Higgs boson searches at ATLAS

Recent updates

Univ. of Pennsylvania

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ATLAS Experiment

Brookhaven Forum 2011

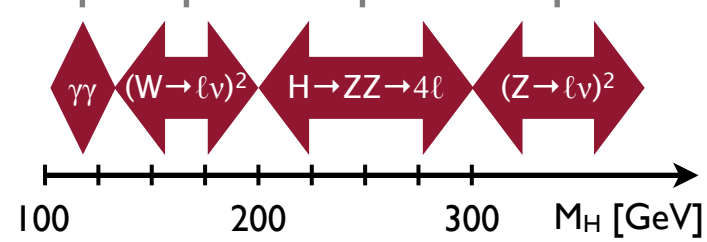
First Glimpse of the Tera Scale

http://www.bnl.gov/bf2011

"Higgs" is a BIG topic.

I'll focus on $H \to WW \to \ell\nu+\ell\nu$, which I work on, and 3 other SM decay modes with the best sensitivity (currently) for some mass ranges. Many decay modes that are not discussed here are also important for understanding the Higgs sector!

- ATLAS detector
- Selected Higgs searches
  - $H \to ZZ^{(*)} \to \ell\ell+\ell\ell$
  - $H \to ZZ^{(*)} \to \ell\ell+\nu\nu$
  - $H \to WW^{(*)} \to \ell\nu+\ell\nu$
  - $H \to \gamma\gamma$
- M_H exclusion limits
- Future outlook
- References, Thanks



This is just a cartoon. In reality, the ranges overlap everywhere & all modes contribute.

$|\eta| < 2.7$

$\frac{\sigma}{P_T} = 2\%$ at 50 GeV
$= 10\%$ at 1 TeV

Air-core toroids +
Gas-based chambers

$|\eta| < 1.7$ Fe/scintillator
$1.3 < |\eta| < 4.9$ Cu/W-LAr

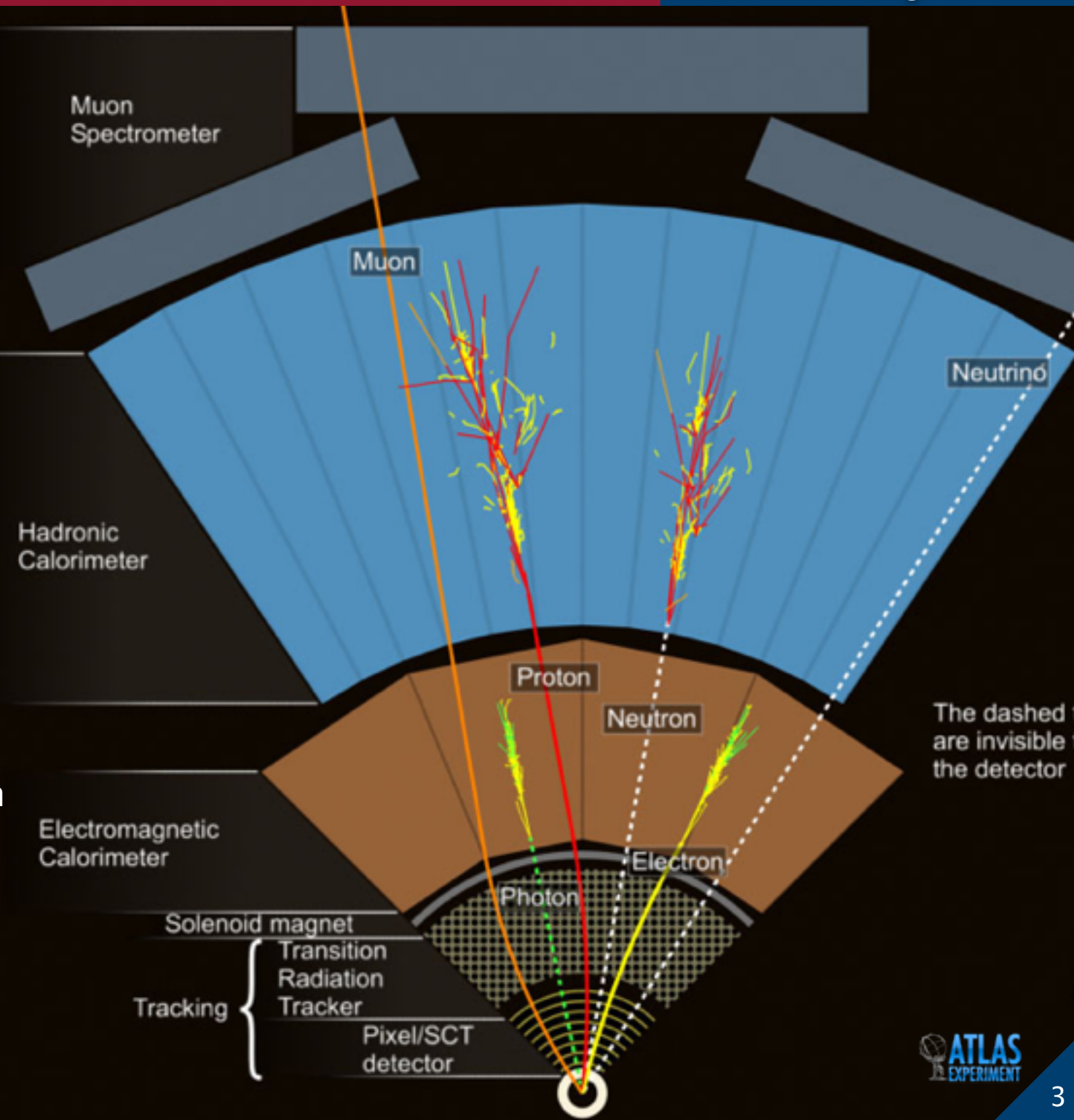
$\frac{\sigma}{E_{jet}} = \frac{50\%}{\sqrt{E}} \oplus 3\%$

$|\eta| < 3.2$ Pb-LAr accordion
$\frac{\sigma}{E} = 10\%\sqrt{E} \oplus 0.7\%$

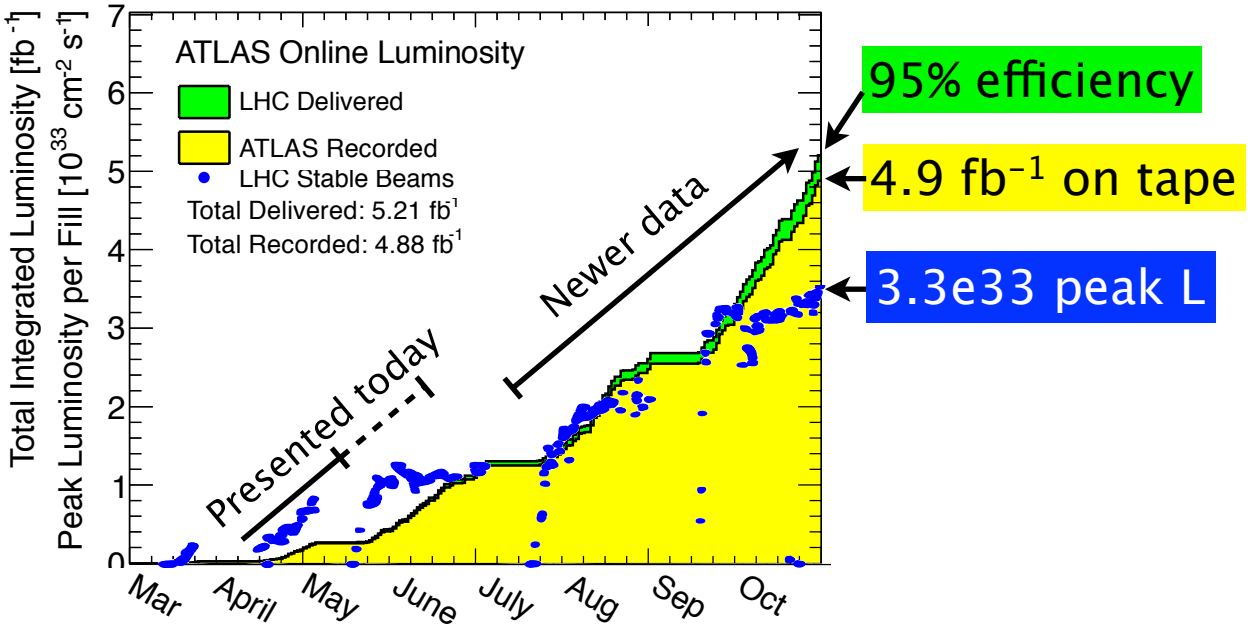
2 Tesla field

$|\eta| < 2.5$

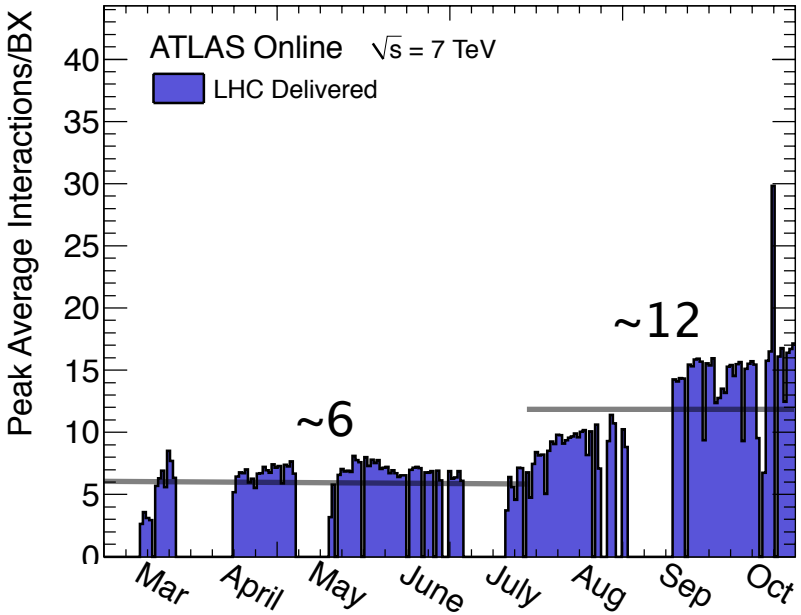
$\frac{\sigma}{P_T} = 0.05\% \, P_T\,(\text{GeV}) \oplus 1\%$

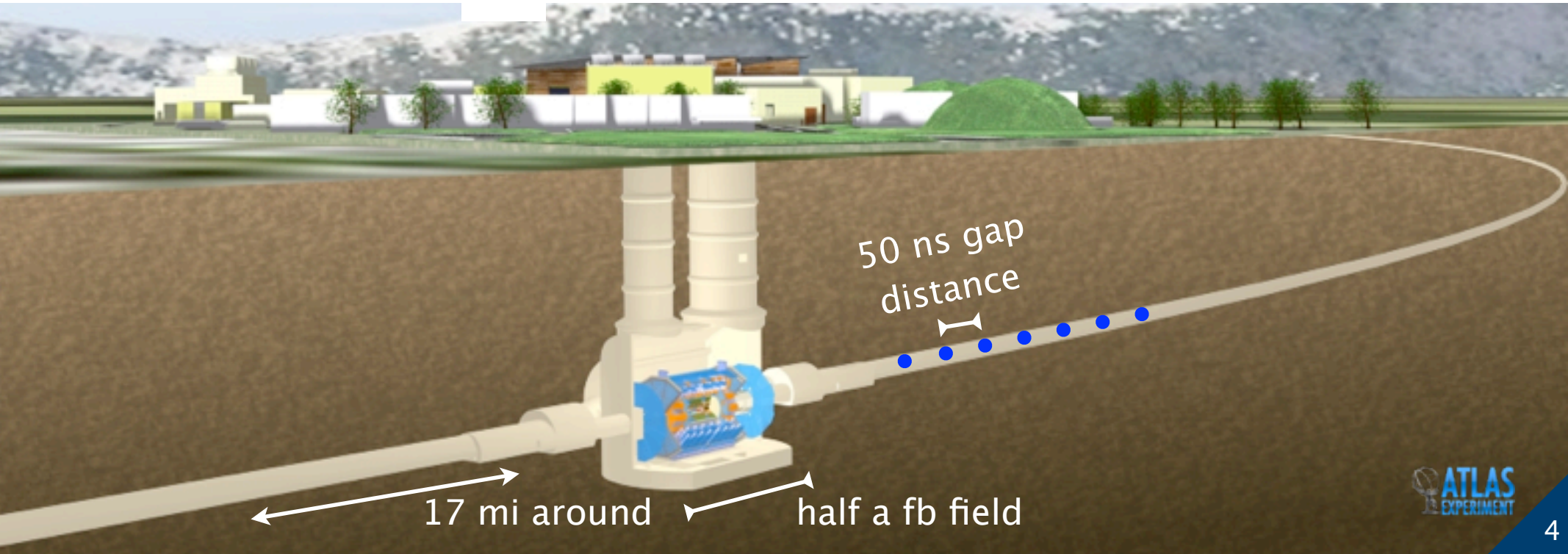


~100 pb^{-1} / day since Sept.



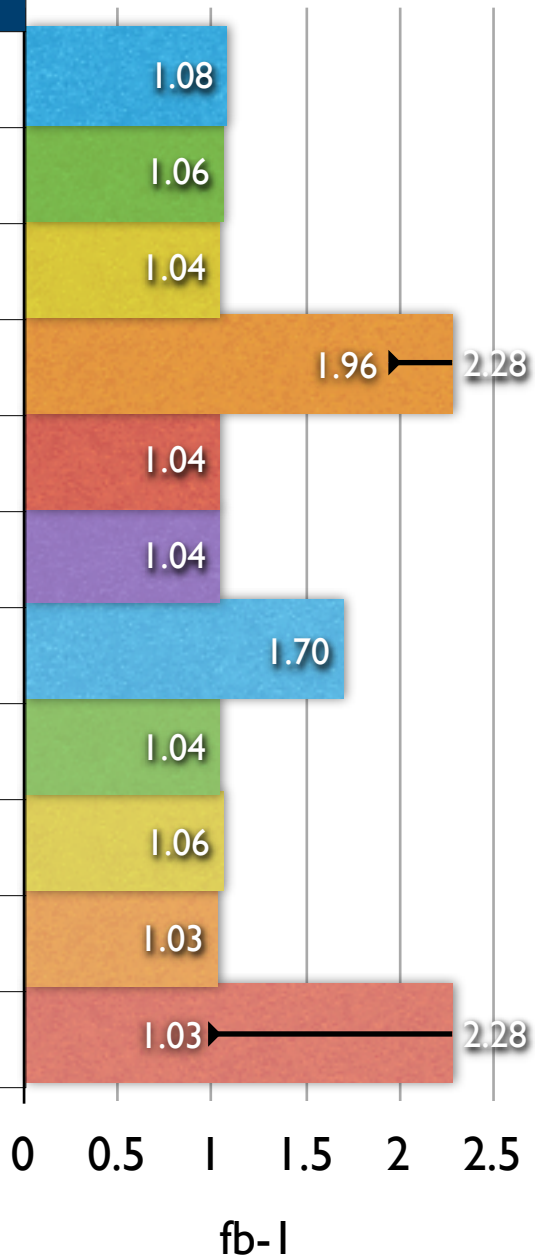
Pile-up 50 ns bunch trains





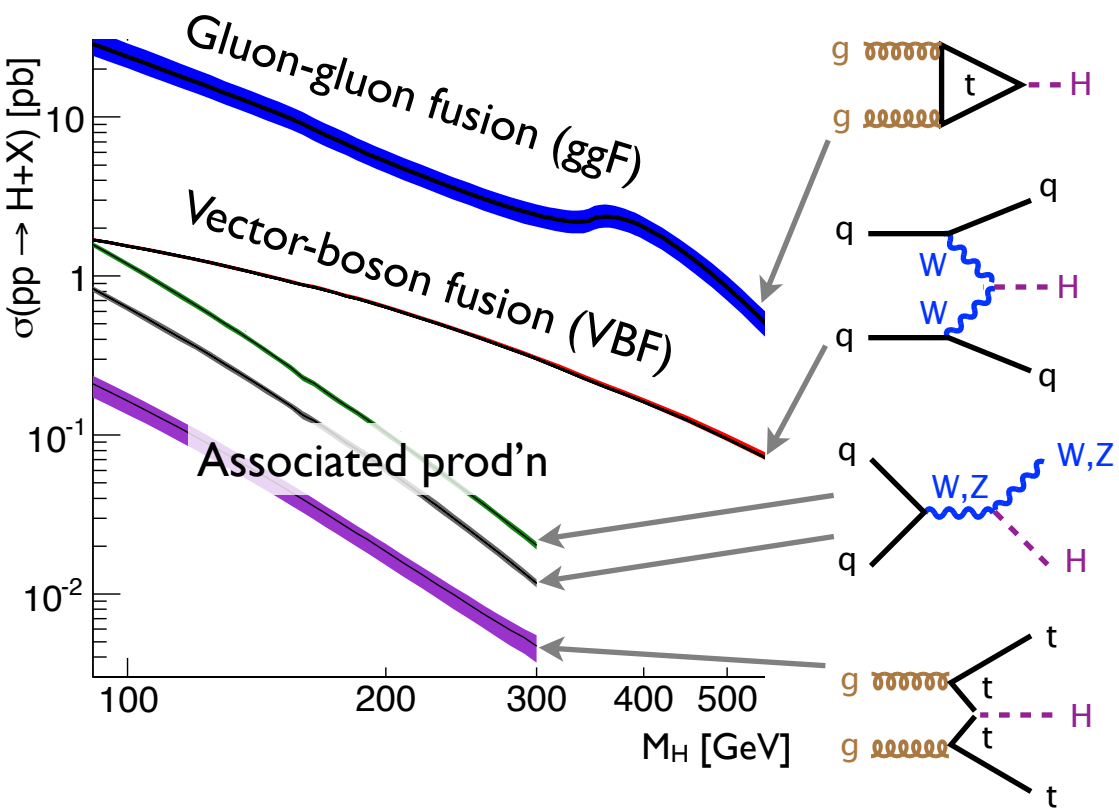
We have ~5 fb^{-1} on tape; see p.20.

Decay	Reference
$H \to \gamma\gamma$	arXiv:1108.5895
$H \to \tau\tau$	ATLAS-CONF-2011-133
$H \to bb$	ATLAS-CONF-2011-103
$H \to ZZ^{(*)} \to \ell\ell+\ell\ell$	arXiv:1109.5945
$H \to ZZ^{(*)} \to \ell\ell+qq$	arXiv:1108.5064
$H \to ZZ^{(*)} \to \ell\ell+\nu\nu$	arXiv:1109.3357
$H \to WW^{(*)} \to \ell\nu+\ell\nu$	ATLAS-CONF-2011-134
$H \to WW^{(*)} \to \ell\nu+qq$	arXiv:1109.3615
MSSM $H \to \tau\tau$	ATLAS-CONF-2011-132
MSSM H^+	ATLAS-CONF-2011-138
SM Higgs combination	ATLAS-CONF-2011-135



Higgs production

ggF is dominant (10× Tevatron)



Prod'n × decay

SM Higgs at 7 TeV
- ℓ = e or μ
- ν = all 3 flavors
- q = exclude top

3 mass regions

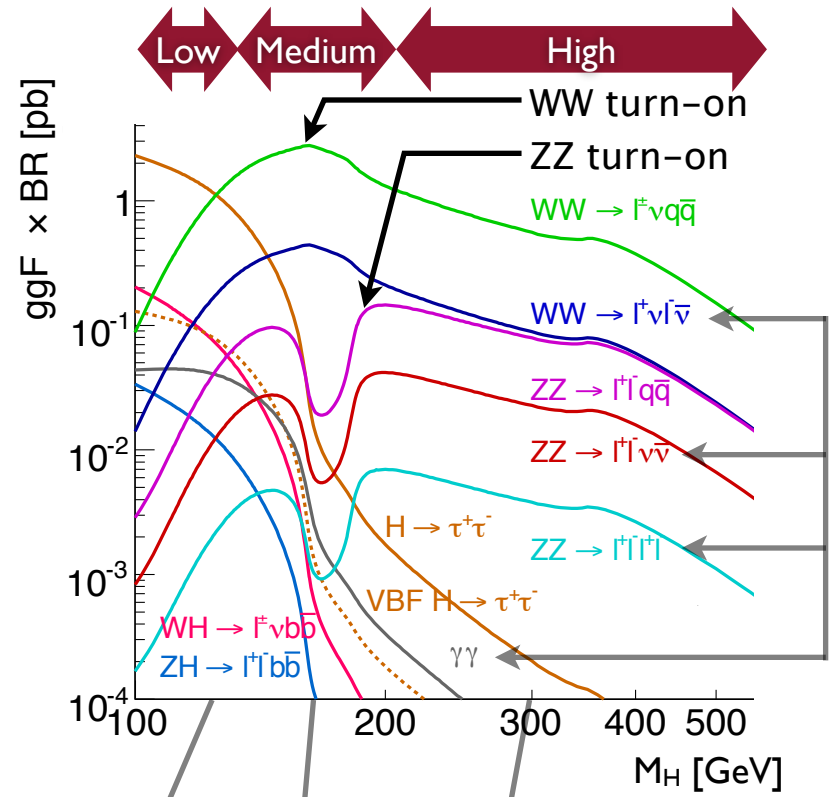
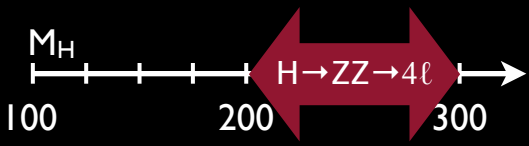


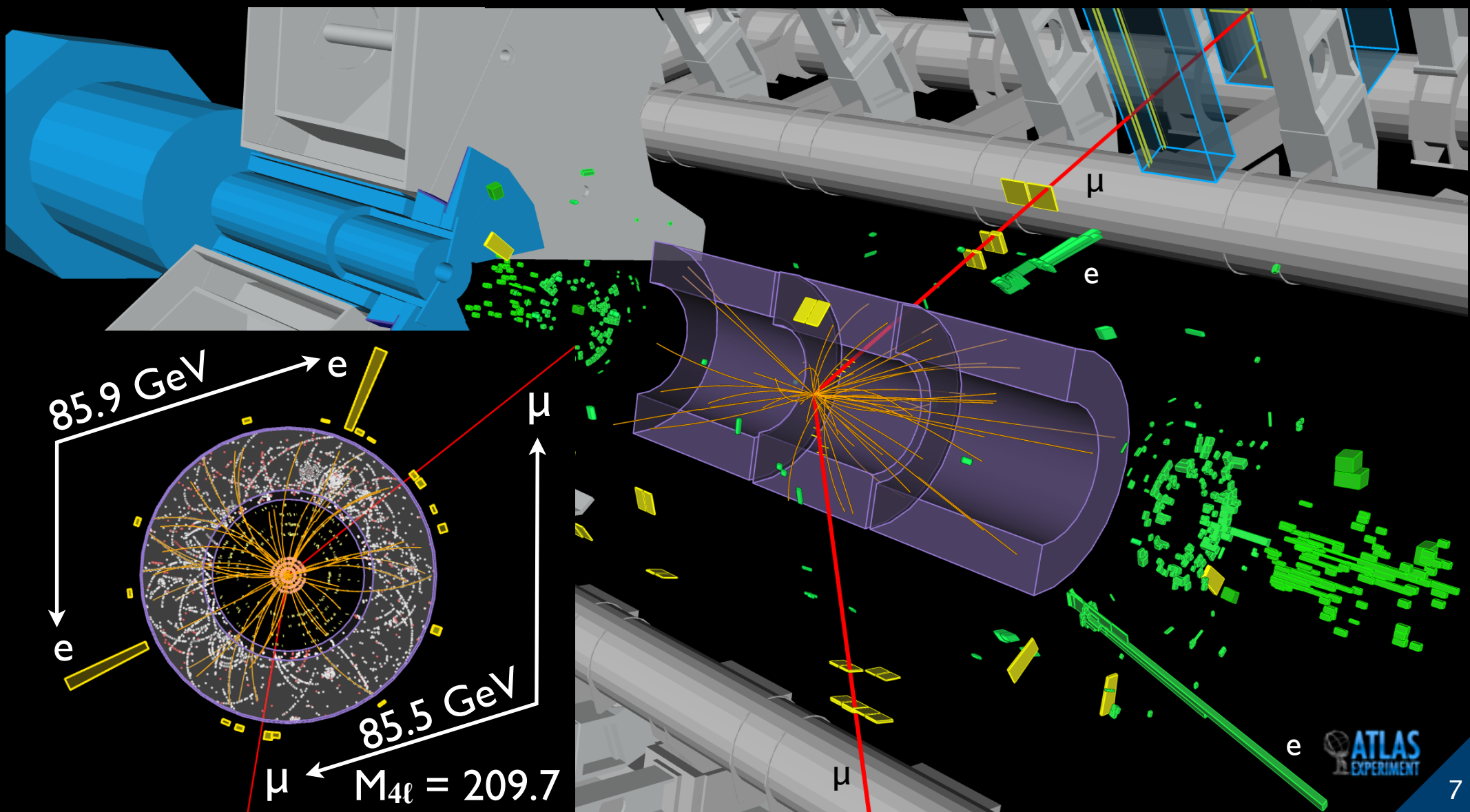
Table of events expected per fb^{-1}

Does not include acceptance

Decay	M_H=120	M_H=150	M_H=300
$H\to\gamma\gamma$	43	16	0.04
$H\to WW^{(*)}\to\ell\nu+\ell\nu$	127	390	89
$H\to ZZ^{(*)}\to\ell\ell+\ell\ell$	1.5	4.6	3.8

- $H \to ZZ^{(*)} \to \ell\ell+\ell\ell$: full reco = mass peak
- Clean! $M(\ell^+\ell^-) \sim M_Z$
- Sensitivity ~ $200<M_H<300$

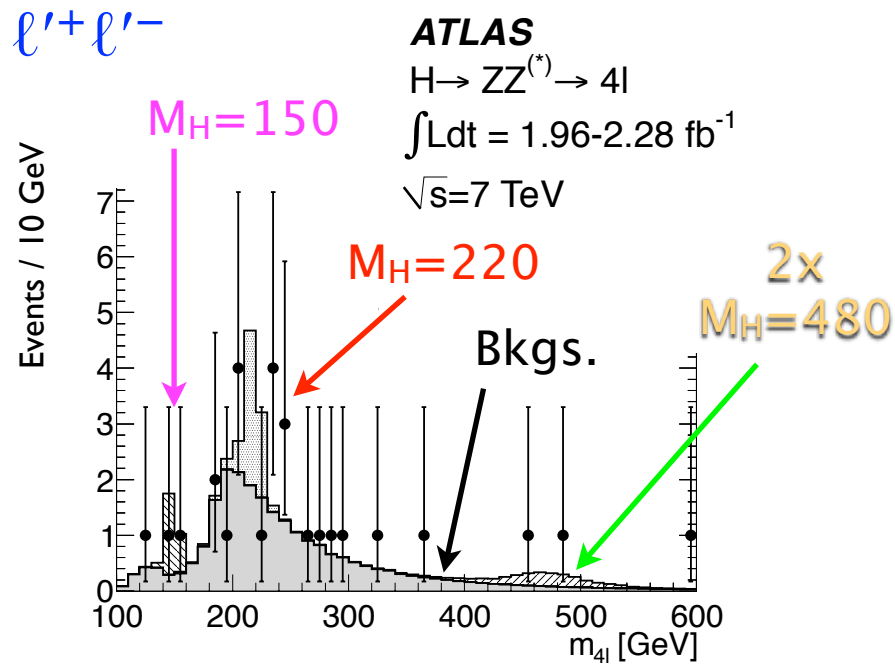




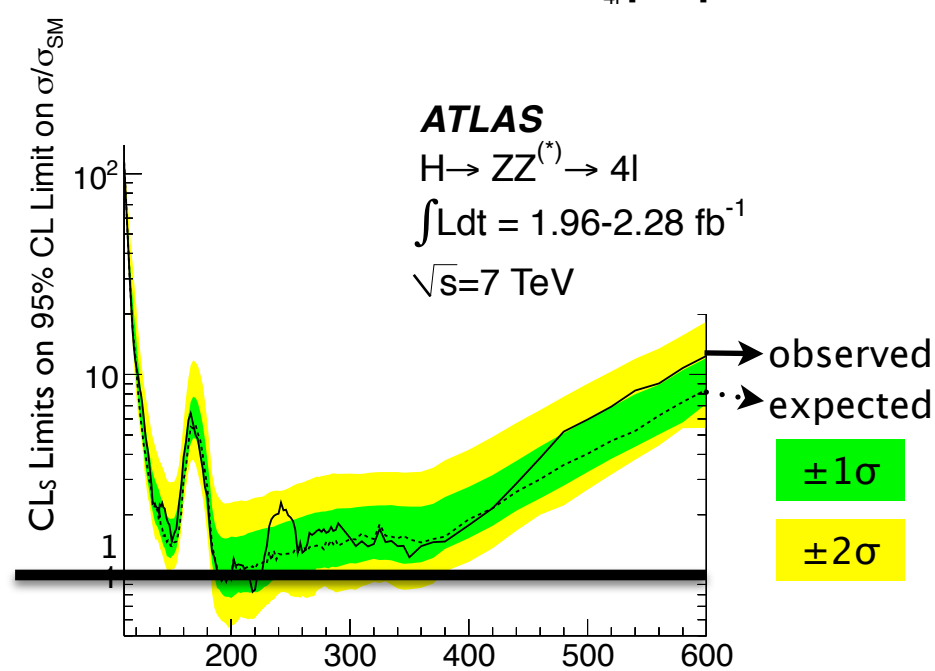
Want $|M(\ell^+\ell^-)-M_Z|<15$ with another $\ell'^+\ell'^-$

- Lepton selection : Two $P_T>20$, All $P_T>7$
- Split data at $M_H=180$ where ZZ turns-on

		Expected SM			Expected for M_H				
M_H	Data	Total	SM ZZ	Zbb, ttbar	130	150	200	300	400
<180	3	3.0	2.4	0.6	1.0	2.3	N/A		
≥180	24	21	21	0.3	N/A		5.9	3.5	2.6



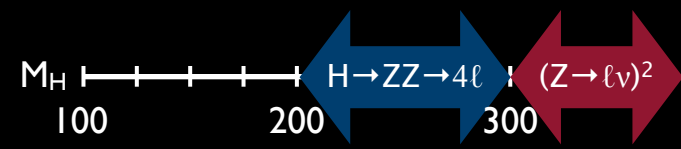
- Backgrounds
  - SM $ZZ^{(*)}\rightarrow\ell\ell+\ell\ell$: Use MC ; Err~15%
  - Z+bb, $b\rightarrow\ell$ fake : Use data; Err~20-40%
  - ttbar→$(Wb)^2$, $W\rightarrow\ell\nu$: Use MC ; Err~10%

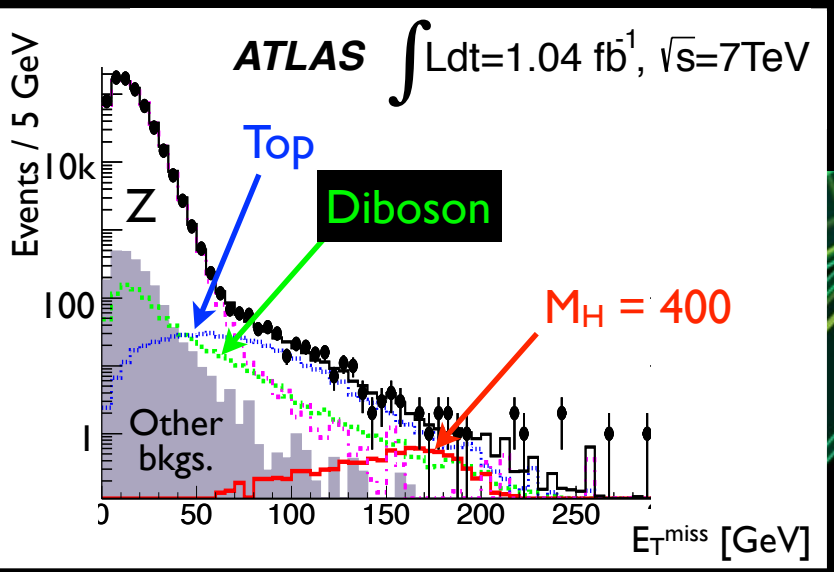


Excluded Higgs masses

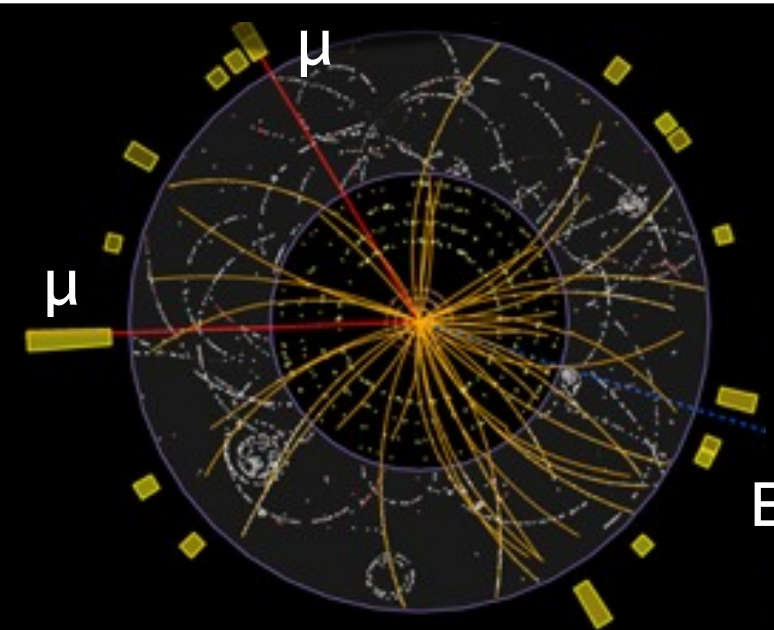
- 95% confidence level limits using CL_S
- Expected : 194 GeV is closest at 1.01×SM
- Observed : 191-197, 199-200, 214-224

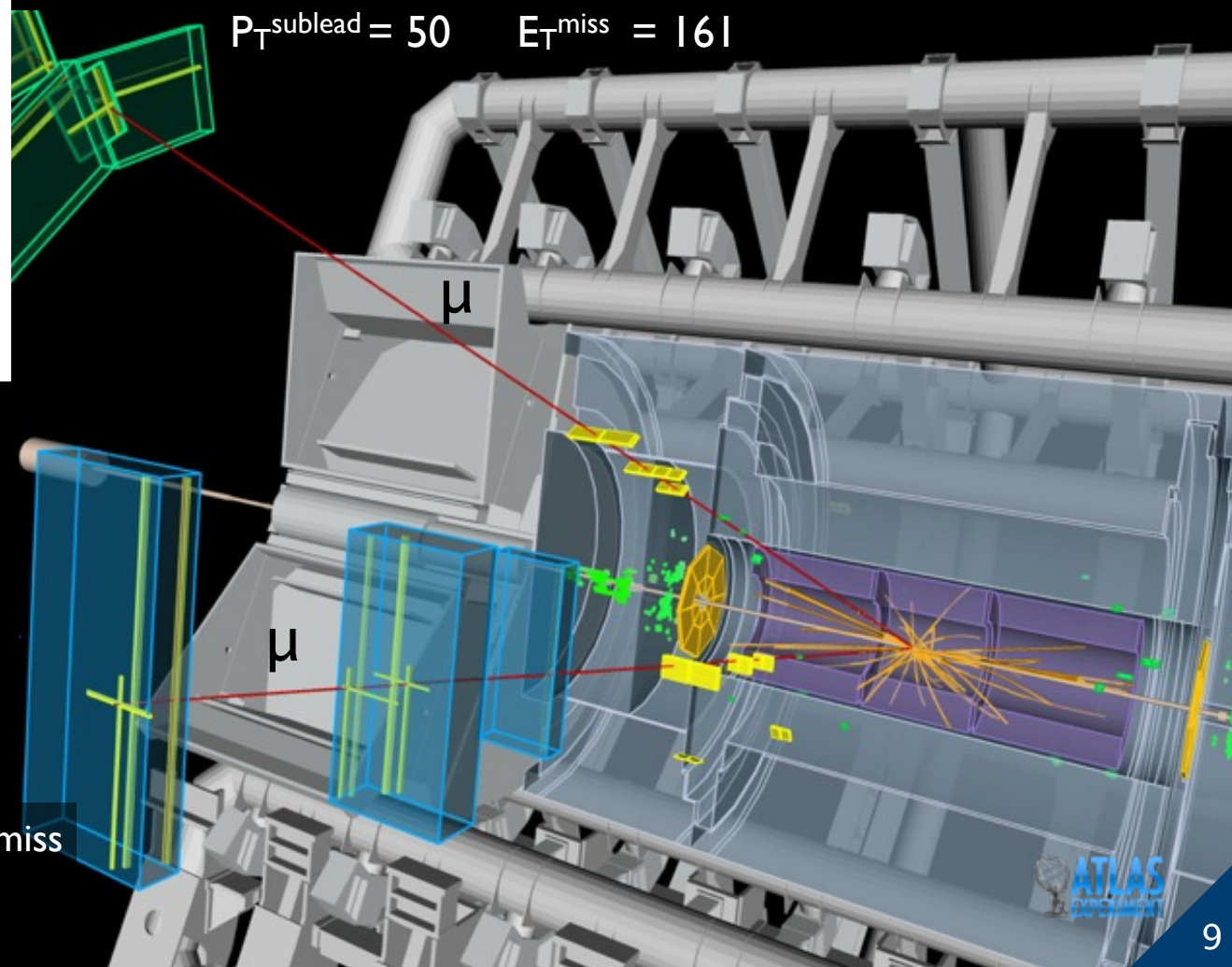
- $H \to ZZ^{(*)} \to \ell\ell+\nu\nu$: partial reco = count
- $M(\ell^+\ell^-) \sim M_Z$ with E_T^{miss} for $\nu\nu$
- Sensitivity ~ $M_H > 300$





$P_T^{lead} = 126$ $M_{\ell\ell} = 94$
$P_T^{sublead} = 50$ $E_T^{miss} = 161$





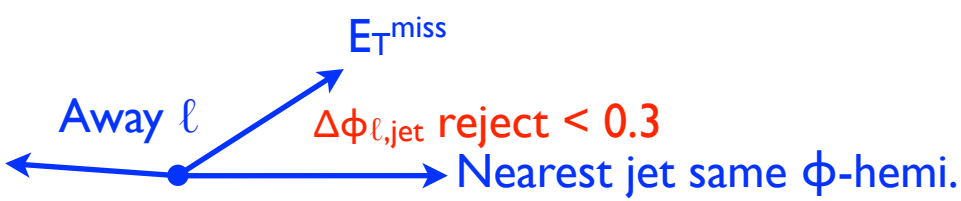
Want $M(\ell^+\ell^-)=M_Z$ with E_T^{miss}

- Lepton selection : Leading P_T >25 GeV
- Backgrounds : top, SM ZZ, WZ, WW
- Split data at M_H=280 : ZZ become boosted

		Expected SM					Expected for M_H				
M_H	Data	Total	Z+j	W+j	top	VV	200	300	400	500	600
<280	85	105	19	8.5	30	47	5.0	N/A			
≥280	47	55	6.0	3.1	15	31	N/A	10	10	4.5	1.8

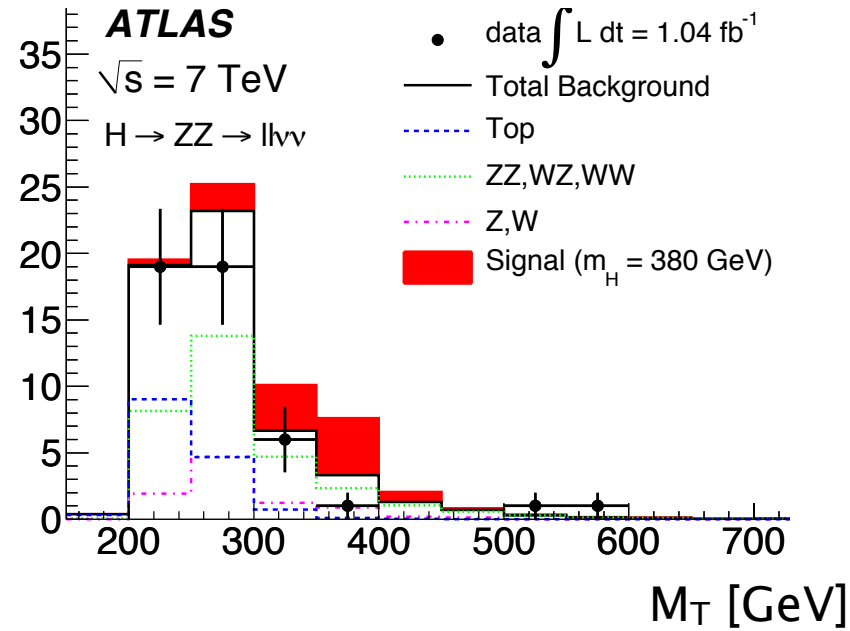
Err ~15%, σ_W, σ_{top} biggest 3% ←reco.→ ~50%

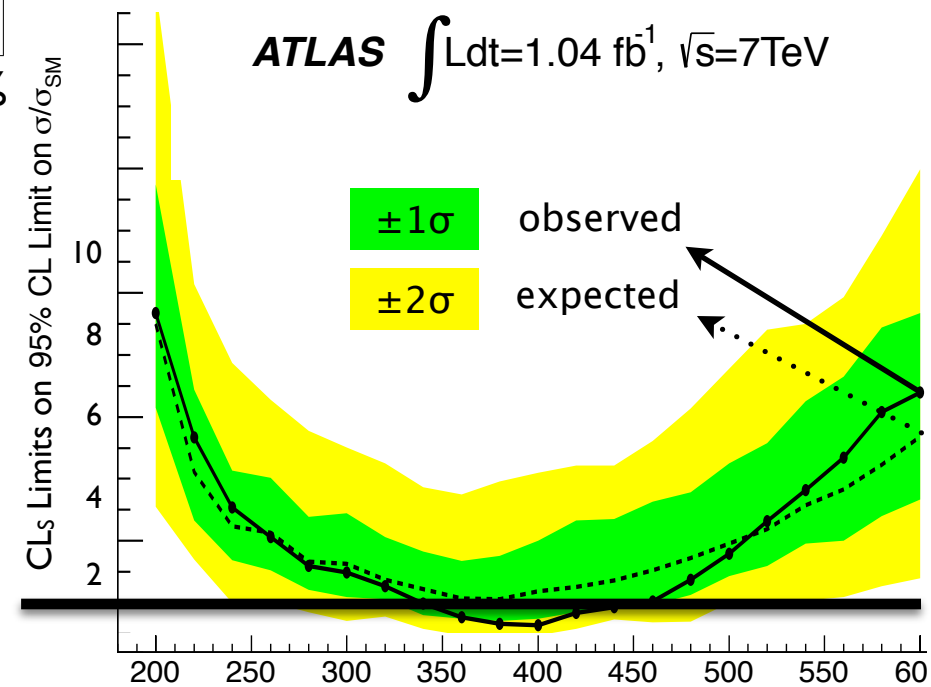
- Reject fake E_T^{miss} from jet mismeas't with



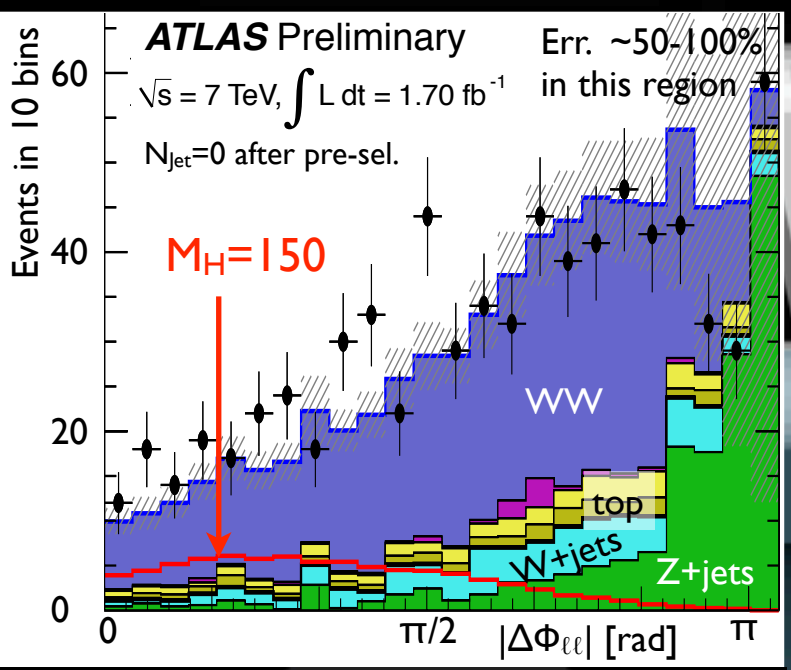
Excluded Higgs masses

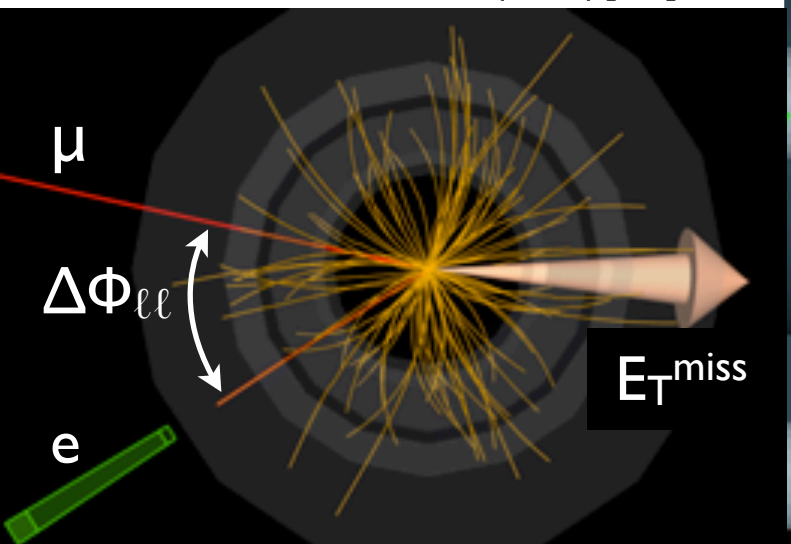
- Use bins $M_T^2 = (E_T^{\ell\ell} + E_T^{miss})^2 - (\mathbf{P}_T^{\ell\ell}+\mathbf{P}_T^{miss})^2$
- Expected : 380 GeV is closest at 1.1×SM
- Observed : 340 < M_H < 450 GeV

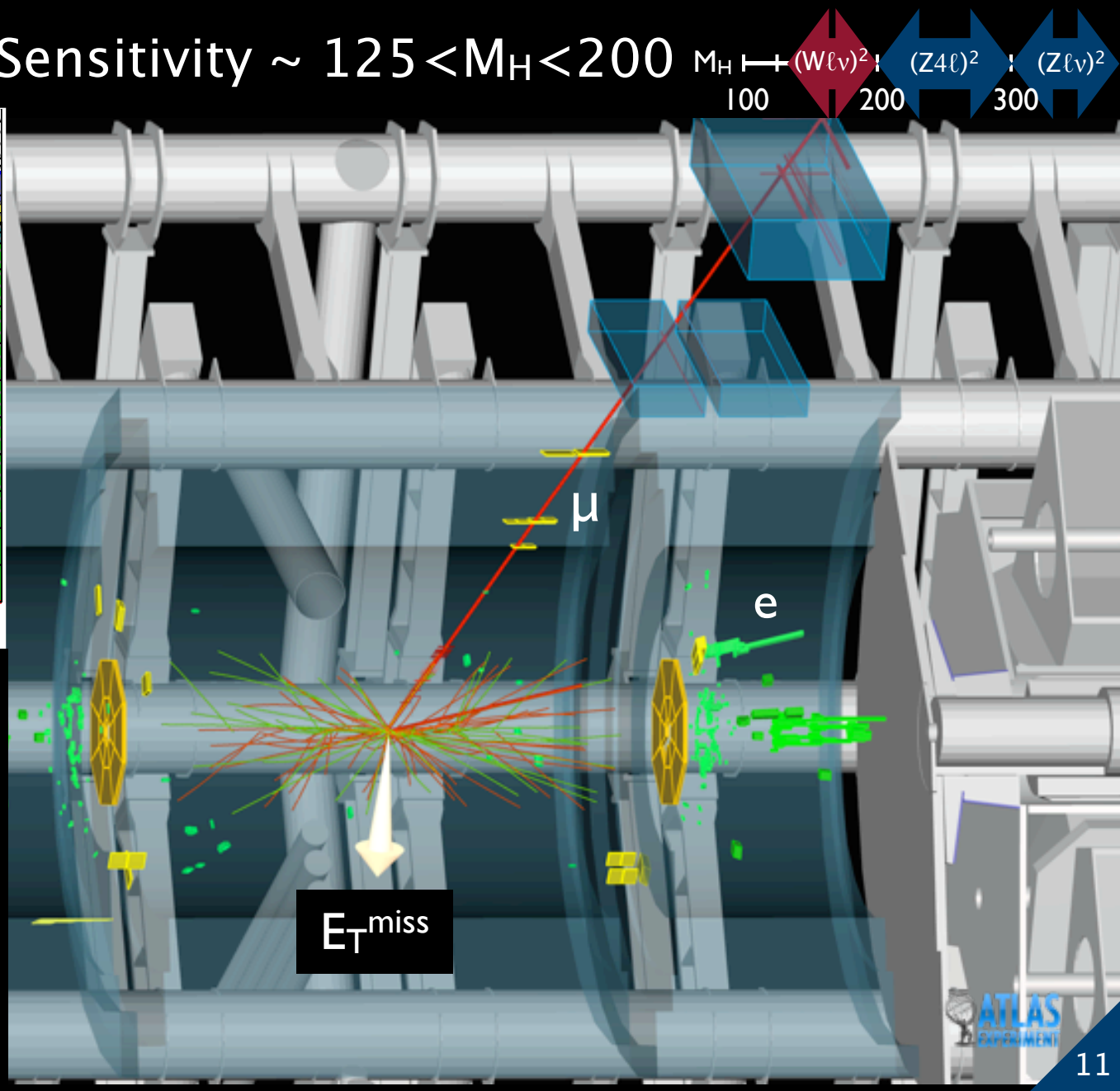




- $H \to WW^{(*)} \to \ell\nu+\ell\nu$: partial reco = count
- Similar to $ZZ^{(*)} \to \ell\ell+\nu\nu$, but $M(\ell\ell) \neq M_Z$
- Sensitivity ~ $125 < M_H < 200$







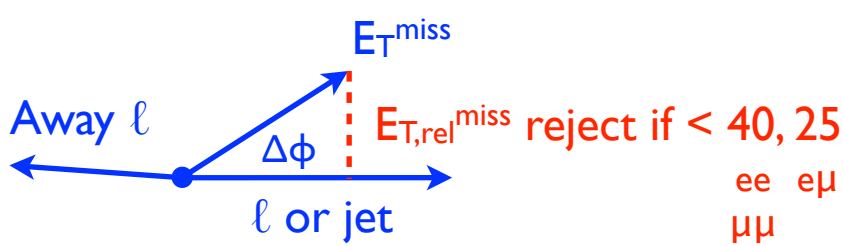
Want $M(\ell^+\ell^-) \neq M_Z$ with E_T^{miss}

- Leading lept. P_T : e, μ=25
- Sublead. lept. P_T : e=20, μ=15
- Backgrounds : Next slide
- $E_{T,rel}^{miss}$ cut : ee, μμ=40, eμ=25

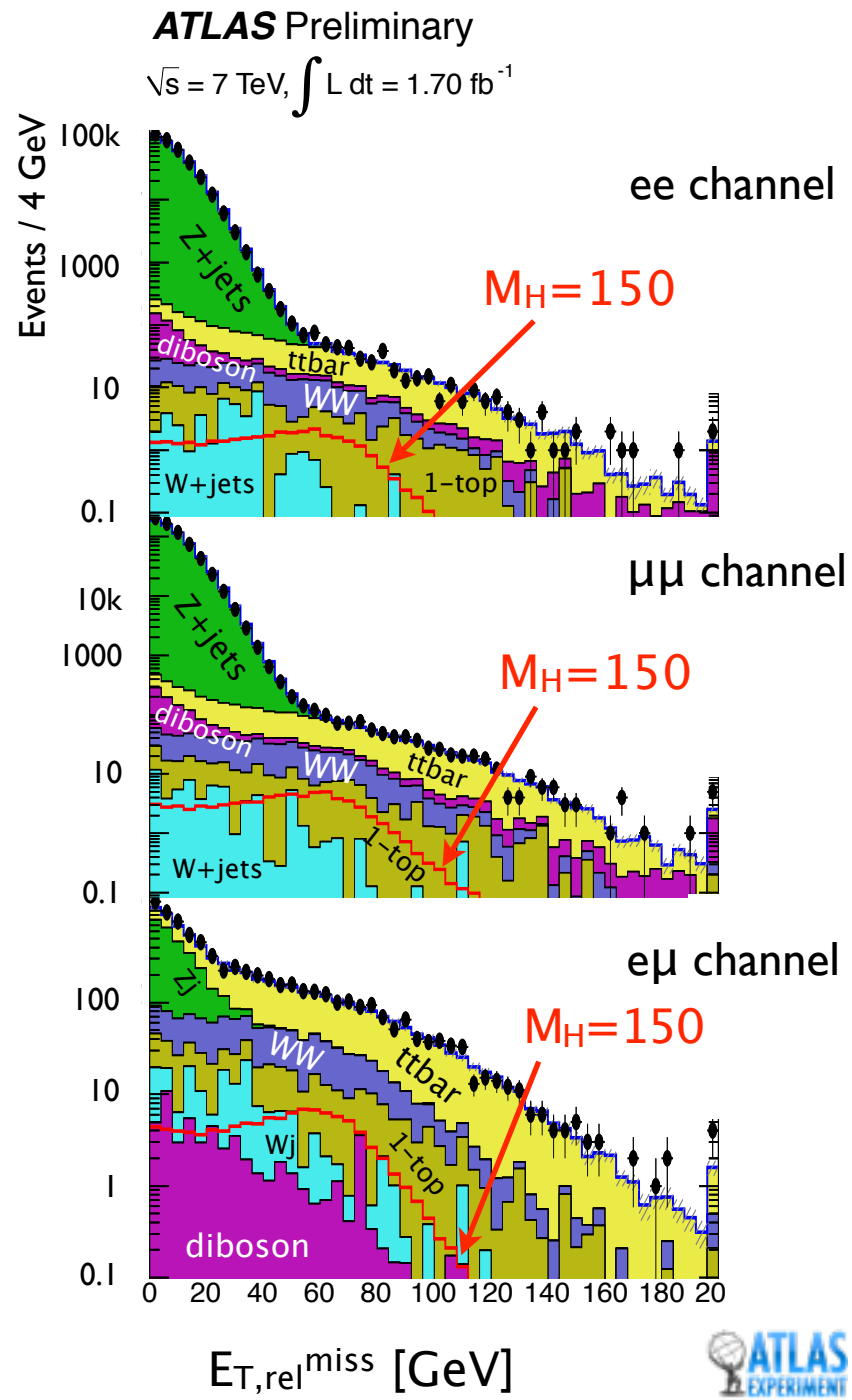
Selection	Data	Expected SM					
		Total	SM WW	top	W+j	Z+j	VZ
$M_{\ell\ell}>15$, $M_{e\mu}>10$	1E+06	1M	1.4k	7k	data-derived	1M	1k
$\lvert M_{\ell\ell \text{ or } e\mu}-M_Z\rvert>15$	1E+05	.1M	1.2k	6k		.1M	100
$E_{T,rel}^{miss}$	4051	4k	660	3k		300	30

- Definition of $E_{T,rel}^{miss}$

If such ℓ or jet in same ϕ-hemisph.,



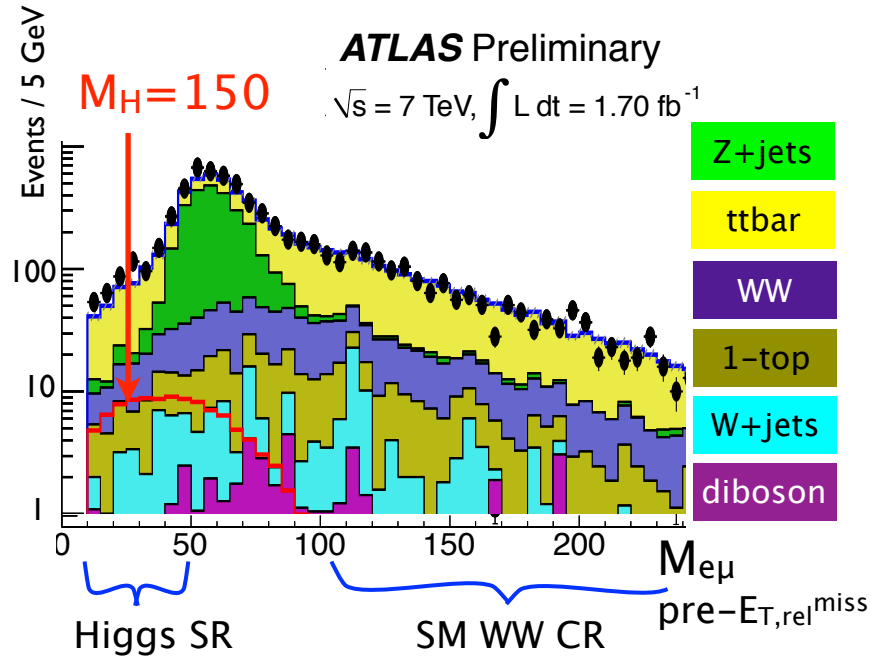
Otherwise, $E_{T,rel}^{miss} = E_T^{miss}$



Backgrounds

Mostly data-derived quantitites

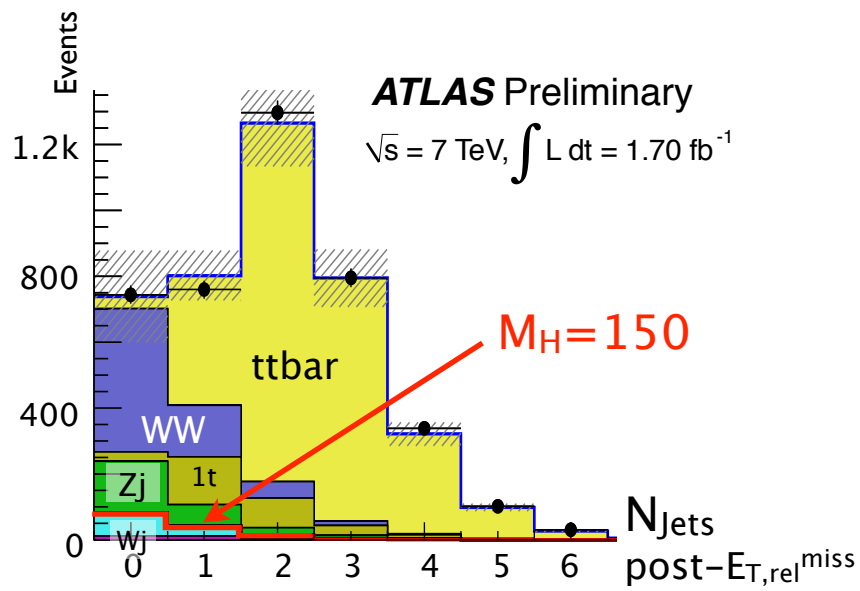
- SM WW(*) : $M_{\ell\ell}$ data CR →SR w/MC ; Err~10%
- top : b-jet data CR →SR w/MC ; Err~10%
- W+jet : di-jet data CR →SR w/data ; Err~30%
- Others : MC predictions, small



Final selection

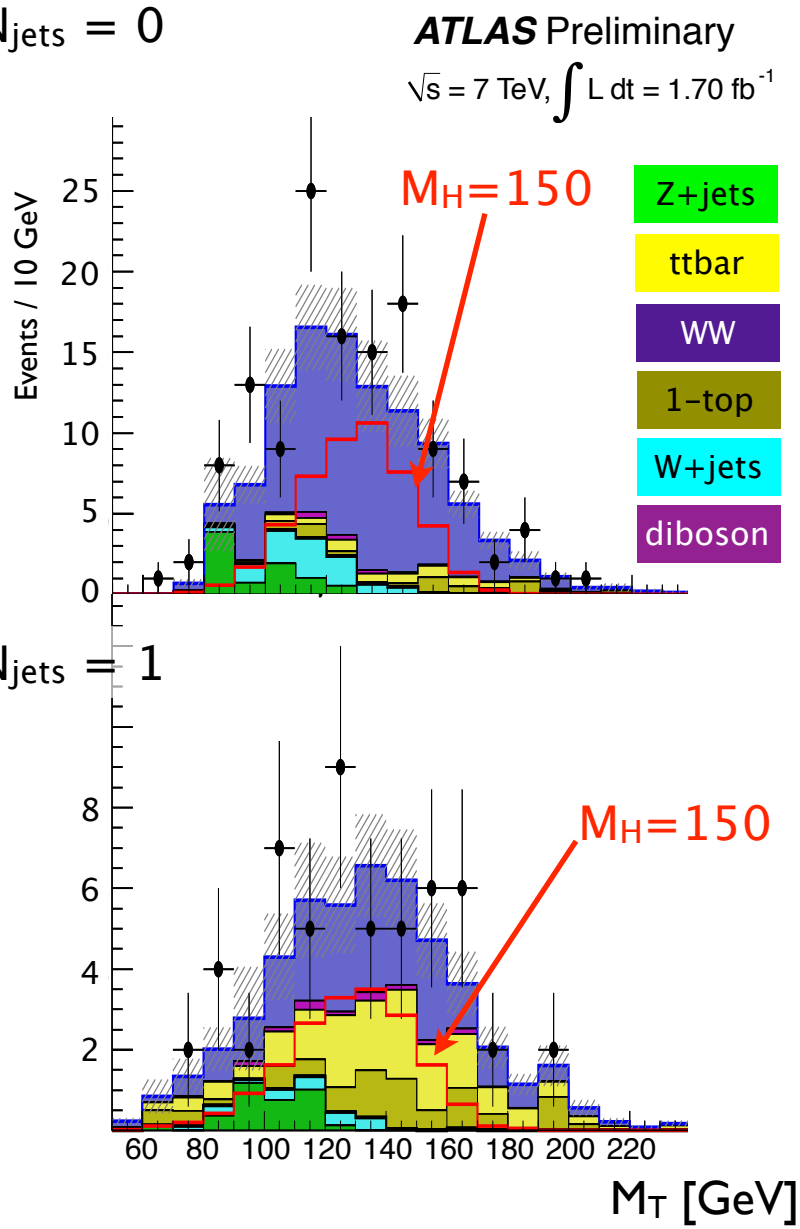
- Split data into N_{jets} = 0, 1 (reject b-jets)
- "Topological" cuts exploit spin-0 decay
  - small $\Delta\Phi_{\ell\ell}$, large $P_T^{\ell\ell}$, low $M_{\ell\ell}$
  - M_T (defined on p.10)

Selection	Data	Expected SM						Higgs
		SM WW	top	W+j	Z+j	VV	Total	M_H = 150
N_{jets}=0	70	43±6	2.2±1.4	4.7±1.5	1.8±3.6	0.7±3.6	53±9	34±7
N_{jets}=1	23	10±1.5	6.9±1.9	0.7±0.4	1.2±1.1	0.6±0.2	23±4	12±2



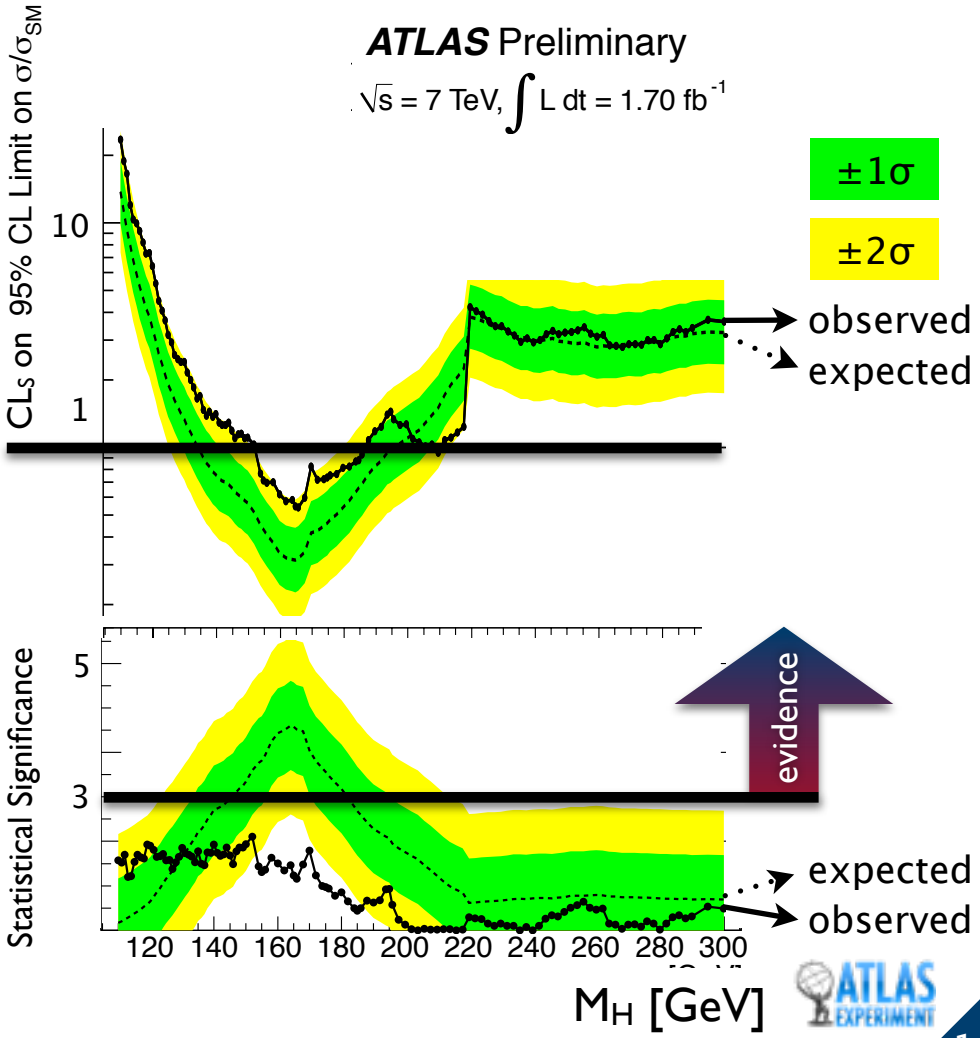
M_T, Transverse mass (last cut)

- $N_{jets} = 0$
- $N_{jets} = 1$

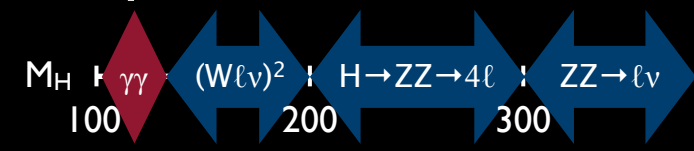


Excluded Higgs masses

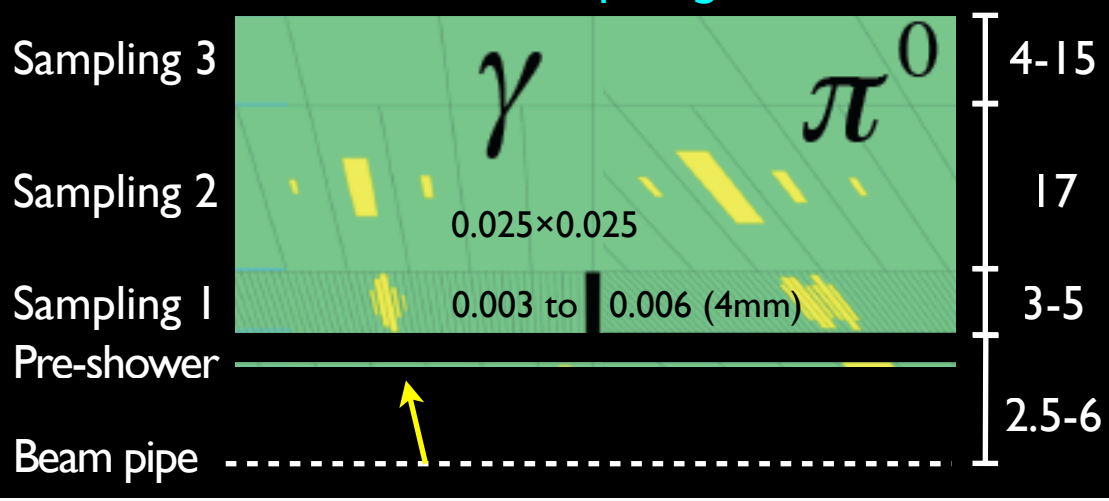
- Expected : $135 < M_H < 196$ GeV
- Observed : $154 < M_H < 186$ GeV
- 2 sigma excess below ~160 GeV



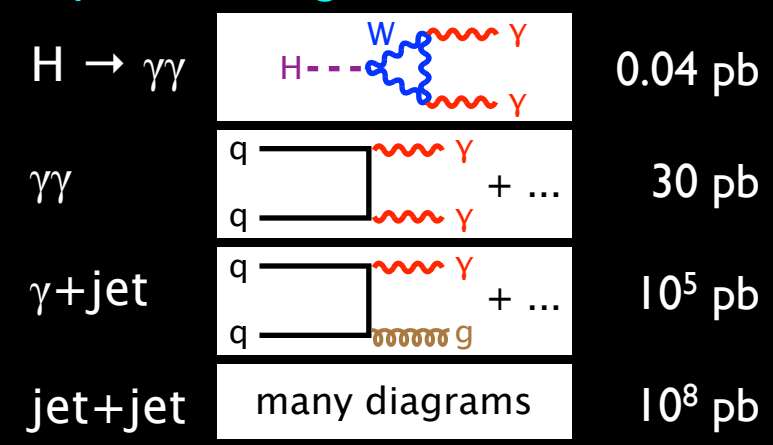
- H → γγ : full reco = mass peak
- Sensitivity ~ M_H<125



Data from Spring 2011

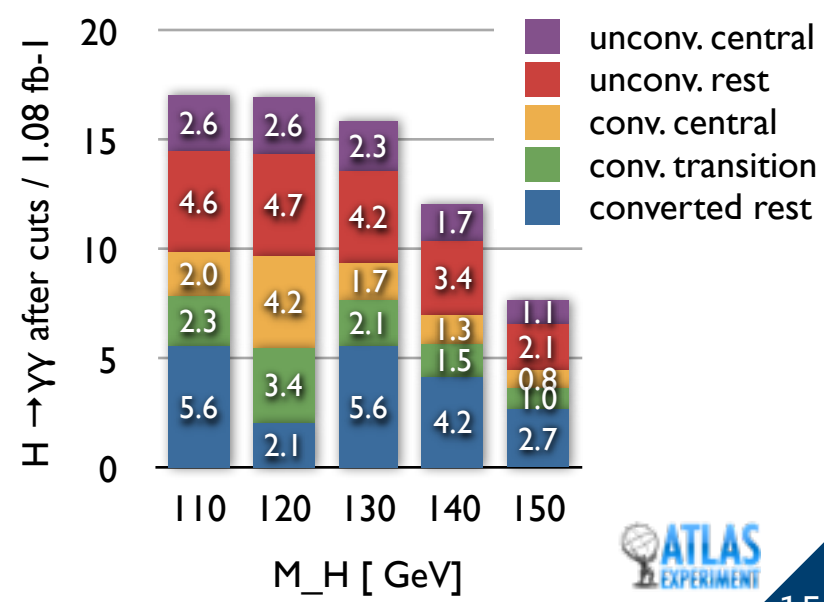


Feynman diag. & cross-sections

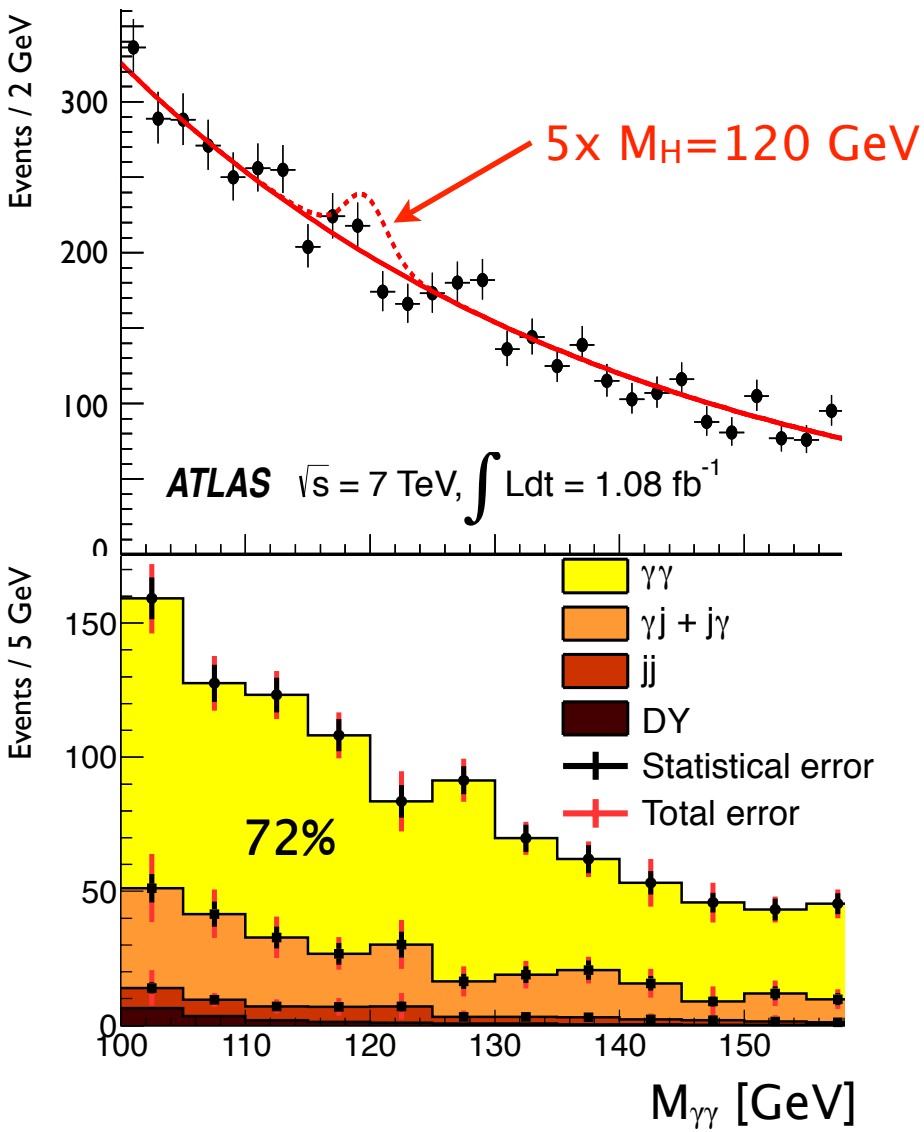


Want two isolated photons

- Photon selection : P_T > 40, 25
- Photon identif'n : Use lat.+long. segmentation
- Backgrounds : See top-right
  - Data-derived e → γ
  - Relaxed isolation, identification
- Split data into detector region, γ→ee conversion

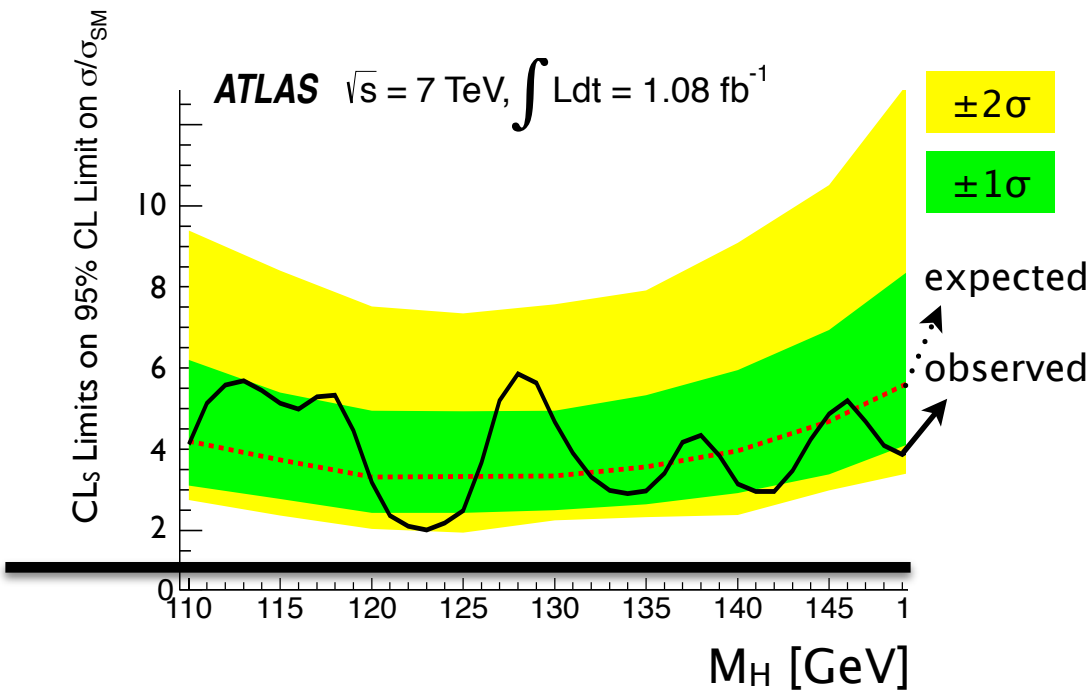


Mass resolution = 1.4 – 2.1 GeV



Excluded Higgs masses

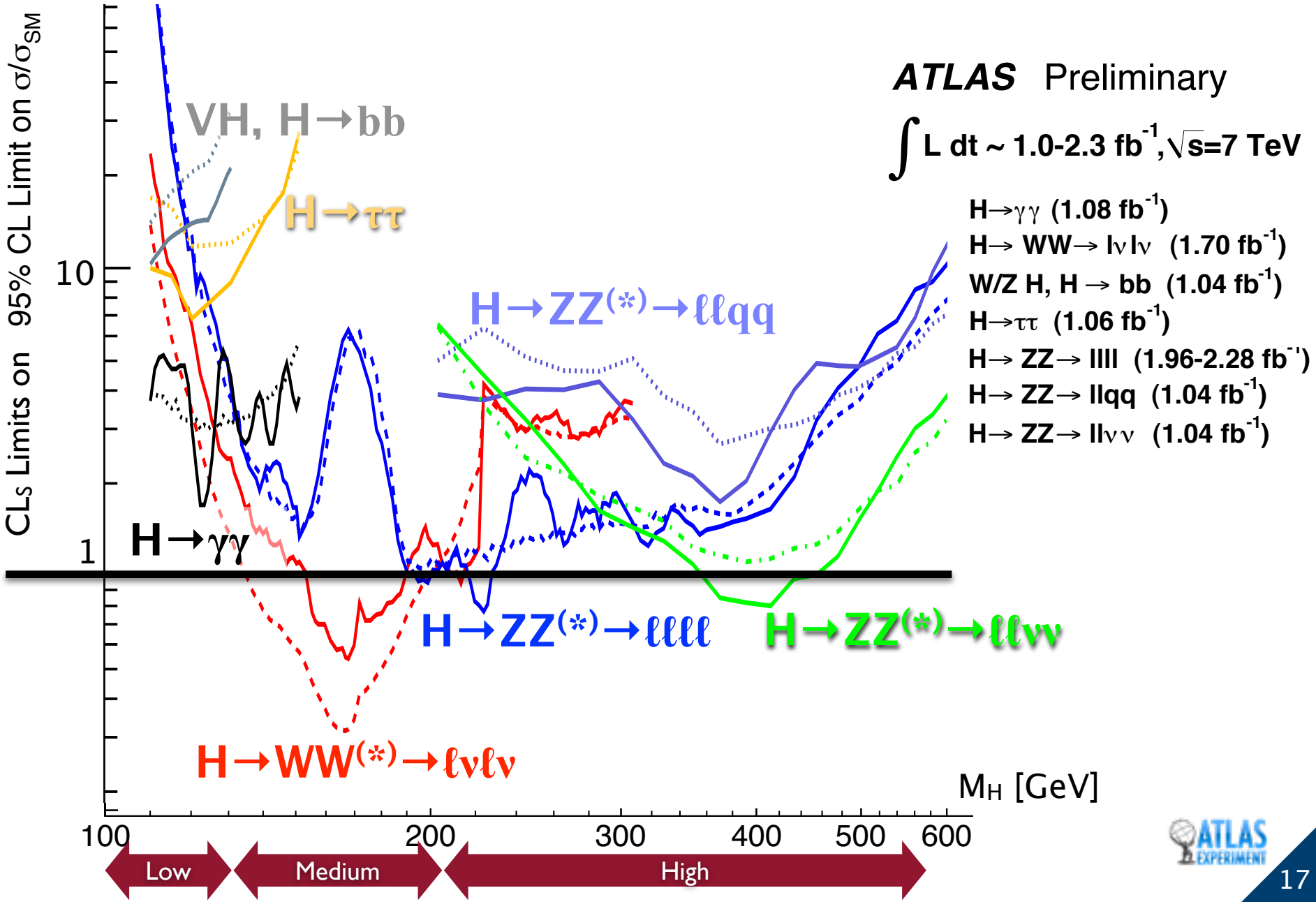
- Fit with exponential + signal shape.
- No range is excluded yet, but 120<M_H<130 GeV is getting close.



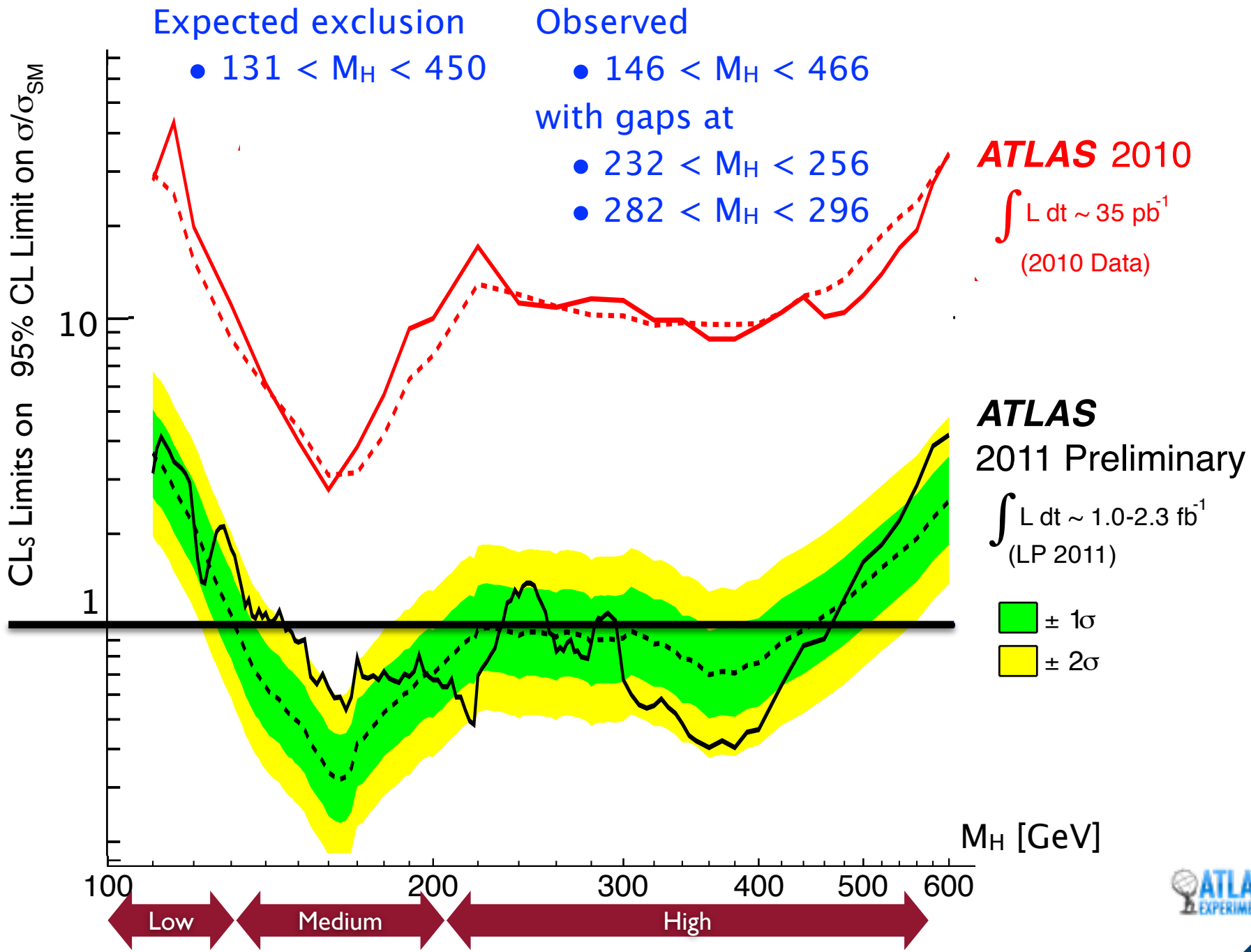
We're closing-in on the LEP limit!

Exclusion limits of various results: solid is observed, dotted is expected

For results were not discussed in prev. slides see p.3.

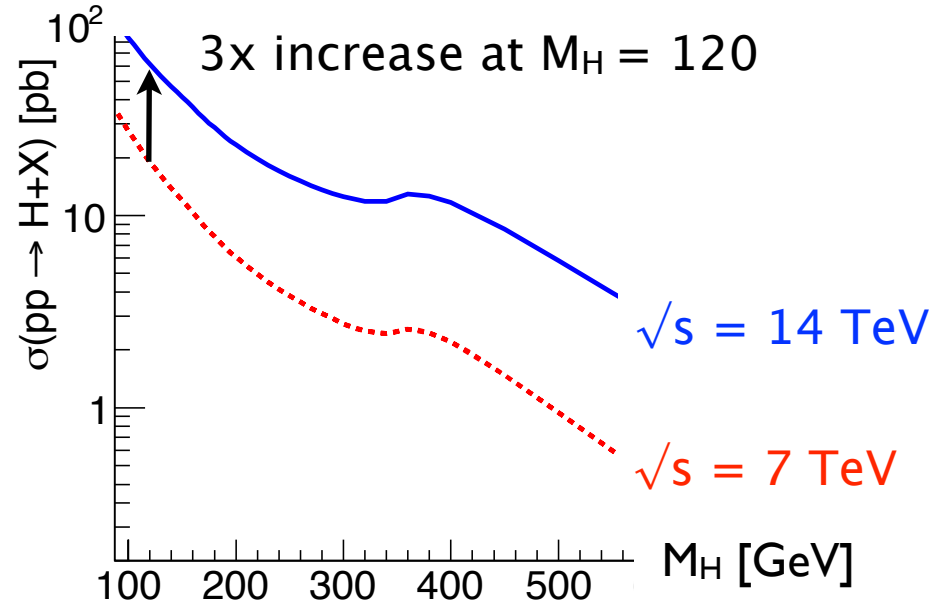


Combined exclusion limits: solid is observed, dotted is expected



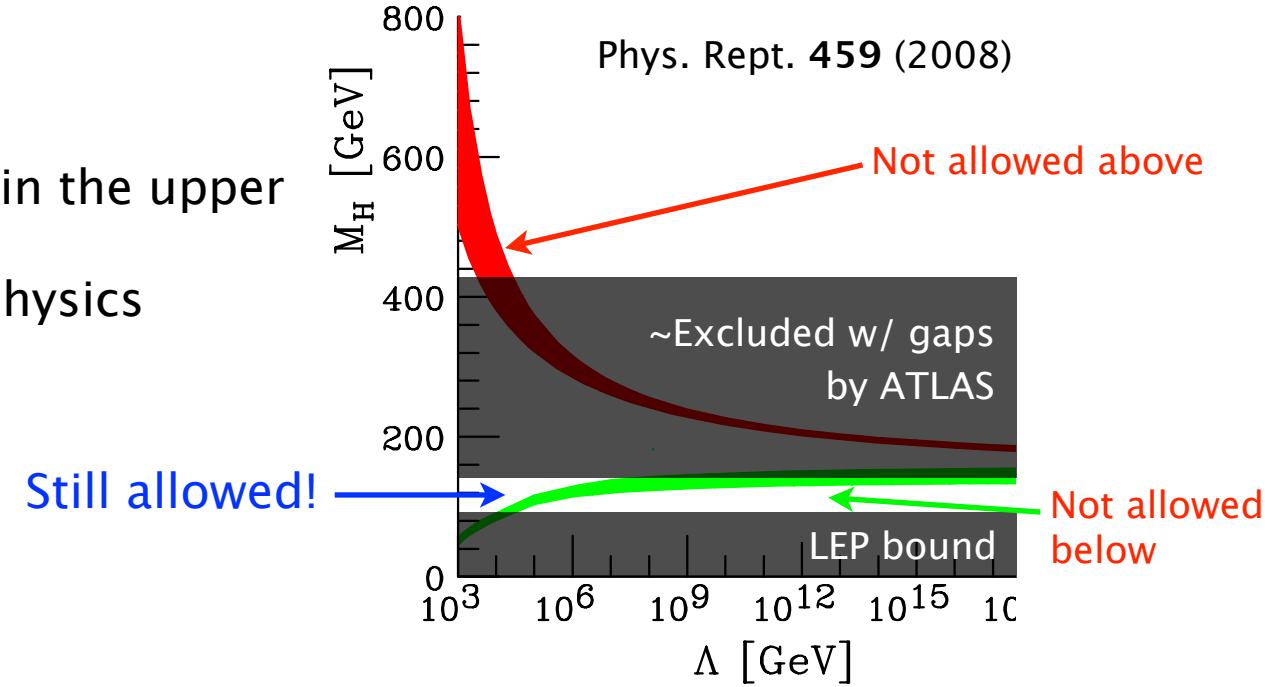
Next steps

- Analysis : Lower lep. P_T; multivar. techn.
- Background : Improve data-derived est.
- Prepare for : LHC upgrades of lumi, $\sqrt{s}$



Implications

- Exp't limits on M_H help constrain the upper bound on Λ, the scale of new physics



It's an exciting time to study Higgs physics!

References

Slide	Source
3	http://www.interactions.org/cms/?pid=2100&image_no=CE0155
4	https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResults
4	http://www.interactions.org/cms/?pid=2100&image_no=CE0152
5	From S. Kortner's ATLAS Week Higgs talk on Oct. 11, 2011 (**ATLAS internal**)
6, 15	http://cdsweb.cern.ch/record/1385868/files/ATL-PHYS-SLIDE-2011-578.pdf
6	https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections
7-8	https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2011-131/
9	E. Gross' talk https://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=141983
9-10	http://arxiv.org/abs/1109.3357
11	https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2011-015/
11-14	https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2011-134/
15-16	http://arxiv.org/abs/1108.5895
17	https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2011-135/
18	https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPlotsLPCCCombination
19	A. Djouadi's paper http://arxiv.org/abs/hep-ph/0503172 Phys. Rept. 459 (2008)

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