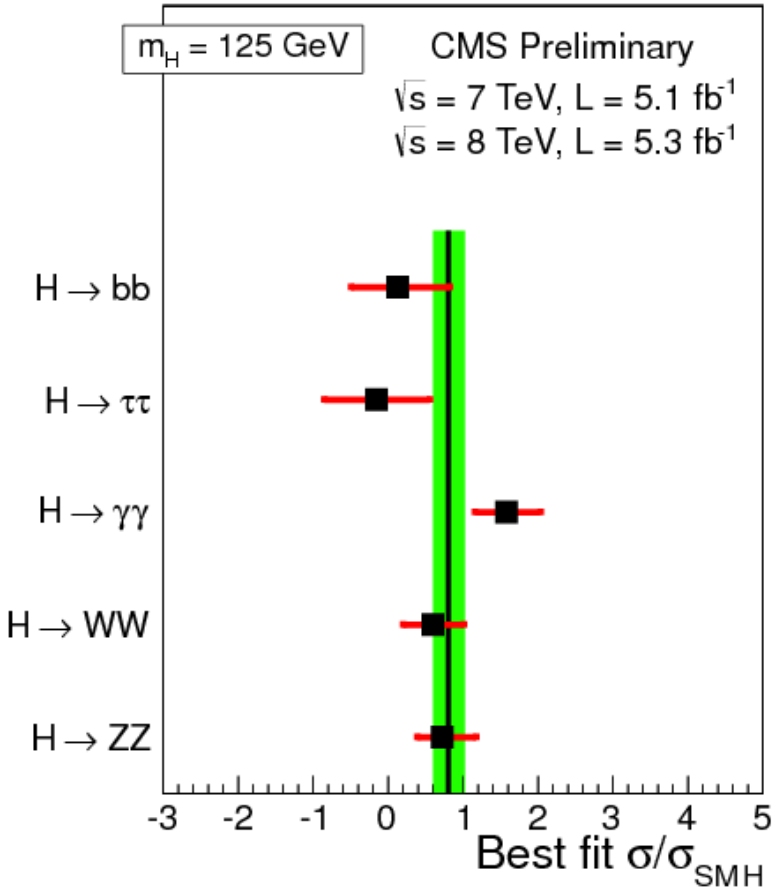
- Best signal fit: $\mu = 0.7 \pm 0.4$
- Significance:
  - local: 3.2σ
  - global: ??



CMS: combinaison

- Best signal fit: $\mu = 0.8 \pm 0.2$
- Significance:
  - local: 4.9σ
  - global: 4.0σ





hep-ph on arXiv since 4th of July

1. arXiv:1207.2027 [pdf, ps, other]
Constraints on TeV scale Majorana neutrino phenomenology from the Vacuum Stability of the Higgs
Joydeep Chakrabortty, Moumita Das, Subhendra Mohanty
Comments: 13 pages, 7 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

2. arXiv:1207.1906 [pdf, ps, other]
Electroweak Radiative Corrections to Higgs Production via Vector Boson Fusion using SCET: Numerical Results
Fabio Siringo, Giuseppe Buccheri
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

3. arXiv:1207.1839 [pdf, other]
Implications of the Higgs Boson Discovery for mSUGRA
Sujeet Akula, Pran Nath, Gregory Peim
Comments: 5 pages, 3 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Astrophysical Phenomena (astro-ph.HE); High Energy Physics - Experiment (hep-ex)

4. arXiv:1207.1718 [pdf, other]
Higgs After the Discovery: A Status Report
Dean Carmi, Adam Falkowski, Eric Kuflik, Tomer Volansky, Jure Zupan
Comments: 35 pages; v2: ATLAS dijet-tag diphoton channel added, dilaton and doublet-singlet bugs corrected, references added
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

5. arXiv:1207.1717 [pdf, other]
First Glimpses at Higgs' face
J. R. Espinosa, C. Grojean, M. Muhlleitner, M. Trott
Comments: 24 pages, 7 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

6. arXiv:1207.1716 [pdf, other]
Higgs discovery: the beginning or the end of natural EWSB?
Marc Montull, Francesco Riva
Comments: 8figures 8 pages
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

7. arXiv:1207.1710 [pdf, ps, other]
GUT Scalar Potentials for Higgs Inflation
Martin B. Einhorn, D. R. Timothy Jones
Comments: 34 pages, no figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; General Relativity and Quantum Cosmology (gr-qc); High Energy Physics - Theory (hep-th)

8. arXiv:1207.1693 [pdf, other]
Global Analysis of the Higgs Candidate with Mass ~ 125 GeV
John Ellis, Tevong You
Comments: 22 pages, 9 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

9. arXiv:1207.1590 [pdf]
Heavy neutrinos, Z' and Higgs bosons at the LHC: new particles from an old symmetry
S. Khalil, S. Moretti
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

10. arXiv:1207.1545 [pdf, other]
Could two NMSSM Higgs bosons be present near 125 GeV?
John F. Gunion, Yun Jiang, Sabine Kraml
Comments: 8 pages, 8 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

11. arXiv:1207.1541 [pdf, other]
S and T Parameters from a Light Nonstandard Higgs versus Near Conformal Dynamics
Roshan Foadi, Francesco Sannino
Comments: 13 pages, 3 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

12. arXiv:1207.1451 [pdf, ps, other]
The apparent excess in the Higgs to di-photon rate at the LHC: New Physics or QCD uncertainties?
J. Baglio, A. Djouadi, R. M. Godbole
Comments: LaTeX, 2 figures, 9 pages. V2: 2 important footnotes added
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

13. arXiv:1207.1445 [pdf, other]
Are There Hints of Light Stops in Recent Higgs Search Results?
Matthew R. Buckley, Dan Hooper
Comments: 6 pages, 5 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

14. arXiv:1207.1435 [pdf, other]
Precision Unification in λSUSY with a 125 GeV Higgs
Edward Hardy, John March-Russell, James Unwin
Comments: 14 pages, 5 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

15. arXiv:1207.1348 [pdf, other]
The Higgs sector of the phenomenological MSSM in the light of the Higgs boson discovery
Alexandre Arbey, Marco Battaglia, Abdelhak Djouadi, Farvah Mahmoudi
Comments: 21 pages, 9 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

16. arXiv:1207.1347 [pdf, other]
Is the resonance at 125 GeV the Higgs boson?
Pier Paolo Giardino, Kristjan Kannike, Martti Raidal, Alessandro Strumia
Comments: 9 pages, 6 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

17. arXiv:1207.1344 [pdf, ps, other]
Constraining anomalous Higgs interactions
Tyler Corbett, O. J. P. Eboli, J. Gonzalez-Fraile, M. C. Gonzalez-Garcia
Comments: 10 pages, 3 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

18. arXiv:1207.1246 [pdf, ps, other]
Effect of earth rotation on pair production of Standard Model Higgs bosons at linear colliders in the noncommutative spa
Prasanta Kumar Das, Abhishodh Prakash
Comments: 20 pages, 16 eps figures. arXiv admin note: substantial text overlap with arXiv:1009.3571
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

19. arXiv:1207.1093 [pdf, ps, other]
Have We Observed the Higgs (Imposter)?
Ian Low, Joseph Lykken, Gabe Shaughnessy
Comments: 20 pages, 4 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

20. arXiv:1207.1083 [pdf, other]
Constraining parameter space in type-II two-Higgs doublet model in light of a 125 GeV Higgs boson
H.S. Cheon, Sin Kyu Kang
Comments: 13 pages, 6 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

21. arXiv:1207.1065 [pdf, ps, other]
Higgs boson decays to $γγ$ and $Z γ$ in models with Higgs extensions
Cheng-Wei Chiang, Kei Yagyu
Comments: 4 pages, 6 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

22. arXiv:1207.1051 [pdf, ps, other]
Testing No-Scale F-SU(5): A 125 GeV Higgs Boson and SUSY at the 8 TeV LHC
Tianjun Li, James A. Maxin, Dimitri V. Nanopoulos, Joel W. Walker
Comments: 7 Pages, 2 Figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

23. arXiv:1207.1014 [pdf, ps, other]
Higgs boson of mass 125 GeV in GMSB models with messenger-matter mixing
A. Albaid, K.S. Babu
Comments: 31 pages, LaTeX
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

24. arXiv:1207.0980 [pdf, ps, other]
The top quark and Higgs boson masses and the stability of the electroweak vacuum
S. Alekhin, A. Djouadi, S. Moch
Comments: 12 pages, 1 figure. v2: lapsus corrected in the abstract
Subjects: **High Energy Physics - Phenomenology (hep-ph)**

- ZV


The Force is an energy field created by all living things. It surrounds us and penetrates us; it binds the galaxy together.
The Higgs Field is an energy field proposed by Professor Peter Higgs. It surrounds us and penetrates us; it binds the galaxy together. By giving it mass.