TH uncertainties: towards harmonization across LHC

Summary of CMS and ATLAS TOP LHC WG discussions

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Outline

Relatively recent (started in March 2012) **TOP LHC WG effort to use and quote TH uncertainties definitions in comparable manner for the top group results.**
Benefits:

- **ATLAS and CMS combination**
- comparing any ATLAS and CMS top group results
- etc.

In the following slides:

- **brief** (and therefore incomplete) **presentation of CMS and ATLAS signal generator setups**
- **status of the definition of TH uncertainties in CMS and ATLAS**
  - focus on 7 TeV prescriptions
- **main CMS vs ATLAS differences in quoting TH uncertainties**
- **status of harmonization discussions and agreements**
  - hopefully fully effective for 8 TeV results, also affect 7 TeV results
  - discussed/listed in the slides = will be considered by both experiments.

TH uncertainty prescriptions

Uncertainty estimations are obtained by performing:

- **generator vs generator comparisons;**
  - these include using different generators for the simulation of the hard process and/or the parton shower, hadronization and the underlying event.
  - The uncertainties are obtained using sub-sets of generator setups we have for a process in question.

- **generator parameter variations (discussed most);**
  - ME generator parameter variations (CMS)
  - supervising generator parameter variations currently relying on **Pythia 6** in both ATLAS and CMS; choice of generator to be used for variations reflects generators used for sample production

- **using other prescriptions;**
  - PDF systematics: reweighting
  - top mass: generate samples with different top mass values

  no immediate key differences / controversies between the experiments identified during the discussions and harmonization not discussed in much detail. Will not make further statements on these in the following.

Pythia 6 parameters used for variation samples

Discussed in the following, so I define the most important ones for variation samples use-case;(details in Pythia 6 update notes and Manual)

Parton Shower (ATLAS and CMS):

- PARP(67) (ATLAS)[1]: pT-ordered PS: allowed phase space for first ISR branching; the branching is power-suppressed if:

$$\mathrm{pTevol} > \mathrm{m_{dip}}/2 * \mathrm{PARP(67)}$$

  where $\mathrm{m_{dip}}$ is the invariant mass of the ISR parton being evolved together with its final-state color partner.
- PARP(64) (CMS and ATLAS): factor with effect $\propto 1/(\Lambda^2_{\mathrm{ISR}})$,
- PARP(72) (CMS and ATLAS): Λ_{FSR}.

Underlying event (ATLAS):

- PARP(84): fractional core radius of the hadronic matter overlap,
- PARP(90), PARP(82): related to the MI IR pt cutoff;

$$pt^2_{min} = \mathrm{PARP(82)}^2 \left(\frac{s}{s_{ref}}\right)^{\mathrm{PARP(90)}}.$$

- parameters with comparable meaning also used for Jimmy UE tuning.

[1] For MSTP(67)=2 used by CMS and ATLAS tunes

Pythia 6 Tunes used by CMS and ATLAS

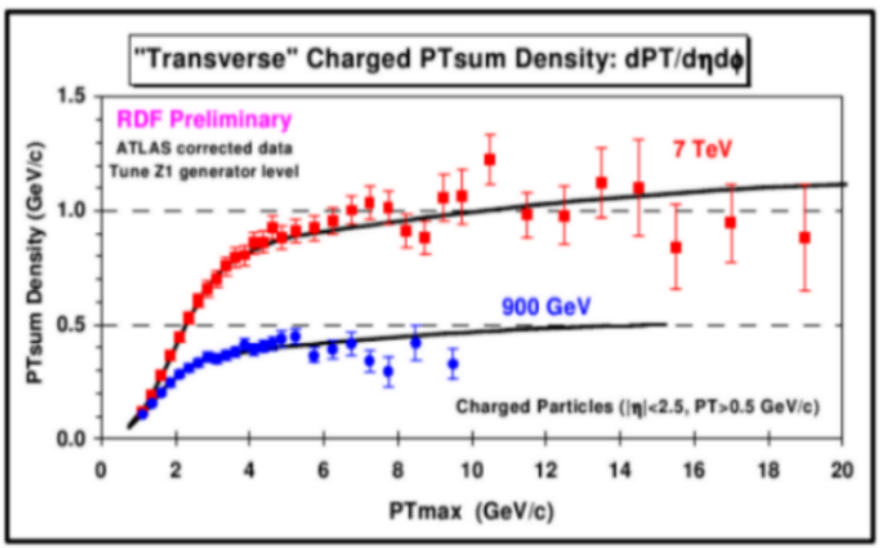
Both experiments using new PS/MPI Pythia 6 model (pT-ordered PS, interleaved ISR-MPI evolution).

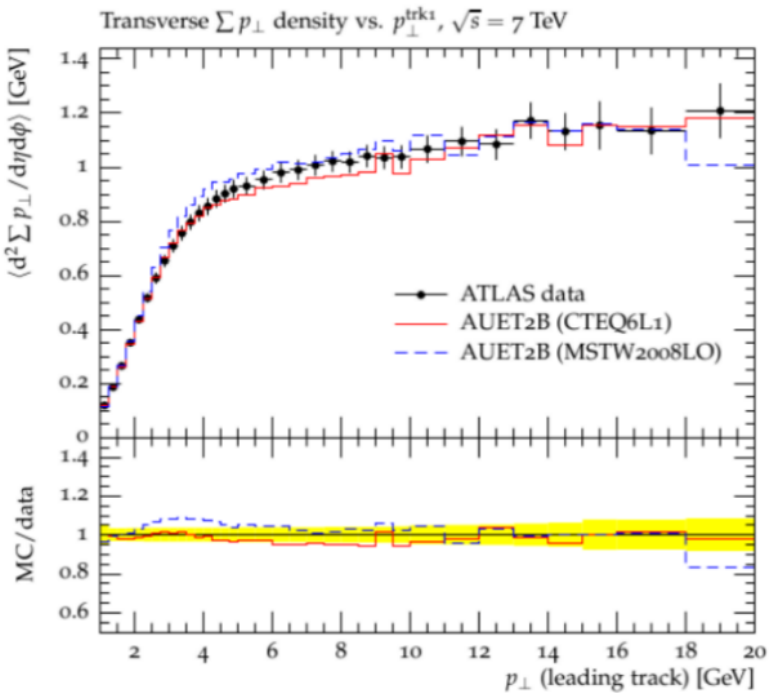
References:

- CMS: Z2(*), arXiv:1010.3558v1 [hep-ph] (LHS Fig.)
- ATLAS: AUET* series, ATL-PHYS-PUB-2011-009 (RHS Fig.)

Data used for tuning for 7 TeV data production round:

- LHC UE for both ATLAS and CMS
- ATLAS: attempt to tune PS parameters acc. to QCD jet shapes, QCD dijet decorrelations . . .
- data constraints on systematics relevant for top taken into account with shorter turn-arround that change of production tune





CMS generator setups

courtesy of M. Gosselink (CMS)

process	ME	PS	method	PDF	Tune
$t\bar{t} + 0, 1, 2, 3$	MadGraph v5.1.x	Pythia v6.42x	ME+PS	CTEQ6L1	Z2(*)
$t\bar{t}$	POWHEG-box	Pythia v6.42x	NLO	CTEQ6M	Z2(*)
$t\bar{t}$	MC@NLO v3.41	Herwig v6.510	NLO	CTEQ6M	–
$t/\bar{t}$ (s,t,tW)	POWHEG-box	Pythia v6.42x	NLO	CTEQ6M	Z2(*)
$t/\bar{t}$ (s,t)	CompHEP v4.5.1	Pyhtia v6.42x	ME	CTEQ6M	Z2(*)

- Pythia with p_T^2-ordered PS (pre-2011: q^2-ordered with D6T UE tune)
- Herwig $\rightarrow$ Jimmy for UE
- Main background V+jets with MadGraph + Pythia

CMS TH systematics

generator vs generator comparisons:

- compare the setups in p6

single top Wt-chan.:

- DR vs DS schemes (on ATLAS side studied but not quoted)

generator parameter variations:

Non-perturbative systematics:

- colour reconnections: using Pythia 6, P2011 and P2011NoCR
- underlying event: intention to use Pythia 6, author P2011 variations

Matching-related uncertainties for MadGraph + Pythia 6:

- variation of MG parameter QCUT[2] by 0.5 and 2 wrt. to default
- applied to $t\bar{t}$ and V+jets samples

[2] Jet measure cutoff used by Pythia for matching using k_T scheme

CMS TH systematics cont'd

Q^2 parameter variations, courtesy of M. Gosselink (CMS)

Variation of Q (Q^2) with a factor 0.5 and 2.0 (0.25 and 4.0)

More explicitely:

- matrix element:
  - $Q^2 = m_t^2 + \sum p_T^2$ (MadGraph) and $Q^2 = m_t^2$ (POWHEG)
  - `scalefact`/`facscfact` (scale factor for event-by-event scales)
  - `alpsfact`/`renscfact` (scale factor for QCD emission vx)
- parton shower:
  - factor for k_T^2 evolution scale in α_s (space-like, ISR)
    `PARP(64)=0.25/4.0` (D=1.0)
  - Λ scale in α_s (time-like, FSR)
    `PARP(72)=0.5/0.125` (D=0.25), but `MSTP(3)=2` (D)
  - NOTE: implicitly starting scale of the PS changes accordingly

ATLAS generator setups

$t\bar{t}$:

- MC@NLO 4.0X + fHerwig (6.520) + Jimmy (4.31): main sample generator,
- POWHEG-hvq-patch4, POWHEG BOX (1.0.X) + Pythia 6 6.42X, X$\geq$5 or fHerwig + Jimmy
- *Alpgen 2.1X (Np5), X$\geq$3 + fHerwig + Jimmy*
- AcerMC 3.8 + Pythia 6 for I/FSR systematics

single top:

- MC@NLO + fHerwig + Jimmy (not used for t-chan.)
- AcerMC + Pythia 6, incl. I/FSR systematics
- I/FSR systematics prescriptions and variation ranges are the same as for the ttbar

main backgrounds (W,Z+jets, diboson prod.):

- Alpgen 2.1X (Np5), X$\geq$3 + fHerwig

fHerwig + Jimmy tunes (Pythia 6 tunes described earlier):

- ATL-PHYS-PUB-2011-008, include LHC UE, but data-MC agreement not comparably good to what can be obtained when using Pythia 6

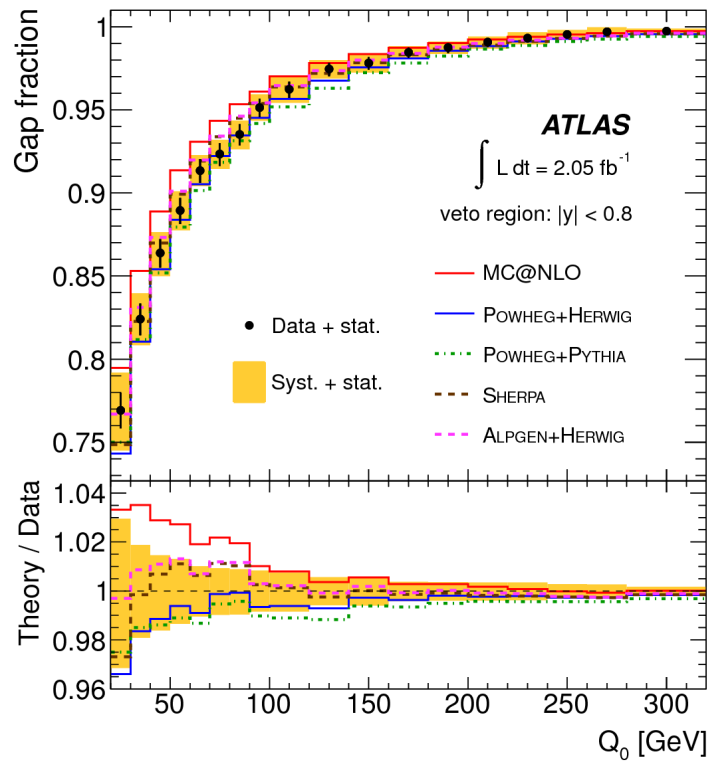
ATLAS TH systematics

generator vs generator comparisons: 2 sources quoted for $t\bar{t}$ production

- **Generator Systematics:** POWHEG-X+fHerwig vs MC@NLO+fHerwig (we also have multi-leg samples available in the $t\bar{t}$ case, which analyses may use),
- **Parton Shower / Hadronization Systematics:** POWHEG-X+fHerwig vs POWHEG-X+Pythia 6,

parameter variation samples: I/FSR:

- LO generator based, no matching
- Pythia 6 parameters: PARP(67),PARP(64),PARP(72),PARJ(82)
- easy to and put on top of the data and construct DD systematics bands (should also be true for multi-leg generators for many observables with the anticipated benefit of larger predictive power)
- a public analysis in $t\bar{t}$ events already in Rivet (Fig., Eur.Phys.J. C72 (2012) 2043)
- more in use / to come



ATLAS: nonperturbative systematics

Based on Pythia 6 + parameter variations;
Underlying event:

- Parameter variations performed around the central ATLAS tune using Professor eigentunes.
- Variations ranges: $\pm \sim 10\%$ activity with respect to the central tune (charged particle multiplicity, average pt as a function of leading jet) in the transverse region plateau of the track based ATLAS UE study (Phys. Rev. D 83 (2011) 112001, arXiv:1012.0791).
- The parameters varied are PARP(84), PARP(90), PARP(82).
- CR parameters are kept fixed.

Color reconnections:

- systematic variation due to the phenomenological description of the color reconnections between the final state particles.
- estimated to be relevant for the top quark mass measurement at Tevatron
- have adopted variations similar to the ones used at Tevatron;
- Perugia 2011 and Perugia 2011 NOCR (both using the new PS/MI Pythia model),
- tune A-Pro and ACR-Pro (both using old PS/MI Pythia model).

Relatively small wrt. to other sources, if/once large one should aim to get better estimates.

ATLAS vs CMS TH systematics categories

Take **LHC Top mass combination (see Giorgio's talk)** as an example; systematics grouped well such as to be comparable between the ATLAS and CMS, but:

- **differences in categories**, most notably for **Rad**iation
- some systematics in table below (most notably NP) were missing and are based on assumptions rather than actually evaluated
- **progress made on both of these in the mean time**

Uncertainty Categories			Size [GeV]						
			ATLAS			CMS			
Tevatron	ATLAS	CMS	2010 l+jets	2011 l+jets	2011 all jets	2010 di-l	2010 l+jets	2011 di-l	2011 μ+jets
MC	MC Generator	MC Generator	0.7	0.3	0.5	0.4		0.1	
	Hadronisation		0.7	0.2	(*)				
	Sum	Sum	1.0	0.4	0.5	0.4		0.1	
Rad	ISR/FSR	ISR/FSR	2.5	1.0	1.7	0.2	0.2		
		Q-Scale				0.6	1.1	0.4	0.8
		Jet-Parton Scale				0.7	0.4	0.7	0.3
	Sum	Sum	2.5	1.0	1.7	0.9	1.2	0.8	0.8
CR	Colour Recon.		*0.6*	0.6	*0.6*	*0.5*	*0.5*	0.5	0.5
UE	Underlying Event	Underlying Event	*0.6*	0.6	*0.6*	1.4	0.2	*0.6*	*0.6*

Harmonization of signal TH uncertainties

Categories and status:

- **Generator modeling:**
  - comparison of central predictions from generators
  - + sources not fitting any other category.
  - general guidelines for ttbar signal: use at least one multileg generator and at least one NLO generator,
  - general guidelines for single top: use at least two different models (one of which NLO).
  - As of now no detailed agreement on e.g. exact generators and tunes.
- **Radiation description:**
  - give multi-leg generators a try for ttbar also on ATLAS side in which case comparable systematics sources can be quoted
  - to be discussed: where to include hard process scale variations in this box (to be discussed)
- **Matching (multi-leg):**
  - change ME and PS gen. matching thresholds
  - . thresholds should be "sufficiently" away from zero and "much smaller" than the process scale. The extreme of the variation range should be such that the good properties of the matching are checked to still hold (differential jet rates, and other differential cross sections, continuous with continuous derivatives after the matching)
- **UE:** using generator tunes with different levels of UE activity (experiments currently using different tunes, so the prescription will not be identical). Plan to use Pythia 6 for now.
- **CR:** compare tunes with/without a CR model. There are measurements particularly sensitive to CR, so experiments will consider an update of this prescription. Plan to use Pythia 6 for now.

Other agreements / initiatives

Constraining systematics from the data:

- we have enough data to enable the ad-hoc numerical prescriptions on parameter variations to be avoided for most (any?) relevant systematics source
- desired both for signal and backgrounds
- very much hope sensitive the measurements can be unfolded and implemented in **Rivet** (at least for signal), so that **everyone can benefit** from using them.

Background systematics:

- using multi-let generators is a must for most top production background processes, so agreement easier to reach
- use guidelines comparable to the signal generator modeling ones for the case of multi-leg gen.

Generator cards:

- the full generator cards and PS setups, as well as the generator versions used for the systematics should be public
- in this way the samples are in principle reproducible for a person not internal to an individual experiment.
- the TOP LHC WG twikis are likely the right places where to put this information.

Hopefully this all helps with the challenge to reach agreement and stay in agreement when adding new generator models!