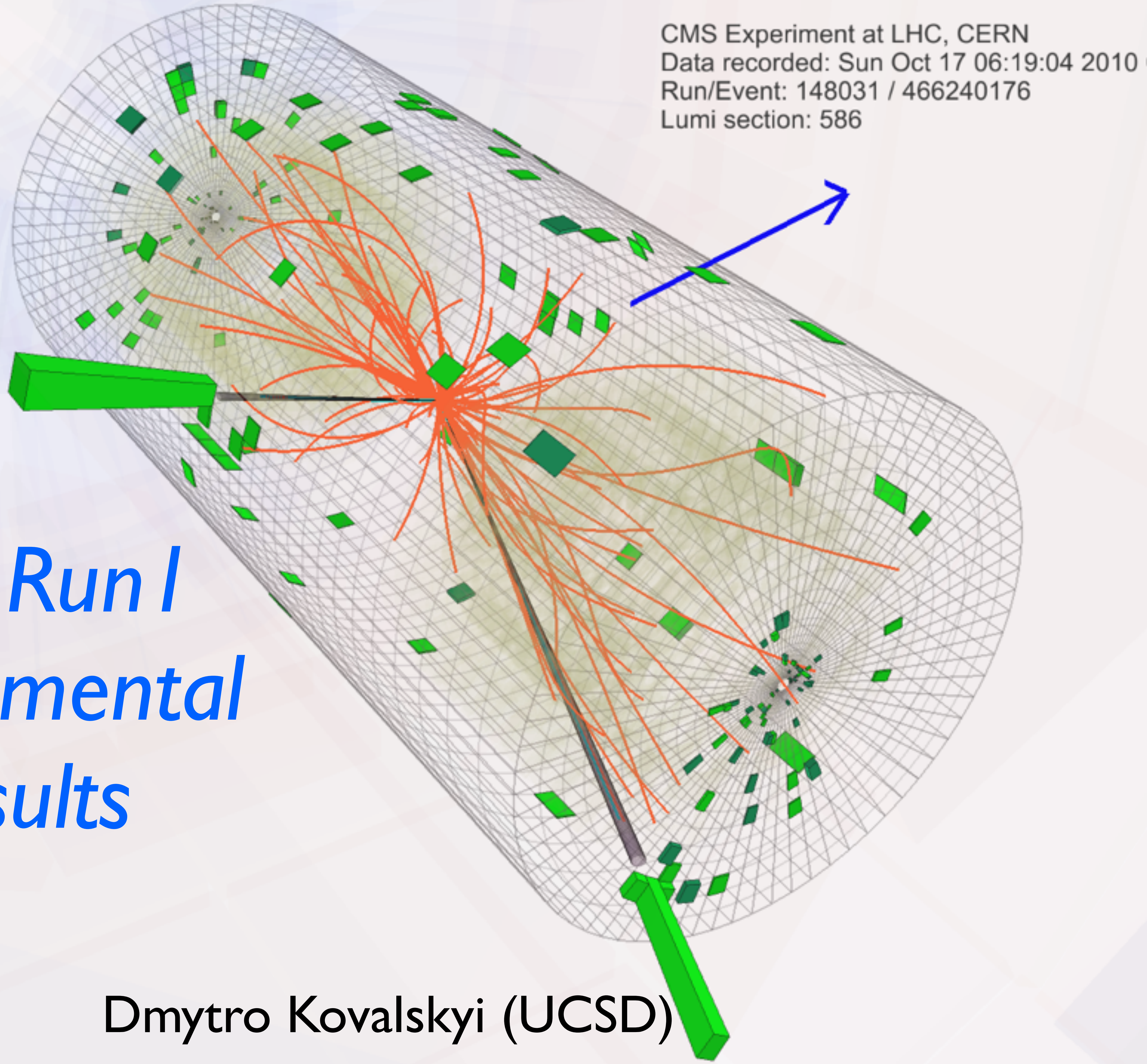
LHC Run I Experimental Results



Dmytro Kovalskyi (UCSD)

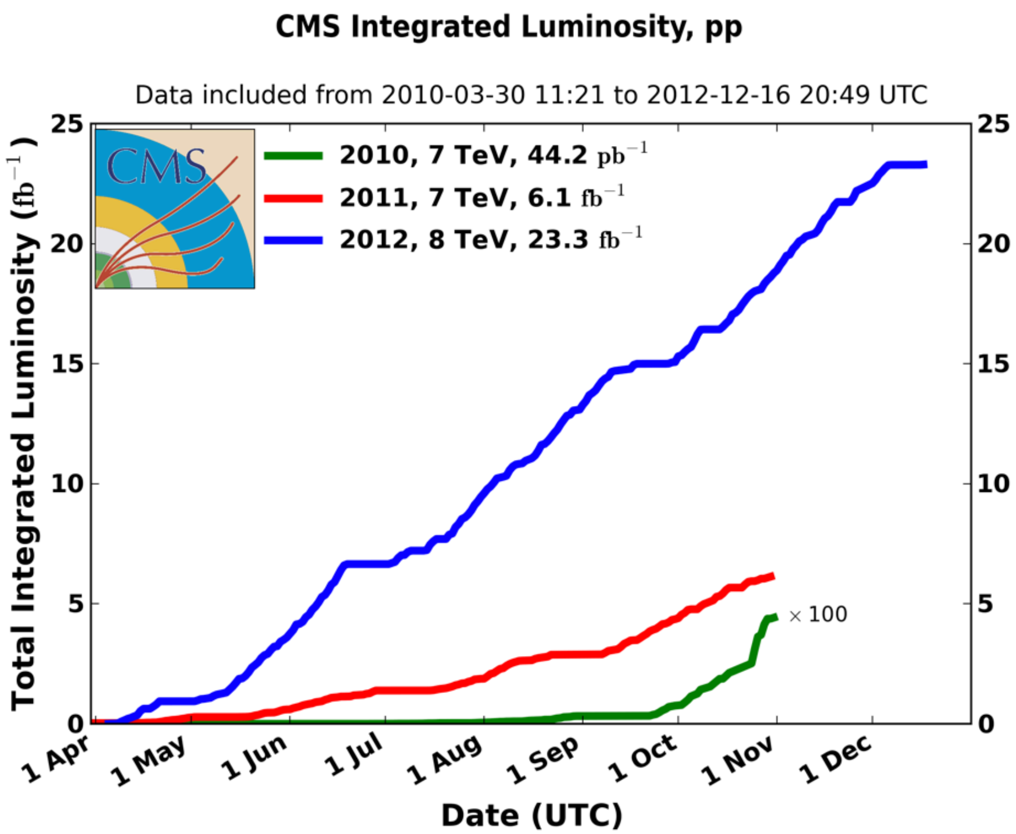
Introduction

- There are many interesting results produced by LHC experiments
- It's unrealistic to show them all
- I'll concentrate on a few topics that are interesting from my point of view
- Latest Moriond experimental summary talks:
  - Pierluigi Campana (Frascatti)
    - http://moriond.in2p3.fr/QCD/2014/Saturday/Campana.pdf
  - Kevin Einsweiler (Lawrence Berkeley Lab)
    - https://indico.in2p3.fr/getFile.py/access?contribId=227&sessionId=1&resId=1&materialId=slides&confId=9116

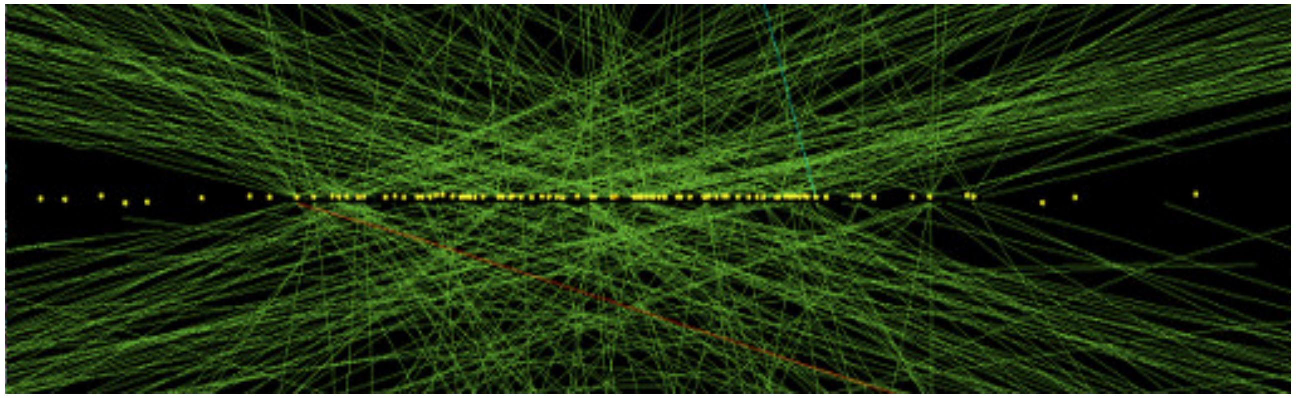
Overview

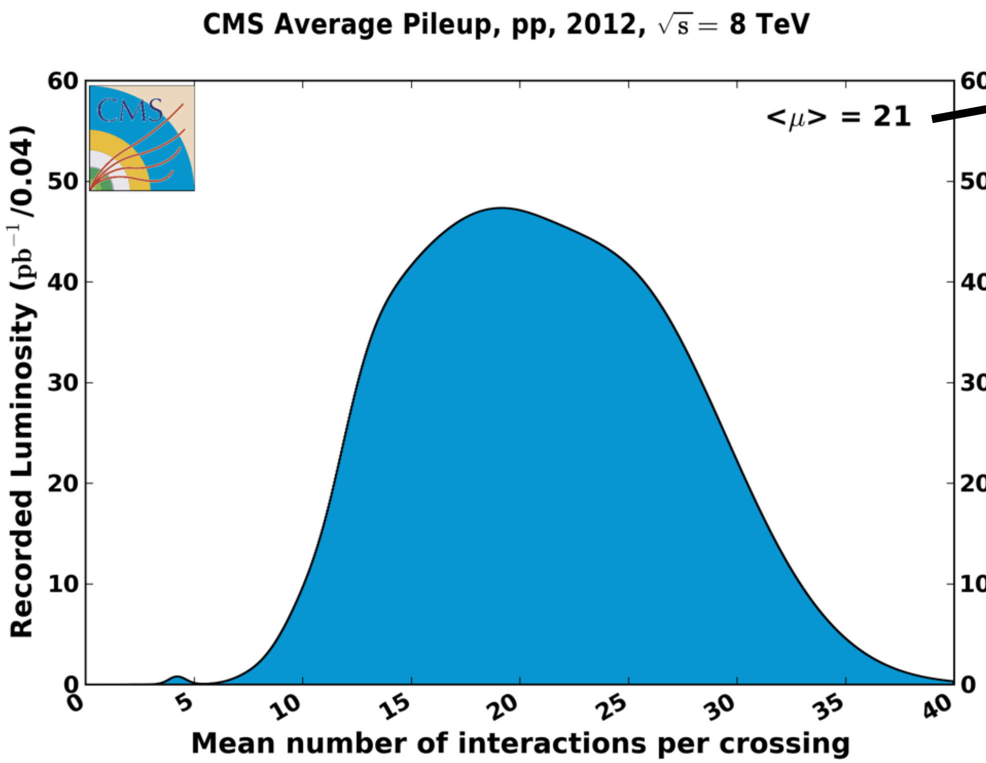
- Run1 overview and Run2 projections
- Standard Model
  - Higgs boson is discovered - SM is complete
    - In depth: Higgs width measurement
  - SM Properties
- Physics beyond the Standard Model
  - Direct searches for SUSY and Exotic models
  - Indirect searches by exploring vector boson scattering
- Vacuum stability and top mass

LHC Run 1

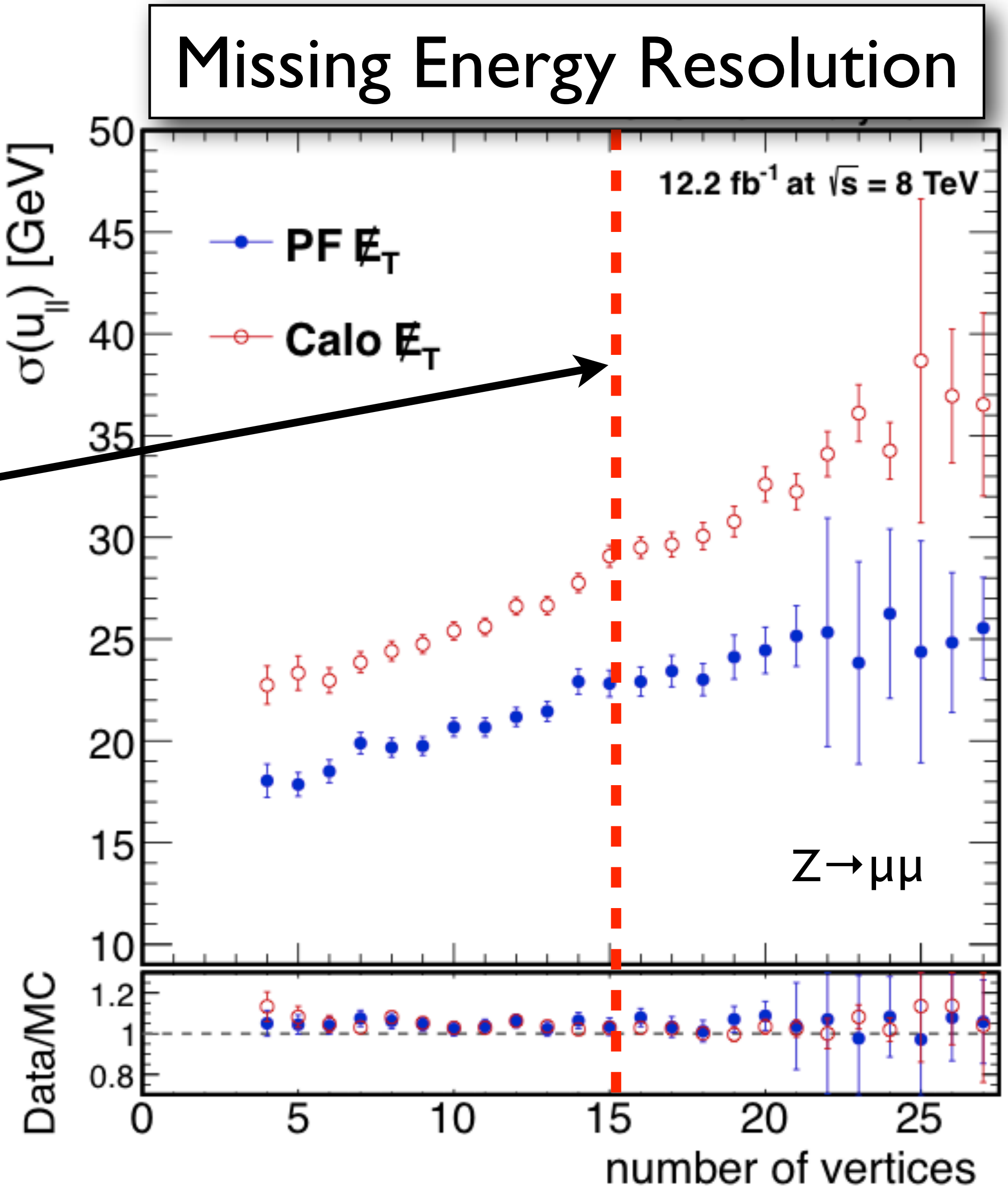


CMS Integrated Luminosity, pp
Data included from 2010-03-30 11:21 to 2012-12-16 20:49 UTC
2010, 7 TeV, 44.2 pb^{-1}
2011, 7 TeV, 6.1 fb^{-1}
2012, 8 TeV, 23.3 fb^{-1}
× 100
Total Integrated Luminosity (fb^{-1})
Date (UTC)
1 Apr
1 May
1 Jun
1 Jul
1 Aug
1 Sep
1 Oct
1 Nov
1 Dec





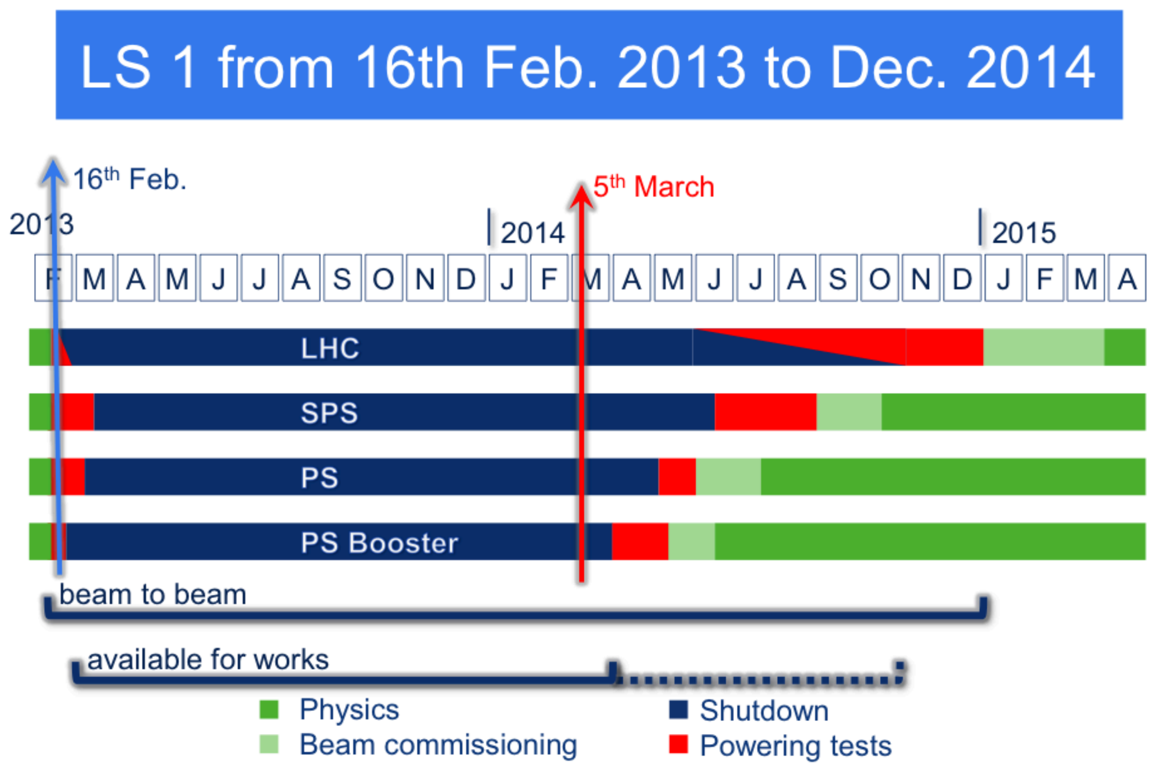
CMS Average Pileup, pp, 2012, $\sqrt{s}$ = 8 TeV
<μ> = 21
Recorded Luminosity (pb^{-1}/0.04)
Mean number of interactions per crossing



Missing Energy Resolution
12.2 fb^{-1} at $\sqrt{s}$ = 8 TeV
PF $\not\!\!E_T$
Calo $\not\!\!E_T$
$\sigma(u_{\parallel})$ [GeV]
Z→μμ
Data/MC
number of vertices

Run 2: 2015-2017

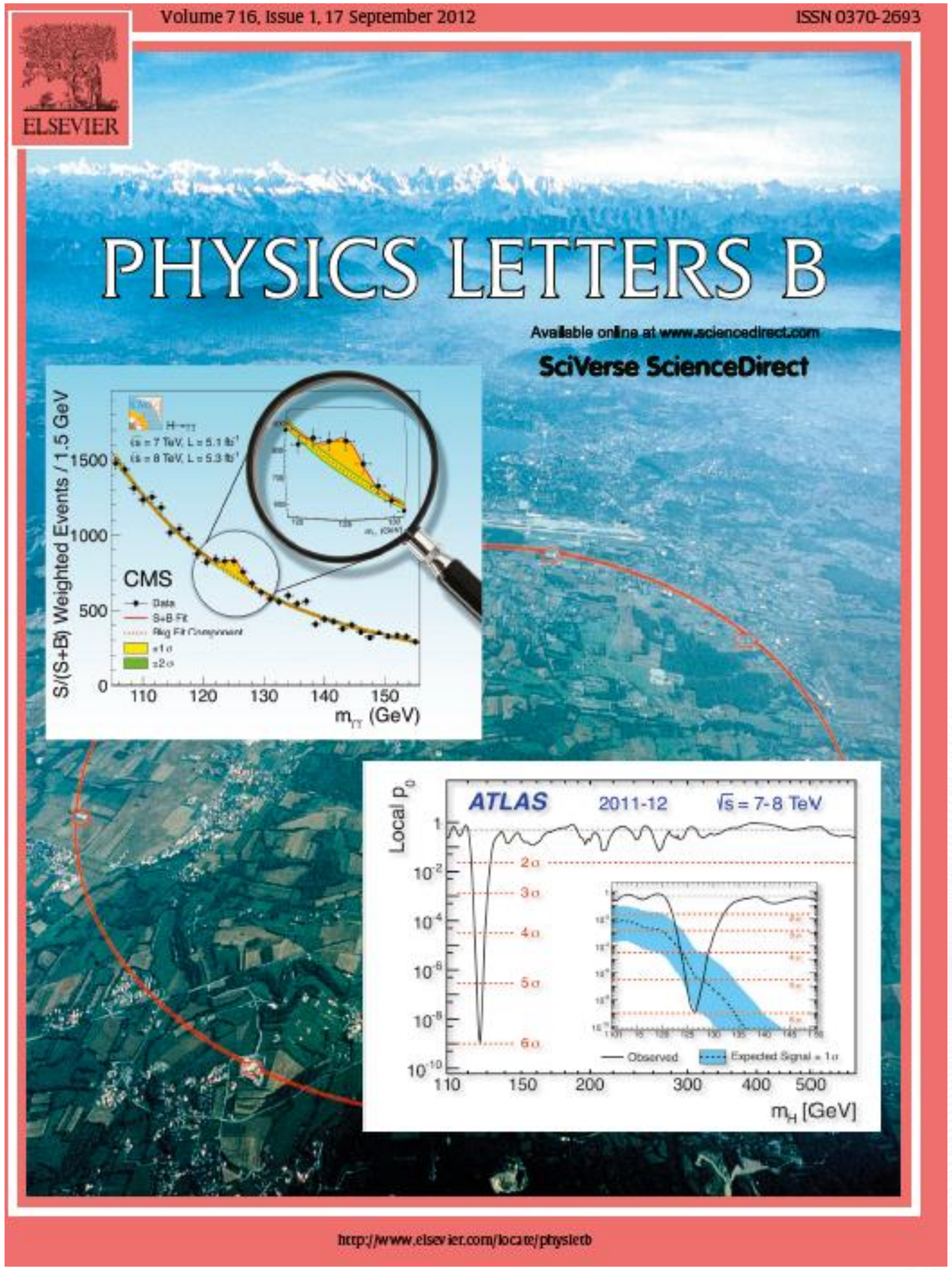
Scheme	Number of bunches	Protons per bunch $[10^{11}]$	$\beta_x^*[\mathrm{cm}]/\beta_y^*[\mathrm{cm}]/$ half crossing angle $[\mu\mathrm{rad}]$	Emittance $[\mu\mathrm{m}]$	Peak luminosity	Iile-up	Int. lumi fb^{-1}
25 ns	2760	1.15	55/43/189	3.75	9.3e33	25	24
25 ns BCMS	2520	1.15	45/43/149	1.9	1.7e34	52	45
50 ns	1380	1.6	42/43/136	2.3	1.6e34 level to 0.8e34	87 level to 44	40
50 ns BCMS	1260	1.6	38/43/115	1.6	2.3e34 level to 0.8e34	138 level to 44	40

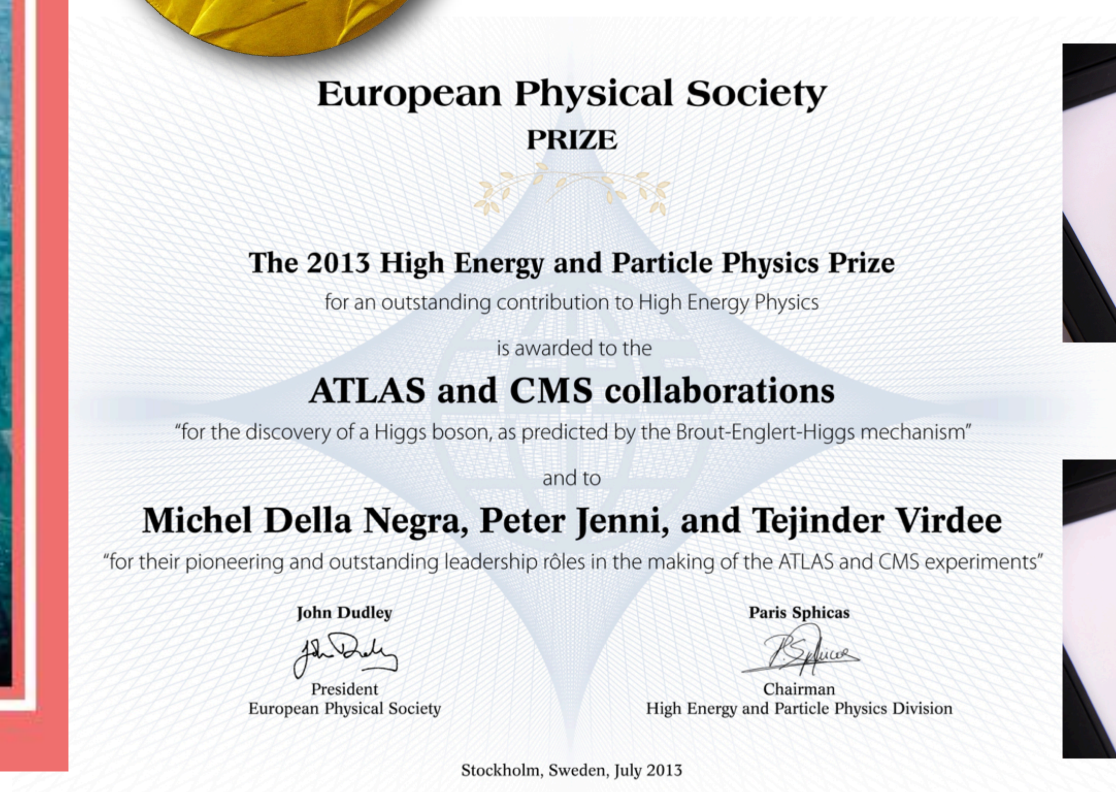


- Target Integrated lumi: 100/fb
- Pileup is a real concern
  - Jet and MET resolution degrades
  - Event reconstruction issues
- Triggers for Higgs and lighter object is a challenge

Higgs Discovery

Discovery





European Physical Society
PRIZE

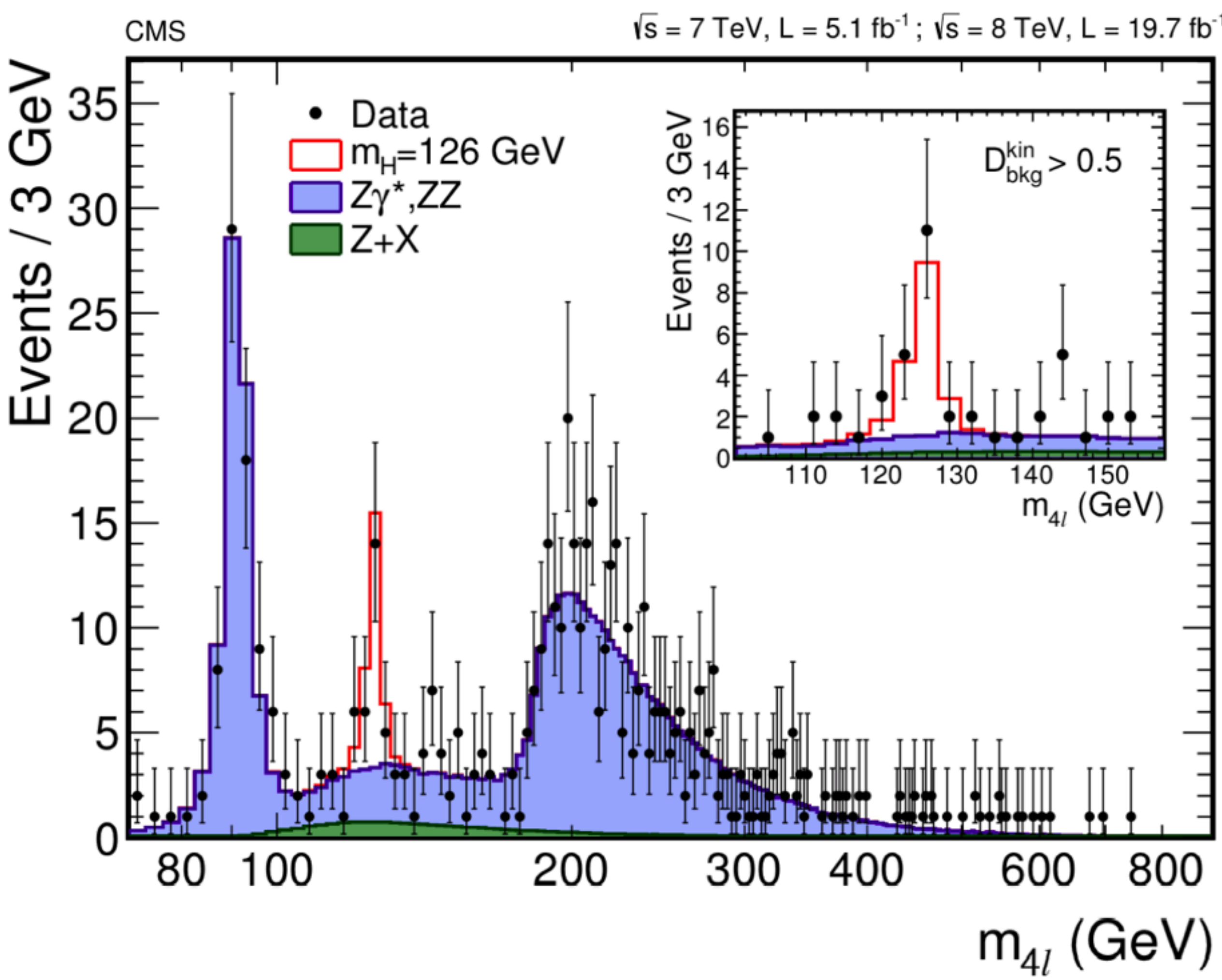
The 2013 High Energy and Particle Physics Prize
for an outstanding contribution to High Energy Physics
is awarded to the
ATLAS and CMS collaborations
"for the discovery of a Higgs boson, as predicted by the Brout-Englert-Higgs mechanism"
and to
Michel Della Negra, Peter Jenni, and Tejinder Virdee
"for their pioneering and outstanding leadership rôles in the making of the ATLAS and CMS experiments"

John Dudley
President
European Physical Society

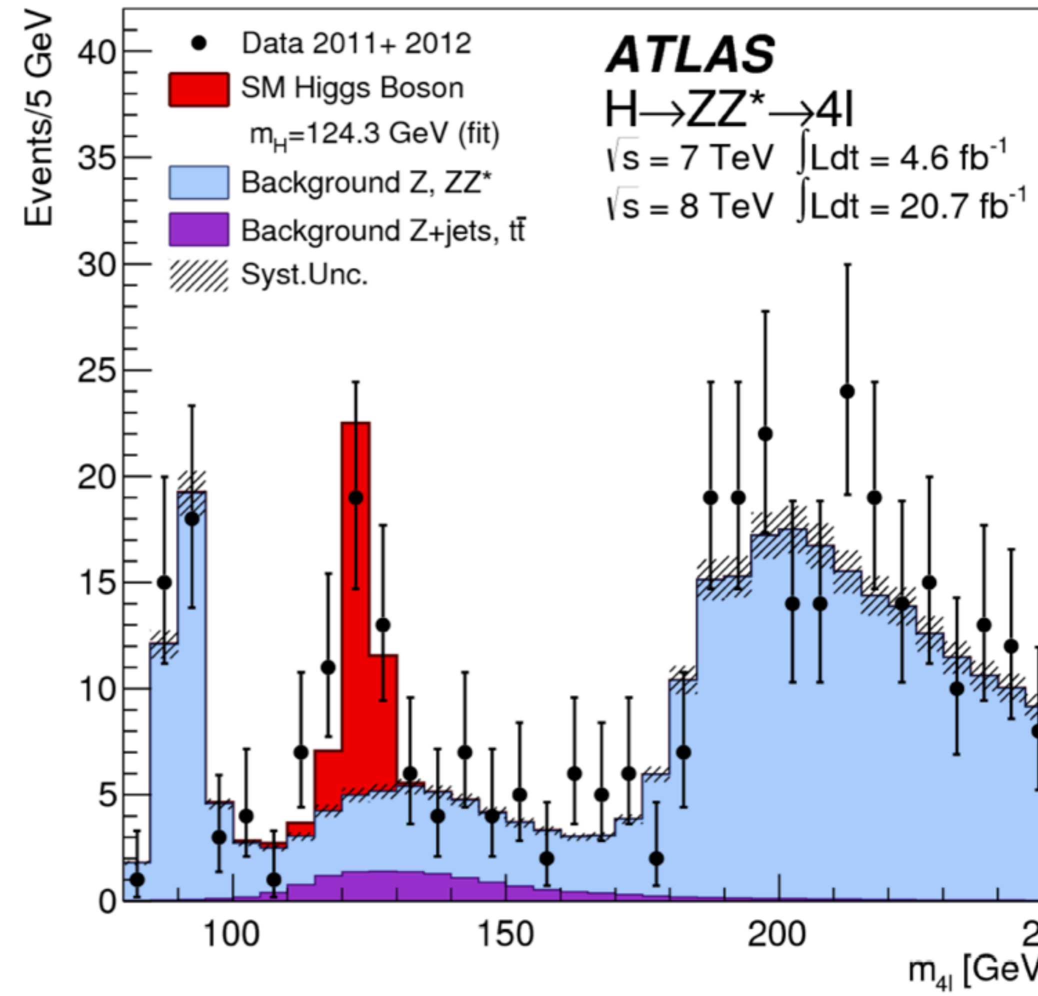
Paris Sphicas
Chairman
High Energy and Particle Physics Division

Stockholm, Sweden, July 2013

Signal is Solid



arXiv:1312.5353



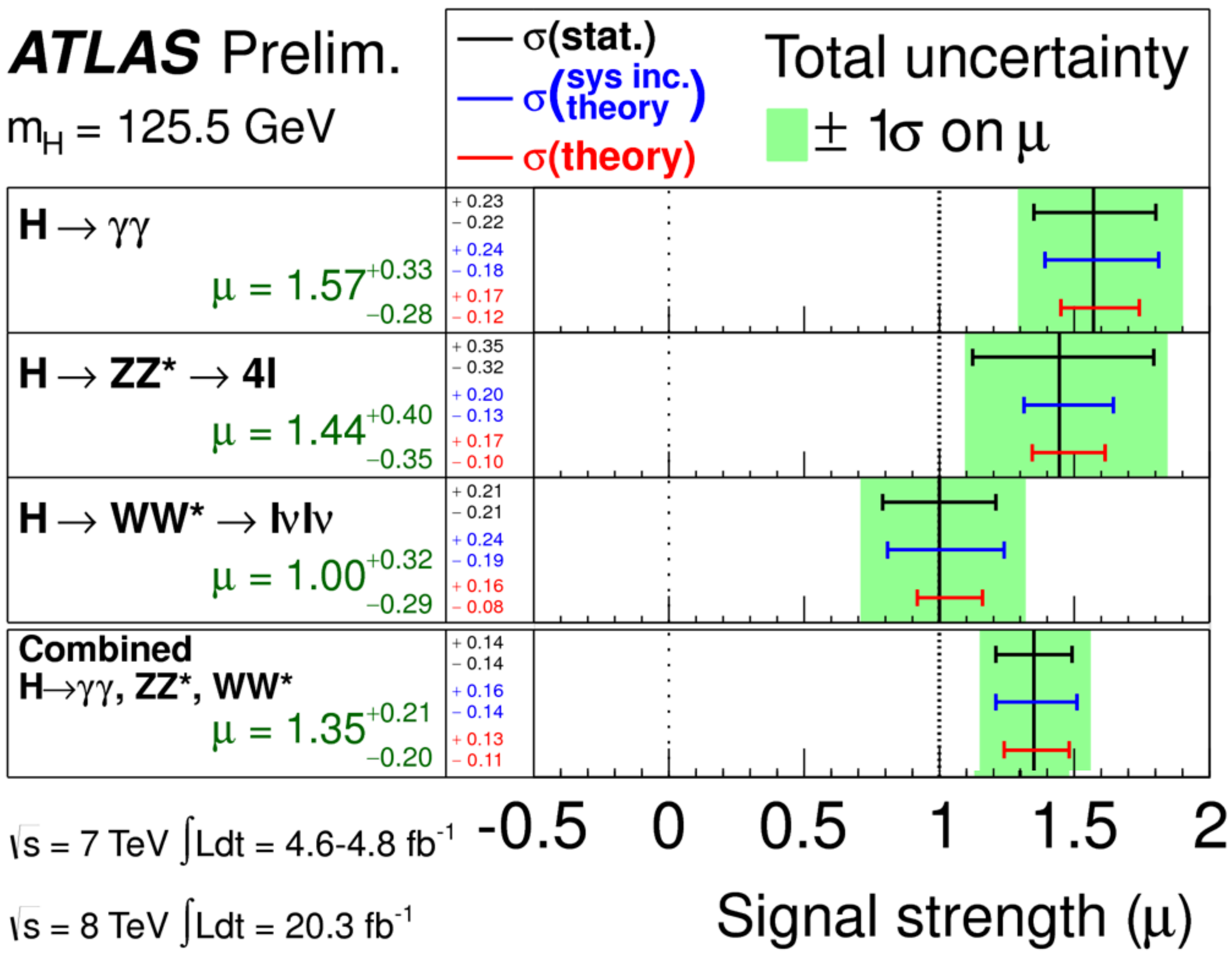
PLB 726 (2013), 88-119

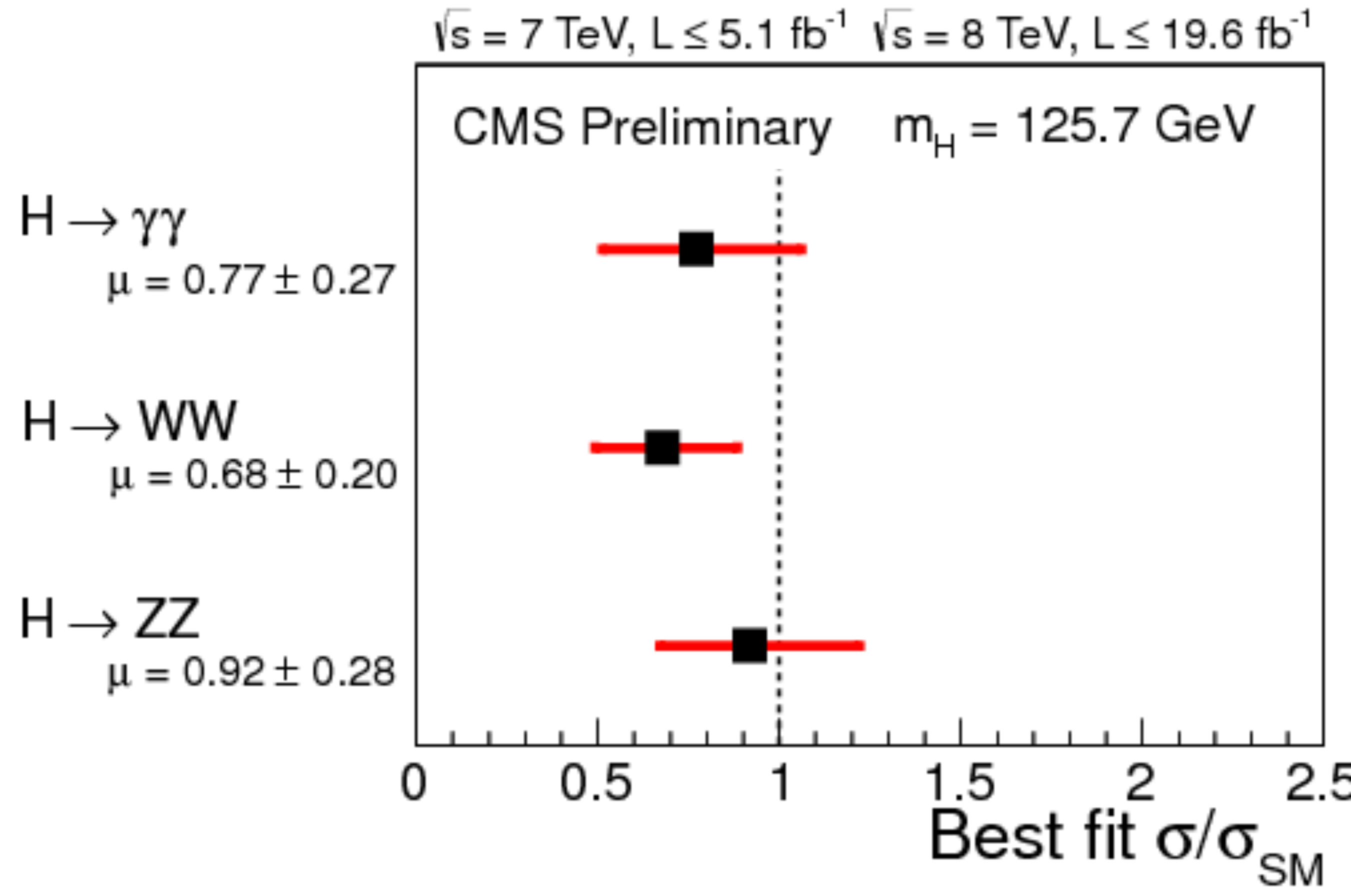
H→ZZ→4l - golden channel

$$\mathrm{ATLAS}: \mu_{ZZ}(\mathrm{m_H} = 125.5) = 1.44^{+0.40}_{-0.35} \qquad \mathrm{ATLAS}: 6.6\sigma(4.4\sigma\mathrm{expected})$$

$$\mathrm{CMS}: \mu_{ZZ}(\mathrm{m_H} = 125.6) = 0.93^{+0.29}_{-0.25} \qquad \mathrm{CMS}: 6.8\sigma(6.7\sigma\mathrm{expected})$$

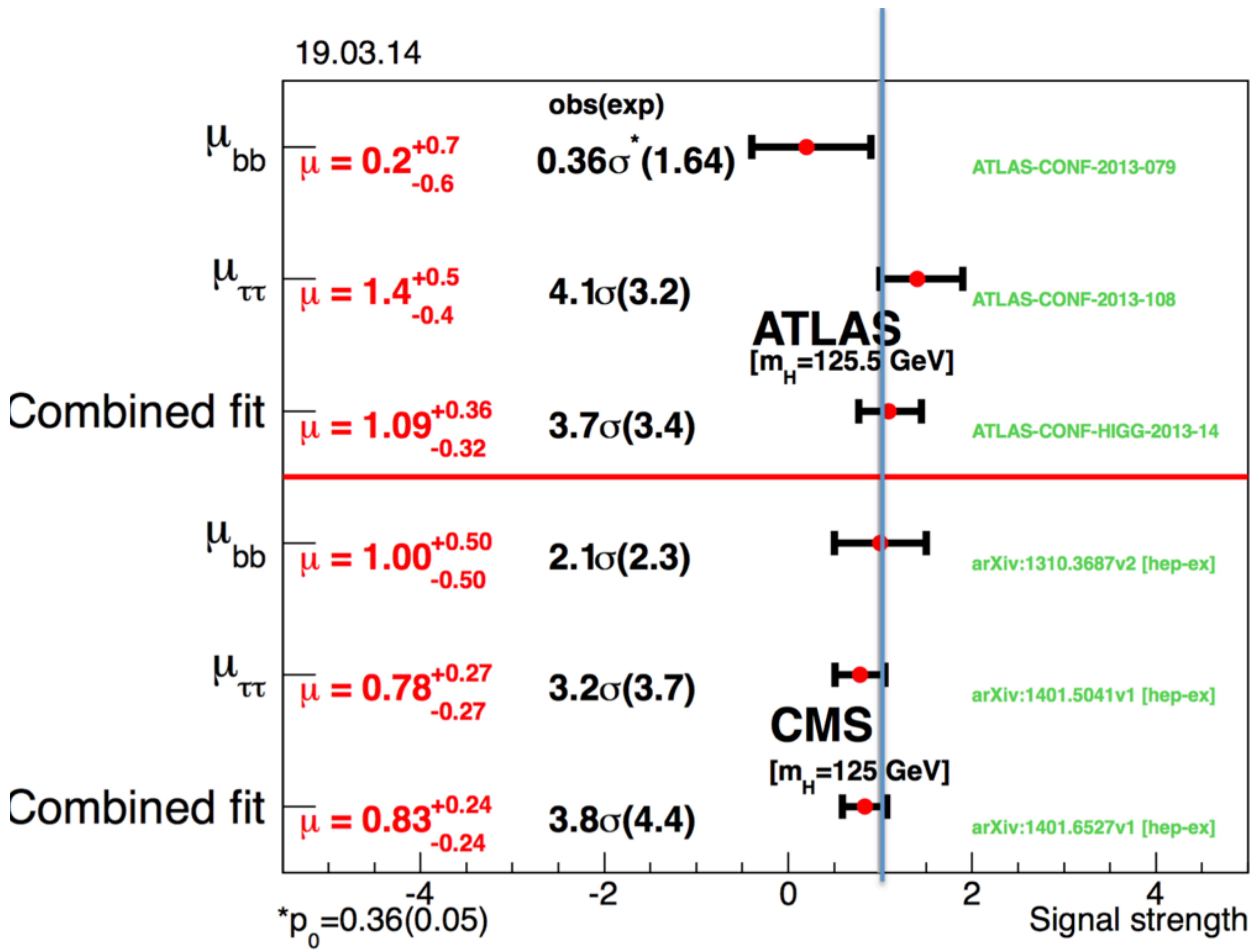
Higgs to VV

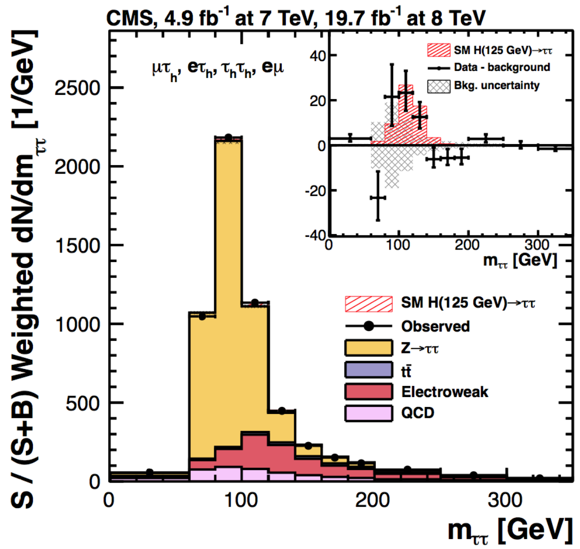


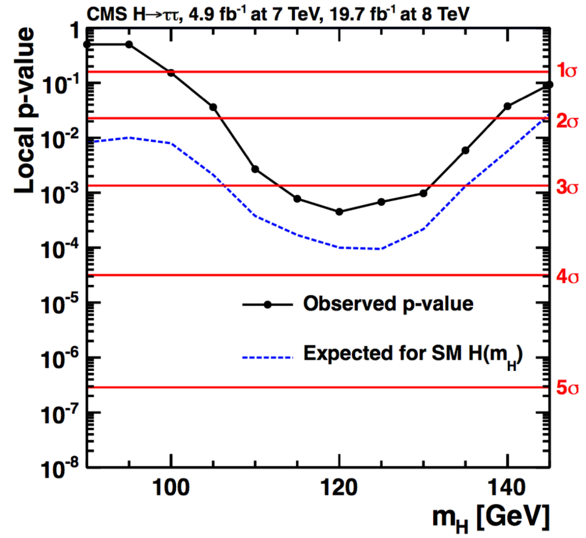


- Main decay channels: ZZ, WW, γγ
- Signal present in all of them - consistent with SM

Fermionic decay channels



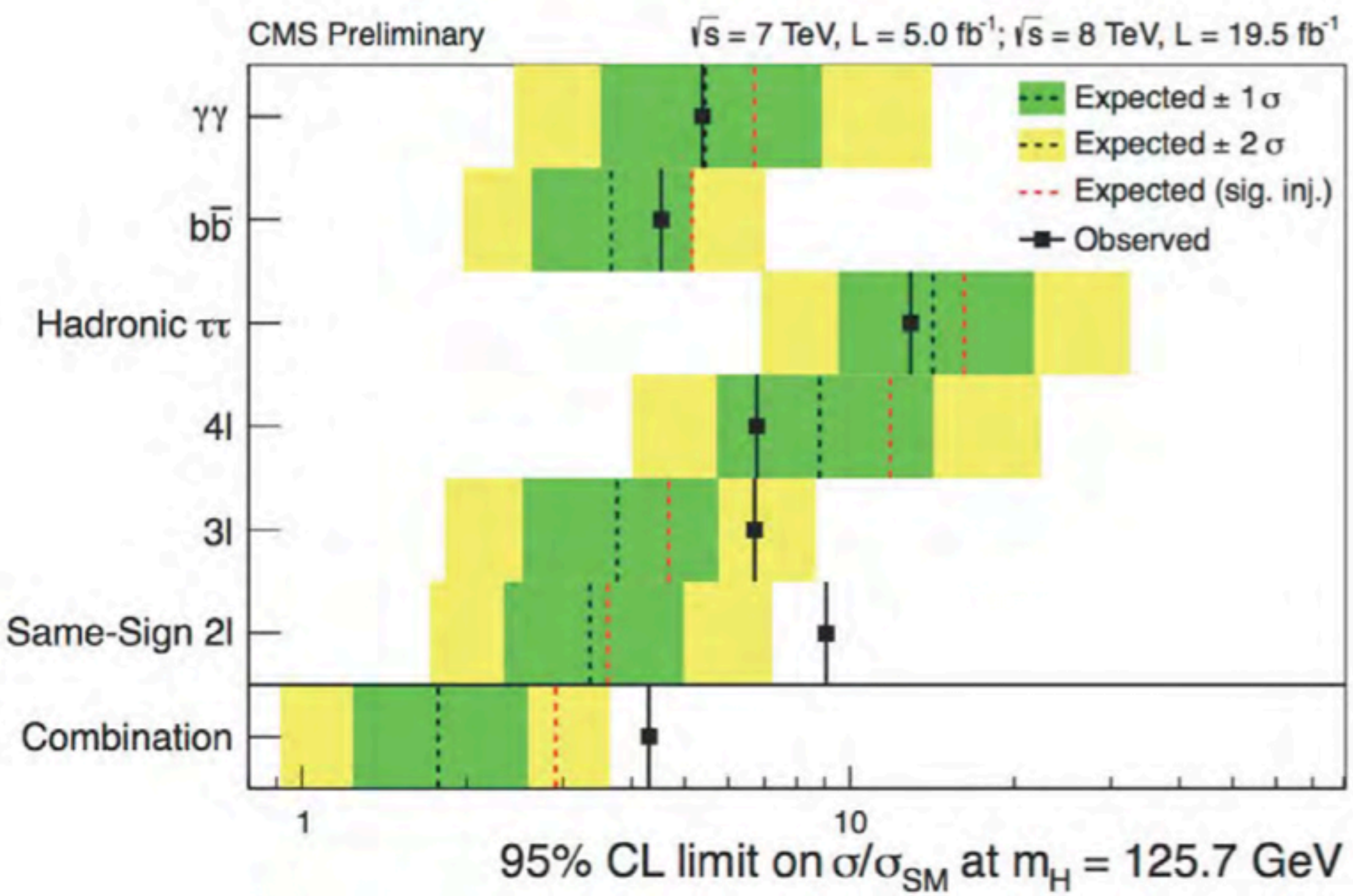




- H→ττ more than 5σ significance if combine ATLAS and CMS
- First hints of H→bb - need more data

CMS ttH

- **CMS has performed a search in ttbar+H; H -> $\gamma\gamma$, bb, $\tau_h\tau_h$, leptonic (2l SS, 3l, 4l), and combined**
- **Result is limit of μ = 4.3 (expected 2.9) 95% CL. Best fit value is μ = 2.5 + 1.1 – 1.0 (excess all in 2l SS).**



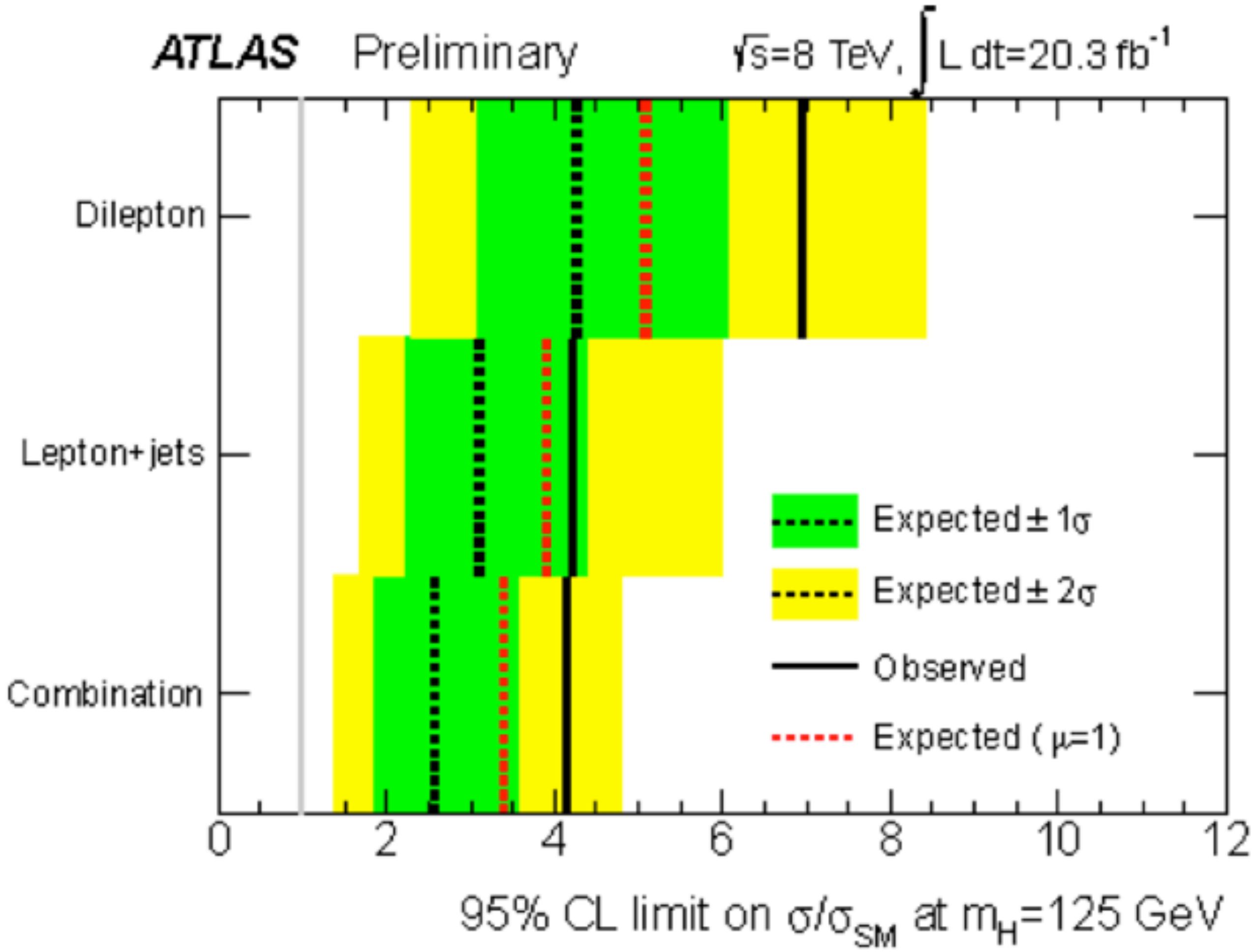
Internal consistency for common value is 22%.

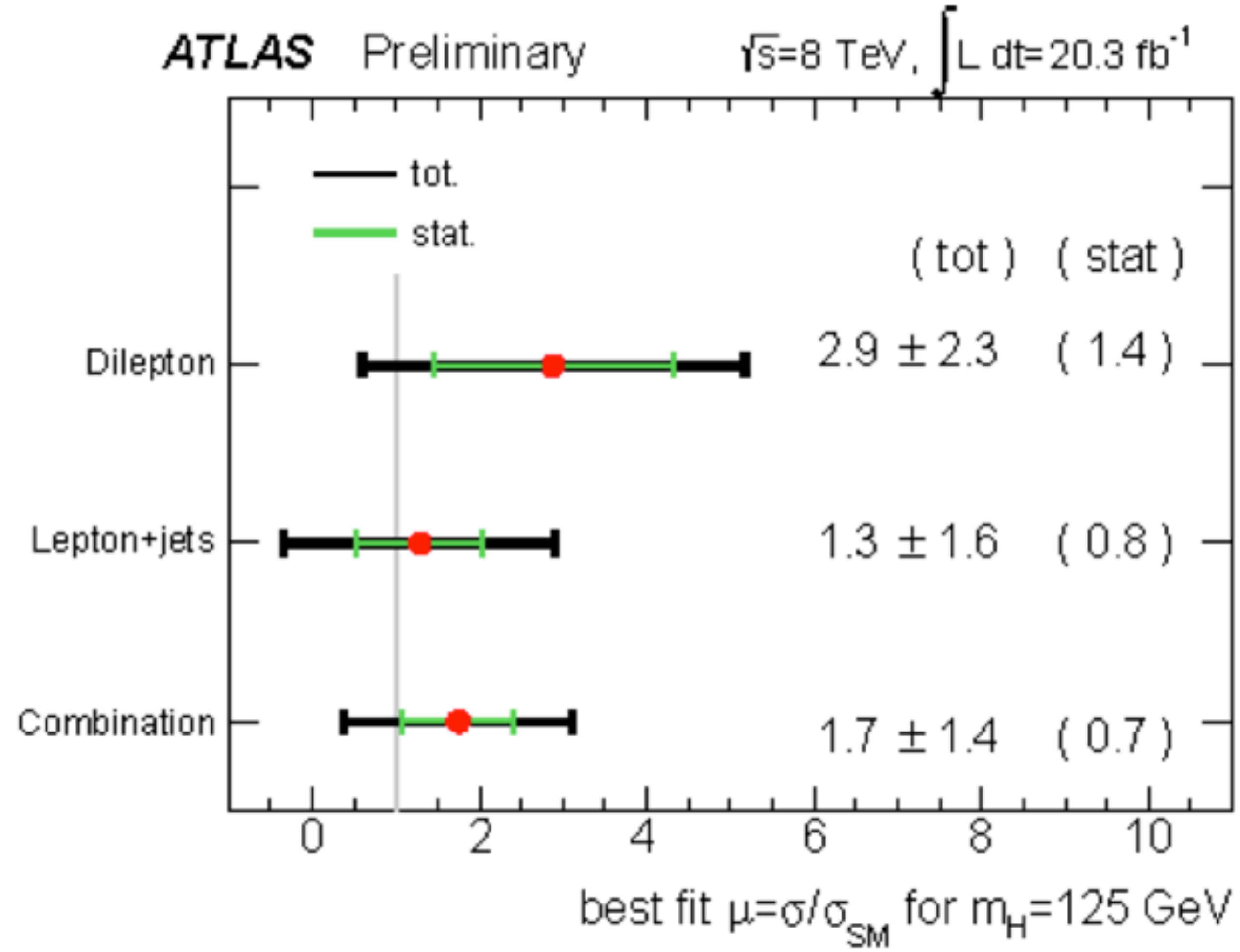
P-value for μ = 1 is 1.6σ

Note: ttbarH increases by almost 5 for Run2 @ 13 TeV

ATLAS ttH

- ATLAS has performed a search in ttbar+H; H -> $\gamma\gamma$. Observed limit of μ = 4.7 (5.4 expected). Leptonic (2l, 3l, 4l, $\tau\tau$) modes in progress
- New analysis in ttbar+H; H -> bb. Result is limit of μ = 4.1 (expected 2.6) 95% CL. Best fit value is μ = 1.7 +/- 1.4

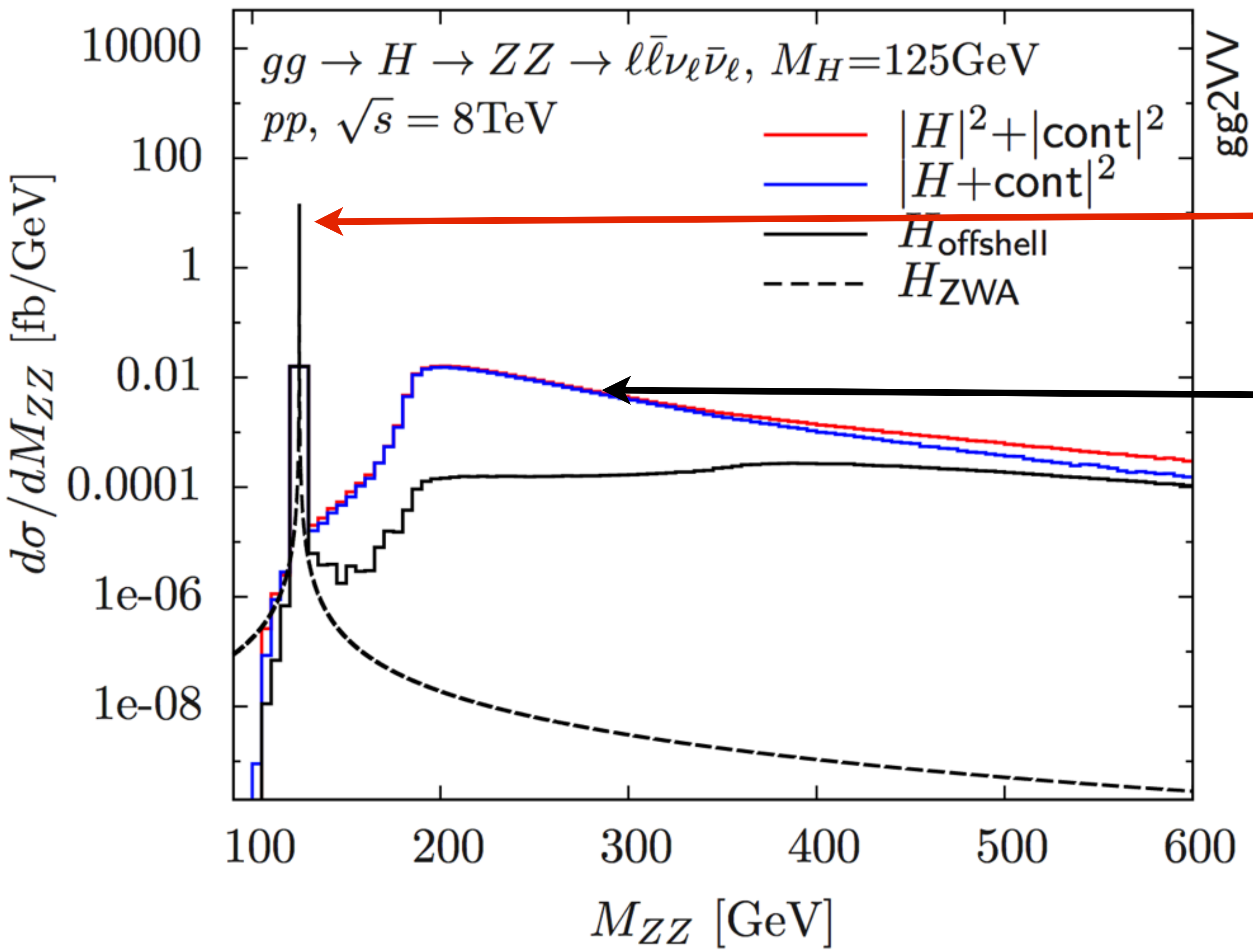




Higgs Properties

Higgs Widths

N. Kauer and G. Passarino, JHEP 08 (2012) 116



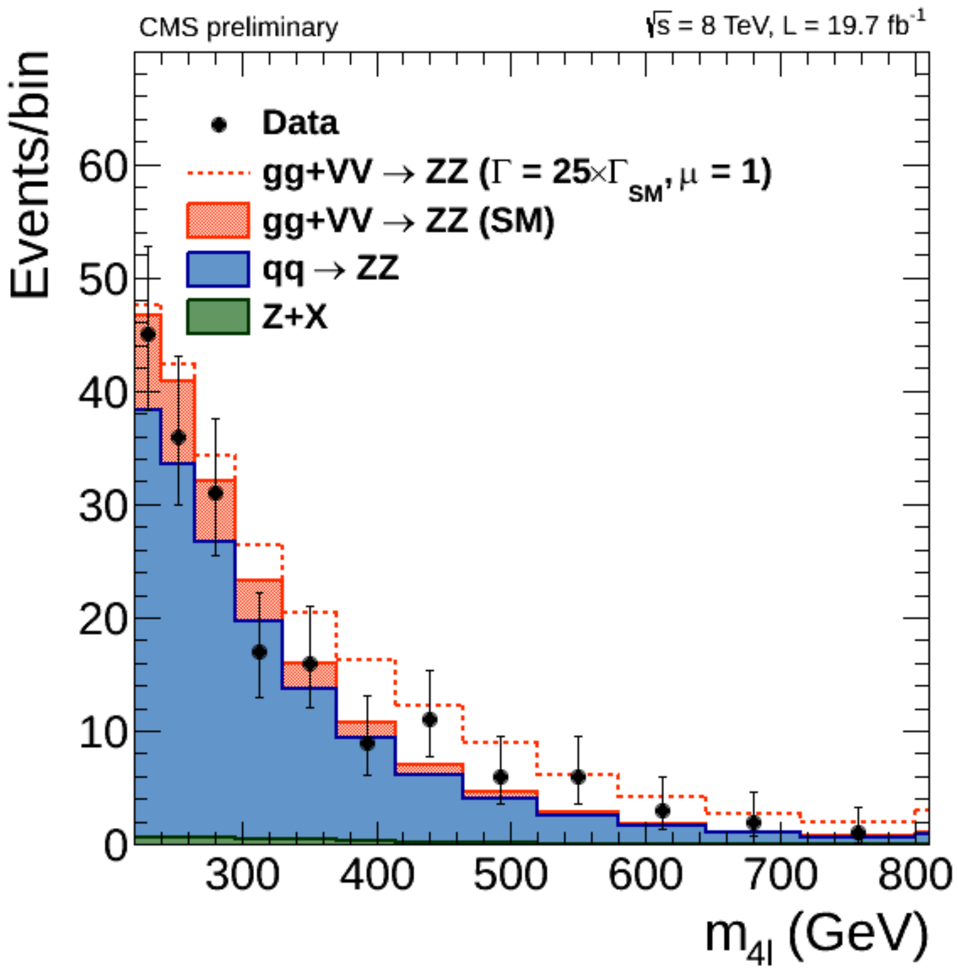
$$\sigma_{\text{on-peak}} \propto \frac{g^2_{ggH} g^2_{HZZ}}{\Gamma_H}$$

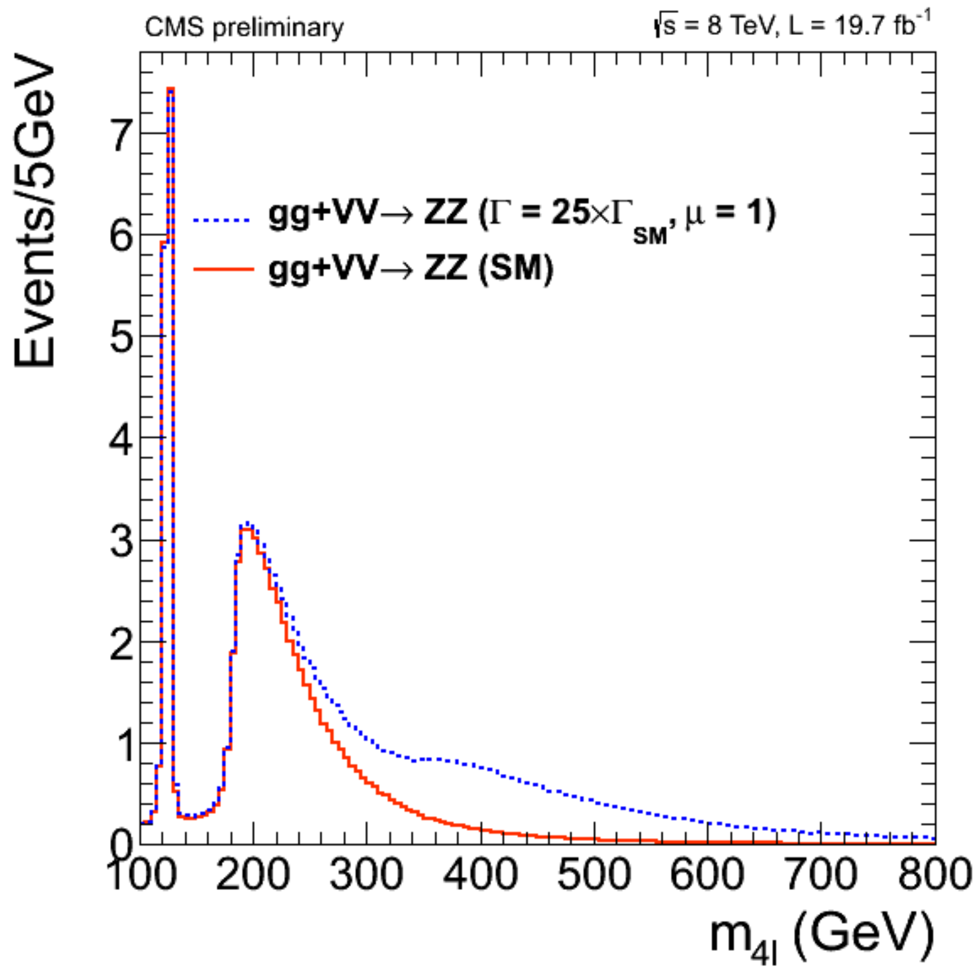
$$\sigma_{\text{off-peak}} \propto g^2_{ggH} g^2_{HZZ}$$

- Direct limit on Higgs width:
  - 3.4GeV @ 95%C.L
- About 7.6% of total cross-section in the ZZ final state, but can be enhanced by experimental cuts

	Tot[pb]	$M_{ZZ} > 2\,M_Z$[pb]	R[%]
$gg \to H \to$ all	19.146	0.1525	0.8
$gg \to H \to ZZ$	0.5462	0.0416	7.6

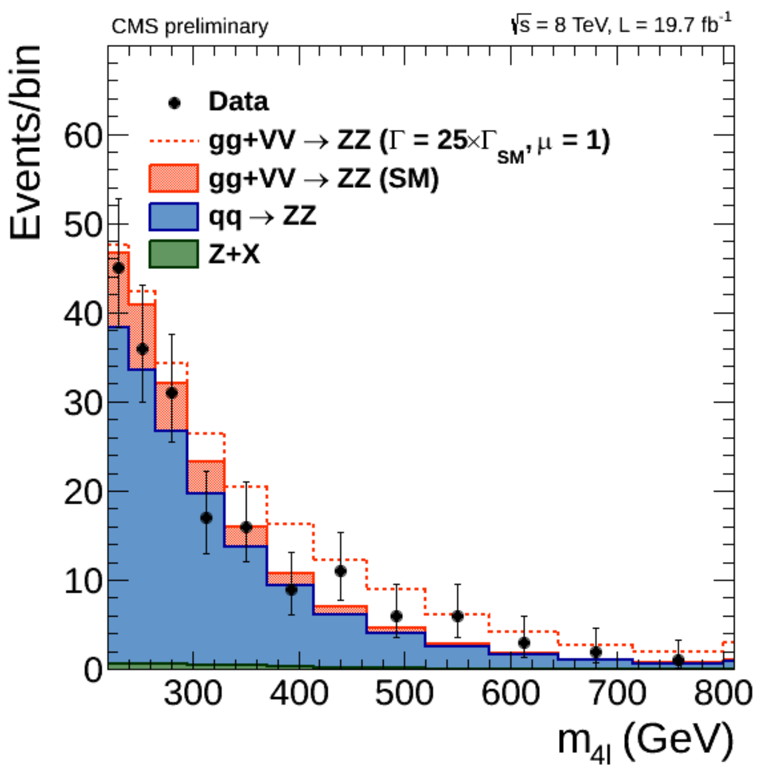
Analysis Strategy



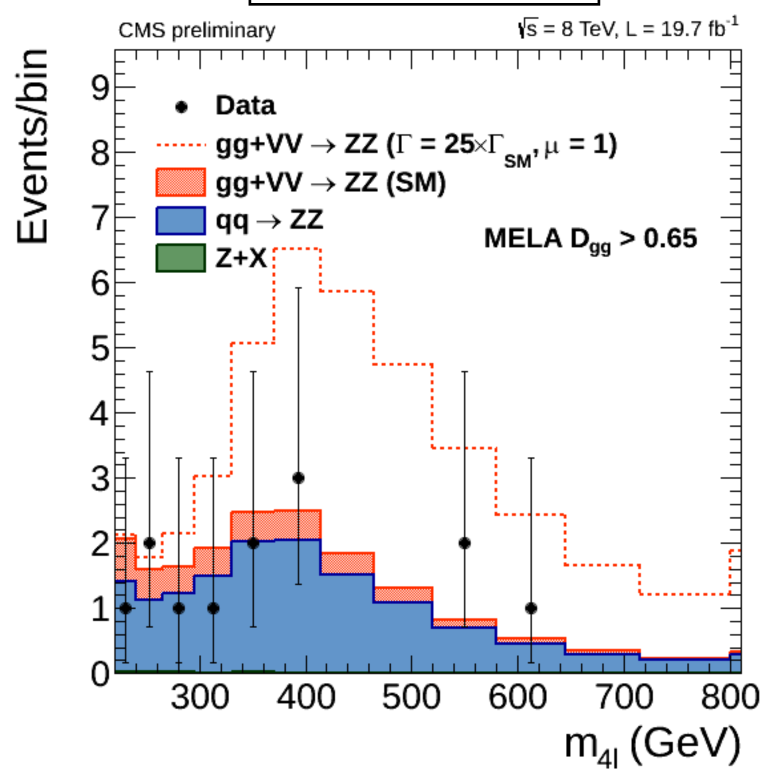


- On-peak cross-section - Standard Higgs analysis
- Off-peak component predicts a broad excess at larger mass
  - ZZ has best sensitivity in this region
- Closer to the peak backgrounds are getting larger and more complex to measure a broad excess
- Dominant background is qq→ZZ

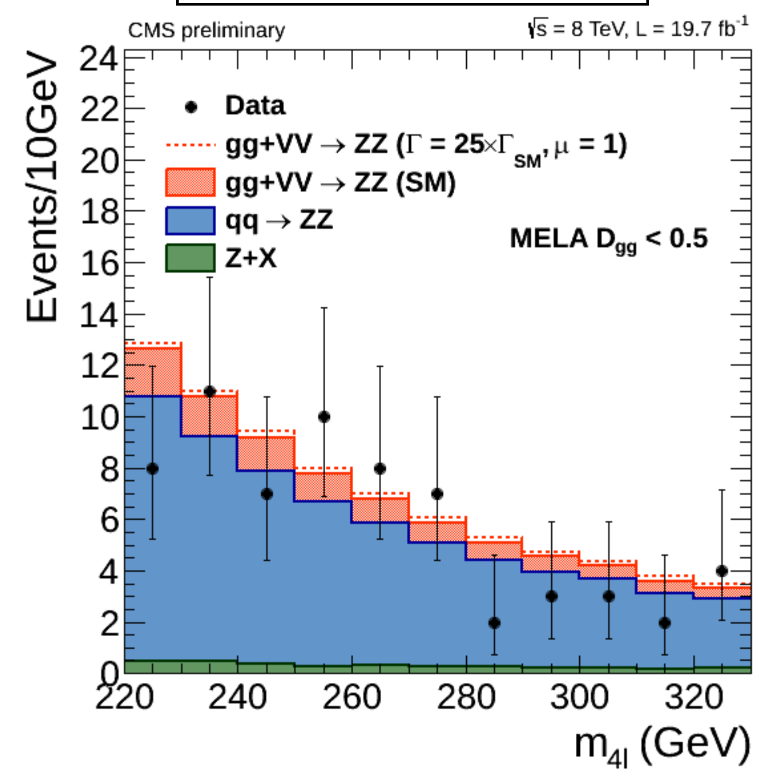
Channels and Methods

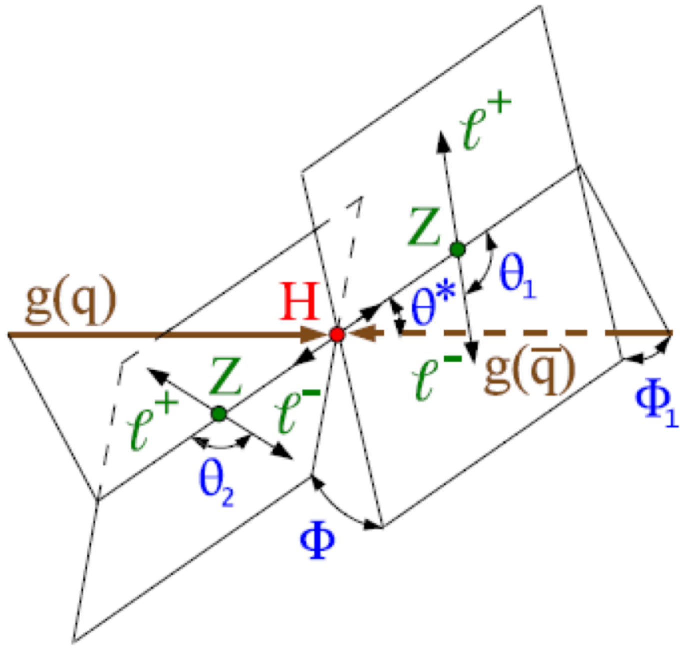


Signal Enhanced



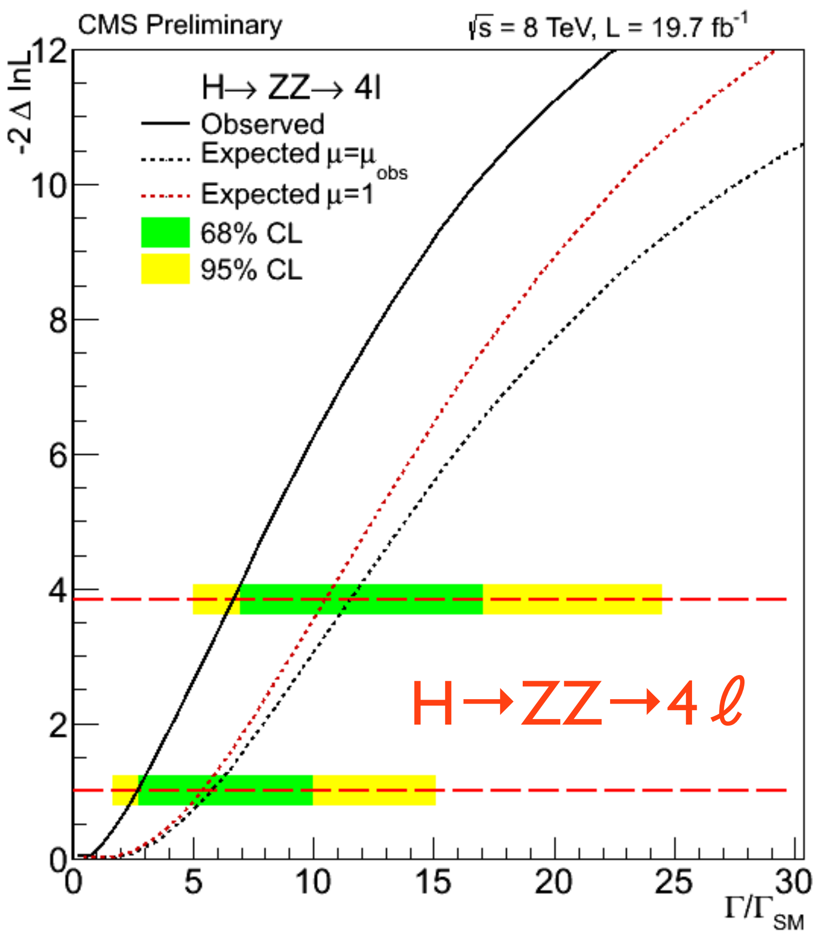
Background Enhanced

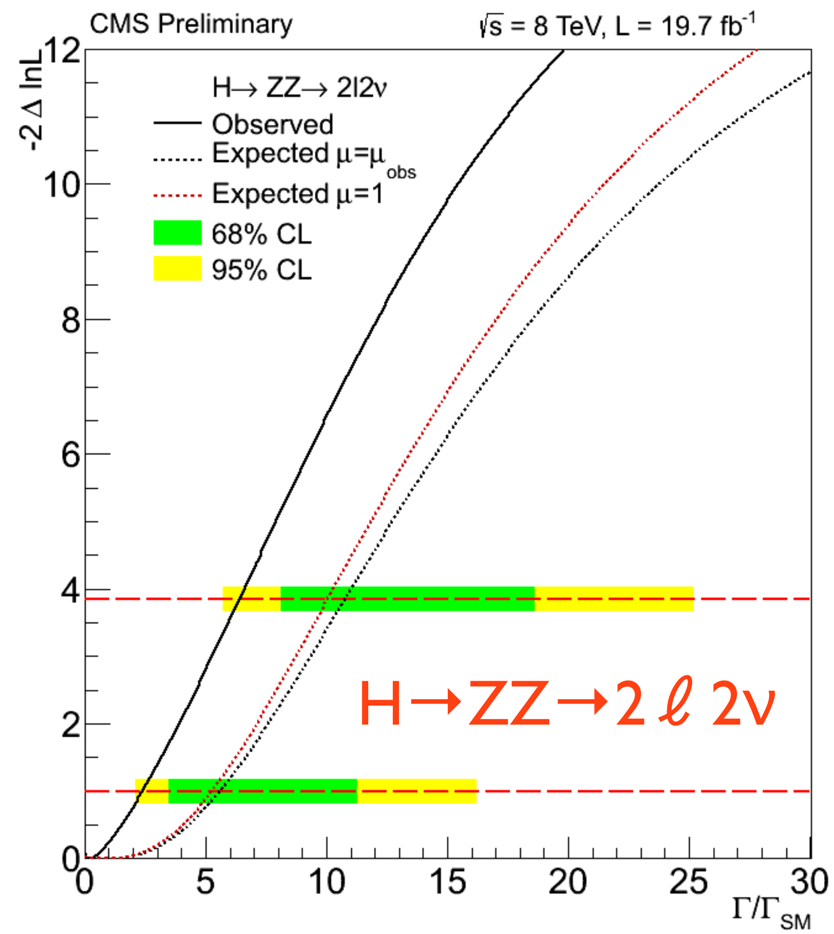


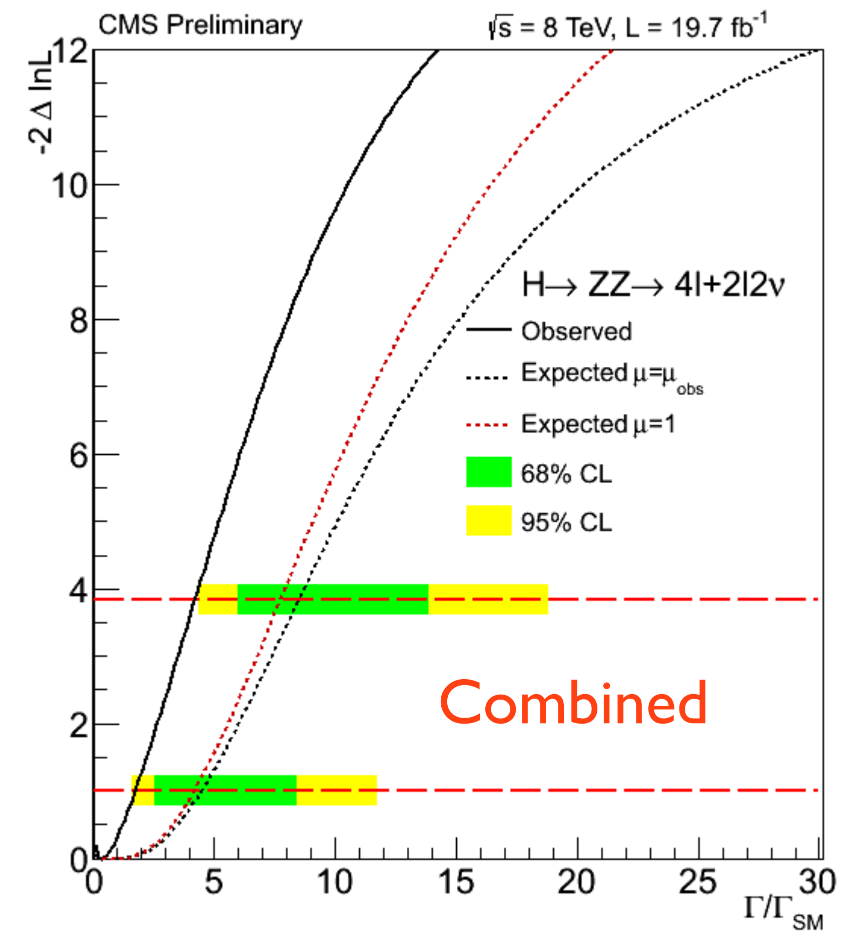


- $H \to ZZ \to 4\ell$ uses special discriminator:
  - MELA (matrix element with mZ1, mZ2 and 5 angles)
- $H \to ZZ \to 2\ell 2\nu$

Results

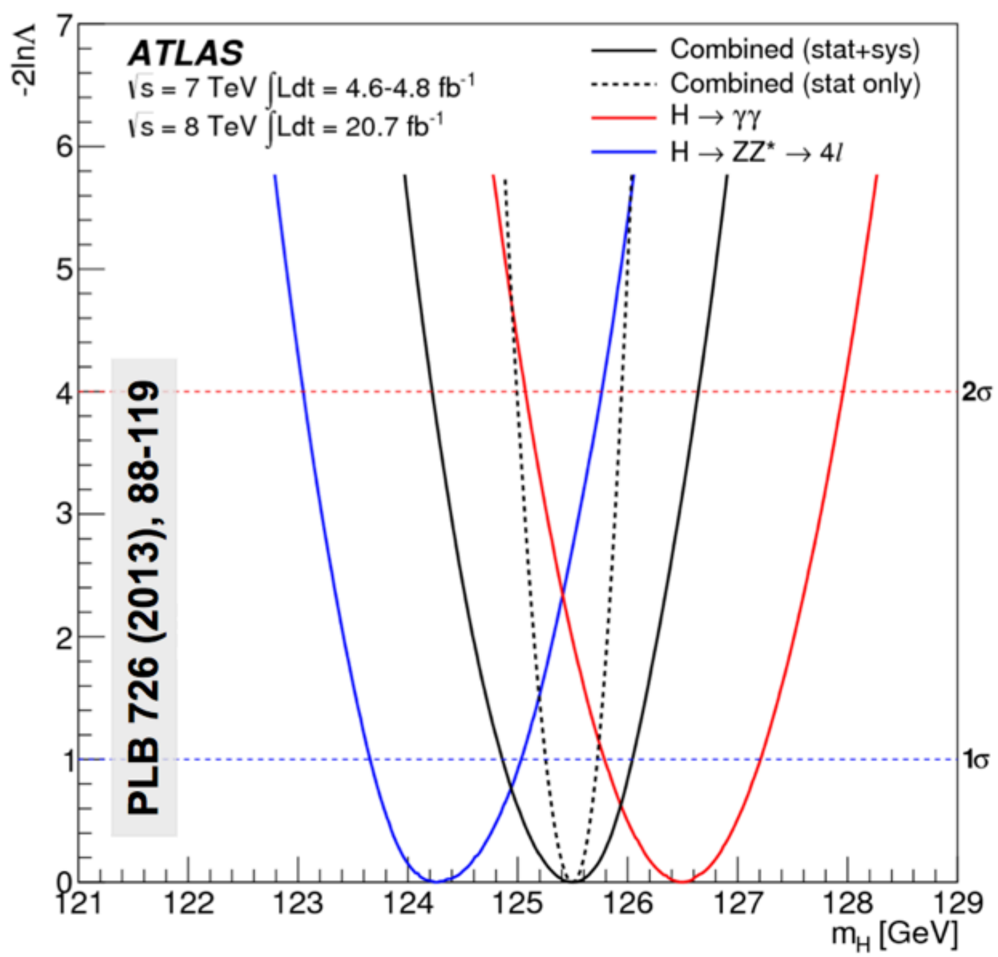


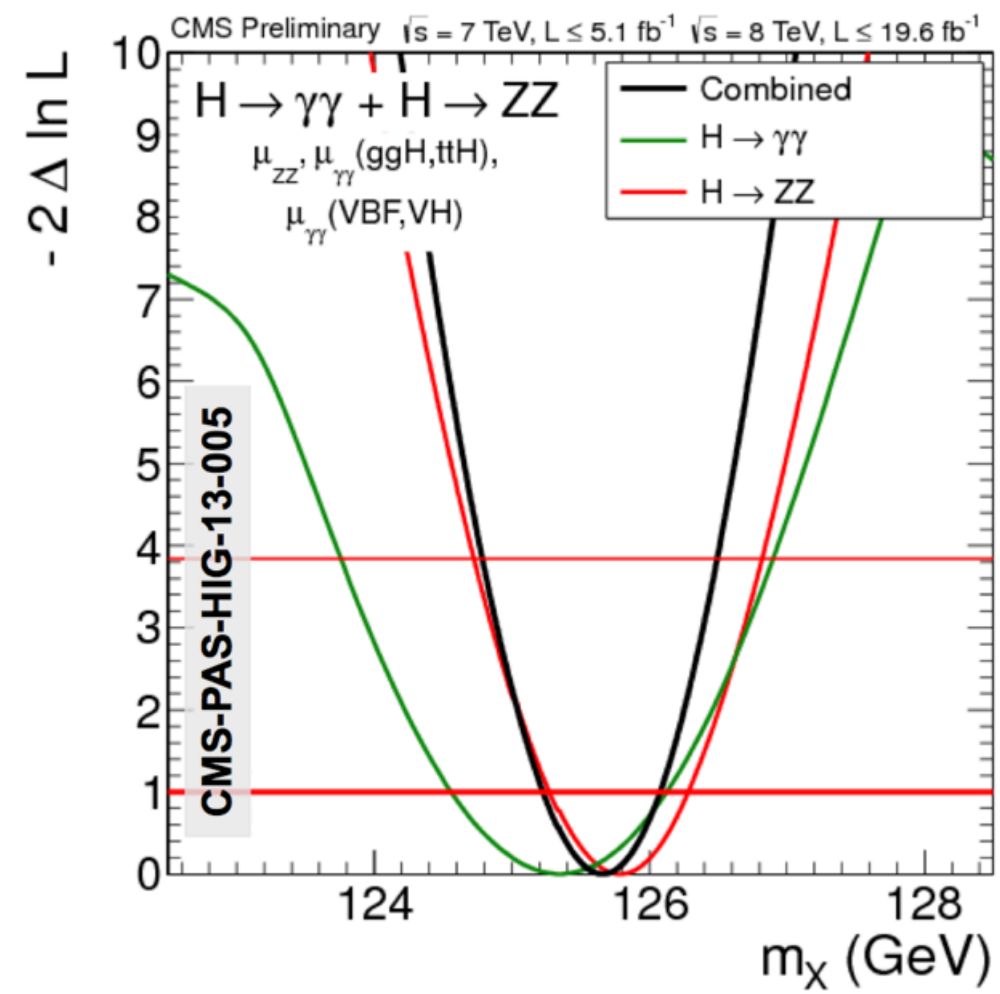




	4ℓ	$2\ell 2\nu$	Combined
Expected 95% CL limit, r	11.5	10.7	8.5
Observed 95% CL limit, r	6.6	6.4	4.2
Observed 95% CL limit, Γ_{H} (MeV)	27.4	26.6	17.4
Observed best fit, r	$0.5\,^{+2.3}_{-0.5}$	$0.2\,^{+2.2}_{-0.2}$	$0.3\,^{+1.5}_{-0.3}$
Observed best fit, Γ_{H} (MeV)	$2.0\,^{+9.6}_{-2.0}$	$0.8\,^{+9.1}_{-0.8}$	$1.4\,^{+6.1}_{-1.4}$

Higgs Mass

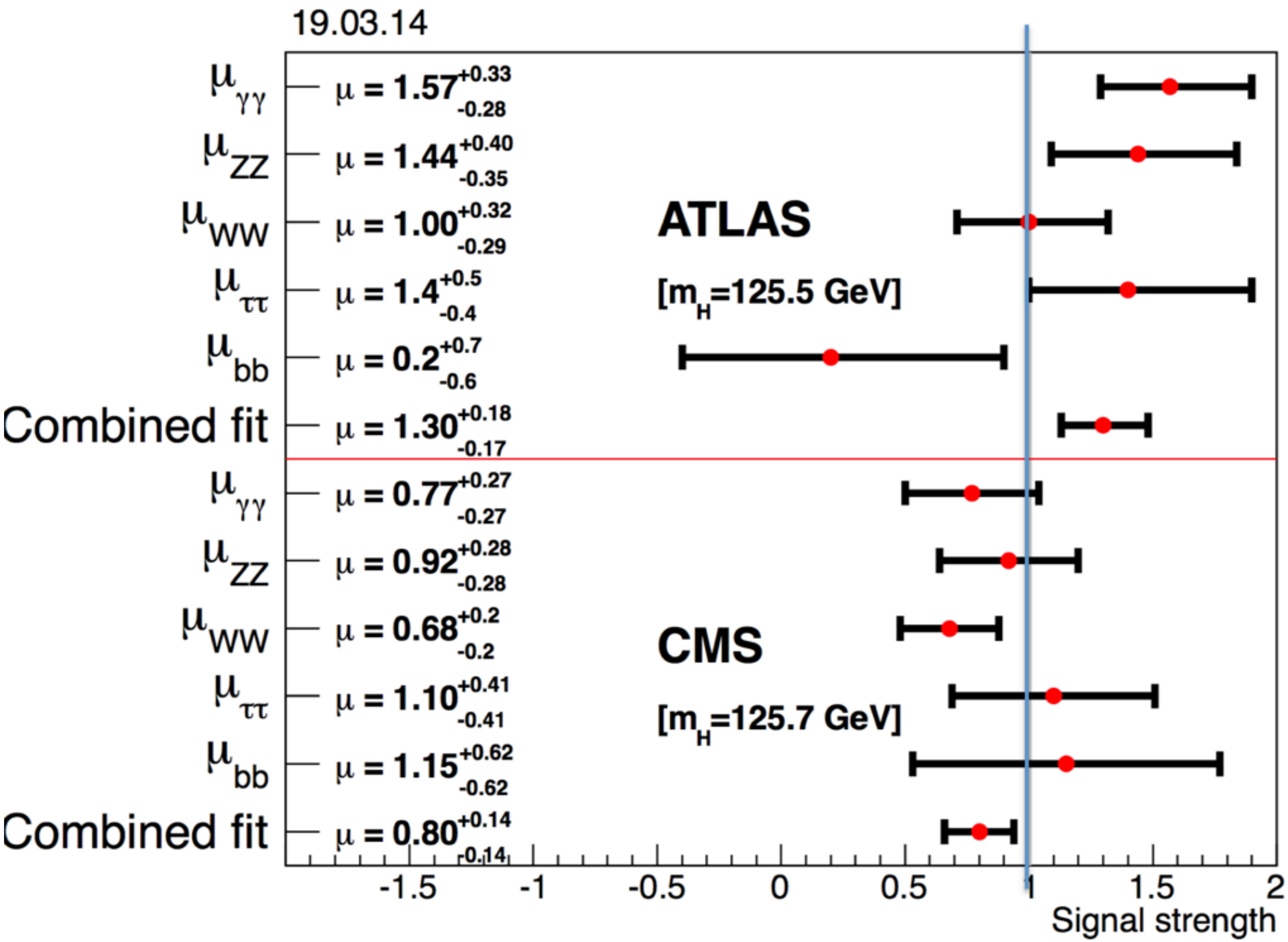




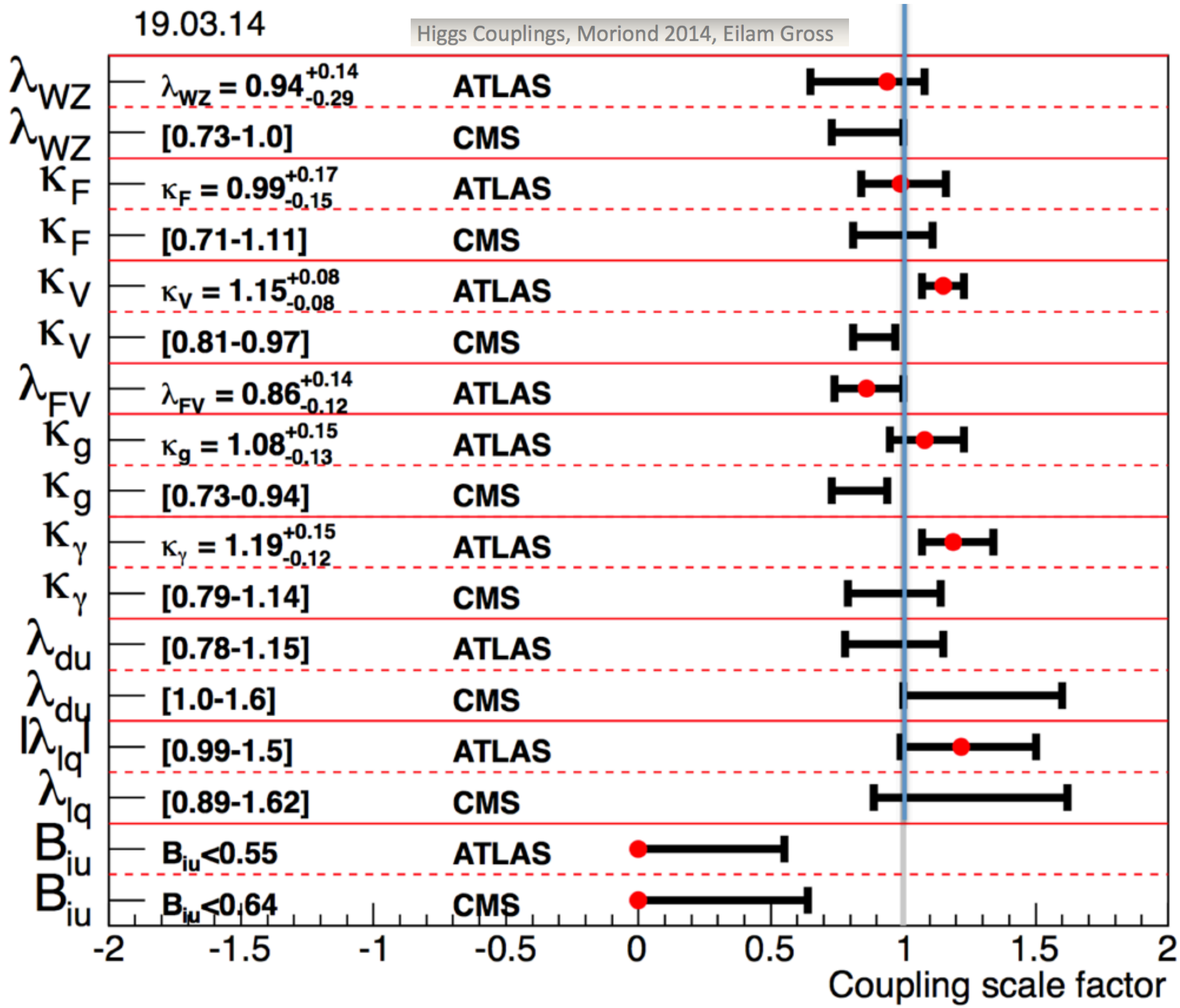
ATLAS	CMS (new ZZ(4l) not used)
125.5 +-0.2 (stat) $^{+0.5}_{-0.6}$(syst) GeV	125.7 +- 0.3(stat) +- 0.3(syst) GeV

- ATLAS measures somewhat different mass in $H \to ZZ \to 4\ell$ vs $H \to \gamma\gamma$
  - The difference is not statistically significant
- Both ATLAS and CMS combined results are fully consistent

Relative Cross-section

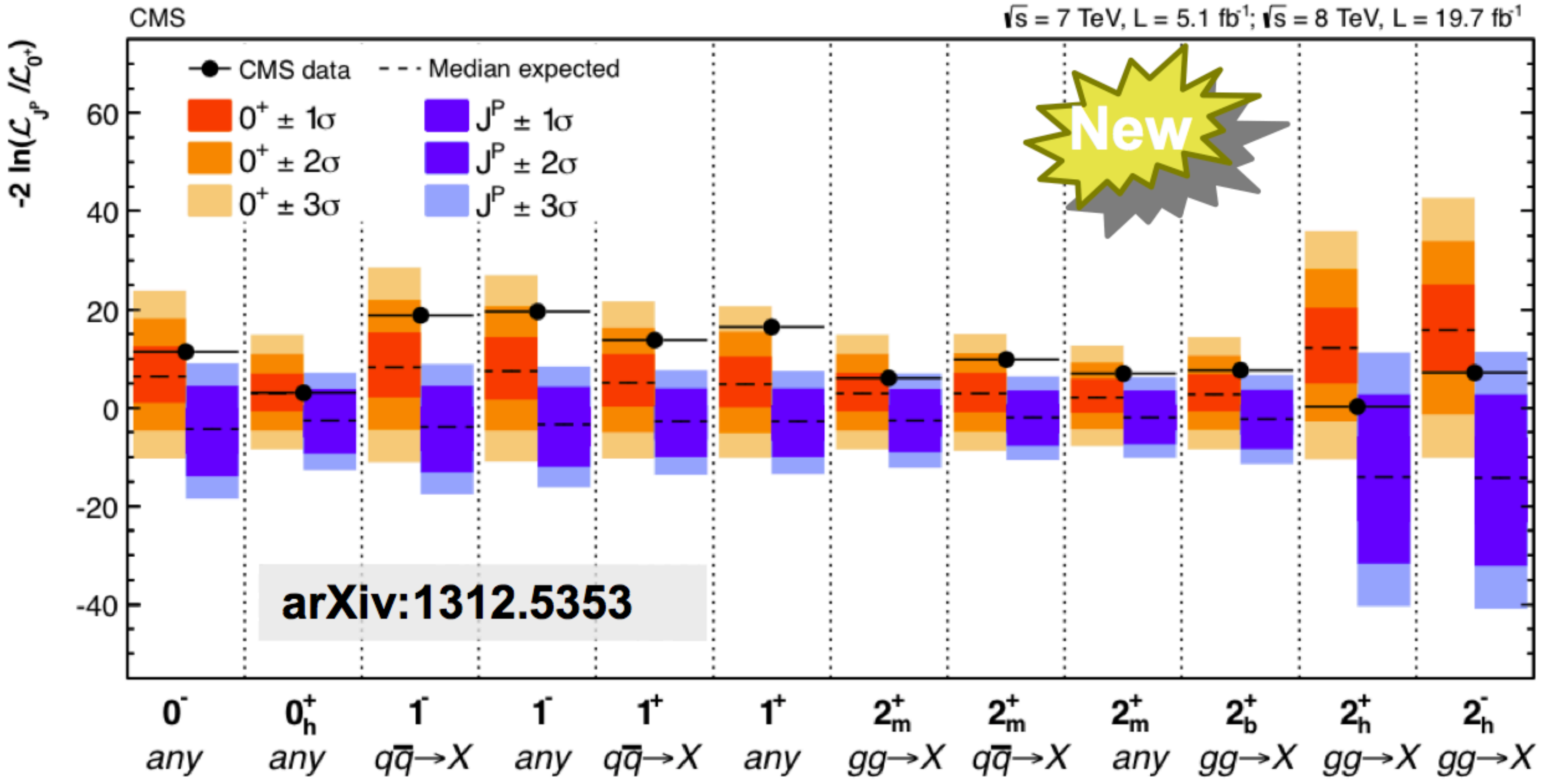


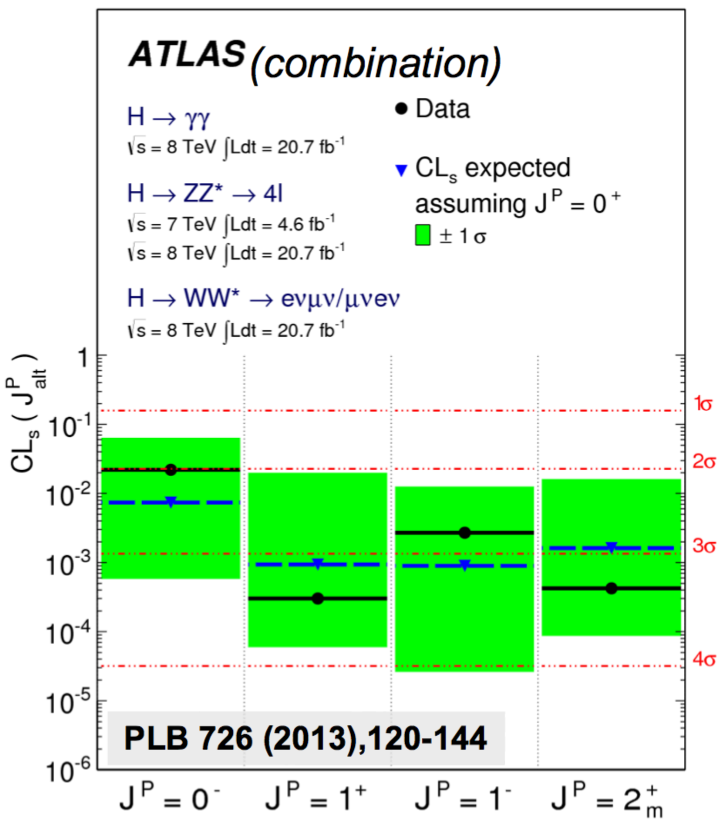
Couplings



19.03.14
Higgs Couplings, Moriond 2014, Eilam Gross
λ_{WZ} | $\lambda_{WZ} = 0.94^{+0.14}_{-0.29}$ | ATLAS
λ_{WZ} | [0.73-1.0] | CMS
κ_F | $\kappa_F = 0.99^{+0.17}_{-0.15}$ | ATLAS
κ_F | [0.71-1.11] | CMS
κ_V | $\kappa_V = 1.15^{+0.08}_{-0.08}$ | ATLAS
κ_V | [0.81-0.97] | CMS
λ_{FV} | $\lambda_{FV} = 0.86^{+0.14}_{-0.12}$ | ATLAS
κ_g | $\kappa_g = 1.08^{+0.15}_{-0.13}$ | ATLAS
κ_g | [0.73-0.94] | CMS
κ_γ | $\kappa_\gamma = 1.19^{+0.15}_{-0.12}$ | ATLAS
κ_γ | [0.79-1.14] | CMS
λ_{du} | [0.78-1.15] | ATLAS
λ_{du} | [1.0-1.6] | CMS
$|\lambda_{lq}|$ | [0.99-1.5] | ATLAS
λ_{lq} | [0.89-1.62] | CMS
B_{iu} | B_{iu}<0.55 | ATLAS
B_{iu} | B_{iu}<0.64 | CMS
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Coupling scale factor

Spin





- Results are consistent with CP even SM Higgs

La Combinaison

....not just yet..... but it's coming...

	2011 $\sqrt{s}$ =7 TeV	
$H \to \gamma\gamma$	–	
$H \to ZZ^{(*)}$	4ℓ	
$H \to WW^{(*)}$	$\ell\nu\ell\nu$	
$VH \to Vbb$	$Z \to \nu\nu$	E_T^{miss}
	$W \to \ell\nu$	$p_T^W \in$
	$Z \to \ell\ell$	$p_T^Z \in$

new

ATLAS-CONF-2014-009

		2012 $\sqrt{s}$ =8 TeV	
$H \to \gamma\gamma$	–	14 categories: $\{p_{Tt} \otimes \eta_\gamma \otimes$ conversion$\} \oplus$ {loose, tight 2-jet VBF} $\oplus$ {ℓ-tag, E_T^{miss}-tag, 2-jet VH}	20.3
$H \to ZZ^{(*)}$	4ℓ	$\{4e, 2e2\mu, 2\mu 2e, 4\mu$, 2-jet VBF, ℓ-tag}	20.3
$H \to WW^{(*)}$	$\ell\nu\ell\nu$	$\{ee, e\mu, \mu e, \mu\mu\} \otimes$ {0-jet, 1-jet, 2-jet VBF}	20.3
$VH \to Vbb$	$Z \to \nu\nu$	$E_T^{miss} \in \{120-160, 160-200, \geq 200$ GeV$\} \otimes$ {2-jet, 3-jet}	20.3
	$W \to \ell\nu$	$p_T^W \in$ {<90, 90-120, 120-160, 160-200, ≥200 GeV} $\otimes$ {2-jet, 3-jet}	20.3
	$Z \to \ell\ell$	$p_T^Z \in$ {<90, 90-120, 120-160, 160-200, ≥200 GeV} $\otimes$ {2-jet, 3-jet}	20.3
$H \to \tau\tau$	$\tau_{lep}\tau_{lep}$	$\{ee, e\mu, \mu\mu\} \otimes$ {boosted, 2-jet VBF}	20.3
	$\tau_{lep}\tau_{had}$	$\{e, \mu\} \otimes$ {boosted, 2-jet VBF}	20.3
	$\tau_{had}\tau_{had}$	{boosted, 2-jet VBF}	20.3

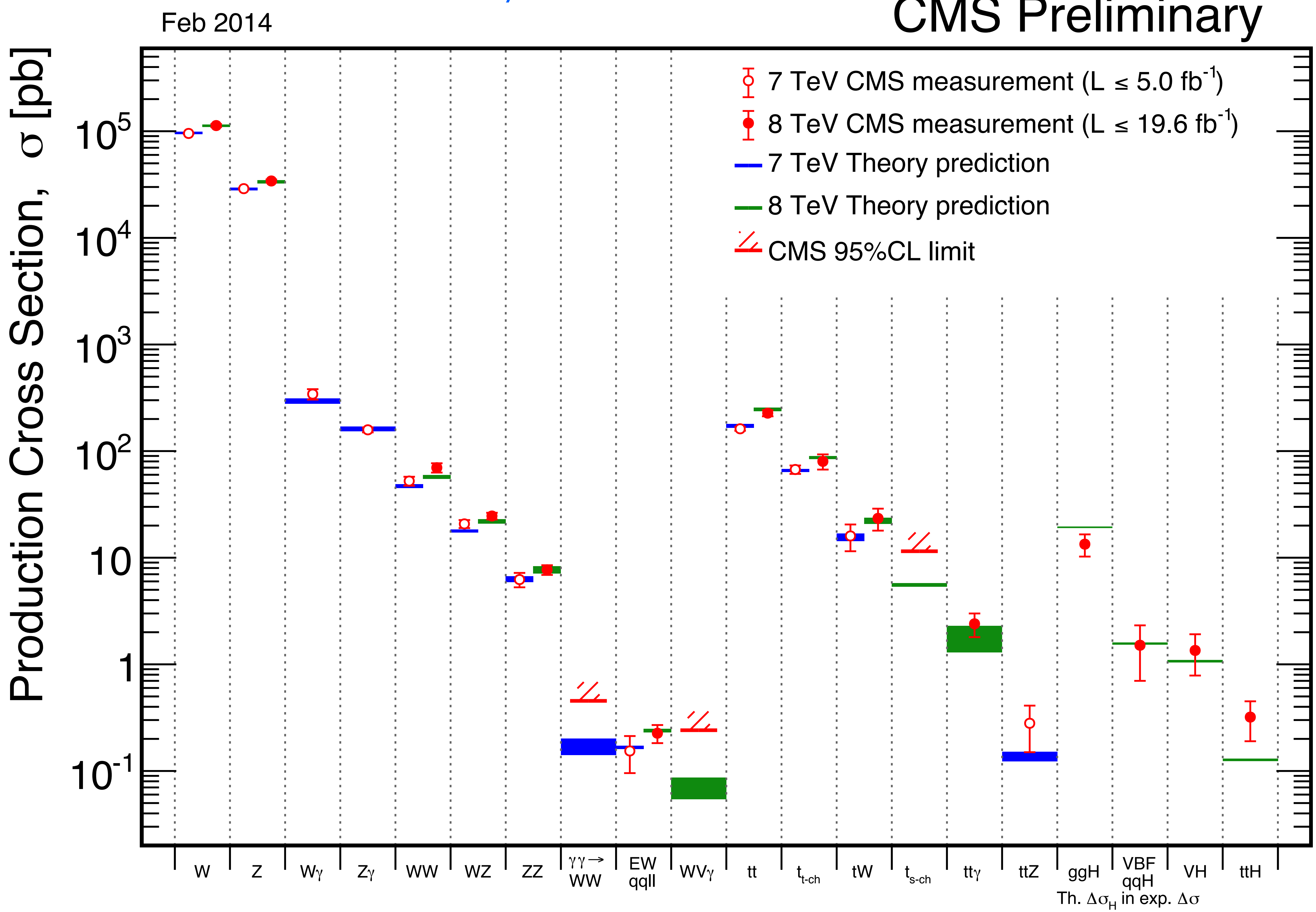
CMS PAS HIG-13-005

	Analyses		No. of	m_H	Lumi (fb^{-1})	
H decay	Prod. tag	Exclusive final states	channels	resolution	7 TeV	8 TeV
$\gamma\gamma$	untagged	$\gamma\gamma$ (4 diphoton classes)	4 + 4	1-2%	5.1	19.6
	VBF-tag	$\gamma\gamma + (jj)_{VBF}$ (two dijet classes for 8 TeV)	1 + 2	<1.5%	5.1	19.6
	VH-tag	$\gamma\gamma$ + (e, μ, MET)	3	<1.5%		19.6
$ZZ \to 4\ell$	$N_{jet} < 2$	4e, 4μ, $2e2\mu$	3 + 3	1-2%	5.1	19.6
	$N_{jet} \geq 2$		3 + 3			
$WW \to \ell\nu\ell\nu$	0/1-jets	(DF or SF dileptons) × (0 or 1 jets)	4 + 4	20%	4.9	19.5
	VBF-tag	$\ell\nu\ell\nu + (jj)_{VBF}$ (DF or SF dileptons for 8 TeV)	1 + 2	20%	4.9	12.1
	WH-tag	$3\ell 3\nu$ (same-sign SF and otherwise)	2 + 2		4.9	19.5
$\tau\tau$	0/1-jet	($e\tau_h$, $\mu\tau_h$, $e\mu$, $\mu\mu$) × (low or high p_T^τ)	16 + 16	15%	4.9	19.6
	1-jet	$\tau_h\tau_h$	1 + 1			
	VBF-tag	($e\tau_h$, $\mu\tau_h$, $e\mu$, $\mu\mu$, $\tau_h\tau_h$) + $(jj)_{VBF}$	5 + 5			
	ZH-tag	(ee, $\mu\mu$) × ($\tau_h\tau_h$, $e\tau_h$, $\mu\tau_h$, $e\mu$)	8 + 8		5.0	19.5
	WH-tag	$\tau_h\mu\mu$, $\tau_h e\mu$, $e\tau_h\tau_h$, $\mu\tau_h\tau_h$	4 + 4			
bb	VH-tag	($\nu\nu$, ee, $\mu\mu$, $e\nu$, $\mu\nu$ with 2 b-jets) × (low or high $p_T(V)$ or loose b-tag)	10 + 13	10%	5.0	12.1
	ttH-tag	(ℓ with 4, 5 or ≥6 jets) × (3 or ≥4 b-tags);	6 + 6		5.0	5.1
		(ℓ with 6 jets with 2 b-tags); ($\ell\ell$ with 2 or ≥3 b-tagged jets)	3 + 3			

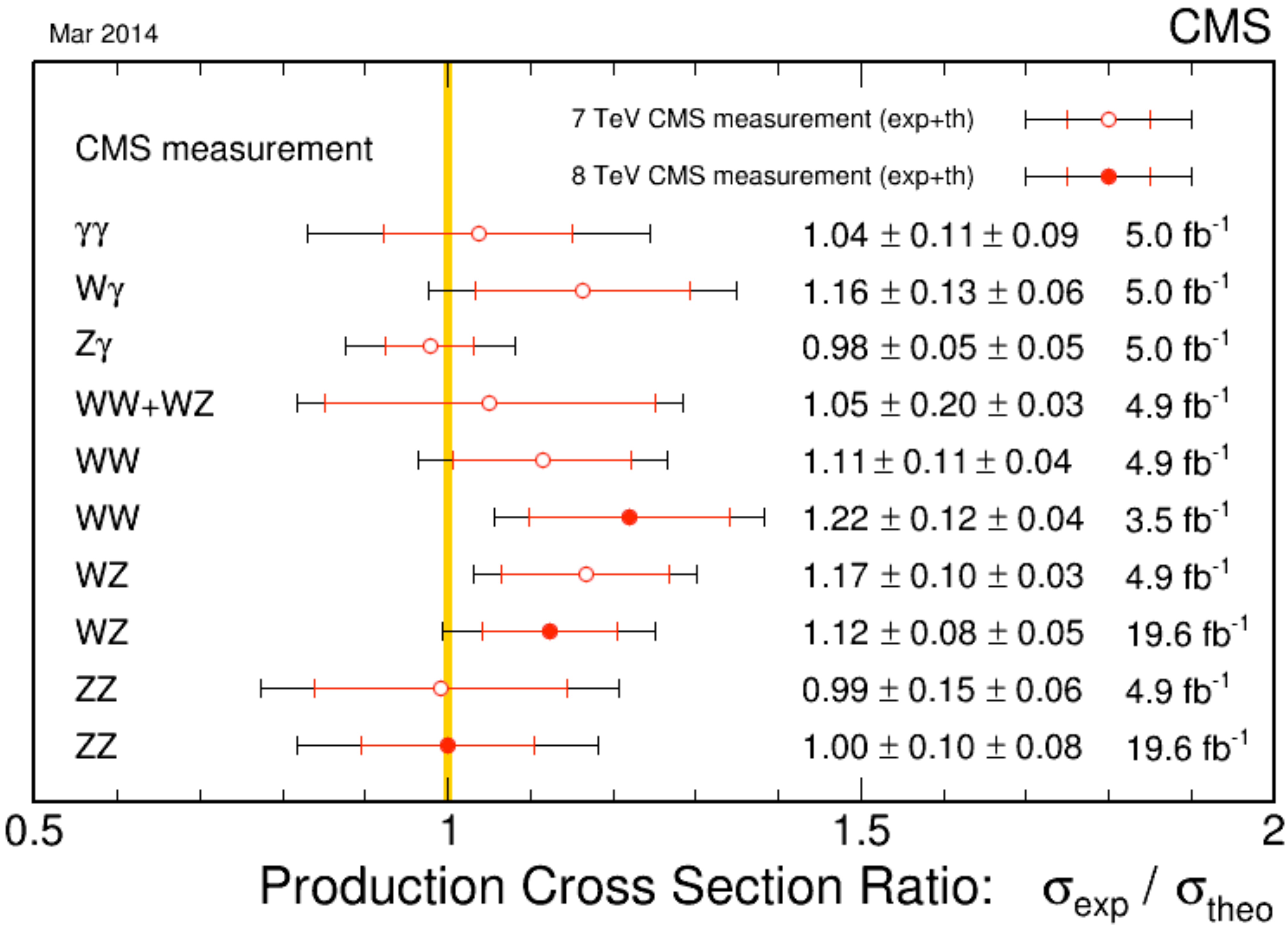
SM Properties

SM Cross Sections

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsCombined

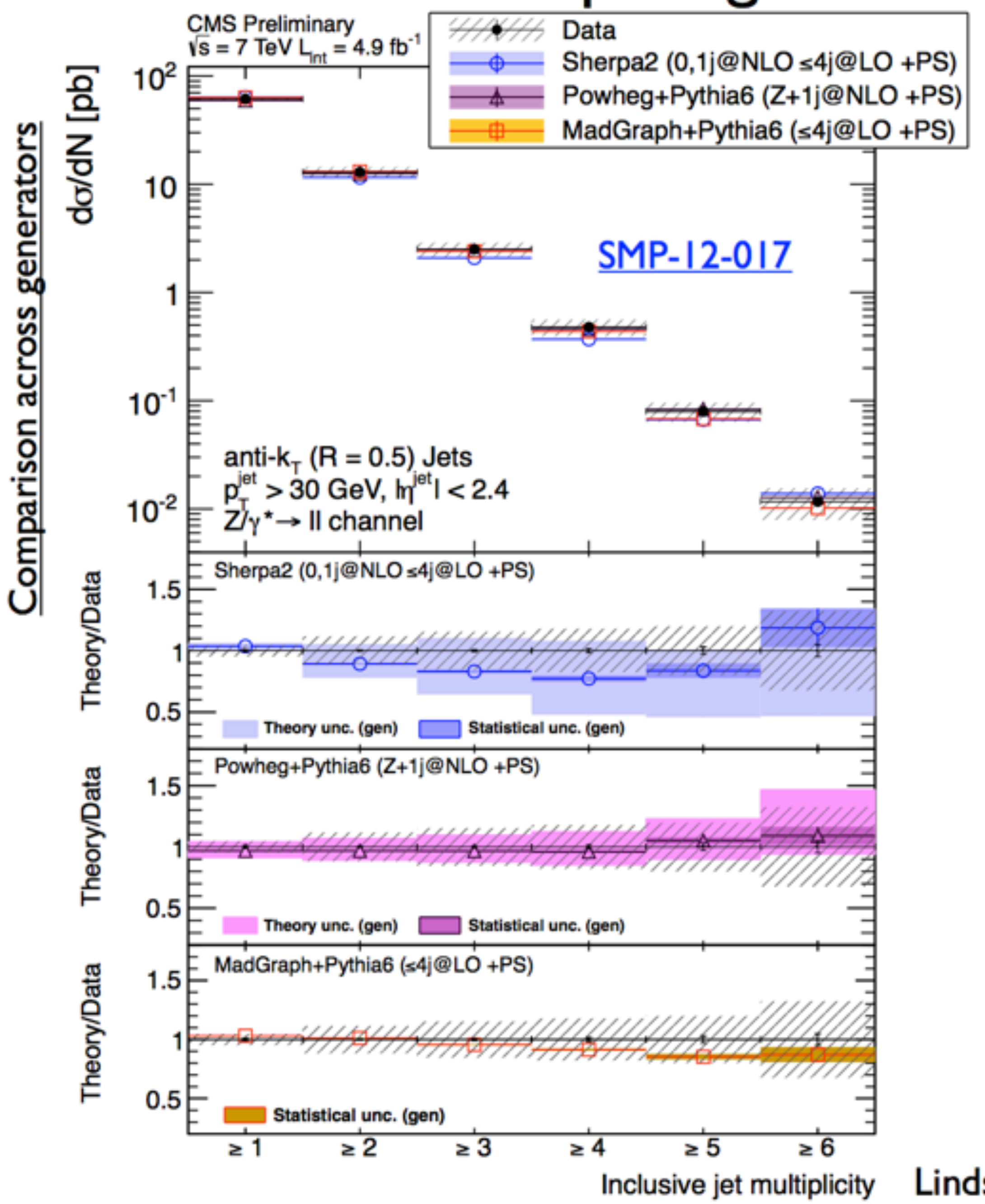


Diboson Cross-section



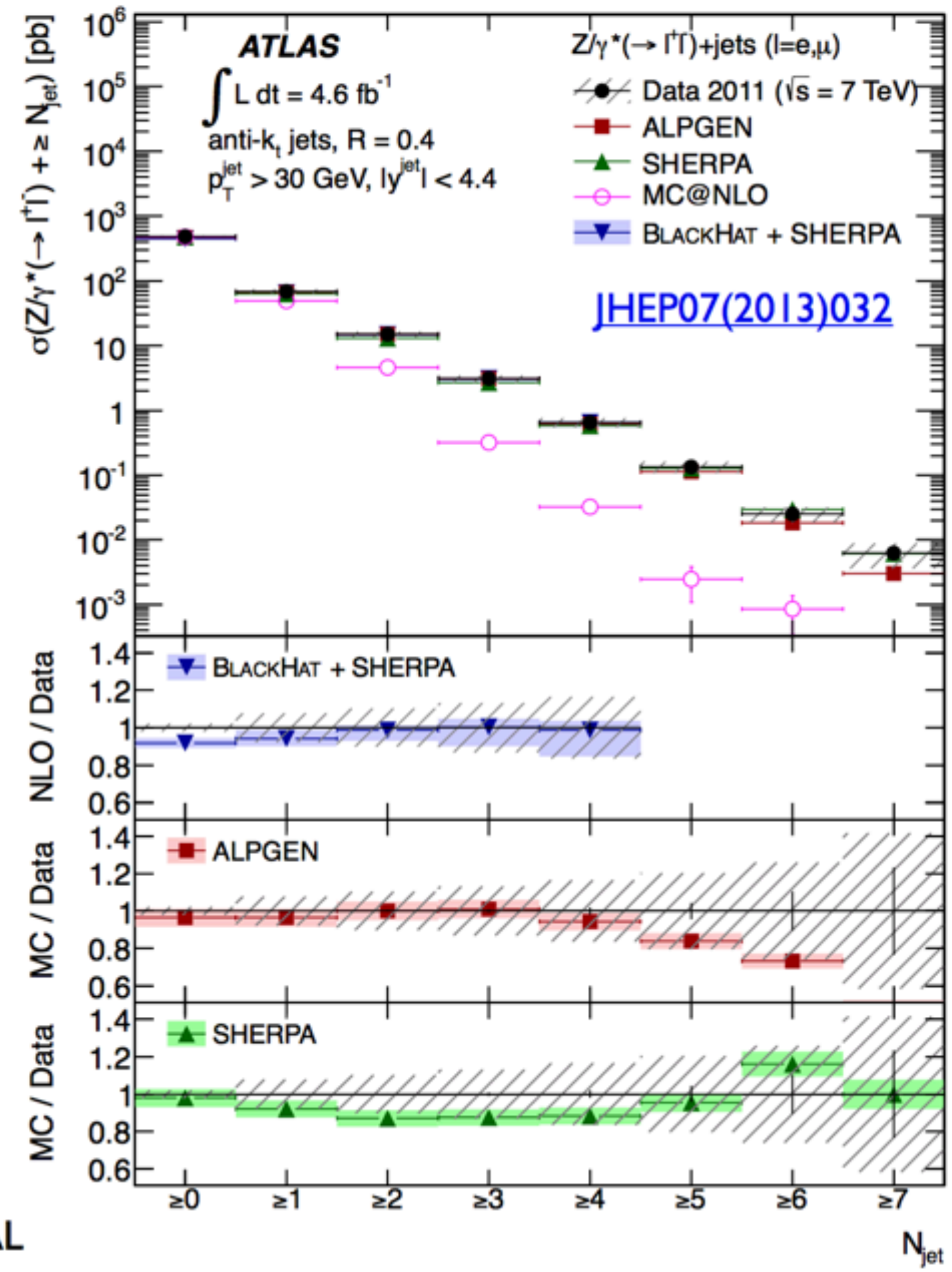
QCD (Z+jets)

- Discrepancies in basic jet distributions observed in CMS result when comparing SHERPA2



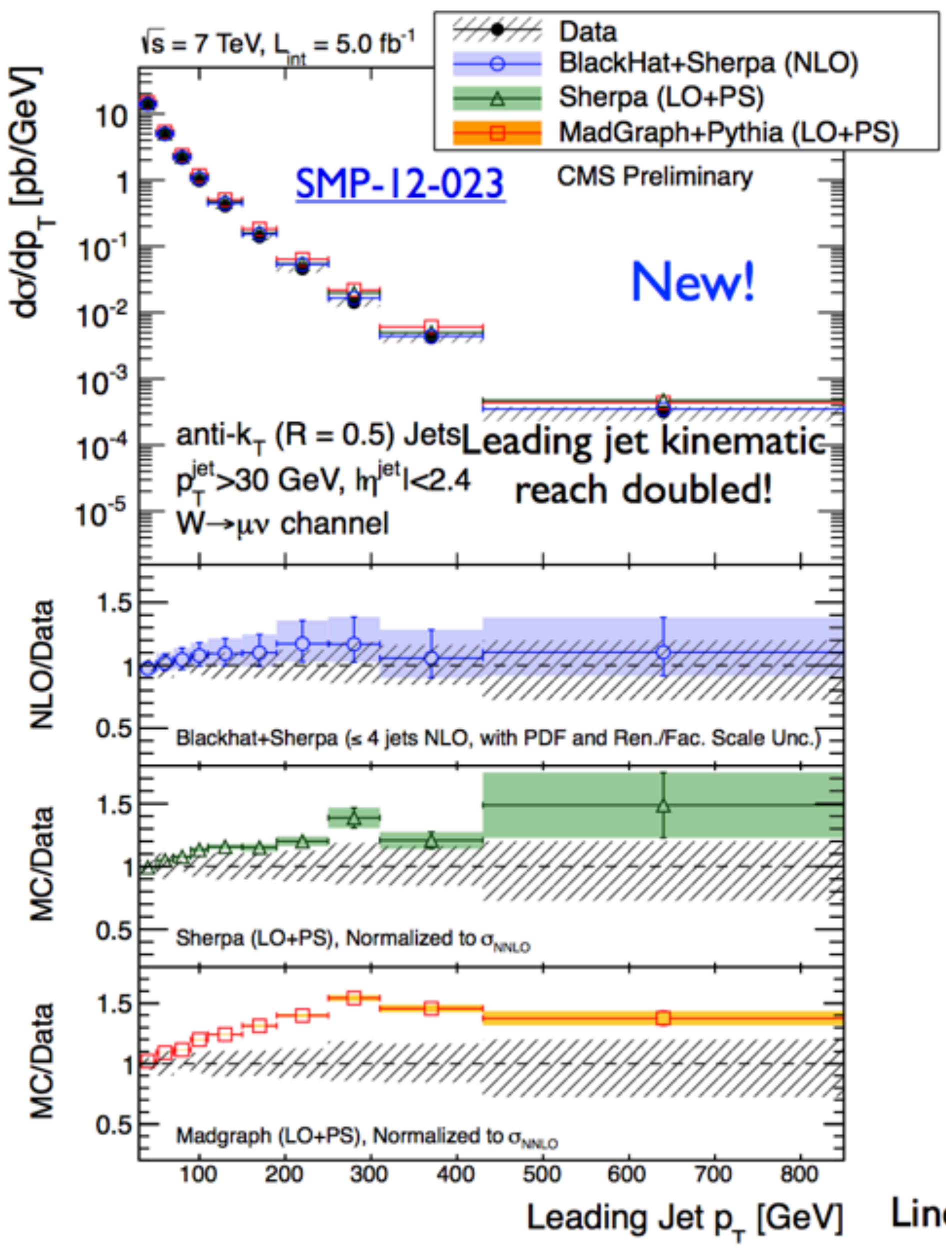
Lindsey Gray, FNAL

- Tension with data is less marked in ATLAS result due to higher order calculation in SHERPA+BlackHat



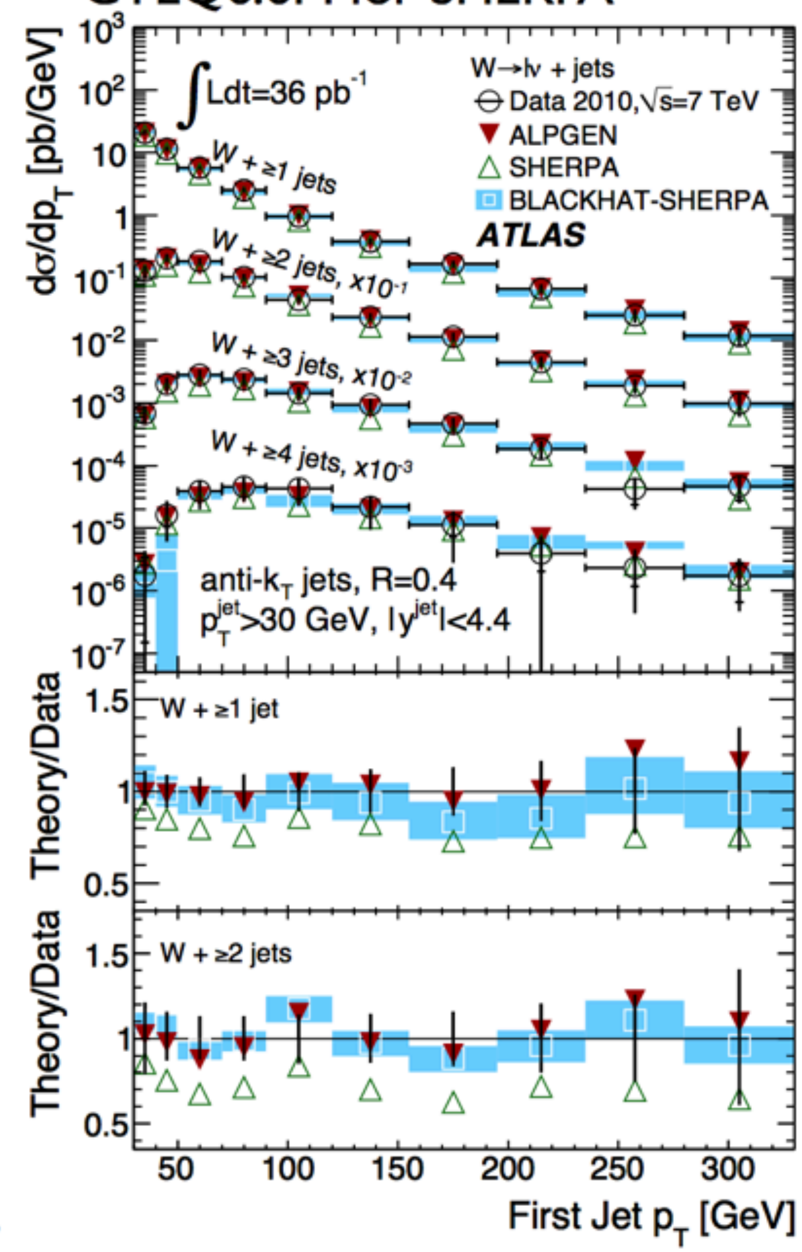
QCD (W+jets)

- Compare with SHERPA1.4 (+ BlackHat), MadGraph5 (normalized to FEWZ)
- CT10 for SHERPA



Lindsey Gray, FNAL

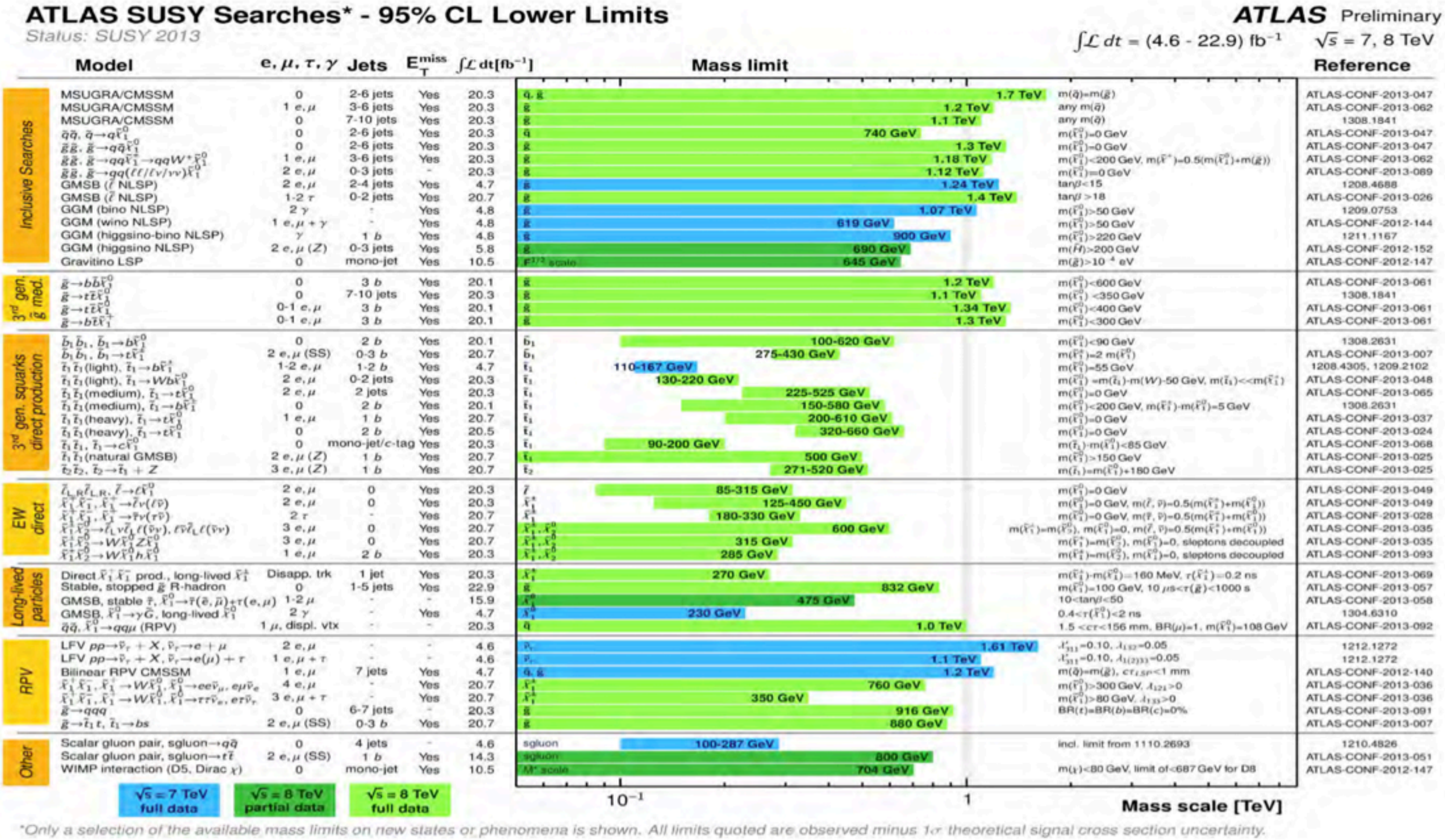
- Comparison with SHERPA1.3 (+ BlackHa ALPGEN
- CTEQ6.6M for SHERPA



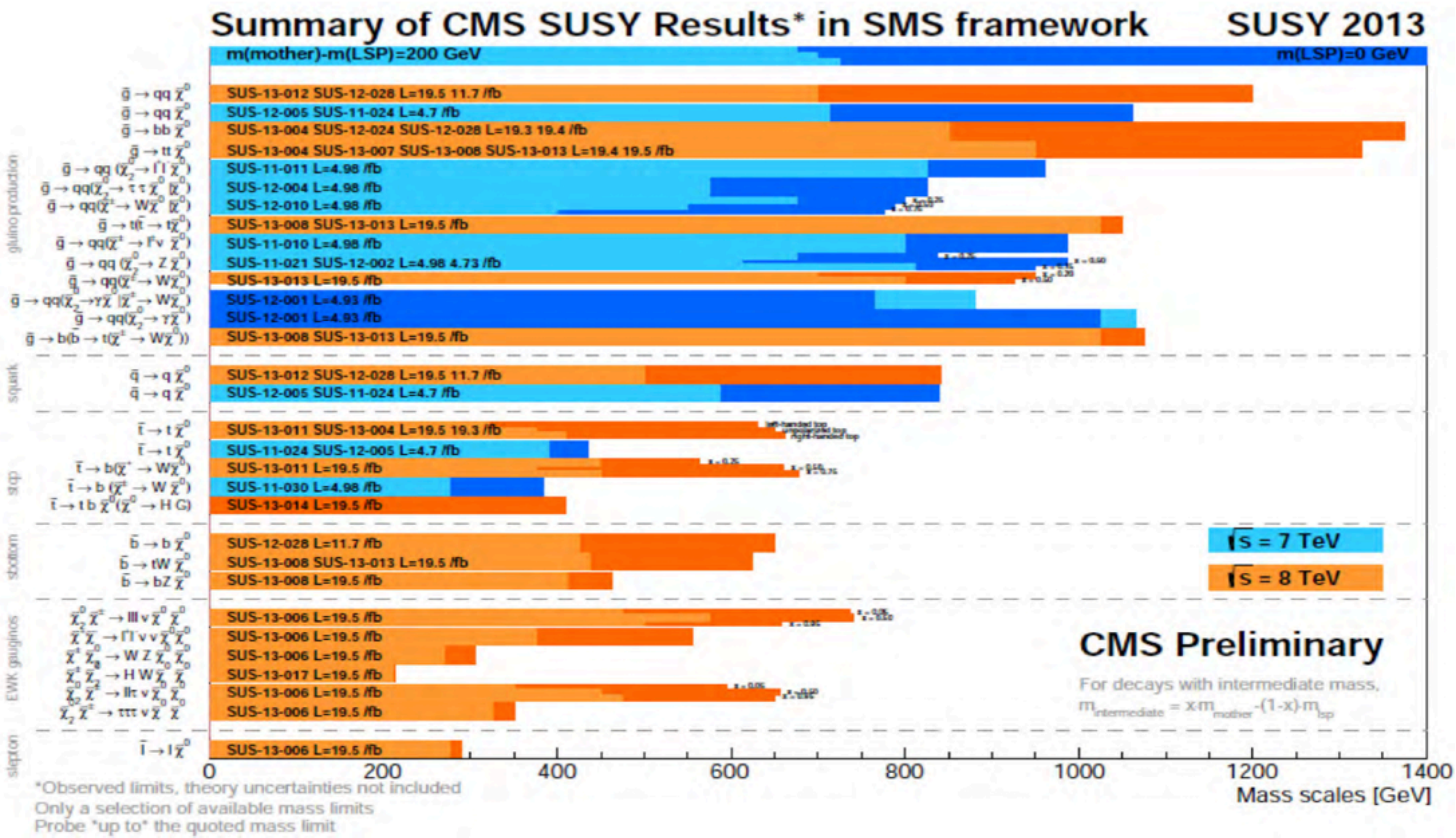
Physics Beyond Standard Model (direct searches)

ATLAS SUSY Limits

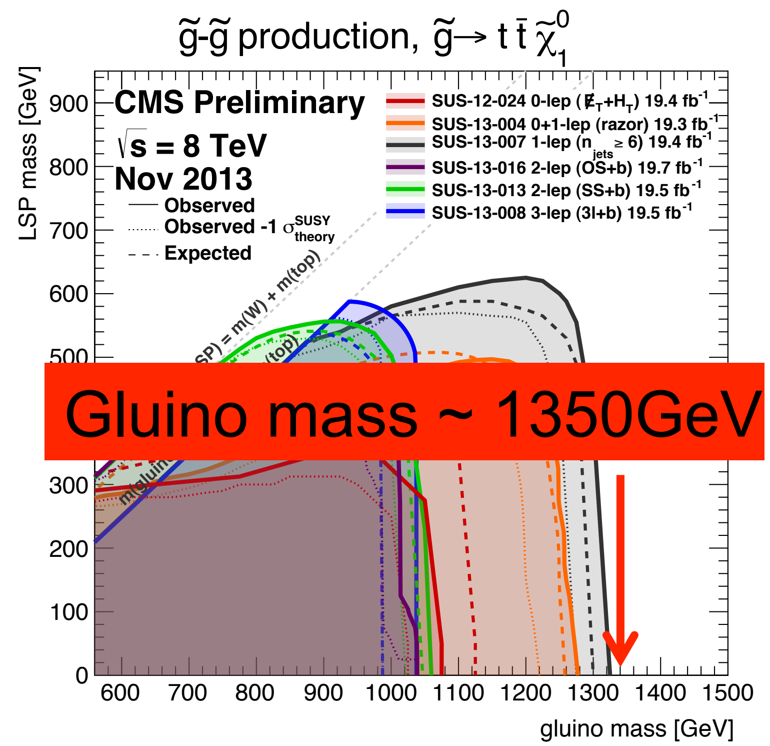
Squarks/gluinos are > O(1 TeV), Stop/sbottom > O(300-600 GeV)



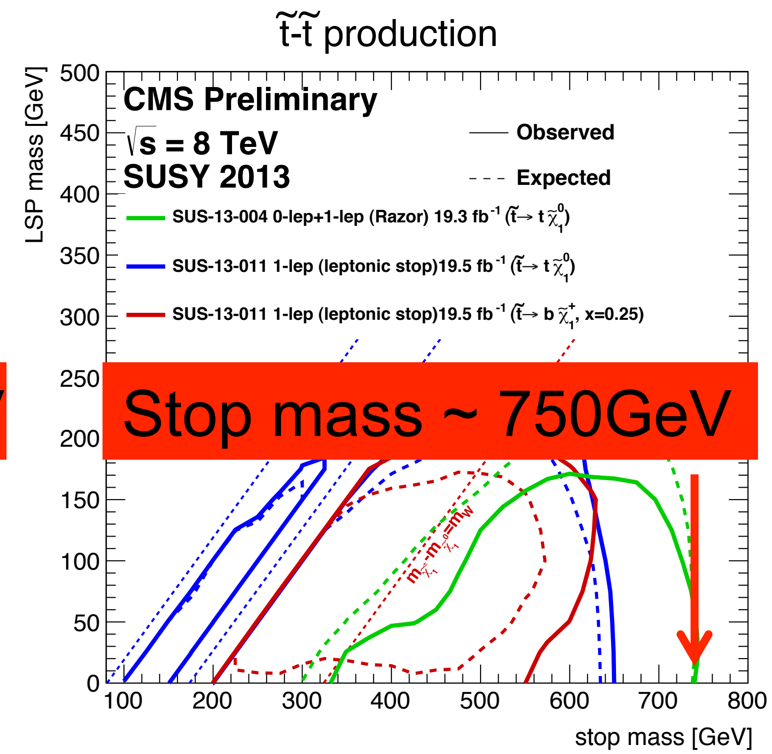
CMS SUSY Limits



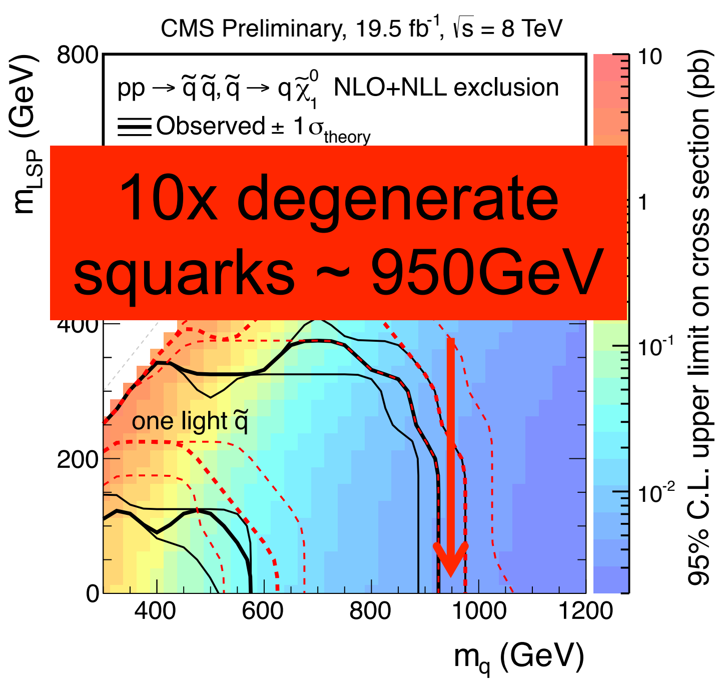
SUSY



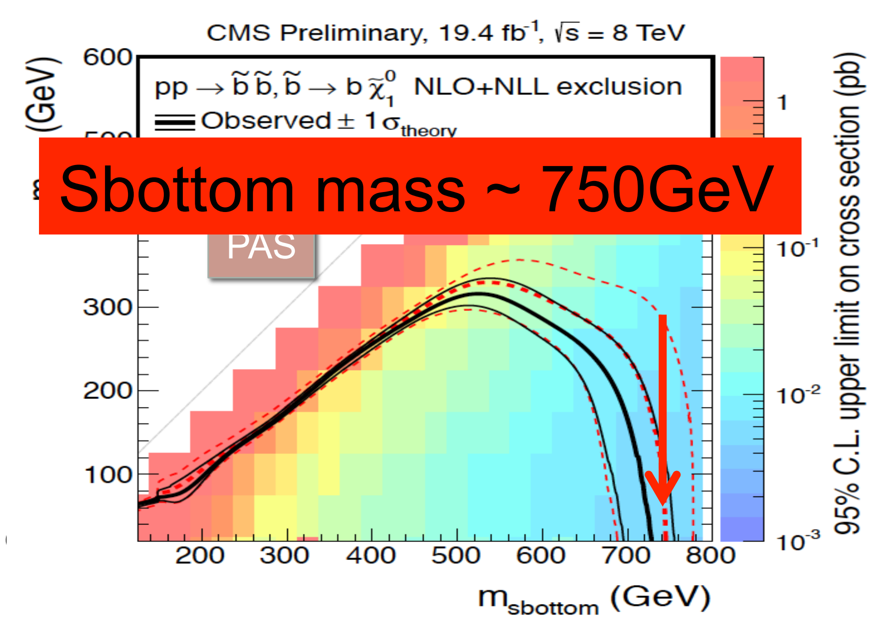
g̃-g̃ production, g̃→ t t̄ χ̃⁰₁
CMS Preliminary
√s = 8 TeV
Nov 2013
Observed
Observed -1 σ theory SUSY
Expected
SUS-12-024 0-lep (E̸T+HT) 19.4 fb⁻¹
SUS-13-004 0+1-lep (razor) 19.3 fb⁻¹
SUS-13-007 1-lep (n jets ≥ 6) 19.4 fb⁻¹
SUS-13-016 2-lep (OS+b) 19.7 fb⁻¹
SUS-13-013 2-lep (SS+b) 19.5 fb⁻¹
SUS-13-008 3-lep (3l+b) 19.5 fb⁻¹
LSP mass [GeV]
gluino mass [GeV]
Gluino mass ~ 1350GeV



t̃-t̃ production
CMS Preliminary
√s = 8 TeV
SUSY 2013
Observed
Expected
SUS-13-004 0-lep+1-lep (Razor) 19.3 fb⁻¹ (t̃→ t χ̃⁰₁)
SUS-13-011 1-lep (leptonic stop)19.5 fb⁻¹ (t̃→ t χ̃⁰₁)
SUS-13-011 1-lep (leptonic stop)19.5 fb⁻¹ (t̃→ b χ̃⁺₁, x=0.25)
LSP mass [GeV]
stop mass [GeV]
Stop mass ~ 750GeV



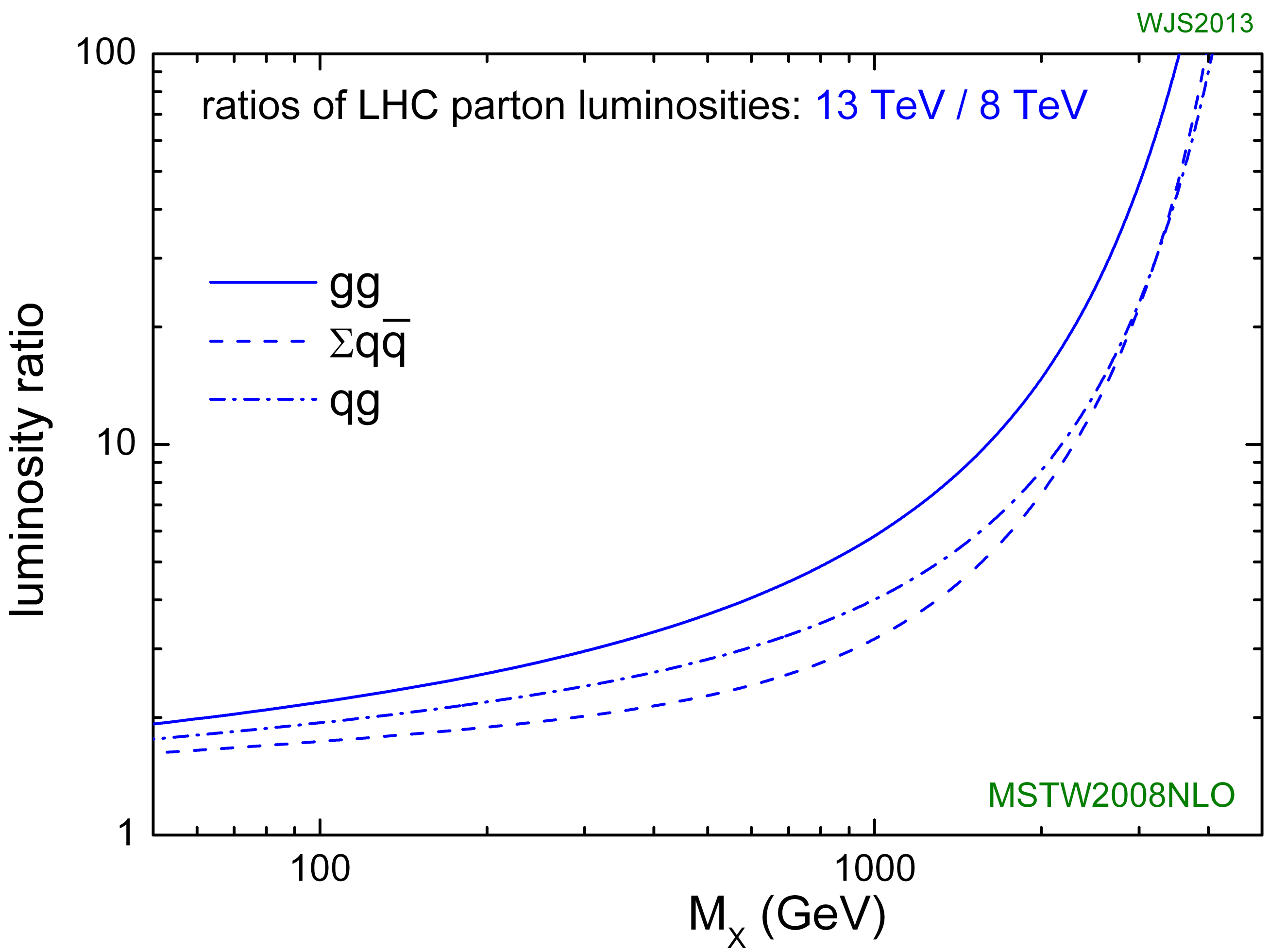
CMS Preliminary, 19.5 fb⁻¹, √s = 8 TeV
pp → q̃ q̃, q̃ → q χ̃⁰₁ NLO+NLL exclusion
Observed ± 1 σ theory
one light q̃
m LSP (GeV)
m q (GeV)
95% C.L. upper limit on cross section (pb)
10x degenerate
squarks ~ 950GeV



CMS Preliminary, 19.4 fb⁻¹, √s = 8 TeV
pp → b̃ b̃, b̃ → b χ̃⁰₁ NLO+NLL exclusion
Observed ± 1 σ theory
PAS
m sbottom (GeV)
95% C.L. upper limit on cross section (pb)
Sbottom mass ~ 750GeV

4

Cross-section Scaling 8→13 TeV



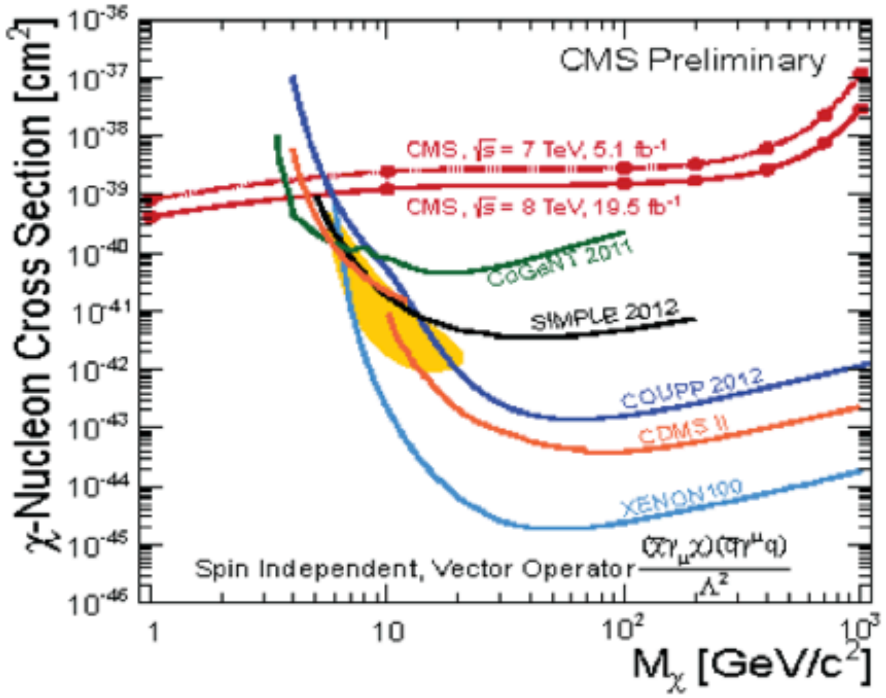
Xsection Ratios 13/8 TeV

1350GeV gluino: x30
950GeV squark: x20
750GeV squark: x9
350GeV $X^{+-}X^0$: x3
top pairs: x4

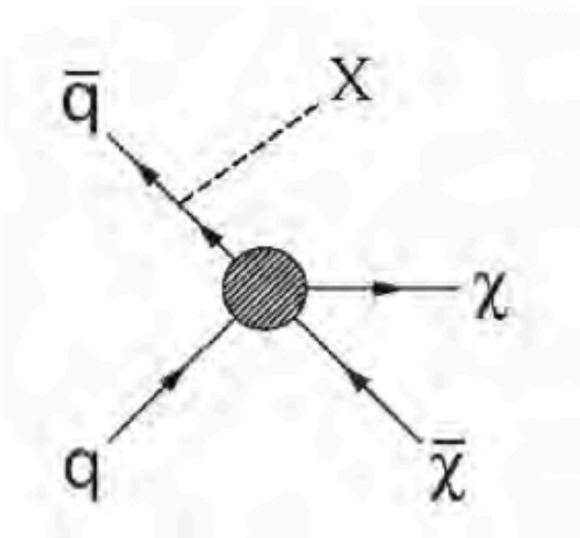
~1/fb of 13TeV data surpasses our best gluino limits.
~3/fb of 13TeV data surpasses our sbottom and stop limits.

- **Assume DM is pair-produced, but invisible. Then trigger/reconstruct using ISR hard emission**
- **Refer to this as "mono-X", where X = jet, γ, W/Z, Top.**
- **If mediator is heavy, interpret using EFT ("contact int")**
- **Alternatively: use simplified models (no validity issue).**

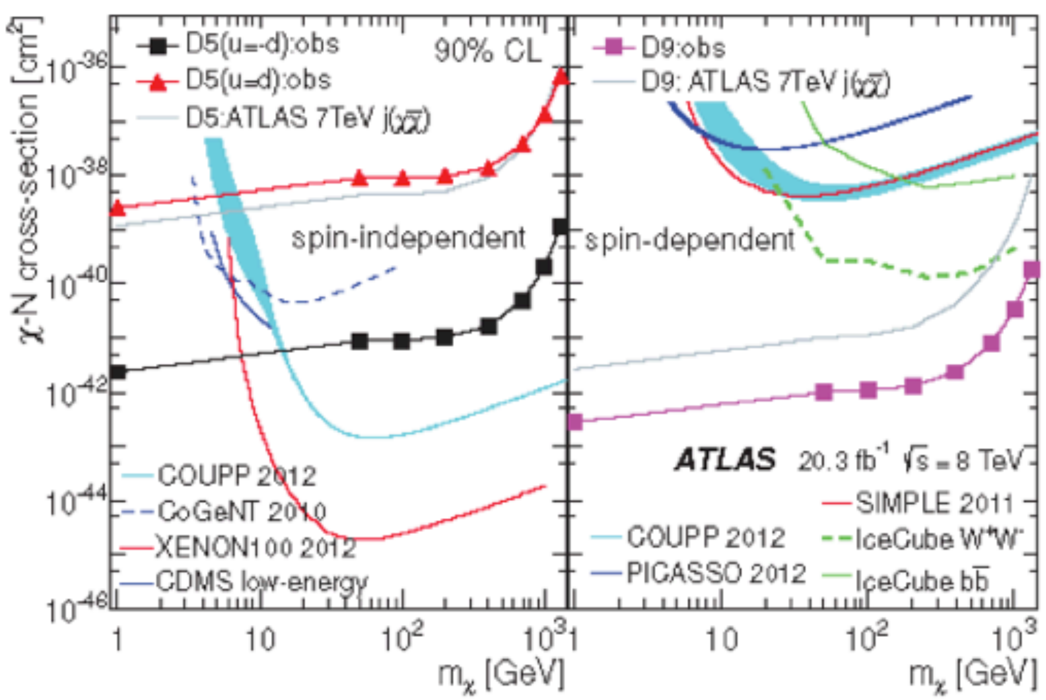
CMS Mono-jet



Production Diagram

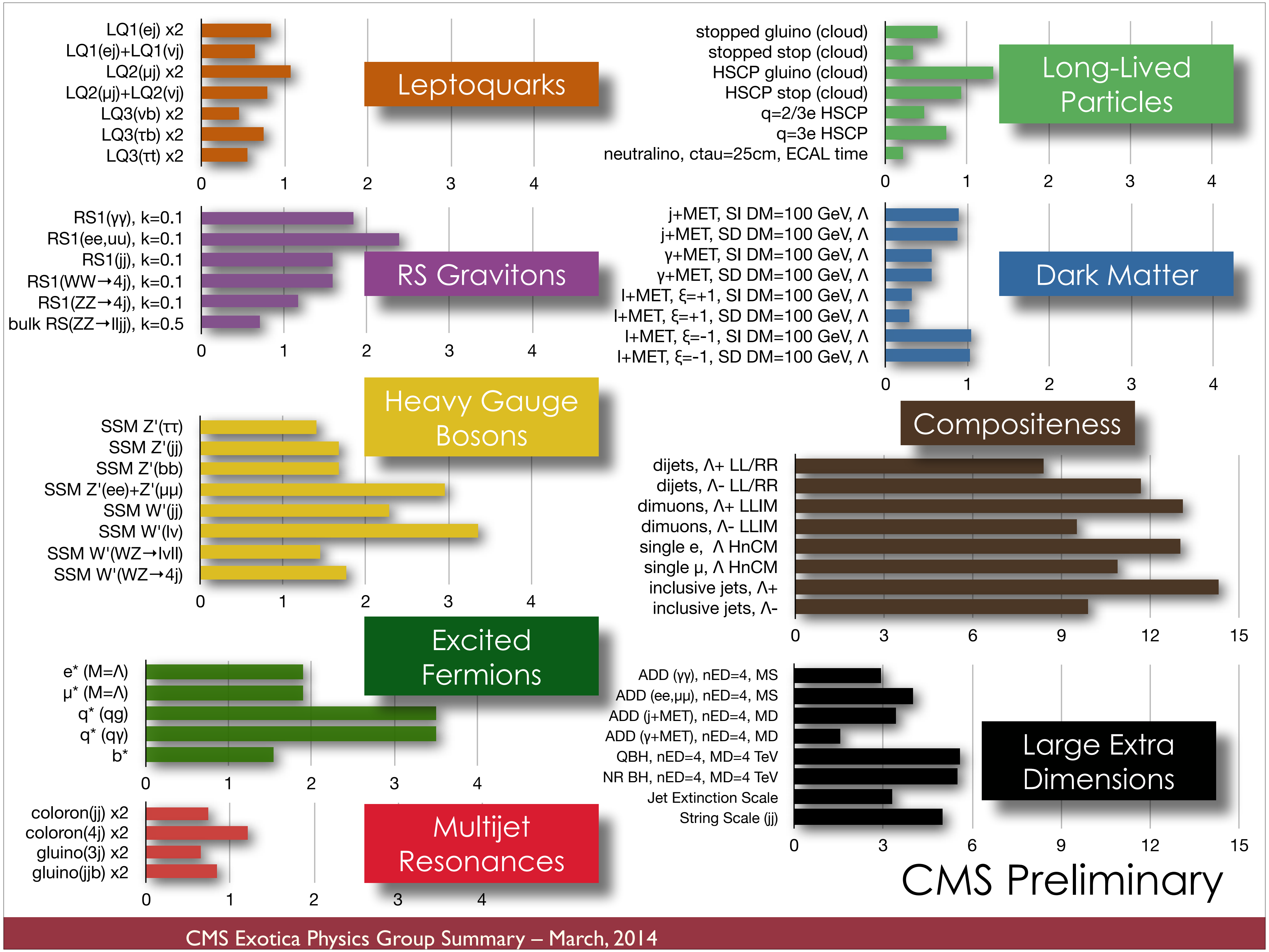


ATLAS Mono-W/Z(qq)

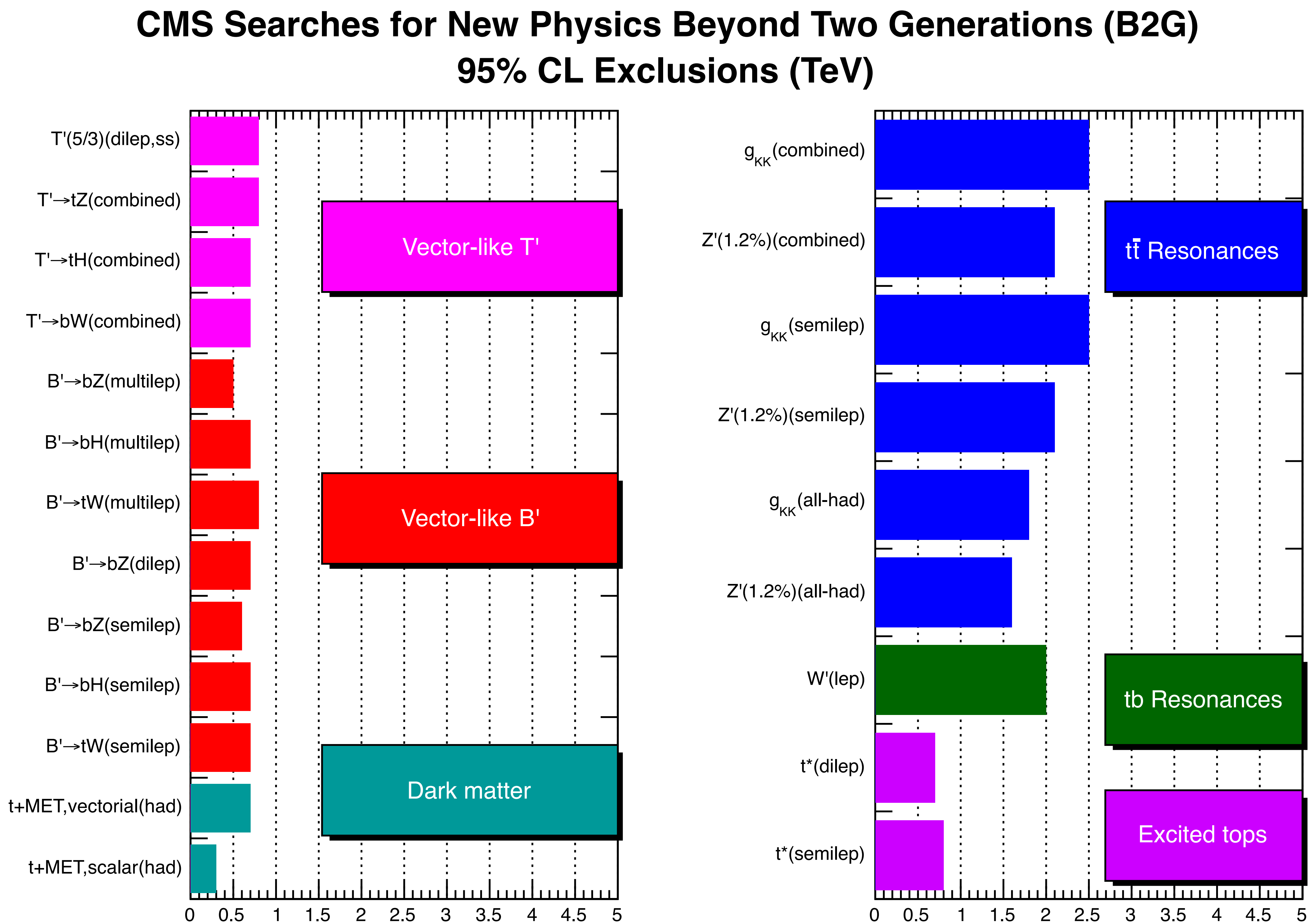


CMS Exotica Results

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO



Boosted Top



CMS Searches for New Physics Beyond Two Generations (B2G)
95% CL Exclusions (TeV)
T'(5/3)(dilep,ss)
T'→tZ(combined)
T'→tH(combined)
T'→bW(combined)
B'→bZ(multilep)
B'→bH(multilep)
B'→tW(multilep)
B'→bZ(dilep)
B'→bZ(semilep)
B'→bH(semilep)
B'→tW(semilep)
t+MET,vectorial(had)
t+MET,scalar(had)
Vector-like T'
Vector-like B'
Dark matter
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
gKK(combined)
Z'(1.2%)(combined)
gKK(semilep)
Z'(1.2%)(semilep)
gKK(all-had)
Z'(1.2%)(all-had)
W'(lep)
t*(dilep)
t*(semilep)
tt̄ Resonances
tb Resonances
Excited tops
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5

Beyond SM with Higgs

- **Two different approaches: “indirect” using coupling results, “direct” using targeted searches**
- **Limits from recent ATLAS couplings analysis:**
  - **Minimal Composite Higgs (MCHM)**
  - **Additional EW singlet**
  - **2HDM**
  - **Simplified MSSM**
  - **Higgs Portal**

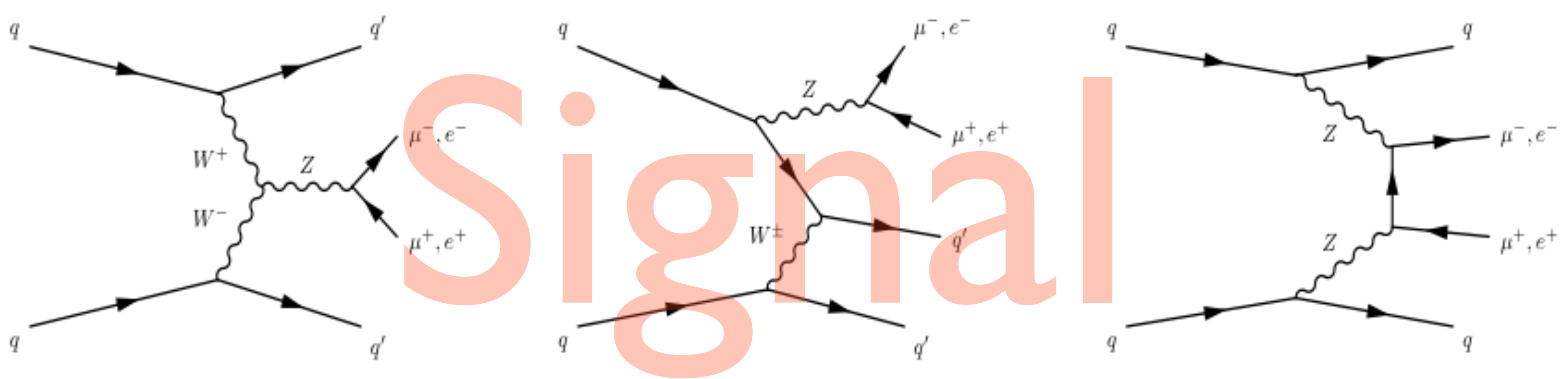
No sign of BSM Higgs (yet) !

- **Limits from direct Searches:**
  - **H -> hh, A -> Zh (CMS)**
  - **2HDM limits (CMS)**
  - **t -> cH (CMS) and t -> qH (ATLAS)**
  - **MSSM H -> $\tau\tau$ (CMS)**
  - **Charged Higgs (ATLAS)**

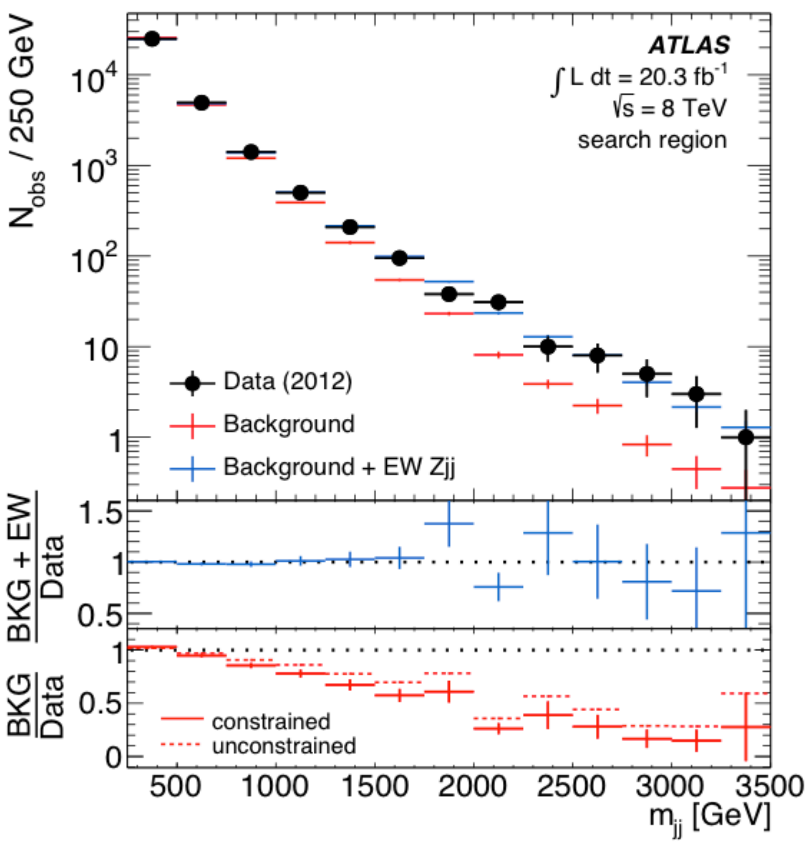
Vector Boson Scattering (indirect searches)

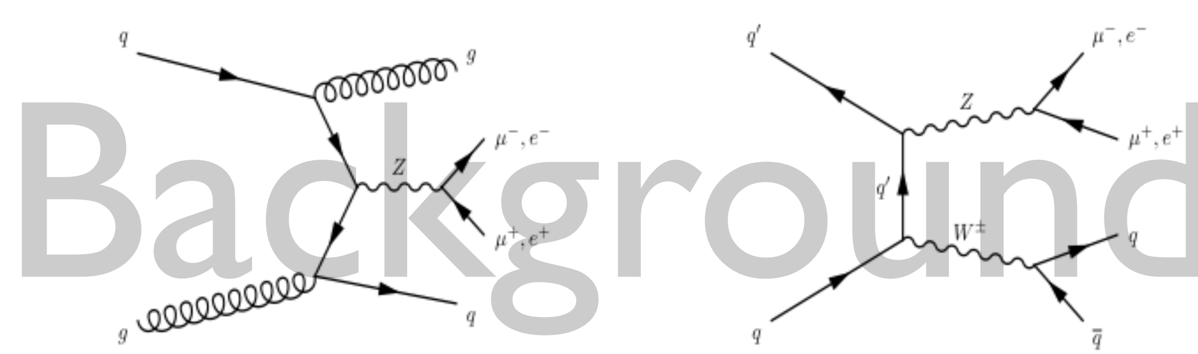
EWK W/Z production

arXiv:1401.7610



(a) vector boson fusion (b) Z-boson bremsstrahlung (c) non-resonant $\ell^+\ell^- jj$

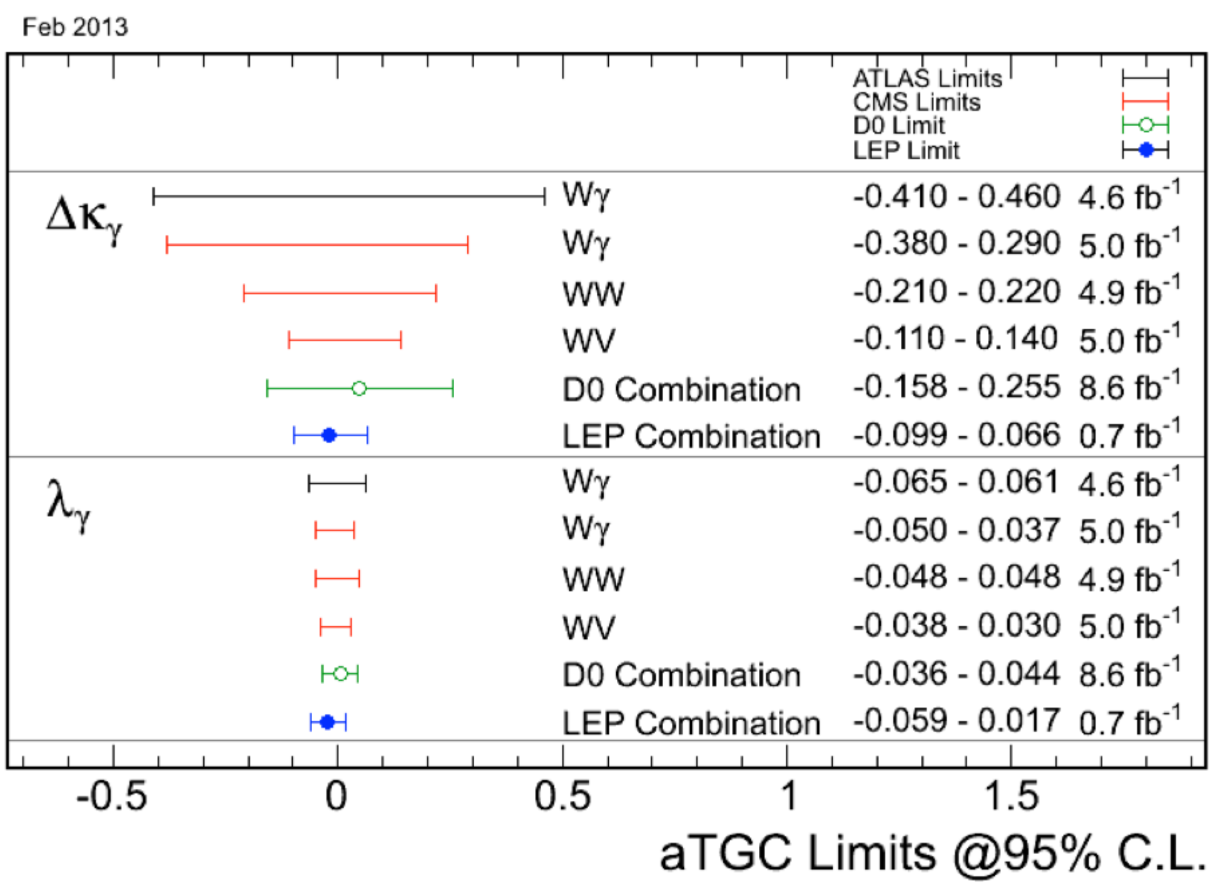


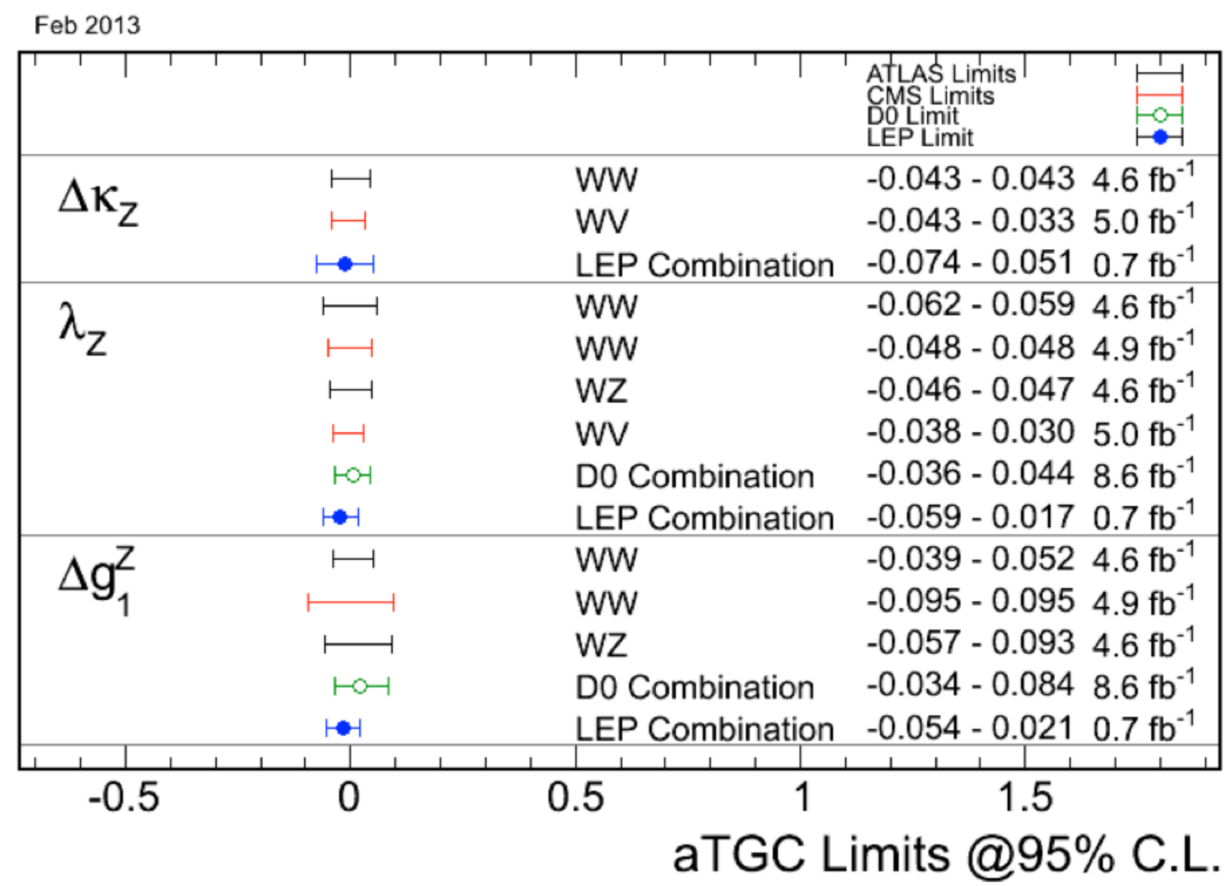


(a) strong Zjj production (b) diboson-initiated

- EWK: t-channel vector boson exchange
- Observed 5σ effect

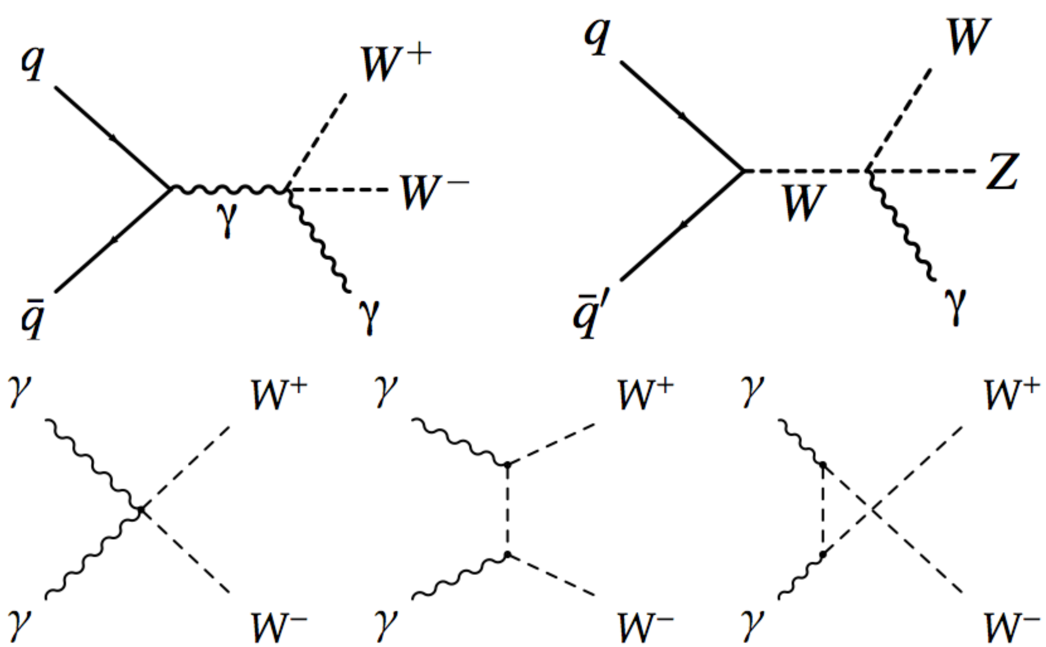
Anomalous Triple Gauge Couplings

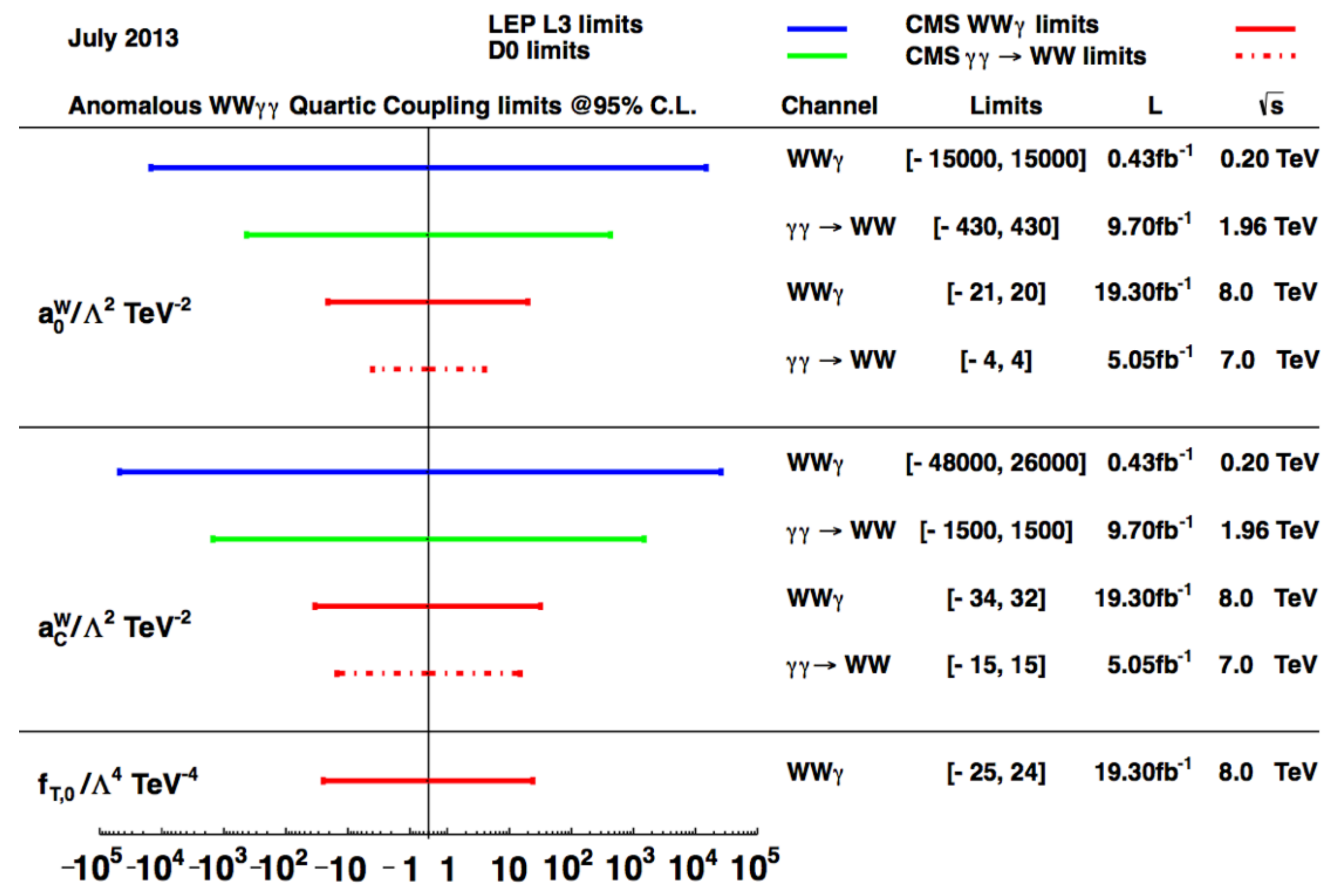




- Approaching LEP limits
- New methods: merged fat jet
- Results are coming slowly
  - Trying to fix it for next RUN

Anomalous Quoter Gauge Couplings



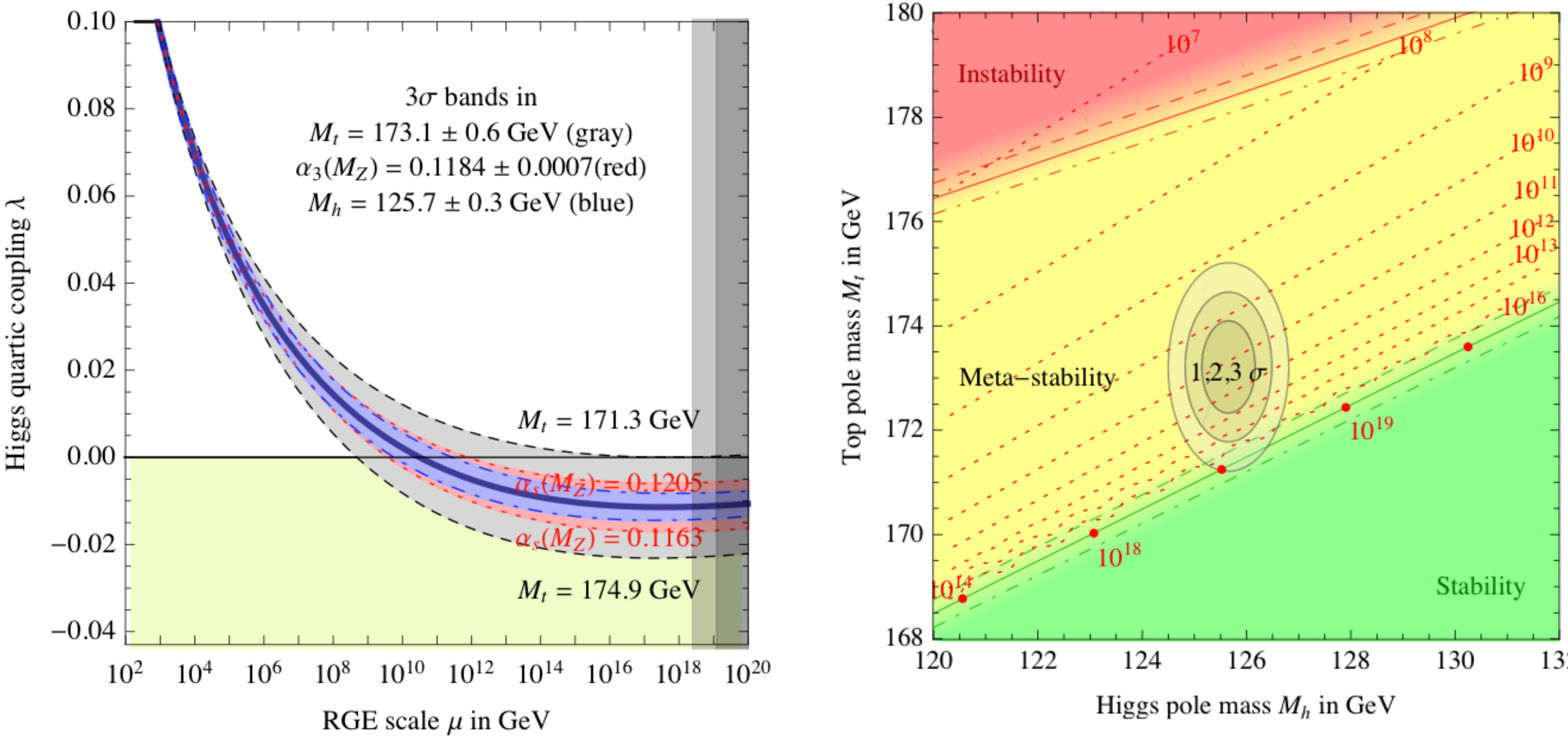


- Exclusive γγ→WW exceptional sensitivity
  - Very hard (impossible?) in high pileup
- Tools and Methods are in development
  - EFT with FeynmanRules in Madgraph becomes default

Top Mass

Stability of the SM vacuum

SM Higgs discovered, no BSM. Pushing SM to Plank scale the measured Mh and Mtop place the SM vacuum in a meta-stable state due to negative Higgs coupling



$$M_h > 129.1\,\text{GeV} + 2.0(M_t - 173.10\,\text{GeV}) - 0.5\,\text{GeV}\,\frac{\alpha_3(M_Z) - 0.1184}{0.0007} \pm 0.3\,\text{GeV}$$

arXiv:1307.3536
Buttazzo et al

Top Mass Combination

LHC/Tevatron NOTE

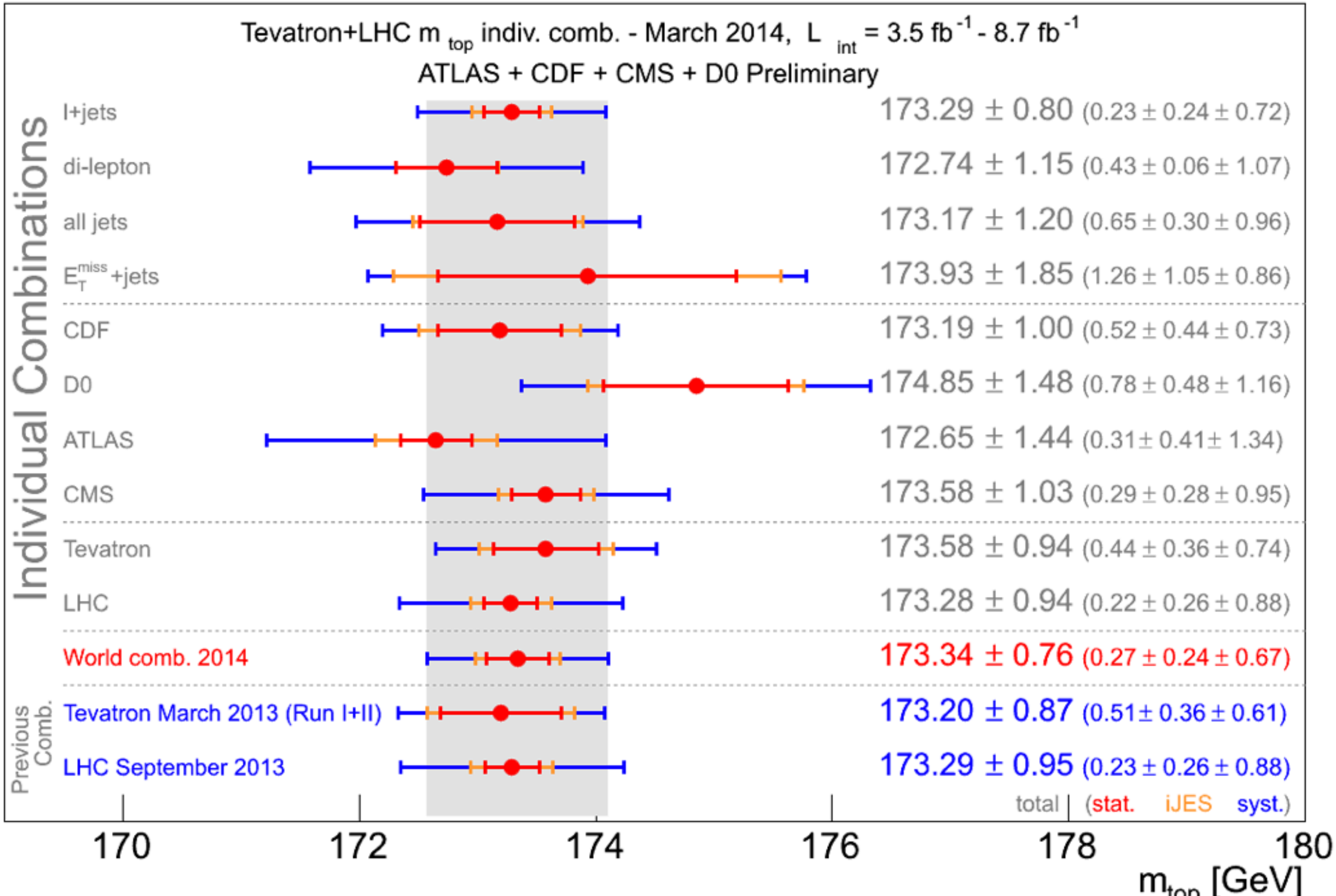
ATLAS-CONF-2014-008
CDF Note 11071
CMS PAS TOP-13-014
D0 Note 6416

March 17, 2014

CERN/FNAL Press Release:

A total of more than six thousand scientists from more than 50 countries participate in the four experimental collaborations. The CDF and DZero experiments discovered the top quark in 1995, and the Tevatron produced about 300,000 top quark events during its 25-year lifetime, completed in 2011. Since it started collider physics operations in 2009, the LHC has produced close to 18 million events with top quarks, making it the world's leading top quark factory.

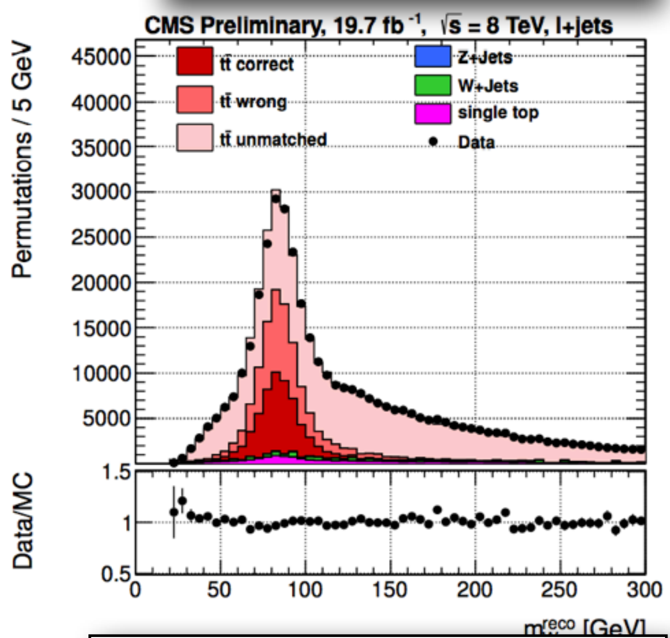
Top Mass combination



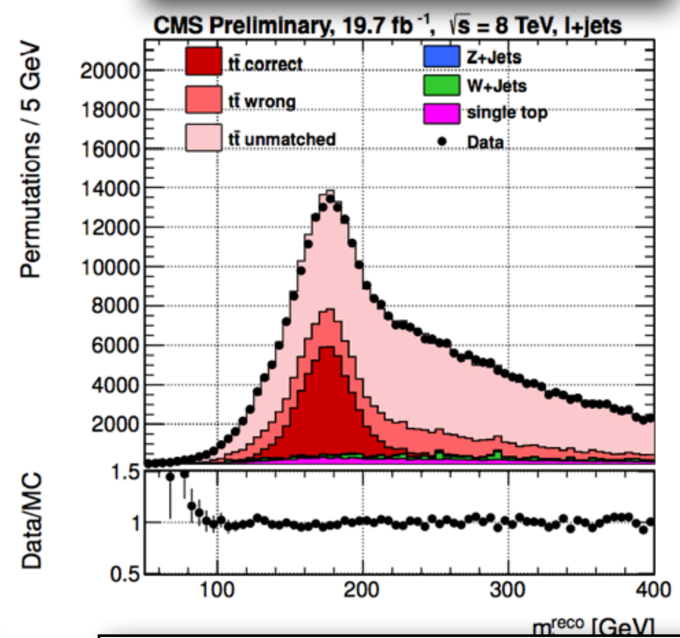
LHC vs Tevatron - remarkably consistent results

Top Mass - Latest from CMS

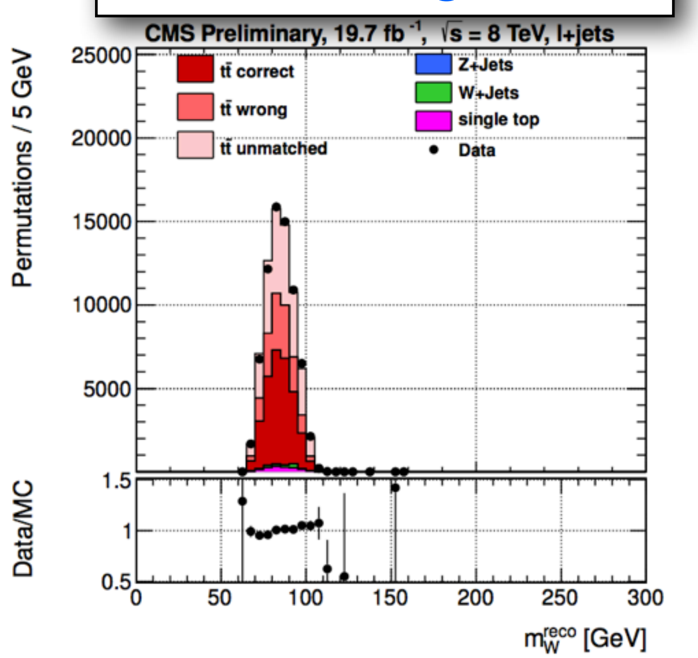
W mass before fit



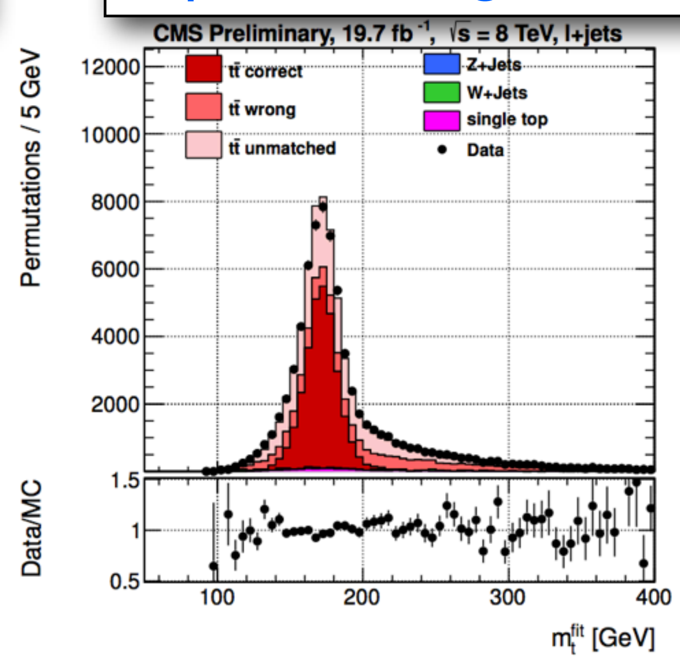
Top mass before fit



W mass for good fits



Top mass for good fits



$$\sigma = 172.04 \pm 0.19 \pm 0.75 GeV$$

- Lepton+MET+jets
- Simultaneous fit for top mass and energy scale using W-mass constraint
- Significant change in the central value

Systematics

Table 1: List of systematic uncertainties for the combined fit to the entire lepton+jets data set.

	δm_t^{2D} (GeV)	δJSF	δm_t^{1D} (GeV)
Experimental uncertainties			
Fit calibration	0.10	0.001	0.06
p_T- and η-dependent JES	0.18	0.007	1.17
Lepton energy scale	0.03	<0.001	0.03
MET	0.09	0.001	0.01
Jet energy resolution	0.26	0.004	0.07
b tagging	0.02	<0.001	0.01
Pileup	0.27	0.005	0.17
Non-$t\bar{t}$ background	0.11	0.001	0.01
Modeling of hadronization			
Flavor-dependent JSF	0.41	0.004	0.32
b fragmentation	0.06	0.001	0.04
Semi-leptonic B hadron decays	0.16	<0.001	0.15
Modeling of the hard scattering process			
PDF	0.09	0.001	0.05
Renormalization and factorization scales	0.12±0.13	0.004±0.001	0.25±0.08
ME-PS matching threshold	0.15±0.13	0.003±0.001	0.07±0.08
ME generator	0.23±0.14	0.003±0.001	0.20±0.08
Modeling of non-perturbative QCD			
Underlying event	0.14±0.17	0.002±0.002	0.06±0.10
Color reconnection modeling	0.08±0.15	0.002±0.001	0.07±0.09
Total	0.75	0.012	1.29

Summary

- Higgs discovered
  - Standard Model is complete
- Higgs boson looks exactly as SM predicts
- Searches for BSM show nothing new
  - Naturalness is looking decidedly less natural
- Run2 will increase energy to 13TeV
  - Last time in a while that we may have a quick discovery