

# Likelihood Functions and PDFs

Robert Thorne

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University College London

# Illustration of a reasonably typical set of uncertainties 1511.04716.

ATLAS single differential distributions for top-pair production at 8 TeV.

Some significant sources highly asymmetric, clearly not normal distributed.

Others, based on Monte Carlo modelling, assumed entirely symmetric, Gaussian, and 100% correlated across bins and distributions.

The latter type can be dominant and even enormous.

SQRT(S)(Q = 8 TEV)	8000.0 GeV	
MASS_TTBAR [GeV]	DSIG/DMASS_TTBAR	DSIG/DMASS_TTBAR (breakdown of systematics)
225.0 - 345.0	0.0168532 $\pm$ 1.402% stat <div style="font-size: small; margin-top: 5px;"> <span style="color: red;">+58.586%</span> sys  <span style="color: red;">-34.331%</span> sys  <math>\pm</math>2.8%  <span style="color: red;">sys,luminosity uncertainty</span> </div>	0.0168532 $\pm$ 1.402% stat <span style="color: red;">+0.318%</span> sys_singletop-xsec <div style="font-size: x-small; margin-top: 5px;"> <span style="color: red;">+0.824%</span> sys,wjet-scale <span style="color: red;">-0.232%</span> sys,laltrealcr-mujet-fake  <span style="color: red;">-0.517%</span> <span style="color: red;">+0.232%</span>  <span style="color: red;">-1.018%</span> sys,eta-jes <span style="color: red;">+1.584%</span> sys,statNP3-jes  <span style="color: red;">+1.233%</span> <span style="color: red;">-1.789%</span>  <math>\pm</math>0.237% sys,laltrealcr-ejet-fake <span style="color: red;">+0.382%</span> sys,pileoffmu-jes  <span style="color: red;">-0.437%</span> sys,lstat-ejet-fake <span style="color: red;">+0.148%</span> sys,lstat-mujet-fake  <span style="color: red;">+0.339%</span> <span style="color: red;">0.0%</span>  <span style="color: red;">+0.085%</span> sys,etmsoft-scale <span style="color: red;">-12.331%</span> sys,hardscat-model  <span style="color: red;">0.0%</span> <span style="color: red;">+12.331%</span>  <span style="color: red;">-0.11%</span> sys,statNP2-jes <span style="color: red;">-0.347%</span> sys,ejen-scale  <span style="color: red;">+0.281%</span> <span style="color: red;">+0.387%</span>  <span style="color: red;">+0.072%</span> sys,punch-jes <span style="color: red;">+0.832%</span> sys,pileoffnpv-jes  <span style="color: red;">0.0%</span> <span style="color: red;">-0.713%</span>  <span style="color: red;">+0.288%</span> sys,lrec-eff <span style="color: red;">+0.17%</span> sys,pileoffpt-jes  <span style="color: red;">-0.16%</span> <span style="color: red;">0.0%</span>  <span style="color: red;">-3.412%</span> sys,jeten-res <span style="color: red;">+0.833%</span> sys,lighttag-eff  <span style="color: red;">+3.412%</span> <span style="color: red;">-0.348%</span>  <math>\pm</math>0.744% sys,laltfakecr-ejet-fake <math>\pm</math>0.158% sys,laltpar-mujet-fake  <span style="color: red;">-0.128%</span> sys,jetrec-eff <span style="color: red;">+1.389%</span> sys,c/tautag-eff  <span style="color: red;">+0.128%</span> <span style="color: red;">-1.185%</span>  <math>\pm</math>0.147% sys,dibos-xsec <span style="color: red;">+0.082%</span> sys,ejen-res  <span style="color: red;">0.0%</span> <span style="color: red;">0.0%</span>  <span style="color: red;">-0.42%</span> sys,flavcomp-jes <span style="color: red;">-0.022%</span> sys,detNP2-jes  <span style="color: red;">+0.832%</span> <span style="color: red;">+0.23%</span>  <span style="color: red;">-0.17%</span> sys,detNP3-jes <span style="color: red;">-1.328%</span> sys,jetvfrac  <span style="color: red;">+0.272%</span> <span style="color: red;">+1.193%</span>  <span style="color: red;">+1.382%</span> sys,ltrig-eff <span style="color: red;">-3.073%</span> sys,btag-jes  <span style="color: red;">-1.298%</span> <span style="color: red;">+3.332%</span>  <span style="color: red;">+0.031%</span> sys,mup-scale <span style="color: red;">+0.033%</span> sys,singlephpt-jes  <span style="color: red;">0.0%</span> <span style="color: red;">0.0%</span>  <span style="color: red;">+0.0%</span> sys,etmsoft-res <span style="color: red;">-1.82%</span> sys,detNP1-jes  <span style="color: red;">-0.043%</span> <span style="color: red;">+2.118%</span>  <math>\pm</math>0.277% sys,laltpar-ejet-fake <span style="color: red;">+0.134%</span> sys,statNP1-jes  <span style="color: red;">0.0%</span> <span style="color: red;">0.0%</span>  <math>\pm</math>0.01% sys,muid-res <span style="color: red;">-0.08%</span> sys,pdf <span style="color: red;">-3.173%</span> sys,isr-fsr  <span style="color: red;">+0.08%</span> <span style="color: red;">+3.987%</span>  <math>\pm</math>1.125% sys,zjet-xsec <span style="color: red;">-34.438%</span> sys,ps-model  <span style="color: red;">+34.438%</span>  <span style="color: red;">+1.174%</span> sys,flavres-jes <math>\pm</math>0.906% sys,laltfakecr-mujet-fake  <span style="color: red;">-1.031%</span>  <math>\pm</math>0.05% sys,mums-res <span style="color: red;">+0.104%</span> sys,mod-NP2-jes  <span style="color: red;">0.0%</span>  <span style="color: red;">+1.305%</span> sys,lid-eff <span style="color: red;">+0.342%</span> sys,mixNP2-jes  <span style="color: red;">-1.199%</span> <span style="color: red;">0.0%</span>  <span style="color: red;">-1.874%</span> sys,mixNP1-jes <span style="color: red;">+4.88%</span> sys,btag-eff  <span style="color: red;">+2.003%</span> <span style="color: red;">-4.479%</span>  <span style="color: red;">-2.048%</span> sys,pileoffrho-jes <span style="color: red;">-0.232%</span> sys,modNP4-jes  <span style="color: red;">+2.28%</span> <span style="color: red;">+0.342%</span>  <math>\pm</math>0.339% sys,mcstat <span style="color: red;">+1.788%</span> sys,modNP3-jes  <span style="color: red;">-1.524%</span>  <span style="color: red;">-4.481%</span> sys,mod-NP1-jes <math>\pm</math>2.8% sys,luminosity uncertainty  <span style="color: red;">+4.888%</span> </div>

Effect of fitting single-differential  $t\bar{t}$  ATLAS 8 TeV distributions with different (both wrong) approaches to asymmetric uncertainties.

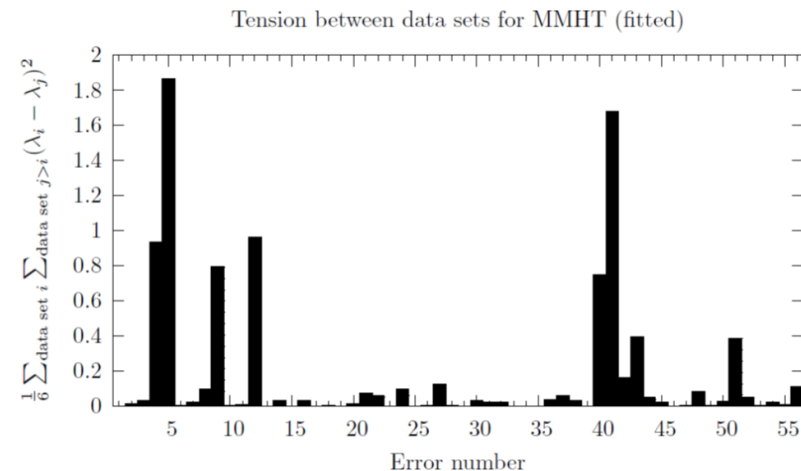
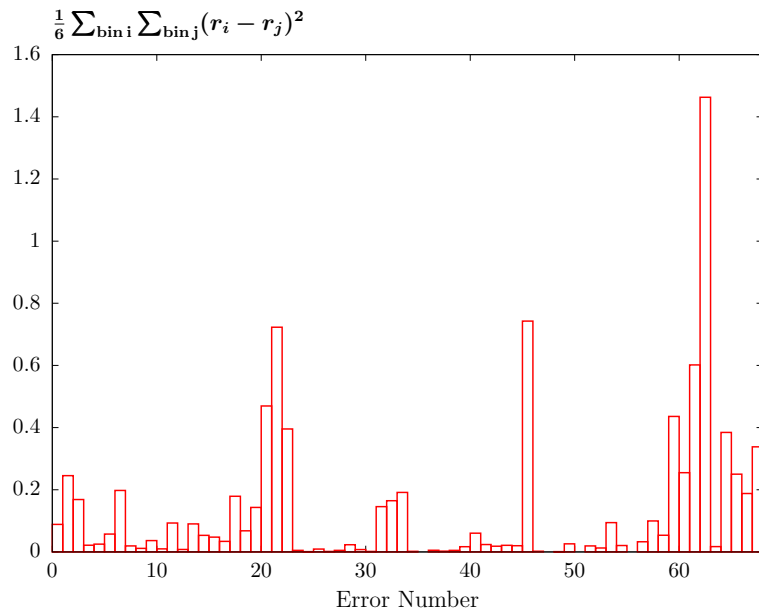
distribution	$N_{\text{pts}}$	$\chi_A^2$	$\chi_B^2$
$p_t$	8	6.32	5.84
$y_t$	5	12.54	9.37
$y_{t\bar{t}}$	5	16.59	14.78
$m_{t\bar{t}}$	7	8.50	7.17

Highlights (probably) a minimum effect in fit quality in non Gaussian behaviour of some sources of uncertainty.

## Inclusion of LHC data - systematic uncertainties

Generally the fit is good. However, the most straightforward approach gives a distinctly poor fit quality to some data sets.

Tensions between different kinematic regions (e.g. rapidity bins) or differential distributions. Sometimes clearly related to modelling-type systematic uncertainties. (Particularly jet and  $t\bar{t}$  data.)



Discussed in detail in [Eur.Phys.J.C 78 \(2018\) 248](#), [80 \(2020\) 60](#).

For some sets use the sort of smooth decorrelation advocated in [ATLAS – JHEP 09 020 \(2017\)](#).

# Illustration of a reasonably typical set of uncertainties for normalised data 1505.047480.

CMS single differential distributions for top-pair production at 8 TeV.

No information on any differing signs in uncertainties.

Unidirectional – clearly not consistent with normalisation preservation.

RE	P P --> TOP TOPBAR X							
SQRT(S)	8000.0 GeV							
Source	Uncertainty [each bin (in [%])]							
LEP	0.1	0.1	0.0	0.1	0.2	0.2	0.3	0.3
JES	4.1	0.7	0.9	1.9	1.6	1.5	2.9	3.9
JER	0.3	0.2	0.2	0.5	0.6	1.1	0.4	0.5
BG	0.7	0.6	0.2	0.3	0.5	0.4	0.5	0.9
Btag	1.1	0.4	0.2	0.5	0.9	1.2	1.4	1.6
PU	0.6	0.0	0.1	0.1	0.3	0.3	0.5	1.0
TopScale	1.4	1.5	1.6	1.8	2.5	4.0	4.7	7.0
TopMatch	1.1	1.0	1.9	1.2	0.7	1.4	1.4	3.4
Hadronization	1.3	0.8	1.6	1.7	0.7	4.0	5.5	5.4
TopMass	0.5	0.7	1.2	0.8	0.9	1.1	1.3	0.7
PDF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3