

- En physique des particules, conférences d'hiver (Moriond) et d'été (ICHEP, Lepton-Photon, EPS-HEP)
- ICHEP: conférence mondiale, organisée par l'International Union of Pure and Applied Physics, tous les deux ans dans un endroit différent (Europe, Amérique, Asie)
- 1 semaine, à Valence
- Près de 1000 participants littéralement du monde entier
- 3 premiers jours de sessions parallèles (9 sessions par thématiques, 15 à 20 minutes sur un sujet ciblé)

Brout-Englert-Higgs physics, Beyond the Standard Model, SUSY and Exotics, Top-quark and ElectroWeak Physics, Flavour Physics, Strong Interactions and Hadron Physics, Lattice QCD, Heavy Ion Physics, Neutrino Physics, Astroparticle Physics and Cosmology, Formal Theory Developments, Detector RD and Performance, Computing and Data Handling, Accelerator Physics and Future Colliders, Education and Outreach, Lepton Flavour Violation



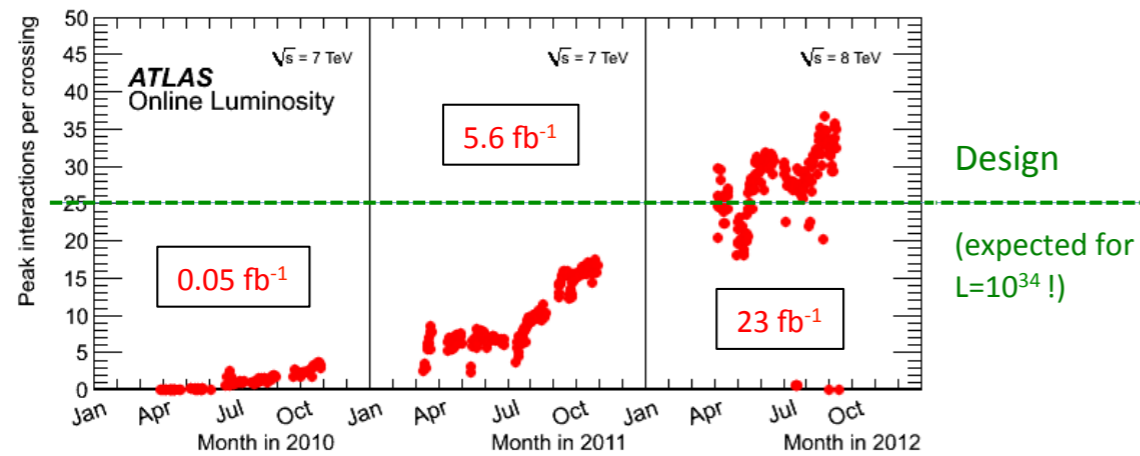
- Un dimanche pour digérer les résultats, travailler, faire du tourisme...
- 3 jours de sessions plénières (exposés plus longs faisant le bilan d'un domaine)
- Autant pour les présentations, calibrées, que pour les discussions, informelles, aux pauses (rumeurs...)
- Une intervention d'Alan Guth (Prix Gruber de cosmologie 2004), des conférences grand public, des prix pour de jeunes chercheurs, des séances d'affiches...
- Prospective pour la physique des hautes énergies dans les différentes régions du monde
- Autres occasions de rencontres: réunions satellites (accélérateurs), conférences thématiques, workshops spécialisés, séminaires....

09:00	CERN Director General <i>Auditorium 1</i>	<i>Prof. Rolf-Dieter HEUER</i> 09:00 - 09:10
	Valencian Ministry of Education, Culture and Sports <i>Auditorium 1</i>	<i>Mrs. Maria José CATALÁ</i> 09:10 - 09:20
	Spanish Secretary of State for Research, Development and Innovation <i>Auditorium 1</i>	<i>Dr. Carmen VELA</i> 09:20 - 09:30
	Inflationary Cosmology and Particle Physics <i>Auditorium 1</i>	<i>Prof. Alan GUTH</i>
10:00		09:30 - 10:15
	Coffee <i>Valencia, Spain</i>	10:30 - 10:45
	Physics of the Brout-Englert-Higgs boson in ATLAS <i>Auditorium 1</i>	<i>Dr. Marumi M. KADO</i> 10:45 - 11:15
11:00		
	Physics of the Brout-Englert-Higgs boson in CMS <i>Auditorium 1</i>	<i>Dr. André DAVID</i> 11:15 - 11:45
	Physics of the Brout-Englert-Higgs boson: theory <i>Auditorium 1</i>	<i>Prof. Christophe GROJEAN</i> 11:45 - 12:15
12:00		
	Results on Physics Beyond the Standard Model from ATLAS and CMS <i>Auditorium 1</i>	<i>Dr. Frank WUERTHWEIN</i> 12:15 - 12:45
	Physics Beyond the Standard Model: theory <i>Auditorium 1</i>	<i>Dr. Marcela CARENA</i> 12:45 - 13:15
13:00		
	Electroweak Physics: highlights of experimental results at low energy <i>Auditorium 1</i>	<i>Dr. Roger CARLINI</i> 13:15 - 13:45
14:00		
	Lunch <i>Valencia, Spain</i>	13:45 - 15:00
15:00		
	Electroweak Physics: highlights of experimental results from hadron colliders <i>Auditorium 1</i>	<i>Dr. Jeffrey BERRYHILL</i> 15:00 - 15:30

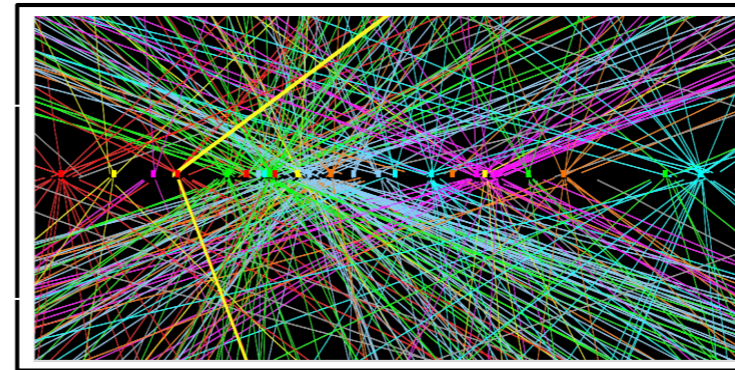
Higgs, cet inconnu



Three Years of Remarkable LHC operations at the Energy frontier (Run-1)



O(25) Pile Up (PU) events



Trigger Challenge : How to select 400 out of 20M events per second while keeping the interesting (including unknown) physics

Computing Challenge : Reconstruct, store and distribute 400 complex events per second (Reached 120 PB of data and simulation)

- Après l'émotion de la découverte, le boson de Higgs commence à être étudié avec précision
- Ce qui ouvre de nouvelles perspectives pour le programme de physique

Landscape Redefined Expansion of the Higgs Physics Program!

Precision

- Mass and width
- Coupling properties
- Quantum numbers (Spin, CP)
- Differential cross sections
- Off Shell couplings and width
- Interferometry

Rare decays

- $Z\gamma$
- Muons $\mu\mu$
- LFV $\mu\tau, e\tau$
- $J/\Psi\gamma, ZY, \text{etc...}$

H^0

Is the SM minimal?

- 2 HDM searches
- MSSM, NMSSM searches
- Doubly charged Higgs bosons

Tool for discovery

- Portal to DM (invisible Higgs)
- Portal to hidden sectors
- Portal to BSM physics with H^0 in the final state (ZH^0, WH^0, H^0H^0)

...and More!

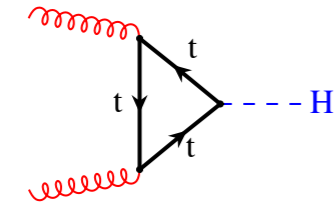
- FCNC top decays
- Di-Higgs production
- Trilinear couplings prospects
- Etc...

*Disclaimer: Not all subjects will be covered in this talk

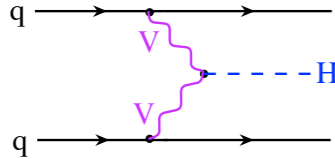
How SM Higgses come to be

[http://cern.ch/go/cWH8] [http://cern.ch/go/SnJ8]

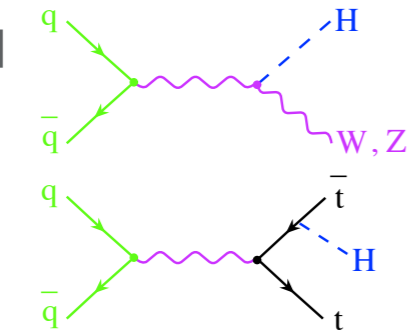
□ **Gluon fusion**



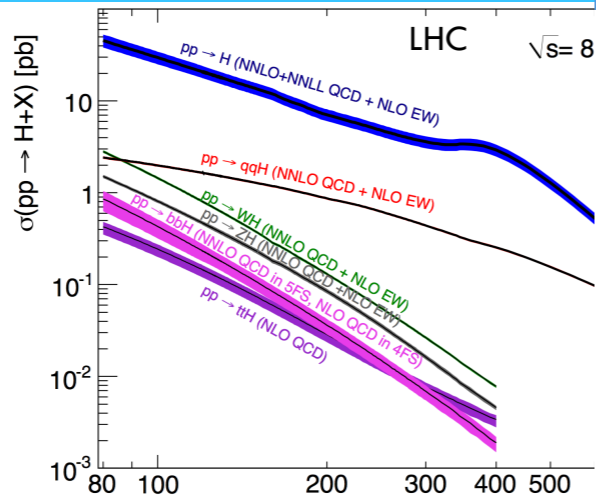
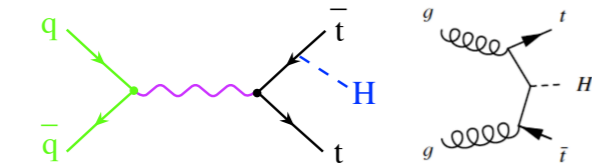
□ **VBF**



□ **WH, ZH**



□ **bbH, ttH**



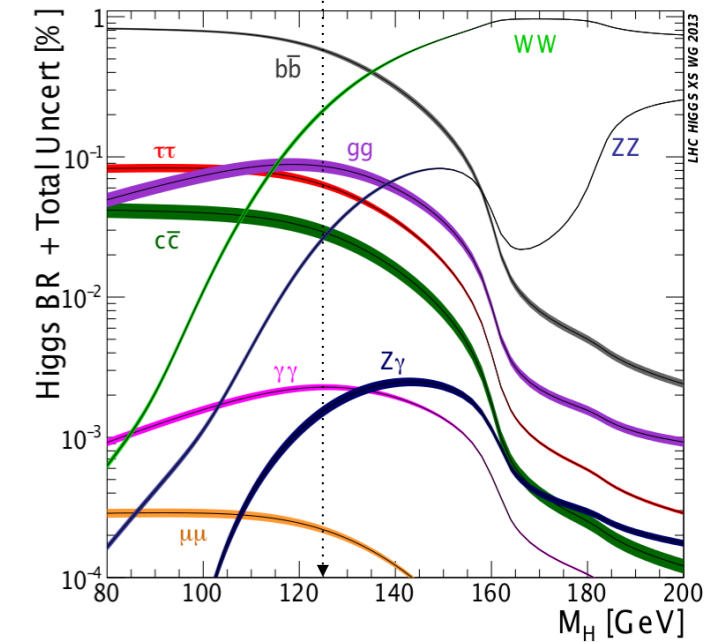
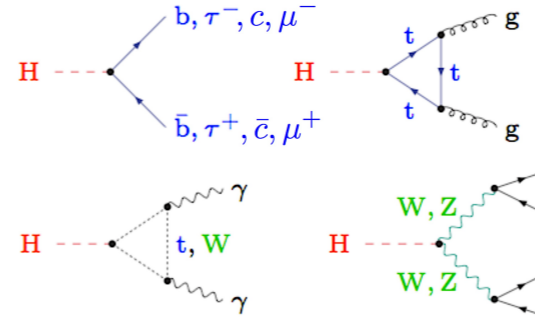
a.david@cern.ch @CMSexperiment @ICHEP...

How SM Higgses pass away

[http://cern.ch/go/qkh6]

□ Couplings and kinematics drive BR ($b\bar{b}$, WW , $\tau\tau$, ZZ).

□ Decays to photons ($\gamma\gamma$, $Z\gamma$) through loops.



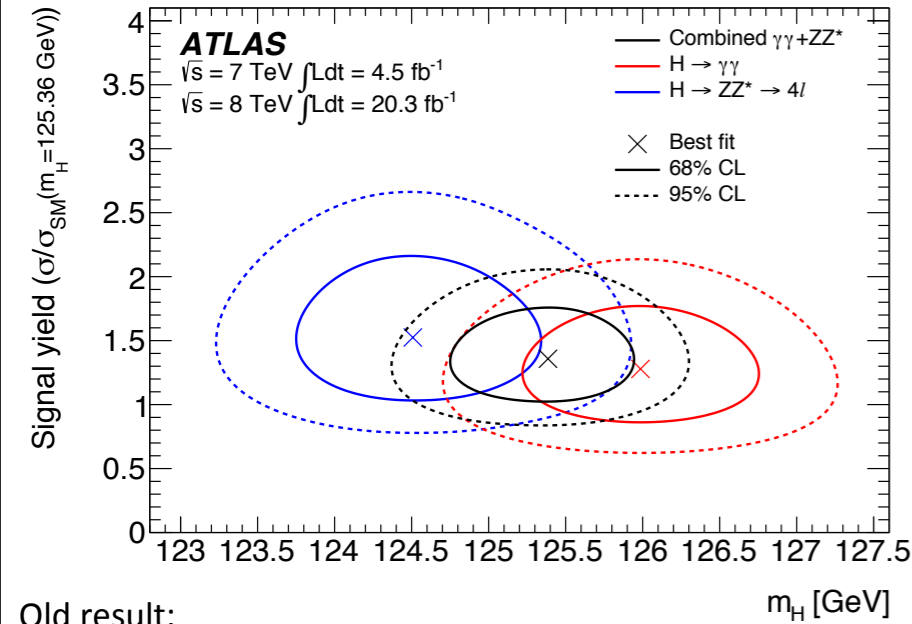
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- Plusieurs modes de production
- Plusieurs modes de désintégrations
- Et tous les modes n'ont pas encore été observés !

"seen" ★ "tried" ☆	$H \rightarrow b\bar{b}$	$H \rightarrow \tau\tau$	$H \rightarrow WW$	$H \rightarrow ZZ$	$H \rightarrow \gamma\gamma$	$H \rightarrow Z^{(*)}\gamma$	$H \rightarrow \text{inv.}$	$H \rightarrow \mu\mu$	$H \rightarrow c\bar{c}$ $H \rightarrow HH$
ggH		★	★	★	★	☆		☆	
VBF	☆	★	★	☆	★	☆	☆	☆	
VH	★	☆	☆	☆	☆		☆		
ttH	☆	☆	☆		☆				

Measurement of the Higgs boson mass (and signal strengths)

Submitted to PRD arXiv:1406.3827



Note measure channels
signal strength

$$\mu_{(m_H=125.98\text{ GeV})}^{\gamma\gamma} = 1.29 \pm 0.30$$

$$\mu_{(m_H=124.51\text{ GeV})}^{ZZ} = 1.66^{+0.45}_{-0.38}$$

ZZ and $\gamma\gamma$ compatibility

Old $\left\{ \begin{array}{l} \Delta m = 2.3 \pm 0.9 \\ \text{Compatibility } 2.4\sigma \end{array} \right.$

$$\Delta m = 1.47 \pm 0.72$$

Compatibility 1.97σ

- Higgs : résonance avec largeur $\Gamma_{SM}=4.2$ MeV
- Comparaison de la section efficace H->ZZ sur le pic du Higgs ou loin du pic donne une information sur la largeur
- $\Gamma_H/\Gamma_{SM} < 5.7$ (ATLAS) ou 5.4 (CMS) à 95% CL

Old result:

$$125.5 \pm 0.2 \text{ (stat)}^{+0.5}_{-0.6} \text{ (syst) GeV}$$

New:

$$125.36 \pm 0.37 \text{ (stat)} \pm 0.18 \text{ (syst) GeV}$$

0.3% Precision measurement (statistical uncertainty dominant)

- Masse obtenue en combinant $\gamma\gamma$ et ZZ^* , en très bon accord entre ATLAS et CMS
- Tous les tests en très bon accord avec spin 0 : c'est un scalaire !



H* – going off-shell

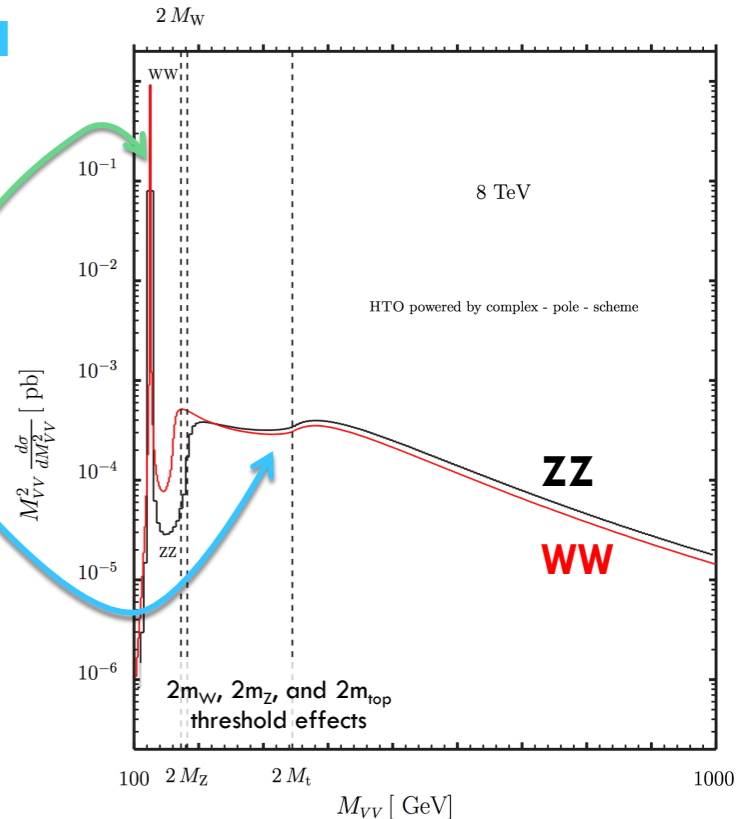
71 [arXiv:1405.3455, accepted by PLB] [arXiv:1206.4803]

$$\frac{d\sigma_{gg \rightarrow H \rightarrow ZZ}}{dm_{ZZ}^2} \sim \frac{g_{ggH}^2 g_{HZZ}^2}{(m_{ZZ}^2 - m_H^2)^2 + m_H^2 \Gamma_H^2}$$

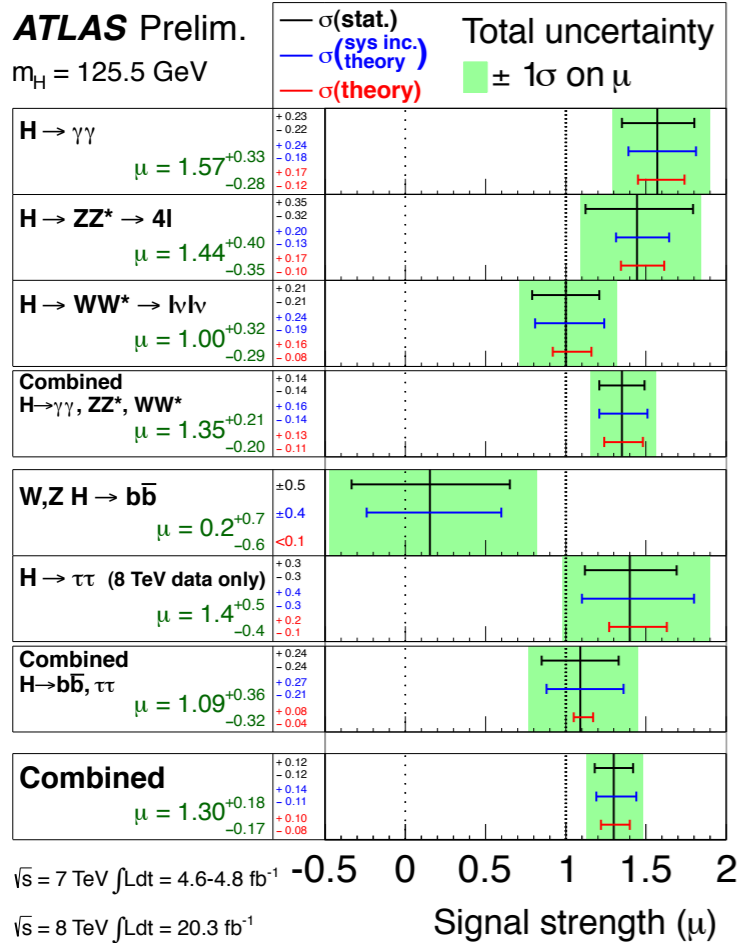
$m_{ZZ} \sim m_H$ \rightarrow $\sigma_{gg \rightarrow H \rightarrow ZZ}^{\text{on-shell}} \sim \frac{g_{ggH}^2 g_{HZZ}^2}{m_H \Gamma_H}$

$m_{ZZ} \gg m_H$ \rightarrow $\sigma_{gg \rightarrow H \rightarrow ZZ}^{\text{off-shell}} \sim \frac{g_{ggH}^2 g_{HZZ}^2}{(2m_Z)^2}$

$$\frac{\sigma_{gg \rightarrow H \rightarrow ZZ}^{\text{off-shell}}}{\sigma_{gg \rightarrow H \rightarrow ZZ}^{\text{on-shell}}} \sim \Gamma_H$$



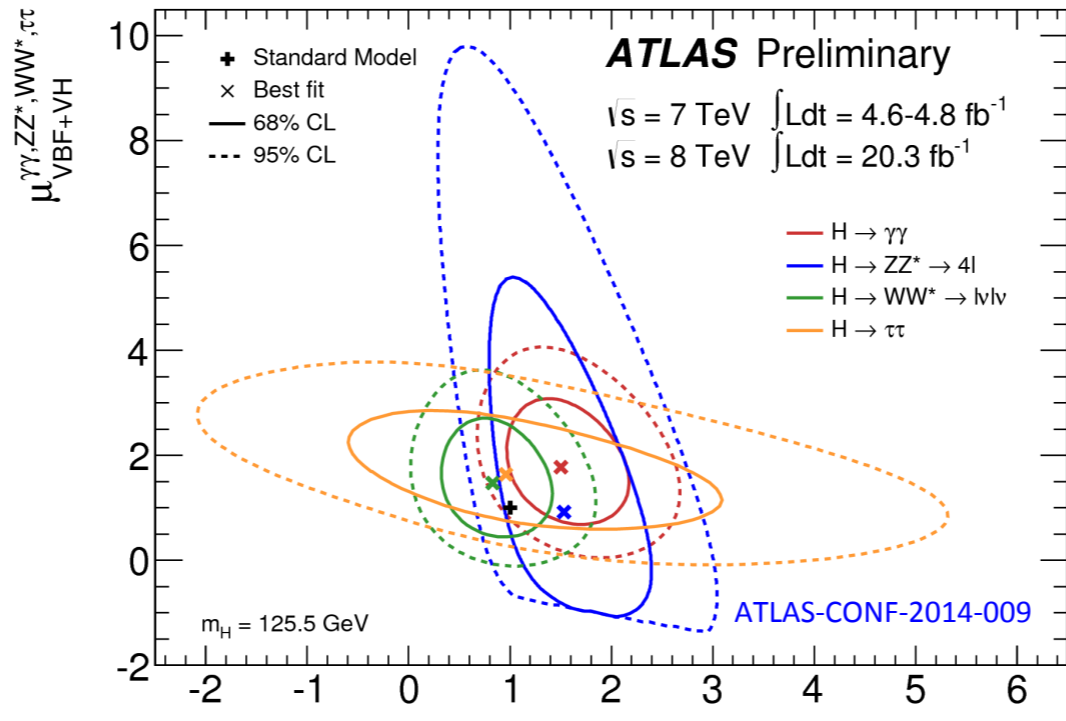
Main Decay and Production Modes



ATLAS-CONF-2014-009

$\mu = 1.30 \pm 0.12$ (stat) ± 0.10 (th) ± 0.09 (syst)

- Bon accord des différents canaux avec le Modèle Standard
- ATLAS: globalement un peu au-dessus du MS (mais en accord)
- CMS: pile sur le MS (seule production par ttH s'écarte des attentes du MS).

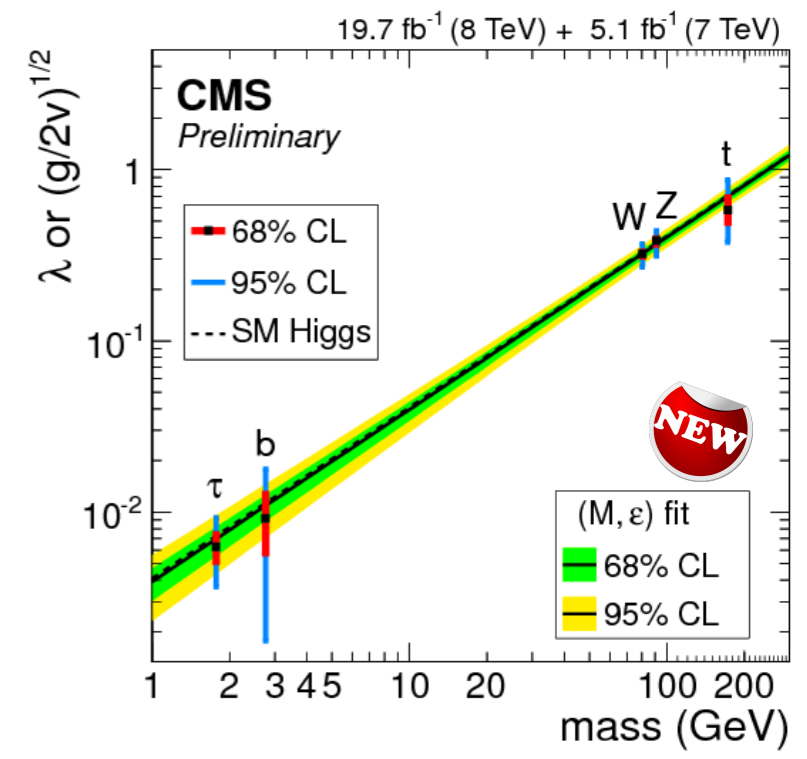


Assumes SM branching fractions and prod

Signal strength

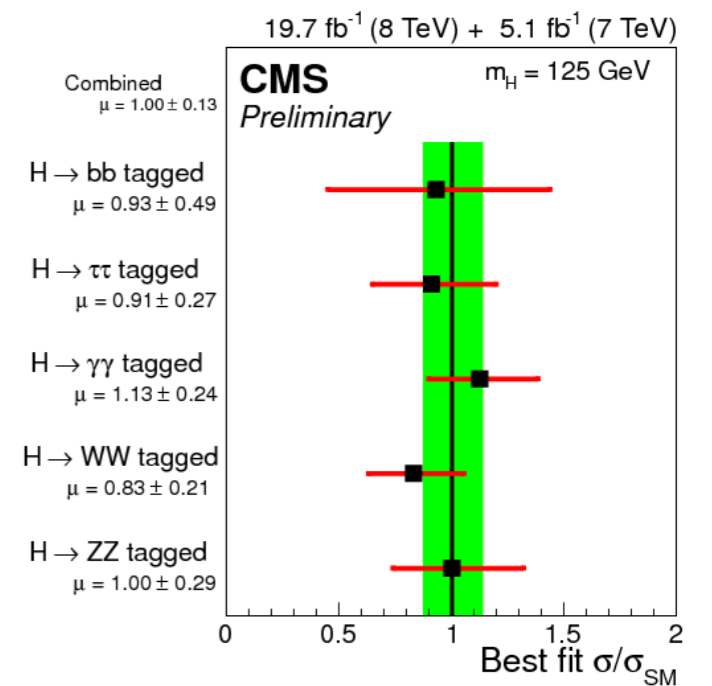
51 [CMS-PAS-HIG-14-009]

$m_H = 125.03 \pm 0.30$ $\left[\begin{matrix} +0.26 \\ -0.27 \end{matrix} \right]$ (stat.) $\left[\begin{matrix} +0.13 \\ -0.15 \end{matrix} \right]$ (syst.) GeV

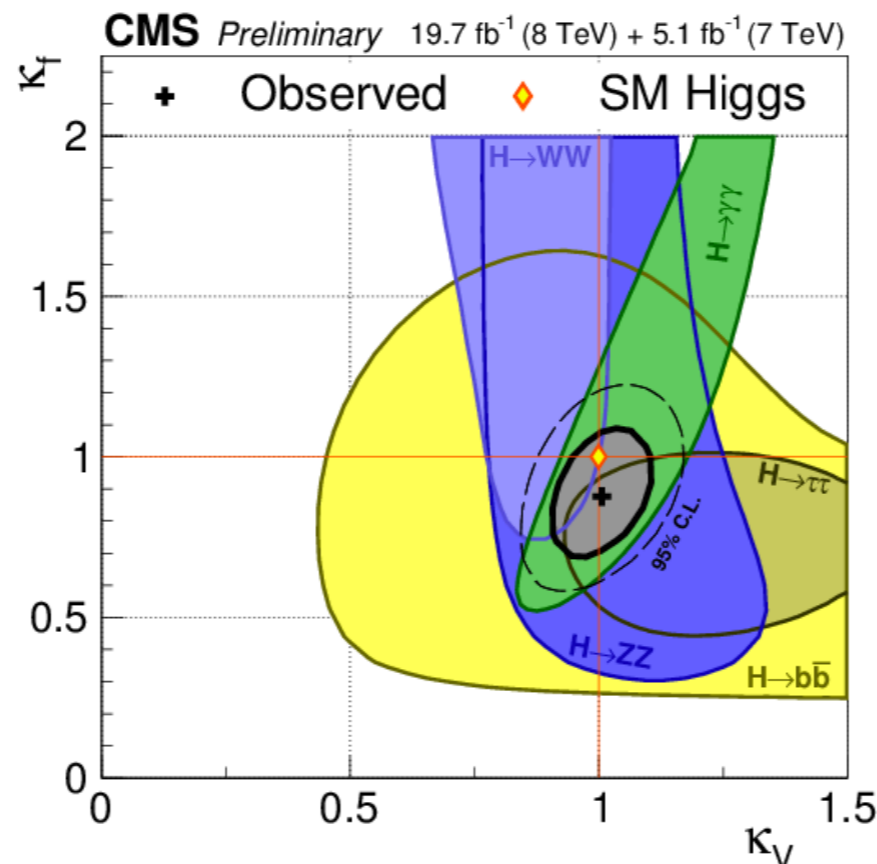


$\sigma/\sigma_{SM} = 1.00 \pm 0.13$ $\left[\pm 0.09(\text{stat.}) \begin{matrix} +0.08 \\ -0.07 \end{matrix} (\text{theo.}) \pm 0.07(\text{syst.}) \right]$

- Grouped by dominant decay:
 - $\chi^2/\text{dof} = 0.9/5$
 - p-value = 0.97 (asymptotic)

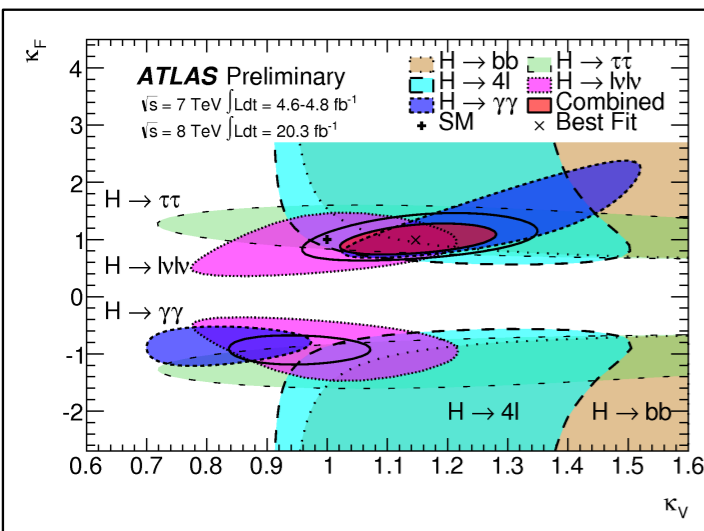


- Scaling the couplings to fermions (κ_f) and vector bosons (κ_V).
- All decay channels converging around SM expectation.



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Probing the Higgs couplings



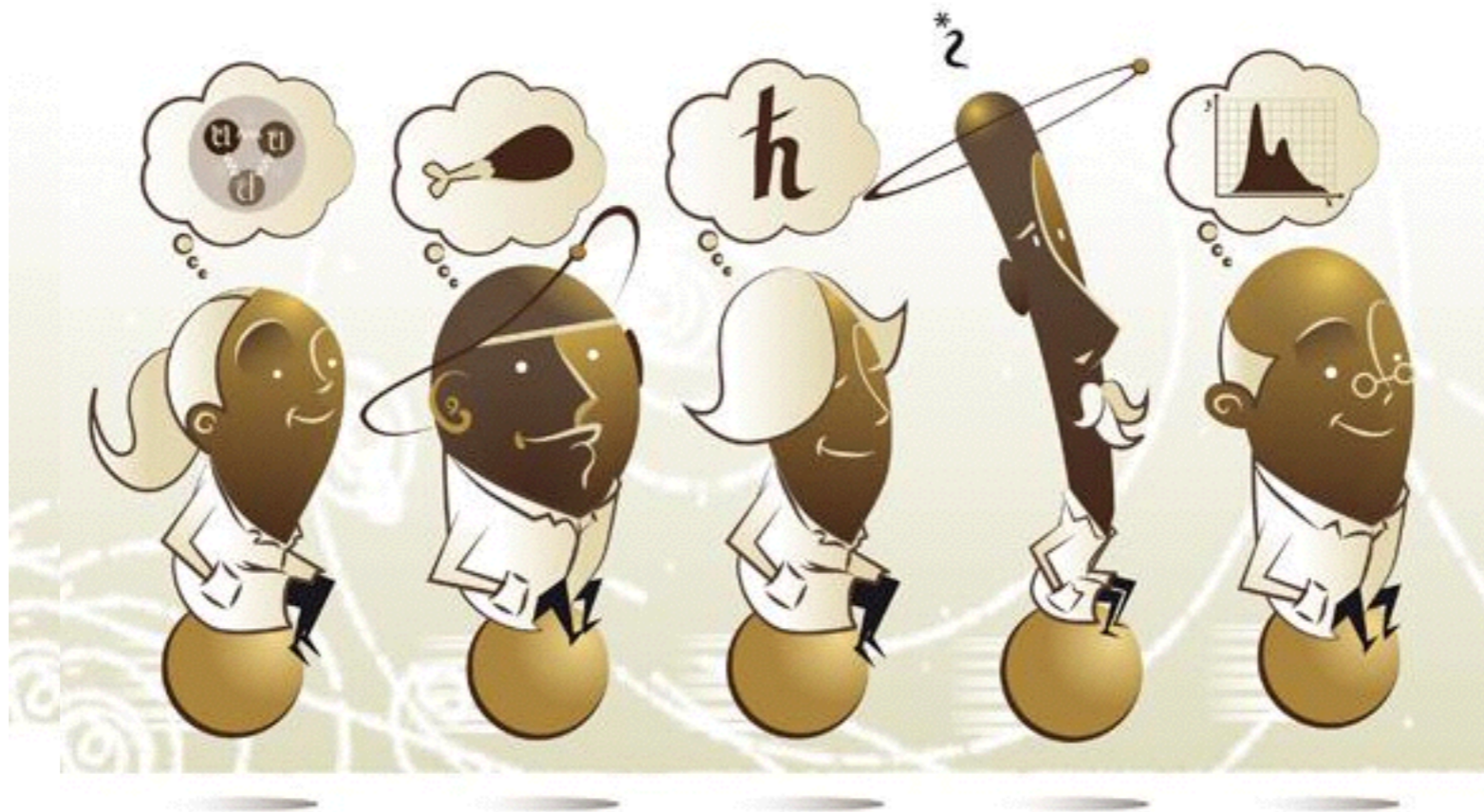
ATLAS-CONF-2014-009

Assuming no BSM in the production and decay

- Compatible with SM
- Negative κ_t (relative to κ_V) disfavored (but still possible solution)
- Already excluding composite models

- Si on suppose que les couplages aux fermions d'une part et aux bosons d'autre part sont multipliés par un même facteur par rapport au Modèle Standard
- Les différentes mesures contraignent chacun des paramètres
- Aboutissant à des valeurs totalement compatibles avec les Modèle Standard

t, W, Z... et les autres





On the shoulders of giants: detector makers & theory calculators

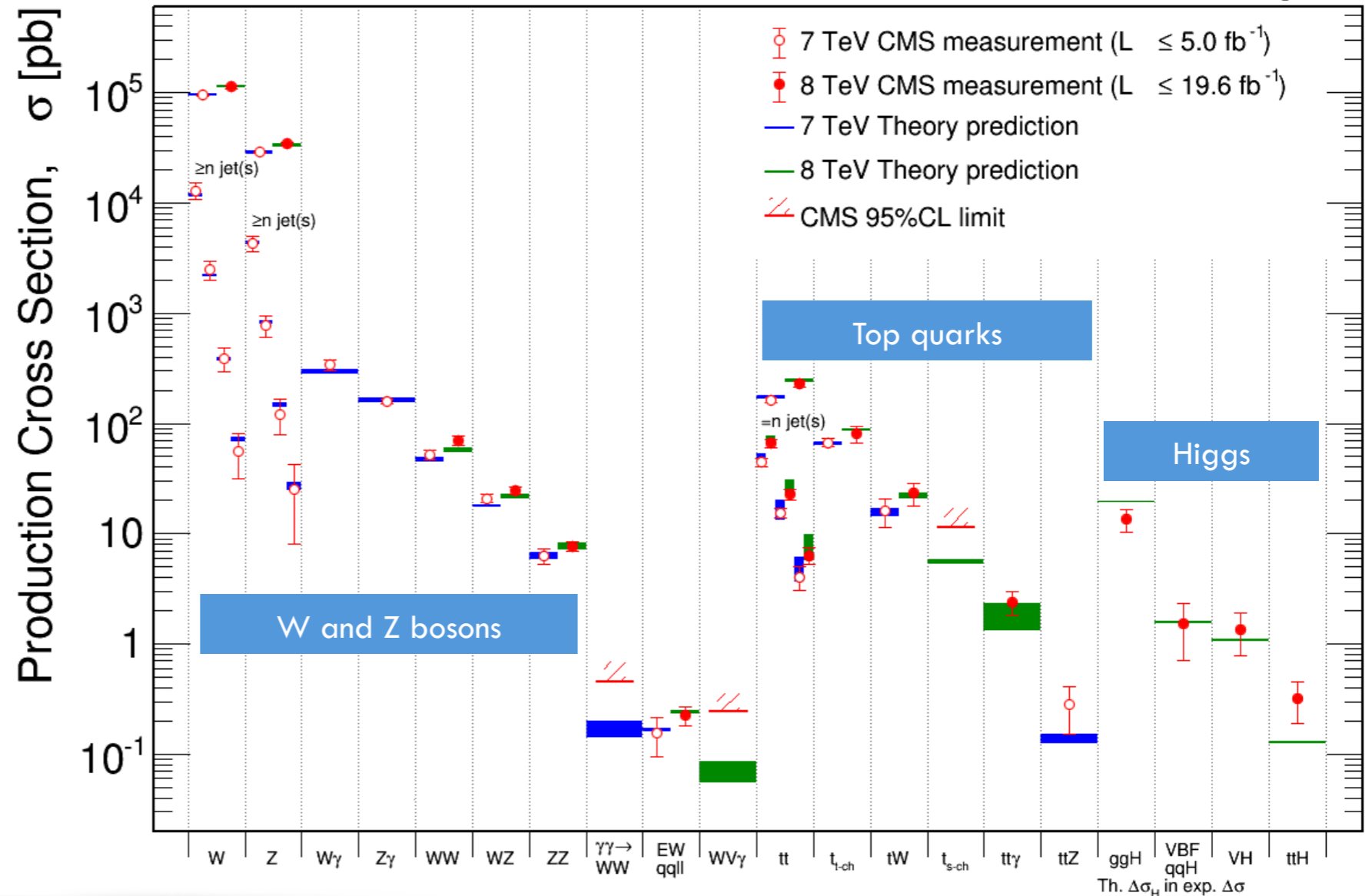
7

"Yesterday's discovery is today's calibration, and tomorrow's background." – V. L. Telegdi [http://cern.ch/go/lf9C] [http://cern.ch/go/KD8D]

Inelastic collisions: $\sim 7 \times 10^{10}$ Feb 2014

CMS Preliminary

Six orders of magnitude of EWK, top, and Higgs Physics



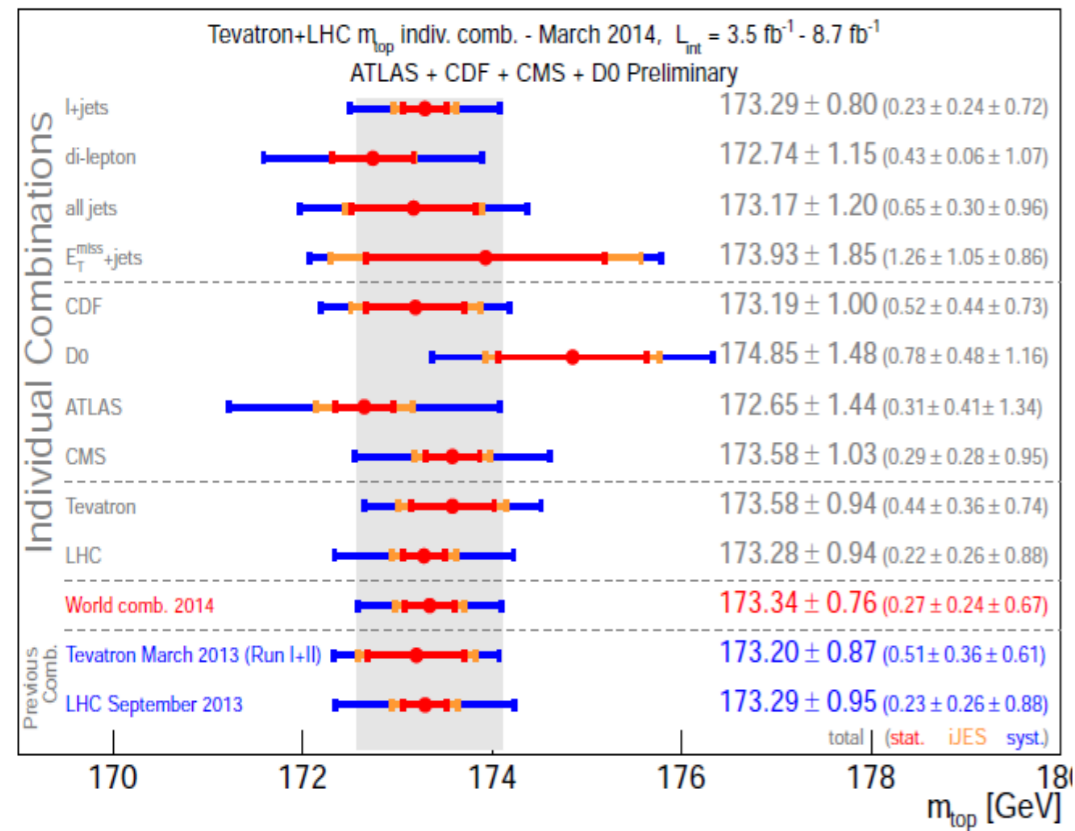
- Très bon accord avec la théorie électrofaible...
- ... sur six ordres de grandeur

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Top mass world average 2014

Tevatron combination November 2012 May 2013
 LHC combination July 2012 September 2013
 World combination March 2014 arXiv:1403.4427



$$m_{top} = 173.34 \pm 0.27 \text{ (stat)} \pm 0.24 \text{ (iJES)} \pm 0.67 \text{ (syst)} \text{ GeV}$$

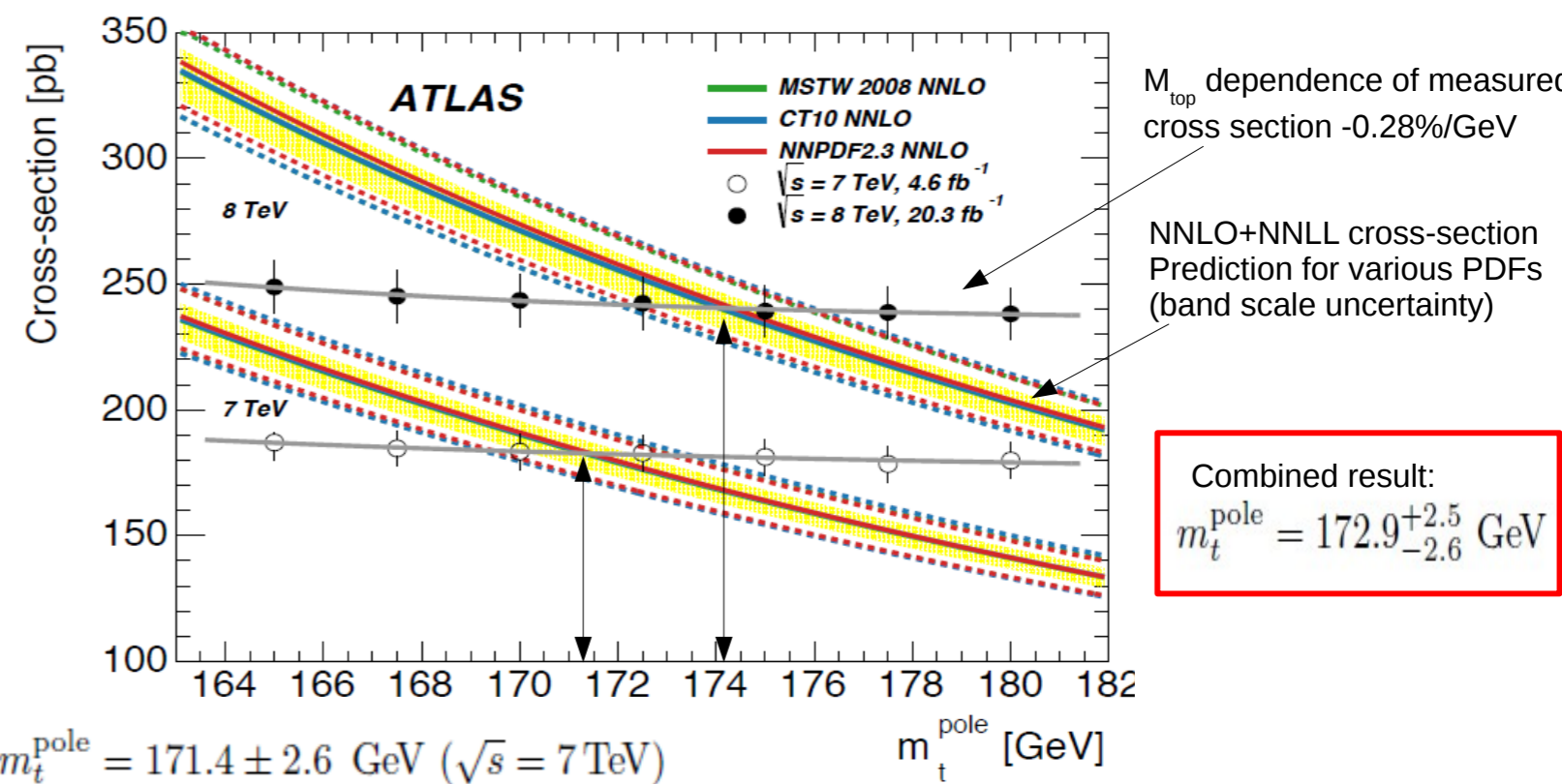
precision on M_{top} 0.44%

- Grace aux efforts combinés du LHC (ATLAS/CMS) et du Tevatron (CDF/D0), la masse du quark top est connue avec une grande précision expérimentale... mais définition théorique ?
- Des efforts théoriques pour attribuer à cette masse une définition théorique solide, via d'autres processus (par exemple $pp \rightarrow t + tbar + X$).

Top mass determination from inclusive top anti-top cross section

Comparing NNLO+NNLL QCD top pair cross section to data determine top mass in a well defined renormalisation scheme (here: pole mass) and theory uncertainties

CMS Phys. Lett. B 728 (2013) 496
 ATLAS arXiv:1406.5375



$$m_t^{pole} = 171.4 \pm 2.6 \text{ GeV } (\sqrt{s} = 7 \text{ TeV})$$

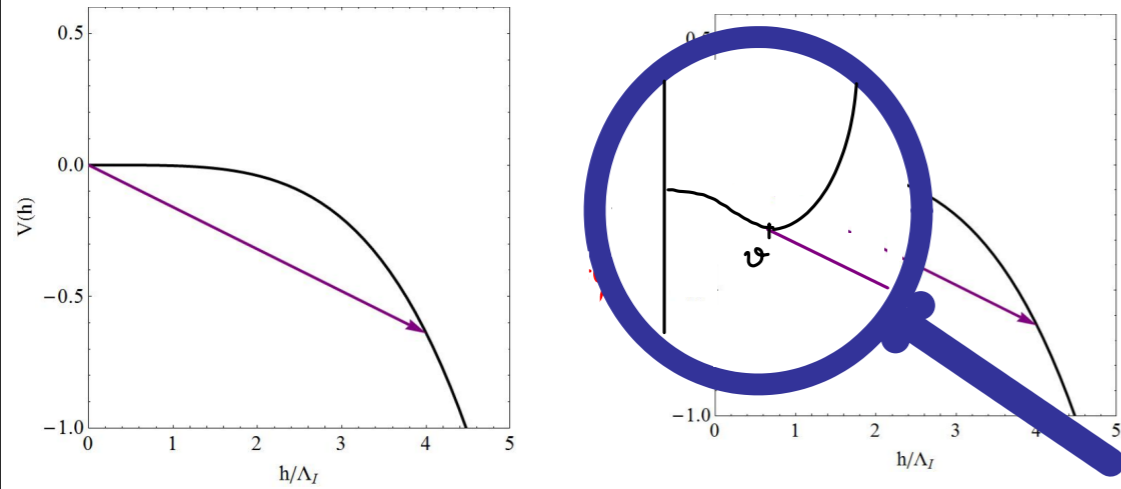
$$m_t^{pole} = 174.1 \pm 2.6 \text{ GeV } (\sqrt{s} = 8 \text{ TeV})$$

Largest exp. syst. (luminosity) uncorrelated for 7 and 8 TeV
 Results consistent within 1.7 sigma

Is the Higgs temporary?

If λ becomes negative, the EW vacuum is meta/unstable

(courtesy of JR Espinosa)



- Avec les valeurs actuelles de la masse du top et la masse du Higgs...
- ... et si nous supposons que le MS est valable jusqu'à des échelles très élevées (proche de la masse de Planck)...
- ... l'état fondamental du MS serait métastable (instable, car il existerait un autre vide, d'E plus faible)

and the Higgs and our EW vacuum are only tempor

Are we living at a edge of the phase diagram?

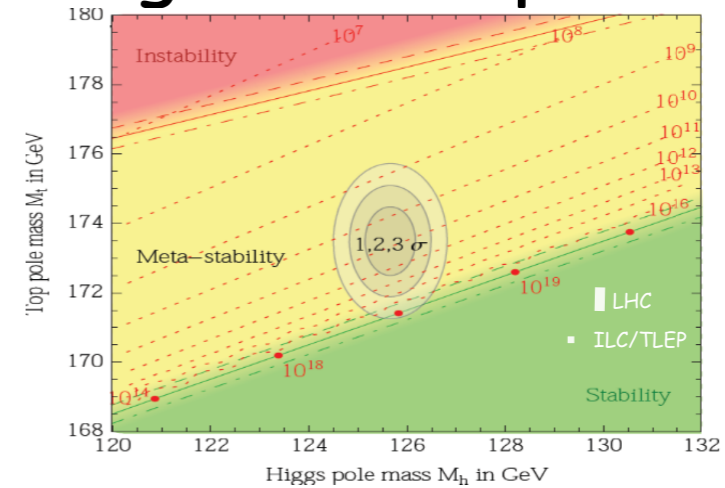
Christophe Grojean

Higgs Physics - Theory

10

v

Parameter	Present	LHC	ILC/GigaZ	TLEP
M_H [GeV]	0.4 \Rightarrow < 0.1	< 0.1	< 0.1	< 0.1
M_W [MeV]	15 \Rightarrow 8	8	5	1.3
M_Z [MeV]	2.1	2.1	2.1	0.1
m_t [GeV]	0.9 \Rightarrow 0.6	0.6	0.1	0.08

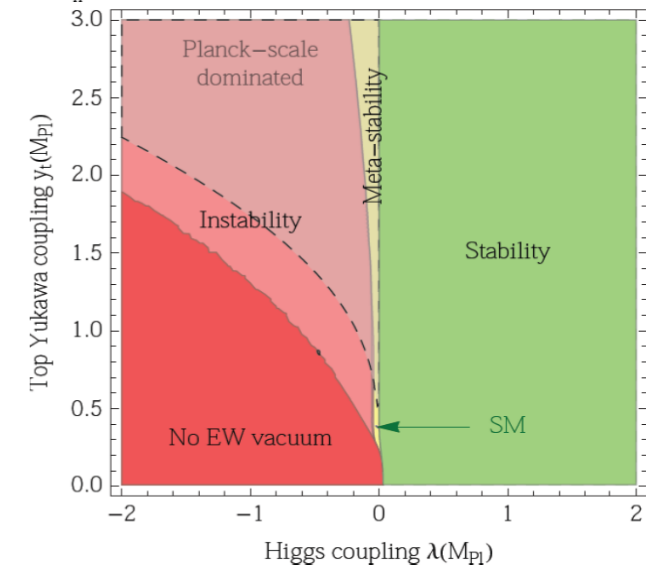
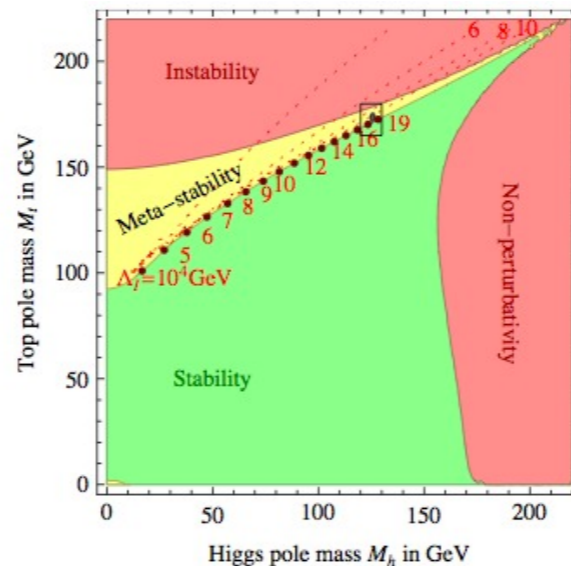


Buttazzo et al '13

see also:

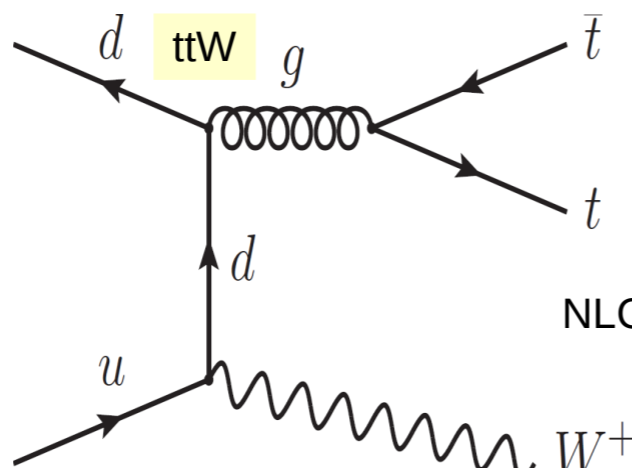
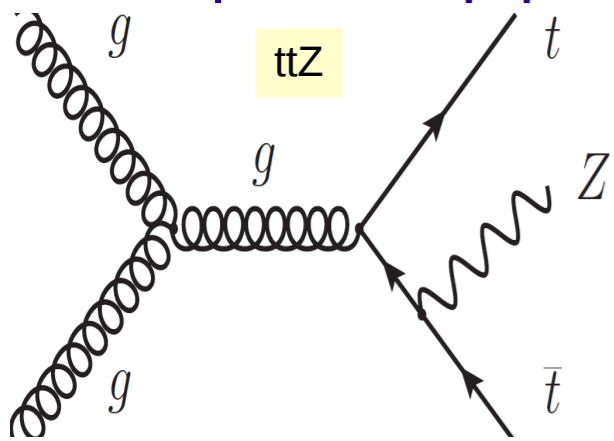
Bezrukov et al '12

Degrassi et al '12



The (near) criticality of our vacuum calls for a precise measurement

Top anti-top production in association with W/Z bosons



Garzelli et al [JHEP 1211\(2012\) 056](#)
Campbell/Eliis [JHEP 1207 \(2012\) 052](#)

NLO QCD cross section about 200 fb

Process allow test of electroweak coupling of the top quark

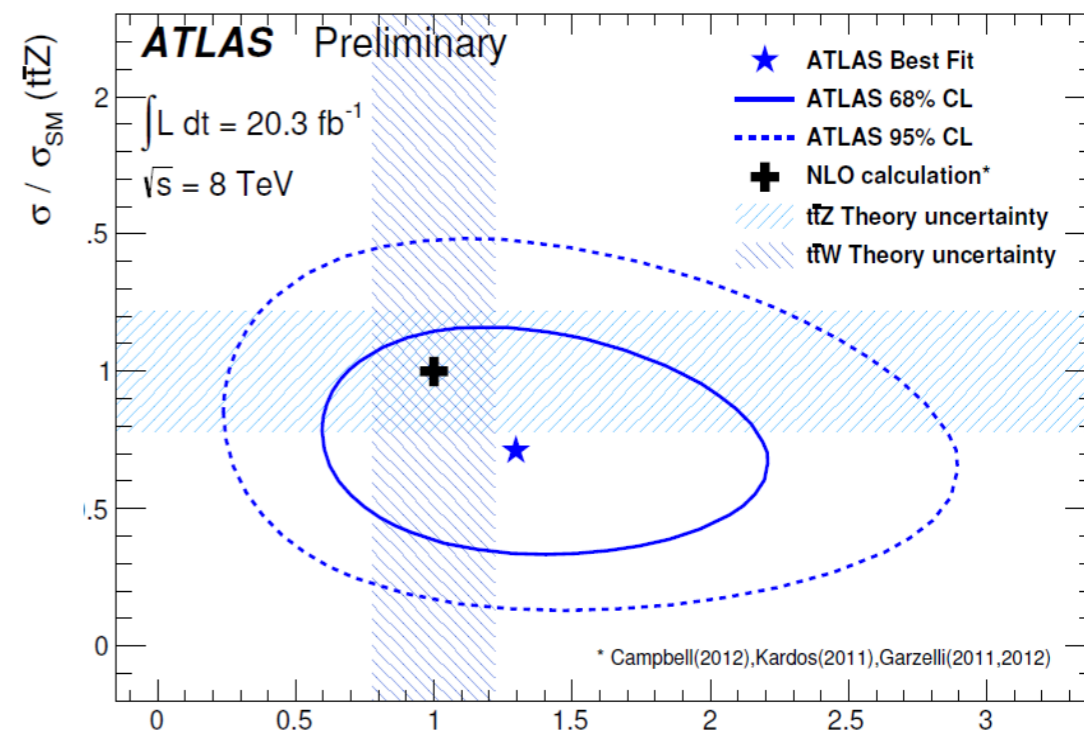
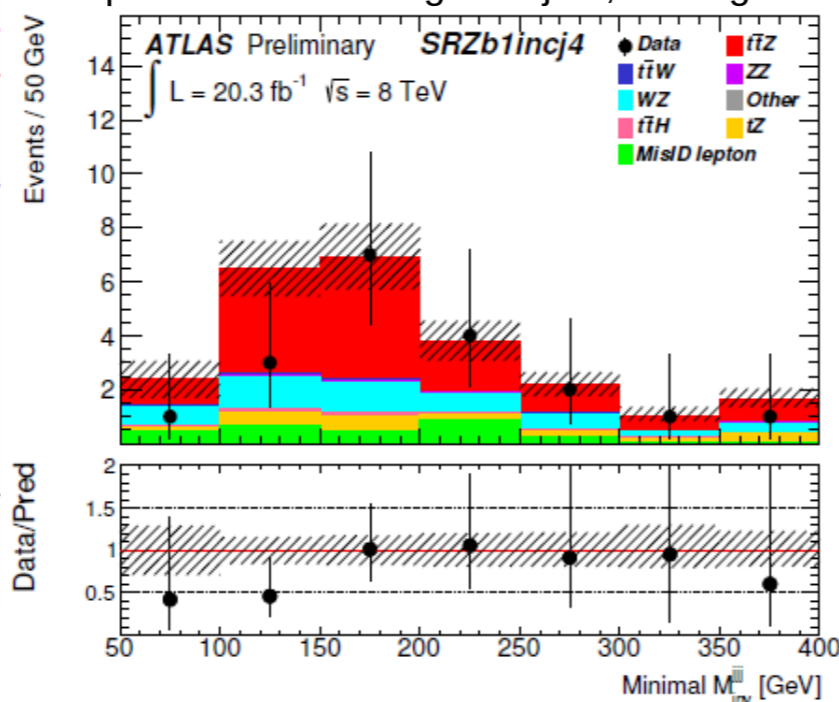
Experimental signature number of leptons

- Production associant t,W et/ou Z...
- ... un autre test de la dynamique electrofaible

Top anti-top production in association with W/Z bosons

ATLAS ATLAS-CONF-2014-038

Example:
3 lepton in Z mass region 4 jets, 1 b-tag



2 leptons same+opposite sign and 3 leptons combined:

Process	Observed σ
$t\bar{t}V$	4.9
$t\bar{t}W$	3.1
$t\bar{t}Z$	3.2

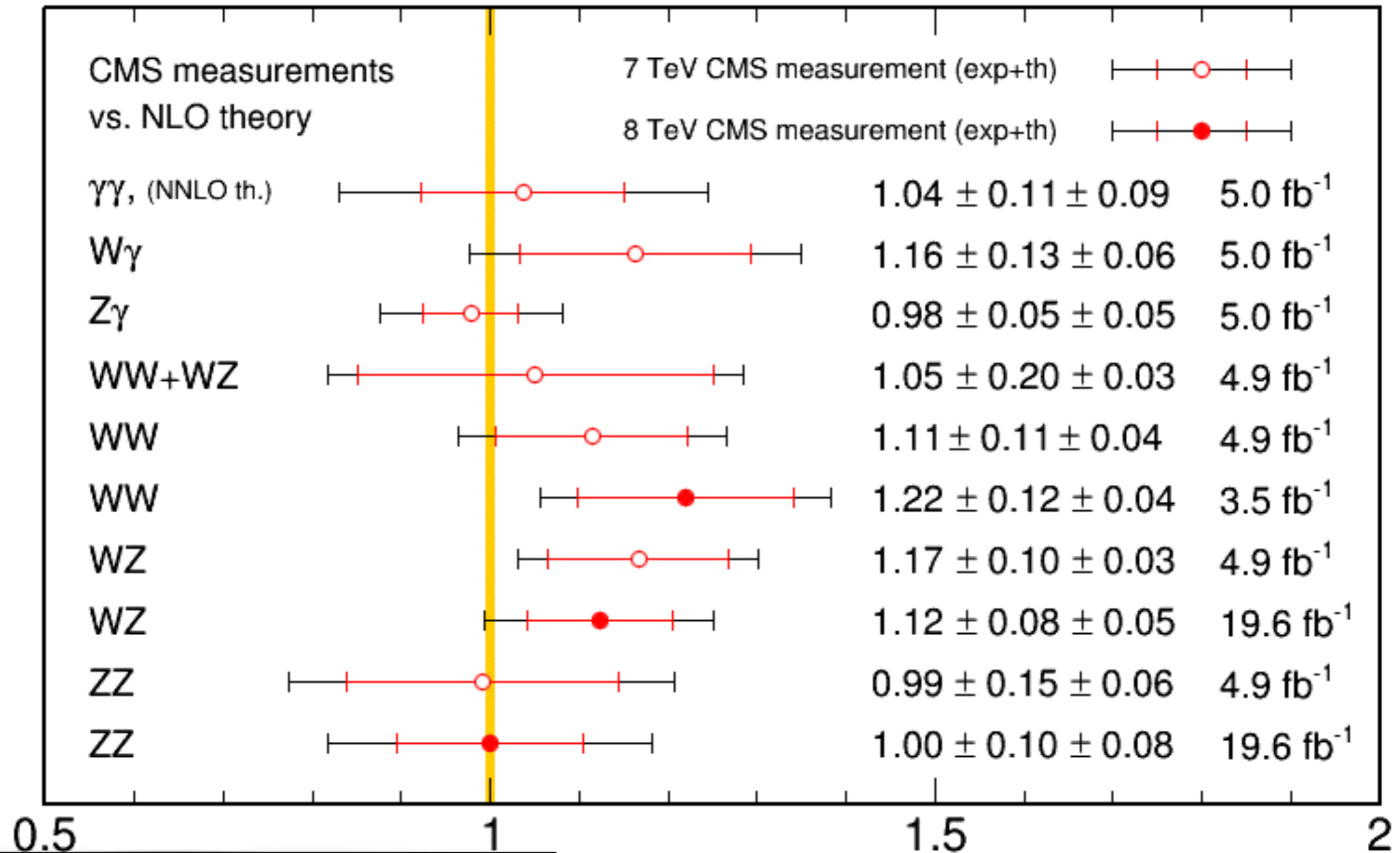
Summary of combined simultaneous fit results

Process	Measured cross-sections	Observed σ
$t\bar{t}Z$	$150^{+58}_{-54}(\text{total}) = 150^{+55}_{-50}(\text{stat.}) \pm 21(\text{syst.}) \text{ fb}$	3.1
$t\bar{t}W$	$300^{+140}_{-110}(\text{total}) = 300^{+120}_{-100}(\text{stat.})^{+70}_{-40}(\text{syst.}) \text{ fb}$	3.1

CMS Diboson Summary

Apr 2014

CMS Preliminary



La production de deux bosons électrofaibles semble bien comprise et mesurée par ATLAS et CMS (tests des vertex à 3 bosons)

Cross Section Ratio: $\sigma_{\text{exp}} / \sigma_{\text{theo}}$

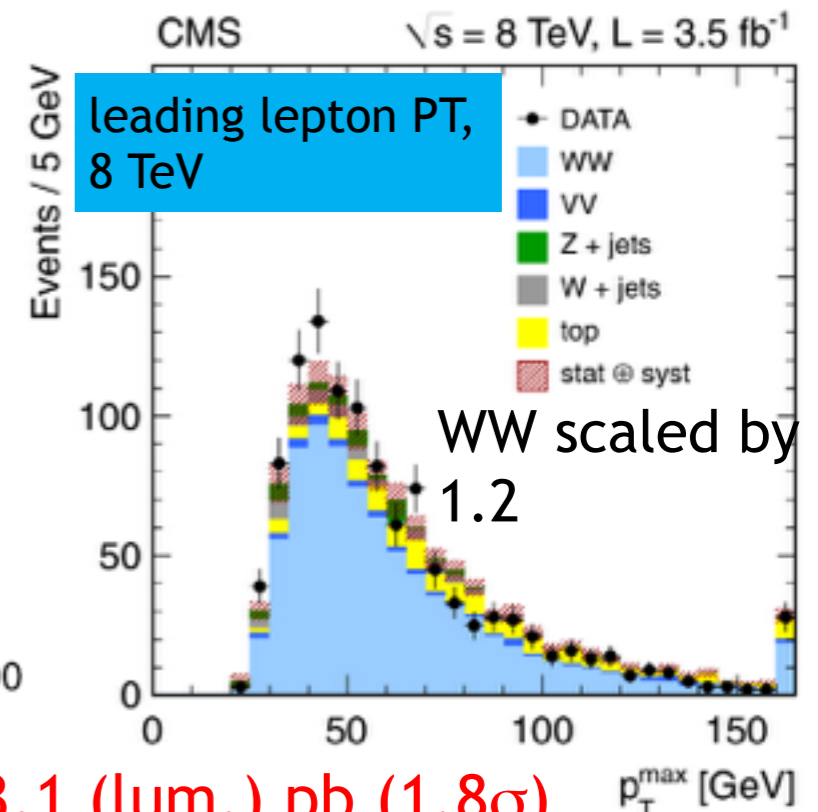
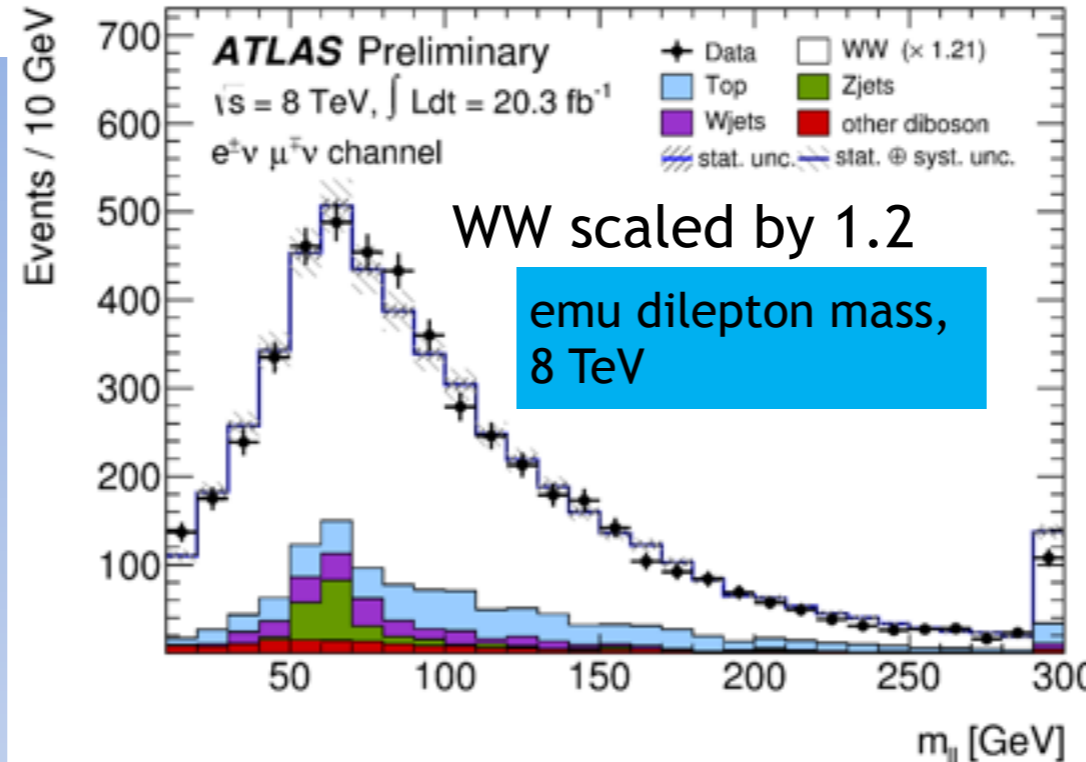
WW Production (8 TeV)

PLB 721 (2013) 190

ATLAS-CONF-2014-033

NEW for ICHEP14

- Kinematic shapes agree with prediction, but cross section excess observed at 20% level in CMS and ATLAS
- ~5000 emu ATLAS candidates with 20/fb!
- Systematics from jet veto acceptance, background methods
- Not yet reporting: CMS lvlv 20/fb, WW → lvjj 20/fb
- Theory calculation being actively studied (jet vetoes, NNLO)

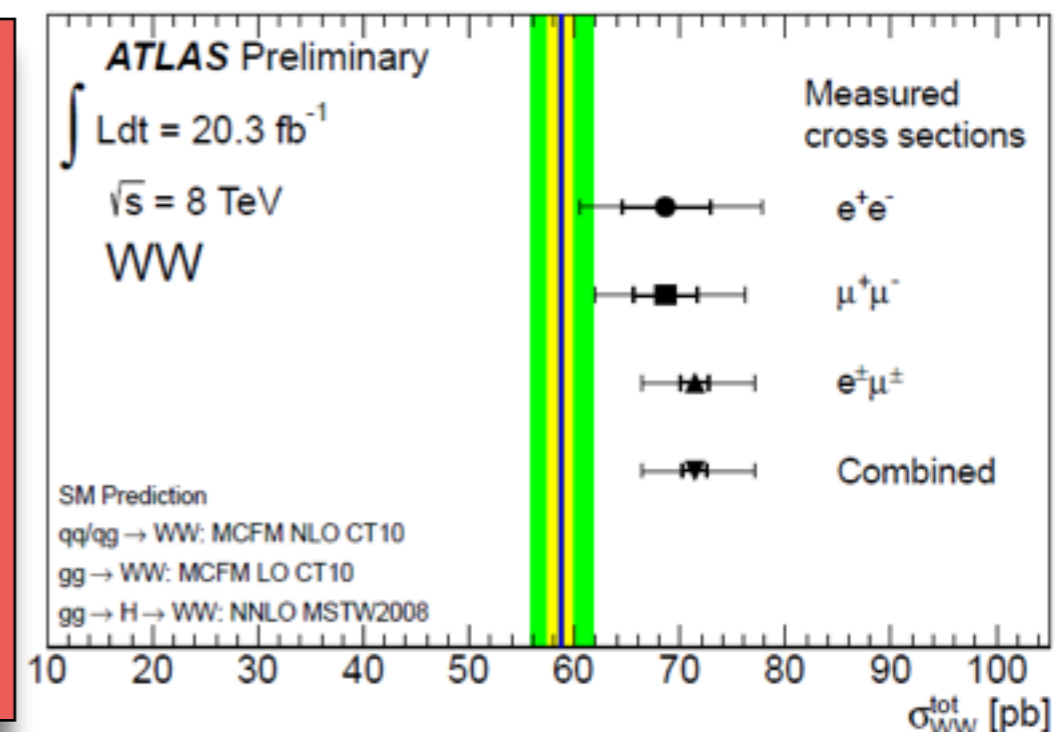


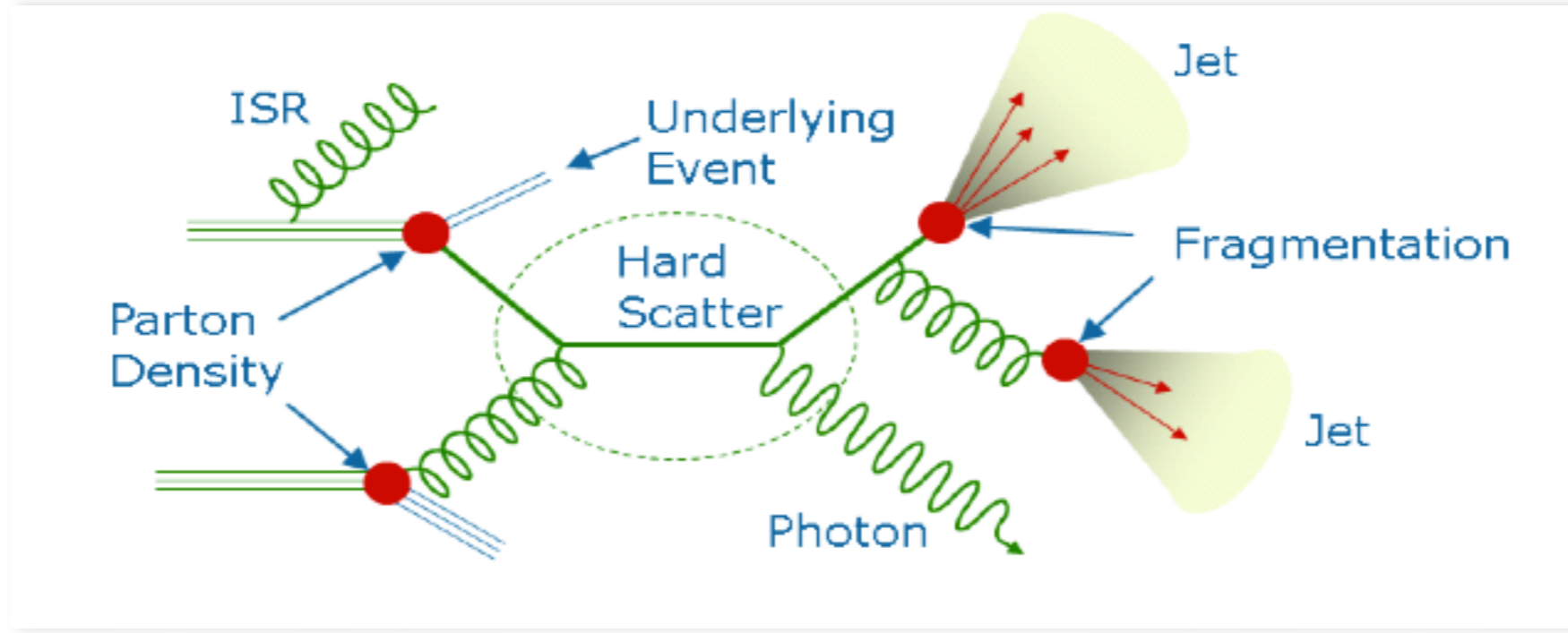
CMS $69.9 \pm 2.8 \text{ (stat.)} \pm 5.6 \text{ (syst.)} \pm 3.1 \text{ (lum.) pb (1.8}\sigma)$

ATLAS $71.4 \pm 1.2 \text{ (stat.)} \pm 5.0 \text{ (syst.)} \pm 2.2 \text{ (lum.) pb (2.1}\sigma)$

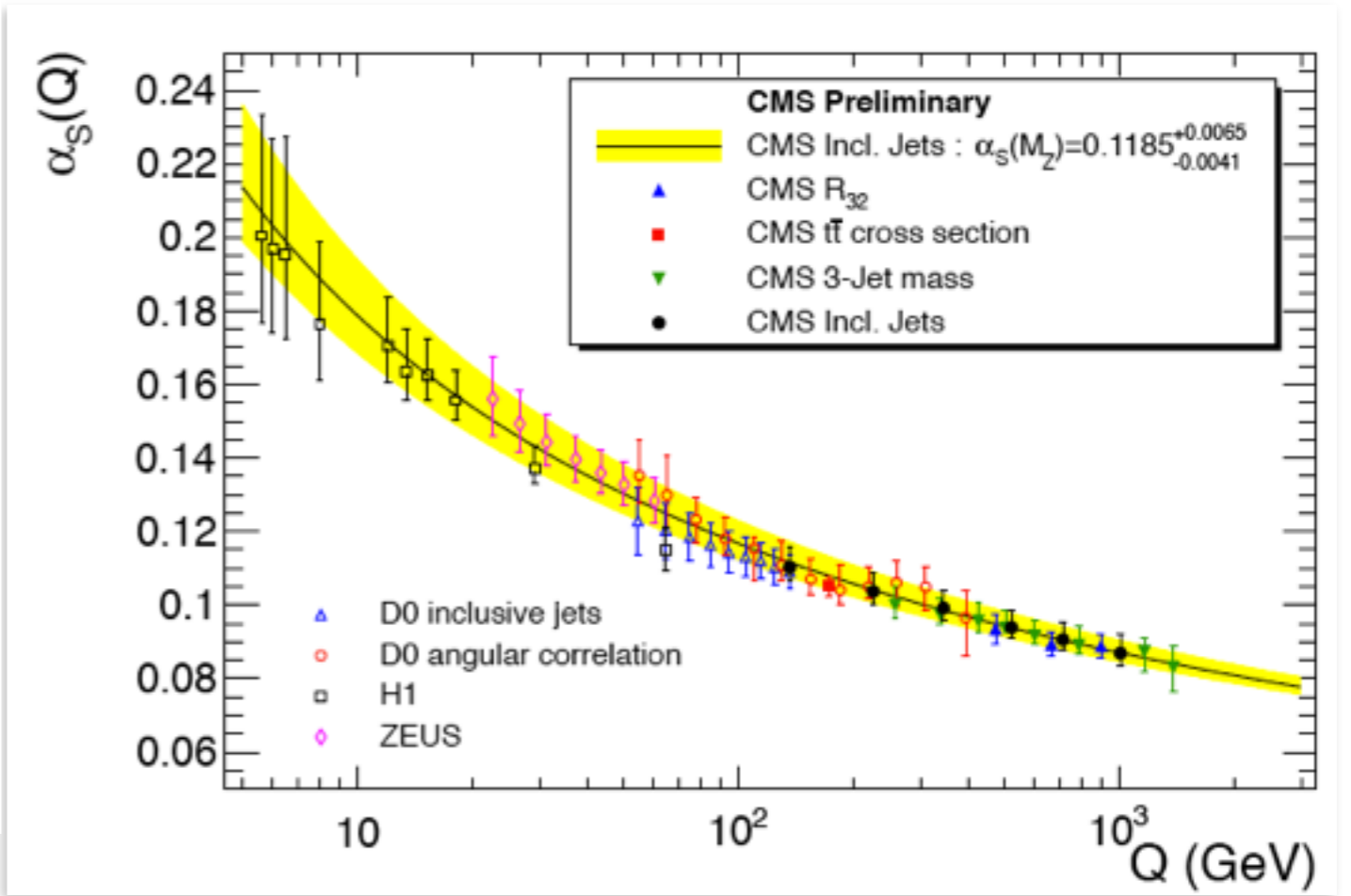
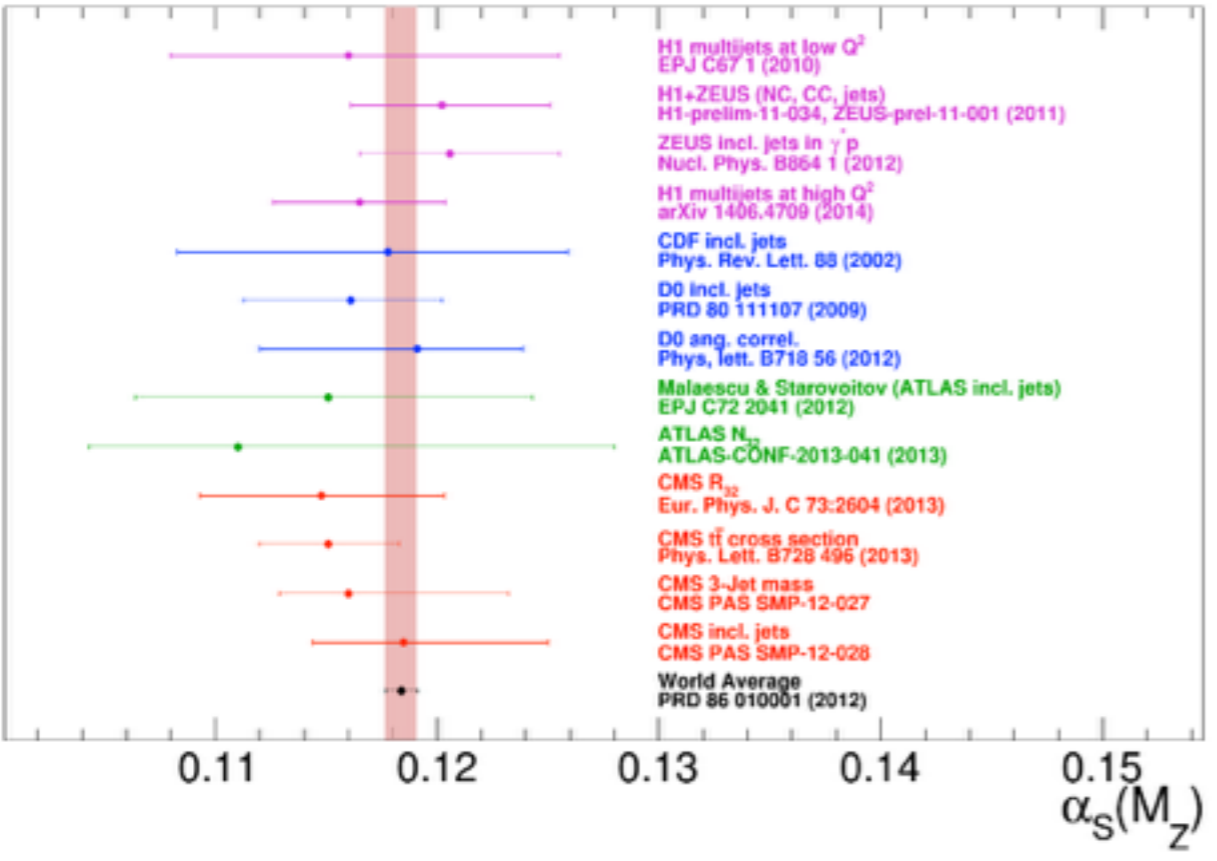
MCFM $58.7 \pm 3.0 \text{ (syst.) pb}$

- La production WW observée avec un excès de 20% dans ATLAS et CMS...
- Un effet hadronique mal compris, ou de la Nouvelle Physique ?

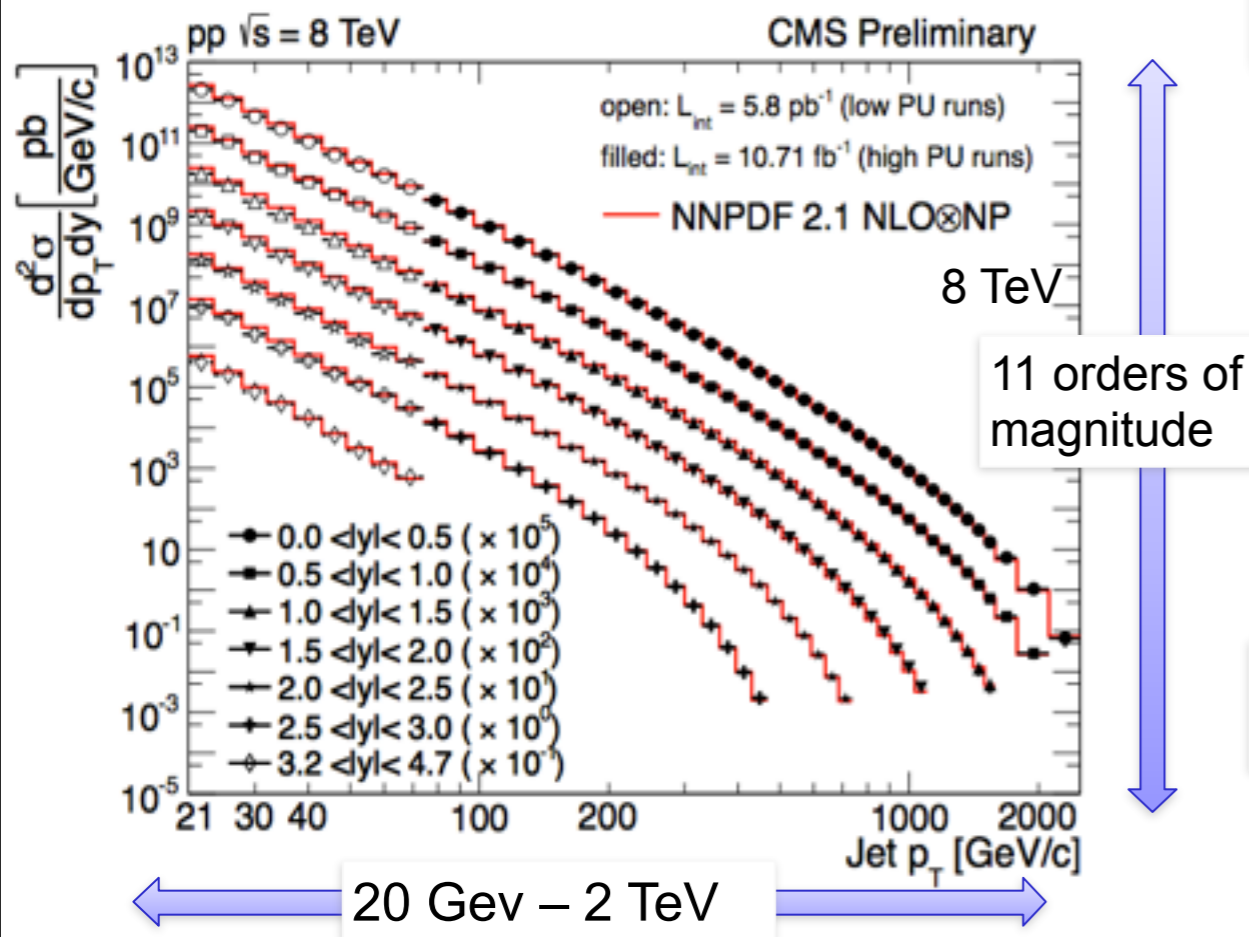




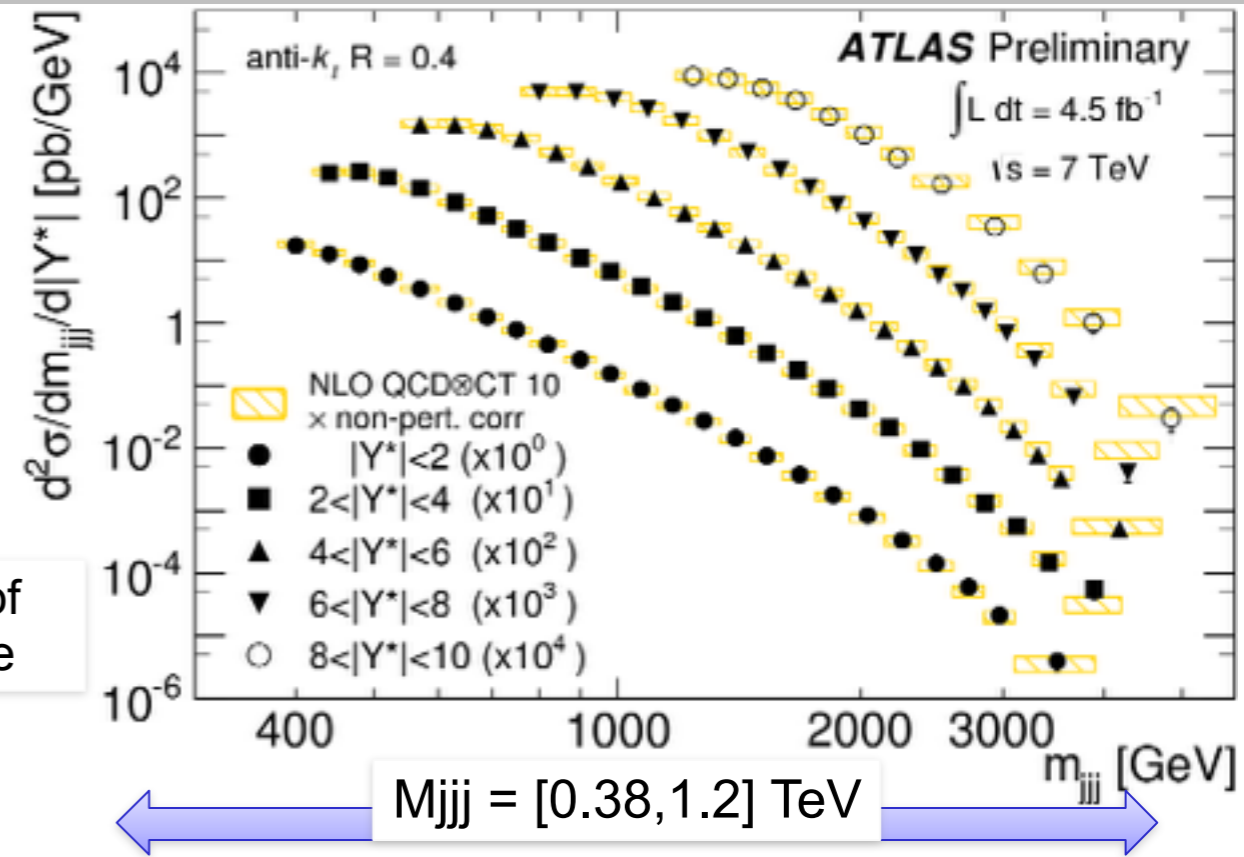
Le LHC donne l'occasion de tester QCD dans tous ses domaines cinématiques, permettant par exemple de mesurer la constante de couplage de QCD, et de vérifier la dépendance sur l'échelle



Inclusive cross-section @ 8 TeV



More challenge... higher multiplicities



- Nécessite de fixer certains ingrédients sur la partie hadronique... pour ensuite permettre de faire des prédictions sur plusieurs ordres de grandeur
- Progrès dans les calculs théoriques NLO -> NNLO: production t-tbar, jets gg->gg, qqbar -> gg
- Progrès dans la combinaison calcul perturbatif + gerbe hadronique

Double differential Z+jet @ 8 TeV

