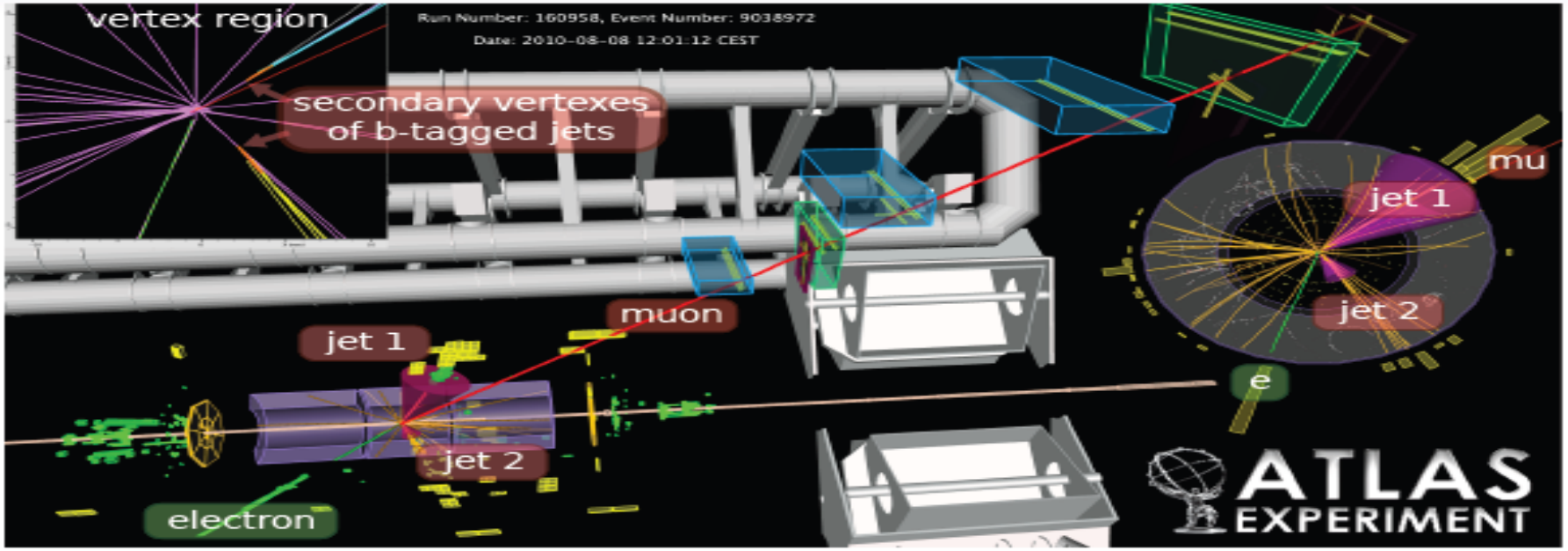

First observation of top-antitop pairs, and cross section measurement at 7 TeV

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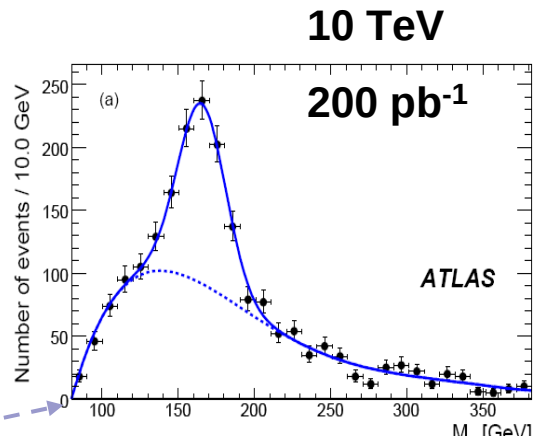
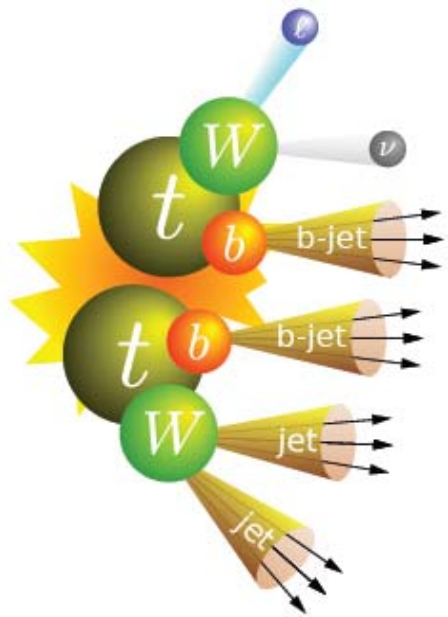
Outline

- Analysis strategy;
- Data & MC samples;
- Objects definition
- Focus on semileptonic channel:
  - Event selection;
  - QCD & W+jets “Data driven” Background estimation;
  - Cross-section evaluation;
- Combination e/μ + jets and dilepton channel;
- Conclusions and outlooks

Analysis strategy

- **Lepton+jets** → look for events with
  - **At least 4 jets, of which 2 are b-jets**
  - **Hard lepton, missing E_T**
  - Can reconstruct also the invariant mass of jets from hadronic side t→W(qq)b ;
- **Strategy**: Evidence for top based on excess of events w.r.t known backgrounds
- **Understanding of backgrounds** is key
  - Use data driven approach whenever possible





Data & MC samples

- DATA taken in DQ periods A-F passing 'top' GRL → all detectors & relevant triggers fully operational
  - **Total luminosity = 2.9 pb^{-1}**
- TRIGGERS used (evolved with instantaneous luminosity):

  Single lepton trigger with threshold fully efficient for leptons with P_T>20 GeV
  - **L1_ MU10 or EF_mu10_MSonly**
  - **L1_EM10,EF_g17_etcut or EF_e10_medium**
- MC SAMPLES: ATLAS full simulation (GEANT4)
  - **ttbar** → MC@NLO with m(top)=172.5 GeV, x-sec(NNLO)=165 pb.
  - **QCD multijets**→ ALPGEN + HERWIG/Jimmy; filter at generation level on muons (P_T>20 GeV) and jets (at least 3 with P_T>25 GeV, cut on 4-th jet: P_T> 17 GeV);
  - **W/Z+jets** → ALPGEN with K-factor=1.22. Overlap removal procedure on Heavy Flavors (Wbb/Wcc+jets) to avoid double counting with W+light jets sample.

Objects definition: leptons

- **Electron** = 'Robust medium electron' with P_T>20GeV
  - E/p (as in "tight" electron), track with b-layer hit (except 2% dead mod.) to suppress γ conversion;
  - $|\eta_{cluster}|$<2.47 (excluding 1.37<η<1.52)
  - Isolation: $E_T(R=0.2)< 4 + 0.023*E_T(el)$ GeV
- **Muon** = 'MUID tight', P_T>20 GeV, $|\eta|$<2.5
  - Isolation: $E_T(R=0.3)$<4 GeV, $P_T(R=0.3)$<4 GeV
  - ΔR>0.4 w.r.t nearest jet with P_T>20 GeV

to suppress bckg from hadron and b,c, decays

Details in https://twiki.cern.ch/twiki/bin/view/AtlasProtected/TopCommonObjects

Objects definition: jets & MET

- **Jet** = **AntiKt4 TopoCluster jets EM+JES** (MC hadron scale p_T,η dependent);
  - ΔR(jet-el)>0.2 (to avoid double counting electron as jet).
- **B-jet** ***Contribution from Genova group for the efficiencies***

  (http://indico.cern.ch/getFile.py/access?contribId=3&resId=1&materialId=slides&confId=105461)

  Jet + SV0 cut at 50% MC efficiency point

  Early tagger - efficiency for ttbar OK; ~220 rejection of light jets
- **Missing E_T** = **Simplified METRefFinal** with contribution from selected muons included
- Require a primary vertex with #tracks>4.

  Discard events with "bad" jets P_T>15 GeV

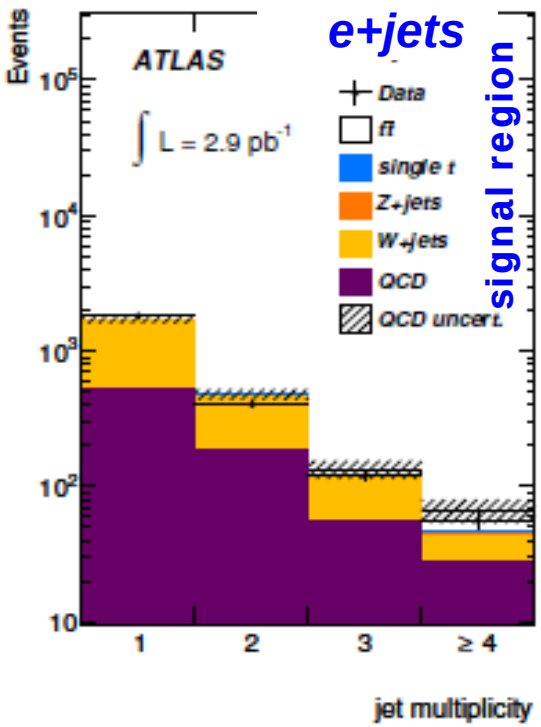
Details in https://twiki.cern.ch/twiki/bin/view/AtlasProtected/TopCommonObjects

Analysis in the semileptonic channel

- The appropriate **single electron or muon trigger** has fired
- **Exactly one lepton** (e or μ) with **P_T>20 GeV**, matching the corresponding trigger object (e)
- **E_T^{MISS}>20 GeV** and **E_T^{MISS}+M_T(W)>60 GeV**
- Exactly N **jets with P_T>25 GeV** (N=1,2,3) or >=4 jets (N=4)

against QCD

against QCD, W



56 events

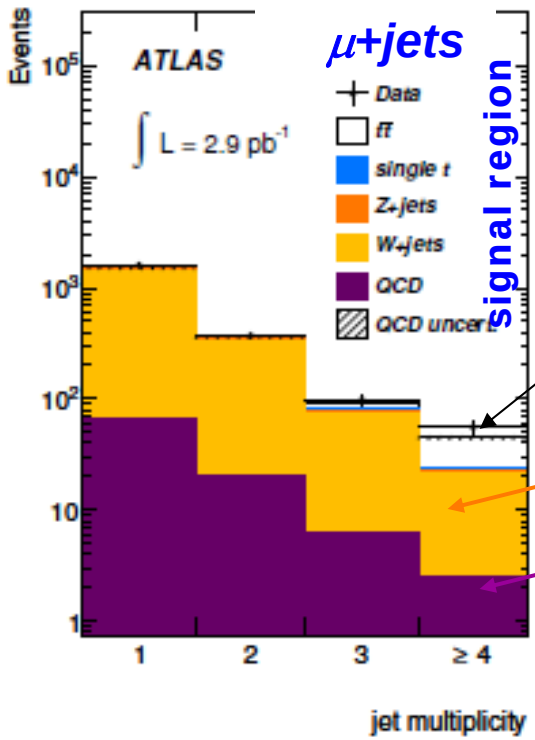
expected:

20.3±7.1 ttbar

2.9±1.4 t, Z+j

11.2±4.1 W+jets

27.8±11.3 QCD



56 events

expected:

20.5±7.0 ttbar

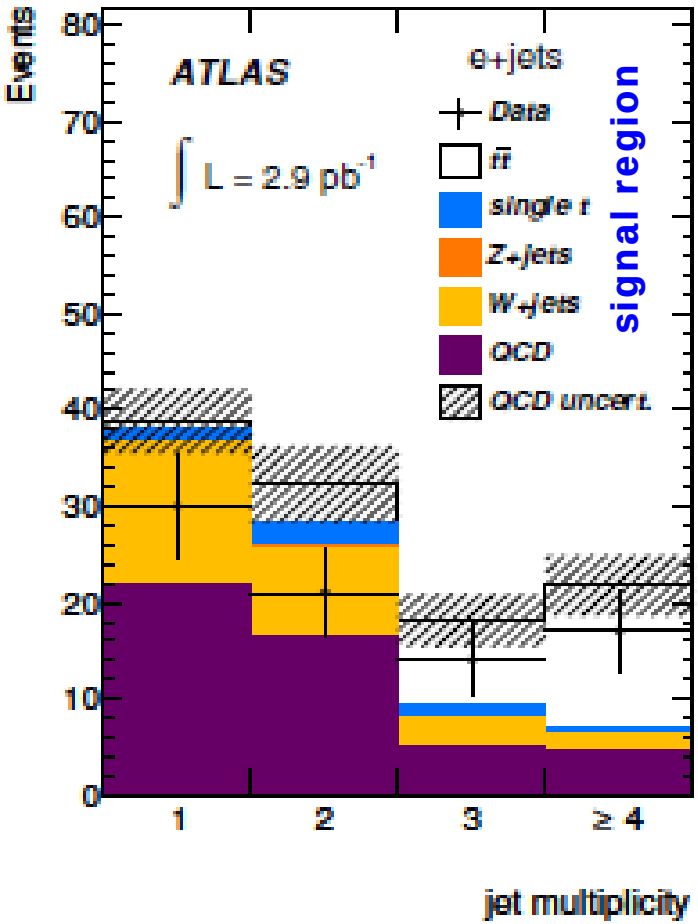
2.3±0.9 t, Z+j

18.9±4.6 W+jets

2.5±1.2 QCD

Analysis with b-tagging…

- Added requirement = **≥1 b-tagged jet with P_T>25**



17 events

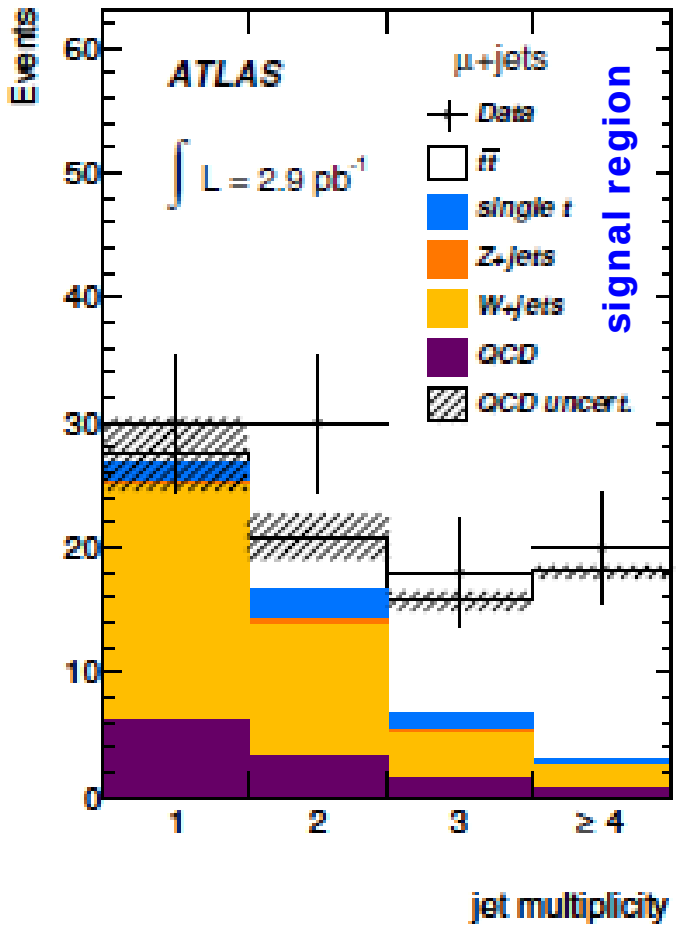
expected:

14.8±6.7
ttbar

0.8±0.2
Sing. t, Z

1.9±1.1
W+jets

4.8±3.1
QCD



20 events

expected:

14.9±6.6
ttbar

0.8 ±0.2
Single t, Z

3.2±1.7
W+jets

0.8±0.5
QCD

W+jets and QCD backgrounds are from Data-driven estimation methods

QCD backgrounds: muon channel

HF semilept. decays, fake leptons, γ conversion (in e+jets channel);

- Matrix Method: Ok for **μ-channel**,not for e-channel (contamination in Control Reg.)

  - Define 2 samples: **'tight'** μ (μ ID cut) vs. **'loose'** μ (μ ID cut except for isolation);

$$N_{LOOSE} = N^{REAL}_{LOOSE} + N^{FAKE}_{LOOSE}$$

  - Then:

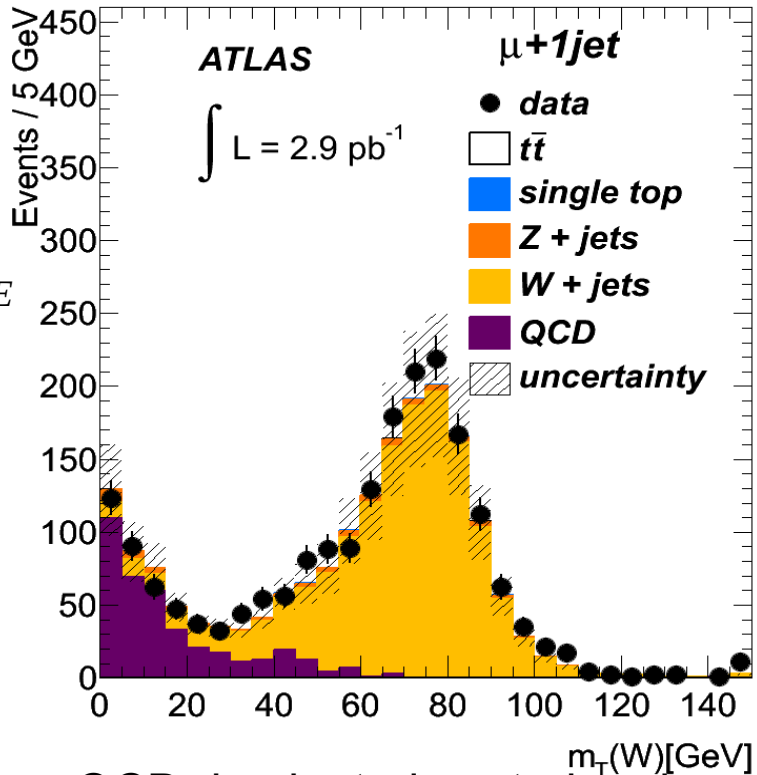
$$N_{TIGHT} = \varepsilon_{REAL} N^{REAL}_{LOOSE} + \varepsilon_{FAKE} N^{FAKE}_{LOOSE}$$

where ε is the probability for a real (fake) μ to pass both ID criteria.

  - Inverting the formula we have

$$N^{FAKE}_{TIGHT} = \frac{\varepsilon_{FAKE}}{\varepsilon_{REAL} - \varepsilon_{FAKE}} \left(\varepsilon_{REAL} N_{LOOSE} - N_{TIGHT} \right)$$

with the 2 efficiencies that need to be measured to do the estimation.



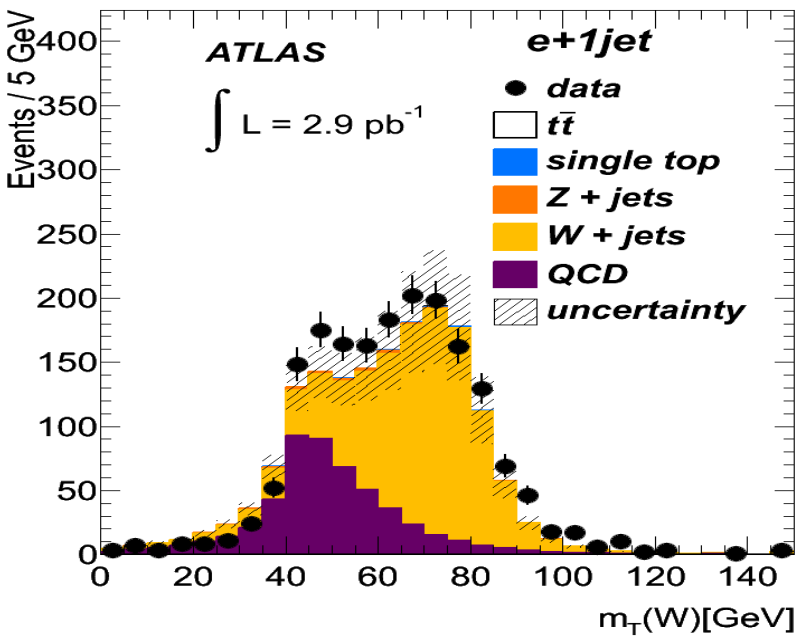
  - ε_{REAL} from Z($\mu\mu$) events = 0.990±0.003; ε_{FAKE} from QCD dominated control region (2 regions defined: MET < 10 GeV or d_0-sig(μ)>5+ MET>20 GeV) → 0.339±0.013

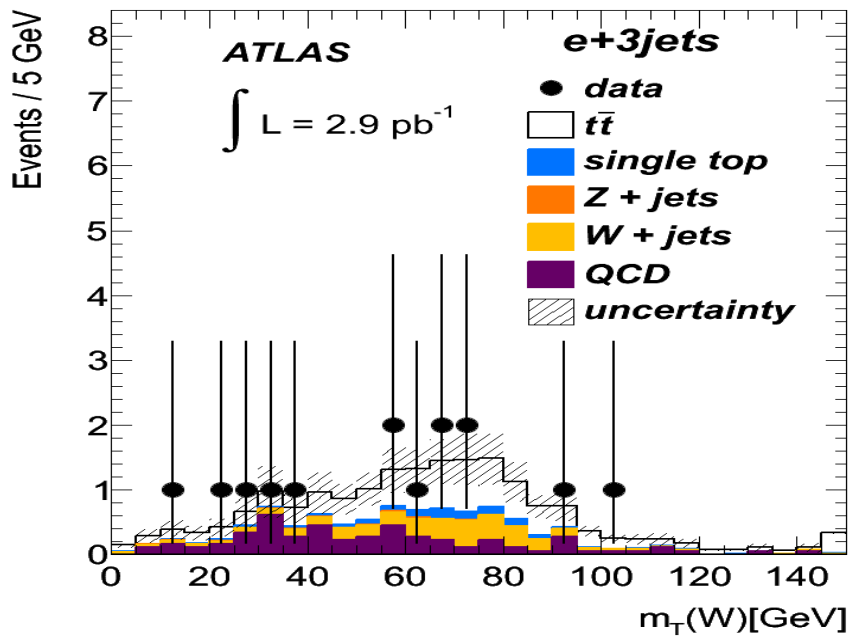
  - Final rescaling to "tagged" events: multiply N^{FAKE}_{TIGHT} for the probability for a QCD multi-jet event to have at least 1 b-tagged jet.

QCD backgrounds: electron channel

Contribution from Milano group in e-channel MM

- Multiple sources (Heavy Flavour, $\gamma \rightarrow e^+e^-$,hadrons): challenging for Matrix-Method. Not used here but probably more competitive with more data and more time to develop it.
- MET fitting method: 2 Control Regions “Jet-electron” (substitute the electron with a jet similar to it),”anti-electron”(invert e-ID selection criteria)
- Fit MET<20 GeV distribution in data + MC templates for tt, W/Z+j. contrib. and then extrapolate in signal regions MET>20 GeV.





W+jets background estimation

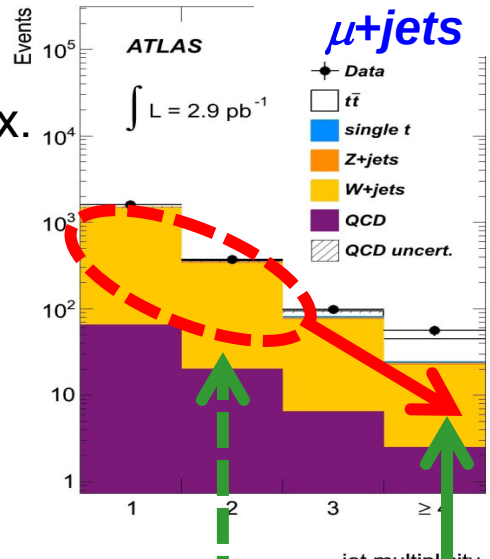
Contribution from Milano group

- **Estimation in 4-jet pre-tag region**

  'Berends-Giele' scaling: W+N+1 jets/W+N jets approx. constant for each N

$$W^{\geq 4\ jets} = W^{2\ jets} \cdot \sum_{k=2}^{\infty} \left(W^{2\ jets} / W^{1\ jet} \right)^{k}$$

  Measure W+1,2 jets by subtracting data driven QCD estimate from 1,2-jet pre-tag bins (+ MC estimates for other processes) and extrapolate to signal region.



- **Estimation in 4-jet tagged region**

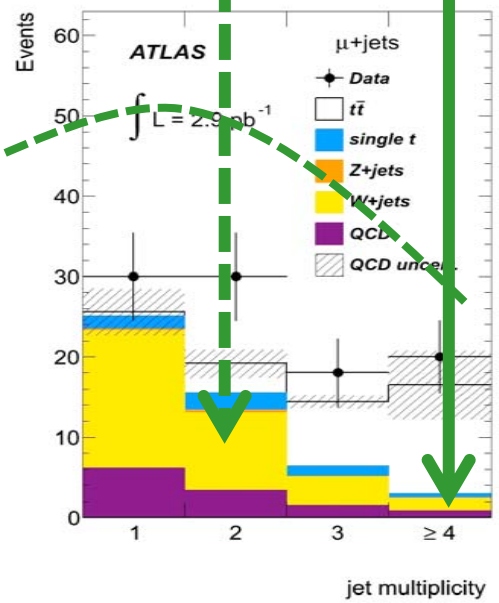
$$W^{\text{tagged}-\geq 4\text{jet}} = W^{\text{pretag}-\geq 4\text{jet}} \cdot f_{\text{tagged}}^{\geq 4-\text{jet}}$$

From data with muon

where

From MC

$$f_{\text{tagged}}^{\geq 4-\text{jet}} = f_{\text{tagged}}^{2-\text{jet}} \cdot f_{2\rightarrow\geq 4}^{\text{corr}}$$



W(ev)tagged≥4jet = 1.9 ± 0.7(stat) ± 0.9(syst)

W(μν)tagged≥4jet = 3.2 ± 1.2(stat) ± 1.2(syst)

Cross-section evaluation

- **Cut & Count method:** Calculate ttbar event yield – subtract all backgrounds

Source	e+jets	μ+jets
W+jets	1.9 ± 1.1	3.2 ± 1.7
QCD	4.8 ± 3.1	0.77 ± 0.51
single top	0.66 ± 0.19	0.67 ± 0.17
Z+jets	0.16 ± 0.11	0.08 ± 0.06
di-bosons	0.024 ± 0.020	0.025 ± 0.020

Udine group contribution

e+j. N_{obs}= 17 → N_{ttbar}= 9.5 ± 4.1 ± 1.5

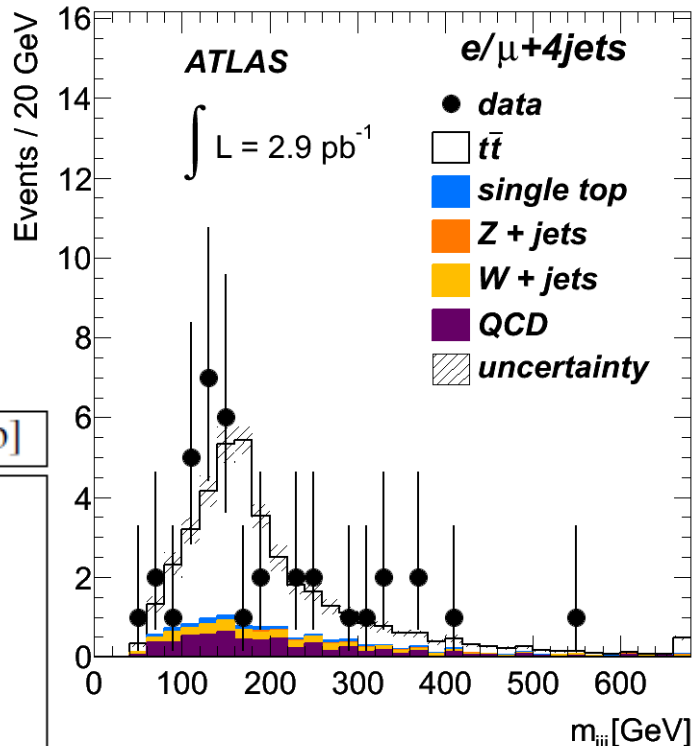
μ+j. N_{obs}= 20 → N_{ttbar}=15.3 ± 4.4 ± 1.3

Acceptance/efficiencies from MC@NLO

[σ(theory - NNLO)=165 pb]

- **2 alternative methods:** Keep the invariant mass distribution of the **3 jets** combination with **highest P_T** from data, use templates shape for other backgrounds and **fit simultaneously ttbar and W+jets** contribution. First method uses **3-jet** and **4-jet** "**untagged events**", the second one **4 jet events** with 0 and ≥ 1 b-tag jet.

Channel	Counting σ [pb]	Fitted σ (A) [pb]	Fitted σ (B) [pb]
e + jets	$105 \pm 46\ ^{+43}_{-38}$	$98 \pm 61 \pm 29$	$109 \pm 47^{+32}_{-37}$
μ + jets	$168 \pm 49\ ^{+41}_{-34}$	$170 \pm 68\ ^{+43}_{-36}$	$150 \pm 52^{+39}_{-42}$
e or μ +jets	$142^{+36\ +44}_{-32\ -28}$	$131 \pm 44\ ^{+34}_{-28}$	$127 \pm 34\ ^{+32}_{-35}$



Combination results

Bologna group contribution

The use of Markov Chain MC allows the solution of the Bayes formula:

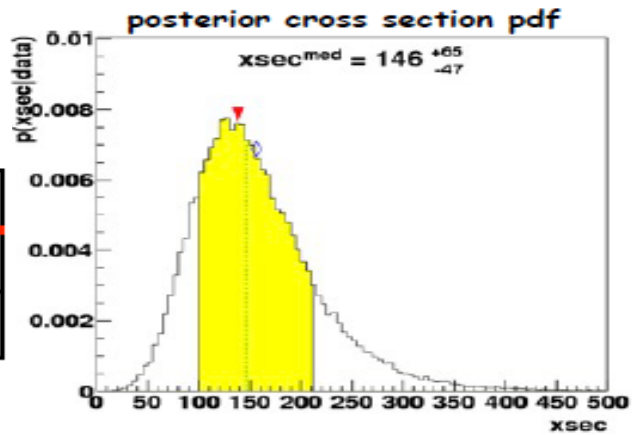
$$f(\sigma|N_{obs}) = \frac{P(N_{obs}|\sigma) f_0(\sigma)}{\int_0^\infty P(N_{obs}|\sigma) f_0(\sigma) d\sigma}$$

in presence of systematic errors related to background estimation, acceptance and luminosity. The aim is to evaluate a posterior x-sec distribution.

lepton+jets (e/μ)

ch.\sources	Nobs	QCD	W+jets	Z+jets	Single top
e+jets	17	4.78	1.9	0.15	0.67
μ+jets	20	0.77	3.2	0.08	0.68

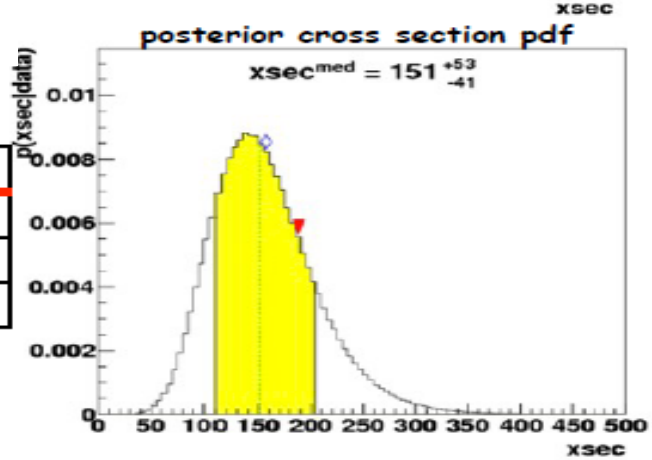
$$\sigma_{l+jets} = 146(median)^{+65}_{-47}\ \text{pb}$$



lepton+jets (e/μ) + dilepton(ee/μμ/eμ)

ch.\sources	Nobs	DrellYan	Zττ	Diboson	Single top
ee	2	0.25	0.07	0.04	0.08
μμ	3	0.69	0.14	0.07	0.07
eμ	4	-	0.13	0.15	0.22

$$\sigma_{5ch} = 151(median)^{+53}_{-41}\ \text{pb}$$

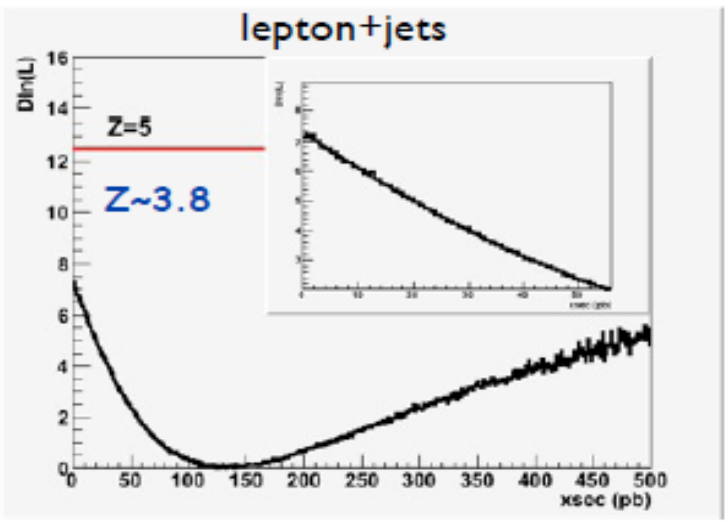


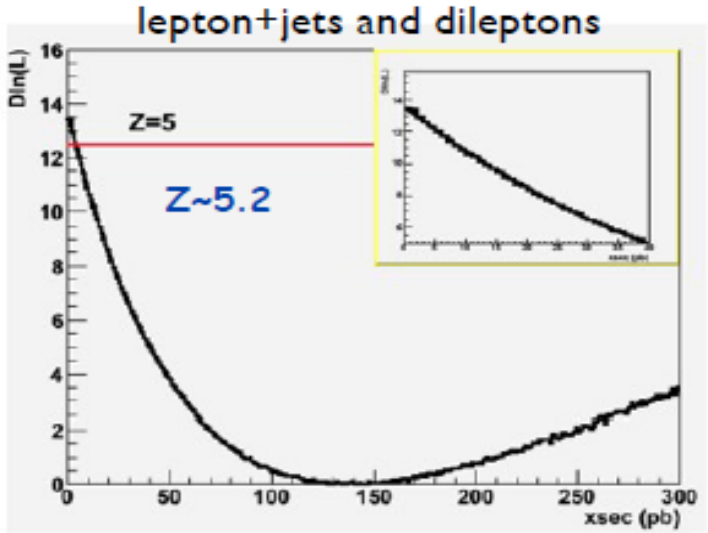
Significance of the observation

Bologna group contribution

The significance of the signal has been evaluated looking at the log difference between the maximum and the σ=0 level of the cross section posterior. In case of a normal distribution this difference can be translated in a Z-significance (number of standard deviation distance from mean value) by the following relationship:

$$-2 \times (\log(p(\sigma = max)) - log(p(\sigma = 0))) = Z^2$$



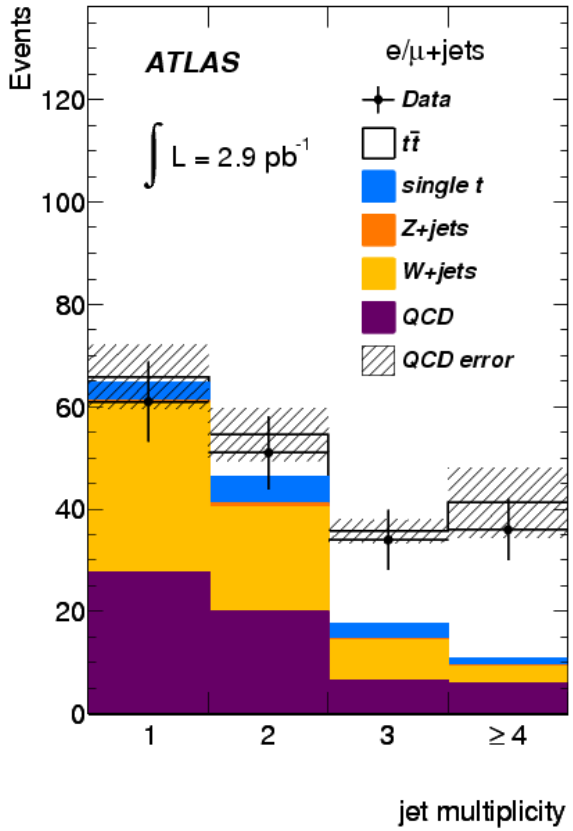


All results in overall good agreement with an alternative classical method

more info: https://twiki.cern.ch/twiki/bin/view/Main/Combination#Input_from_the_dilepton_analysis

Conclusions & outlooks

- We observe a clear excess of events in 3,4-jet tagged samples consistent with ttbar;
- Have fully data driven estimate of QCD background and almost fully data driven estimate of W+jets background;
- Extract ttbar yield/ cross section using counting method and cross check with other methods with different assumptions on bckg modeling are consistent.
- Signal significance in l+jets likely just short of 4σ, becoming 4.8σ after combination with dilepton.
- Italian contribution is clearly visible; it could be probably strengthened but we are already competitive and we can maintain our “positions”.



- In the next future (i.e. Moriond Conference), the idea is to use the Cut&Count method (and possibly improve some data-driven background estimation) until it is competitive w.r.t. the fit methods.
- Then we should try to find such a collaboration looking to other channels.

The "latest and greatest"….