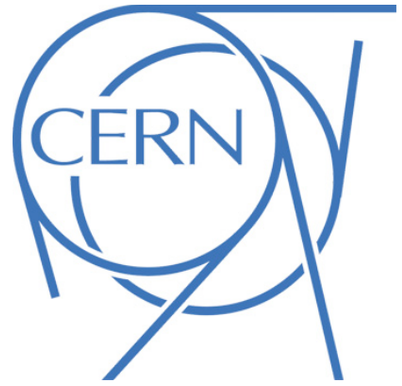
ATLAS NOTE

ATLAS-CONF-2011-121

August 21, 2011



Measurement of the $t\bar{t}$ production cross-section in pp collisions at $\sqrt{s} = 7$ TeV using kinematic information of lepton+jets events

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HELMHOLTZ ASSOCIATION

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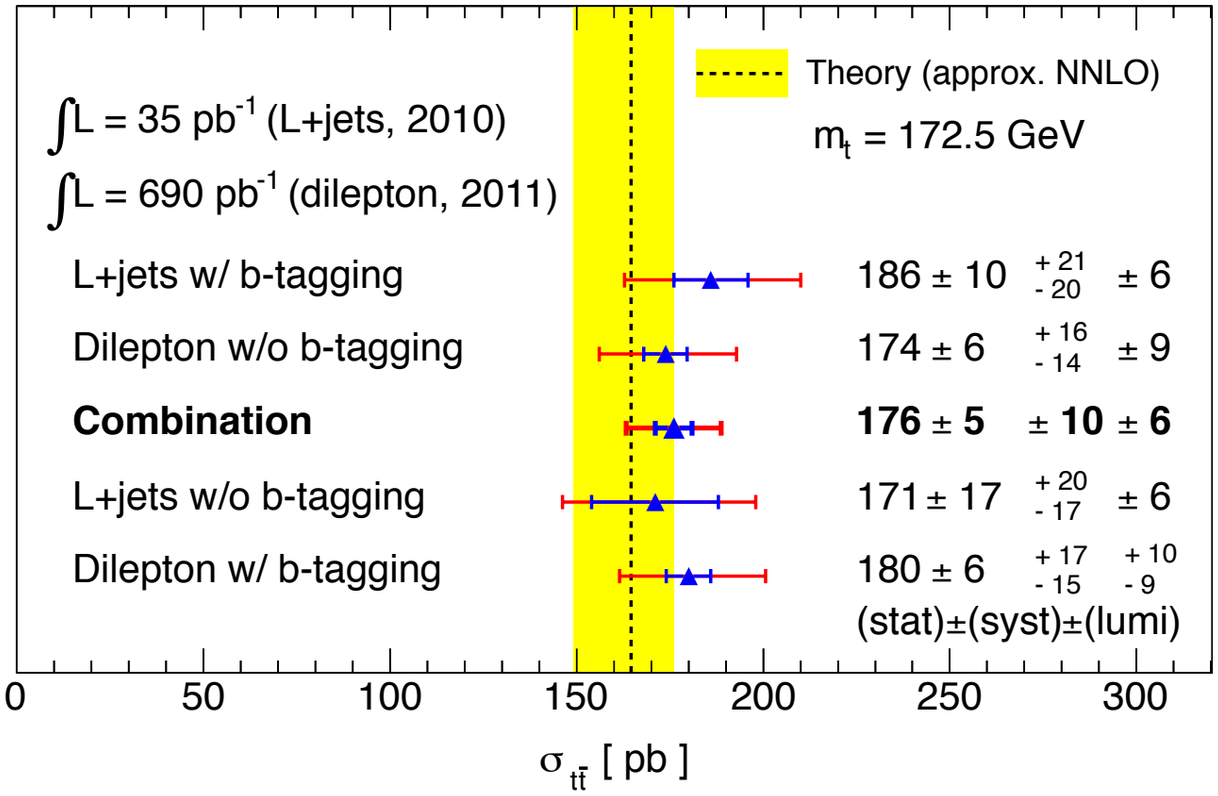
top pair cross-section

- **basic ingredient** for several top-related studies
- opens up field of **high-p_T precision** physics
- previous ATLAS measurement (ATLAS-CONF-2011-035):
  - 2010 dataset (35 pb^{-1})
  - using b-tagging information
  - (+12.9 / -12.3)% total uncertainty
- this measurement:
  - **no** use of b-tagging information
  - using 0.7 fb^{-1} of 2011 data
- aim to get **competitive with Tevatron (~9%, 7% from tt/Z ratio) and theoretical predictions (~9%)**

ATLAS-CONF-2011-108



Theory expectation
(mt=172.5 GeV, approx. NNLO, CTEQ66):

$$\sigma_{t\bar{t}}(\text{theory}) = 164.57^{+4.30}_{-9.27}(\text{scale})^{+7.15}_{-6.15}\,(\text{PDF})\,\text{pb}.$$

analysis idea

- extract top pair cross section using event kinematics
- select **few well-modelled variables** to discriminate top from W+jets
- combine in **projective likelihood discriminant** using TMVA:

$$D = \frac{\prod_{j=1}^{k} p_{i,S}(x_j)}{\prod_{j=1}^{k} p_{i,S}(x_j) + \prod_{j=1}^{k} p_{i,B}(x_j)}$$

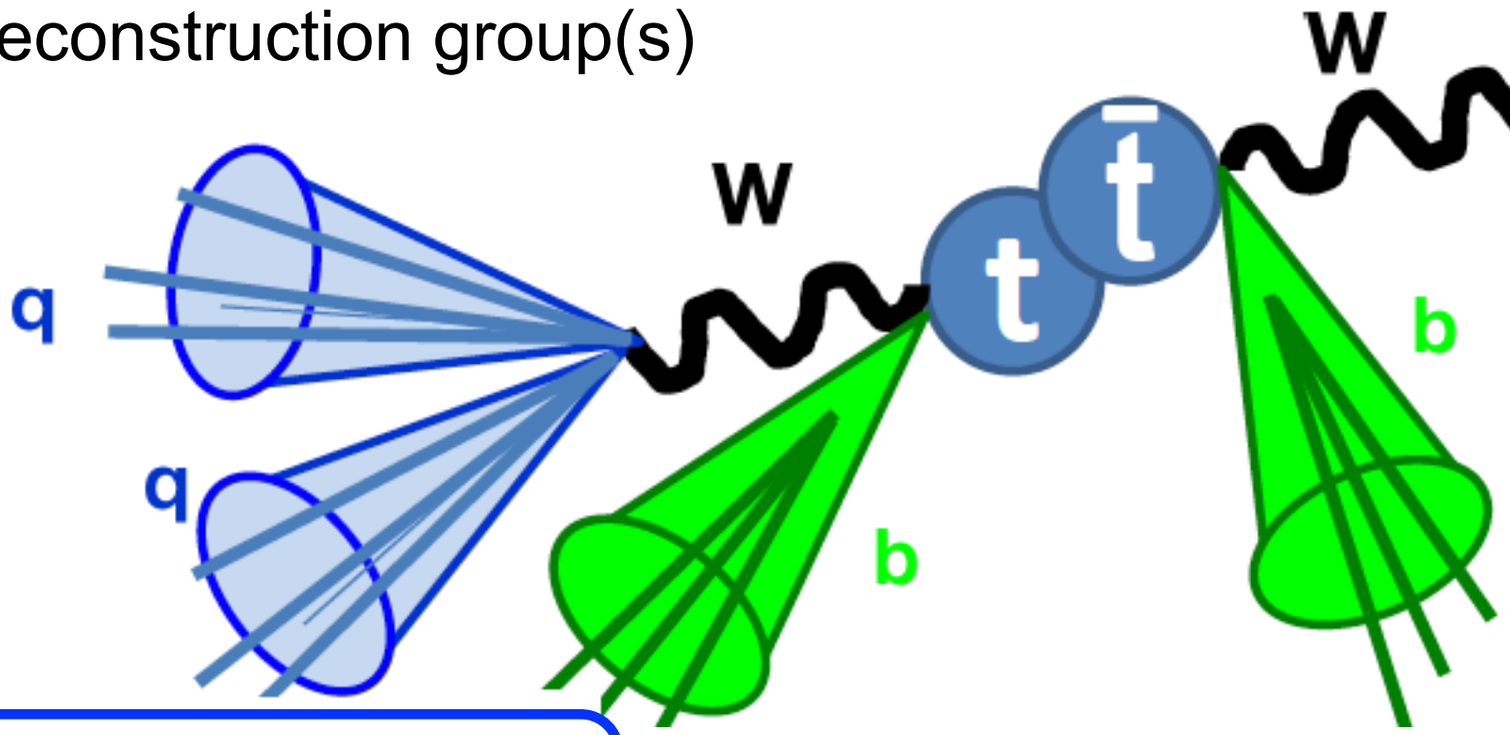
- create templates of this discriminant for all signal and background processes
- perform **binned profile likelihood** fit to signal and background templates
  - simultaneous fit in **six channels**: electron+jets, muon+jets with 3, 4, ≥5 jets
  - measure σ_{tt} and background normalisations (especially W+jets)
  - treat (most) systematic uncertainties as nuisance parameters in fit and allow them to be constrained by data

object and event selection

- common top group lepton+jets selection
- object corrections according to performance/top reconstruction group(s)

electrons:
- 1 tight, isolated electron
- trigger fired and matched
- E_T > 25 GeV
- $|\eta|$ < 2.47 (excluding transition region barrel-endcap)

muons:
- 1 tight, isolated muon
- trigger fired and matched
- p_T > 20 GeV
- $|\eta|$ < 2.5



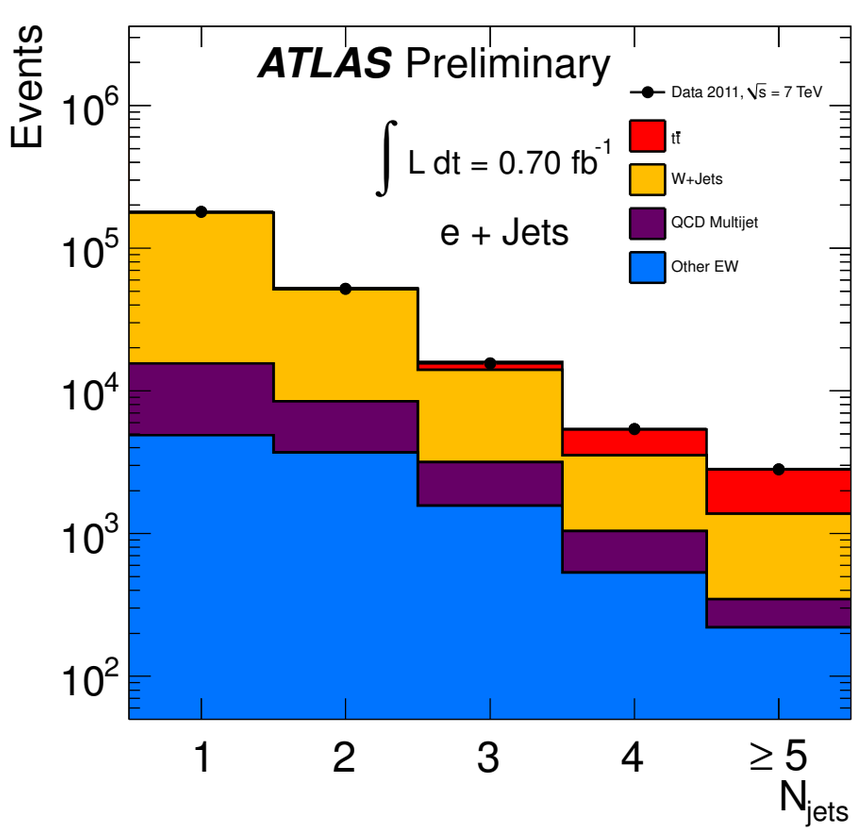
missing transverse E:
- RefFinal_em_tight
- e+jets: MET > 35 GeV, $m_T(W)$ > 25 GeV
- μ+jets: MET > 20 GeV, MET + $m_T(W)$ > 60 GeV

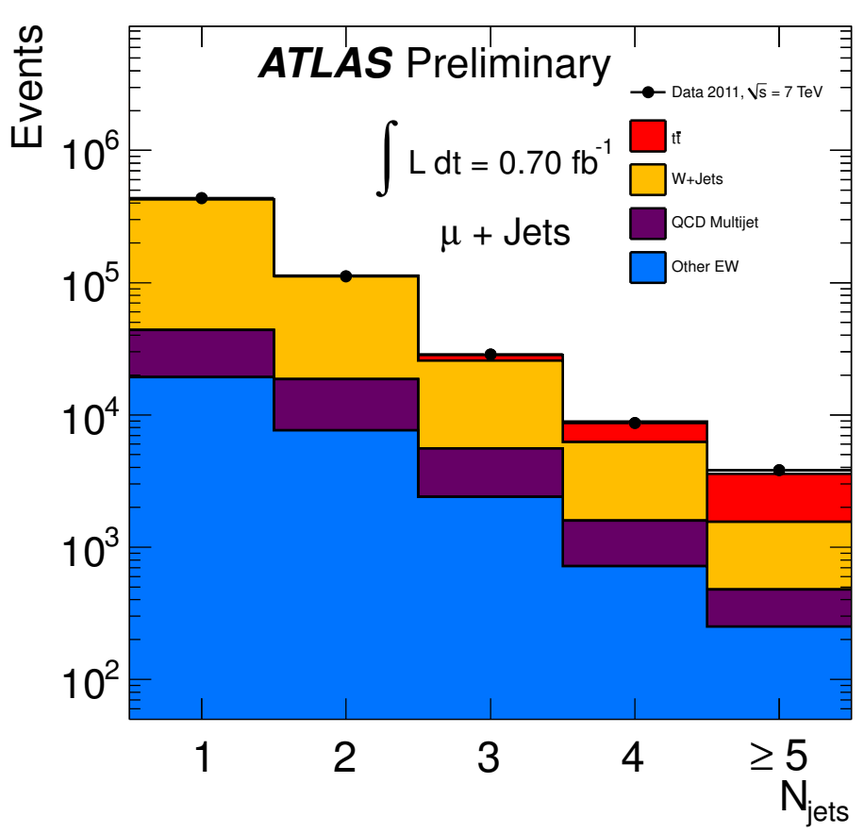
jets
- topological cluster
- anti-k_T (R=0.4)
- EM+JES
- p_T > 25 GeV
- $|\eta|$ < 2.5

event cleaning:
- top GRL
- primary vertex with at least 5 tracks
- bad jet veto
- LAr hole treatment

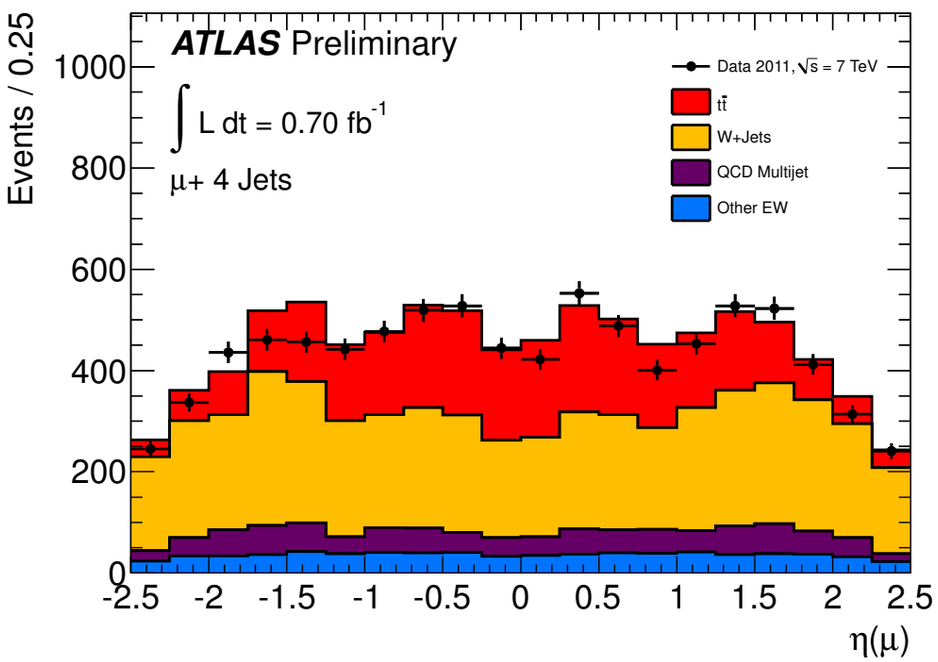
background estimates

- QCD multi-jets from data (using matrix method), alternative models as systematic uncertainty
- W+jets:
  - shape from Alpgen Monte Carlo
  - normalization taken from W charge asymmetry measurement (ATLAS-CONF-2011-106)
- all other smaller background taken from MC and normalised to theory expectation (Z+jets, diboson, single top)

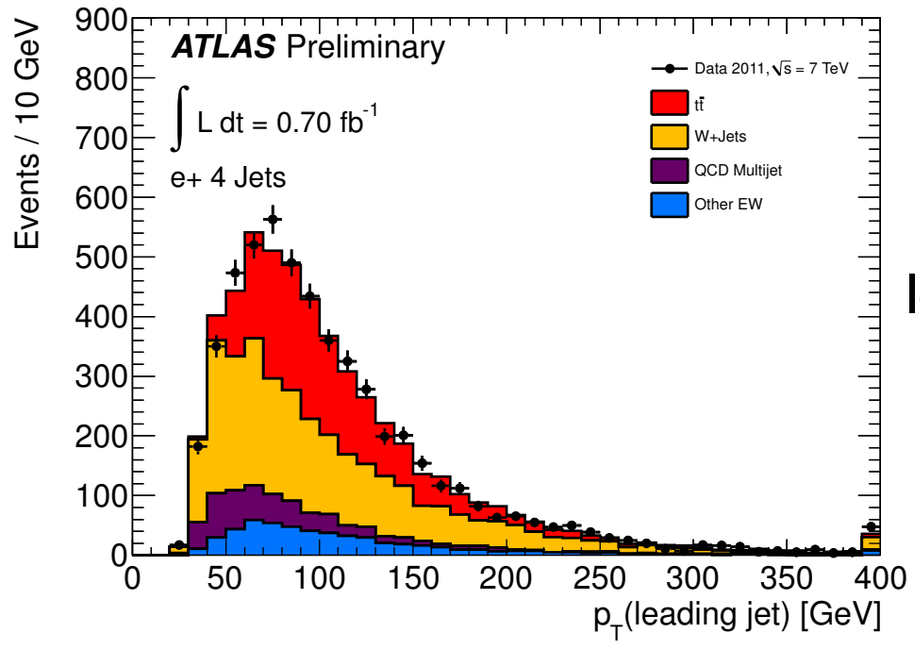




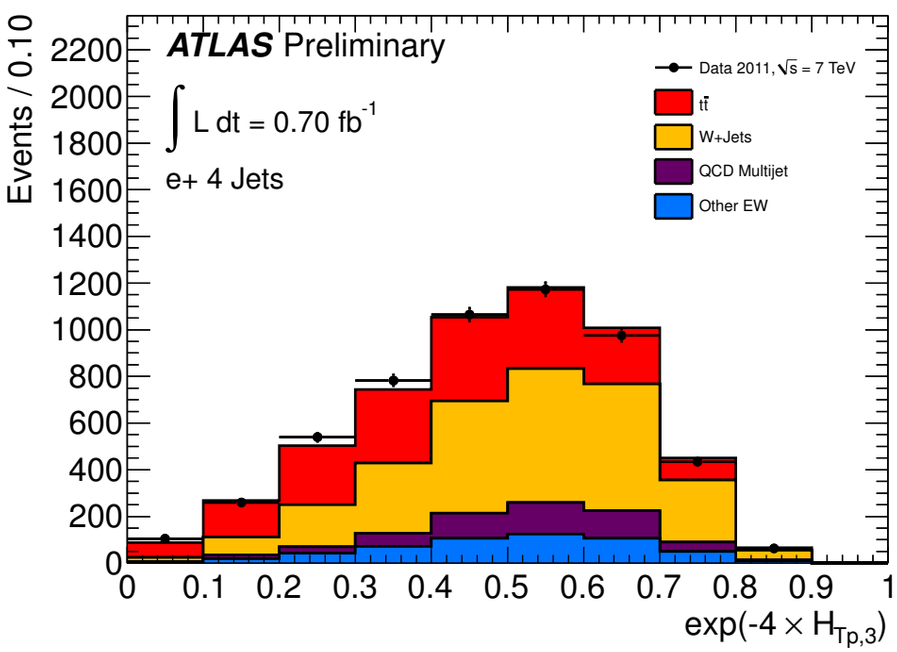
input variables



lepton η

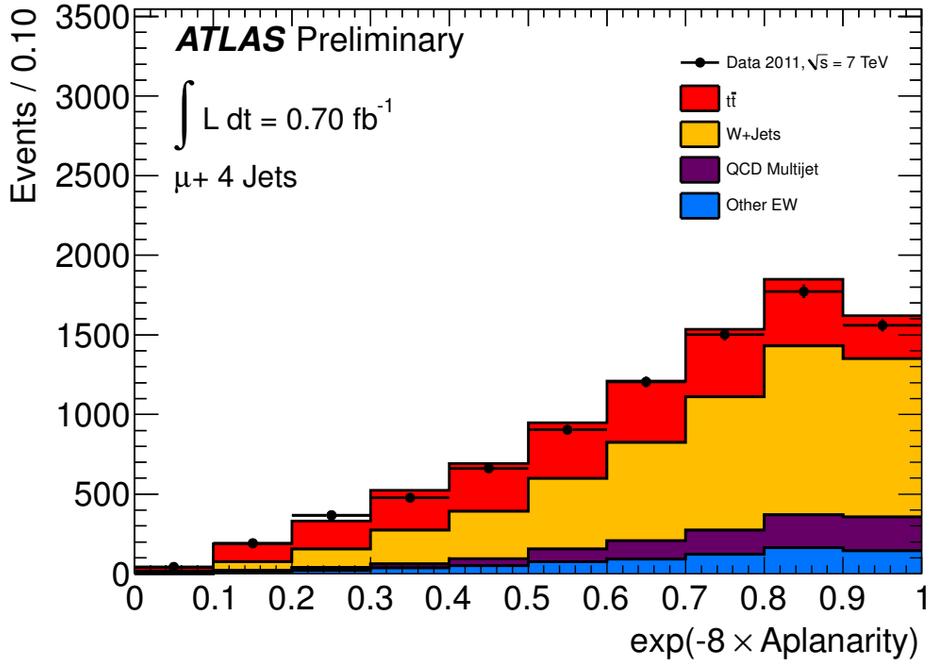


leading jet p_T



p_T of 3rd (and 4th) leading jet normalised to absolute sum of all longitudinal momenta in the event:

$$H_{T,3p} = \frac{\sum_{i=3}^{N_{\text{jets}} \leq 4} |p_{T,i}|}{\sum_{j=1}^{N_{\text{objects}}} |p_{z,j}|}$$

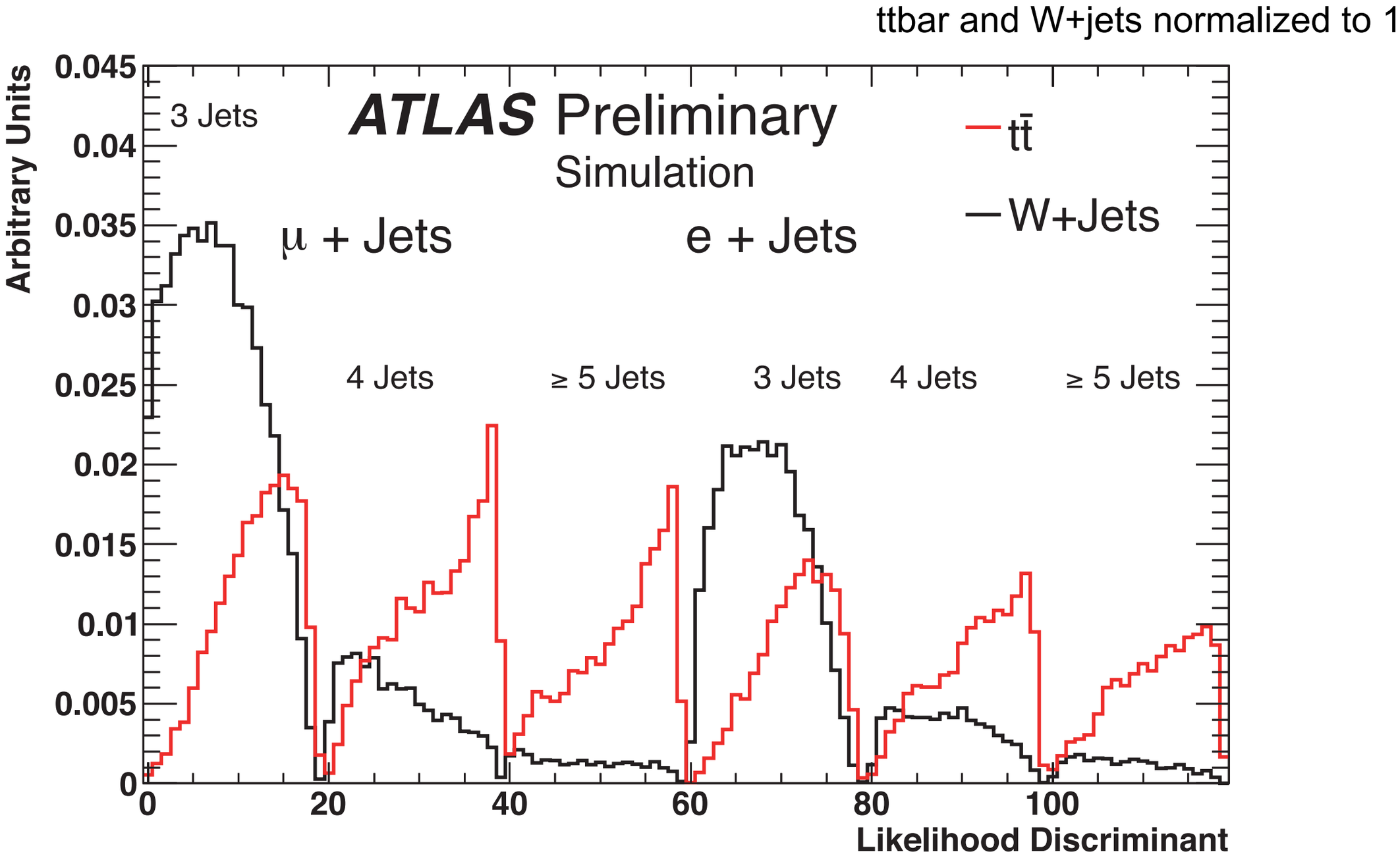


aplanarity: 1.5 times smallest eigenvalue of the momentum tensor:

$$M_{ij} = \frac{\sum_{k=1}^{N'_{\text{objects}}} p_{ik} p_{jk}}{\sum_{k=1}^{N'_{\text{objects}}} p_k^2}$$

likelihood discriminant

- projective likelihood discriminant shows good separation between ttbar and W+jets



likelihood fitter setup

- likelihood function:

Poisson probability

systematic uncertainties

$$\mathcal{L}(\vec{\beta},\vec{\delta}) = \prod_{k=1}^{120} \mathcal{P}(\mu_k, n_k) \times \prod_j \mathcal{G}(\beta_j, \Delta_j) \times \prod_i \mathcal{G}(\delta_i, 1)$$

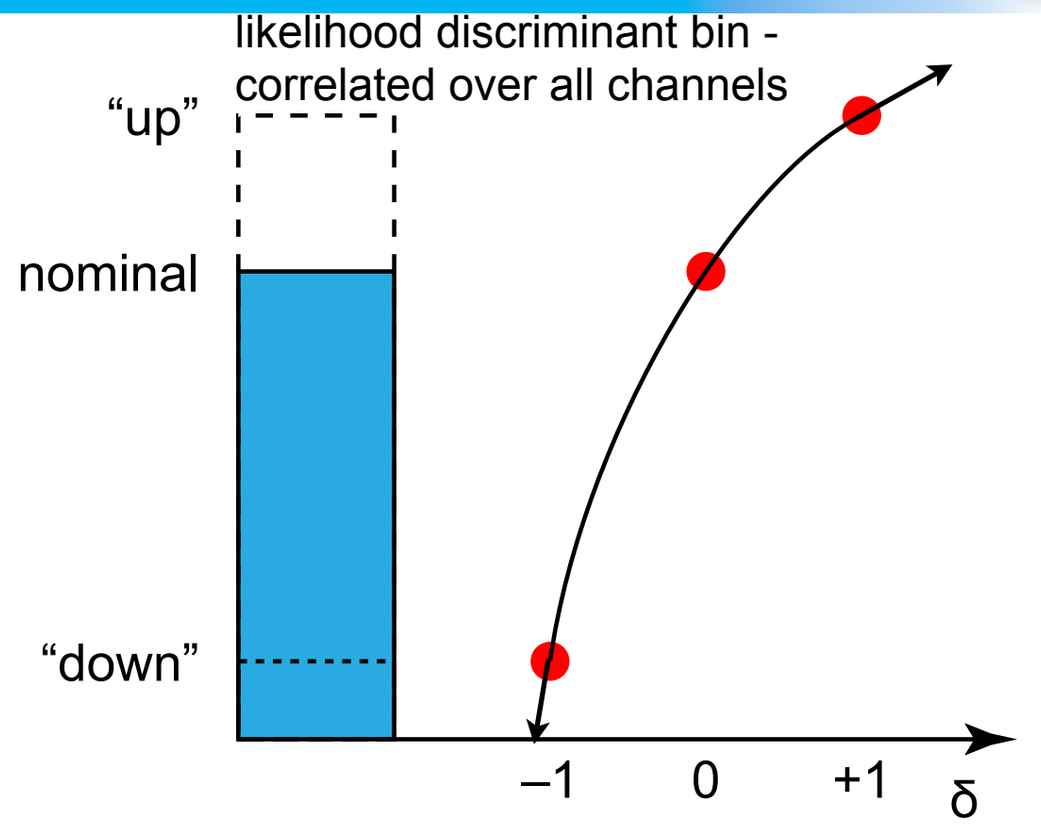
Gaussian constraints on backgrounds

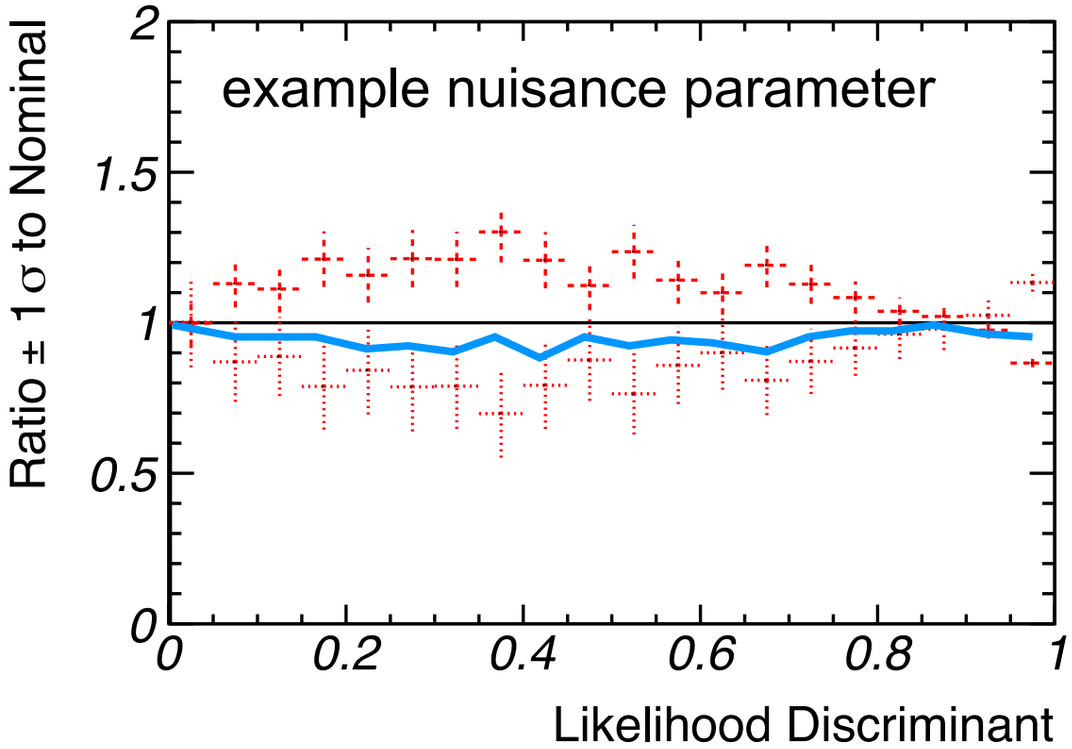
- Gaussian constraints to background parameters:

process	parameters	constraints	normalization before fit
ttbar	β_0	-	theory
W+jets	β_1-β_6 (separate for six channels)	3 jets: 42% (Behrends sca- 4 jets: 48% ling and theory) ≥5 jets: 54%	W charge asymmetry measurement
Z+jets	β_7	30 %	theory
single top	β_8	3.7% ⊕ 10% (lumi⊕theory)	theory
diboson	β_9	3.7% ⊕ 5% (lumi⊕theory)	theory
QCD	β_{10}-β_{15} (separate for six channels)	50 %	matrix method

likelihood fitter setup (2)

- systematic uncertainties considered as nuisance parameters δ_i
  - „up“ and „down“ templates in addition to nominal for each ±1σ variation
- each nuisance parameter assumed to be Gaussian with mean 0
  - vertical morphing of templates → continuous parameters δ_i
  - quadratic interpolation for $|\delta_i| < 1$ (Lagrange polynomials), linear extrapolation beyond
- systematics enter as parameters in the minimisation process
- let data adjust size of corresponding systematic uncertainty





uncertainties

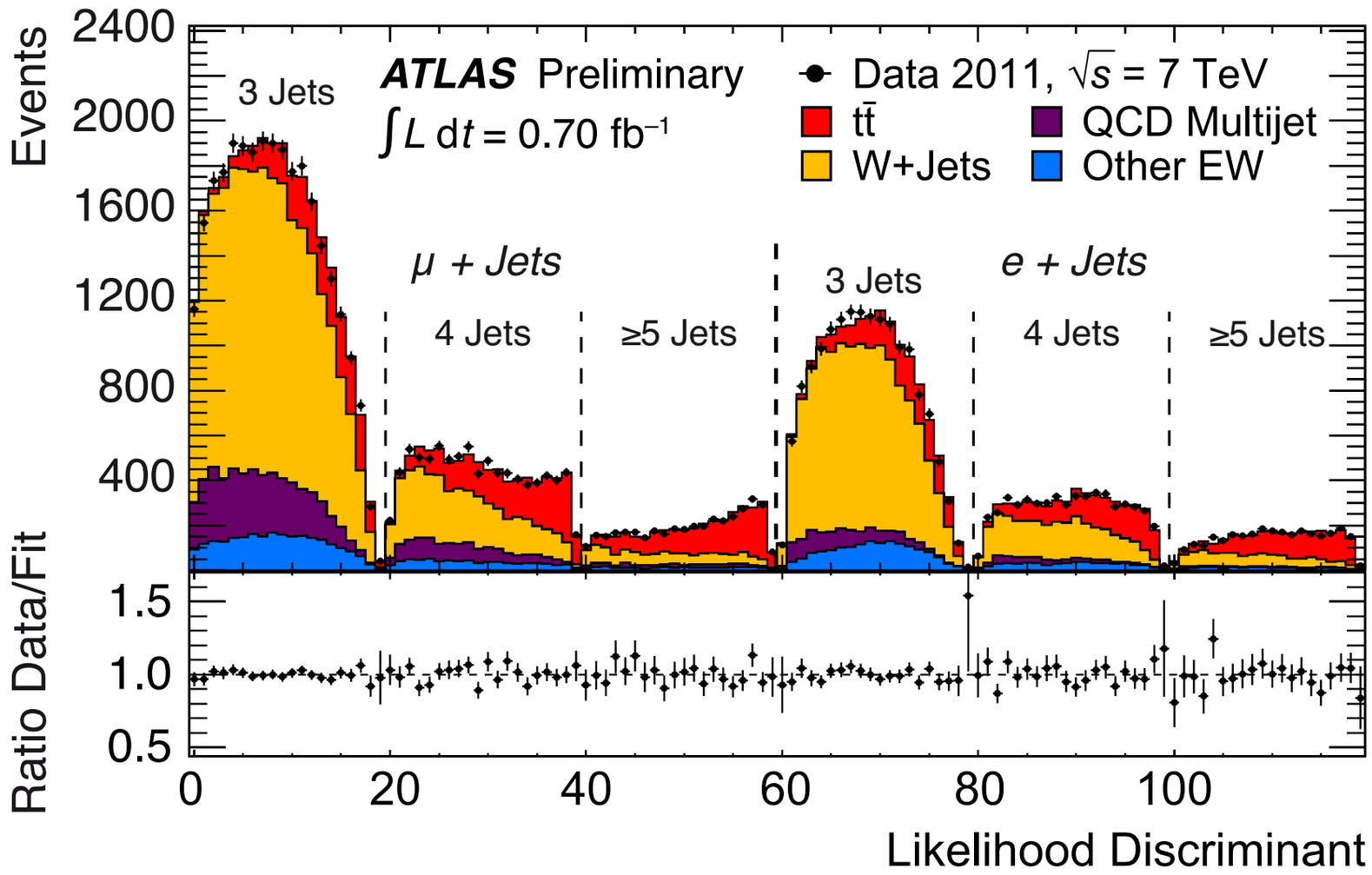
- fitter concept: trade systematic uncertainties against fit uncertainty on β_0
- **no direct access** to systematic uncertainties
- evaluate indirectly by performing fit with **nuisance parameter in question fixed**
- take quadratic difference as measure of systematic uncertainty
- external uncertainties evaluated using PEs
  - shift of mean taken as uncertainty
- **only 6.6% uncertainty (including luminosity)!**

Uncertainty	up (pb)	down (pb)	up (%)	down (%)
Statistical	3.9	−3.9	2.2	−2.2
Detector simulation				
Jets	3.2	−4.3	1.8	−2.4
Muon	4.1	−4.1	2.3	−2.3
Electron	2.7	−3.0	1.5	−1.7
MET	2.0	−1.6	1.1	−0.9
Signal model				
Generator*)	5.4	−5.4	3.0	−3.0
Hadronization*)	0.9	−0.9	0.5	−0.5
ISR/FSR	3.0	−2.3	1.7	−1.3
PDF*)	1.8	−1.8	1.0	−1.0
Background model				
QCD shape*)	0.7	−0.7	0.4	−0.4
W shape*)	0.9	−0.9	0.5	−0.5
Method*)	3.2	−3.2	1.8	−1.8
Systematic	9.0	−9.0	5.0	−5.0
Stat. & Syst.	9.8	−9.8	5.4	−5.4
Luminosity	6.6	−6.6	3.7	−3.7
Total	11.8	−11.8	6.6	−6.6

*) evaluated externally

result

- combined binned profile likelihood fit in all 6 channels and bins simultaneously
- likelihood distribution with 20 bins in each channel
- all contributions scaled to their fit values
- very good data-MC agreement
- data-MC agreement improves for basic variables if fitted β and δ values are used

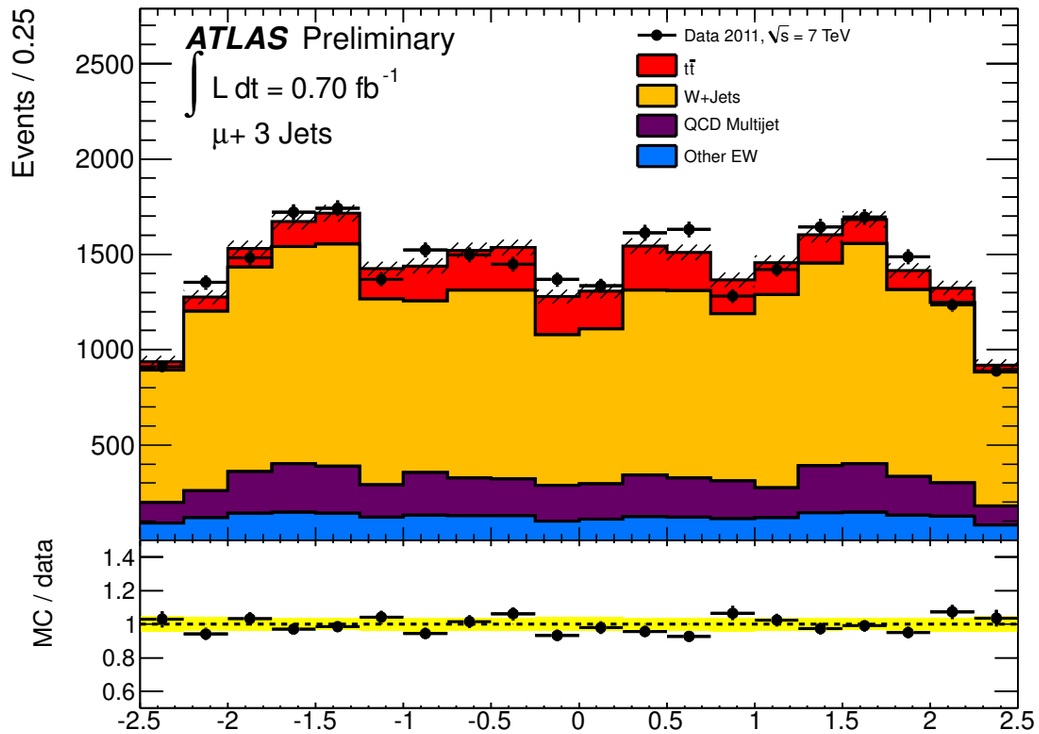


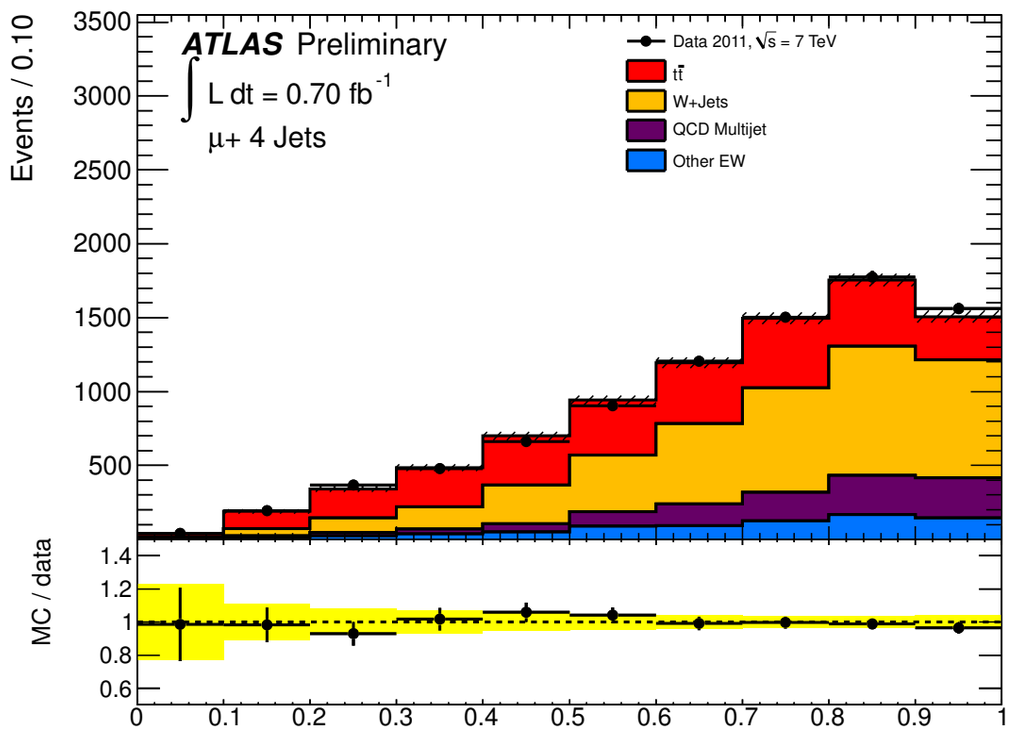
$$\sigma_{t\bar{t}} = 179.0 \pm 3.9\,(\text{stat}) \pm 9.0\,(\text{syst}) \pm 6.6\,(\text{lumi})\ \text{pb}$$

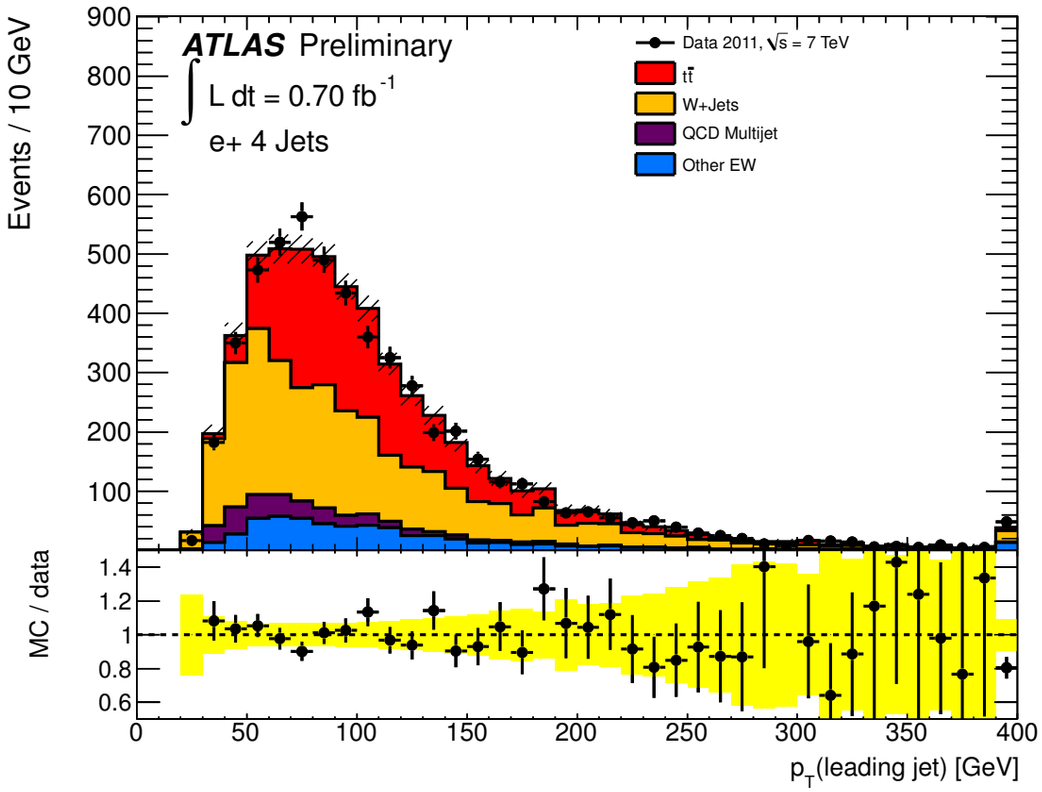
- in agreement with theory and smaller than theory uncertainties

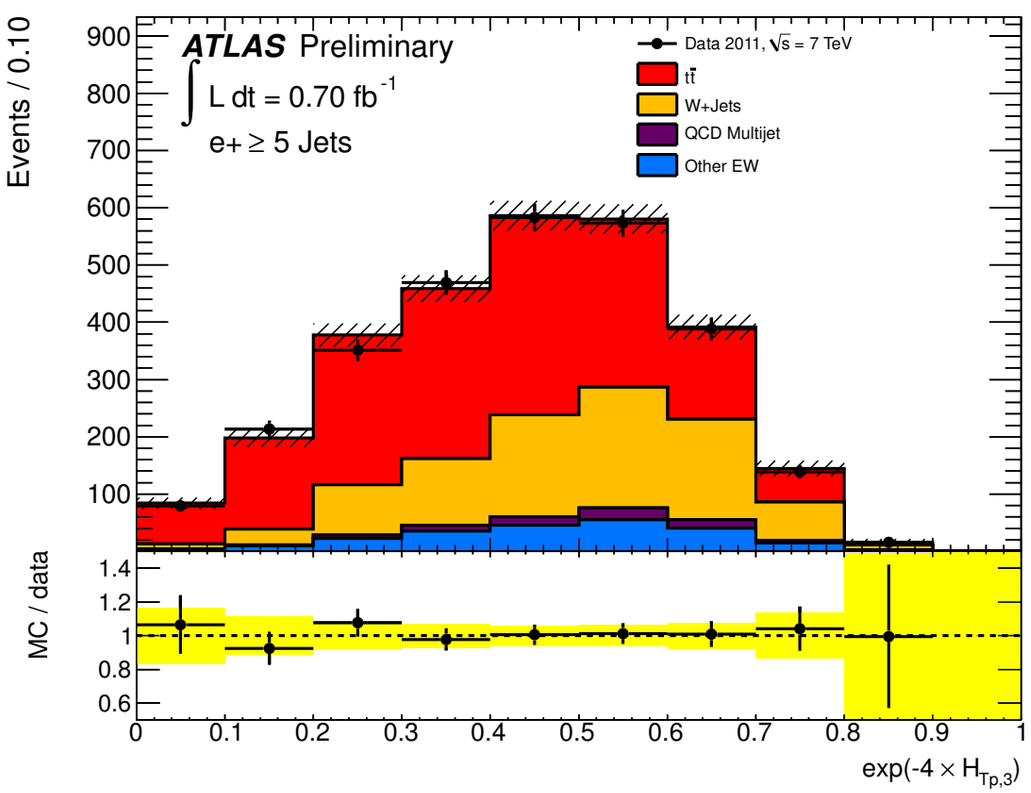
control plots after fit

scaled according to β and δ values
errorband statistical uncertainty only









summary

- performed cross section measurement using binned profile likelihood method
- obtained the single-most precise ttbar production cross section measurement worldwide:

$$\sigma_{t\bar{t}} = 179.0 \pm 3.9\,(\text{stat}) \pm 9.0\,(\text{syst}) \pm 6.6\,(\text{lumi})\,\text{pb}$$

- uncertainties competitive with theory