# Signal Modelling Systematics at ATLAS

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# Modelling Parameters

- event generators: MC@NLO vs. POWHEG vs. ALPGEN

- parton shower: POWHEG with two different parton showers models, HERWIG and PYTHIA

- PDF: envelope of PDF sets from different collaborations according to PDF4LHC recommendation

- ISR/FSR: ACERMC interfaced with PYTHIA with different settings

- top quark mass: MC@NLO with different top quark masses

- colour reconnection: ACERMC Perugia2011 with and without colour reconnection (with new PS/MI Pythia model) and
Tevatron tune A-Pro and ACR-Pro (with old PS/MI Pythia model)

# Event Generators

Compare results using three different event generators

standard generator:
MC@NLO 4.0x with HERWIG 6.520 for parton shower and JIMMY 4.31 for underlying event

compare to:
POWHEG-hvq-patch4(BOX 1.0.x) and ALPGEN 2.1x with same settings,
**take largest difference as uncertainty**

choice of generator difficult, each generator describes data well in different part of phase space

main difference between generators in acceptance

→ making looser cuts reduces dependency on generator
→ aim at using boost invariant variables

# Event Generators

analysis of tt production with veto on additional central jets

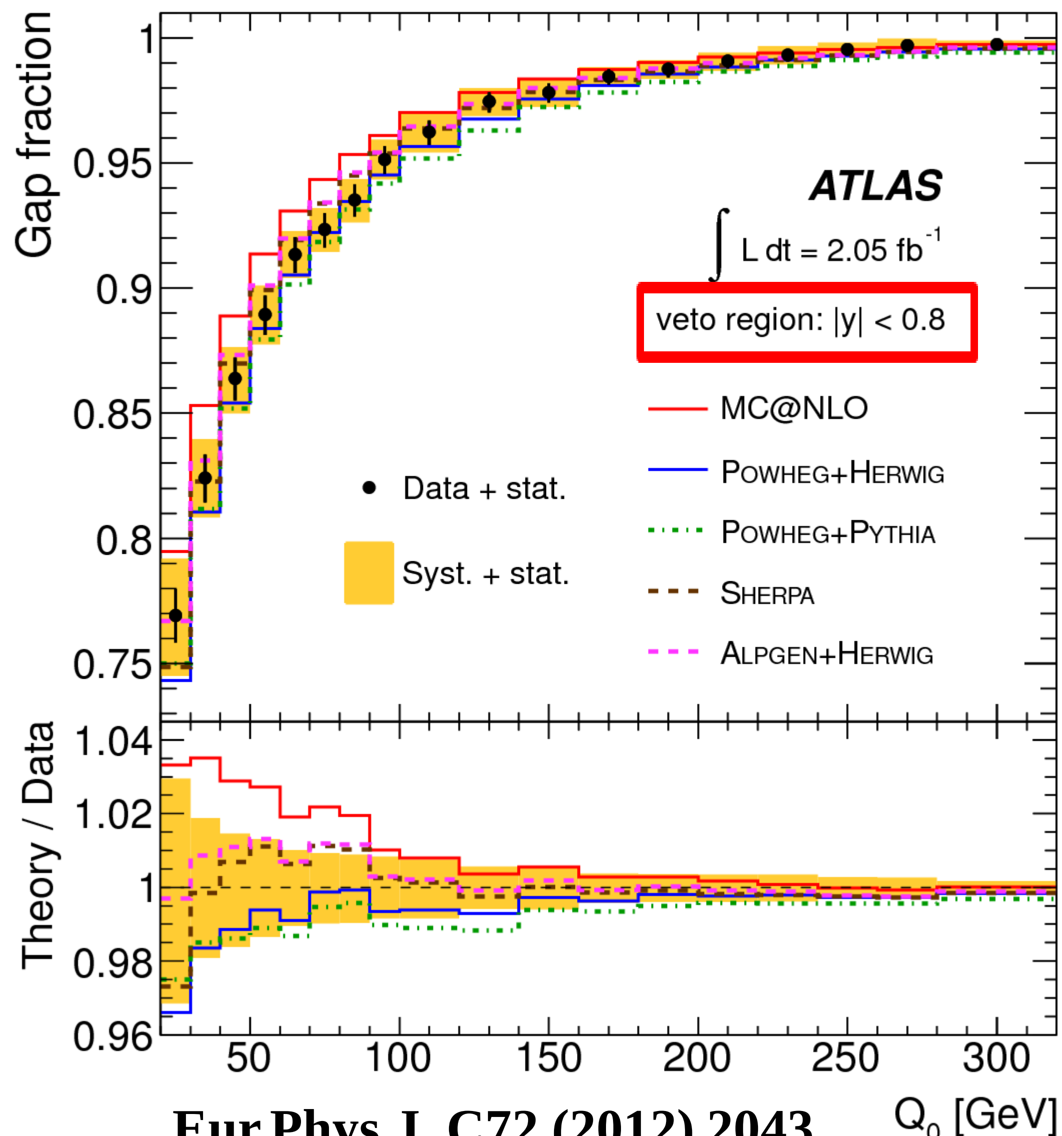
comparision of several generators

$Q_0$: exclude events with additional jets with $p_T > Q_0$ in given central rapidity interval y

gap fraction: number of events that do not contain an event with an additional jet with $p_T > Q_0$ over total number of events

significant difference between MC@NLO and POWHEG

result unfoldet for detector effects, available in Rivet: ATLAS_2012_I1094568

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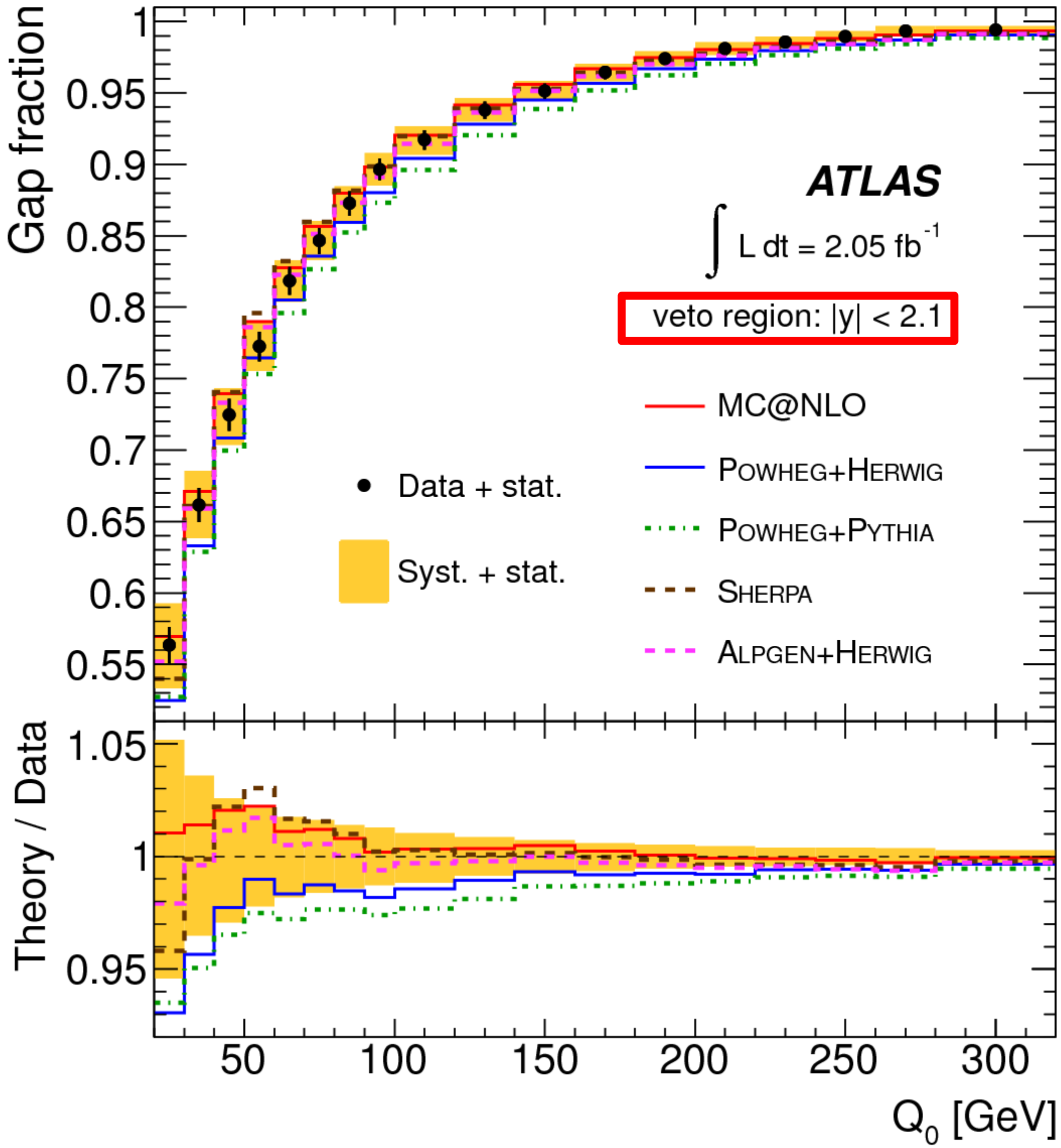
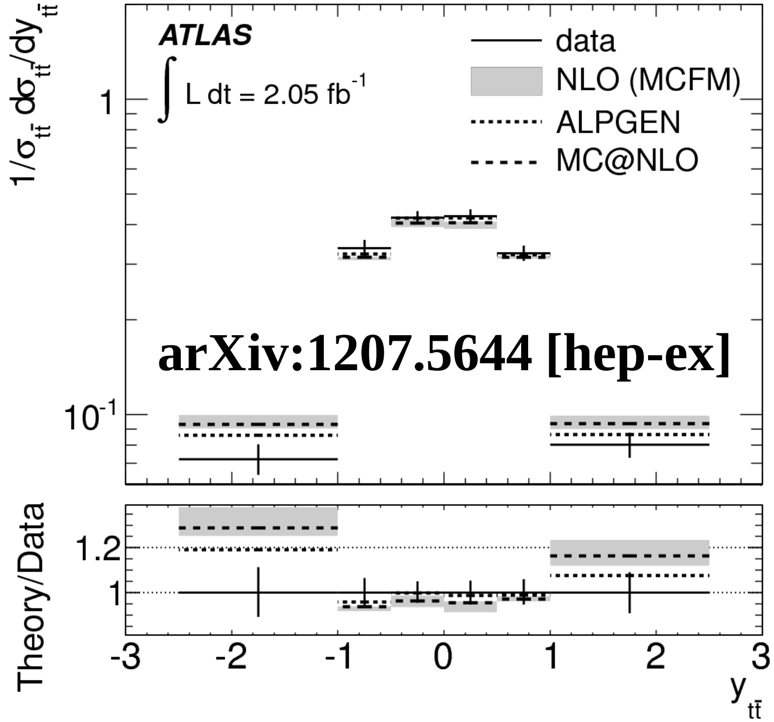


# Event Generators

differential cross sections for tt system
data unfolded for detector effects and corrected for acceptance
NLO predictions: MCFM and MC@NLO
LO + multi leg prediction: ALPGEN
some discrepancies for large rapitidies




resulting uncertainties:

| | |
|---|---|
| - cross section: | ~5 % MC@NLO vs POWHEG |
| | up to 10 % MC@NLO vs ALPGEN |
| - cross section ttj: | 21 % (ATLAS-CONF-2012-083) |
| - mass: | 0.3 GeV (single lepton channel, template method, arXiv:1203.5755v2) |
| | 1.3 GeV (eμ channel, $m_{T2}$ method, ATLAS-CONF-2012-08) |
| - charge asymmetry: | 10 - 50 % of total systematic |
| - spin correlation: | 25 % of total systematic |
| - W helicity: | 10 – 30 % of total systematic |

# Parton Shower Generator Tuning

parameters in PYTHIA for parton shower (PS) and underlying event (UE) are tuned to match data from LHC
[ATLAS-PHYS-PUB-2011-008, ATLAS-PHYS-PUB-2011-009]

PYTHIA: separate tunes for minimum bias (MB) and underlying event (UE) parameters

- flavour parameters
- FSR and hadronisation
- ISR
- multiple-parton interactions (MPI)

HERWIG and JIMMY (UE) parameters also tuned

tuning started on Tevatron data (pre LHC data taking period)
now use also ATLAS LHC data at $\sqrt{s}$ = 7 TeV

# PYTHIA and HERWIG+JIMMY tunes

tuning done using Rivet and professor tool

PYTHIA6:

first tunes using MRST LO* PDF → AUET1, AMBT1

tunes using ATLAS data at $\sqrt{s}$ = 7 TeV and several PDFs → AUET2B, AMBT2B

tunes for PYTHIA8 available, but not yet used extensively for top quark production process simulation

HERWIG + JIMMY:

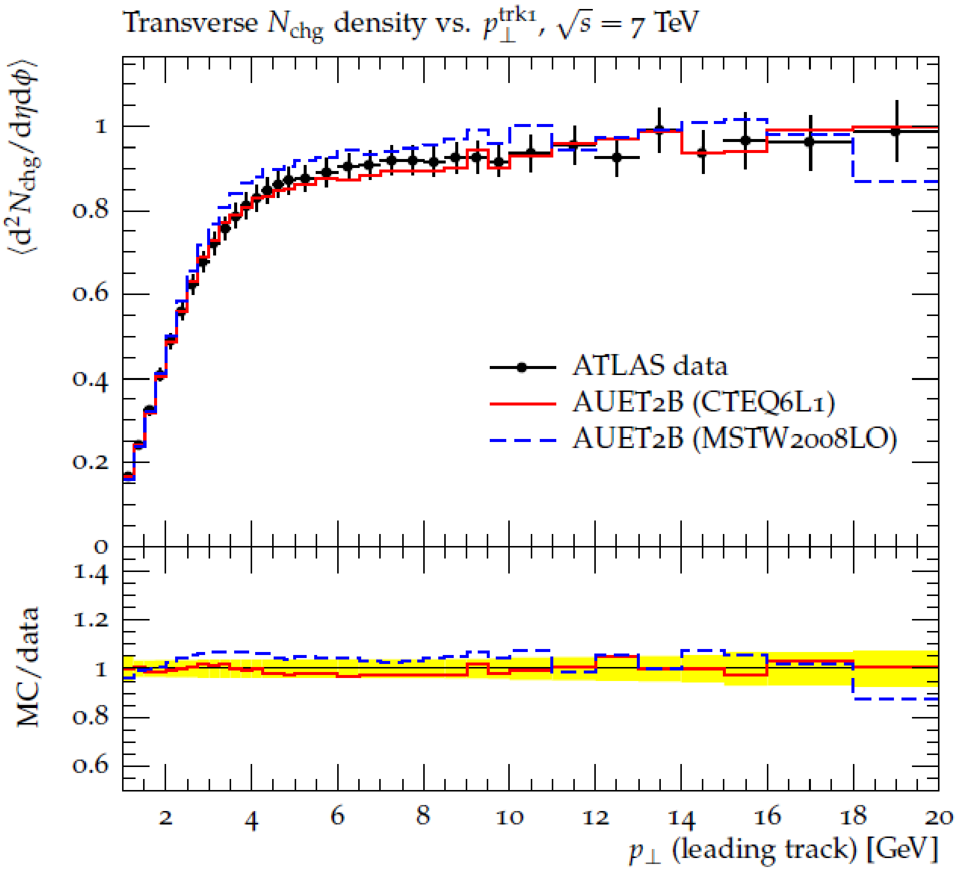
tune only MPI parameters of JIMMY (as HERWIG does not have MPI model)

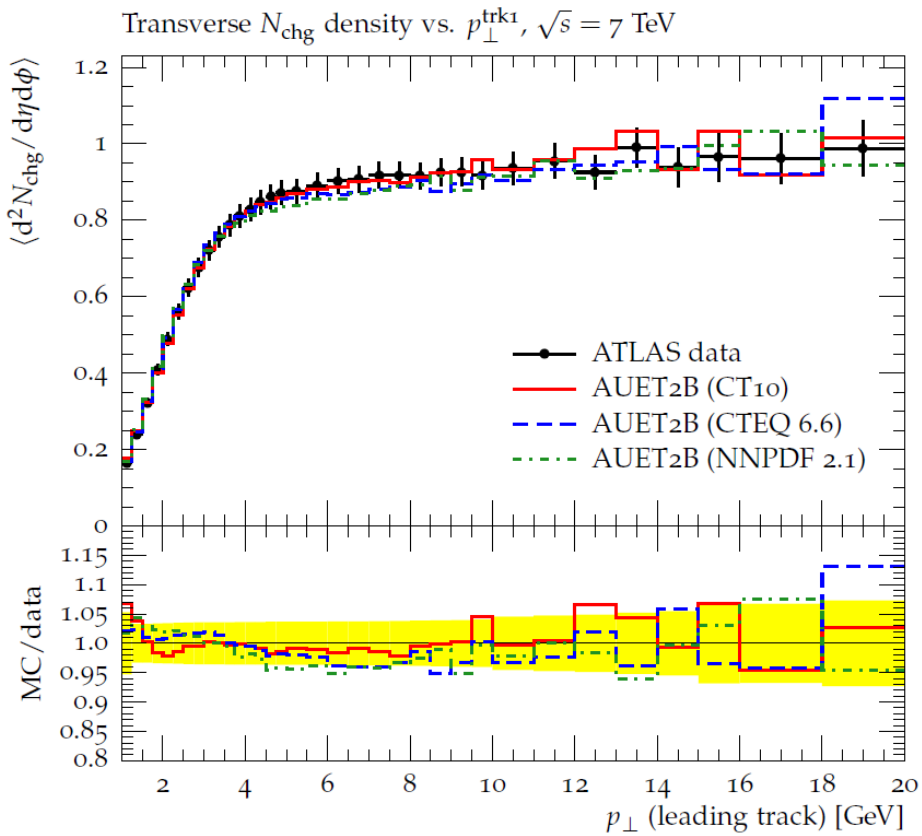
MB data cannot be used → only UE event tune using several PDFs

(LO: CTEQ6L1, MSTW08LO, mLO: MRSTMCal(LO**), CT09MC2,
NLO: CTEQ6.6, CT10, MSTW08NLO, HERAPDF1.0, HERAdis, NNPDF2.1)

# LO vs NLO PDFs

PYTHIA 6 tunes **ATL-PHYS-PUB-2011-014**



# Parton Shower

two different parton shower and hadronisation models

POWHEG with CT10 (prev. CTEQ6.6) PDF and

- HERWIG + JIMMY (AUET2B) (prev. AUET1)
- PYTHIA  (AUET2B) (prev. AMBT1)

resulting uncertainties:

| | |
|---|---|
| - cross section: | 2 % |
| - mass: | 0.15 GeV |
| - charge asymmetry: | 4 - 42 % of total systematic |
| (dilepton channel has smaller uncertainty) | |
| - spin correlation: | 32 % of total systematic |

# ISR/FSR

ISR is fit and constrained by data in ATLAS tunes of generators

use ACERMC 3.8 + PYTHIA 6.42x with parameters:

**PARP(67): controls suppression of ISR**
**PARP(64): multiplies $\alpha_{QCD}$ evolution scale**

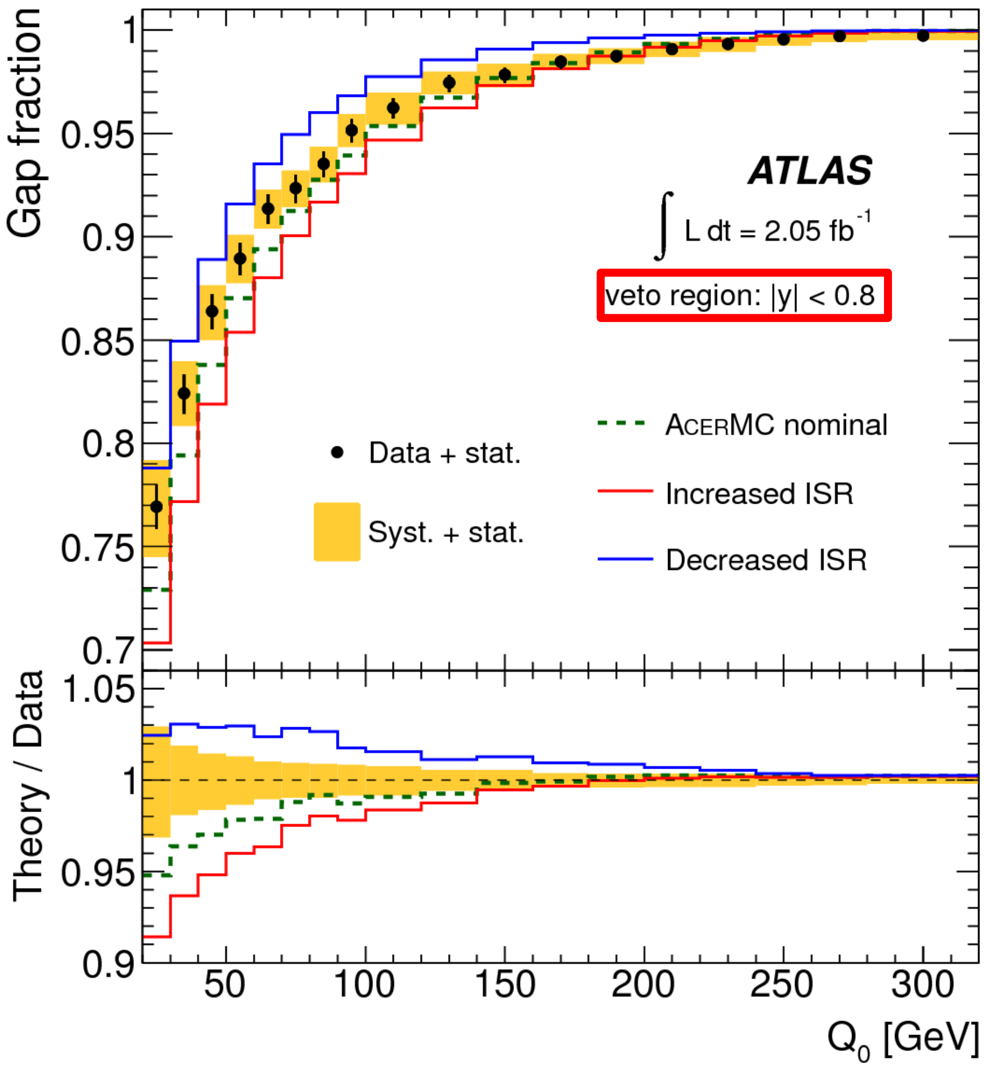
PARP(67) = 1.0, PARP(64) = 0.68

increased ISR:
PARP(67) = 1.75, PARP(64) = 0.60

decreased ISR:
PARP(67) = 0.70, PARP(64) = 3.60

measurement enabled constraining uncertainty

ISR variations preceding results from this analysis



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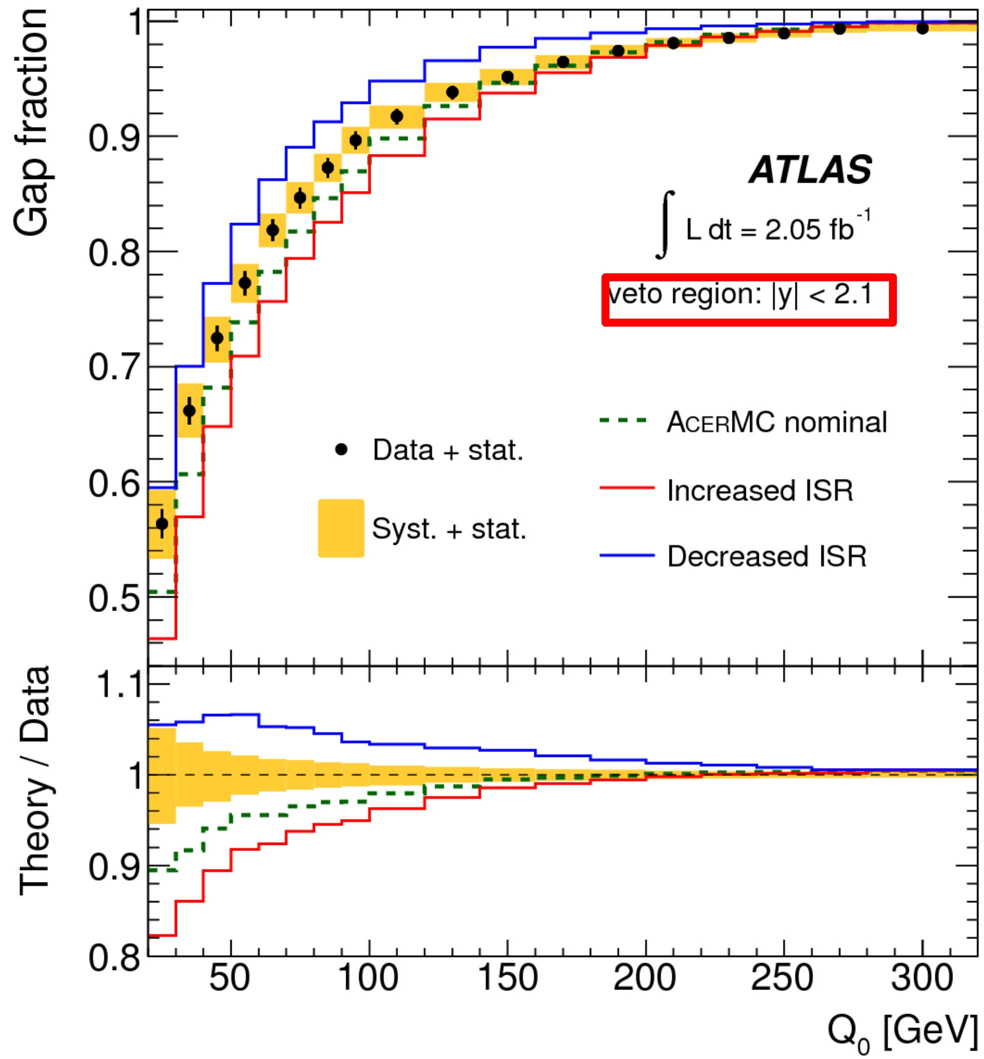


# ISR/FSR

resulting uncertainties:

| | |
|---|---|
| - cross section: | 2 – 5 % |
| - cross section ttj: | 3 % |
| - mass: | 0.5 GeV eμ channel |
| | 1.1 GeV single lepton channel, template method |
| - charge asymmetry: | 12 - 86 % of total systematic |
| - spin correlation: | 28 % of total systematic |
| - W helicity: | 17 – 25 % of total systematic |

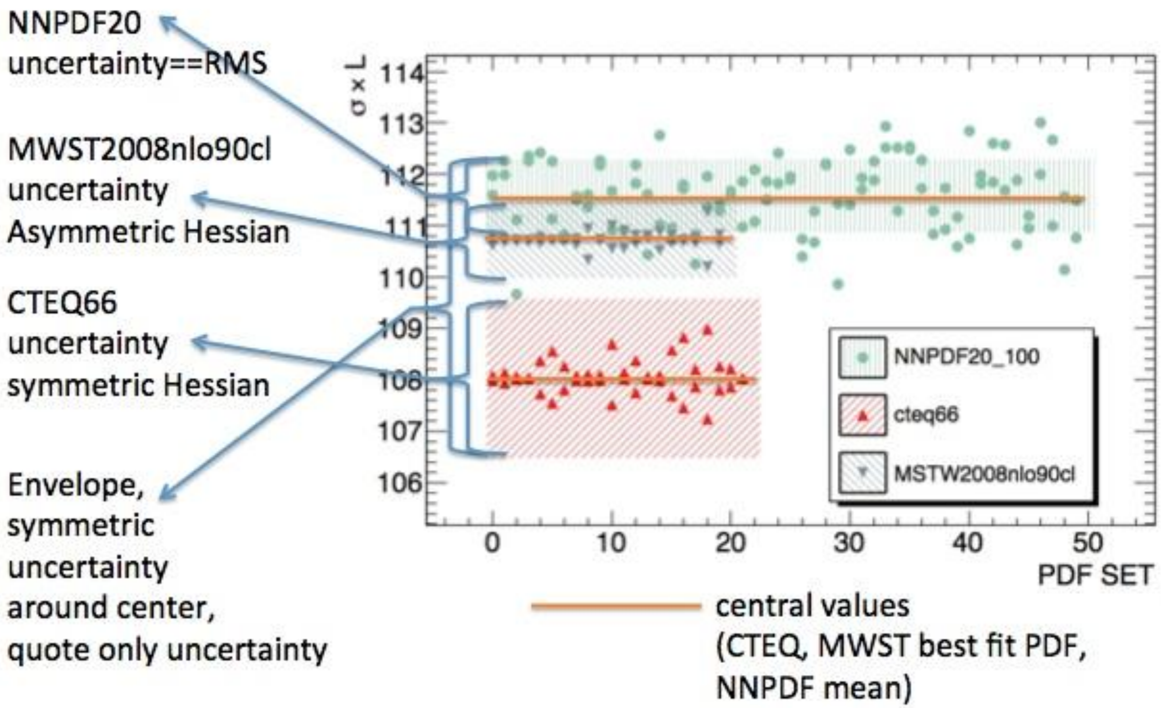
# Parton Density Functions

recommendation from PDF4LC working group

compare MSTW08, CTEQ6.6 (CT10) and NNPDF2.0

use all sets for one PDF and $\alpha_s$ uncertainty

use envelope of all three PDFs as uncertainty for analysis



# Parton Density Functions

resulting uncertainties:

| | |
|---|---|
| - cross section: | 1 – 3 % |
| - cross section ttj: | < 1 % |
| - mass: | 0.1 GeV (single lepton and eμ channel) |
| - charge asymmetry: | < 1 % of total systematic |
| - spin correlation: | 28 % of total systematic |
| - W helicity: | 15 – 20 % of total systematic |

uncertainties much smaller than those mentioned before

# Top Quark Mass

Top quark mass known with precision of 0.9 GeV from Tevatron

central value of 172.5 GeV used in MC@NLO + HERWIG + JIMMY sample

samples produced with MC@NLO for top quark masses
from 167.5 – 177.5 GeV with 2.5 GeV mass spacing

differences from using these samples scaled to 0.9 GeV

resulting uncertainties:

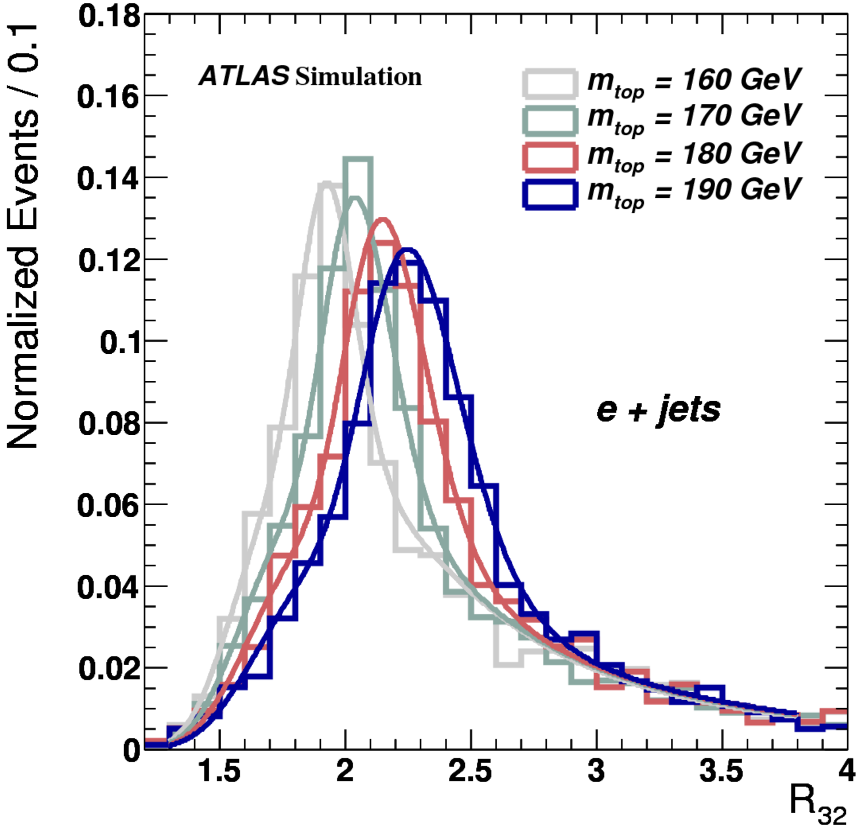
- cross section: 0.5 – 1.0 %
- charge asymmetry: 25 % of total systematic
- spin correlation: 4 % of total systematic
- W helicity: 20 – 30 % of total systematic

# Top Quark Mass

cross section results can be given as function of top quark mass, but dependency is < 1% per 1 GeV.

strong dependency of many parameters on top quark mass, but knowledge of mass very good (< 0.9 GeV)

→ mostly small contribution to total systematic uncertainty



# Colour Reconnection

ACERMC + PYTHIA
Perugia2011 with and without colour reconnection (with new PS/MI Pythia model)
and
Tevatron tune A-Pro and ACR-Pro (with old PS/MI Pythia model )

used in recent analyses, especially in top quark mass determination
→ 0.55 GeV uncertainty in single lepton channel, template method
→ 1.5 GeV uncertainty in eμ channel, $m_{T2}$ method

# Summary and Outlook

main uncertainties are:

- generator choice
- parton shower model
- ISR/FSR (reduced by recent studies)

smaller dependency on
- PDF
- top quark mass
- colour reconnection
- matching algorithm

**Outlook**:

- use more generators, e.g. Sherpa
- use data to achieve further constraints + add to Rivet

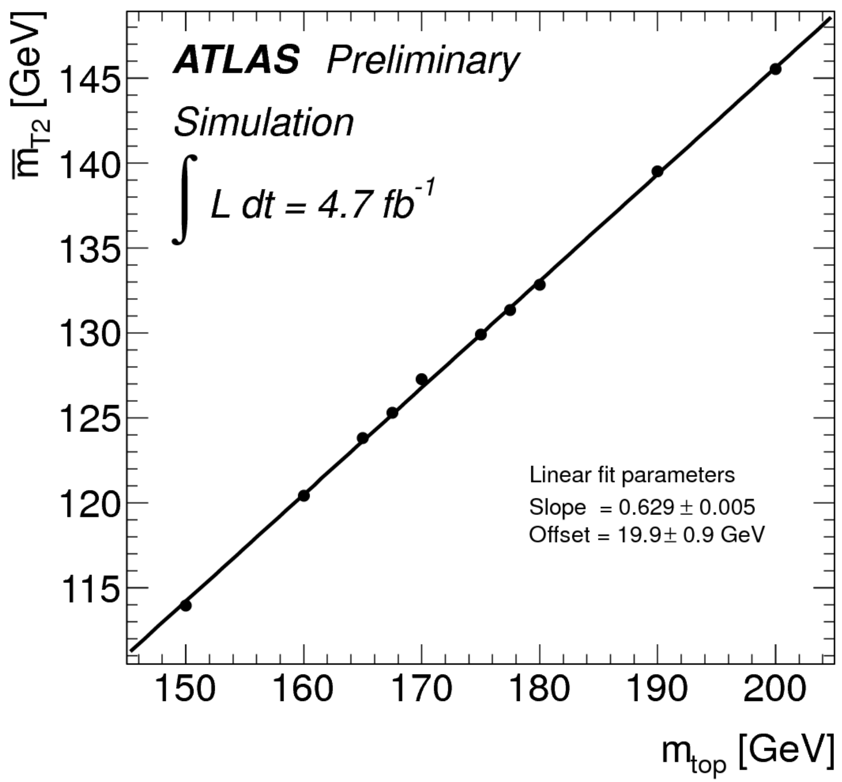
# Backup

# PDF

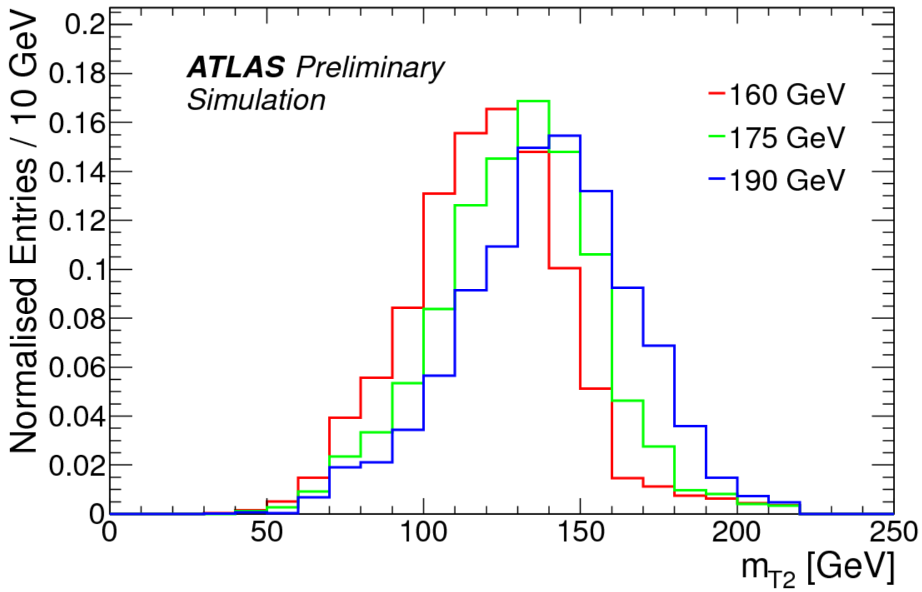
symmetric Hessian uncertainty: $\delta X = 0.5 * \sqrt{\sum (X_i^+ - X_i^-)^2}$

asymmetric Hessian uncertainty: $\delta X = \sqrt{\sum (X_i - X_0)^2}, \text{for } X_i - X_0 > 0$

$X_i$: result from PDF variation i by + or - 1σ



ATLAS Preliminary
Simulation
∫ L dt = 4.7 fb^-1
Linear fit parameters
Slope = 0.629 ± 0.005
Offset = 19.9 ± 0.9 GeV
m̄T2 [GeV]
mtop [GeV]

ATLAS Preliminary
Simulation
160 GeV
175 GeV
190 GeV
Normalised Entries / 10 GeV
mT2 [GeV]