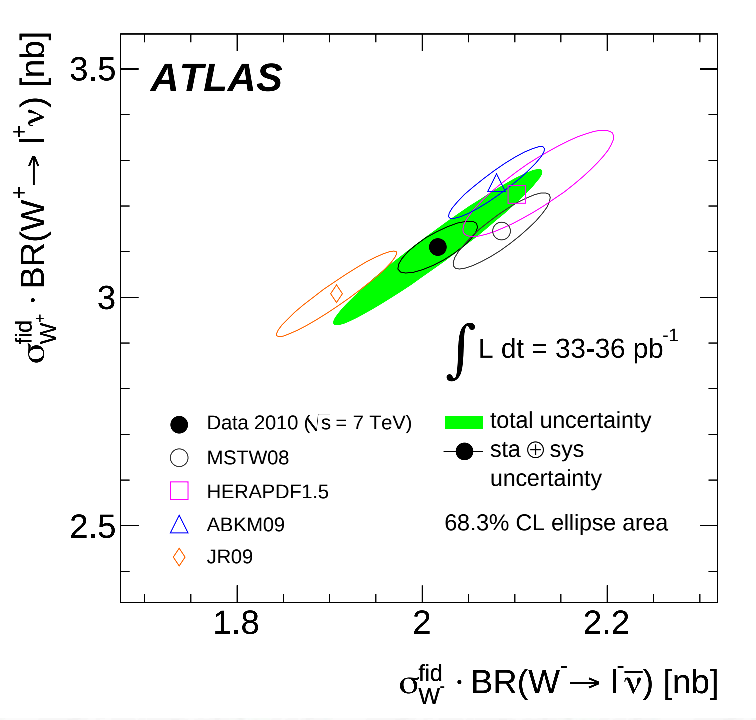
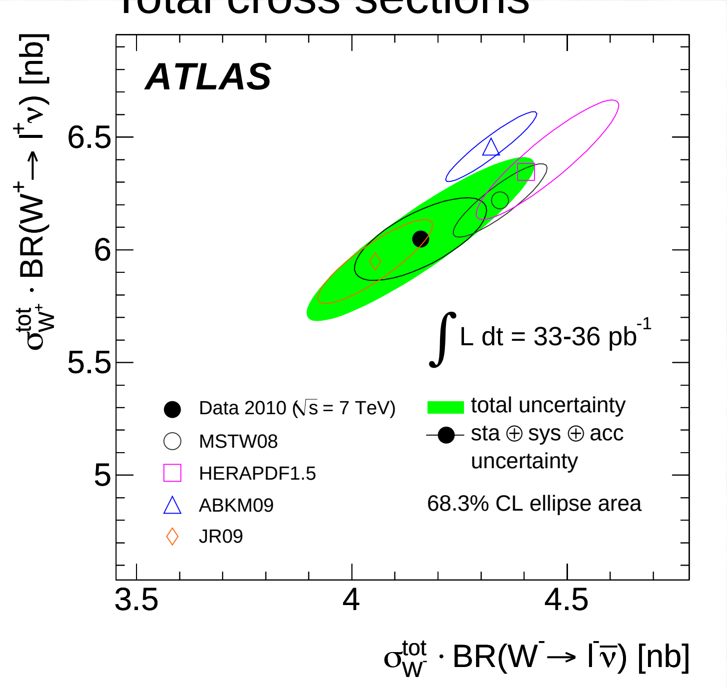
From fiducial cross sections to total cross sections

Fiducial cross sections



Total cross sections



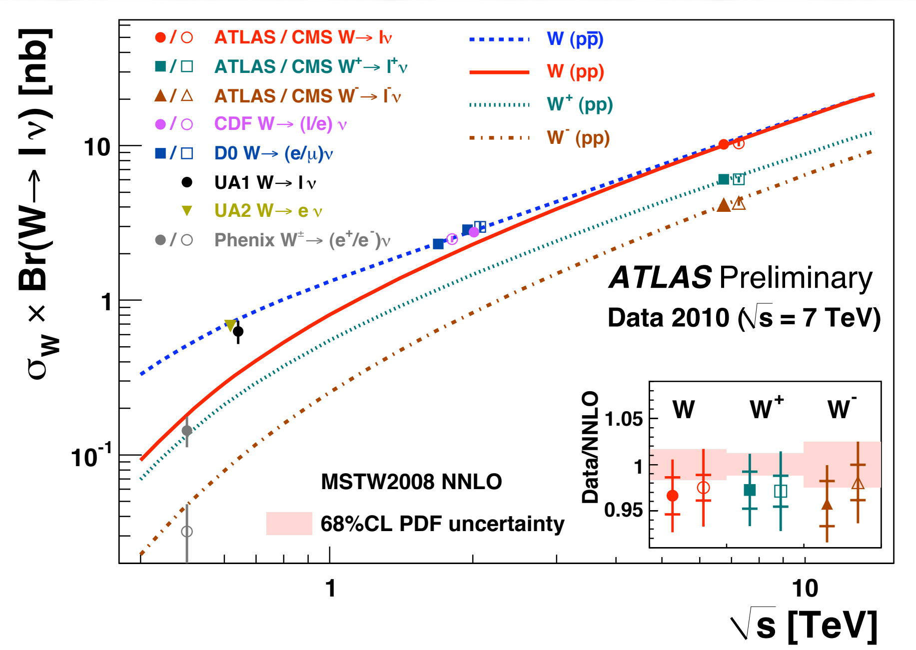
$P_T(e) > 20$ GeV, $\eta < 2.5$
$P_T(\nu) > 25$ GeV
$m_T(e\,\nu) > 40$ GeV

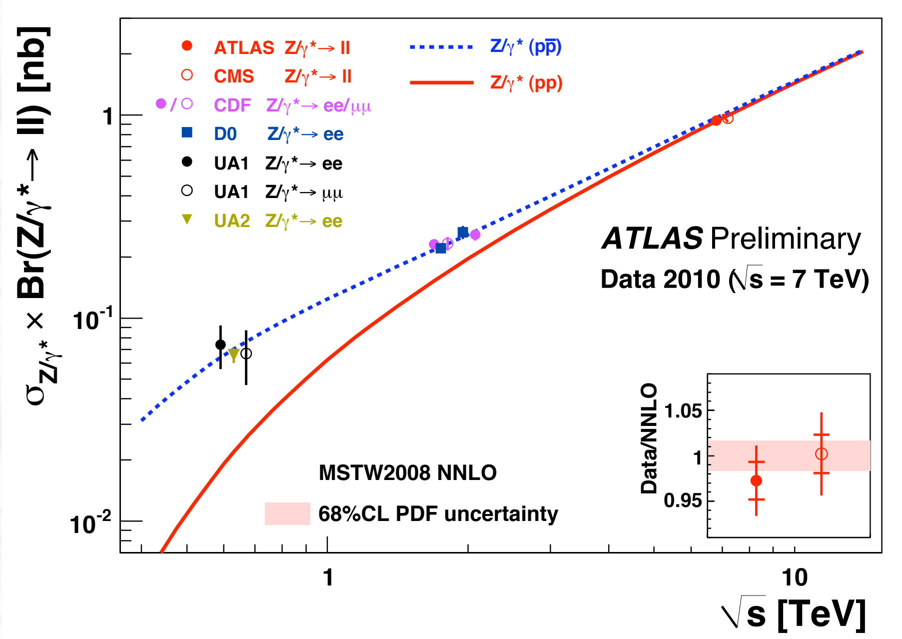
Uncertainties in W/Z cross section measurements

Electron channels (%)	$W^{\pm}$	W^{+}	W^{-}	Z
Trigger	0.4	0.4	0.4	<0.1
Reconstruction	0.8	0.8	0.8	1.6
Identification	0.9	0.8	1.1	1.8
Isolation	0.3	0.3	0.3	—
Energy scale and resolution	0.5	0.5	0.5	0.2
Defective LAr channels	0.4	0.4	0.4	0.8
Charge misidentification	<0.1	0.1	0.1	0.6
$E_{\mathrm{T}}^{\mathrm{miss}}$	0.8	0.7	1.0	—
Pile-up	0.3	0.3	0.3	0.3
Vertex position	0.1	0.1	0.1	0.1
QCD Background	0.4	0.4	0.4	0.7
EWK+$t\bar{t}$ Background	0.2	0.2	0.2	<0.1
$C_{W/Z}$ Theor. uncertainty	0.6	0.6	0.6	0.3
Total Exp. uncertainty	**1.8**	**1.8**	**2.0**	**2.7**
$A_{W/Z}$ Theor. uncertainty	1.4	1.6	1.9	1.9
Total excluding Luminosity	2.3	2.4	2.8	3.3

In addition: luminosity uncertainty ±3.4%
(now better known in both experiments, better than ±2%

W and Z production cross sections at hadron colliders



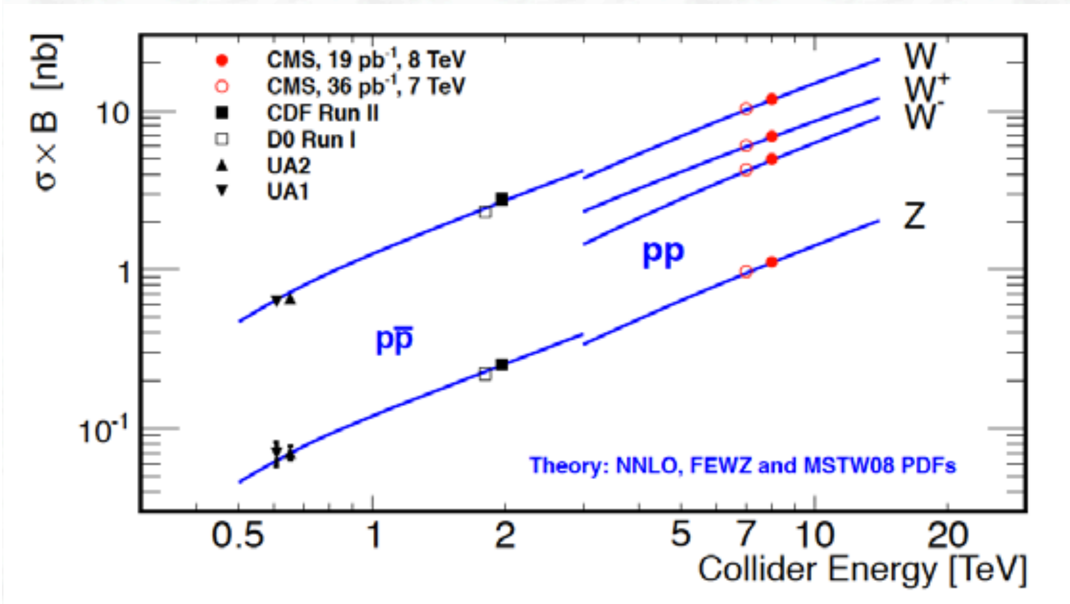


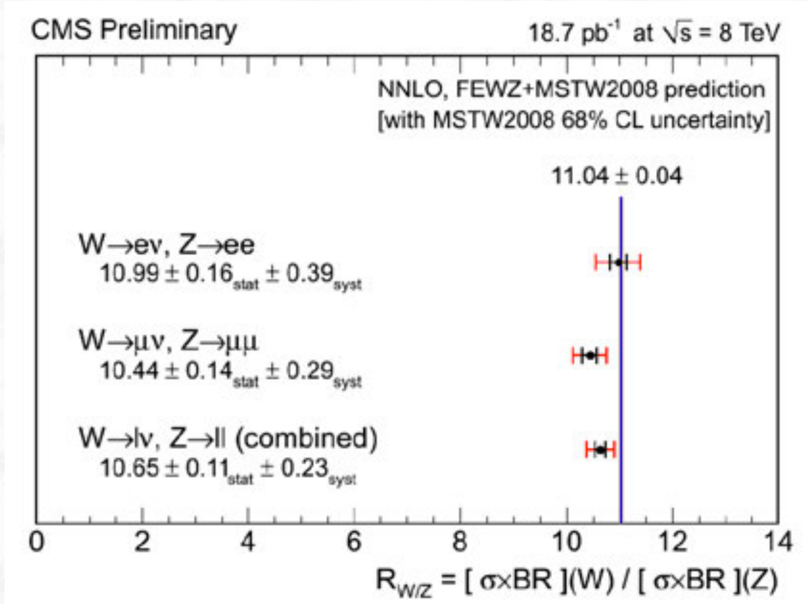
- Theoretical NNLO predictions in very good agreement with the experimental measurements (for pp, ppbar and as a function of energy)

- Good agreement as well between the ATLAS and CMS experiments

W and Z production cross sections at √s = 8 TeV

- CMS has already presented first results at 8 TeV (the first 18.7 pb^{-1})
  About 75.000 W → eν and 4.800 Z → ee candidates

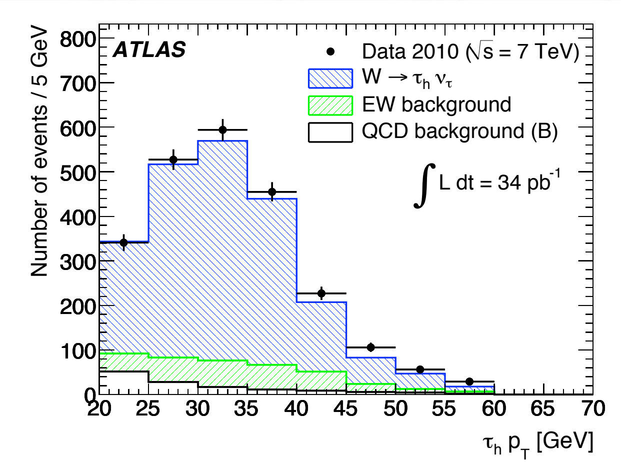


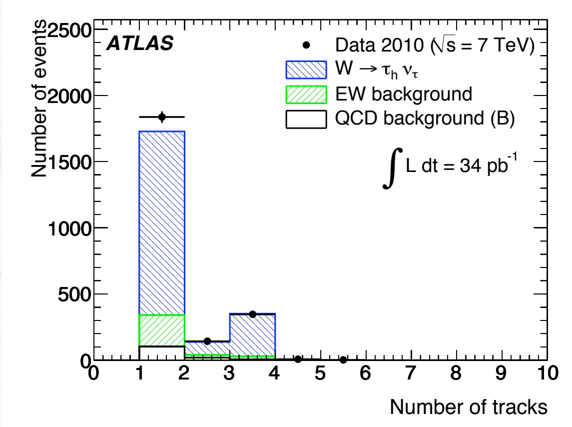


- No surprise at the new energy, theoretical predictions in good agreement with the measurements
- W/Z cross-section ratio remains a bit high, but consistent within uncertainties

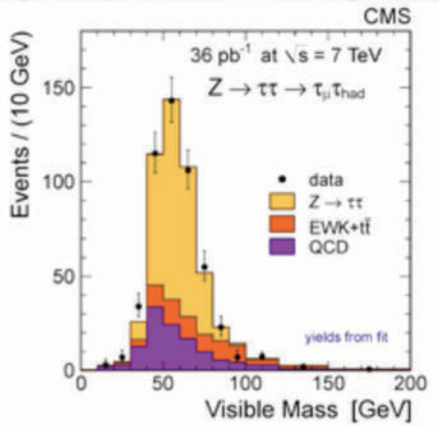
First physics signals with hadronic tau final states

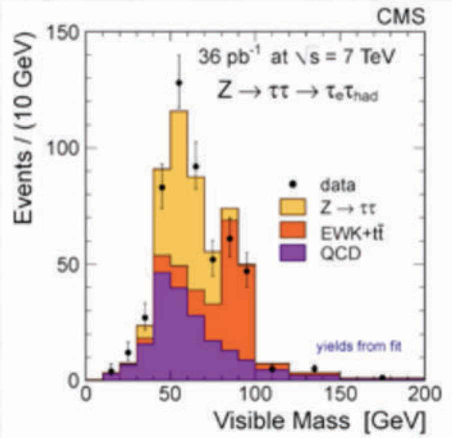
- Taus are more difficult to detect
- They decay with a short lifetime (0.3 ps) into 1 or 3 charged hadrons (65%) and a neutrino
- Taus have to be separated from hadronic jets





W → τ ν



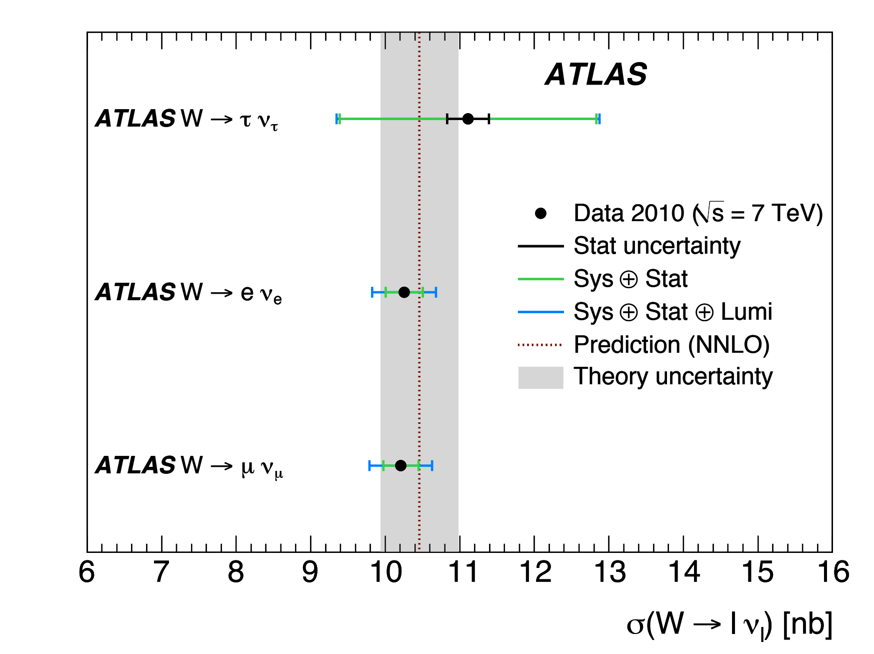


Z → τ τ

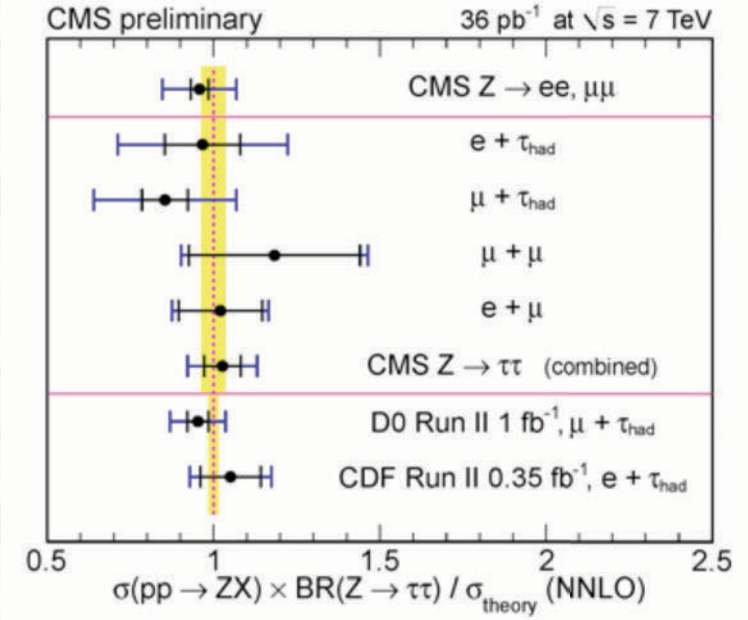
- First tau signals established in both ATLAS and CMS
- Important reference signals for searches with taus in Higgs and SUSY areas

First physics signals with hadronic tau final states

$W \rightarrow \tau \nu$



$Z \rightarrow \tau \tau$



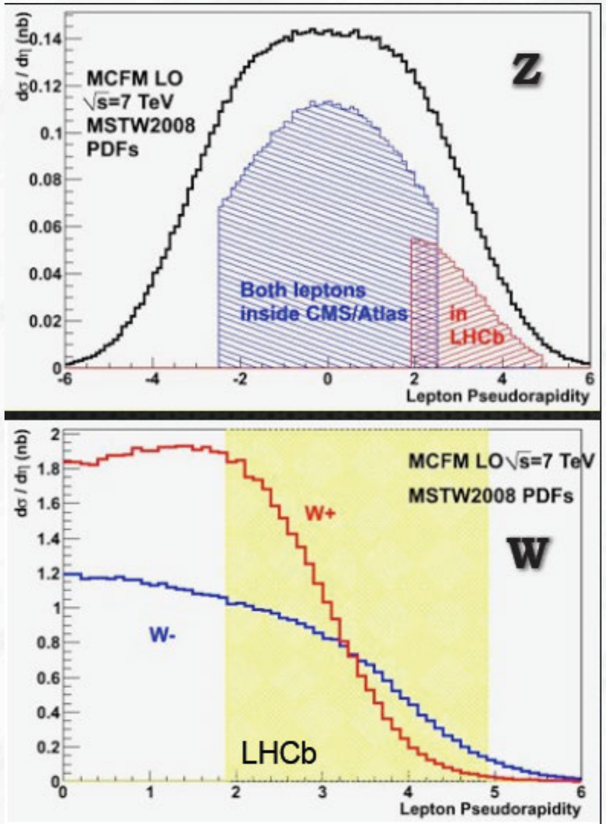
- Good agreement between the measured cross sections in the three lepton flavours
- Experimental uncertainites ($Z \rightarrow \tau\tau$) already comparable to Tevatron measurements

Can the parton distribution functions be constrained?

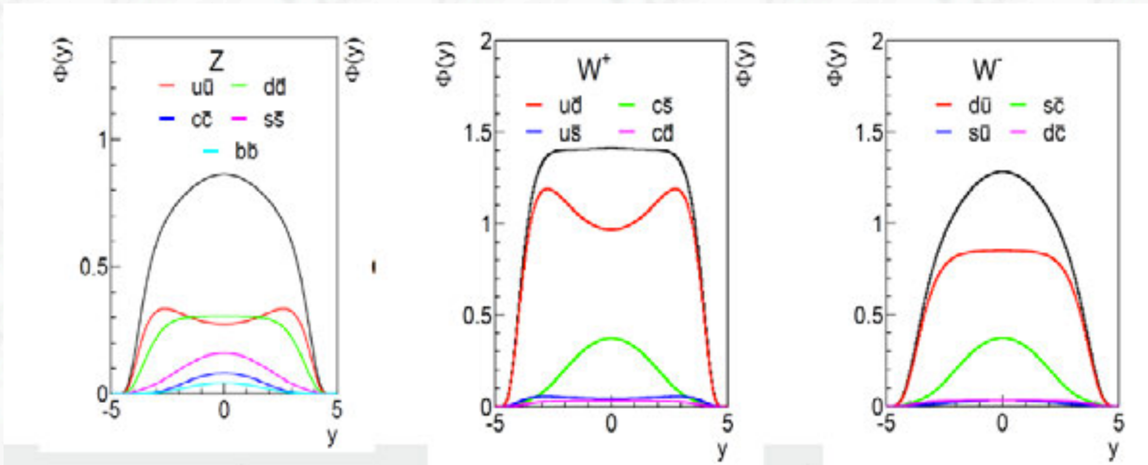
- Sensitive measurements: differential W and Z production cross sections as function of lepton or boson rapidity, charge separated for W^+ and W^-

  LHCb experiment can contribute significantly in the forward region: η coverage from 1.9 – 4.9

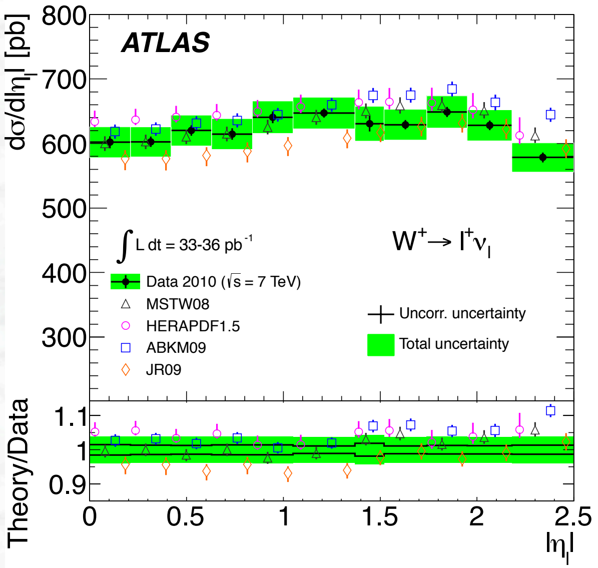
- Derived quantity: charge asymmetry: $\sigma(W^+) - \sigma(W^-)$ / $[\sigma(W^+) + \sigma(W^-)]$

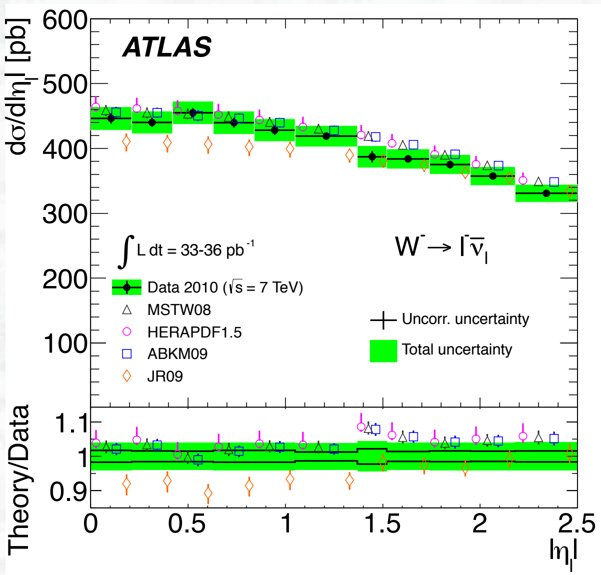


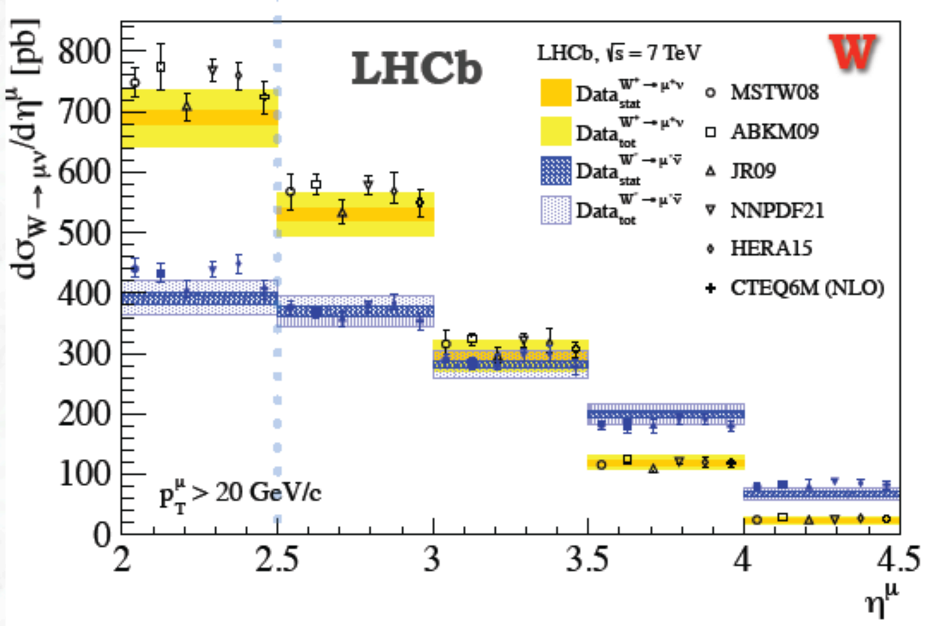
Leading order (tree level) contributions to W/Z production



Differential cross section measurements



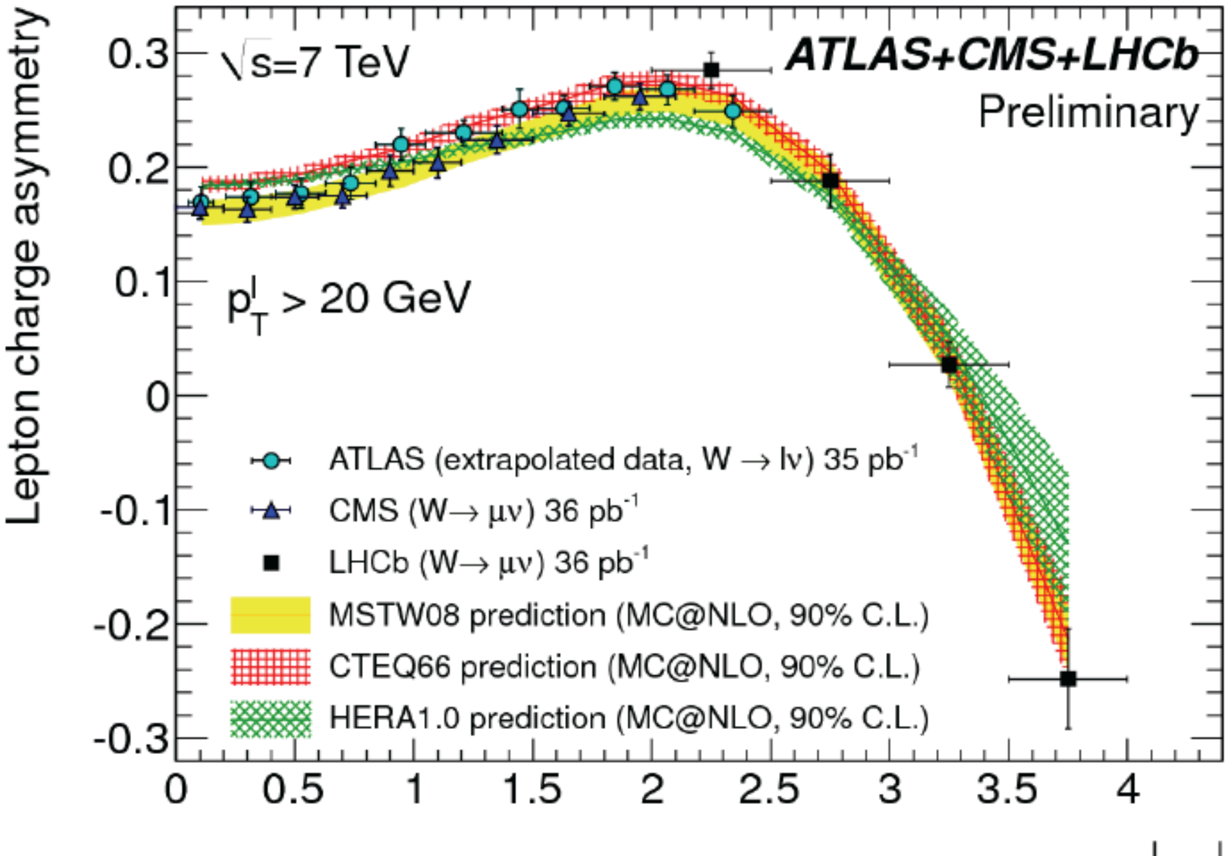




- Rough features of the measured differential cross sections are well described; (some tension at intermediate η region)
- Data start to be discriminating between pdf models;

These data will have impact on pdf uncertainties

W charge asymmetries



First LHC combined plot (LHC EWK WG)

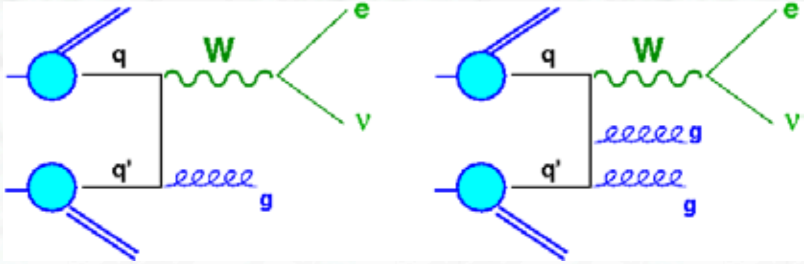
$$A(\eta_\ell) = \frac{d\sigma_{W+}(\eta_\ell) - d\sigma_{W-}(\eta_\ell)}{d\sigma_{W+}(\eta_\ell) + d\sigma_{W-}(\eta_\ell)}$$

All data are unfolded,

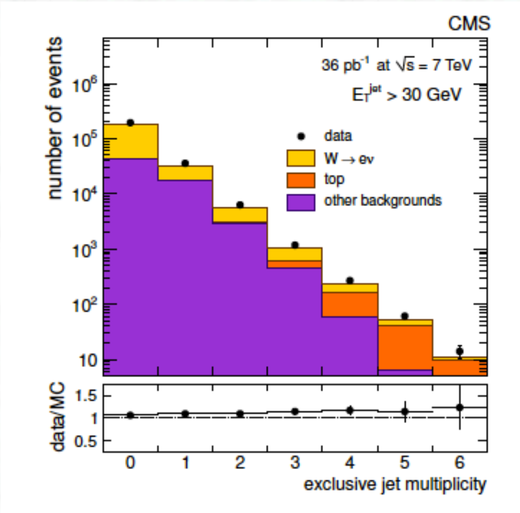
$P_T(l) > 20$ GeV

- Combination of the LHC experiments leads to large η coverage interesting constraints already today

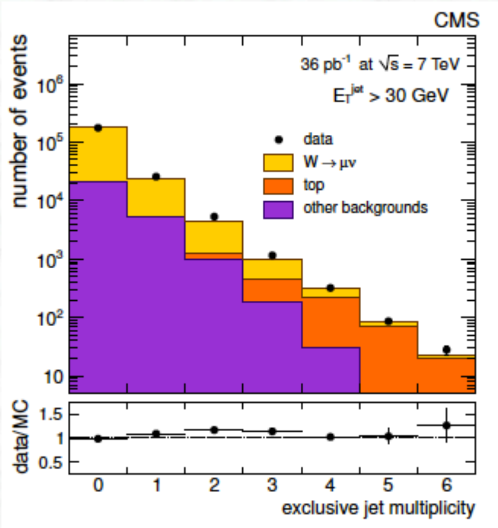
QCD Test in W/Z + jet production



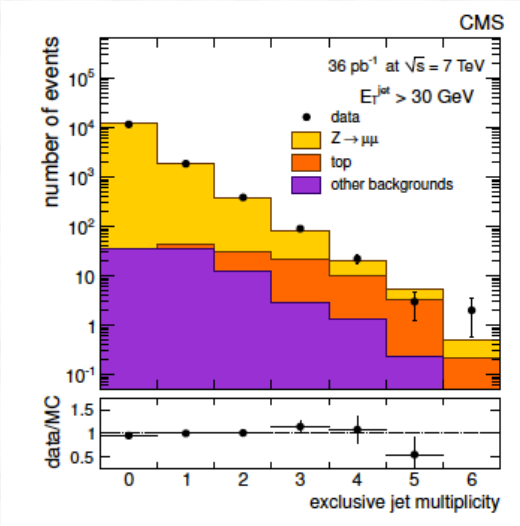
- CMS inclusive spectra of jets associated to W/Z production (36 pb^{-1});
- At detector level, compared to Monte Carlo Simulation (Madgraph + PYTHIA) (normalized to (N)NLO calculations)



W → eν



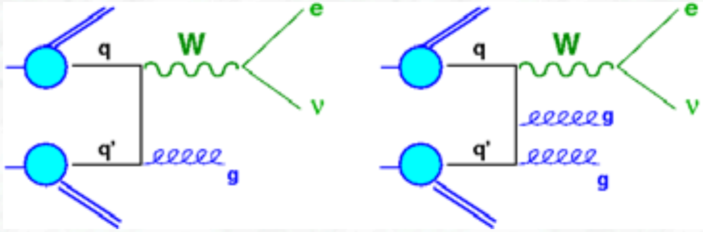
W → μν



Z → μμ

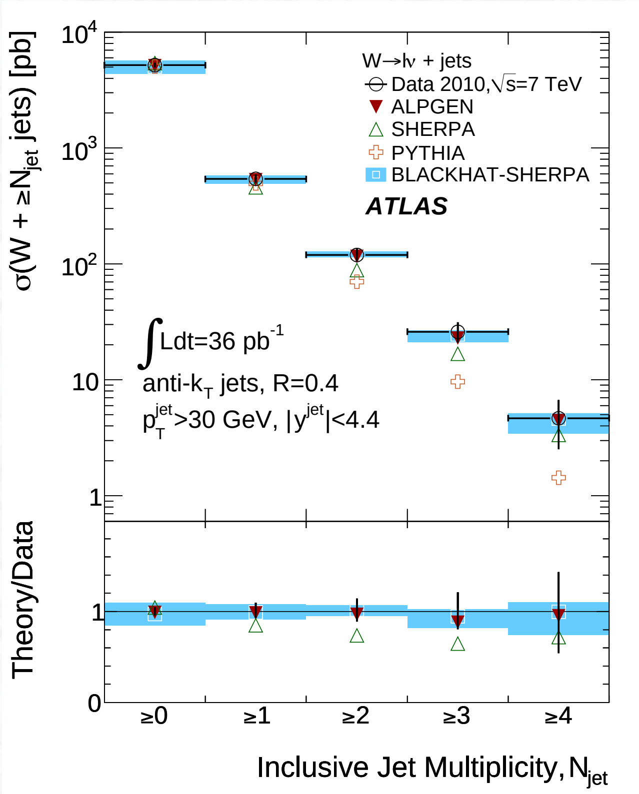
- Good agreement at that stage (jets with p_T > 30 GeV),
- Top contribution clearly visible in high multiplicity bins of W + jet production

W/Z + jet cross section measurements

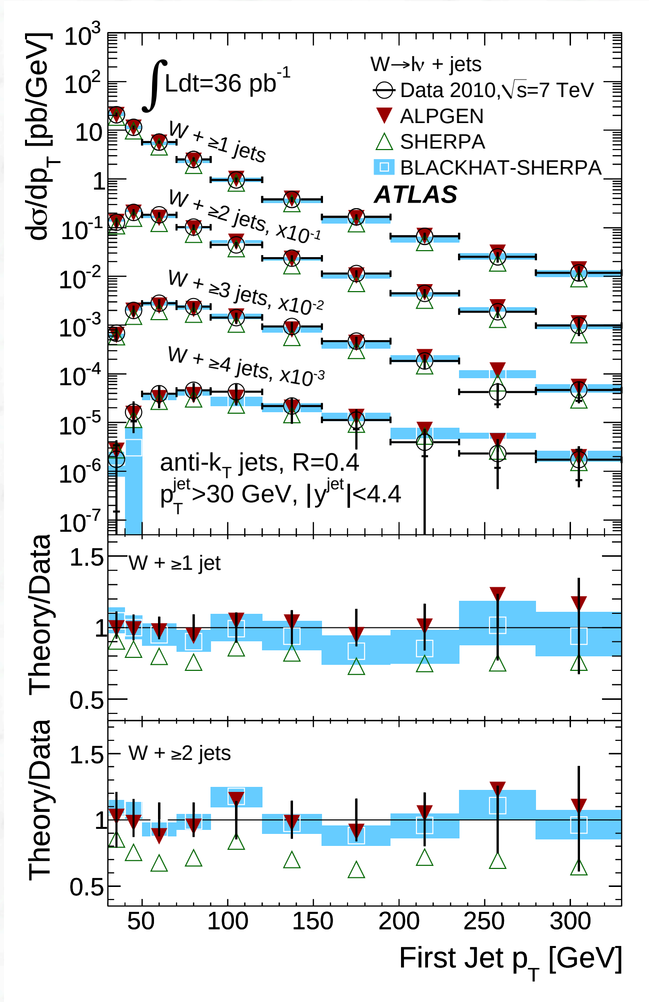


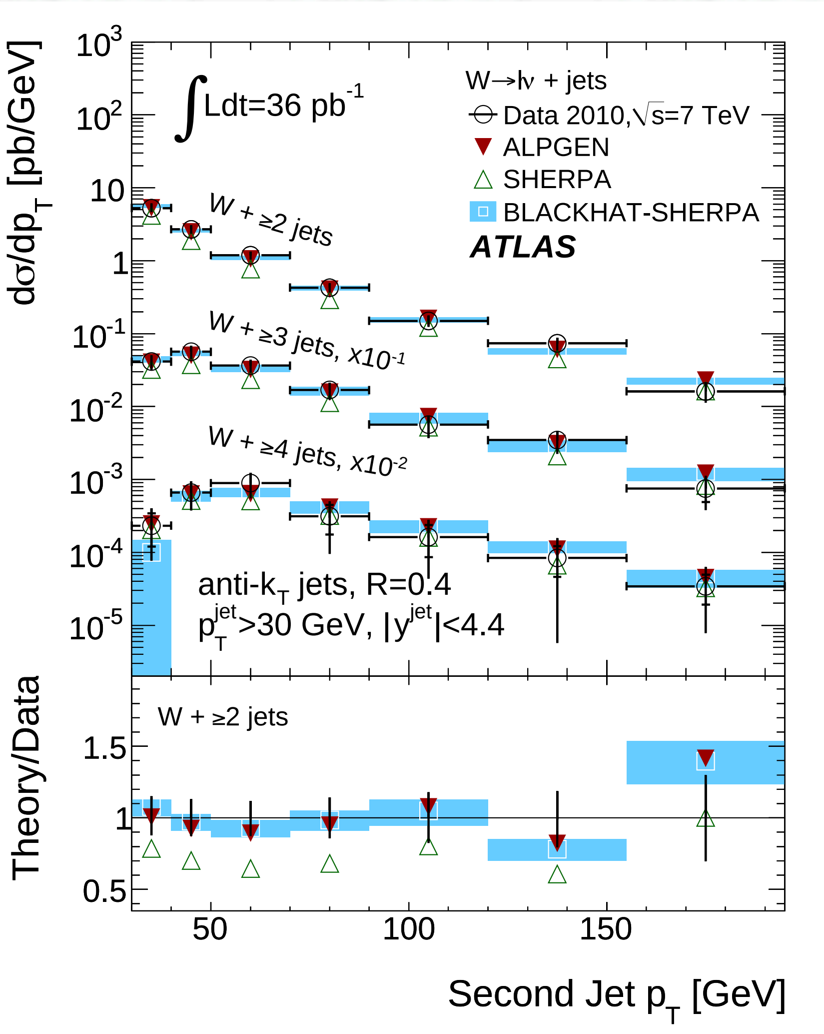
- LO predictions fail to describe the data;
- Jet multiplicities and p_T spectra in agreement with NLO predictions within errors;

Jet multiplicities in W+jet production

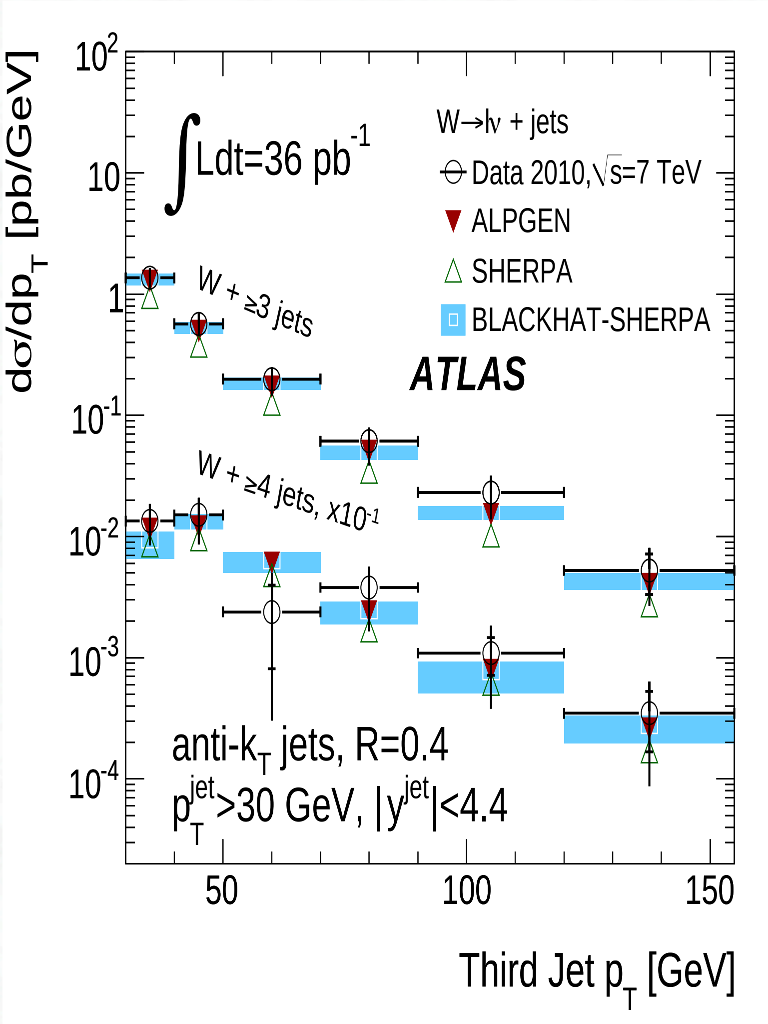


p_T spectrum of leading jet





$\int$Ldt=36 pb^{-1}
W→lν + jets
Data 2010,√s=7 TeV
ALPGEN
SHERPA
BLACKHAT-SHERPA
ATLAS
W + ≥2 jets
W + ≥3 jets, x10^{-1}
W + ≥4 jets, x10^{-2}
anti-k$_T$ jets, R=0.4
p$_T^{jet}$>30 GeV, |y^{jet}|<4.4
dσ/dp$_T$ [pb/GeV]
Theory/Data
W + ≥2 jets
Second Jet p$_T$ [GeV]



$\int$Ldt=36 pb^{-1}
W→lν + jets
Data 2010,√s=7 TeV
ALPGEN
SHERPA
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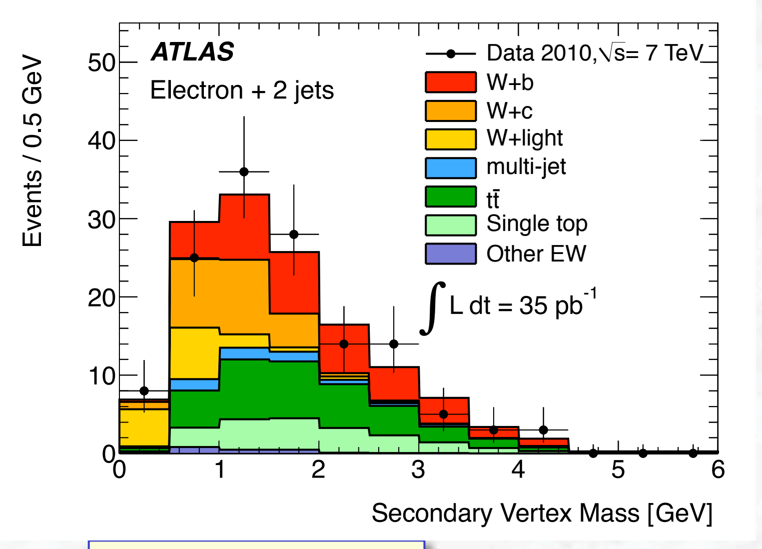
ATLAS
W + ≥3 jets
W + ≥4 jets, x10^{-1}
anti-k$_T$ jets, R=0.4
p$_T^{jet}$>30 GeV, |y^{jet}|<4.4
dσ/dp$_T$ [pb/GeV]
Third Jet p$_T$ [GeV]

W + b jets

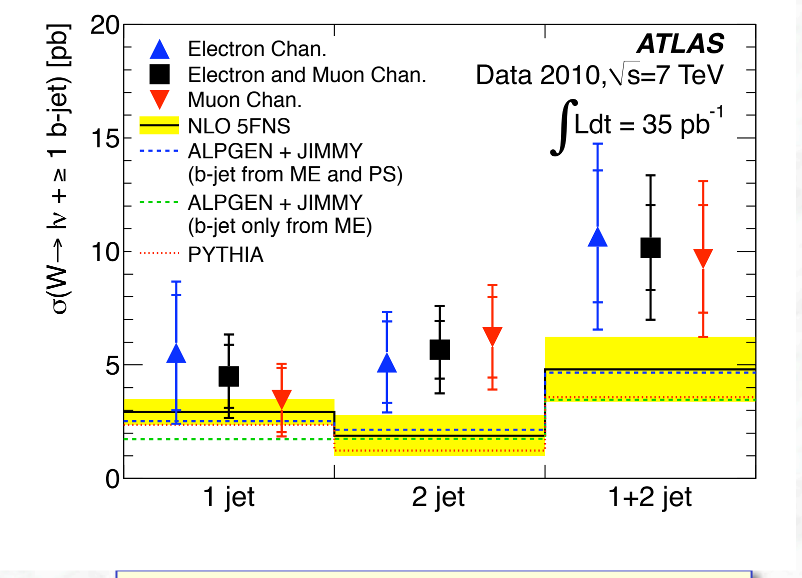
- Important background for many studies (Higgs, SUSY, top)
- Measurements at the Tevatron exceed NLO prediction

- Measured by ATLAS using 2010 data sample
  - studied W + 1 jet and W + 2 jets
  - require at least one b-tagged jet



W→ e ν + 2 jets

Distribution of the mass of the particles associated to the secondary vertex for b-tagged jets

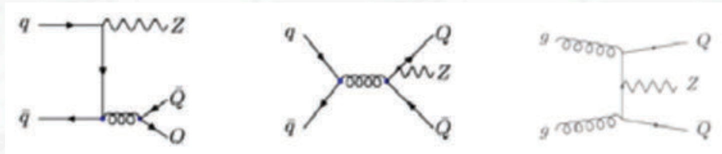


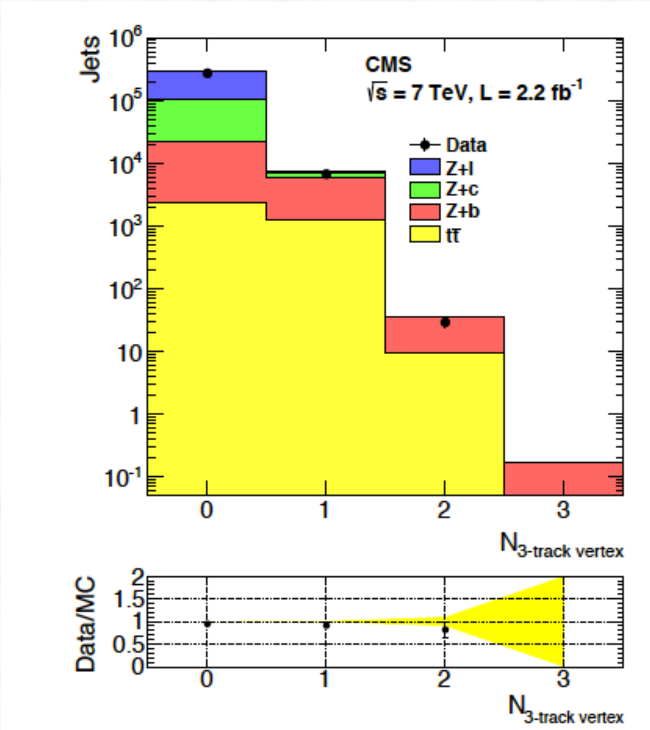
Results from e and μ combined. Measurements ~1.5σ above NLO prediction, but still consistent within uncertainties

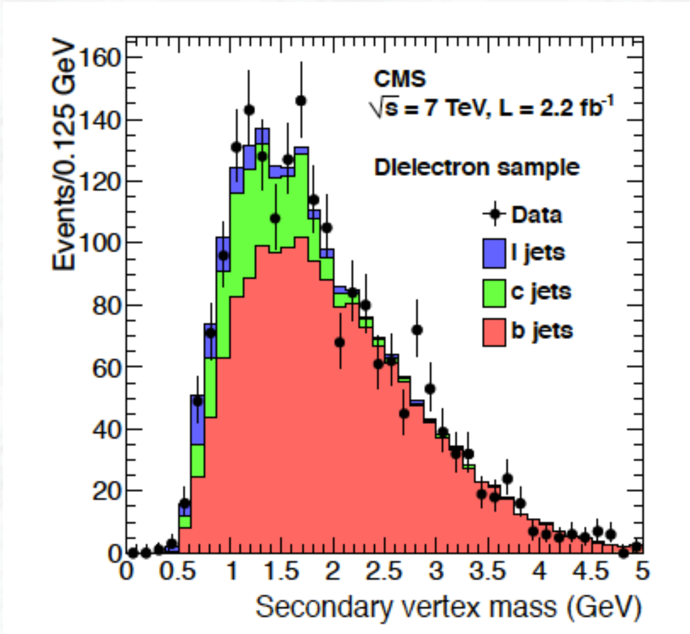
Z + b jets

- Important background for many studies (Higgs, SUSY, top)

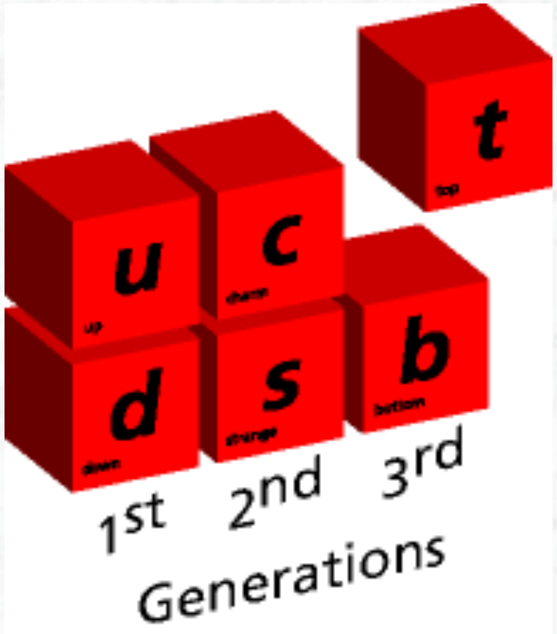
- Measured by CMS using 2011 data sample



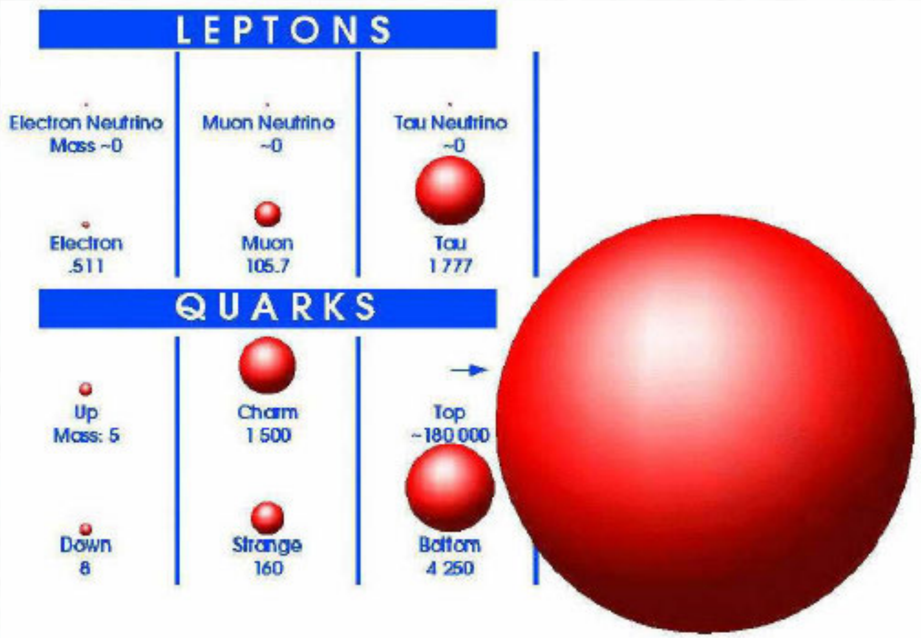




Top Quark Physics



Why is Top-Quark so important ?



The top quark may serve as a window to **New Physics** related to the electroweak symmetry breaking;

Why is its Yukawa coupling ~ 1 ??

$$M_t = \frac{1}{\sqrt{2}} \lambda_t v$$

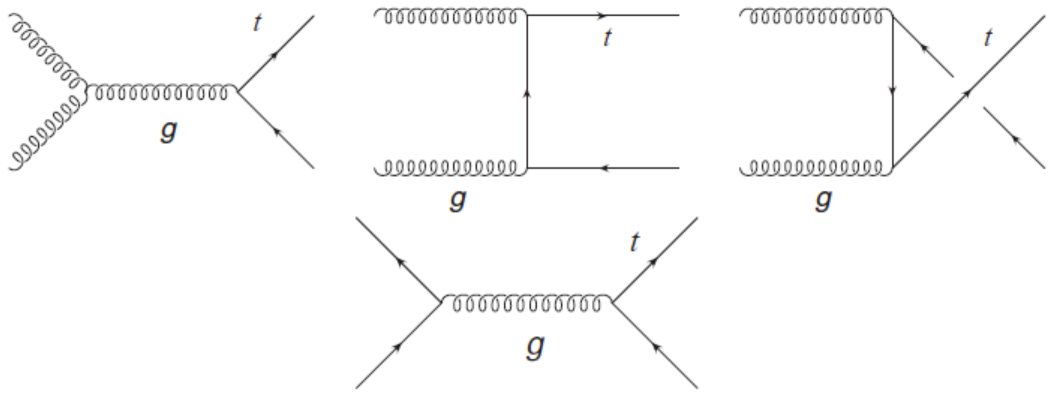
$$\Rightarrow \lambda_t = \frac{M_t}{173.9\ \mathrm{GeV}/c^2}$$

- A unique quark: decays before it hadronizes, lifetime ~10^{-25} s
  no “toponium states”
  remember: bb, bd, bs….. cc, cs….. bound states (mesons)

- We still know little about the properties of the top quark:
  mass, spin, charge, lifetime, decay properties (rare decays), gauge couplings, Yukawa coupling,…

Top Quark Production

Pair production: qq and gg-fusion



Top-quark pair production in the Born approximation.

- NLO corrections completely known
- NNLO partly known

approximate NNLO results:

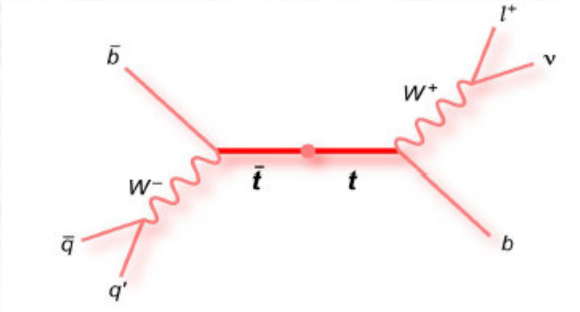
$$\sigma_{\text{LHC}} = (887^{+9}_{-33}\,(\text{scale})^{+15}_{-15}\,(\text{PDF}))\ \text{pb} \qquad (14\ \text{TeV}),$$

$$\sigma_{\text{Tev}} = (7.04^{+0.24}_{-0.36}\,(\text{scale})^{+0.14}_{-0.14}\,(\text{PDF}))\ \text{pb} \qquad (1.96\ \text{TeV}).$$

	Tevatron 1.96 TeV	LHC 14 TeV
qq gg	85% 15%	5% 95%
σ (pb)	7.0 pb	887 pb

For LHC running at √s = 7 TeV, the cross section is reduced by a factor of ~5, but it is still a factor 25 larger than the cross section at the Tevatron

Top Quark Decays



BR (t→Wb) ~ 100%

Dilepton channel:

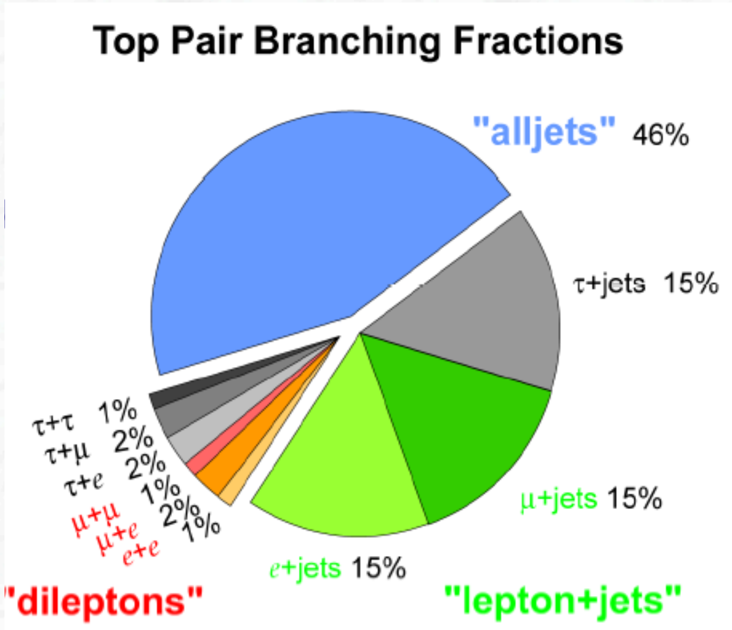
Both W's decay via W→ ℓν (ℓ=e or μ; 4%)

Lepton + jet channel:

One W decays via W → ℓν (ℓ=e or μ; 30%)

Full hadronic channel:

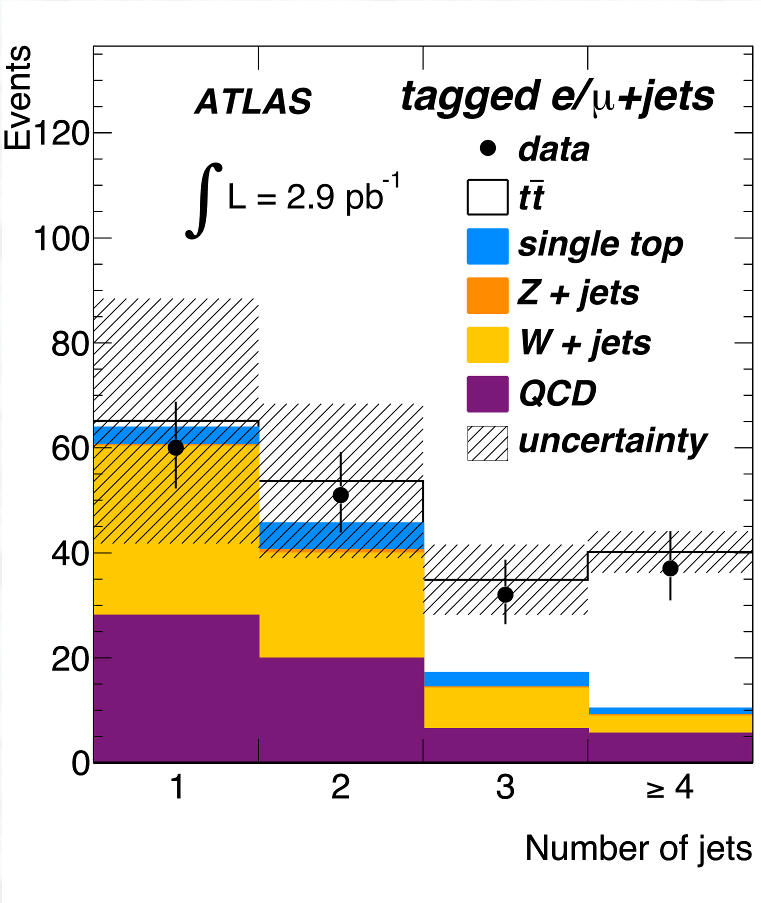
Both W's decay via W→qq (46%)



<u>Important experimental signatures</u>: : - Lepton(s)

- Missing transverse momentum
- b-jet(s)

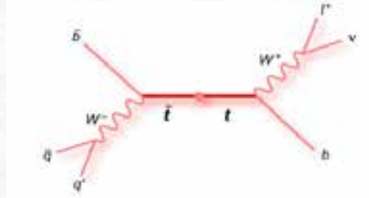
First results on top production from the LHC

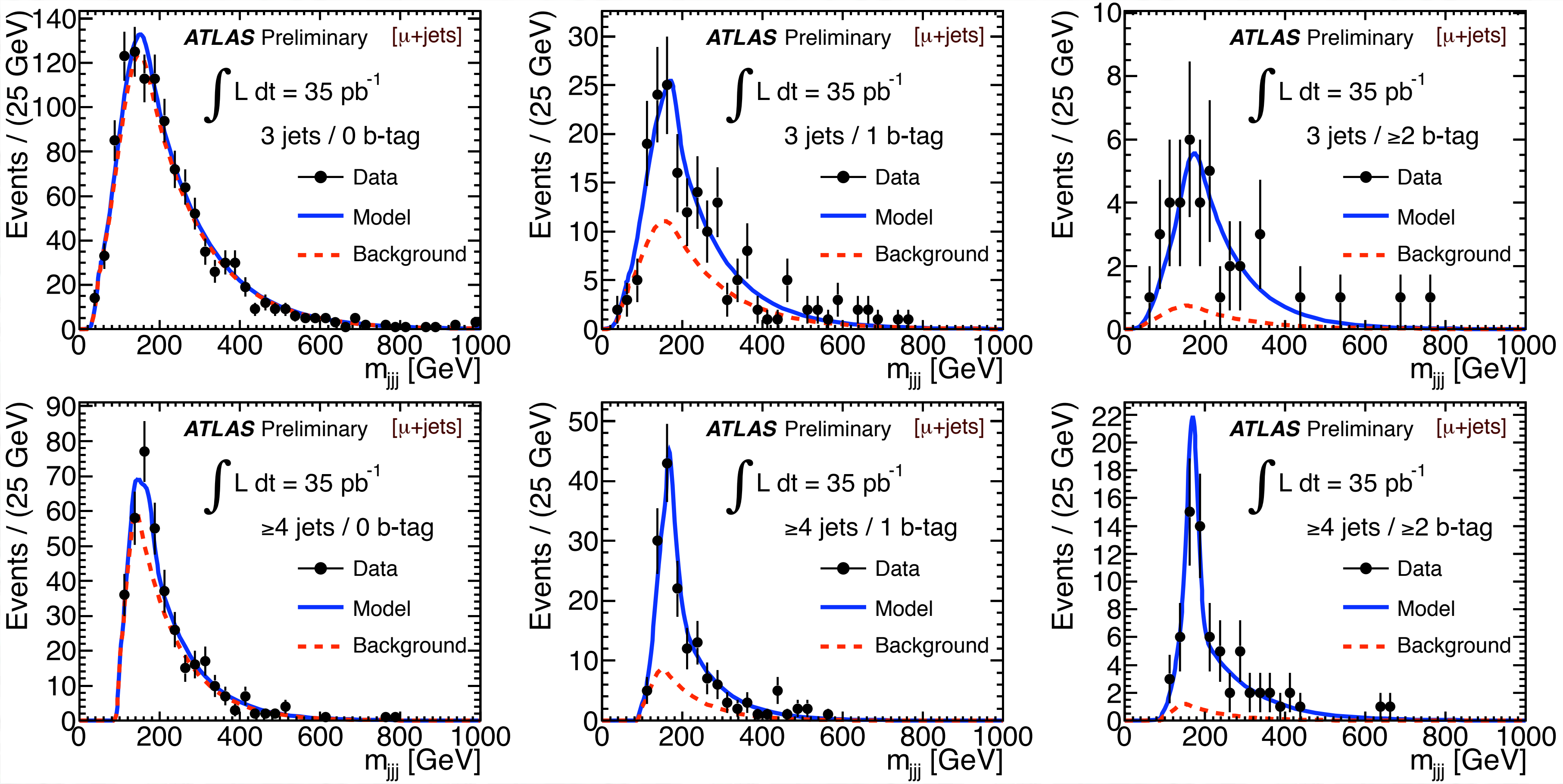


Event Selection:

- Lepton trigger
- One identified lepton (e,μ) with $p_T > 20$ GeV
- Missing transverse energy: $E_T^{miss} > 35$ GeV (significant rejection against QCD events)
- Transverse mass: $M_T(l,\nu) > 25$ GeV (lepton from W decay in event)
- One or more jets with $p_T > 25$ GeV and $\eta < 2.5$

Invariant mass distributions in the l-had channel



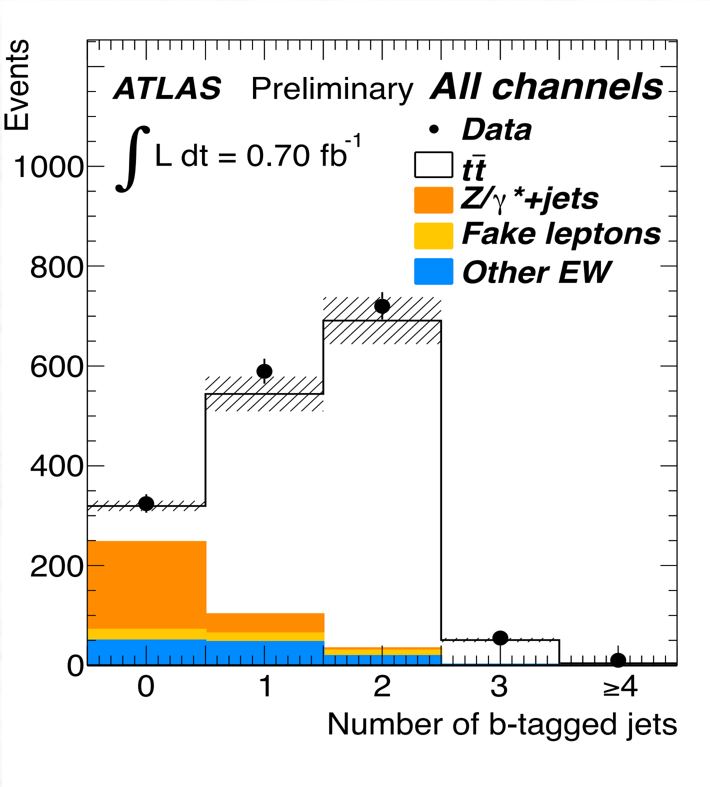


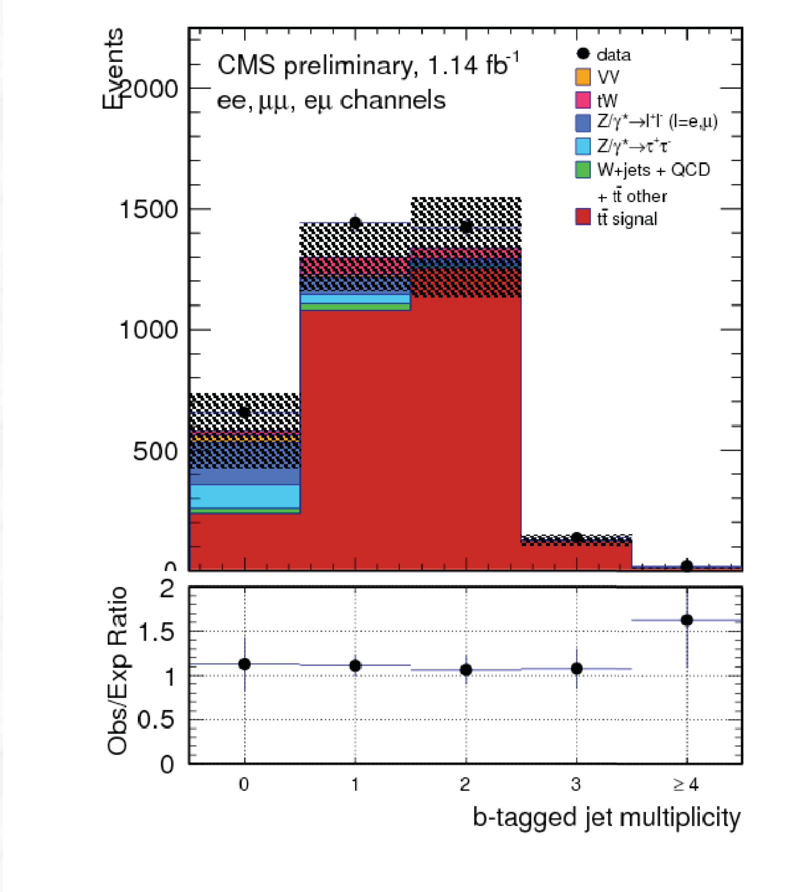
- Top fractions increase with number of b-tags
- Good description for all jet-multiplicity and b-tag combinations
- Data are consistent with top quark production with mass of 173 GeV

Top-quark production measured in many different decay modes

(i) Di-lepton selection in both ATLAS and CMS (0.7 fb^{-1} – 1.14 fb^{-1})

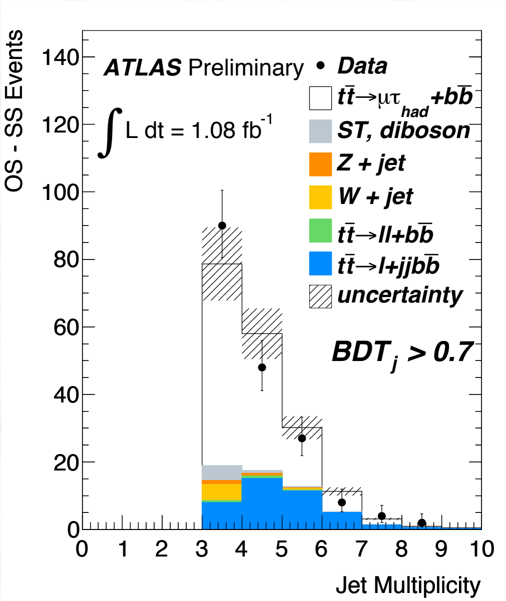
Multiplicity distributions of b-tagged jets
(small backgrounds, mainly from Z+jet production)

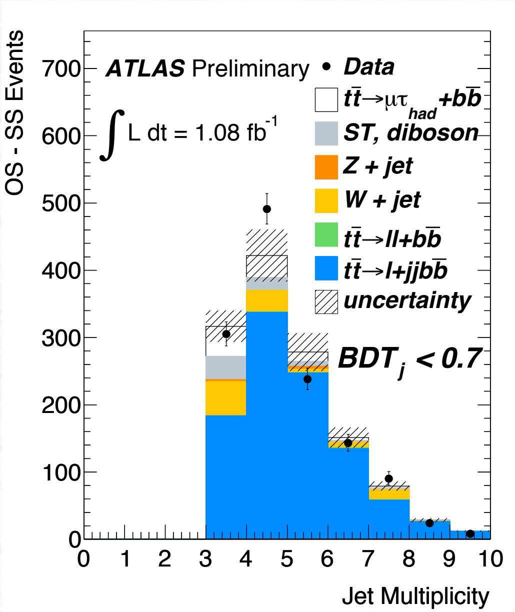


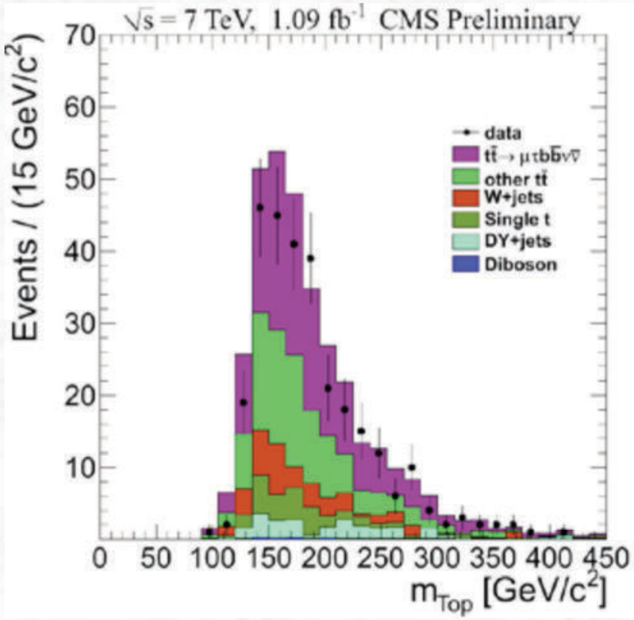


(ii) $\mu + \tau$ final states in both ATLAS and CMS (0.7 fb^{-1} – 1.14 fb^{-1})

Require: μ + hadronically decaying τ, E_T^{miss} + b-jets
(significant backgrounds, but signal contribution needed)





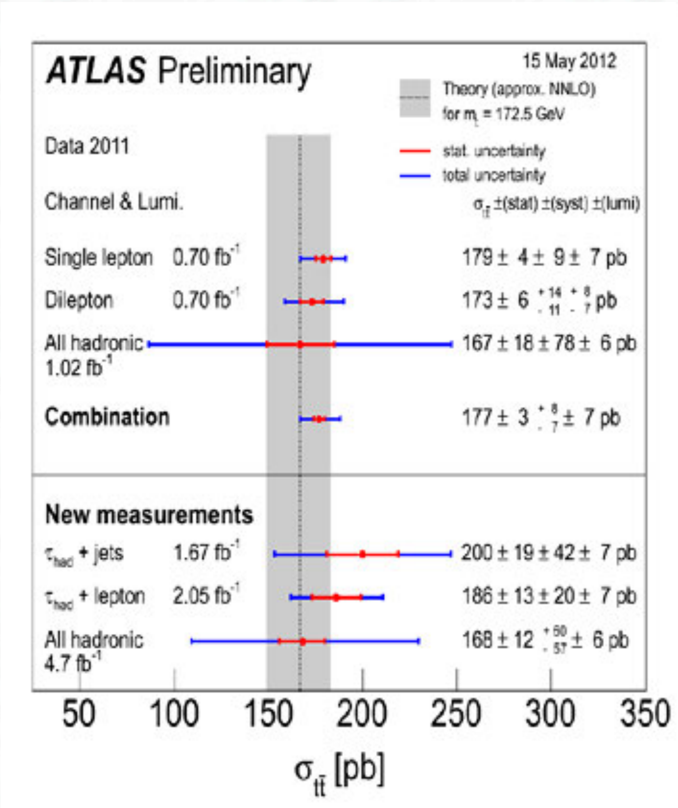


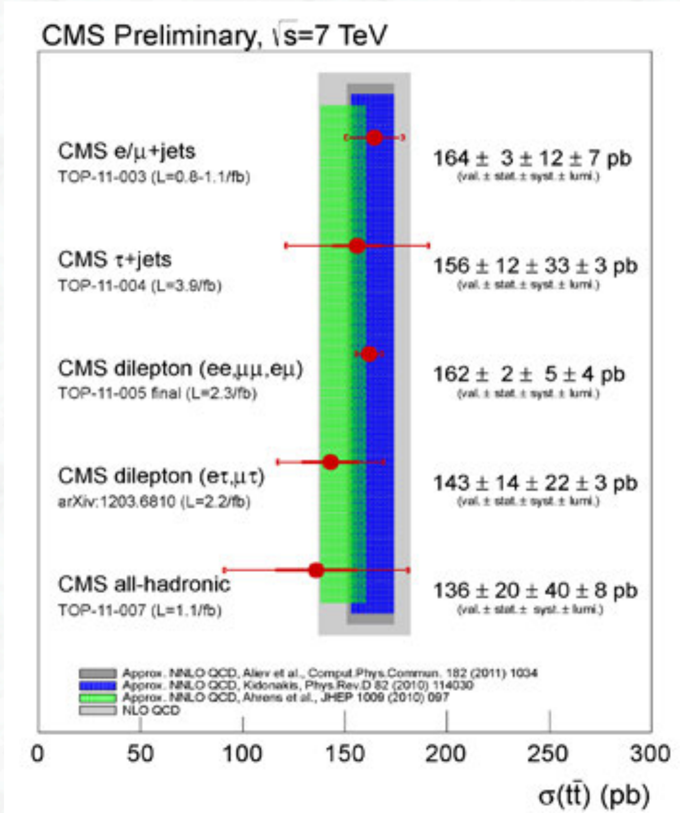
ATLAS: Multivariate analysis
Jet multiplicity distribution in signal (left)
and background (right) regions

reconstructed mass in CMS

Top pair production cross section measurements

-likelihood combination of all channels-





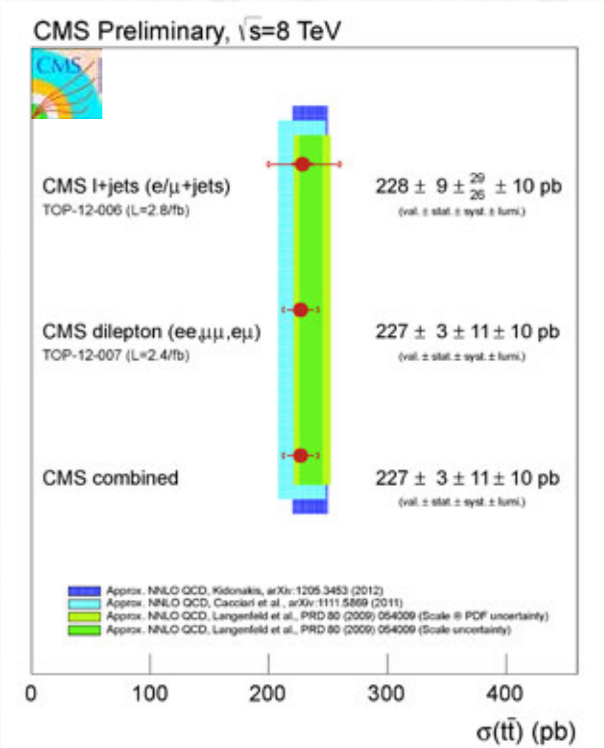
σ = 177 ± 3 (stat) ± 7 (syst) ± 7 (lum) pb

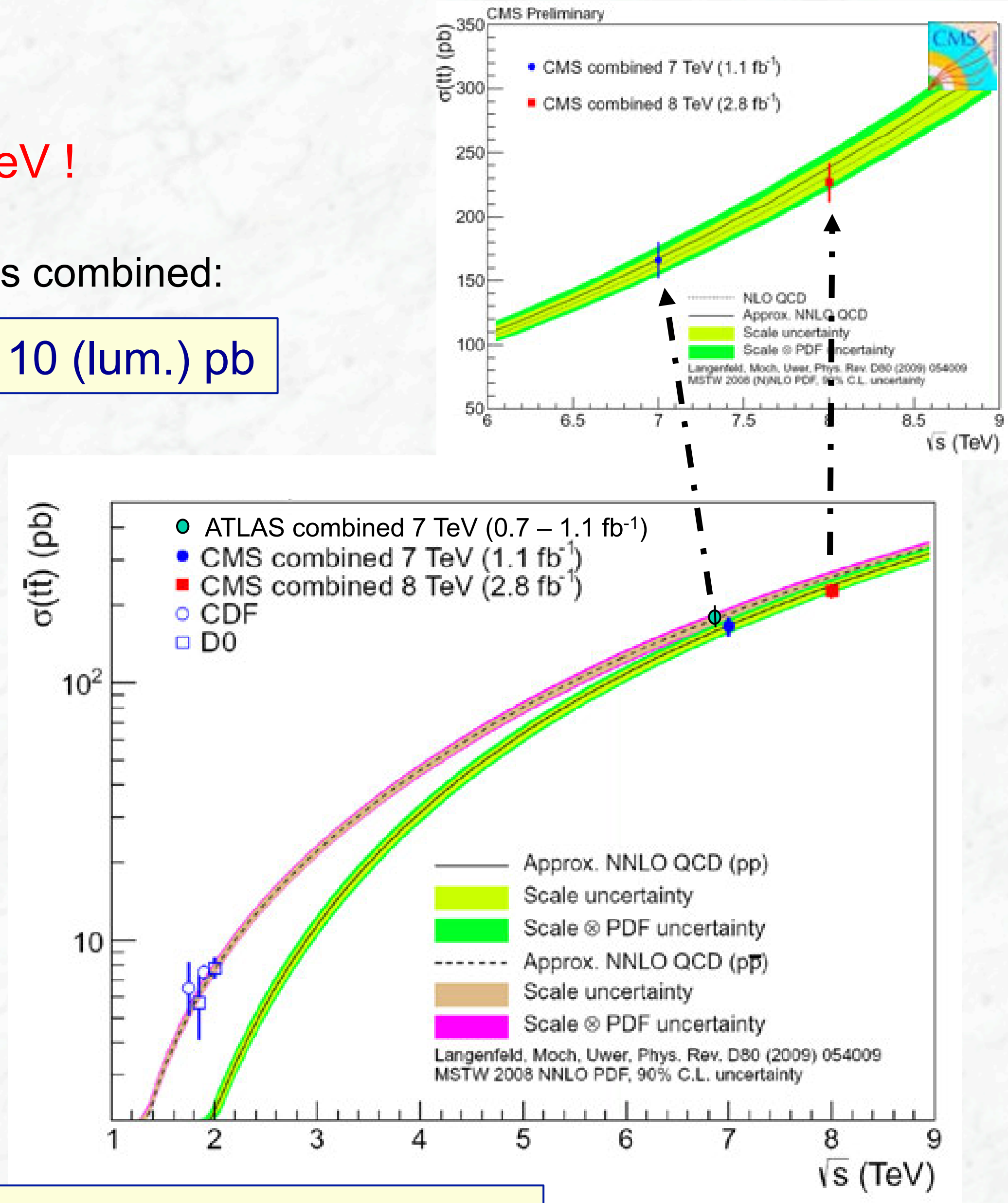
σ = 165.8 ± 2.2 (stat) ± 10.6 (syst) ± 7.8 (lum) pb

- Perturbative QCD calculations (approx. NNLO) describe the data well;
- The two LHC experiments agree within the systematic uncertainties
- Total uncertainty already at the level of ±6%

- CMS: new measurement at 8 TeV !
- Lepton + jets and di-lepton channels combined:

$\sigma = 227 \pm 3\ \text{(stat)} \pm 11\ \text{(syst.)} \pm 10\ \text{(lum.) pb}$



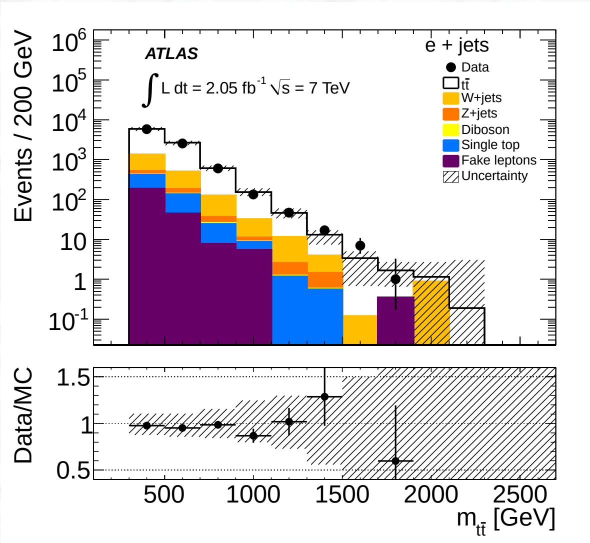


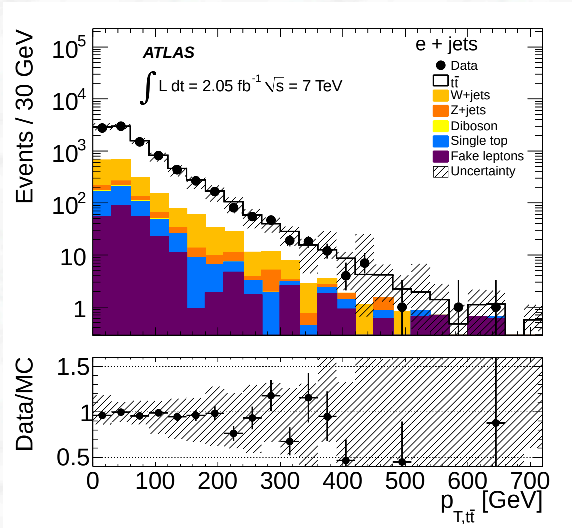
$\sigma(8\text{TeV})/\sigma(7\text{TeV}) = 1.41 \pm 0.11$; no correlation assumed

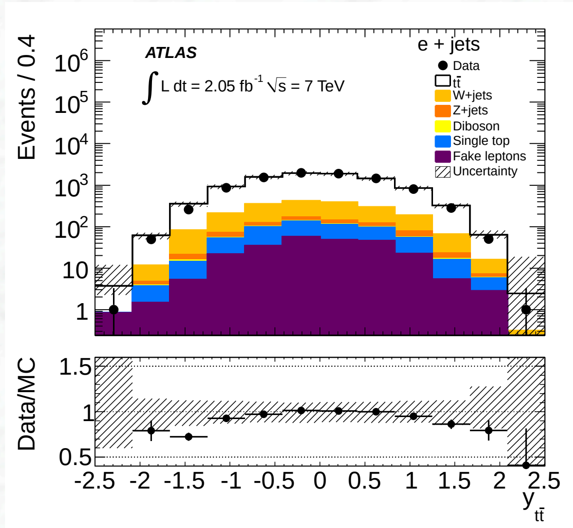
Top-antitop differential cross sections

- Important test of the Standard Model (perturbative QCD), deviations may indicate new physics
  e.g. new particles (resonances) decaying into tt, or other new/unexpected effects (→ Tevatron charge asymmetry)

- Important variables studied: - tt mass distribution
  - Rapidity y and p_T of the tt system



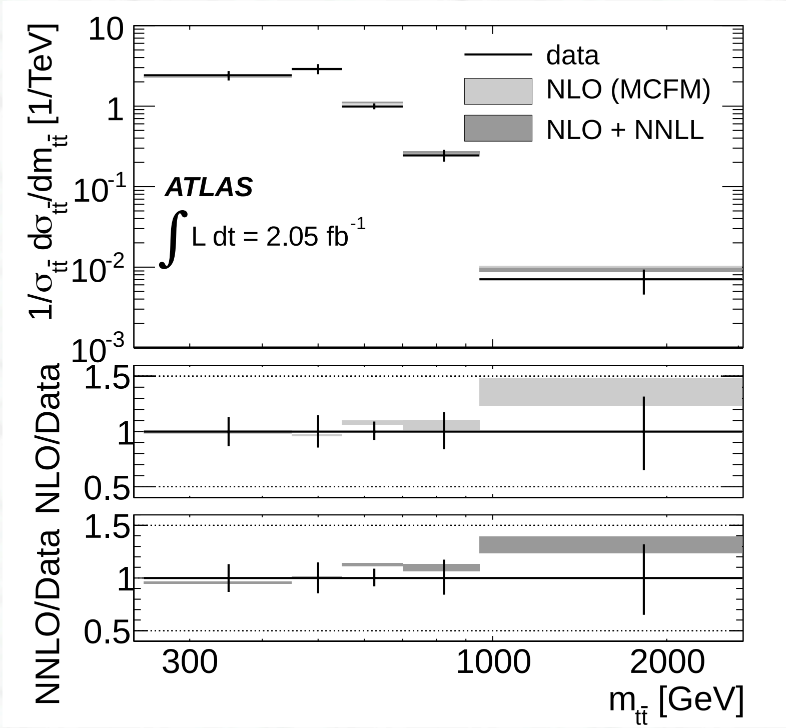


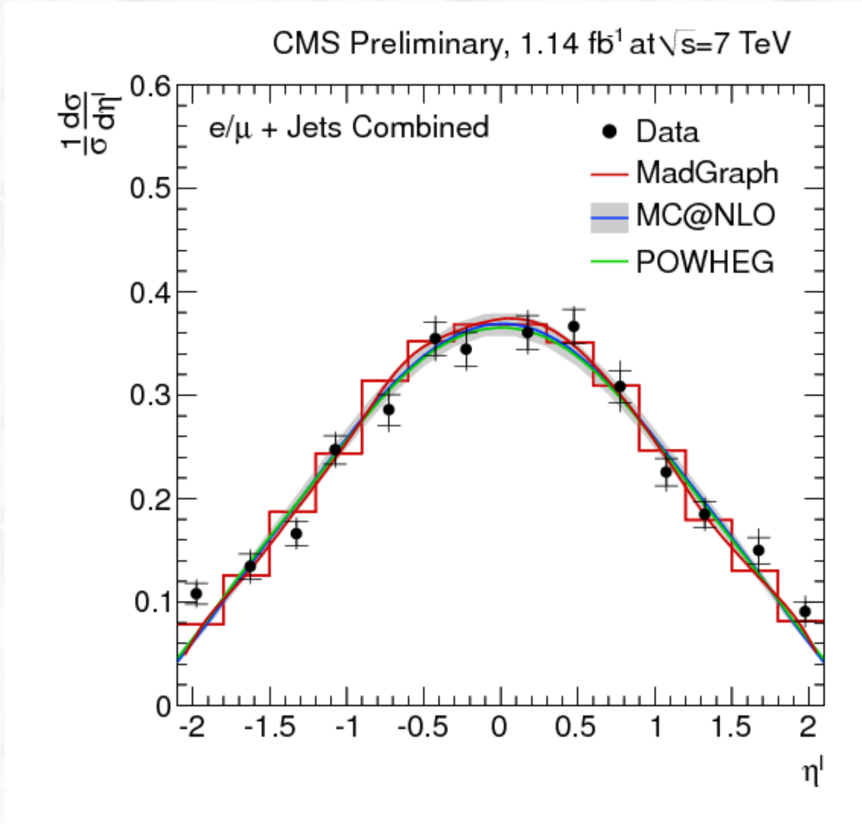


ATLAS comparison on detector level shows good agreement in all variables (background partially extracted from data)

→ not much room left / no signs yet of Physics beyond the Standard Model (more in the lecture of M. Narain)

- Both collaborations have unfolded the detector effects and have extracted differential cross-section measurements
  (normalized to the tt cross section → sensitivity in shapes of distributions)





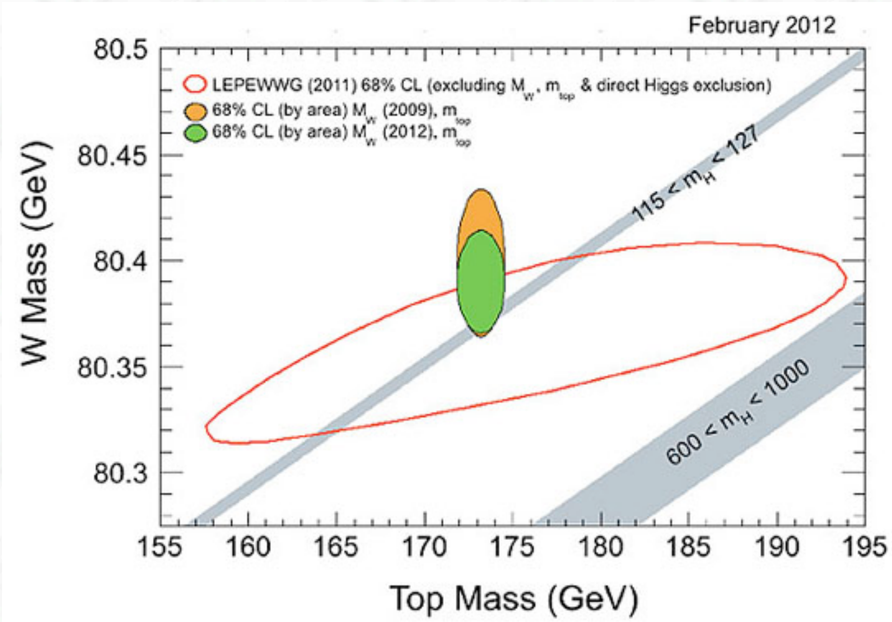
new

Part 3: Electroweak parameters

- W mass

- Top Quark Mass & Properties

- Gauge Boson pair production
  (WW, WZ, ZZ production)



All this is highly related to the Higgs boson search / discovery or to a consistency check / ultimate test of the Standard Model

Precision measurements of m_W and m_{top}

Motivation:

W mass and top quark mass are fundamental parameters of the Standard Model;
The standard theory provides well defined relations between m_W, m_t and m_H

$$m_W = \left(\frac{\pi \alpha_{EM}}{\sqrt{2} G_F} \right)^{1/2} \frac{1}{\sin \theta_W \sqrt{1 - \Delta r}}$$

Electromagnetic constant
measured in atomic transitions, e^+e^- machines, etc.

Fermi constant
measured in muon decay

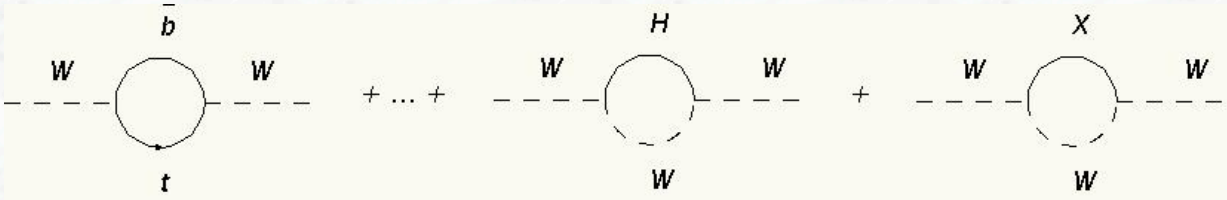
weak mixing angle
measured at LEP/SLC

radiative corrections
$\Delta r \sim f(m_{top}^2, \log m_H)$
$\Delta r \approx 3\%$

G_F, α_{EM}, $\sin \theta_W$

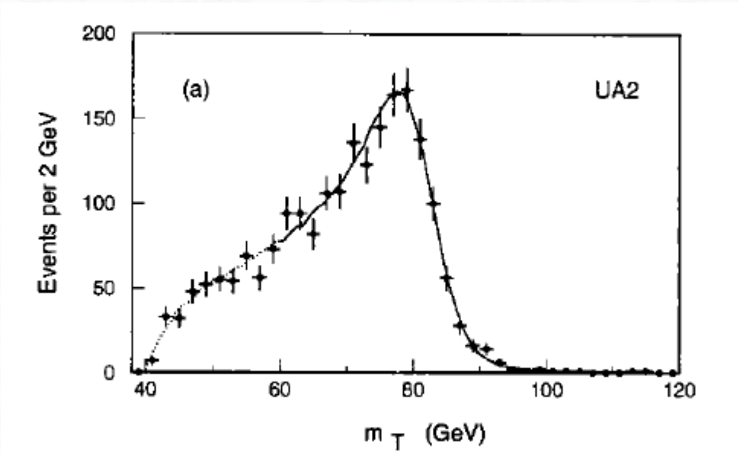
are known with high precision

Precise measurements of the W mass and the top-quark mass constrain the Higgs-boson mass
(and/or the theory, radiative corrections)

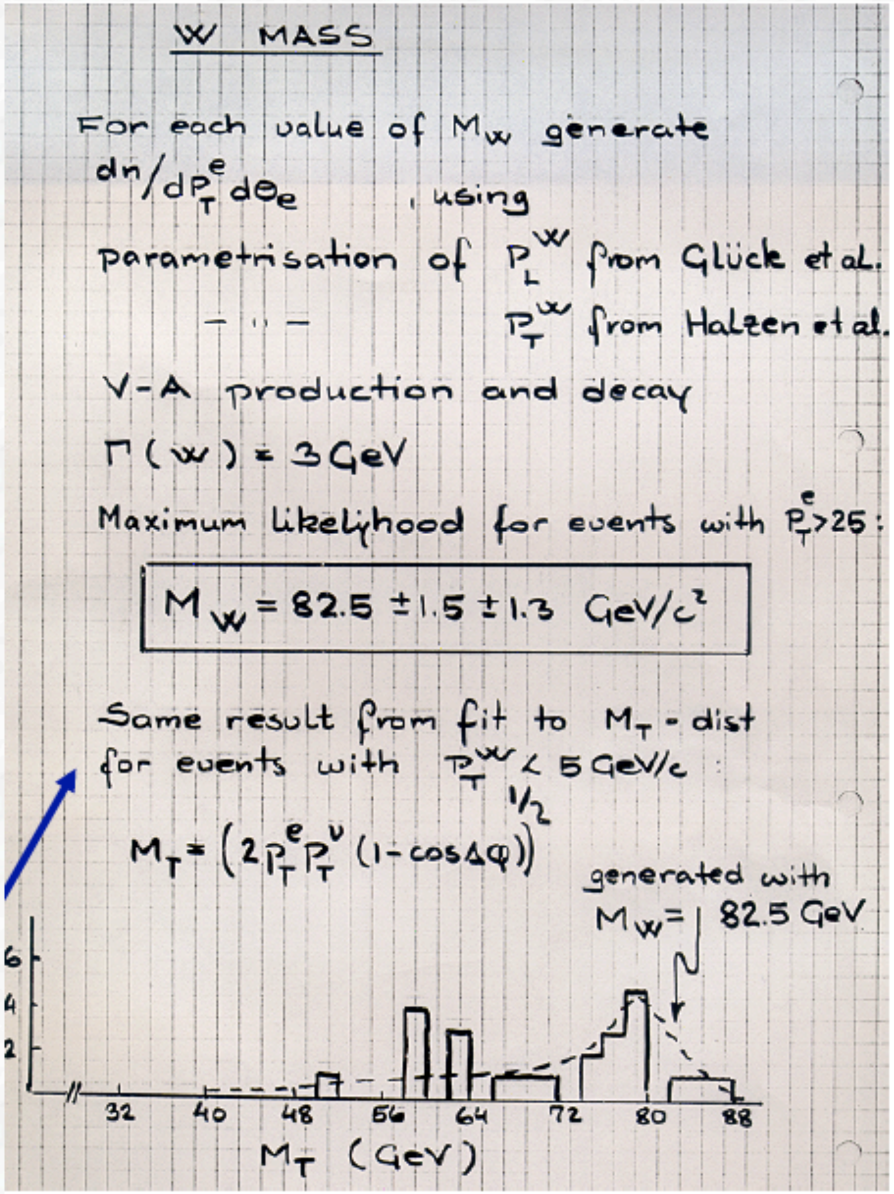


3.1 W mass measurements

The beginning

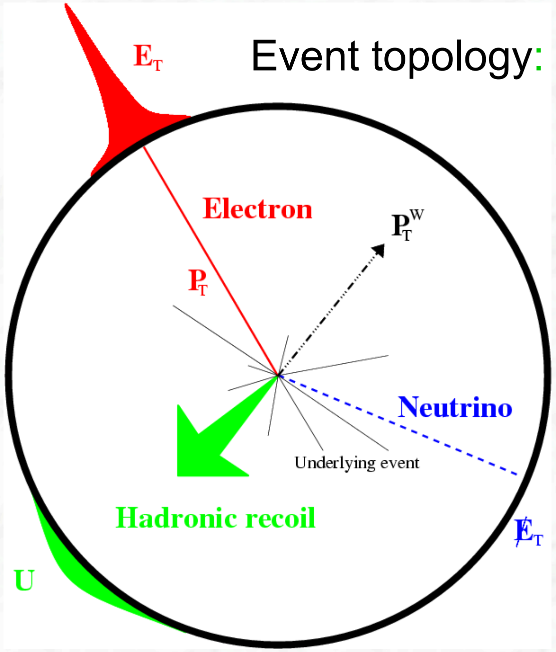


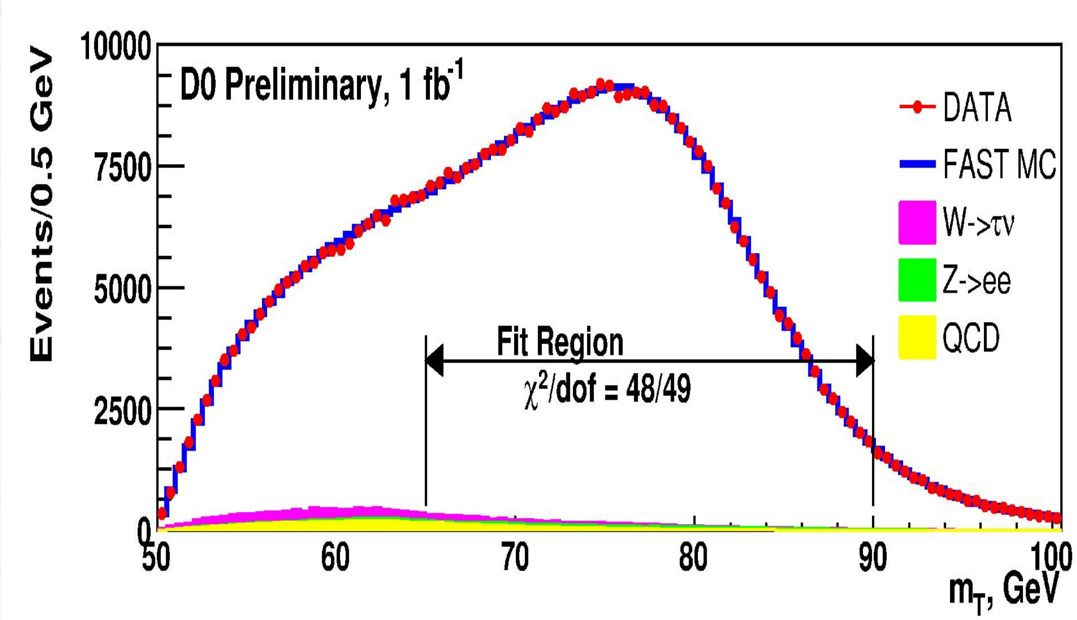
$$m_W = 80.35 \pm 0.33 \pm 0.17 \text{ GeV}$$



D. Froidevaux, Blois 2012

Technique used for W mass measurement at hadron colliders:





Observables: $P_T(e)$, $P_T(had)$

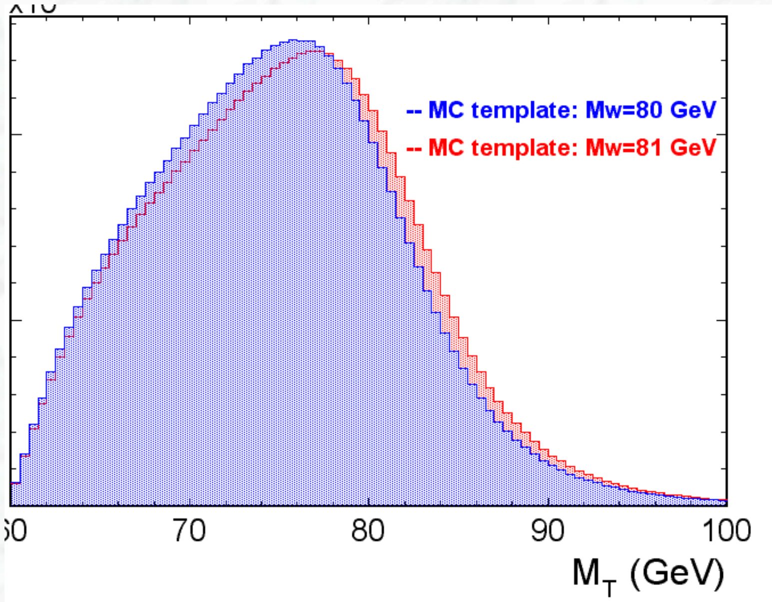
$\Rightarrow$ $P_T(\nu)$ = - ($P_T(e)$ + $P_T(had)$) long. component cannot be measured

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

In general the transverse mass M_T is used for the determination of the W mass (smallest systematic uncertainty).

This might not be true at the LHC !

Shape of the transverse mass distribution is sensitive to m_W, the measured distribution is fitted with Monte Carlo predictions, where m_W is a parameter



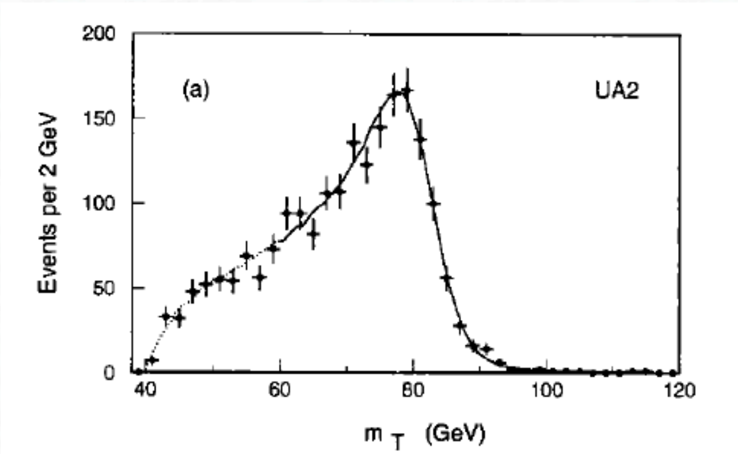
Main uncertainties:

Ability of the Monte Carlo to reproduce real life:

- Detector performance
  (energy resolution, energy scale, ...)
- Physics: production model
  $p_T(W)$, Γ_W, ...
- Backgrounds

W mass measurements

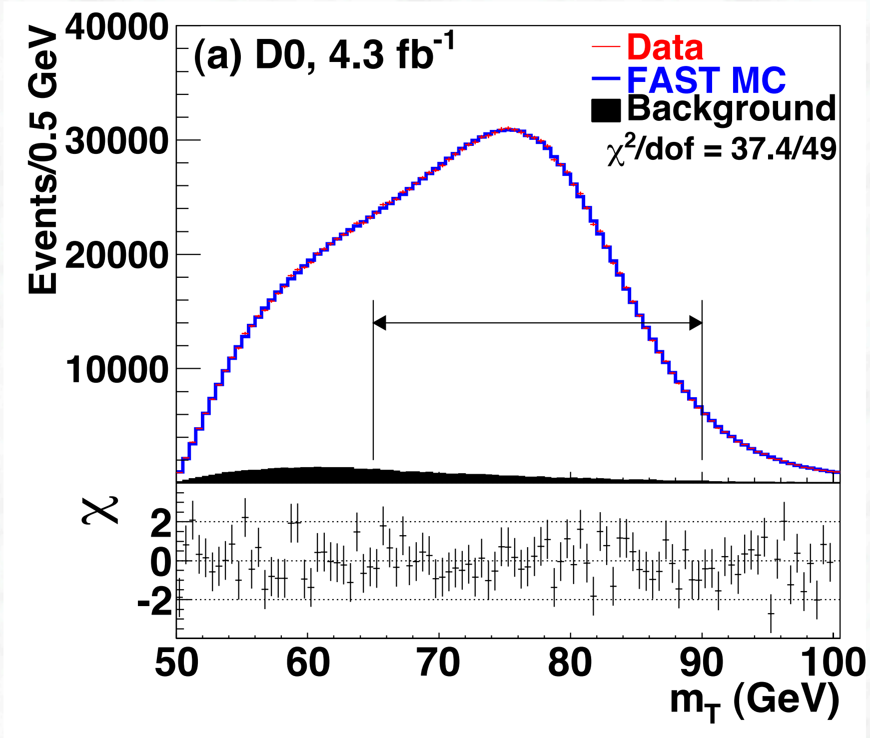
The beginning



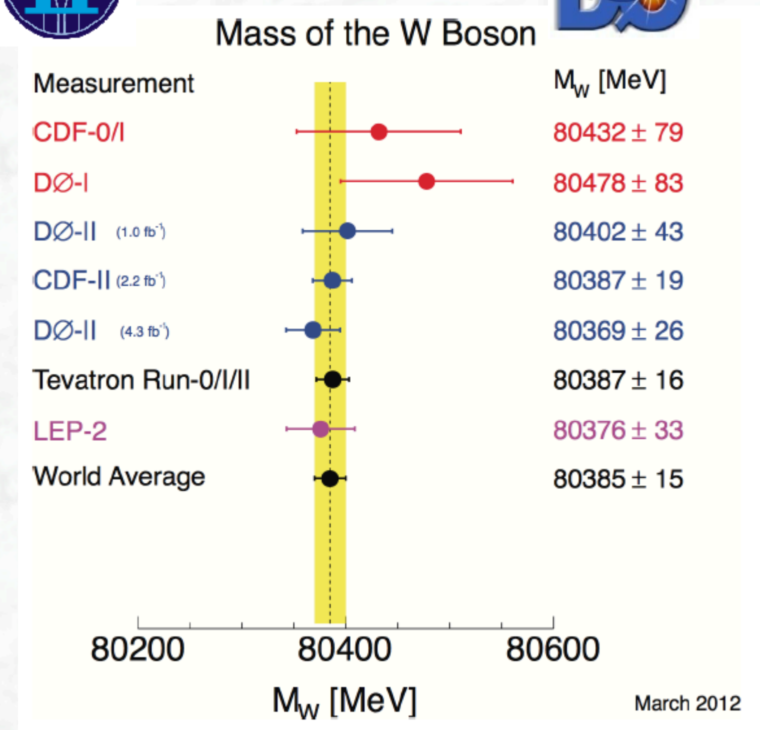
$$m_W = 80.35 \pm 0.33 \pm 0.17 \text{ GeV}$$

State of the art, today

1.68 M events, electrons $|\eta| < 1.05$



m_W = 80.371 ± 0.013 (stat.) GeV



Systematic uncertainties:

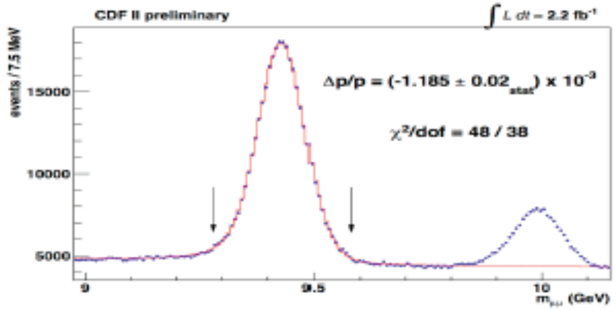
New CDF Result (2.2 fb^{-1})
Transverse Mass Fit Uncertainties (MeV)

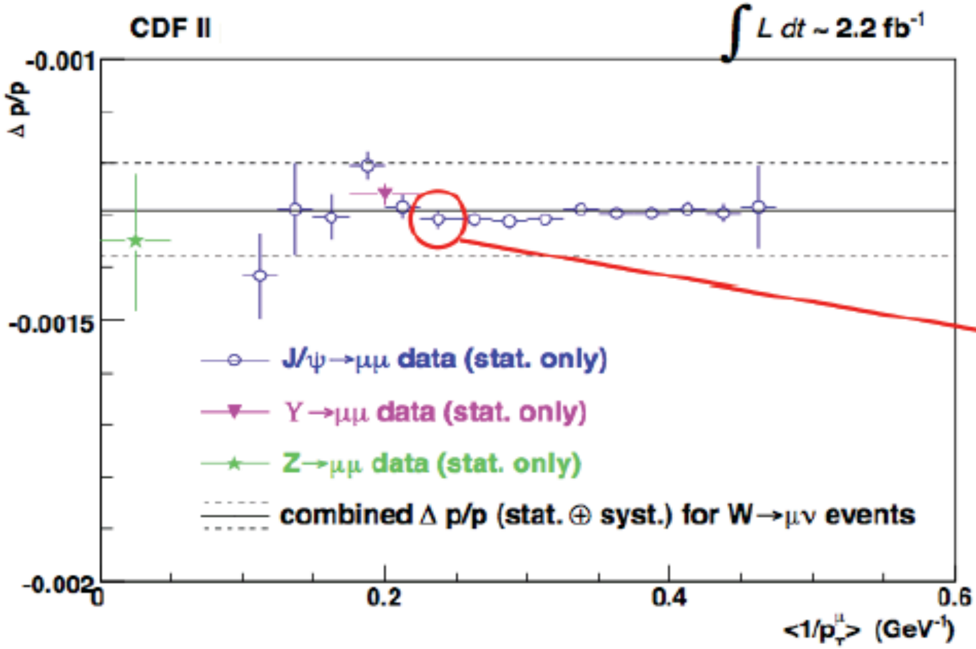
	electrons	*muons*	*common*
W statistics	19	16	0
Lepton energy scale	10	7	5
Lepton resolution	4	1	0
Recoil energy scale	5	5	5
Recoil energy resolution	7	7	7
Selection bias	0	0	0
Lepton removal	3	2	2
Backgrounds	4	3	0
pT(W) model	3	3	3
Parton dist. Functions	10	10	10
QED rad. Corrections	4	4	4
Total systematic	18	16	15
Total	26	23	

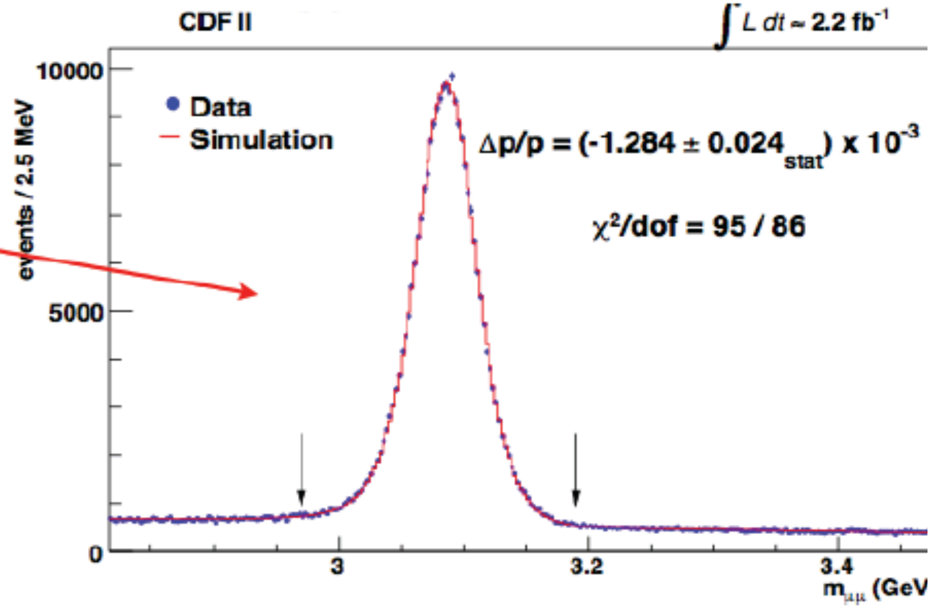
- Precision in a single Tevatron experiment better than the LEP-2 combination
- Still further improvements possible
  (inclusion of more data, reduction of statistical and systematic uncertainties)
- Further improvements on parton distribution functions expected (LHC)
- Support from theory side on better calculation / simulation of QED radiation and $p_T(W)$ expected

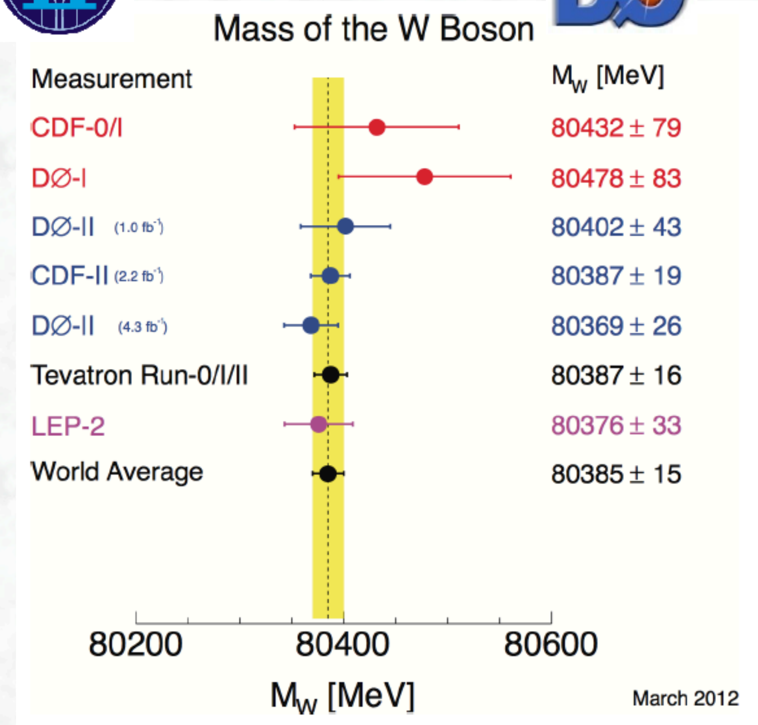
Momentum Scale Calibration

- “Back bone” of CDF analysis is track p_T measurement in drift chamber (COT)
- Perform alignment using cosmic ray data: ~50μm→~5μm residual
- Calibrate momentum scale using samples of dimuon resonances (J/ψ, Υ, Z)
  - Span a large range of p_T
  - Flatness is a test of dE/dx modeling
- Final scale error of 9×10^{-5}: $\Delta m_W = 7$ MeV









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pT(W) model	3	3	3
Parton dist. Functions	10	10	10
QED rad. Corrections	4	4	4
Total systematic	18	16	15
Total	26	23	

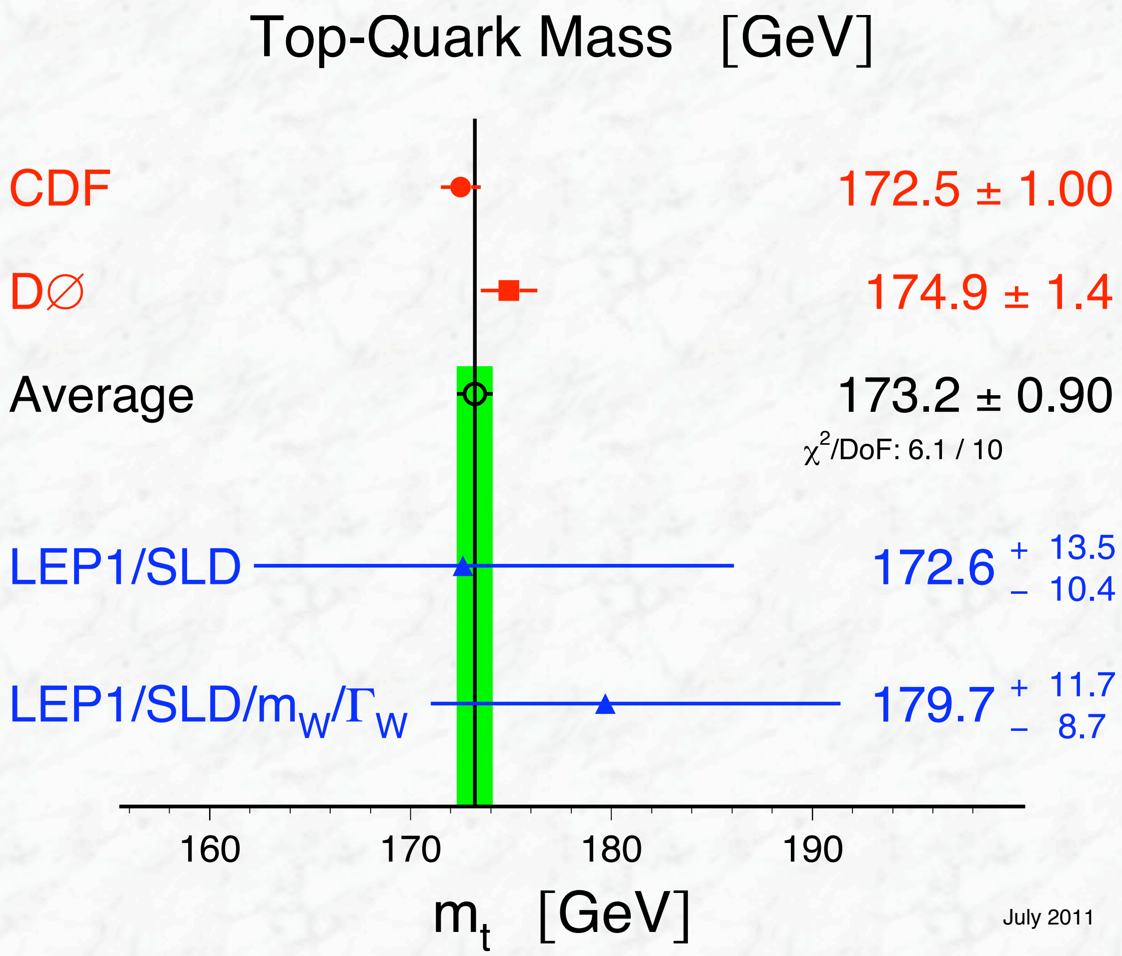
Can the LHC improve on this?

In principle yes, but probably not soon .and. not with 30 pileup events

- Very challenging (e-scale, hadronic recoil, p_T (W),..)

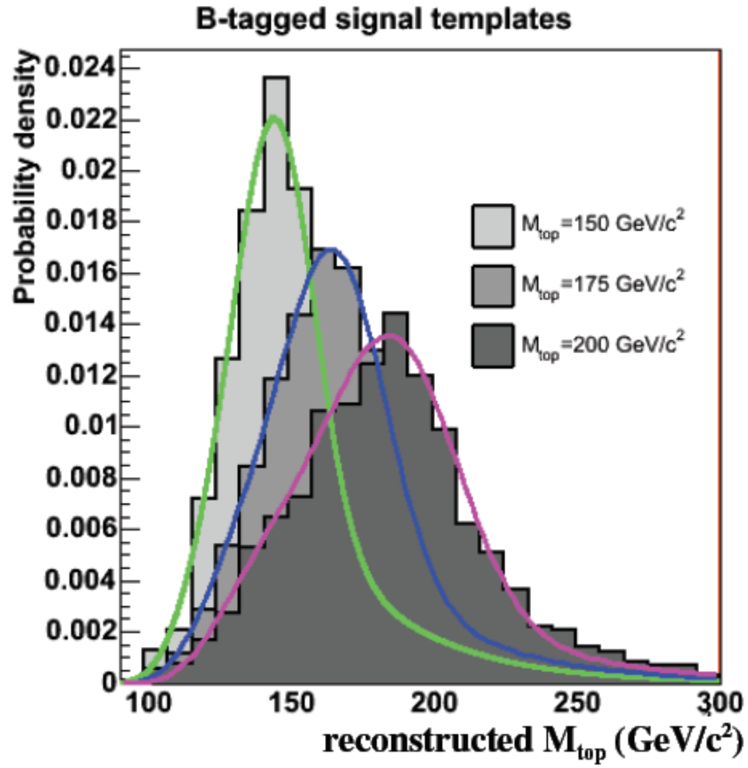
- However, there is potential for reduction of uncertainties
  - statistics
  - statistically limited systematic uncertainties (marked in green above)
  - pdfs, energy scale, …., recoil(?)

3.2 Top-quark mass measurement



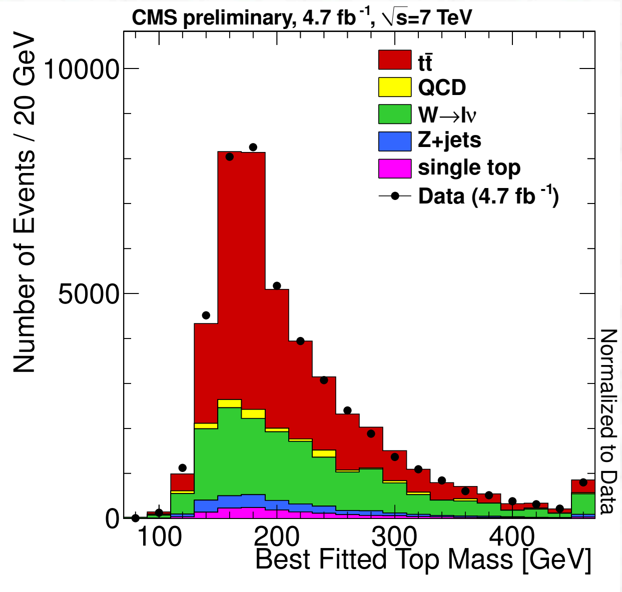
Example: template method

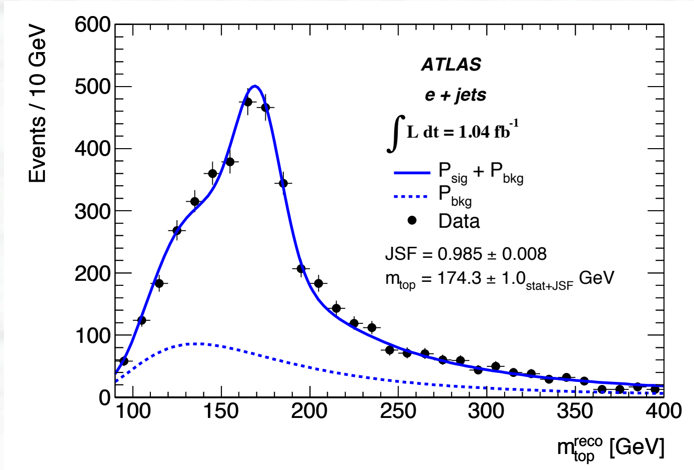
- Calculate a per-event observable that is sensitive to m_t
- Make templates from signal and background events
- Use pseudo-experiments (Monte Carlo) to check that method works
- Fit data to templates using maximum likelihood method

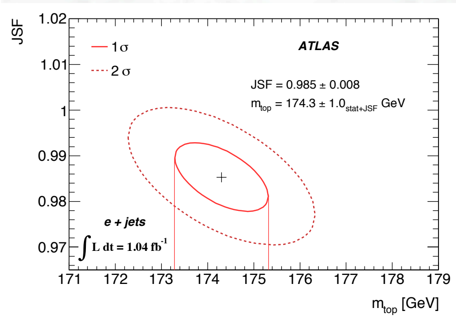


First top quark mass measurements at the LHC

- Measurements in all channels available (ll, l+jets, all jets; at least 1 b-tagged jet)
- 2011 data already included
- Combined fit of top mass and jet energy scale (in situ) à la Tevatron







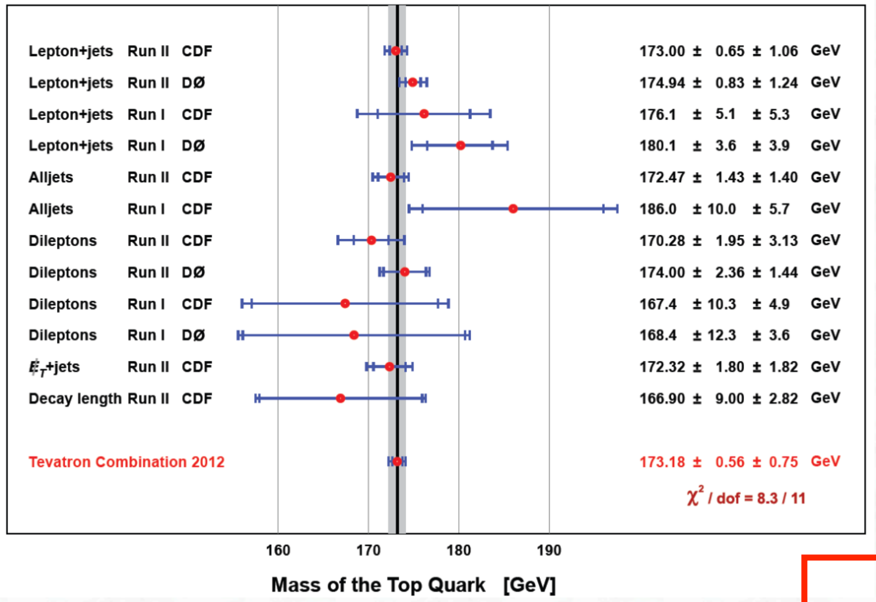
Results of best measurements in the l + jets channels:

CMS:	m_t = 172.6 ± 0.5 (stat) ± 1.5 (syst) GeV
ATLAS:	m_t = 174.5 ± 0.6 (stat) ± 2.3 (syst) GeV

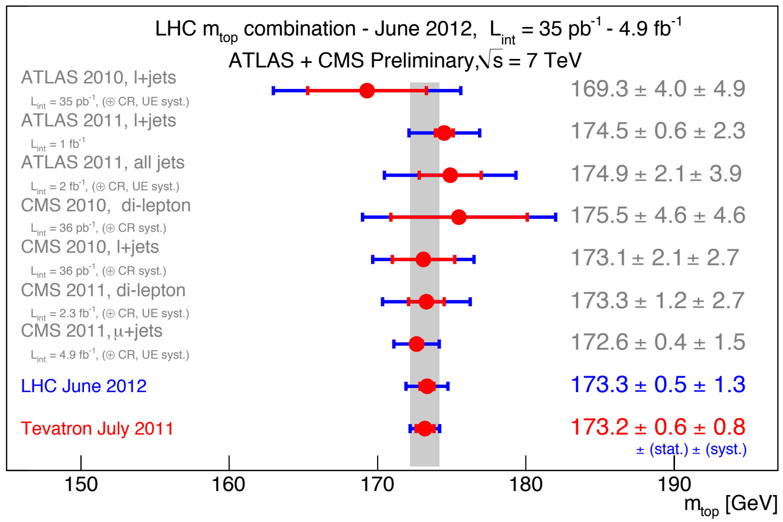
Already impressive precision reached at that early stage of the experiment !

Summary of top quark mass measurments

– Tevatron combination



– LHC combination and perspectives



Tevatron:

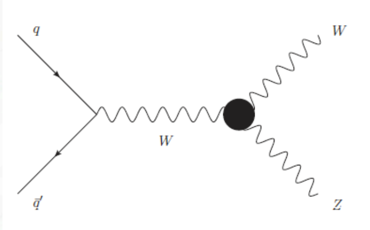
$$m_t^{comb} = 173.18 \pm 0.56\,(\text{stat}) \pm 0.75\,(\text{syst})\ \text{GeV}$$
$$= 173.18 \pm 0.94\ \text{GeV}$$

LHC:

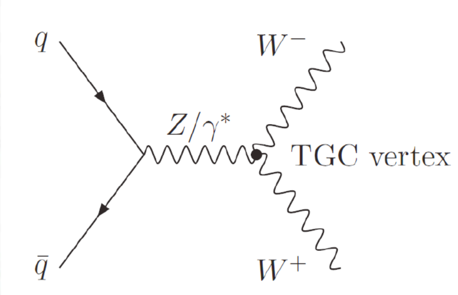
$$m_{top} = 173.3 \pm 0.5\,(\text{stat}) \pm 1.3\,(\text{syst})\ \text{GeV}$$
$$= 173.3 \pm 1.4\ \text{GeV}$$

3.3 Di-boson production: $W\gamma$, WW, WZ, ZZ

- Motivation: - Test of the Standard Model gauge structure
  - Search for deviations,
    anomalous triple gauge couplings (TGC)



- Allowed Standard Model vertices
  - $\gamma/Z \rightarrow WW$
  - $W \rightarrow W\gamma$
  - $W \rightarrow WZ$

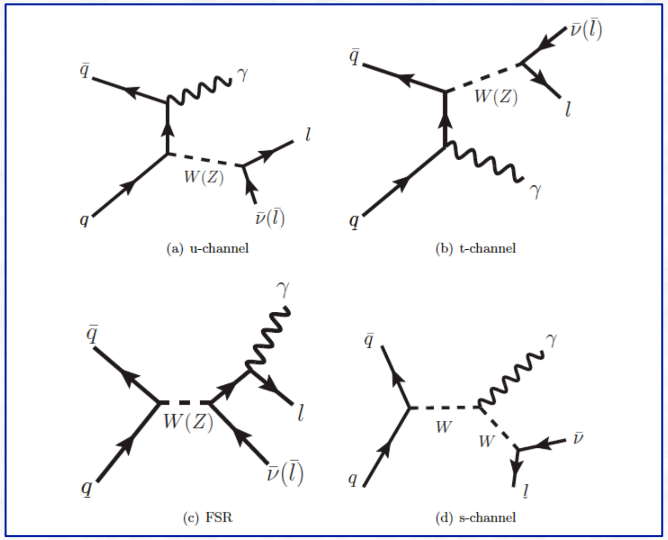


- Forbidden Standard Model vertices: $\gamma \rightarrow ZZ$ or $Z\gamma$
  $Z \rightarrow ZZ$ or $Z\gamma$

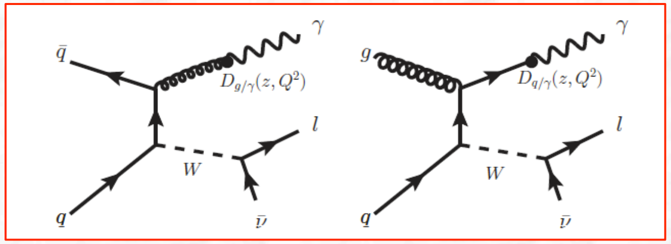
- Start from most general ansatz for TGCs in Lagrangian
  → 14 couplings
  CP invariance and gauge invariance
  → 5 parameters $\lambda_\gamma = \lambda_Z = 0$
  $g_1 = K_\gamma = K_Z = 1$

Wγ and Zγ production

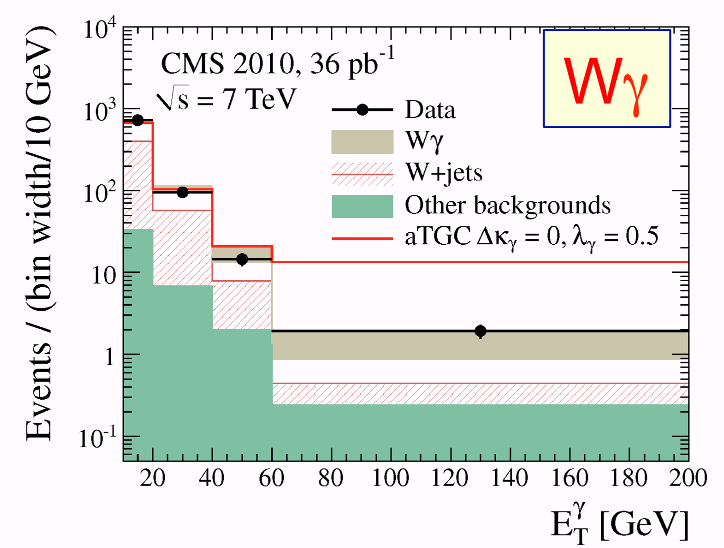
- Expected contributions within the Standard Model (including initial and final state radiation)

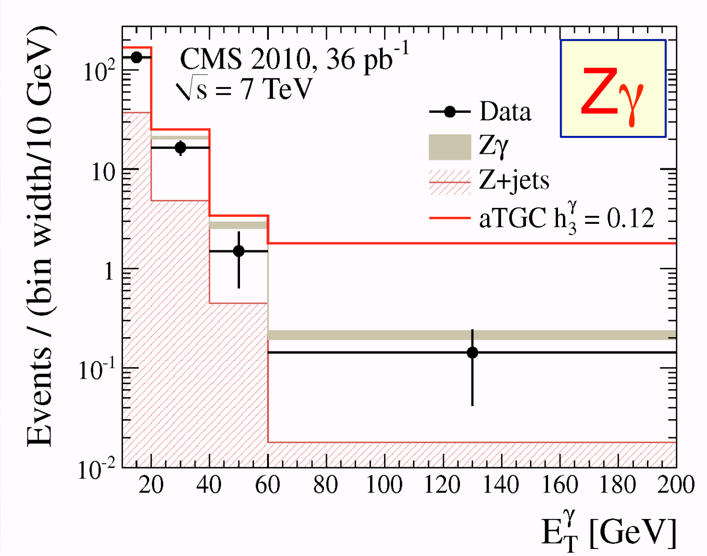


- Additional contribution from quark and gluon fragmentation (W/Z + jet production)



- Search for an additional isolated photon in W and Z events
- E_T spectra of photons are in agreement with the expectations from the Standard Model

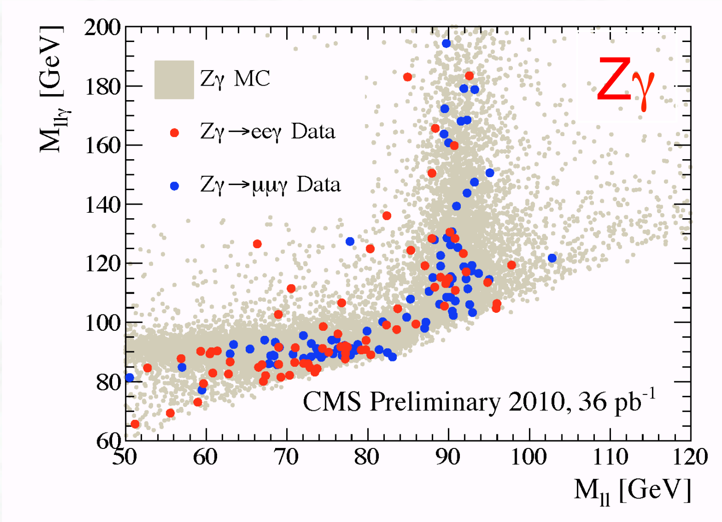


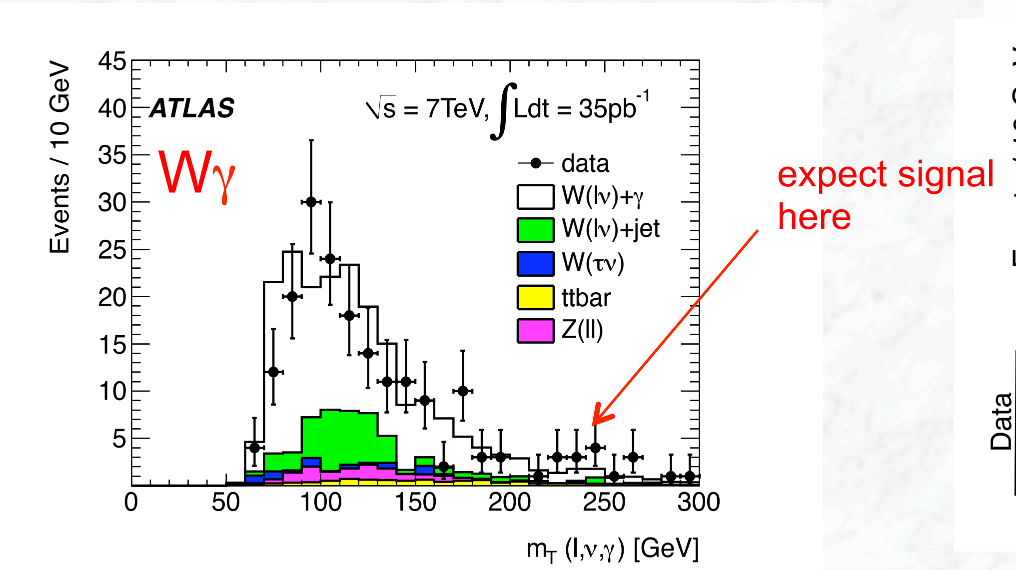


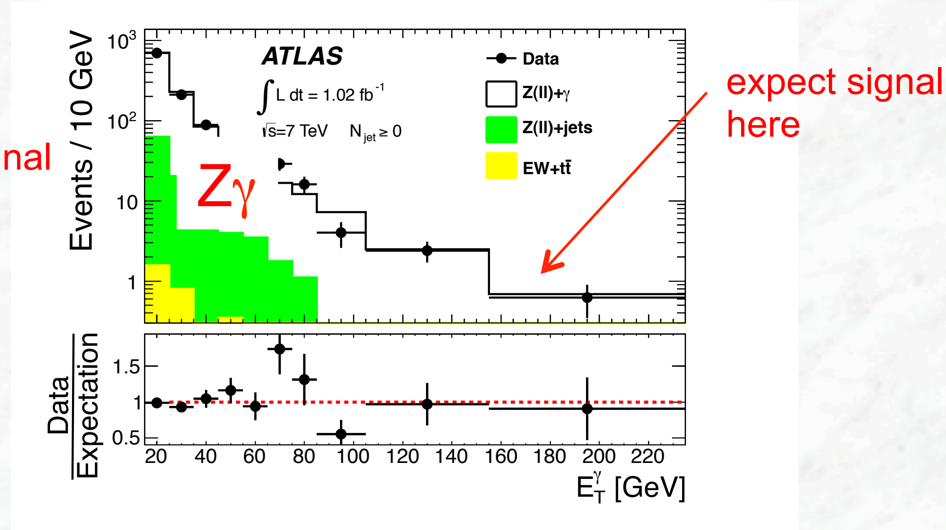
Wγ and Zγ production (cont.)

- Also kinematic distributions are well described by Standard Model processes

- No evidence for anomalous couplings / anomalous Wγ / Zγ production

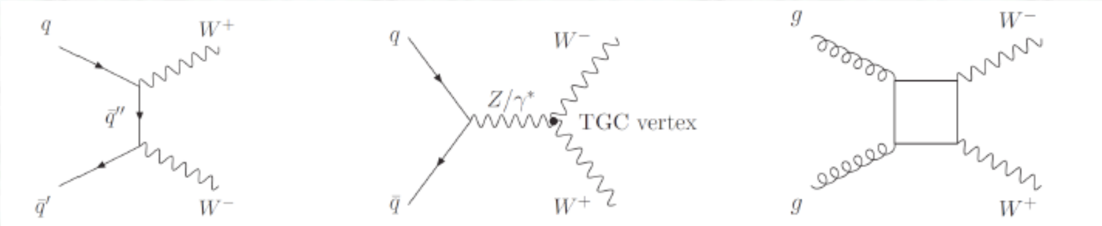






WW production

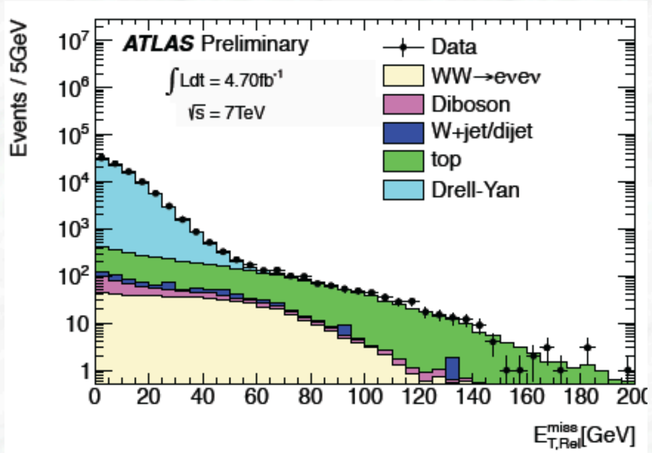
- Expected contributions within the Standard Model
  (TGC contribution, gg-box is higher order)

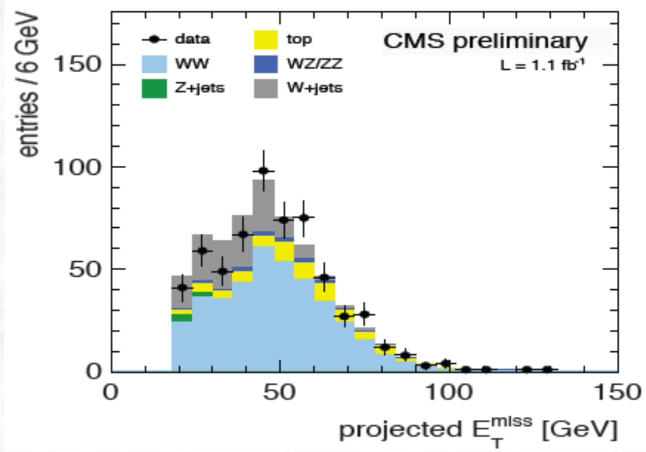


- Search for WW production in di-leptonic decays
  (WW→ lν lν)

- Major backgrounds:
  - Drell-Yan production pp → Z/γ* → ll
  - W → lν + jet production, one jet fakes a lepton,
    E_T^{miss} from mis-measurement
  - tt production, with di-leptonic decays: tt → lν b lν b

- This is an important background process for Higgs boson searches in the H → WW → lν lν channel



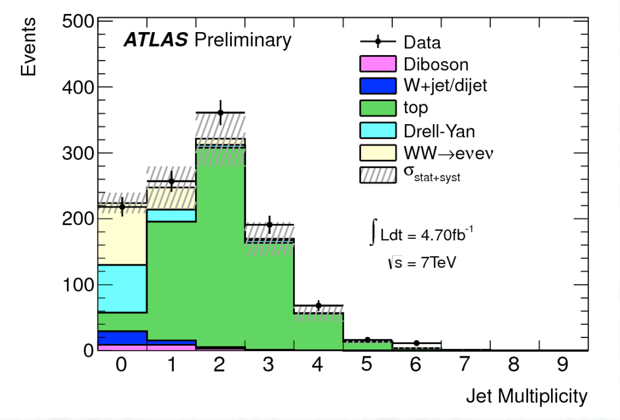


Good understandig of E_T^{miss} necessary, achieved in both experiments

require two
high p_T leptons (25 / 20 GeV)

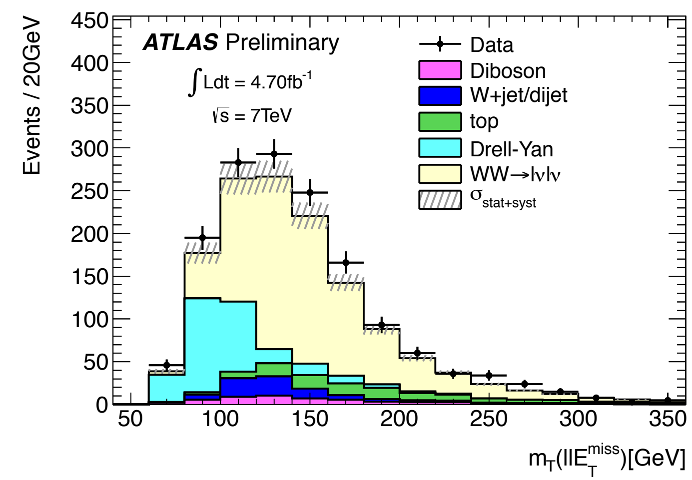
WW production (cont.)

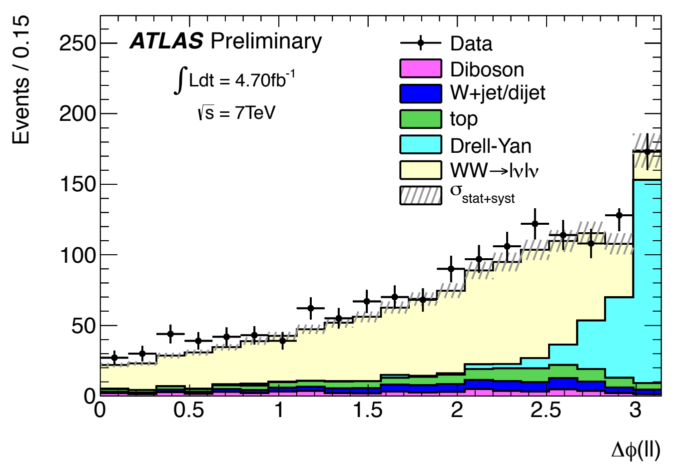
- Jet multiplicity distribution after lepton, E_t^{miss} and Z veto cuts:



→ apply a jet veto to suppress the large remaining contribution from top production
i.e. require no jet with p_T > 30 GeV within $|\eta|$ < 4.5

- Important kinematic distributions after jet veto cut: (important for H → WW search)

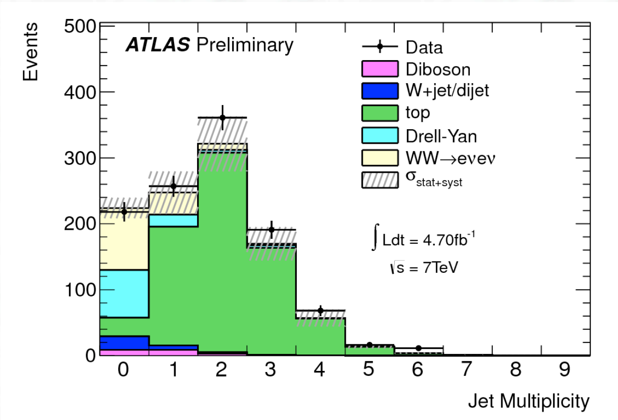




→ good signal-to-background ratio (2:1);
background largely estimated from data in control regions
(define control regions that are dominated by one background source, normalize there, use Monte Carlo for extrapolation in signal region)

WW production (cont.)

- Jet multiplicity distribution after lepton, E_t^{miss} and Z veto cuts:



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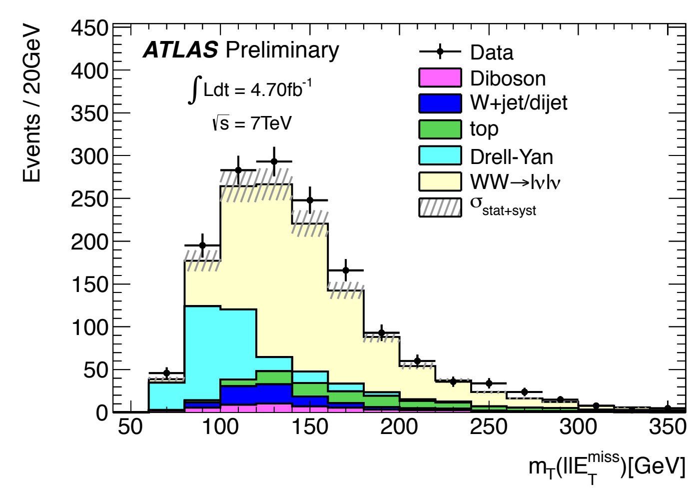
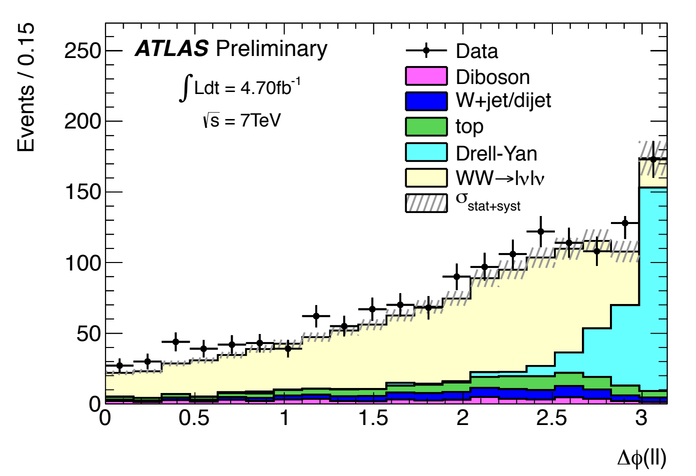
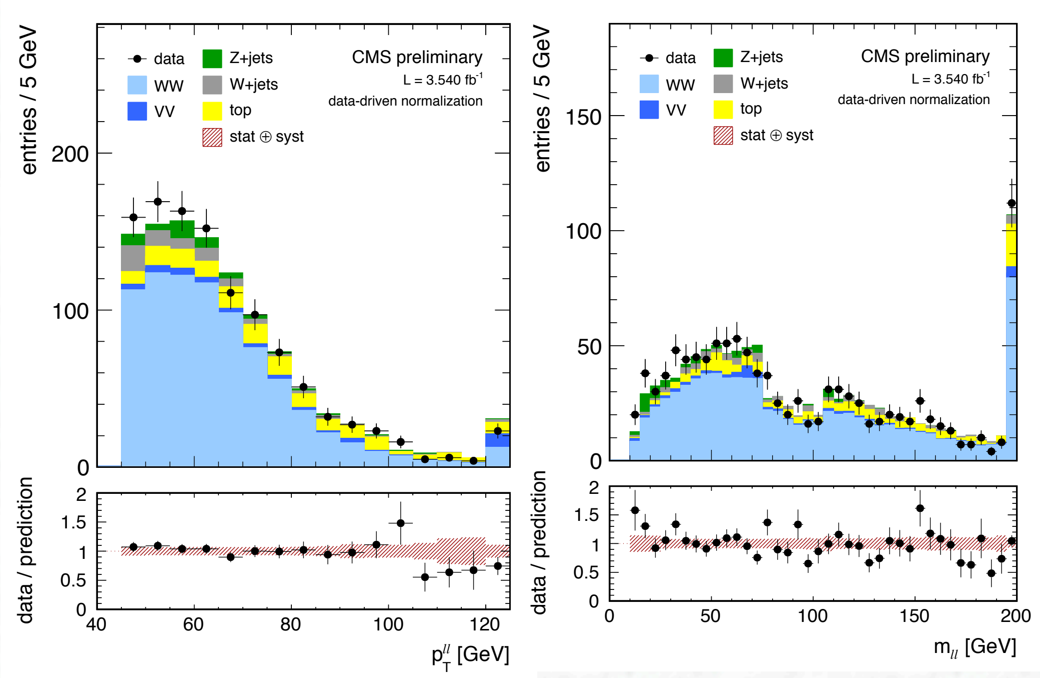




→ good signal-to-background ratio (2:1);
background largely estimated from data in control regions
(define control regions that are dominated by one background source, normalize there, use Monte Carlo for extrapolation in signal region)

WW production at √s = 8 TeV

- CMS has already analyzed 3.5 fb^{-1} of 2012 data
- Kinematical distributions for combined ee, eμ, μμ channels:



Measured cross sections are slightly higher than NLO prediction:

√s = 7 TeV

ATLAS:

$\sigma = 53.4 \pm 2.1 \pm 4.5 \pm 2.1$ pb

CMS:

$\sigma = 52.4 \pm 2.0 \pm 4.5 \pm 1.2$ pb

Theory:

$\sigma = 45.1 \pm 2.8$ pb

√s = 8 TeV

CMS:

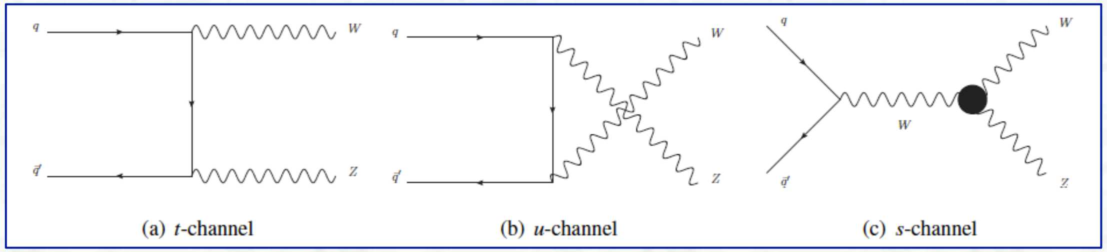
$\sigma = 69.9 \pm 2.8 \pm 5.6 \pm 3.1$ pb

Theory:

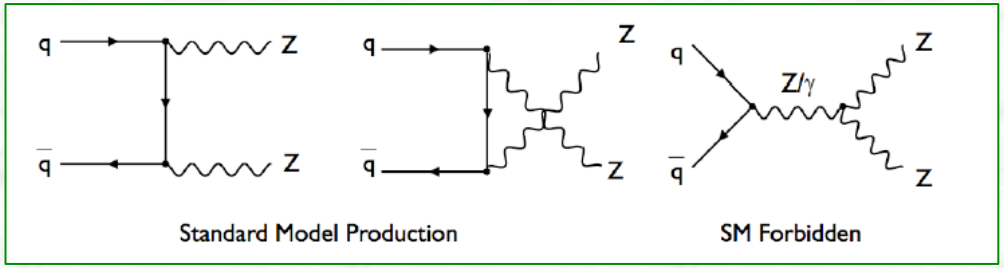
$\sigma = 57.3^{+2.4}_{-1.6}$ pb

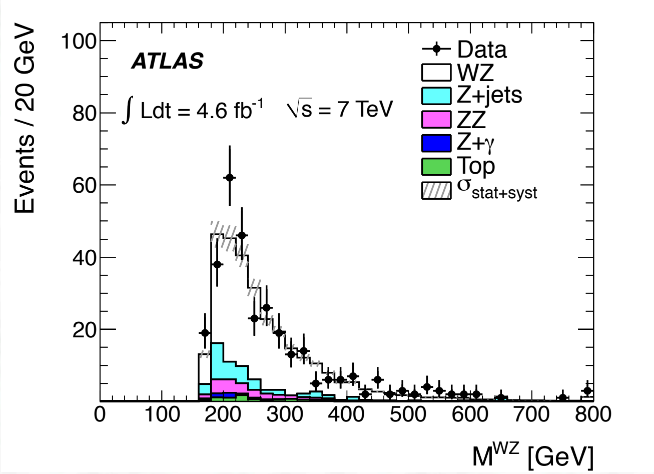
WZ and ZZ production

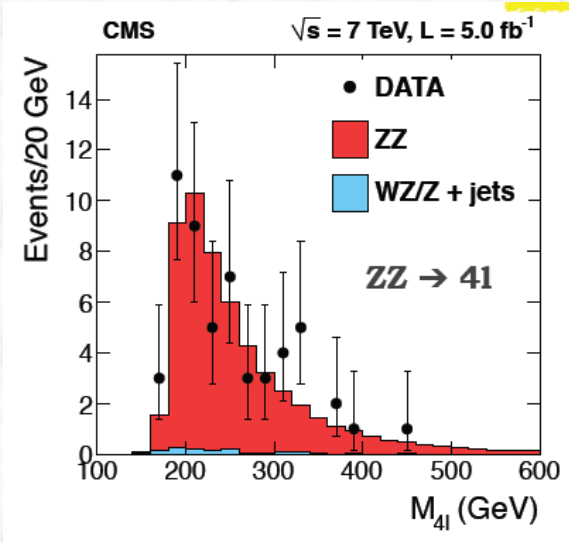
- Expected contributions within the Standard Model
  (t-, u, s-channel contributions for WZ)



(t- and u- channel contributions for ZZ)



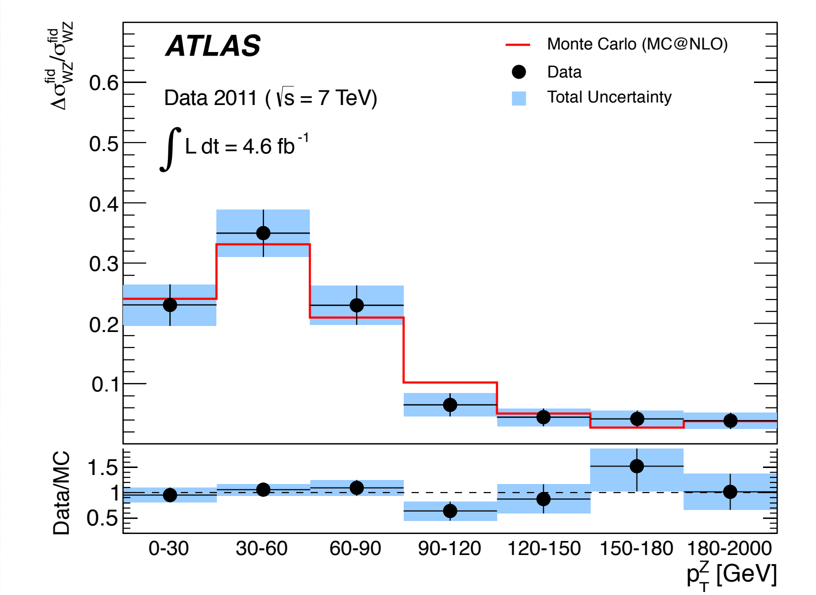


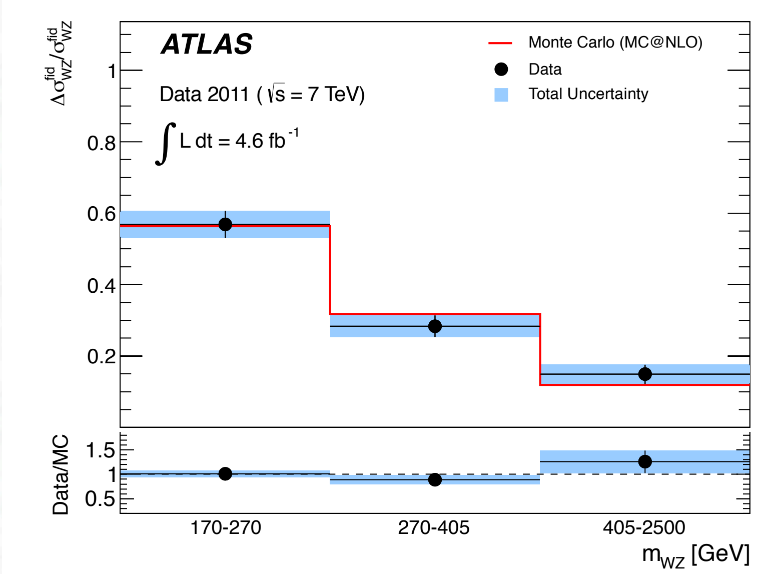


- Search for di-boson production in three (WZ→ lν ll) and four (ZZ→ ll ll) lepton final states

- These are important background processes for Higgs boson searches, e.g. H → 4 l

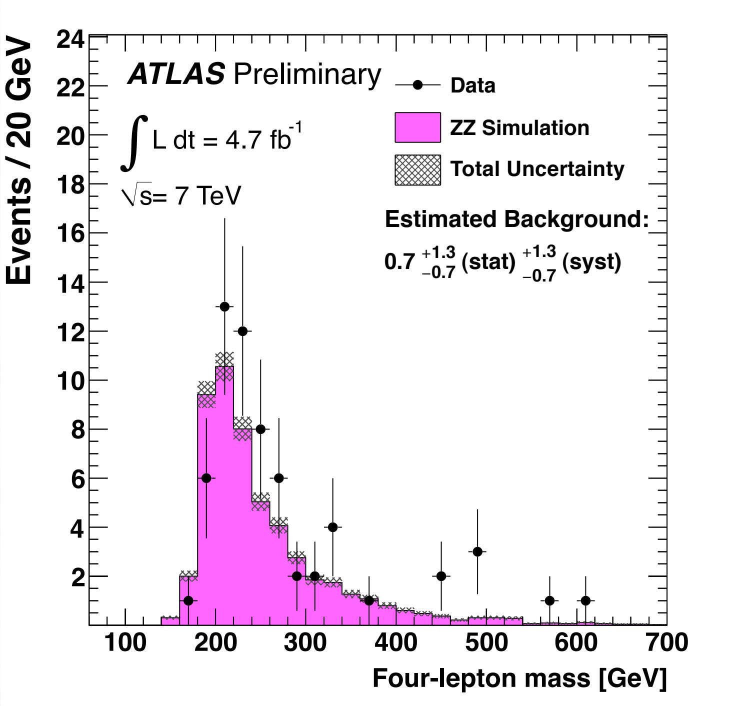
WZ differential production cross sections

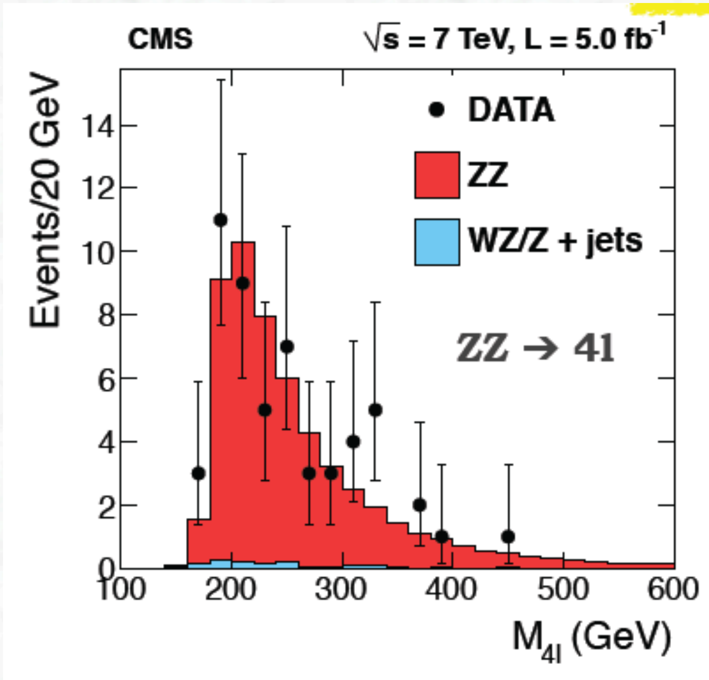




WZ	$N_{observed}$	N_{bkg}	$\sigma_{measured}$ (pb)	σ_{NLO} (pb)
ATLAS	317	68 ± 8	$19.0^{+1.4}_{-1.3} \pm 0.8 \pm 0.4$	$17.6^{+1.1}_{-1.0}$
CMS	75 (1.1 fb^{-1})	~9.1	17.0 ± 2.4 ± 1.1 ± 1.0	17.5 ± 0.6

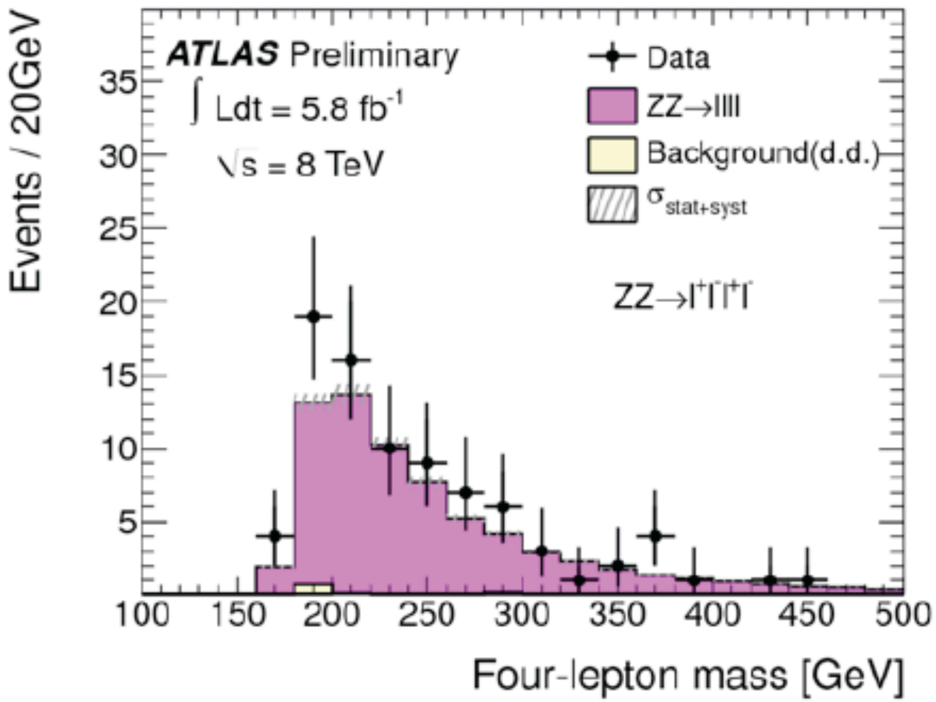
ZZ cross sections

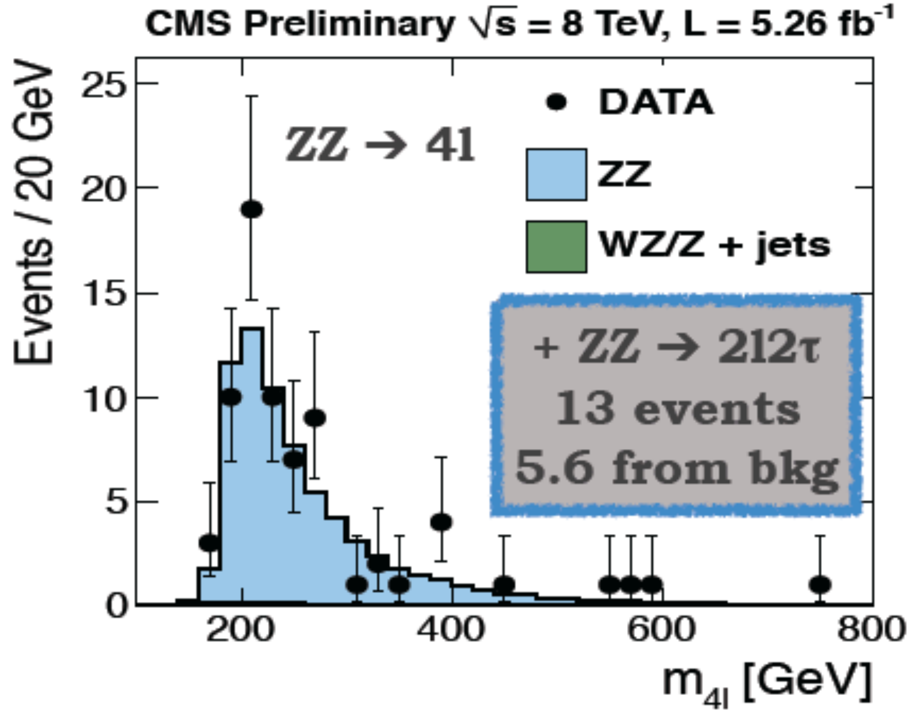




ZZ	$N_{obs(4l)}$	$N_{signal(4l)}$	$N_{bkg(4l)}$	$\sigma_{measured}$ (pb)	σ_{NLO} (pb)
ATLAS	62	53.2 ± 2.2	0.7± 2.1	$7.2\ ^{+1.1}_{-0.9}\ ^{+0.4}_{-0.3} \pm 0.3$	$6.5\ ^{+0.3}_{-0.2}$
CMS	54	54.4 ± 4.8	1.4 ± 0.5	(*) $6.24\ ^{+0.86}_{-0.80}\ ^{+0.41}_{-0.32} \pm 0.14$	6.3 ± 0.4

ZZ cross sections at √s = 8 TeV





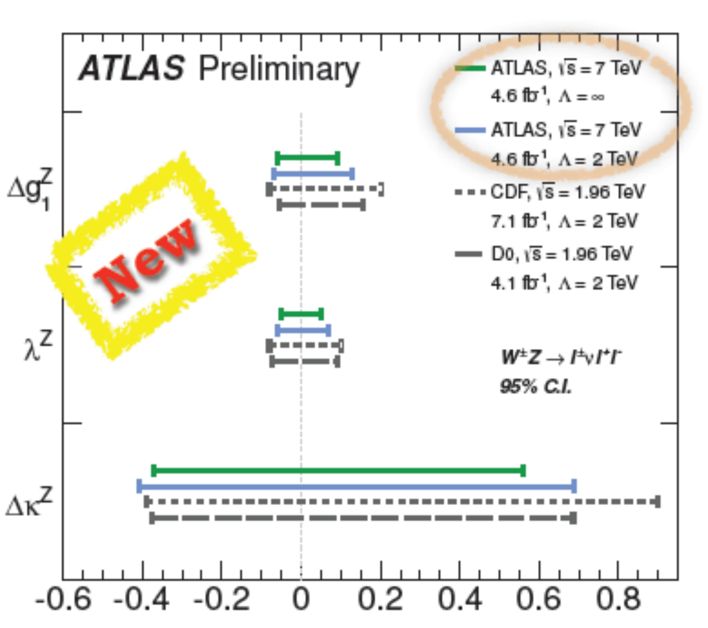
(*) includes $ZZ \rightarrow 2l2\tau$

ZZ	$N_{obs(4l)}$	$N_{signal(4l)}$	$N_{bkg(4l)}$	$\sigma_{measured}$ (pb)	σ_{NLO} (pb)
ATLAS	85	70.5 ± 1.7	1.5 ± 1.3	$9.3^{+1.1}_{-1.0}{}^{+0.4}_{-0.3} \pm 0.3$	7.4 ± 0.4
CMS	71	64.3 ± 4.4	1.3 ± 0.5	(*) 8.4 ± 1.0 ± 0.7 ± 0.4	7.7 ± 0.4

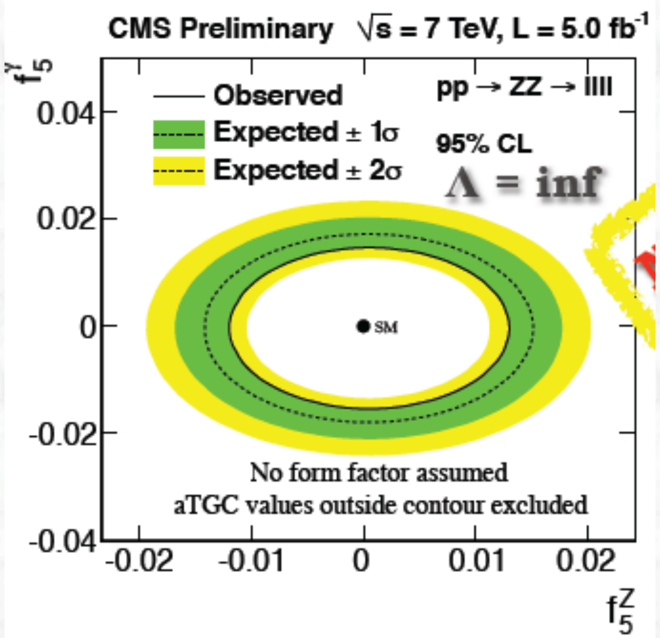
Limits on anomalous gauge couplings

- Observed rates and differential distributions do not allow for significant contributions from anomalous gauge couplings
  → 95% C.L. limits on anomalous couplings are extracted;
  to avoid unitarity violation at high energies, a form factor is introduced.

$$\alpha(\hat{s}) = \frac{\alpha_0}{(1+\hat{s}/\Lambda^2)^2}$$



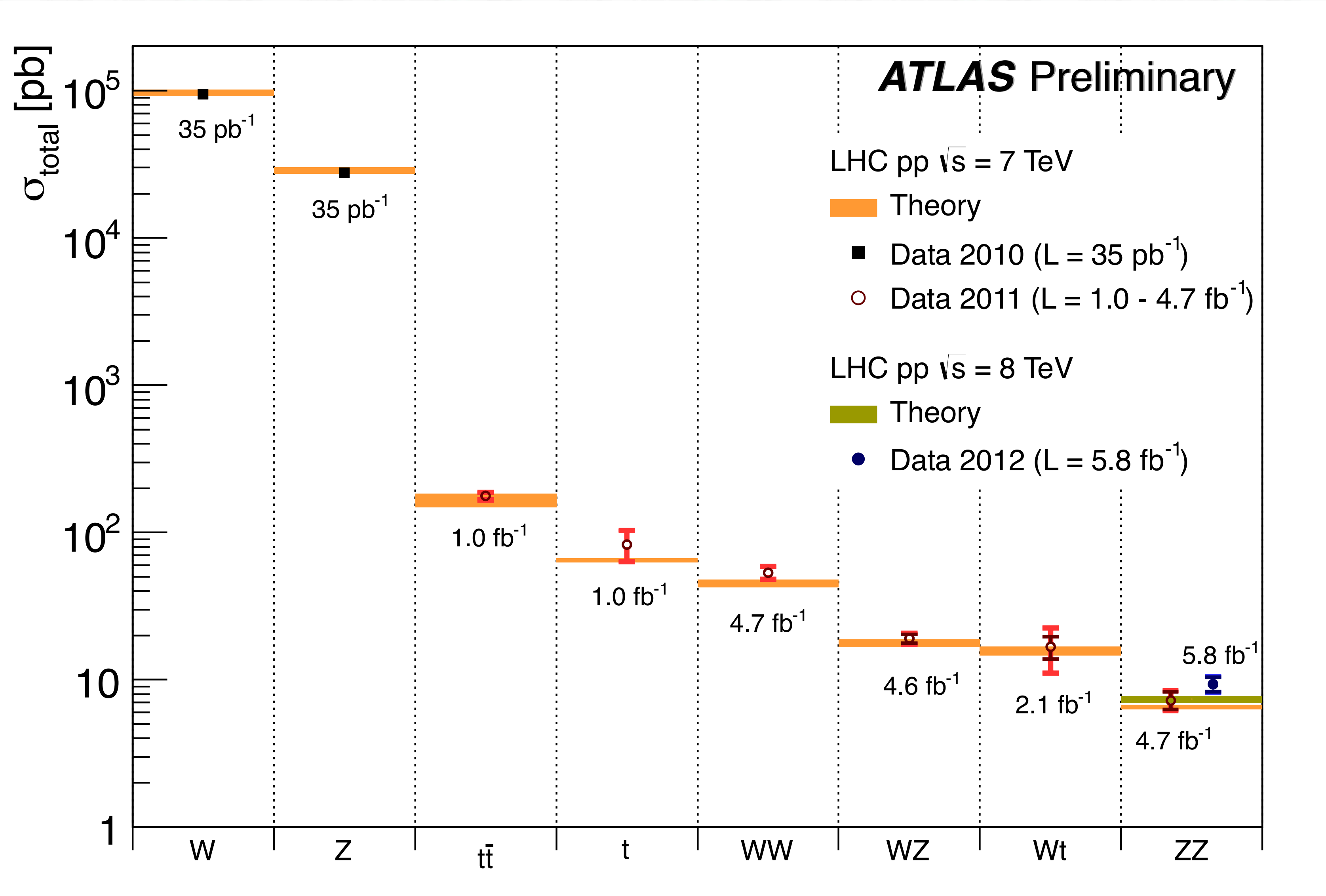
WZZ couplings



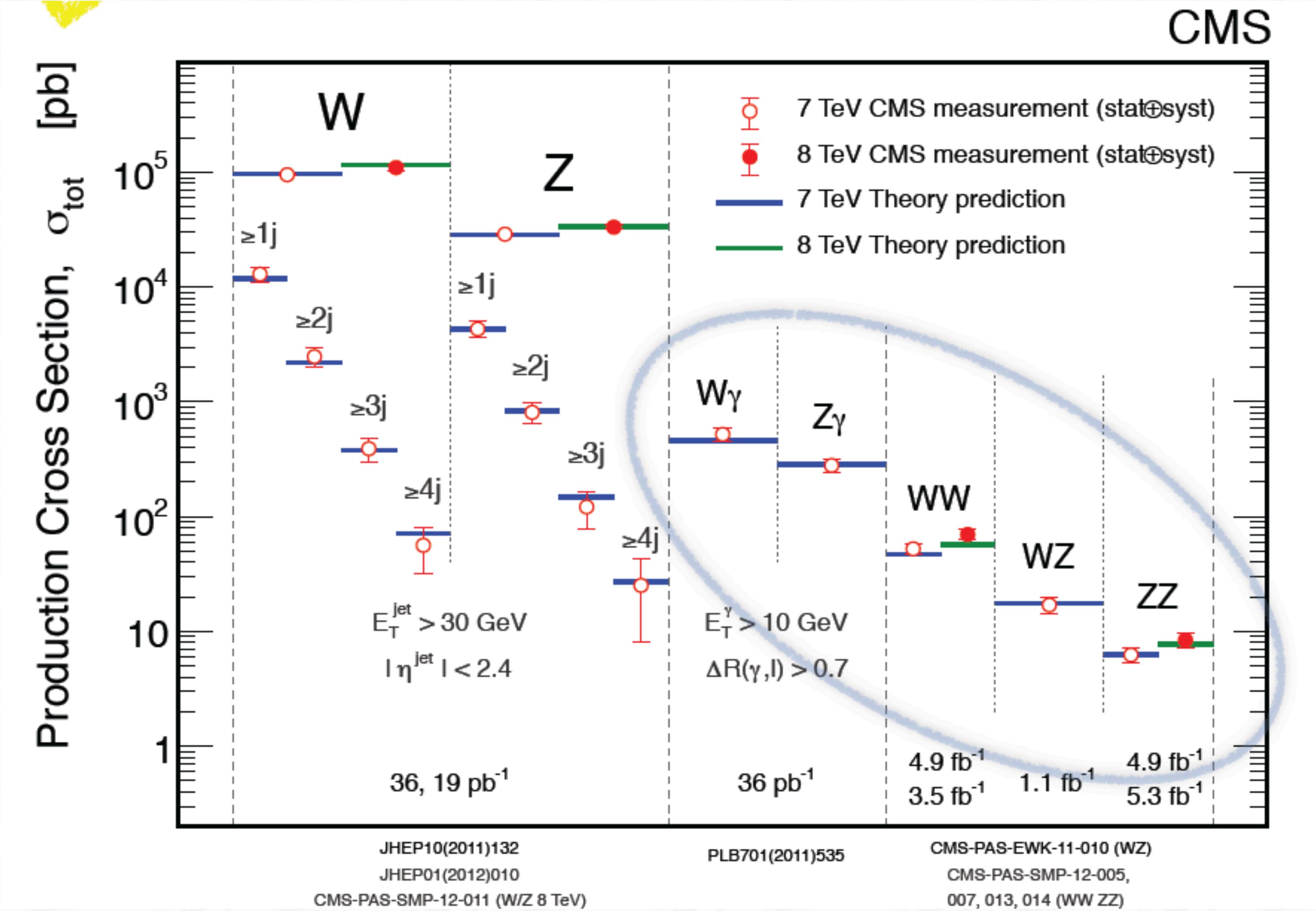
ZZγ and ZZZ couplings

- LHC limits are surpassing limits from the Tevatron (significant gain expected with more data)

Final cross section summary

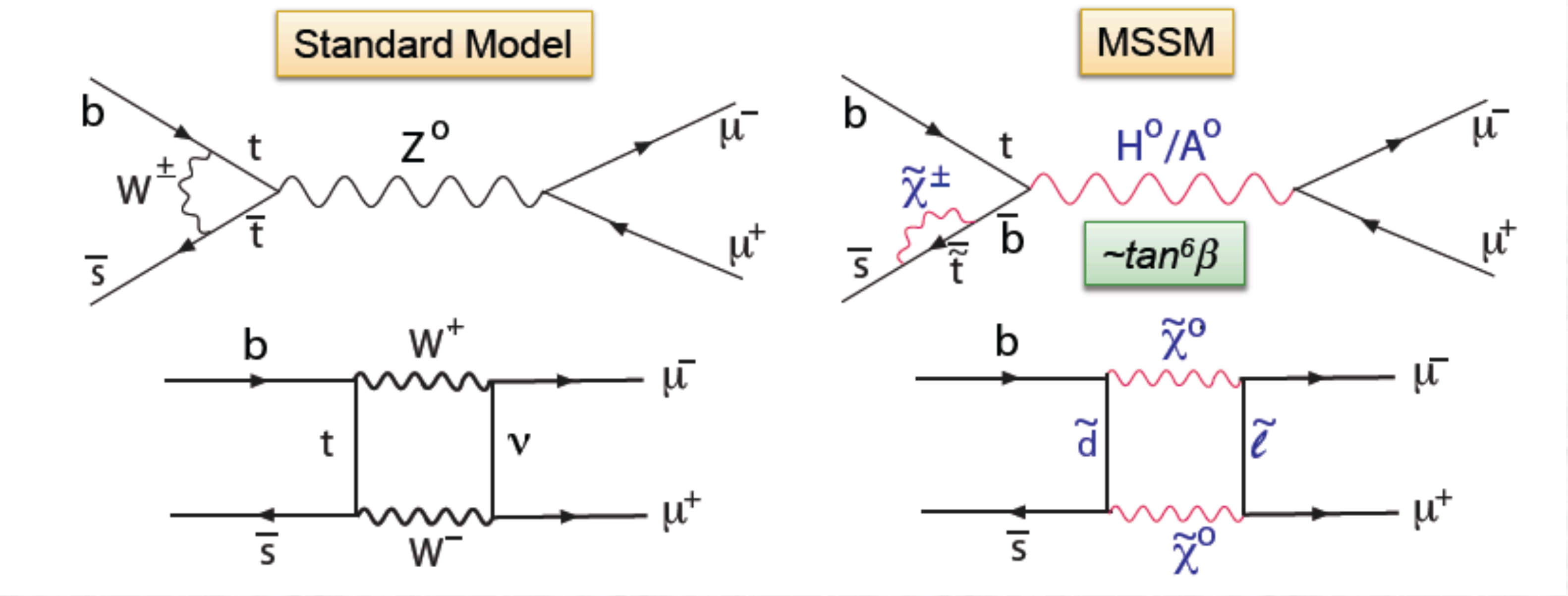


Final cross section summary



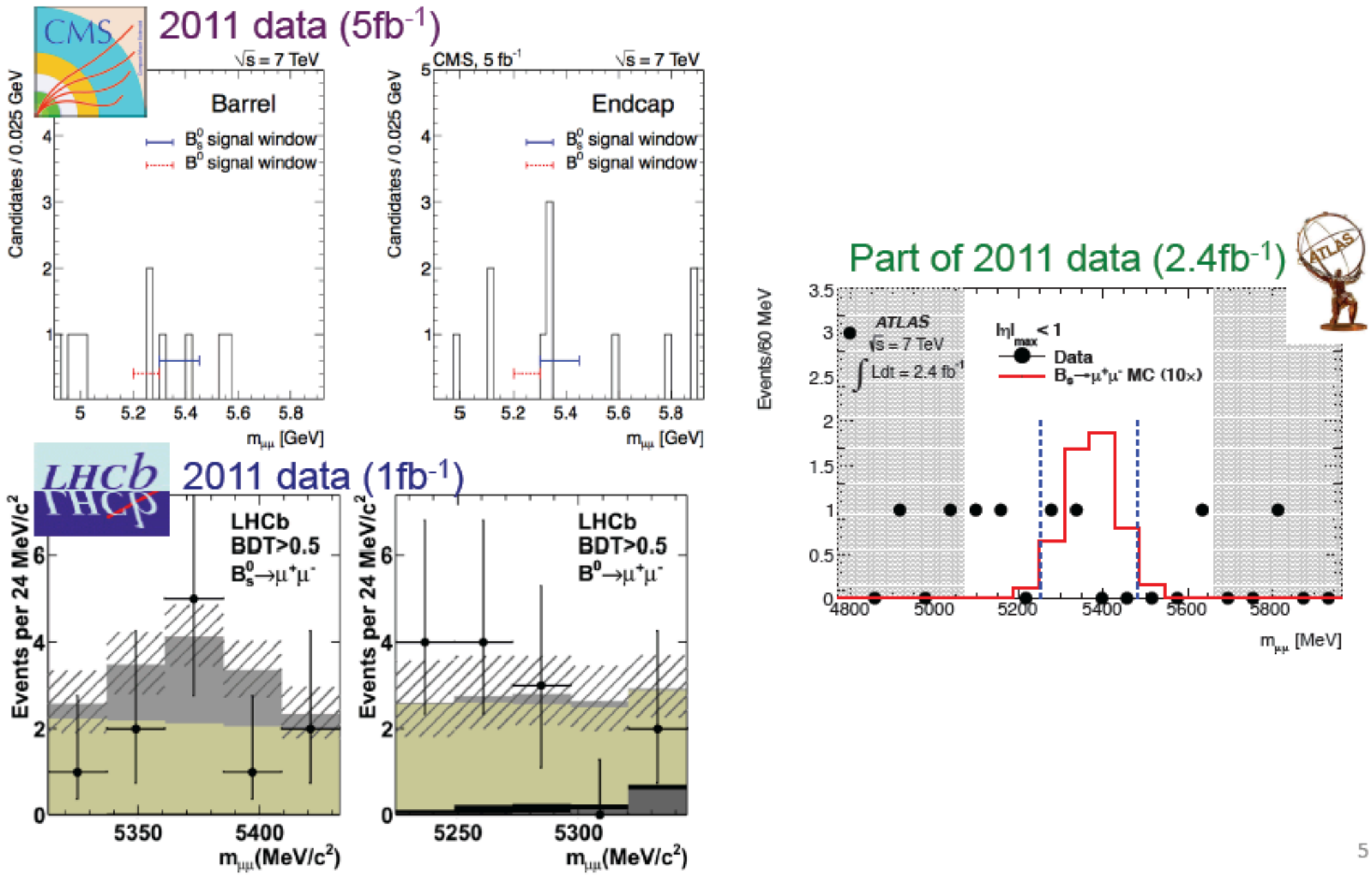
3.4 Search for the decays $B_0 \rightarrow \mu^+\mu^-$ and $B_o^s \rightarrow \mu^+\mu^-$

- Rare decay in the Standard Model: Braching ratio for $B_0^s \rightarrow \mu\,\mu$ is $(3.2 \pm 0.2)\ 10^{-9}$
- Contributions from New Physics can be large (also from non-SUSY models)



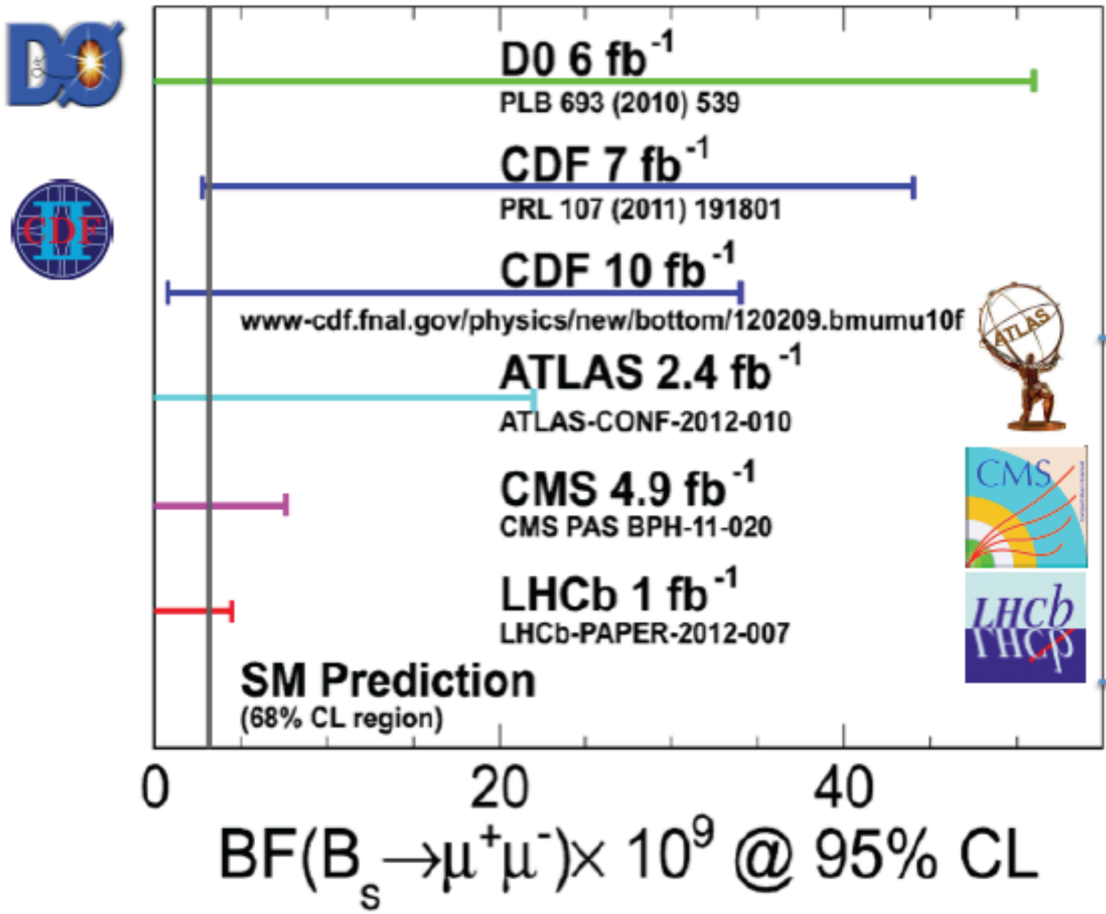
- Huge b-production rates at the LHC → all LHC experiments are searching for this decay mode

The data:



CMS
2011 data (5fb-1)
√s = 7 TeV
Barrel
Endcap
CMS, 5 fb-1
Candidates / 0.025 GeV
B0s signal window
B0 signal window
mμμ [GeV]
LHCb
2011 data (1fb-1)
LHCb
BDT>0.5
B0s→μ+μ-
B0→μ+μ-
Events per 24 MeV/c2
mμμ(MeV/c2)
Part of 2011 data (2.4fb-1)
ATLAS
√s = 7 TeV
∫Ldt = 2.4 fb-1
|η|max < 1
Data
Bs→μ+μ- MC (10×)
Events/60 MeV
mμμ [MeV]
5

The limits:



NEW LHC combination…