Measurements with ATLAS detector of Jets containing Charm and Bottom quarks

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Outline

1. Introduction
2. Inclusive $b$-jet and $b\bar{b}$-dijet
3. $D^{*\pm}$ meson in jets
4. Conclusions
Next slides are about...

1. Introduction
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Motivation

- Heavy quark (c and b) production in pp collisions $\Rightarrow$ test of perturbative QCD
- Next-to-leading order calculations of production cross-section $\Rightarrow$ interest of comparison between predictions and measurements
- Heavy quarks are often in background to new physics search $\Rightarrow$ need to understand the QCD production
Analyses presented today

- Measurements with ATLAS detector at $\sqrt{s} = 7$ TeV (2010)
- Measurement of inclusive $b$-jet and $b\bar{b}$-dijet production cross-sections:
  - measurement as function of jet $p_T$, jet rapidity $y$ (inclusive)
  - measurement as function of dijet invariant mass $m_{jj}$, angle between jets $\Delta\phi$, angular variable $\chi = \exp|y_1 - y_2|$ ($b\bar{b}$)
- Measurement of $D^{*\pm}$ meson production in jets:
  - measurement as function of jet $p_T$ and $z = \frac{p_{\parallel}(D^{*\pm})}{E(\text{jet})}$
- Comparison with theoretical predictions using simulated events
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Introduction

Inclusive $b$-jet and $b\bar{b}$-dijet production cross-sections

Conclusions

Analysis in a nutshell

Inclusive $b$-jet and $b\bar{b}$-dijet production cross-sections

1. Selection of events with jets; jet reconstruction
2. Applying $b$-tagging on jets (with lifetime-based method)
3. $b$-tagging efficiency determination (with $p_T^{rel}$ method)
4. $b$-jet purity determination (using secondary vertex mass)
5. Measurement of the production cross-sections
   - using the $p_T^{rel}$ method for a complementary measurement (muon-based measurement)
   - bin-by-bin unfolding
6. Comparison with simulated data
Event selection and reconstruction

- 2010 ATLAS data, L = 34.0 ± 1.2 pb\(^{-1}\) at \(\sqrt{s} = 7\) TeV
- Trigger requires a jet (and a muon for the muon-based measurement)
- Jet reconstruction with anti-\(k_t\) algorithm (\(R = 0.4\))
- Quality selections on jets
- \(b\)-tagging with lifetime-based method:
  - reconstruction of secondary vertex from tracks within jet
  - measurement of signed decay length significance \(L/\sigma_L\)
Estimation with $p_T^{\text{rel}}$ method

- For jets containing a muon:
  - $p_T^{\text{rel}}$ is momentum of muon, transverse to jet
  - $p_T^{\text{rel}}$ spectrum harder for $b$-jets
- Templates of $p_T^{\text{rel}}$ shape for each jet flavour:
  - from simulation for $c$-jets and $b$-jets
  - from data for light-jets (enriched sample)
- Fit of measured $p_T^{\text{rel}}$ spectrum, adjusting templates, before and after $b$-tagging
  - $b$-tagging efficiency extraction
Estimation with $p_T^{rel}$ method

Example of $p_T^{rel}$ distribution for all jets
Estimation with $p_T^{\text{rel}}$ method

Example of $p_T^{\text{rel}}$ distribution for $b$-tagged jets

For jets containing a muon:

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- $p_T^{\text{rel}}$ spectrum harder for $b$-jets
- Templates of $p_T^{\text{rel}}$ shape for each jet flavour:
  - from simulation for $c$-jets and $b$-jets
  - from data for light-jets (enriched sample)

Fit of measured $p_T^{\text{rel}}$ spectrum, adjusting templates, before and after $b$-tagging

$⇒ b$-tagging efficiency extraction

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DIS2012 / ATLAS: b-jets, c-jets
Complementary method

Muon-based analysis

- Fit of measured $p_T^{\text{rel}}$ spectrum before $b$-tagging
  $\Rightarrow$ $b$-jet purity extraction
- Complementary to lifetime-based analysis because of different systematic uncertainties and event samples
- But: method only for jets with $\mu$ and with jet $p_T$ in range $30 < p_T < 140$ GeV
  $\Rightarrow$ Reduced statistics and range (only as a cross-check)
Efficiency as a function of $p_T$ and $y$

- $\sim 20\%$ at low $p_T$ and high $y$
- $\sim 55\%$ for $p_T \sim 200$ GeV and low $y$
- For $p_T > 140$ GeV: from simulation and correction factor (from $p_{rel}^T$)
Secondary vertex mass method

- Secondary vertex mass increases with flavour of jet
- Templates of vertex mass shape for each jet flavour (from simulation)
- Fit of measured vertex mass spectrum, adjusting templates

⇒ $b$-jet purity (fraction of $b$-jets in sample of $b$-tagged jets)

- For $b\bar{b}$-dijet sample:
  - fit of sum of masses of both $b$-jets secondary vertices
  - $b$-template with both jets matched to true $b$-jets (simulation)
  - non-$b$ template when at least one of the jets is not matched
  - reduced statistics ⇒ parameterization
Introduction

Inclusive $b$-jet and $b\bar{b}$-dijet

$D^*\pm$ meson in jets

Conclusions

$b$-jet purity determination

Secondary vertex mass method

Example of secondary vertex mass fit

ATLAS

$80 < p_T < 110$ GeV, $|y| < 0.3$

• Data 2010
• light-flavour template
• $c$-template
• $b$-template
• MC stat. uncertainty

$b$-frac. = $0.69 \pm 0.04$

$\chi^2$/DoF = 25.9/26
Secondary vertex mass method

Example of fit for the $b\bar{b}$-dijet
Systematic uncertainties for lifetime-based analysis

- Dominant: $b$-jet energy scale calibration, $b$-tagging efficiency and purity determinations
Inclusive $b$-jet cross-section measurement

$\Rightarrow$ Lifetime-based and muon-based analyses agree

Different binnings $\Rightarrow$ bin-by-bin comparison not possible
Inclusive $b$-jet cross-section measurement

- Pythia prediction scaled by 0.67 to match measured integrated cross-section
- General features are reasonably well reproduced by simulation
Inclusive $b$-jet cross-section comparison: POWHEG+Pythia

- Good agreement in all rapidity regions
Inclusive $b$-jet cross-section comparison: MC@NLO + Herwig

- Differences in different rapidity regions
- Effect averages out in integrated cross-section but still global deficit
Inclusive $b$-jet cross-section comparison:

POWHEG+Herwig

- POWHEG+Herwig: similar rapidity behaviour to POWHEG+Pythia, but lower cross-section
  ▸ Deficit in MC@NLO+Herwig partly due to Herwig, but not the rapidity dependence
**b\bar{b}-dijet cross-section measurement**

**Results**

\[ \frac{d\sigma}{dm_{jj}} \text{ [ pb/GeV] } \]

\[ \frac{1}{\sigma_{\text{ATLAS}}} \frac{d\sigma_{\text{h}\phi}}{d\phi} \text{ [ rad^{-1}] } \]

\( \sqrt{s} = 7 \text{ TeV}, \int L dt = 34 \text{ pb}^{-1} \)
**$b\bar{b}$-dijet cross-section measurement**

\[
\chi = \exp |y_1 - y_2| \quad \text{for events with} \quad |y_{\text{boost}}| = \frac{1}{2} |y_1 + y_2| < 1.1
\]
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Analysis in a nutshell

$D^{*\pm}$ meson production in jets

1. Selection of events with jets; jet reconstruction
2. Full reconstruction of $D^{*\pm}$ mesons
3. Measurement of $R(p_T, z) = \frac{N_{D^{*\pm}}(p_T, z)}{N_{jet}(p_T)}$ with $z = p_{||}(D^{*\pm})/E(jet)$ ($p_{||}$ along jet axis)
   - Bayesian unfolding
4. Comparison with simulated data
April-July 2010 ATLAS data, $L = 0.30 \pm 0.01 \text{ pb}^{-1}$ at $\sqrt{s} = 7 \text{ TeV}$

- Trigger requires a jet
- Jet reconstruction with anti-$k_t$ algorithm ($R = 0.6$)
- Quality selection on jets, $25 < p_T < 70 \text{ GeV}$, $|\eta| < 2.5$
Full reconstruction of $D^{*\pm}$ meson

- Reconstructed decays:
  - $D^{*+} \rightarrow D^0 \pi^+$ or $D^{*-} \rightarrow \bar{D}^0 \pi^-$ ($p_T^{\pi} > 0.5$ GeV)
  - $D^0 \rightarrow K^- \pi^+$ or $\bar{D}^0 \rightarrow K^+ \pi^-$ ($p_T^{K,\pi} > 1$ GeV)

- Selections criteria:
  - $D^0/\bar{D}^0$ candidate with positive transverse decay length,
    $|m_{K\pi} - m_{D^0}^{PDG}| < 50$ MeV
  - $D^{*\pm}$ candidate with $p_T > 7.5$ GeV
Jet matching and $D^{*\pm}$ jet yield

- **Matching with a jet:**
  - $D^{*\pm}$ direction within $\Delta R < 0.6$ of jet axis
  - $z > 0.3$
  - selected jets are $D^{*\pm}$ jets
- **$D^{*\pm}$ jet yield:**
  - distribution of $\Delta m = m(K^\mp \pi^\pm \pi^\pm) - m(K^\mp \pi^\pm) - m(\pi^\pm)$
  - fit of distribution with double gaussian for signal, $\Delta m^a e^{b\Delta m}$ for background
Jet matching and $D^{*\pm}$ jet yield

Example of $\Delta m$ distribution

![Graph showing $\Delta m$ distribution](image)

- ATLAS
- $25 < p_T < 30$ GeV
- $0.3 < z < 0.4$
Jet matching and $D^{*\pm}$ jet yield

Example of $\Delta m$ distribution

- $30 < p_T < 40$ GeV
- $0.4 < z < 0.5$

ATLAS
Jet matching and $D^{*\pm}$ jet yield

Example of $\Delta m$ distribution

$c)$

ATLAS

$40 < p_T < 50$ GeV

$0.5 < z < 0.6$
Jet matching and $D^{*\pm}$ jet yield

Example of $\Delta m$ distribution
Jet matching and $D^{*\pm}$ jet yield

Example of $\Delta m$ distribution

![Graph showing $\Delta m$ distribution for ATLAS]

- $60 < p_T < 70$ GeV
- $0.7 < z < 1$

$\Delta m$ [MeV]

Entries / MeV

$ATLAS$

$\Delta m$ [MeV]

$0$ $10$ $20$ $30$ $40$
Jet matching and $D^{*\pm}$ jet yield

All reconstructed $D^{*\pm}$ candidates

![Graph showing distribution of $\Delta m$ with double Gaussian fit for signal and background.](graph.png)

- Right charge combinations
- Wrong charge combinations

$\Delta m$ [MeV]

- $m[K^{\pm}/\pi^{\pm}/\pi^{\pm}] - m[K^{\pm}/\pi^{\pm}/\pi^{\pm}]$
- $p_T > 25$ GeV
- $z > 0.3$

ATLAS
Introduction

Inclusive $b$-jet and $b\bar{b}$-dijet

$D^{*\pm}$ meson in jets

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Systematic uncertainties

Systematic uncertainties (integrated over all bins in $p_T$)

![Graph showing fractional systematic uncertainties for various sources like trigger efficiency, track reconstruction efficiency, jet energy scale, jet energy resolution, event selection, and MC statistics. The graph covers $z = \frac{p_{||}(D^{*\pm})}{E\text{(jet)}}$ from 0.3 to 1.0, with fractional uncertainties ranging from $10^{-3}$ to $10^2$.]

$ATLAS$ 25 < $p_T$ < 70 GeV

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Measurement of $D^{*\pm}$ production in jets

- $\mathcal{R} = 0.025 \pm 0.001\text{(stat.)} \pm 0.004\text{(syst.)}$
- Ratio $\Rightarrow$ LO and NLO predictions similar
- Theoretical predictions do not reproduce data for $z < 0.7$
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  - good agreement for POWHEG+Pythia
  - discrepancies for MC@NLO+Herwig in term of rapidity variation
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  - good agreement with generators
  - only leading and sub-leading jets are $b$-tagged $\Rightarrow$ low contribution from gluon splitting
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  - good agreement with generators
  - only leading and sub-leading jets are $b$-tagged $\Rightarrow$ low contribution from gluon splitting

- Measurement of fraction of jets which contain a $D^{*\pm}$ meson:
  - $\mathcal{R} = 0.025 \pm 0.001\text{(stat.)} \pm 0.004\text{(syst.)}$
  - discrepancy with generators for $z < 0.7$
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- Measurement of fraction of jets which contain a $D^{*\pm}$ meson:
  - $R = 0.025 \pm 0.001\text{(stat.)} \pm 0.004\text{(syst.)}$
  - discrepancy with generators for $z < 0.7$

- Measurements are dominated by systematic uncertainties
References

- Measurement of the inclusive and dijet cross-sections of $b$-jets in $pp$ collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector
  arXiv:1109.6833

- Measurement of $D^{*\pm}$ meson production in jets from $pp$ collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector
  Accepted in Physical Review D (2012)
  arXiv:1112.4432
Thank you for your attention
Additional slides
ATLAS detector
Monte Carlo generators

- **LO:** Pythia 6.423
  - pQCD matrix elements for 2→2 processes
  - $p_T$-ordered parton-showers calculated in leading-log approximation
  - underlying event simulation with multi-parton interactions
  - Lund string model for hadronisation
  - set of parameters: AMBT1 with MRST LO* PDF

- **NLO:**
  - POWHEG + Pythia 6
  - MC@NLO + Herwig 6:
    - AUET1 tune
    - angular-ordered parton-shower model
    - cluster hadronisation
  - MSTW 2008 NLO PDFs
  - $b$-quark mass of 4.95 GeV
True jet flavour definition

- Tagged as $b$-jet if $b$-hadron (with $p_T > 5$ GeV) within $\Delta R = 0.3$ of jet axis
- Or $c$-jet if $c$-hadron within same distance
- Light-jet otherwise
Event selection

- **Lifetime-based analysis:**
  - L1 or HLT jet triggers
  - MBTS trigger for $20 < p_T < 40$ GeV (inclusive cross-section)
  - Efficiency for $b$-jet above 97% (typically close to 100%)

- **Muon-based analysis:**
  - Combination of jet and $\mu$ triggers
  - Efficiency $\sim 35\%$ ($p_T < 50$ GeV) to 65% ($p_T > 105$ GeV)
  - Higher stat. due to different prescale than inclusive jet triggers

- **Quality selections:**
  - Reconstructed jets not produced by poorly calibrated or noisy cells
  - Charged particle tracks of good quality (for $b$-tagging)
  - Good reconstructed primary vertex (at least 10 tracks with $p_T > 150$ MeV)
  - Reconstruction and quality req. efficiency above 96% for $b$-jets
Lifetime-based $b$-tagging algorithm

- SV0: reconstruction of secondary vertex from charged particles with high 3D impact parameter significance
- Reject vertex compatible with primary vertex or located at pixel detector layer
- Reject vertex with mass consistent with $K_S^0/\Lambda^0$ decay or $\gamma$ conversion
- Signed decay length $L$ (sign from projection onto jet axis)
- Jet is $b$-tagged if $L/\sigma_L > 5.85$
- Cut tuned for 50% efficiency in simulated $t\bar{t}$ events
Distribution of $L/\sigma_L$
Lifetime-based $b$-tagging efficiency

- Efficiency estimated with data-driven method
- Jets containing a $\mu$: $p_T^{rel}$ ($p_\mu$ transverse to $p_\mu + p_{jet}$)
- $p_T^{rel}$ spectrum harder for $b$-jets
- $p_T^{rel}$ shape for each jet flavour:
  - simulation for $c$-jets and $b$-jets
  - data for light-jets (enriched sample)
- Fit of measured $p_T^{rel}$ spectrum, adjusting templates

$\Rightarrow$ $b$-tagging efficiency from $\epsilon_b = \frac{f_b^{tag} N^{tag}}{f_b N} C$ ($C \sim$ few %)

- Estimation extended to all $b$-jets (not only decaying to $\mu$), systematic uncertainty taken into account
- Only possible for $p_T < 140$ GeV $\Rightarrow$ above use simulation and correction factor $0.88 \pm 0.18$ (from range 90-140 GeV)
Lifetime-based $b$-tagging efficiency

![Graph showing $b\bar{b}$ dijet mass vs. $b$-tagging efficiency. The graph displays a rise in efficiency with increasing dijet mass. The data points are represented with error bars, and the fit result is indicated by a dashed line. Additionally, the systematic error is represented by a yellow shaded area. The title "ATLAS" is placed above the graph, indicating the source of the data.](image)
Systematic uncertainties for lifetime-based analysis

- **10-20% — b-jet energy scale calibration:**
  - inclusive jet energy scale: 2-6%
  - +2.5% for b-jets (comparing particle-level jets to reconstructed jets in simulation)
  - includes different shower and hadronisation models
- **5-20% (incl.) 30-50% (dijet) — b-tagging efficiency:**
  - modelling of $\mu$ in simulation
  - application of efficiency of jets with $\mu$ to all jets
  - limited stat. of templates for $p_T^{\text{rel}}$ fits
- **3-8% (incl.) 20-30% (dijet) — b-jet purity:**
  - study of secondary vertex mass distribution in light-jet/b-jet enriched samples
  - limited stat. of templates for $b\bar{b}$
- **3.4% — luminosity**
- **2% — other sources** (jet energy resolution, trigger efficiency, jet selection efficiency, ...)
Vertex mass uncertainty: studies of anti-$b$-tag and second $b$-jet
Muon-based analysis

- Jets with $\mu$ within $\Delta R < 0.4$ of jet axis and $p_T \mu > 4$ GeV
- Using $p_T^{rel}$ in range $30 < p_T < 140$ GeV
- Template shapes for $c$-jets and $b$-jets from simulation
- Template shape for light-jets from data:
  - jets with anti-$b$-tagging, correction for $b$-jets contamination from simulation
  - inclusive jets without $\mu$, taking charged track inside jet as $\mu$
- Fit of measured $p_T^{rel}$ spectrum, adjusting templates
  $\Rightarrow$ $b$-jet fraction extraction
- Complementary to lifetime-based analysis because of different systematic uncertainties and event samples
Systematic uncertainties for muon-based analysis

- 15-20% — *b*-jet energy scale (same as lifetime-based study)
- 8-18% — *b*-jet purity:
  - different methods of light-jets shape estimation
  - limited stat. of templates fit
  - modelling of semileptonic *b*-hadron decays (variation of $p_\mu$ in *b*-hadron rest frame between two measurements: DELPHI and BaBar)
  - modelling of *b*-fragmentation (variation of $\pm 5\%$)
- 3.4% — luminosity
- 3% — other sources (jet energy resolution, trigger efficiency, jet selection efficiency, ...)

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Unfolding

- Measured cross-sections corrected for experimental effects
- Bin-by-bin correction from Pythia dijets events:
  - cross-section for particle-level $b$-jets
  - cross-section for reconstructed $b$-jets
  $\Rightarrow$ ratio of cross-sections
References for inclusive $b$-jet and $b\bar{b}$-dijet

- CMS Collaboration, Inclusive $b$-jet production in pp collisions at $\sqrt{s} = 7$ TeV

- CMS Collaboration, Measurement of $B\bar{B}$ angular correlations based on secondary vertex reconstruction at $\sqrt{s} = 7$ TeV

- LHCb Collaboration, Measurement of $\sigma(pp \rightarrow b\bar{b}X)$ at $\sqrt{s} = 7$ TeV in the forward region
Monte Carlo generators

- **LO:**
  - Pythia 6.421 with MSTW LO PDF
  - Herwig 6 with AUET1 tune (underlying event with JIMMY)

- **NLO:** POWHEG
  - CTEQ 6.6

- $c$-quark mass of 1.5 GeV, $b$-quark mass of 4.75 GeV

\[ f(c \rightarrow D^{*+}) = 0.224, \quad f(b \rightarrow D^{*+}X) = 0.173 \]
Full reconstruction of $D^{*\pm}$ meson

- Two oppositely-charged tracks ($p_T > 1$ GeV) combined, two candidates:
  - $D^0 \rightarrow K^- \pi^+$ and $\bar{D}^0 \rightarrow K^+ \pi^-$
  - keep candidate within 50 MeV of PDG mass
  - keep candidate with positive transverse decay length

- Add track ($p_T > 0.5$ GeV) with same charge as selected pion:
  - $D^{*+} \rightarrow D^0 \pi^+$ or $D^{*-} \rightarrow \bar{D}^0 \pi^-$
  - keep candidate if $D^{*\pm} p_T > 7.5$ GeV
Transverse decay length of $D^0$ candidate

- $D^0$ decay vertex reconstructed from $K$ and $\pi$ tracks
- $\vec{r}$ is displacement vector pointing from the primary vertex to the $D^0$ decay vertex, in the transverse plane
- $L_{xy} = \vec{r}.\vec{p_T}/|\vec{p_T}|$
- Cut on $L_{xy} > 0$:
  - rejects half of combinatorial background
  - keeps 89% of signal
Unfolding

\[ R(p_T, z) = \frac{N_{\text{reco}}^{D^*\pm}(p_T, z)/\epsilon_{D^*\pm}(p_T, z)}{\beta(D^*\pm \rightarrow K^{\pm} \pi^{\pm} \pi^{\pm})N_{\text{jet}}^{\text{reco}}(p_T)/\epsilon_{\text{jet}}(p_T)} \]

- \( \epsilon_{D^*\pm}(p_T, z) \approx 15\text{-}45\% \) from simulation
- Finite resolution on jet energy \( \Rightarrow \) reconstructed and particle-level \( p_T \) and \( z \) differ
  \( \Rightarrow \) Bayesian iterative unfolding algorithm:
  - based on response matrix derived from simulated events
  - probability for a true \( D^*\pm \) jet with a given \( p_T \) and \( z \) to be reconstructed in any given \( p_T \) and \( z \) bin
  - simulated distributions of \( p_T \) and \( z \) are reweighted to match measured distributions
  - same procedure for inclusive jets with \( p_T \) only
  - algorithm validated with 1000 simulated ensembles \( \Rightarrow \) no bias
$D^{*\pm}$ jet reconstruction efficiency

![Heatmap of jet reconstruction efficiency](image-url)

- **$D^{*\pm}$ analysis**
- **$D^{*\pm}$ jet reconstruction efficiency**

**ATLAS**

- **truth $z$**
- **truth $p_T$(jet) [GeV]**

- Color scale ranging from 0.1 to 0.5

**Data Points**:

- **$p_T$(jet) [GeV]**: 25, 30, 35, 40, 45, 50, 55, 60, 65, 70
- **$z$**: 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1

**Values**:

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**Additional Information**

- **(jet)** [GeV]
- **ATLAS**

**Authors**

- **David Calvet**

**Conference**

- **DIS2012 / ATLAS: b-jets, c-jets**
Before reweighting simulation to data

ATLAS

\[ N(D^{*\pm}) / 5 \text{ GeV} \]

\[ p_T(D^{*\pm} \text{ jet}) \text{ [GeV]} \]

\[ z = p_{\parallel}(D^{*\pm}) / E(\text{jet}) \]
After reweighting simulation to data

ATLAS

Data

reweighted MC

\( N(D^{*\pm}) / 5 \text{ GeV} \)

\( p_T(D^{*\pm} \text{ jet}) \ [\text{GeV}] \)

Data

reweighted MC

\( N(D^{*\pm}) / 0.1 \)

\( z = p_{||}(D^{*\pm}) / E(\text{jet}) \)
Systematic uncertainties

- **14% — trigger efficiency:**
  - $r = \frac{N_{D^{*\pm}}^{reco}}{N_{jet}^{reco}}$ and $\rho = \frac{r_{jet-trig}}{r_{MBTS}}$
  - no jet selection in MBTS trigger
  - agreement for $\rho$ in data and simulation
  - statistical uncertainty of 14% on $\rho$ on data (due to limited size of MBTS sample)

- **8% — track reconstruction efficiency:**
  - each reconstructed $D^{*\pm}$ has a weight $w_{trks}$
  - $w_{trks} = (1 + s_K) \times (1 + s_{\pi 1}) \times (1 + s_{\pi 2})$
  - $s_K, s_{\pi 1}, s_{\pi 2} = \pm 1\sigma$ of track reconstruction efficiency (depends on $p_T$ and $\eta$, measured in data)
  - two measurements of $R$ with $s = \sigma$ and $s = -\sigma$

- **3.4% — luminosity**

- **3% — jet energy scale**

- **3% — transverse decay length efficiency**

- **1.5% — decay branching fraction of $D^{*\pm}$**
Systematic uncertainties

**ATLAS** 25 < p_T < 30 GeV

**ATLAS** 30 < p_T < 40 GeV

\[ z = \frac{p_{||}(D^*)}{E(jet)} \]
Systematic uncertainties

Fractional systematic uncertainty

- Trigger efficiency
- Track reconstruction efficiency
- Jet energy scale
- Jet energy resolution
- Event selection
- MC statistics
- Flavor composition
- Signal PDF
- Charm meson BR
- Total systematic uncertainty

ATLAS 40 < \( p_T \) < 50 GeV

ATLAS 50 < \( p_T \) < 60 GeV
Systematic uncertainties

\[ \frac{\text{Fractional systematic uncertainty}}{p_T} \]

\[ z = \frac{p_T (D^{*\pm})}{E_{\text{jet}}} \]

- Trigger efficiency
- Track reconstr. efficiency
- Jet energy scale
- Jet energy resolution
- Event selection
- Flavor composition
- Signal PDF
- Charm meson BR
- Total syst. uncertainty

**ATLAS** 60 < \( p_T < 70 \text{ GeV} \)

**ATLAS** 25 < \( p_T < 70 \text{ GeV} \)

David Calvet  
DIS2012 / ATLAS: b-jets, c-jets
Measurement of $D^{*\pm}$ production in jets

\[ z = \frac{p_{T}(D^{*})}{E_{\text{jet}}} \]

- Data/Theory
- ATLAS
- PYTHIA
- HERWIG
- POWHEG+PYTHIA
- POWHEG+HERWIG
- Data with stat. uncertainty
- stat. + syst. uncertainty

$\sqrt{s} = 7$ TeV, $\int L dt = 0.30$ pb$^{-1}$
$25 < p_{T} < 30$ GeV, $|\eta| < 2.5$
Measurement of $D^{*\pm}$ production in jets

\begin{align*}
\frac{R(p_T^z)}{\Delta z} &= \frac{2 \left( \frac{p_T}{p_T^0} \right)}{\Delta z} \\
\Delta z &= (z = p_T / E_{\text{jet}})
\end{align*}

\begin{align*}
\bar{s} &= 7 \text{ TeV, } \int Ldt = 0.30 \text{ pb}^{-1} \\
30 < p_T < 40 \text{ GeV, } |\eta| < 2.5
\end{align*}
Measurement of $D^{*\pm}$ production in jets

$\sqrt{s} = 7 \text{ TeV}, \int \text{Ldt} = 0.30 \text{ pb}^{-1}$
$40 < p_T < 50 \text{ GeV}, |\eta| < 2.5$

ATLAS
Measurement of $D^*\pm$ production in jets

$\sqrt{s} = 7$ TeV, $\int L dt = 0.30$ pb$^{-1}$

$50 < p_T < 60$ GeV, $|\eta| < 2.5$

$z = p_{T}(D^*)/E_{\text{jet}}$

Data/Theory

$R(p_T^z)/A_{\Delta z}$
Measurement of $D^{*\pm}$ production in jets

$\sqrt{s} = 7$ TeV, $\int L dt = 0.30$ pb$^{-1}$

$60 < p_T < 70$ GeV, $|\eta| < 2.5$

Data/Theory