Strategies for top pair cross section measurements in ATLAS

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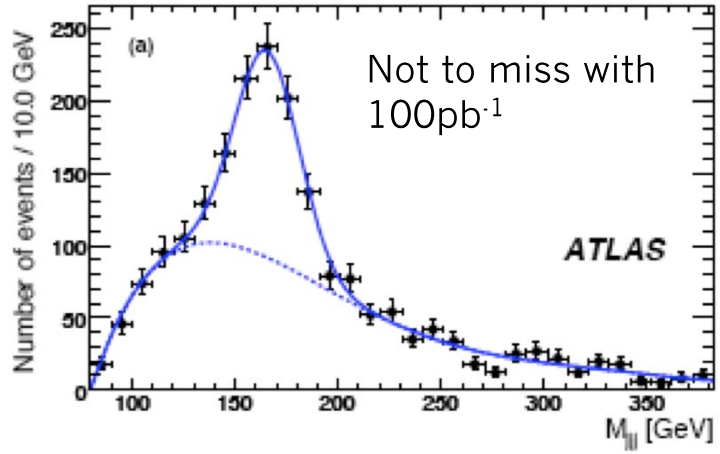
Why precise cross section measurements?

Overview of Strategies and Analyses

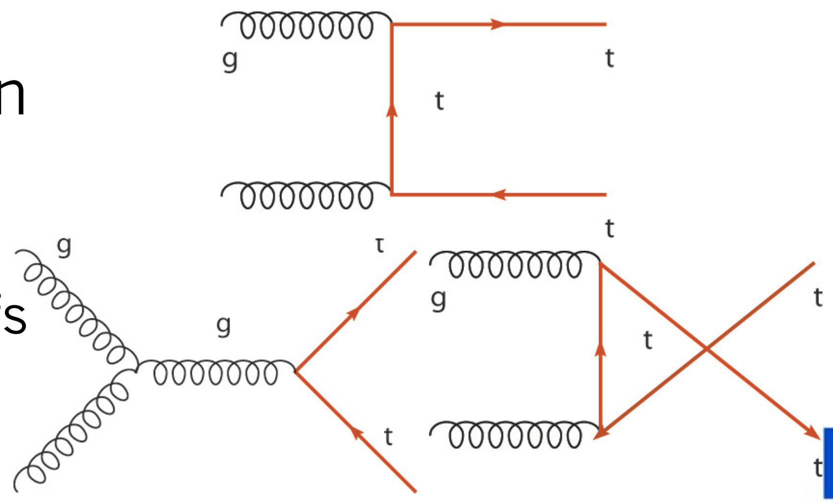
Towards first data

Why precise cross section measurement?

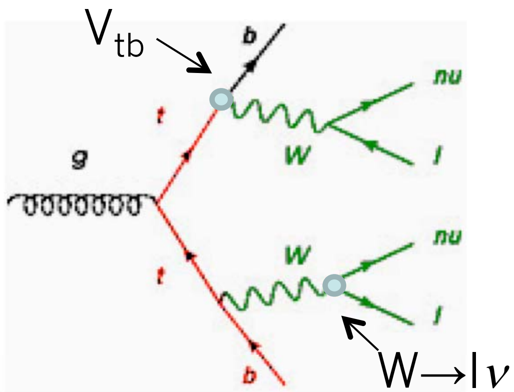
- 1 $t\bar{t}$ pair per second, top peak visible after a few weeks
  - Theoretical prediction **$(918^{-9}_{-39}(\text{scales})^{+30}_{-30}(\text{pdf}))$pb**
    E_{CM}=14TeV, m_T=171GeV in approx. NNLO Moch and Uwer arXiv/0804.1476
    @E_{CM}=10TeV: **414pb** (NLL resum.)

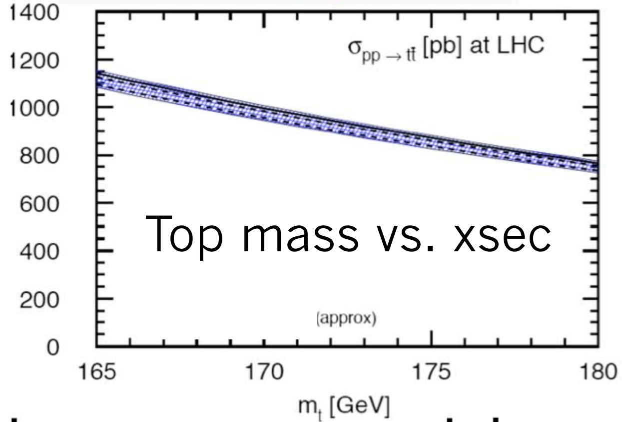


- ~90% top pair production at LHC via gluons
  - Measurement would test QCD calculation, gluon pdfs



- Test of EW theory
  - Top quark decay (V_{tb}) of EW nature
  - W properties (BR $W \rightarrow l\nu$)
  - sensitivity to top mass
- New physics searches
  - $t \rightarrow H^{+} + b$, rare top decays
  - resonances $Z' \rightarrow t\bar{t}$
- Background to other analyses
  - Single Top, Higgs, SUSY

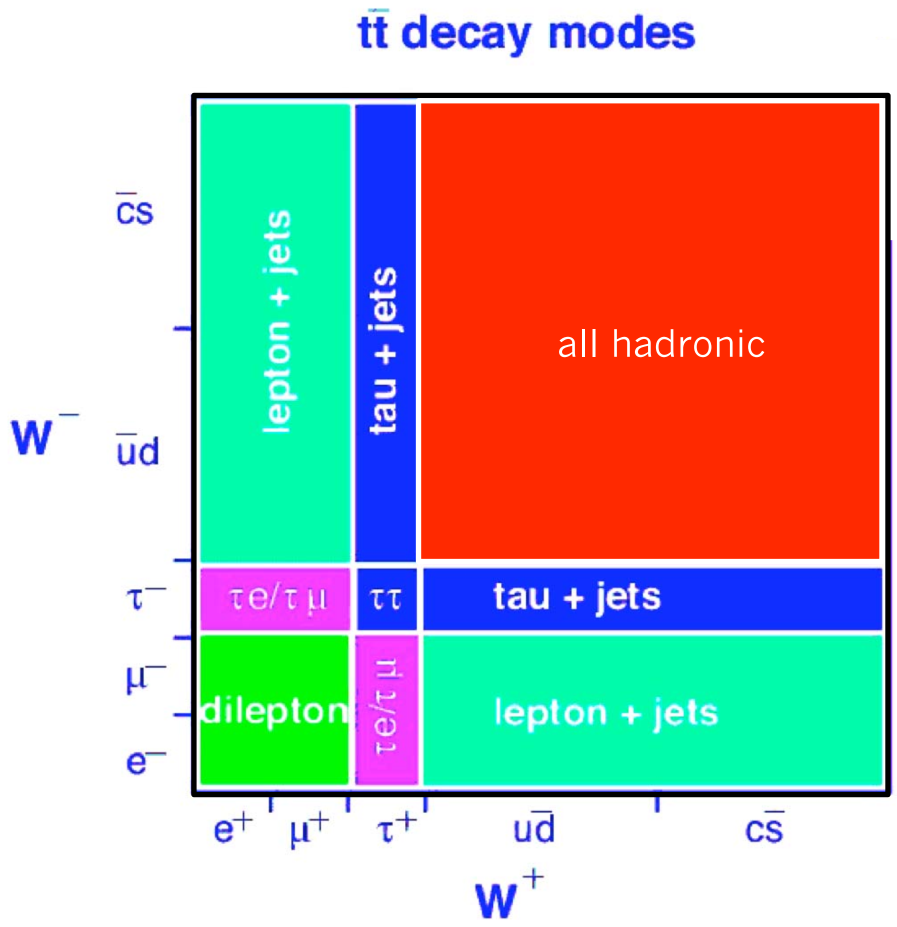




- Measurement of cross section can provide consistency test of SM and physics beyond SM

General strategies

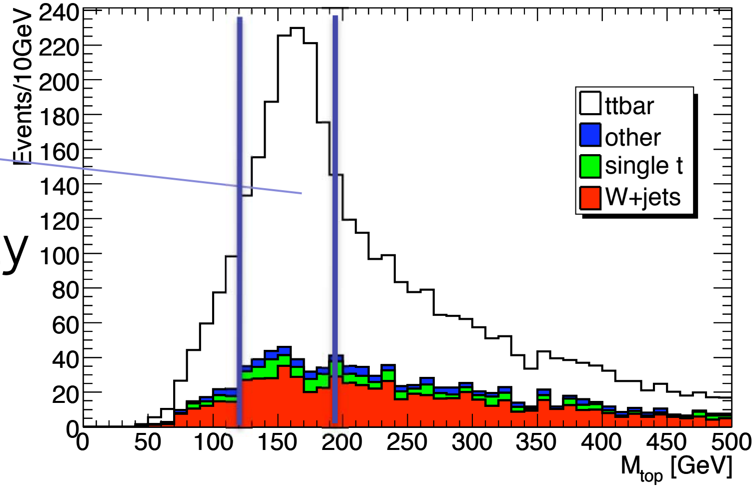
- Measurement in different W decay modes:
  - lepton+jets
    - „golden” channel
  - di-leptonic
    - cleanest selection possible
    - include leptonically decaying τ
  - all hadronic
    - 6-jet environment, most difficult
  - different backgrounds, different systematic issues, use as consistency check
- with or without b-tagging
  - w/o b-tagging suitable for first measurements
  - with b-tagging cleaner selection at later stage



General strategies (II)

- cut and count
  - simple and powerful for first measurements

$$\sigma = \frac{N_{measured} - N_{background}}{A \cdot \varepsilon \cdot L}$$

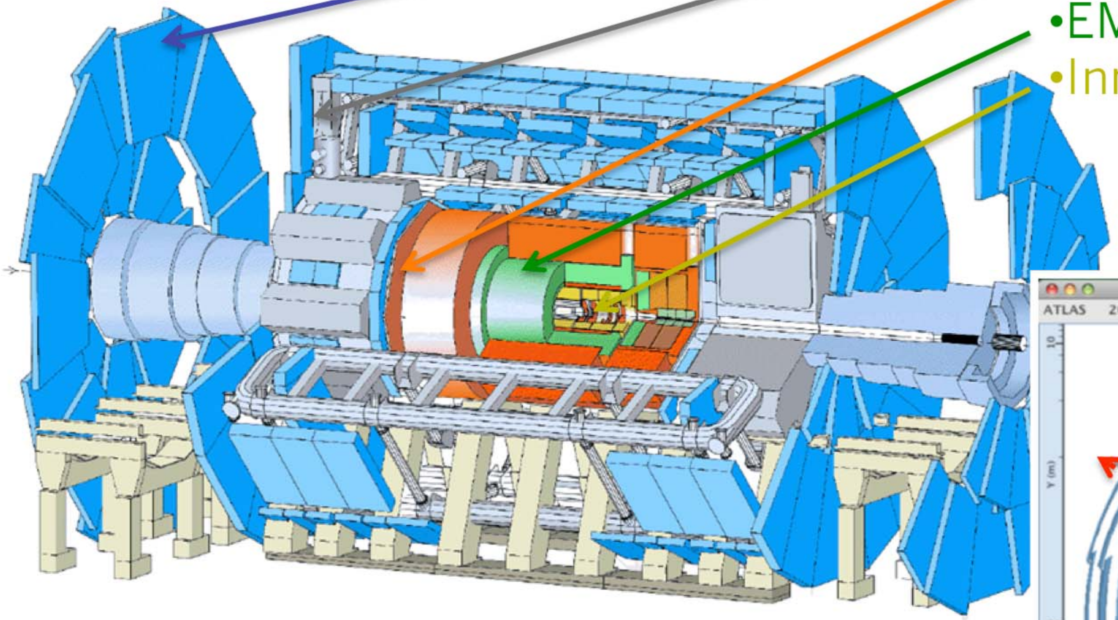


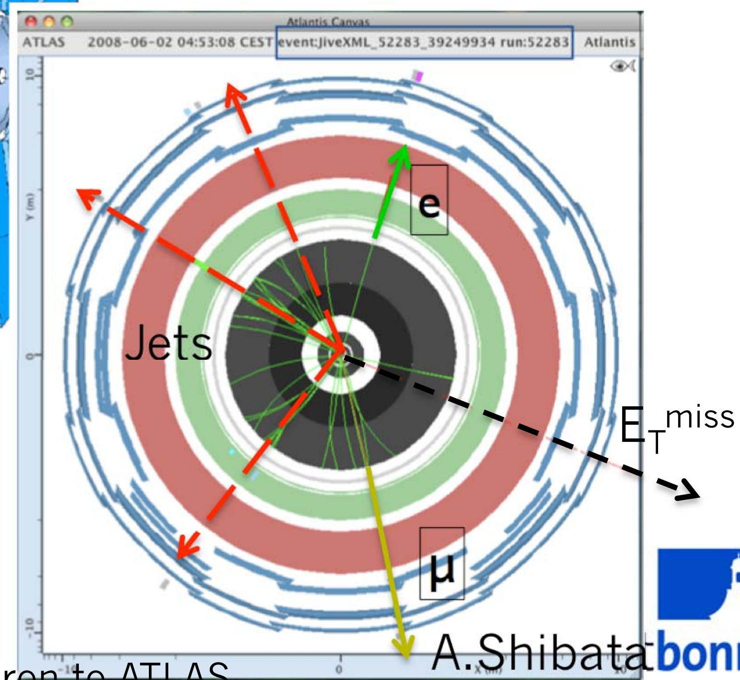
  - use selection for further top property measurement

- Likelihood fit methods
  - Construct likelihood as function of signal and bkg event numbers
  - more sensitive to actual top event topology
  - Fit more quantities at the same time

ATLAS Detector

- Muon sprectrometer
- Toroid magnet
- Hadronic calorimeter
- EM calorimeter
- Inner tracker + solenoid magnet



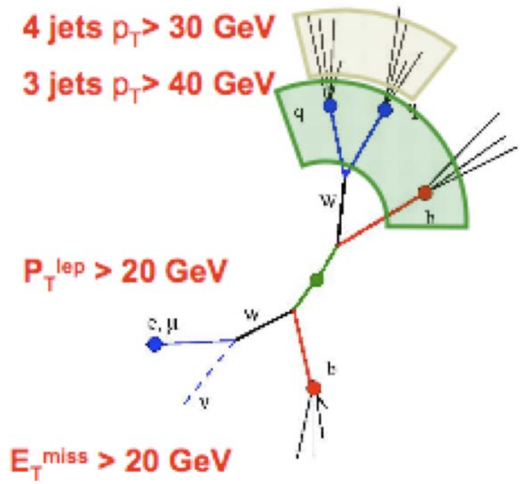


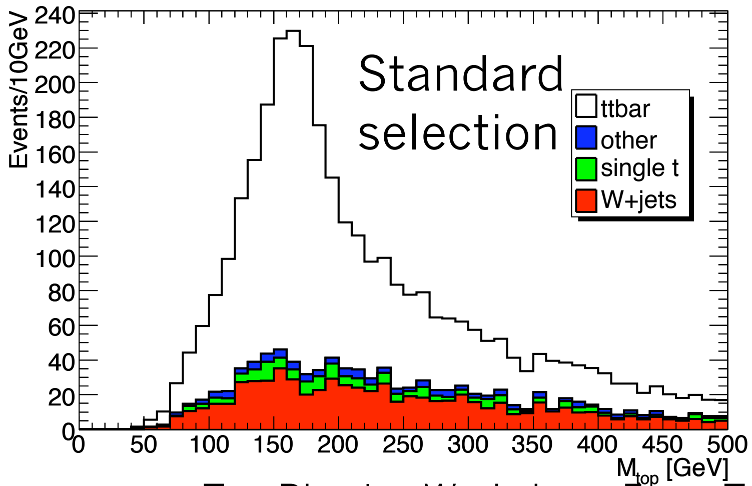
MC Top-Antitop
eμ-candidate

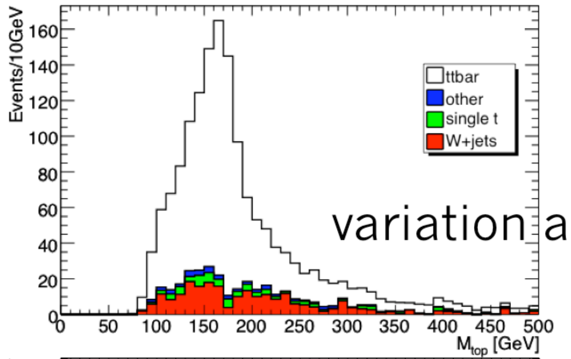
A.Shibata

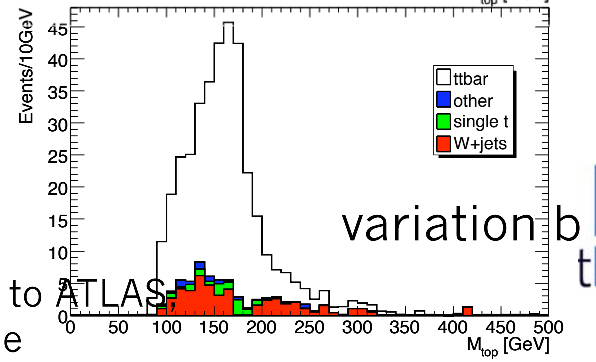
l+jets channel (commissioning analysis)

- Study for the first 100pb^{-1}
- No b-tagging
- Selection variations and purification:
  - Sum of highest p_T jets = hadronic top candidate
  - (a) Require at least one combination within 10GeV of the peak in distribution of invariant mass of all two jet combinations
  - (b) In addition require $|\eta|<1$ for the first three jets









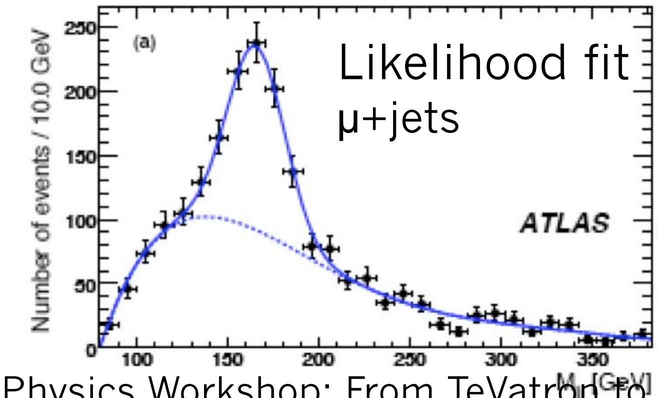
l+jets channel (II)

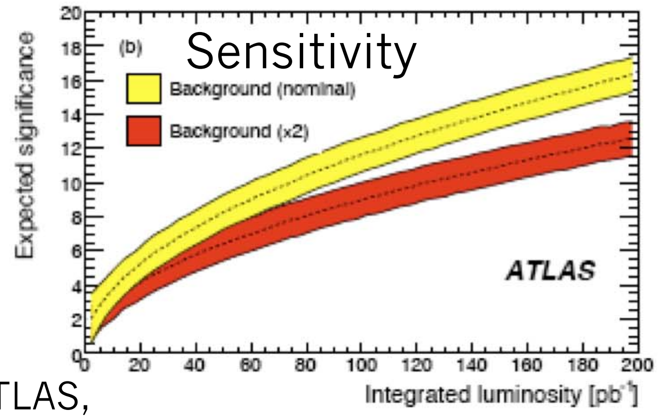
- Considered background contributions:
  - W+jets (cc,bb)
  - (QCD negligible)
  - Single top
  - Z/Drell-Yan and di-boson

- Cut and count method:
  - Purity of 80% after $141 < m_T < 189$ GeV

	default	var a m_W	var b $\|\eta\|<1$	m_t-window
S/B e+j	2.2	3.4	4.8	5.8
ε [%]	18.2	9.0	2.2	4.0
S/B μ+j	2.2	3.2	4.6	5.3
ε [%]	23.6	11.6	2.8	5.4

- Likelihood fit method:
  - Fit using Gauss (signal) +CC poly (bkg) Likelihood





l+jets channel (III)

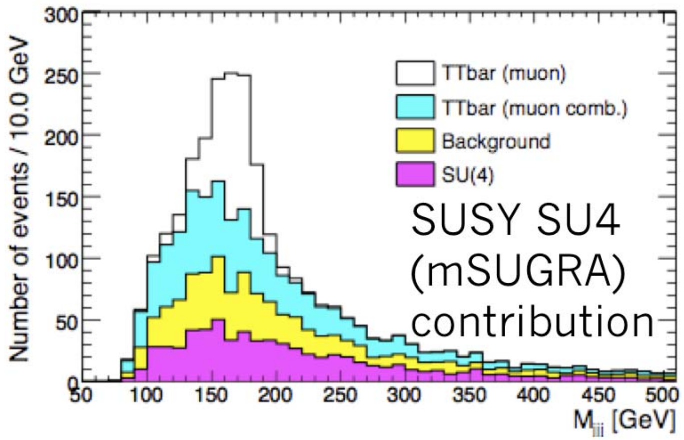
- Results:

uncert. in %	Likelihood fit		Cut and count	
Source	e+jets	μ+jets	e+jets	μ+jets
stat.	10.5	8.0	2.7	3.5
Lepton ID	1.0	1.0	1.0	1.0
Lepton trigger	1.0	1.0	1.0	1.0
W+jets +50%	1.0	0.6	14.7	9.5
W+jets +20%	0.3	0.3	5.9	3.8
JES (5%)	2.3	0.9	13.3	9.7
PDFs	2.5	2.2	2.3	2.5
ISR/FSR	8.9	8.9	10.6	8.9
Shape of fit func	14.0	10.4		

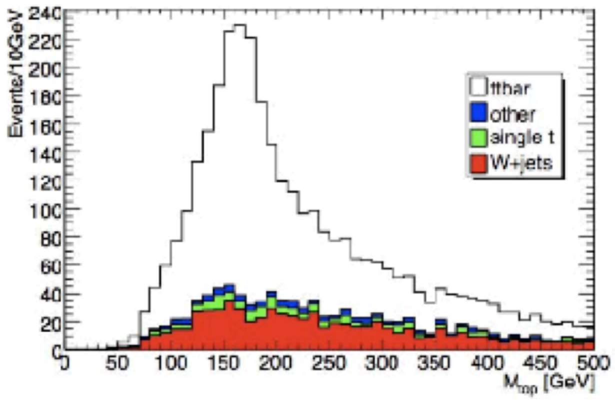
Likelihood method: $\Delta\sigma/\sigma$= **(7(stat) ±15(sys) ±3 (pdf) ±5 lumi))%**
Cut and count: $\Delta\sigma/\sigma$= **(3(stat) ±16(sys) ±3 (pdf) ±5 lumi))%**

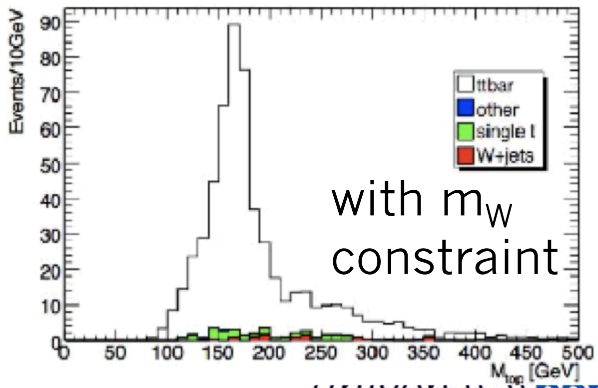
l+jets channel (IV)

- Contribution from new physics:
  - $V \rightarrow t\bar{t}$ $\varepsilon\sim1\%$
  - but SUSY SU4 (mSUGRA) with xsec of 1/3 of ttbar



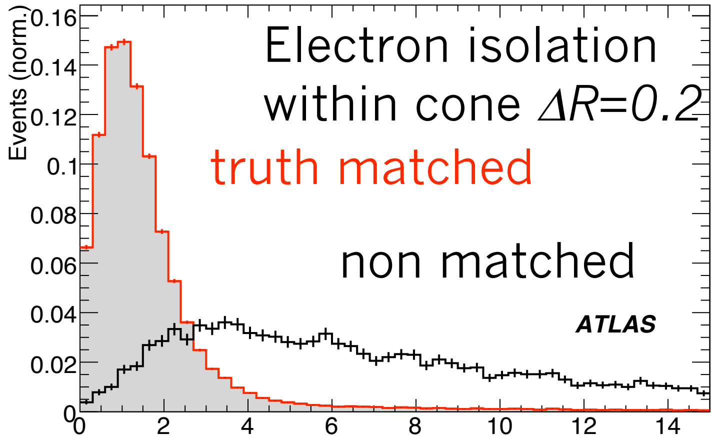
- Adding b-tagging
  - Using IP3D+SV1 tagger @ ε_b~63% and R_u~250
  - Purity ~ x4
  - $\varepsilon \sim x\ 50\%$

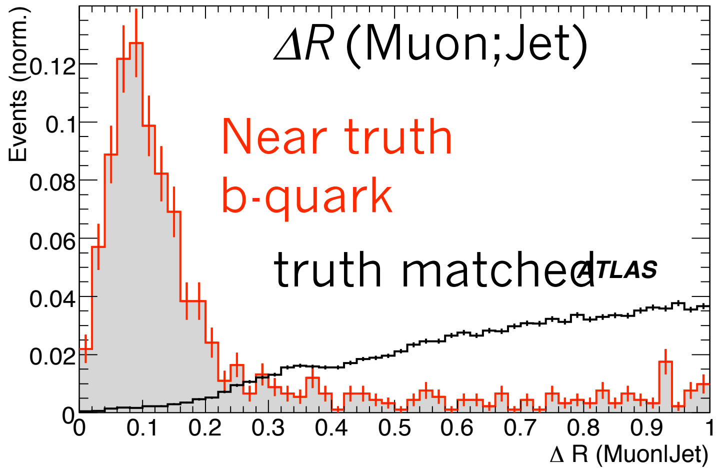




Di-lepton channel

- Number in these studies for $100pb^{-1}$
- High quality isolated leptons
  - Require isolation of energy deposits around electron and muon
  - Additionally require isolation of muons against jets
- **Cut analysis** optimized against best $S/\sqrt{S+B}$:
  - 2 isolated, opposite signed leptons, p_T>20GeV
  - 2 jets p_T>20GeV, no b-tagging
  - $|\eta|$<2.5 for all objects
  - E_T^{Miss}>20 GeV for eμ, E_T^{Miss}>35 GeV for ee and μμ



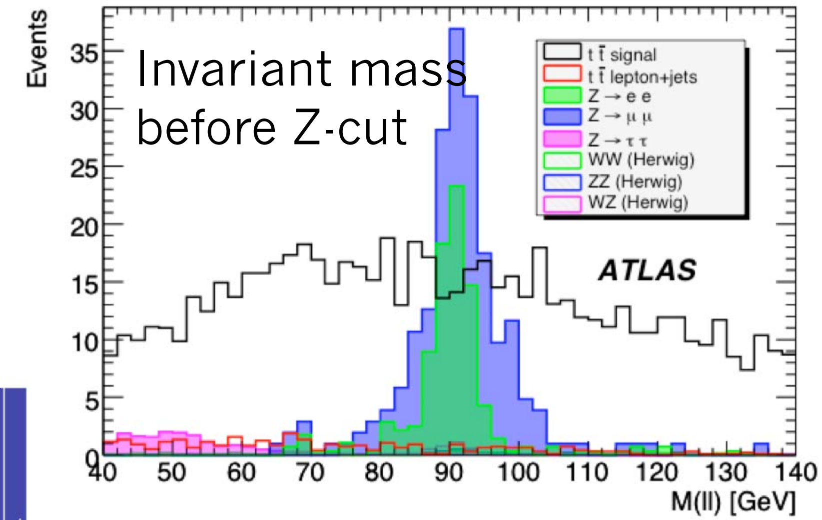


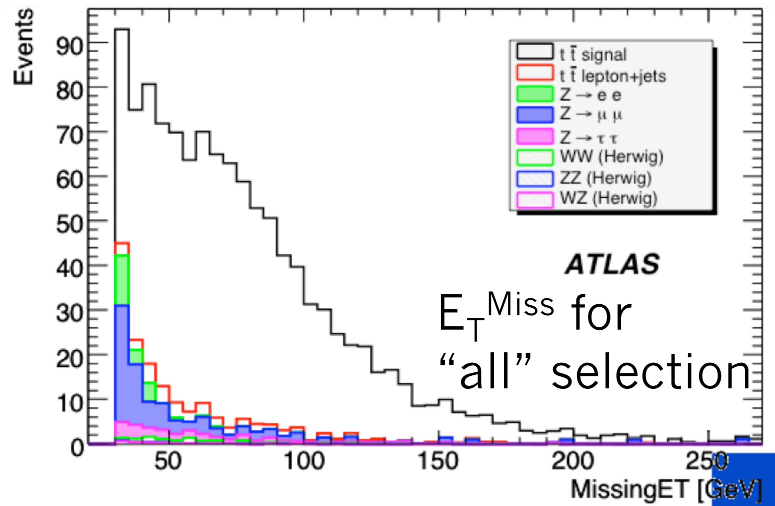
Di-lepton channel(II)

– Additional cut on invariant mass for ee and μμ channel 90±5GeV

	eμ	ee	μμ	all (E_T^{Miss}> 30GeV)
signal	555	202	253	987
ε[%]*	20.7	14.7	18.3	17.9
bkg.	86	36	73	228
S/B	6.3	5.6	3.4	4.3

*efficiency including leptonic tau decay





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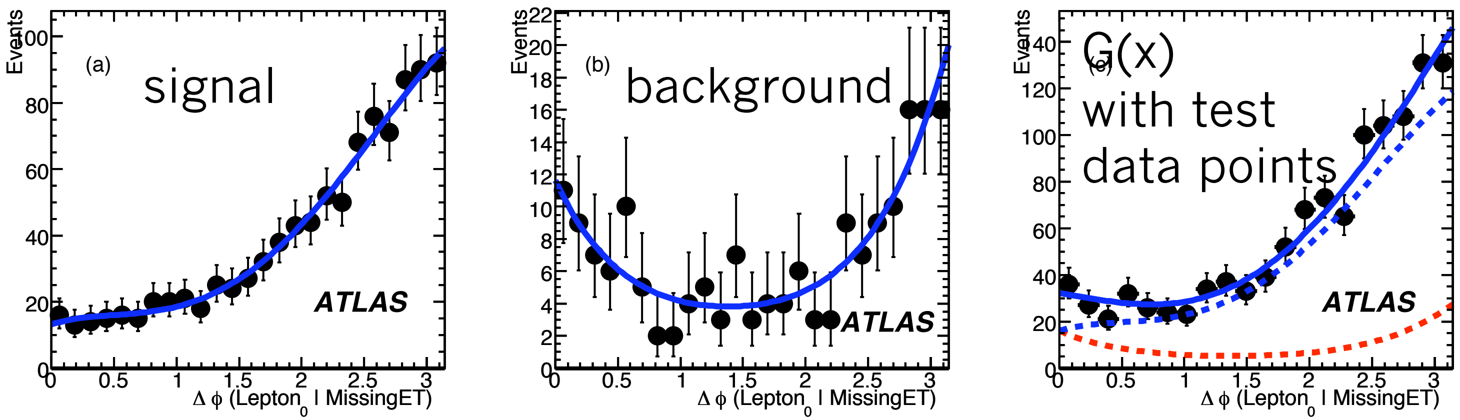
Di-lepton channel(III)

- **Likelihood fit method:**
  - Construct unbinned likelihood with $G(x)=N_s$ signal(x) + N_b bkg(x) and $N_{tot}=N_s+N_b$:

$$L = -\sum_{i=1}^{n} \ln(G(x \mid N_s, N_b)) + N_{tot}$$

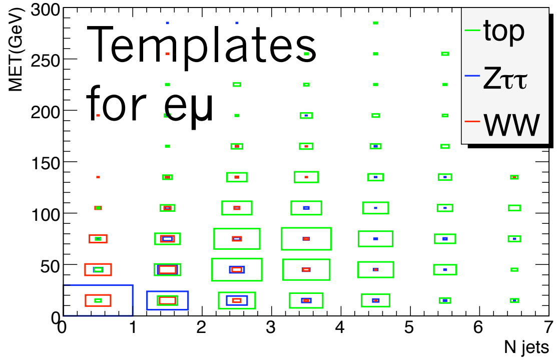
  - Two dimensional G with $\Delta\varphi$ (highest p_T Lep|E_T^{Miss}) and $\Delta\varphi$ (highest p_T Jet|E_T^{Miss}) fitted from MC

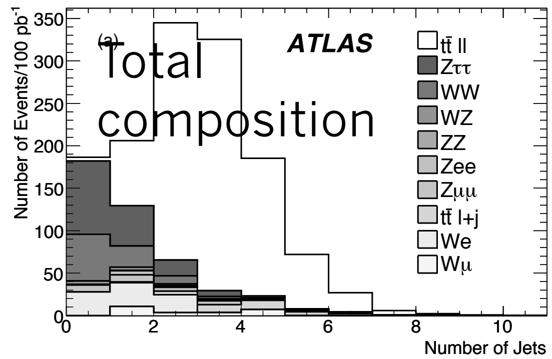
$\Delta\varphi$(highest p_T Lep|E_T^{Miss})

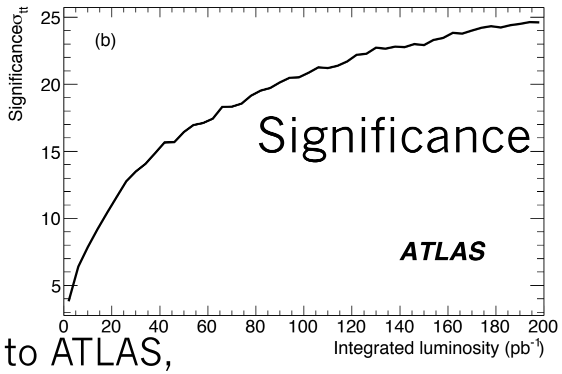


Di-lepton channel(IV)

- **Inclusive template method:**
  - Selection even tighter on electrons, muons must not be aligned with E_T^{Miss} to fight lepton fakes
  - For ee, μμ: Z-veto and E_T^{Miss}>35GeV
  - Binned likelihood in E_T^{Miss} and jet multiplicity space
  - Likelihood as a function of cross sections, acceptance and background normalisation (ten parameters)







Di-lepton channel(V)

- Results:

Δσ/σ [%]	eμ		ee		μμ	
stat. 100pb^{-1}	**4.5**	9.1	**7.6**	16	**7.6**	7.8
JES ±5%	**-2.0** **2.4**	-5.4 7.8	**0.0** 4.1	1.1 **3.9**	**-3.1** 4.7	4.9 **-4.6**
FSR	2.0	**0.2**	2.0	**0.4**	**4.0**	0.0
ISR	**1.1**	1.8	**1.1**	1.8	**1.2**	0.0
PDF (CTEQ)	2.4	2.4	2.9	2.9	2.0	2.0
PDF(MRST)	0.9	0.9	1.1	1.1	0.7	0.7
syst. +	**4.1**	8.6	5.5	**4.5**	**6.6**	8.2
syst. -	**-3.1**	-6.2	-2.9	**-0.3**	-3.7	**-2.1**

↑ cut and count ↑ likelihood fit

Cut and count: $\Delta\sigma/\sigma$ **=(4(stat)** $^{+5}_{-2}$**(syst) ±2(pdf) ±5(lumi))%**

Likelihood fit: $\Delta\sigma/\sigma$ **=(4(stat)** $^{+8}_{-5}$**(syst) ±2(pdf) ±5(lumi))%**

Incl. template: $\Delta\sigma/\sigma$ **=(5(stat) ±4(syst) ±2(pdf) ±5(lumi))%**

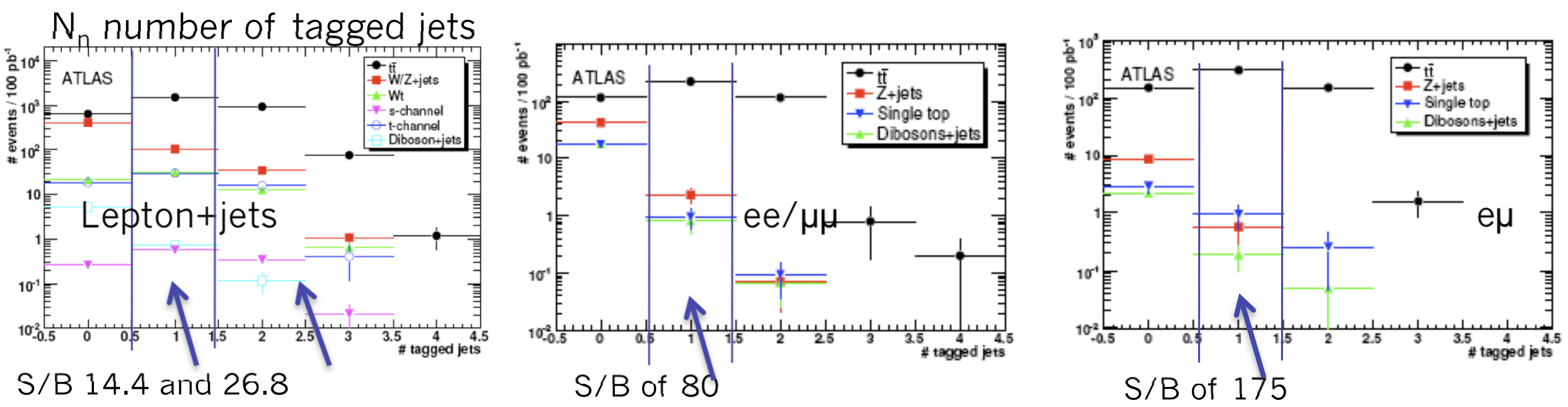
Likelihood method

- Tag counting method
  - Simultaneous measurement of b-tagging efficiency and cross section in lepton+jets and di-lepton channel
  - Count events with 0,1,2... tagged b-jets, c-jets and light jets in MC
  - extract expectation on number N_n of tagged depending of tagging efficiency and cross section

$$< N_n >= $$
$$(L \cdot \sigma_{t\bar{t}} \cdot A_{pre-tag}) \cdot \Sigma_{i,j,k} F_{i,j,k} \Sigma_{combi.} A_i^{i'} \cdot \epsilon_b^{i'} \cdot (1-\epsilon_b)^{i-i'} \cdot A_j^{j'} \cdot \epsilon_c^{j'} \cdot (1-\epsilon_c)^{j-j'} \cdot A_k^{k'} \cdot \epsilon_l^{k'} \cdot (1-\epsilon_l)^{k-k'}$$

  - In practise use
    - 1,2,3 tagged jets and fix ε_l in lepton+jets channel
    - 1,2 tagged jets and fix ε_l and ε_c in di-lepton channel

Likelihood method (II)



- Correlation between tags ~8.8•10^{-4} results in 0.2% systematic error
- Background uncertainty is taken as 100% resulting in 4.8% resp. 0.4% for lepton+jets and di-lepton
- Largest uncertainty from ISR/FSR 8.9% resp. 4%

lepton+jets: $\Delta\sigma/\sigma$**= (2.4(stat) $^{+12.4}_{-14.4}$(sys) ±2.8(pdf) ±5(lumi))%**

di-lepton: $\Delta\sigma/\sigma$**= (4.8(stat) $^{+6.6}_{-7.2}$(sys) ±2.8(pdf) ±5(lumi))%**

Towards first data

- Now exercise Data driven methods:
  - Tag and probe:
    - Clean selection of tag events (e.g. Z events)
    - Trigger efficiencies
    - Trigger turn-on curves
    - Compare MC lepton-ID efficiencies with efficiencies in data
  - Background estimation from data
    - Shapes and tails of Z events
    - Overcome MC and theoretical uncertainties on e.g. W+jets cross section
  - Fake rates from data
    - Directly measure in QCD events
    - Matrix method

Conclusion

- For first data we have covered the most promising channels
  - cut and count analysis
  - elaborate methods such as likelihood analysis are also available

lepton+jets

Cut and count: $\Delta\sigma/\sigma$ **= (3(stat) ±16(sys) ±3(pdf) ±5(lumi))%**

Likelihood method: $\Delta\sigma/\sigma$ **= (7(stat) ±15(sys) ±3(pdf) ±5(lumi))%**

di-lepton

Cut and count: $\Delta\sigma/\sigma$ **=(4(stat)** $^{+5}_{-2}$**(syst) ±2(pdf) ±5(lumi))%**

Likelihood fit: $\Delta\sigma/\sigma$ **=(4(stat)** $^{+8}_{-5}$**(syst) ±2(pdf) ±5(lumi))%**

Incl. template: $\Delta\sigma/\sigma$ **=(5(stat) ±4(syst) ±2(pdf) ±5(lumi))%**

- Concentrate on exercise with data driven methods
  - Being used and developed
  - close collaboration with performance groups foreseen