

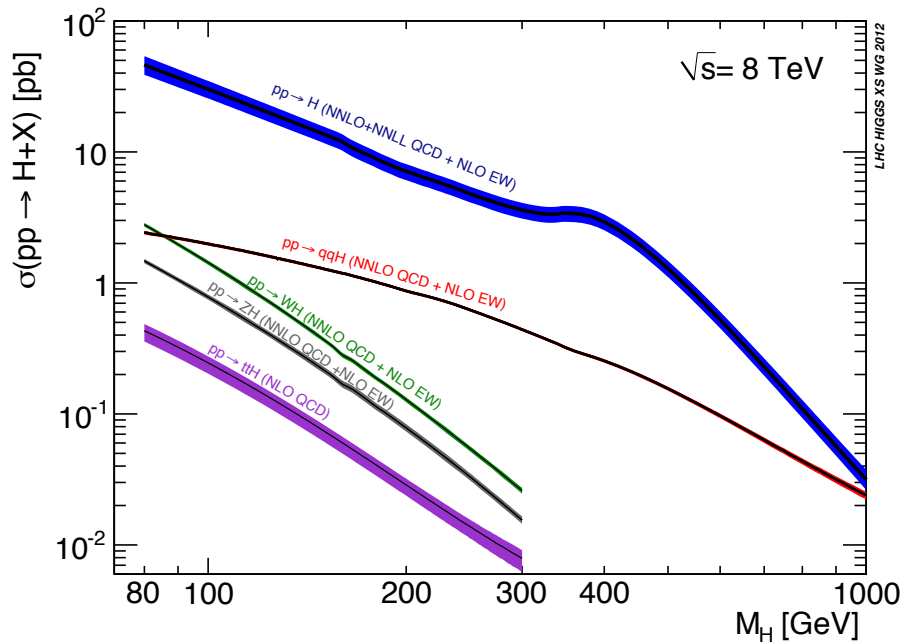
Ultimi risultati dell'analisi $H \rightarrow \gamma\gamma$ e $H \rightarrow Z\gamma$ dall'esperimento ATLAS



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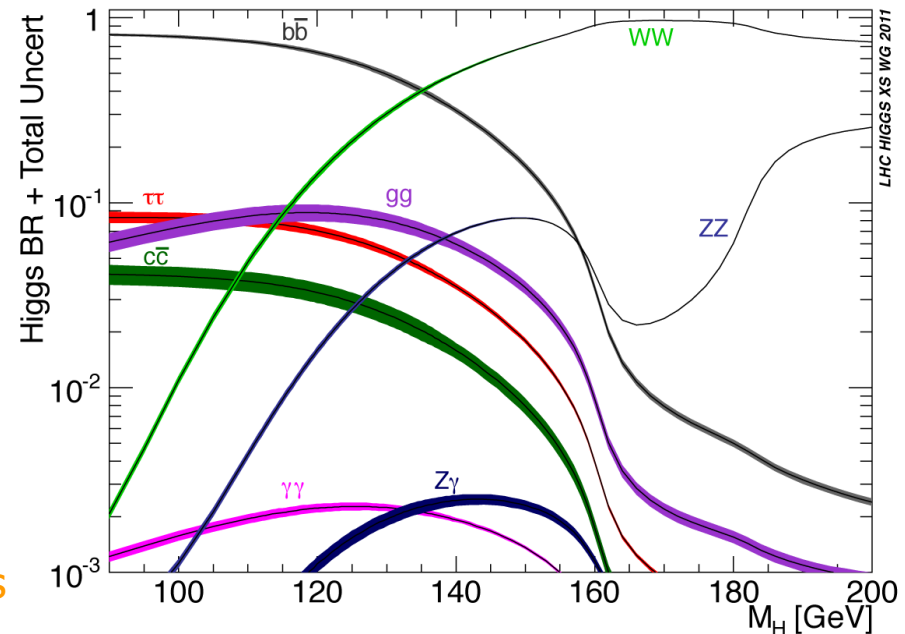


Decadimento del Bosone di Higgs dello SM in $\gamma\gamma$ e $Z\gamma$



- $BR_{SM}(H \rightarrow \gamma\gamma) \sim BR_{SM}(H \rightarrow Z\gamma) \sim 0.2\%$
 - $BR(Z \rightarrow ll) \sim 6.7\%$ ($l = e, \mu$) quindi uno yields simile a $4l$
- Attesi ~ 15 eventi in $Z\gamma$ da 2011+2012 ma con piu' background che in $\gamma\gamma$
- Il rapporto $BR_{SM}(H \rightarrow \gamma\gamma)/BR_{SM}(H \rightarrow Z\gamma)$ sensibile alla fisica BSM

- Meccanismo di produzione principale gluon-gluon fusion (84% a $M_H \sim 125$ GeV)
- VBF circa 10% e VH circa 5%

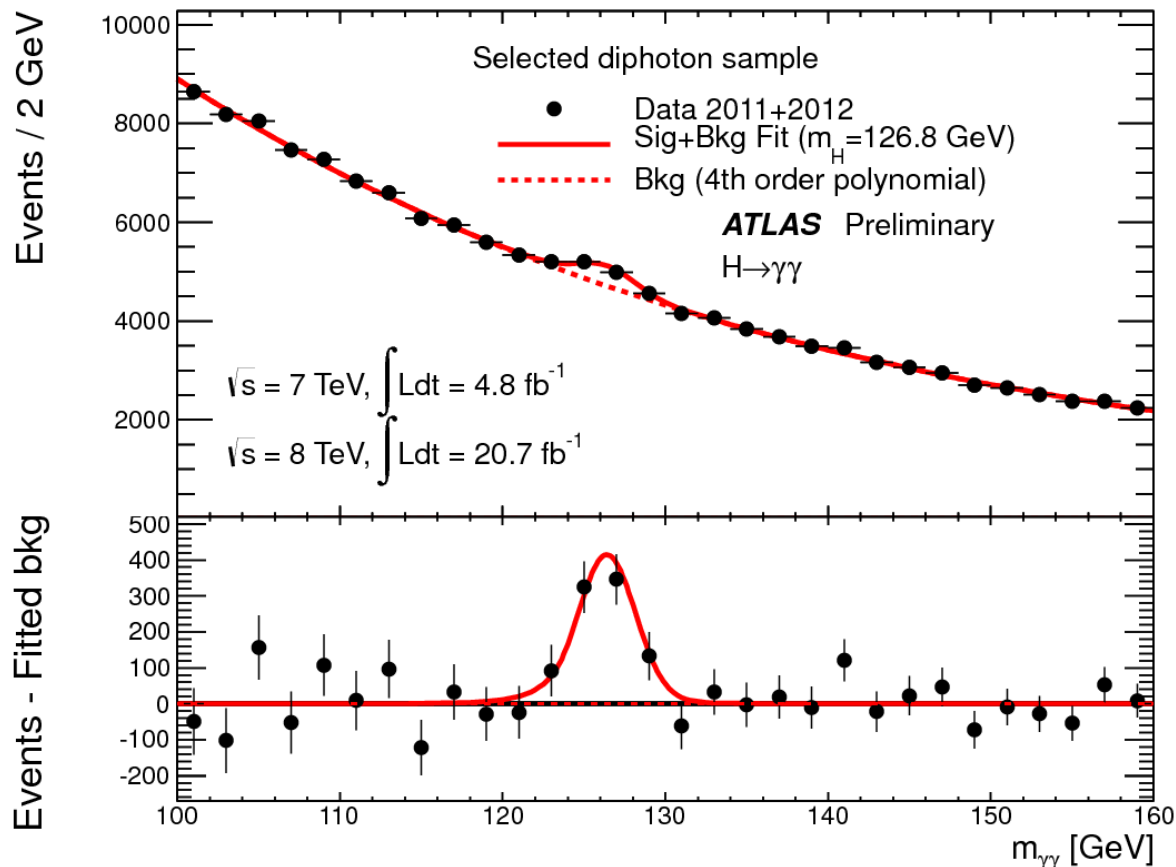
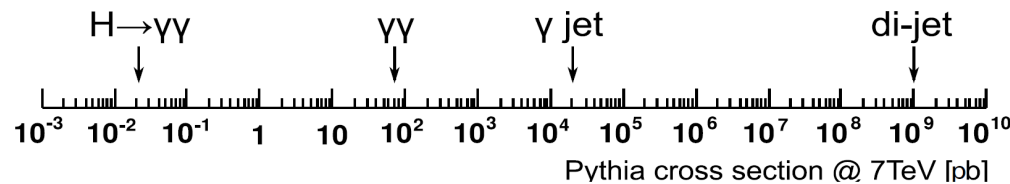


Risultati aggiornati a $\sim 4.8 \text{ fb}^{-1}$ nel 2011 e 20.7 fb^{-1} nel 2012

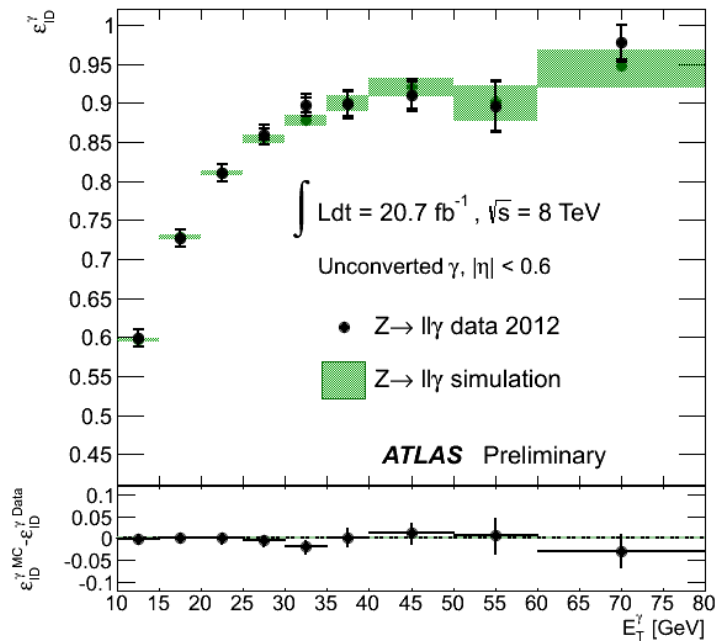
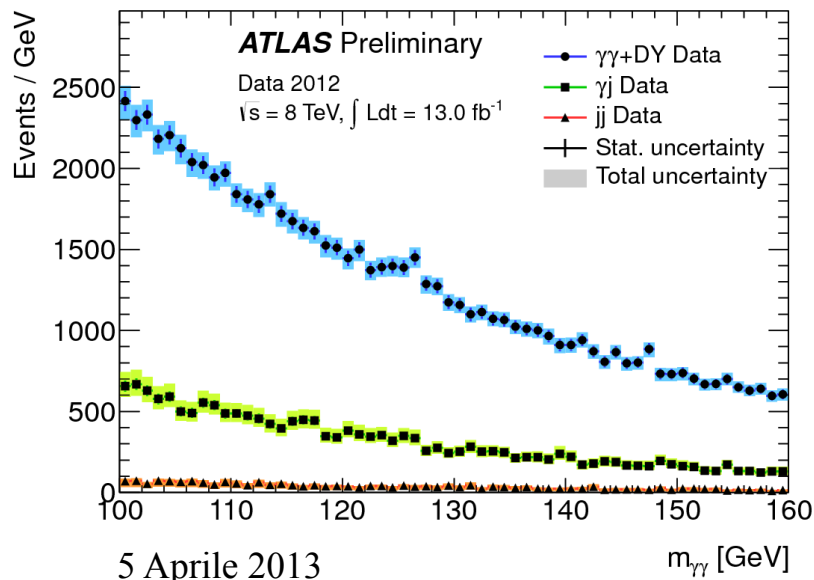
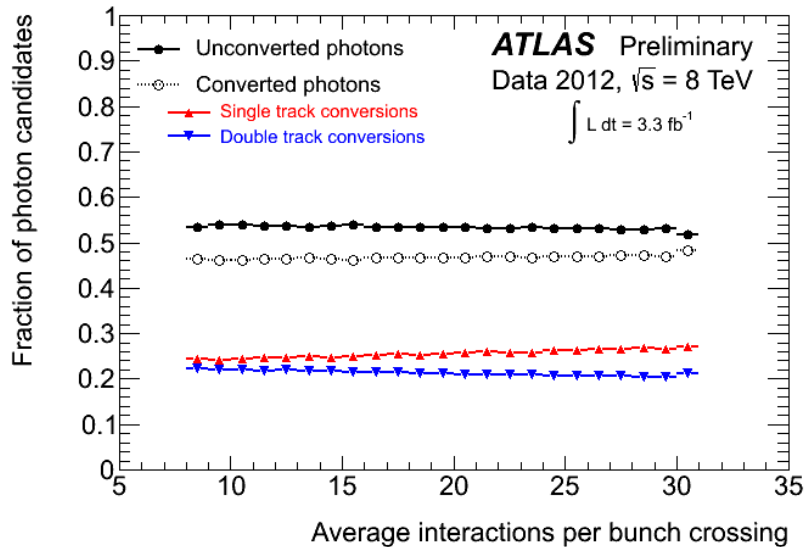
- Nuove categorie per aumentare la sensitivita' verso i diversi processi di produzione
- aggiornamento delle misure di massa e spin

Analisi $H \rightarrow \gamma\gamma$: uno sguardo ai dati

- ❑ Segnatura "semplice" : 2 fotoni energetici ($E_T > 40$ e 30 GeV) isolati
 - ❑ Categorie con jets, MET, leptoni...
- ❑ Basso BR e alto fondo : cruciale il controllo delle performance di photon reconstruction/identification e calibrazione
- ❑ 142681 eventi nel range $100 \text{ GeV} < m_{\gamma\gamma} < 160 \text{ GeV}$
- ❑ $S/N \sim 3\%$ per uno SM Higgs in una mass window con 90% del segnale



Analisi $H \rightarrow \gamma\gamma$: identificazione del segnale e comprensione del background

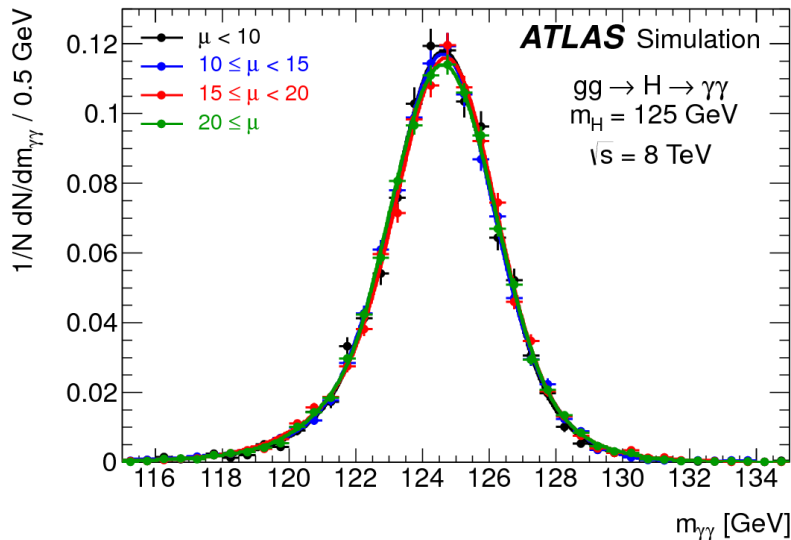
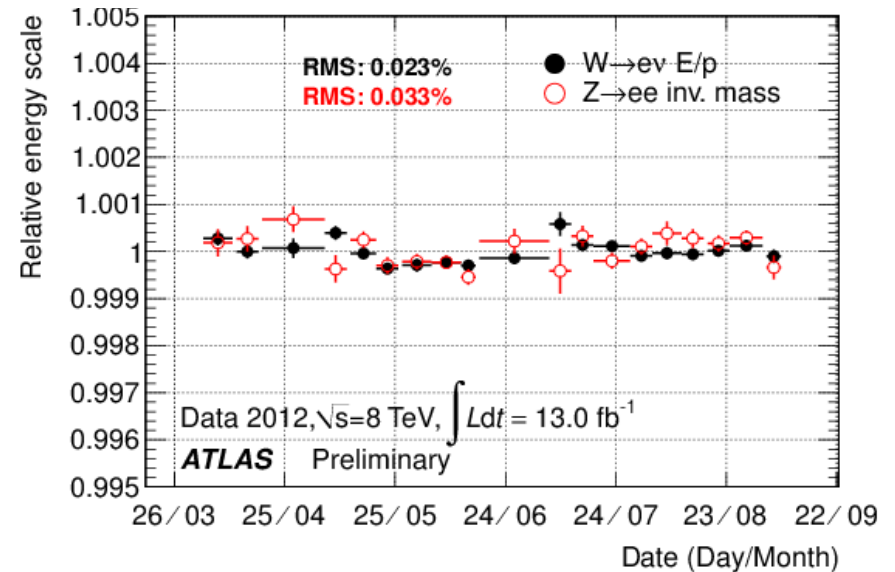
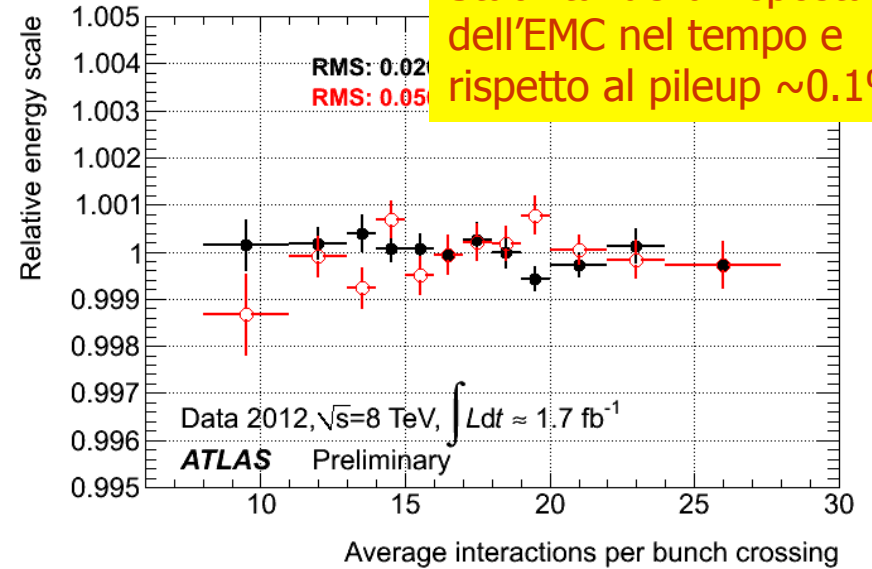


- ❑ Fotoni ricostruiti a partire da un seed nell'EMC : ricostruzione delle conversioni robusta rispetto al pileup
- ❑ Identificazione dei fotoni (NN per 2011 e cut based per 2012) misurata accuratamente in situ : efficienza sul segnale $\sim 40\%$
- ❑ Rigezione di jets : composizione del background studiata in situ, componente riducibile 25% del totale

Analisi $H \rightarrow \gamma\gamma$: calibrazione e risoluzione massa invariante

- ❑ Calibrazione MC based per conv/unconv
- ❑ Risoluzione in massa stabile nel tempo e rispetto al pileup ~ 1.7 GeV (sigma CB)
- ❑ Contributo trascurabile dalla determinazione del PV grazie al calorimeter pointing
 - ❑ BDT con informazioni da tracce e calorimetro
- ❑ Scala in situ da confronto Z in data e MC

Stabilità' della risposta dell'EMC nel tempo e rispetto al pileup $\sim 0.1\%$



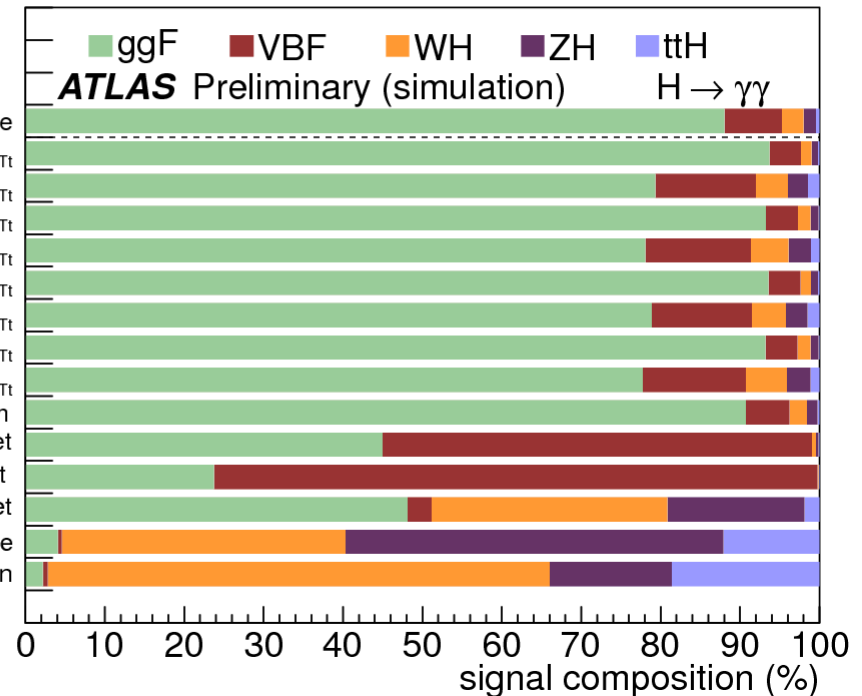
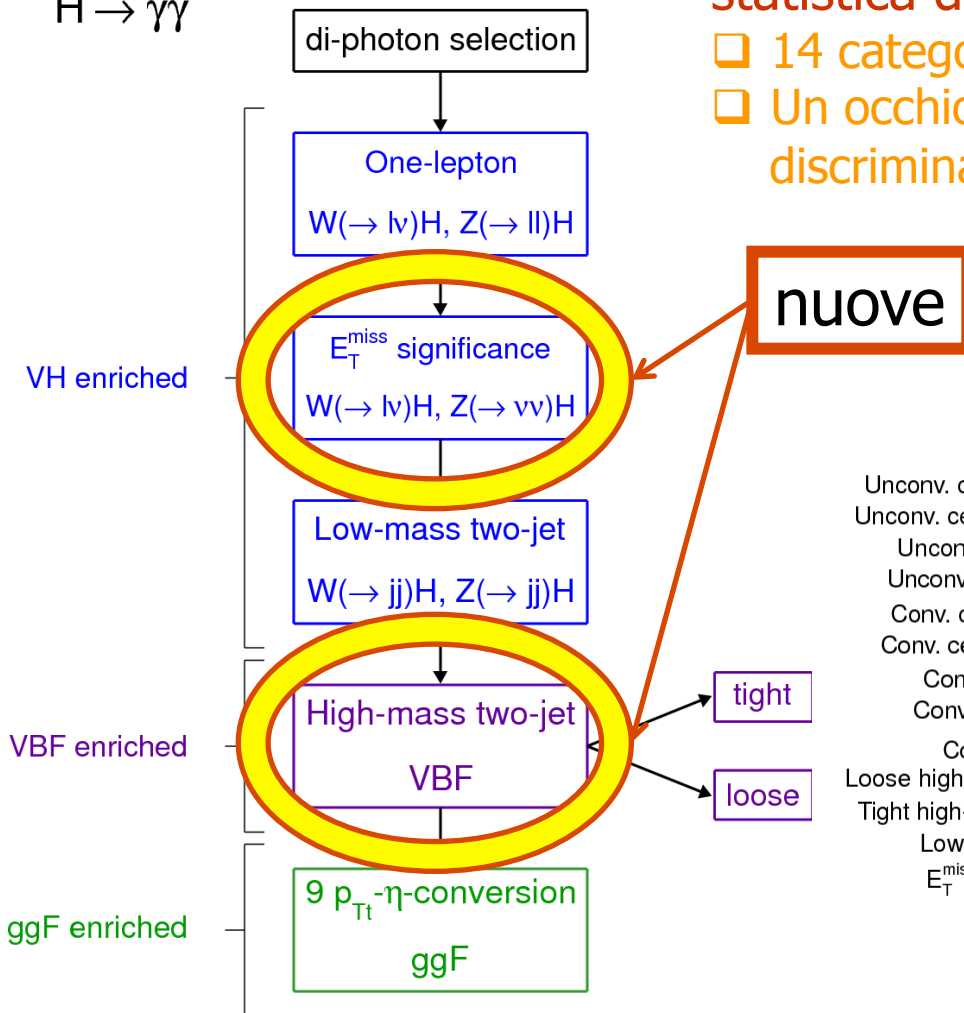
Analisi $H \rightarrow \gamma\gamma$: categorie

ATLAS Preliminary

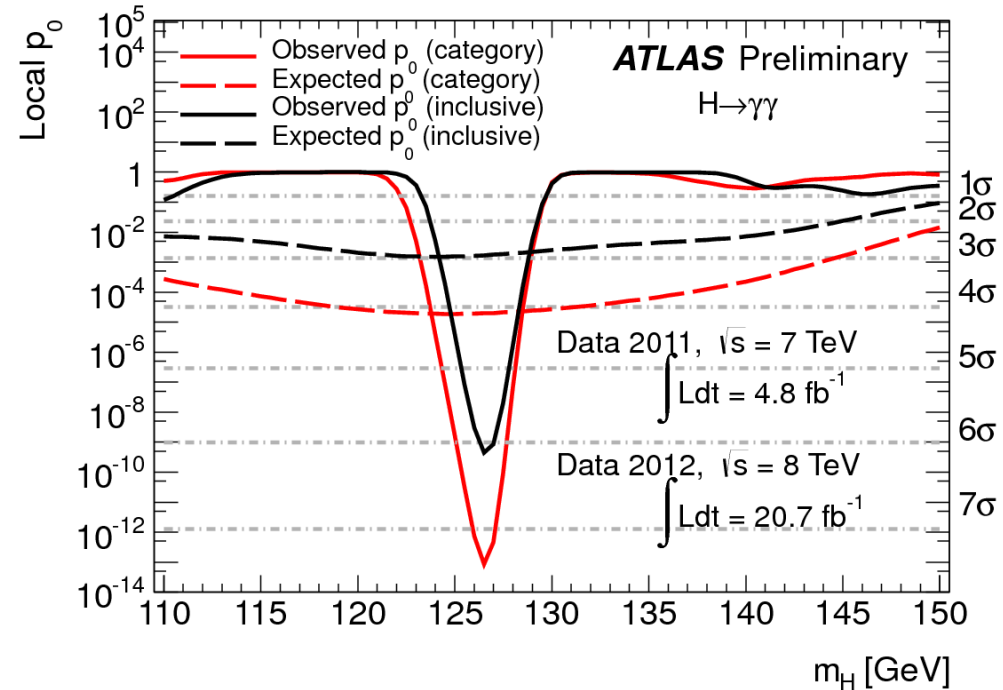
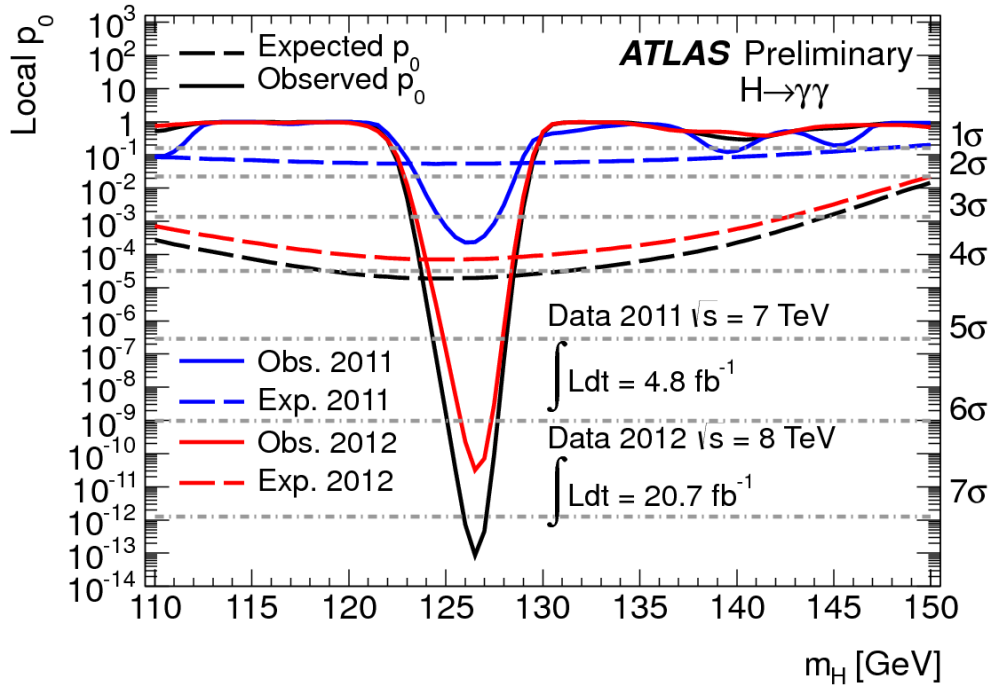
$H \rightarrow \gamma\gamma$

Categorie riottimizzate per l'analisi di tutta la statistica disponibile nel 2012

- 14 categorie con diversi S/N e mass resolutions
- Un occhio particolare ad incrementare la capacita' di discriminare i processi di produzione



Analisi $H \rightarrow \gamma\gamma$: stato dell'eccesso

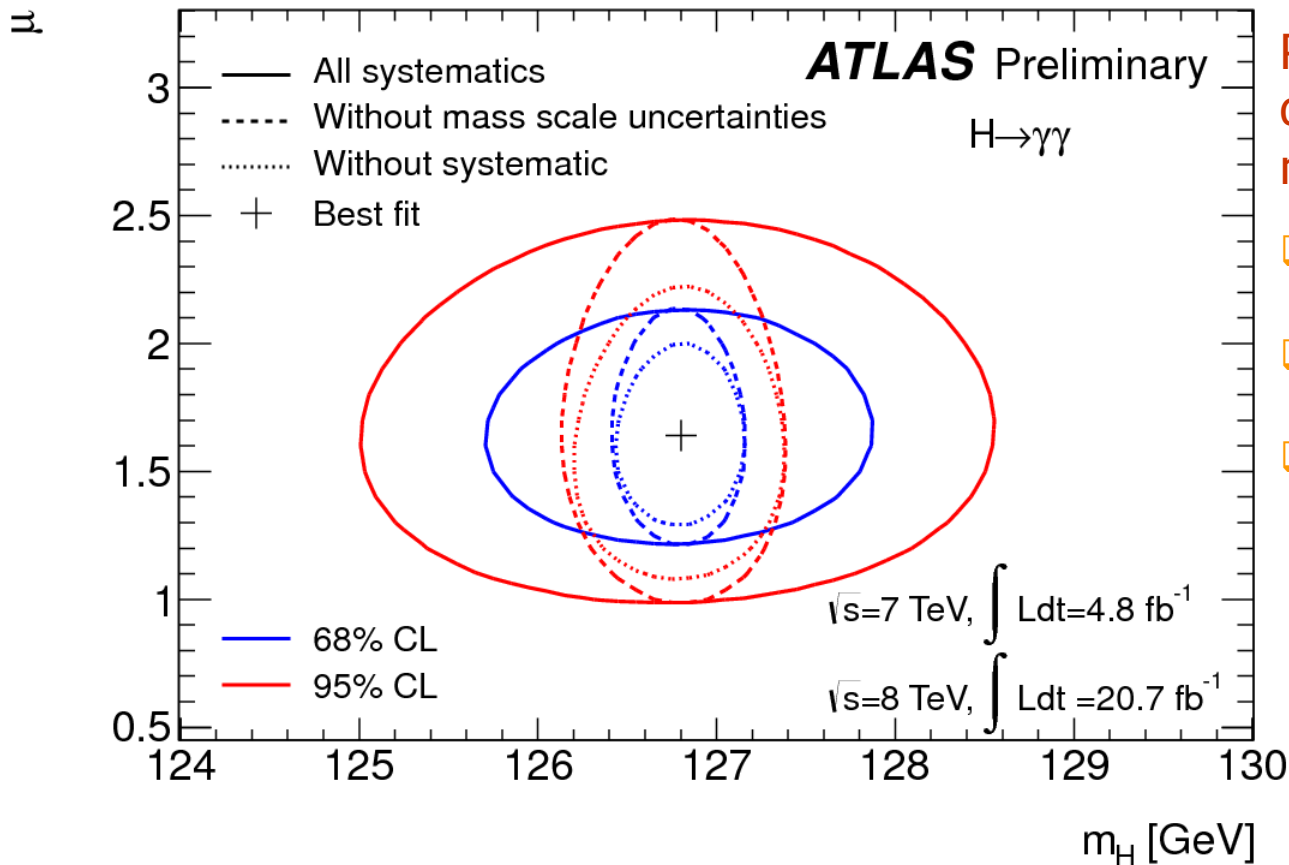


Combinando 2011-2012 il massimo della significanza (locale) a $m_H = 126.5$ GeV

□ 7.4 σ (attesa 4.1 σ) nel caso a 14 categorie

□ 6.1 σ (attesa 2.9 σ) nel caso inclusivo

Analisi $H \rightarrow \gamma\gamma$: massa e signal strength



Photon Energy Scale contributo dominante all'incertezza nella misura della massa :

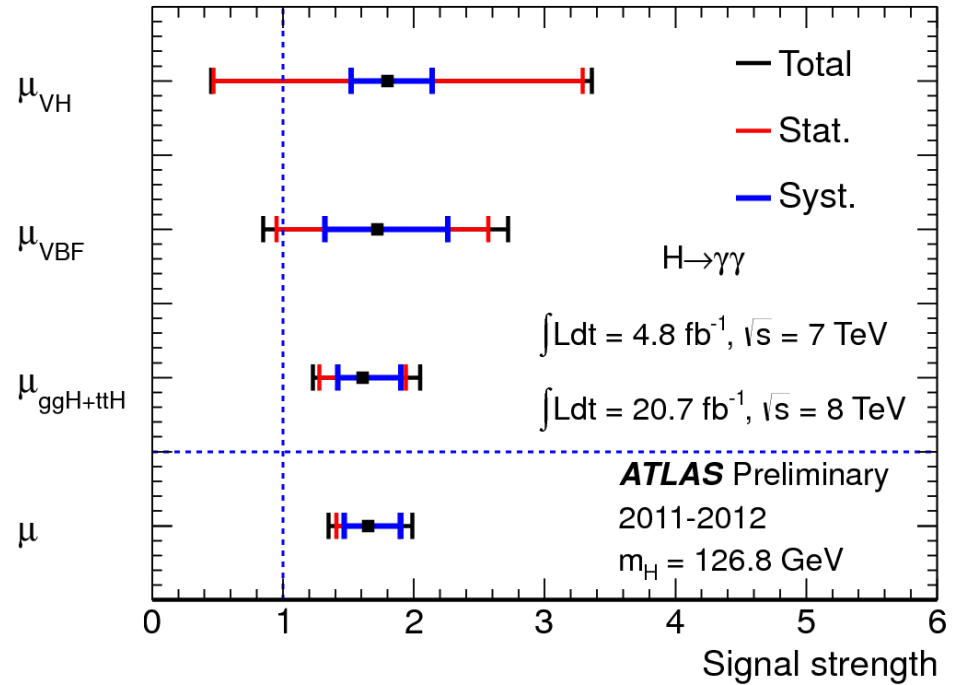
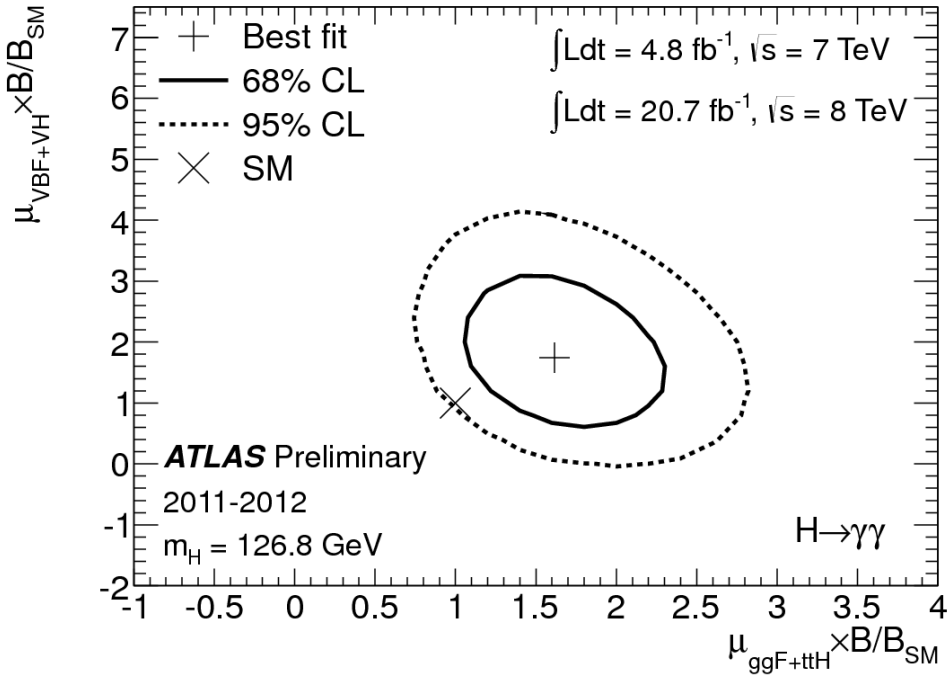
- Incertezza sull'estrazione della scala da eventi di $Z \rightarrow ee$: $\sim 0.3\%$
- Incertezza sul materiale davanti al calorimetro EM : $\sim 0.3\%$
- Incertezza sulla scala del presampler : 0.1%

- $m_H = 126.8 \pm 0.2$ (stat) ± 0.7 (sys) GeV
- $\mu = 1.65 \pm 0.24$ (stat) $_{-0.18}^{+0.25}$ (syst)
- $\sigma_{\text{fiducial}} \times \text{BR} = 56.2 \pm 10.5$ (stat) ± 6.5 (syst) ± 2.0 (lumi)fb

Analisi $H \rightarrow \gamma\gamma$: ancora sulla signal strength

Misura separata degli accoppiamenti con top (ggF+ttH) o gauge bosons (VBF+VH)

Accoppiamenti per processo



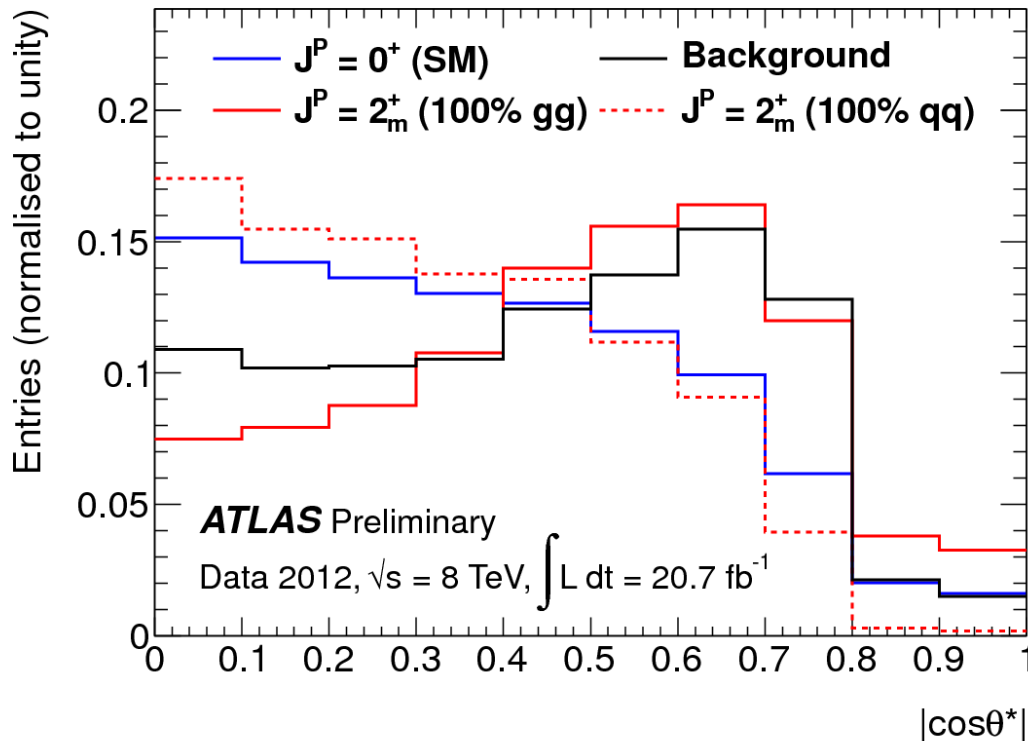
- ☐ Accordo con lo Standard Model a 2σ
- ☐ Migliorati gli errori sulla misura di μ_{VH} e

μ_{VBF}

- ☐ $\mu_{VH} \times B/B_{SM} = 1.8^{+1.5}_{-1.3}(\text{stat})^{+0.3}_{-0.3}(\text{syst})$
- ☐ $\mu_{VBF} \times B/B_{SM} = 1.7^{+0.8}_{-0.8}(\text{stat})^{+0.5}_{-0.5}(\text{syst})$
- ☐ $\mu_{ggF+ttH} \times B/B_{SM} = 1.6^{+0.3}_{-0.3}(\text{stat})^{+0.3}_{-0.2}(\text{syst})$

Analisi $H \rightarrow \gamma\gamma$: misura dello spin

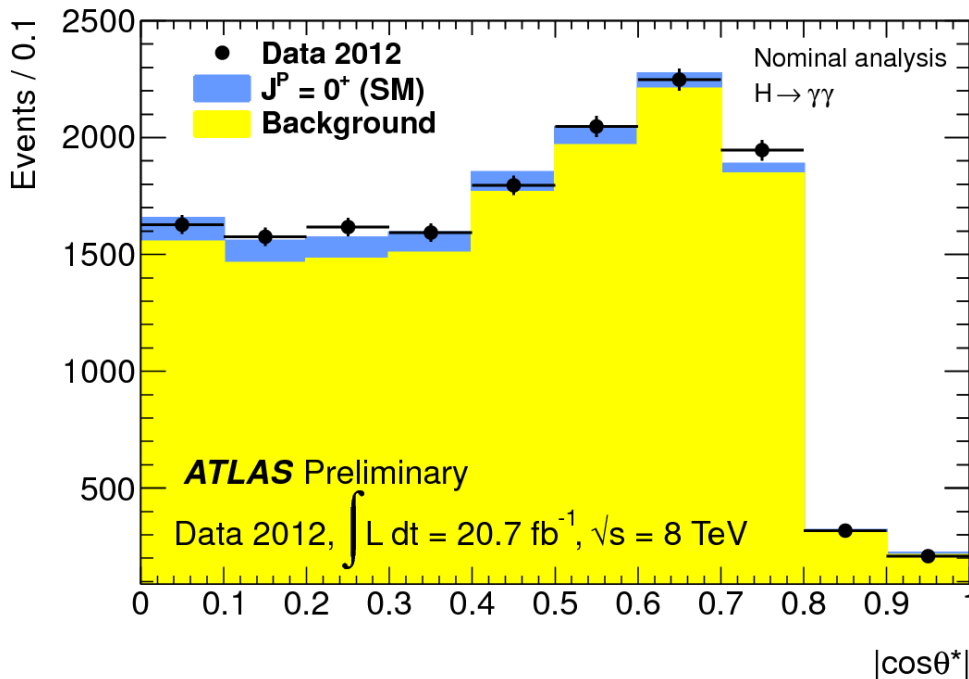
- L'ipotesi di spin 1 fortemente sfavorita dal teorema di Landau-Yang
- Discriminare tra spin-0 e spin-2 sfruttando la diversa distribuzione dell'angolo polare θ^* rispetto all'asse Z nel Collins-Soper frame nelle diverse spin hypothesis:



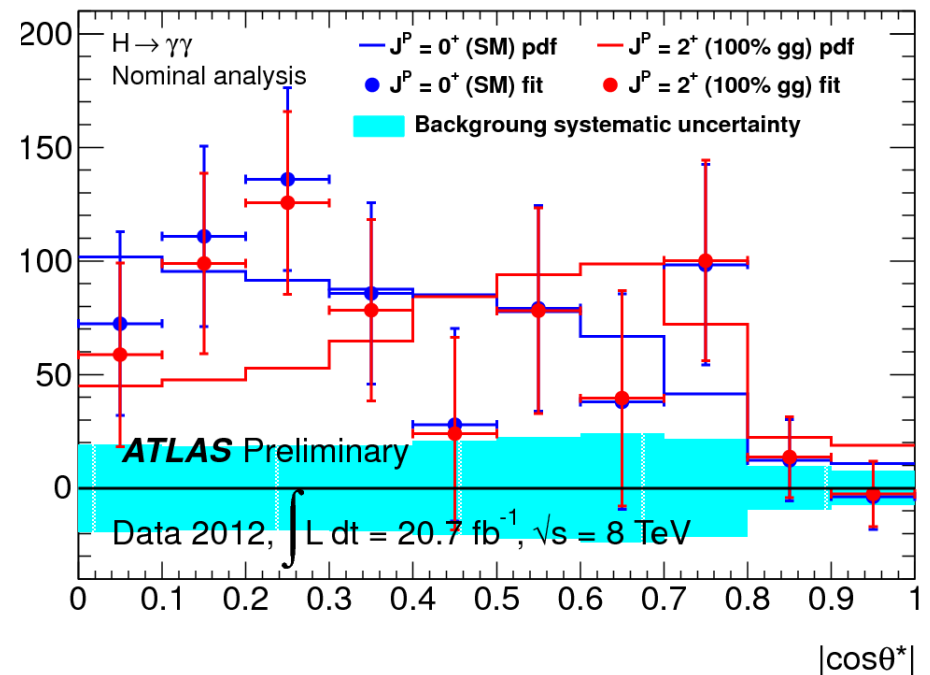
- $dN/d|\cos\theta^*|$ uniforme nella per spin0 prima di acceptance cuts
- In un modello 'graviton like' con minimal couplings $dN/d|\cos\theta^*| = 1 + 6 \cos^2\theta + \cos^4\theta^*$ (nel caso 100% gg production mode) o $1 - \cos^4\theta^*$ (100% qq production mode)
- Testati 5 diversi scenari di composizione (gg – qq)
- Determinazione della distribuzione per il background e' il punto piu' critico

Analisi $H \rightarrow \gamma\gamma$: misura dello spin

- ❑ “Nominal” analysis : 2D fit usando $m_{\gamma\gamma}$ e $\cos\theta^*$ sfruttando l’ipotesi di non-correlazione fra le due variabili
 - ❑ Background $\cos\theta^*$ PDF from $m_{\gamma\gamma}$ sidebands, $m_{\gamma\gamma}$ PDF from background only fits on data
- ❑ “Alternative” analysis : fit su $m_{\gamma\gamma}$ in 10 bins di $\cos\theta^*$
 - ❑ fit background indipendente in ogni $\cos\theta^*$ bin



5 Aprile 2013

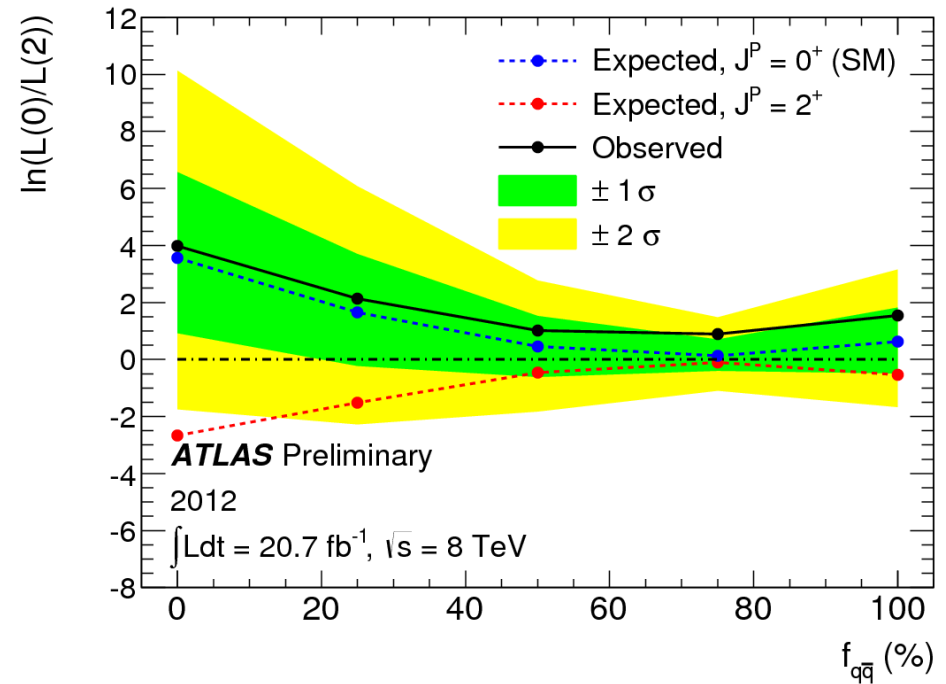
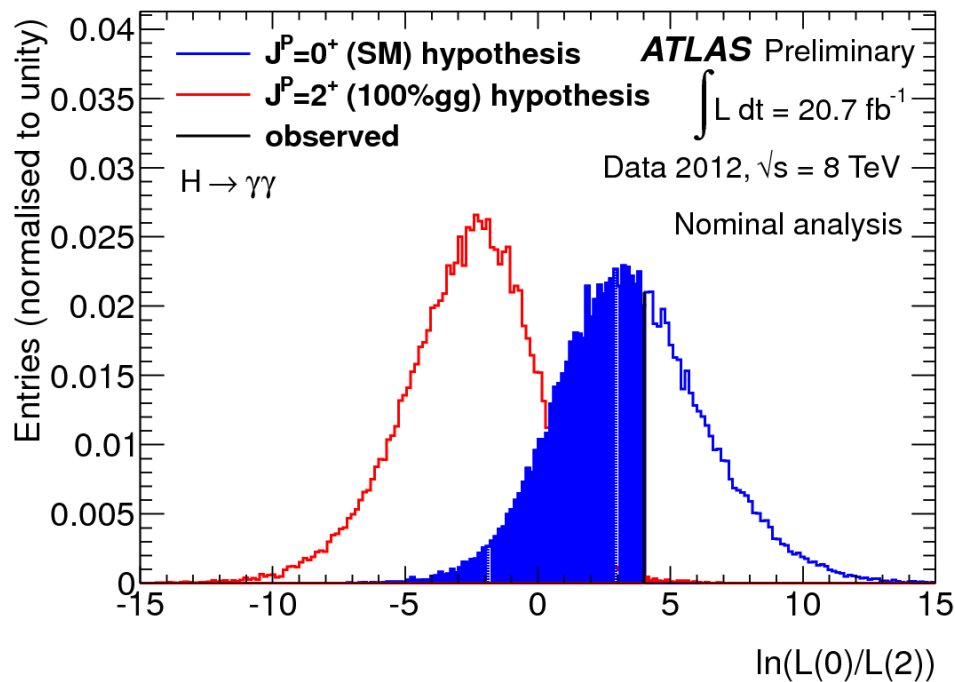


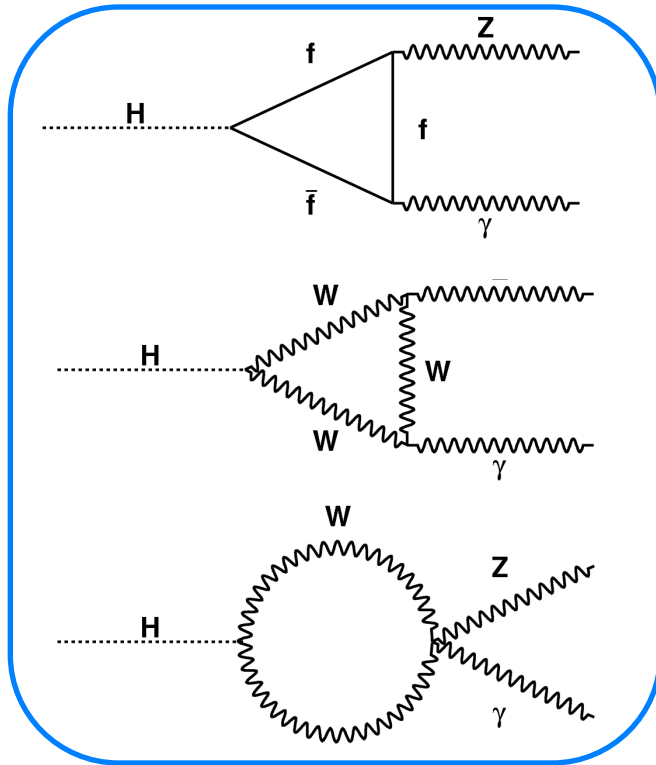
IFAE 2013

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Analisi $H \rightarrow \gamma\gamma$: misura dello spin

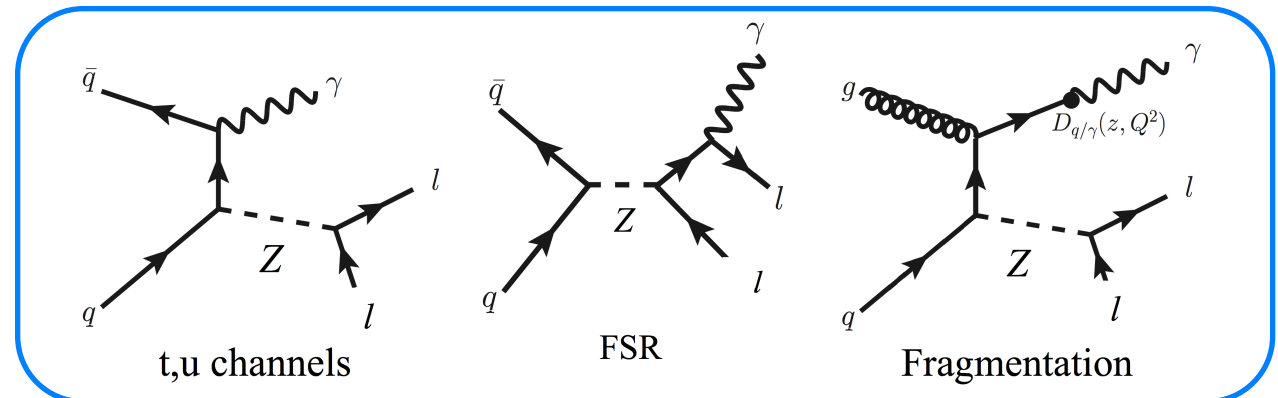
- ❑ Nel caso di 100% gg-production l'ipotesi spin 2 puo' essere esclusa al 99.3% CL (0.3% rejection p-value), buon accordo con spin 0 ipotesi (58.8 % rejection p-value)
- ❑ Nel caso di contributo di qq il potere discriminatorio e' sotto i 2σ



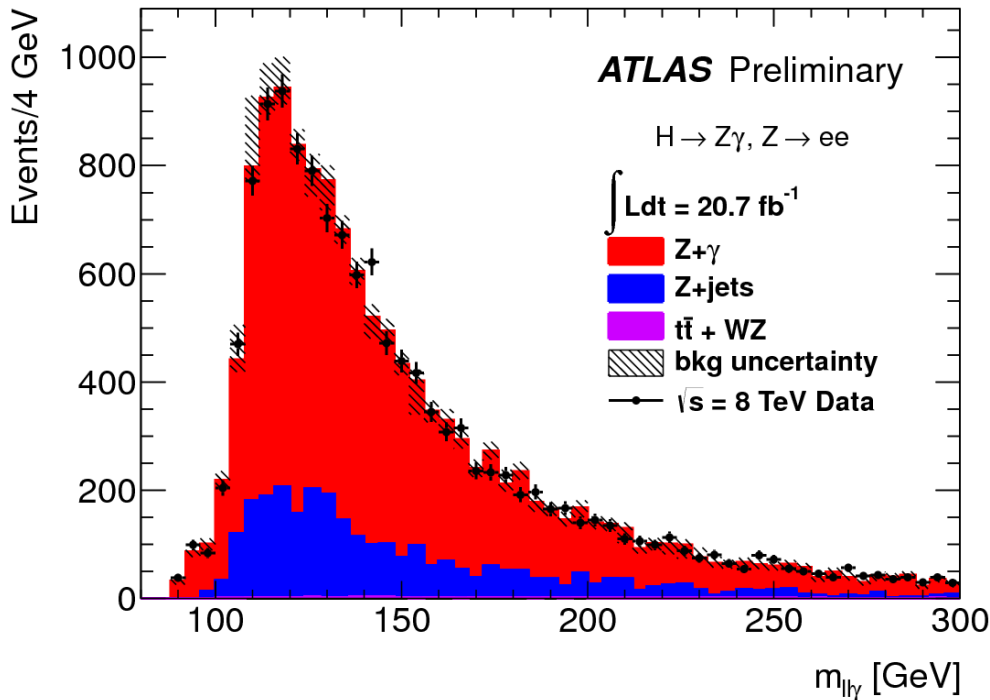
Analisi $H \rightarrow Z\gamma$ 

- ❑ Cercare due SF-OS leptoni isolati (elettroni o muoni) e un fotone isolato
 - ❑ $P_T > 10$ GeV e un fotone isolato $E_T > 15$ GeV
- ❑ Background principali :
 - ❑ Riducibile : Z+jets con jet scambiato per un fotone : tight identification aiuta a ridurre questo background
 - ❑ Irriducibile : Z+ γ (ISR, FSR and fragmentation) : $m_{ll} > m_Z - 10$ GeV e $\Delta R_{l\gamma} > 0.3$ aiutano a sopprimere FSR contribution

Decomposizione data driven : 82% Z+g e 17% di Z+jet (tt and W/Z < 1% from MC)



Analisi $H \rightarrow Z\gamma$: background

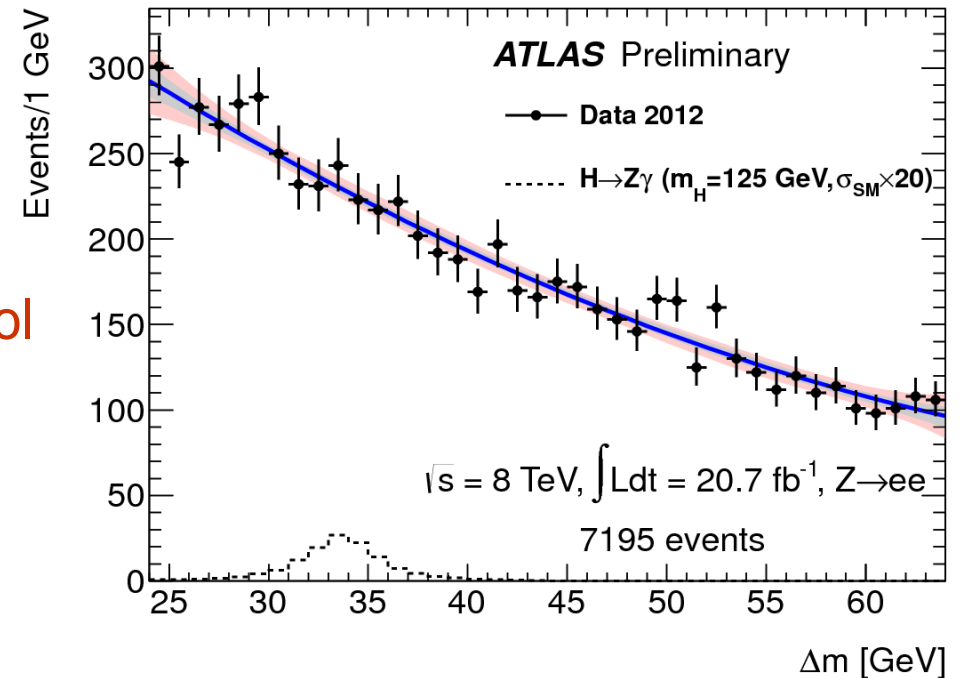


Background fittato sui dati in Δm in control regions (no MC per il fit) :

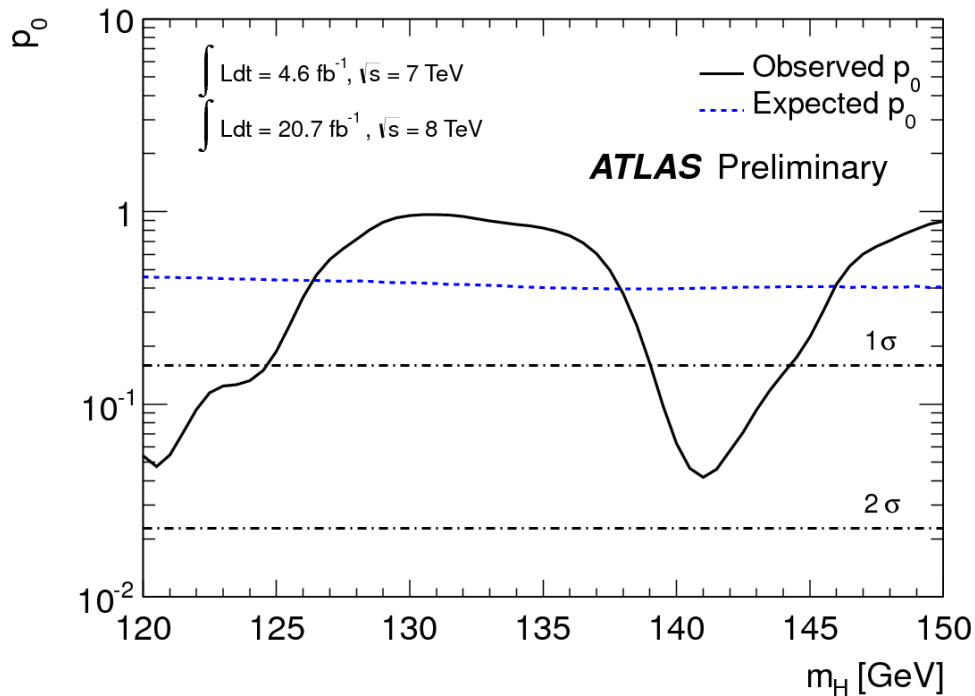
- riduce l'effetto delle incertezze su energy scale
- Insensibile a contaminazioni di $H \rightarrow ll\gamma$

Decomposizione del background data driven usando un 2 dimensional sideband method :

- 82% Z+ γ e 17% di Z+jet ($t\bar{t}$ and W/Z < 1% from MC)
- MC (normalizzato sulle misure data-driven) riproduce bene la shape dei dati

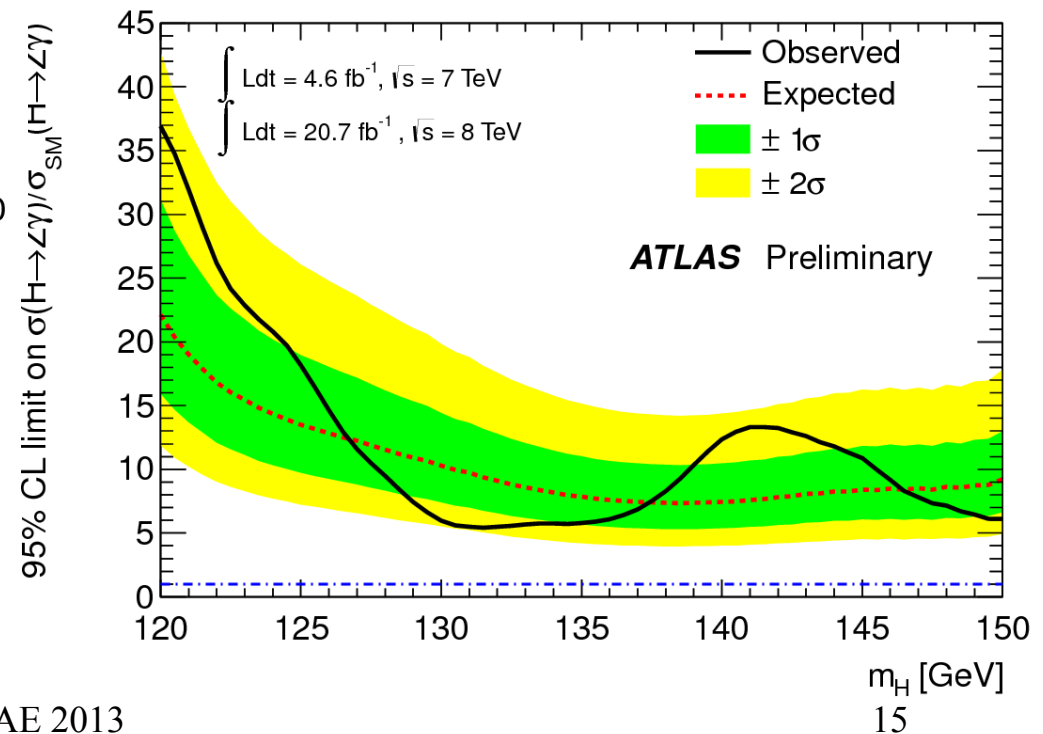


Analisi $H \rightarrow Z\gamma$: risultati



- ❑ Massima significanza osservata : 1.7σ a 141 GeV
- ❑ Significanza a 125 GeV : 0.89σ osservata, 0.14σ attesa

- ❑ Esclusione a 125 GeV : $18.2 \times \text{SM}$ osservata, $13.5 \times \text{SM}$ attesa



Summary

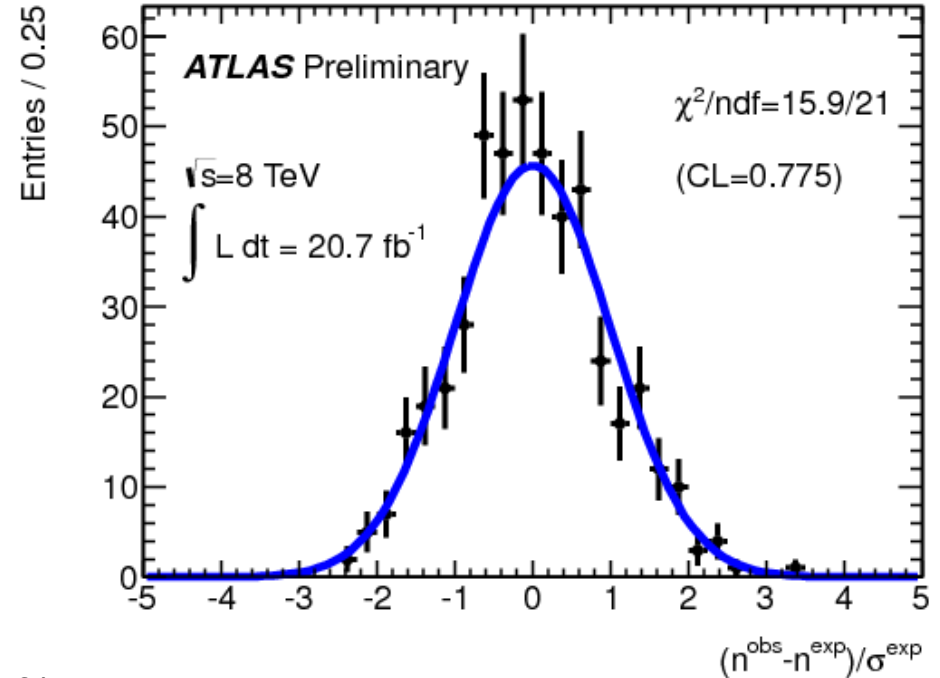
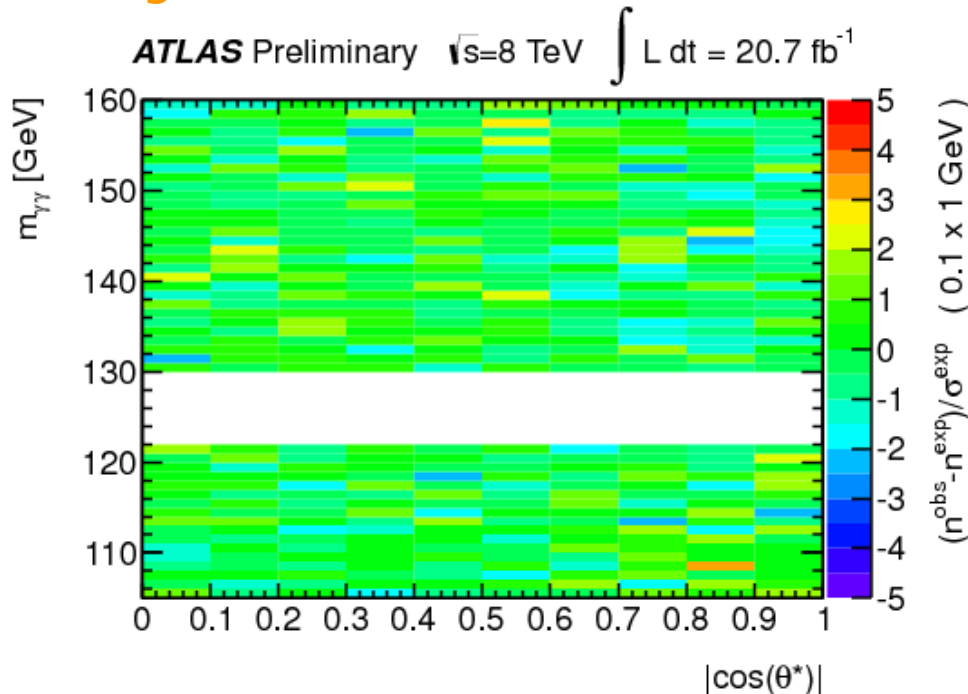
- ❑ Abbiamo presentato i risultati aggiornati a tutta la statistica disponibile le analisi del decadimento in due fotoni e in $Z\gamma$
 - ❑ 4.7 fb^{-1} nel 2011 (7 TeV) e 20.7 fb^{-1} nel 2012 (8 TeV)

- ❑ Higgs in due fotoni : si incomincia la fase delle misure di 'precisione' delle proprieta' della nuova particella scoperta
 - ❑ Signal significance : 7.4σ
 - ❑ $m_H = 126.8 \pm 0.2$ (stat) ± 0.7 (syst) GeV
 - ❑ Precisione sulla massa allo 0.5% dominato da photon energy scale
 - ❑ $\mu = 1.65 \pm 0.34$:
 - ❑ 2.3σ deviation dallo SM
 - ❑ Fiducial cross section : $\sigma \times \text{BR} = 56.2 \pm 12.5 \text{ fb}$
 - ❑ Misura della signal strenght nei vari processi
 - ❑ Misura di spin : favorito lo SM 0^+ rispetto a 2^+

- ❑ Limite su Higgs in $Z\gamma$: $18.2 \times \text{SM}$ a 125 GeV

Backup slides

Categoria VBF



Difference between the number of observed events (n_{obs}) in intervals of $|\cos \theta^*| \times m_{gg} = 0.1 \times 1$ GeV (excluding the signal region $122 < m_{gg} < 130$ GeV) and the number of expected events (n_{exp}) divided by the associated uncertainty (σ_{exp}) as a function of $|\cos \theta^*|$ and the invariant mass m_{gg} , in GeV (left). The distribution of this quantity is shown on the right plot, overlaid with a normalised Gaussian distribution. The number of expected events in each interval is given by the product of the marginal pdfs of m_{gg} and $|\cos \theta^*|$, obtained by projecting the two-dimensional distribution of $m_{gg} \times |\cos \theta^*|$ in either dimension. The compatibility between the histogram and the curve, expressed in terms of the chi2 divided by the number of degrees of freedom (ndf) and the confidence level (CL), indicates that the data is consistent with the absence of correlations between $|\cos \theta^*|$ and m_{gg} .

$$\begin{aligned} \cos \theta_{CS}^* &= \frac{(E_1 + p_{z,1})(E_2 - p_{z,2}) - (E_1 - p_{z,1})(E_2 + p_{z,2})}{m \cdot \sqrt{m^2 + p_T^2}} \\ &= \frac{\sinh(\eta_1 - \eta_2)}{\sqrt{1 + p_T^2/m^2}} \frac{p_{T,1} \cdot p_{T,2}}{m^2} \end{aligned}$$

Incertezze sulla misura di M_H

Main uncertainties

- ❑ Photon energy scale, extrapolated from $Z \rightarrow ee$ events ("method"): 0.3%
- ❑ Modeling of the material in front of the EMC: 0.3%
- ❑ EMC PreSampler energy scale uncertainty: 0.1%
- ❑ Total: 0.45% (0.6 GeV)

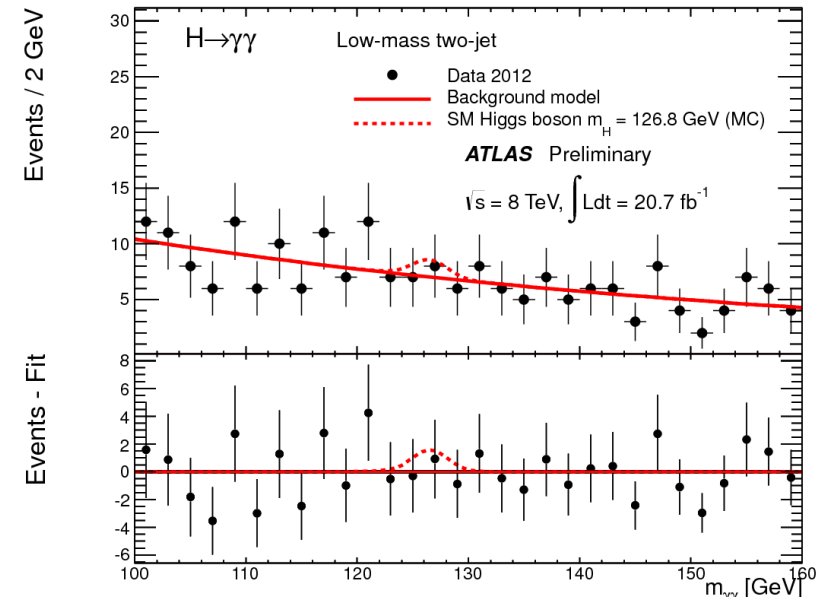
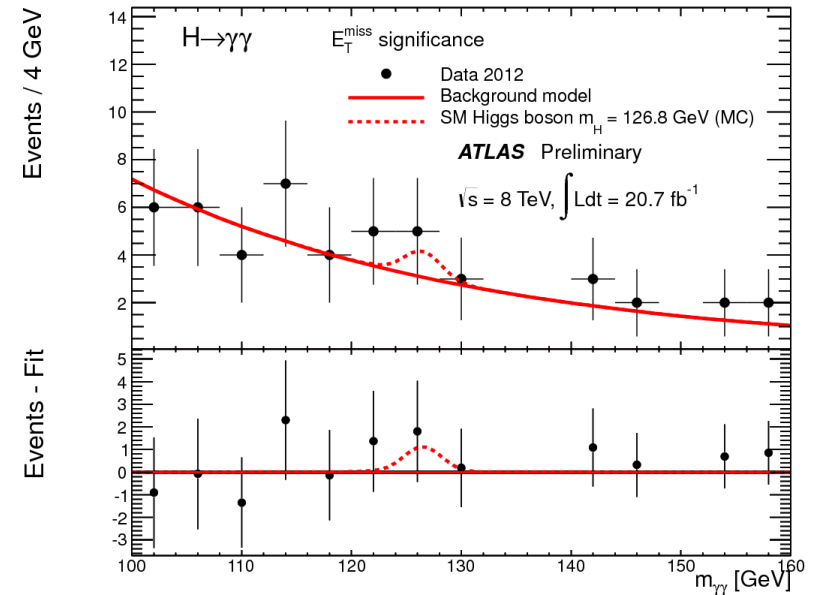
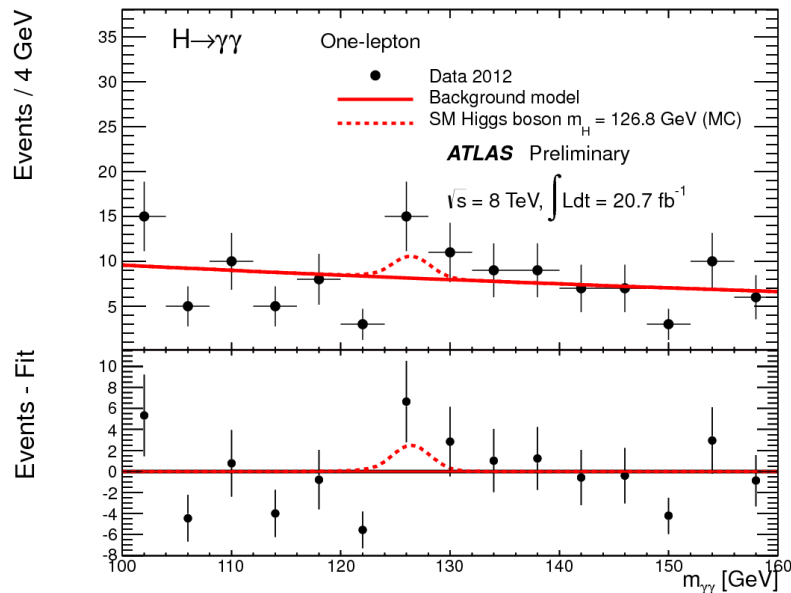
Other uncertainties

- ❑ Conversion fraction
- ❑ Lateral leakage: $e \rightarrow \gamma$
- ❑ Lateral leakage: energy dependence
- ❑ LAr cell gain mis-calibration
- ❑ $E1/E2$ inter-calibration
- ❑ Primary vertex
- ❑ Background model
- ❑ Resolution
- ❑ Total: 0.32% (0.4 GeV)

Total: 0.55% (0.7 GeV)

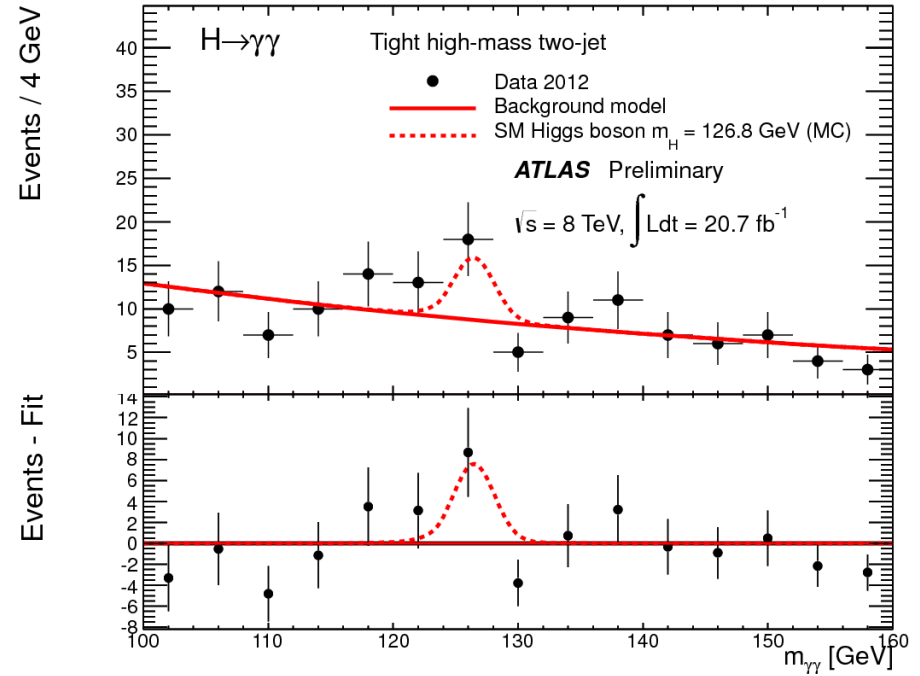
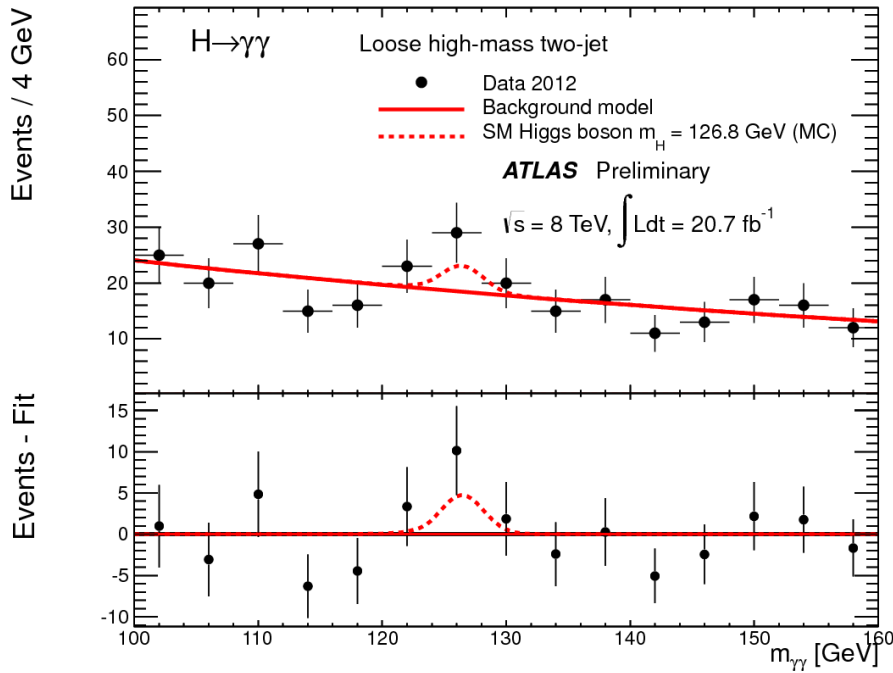
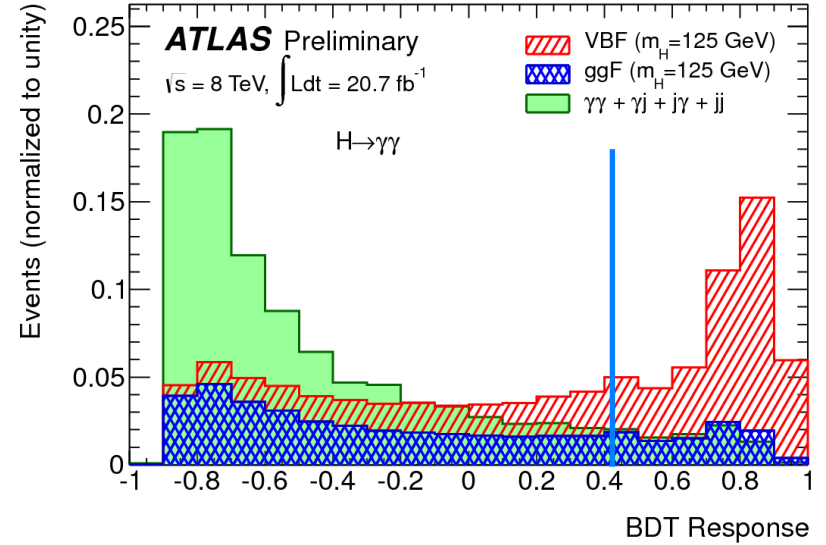
Categorie per VH

- ❑ "One lepton" : almeno un leptone (e o μ) ben ricostruito e isolato
 - ❑ Intercetta $W(l\nu)H$ e $Z(l\nu)H$
- ❑ "MET significance" : $E_T^{\text{miss}}/0.67 \times \Sigma E_T > 5$
 - ❑ Intercetta $W(l\nu)H$ e $Z(\nu\nu)H$
- ❑ "Low mass two jets" : $60 \text{ GeV} < m_{jj} < 110 \text{ GeV}$
 - ❑ Intercetta $W(jj)H$ e $Z(jj)H$

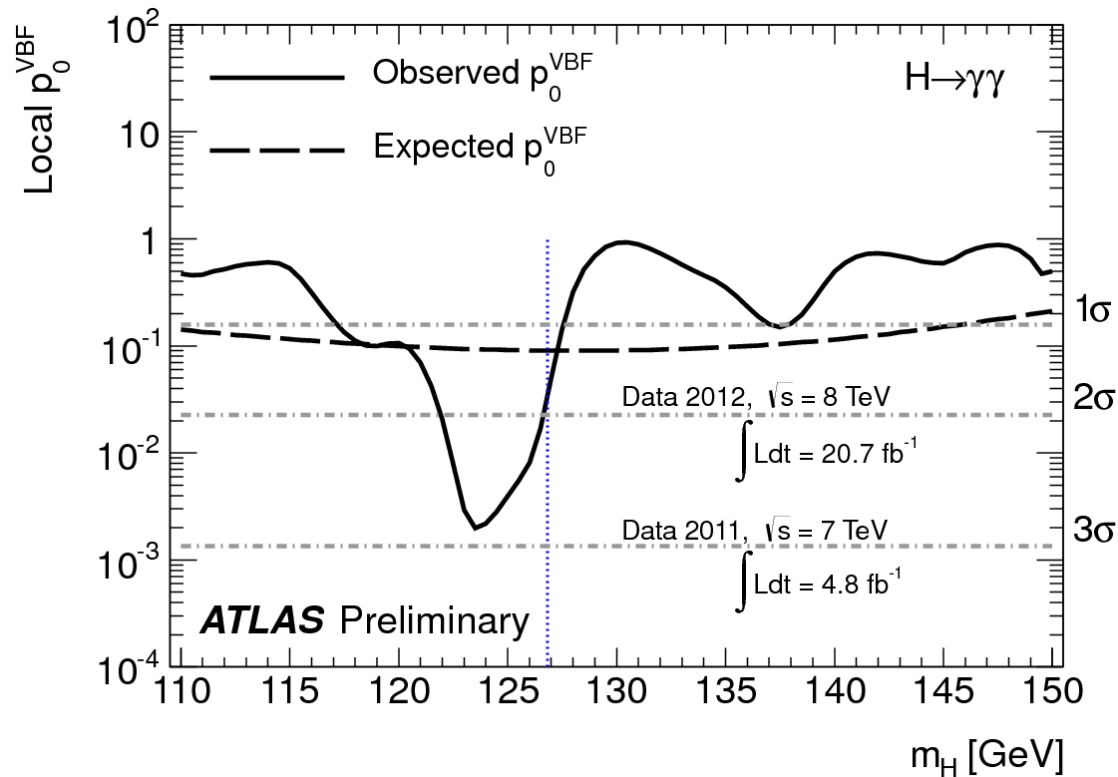


Categoria VBF

- Tipica segnatura con 2 jets separati in η
- BDT su m_{jj} $\Delta\eta_{jj}$ η_{j1} η_{j2} P_{Tt} $\Delta\Phi_{\gamma\gamma;jj}$ η^* $\Delta R_{\min}^{\gamma j}$ per massimizzare la sensitività VBF contro ggH e background
- Buon accordo di BDT output tra MC e data contro samples



Categoria VBF



- Massima significanza osservata a $M_H = 123.5$ GeV pari 2.9σ contro 1.3σ attesa
- Significanza a 126.8 GeV : 2.0σ osservata, 1.3σ attesa

Sistematici

Table 5: Summary of the impact of systematic uncertainties on the signal yields for the analysis of the 8 TeV data.

Systematic uncertainties	Value(%)			Constraint
Luminosity	±3.6			
Trigger	±0.5			
Photon Identification	±2.4			Log-normal
Isolation	±1.0			
Photon Energy Scale	±0.25			
Branching ratio	±5.9% – ±2.1% ($m_H = 110 - 150$ GeV)			Asymmetric Log-normal
Scale	ggF: $\begin{matrix} +7.2 \\ -7.8 \end{matrix}$ ZH: $\begin{matrix} +1.6 \\ -1.5 \end{matrix}$	VBF: $\begin{matrix} +0.2 \\ -0.2 \end{matrix}$ ttH: $\begin{matrix} +3.8 \\ -9.3 \end{matrix}$	WH: $\begin{matrix} +0.2 \\ -0.6 \end{matrix}$	Asymmetric Log-normal
PDF+ α_s	ggF: $\begin{matrix} +7.5 \\ -6.9 \end{matrix}$ ZH: ±3.6	VBF: $\begin{matrix} +2.6 \\ -2.7 \end{matrix}$ ttH: ±7.8	WH: ±3.5	Asymmetric Log-normal
Theory cross section on ggF	Tight high-mass two-jet:	±48		Log-normal
	Loose high-mass two-jet:	±28		
	Low-mass two-jet:	±30		

Table 6: Systematic uncertainties on the signal assignment to categories (migration) for the analysis of the 8 TeV data.

Systematic uncertainties	Category	Value(%)			Constraint
Underlying Event	Tight high-mass two-jet	ggF: ± 8.8	VBF: ± 2.0	VH, ttH: ± 8.8	Log-normal
	Loose high-mass two-jet	ggF: ± 12.8	VBF: ± 3.3	VH, ttH: ± 12.8	
	Low-mass two-jet	ggF: ± 12	VBF: ± 3.9	VH, ttH: ± 12	
Jet Energy Scale	Low p_{T1}	ggF: -0.1	VBF: -1.0	Others: -0.1	Gaussian
	High p_{T1}	ggF: -0.7	VBF: -1.3	Others: $+0.4$	
	Tight high-mass two-jet	ggF: $+11.8$	VBF: $+6.7$	Others: $+20.2$	
	Loose high-mass two-jet	ggF: $+10.7$	VBF: $+4.0$	Others: $+5.7$	
	Low-mass two-jet	ggF: $+4.7$	VBF: $+2.6$	Others: 1.4	
	E_T^{miss} significance one-lepton	ggF: 0.0	VBF: 0.0	Others: 0.0	
Jet Energy Resolution	Low p_{T1}	ggF: 0.0	VBF: 0.2	Others: 0.0	Gaussian
	High p_{T1}	ggF: -0.2	VBF: 0.2	Others: 0.6	
	Tight high-mass two-jet	ggF: 3.8	VBF: -1.3	Others: 7.0	
	Loose high-mass two-jet	ggF: 3.4	VBF: -0.7	Others: 1.2	
	Low-mass two-jet	ggF: 0.5	VBF: 3.4	Others: -1.3	
	E_T^{miss} significance one-lepton	ggF: 0.0	VBF: 0.0	Others: 0.0	
η^* modelling	Tight high-mass two-jet	+7.6			Gaussian
	Loose high-mass two-jet	+6.2			
Dijet angular modelling	Tight high-mass two-jet	+12.1			Gaussian
	Loose high-mass two-jet	+8.5			
Higgs p_T	Low p_{T1}	+1.3			Gaussian
	High p_{T1}	-10.2			
	Tight high-mass two-jet	-10.4			
	Loose high-mass two-jet	-8.5			
	Low-mass two-jet	-12.5			
	E_T^{miss} significance one-lepton	-4.0			
Material Mismodelling		Unconv: -4.0	Conv: $+3.5$		Gaussian
JVF	Loose High-mass two-jet	ggF: -1.2	VBF: -0.3	Others: -1.2	Gaussian
	Low-mass two-jet	ggF: -2.3	VBF: -2.4	Others: -2.3	
E_T^{miss}	E_T^{miss} significance	ggF: $+66.4$	VBF: $+30.7$	VH, ttH: $+1.2$	Gaussian
e reco and identification		one-lepton: < 1			Gaussian
e Escale and resolution		one-lepton: < 1			Gaussian
μ reco, ID resolution		one-lepton: < 1			Gaussian
μ spectrometer resolution		one-lepton: 0			Gaussian