Inclusive ttbar cross-section in μ+Jets channel using data driven techniques

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Outline

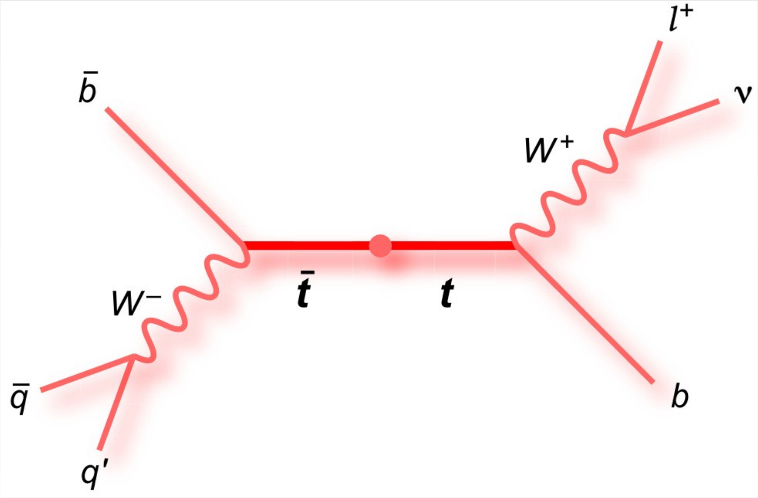
Disclaimer: Results in this talk are still preliminary!

- Introduction
- Event Selection
- Analysis Method (selection & background estimation)
- Systematic Uncertainties
- Neyman Construction from pseudo experiments to obtain final σ_{tt} result with full uncertainty
- Conclusions

Introduction

Motivation:

- **Heaviest particle** and therefore tightly coupled to the Higgs
- Provides good test of **standard model**
- Background to various BSM signals

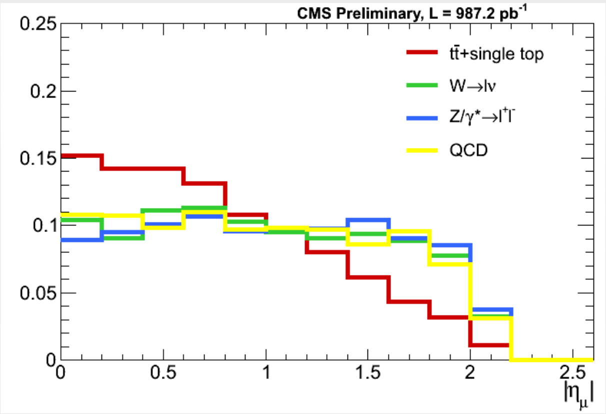


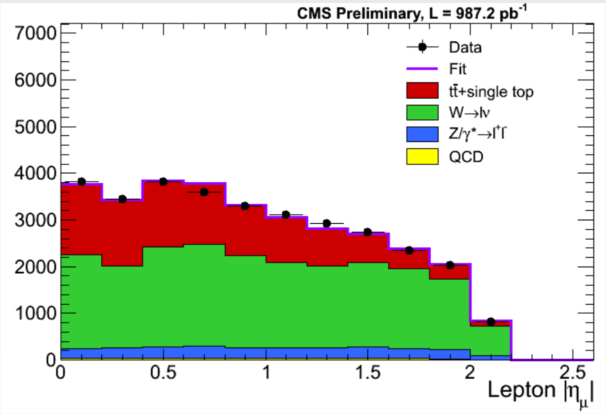
- ttbar pairs are **produced** 90% of the time through **gluon-gluon fusion**
- **Decay** rapidly ~100% to a W and a b quark
- Theoretical $\boldsymbol{\sigma_{tt}}$ **~ 158 pb**

Analysis Method

- Full PF event reconstruction used
- Cross section measured by means of maximum likilihood fit of $|\eta_{lepton}|$ distribution.
- Fit parameters are normalisation factors $N_{sig}(N_{tt}+N_{sing\text{-}t})$, N_{W}, N_{Z}, N_{QCD}. Starting values taken from MC estimation.
- Signal template from MC
- **Data driven BG templates:**

  using BG enriched regions





Event Selection

- **Muon**: HLT_Mu30 (987.2 pb^{-1})

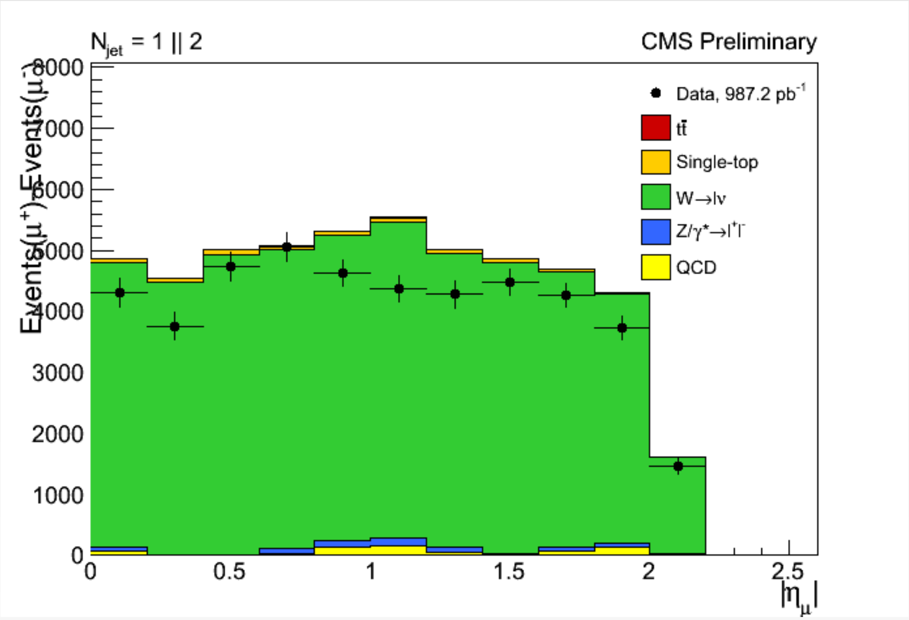
1. Exactly 1 high p_t (> 35 GeV), isolated muon (<0.125), $|\eta_\mu| < 2.1$ & mu ID
2. Loose muon veto (p_t>10 GeV, $|\eta_\mu| < 2.5$, relIso < 0.2)
3. Loose electron veto (p_t>15 GeV, $|\eta_e| < 2.5$, relIso < 0.2)
4. Jet selection: require >=3 jets (loose ID, p_t>30 GeV, $|\eta_j| < 2.4$)

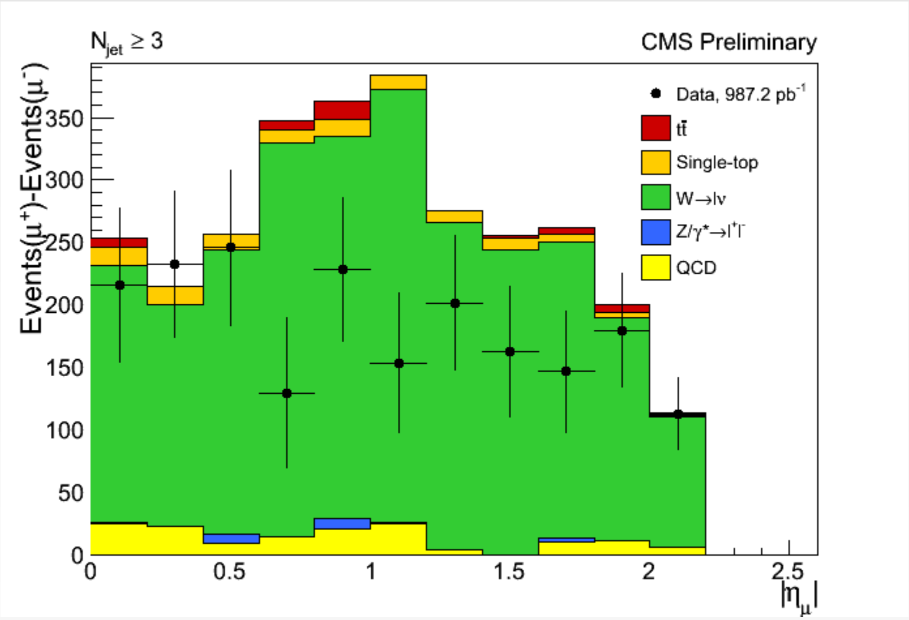
Cut Flow:

2011 MC Events scaled to 987.2pb^{-1}							
# Events	$t\bar{t}$	W+jets	Z+jets	QCD	Single-t	Total MC	Data
Initial	155484	30913180	3008985	83595406	83851	1.17757e+08	46976284
trigger and PV	24496	3825206	601544	3985165	6991	8.4434e+06 (7.1702)	14817498 (31.5425)
1==mu	14910	2209137	263201	17812	4476	2.50954e+06 (29.7219)	2558884 (17.2693)
loose mu veto	14240	2209105	110793	17706	4401	2.35624e+06 (93.8917)	2394181 (93.5635)
loose e veto	12794	2208666	110186	17529	4246	2.35342e+06 (99.8801)	2390848 (99.8608)
> 3jet	9620	17889	2221	317	1047	31094 (1.32123)	31955 (1.33656)

W+Jets Template Extraction

- pp collisions produce more W_+ than W_-
- Use $|\eta_{l+}| - |\eta_{l-}|$ and then correct to get the charge sum distribution
- Charge subtracted distributions done in 1||2 jet bin:





- Gives a relatively pure W+Jets sample

W+Jets Template Extraction

- **Correction factors** required to account for different |η| shapes for l+ and l-

σ_{w+}/σ_{w-} = 1.6 ± 0.3
[EWK-10-012]

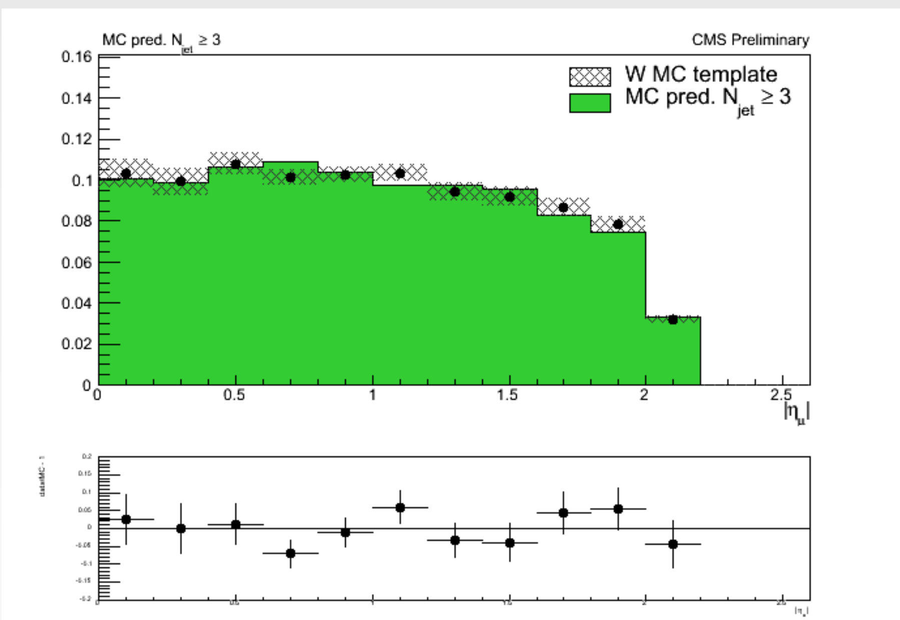
$$c_{\mathrm{W}}^{i} = \left(1 + \frac{2}{R\rho_{\varepsilon}\rho_{i} - 1}\right)$$

Normalised differential didtribution

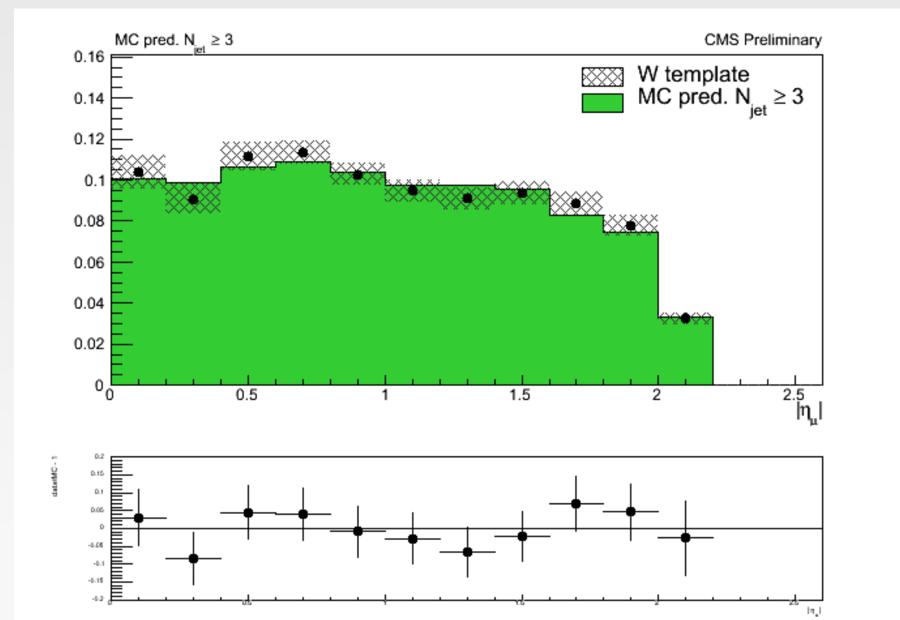
Accounts for selection effects

- Multiply charge subtracted (1||2 jets) by correction factors calculated using the MCFM package @NLO

Closure Tests Performed On Monte Carlo:

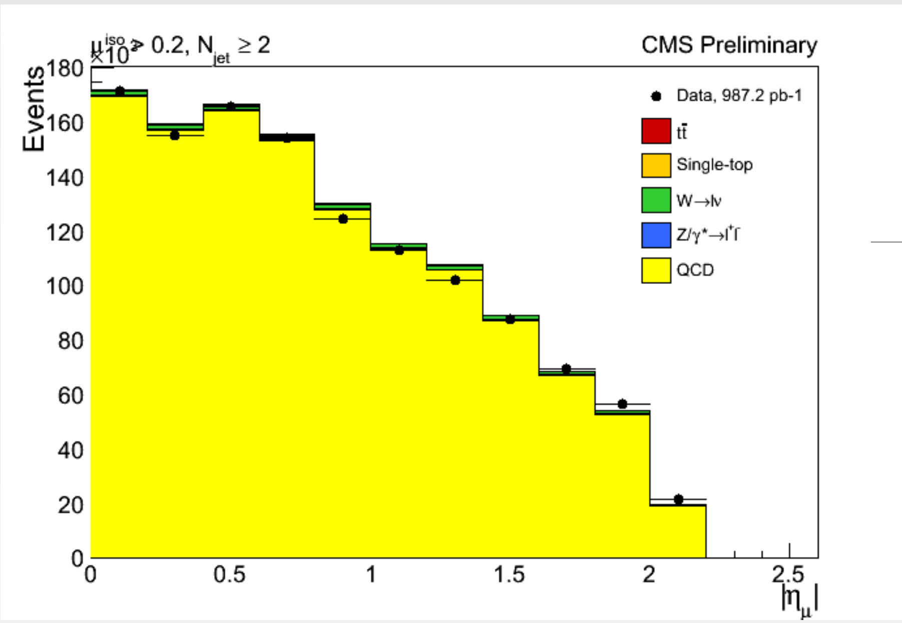


Applying correction factors to data gives our data driven template:

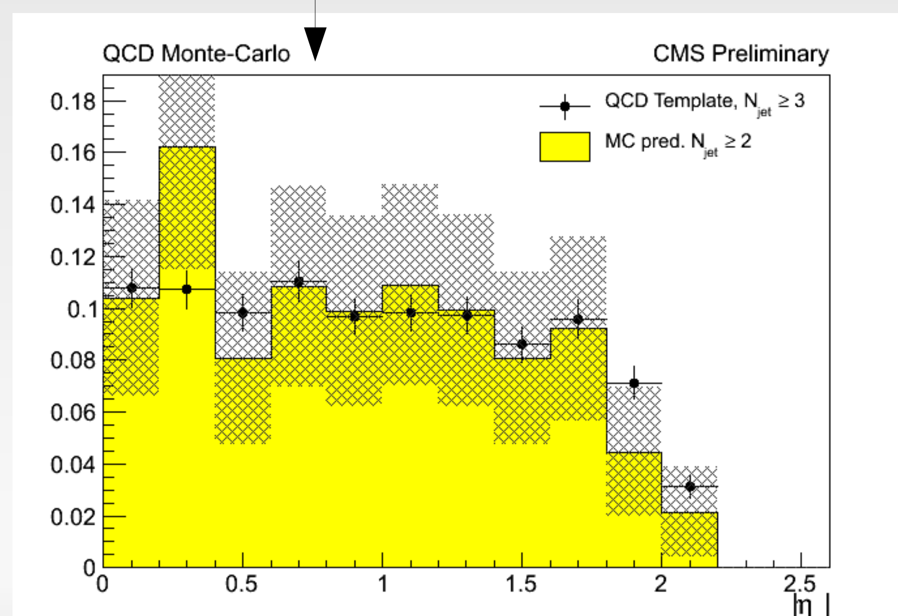


QCD Template Extraction

- Invert the relIso cut (>0.2) to obtain a pure QCD sample

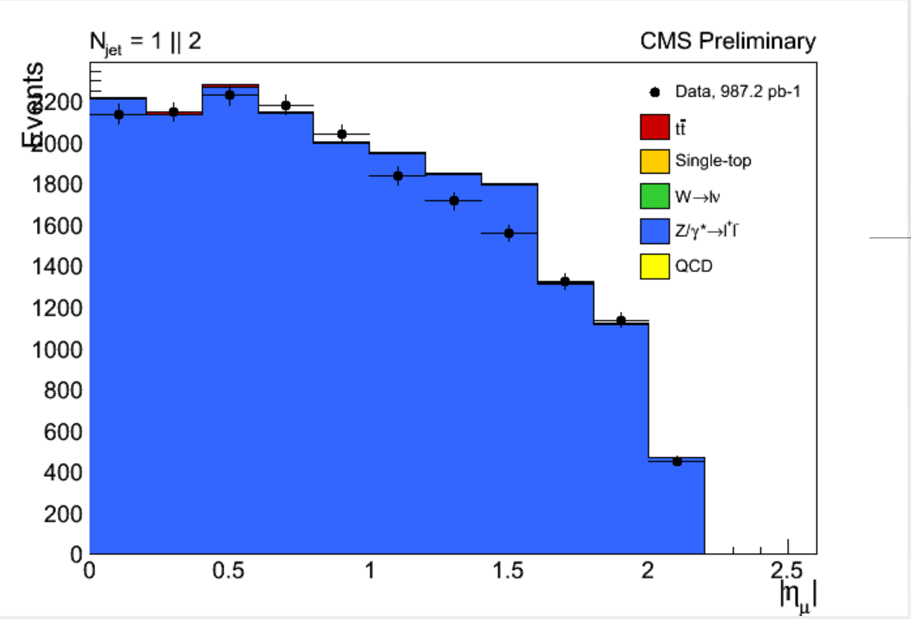


Correction factors need to be applied to account for relIso efficiency as a function of η

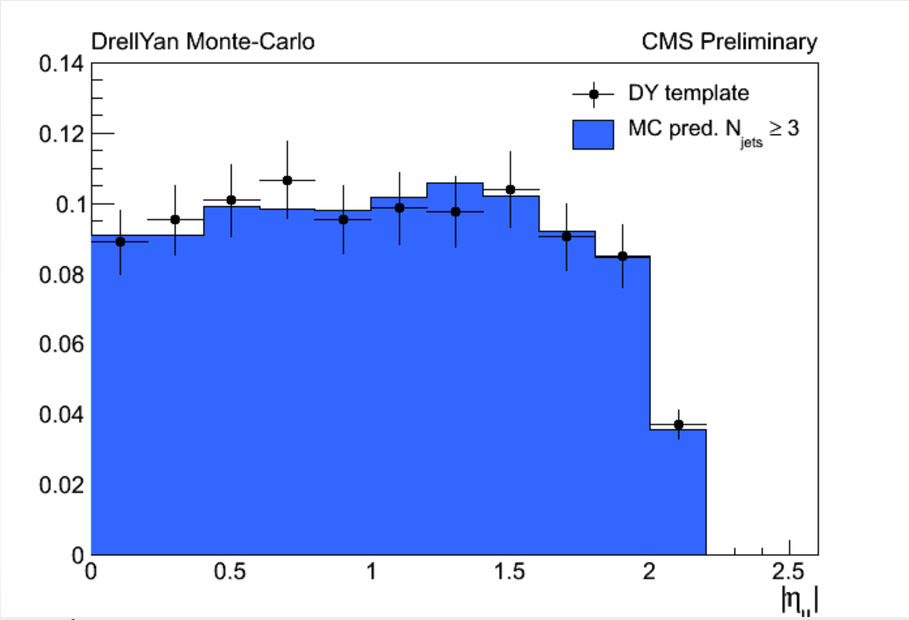


Z+Jets Template Extraction

- Select opposite charge di-lepton events with invariant mass $|m_{ll} - m_Z| < 15$ GeV

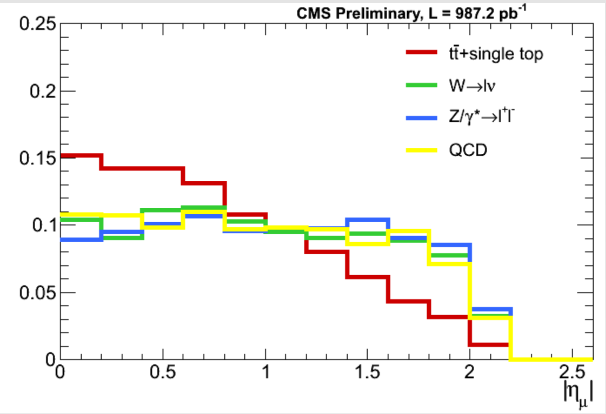


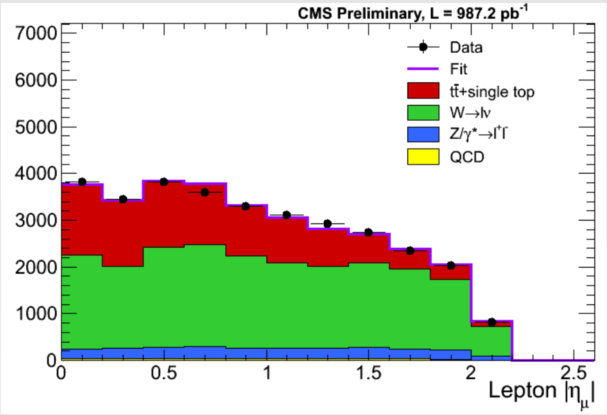
Apply a correction for going from 2 → 1 muon events on the data



Template Fit

- Perform a binned template fit method on the **normalised** $|\eta_l|$ templates where the likelihood function is maximised:





- Constrain N_{QCD} to within 100% and N_z/N_w to within 5% of expected MC values
- From this extract the **number of signal events** and get the cross-section:

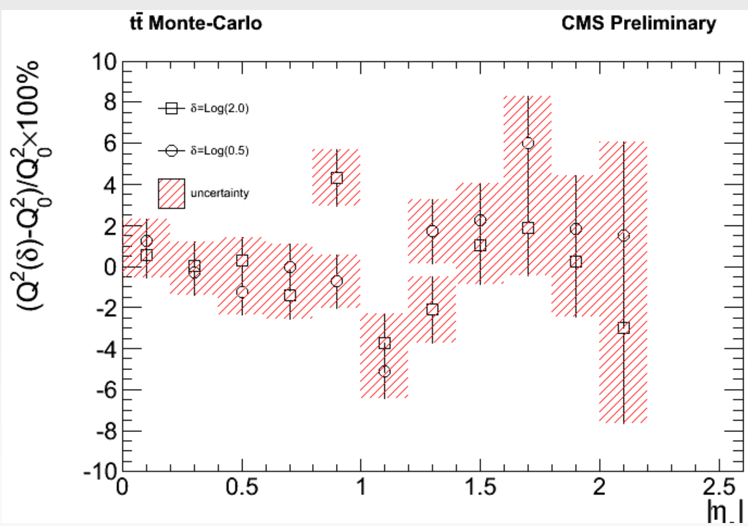
$$\sigma^{fit}_{t\bar{t}} = \frac{N^{fit}_{t\bar{t}} - N^{MC}_{stop}}{\epsilon_{t\bar{t}}\mathcal{L}}$$

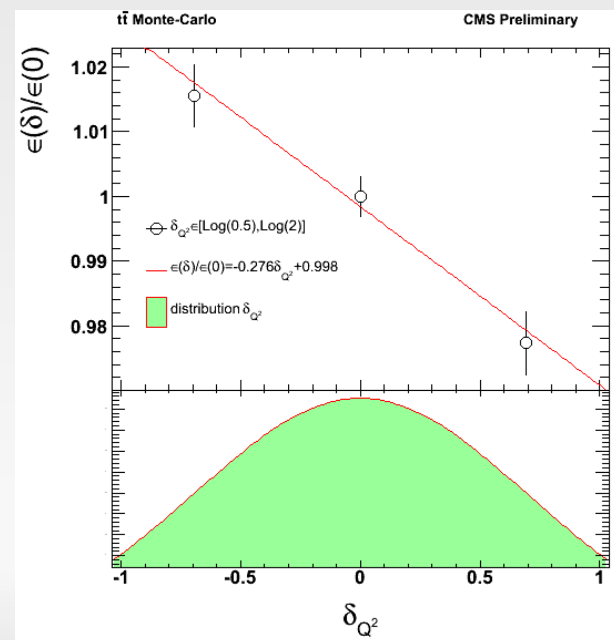
σ_{tt} = 145.6 ± 8.2 pb

→ $\beta_{fit} = \sigma_{fit}/\sigma_{theory}$ = 0.92 ± 0.05

Systematic Uncertainties

- **Since BG templates extracted from data only need to account for theoretical/experimental uncertainties and statistical limitations.**
- **Other uncertainties are applied to the signal**
- **For JES** : vary the jet pt by ± 1σ according to η and pt dependent corrections
- Scale up/down MC samples used for $\mathbf{Q^2}$ and **matching threshold**
- 30% error assigned to single-top xs and 4% to lumi



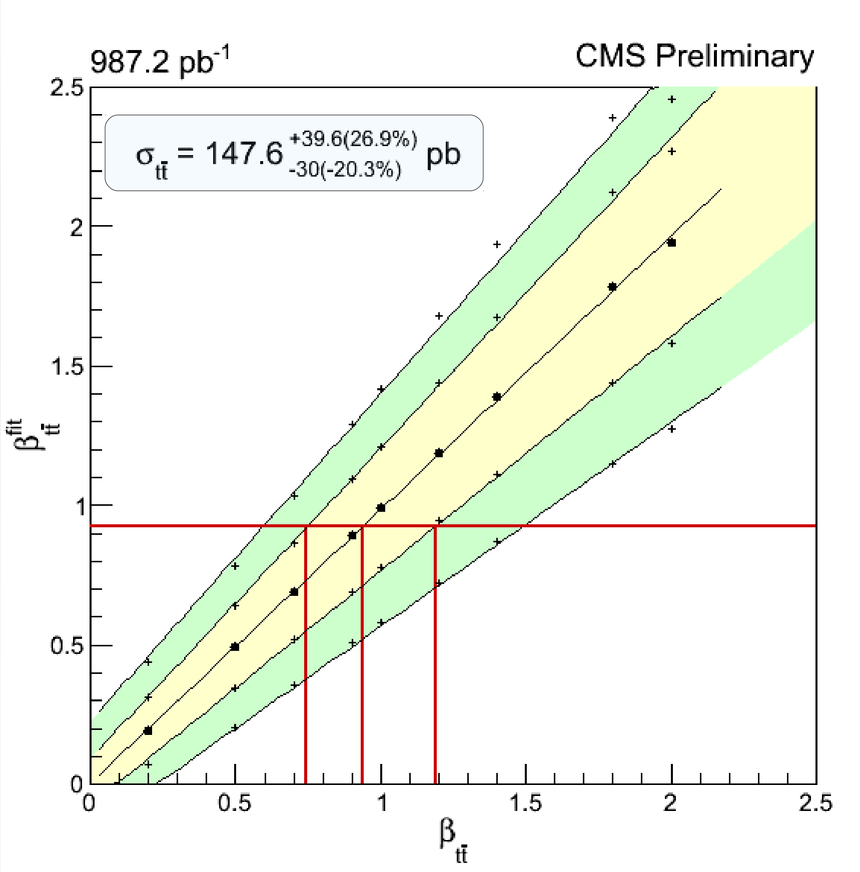


Full Neyman Construction

- **Systematic uncertainties** enter the pseudo experiments.
- Throw 100,000 experiments for various values of β_{tt} [0.2,2.0].

  For each experiment:

- Smear BG templates within statistical (+correction factor) error (corresponds to systematic) for each bin.
- For Signal (ttbar & single-top) smear shape within statistical error (MC). Then throw efficiency within systematic uncertainty. Systematics have no/little effect on |η| shape.
- Throw a Poissonian about each bin for templates (**stat.**).
- We then have the pseudo data (=pseudo BG + pseudo signal) and the pseudo BG templates to perform the likelihood fit.



$$\sigma_{t\bar{t}} := \sigma^{\text{nominal}}_{t\bar{t}} \times \left(\beta_{t\bar{t}} + \Delta^{+}_{t\bar{t}} - \Delta^{-}_{t\bar{t}}\right)$$

Conclusions & Future Plans

- Analysis uses fully **data driven techniques** to extract the background templates
- Obtiained a cross-section measurement **within SM prediction**
- Sensitivity of measurement could be improved with increased statistics and **rebinning**

- Next, plan to use similar techniques to reconstruct the **MET** distribution
- Would then be interested to look at ttbar events with large **MET**

Thanks for your attention!

Backup

Back up: Samples & Triggers

Data:

/SingleMu/Run2011A-May10ReReco-v1 up to 163869

/SingleMu/Run2011A-PromptReco-v4 165088-167284

→ ~1fb^{-1}

MC Samples:

/TTJets_TuneZ2_7TeV-madgraph-tauola/Summer11-PU_S4_START42_V11-v1

/WJetsToLNu_TuneZ2_7TeV-madgraph-tauola/Summer11-PU_S4_START42_V11-v1

/DYJetsToLL_TuneZ2_M-50_7TeV-madgraph-tauola/Summer11-PU_S4_START42_V11-v1

/QCD_Pt-20_MuEnrichedPt-15_TuneZ2_7TeV-pythia6/Summer11-PU_S4_START42_V11-v1

/T_TuneZ2_t-channel_7TeV-powheg-tauola/Summer11-PU_S4_START42_V11-v1

/Tbar_TuneZ2_t-channel_7TeV-powheg-tauola/Summer11-PU_S4_START42_V11-v1

/T_TuneZ2_s-channel_7TeV-powheg-tauola/Summer11-PU_S4_START42_V11-v1

/Tbar_TuneZ2_s-channel_7TeV-powheg-tauola/Summer11-PU_S4_START42_V11-v1

/T_TuneZ2_tW-channel-DR_7TeV-powheg-tauola/Summer11-PU_S4_START42_V11-v1

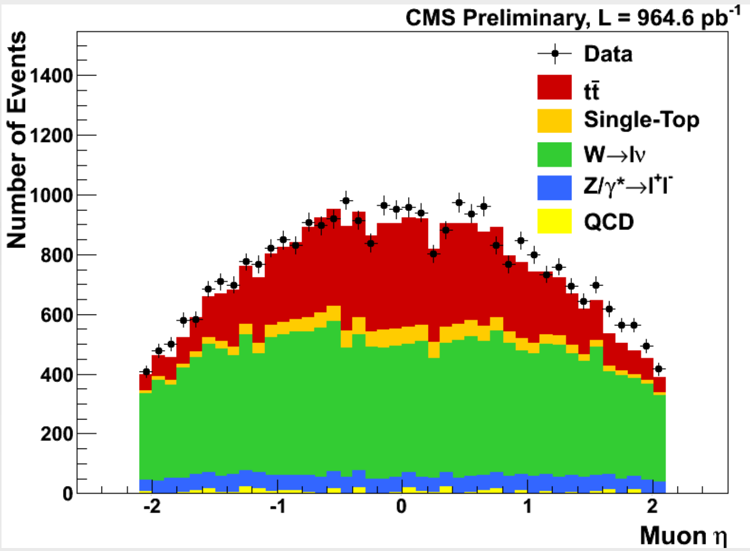
/Tbar_TuneZ2_tW-channel-DR_7TeV-powheg-tauola/Summer11-PU_S4_START42_V11-v1

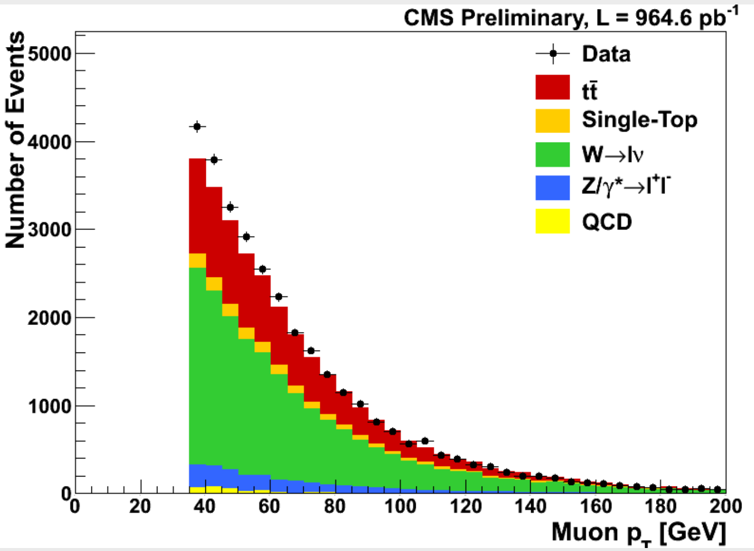
Triggers (same as sHyFT group):

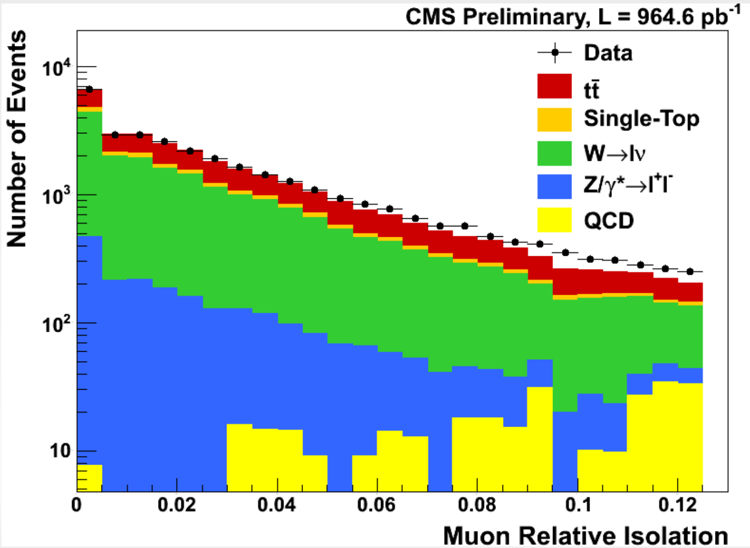
HLT_Mu30_v(1-5)

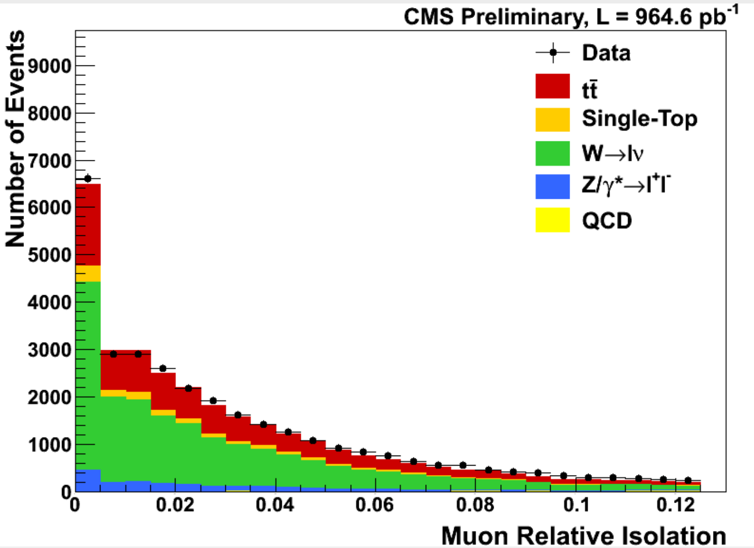
Control Plots (μ kinematics)

(After event selection)



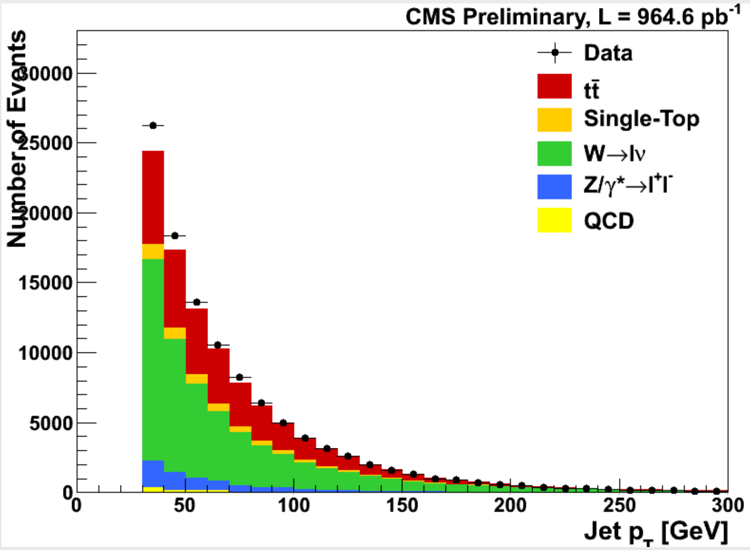


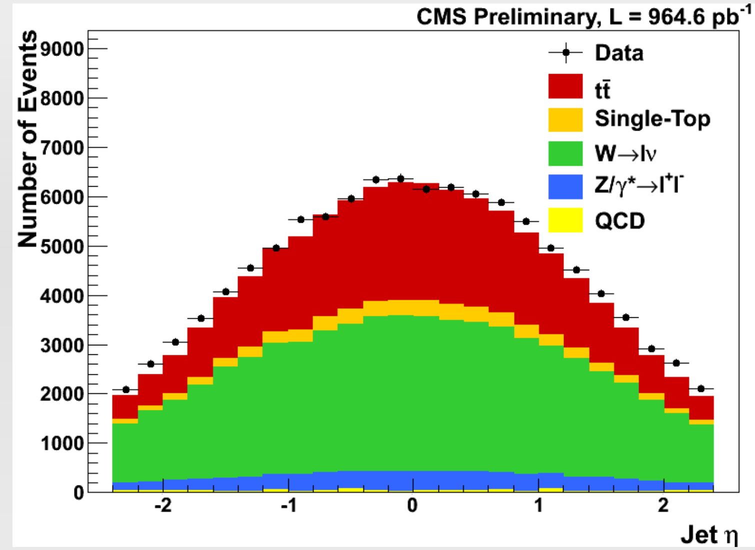


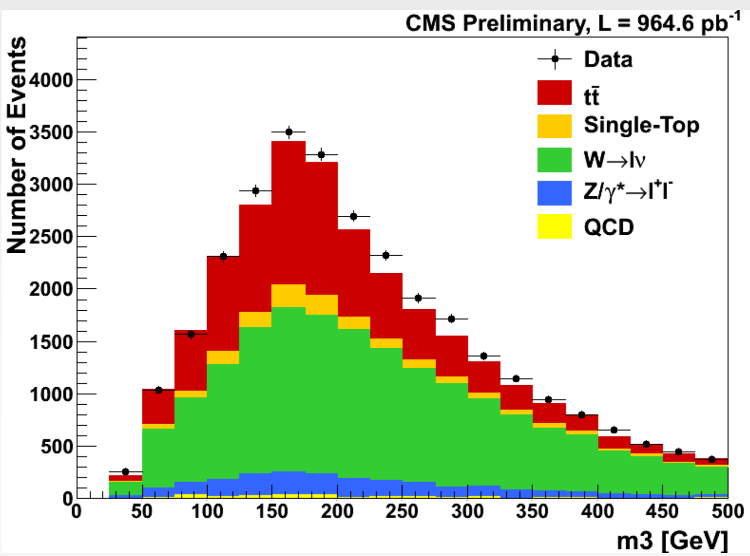


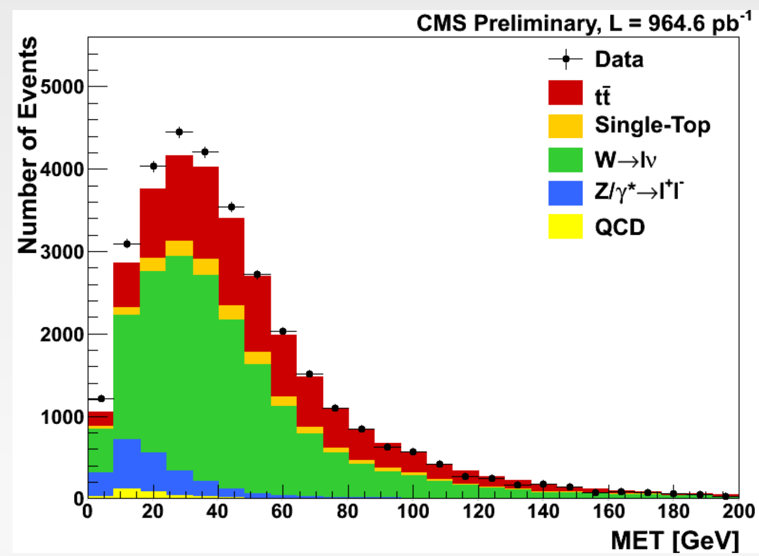
Control Plots (Jet/MET kinematics)

(After event selection)



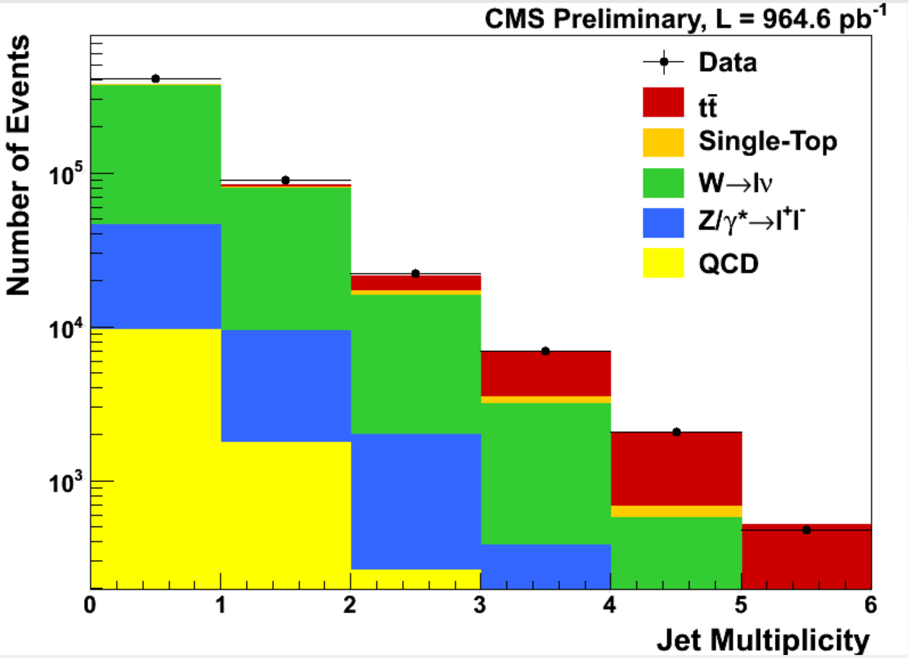






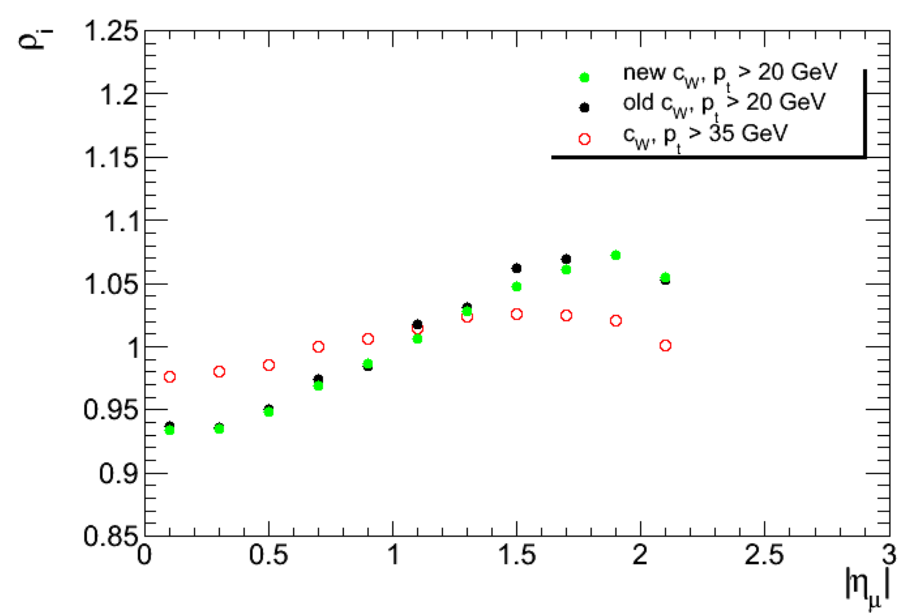
Invariant mass of 3 leading jets

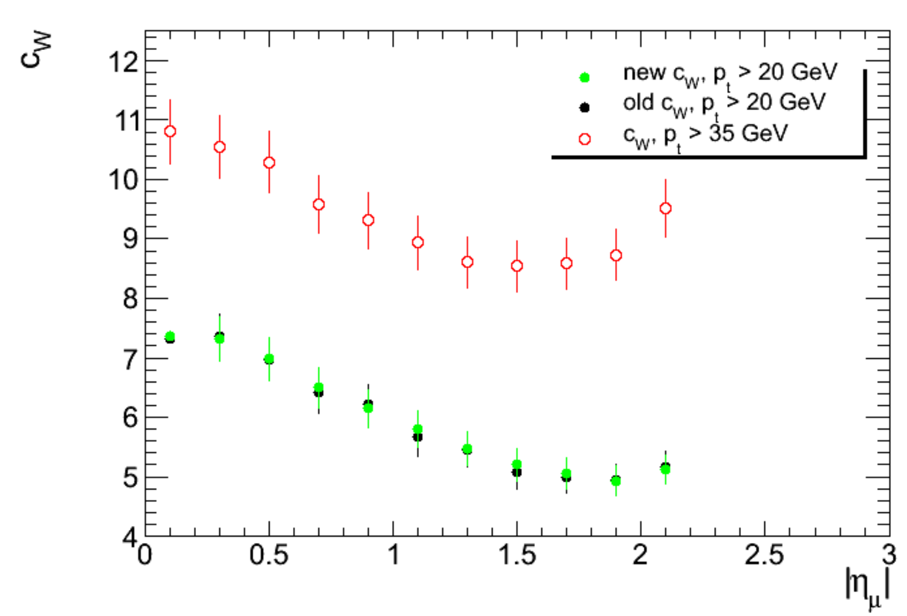
Backup: Jet Multiplicity Plot



W+Jets correction factors

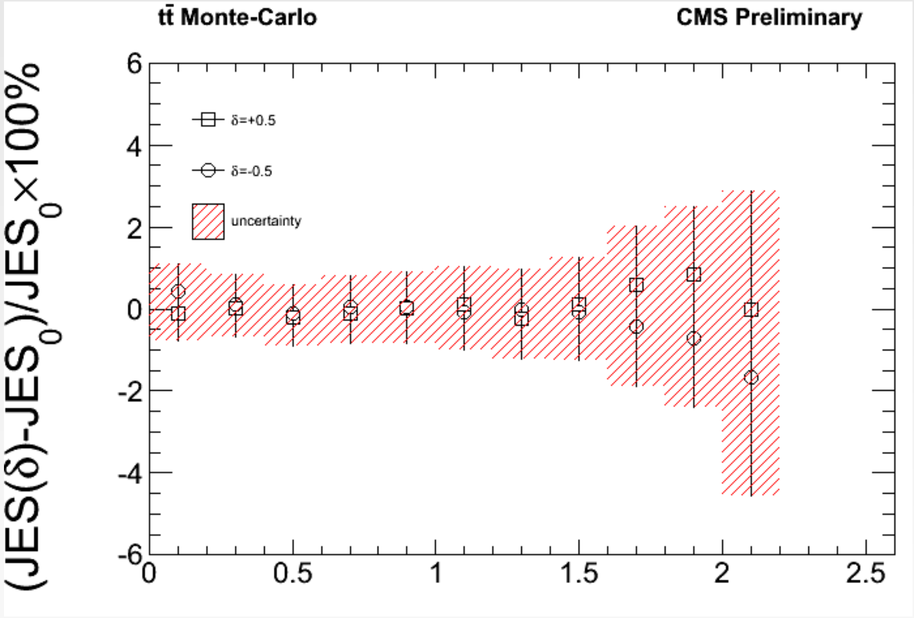
- Go from charge subtracted to charge sum: $\Delta^i_\mu = \#(|\eta_{\mu^+}|)^i - \#(|\eta_{\mu^-}|)^i, \longrightarrow \Sigma^i_\mu = \#(|\eta_{\mu^+}|)^i + \#(|\eta_{\mu^-}|)^i,$
- Use bin (i) wise correction factors (c_W) for this: $\Sigma^i_\mu = c^i_W \times \Delta^i_\mu.$
- Construct correction factors as: $c^i_W = \left(1 + \frac{2}{R_i - 1}\right).$
- Where: $R_i = R\frac{\varepsilon_{W^+}}{\varepsilon_{W^-}}\left(\frac{d\bar{\sigma}_{W^+}}{d|\eta_\mu|}\right)_i\left(\frac{d\bar{\sigma}_{W^-}}{d|\eta_\mu|}\right)^{-1}_i =: R\,\rho_\varepsilon\,\rho_i,$
- R = 1.435 (NNLO) & ρ_ε = 0.98 for p_t>20 & 0.85 for p_t>35

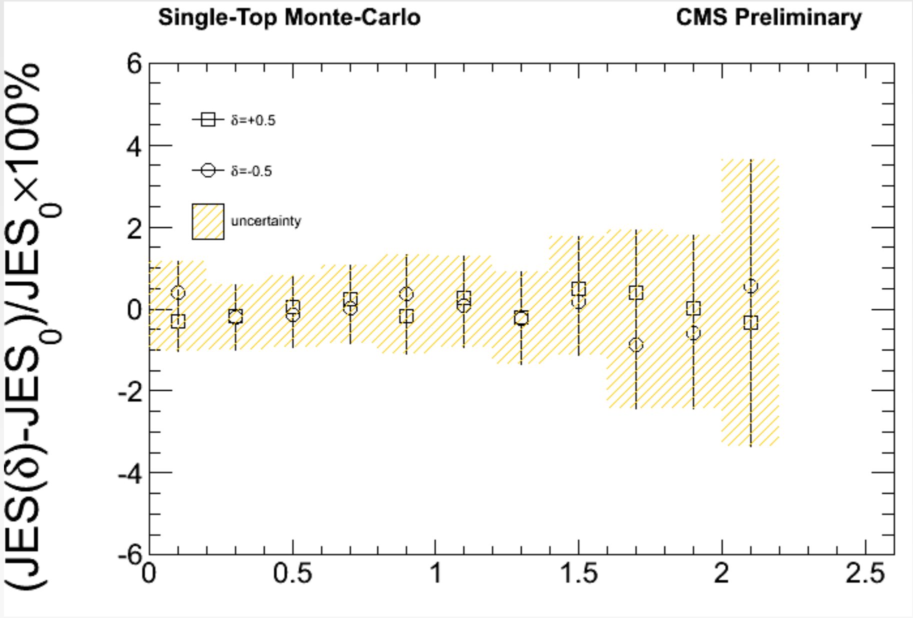




JES Uncertainty

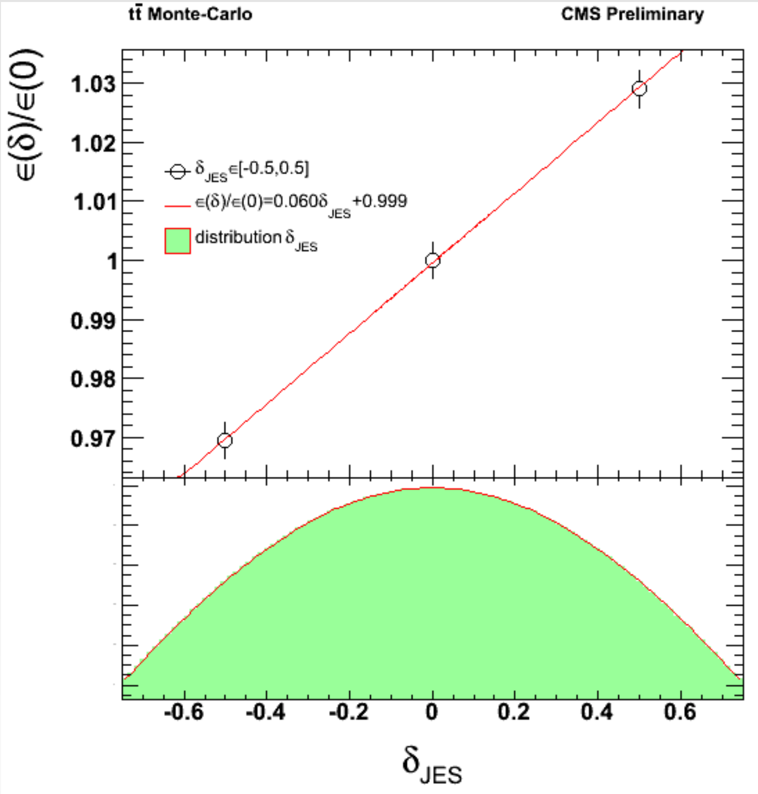
- A strength parameter is chosen arbitrarily such that ±1σ corresponds to ±0.5.
- This parametrises the error.
- In both top and single top there is little effect on the shape.

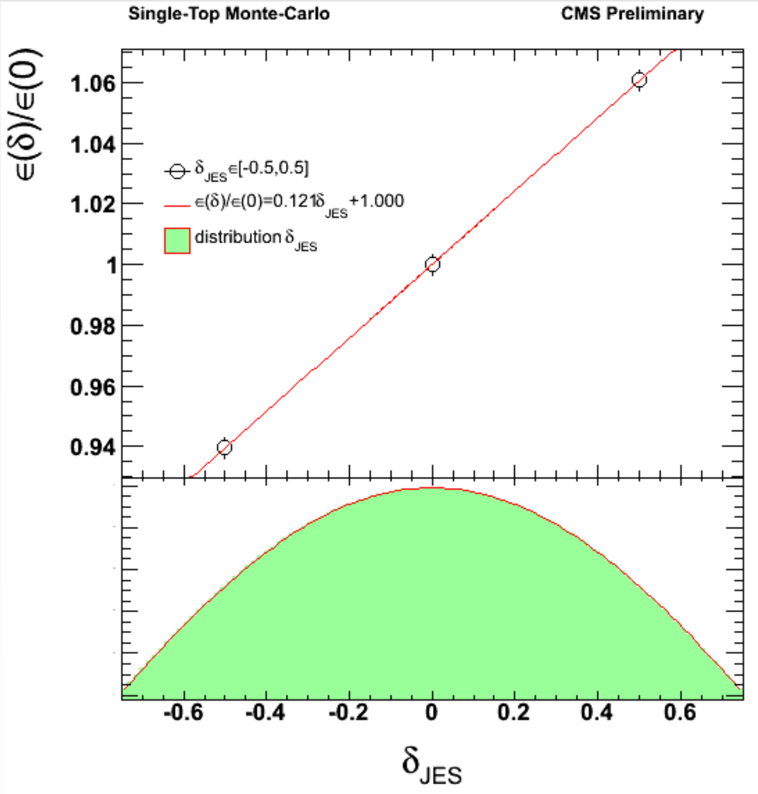




JES Error: Efficiency Effect

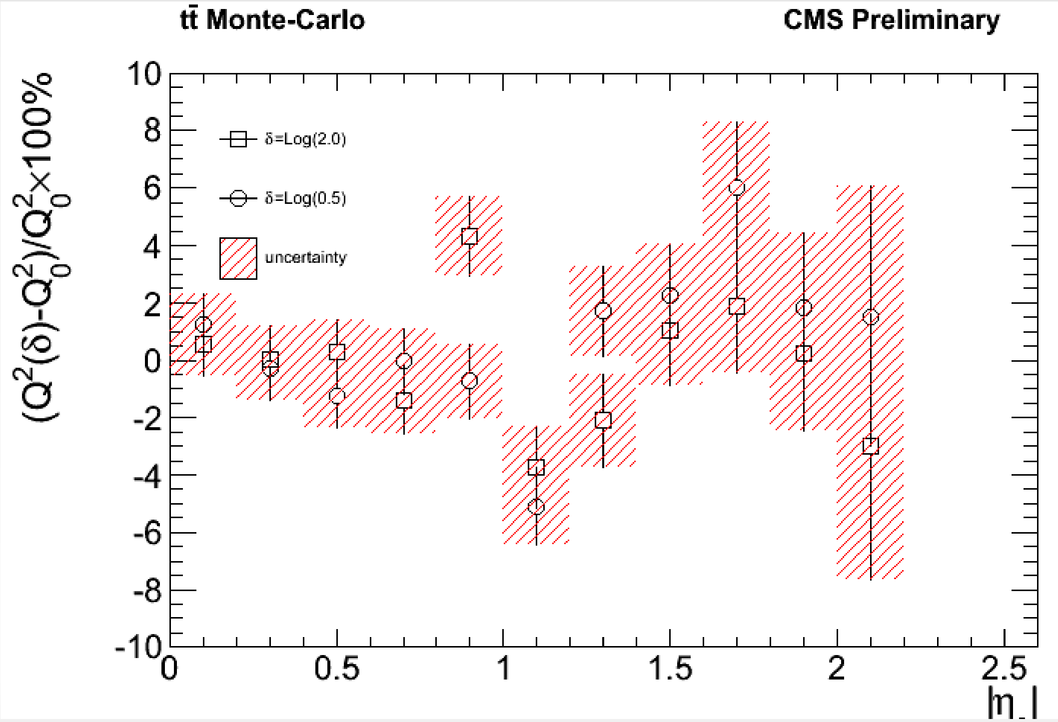
- A linear function can be fit to describe the JES errors' effect on the ttbar and single-top selection efficiencies.
- ε(0) corresponds to the nominal efficiency.





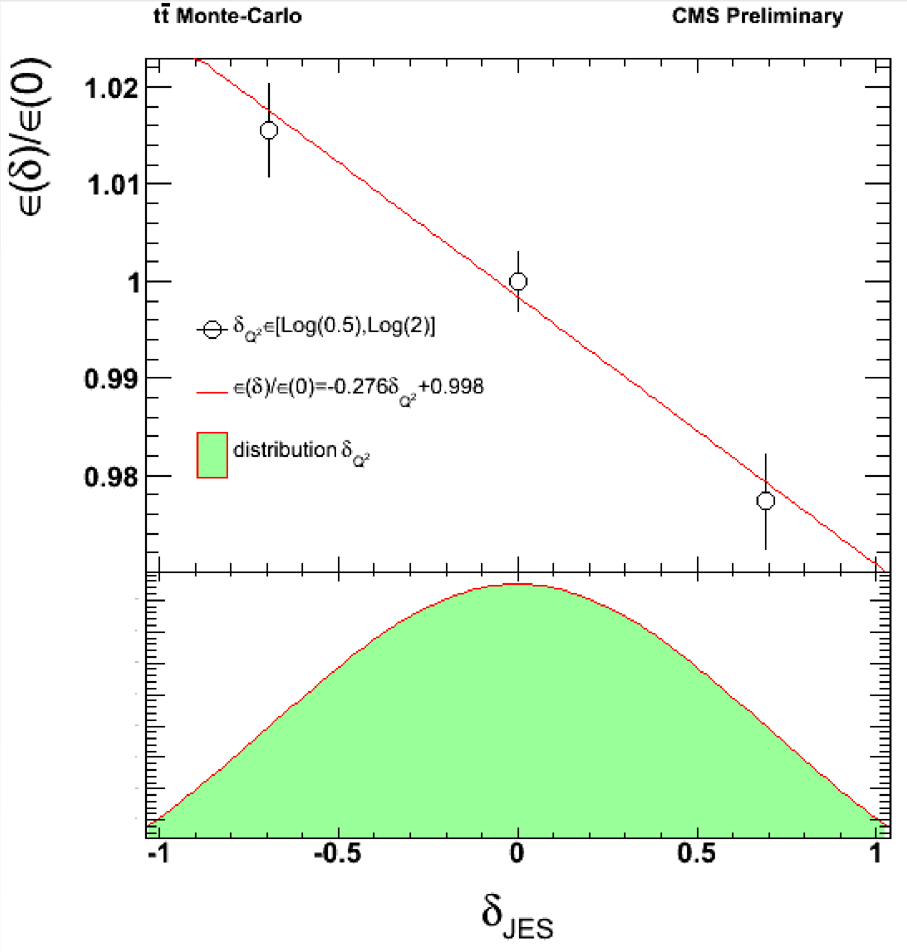
Q^2 Uncertainty

- TTjets_TuneZ2_scaleup_7TeV-madgraph-tauola/Summer11-PU_S4_START42_V11-v1/AODSIM
- Ttjets_TuneZ2_scaledown_7TeV-madgraph-tauola/Summer11-PU_S4_START42_V11-v1/AODSIM
- Parametrise this error with ±1σ [log(0.5), log(2)]
- ttbar shape within statistical errors of fluctuations



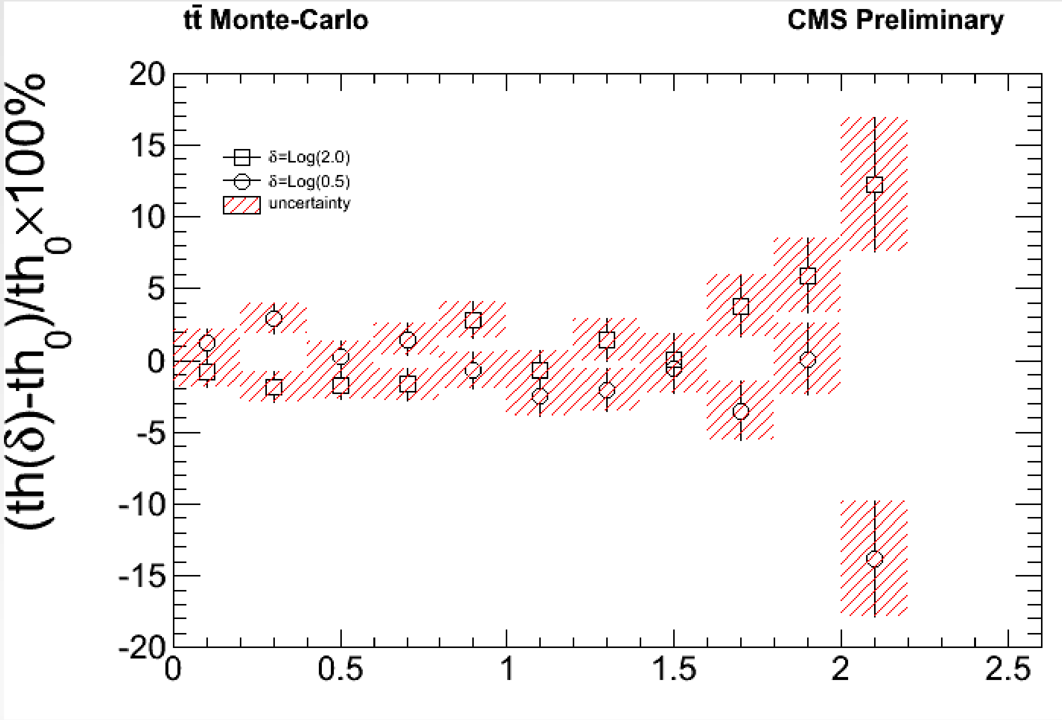
Q^2 Efficiency Effect

- We can see what effect the Q^2 uncertainty has on the ttbar selection efficiency
- A linear function is used to describe it's effect.



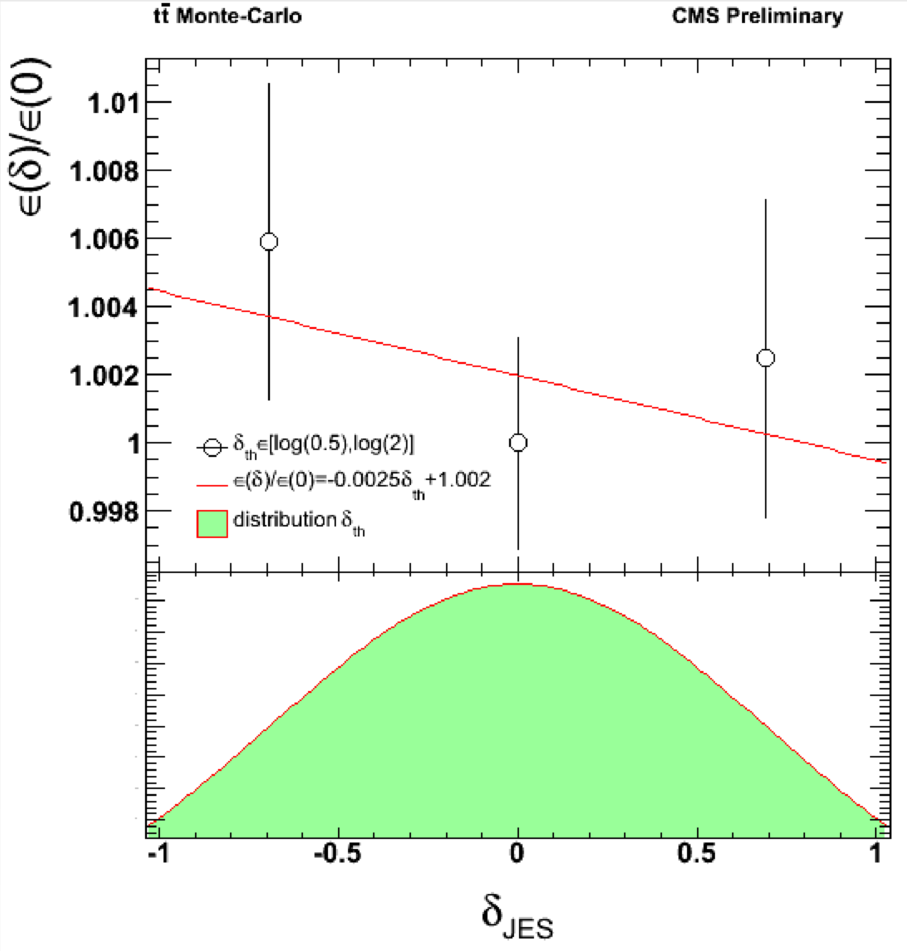
Matching Threshold

- TTjets_TuneZ2_matchingup_7TeV-madgraph-tauola/Summer11-PU_S4_START42_V11-v1/AODSIM
- TTjets_TuneZ2_matchingdown_7TeV-madgraph-tauola/Summer11-PU_S4_START42_V11-v1/AODSIM
- Also parametrise this error with ±1σ [log(0.5), log(2)]
- ttbar shape within statistical errors of fluctuations apart from at large η?



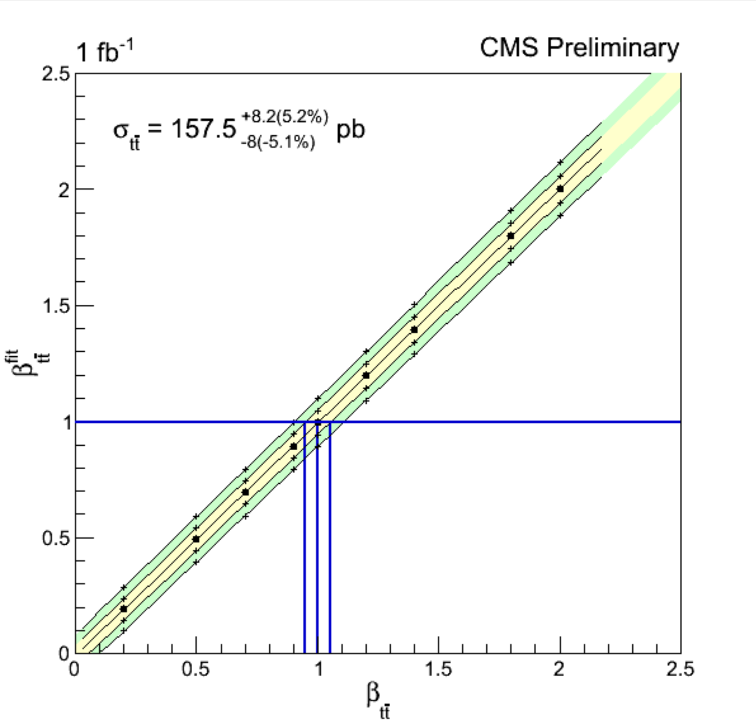
Matching Threshold Efficiency Effect

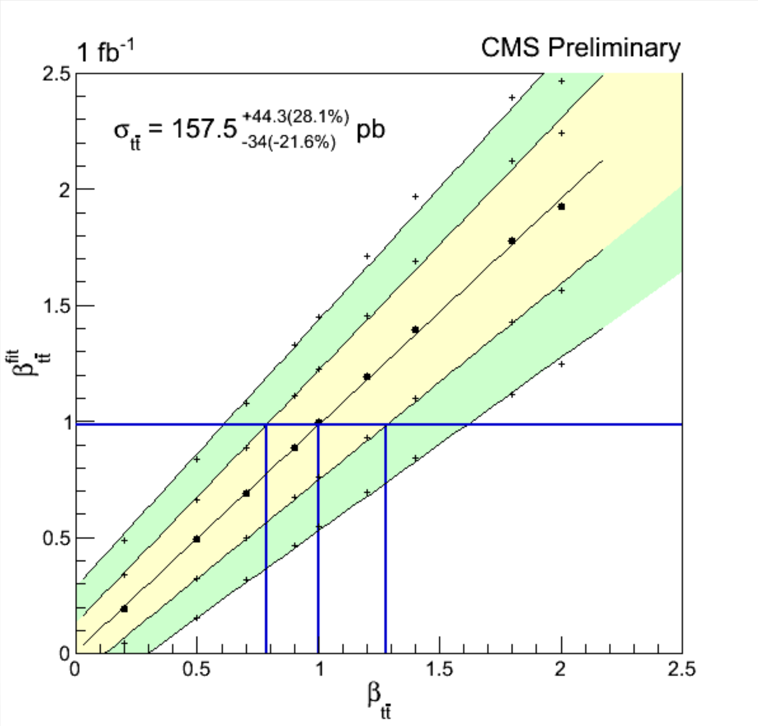
- We can see what effect the matching threshold uncertainty has on the ttbar selection efficiency
- Linear function doesn't fit so error doesn't have very much effect on efficiency compared to Q^2 and JES.



Sensitivity of Measurement (1/fb)

- Can measure the sensitivity using β_{tt} = 1 and extrapolate accross the Neyman plot to ±1σ.
- With stats only get ~ ±8 pb (5.1%) uncertainty.
- For syst+stat we get +44.3 pb (28.1%) -34.0 pb (21.6%)
- Systematics still dominated by statisical uncertainty on data driven templates.





See backup for pull and var distributions for stat only

Systematic Breakdown

Source	$\beta_{t\bar{t}}^{fit}(-\sigma)$ pb (%)	$\beta_{t\bar{t}}^{fit}(0)$	$\beta_{t\bar{t}}^{fit}(+\sigma)$ pb (%)
W+jets Temp stat.	-20.6 (-16.4 %)	0.797	20.6 (16.4 %)
DY Temp stat.	-3.2 (-2.6 %)	0.796	3.2 (2.6 %)
QCD Temp stat.	-0.5 (-0.4 %)	0.796	0.5 (0.4 %)
All BG stat.	-20.8 (-16.6 %)	0.796	20.9(16.7 %)
JES	-3.6 (-2.9 %)	0.797	4.0(3.2 %)
Q^2 scale	-19.5 (-15.5 %)	0.799	27.7(22 %)
matching threshold	-0.2 (-0.2 %)	0.795	0.2(0.2 %)
luminosit	-5.8 (-4.6 %)	0.796	6.2(4.9 %)
single top xsect.	-7.0 (-5.6 %)	0.796	6.9(5.5 %)
stat.	-8.1 (-6.5 %)	0.797	8.2(6.5 %)
syst. + stat.	-31.2 (-24.8 %)	0.8	40.0(31.7 %)