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Top quark production in the ATLAS detector of the LHC

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Introduction

- Top has a large production cross section. Including associated production because of the large phase space.
- Complex final state, top pair production is background for a number of SUSY searches

0 leptons + 2 b-jets + Etmiss	[Sbottom/stop]	arxiv:1308.2631
0 leptons + >=7-10 jets + Etmiss	[Incl. strong production]	arxiv:1308.1841
2 leptons + (b)jets + Etmiss	[Medium stop]	ATLAS-CONF-2013-065
1-2 leptons + 3-6 jets + Etmiss	[Incl. strong production, mUED]	ATLAS-CONF-2013-062
0-1 leptons + >=3 b-jets + Etmiss	[3rd gen. Squarks]	ATLAS-CONF-2013-061
1 lepton + 4(1 b-)jets + Etmiss	[Medium / heavy stop]	ATLAS-CONF-2013-037
0 lepton + 6 (2 b-)jets + Etmiss	[Heavy stop]	ATLAS-CONF-2013-024
1-2 taus + jets + Etmiss	[GMSB]	ATLAS-CONF-2013-026

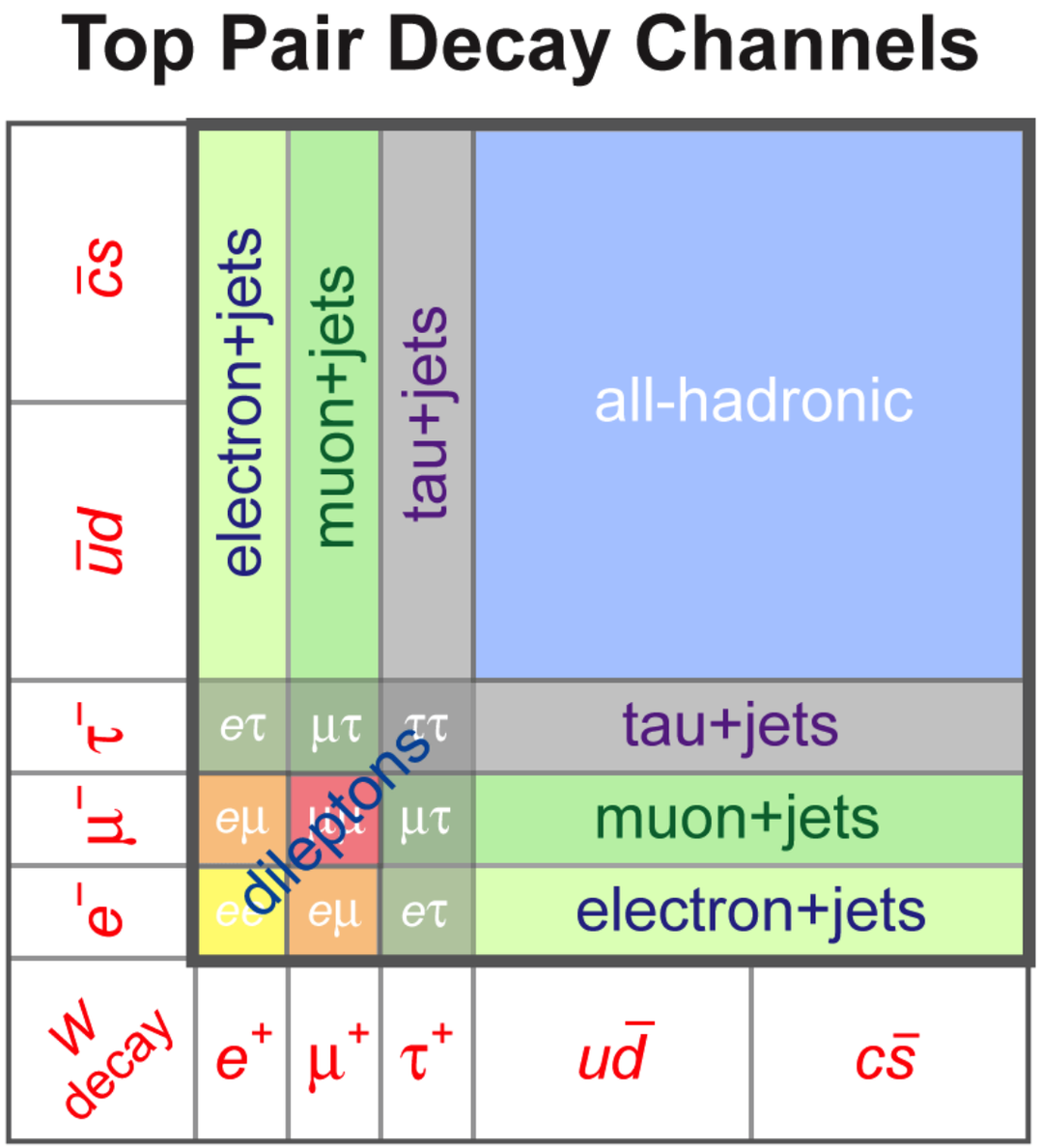
- The LHC has produced a large dataset of tops to analyze
  - This allows for differential measurements, observation of difficult decay channels, associated production, etc
- Precision measurements allow for a better understanding and reduced systematics
- I will show results from six ATLAS results, showing inclusive and differential measurements

Introduction

- Top quark is the heaviest SM particle, decays ~100% of the times to Wb
- Analyses are defined by decay of W boson

Single lepton (e/μ) + jets	34.3%
Dilepton (ee/eμ/μμ)	6.4%
All hadronic	45.7%
Tau + jets	9.8%
Tau + lepton	3.7%

- 2 b-quarks per event, usage of b-tagging to increase ttbar contribution

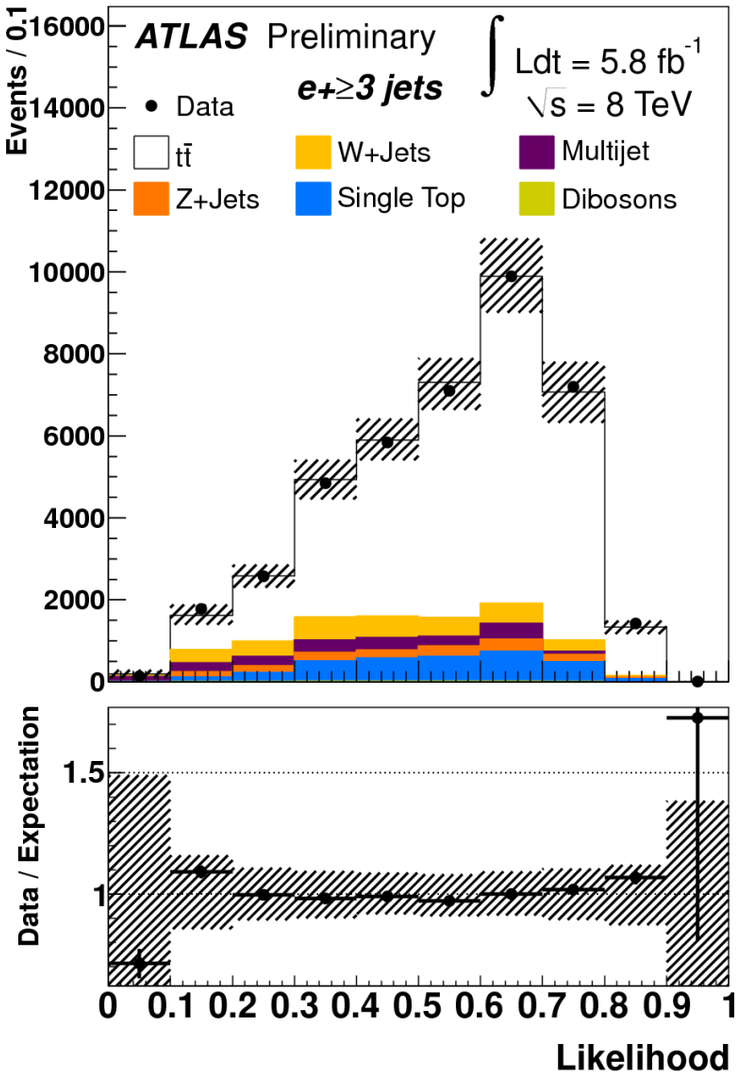


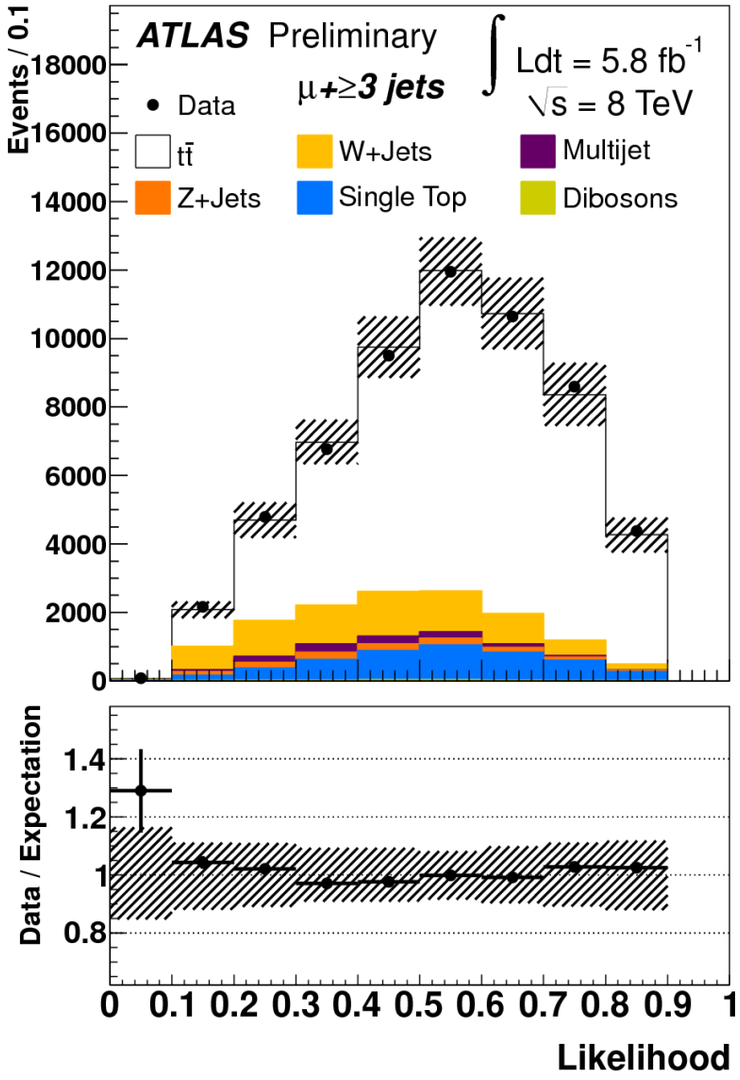
Analyses covered in this talk

- **Total inclusive cross section**
  - Measurement of the top quark pair production cross section in the single-lepton channel with ATLAS in proton-proton collisions at 8 TeV using kinematic fits with b-tagging: Link
  - Measurement of the ttbar production cross section in the tau+jets channel using the ATLAS detector: Link
- **Differential cross section**
  - Measurement of ttbar production with a veto on additional central jet activity in pp collisions at √s = 7 TeV using the ATLAS detector: Link
  - Measurement of the jet multiplicity in top-anti-top final states produced in 7 TeV proton-proton collisions with the ATLAS detector: Link
  - Measurements of top quark pair relative differential cross-sections with ATLAS in pp collisions at √s = 7 TeV: Link
- **Associated production**
  - A study of heavy flavor quarks produced in association with top quark pairs at √s = 7 TeV using the ATLAS detector: Link

Top pair cross section in lepton+jets

- Dataset: 5.8 fb^{-1} @8TeV
- 1 lepton (e/μ, p_T>40GeV), 3 or more jets (p_T>25GeV), 1 or more b-tags (70% efficiency), large E_T^{miss} and m_T(W)
- Likelihood discriminant based on transformed aplanarity[*] and lepton pseudorapidity
- Fit the discriminant for ttbar and W+jets normalization
  → extract ttbar cross section





ATLAS-CONF-2012-149

- Result: $\sigma_{t\bar{t}} = \mathbf{241 \pm 2(stat) \pm 31(syst) \pm 9(lumi)\ pb}$

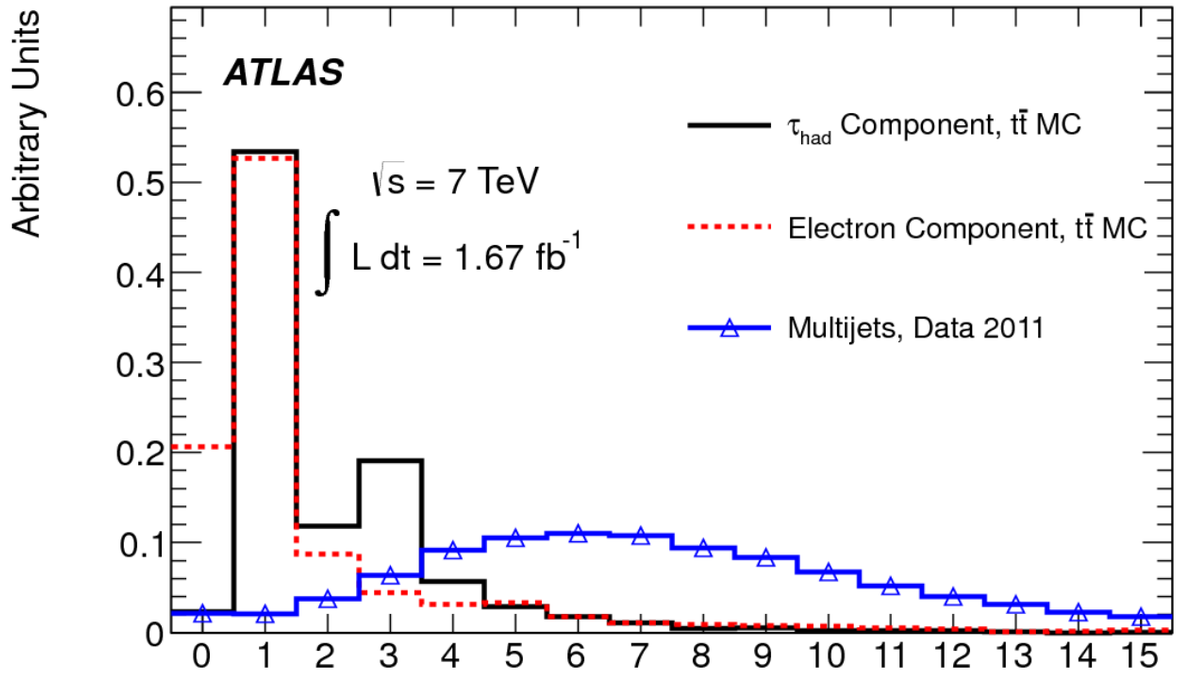
  NNLO+NNLL: $\sigma_{t\bar{t}}^{NNLO} = \mathbf{253^{+13}_{-15}\ pb}$

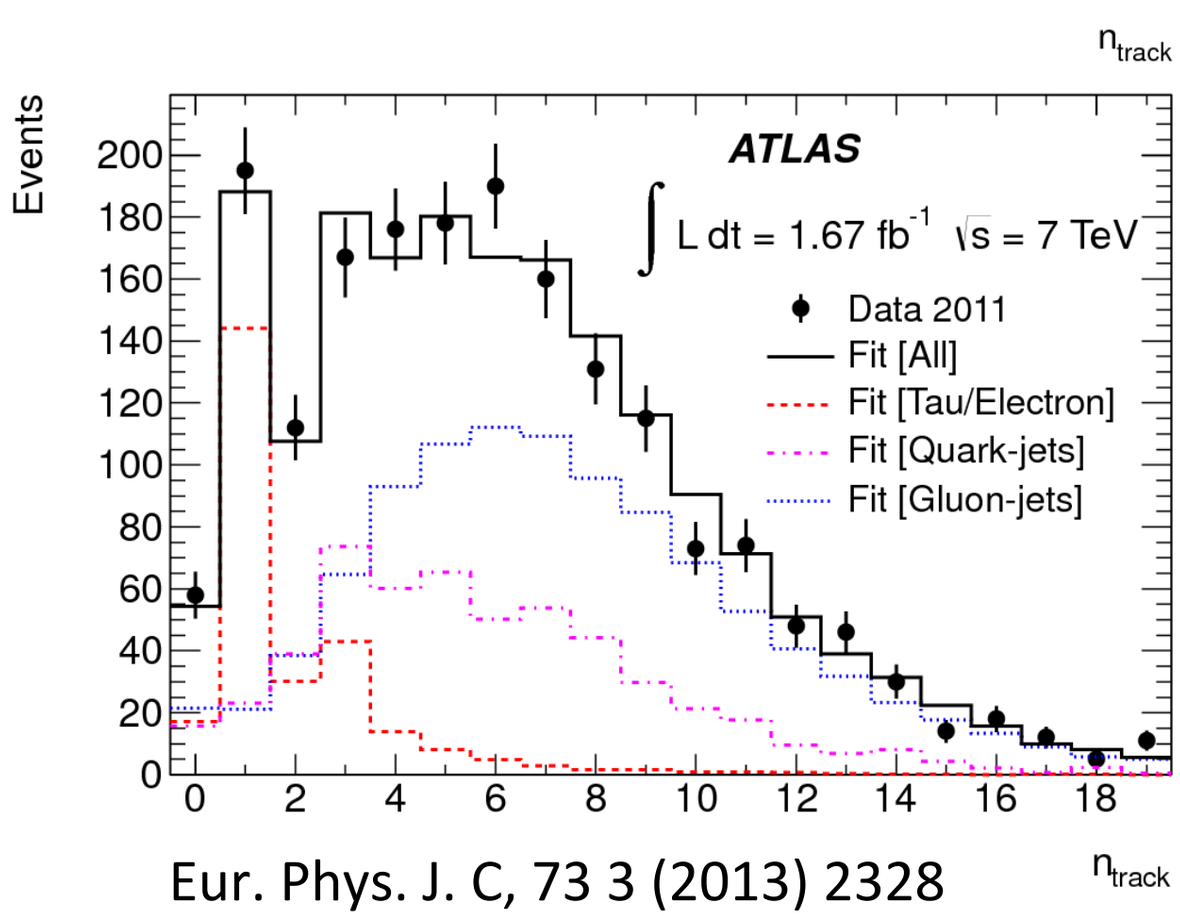
[*] A' = exp(−3/4 λ_3)

λ_3 being the smallest eigenvalue of the normalized momentum tensor

Top pair cross section in tau+jets

- Dataset: 1.67 fb^{-1} @7TeV
- 5 or more jets (p_T>20GeV), 2 or more b-tags (60% efficiency), high E_T^{miss} significance
- Top candidate is built from 1 tagged + 2 untagged jets with highest p_T sum.
  Remaining non b-tagged jet is τ candidate
- Likelihood fit to <u>number of tracks</u> distribution with three templates: τ/electron, gluon-jet (from multi-jet), quark-jet (from $t\bar{t}$ and W+jets)
- Result: $\sigma_{t\bar{t}} = 194 \pm 18(\mathrm{stat}) \pm 46(\mathrm{syst})$ pb
  NNLO+NNLL: $\sigma_{t\bar{t}}^{NNLO} = 177^{+10}_{-11}$ pb
- Why tau+jets?
  - Probe flavor-dependent effects, test lepton universality
  - Background for BSM scenarios such as charged Higgs



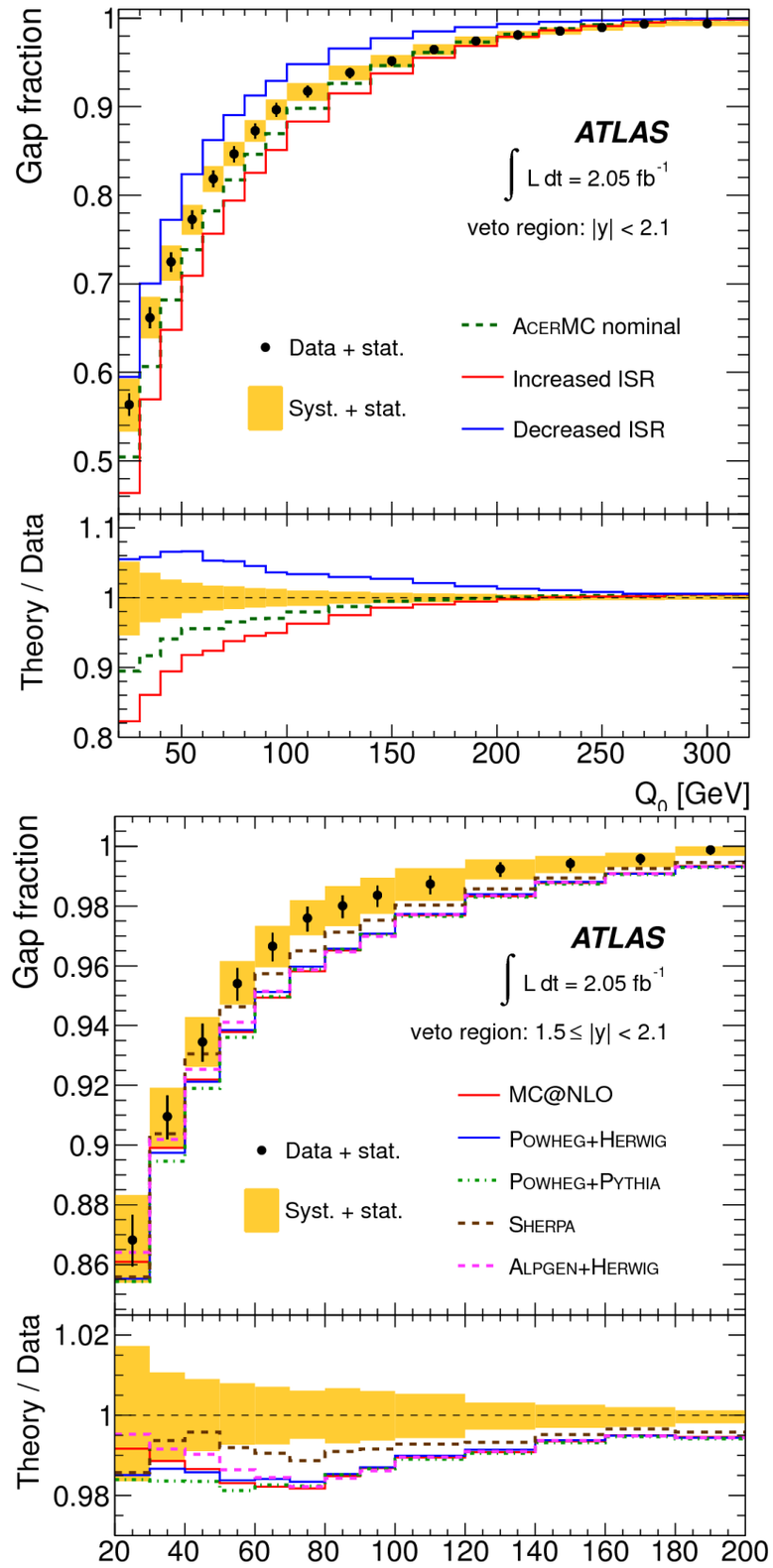


Eur. Phys. J. C, 73 3 (2013) 2328

Top pair production with additional jet veto

- Dataset: 2.05 fb^{-1} @7TeV, dilepton channel
- Very precise measurement. Is able to constrain modeling uncertainties and reduce their impact on other top quark measurements
- Select dilepton events with 2 b-tags, very high purity
- Define gap fraction: $\mathbf{f(Q_0) = \frac{n(Q_0)}{N}}$

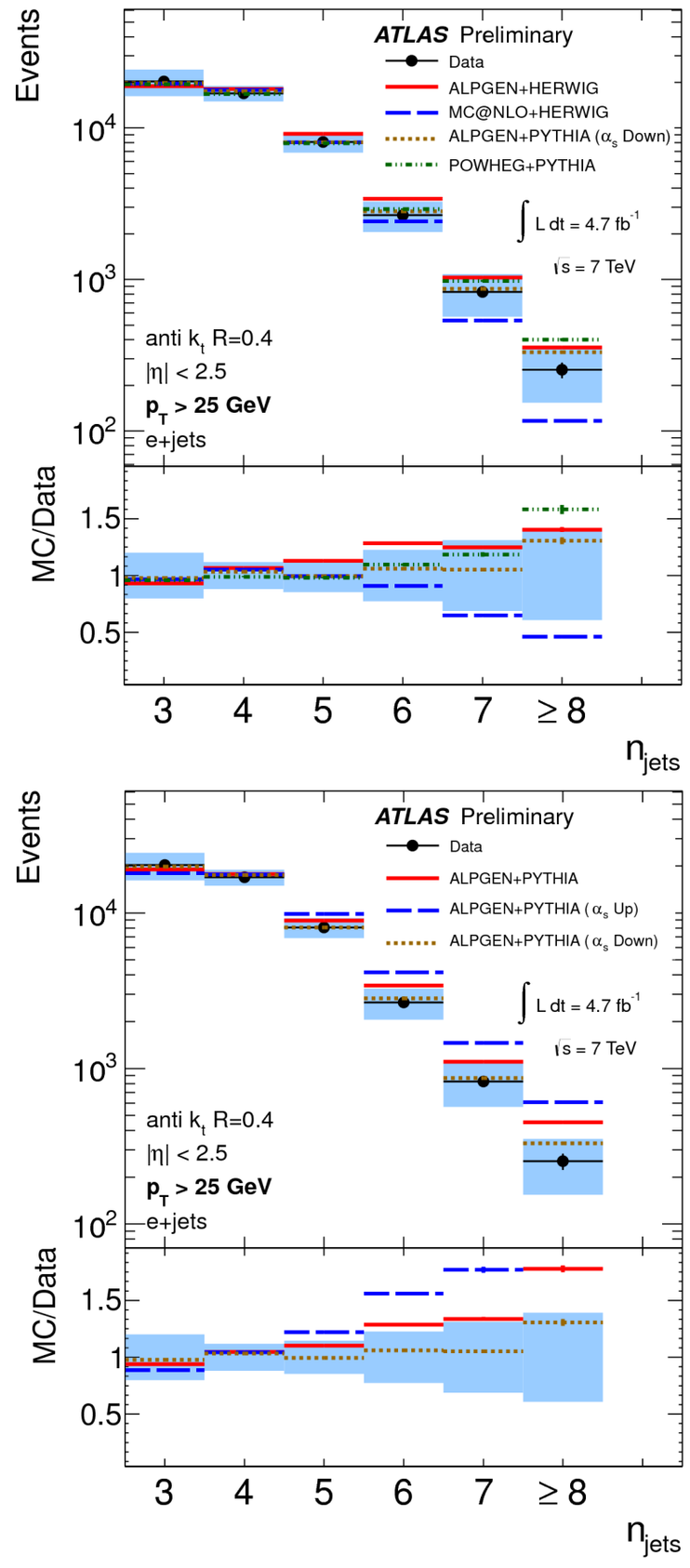
  N is the number of selected events, n(Q_0) is the subset that do **not** contain an additional central jet with $p_T > Q_0$
- Compare NLO generators (MC@NLO, POWHEG), multileg LO generators (ALPGEN, SHERPA) and initial state radiation systematics (ISR) with AcerMC, and constrain the allowed range for the variations.
- All generators predict too much forward activity. MC@NLO predicts too little activity in central region



Eur.Phys.J. C72 (2012) 2043

Measurement of jet multiplicity in $t\bar{t}$ final states

- Dataset: 4.7 fb^{-1} @7TeV, lepton+jets channel
- Motivation: constrain models of additional QCD radiation in ttbar events, test perturbative QCD
- Differential measurement in Njets for jet p_T thresholds at 25, 40, 60, 80 GeV
- Background-subtracted events, unfolded into particle-jet[*] multiplicity distribution
- MC@NLO+HERWIG model disfavored, predicts lower jet multiplicity and softer jets
- ALPGEN+PYTHIA nominal and α_S-up predict too high jet multiplicities



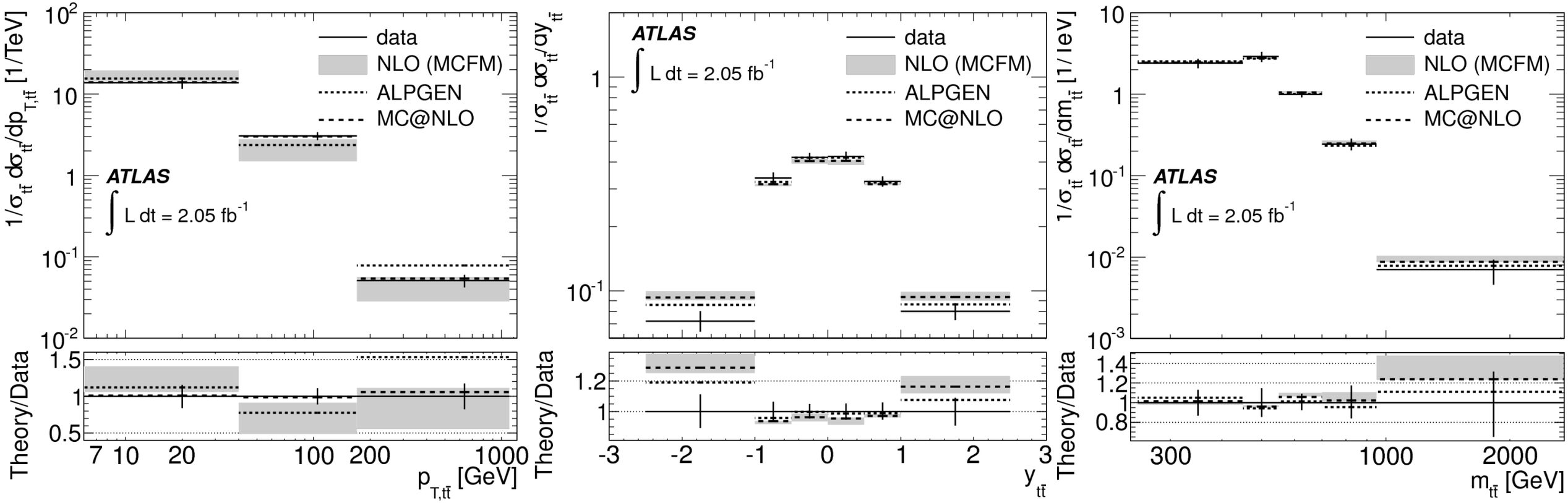
ATLAS-CONF-2012-155

[*] Stable particles except muons and neutrinos, clustered with anti-kt algorithm, R=0.4

Top pair differential cross section

- Dataset: 2.05 fb^{-1} @7TeV, lepton+jets channel
- Relative differential cross-sections as a function of the invariant mass $M_{t\bar{t}}$, the transverse momentum $p_{T,t\bar{t}}$, and the rapidity $y_{t\bar{t}}$ of the top quark pair system
- Precision SM test. $M_{t\bar{t}}$ sensitive to new physics in s-channel

- 1 lepton (e/μ, p_T>25GeV), 4 or more jets (p_T>25GeV), 1 or more b-tags (70% efficiency), large E_T^{miss} and m_T(W)
- Kinematic likelihood fit of the event, cut on the likelihood improves purity of the sample
- Background-subtracted events, unfolded into parton-level kinematic distribution
- Measurement consistent with SM expectation



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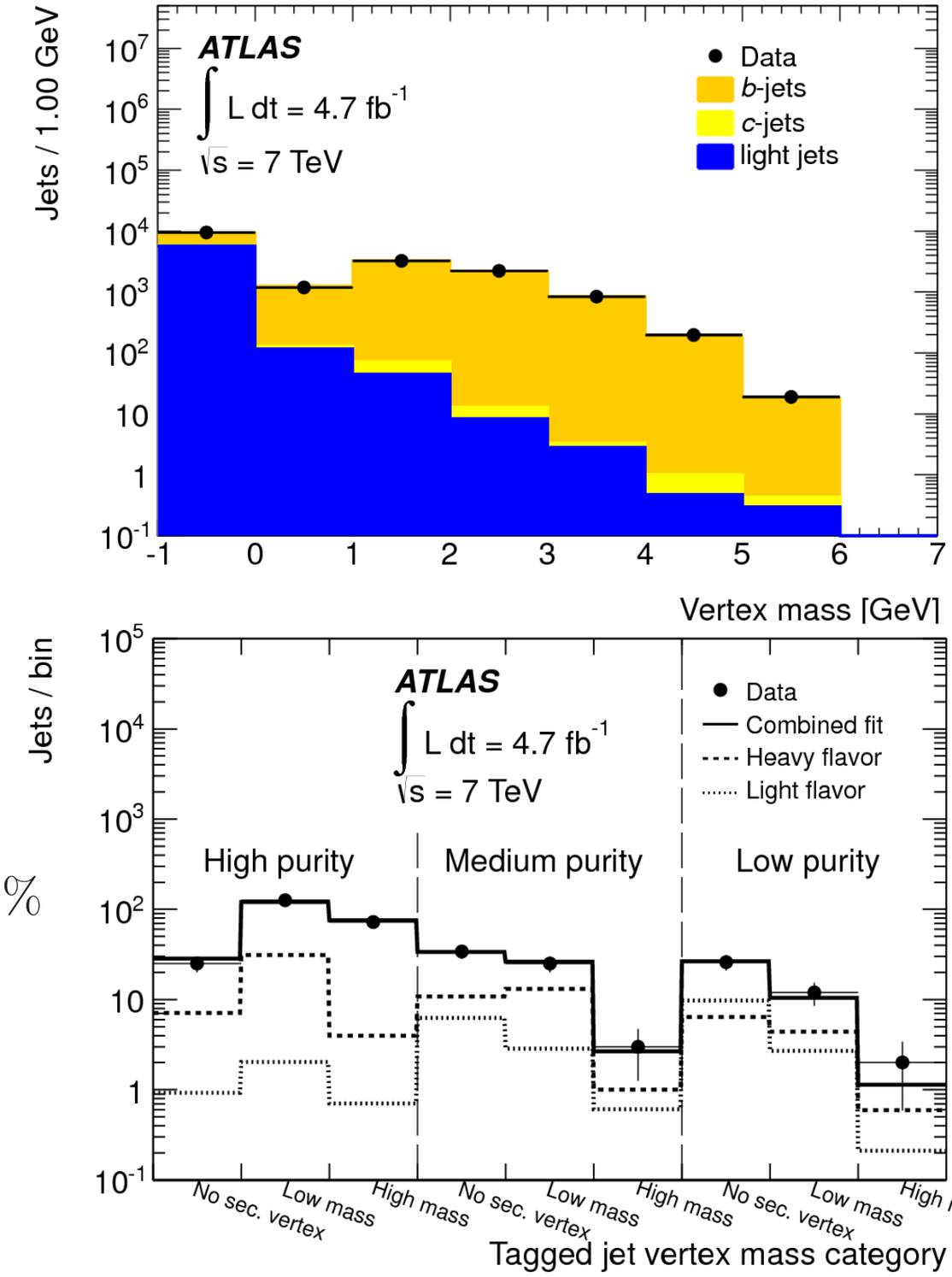
Top pair with associated heavy flavor quarks

- Dataset: 4.7 fb^{-1} @7TeV, dilepton channel
- Fiducial cross section measurement and ratio, 2 charged leptons (p_T>25GeV, |eta| < 2.5), 3 or more jets (p_T>25GeV, |eta| < 2.5)
- tt+HF measured from events with at least 3 b-tags
  tt+j measured from events with 3 jets, 2 b-tags
- Maximum likelihood fit to separate light/heavy flavor, 2D templates: vertex mass and jet p_T
- Fit performed in 3 mutually exclusive bins of b-jet purity. Boundaries defined at operating points of 60, 70, 75% efficiency

$$\mathbf{R_{HF}} = \frac{\sigma_{\mathbf{fid}}\left(\mathbf{t\bar{t}+HF}\right)}{\sigma_{\mathbf{fid}}\left(\mathbf{t\bar{t}+j}\right)} = \mathbf{7.1 \pm 1.3}(\mathrm{stat})^{+\mathbf{5.3}}_{-\mathbf{2.0}}(\mathrm{syst})\%$$

  Compared to ALPGEN **3.4%** and POWHEG **5.2%**

- Why tt+HF?
  - Background for ttH(H→bb), H+→tb, composite Higgs, 4 tops



Submitted to PRD

Conclusions

- Results agree well with SM theory predictions
- ATLAS is testing the SM at high precision with inclusive and differential cross section measurements
  - In some cases the measurements are reaching enough precision to constrain the range of systematic variations and disfavor generator models
    - Smaller uncertainties → better sensitivity for searches :)
- Better understanding of QCD in ttbar final states through differential measurements paves the way for more precision in the future
- Please see: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults for the full list of ATLAS top quark publications, only a subset has been shown here