The University of Manchester

Measurement of top-antitop production with a veto on additional central jet activity

arXiv:1203.5015 - Eur. Phys. J. C (2012) 72:2043

Low-X 2012

Kiran Joshi

on behalf of the ATLAS collaboration

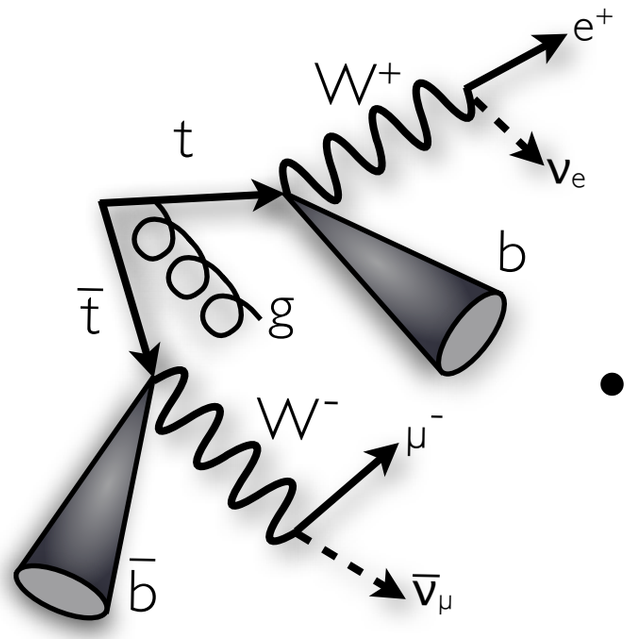
Outline:

- Motivation
- Object & event selection
- Variable definition
- Systematic uncertainties
- Results
- Summary

ATLAS EXPERIMENT

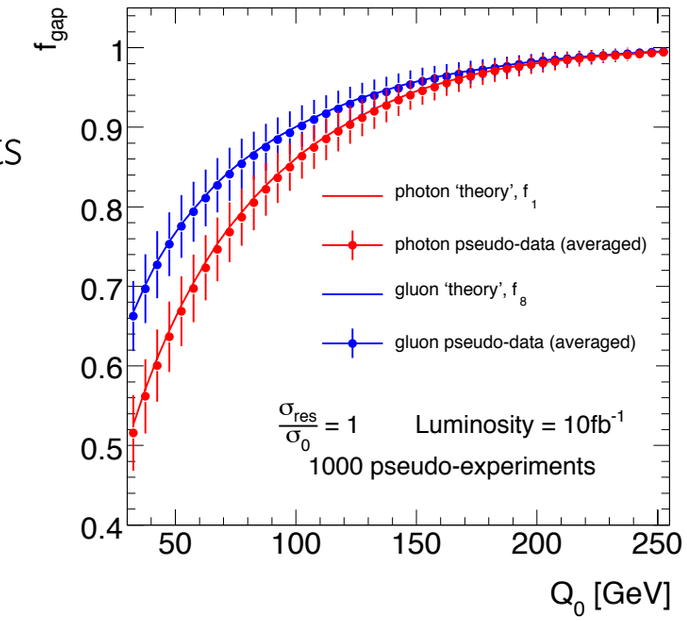
http://atlas.ch

Why top-antitop events?



- Jet vetoes are useful tools for measuring QCD activity.

(*Sung* Phys.Rev. D80 (2009) 094020)
Ask et. al. JHEP 1201 (2012) 018

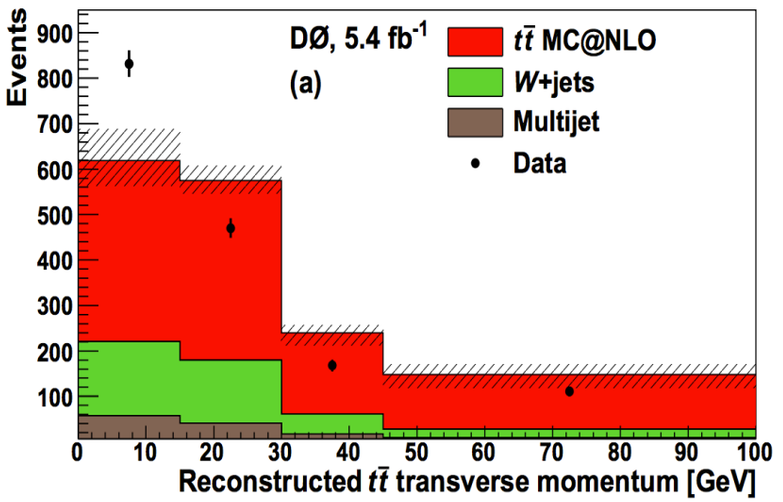


- Analyses of **top-antitop** final-states are good tests of the SM, and will be important **probes of new physics** at the LHC.

- E.g. properties of new heavy resonances, decaying to **tops**, could be measured by looking at the **associated QCD radiation**.

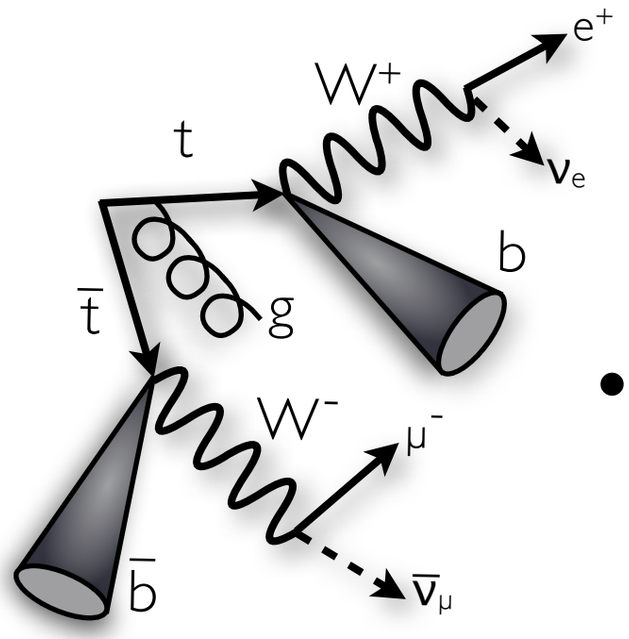
- Furthermore, interpretation of recent Tevatron results (A_{FB}) are obscured by data-MC disagreement and uncertainties in modelling the top-antitop final state.

D0 Collabroation Phys. Rev. D 84, 112005 (2011)



- Our aim to perform a precise measurement of **QCD** in **top-antitop** final-states, which are **not yet well-explored**.

Why top-antitop events?



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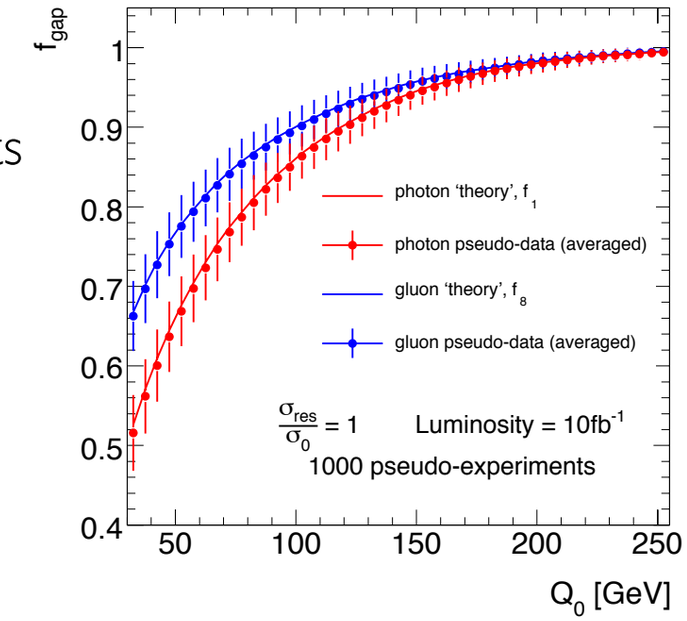

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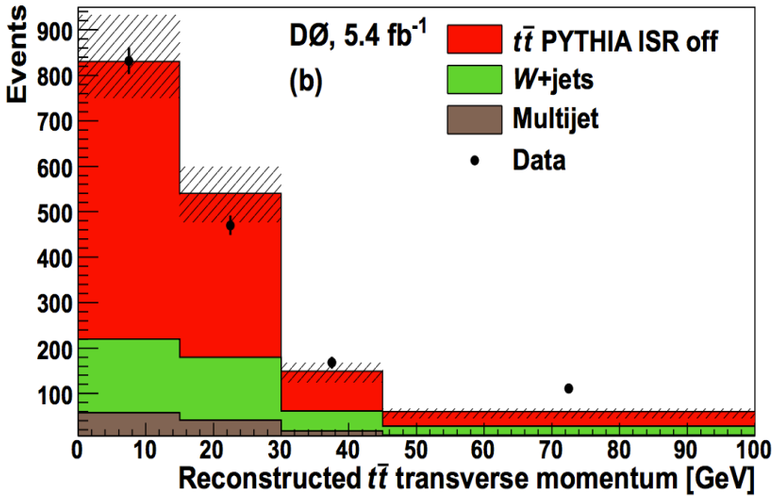


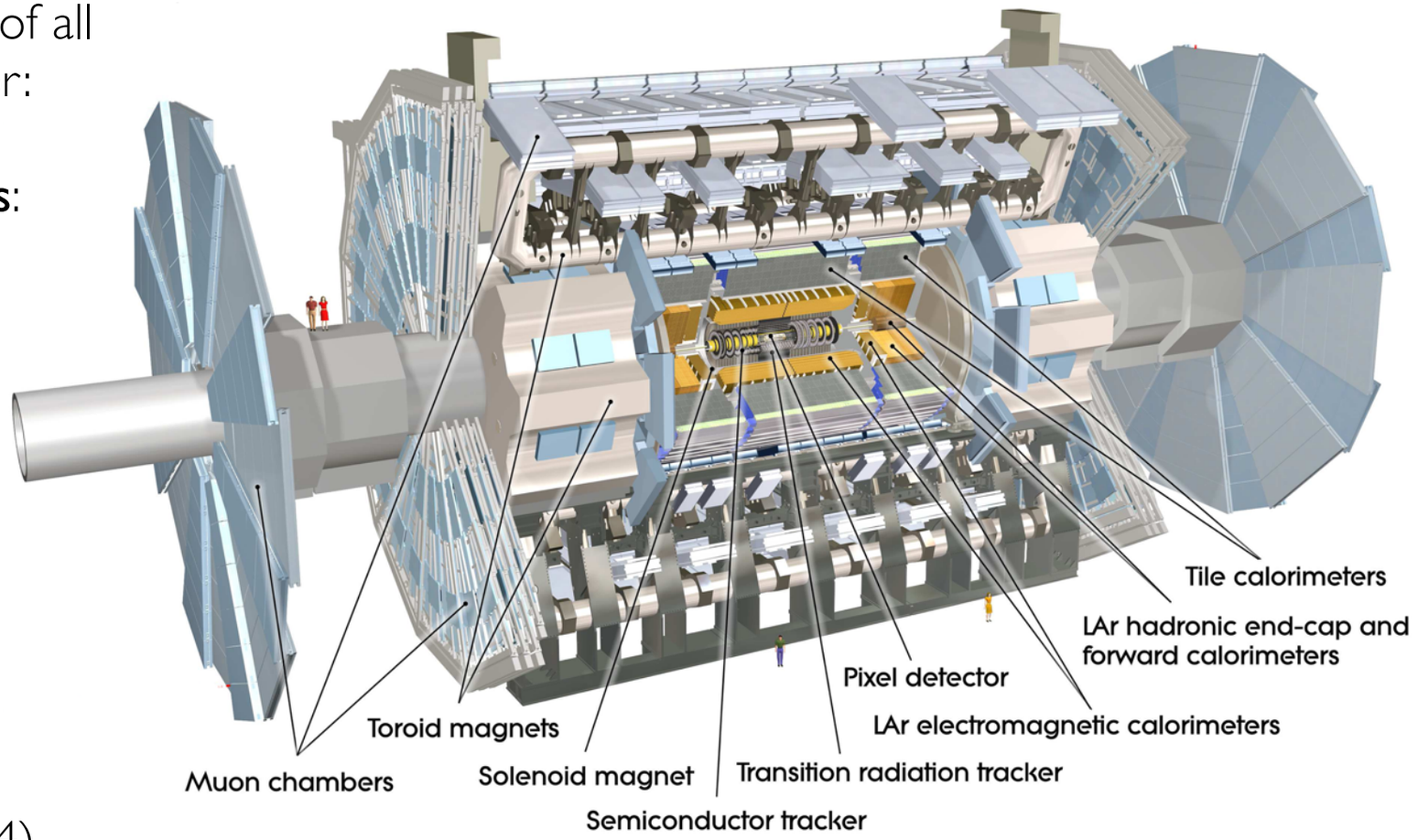
- Our aim to perform a precise measurement of **QCD** in **top-antitop** final-states, which are **not yet well-explored**.

How do we identify tops?

- Top-antitop final-state makes use of all subsystems of the ATLAS detector:

- High-p_T, central, isolated **electrons**:
  $p_T > 25$ GeV, $|\eta| < 2.47$
  (excluding $1.37 < |\eta| < 1.52$)

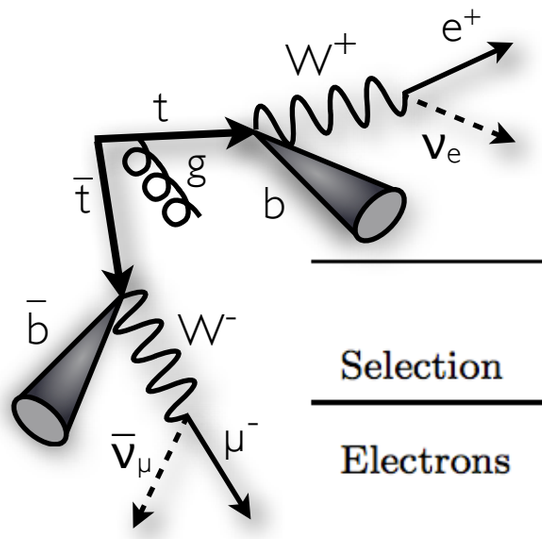
- High-p_T, central, isolated **muons**:
  $p_T > 20$ GeV, $|\eta| < 2.5$



- High-p_T, central **jets**: (anti-k_t, R=0.4)
  $p_T > 25$ GeV, $|y| < 2.4$*

- * Jets are matched to vertices. Only jets consistent with the **primary vertex** (containing b-jets and leptons) are used in the analysis.

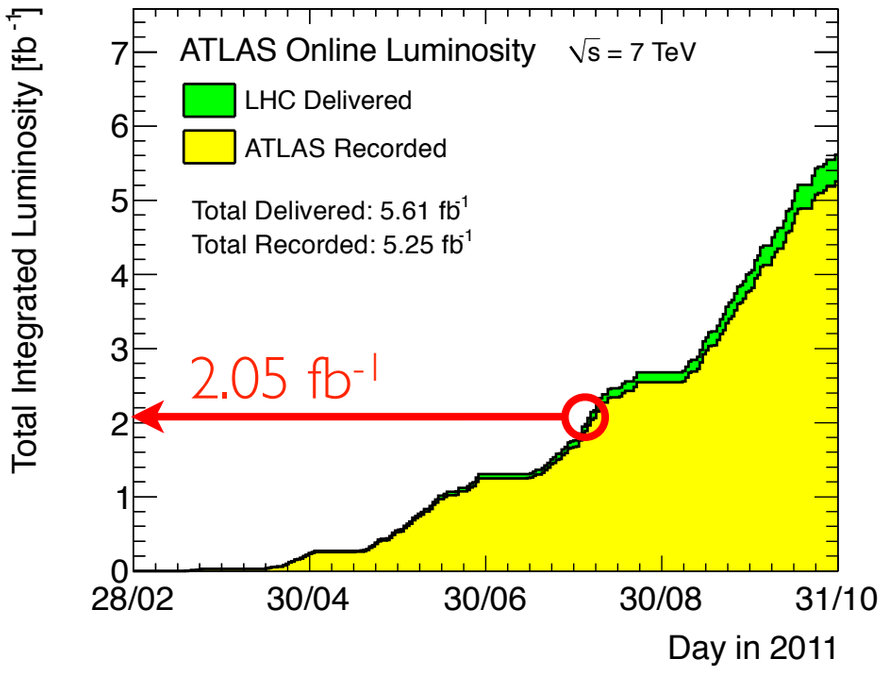
Which events do we use?

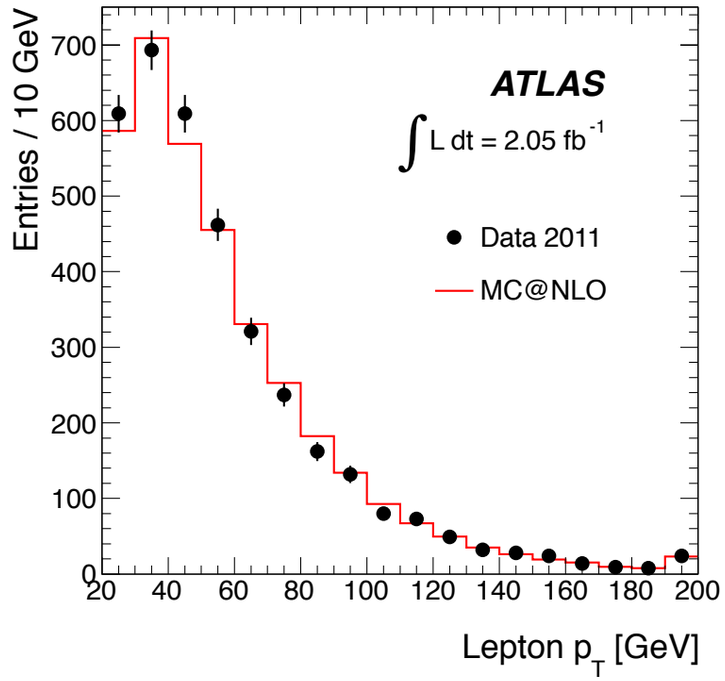


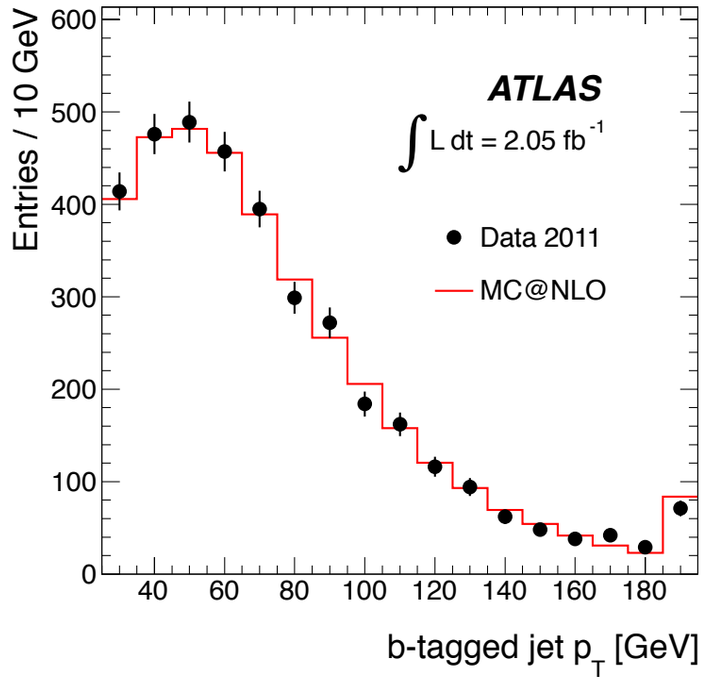
Selection	Channel		
	ee	$\mu\mu$	$e\mu$
Electrons	2 with $E_{\mathrm{T}} > 25$ GeV, $\lvert\eta\rvert < 2.47$	–	1 with $E_{\mathrm{T}} > 25$ GeV, $\lvert\eta\rvert < 2.47$
Muons	–	2 with $p_{\mathrm{T}} > 20$ GeV, $\lvert\eta\rvert < 2.5$	1 with $p_{\mathrm{T}} > 20$ GeV, $\lvert\eta\rvert < 2.5$
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 40 GeV	> 40 GeV	–
H_T	–	–	> 130 GeV
$m_{\ell\ell}$	> 15 GeV $\lvert m_{\ell\ell} - 91\,\mathrm{GeV}\rvert > 10$ GeV	> 15 GeV $\lvert m_{\ell\ell} - 91\,\mathrm{GeV}\rvert > 10$ GeV	–
b-tagged jets	At least 2 with $p_{\mathrm{T}} > 25$ GeV, $\lvert y\rvert < 2.4$, $\Delta R(j, \ell) > 0.4$		

- b-tagging algorithm based on impact parameter and secondary vertex information.
  - Average per-jet efficiency of 70% for b-jets in simulated top-antitop events.
  - Rejects ~99% of jets originating from light quarks and gluons.

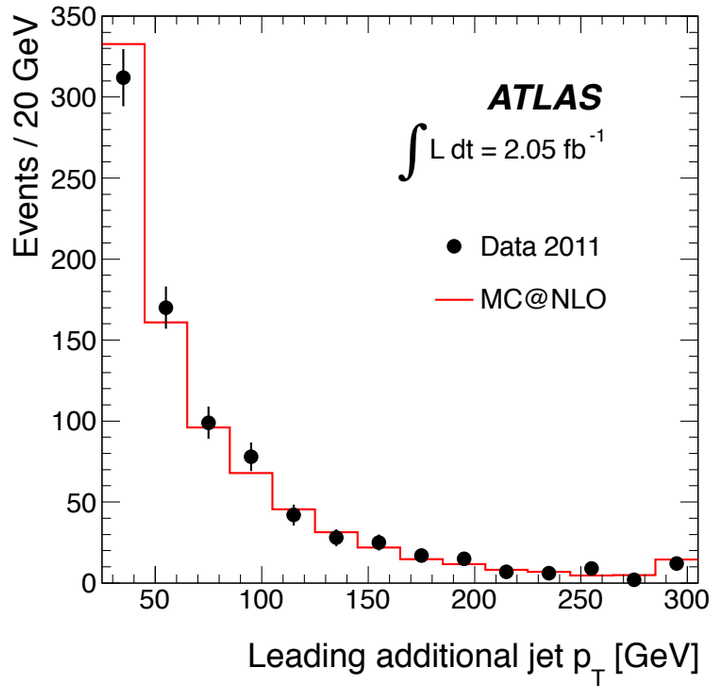
Selected events

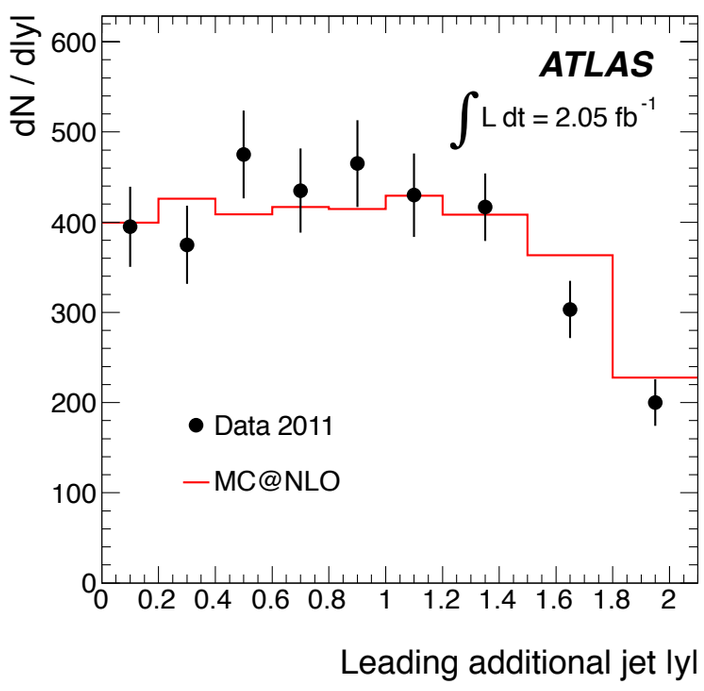






- **1773 top-antitop events** remain after selection.
  - No backgrounds subtracted from data. (Total background contamination ~ 6%.)
- Tight event selection provides a very pure sample of top-antitop events.





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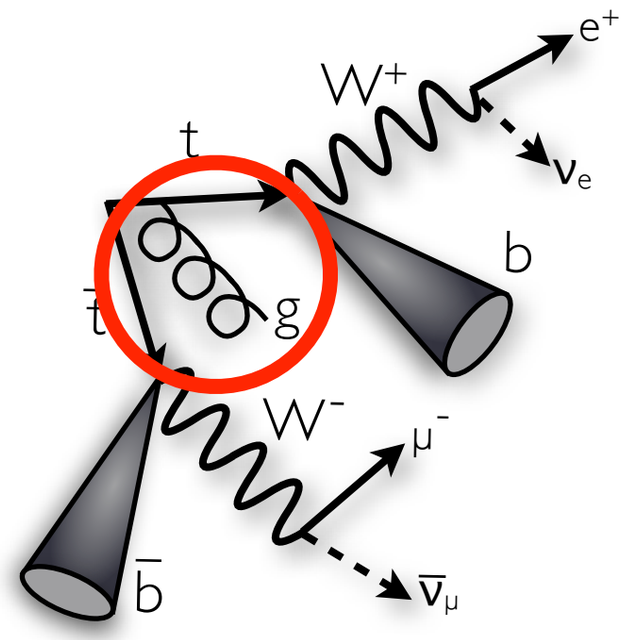

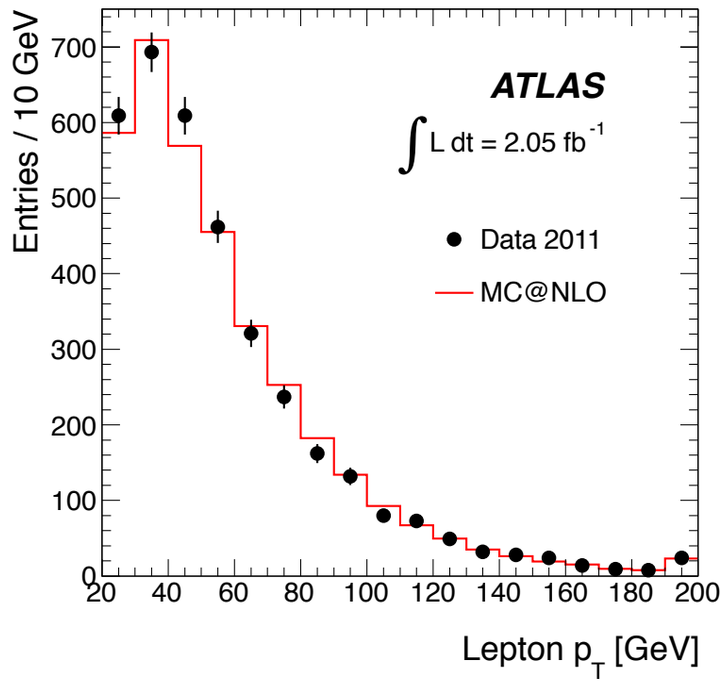

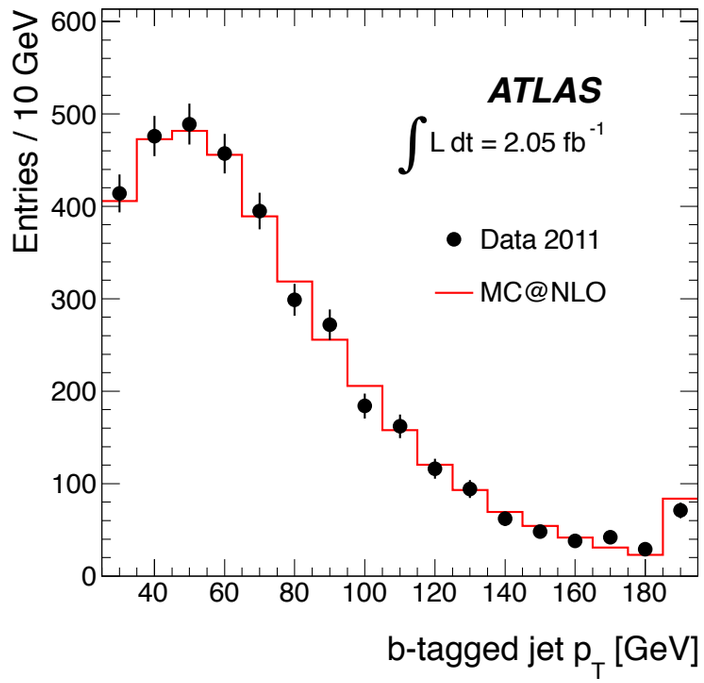

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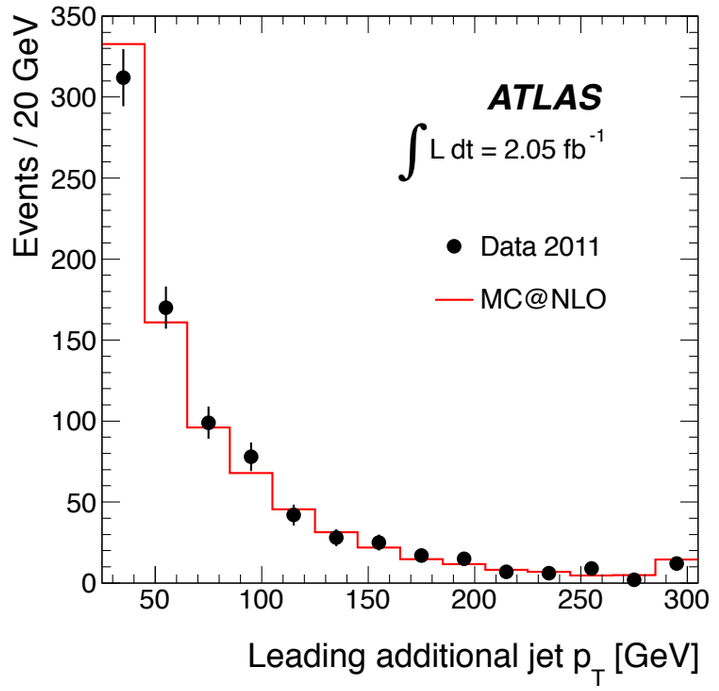
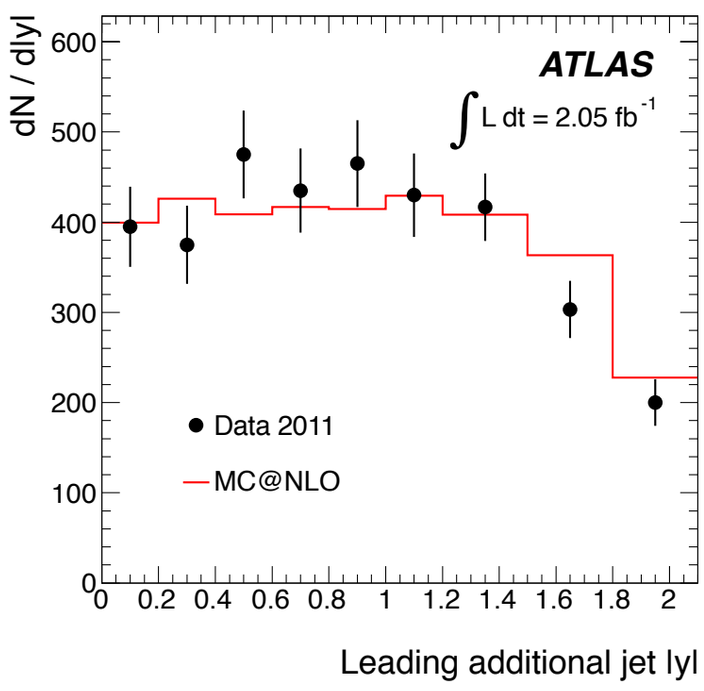
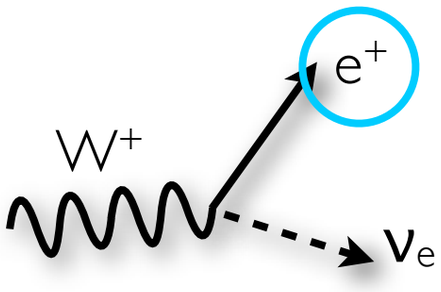


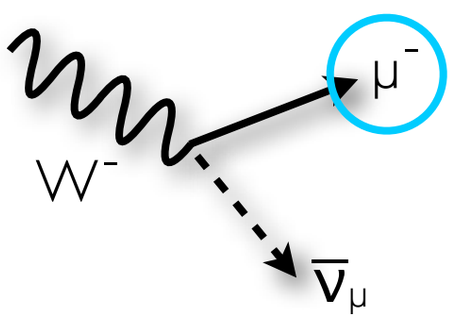


Jet vetoing in top-antitop events

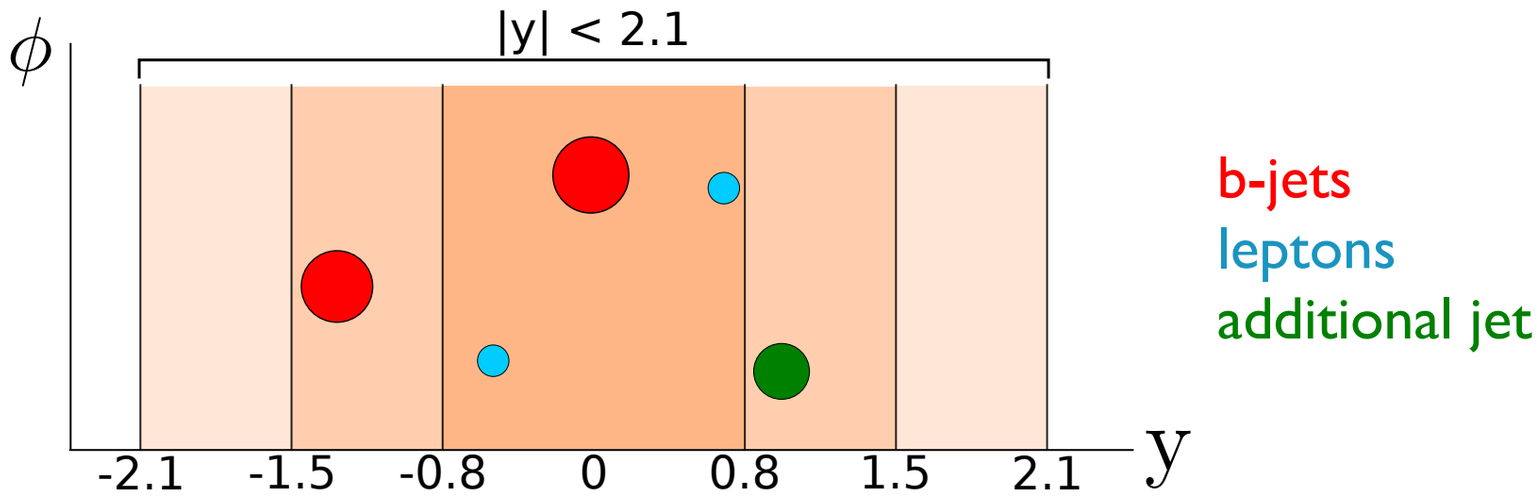
- Study the fraction of ttbar events that do **NOT** contain an additional jet, in a central rapidity interval, with $p_T > Q_0$:

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





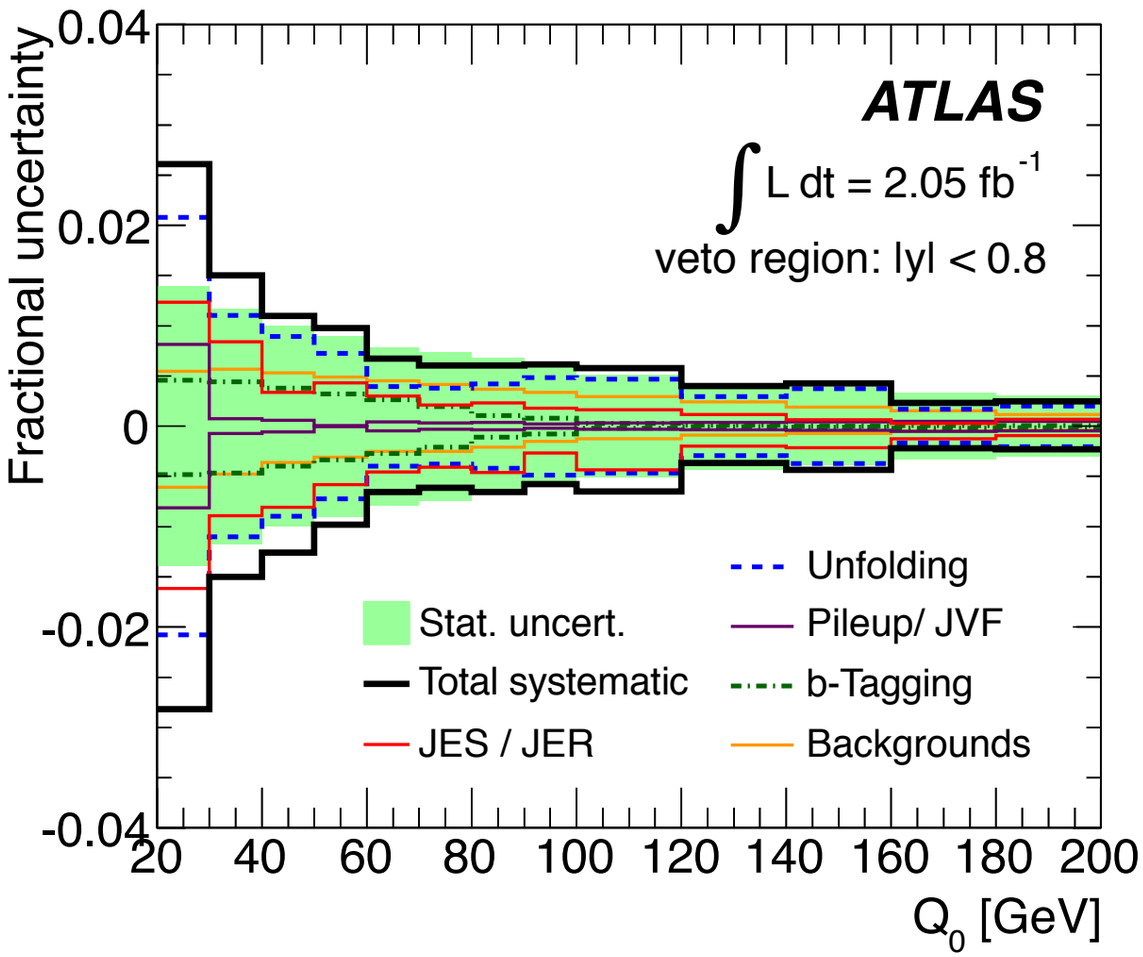
- Dileptonically-decaying top-antitop events provide a clean environment to probe the additional radiation.
  - Jets originating from **b-quarks** are **easily distinguished** from additional jets using b-tagging.
  - **No complications from jet combinatorics**, like in lepton+jets channel analyses.



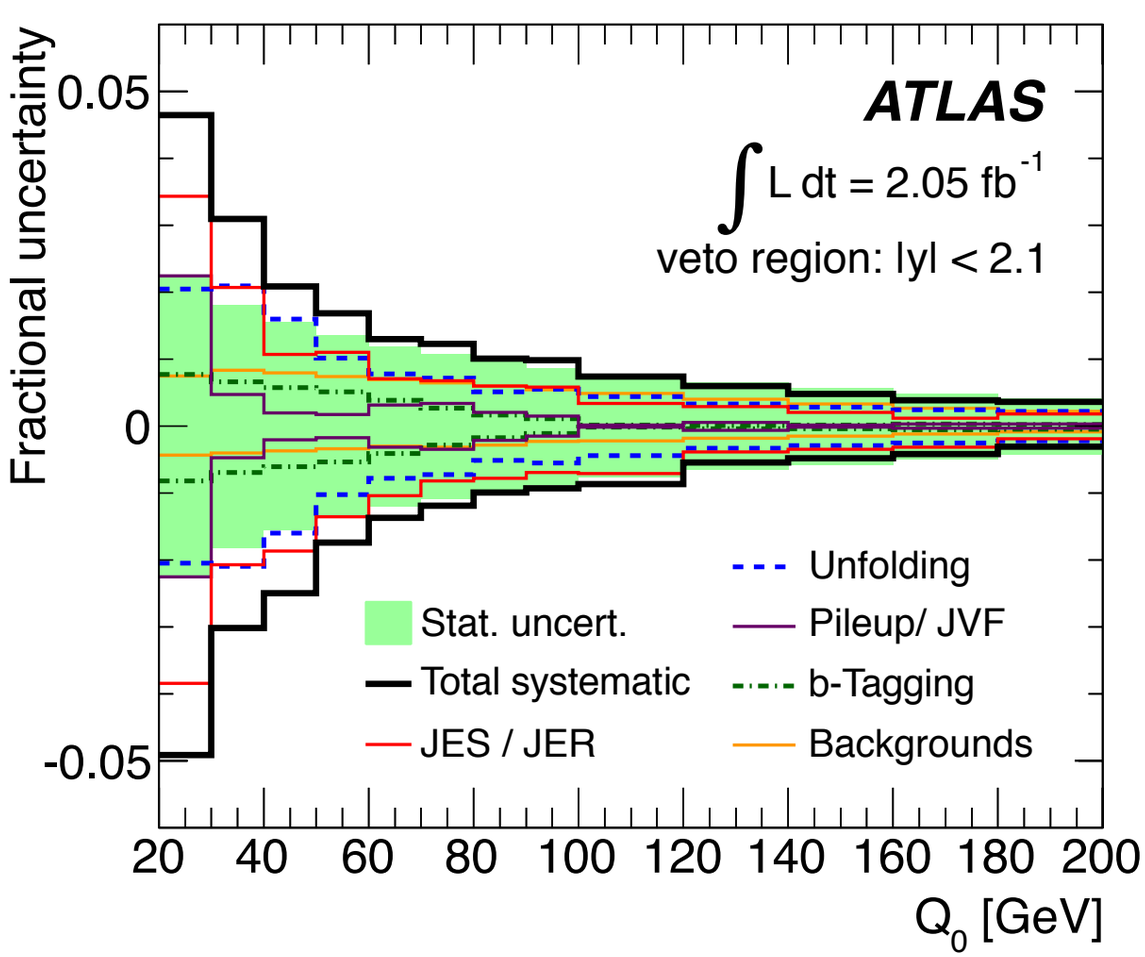
- Measured data corrected for detector effects and presented in a fiducial region.

Systematic uncertainties

- Many uncertainties cancel in the ratio. Those affecting the additional jet(s) do not.
- Pileup under control. Backgrounds, b-tagging uncertainties very small.
- Data corrected to particle-level with a point-by-point technique: $C(x) = \frac{f^{truth}(x)}{f^{reco}(x)};\ x = Q_0$

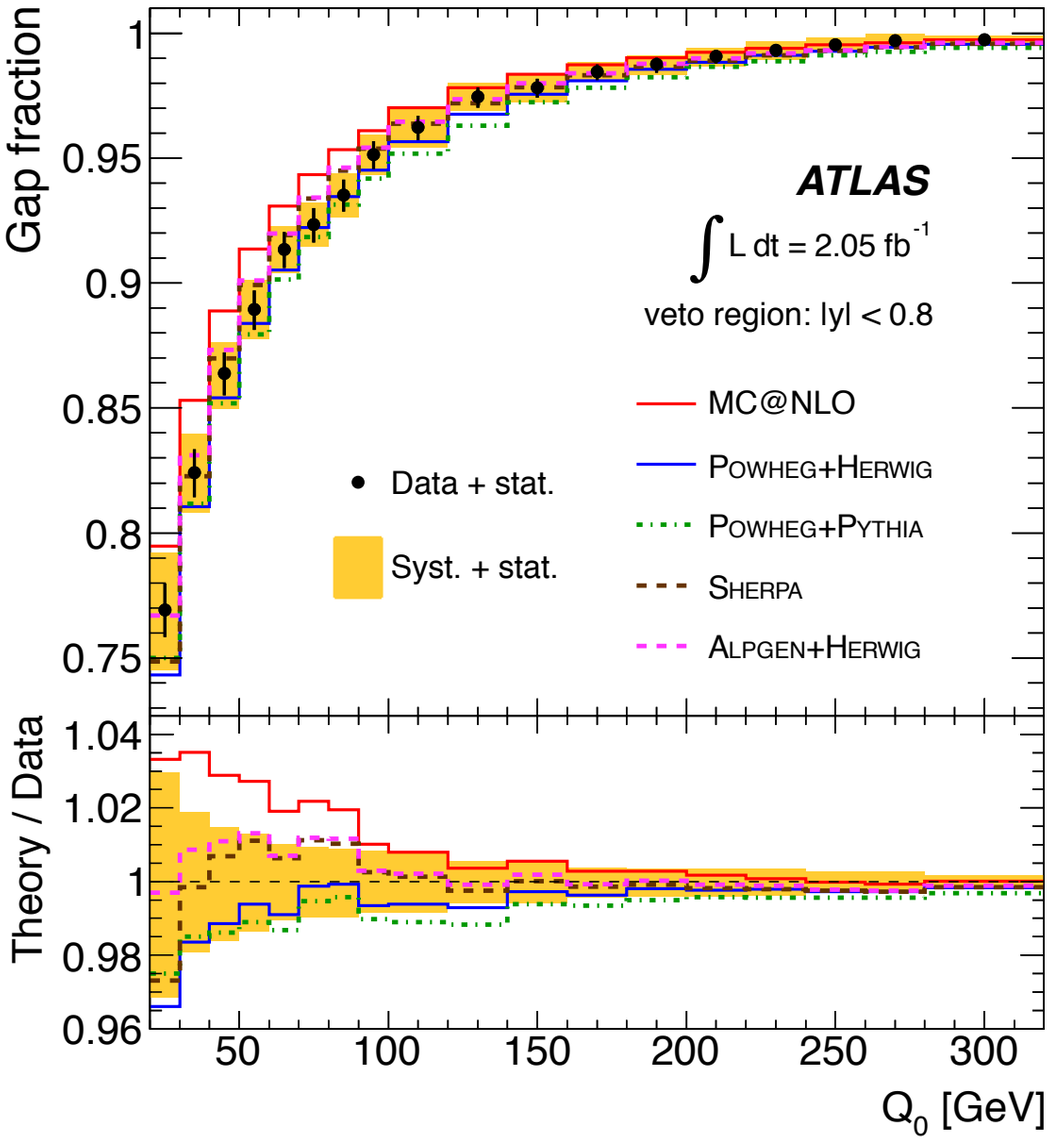


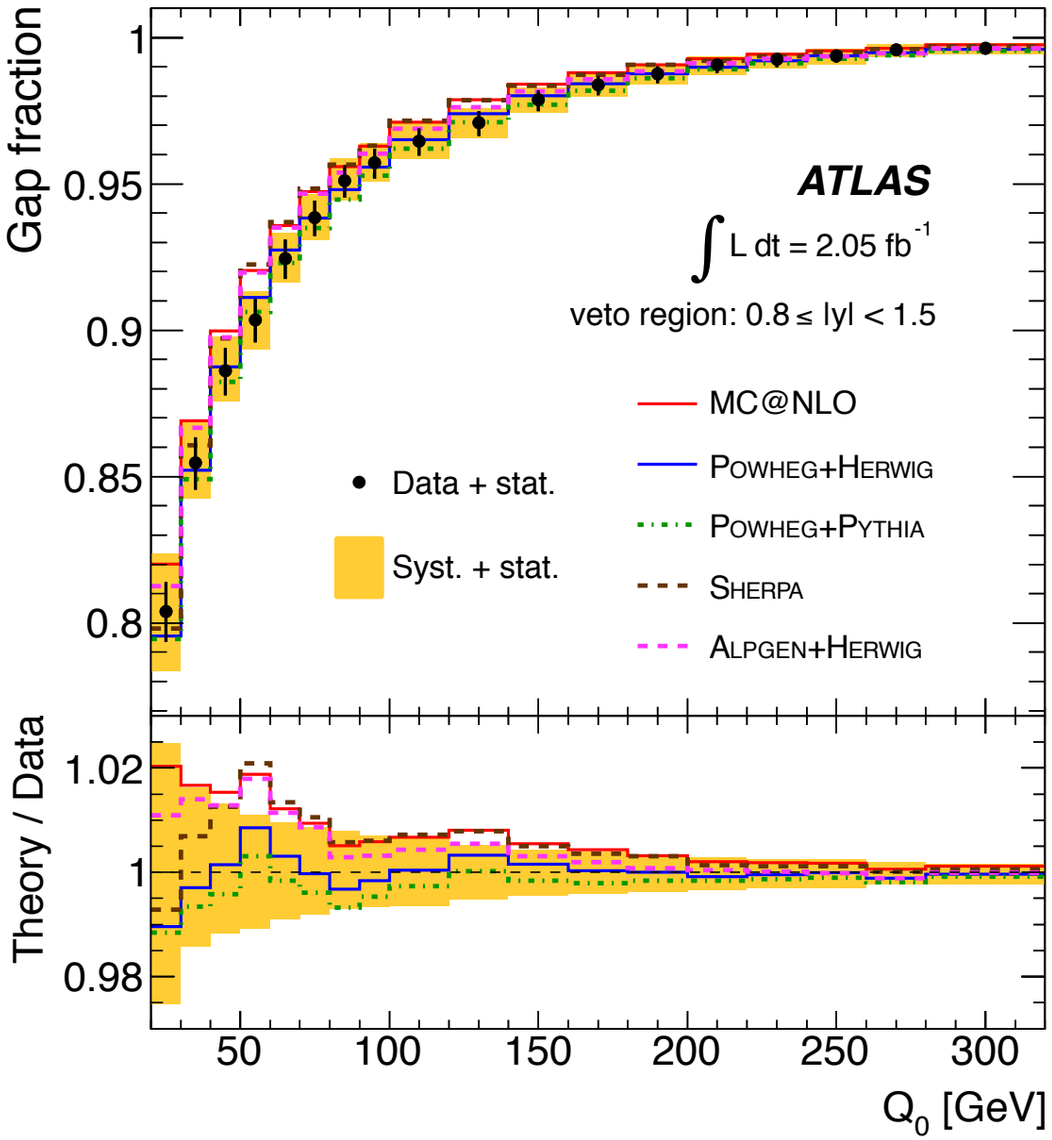
Unfolding uncertainty largest for $|y| < 0.8$.
Jets well-measured in very central region.



JES and JER dominate for $|y| < 2.1$.
Total systematic uncertainty ~1% at Q_0=100 GeV

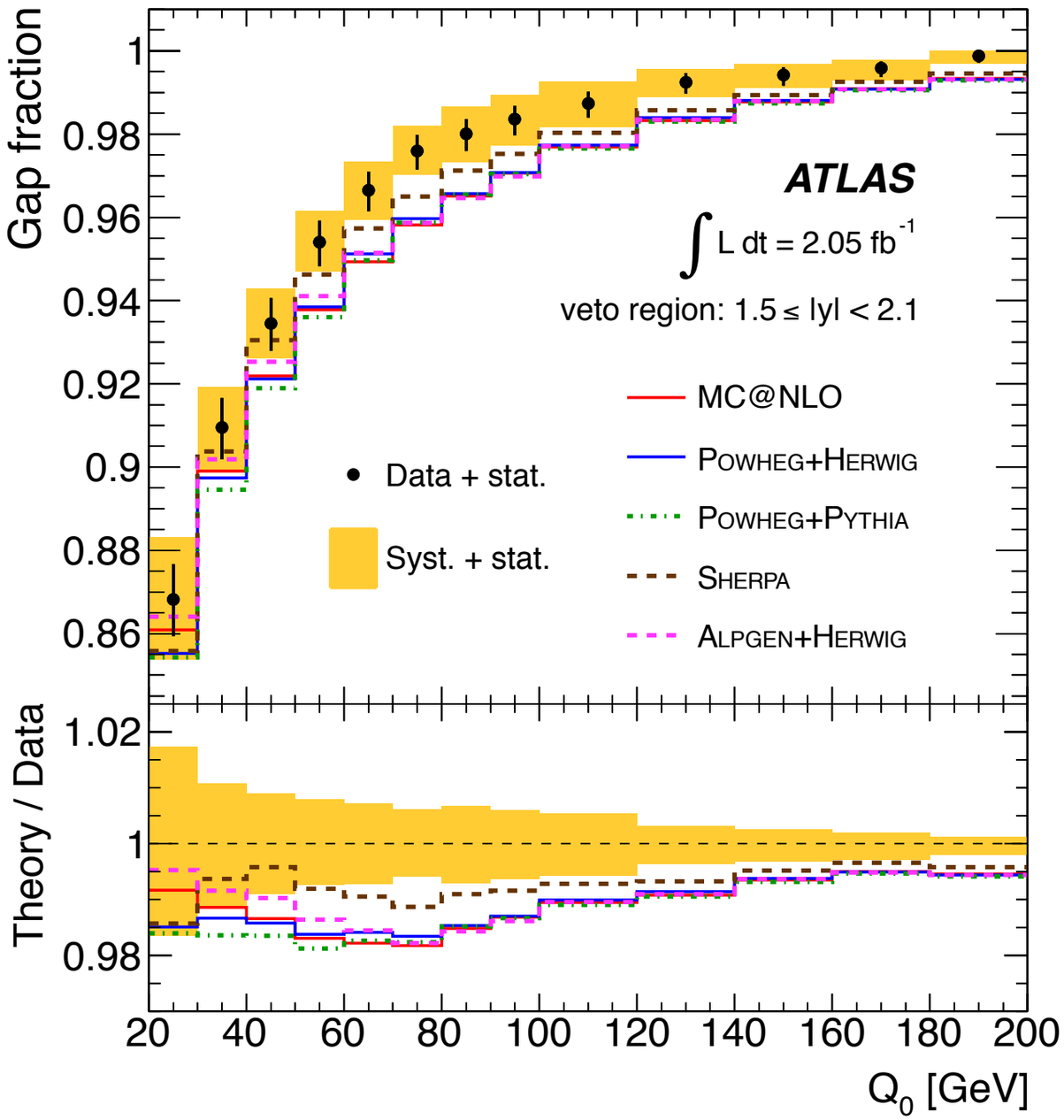
Central jet vetoes

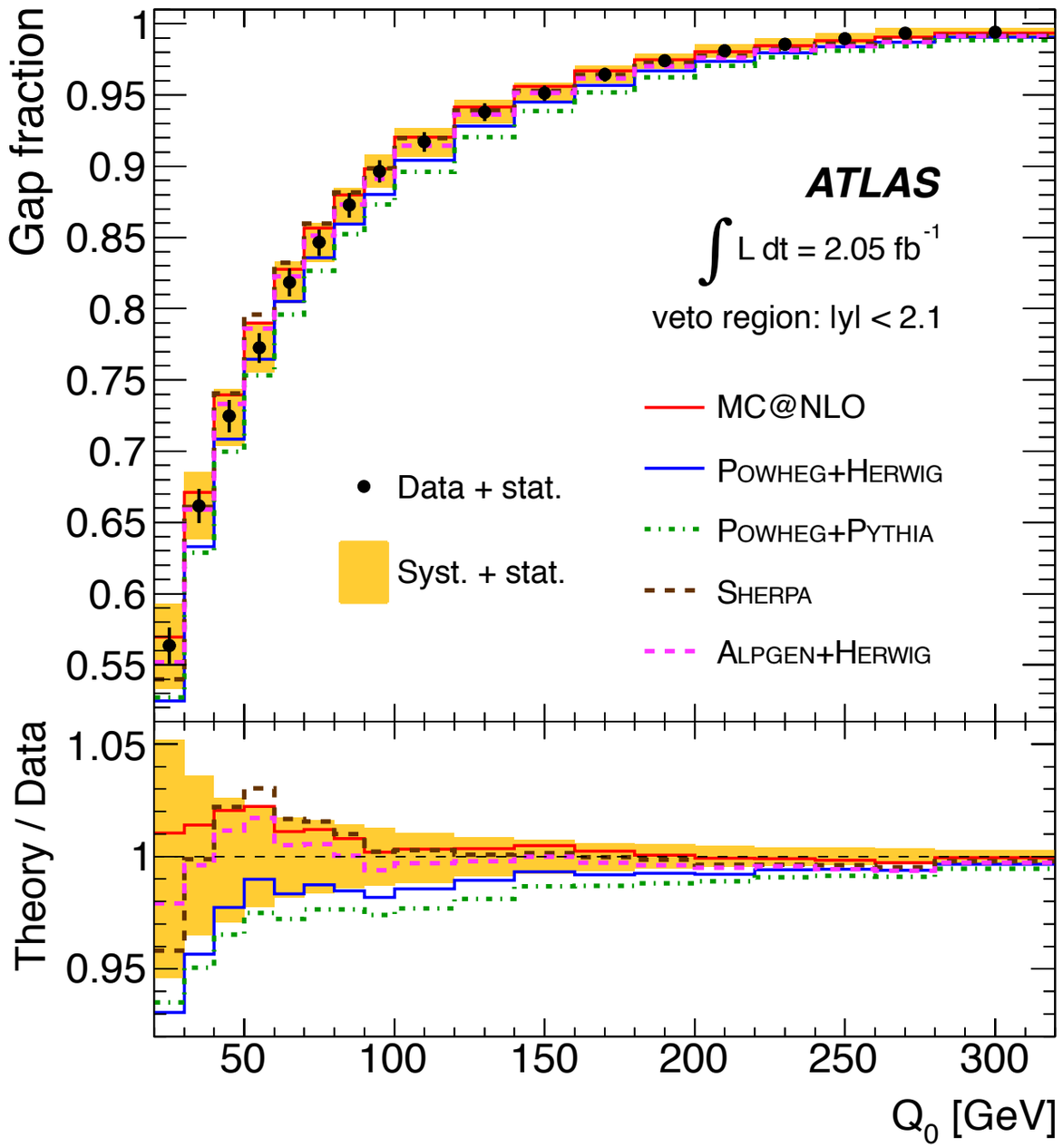




- Data compared to NLO+PS (MC@NLO, POWHEG) and ME+PS (SHERPA, ALPGEN) generators.
- MC@NLO slightly underestimates amount of additional radiation with $|y| < 0.8$.
  - Gap fraction **sensitive** to "dead zone" in HERWIG shower. *Mangano et. al.* JHEP 01(2007)013

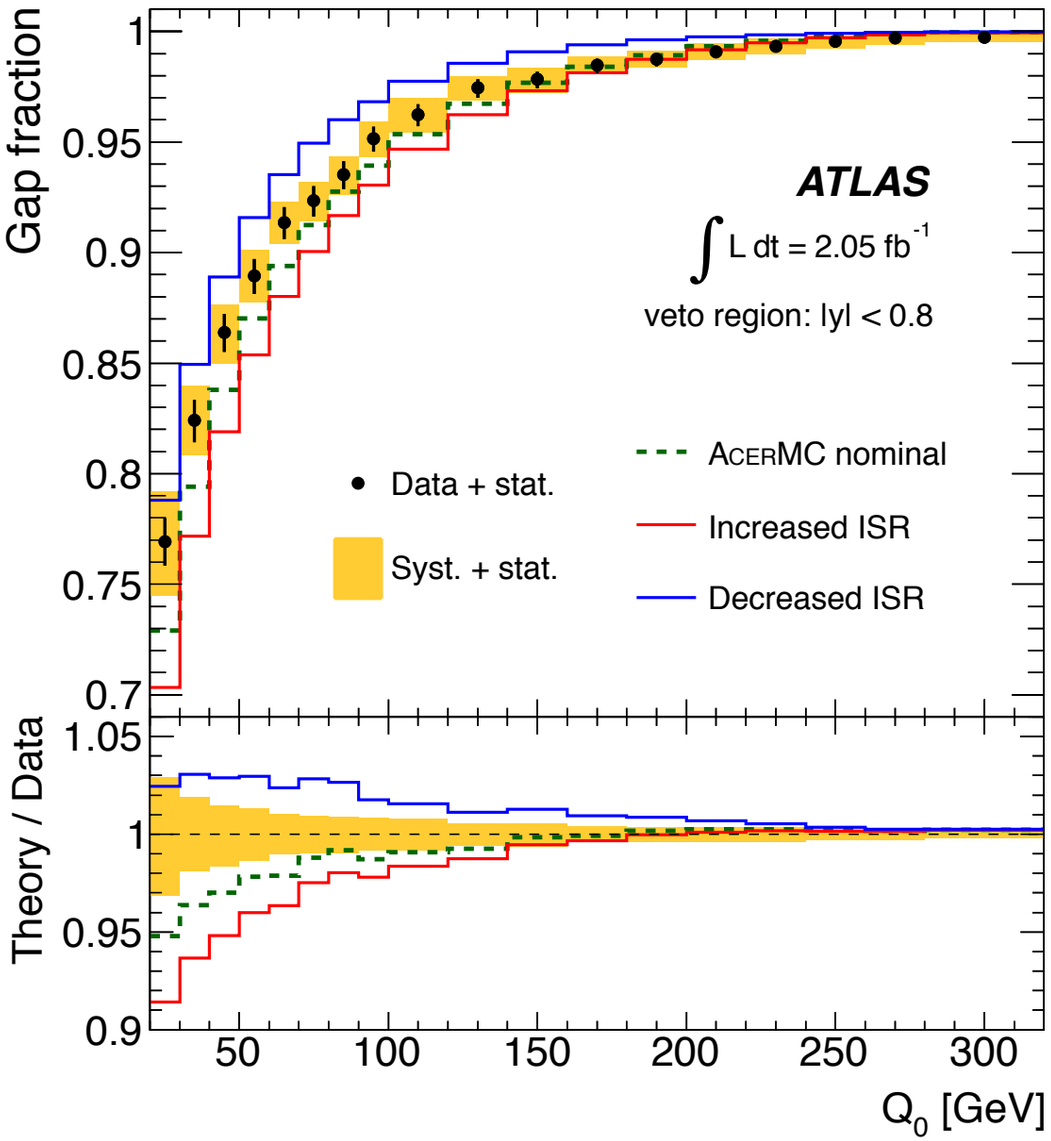
Jet vetoes in more forward regions

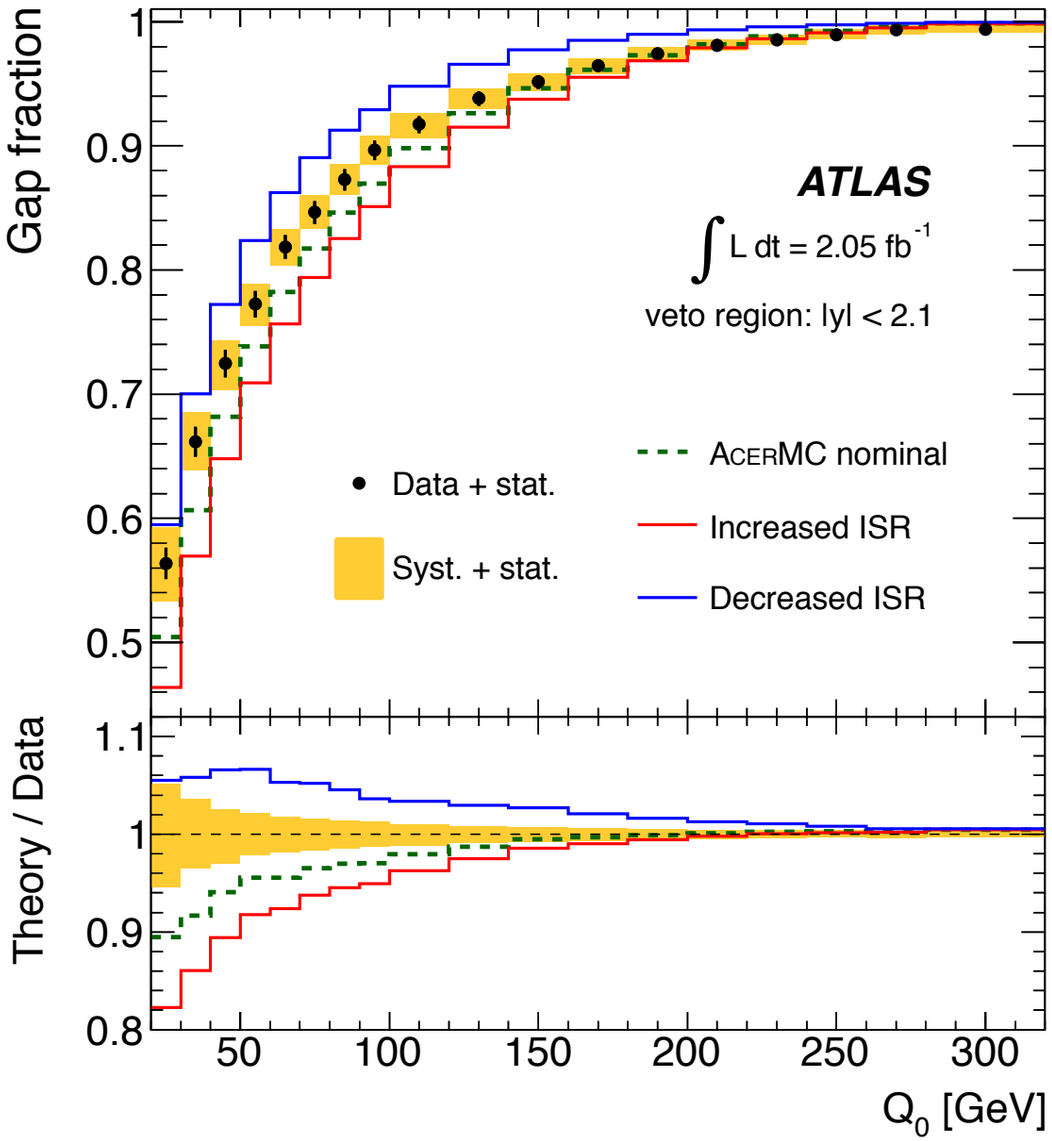




- All Monte Carlos **overestimate** the amount of additional radiation in the **1.5 ≤ |y| < 2.1 region.**
- General description of the data in the most inclusive, |y| < 2.1, region is very good.

Modelling uncertainty in top-antitop events





- Modelling uncertainties can obscure interpretation of new physics results.
- Large variation band. **Uncertainty is too conservative**.
- These variations are now **constrained** by data.

Summary

- **First** corrected measurement of **QCD** activity in **top-antitop** final states. **arXiv:1203.5015**
  - Data fully corrected in four rapidity regions.
    - Corrected data submitted to HEPDATA. Rivet routine available to access the analysis result.
- Small experimental uncertainty. **High-precision** measurement.
- State-of-the-art generators give a good description of the additional radiation.
  - Slight **data-MC deviation** in most-**forward region**, $1.5 \leq |y| < 2.1$.
- Data has been used to **constrain** the size of **uncertainties on modelling of additional radiation**.

Potential further study

- Extend to further-forward jets. (More BFKL-like?)
- Gap fraction in bins of $M_{t\bar{t}}$, $p_T^{t\bar{t}}$.

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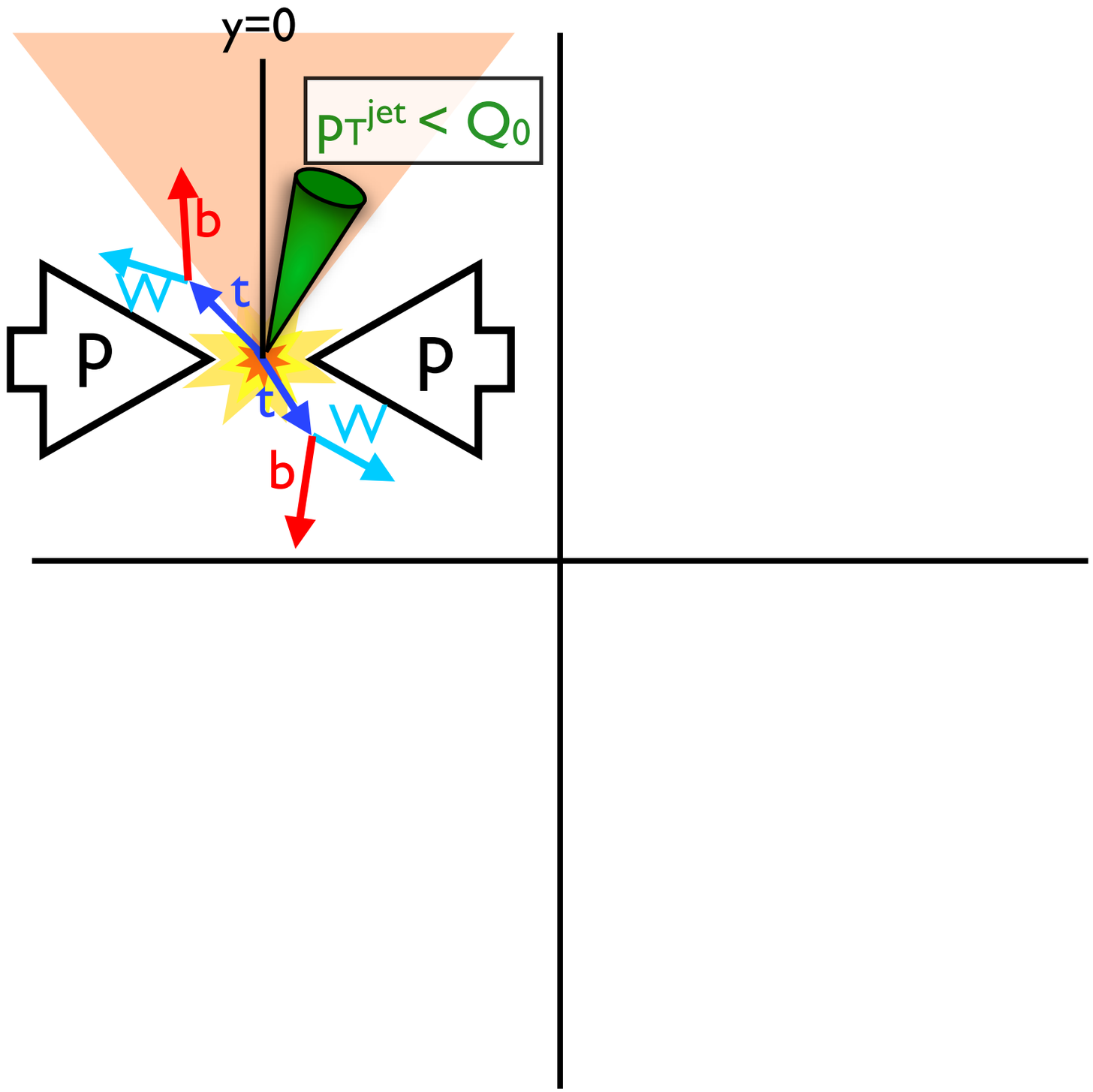
Backup slides

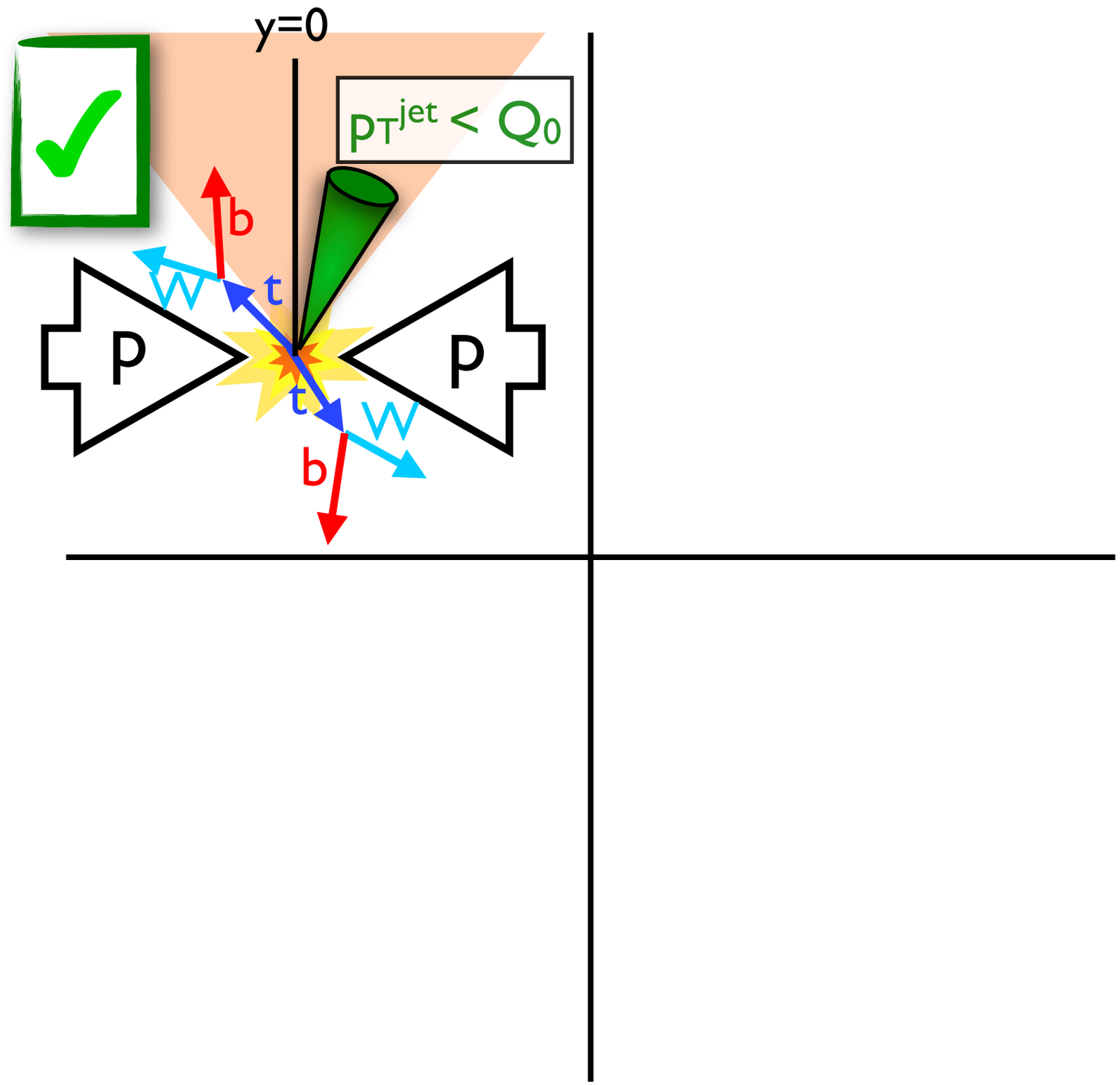
Gap fraction



Fixed rapidity interval

Gap fraction

Fraction = 1/1



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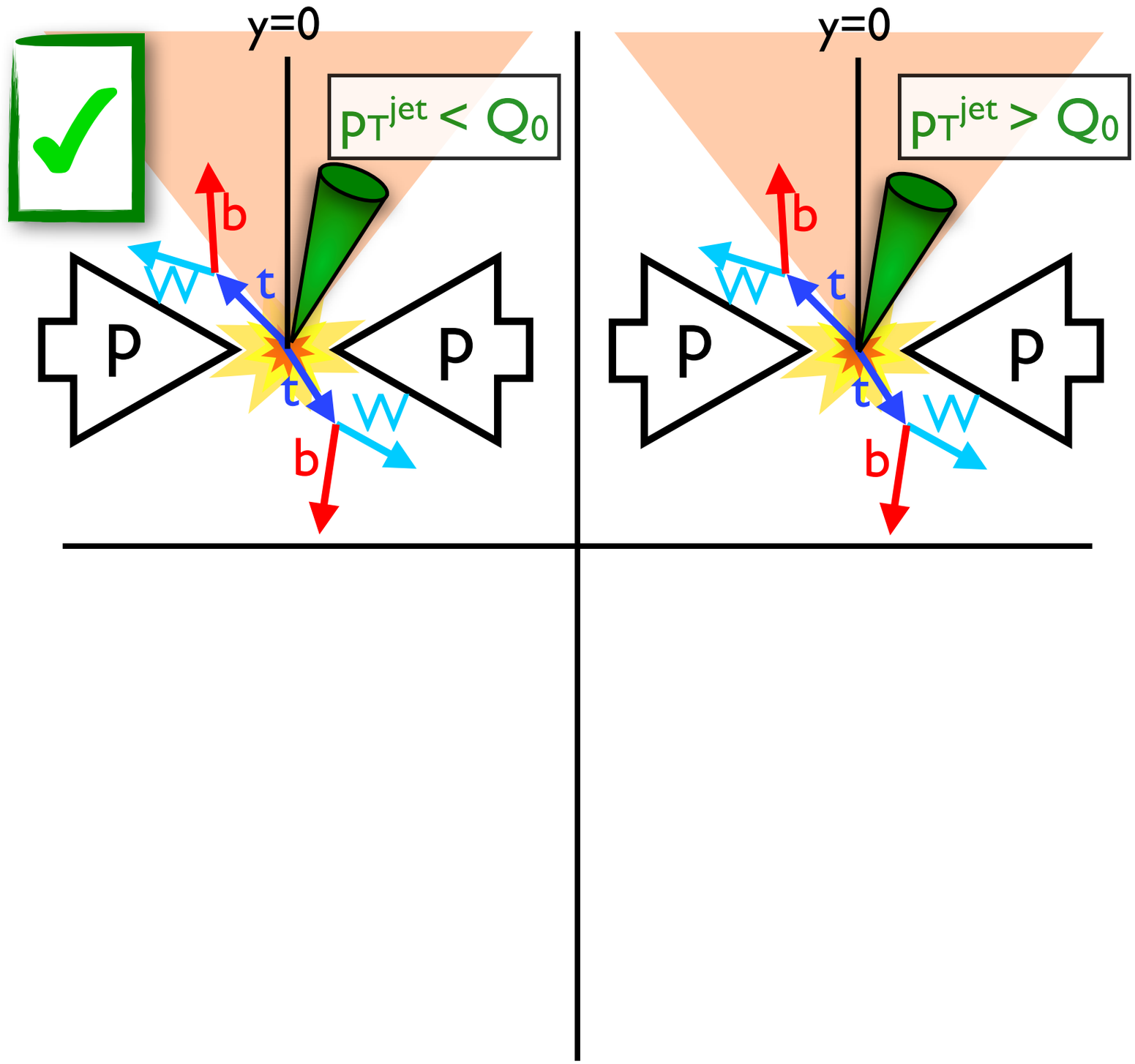
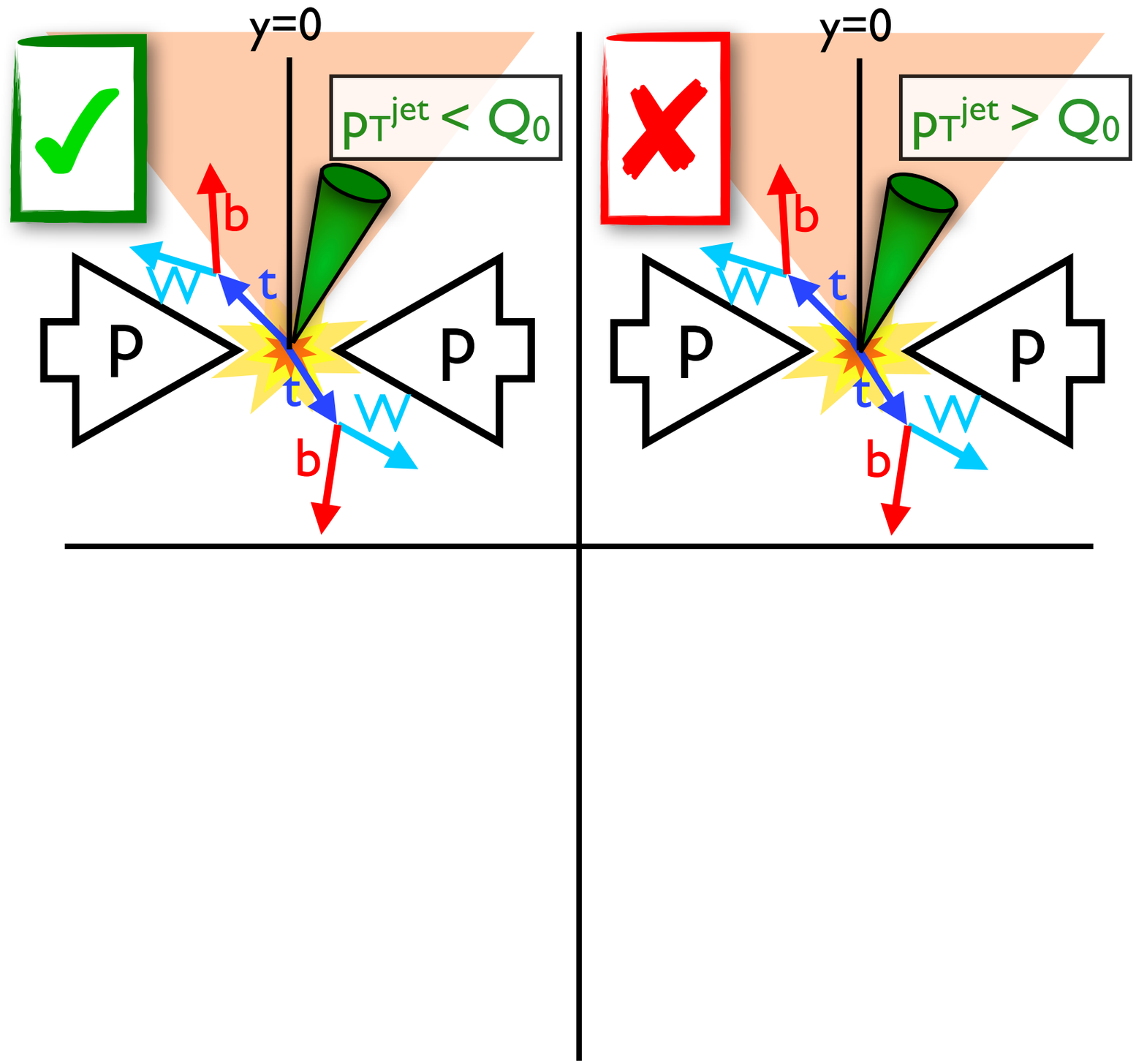


Fixed rapidity interval

Gap fraction

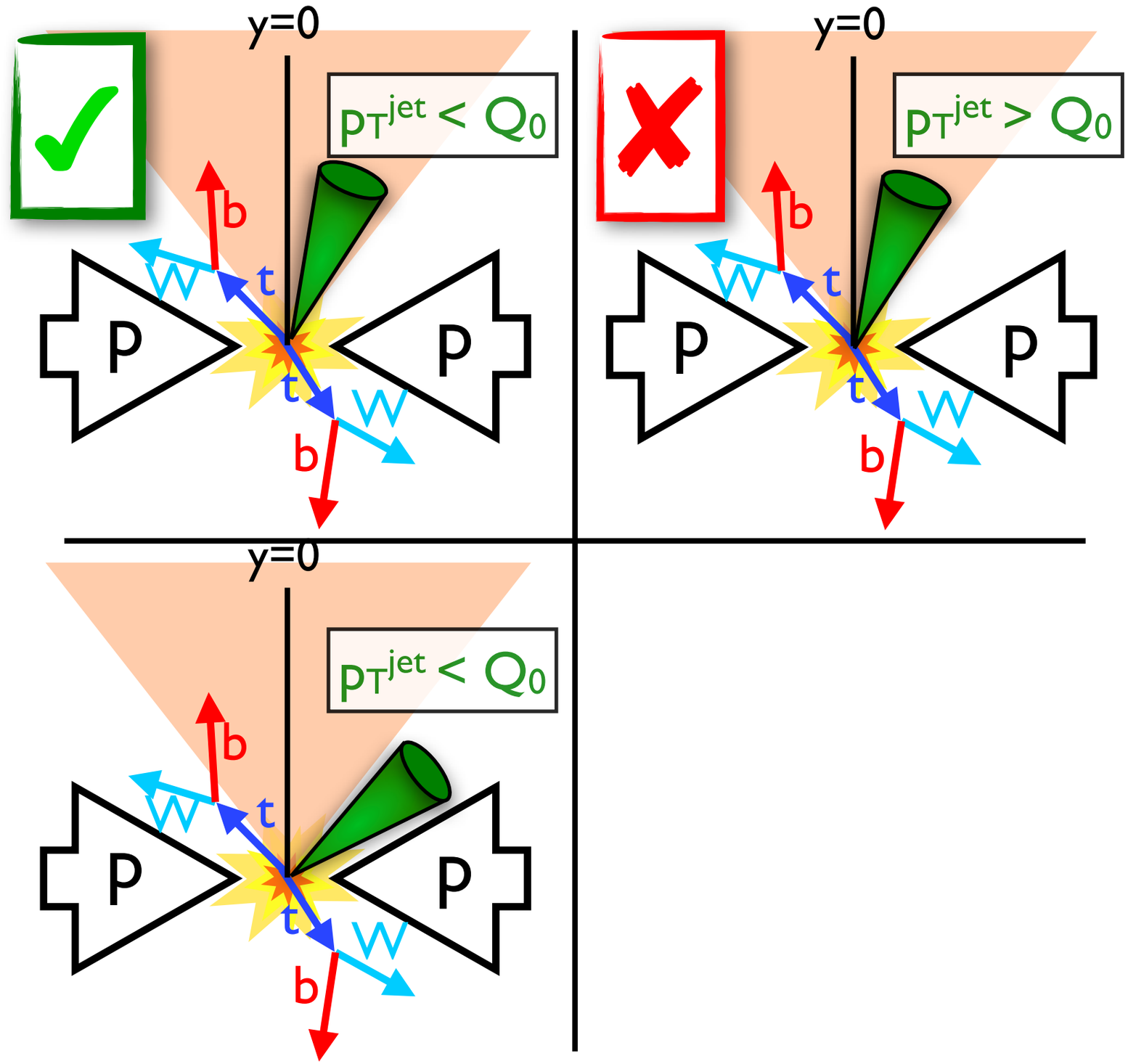
Fraction = 1/2



Fixed rapidity interval

Gap fraction

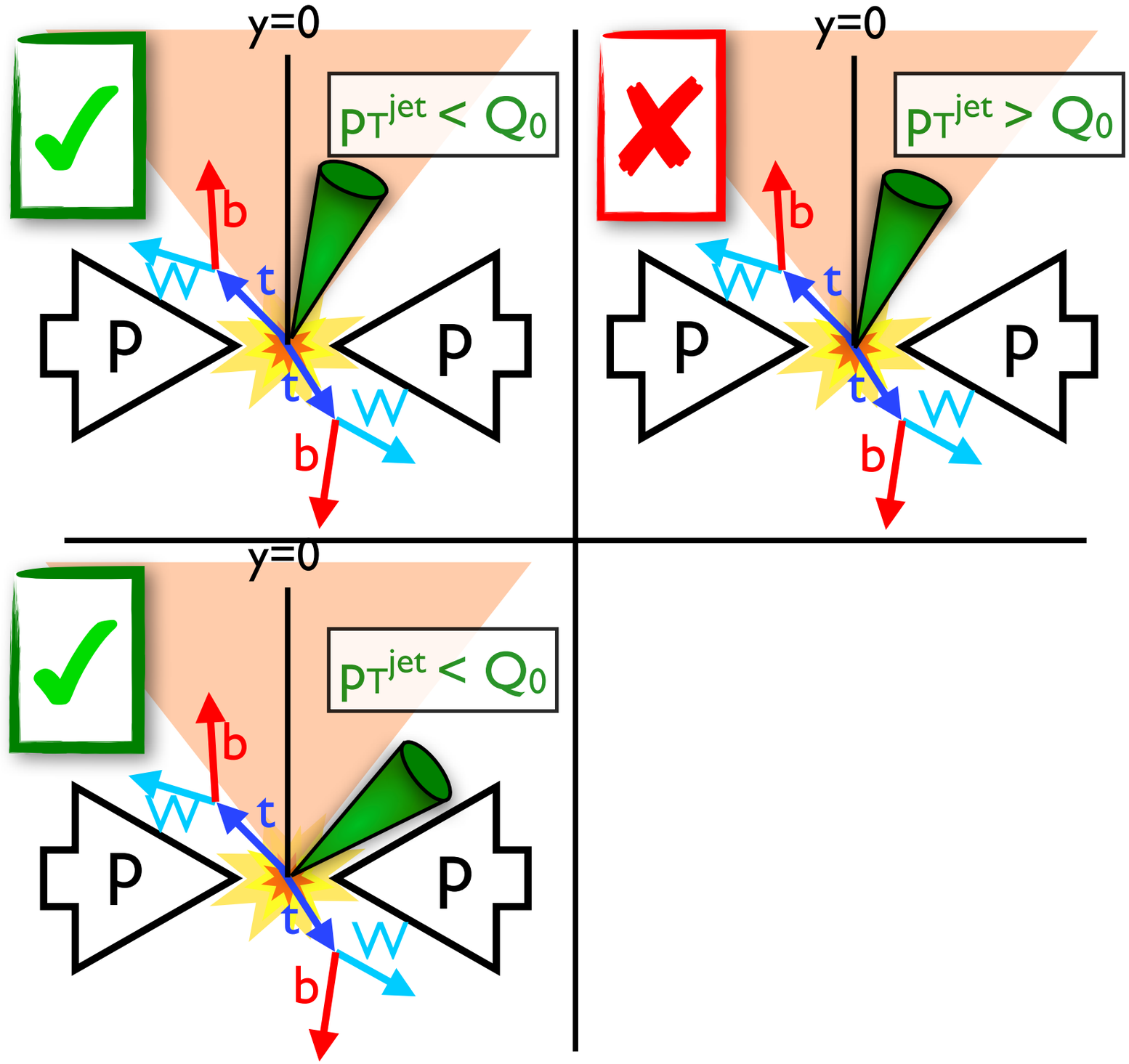
Fraction = 1/2



Fixed rapidity interval

Gap fraction

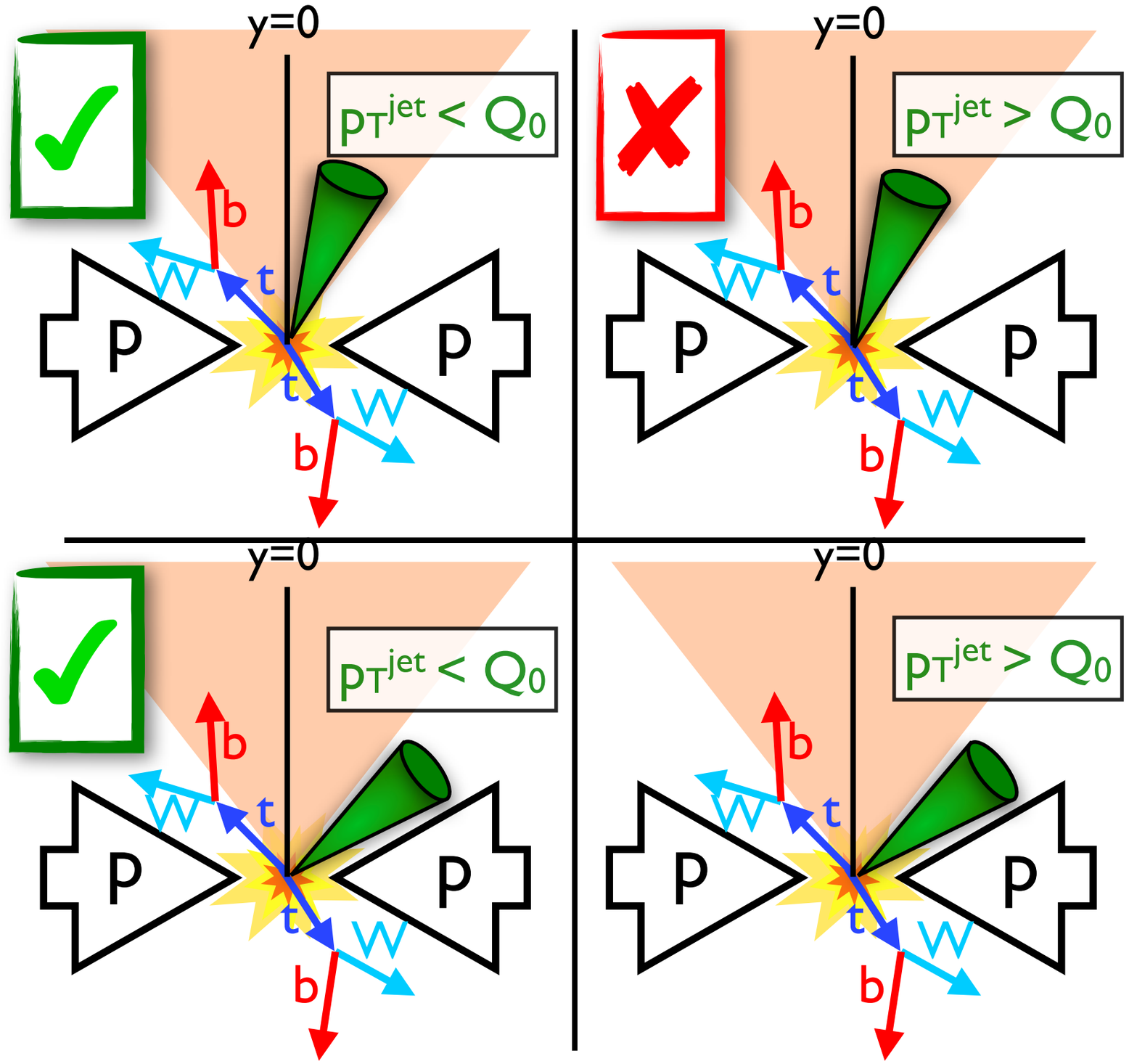
Fraction = 2/3



Fixed rapidity interval

Gap fraction

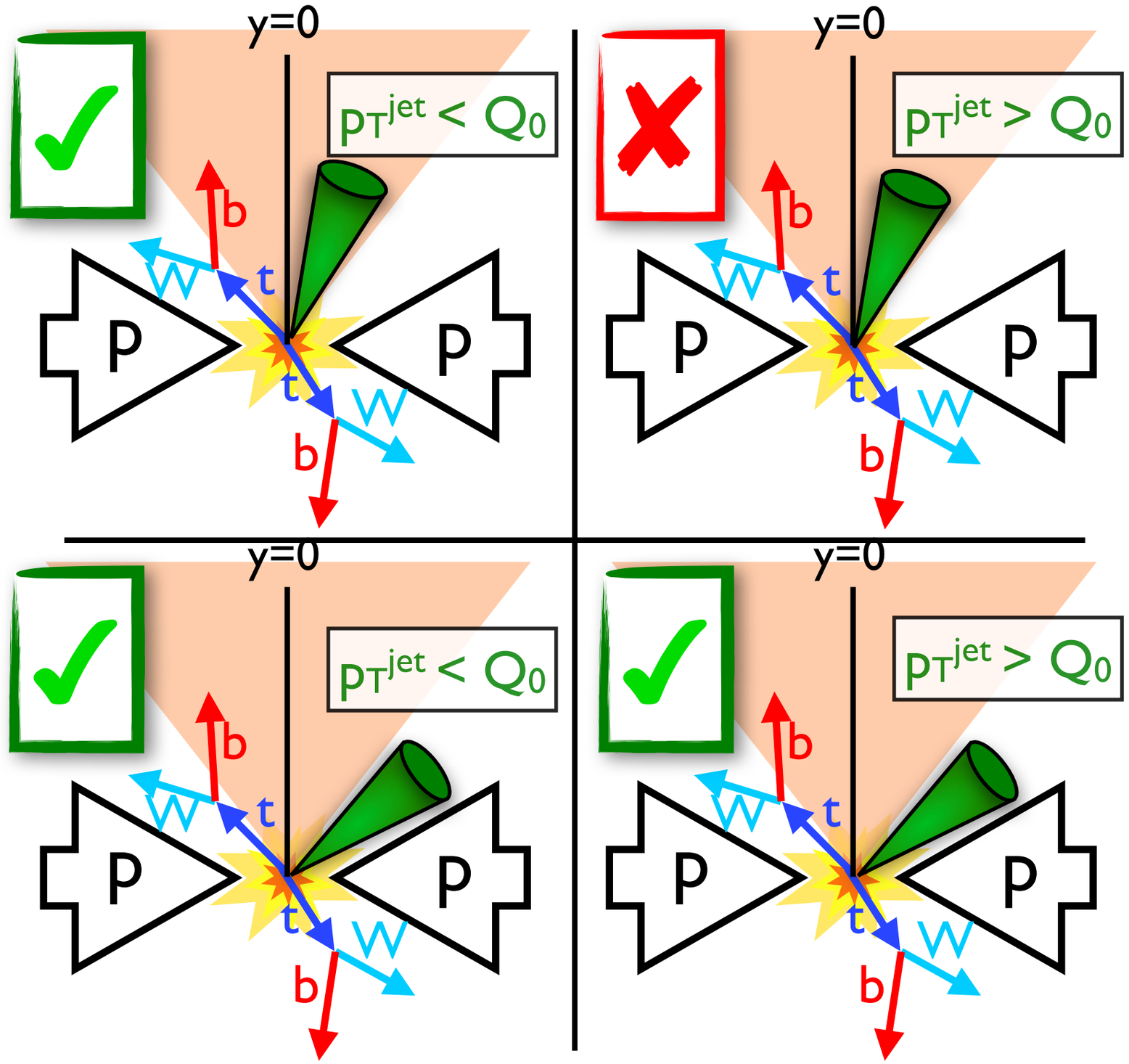
Fraction = 2/3



Fixed rapidity interval

Gap fraction

Fraction = 3/4



Fixed rapidity interval

Gap fraction

- The gap fraction can be expressed as a ratio of cross sections:

$$f(Q_0) = \frac{n(Q_0)}{N} = \frac{\sigma^f_{t\bar{t}+0\text{ jet}}}{\sigma^f_{t\bar{t}}} = 1 - \frac{\sigma^f_{t\bar{t}+\geq 1\text{ jet}}}{\sigma^f_{t\bar{t}}}$$

$\sigma^f_{t\bar{t}}$ = fiducial cross section for dilepton top-antitop events

$\sigma^f_{t\bar{t}+0\text{ jet}}$ = fiducial cross section for dilepton top-antitop events with no additional radiation with $p_T > Q_0$, in the rapidity interval.

$\sigma^f_{t\bar{t}+\geq 1\text{ jet}}$ = fiducial cross section for dilepton top-antitop events with **at least one jet** with $p_T > Q_0$, in the rapidity interval.

Unfolding

- Distributions corrected back to particle-level:
- Jets defined with anti-k_t algorithm. R=0.4, using all interacting final-state particles (no muons or neutrinos). Jets must have $p_T > 25$ GeV, $|y| < 2.4$.
  - b-jets defined by ΔR(jet, B-hadron) < 0.3.
- Leptons defined using stables truth particles.
  - Kinematic cuts as for reconstructed objects.
- Missing E_T defined as vector sum of all final-state neutrinos.
- H_T calculated as scalar summed p_T of selected leptons and good jets.
- Event selection applied as outlined on slide 5 in ee, μμ and eμ channels.

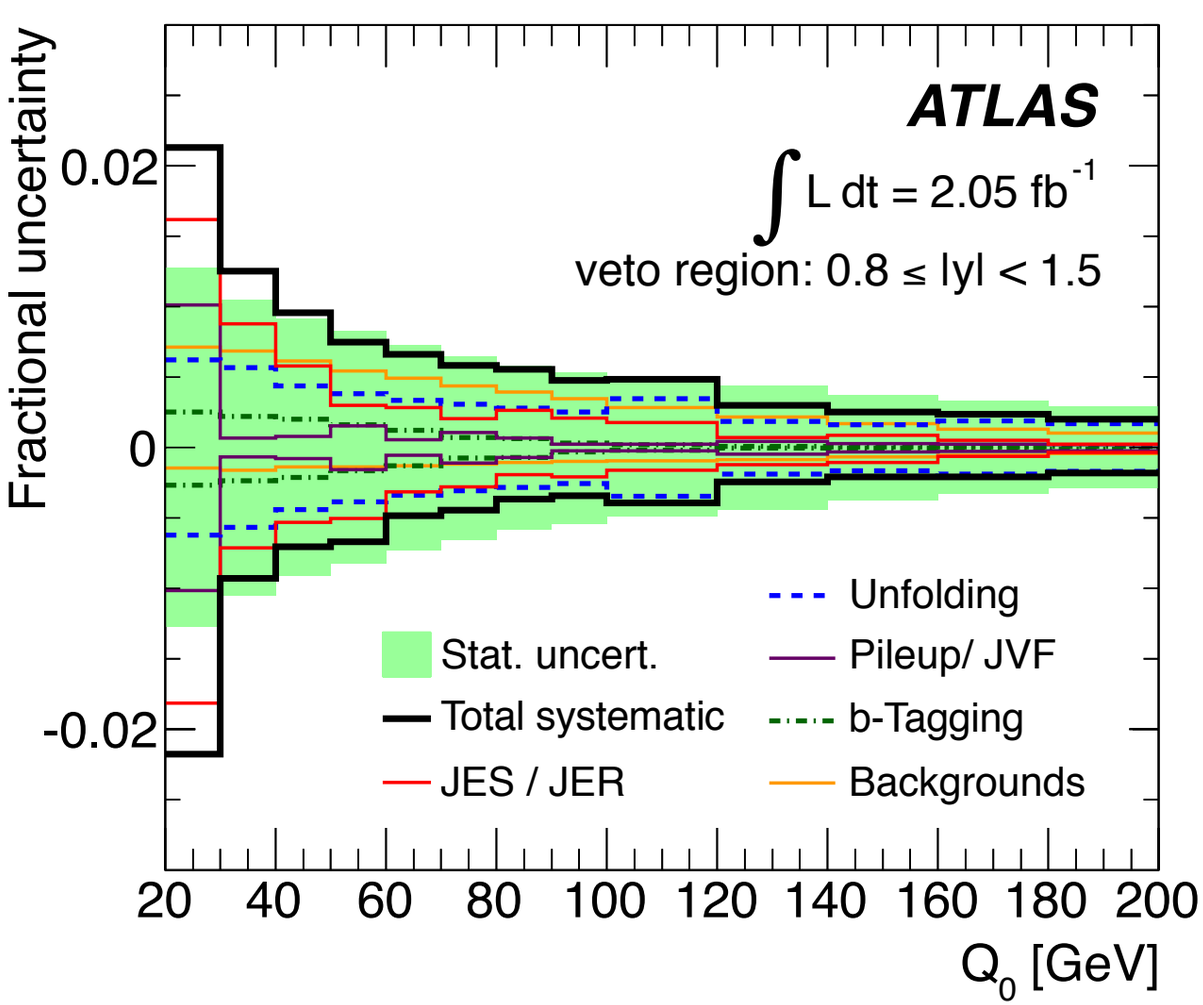
Unfolding

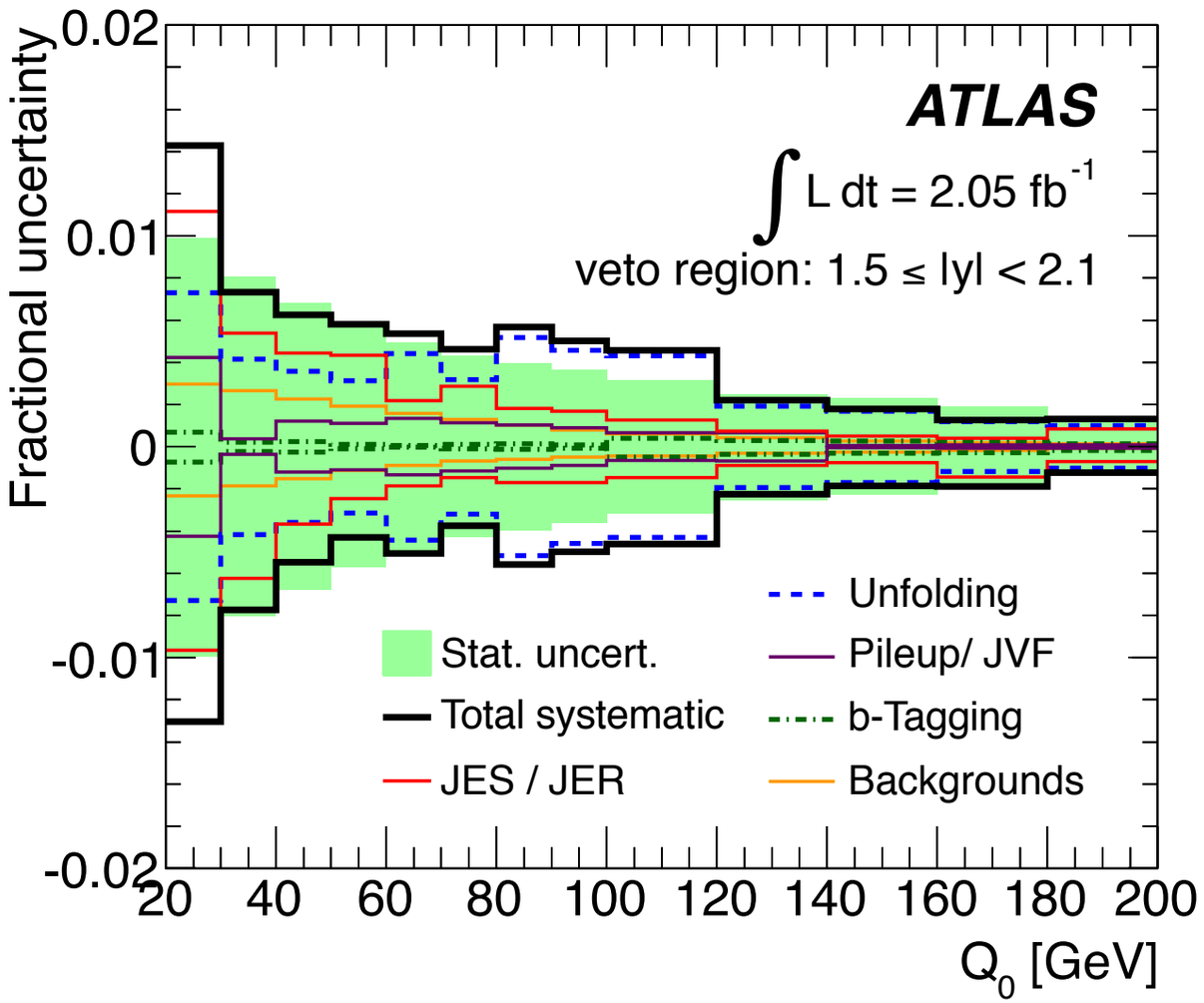
- Data corrected using point-by-point technique.
- At each value of Q_0 / Q_{sum}, a correction factor is defined using MC events, as:

$$C(x) = \frac{f^{truth}(x)}{f^{reco}(x)};\ x = Q_0,\ Q_{sum}$$

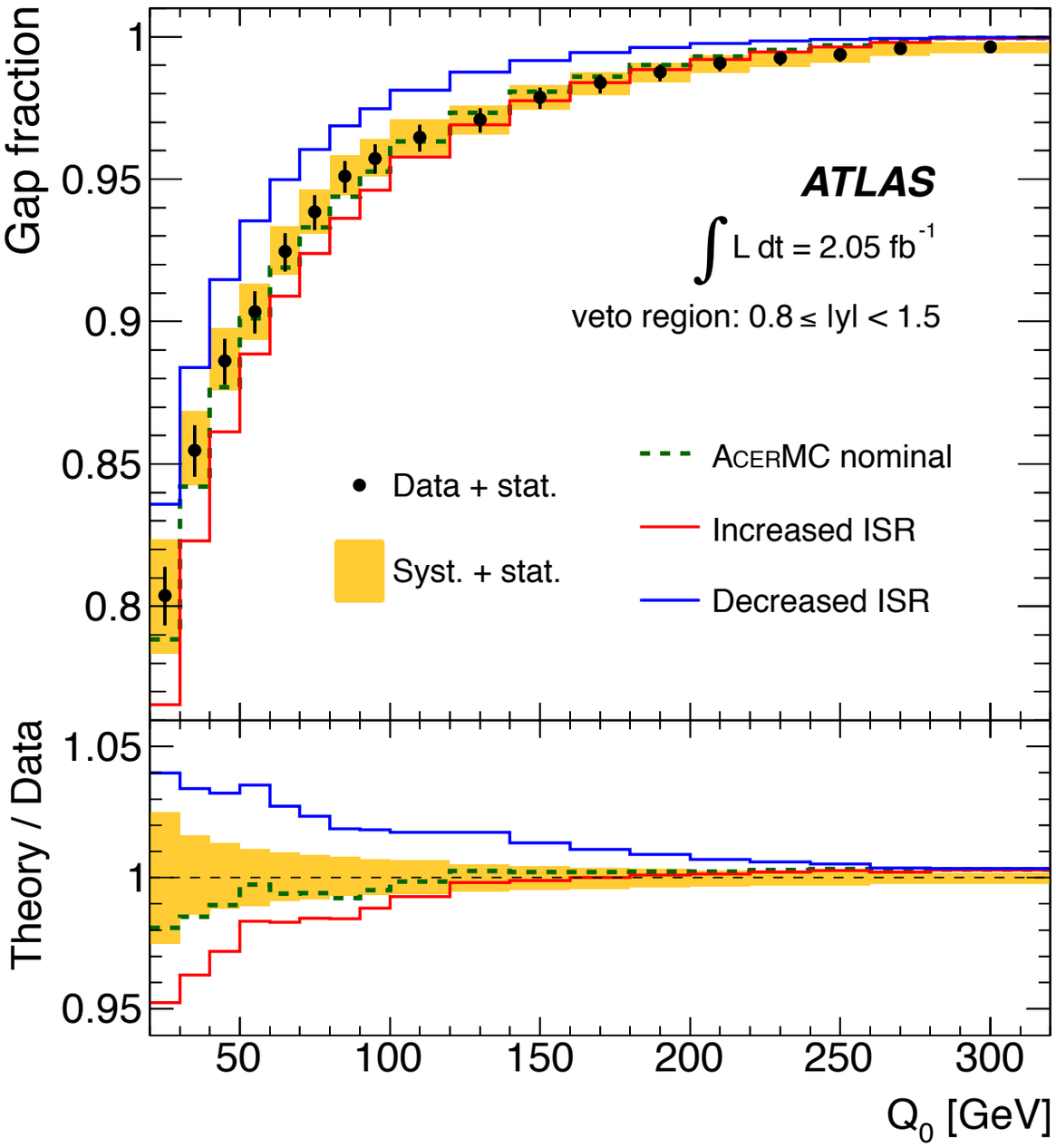
- Default correction factors taken from **MC@NLO**.
- Systematic uncertainty due physics modelling assessed by comparing to correction factors produced with POWHEG+Pythia & POWHEG+HERWIG.
- Uncertainty taken to be the largest of:
  - Difference between MC@NLO and either POWHEG sample.
  - Statistical uncertainty in the POWHEG+HERWIG.

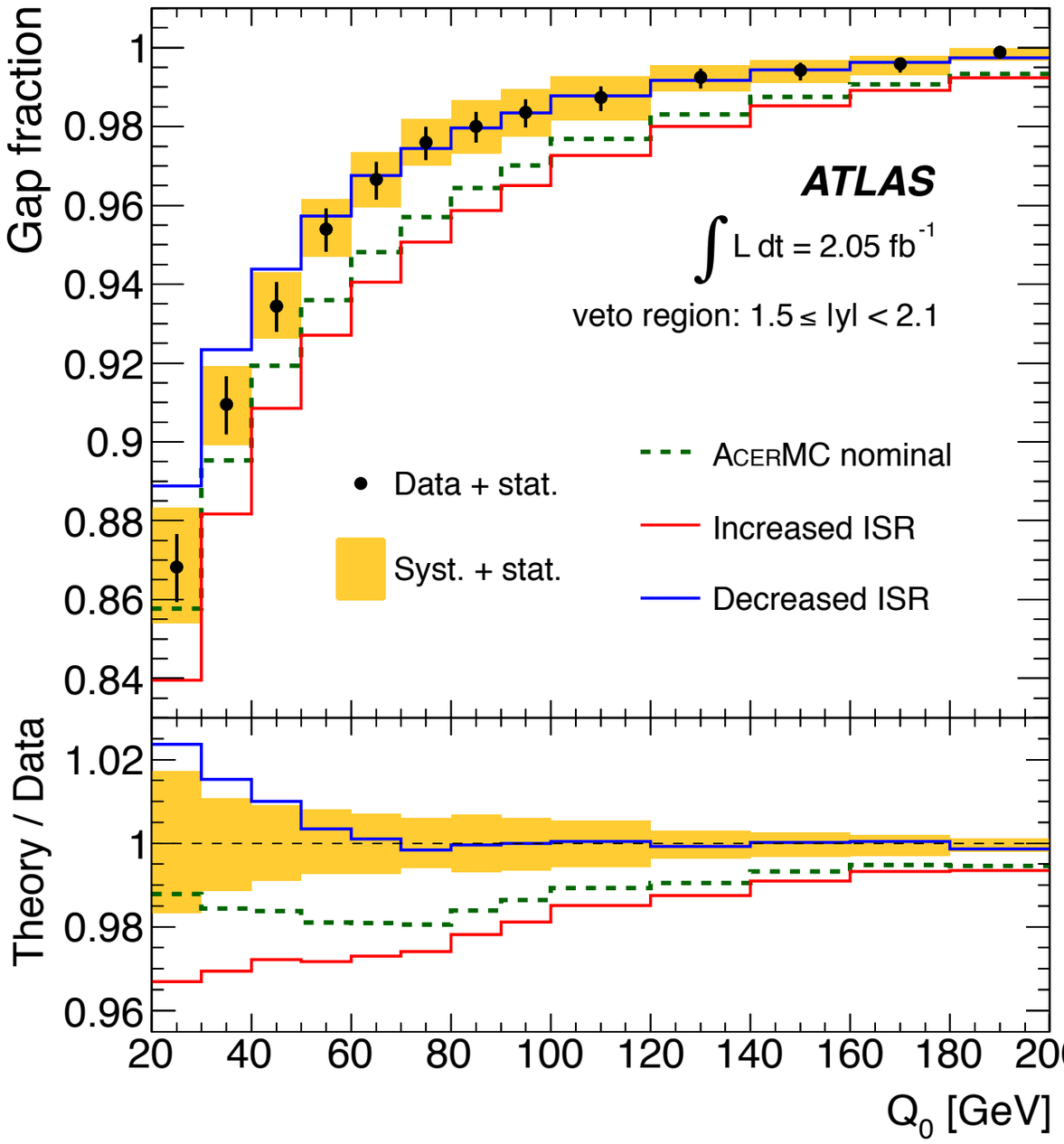
Systematic uncertainties



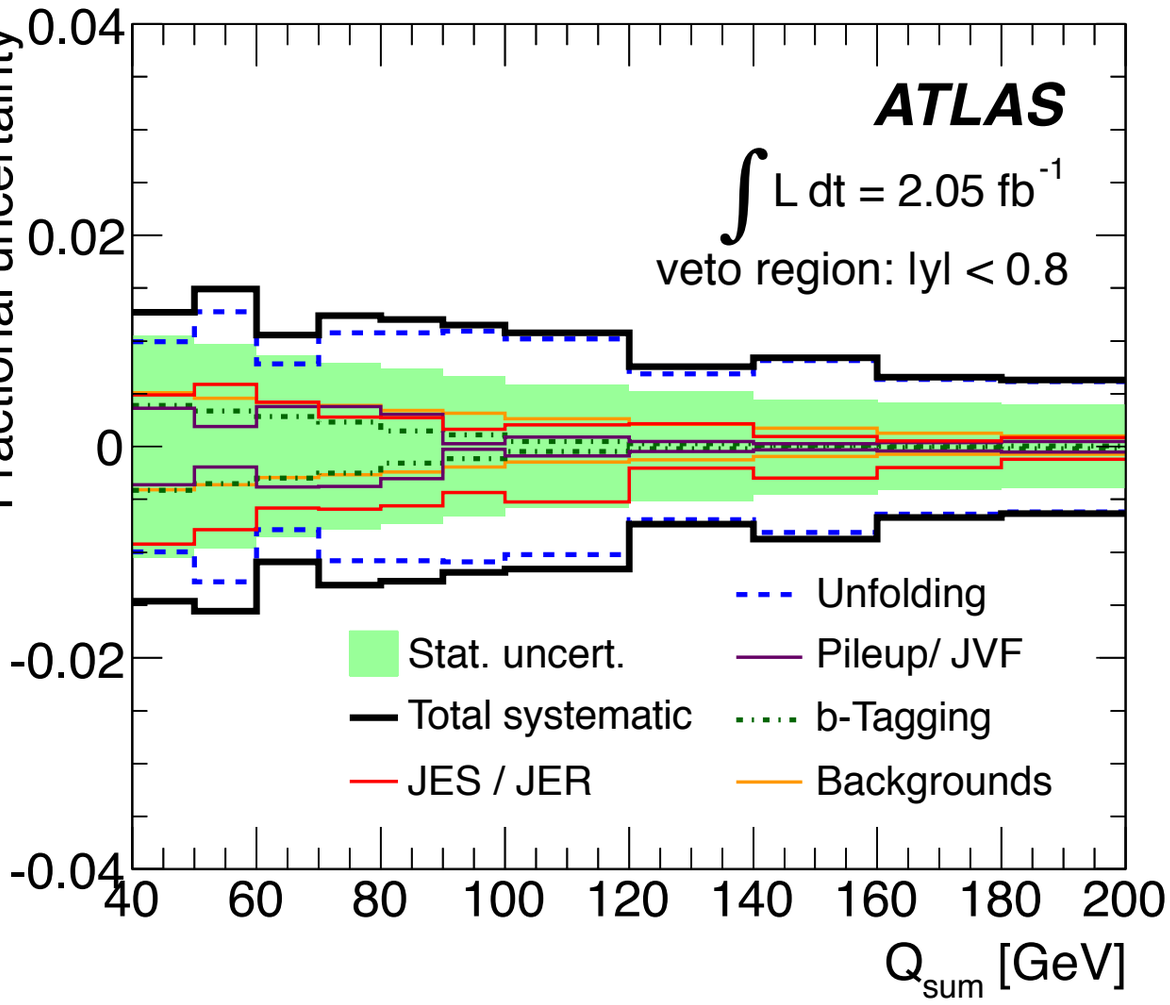


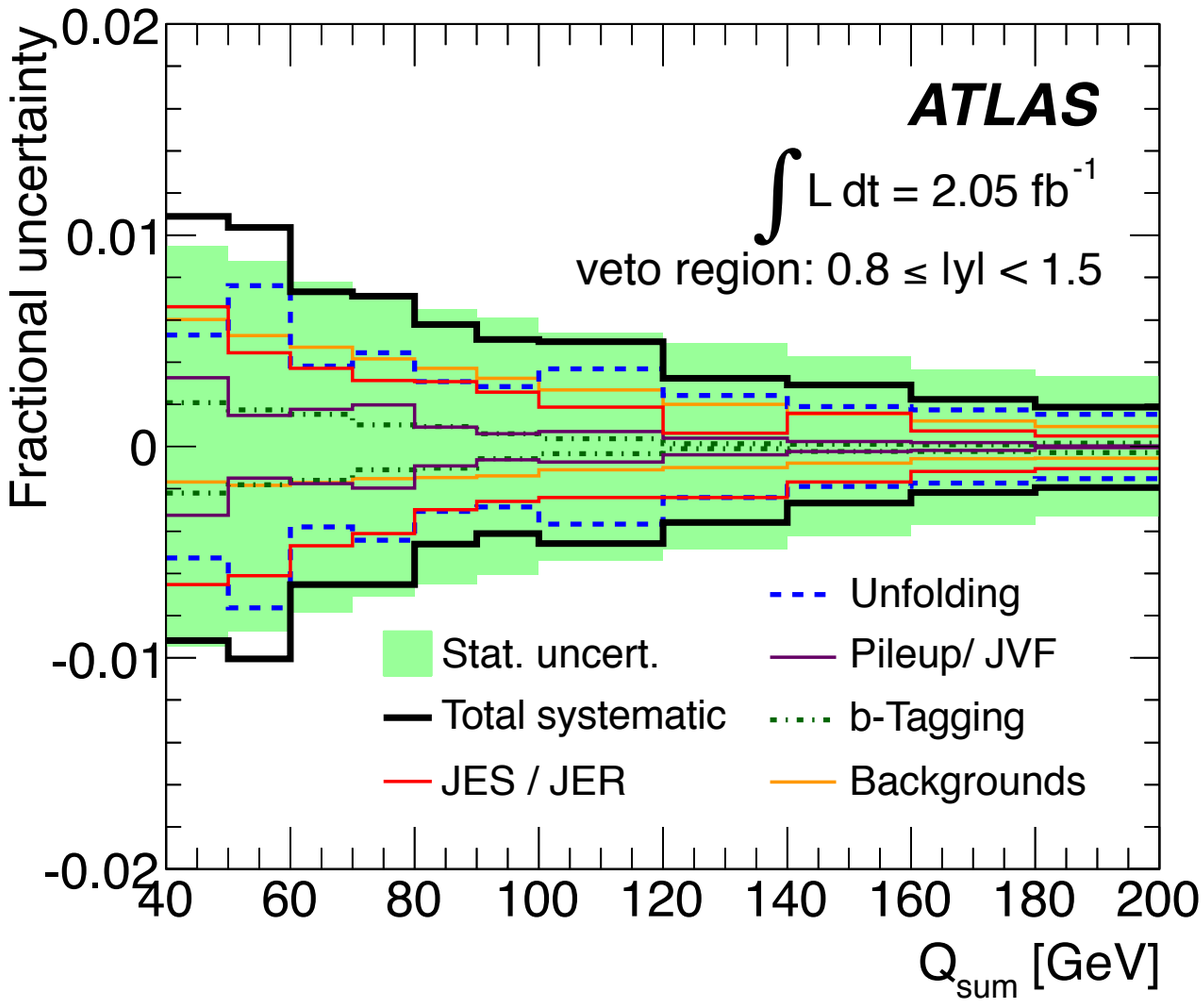
Results: ISR variations in forward regions





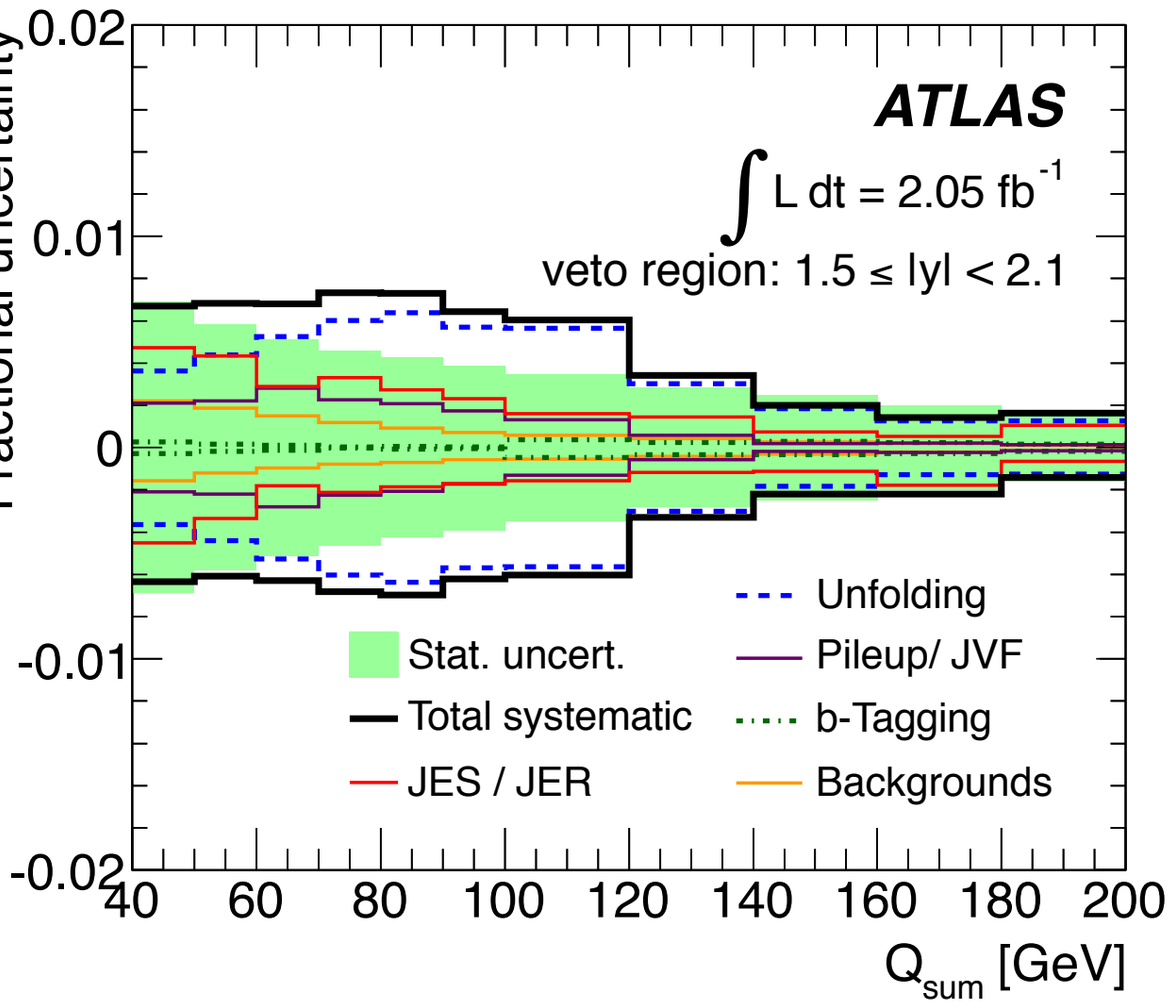
Systematic uncertainties: Q_{sum}

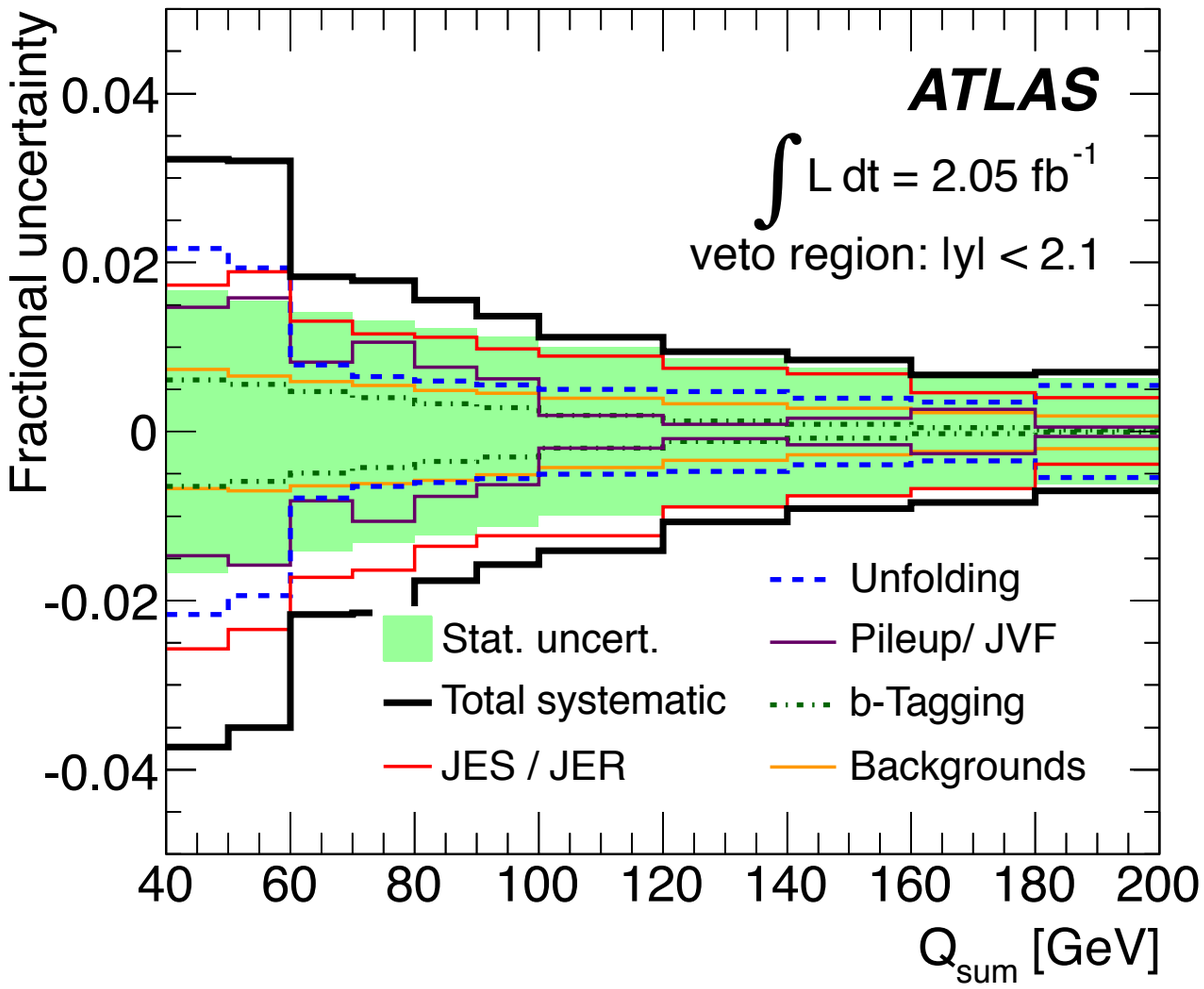




Q_{sum} = scalar-summed p_T of all jets in veto region: $f(Q_{sum}) = \frac{n(Q_{sum})}{N}$

Systematic uncertainties: Q_{sum}





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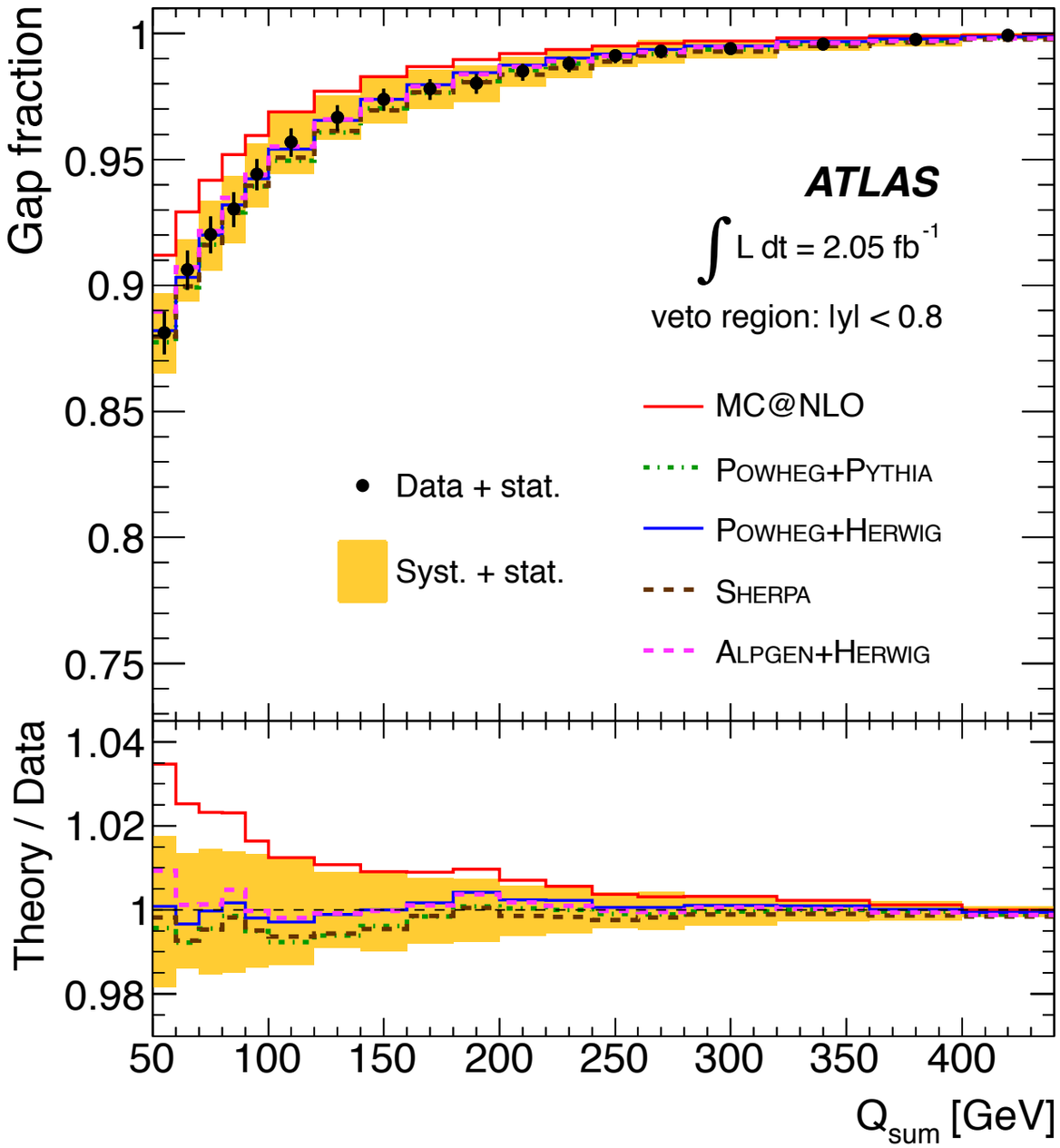
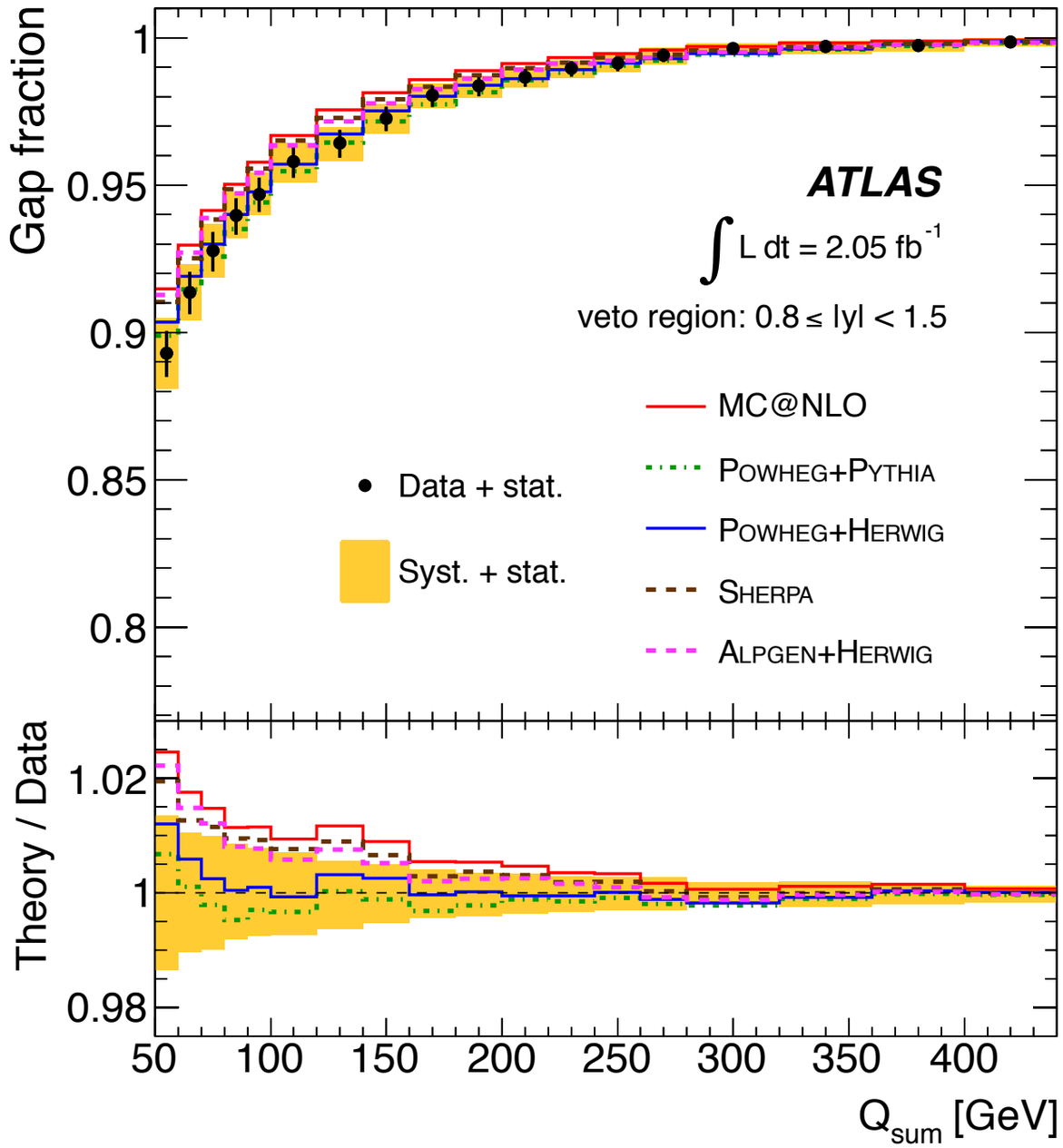
Results: Q_{sum}





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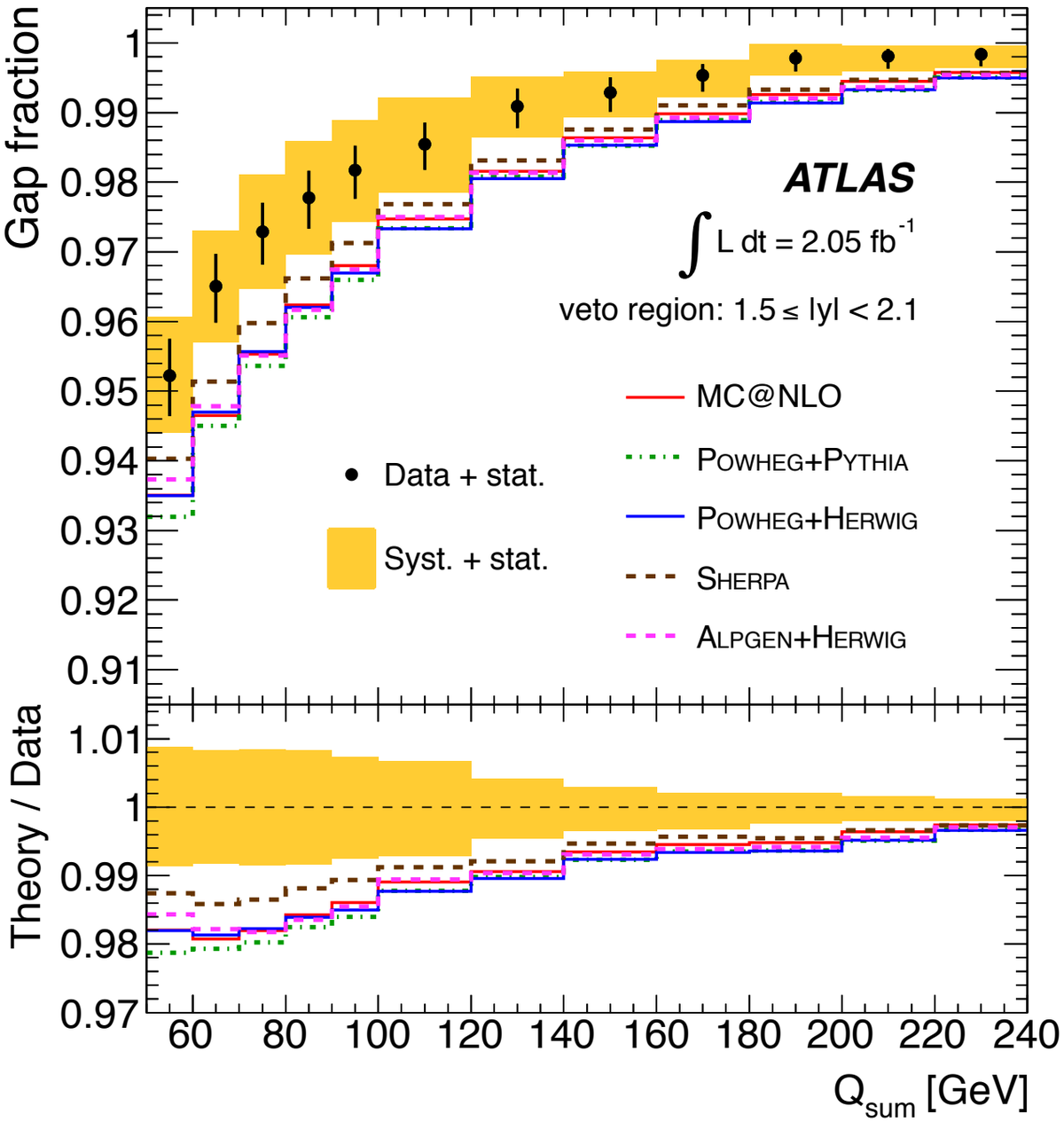

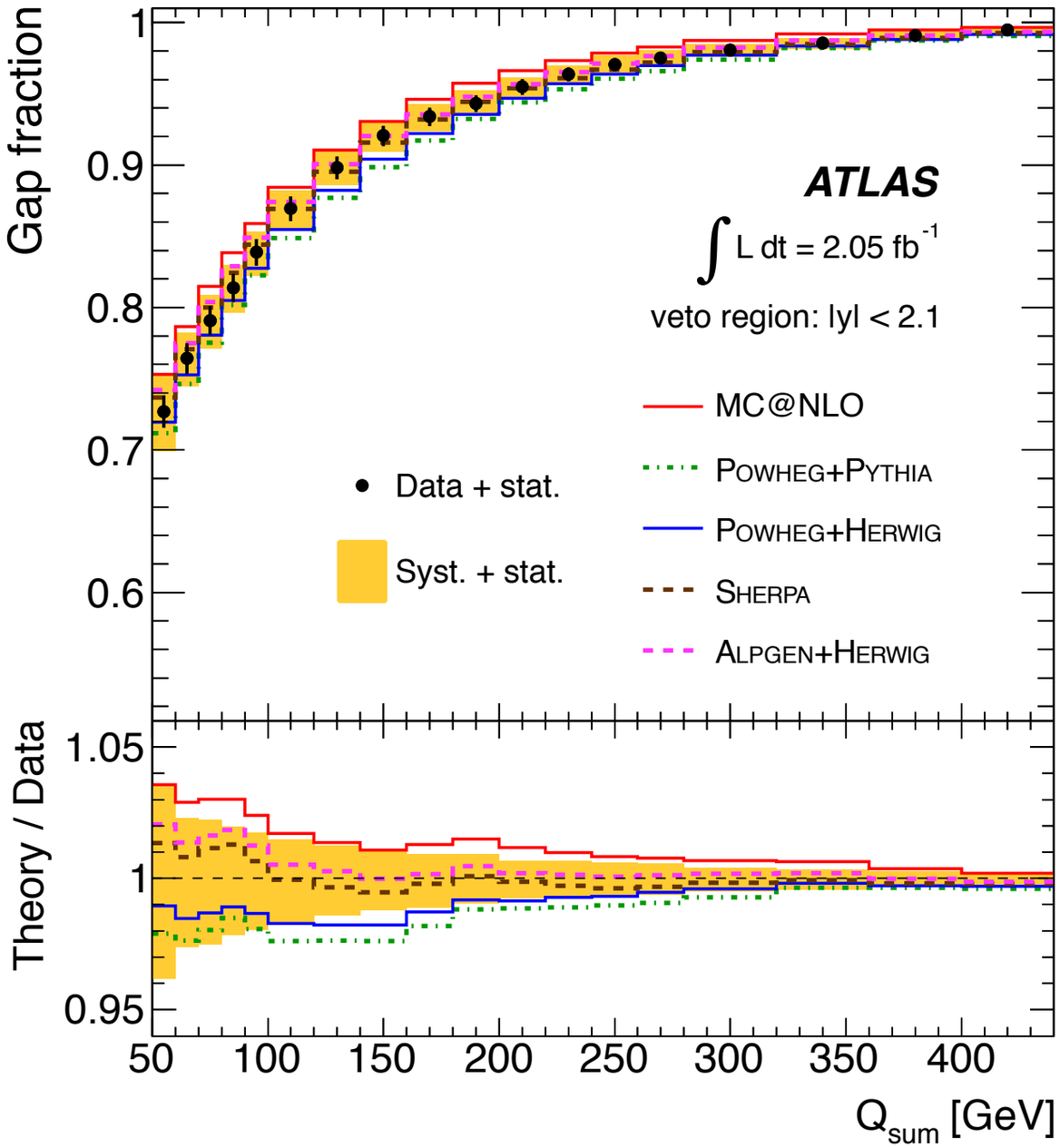

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