Overview des les systématiques liées aux radiations

(parton-shower, ISR/FSR,
color reconnection, underlying évent)

L. Mijović

jeudi, le 21 mars

top LHC-France 2013

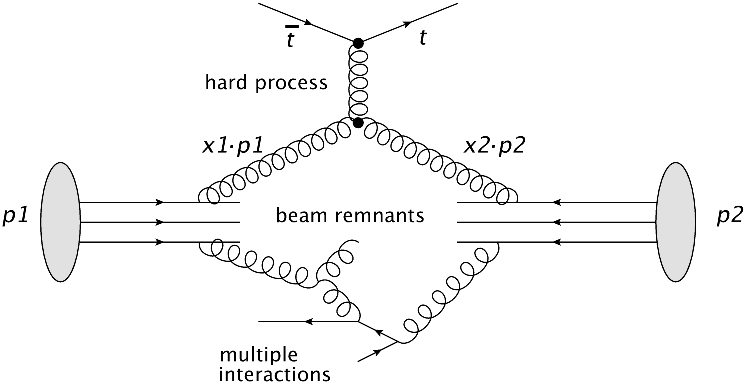
Outline

I will:

- **explain what parton-shower, ISR/FSR, color reconnection, underlying event are**
- **summarize systematics prescriptions used by CMS and ATLAS (+ pass an overview of generator settings used by the experiments)**
- **share some suggestions on ways to improve the systematics prescriptions in the future**

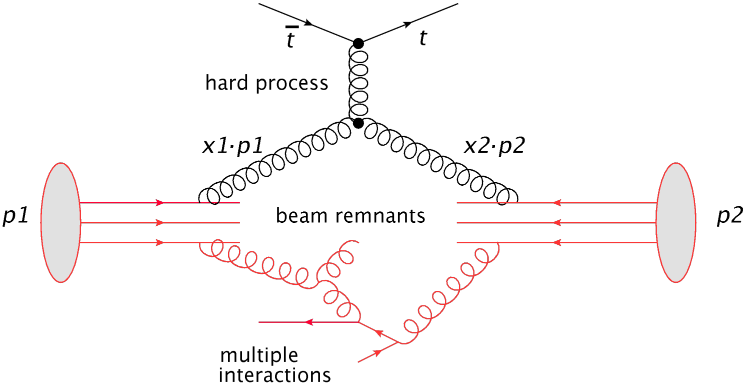
Top Quark Production In $p-p$ Collisions

- take $t\bar{t}$ production + a single $p-p$ collisions
- Hard process: perturbative QCD calculation.
- beam remnants, multiple interactions: effective model.
- final state particles from interactions other than the process of interest $\sim$ Underlying Event



Top Quark Production In $p - p$ Collisions

- take $t\bar{t}$ production + a single $p - p$ collisions
- Hard process: perturbative QCD calculation.
- beam remnants, multiple interactions: effective model.
- final state particles from interactions other than the process of interest $\sim$ Underlying Event



Hard Process Matrix Element

Best choices depend on the use-case:[1]

- **use NLO calculation : limited number of final state legs**
- **use LO calculation : can producing ttbar final states with up to 5 extra final state partons**

Which one to use ?

- **NLO : (will likely do) better** for the top kinematics and direct decay products**
- **multi-leg : (will likely do) better** for high multiplicity final states**
- **$\Rightarrow$ in general we need both.**
- ****ultimately, one should check which setup is in better agreement with the relevant data distributions.**

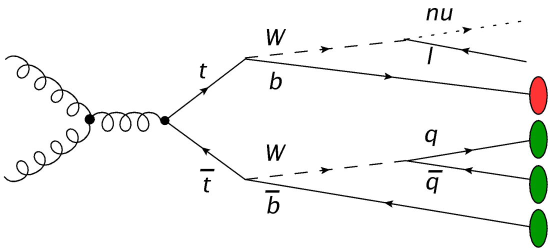
Generators frequently used by CMS and ATLAS:

- **NLO : MC@NLO, PowHeg-BOX(hvq)**
- **multi-leg : Alpgen, MadGraph**

[1] Though models merging the best of two approaches exist and are being tested by the collaborations, the usage is not yet wide-spread.

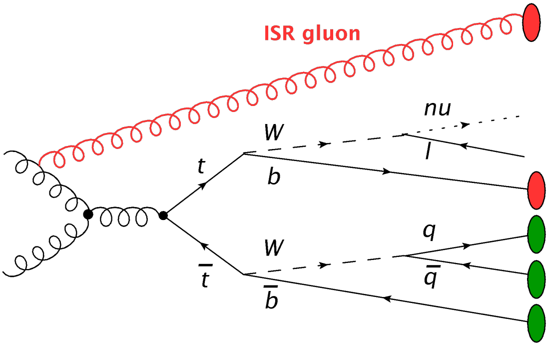
From $t\bar{t}$ Pair To Observable Final State

- Hard process: evolution to lower scales in PDFs and hardonization:
- Initial State Radiation (ISR) [adds jets to the event]
- Final State Radiation (FSR) [takes energy from the jet]
- ISR + FSR = Parton Shower
- Underlying Event (UE) adds soft particles to the final state
- Colour Reconnection (CR) : colour exchange between the decay products
- e.g. $q\bar{q}$ from W hardonizes collectively with the rest of the event
- affects final state hadrons direction



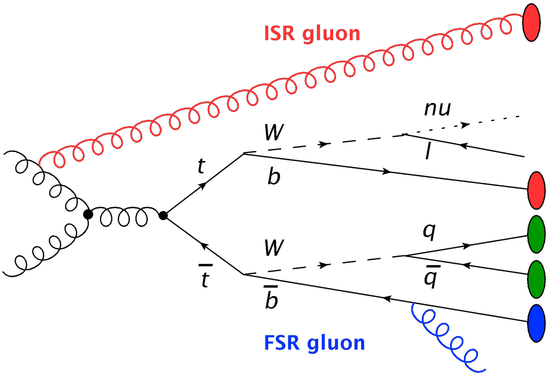
From $t\bar{t}$ Pair To Observable Final State

- Hard process: evolution to lower scales in PDFs and hardonization:
- Initial State Radiation (ISR) [adds jets to the event]
- Final State Radiation (FSR) [takes energy from the jet]
- ISR + FSR = Parton Shower
- Underlying Event (UE) adds soft particles to the final state
- Colour Reconnection (CR) : colour exchange between the decay products
- e.g. $q\bar{q}$ from W hardonizes collectively with the rest of the event
- affects final state hadrons direction



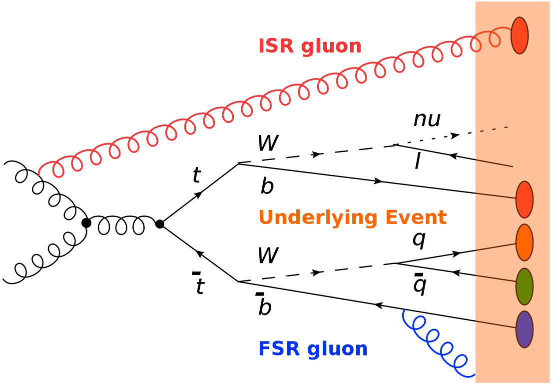
From $t\bar{t}$ Pair To Observable Final State

- Hard process: evolution to lower scales in PDFs and hardonization:
- Initial State Radiation (ISR) [adds jets to the event]
- Final State Radiation (FSR) [takes energy from the jet]
- ISR + FSR = Parton Shower
- Underlying Event (UE) adds soft particles to the final state
- Colour Reconnection (CR) : colour exchange between the decay products
- e.g. $q\bar{q}$ from W hardonizes collectively with the rest of the event
- affects final state hadrons direction



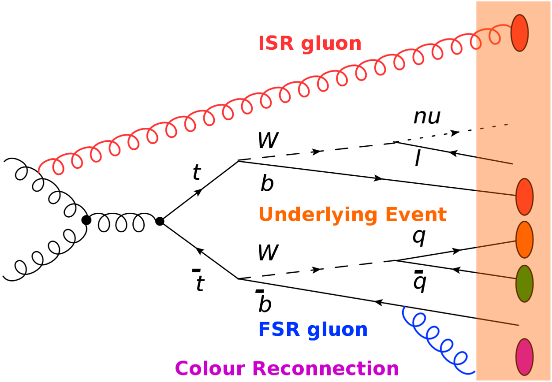
From $t\bar{t}$ Pair To Observable Final State

- Hard process: evolution to lower scales in PDFs and hardonization:
- Initial State Radiation (ISR) [adds jets to the event]
- Final State Radiation (FSR) [takes energy from the jet]
- ISR + FSR = Parton Shower
- Underlying Event (UE) adds soft particles to the final state
- Colour Reconnection (CR) : colour exchange between the decay products
- e.g. $q\bar{q}$ from W hardonizes collectively with the rest of the event
- affects final state hadrons direction



From $t\bar{t}$ Pair To Observable Final State

- Hard process: evolution to lower scales in PDFs and hardonization:
- Initial State Radiation (ISR) [adds jets to the event]
- Final State Radiation (FSR) [takes energy from the jet]
- ISR + FSR = Parton Shower
- Underlying Event (UE) adds soft particles to the final state
- Colour Reconnection (CR) : colour exchange between the decay products
- e.g. $q\bar{q}$ from W hardonizes collectively with the rest of the event
- affects final state hadrons direction



Efective Models and Systematics

Effective models are used for all of :

- Initial State Radiation (ISR) [adds jets to the event]
- Final State Radiation (FSR) [takes energy from the jet]
- Underlying Event (UE) adds soft particles to the final state
- Colour Reconnection (CR) affects final state hadrons direction

Generators most widely used so far by CMS and ATLAS :

- fortran **Pythia** 6.4X
- fortran **Herwig** 6.5X

There are many newer models on the market . . .

Systematics

Modelling assumptions can affect the simulated observables distributions;

- **different generators can be used for the hard process ME**
- **Different assumptions are made in different effective models (ISR/FSR,UE,CR)**
  $\Rightarrow$ systematics can be assessed by comparing different models
- **The effective model contains free parameters to be tuned to the data**
  $\Rightarrow$ systematics can be assessed by comparing samples with different model parameter settings

In the following slides I will try to set up the basis for the discussion by:

- **summarizing the way the systematic uncertainties related are evaluated in ATLAS and CMS**

- **+ (briefly) sharing some thoughts on ways to improve them in the future;**
- **and hoping to hear your opinion and ideas on this point!**

For recent comprehensive summaries, see modeling related talks at the TOP LHC WG meetings:

`https://indico.cern.ch/conferenceDisplay.py?confId=189617`
`http://indico.cern.ch/conferenceDisplay.py?confId=217721`

Pythia 6 Tunes used by CMS and ATLAS

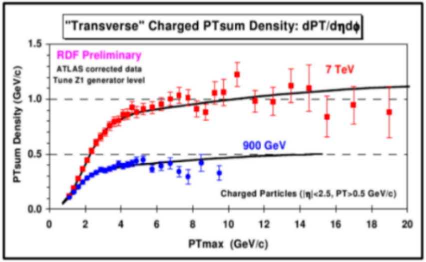
Both experiments using new PS/MPI Pythia 6 model (pT-ordered PS, interleaved ISR-MPI evolution).

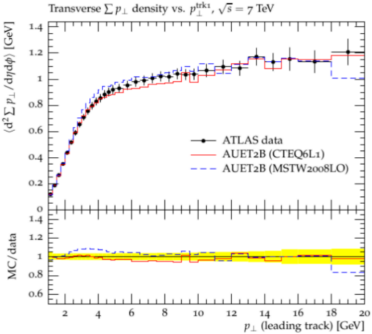
References:

- CMS: Z2(*), arXiv:1010.3558v1 [hep-ph] (LHS Fig.)
- ATLAS: AUET* series, ATL-PHYS-PUB-2011-009 (RHS Fig.)
- both also use author Perugia2011 tune series (arXiv:1005.3457 [hep-ph])

Data used for tuning for 7 TeV data production round:

- LHC UE for both ATLAS and CMS
- PS parameters acc. to QCD jet shapes, QCD dijet decorrelations . . .
- data constraints on systematics relevant for top taken into account with shorter turn-around 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≥5 or fHerwig + Jimmy
- *Alpgen 2.1X (Np5), X≥3 + fHerwig + Jimmy or + Pythia 6*
- AcerMC 3.8 + Pythia 6 for I/FSR systematics (+ *attempts with Alpgen 2.1X + Pythia 6*)

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≥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

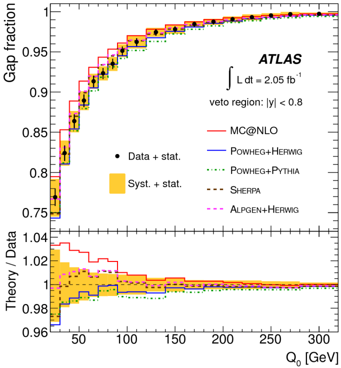
ATLAS TH systematics

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
- DD systematics bands using jet veto analysis
- Fig: Eur.Phys.J. C72 (2012) 2043
- multi-leg Alpgen + Pythia similar to CMS 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).
- CR parameters are kept fixed.

Color reconnections:

- Perugia 2011 and Perugia 2011 NOCR (both using the new 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** 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*

Ideas For Improvement

- **more constraints from the data**
  - more measurements in $t\bar{t}$ (or eventually even single top)
    CMS and ATLAS ideas :
    `http://indico.cern.ch/conferenceDisplay.py?confId=217721`
  - more measurements from other high-pt processes

- **use more/newer generators**
  - esp. for parton shower, UE, CR fHerwig and Pythia 6 are superseded by newer models
  - Herwig++, Pythia8, Sherpa

- **systematics categories synchronization between ATLAS and CMS**
  - a lot of progress made in the TOPLHC WG headed by Roberto Chierici and Markus Cristinziani
  - room for improvement, esp. in synch with progress in the first two items