

Top physics results from CMS

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Motivation

- Large $t\bar{t}$ cross-section
 - About 20× Tevatron at 7 TeV
- Opportunity to study “bare” quark
 - Decays before hadronisation
- Handles on New Physics
 - Higgs mass uncertainties
 - New phenomena coupling to top
 - Top as background to discovery channels
- Exercise full detector and reconstruction in complex multi-parton events



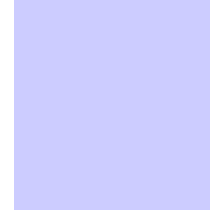
Top production and decay

- Top pair production from initial gg pair dominates
- Top pair decay modes
 - All hadronic (6 jets) – large BR, large QCD background
 - Lepton+jets (4 jets) – smaller BR (per lepton), smaller background
 - Dileptonic (2 jets) – smallest BR, cleanest
- Also consider single top production



Top@CMS in 2010

- 36 pb⁻¹ collected
- Focus on channels with muons and electrons
- Main measurement: top pair cross-section
- First look at other quantities
 - Top quark mass
 - Production asymmetry
 - Top pair invariant mass
 - Single top



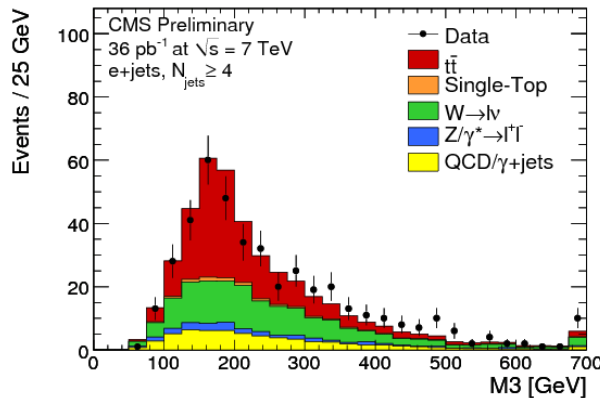
Top pair cross-section



Leptons+jets event selection

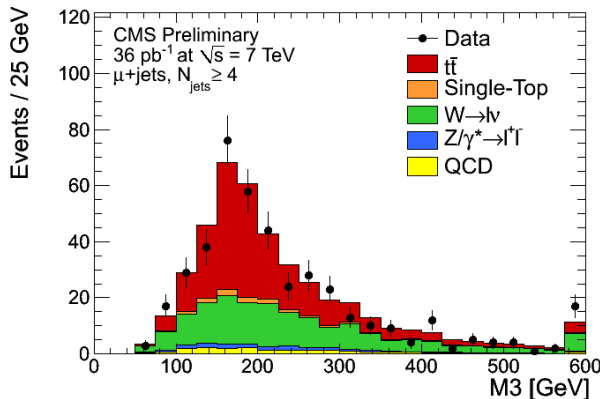
M3 is "poor man's" top mass estimate

e+jets

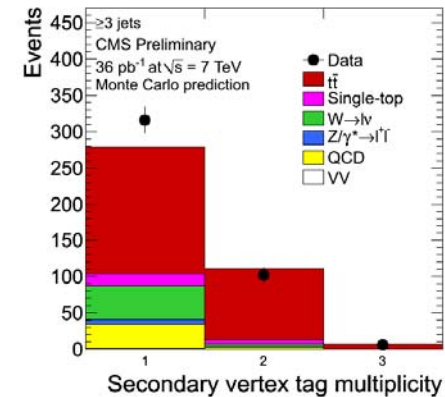


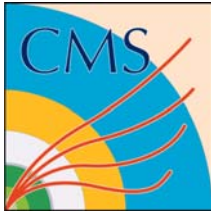
	electron+jets		muon+jets	
	$N_{\text{jet}} = 3$	$N_{\text{jet}} \geq 4$	$N_{\text{jet}} = 3$	$N_{\text{jet}} \geq 4$
$t\bar{t}$	157 ± 25	168 ± 27	197 ± 31	211 ± 33
single top	22 ± 1	8.8 ± 0.6	30 ± 1	11 ± 1
W+jets	374 ± 27	94 ± 7	486 ± 34	115 ± 9
Z+jets	66 ± 5	15 ± 1	46 ± 3	11 ± 1
QCD	314 ± 19	53 ± 8	49 ± 3	8.9 ± 1.0
sum MC	934 ± 55	339 ± 32	807 ± 53	358 ± 37
Data	1183	428	1064	423

μ +jets



b-tagging improves purity (e+jets)





Cross-section with b tags

μ +jets

1-tag

Divide sample according to n. jets and n. b tags

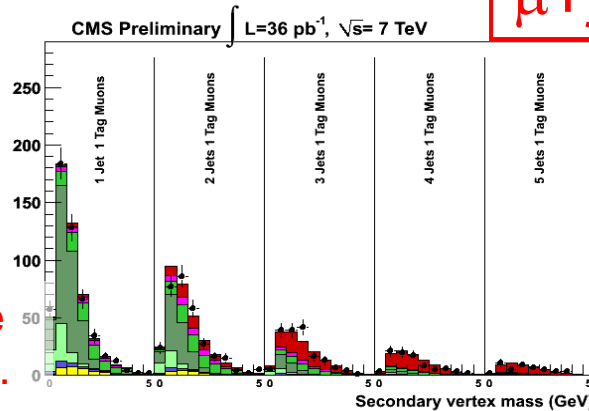


Table 1: Results of the fit for muon+jet events with at least 1 b-tag.

	Data	Total Fit	Top	SingleTop	Wbx	Wcx	Wqq	Zjets	QCD
1 Jet 1 Tag	505	504.0	13.3	25.0	94.2	255.1	81.9	13.9	20.6
2 Jets 1 Tag	314	318.2	51.0	29.4	82.6	97.7	35.0	7.3	15.1
3 Jets 1 Tag	166	158.5	78.3	14.8	29.5	21.9	10.4	2.8	0.8
4 Jets 1 Tag	85	89.2	60.6	4.9	12.8	5.5	3.3	1.3	0.8
5 Jets 1 Tag	45	43.8	34.6	1.5	4.6	1.8	0.9	0.2	0.2
2 Jets 2 Tags	29	24.1	14.7	3.3	5.3	0.5	0.2	0.2	0.0
3 Jets 2 Tags	37	44.0	35.2	3.8	3.9	0.8	0.0	0.2	0.0
4 Jets 2 Tags	41	41.0	36.2	1.9	2.4	0.4	0.0	0.1	0.0
5 Jets 2 Tags	27	26.0	24.0	0.8	1.0	0.1	0.1	0.1	0.0
Total	1249	1248.8	347.8	85.4	236.2	383.8	131.8	26.1	37.6

2-tag

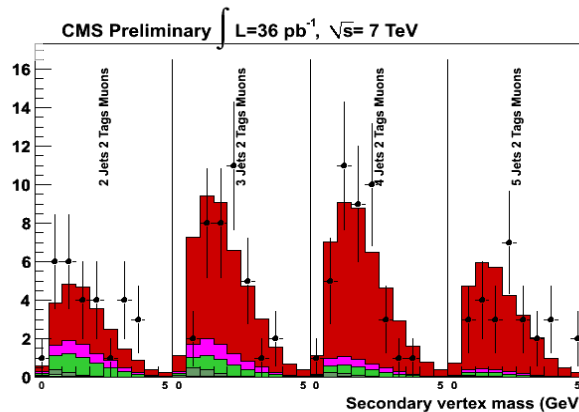


Table 2: List of systematic uncertainties for the muon analysis. Due to the correlation between parameters in the fit, the combined number is not the sum of the squares of the contributions.

Source	Uncertainty (%)
Systematic uncertainties	
Lepton ID/reco/trigger	3
Unclassified E_T^{miss} resolution	< 1
$t\bar{t}$ Jets Q^2 -scale	2
ISR/FSR	2
ME to PS matching	2
PDF	3.4
Profile likelihood parameters	
Jet energy scale and resolution	9.5
b tag efficiency	9.1
W+Jets Q^2 -scale	3.8
Combined	12.5



Cross-section with b tags

e+jets

1-tag

Divide sample according to n. jets and n. b tags

2-tag

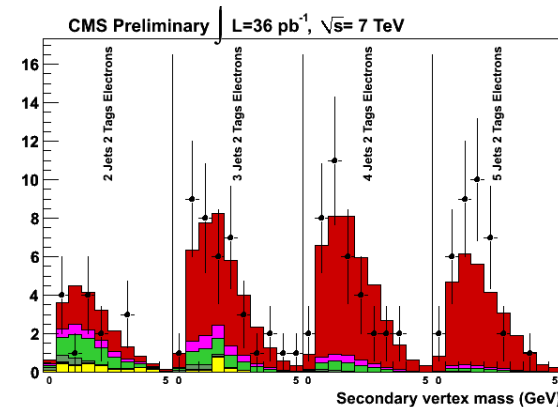
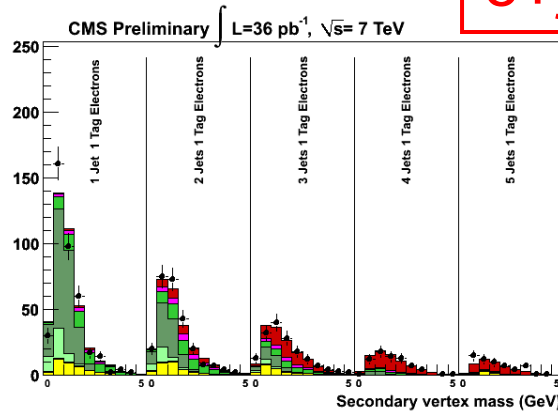


Table 3: Results of the electron+jet fit for events with at least 1 b-tag.

	Data	Total Fit	Top	SingleTop	Wbx	Wcx	Wqq	ZJets	QCD
1 Jet 1 Tag	388	389.8	6.0	14.1	42.4	249.5	26.9	3.1	47.9
2 Jets 1 Tag	252	245.3	31.7	21.0	44.4	104.0	14.8	3.3	26.2
3 Jets 1 Tag	159	156.0	62.7	12.2	23.5	34.4	5.1	2.1	16.0
4 Jets 1 Tag	71	80.7	60.6	4.8	8.2	9.2	1.4	0.8	-4.3
5 Jets 1 Tag	57	52.1	40.9	1.6	2.6	3.0	0.5	0.4	3.0
2 Jets 2 Tags	14	19.9	9.4	2.3	4.7	1.2	0.1	0.2	2.0
3 Jets 2 Tags	39	38.1	29.1	3.1	3.8	0.9	0.0	0.2	0.9
4 Jets 2 Tags	37	41.3	37.1	1.9	1.9	0.4	0.0	0.1	0.0
5 Jets 2 Tags	37	30.7	28.8	0.9	0.8	0.2	0.0	0.1	0.0
Total	1054	1053.8	306.3	61.8	132.1	402.7	48.9	10.3	91.6

Table 4: List of systematic uncertainties for the electron fit. Due to the correlation between parameters in the fit, the combined number is not the sum of the squares of the contributions.

Source	Uncertainty (%)
Systematic uncertainties	
Lepton ID/reco/trigger	3
Unclustered E_{T}^{miss} resolution	< 1
$t\bar{t}$ + Jets Q^2 -scale	2
ISR/FSR	2
ME to PS matching	2
PDF	3.4
Profile likelihood parameters	
Jet energy scale and resolution	8.5
b tag efficiency	8.3
W+Jets Q^2 -scale	3.2
Combined	11.9



l+jets cross-section

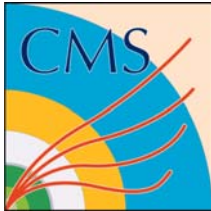
- b-tagged analysis gives best precision
- Independent result without b-tags

$$\sigma_{\bar{t}t} = 150 \pm 9 \text{ (stat.)} \pm 17 \text{ (syst.)} \pm 6 \text{ (lum.) pb.}$$

$$\sigma_{\bar{t}t} = 173_{-32}^{+39} \text{ (stat + syst)} \pm 7 \text{ (lumi) pb}$$

with b-tags

w/o b-tags



Cross-section from dilepton events

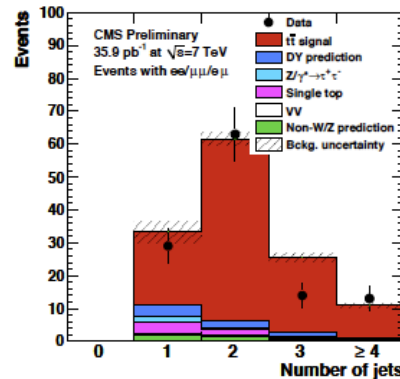
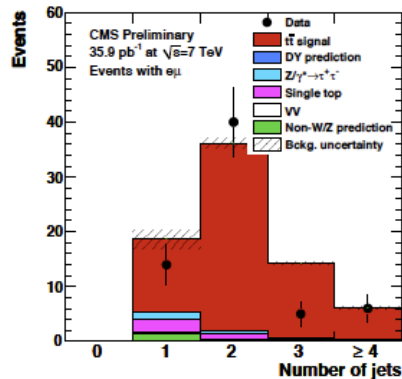
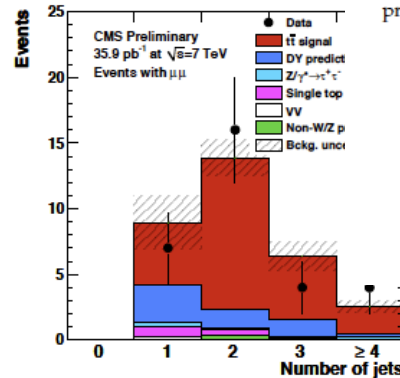
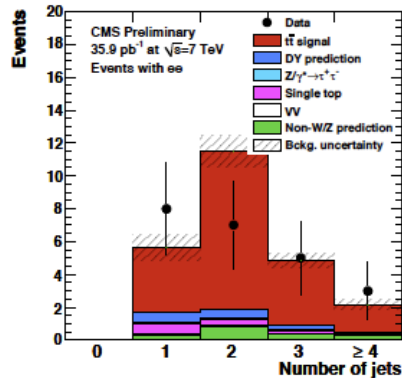
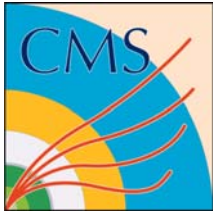


Table 5: Expected signal and background contributions compared to the number of events observed in data passing signal selection with at least two jets and at least one b-tagged jet. The format of the presented results is the same as in Table 4.

Source	e ⁺ e ⁻	$\mu^+\mu^-$	e [±] μ^{\mp}
Dilepton tt	13.3 ± 1.3 ± 2.1	17.2 ± 1.6 ± 2.7	48.5 ± 3.9 ± 7.5
VV	0.09 ± 0.03	0.09 ± 0.03	0.2 ± 0.1
Single top - tW	0.5 ± 0.2	0.6 ± 0.2	1.6 ± 0.5
Drell-Yan $\tau^+\tau^-$	0.2 ± 0.1	0.2 ± 0.1	0.7 ± 0.3
Drell-Yan e ⁺ e ⁻ , $\mu^+\mu^-$	0.7 ± 0.7	2.6 ± 1.8	N/A
Non-W/Z leptons	0.9 ± 1.2	0.3 ± 0.8	0.5 ± 1.1
Total backgrounds	2.3 ± 1.4	3.8 ± 2.0	3.0 ± 1.4
Data	15	24	51

Cross-section result

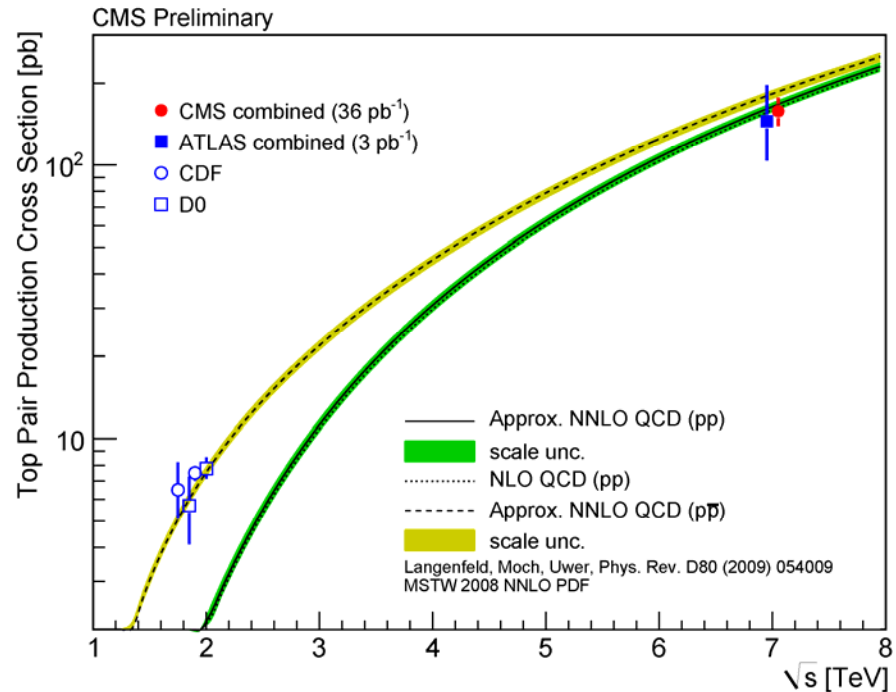
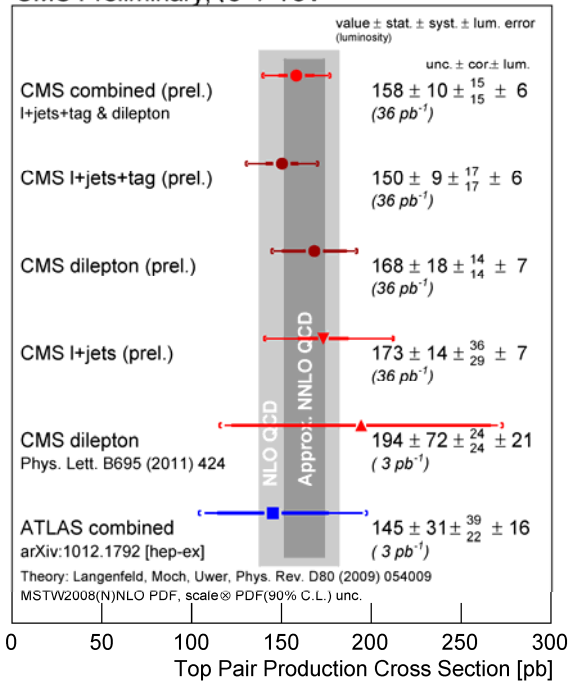
$$168 \pm 18(\text{stat}) \pm 14(\text{syst}) \pm 7(\text{lum}) \text{ pb}$$

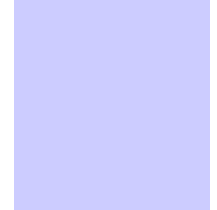


Cross-section combination (CMS TOP-11-001)

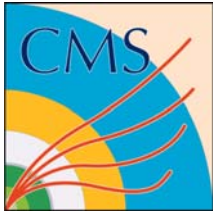
- Combination of b-tagged l+jets with dilepton measurement
- Uses Best Linear Unbiased Estimate (BLUE) technique

CMS Preliminary, $\sqrt{s}=7$ TeV



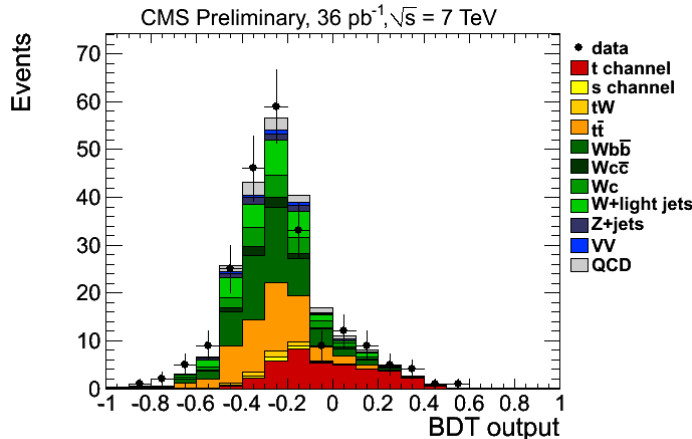
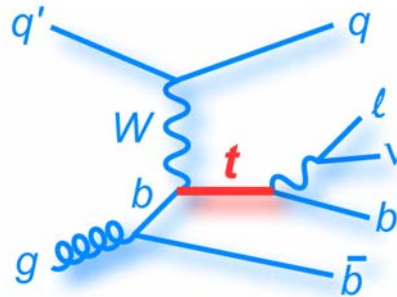


Other measurements

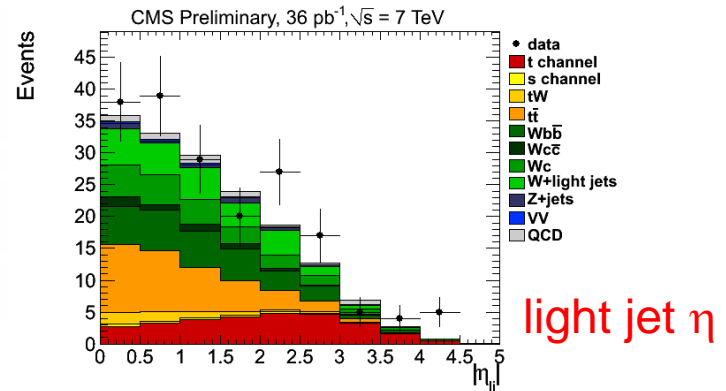


Single top cross-section (CMS TOP-10-008)

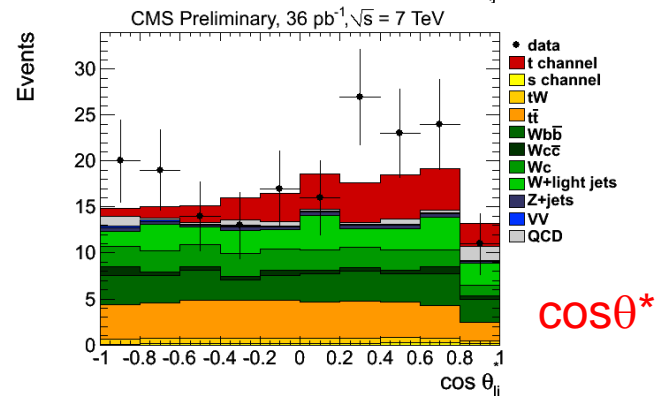
- t-channel (dominant)
 - Central b-tagged jet
 - Forward light jet
- Leptonic decay of W
 - Isolated lepton
 - Large $M_T(l\nu)$
- Two approaches
 - Backgrounds are large



Boosted decision tree (BDT)



light jet η



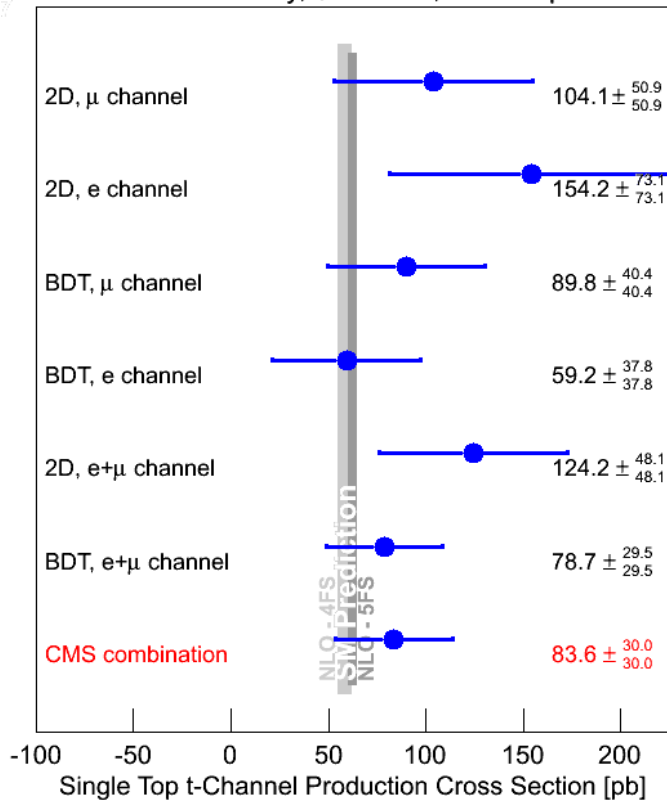
$\cos\theta^*$

"2-D" fit



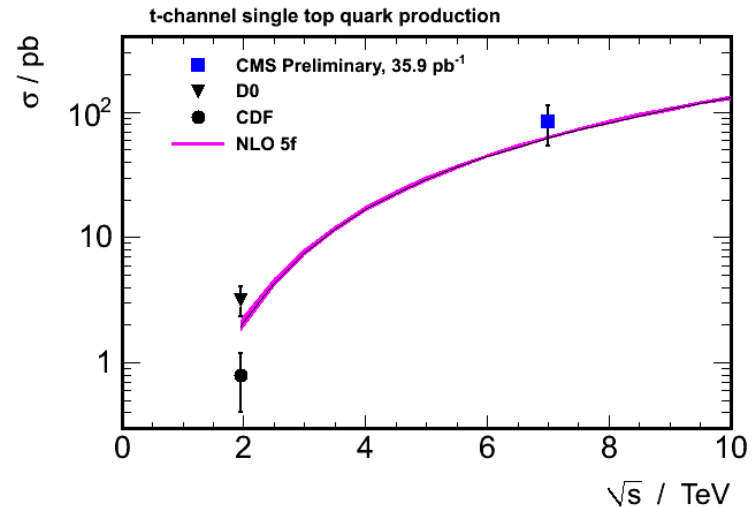
Single top results

CMS Preliminary, $\sqrt{s}=7$ TeV, $L=35.9$ pb $^{-1}$



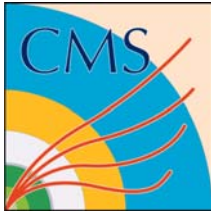
Combination using BLUE:

$$\sigma = 84 \pm 30 \text{ pb}$$

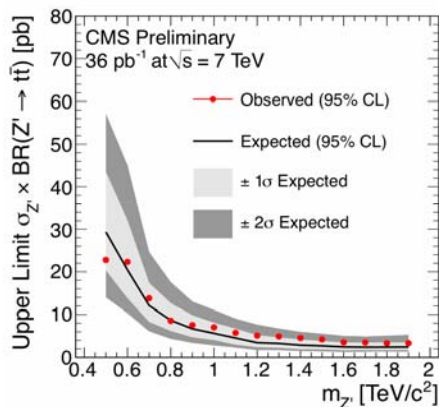
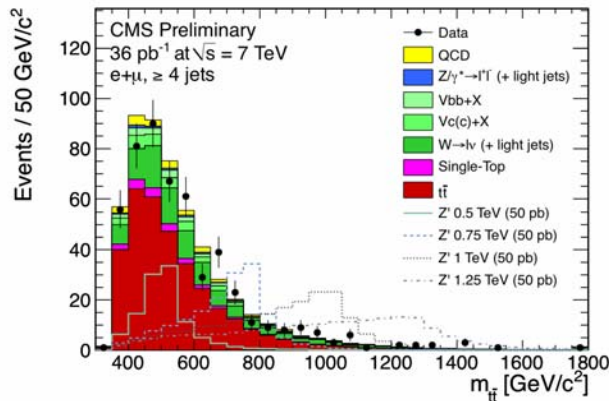


Significance (2D) 3.7σ obs/ 2.1σ exp

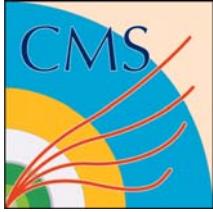
Significance (BDT) 3.5σ obs/ 2.9σ exp



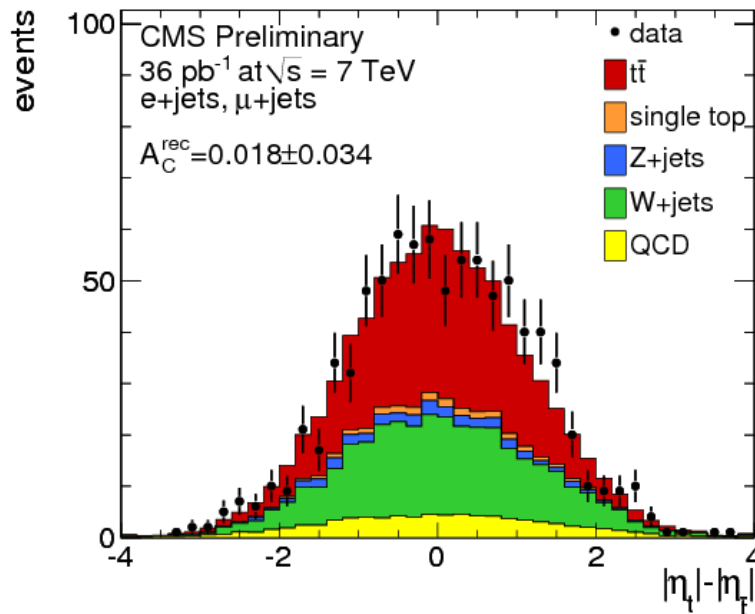
Top pair invariant mass (CMS TOP-10-007)



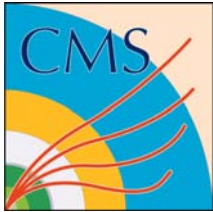
- Lepton+jets selection
 - Electron and muon channels
 - Additional cuts on jet p_T , MET
- Kinematic fit to top pair hypothesis
- Search for narrow resonance in invariant mass spectrum
 - Template fit to distributions in different categories
 - lepton type, n. jets, n. b tags
 - Good agreement with Standard Model expectations
- Limits set for Z' production



Charge asymmetry (CMS TOP-10-010)

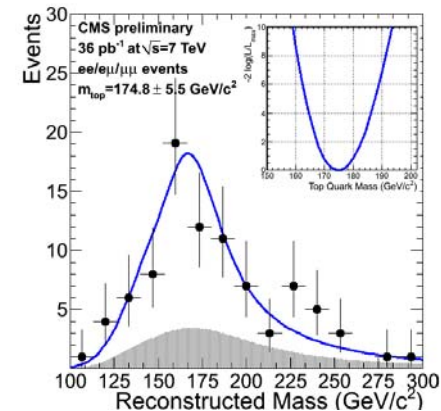


- Small effect predicted in SM
 - Top quark η distribution *narrower* than antiquark
 - But dominant gg production is symmetric
 - Measured quantity:
$$|\eta_t| - |\eta_{\bar{t}}|$$
 - Asymmetry prediction from SM
 - $A_C = 0.0130(11)$
- Lepton+jets selection
- Fit to identify top and anti-top
- Unfold measured asymmetry
 - $A_C = 0.06 \pm 0.13(\text{stat}) \pm 0.03(\text{syst})$

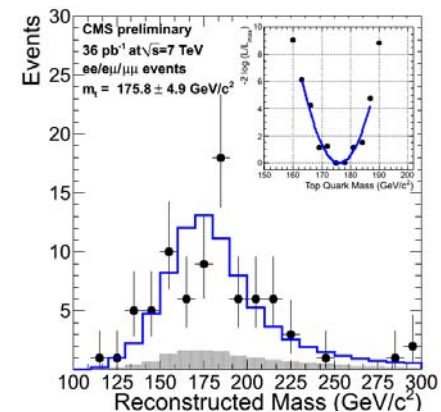


Top mass measurement (CMS TOP-10-006)

- Top mass measurement in dilepton channel
- Two numerical methods
 - Kinematic analysis
 - Analytical matrix element weighting
- Use of b tag information improves reconstruction



Kinematic
fit



Matrix
weighting



First top mass result

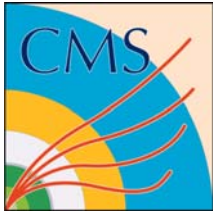
Table 2: Summary of the systematic uncertainties (in GeV/c^2) in the measurement of m_{top} , together with their correlations and combined values.

Source	KINb	AMWT	Correlation factor	Combination
jet energy scale	+3.1/-3.7	3.0	1	3.1
<i>b</i> -jet energy scale	+2.2/-2.5	2.5	1	2.5
Underlying event	1.2	1.5	1	1.3
Pileup	0.9	1.1	1	1.0
Jet-parton matching	0.7	0.7	1	0.7
Factorization scale	0.7	0.6	1	0.6
Fit calibration	0.5	0.1	0	0.2
MC generator	0.9	0.2	1	0.5
Parton density functions	0.4	0.6	1	0.5
<i>b</i> -tagging	0.3	0.5	1	0.4

Table 3: Summary of measured top quark mass for the KINb and AMWT methods with the contributing weights to the combined mass value.

Method	Measured m_{top} (in GeV/c^2)	Weight
AMWT	$175.8 \pm 4.9(stat) \pm 4.5(syst)$	0.65
KINb	$174.8 \pm 5.5(stat)_{\pm 5.0}^{+4.5}(syst)$	0.35
combined	$175.5 \pm 4.6(stat) \pm 4.6(syst)$ $\chi^2/dof=0.040$ (p-value=0.84)	

Combined result using BLUE



Summary and outlook

- First results from CMS across a range of top physics areas
 - SM measurements
 - Quantities sensitive to deviations from SM
- Lots more data in 2011
 - Improved statistics and systematics
 - Cover all decay channels (tau and all-hadronic)
 - Wider range of analyses

