SM + Top (ATLAS/CMS)

Enrique Palencia Cortezón

Universidad de Oviedo

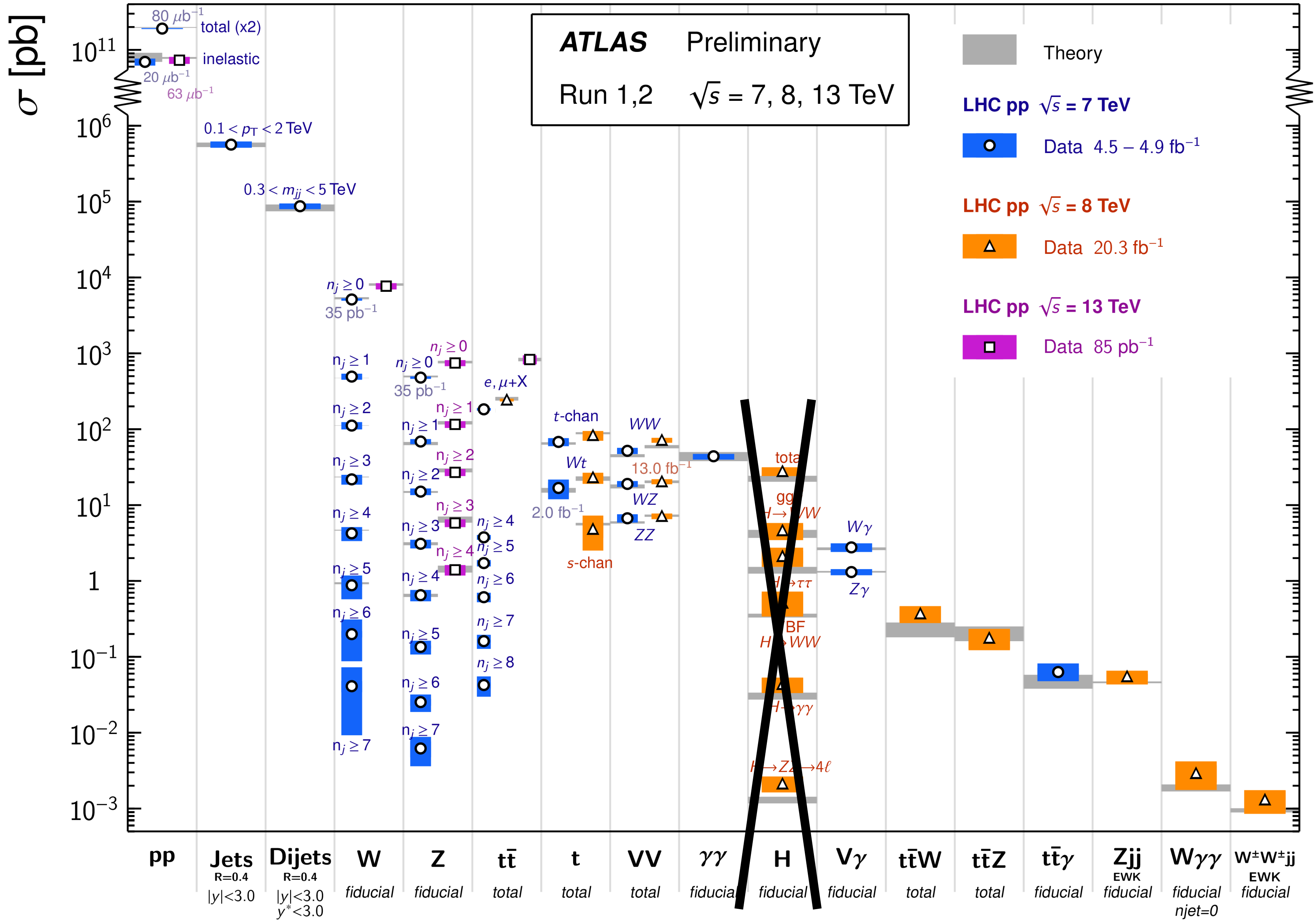
XLIV International Meeting
on Fundamental Physics

April 4, 2016

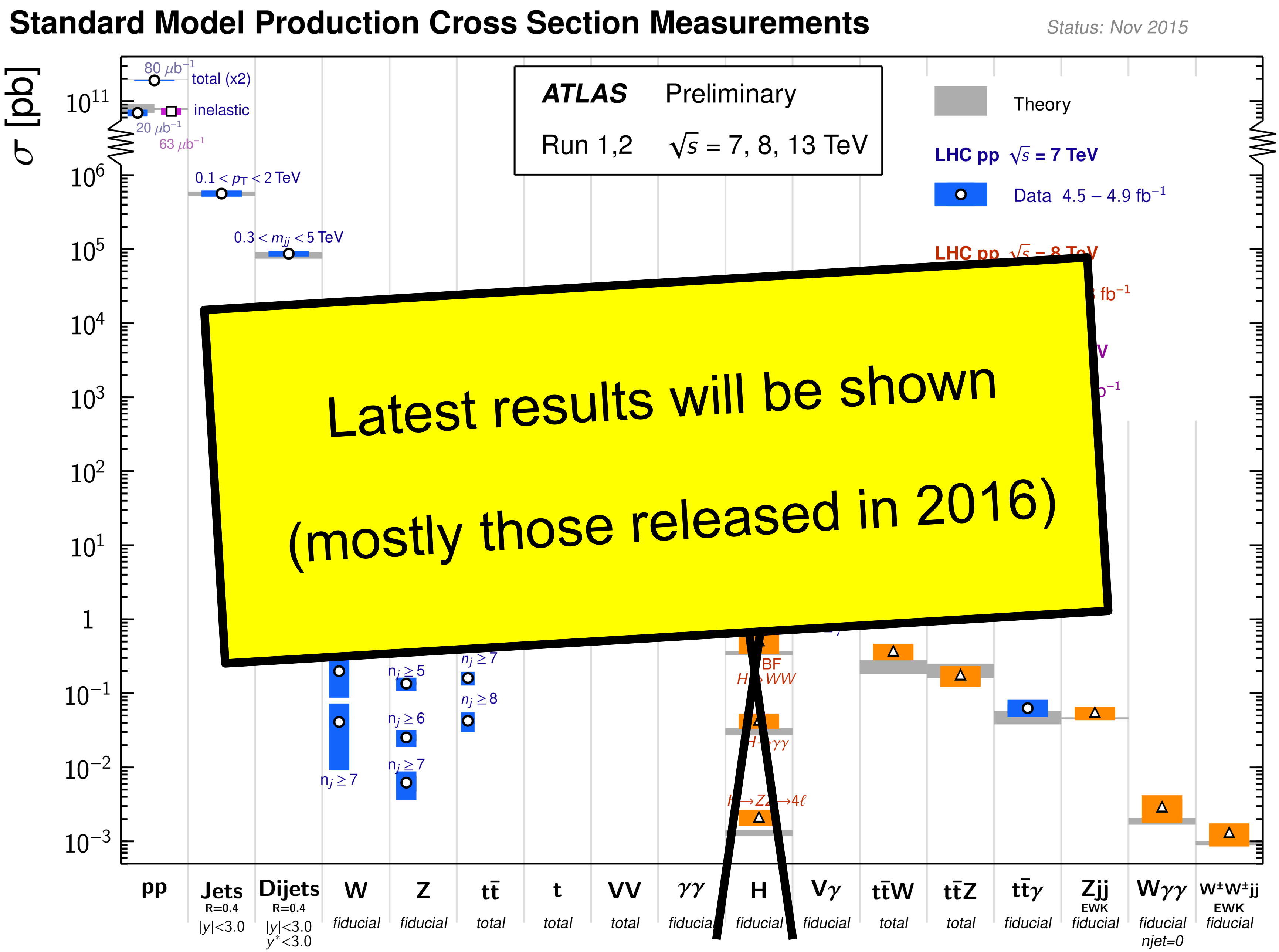
Outline

Standard Model Production Cross Section Measurements

Status: Nov 2015



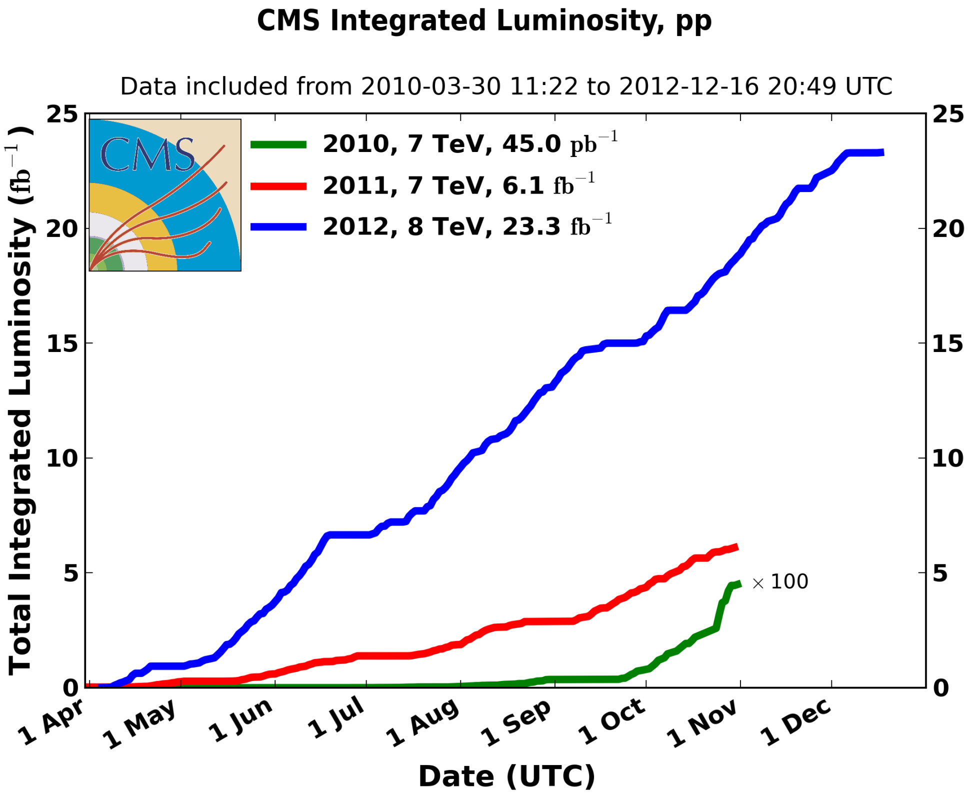
Outline

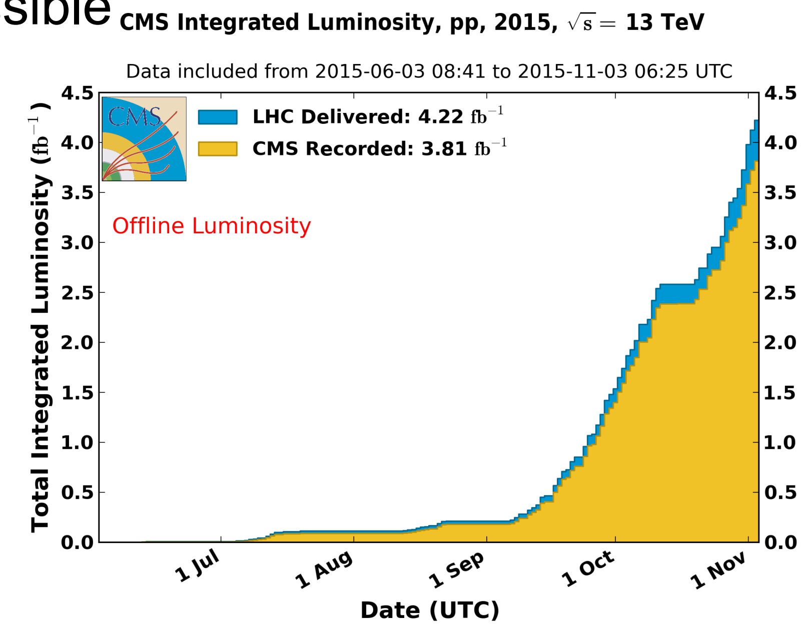


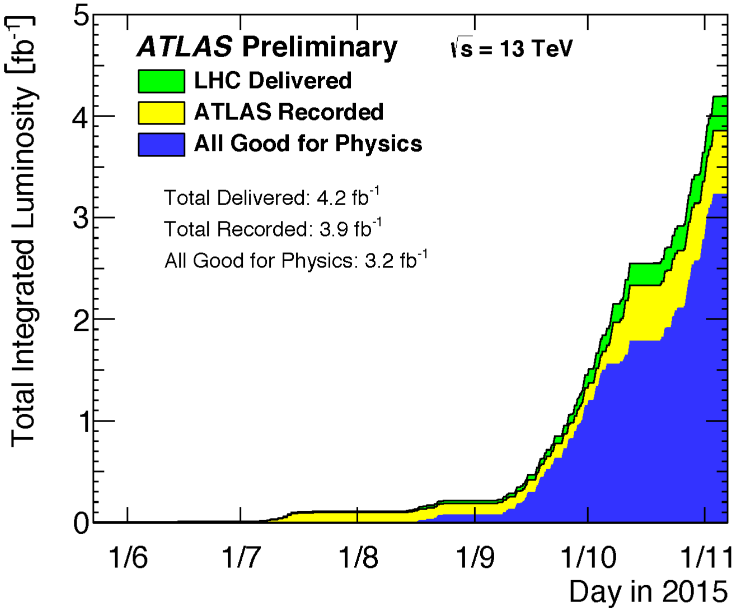
Standard Model Production Cross Section Measurements
Status: Nov 2015
σ [pb]
ATLAS Preliminary
Run 1,2 √s = 7, 8, 13 TeV
Theory
LHC pp √s = 7 TeV
Data 4.5 – 4.9 fb⁻¹
total (x2)
inelastic
0.1 < pT < 2 TeV
0.3 < mjj < 5 TeV
Latest results will be shown
(mostly those released in 2016)
pp
Jets R=0.4 |y|<3.0
Dijets R=0.4 |y|<3.0 y*<3.0
W fiducial
Z fiducial
tt̄ total
t total
VV total
γγ fiducial
H fiducial
Vγ fiducial
tt̄W total
tt̄Z total
tt̄γ fiducial
Zjj EWK fiducial
Wγγ fiducial njet=0
W±W±jj EWK fiducial

LHC Performance

- Without the **high luminosity and outstanding performance of the accelerator chain**, the results shown here would just not be possible





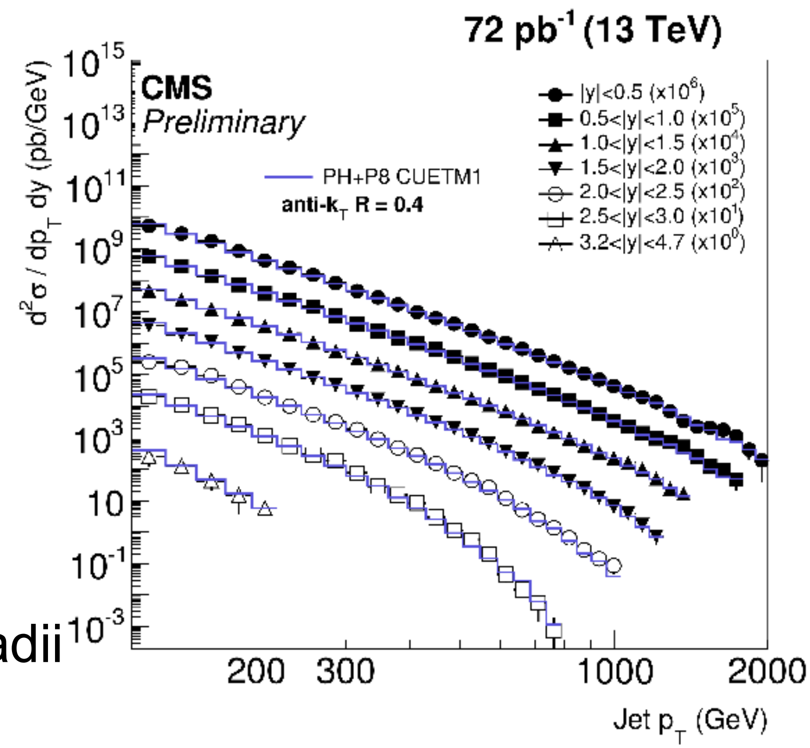


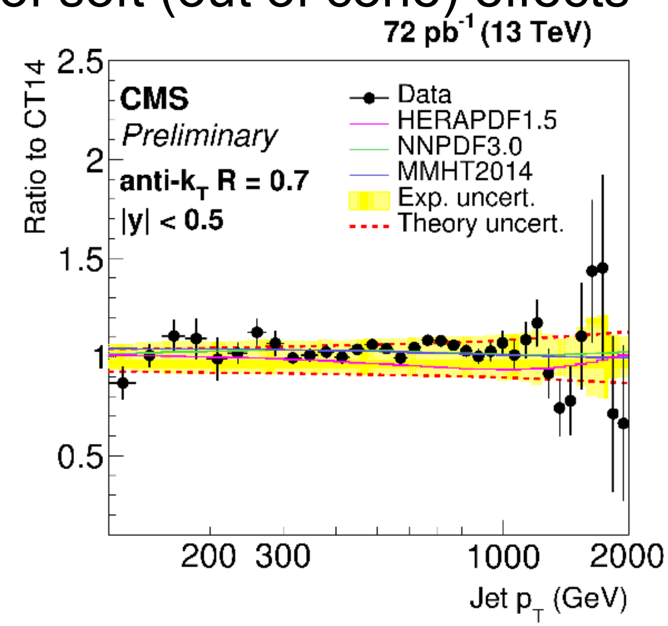
Jets

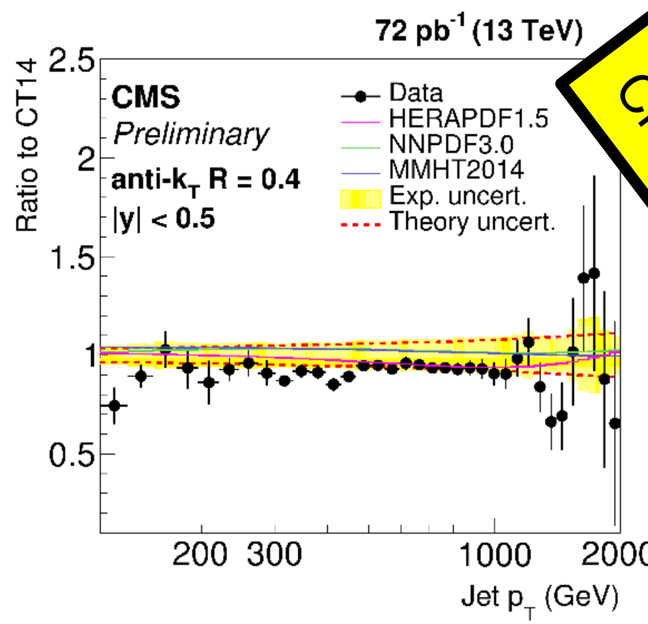
- QCD: very successful theory tested over decades in many experiments
- A deeper understanding of the jet production allow us to better understand
  - Scale uncertainties (important in many measurements)
  - Hadronization and fragmentation effects
- Typically, jet cross-section measurements are also important to validate the detector/trigger/reconstruction chain (first measurements at each new energy)

Inclusive Jet Cross Section @ 13 TeV (CMS)

- Double-differential cross-section for inclusive jets with R=0.7 and 0.4
- Compared to Powheg + Pythia8, NLOJet++ + NP and LO MC
- Agreement with NLO is in general better than LO
- Different behaviour observed between the two jet radii
  - Indication of soft (out of cone) effects



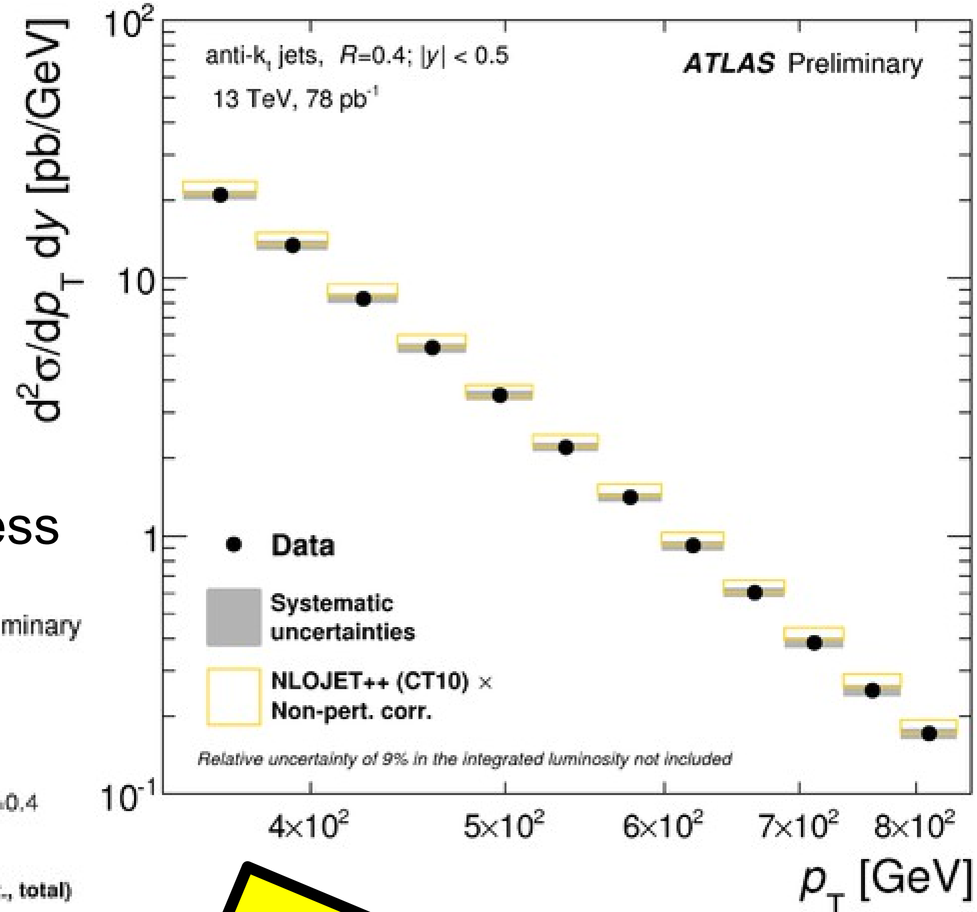


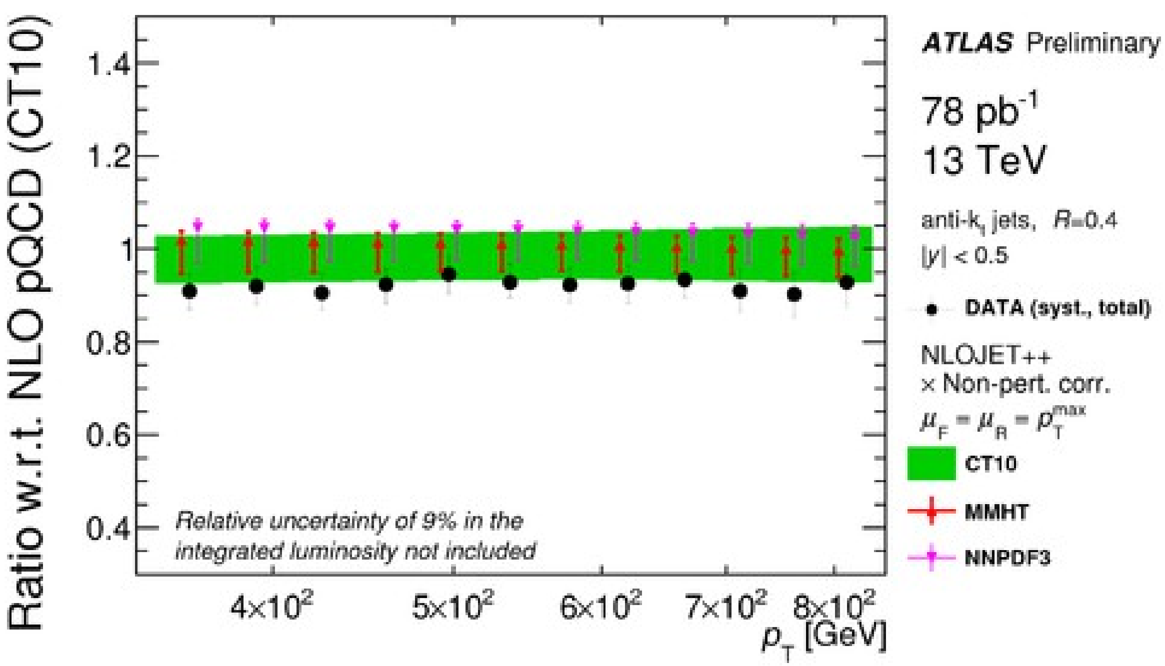


CMS-PAS-SMP-15-007

Inclusive Jet Cross Section @ 13 TeV (ATLAS)

- Measurement so far restricted to R=0.4 jets and only the central rapidity bin
- Iterative unfolding applied to data
- Comparison performed with NLOJet++ + NP corr., and two PDF sets
- Uncertainties highly correlated, proper estimate of compatibility with theory in progress





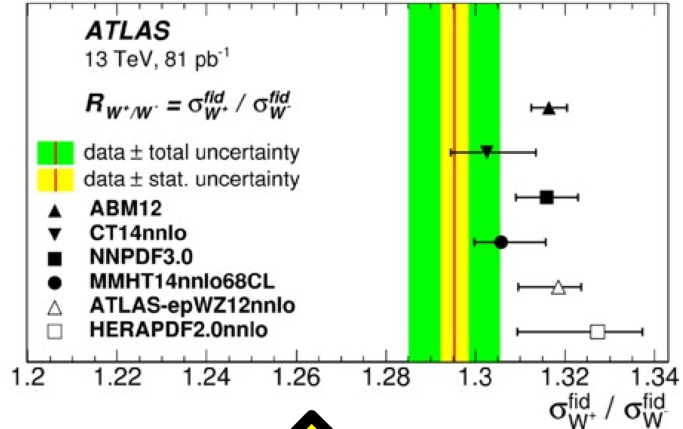
ATLAS-CONF-2015-034

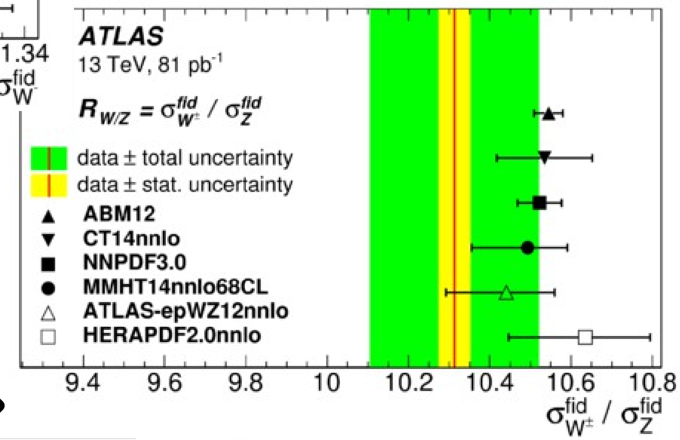
Inclusive Single Boson Production

- Cross-section measurements and ratios are sensitive to PDFs
  - Used to constrain PDFs - important for other LHC measurements
- Measurements made for electrons and muons in fiducial cross-section (also extrapolated to total cross-section measurements)
- Measured cross-sections (and ratios) compared to theoretical predictions from different PDF sets

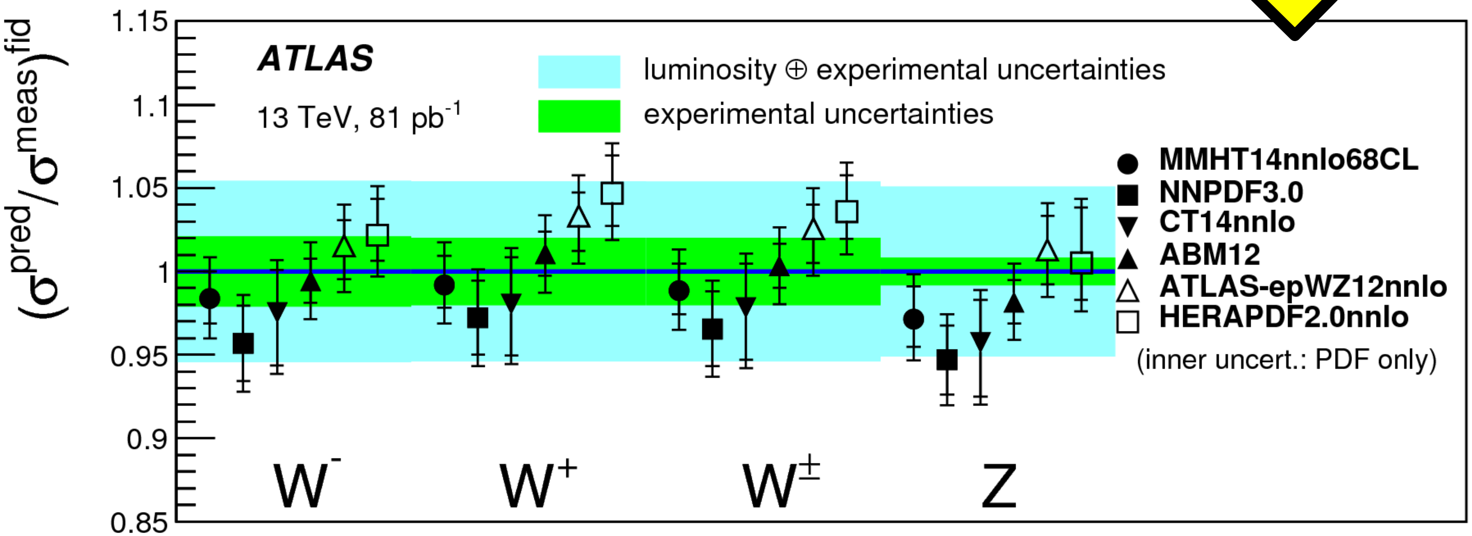
W/Z Production Cross Section @ 13 TeV (ATLAS)

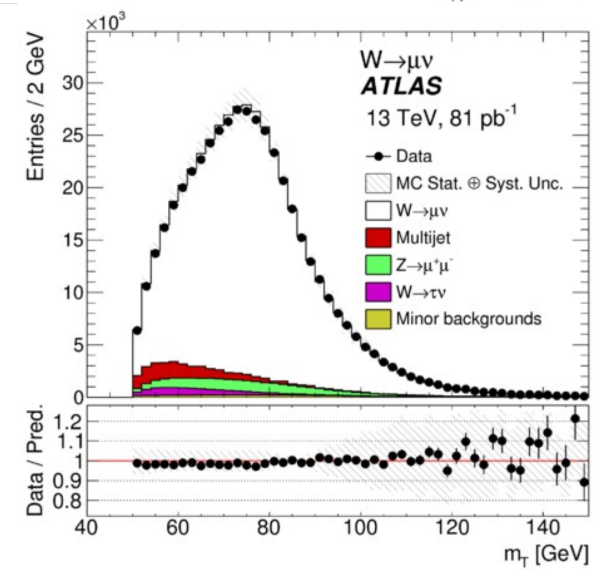
- Z selection:
  - $p_T(\ell) > 25$ GeV, $|\eta(\ell)| < 2.5$
  - $66 < m(\ell^+\ell^-) < 116$ GeV
- W selection:
  - $p_T(\ell) > 25$ GeV, $|\eta(\ell)| < 2.5$
  - MET > 25 GeV, $m_T > 50$ GeV
- Good agreement with theoretical predictions





arXiv:1603.09222

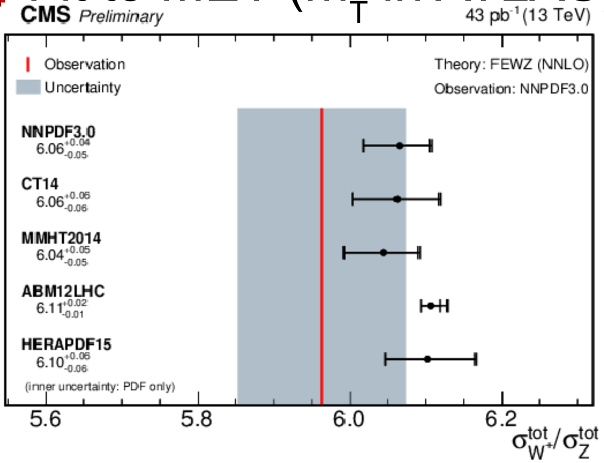


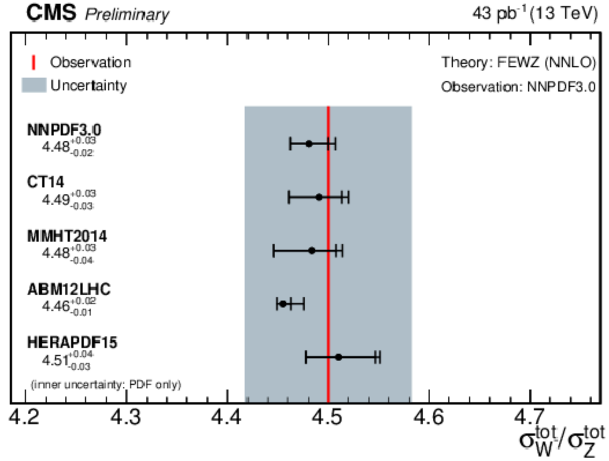


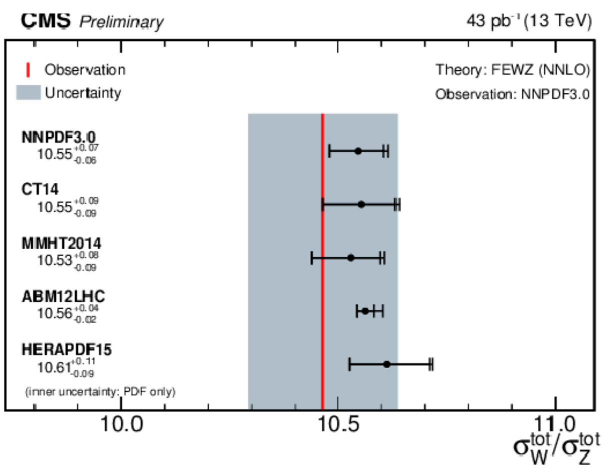
W/Z Production Cross Section @ 13 TeV (CMS)

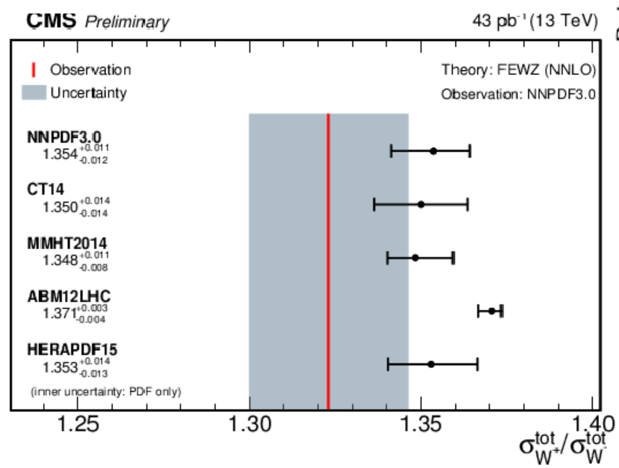
CMS-PAS-SMP-15-004

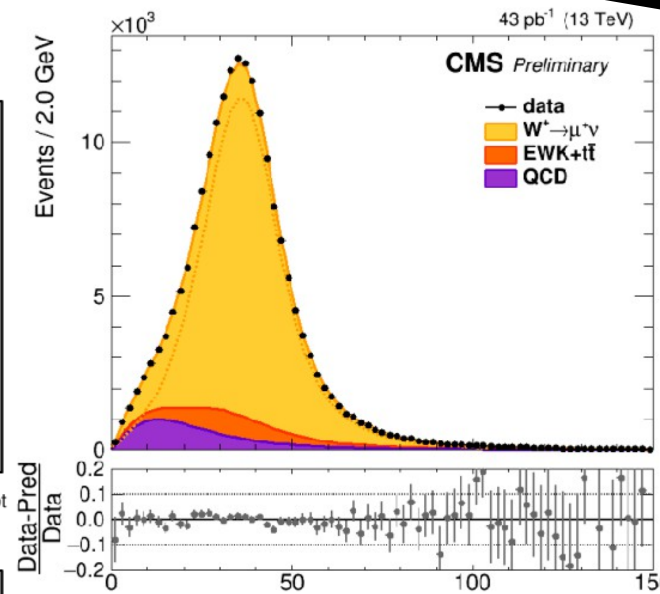
- Similar selection except 60 < $m(\ell^+\ell^-)$ < 120 GeV for Z boson
- Fit to MET (m_T in ATLAS)



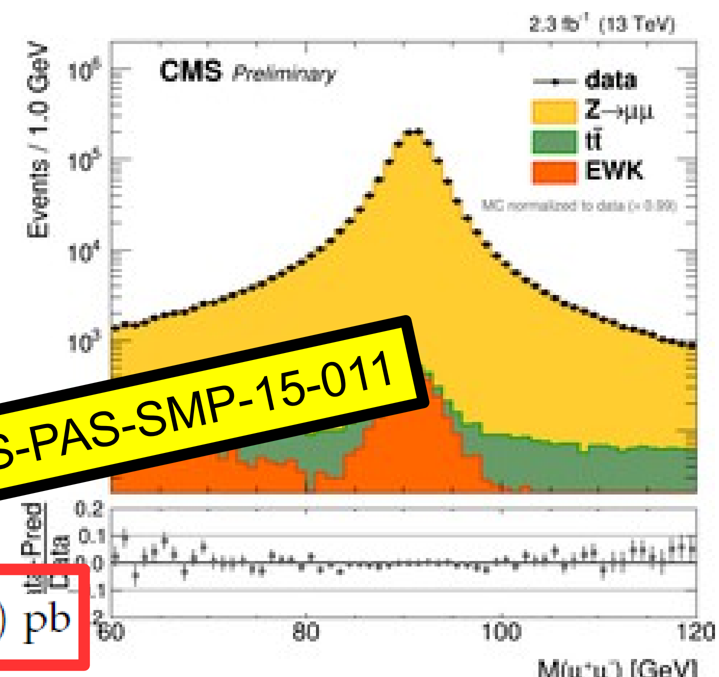








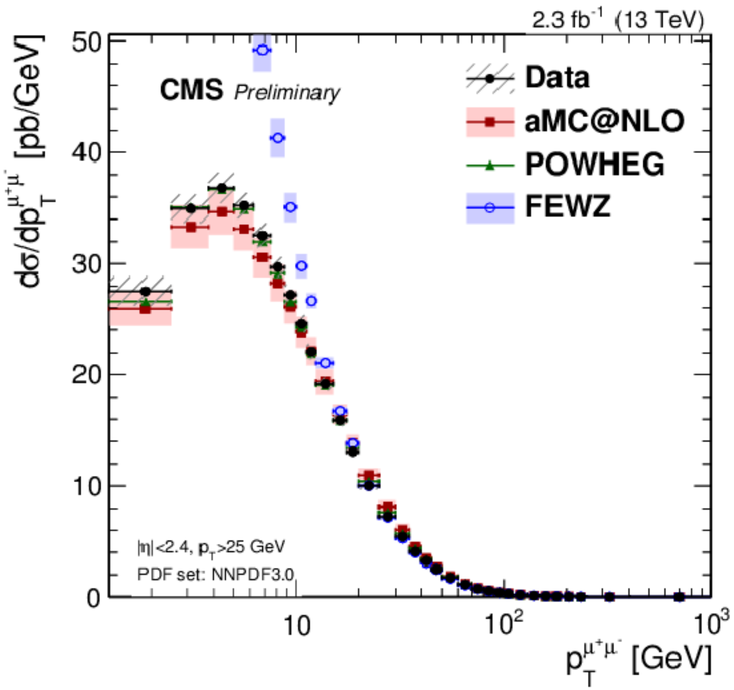
- Cross-section ratios in agreement with NNLO
- CMS: Z→μμ updated with full dataset



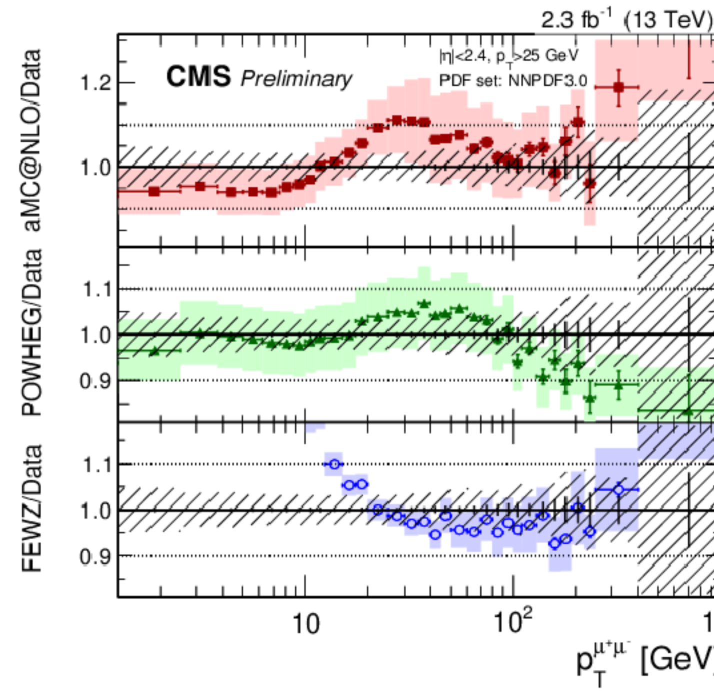
CMS-PAS-SMP-15-011

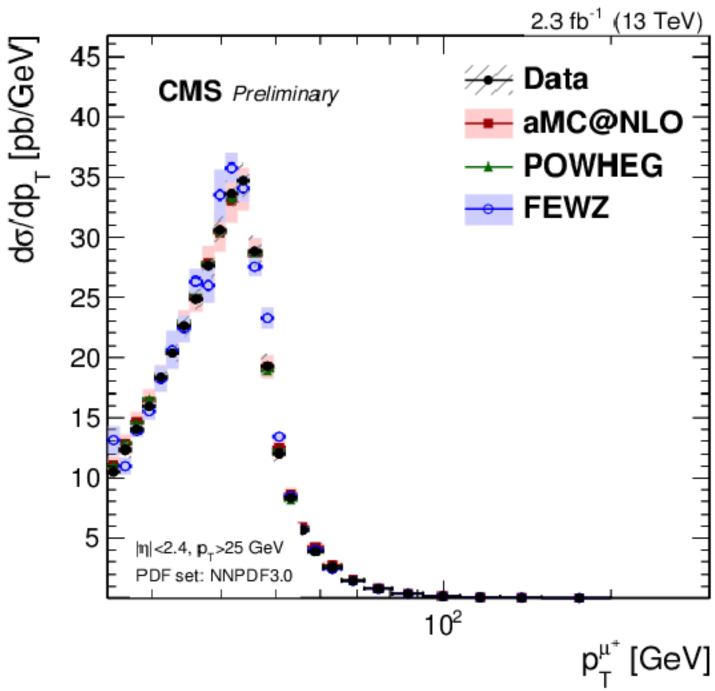
$$\sigma(pp \to ZX) \times \mathcal{B}(Z \to \mu^+\mu^-) = 1870 \pm 2\ (\mathrm{stat}) \pm 35\ (\mathrm{syst}) \pm 51\ (\mathrm{lumi})\ \mathrm{pb}$$

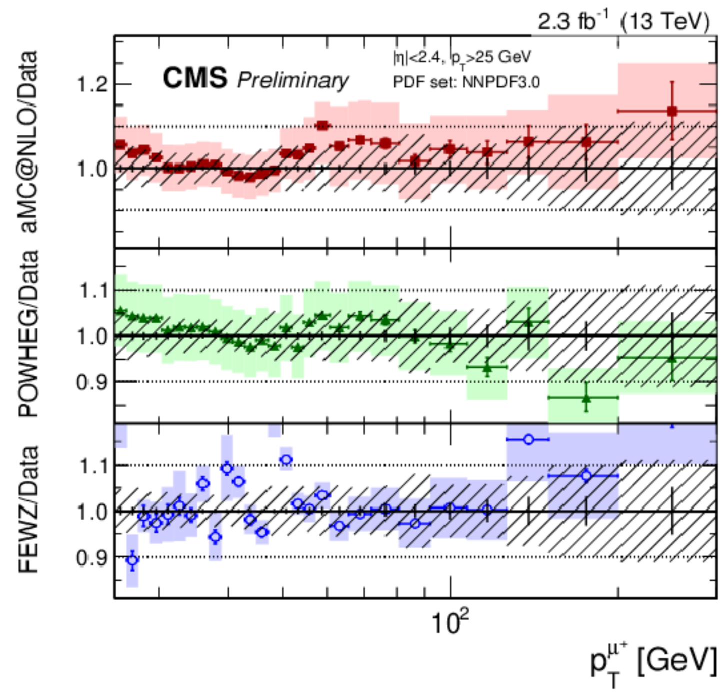
Z Differential Cross Section @ 13 TeV



CMS-PAS-SMP-15-011





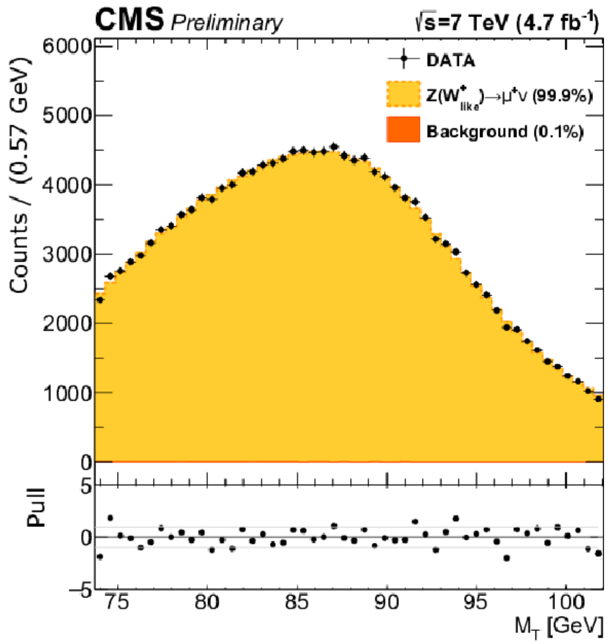


W-like measurement of the Z mass @ 7 TeV

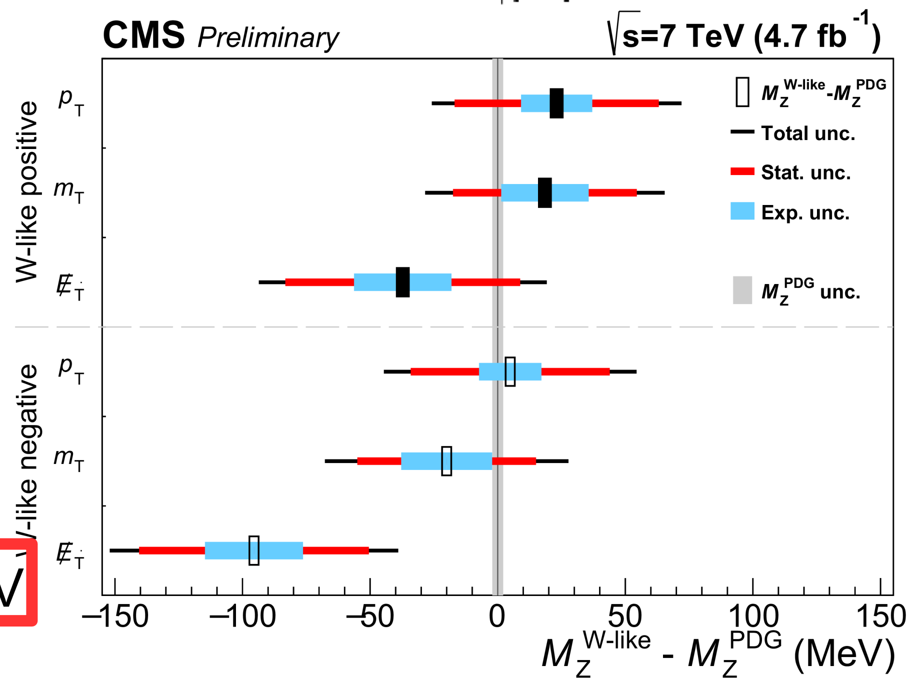
- Proof of principle and quantitative validation of techniques developed for a high-precision measurement of m_W in $W \to \mu\nu$ events
- Sample of 2×10^5 $Z\to\mu^+\mu^-$ used
  - $m(\mu^+\mu^-) > 50$ GeV
  - Event enters in the + (-) W-like sample if
    - μ^+ (μ^-) has $p_T > 30$ GeV, $|\eta| < 0.9$
    - μ^- (μ^+) has $p_T > 10$ GeV and $|\eta| < 2.1$
- Z mass extracted through the W-like lepton p_T, m_T and MET
- Lowest uncertainty for W-like+ m_T

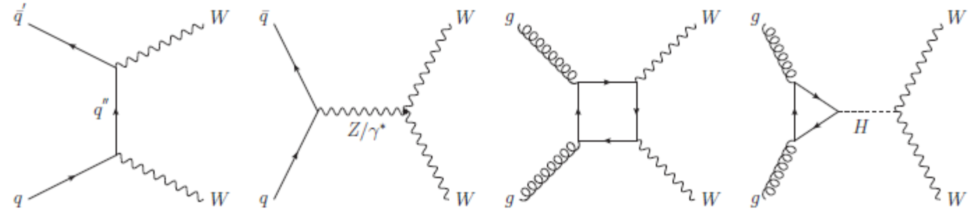
m(W-like Z) = 91206 ± 36 (stat) ± 30 (syst) MeV

m(Z PDG) = 91187.6 ± 2.1 MeV



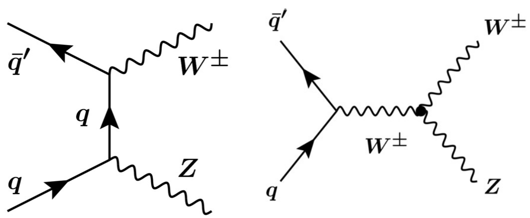
CMS-PAS-SMP-14-007

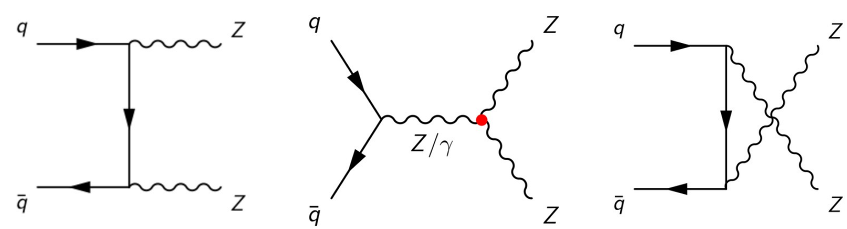




(a) t- channel (b) s- channel (TGC vertex) (c) gluon fusion (d) Higgs boson production

Inclusive Diboson Production

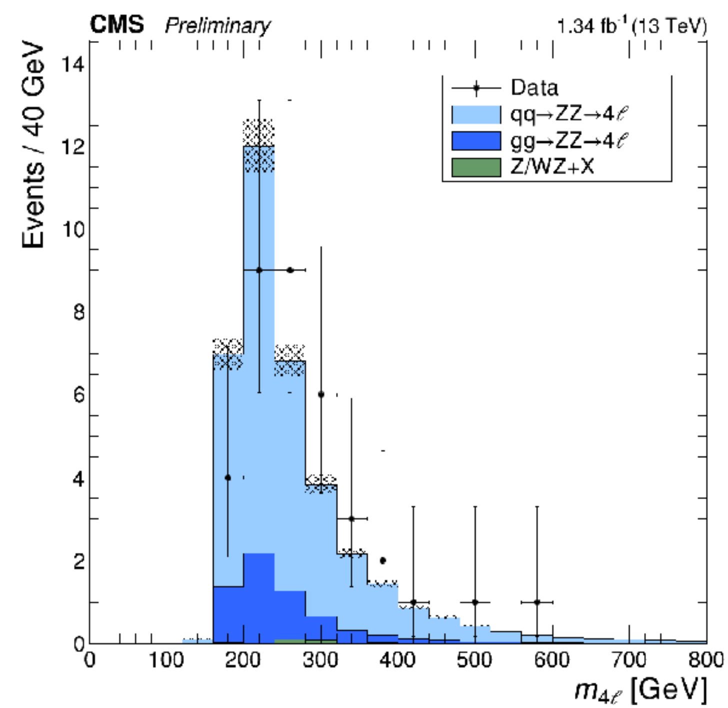




- WW, WZ, ZZ, Wγ, Zγ
- EWK precision measurements with higher order corrections
- Explore new final states never observed before
- Searching for SM breakdown → new physics beyond SM

ZZ (→ ℓ⁺ℓ⁻ℓ'⁺ℓ'⁻) Production @ 13 TeV

- Selection: 4 OS leptons ($e^+e^-e^+e^-$, $e^+e^-\mu^+\mu^-$, $\mu^+\mu^-\mu^+\mu^-$)
  - CMS: $p_T(Z, \ell 1) > 20$ GeV, $p_T(Z, \ell 2) > 10$ GeV
    $60 < M(Z_{1,2}) < 120$ GeV
  - ATLAS: $p_T(Z, \ell 1) > 20$ GeV; $66 < m(Z_{1,2}) < 116$ GeV
- Fake background measured from data
- CMS (ATLAS) observes 36 (63) events
  with 0.1 (0.62) expected bkg



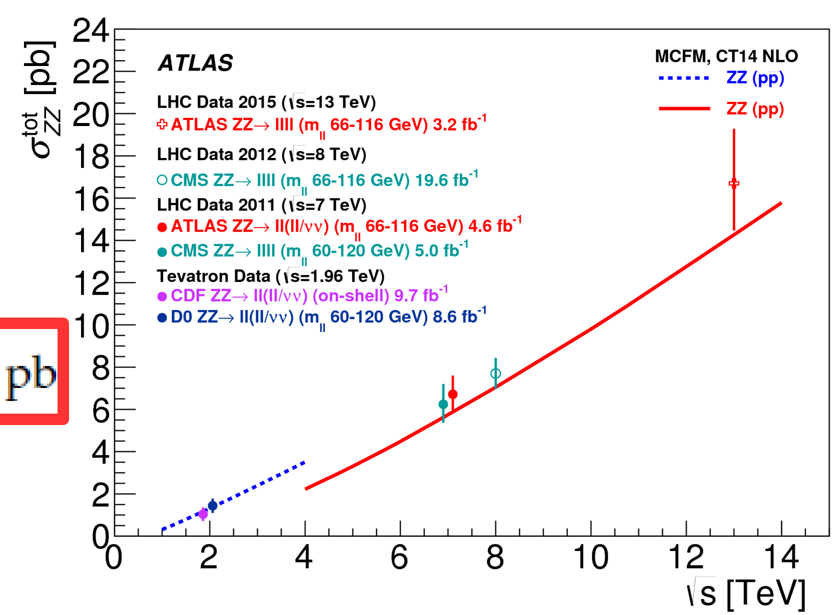
Phys. Rev. Lett. 116, 101801 (2016)

$$16.7\ ^{+2.2}_{-2.0}(\text{stat.})\ ^{+0.9}_{-0.7}(\text{syst.})\ ^{+1.0}_{-0.7}(\text{lumi.})\ \text{pb}$$

CMS-PAS-SMP-15-005

$$\sigma(\text{pp}\to\text{ZZ}) = 16.7^{+2.9}_{-2.6}\,(\text{stat})^{+0.7}_{-0.5}\,(\text{syst}) \pm 0.3\,(\text{theo}) \pm 0.8\,(\text{lum})\,\text{pb}$$

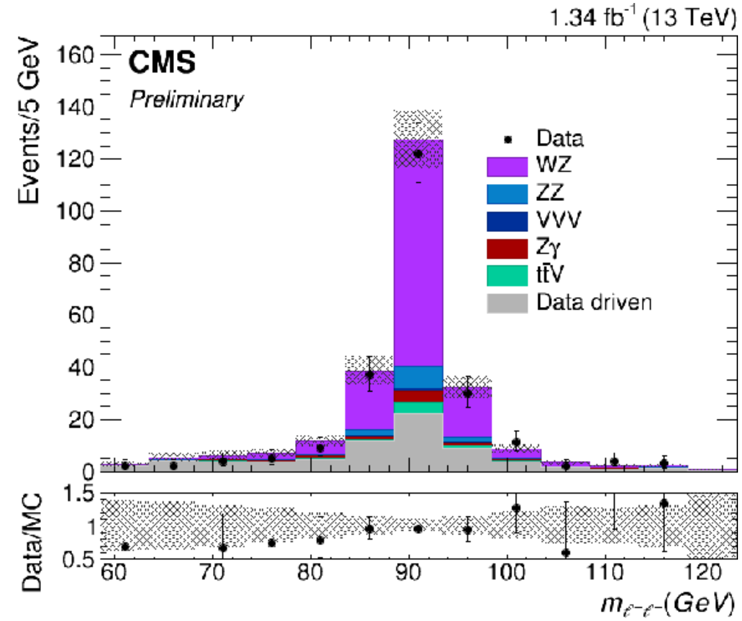
$$\sigma(\text{NNLO}) = 16.5^{+0.7}_{-0.5}\ \text{pb}$$



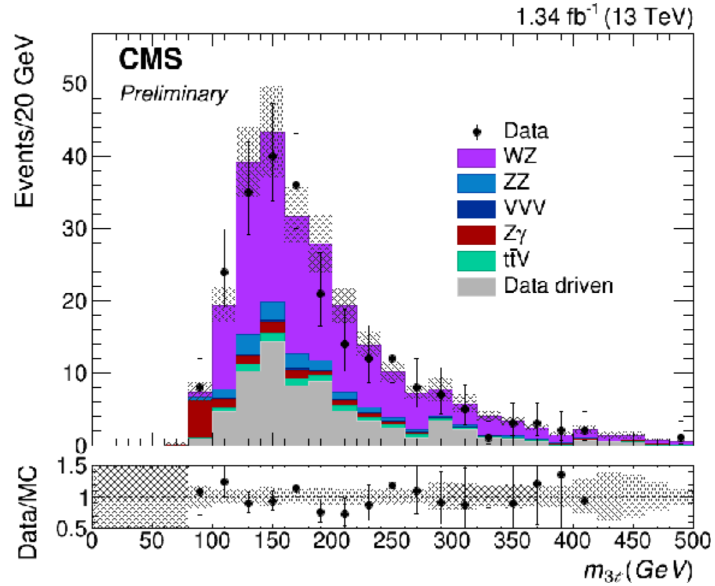
- Statistics main uncertainty

WZ ($\to \ell^+\ell\ell'\nu$) Production @ 13 TeV (CMS)

- Selection: 3 leptons ($e^\pm e^\mp \mu^\pm$, $\mu^\pm \mu^\mp e^\pm$)
  - W: $p_T(W, \ell 1) > 20$ GeV, MET > 30 GeV
  - Z (OS SF 2ℓ): $p_T(Z, \ell 1) > 20$ GeV, $p_T(Z, \ell 2) > 10$ GeV, $106 < m(Z) < 120$ GeV
  - $m(3\ell) > 100$ GeV



- Fake background measured from data (main systematic)



CMS-PAS-SMP-15-006

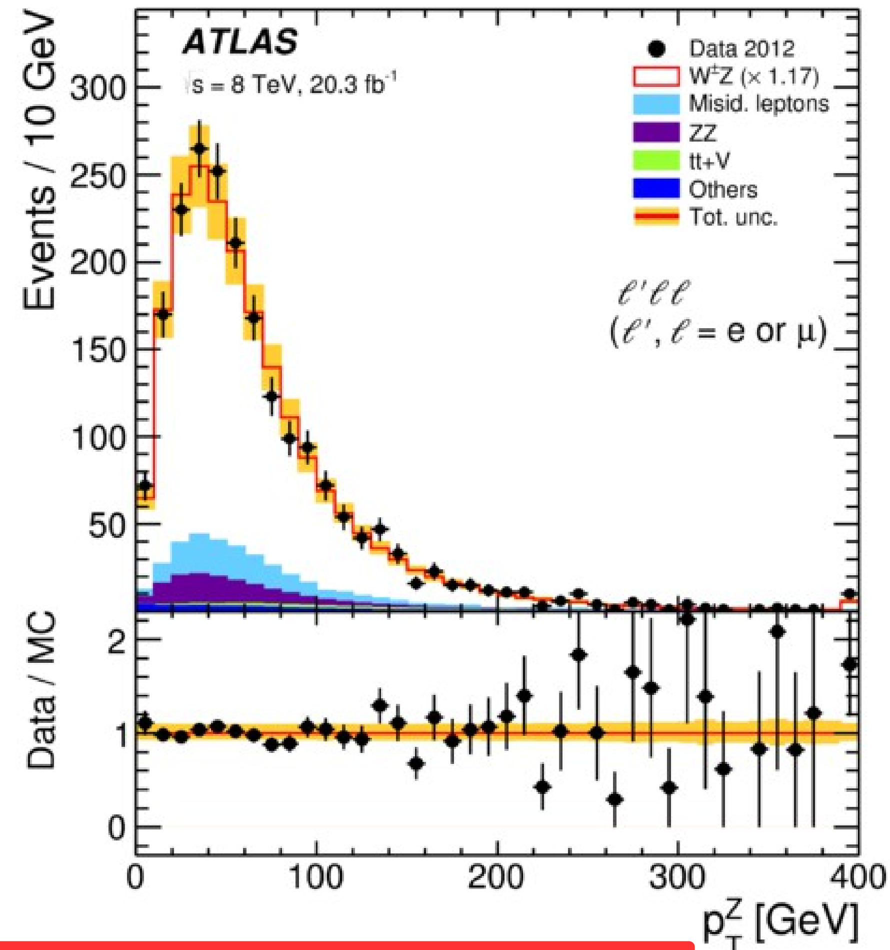
$$\sigma(pp \to WZ) = 36.8 \pm 4.6\,(\mathrm{stat})^{+8.1}_{-6.2}\,(\mathrm{syst}) \pm 0.6\,(\mathrm{theo}) \pm 1.7\,(\mathrm{lum})\ \mathrm{pb}$$

- Consistent with NLO prediction: $\sigma^{tot}_{NLO} = 42.7^{+1.6}_{-0.8}$ pb
- Dominated by systematic uncertainties

WZ ($\rightarrow \ell^+\ell^-\ell'\nu$) Production @ 8 TeV (ATLAS)

- Similar selection
  - Additional lepton $p_T(Z, \ell 2)$ > 20 GeV

Channel	eee	μee	$e\mu\mu$	$\mu\mu\mu$	All
Data	406	483	539	663	2091
Total expected	336.7 ± 2.2	410.8 ± 2.4	469.1 ± 2.1	608.2 ± 3.5	1824.8 ± 7.0
WZ	255.7 ± 1.1	337.2 ± 1.0	367.0 ± 1.1	495.9 ± 2.3	1455.7 ± 5.5
Misid. leptons	43.7 ± 1.9	32.2 ± 2.1	50.2 ± 1.7	52.8 ± 2.6	178.9 ± 4.2
ZZ	25.9 ± 0.2	26.7 ± 0.3	36.1 ± 0.3	39.5 ± 0.3	128.2 ± 0.6
$t\bar{t} + V$	5.5 ± 0.2	6.7 ± 0.2	7.2 ± 0.3	9.1 ± 0.3	28.5 ± 0.5
tZ	4.2 ± 0.1	5.5 ± 0.2	6.0 ± 0.2	7.7 ± 0.2	23.3 ± 0.3
DPS	1.2 ± 0.1	1.9 ± 0.1	1.8 ± 0.1	2.3 ± 0.2	7.2 ± 0.3
VVV	0.5 ± 0.0	0.7 ± 0.0	0.8 ± 0.0	0.9 ± 0.0	3.0 ± 0.1



- Main syst: fake lepton and electron id

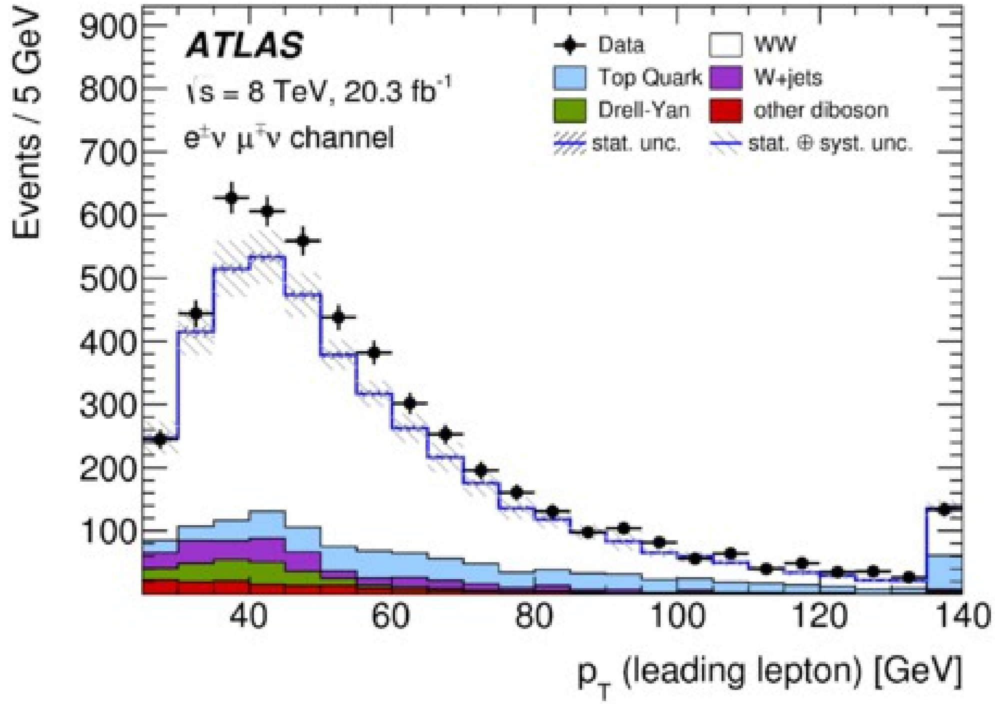
$$\boxed{\sigma^{\text{tot.}}_{W^\pm Z} = 24.3 \pm 0.6\,(\text{stat.}) \pm 0.6\,(\text{sys.}) \pm 0.4\,(\text{th.}) \pm 0.5\,(\text{lumi.})\ \text{pb}}$$

σ(NLO) = 21.0 ± 1.6 pb

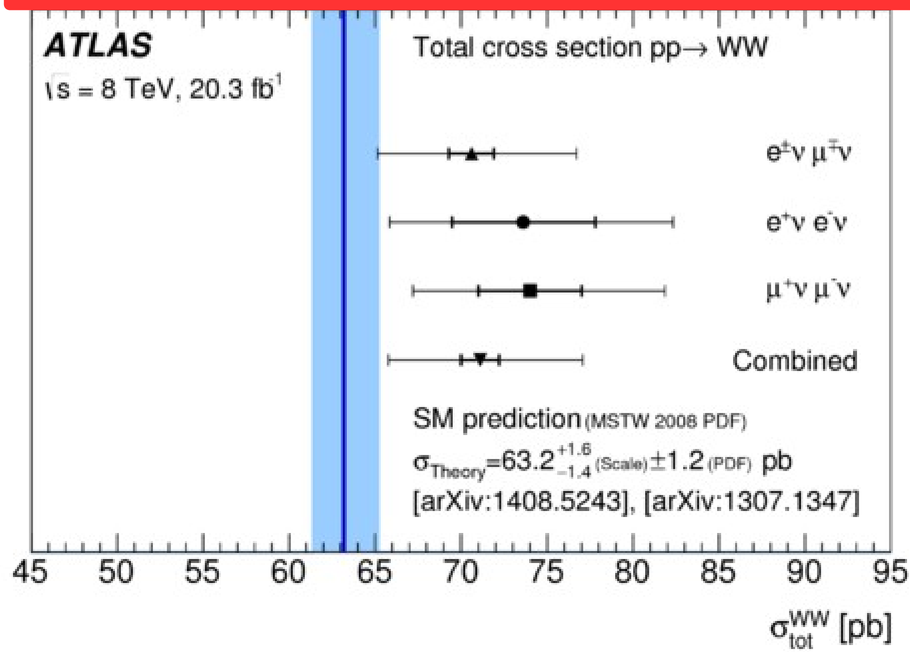
arXiv:1603.02151

WW ($\to \ell^+\nu\ell^-\nu$) Production @ 8 TeV (ATLAS)

- Selection: 2 OS leptons (e^+e^-, $e^\pm\mu^\mp$, $\mu^+\mu^-$)
  - $p_T(W, \ell1) > 25$ GeV , $p_T(W, \ell2) > 20$ GeV
  - MET > 45 (20) GeV for ee and μμ (eμ)
  - $m(\ell\ell) > 15$ (10) GeV for ee and μμ (eμ)
  - Other vetos: jet, Z, third lepton, top
- Signal modeling main systematic



$$\sigma = 71.1 \pm 1.1(\text{stat})\ {}^{+5.7}_{-5.0}(\text{syst}) \pm 1.4(\text{lumi})$$



- Consistent within 1.4 sigma with NLO prediction (Higgs → WW as signal):

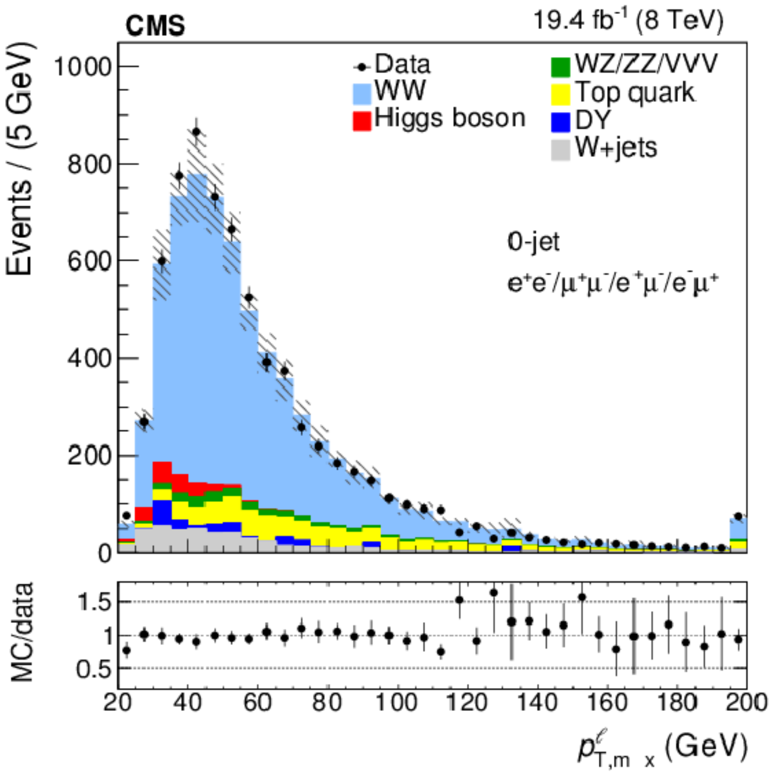
$$\sigma(\text{NNLO}) = 63.2^{+1.6}_{-1.4}(\text{scale}) \pm 1.2(\text{PDF})$$

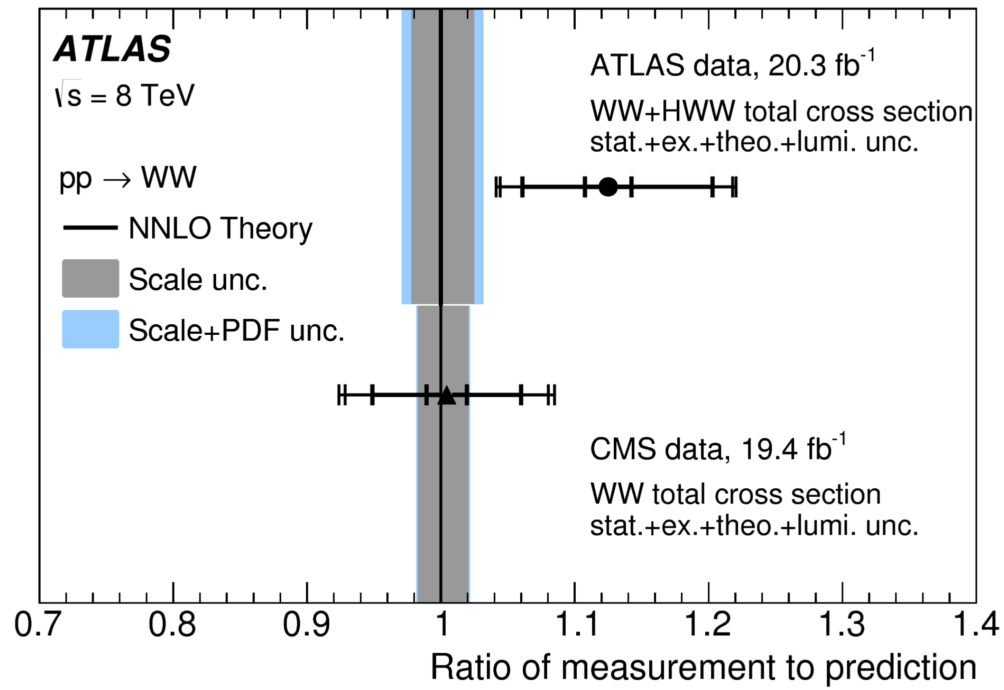
arXiv:1603.01702

WW ($\to \ell^+\nu\ell^-\nu$) Production @ 8 TeV (CMS)

arXiv: 1507.03268

- Similar selection
  - p_T(W, ℓ1 and ℓ2) > 20 GeV
  - MET > 20 GeV
  - m(ℓℓ) > 12 GeV
  - Other vetos: jet, Z, third lepton, top





$$\sigma_{W^+W^-} = 60.1 \pm 0.9\,(\mathrm{stat}) \pm 3.2\,(\mathrm{exp}) \pm 3.1\,(\mathrm{theo}) \pm 1.6\,(\mathrm{lumi})\,\mathrm{pb} = 60.1 \pm 4.8\,\mathrm{pb}$$

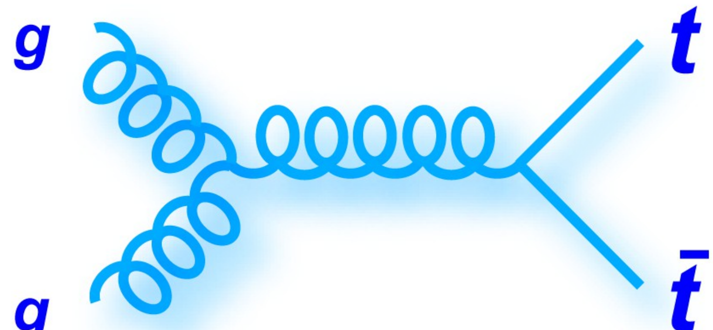
- Good agreement with NNLO (no Higgs → WW): σ(NNLO) = $59.8^{+1.3}_{-1.1}$ pb

Top Physics

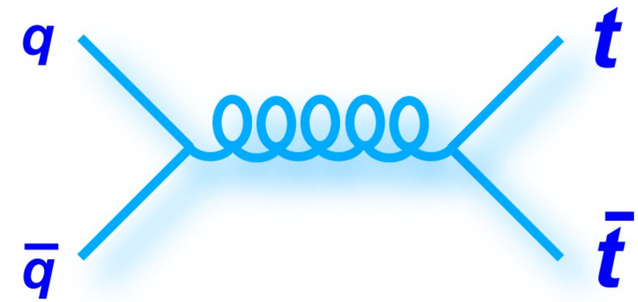
Top Quark Production @LHC

- Top quark pairs are produced via QCD production

CME	σ (pb)
7 TeV	177.3
8 TeV	252.9
13 TeV	831.7



Gluon fusion (85%)

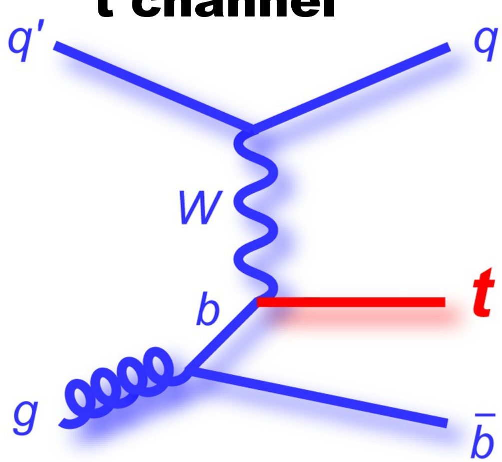


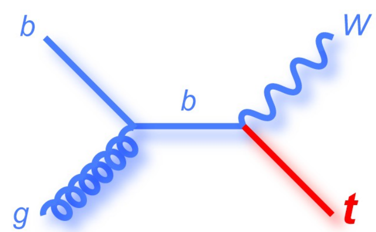
qq annihilation (15%)

- Single top quarks are produced via EWK interaction

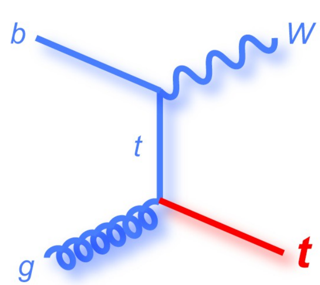
	σ (pb)		
CME	**t-channel**	**tW**	**s-channel**
7 TeV	63.9	15.7	4.3
8 TeV	84.7	22.2	5.6
13 TeV	217.0	71.2	11.4

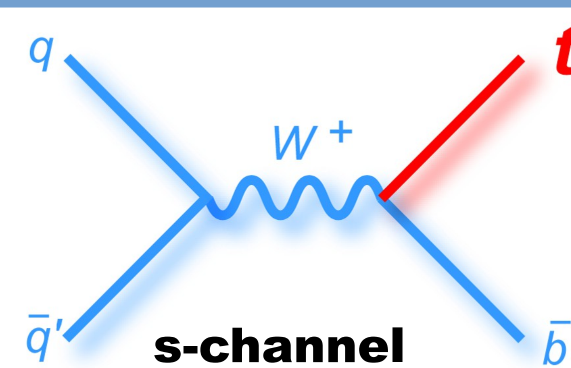
t channel





tW channel

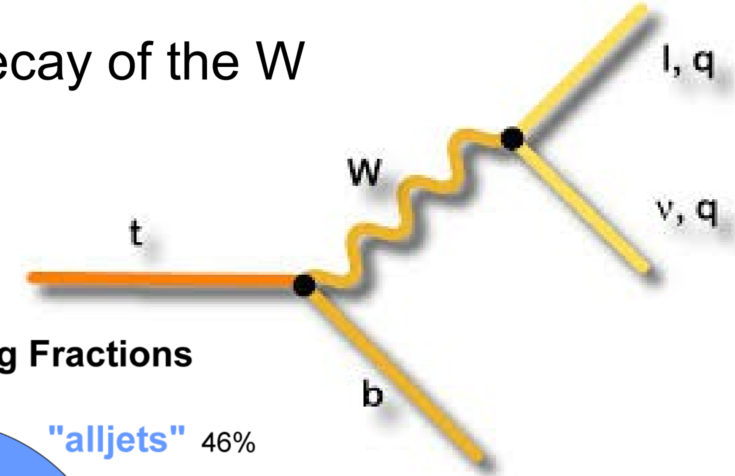




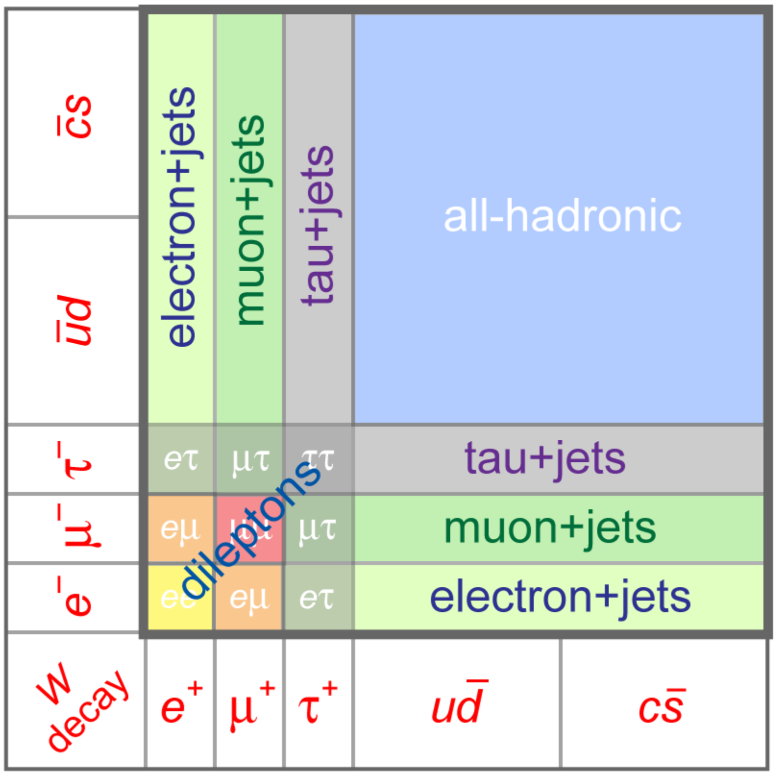
s-channel

Top Quark Decay

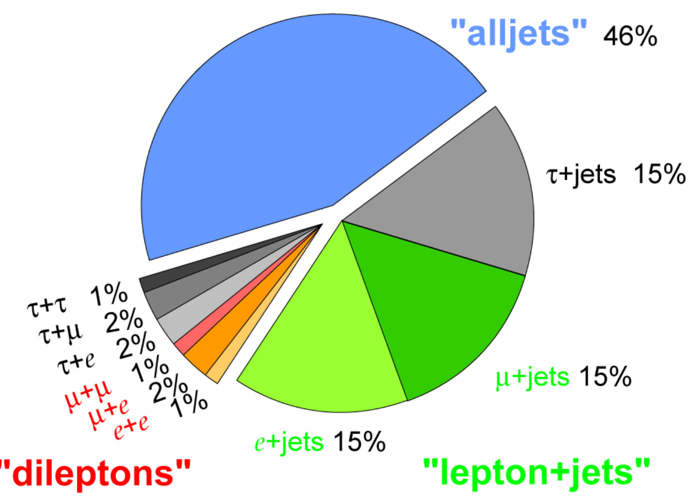
- BR(t → Wb) ≈1 ⇒ top quark decay is driven by the decay of the W

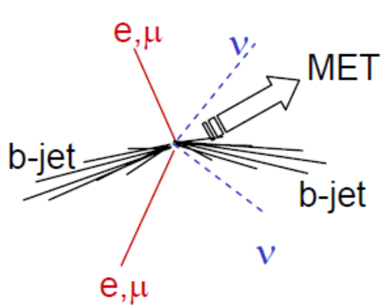


Top Pair Decay Channels

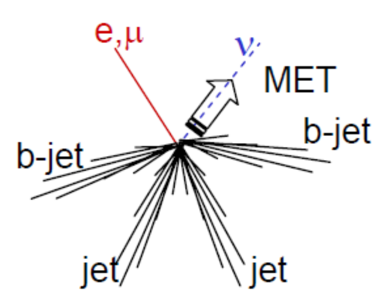


Top Pair Branching Fractions

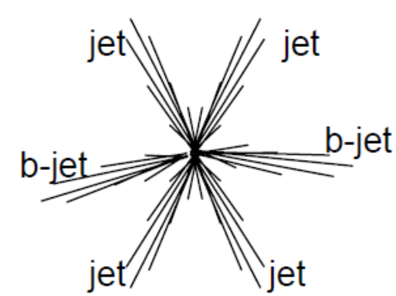




dileptons



lepton + jets

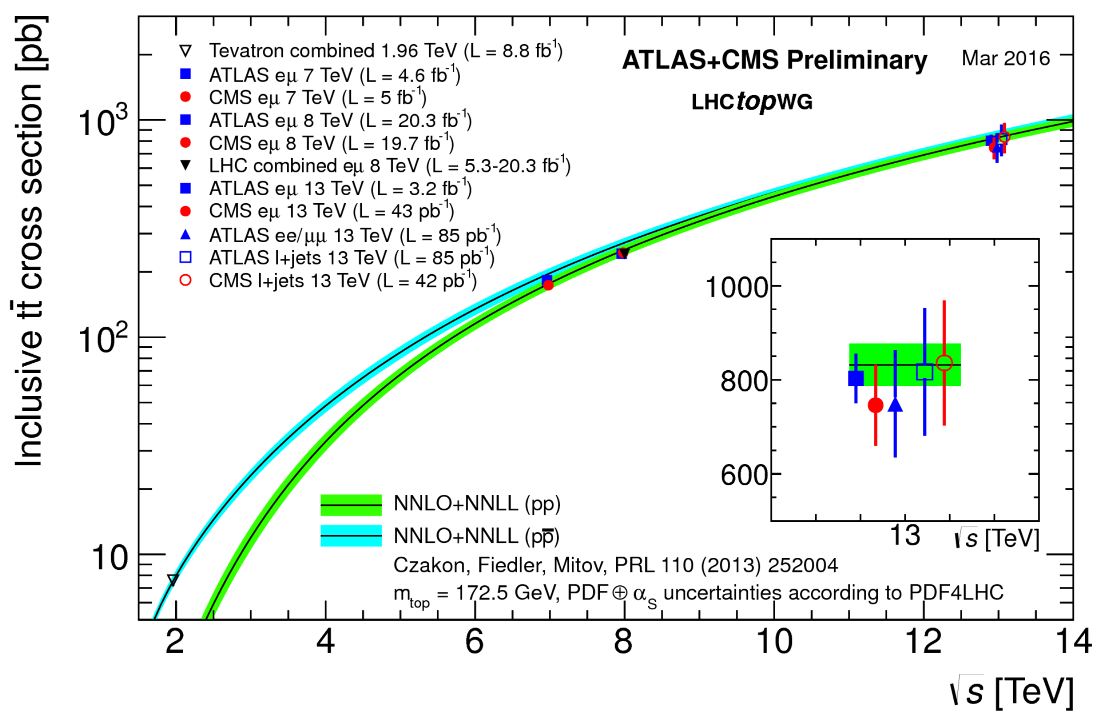


all hadronic

Top pair production cross sections

- Stringent test of pQCD predictions
- Rediscovery → precision
  - 8 TeV: experimental uncertainty better than theory
  - 13 TeV: getting closer
- Useful as **probe for new Physics!**

pp → X → tt



Inclusive Cross Section @ 13 TeV (ATLAS)

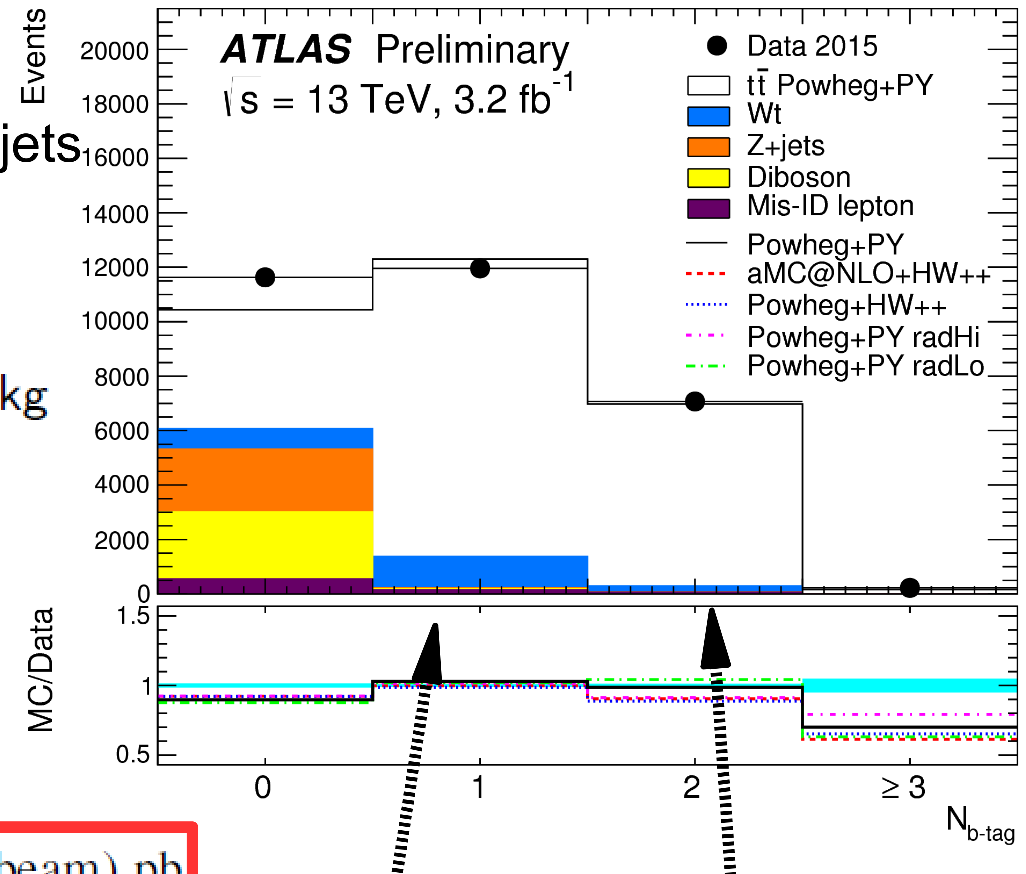
ATLAS-CONF-2016-005

- Dilepton (e-mu) channel
- Fit σ(tt) and ε_b using number of b-tagged jets
  - Jets with p_T> 25 GeV and $|\eta|$< 2.5

$$N_1 = L\sigma_{t\bar{t}}\epsilon_{e\mu}2\epsilon_b(1 - C_b\epsilon_b) + N_1^{\mathrm{bkg}}$$

$$N_2 = L\sigma_{t\bar{t}}\epsilon_{e\mu}C_b\epsilon_b^2 + N_2^{\mathrm{bkg}}$$

  - Profit from statistics to constraint in-situ some systematics



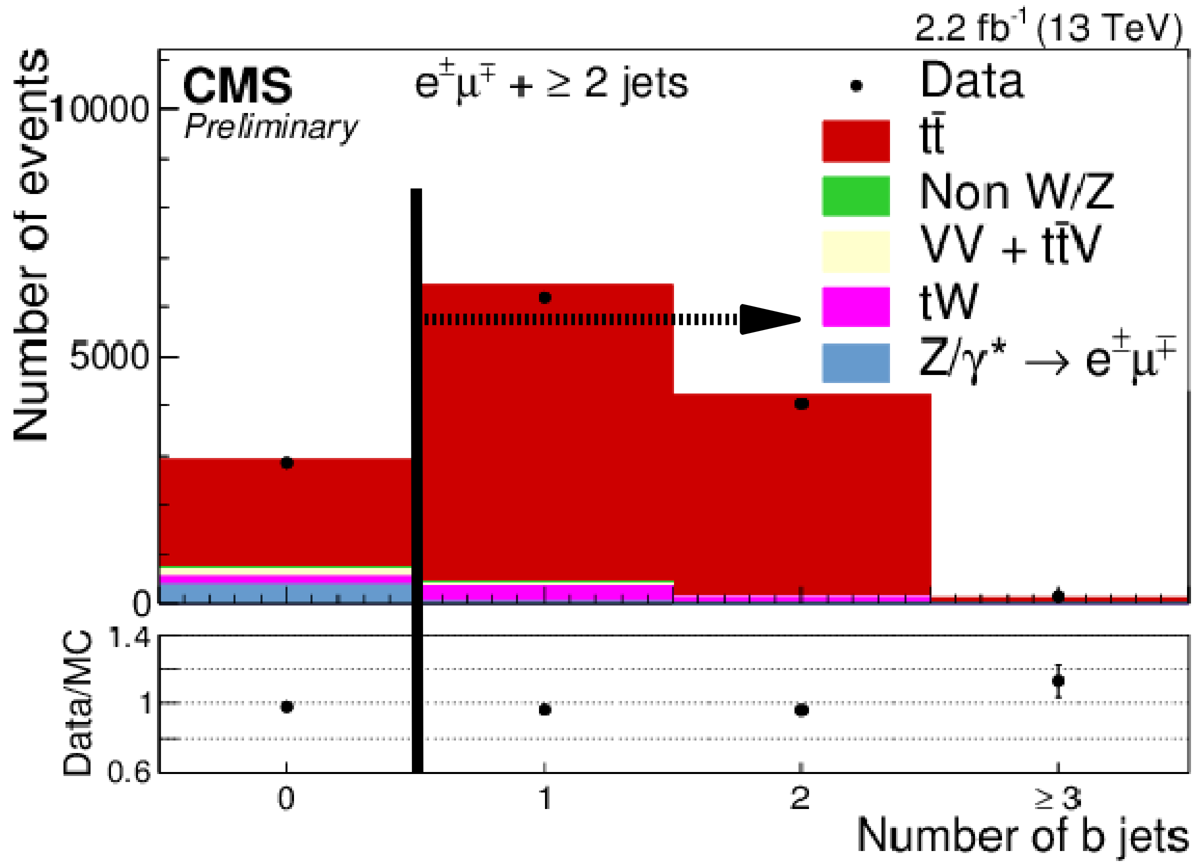
$$\sigma_{t\bar{t}} = 803 \pm 7\ (\mathrm{stat}) \pm 27\ (\mathrm{syst}) \pm 45\ (\mathrm{lumi}) \pm 12\ (\mathrm{beam})\ \mathrm{pb}$$

- Largest uncertainty: hadronization, luminosity

Inclusive Cross Section @ 13 TeV (CMS)

- Dilepton (e-mu) channel
- On top of the dilepton selection:
  - ≥ 2 jets with with p_T> 30 GeV and |η|< 2.4
  - ≥ 1 b-tag jet
- Simple and robust cut and count technique

$$\sigma(t\bar{t}) = \frac{N_{data} - N_{bkg}}{A \cdot \epsilon \cdot BR \int dt\, L}$$

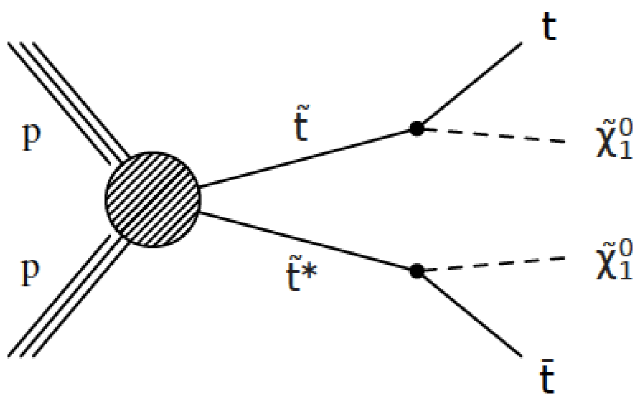


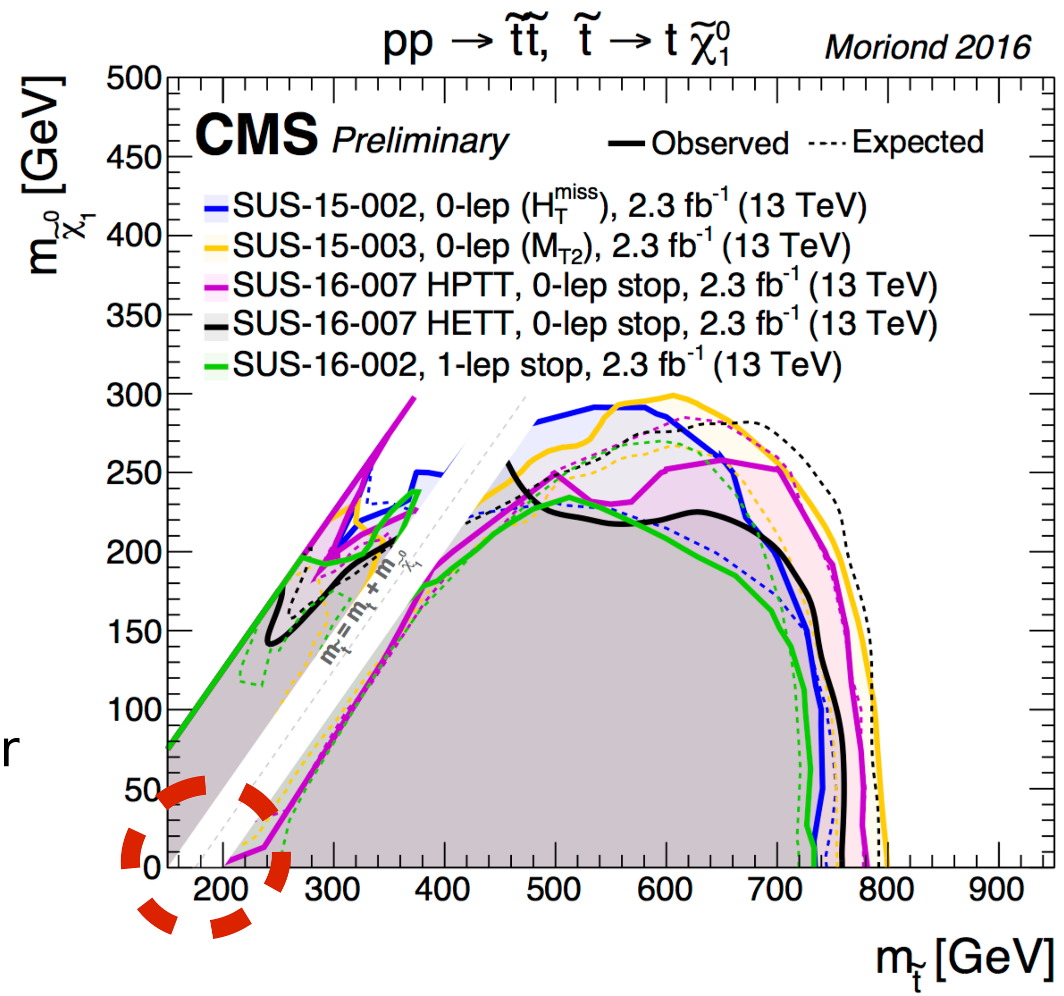
$$\sigma_{t\bar{t}} = 793 \pm 8\,(\mathrm{stat}) \pm 38\,(\mathrm{syst}) \pm 21\,(\mathrm{lumi})\,\mathrm{pb}$$

- Largest uncertainty: NLO generator, JES, lepton Id

CMS-PAS-TOP-16-005

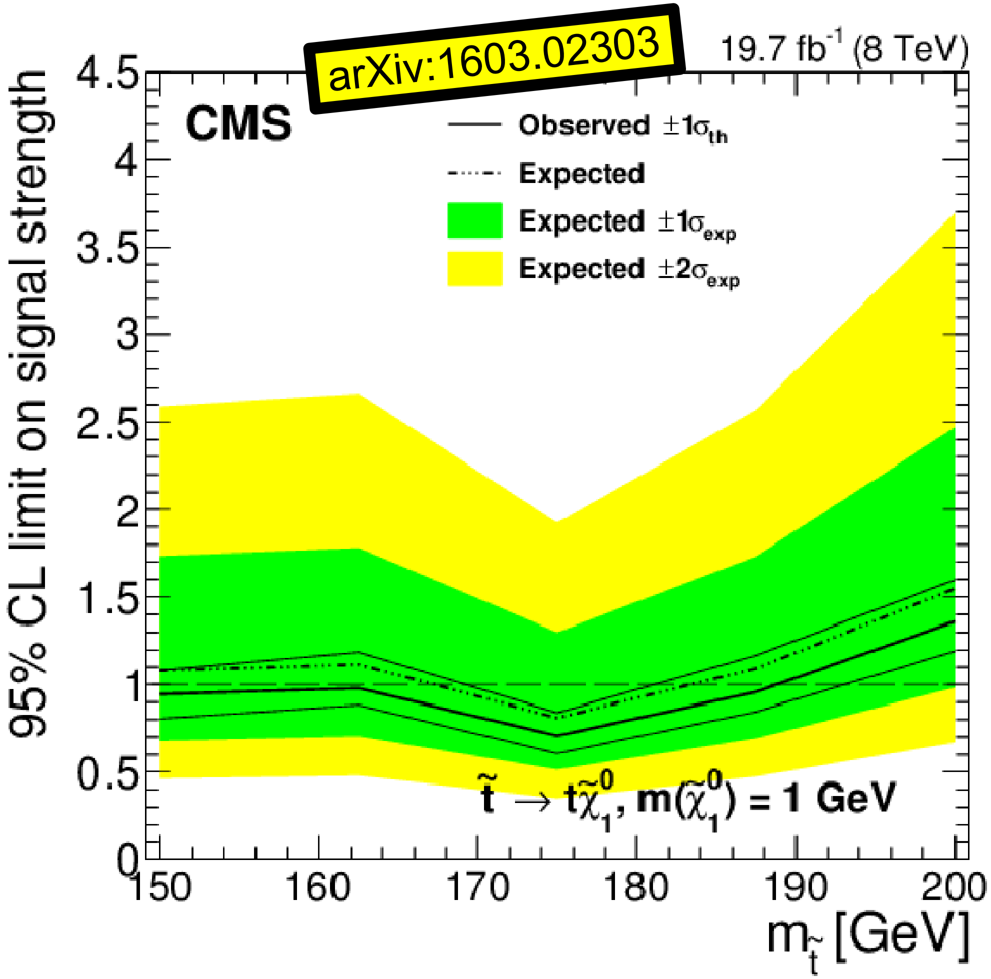
- No exclusion at the top mass threshold $m_{stop} - m_{LSP} = m_{top}$ from direct searches because (in part) stop becomes indistinguishable from top
- Stop quark events would produce final states very much ttbar like

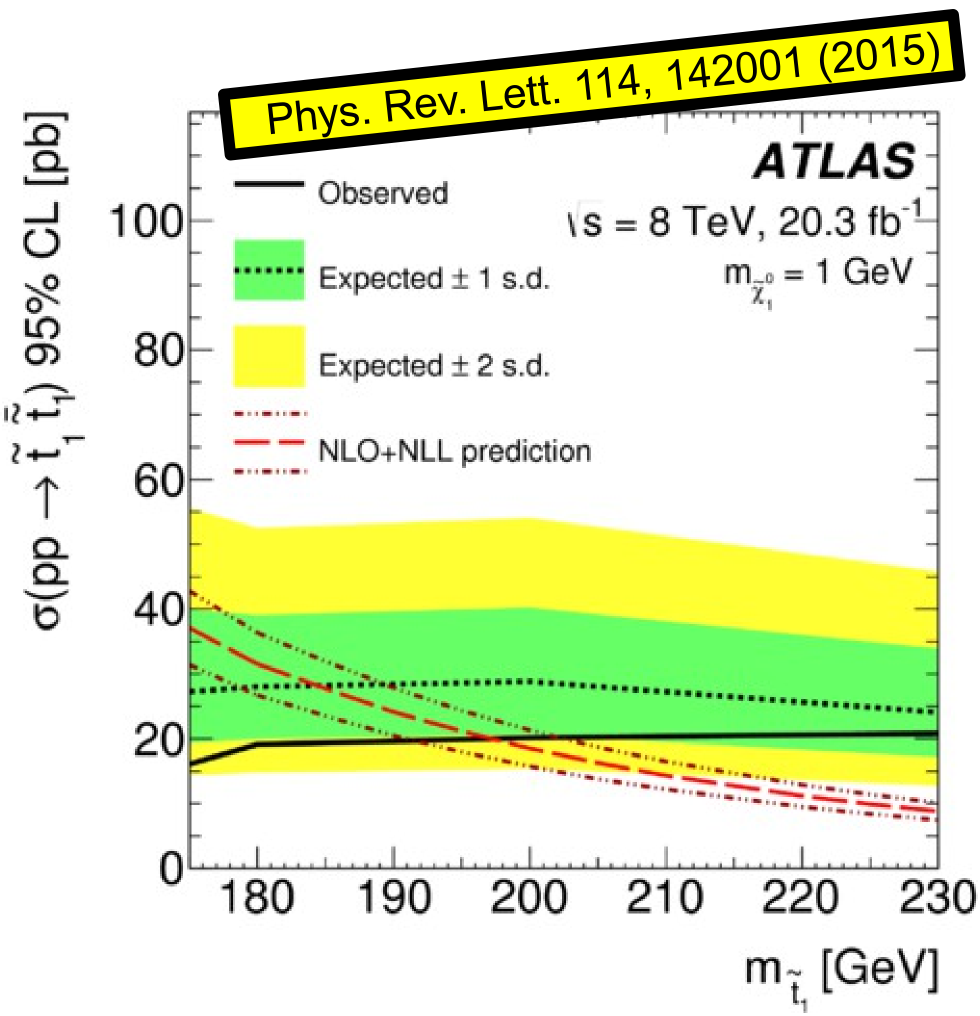




- Everything that produces ttbar could "in principle" be seen as an excess of ttbar events ⇒ differences between theoretical calculations and measuremer
- We can set limits based on the ttbar expected yields and uncertainties

SUSY Constraints from ttbar Cross Section





Differential top pair production measurements

Measure ttbar Differentially

- Why?
  - Extensive test of pQCD
  - Help to constrain PDF and some MC parameters
  - The huge amount of data collected in allow us to do it!

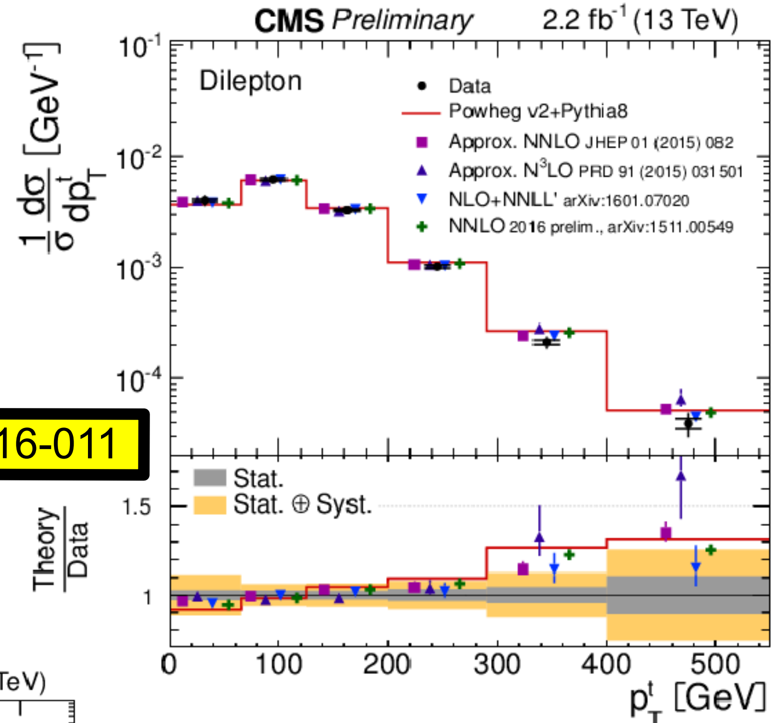
Normalized Differential Cross Section: Master Formula

$$\frac{1}{\sigma}\frac{d\sigma_i}{dX} = \frac{1}{\sigma}\frac{\mathrm{unfold}(s_i^X - b_i^X)}{\Delta_i^X \cdot \int \mathcal{L}\, dt}$$

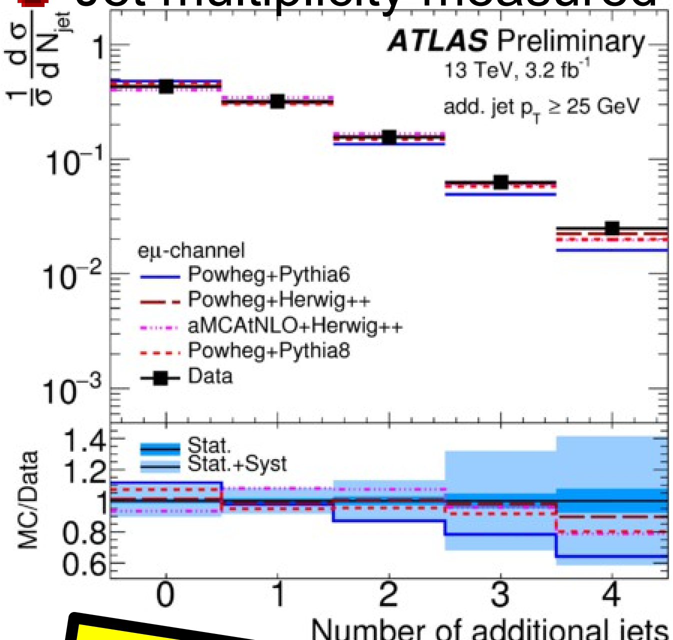
- How?
  - Use a tight event selection to have a pure tt sample
  - Top quark kinematic reconstruction
  - Background subtraction
  - Apply corrections (detector acceptance, resolution) → unfolding techniques
  - Compare to theory predictions at parton or particle level

Differential Cross Section @ 13 TeV (dilepton)

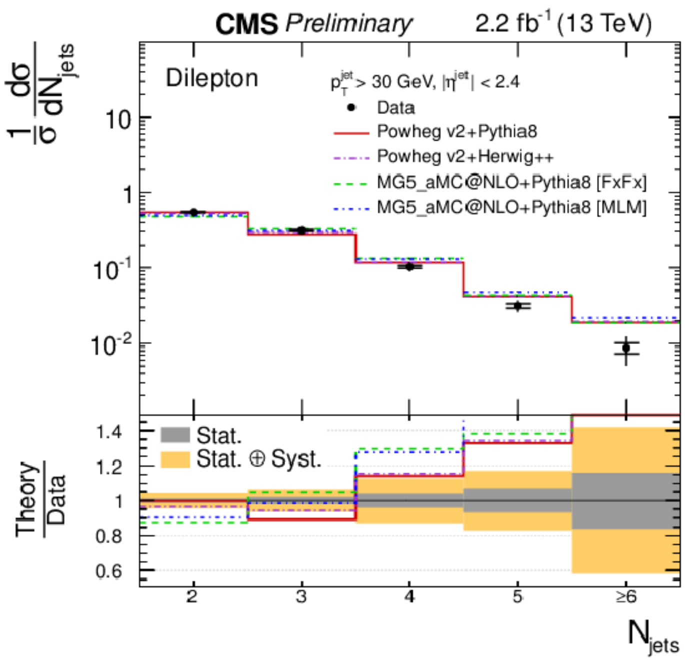
- Kinematic reconstruction algorithm, measure top and tt observables at parton level
- Results compared with several perturbative QCD calculations found to be broadly in agreement
- Top p_T better described at NNLO
- Jet multiplicity measured in both channels

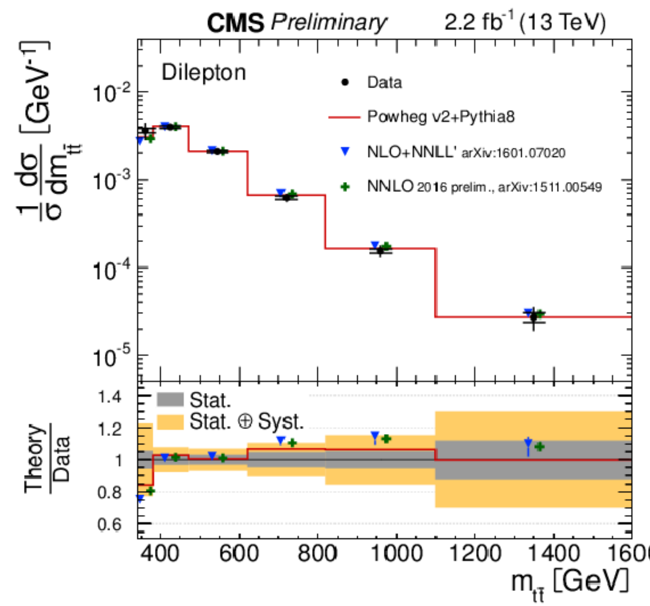


CMS-PAS-TOP-16-011



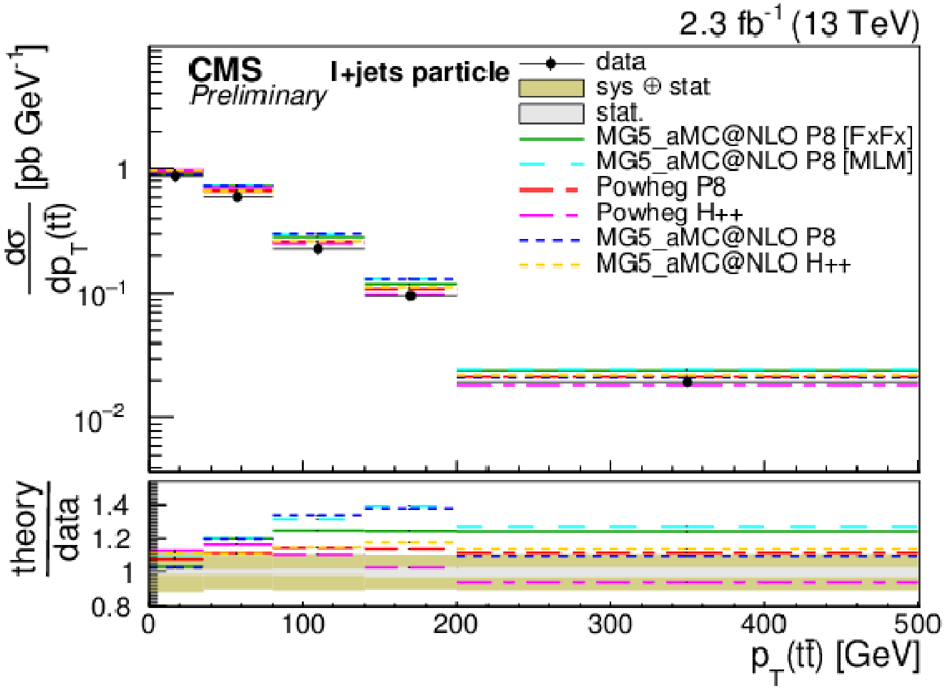
ATLAS-CONF-2015-065

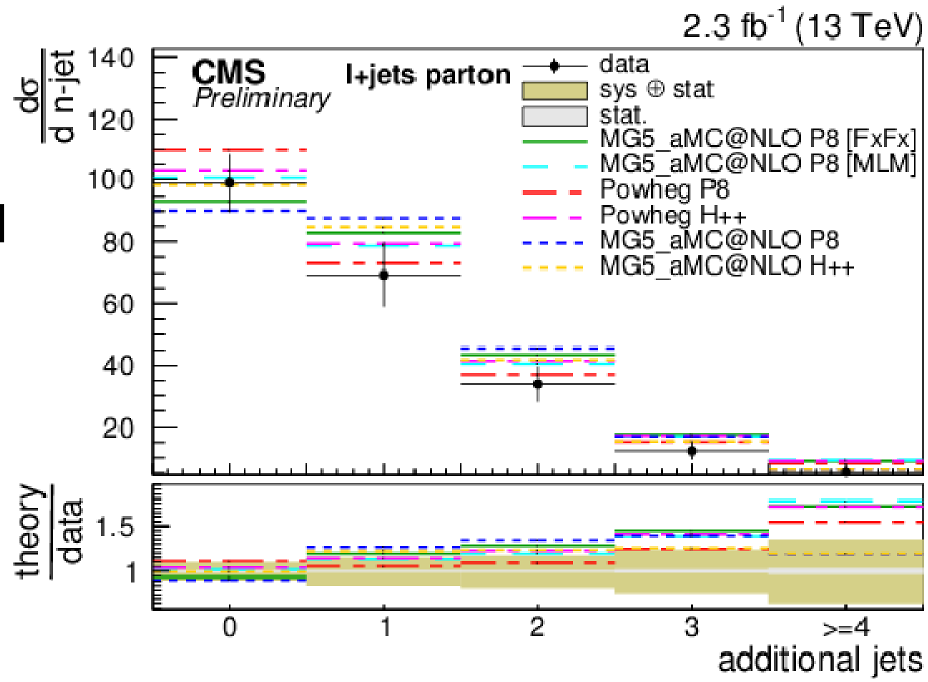




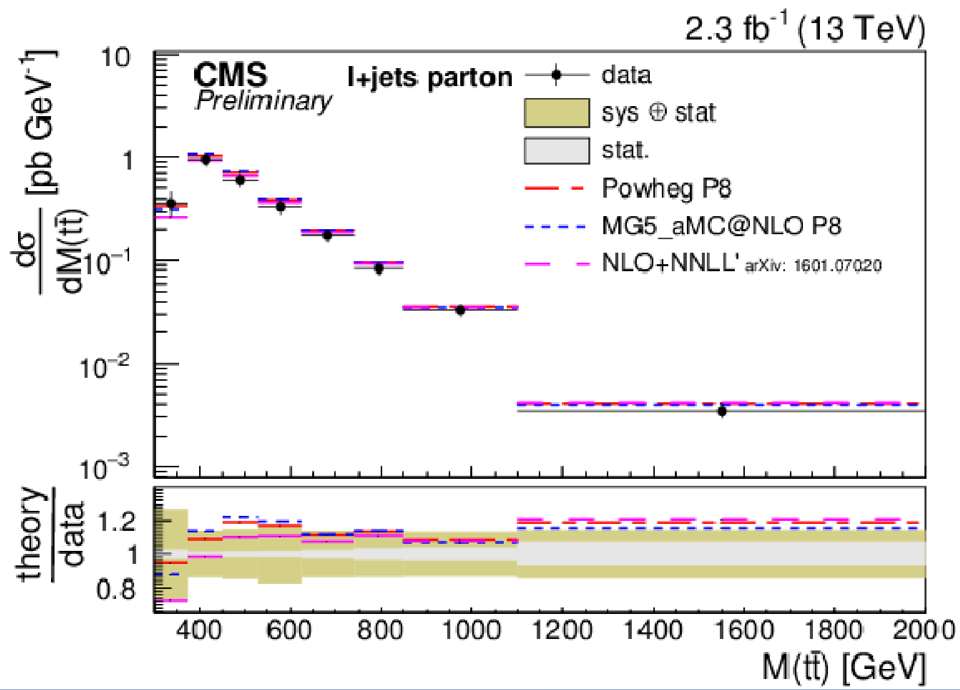
Differential Cross Section @ 13 TeV (l + jets)

- Analytic solution for neutrino momentum, find best top candidates by mass constraints
- Measure top and tt observables at parton and particle level





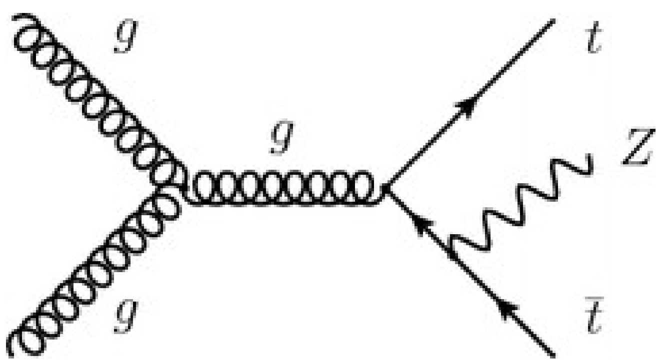
CMS-PAS-TOP-16-008



- Overall good agreement with NNLO

Top pair production in association with a vector boson

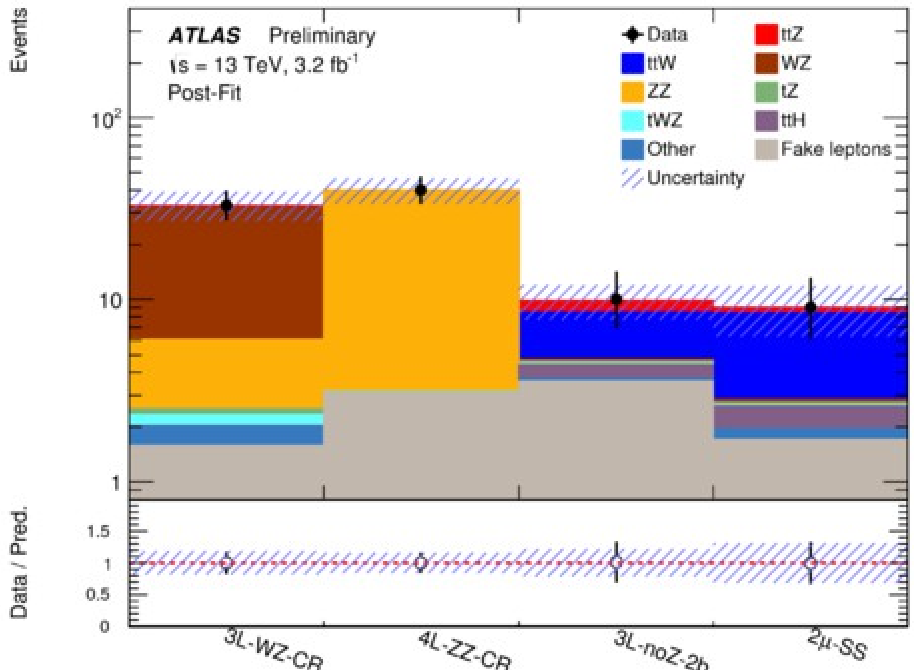
- Expected small SM cross sections (~200 fb @ 8TeV) but probe for BSM
- Test top quark coupling to bosons
- Background for ttH and BSM searches

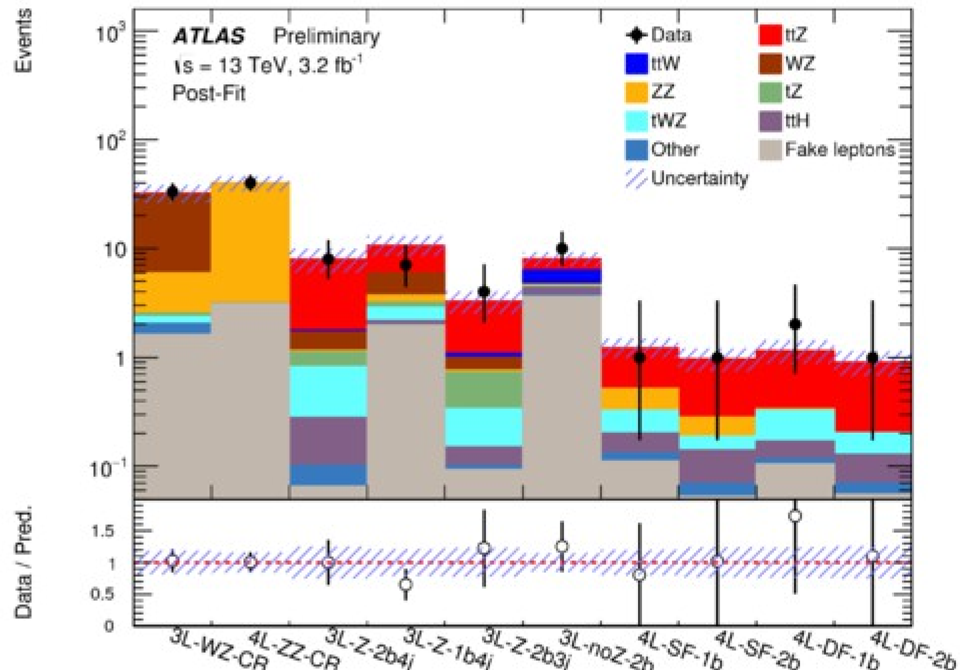


tt + V production @ 13 TeV (ATLAS)

- ttW: select events with (b) jets and 2 or 3 leptons (one same-sign pair)
- ttZ: select events with (b) jets and 3 or 4 leptons (one Z → ℓℓ candidate)
- Diboson backgrounds from control regions
  - WZ: 3ℓ, 1 Z candidate, 3 untagged jets
  - ZZ: 4ℓ, 2 Z candidates, low MET

ATLAS-CONF-2016-003





$$\sigma_{t\bar{t}Z} = 0.92 \pm 0.30\,(\text{stat.}) \pm 0.11\,(\text{syst.})\,\text{pb}$$

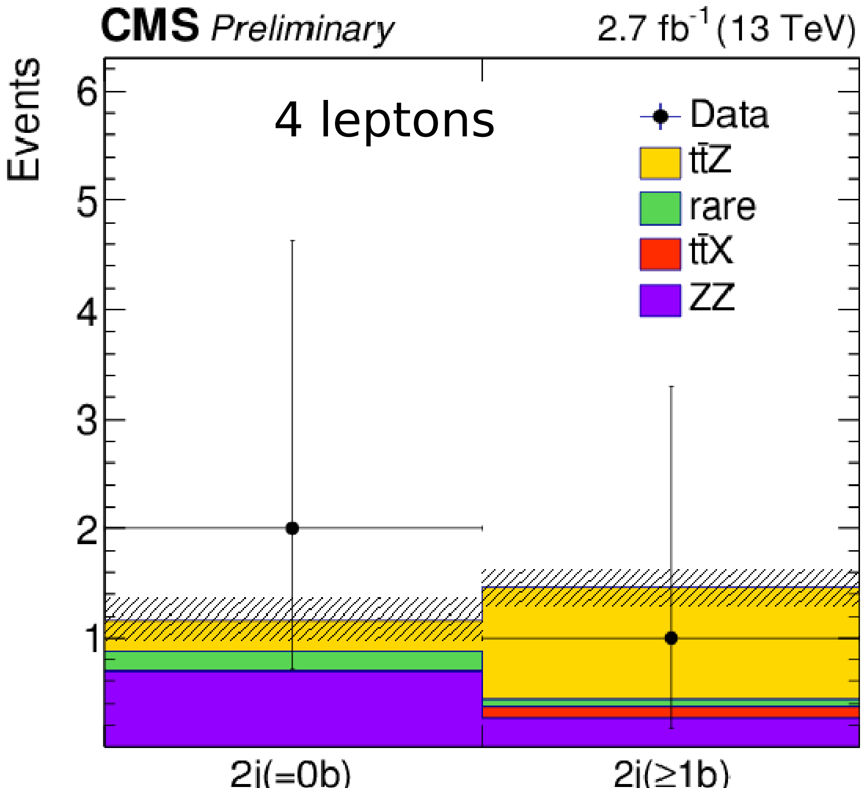
$$\sigma_{t\bar{t}W} = 1.38 \pm 0.70\,(\text{stat.}) \pm 0.33\,(\text{syst.})\,\text{pb}$$

NLO: $\sigma_{t\bar{t}Z} = 0.76 \pm 0.08\,\text{pb}$

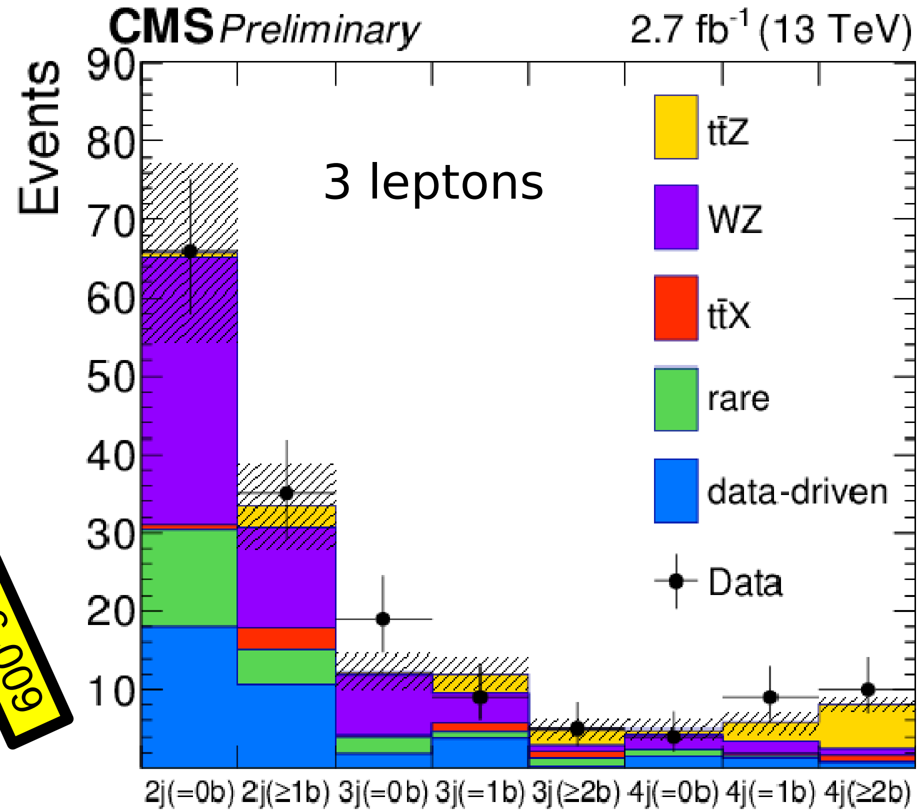
NLO: $\sigma_{t\bar{t}W} = 0.57 \pm 0.06\,\text{pb}$

tt + Z production @ 13 TeV (CMS)

- Select events with 3 or 4 leptons and at least 2 jets
- Data-driven estimates for non-prompt leptons, control regions for WZ and ZZ
- Binned likelihood fit to all categories, including nuisance parameters
  - Jet and b-jet multiplicities exploited to enhance the signal over bkg ratio



CMS-PAS-TOP-16-009

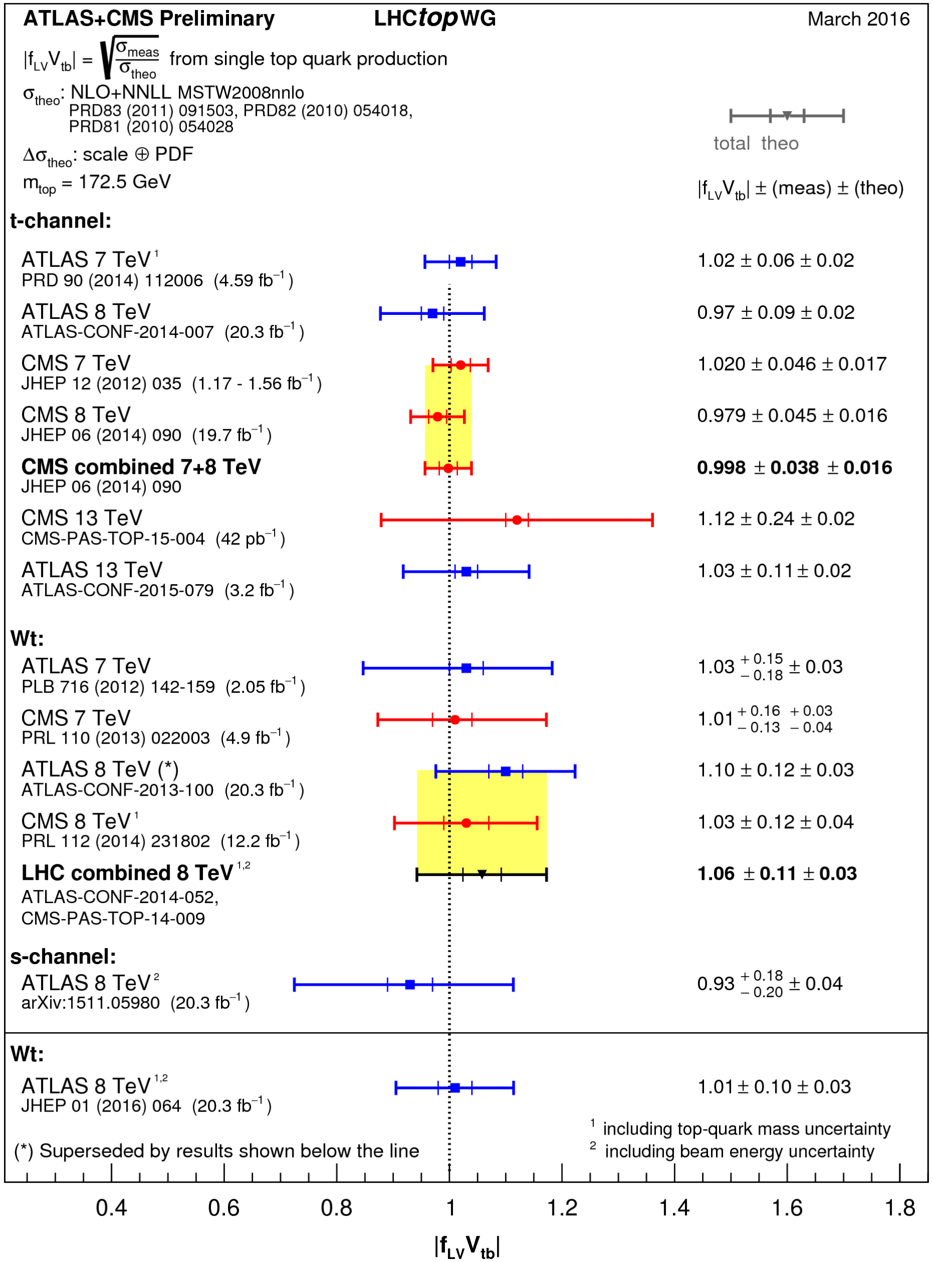


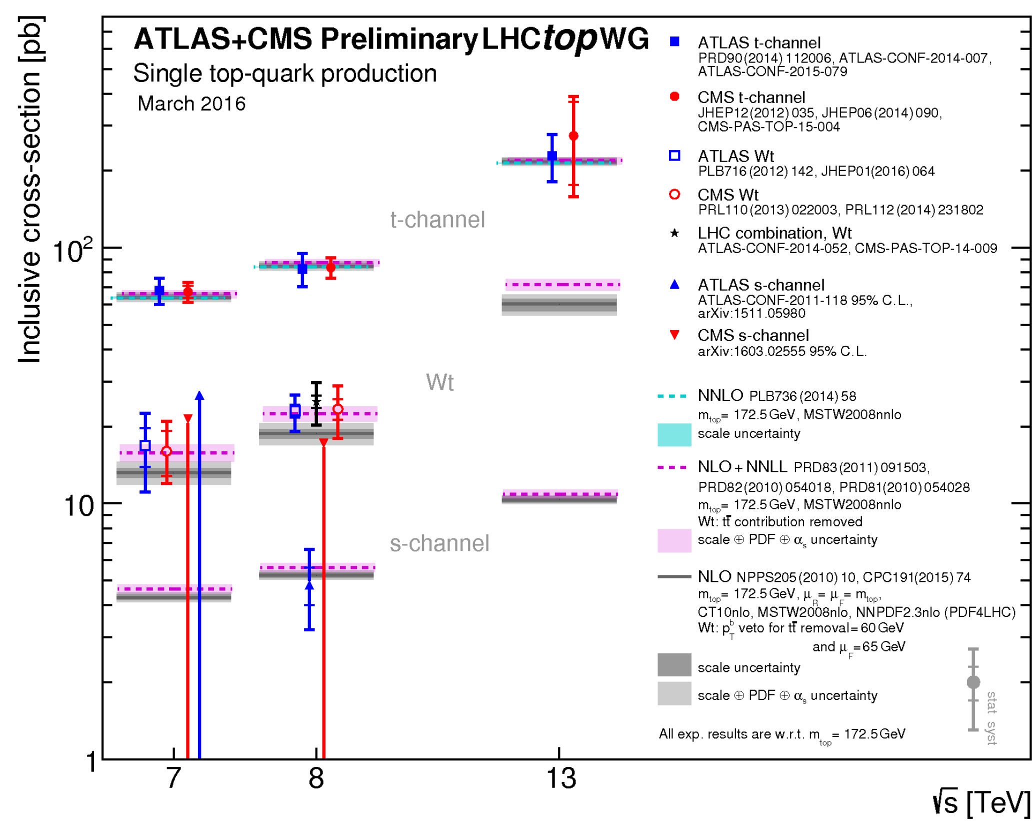
$$\sigma(pp \to t\bar{t}Z) = 1065\ ^{+352}_{-313}(\text{stat.})\ ^{+168}_{-142}(\text{sys.})\ \text{fb}$$

- Significance: 3.1 expected, 3.6 observed

Single Top

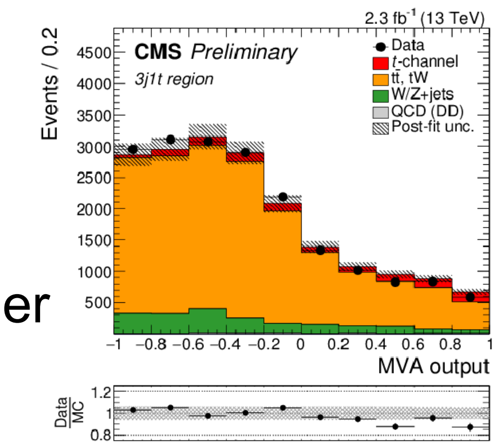
- Test the EW couplings, PDF, V_{tb}

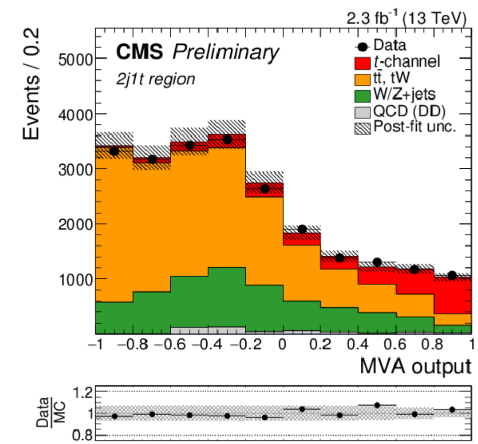




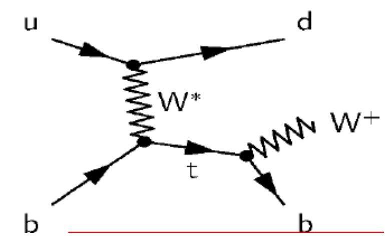
Single Top t-channel @ 13 TeV

- Signal extraction **CMS-PAS-TOP-16-003**
  - MVA based on 11 kinematic variables
  - Binned likelihood fit on the MVA output
  - Bkgs with similar templates grouped together
  - Simultaneous fit to the signal region (2j1t) and to the two bkg regions (3j1t, 3j2t)



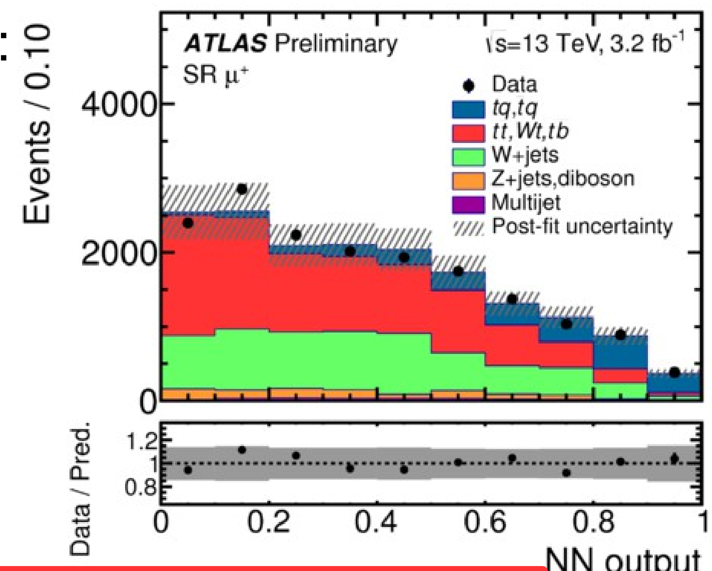


$$\sigma_{t\text{-ch.}} = 227.8 \pm 9.1\,(\text{stat.}) \pm 14.0\,(\text{exp.})\,^{+28.7}_{-27.7}\,(\text{theo.}) \pm 6.2\,(\text{lumi.})\ \text{pb}$$



- Total uncertainty of 14.8%. Main systematics:
  - Signal modeling, JES, b-tagging, PDF

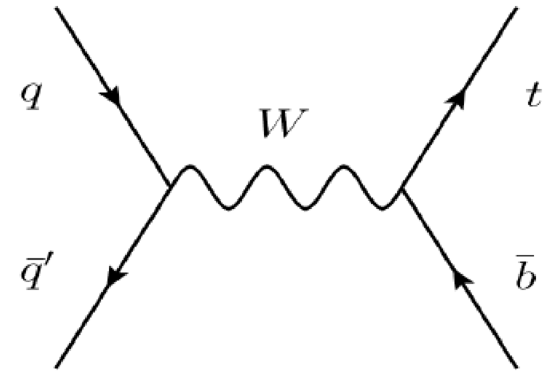
- ATLAS **ATLAS-CONF-2015-079**
  - Binned maximum likelihood fit on a NN
  - Total uncertainty of 21%
  - Similar dominant systematics



$$\sigma(tq + \bar{t}q) \quad = \quad 229 \pm 48\ \text{pb}$$

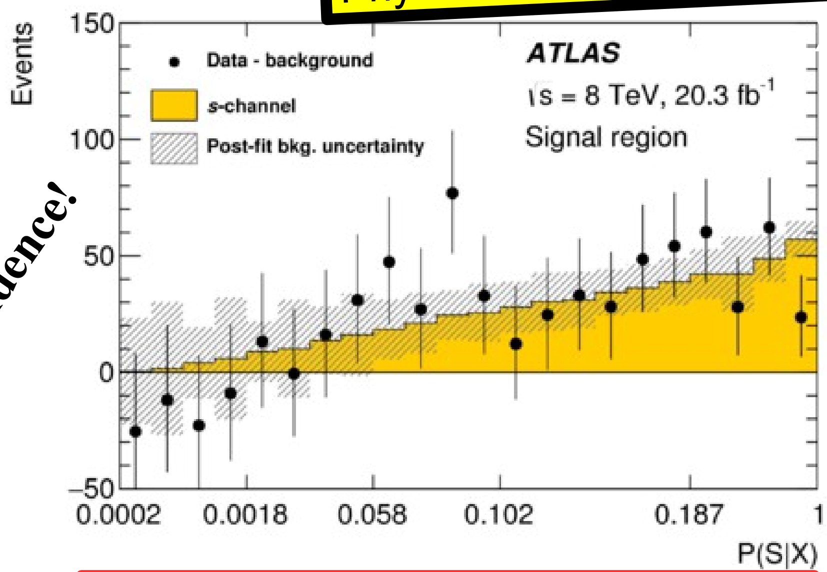
Single Top s-channel @ 7 and 8 TeV

- Rare process, grows much slower with ECM than other top production modes
- Binned likelihood fit on the ME discriminant (ATLAS) and MVA output (CMS)
- Main systs: JES, generator (CMS only), b-tagging



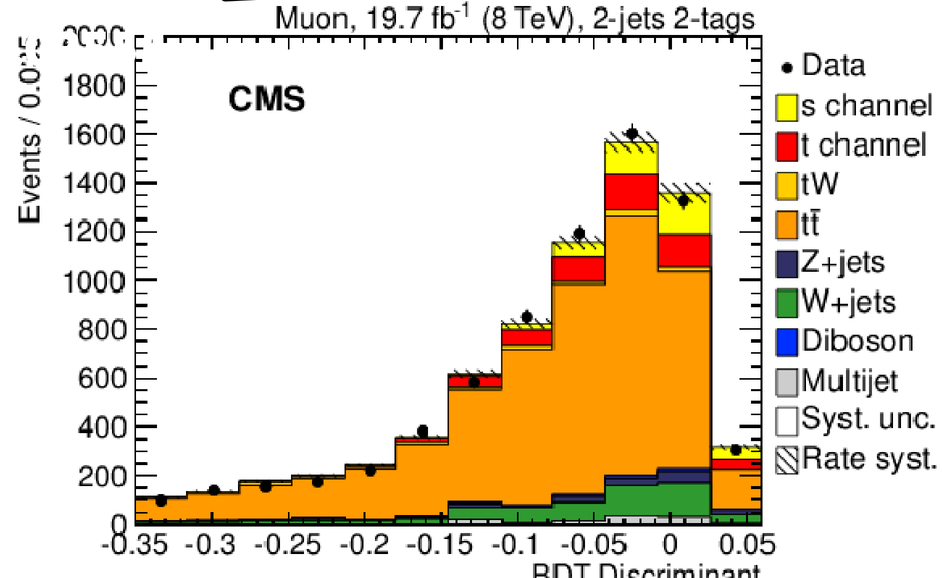
Phys.Lett B 756 (2016) 228

Evidence!



$$\sigma_{s-chan.} = 4.8 \pm 0.8 (stat.)^{+1.6}_{-1.3} (syst.)\ pb$$

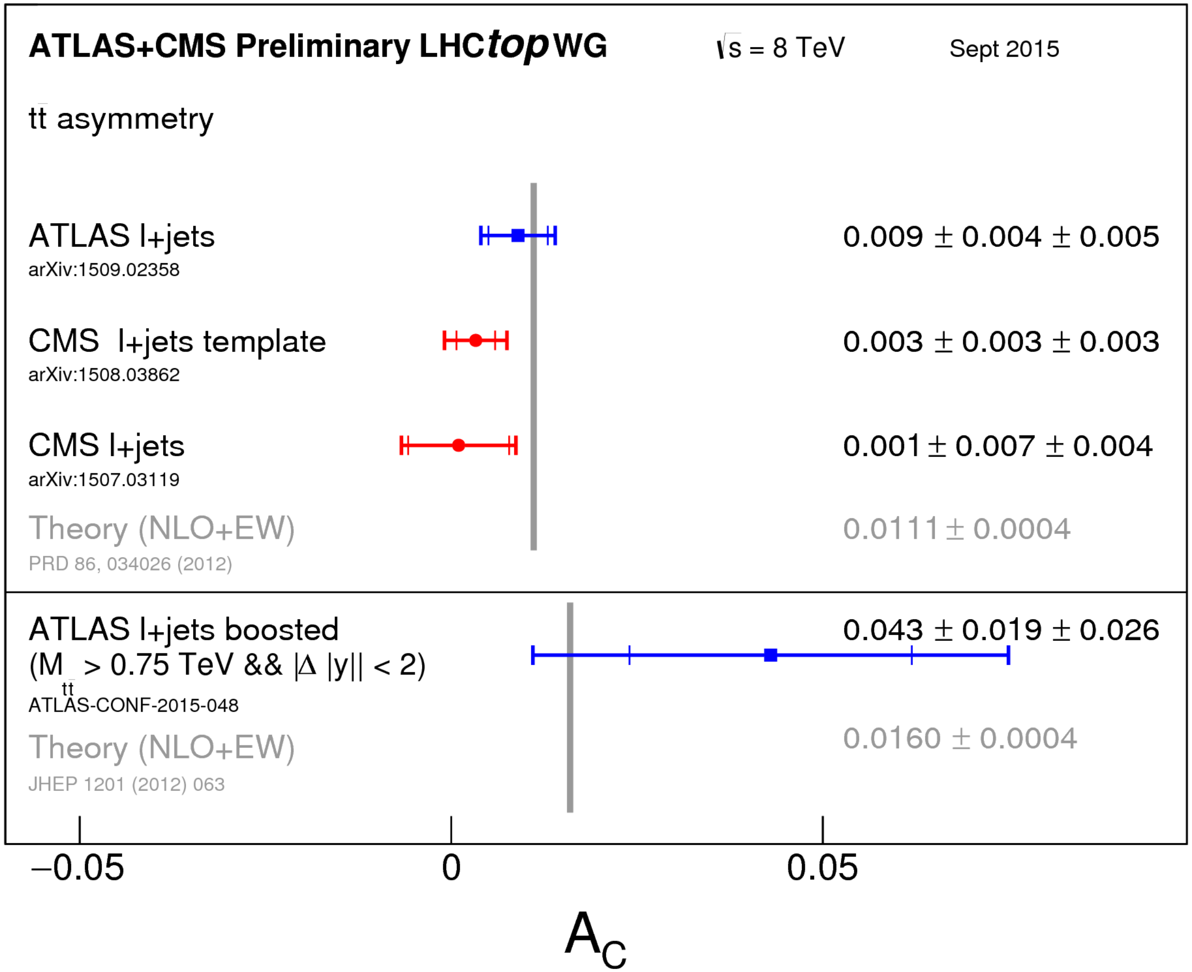
arXiv:1603.02555



$$\sigma_{s-chan.}(8\,TeV) = 13.4 \pm 7.3\ pb$$

Top Properties

- Decay before hadronization (probe bare quark) and before spin decorrelation (predicted by QCD)
- Access to 'bare' quark properties through decay products
- Properties sensitive to new physics
  - Look at spin, charge, FCNC…



Charge Asymmetry @ 8 TeV

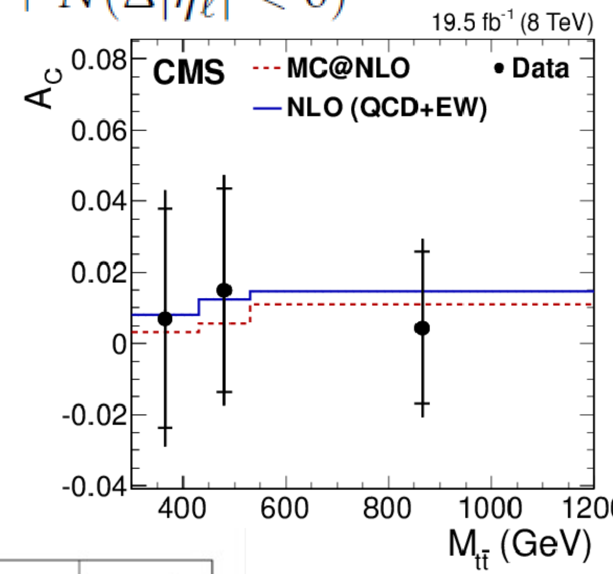
arXiv:1603.06221

- Asymmetry defined with decay leptons and reconstructed tops

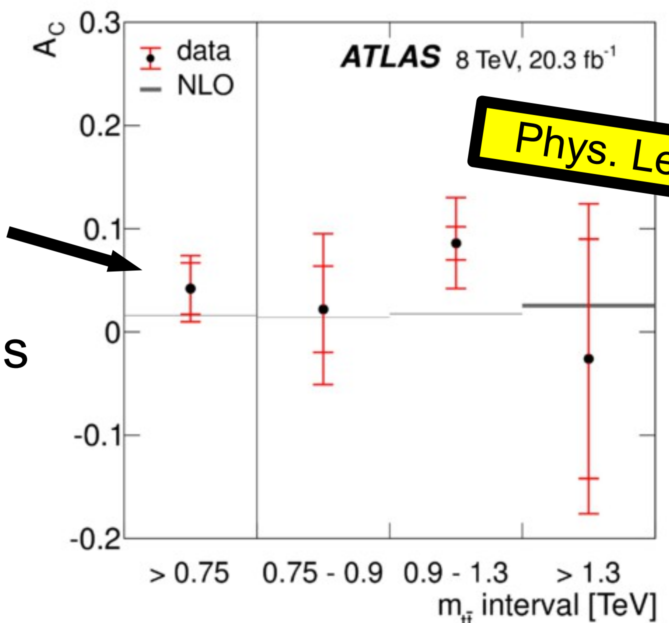
$$A_C = \frac{N(\Delta|y|>0) - N(\Delta|y|<0)}{N(\Delta|y|>0) + N(\Delta|y|<0)} \qquad A_C^{\mathrm{lep}} = \frac{N(\Delta|\eta_\ell|>0) - N(\Delta|\eta_\ell|<0)}{N(\Delta|\eta_\ell|>0) + N(\Delta|\eta_\ell|<0)}$$

- Dilepton channel: 2 OS leptons, ≥2 jets, ≥1 b-tag
- Top reconstruction using matrix weighting technique
- Differential measurement in m(tt), |y(tt)| and p_T(tt)

A_C = [1.1 ± 1.3 (stat+syst)] %
SM pred: (1.11 ± 0.04)%
A^{lep}_C = [0.3 ± 0.7 (stat+syst)] %
SM pred: (0.64 ± 0.03)%

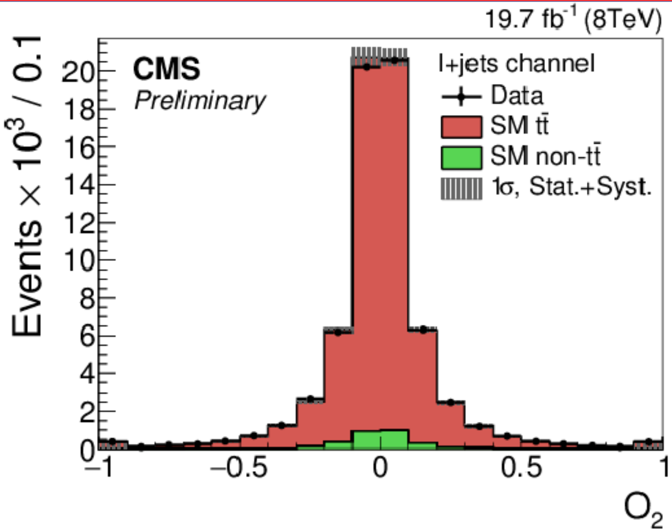


- Asymmetry in highly boosted top quarks
- Results in agreement with SM predictions



Phys. Lett. B 756 (2016) 52

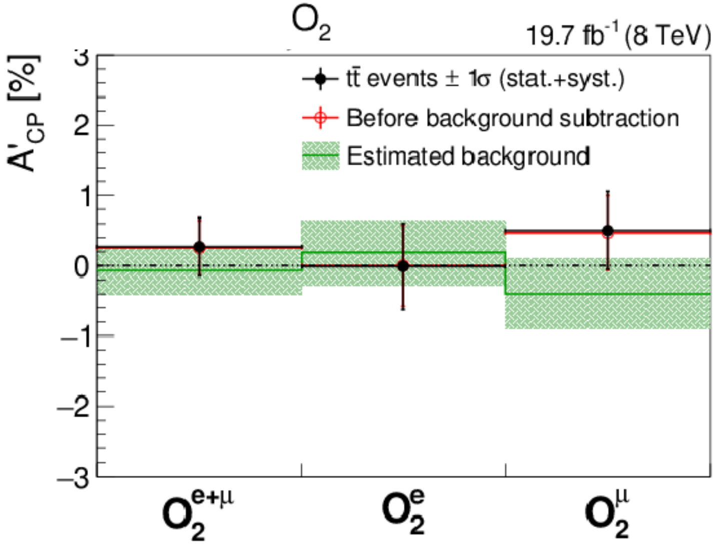
CP Violation @ 8 TeV



CMS-PAS-TOP-16-001

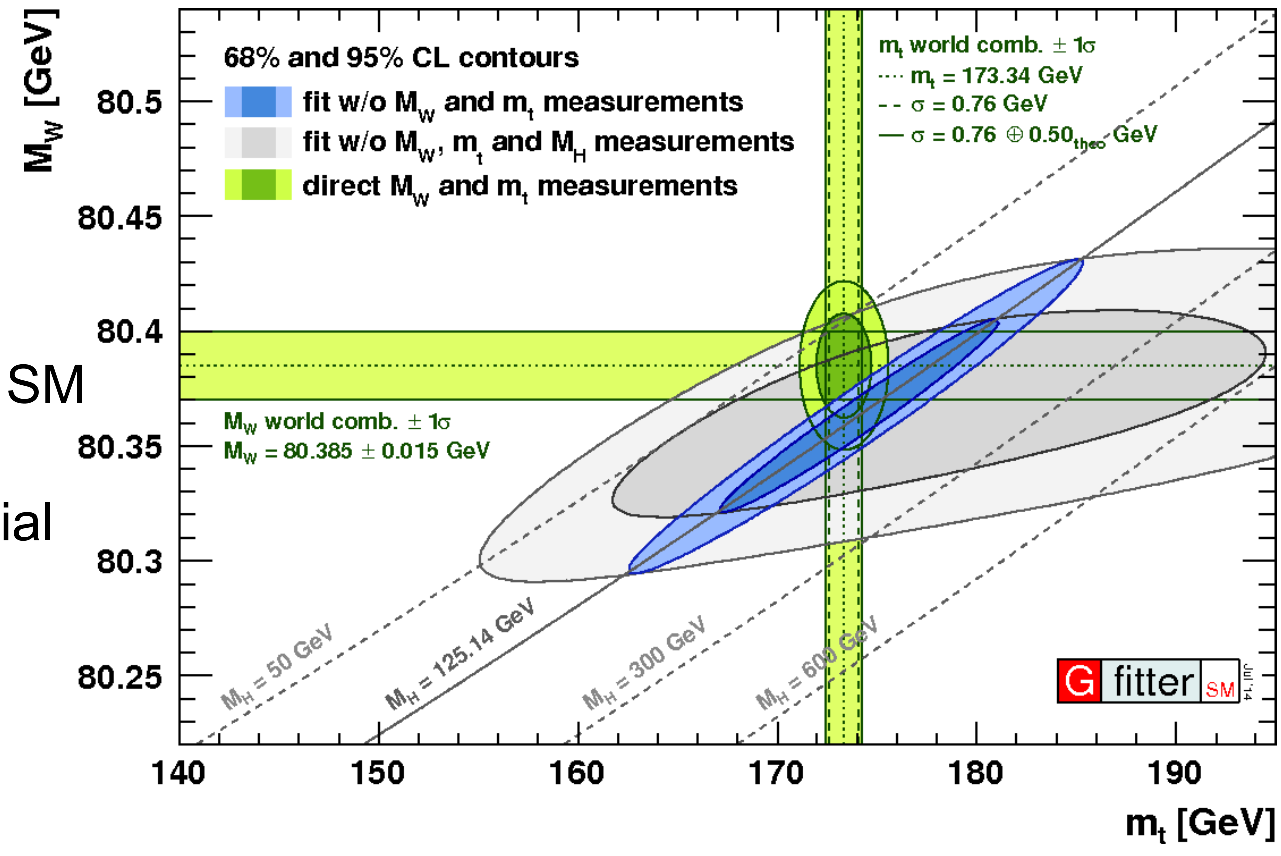
- Semi-leptonic ttbar channel
- Asymmetries based on T-odd triple products (T is the time-reversal operator)
  - First time!
- CP violation if non-zero value of

$$A_{CP}(O_i) = \frac{N_{events}(O_i > 0) - N_{events}(O_i < 0)}{N_{events}(O_i > 0) + N_{events}(O_i < 0)}$$



$A'_{CP}(O_i)$	e+jets	μ+jets	ℓ+jets
O_2	$-0.01 \pm 0.61 \pm 0.01$	$+0.50 \pm 0.56 \pm 0.02$	$+0.27 \pm 0.41 \pm 0.01$
O_3	$-0.34 \pm 0.61 \pm 0.02$	$-1.03 \pm 0.56 \pm 0.04$	$-0.71 \pm 0.41 \pm 0.03$
O_4	$-0.24 \pm 0.61 \pm 0.02$	$-0.49 \pm 0.56 \pm 0.04$	$-0.38 \pm 0.41 \pm 0.03$
O_7	$-0.42 \pm 0.61 \pm 0.00$	$+0.46 \pm 0.56 \pm 0.01$	$-0.06 \pm 0.41 \pm 0.01$

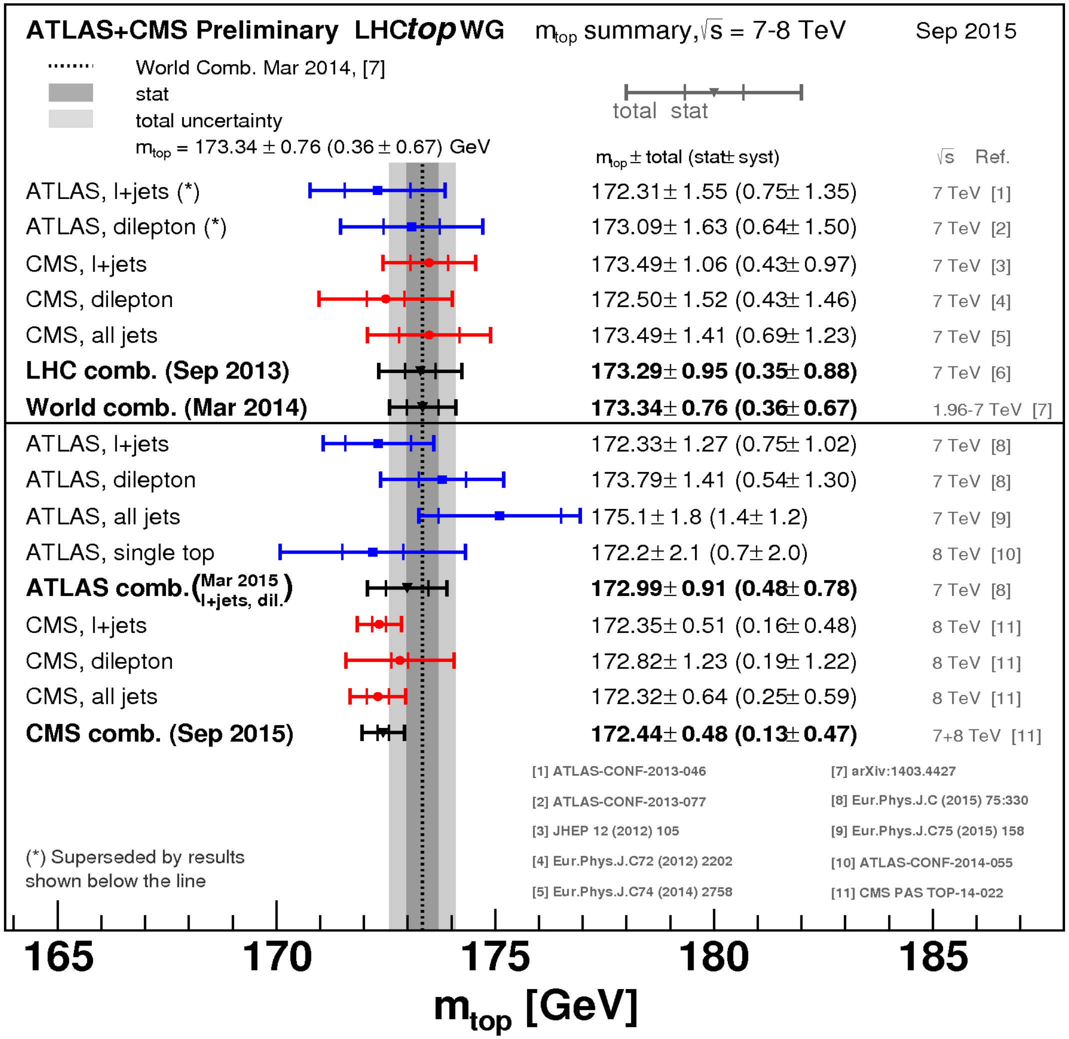
Top Mass



- Fundamental parameter of the SM
- Precise knowledge of m_{top} crucial for testing the SM

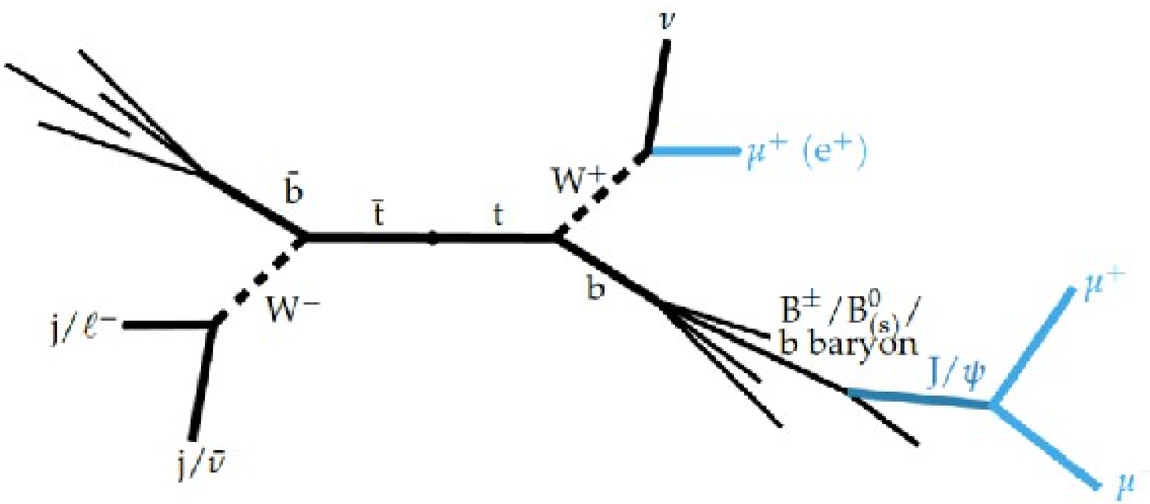
Top Mass: Current Status

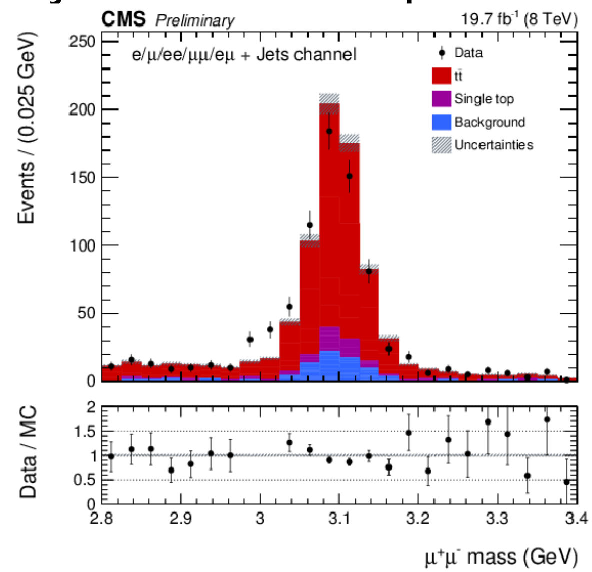
- World combination reaching a precision of 0.5 GeV (<0.3%)
- Precision limited by understanding of hadronization modeling
- Different ways to improve
- Use cleaner observables
  - Avoid jets
- Use theoretically calculable observables sensitive to the mass
  - σ(tt), m(lb)
- Constrain modeling systematics



Lepton(s) + J/Ψ Events @ 8 TeV

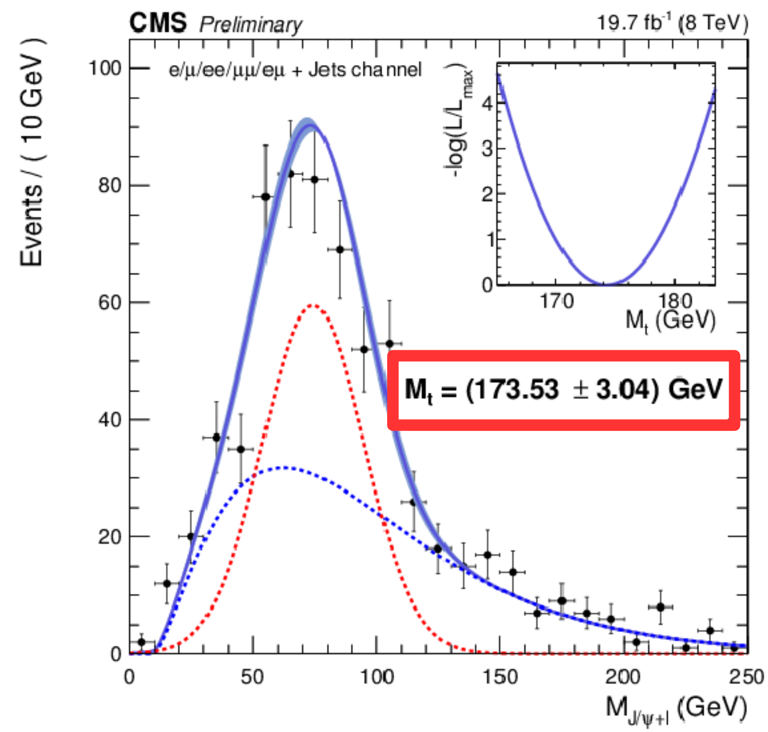
- Select events in the main leptonic top quark decay where the b-quark decays via b → J/ψ + X → $\mu^+\mu^-$ + X





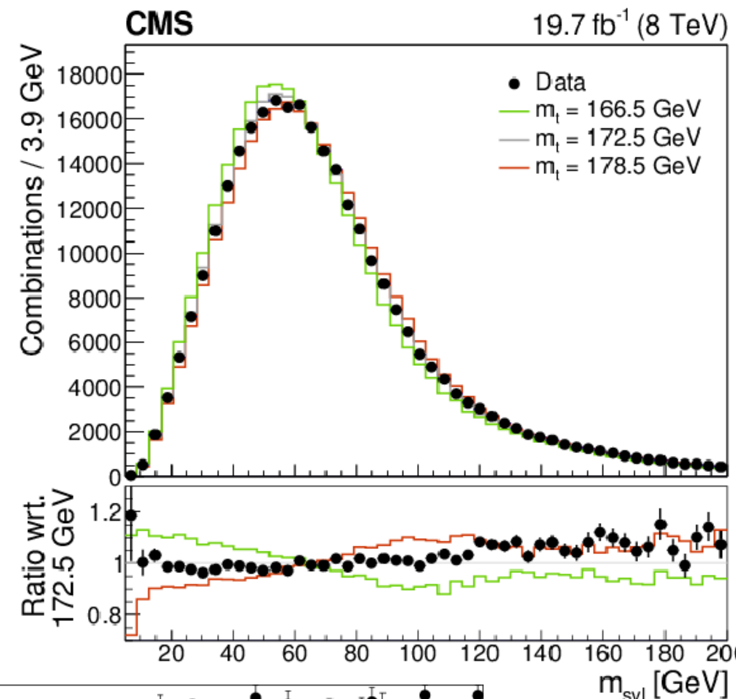
CMS-PAS-TOP-15-014

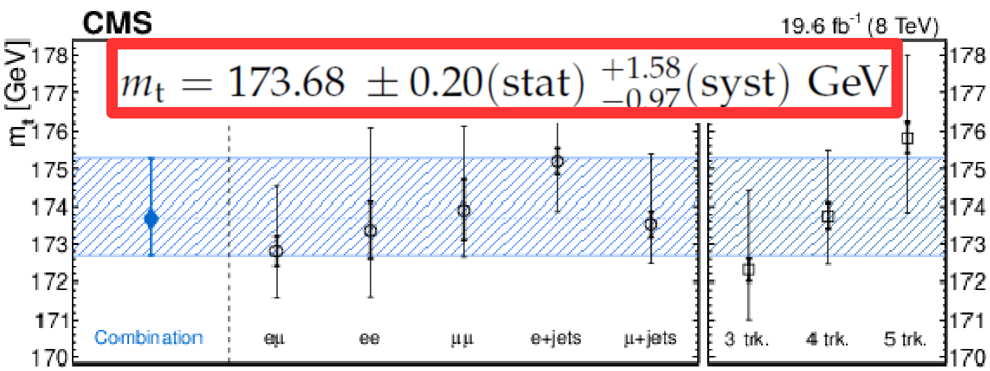
- Very small BR ⇒ statistically limited (for now)
  - 666 events ⇒ stat. unc. of 3.0 GeV
- But no use of jets to build observable
  - Avoid JES/bJES
  - Systematic uncertainty < 1 GeV
  - Limited by top p_T modeling, QCD scales

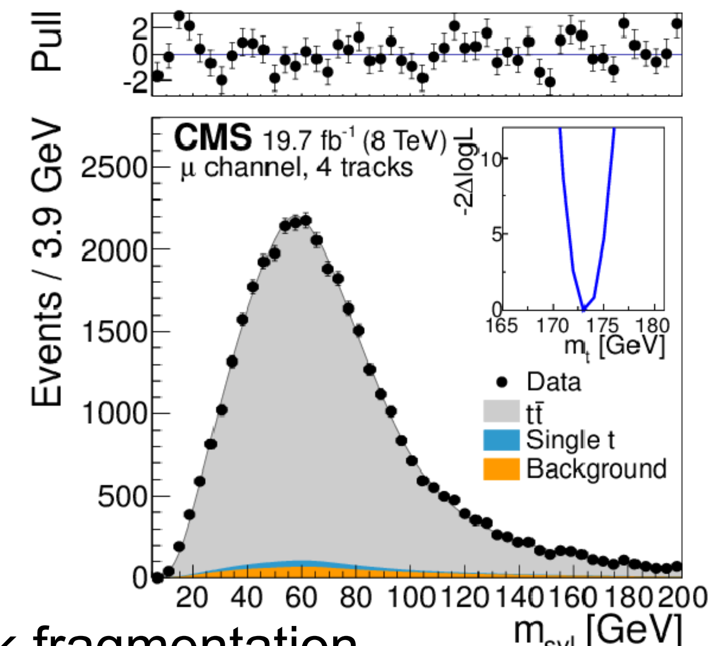


Lepton + Secondary Vertices @ 8 TeV

- More general version of J/ψ analysis
- Sensitivity to m_{top} from leptons (e/μ) and via decay lengths of charged hadrons (from b-quark decay)
  - Stronger sensitivity to m_{top} without inclusion of jets
- Semileptonic and dileptonic channels
- Invariant mass of lepton and secondary vertex used as observable (in bins of SV--track multiplicity)







arXiv:1603.06536

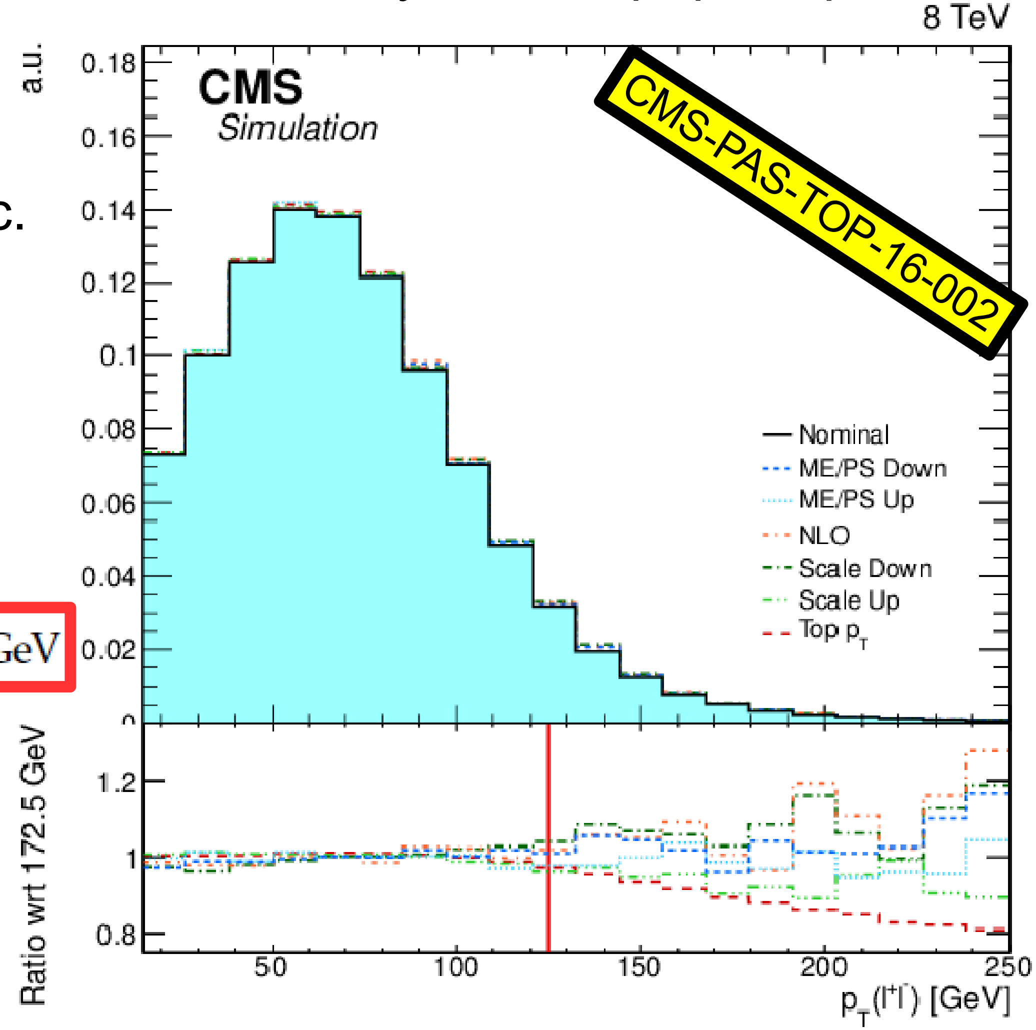
- Experimental uncertainties <500 MeV
- Dominant systematic: top quark p_T and b-quark fragmentation

Top Mass from Leptonic Observables @ 8 TeV

- Dilepton channel
- The transverse momentum of the lepton pair from the decay of the top quark pair is chosen to extract the top quark mass
- Clean but overwhelmed by QCD scale unc.
- Based on LO Madgraph (Run I MC)
  - Expected to improve using NLO+PS
- After the calibration with simulated events

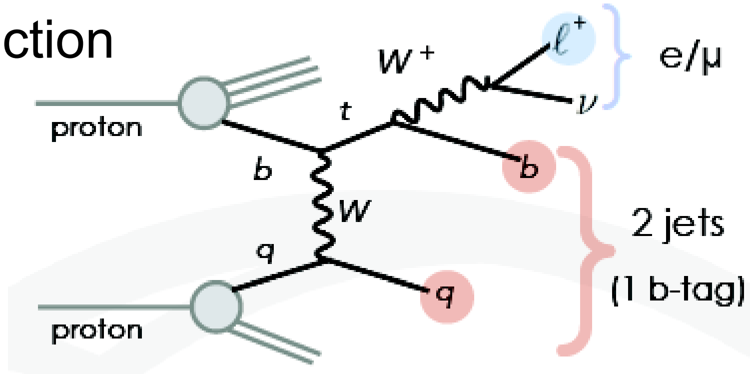
$$m_t = 171.7 \pm 1.1\,(\text{stat.}) \pm 0.5\,(\text{exp.})\,^{+2.5}_{-3.1}\,(\text{th.})\,^{+0.8}_{-0.0}\,(p_T\,(t))\ \text{GeV}$$

- Signal modeling is the dominant systematic uncertainty



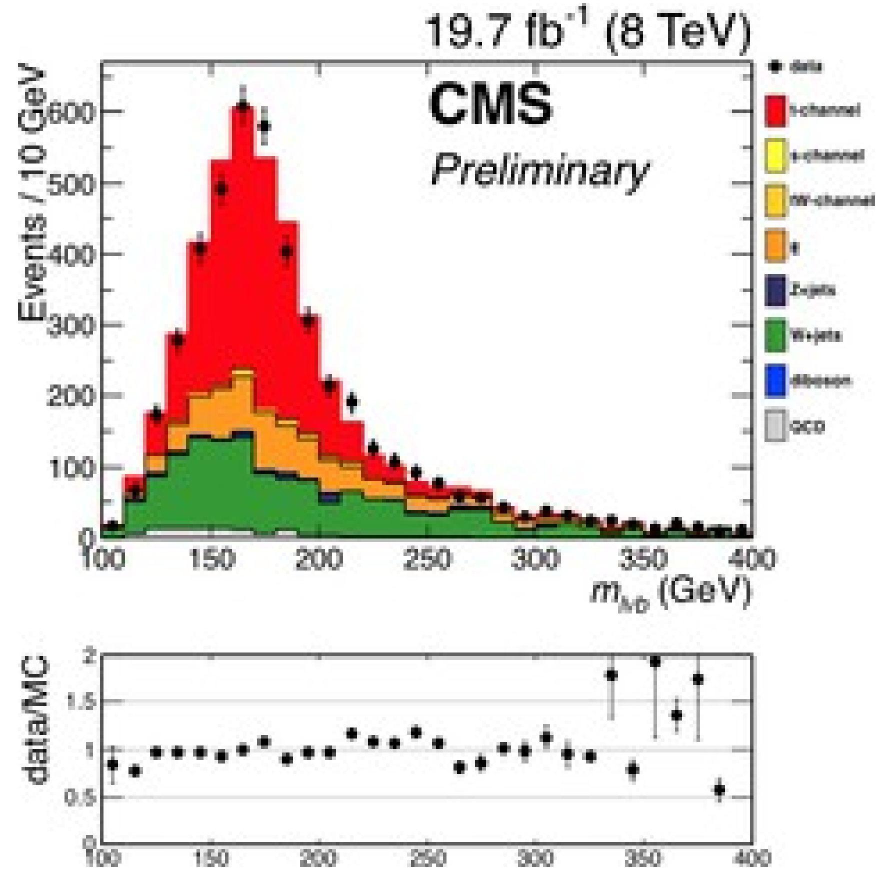
Top Mass from Single Top (t-channel) @ 8 TeV

- Analyses targeting alternative topologies can give further insights, e.g. pure EW production



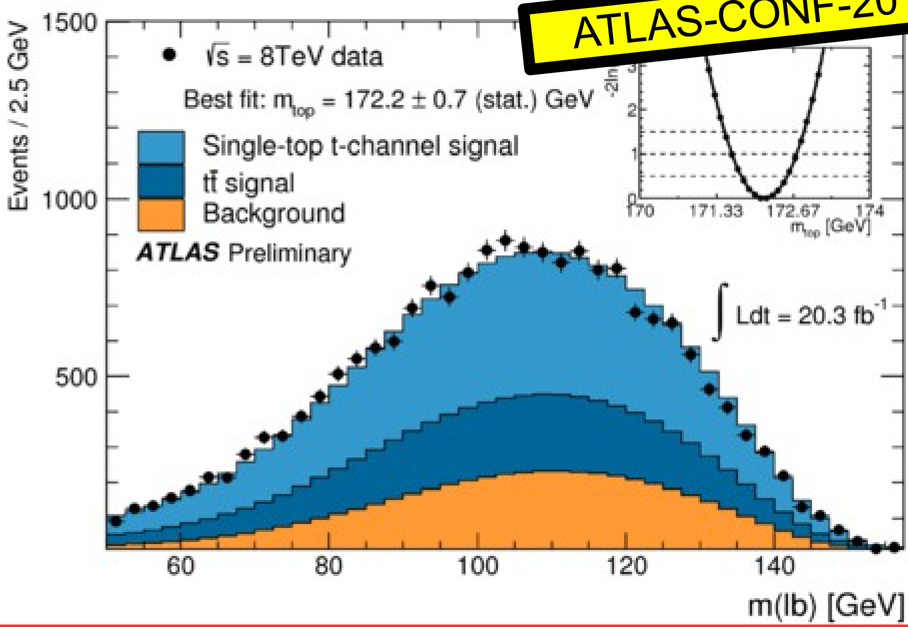
CMS-PAS-TOP-15-001

$$m_t = 172.60 \pm 0.77\ (\text{stat})\ {}^{+0.97}_{-0.93}\ (\text{syst})\ \text{GeV}$$



- JES main systematic uncertainty

ATLAS-CONF-2014-055

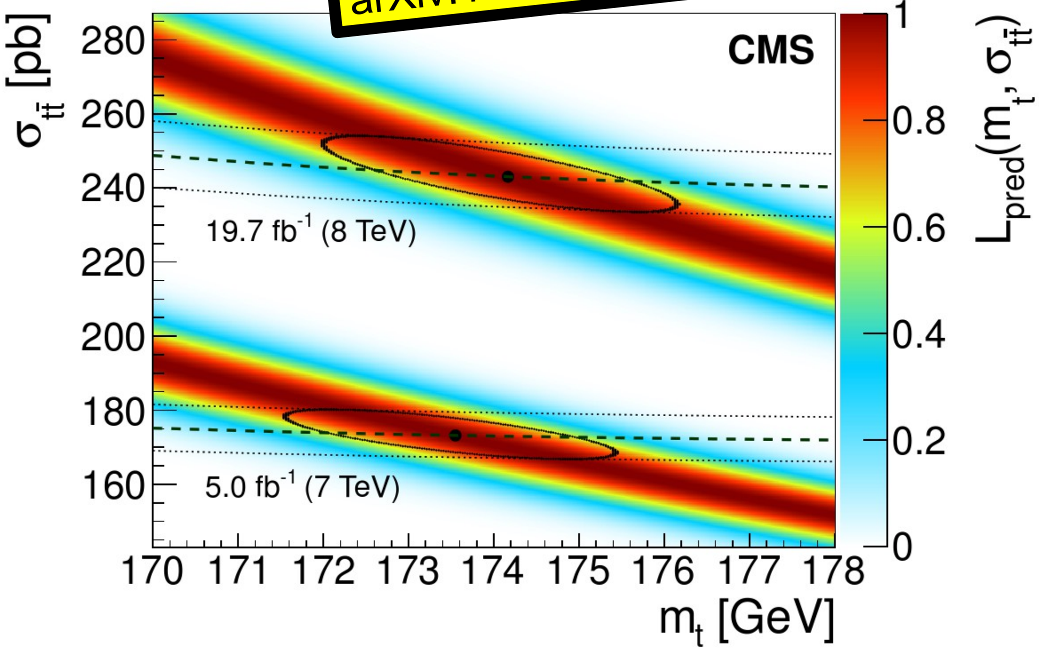


$$m_{\text{top}} = 172.2 \pm 0.7\,(\text{stat.}) \pm 2.0\,(\text{syst.})\ \text{GeV}$$

Top Pole Mass

- Extract m_{top} from production cross section
- Calculate mass dependence at NNLO

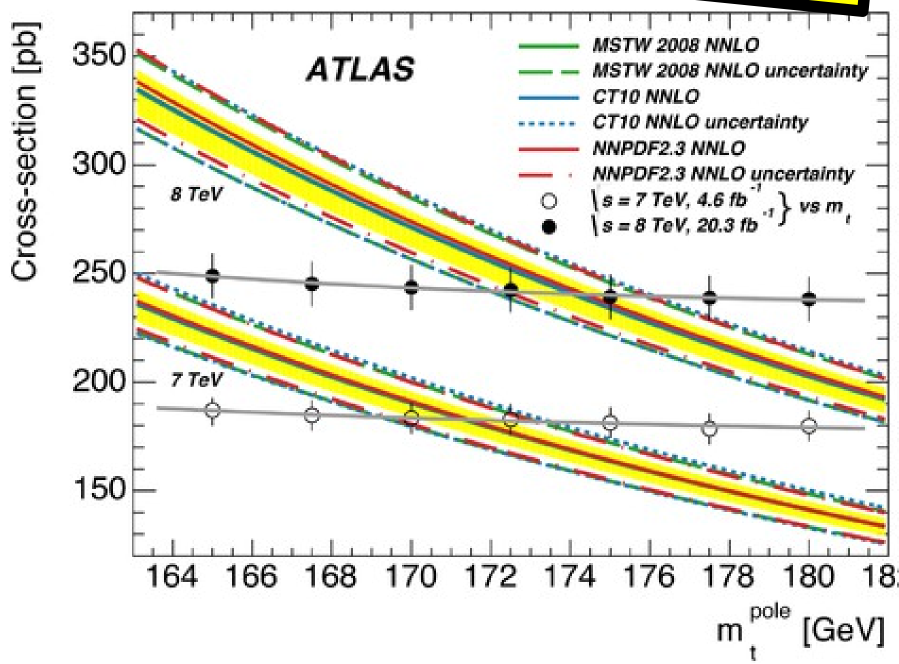
arXiv:1603.02303



$$m_t^{\text{pole}} = 173.8^{+1.7}_{-1.8}\ \text{GeV}$$

PDF set: NNPDF3.0 (consistent results with CT14 and MMHT2014)

Eur.Phys.J. C74 (2014) 3109



$$m_t^{\text{pole}} = 172.9^{+2.5}_{-2.6}\ \text{GeV}$$

PDF sets: MSTW2008, CT10, and NNPDF2.3

- Main systematics (for both experiments): PDF, luminosity

Summary

- Both ATLAS/CMS have a very comprehensive program in SM and Top physics
  - Great coverage over the full spectrum
- Most of the results shown today have been released very recently
  - In time for the winter 2016 conferences
  - And many with the full 13 TeV dataset
- In general, good agreement between experiments
  - **Discrepancies** are **under investigation**
- So far, no significant deviation with respect to the SM has been observed
  - But we will keep testing the SM in all its corners!
- **Stay tuned!!!** More results are just around the corner

http://cms-results.web.cern.ch/cms-results/public-results/publications/

https://twiki.cern.ch/twiki/bin/view/AtlasPublic

Thank you

for your

attention!