Measurement of $t\bar{t}$ production with a veto on additional central jet activity in pp collisions

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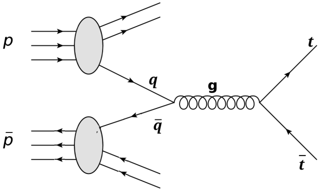
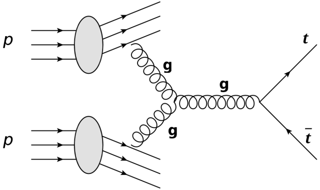
Outline

$t\bar{t}$ pairs can be produced through

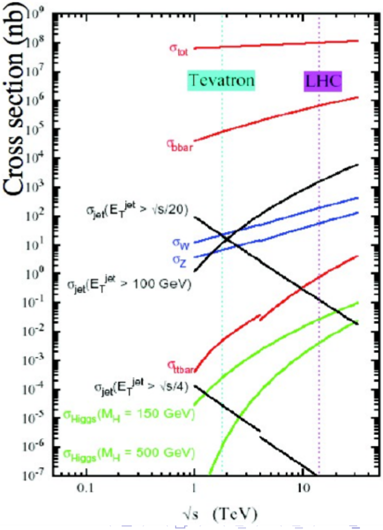
- $q\bar{q}$ production, Tevatron mostly;



- gluon production, LHC almost exclusively ($gg \to t\bar{t}$, 80%).

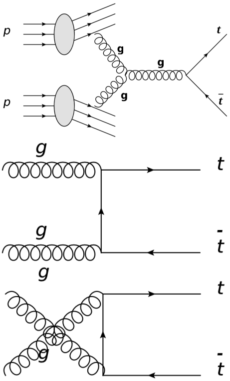


Proton-(anti)proton collisions:

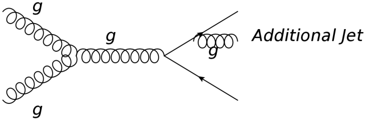


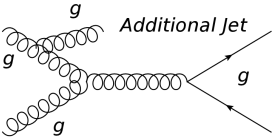
Top Pair Production at LHC

Possible $t\bar{t}$ pair productions through gluon channels at LHC:



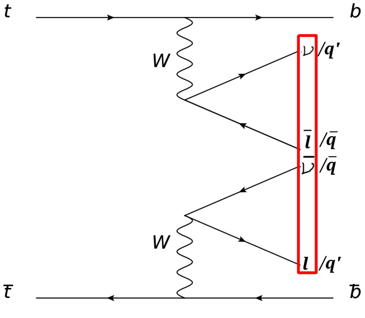
What processes interested in?
The next leading order events, which has an additional jet(s), mainly from gluons:



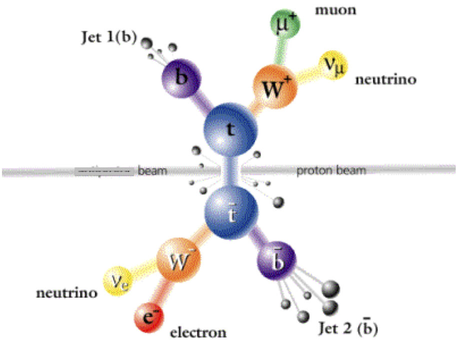


Top Pairs Decay

- 99.8% of top quarks decay into W bosons and b quarks: $t \to W^+ + b$
- Most propable final states of $t\bar{t}$ decay:
  - **Dilepton**: 2 b-jets, 2 leptons and missing E_T (used in this paper)
  - Lepton+jet: 2 b-jets, 1 lepton, 2 jets and missing E_T
  - Hadronic: 2 b-jets, 4 other jets



$t\bar{t}$ decay



Gap Fraction

Gap fraction is defined as:

$$f(Q_0) = \frac{n(Q)}{N}$$

$$\downarrow$$

$$C(x) = \frac{f^{truth}}{f^{reconstruction}}$$

$$\Downarrow$$

$$f(Q_0) = \frac{\sigma(Q_0)}{\sigma}$$

&

$$f(Q_{sum}) = \frac{n(Q_{sum})}{N} \equiv \frac{\sigma(Q_{sum})}{\sigma}$$

- N: total number of $t\bar{t}$ events
- $n(Q_0)$: with NO additional central jets ($p_T > Q_0$) over threshold.

$C(x)$ is the correction factor of detectors which is $2 \sim 5\%$ at $Q_0 = 25 GeV$, decreasing with Q_0.

- σ: total fiducial cross section of inclusive $t\bar{t}$ events
- $\sigma(Q_0)$: with NO additional jets over threshold.

The **uncertainities** of the gap fraction are mostly **due to the additional jets**.

Motivation of Gap Fraction

Gap fraction can be simulated with Monte Carlo generators and its uncertainty is from how the additional jets are treated theoretically through parameters, therefore it is useful to

- test QCD and
- reduce the uncertainty of e.g. top quark mass measurement.
- For example, MC parameters, initial state & final state QCD radiation (ISR & FSR) contribute a large proportion to the total uncertainty:

	1d-analysis		2d-analysis		Combinations		Correlation
	$e+$jets	$\mu+$jets	$e+$jets	$\mu+$jets	1d	2d	ρ
Measured value of m_{top}	172.93	175.54	174.30	175.01	174.35	174.53	
… …							
ISR and FSR (signal only)	1.45	1.40	1.04	0.95	1.42	1.01	1
… …							
Total systematic uncertainty	2.46	2.56	2.31	2.57	2.50	2.31	
Total uncertainty	2.86	2.80	2.46	2.68	2.66	2.39	

Event Selection I

Dilepton decay events are selected according to

- 2 energetic and central leptons ($E_T > 25 GeV$ and $|\eta| < 2.5$)
- 2 b-tagged jets based on secondary vertex and well-separated from leptons ($E_T > 25 GeV$ and $R(j, \ell) > 0.4$)
- missing transverse momentum with similar energy scale of leptons ($E_T^{missing} > 40 GeV$)

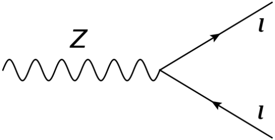
Some information about jet reconstruction:

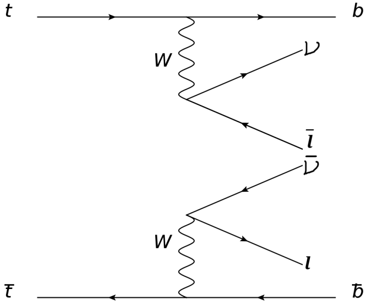
- jets are reconstructed with anti-k_t algorithm (with adjacent calorimeter cells calibrated at EM energy scale)
- jets are corrected for calorimeter response (and other effects) with energy and pseudo-rapidity η dependent factors
- calibrated jets are required to be well-separated from leptons, i.e. $\Delta R(\ell, j) = \sqrt{(\Delta\phi(\ell, j))^2 + (\Delta\eta(\ell, j))^2} > 0.4$

Event Selection II

Main background of di-lepton channel arises from Z boson decay:

- di-lepton mass $m_{\ell\ell}$ not in Z range $|m_{\ell\ell} - m_Z| > 10GeV$ required
- $Z \rightarrow ee/\mu\mu$ suppressed by $E_T^{missing} > 40GeV$
- $Z \rightarrow e\mu$ suppressed by scalar sum of visible momentum $H_T > 130GeV$



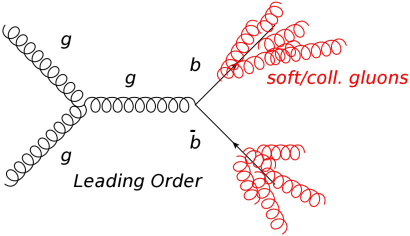


Other backgrounds are small enough to ignore.

Monte Carlo Simulations

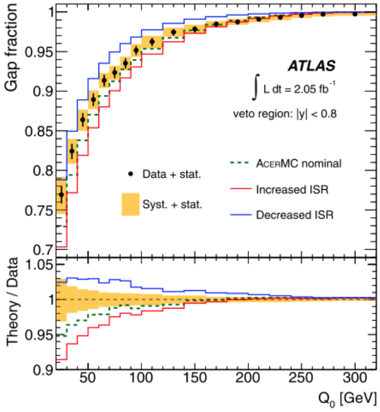
Concept of Monte Carlo event generators and QCD implementation:

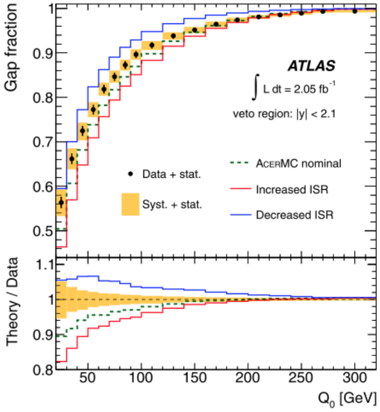
- Calculate the matrix element ($\mathcal{M} \propto \sqrt{\sigma}$), according to QCD, for hard scattering processes from all possible Feynman Diagrams to the leading order (LO) or next leading order (NLO).
- Parton shower us modelled by adding soft/collinear gluons and quarks.
- Hadronisation (is done in different models: independent fragmentation, string model and cluster model).



LO MC Simulation

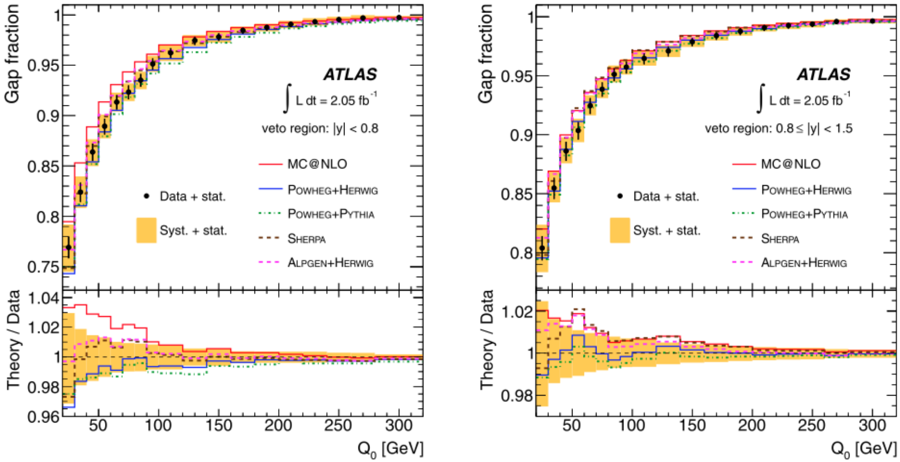
- LO event generators (e.g. ACERMC) aproximate the NLO gluons to soft gluons → the final result depends strongly on the parameter in algorithm.
- NLO event generators (e.g. MC@NLO and POWHEG) do not need this approximation and work better





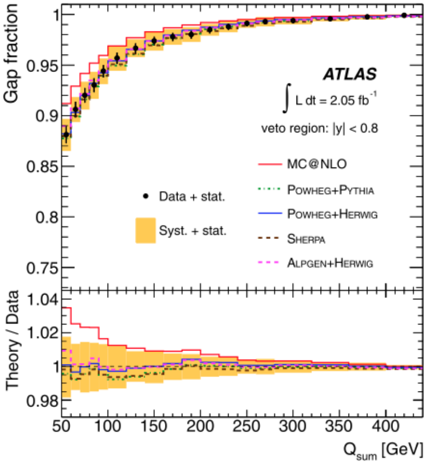
Results on Gap Fraction I

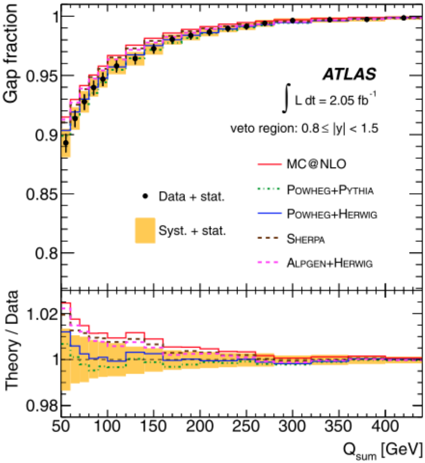
pp collisions at cms energy $\sqrt{s} = 7\,TeV$, integrated luminosity $2.05 fb^{-1}$.
Good agreement (POWHEG) in low rapidity region for single additional jet:



Results on Gap Fraction II

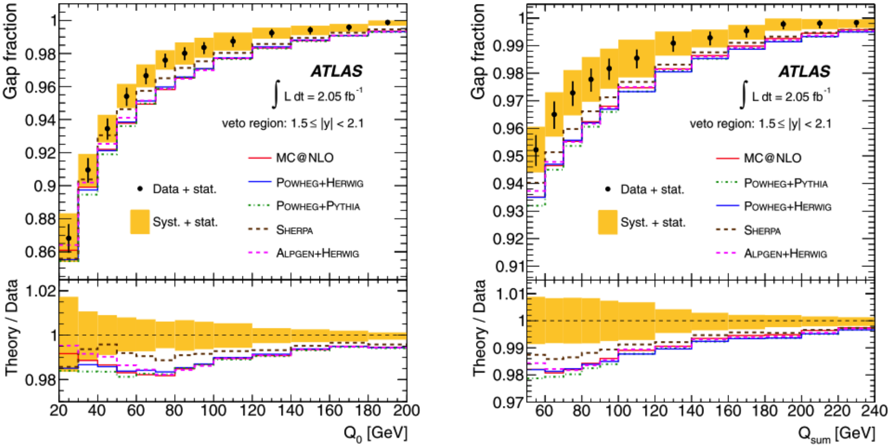
Good agreement in low rapidity region for more additional jets as well (again, lower gap with higher threshold):





Results on Gap Fraction III

Monte Carlo simulations predict too much jet activity in the forward rapidity region (larger gap):



Conclusion

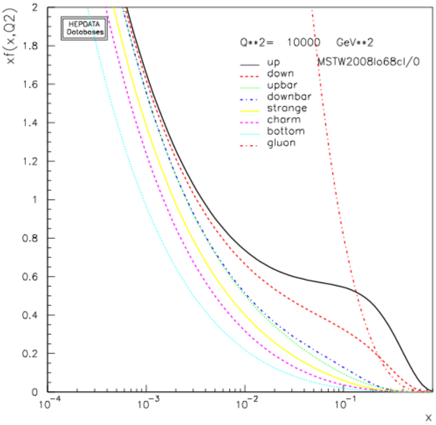
- Pure $t\bar{t}$ events are selected.
- Extra radiations for production processes are measured and compared with Monte Carlo simulations.
- Monte Carlo simulations give a good agreement in the central region, but over-estimated in higher rapidity region.

Reference

- The ATLAS Collaboration, Eur. Phys. J. C (2012) 72:2043. DOI 10.1140/epjc/s10052-012-2043-9
- The ATLAS Collaboration, Eur. Phys. J. C (2012) 72:2046. DOI 10.1140/epjc/s10052-012-2046-6
- J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012).

Thank you very much!

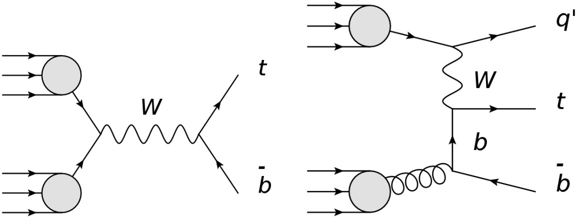
Why gluons for production?
At higher energy colliders such as LHC, the target fraction of proton energy is most probably carried by gluons.
Also, the quark production needs a quark and an anti-quark (much less likely to find in pp collisions, see pdf distribution)



Backup for Event Selection

After the event selection process, still exists background from:

- Single top events if a lepton from heavy flavour decay or



- Jet misidentification.