Selected Highlights from Run-I from the CMS Experiment

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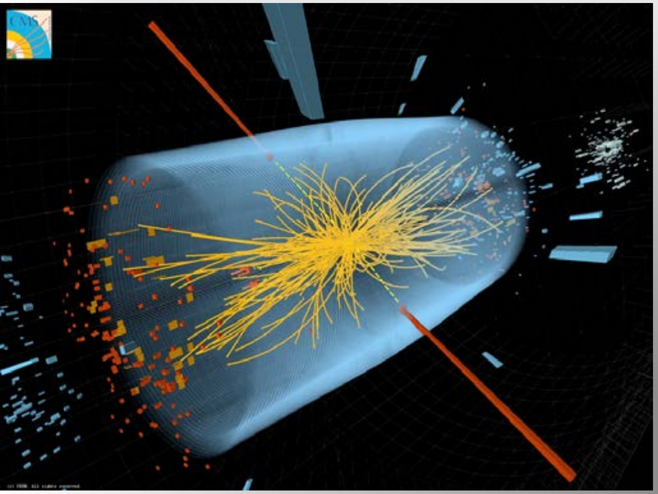
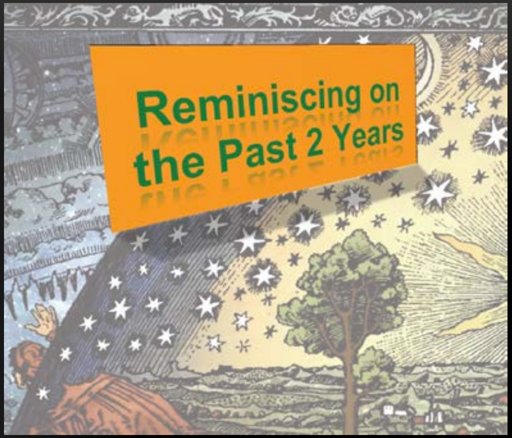


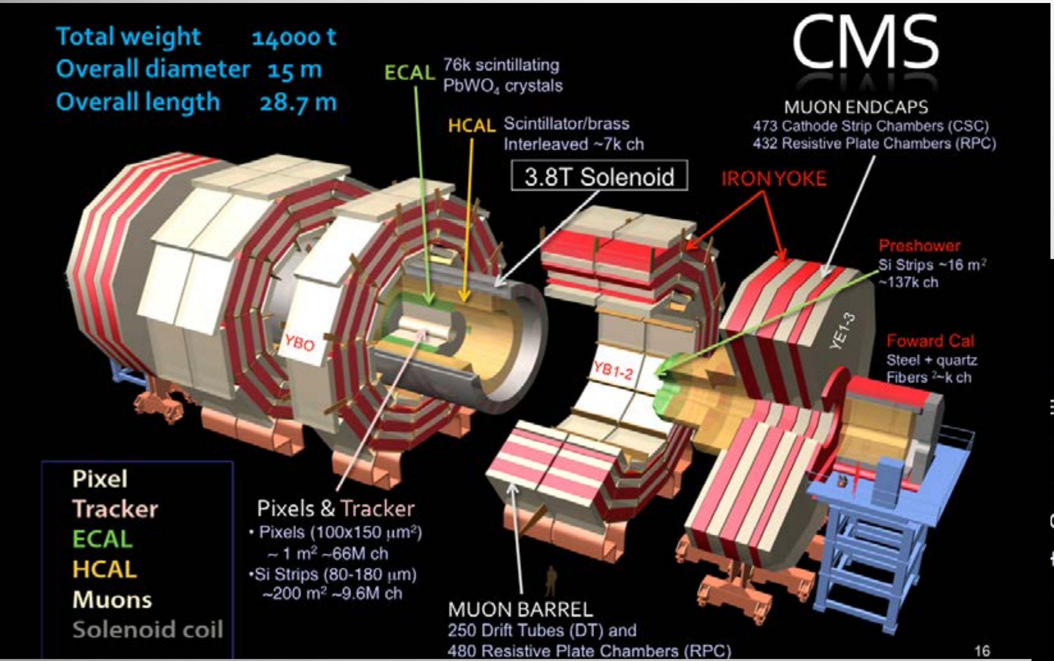
Outline

- Standard Model Physics Results
- Beyond the Standard Model!
  “In Search of new Physics”
- The Higgs Particle!!
- Summary

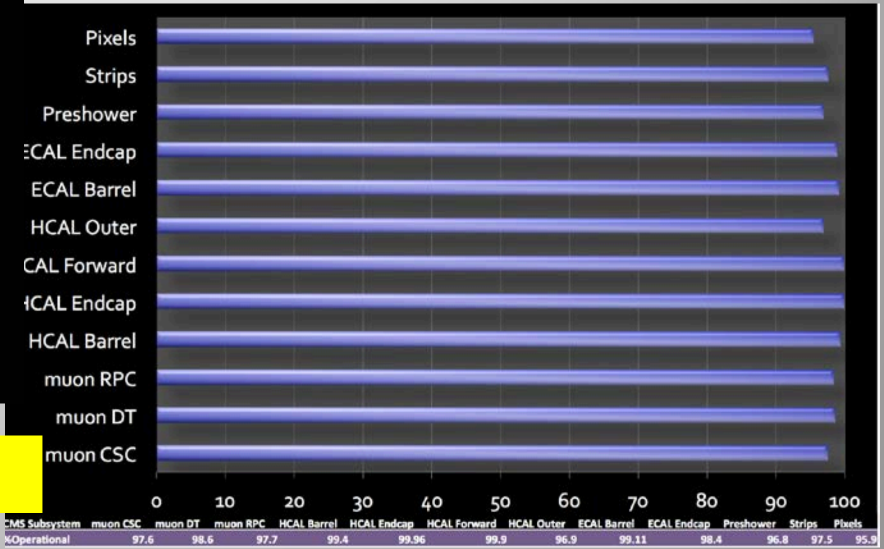
Disclaimer: selected highlights
No discussion on details



Operation of the Experiment



pp collisions luminosity for analysis:
5 fb^{-1} @ 7 TeV
20 fb^{-1} @ 8 TeV

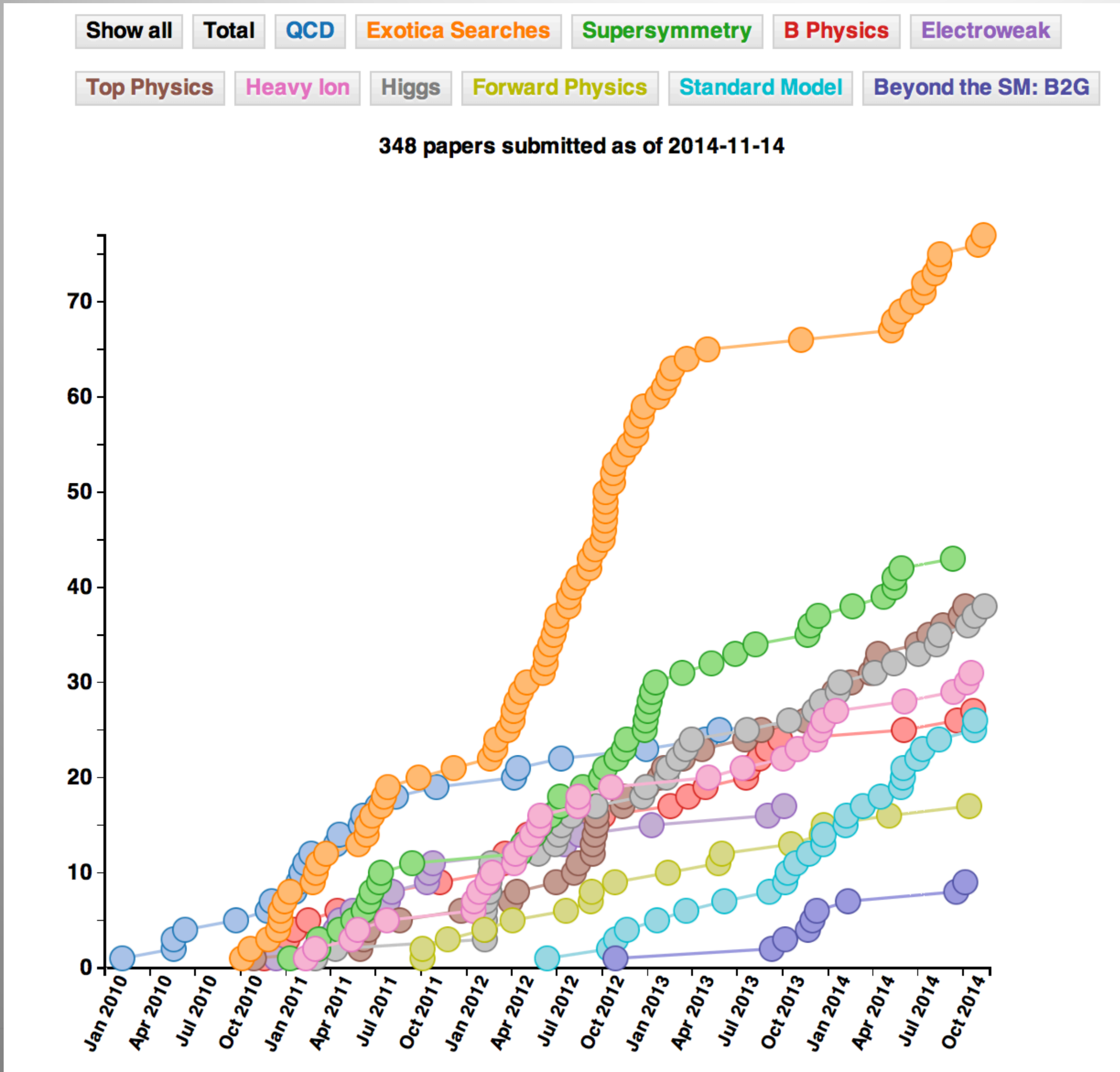


CMS: sub-detector operation

CMS: sub-detector operation efficiency in 2012

Period	Delivered* fb^{-1}	Recorded* fb^{-1}	Efficiency	Downtime	Dead-time
April - June	6.78	6.26	92.3%	5.9%	1.8%
July - 21Aug**	4.97	4.73	95.1%	3.8%	1%
22Aug - 16 Sep	2.99	2.74	94.4%	4.1%	1.5%
26 Sept – 7 Oct	1.44	1.37	95.1%	3.4%	1.5%
9 Oct – 3 Dec	6.9	6.5	94.8%	3.7%	1.5%

CMS Publications



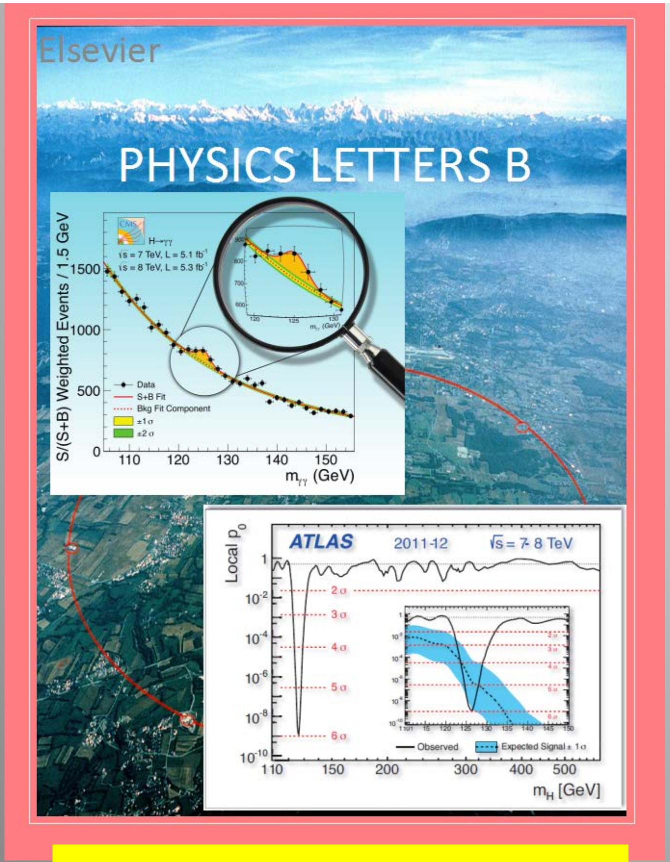
348 publications on pp (and pPb/PbPb) physics since January 2010 (14/11/2014)

Mostly on exotica searches and supersymmetry (>120 papers together)

Slightly too much For 45 minutes ☹

Most cited paper so far...

Special Physics Letters B edition with the ATLAS and CMS CMS papers on the Higgs Discovery



More than 3500 times cited so far...

Also...

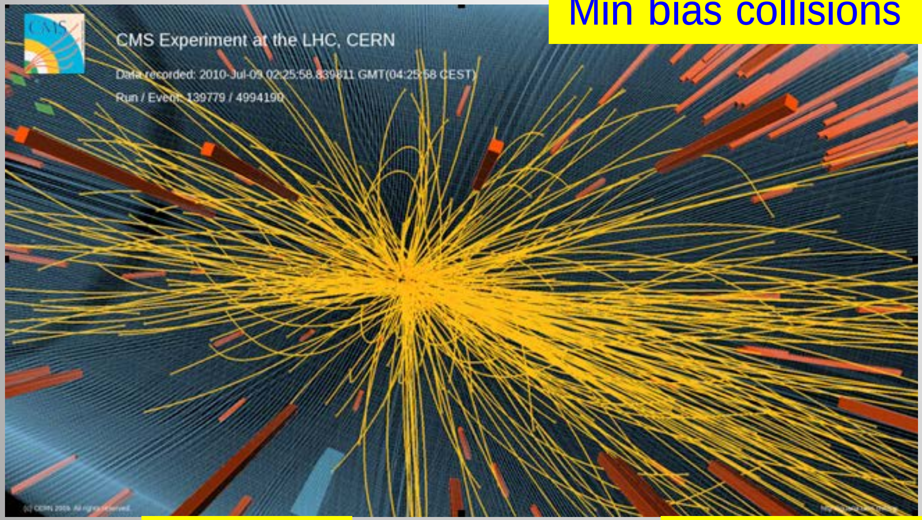
Standard Model Studies

The study of the Standard Model at 13/14 TeV will be one of the first points to tackle at the new energy.
The first QCD and Electroweak Studies can be done with << fb^{-1}

Luminosity profile in 2015 not fixed yet but the LHC is likely to make a careful start with low luminosity for some time, with a stop after ~ the first 1 fb^{-1}

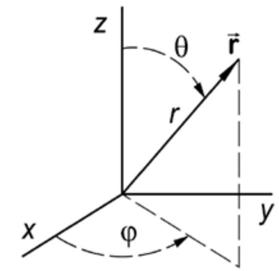
Correlations Between Produced Particles

Min bias collisions

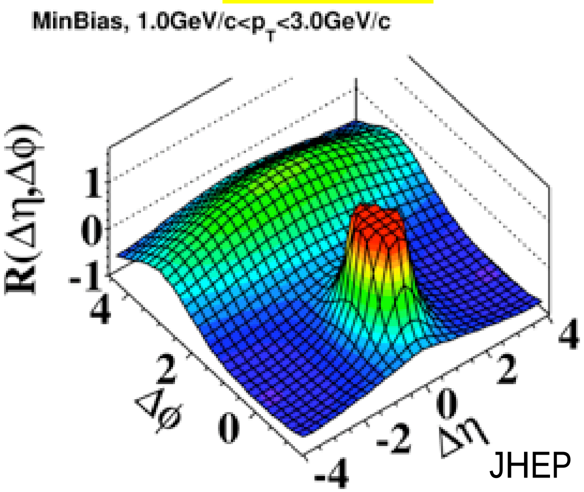


- Select high multiplicity events
- Study the correlation between two charged particles in the angles φ (transverse): Δφ and θ (longitudinal): Δθ

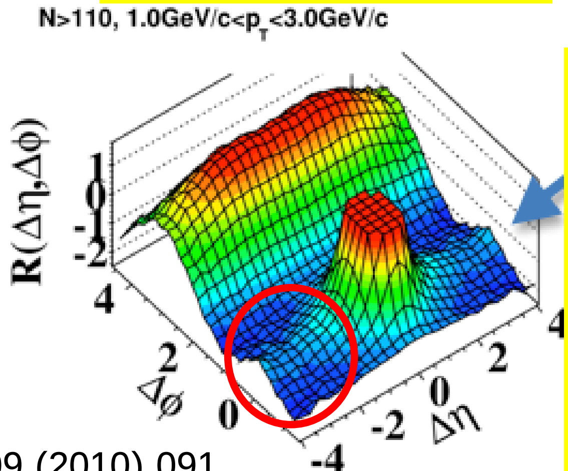
$\eta = -\ln \tan\theta/2$



All events



High multiplicity events



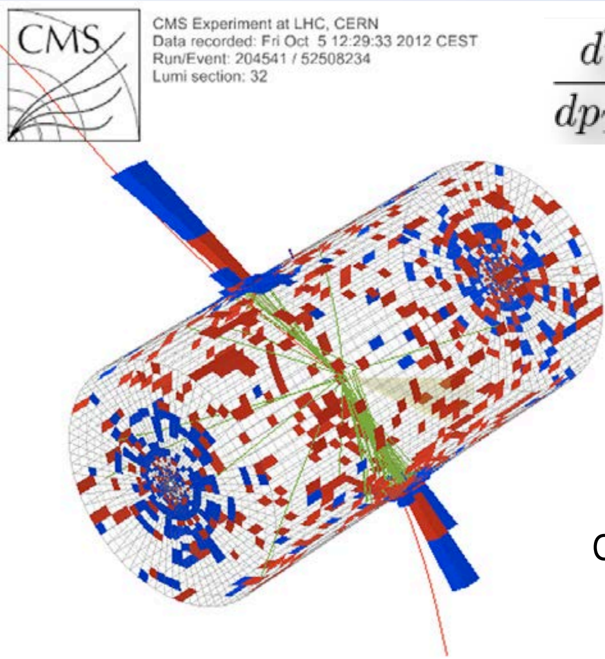
JHEP 1009 (2010) 091

A new phenomenon in the ‘stronge force’?

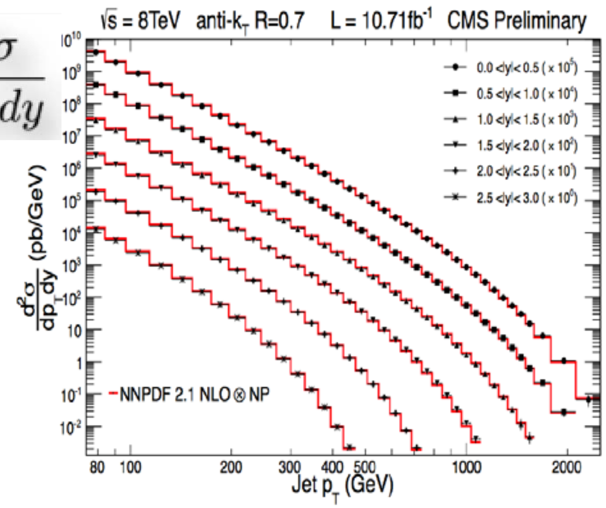
- Multiple interactions?
- Glass condensates?
- Hydrodynamic models?Still not quant.

This was the first (subtle) new effect, in 2010, studying the strong force...
Was first seen in AA, then pp (unexpected) and now also pA (~unexpected)

Jets, EWK Bosons, Top…

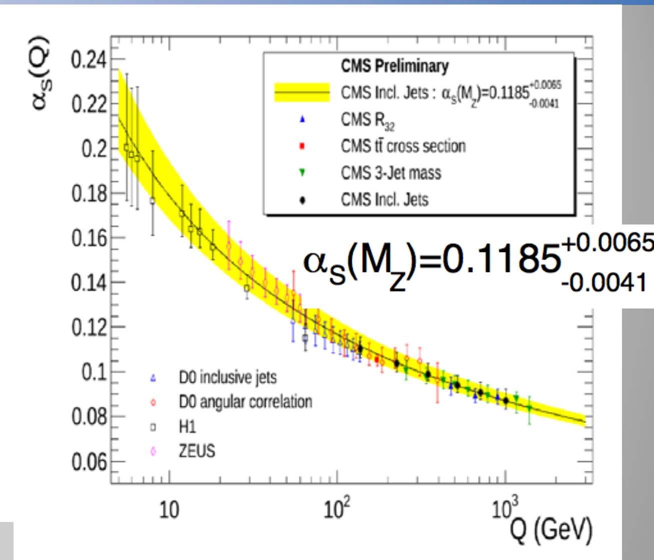


$$\frac{d^2\sigma}{dp_T dy}$$



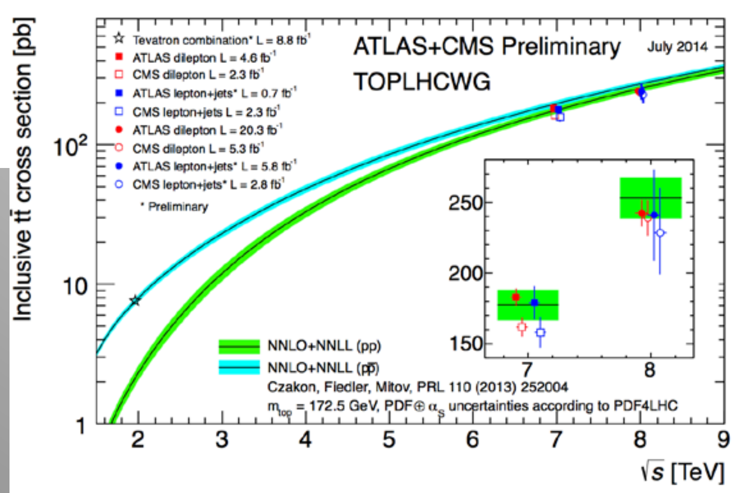
CMS-PAS-SMP-12-012

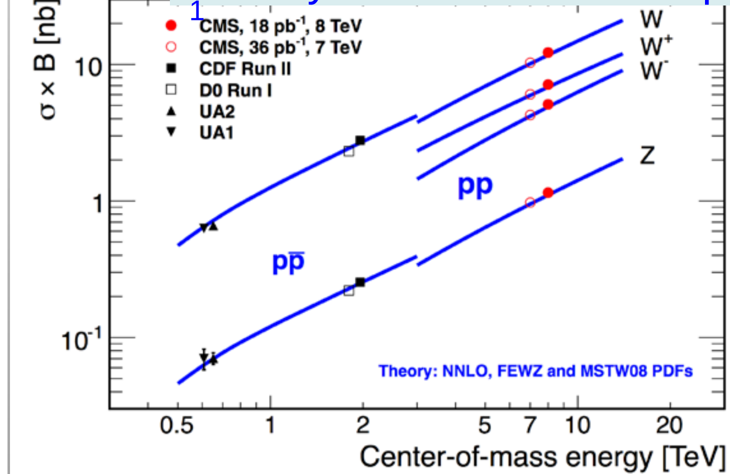
pQCD ⊗ non-perturbative corrections



Precise measurements can already be made with ~ 10 pb^-1

Di-jet invariant mass = 5.15 TeV (R=1.1 jets)

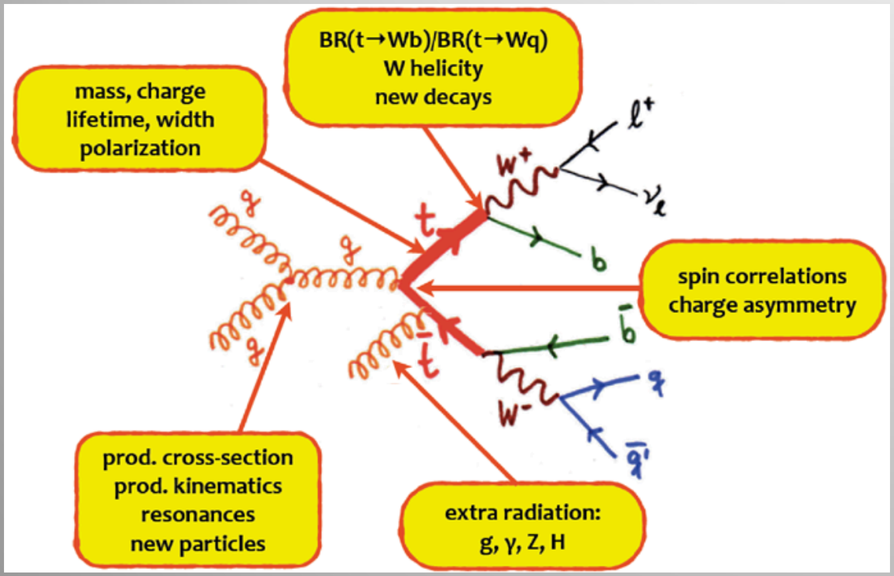




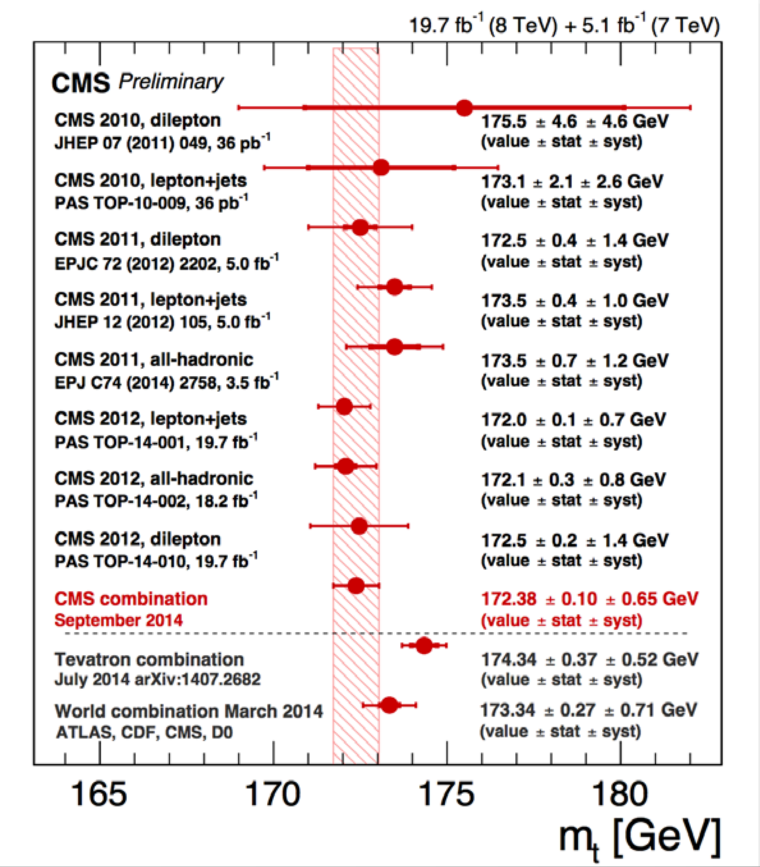
Measurements at 7/8 TeV in agreement with (N)NLO QCD

Example: LHC as a Top Factory

Cross section ~ 250 pb (8 TeV)
-> ~5.10^6 produced tt-pairs (2012)



Top mass determination

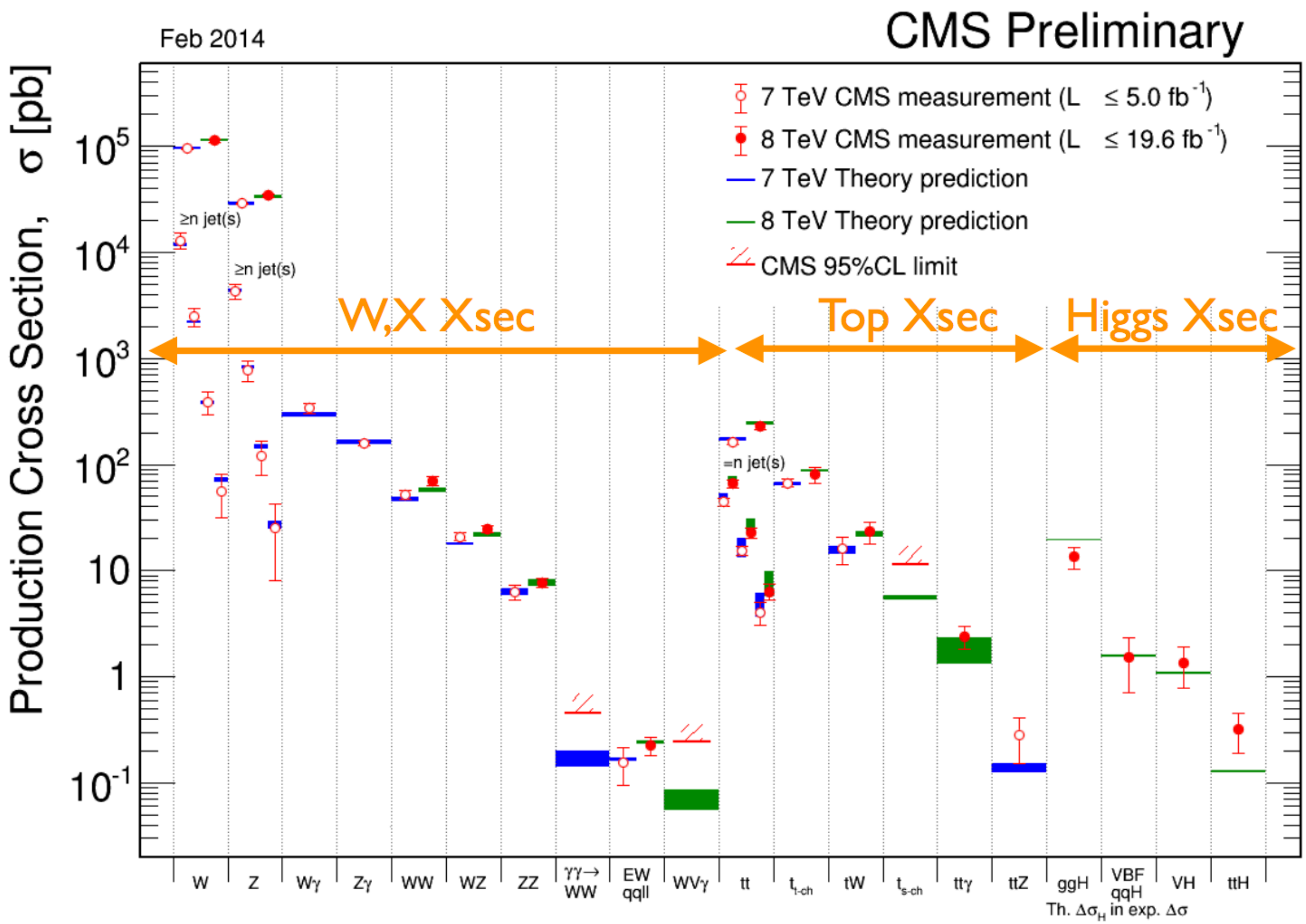


Using Tevatron and LHC combination of the mass measurements

$$m_t = 173.34 \pm 0.76 \text{ GeV}$$

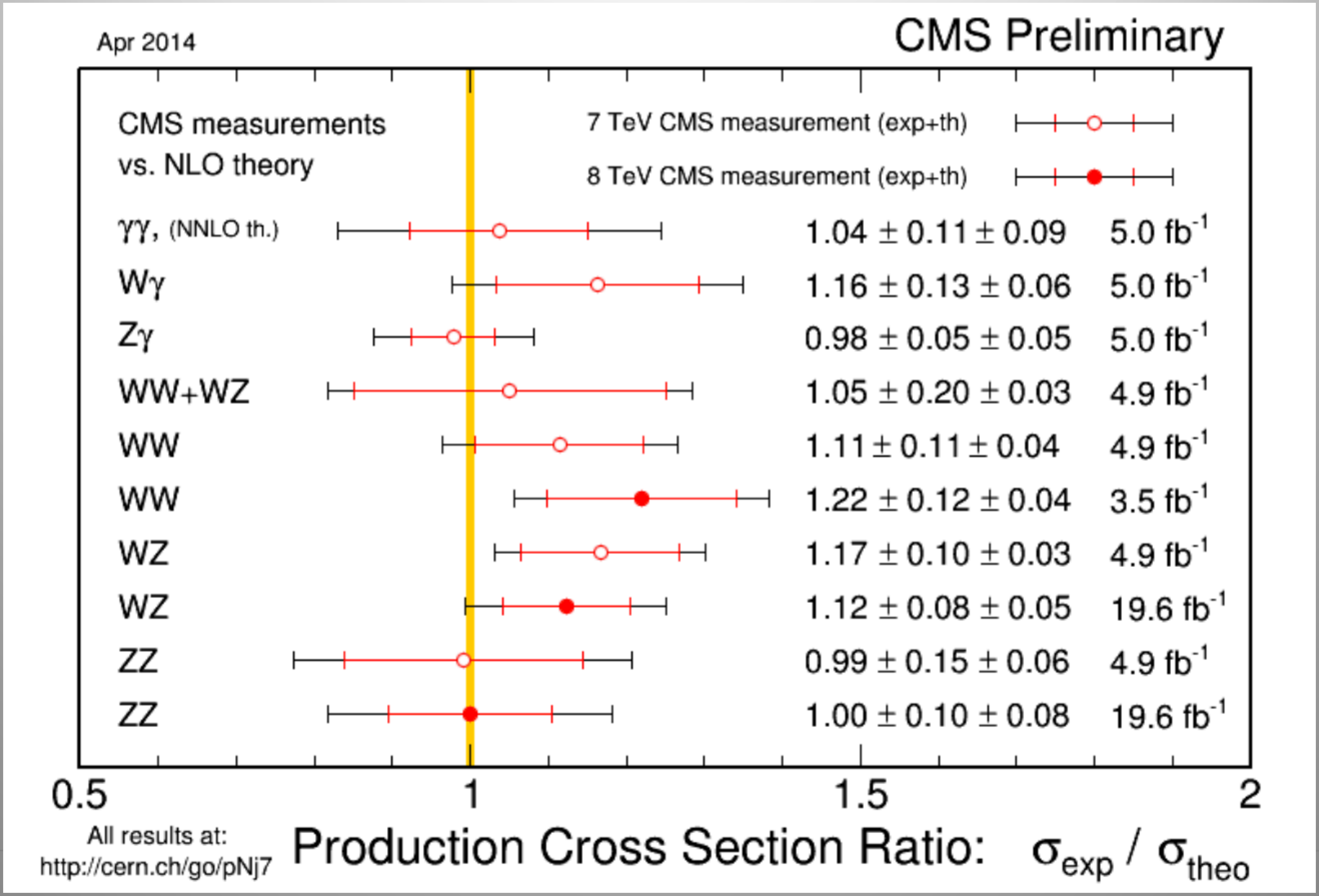
Meanwhile:
CMS update: 172.38±0.10 (stat)±0.65 (syst) GeV
Tevatron update: 174.34 ± 0.64 GeV

Cross Sections at 7/8 TeV



Measurements in good agreement with the Standard Model predictions

Di-boson Production



WW Production

Di-boson production: This should not be a problem for theory, no?

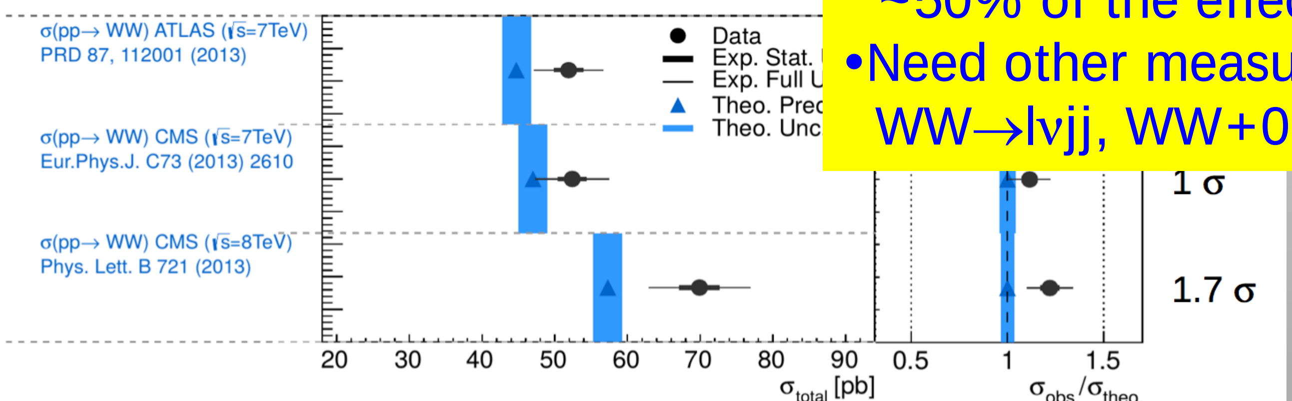
$$\text{Standard Model prediction: } 58.7^{+1.0}_{-1.1}\ \text{(PDF)}\ ^{+3.1}_{-2.7}\ \text{(total) pb}$$

8 TeV

Contributions neglected in this SM prediction

- $q\bar{q} \to WW$ (NLO → NNLO+NNLL k-factor)
- $gg \to WW$ (LO → NNLO+NNLL k-factor)

- Electroweak corrections – 0.5 pb
- γγ-induced WW + 0.5 pb
- Vector boson scattering + 0.5 pb
- Double parton interaction + 0.04 pb



My take:

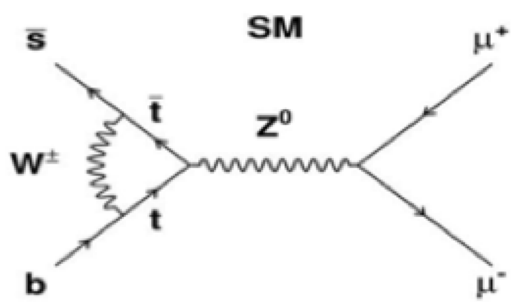
- Need to have a careful look at QCD corrections, effects of the jet veto... Improved calculations: can explain ~50% of the effect (to be continued)
- Need other measurements eg $WW \to l\nu jj$, WW+0/1/2 jets...

New in ATLAS:

$$\sigma^{tot}_{WW} = 71.4\ ^{+1.2}_{-1.2}(\text{stat})\ ^{+5.0}_{-4.4}(\text{syst})\ ^{+2.2}_{-2.1}(\text{lumi})\ \text{pb}$$

Bizar: all measurements so far gave a systematically higher value!
Less the case for ZZ and WZ as far as we can see...

Precision Measurements: $B_s \rightarrow \mu\mu$



- A B_s particle is a particle consisting of a beauty-quark and strangeness-quark, with a mass of ~ 10 GeV
- Three B_s particles in a million will decay into two muons. This decay has been chased since 30 years.
- New physics modifies these Standard Models predictions

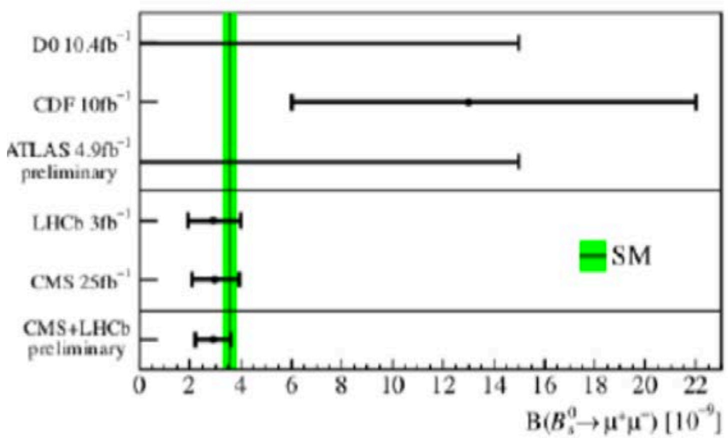
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-)_{\rm SM} = (3.66 \pm 0.23) \times 10^{-9}$$

Observation:

$$\text{BR}(B_s \to \mu^+\mu^-) = (2.9 \pm 0.7) \times 10^{-9}$$

Summer 2013

CMS-BPH-13-007 / LHCb



Results from LHCb + CMS experiments combined

Combined CMS+LHCb submitted to Nature this month; see later this meeting
But no sign of New Physics here...☹

Searches for Supersymmetry or other Exotic New Physics

We understand the Standard Model at 7 & 8 TeV from the Standard Model measurements made, as reported before

Ready to search for physics BEYOND THE STANDARD MODEL

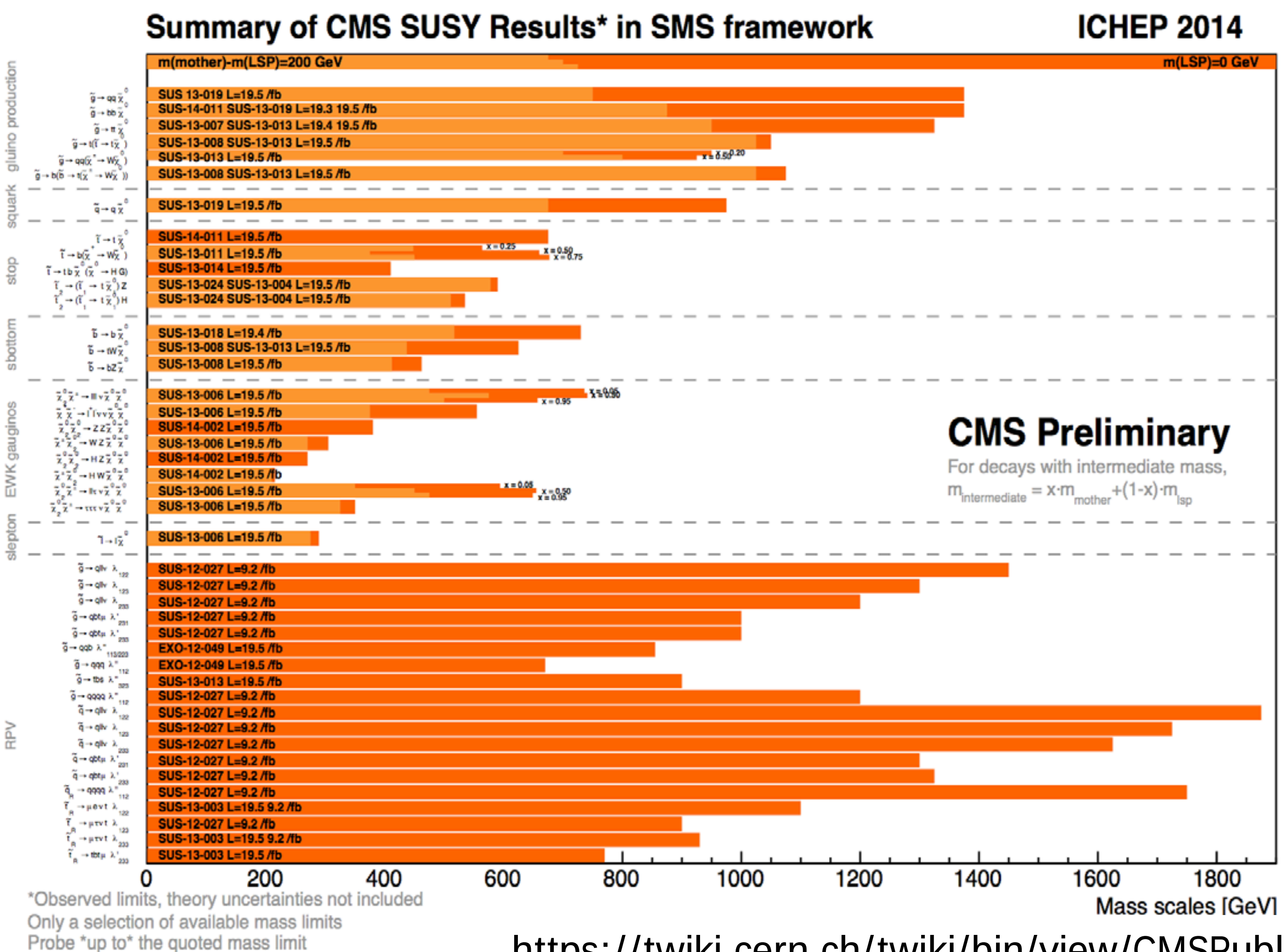
Searches in CMS

- Searching for SUSY
  - Recently special attention to Natural SUSY and more difficult scenarios eg. compressed scenarios
- Searching for Exotica
  - New gauge bosons
  - New partners of the fermions
  - Mono-objects for extra dimension and dark matter searches
  - Resonances with boosted techniques, eg for top-antitop
  - Unusal topologies…
  - Unusual signals in the detectors (heavy particles, ionization…)
  - ….
- Some 2-3 σ effects are seen (and expected!)

  Many (all?) of these are expected to be statistical fluctuations but are worth checking in Run-II

Summary of SUSY Searches

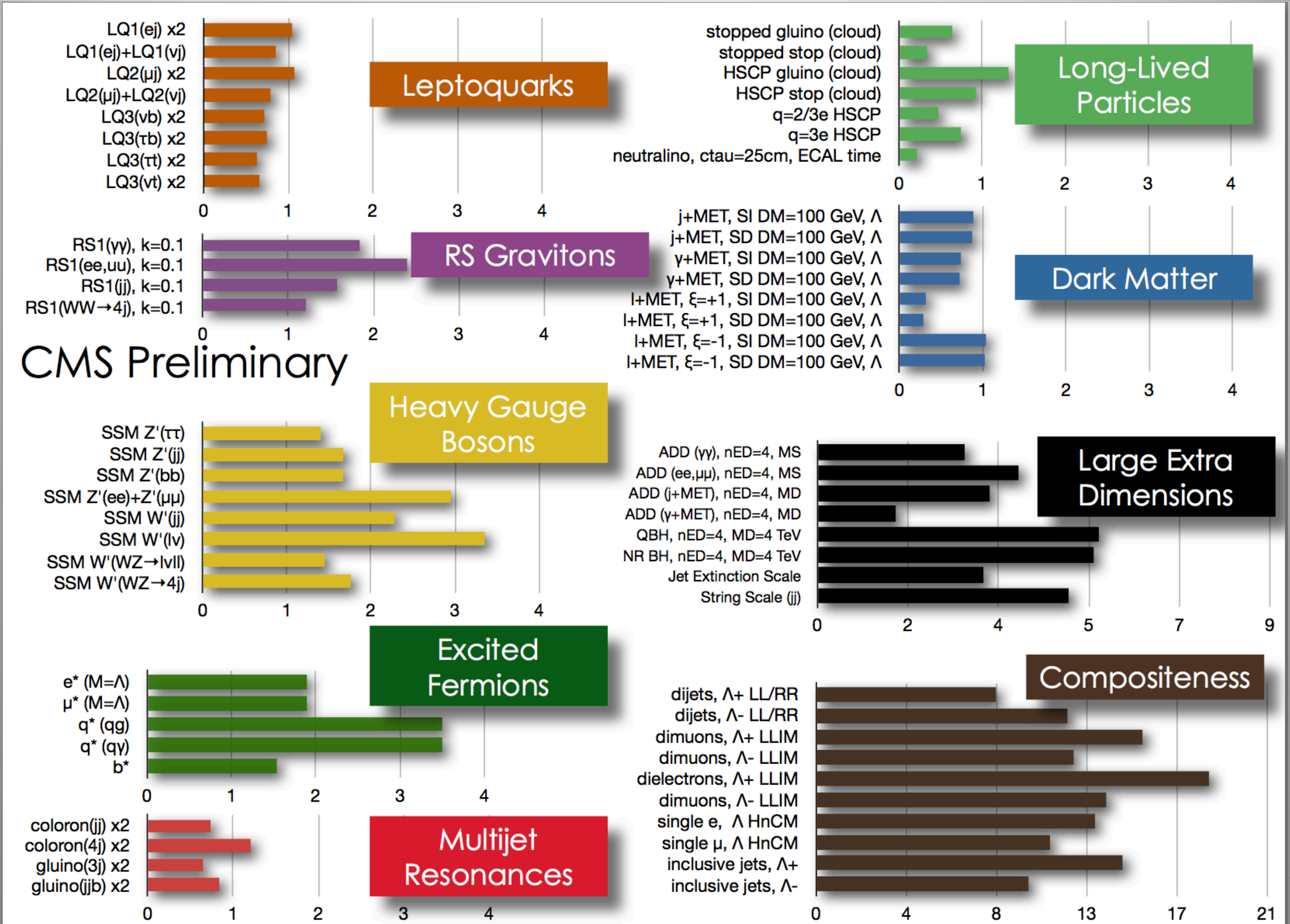
In short: no sign of SUSY with the data collected so far



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

New: compressed spectra, heavy stop (t_2) search, extended incl. searches...

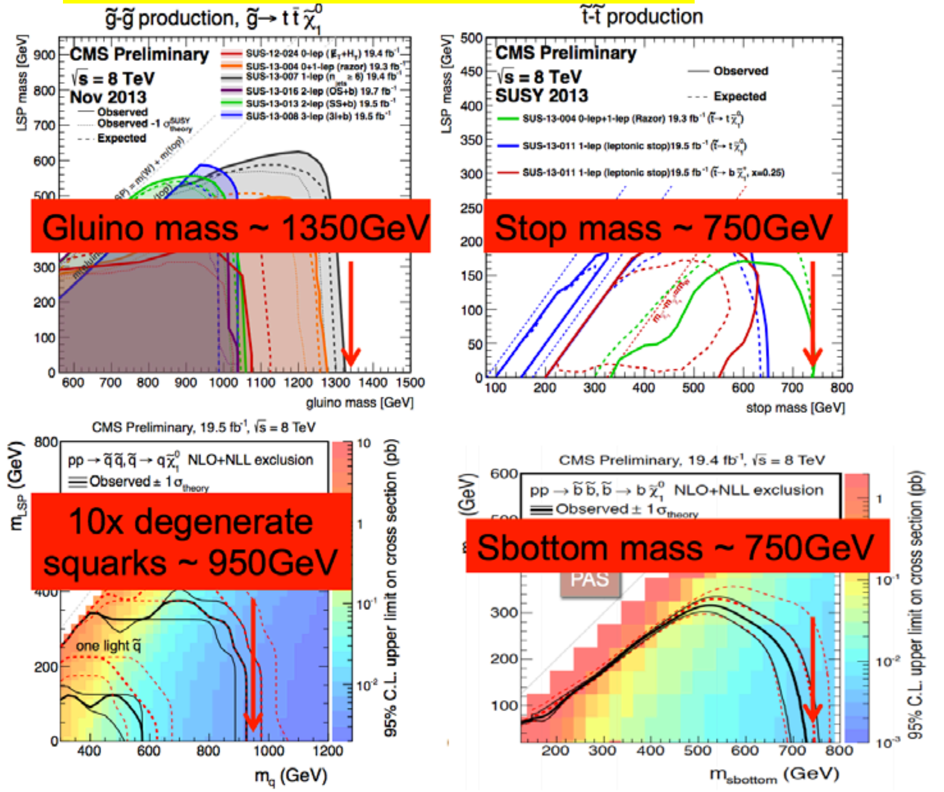
Summary of Exotica Searches



SUSY Prospects @ 2015/2016

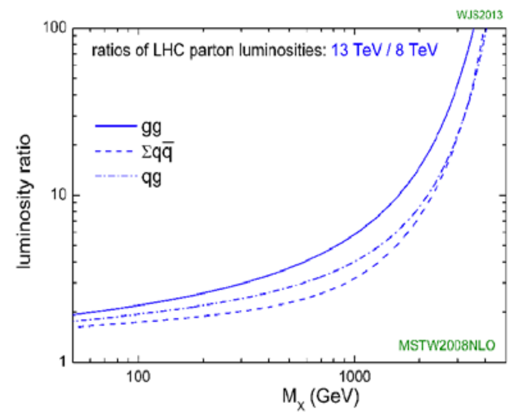
Expect ~ 10-20 fb^{-1} in 2015 & 40 fb^{-1} in 2016 (present estimates)

Now: 2014 typical values



2015-2016

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.
There will be no relevant SM measurements at 13TeV by the time we have already stepped well into new territory!!!

More results & details later at this meeting

0.5-1 fb^{-1} would be enough for first analyses entering new territory
We expect that have such a sample by Summer 2015!!

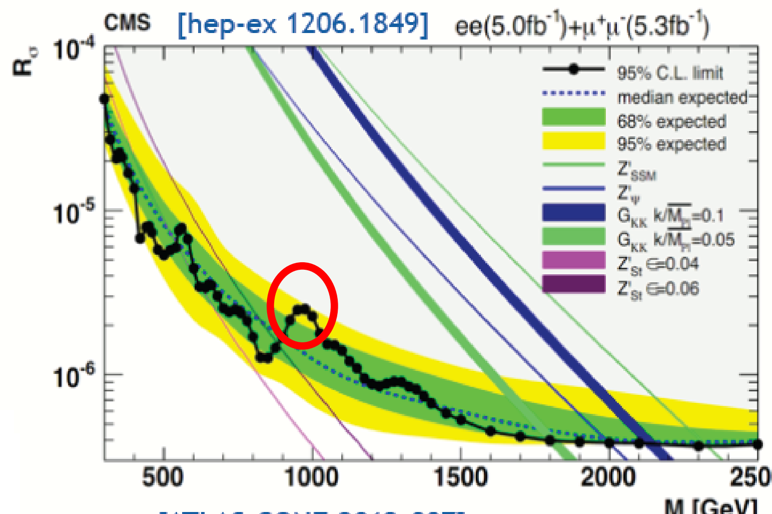
2011: Z' Boson to ee or μμ?

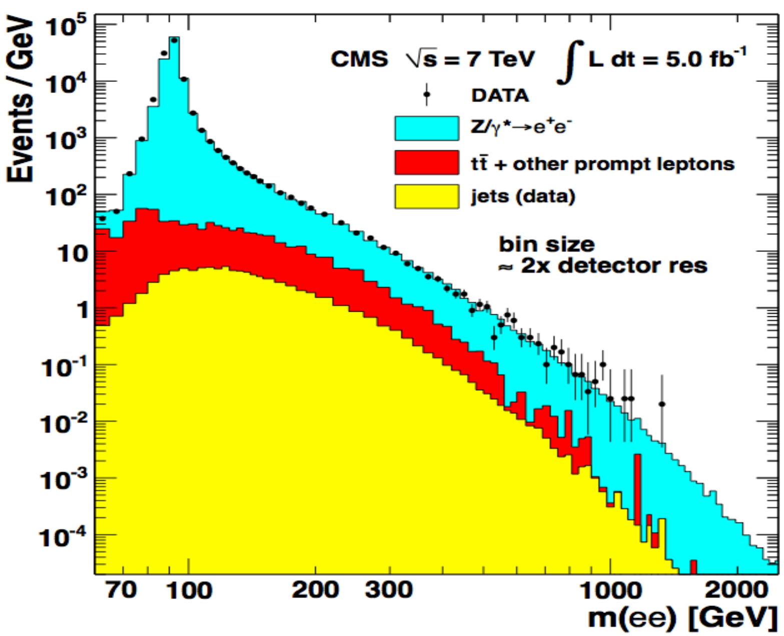
$$SU(3)_C \times SU(2)_L \times U(1)_Y$$

Extension of the symmetry?
New Gauge bosons?

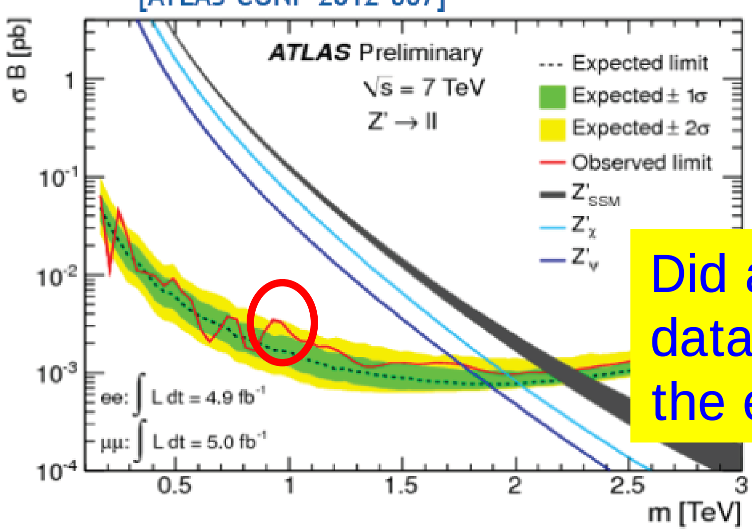
- Many new models have Z-like narrow resonances decaying to dileptons
- Interesting features in dilepton spectra
  - around 2σ each for CMS & ATLAS in e+μ
  - similar in scale to 2011 Higgs excess

Worth watching in 2012's 8 TeV data…





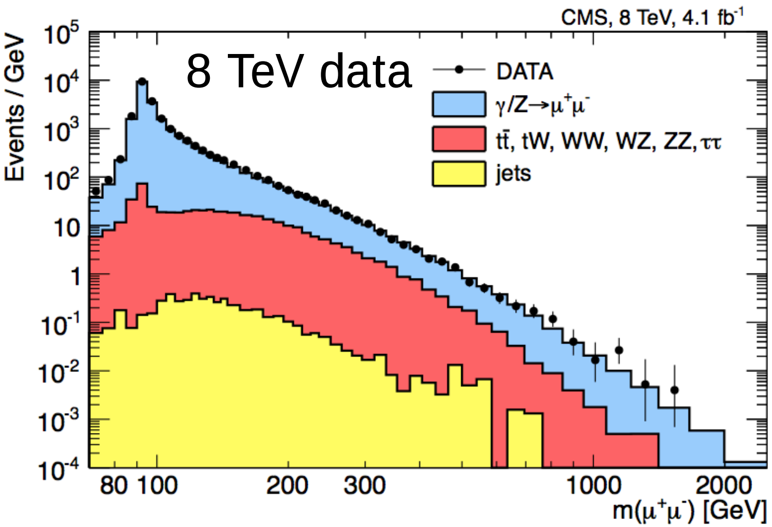
[ATLAS-CONF-2012-007]

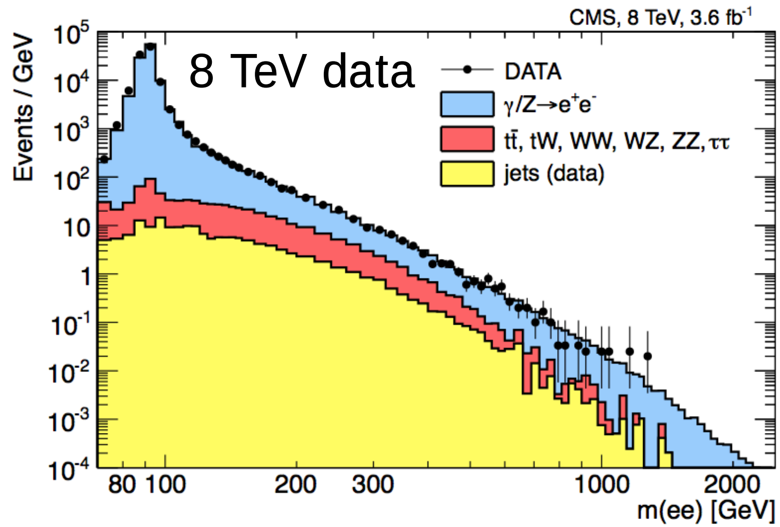


Did additional data confirm the excess??

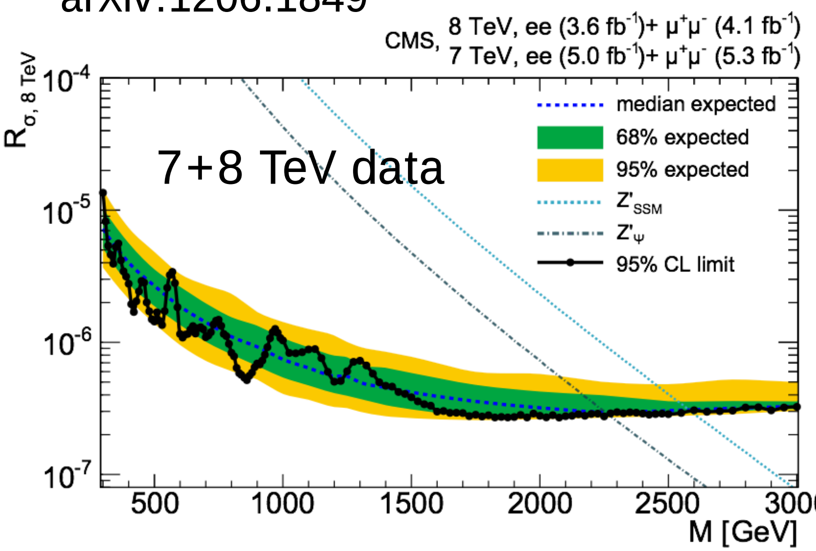
Z' Combination of 7 & 8 TeV Data

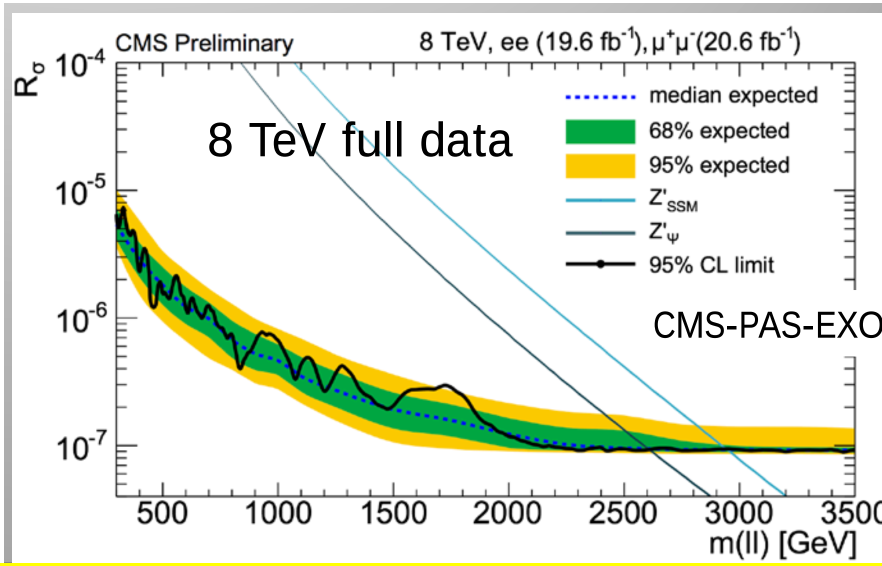
No... ☹





arXiv:1206.1849



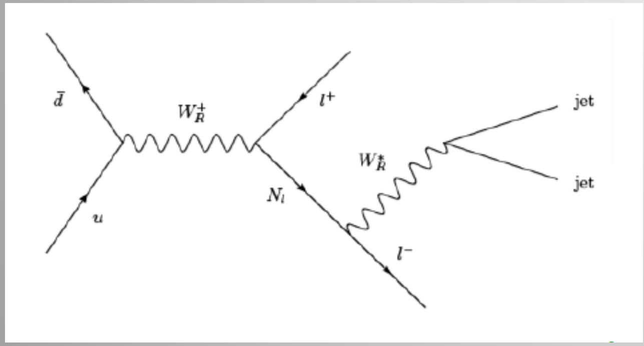


CMS-PAS-EXO-12-061

Remains an interesting channel to be watched for new mass reach in Run-II

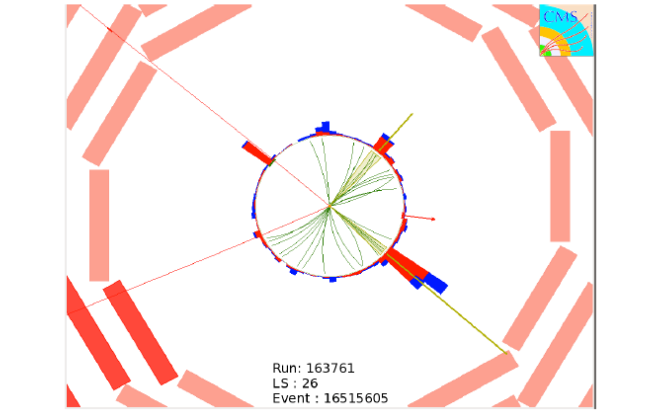
Search for Heavy Neutrinos and W_R

Left-right symmetric extension of the Standard Model

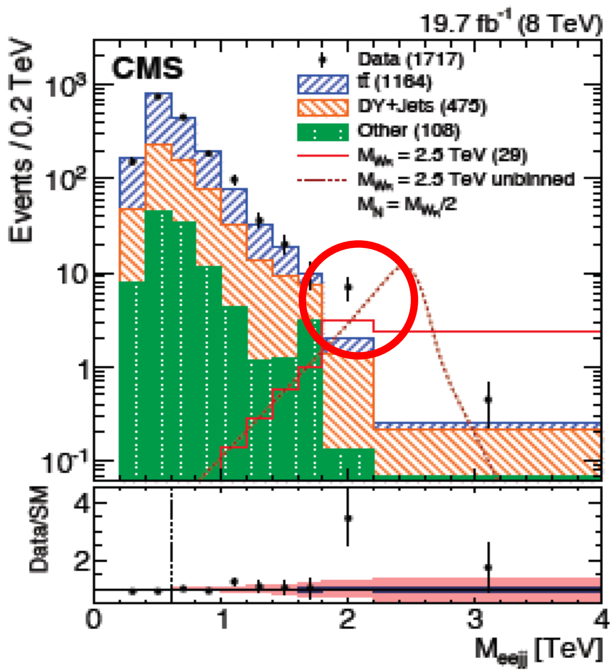


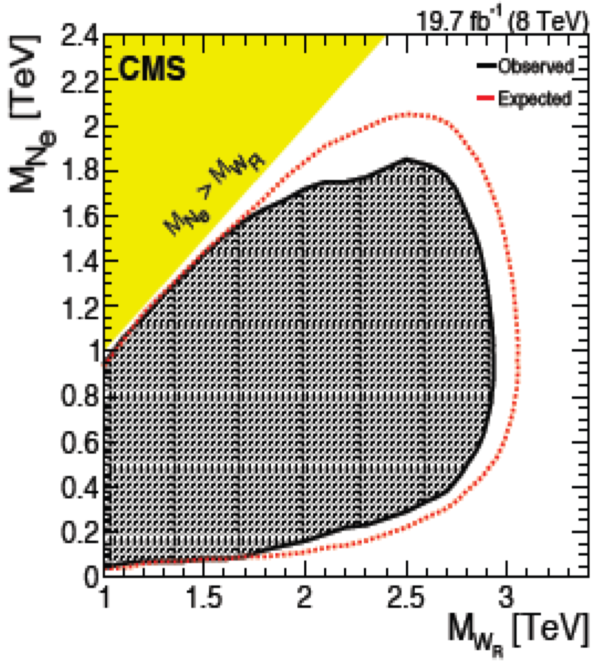
arXiv:1407.3683

Select events with 2 leptons and 2 jets



Muon channel: Event with $M_{\mu\mu}$ = 331 GeV, $M_{\mu\mu jj}$ = 881 GeV





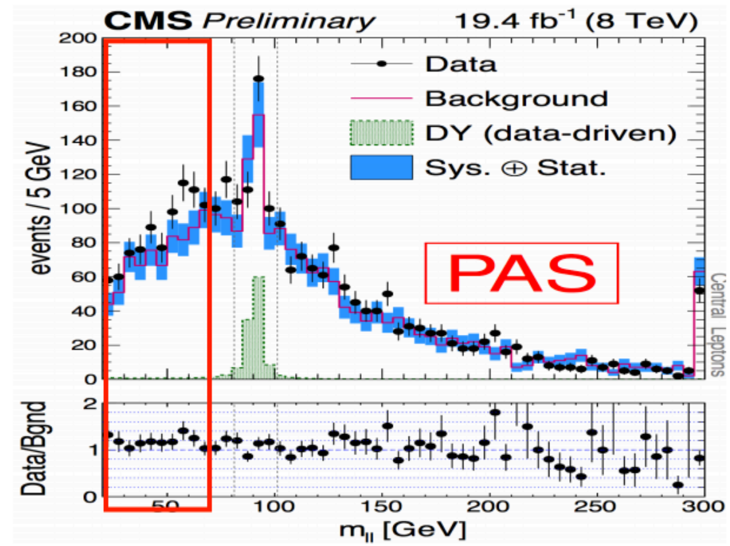
Large exclusion range in mass of the W_R and heavy neutrino

Observe a 2.8 sigma excess in the electron channel around 2 TeV W_R mass

More Searches to Watch…

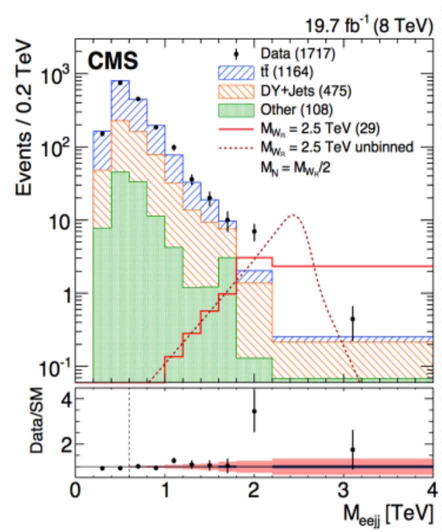
The di-lepton edge analysis (SUS-12-019)

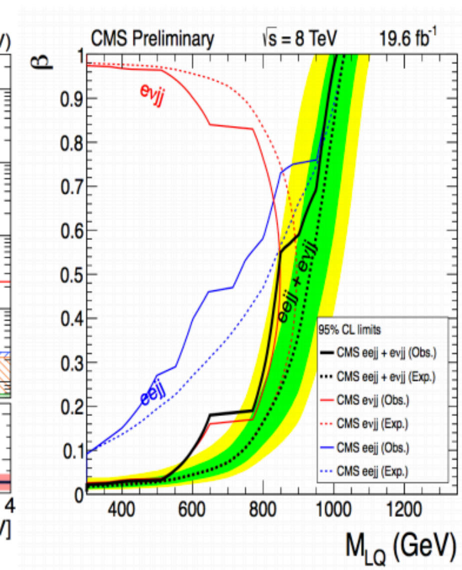
- There is an excess (2.6 σ)visible on the low di-lepton invariant mass
- Any plausible hypothesis of new physics is not corroborated by evidence in other channels.



The "electron excess":

- There is an excess (2.8 σ @2.1 TeV) visible on the eejj invariant mass in the search for W_R (but not in μμjj !)
- A similar excess is observed in both eejj and evjj channel in leptoquarks searches
- The correlation between the two is minimal but has generated a lot of literature:
  - http://arxiv.org/pdf/1407.4466v1.pdf
  - http://arxiv.org/pdf/1407.5384v1.pdf
  - http://arxiv.org/pdf/1407.6908v1.pdf
  - http://arxiv.org/pdf/1408.1082v1.pdf

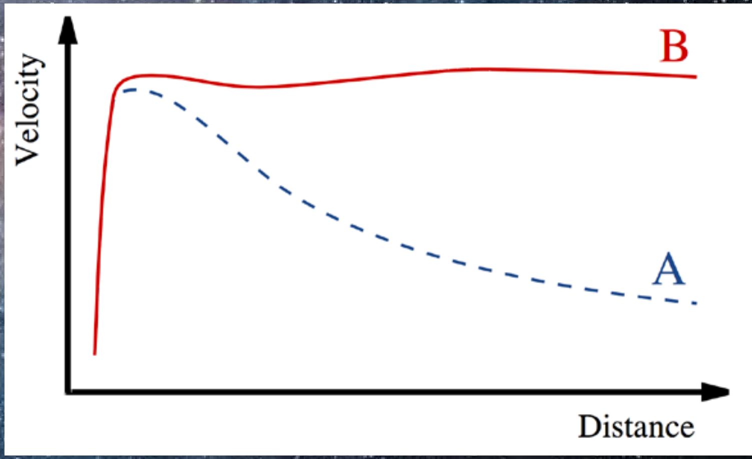




Global CMS statistical analysis (MUSIC) on all channels ongoing

Dark Matter: The Next Challenge !?!

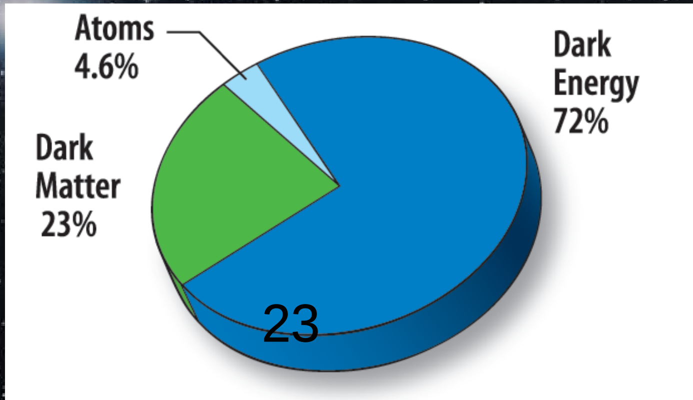
Astronomers found that most of the matter in the Universe must be invisible Dark Matter



'Supersymmetric' particles ?

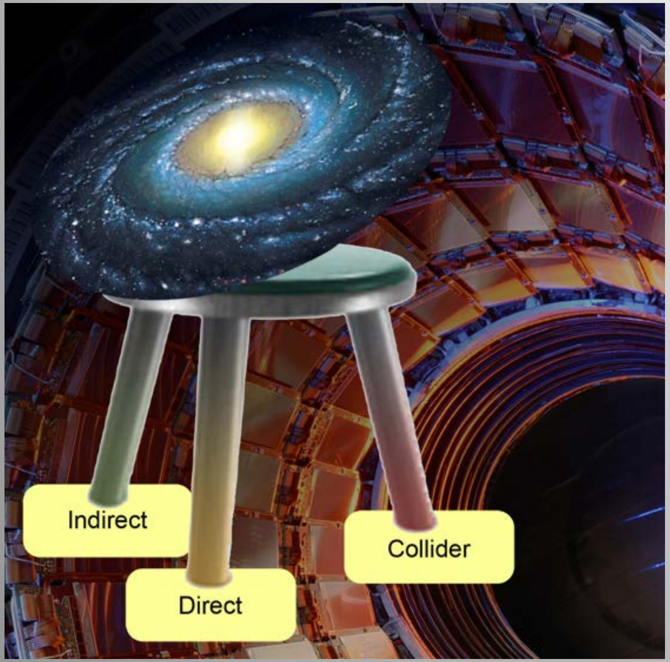
F. Zwicky 1898-1974

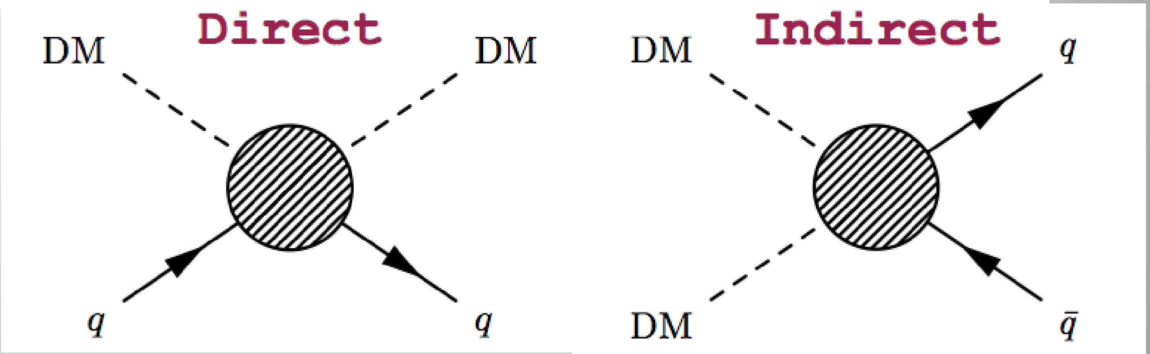
Vera Rubin ~ 1970

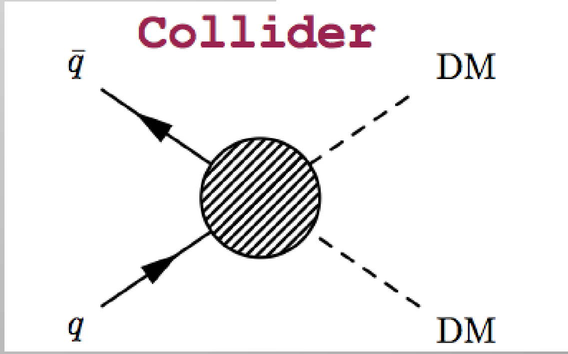


The Generic Dark Matter Connection

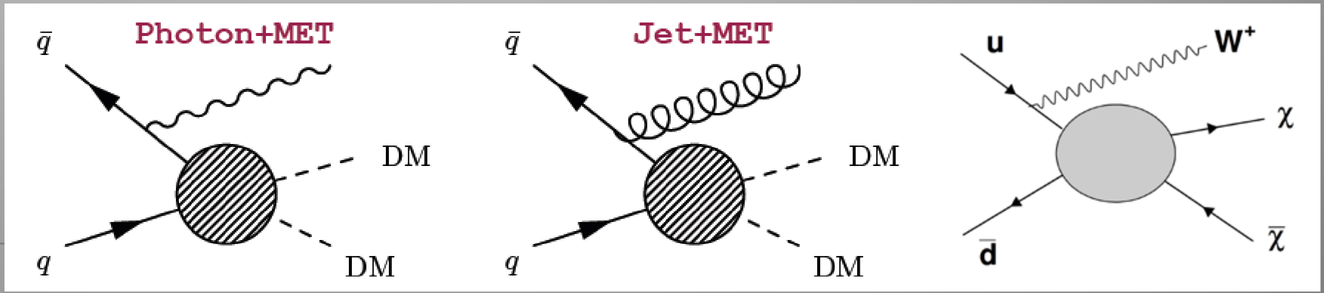
Searches for mono-jets and mono-photons can be used to search for Dark Matter (DM)







Use effective theory or better simplified models to relate measurements to Dark Matter studies

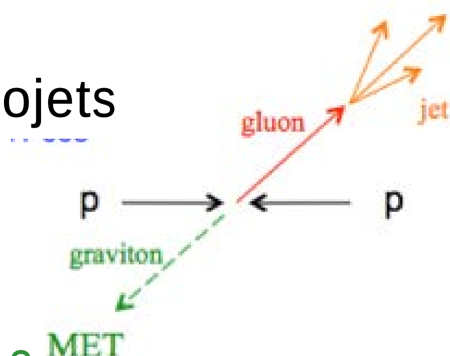


Mono-object Searches in CMS

- Mono-jets: Generally the most powerful
- Mono-photons: First used for dark matter Searches
- Mono-Ws: Distinguish dark matter couplings to u- and d-type of quarks
- Mono-Zs: Clean signature
- Mono-Tops: Couplings to tops
- Mono-Higgs: Higgs-portals
- Higgs Decays?

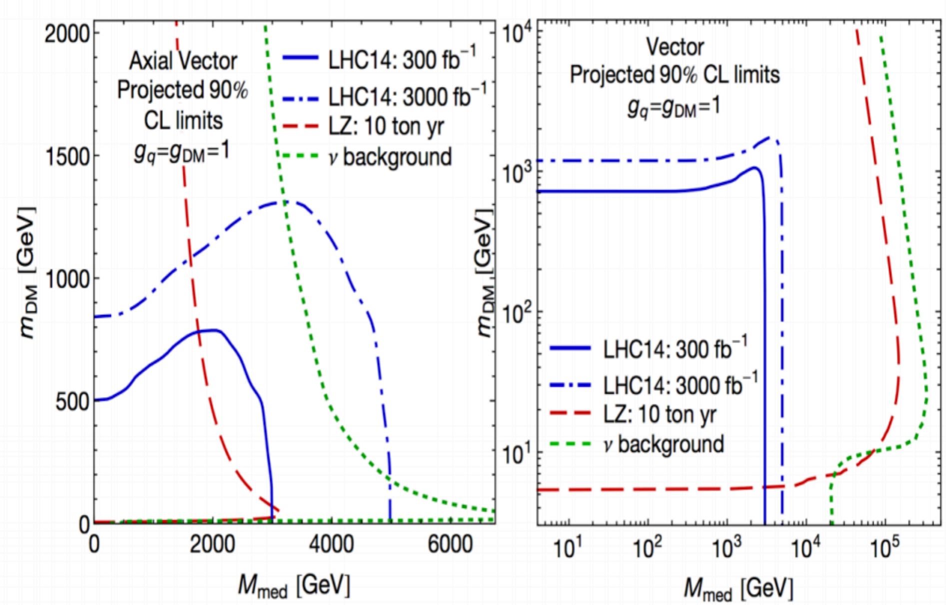
Effective Field Theories for DM interpretation are under attack!
Alternatives like SMS proposed...

Example Monojets



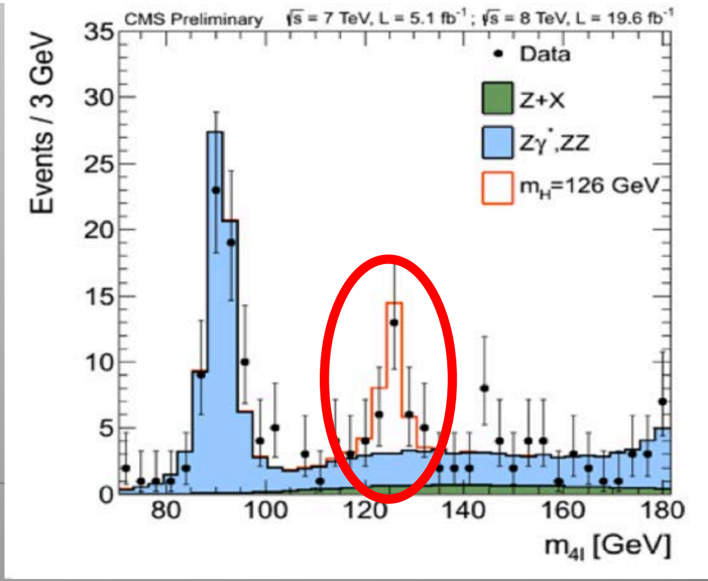
Dark Matter?

arXiv:1407.8257

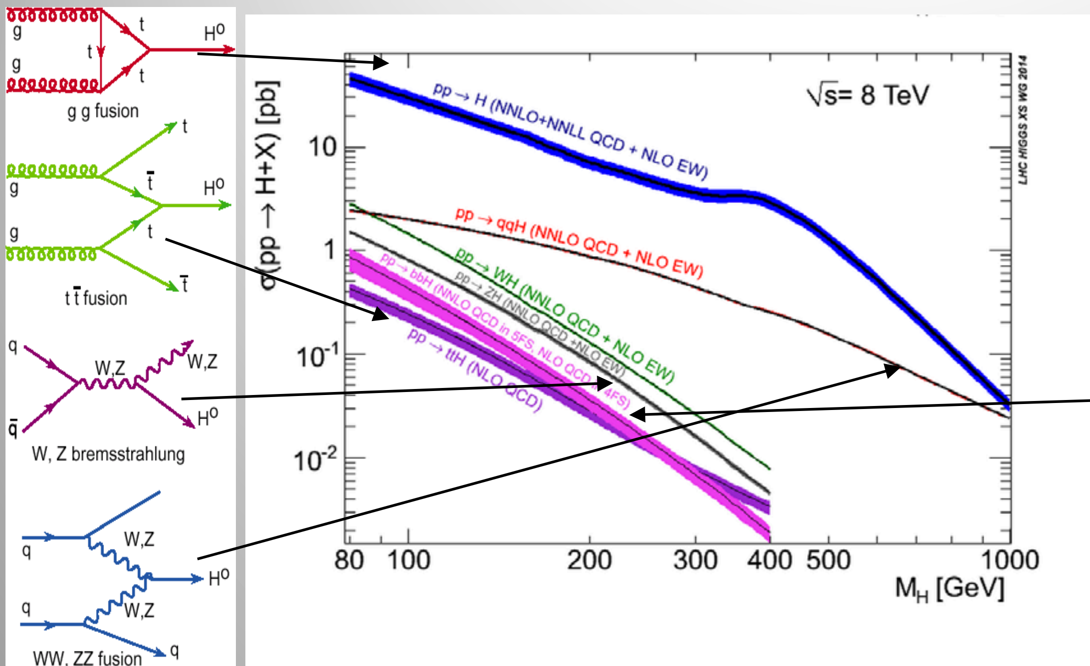


Higgs!

We discovered a Higgs particle!

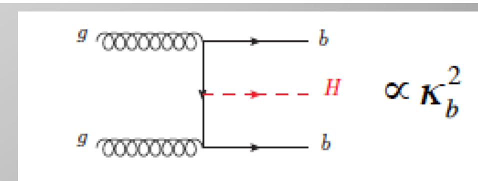


Higgs Production & Decay



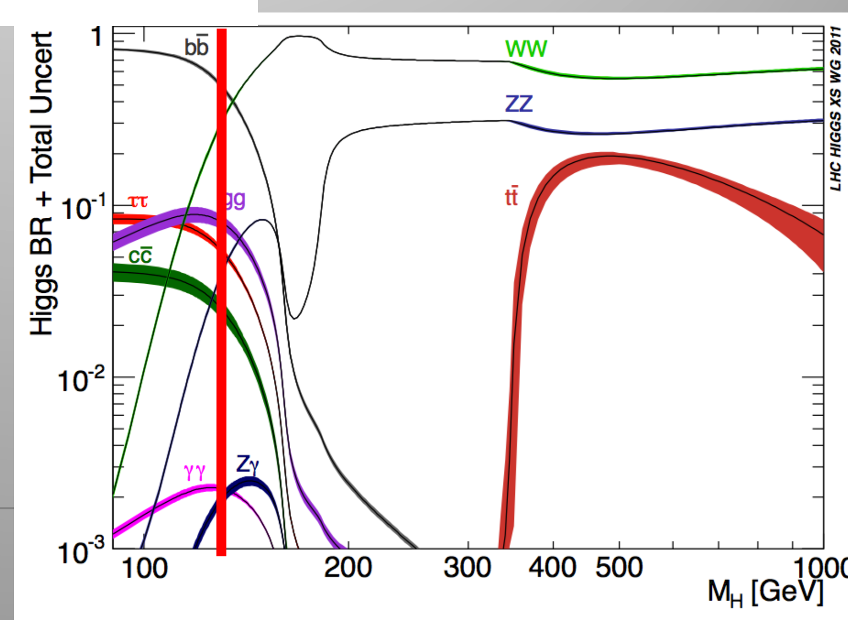
Processes

- •Gluon fusion
- •Vector Boson Fusion
- •W/Z associated prod.
- •Top associated prod
- •B-quark associated prod?



Numbers taken from the
LHC Higgs Cross Section WG

See yellow reports:
YR1: Inclusive cross sections
YR2: Differential cross sections
YR3: Properties



Higgs Hunting: Channel Overview

Processes/decays studied:

Results released (green) | In progress (yellow)

	untagged	VBF	VH	ttH
H-> gamgam	Results released	Results released	Results released	Results released
H-> ZZ	Results released	Results released	Results released	Results released
H->WW	Results released	Results released	Results released	Results released
H-> bb		In progress	Results released	Results released
H-> tau tau	Results released	Results released	Results released	Results released
H-> Zgamma	Results released	Results released		
H-> mumu	Results released	Results released	Results released	
H-> invisible	In progress	Results released	Results released	In progress

bbH?

+ more exotic channels

Main decay channel characteristics:

Channel	m_H range (GeV/c^2)	Data used 7+8 TeV (fb^{-1})	m_H resolution
H -> γγ	110-150	5.1+19.6	1-2%
H -> tautau	110-145	4.9+19.6	15%
H -> bb	110-135	5.0+19.0	10%
H -> WW -> lnulnu	110-600	110-1000	20%
H -> ZZ -> 4l	110-1000	5.1+19.6	1-2%

"the big five"

CMS Higgs Analyses

- In summer 2012 we called it a “Higgs-like” particle
- In spring 2013 (with 3x more data) we called it a Higgs particle

Spin/parity 0^+ favored, couplings roughly as in SM for Bosons

What happened Next?

- More detailed analyses of the 125 GeV particle, in particular the search for direct decays into fermions, ttH channel,...
- More precise measurements of the “signal strength σ/σ_{SM}“ and of the mass of the particle, and the spin (0^{++}), couplings
- Searches for Higgs like particles at higher masses
- Searches for exotic, non-SM decays (none found so far)
- Searches for di-Higgs events (in BSM scenarios, none found so far)
- Differential distributions + fiducial volume cross sections (in progress)

→CMS has published Run-I legacy papers (apart comb.)

The Higgs is the new playground: Room for new experimental/theoretical ideas!!

Remember: we have already ~1 Million Higgses produced at the LHC

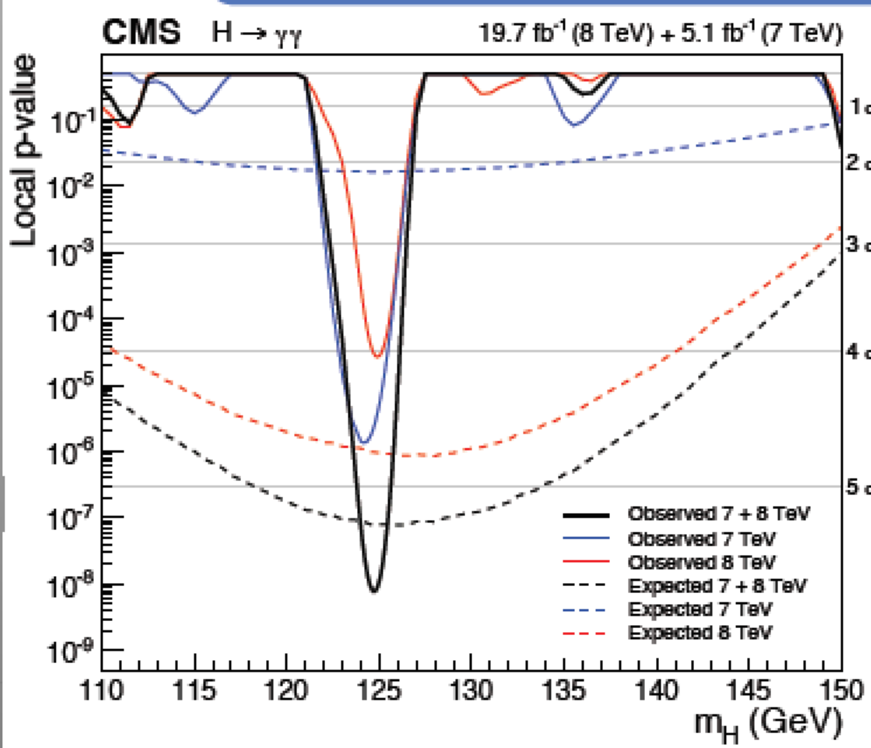
Higgs → γγ

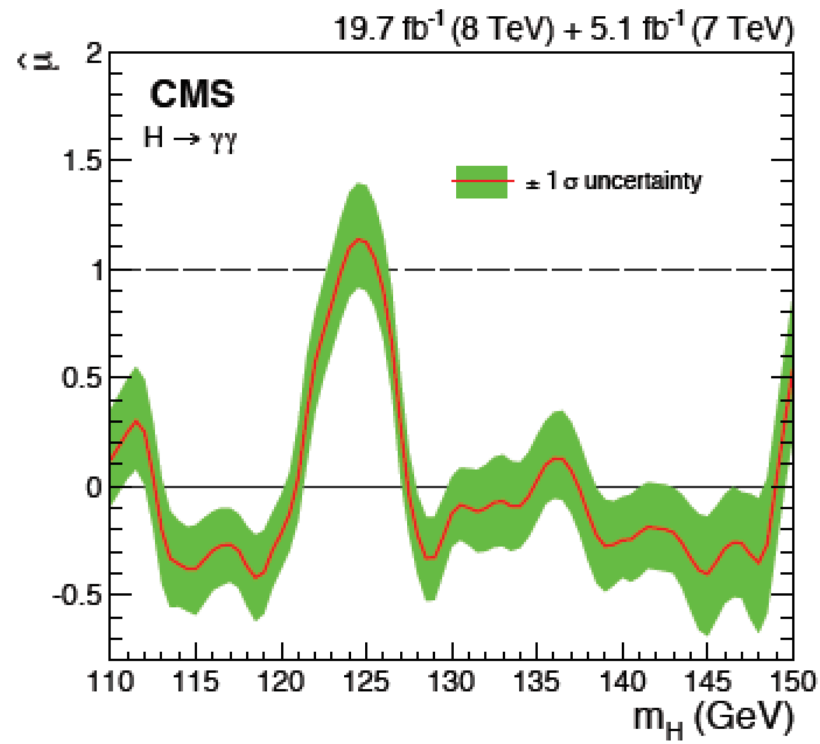
Signal Strength:

arXiv:1407.0558

Dataset	Significance (obs)	σ/σ_{SM}	m_H (GeV)
7 TeV	4.7σ	$2.22^{+0.62}_{-0.55}$	124.2
8 TeV	4.0σ	$0.90^{+0.26}_{-0.23}$	124.9
7 + 8 TeV	**5.7σ**	$\mathbf{1.14^{+0.26}_{-0.23}}$	**124.7**

$$\sigma/\sigma_{SM} = 1.14^{+0.26}_{-0.23}\left[{}^{+0.21}_{-0.21}(\text{stat.})^{+0.09}_{-0.05}(\text{syst.})^{+0.13}_{-0.09}(\text{th.})\right]$$

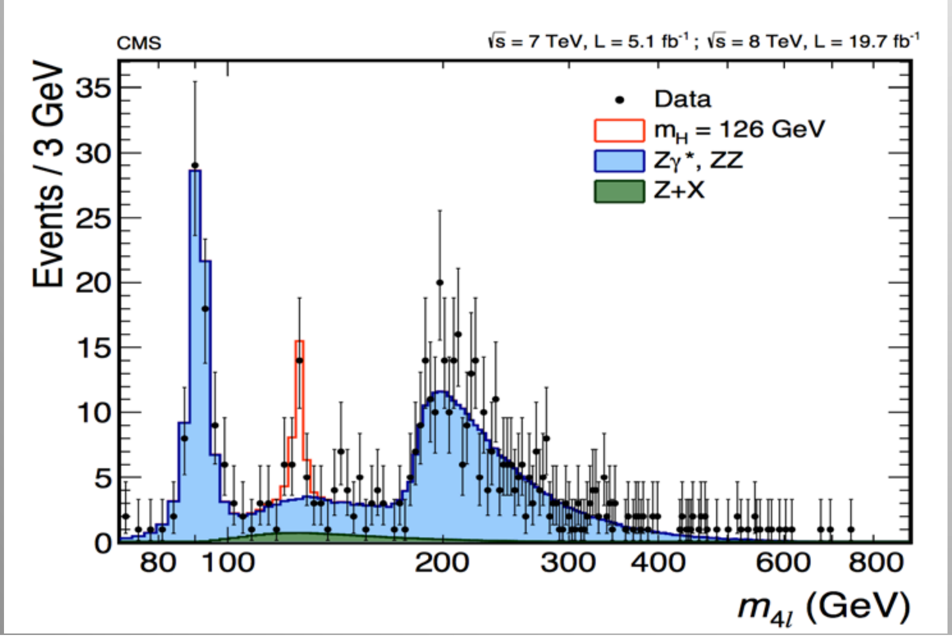




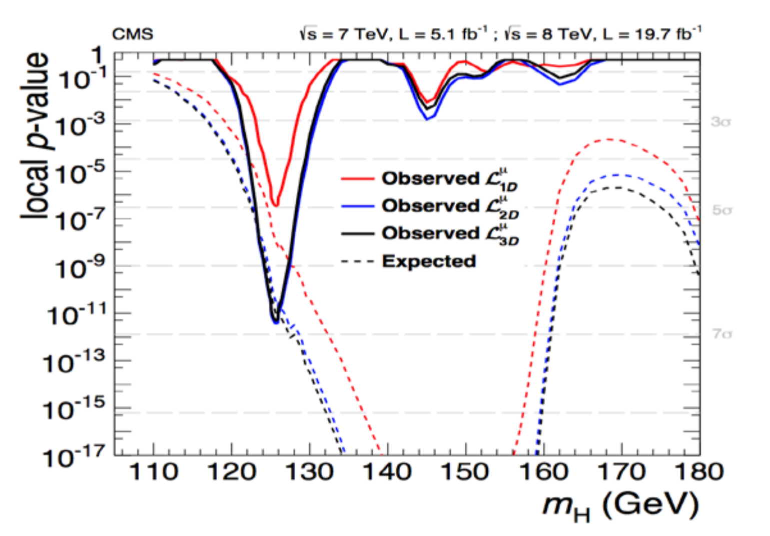
$H \to ZZ \to 4l$

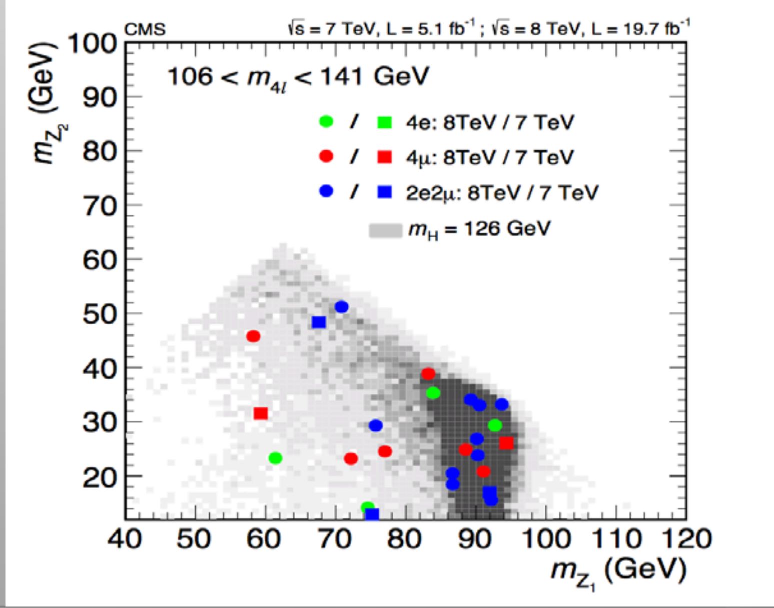
CMS: arXiv:1312.5353

- Search for a narrow peak in 4-lepton inv. Mass
- Low statistics & background channel
- Use kinematical discriminators and categories



CMS: Expected: 6.7σ Observed: 6.8σ
$\to \mu = 0.93^{+0.29}_{-0.24}$



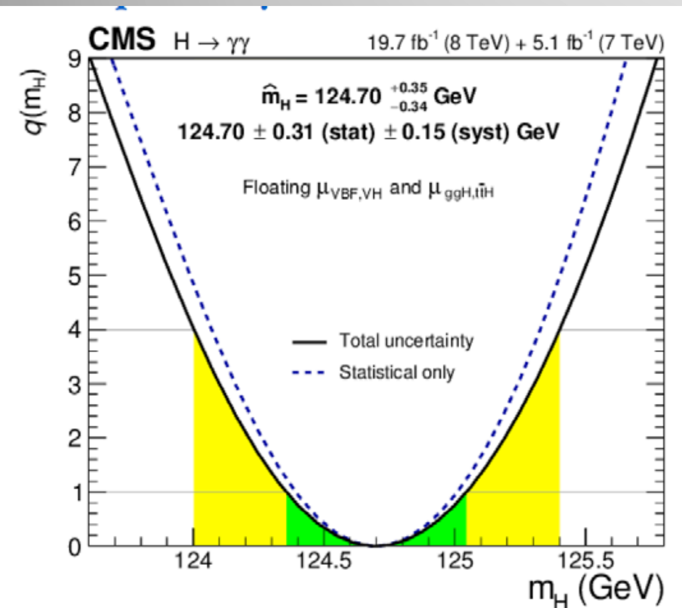


Significance is well over 6 standard deviations in this channel

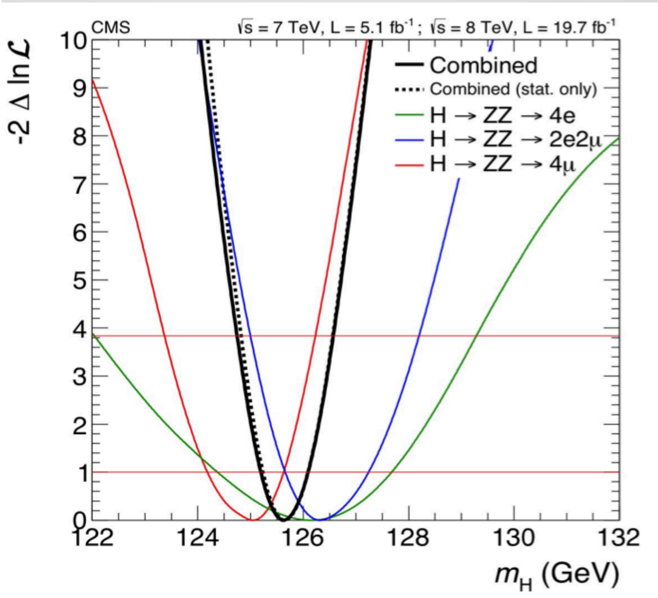
The Mass of the New Particle

Determine the mass from ZZ and 2-photon channels which show a peak!

New calibration & strong effort on systematics



$m_H = 124.70 \pm 0.31\,(stat) \pm 0.15\,(syst)\,GeV$



$m_H = 125.6 \pm 0.4\,(stat) \pm 0.2\,(syst)\,GeV$

$$m_H = 125.03\,^{+0.26}_{-0.27}\,(stat)\,^{+0.13}_{-0.15}\,(syst) = 125.03\,^{+0.29}_{-0.31}\,(tot)\,GeV$$

Two-photon and two Z channel mass estimates agree (within 1.6σ)

Mass value is about 125.0 GeV with 0.3 GeV uncertainty

Old value: 125.5 GeV

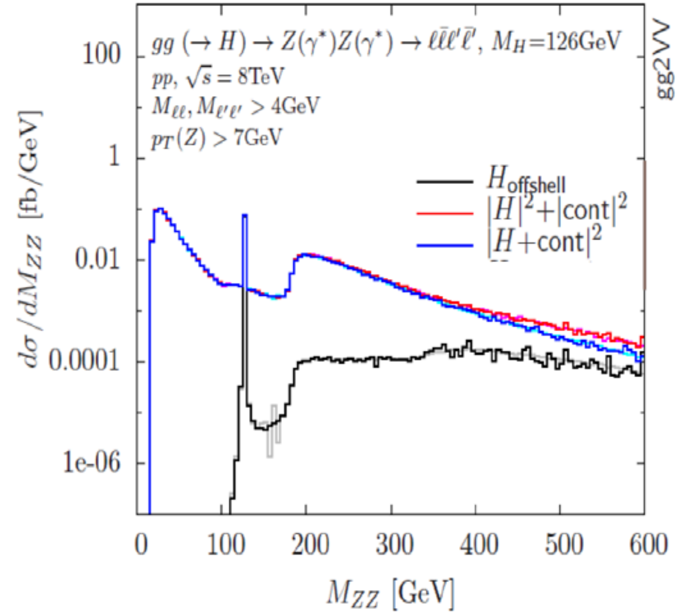
The Total Width of the Higgs

Recent History

arXiv:1405.3455

Direct width limits so far 3.4 GeV in ZZ and 6.9 GeV in two-photon decays (95% CL) from the resonance peak measurement
→Dominated by experimental resolution

- Until recently it seemed unlikely the LHC could measure the total Higgs width (~4.2 MeV in SM)
- In 2012 it was noted that 7.6% of the Higgs to ZZ cross section is above 180 GeV arXiv:1206.4803
- The off-shell contribution is independent of the total width!
- The ratio of on-shell to off-shell can thus provide information on the width
- Interference of the signal with ZZ continuum is important and must be taken into account



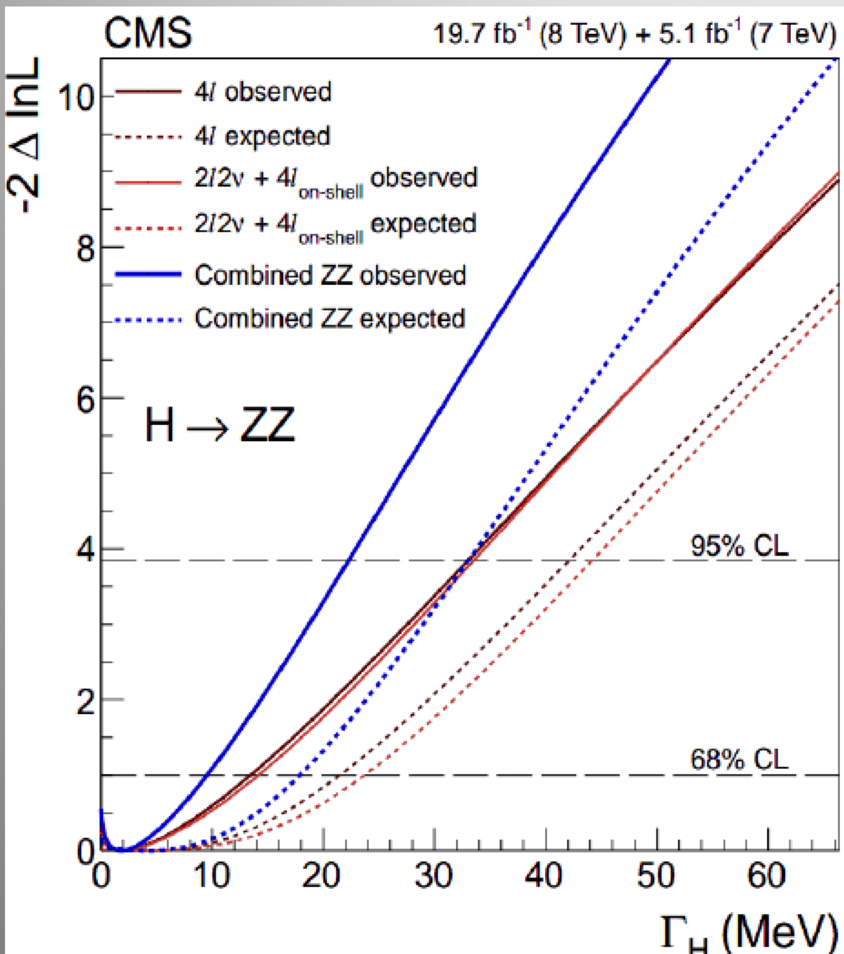
2012/13: Kauer, Passarino; Caola, Melnikov; Campbell, Ellis, Williams ...

$$\sigma^{\rm on-peak}_{gg\to H\to ZZ} \propto \frac{g^2_{ggH}g^2_{HZZ}}{\Gamma_H}, \qquad \sigma^{\rm off-peak}_{gg\to H\to ZZ} \propto g^2_{ggH}g^2_{HZZ}.$$

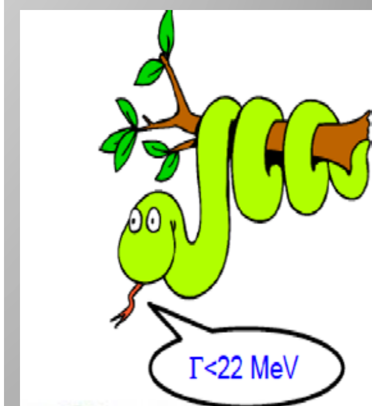
$$r = \Gamma_H/\Gamma_H^{SM}$$

The Total Width of the Higgs

- Study Higgs $\rightarrow$ ZZ in the 4 charged lepton and 2 charged lepton + 2ν decay
- Determine the total Higgs width in the two channels separately
- Use a kinematic discriminant and m_T distributions to reduce ZZ continuum



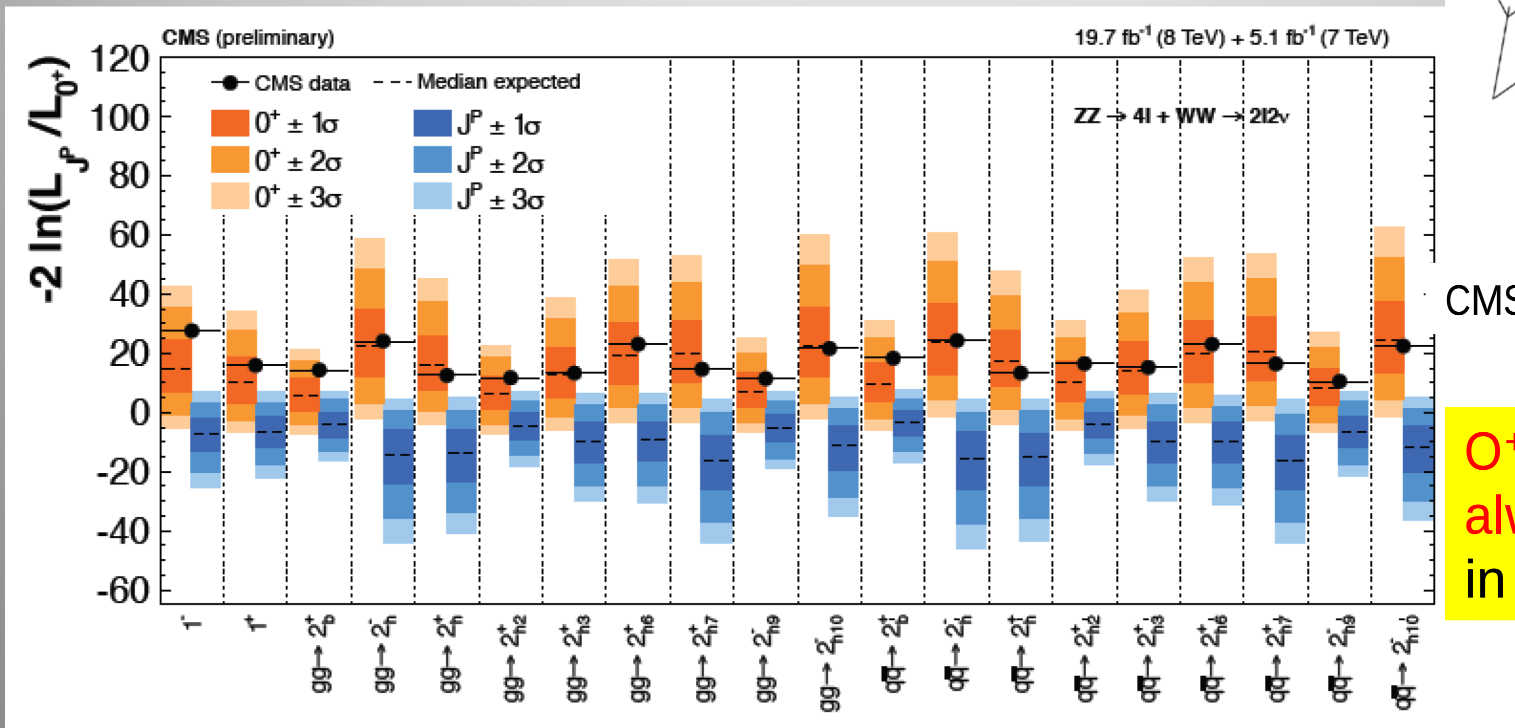
- **Reminder : SM predicts :**
  - $\Gamma_H = 4.2$MeV
- **95% C.L. Limits on Γ_H :**
  - Expected : 33MeV
  - Observed : 22MeV
- **Γ_H Measurement :**
  - Expected : $4.2^{+13.5}_{-4.2}$ MeV
  - Observed : $1.8^{+7.7}_{-1.8}$ MeV
- **Combination** improves the individual limits by ~20%
- Compatibility between the observed results and the SM hypothesis lead to a **p-value of 0.24**

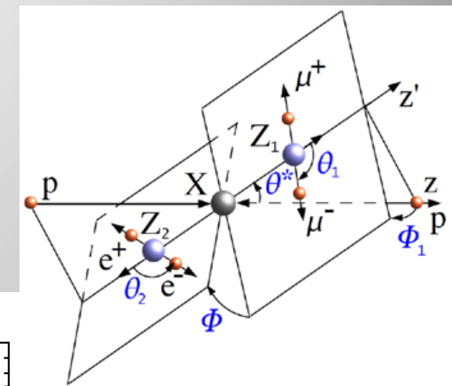


Spin/Parity Studies: ZZ/WW

Combined study of H→ZZ and H→WW

- Tested using all diboson channels
- Hypotheses comparison O^+/other states





CMS-PAS-HIG-14-014

O^+ hypothesis is always favoured in the comparison

All "exotic" scenarios excluded scenarios excluded with 99.9% CL

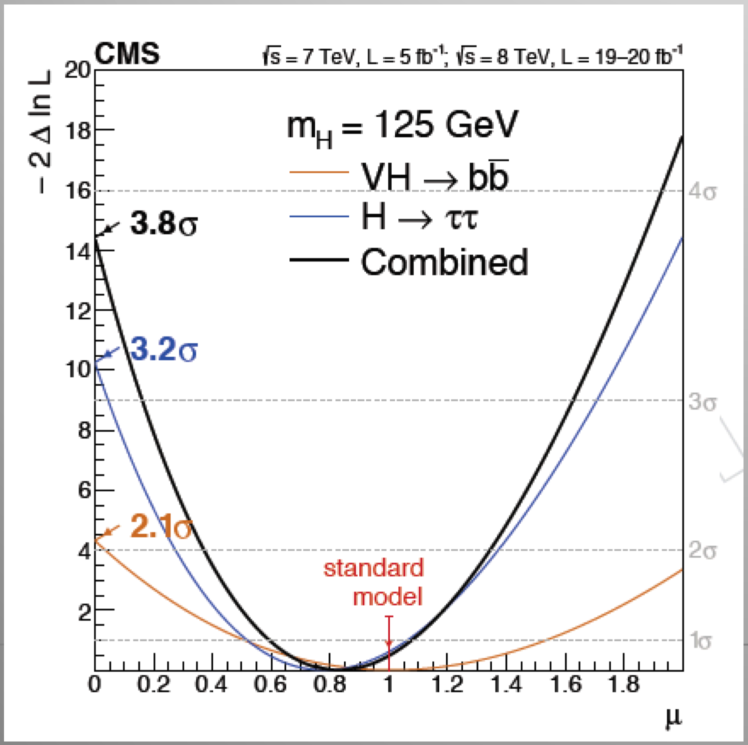
Also CP studies of $J=0^{++}$ state → Results consistent with SM

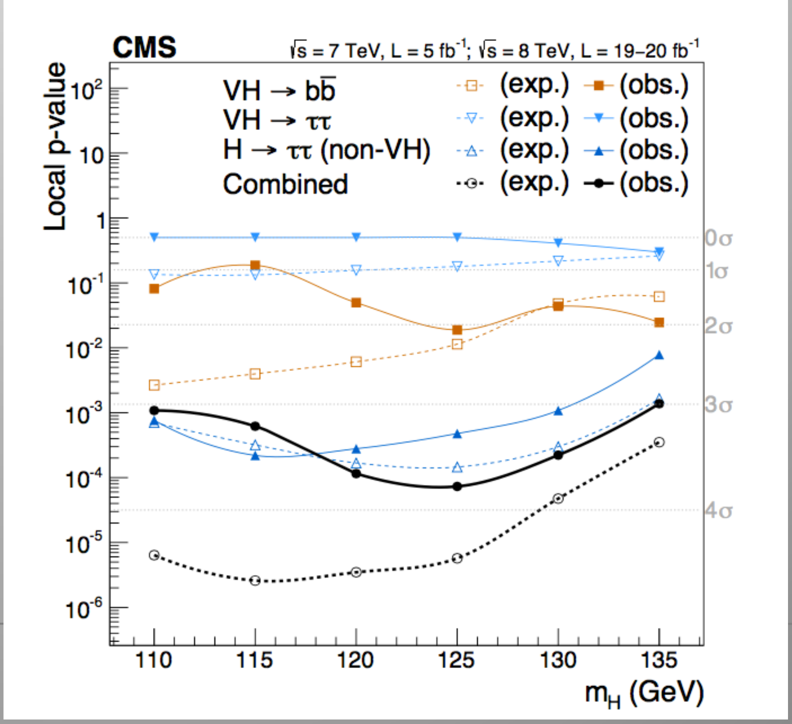
Higgs → Fermions Combination

- The combined H(ττ) and H(bb) result establishes a strong evidence for coupling of the Higgs boson to down-type third generation fermions
- Indirect and direct results on ttH coupling also evident for a coupling to up-type fermions

arXiv:1401.6527 and
Nature Physics 10 (2014)

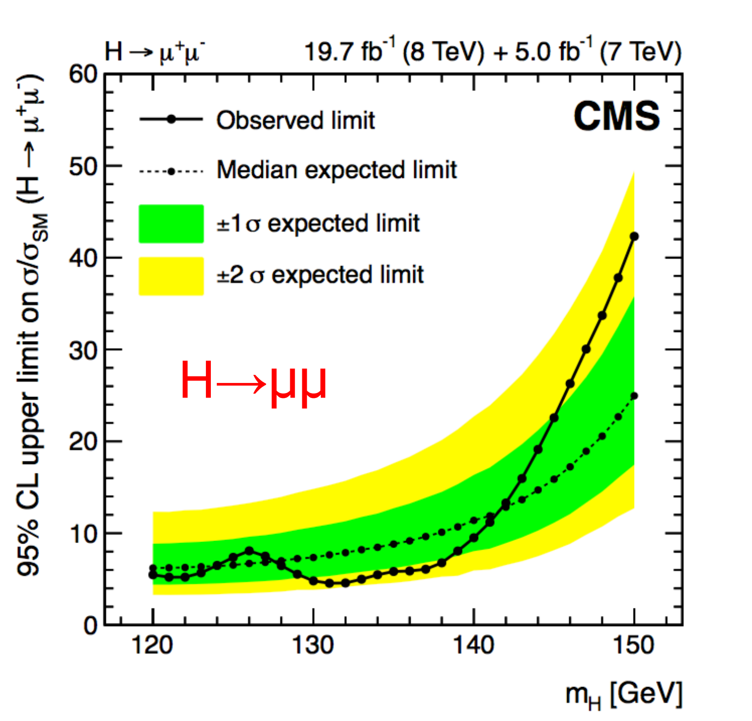
Channel ($m_H = 125$ GeV)	Significance (σ) Expected	Significance (σ) Observed	Best-fit μ
$VH \to b\bar{b}$	2.3	2.1	1.0 ± 0.5
$H \to \tau\tau$	3.7	3.2	0.78 ± 0.27
Combined	4.4	3.8	0.83 ± 0.24

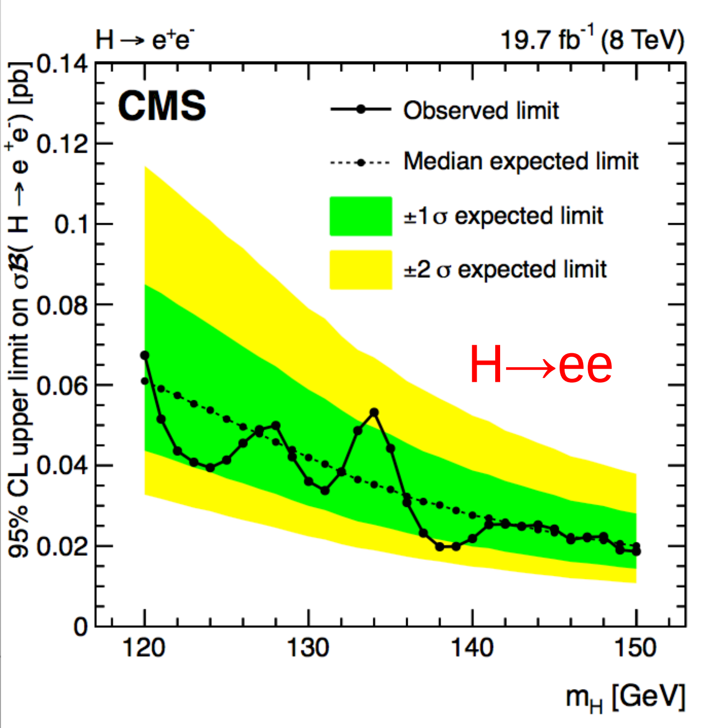




Higgs → μμ (ee)

- Observing H(μμ) decay may be the only way to show the flavor non-universal couplings   The coupling to charm will be hard to probe
- Requires very large statistics for an observation: a strong case for the High Luminosity-LHC: HL-LHC
- First searches have been already done (@125 GeV)   arXiv:1410.6679
  - -H→μμ   μ < 7.4 (6.5 expected) @ 95% CL
  - -BR(H→ee) < 1.9×10^{-3} @ 95% CL

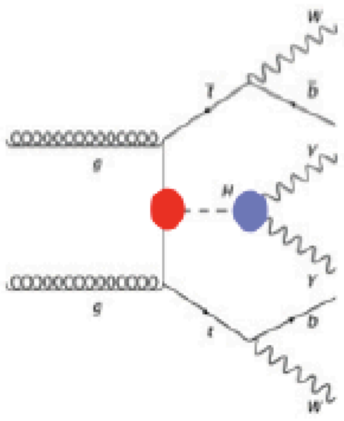




Higgs-Top Associated Production

Various decay modes of the Higgs are considered

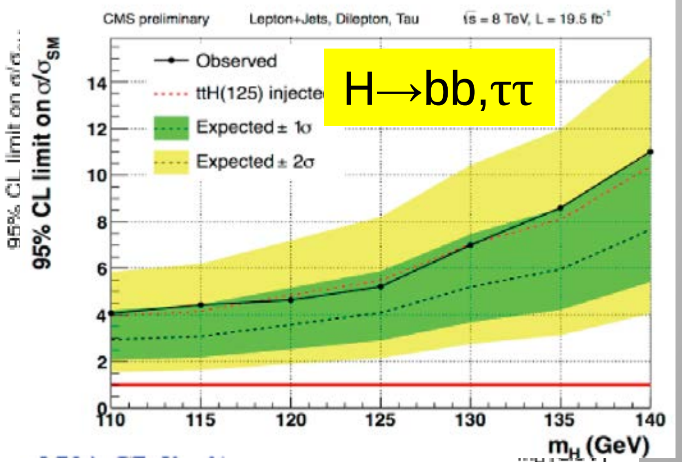
arXiv:1408.1682

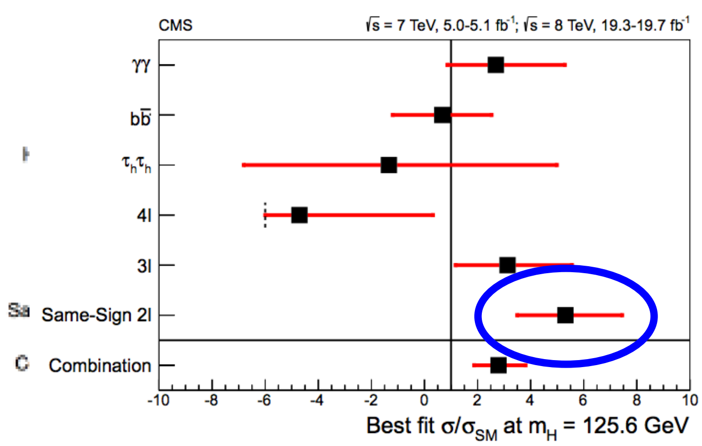


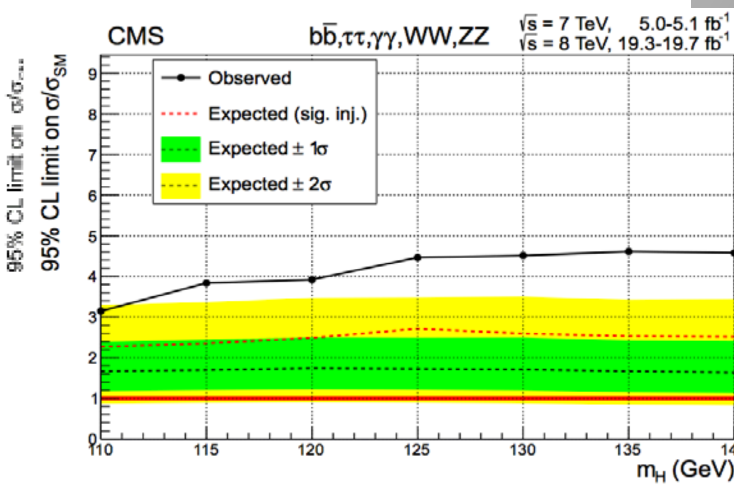
Probe of the H-top Yukawa coupling

CMS:

- H → γγ → HIG-13-015
- H → bb → HIG-13-019
- H → ττ → HIG-13-019
- H → ZZ → HIG-13-020
- H → WW → HIG-13-020







CMS: μ < 4.5 (1.7 expected) @ 95% CL μ= 2.8±1.0

Improvement H->bb with matrix element methods: μ= 1.2+1.6-1.5 CMS-PAS-HIG-14-010

Single Top + Higgs Production

- Direct coupling to the top quark -> C_t=-1 or large cancelations in the SM?
- Cross sections could be surprisingly large if there are deviations from SM

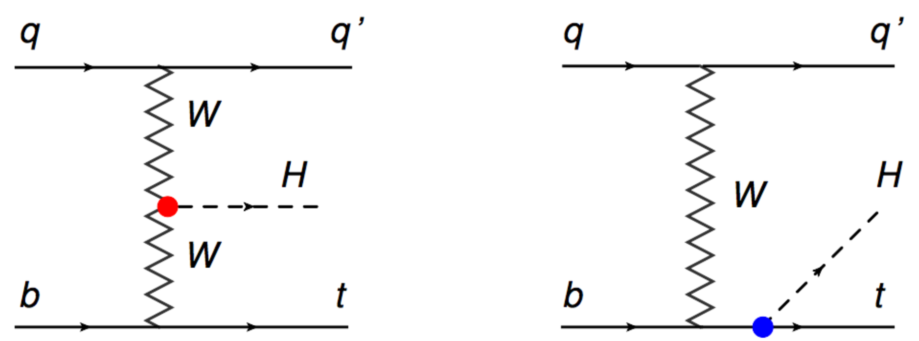
  Negative C_t gives 15x increased cross section plus 2x Higgs to 2 photons.
- Composite Higgs models heavy t' -> top + Higgs..

- Study the Higgs decay to two photon decay channel

  No events found top + two photon selection

  95% upper limit is 4.1 times the expected cross section for C_t=-1

CMS-PAS-HIG-14-001

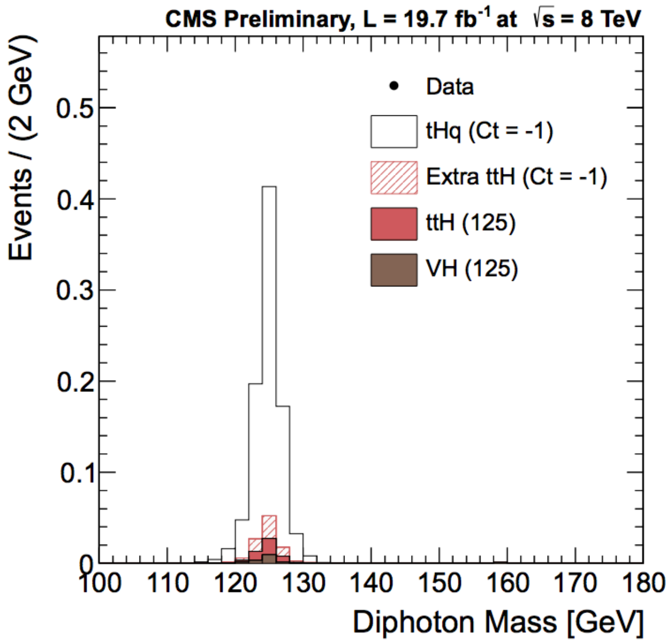


New: single top with Higgs into bb

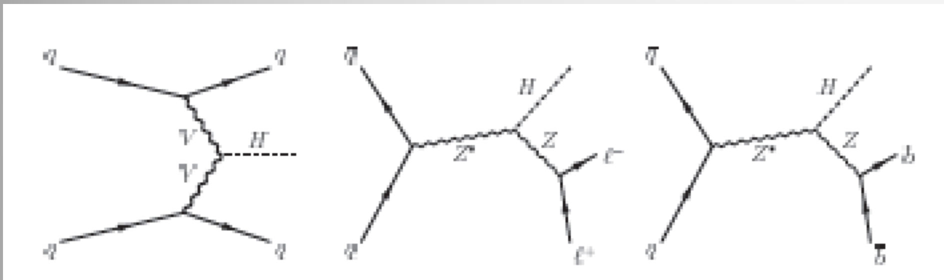
~7.6 times the cross section for C_t=-1 (95%CL)

CMS-PAS-HIG-14-015

	Expected	Observed
MC-driven	$5.14^{+2.14}_{-1.44}$	7.57
Data-driven cross-check	$6.24^{+2.26}_{-1.71}$	6.95



Invisible Higgs Decay Channel

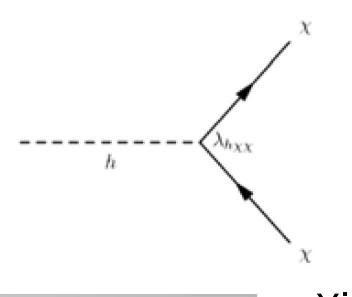


Search for invisible Higgs decays using

Z+H → 2 leptons + missing E_T

VBF H → 2 jets + missing E_T

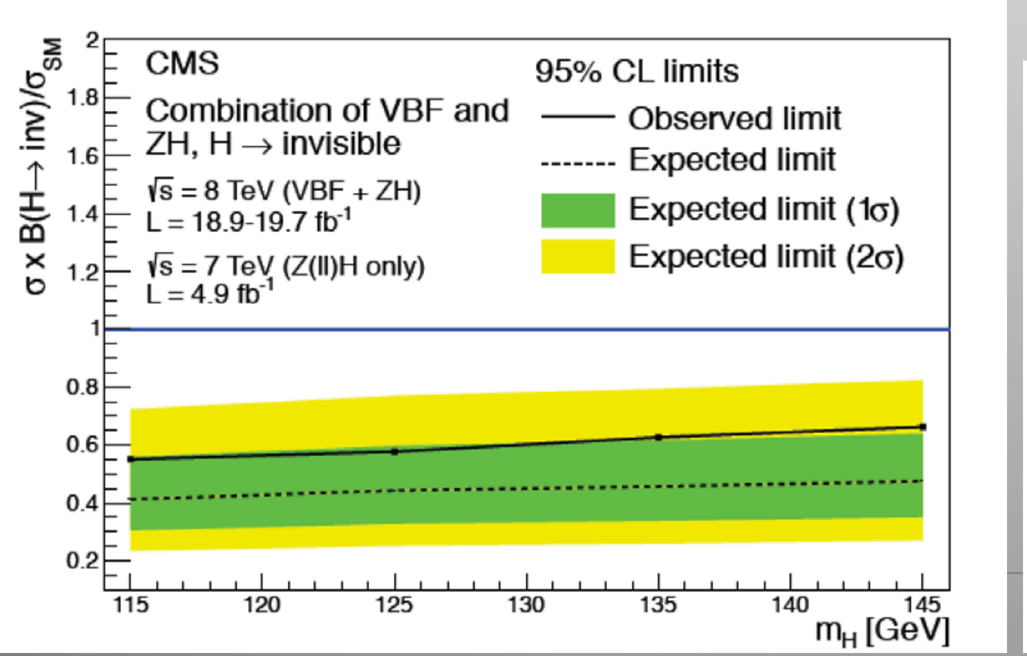
Possible decay in Dark Matter particles (if $M<M_H/2$): Higgs Portal Models



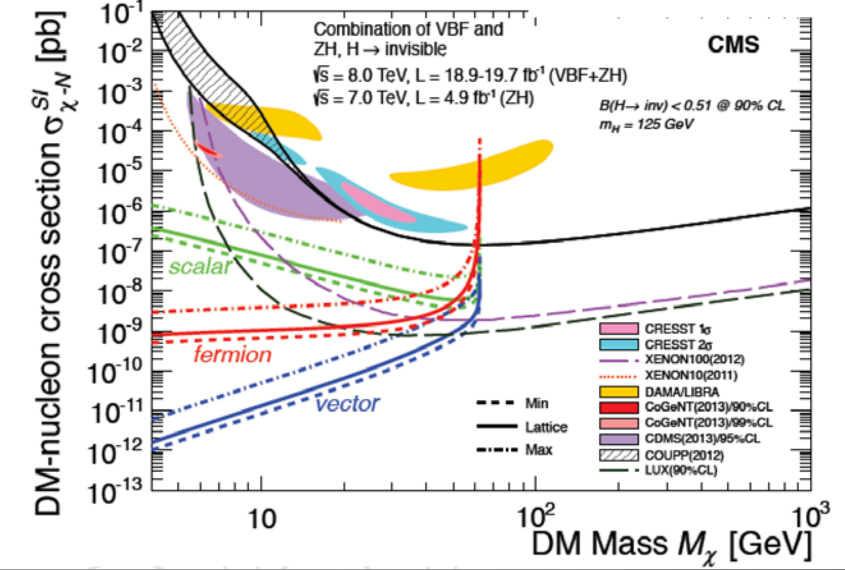
Combined result from the three channels

BR(H→invisible)<58%(44% exp) at 95% CL.

for a Higgs with a mass of 125 GeV



arXiv1404.1344

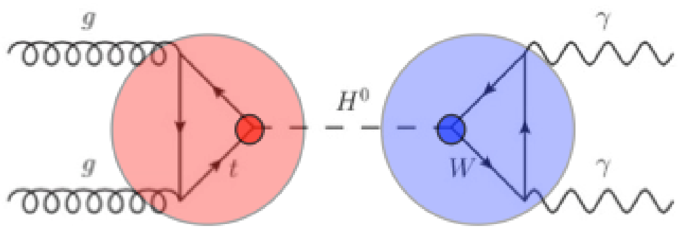


Coupling Measurements

Assume the observed signal stems from one narrow resonance.

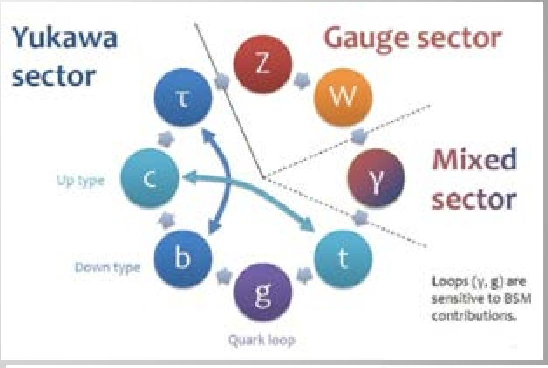
$$(\sigma \cdot \mathrm{BR})\,(ii \to \mathrm{H} \to ff) = \frac{\sigma_{ii} \cdot \Gamma_{ff}}{\Gamma_{\mathrm{H}}}$$

Parametrize deviations w.r.t. the SM in production and decay. This implies precise knowledge of the SM Higgs. Not considered are BSM acceptance effects.



$$(\sigma \cdot \mathrm{BR})\,(\mathrm{gg} \to \mathrm{H} \to \gamma\gamma) = \sigma_{\mathrm{SM}}(\mathrm{gg} \to \mathrm{H}) \cdot \mathrm{BR}_{\mathrm{SM}}(\mathrm{H} \to \gamma\gamma) \cdot \frac{\kappa_g^2 \cdot \kappa_\gamma^2}{\kappa_{\mathrm{H}}^2}$$

$$\kappa_H^2 = \sum_X \kappa_X^2 \frac{\mathrm{BR}_{\mathrm{SM}}(H \to X)}{1 - \mathrm{BR}_{\mathrm{BSM}}}$$



- one common scale factor
- scale vector and fermion coupling
- custodial symmetry
- new physics in loops
- BSM Higgs decays
- ...

Decay tag	incl.(ggH)	VBF tag	VH tag	ttH tag
H→ZZ	✔	✔		
H→γγ	✔	✔	✔	✔
H→WW	✔	✔	✔	✔
H→ττ	✔	✔	✔	✔
H→bb		✓	✔	✔
H→Zγ	✓	✓		
H→μμ	✓	✓		
H→inv.		✓	✓	

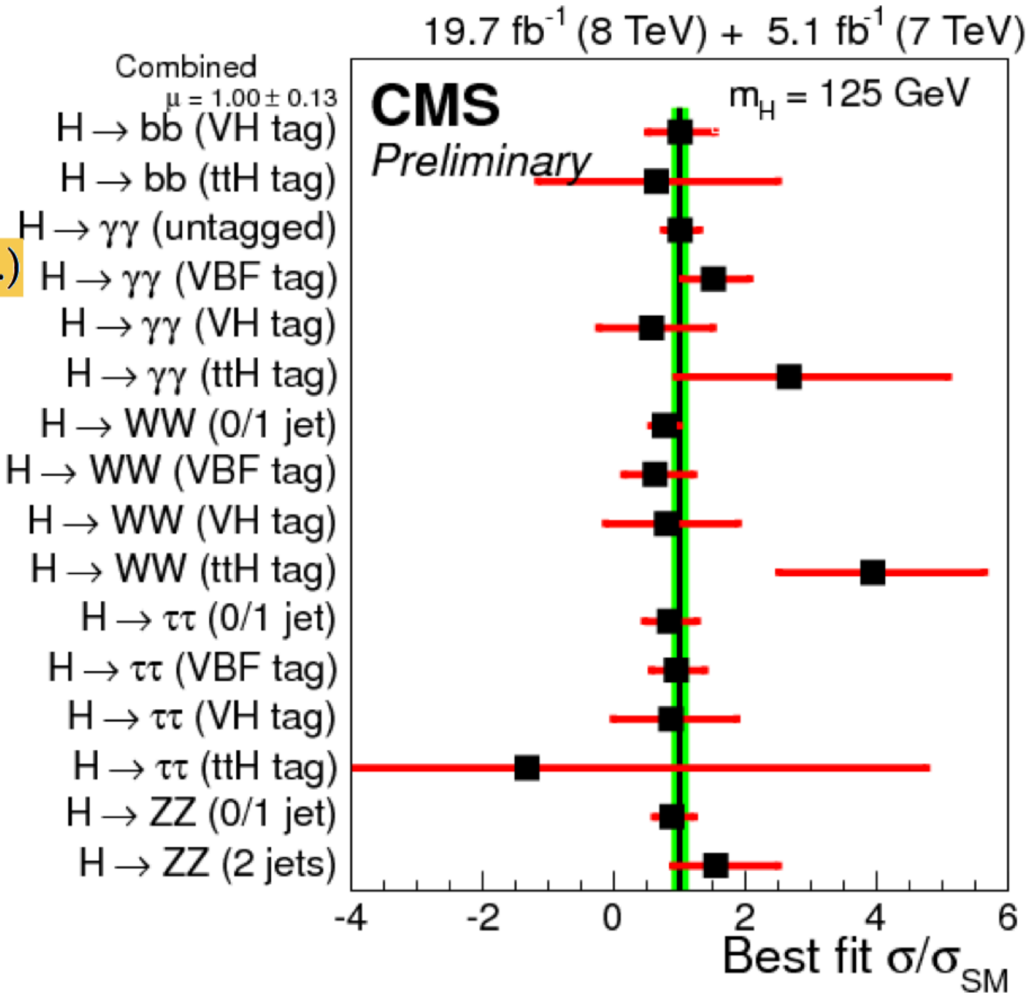
✔ Used in the **NEW** combination

CMS-PAS-HIG-14-009

- New update of overall combination since spring 2013

All Channels in Overview

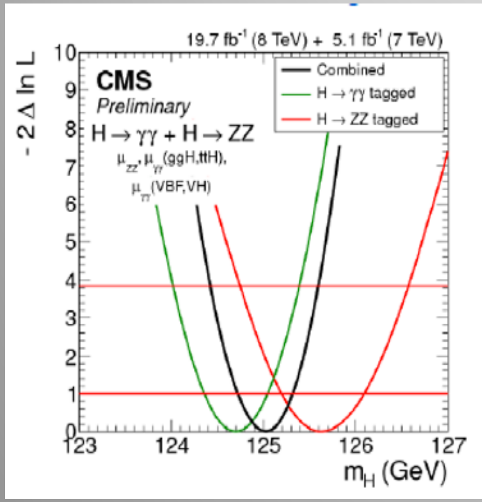
- Overall signal strength
  1.00 ± 0.13
  $1.00 \pm 0.09\,(\text{stat.})\ ^{+0.08}_{-0.07}\,(\text{theo.}) \pm 0.07\,(\text{syst.})$
  - "theo." includes QCD scales, PDF+α_s, UEPS, and BR
- Per production and decay tag:
  - χ^2/dof = 10.5/16
  - p-value = 0.84 (asymptotic)

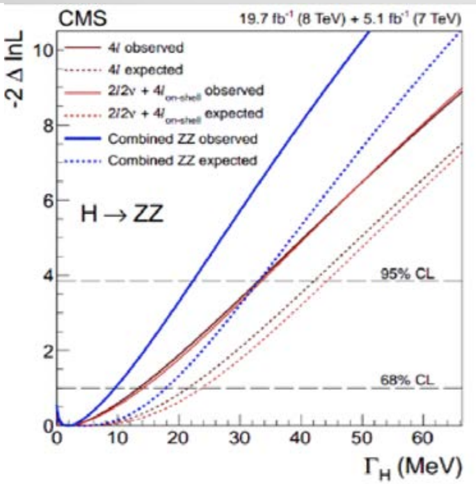


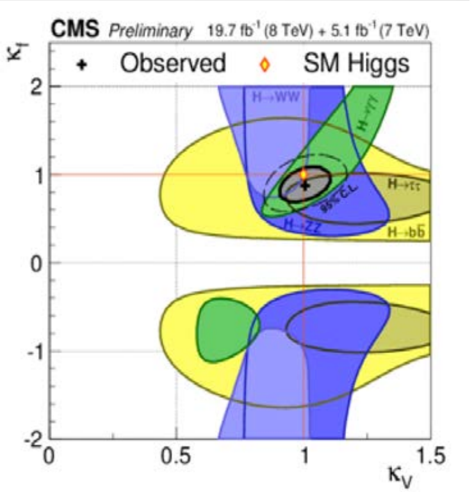
Overall strength was 0.82 ± 0.15 before ICHEP14 (spring 2013)

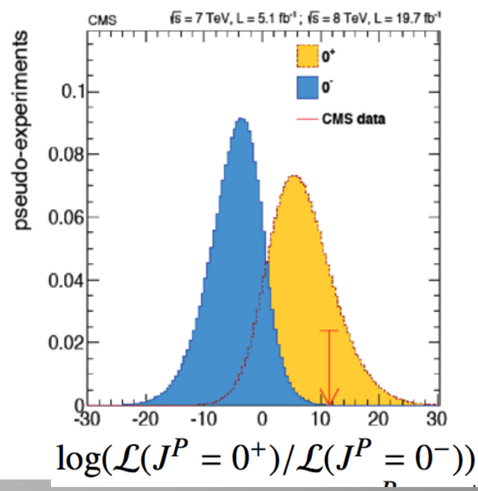
Brief Higgs Summary

We know already a lot on this brand new Higgs Particle!!









Mass =
125.0 ±0.3 GeV

Width =
< 22 MeV
(95%CL)

Couplings are
within 15-20% of
the SM values

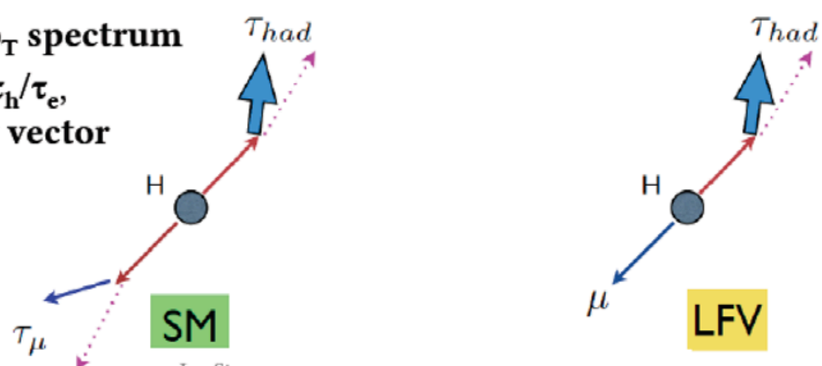
Spin =
0^+ preferred
over 0^-,1,2

The Higgs is the new playground: Room for new experimental/theoretical ideas!!
Remember: we have already ~1 Million Higgses produced at the LHC

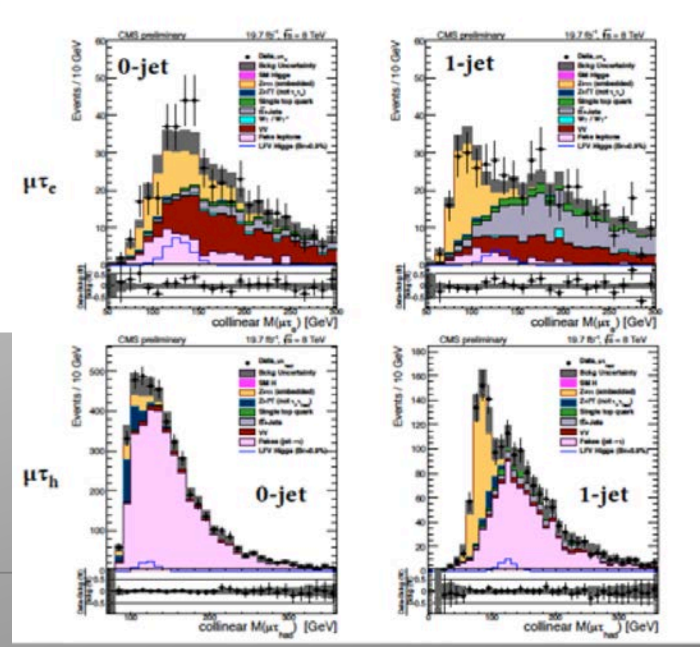
Search for LFV Decays: H $\rightarrow \mu\tau$

CMS-PAS-HIG-14-005

- Previous best limits on B(H→μτ) <~ 10% from reinterpretation of LHC H→ττ searches and from τ→μγ arXiv:1209.1397
  - **Can do better with first dedicated search**
- Consider hadronic (τ_h) and electron (τ_e) tau decays
- Same basic event selection and jet categories as SM H→ττ analysis (0-jet, 1-jet, VBF-tag)
- Differences in kinematics
  - **Harder muon p_T spectrum**
  - **Δϕ between μ, τ_h/τ_e, missing energy vector**

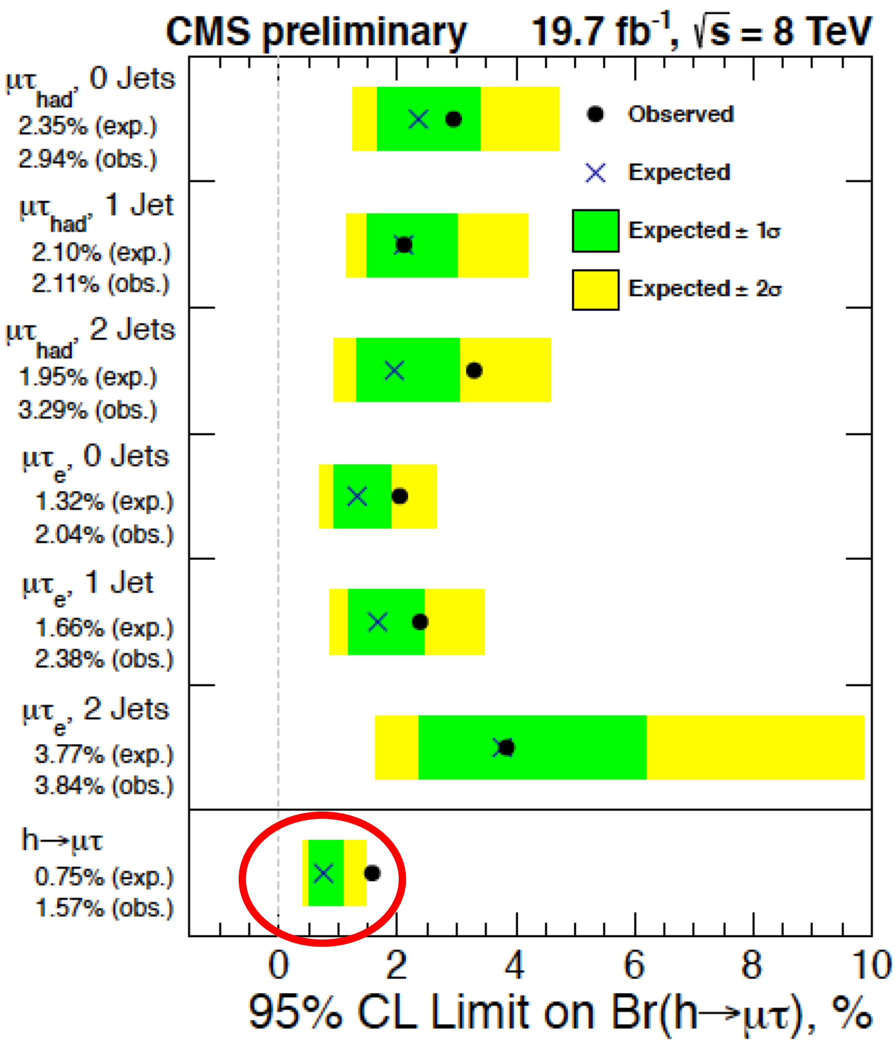


On public demand from our theory friends ☺



Search for LFV Decays: H →μτ

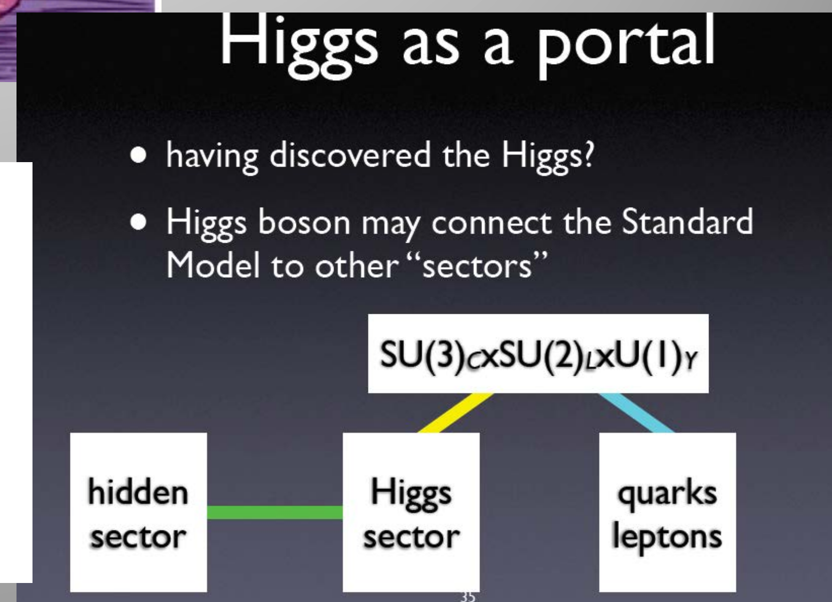
- Comparable sensitivity from all channels
- Observed limit 1.57% (exp. 0.75%)
- **Large improvement of previous limits**
- **Background-only p-value of 0.007 (2.46σ)**
  - Best-fit $B(H\to\mu\tau) = 0.89^{+0.40}_{-0.37}\%$



Mild excess giving a 2.5σ effect… To be watched!!!

The Future: Studying the Higgs…

Higher Energy in 2015!
LHC lumi upgrade !
Experiment upgrades!!
(Other/new machines?)



Many questions are still unanswered:

- What explain a Higgs mass ~ 126 GeV?
- What explains the particle mass pattern?
- Connection with Dark Matter?
- Where is the antimatter in the Universe?
- ⑤

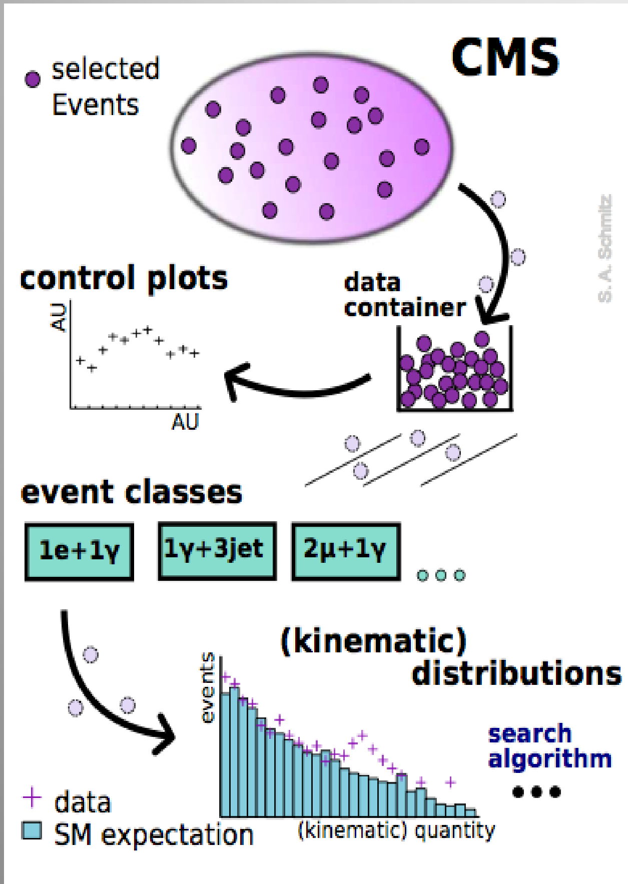
Summary

- Run-I delivered many measurements of Standard Model processes, eg on the top quark, EWK and in QCD. Some features of multiparticle production are not yet understood
- A prime goal for the LHC is to look for New Physics. The Run-I data have cut strongly in the phase space of NP eg: Supersymmetry, putting Constrained and Natural models in trouble. 14 TeV data can be conclusive…
- Understanding Dark Matter is the next big challenge! Generic studies with MET are a high priority. Maybe dark matter couples to the Higgs directly?
- With one to a few fb^{-1} of 2015 data, the LH the run-I searches. 2015-2016 could well – and very exciting years!!!
- And maybe soon…

Backup

Finally: a Global View!

CMS-EXO-10-021

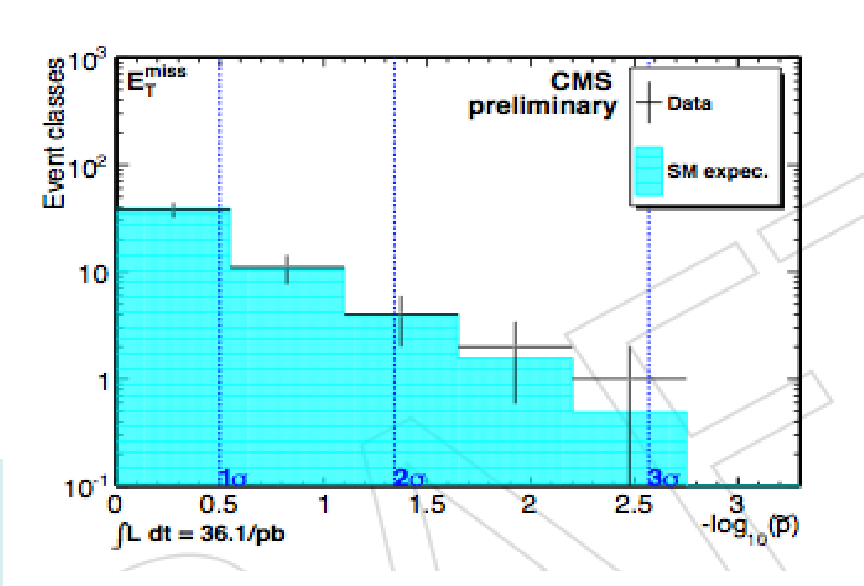


Model independent search

- Divide events into exclusive classes
- Study deviations from SM predictions in a statistical way

Distributions in each class

- $\sum p_T$ - Most general
- $M_{inv}^{(T)}$ - Good for resonances
- MET - Escaping particles

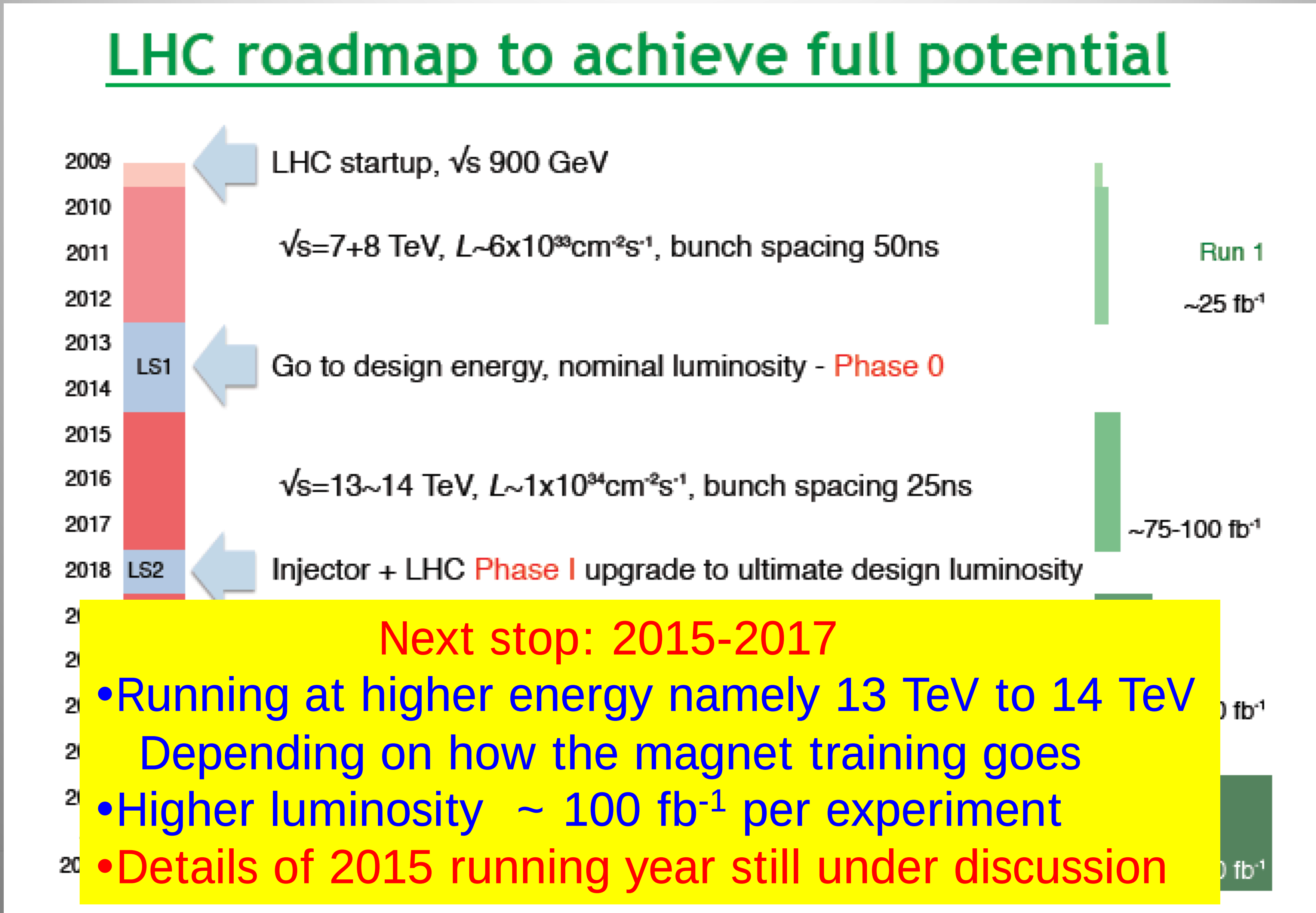


Probability distribution as expected for 35 pb^{-1} for CMS

→muons, electrons, photons, (b)jets, MET

Being completed for 2012 data

The LHC schedule



Next stop: 2015-2017

- Running at higher energy namely 13 TeV to 14 TeV
  Depending on how the magnet training goes
- Higher luminosity ~ 100 fb^{-1} per experiment
- Details of 2015 running year still under discussion

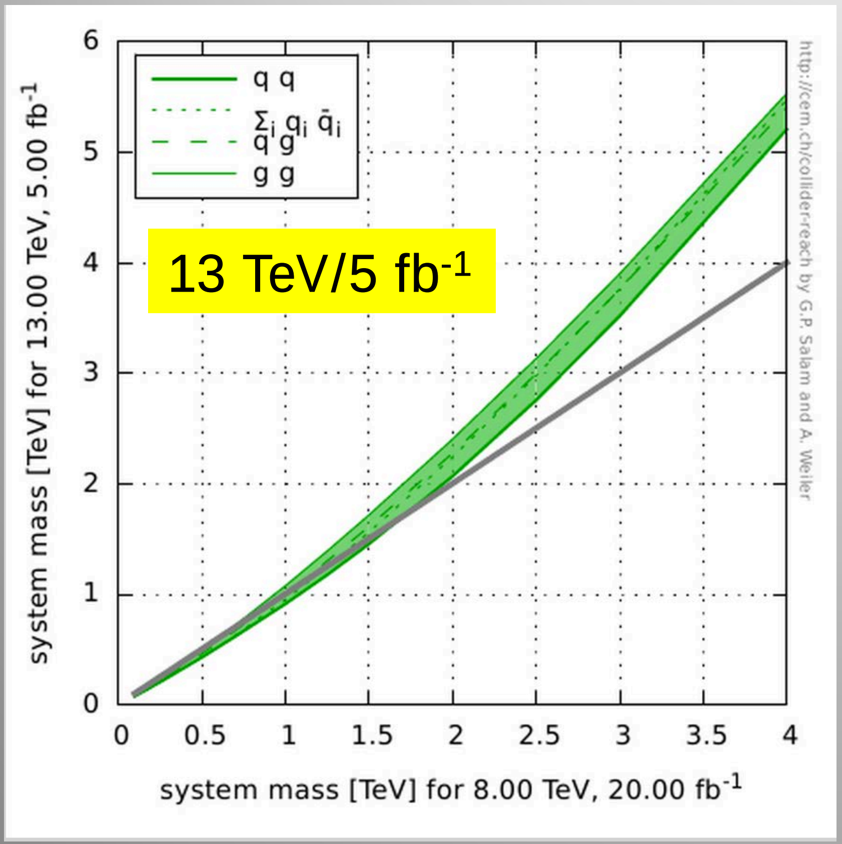
Reach at the Start of Run-II

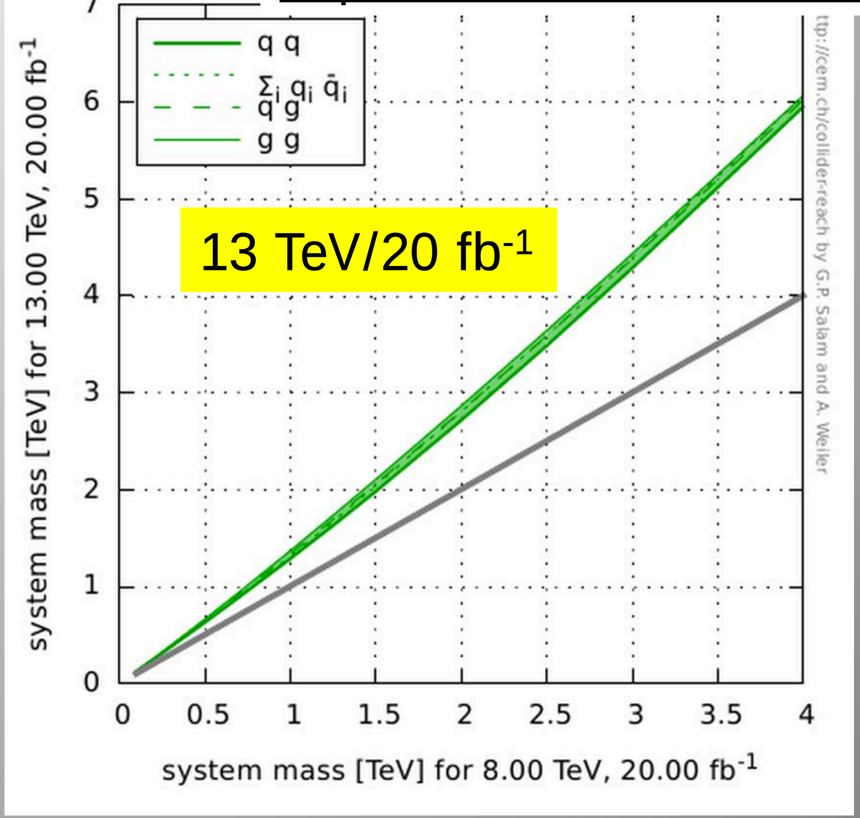
What can we expect in reach at 13 TeV with 5 or 20 fb^{-1}?

- Look at the parton luminosities to predict sensitivity
- Compare reach @8 TeV/20 fb^{-1} with future energy/luminosity

Salam & Weiler

http://cern.ch/collider-reach/

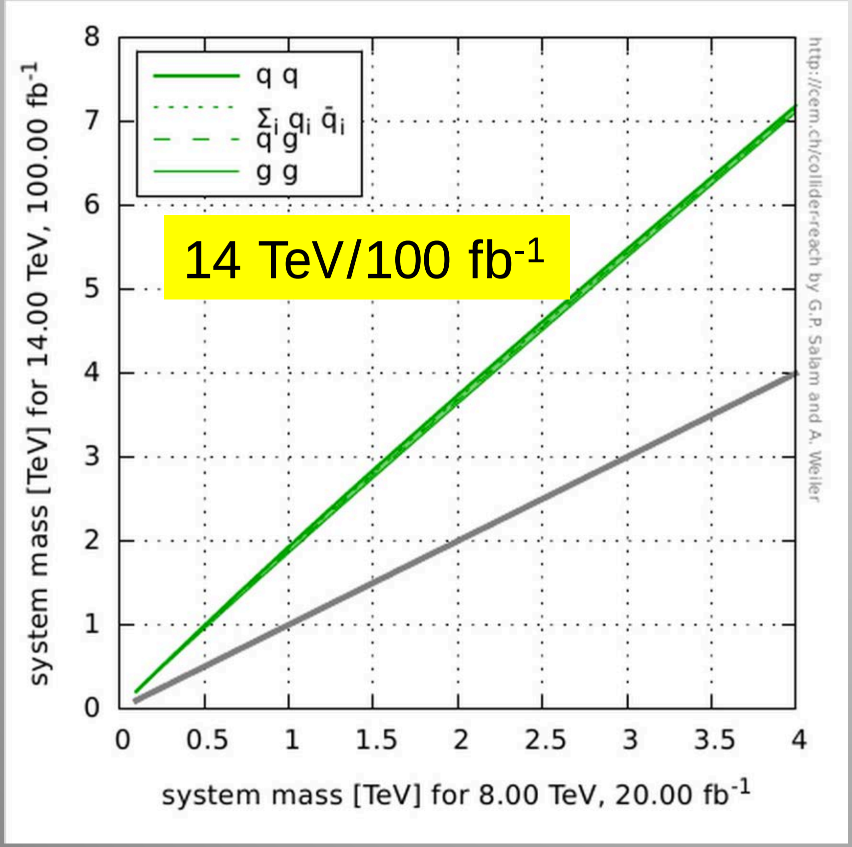


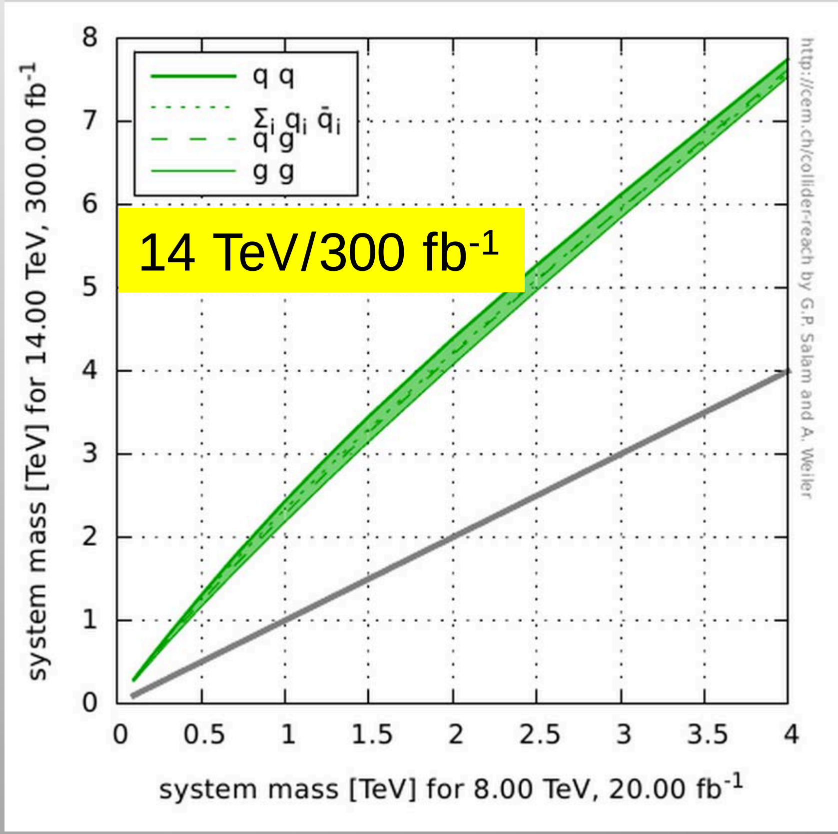


Expect about 20 fb^{-1} in 2015: Expect gain in reach of ~50% at high mass!!

Reach with Run-II

What can we expect in reach at 14 TeV with 100-300 fb^{-1}?
- Look at the parton luminosities to predict sensitivity
- Compare reach @8 TeV/20 fb^{-1} with future energy/luminosity





Phase-I LHC Expect gain in reach of a factor of two at high mass!!