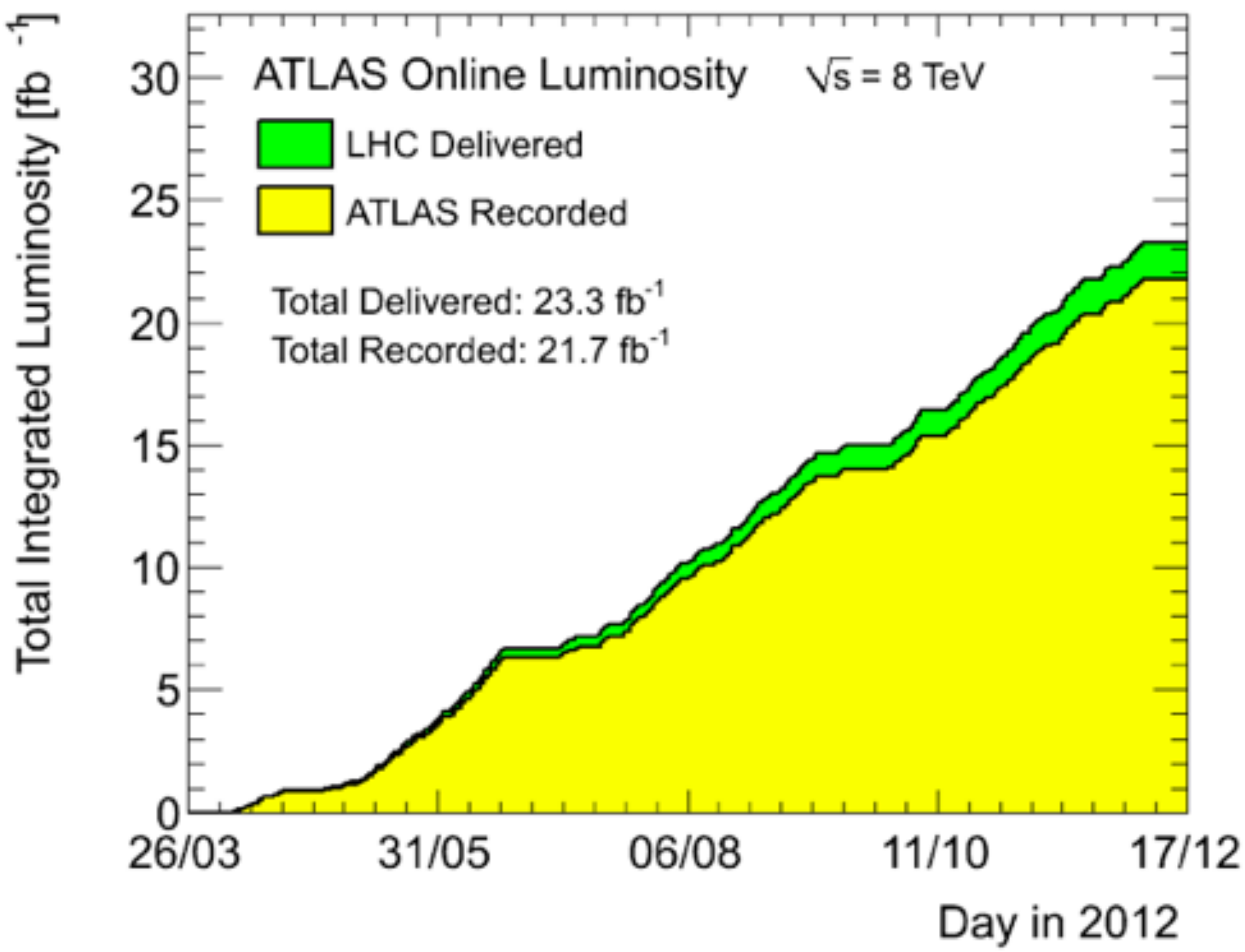
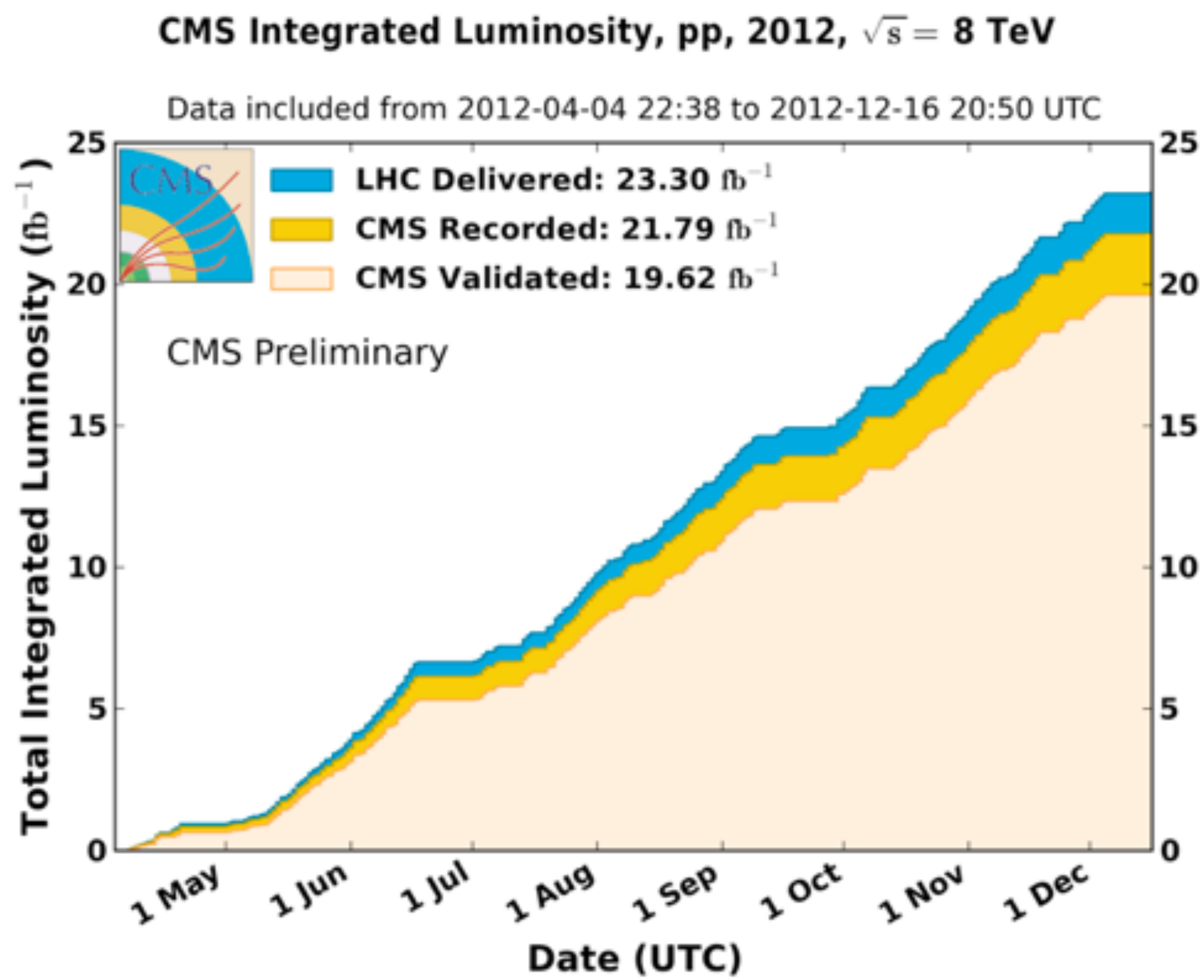
HIGGS HUNTING 2013
EXPERIMENTAL SUMMARY

Gigi Rolandi - CERN and Scuola Normale

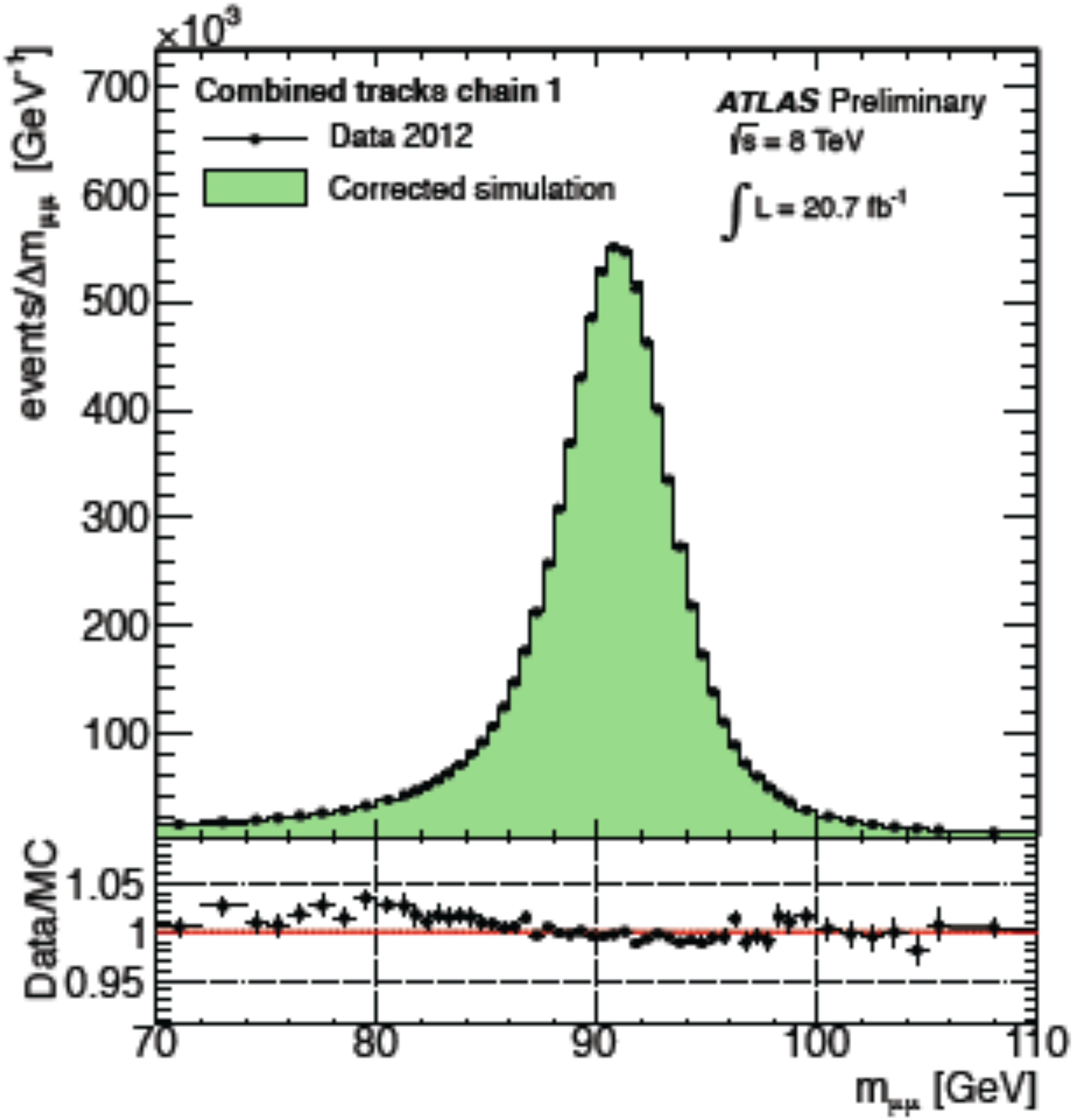
Where do we stand 13 months after July 4th 2012 ?





5 fb-1 @ 7 TeV and 20 fb-1 @ 8 TeV analyzed

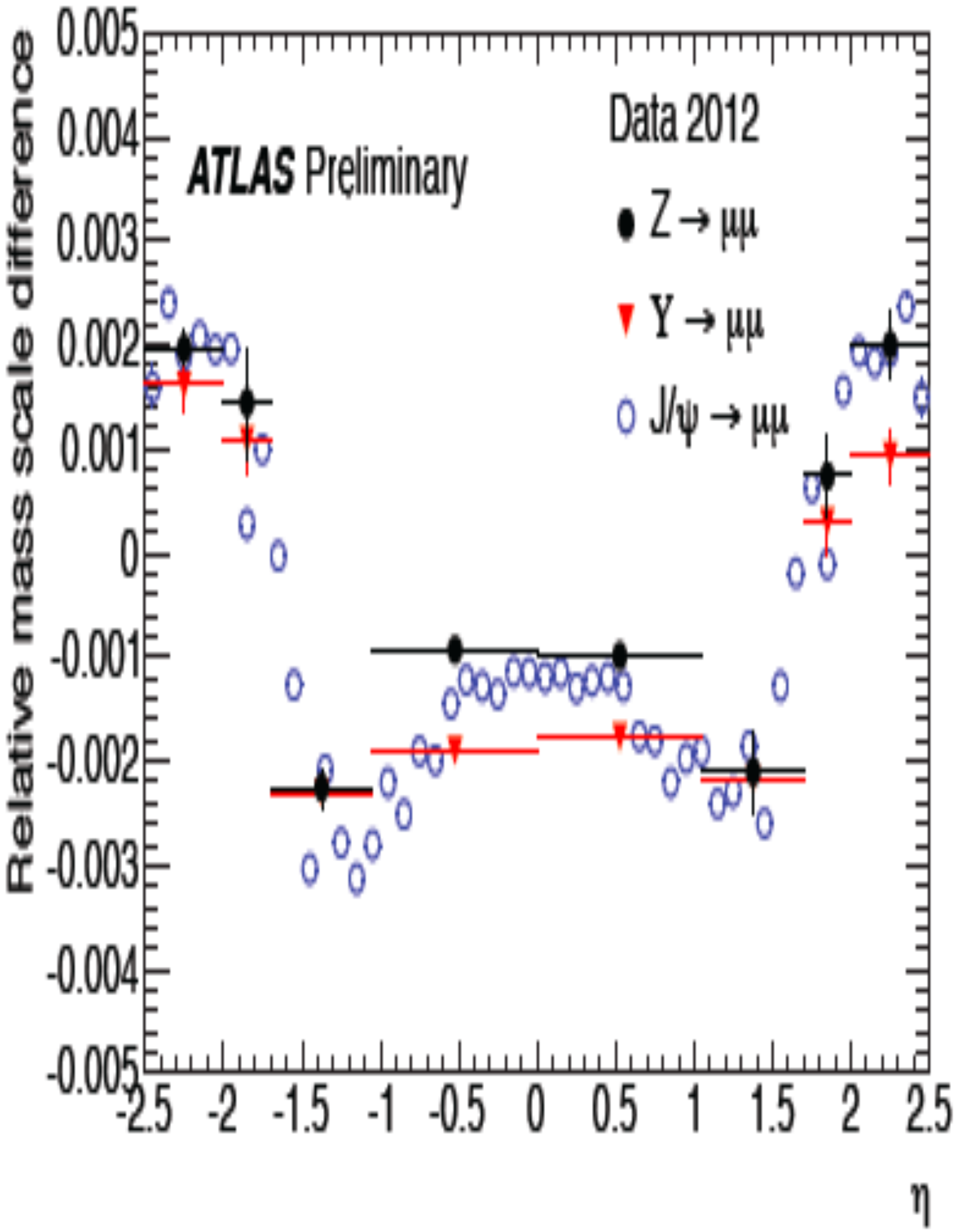
Millions of Z events allow careful calibration of the detector

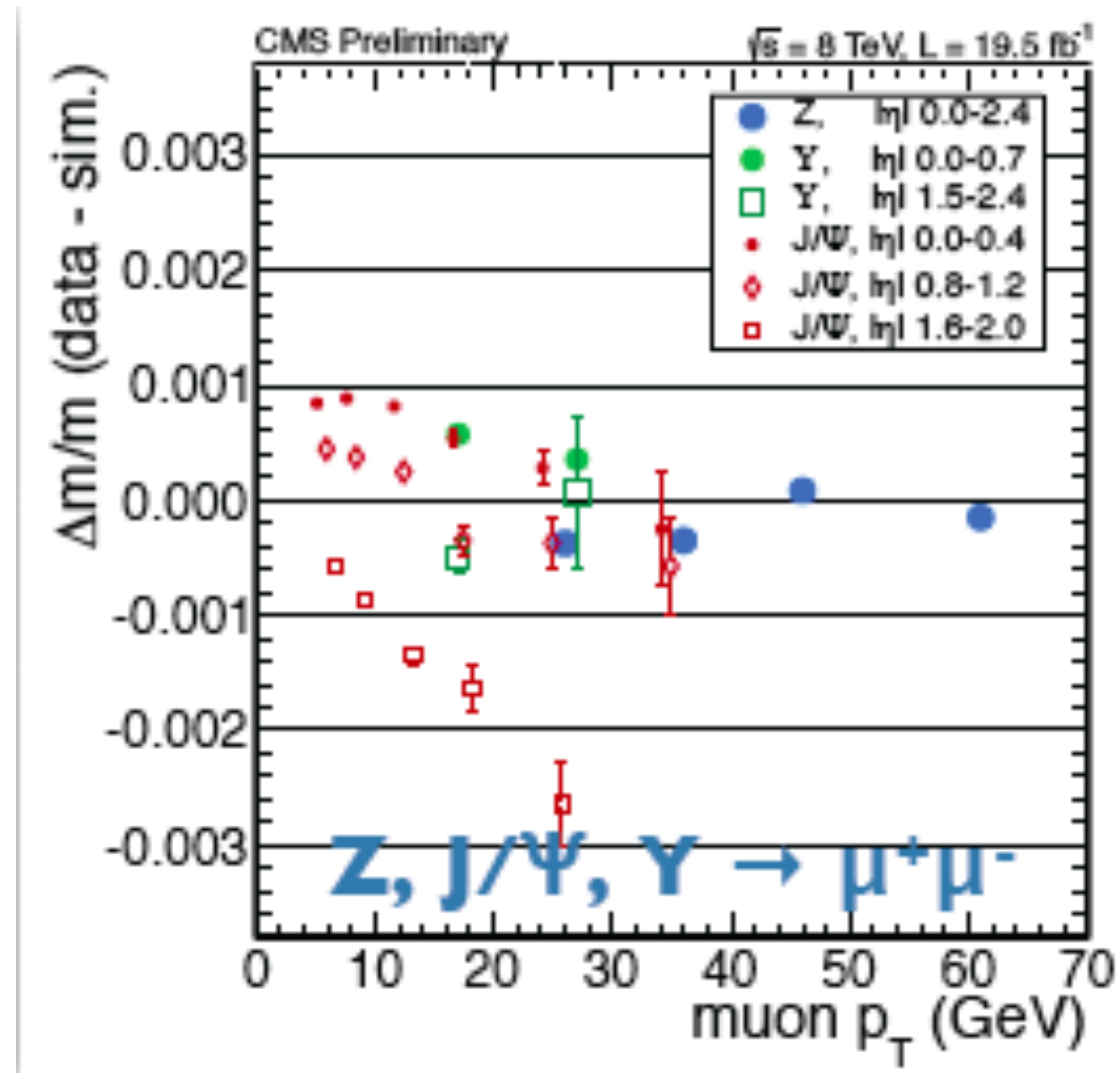


+ J/Psi + Y

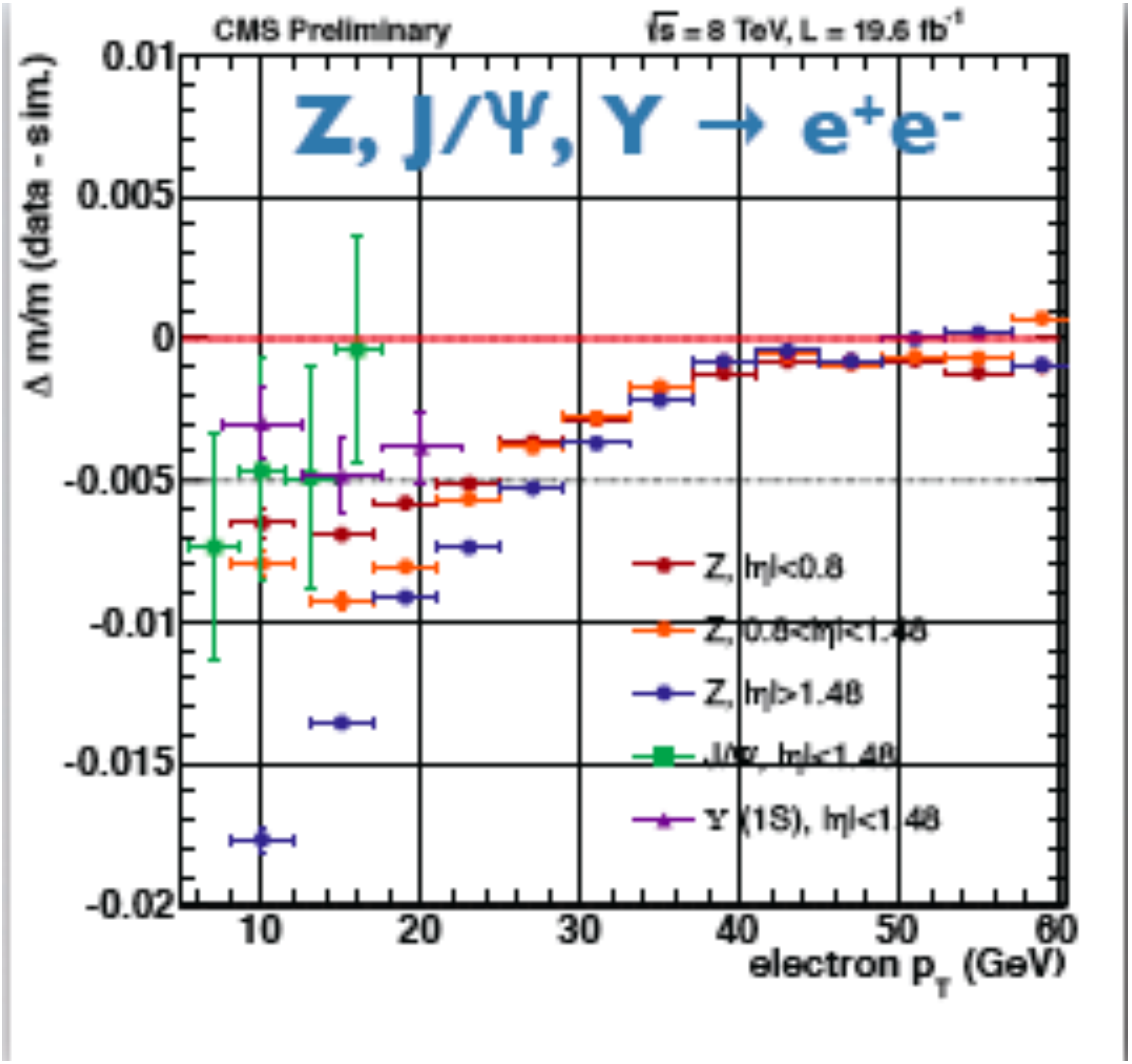
Muon energy scale at few 0.1% level

Muon relative scale difference

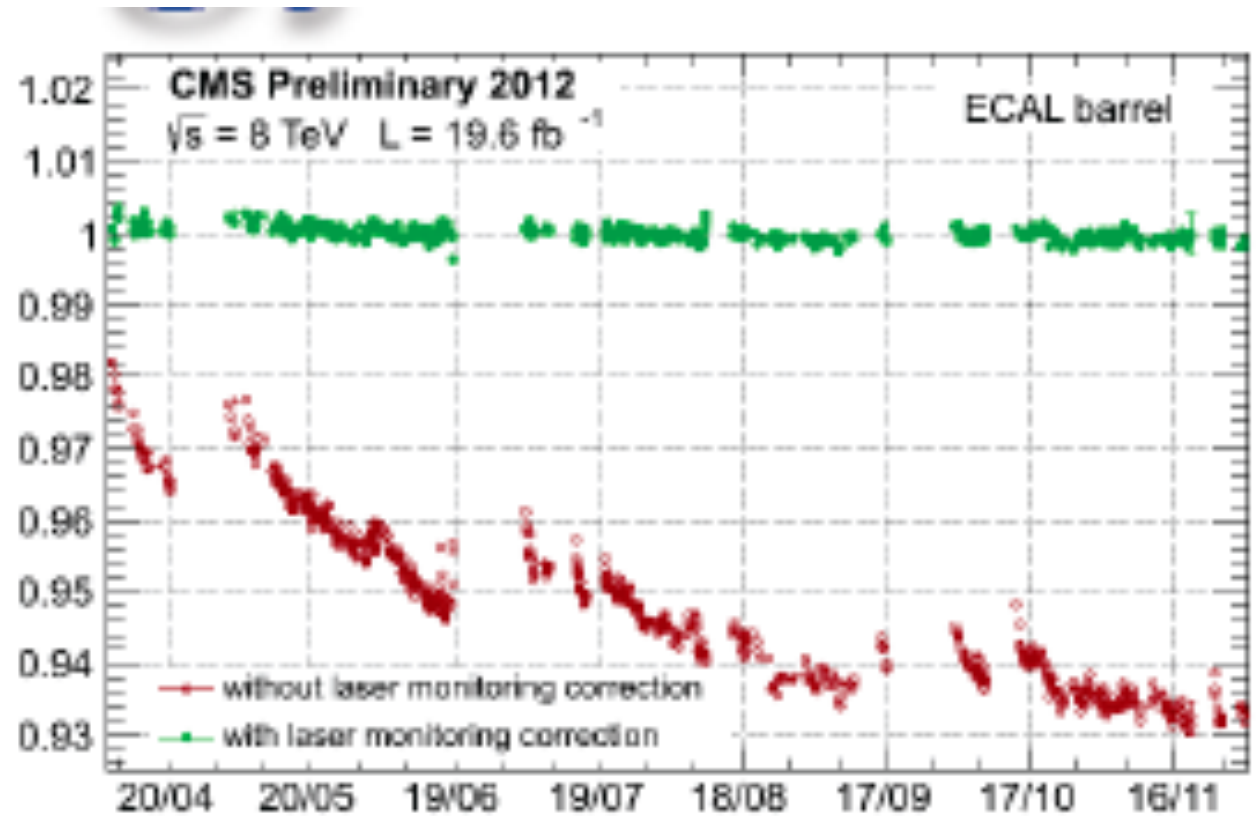


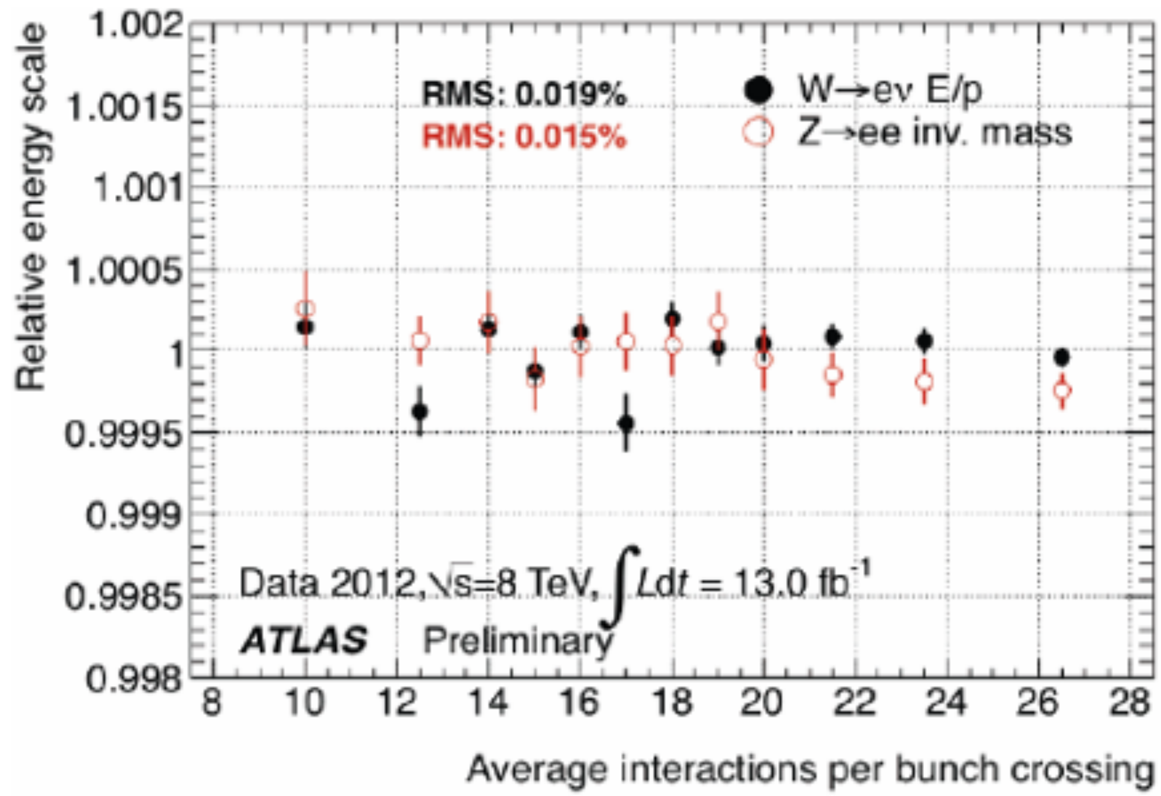


Electron energy scale below 1%

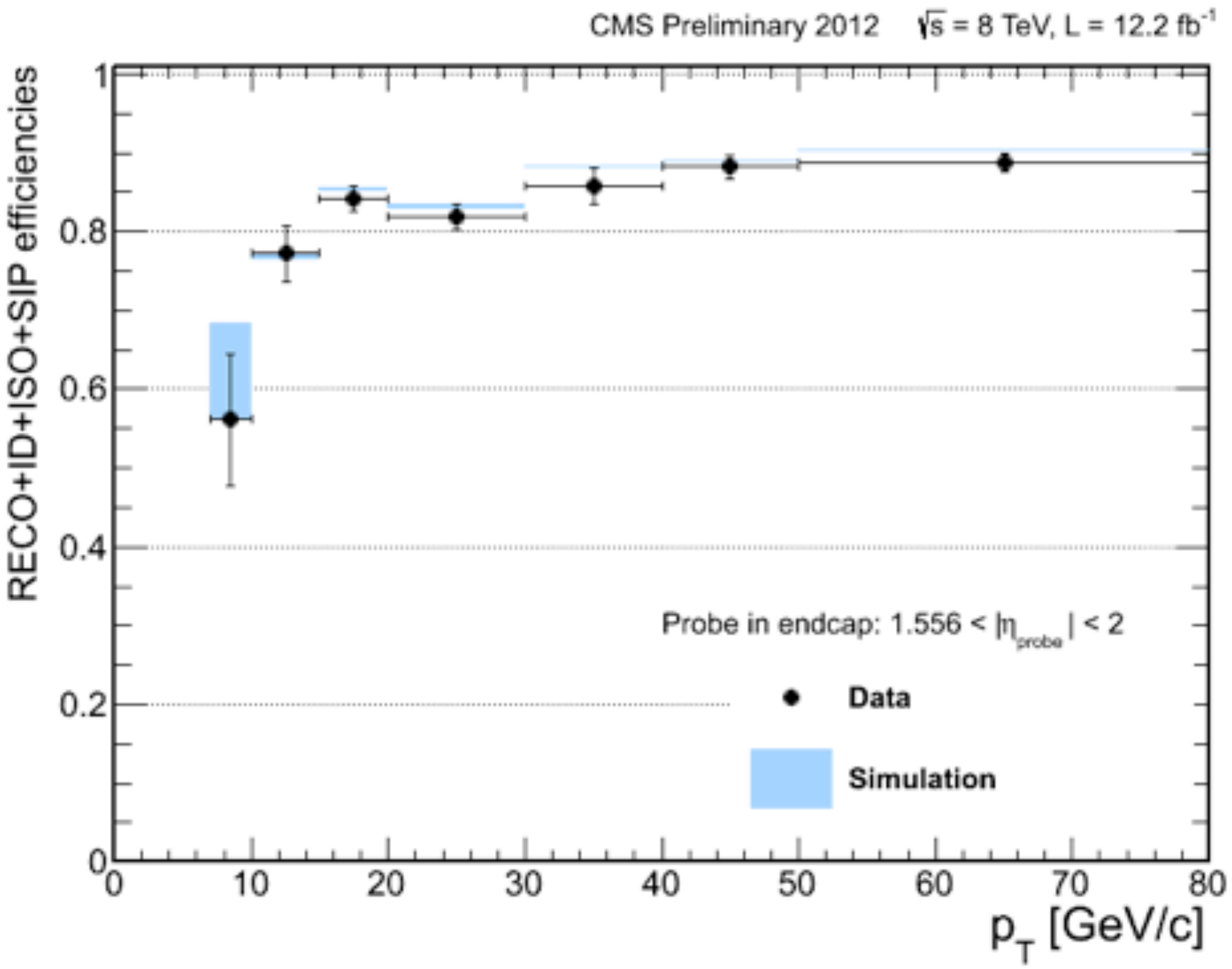


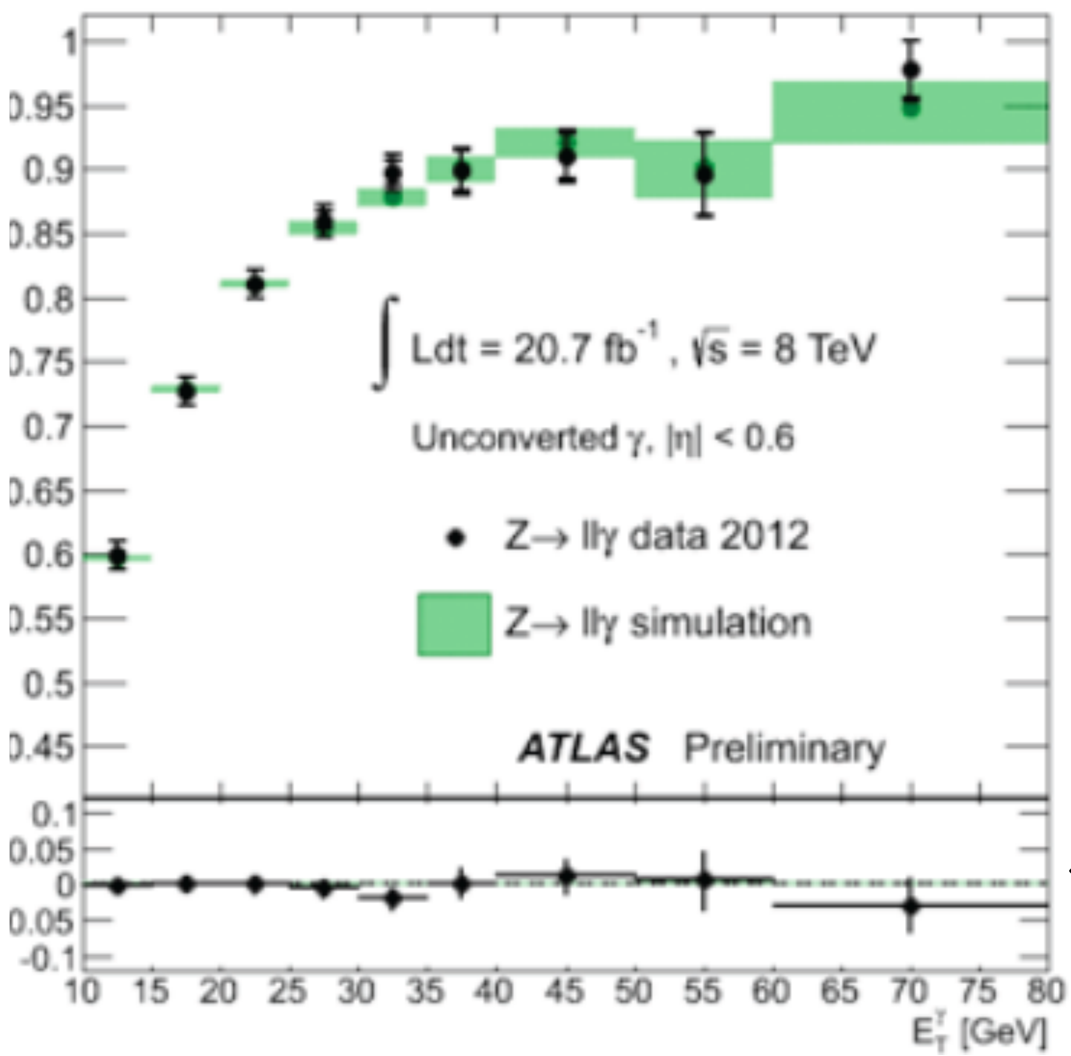
Relative energy scale of the calorimeter





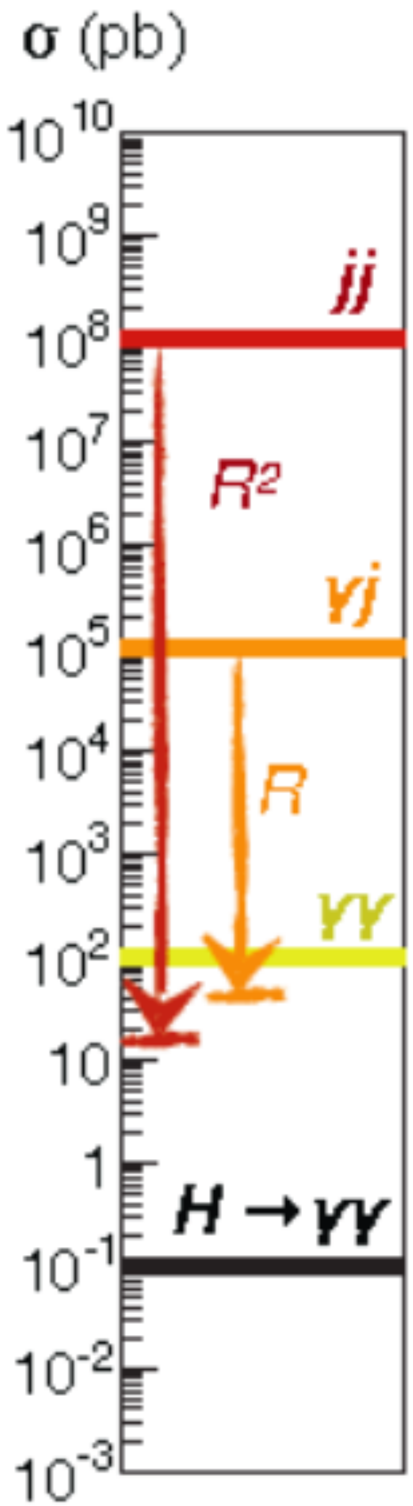
Efficiency in electron/photon identification



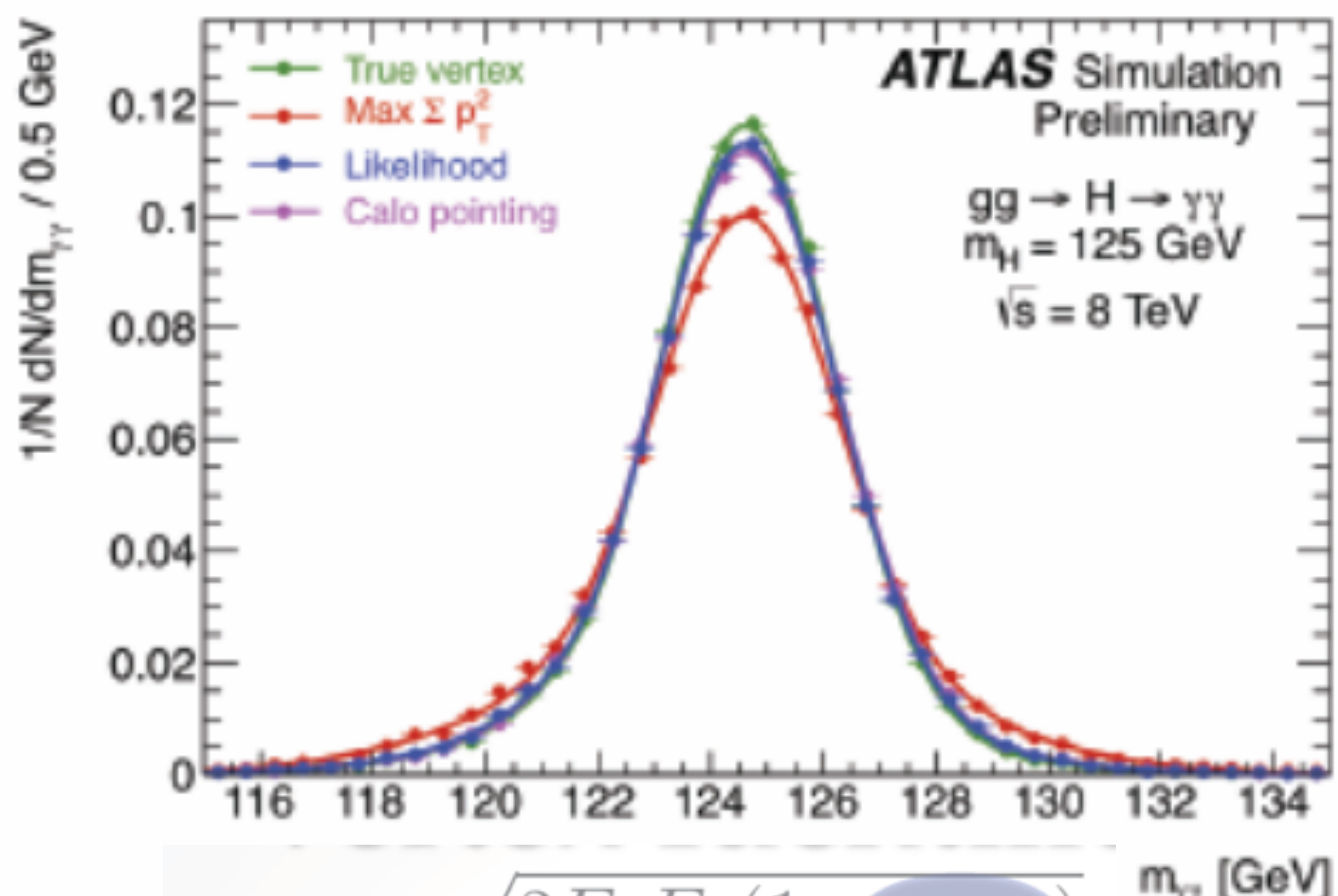


H-->γγ

Calderini - Kenzie



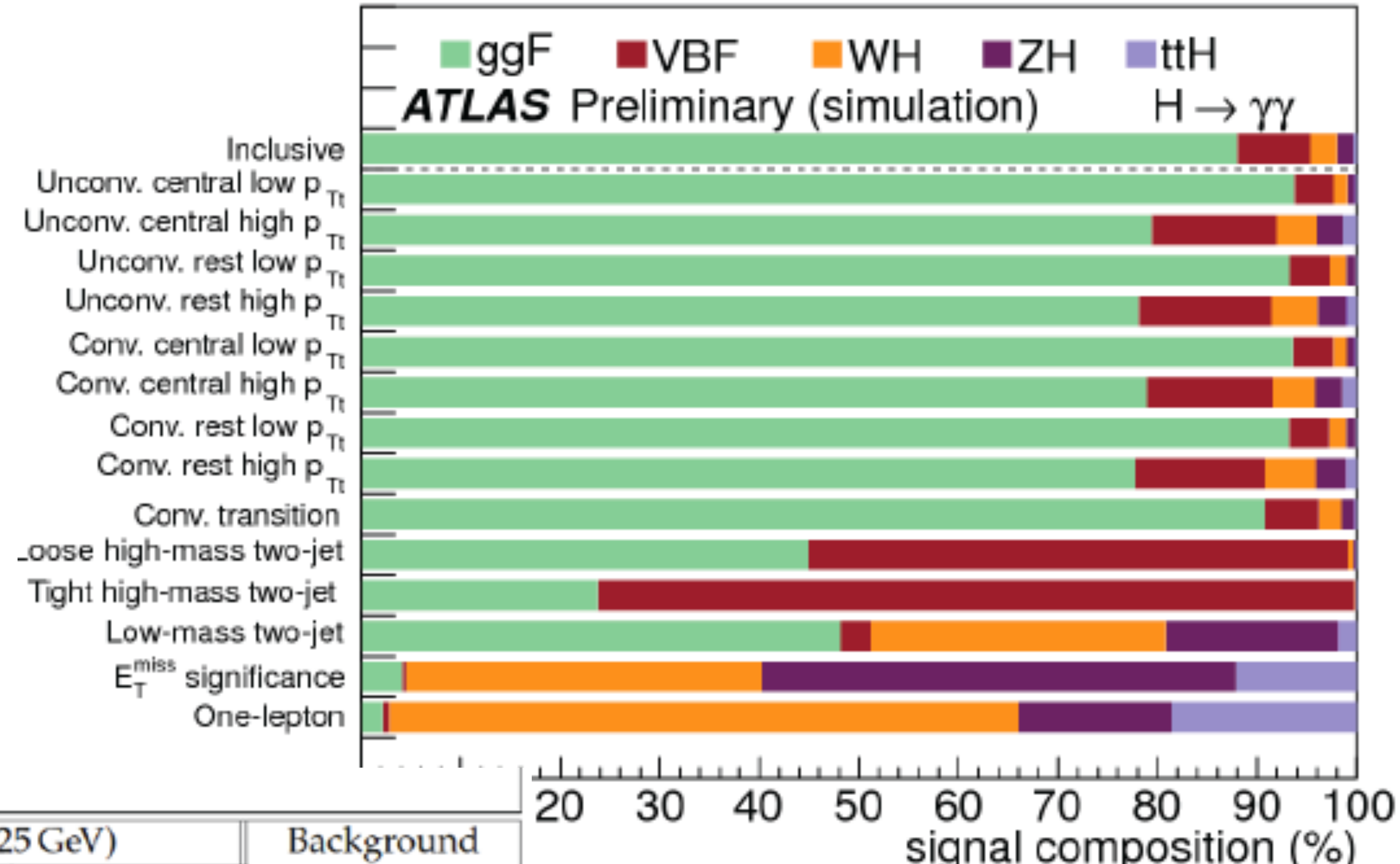
γγ fraction 75(70)% ATLAS(CMS)



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

H-->γγ

Categorization

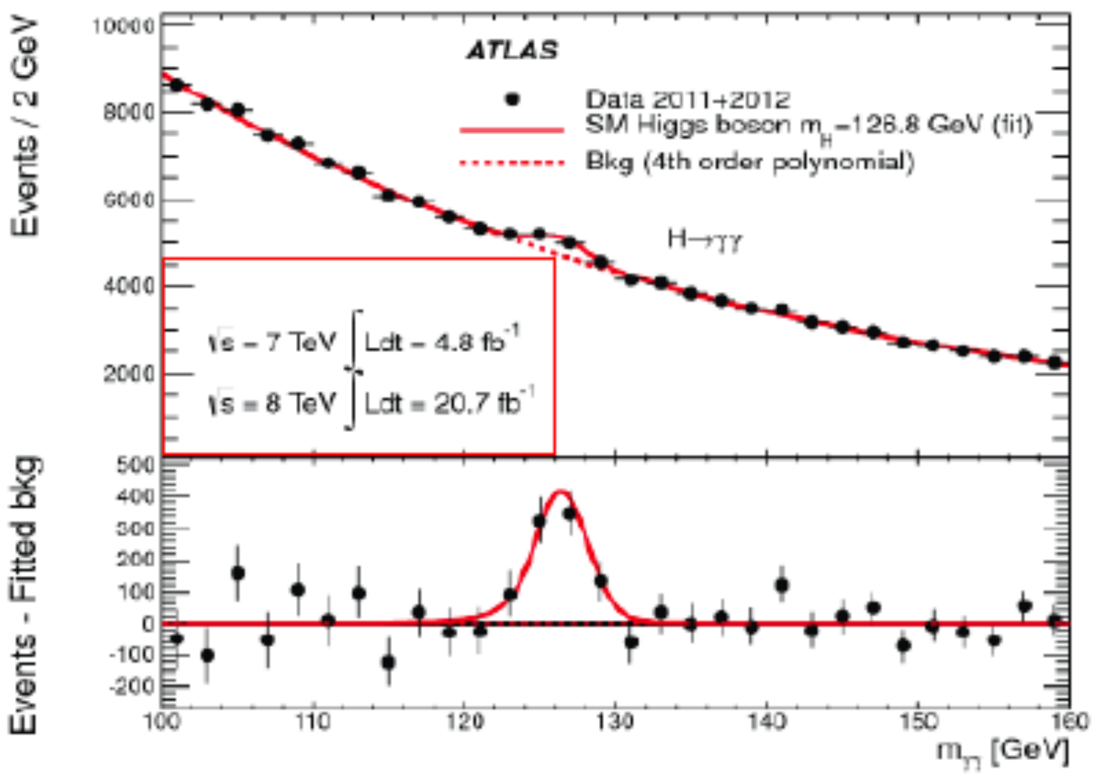


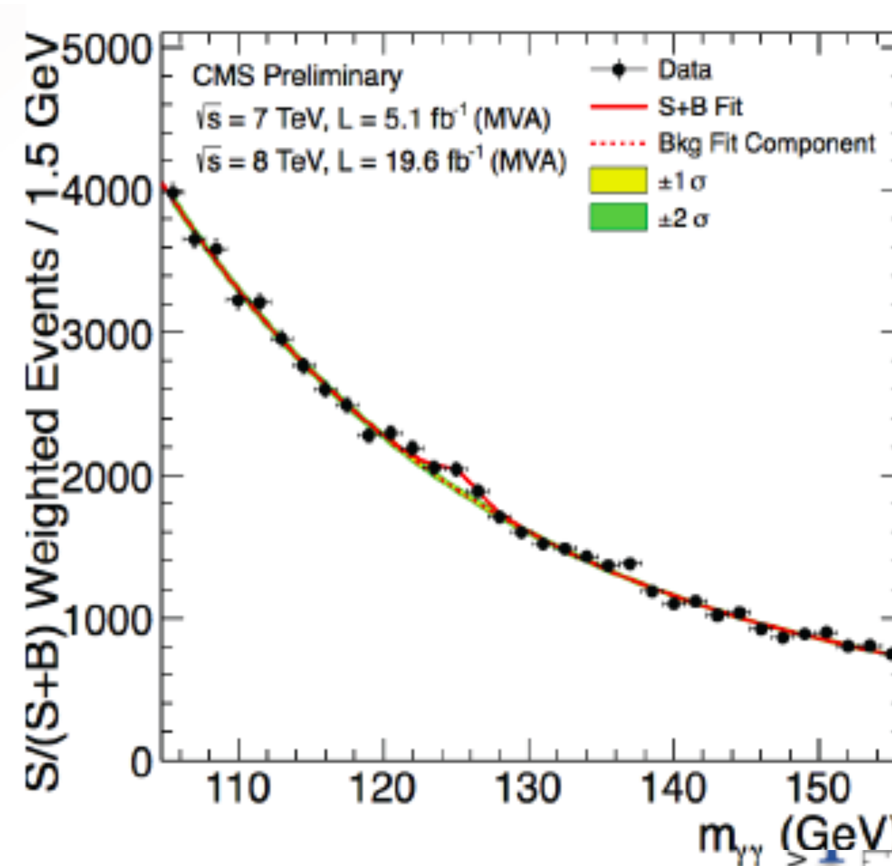
CMS

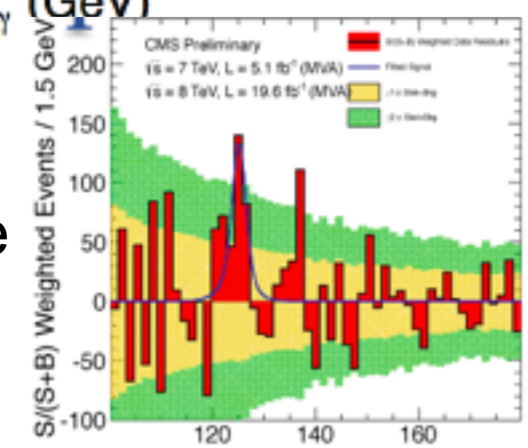
ected signal and estimated background

ent classes	SM Higgs boson expected signal (m_H=125 GeV) Total	ggH	VBF	VH	ttH	σ_{eff} (GeV)	FWHM/2.35 (GeV)	Background $m_{\gamma\gamma}$ = 125 GeV (ev./GeV)
Untagged 0	3.2	61.4%	16.8%	18.7%	3.1%	1.21	1.14	3.3 ± 0.4
Untagged 1	16.3	87.6%	6.2%	5.6%	0.5%	1.26	1.08	37.5 ± 1.3
Untagged 2	21.5	91.3%	4.4%	3.9%	0.3%	1.59	1.32	74.8 ± 1.9
Untagged 3	32.8	91.3%	4.4%	4.1%	0.2%	2.47	2.07	193.6 ± 3.0
Dijet tag	2.9	26.8%	72.5%	0.6%	–	1.73	1.37	1.7 ± 0.2
Untagged 0	17.0	72.9%	11.6%	12.9%	2.6%	1.36	1.27	22.1 ± 0.5
Untagged 1	37.8	83.5%	8.4%	7.1%	1.0%	1.50	1.39	94.3 ± 1.0
Untagged 2	150.2	91.6%	4.5%	3.6%	0.4%	1.77	1.54	570.5 ± 2.6
Untagged 3	159.9	92.5%	3.9%	3.3%	0.3%	2.61	2.14	1060.9 ± 3.5
Dijet tight	9.2	20.7%	78.9%	0.3%	0.1%	1.79	1.50	3.4 ± 0.2
Dijet loose	11.5	47.0%	50.9%	1.7%	0.5%	1.87	1.60	12.4 ± 0.4
Muon tag	1.4	0.0%	0.2%	79.0%	20.8%	1.85	1.52	0.7 ± 0.1
Electron tag	0.9	1.1%	0.4%	78.7%	19.8%	1.88	1.54	0.7 ± 0.1
E_T^{miss} tag	1.7	22.0%	2.6%	63.7%	11.7%	1.79	1.64	1.8 ± 0.1

H-->γγ







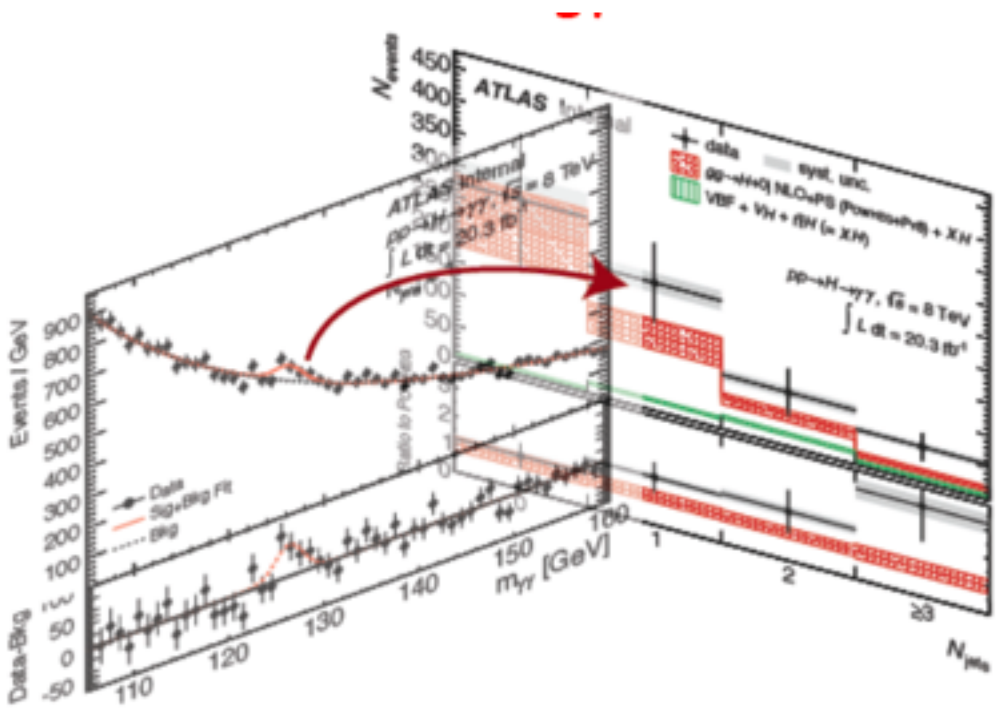
in Δm=± 4 GeV (4 bins)
~ 1000 signal events above
~17000 bkg events

Significance 7.4 (4.1)

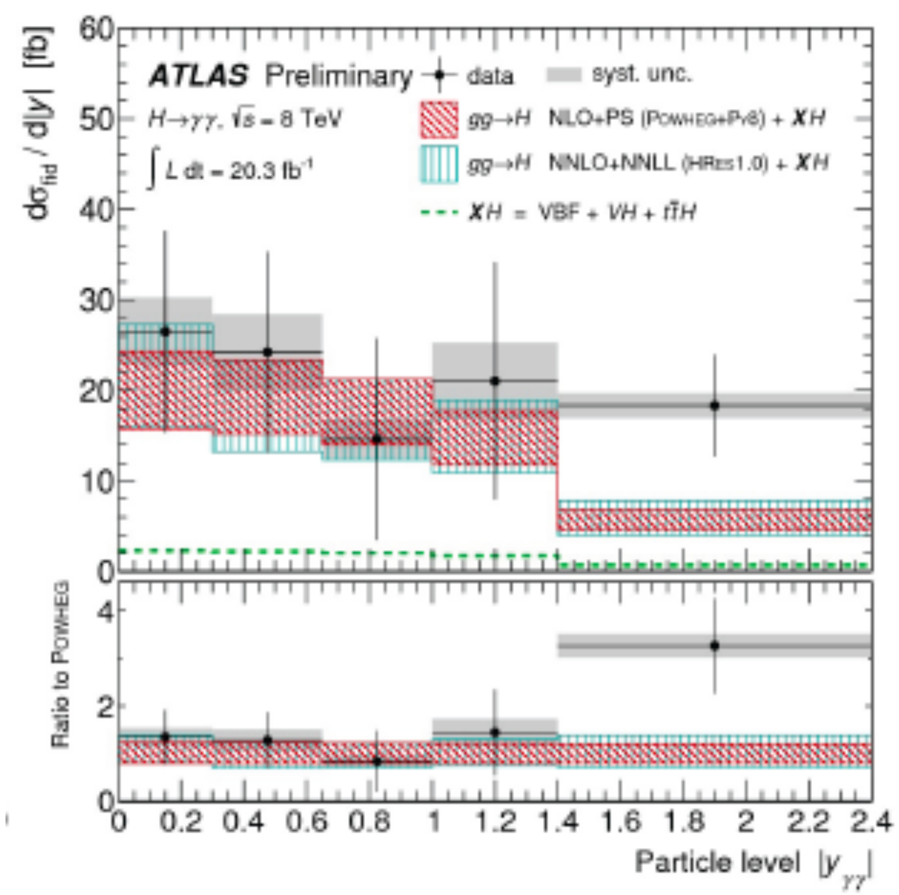
in Δm=± 2.2 GeV (3 bins)
~ 250 signal events above
~ 7000 bkg events

Significance 3.2 (4.2)

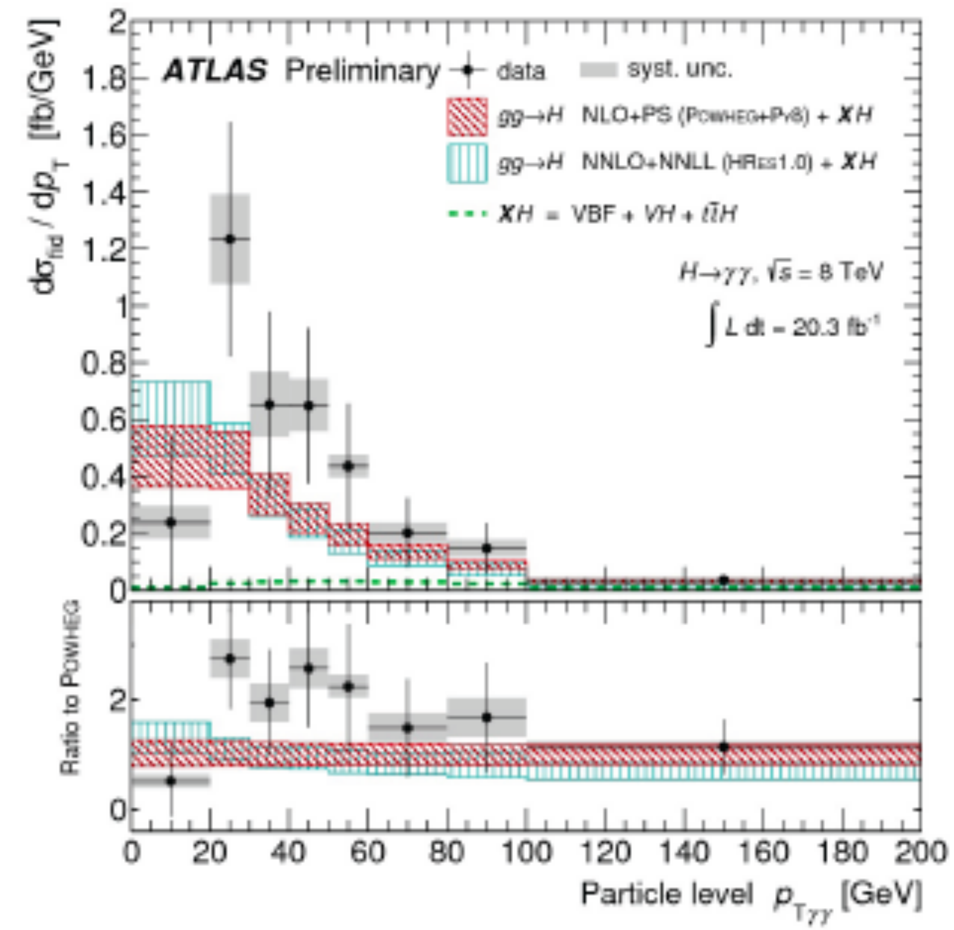
Differential distribution of H-->γγ events



$\eta_{\gamma\gamma}$

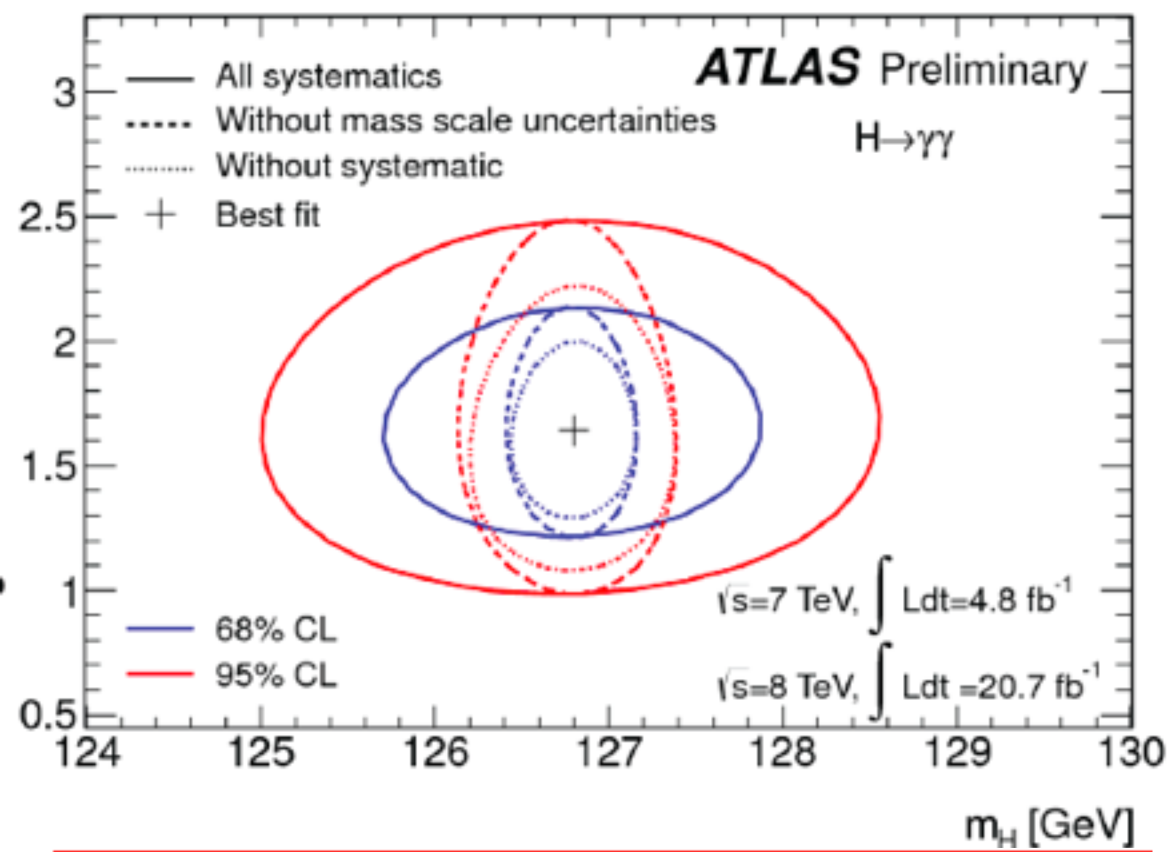


$P_{T\gamma\gamma}$

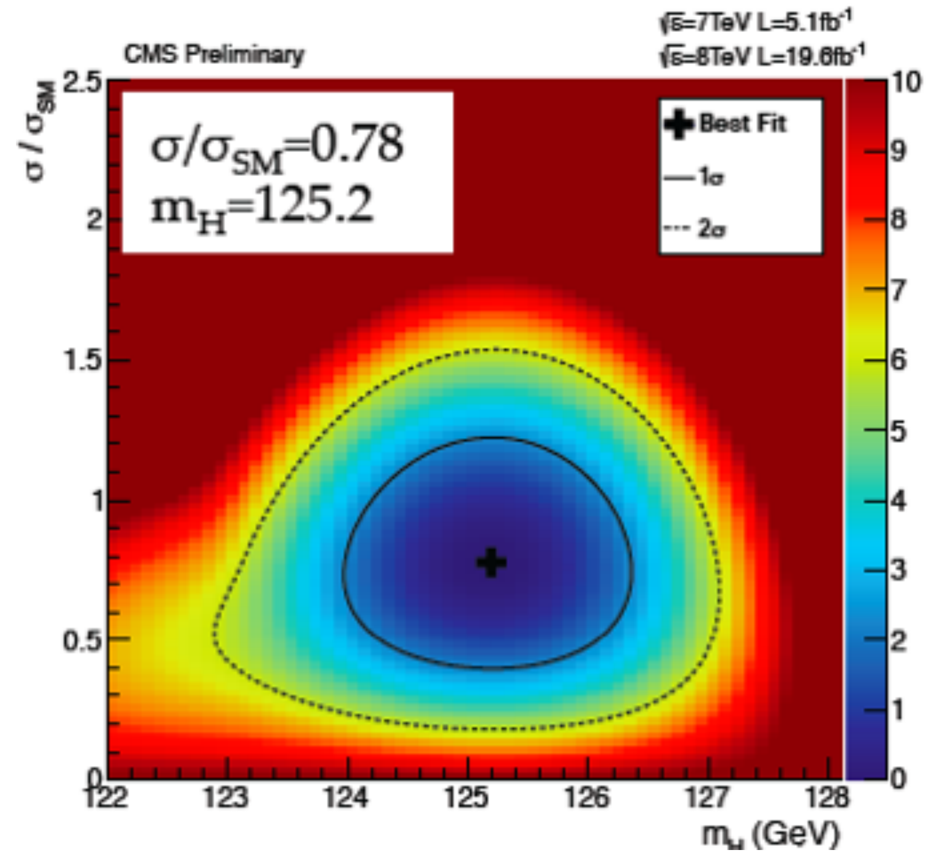


Mass from gamma gamma events

Y.Yamaguchi



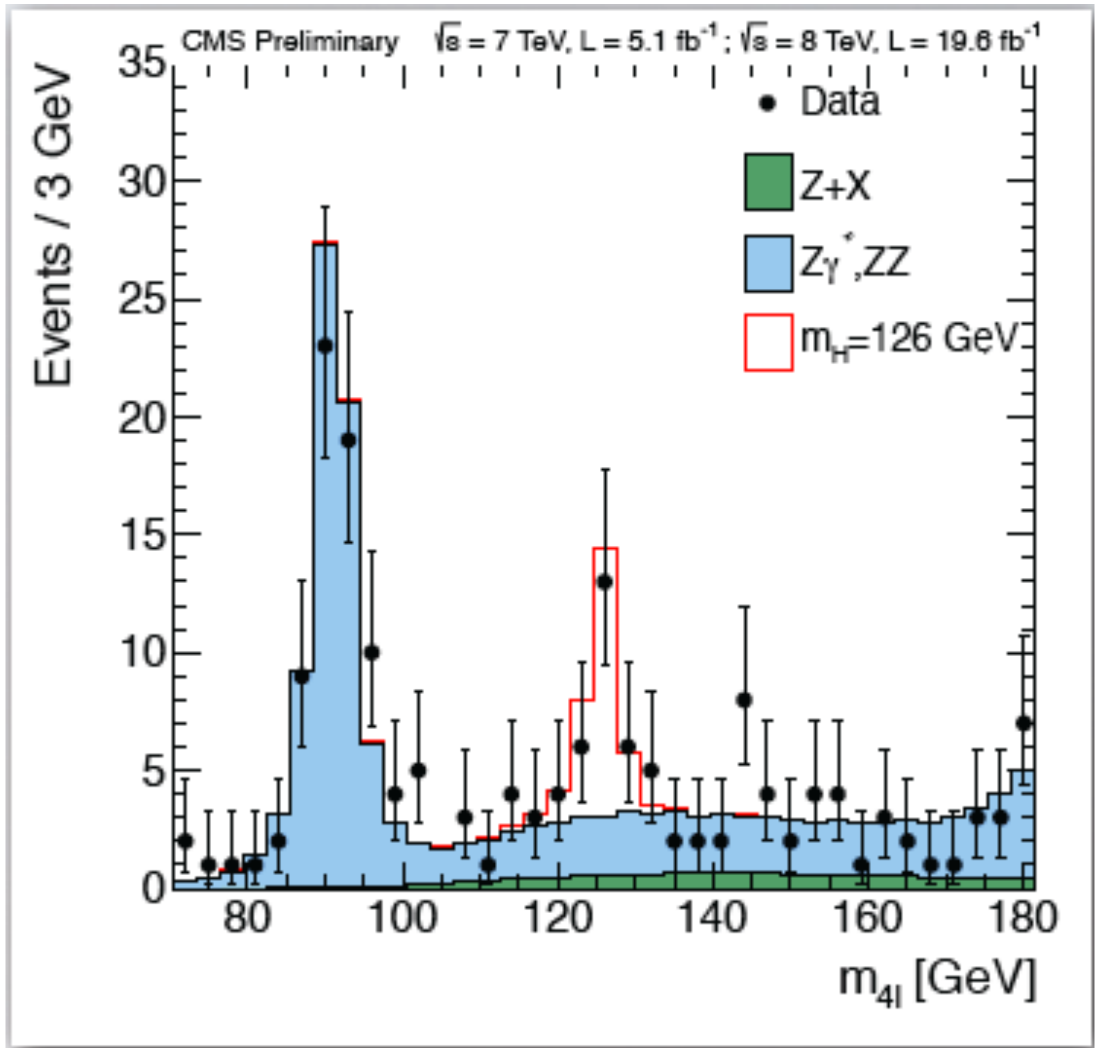
$m_H = 126.8 \pm 0.2_{stat} \pm 0.7_{syst}\ \mathrm{GeV}/c^2$

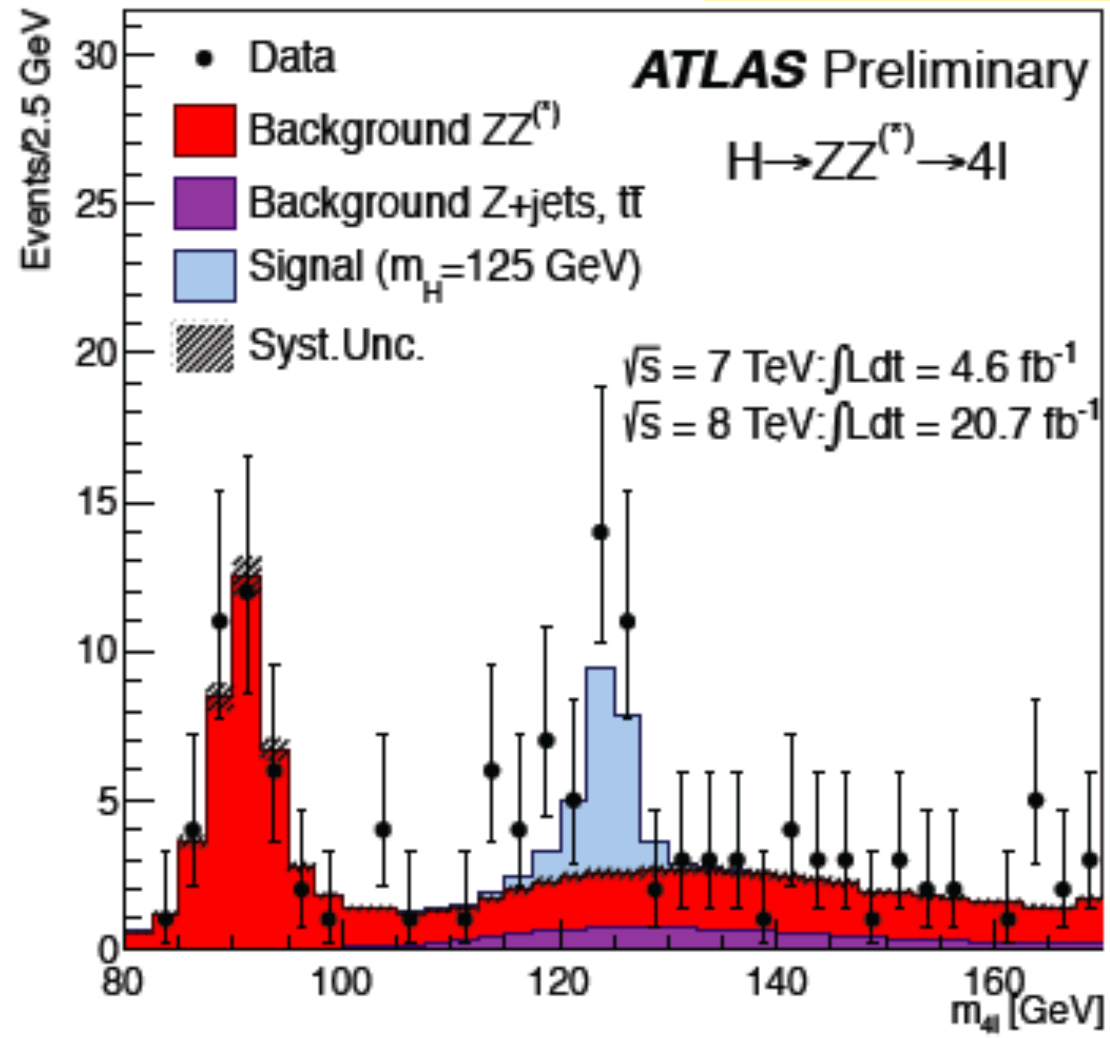


mH = 125.4±0.5(stat)±0.6(syst)

H-->4 leptons

van Eldik - Milenovic





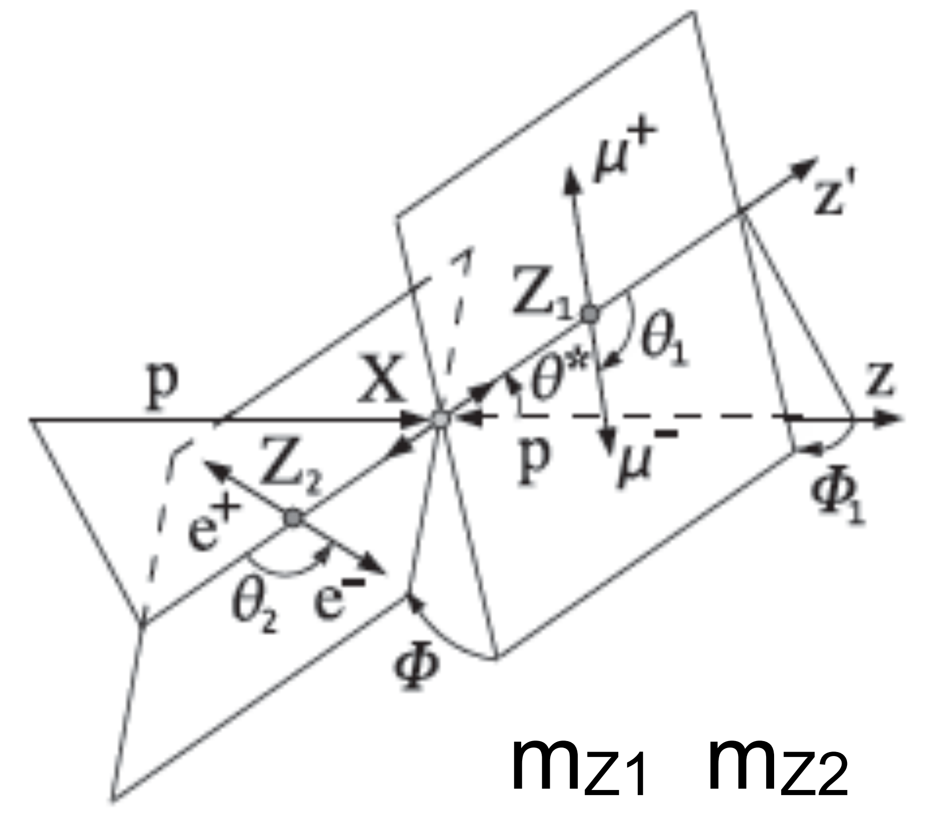
in $\Delta m = \pm$ 4.5 GeV (3 bins)
~ 16 signal events above
~ 9 bkg events

Significance 4.7 (5.6)

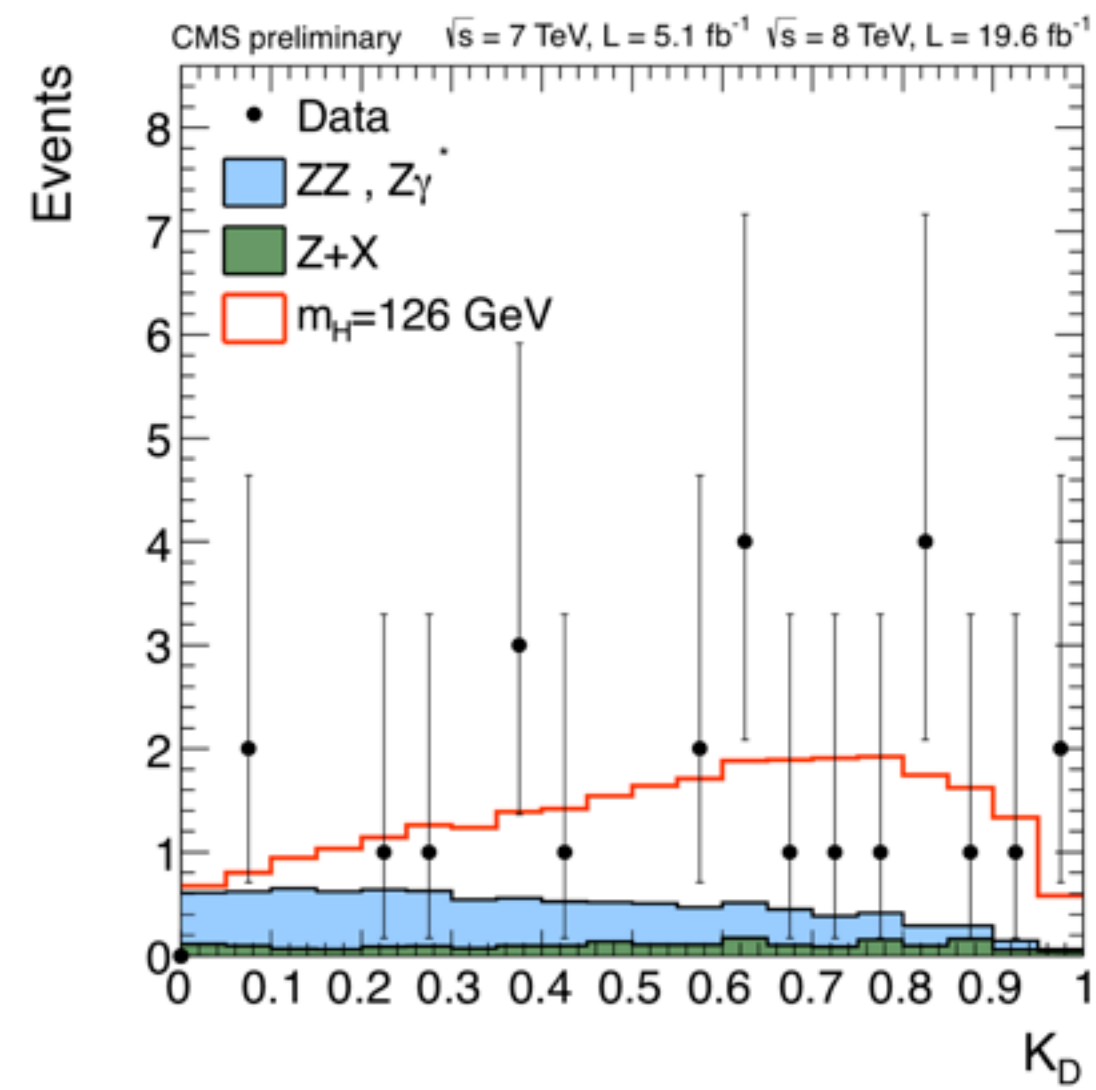
in $\Delta m = \pm$ 3.7 GeV (3 bins)
~ 22 signal events above
~ 8 bkg events

Significance 6.6 (4.4)

H-->4 leptons



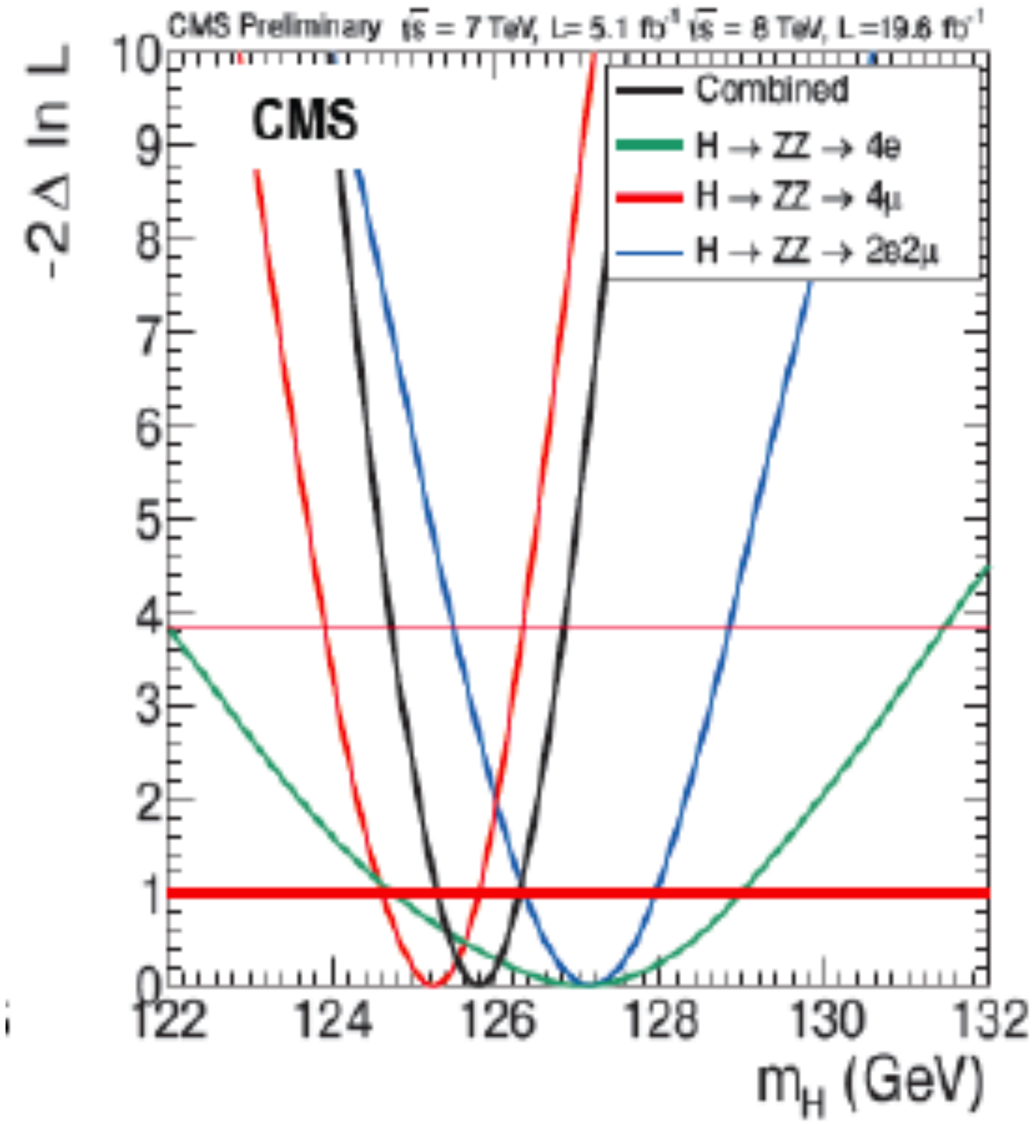
m_{Z1} m_{Z2}

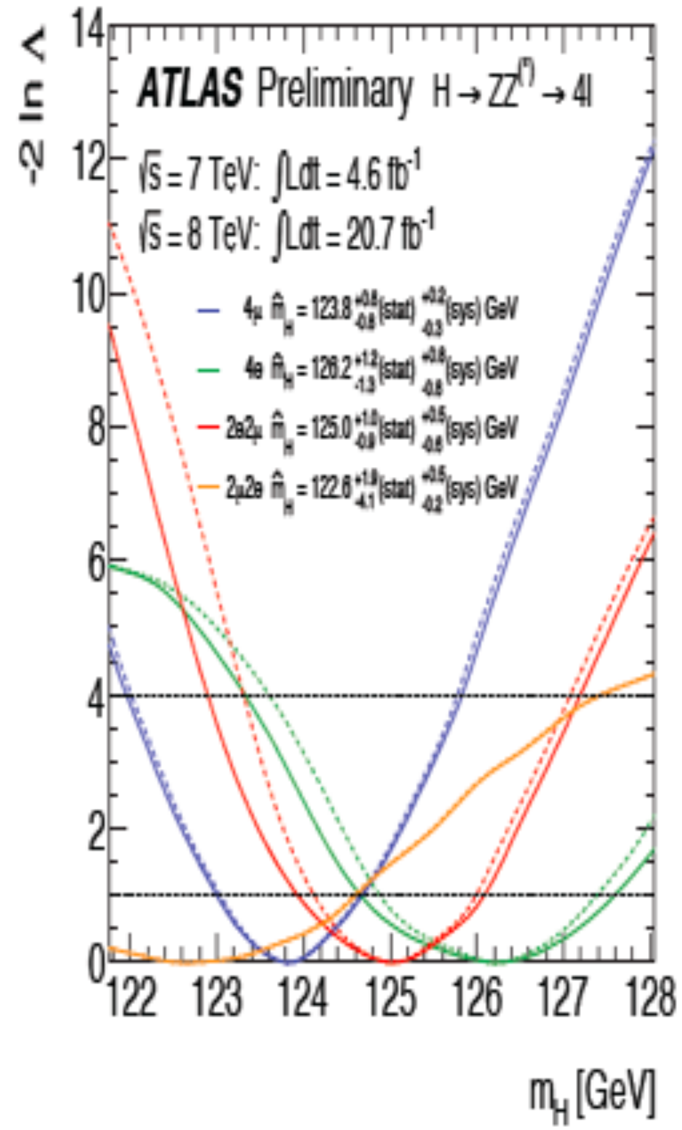


Significance 4.7 (5.6)

Significance 6.6 (6.9)

Mass in 4 lepton channel





m_{4l} = 125.8 ± 0.5$_{stat}$ ± 0.2$_{syst}$ GeV

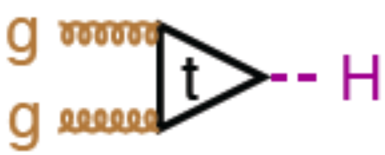
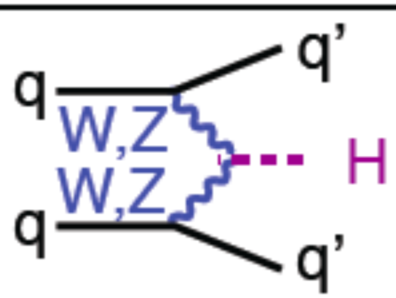
m_H = 124.3 $^{+0.6}_{-0.5}$ (stat) $^{+0.5}_{-0.3}$ (syst) GeV

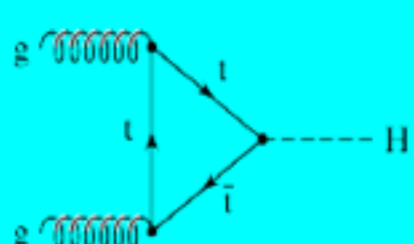
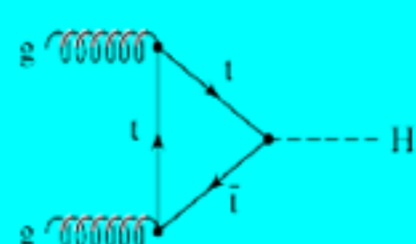
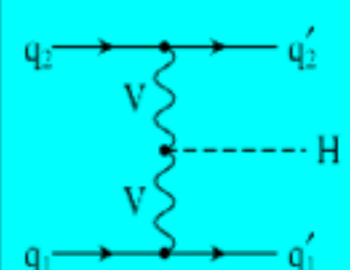
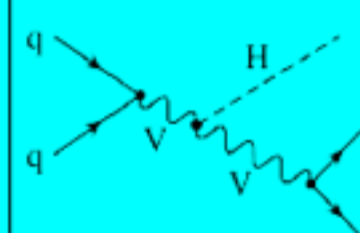
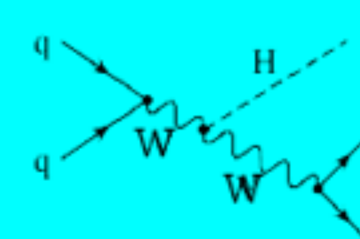
Higgs Mass

Collaboration	channel	mass (GeV)
ATLAS	$\gamma\gamma$	$126.8 \pm 0.2 \pm 0.7$
CMS	$\gamma\gamma$	$125.4 \pm 0.5 \pm 0.6$
ATLAS	4ℓ	$124.3^{+0.6+0.5}_{-0.5-0.3}$
CMS	4ℓ	$125.8 \pm 0.5 \pm 0.2$
ATLAS	combination	$125.5 \pm 0.2^{+0.5}_{-0.6}$
CMS	combination	$125.7 \pm 0.3 \pm 0.3$

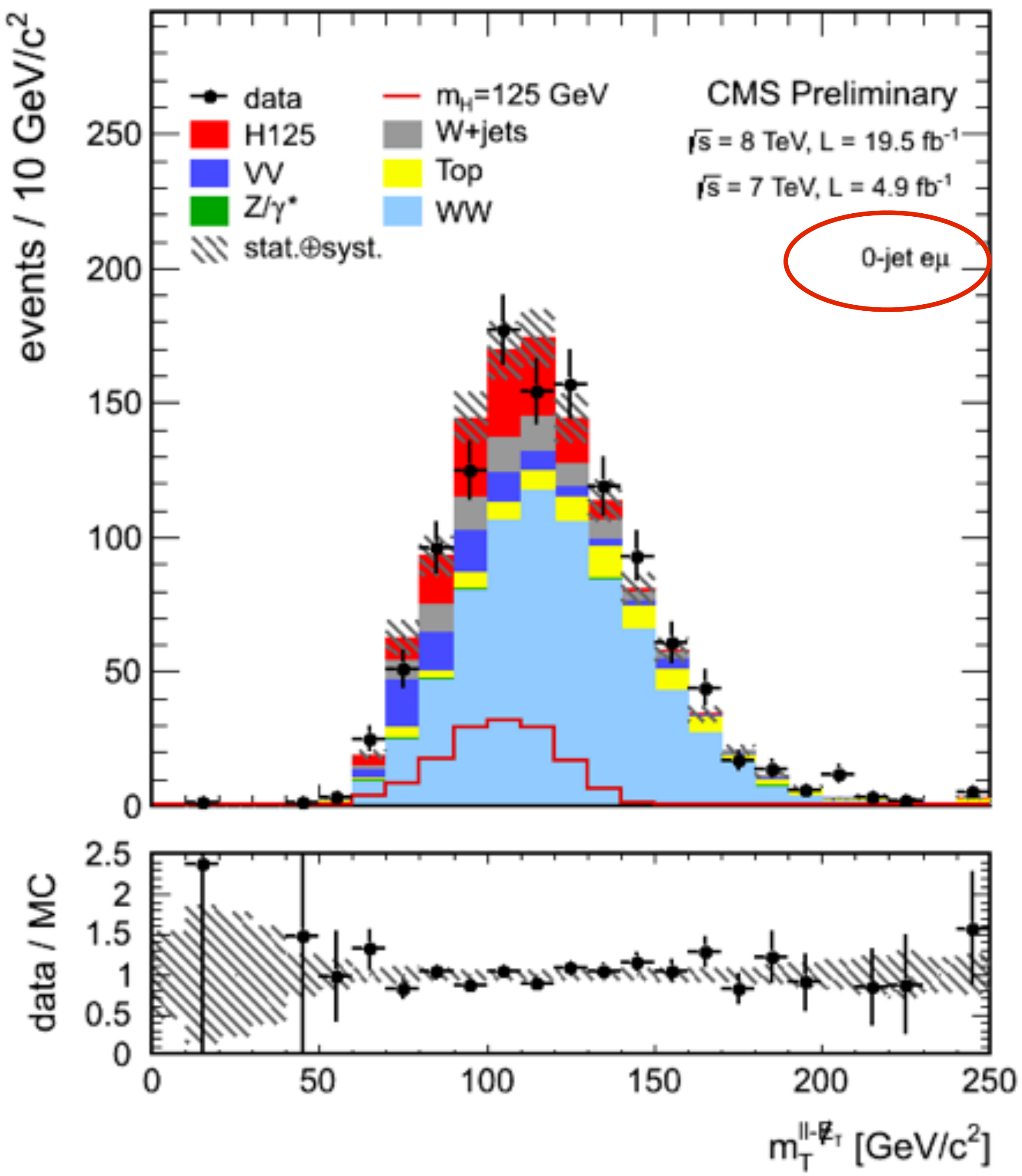
H-->WW-->llvv

Min Hong - Massironi

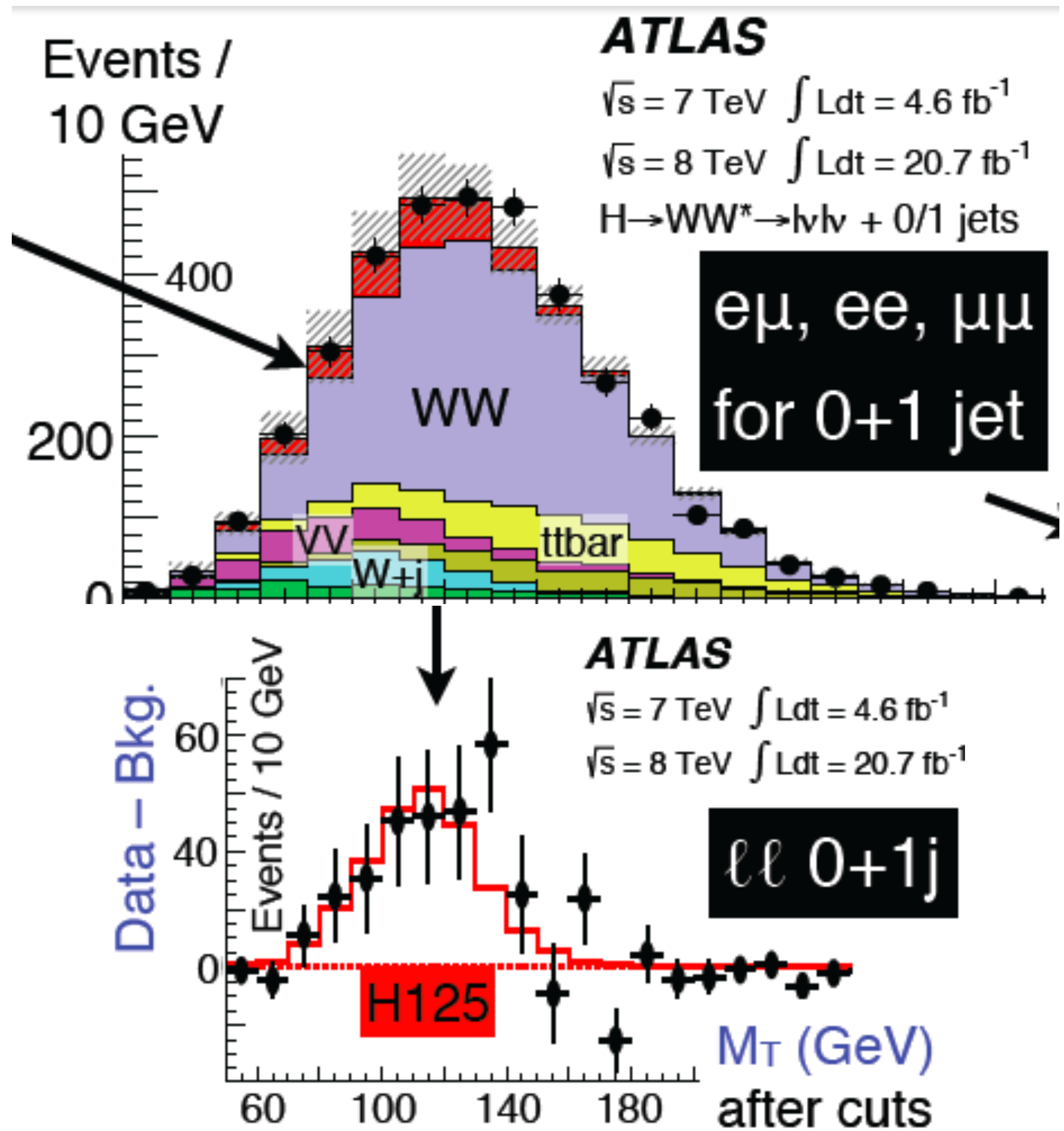
	σ (fb) [8] M_H=125	# of H 20.7fb^{-1}	# $\to WW^*$ BR = 0.21	# $\to \ell\nu\ell\nu$ BR = 0.04	After cuts This analysis
	19,500	400,000	92,000	3,700	137 ATLAS
	1,580	33,000	6,900	280	11

signature	0 jet	1 jet	2 jet		3 leptons
	ggH	mainly ggH	ggH and VBF	ggH and VH	WH
					
bkg	WW & Wjets	WW and Top	Top	Top	WZ

H-->WW-->llvv



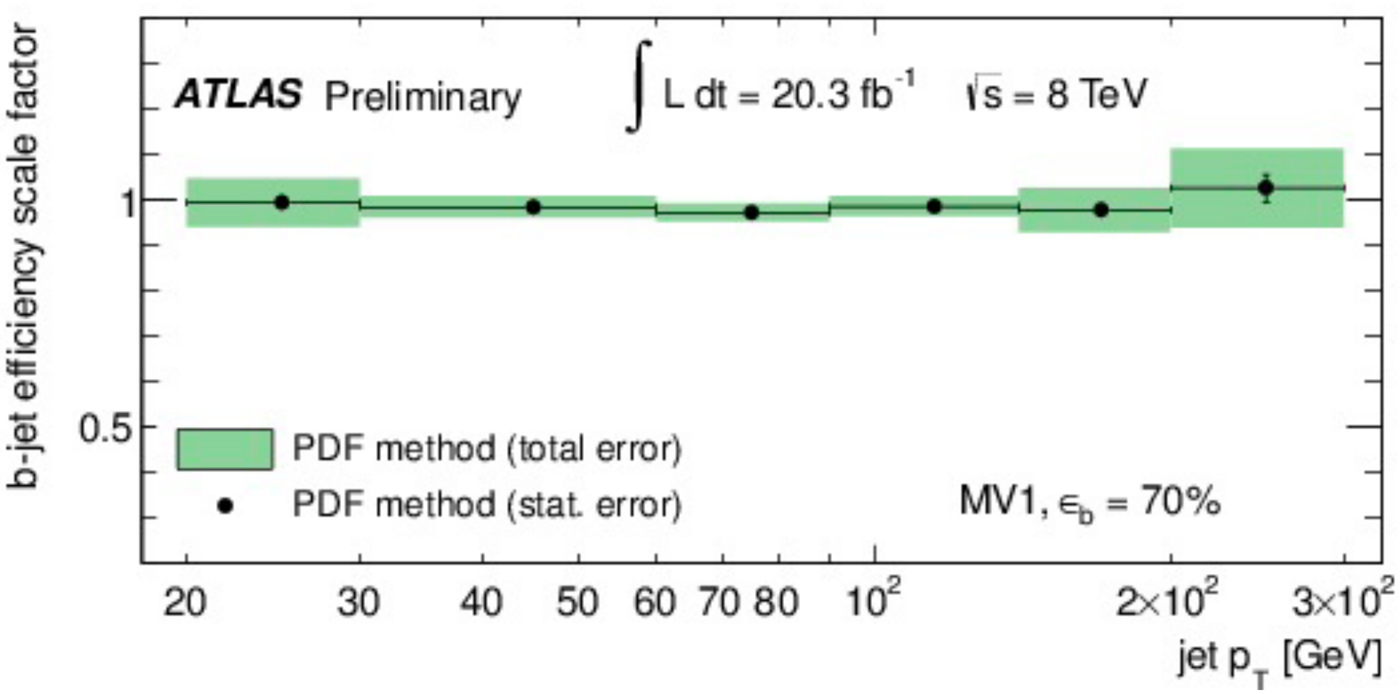
Significance 4.0 (5.1) σ
all channels included

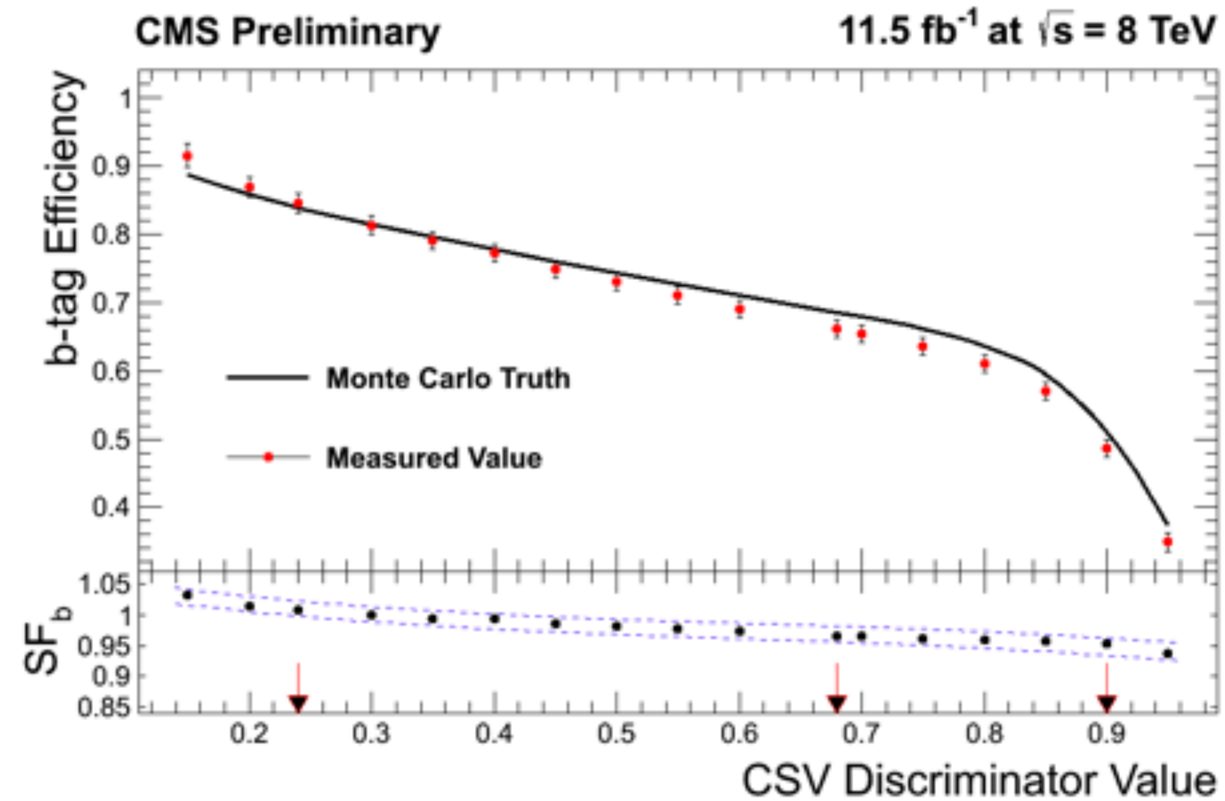


Significance 3.8 (3.8) σ

~ 200 signal events above
~ 1200 bkg events

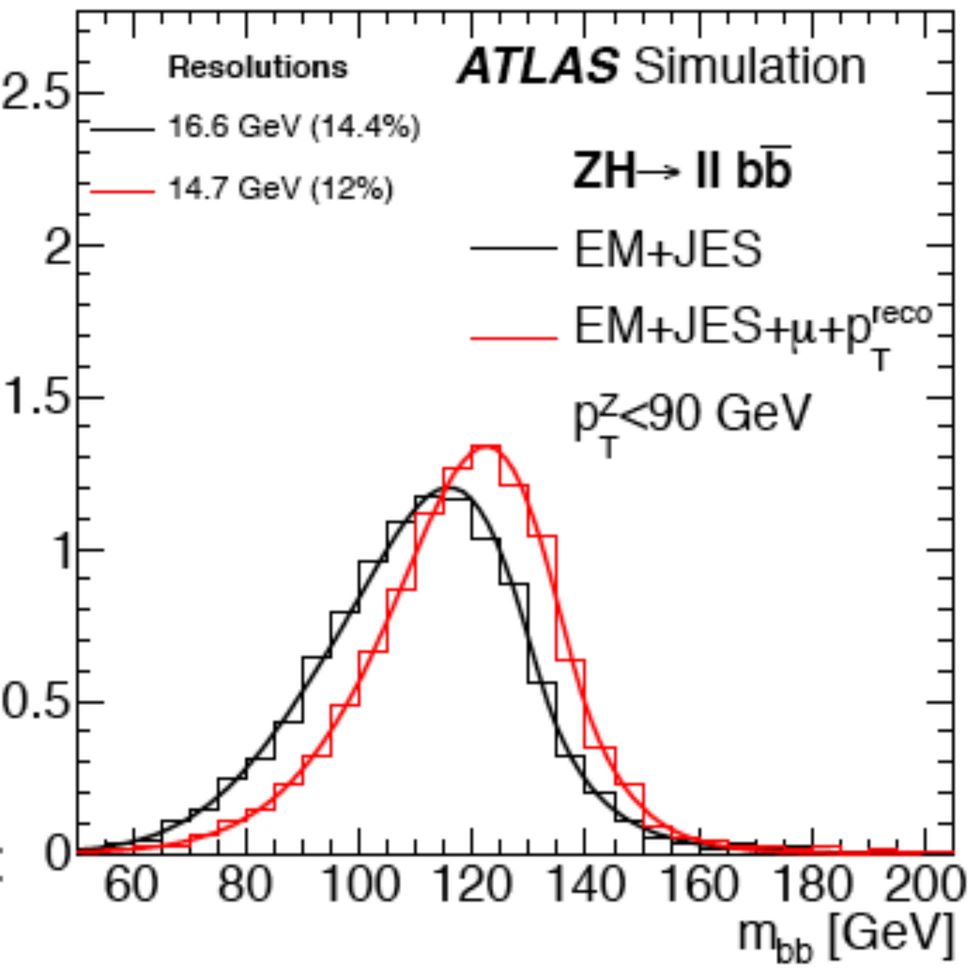
b - tagging

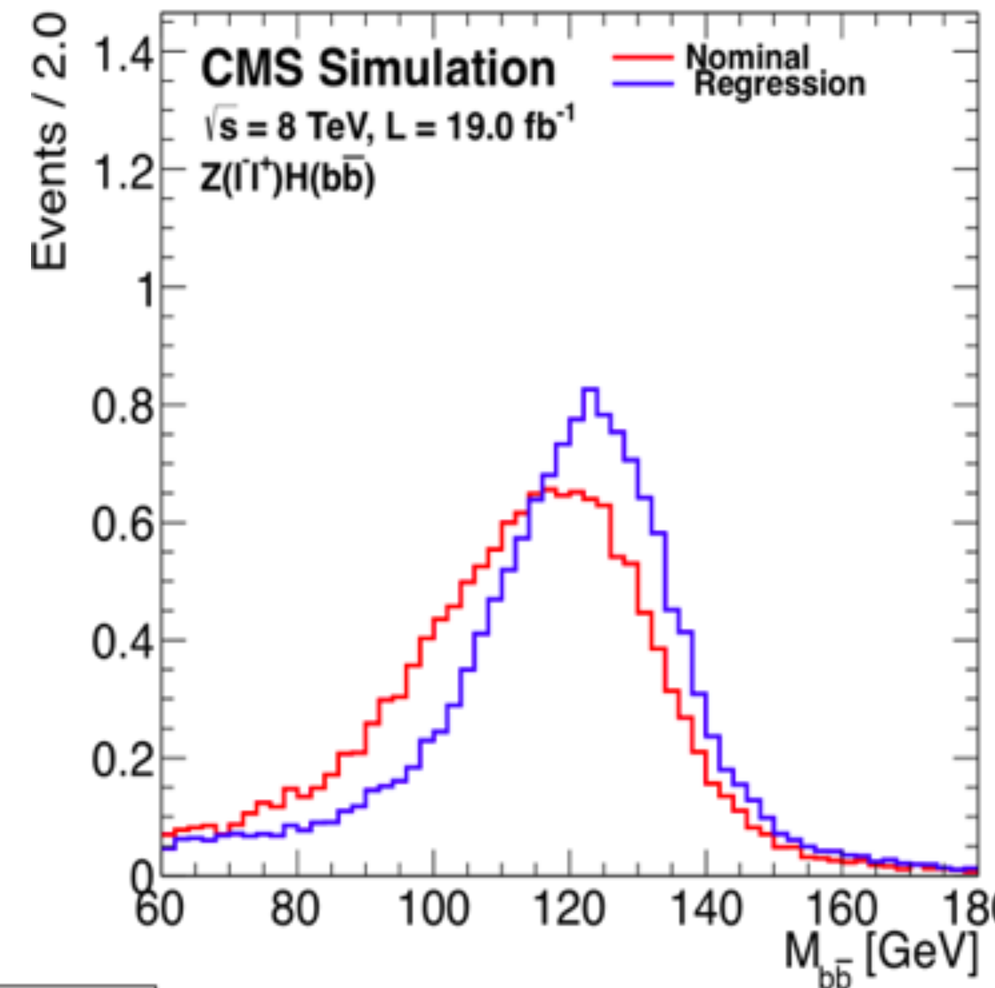


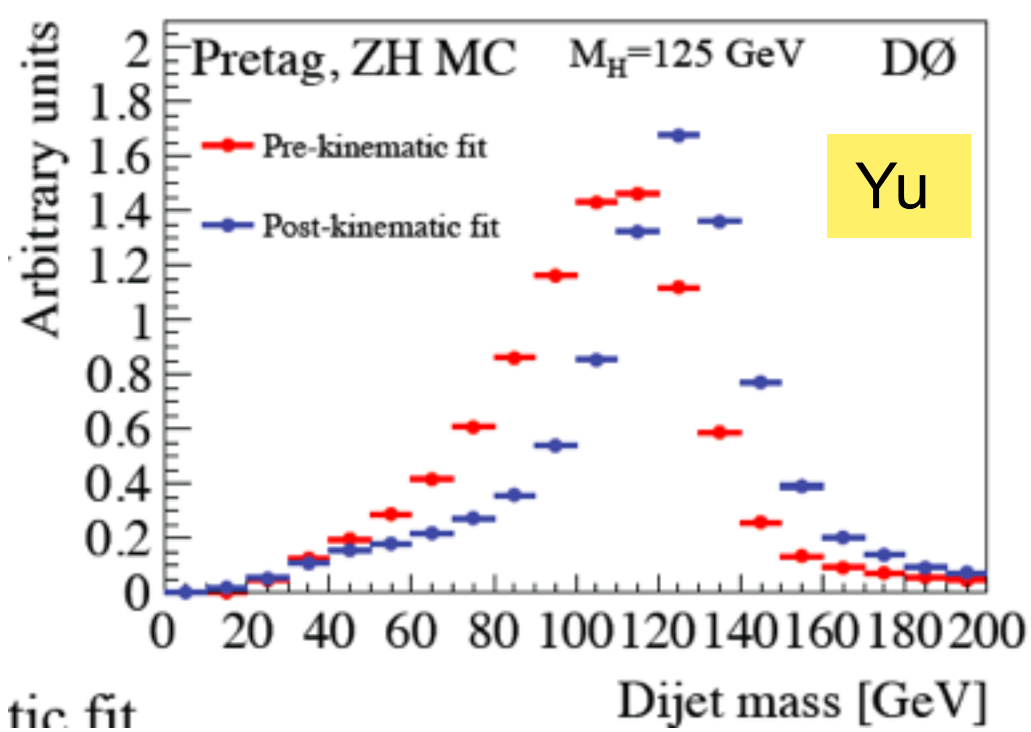


	ε_b		ε^{udsg}
ATLAS	70%	vs	0.6%
CDF/D0	60%	vs	1.0%
CMS	70%	vs	1.0%

Jet-Jet mass resolution



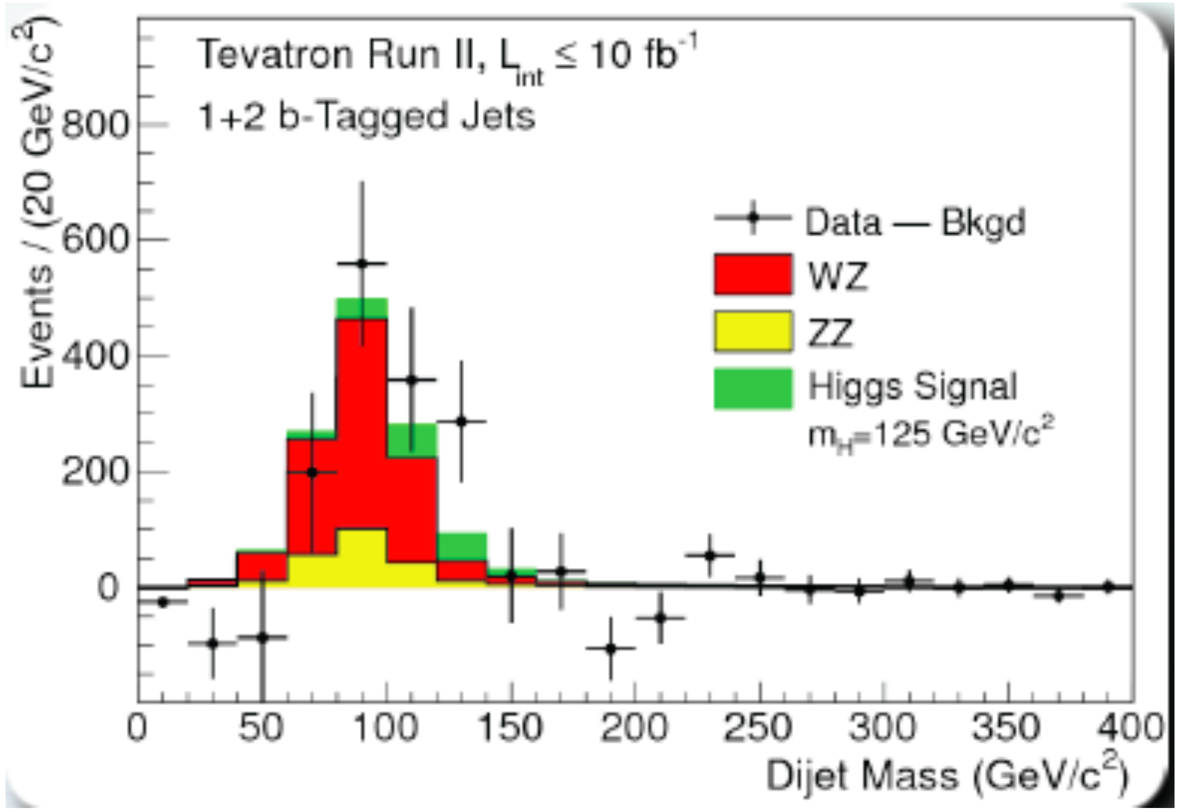




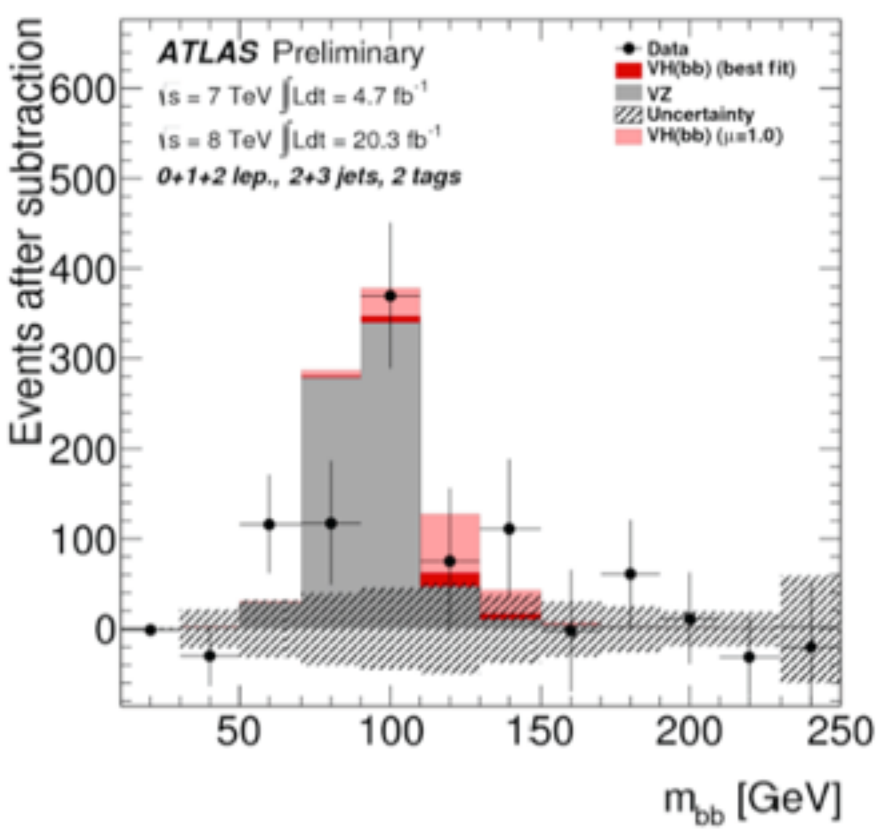
tic fit

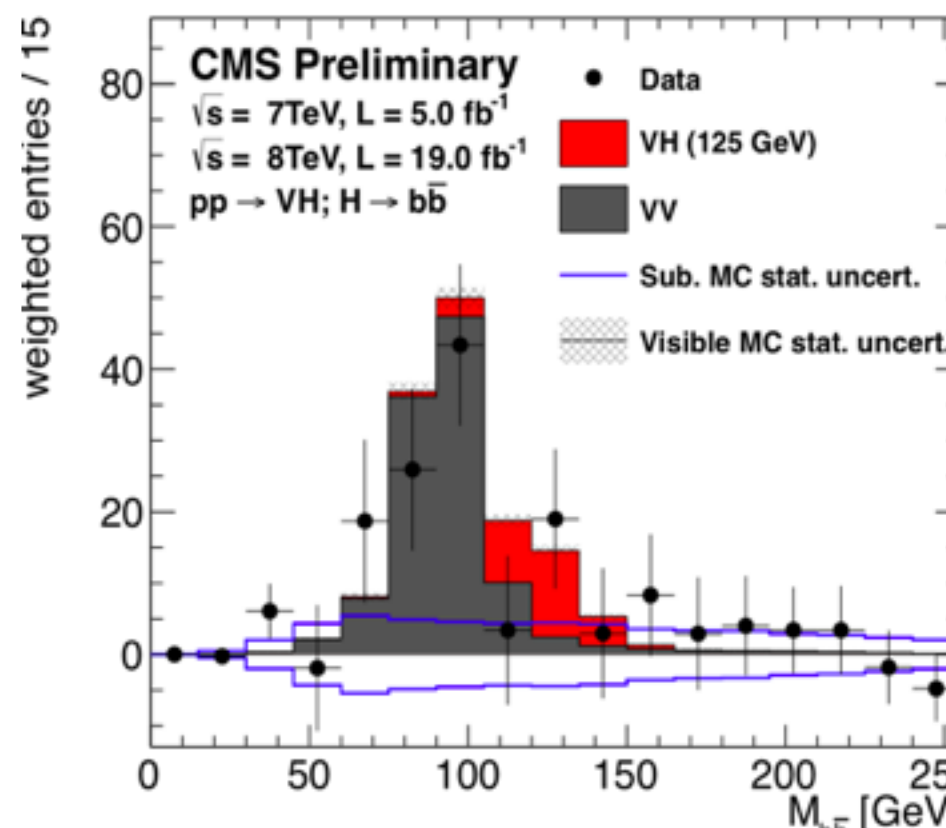
VH-->Vbb :Calibration for VH-->Vbb

Lee - Zenz - Shalhout
Ochoa- Eller

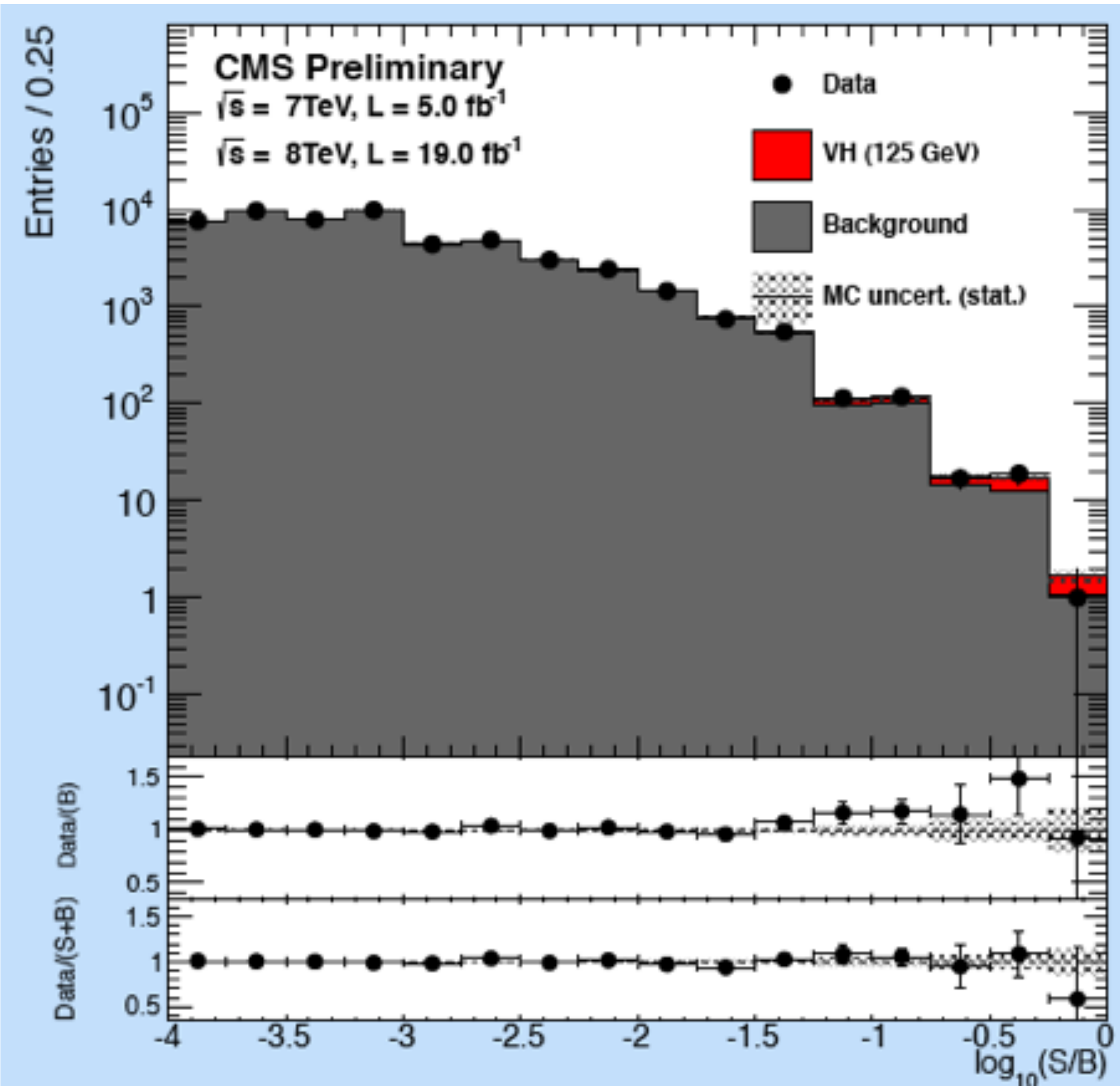


ev/ 20 GeV

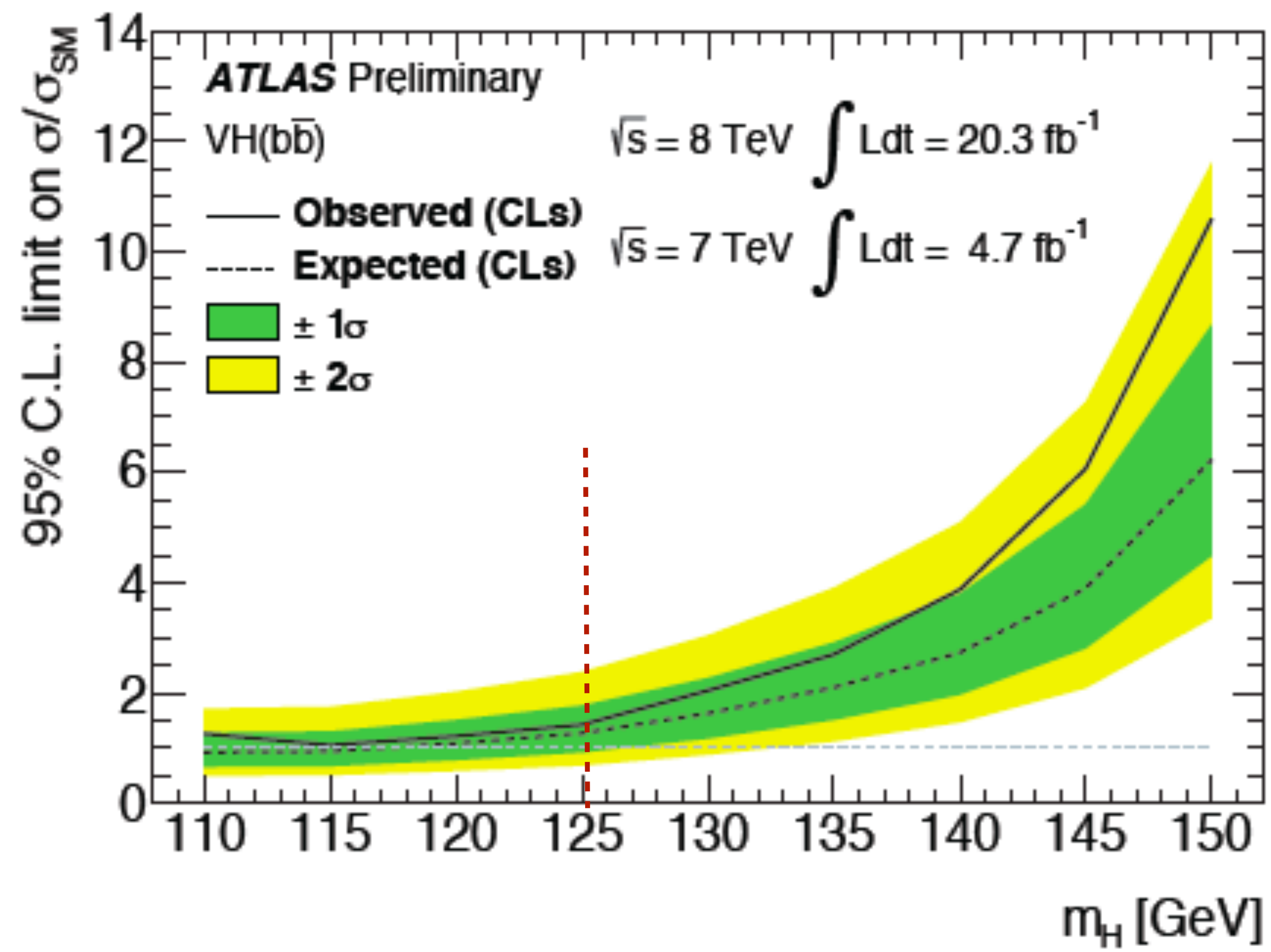




VH-->Vbb

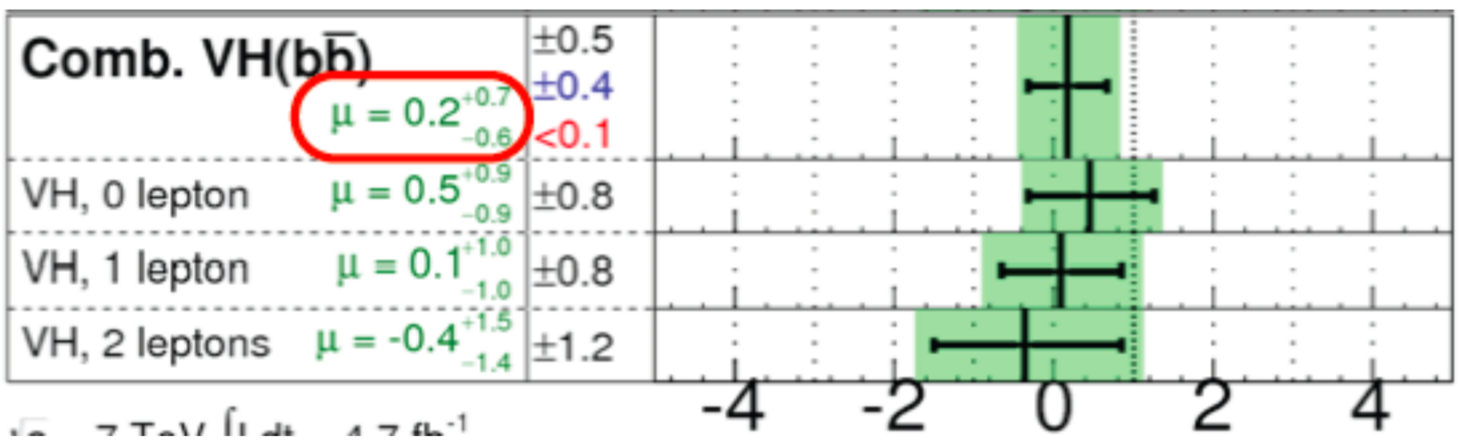


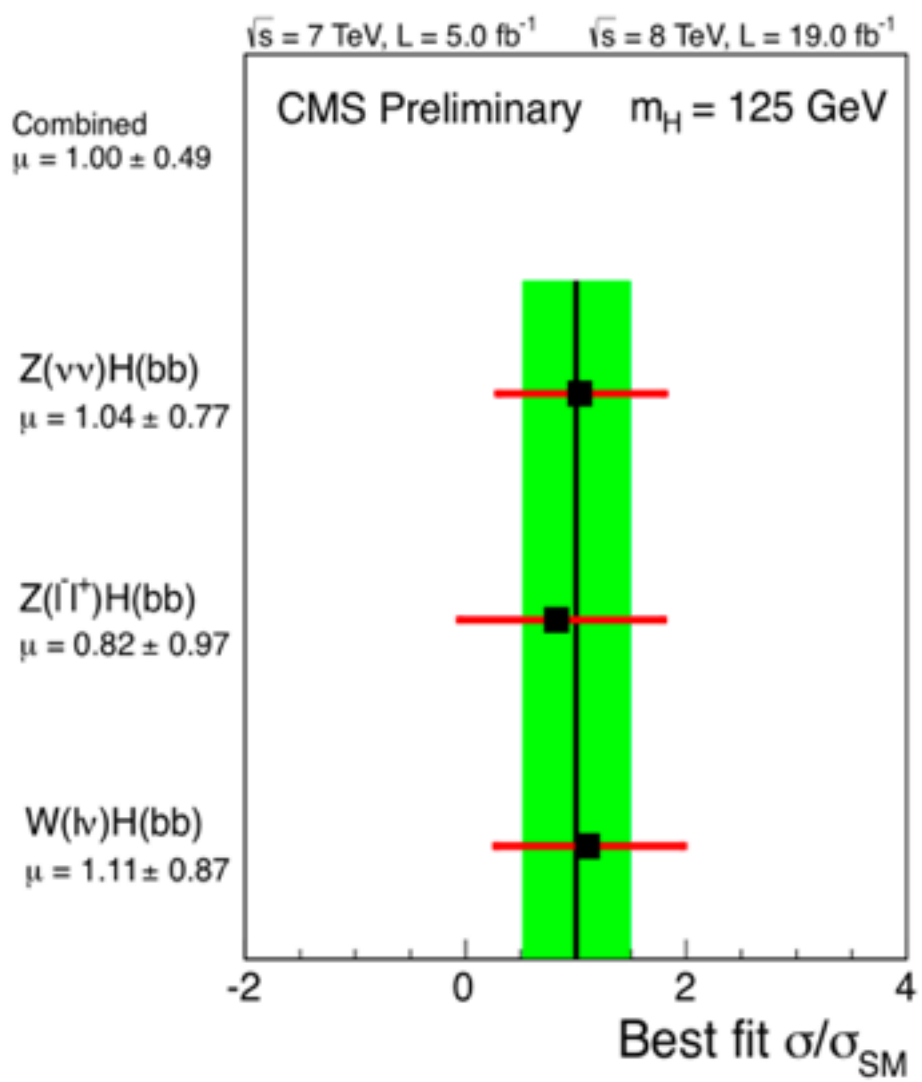
CMS Preliminary
$\sqrt{s}$ = 7TeV, L = 5.0 fb^{-1}
$\sqrt{s}$ = 8TeV, L = 19.0 fb^{-1}
Data
VH (125 GeV)
Background
MC uncert. (stat.)
Entries / 0.25
Data/(B)
Data/(S+B)
$\log_{10}$(S/B)



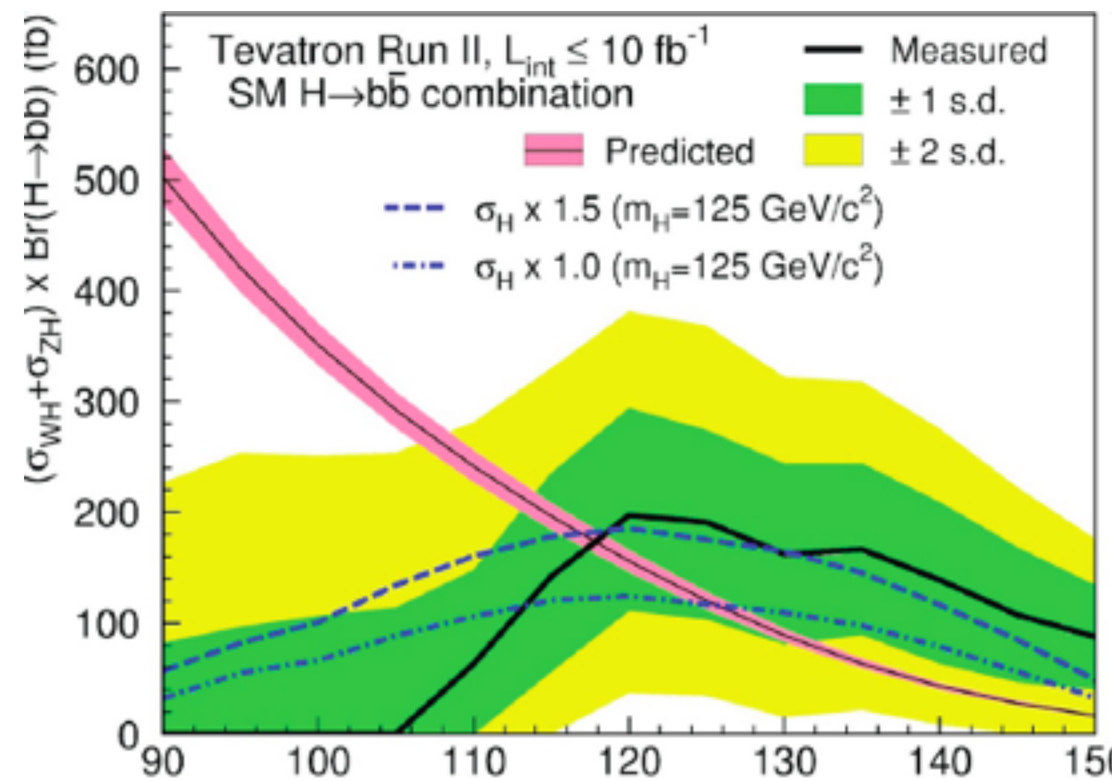
ATLAS Preliminary
VH($b\bar{b}$)
$\sqrt{s}$ = 8 TeV $\int$Ldt = 20.3 fb^{-1}
$\sqrt{s}$ = 7 TeV $\int$Ldt = 4.7 fb^{-1}
Observed (CLs)
Expected (CLs)
± 1σ
± 2σ
95% C.L. limit on σ/σ_{SM}
m_H [GeV]

VH-->Vbb





Significance 2.1 σ



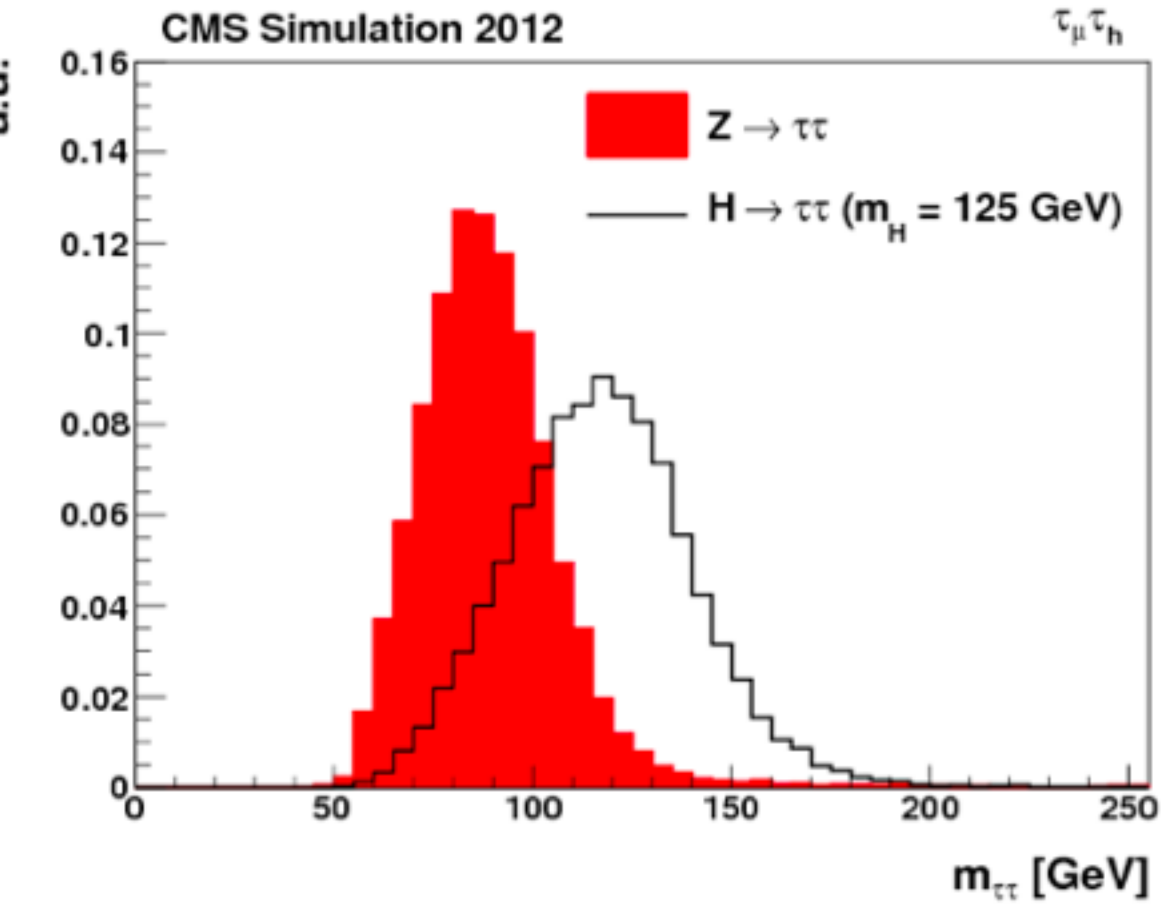
$$(\sigma \times B)/\ SM = 1.59^{+0.69}_{-0.72}$$

@ m_H=125 GeV

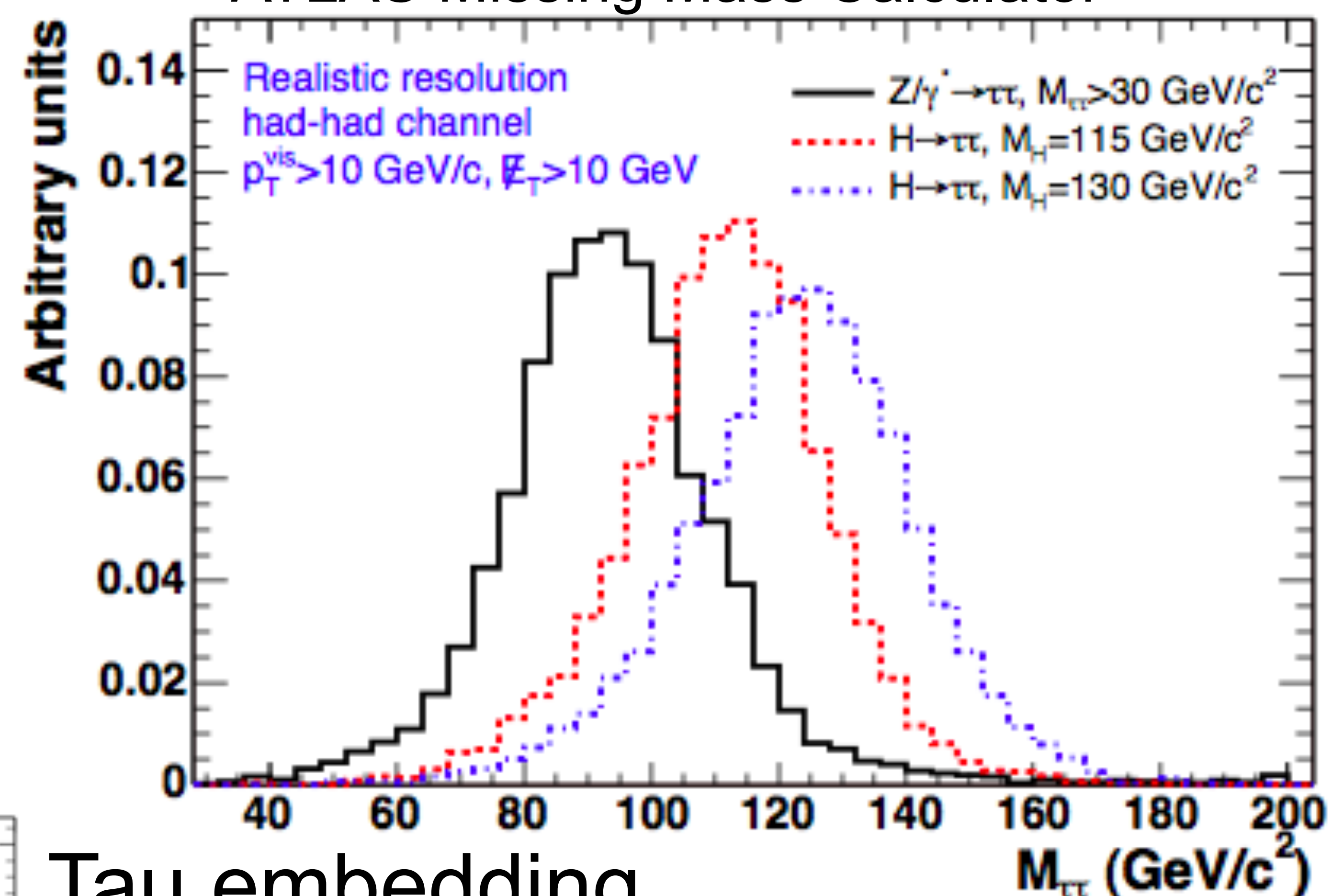
Significance: No official number , somewhat <3 σ

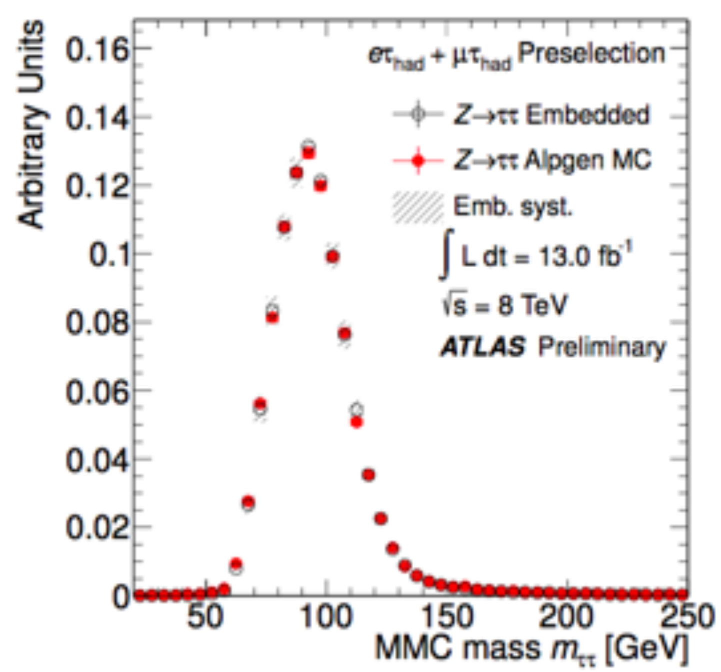
H-->TauTau

Bianchini - Tanasijczuk



ATLAS Missing Mass Calculator

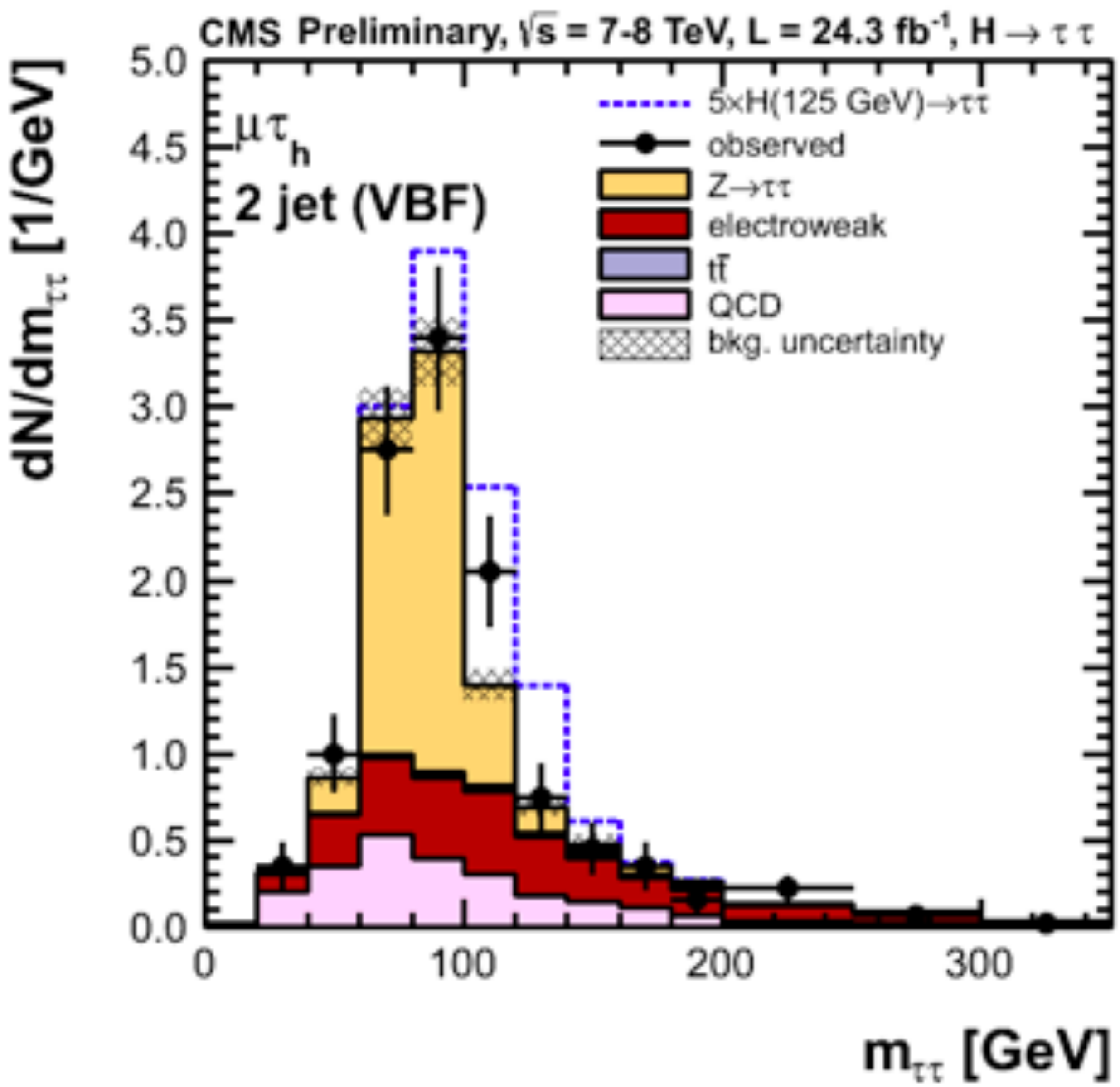


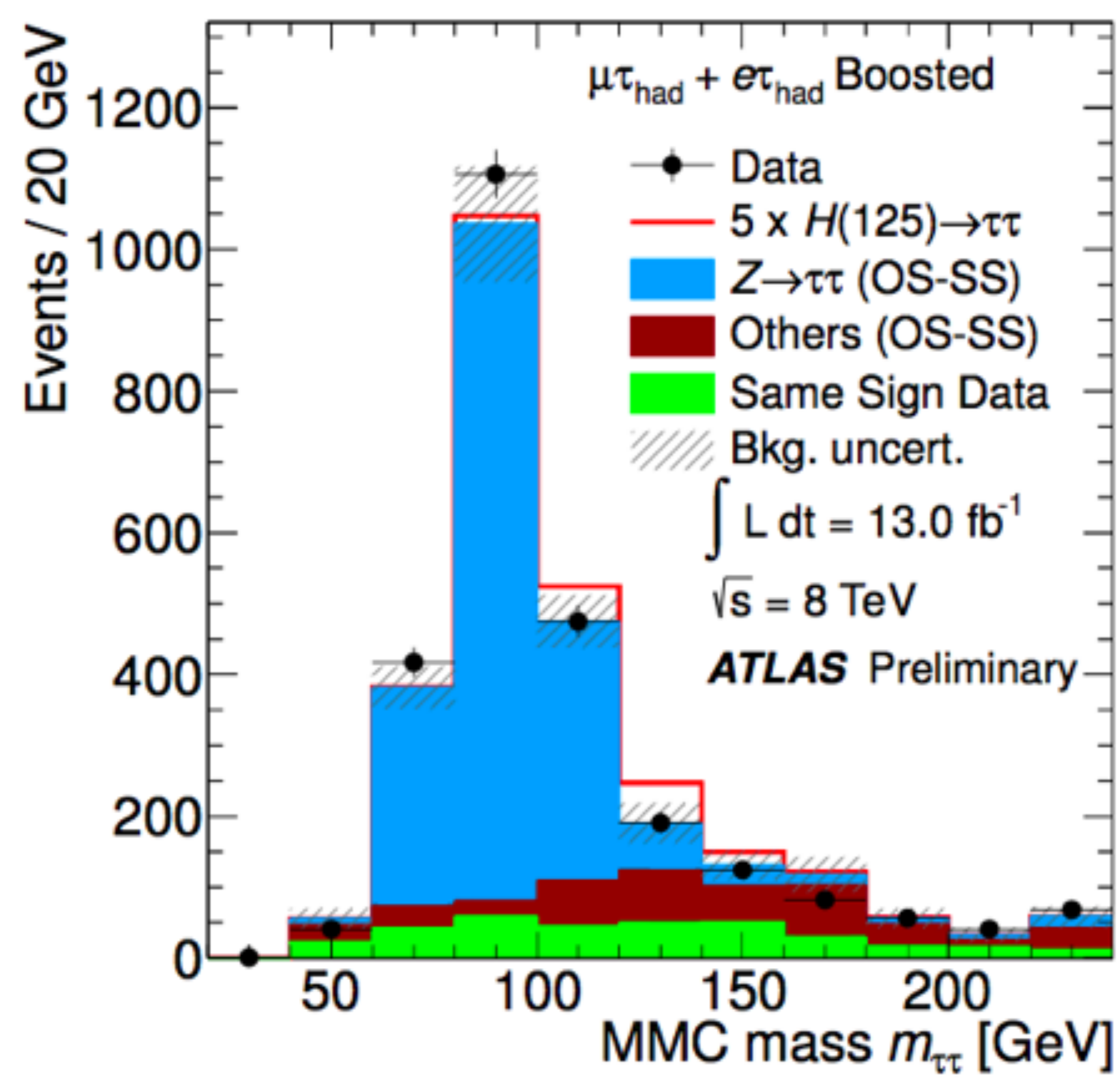


Tau embedding

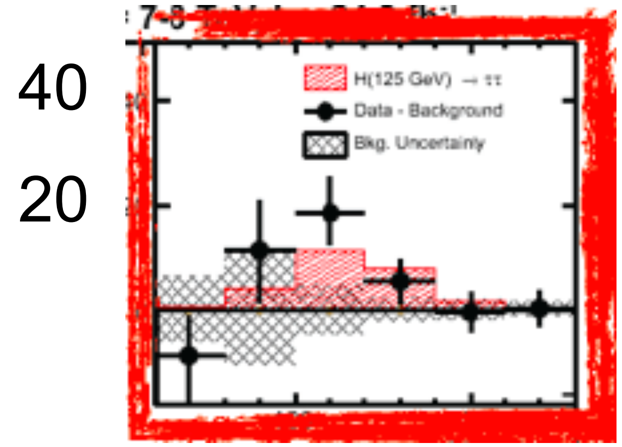
H-->TauTau

Data compared with 5 x expected signal



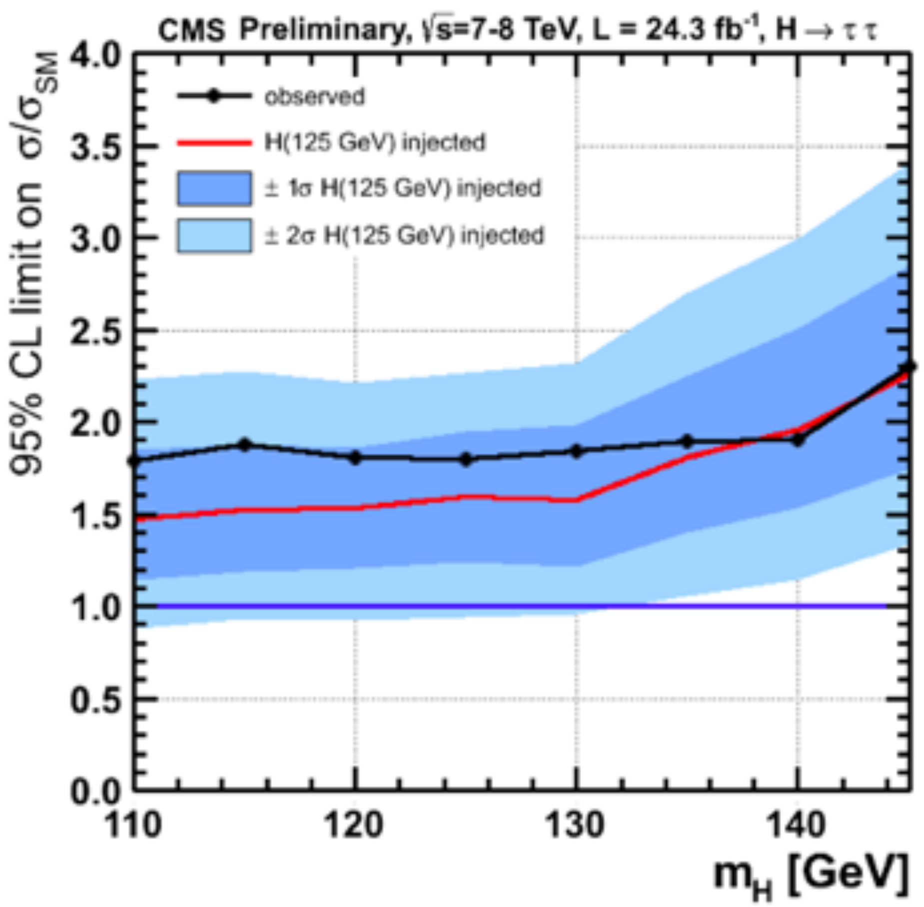


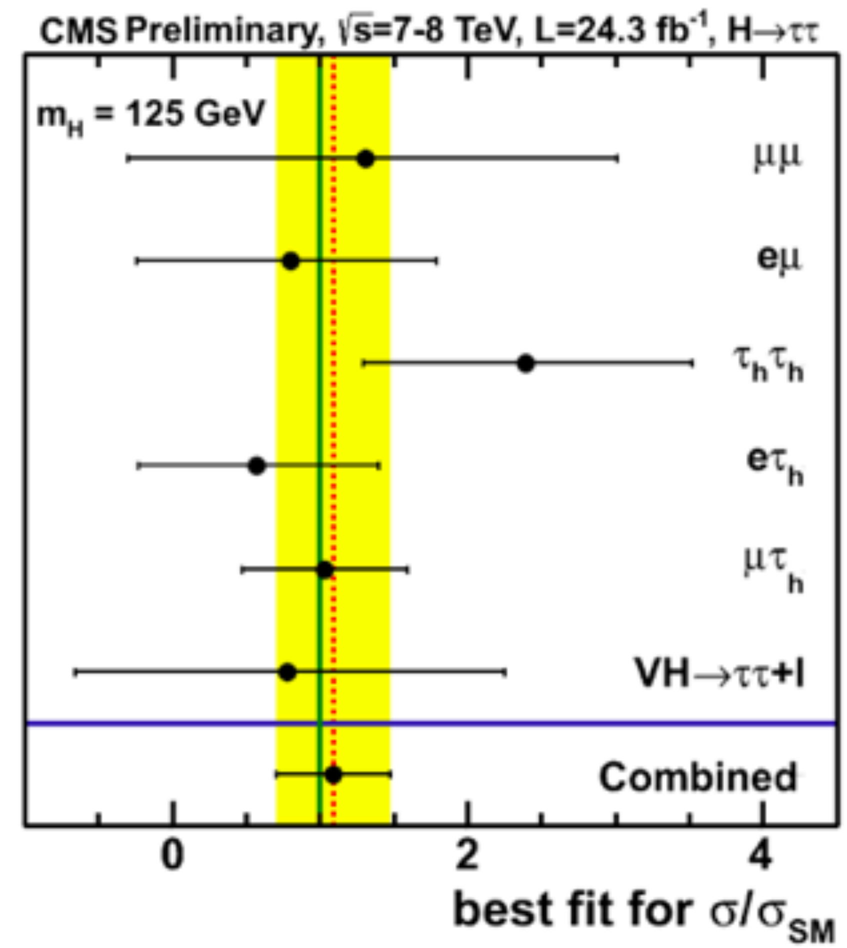
H-->TauTau



~ 20 H-->tau tau

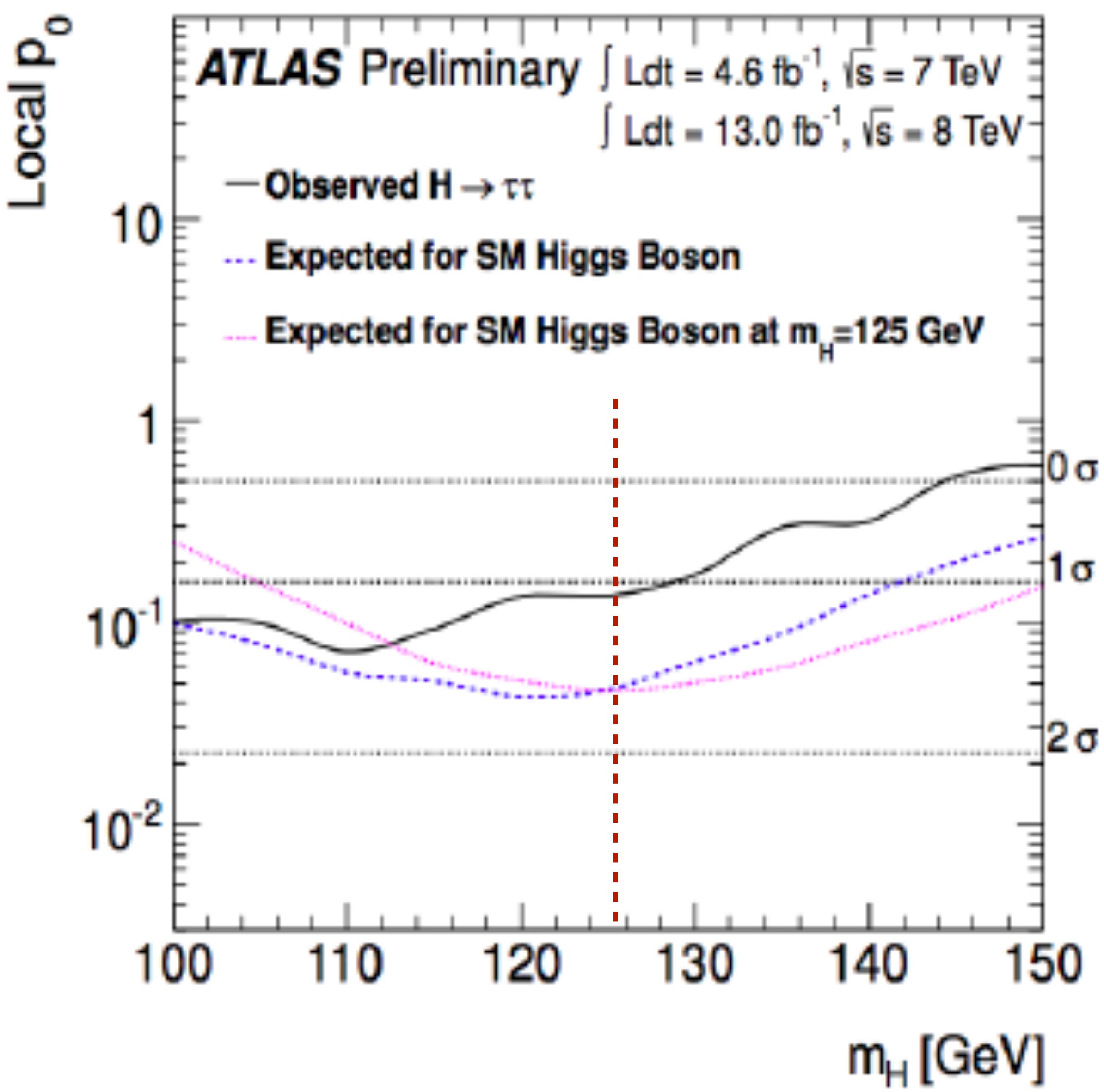
Significance
2.8 σ

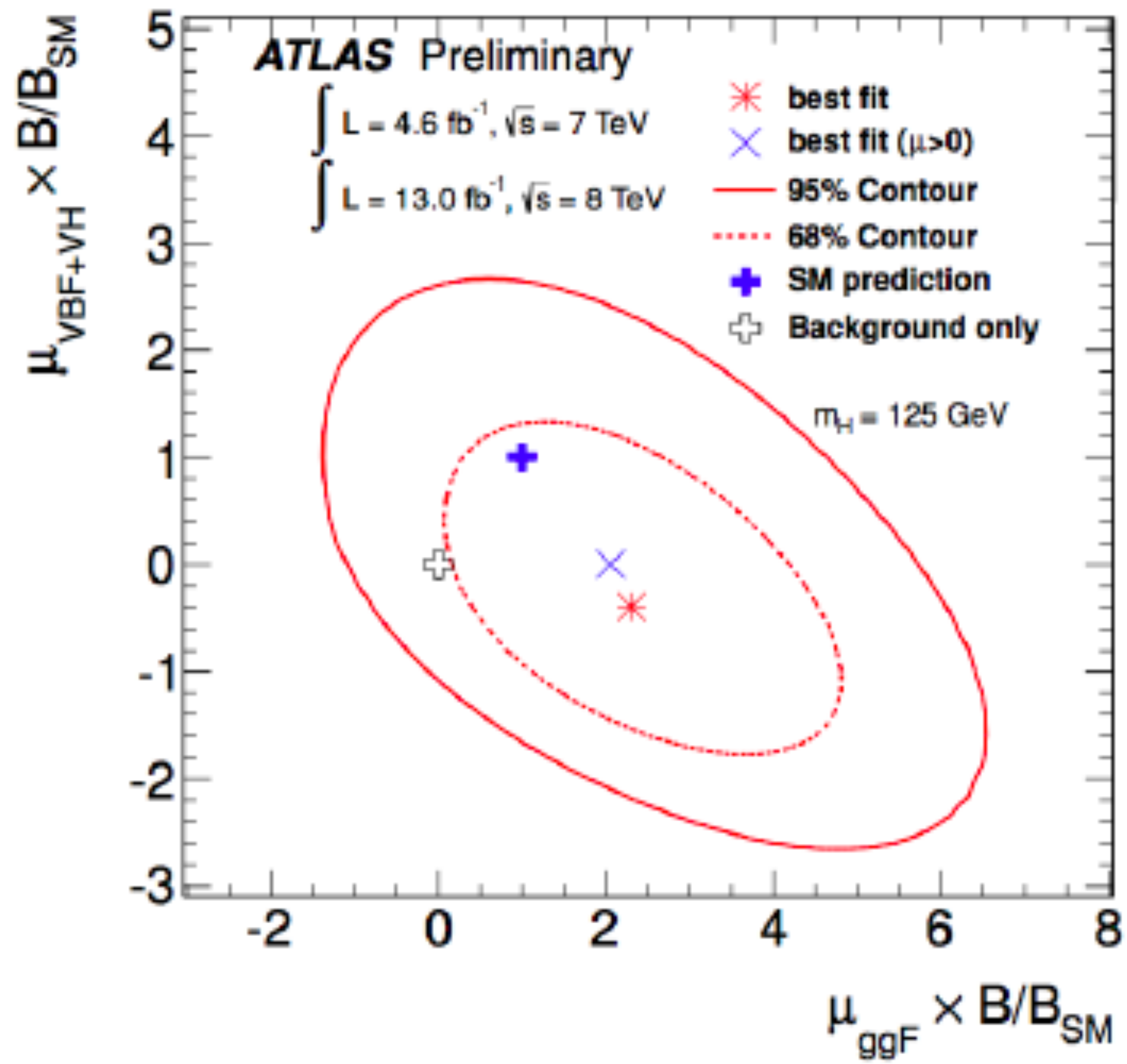




$\mu(\mathrm{SM}) = 1.1 \pm 0.4$ at $M_H = 125$ GeV

H-->TauTau

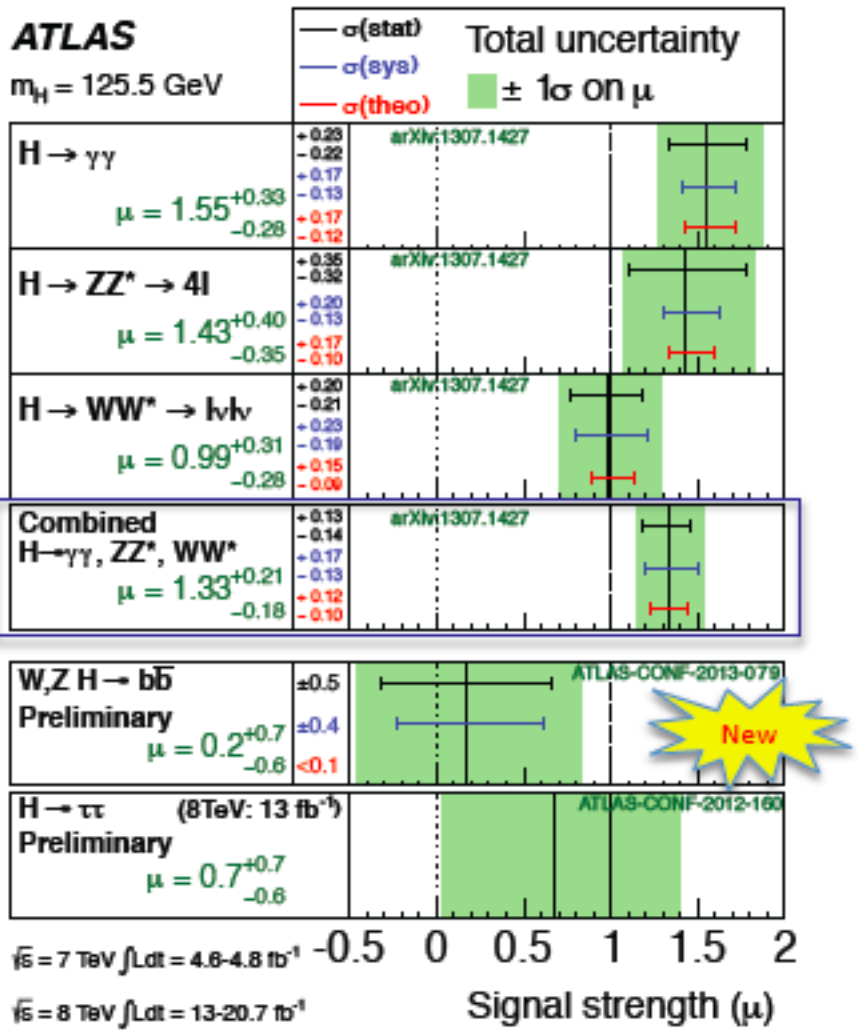


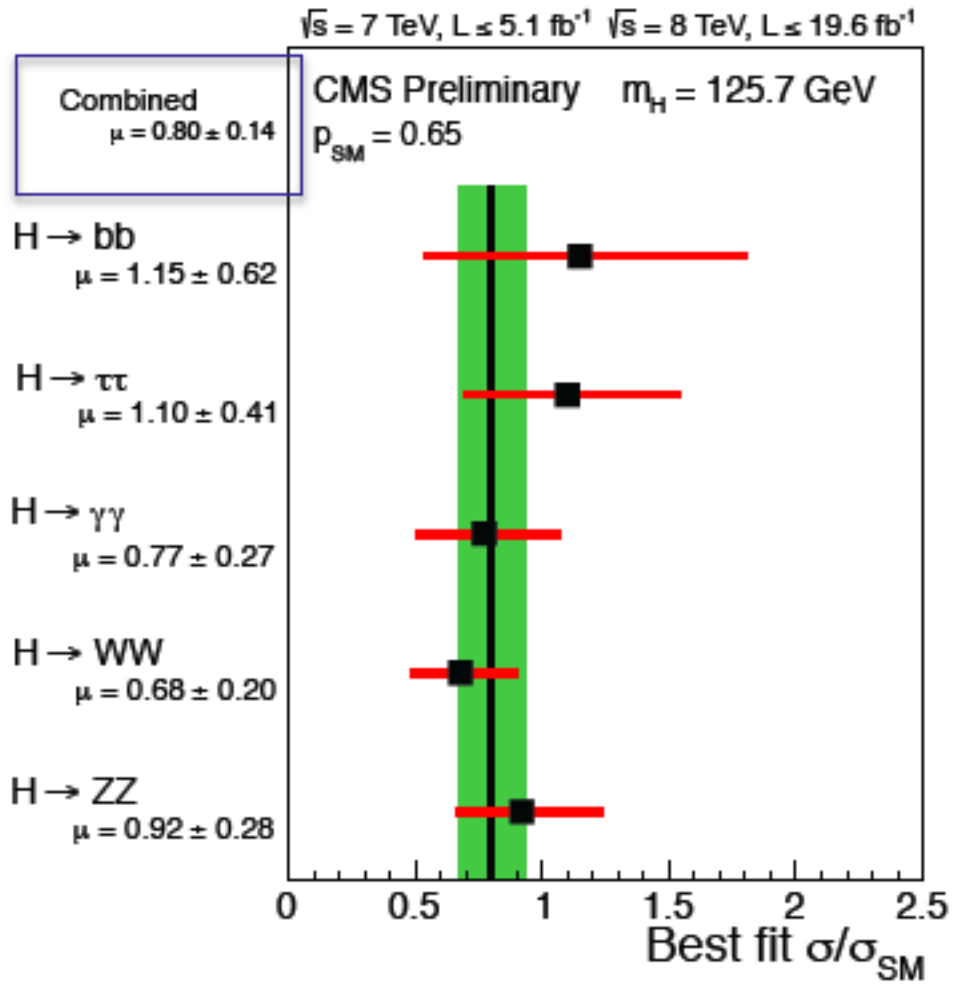


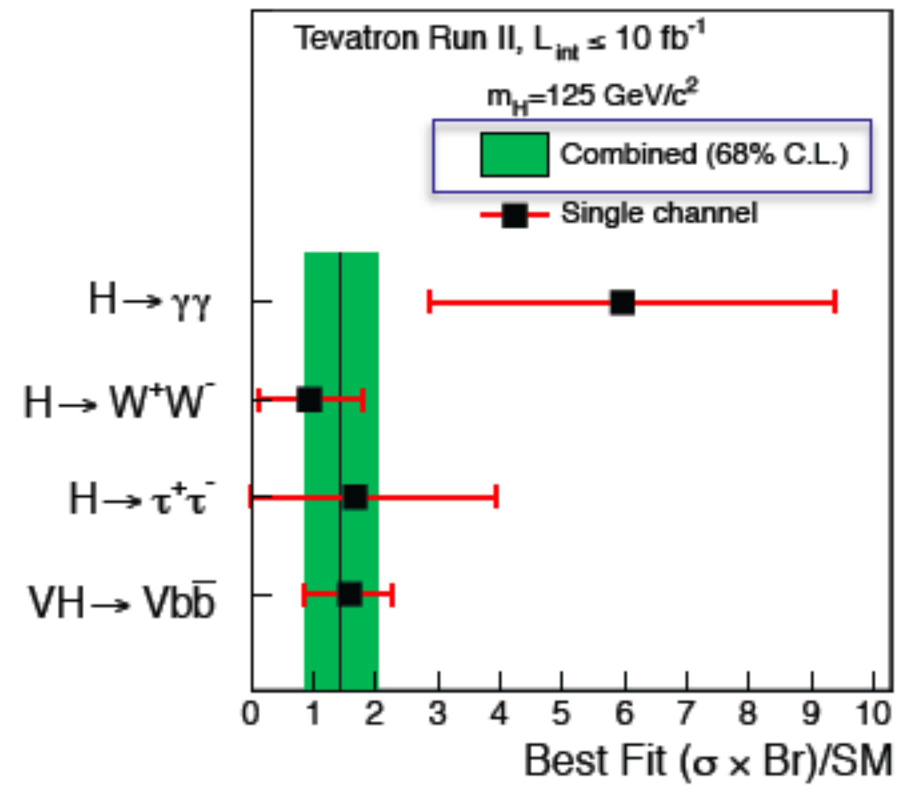
Significance 1.1 (1.7) σ

$\mu_{best} = 0.7 \pm 0.7$

Signal Strength

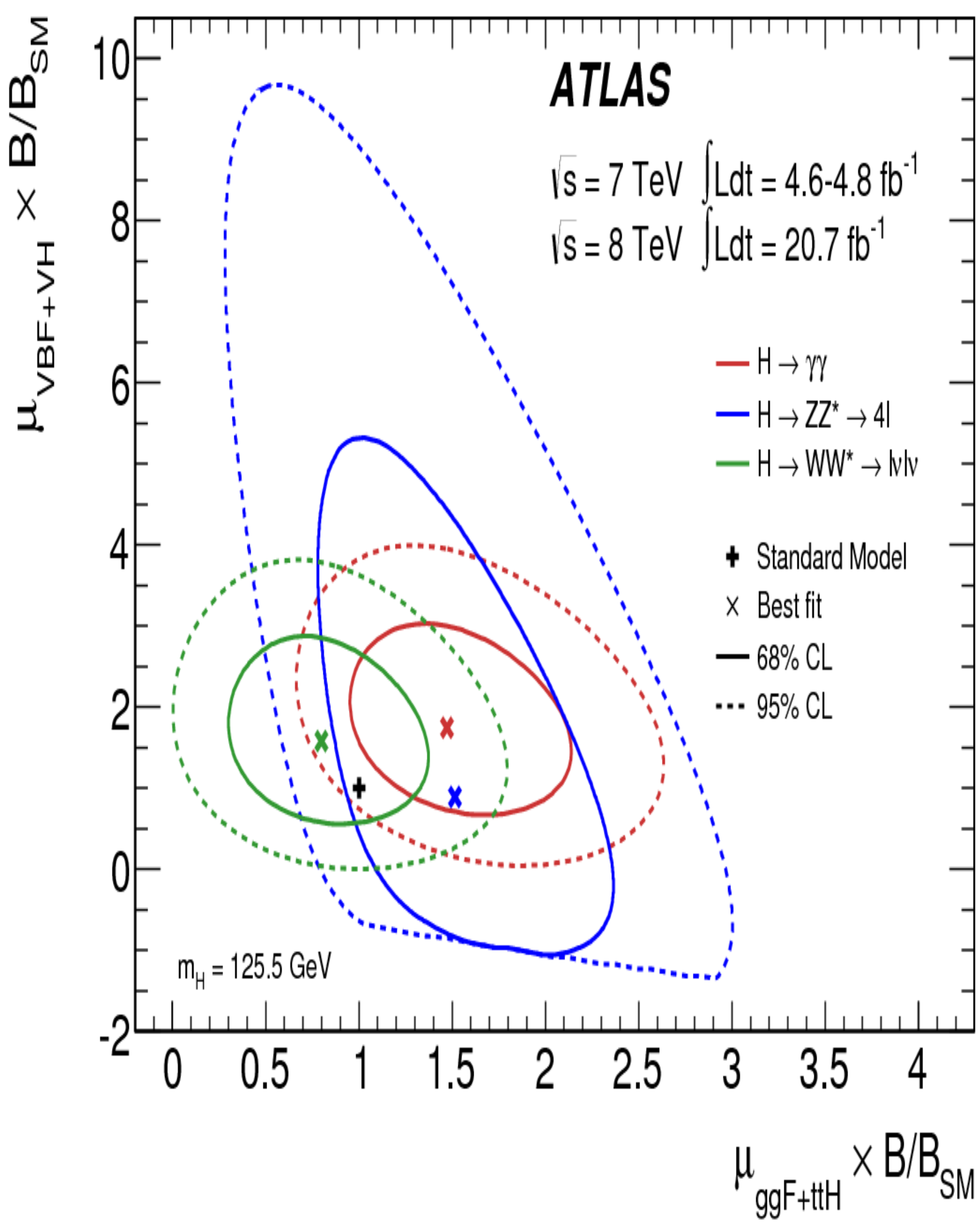


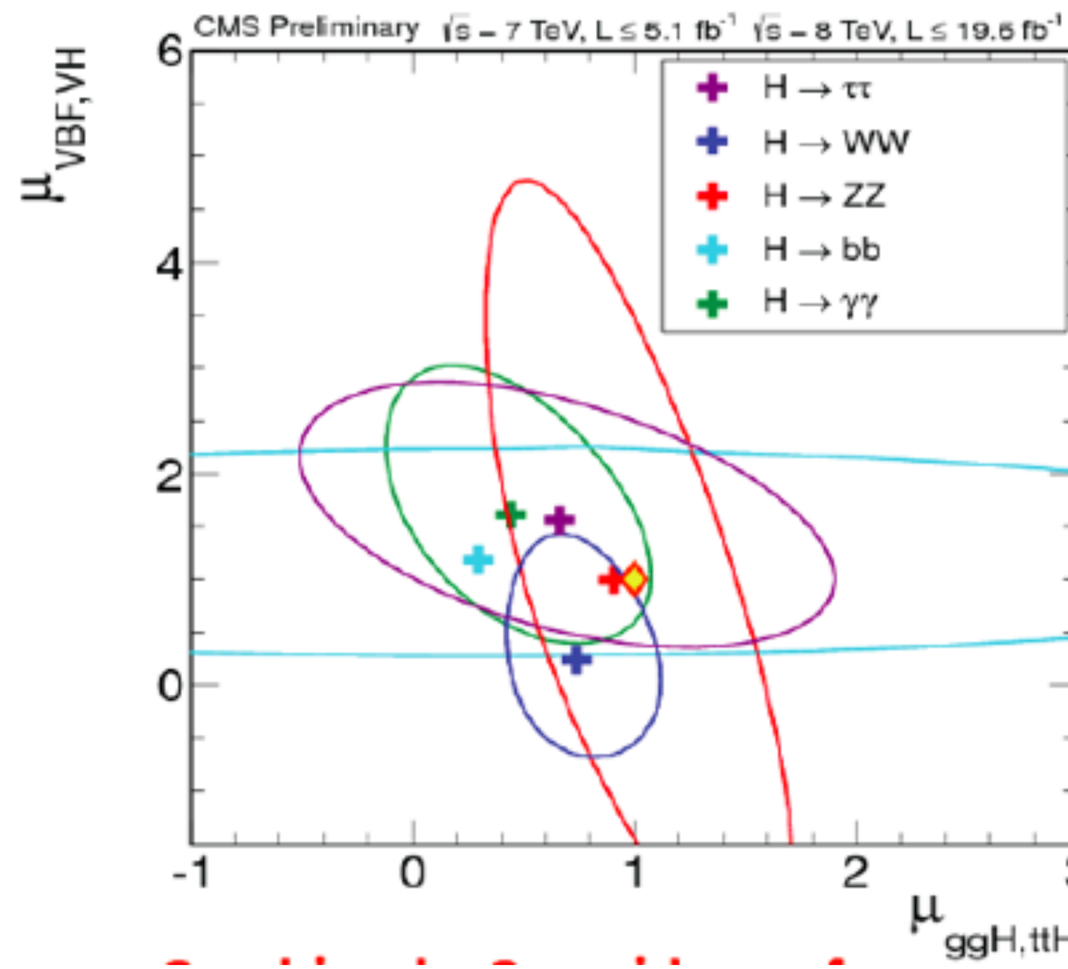




- ATLAS (γγ, WW* and ZZ*) μ = (1.33 ± 0.20)
- CMS (γγ, ττ, bb, WW* and ZZ*) μ = (0.80 ± 0.14)
- TEVATRON (bb, γγ, ττ, WW*) μ = (1.44 ± 0.60)

Production Modes

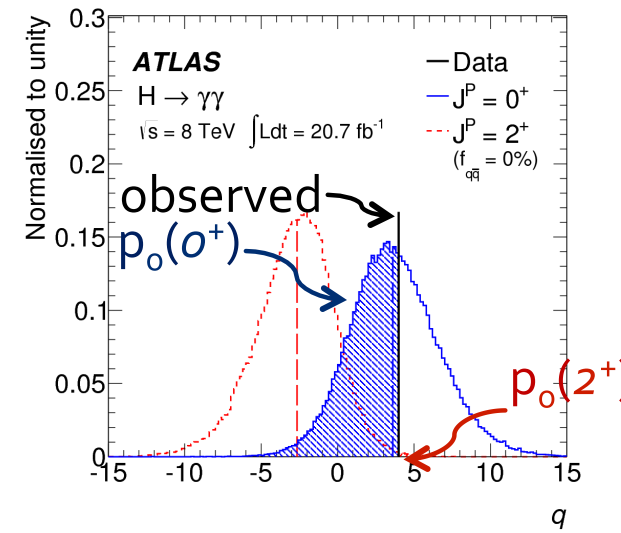


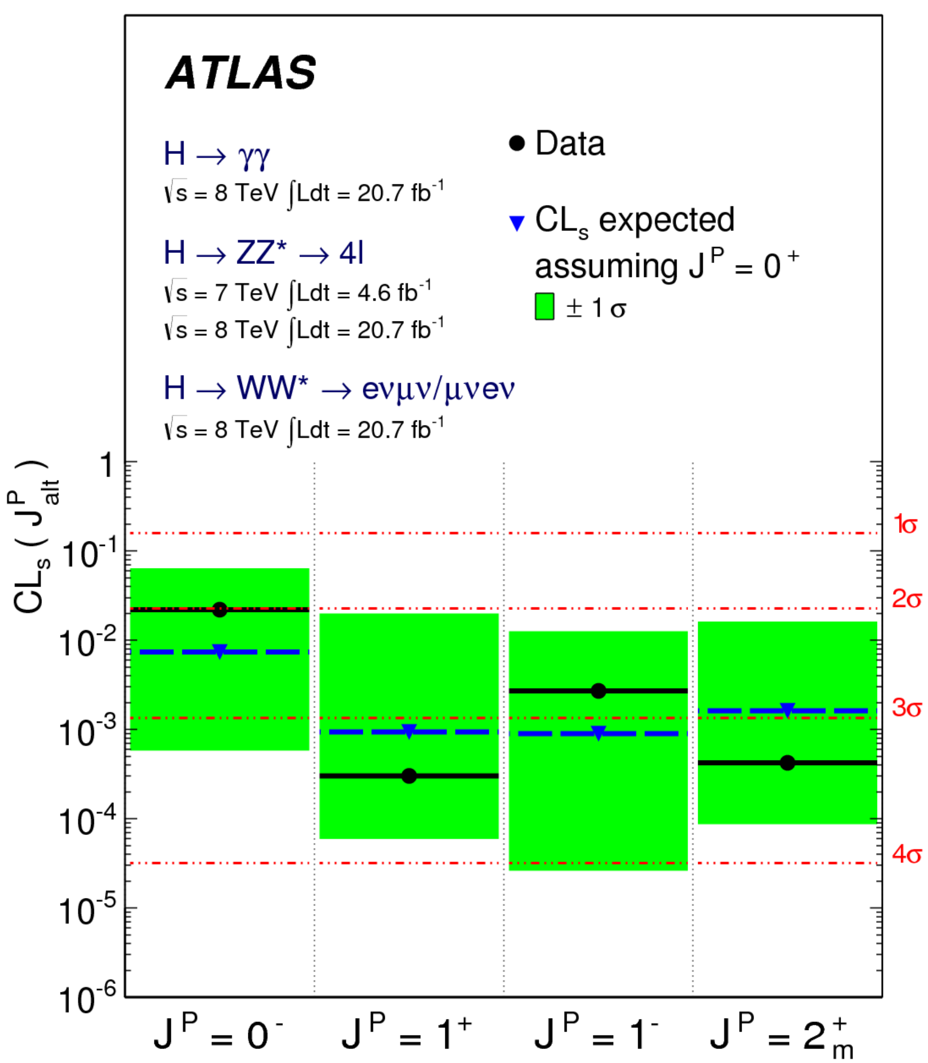


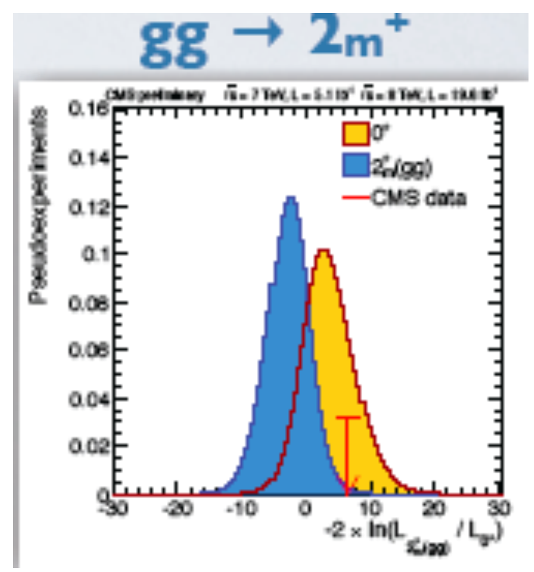
Spin Parity Hypothesis Testing

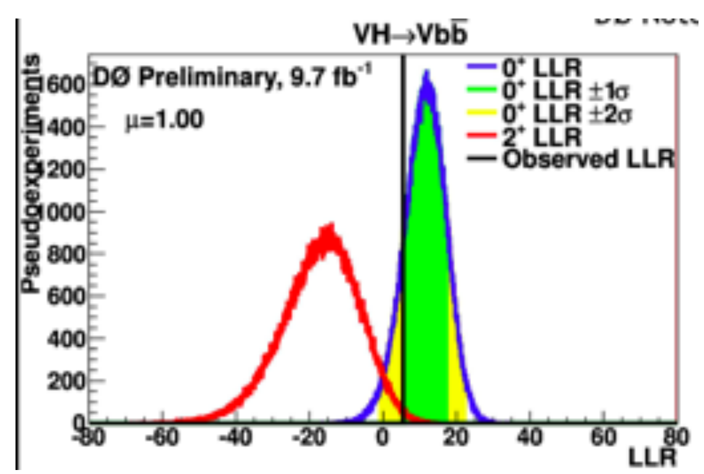
Bolognesi-Doyle-Luyckx-Davies

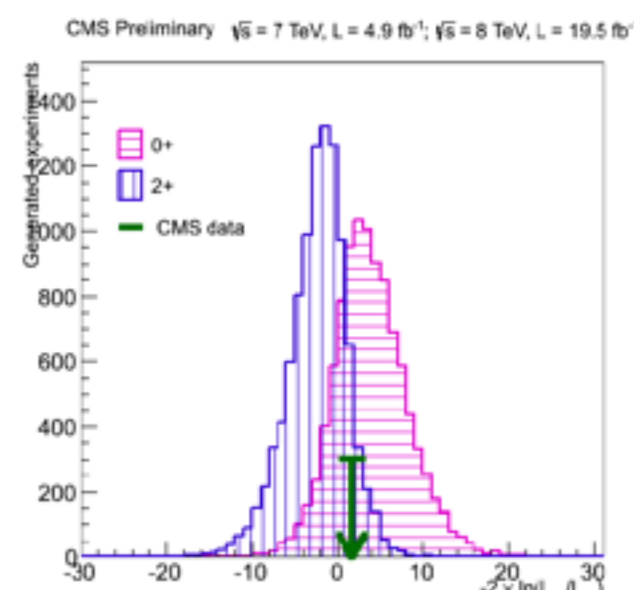
CLs results	ZZ->4l	WW->2l2n	comb ZZ-WW	γγ NEW !!
0^-	**0.16%**	-	-	N/A
0_h^+	8.1%	-	-	-
2_m^+ (gg)	1.5%	14%	**0.6%**	60.9%
2_m^+ (qq)	**0.1%**	-		16.9%











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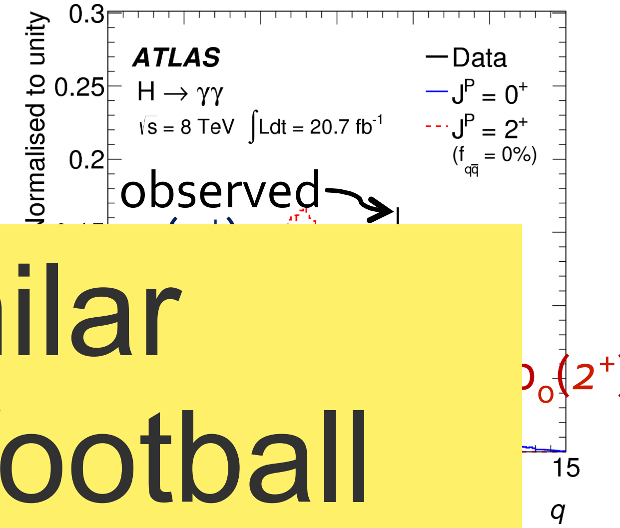
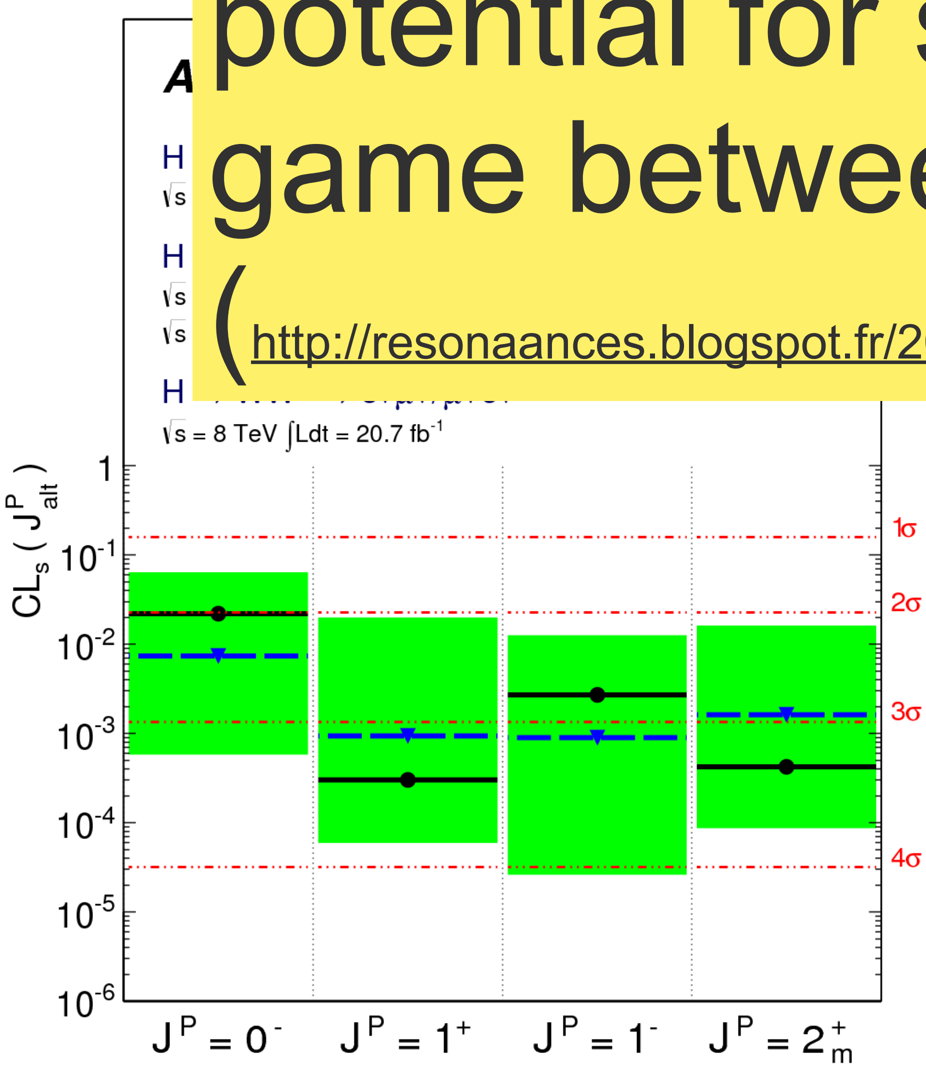
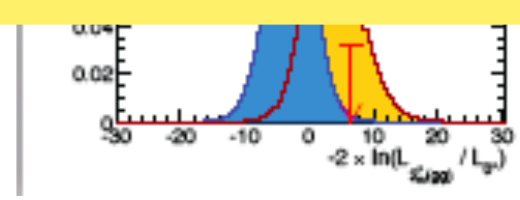
2_m^+ (qq)	[illegible]	[illegible]	[illegible]	[illegible]

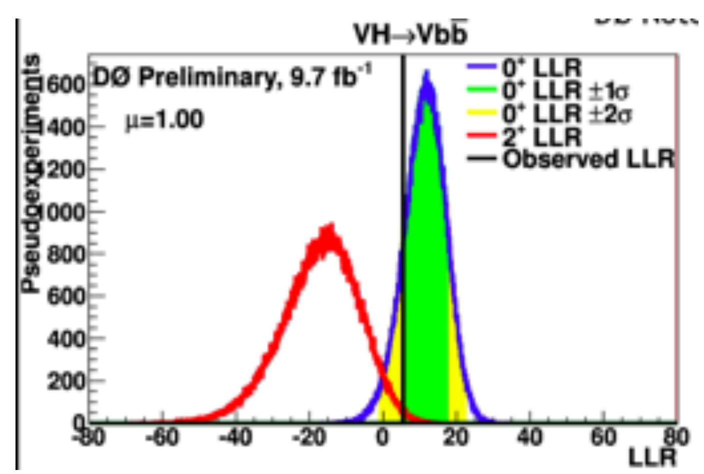
Bolognesi-Doyle-Luyckx-Davies

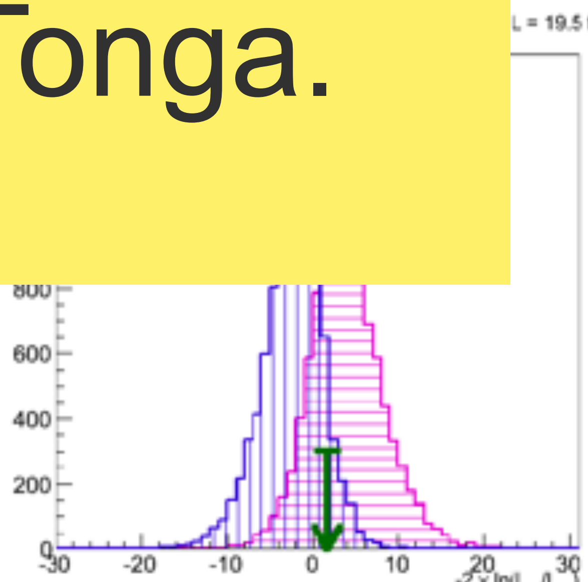


This question carries a similar potential for surprise as a football game between Brazil and Tonga.
(http://resonaances.blogspot.fr/2012/10/higgs-new-deal.html)









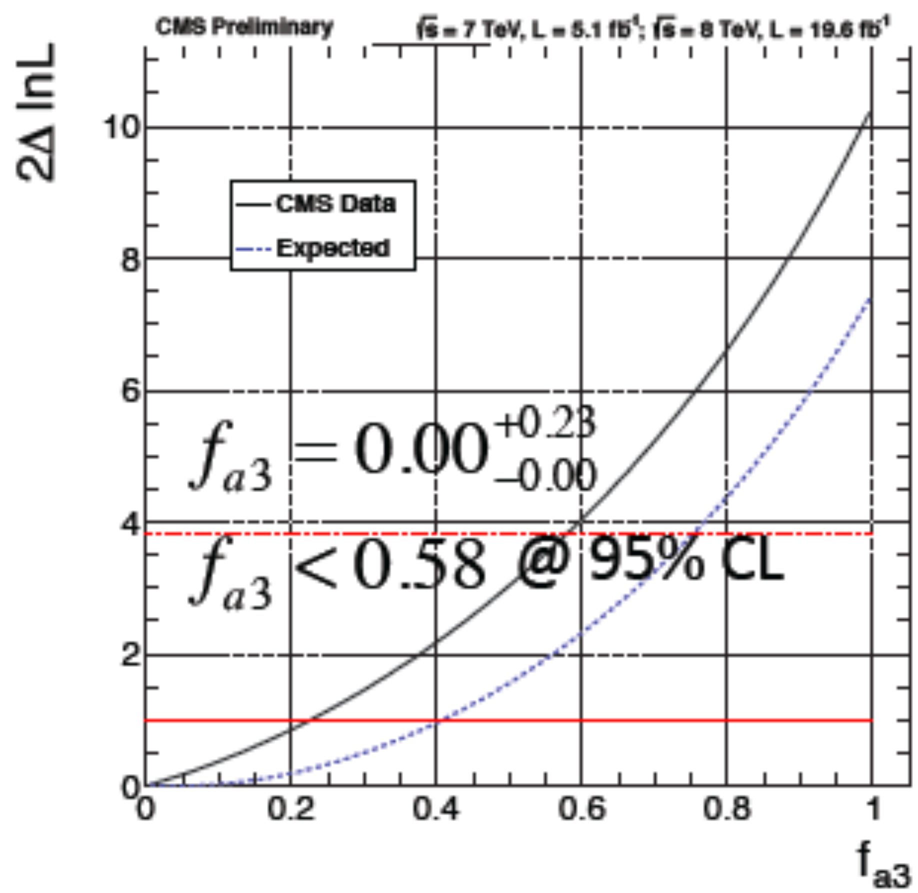
Toward CP-Mixing

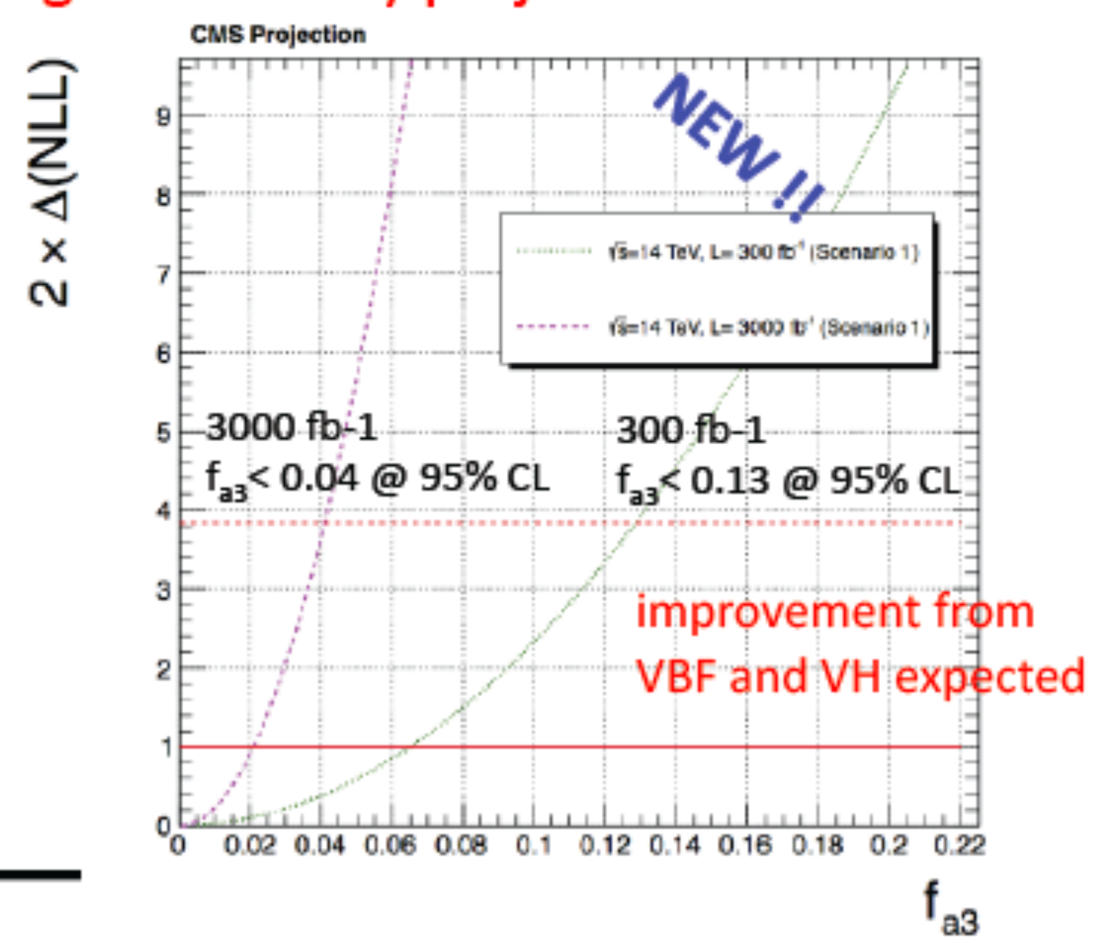
- **Extract couplings from fit to kinematical distributions**

$$A(X \to V_1V_2) = v^{-1}\varepsilon_1^{*\mu}\varepsilon_2^{*\nu}\left(a_1 g_{\mu\nu}M_X^2 + a_2 q_{1\mu}q_{2\nu} + a_3\varepsilon_{\mu\nu\alpha\beta}q_1^{\alpha}q_2^{\beta}\right)$$

f_{a3} (fraction of a_3 component over total xsec) very important parameter which quantify the CP-mixing of the resonance, as predicted in SUSY models

- (only?) alternative spin/parity hypothesis really theoretically motivated
- **first measurement in H->4l**
- expected very small: 0- has not LO couplings to VV -> CMS high luminosity projections





THE question

SM Higgs ?

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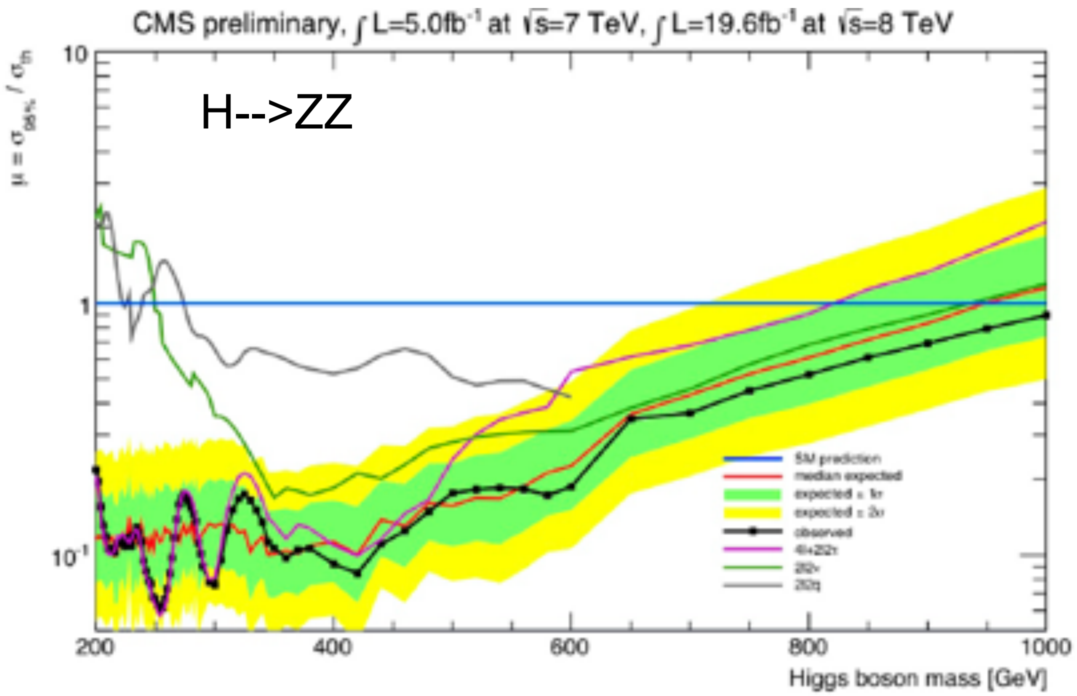
SM Higgs ?

BSM Higgs ?

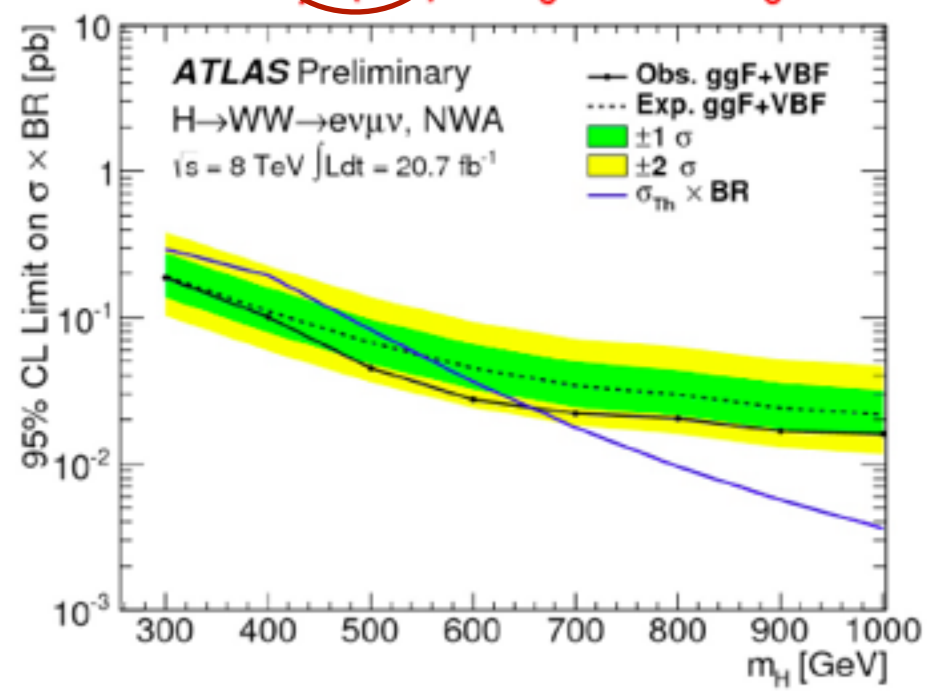
Another Higgs with higher mass?

WANG



Fixed 1GeV wide BW lineshape

Motivated by h(126) mixing with EW singlet model



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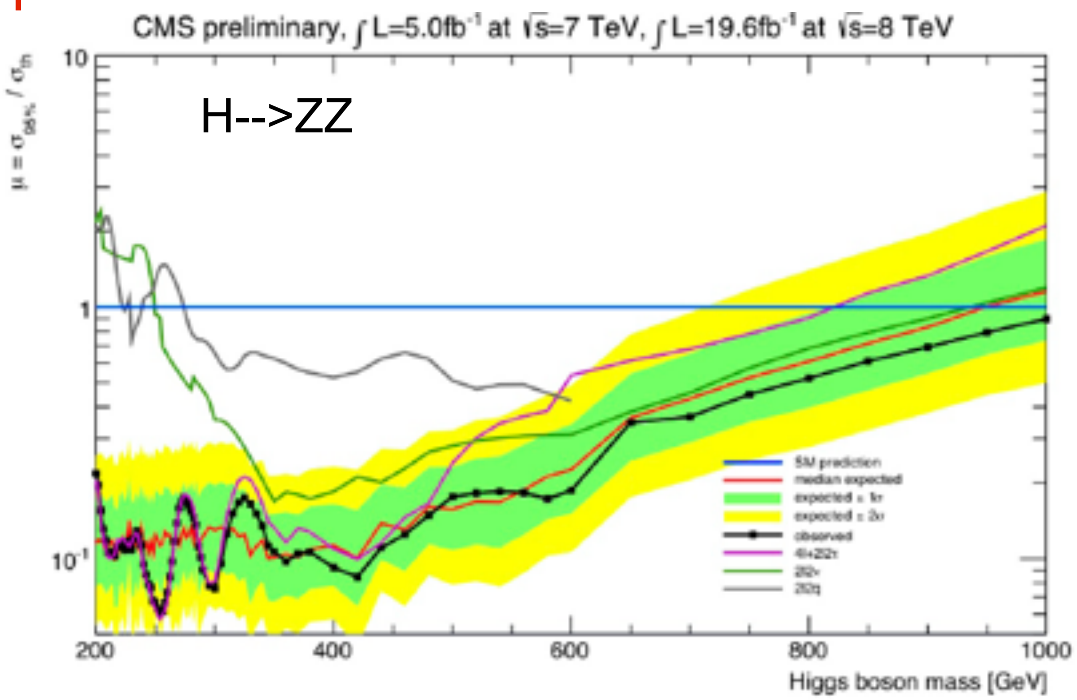

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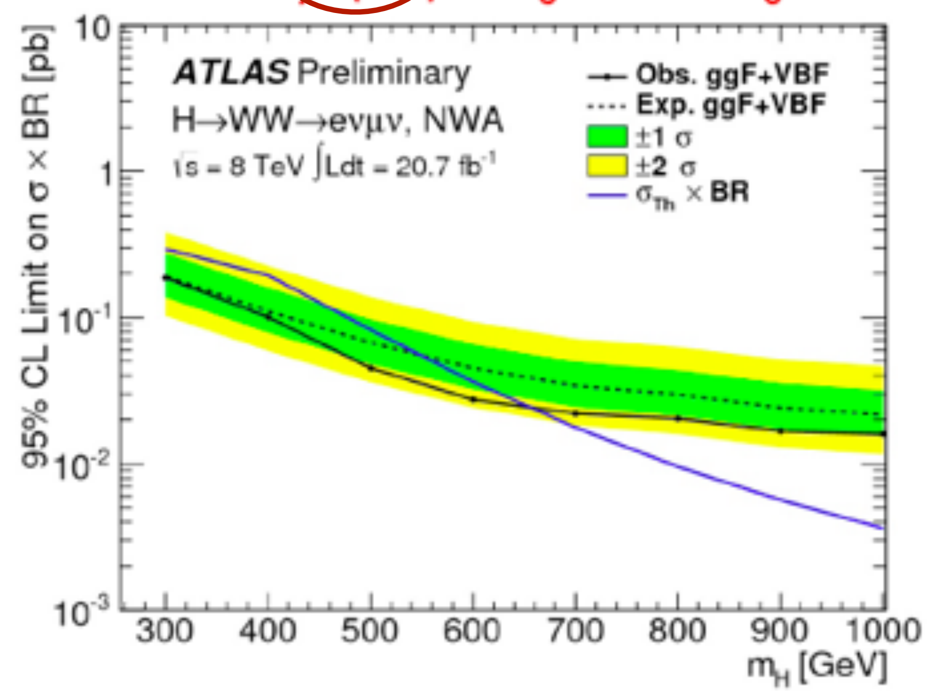

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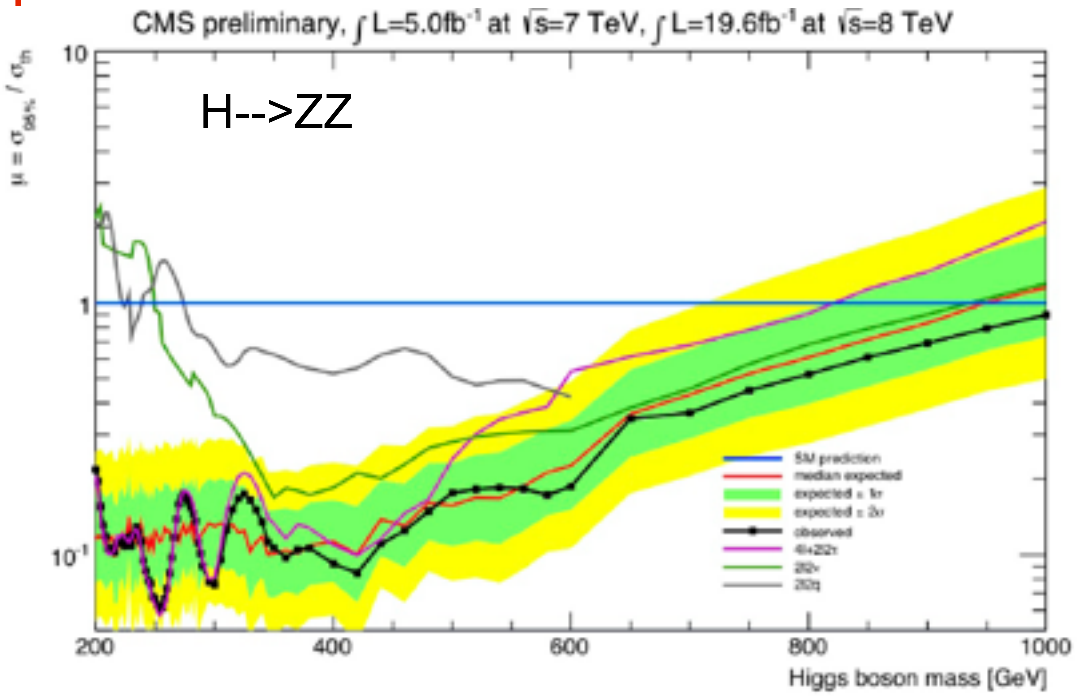

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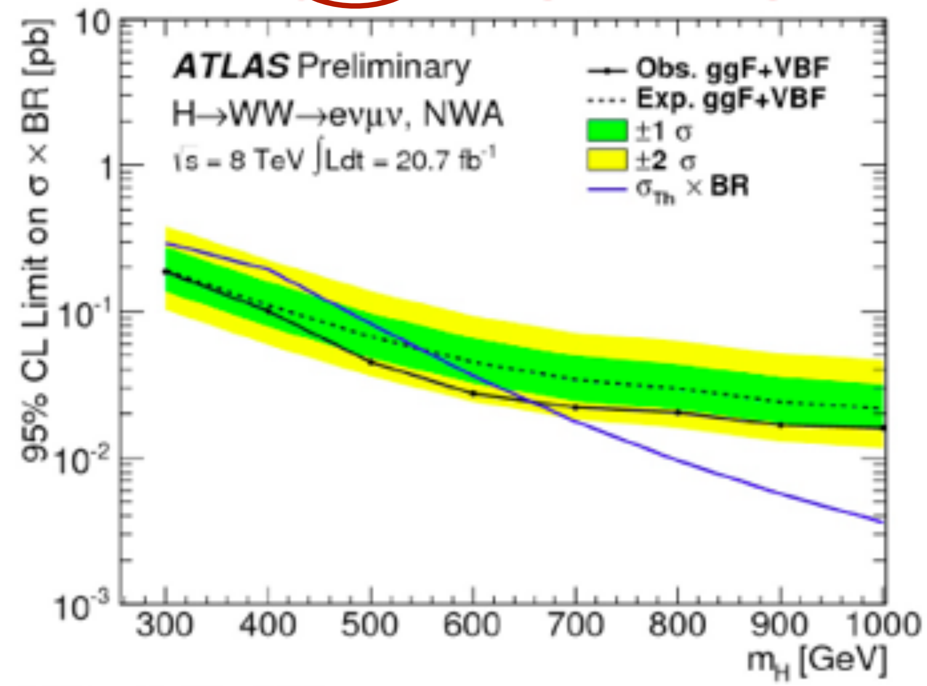
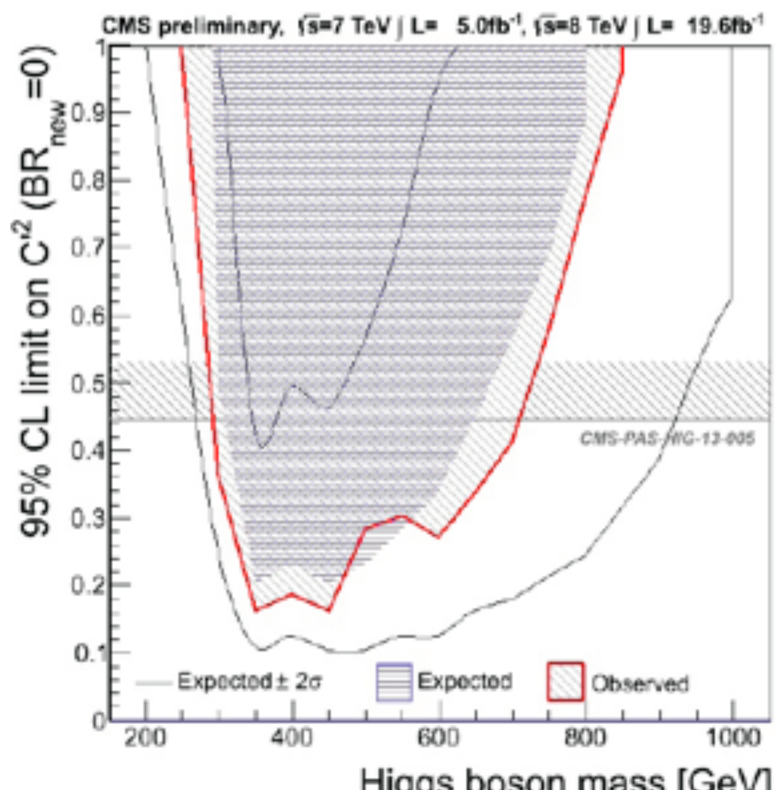


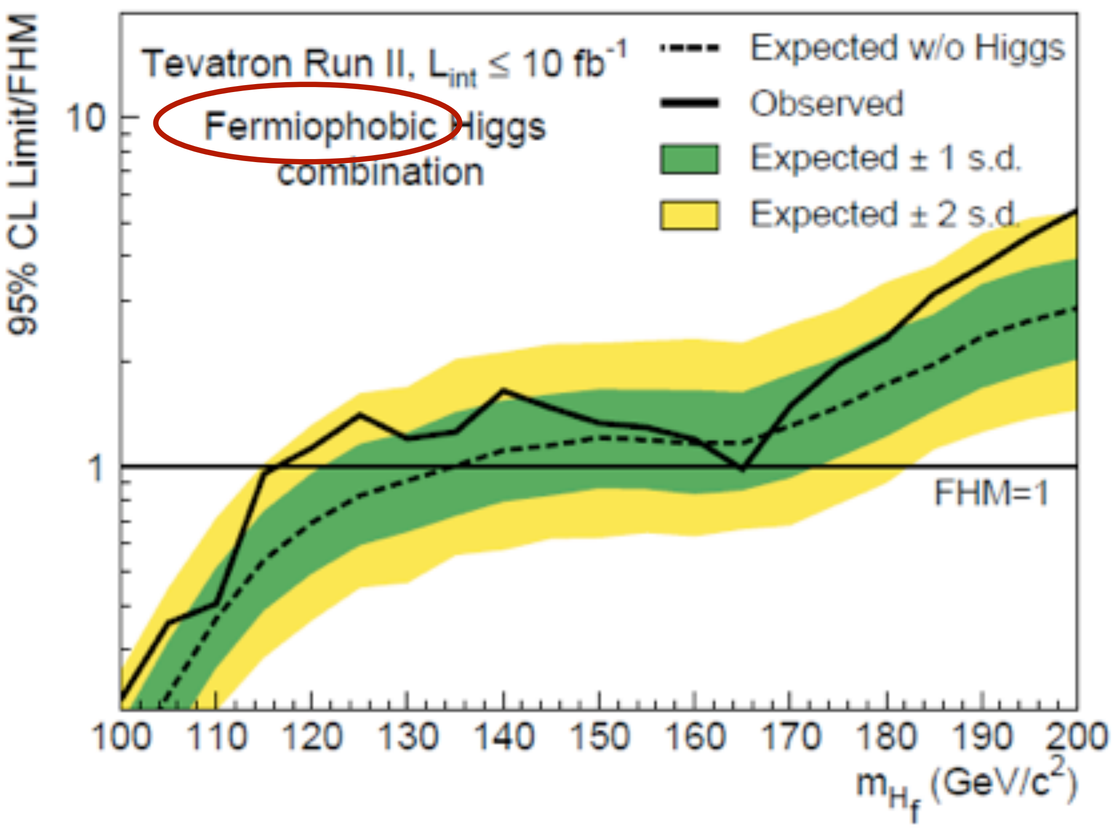


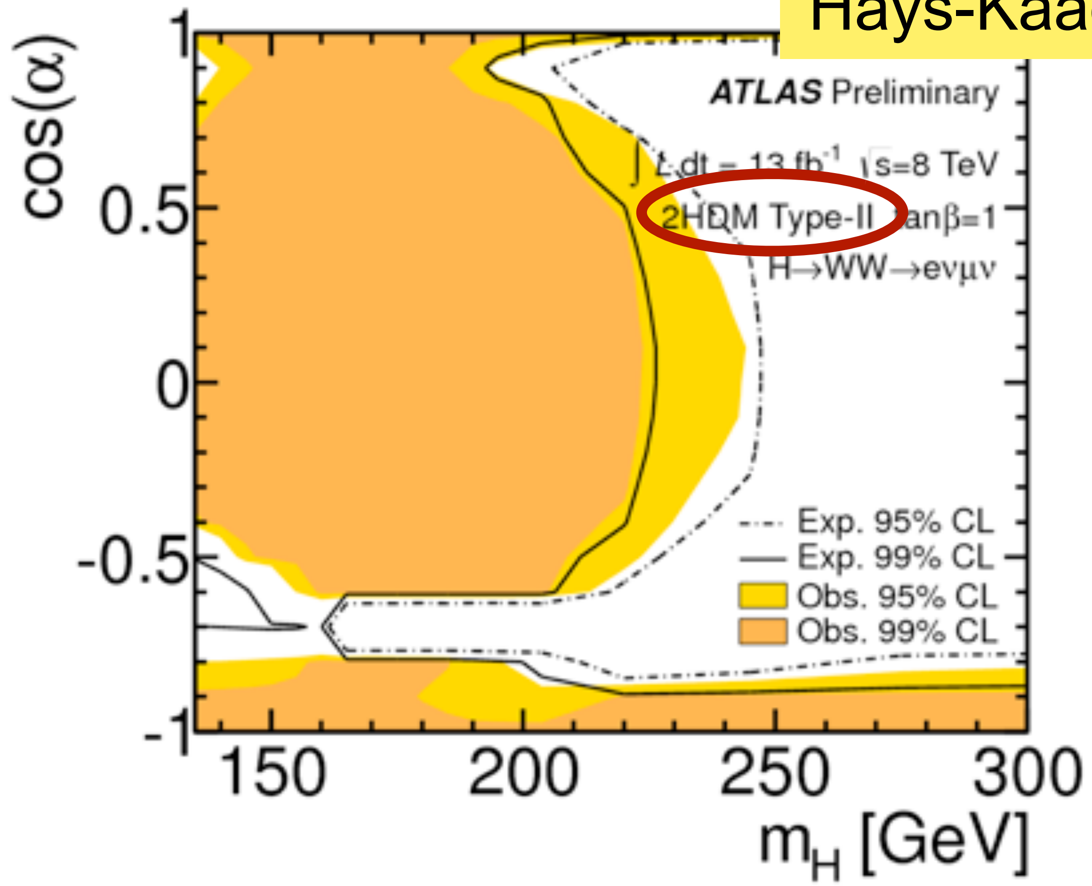
Limits on C'^2 as a function of mH

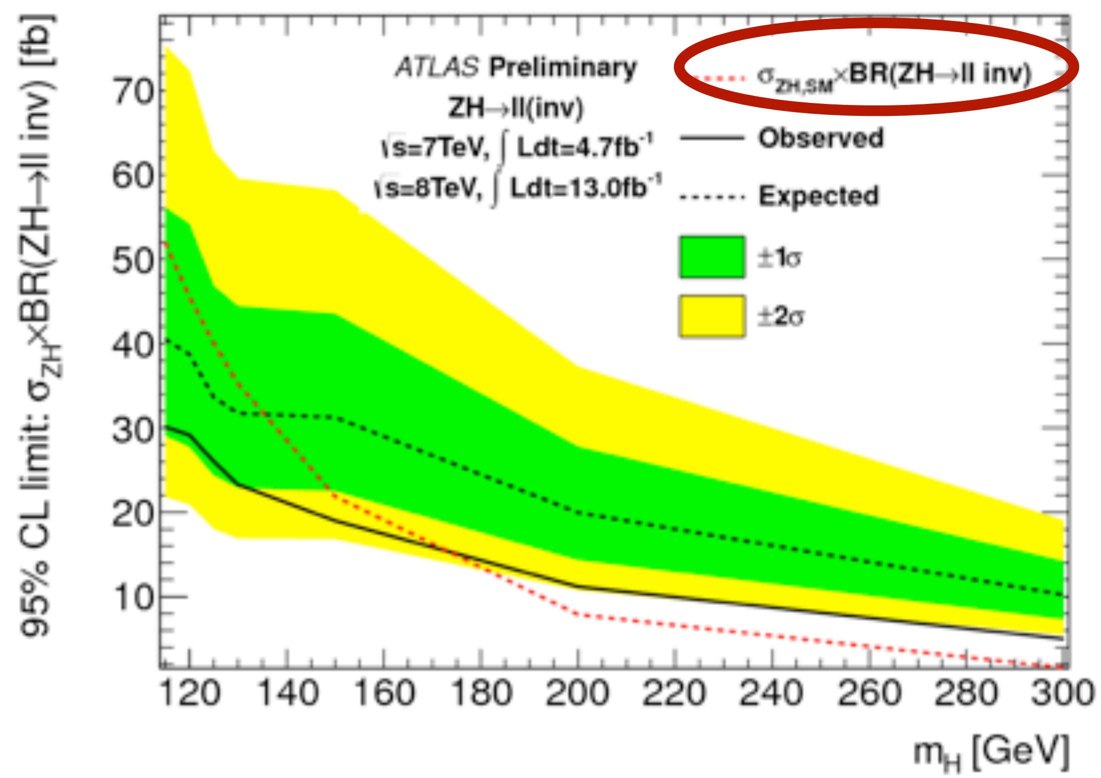
EW singlet mixing with h(125)

BSM Higgs

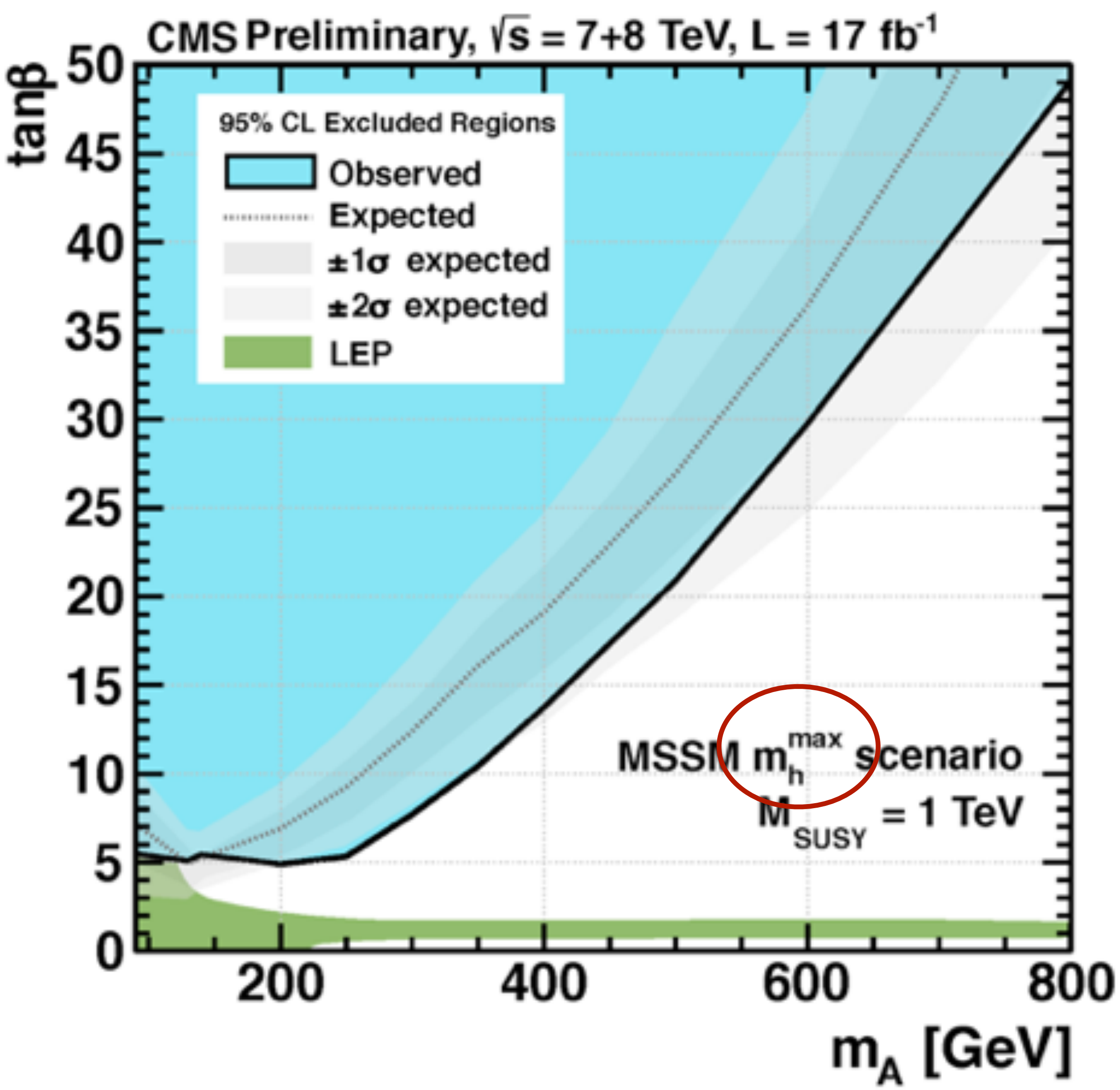
Hays-Kaadze



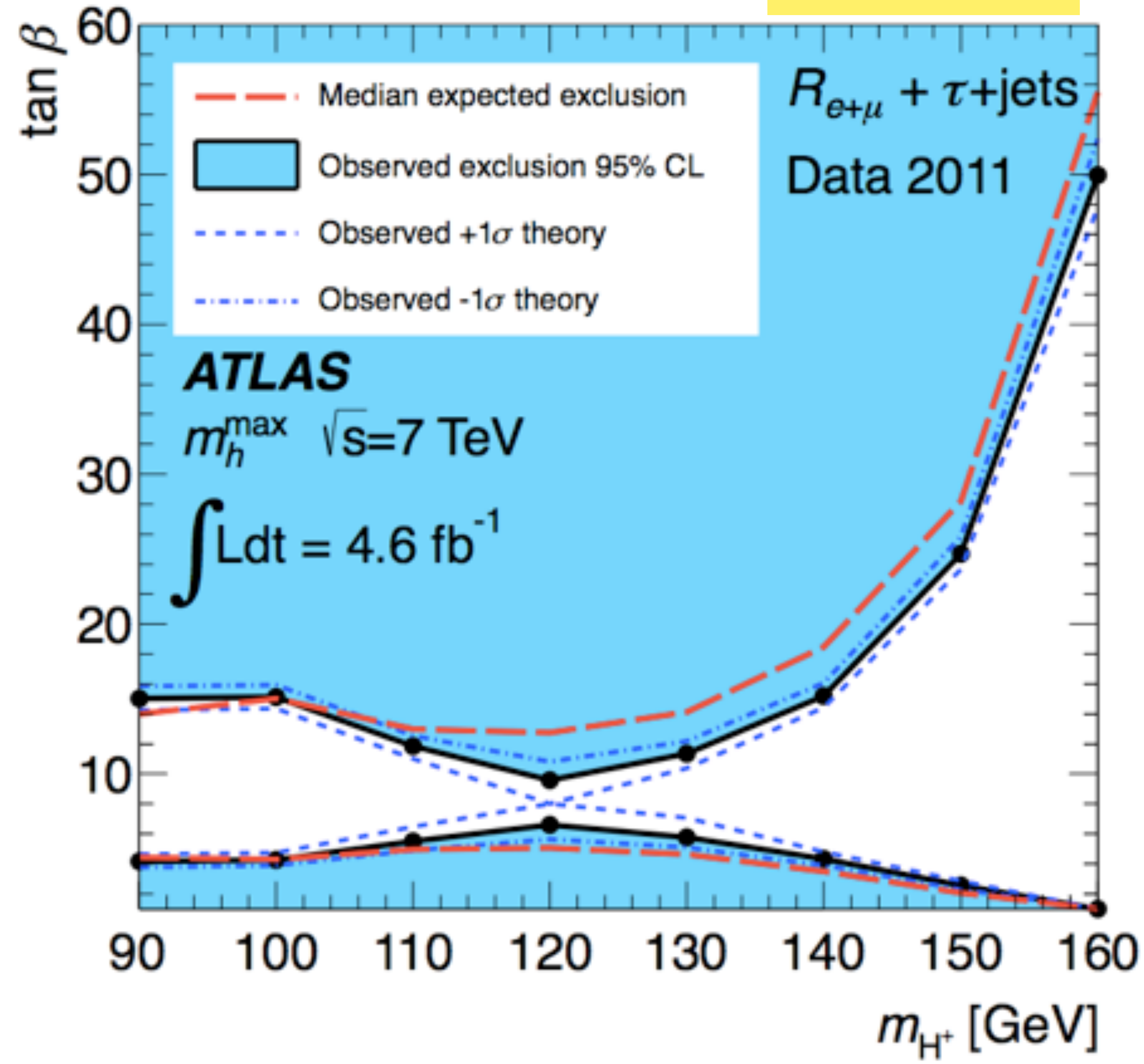




MSSM

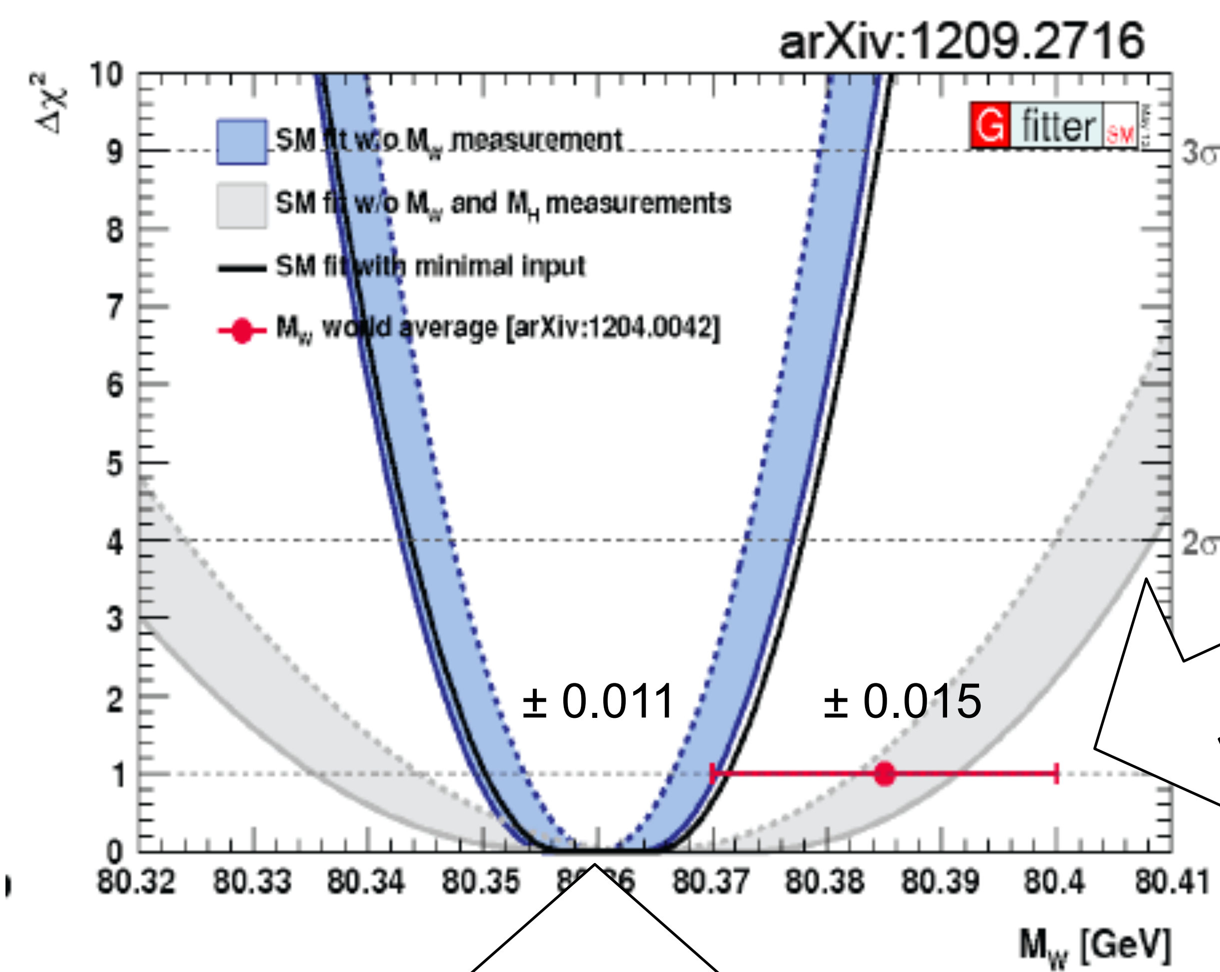

CMS Preliminary, √s = 7+8 TeV, L = 17 fb-1
tanβ
95% CL Excluded Regions
Observed
Expected
±1σ expected
±2σ expected
LEP
MSSM m_h^max scenario
M_SUSY = 1 TeV
m_A [GeV]
0
5
10
15
20
25
30
35
40
45
50
200
400
600
800

Madsen


tan β
Median expected exclusion
Observed exclusion 95% CL
Observed +1σ theory
Observed -1σ theory
R_e+μ + τ+jets
Data 2011
ATLAS
m_h^max √s=7 TeV
∫Ldt = 4.6 fb-1
m_H+ [GeV]
10
20
30
40
50
60
90
100
110
120
130
140
150
160

Precision Measurements

Juste



Projected M_W uncertainty:

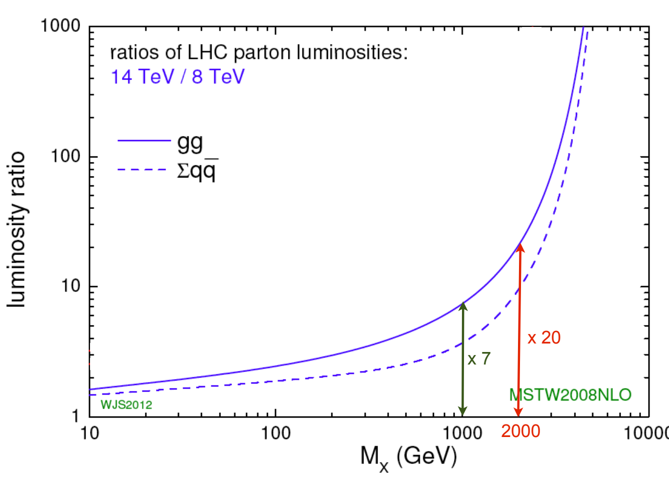
- CDF: 10 MeV
- DØ: 15 MeV
- Combination: <10 MeV

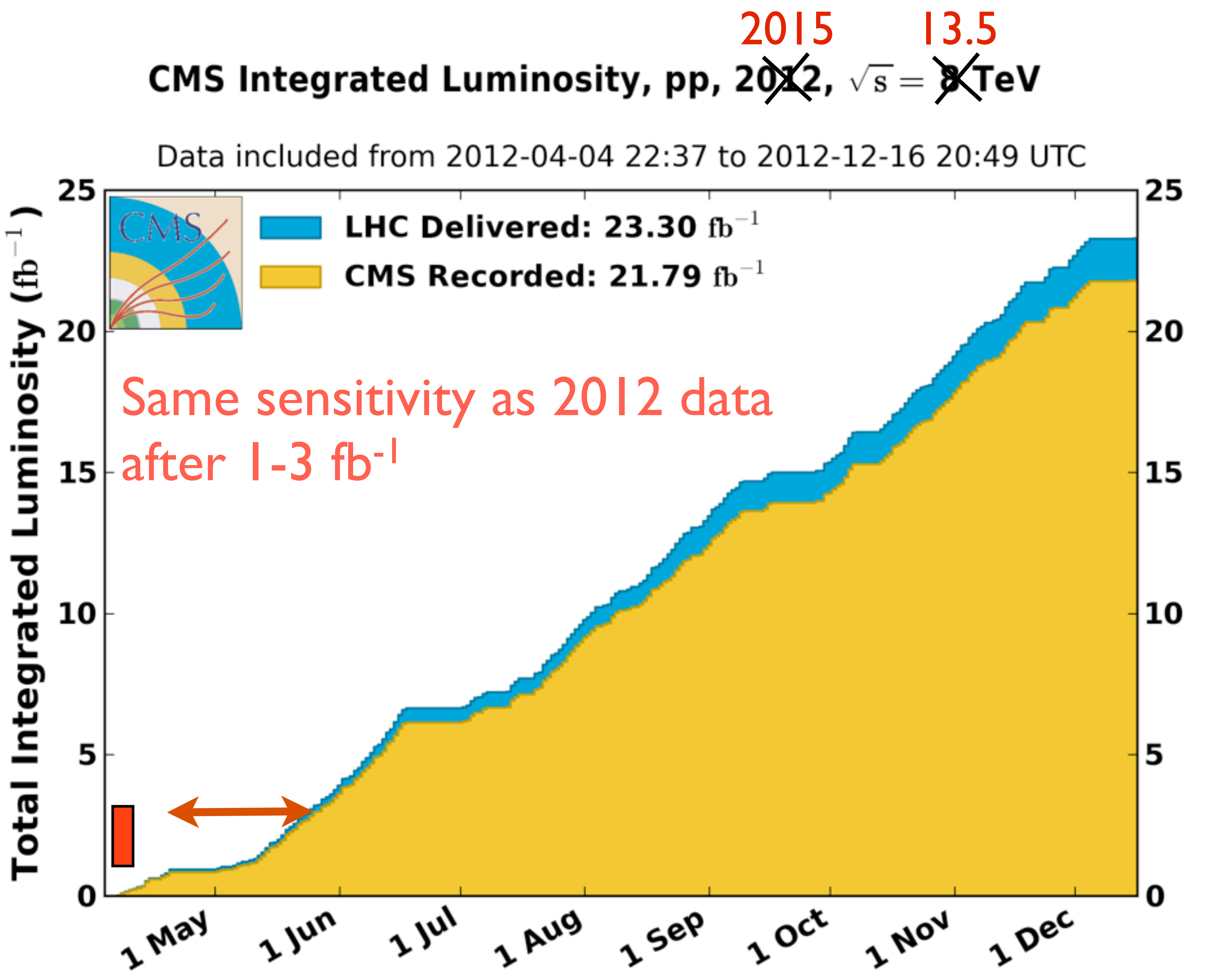
LHC ?

$$M_W = 80.3593 \pm 0.0056(m_t) \pm 0.0026(M_Z) \pm 0.0018(\Delta\alpha_{had})$$
$$\pm 0.0017(\alpha_s) \pm 0.0002(M_H) \pm 0.0040(theo) \text{ GeV}$$

Using Δm_t 0.94 GeV

LHC Startup 2014/15 : the first months

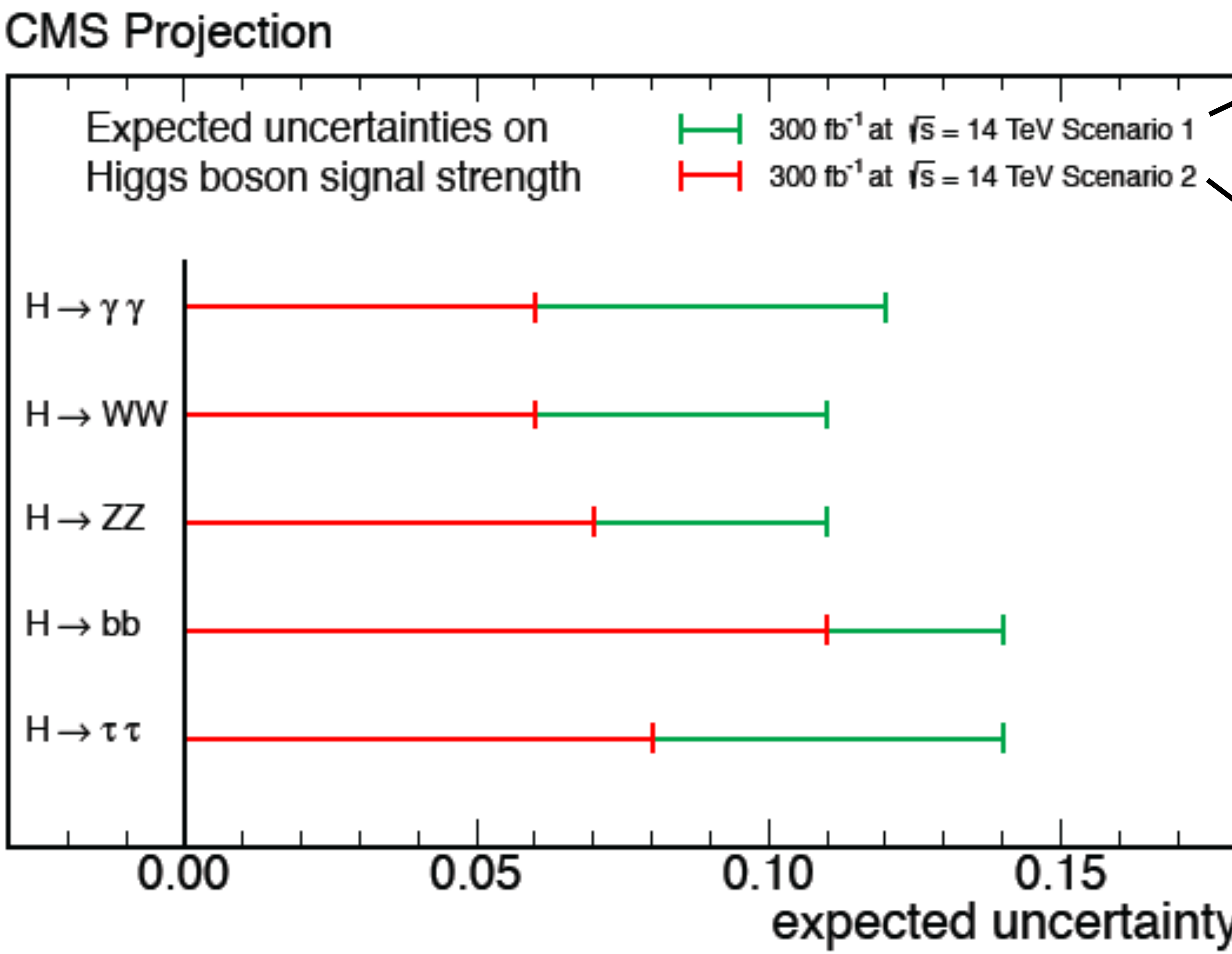




Same sensitivity as 2012 data after 1-3 fb^{-1}

LHC 300 fb^{-1}

Schumacher



Syst Unchanged

Theory sys*0.5
Exp. sys ~ 1/√L

Conclusions

- 2012 has been a remarkable year and 2013 has been consolidation. h(125.6) looks like the SM Higgs, in the precision of experimental data. Precision of the couplings will improve in the next few years @ LHC.

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Thank You !

Conclusions 2

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