

Osservazione di una risonanza alla massa  
di circa 126 GeV nella ricerca del bosone  
di Higgs del Modello Standard con  
l'esperimento ATLAS

**Cesare Bini**

*Sapienza Università e INFN Roma*

ATLAS-Roma1

10 luglio 2012

# I dati da LHC 11-12:

2011:

$$\sqrt{s} = 7 \text{ TeV}$$

$$L_{\text{max}} = 3.6 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$$

$$L = 5.6 \text{ fb}^{-1}$$

2012:

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

$$L_{\text{max}} = 6.8 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$$

$$L = 6.6 \text{ fb}^{-1}$$

(2012)  $\approx 1.5 \times$  (2011)

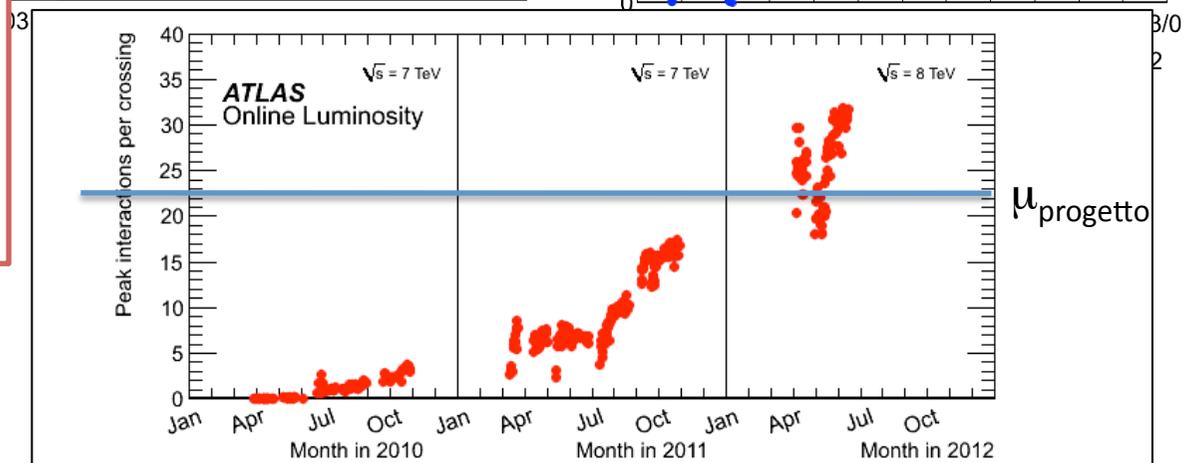
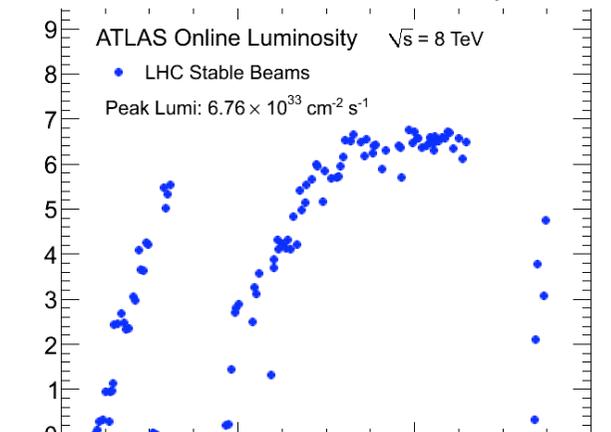
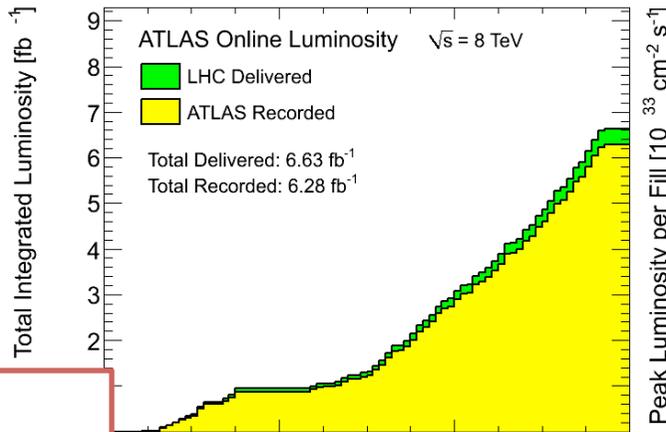
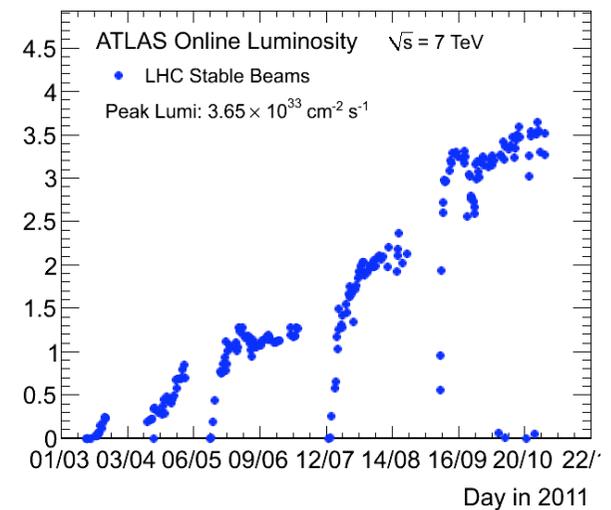
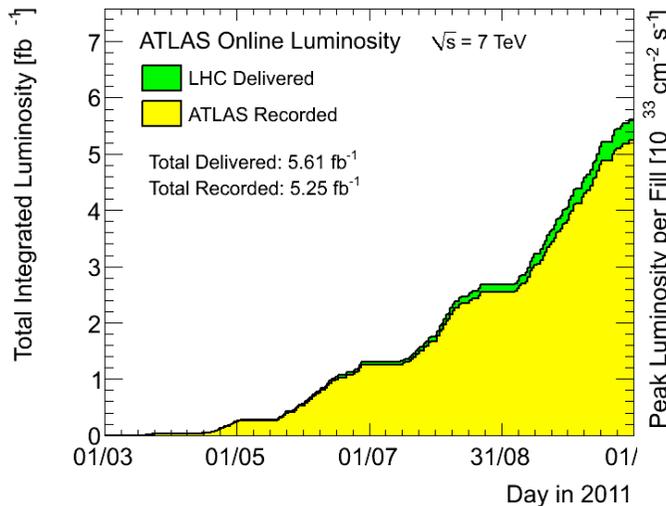
→ Efficienza ATLAS  $\approx 90\%$   
(Detector on AND DQ ok)

$$4.8 + 5.8 = 10.6 \text{ fb}^{-1}$$

→ Fine presa dati 18/06:  
risultati "pronti" 10 giorni dopo.

Questione "pile-up":

Nel 2012  $\langle \mu \rangle > \mu_{\text{progetto}}$

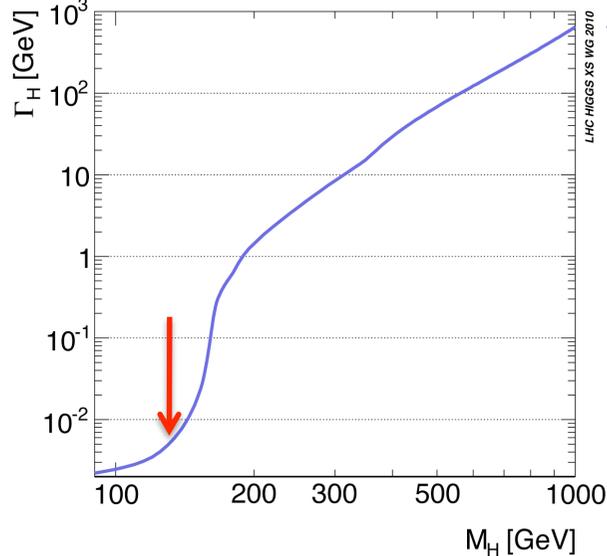
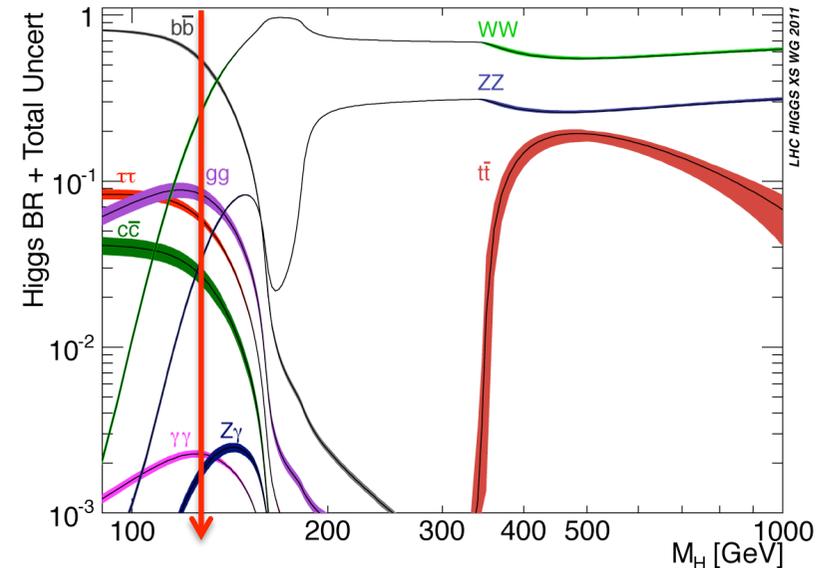
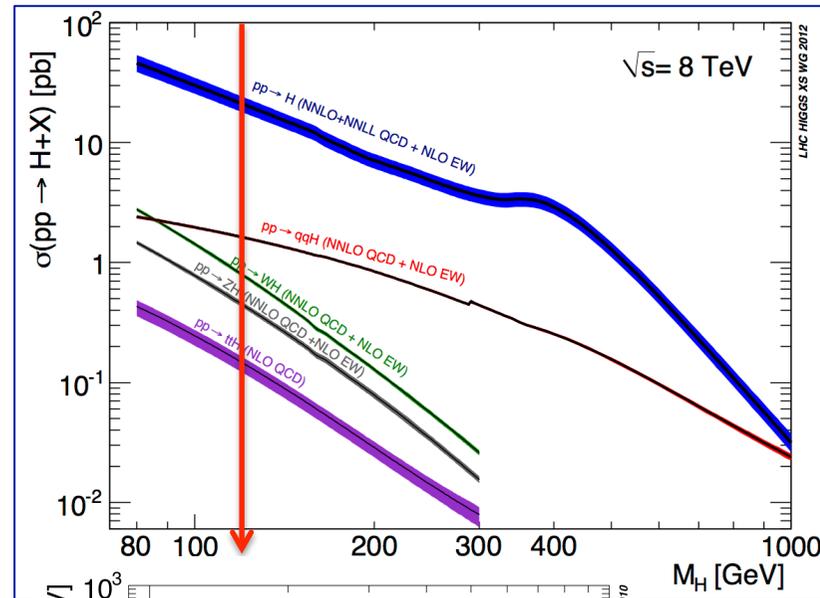


# Come si cerca il bosone di Higgs in collisioni p-p a 7-8 TeV ?

Per ogni valore di  $M_H$  predizioni della teoria al  $\approx 10\text{-}20\%$ . @  $M_H = 125$  GeV:

Produzione in gluon-gluon fusione (VBF < 10% ma interessante);

Molti canali di decadimento attivi; Larghezza intrinseca molto piccola.



Conseguenze:

→ Higgs prodotto “da solo” (non associato);

→ Analisi “multi-canale” inevitabile !

→ golden channels ( $\gamma\gamma$ ,  $ZZ$ ) rari

→ alta accettazione !

→ Importanza della risoluzione in massa.

## ATLAS luglio 2012: strategia per l'osservazione.

Presentiamo ed utilizziamo nella combinazione:

Per  $H \rightarrow \gamma\gamma$  e  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  l'analisi completa del campione 2011 (con *analisi migliorata*) e del campione 2012;

Per gli altri canali (in particolare  $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ ,  $H \rightarrow \tau^+\tau^-$ ,  $W/Z H \rightarrow bb$ ) i risultati basati sul campione 2011 (già pubblicati);

Analisi tradizionali, adatte per la "scoperta".

Perché ?

$H \rightarrow \gamma\gamma$  e  $H \rightarrow ZZ^{(*)} \rightarrow 4l$  sono i "golden channels", analisi semplice, fondo stimato dai dati e dipendenza dal pile-up ben capita;

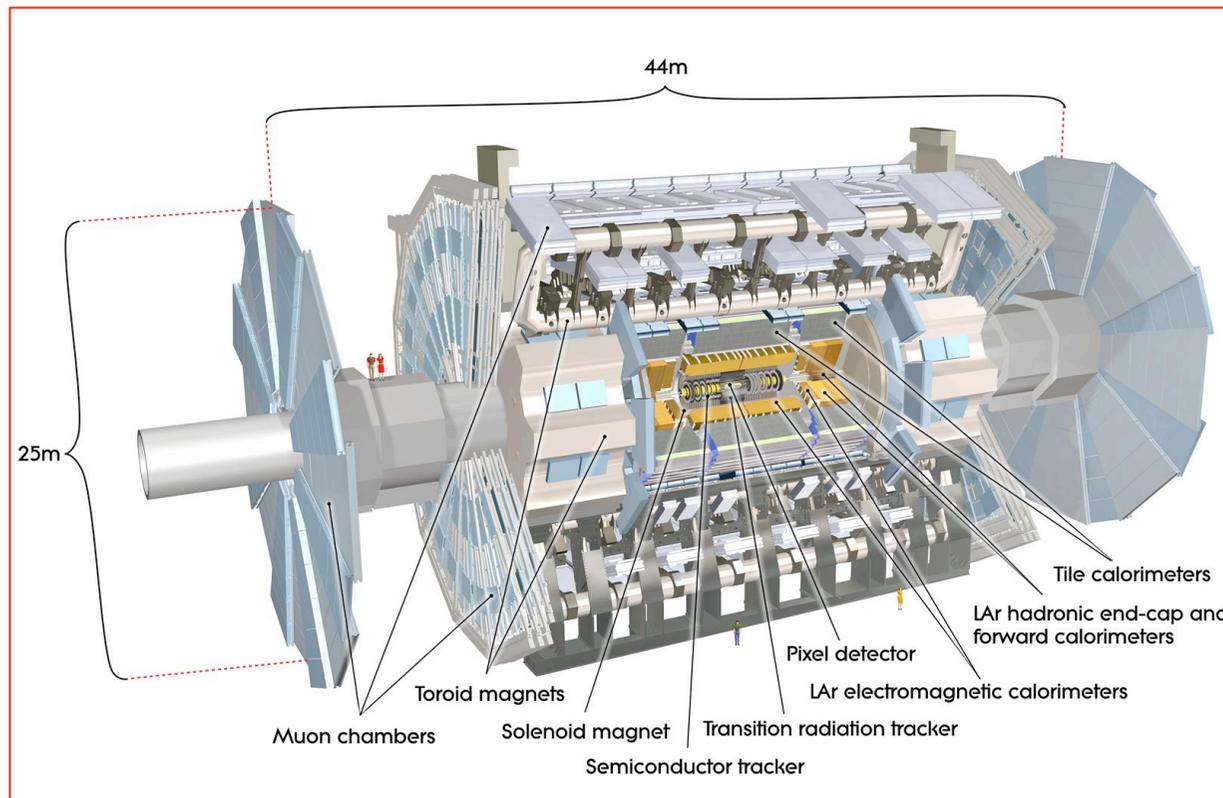
Gli altri canali dipendono da oggetti più sensibili alla problematica del pile-up e dell'alta luminosità (e.g.  $E_t^{\text{miss}}$ , *Jet reconstruction*, ...).

Next...

Nell'articolo di fine luglio, per il canale  $H \rightarrow WW \rightarrow l\nu l\nu$  sarà aggiunta anche l'analisi 2012;

A seguire, update di  $H \rightarrow \tau^+\tau^-$ ,  $W/Z H \rightarrow bb$ .

# Il rivelatore ATLAS

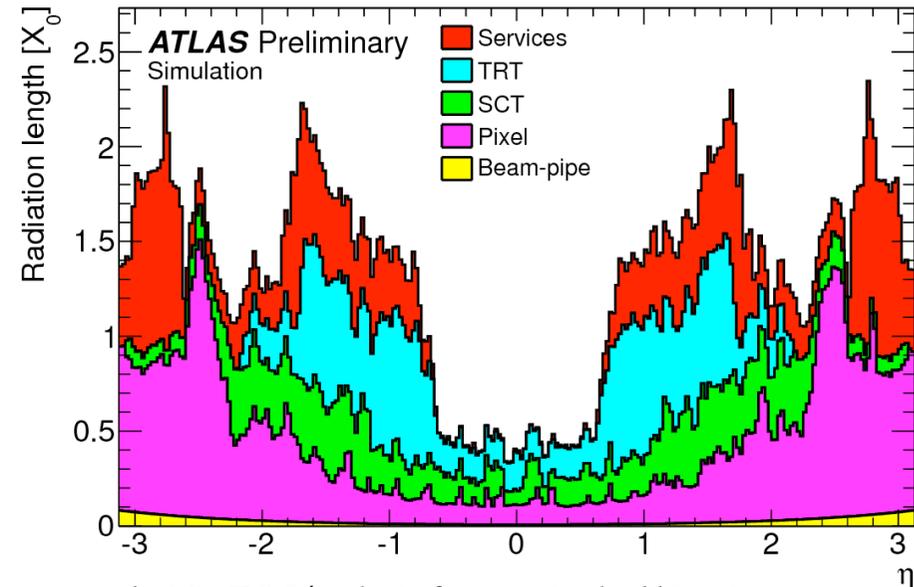
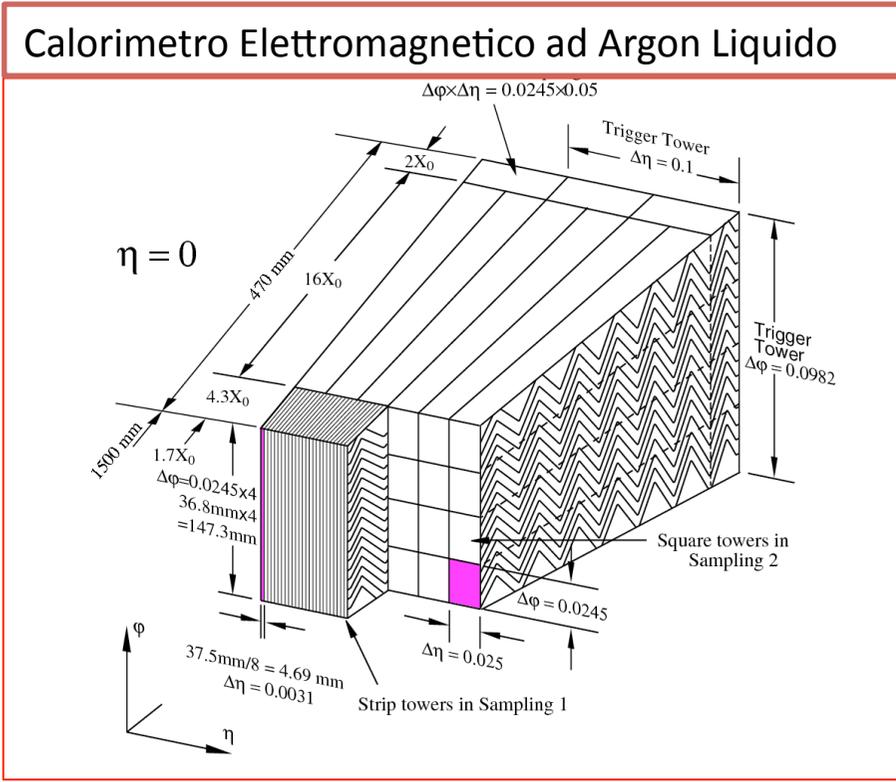


Item	pT threshold (GeV)	Rate (Hz) @ $5 \times 10^{33}$
incl. e	24	70
incl. $\mu$	24	45
ee	12	8
$\mu\mu$	13	5
$\tau\tau$	29,20	12
$\gamma\gamma$	35,20	10
$E_T^{\text{miss}}$	80	17
5j	55	8

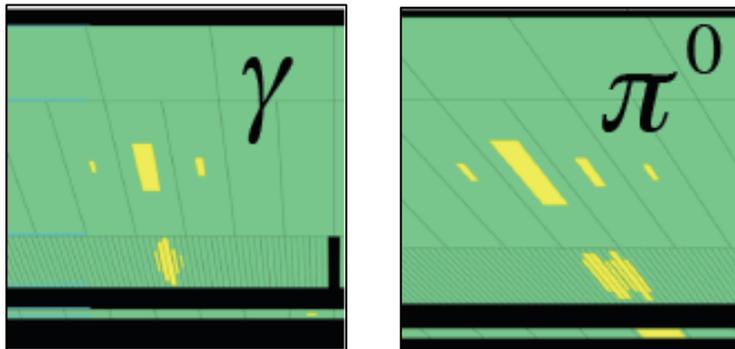
Tutte le parti del rivelatore entrano nei risultati che presentiamo.

Trigger molto “robusto” e versatile: rate  $O(100 \text{ Hz})$  senza perdita rilevante sulla fisica di alto  $p_T$ .

**H  $\rightarrow \gamma\gamma$**  Selezione di coppie di  $\gamma$  “isolati” in accettazione e di alta  $E_T$ :  
 $E_T > 40, 30 \text{ GeV}$ ,  $|\eta| < 1.37$  or  $1.52 < |\eta| < 2.37$ ;  
 Misura della massa invariante  $M_{\gamma\gamma}$ . ( $\sigma = 40 \div 50 \text{ fb} \rightarrow$  attesi  $O(10^2)$  evts)  
 Fondi:  $\gamma\gamma$  dal continuo (75-80%),  $1\gamma + 1 \text{ fake jet}$  (20%),  $2 \text{ fake-jets}$  (2%)  $\rightarrow O(10^4)$  evts



Il 40-50% dei fotoni dall'Higgs “convertono”, ricostruiti con l'ID



Efficienza per coppie di  $\gamma$  da Higgs:

Trigger 2g  $\epsilon = 98.9 \div 99.6\%$   
 Selezione  $\epsilon = 38 \div 43 \%$

# eventi nei dati ( $100 < M_{\gamma\gamma} < 160 \text{ GeV}$ ):

23788 (campione 2011)

35271 (campione 2012)

## Misura della massa invariante $M_{\gamma\gamma}$

$$M_{\gamma\gamma} = 2E_1E_2(1 - \cos\alpha)$$

### Misura di energia:

Risoluzione  $\approx 10\% / \sqrt{E} + 1\%$

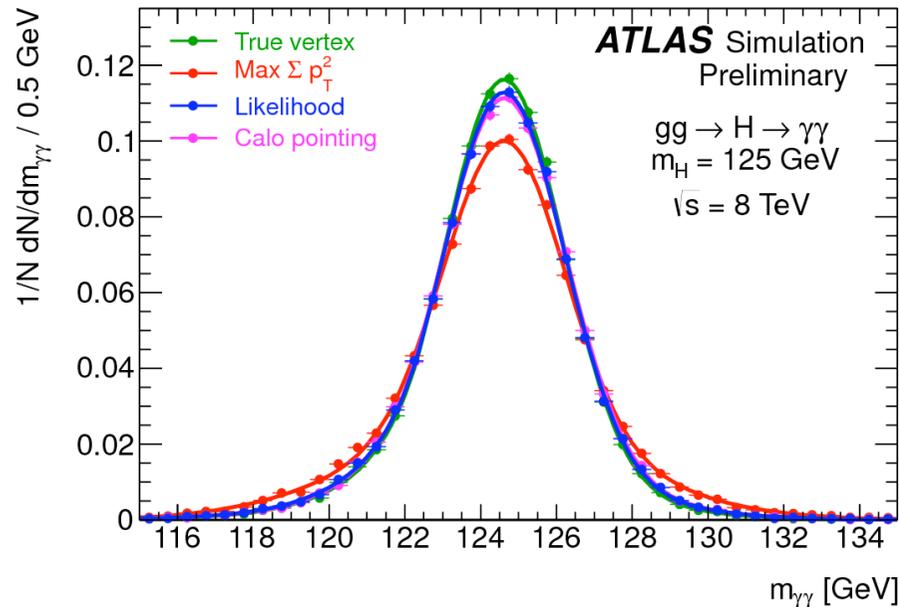
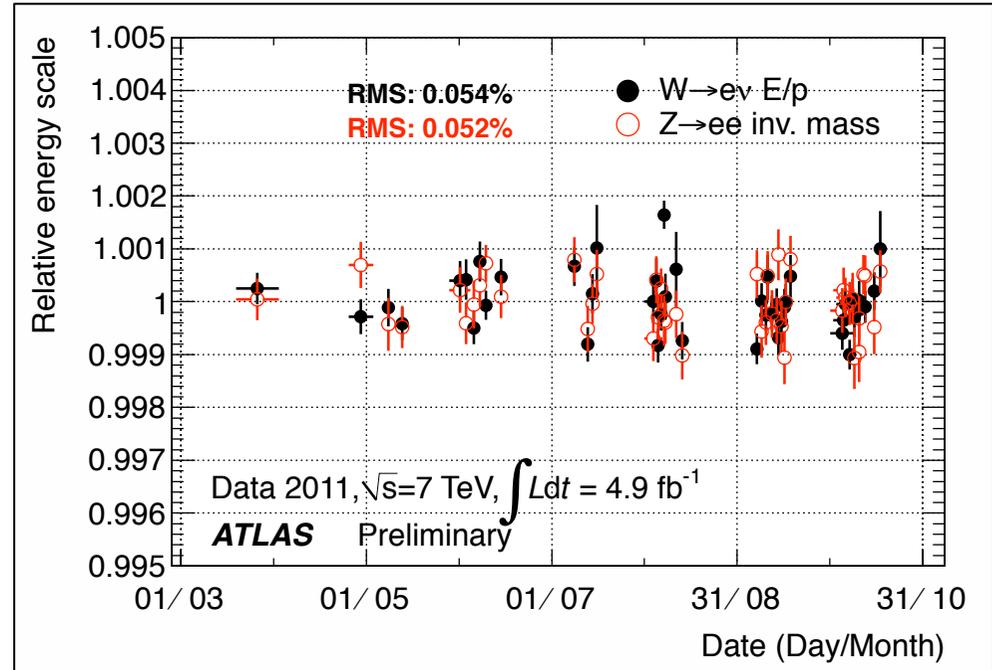
Stabilità della risposta  $< 0.1\%$ ;

Calibrazione assoluta  $< 0.3\%$ .

### Misura dell'apertura angolare $\alpha$

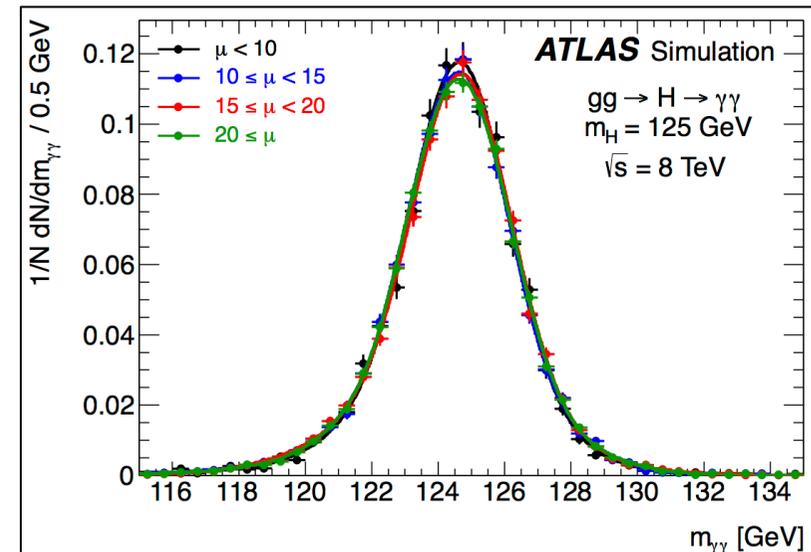
“Traiettorie” dei fotoni estrapolate alla linea dei fasci ( $\sigma(Z) \approx 1.5$  cm)

+  $\Sigma p_T^2$  delle tracce

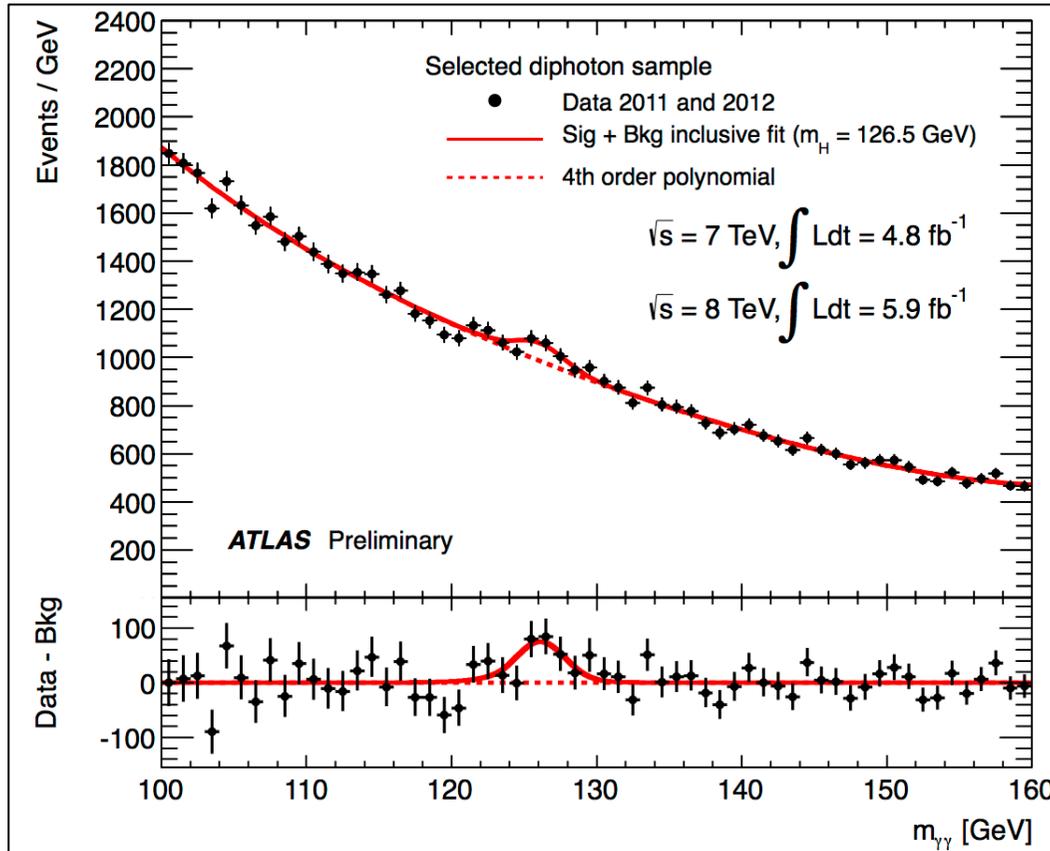


### Risoluzione in $M_{\gamma\gamma}$ : $1.4 \div 2.6$ GeV

Indipendente da  $\mu = N(\text{vertici})$



# Spettro in massa invariante "raw" complessivo 2011 + 2012



Fit:

- fondo polinomiale
- segnale Gaussiana + CB

Suddivido il campione in **10 categorie**:

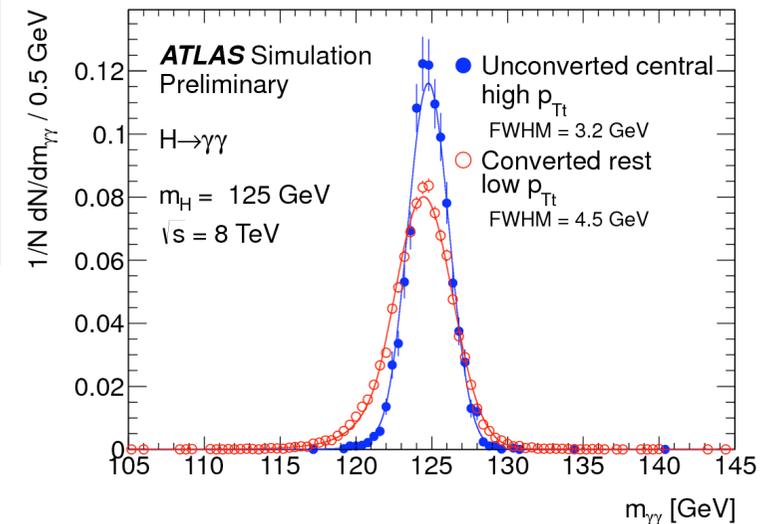
Convertito / non Convertito

Centrale / periferico

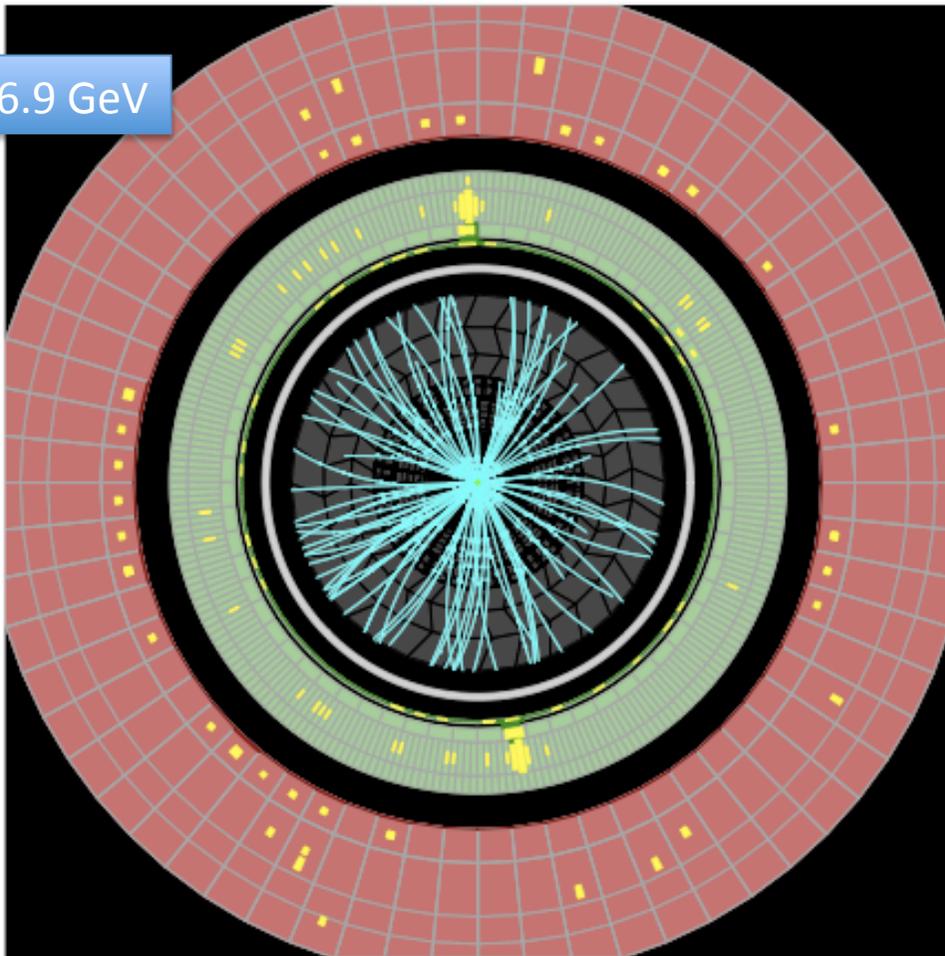
Alto  $P_{Tt}$  / Basso  $P_{Tt}$

VBF (presenza di 2 jet) (Introdotta in questa analisi)

→ 20 fit indipendenti (10x2) con diverse sensibilità → analisi statistica



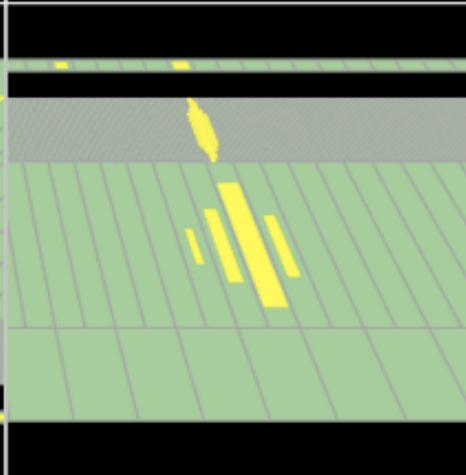
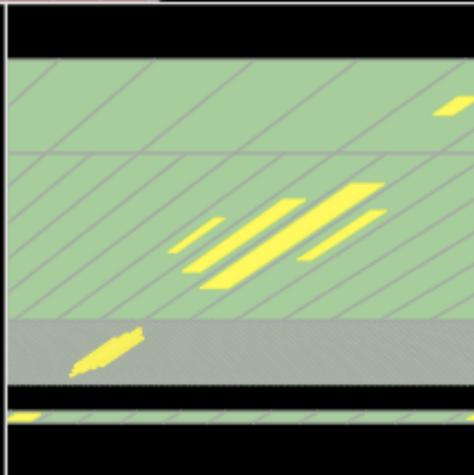
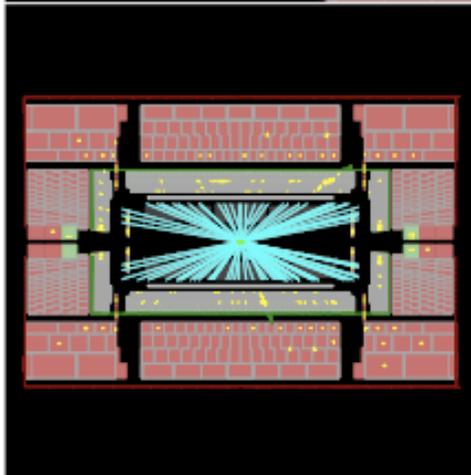
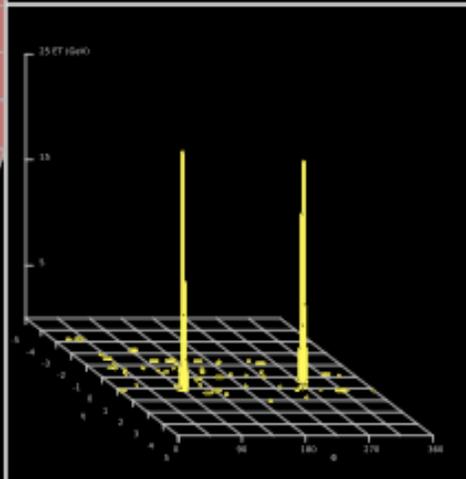
$M_{\gamma\gamma} = 126.9 \text{ GeV}$



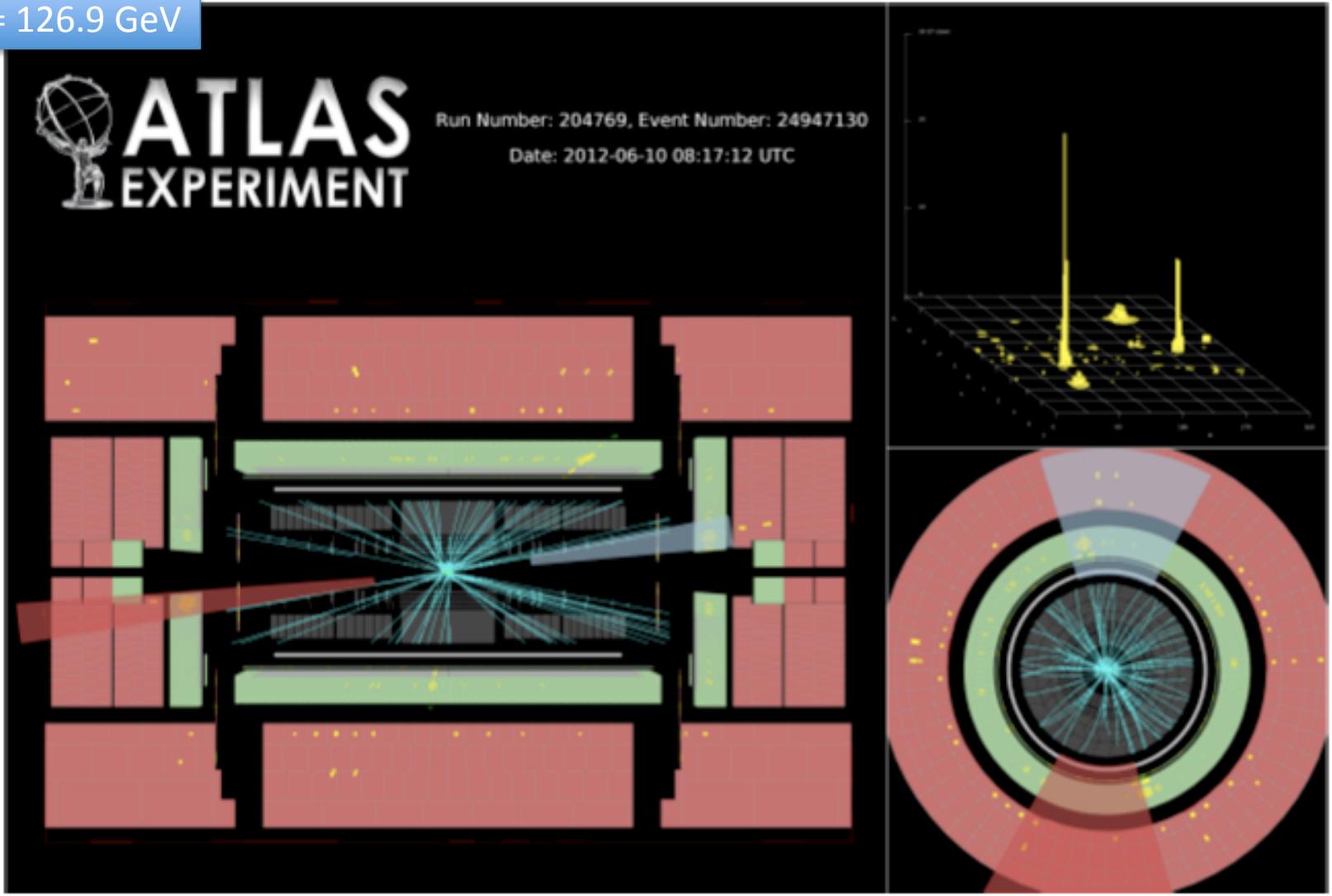
 **ATLAS**  
EXPERIMENT

Run Number: 203779, Event Number: 56662314

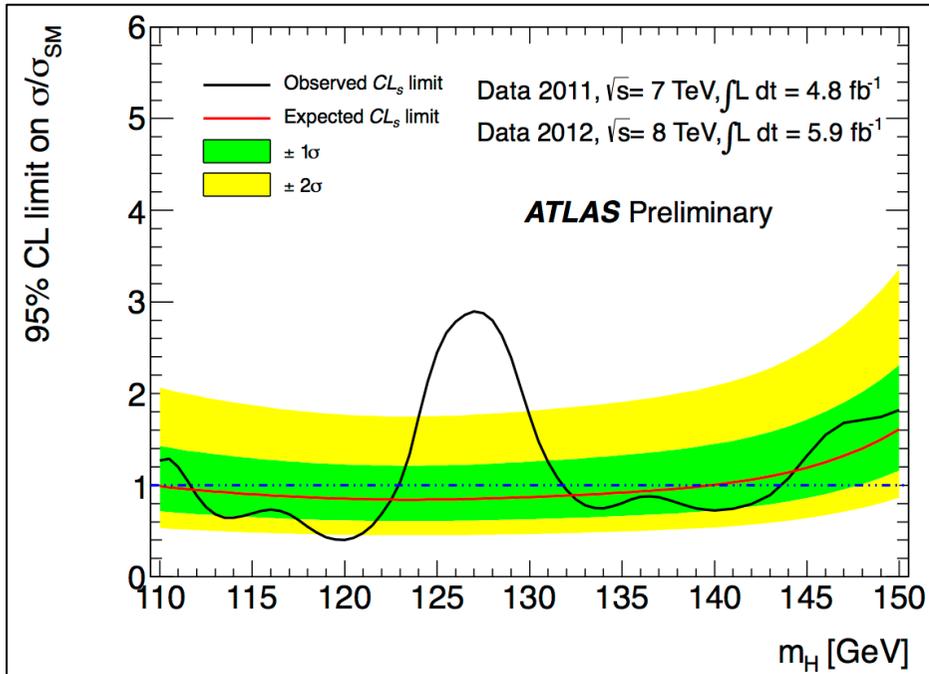
Date: 2012-05-23 22:19:29 CEST



$M_{\gamma\gamma} = 126.9 \text{ GeV}$



Analisi statistica (likelihood ratio + nuisance parameters per sistematiche):  
 Grafico di “esclusione” basato sul metodo  $CL_s$   
 Grafico del  $p_0$ -value locale

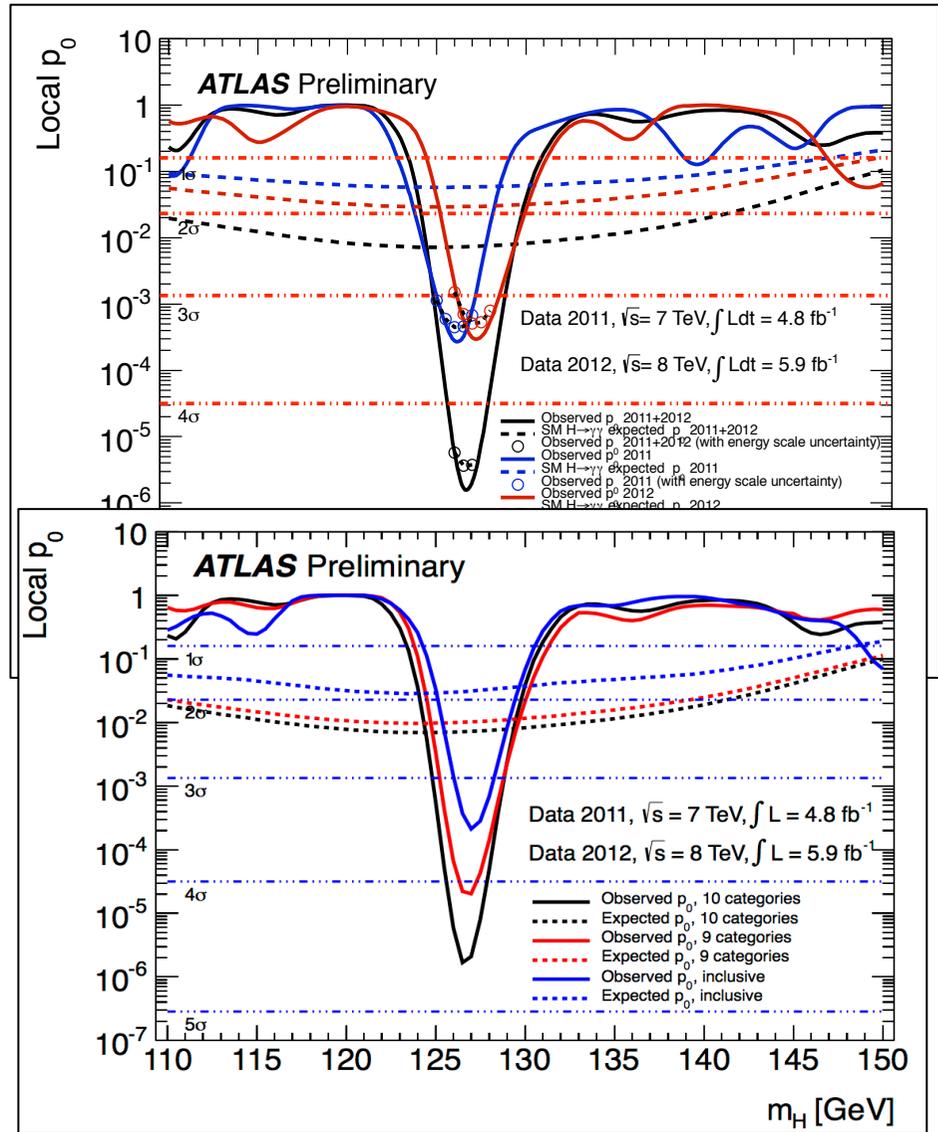


Esclusione @ 95% C.L.:

**112 ÷ 122.5 GeV AND 132 ÷ 143 GeV**  
 (expected 110 ÷ 139 GeV)

Significatività @126.5 GeV:

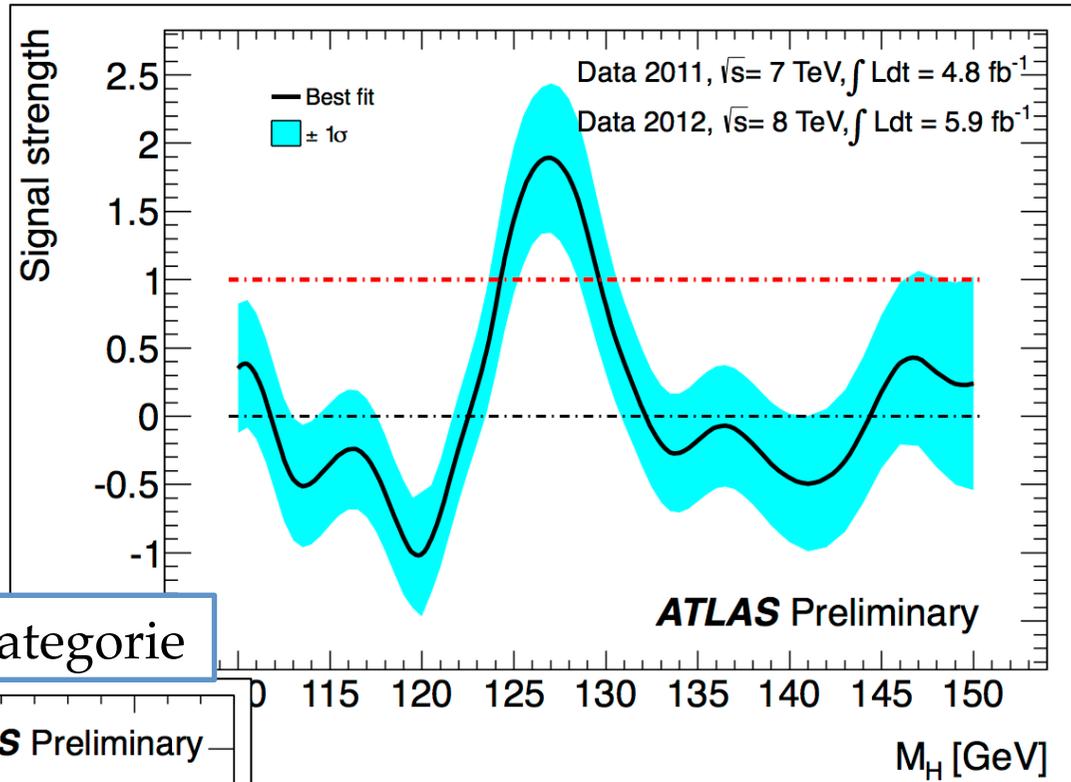
“locale” **4.5 $\sigma$  (2.4 $\sigma$  attesa SM)**  
 “globale” **3.6 $\sigma$  (LEE 110 – 150 GeV)**



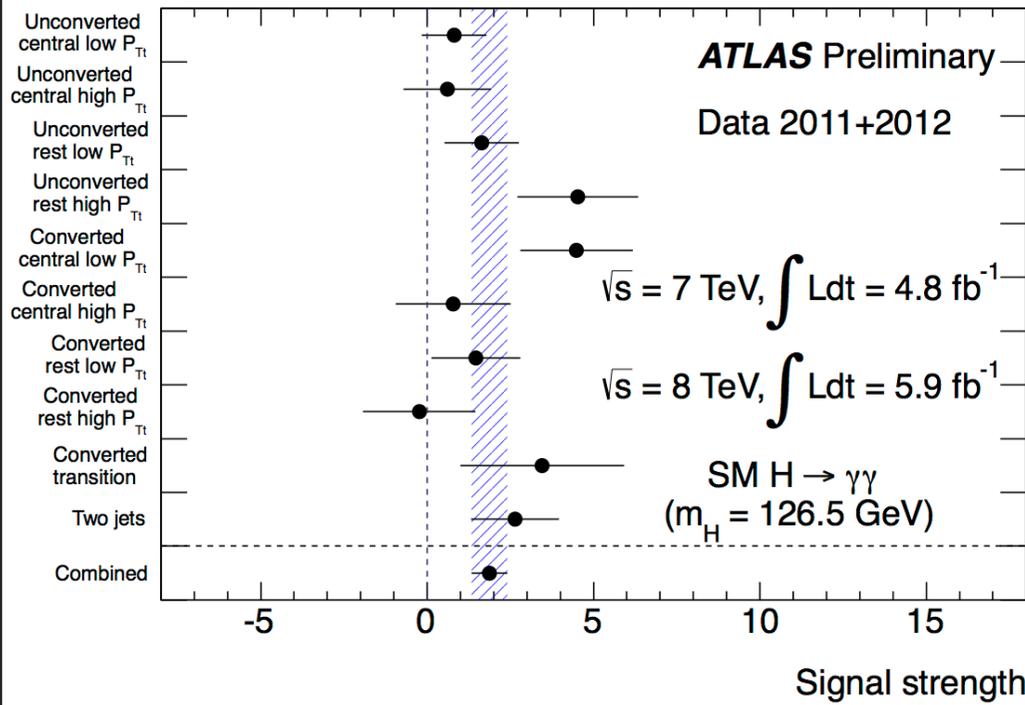
“Signal Strength”  $\mu = \sigma / \sigma_{SM}$

Miglior Fit @ 126.5 GeV:

$$\mu = 1.9 \pm 0.5$$



“Signal Strength” dalle diverse categorie



## H $\rightarrow$ ZZ<sup>(\*)</sup> $\rightarrow$ 4leptoni

Canale molto raro,  $\sigma = 2.3 \div 2.9$  fb  $\rightarrow$  attesi O(10) evts;

Ma segnatura molto chiara (*golden channel*) e fondi limitati O(10<sup>2</sup>) evts;

Ricerca nell'intero intervallo di massa  $110 < M_H < 600$  GeV

Stati finali con:

2 bosoni Z, uno reale, il secondo reale o virtuale (bassa  $M_H$ )

3 possibilità: 4e / 2e2 $\mu$  / 4 $\mu$  - (0.25 / 0.5 / 0.25)

Principali fondi:

pp  $\rightarrow$  ZZ<sup>(\*)</sup>  $\rightarrow$  4leptoni ; dal continuo (irriducibile)

Z+jets ; (in particolare Z+bb) e tt (riducibili)

Trigger singolo o doppio leptone ( $\epsilon(\text{trig}/\text{ricos}) \approx 99\%$ )

Selezione dei candidati

2 coppie di leptoni, stesso "flavour", carica opposta;

leptoni con:  $p_T > 20, 15, 10, 6$  (7) GeV;  $|\eta_e| < 2.47, |\eta_\mu| < 2.7$ ;

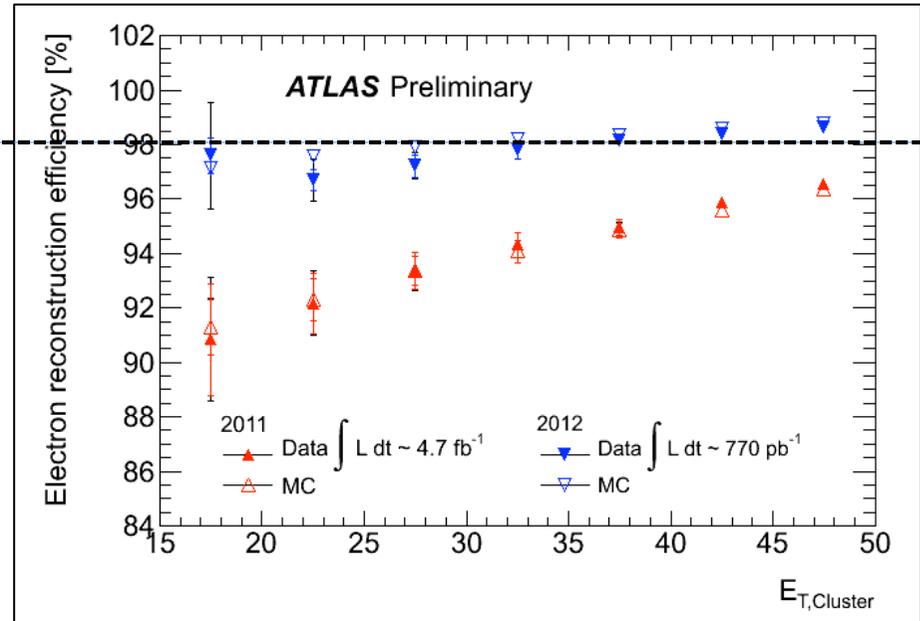
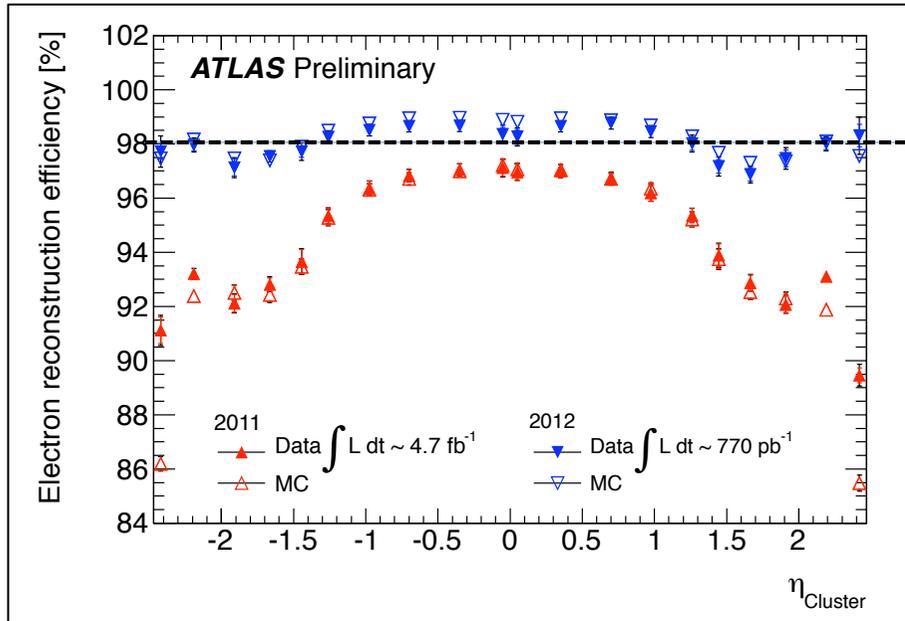
Masse delle Z:  $50 < M_{12} < 106$  GeV AND  $M_{\min}(M_{4l}) < M_{34} < 115$  GeV,  $M_{ll} > 5$  GeV

leptoni "isolati" (ID e Calorimetro) e provenienti dal vertice primario

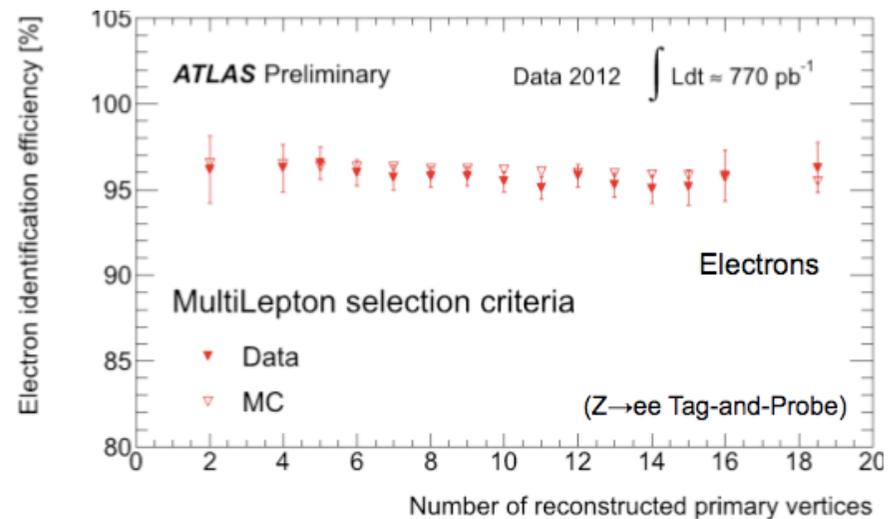
Efficienza	2011 (old)	2011 (new)	2012	
4 $\mu$	27%	43%	41%	+40%
2e2 $\mu$	18%	23%	27%	
4e	14%	17%	23%	+60%

# Elettroni:

BREM recovery molto efficace su efficienza e risoluzione

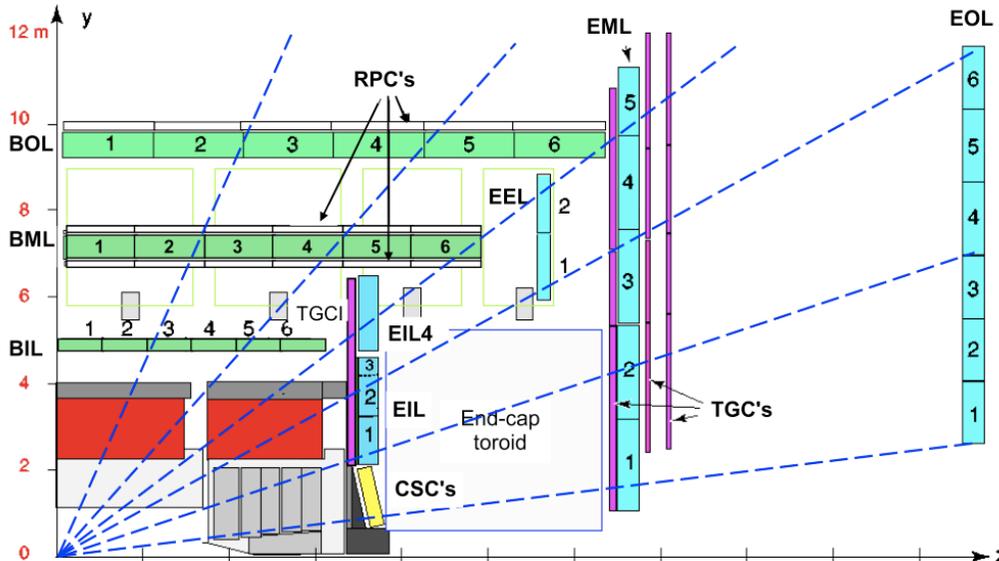


- Candidati elettroni ri-fittati tenendo conto della bremsstrahlung;
- Modificate le richieste per il matching con il cluster;
- L'efficienza (e le variabili di shape) sono  $\approx$  indipendenti da  $N_{\text{vtx}}$ .

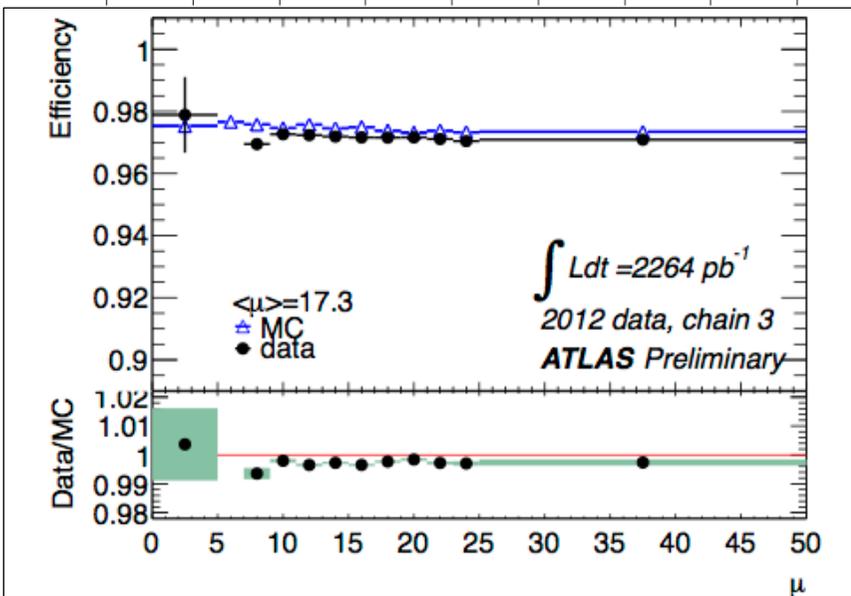


# Muoni:

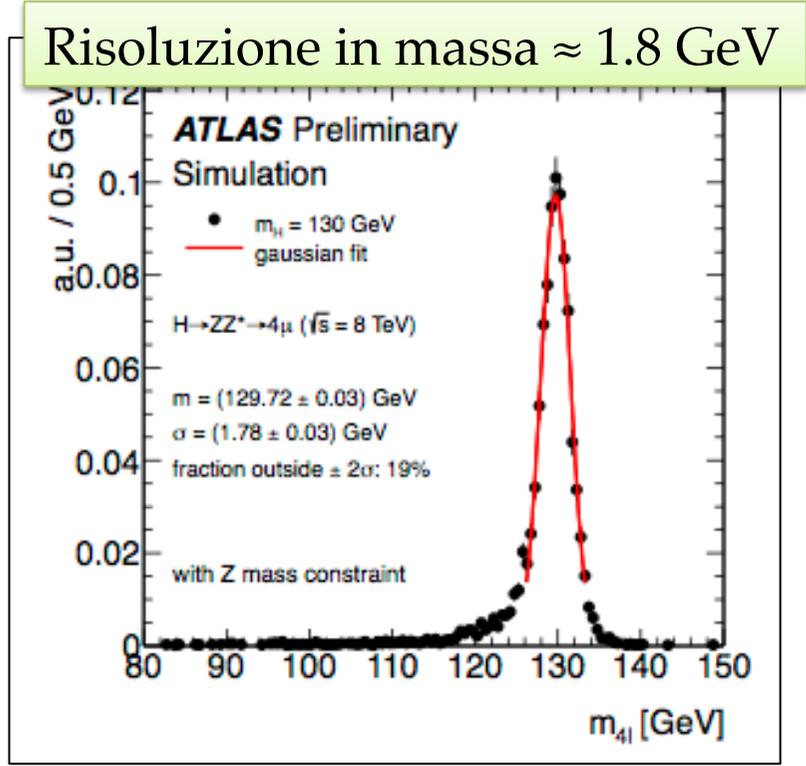
Estesa l'accettazione a muoni "standalone" e "calomuons"



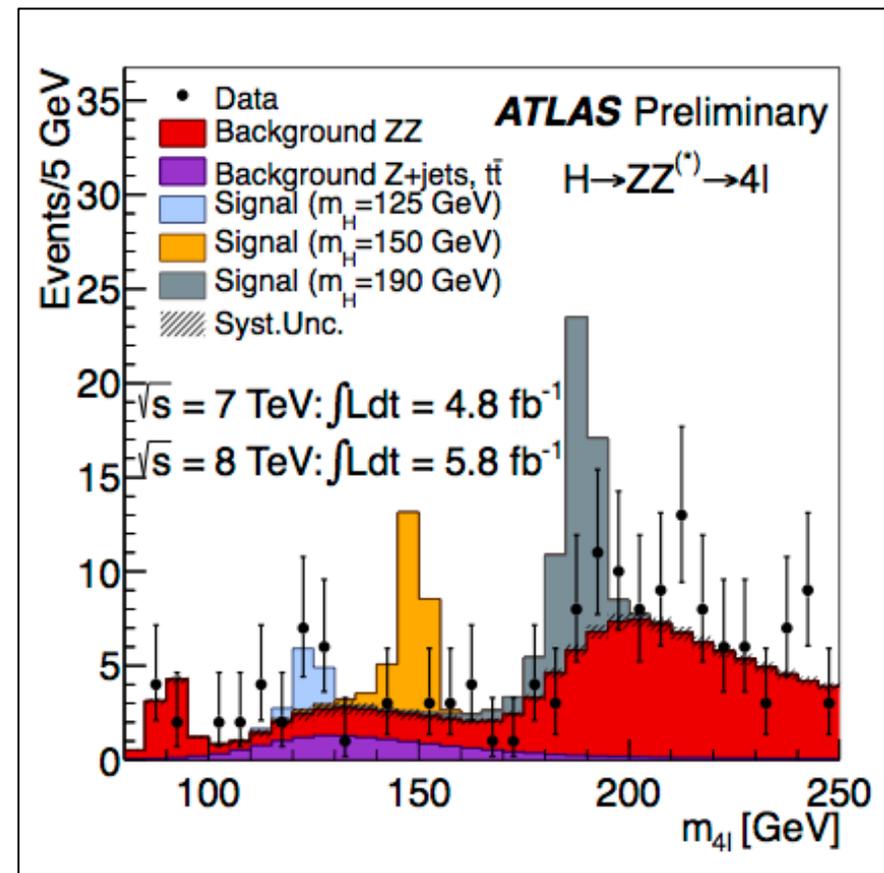
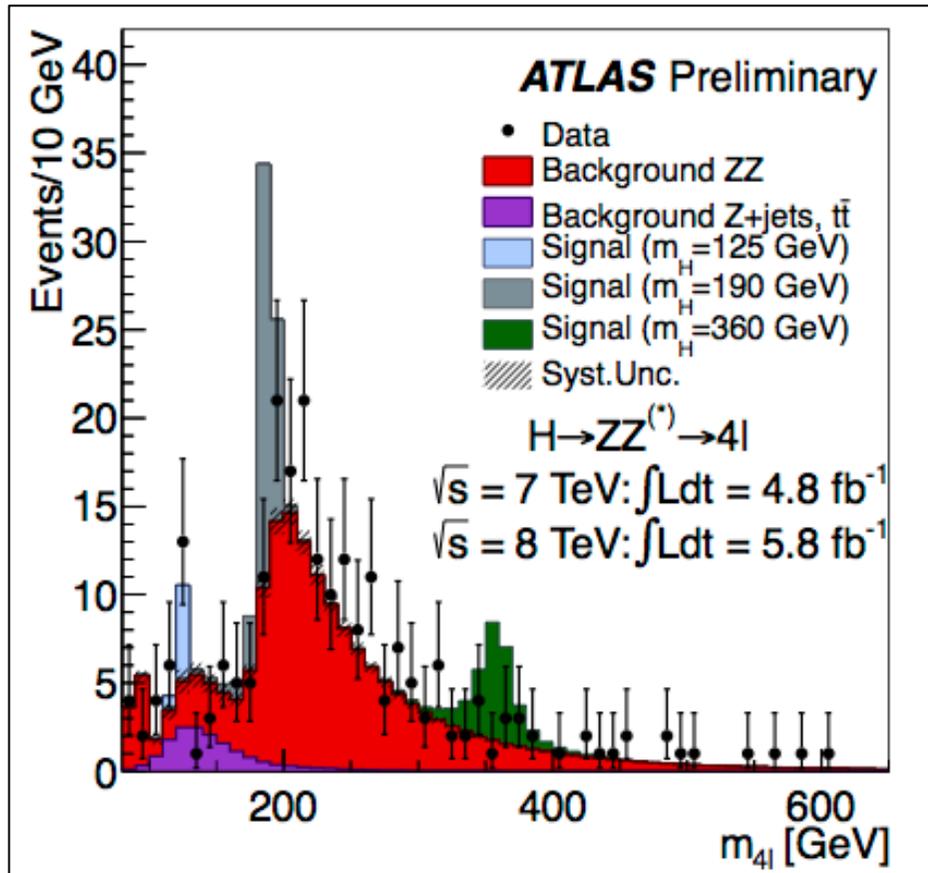
Muoni combinati o tagged +  
 Muoni standalone ( $2.5 < |\eta| < 2.7$ )  
 Calomuons ( $|\eta| < 0.1, p_T > 15 \text{ GeV}$ )  
 Abbassate soglie in  $p_T$   
 Ottimizzati tagli sulle masse Z  
 → +40% rispetto a dicembre



Efficienza "robusta" rispetto al pile-up



Risultati: selezionati 230 evts (88 + 142): spettro in massa invariante “raw”



Fondo ZZ: forma e normalizzazione MC

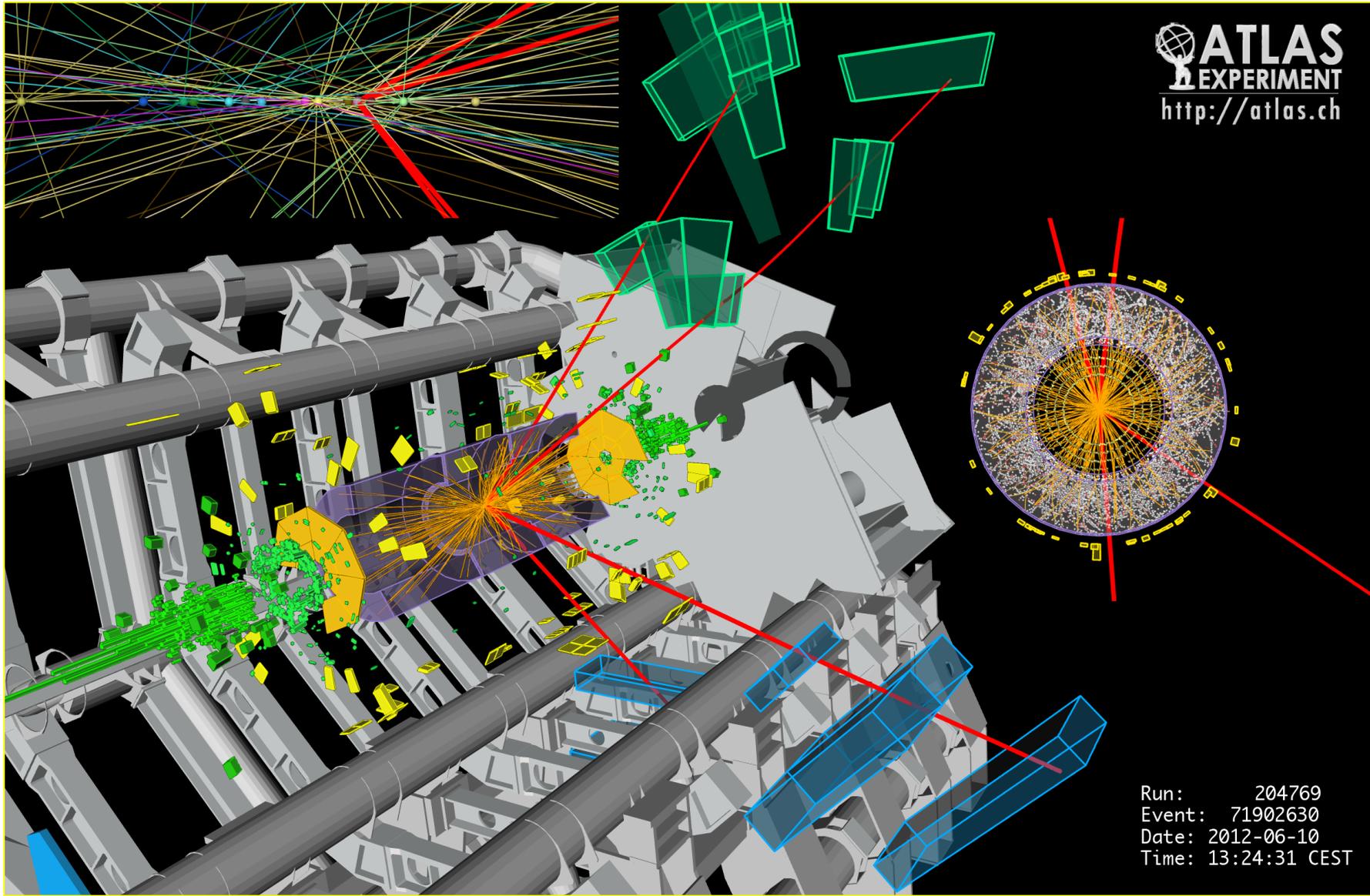
Accordo entro  $2\sigma$  norm. con dati,  
effetto molto limitato a 125 GeV

Fondo Z+jets, tt: regioni di controllo + MC

Eventi in  $M_{4l} = 125 \pm 5$  GeV

	2011	2012	combined
exp.bckg.	$2.1 \pm 0.3$	$2.9 \pm 0.4$	$5.1 \pm 0.8$
exp.signal	$2.0 \pm 0.3$	$3.3 \pm 0.5$	$5.3 \pm 0.8$
data	4	9	13

Evento  $4\mu$ :  $M_{4l} = 125.1 \text{ GeV}$



# Evento 4e: $M_{4l} = 124.6$ GeV

**ATLAS**  
EXPERIMENT

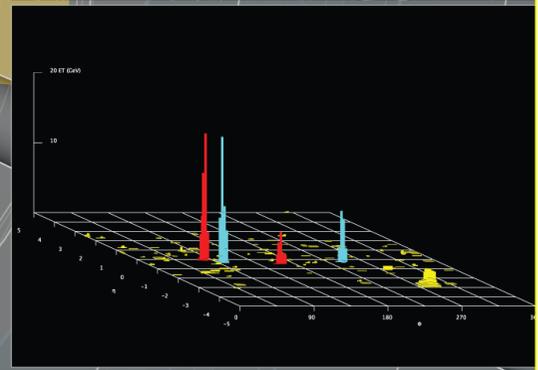
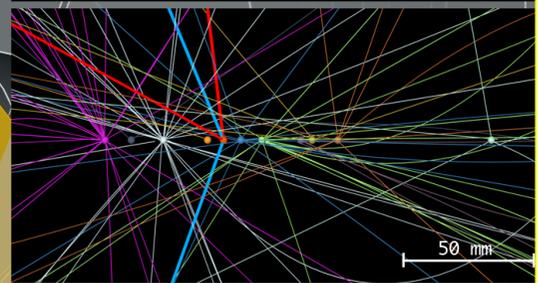
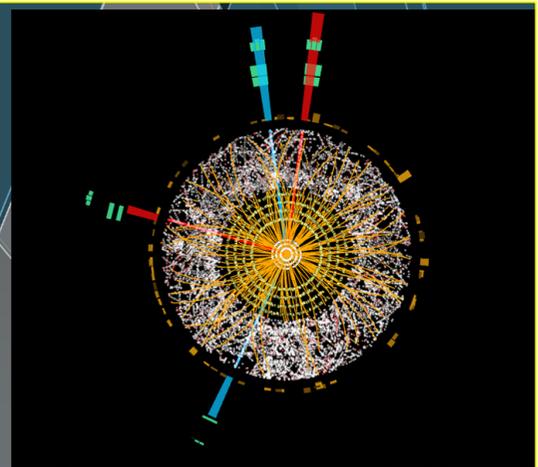
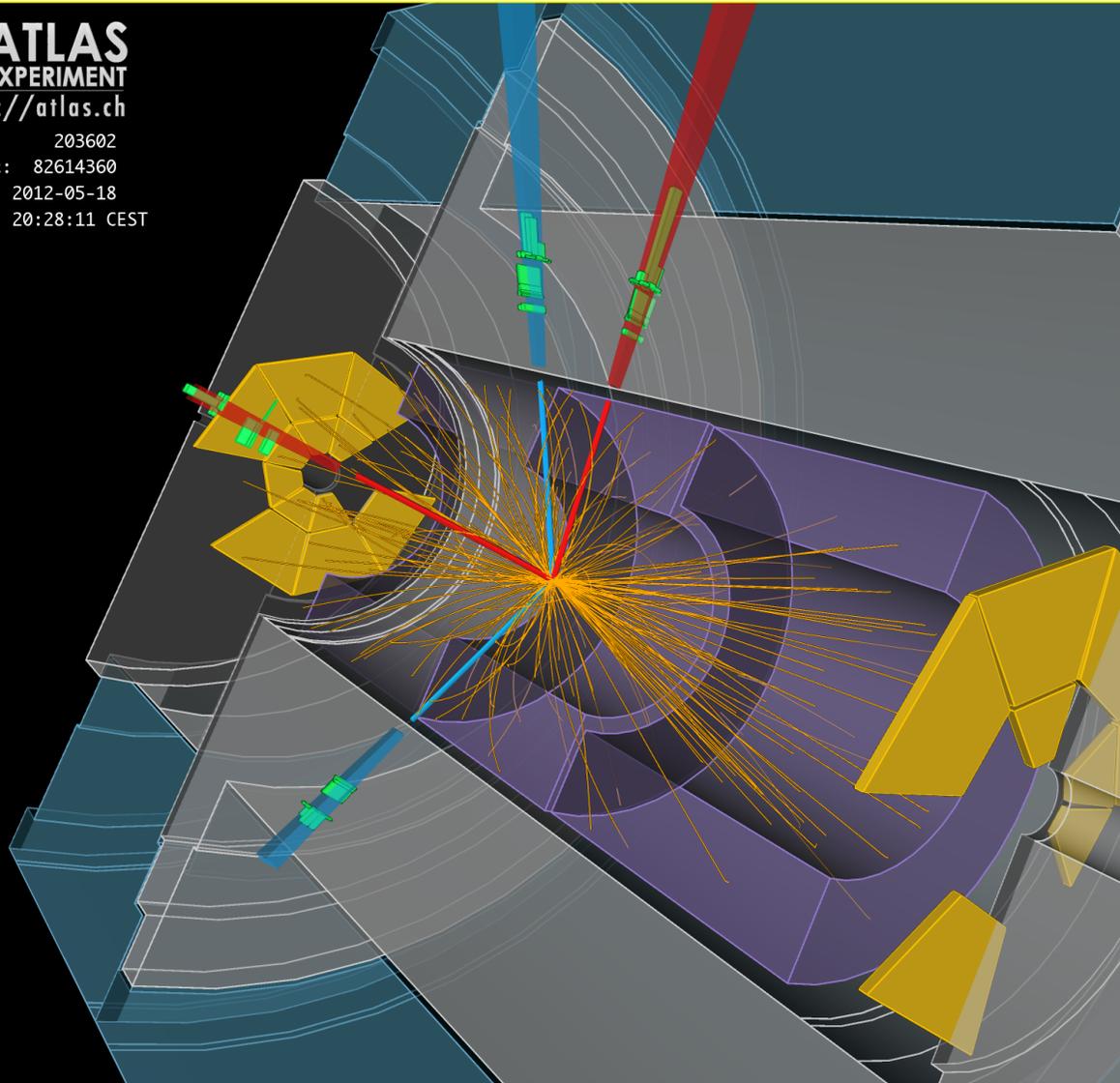
<http://atlas.ch>

Run: 203602

Event: 82614360

Date: 2012-05-18

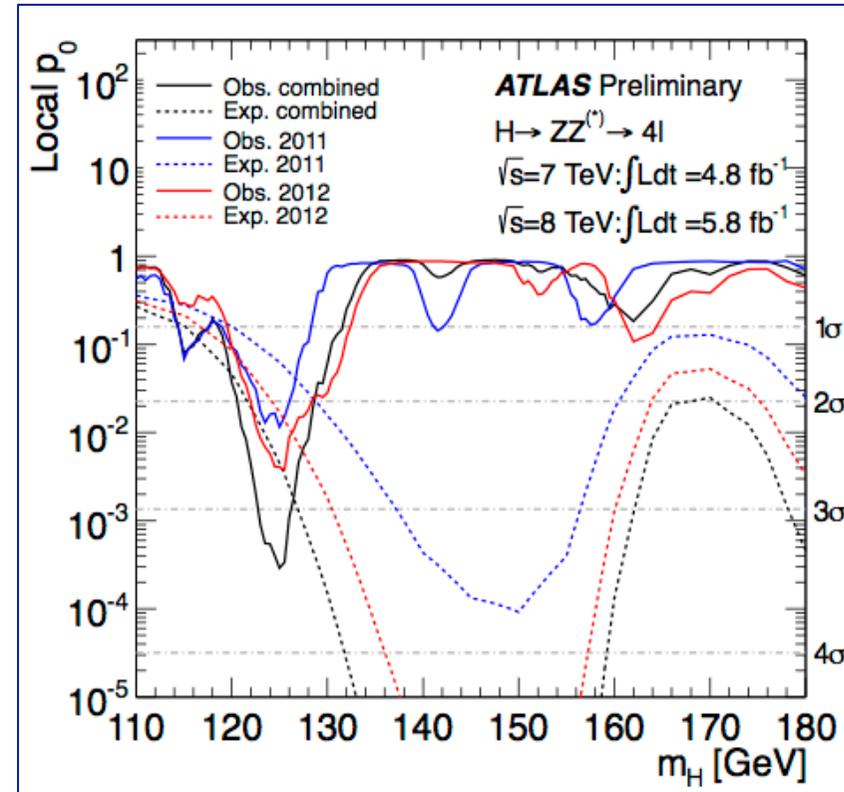
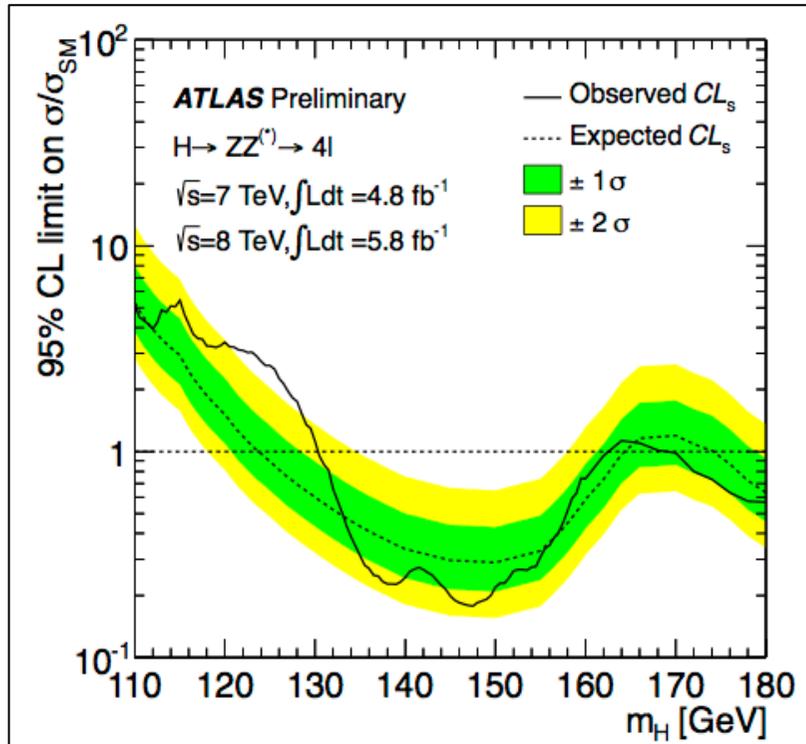
Time: 20:28:11 CEST



Analisi statistica (likelihood ratio + nuisance parameters per sistematiche):

Grafico di “esclusione” basato sul metodo  $CL_s$

Grafico del  $p_0$ -value locale



Esclusione @ 95% C.L.:

**131 ÷ 162 GeV AND 170 ÷ 460 GeV** (expected: 124 ÷ 174 AND 176 ÷ 500 GeV)

Significatività @125 GeV:

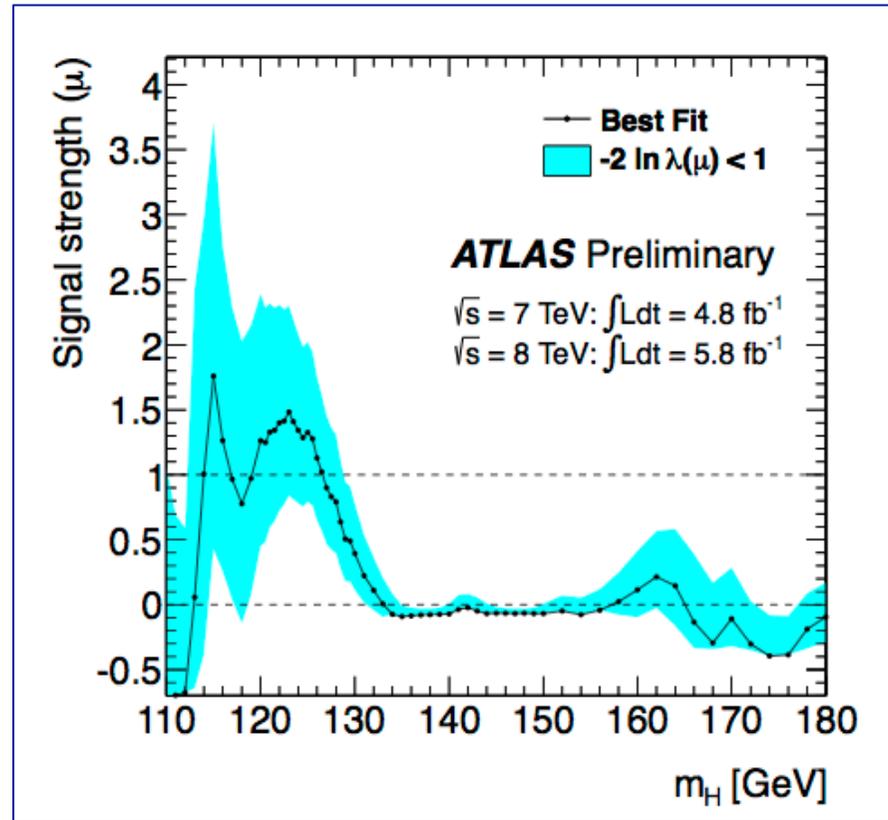
**“locale” 3.4 $\sigma$  (2.6 $\sigma$  attesa SM)**

**“globale” 2.1 $\sigma$  (LEE 110 – 600 GeV)**

“Signal Strength”  $\mu = \sigma / \sigma_{SM}$

Miglior Fit @ 125.0 GeV:

$$\mu = 1.3 \pm 0.6$$

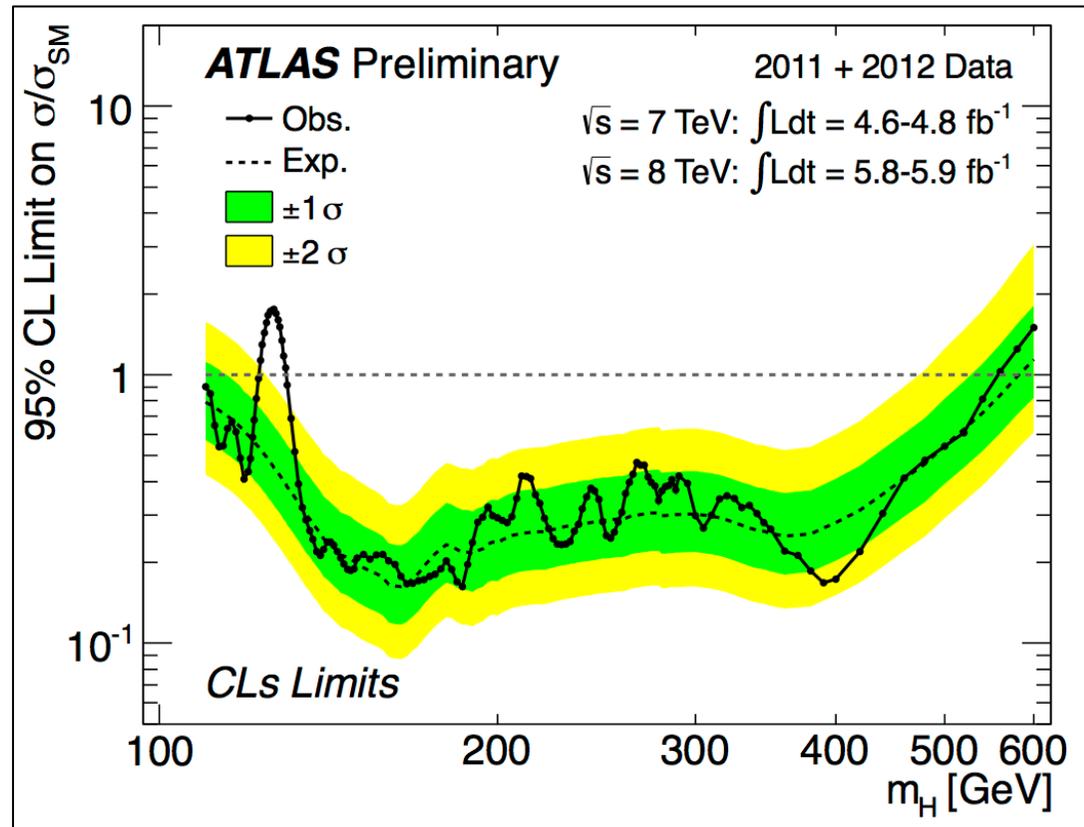


# Combinazione - I

$H \rightarrow \gamma\gamma$ , 4l

Tutti gli altri canali, solo dati 2011 analisi pubblicata

$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$
$H \rightarrow WW \rightarrow l\nu qq$
$H \rightarrow ZZ \rightarrow ll\nu\nu$
$H \rightarrow ZZ^{(*)} \rightarrow llqq$
$H \rightarrow \tau\tau$
$WH \rightarrow l\nu bb$
$ZH \rightarrow llbb$
$ZH \rightarrow \nu\nu bb$



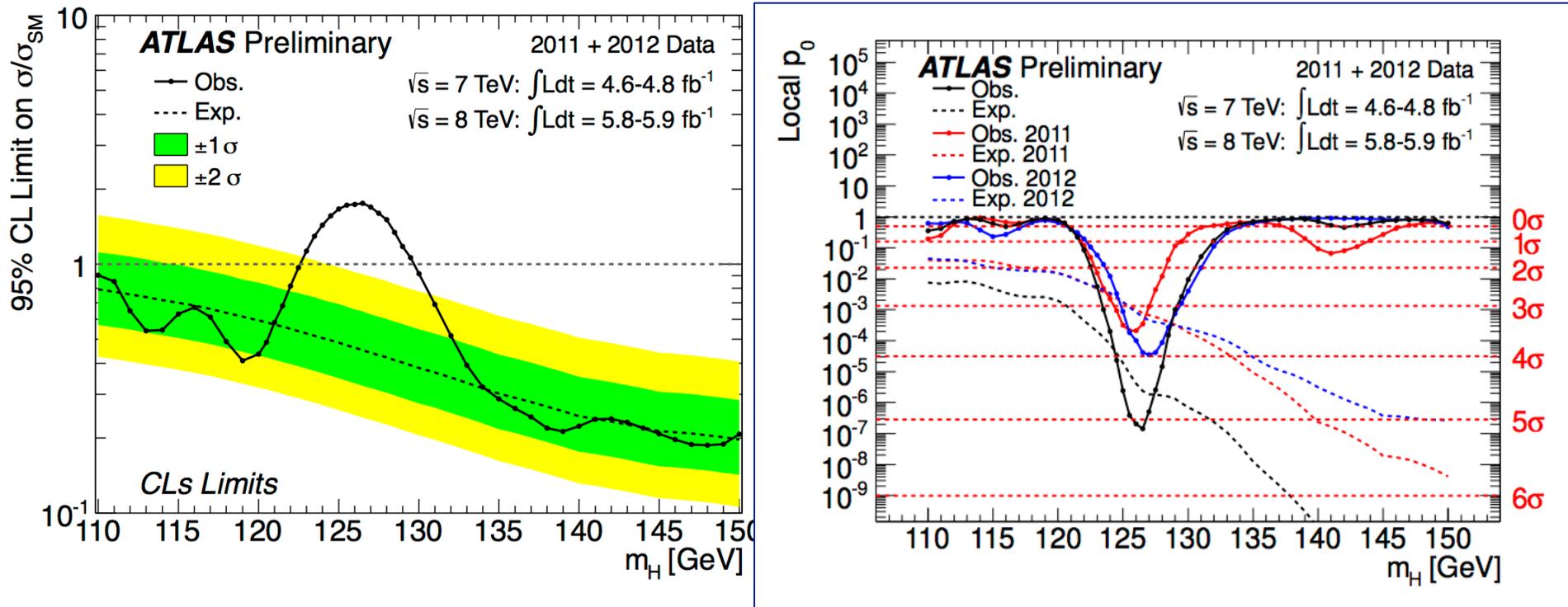
Esclusione:

@ 95% C.L. **110.0 ÷ 122.6** AND **129.7 ÷ 557.6** GeV (110 ÷ 582 GeV exp.)

@ 99% C.L. **111.7 ÷ 121.8** AND **130.7 ÷ 522.6** GeV

# Combinazione - II

Significatività del segnale @ 126 GeV



La probabilità che un esperimento di solo fondo fluttui come o più dei dati corrisponde a 5.1 deviazioni standard gaussiane.

L'effetto delle sistematiche su Scala e Risoluzione in Energia  $\rightarrow$  5.0

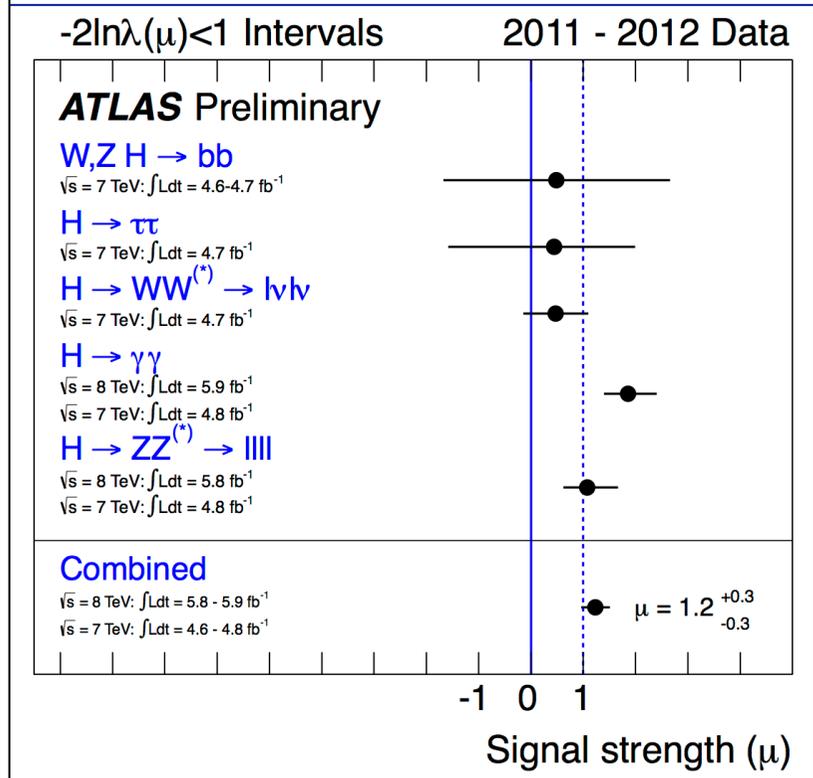
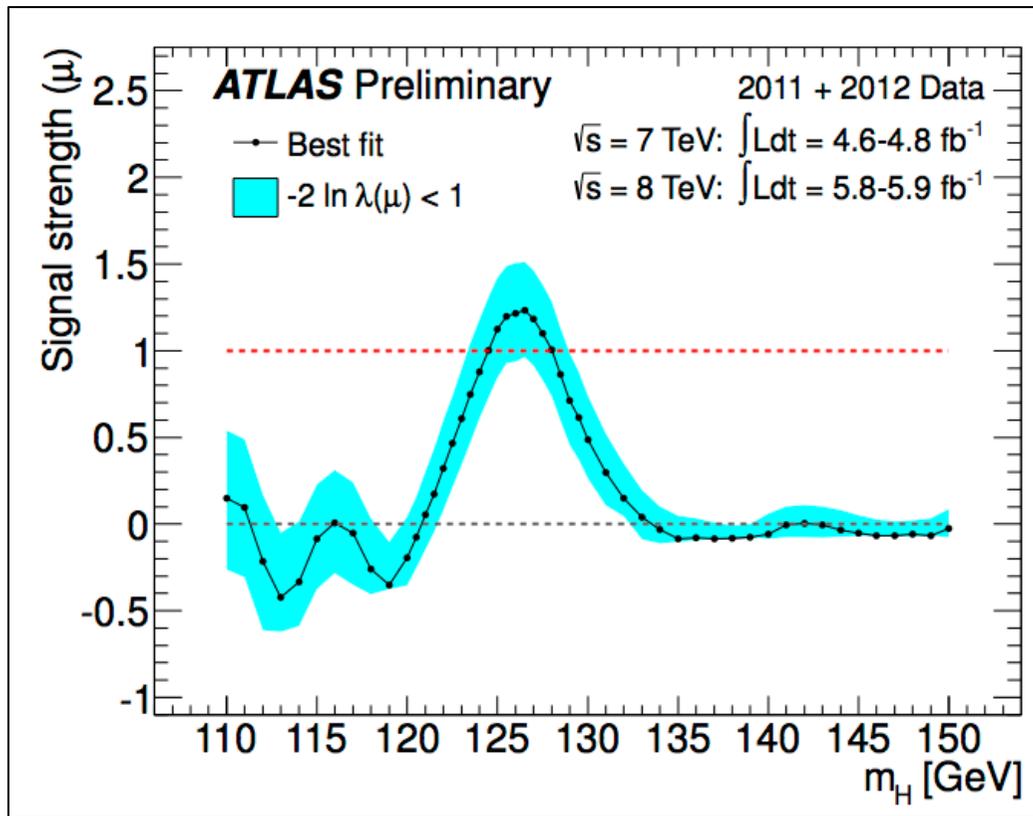
**$p_0$ -value @ 126.5 GeV = 5.0  $\sigma$  (expected 4.6  $\sigma$ )**

# Combinazione - III

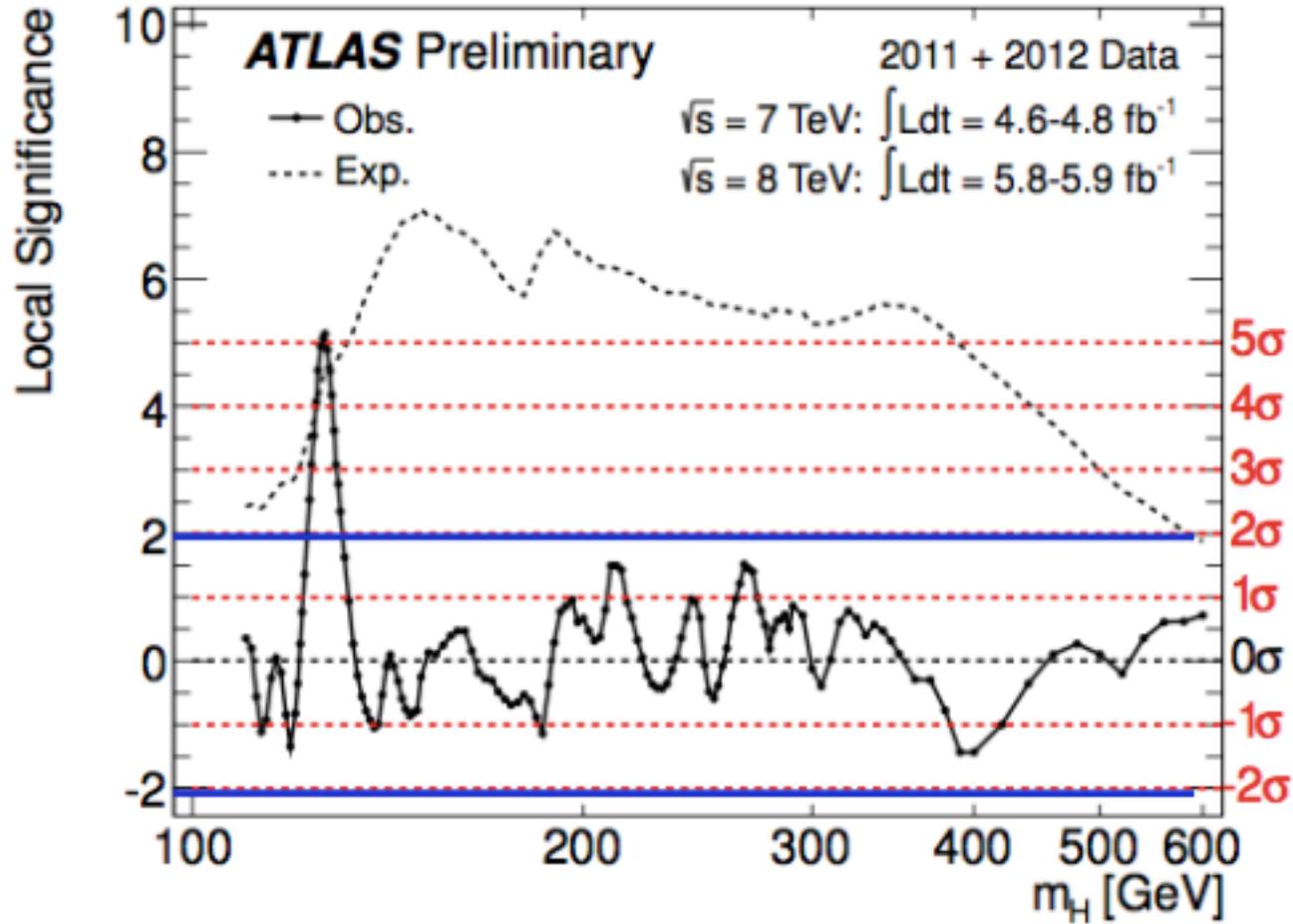
“Signal Strength”  $\mu = \sigma / \sigma_{\text{SM}}$

Miglior Fit @ 126.5 GeV:

$$\mu = 1.2 \pm 0.3$$



Significatività dell'eccesso su tutta la finestra di massa esplorata:  
quella a 126 GeV è l'unica fluttuazione che osserviamo !

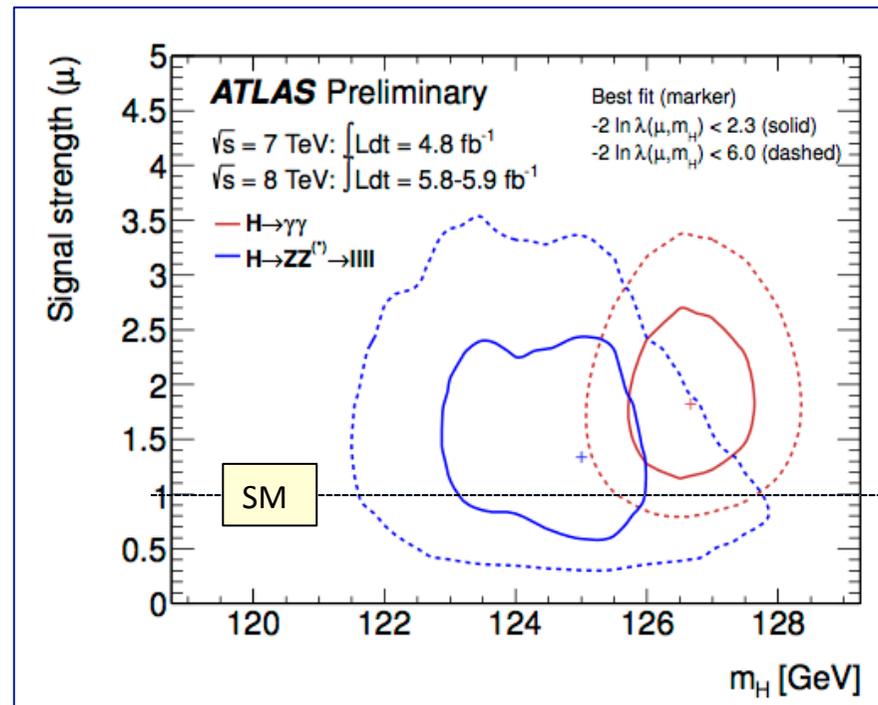


## Ricapitolando: Significatività dell'osservazione

	local signif. ( $\sigma$ )	signal strength $\mu = \sigma/\sigma_{SM}$
$H \rightarrow \gamma\gamma$	4.5 (2.4)	$1.9 \pm 0.5$ (126.5 GeV)
$H \rightarrow 4l$	3.4 (2.6)	$1.3 \pm 0.6$ (125.0 GeV)
combinazione	5.0 (4.6)	$1.2 \pm 0.3$ (126.5 GeV)

## Consistenza tra i due principali canali

$p=20\%$   
prob. di avere una  
differenza di massa  
 $\geq$  questa osservata  
 $\rightarrow$  consistenti.



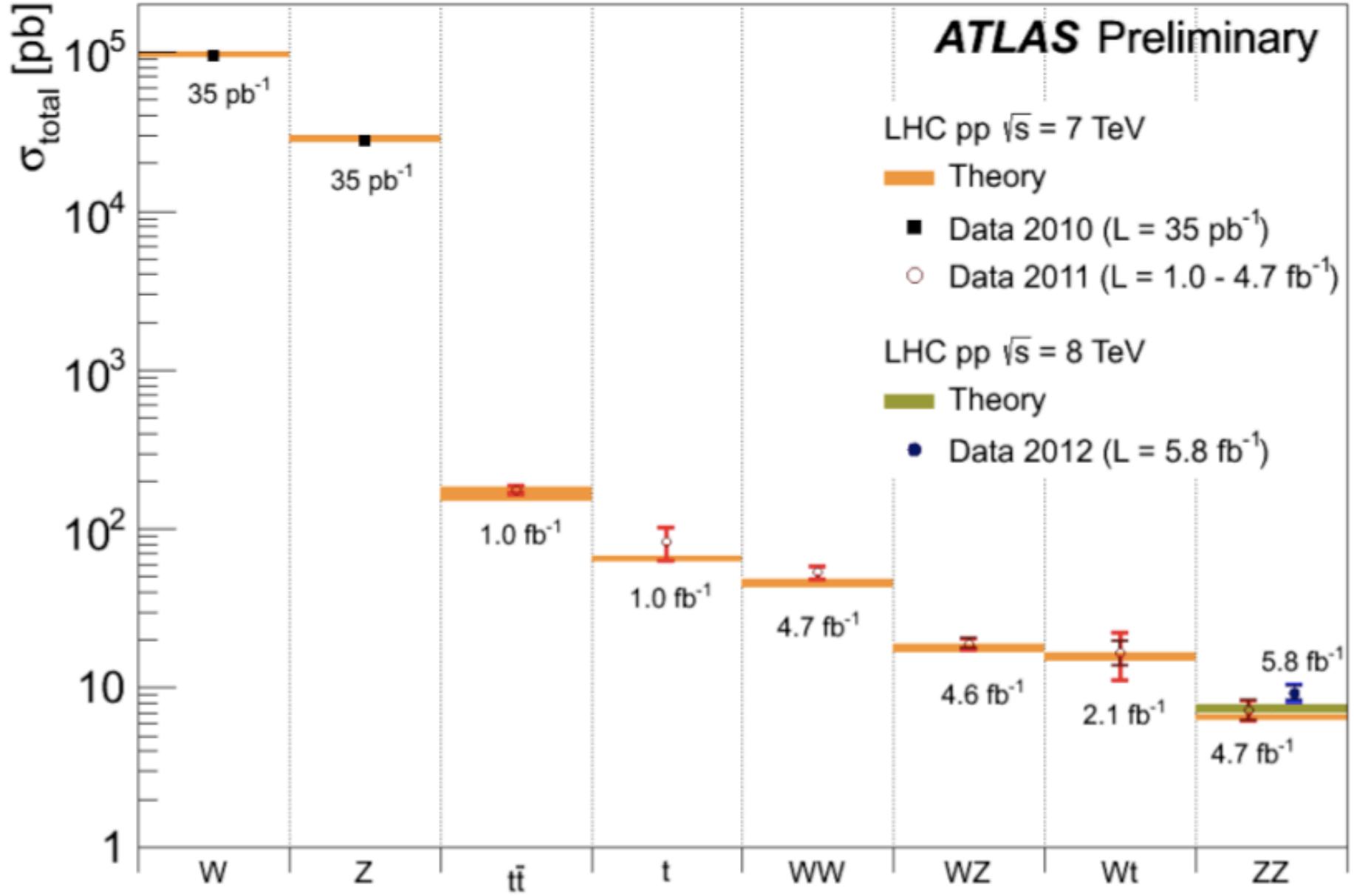
## Conclusioni.

- ATLAS esclude il bosone di Higgs SM in tutto l'intervallo di massa esplorato eccetto la regione  $122.7 \div 129.0$  GeV;
- ATLAS osserva un eccesso di eventi rispetto al fondo in due canali indipendenti alla stessa massa  $M \approx 126$  GeV e coerentemente tra 2011 e 2012.
- L'eccesso ha una **significatività di 5 "sigma"** (4.6 attese SM).
- Le sezioni d'urto sono consistenti con le predizioni SM per il bosone di Higgs
- Il decadimento in  $\gamma\gamma$  implica **che si tratta di un bosone** (spin=0, 2, ...)

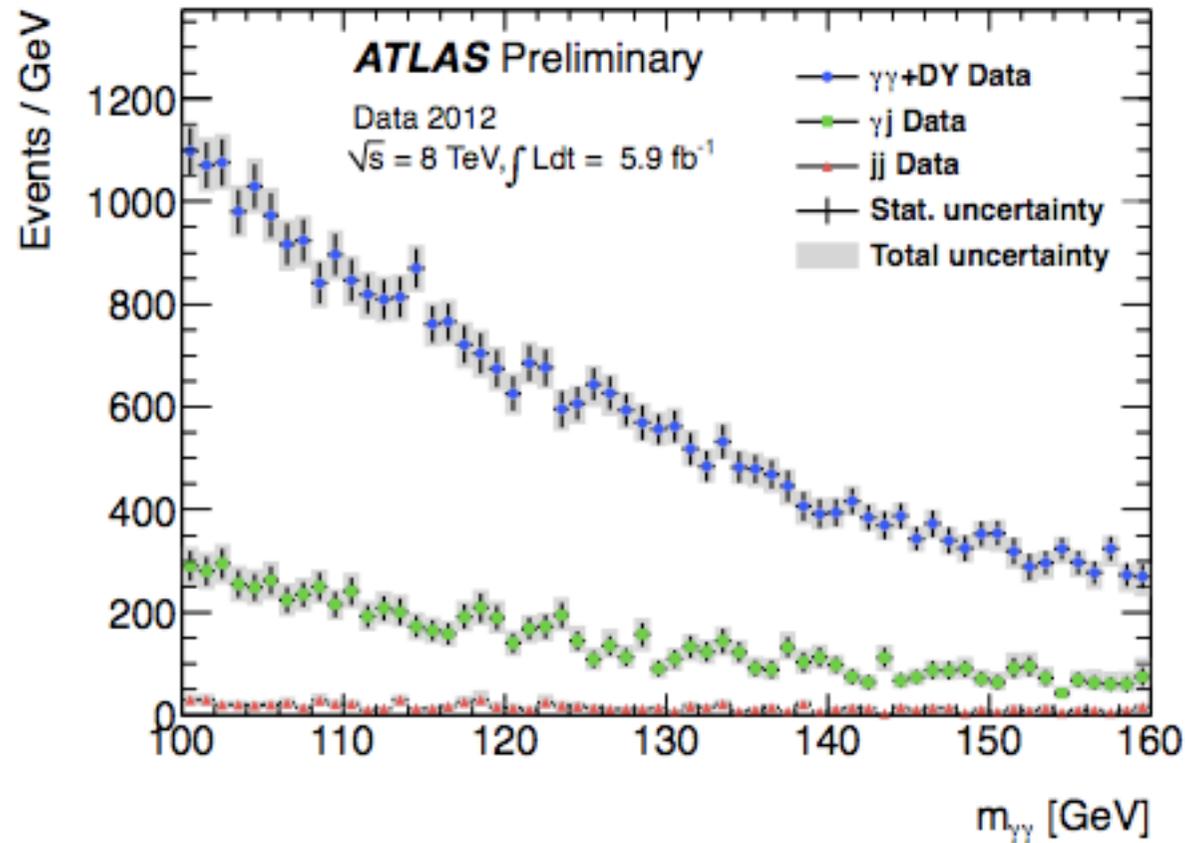
### • Prossimi passi:

1. **Ampi margini di miglioramento delle tecniche di analisi**
2. **Statistica di 20-30 fb<sup>-1</sup> a 8 TeV a fine anno realistica**
  - ➔ **Consolidamento dell'osservazione**
  - ➔ **Estensione al canale WW e ai canali fermionici**
  - ➔ **Studio delle proprietà della particella osservata**

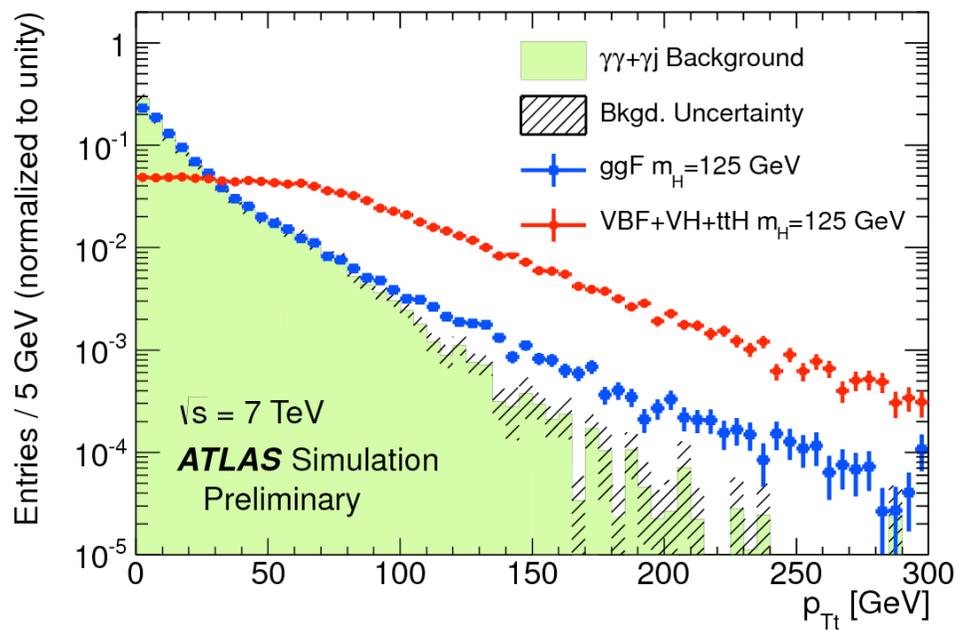
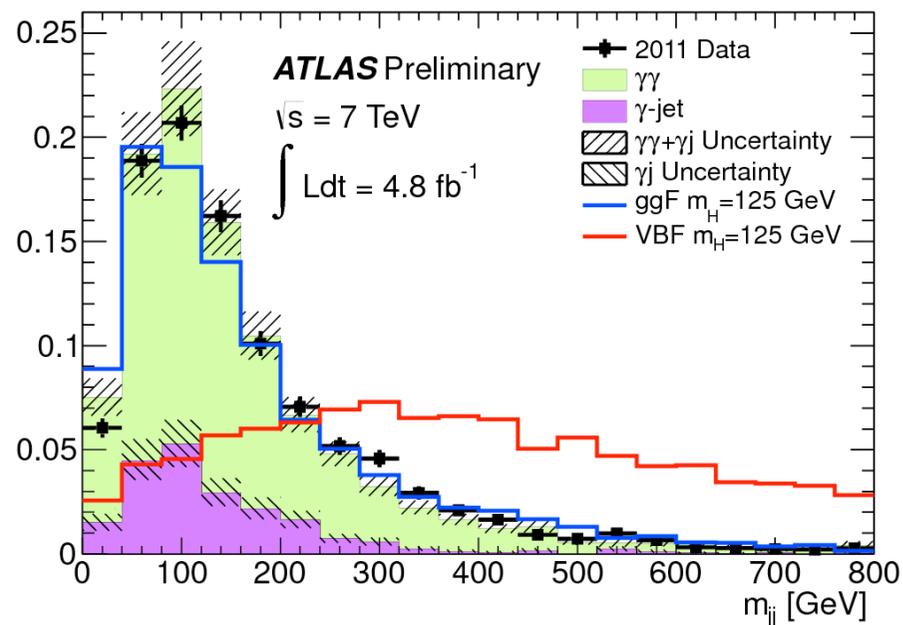
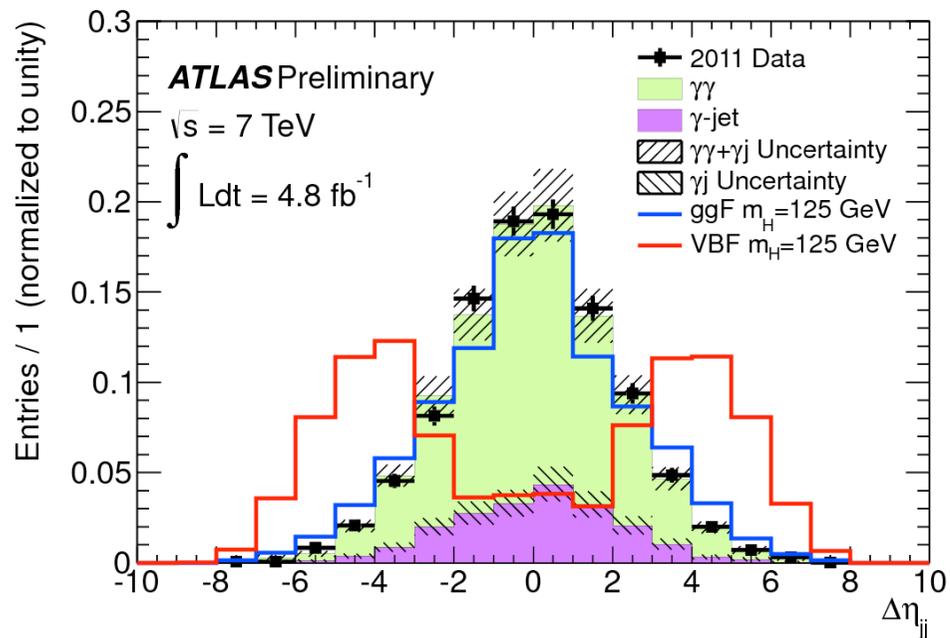
Backup

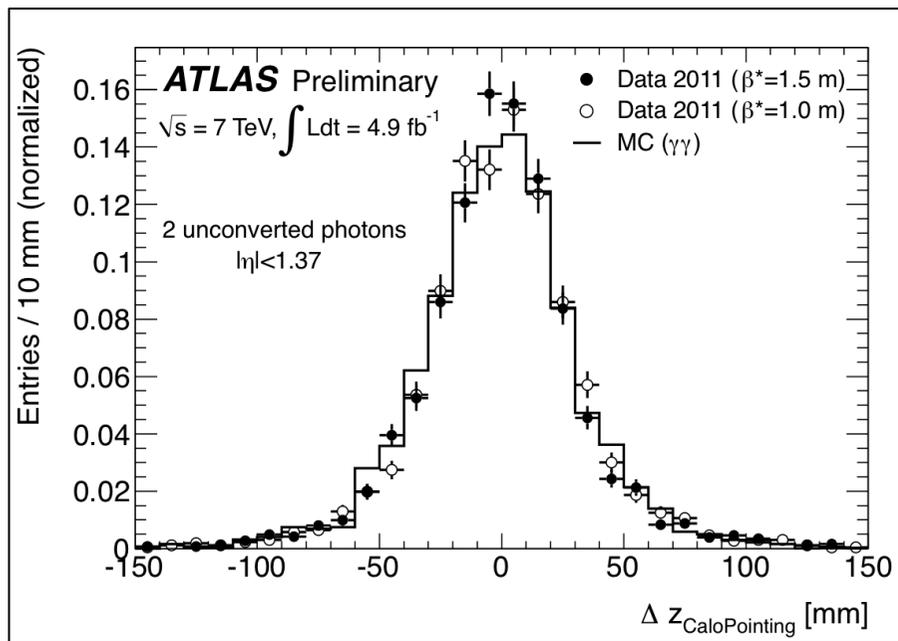


# Determinazione “data-driven” della composizione del campione

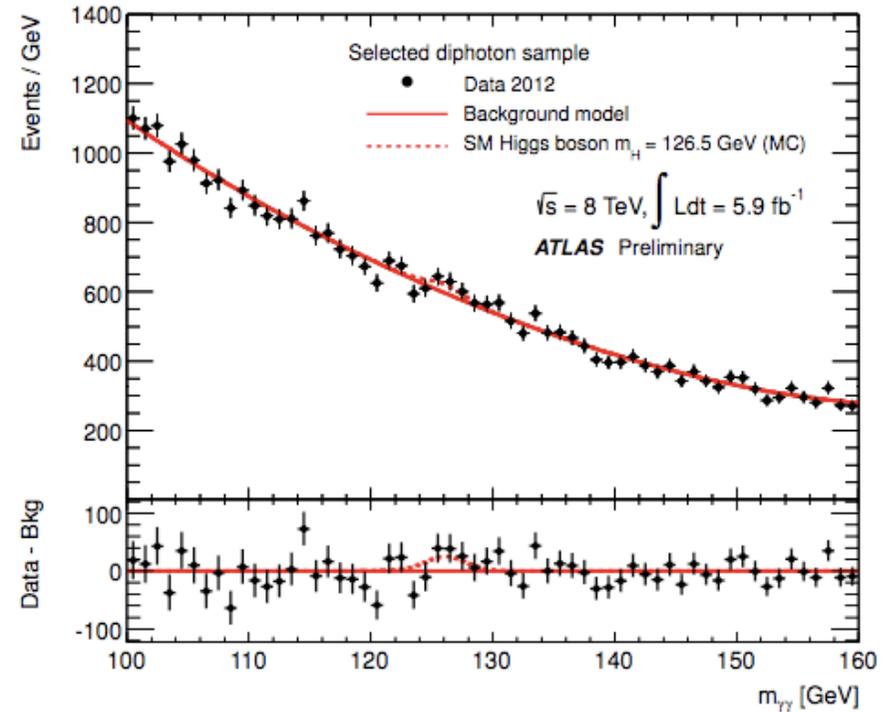
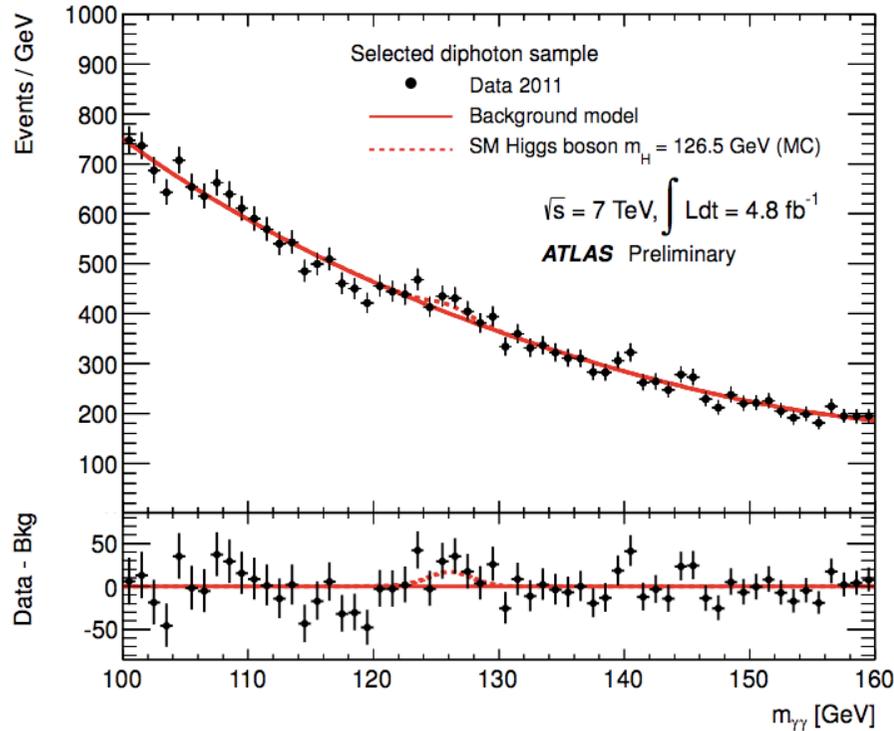


	$\gamma\gamma$ +DY	$\gamma$ -jet	jet-jet
7 TeV (NN ID)	$(80 \pm 4)\%$	$(19 \pm 3)\%$	$(1.8 \pm 0.5)\%$
8 TeV (Cut ID)	$(75 \pm 3)\%$	$(22 \pm 2)\%$	$(2.6 \pm 0.5)\%$





# Spettri in massa invariante “raw”: campioni 2011 e 2012 (ricerca limitata alla regione $110 < M_{\gamma\gamma} < 150$ )



Background:

Parametrizzazioni ottenute da fit a campioni MC di puro fondo  
Parametri aggiustati dal fit dei dati di “puro-background”

Nella zona di 125 GeV si osservano fluttuazioni positive

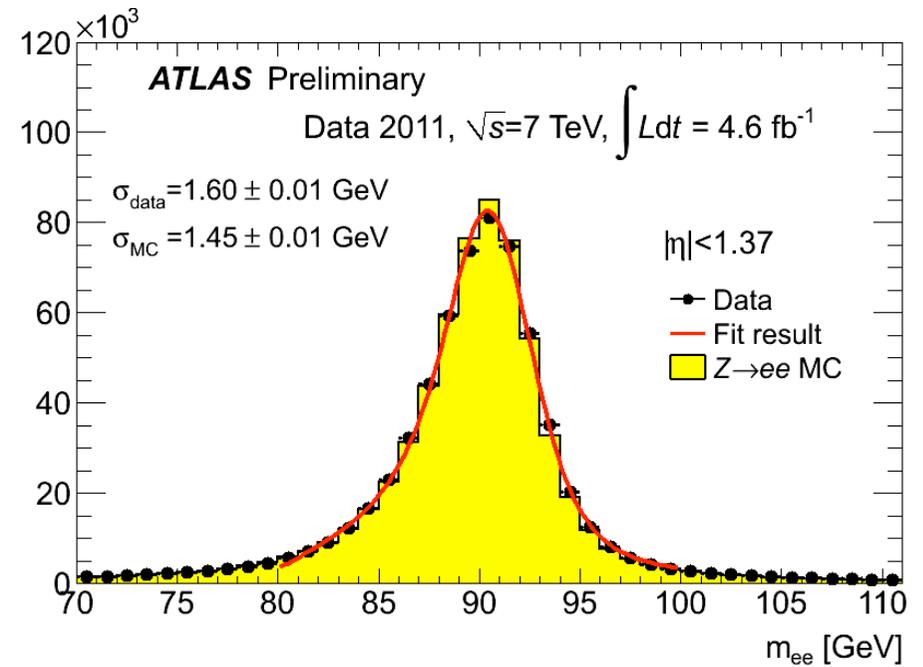
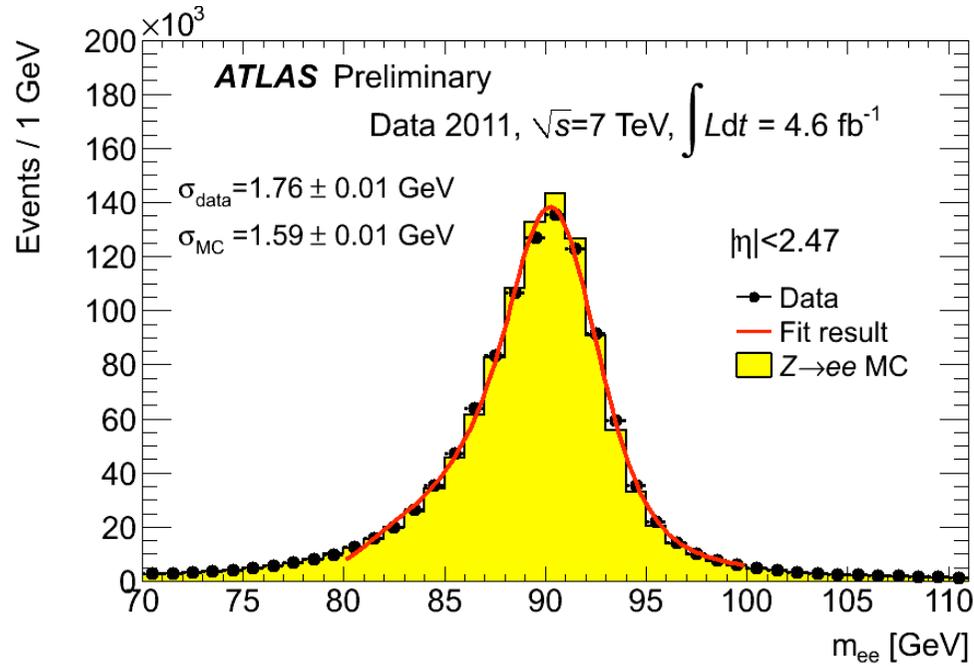
Table 2: Number of expected signal  $S$  and background events  $B$  in mass a window around  $m_H = 126.5$  GeV that would contain 90% of the expected signal events, along with the observed number of events in this window. In addition,  $\sigma_{CB}$ , the Gaussian width of the Crystal Ball function describing the invariant mass distribution (see Sec. 6), and the FWHM of the distribution, are given. The numbers are given for the data and simulation at  $\sqrt{s} = 8$  TeV for different categories and the inclusive sample.

Category	$\sigma_{CB}$ [GeV]	FWHM [GeV]	Observed [ $N_{\text{evt}}$ ]	$S$ [ $N_{\text{evt}}$ ]	$B$ [ $N_{\text{evt}}$ ]
Inclusive	1.63	3.87	3693	100.4	3635
Unconverted central, low $p_{Tt}$	1.45	3.42	235	13.0	215
Unconverted central, high $p_{Tt}$	1.37	3.23	15	2.3	14
Unconverted rest, low $p_{Tt}$	1.57	3.72	1131	28.3	1133
Unconverted rest, high $p_{Tt}$	1.51	3.55	75	4.8	68
Converted central, low $p_{Tt}$	1.67	3.94	208	8.2	193
Converted central, high $p_{Tt}$	1.50	3.54	13	1.5	10
Converted rest, low $p_{Tt}$	1.93	4.54	1350	24.6	1346
Converted rest, high $p_{Tt}$	1.68	3.96	69	4.1	72
Converted transition	2.65	6.24	880	11.7	845
2-jets	1.57	3.70	18	2.6	12

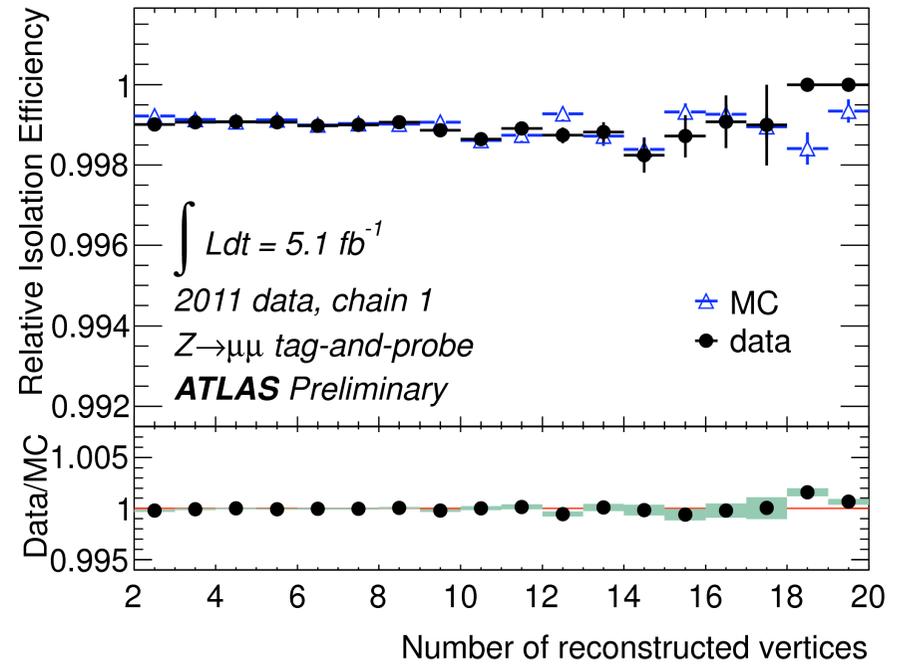
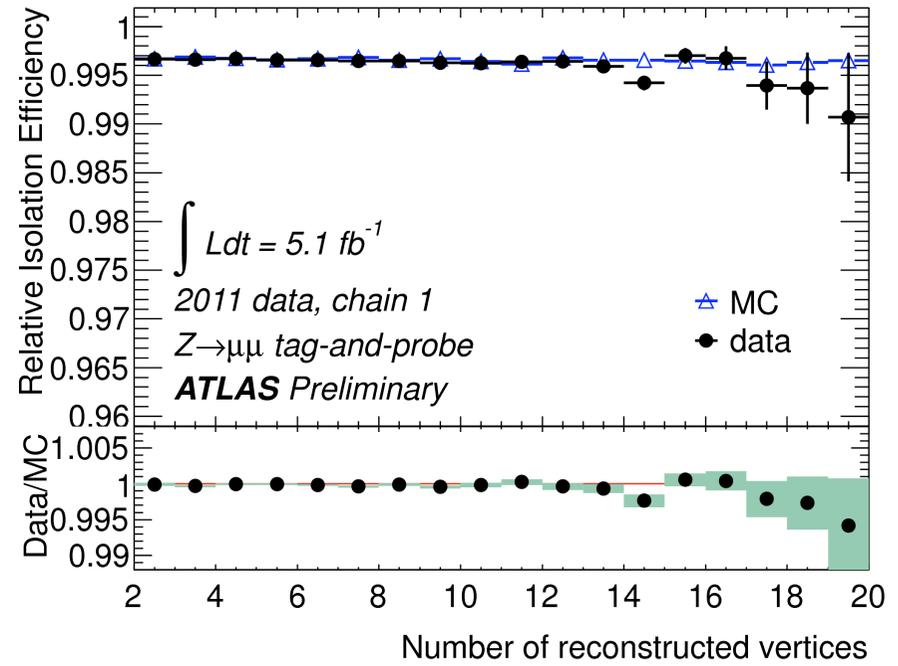
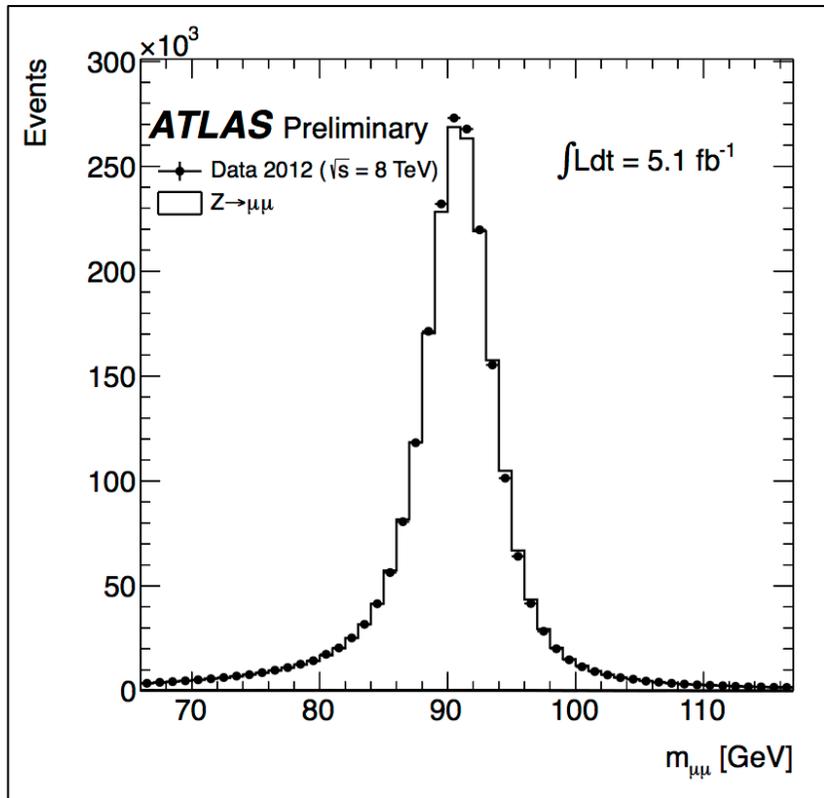
Table 6: Number of expected signal events per category at  $m_H = 126.5$  GeV, at  $\sqrt{s} = 7$  TeV (top) and  $\sqrt{s} = 8$  TeV (bottom) and breakdown by production process.

$\sqrt{s}$	Category	Events	$gg \rightarrow H$ [%]	VBF [%]	$WH$ [%]	$ZH$ [%]	$ttH$ [%]
7 TeV	Inclusive	79.3	87.8	7.3	2.9	1.6	0.4
	Unconverted central, low $p_{Tt}$	10.4	92.9	4.0	1.8	1.0	0.2
	Unconverted central, high $p_{Tt}$	1.5	66.5	15.7	9.9	5.7	2.4
	Unconverted rest, low $p_{Tt}$	21.6	92.8	3.9	2	1.1	0.2
	Unconverted rest, high $p_{Tt}$	2.7	65.4	16.1	10.8	6.1	1.8
	Converted central, low $p_{Tt}$	6.7	92.8	4.0	1.9	1.0	0.2
	Converted central, high $p_{Tt}$	1.0	66.6	15.3	10	5.7	2.5
	Converted rest, low $p_{Tt}$	21.0	92.8	3.8	2.0	1.1	0.2
	Converted rest, high $p_{Tt}$	2.7	65.3	16.0	11.0	5.9	1.8
	Converted transition	9.5	89.4	5.2	3.3	1.7	0.3
2-jets	2.2	22.5	76.7	0.4	0.2	0.1	
8 TeV	Inclusive	111.6	88.5	7.4	2.7	1.6	0.5
	Unconverted central, low $p_{Tt}$	14.4	92.9	4.2	1.7	1.0	0.2
	Unconverted central, high $p_{Tt}$	2.5	72.5	14.1	6.9	4.2	2.3
	Unconverted rest, low $p_{Tt}$	31.4	92.5	4.1	2.0	1.1	0.2
	Unconverted rest, high $p_{Tt}$	5.3	72.1	13.8	7.8	4.6	1.7
	Converted central, low $p_{Tt}$	9.1	92.8	4.3	1.7	1.0	0.3
	Converted central, high $p_{Tt}$	1.6	72.7	13.7	7.1	4.1	2.3
	Converted rest, low $p_{Tt}$	27.3	92.5	4.2	2.0	1.1	0.2
	Converted rest, high $p_{Tt}$	4.6	70.8	14.4	8.3	4.7	1.7
	Converted transition	13.0	88.8	6.0	3.1	1.8	0.4
2-jets	2.9	30.4	68.4	0.4	0.2	0.2	

# Z → ee lineshape e confronto con la simulazione



# Performance muoni: Isolamento Risoluzione



# H4l: valutazione del fondo "riducibile": Z+jets, ttbar

Logica:

campione "background-enriched" su dati  
MC per estrapolare a regione di segnale

(1)  $ll+\mu\mu$ : dominano Zbb e ttbar

→ per la coppia di muoni sub-leading:

NO richiesta isolamento

1  $\mu$  NO puntamento al vertice

Spettro M12 discriminante tra le due  
componenti

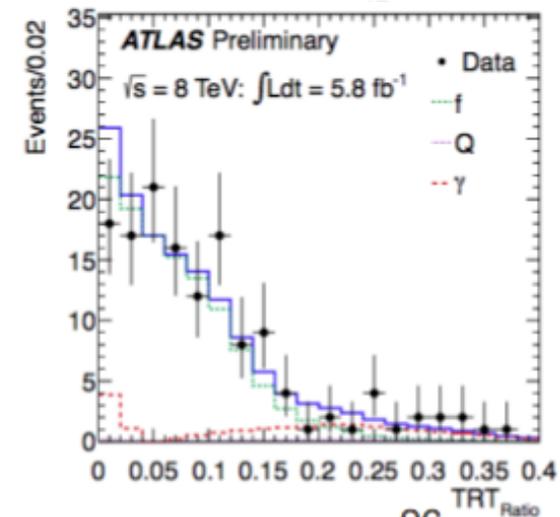
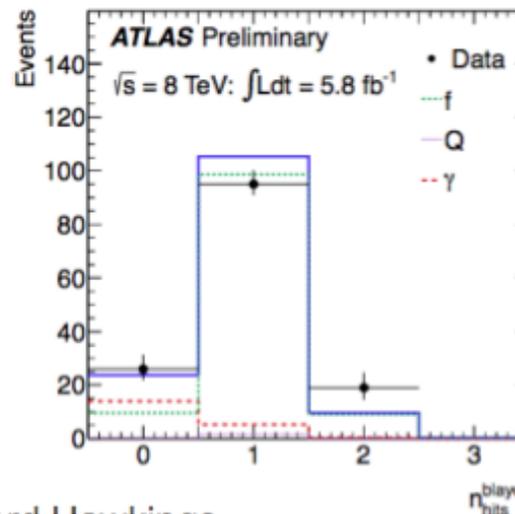
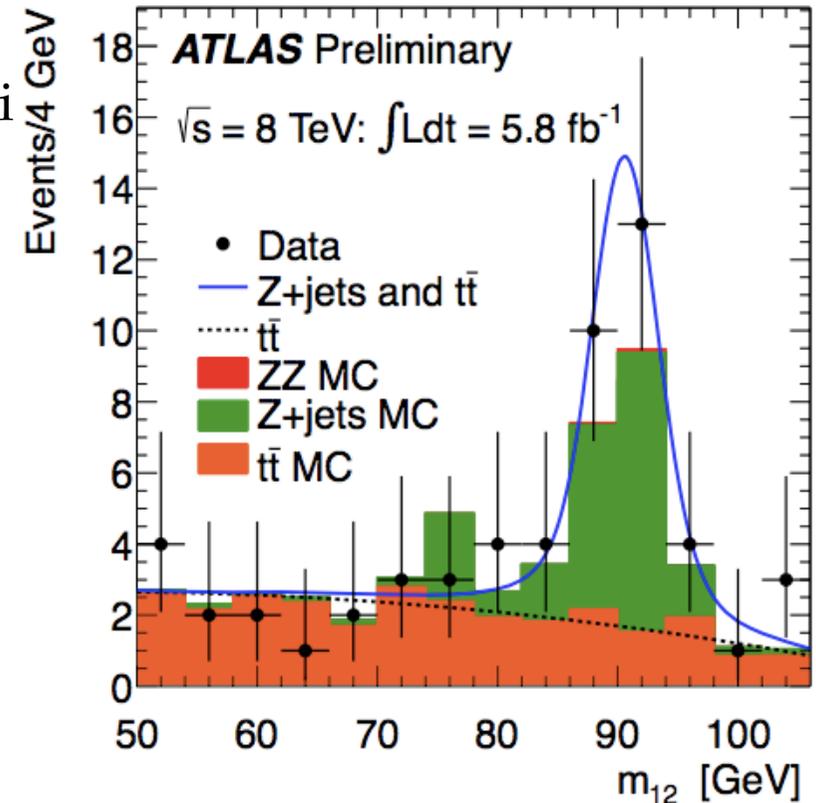
(2)  $ll+ee$ : domina Z+jets "γ fake e"

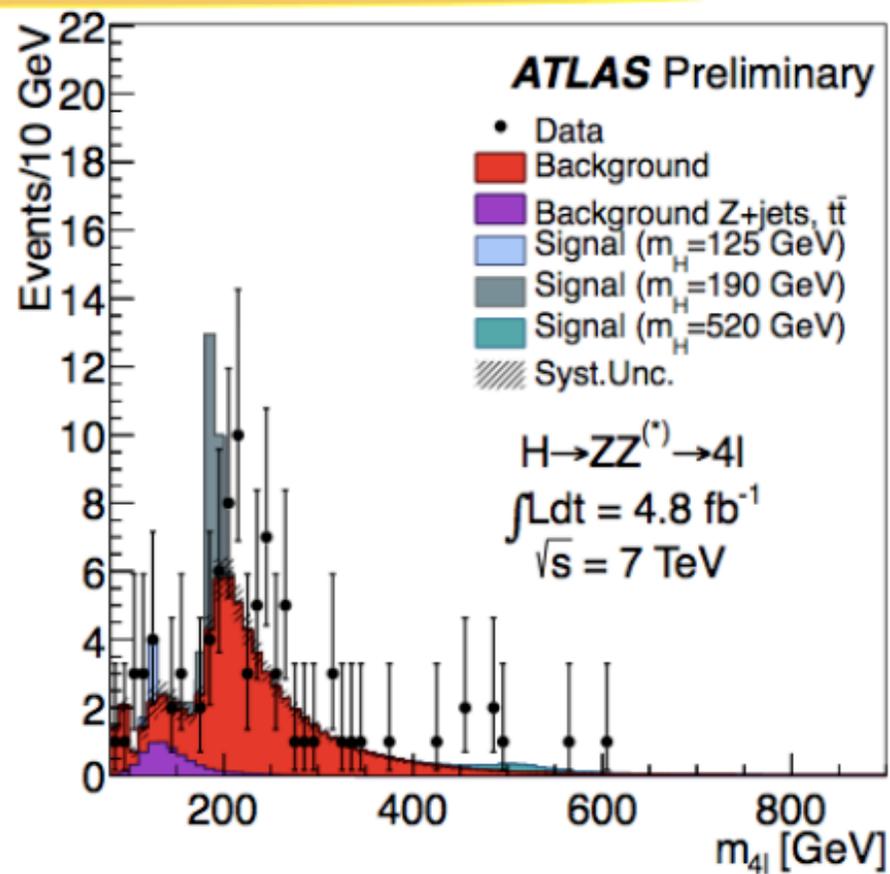
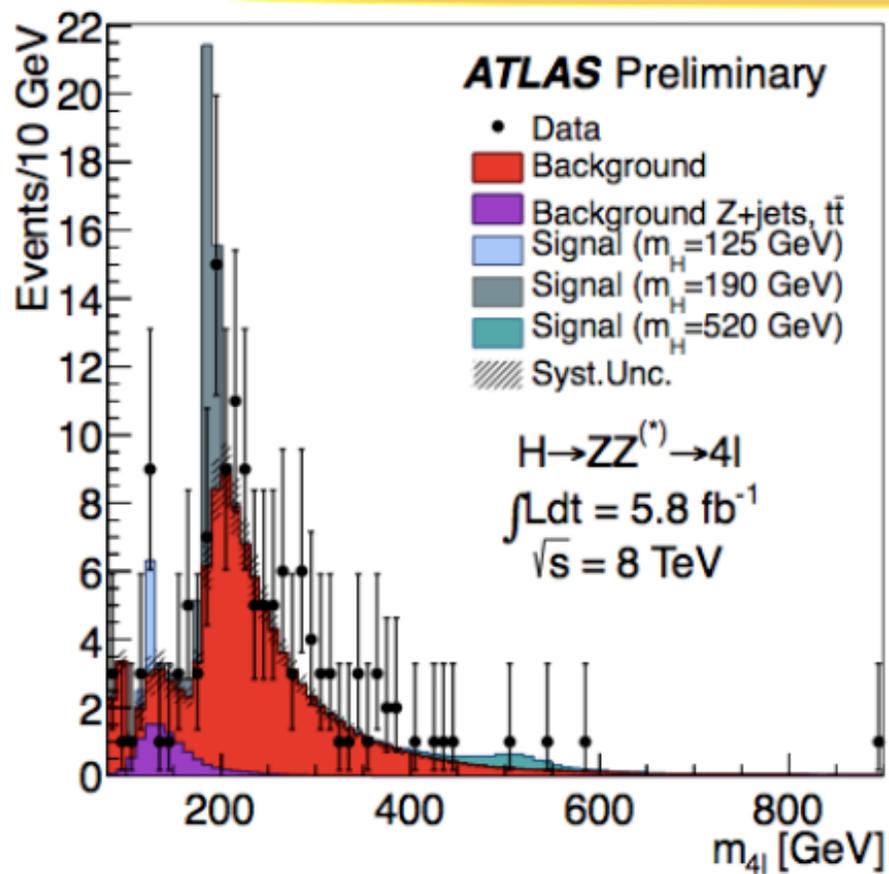
→ per la coppia di elettroni sub-leading:

NO B-layer hits

Alto TRT-ratio

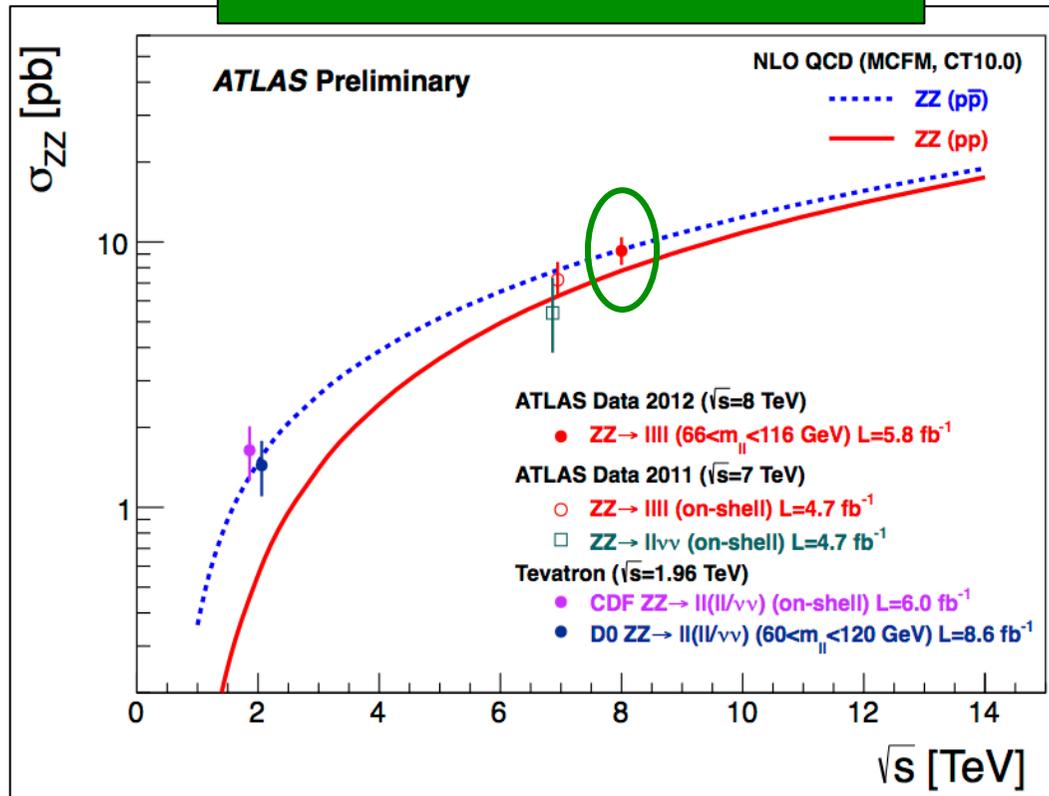
Controllo con selezione  
"same-sign"





Misura della sezione d'urto  $pp \rightarrow ZZ$  a 7 TeV e 8 TeV:  
 Nel canale  $ZZ \rightarrow 4l$   $\sigma(ZZ) > \sigma_{SM}(ZZ)$

Measured  $\sigma(ZZ) = 9.3 \pm 1.2$  pb  
 SM (NLO)  $\sigma(ZZ) = 7.4 \pm 0.4$  pb

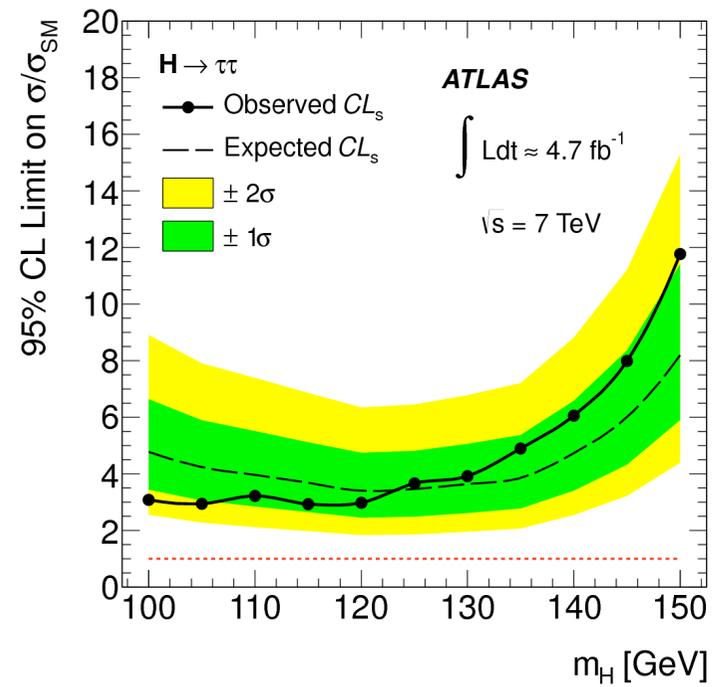
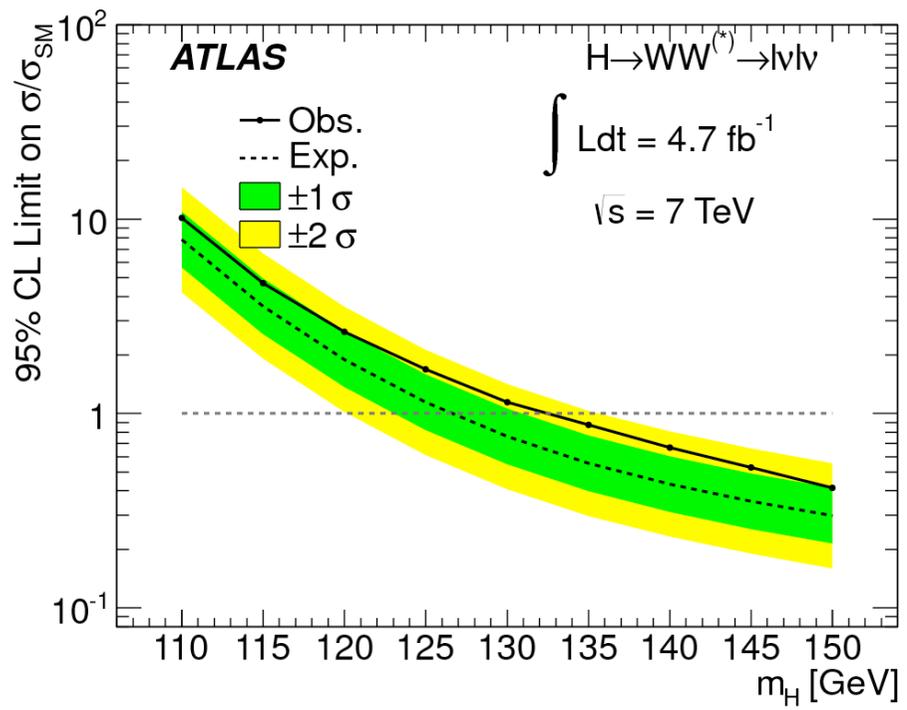
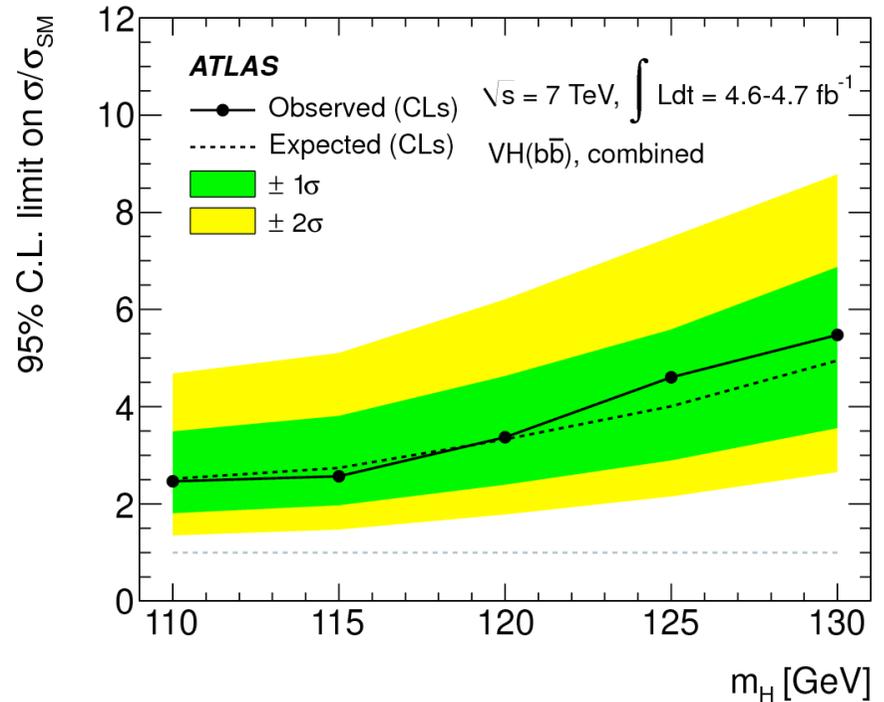


# Limiti pubblicati (dati 2011)

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

$$VH \rightarrow b\bar{b}$$

$$H \rightarrow \tau\tau$$



# ATLAS Exotics Searches\* - 95% CL Lower Limits (Status: ICHEP 2012)

Extra dimensions  
 CI  
 V  
 LQ  
 New quarks  
 Excit. ferm.  
 Other

Large ED (ADD) : monojet  
 Large ED (ADD) : monophoton  
 Large ED (ADD) : diphoton  
 UED :  $\gamma\gamma + E_{T,miss}$   
 RS1 with  $k/M_{Pl} = 0.1$  : diphoton,  $m_{\gamma\gamma}$   
 RS1 with  $k/M_{Pl} = 0.1$  : dilepton,  $m_{ll}$   
 RS1 with  $k/M_{Pl} = 0.1$  : ZZ resonance,  $m_{llll} / lljj$   
 RS1 with  $k/M_{Pl} = 0.1$  : WW resonance,  $m_{T,lvlv}$   
 RS with  $g_{ggKK} / g_s = -0.20$  :  $tt \rightarrow l+jets$ ,  $m_{ll}$   
 RS with  $BR(g_{KK} \rightarrow tt) = 0.925$  :  $tt \rightarrow l+jets$ ,  $m_{ll}$   
 ADD BH ( $M_{TH} / M_D = 3$ ) : SS dimuon,  $N_{ch,part}$   
 ADD BH ( $M_{TH} / M_D = 3$ ) : leptons + jets,  $\Sigma p_T$   
 Quantum black hole : dijet,  $F(m_{ij})$   
 qqqq contact interaction :  $\chi(m_{ij})$   
 qqll CI :  $ee, \mu\mu$  combined,  $m_{ll}$   
 uutt CI : SS dilepton + jets +  $E_{T,miss}$   
 Z' (SSM) :  $m_{ee/\mu\mu}$   
 Z' (SSM) :  $m_{ee/\mu\mu}$   
 Z' (SSM) :  $m_{tt}$   
 W' (SSM) :  $m_{T,e/\mu}$   
 W' ( $\rightarrow tq, g_s=1$ ) :  $m_{tq}$   
 W' ( $\rightarrow tb, SSM$ ) :  $m_{tb}$   
 Scalar LQ pairs ( $\beta=1$ ) : kin. vars. in  $eejj, evjj$   
 Scalar LQ pairs ( $\beta=1$ ) : kin. vars. in  $\mu\mu jj, \mu\nu jj$   
 4<sup>th</sup> generation :  $Q \bar{Q}_4 \rightarrow WqWq$   
 4<sup>th</sup> generation :  $u \bar{u}_4 \rightarrow WbWb$   
 4<sup>th</sup> generation :  $d \bar{d}_4 \rightarrow WtWt$   
 New quark b' :  $b \bar{b}' \rightarrow Zb+X, m_{T2}$   
 TT<sub>top partner</sub>  $\rightarrow tt + A_0 A_0$  : 2-lep + jets +  $E_{T,miss}$  ( $M_{T2}$ )  
 Vector-like quark : CC,  $m_{lvq}$   
 Vector-like quark : NC,  $m_{lq}$   
 Excited quarks :  $\gamma$ -jet resonance,  $m_{\gamma jet}$   
 Excited quarks : dijet resonance,  $m_{ll}$   
 Excited electron : e- $\gamma$  resonance,  $m_{e\gamma}$   
 Excited muon :  $\mu$ - $\gamma$  resonance,  $m_{\mu\gamma}$   
 Techni-hadrons : dilepton,  $m_{ee/\mu\mu}$   
 Techni-hadrons : WZ resonance ( $\nu ll$ ),  $m_{T,WZ}$   
 Major. neutr. (LRSM, no mixing) : 2-lep + jets  
 W<sub>R</sub> (LRSM, no mixing) : 2-lep + jets  
 H<sub>L</sub><sup>±±</sup> (DY prod., BR(H<sub>L</sub><sup>±±</sup> → μμ)=1) : SS dimuon,  $m_{\mu\mu}$   
 Color octet scalar : dijet resonance,  $m_{ll}$

L=4.7 fb <sup>-1</sup> , 7 TeV [CONF-2012-TBC]	3.8 TeV	M <sub>D</sub> (δ=2)
L=4.6 fb <sup>-1</sup> , 7 TeV [CONF-2012-TBC]	1.7 TeV	M <sub>D</sub> (δ=2)
L=2.1 fb <sup>-1</sup> , 7 TeV [1112.2194]	3.0 TeV	M <sub>S</sub> (GRW cut-off)
L=4.8 fb <sup>-1</sup> , 7 TeV [CONF-2012-TBC]	1.41 TeV	Compact. scale 1/R
L=4.9 fb <sup>-1</sup> , 7 TeV [CONF-2012-TBC]	2.06 TeV	Graviton mass
L=4.9-5.0 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-007]	2.16 TeV	Graviton mass
L=1.0 fb <sup>-1</sup> , 7 TeV [1203.0718]	845 GeV	Graviton mass
L=4.7 fb <sup>-1</sup> , 7 TeV [CONF-2012-TBC]	1.23 TeV	Graviton mass
L=2.1 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-029]	1.03 TeV	KK gluon mass
L=2.1 fb <sup>-1</sup> , 7 TeV [CONF-2012-TBC]	1.50 TeV	KK gluon mass
L=1.3 fb <sup>-1</sup> , 7 TeV [1111.0080]	1.25 TeV	M <sub>D</sub> (δ=6)
L=1.0 fb <sup>-1</sup> , 7 TeV [1204.4646]	1.5 TeV	M <sub>D</sub> (δ=6)
L=4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-038]	4.11 TeV	M <sub>D</sub> (δ=6)
L=4.8 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-038]	7.8 TeV	Λ
L=1.1-1.2 fb <sup>-1</sup> , 7 TeV [1112.4462]	10.2 TeV	Λ (constructive int.)
L=1.0 fb <sup>-1</sup> , 7 TeV [1202.5520]	1.7 TeV	Λ
L=4.9-5.0 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-007]	2.21 TeV	Z' mass
L=4.1 fb <sup>-1</sup> , 8 TeV [CONF-2012-TBC]	2.4 TeV	Z' mass
L=4.7 fb <sup>-1</sup> , 7 TeV [CONF-2012-TBC]	1.3 TeV	Z' mass
L=4.7 fb <sup>-1</sup> , 7 TeV [CONF-2012-TBC]	2.55 TeV	W' mass
L=4.7 fb <sup>-1</sup> , 7 TeV [CONF-2012-TBC]	350 GeV	W' mass
L=1.0 fb <sup>-1</sup> , 7 TeV [1205.1016]	1.13 TeV	W' mass
L=1.0 fb <sup>-1</sup> , 7 TeV [1112.4828]	660 GeV	1 <sup>st</sup> gen. LQ mass
L=1.0 fb <sup>-1</sup> , 7 TeV [1203.3172]	685 GeV	2 <sup>nd</sup> gen. LQ mass
L=1.0 fb <sup>-1</sup> , 7 TeV [1202.3389]	350 GeV	Q <sub>4</sub> mass
L=1.0 fb <sup>-1</sup> , 7 TeV [1202.3076]	404 GeV	u <sub>4</sub> mass
L=1.0 fb <sup>-1</sup> , 7 TeV [1202.6540]	480 GeV	d <sub>4</sub> mass
L=2.0 fb <sup>-1</sup> , 7 TeV [1204.1265]	400 GeV	b' mass
L=1.0 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-TBC]	483 GeV	T mass (m(A <sub>0</sub> ) < 100 GeV)
L=1.0 fb <sup>-1</sup> , 7 TeV [1112.5755]	900 GeV	Q mass (coupling κ <sub>qQ</sub> = v/m <sub>Q</sub> )
L=1.0 fb <sup>-1</sup> , 7 TeV [1112.5755]	760 GeV	Q mass (coupling κ <sub>qQ</sub> = v/m <sub>Q</sub> )
L=2.1 fb <sup>-1</sup> , 7 TeV [1112.3580]	2.46 TeV	q* mass
L=5.8 fb <sup>-1</sup> , 8 TeV [CONF-2012-TBC]	3.66 TeV	q* mass
L=4.9 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-023]	2.0 TeV	e* mass (Λ = m(e*))
L=4.8 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-023]	1.9 TeV	μ* mass (Λ = m(μ*))
L=1.1-1.2 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2011-125]	470 GeV	ρ <sub>1</sub> /ω <sub>τ</sub> mass (m(ρ <sub>1</sub> /ω <sub>τ</sub> ) - m(π <sub>τ</sub> ) = 100 GeV)
L=1.0 fb <sup>-1</sup> , 7 TeV [1204.1648]	483 GeV	ρ <sub>τ</sub> mass (m(ρ <sub>τ</sub> ) = m(π <sub>τ</sub> ) + m <sub>W</sub> , m(a <sub>τ</sub> ) = 1.1 m(ρ <sub>τ</sub> ))
L=2.1 fb <sup>-1</sup> , 7 TeV [1203.5420]	1.5 TeV	N mass (m(W <sub>R</sub> ) = 2 TeV)
L=2.1 fb <sup>-1</sup> , 7 TeV [1203.5420]	2.4 TeV	W <sub>R</sub> mass (m(N) < 1.4 GeV)
L=1.6 fb <sup>-1</sup> , 7 TeV [1201.1091]	355 GeV	H <sub>L</sub> <sup>±±</sup> mass
L=4.8 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-038]	1.94 TeV	Scalar resonance mass

**ATLAS**  
 Preliminary

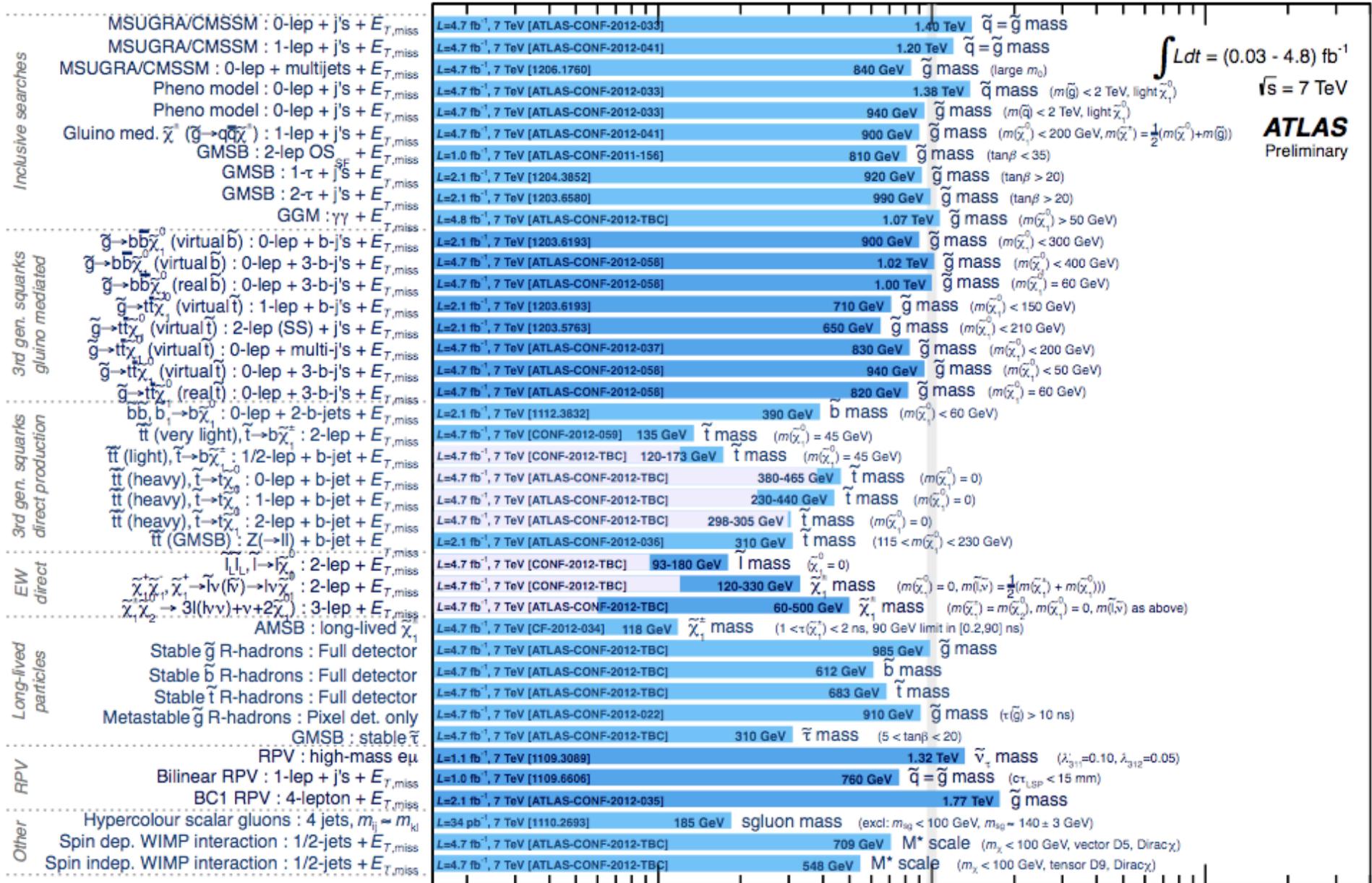
$$\int L dt = (1.0 - 5.8) \text{ fb}^{-1}$$

$$\sqrt{s} = 7, 8 \text{ TeV}$$



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

# ATLAS SUSY Searches\* - 95% CL Lower Limits (Status: ICHEP 2012)



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

Mass scale [TeV]

- 3 neutral Higgs bosons  $\Phi$  in MSSM:  $h$ ,  $H$  and  $A$ 
  - Production via gluon fusion and b-quark annihilation
    - Cross-sections rise with  $\tan\beta$ , b-assoc. becomes dominant
  - Decay into  $b\text{-}\bar{b}$  (90%),  $\tau\tau$  (10%),  $\mu\mu$  (0.04%)
- Search in both b-tagged and b-vetoed samples
  - $\mu\mu$ : clean signature, good mass resolution, but low rates
  - $\tau\tau$ : Similar to SM  $H\rightarrow\tau\tau$  but with b-tagged/vetoed sel
  - Set limits in  $(m_A, \tan\beta)$  plane and generically on  $\sigma\text{.BR}$

