8. Physics of the Top Quark

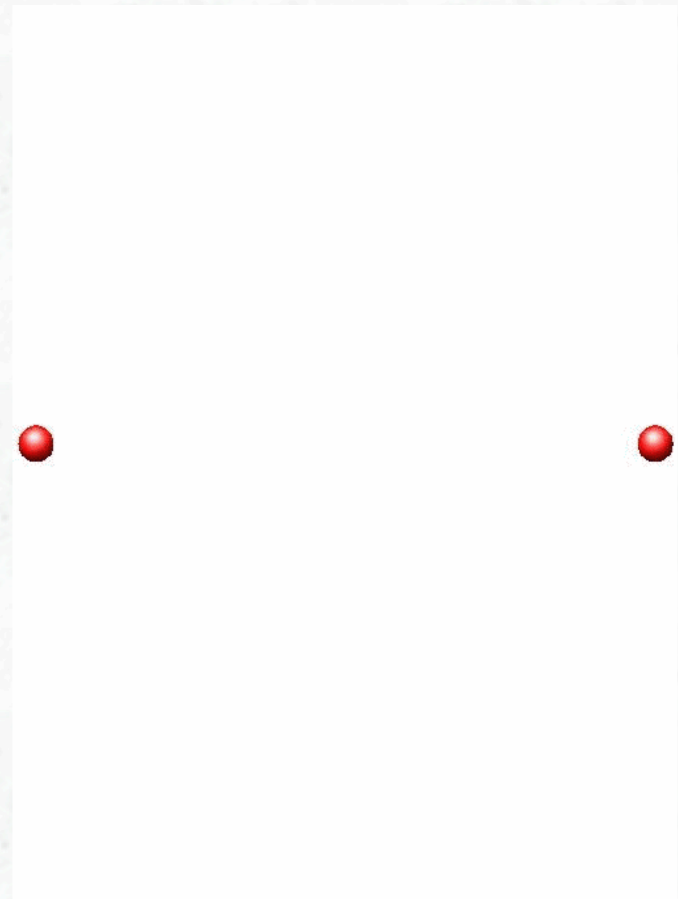
8.1 Introduction (The top quark in the Standard Model)

8.2 Top quark production at the Tevatron

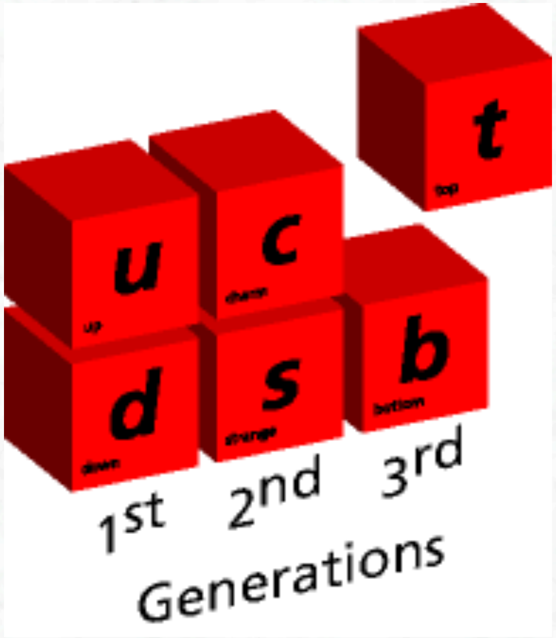
8.3 Top quark production at the LHC

8.4 Top-quark mass measurements (Tevatron and LHC)

8.5 Constraints on the Standard Model



8.1 Introduction to Top Quark Physics



- Discovered by the CDF and DØ collaborations at the Tevatron in 1995

- Tevatron Run I top physics results are consistent
- with expectations from the Standard Model
  (Errors dominated by statistics)

- Run II top physics program profits a lot from the higher statistics

- LHC: huge production rates
  (for √s = 7 TeV: about a factor 25 larger cross sections than at the Tevatron)

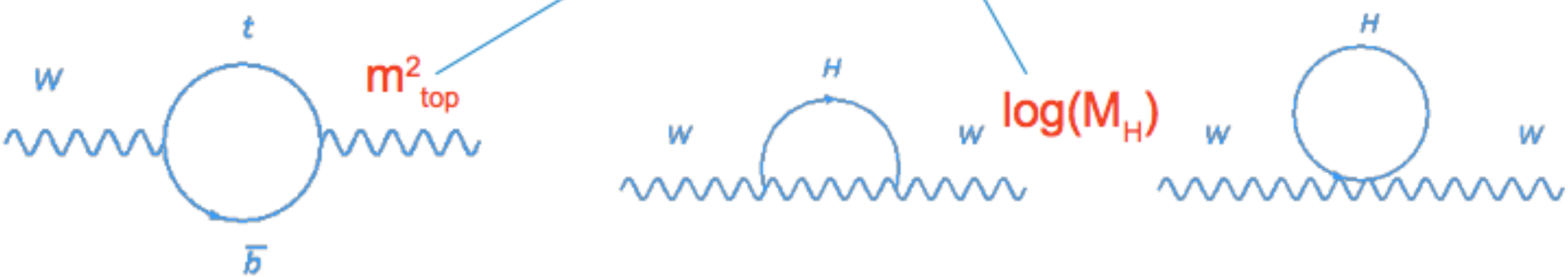
  - Better precision
  - Search for deviations from Standard Model expectations

Die Masse des W-Bosons

- Wichtiger Konsistenzest, auch wenn SM Higgs-Boson gefunden ist

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

Strahlungskorrekturen
$\Delta r \sim 3\ \%$



- G_F, α_{EM} und $\sin\theta_W$ sind mit großer Präzision gemessen – nicht limitierend

What do we know about the top quark?

- The top quark is the heaviest know fermion

  m_t ~173 GeV (from experiment)

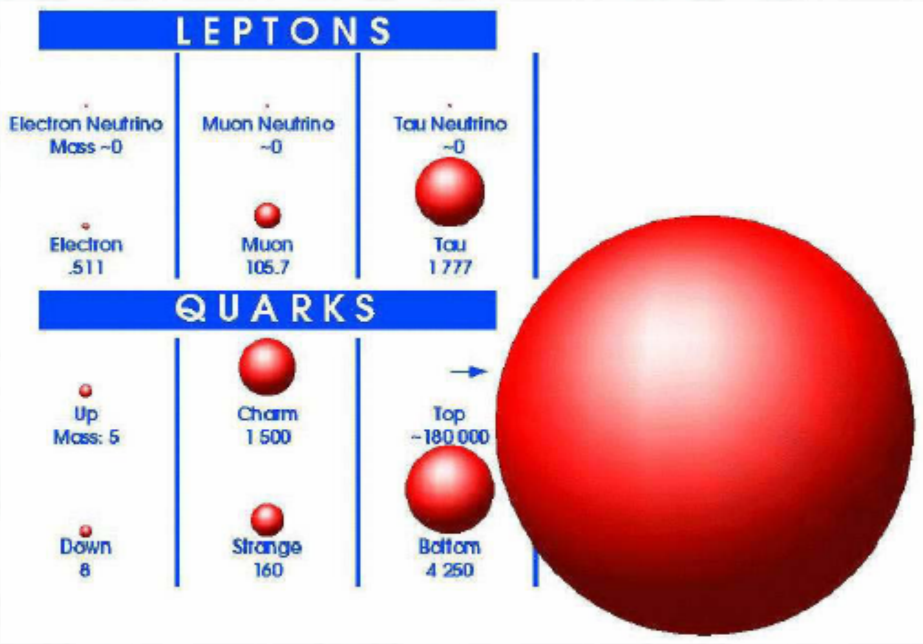
- Lifetime $\tau \sim 5\ 10^{-25}$ s (theory, Standard Model decays)

  no hadronisation, behaves like a quasi-free quark !

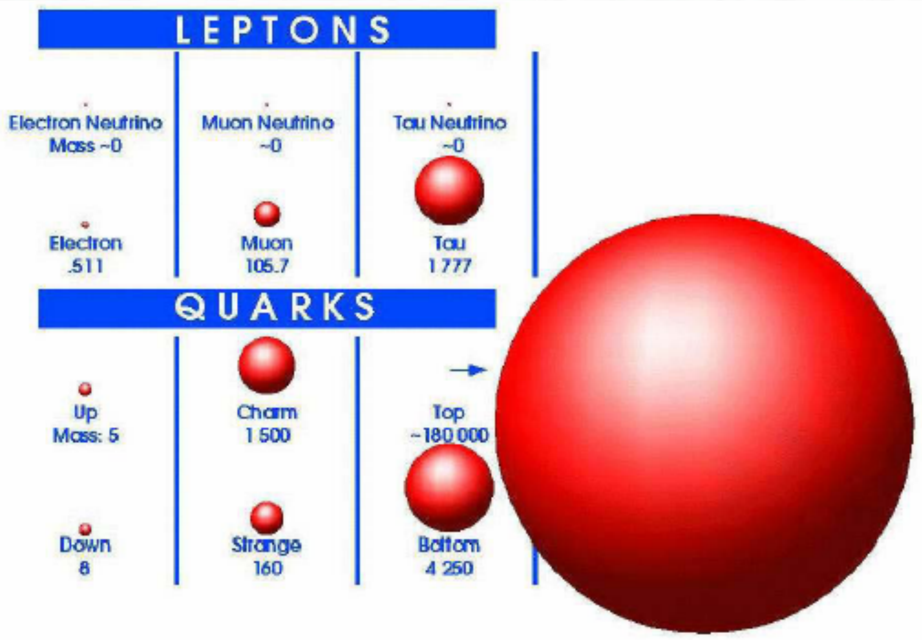
- Predominant decays:
  t → Wb (BR ~100%)

  largely determined from very small CKM matrix elements V_{td}, V_{ts}

- Electric charge Q_t = +2/3



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 ??

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

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

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

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

Top Quark Production

Pair production: qq and gg-fusion

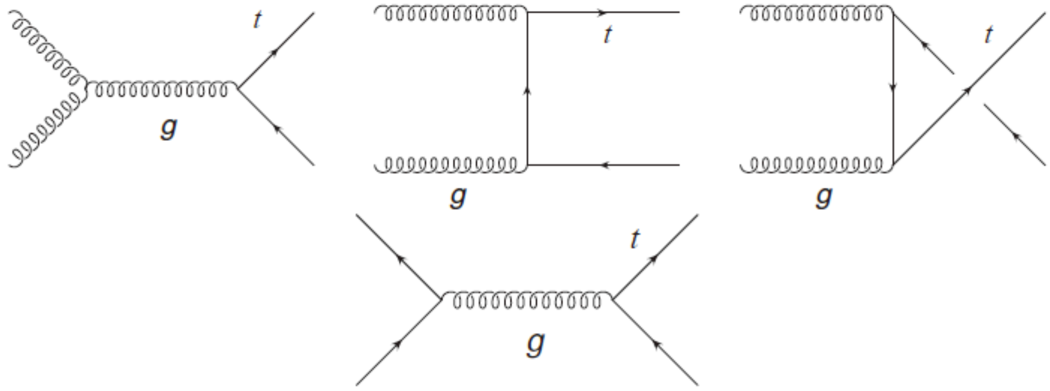


Figure 9.3 Top-quark pair production in the Born approximation.

- NLO corrections completely known
- NNLO partly known

approximate NNLO results:

$$\sigma_{\rm LHC} = (887^{+9}_{-33}\,({\rm scale})^{+15}_{-15}\,({\rm PDF}))\ {\rm pb} \qquad (14\ {\rm TeV})\,,$$
$$\sigma_{\rm Tev} = (7.04^{+0.24}_{-0.36}\,({\rm scale})^{+0.14}_{-0.14}\,({\rm PDF}))\ {\rm pb} \qquad (1.96\ {\rm TeV})\,.$$

	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

Single Top Quark Production

Electroweak production of single top-quarks
(Drell-Yan and Wg-fusion)

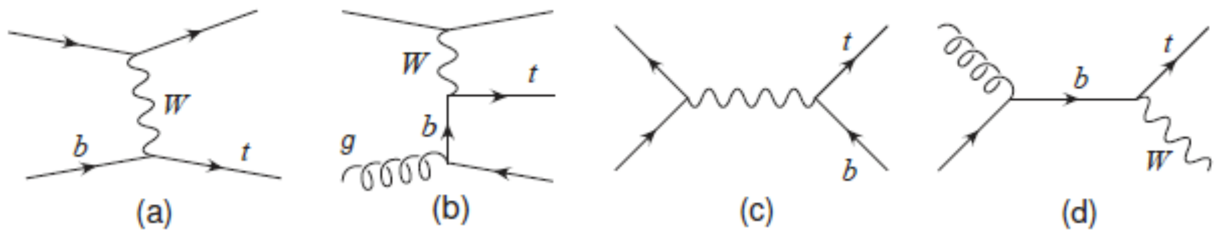
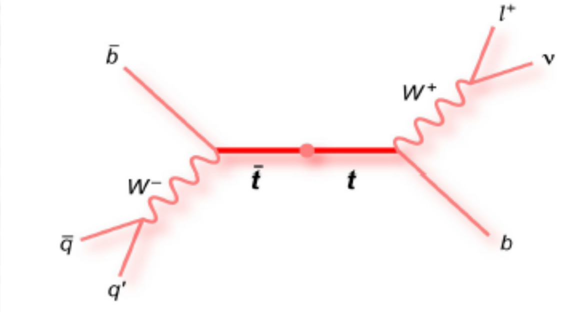


Figure 9.5 Representative Feynman diagrams for the three single top-quark production modes. The graphs show single top-quark production; the diagrams for single antitop-quark production can be obtained by interchanging quarks and antiquarks.

Process	$\sqrt{s}$	$\sigma_{tq\bar{b}}$	$\sigma_{t\bar{b}}$	σ_{Wt}
$p\bar{p} \to t/\bar{t}$	1.96 TeV	$1.86^{+0.19}_{-0.16}$ pb	1.02 ± 0.08 pb	0.25 ± 0.03 pb
$pp \to t$	14.0 TeV	149.4 ± 4.1 pb	$7.23^{+0.55}_{-0.47}$ pb	41.1 ± 4.2 pb
$pp \to \bar{t}$	14.0 TeV	88.9 ± 2.4 pb	$4.03^{+0.14}_{-0.16}$ pb	41.1 ± 4.2 pb

Table 9.2 Predicted total cross sections for single top-quark production processes at the Tevatron and the LHC. The cross sections of the t-channel process are taken from [22]. The values for s-channel and associated production are taken from [23]. All cross sections are evaluated at $m_t = 175$ GeV.

Top Quark Decays



BR (t→Wb) ~ 100%

Dilepton channel:

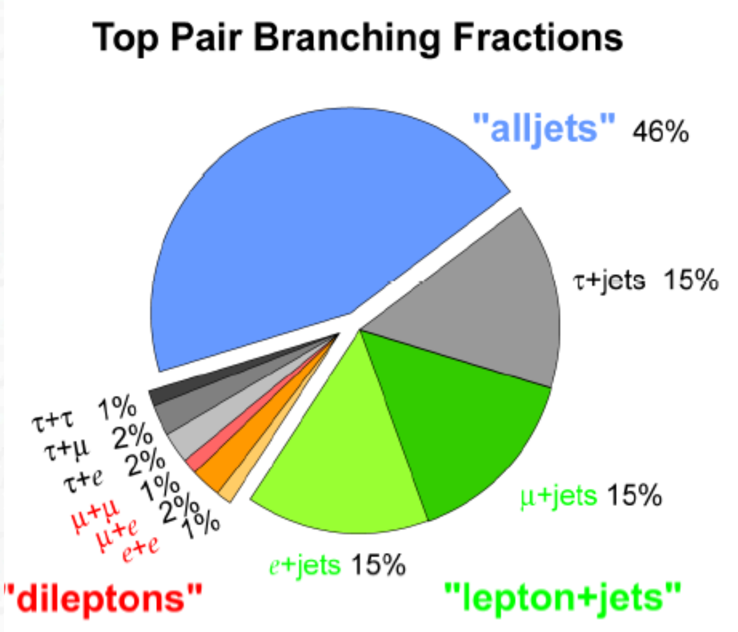
Both W's decay via W→ ℓν (ℓ=e or μ; 4%)

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%)



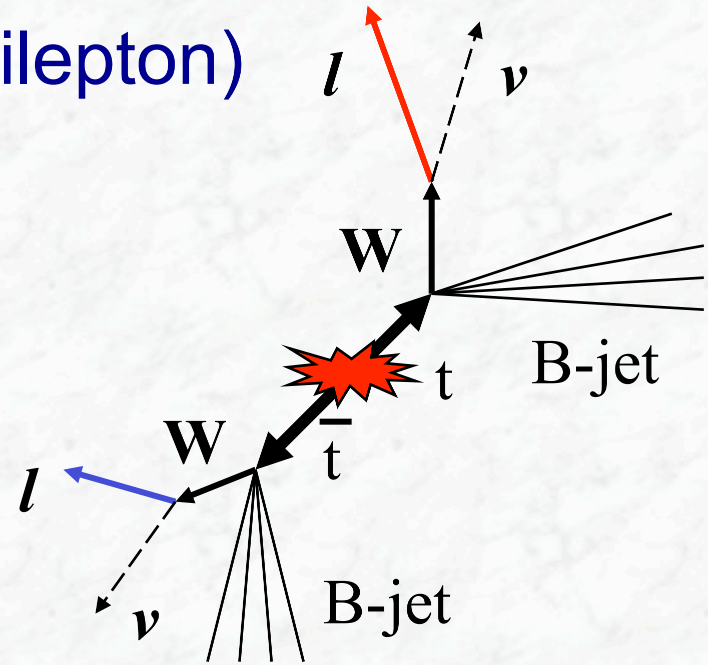
Important experimental signatures: : - Lepton(s)

- Missing transverse momentum
- b-jet(s)

8.2 Measurement of Top Quark production

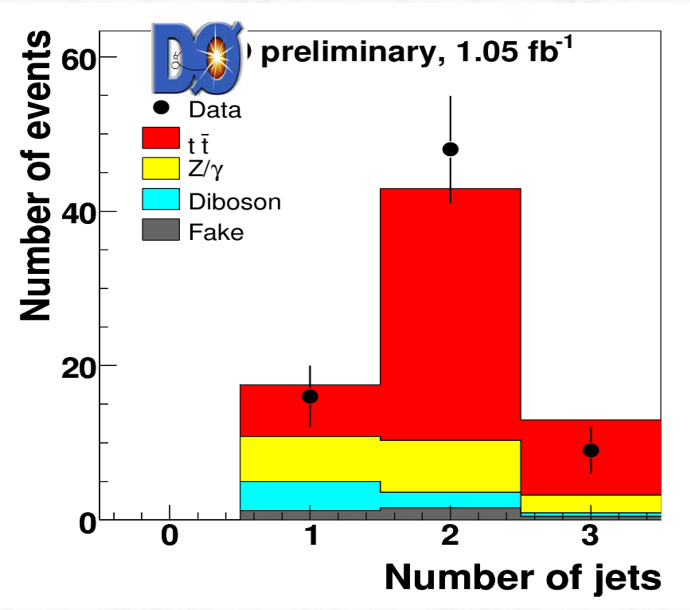
at the Tevatron

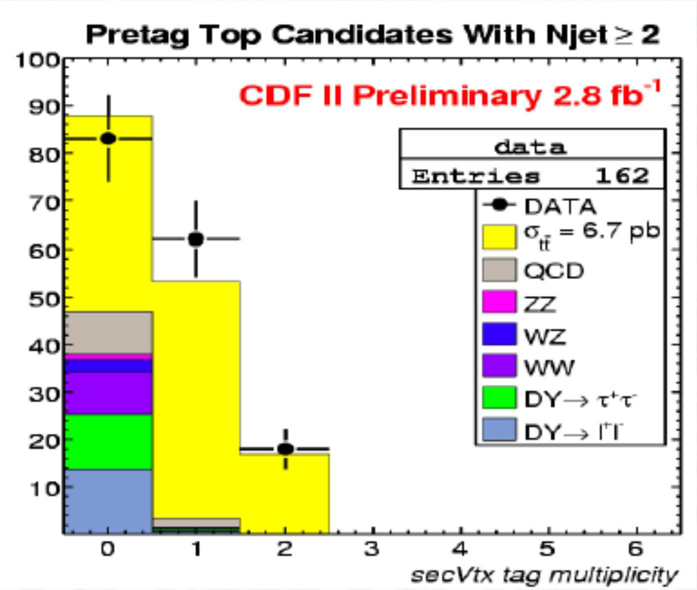
tt cross section (dilepton)



- Two high p_T leptons (opposite charge)
  ee, eμ, μμ
- Significant missing transverse momentum
- ≥ 1 jet (eμ), ≥ 2 jets (ee, μμ)

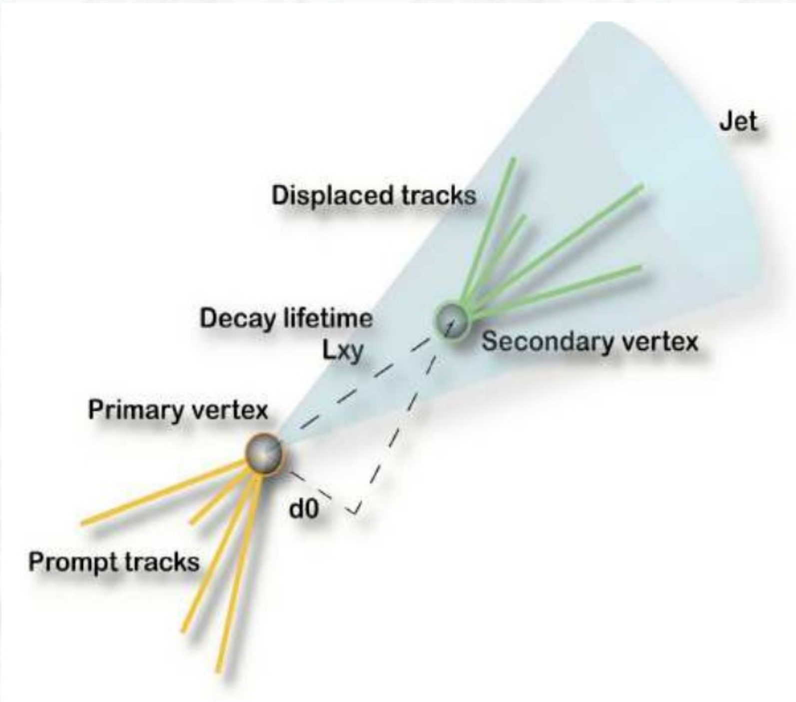
ee,eμ and μμ combined

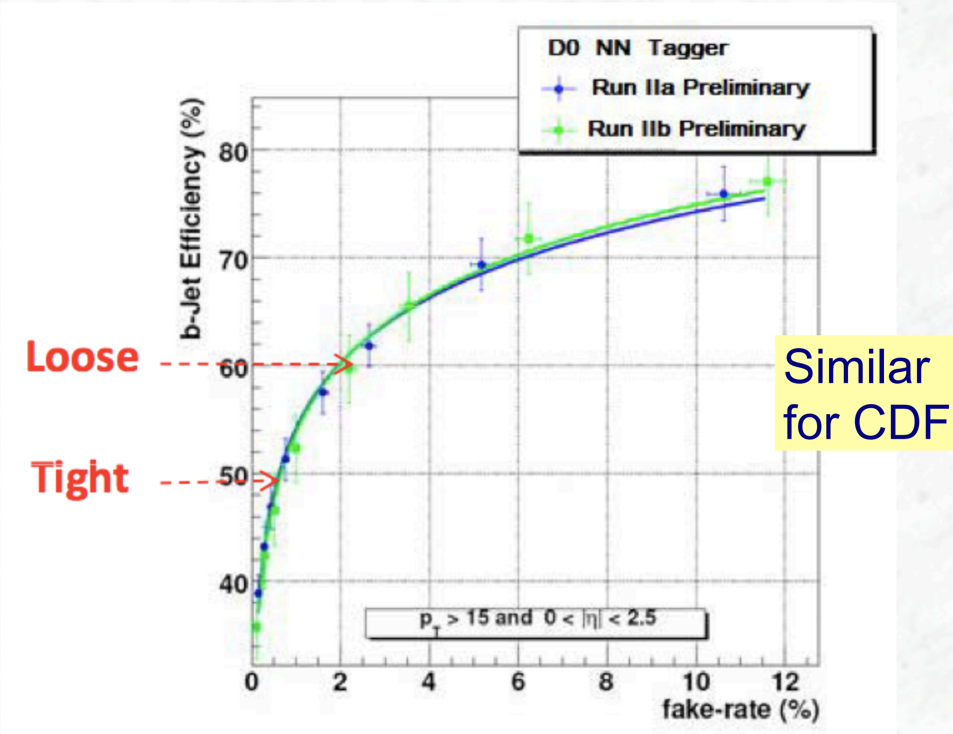




Top quark is needed to describe the
b-jet multiplicity distribution in dilepton events

Tevatron b-tagging performance



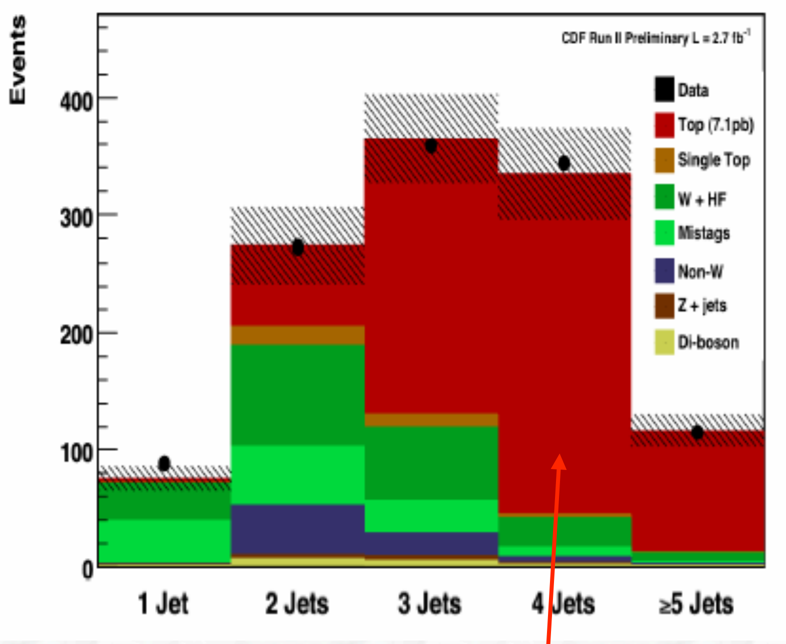


Neural networks are used for optimal combination of tagging information

tt cross section (lepton + jets)   (including b-tagging)

<u>b-tag selection:</u>

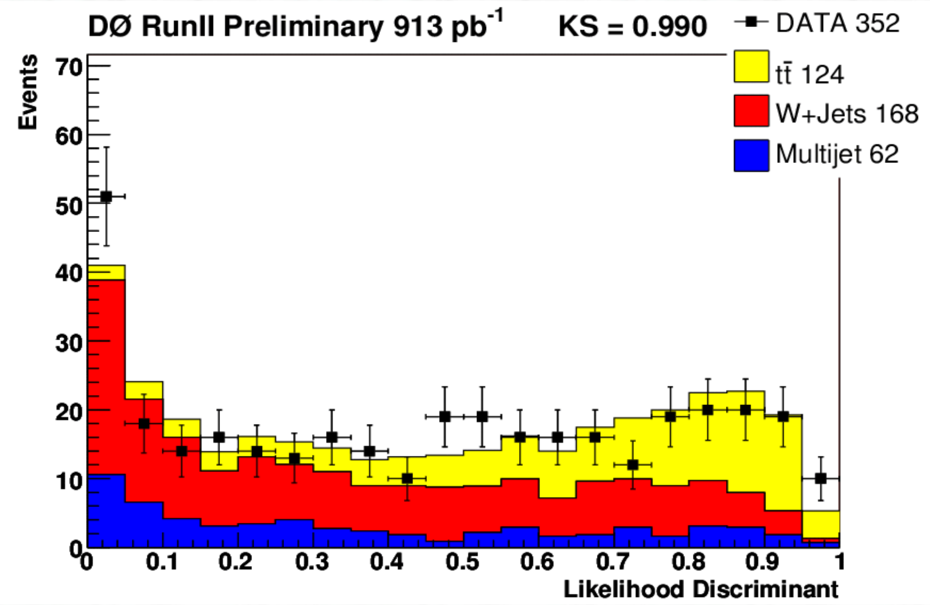
- One high P_T lepton (e, μ)
- Significant E_T^{miss}
- ≥ 1 b-tagged jet



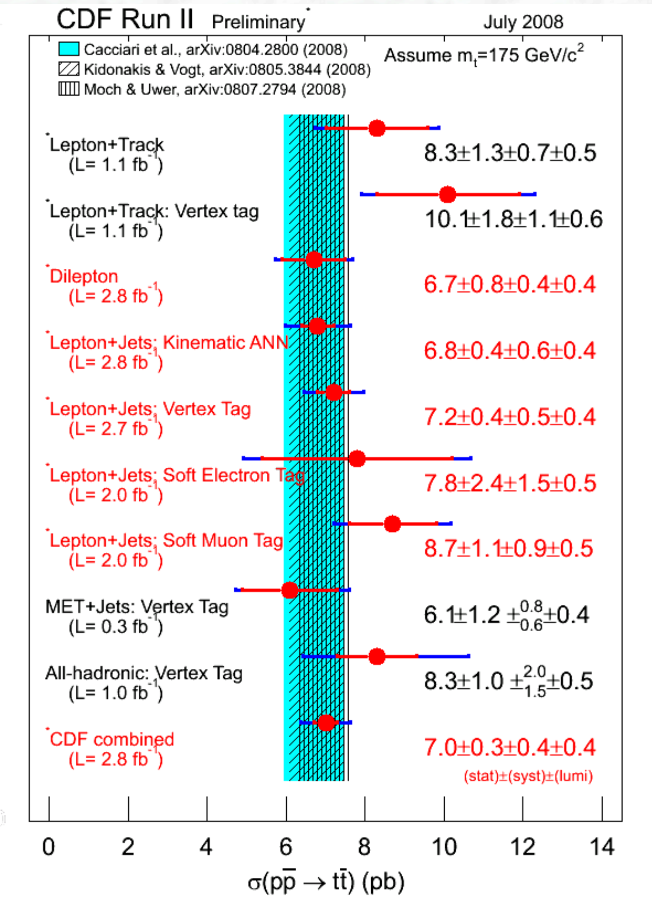
Clear excess above the W+ jet background in events with high jet multiplicity

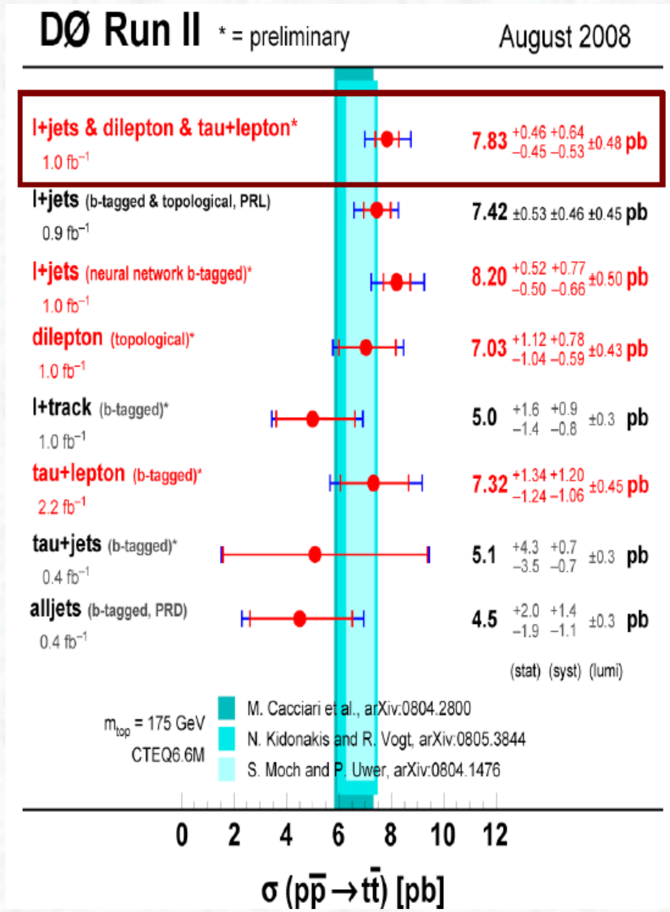
<u>Kinematic selection:</u>

- One high P_T lepton (e, μ)
- Significant E_T^{miss}
- ≥ 4 jets
- Likelihood discriminant (tt vs. W+jets)



tt cross section summary from the Tevatron





Summary of syst. uncertainties

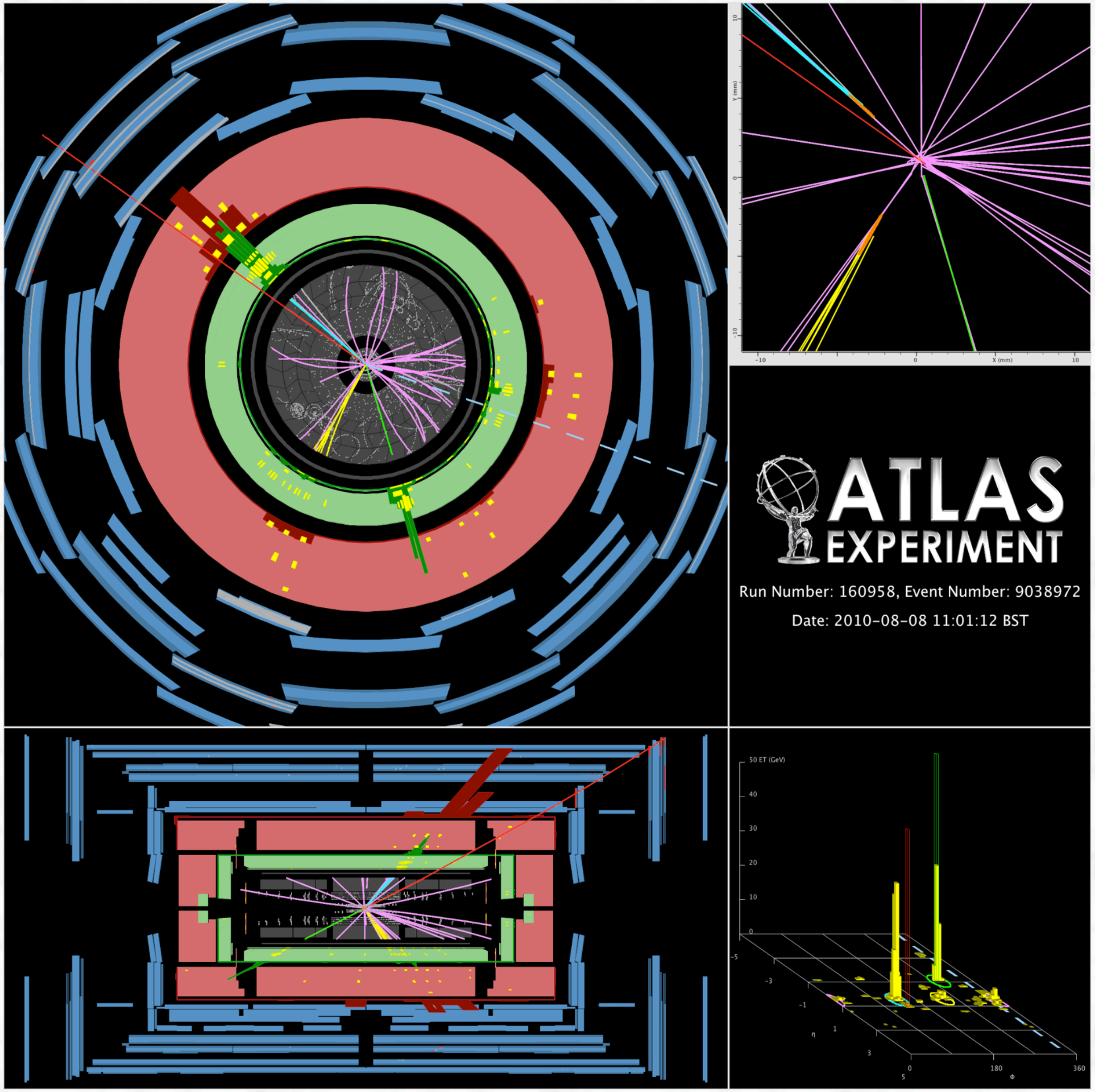
b-tag analysis (2.7 fb^{-1}):

SYSTEMATIC	$\Delta\ \sigma$ pb	$\Delta\ \sigma / \sigma$ %
JET ENERGY SCALE	0.16	2.2
BOTTOM TAGGING	0.38	5.2
CHARM TAGGING	0.08	1.1
MIS-TAGS	0.15	2.1
HEAVY FLAVOR CORRECTION	0.23	3.2
LUMINOSITY	0.42	5.8
QCD FRACTION	0.02	0.2
PARTON SHOWER MODELING	0.13	1.8
INITIAL/FINAL STATE RADIATION	0.04	0.6
TRIGGER EFFICIENCY	0.05	0.6
PDF	0.06	1.0
TOTAL	0.67	9.3

CDF Run II Preliminary L=2.7 fb^{-1}

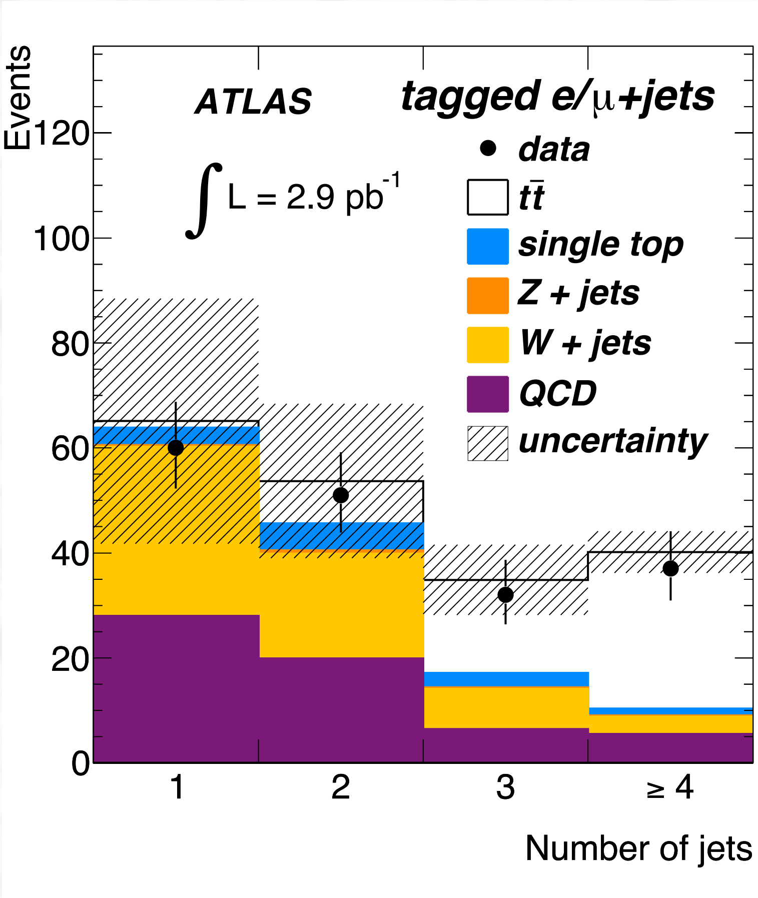
Good agreement:
- among various exp. measurements (two experiments)
- and with NLO + LL QCD prediction
- Systematic uncertainties at the 10% level
  (luminosity, b-tagging)

8.3 First measurements of Top Quark production at the LHC



Event display of a top pair e-μ dilepton candidate with two b-tagged jets. The electron is shown by the green track pointing to a calorimeter cluster, the muon by the long red track intersecting the muon chambers, and the missing ET direction by the dotted line on the xy-view.
The secondary vertices of the two b-tagged jets are indicated by the orange ellipses on the zoomed vertex region view.

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,ν) > 25 GeV (lepton from W decay in event)
- One or more jets with p_T > 25 GeV and η < 2.5

Details on the composition of the event samples:

ATLAS experiment, L = 35 pb^{-1} (data from 2010)

Table 1: Number of observed events in the data in the electron and muon channels after the selection cuts as a function of the jet multiplicity. The expected signal and background contributions are also given. All simulated processes are normalized to theoretical SM predictions, except the multijet background which uses the normalisation presented in Sec. 6. The quoted uncertainties include statistical, systematic and theoretical components, except for the multijet background. All numbers correspond to an integrated luminosity of 35 pb^{-1}.

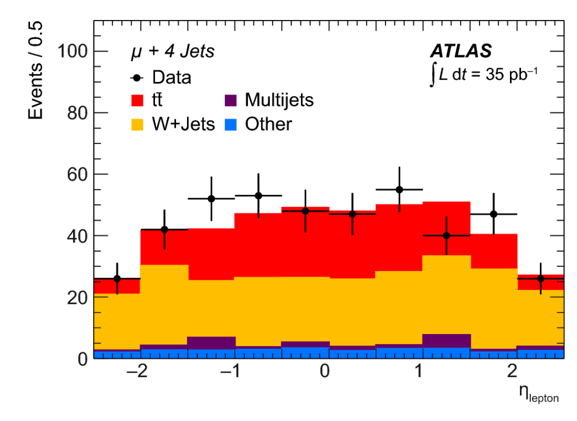
Electron channel	3 jets	4 jets	≥ 5 jets
$t\bar{t}$	117 ± 16	109 ± 15	76 ± 19
W+jets	524 ± 225	124 ± 77	35 ± 23
Multijet	64 ± 32	12 ± 6	8 ± 4
Single top	21 ± 5	7 ± 3	3 ± 2
Z+jets	60 ± 28	21 ± 15	8 ± 6
Diboson	9 ± 3	1.9 ± 1.5	0.4 ± 0.8
Predicted	795 ± 236	275 ± 84	130 ± 35
Observed	755	261	123

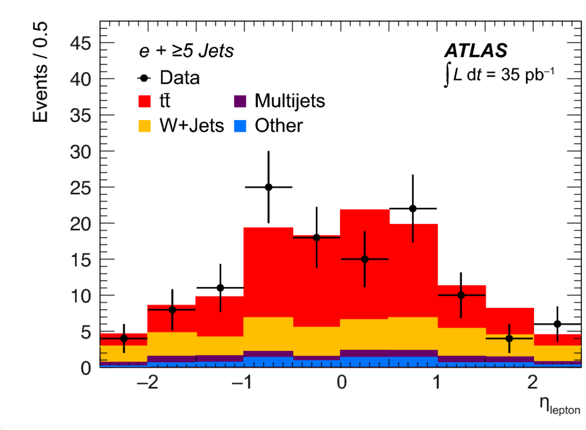
Muon channel	3 jets	4 jets	≥ 5 jets
$t\bar{t}$	165 ± 22	156 ± 18	108 ± 27
W+jets	976 ± 414	222 ± 139	58 ± 38
Multijet	79 ± 24	18 ± 6	11 ± 3
Single top	31 ± 7	10 ± 4	4 ± 2
Z+jets	58 ± 26	14 ± 10	5 ± 4
Diboson	16 ± 4	3 ± 2	0.6 ± 0.8
Predicted	1325 ± 422	423 ± 143	186 ± 51
Observed	1289	436	190

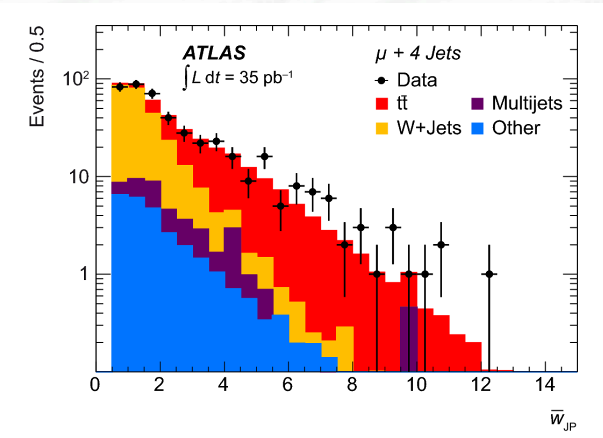
Final 35 pb^{-1} results obtained in a >3 jet selection.

Cross section obtained by a combined fit in different jet multiplicity regions

Distributions for different jet multiplicities







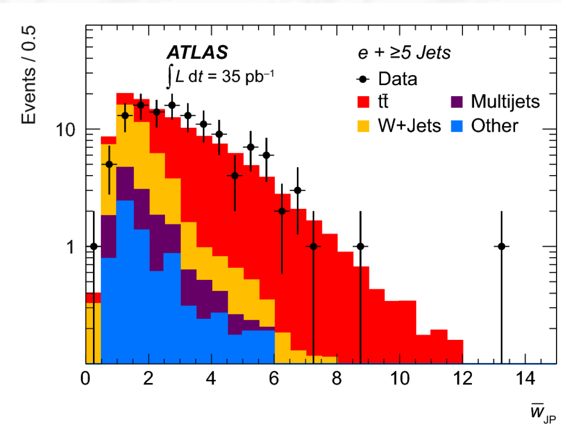


Table 2: Statistical and systematic uncertainties on the measured $t\bar{t}$ cross-section in the untagged and tagged analyses. Multijet and small backgrounds normalisation uncertainties are already included in the statistical uncertainty (*a/i*) in the tagged analysis. *W*+jets heavy-flavour content and *b*-tagging calibration do not apply (*n/a*) to the untagged analysis. The luminosity uncertainty is not included in the table.

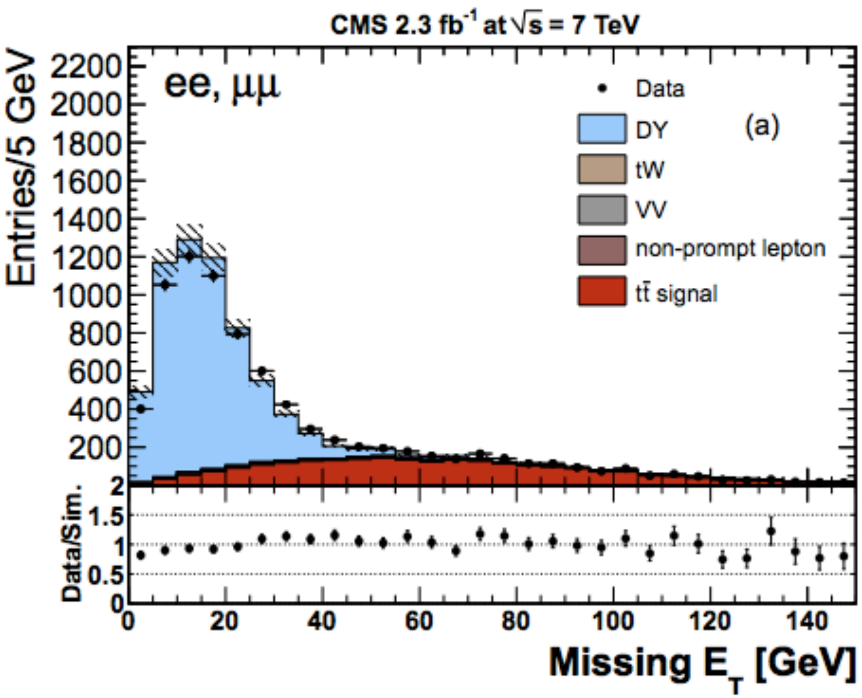
Method	Untagged		Tagged	
Statistical Error (%)	+10.1	−10.1	+5.8	−5.7
Object selection (%)				
JES and jet energy resolution	+4.1	−5.4	+3.9	−2.9
Lepton reconstruction, identification and trigger	+1.7	−1.6	+2.1	−1.8
Background modelling (%)				
Multijet shape	+3.5	−3.5	+0.8	−0.8
Multijet normalisation	+1.1	−1.2	*a/i*	
Small backgrounds norm.	+0.6	−0.6	*a/i*	
W+jets shape	+3.9	−3.9	+1.0	−1.0
W+jets heavy-flavour content	*n/a*		+2.7	−2.4
b-tagging calibration	*n/a*		+4.1	−3.8
$t\bar{t}$ signal modelling (%)				
ISR/FSR	+6.3	−2.1	+5.2	−5.2
NLO generator	+3.3	−3.3	+4.2	−4.2
Hadronisation	+2.1	−2.1	+0.4	−0.4
PDF	+1.8	−1.8	+1.5	−1.5
Others (%)				
Simulation of pile-up	+1.2	−1.2	< 0.1	
Template statistics	+1.3	−1.3	+1.1	−1.1
Systematic Error (%)	+10.5	−9.4	+9.7	−9.0

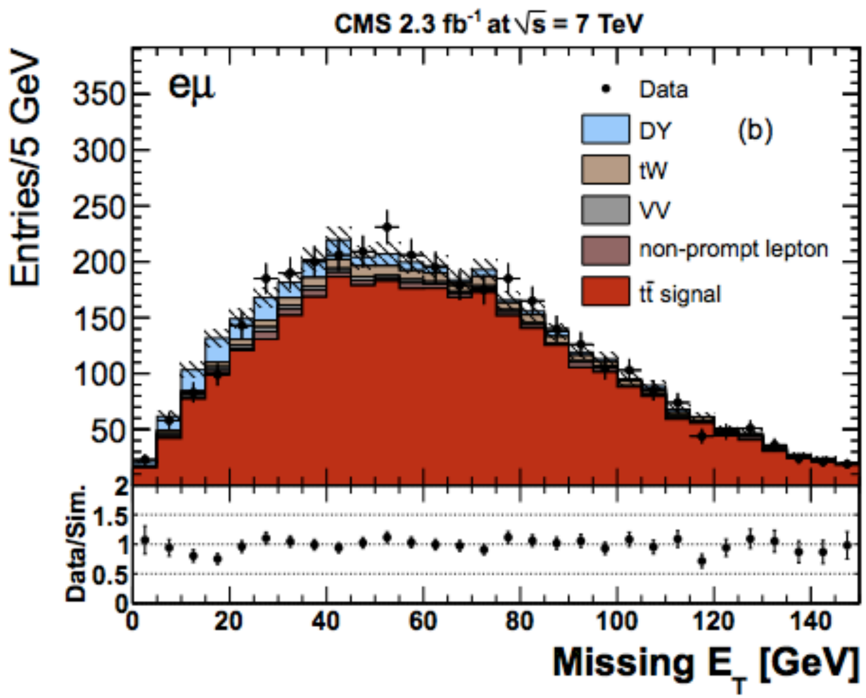
Cross section result

- $\sigma=(173 \pm 17(\text{stat})^{+18}_{-16}(\text{syst}) \pm 6(\text{lumi}))$ pb (untagged analysis)
- $\sigma=(187 \pm 11(\text{stat})^{+18}_{-17}(\text{syst}) \pm 6(\text{lumi}))$ pb (tagged analysis)
- SM prediction (NLO + NLL): $\sigma=165^{+11}_{-16}$ pb

- Good agreement between the SM prediction and the measurement

CMS tt signals in the di-lepton channel





Missing ET distribution for same flavour and different flavour leptons

CMS tt signals in the di-lepton channel

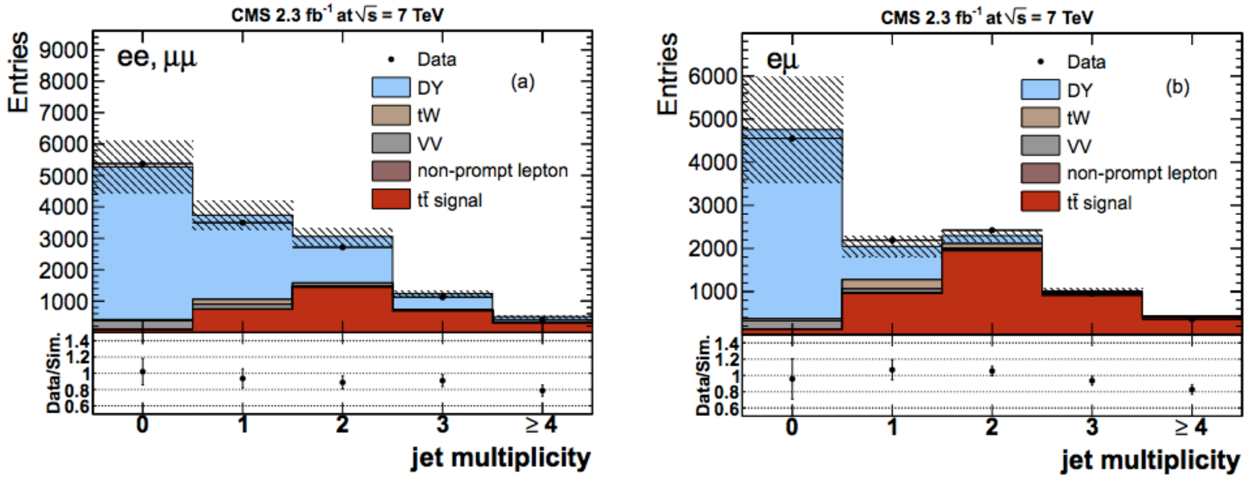


Figure 5. The jet multiplicity for events passing the dilepton and $\not\!\!E_T$ criteria, but before the b-tagging requirement, for (a) the sum of e^+e^- and $\mu^+\mu^-$ channels, and (b) the $e^\pm\mu^\mp$ channel.

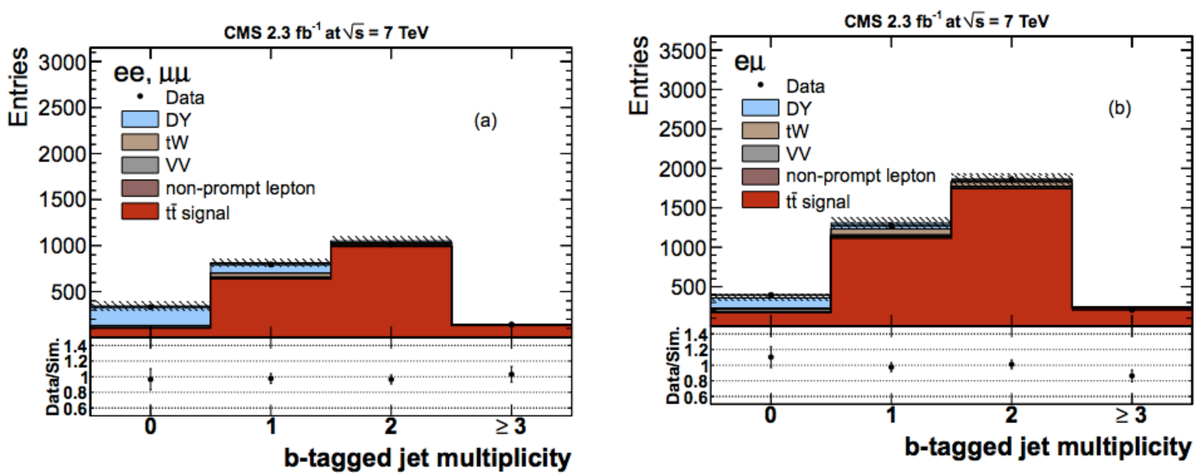


Figure 6. The multiplicity of b-tagged jets in events passing full event selections for (a) the summed e^+e^- and $\mu^+\mu^-$ channels, and (b) the $e^\pm\mu^\mp$ channels.

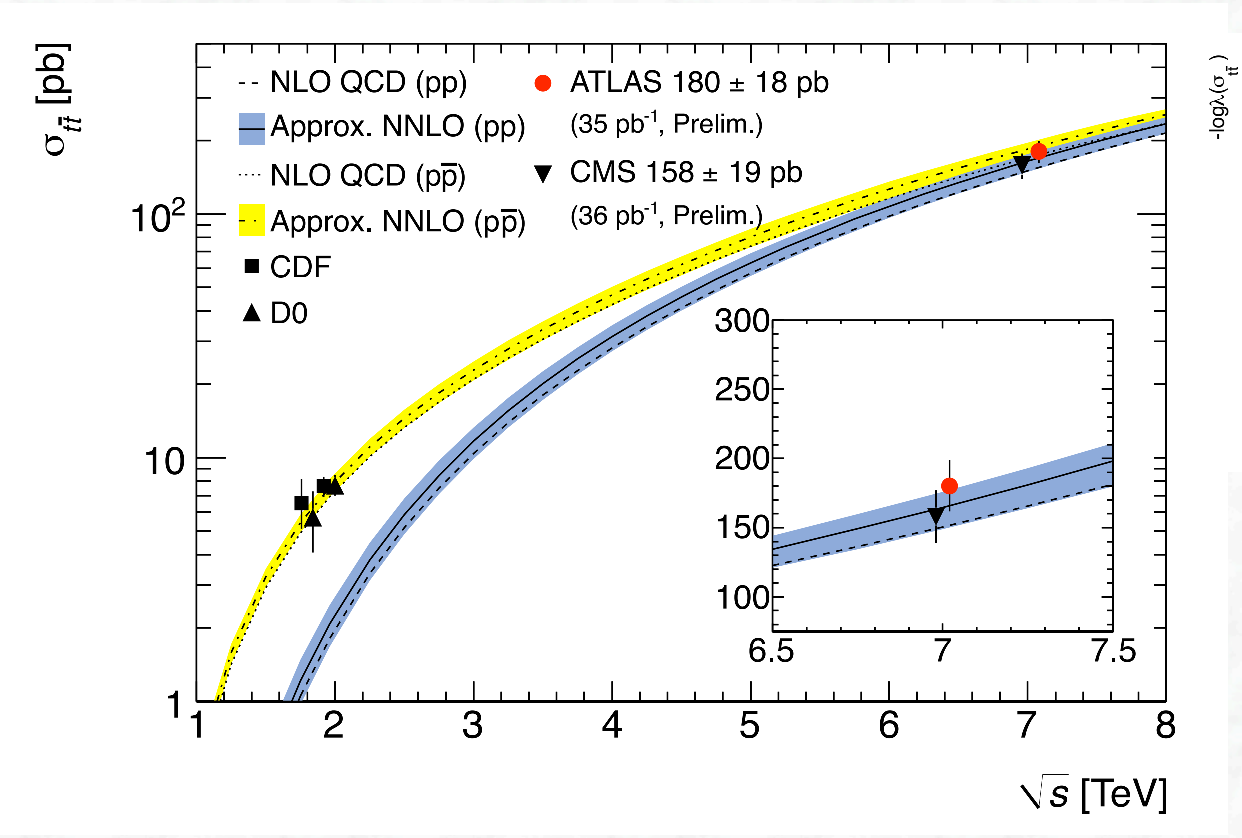
CMS – dilepton channel results

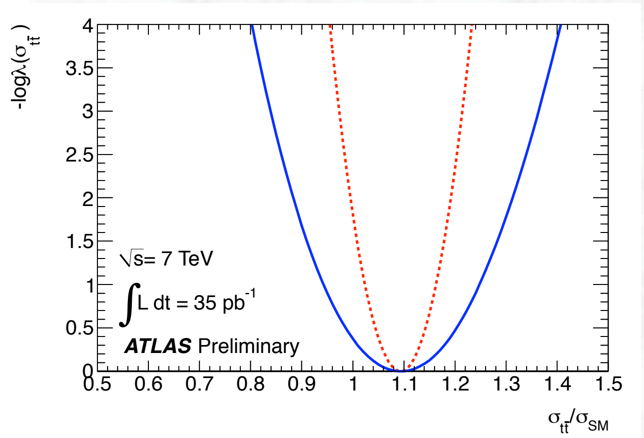
- Cross section results, di-lepton channel, CMS

Channel	PLR method	Counting analysis
ee	$168.0 \pm 6.6^{+7.6}_{-7.0} \pm 3.7$	$165.9 \pm 6.4 \pm 7.0 \pm 3.6$
$\mu\mu$	$156.3 \pm 5.6^{+7.7}_{-6.6} \pm 3.5$	$153.8 \pm 5.4 \pm 6.6 \pm 3.4$
eμ	$161.9 \pm 3.1^{+5.8}_{-5.4} \pm 3.6$	$161.6 \pm 3.1 \pm 5.6 \pm 3.6$
Combined	$161.9 \pm 2.5^{+5.1}_{-5.0} \pm 3.6$	$161.0 \pm 2.6 \pm 5.6 \pm 3.6$

Table 4. Measured $\sigma_{t\bar{t}}$ in pb for a top quark mass of 172.5 GeV for each of the dilepton channels, as well as for their combination. The quoted uncertainties are, respectively, from statistical and systematic sources and the contributions from integrated luminosity.

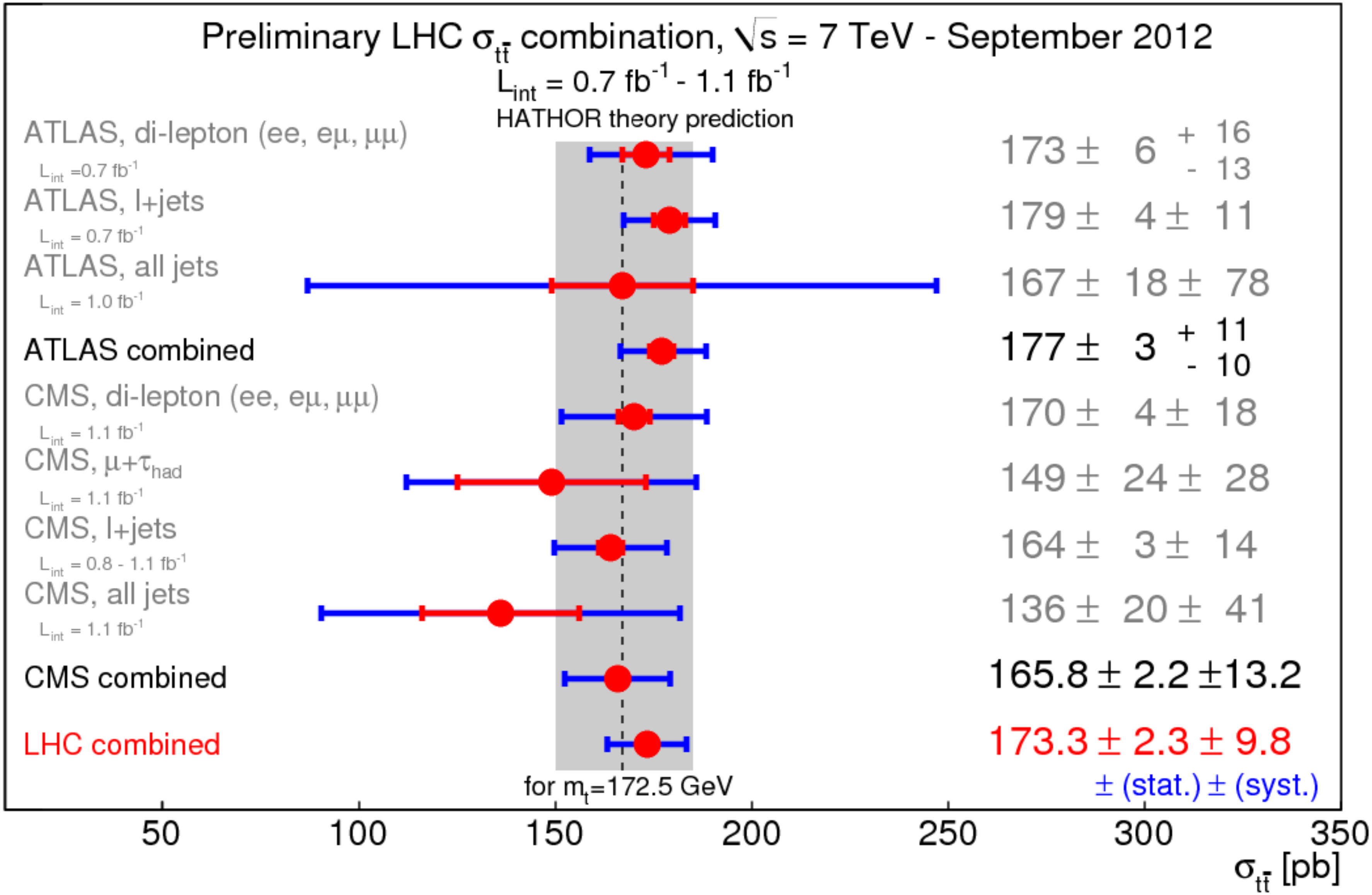
Top cross section measurements based on 2010 data from ATLAS and CMS





Best fit (ATLAS) gives a slightly higher cross-section than the expected approx. NNLO QCD value, but consistent within 1 σ (red: likelihood, stat errors only; blue: stat + syst. uncertainties)

- Results between the two experiments are consistent
- Perturbative QCD calculations are in agreement with the obtained results



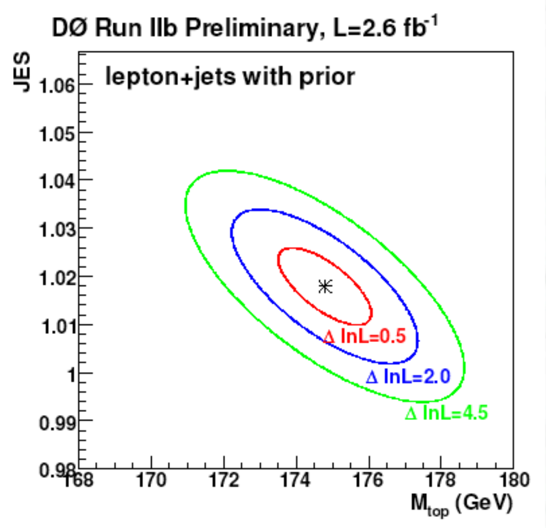
Preliminary LHC $\sigma_{t\bar{t}}$ combination, $\sqrt{s}$ = 7 TeV - September 2012
L_{int} = 0.7 fb^{-1} - 1.1 fb^{-1}
HATHOR theory prediction
ATLAS, di-lepton (ee, eμ, μμ)
L_{int} =0.7 fb^{-1}
$173 \pm 6 \, ^{+16}_{-13}$
ATLAS, l+jets
L_{int} = 0.7 fb^{-1}
179 ± 4 ± 11
ATLAS, all jets
L_{int} = 1.0 fb^{-1}
167 ± 18 ± 78
ATLAS combined
$177 \pm 3 \, ^{+11}_{-10}$
CMS, di-lepton (ee, eμ, μμ)
L_{int} = 1.1 fb^{-1}
170 ± 4 ± 18
CMS, $\mu+\tau_{had}$
L_{int} = 1.1 fb^{-1}
149 ± 24 ± 28
CMS, l+jets
L_{int} = 0.8 - 1.1 fb^{-1}
164 ± 3 ± 14
CMS, all jets
L_{int} = 1.1 fb^{-1}
136 ± 20 ± 41
CMS combined
165.8 ± 2.2 ±13.2
LHC combined
173.3 ± 2.3 ± 9.8
for m_t=172.5 GeV
± (stat.) ± (syst.)
50
100
150
200
250
300
350
$\sigma_{t\bar{t}}$ [pb]

8.4 Top-quark mass measurement

Top mass measurements

- Top mass determination:
  No simple mass reconstruction possible,
  Monte Carlo models needed

  → template methods,…
  matrix element method…

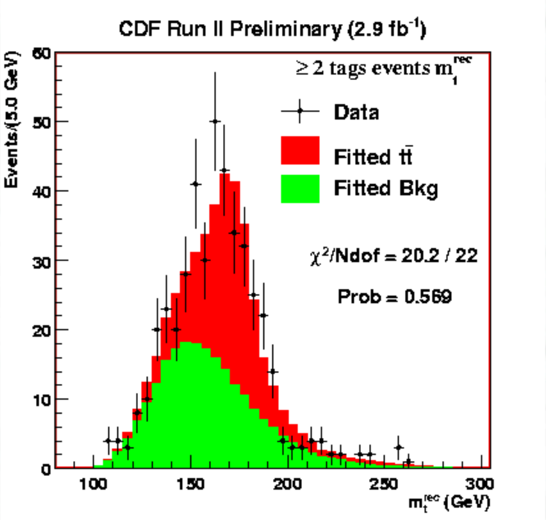


<u>Most precise single measurements</u>:

m_{top} = 172.1 ± 0.9 (stat) ± 1.3 (syst) GeV/c^2 (CDF)

m_{top} = 173.7 ± 0.8 (stat) ±1.6 (syst) GeV/c^2 (DØ)

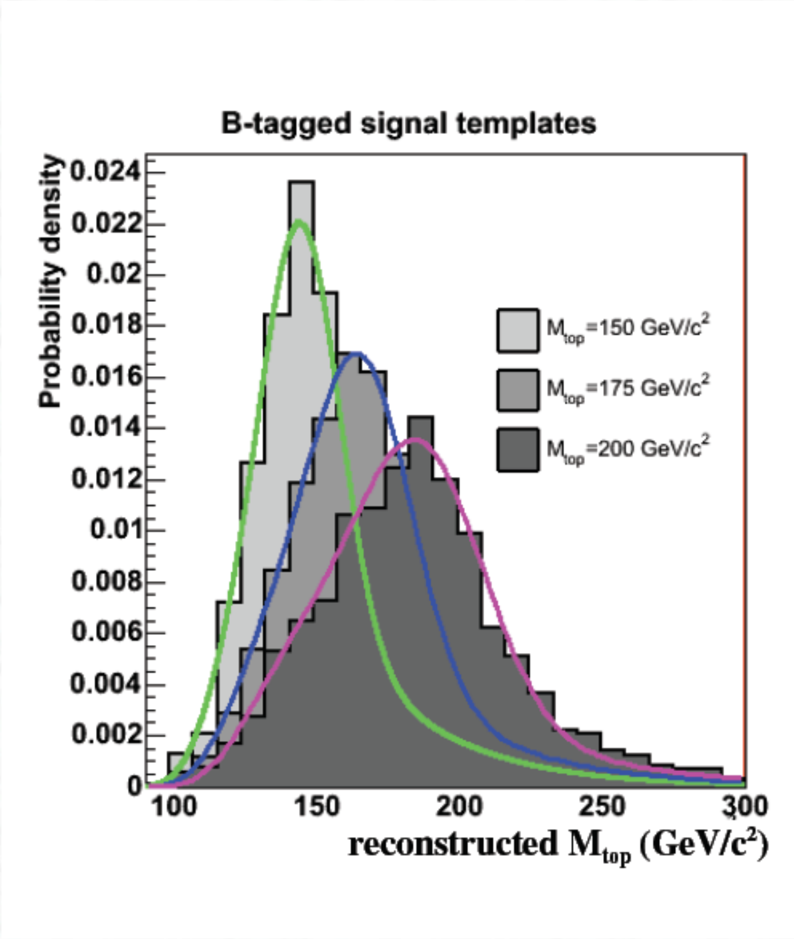
- Reduce jet energy scale systematic by using in-situ hadronic W mass in tt events
  (simultaneous determination of m_t and energy scale)



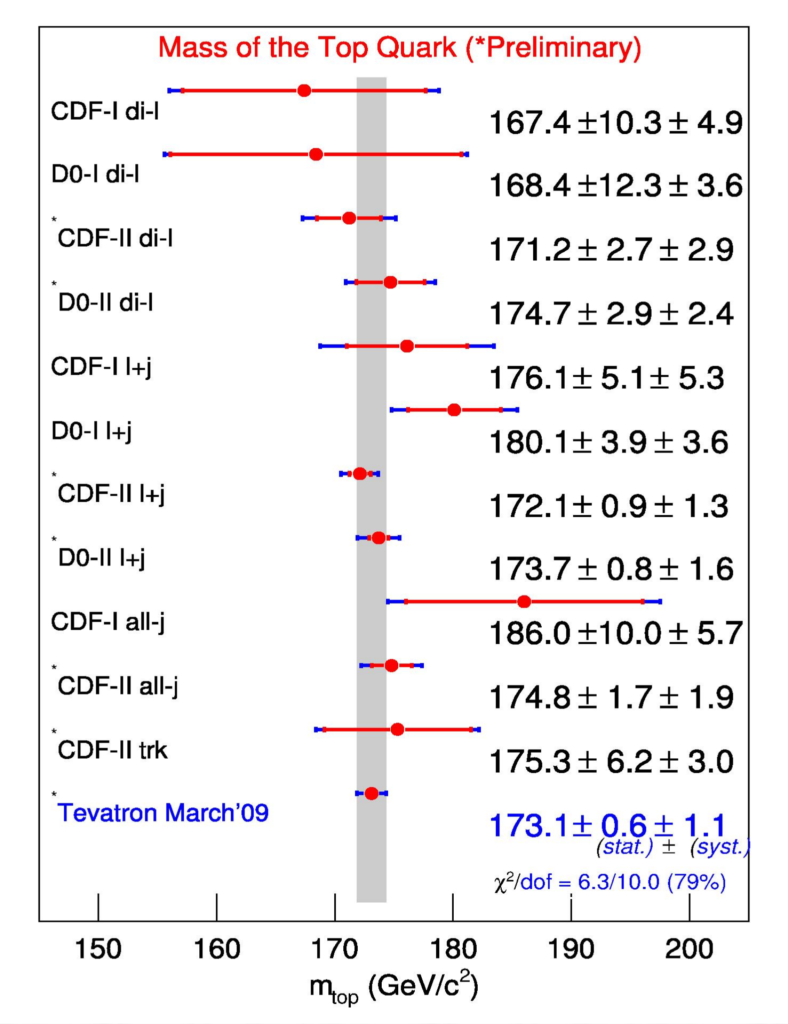
full hadronic channel

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



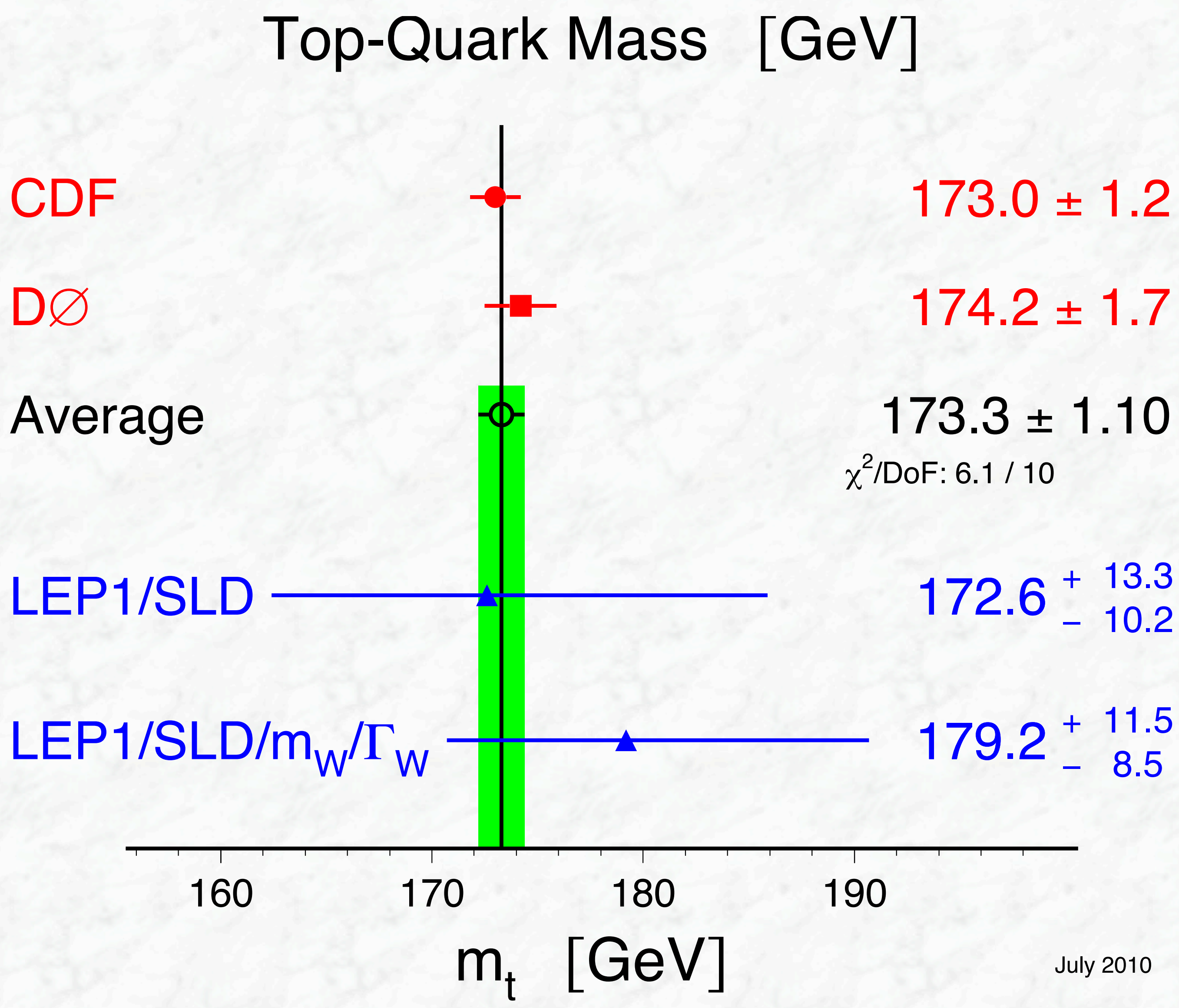
Summary of present results and future prospects



Expected LHC precision for 10 fb^{-1}:

(Combination of several methods, maybe somewhat conservative)

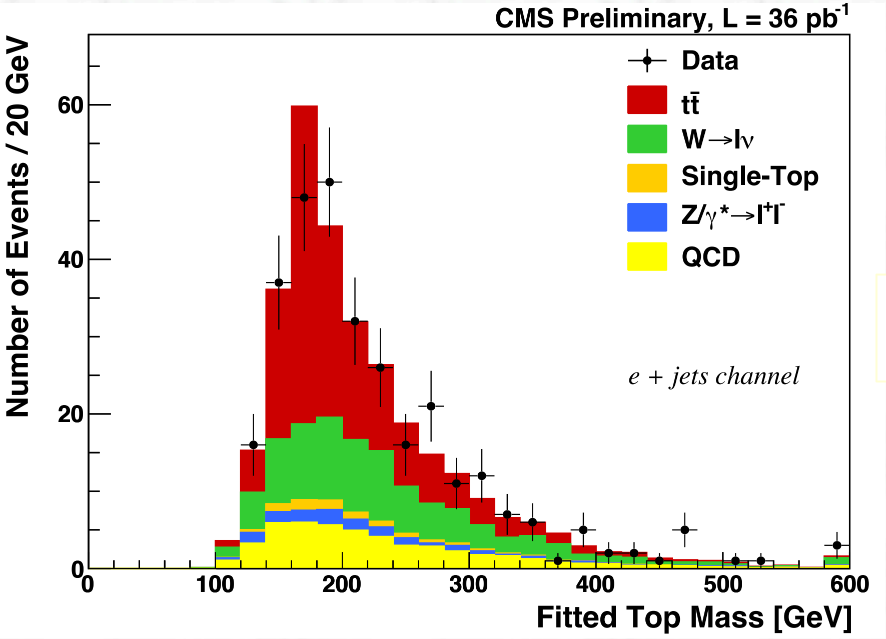
< ~ 1 GeV/c^2


Top-Quark Mass [GeV]
CDF
173.0 ± 1.2
DØ
174.2 ± 1.7
Average
173.3 ± 1.10
χ^2/DoF: 6.1 / 10
LEP1/SLD
172.6 + 13.3 − 10.2
LEP1/SLD/m_W/Γ_W
179.2 + 11.5 − 8.5
160
170
180
190
m_t [GeV]
July 2010

First top quark mass measurements from CMS

CMS, 06.06.2011

- Use lepton + jet channel
- Full 2010 data set
- 637 candidate events selected



Top quark mass after the fit of the e+jets selected sample for an integrated luminosity of 36/pb after applying the event selection and requesting at least one solution with chi2<10.

$$m_{\mathrm{t}} = 173.4 \pm 1.9(\mathrm{stat}) \pm 2.7(\mathrm{syst})\ \ \mathrm{GeV}.$$

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

Estimated error compared to expectations from Monte Carlo simulations:

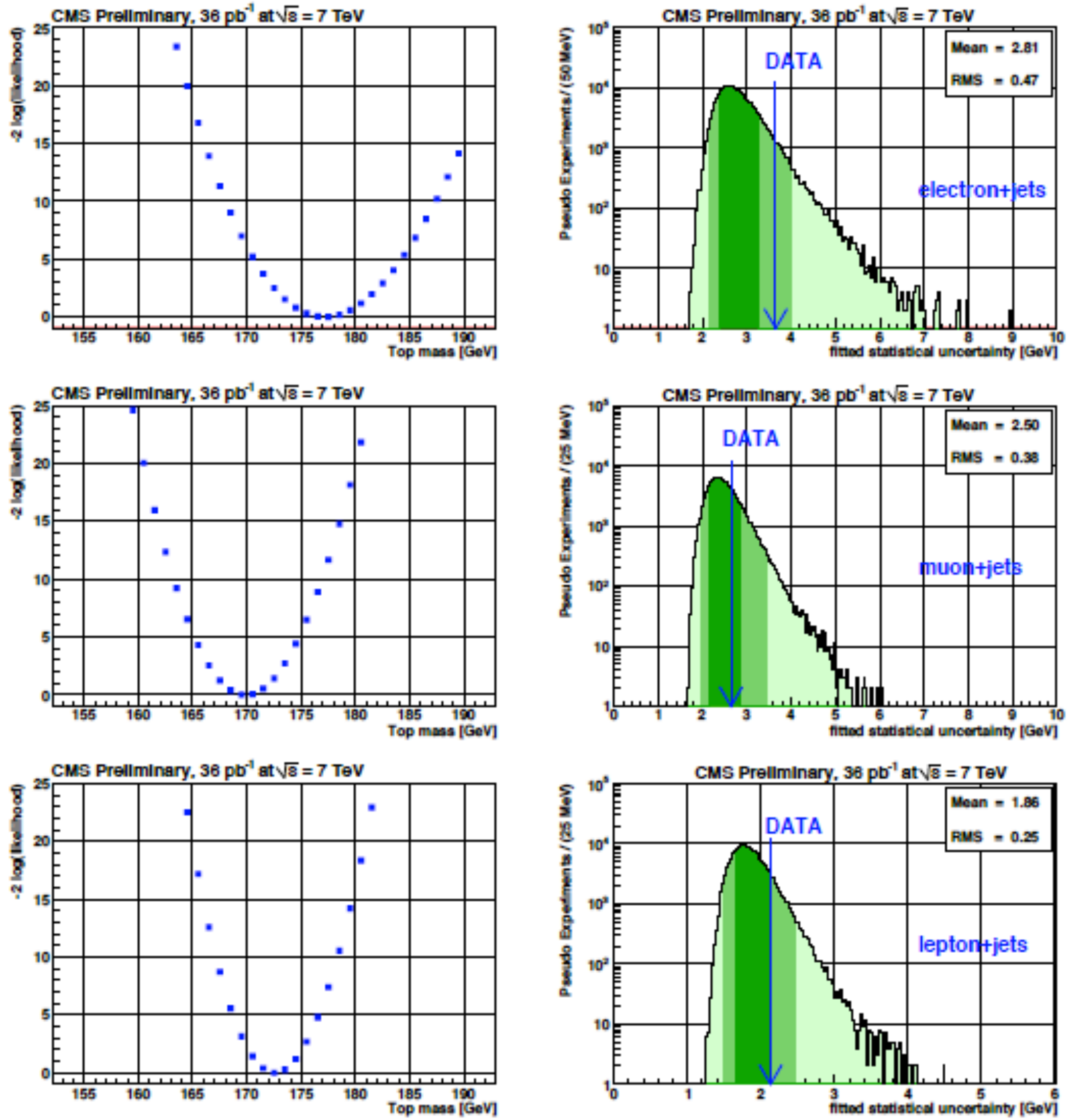
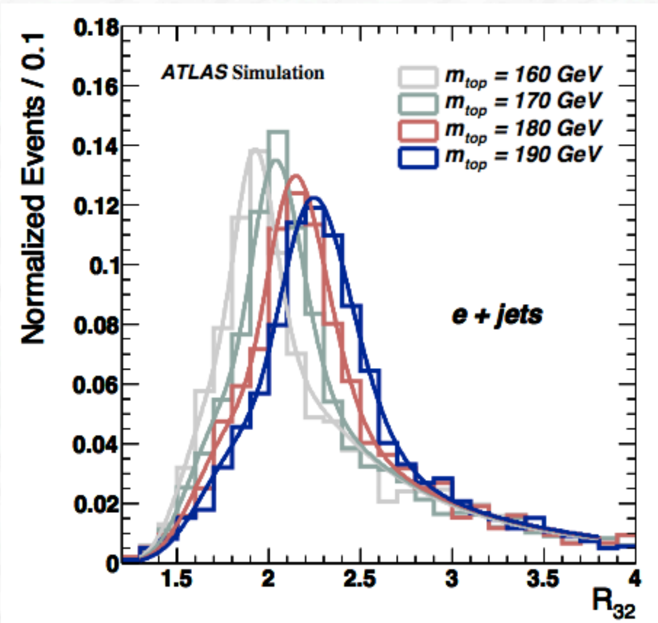


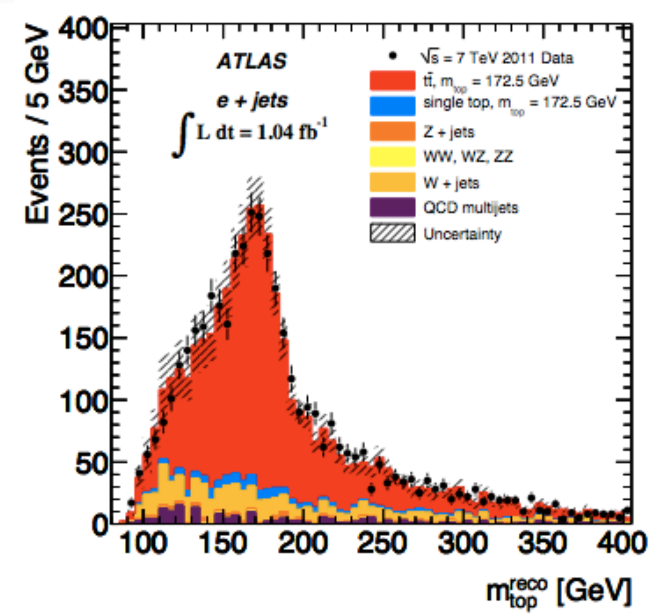
Figure 7: Likelihood as a function of the top quark mass from the fit to the data (left) and the estimated uncertainty compared to the expectation from MC pseudo-experiments (right), for the electron+jets (top), muon+jets (middle), and the combined lepton+jets channel (bottom).

ATLAS top mass measurement

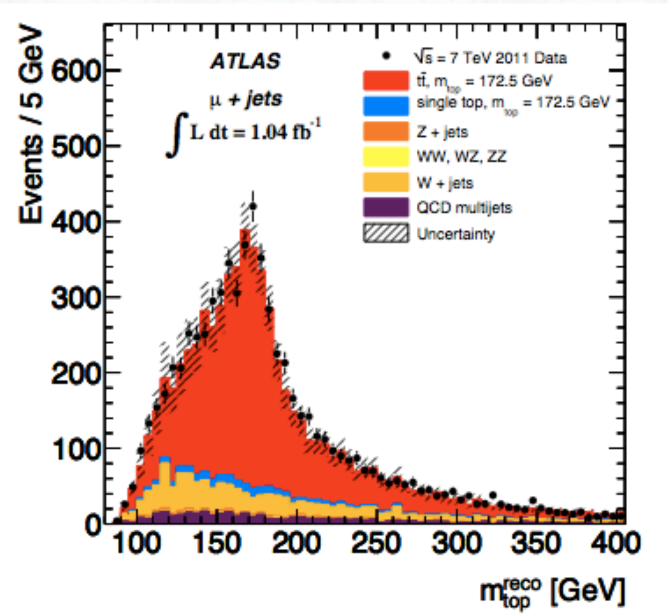


R_{32} = ratio between the reconstructed Top and W mass

$$m_{\text{top}} = 174.5 \pm 0.6_{\text{stat}} \pm 2.3_{\text{syst}}\ \text{GeV}$$

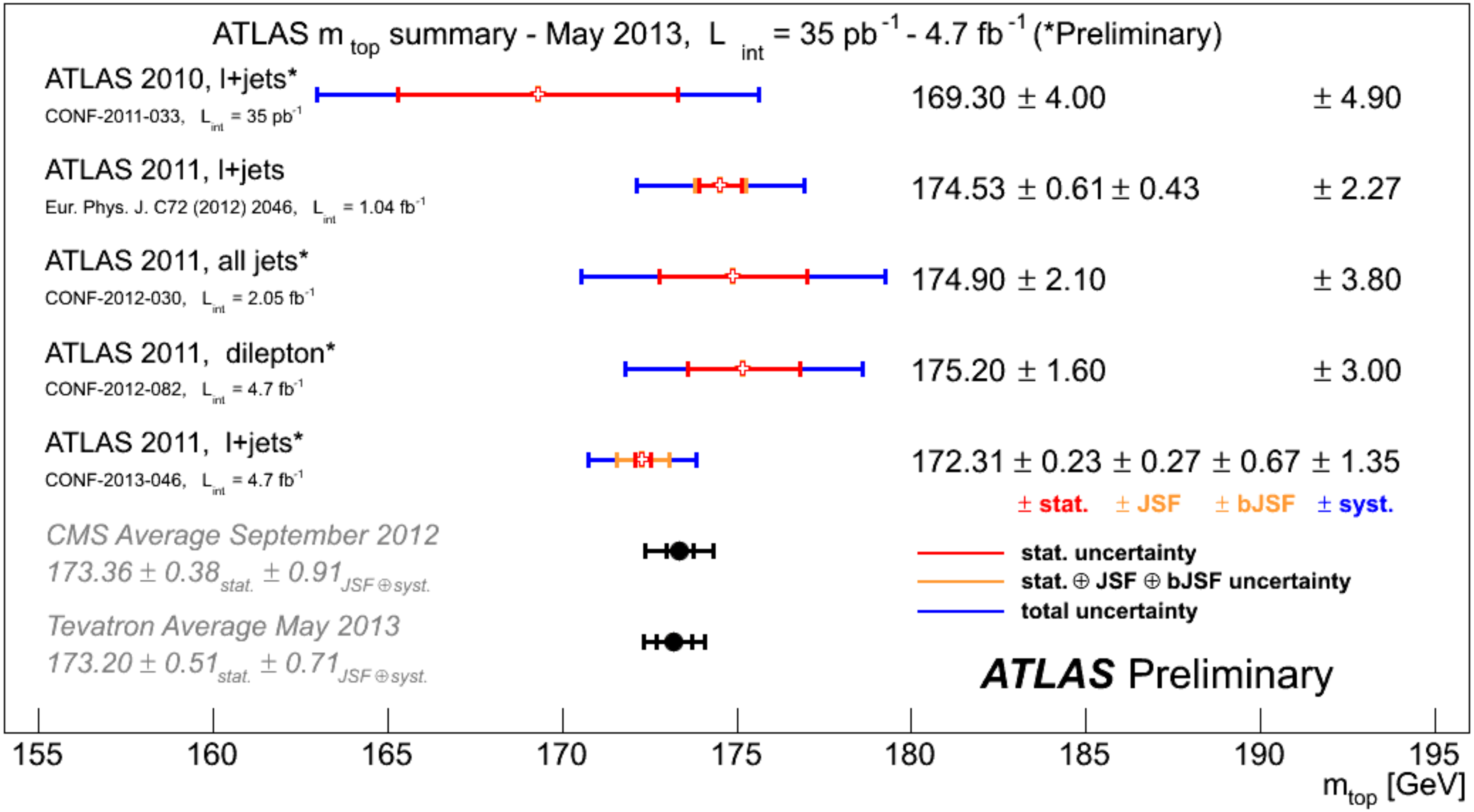


(c) e+jets channel

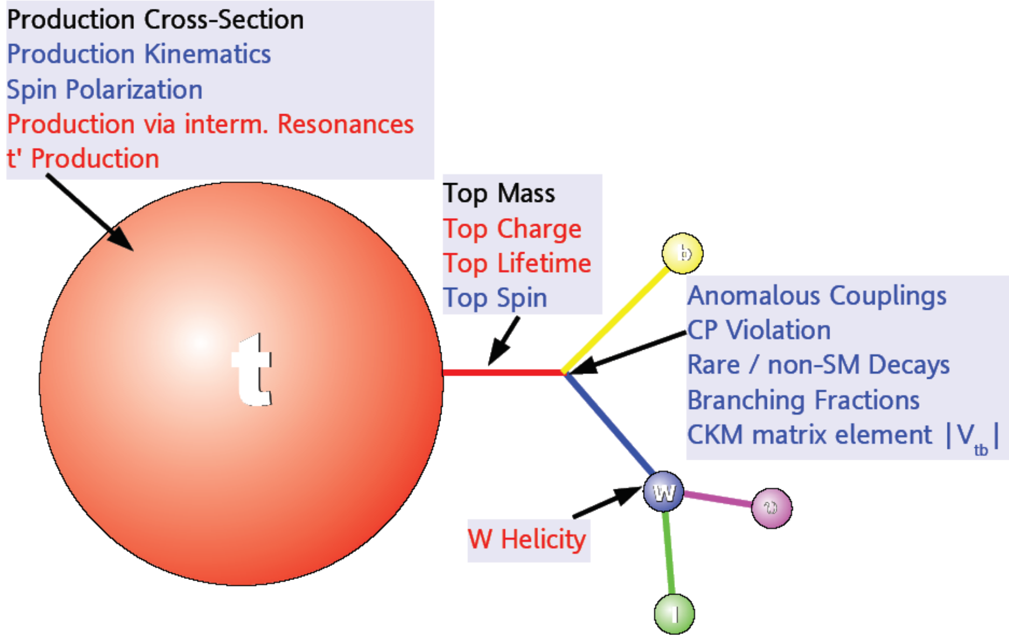


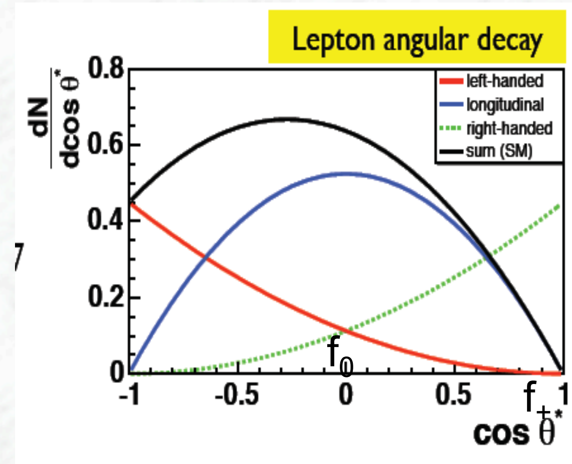
(d) μ+jets channel

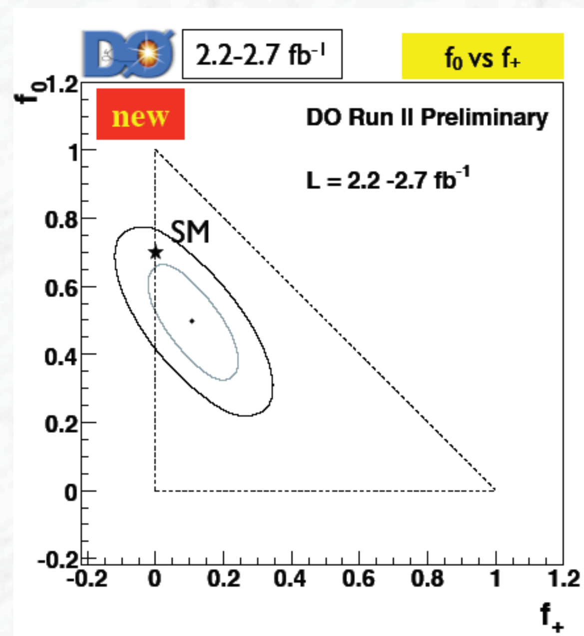
Summary on top mass



Other top properties





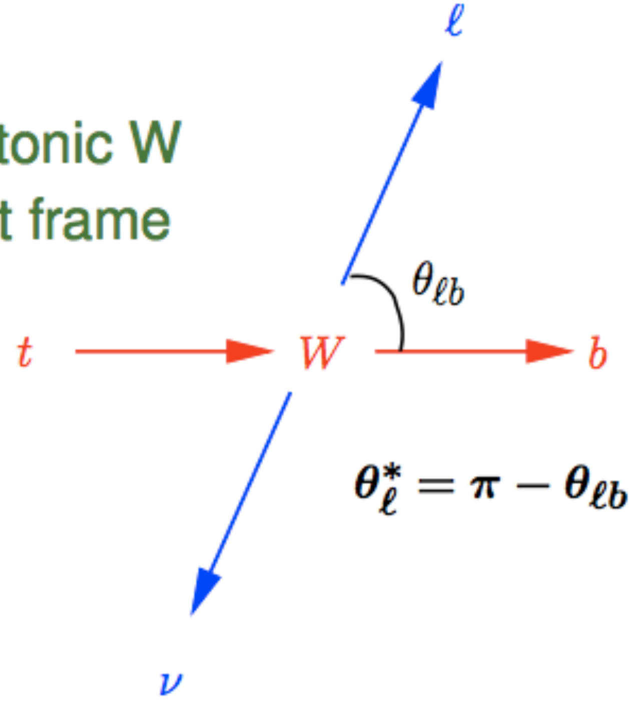


	Tevatron Result	luminosity (fb^{-1})
Mass	173.1 ± 1.1 GeV	~ 5.0
W helicity	CDF: f_0 = 0.66 ± 0.16, f_+ = -0.03 ± 0.07 DØ: f_0 = 0.49 ± 0.14 f_+ = 0.11 ± 0.08	1.9 2.2 – 2.7
Charge Lifetime **V_{tb}** BR(t→Wb) / BR (W→Wq) BR (t → Zq)	rule out Q = +4/3 (90.% C.L.) Γ_t < 13.1 GeV (95% C.L.) V_{tb} > 0.89 (95% C.L.) R = 0.97 (+0.09) (-0.08) < 3.7% (95% C.L.)	1.5 ~ 1.0 0.9

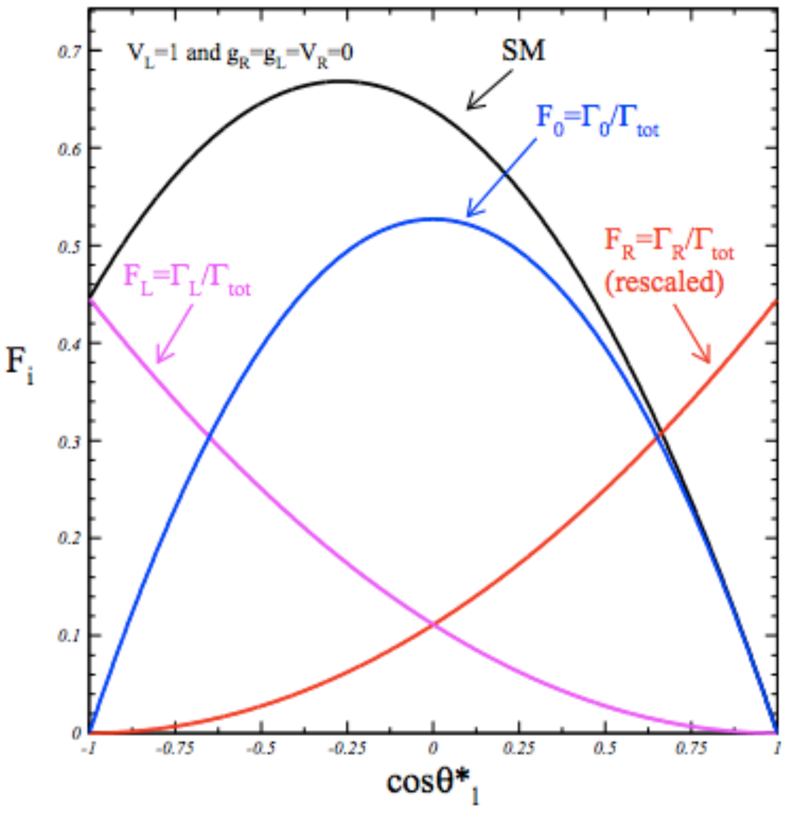
W polarization in top decays

$$\frac{1}{N}\frac{\mathrm{d}N}{\mathrm{d}\cos\theta_\ell^*} = \frac{3}{2}\left[F_0\left(\frac{\sin\theta_\ell^*}{\sqrt{2}}\right)^2 + F_L\left(\frac{1-\cos\theta_\ell^*}{2}\right)^2 + F_R\left(\frac{1+\cos\theta_\ell^*}{2}\right)^2\right]$$

leptonic W
rest frame



$$\theta_\ell^* = \pi - \theta_{\ell b}$$



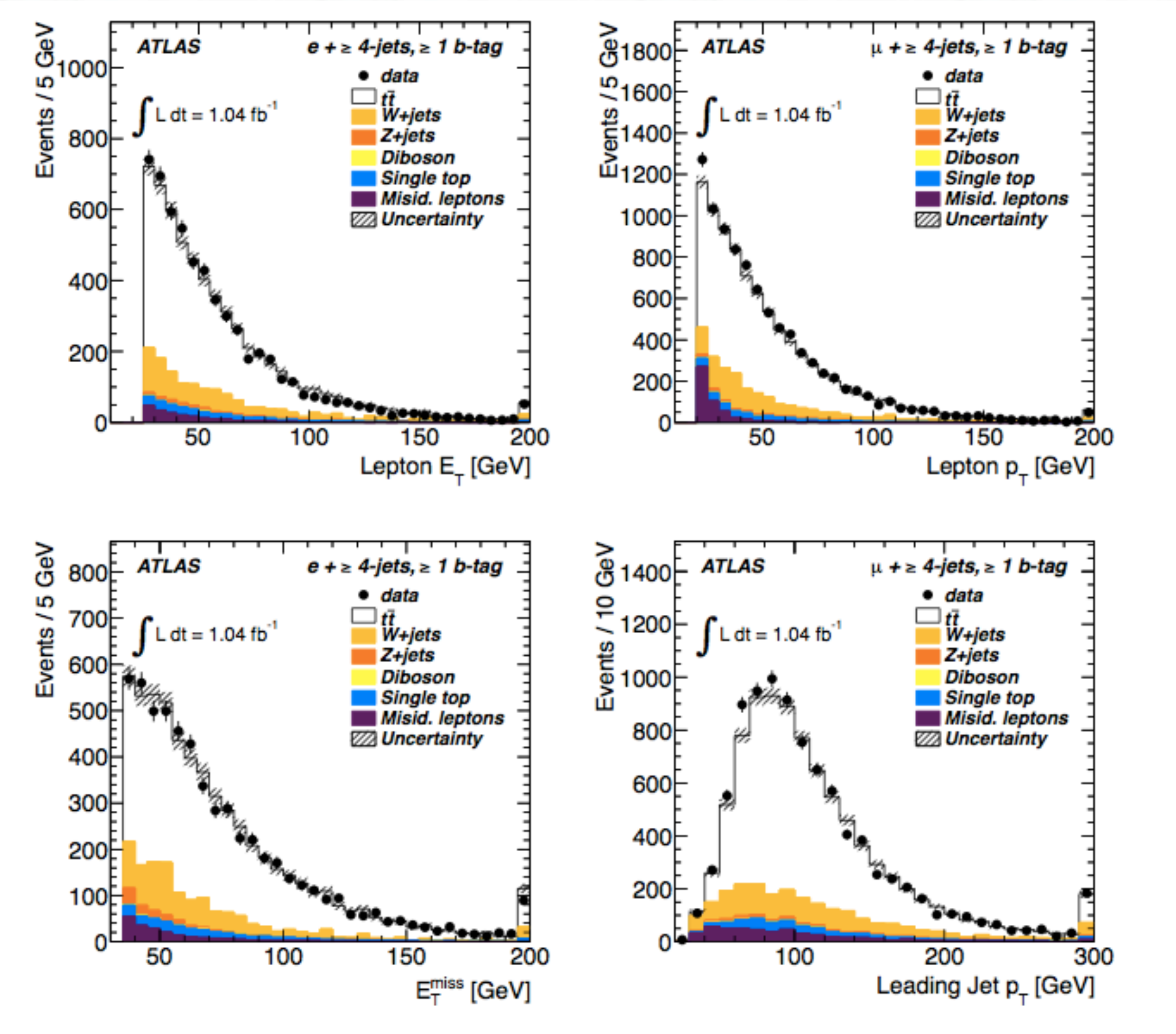
W polarization in top decays

Measurement in both single and dilepton channels (we focus on the single Lepton channel)

- the appropriate single-electron or single-muon trigger had fired;
- events were required to contain exactly one isolated electron or muon;
- in the single-electron channel, $E_{\mathrm{T}}^{\mathrm{miss}} > 35$ GeV and $m_{\mathrm{T}}(W) > 25$ GeV were required[2] while in the single-muon channel the criteria were $E_{\mathrm{T}}^{\mathrm{miss}} > 20$ GeV and $E_{\mathrm{T}}^{\mathrm{miss}} + m_{\mathrm{T}}(W) > 60$ GeV;
- events were required to have at least four jets, with at least one of them being tagged as a b-jet.

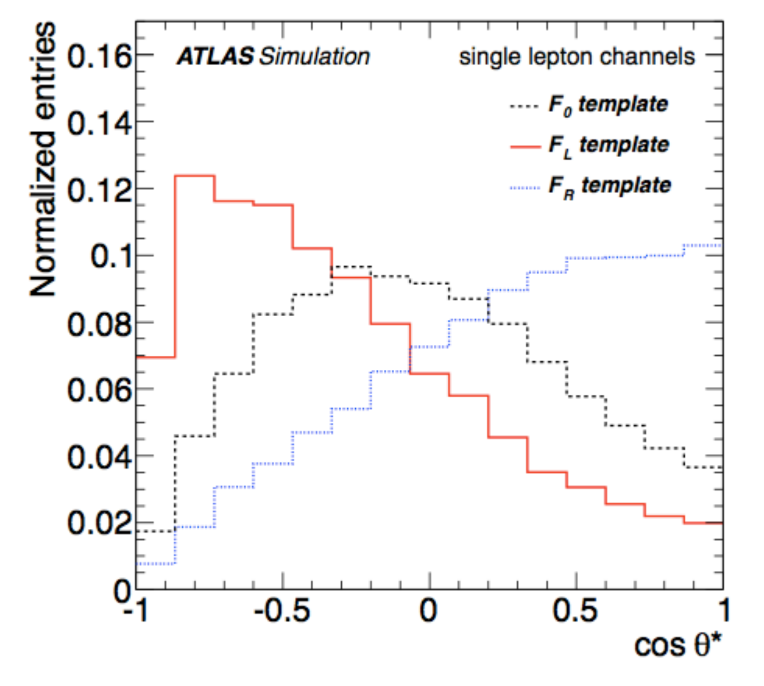
Kinematic fit determination to reconstruct the lepton angle in the W frame

W polarization in top decays



W polarization in top decays

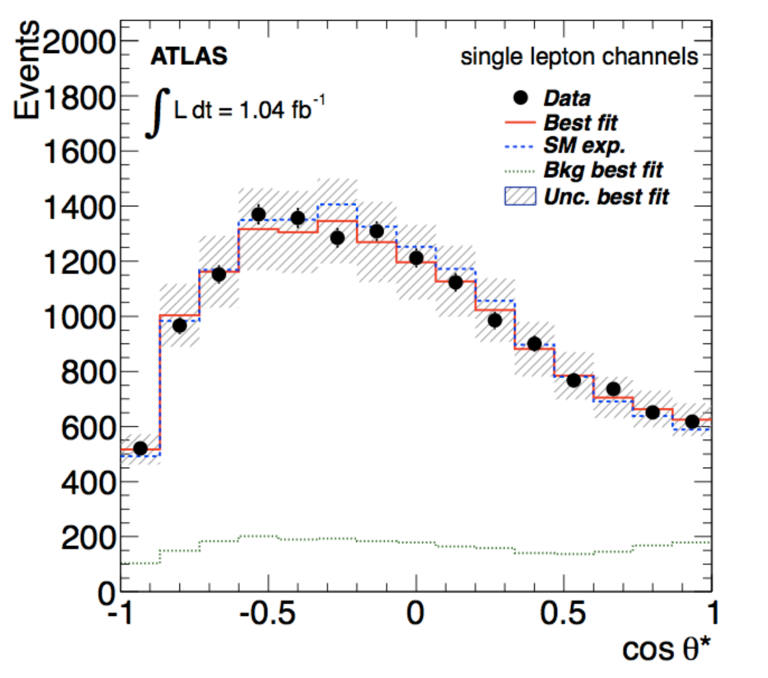
Process	Single electron	Single muon
$t\bar{t}$	4400 ± 1100	6500 ± 1400
W+jets	900 ± 700	1400 ± 1000
Z+jets	120 ± 90	140 ± 90
Diboson	14 ± 12	22 ± 12
Single top	260 ± 90	360 ± 110
Misidentified leptons	220 ± 220	500 ± 500
Total predicted	5900 ± 1300	9000 ± 1800
Data	5830	9121

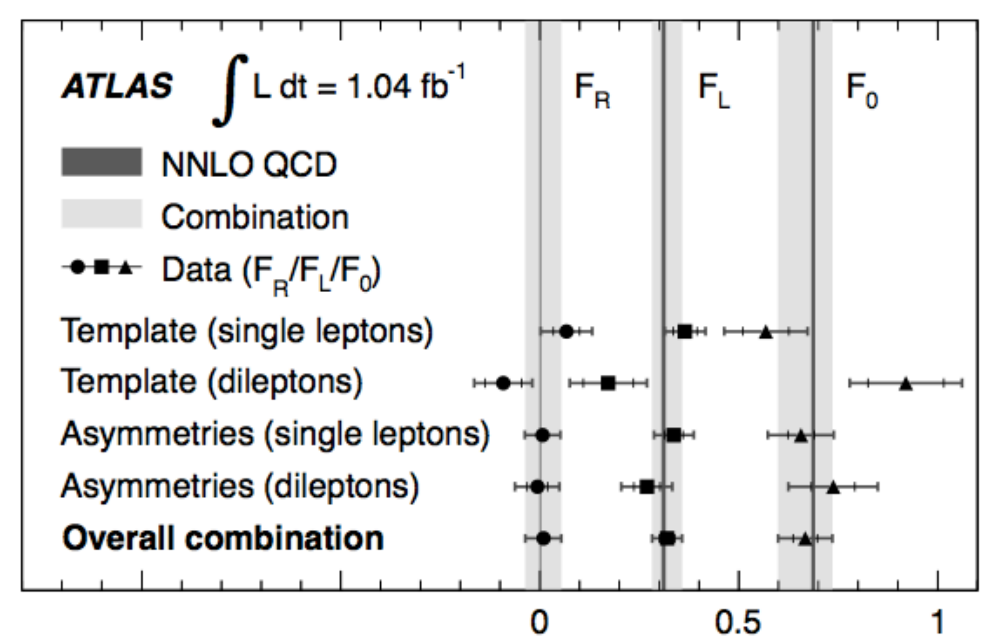


Combined fit to the final distribution with three pure helicity states templates plus three background components (W, non-prompt leptons, everything else)

W polarization in top decays

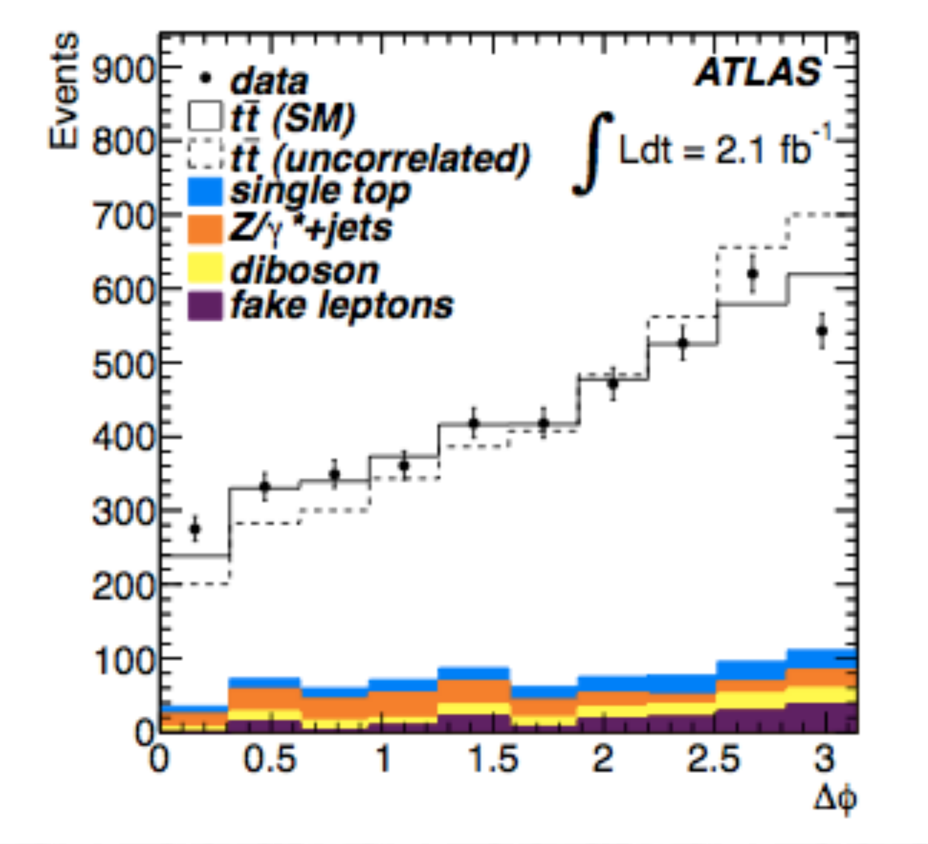
$$F_0 = 0.67 \pm 0.03\ (\text{stat.}) \pm 0.06\ (\text{syst.})\,,$$
$$F_L = 0.32 \pm 0.02\ (\text{stat.}) \pm 0.03\ (\text{syst.})\,,$$
$$F_R = 0.01 \pm 0.01\ (\text{stat.}) \pm 0.04\ (\text{syst.})\,.$$





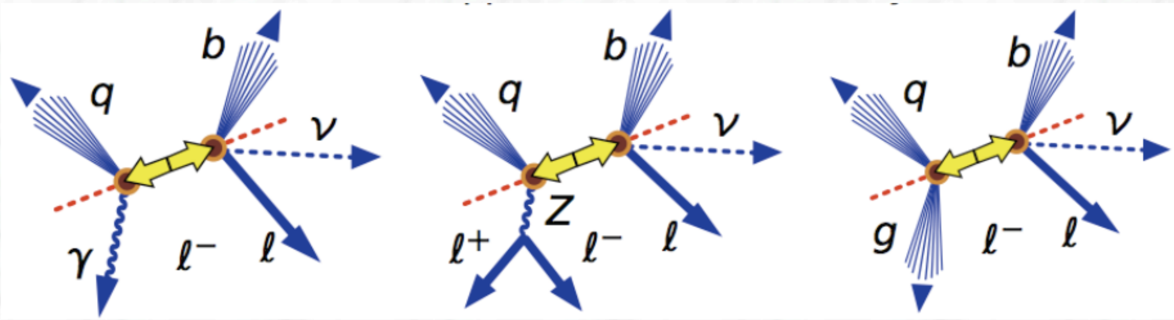
Spin correlations

- Different production channels at the LHC and Tevatron
- This means different spin correlations in the final state -> complementary measurements from Tevatron and LHC
- Angular distribution consistent with the SM
- Absence of correlations excluded at 5.1 sigma



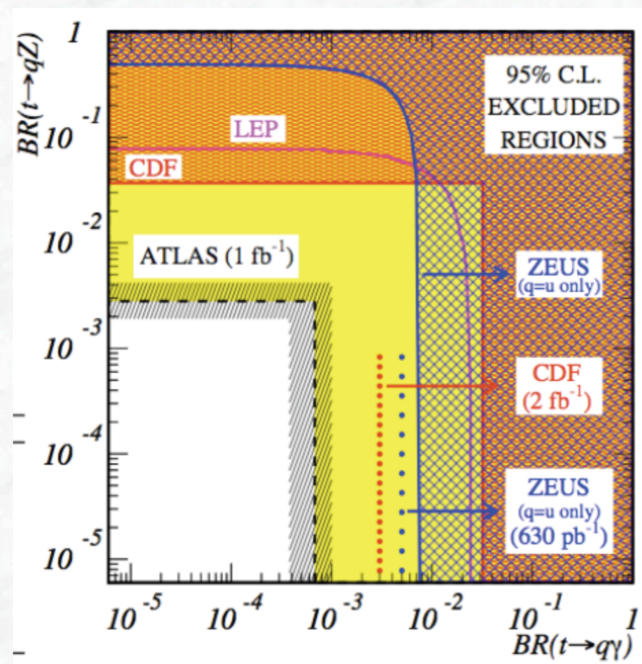
LHC sensitivity for Rare Top Quark Decays

FCNC decays into qγ, qZ and qg



BR in Standard Model:
~ 10^{-12} for qγ and qZ
~ 10^{-10} for qg

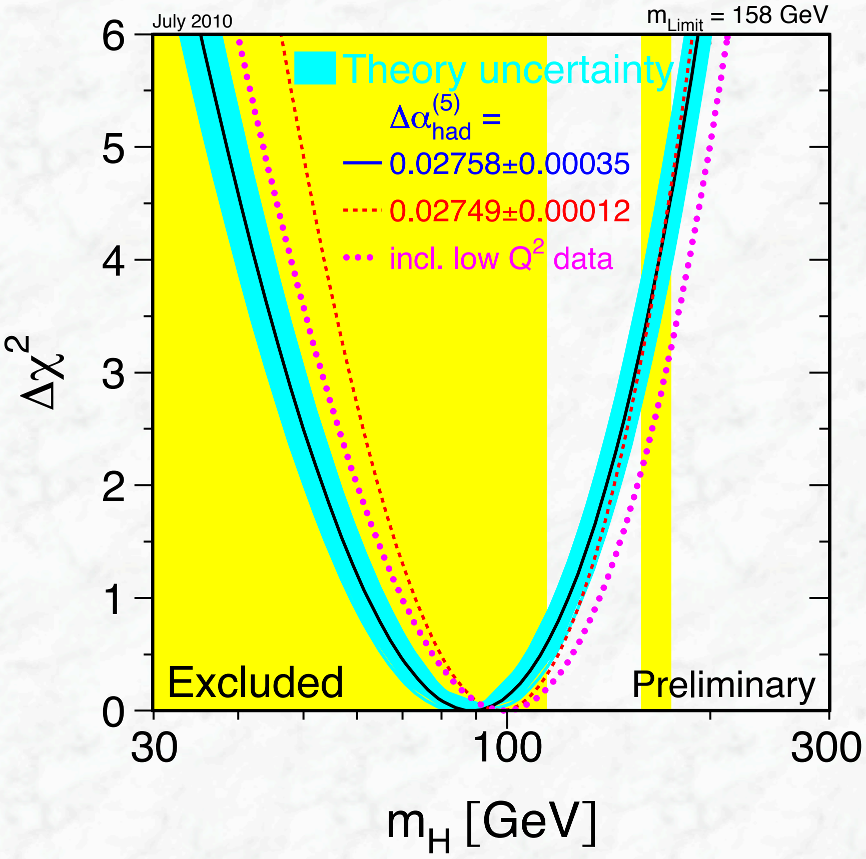
Process	Expected 95% C.L. sensitivity (1 fb^{-1})
$t \rightarrow q\,\gamma$	$6.8 \cdot 10^{-4}$
$t \rightarrow q\,Z$	$2.8 \cdot 10^{-3}$
$t \rightarrow q\,g$	$1.2 \cdot 10^{-2}$

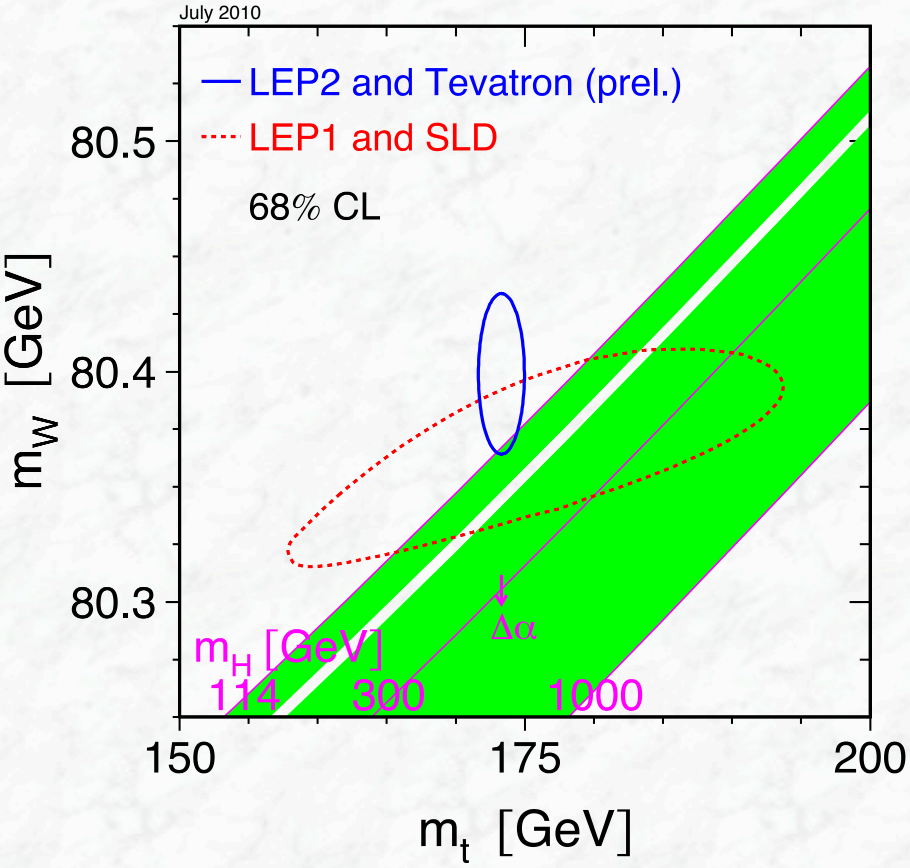


Expected 5σ discovery sensitivity for 100 fb^{-1}:
for qg and qZ final states: ~ 10^{-4}

8.5 Constraints on the Standard Model

Pre – Higgs discovery: the Higgs boson mass enters logarithmically in loop corrections to the W mass



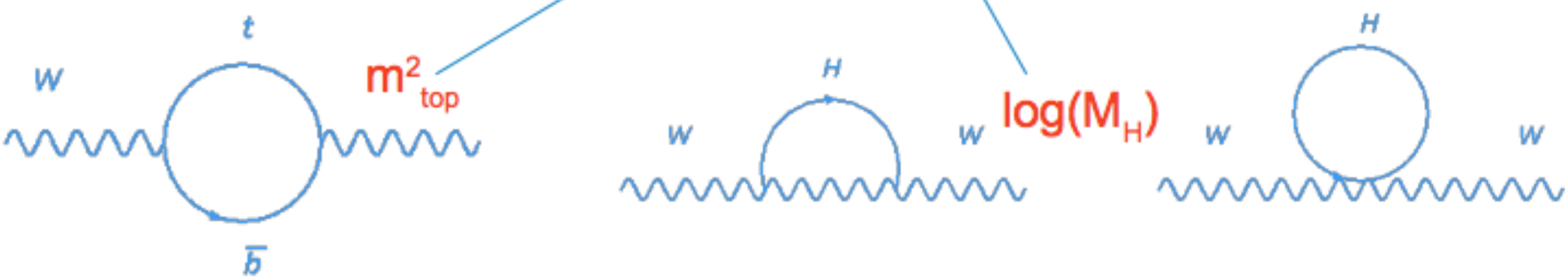


Die Masse des W-Bosons

- Wichtiger Konsistenzest, auch wenn SM Higgs-Boson gefunden ist

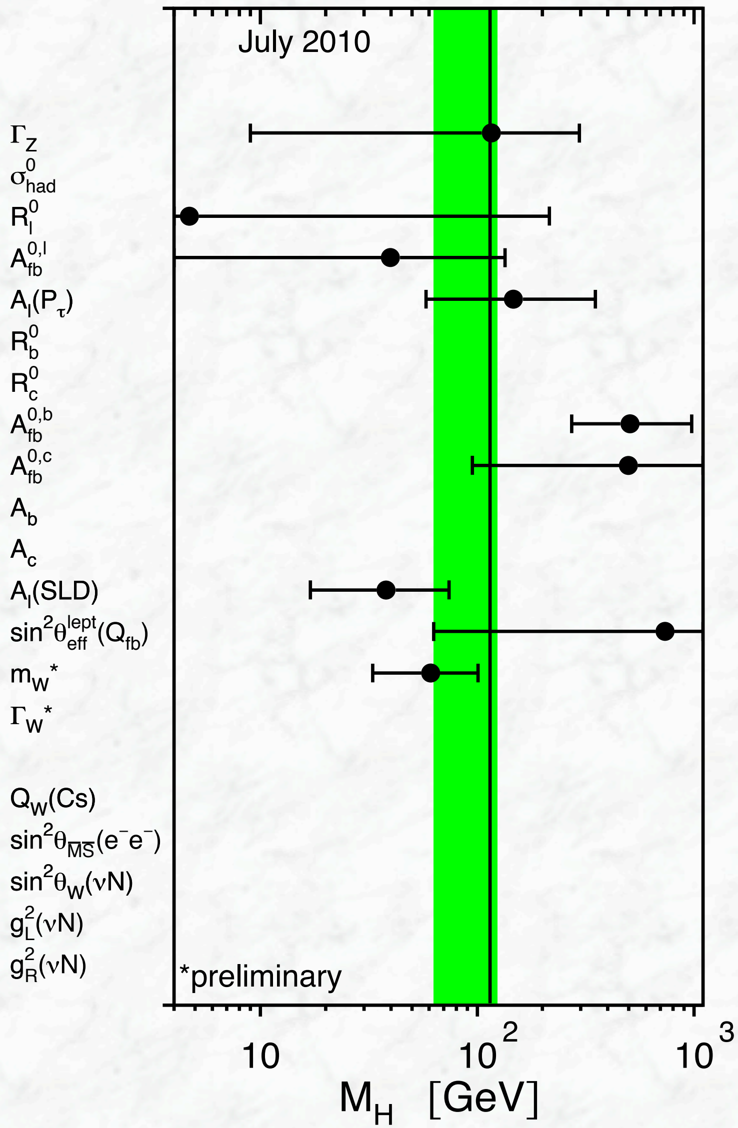
$$m_W = \left(\frac{\pi \, \alpha_{EM}}{\sqrt{2}\, G_F} \right)^{1/2} \frac{1}{\sin\theta_W \sqrt{1 - \Delta r}}$$

Strahlungskorrekturen
$\Delta r \sim 3\ \%$

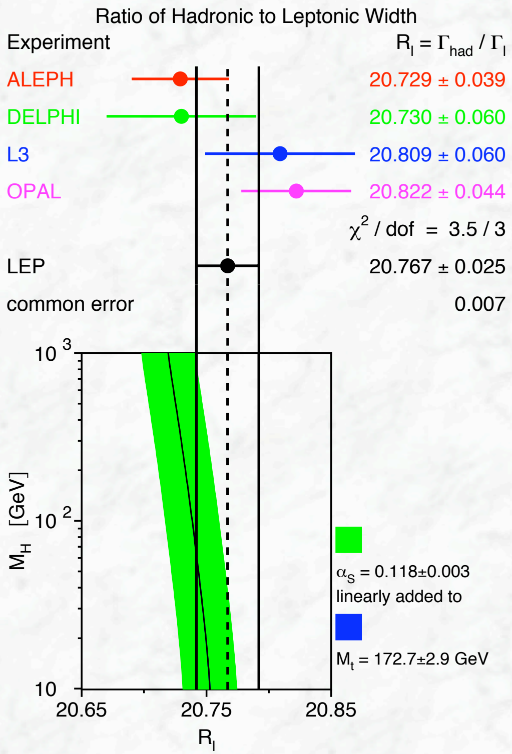


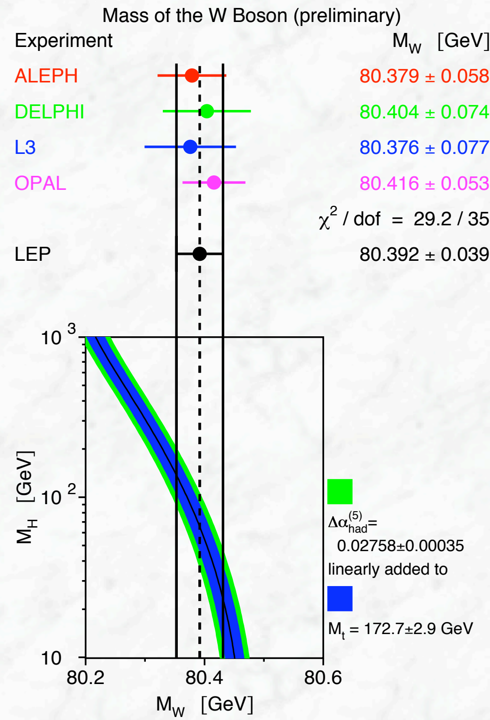
- G_F, α_{EM} und $\sin\theta_W$ sind mit großer Präzision gemessen – nicht limitierend

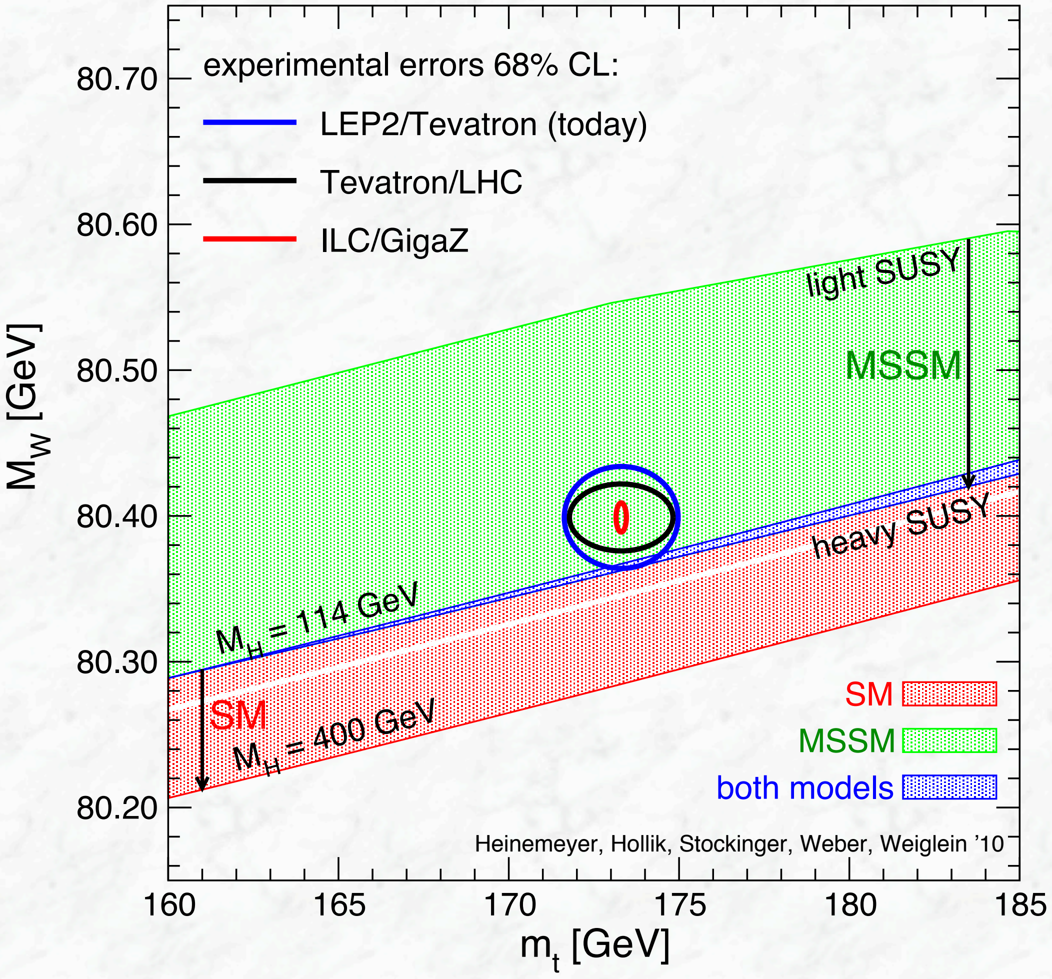
Best estimate for the Higgs boson mass from the different electroweak observables:



Examples: R_l and m_W



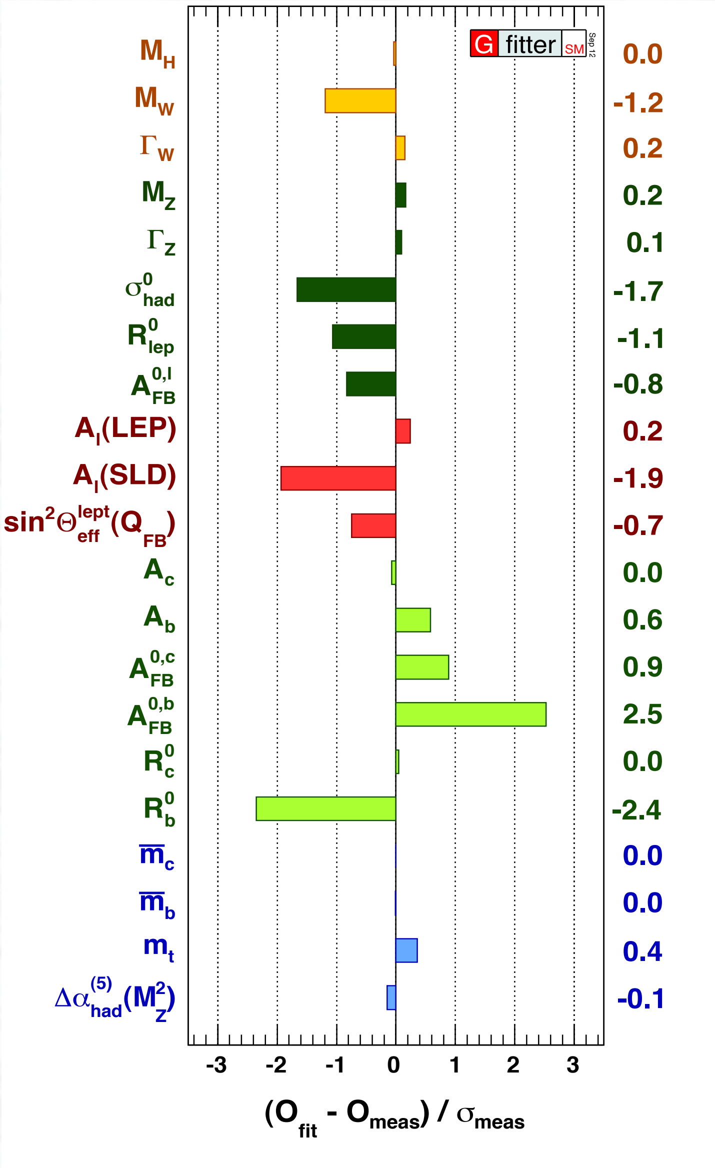


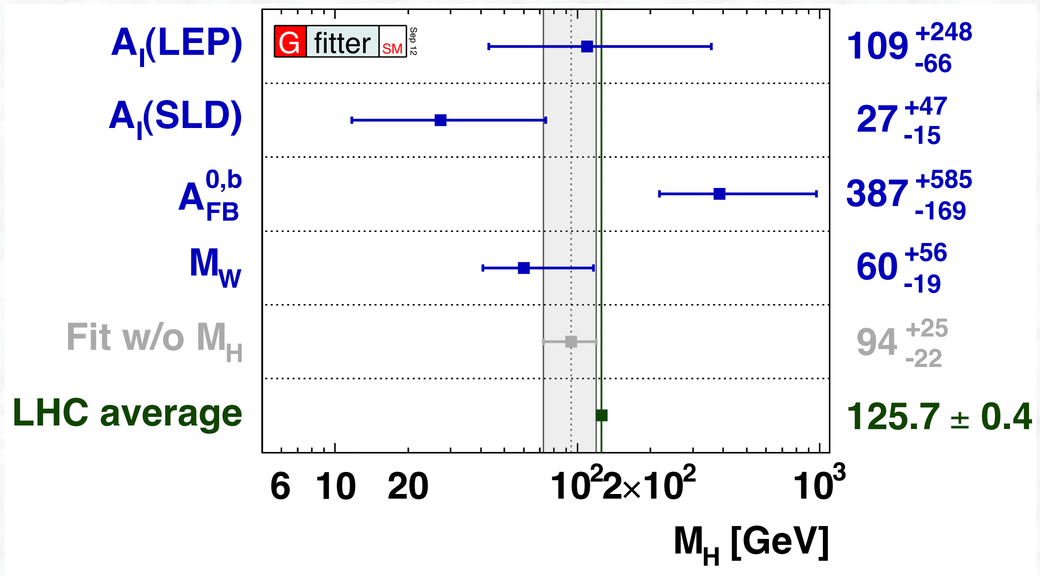


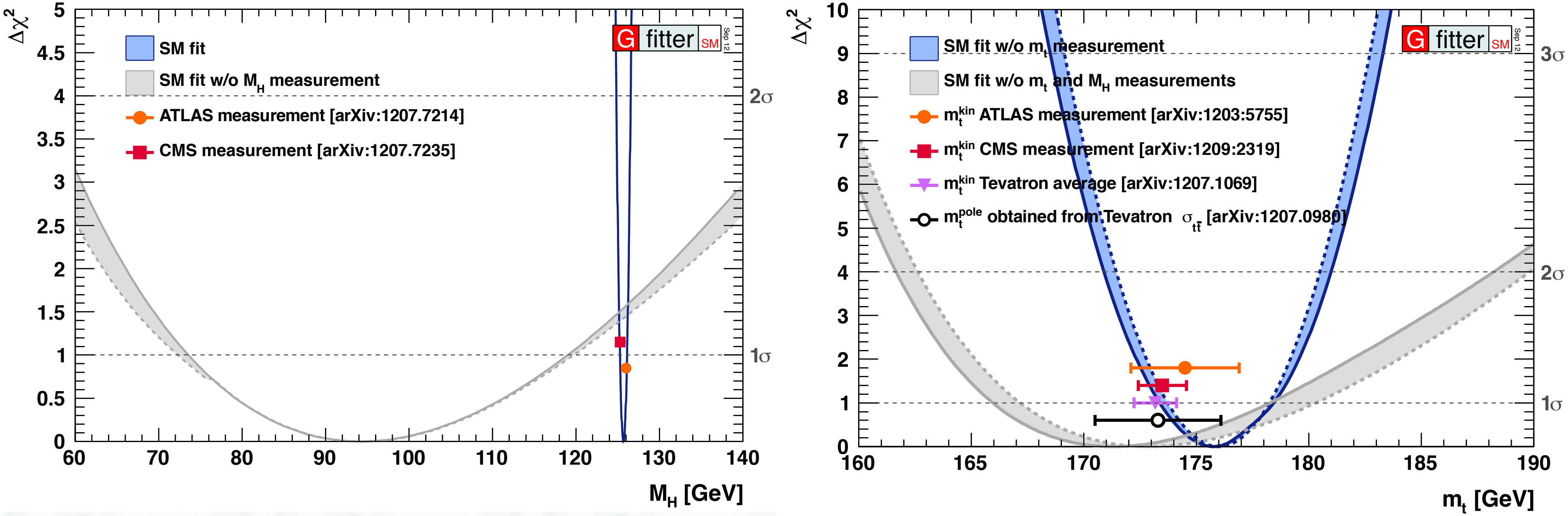
Predictions for future precision (including LHC), compared to the Standard Model and its Minimal Supersymmetric Extension (MSSM)

Ultimate test of the Standard Model: compare direct prediction of Higgs mass with direct observation

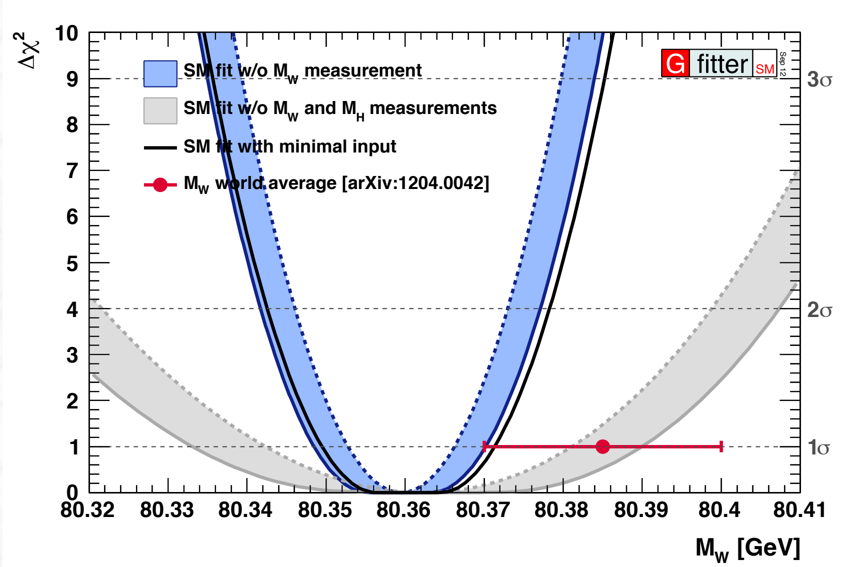
After the Higgs discovery



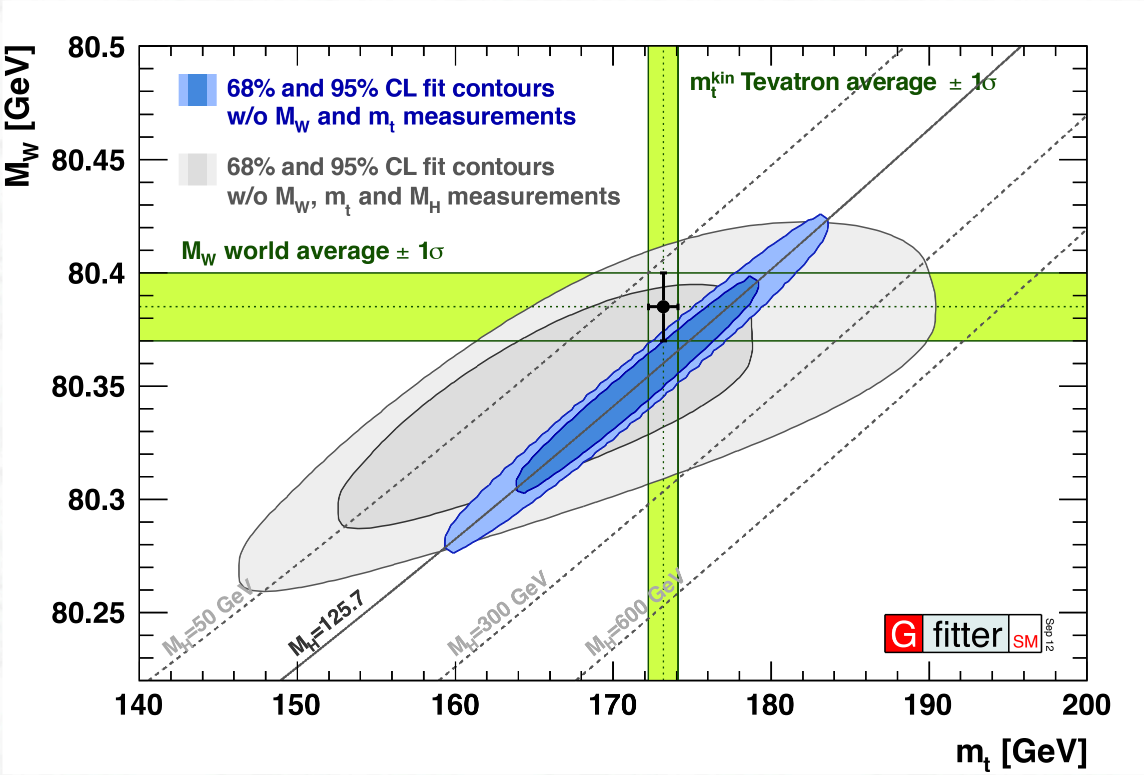




SM fit
SM fit w/o M_H measurement
ATLAS measurement [arXiv:1207.7214]
CMS measurement [arXiv:1207.7235]
M_H [GeV]
Δχ²
2σ
1σ
G fitter SM
SM fit w/o m_t measurement
SM fit w/o m_t and M_H measurements
m_t^kin ATLAS measurement [arXiv:1203:5755]
m_t^kin CMS measurement [arXiv:1209:2319]
m_t^kin Tevatron average [arXiv:1207.1069]
m_t^pole obtained from Tevatron σ_tt̄ [arXiv:1207.0980]
m_t [GeV]
3σ



$\Delta\chi^2$
SM fit w/o M_W measurement
SM fit w/o M_W and M_H measurements
SM fit with minimal input
M_W world average [arXiv:1204.0042]
G fitter SM
Sep 12
3σ
2σ
1σ
0
1
2
3
4
5
6
7
8
9
10
80.32
80.33
80.34
80.35
80.36
80.37
80.38
80.39
80.4
80.41
M_W [GeV]



M_W [GeV]
68% and 95% CL fit contours
w/o M_W and m_t measurements
68% and 95% CL fit contours
w/o M_W, m_t and M_H measurements
m_t^{kin} Tevatron average $\pm 1\sigma$
M_W world average $\pm 1\sigma$
M_H=50 GeV
M_H=125.7
M_H=300 GeV
M_H=600 GeV
G fitter SM
Sep 12
80.5
80.45
80.4
80.35
80.3
80.25
140
150
160
170
180
190
200
m_t [GeV]