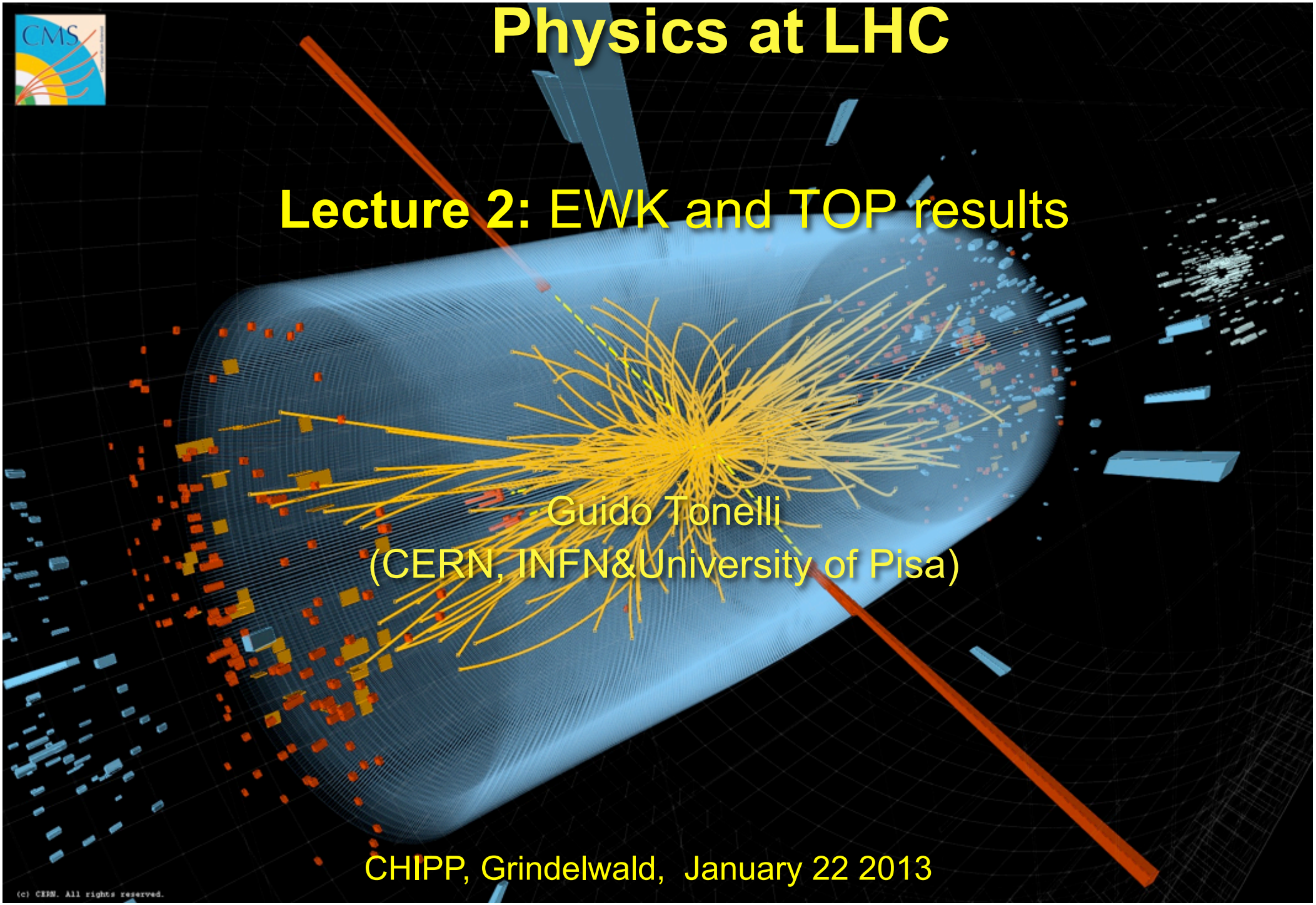
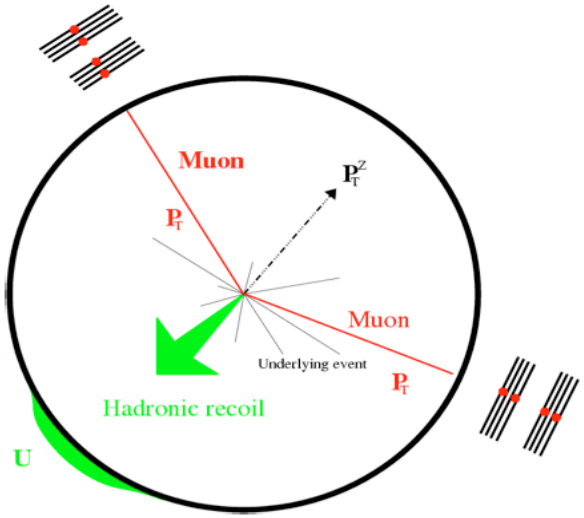
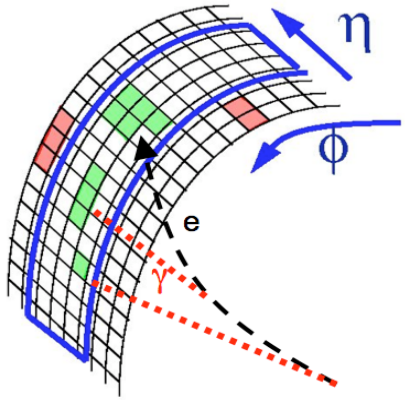

Physics at LHC
Lecture 2: EWK and TOP results
Guido Tonelli
(CERN, INFN&University of Pisa)
CHIPP, Grindelwald, January 22 2013
(c) CERN. All rights reserved.

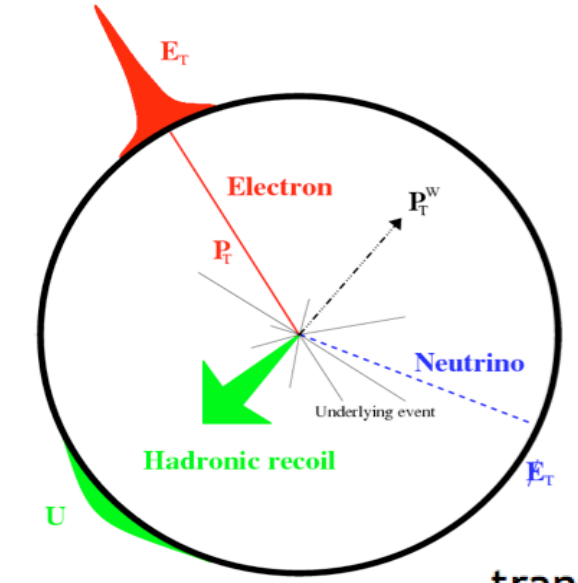
Experimental signatures for W and Z



Z: pair of charged leptons
- high-p_T (> 20 GeV)
- isolated
- opposite charge
- ~60 < m_{ll} < ~120 GeV



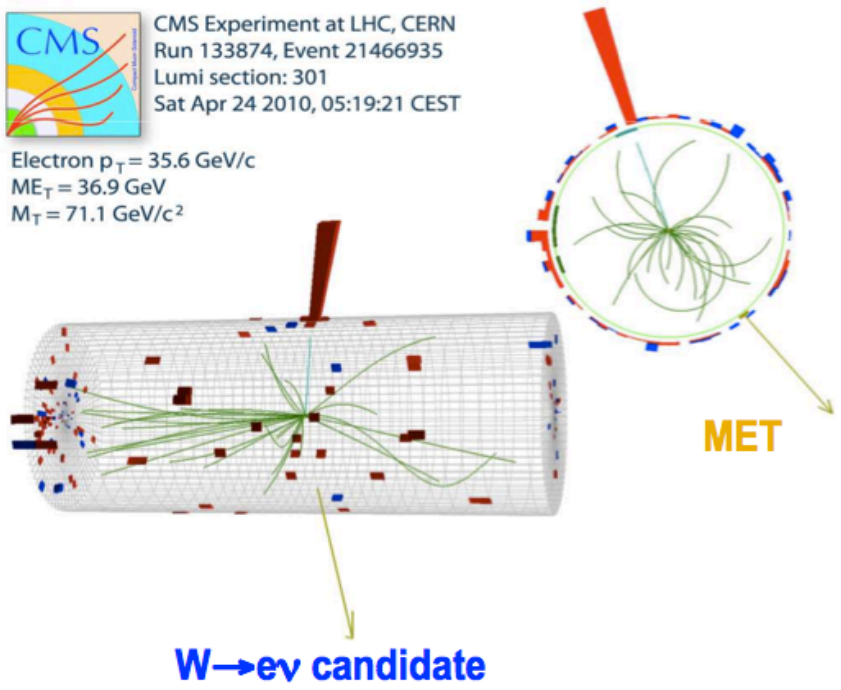
Example: electron reconstruction
- isolated cluster in EM calorimeter
- p_T > 20 GeV
- shower shape consistent with expectation from electrons
- matching charged track

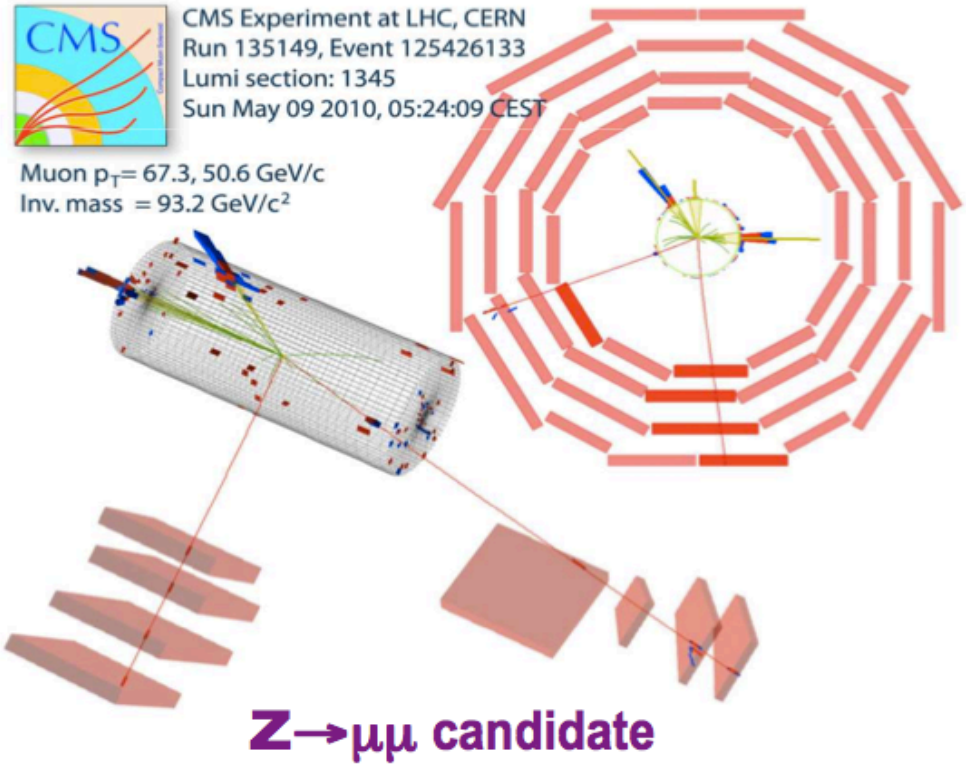


W: single charged leptons
- high-p_T (> 20 GeV)
- isolated
- $E_{T,miss}$ (from neutrino)

transverse mass: $M_W^T = \sqrt{2 \cdot P_T^l \cdot P_T^\nu \cdot \left(1 - \cos\Delta\phi^{l,\nu}\right)}$

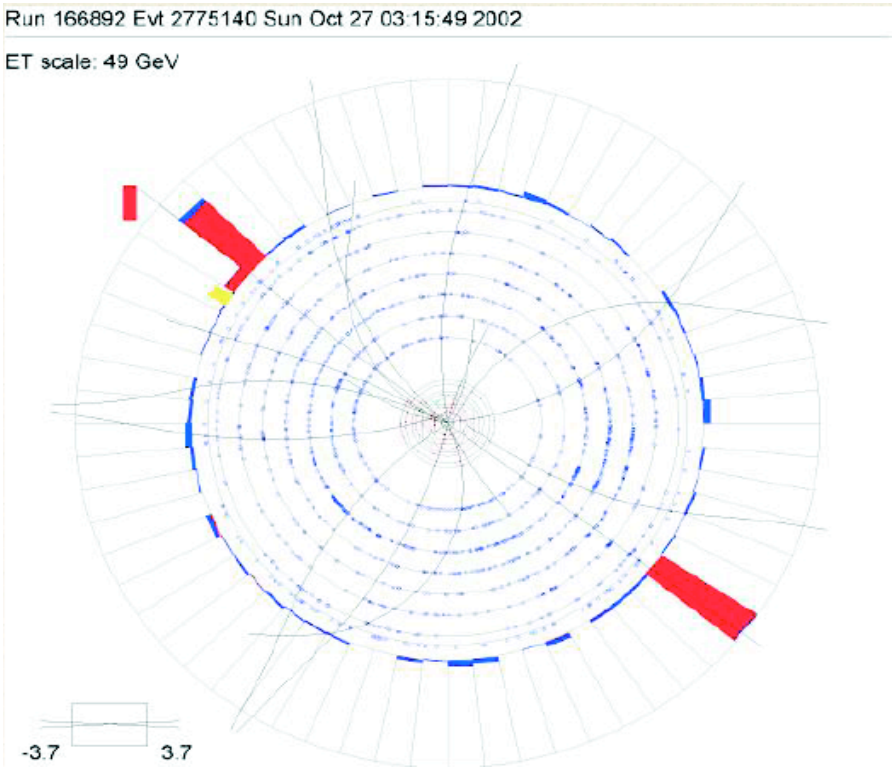
Signatures

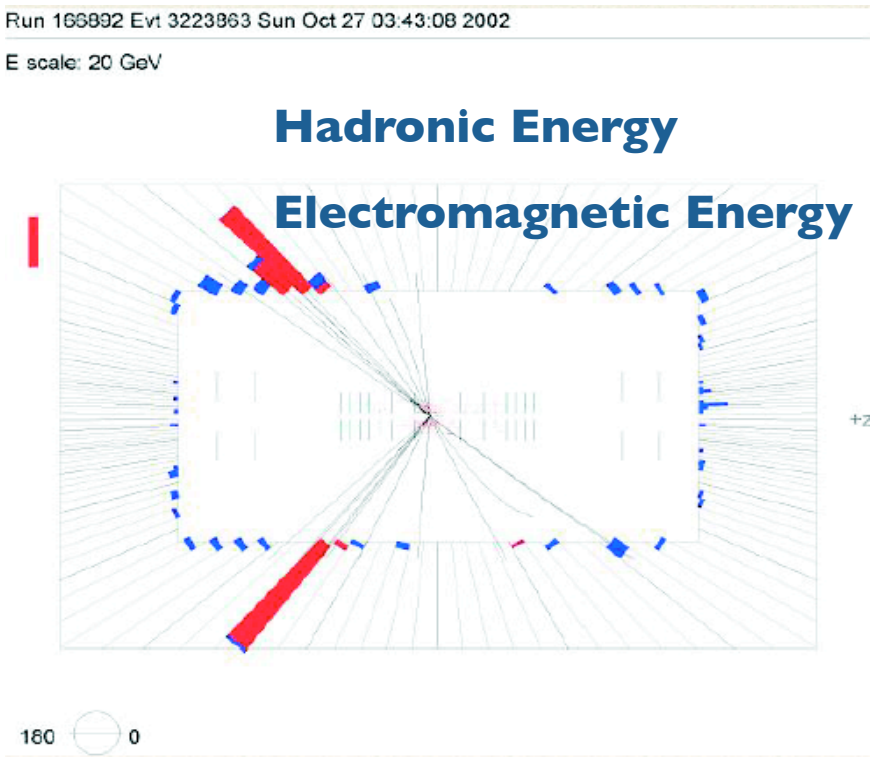

CMS Experiment at LHC, CERN
Run 133874, Event 21466935
Lumi section: 301
Sat Apr 24 2010, 05:19:21 CEST
Electron p_T = 35.6 GeV/c
ME_T = 36.9 GeV
M_T = 71.1 GeV/c²
MET
W→eν candidate


CMS Experiment at LHC, CERN
Run 135149, Event 125426133
Lumi section: 1345
Sun May 09 2010, 05:24:09 CEST
Muon p_T= 67.3, 50.6 GeV/c
Inv. mass = 93.2 GeV/c²
Z→μμ candidate

W/Z : electrons and jets

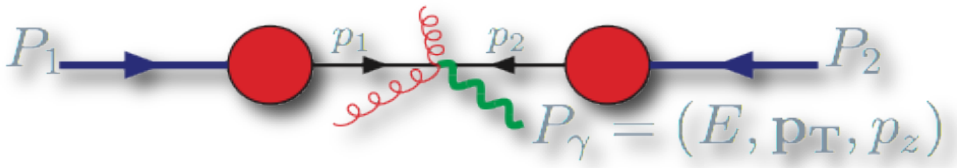
Jets can fake leptons. In the case of the electrons you can see why.
The fake rate has to be evaluated in order to understand the backgrounds





Jets can look like electrons, e.g.:
-photon conversions from π^0's: ~13% of photons convert
-early showering charged pions
And there are lots of jets!!!

Predictions: known up to NNLO in pQCD

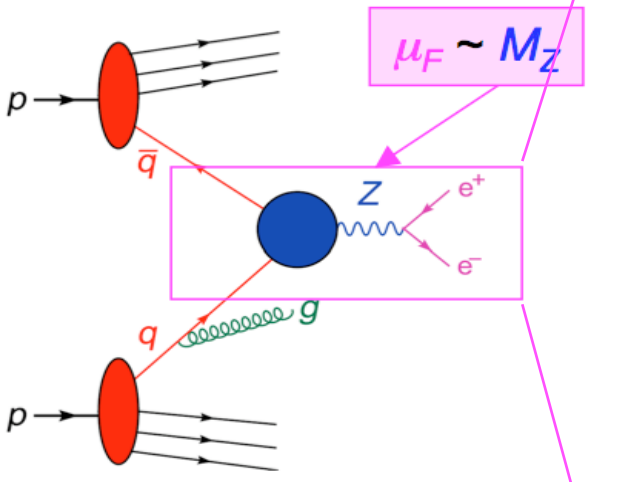


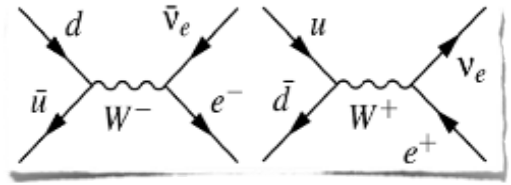
Using FEWZ and MSTW2008, at 7 TeV:

$$\sigma^{NNLO}_{W^+ \to \ell^+ \nu} = 6.16 \text{ nb}$$

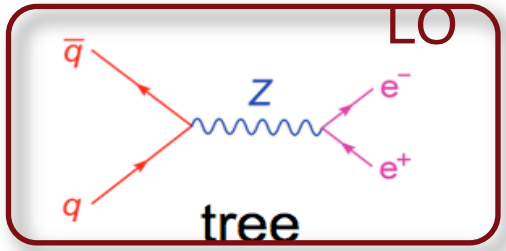
$$\sigma^{NNLO}_{W^- \to \ell^- \bar{\nu}} = 4.30 \text{ nb}$$

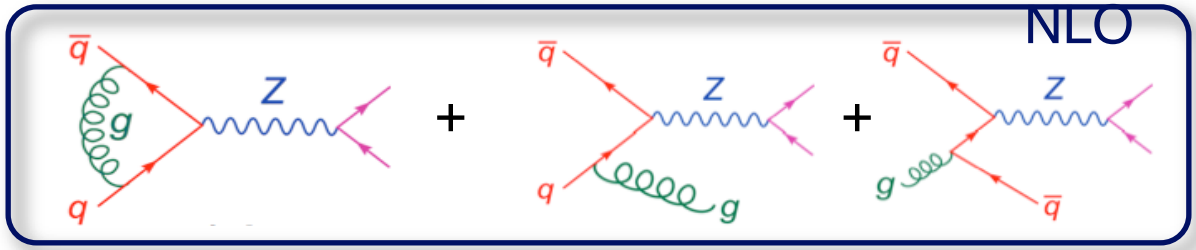
$$\sigma^{NNLO}_{Z/\gamma^* \to \ell\ell} = 0.96 \text{ nb}$$

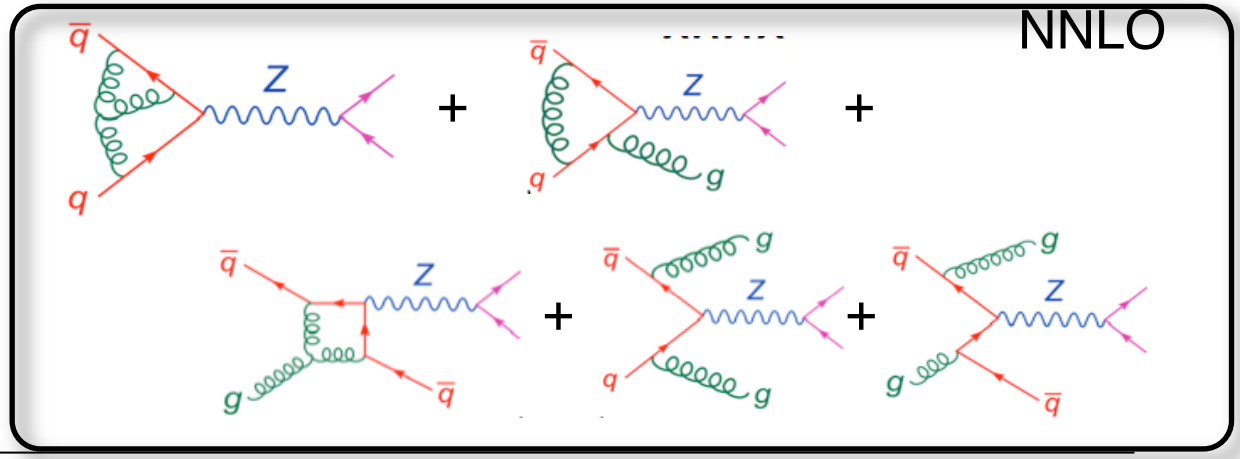




Produce more W+ than W- (prevalence of u quarks over d quarks)





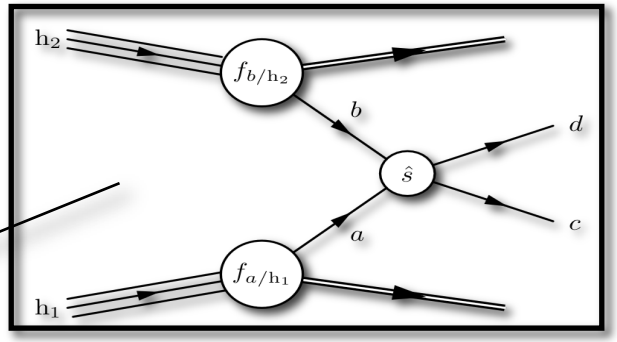


Uncertainties.

NNLO scale uncertainty<1%

Dominant uncertainty for absolute W and Z cross section:

PDFs : 4 - 5 %

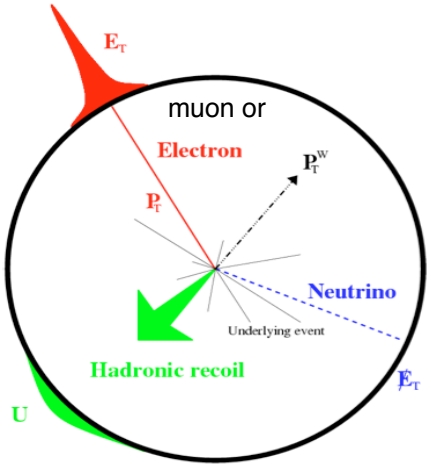


$$d\sigma(h_1 h_2 \to cd) = \int_0^1 dx_1 dx_2 \sum_{a,b} f_{a/h_1}(x_1, \mu_F^2) f_{b/h_2}(x_2, \mu_F^2) d\hat{\sigma}^{(ab\to cd)}(Q^2, \mu_F^2)$$

so : if we measure precisely this, can we constrain this?

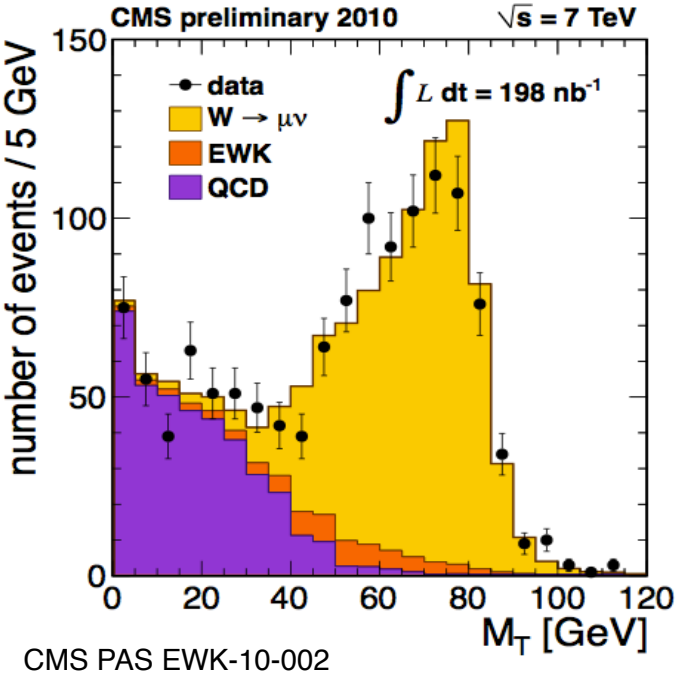
known precisely up to NNLO

Background subtraction in W selection



W: decay to charged leptons
- high-p_T
- isolated
- $E_{T,miss}$ (from neutrino)

transverse mass: $M_T = \sqrt{2p_T(\mu)\not{E}_T(1-\cos(\Delta\phi_{\mu,\not{E}_T}))}$



CMS PAS EWK-10-002

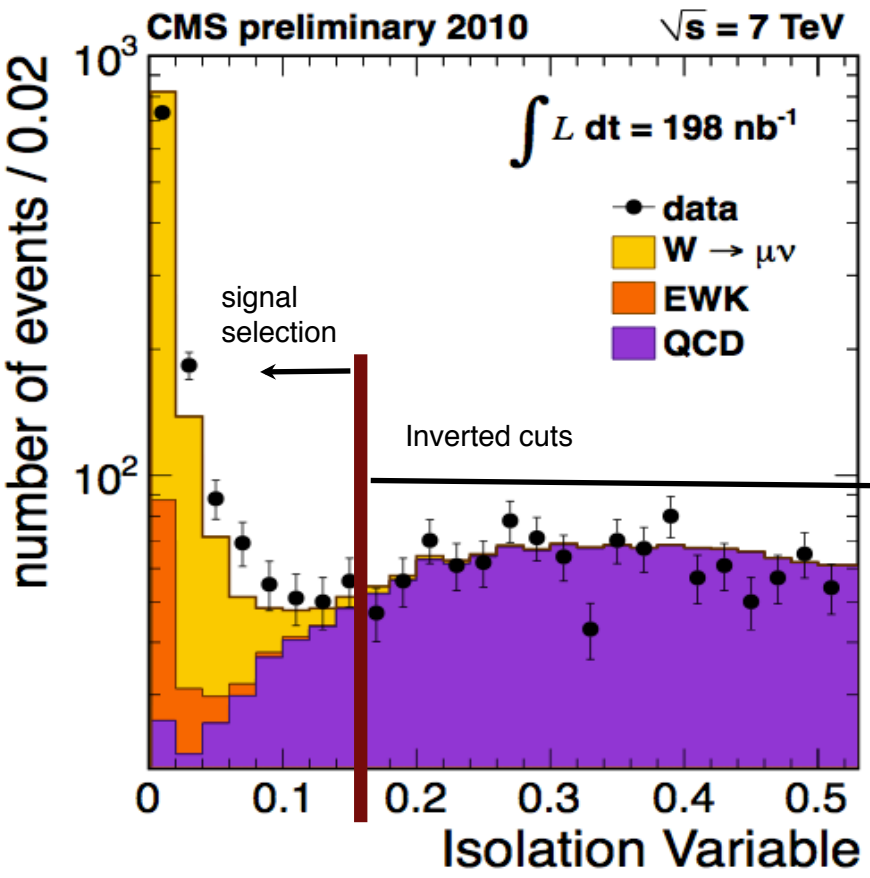
after cut on important selection variable, the relative isolation:

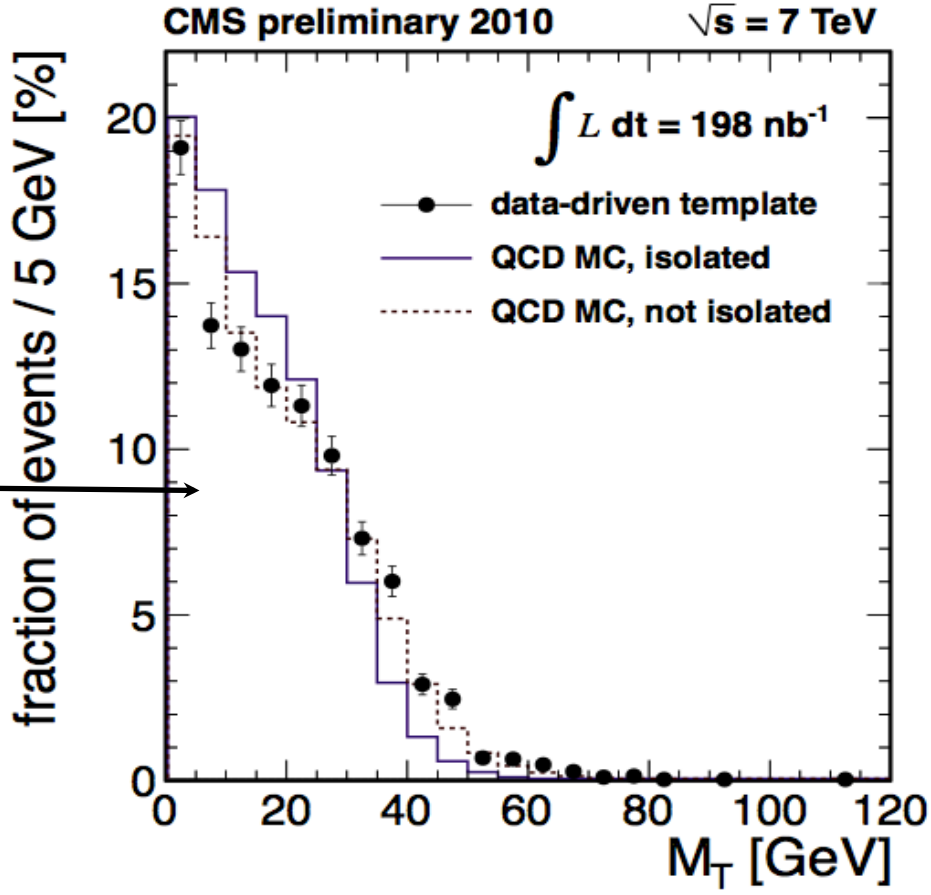
$$I^{rel}_{comb} = \left\{ \sum (p_T(tracks) + E_T(em) + E_T(had)) \right\} / p_T(\mu)$$

in cone $\Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} < 0.3$ around the muon

Background subtraction in W selection

CMS PAS EWK-10-002



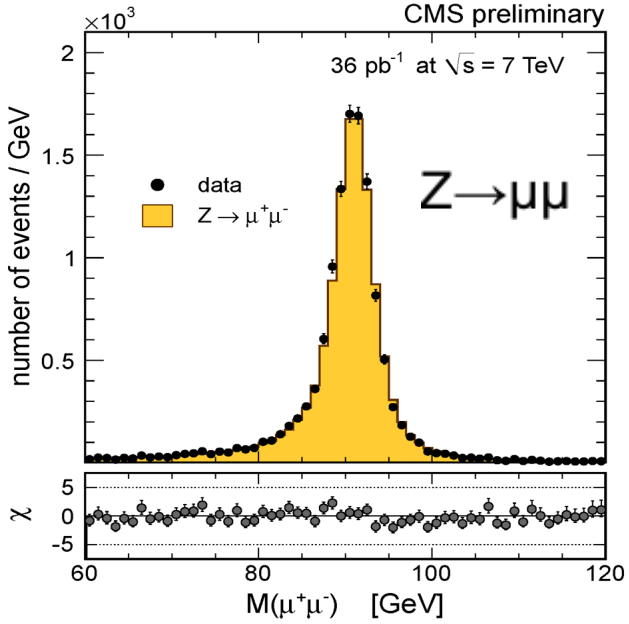


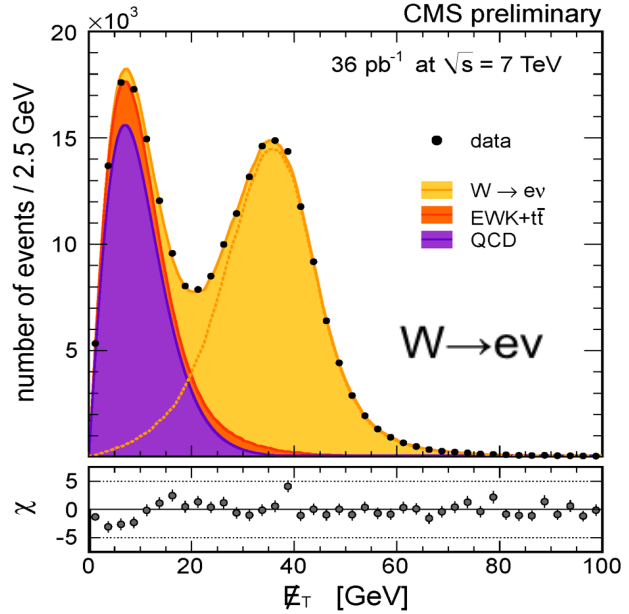
$p_T > 20$ GeV/c in $|\eta| < 2.1$

QCD bkg: mostly b-decays

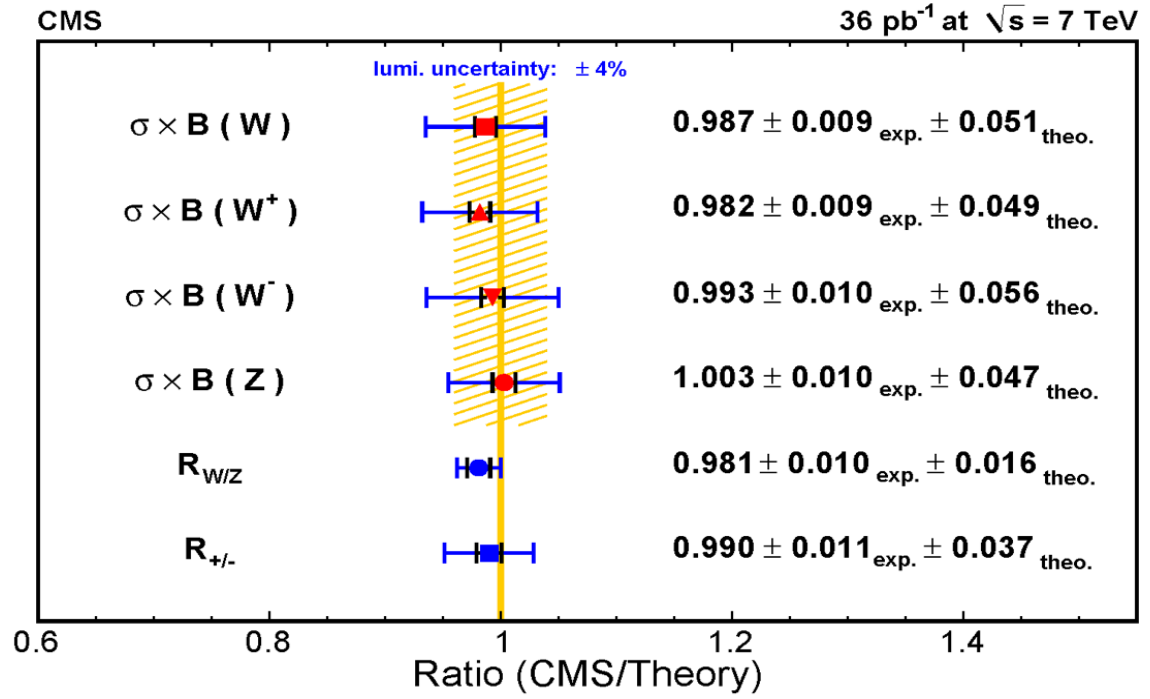
take this shape for fit to M_T distribution

Inclusive W and Z production





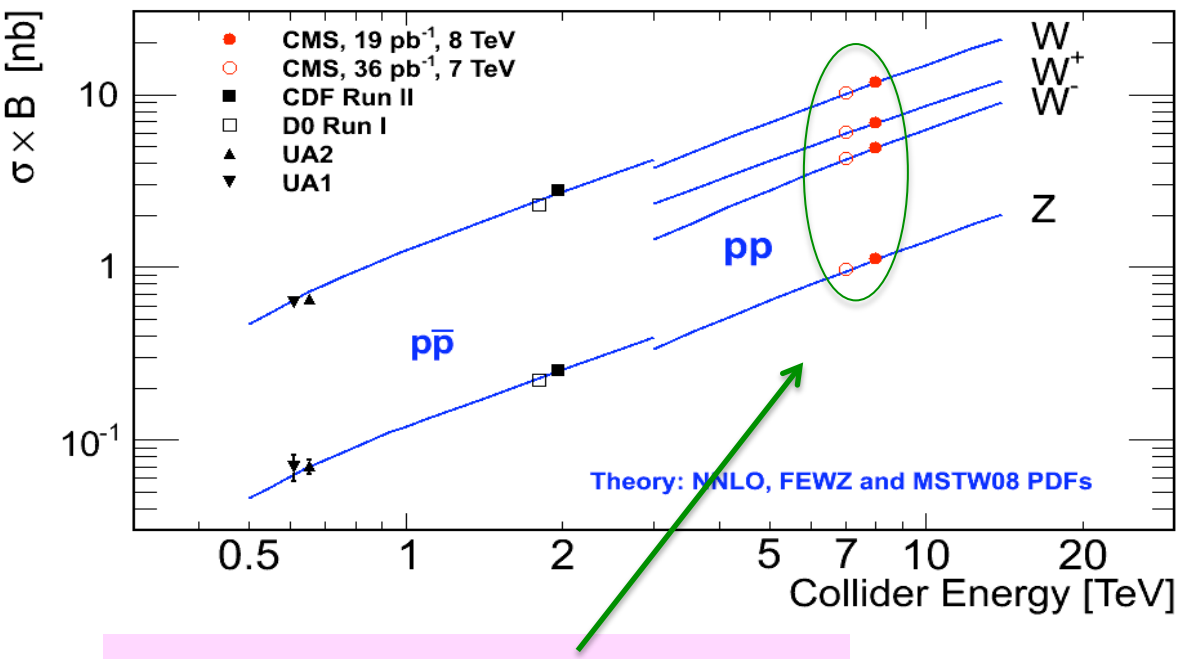
- Z important tool : data-driven methods for controlling lepton eff, scale, resolution, E_{Tmiss} (hadronic recoil).
- In general excellent data-MC agreement



JHEP 10 (2011) 132

Amazing precision reached (~1% experimental !)
Start to put important constraints on theory (NNLO, PDFs)

Inclusive W and Z cross sections



ATLAS points overlap with CMS

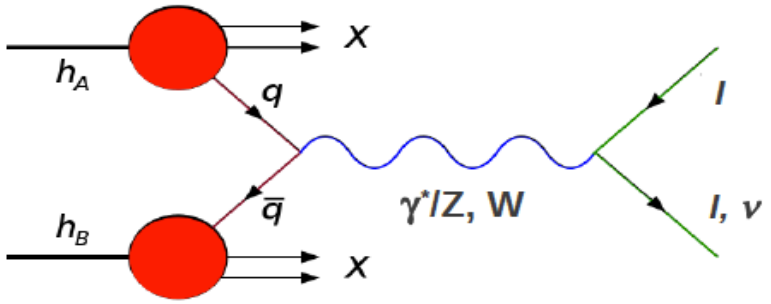
Phys. Rev. D85 (2012) 072004
CMS-PAS-12-011

Measurements already limited by sys and lumi uncertainties

Good agreement with NNLO prediction

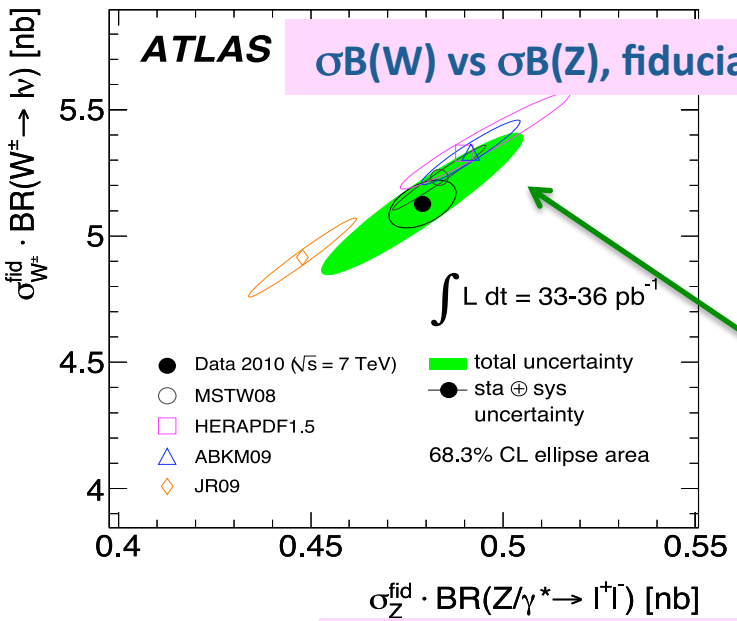
Discriminating power against different PDF sets

	$\sigma_W^{\text{tot}} \cdot \text{BR}(W \to \ell\nu)$ (nb)			
	sta	sys	lum	acc
W^+	$6.048 \pm 0.016 \pm 0.072 \pm 0.206 \pm 0.096$			
W^-	$4.160 \pm 0.014 \pm 0.057 \pm 0.141 \pm 0.083$			
$W^\pm$	$10.207 \pm 0.021 \pm 0.121 \pm 0.347 \pm 0.164$			
	$\sigma_{Z/\gamma^*}^{\text{tot}} \cdot \text{BR}(Z/\gamma^* \to \ell\ell)$ (nb)			
	$66 < m_{\ell\ell} < 116$ GeV			
	sta	sys	lum	acc
Z/γ^*	$0.937 \pm 0.006 \pm 0.009 \pm 0.032 \pm 0.016$			



$$\frac{d^2\sigma}{dQ^2 dx} \sim \Sigma_i q_i(x)\overline{q}_i(x)\hat{\sigma}(Q^2)$$

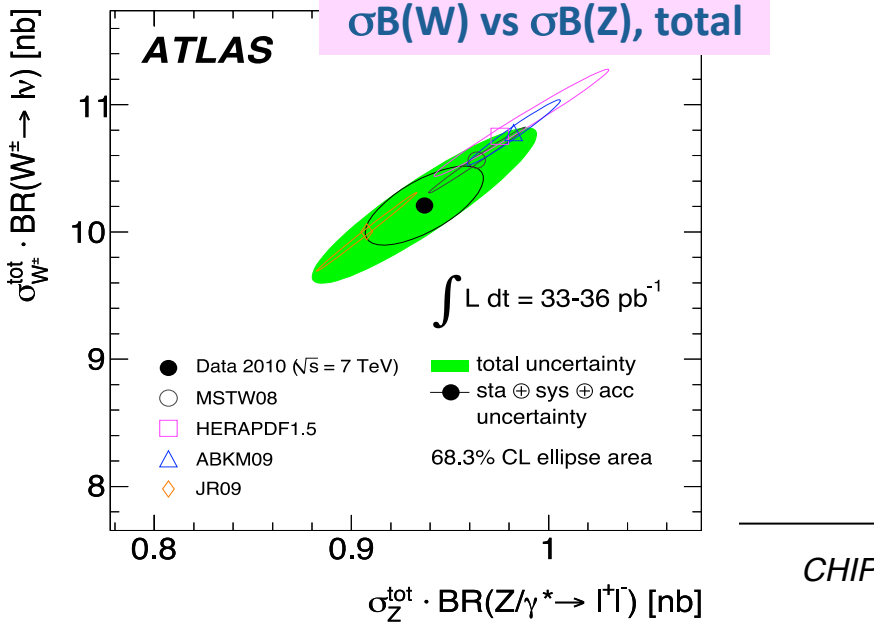
Sensitivity of W/Z cross section to PDF

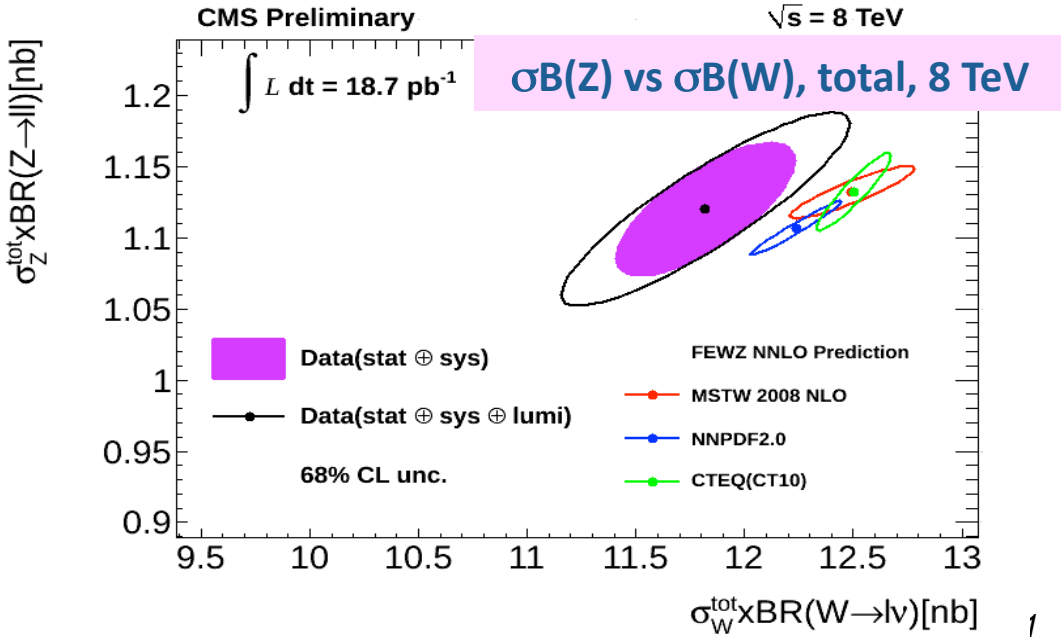


Phys. Rev. D85 (2012) 072004
CMS-PAS-12-011

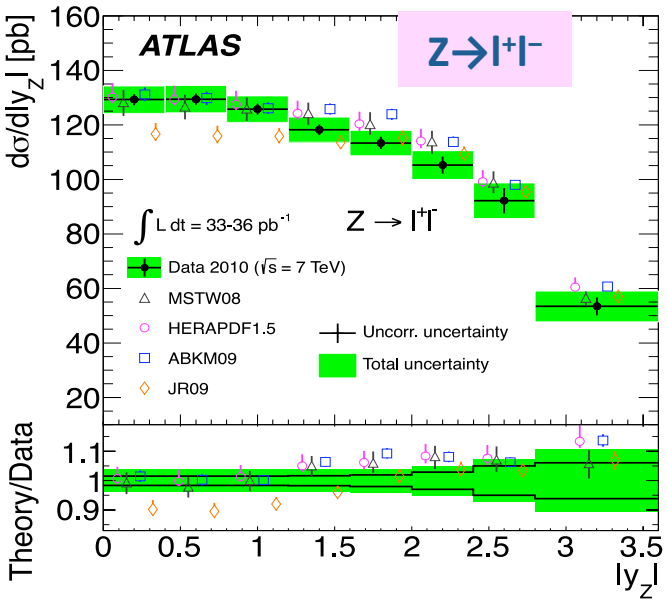
Sensitivity to different PDF sets approaching 1σ!

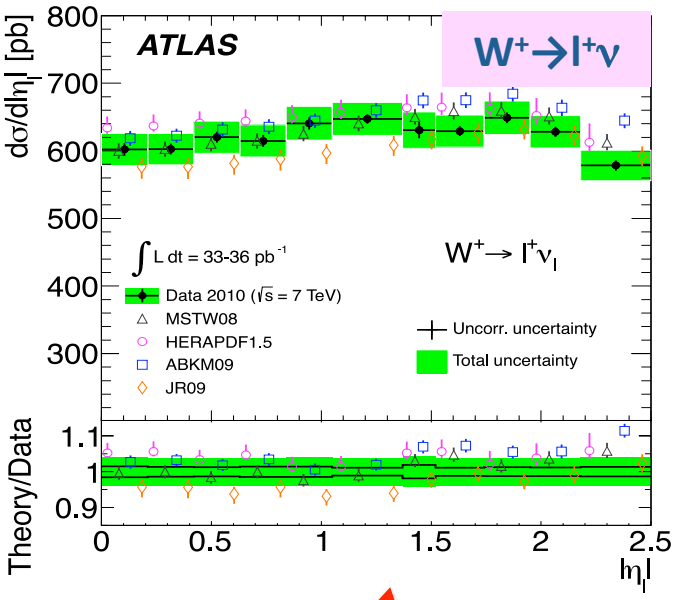
Fiducial cross sections have no theoretical uncertainty from extrapolation to full phase space → better sensitivity

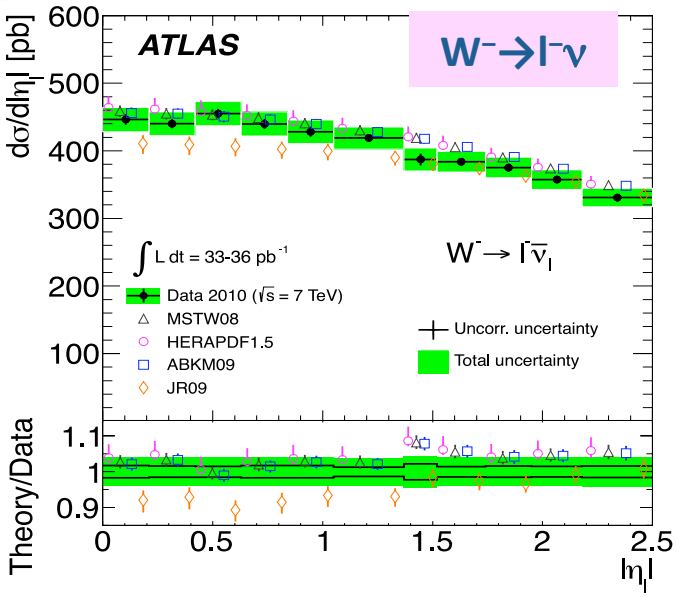


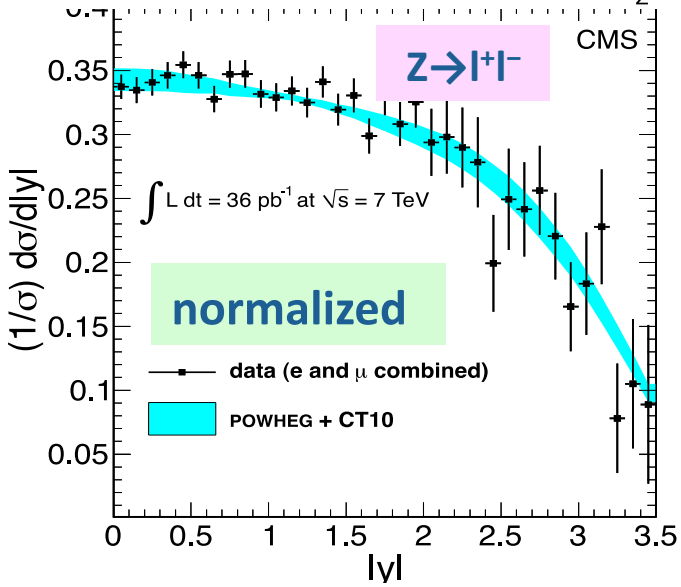


W/Z differential cross sections in rapidity







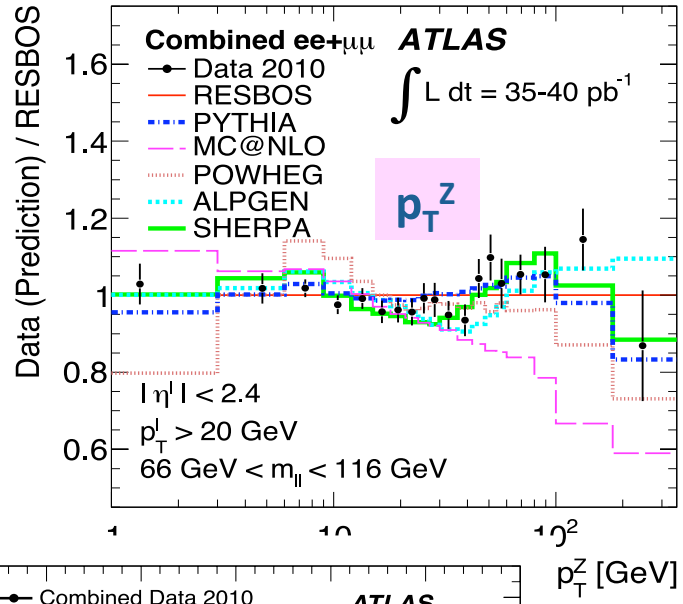


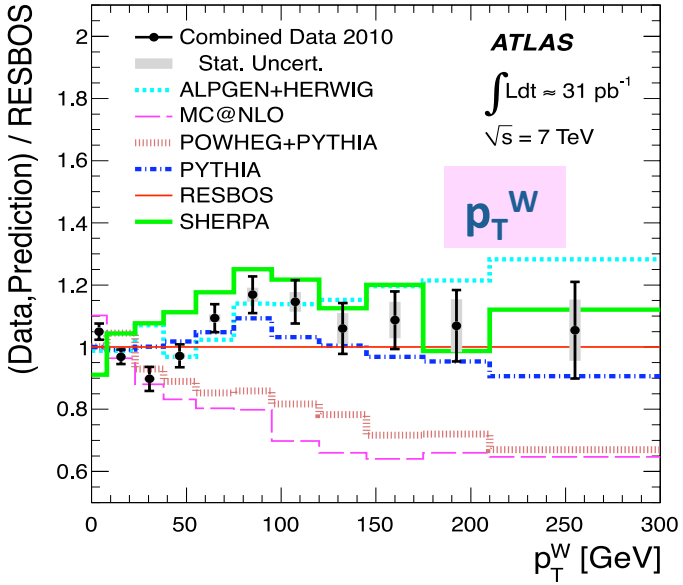
Z, W⁺, W⁻ sensitive to different parton flavour configurations

Impact on the detailed understanding of PDF

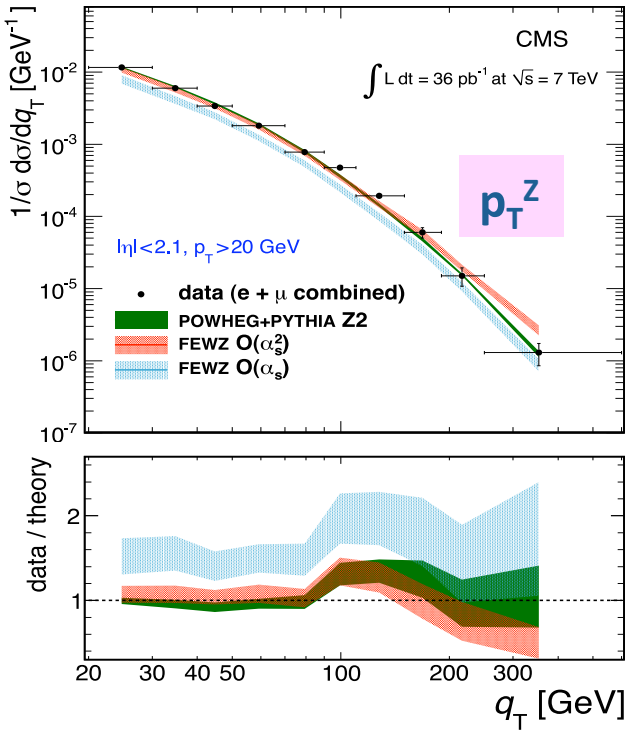
Phys. Rev. D85 (2012) 072004
JHEP 10 (2011) 132

W/Z differential cross sections in p_T





Phys. Rev. D85 (2012) 032002
Phys. Rev. D85 (2012) 012005



- NLO predictions undershoot data at high pT
- NNLO/higher-order Matrix Element predictions restore agreement → higher-order corrections are important
  - eg. for M_W measurement

W charge asymmetries

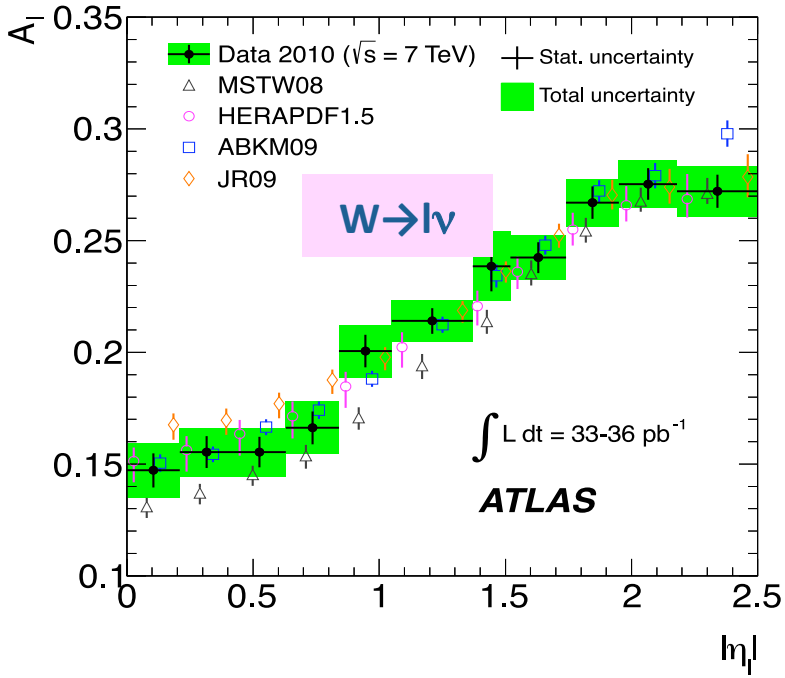
LHC is a pp-collider: prevalence of u quarks
2 valence up quarks,1 valence down quark

Sea quark Valence quark

Since valence quarks have high x
➡ more W^+ (u dbar) than W^-(ubar d)
(remember that the proton is uud)
Here the PDF' are giving very different predictions

$$\mathcal{A}(\eta) = \frac{d\sigma/d\eta(W^+ \to e^+\nu) - d\sigma/d\eta(W^- \to e^-\bar{\nu})}{d\sigma/d\eta(W^+ \to e^+\nu) + d\sigma/d\eta(W^- \to e^-\bar{\nu})}$$

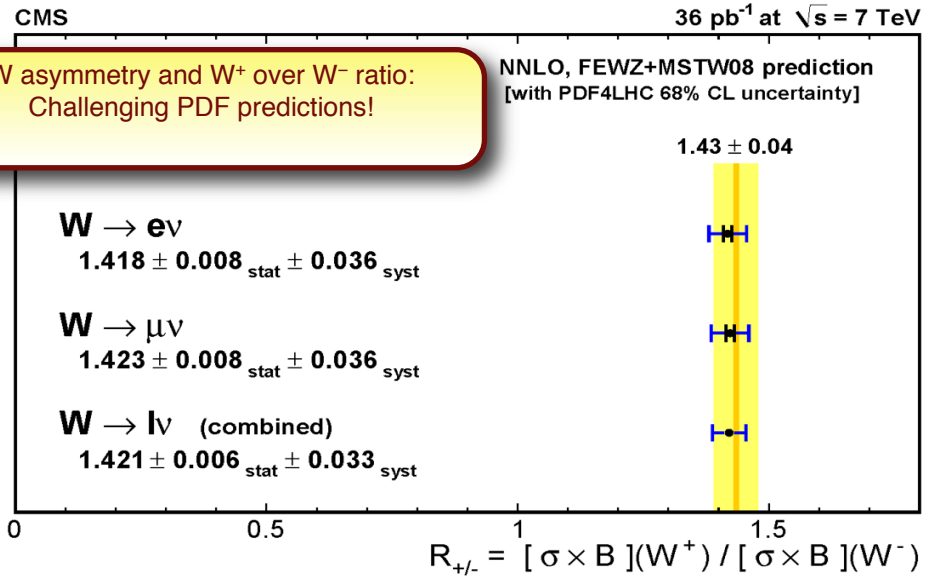
Phys. Rev. D85 (2012) 072004
CMS-PAS-EWK-11-005
arXiv:1206.2598



Sensitive to choices of PDF

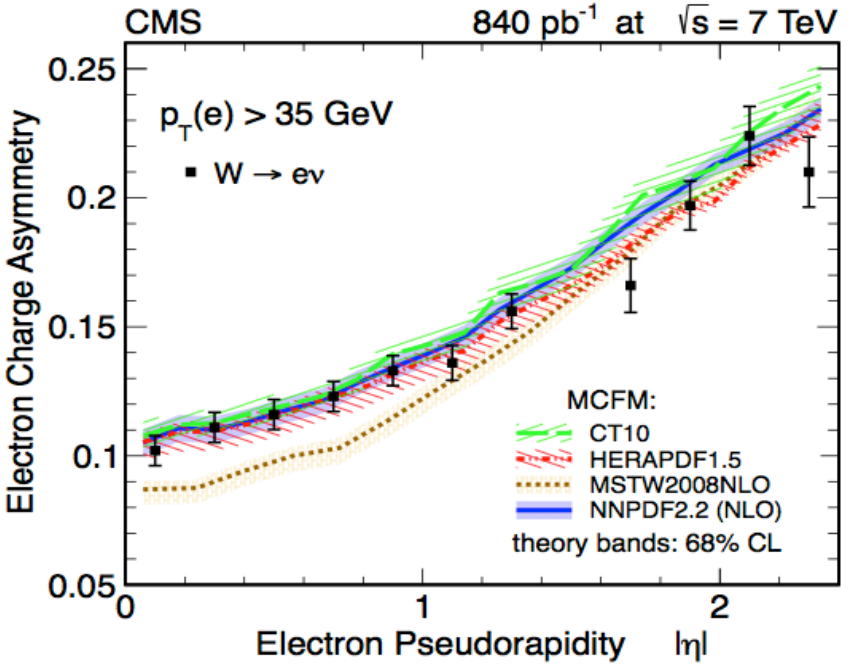
W properties, constraining PDFs

W asymmetry and W^+ over W^- ratio: Challenging PDF predictions!

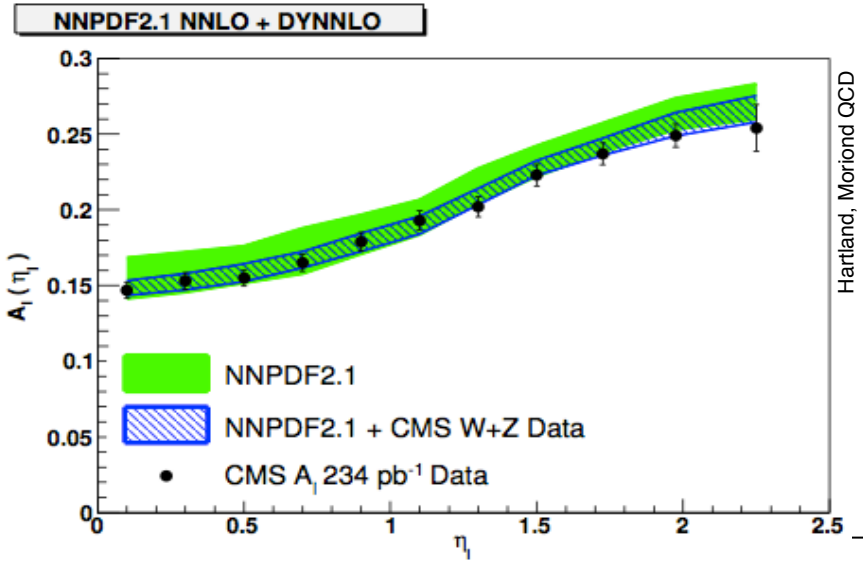


JHEP 10 (2011) 132

$$\mathcal{A}(\eta) = \frac{d\sigma/d\eta(W^+ \to e^+\nu) - d\sigma/d\eta(W^- \to e^-\bar{\nu})}{d\sigma/d\eta(W^+ \to e^+\nu) + d\sigma/d\eta(W^- \to e^-\bar{\nu})}$$



CMS PAS SMP-12-001, arXiv:1206.2598

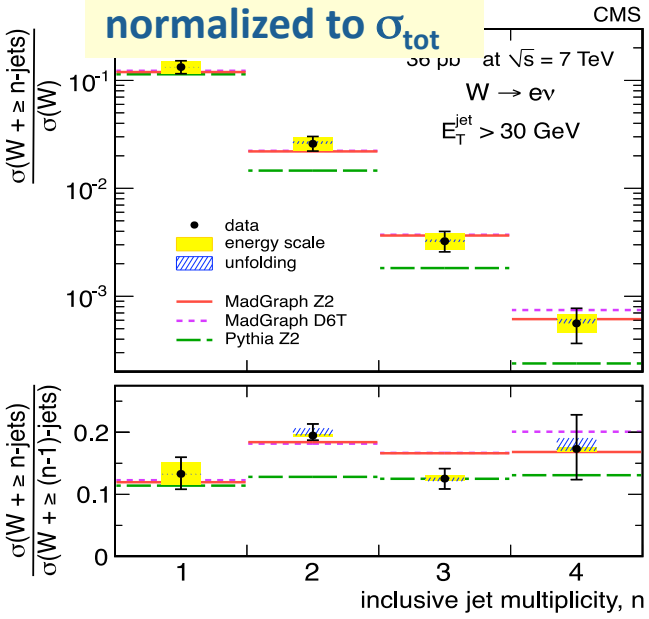


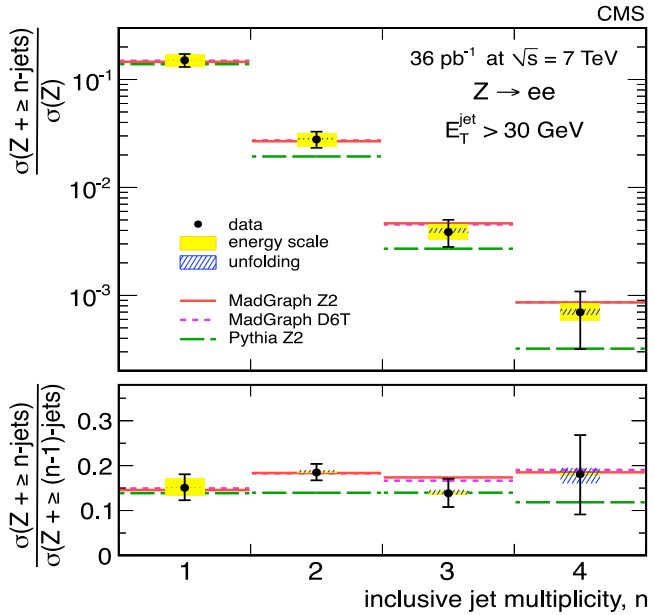
Hartland, Moriond QCD

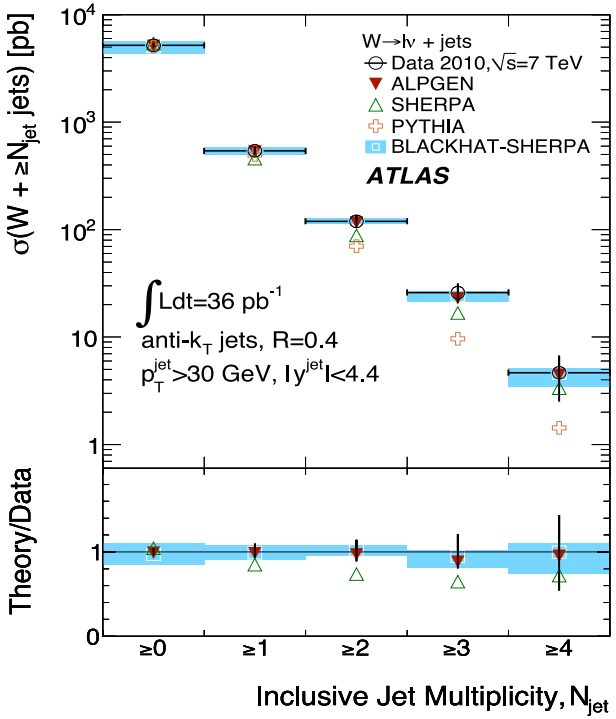
- First results seen from NNPDF group when including such data
- looking forward to further global fits based on LHC data.....

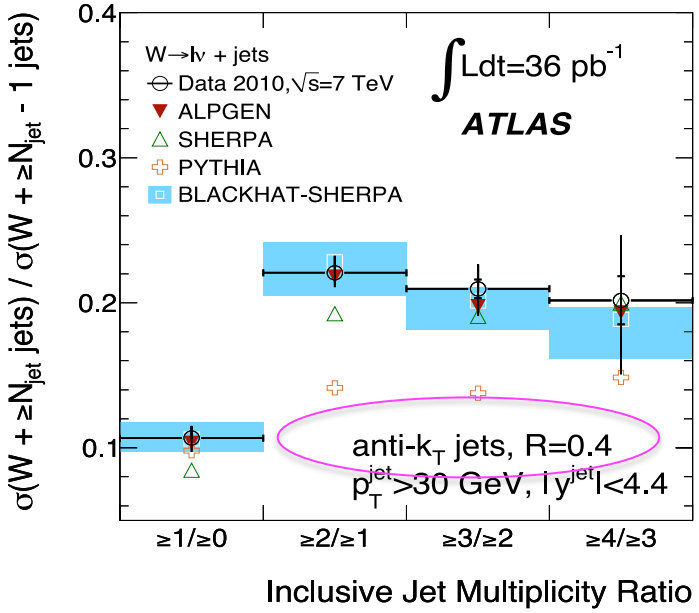
W/Z + jets : jet multiplicities

normalized to σ_{tot}









$$\frac{\sigma(W + \geq \mathrm{n\ jets})}{\sigma(W + \geq \mathrm{n-1\ jets})}$$

Good agreement with multi-parton matrix element + parton shower predictions

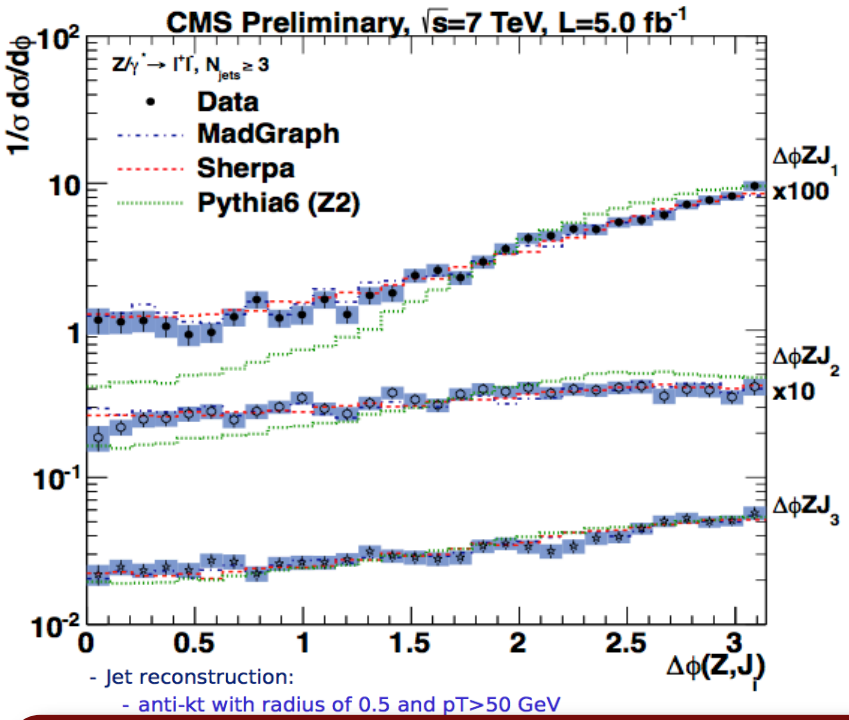
Pure parton shower MC inadequate for describing multi-jet final states

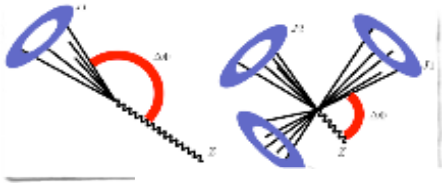
Phys. Rev. D85 (2012) 092002
JHEP 01 (2012) 010

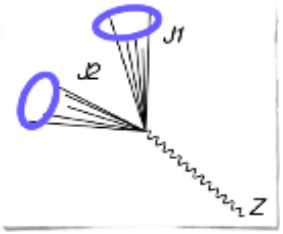
Z+jets: more differential

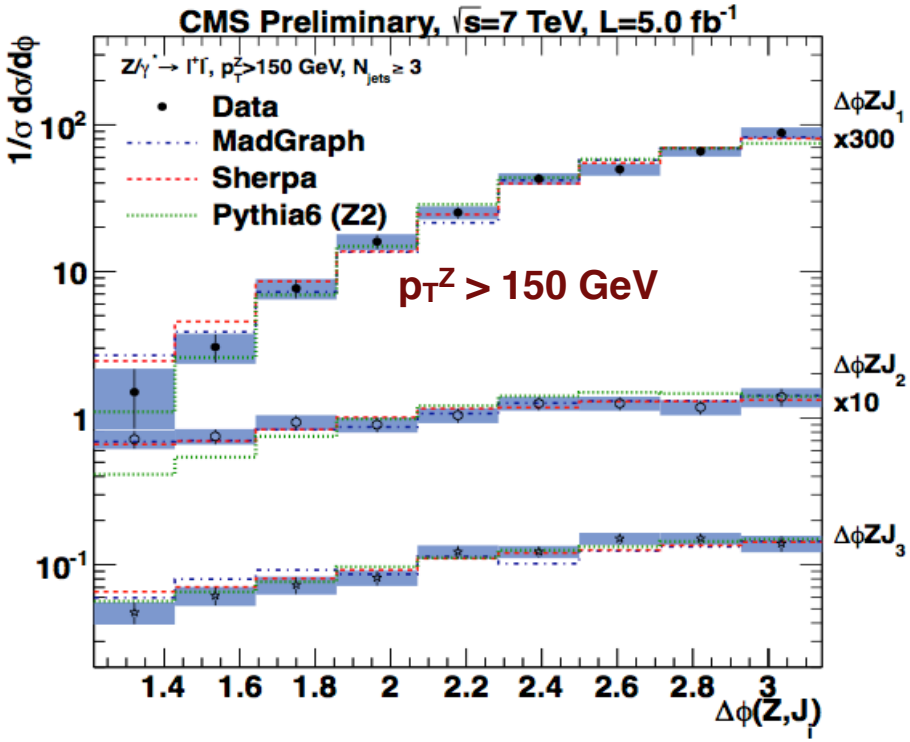
CMS-PAS-EWK-11-021

- **New:** high-stat. measurements of Z+jets production, in particular testing angular correlations and event shapes,
- for different regions of phase space (in p_T^Z) : useful for testing phase space relevant for searches







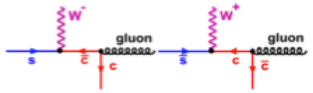


Again: a success for ME+PS matched Monte Carlo models!

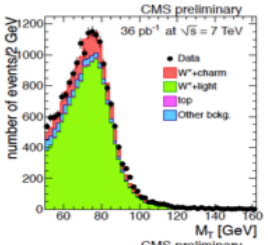
Note: for subleading jets and boosted regime a simple PS does pretty well

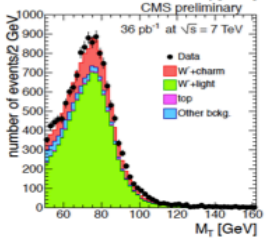
V plus heavy flavour

First Measurement of W+c



Sensitivity to (anti) strange distribution





Transverse mass in W+1 jet

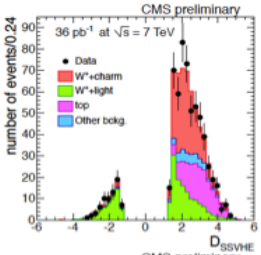
W →μν
Lifetime tag
Measure:

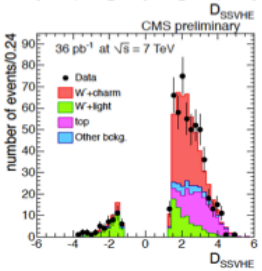
$R_c^{\pm}$ = (W⁺+cbar)/(W⁻+c)
R_c = (W+c)/(W+jet)

$$R_c^{\pm} = 0.92 \pm 0.19\,(stat.) \pm 0.04\,(syst.)$$
$$R_c = 0.143 \pm 0.015\,(stat.) \pm 0.024\,(syst.)$$

MCFM (CT10)	MCFM (MSTW08)	MCFM (NNPDF21)
$0.915^{+0.006}_{-0.006}$	$0.881^{+0.022}_{-0.032}$	0.902 ± 0.008
$0.125^{+0.013}_{-0.007}$	$0.118^{+0.002}_{-0.002}$	0.103 ± 0.005

CMS PAS EWK-11-013



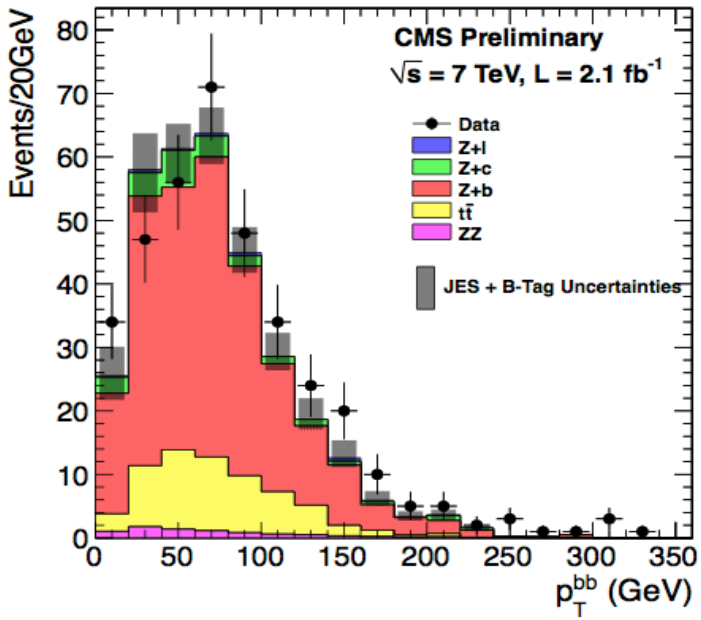


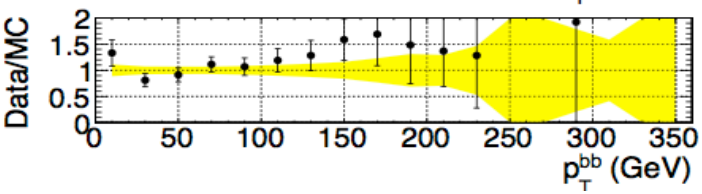
SSVHE: 2nd vtx with >= 2 tracks

M. Klein, Sep11

Z+ bb-jets prod.

CMS-PAS-SMP-12-003



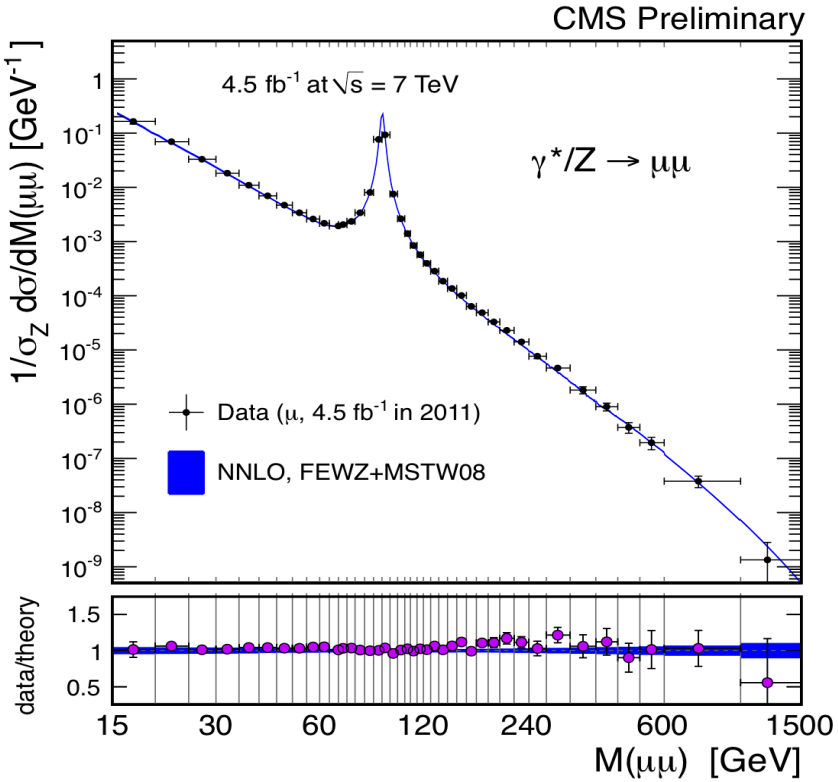


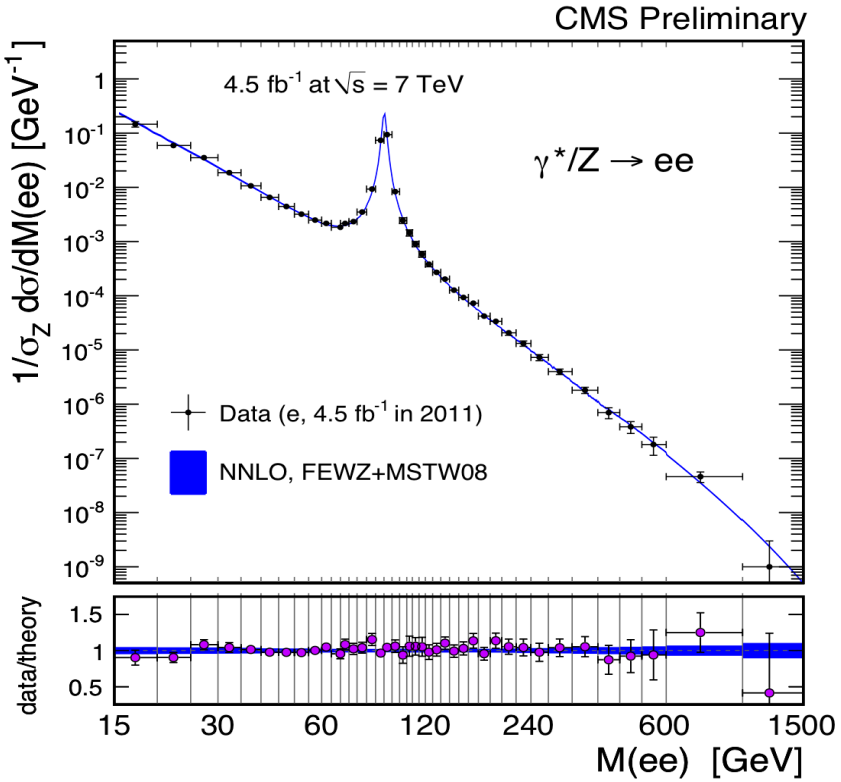
W+c and Z+b most relevant to constrain PDFs, relevant for later high-precision W mass measurement.

So far, no major discrepancies seen compared to NLO (in contrast to W+b prod....)

Drell-Yan production cross sections dσ/dM

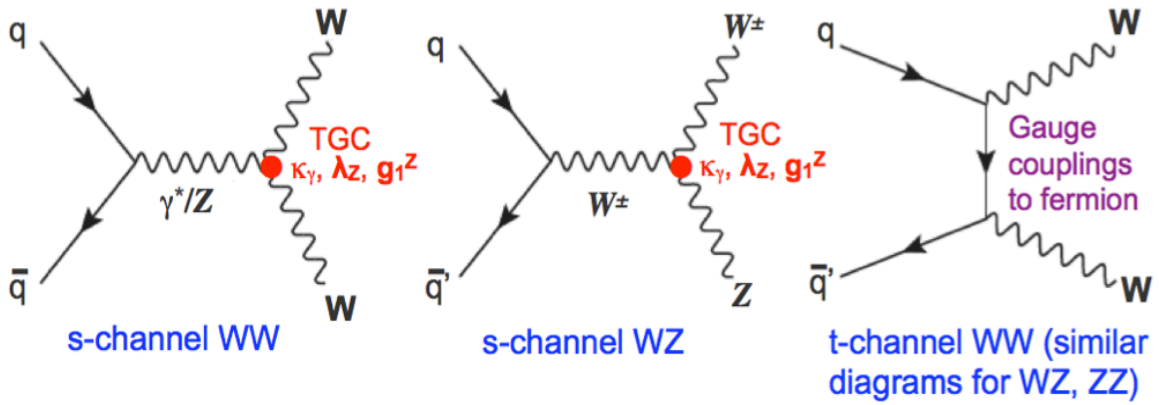
CMS-PAS-EWK-11-007





- Good agreement with NNLO theoretical prediction
- Sensitive tool to check the Standard Model
- Important background to many new physics channels

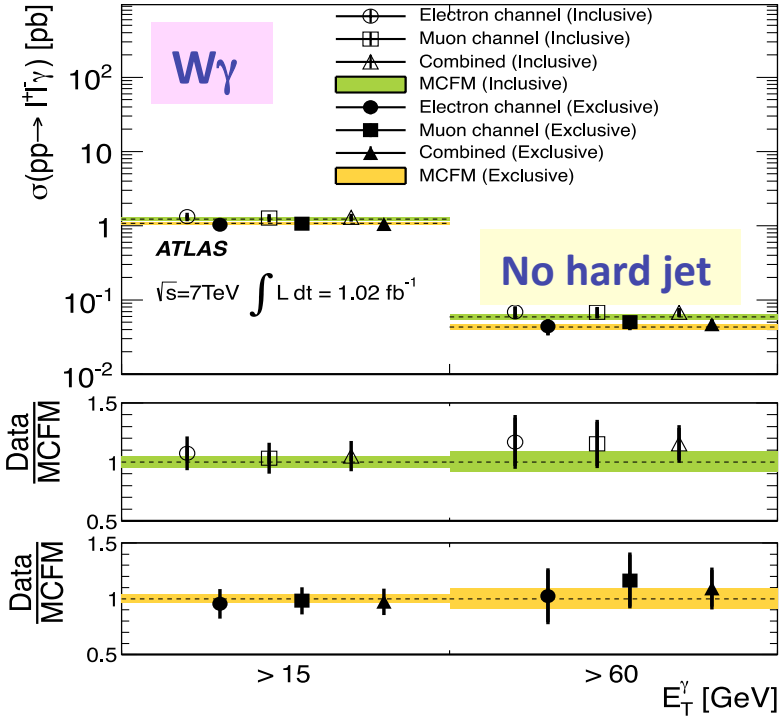
Diboson (Wγ, Zγ, WW, WZ, ZZ,) production

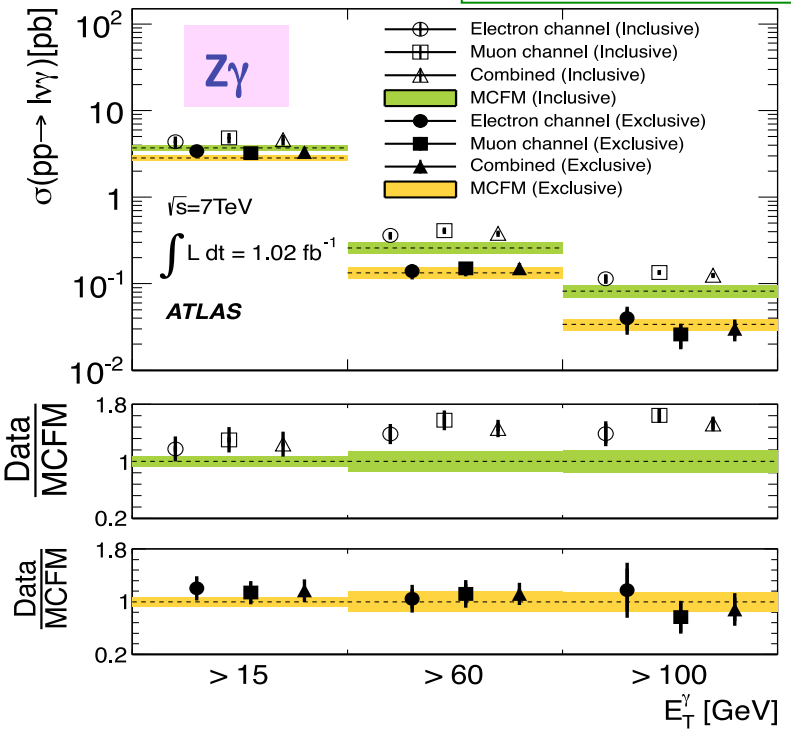


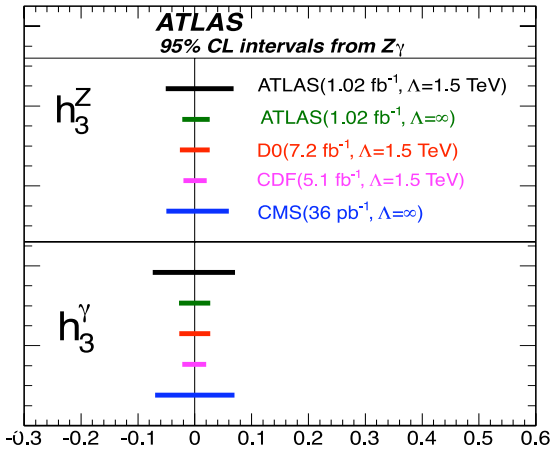
- **Critical test of the gauge structure of the SM**
  - Allows to search for anomalous Triple Gauge Couplings (TGC)
- **Mandatory preliminary study for Higgs searches**: irreducible background for Higgs searches in WW and ZZ modes
- Probe for new physics
  - Resonances with diboson final states

Wγ and Zγ production

arXiv:1205.2531
Phys. Lett. B 701 (2011) 535





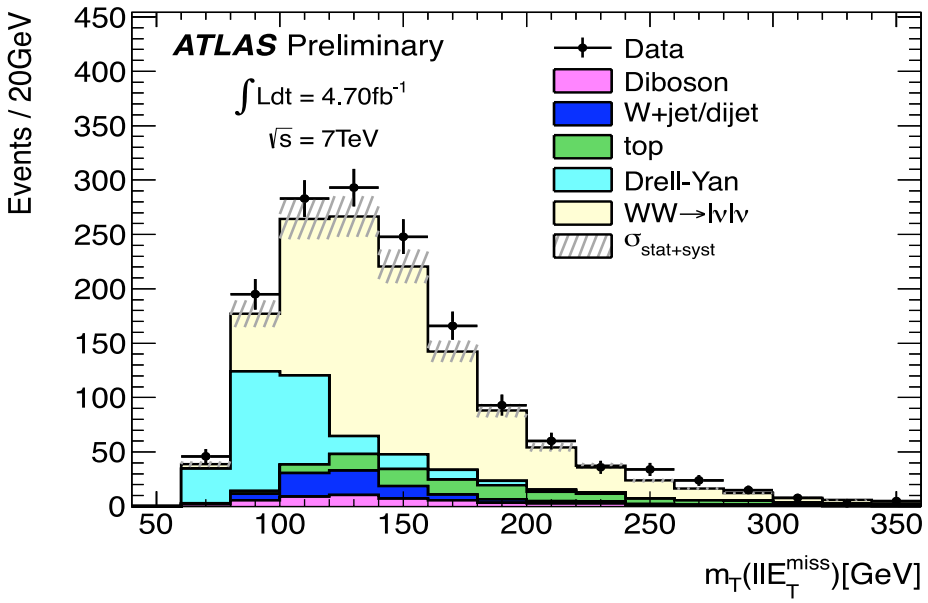


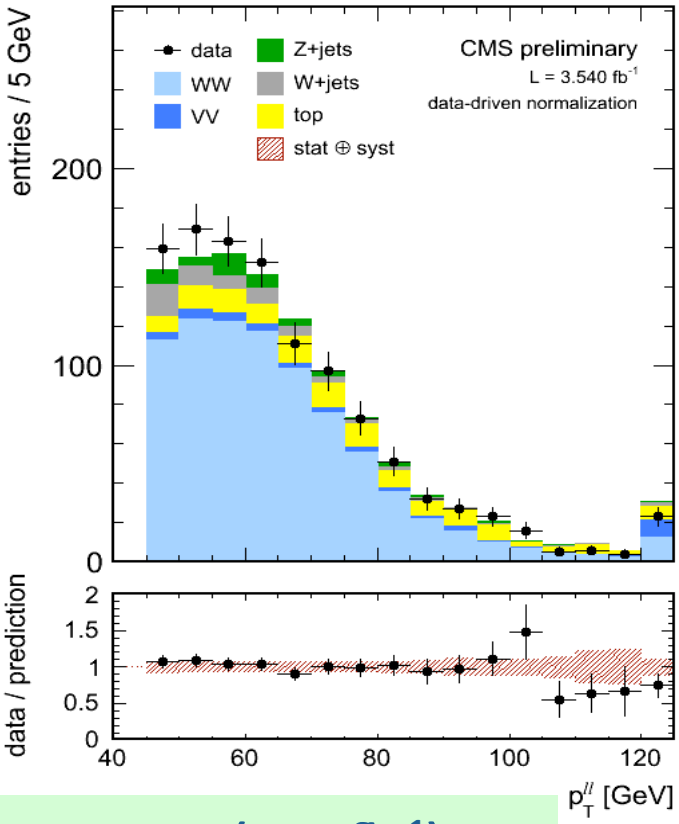
Wγ inclusive above MCFM, particular at high p_T
→ high order effects (NNLO and beyond)

Competitive limits on anomalous WWγ, Zγγ, ZZγ couplings

WW production

Measure cross section in WW→2l2ν channel
→ Need good calibration for missing E_T





7 TeV, ATLAS(4.7 fb^{-1})/CMS(4.92 fb^{-1})

$$\text{ATLAS}: 53.4 \pm 2.1(\text{stat}) \pm 4.5(\text{syst}) \pm 2.1(\text{lumi})\ \text{pb}$$

$$\text{CMS}: \quad 52.4 \pm 2.0(\text{stat}) \pm 4.5(\text{syst}) \pm 1.2(\text{lumi})\ \text{pb}$$

$$\text{NLO}: \quad 45.1 \pm 2.8\ \text{pb}$$

8 TeV, CMS(3.54 fb^{-1})

$$69.9 \pm 2.8(\text{stat}) \pm 5.6(\text{syst}) \pm 3.1(\text{lumi})\ \text{pb}$$

$$\text{NLO}: \quad 57.3^{+2.4}_{-1.6}\ \text{pb}$$

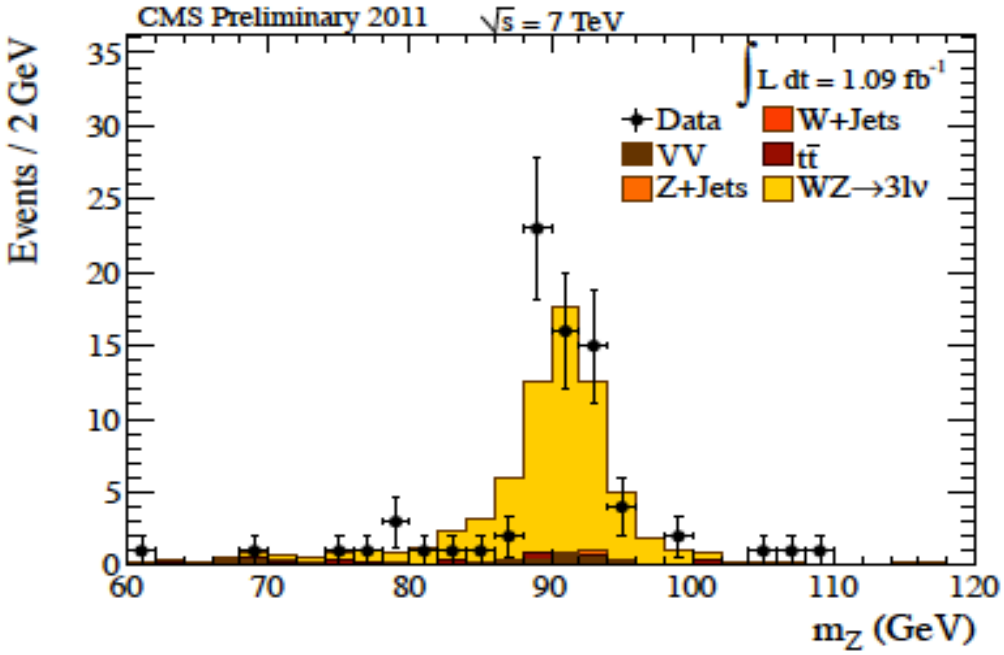
Already systematics limited! A mild "excess" in data ?

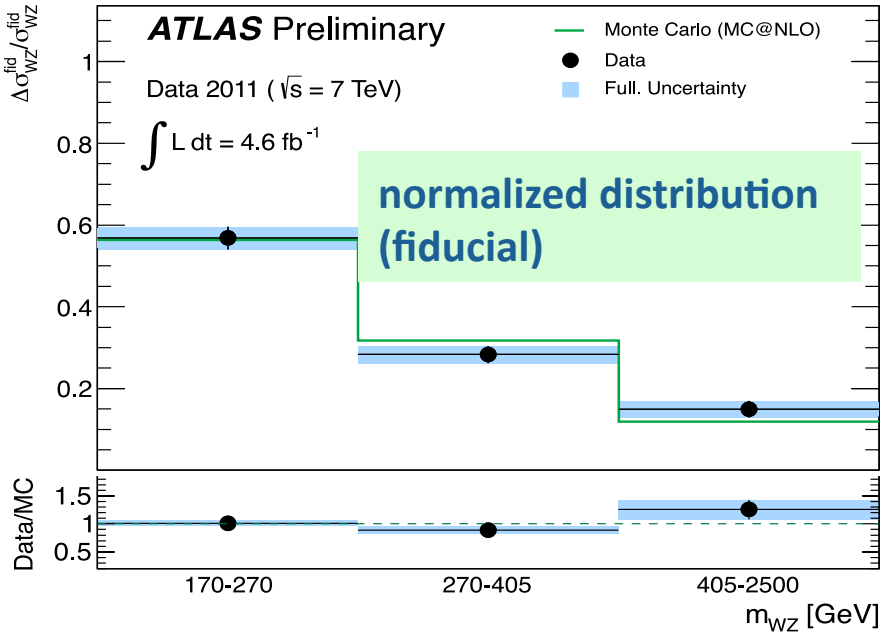
ATLAS-CONF-2012-025
CMS PAS SMP-12-005
CMS PAS SMP-12-013

WZ production

Measure cross section in WZ->3l1ν channel
→ very small bkg, low statistics

ATLAS (ICHEP 2012)
CMS PAS EWK-11-010

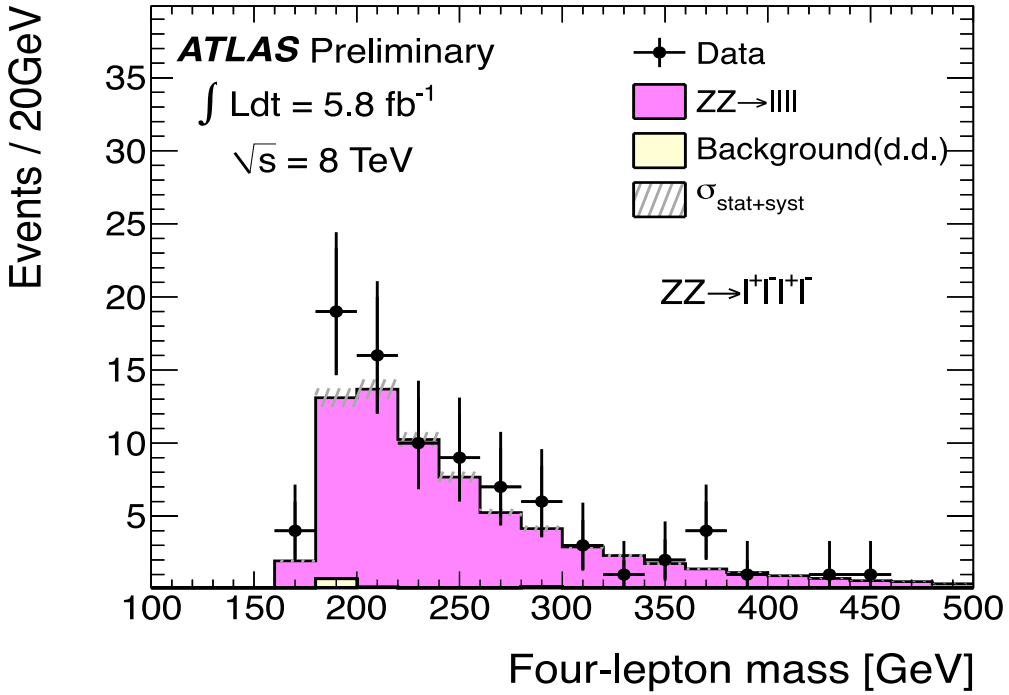


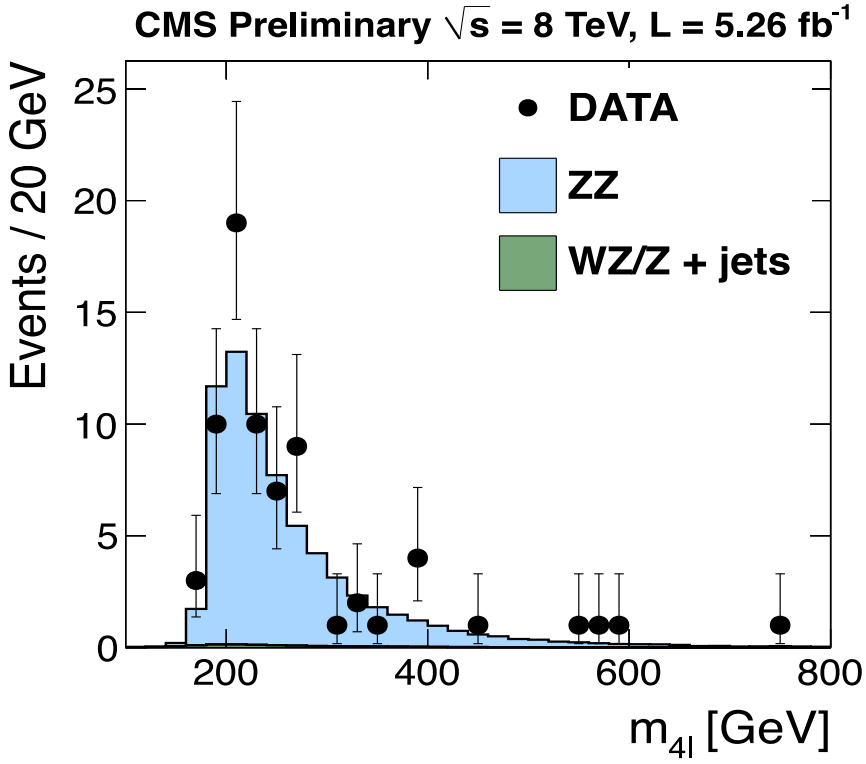


ATLAS (4.6 fb^{-1})	$19.0^{+1.4}_{-1.3}(\text{stat}) \pm 0.8(\text{syst}) \pm 0.4(\text{lumi})$ pb	$17.6^{+1.1}_{-0.6}$ pb
CMS (1.09 fb^{-1})	$17.0 \pm 2.4(\text{stat}) \pm 1.1(\text{syst}) \pm 1.0(\text{lumi})$ pb	17.5 ± 0.6 pb

ZZ production at 8 TeV

ATLAS-CONF-2012-090; CMS-PAS-SMP-12-014



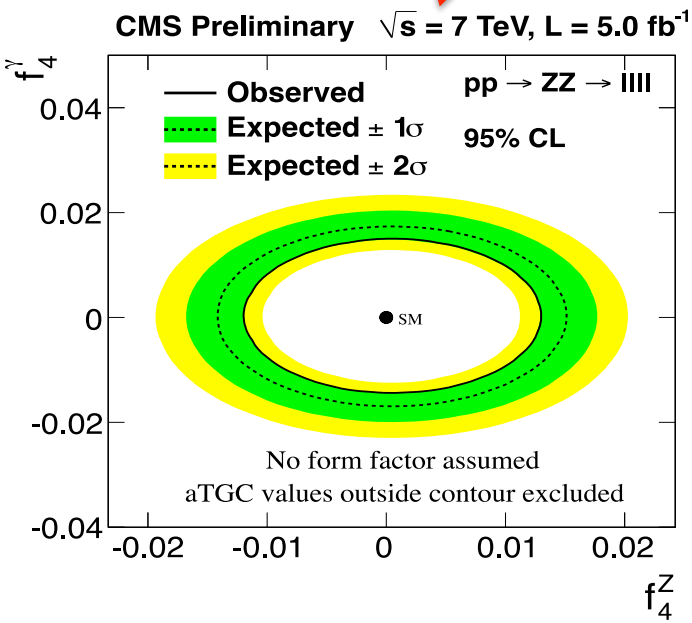


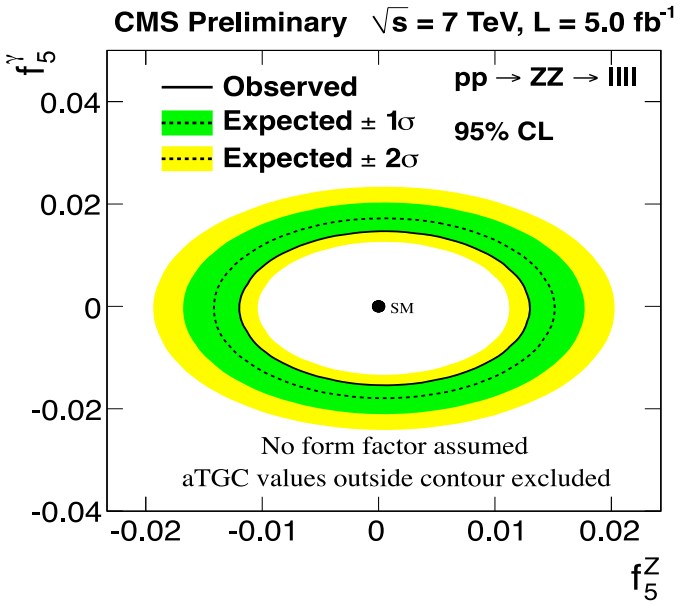
ATLAS (5.8 fb^{-1})	$9.3^{+1.1}_{-1.0}(\text{stat})\pm^{+0.4}_{-0.3}(\text{syst})\pm 0.3(\text{lumi})$ pb	7.4 ± 0.4 pb
CMS (5.26 fb^{-1}) (include 2l2τ)	$8.4 \pm 1.0(\text{stat}) \pm 0.7(\text{syst}) \pm 0.4(\text{lumi})$ pb	7.7 ± 0.4 pb

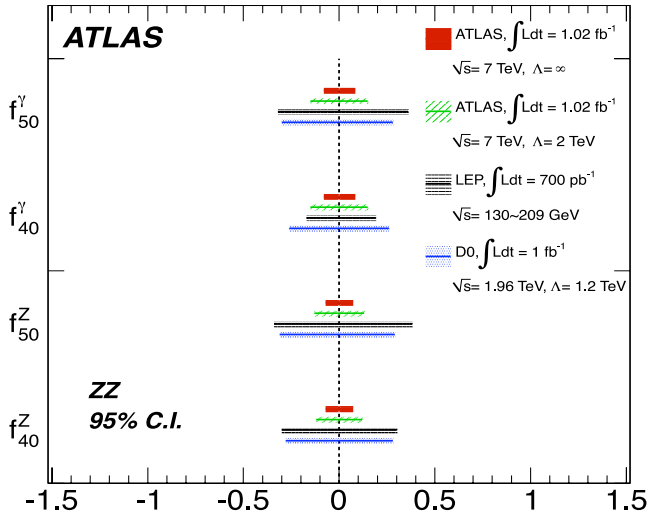
Limits on Triple Gauge Coupling ZZZ and ZZγ

- Set limits to the anomalous couplings assuming an effective Lagrangian
  - Use total number of events (ATLAS) or the shape of the ZZ invariant mass (CMS)

$$\mathcal{L}_{VZZ} = -\frac{e}{M_Z^2}\left[f_4^V(\delta_\mu V^{\mu\beta})Z_\alpha(\delta^\alpha Z_\beta) + f_5^V(\delta^\sigma V_{\sigma\mu})Z^{\mu\beta}Z_\beta\right]$$



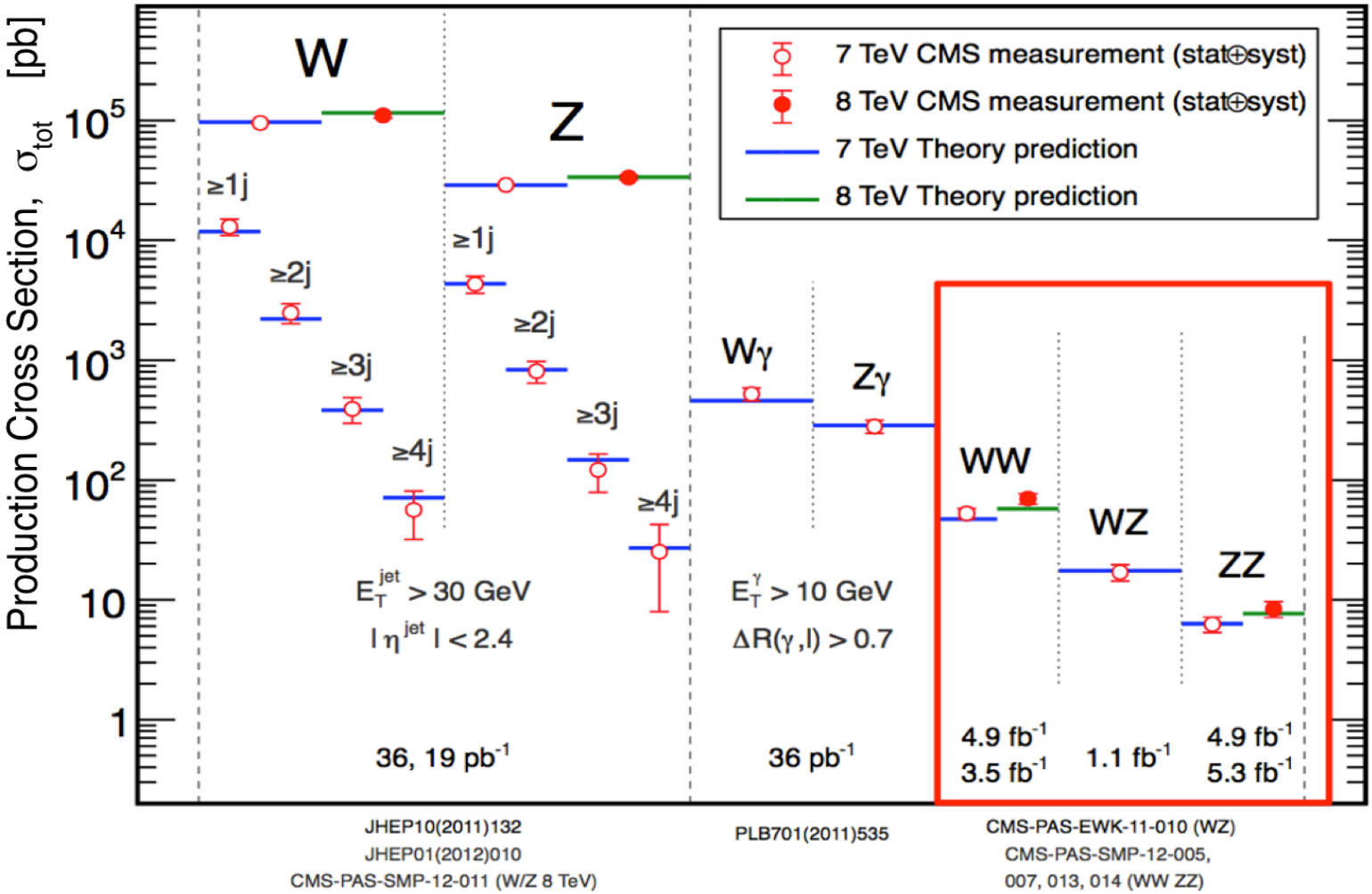




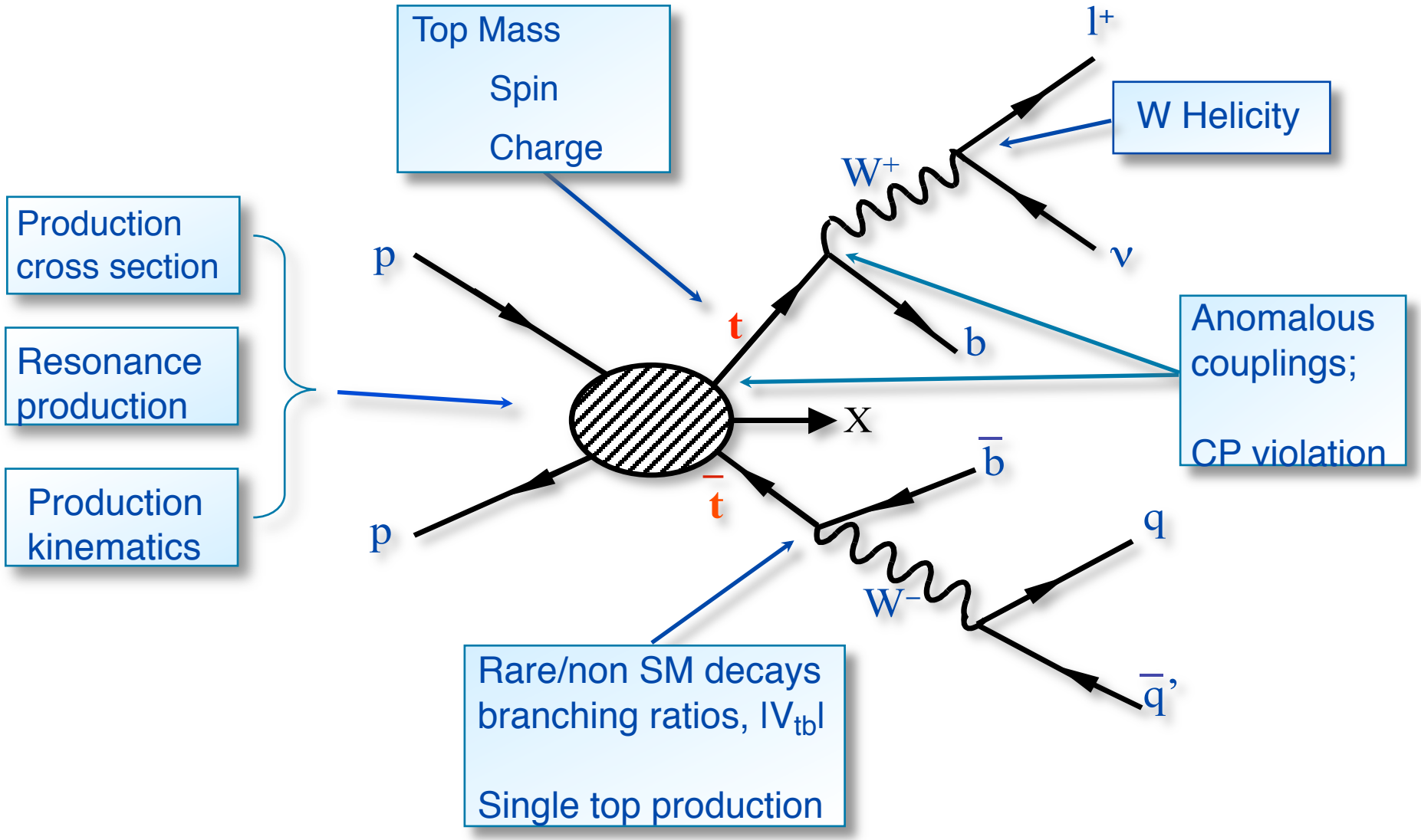
CMS-PAS-SMP-12-007

Phys. Rev. Lett. 108 (2012) 041804

Summary Part 1



Top Quark Physics



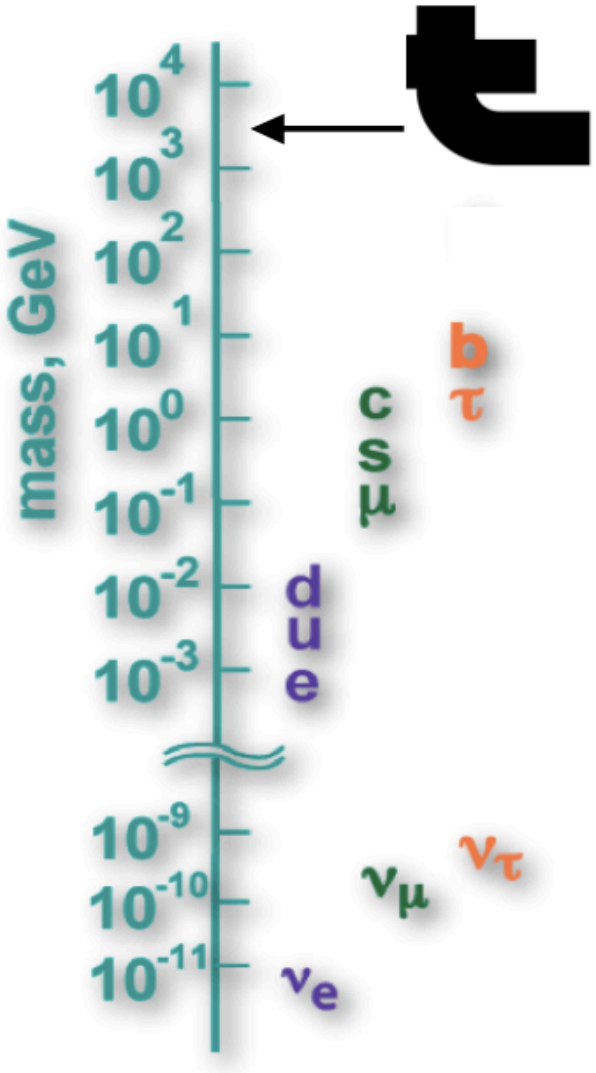
The Top quark seems to be really special

- Top was discovered at Fermilab in 1995
- Its mass much larger than any other fermion
- Using the latest Tevatron-averaged Mtop
  Yukawa coupling = 0.996±0.006

$$L_{\text{Yukawa}} = -\lambda \psi_L \Phi \overline{\psi}_R$$

- Only quark with large coupling to Higgs –
  special role for the top quark?

- Lifetime shorter than hadronization time →only quark that decays before hadronizing



Top Production

Gluon fusion (dominant at LHC)

Quark-antiquark annihilation

	LHC	Tevatron
gg	~85%	~10%
qq	~15%	~90%

Total cross section at 7 TeV:

- NLO (MCFM) $\sigma_{t\bar{t}}^{\mathrm{NLO}} = 158^{+23}_{-24}$ pb
- approx. NNLO
  - Kidonakis, PRD 82 (2010) 114030

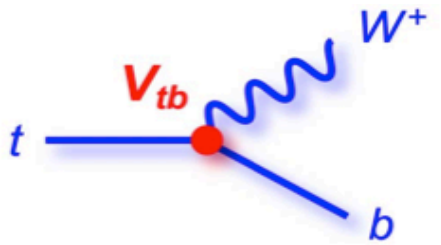
    $\sigma_{t\bar{t}} = 163^{+11}_{-10}$ pb

  - Langenfeld, Moch, Uwer, PRD80 (2009) 054009
  - Aliev et al., CPC182 (2011) 1034

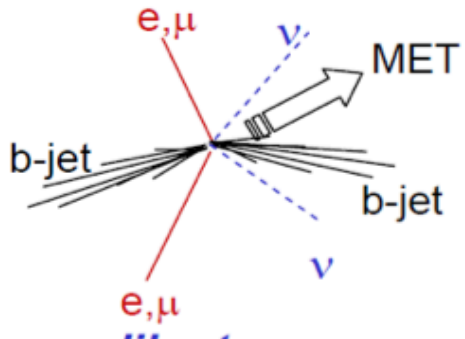
    $\sigma_{t\bar{t}} = 164^{+10}_{-13}$ pb

Top decays and backgrounds

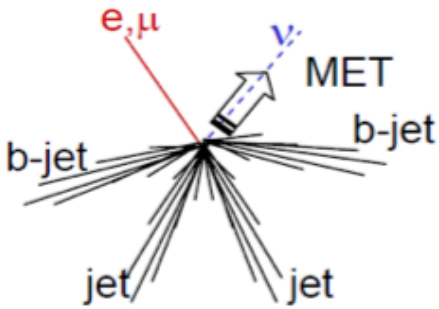
- Top decays before it can hadronize
  - almost exclusively t->Wb



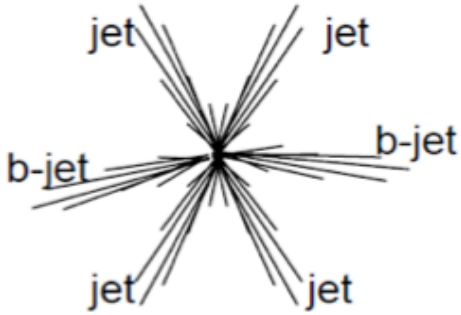
- Top pair event classification according to W decays



dileptons



lepton + jets

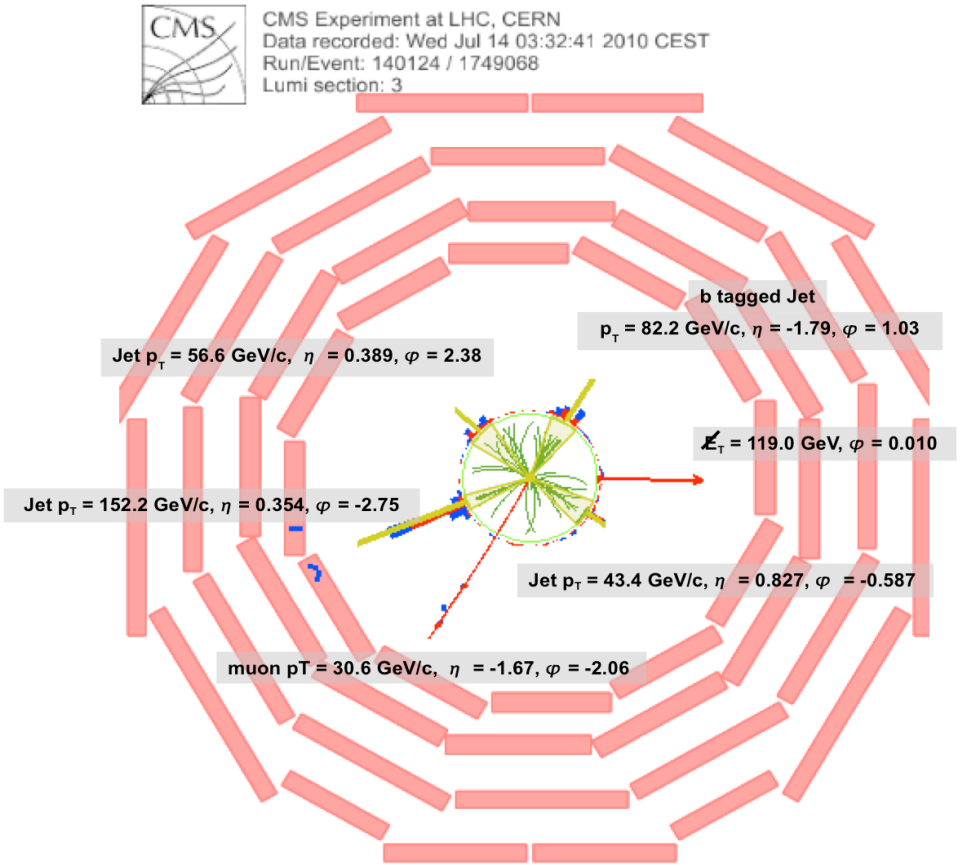


all hadronic

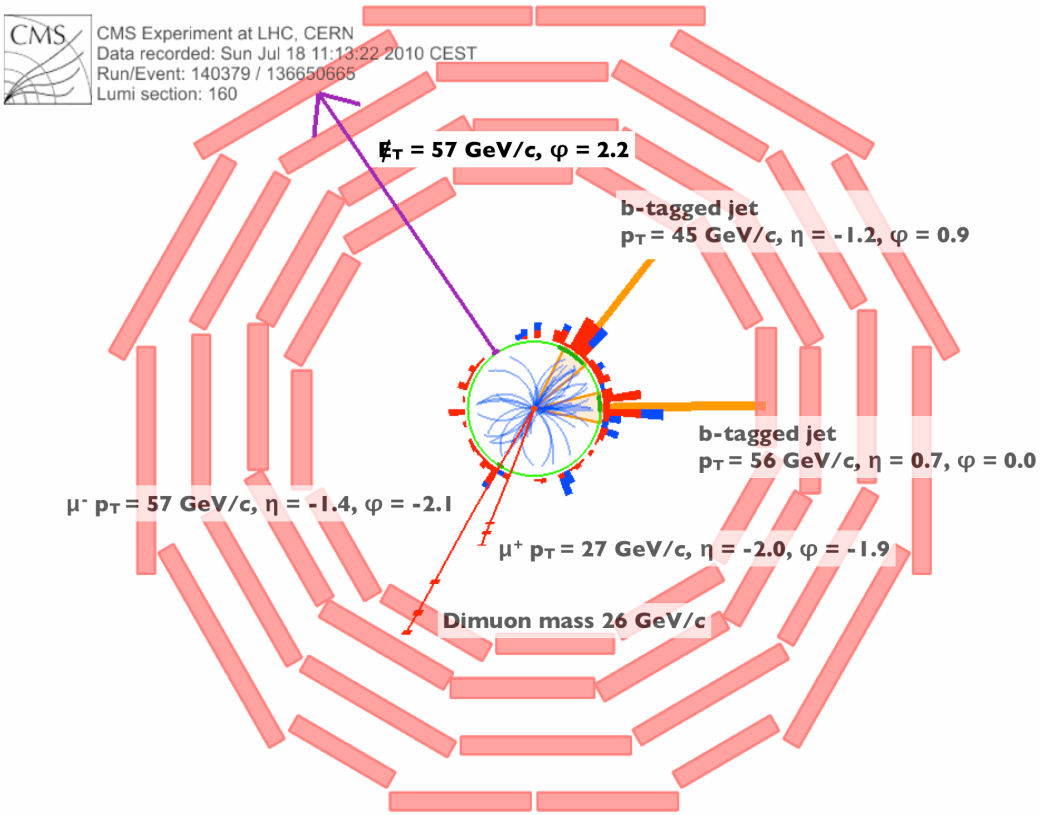
Branching ratio:	~5%	~30%	~46%
Backgrounds:	few (mainly Z+jets)	moderate (mainly W+jets)	huge (mainly QCD)

Typical top candidates

1 lepton+ jets +MET

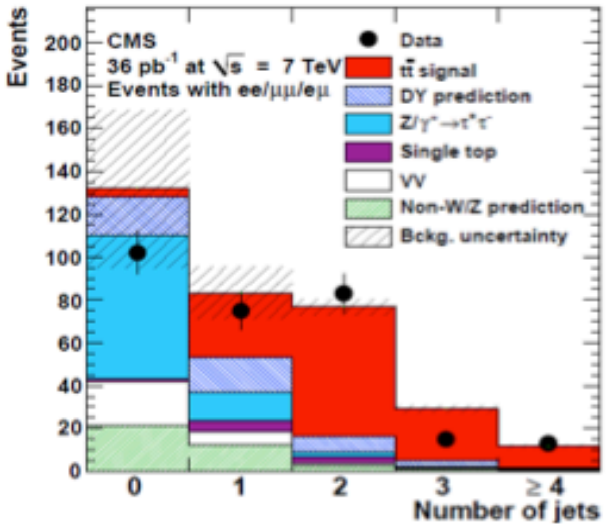


2 leptons (+jets +MET)

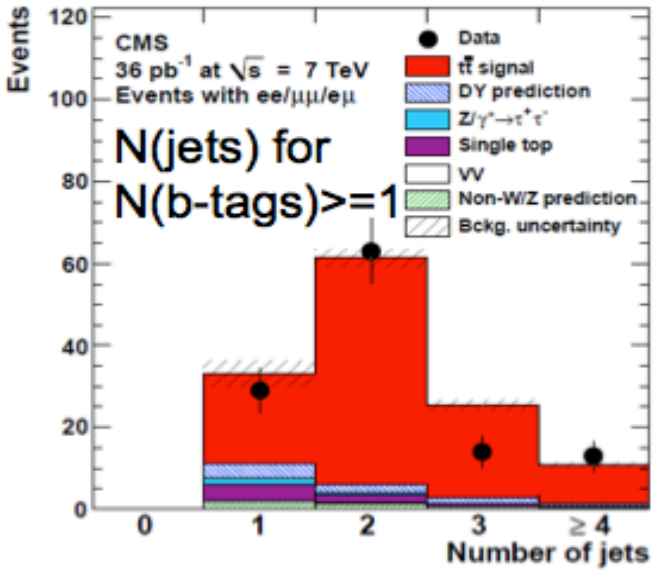


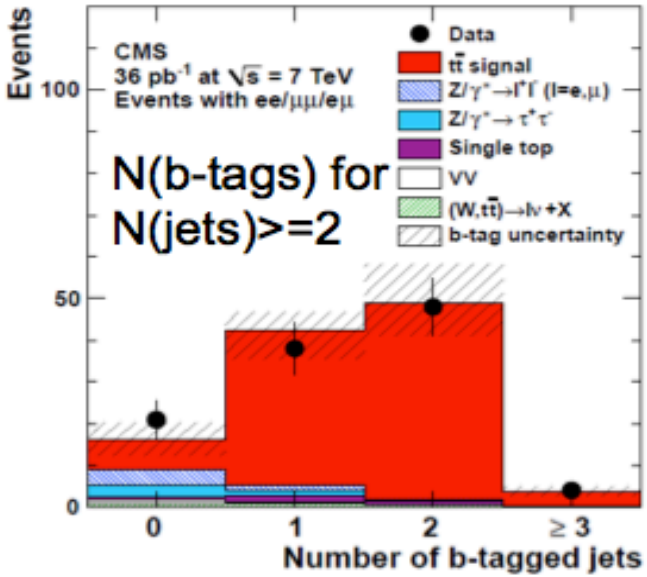
Cross section: di-lepton channel

Jet multiplicity before applying b-tagging



Hatched:
BG uncertainty





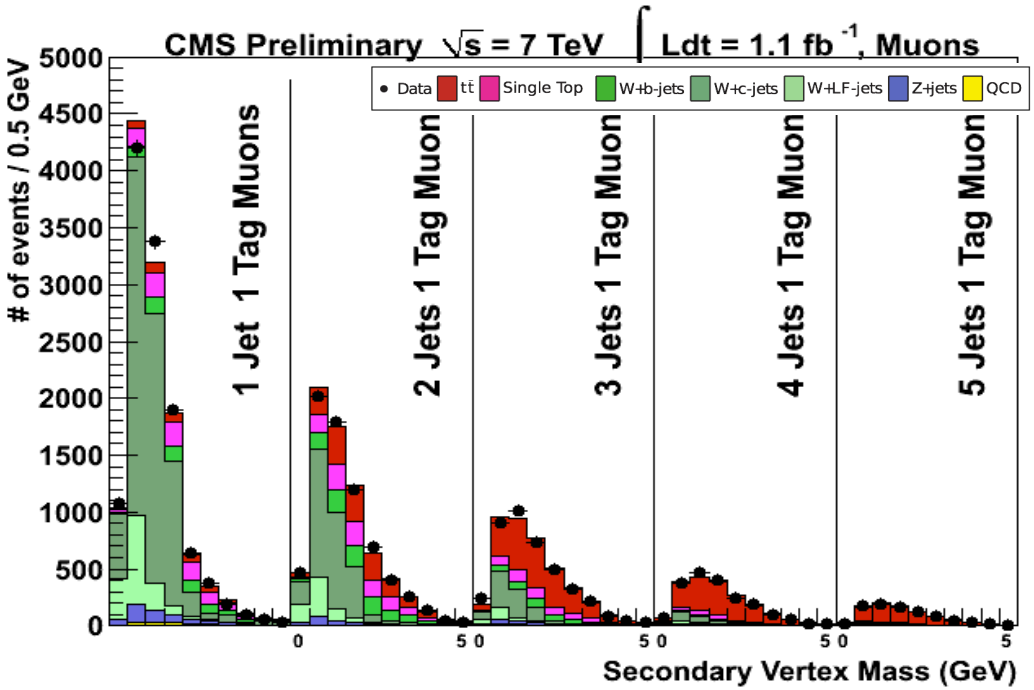
Very pure sample of top events!

Cross section: semi-leptonic channel

CMS TOP-11-003

Lepton+jets, b-tagged

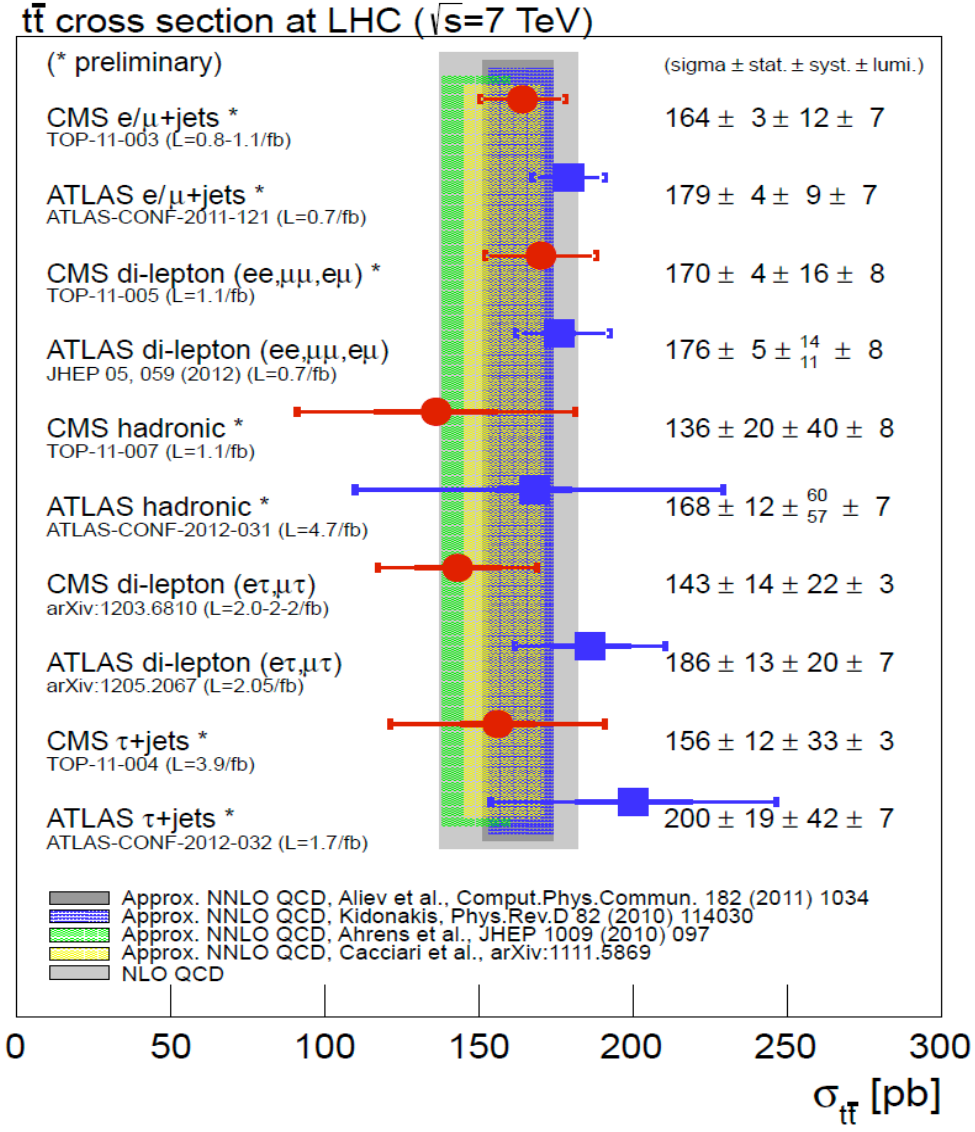
- divide sample into distinct categories: Nr. jets, Nr. of b-tags, electrons, muons
- fit the secondary vertex mass distribution, using templates, simultaneously in all categories
- let also data/MC scale factors (JES, b-tag eff, W+j Q^2-scale) float in the fit
- **Result**:
  - top cross section, with **syst. uncert. at the 7% level !**
  - scale factors consistent with 1, within the fit error



Source	Muon Analysis	Electron Analysis	Combined Analysis
Quantity	Uncertainty (%)		
Lepton ID/reco/trigger	3.4	3	3.4
$\not\!\!E_T$resolution due to unclustered energy	< 1	< 1	< 1
$t\bar{t}$+jets Q^2 scale	2	2	2
ISR/FSR	2	2	2
ME to PS matching	2	2	2
Pile-up	2.5	2.6	2.6
PDF	3.4	3.4	3.4
Profile Likelihood Parameter	Uncertainty (%)		
Jet energy scale and resolution	4.2	4.2	3.1
b-tag efficiency	3.3	3.4	2.4
W+jets Q^2 scale	0.9	0.8	0.7
Combined	7.8	7.8	7.3

A fantastic proof of the excellent understanding of all relevant physics objects, and of their outstanding MC description

Inclusive top cross-section



CMS Combination (~8%) $\sigma_{t\bar{t}}$ [pb]

$$\sigma_{t\bar{t}} = 165.8 \pm 2.2\ (\text{stat.}) \pm 10.6\ (\text{syst.}) \pm 7.8\ (\text{lum.})\ \text{pb}$$

ATLAS Combination (~6%)

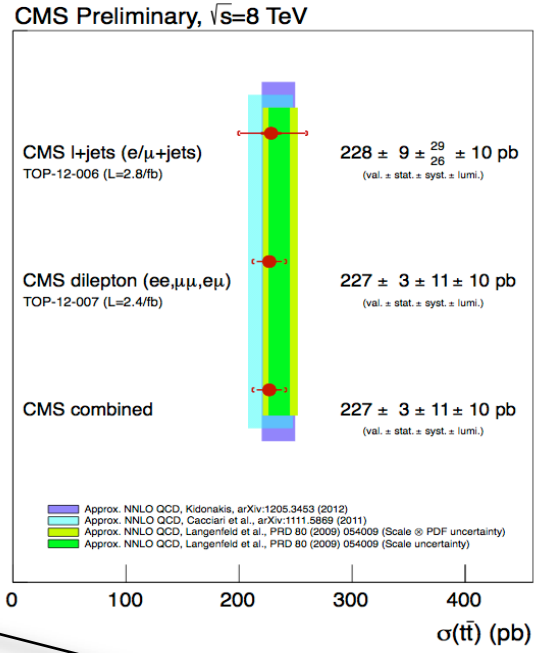
$$\sigma_{t\bar{t}} = 177 \pm 3\ (\text{stat.})^{+8}_{-7}\ (\text{syst.}) \pm 7\ (\text{lum.})\ \text{pb}$$

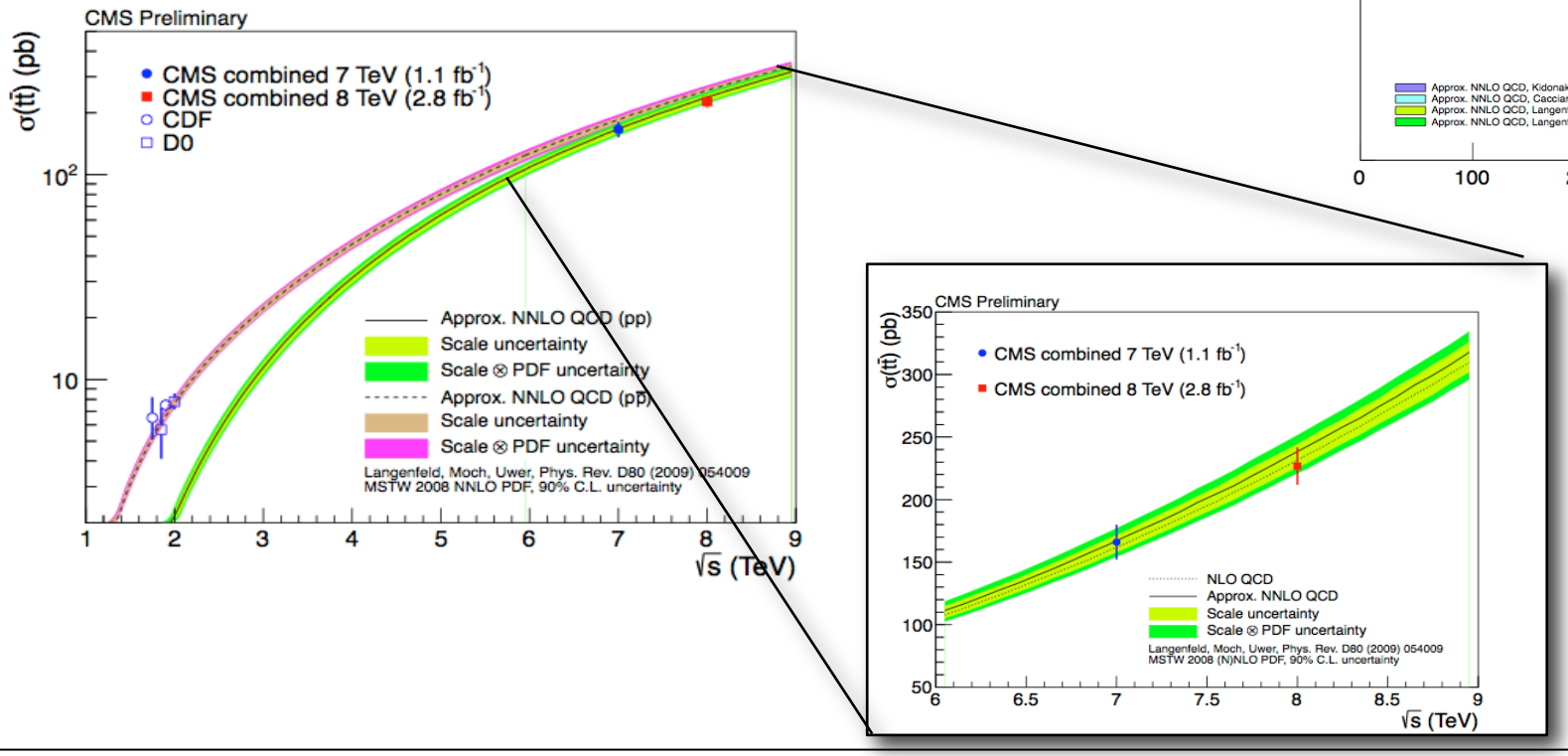
- measurements in several channels
- exp. uncertainty reached 6-8% (!) level, ~ or smaller than theory uncertainty.
- overall impressive agreement with pQCD predictions.
- top pair xsec useful to constrain pdfs?

Approx. NNLO theory calculations	
Authors	Cross Section @ 7 TeV [pb] (+-scale +-PDF)
NLO QCD (MCFM)	160 +20-21 +8-9
Kidonakis	163 +7-5 +9-9
Aliev et al. (HATHOR)	164 +5-9 +9-9
Ahrens et al.	155 +8-9 +8-9
Beneke et al.	163 +7-8 +15-14
Cacciari et al. (TOP++)	159 +12-14 +4-4
Moch et al.	175 +10-13 +5-5

Top cross section rise with energy

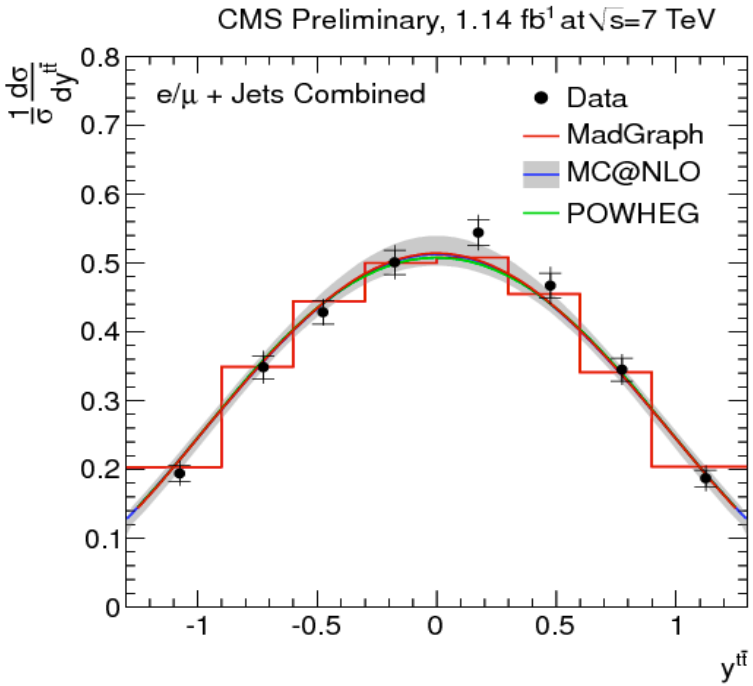
Authors	Cross section at 8 TeV [pb] (+-scale +-PDF)	Details
Moch et al. (arXiv:1203.6282)	250 +14-18 +6-6	MSTW 68%CL , m_t=173 GeV
Moch et al.	203 +11-15 +9-9	ABM11 68%CL
Cacciari et al. (arXiv:1111.5869)	229 +18-20 +6-6	M_t=173.3 GeV, MSTW 68%CL
Kidonakis (arXiv:1205.3453)	234 +10-7 +12-12	MSTW 90%CL
Ahrens et al. (arXiv:1105.5824)	225 +12-12 +11-12	MSTW 90%CL, mt=173.1 GeV



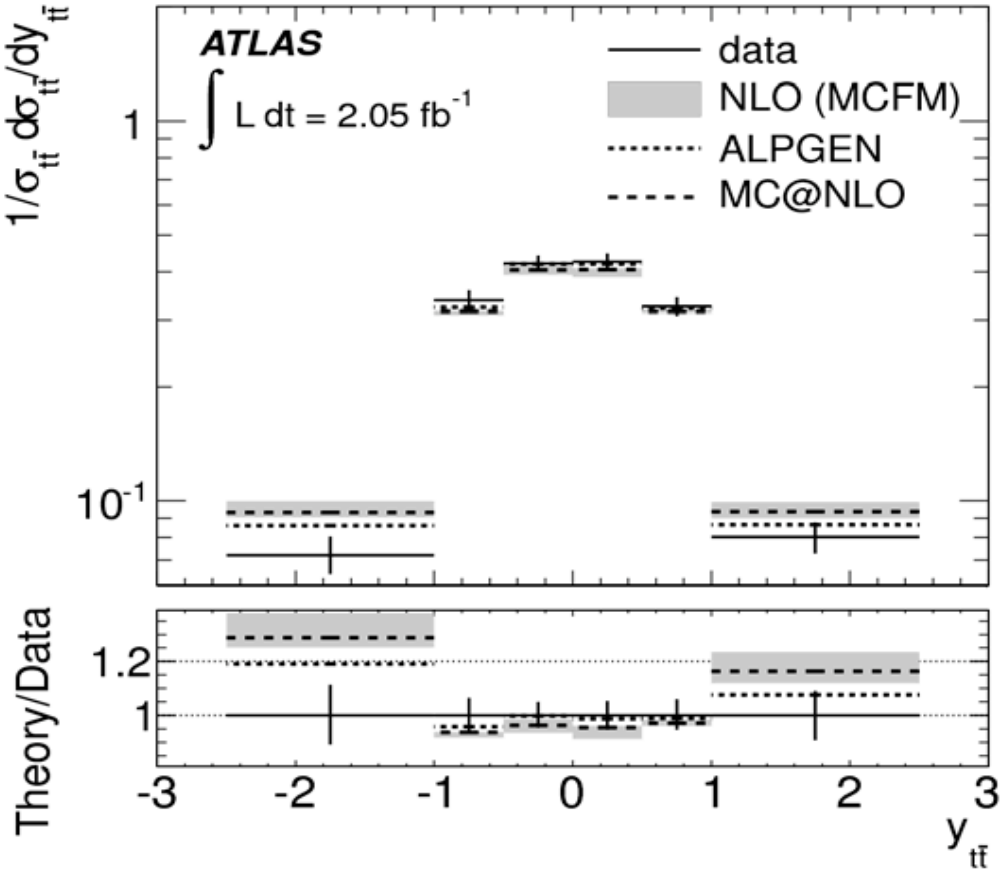


Top differential x-section

Unfolded to parton level normalized: cancellations of many systematic uncertainties



CMS, PAS TOP-11-013, L=1.14/fb
(di-leptons & l+jets, visible PS)



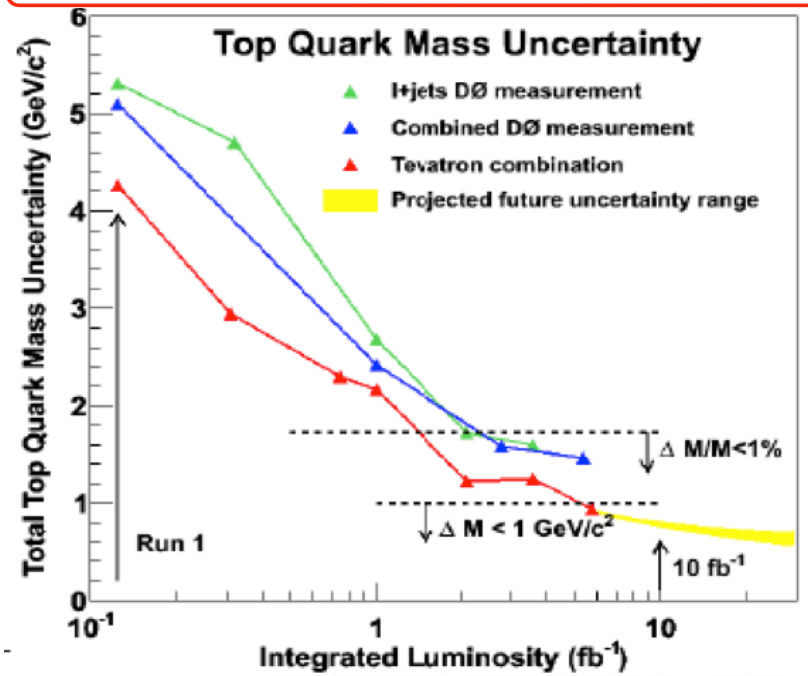
ATLAS, arXiv:1207.5644, L=2.05/fb
(l+jets, full PS)

Good agreement with Madgraph, ALPGEN, MCFM, MC@NLO, POWHEG

TOP mass

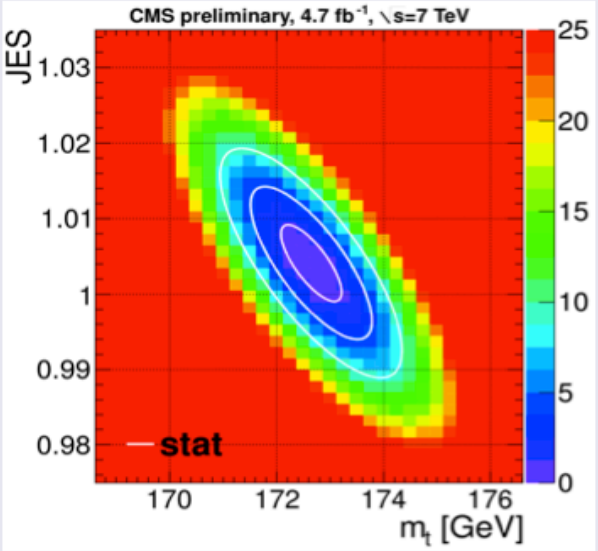
- Tevatron is leading, with LHC catching up....

$$m_{\text{top}} = 173.2 \pm 0.6\,(\text{stat}) \pm 0.8\,(\text{syst})$$



Relative uncertainty: 0.54%
Expect this limit to be improved...

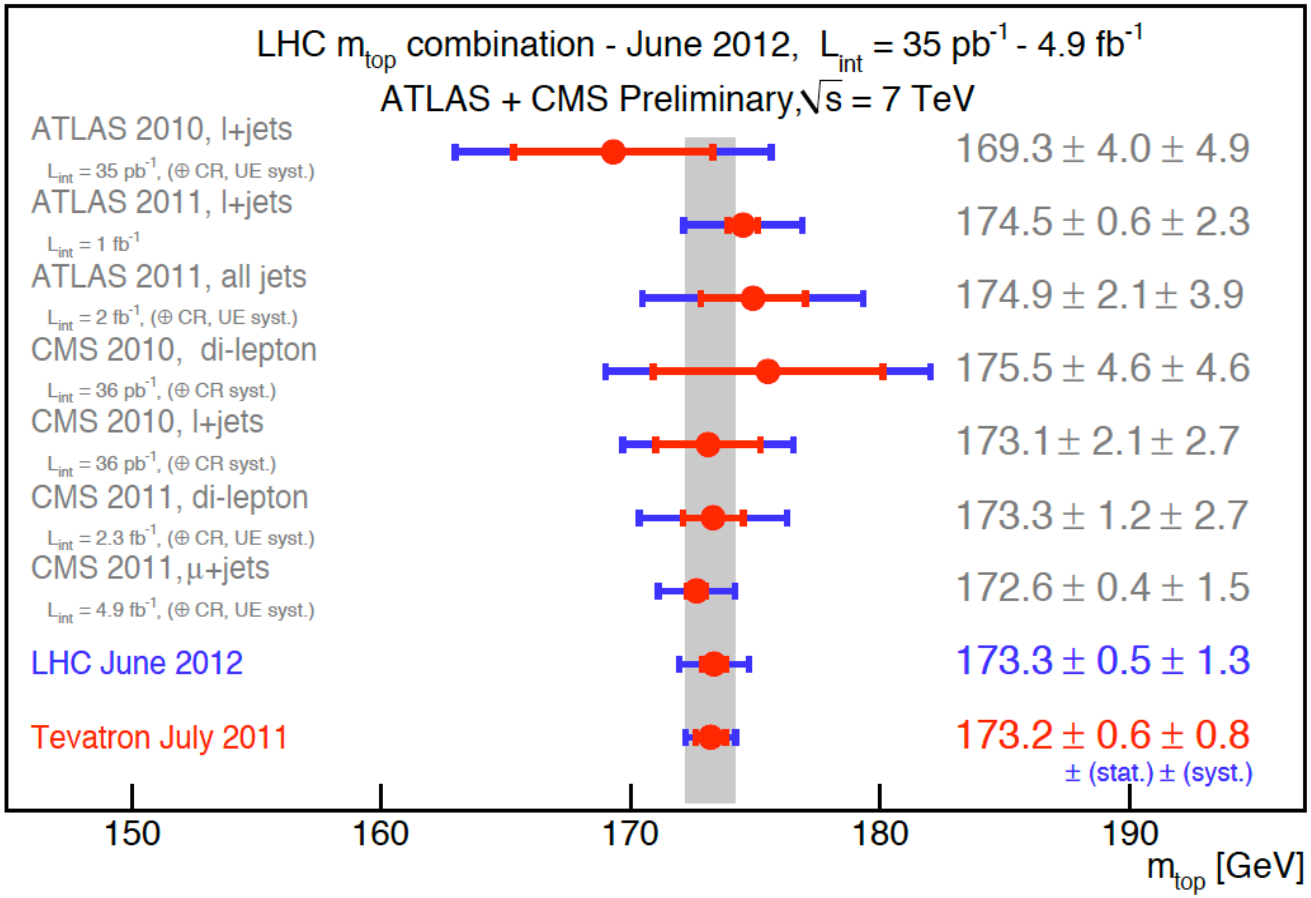
Results on data (4.7 fb^{-1})



$$m_t = 172.6 \pm 0.6_{\text{stat}} \pm 1.2_{\text{syst}}\ \text{GeV}$$

- Most precise LHC measurement

LHC top quark mass



CMS PAS TOP-12-001
ATLAS CONF-2012-095

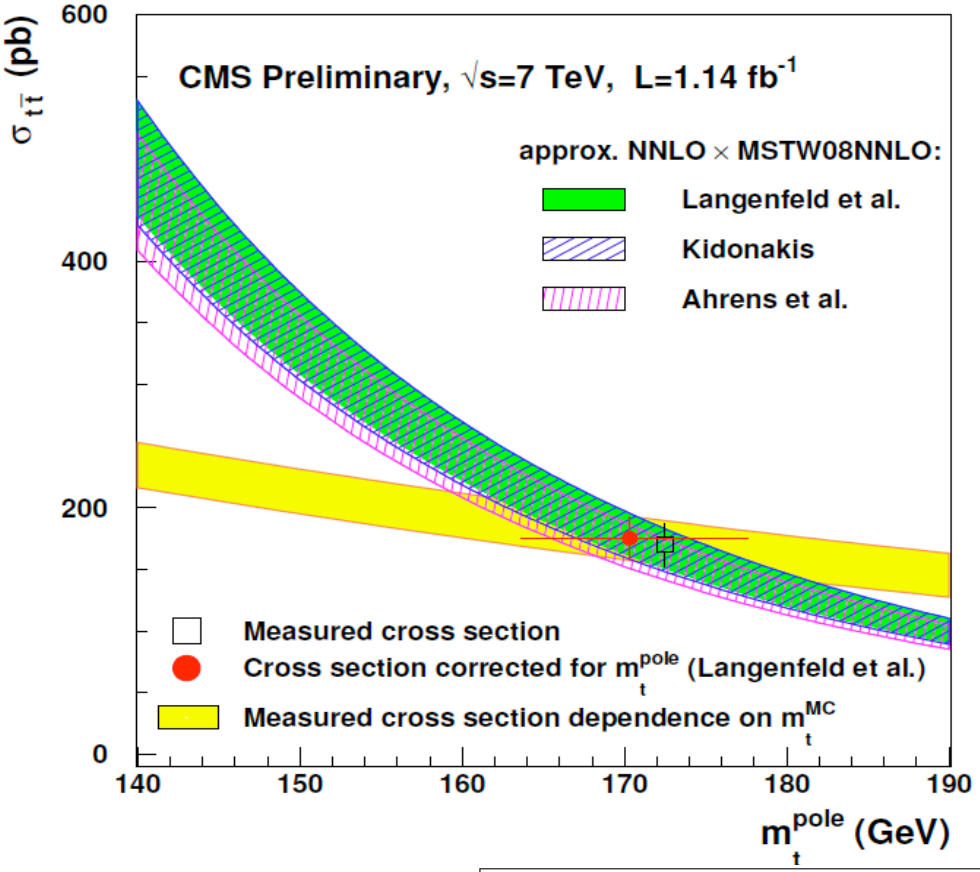
rel. uncertainty of 0.54% on a quark mass!
Tevatron expects to improve to 0.7 -0.8 GeV precision.

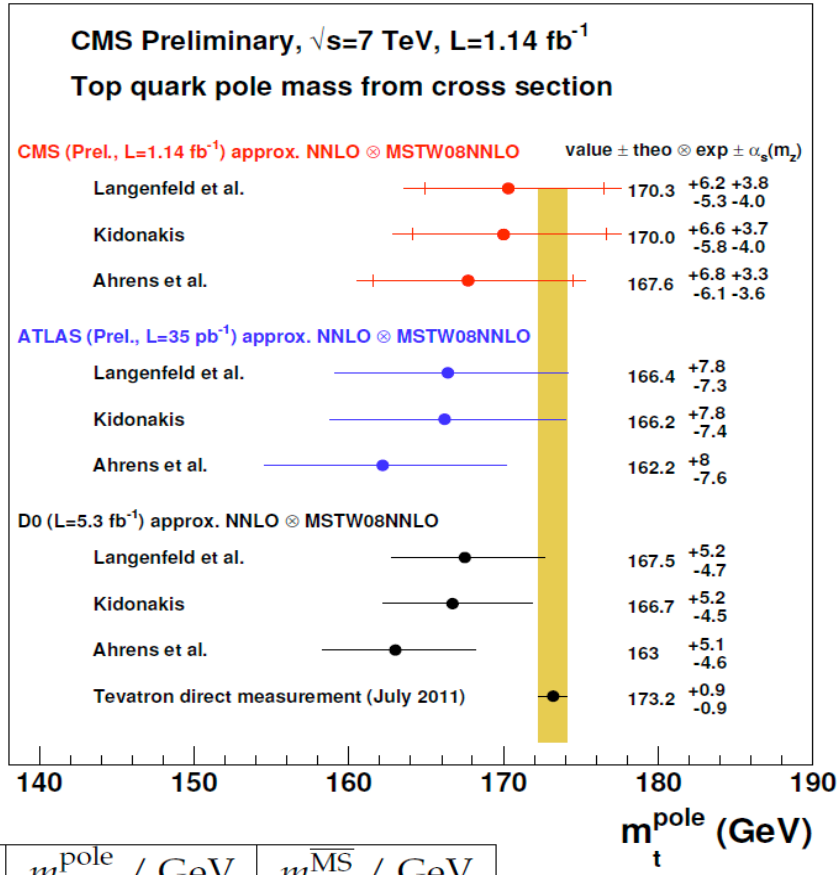
- Based on conventional measurement techniques (template, ideogram etc.)
- 0.8% precision, quickly approaching Tevatron precision
- Dominating systematics: (b-)JES, ISR/FSR, UE..)

Top mass from x-section

Exploit strong dependence of theory x-sec on mtop
Well defined renormalization scheme

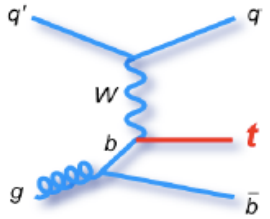
ATLAS CONF-2011-054
CMS PAS TOP-11-008



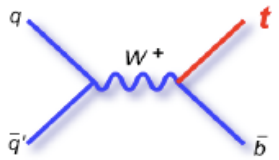


Approx. NNLO × MSTW08NNLO	m_t^{pole} / GeV	$m_t^{\overline{\text{MS}}}$ / GeV
Langenfeld et al. [7]	$170.3^{+7.3}_{-6.7}$	$163.1^{+6.8}_{-6.1}$
Kidonakis [8]	$170.0^{+7.6}_{-7.1}$	–
Ahrens et al. [9]	$167.6^{+7.6}_{-7.1}$	$159.8^{+7.3}_{-6.8}$

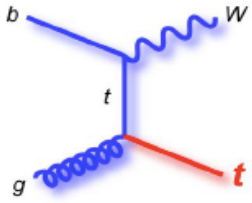
Single Top production



t-channel

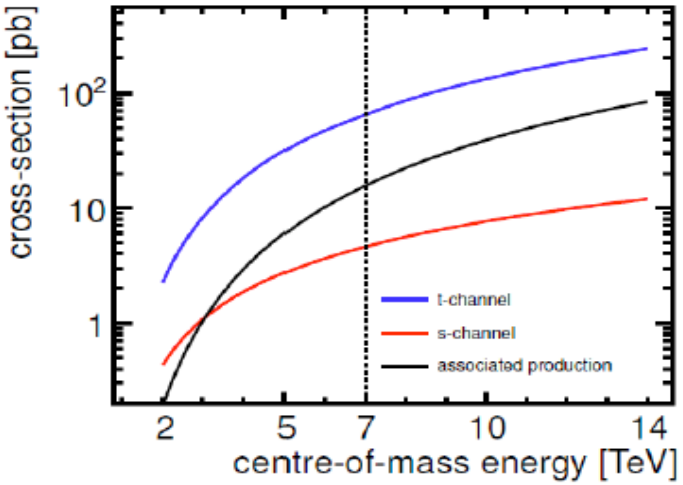


s-channel



tW-channel
(associated production)

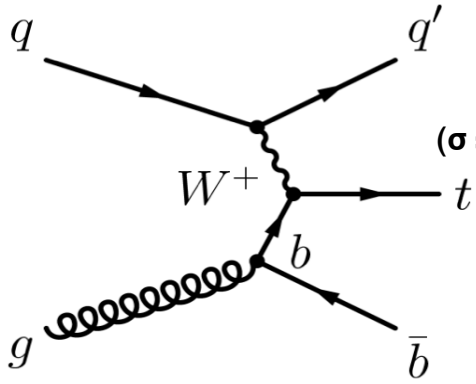
- EWK production of top quarks: test Wtb vertex, measurement of |Vtb|
- PDF sensitivity: b-PDF (t-channel), u/d ratio from R(t/tbar)
- Searches for NP at Wtb vertex, 4° generation, H+, W', FCNC



t-channel	$64.6^{+2.7}_{-2.0}$ pb
Wt	15.7 ± 1.1 pb
s-channel	4.6 ± 0.2 pb

Kidonakis, NLO+NNLL:
t-channel: PRD 83 (2011) 091503
s-channel: PRD 81 (2010) 054028
tW-channel: PRD 82 (2010) 054018

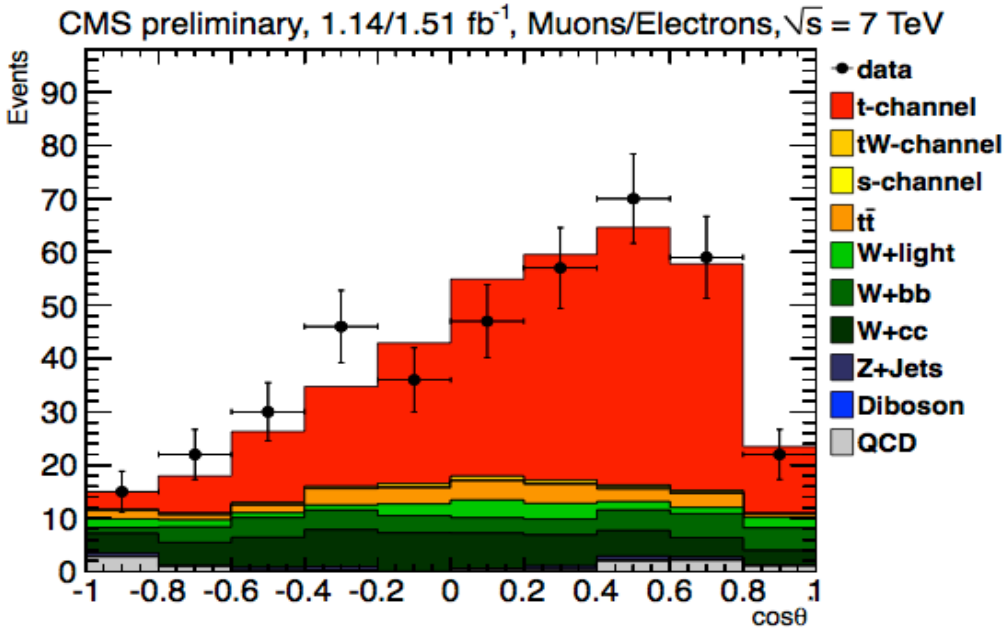
Single top production



t channel
(σ ≈ 62 pb @ 7 TeV)

- Better than 20% accuracy reached.
- CMS : $|V_{tb}|$ extracted at the 10% level!

CMS TOP-11-021



angle between lepton and light jet, in t rest frame

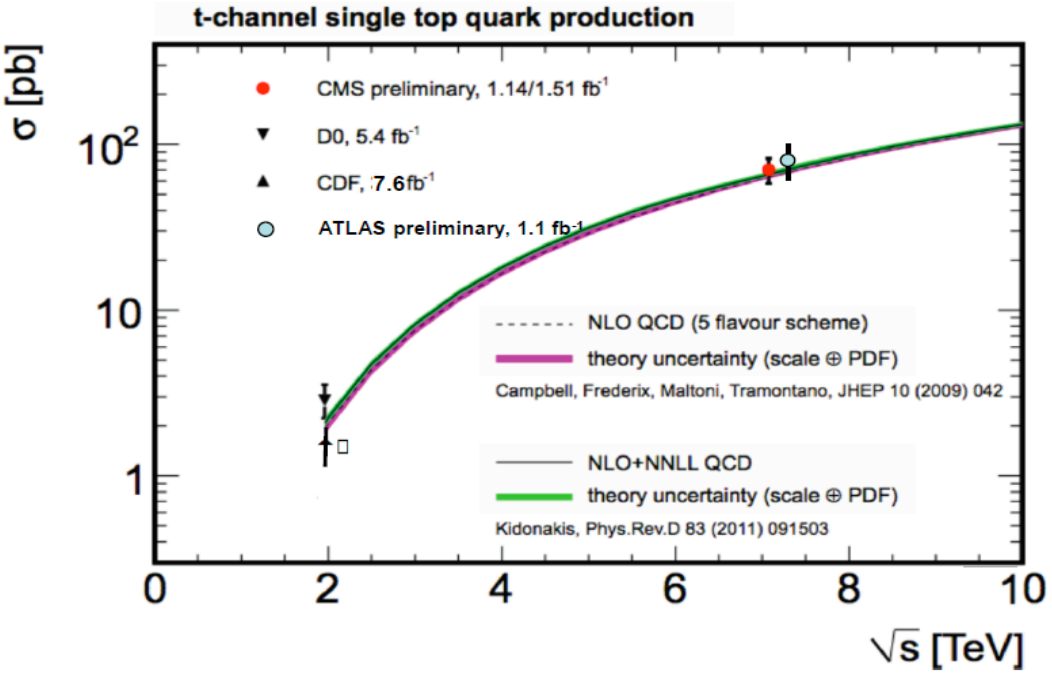
An example of finding **tiny** signals with leptons, MET, b-tag & jets

Showing the readiness for challenging searches such as low-mass Higgs

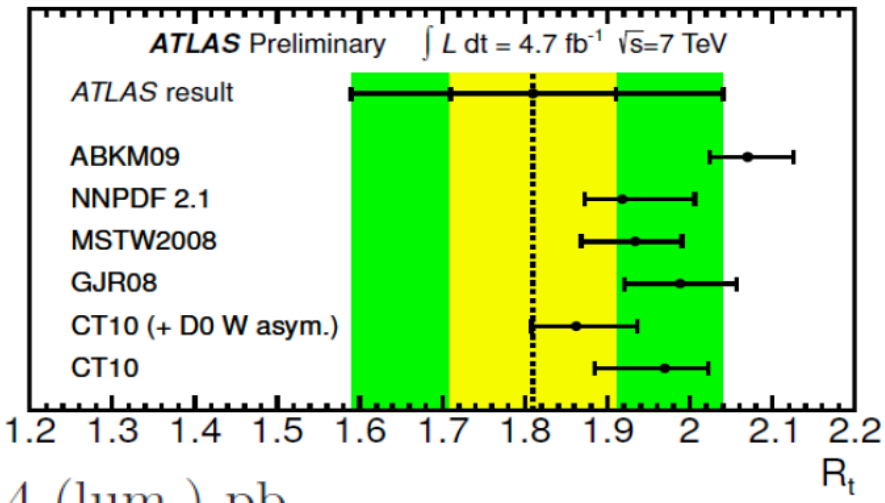
Single Top production: t-channel

Measurements cut-based or MVA

CMS 2010: arXiv:1106.3052
CMS 2011: PAS-TOP-11-021
ATLAS 2011: arXiv:1205.3130
ATLAS-CONF-2012-056 (R(t/tbar))



$$\sigma_t(t) = 53.2 \pm 10.8\ \text{pb}$$
$$\sigma_t(\bar{t}) = 29.5^{+7.4}_{-7.5}\ \text{pb}$$
$$R_t = 1.81^{+0.23}_{-0.22}.$$



ATLAS 2011, 1.04/fb

$$\sigma_{t\text{-ch}} = 83 \pm 4\ (\text{stat.})^{+20}_{-19}\ (\text{syst.})\ \text{pb}$$

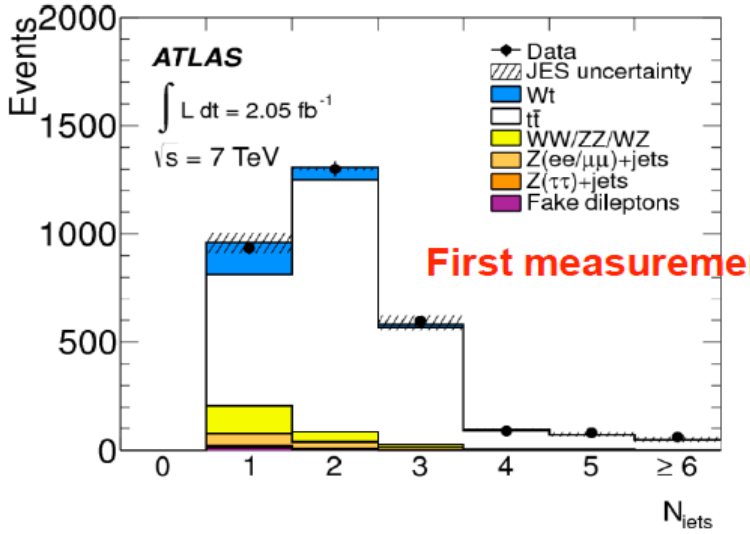
CMS 2011, < 1.5/fb

$$\sigma_{t\text{-ch}} = 70.2 \pm 5.2\ (\text{stat.}) \pm 10.4\ (\text{syst.}) \pm 3.4\ (\text{lum.})\ \text{pb}$$

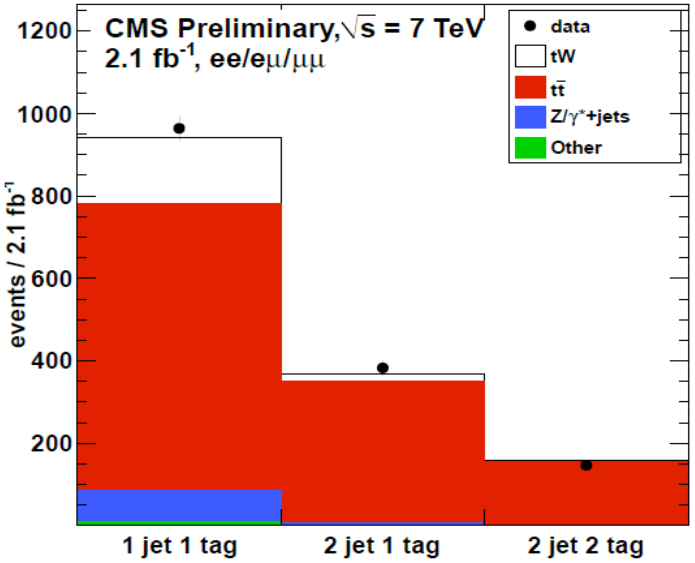
Single Top production: Wt-channel

Problem of signal definition:

- At NLO, interference with top pair production
- Two approaches studied (POWHEG, MC@NLO)
  - Diagram removal (DR): remove doubly resonant contributions
  - Diagram subtraction (DS): subtract gauge invariant term which locally cancels tt contribution
- Treat difference as systematic (few %)



First measurement !



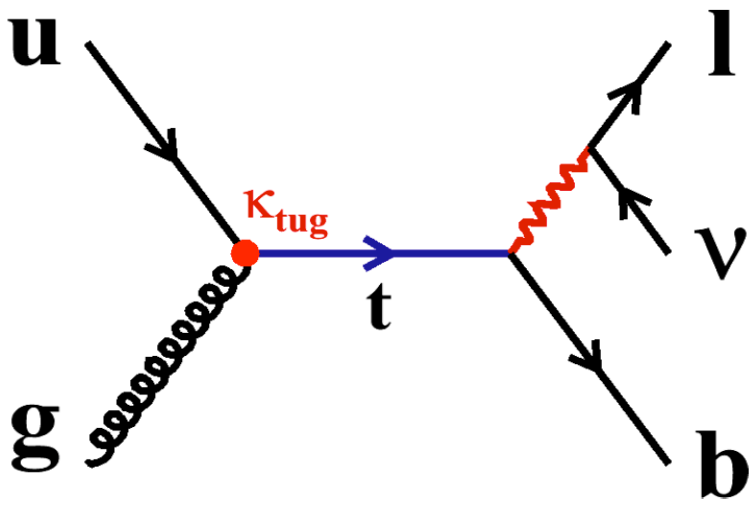
ATLAS: $\sigma = 16.8 \pm 2.9$ (stat.) ± 4.9 (syst.) pb

CMS: $\sigma = 22\ ^{+9}_{-7}$ (stat. + syst.) pb

ATLAS 2011, L=2.05/fb
arXiv:1205.5764

CMS 2011, L=2.1/fb
CMS-PAS-TOP-11-022

Flavour Changing Neutral Currents

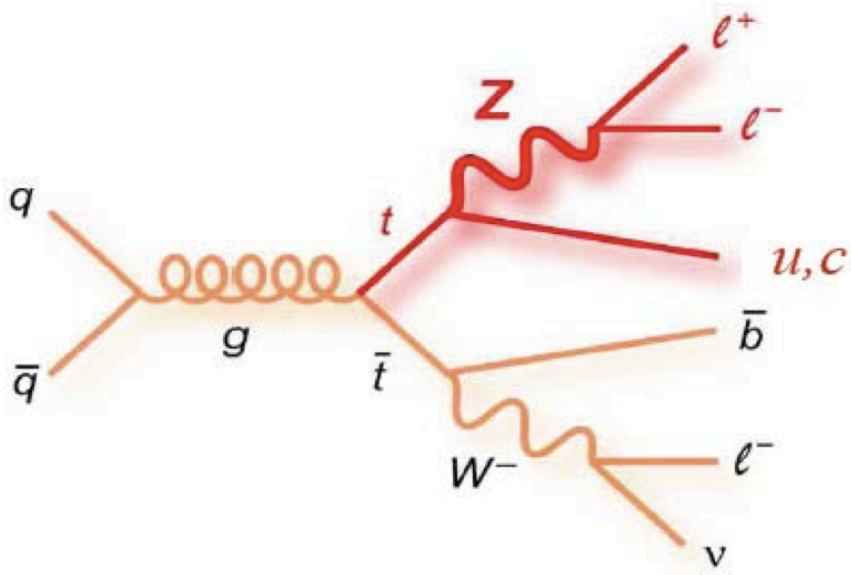


- Top FCNC extremely small in SM ($O(10^{-14})$)
- Beyond SM: up to $O(10^{-14})$
- Any signal = new physics

t→qg Phys. Lett. B 712 (2012) 351

- Search in qg→t→blν
- Single top production

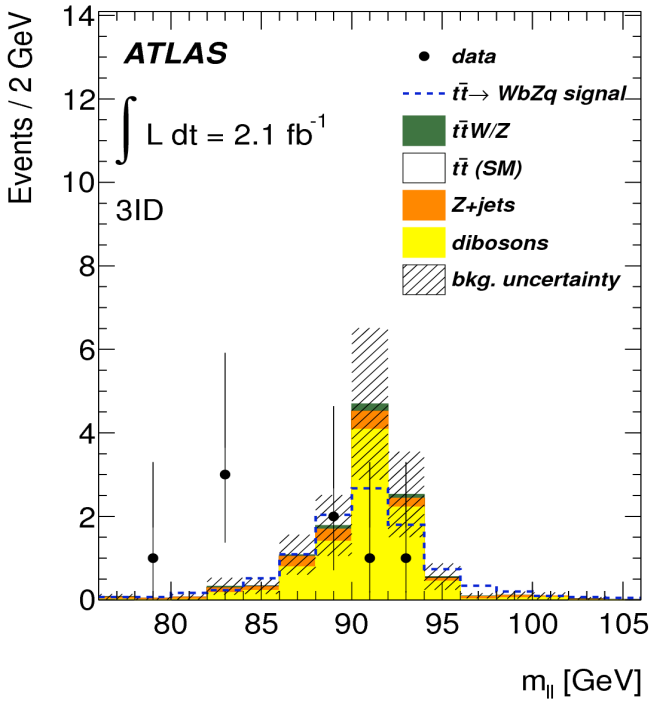
t→qZ arXiv: 1206.0257

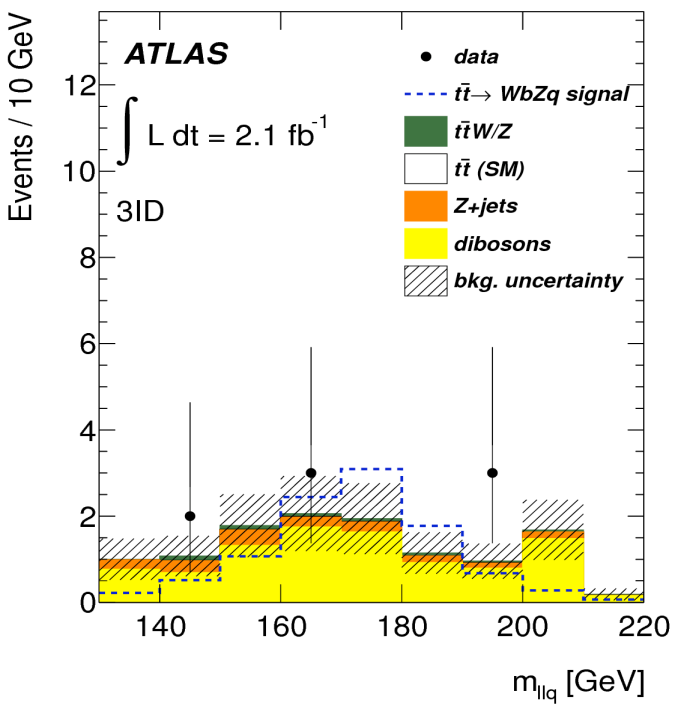


- Search in $t\bar{t} \rightarrow qZ\,bW \rightarrow qll\,blν$
- Final state with three leptons

FCNC

arXiv:1206.0257





Require 3 leptons

- Reconstruct Z
- Combine with jet to reconstruct top

Plus similar analysis with looser lepton reconstruction

For both analysis:

- 16 evts observed
- 20 +-7 expected

$$Br\ (t \rightarrow Zq) < 7.3 \cdot 10^{-3}\ (95\ \%\ C.L.)$$

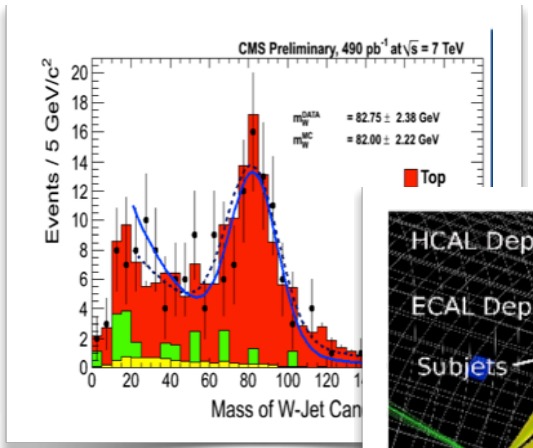
Conclusion

All electroweak measurements performed so far fully consistent with SM expectations.

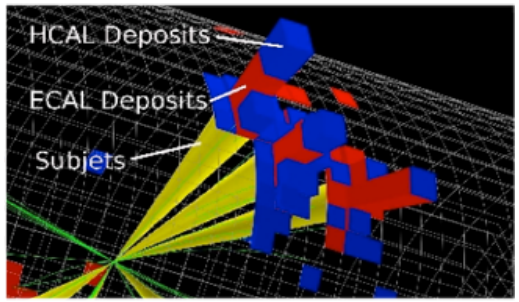
Excellent understanding of the most important SM background for Higgs and new physics searches.

Top properties

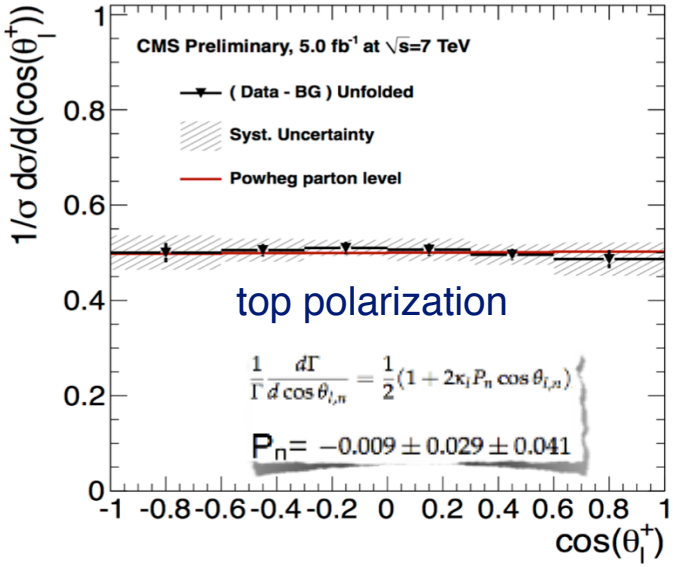
- Many many properties and differential distributions measured
  - spin correlations, W helicity/pol., V_{tb}, m_t-m_{tbar}, top charge, top polarization, charge asymmetry, FCNC, high-mass ttbar pairs (resonances)
  - No anomalies seen so far. Here some examples:



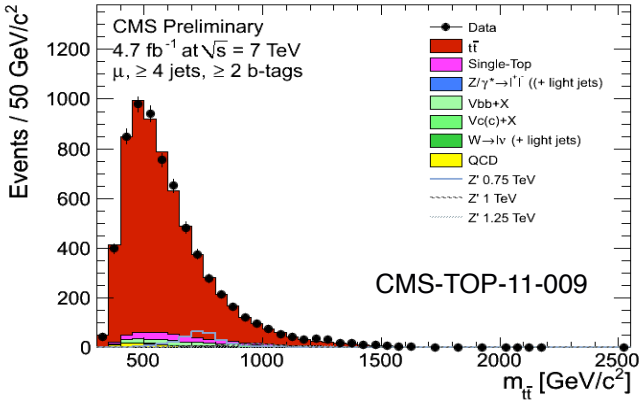
boosted tops, top tagging, subjects



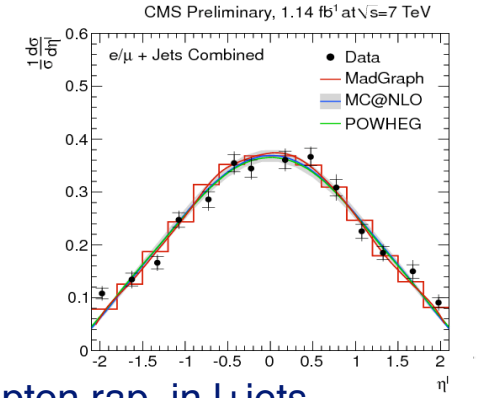
CMS-TOP-12-016



top polarization

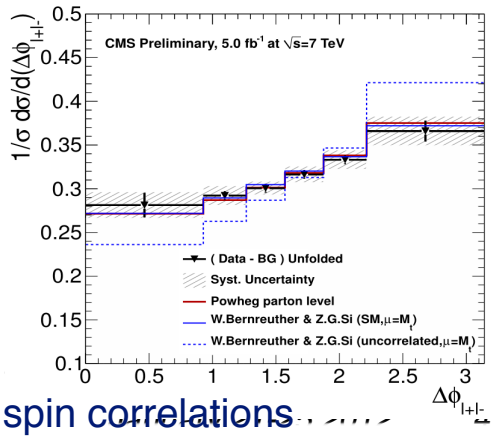


CMS-TOP-11-013



dilepton rap. in l+jets

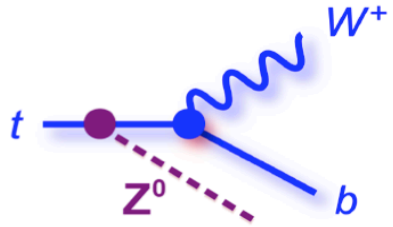
CMS-TOP-12-004



spin correlations

A first: TTbar + V production

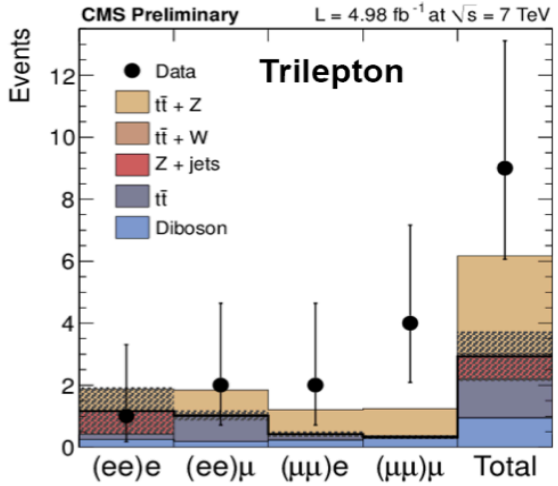
Starting to observe associated production of top pairs with W or Z



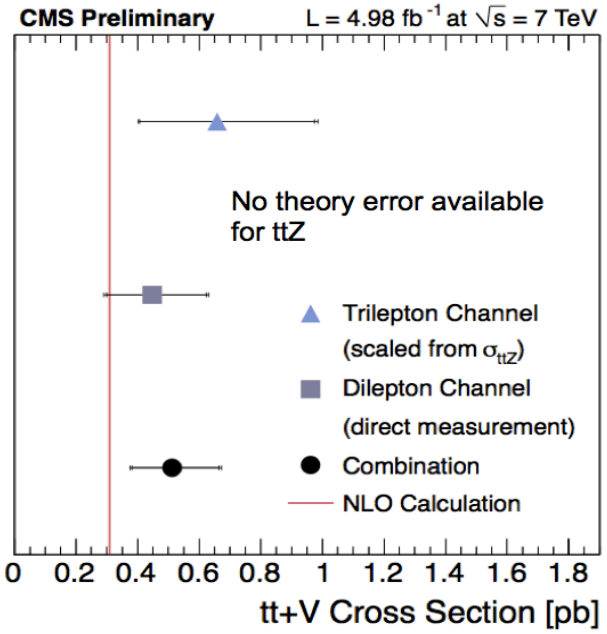
$$\frac{\sigma(t\bar{t})}{\sigma(t\bar{t}+V)} \approx 500$$

Trilepton channel: $\sigma(t\bar{t}Z \to l + \text{jets} + (Z \to ll))$

Same-sign dilepton channel: $\sigma(t\bar{t}V \to l + \text{jets} + (W \to l\nu) \text{ or } (Z \to ll))$



CMS-TOP-12-014



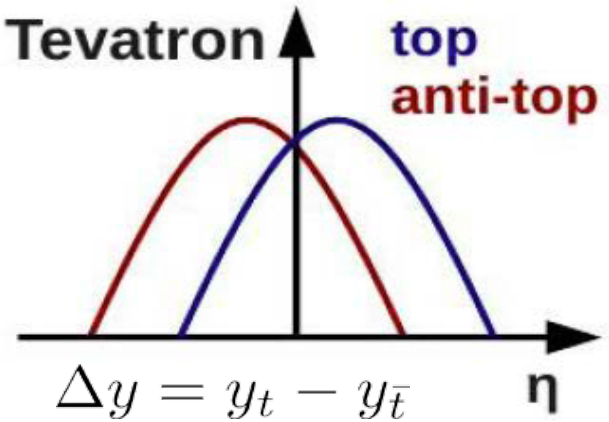
First measurement of *ttV*:

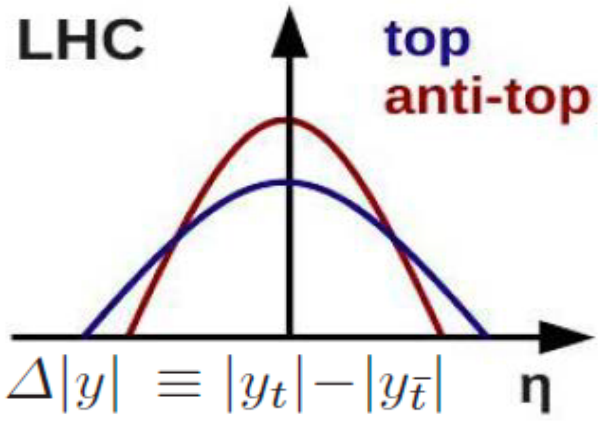
- Result combining all 7 channels:

$$\sigma(t\bar{t}V) = 0.51^{+0.15}_{-0.13}(\text{stat.})^{+0.04}_{-0.02}(\text{syst.})\ \text{pb}$$

➔ Significance of 4.67 σ

Top charge asymmetry





$$A_C = \frac{N^+ - N^-}{N^+ + N^-}$$

- SM: non-zero Ac appears at NLO QCD due to interference of ISR-FSR and Born-Box diagrams
- CDF/D0 observed larger than predicted Ac at Tevatron
- Many new physics models put forward (e.g. Axigluons, new weak bosons, extra dimensions etc.) [must accommodate ttbar cross section, M(ttbar), EWK and same-sign-top limits etc.]
- Asymmetry at LHC diluted due to large fraction of gg initial states

Top charge asymmetry

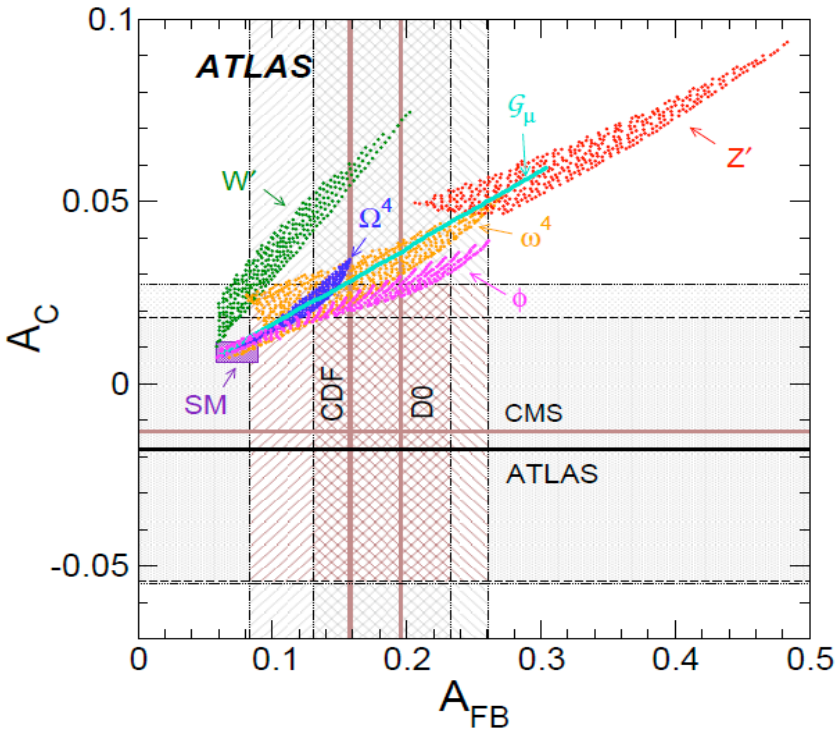
Measurement	Ac $\Delta\|y\| \equiv \|y_t\| - \|y_{\bar{t}}\|$
CMS, L=1.1/fb, l+jets (arXiv:1112.5100)	-0.013 +/- 0.028 +/- 0.030
CMS, L=5.0/fb, l+jets (arXiv:1207.0065)	0.004 +/- 0.010 +/- 0.011
ATLAS, L=1.04/fb, l+jets (arXiv:1203.4211)	-0.019 +/- 0.028 +/- 0.024
ATLAS, L=4.7/fb, dilepton (ATLAS-CONF-2012-057)	0.057 +/- 0.024 +/- 0.015
ATLAS combination	0.029 +/- 0.018 +/- 0.014

MC@NLO Ac=0.006 +/- 0.002
Kuehn, Rodrigo: Ac=0.0115 +/- 0.0006 (arXiv:1109.6830)

ATLAS also measured dilepton asymmetries (no need to reconstruct ttbar system)

All measurements consistent with zero and with SM predictions

Constraining NP parameter space

BSM interpretation in models that could explain anomalous A_C

ATLAS seem to disfavour minimal Z' models