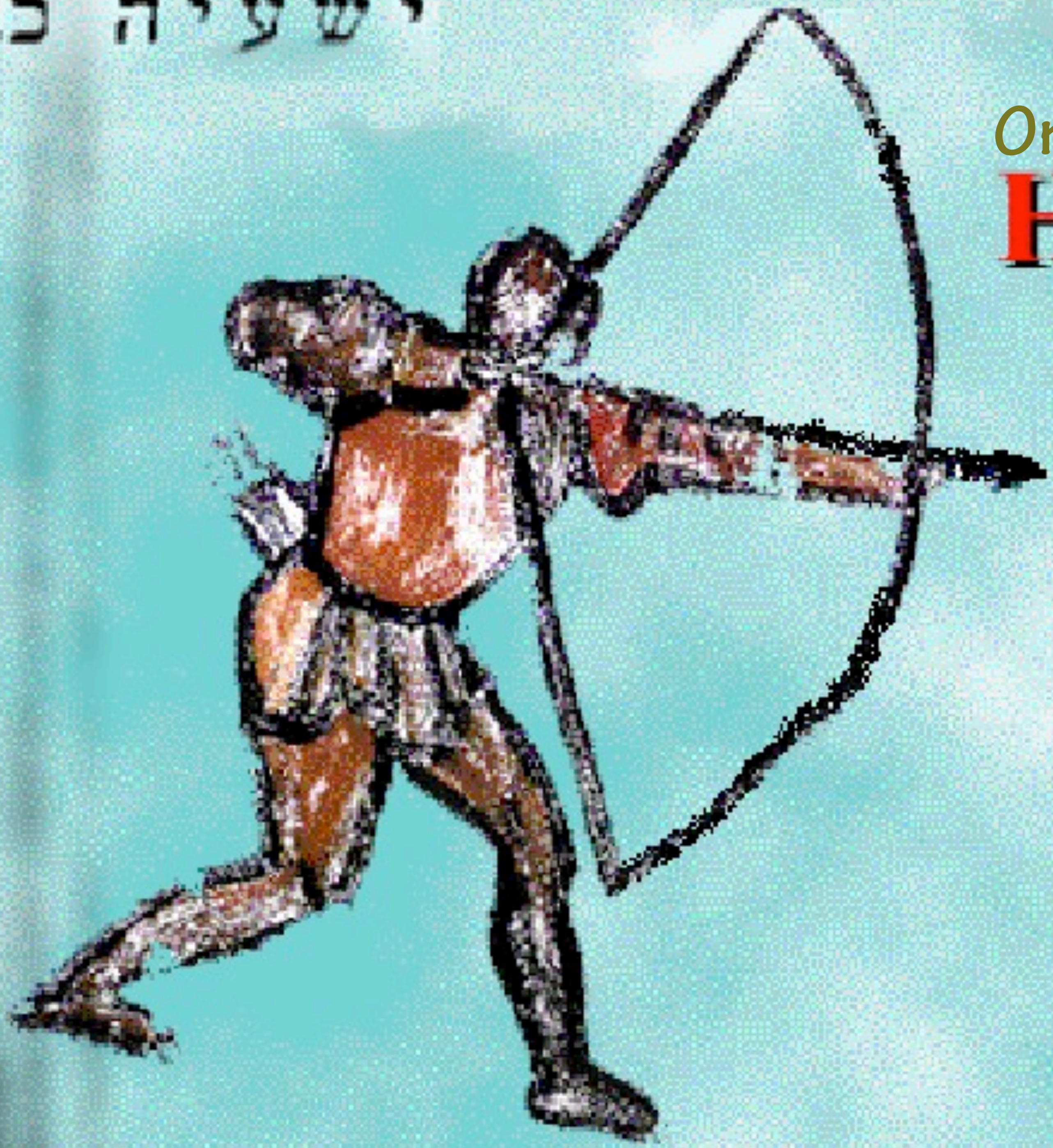
"וְעֵילָם נָשָׂא אַשְׁפָּה..."

ישעיה כב

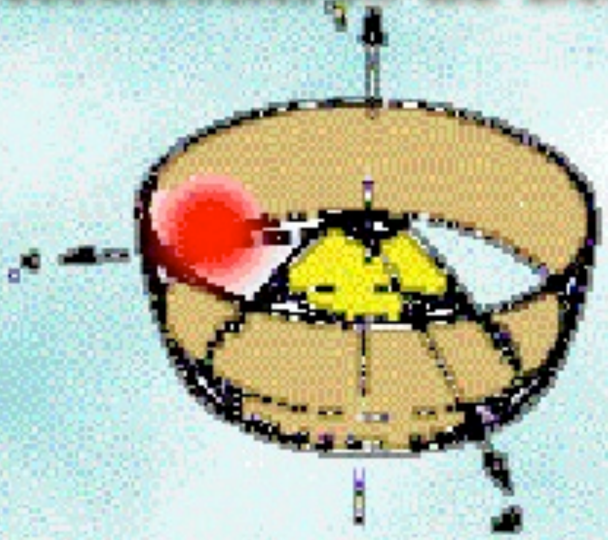


Eilam Gross

On behalf of the ATLAS collaboration

Hunting the Higgs

24th Rencontres de Blois



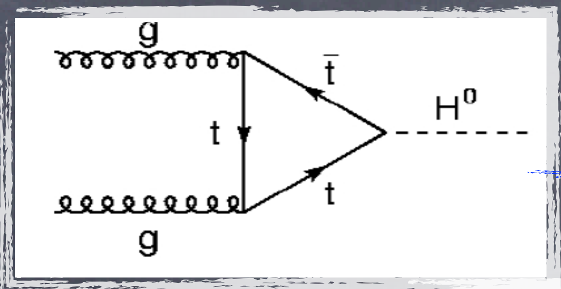
Thanks to many people

"And Eilam bare the quiver..."

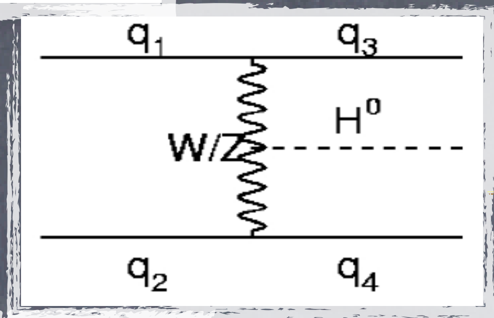
Jesaia 22

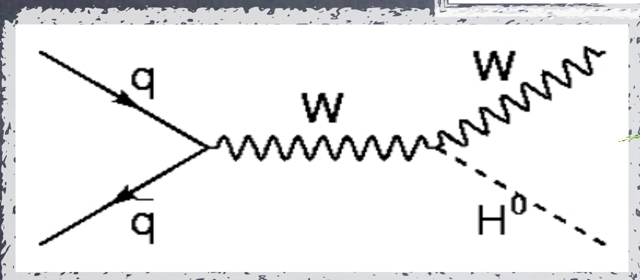

SUX 1

Higgs Production

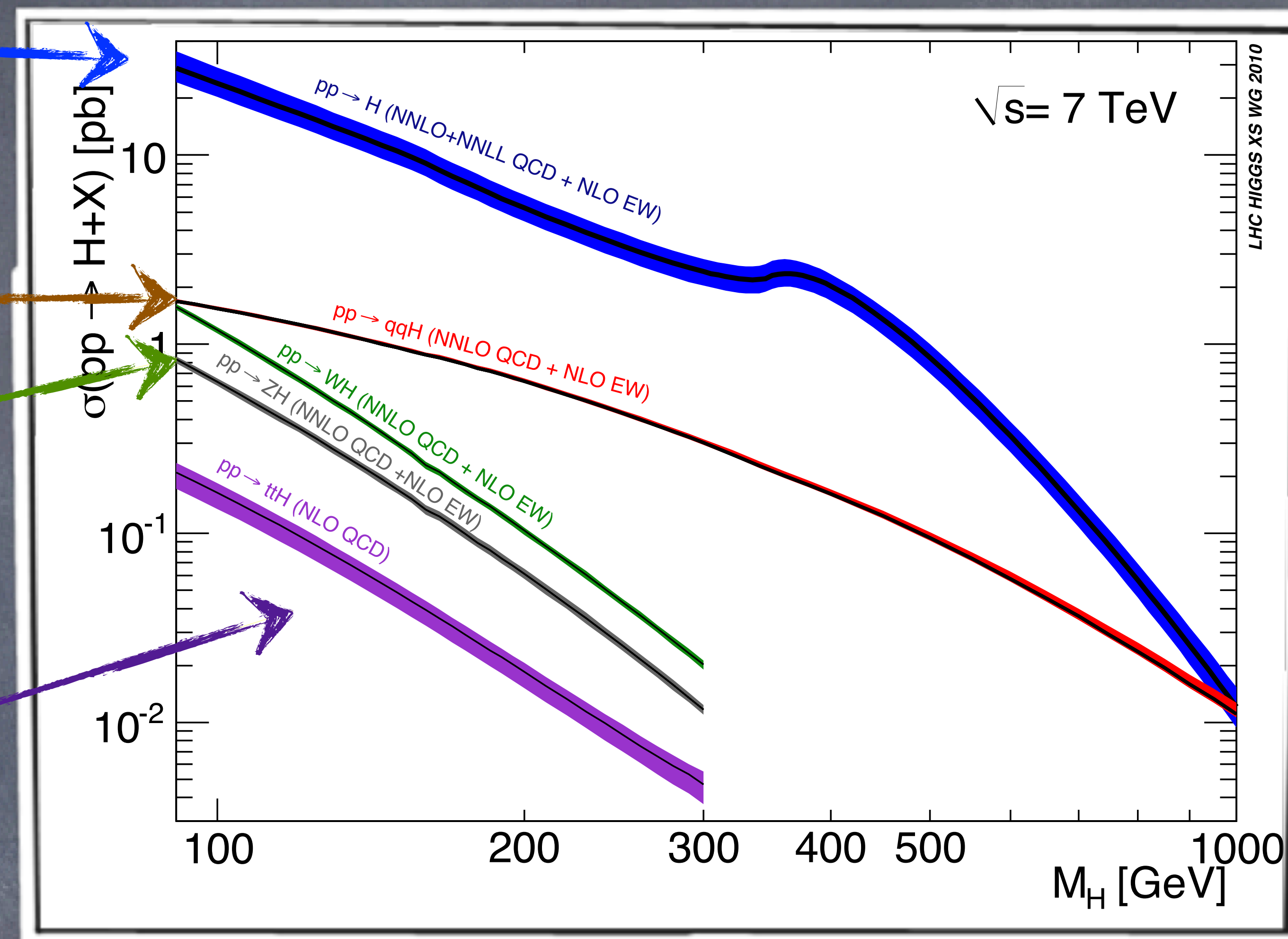


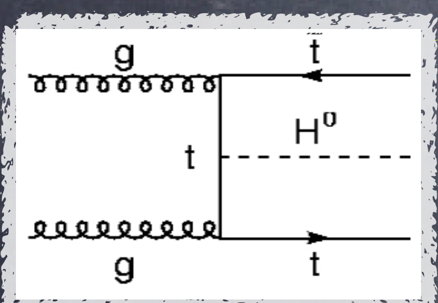
is x10





is even smaller, yet distinct



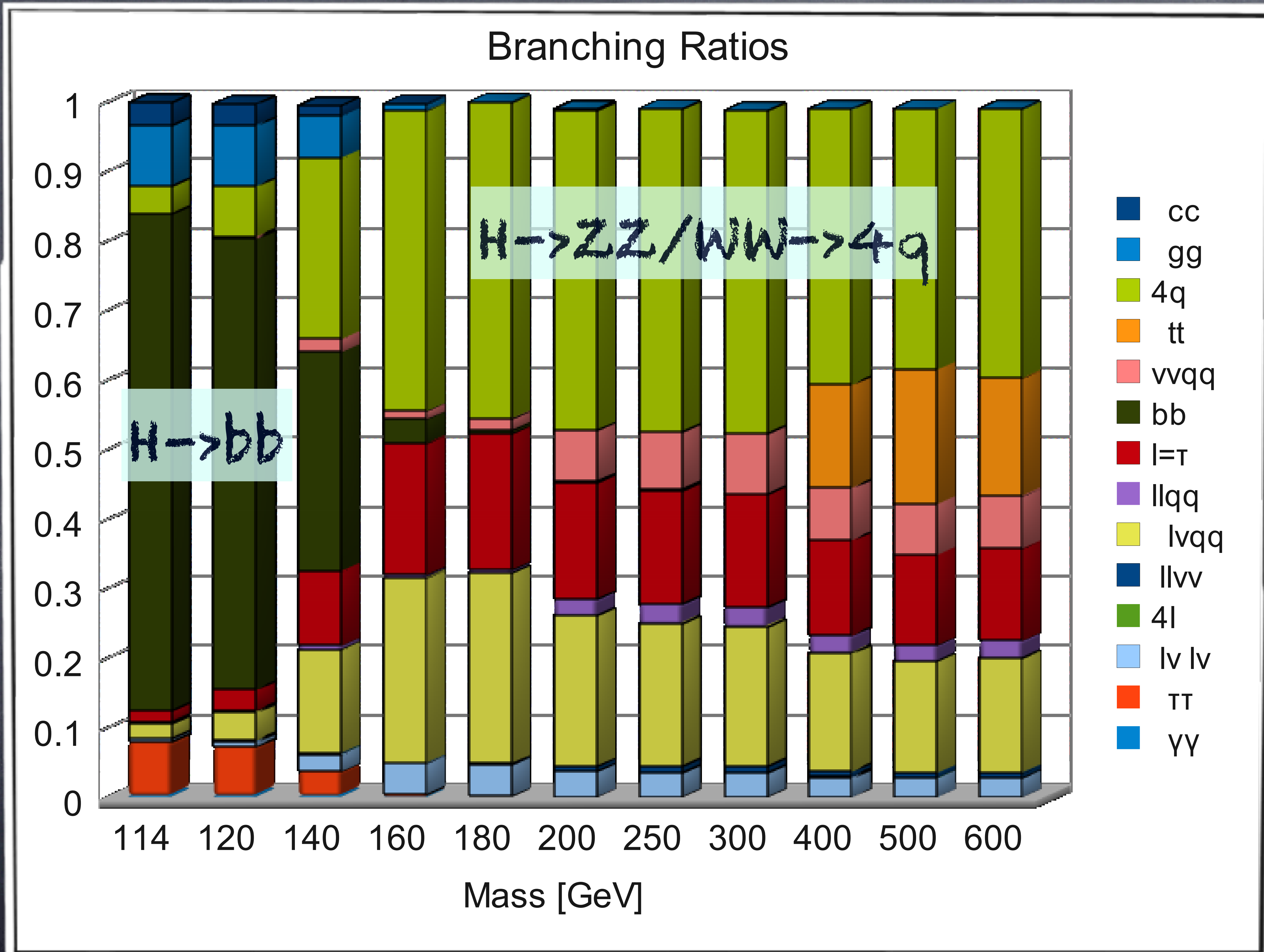


is the smallest and also difficult

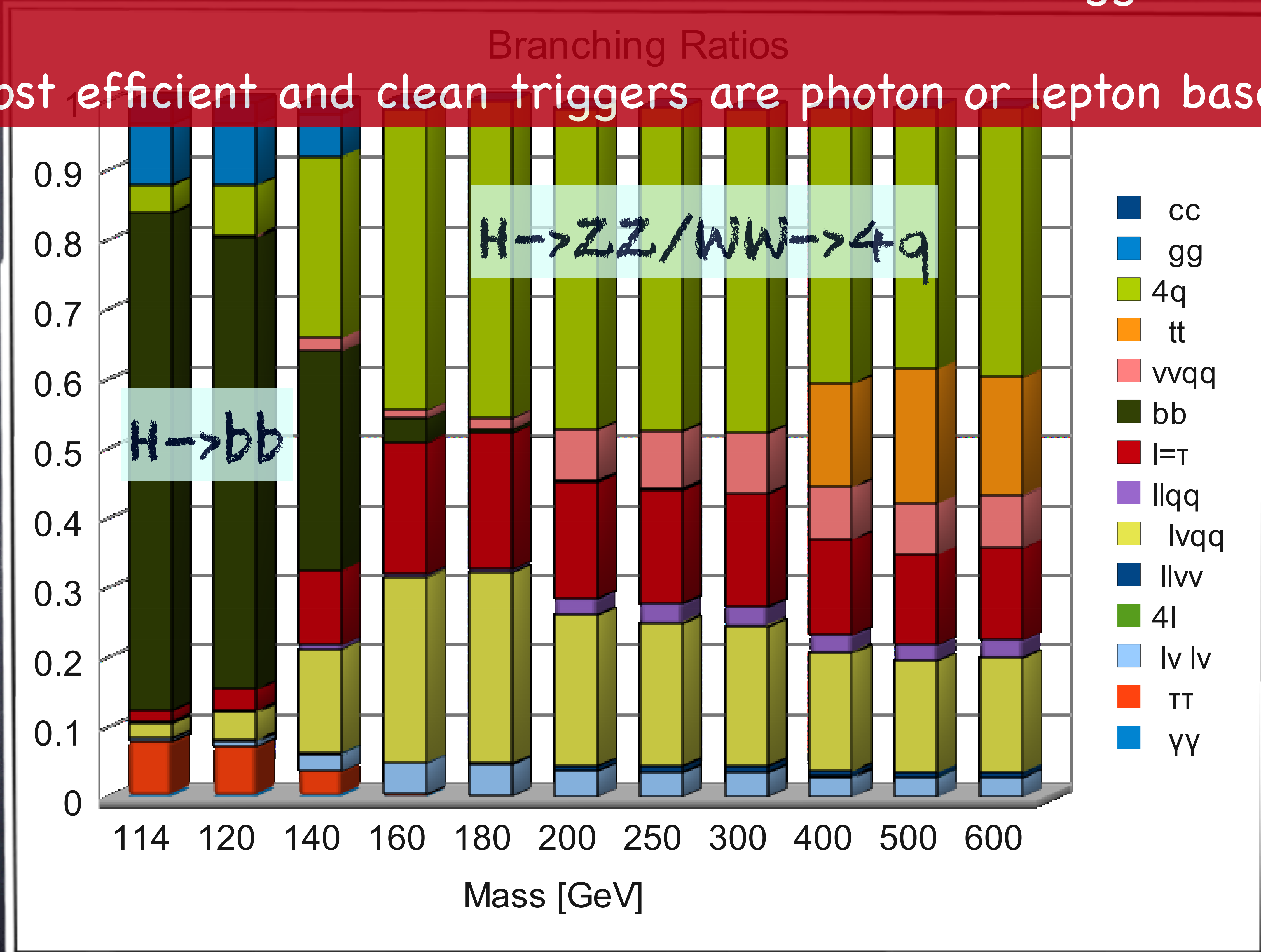
Typical size of uncertainties (exact values depend on M_H):

	ggF	VBF	WH/ZH	$t\bar{t}H$
QCD scale:	$^{+12\%}_{-8\%}$	$\pm1\%$	$\pm1\%$	$^{+3\%}_{-9\%}$
PDF + α_s:	$\pm8\%$	$\pm4\%$	$\pm4\%$	$\pm8\%$
Mass line shape:	$(150\%) \times \left(\frac{M_H}{TeV}\right)^3$			

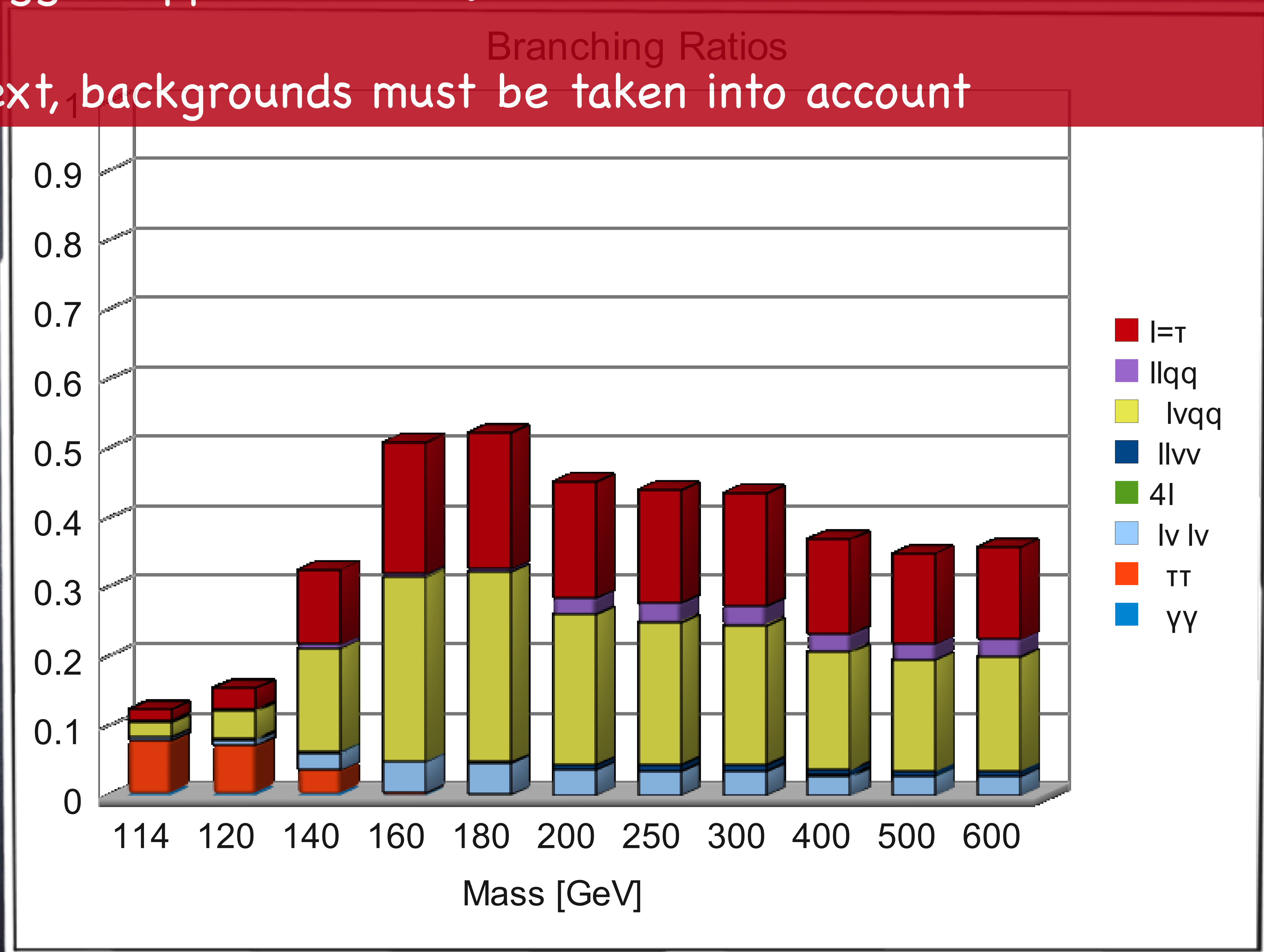
Higgs Decay Rates



- For a channel to be usable, we must be able to trigger it
- Most efficient and clean triggers are photon or lepton based

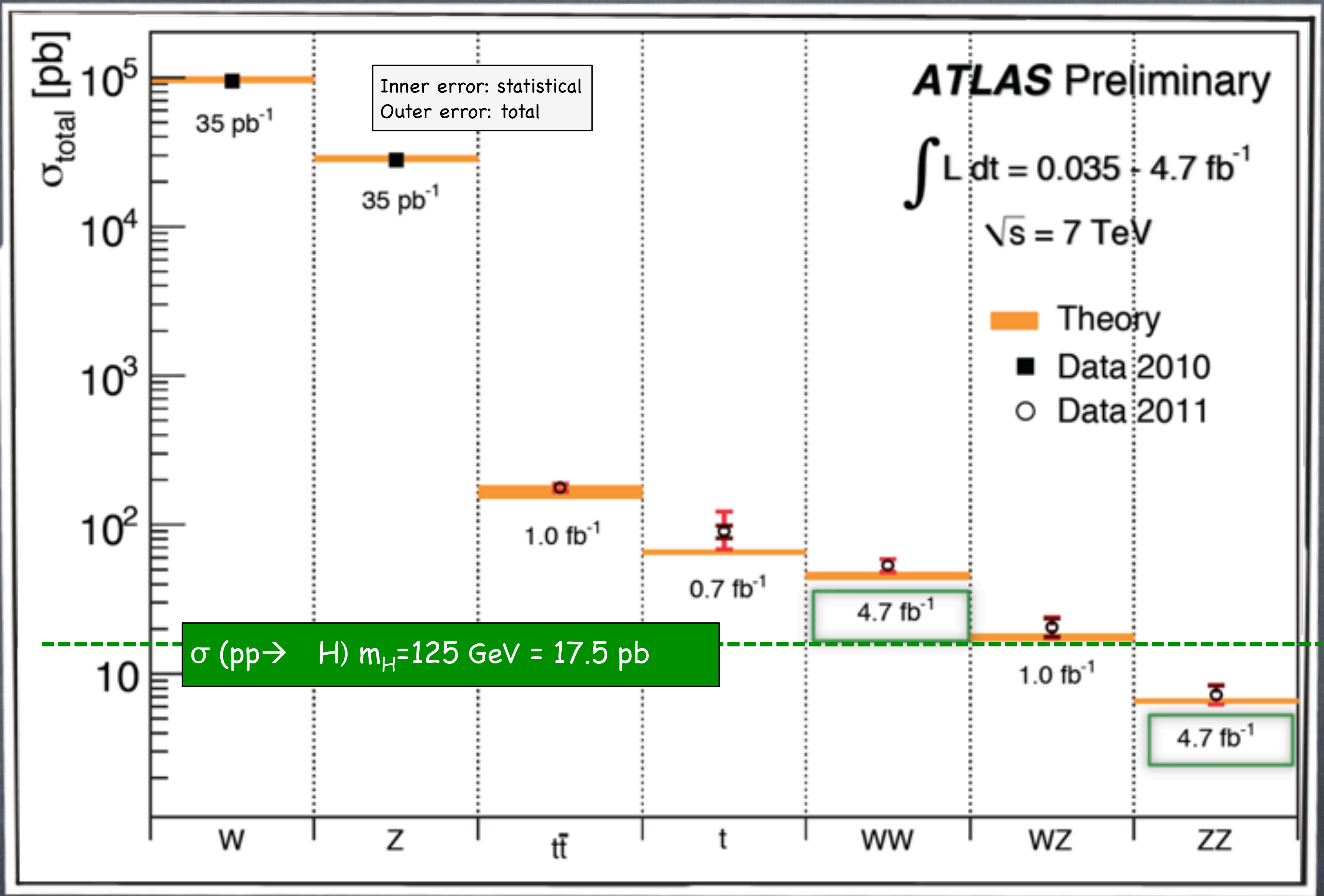


- Trigger ripped off the jet channels
- Next, backgrounds must be taken into account



Electroweak measurements are **Higgs backgrounds**

See talk by daniel froidevaux tomorrow

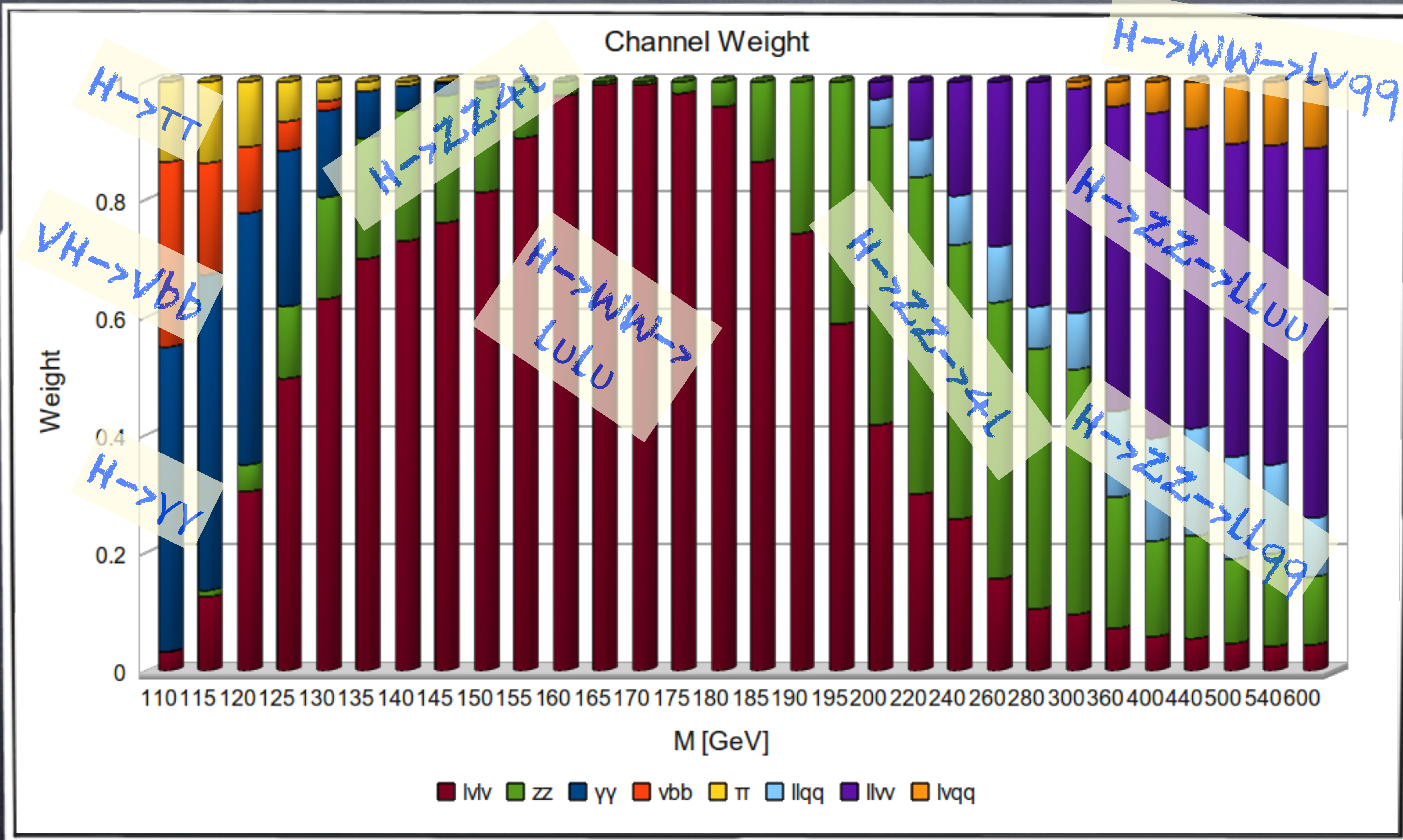


- Good agreement with theory , W, Z, tt become a challenge for theory
- Systematics dominate
- Higgs cross section same order of magnitude as Di-Boson production (WW,WZ,ZZ)

ATLAS EXPERIMENT

Channels Weight

$$w_i \simeq \frac{\left(s_i / \sqrt{s_i + b_i}\right)^2}{\sum_i \left(s_i / \sqrt{s_i + b_i}\right)^2}$$



Probing low mass & the LEP Edge

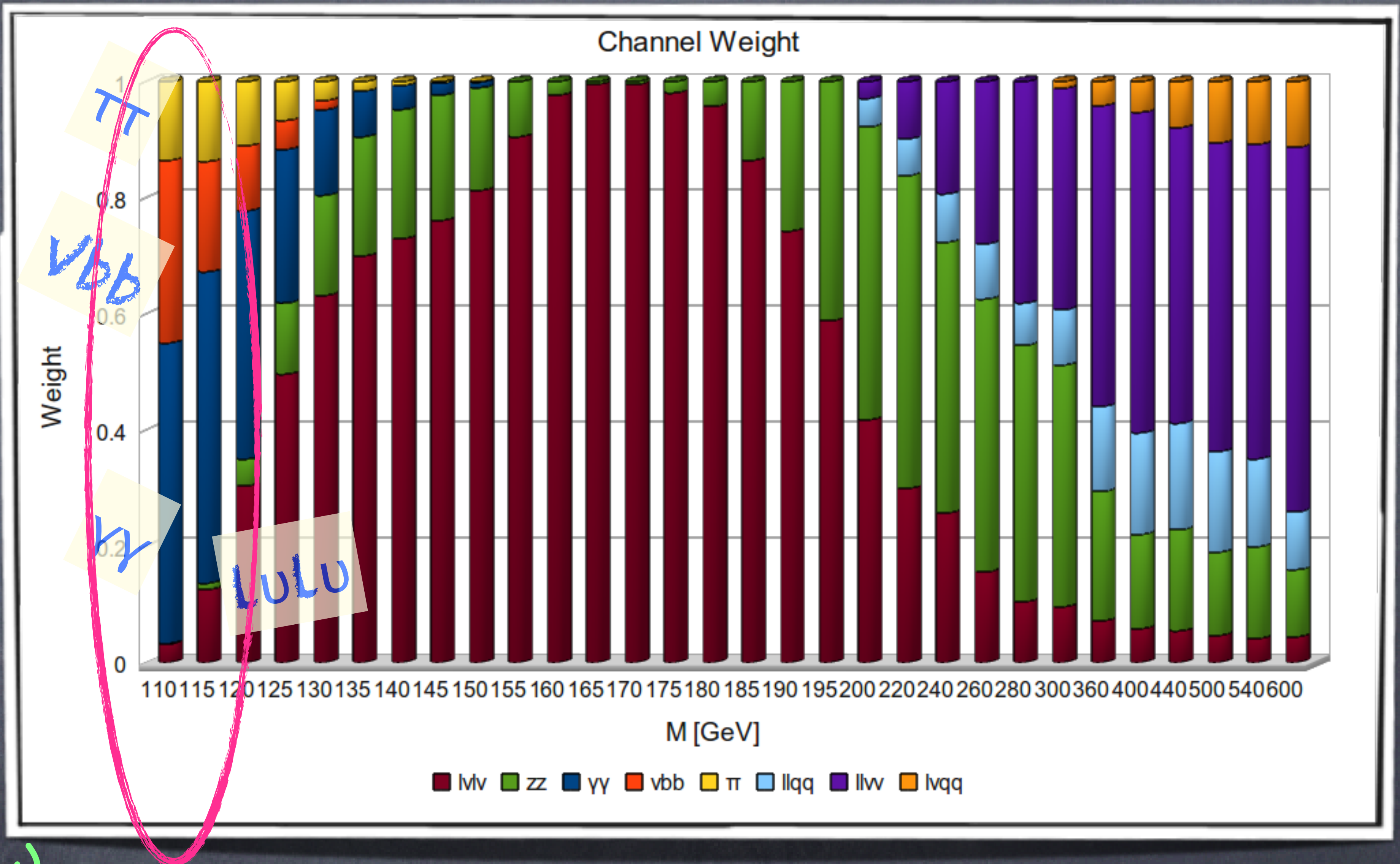
- Probing 114-140 GeV
- Probing channels:

  H->γγ

  VH-> Vbb,

  H-> ττ

  (and H->WW->lνlν)



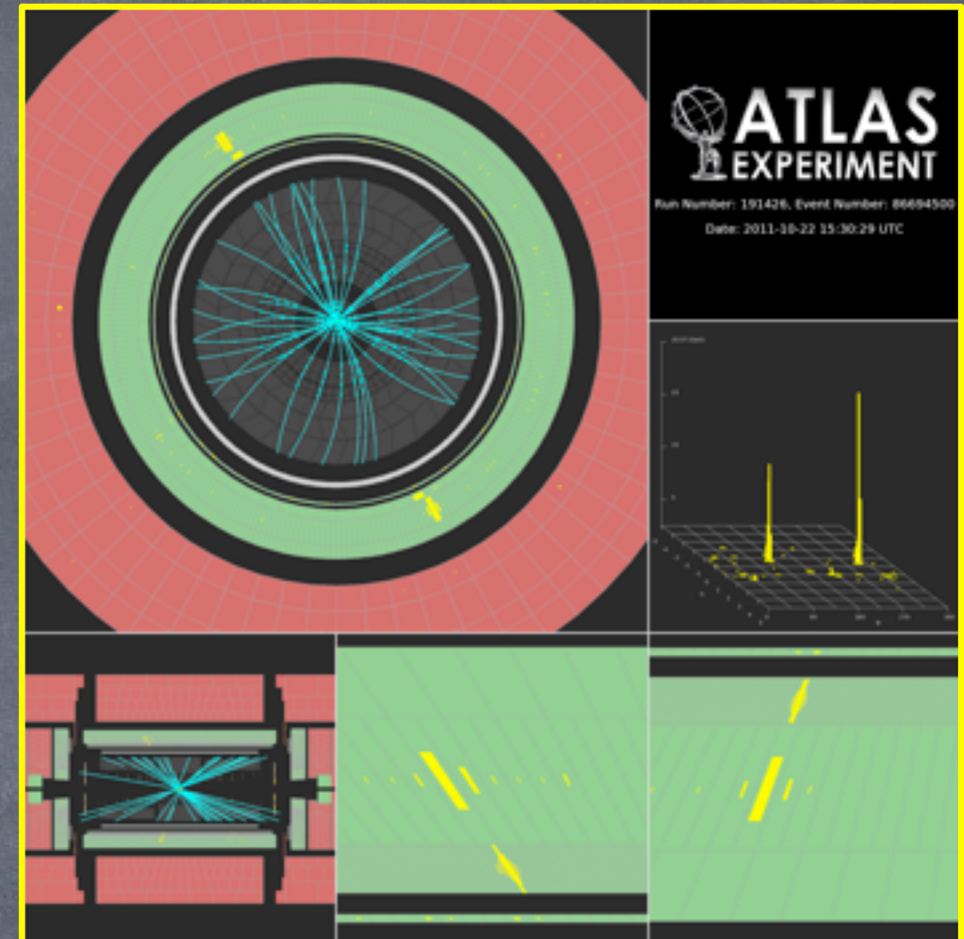
H->γγ Probing LEP 114 GeV

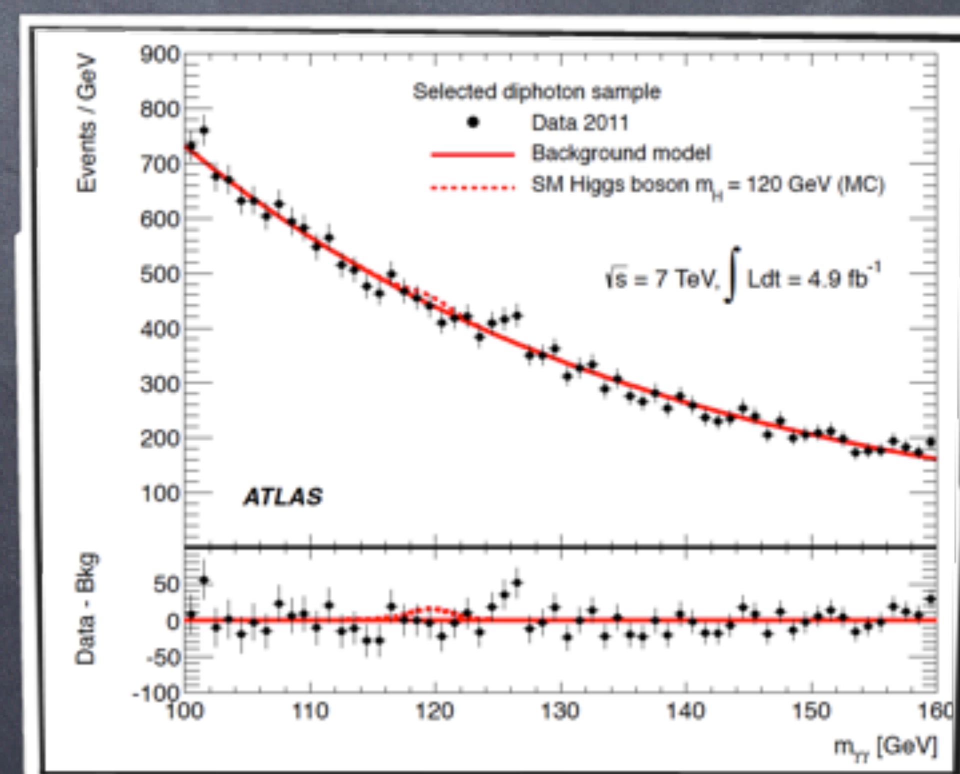
Clean signature: 2 energetic isolated photons->narrow mass peak
E^T ($\gamma 1$, $\gamma 2$) > 40, 25 GeV

A narrow peak is searched for over a large, smooth background.

Data are split into 9 categories based on direction of photons (detector region) , conversion mode (which affect γγ mass resolution, which is excellent)
and $p^T_{\gamma\gamma}$ perpendicular to γγ thrust axis

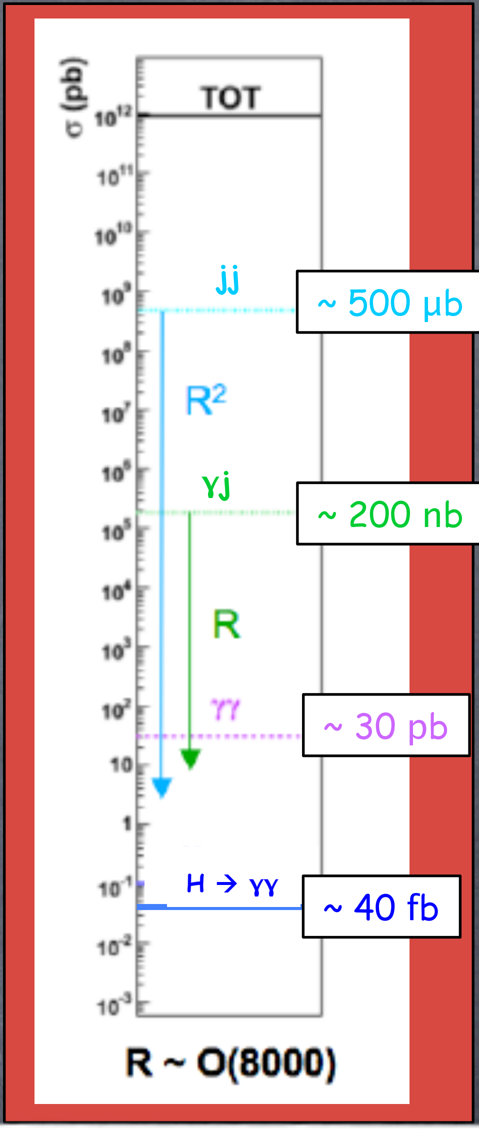
A fit is performed to the background side band under the BG only hypothesis (an exponential in EACH category)
(only data is considered)





H->γγ EXperimental Aspects

.Needs a powerful γ/jet separation to suppress γj and jj background with jet -> π^0 faking single γ

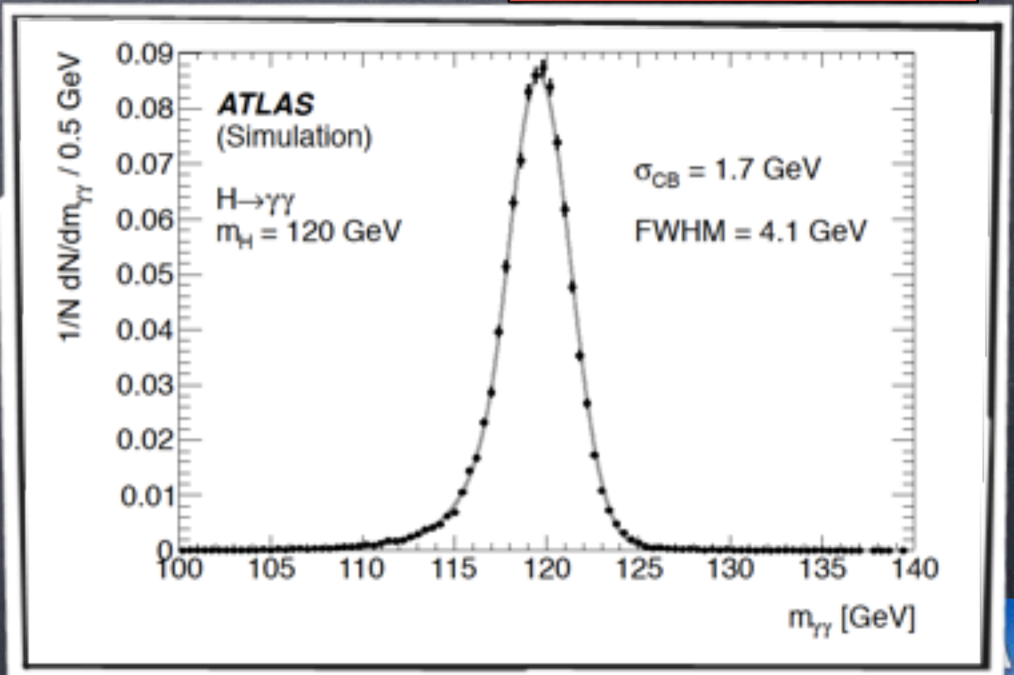


$$m^2_{\gamma_1\gamma_2} = 2E_{\gamma_1}E_{\gamma_2}\left(1 - \cos\sphericalangle(\gamma_1,\gamma_2)\right)$$

The fine longitudinal and lateral segmentation and pointing geometry of the ATLAS EM calorimeter enable good γγ angular separation and better Z-vertex determination. This is crucial in high pile up environment and in identifying fake photons from pions

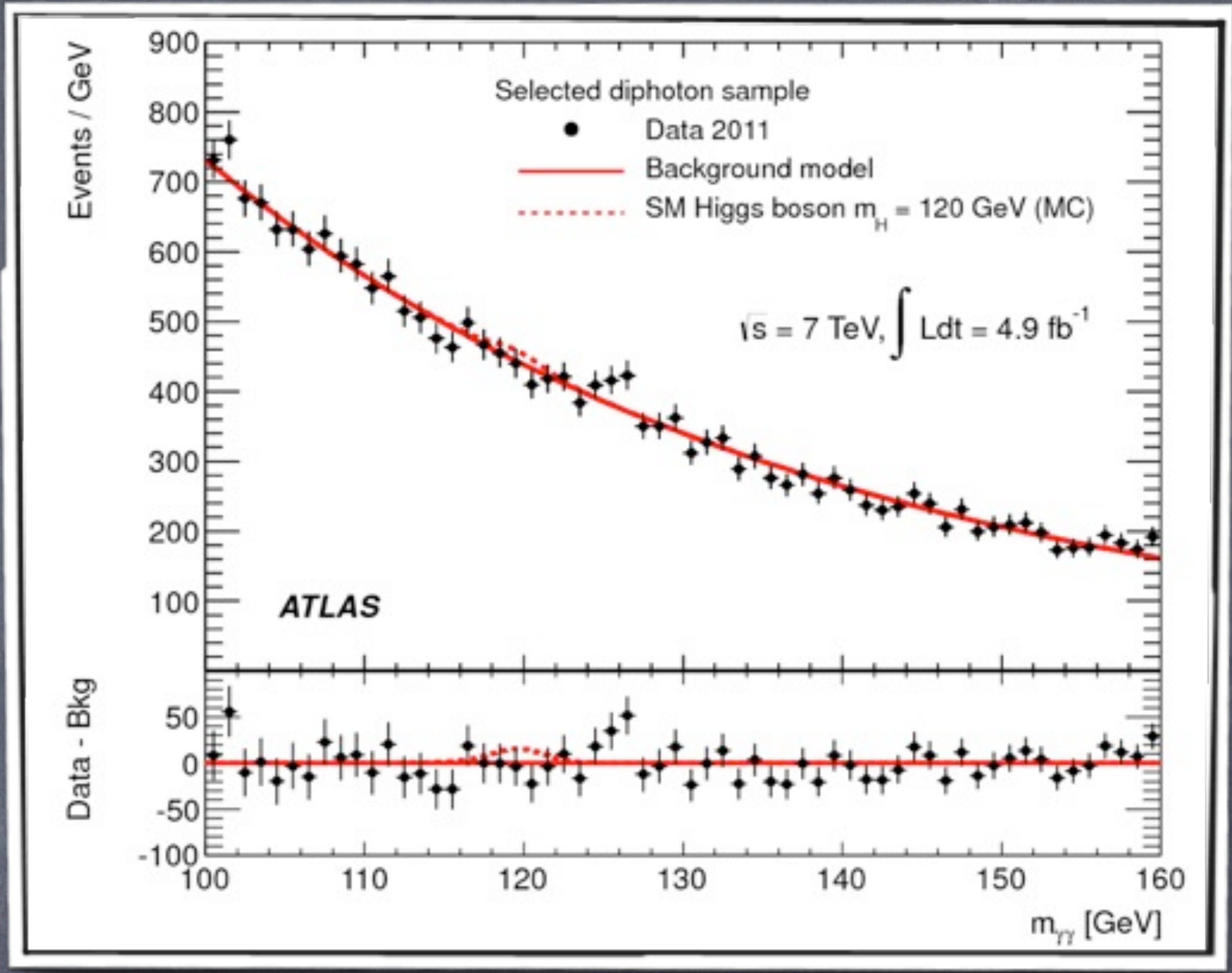
Present understanding of calorimeter E response (from tag&probe Z->ee, J/ψ ->ee, W->eν data and MC)->
Excellent mass resolution

(See talk by Christos Anastopoulos on Thursday)



H->γγ Results

- ~22500 events observed in a mass window $100<m_{\gamma\gamma}<160$ GeV
- $m_{\gamma\gamma}$ was fit (per category) with exponential function for background plus a sum of Crystal Ball and Gaussian (for tails) for signal.
- Background was fitted from data
- ~70 signal events are expected in 4.9 fb^{-1} for m_H=125 GeV
- Out of ~22500 observed events, ~3000 expected in m_H=125 GeV mass window -> S/B~2% in signal mass window



Main systematic uncertainties

Expected signal yield	: ~ 20%
H→ γγ mass resolution	: ~ 14%
H→ γγ p_T modeling	: ~ 8%
Background modeling	: ±0.1-7.9 events

Exclusion: CLs

$$\mu = \frac{\sigma}{\sigma_{SM}(m_H)}$$

->CLs measures the compatibility of the data with the signal hypothesis.

->If CLs<5% the signal hypothesis is excluded at the 95% CL

->μ_{up} is the signal strength for which CLs=5%

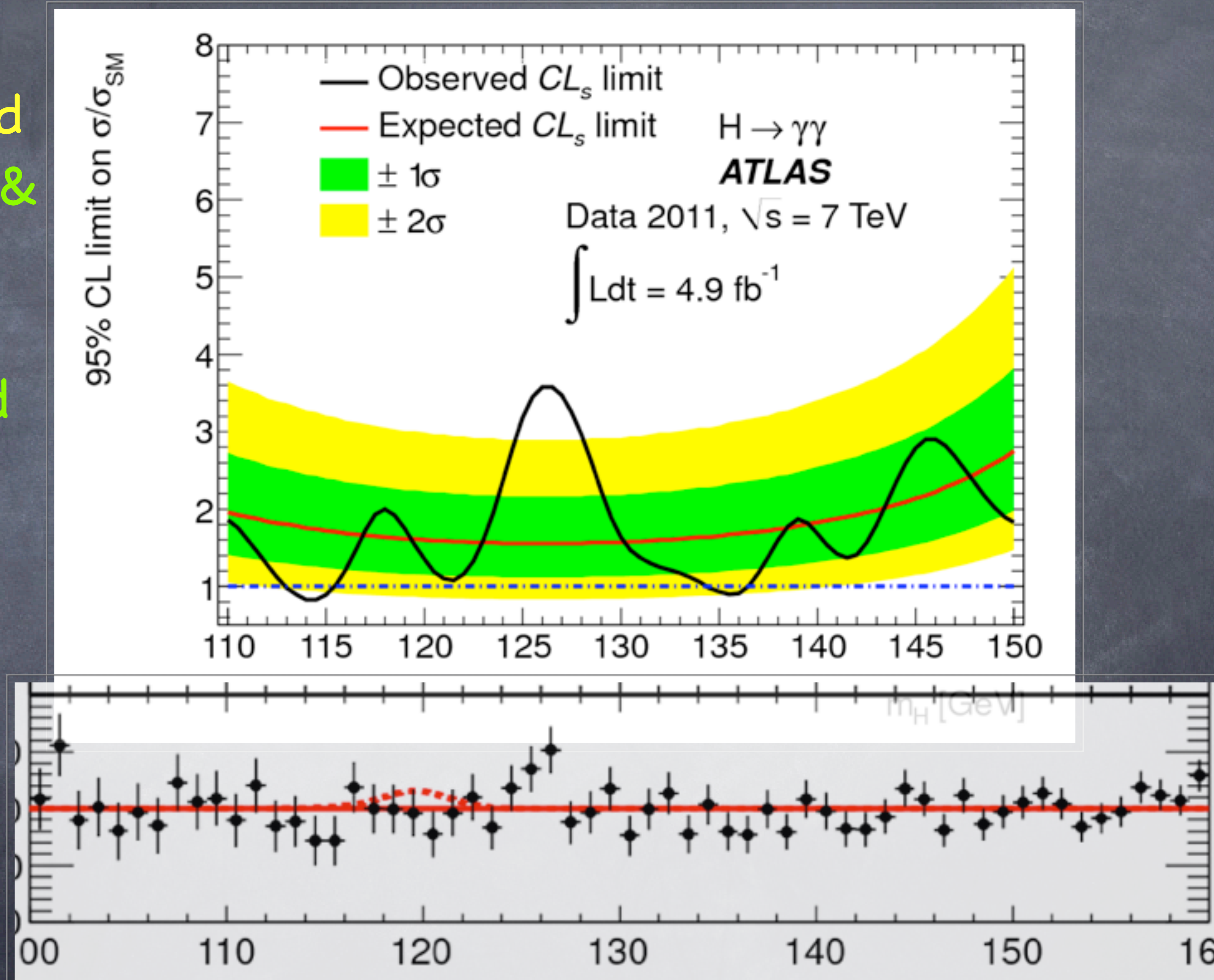
-> If $\mu_{up}<1$ => $\sigma(m_H)<\sigma_{SM}$

=>m_H is excluded at the 95% Confidence Level

H->γγ ATLAS Exclusion

A SM Higgs Boson is excludd @ 113-115 GeV & 134.5-136 GeV due to a large downward fluctuation

Unable to exclude a Higgs Boson all over, in particular around 122-130 GeV



Discovery: p_0

$$q_0 = -2\log \frac{max_{\{b\}} L(b)}{max_{\{\mu,b\}} L(\mu s(m_H) + b)}$$

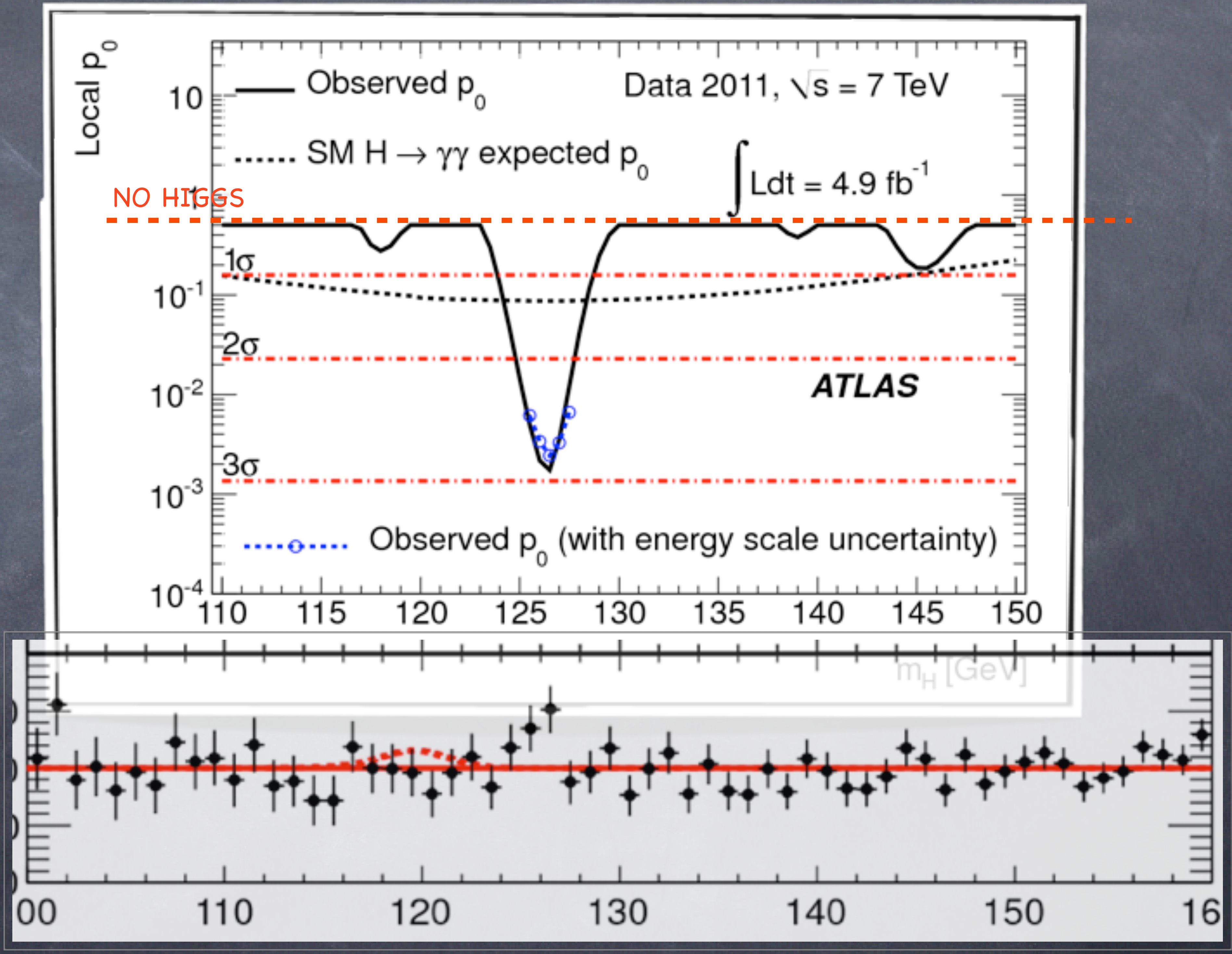
->p_0 measures the compatibility of the data with the NO-HIGGS hypothesis.

->If p_0=0.025 the NO-HIGGS hypothesis is rejected at the 2σ level

$$p_0 = Prob(q_0 > q_0^{obs} \mid H_0)$$

H->γγ ATLAS p_0 results

- ATLAS observes an excess of events with a maximum deviation from the background only expectation at 126.5 GeV.
- The significance of this excess is 2.8σ
- The significance to observe such an excess anywhere in the search mass range is reduced to 1.5σ

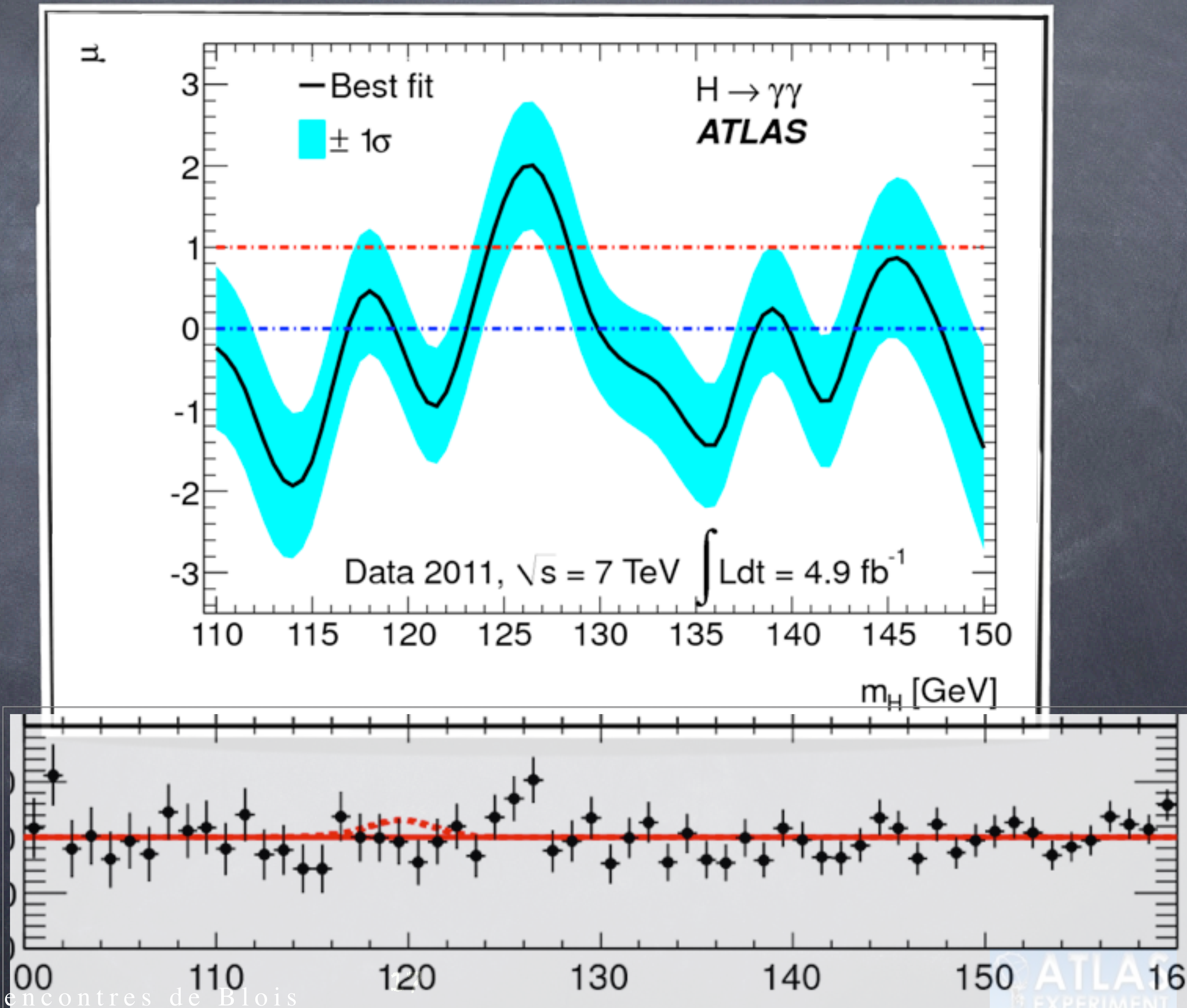


ATLAS EXPERIMENT

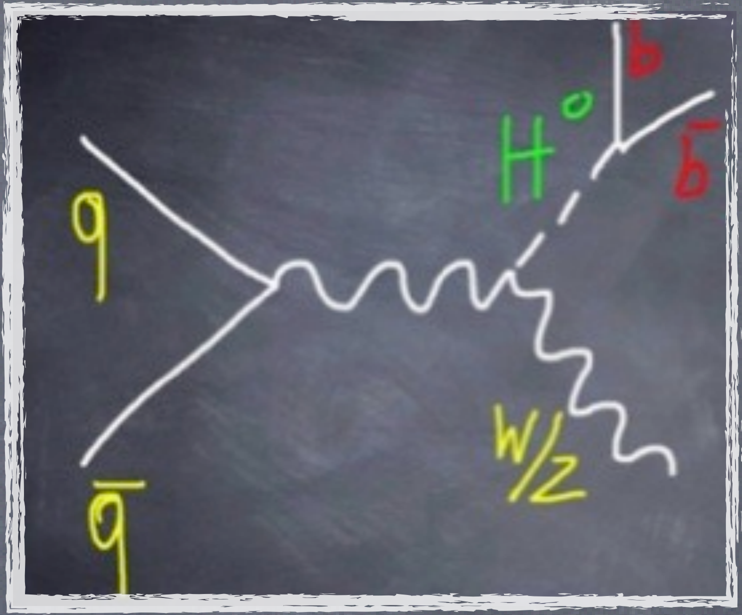
$\mu = \sigma / \sigma SM$ Signal Strength Fit

$$\hat{\mu} = \{\mu | L(\mu s(m_H) + b) = \max L(\mu, b)\}$$

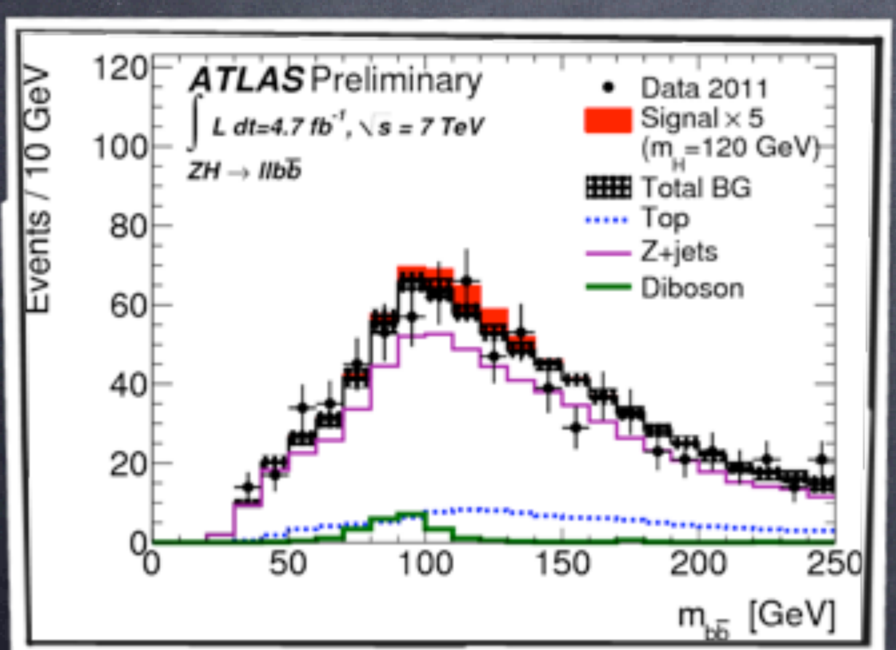
- For a SM Higgs ATLAS sees an excess of ~1.5σ

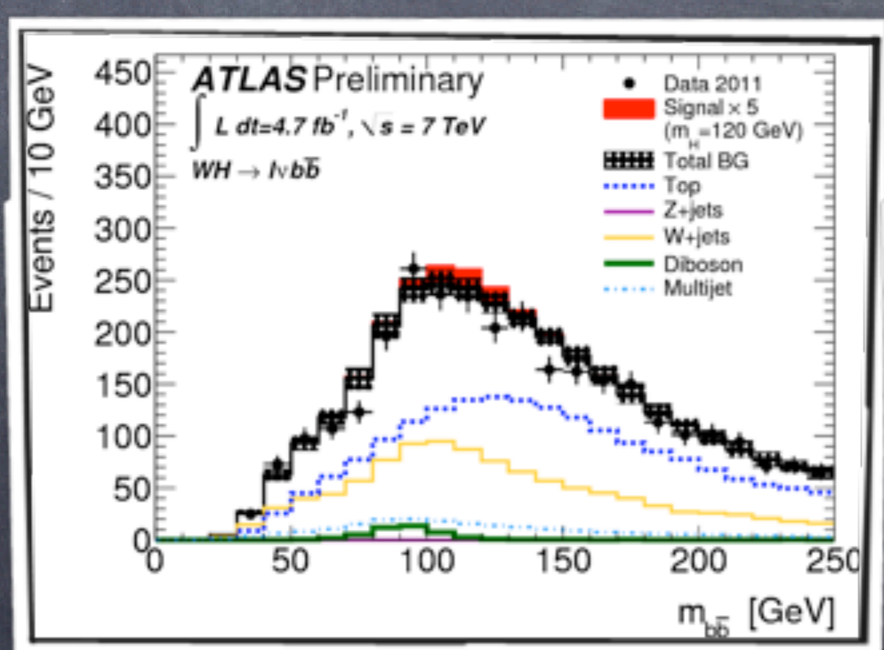


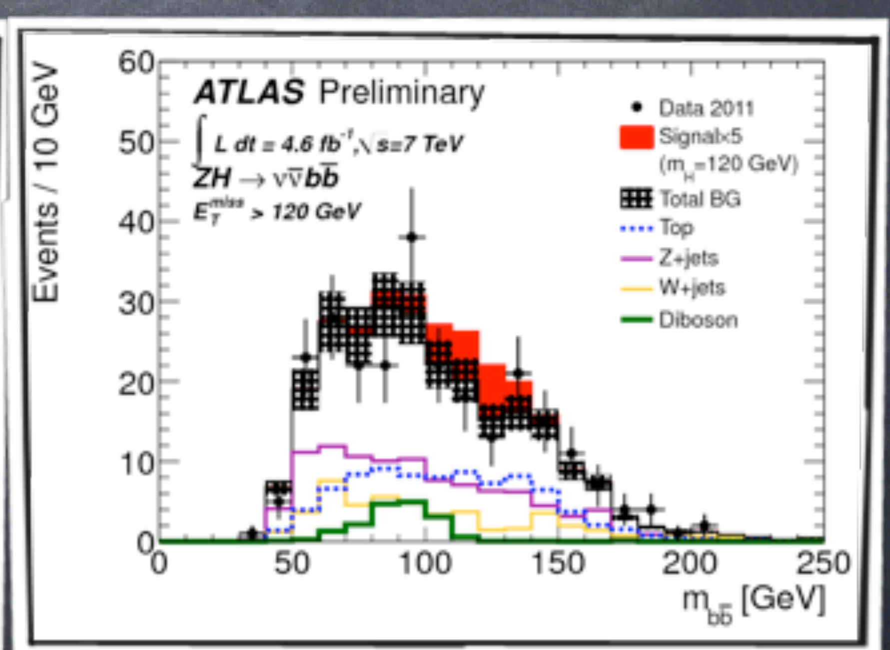
Probing Deeper: W/ZH->W/Zbb



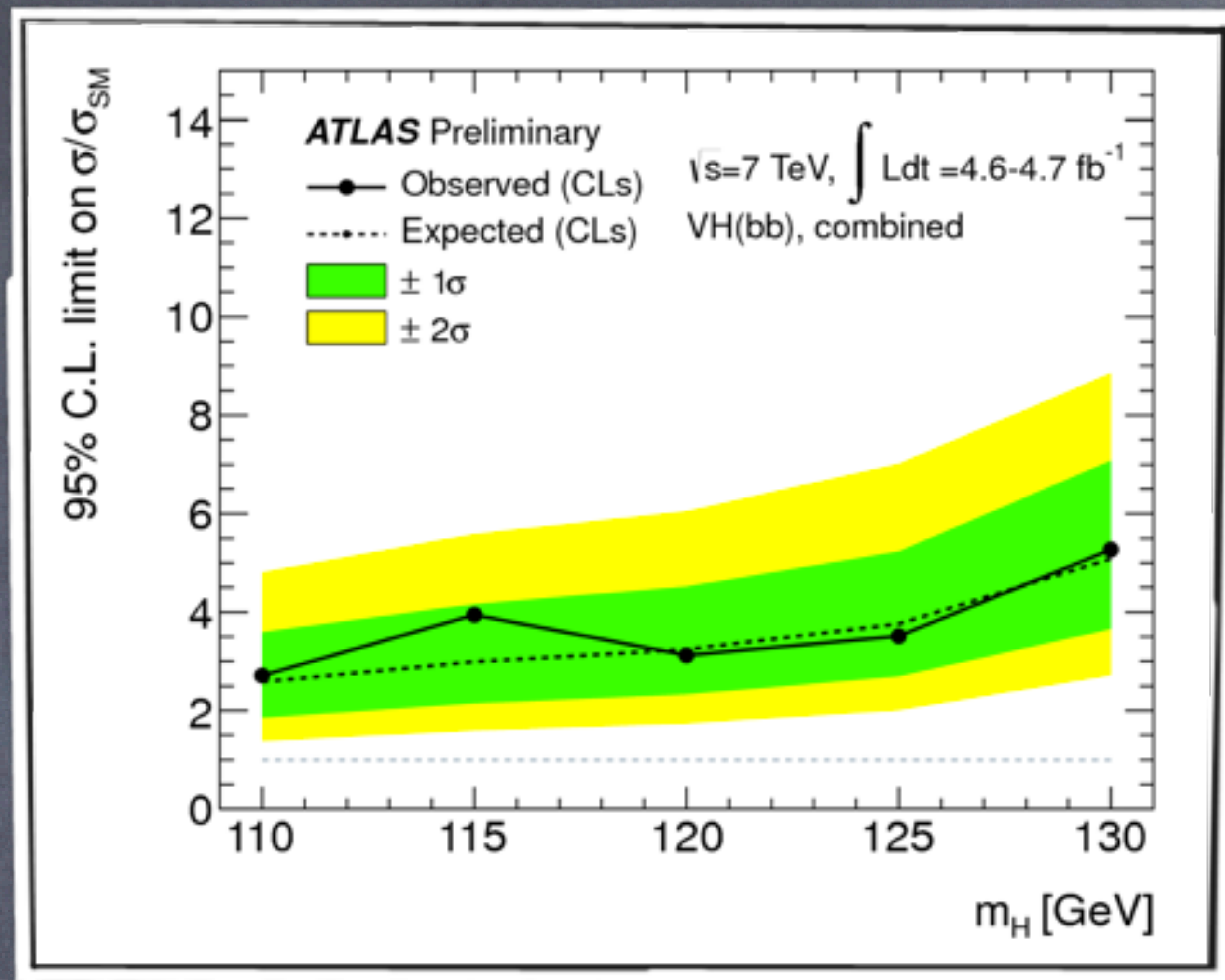
- H->bb is the dominant decay of a low mass Higgs.
  It also extremely important to measure Higgs couplings.
- Multi-jet background kills its inclusive production (though there are hopes with boosted Higgs and jets substructure)
- W/ZH is feasible for low Higgs mass channels: lυbb,llbb and υυbb
- Signature : lepton,MET and b-tag
  (exactly two b-tag jets with E_Tb>45,25 GeV)
- Analysis is performed in p_{TW} (lvH), p_{TZ} (llH) and E_T^{miss} (vvH) , total of 4+4+3 bins
- m_{bb} as a discriminator, dominant Backgrounds:
  Z+jets for ZH->llbb W+jets and tt for WH->lvbb Z+jets and tt for ZH->vvbb

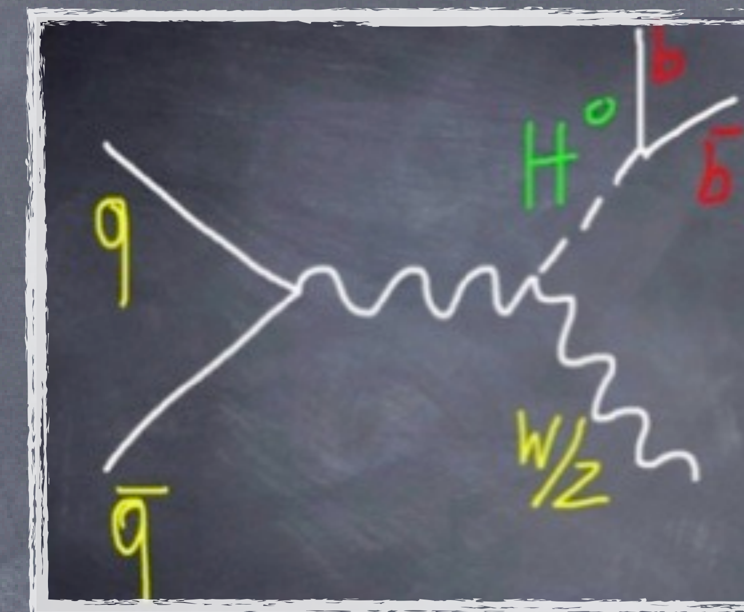






Probing Deeper: W/ZH->W/Zbb





Mass	ZH->llbb		WH->lvbb		ZH->vvbb		Combined	
	obs	exp	obs	exp	obs	exp	obs	exp
125	10.4	8.2	8.0	7.5	5.9	5.6	3.5	3.8

H->ττ

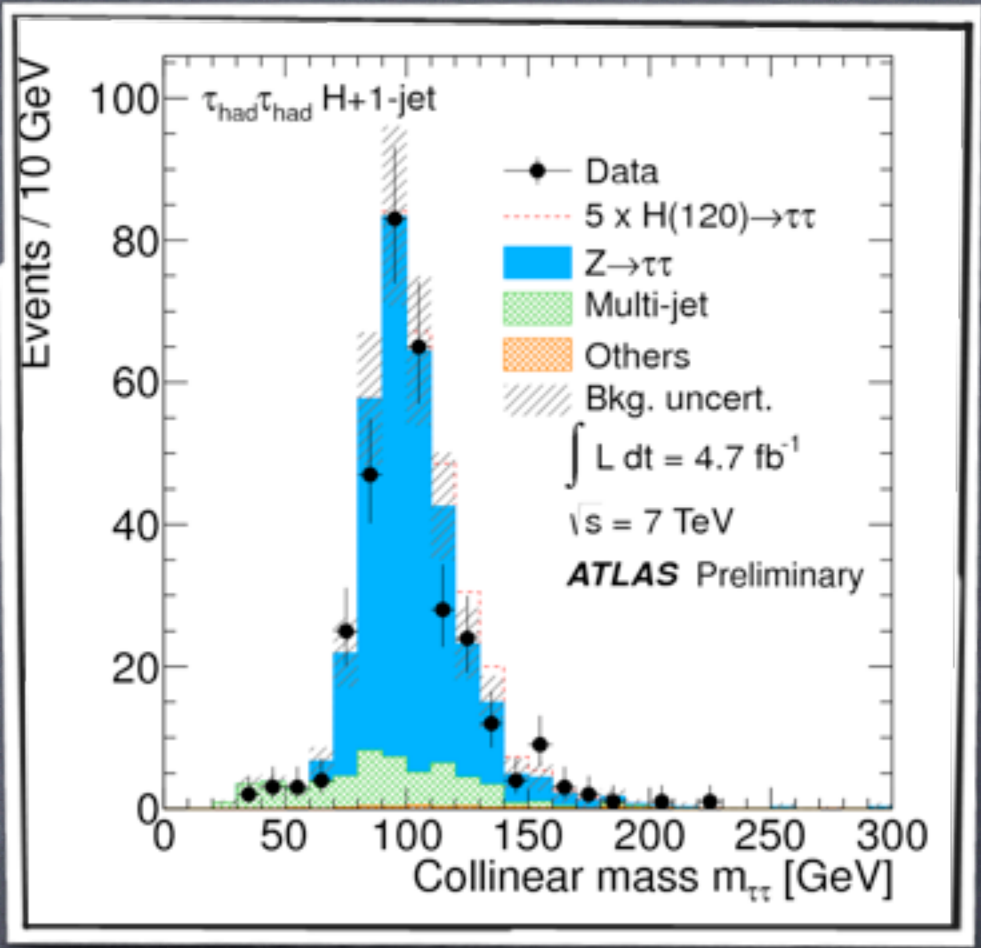
- 3 channels in 12 bins
  (0 jets, 1 jet, 2 jets VBF & VH)

  $H\to\tau_l\tau_l+E_T^{miss}$ in 0 jets (eμ),1 jet, 2jets (VH,VBF)
  $H\to\tau_l\tau_h+E_T^{miss}$ in
  (l=e,μ)⊗(0 jets (2 E_T^{miss} bins),1-jet)⊕VBF
  $H\to\tau_h\tau_h+E_T^{miss}$ with ≥1 jet

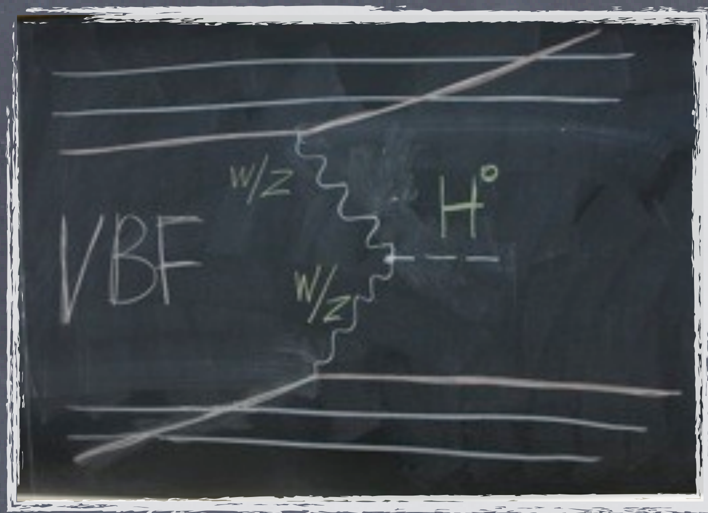
- Discriminator $m_{\tau\tau}$
  (m_{eff}, colinear or MissingMassCalculator)

- Main background from Z->ττ, shape via embedding
  (Z->μμ replacing μ with a τ)

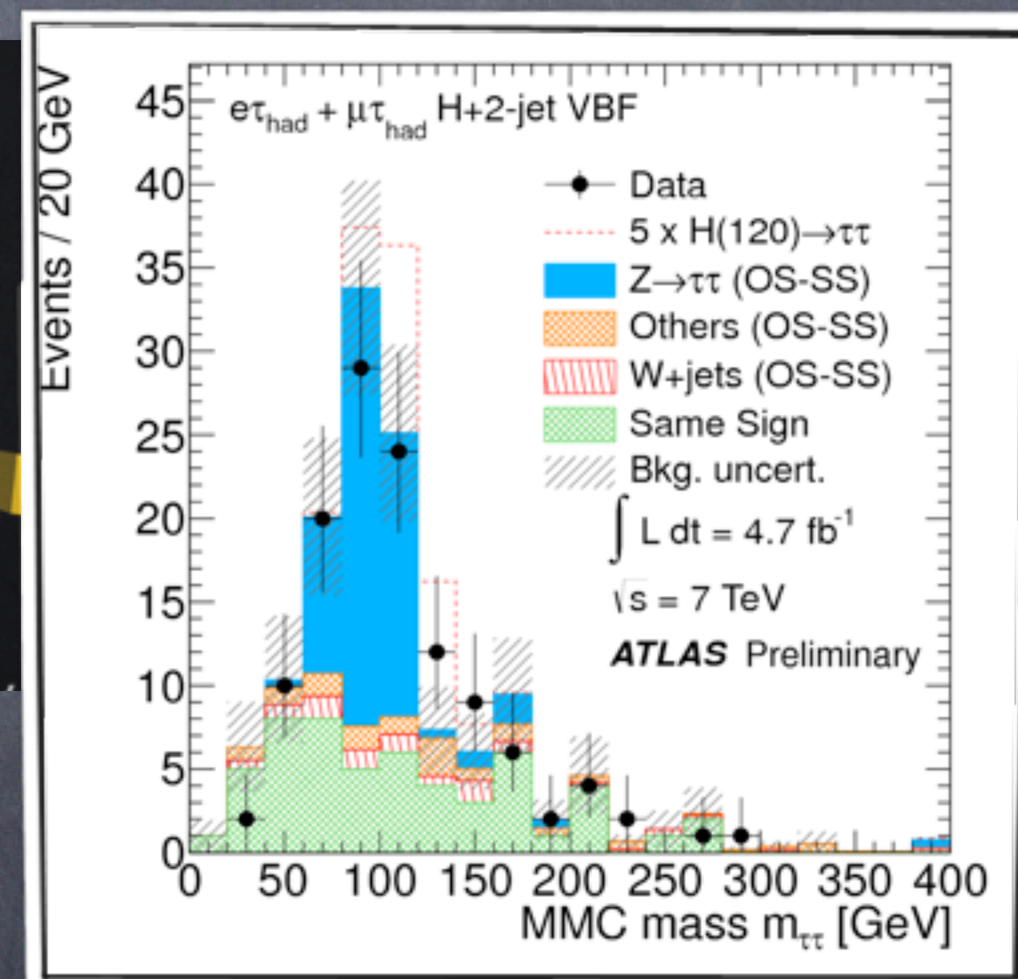
- Fake leptons and τ jets from data with an uncertainty of up to 40%



H->ττ



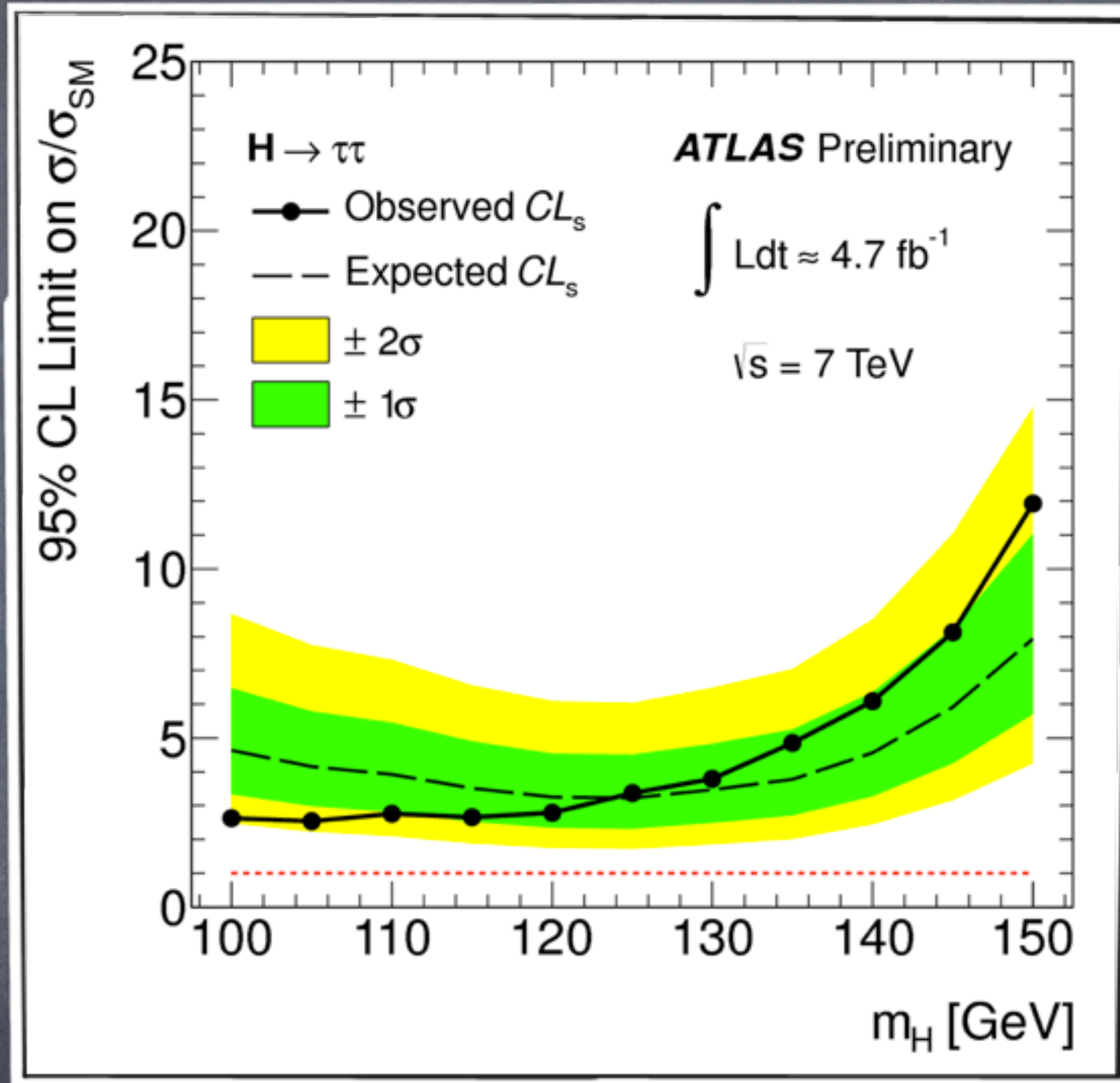
- VBF
  Distinct and characteristic signature
- 2 tagged "back to back" forward jets and two tagged taus



ATLAS EXPERIMENT

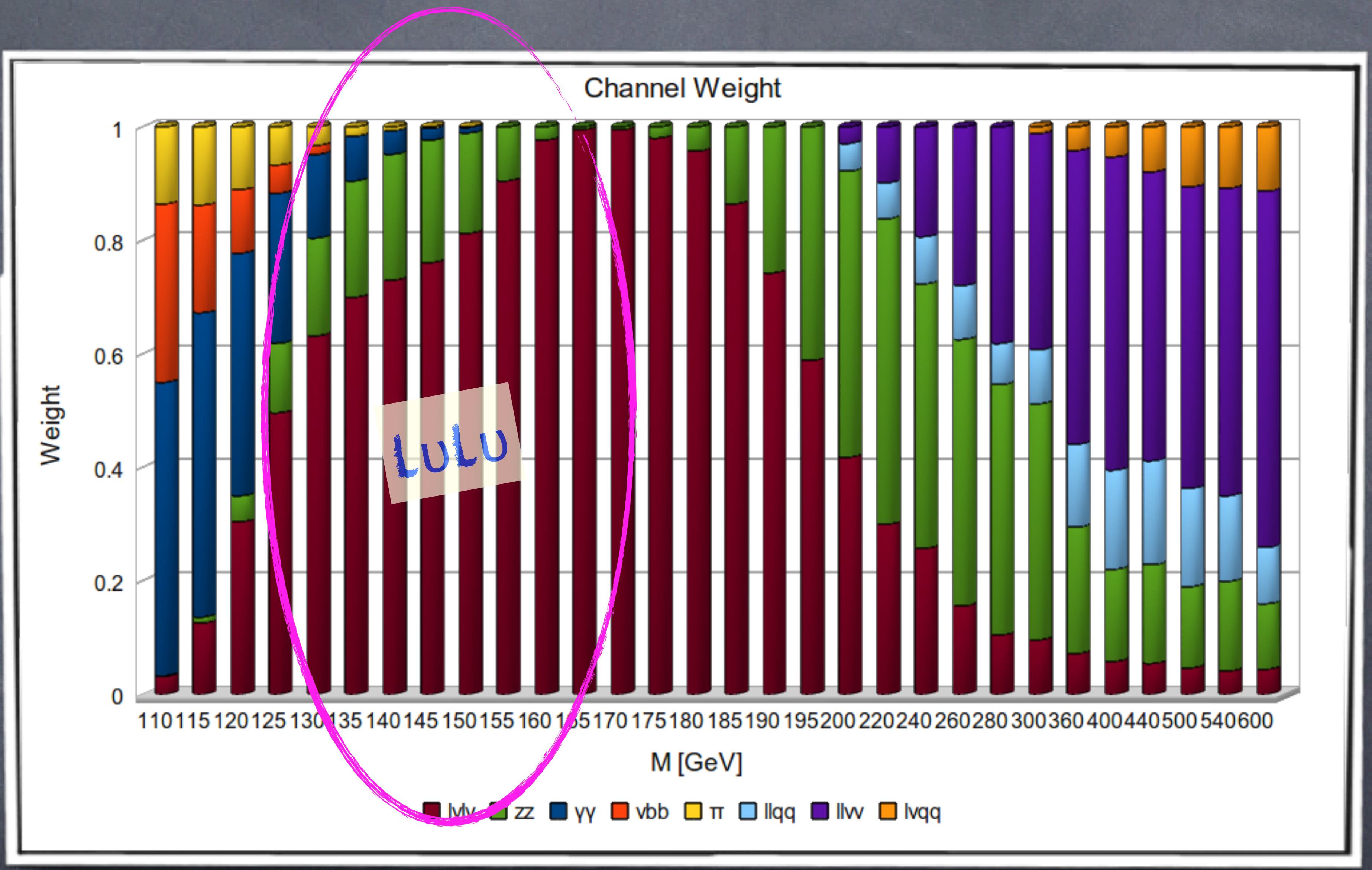
H->ττ

- Expected limit between $\sigma<(3.2\text{–}7.9)\times\sigma_{SM}$
- Sensitive categories
  H+1j in $\tau_{had}\tau_{had}$,
  and
  2-jet VBF in $\tau_l\tau_l$ and $\tau_l\tau_{had}$
- Observed limit $\sigma<(2.5\text{–}11.9)\times\sigma_{SM}$



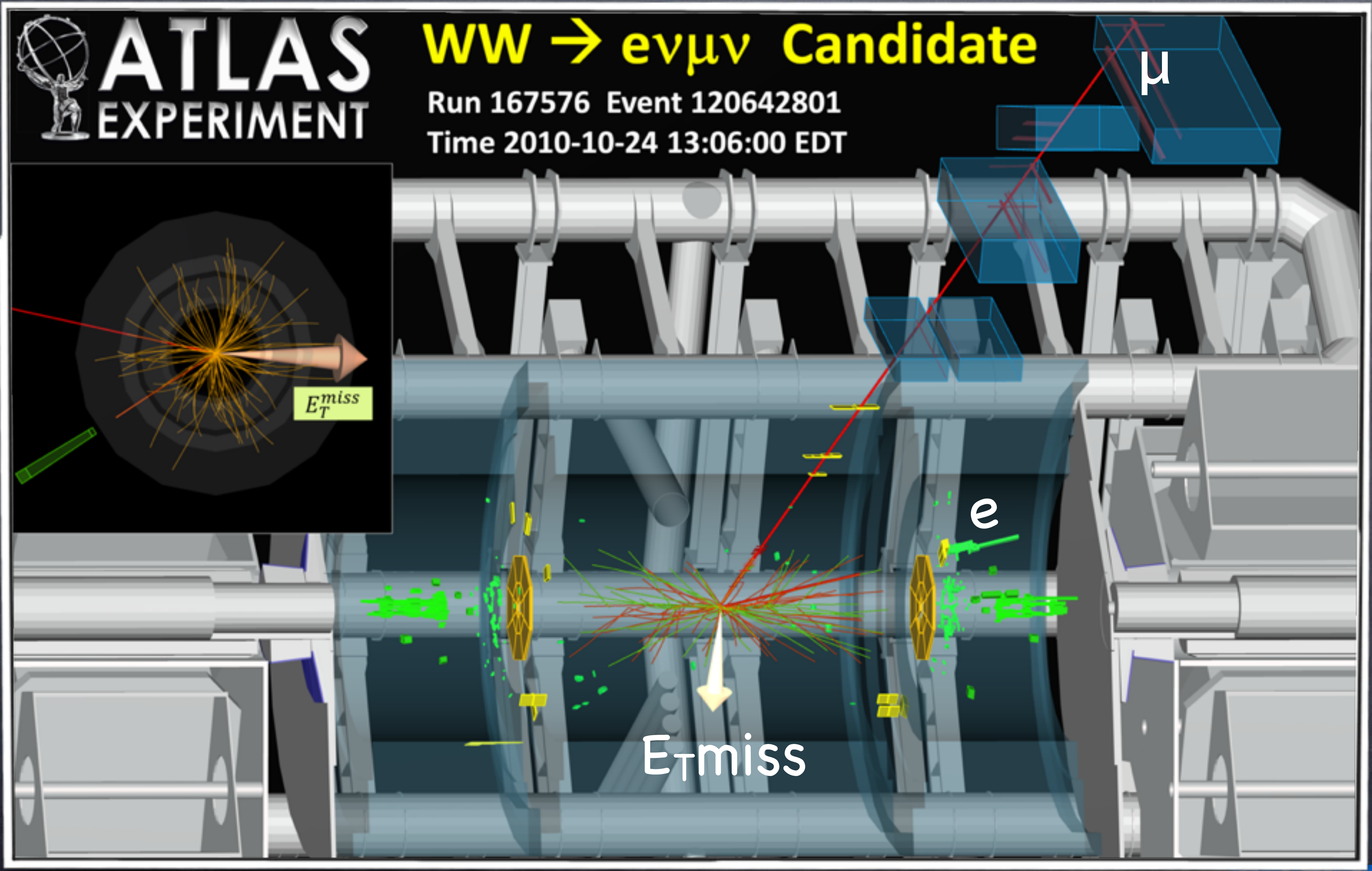
"TEVATRON++" mass region

- "TEVATRON++" mass region 140-200 GeV
- Probing channel: H->WW->lulu



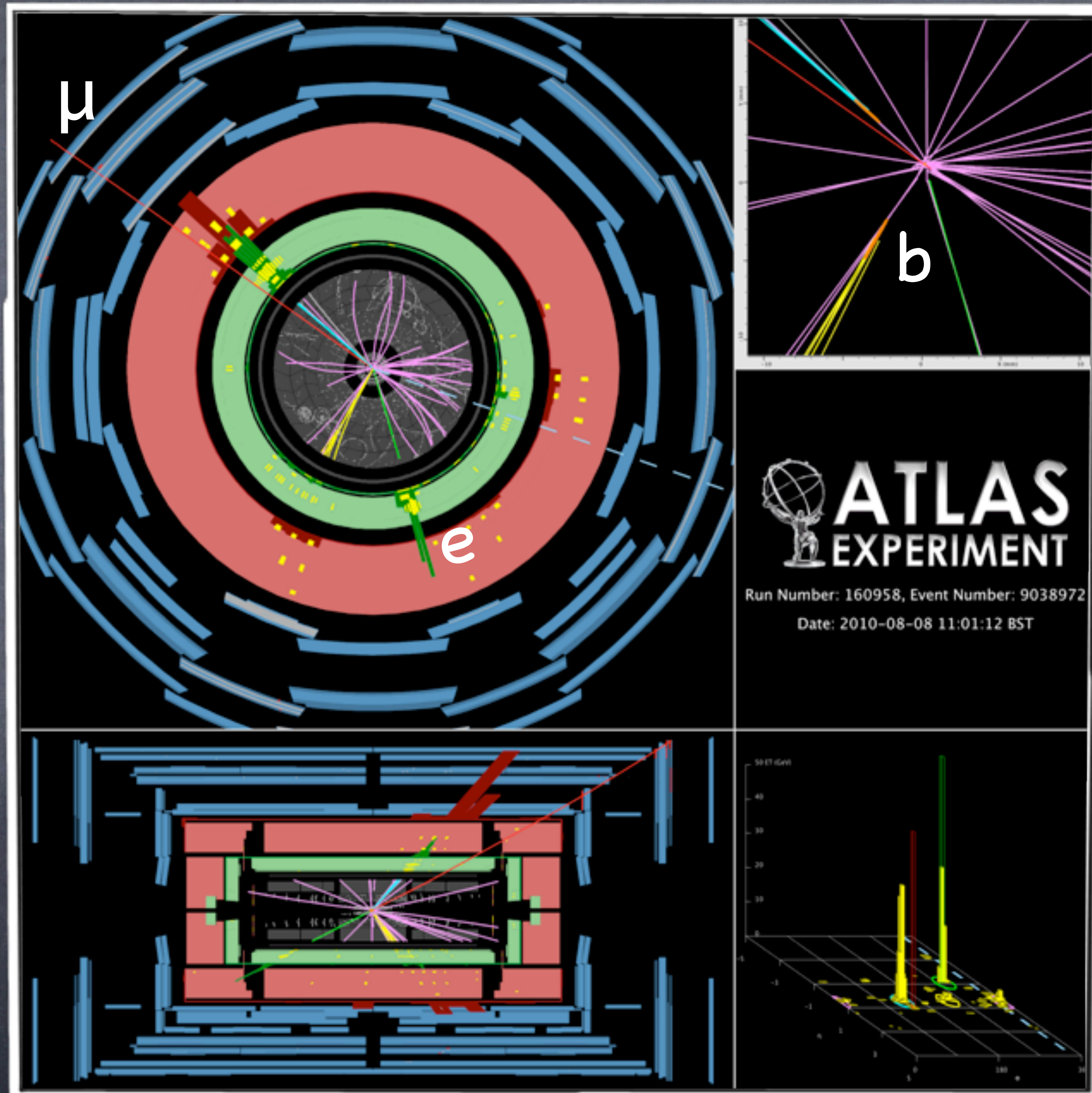
H->WW->lνlν: WW->eνμν "Irreducible" BG

- WW can be reduced by exploiting the Higgs spin, require small $\Delta\Phi_{ll}$



H->WW->lνlν: tt background

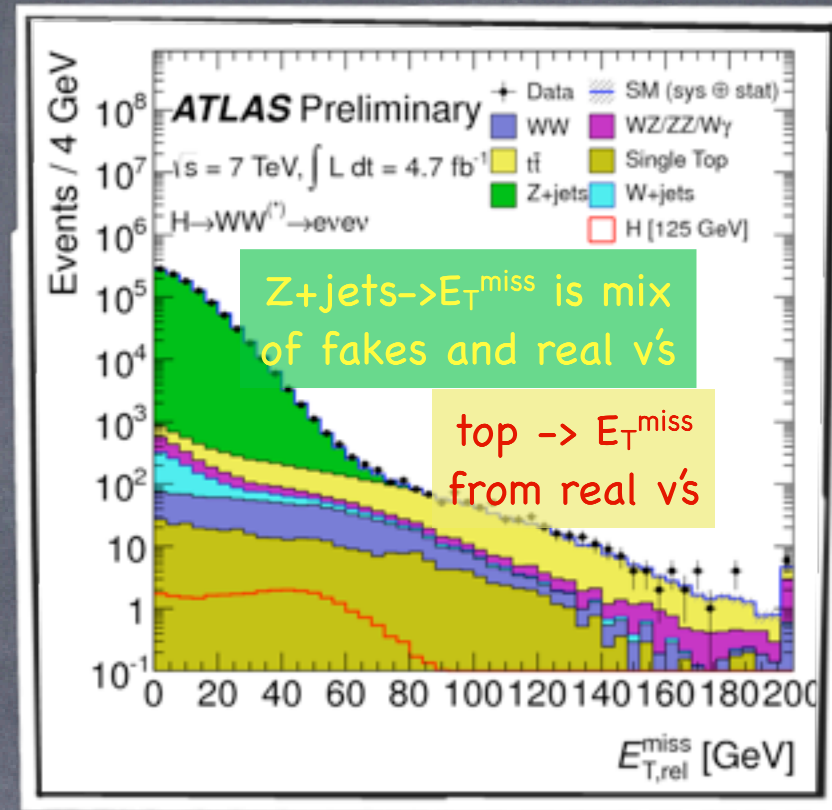
Event display of a top pair e-mu dilepton candidate with two b-tagged jets.
The electron is shown by the green track pointing to a calorimeter cluster, the muon by the long red track intersecting the muon chambers, and the missing ET direction by the dotted line on the XY view. The secondary vertices of the two b-tagged jets are indicated by the orange ellipses on the zoomed vertex region view.

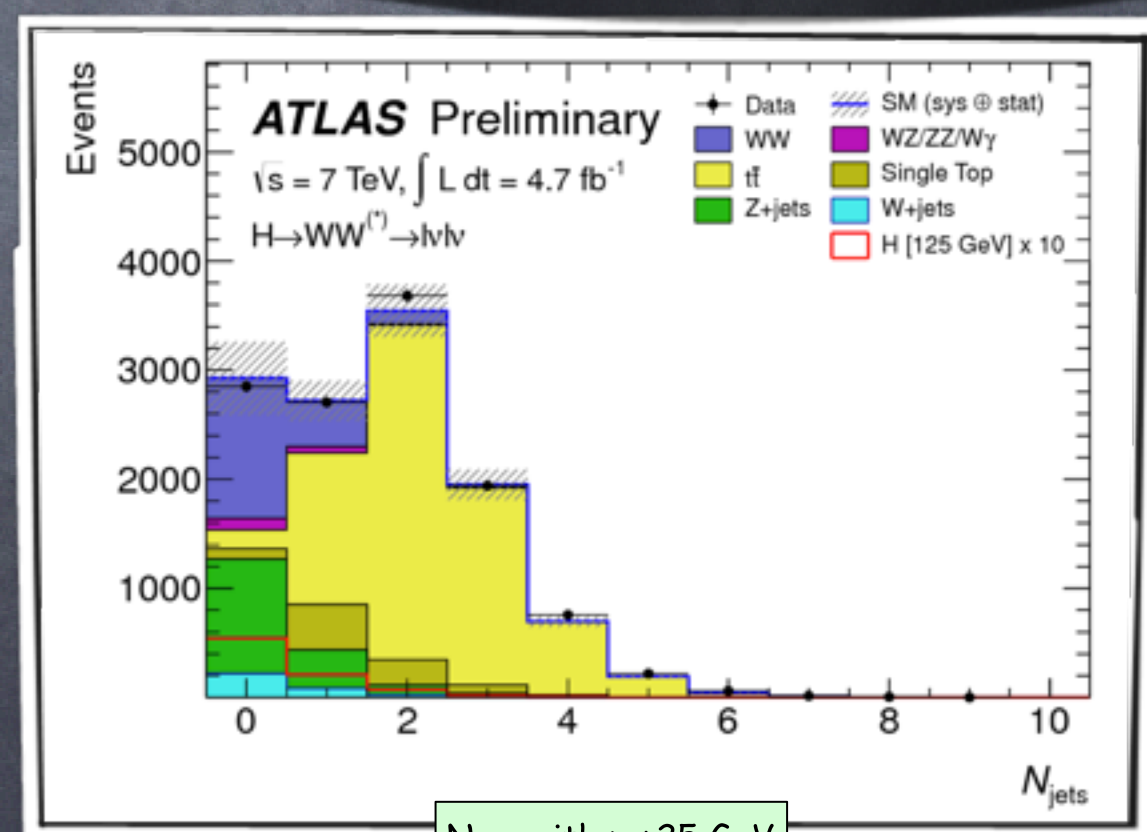


Suppress by b-tag veto

H->WW->lνlν

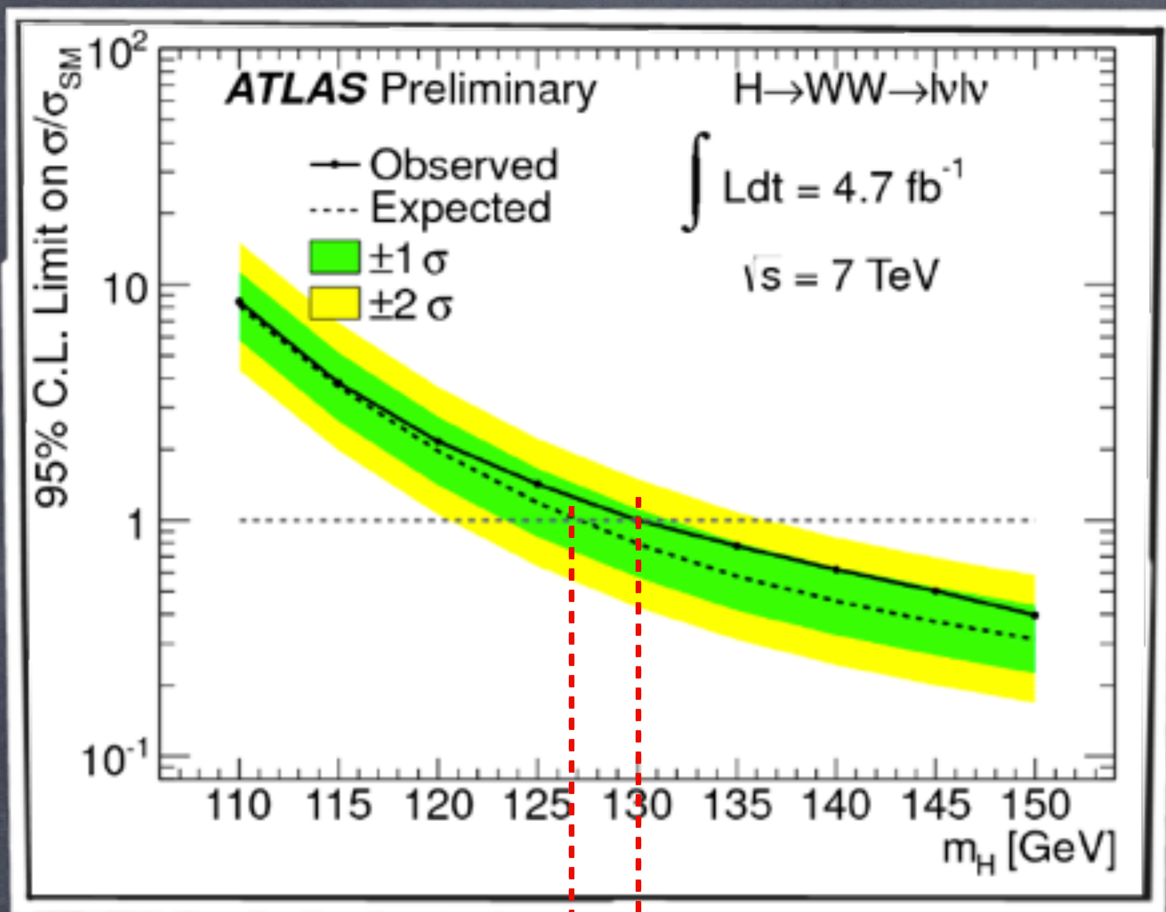
- The channel is challenging
  2 neutrinos- no mass reconstruction ->m_T
- Signature: 2 high p_T opposite sign isolated leptons with large E_T^{miss}->Understanding of E_T^{miss} is crucial
- Main background from WW, top,
  Z+jets, W+jets ->Use of control regions to estimate backgrounds and fakes
- A control region is rich in the measured BG (e.g. WW or top), contaminations are subtracted and then the BG is extrapolated to the signal region (mostly using MC)
  Example: b-veto is inverted to estimate Top BG
- -> large E_T^{miss}, m_{ll} incompatible with m_Z (DY),
  -> b jet veto (tt),
  ->Topological cuts against irreducible WW ($\Delta\Phi_{ll}$)
- Jet bins: +0j, +1, +2jet (VBF)
- Discriminating variable $m_T = \sqrt{(E_T^{ll} + E_T^{miss})^2 + (p_T^{ll} + p_T^{miss})^2}$

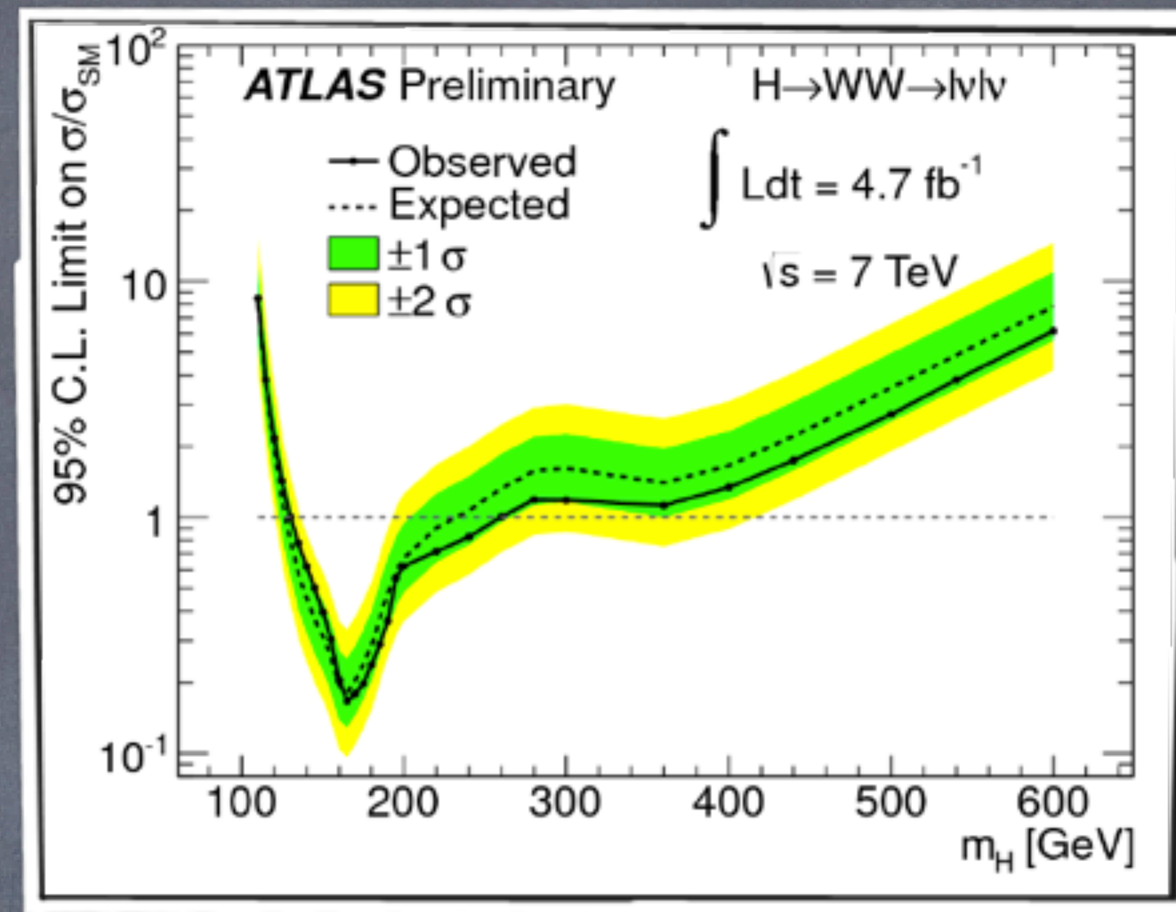




N_{jets} with p_T>25 GeV

H->WW->lνlν (4.7 fb^{-1} ATLAS)





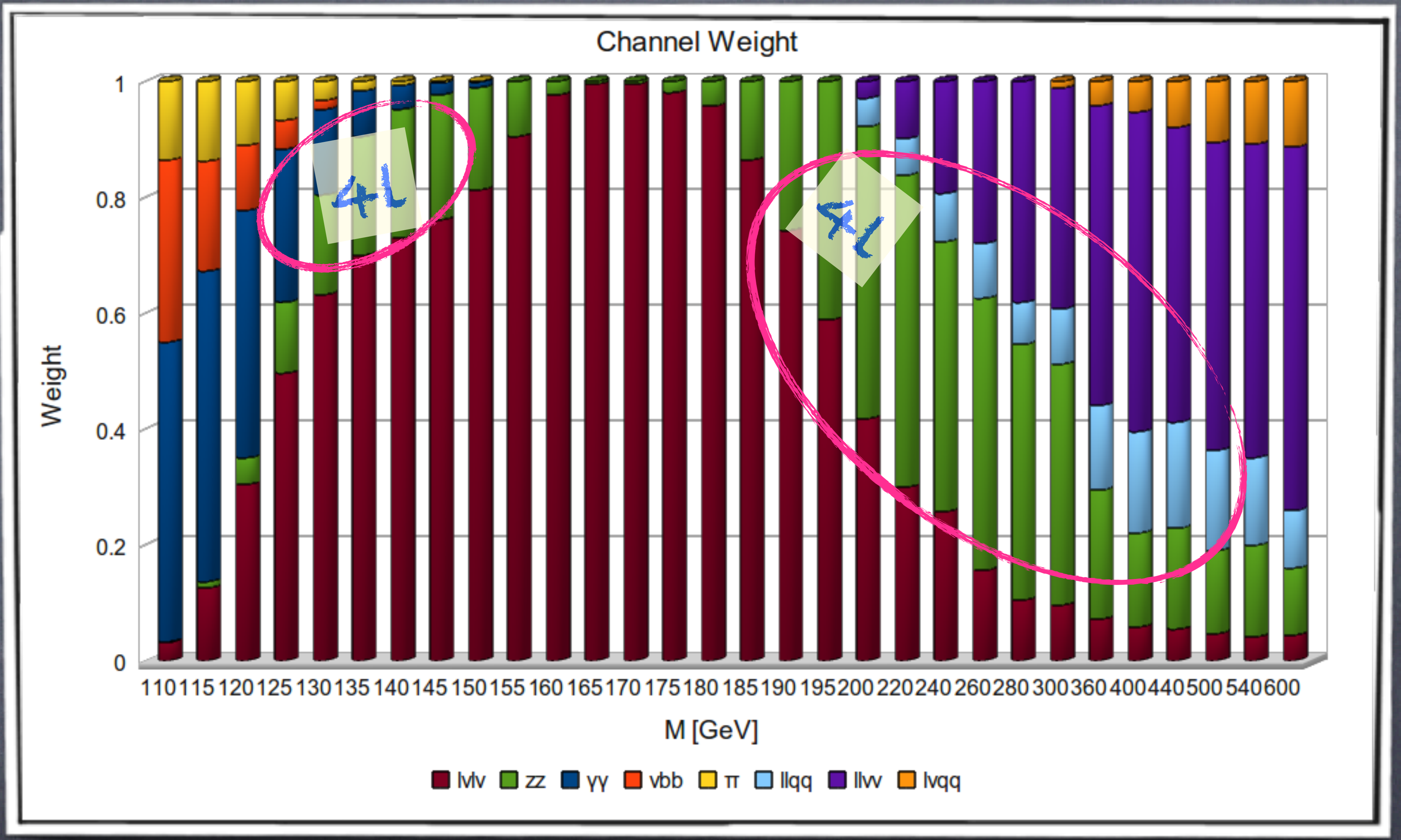
127 130

- ATLAS excludes (4.7 fb^{-1}) $130<m_H<260$ GeV
  (exp 127-234 GeV)

ATLAS EXPERIMENT

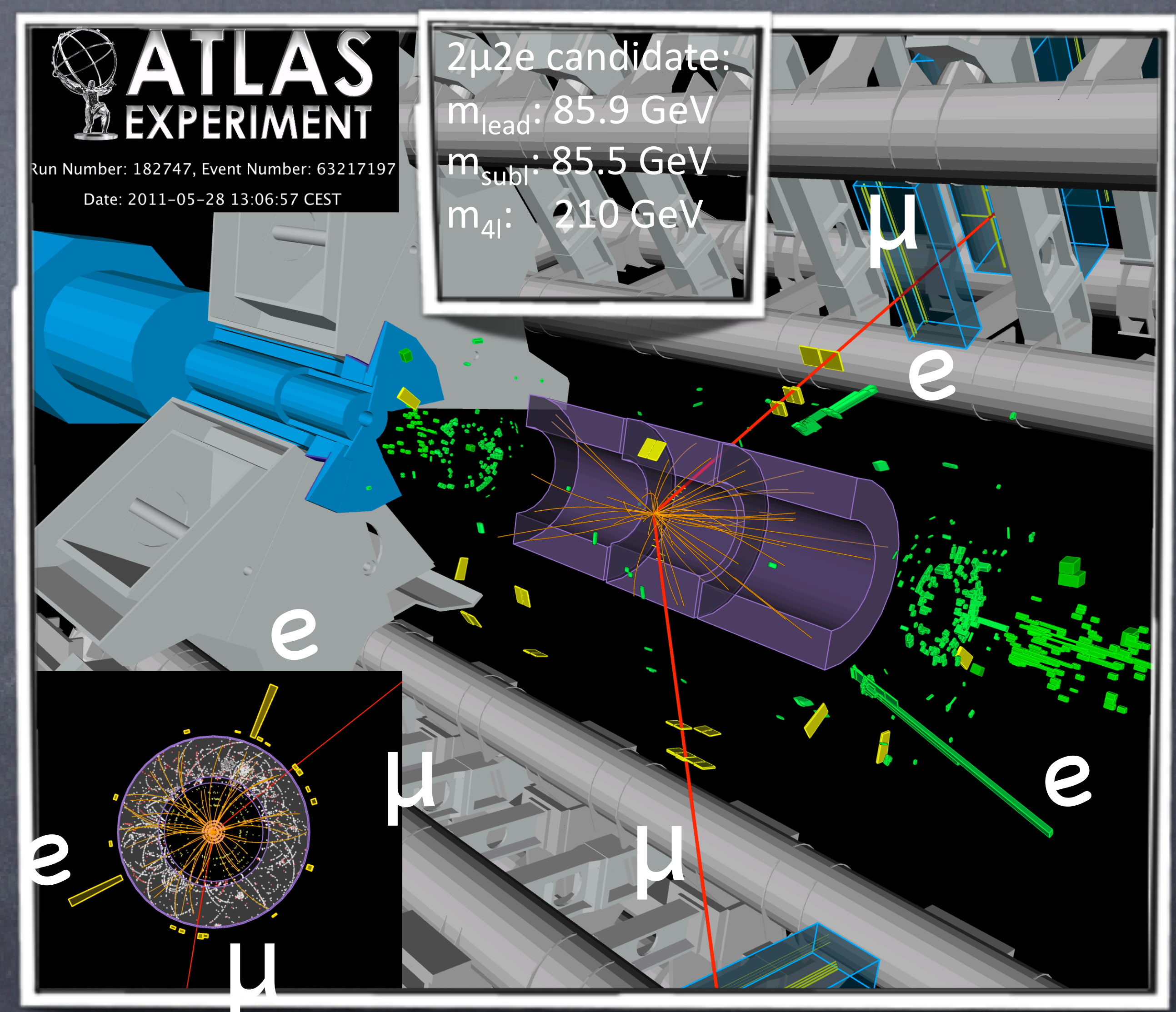
The Golden Channel - H->ZZ->4l

- Around 130 and above 200 GeV
- Probing channel: H->ZZ->4l



The Golden Channel: H->ZZ->4l

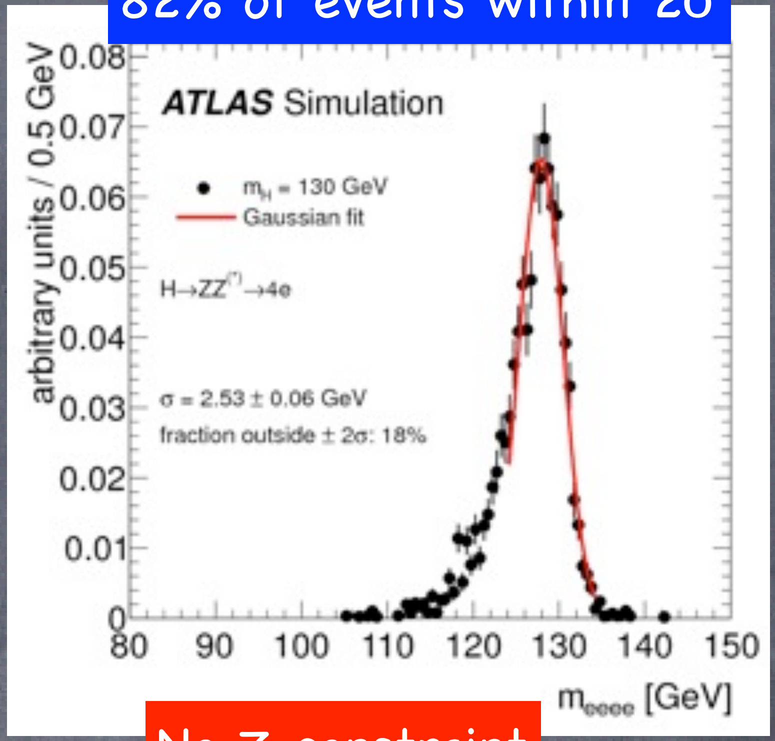
- CLEAN but very low rate (σ~2-5fb), yet probably most trustable
- All information is available, one can fully reconstruct the kinematics and the masses (m_{2l}, m_{4l})
- Signature: Two pairs of same flavor opposite charged isolated leptons, one or both compatible with Z ->narrow peak
- Main backgrounds:
  - ZZ* (irreducible)
  - for $m_H<2m_Z$, Zbb, Z+jets, tt
- Suppress backgrounds with isolation and impact parameters cuts on two softest leptons



H->ZZ->4l experimental aspects

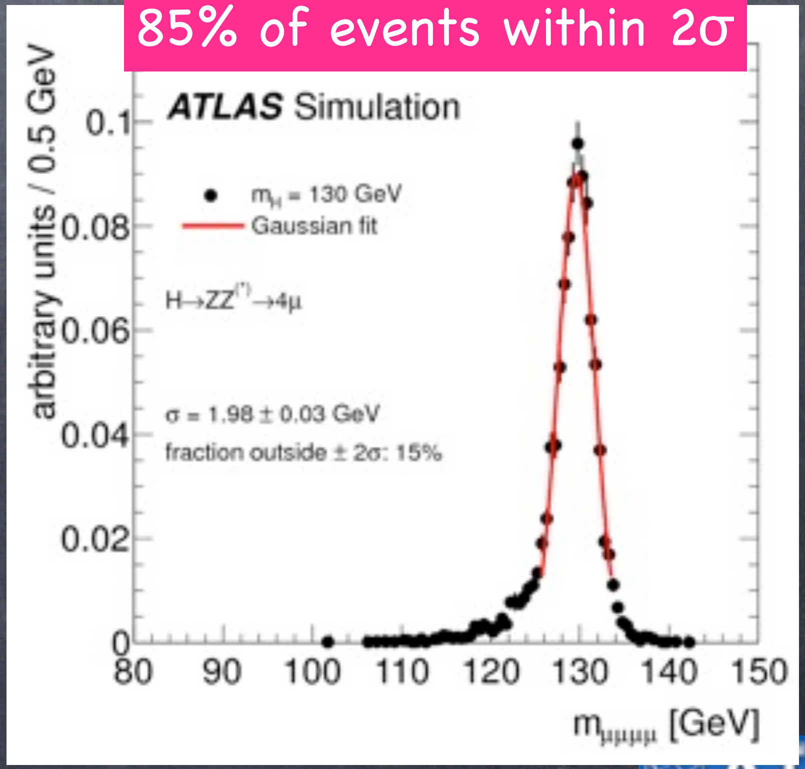
- Highly sensitive to lepton reconstruction and identification efficiency down to low momenta
- High electron efficiency >90% from J/Ψ->ee, W->eυ, Z->ee data
- Muon reconstruction efficiency >95%
- Z+jets (Z+bb) & tt BG estimated from data
- Reducible BG: tt, Zbb removed by isolation and small impact parameter (for $m_{4l}<2m_Z$) requirements

H->4e σ=2.5 GeV
82% of events within 2σ



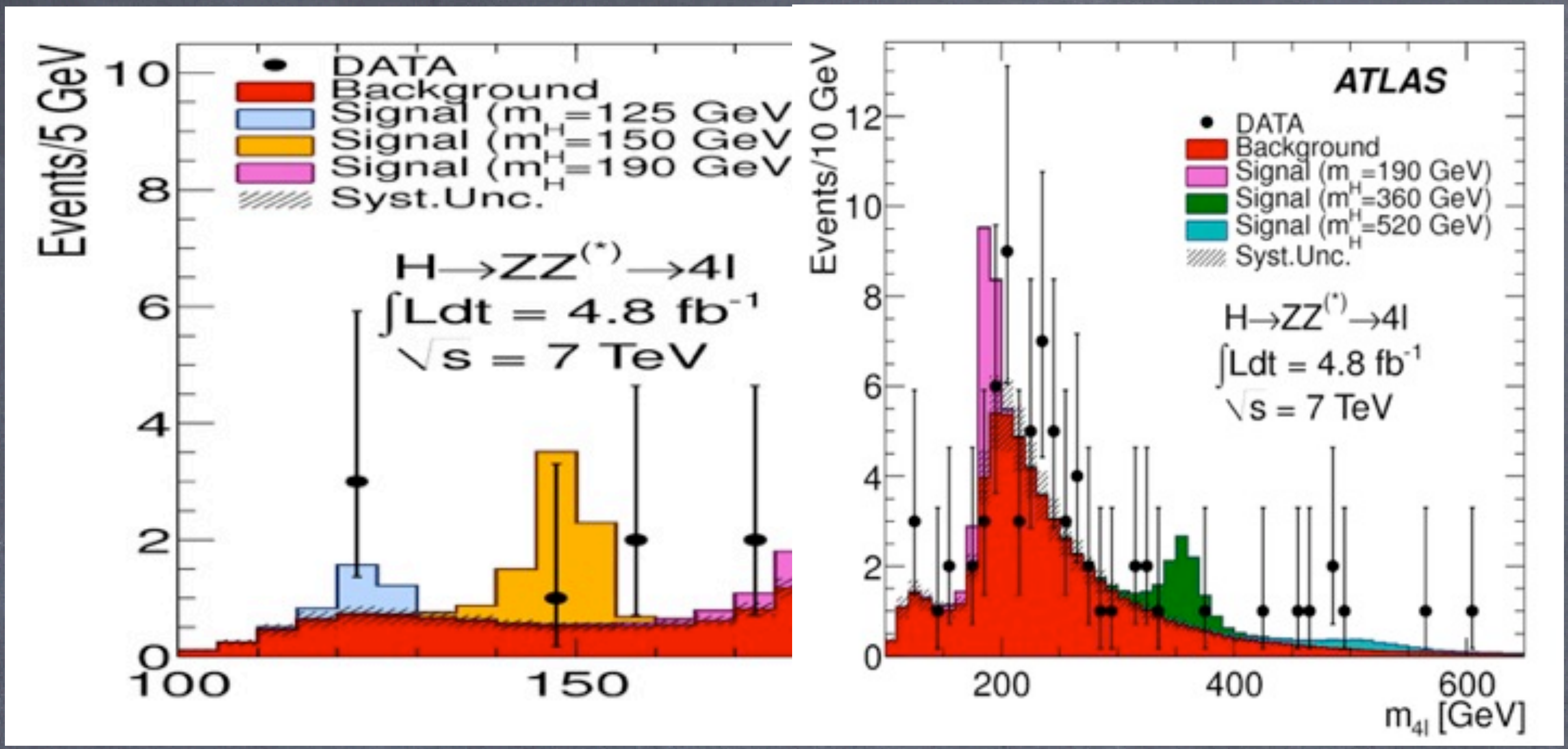
No Z constraint

H->4μ σ=2 GeV
85% of events within 2σ



H->ZZ->4l Results I

Low mass range (<180):
Observed: 8 events,
3 4μ+
3 2e2μ+2 4e
Expected 9.3+-1.5

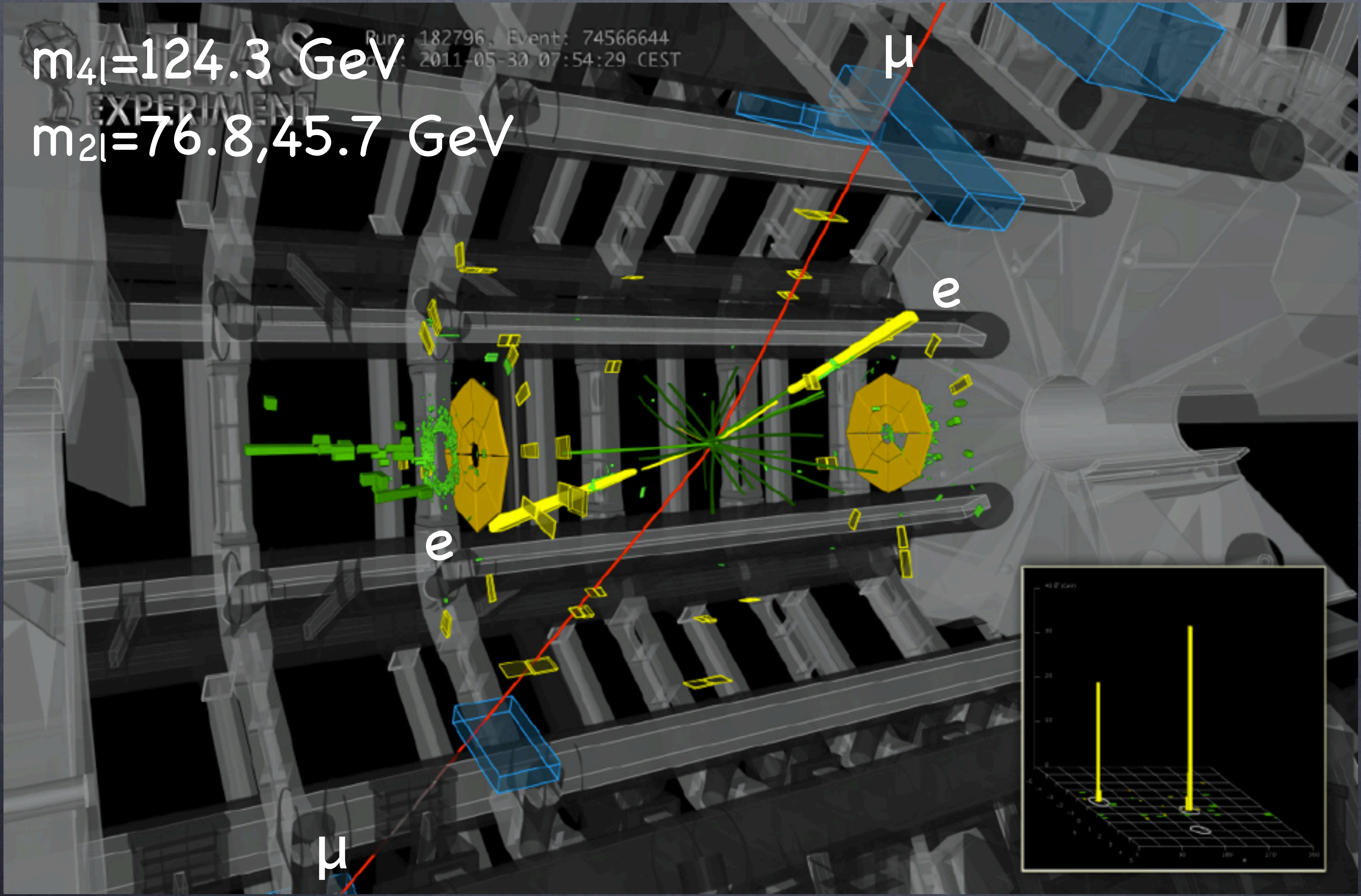


Full mass range:
Observed: 71 events,
24 4μ+
30 2e2μ+
17 4e
Expected 62+-9

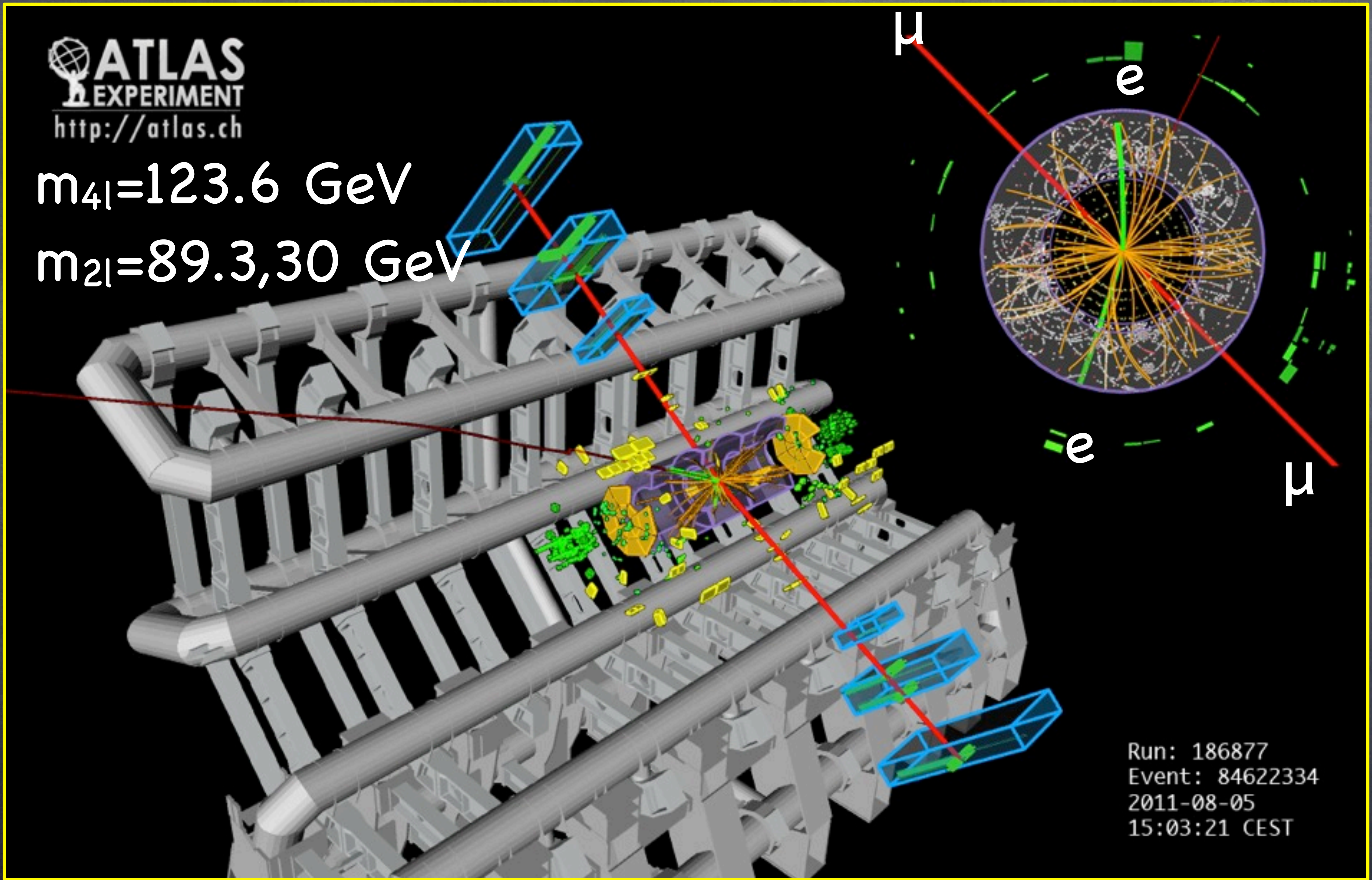
- In the interesting low mass region ATLAS observe 3 events, two 2e2μ (m=123.6,124.3 GeV) and one 4μ (m=124.6)
- In the region around 125 GeV (+-2σ) expect 1.5 BG evens from ZZ* (4μ,4e and 2e2μ) and Z+jets (4e)
- Expected m_H=125 GeV signal is 1.5 events with S/B~2(4μ),1(2e2μ) and 0.3(4e)

Main Systematic Uncertainties	
Higgs cross section	~12% (ggF)
Zbb,Z+jets BG	40-45%
ZZ* BG	14%
E-efficiency	2-8%

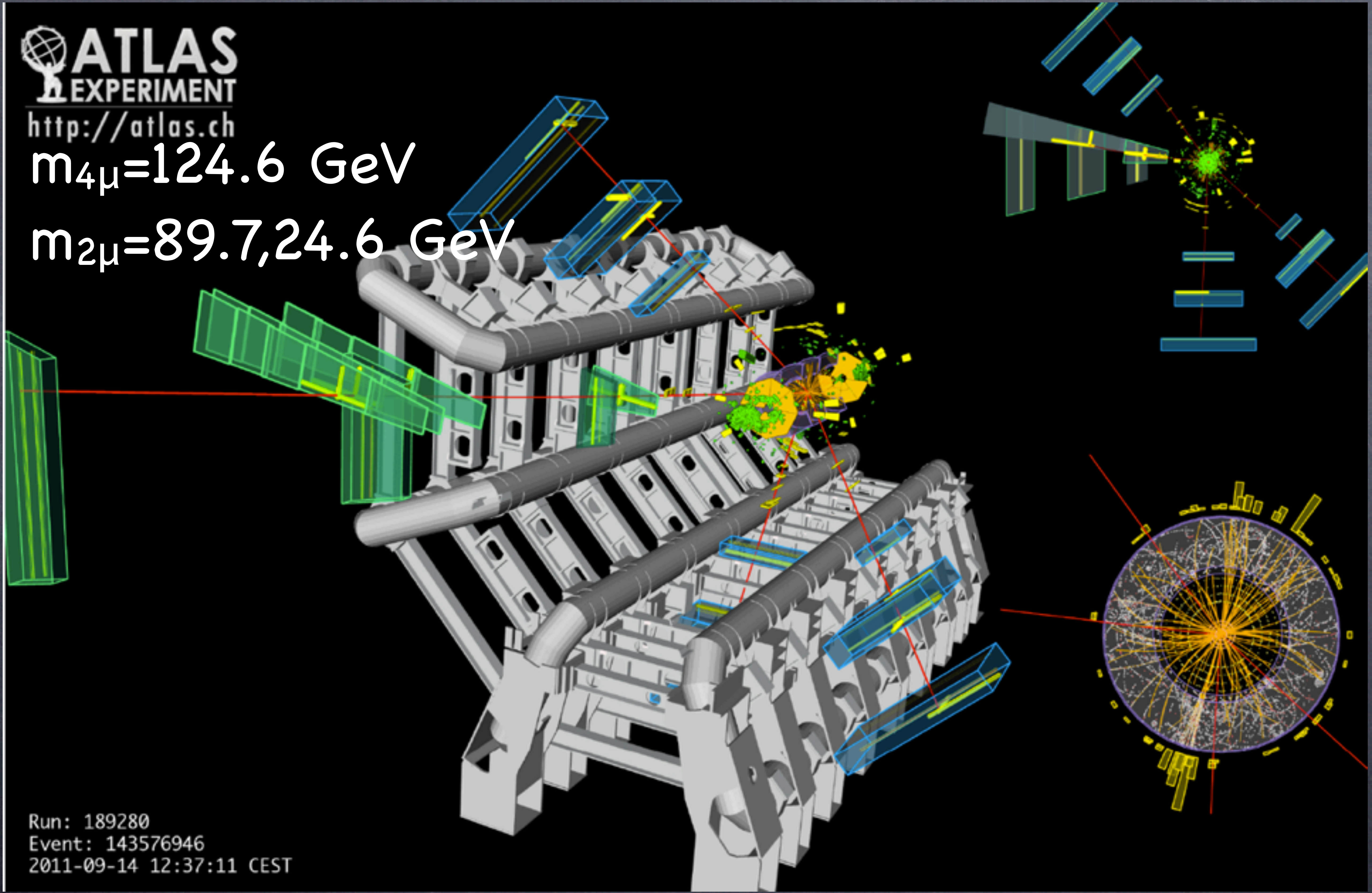
The Golden Channel: H->ZZ->4l



The Golden Channel: H->ZZ->4l



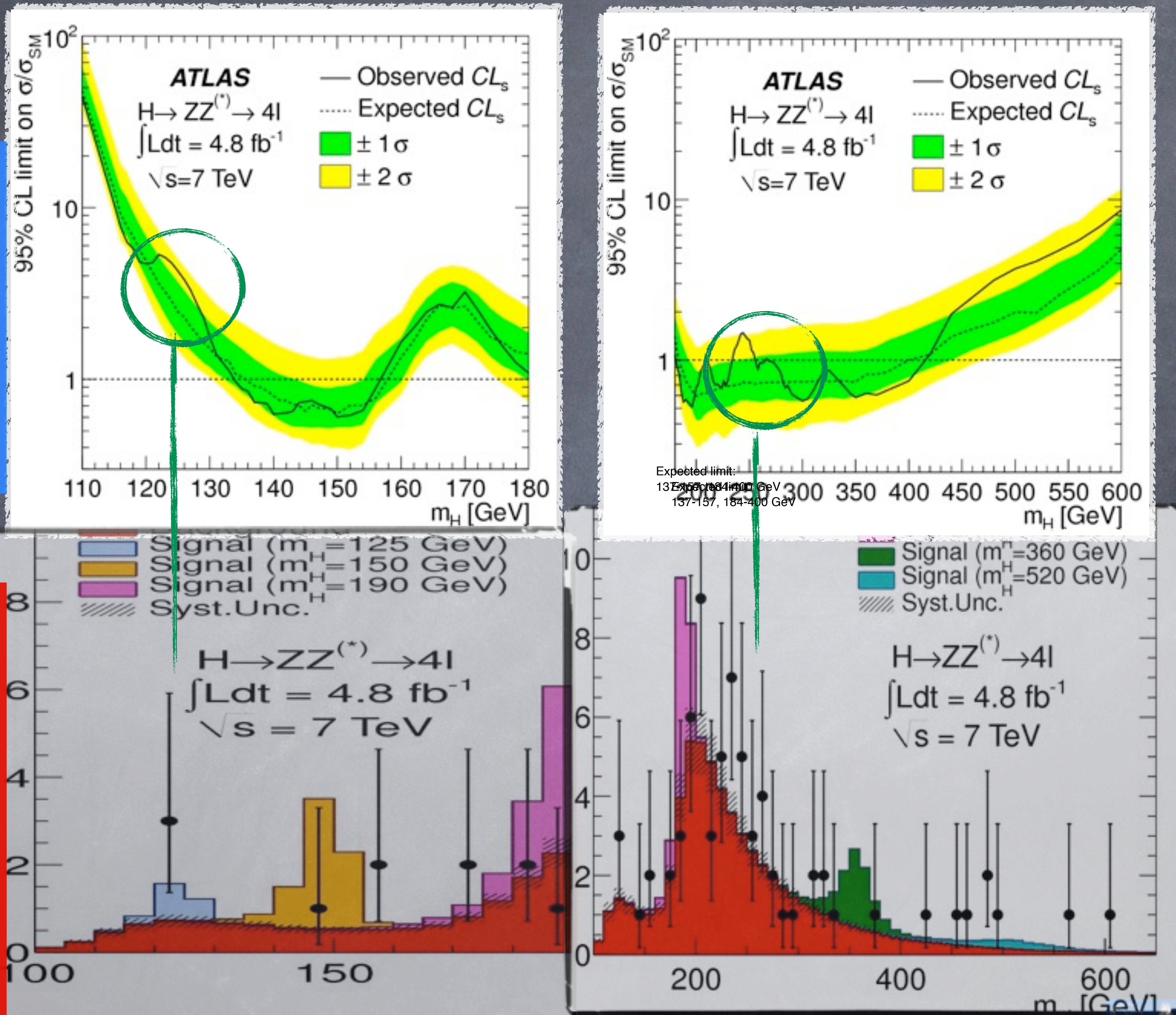
The Golden Channel: H->ZZ->4μ



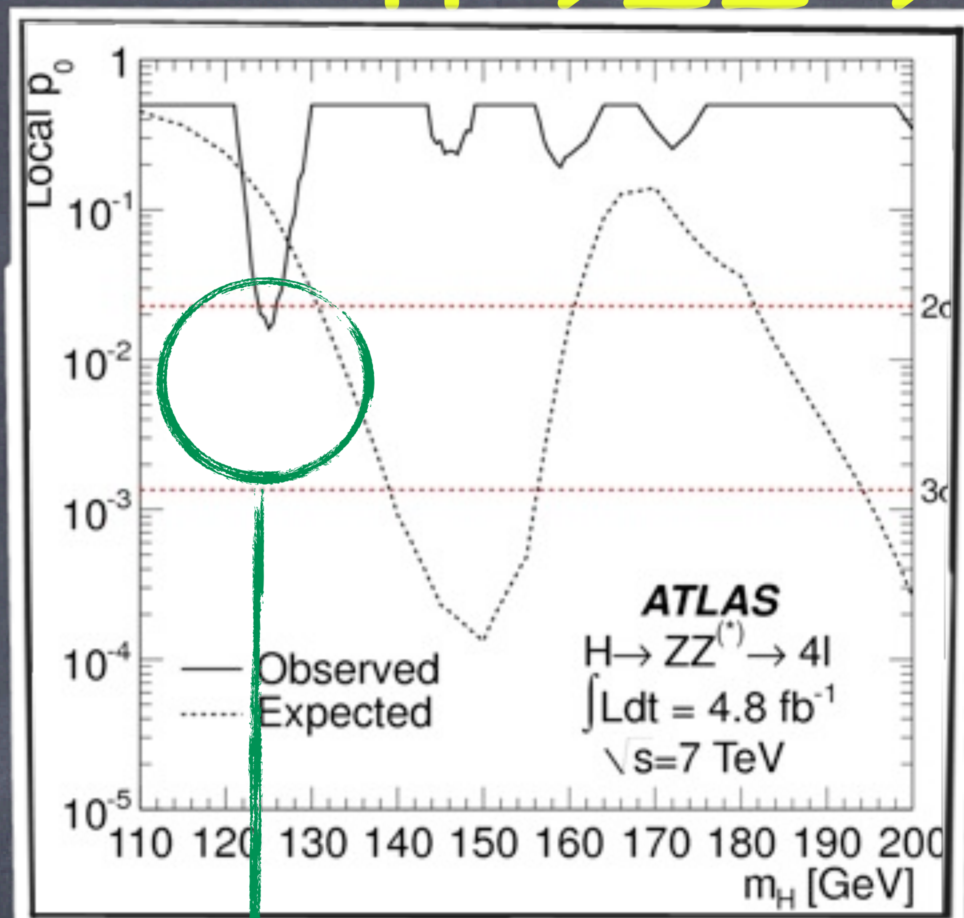
H->ZZ->4l Limits

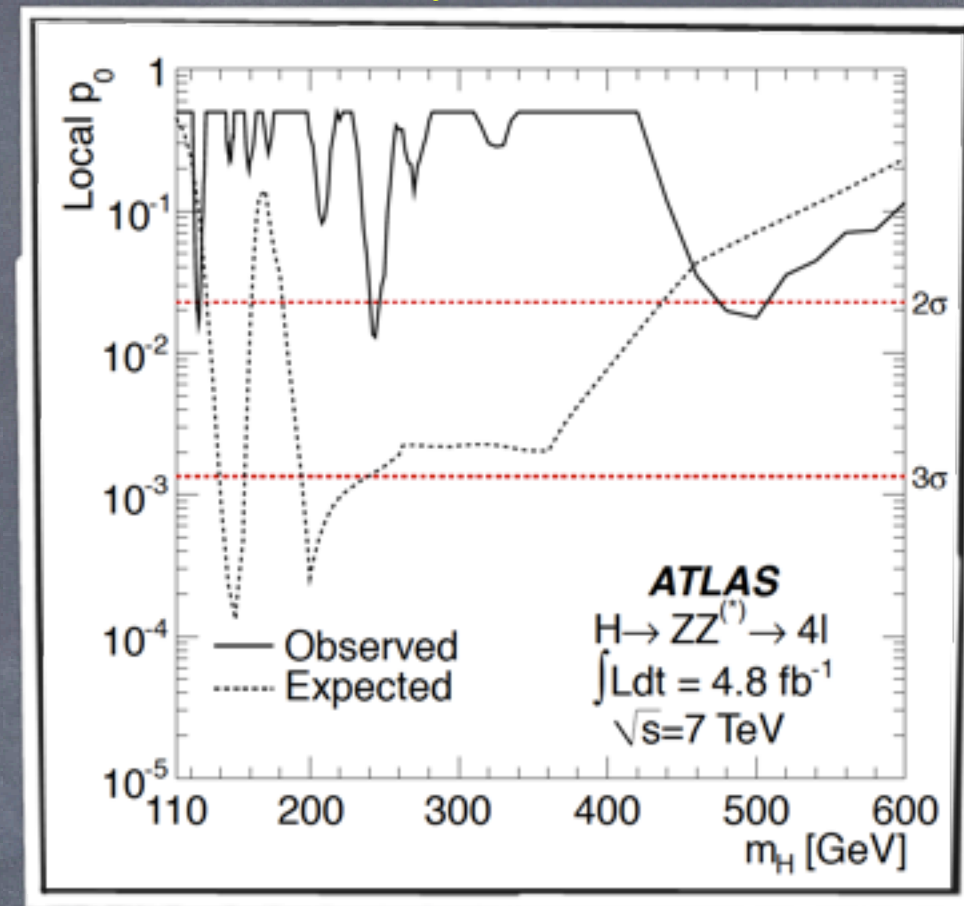
Expected Exclusion
m_H=
137-157
184-400
GeV

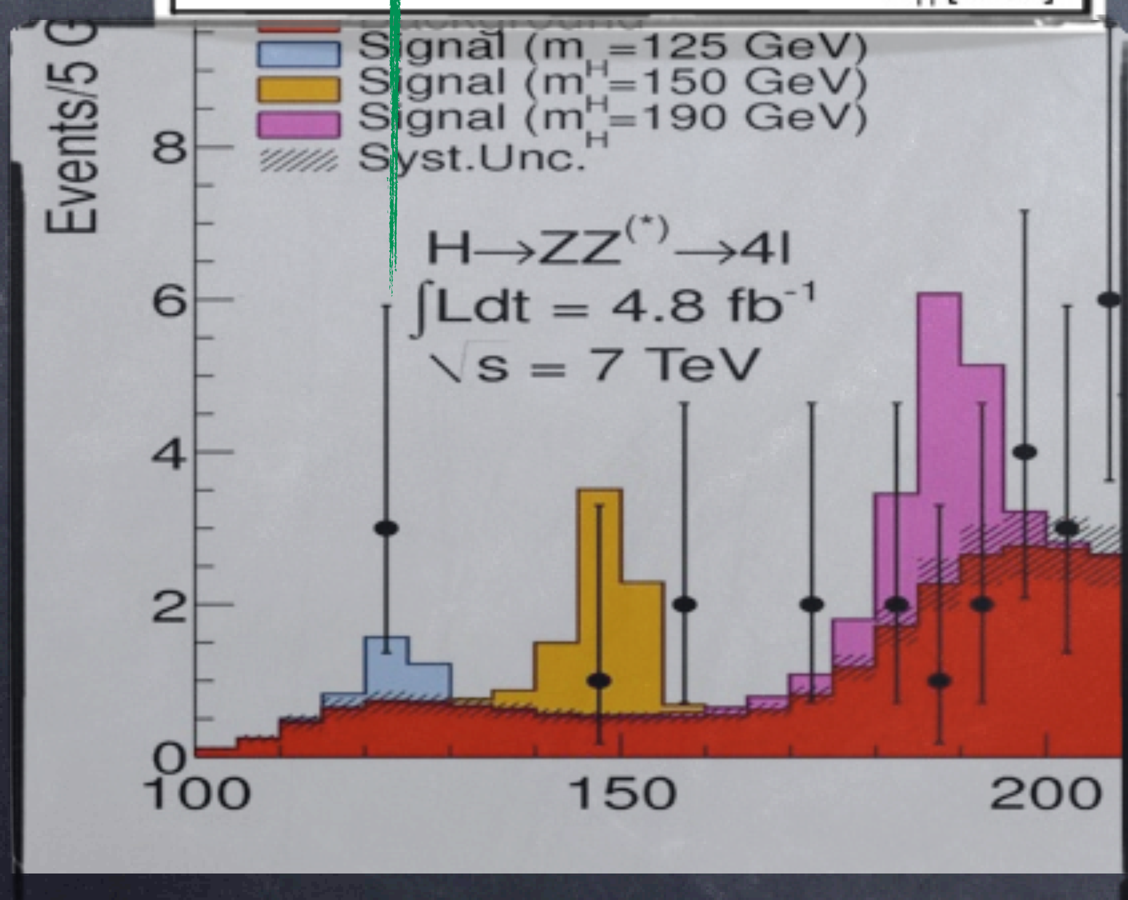
Observed Exclusion
m_H=
134-156
182-233,
256-265
268-415
GeV



H->ZZ->4l ATLAS p0





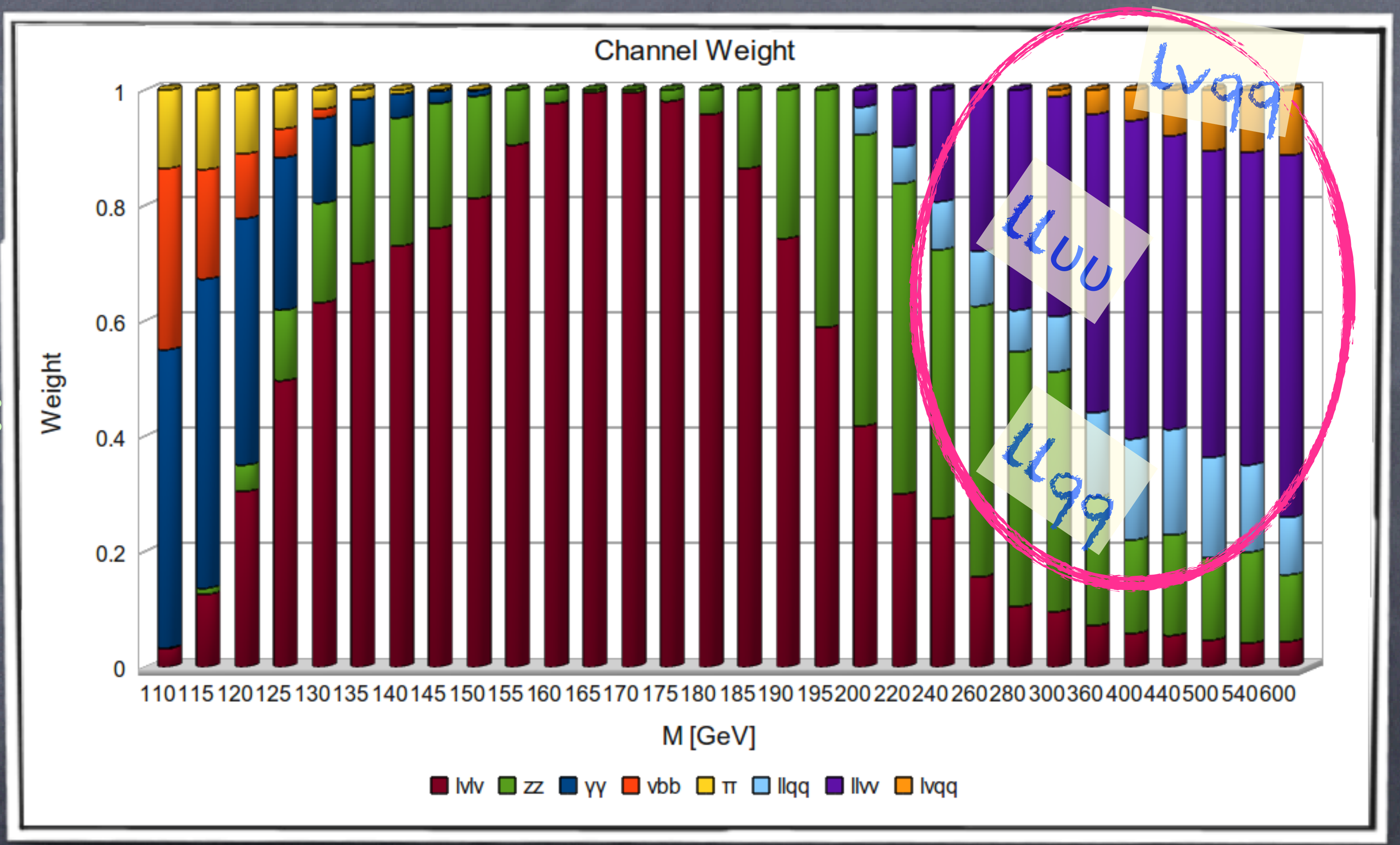


$m_{4\ell}$	125 GeV	244 GeV	500 GeV
Exp. w. signal	1.3σ	3.0σ	1.5σ
Observed	2.1σ	2.2σ	2.1σ

Look Elsewhere Effect :
There is O(50%) probability to have such an excess anywhere in the full mass range

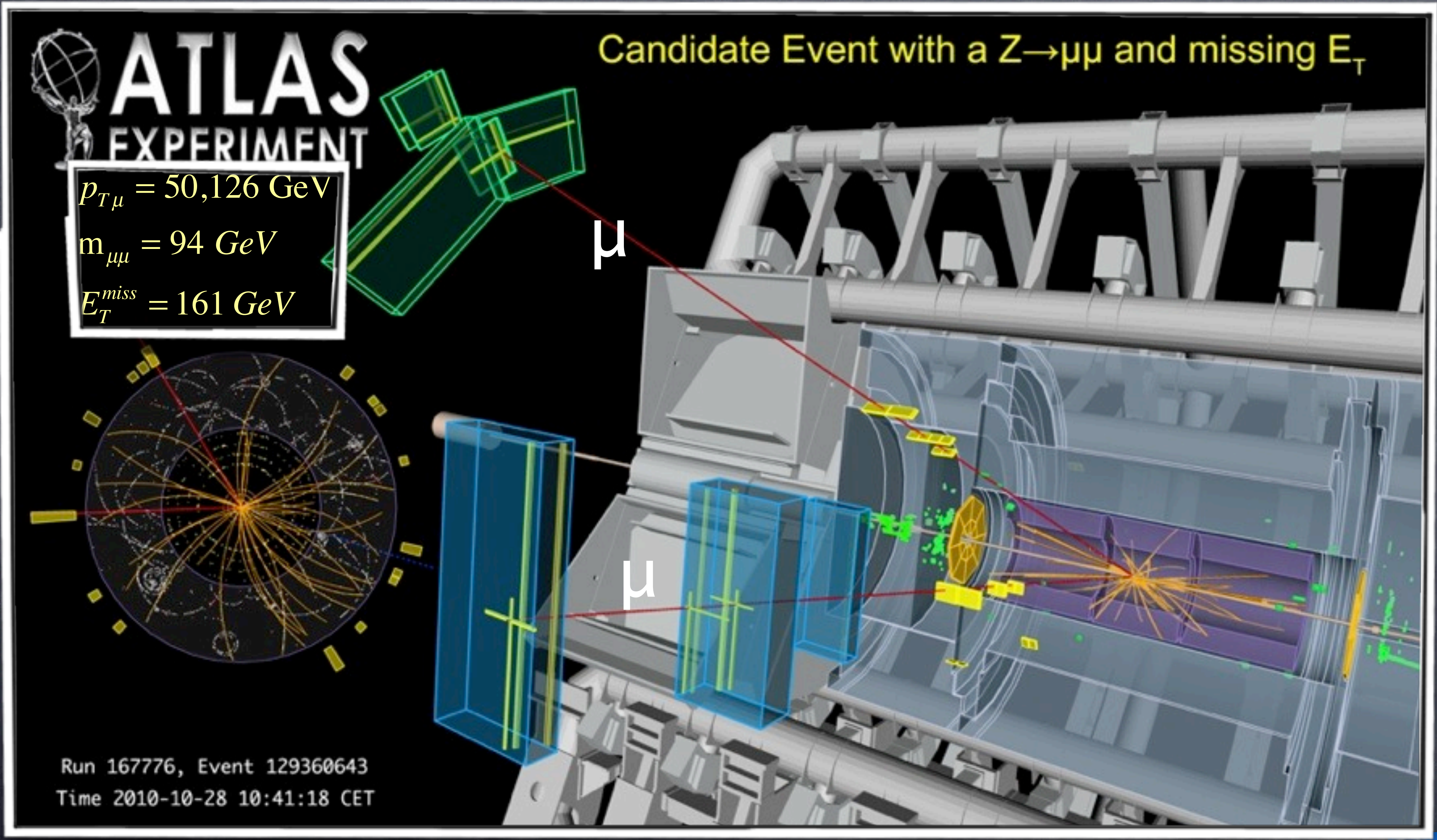
Heavy Higgs

- mH>200
- Probing channels:
  H->ZZ->llvv
  H->ZZ->llqq
  H->WW->lvqq



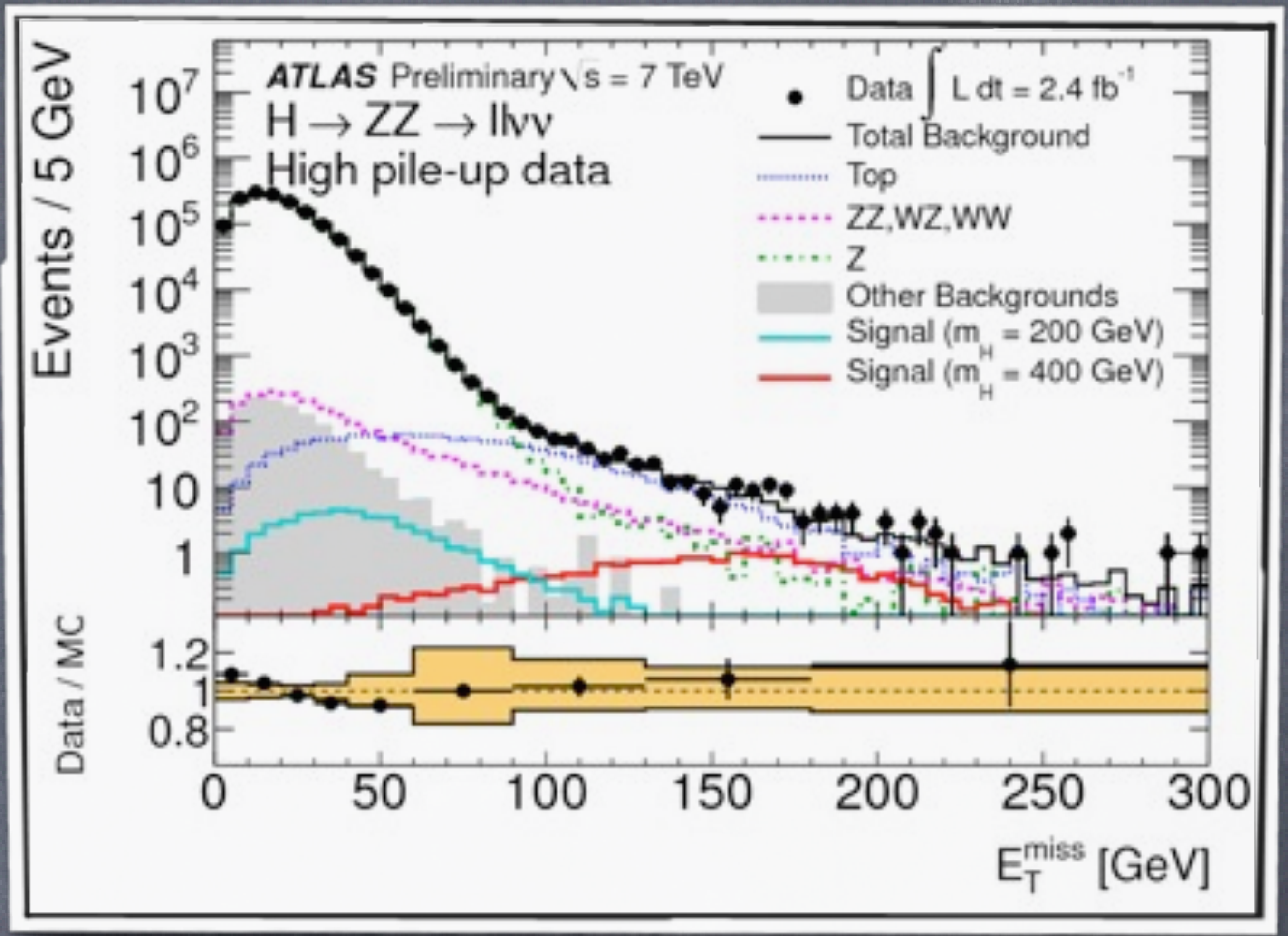
Heavier Higgs: H->llνν

- Signature: two high p_T opposite charged isolated leptons (with m_{ll}~m_Z) with high MET (both Z's are boosted for high m_H)



Heavier Higgs: H->llνν

- Discriminating variables:
  $\Delta\Phi_{ll,MET}$
  Understanding of MET tails is crucial
- Main BG: irreducible di-Boson ZZ,WZ
- Reducible, measured or verified with data control samples:
  QCD, W/Z+jets (suppressed by MET) and top (rejected by anti b-tag)

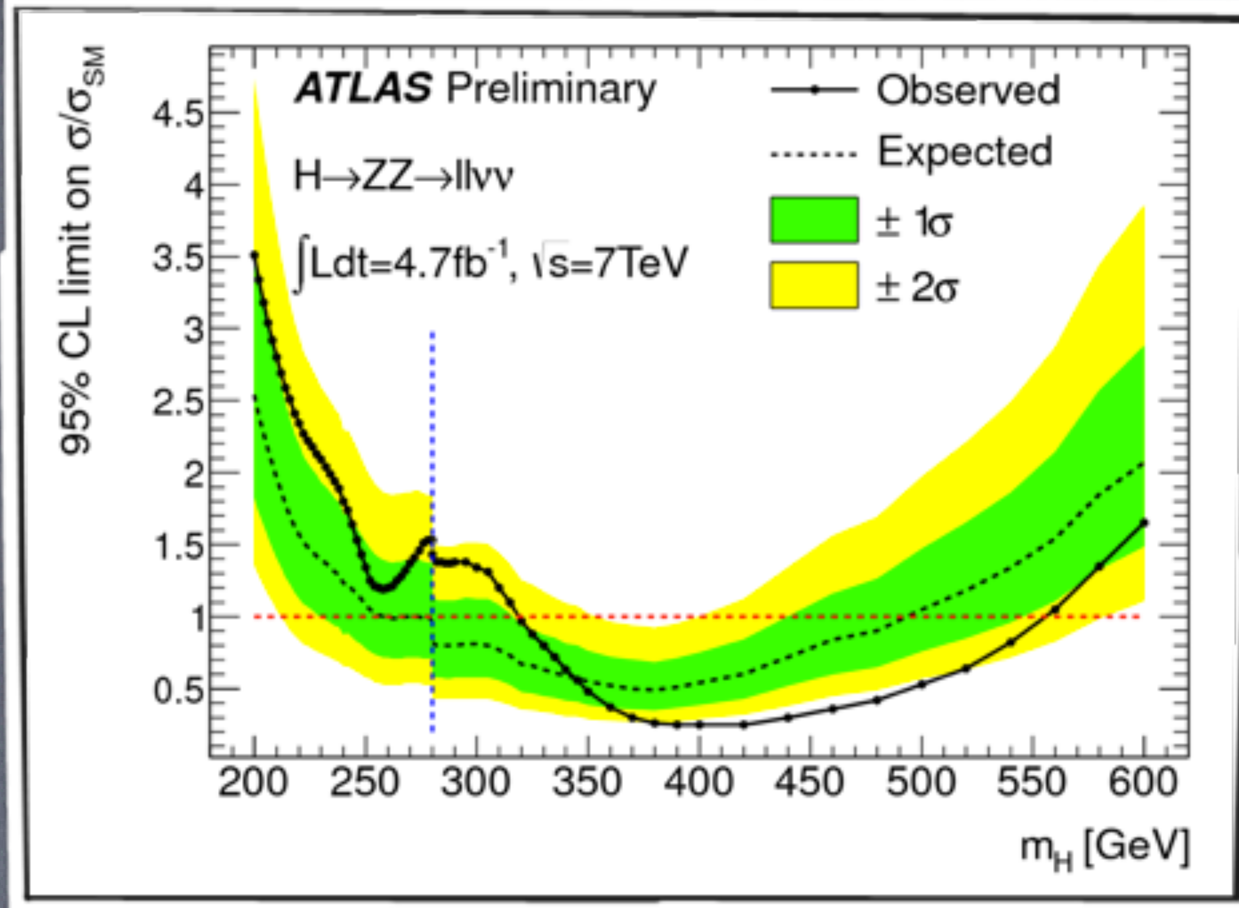


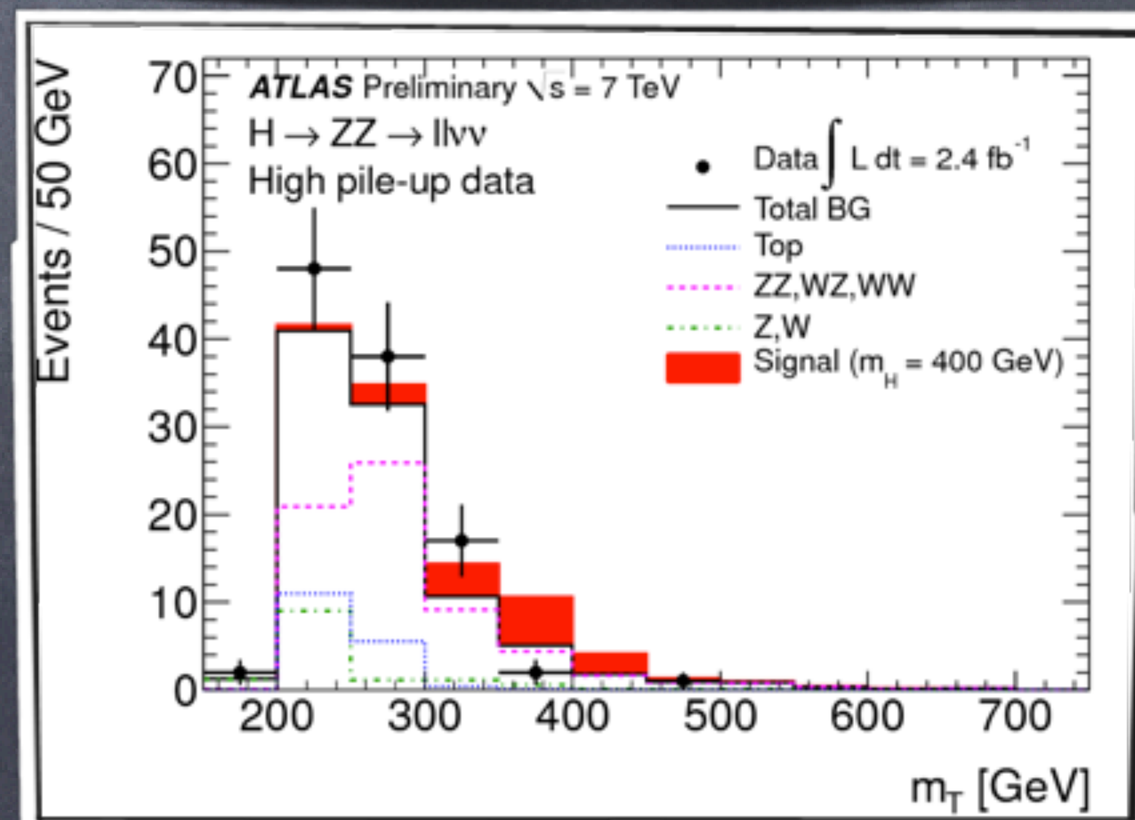
Heavier Higgs: H->llνν

- Transverse mass
  (two mass bins [⋚280 GeV])

$$m_T^2 \equiv \left(\sqrt{\vec{p}_{TZ}^{\,2}+m_Z^2}+\sqrt{|\,\vec{p}_T^{\,miss}\,|^2+m_Z^2}\right)^2-(\vec{p}_{TZ}+\vec{p}_T^{\,miss})^2$$

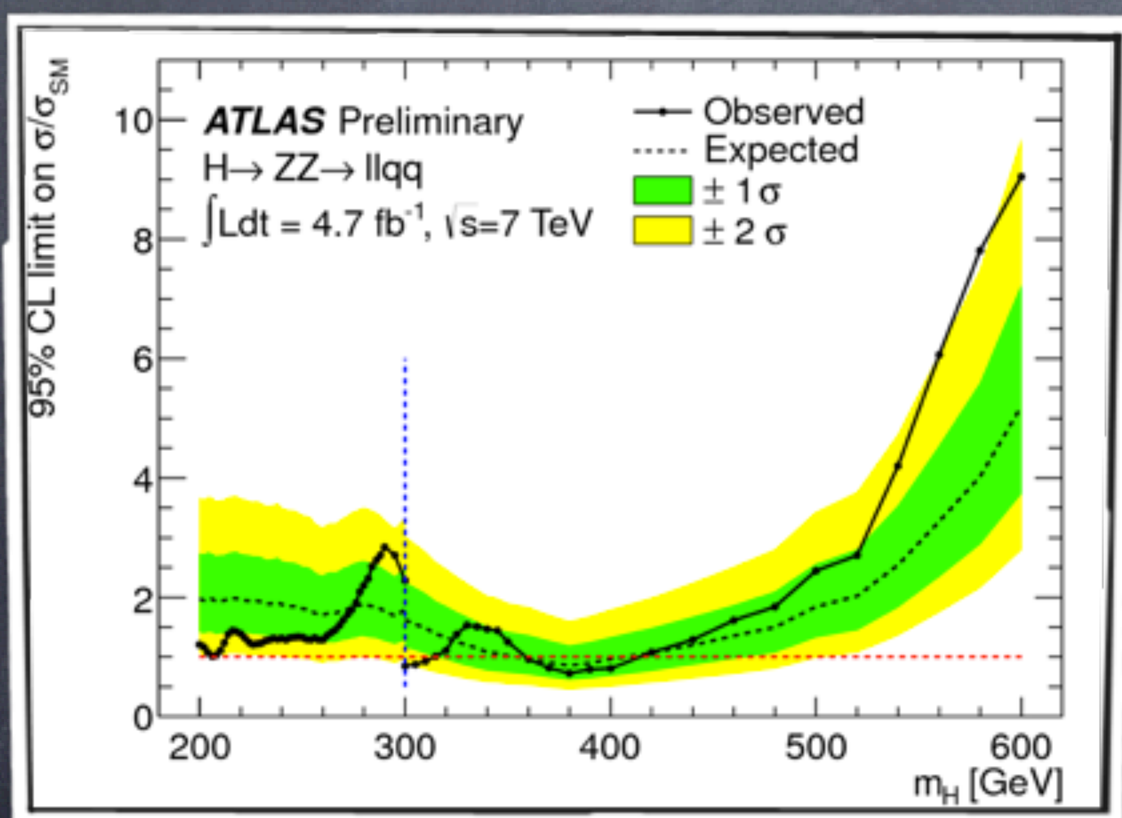
Obs: excl 350<mH<450
Exp: excl 260<mH<490

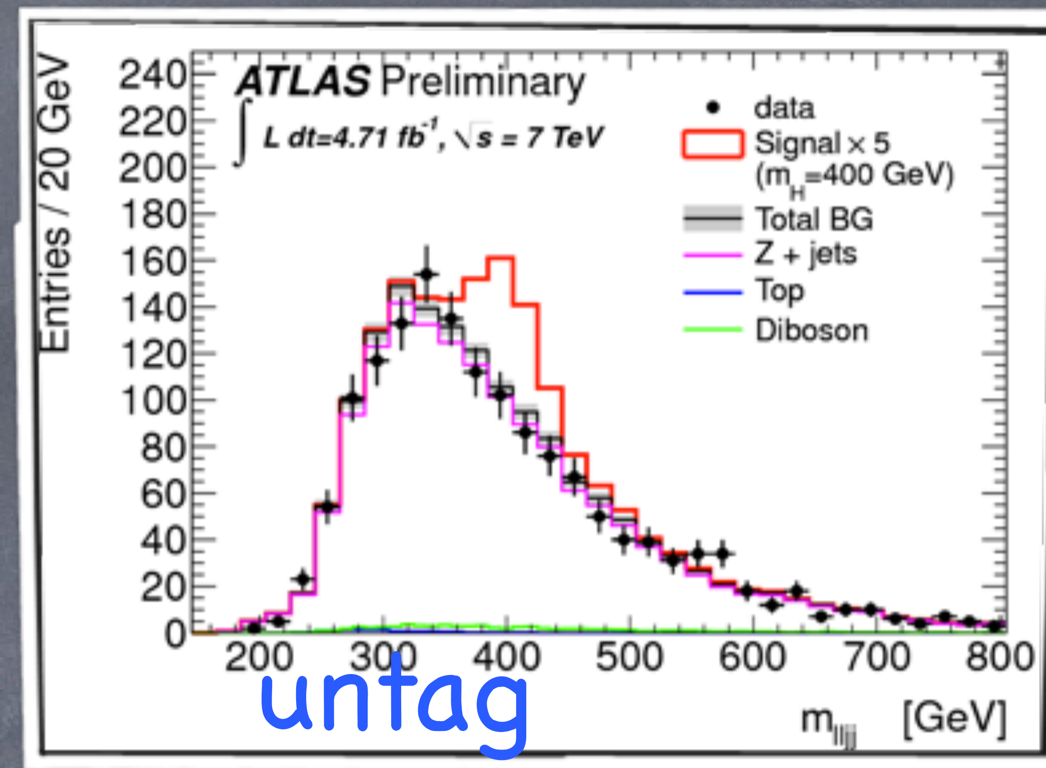


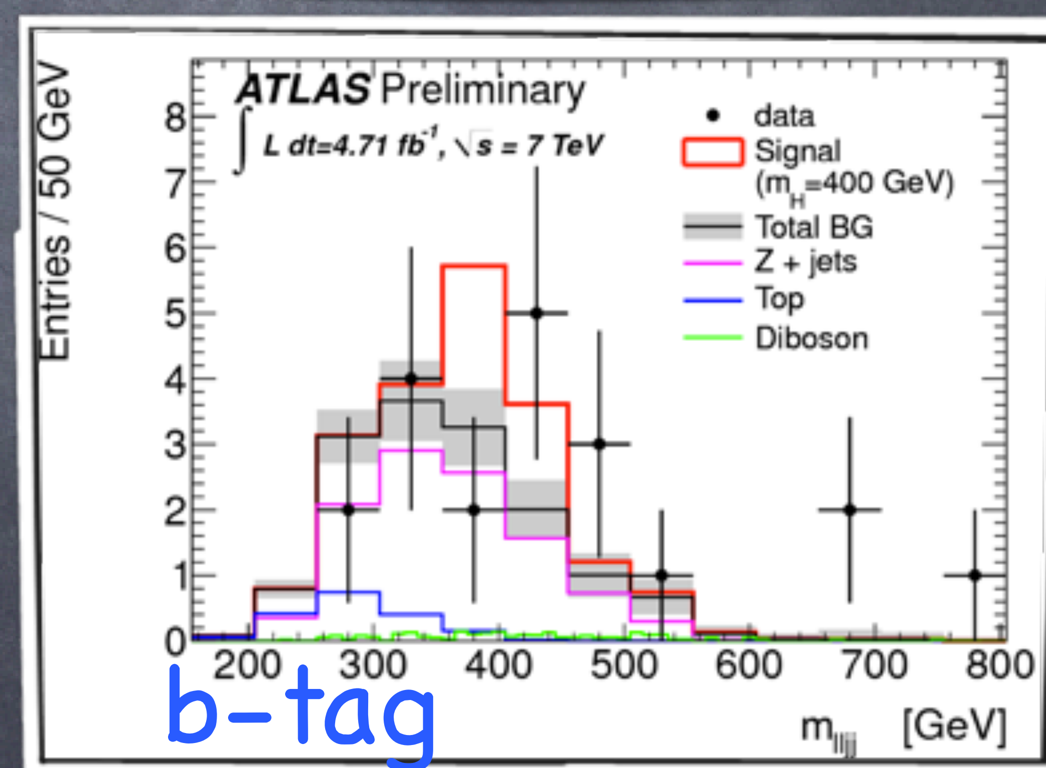


Heavier Higgs: H->llqq,llbb

- Highest rate, yet high Z+jets BG
- Clear signature:
  Exactly one pair of oppositely charged same flavor leptons and a pair of jets.
  both pairs compatible with a Z boson. Low MET
- Discriminating variable m_{lljj}



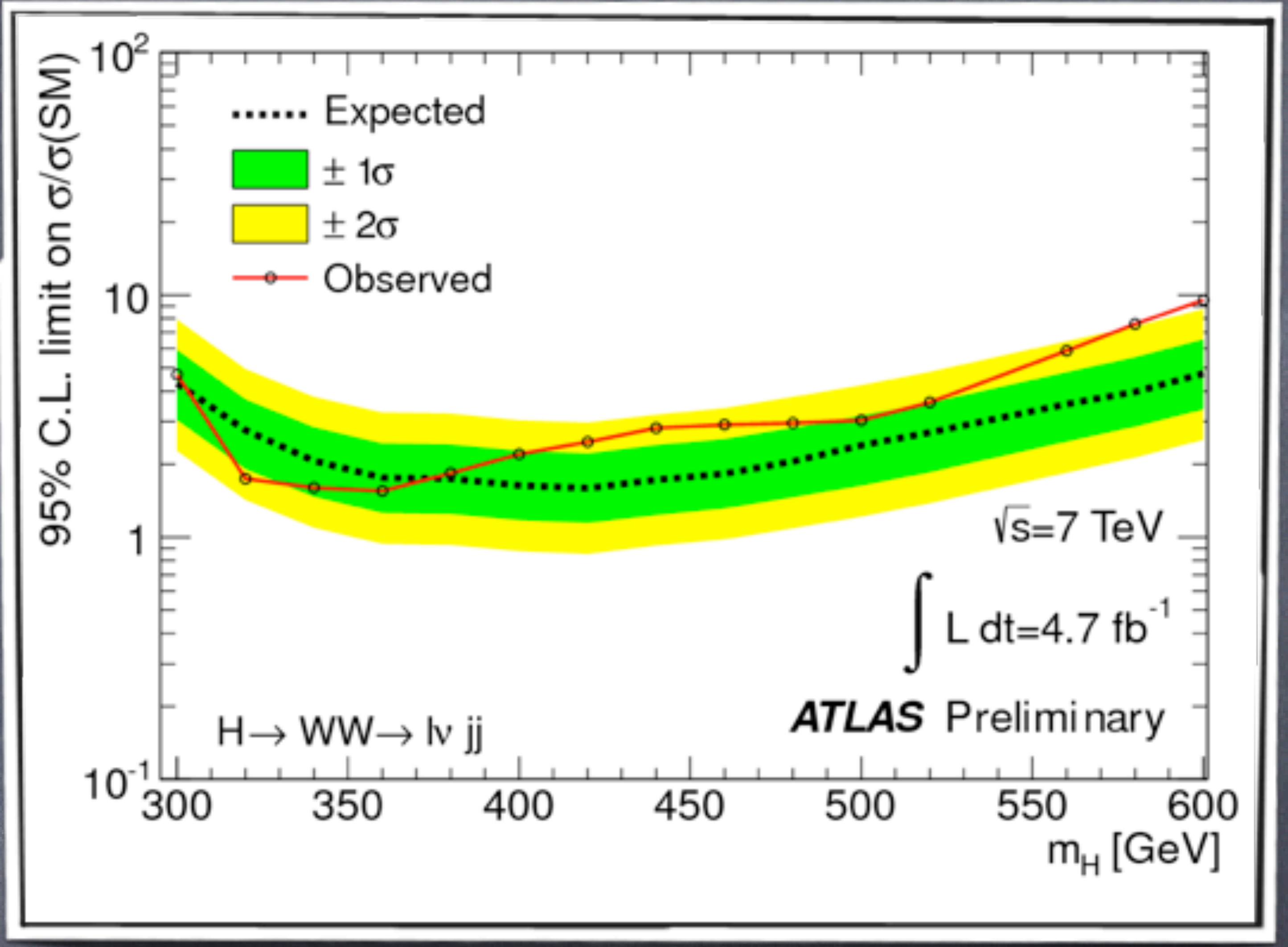




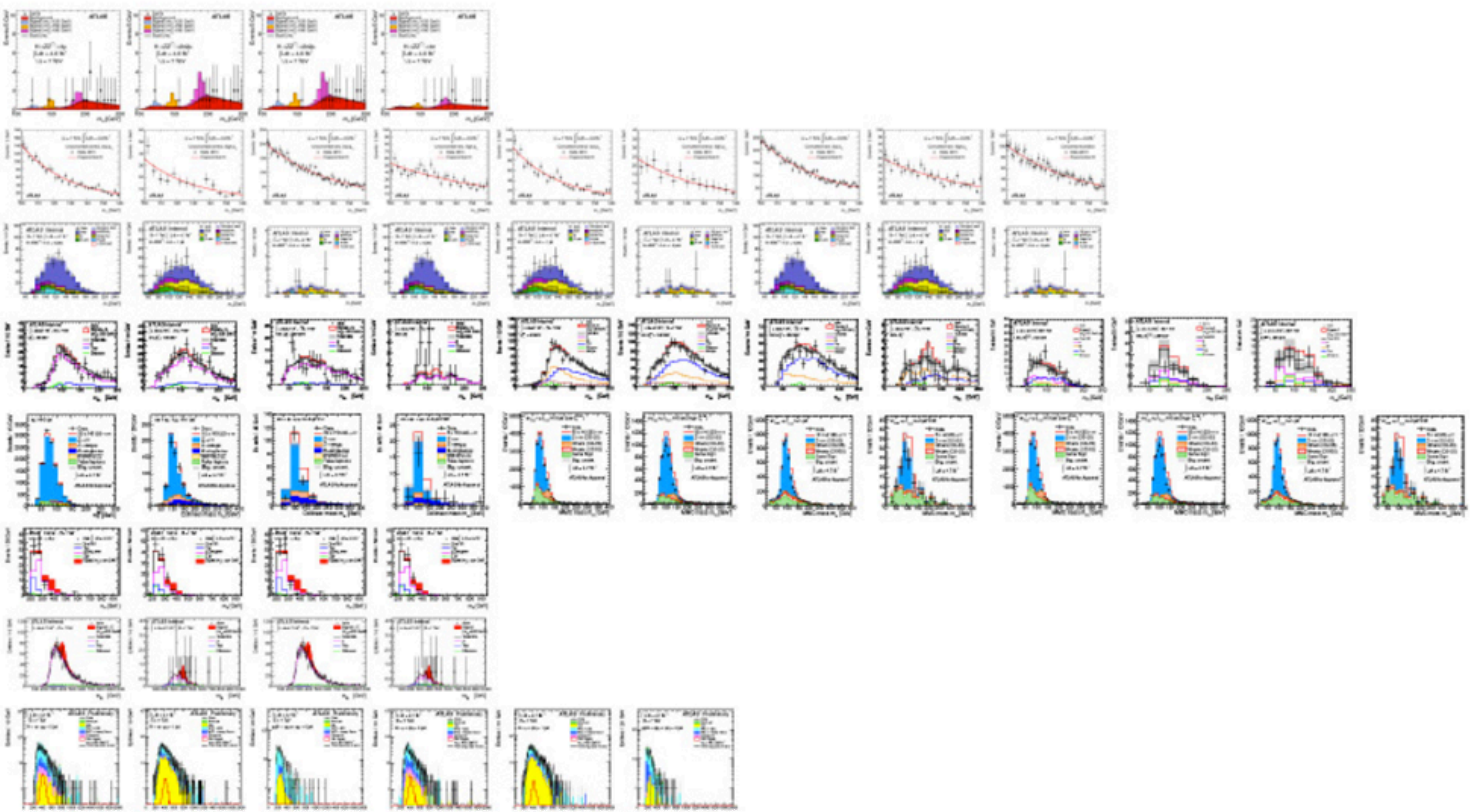
Obs: excl 300<mH<310,
360<mH<400
Exp: excl 360<mH<400

Heavier Higgs: H->WW->lvqq

- An elegant channel
- Search for a signal on top of a falling BG
- $m_{l\nu jj}$ mass is the fully reconstructed mass discriminator
- Analysis in jet bins, 0j, 1j and VBF 2j



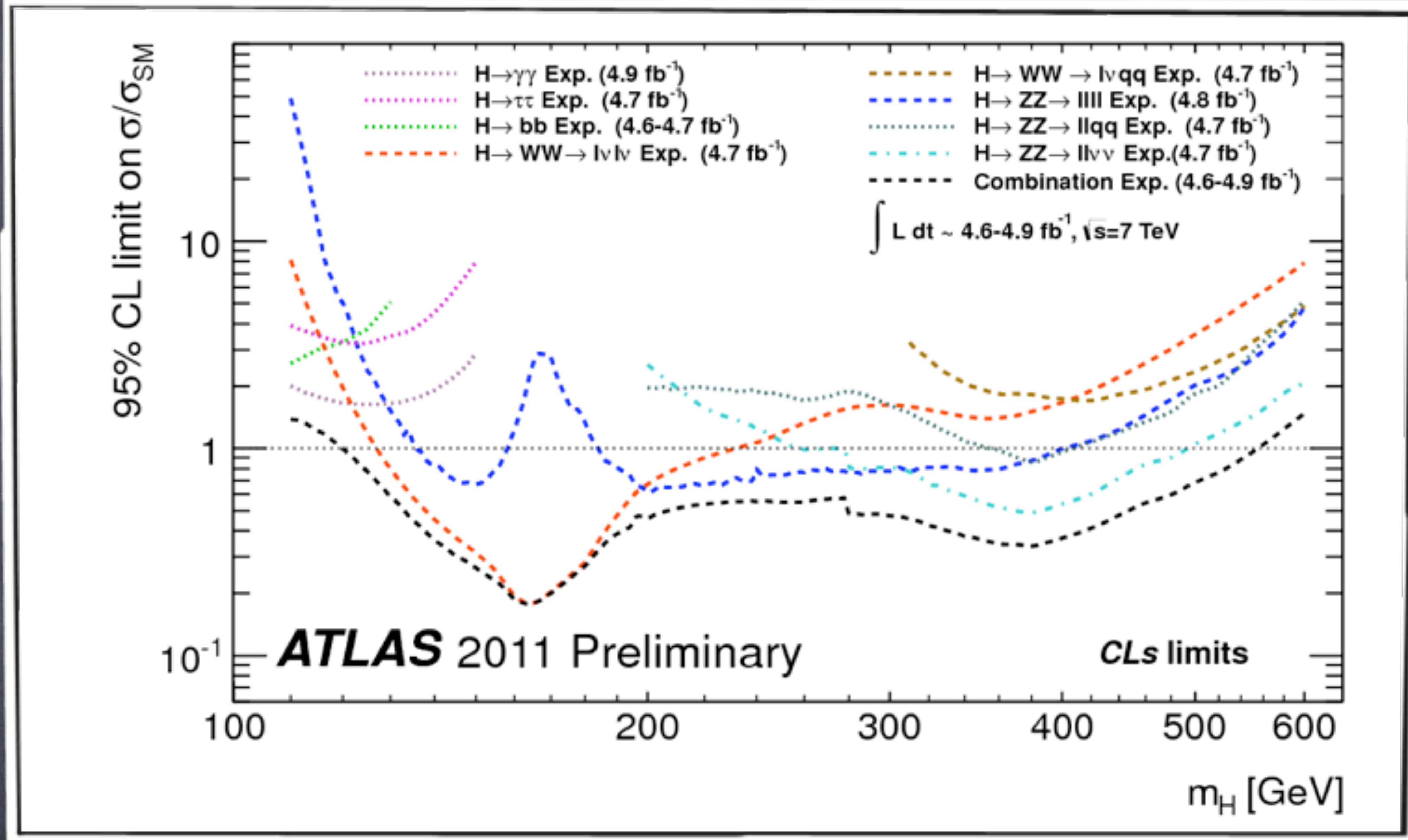
All for one - Combine forces



Disclaimer

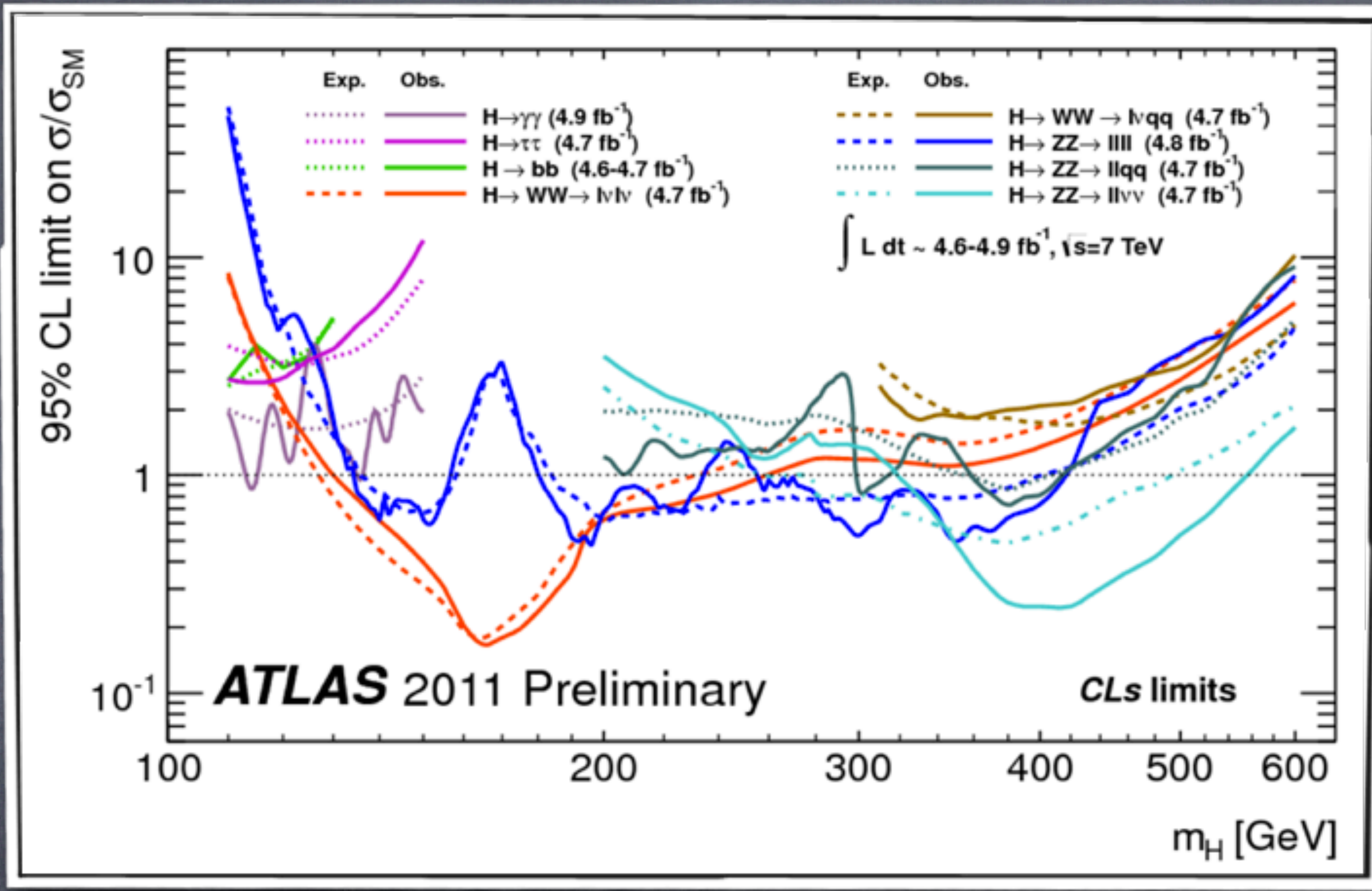
- Correlated uncertainties (Jet energy scales, Luminosity etc… taken into account)
- When data driven methods are used, systematics are not correlated
- Theory uncertaintes are carefully taken into account across channels using the recommendation of the LHC Higgs cross section group

Combined Limit



- WW has highest sensitivity at mH=125, γγ, bb and ττ are next in sensitivity
- High mass completely dominated by llνν

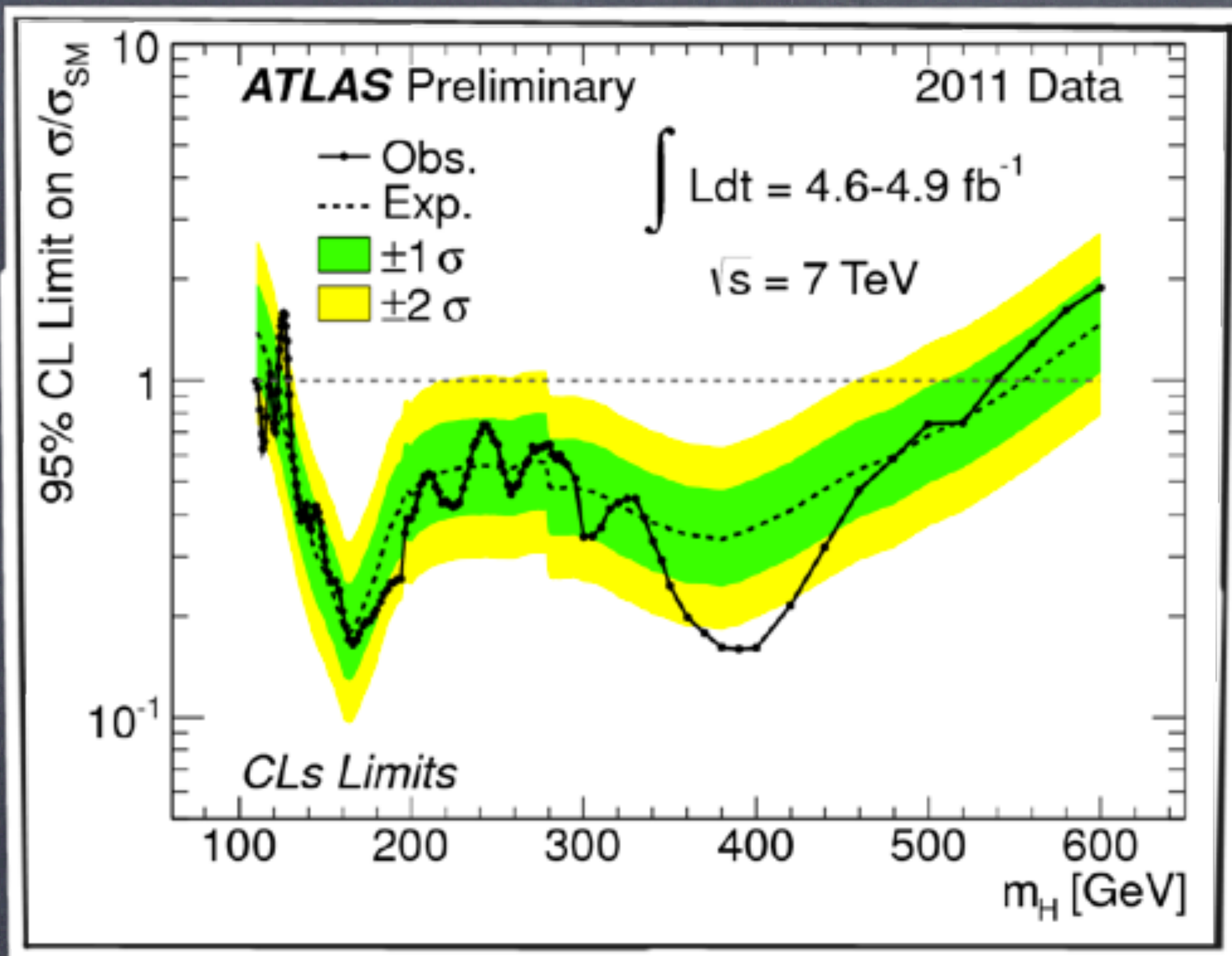
Combined Limit

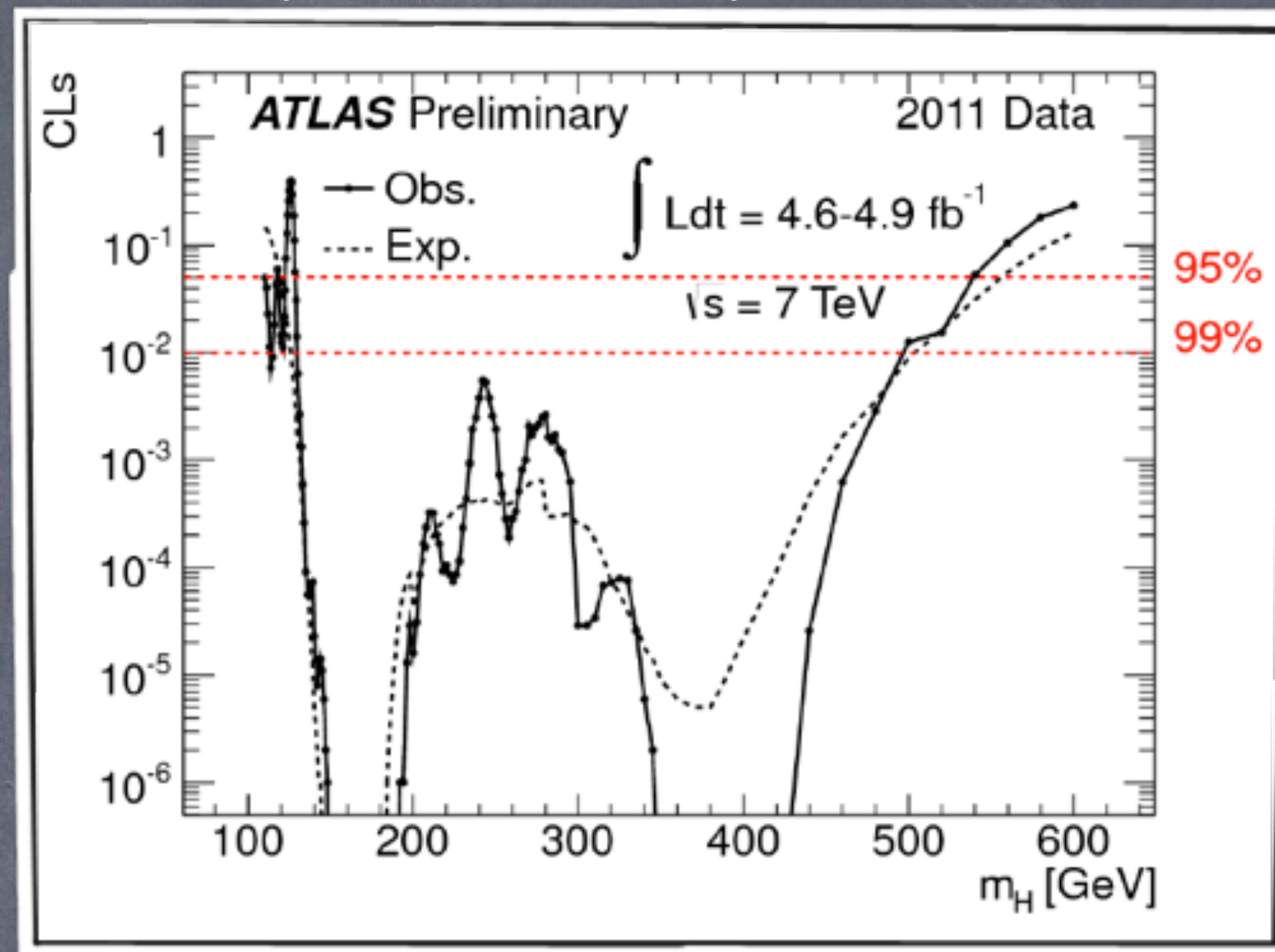


- WW has highest sensitivity at mH=125, γγ, bb and ττ are next in sensitivity
- High mass completely dominated by llνν

ATLAS EXPERIMENT

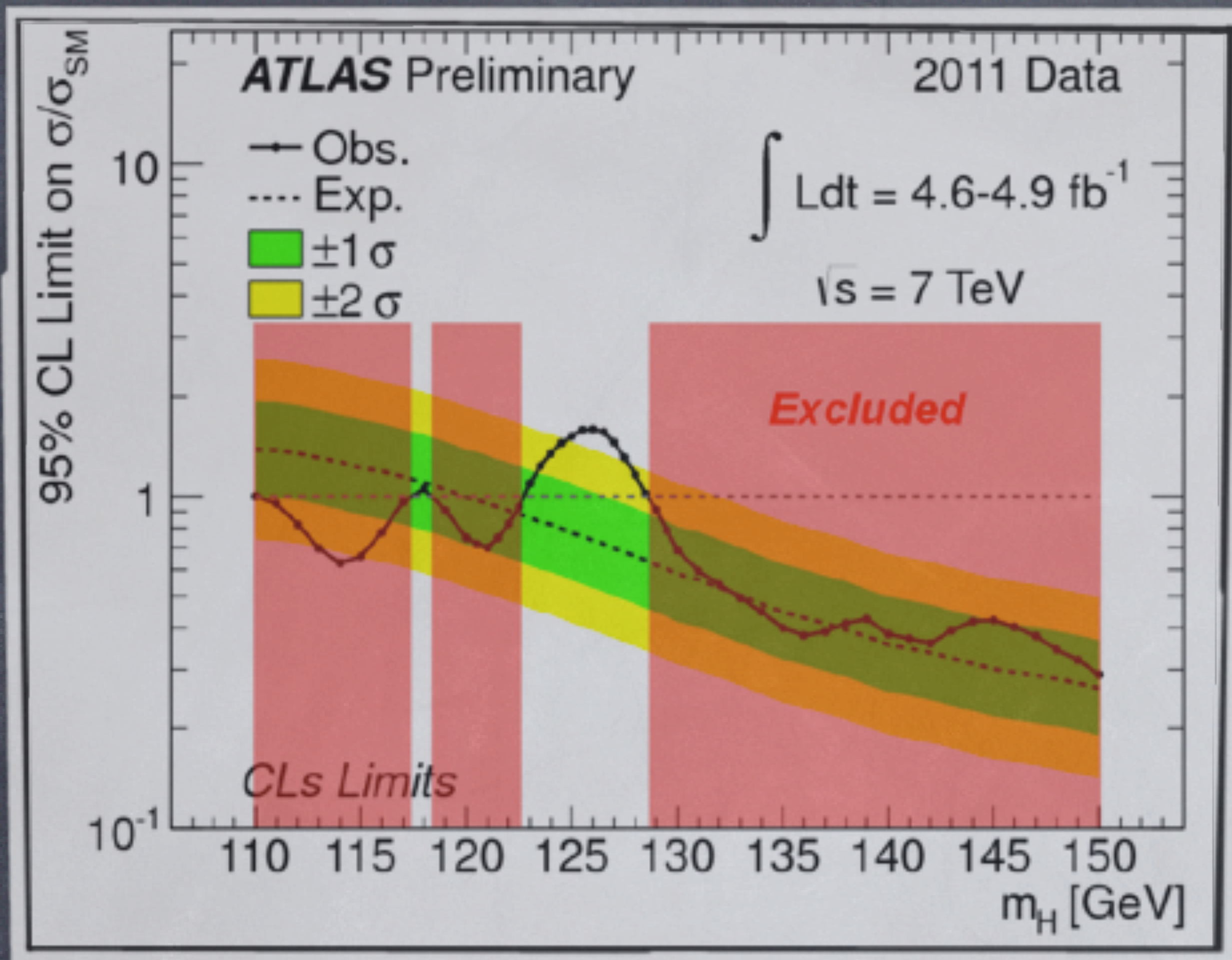
Combined Limit (ATLAS)

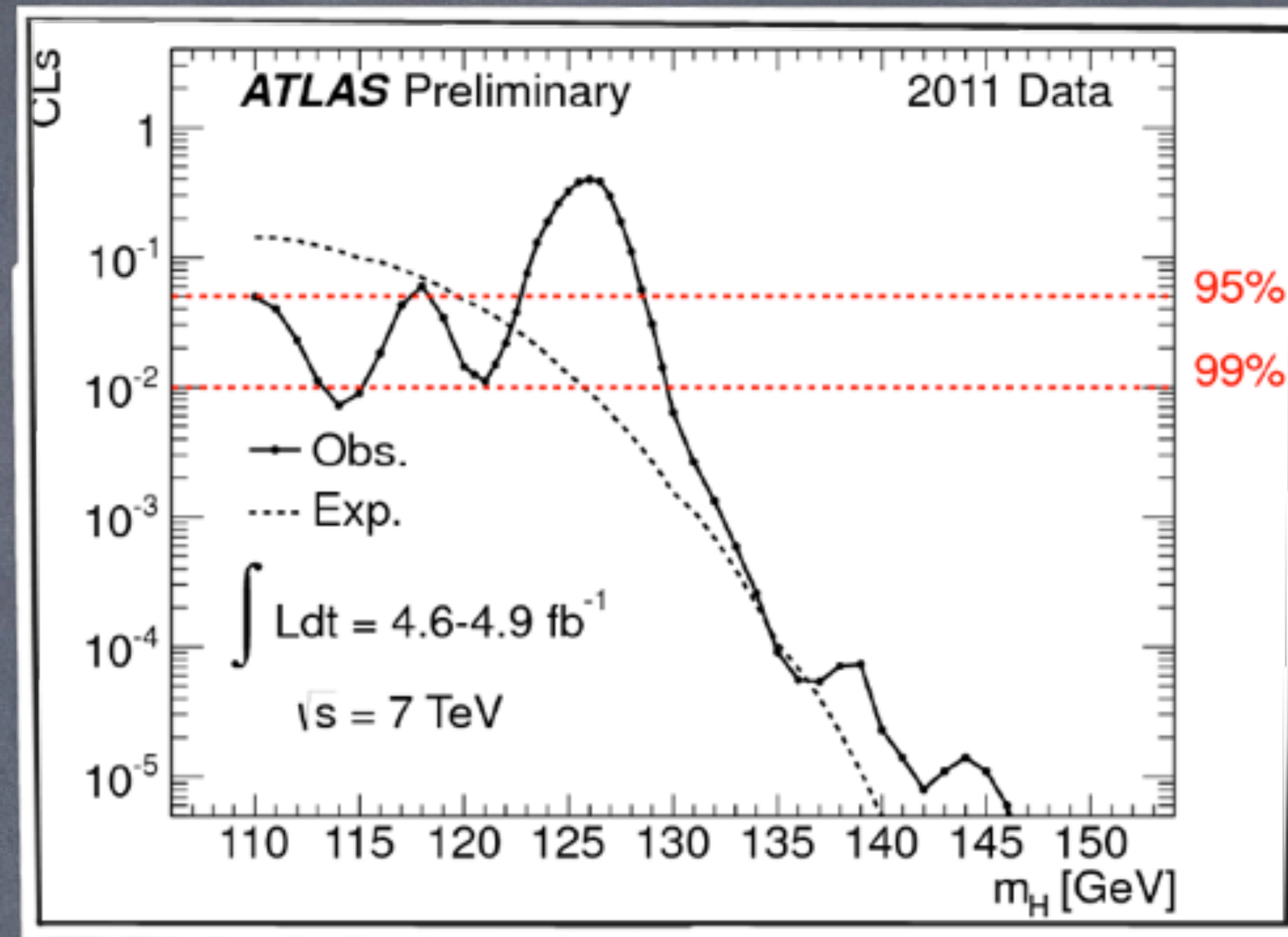




- ATLAS expected @ 95% Confidence Level 120<mH<555 GeV
- ATLAS excluded 95% Confidence Level $110<m_H<117.5$
  $118.5<m_H<122.5$
  $129<m_H<539$ GeV
- ATLAS excluded 99% Confidence Level $130<m_H<486$

Combined Limit





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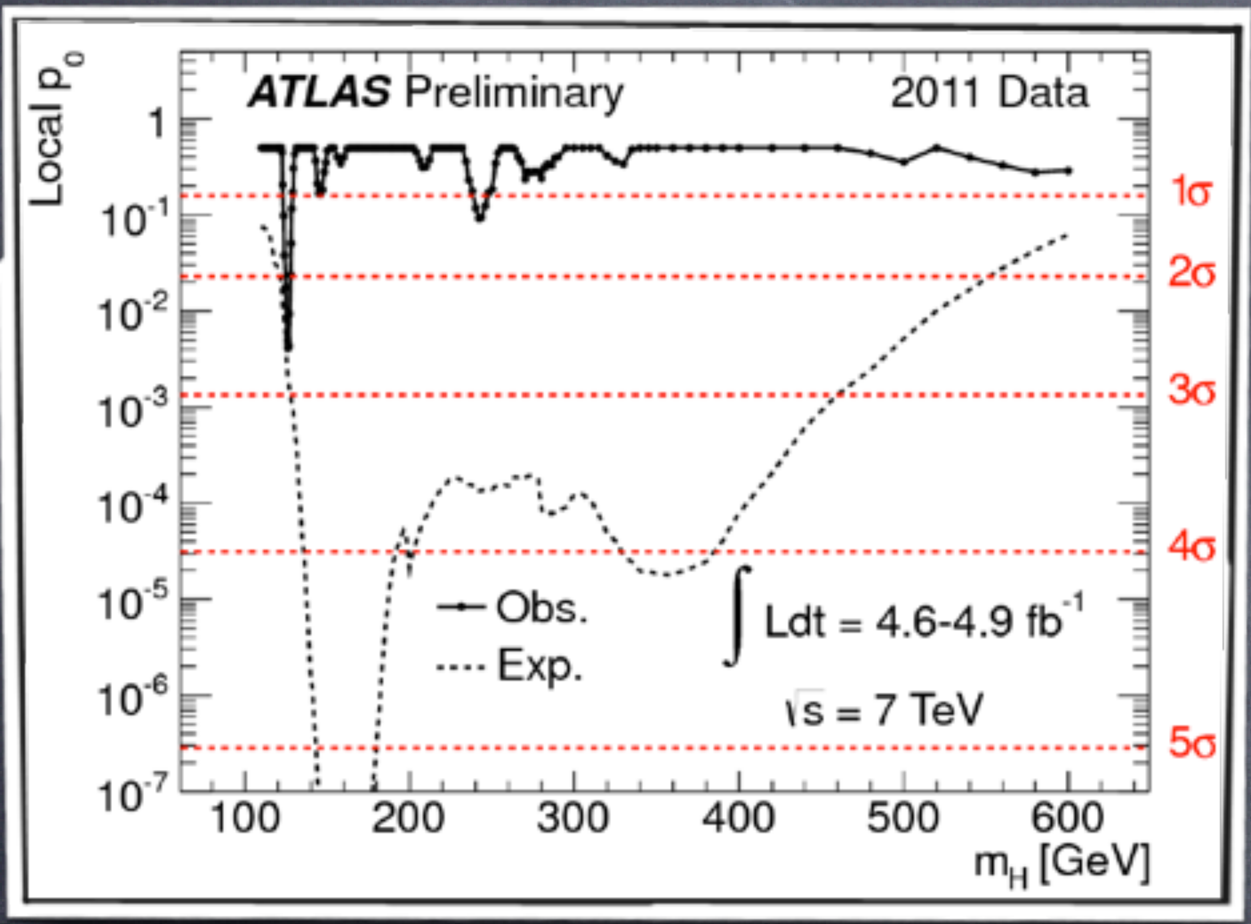
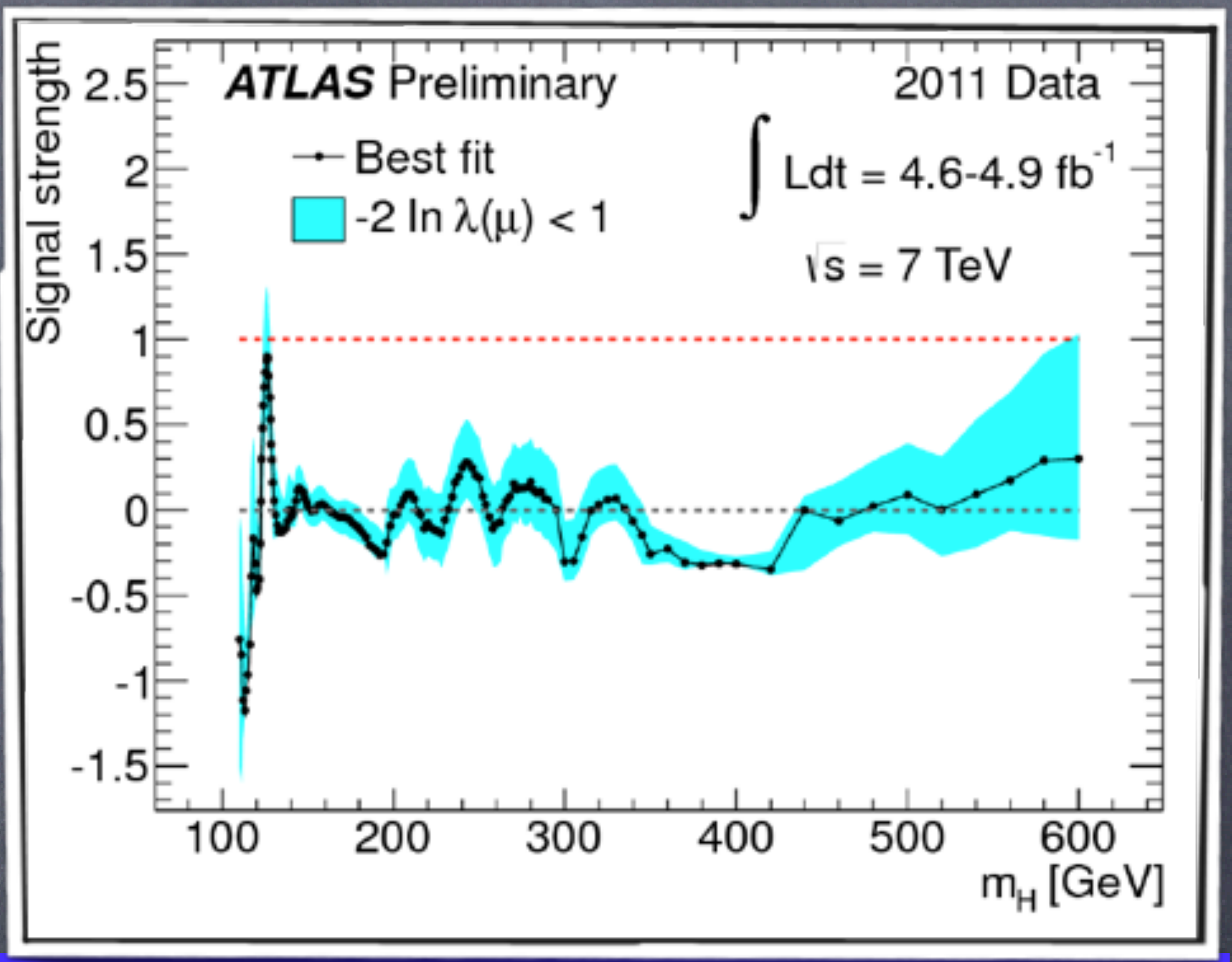
ATLAS combined p_0 and $\hat{\mu}$

$$\mu = \sigma / \sigma SM$$

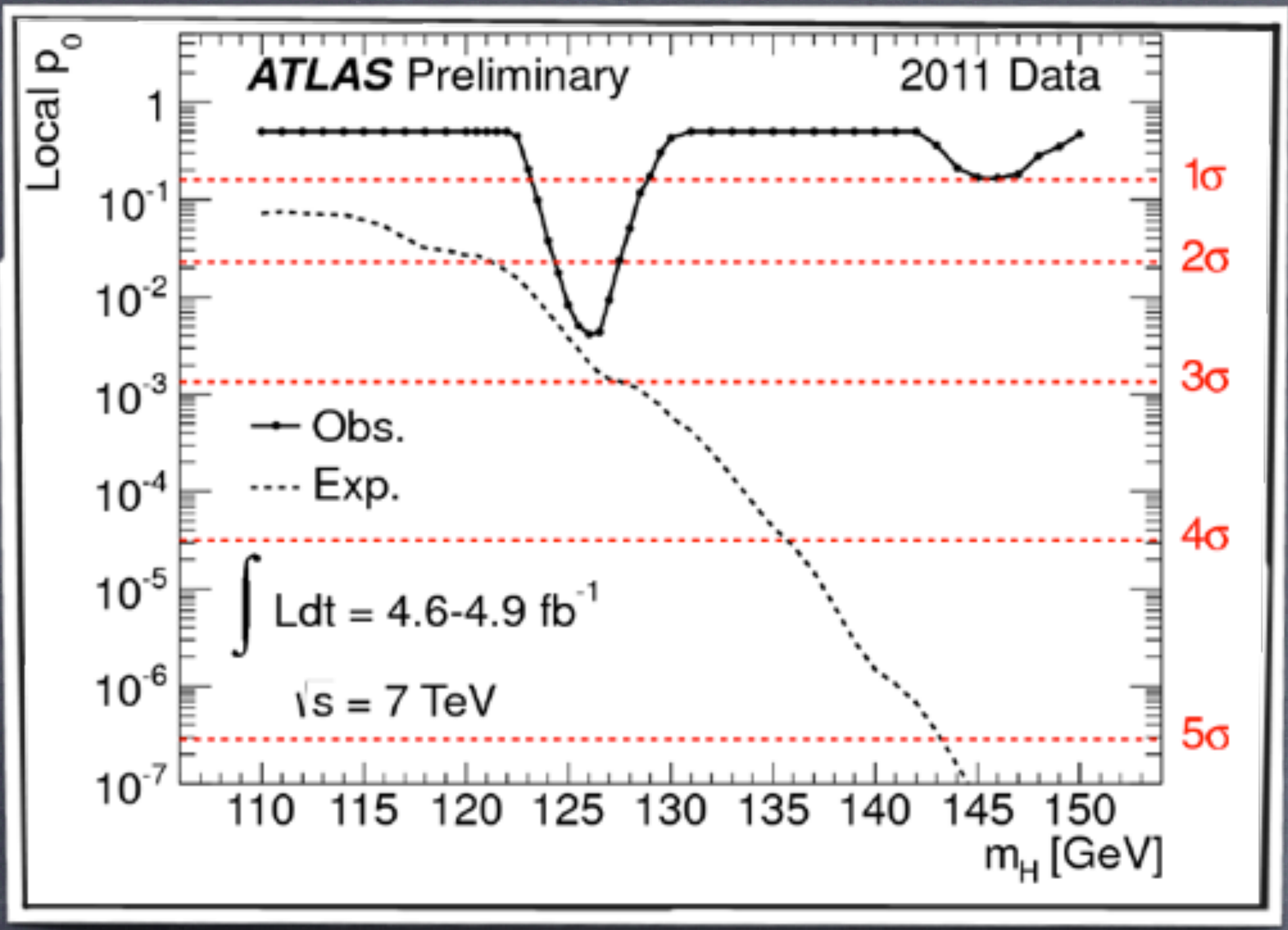
$$\hat{\mu} = \{\mu | L(\mu s(m_H) + b) = \max L(\mu, b)\}$$

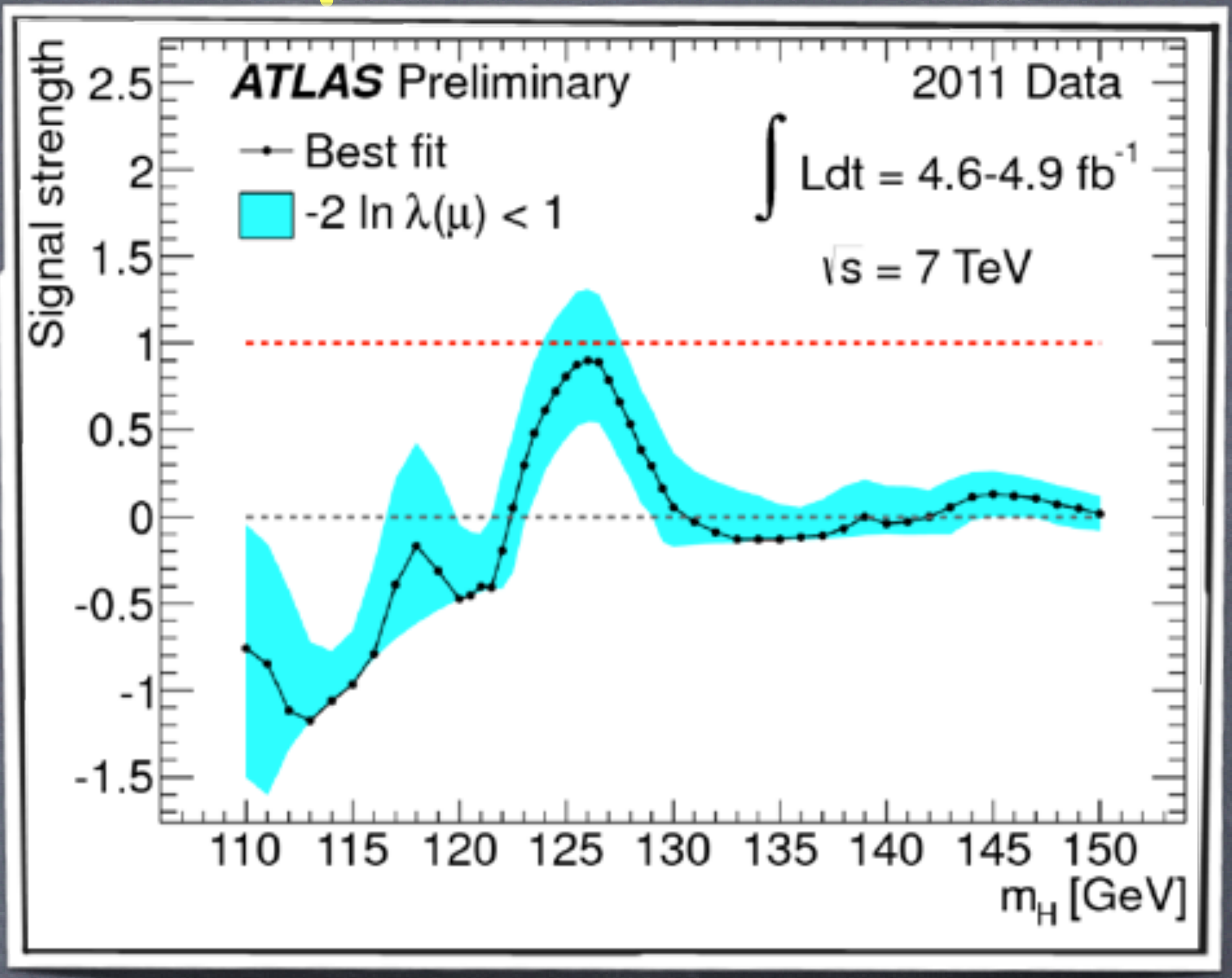




- There is an excess at the low mass that could be compatible with a SM light Higgs

ATLAS combined p_0 and $\hat{\mu}$



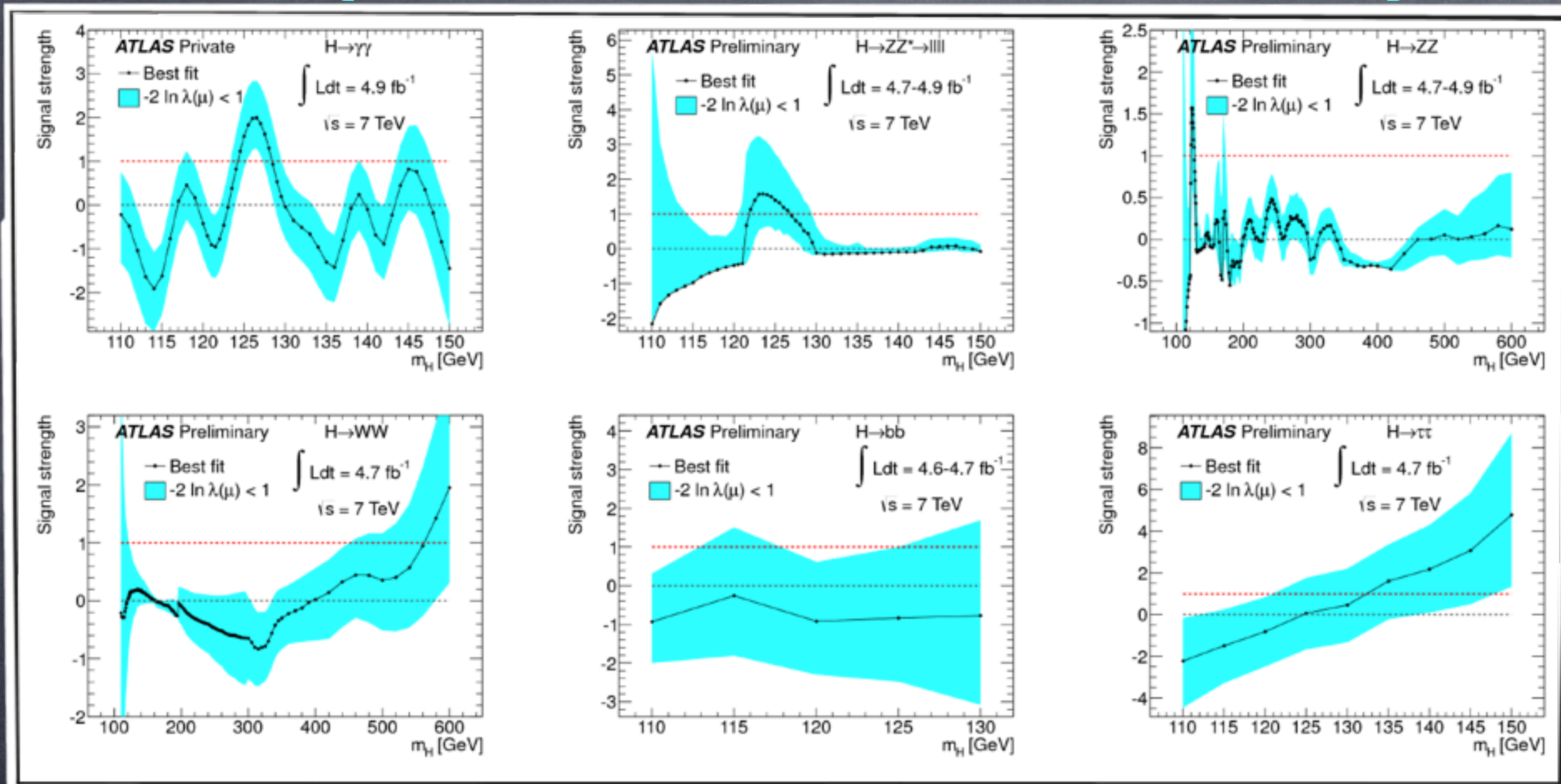


- There is an observed excess at the level of 2.5σ (expected 2.9σ) at m_H=126 GeV
with a best fit signal strength of $\hat{\mu} = 0.9^{+0.4}_{-0.3}$

- Global p_0: 10% with LEE over 110-146 GeV
30% with LEE over 110-600 GeV

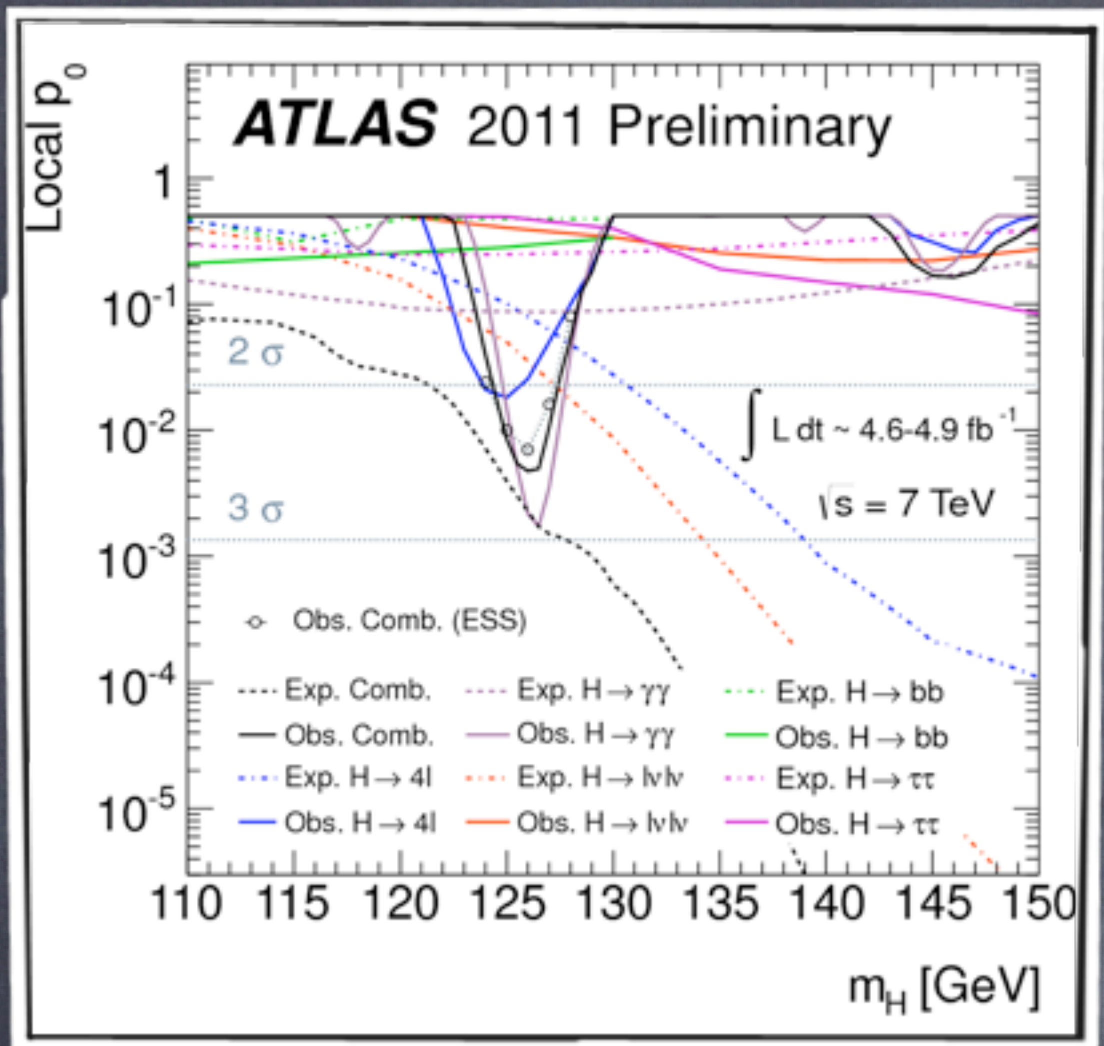
Combined ATLAS signal strength

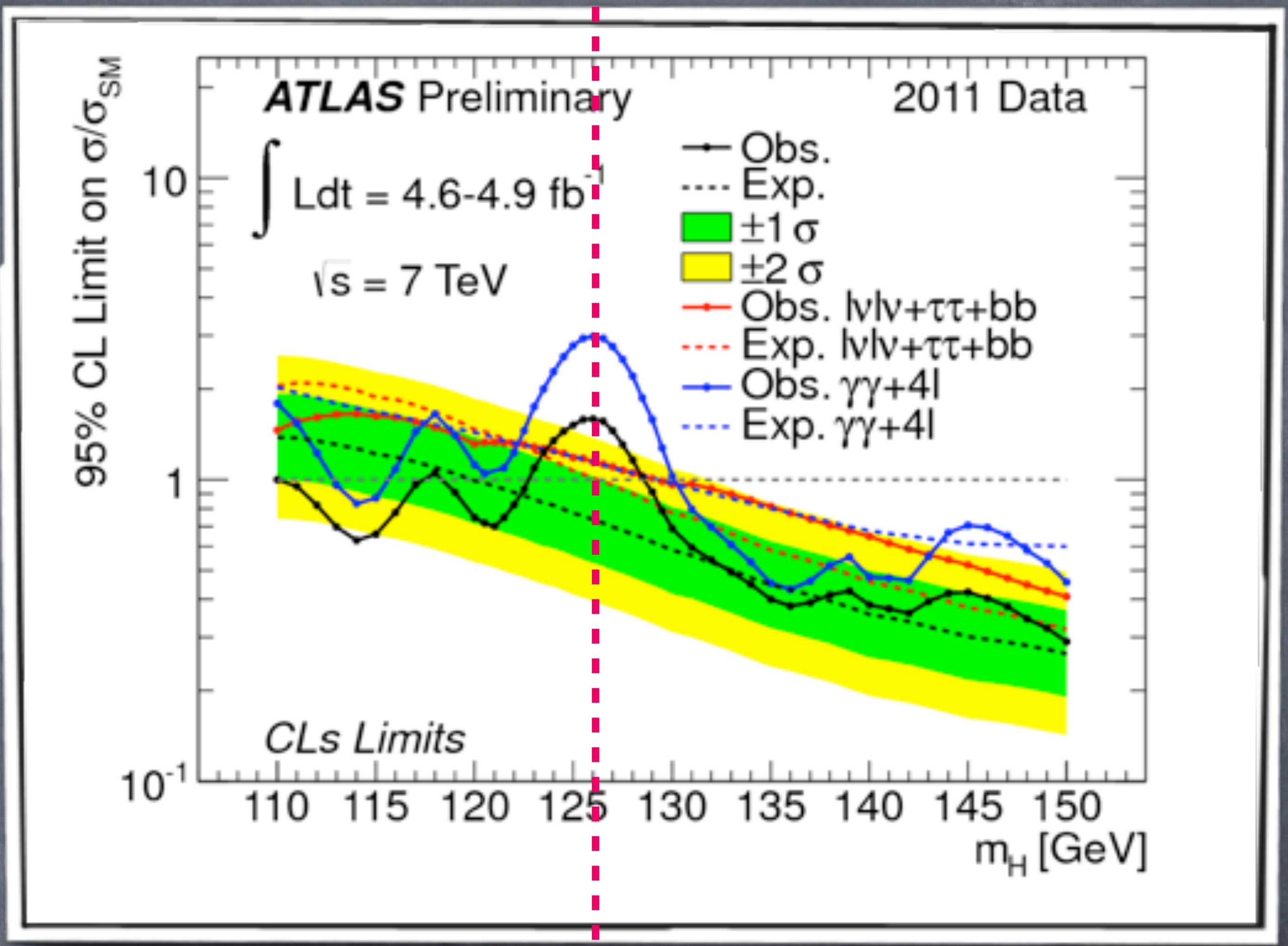
$$\hat{\mu} = \left\{ \mu \middle| L(\mu s(m_H) + b) = \max L(\mu, b) \right\}$$



The observed excess is driven by γγ at 126 GeV, it is larger than 1σ (γγ) from the SM value ($\hat{\mu}_{SM} = 1$) and within 1σ when combined $\hat{\mu} = 0.9^{+0.4}_{-0.3}$

Composition of Excess



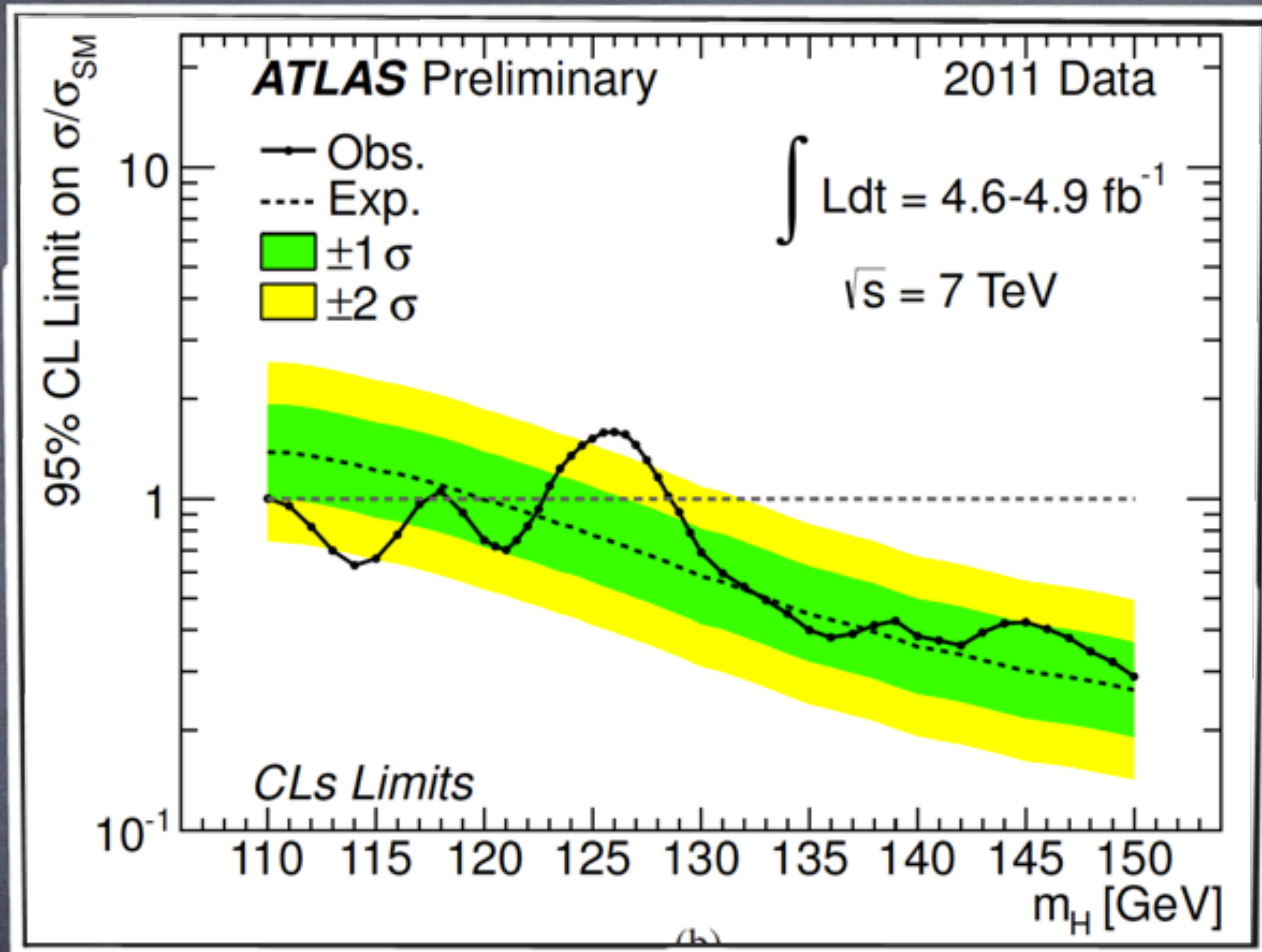


- Excess is mainly composed of the high resolution channels, γγ (obs 2.8σ exp 1.4σ) and 4l (obs 2.1σ, exp 1.4σ)
- Excess is not seen in the low resolution channels WW->lνlν (obs 0.2σ, exp 1.6σ), bb and ττ.
- Combined local significance of 2.5σ (taking Energy Scale Systematics into account)

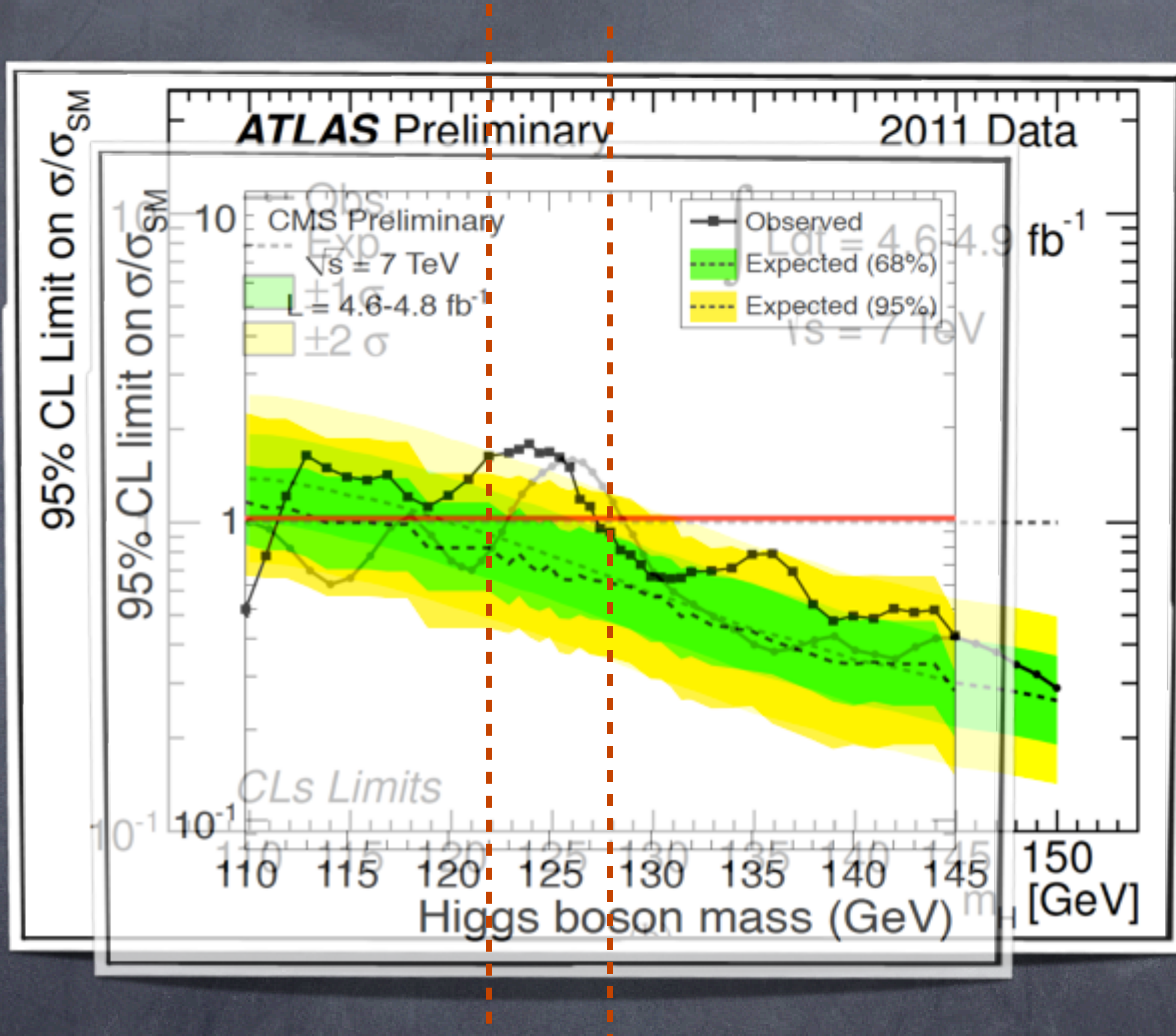
- The low resolution channels do not exclude 126 GeV Higgs

Forbidden Fruits

Cmbined Limit CMS vs ATLAS



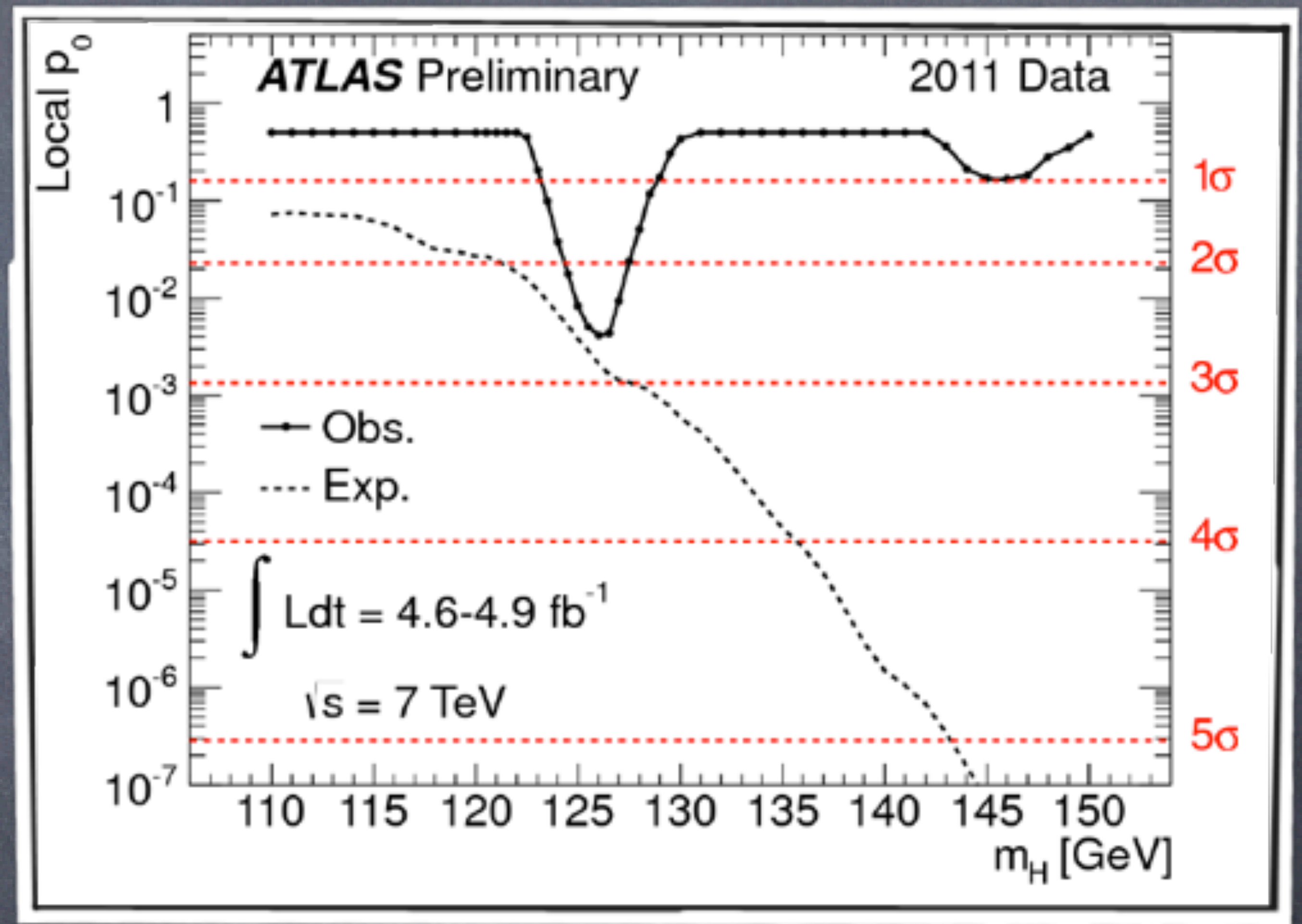
Combined Limit CMS vs ATLAS



- Not much living space for the Higgs to be, around 122-128 GeV

ATLAS vs CMS combined p_0

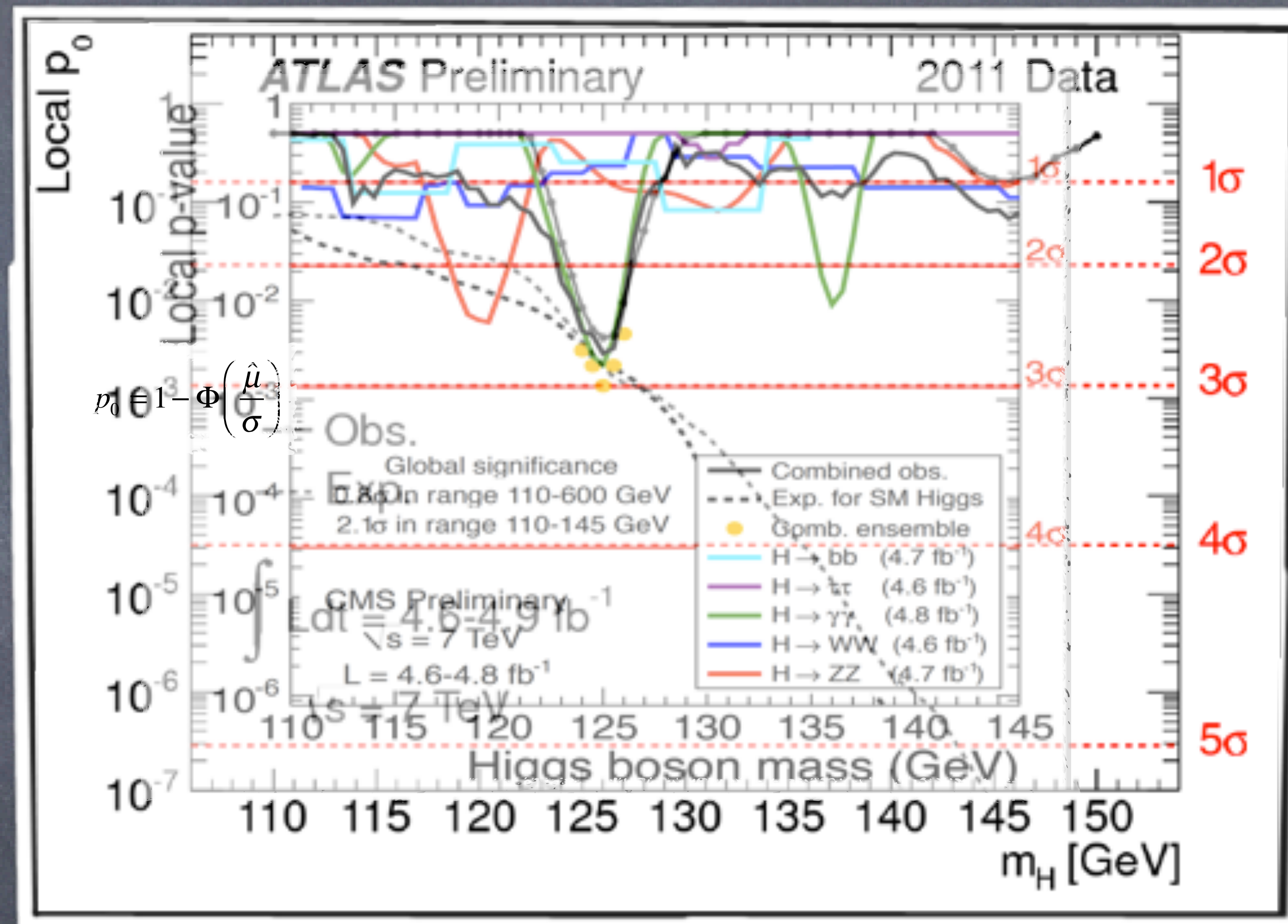
- ATLAS: local excess of 2.5σ at mH=126 GeV
-



ATLAS vs CMS combined p_0

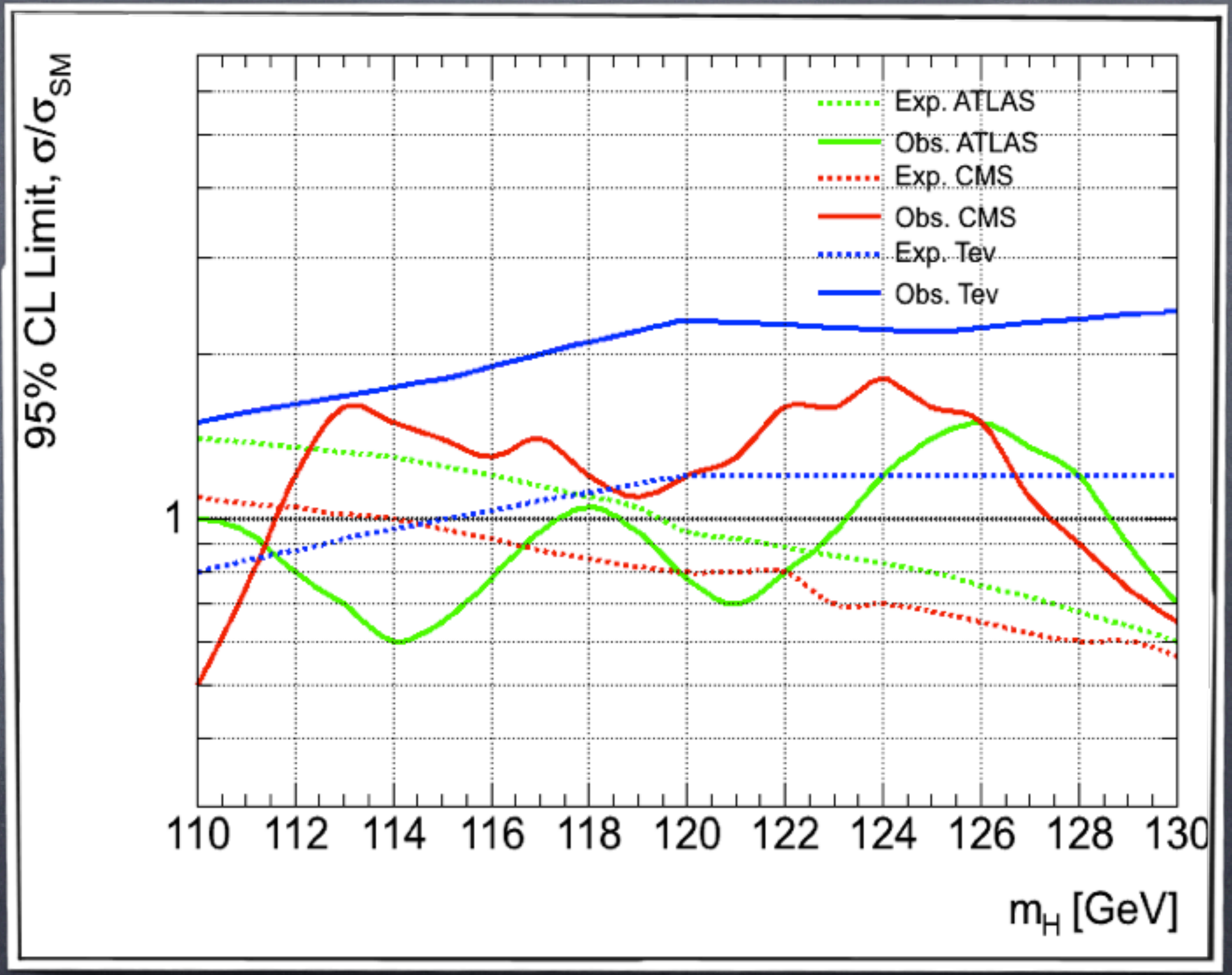
- ATLAS: local excess of 2.5σ at mH=126 GeV

- CMS: local excess of 2.9σ at mH=125 GeV



ATLAS+CMS+TEVATRON

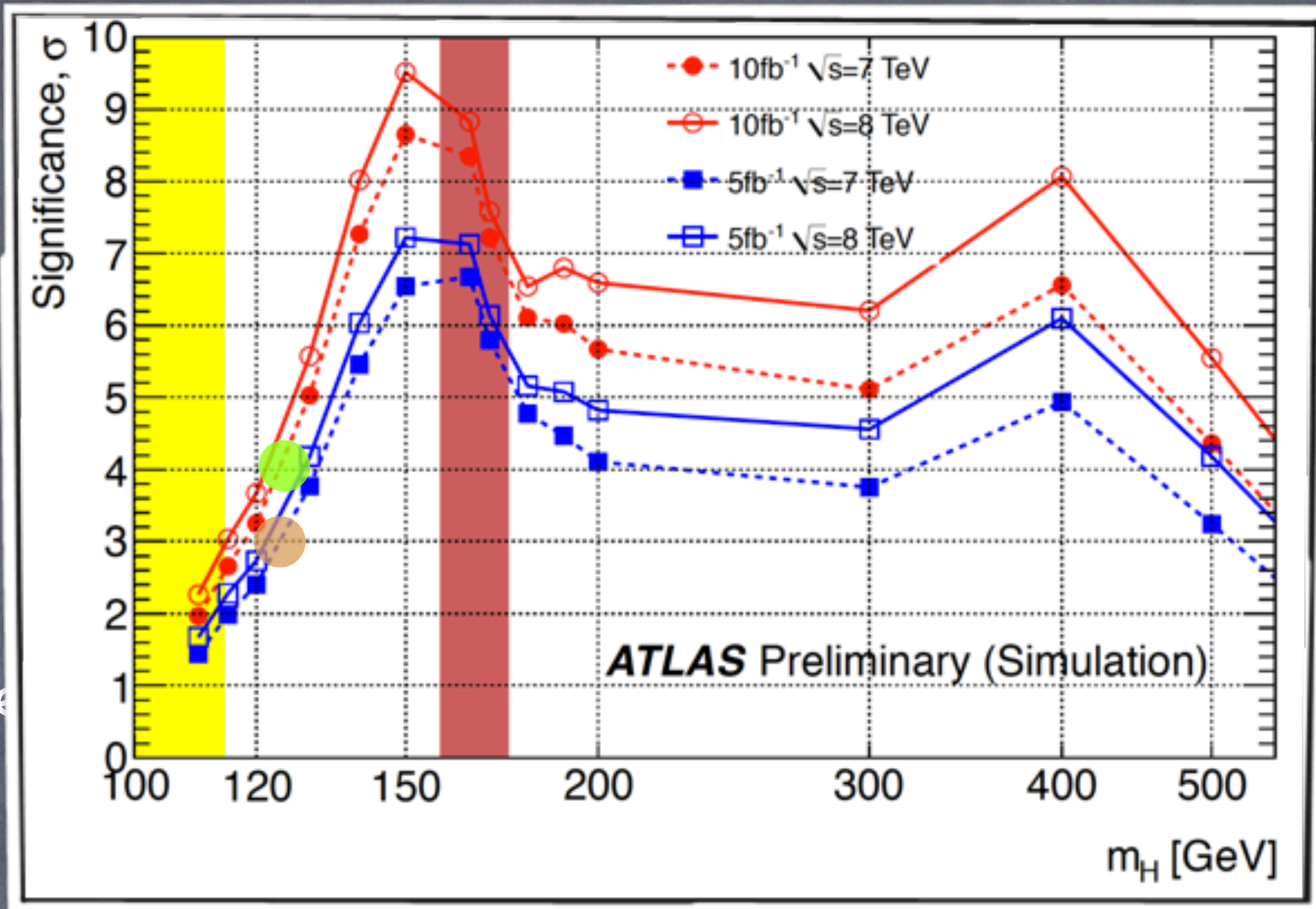
- ATLAS and CMS compensate each other except ~125 GeV
- TEVATRON pulls the combination a bit up
- The observed TEVATRON is too high to affect the combination, yet the expected is low, will reduce the 1σ band size and increase the exclusion significance



from B Murray

Projection into the Future (125 GeV)

- ATLAS expected sensitivity with 5fb-1 @ 7TeV is 3σ (2.9σ with 4.6-4.9fb-1)
- 2xATLAS~ATLAS+CMS sensitivity with 5fb-1 @ 7TeV is 4σ
- Gain in sensitivity from 7->8 TeV is 10% in significance ~ 20% in luminosity
- ->Needs about 12 fb-1 @ 8TeV for 5σ discovery p/exp
- Since observed~expectation, we will certainly have a discovery sensitivity with >11 fb-1 @8 TeV per experiment



- Taking into account the 5fb-1 @ 7 TeV, we find that only 7-8fb-1 p/exp are needed to have a 5σ discovery sensitivity

Conclusions ATLAS

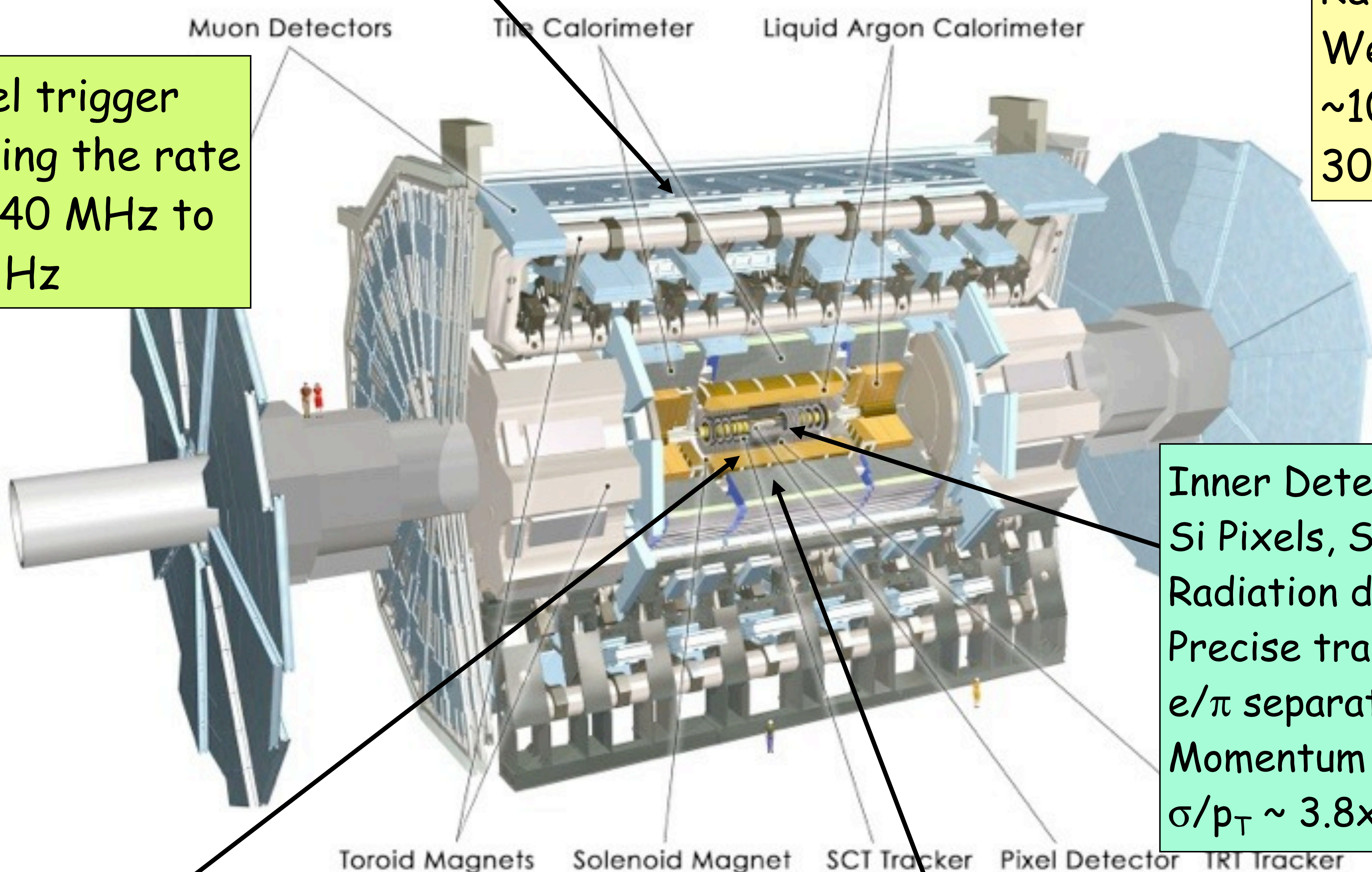
- ATLAS has done great in 2011 thanks also to a fantastic LHC machine
- ATLAS has reduced the living space for the light Higgs to about $122.5<m_H<129$ GeV, approaching the moment of truth
- ATLAS+CMS->
  Not much living space is left for the Higgs boson
- An excess is seen by ATLAS around 126 GeV
  at the level of 2.5σ
- Need more data to conclude!
- I think from any point of view (SM, Exotic, SUSY, Higgs ......)
  this is the prime time for any High Energy Physicist ☺

Backup

Muon Spectrometer ($|\eta|<2.7$) : air-core toroids with gas-based muon chambers
Muon trigger and measurement with momentum resolution < 10% up to E_{μ} ~ 1 TeV

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels
3000 km of cables

3-level trigger reducing the rate from 40 MHz to ~200 Hz



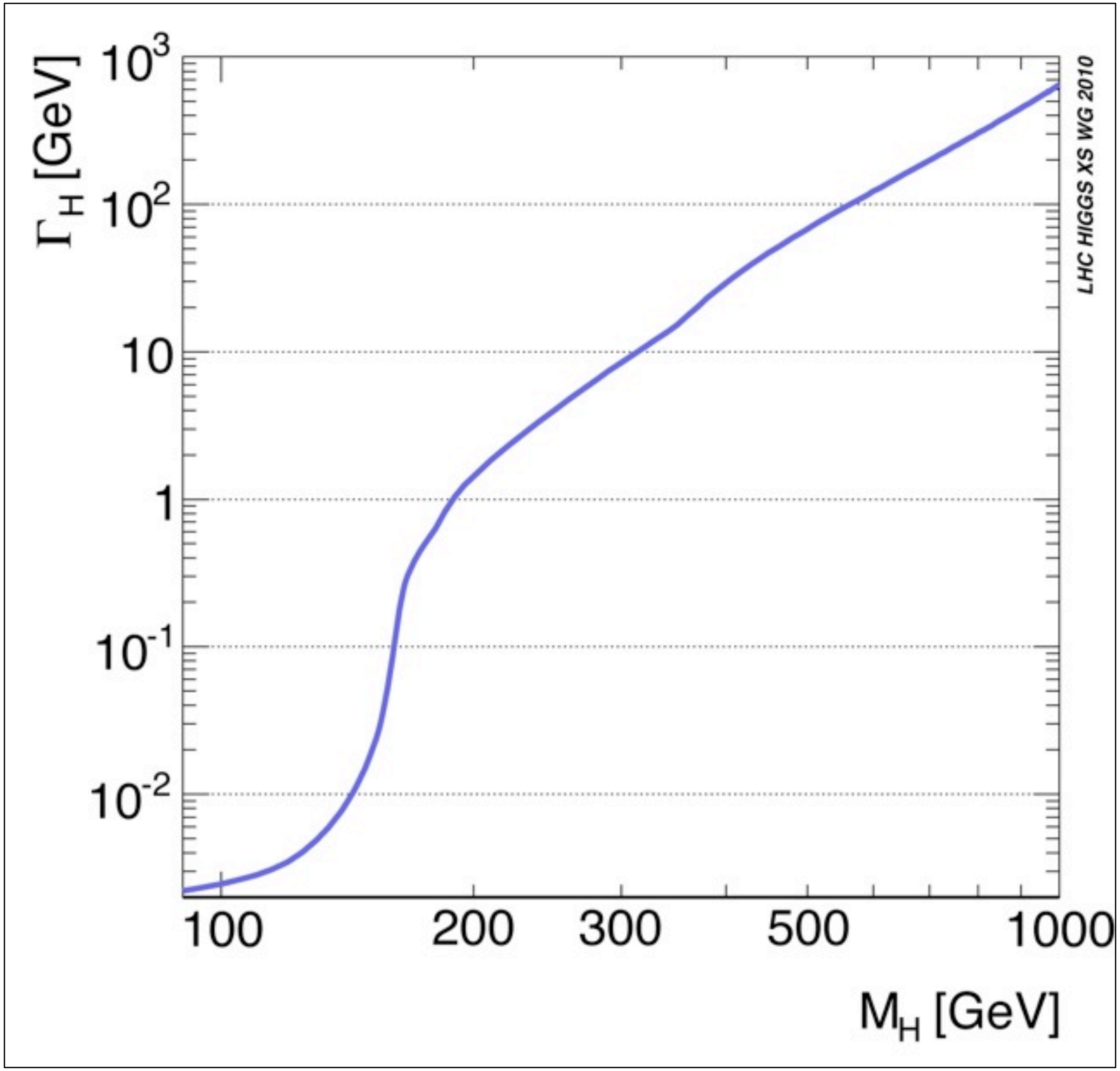
Inner Detector ($|\eta|<2.5$, B=2T):
Si Pixels, Si strips, Transition Radiation detector (straws)
Precise tracking and vertexing,
e/π separation
Momentum resolution:
$\sigma/p_T \sim 3.8\times10^{-4}\, p_T\,(\mathrm{GeV}) \oplus 0.015$

EM calorimeter: Pb-LAr Accordion
e/γ trigger, identification and measurement
E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$

HAD calorimetry ($|\eta|<5$): segmentation, hermeticity
Fe/scintillator Tiles (central), Cu/W-LAr (fwd)
Trigger and measurement of jets and missing E_T
E-resolution: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$

2011 Physics Proton Trigger Menu (end of run L = 3.3 10^{33} $cm^{-2}s^{-1}$)

	Offline Selection	Trigger Selection		L1 Rate (kHz) at 3e33	EF Rate (Hz) at 3e33
		L1	EF		
Single leptons	Single muon > 20GeV	11 GeV	18 GeV	8	100
	Single electron > 25GeV	16 GeV	22 GeV	9	55
Two leptons	2 muons > 17, 12GeV	11GeV	15,10GeV	8	4
	2 electrons, each > 15GeV	2x10GeV	2x12GeV	2	3.3
	2 taus > 45, 30GeV	15,11GeV	29,20GeV	7.5	15
Two photons	2 photons, each > 25GeV	2x12GeV	20GeV	3.5	5
Single jet plus MET	Jet pT > 130 GeV & MET > 140 GeV	50 GeV & 35 GeV	75GeV & 55GeV	0.8	18
MET	MET > 170 GeV	50 GeV	70GeV	0.6	5
Multi-jets	5 jets, each pT > 55 GeV	5x10GeV	5x30GeV	0.2	9
TOTAL				**<75**	**~400 (mean)**



Γ_H [GeV]
10^3
10^2
10
1
10^{-1}
10^{-2}
100
200
300
500
1000
M_H [GeV]
LHC HIGGS XS WG 2010

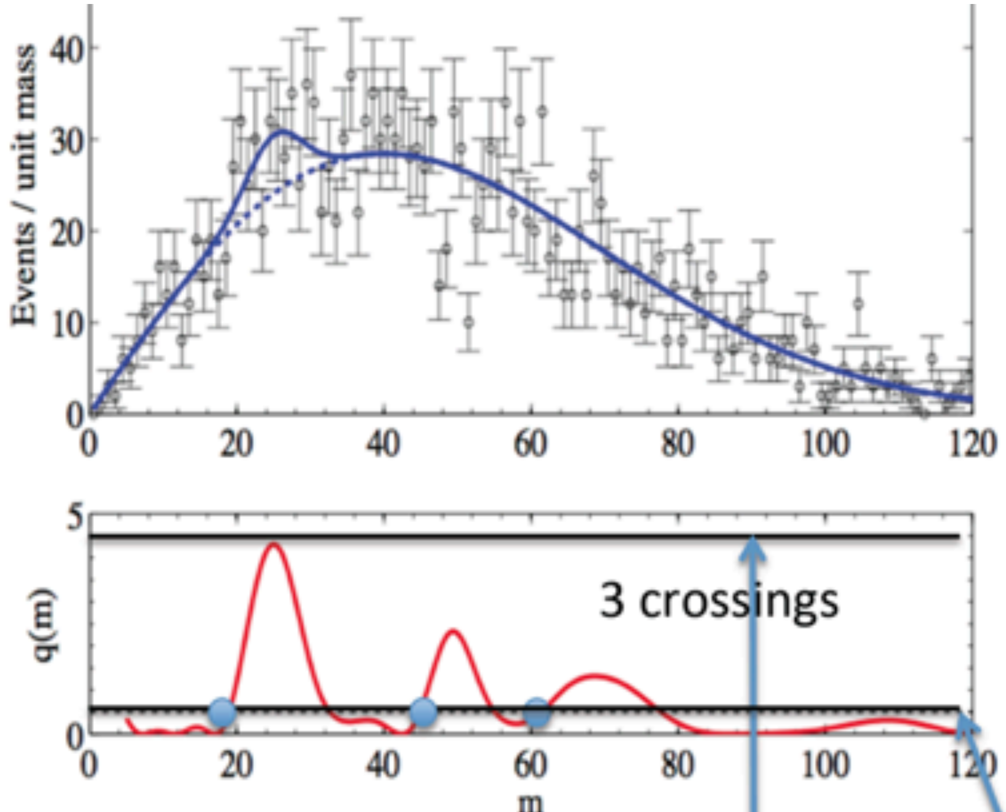
Discovery: Look Elsewhere Effect

- What is the probability to see such an excess (or more) ANYWHERE in the search mass range

$$p_0^{global} = p_0^{local} + \left\langle N(q_{ref}) \right\rangle e^{-(q_{test} - q_{ref})/2}$$

- arXiv 1005.1892

E. Gross and O. Vitells, "Trial factors for the look elsewhere effect in high energy physics", *The European Physical Journal C - Particles and Fields* **70** (2010) 525–530.

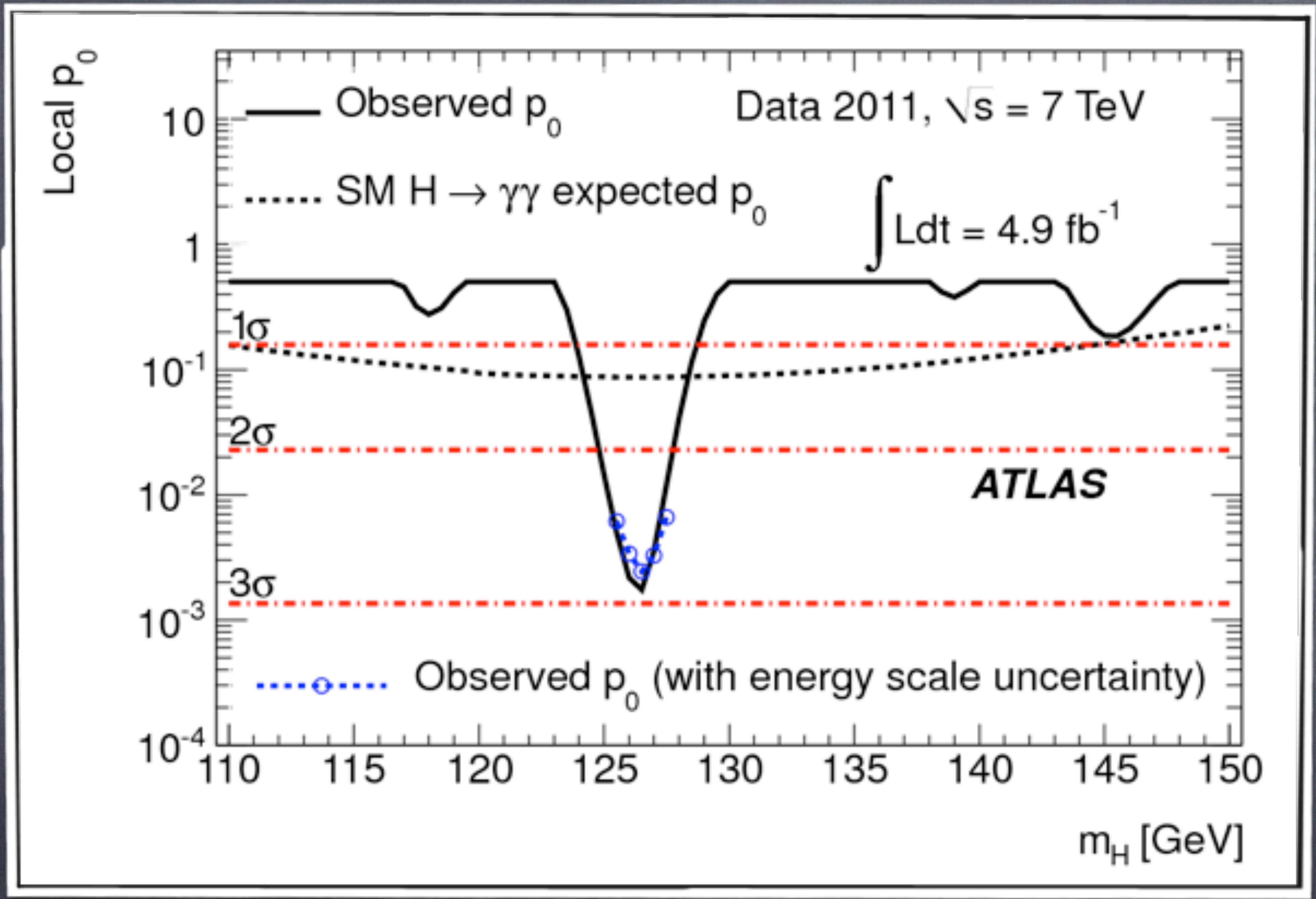


- Example:
  - q_{test}= 4.5 (2.1σ)
  - 3 crossings at 0.5σ
  - significance reduced to about 0.3σ
  - trials factor about 22

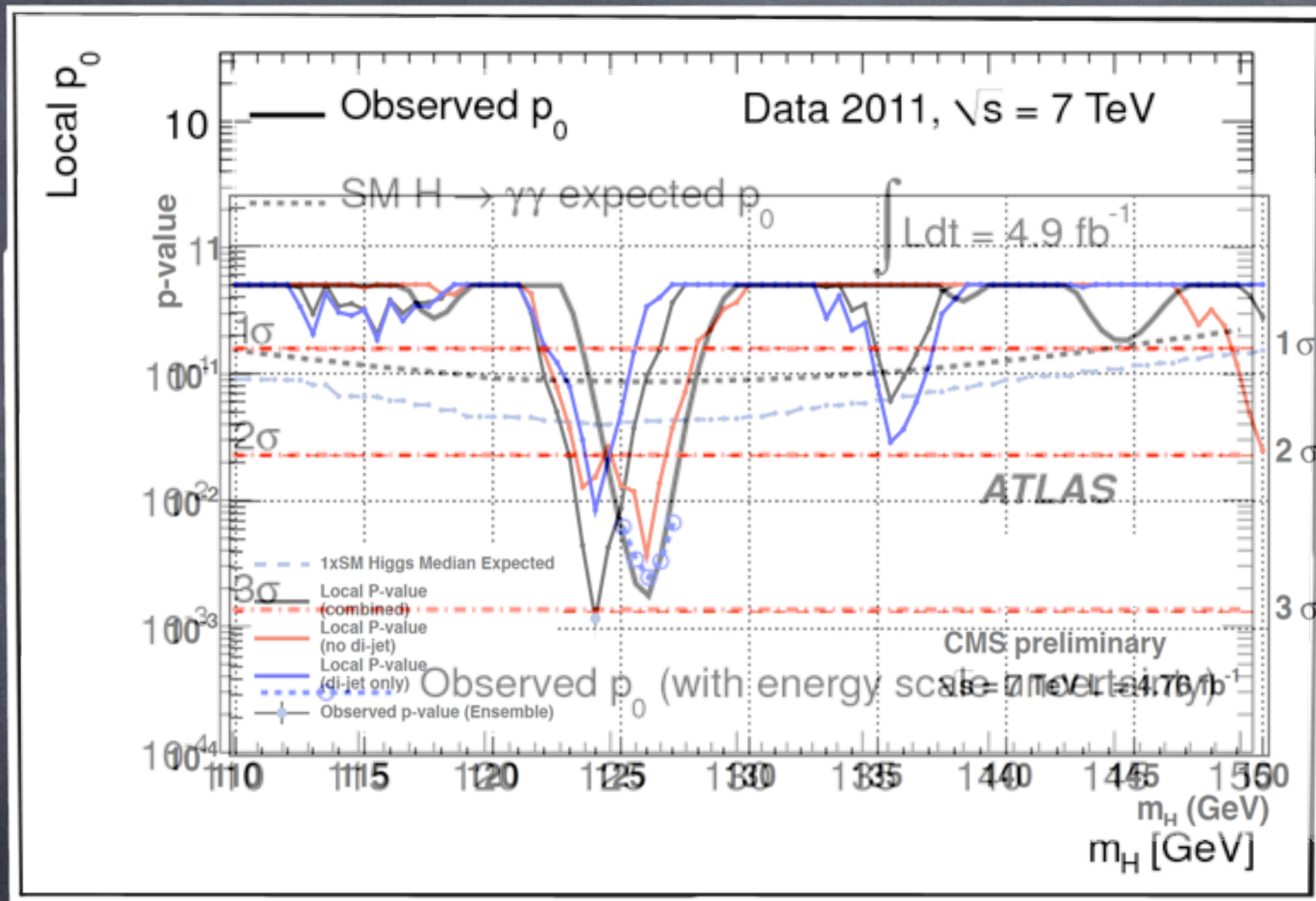
Local σ	Crossings	σ ref.	Trials factor	Global σ
3.5	3	1.0	47	2.3
5.0	3	2.0	290	3.8
7.0	3	2.0	400	6.1

$$p_0^{global} \cong p_0^{local} + \left\langle N(q_{ref}) \right\rangle e^{-(q_{test} - q_{ref})/2}$$

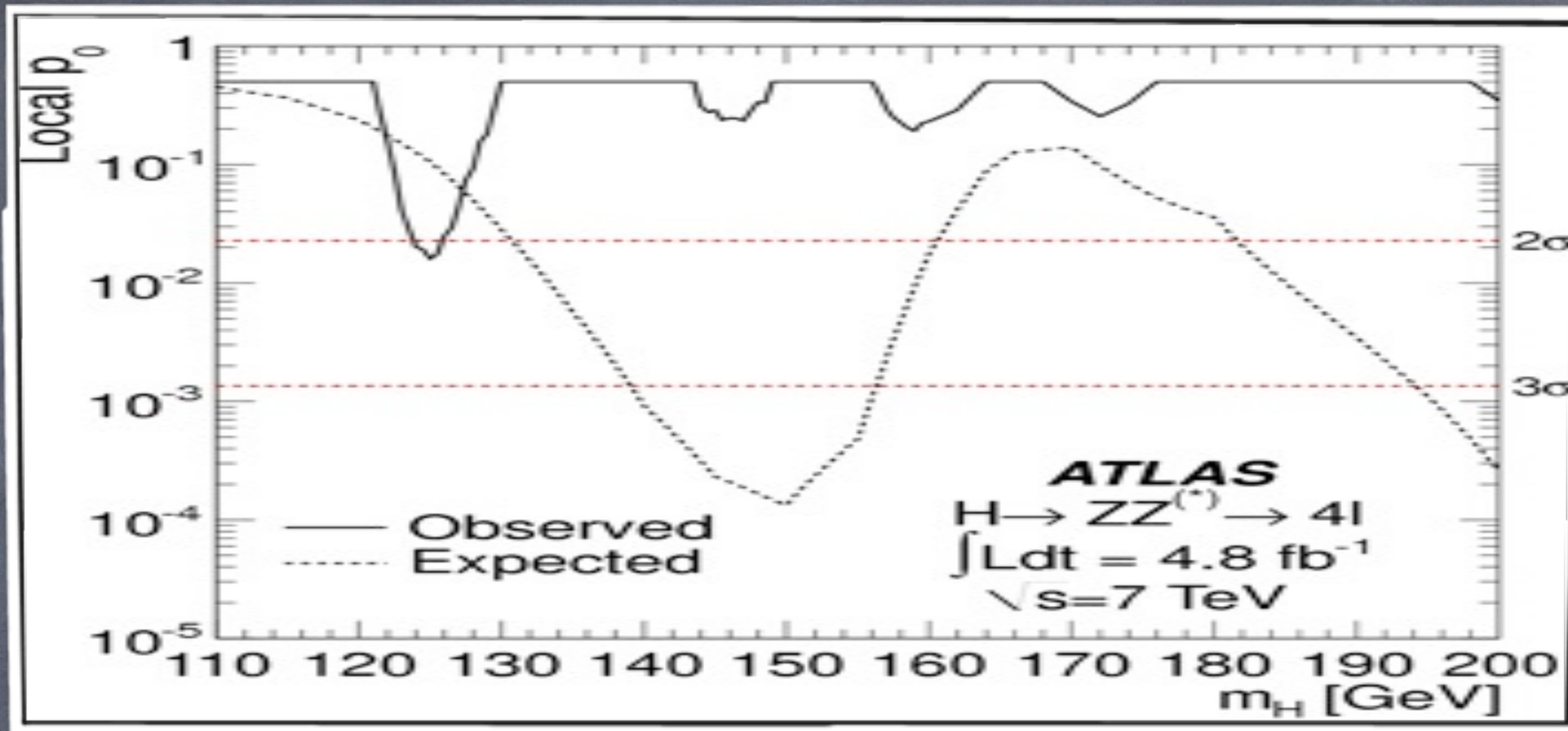
H->γγ ATLAS vs CMS p_0 results



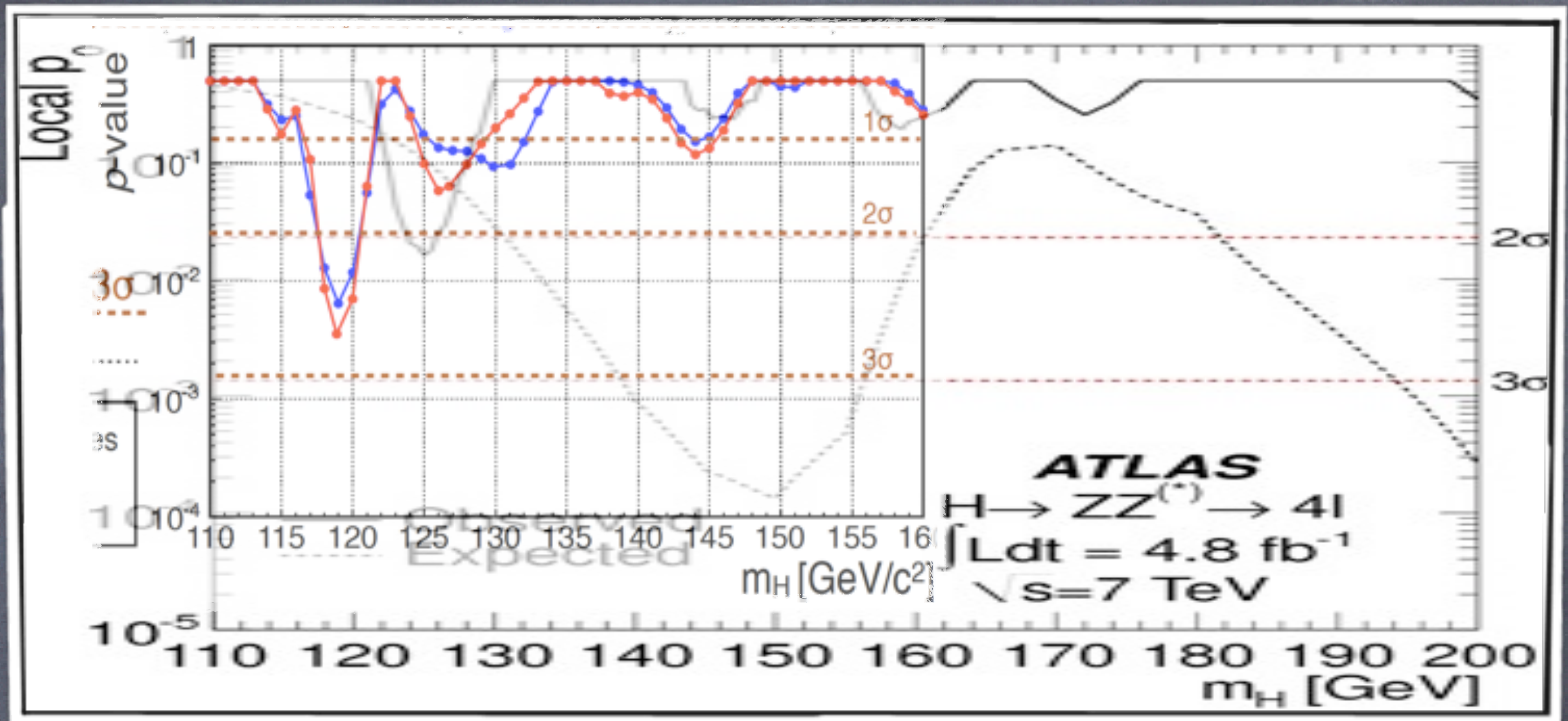
H->γγ ATLAS vs CMS p_0 results



H->ZZ->4l p0 ATLAS vs CMS

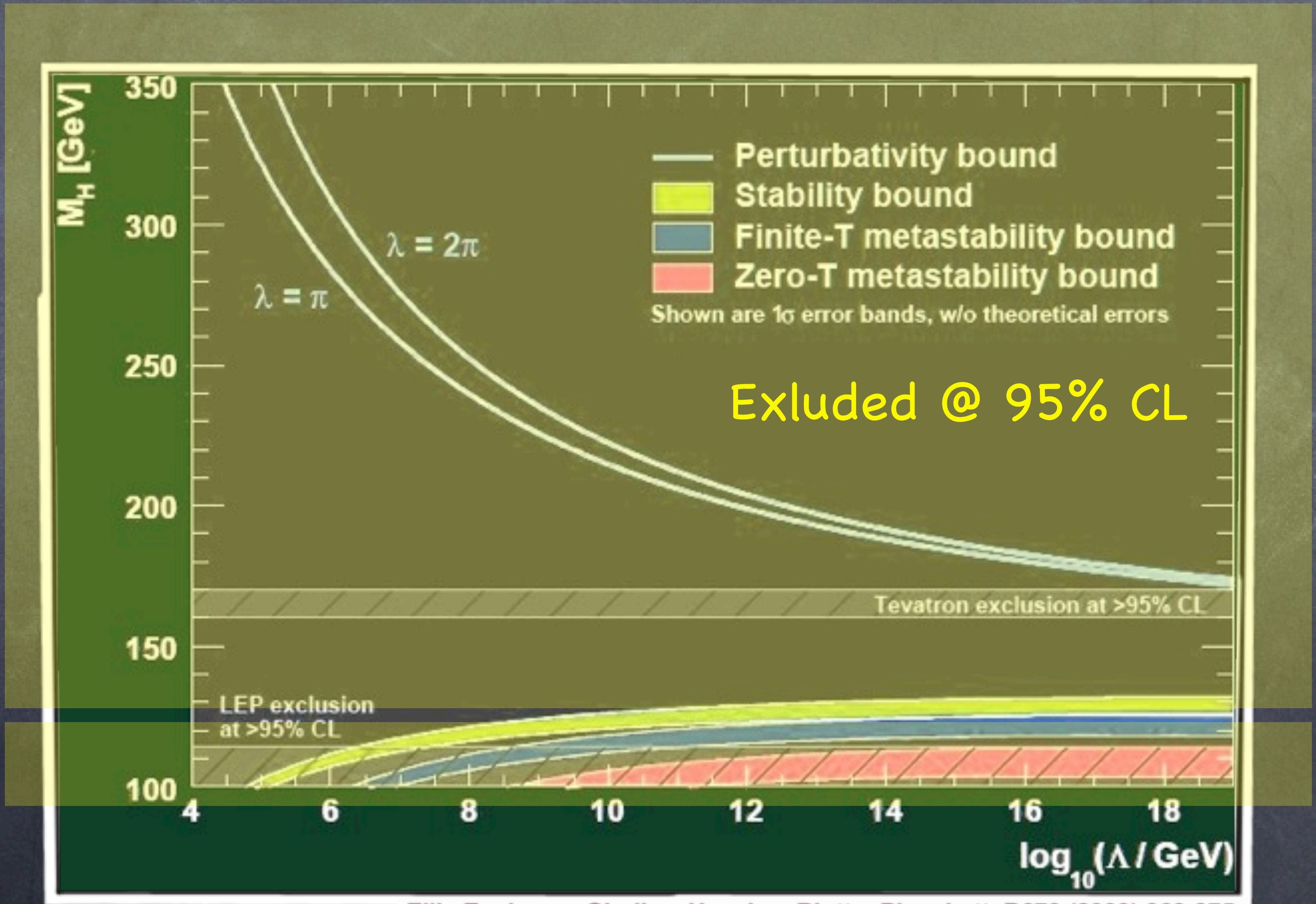


H->ZZ->4l p0 ATLAS vs CMS



Nightmare Scenario I: SM Higgs, period.

- Not much living space is left for the Higgs boson
- Looks like if there is a SM Higgs, it is either not Standard (i.e. not alone) or our vacuum is metastable



Ellis,Espinosa, Giudice, Hoecker, Riotto Phys.Lett. B679 (2009) 369-375

M. Lindner, Z. Phys. C 31, 295 (1986); M. Lindner, M. Sher and H. W. Zaglauer, Phys. Lett. B 228, 139 (1989);

ATLAS EXPERIMENT

Channels Weight

$$\mu = \frac{\sigma}{\sigma_{SM}}$$

- Asymptotically *Cowan et. al. , EPJC 71 (2011) 1-19.*

Luminosity normalized:

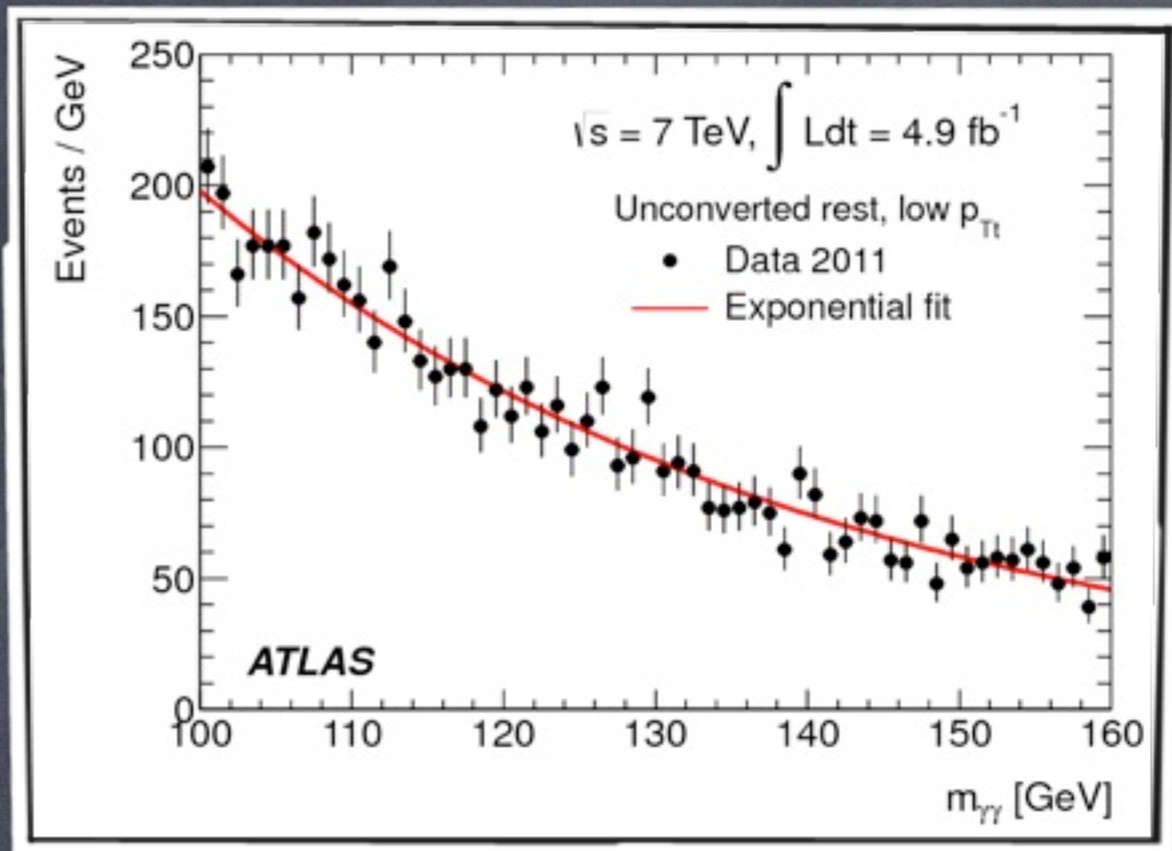
$$\mu_{up,\exp,i}(\mathcal{L}_i) \rightarrow \mu_{up,\exp,i}(\mathcal{L}_0) = \mu_{up,\exp,i}(\mathcal{L}_i)\sqrt{\frac{\mathcal{L}_i}{\mathcal{L}_0}}$$

$$\mathrm{w}_i = \left(\frac{\mu_{up,\exp,C}}{\mu_{up,\exp,i}}\right)^2 = \left(\frac{\dfrac{1}{\mu_{up,\exp,i}}}{\sqrt{\sum\left(\dfrac{1}{\mu_{up,\exp,i}}\right)^2}}\right)^2 \rightarrow \frac{\left(s_i/\sqrt{s_i+b_i}\right)^2}{\sum_i\left(s_i/\sqrt{s_i+b_i}\right)^2}$$

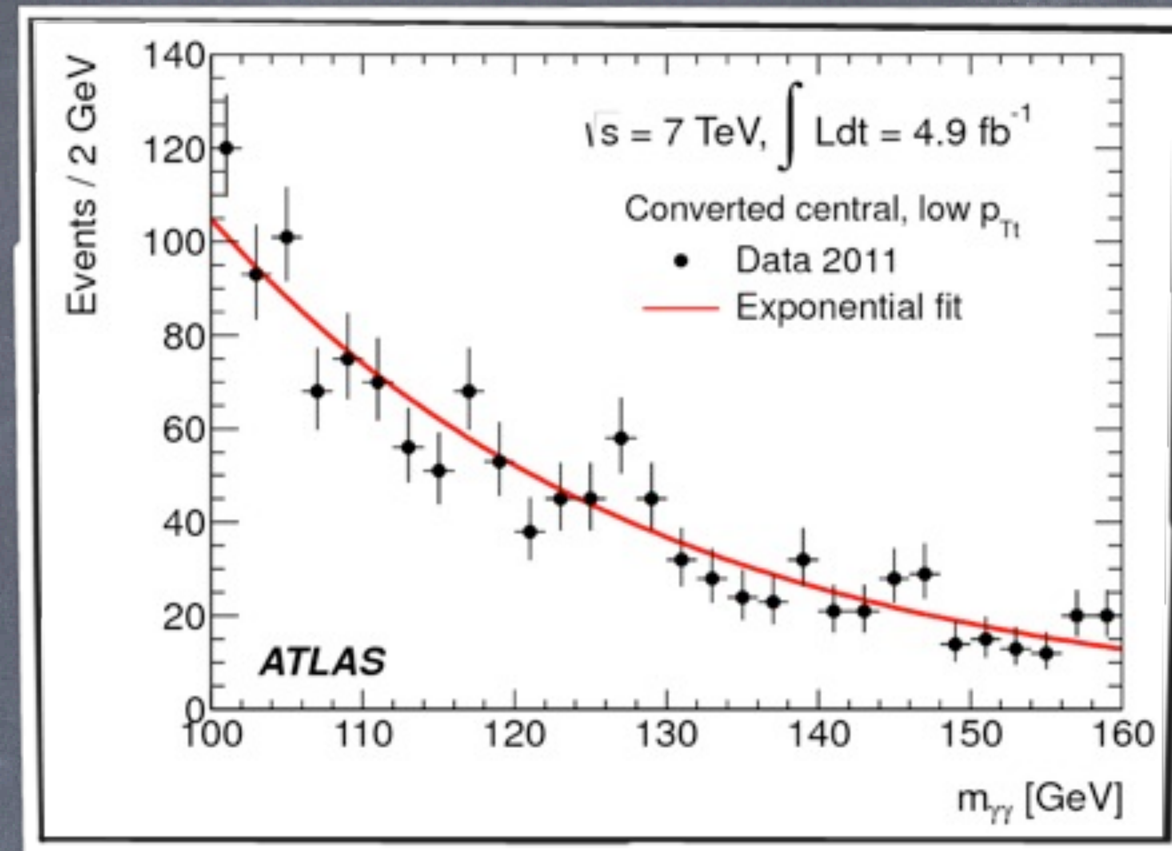
If we normalize individual channels to the same luminosity,
the weight, w_i is independent of the luminosity

ATLAS EXPERIMENT

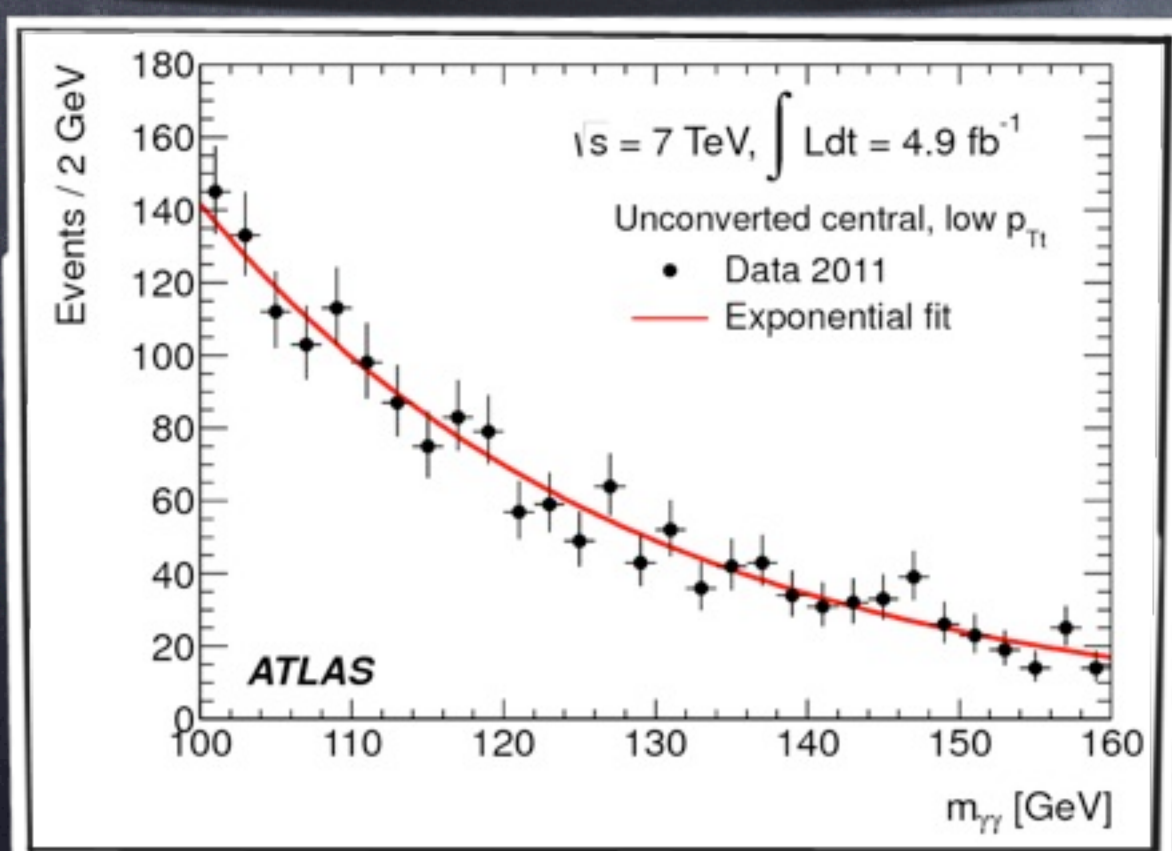
H->γγ Results



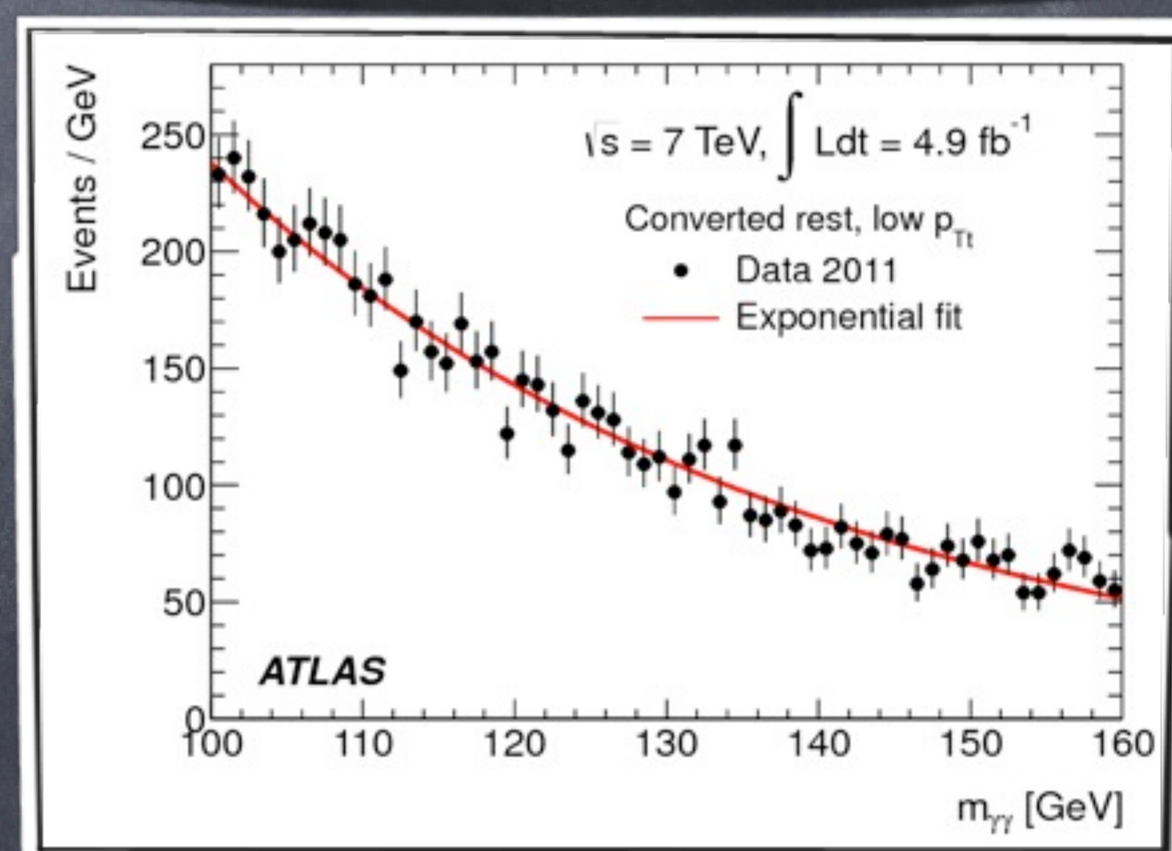
Events / GeV
√s = 7 TeV, ∫ Ldt = 4.9 fb⁻¹
Unconverted rest, low pTt
Data 2011
Exponential fit
ATLAS
m_γγ [GeV]



Events / 2 GeV
√s = 7 TeV, ∫ Ldt = 4.9 fb⁻¹
Converted central, low pTt
Data 2011
Exponential fit
ATLAS
m_γγ [GeV]



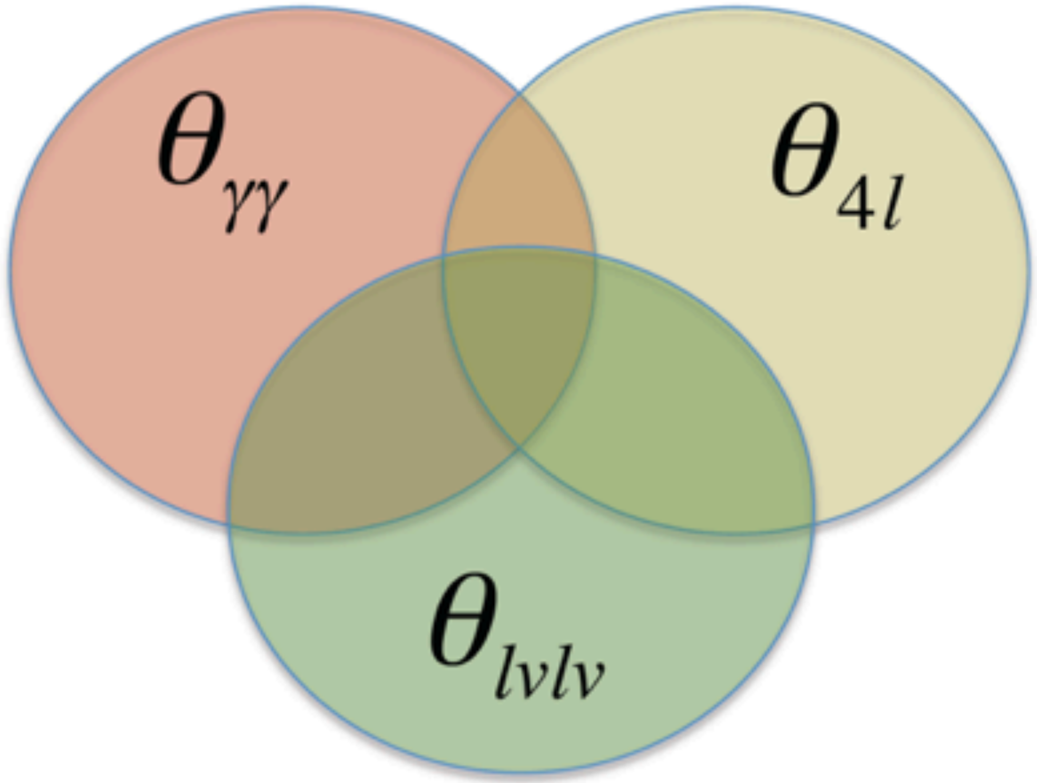
Events / 2 GeV
√s = 7 TeV, ∫ Ldt = 4.9 fb⁻¹
Unconverted central, low pTt
Data 2011
Exponential fit
ATLAS
m_γγ [GeV]



Events / GeV
√s = 7 TeV, ∫ Ldt = 4.9 fb⁻¹
Converted rest, low pTt
Data 2011
Exponential fit
ATLAS
m_γγ [GeV]

Combination : Use Correlations with Caution

$$L_{Combined}(\mu,\theta) = L_{\gamma\gamma}(\mu,\theta_{\gamma\gamma}) \times L_{4l}(\mu,\theta_{4l}) \times L_{l\nu l\nu}(\mu,\theta_{l\nu l\nu}) \times L_{\tau\tau}(\mu,\theta_{\tau\tau})$$



Need to very carefully check the interplay between correlated systematics...

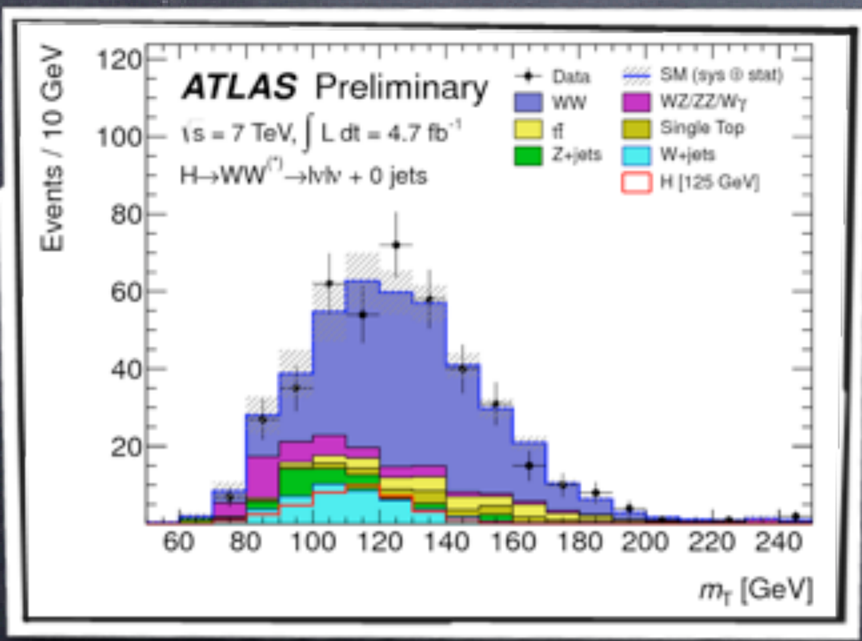
H->WW->lνlν Results

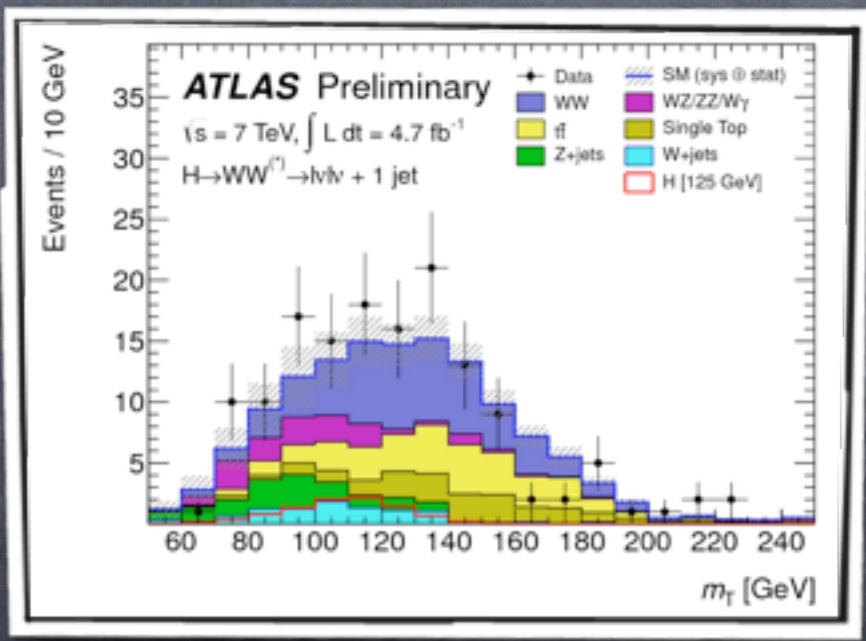
- After all cuts

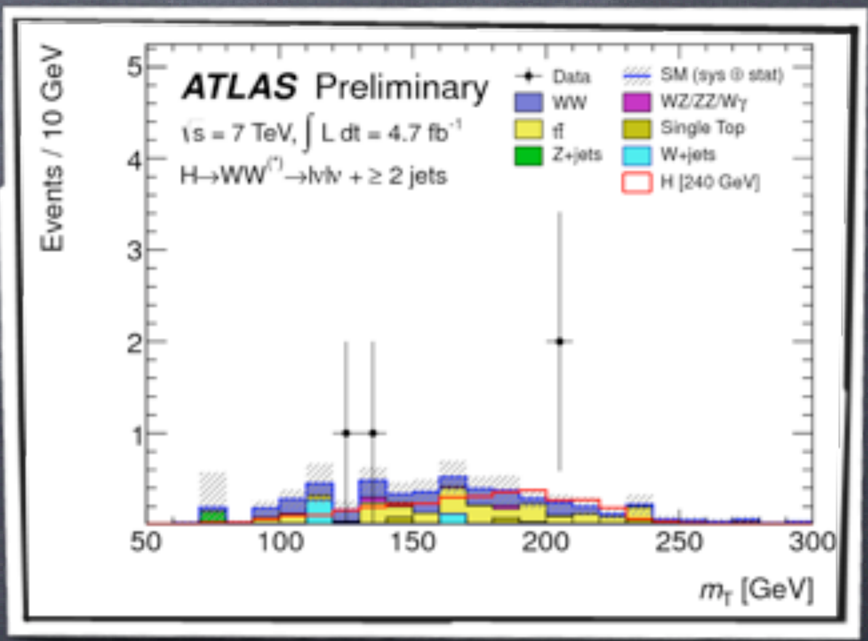
$0.75m_H < m_T < m_H$

		Signal	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	$tW/tb/tqb$	$Z/\gamma^* + \text{jets}$	$W + \text{jets}$	Total Bkg.	Obs.
0-jet	$m_H = 125$ GeV	25 ± 7	110 ± 12	12 ± 3	7 ± 2	5 ± 2	13 ± 8	27 ± 16	173 ± 22	174
	$m_H = 240$ GeV	60 ± 17	432 ± 49	24 ± 3	68 ± 15	39 ± 9	8 ± 2	36 ± 24	607 ± 63	629
1-jet	$m_H = 125$ GeV	6 ± 2	18 ± 3	6 ± 3	7 ± 2	4 ± 2	6 ± 1	5 ± 3	45 ± 7	56
	$m_H = 240$ GeV	23 ± 9	99 ± 22	8 ± 1	73 ± 27	35 ± 19	6 ± 2	7 ± 7	229 ± 55	232
2-jet	$m_H = 125$ GeV	0.4 ± 0.2	0.3 ± 0.2	negl.	0.2 ± 0.1	negl.	0.0 ± 0.1	negl.	0.5 ± 0.2	0
	$m_H = 240$ GeV	2.5 ± 0.6	1.1 ± 0.7	0.1 ± 0.1	2.6 ± 1.3	0.3 ± 0.3	negl.	0.1 ± 0.1	4.2 ± 1.7	2

- Discriminating Variable $m_T = \sqrt{(E_T^{ll} + E_T^{miss})^2 + (p_T^{ll} + p_T^{miss})^2}$

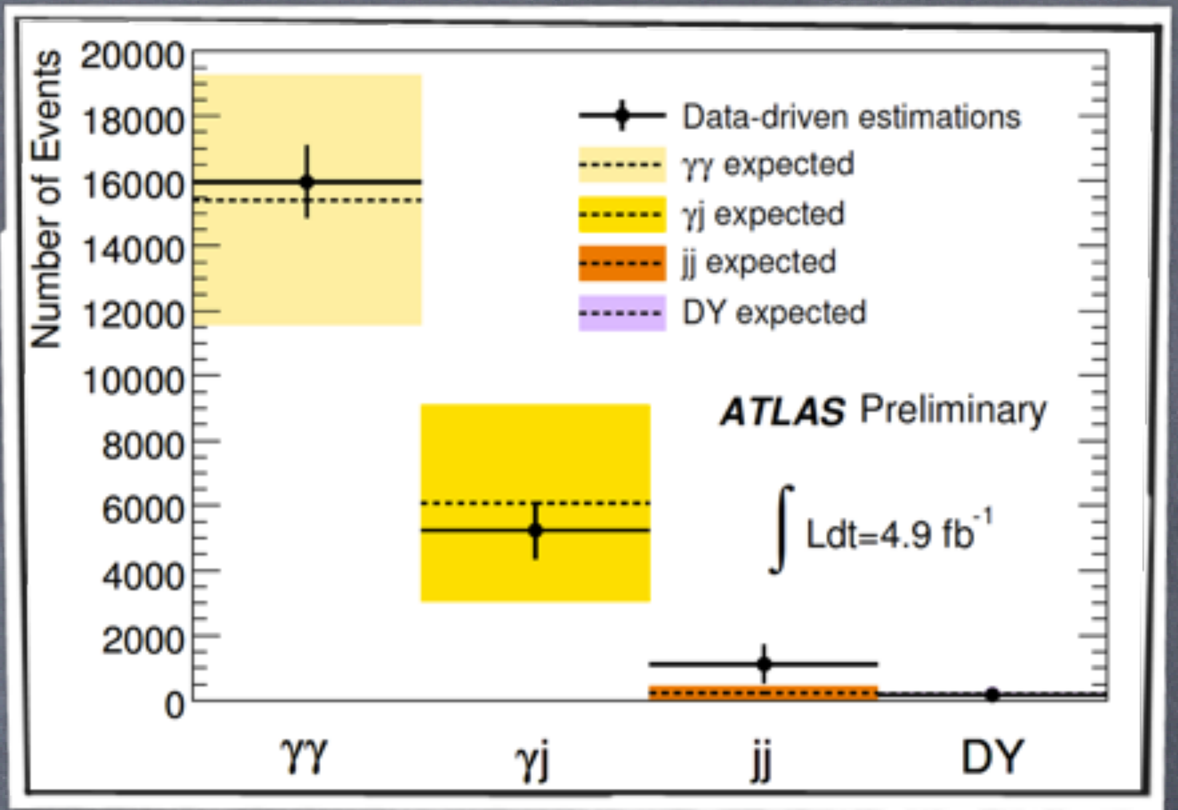






H->γγ Background

	Number of events	Fraction
γγ	16000 ± 1120	71 ±5 %
γj	5230 ± 890	23 ±4 %
jj	1130 ± 600	5 ±3 %
DY/Z	165 ± 8	0.7 ±0.1 %



- Search in the mass range $100 < m_{\gamma\gamma} < 160$ GeV
- Observed ~22500 events of which 71% are γγ (determined from data control samples)