nano-Résumé de la conférence ICHEP

ICHEP2016CHICAGO

38th INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS

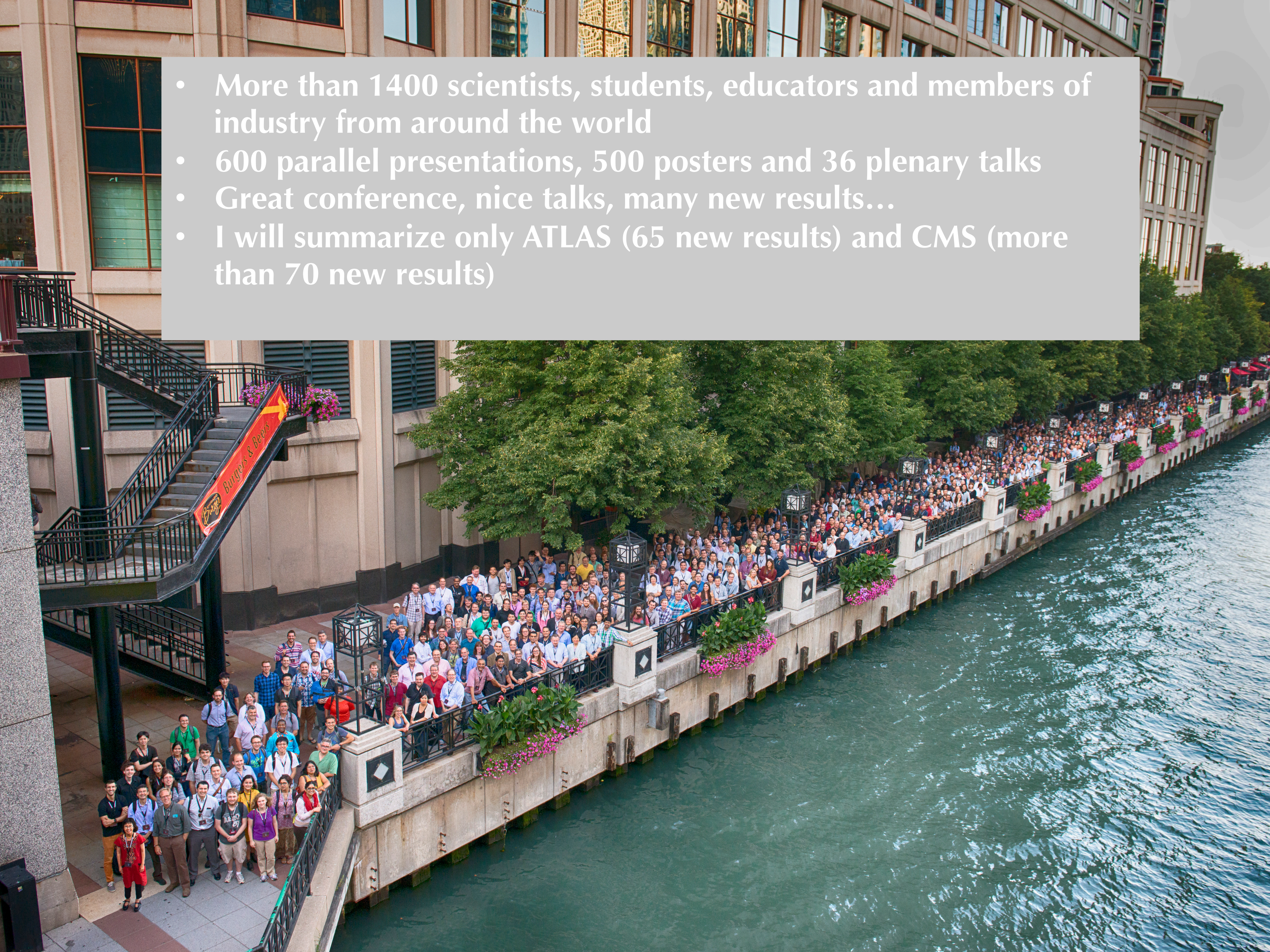
AUGUST 3 - 10, 2016

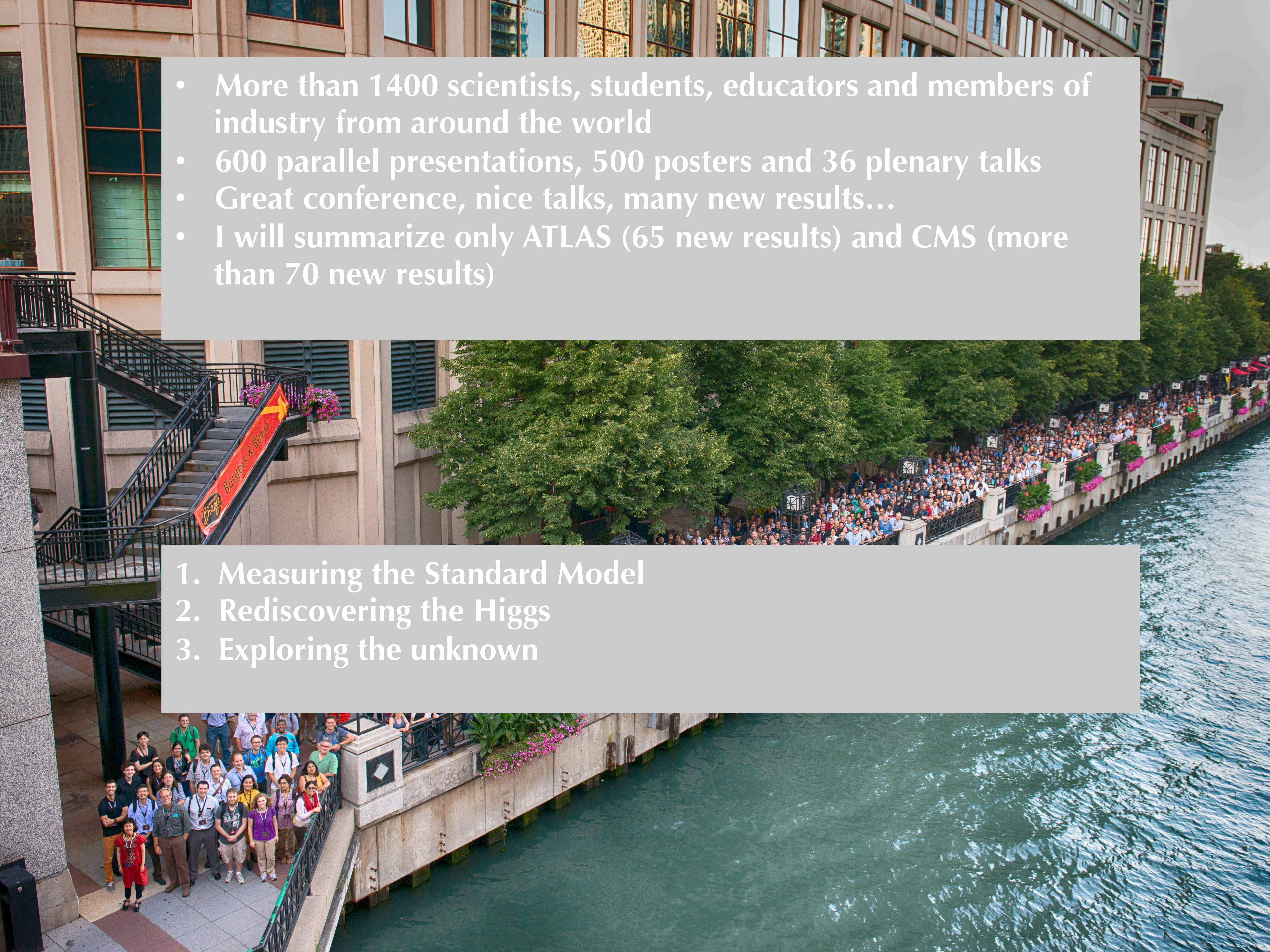
CHICAGO

Samira Hassani

17 Octobre 2016

- More than 1400 scientists, students, educators and members of industry from around the world
- 600 parallel presentations, 500 posters and 36 plenary talks
- Great conference, nice talks, many new results…
- I will summarize only ATLAS (65 new results) and CMS (more than 70 new results)





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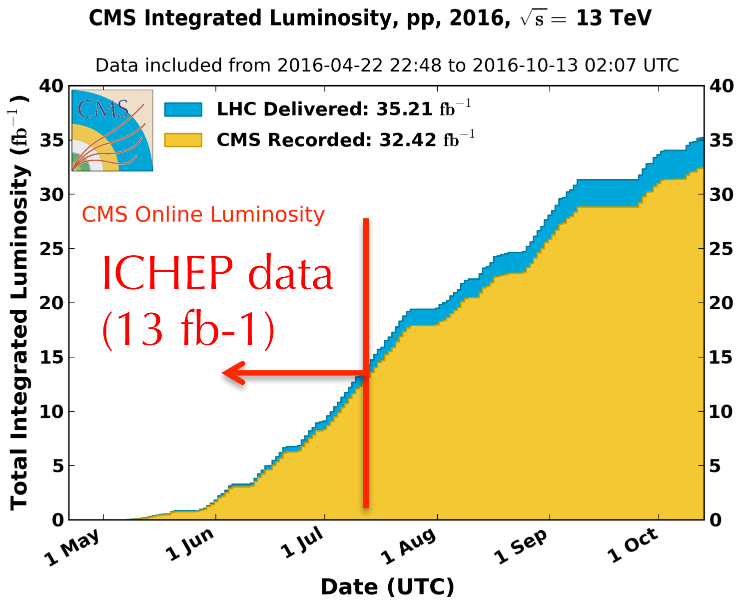
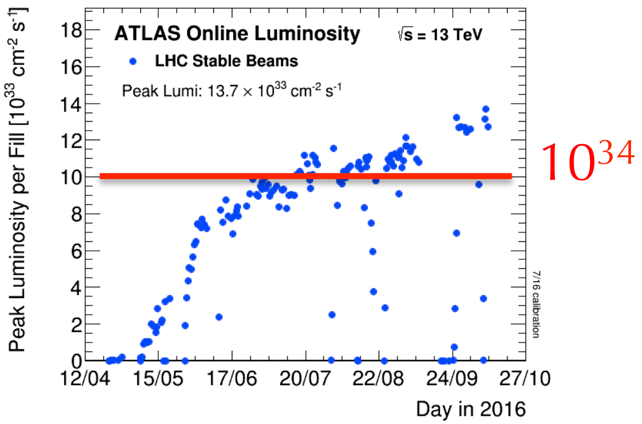
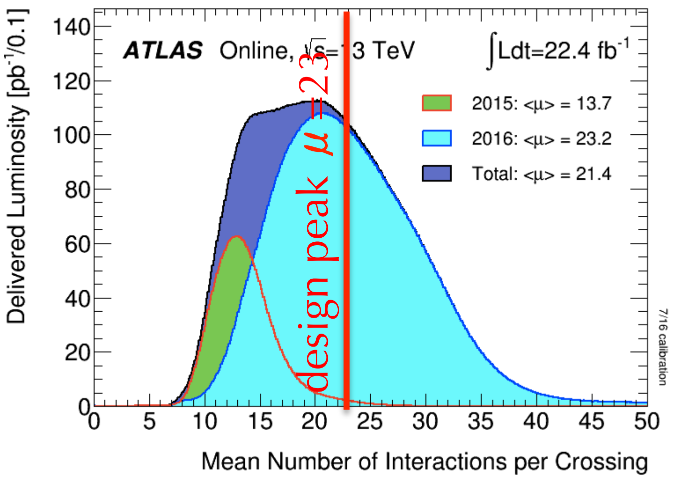
1. Measuring the Standard Model
2. Rediscovering the Higgs
3. Exploring the unknown

Data Samples



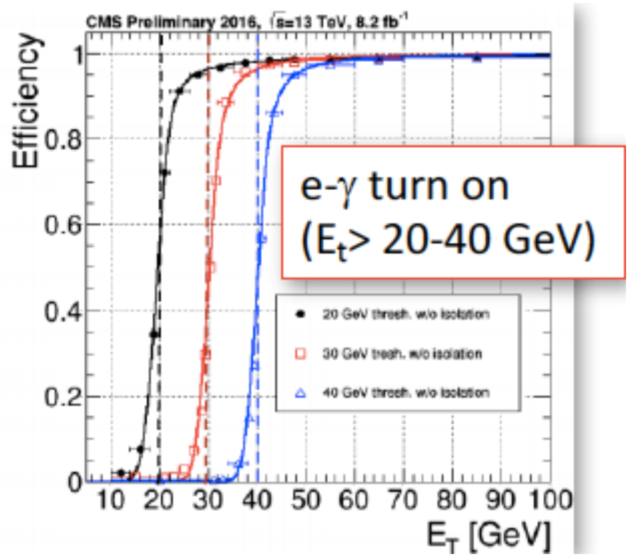


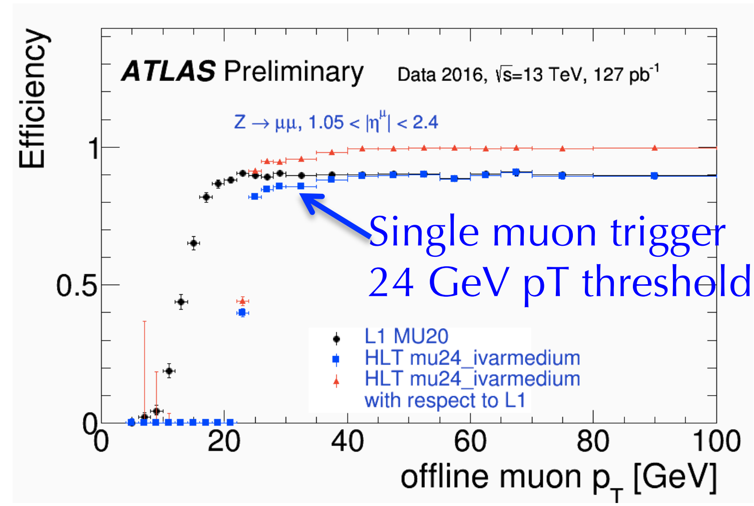
- Spectacular performance of the LHC during 2016
- Data quality in 2016 : >90% of data collected usable for analysis
- Large pile-up : Average number of vertices > 20
  →Many Challenges
  - Detectors (occupancies, ...)
  - Trigger (thresholds, rates)
  - Readout (bandwidth)
  - Offline (Tier-0, Grid)

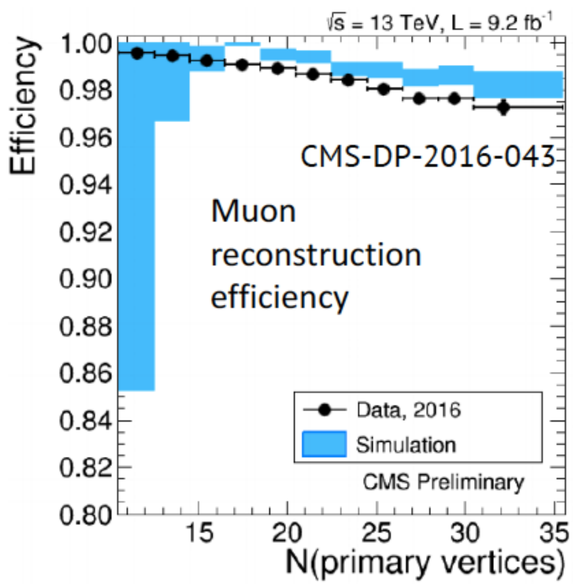


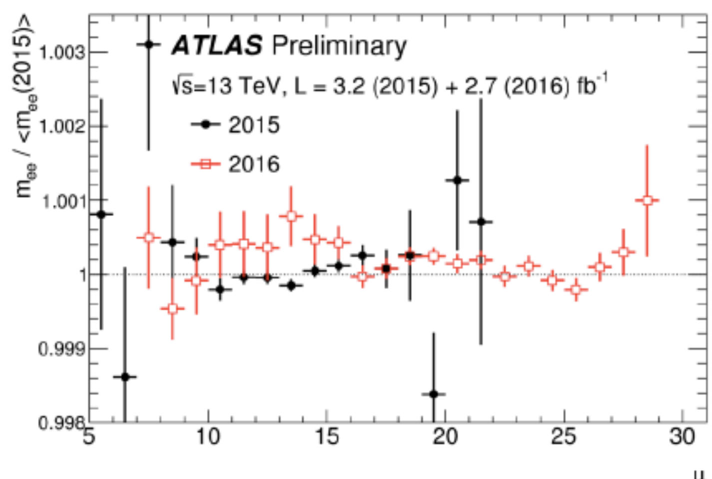
Pileup often above LHC design in 2016

Trigger and Performance



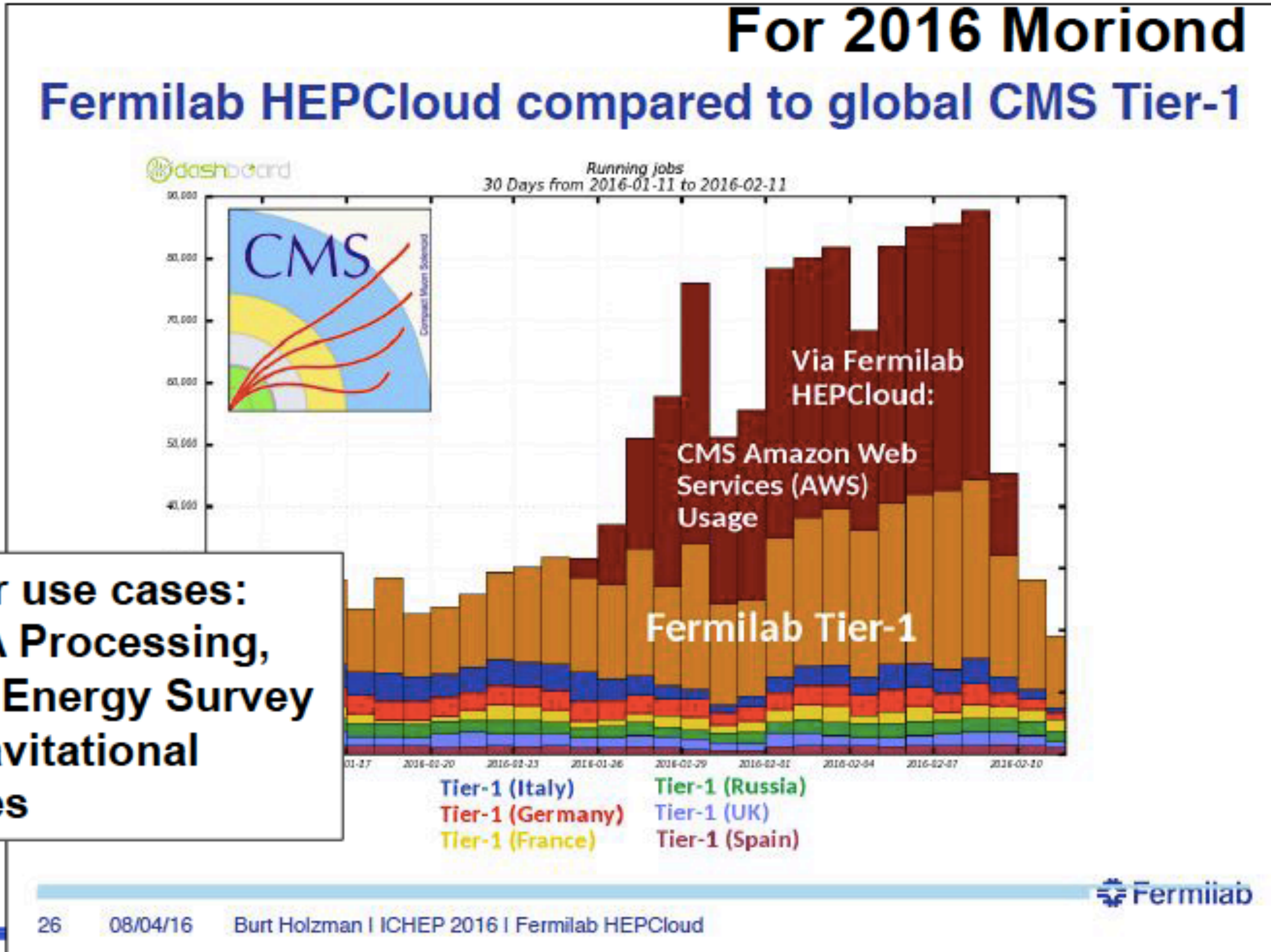






electron energy scale to ~ 0.1-0.2%

Fermilab HEPCloud

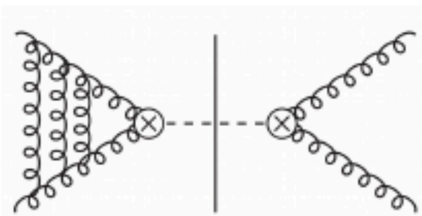


Other use cases: NoVA Processing, Dark Energy Survey – Gravitational Waves

Standard Model Measurements

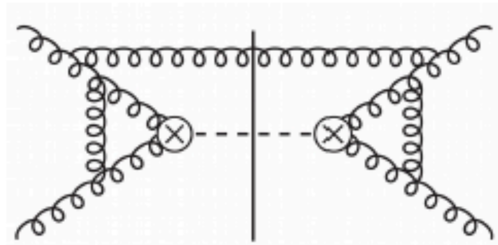
- Many measurements from Run-1 and Run-2
- With very prompt and excellent Luminosity measurement of 2.7% (CMS) and 2.9%(ATLAS)
- Important steps forward in physics modelling in the last years:
  - NLO event generators – now standard
  - (N)NNLO calculations increasingly available
- These help face the challenge of the precision of the LHC data

Status at N3LO



Triple Virtual

Known from QCD Form Factor
[Baikov, Chetyrkin, Smirnov, Smirnov, Steinhauser; Gehrmann, Glover, Huber, Ikizlerli, Studerus]

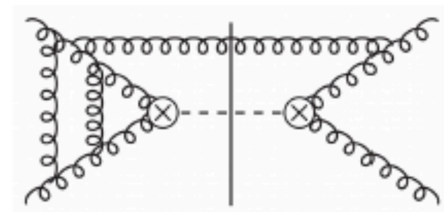


Real-Virtual Squared

Known [Anastasiou, Duhr, Dulat, FH, Mistlberger; Kilgore]

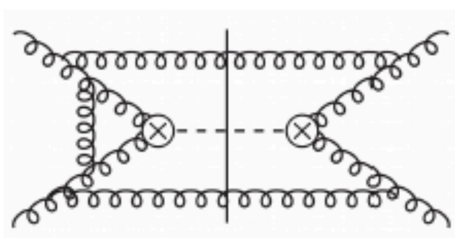
+UV and IR counter terms

Known[Pak, Rogal, Steinhauser; Anastasiou, Buehler, Duhr, FH; Höschele, Hoff, Pak, Steinhauser, Ueda; Buehler, Lazopoulos]

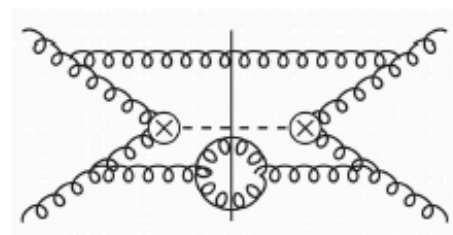


Double Virtual- Real

Known [Dulat, Mistlberger; Duhr, Gehrmann]



Double Real - Virtual



Triple Real

qq` channel known [Chihaya Anzai, Alexander Hasselhuhn, Maik Hoschele, Jens Hoff, William Kilgore, Matthias Steinhauser, Takahiro Ueda]

2 terms in soft expansion [Anastasiou, Duhr, Dulat, FH, Mistlberger,Furlan; Li, Mantueffel, Schabinger, Zhu]
37 terms [Anastasiou, Duhr, Dulat, FH, Mistlberger]
Known [to be published]

2 terms in soft expansion [Anastasiou, Duhr, Dulat, Mistlberger; Zhu]
37 terms [Anastasiou, Duhr, Dulat, FH, Mistlberger]

Why was it only possible last year?

- Have used all the tricks in the box and invented new ones:
  - Reverse Unitarity
  - Differential equations
  - Mellin Barnes Representations
  - Hopf Algebra of Generalized Polylogs
  - Number Theory
  - Black Magic of Soft Expansion by Region
  - Optimised Algorithm for IBP reduction and hugely powerful computing resources

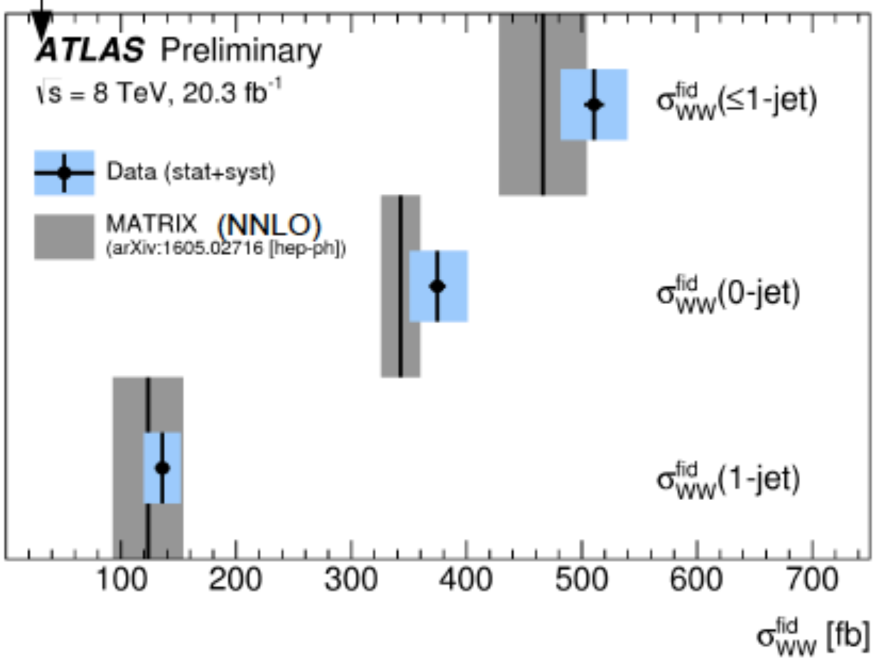
Integral Statistics

	NNLO	N3LO
#diagrams	~1.000	~100.000
#integrals	~50.000	517.531.178
#masters	27	1.028
#soft masters	5	78

Run1: precision, differential, rare processes

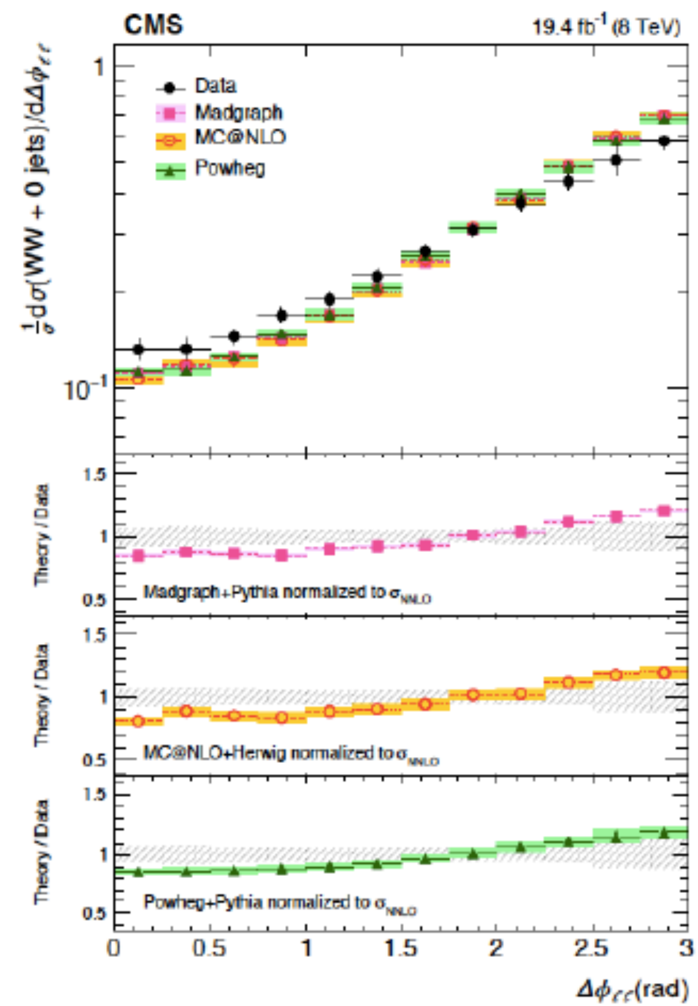
CDF, 9.4fb^{-1}, WW/WZ → lv+bb/ lv+cc
σ(WW+WZ) = 13.7±2.4±2.9 pb
arXiv:1606.06823

ATLAS, 20.3fb^{-1}, 8TeV, WW, eμ, 1 jet
STDM-2015-24



ATLAS , 20.3fb^{-1}, 8TeV, WW, arXiv:1603.01702

CMS , 19.7fb^{-1}, 8TeV, WW, EPJC 76 (2016) 401



Precise diboson inclusive & differential cross sections
(WW: 7%, WZ: 6%, Zγ: 6%, ZZ: 11%)
→ sensitive to higher-order pQCD effects

Precision slightly improved by loosening jet vetos

$\sin^2\Phi_W$ @ hadron colliders

$$A_{q/\mu} = \frac{2g_V^{q/\mu}/g_A^{q/\mu}}{1+(g_V^{q/\mu}/g_A^{q/\mu})^2}$$

.....Extracted from A_{FB} measurement

$$g_V^{q/\mu}/g_A^{q/\mu} = 1 - 4|Q_{q/\mu}|\sin^2\theta_{\text{eff}}^{q/\mu}$$

D0, 9.7fb^{-1}, AFB, $\sin^2\Theta_{W}$eff
PRL 115 (2015)041801

CDF, 9.4fb^{-1}, AFB, $\sin^2\Theta_{W}$eff
PRD 93 (2016) 112016

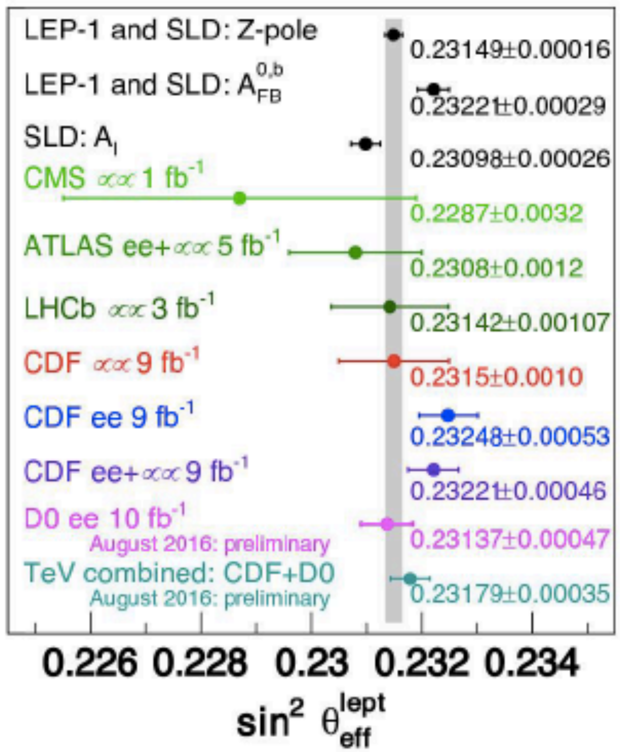
D0+CDF combination $\sin^2\Theta_{W}$eff
Fermilab-Conf-16-295-E

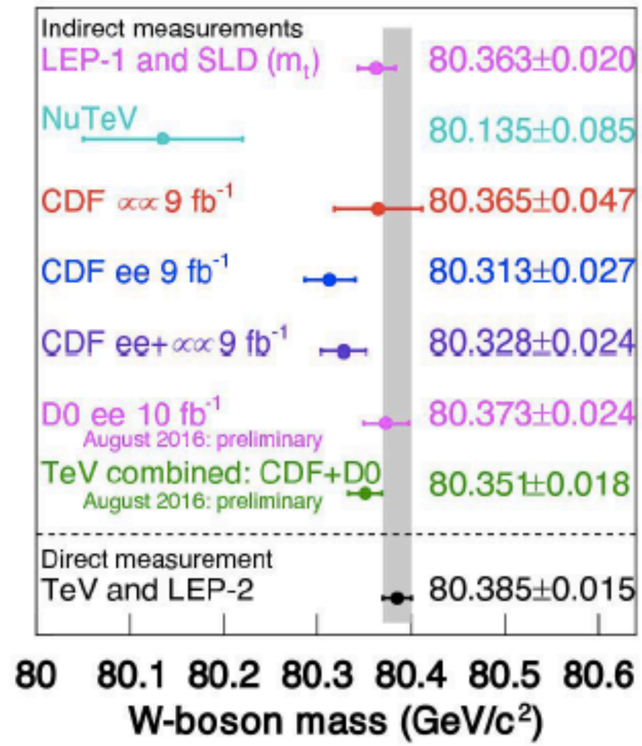
LHCb, 1+2fb^{-1}, 7 & 8TeV,
$Z \to \mu\mu$, JHEP 1511(2015) 190

ATLAS, 4.8fb^{-1}, 7TeV
JHEP09(2015)049

CMS, 1.1fb^{-1}, 7TeV
PRD 84 (2011) 112002

FERMILAB-CONF-16-295-E.





Tevatron: 1.5 permille precission, LHC at 5 permille precission
→ approaching e^+e^- precision, dominant unc.: LHC: PDF, Tevatron: statistical, PDF
Indirect constraint on W mass → consistency of SM

Top pair cross section overview

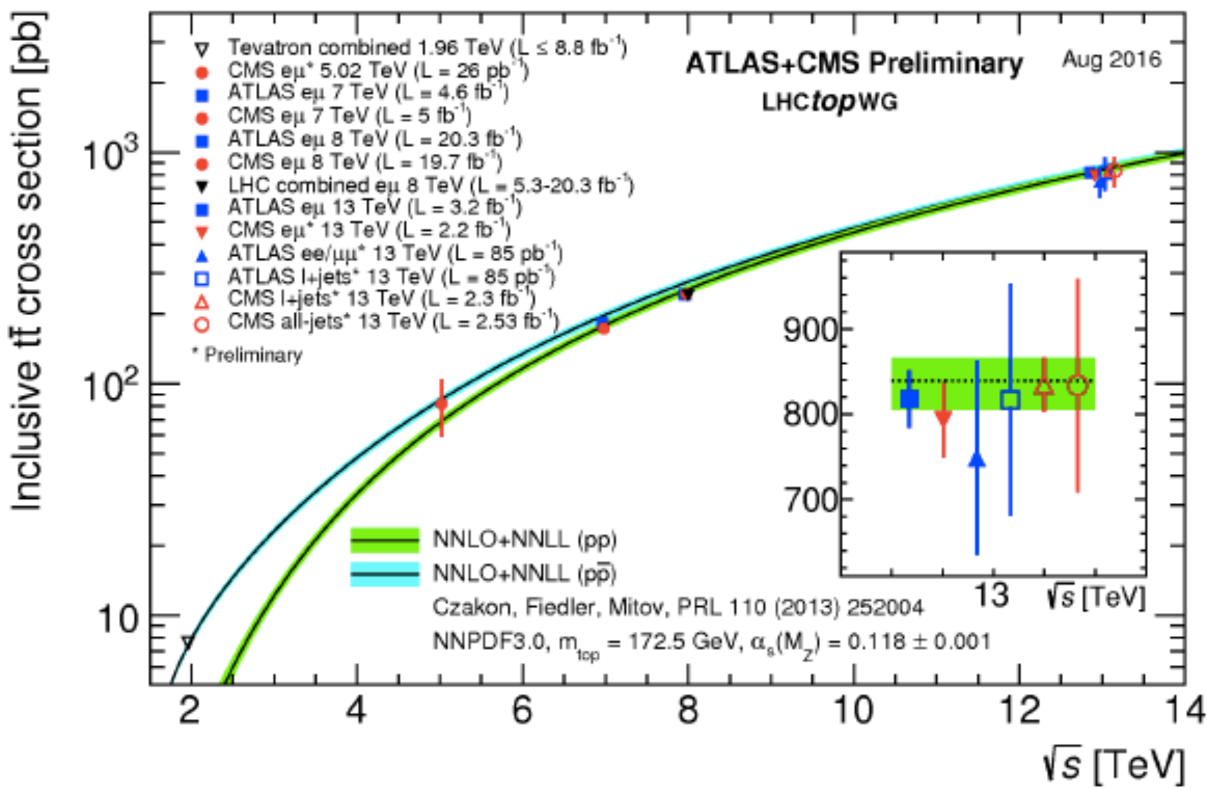
..most recent:

ATLAS, 3.2fb^{-1}, 13TeV,
Dilept., arXiv:1606.02699

CMS, 2.3fb^{-1},13TeV, l+jets
CMS-PAS-TOP-16-006

CMS, 2.53fb^{-1},13TeV, all jets
CMS-PAS-TOP-16-013

CMS, 26pb^{-1},5TeV, dilept.
CMS-PAS-TOP-16-015



CMS ttbar cross section measured at 4 different energies

LHC and Tevatron results consistent and in agreement with NNLO+NNLL over a large range of centre-of-mass energies

Top properties, recent results

Very active field in the past years:

- *Top polarisation*
- *charge asymmetry*
- *W helicity*
- *Spin correlations*
- *Width*
- *coupling to gauge bosons ...*

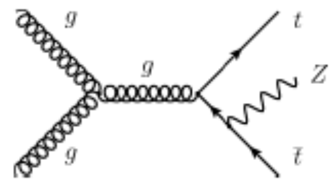
CMS, 12.9 fb^{-1}, 13TeV, ttZ, ttW
CMA-TOP-16-017

ATLAS , 3.2fb^{-1}, 13TeV, tttt search
$\leq 21 \times \sigma_{SM}$, ATLAS-CONF-2016-020

CMS , 2.6fb^{-1}, 13TeV, tttt search
$\leq 10 \times \sigma_{SM}$, CMS PAS TOP-16-016

D0, 9.7fb^{-1}, Top polarisation
l+jets, arXiv:1607.07627

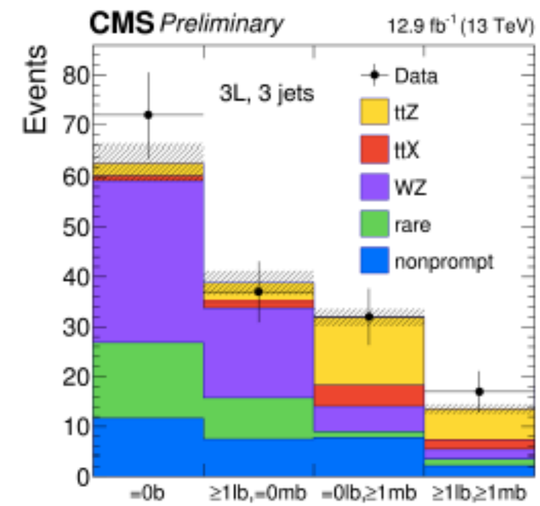
CMS ttZ and ttW



tt-Z coupling
Important backgrounds

$\sigma(ttZ) = 0.70 \ {}^{+0.16}_{-0.15} \ {}^{+0.14}_{-0.12}$ pb
$\sigma(ttW) = 0.98 \ {}^{+0.23}_{-0.22} \ {}^{+0.22}_{-0.18}$ pb

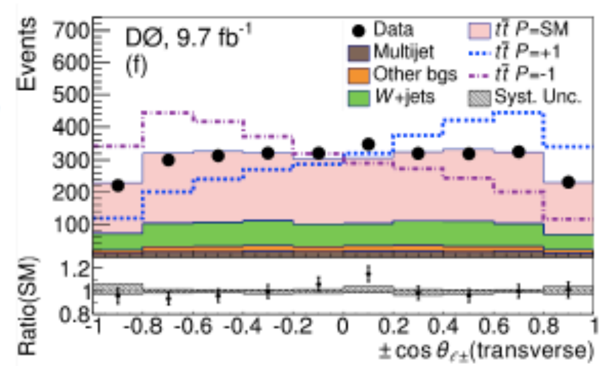
(→ ttW: 3.9σ, ttZ: 4.6σ)



D0 Top polarisation

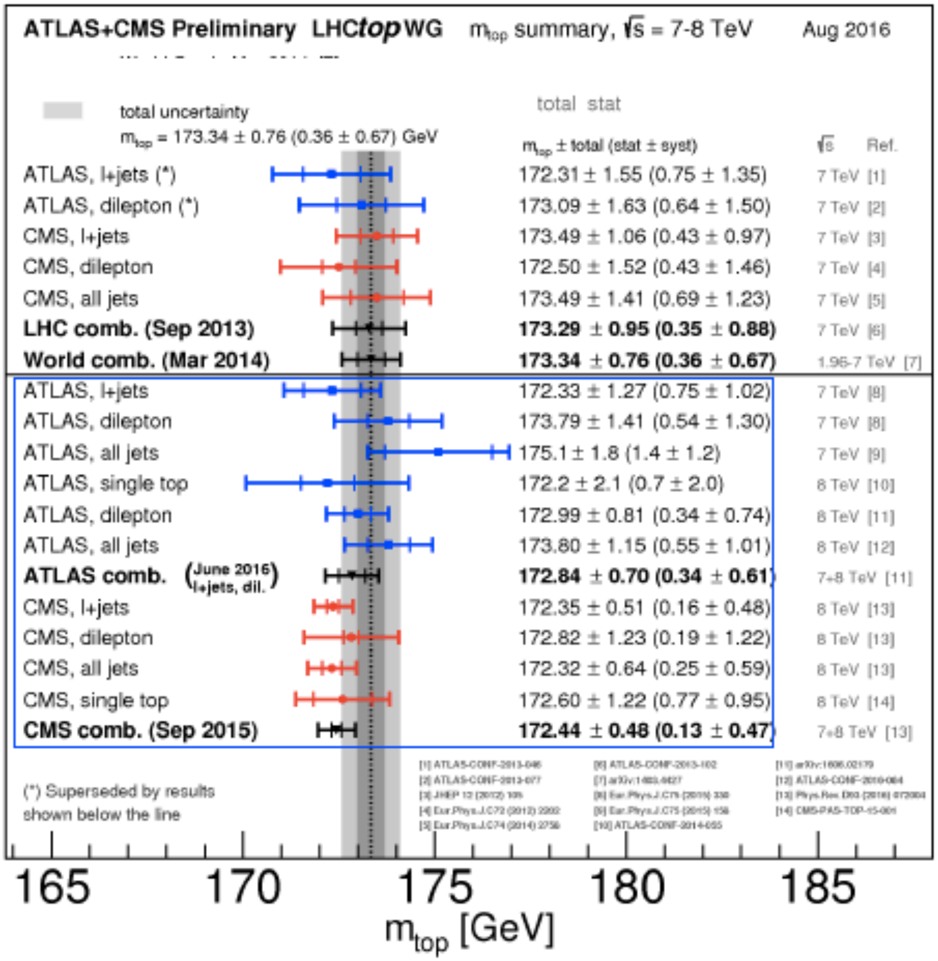
through angular distributions of the decay leptons $\cos\theta_{\hat{n}}$
→ consistent with SM

First measurement of transverse polarisation:
0.040±0.034 (SM: 0.011)

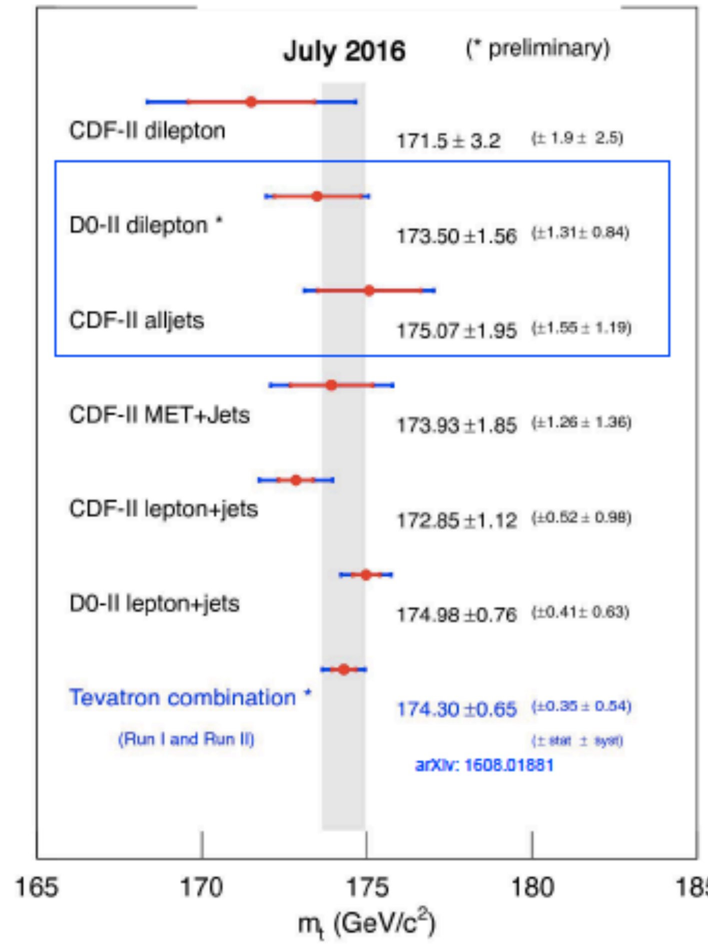


Direct top mass measurements

ATLAS and CMS results



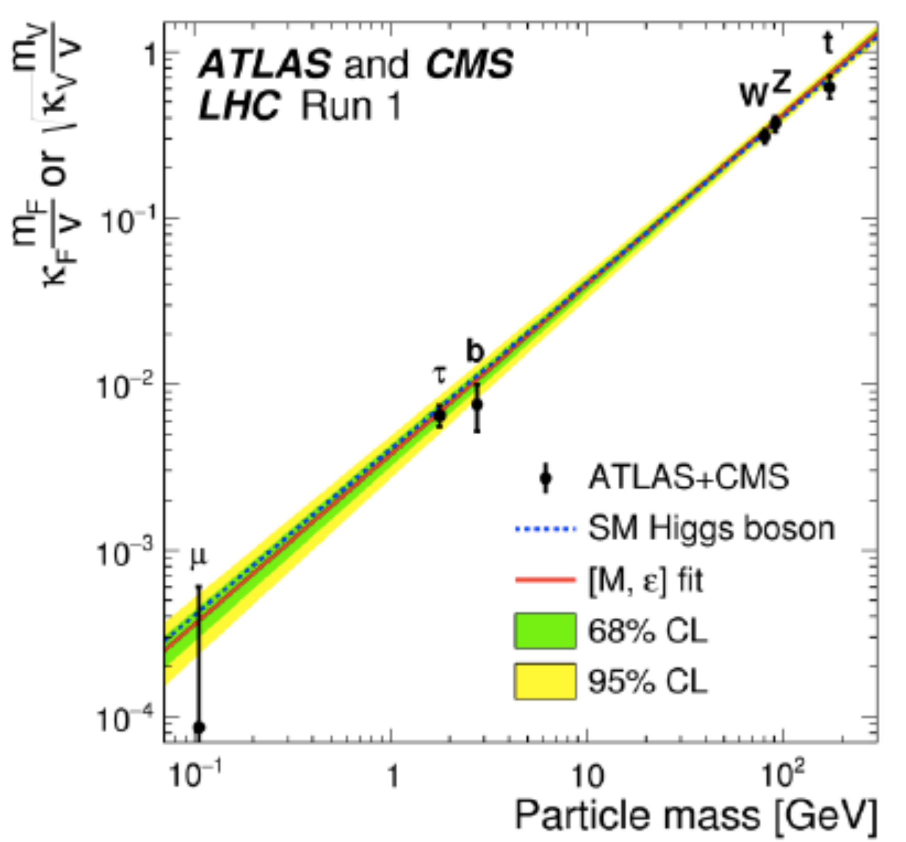
CDF and D0 results



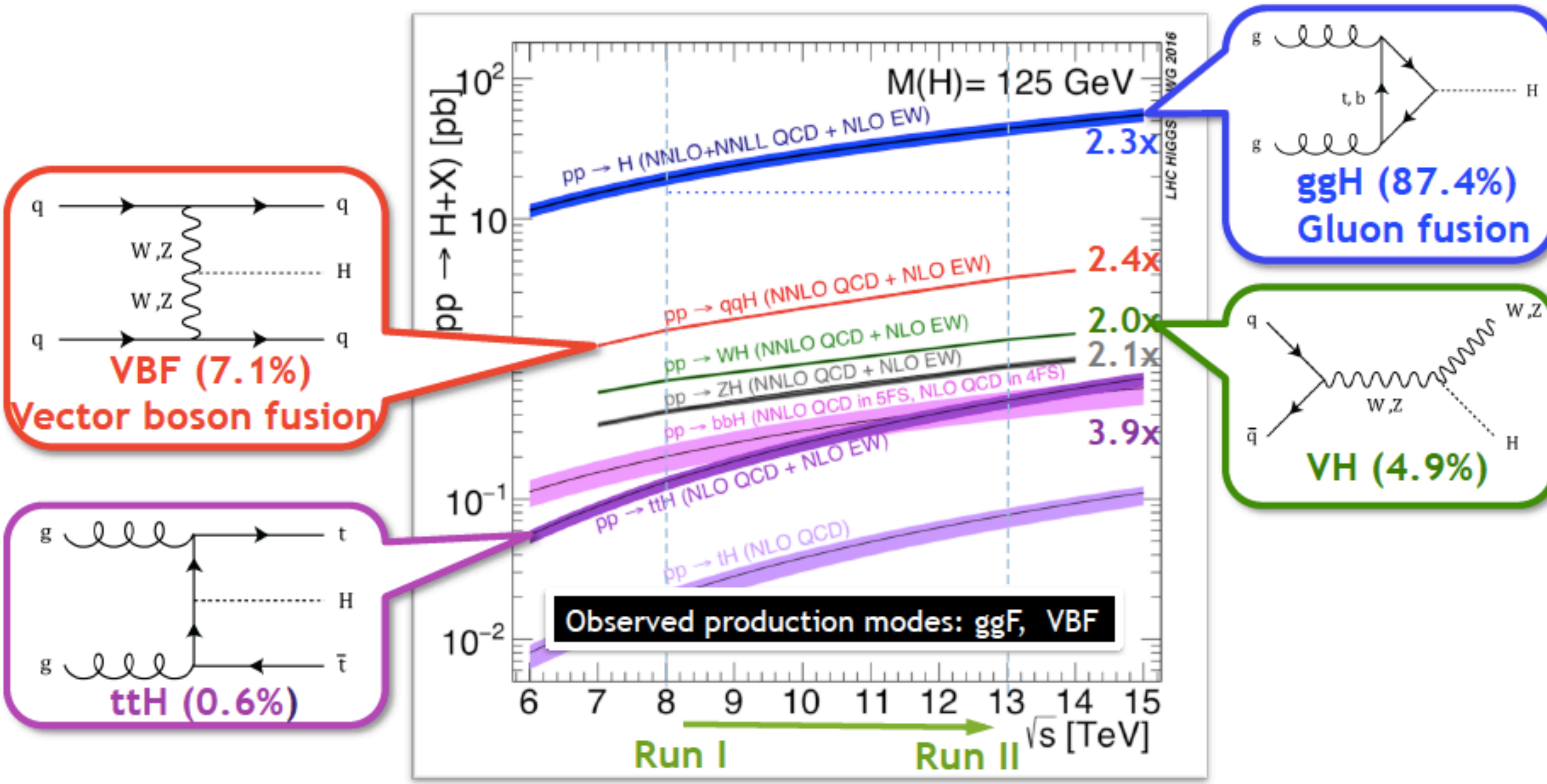
LHC and Tevatron results with nearly comparable precision of 3-4 permille (0.5 GeV)
LHC top mass systematically limited: MC modelling, (b)JES
Template/Matrix element methods → Monte Carlo top mass parameter

Rediscovering the Higgs

- Legacy run-1 results
- Run-2: 13 TeV , many results with > 13 fb-1
  - SM h(125) clearly rediscovered
  - several searches already surpassed run-1 sensitivity



Higgs Boson Production at 125 GeV

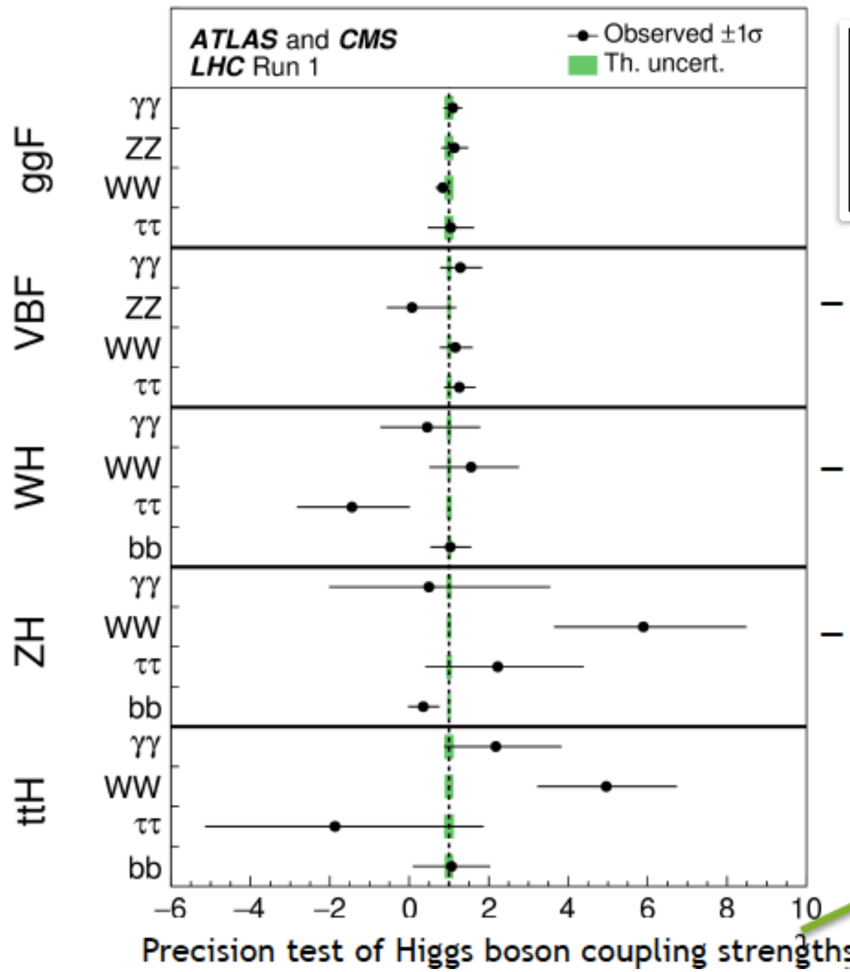


7/8 TeV (2011/2012) 13 TeV (>2015)

Higgs Profile in Run 1

Gluon fusion measurements, starting to approach SM theory uncertainties: 15%

Mild excess in ttH and ZH Production modes



CMS and ATLAS combined 7 and 8 TeV results Run 1 legacy papers:

Mass: Phys. Rev. Lett. 114, 191803
Rates and couplings: arXiv:1606.02266

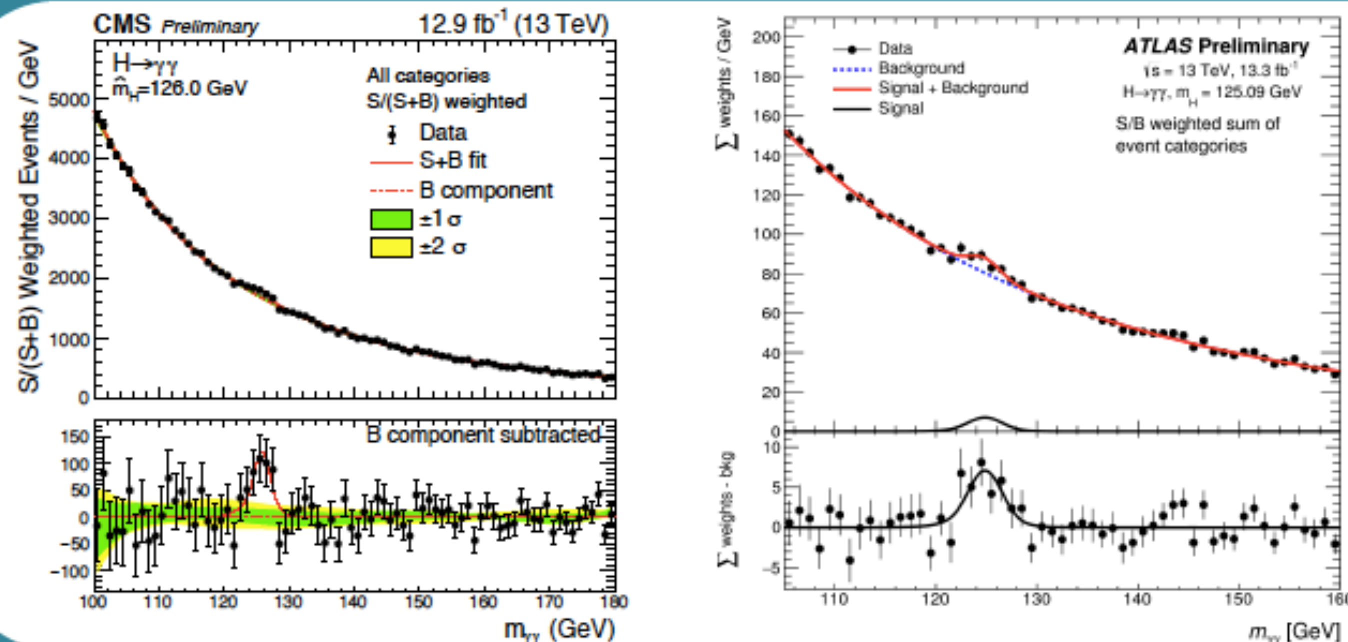
- Mass has been measured to 0.2% precision m_H=125.09±0.24 GeV
- Angular distributions consistent with spin 0 and even parity
- All couplings are consistent with SM within 2.5σ

Coupling strengths

$$\mu = \frac{\sigma}{\sigma_{SM}}$$

Higgs→γγ

- **Signature:** 2 isolated photons
  - All production modes targeted ggF, VBF, VH (only ATLAS), ttH events
- Signal extracted through fit of $m_{\gamma\gamma}$ in different event categories
  - Main backgrounds: γγ and γ-jet production



- **Dominant systematic uncertainty:** photon energy scale and resolution and background choice bias (smaller than statistical uncertainties)

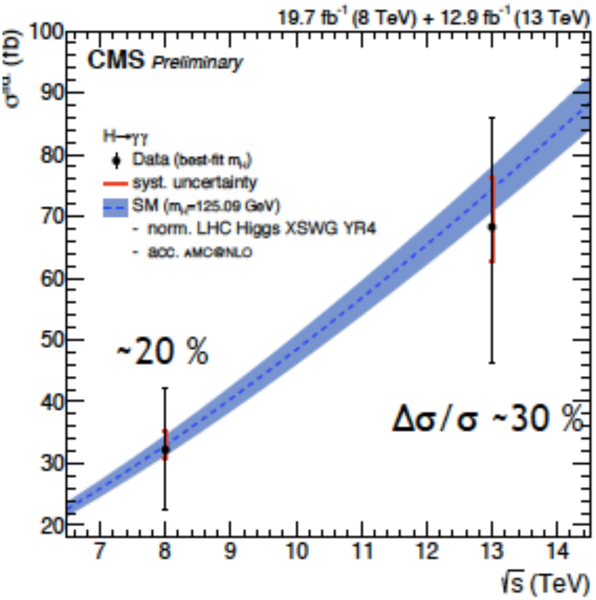
Higgs→γγ

- **Measurements of fiducial cross section**

13 TeV	Fiducial σ (fb)	SM prediction (fb)
ATLAS (13.3 fb^{-1})	43.2±14.9(stat)±4.9(syst)	$62.8^{+3.4}_{-4.4}$ (N³LO+XH)
CMS (12.9 fb^{-1})	69^{+16}_{-22}(stat)$^{+8}_{-6}$(syst)	73.8±3.8

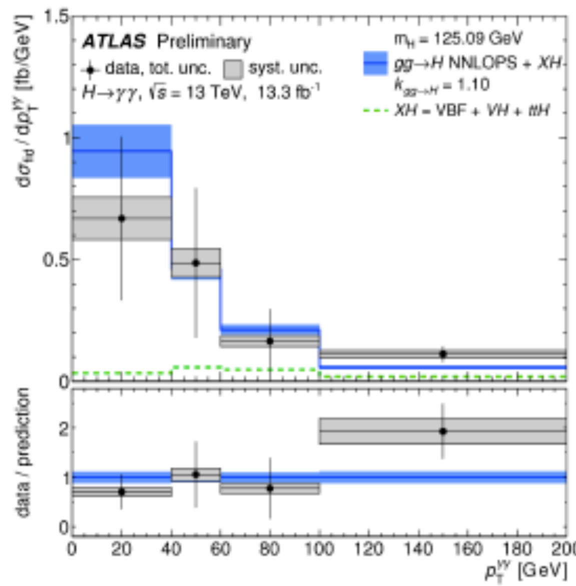
Fiducial σ:
Event yields corrected for detector inefficiency and resolution for minimal theoretical modeling

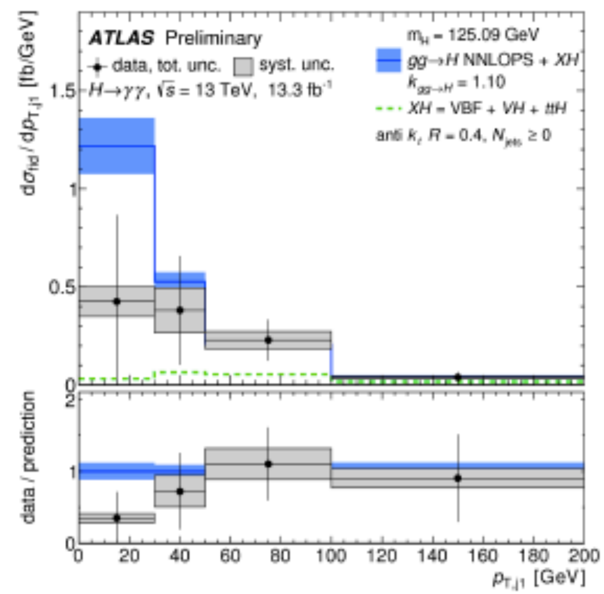
$$\sigma_i = \frac{\nu_i^{sig}}{c_i \int L\,dt}$$



Important to improve MC generators and calculations
→ reduce systematic uncertainties

Differential cross section measurements



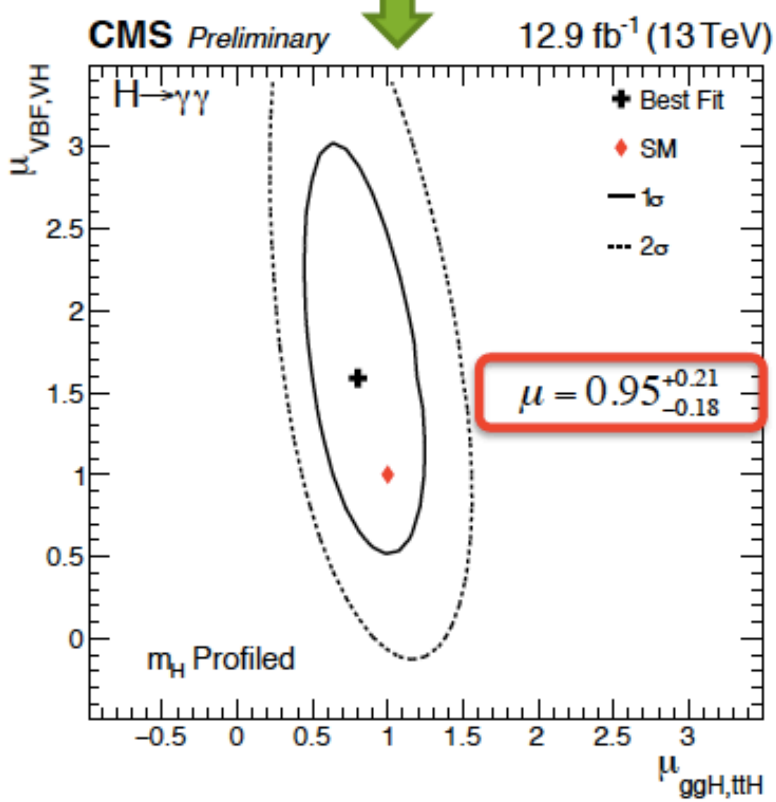


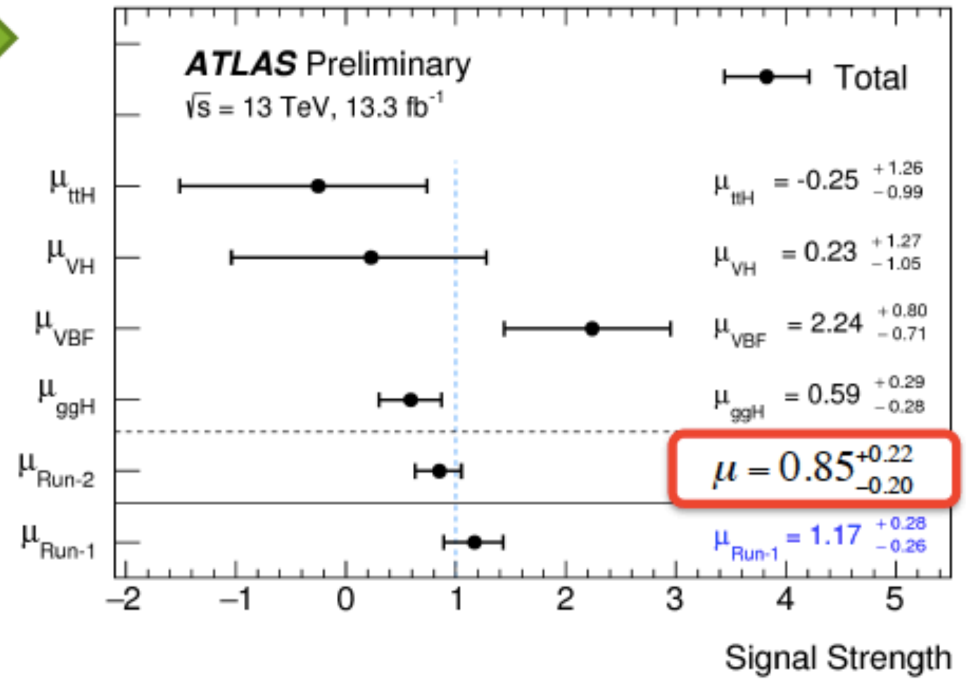
Higgs→γγ

Production cross section and signal strength

- Events are split into orthogonal categories that exploit topological differences between production mechanisms

Extract strength of production processes in a 2-parameter fit





- Achieved similar precision to Run 1
- Measurements compatible with SM
- Results still dominated by statistical uncertainty

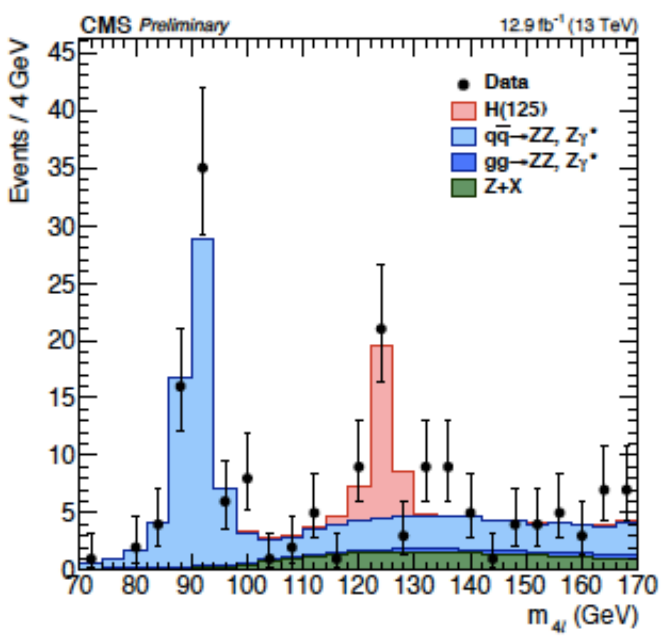
H→ZZ*→4leptons

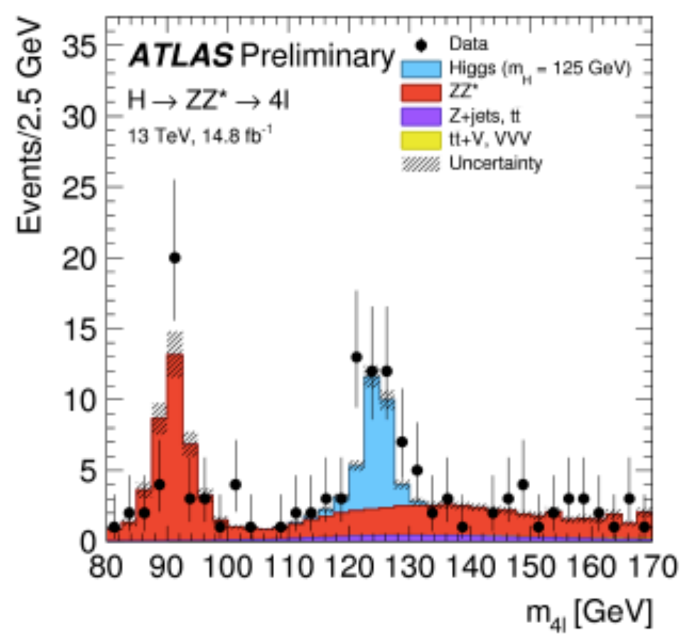
- *Narrow peak over a flat background*

- **Signature:** two pairs of same flavor, opposite sign, isolated leptons
  - All production modes targeted ggF, VBF, VH, ttH events

- Extraction of signal through fit of m_{4l}
  - Also uses kinematic discriminant (e.g. M_{Z1}, M_{Z2}, 5 angles from decay chain, matrix element) used to enhance the signal purity of different production modes

- **Dominant systematic uncertainty:** luminosity and lepton SF (smaller than statistical uncertainty)

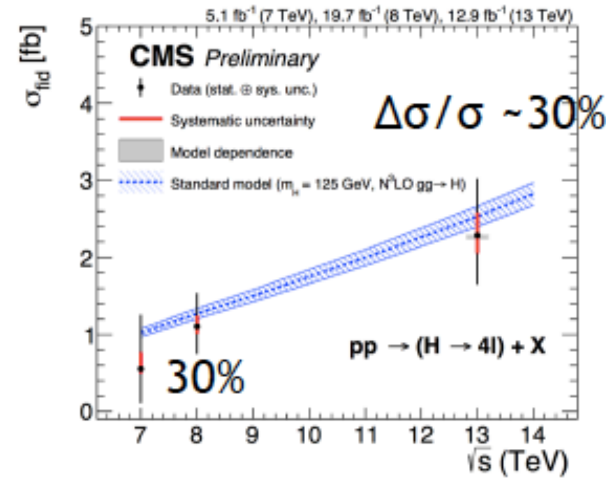




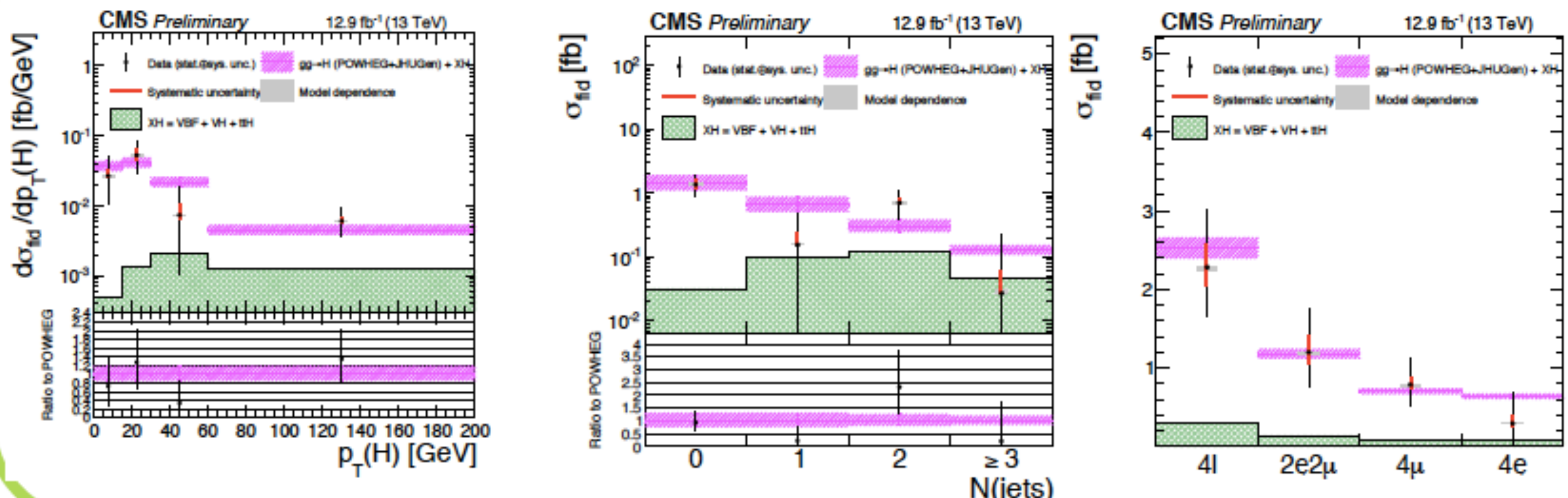
H→ZZ*→4leptons

Measurements of fiducial cross section

13 TeV	Fiducial σ (fb)	SM prediction (fb)
ATLAS (14.8 fb^{-1})	$4.54^{+1.02}_{-0.90}$	$3.07^{+0.21}_{-0.25}$
CMS (12.9 fb^{-1})	$2.29^{+0.74}_{-0.64}(\text{stat})^{+0.30}_{-0.23}(\text{syst})$	2.53 ± 0.13



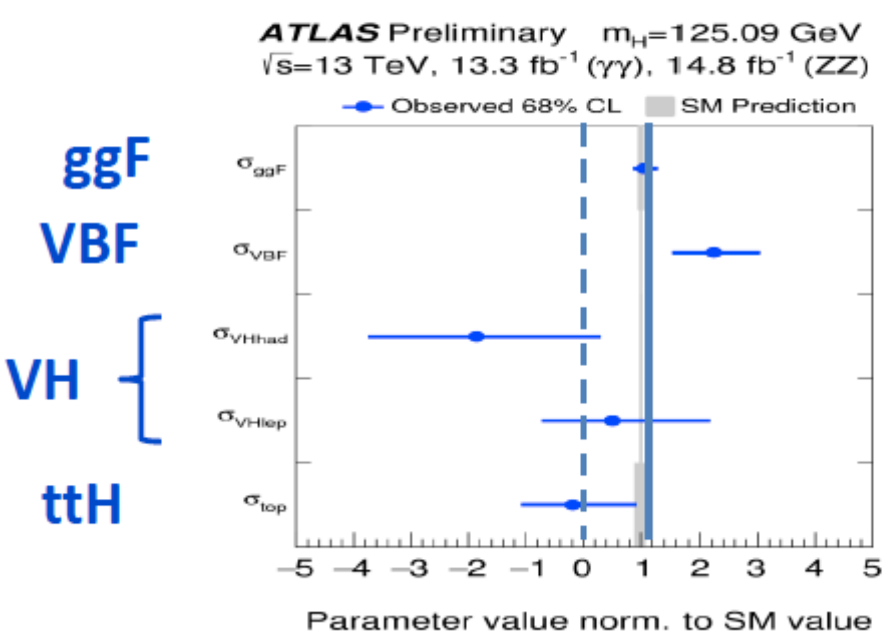
Differential cross section measurements

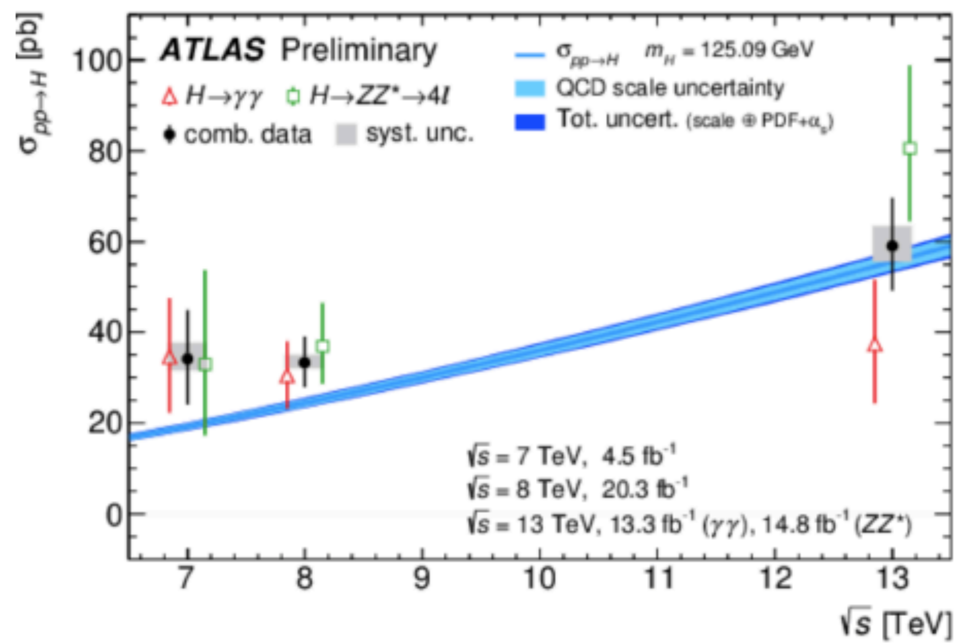


Combination H→γγ and H→ZZ*→4leptons

- Combine H→γγ and H→Z→4l inclusive samples, with no categorization
- Higgs production is observed with 10σ significance (8.6σ expected) with 13 TeV data in agreement with SM expectations

	Measurement at 13 TeV	SM prediction at 13 TeV
σ (pb)	$59.0^{+9.7}_{-9.2}$(stat)$^{+4.4}_{-3.5}$(syst)	$55.5^{+2.4}_{-3.4}$
μ	$1.13^{+0.18}_{-0.17}$	1



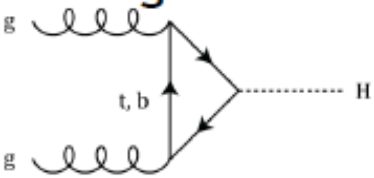


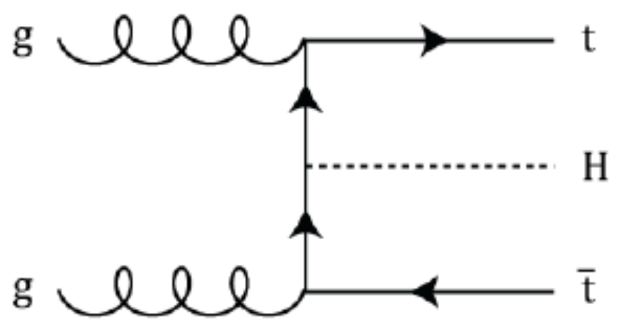
Clear re-discovery of the SM Higgs boson

Comparable precision to Run 1

Towards Discovery - ttH

- Probing the Yukawa coupling between **top and Higgs** at LHC:
  - via gluon fusion cross section, assumes no BSM particles running in the loop
  - **directly at tree level, via associated production:**





ttH(→bb): Uses H→bb with one or two W bosons decaying to e or μ (and ttH (hadronic) with both W bosons decaying hadronically)

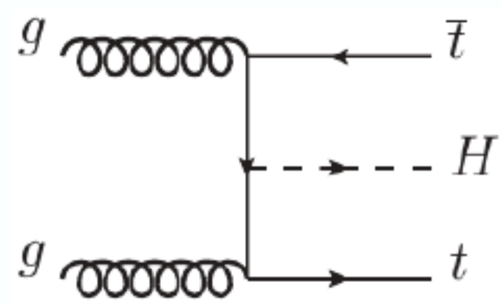
ttH(multileptons): targets H→ WW, ZZ, ττ (τ decaying leptonically and hadronically), and additional leptons from top quark decays

ttH(γγ): included in H→γγ analyses

Higgs decay mode	BR (%)
H→bb	58.1
H→WW	21.5
H→ττ	6.3
H→ZZ	2.6
H→γγ	0.23

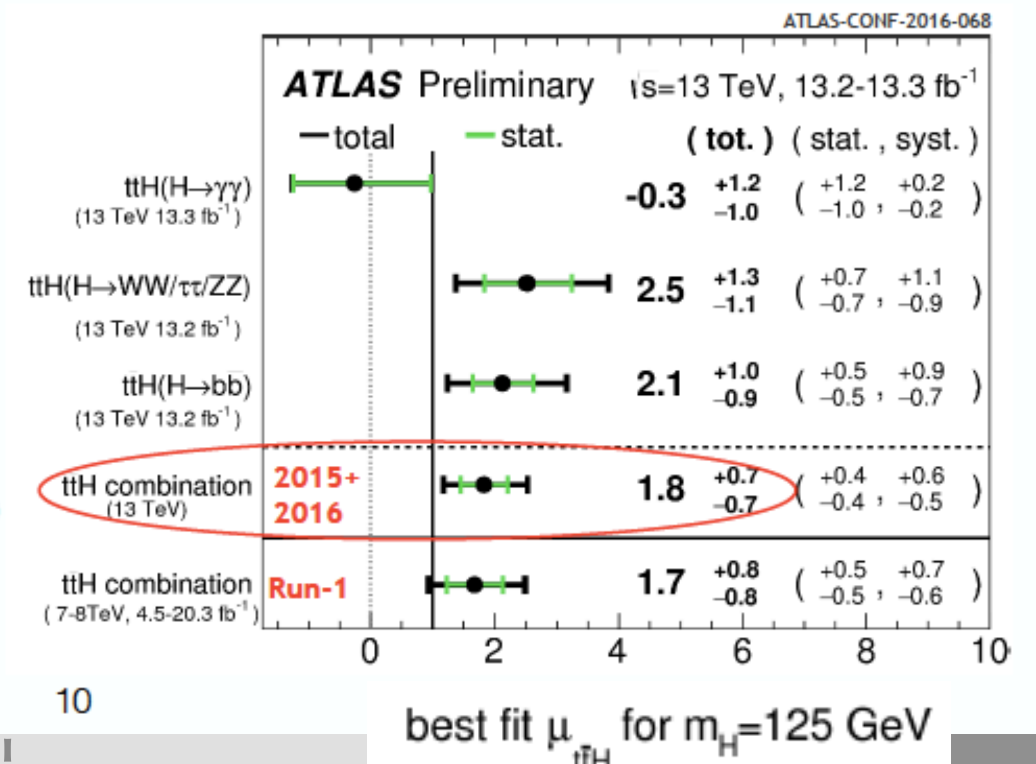
Towards Discovery - ttH

- Direct probe of top Yukawa coupling
- Cross section at 13 TeV is 4 times that at 8 TeV
- Results presented with 2015+2016 data for
  - ttH, $H \to bb$
  - ttH, multilepton final states
  - ttH, $H \to \gamma\gamma$



ATLAS-CONF-2016-068

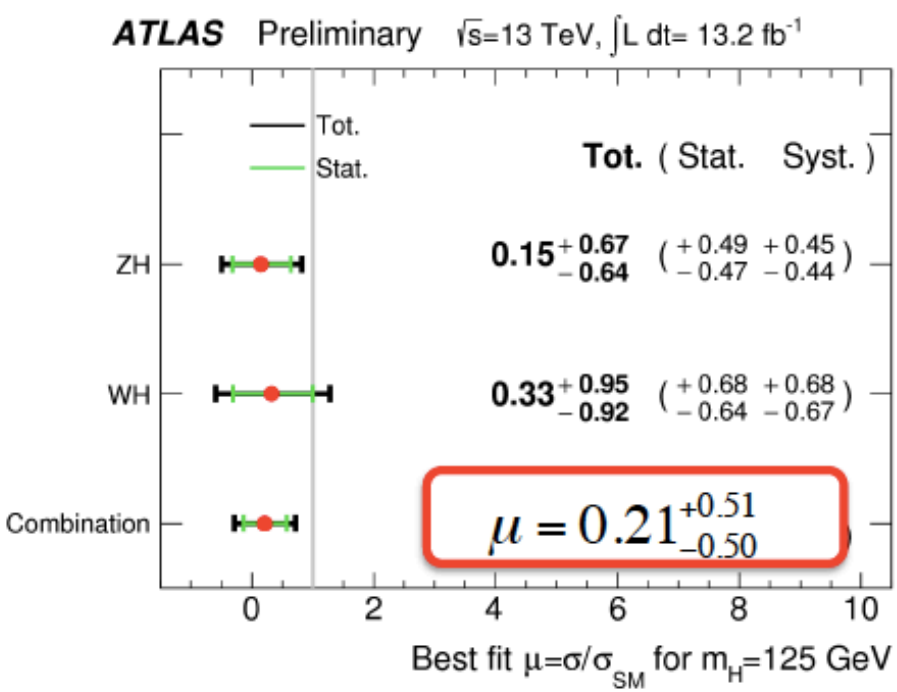
- **ttH Combination**
  - Combine all three 13 TeV analyses
  - Signal strength given relative to SM expectation
  - Observed significance 2.8σ (expect 1.8σ)
  - Upper limit on μ: $\mu_{ttH} < 3.0$ at 95% CL (expected $\mu_{ttH} < 2.1$ for SM case)



VH→bb

- **Analysis strategy:** utilize leptonic decays of Z/W events
  - Multivariate techniques necessary to achieve good S/B
  - Dominant backgrounds, depend on channel: Z+b, tt
  - Most discrimination from m_{bb} and $\Delta R(b_1,b_2)$

- Systematic and statistical uncertainties of the same size



	Significance (expected)
ATLAS (13 TeV)	0.4σ (1.94σ)
ATLAS+CMS (8 TeV)	2.6σ (3.7σ)
Tevatron	2.8σ

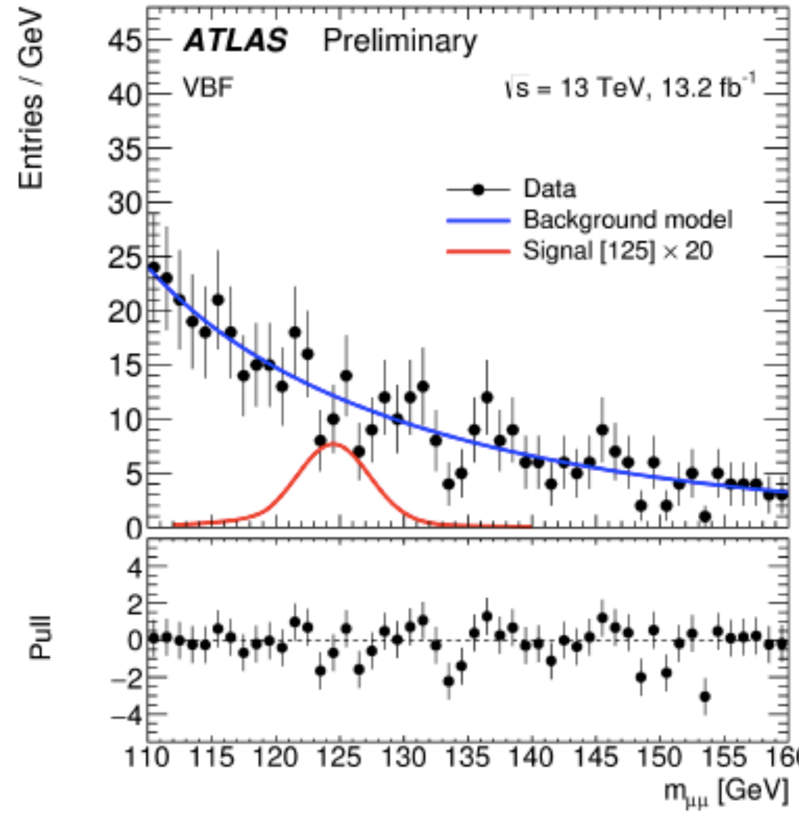
Fit tested on SM

	W(Z)Z(→bb)
Observed μ	0.91±0.17(stat) $^{+0.32}_{-0.27}$(syst)
Significance	3.0σ (expected 3.2σ)

H→μμ rare decays

- A very **rare decay** in the SM
  - Probe Yukawa-coupling to 2nd-generation fermions and mass dependence
  - Test of the Higgs coupling to leptons
- **Signature:** Very clean signature from dimuon final state but $Z/\gamma^* \to \mu\mu$ overwhelming irreducible background
- **Analysis strategy:**

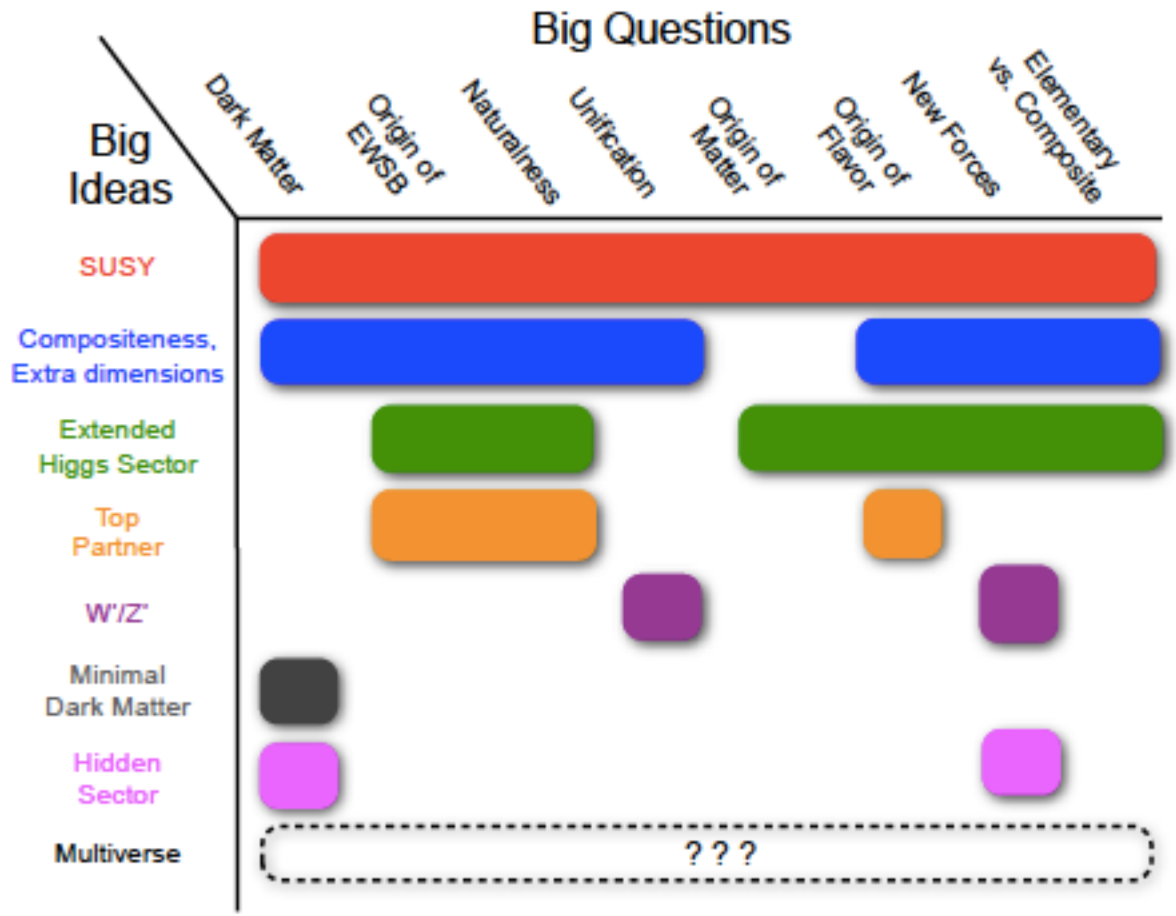
  Search for peak in $m_{\mu\mu}$ spectrum over smoothly falling background
  - Categorize events according to VBF and ggF signature enriched



ATLAS	Upper limit x SM (expected)
Run 1	7.1 (7.2)
Run 2	4.4 (5.5)
Combined Run 1 and Run 2	3.5 (4.5)

Exploring the unknown

arXiv:1311.0299v1

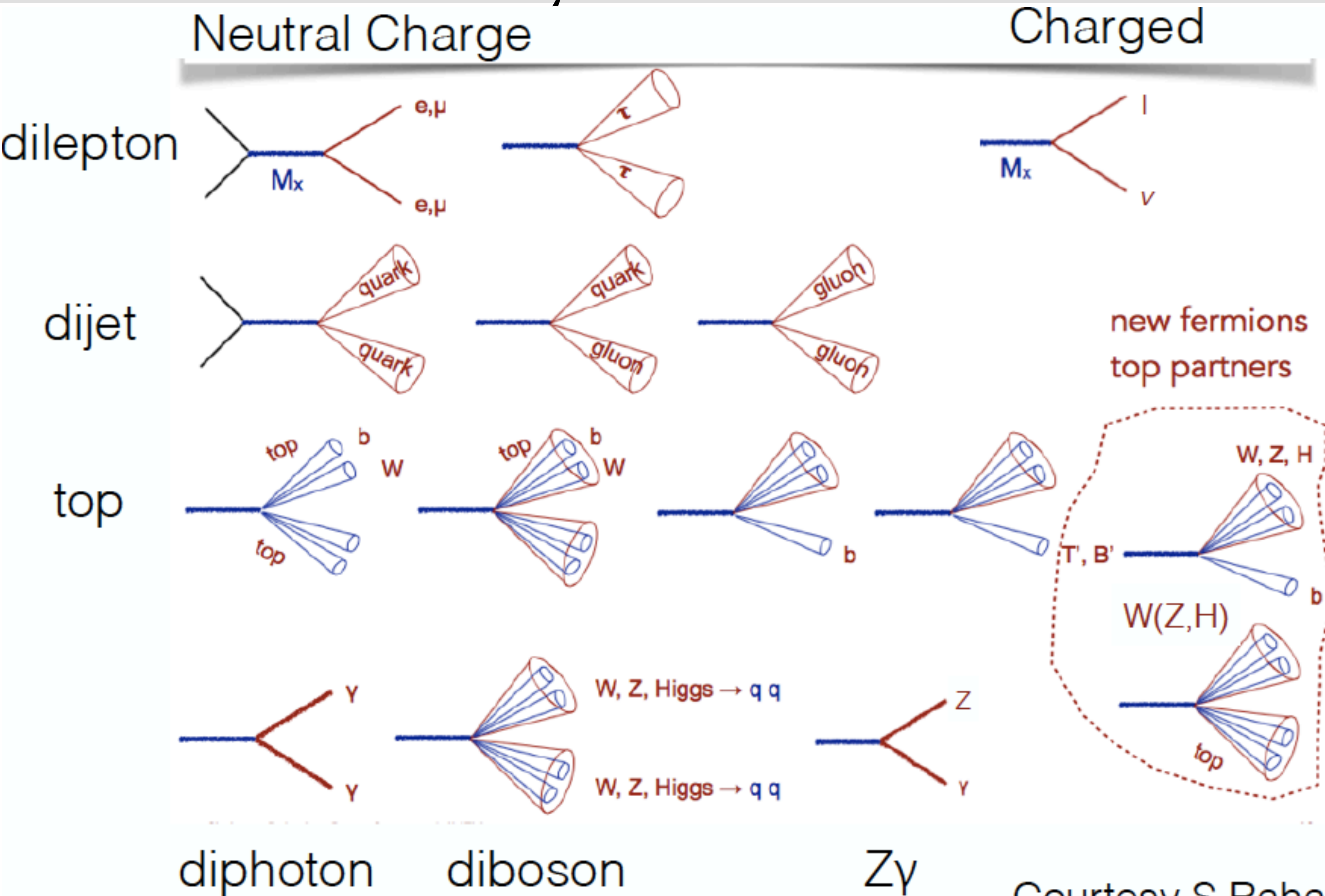


The outstanding goal for the ICHEP conference was to be ready and not miss any potential discovery with this dataset.

Exploring the unknown

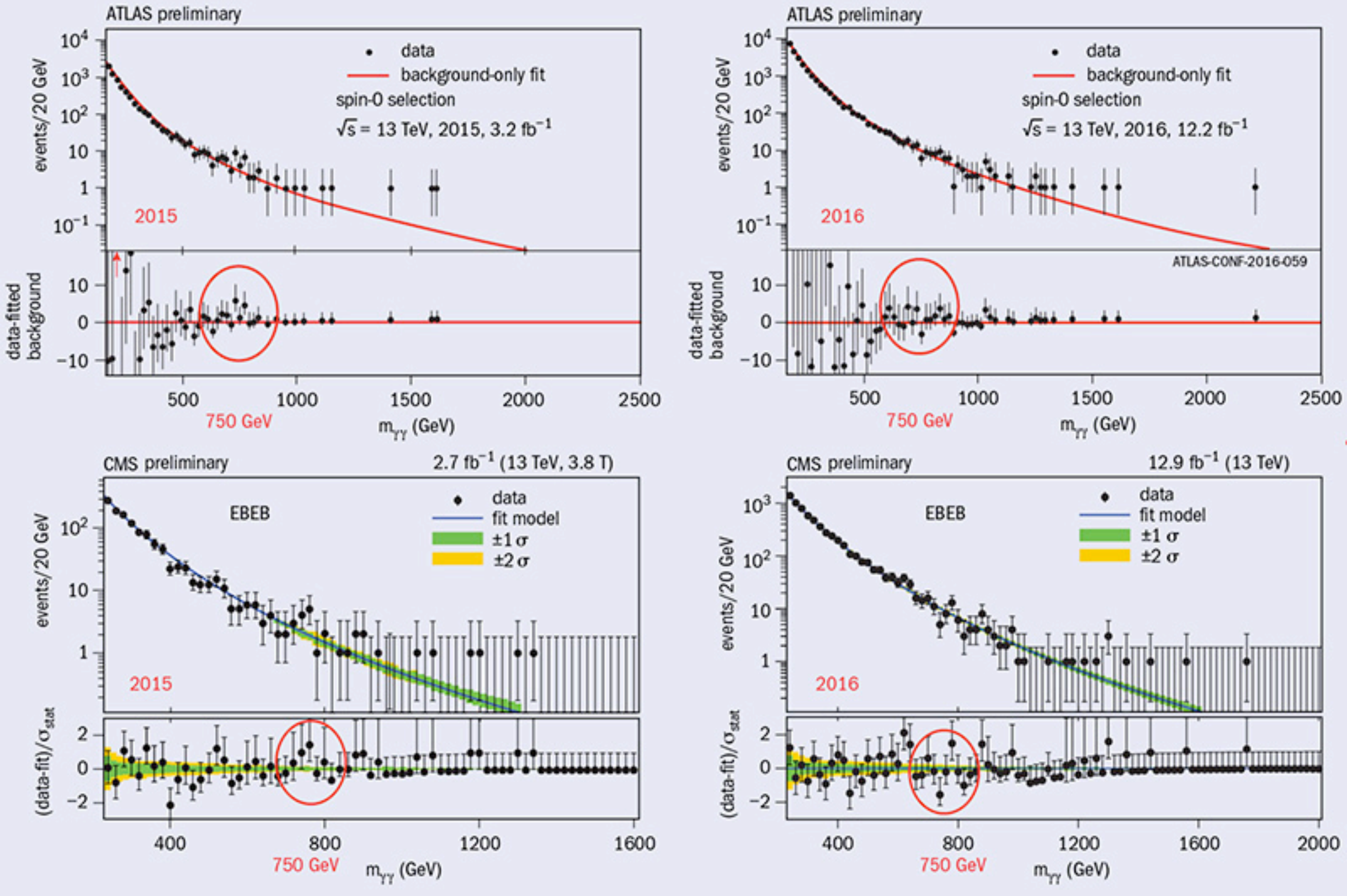
- No significant excess was found, nor previous modest excesses confirmed.
- A few ATLAS non significant but noticeable excesses to follow up:
  - Stops 1L: In (4J, 1b, high MET) 3.3 σ (No excess in CMS)
  - V(W)H(Full hadronic boosted) 3.5 σ (2.5 σ global) at 3TeV (No CMS result)
  - Paired dijet local 2.6 σ (2.1 σ global) at 870GeV (No CMS result)
  - Four leptons high mass 2.9 σ (1.9 σ global) at 705GeV (No excess in CMS)
  - ttH ML in SS-0 τ and SS-1 τ not significant but excesses at Run1 in ATLAS and CMS
- From CMS: γ jet high mass 3.7 σ (2.8 σ global) at ~2 TeV (not seen in ATLAS with similar luminosity)
- However not all results on previous excesses have been released !

Heavy Resonances



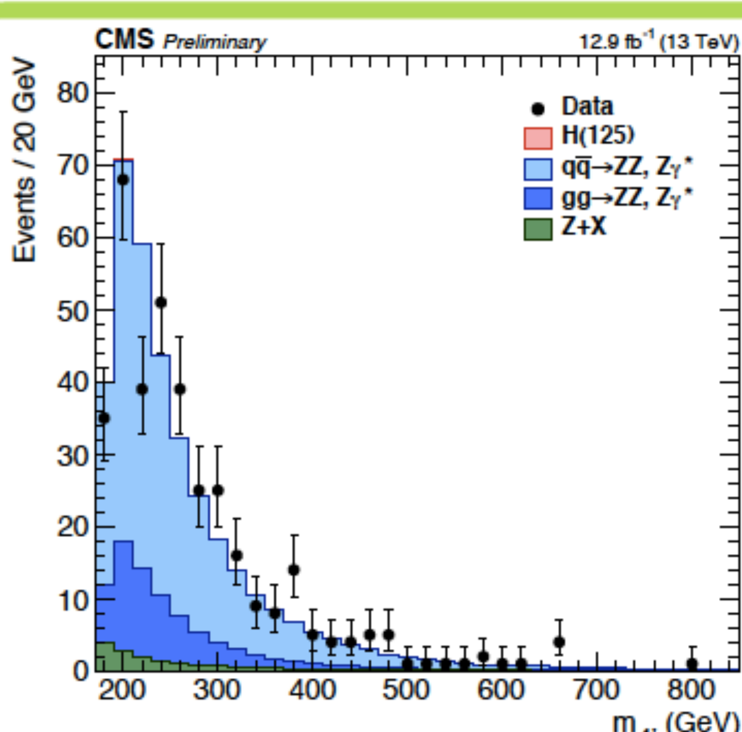
Courtesy S.Rahatlou

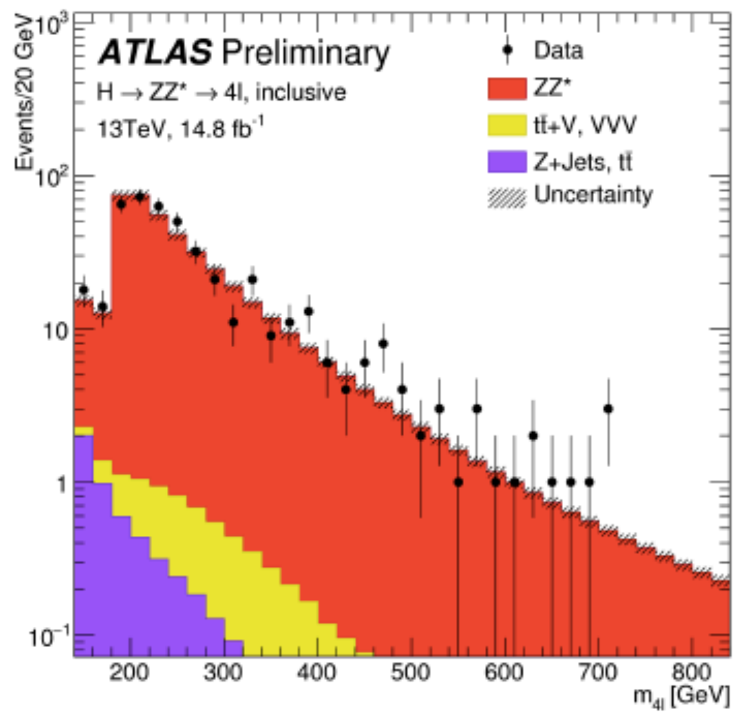
Search for di-photon resonances



Heavy Higgs→ZZ→4l

- Search for an additional heavy scalar
  - Assumed to be produced via the ggF and VBF processes
- Extension of the H→ZZ measurement and fits the m_{4l} distribution
- No signal seen we set limits for different decay width Γ_X assumptions





Heavy Higgs→ZZ→4l

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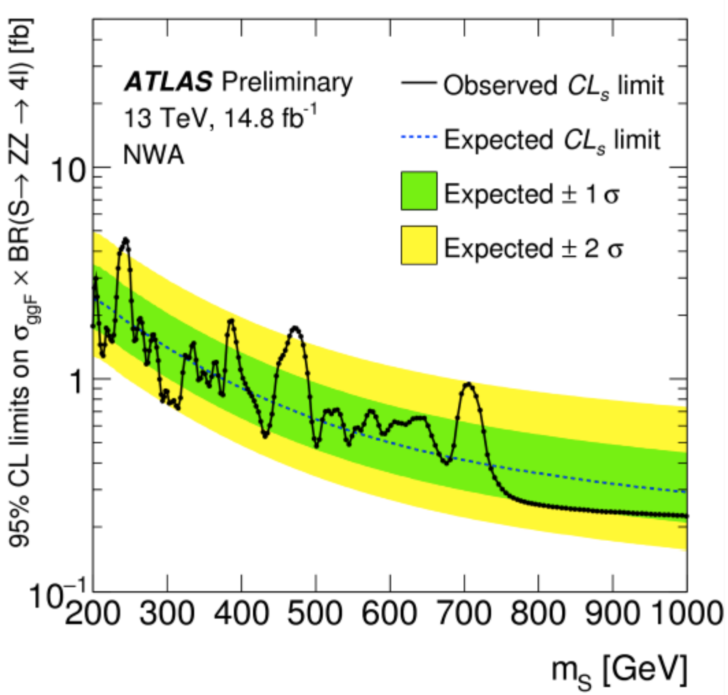
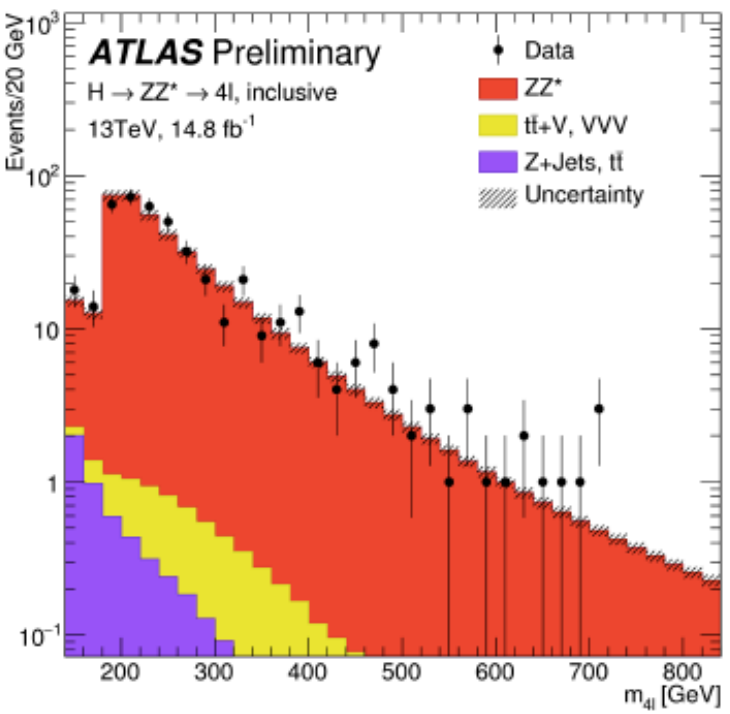
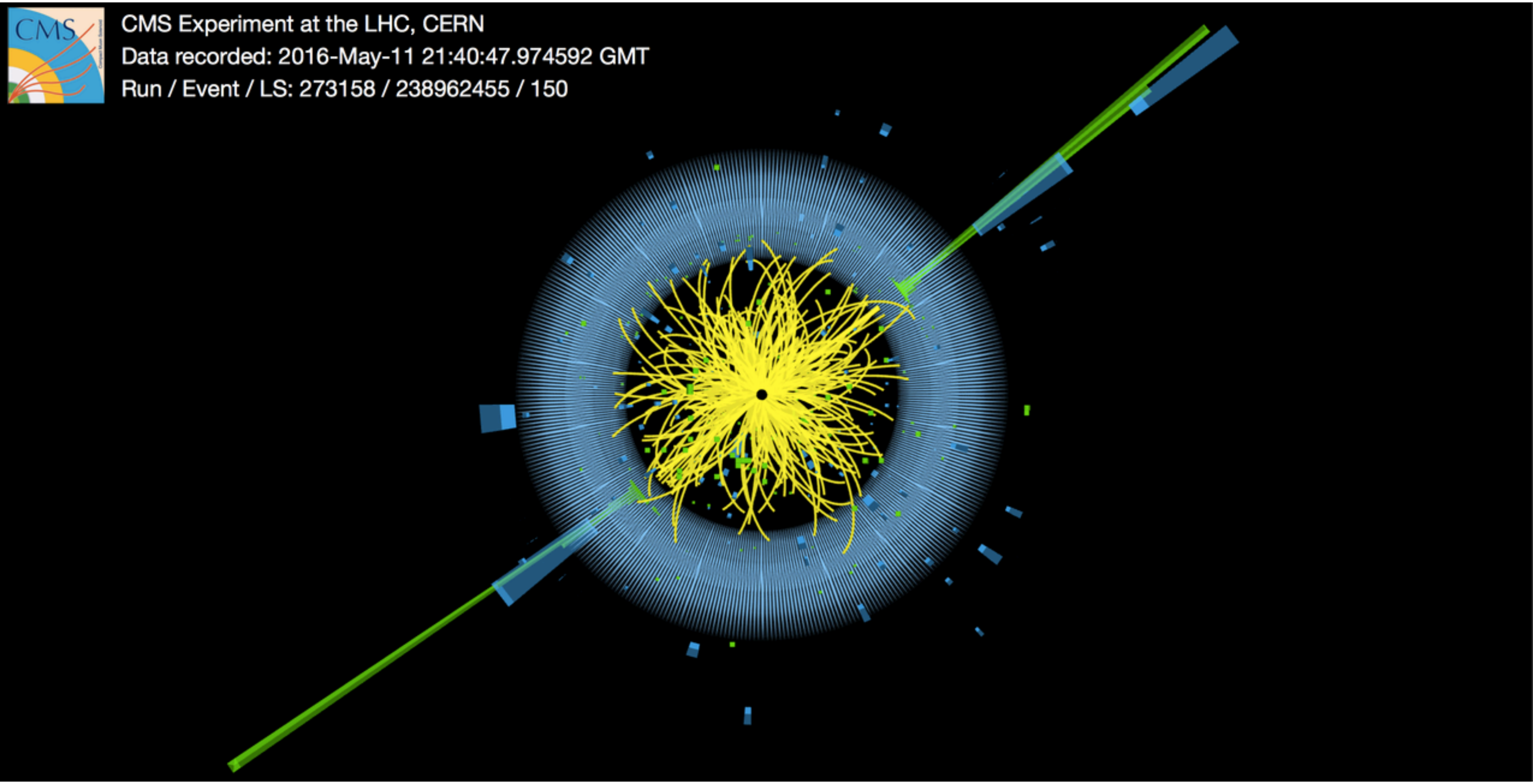




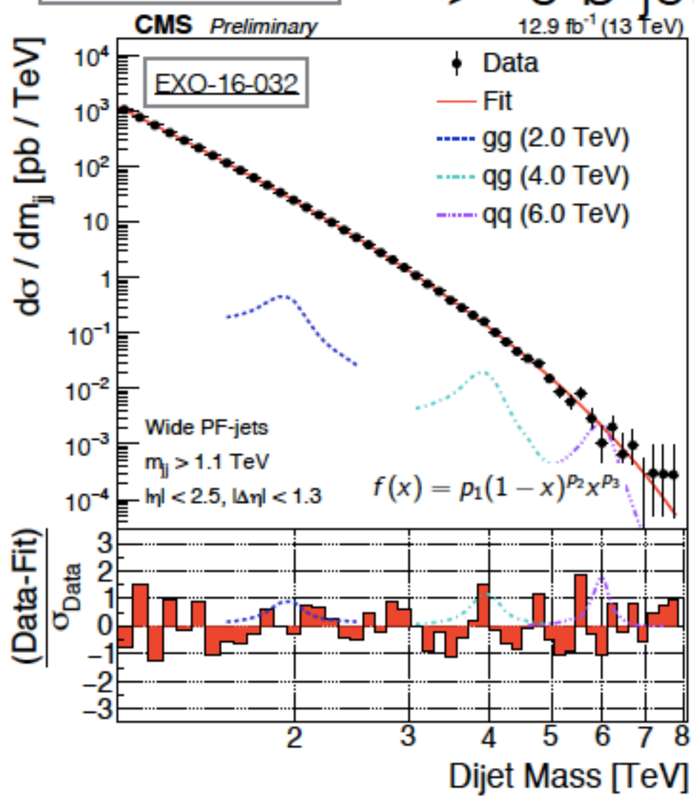
Highest mass di-jet event: 7.7 TeV



Di-jets Resonance Searches

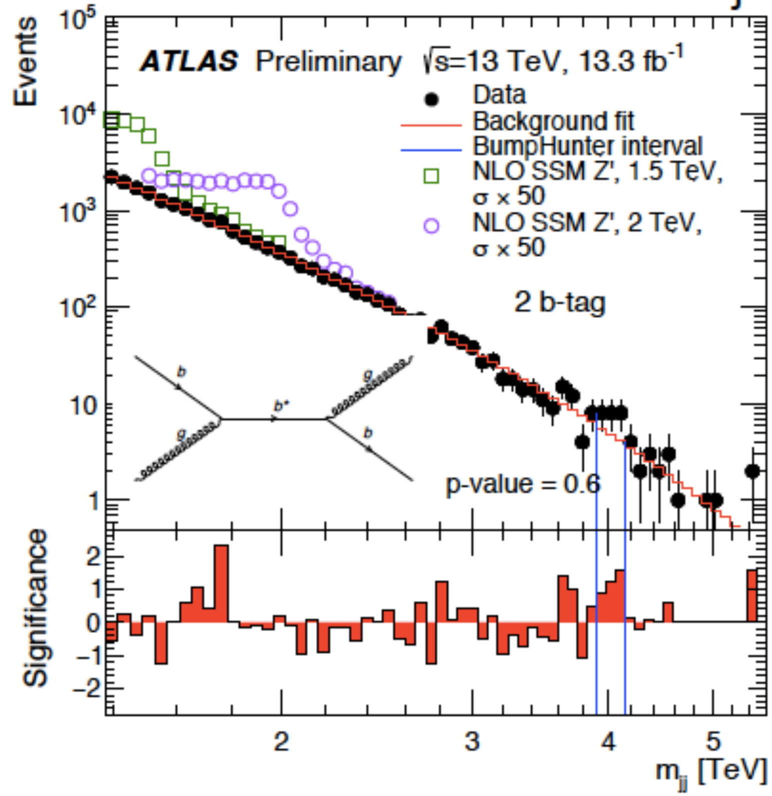
Background modeled by parametrized function for search

ATLAS-CONF-2016-069 >=0 b-jet



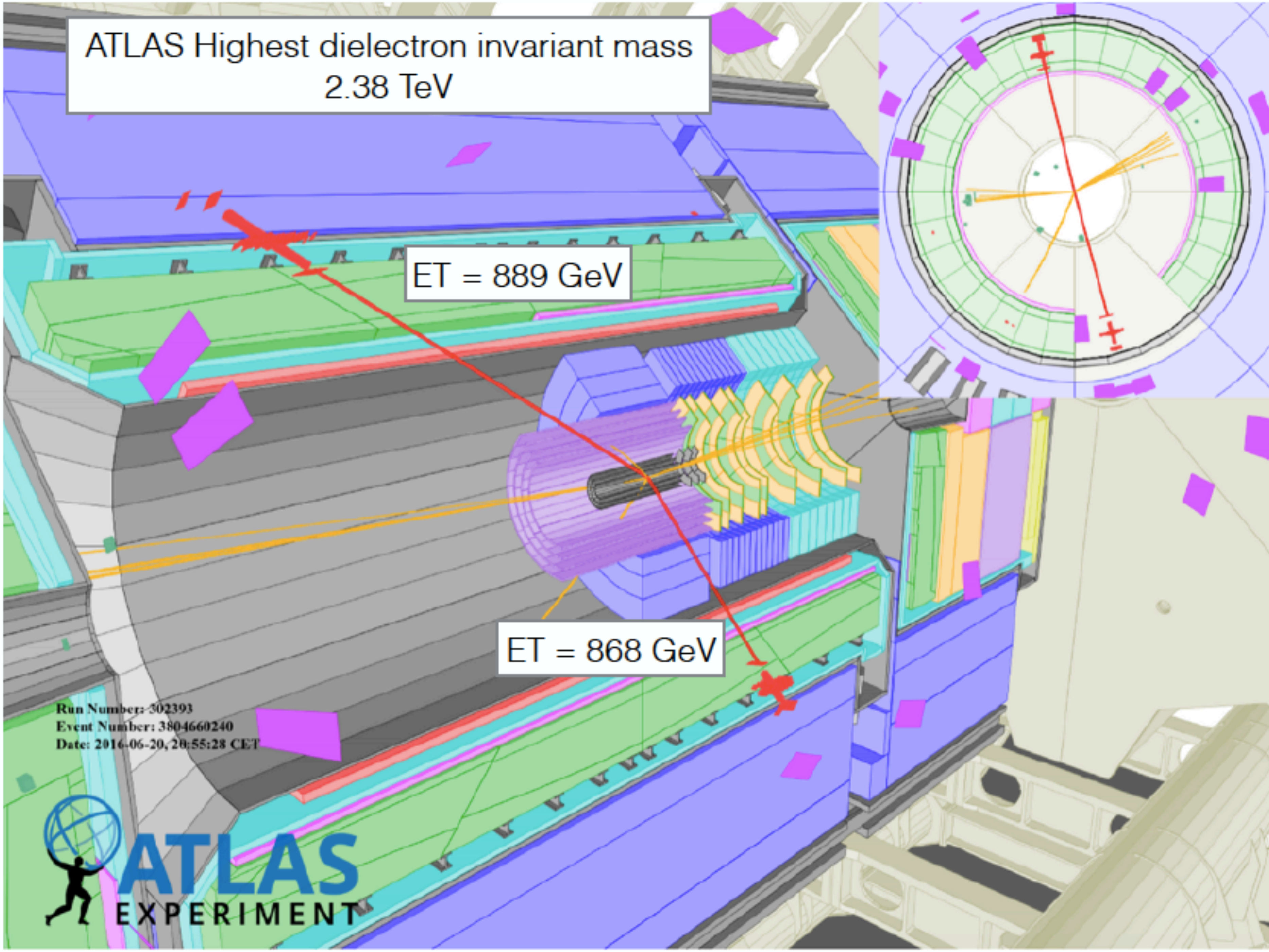
Model	95% CL Exclusion limit Observed	Expected
Quantum black holes, ADD (BlackMax generator)	8.7 TeV	8.7 TeV
Excited quark	5.6 TeV	5.5 TeV
W'	2.9 TeV	3.3 TeV
W^*	3.3 TeV	3.3 TeV
Contact interactions (η_{LL} =+1)	12.6 TeV	13.7 TeV
Contact interactions (η_{LL} =−1)	19.9 TeV	23.7 TeV

ATLAS-CONF-2016-060 >=1 b-jet

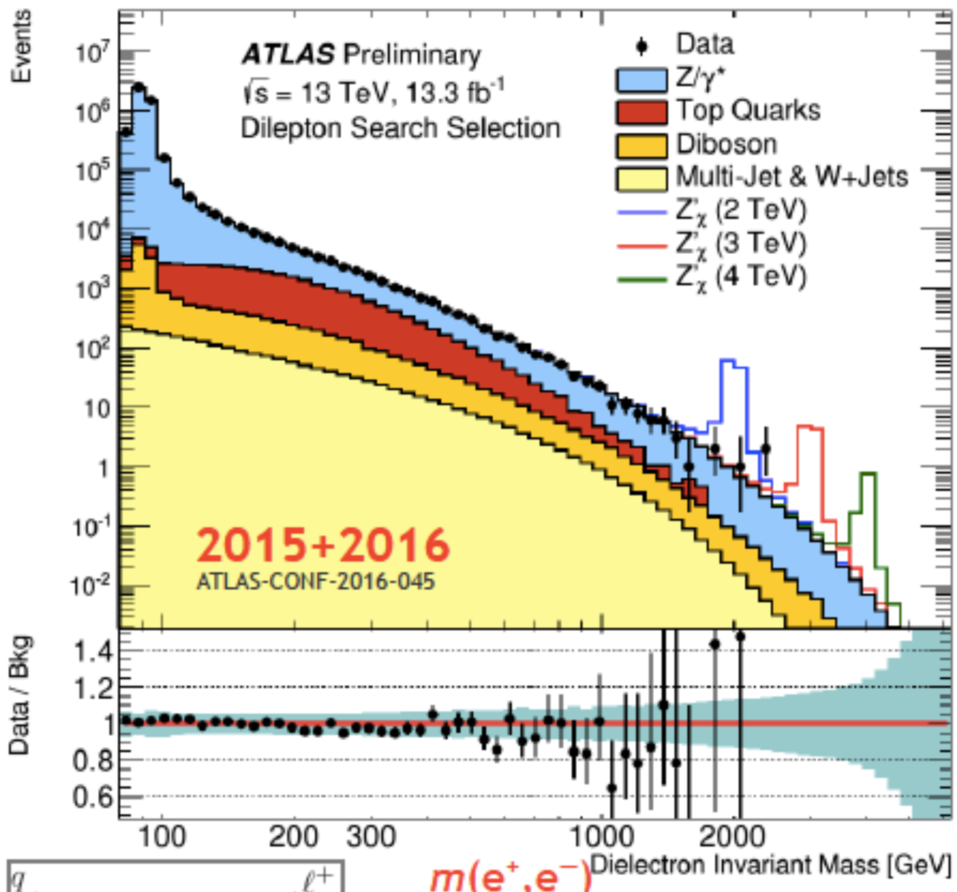


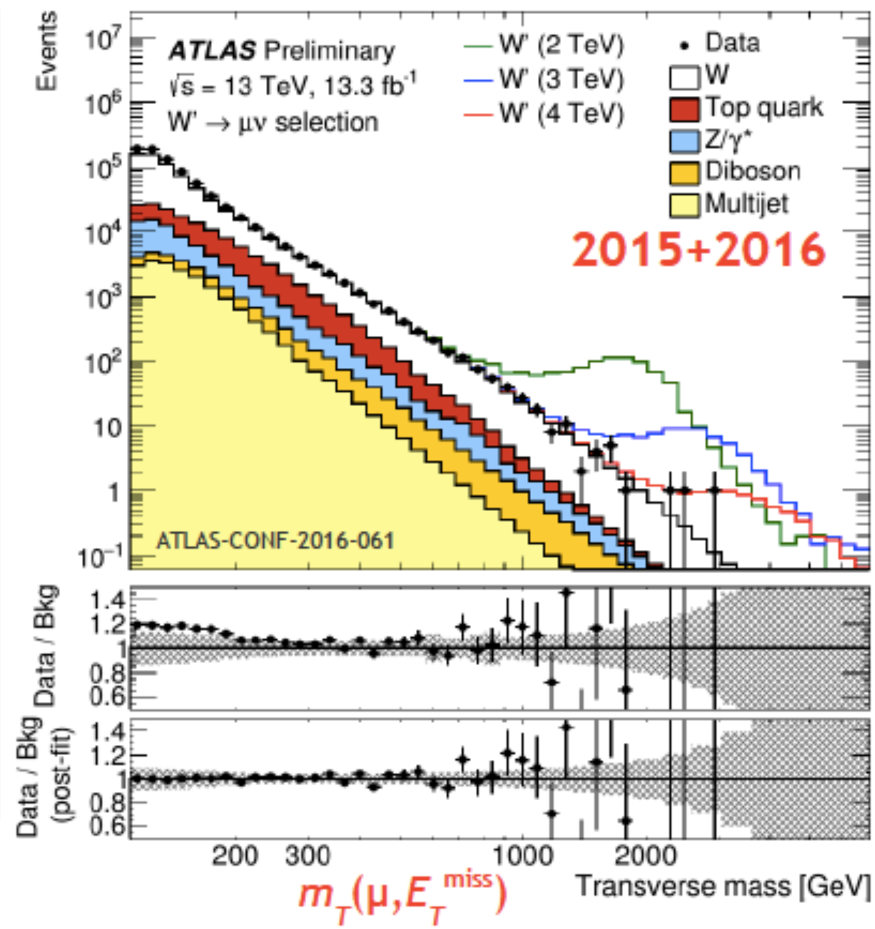
b* (BR(b*→ bg)=0.85) >2.3 TeV

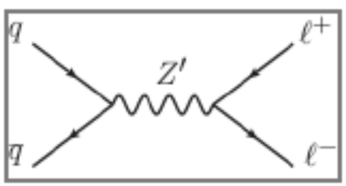
Z' >1.5TeV


ATLAS Highest dielectron invariant mass
2.38 TeV
ET = 889 GeV
ET = 868 GeV
Run Number: 302393
Event Number: 3804660240
Date: 2016-06-20, 20:55:28 CET
ATLAS
EXPERIMENT

Search for di-lepton resonances







Z'_{SSM} (@95%CL): m > 4.05 TeV

(Run-1 m>2.90 TeV)

W' (@95%CL): m > 4.74 TeV

(Run-1 m>3.24 TeV)

VV/Vh/hh Resonance

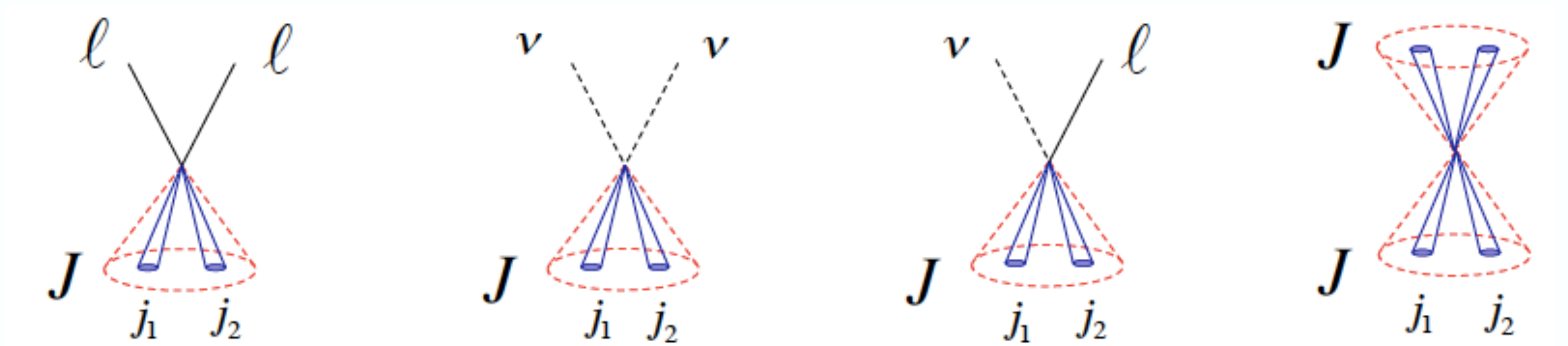
Nikolaos Konstantinidis's talk

Karsten Koeneke's talk

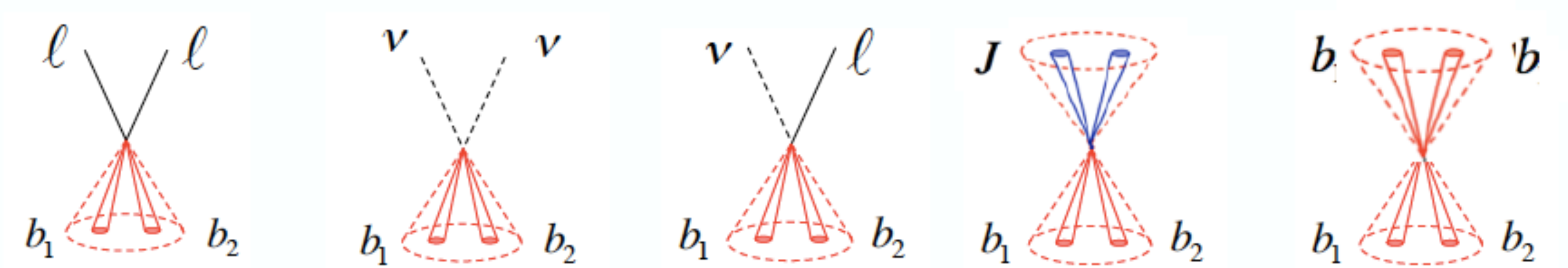
Benedikt Vormwald's talk

- Search for **VV/Vh/hh** resonance in **leptonic/hadronic** decay channels using **large-R jets with jet substructure techniques**

Z(ll)V Z(vv)V W(lv)V VV(JJ)



Z(ll)h Z(vv)h W(lv)h V(J)h hh



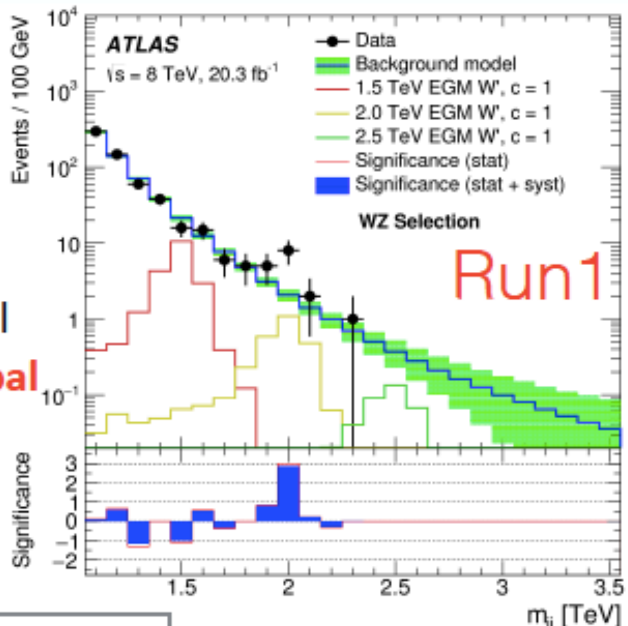
Revisit diboson excesses in Run1

JHEP12(2015)055

m= 2TeV

3.4σ local

2.5σ global

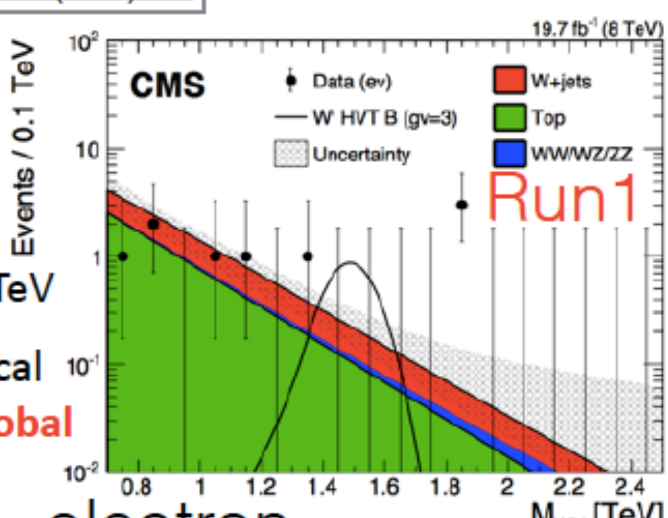


EPJC 76 (2016) 237

m=1.8 TeV

2.9σ local

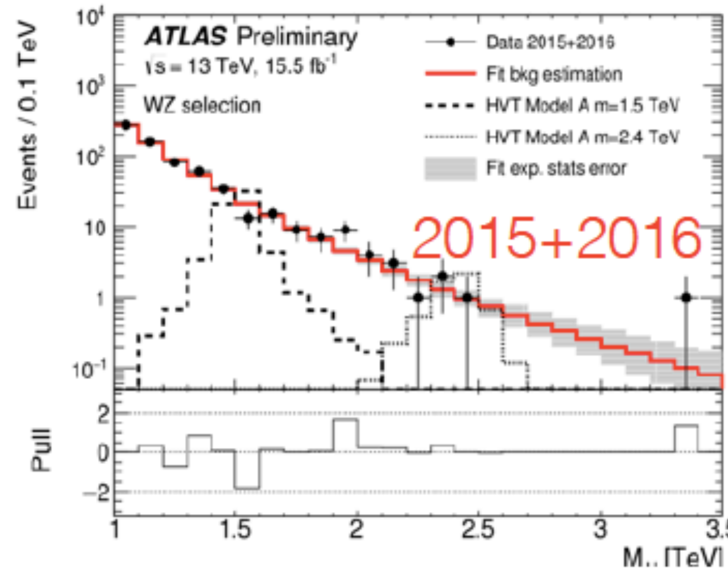
1.9σ global

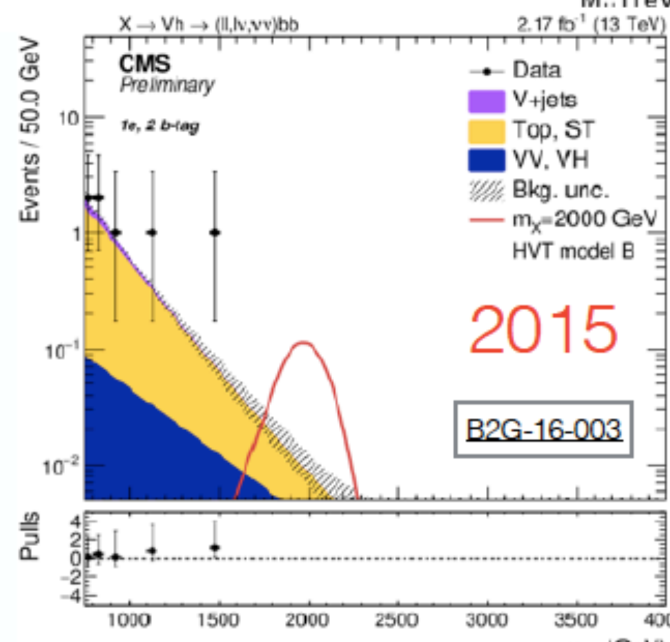


electron

Excesses not confirmed in Run2

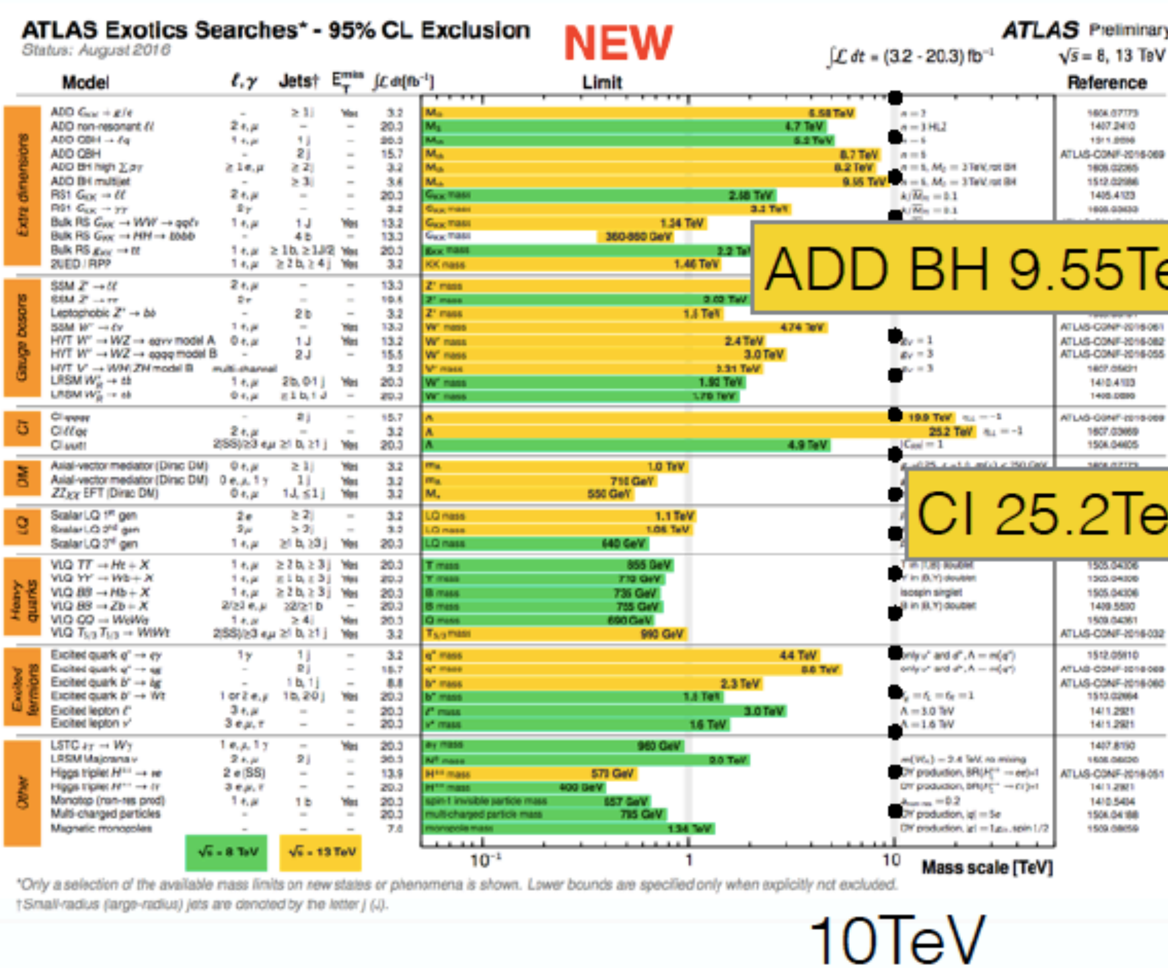
ATL-CONF-2016-055

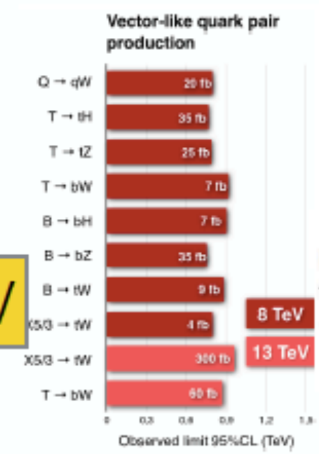


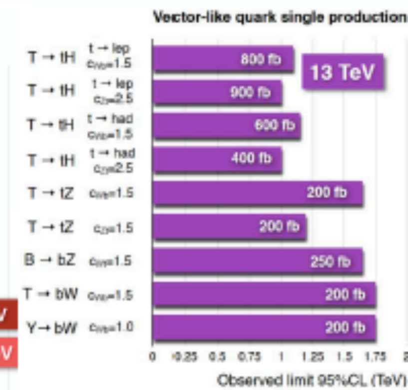


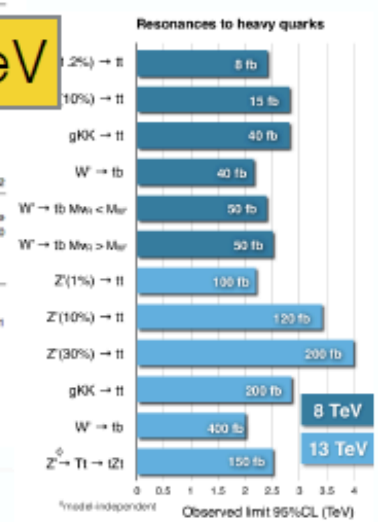
Resonance Search Summary

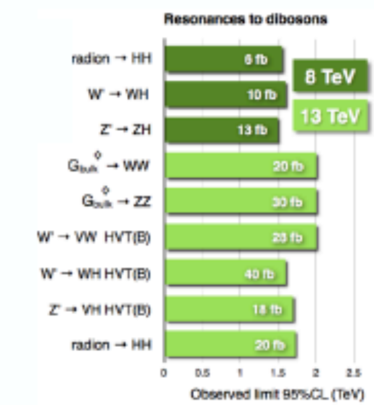
- Up to 25% mass limit increase by extending 2015 to 2016
- ~50% of the analyses updated to Run2







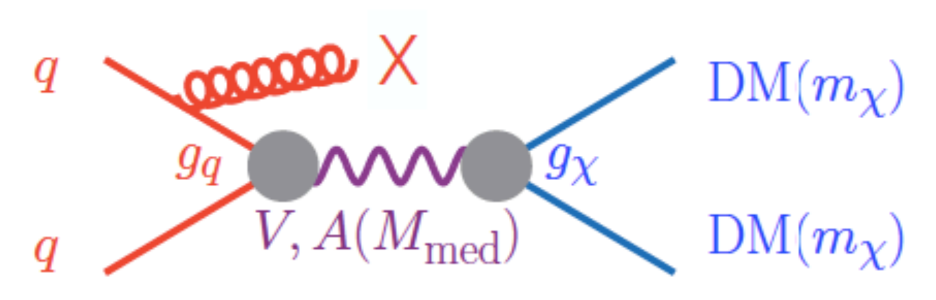


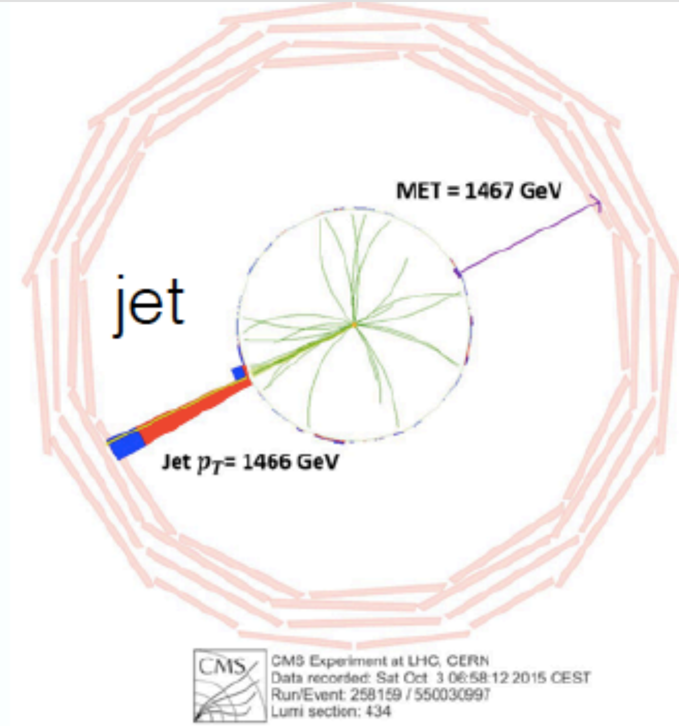


Collider Dark Matter Signature - Mono-X

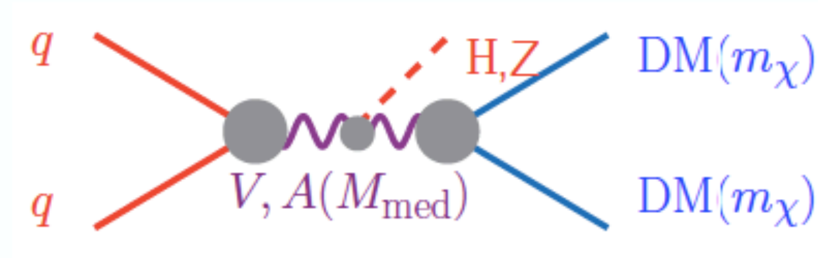
E_T^{miss}+X a.k.a. Mono-X

- X from ISR jet, b, t, γ, W, Z





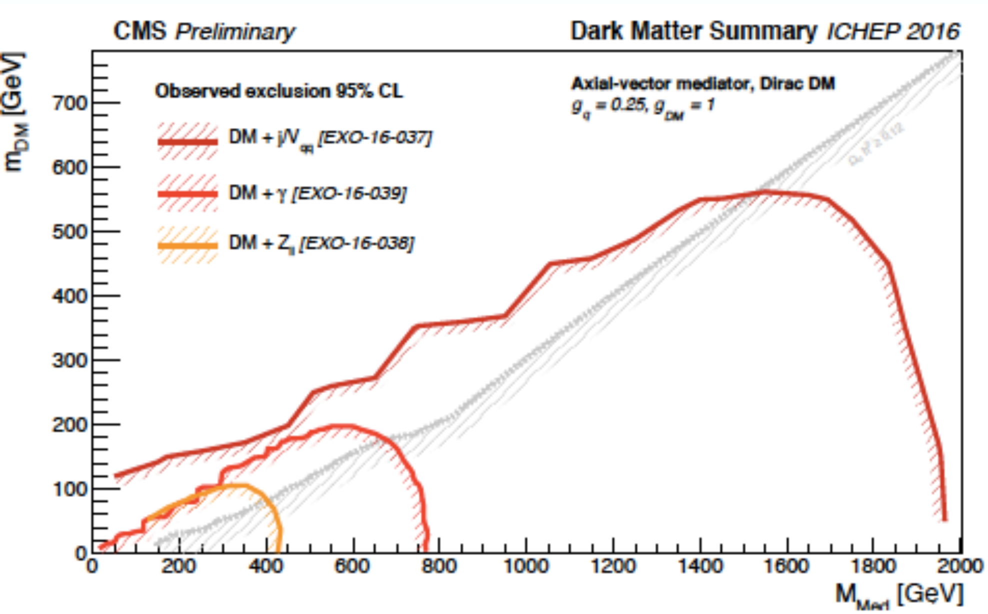
- X from mixing with mediator

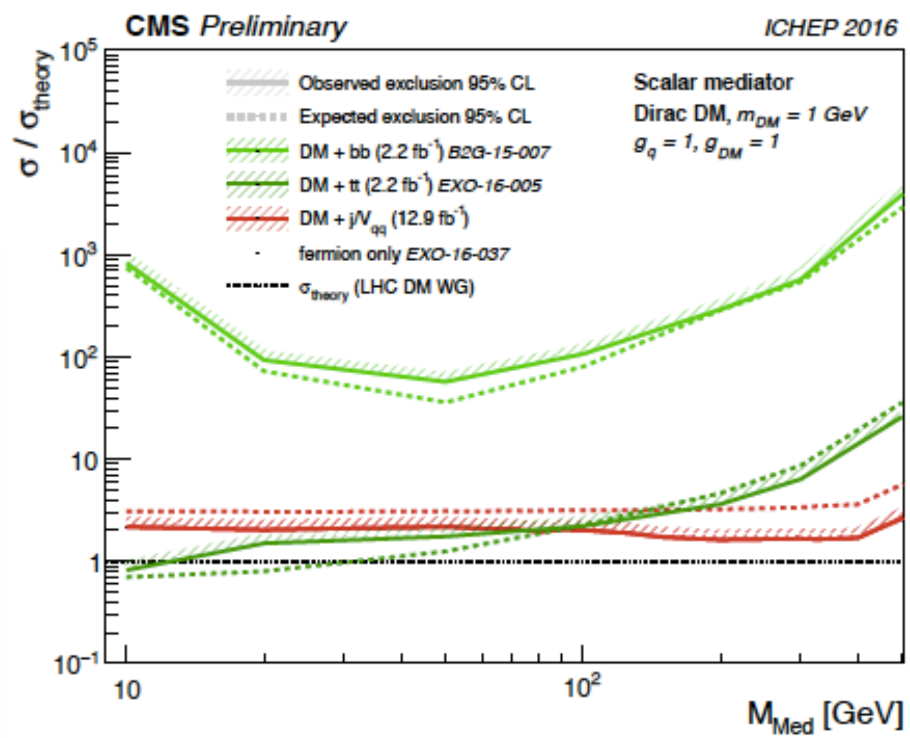


- X from paired $t\bar{t}$, $b\bar{b}$

Dark Matter exclusion limit

- No significant excess observed so far
- DM mass exclusion up to ~550 GeV
- Vector Mediator mass exclusion up to 1.95 TeV





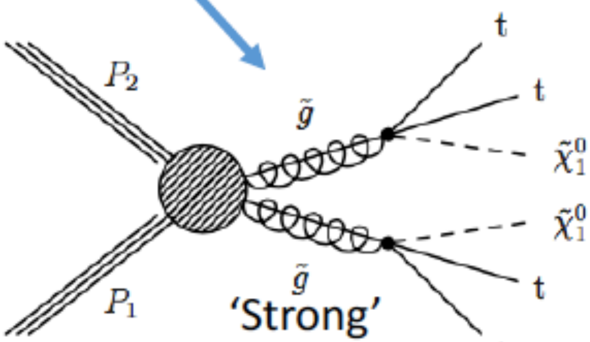
SUSY searches: multileptons

CMS PAS SUS-16-022

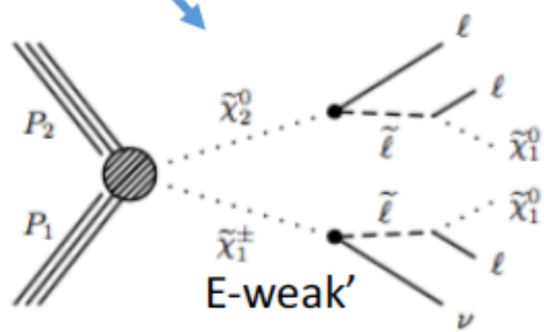
CMS PAS SUS-16-024

Clean signature for complex final states: selecting on the jet activity we can be sensitive to 'strong' SUSY productions or Electroweak SUSY production

Example of two SUSY production



'Strong'
(T1tttt)



E-weak'

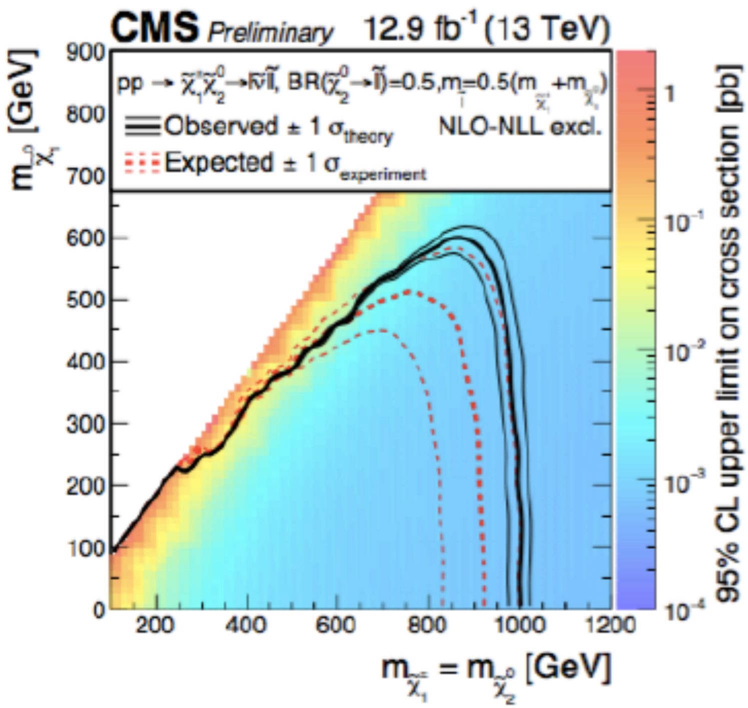
Analyses characterized by large number of Search Regions.

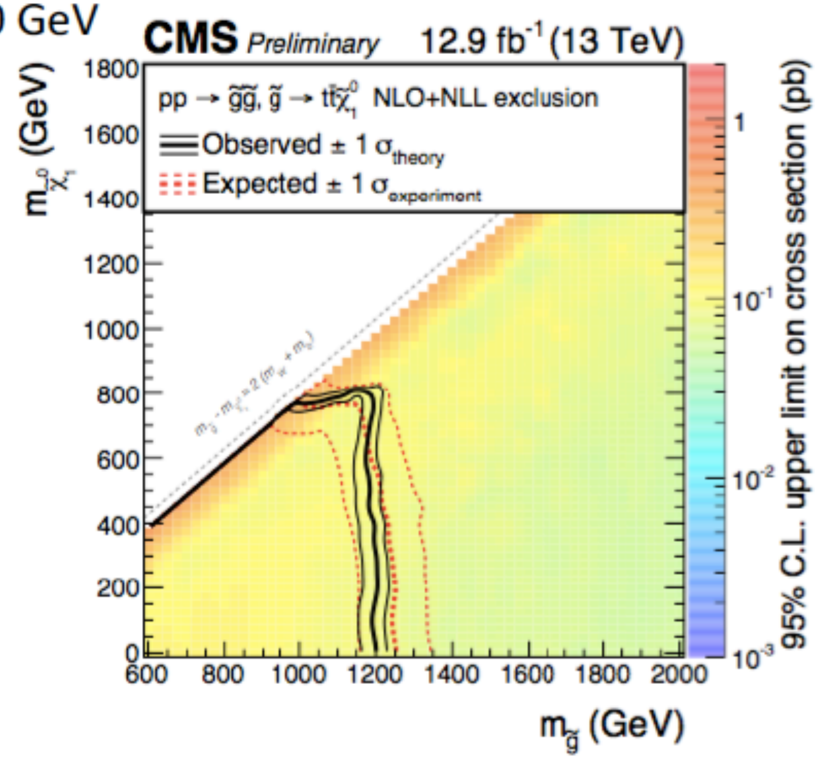
EWK searches: 118 different search regions (dependent on N_jets, N_btag, N_Leptons, flavour, charge…

Strong searches: 32 search regions (nature of jets, $E_T$miss, ΣE_T, di-leptons consistent/not consistent with Z decay.

SUSY Multileptons: some results

None of the search regions has shown significant deviations from the expected SM background : largest deviation 2.5 σ for same sign di-leptons, N_{jet}=1,M_T<100GeV, E_t^{miss}>150 GeV and pt(ll) ≥50 GeV





Electroweak production: In flavor democratic scenario we exclude Chargino masses up to 1 TeV (previous Run1 limit was 750 GeV)

CMS PAS SUS-16-022

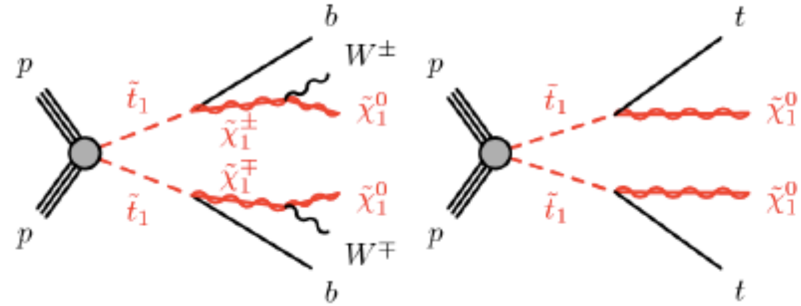
CMS PAS SUS-16-024

Strong production: we exclude gluino masses up to 1250 GeV and LSP masses up to 750 GeV for simplified model of T1tttt

Stop Search: $\tilde{t}\to bW\tilde{\chi}_1^0$, $\tilde{t}\to t\tilde{\chi}_1^0$

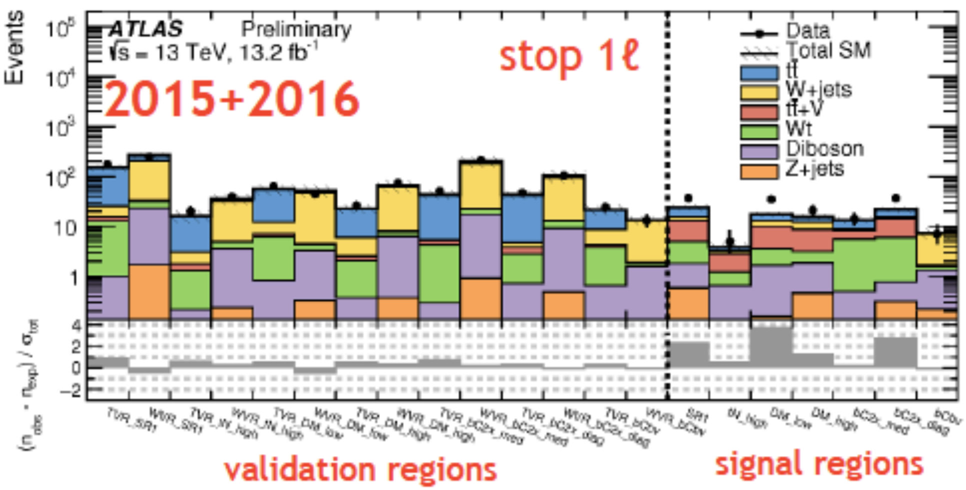
Event topology: WbWb+E_T^{miss}(+jets)

- Divide according to W decays: 0ℓ, 1ℓ, 2ℓ, τ

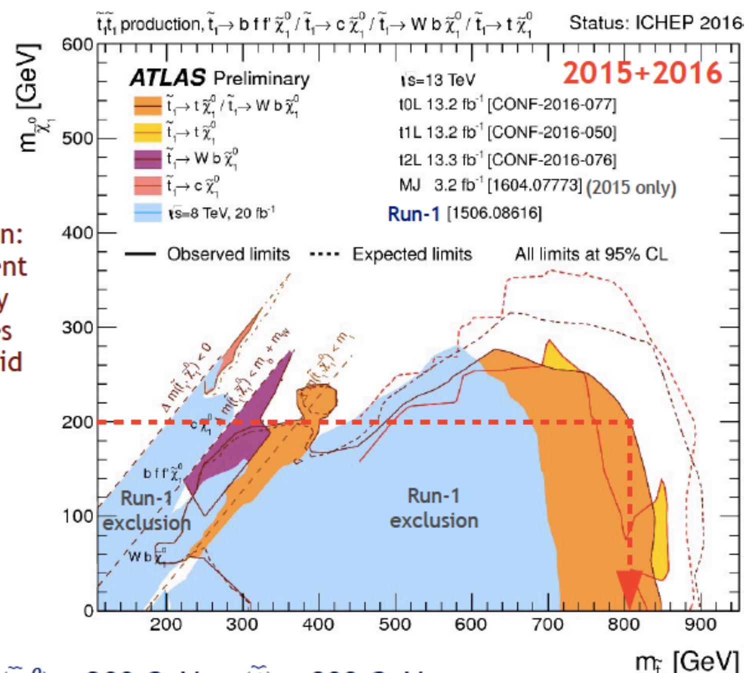


In total, 35 signal regions

- Aiming to cover $m(\tilde{\chi}_1^0)$ vs $m(\tilde{t})$ plane
- Largest excess 3.3σ



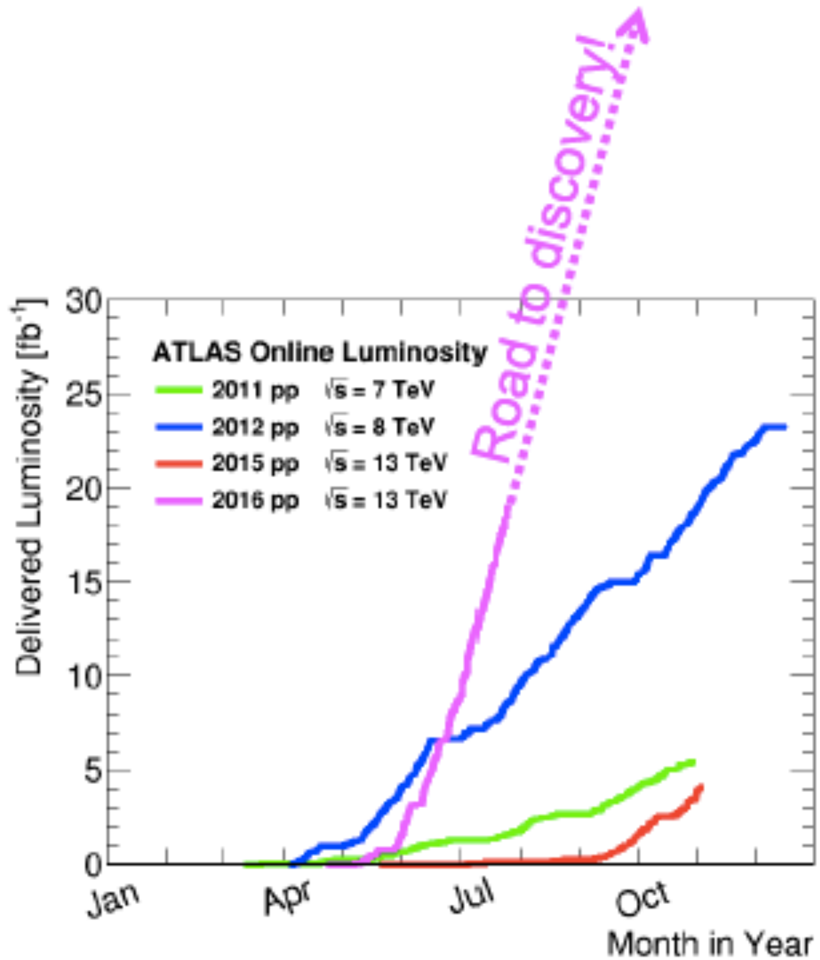
Caution: different decay modes overlaid



For $m(\tilde{\chi}_1^0)$ < 200 GeV, $m(\tilde{t})$ < 800 GeV excluded except in rather small regions

Summary

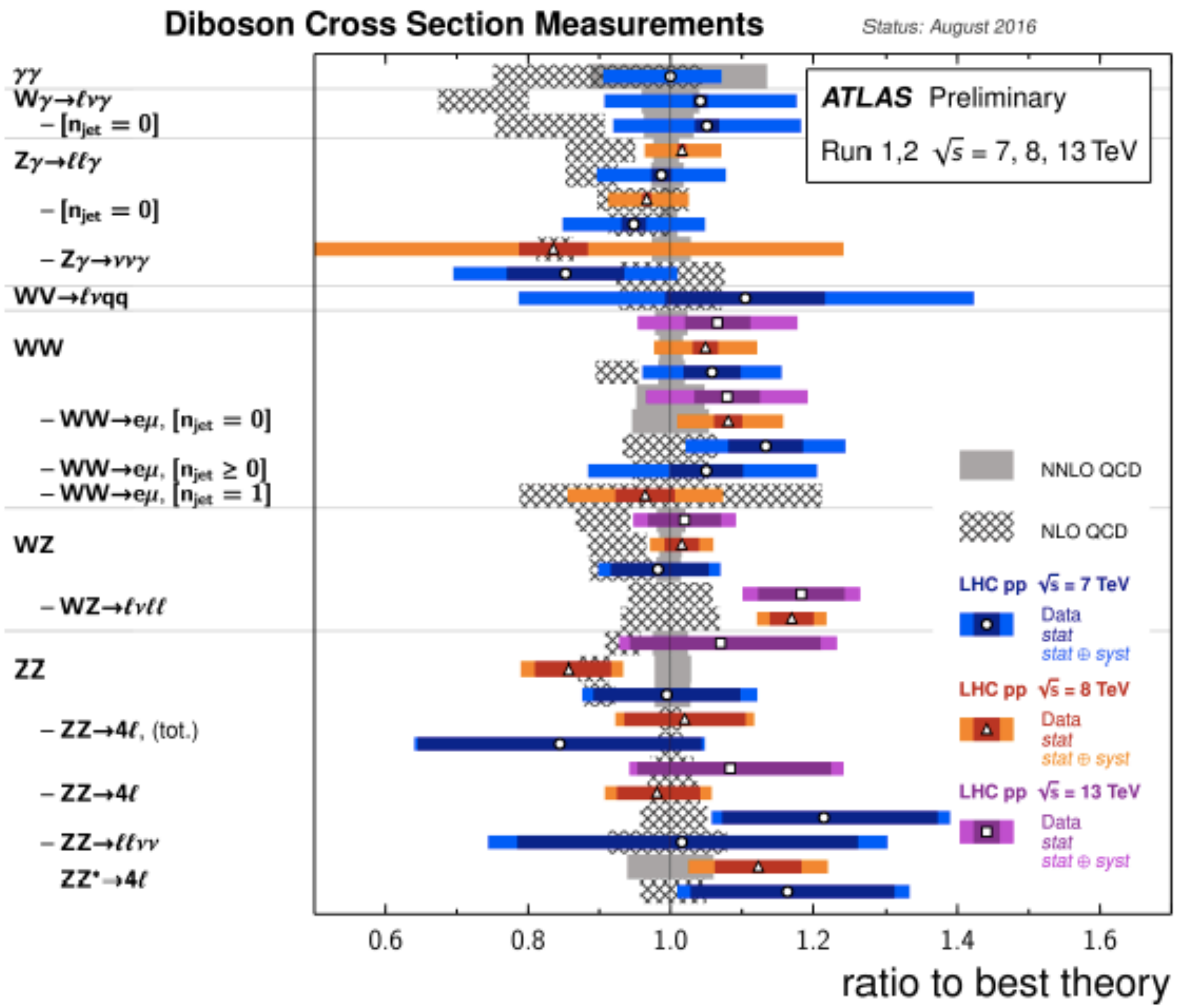
13 fb^{-1}@13TeV not so lucky for ATLAS and CMS!



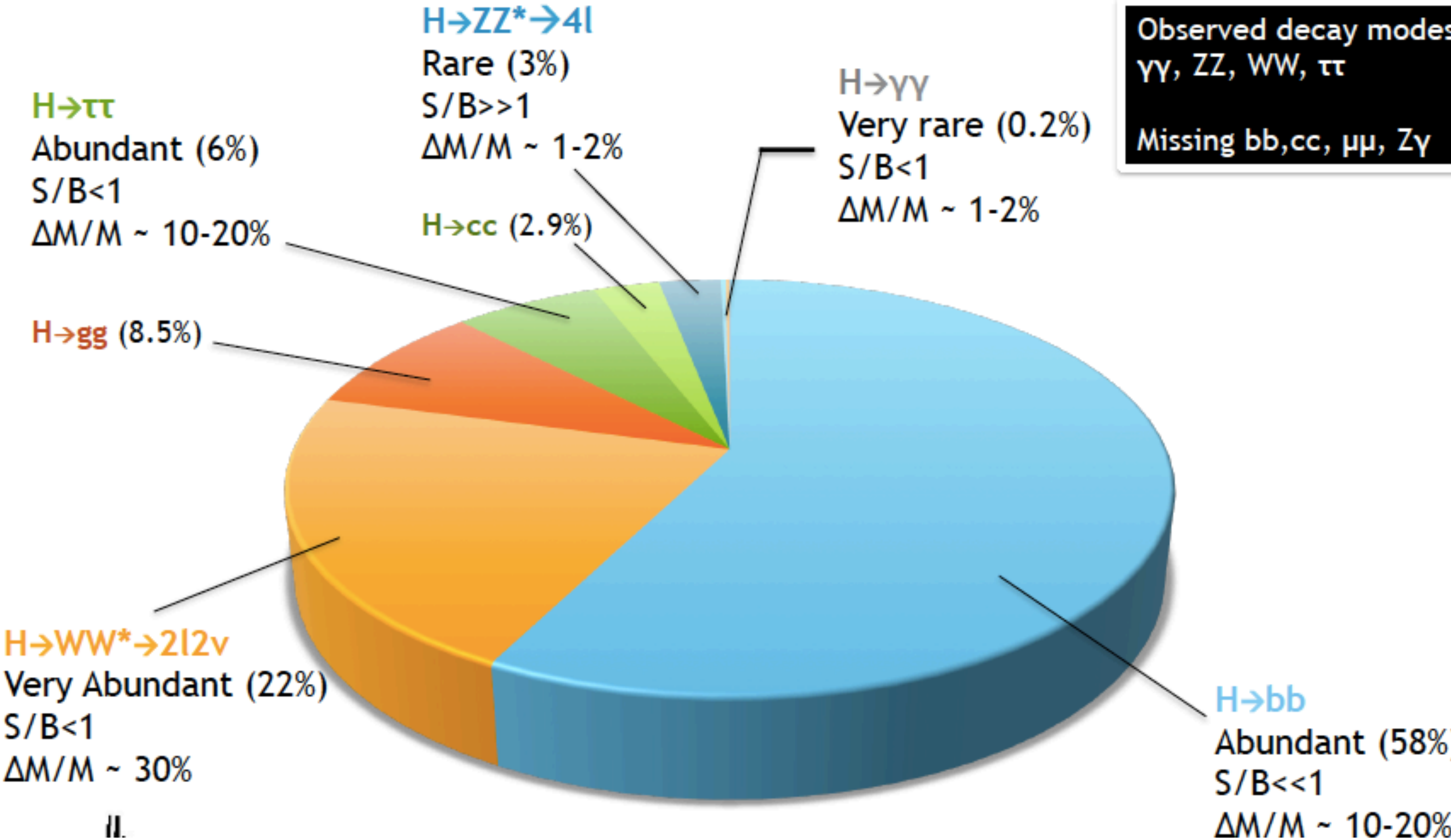
Backup

Diboson cross section summary

Final precise 8TeV diboson cross sections, differential cross sections.
New 13TeV cross section, starting to go differential.
Measurements consistent with NNLO



Higgs Boson Decays at 125 GeV

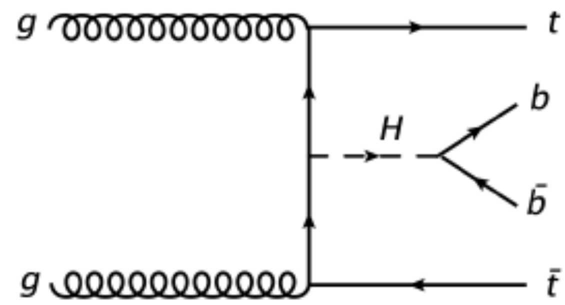


Observed decay modes:
γγ, ZZ, WW, ττ

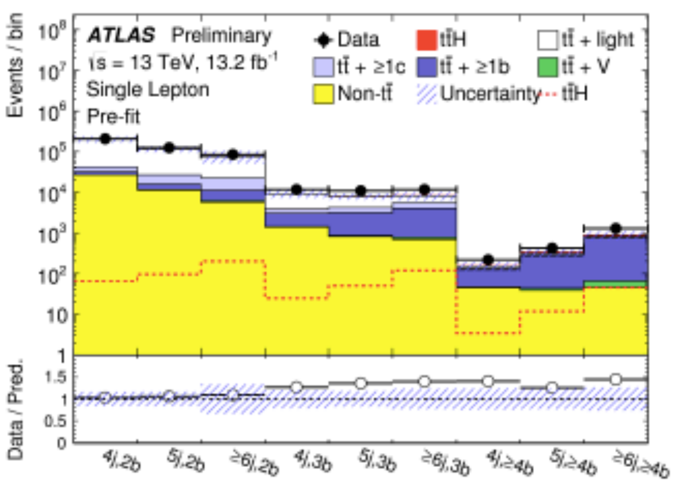
Missing bb,cc, μμ, Zγ

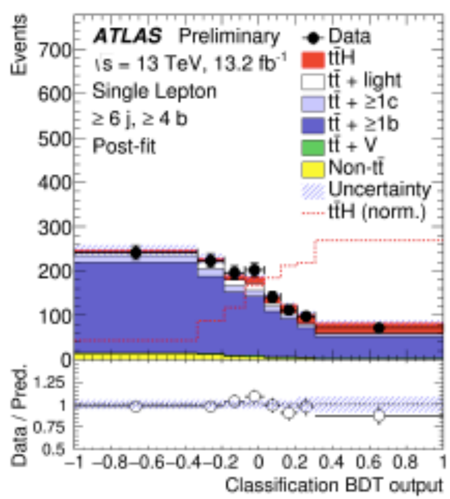
ttH(→bb)

- Largest branching ratio and large background, also offers sensitivity to the Higgs-Bottom Yukawa coupling
- **Analysis strategy:** categorize events according to amount of leptons, jets, b-jets
  - Main background tt+heavy flavour production: very challenging theoretical description
- **Dominant systematic uncertainty:** signal and background modeling and normalization (larger than statistical uncertainty)

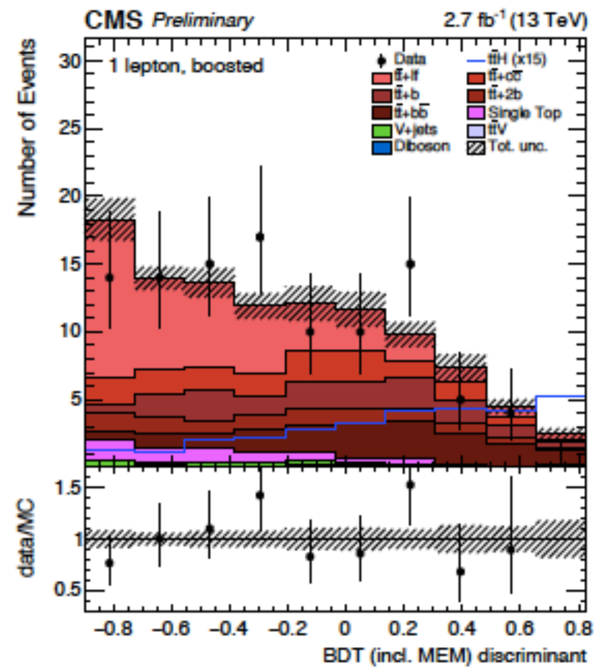


ATLAS uses BDT to reconstruct Higgs and separate signal and background for each category





CMS includes now a boosted category and 2D matrix-element and BDT



ttH(→bb)

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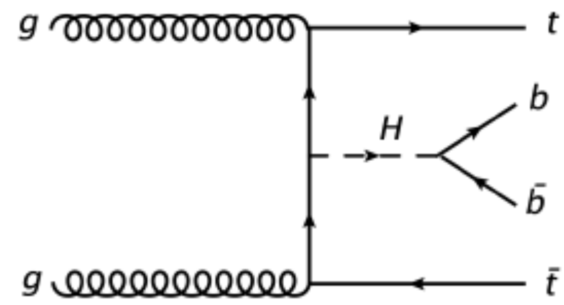
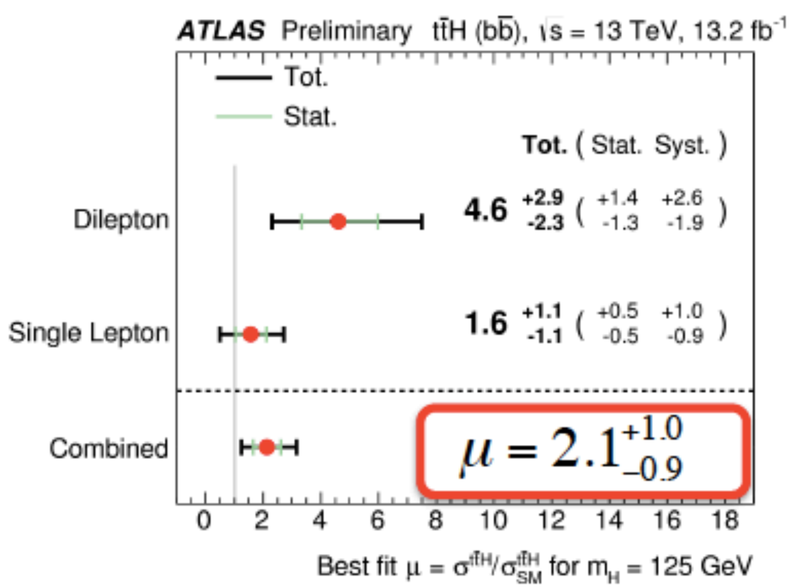
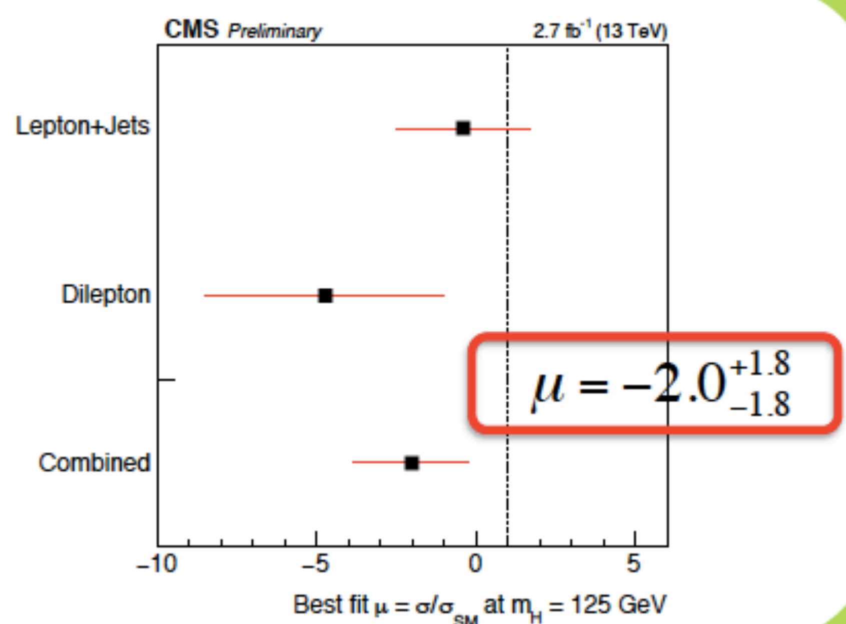
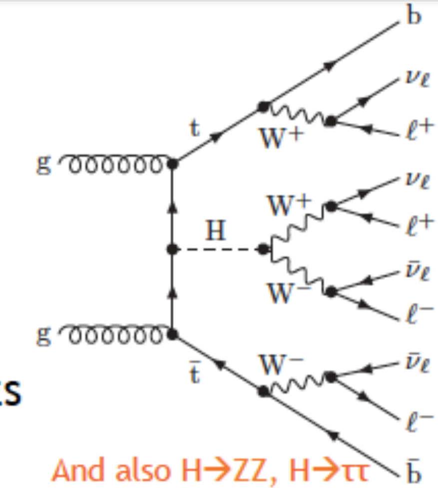






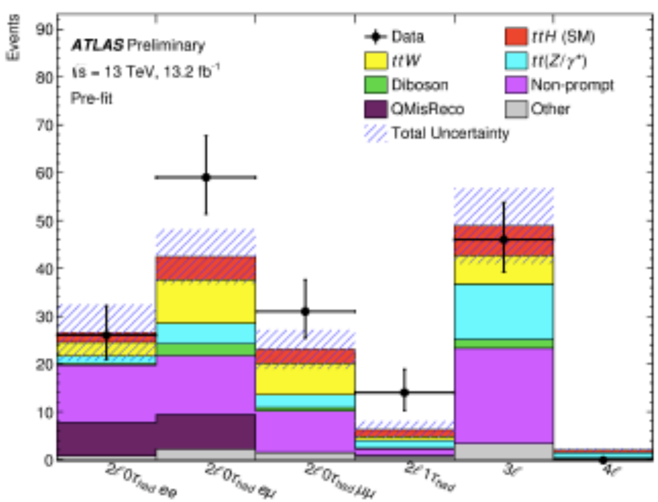
ttH(multileptons)

- Targets Higgs decays and focus on final states with clean signatures and low backgrounds
- **Signature:** 2-4 leptons, 2 or more jets, and at least 1 b-tagged jet. Allows at least one τ_{had}
- **Dominant systematic uncertainty:** fake-rate measurements and non-prompt background estimates

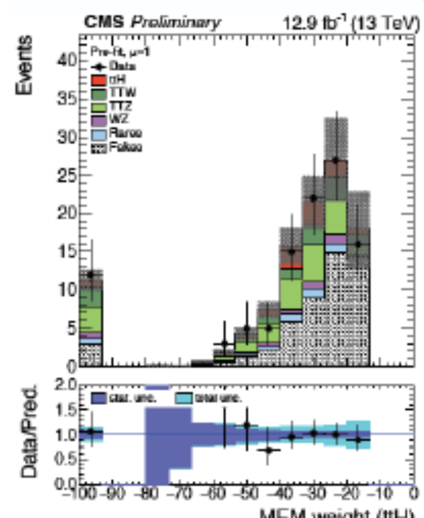


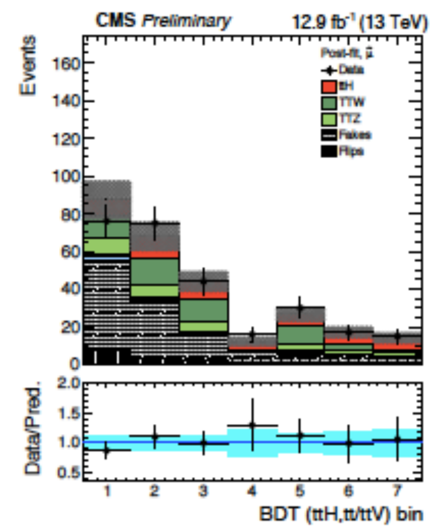
And also H→ZZ, H→ττ

ATLAS cut and count analysis in main different category regions



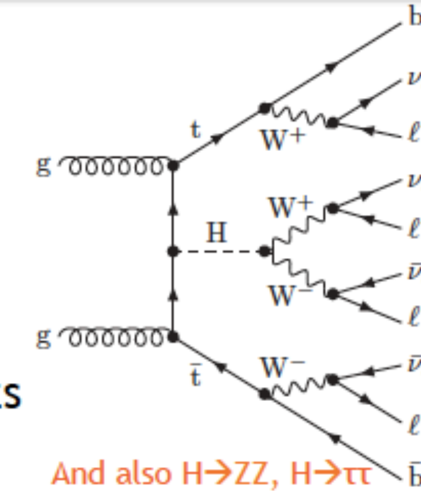
CMS BDT based discriminants including matrix element weights



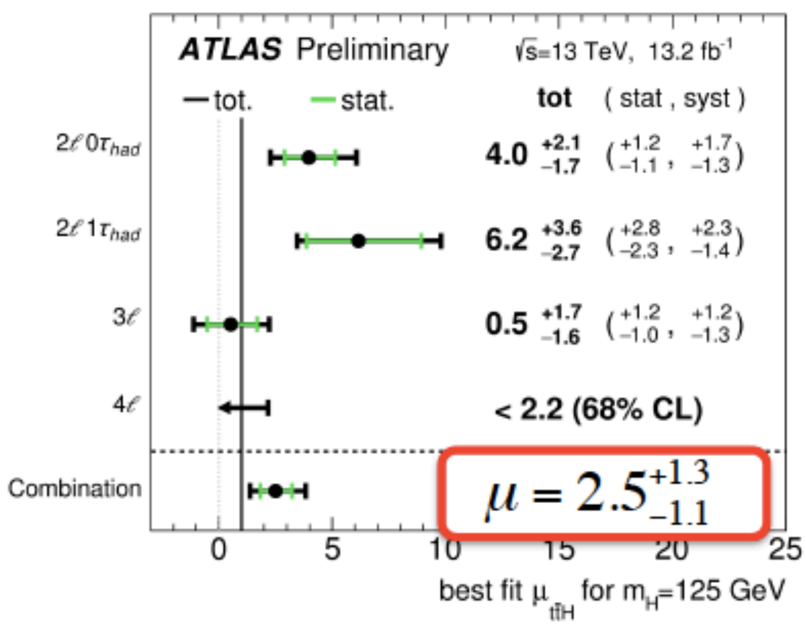


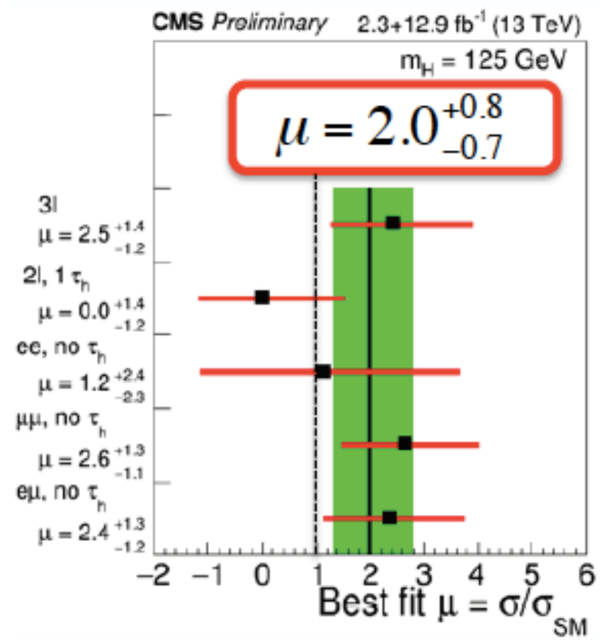
ttH(multileptons)

- Targets Higgs decays and focus on final states with clean signatures and low backgrounds
- **Signature:** 2-4 leptons, 2 or more jets, and at least 1 b-tagged jet. Allows at least one τ_{had}
- **Dominant systematic uncertainty:** fake-rate measurements and non-prompt background estimates



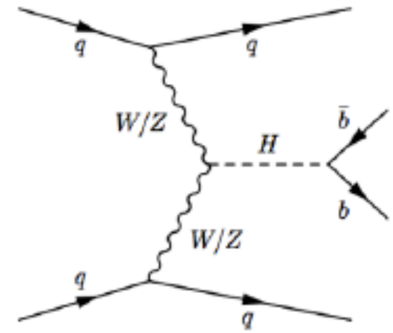
And also H→ZZ, H→ττ



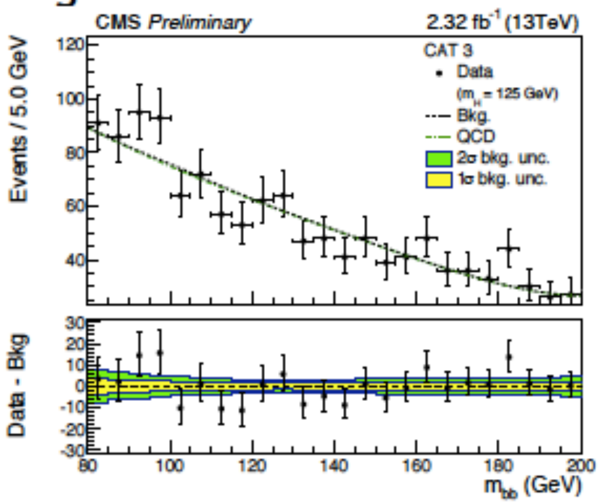


ttH combination $\mu = 1.7^{+0.7}_{-0.8}$ ATLAS-CONF-2016-068

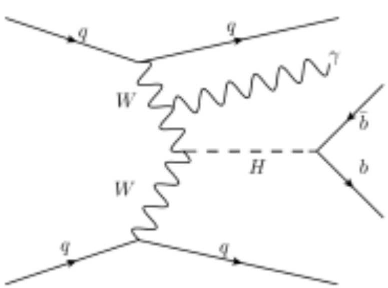
VBF H→bb



- VBF H→bb more difficult to exploit VBF than VH signature for H→bb but larger production cross-section
  - Forward jets are used to trigger and discriminate against multi-jet background
  - Signal extracted via a fit to the m_{bb} spectrum



CMS	Upper limit x SM (expected)	Signal strength μ
Run 1	5.5 (2.5)	$2.8^{+1.6}_{-1.4}$
Run 2	3.4 (2.3)	$1.3^{+1.2}_{-1.1}$



ATLAS result with 12.6 fb^{-1} requiring a high p_T photon to provide a clean signature for efficient triggering

Fit tested on SM

ATLAS	H(→bb) + γj	Z(→bb) + γj
Upper limit at 95% CL	4 x SM (expected 6 x SM)	2 x SM (expected 1.8 x SM)