measurement of semi-leptonic top pair production cross-section

first results of the ATLAS experiment

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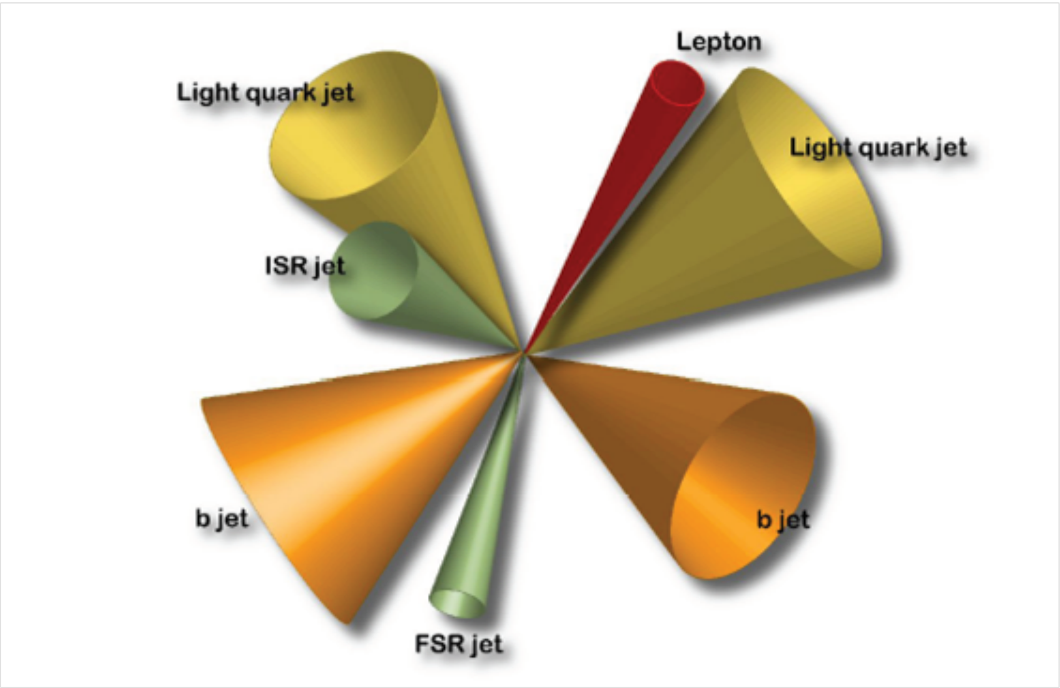
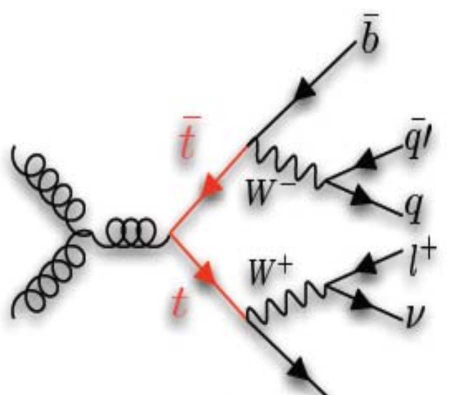
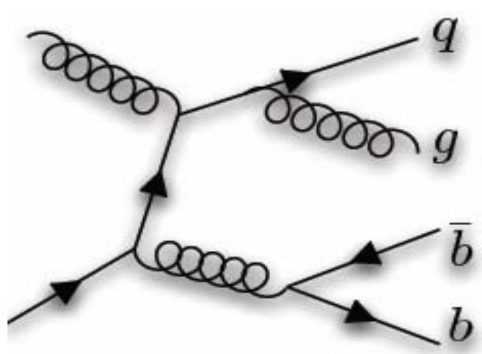
- **>** considering semi-leptonic top decay
  - one W boson decays hadronically
  - other boson decays leptonically
- **>** final state consists of one lepton + missing transverse energy + jets
- **>** event selection follows signal topology
  - require most efficient trigger for signal
  - exactly one isolated high-quality lepton (electron or muon) that matches with trigger (electron), $p_T > 20$ GeV
  - require ≥ 4 jets, $p_T > 25$ GeV
  - one of them b-tagged
  - MET > 20 GeV (neutrino)
  - topological cut on MET to further reduce QCD
- **>** remaining major backgrounds:
  - W + jets and W + heavy flavour
  - QCD multi-jets

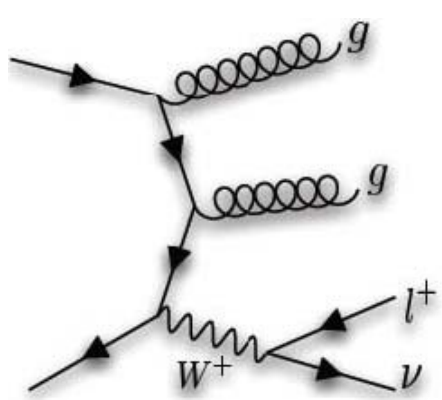




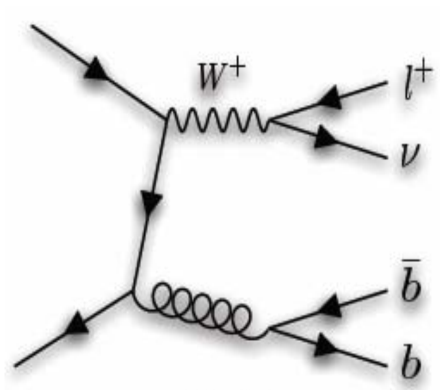
$t\bar{t}$



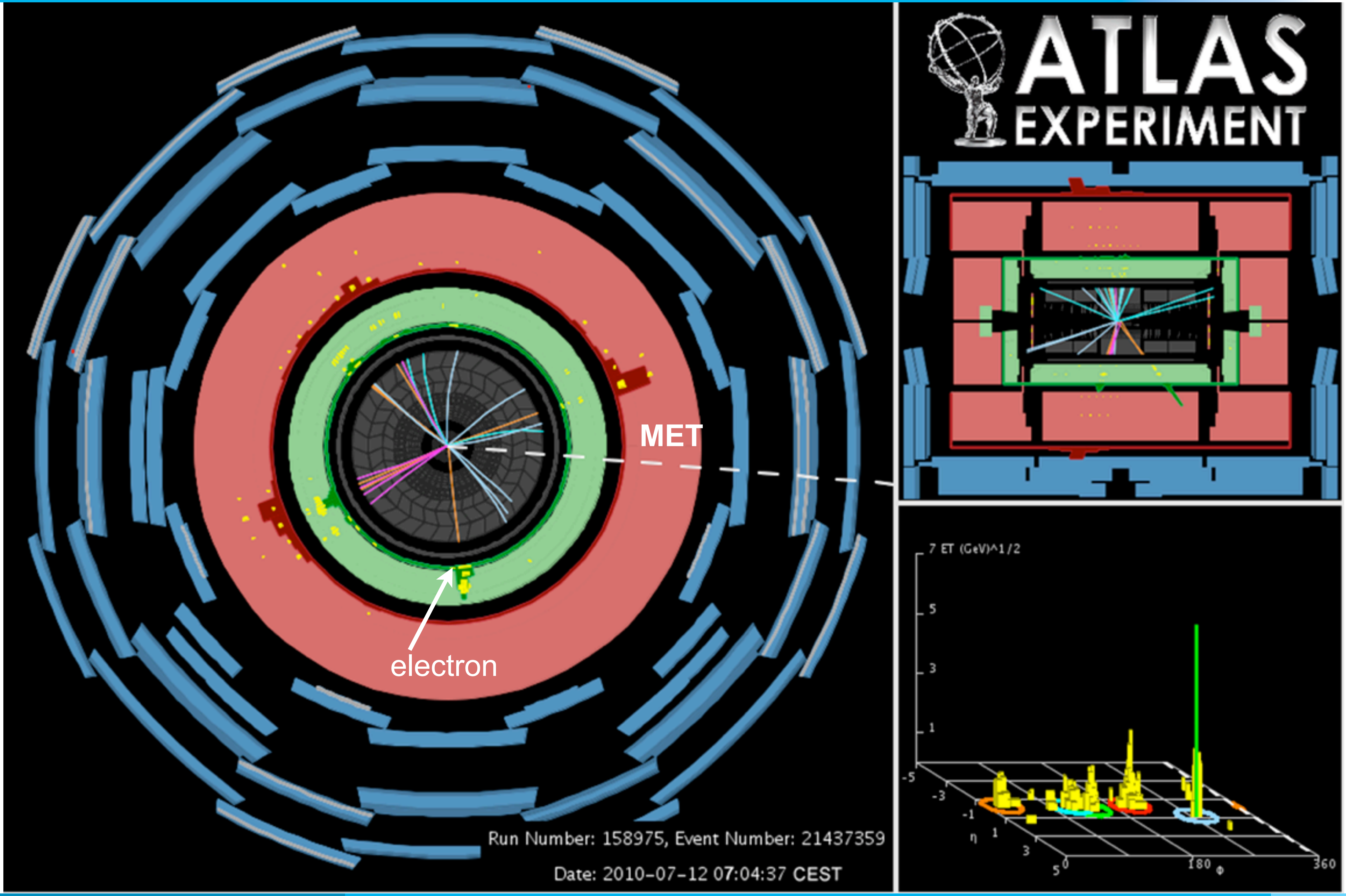
QCD



W+jets



Wbb


MET
electron
Run Number: 158975, Event Number: 21437359
Date: 2010-07-12 07:04:37 CEST
ATLAS EXPERIMENT
7 ET (GeV)^1/2
5
3
1
-5
-3
-1
η
1
3
5
0
180
φ
360

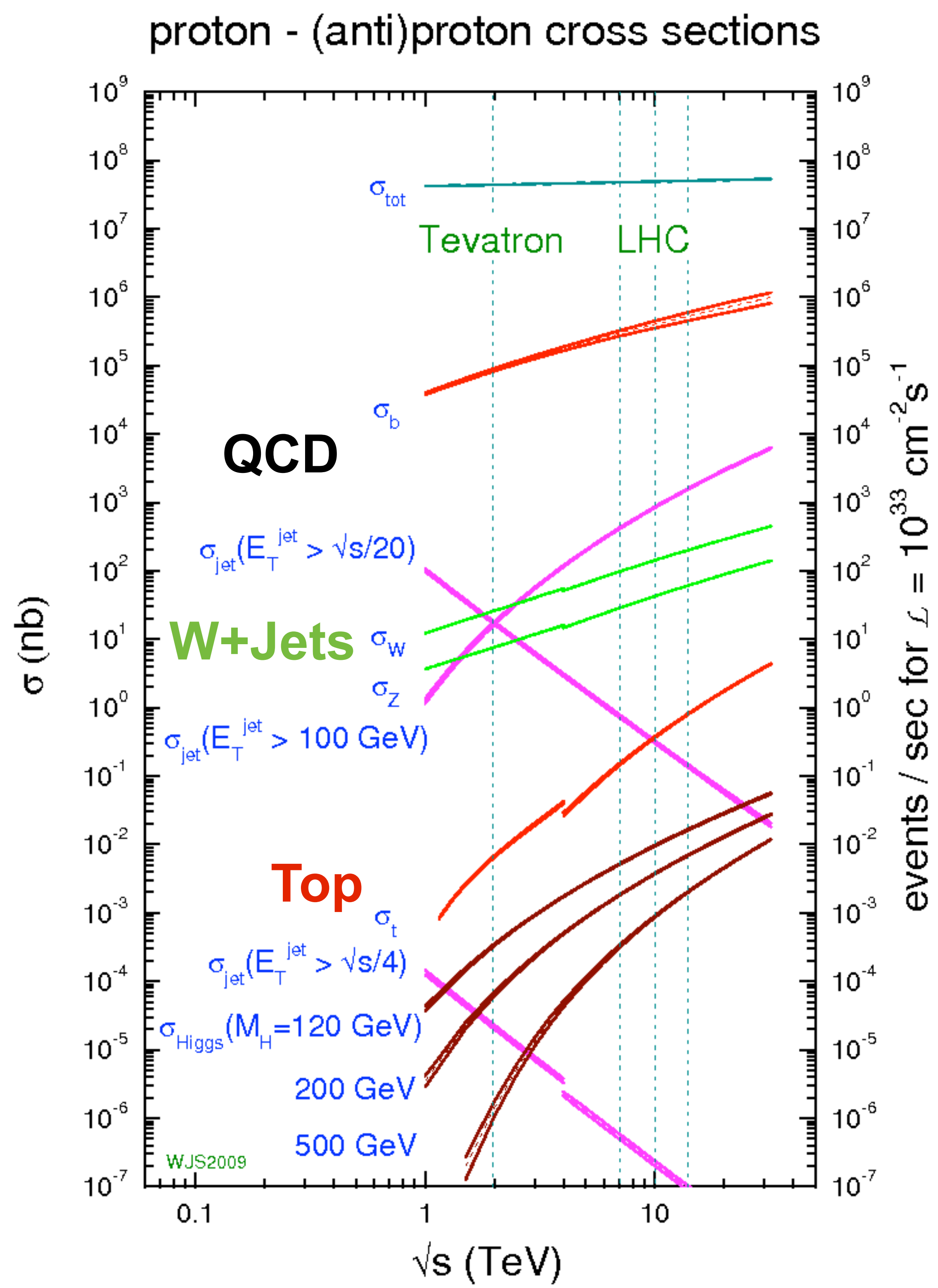
top and background cross-sections

- signal and background cross-sections calculated in theory
- top pair production at 7 TeV and m_t = 172.5 GeV (Moch & Uwer, Beneke et al.), central value at approx. NNLO:

$$\sigma_{t\bar{t}} = 164.6^{+11.4}_{-15.7}\ \mathrm{pb}$$

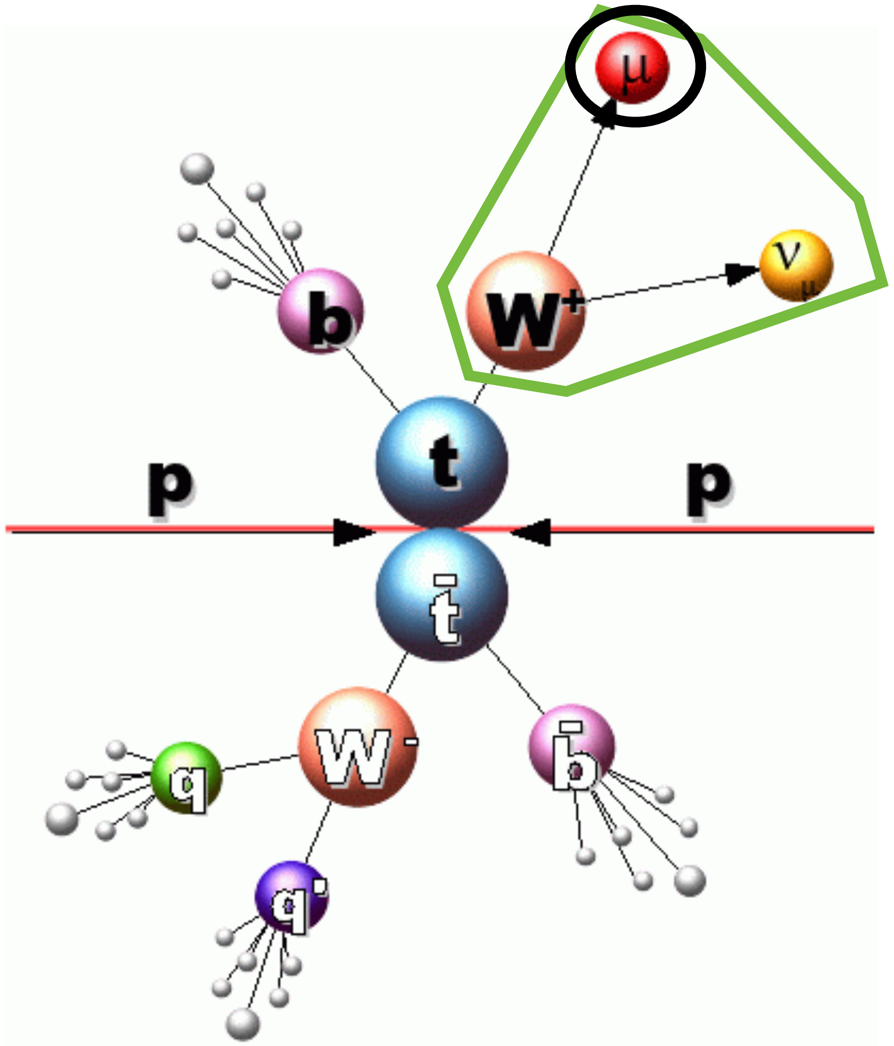
- uncertainty given as linear sum of pdf (CTEQ66) and scale uncertainty
- W+jets production: σ ~ 30 nb
- QCD production: σ ~ μb/mb
- to calculate cross-section in cut and count experiment, need to evaluate background:

$$\sigma = \frac{N_{\mathrm{tot}} - N_{\mathrm{bg}}}{\epsilon \times \mathcal{L}}$$



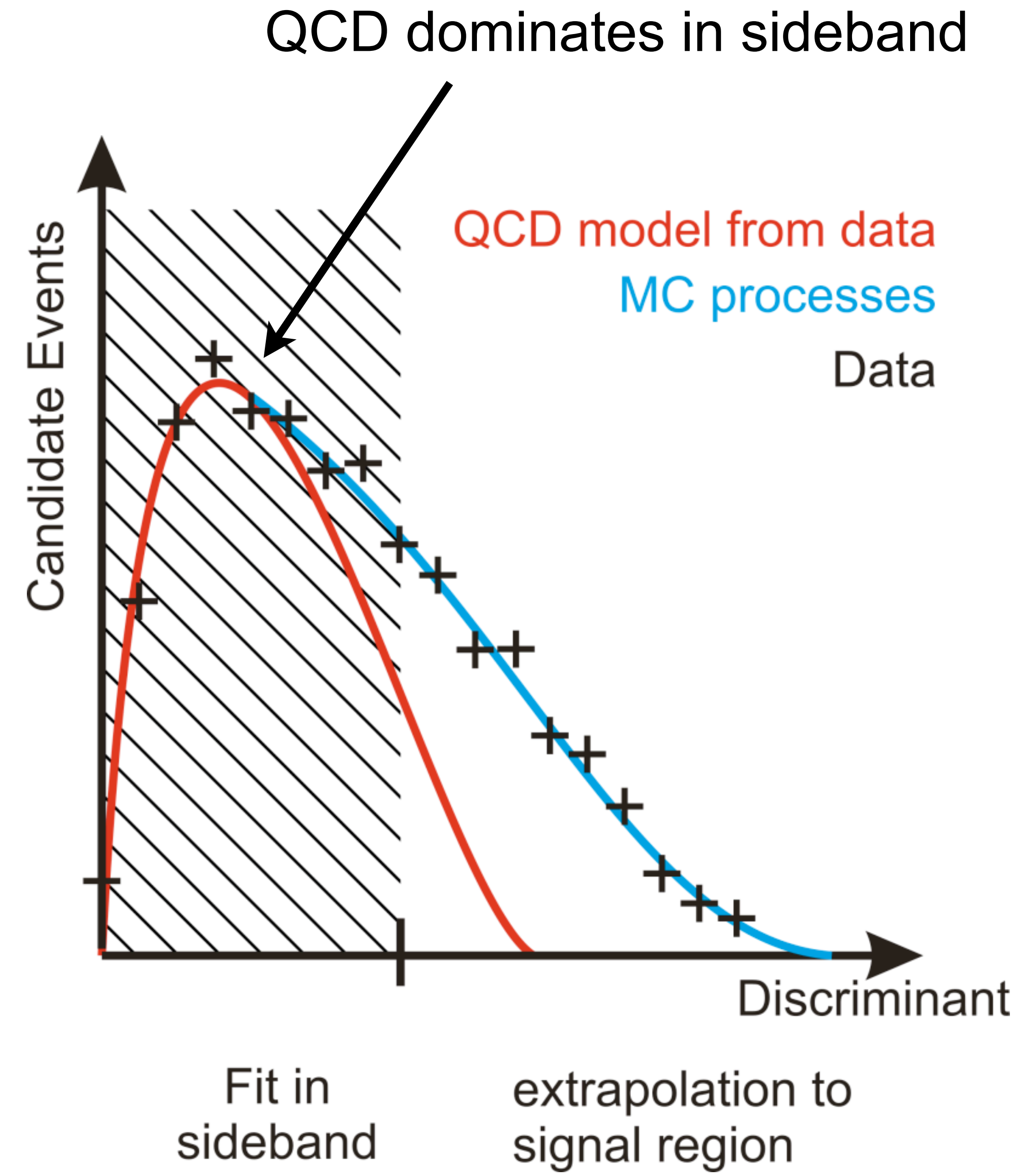
estimating background contribution to signal selection

- apply tight selection cuts to reject backgrounds using MC simulation
- cannot reject W+jets background completely due to similar topology → **estimate using data-driven approach**
- QCD contributes only due to mis-identified leptons (electron fake rate of order 10^{-3}-10^{-4})
- QCD MC production limited by computing power
- mostly instrumental background, difficult to model → **take from data**
- my work: **QCD estimation in electron channel**
- fake electrons mostly collimated jets, photon conversions



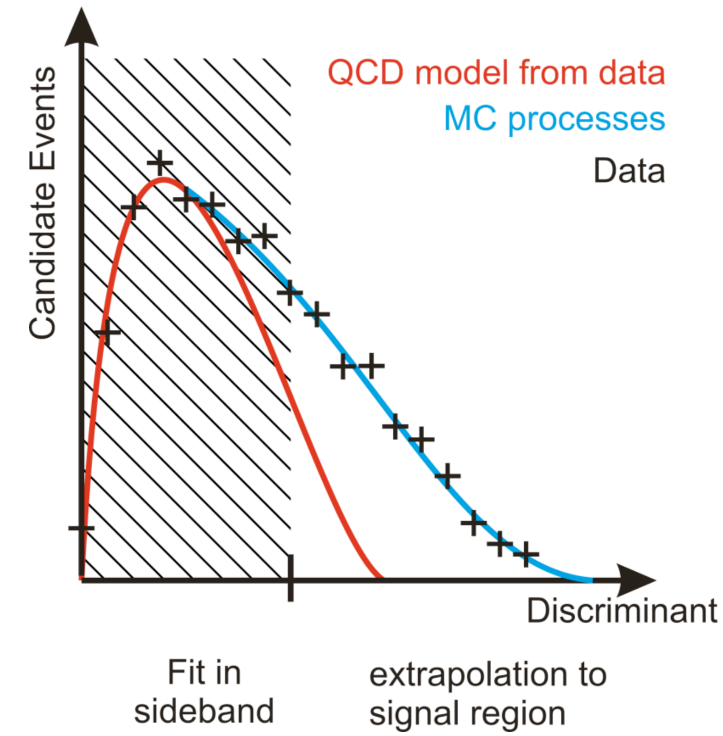
modelling QCD from data

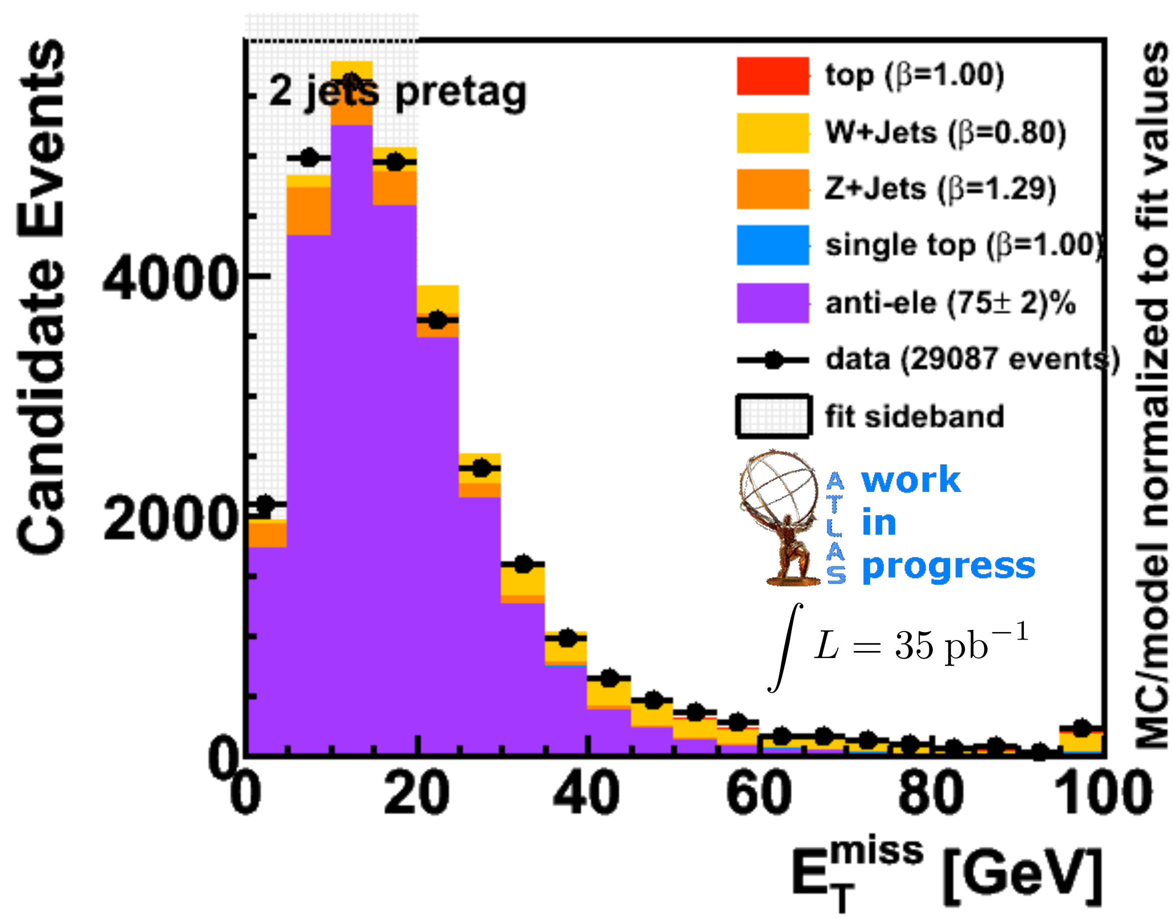
- need to find region where QCD dominates while staying as close as possible to signal selection
- select sample orthogonal to standard top selection by inverting cut on electron particle ID selection **→ anti-electron sample - provides full QCD model**
- find distribution that is sensitive to lepton fakes → **missing transverse energy** (QCD here mostly instrumental background)
- shape of QCD background taken from data, but model provides no cross-section → **determine amount of QCD background from fit**

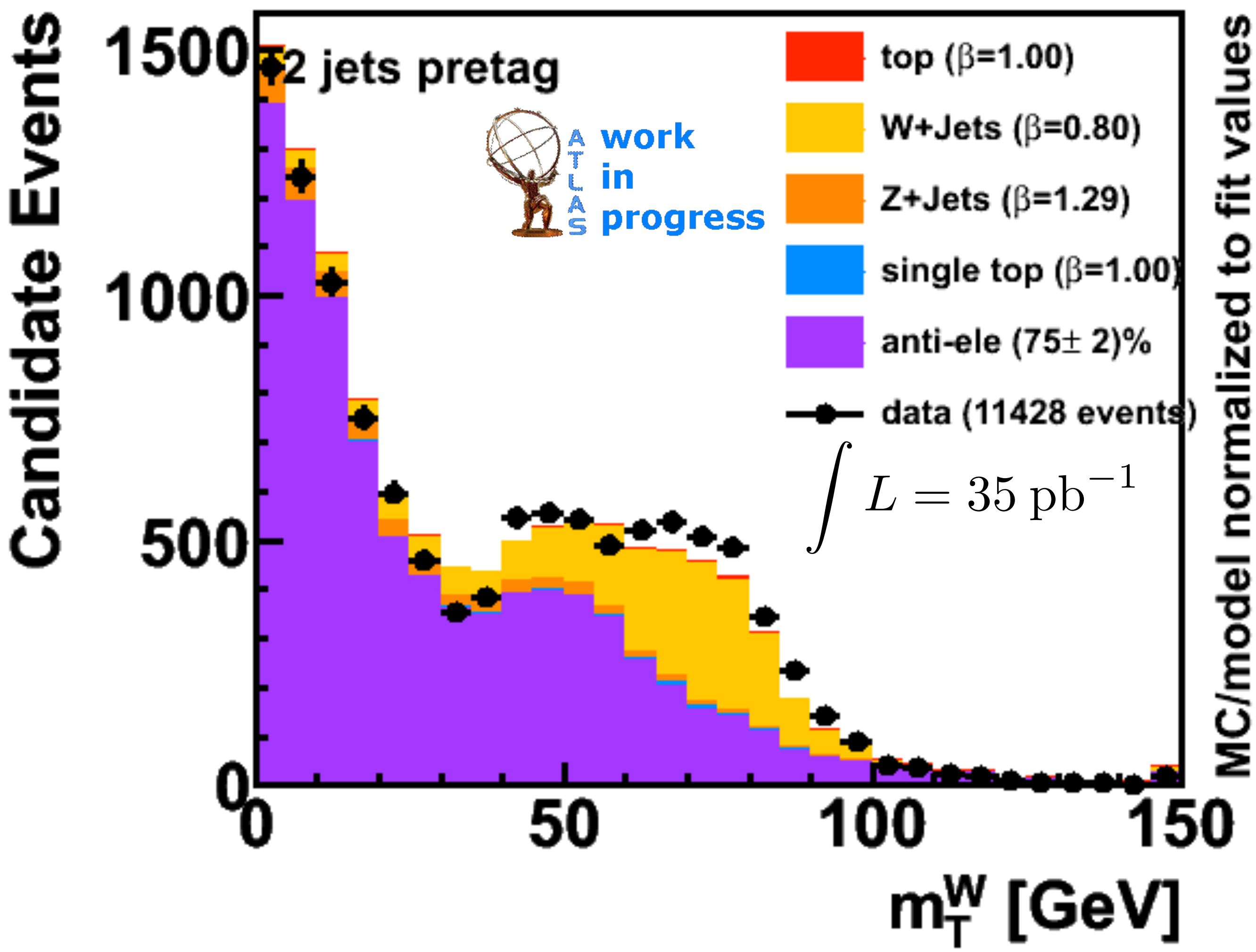


anti-electron model

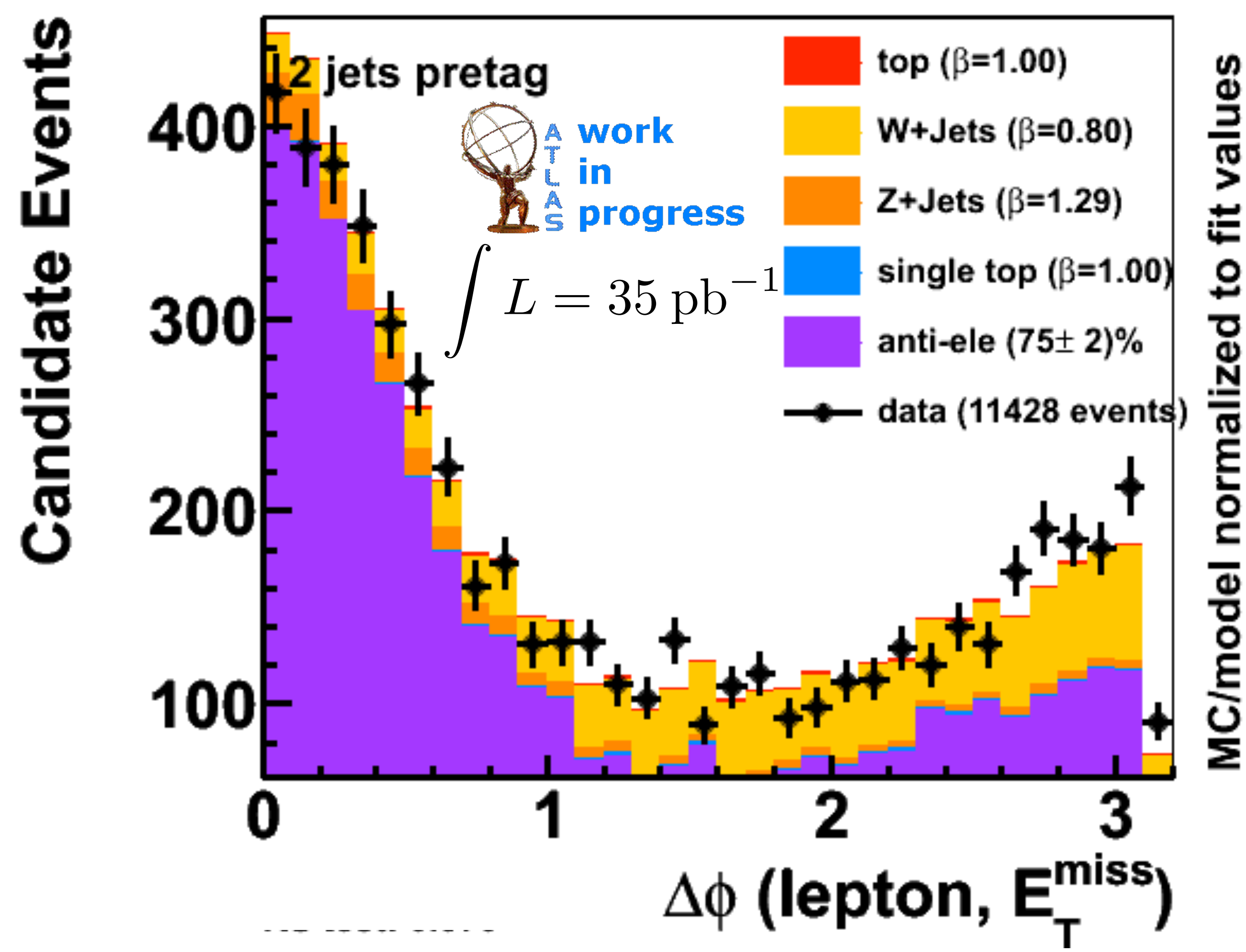
- if we can fit in sideband we can perform another fit (e.g. W+jets background) in the signal region later
- top selection applies MET cut of 20 GeV → **use 0-20 GeV sideband for fit and extrapolate**
- all processes taken from MC and scaled to SM expectation
- **challenge**: tune background model to agree with signal-selected data
- having a full background model should also allow us to look into other kinematic distributions







good agreement with data!



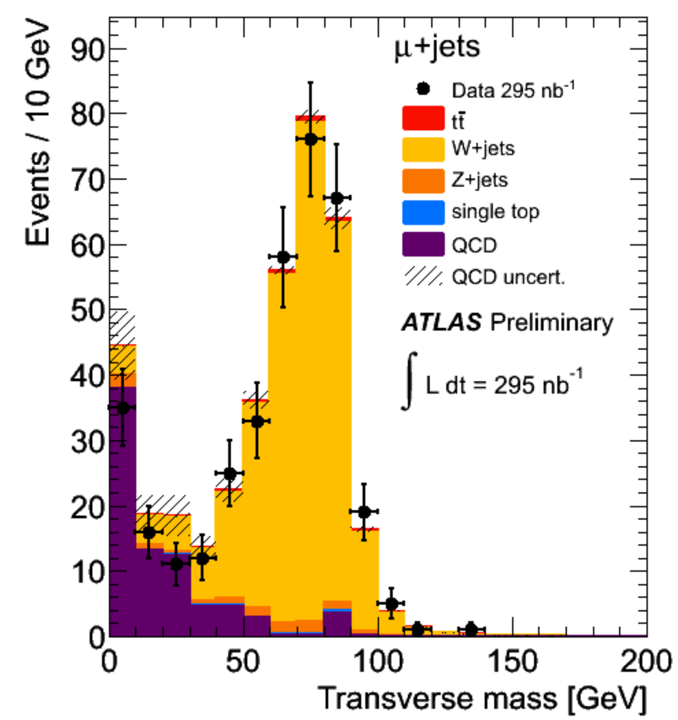
QCD estimation in muon channel

- multijet background predominantly from heavy quark decays (non-prompt leptons)
- top group using matrix method (c.f. ATLAS-CONF-2010-087)
- define „loose“ and „tight“ sample, where „tight“ ∈ „loose“
- measure ε_{fake} in multijet dominated region, ε_{real} from Zμμ events
- two approaches for ε_{fake} estimation:
  - use low MET
  - high muon impact parameter

$$\begin{aligned} N^{\rm loose} &= N^{\rm loose}_{\rm real} + N^{\rm loose}_{\rm fake}\,, \\ N^{\rm tight} &= \varepsilon_{\rm real} N^{\rm loose}_{\rm real} + \varepsilon_{\rm fake} N^{\rm loose}_{\rm fake}\,, \end{aligned}$$

$$\varepsilon_{\rm real} = \frac{N^{\rm tight}_{\rm real}}{N^{\rm loose}_{\rm real}} \qquad \varepsilon_{\rm fake} = \frac{N^{\rm tight}_{\rm fake}}{N^{\rm loose}_{\rm fake}}$$

$$N^{\rm tight}_{fake} = \frac{\varepsilon_{\rm fake}}{\varepsilon_{\rm real} - \varepsilon_{\rm fake}} \left(N^{\rm loose}\varepsilon_{\rm real} - N^{\rm tight}\right)$$

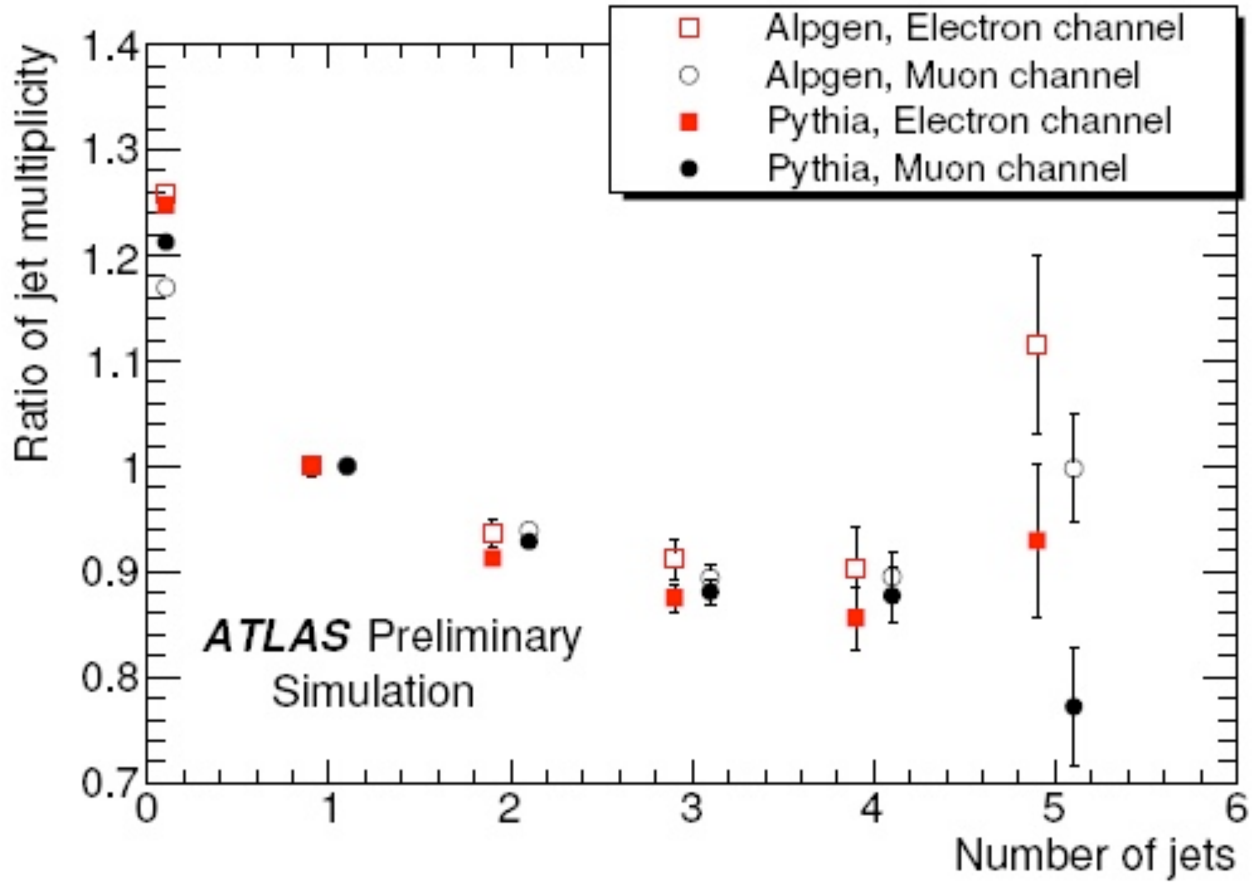


W+jets background estimation (ATL-PHYS-PUB-2009-087)

$$(W^{SR}/W^{CR})_{data} = (Z^{SR}/Z^{CR})_{data} \cdot C_{MC}$$

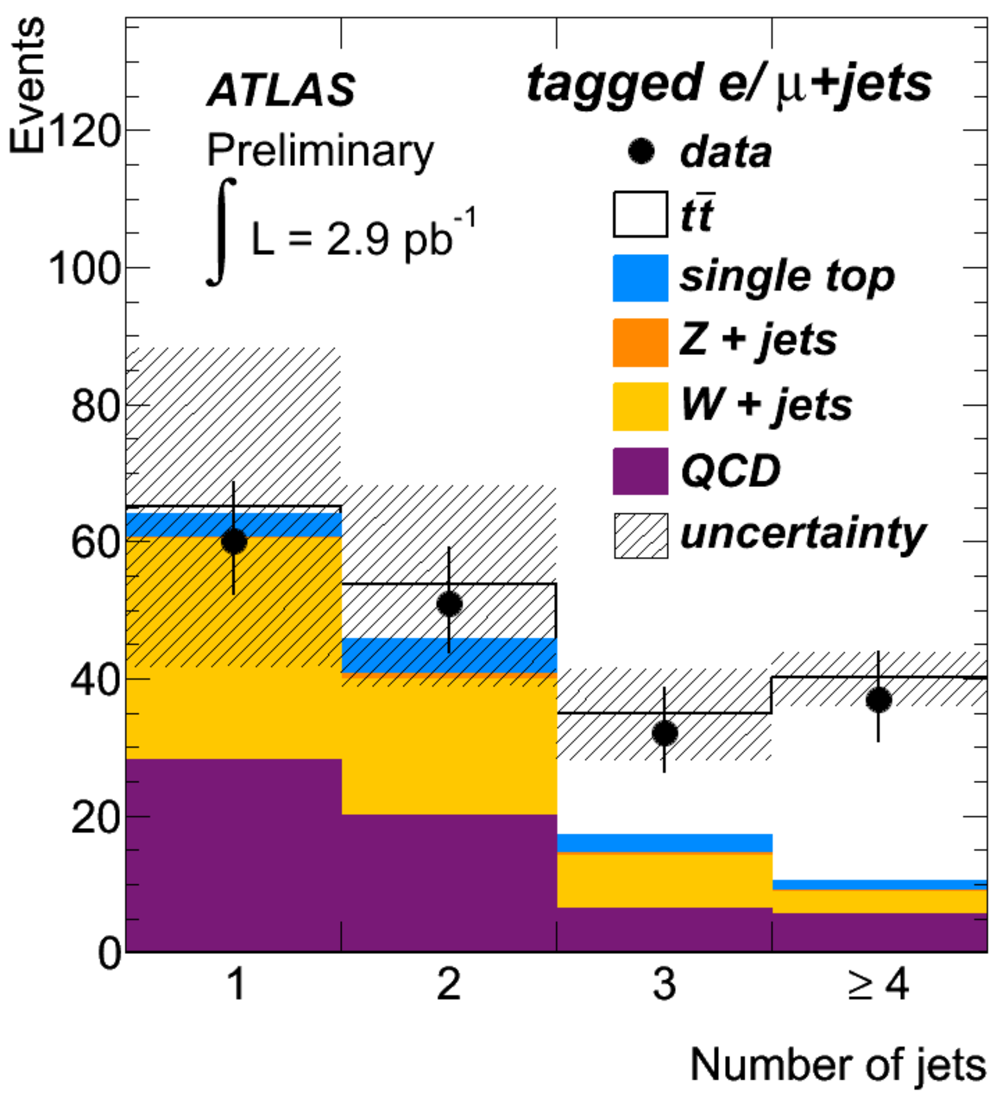
$$C_{MC} = \frac{(W^{SR}/W^{CR})_{MC}}{(Z^{SR}/Z^{CR})_{MC}}$$

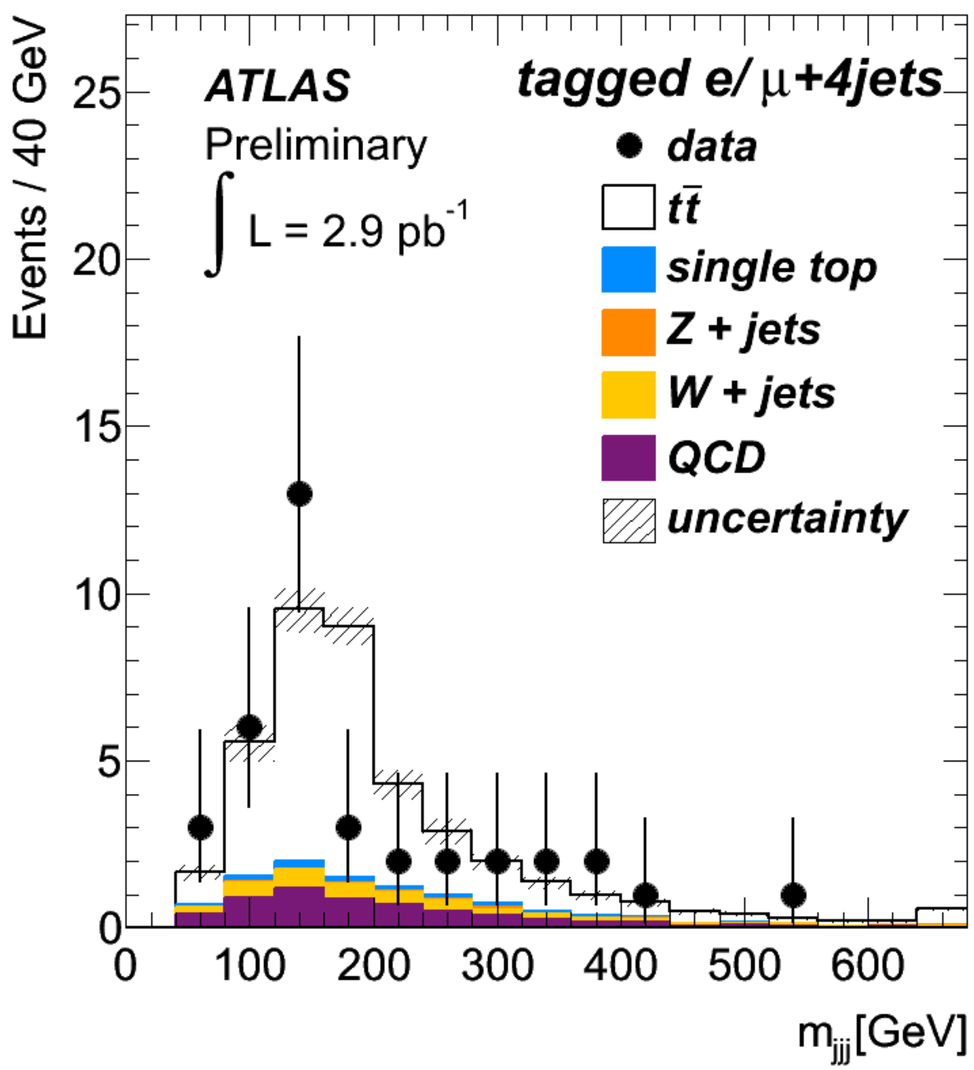
- W to Z ratio predicted with smaller uncertainty than absolute number of W bosons in association with ≥4 jets
- extrapolate from low jet multiplicity control region (CR) to top signal region (SR)
- caveat: QCD contribution in W+jets CR significant - needs to be subtracted
- different approach now used



ATLAS combined top pair cross-section measurement

- electron and muon channel measurement combined
- clear visibility of top signal
- kinematics compatible with top production

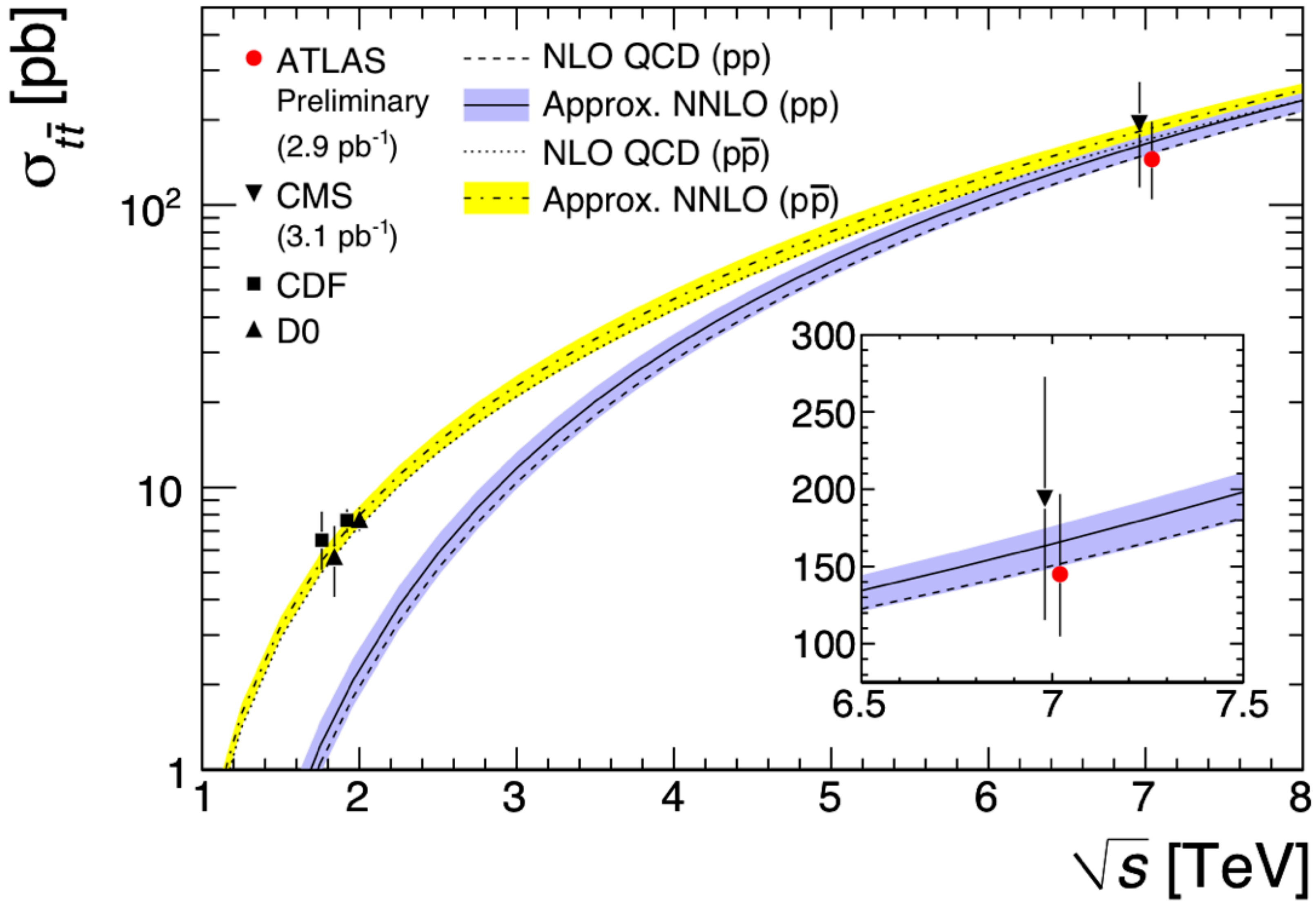




- adding dilepton channel yields a combined cross-section measurement of:

$$\sigma_{t\bar{t}} = 145 \pm 31 \,^{+42}_{-27}\ \text{pb}$$

- agreement with Standard Model
- uncertainty of 36%
- significance of 4.8σ



summary

- top pair cross-section measurement challenging
- anti-electron model allows to model QCD background from data
- matrix method used for muon channel
- W+jets background also obtained from data

- first ATLAS top pair production cross-section measurement available
- will be extended with higher statistics and more advanced methods