Top quarks in ATLAS: the early days and afterwards

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CERN, May 25th 2009

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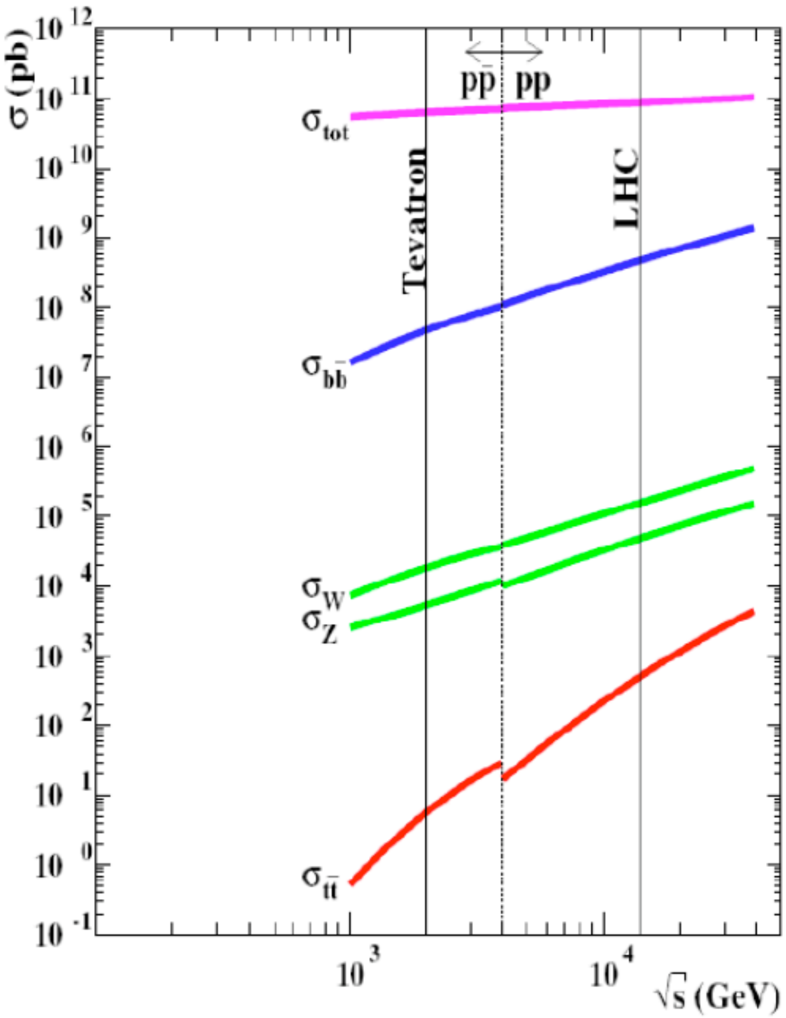
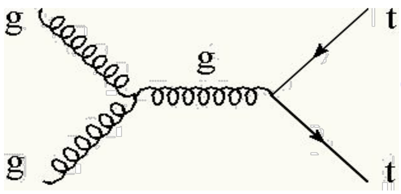
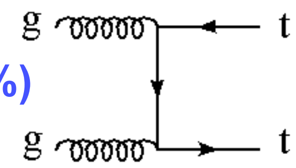
LHC as a top factory

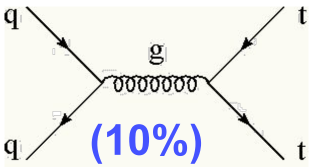


- LHC will produce top quarks in heaps



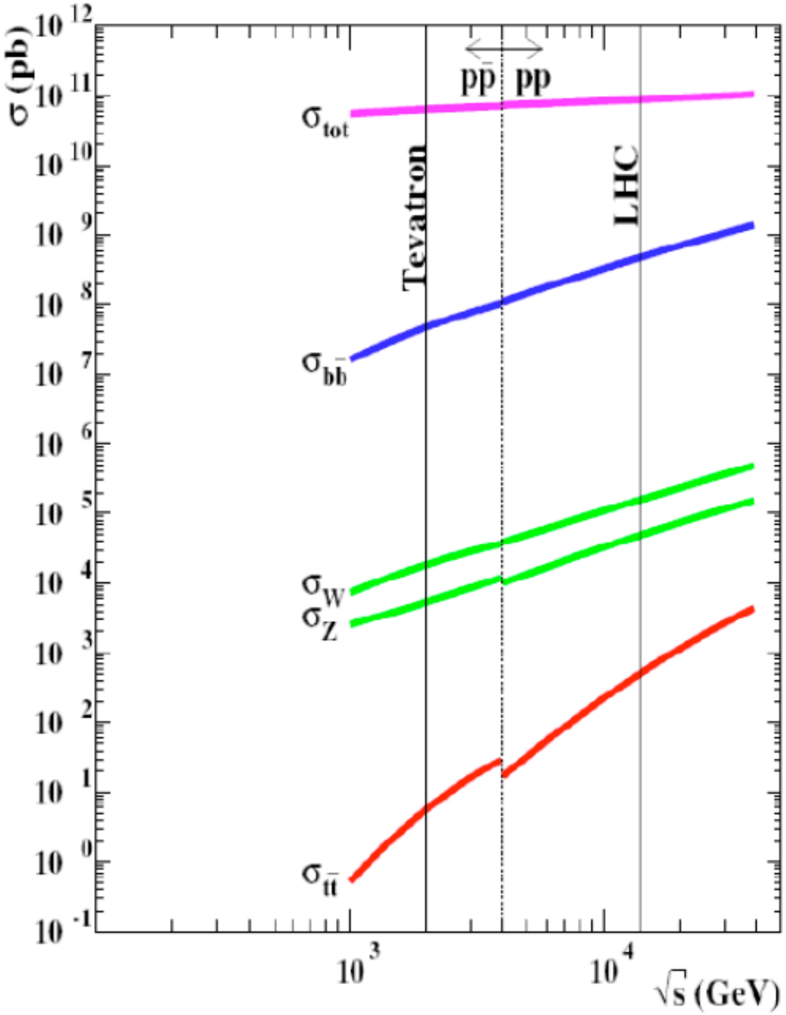
(90%)





  - σ(tt) is about 850 pb (x100 Tevatron) @ 14 TeV
  - rate of tt events is ~ Hz
  - Expect millions per year

LHC as a top factory



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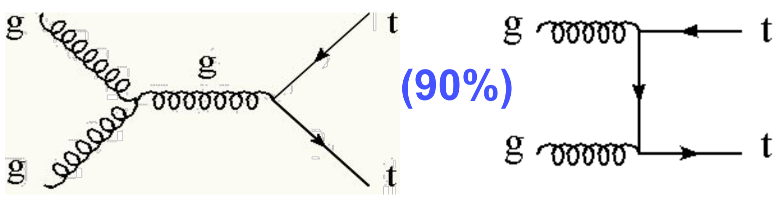
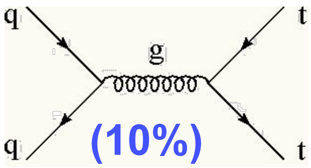




  - σ(tt) is about 850 pb (x100 Tevatron) @ 14 TeV
  - rate of tt events is ~ Hz
  - Expect millions per year

σ(tt) @ 10 TeV ~ ½ σ(tt) @ 14 TeV [**all results here shown for 14 TeV**]

The 2009/10 data sample

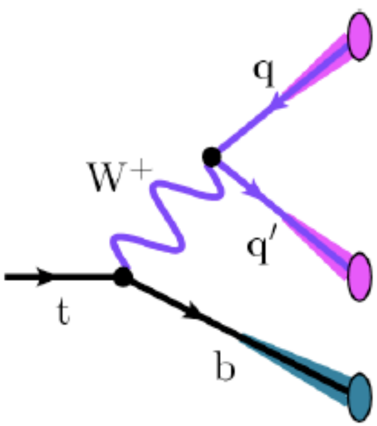
- No winter shutdown in 2009/2010

- Beam energy
  - No intention of long running below 5 TeV/beam
  - Short collision run at injection energy 450 GeV/beam
  - Possibly stop along the way several times for machine commissioning
  - Reach 5 TeV/beam a.s.a.p.

- Data volume
  - Peak Luminosities from 5×10^{31} to 2×10^{32} $cm^{-2}s^{-1}$
  - First 100 days of operation ~ 100 pb^{-1}
  - Next 100 days of operation ~ 200 pb^{-1}

→ Large Uncertainties: somewhere between 100 – 500 pb^{-1} ?

Top reconstruction in LHC



Hadronic (BR≈⅔):

✓ can fully reconstruct W and top momenta

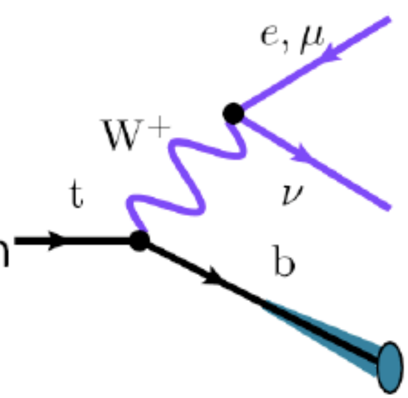
✗ Faked by QCD multijets (esp. heavy flavor)

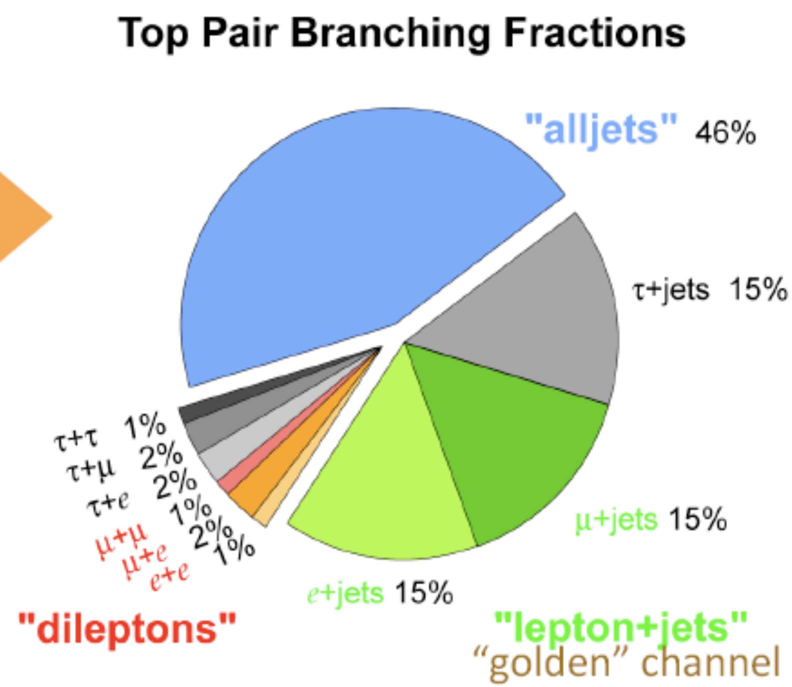
Leptonic (BR≈⅓):

✓ lepton indicates W's charge, helicity

✓ reject QCD via lepton and missing E_T

✗ kinematic info. lost (partly)

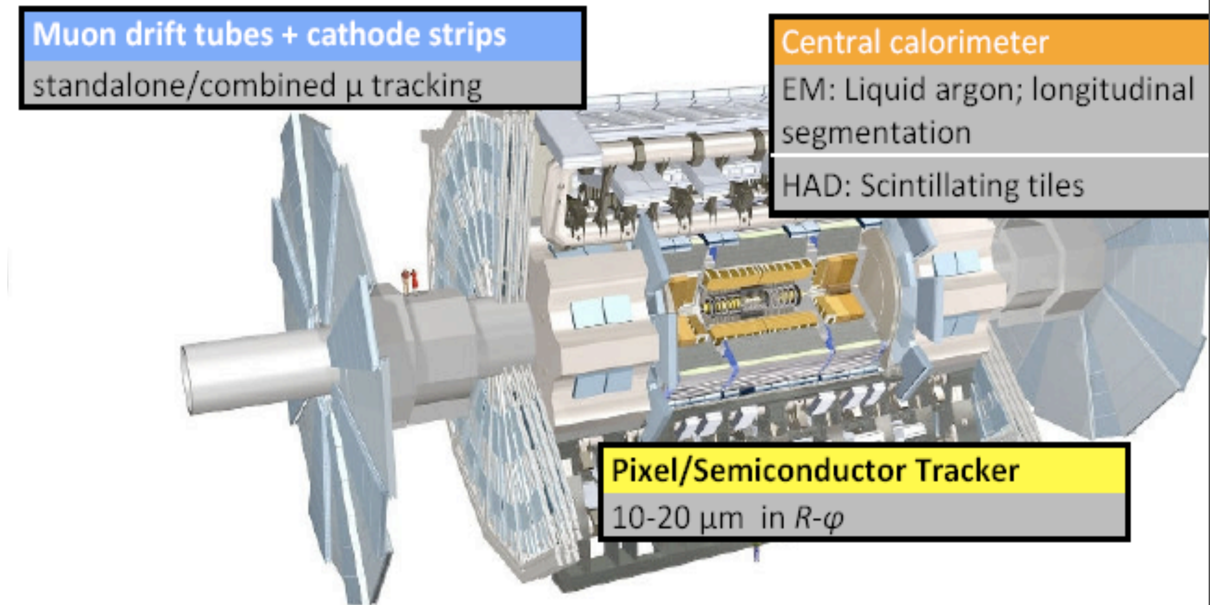




σ_{tt} measurements will validate:

- ★ lepton identification
- ★ jets/missing E_T
- ★ b-tagging

Top reconstruction in ATLAS



Jets	$\|\eta_{jet}\| < 5.0$ (typically: ≤ 2.5 for b-tag or mass resolution)	
Electrons	$\|\eta_{electron}\| \leq 2.5$	*for inner detector track match*
Muon spectrometer	$\|\eta_{muon}\| \leq 2.5$	*for inner detector track match*
Tracks (precision)	$\|\eta_{charged}\| \leq 2.5$	*ATLAS: straw tracker*
Lepton triggers	$\|\eta_{lepton}\| \leq 2.5$; $p_T >$ 20 GeV (e), 20 GeV (μ)	

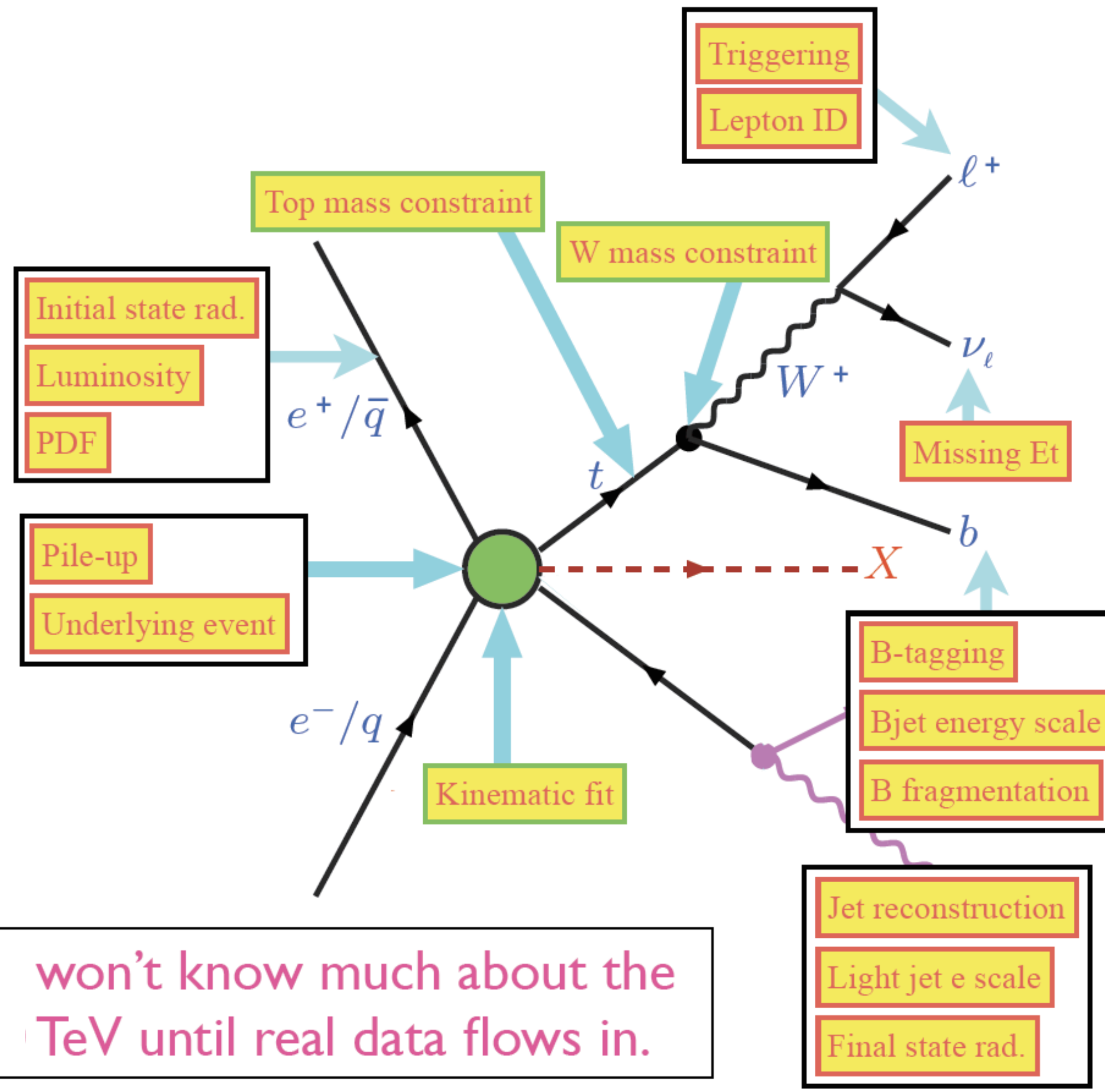
ATLAS: straw tracker

Problems with first data

Several uncertainties affecting our measurements

- Trigger efficiency
- Not “ a regime” detector
- Lepton identification
- Missing E_T calibration
- Light/b-jet JES
- QCD (i.e.ISR/FSR)
- Beam (Pile-up, Lumi)
- PDFs
- Background normalisation

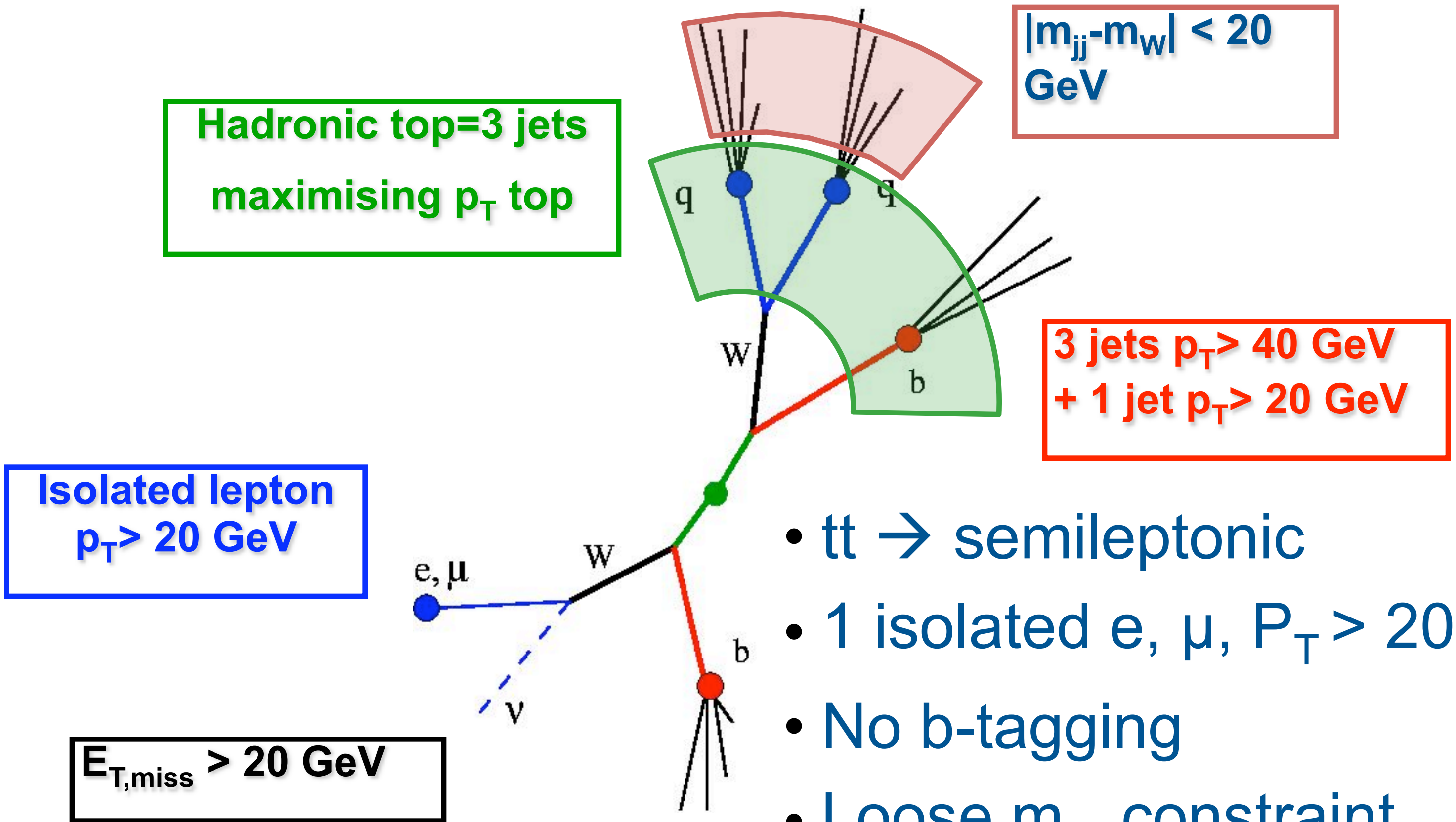
….



won’t know much about the TeV until real data flows in.

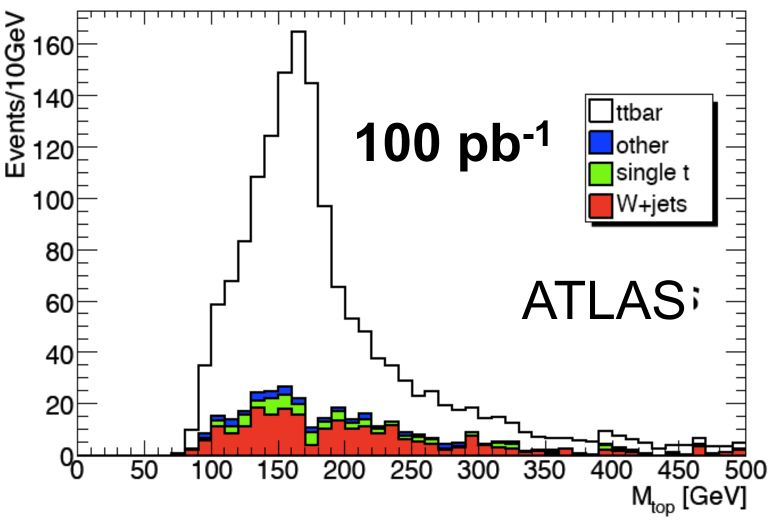
How to see top events on “day 1”

Keep it as simple as possible:

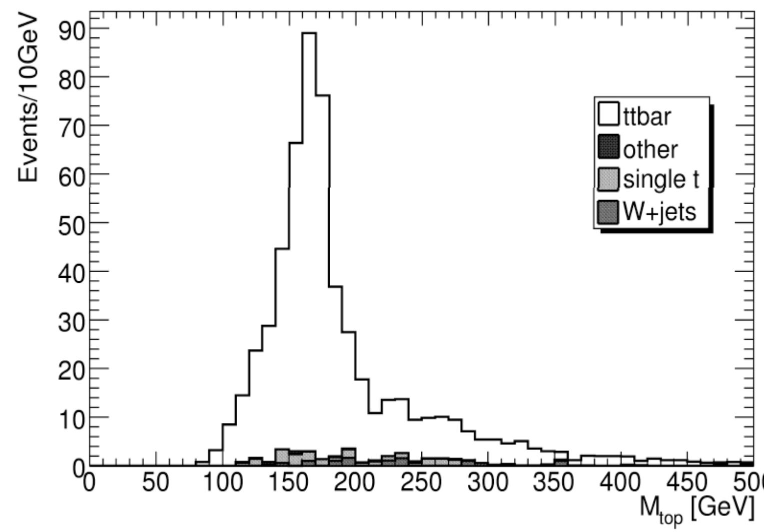


- $t\bar{t}$ → semileptonic
- 1 isolated e, μ, $P_T > 20$ GeV
- No b-tagging
- Loose m_W constraint
- S/B ~ 3.5, ε~ 10%

The first top signal



With b-tag



- Counting method: $\Delta\sigma/\sigma = 3 \oplus 17\%$ (stat $\oplus$ syst)

- More sensitive to background normalization

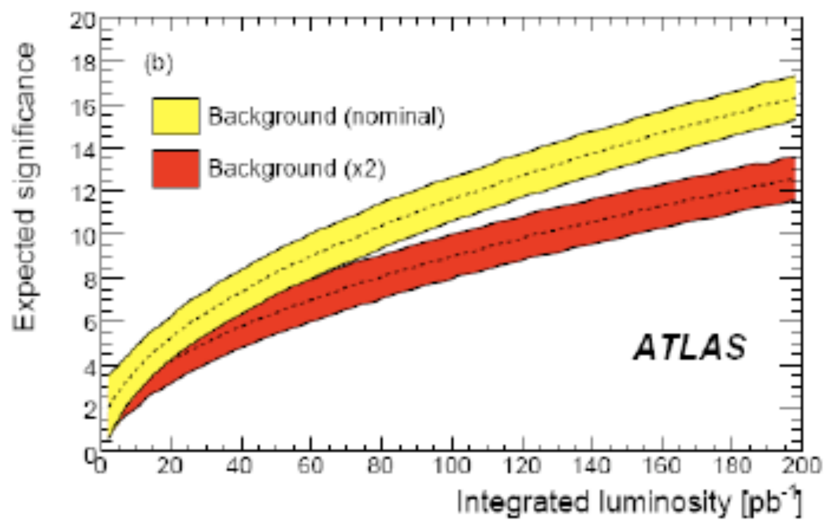
- Likelihood method: $\Delta\sigma/\sigma = 7 \oplus 16\%$ (stat $\oplus$ syst)

- Sensitive to the background shape

The first top signal

Systematics	Likelihood fit		Counting method (elec)	
	Electron	Muon	Default	*W* const.
Statistical	10.5	8.0	2.7	3.5
Lepton ID efficiency	1.0	1.0	1.0	1.0
Lepton trigger efficiency	1.0	1.0	1.0	1.0
50% more *W*+jets	1.0	0.6	14.7	9.5
20% more *W*+jets	0.3	0.3	5.9	3.8
Jet Energy Scale (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 function	14.0	10.4	-	-

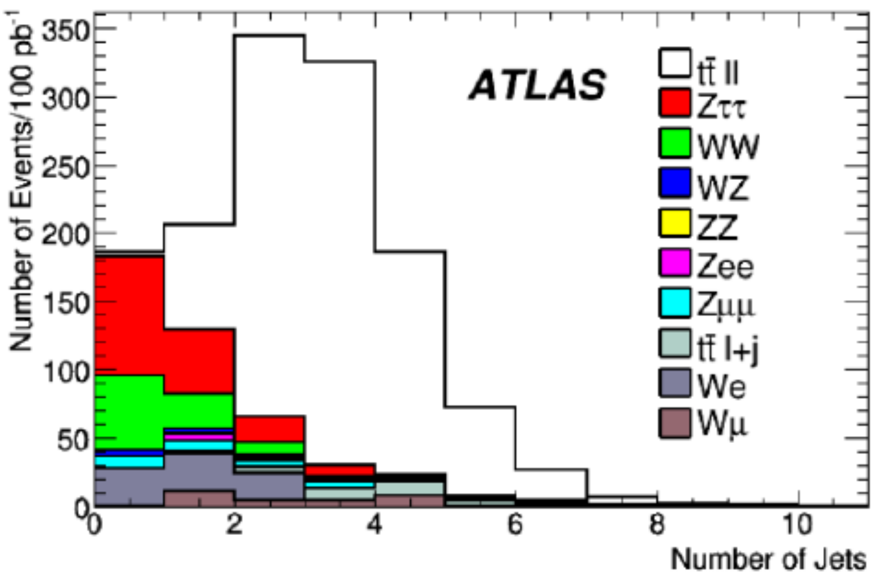
Significance



Di-lepton channel

- 2 leptons wit P_T > 20 GeV
- MET > 25 GeV (30 for ee/μμ)
- At least 2 jets with PT>20 GeV
- Remove m_{ll} ~ 90 GeV (ee/μμ)

6.2% (em), 2.3% (ee), 2.8% (mm)



9% precision

	cut and count method			
$\Delta\sigma/\sigma$ [%]	$e\mu$	ee	$\mu\mu$	all
CTEQ6.1L set	2.4	2.9	2.0	2.4
MRST2001L set	0.9	1.1	0.7	0.9
JES-5%	-2.0	0.0	-3.1	-2.1
JES+5%	2.4	4.1	4.7	4.6
FSR	2.0	2.0	4.0	2.0
ISR	1.1	1.1	1.2	1.1

Systematics include:

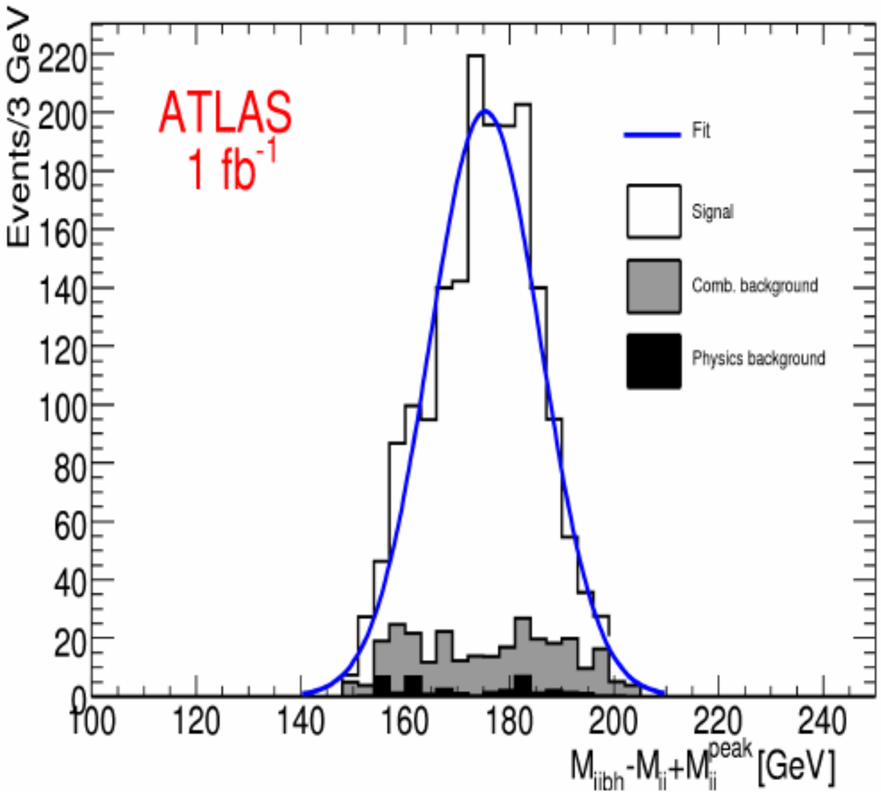
Lepton eff/fake
Rate and theorethical unc.
on assumed cross-section

Cut and Count method: $\Delta\sigma/\sigma = \quad (4(\text{stat})^{+5}_{-2}(\text{syst}) \pm 2(\text{pdf}) \pm 5(\text{lumi}))\%$

Top Mass

- Studies of potential: 14 TeV & 1 fb^{-1}
- Regime of "top factory" → don't worry about acceptances

- Require > 1 or > 2 b-tags
- W with 2 untagged jets
  W-mass window cut
  JES correction using W_{pdg} mass
- Choose b-W assignment
- Improve purity by combinatorial background with additional cuts
- Reconstructed M_{top} as bjj mass and fit with Gaussian+polinomial



M_{top} = 175.3 ± 0.3 GeV (stat)

•

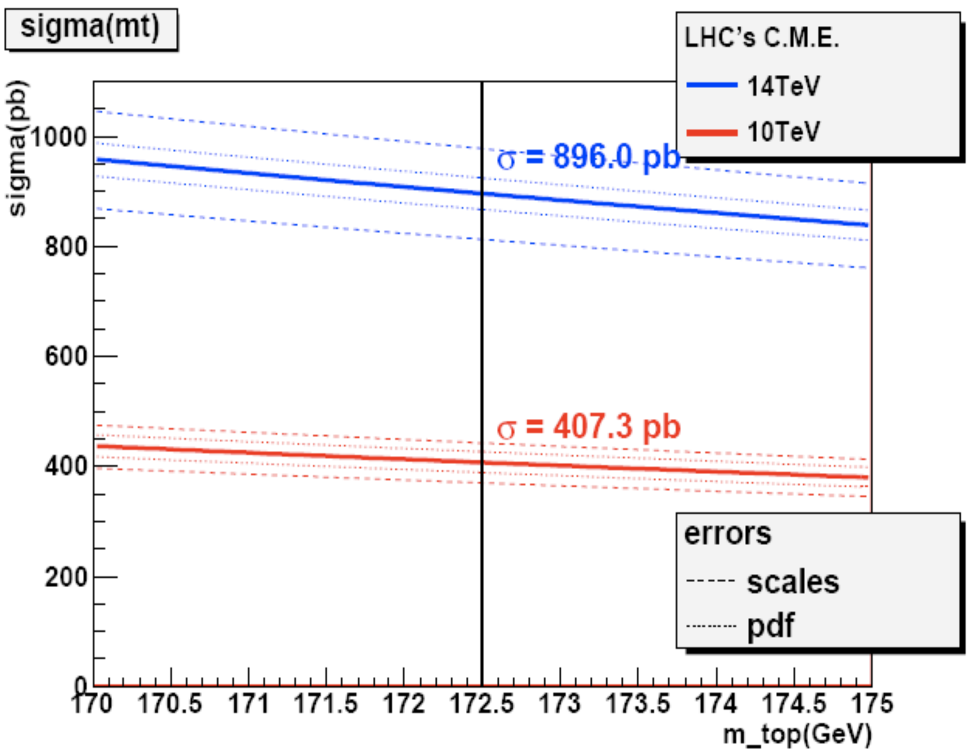
Systematics

Systematic uncertainty	χ^2 minimization method	geometric method
Light jet energy scale	0.2 GeV/%	0.2 GeV/%
b jet energy scale	0.7 GeV/%	0.7 GeV/%
ISR/FSR	$\simeq$ 0.3 GeV	$\simeq$ 0.4 GeV
b quark fragmentation	$\leq$ 0.1 GeV	$\leq$ 0.1 GeV
Background	negligible	negligible
Method	0.1 to 0.2 GeV	0.1 to 0.2 GeV

- Systematics dominates (JES)
- ΔM_{top} =1 to 3,5 GeV if JES 1-5%

At 10 TeV

Numbers from Stefano Frixione et al. [arXiv:0804.2800] NLO+NLL, CTEQ6M, $m_{top} = 172.5 GeV$



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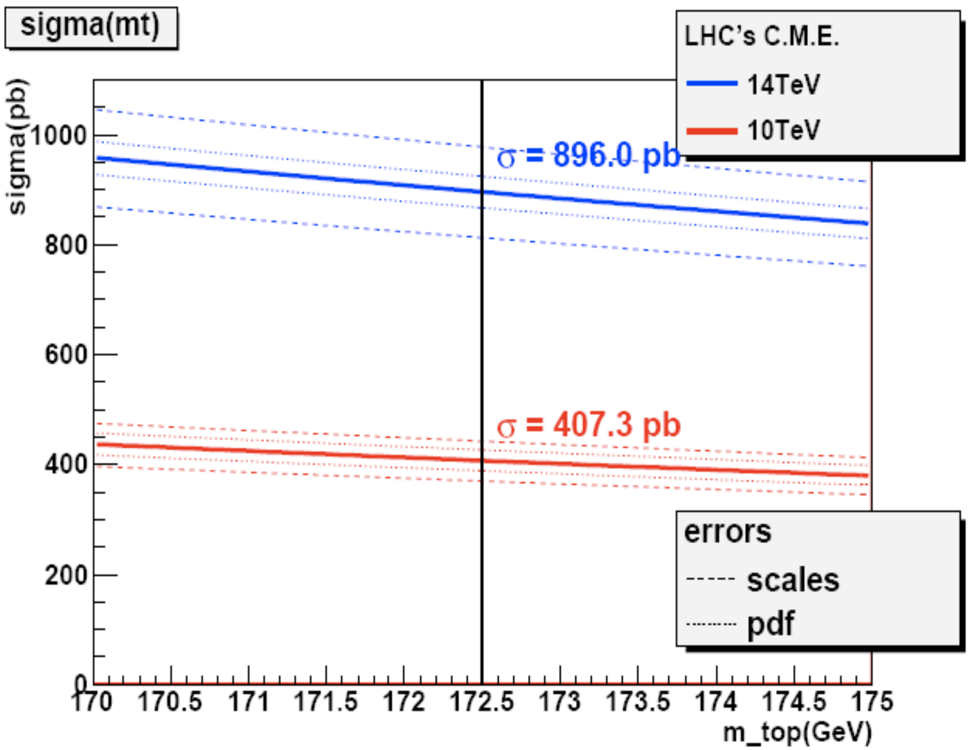
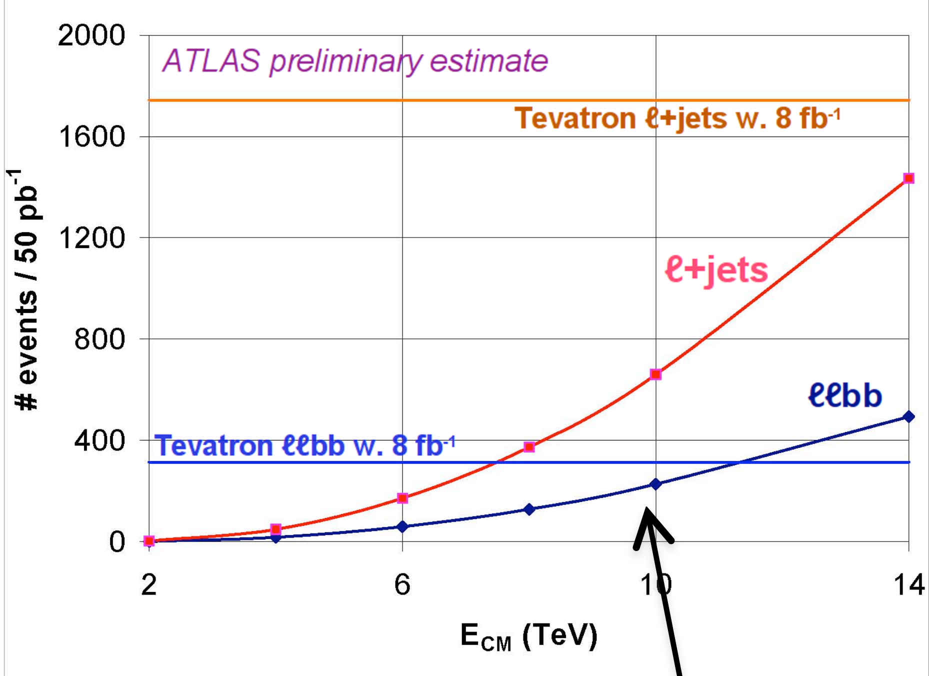
At ~200 pb^{-1} more top-quarks than the Tevatron ....





ATLAS input to LHC Chamonix 2009 meeting (2-6 February 2009)

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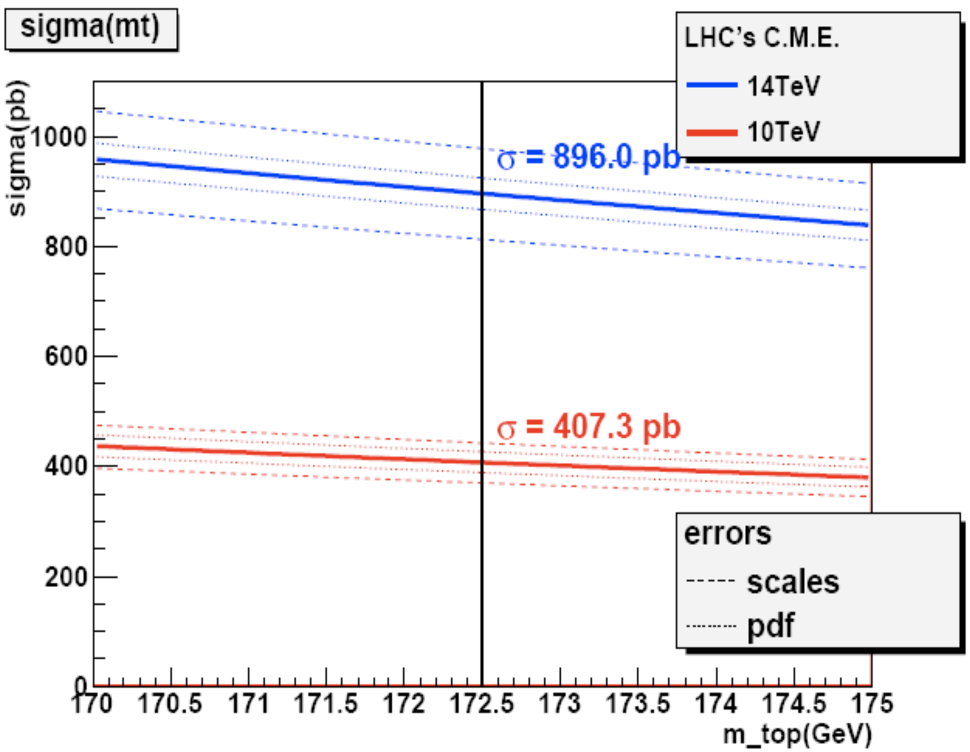
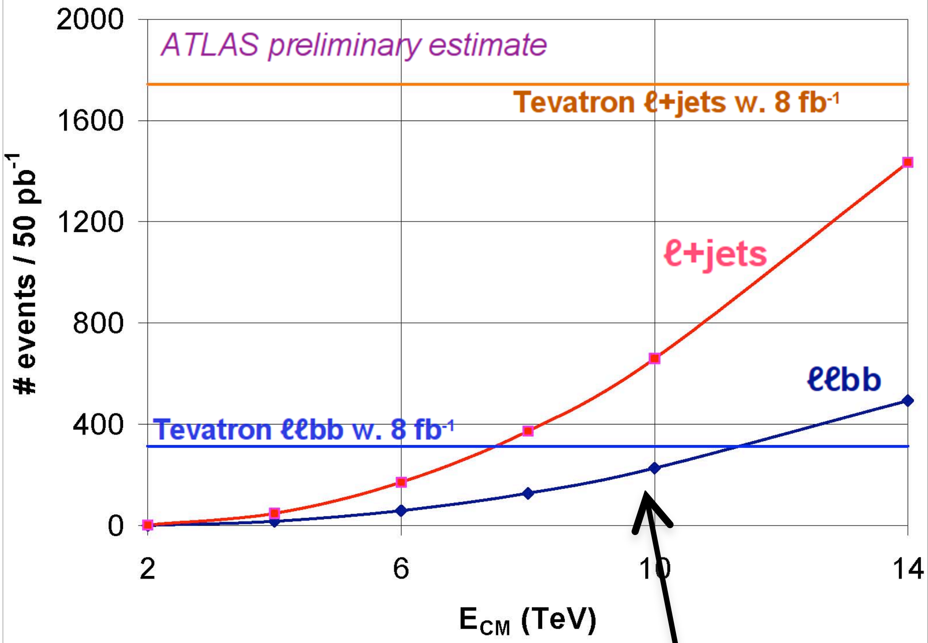


At ~200 pb^{-1} more top-quarks than the Tevatron ....

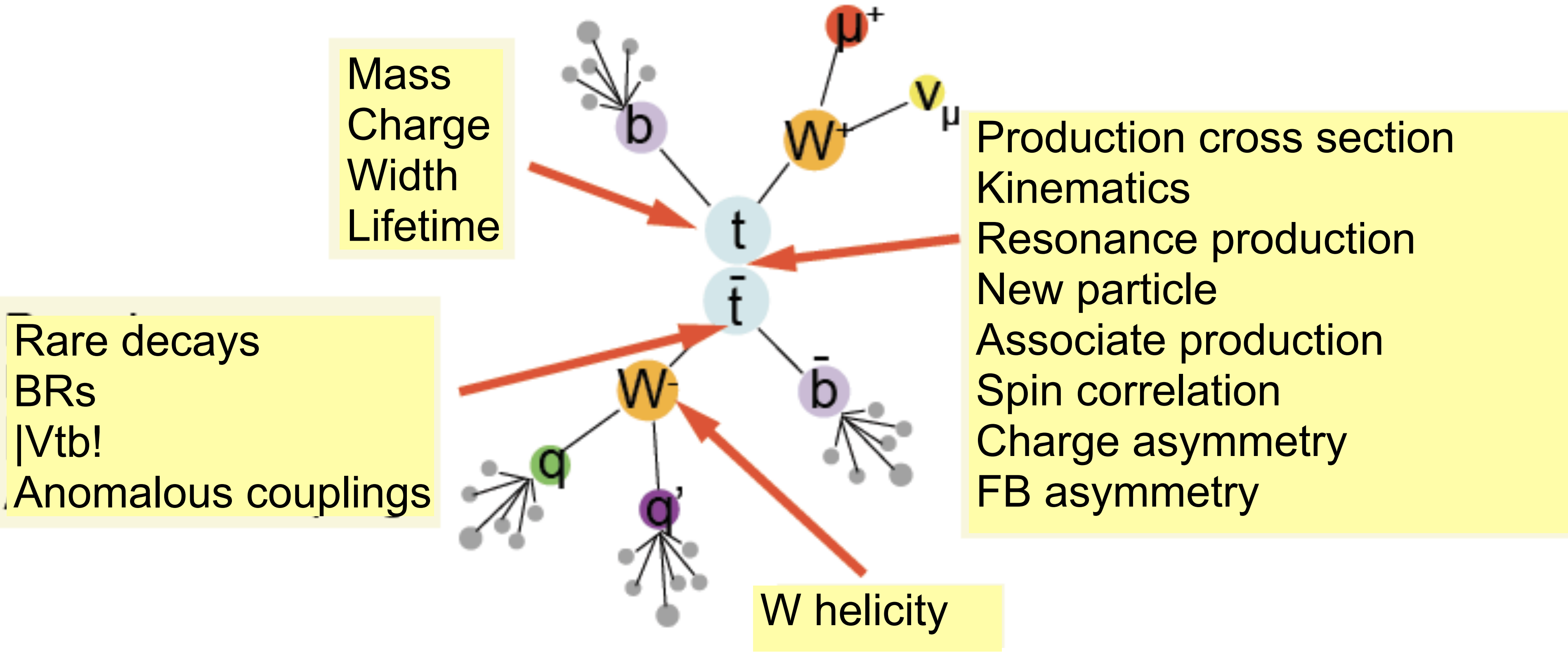
..But background does not scale as top!!!



ATLAS input to LHC Chamonix 2009 meeting (2-6 February 2009)

Top properties

- Top quark provides various handles for New Physics



- Examples for unusual production and rare decays

ttbar mass

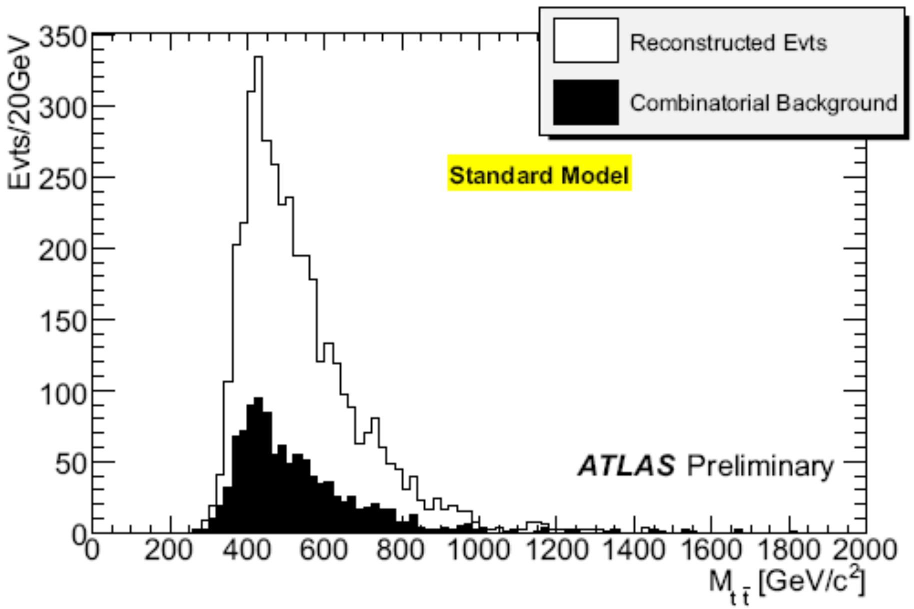
- Theory provides candidates for ttbar resonances
  - Massive Z-like bosons in
  - Kaluza Klein excited states
  - Axigluons
  - Massive gluons
  - Narrow leptophobic Z’ in topcolor models

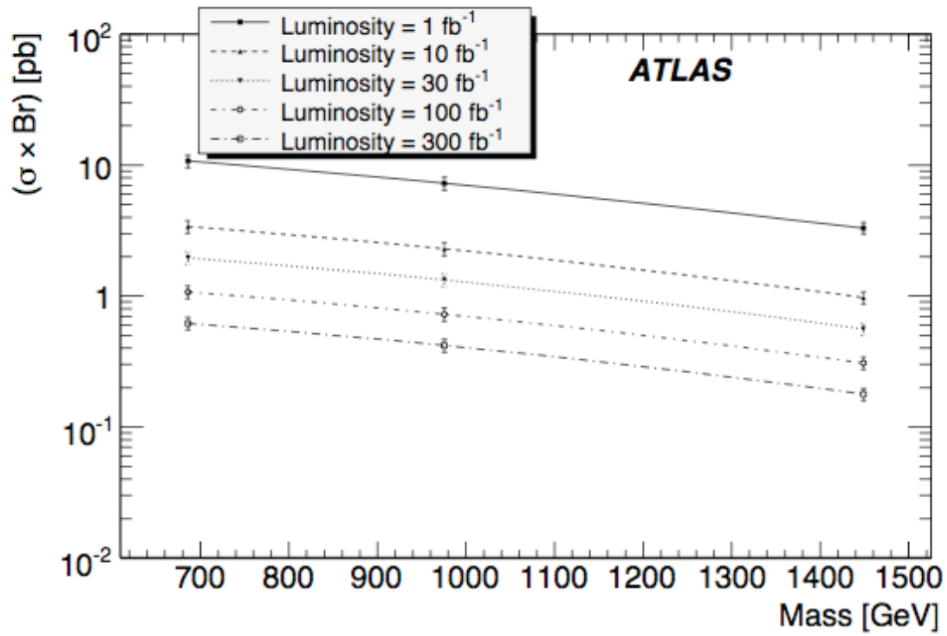
- Narrow resonances (independent of theory) should be visible as peak in invariant mass spectrum of ttbar pairs.

- The differential cross section as a function of the invariant mass can be calculated.

ttbar mass

- Semileptonic decay channel (>=4 jets, =2 b-tags)
- Purely geometric method to minimise sensitivity to JES
  - closest jets = hadronic W + closest b-jet = hadronic top
  - On leptonic side: for p_z(neutrino) M_W constraint





- Count SM ttbar in mass window twice the detector resolution
- Discovery potential for narrow resonances

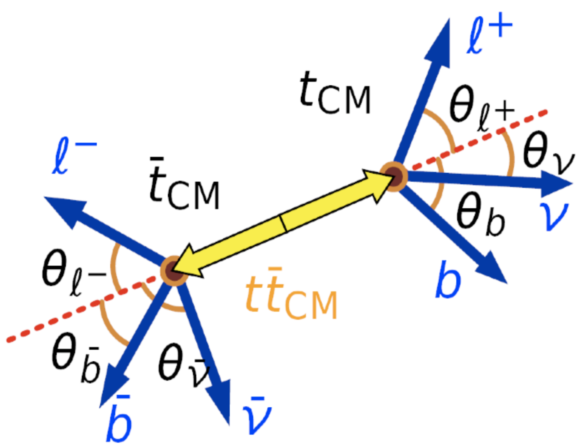
Top spin polarization

- t quark decays before hadronization → spin info conserved
- In SM: top unpolarised, but tt spins correlated
- In new production models: modified correlations

$$\frac{1}{N}\frac{\delta^2 N}{\delta\cos\theta_1 \delta\cos\theta_2} = \frac{1}{4}(1 - A|\alpha_1\alpha_2|\cos\theta_1\cos\theta_2)$$

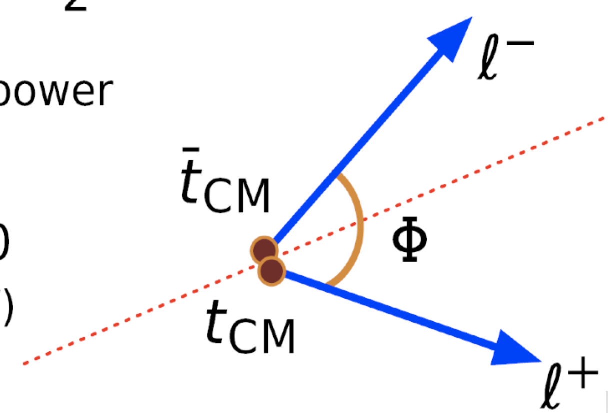
$$A = \frac{N_{same} - N_{opp}}{N_{same} + N_{opp}}$$

$$\frac{1}{N}\frac{dN}{d\cos\Phi} = \frac{1}{2}(1 - A_D|\alpha_1\alpha_2|\cos\Phi)$$



α → spin analysing power

$$A^{SM} = 0.422$$
$$A_D^{SM} = -0.290$$
$(m_{t\bar{t}} < 550\ \text{GeV})$



$\cos\theta$ → angle between the t (in $t\bar{t}$ rest frame) and the t decay product (in t rest frame)

Φ → angle between the two spin analysers (in the corresponding t rest frame)

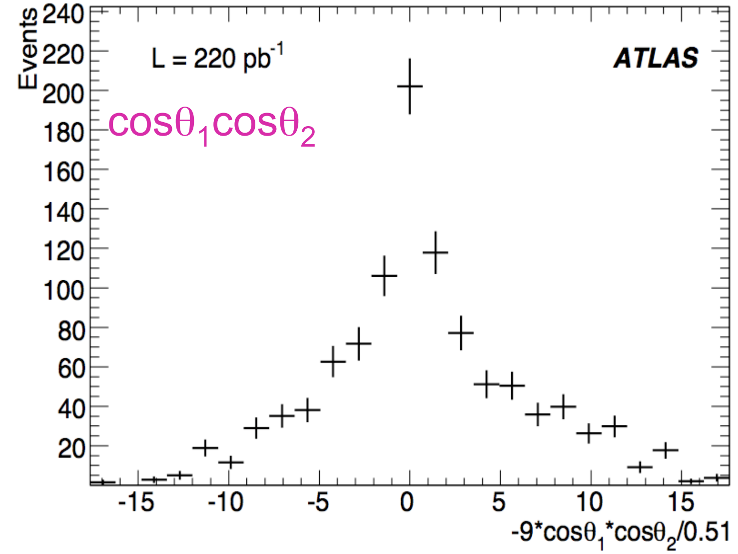
Angular reconstruction and results

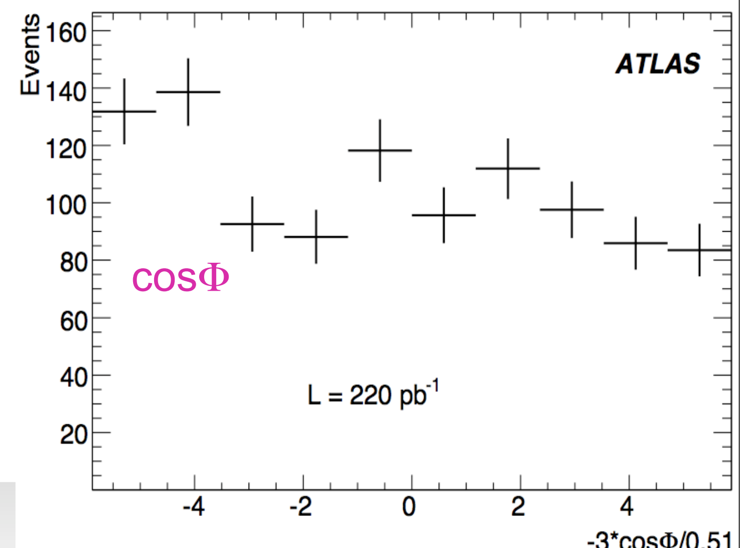
- Light jet pairs which give the mass closest to Mw.
- Pair with b-jet which gives Mjjb closest to Mtop
  - 1D distributions of $\cos\theta_1\cos\theta_2$ and $\cos\Phi$ distributions corrected bin-by-bin back to generator level to extract spin correlation
- Statistical/systematic uncertainties

Measurement	Int L	stat	syst
$A(q\text{-}l) \approx 0.67$	1 fb^{-1}	0,17	0,18
$A_D(q\text{-}l) \approx -0.40$	1 fb^{-1}	0,11	0,09

- Require $O(10\ fb^{-1})$ to observe 5σ
  - Good control of systematics essential
    - B-tagging efficiency, jet energy scale, ISR/FSR

Reconstructed, corrected to generator level

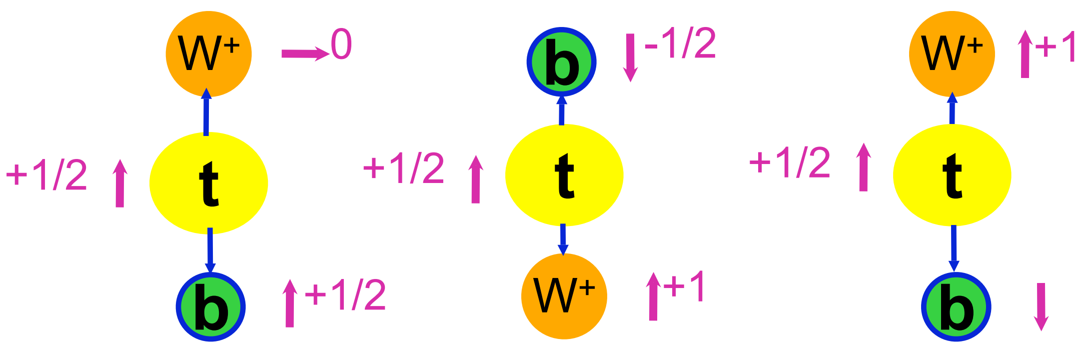


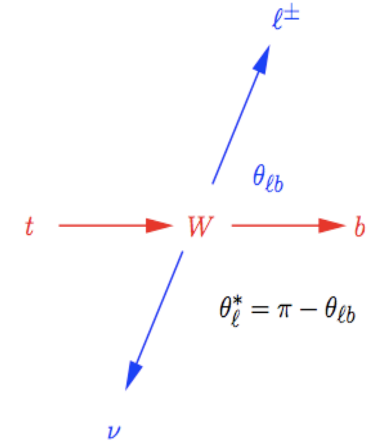


W polarisation in top quark decays

- W produced with different helicities, can be measured by θ_l^*
  - Angle between W in top frame and lepton in W frame

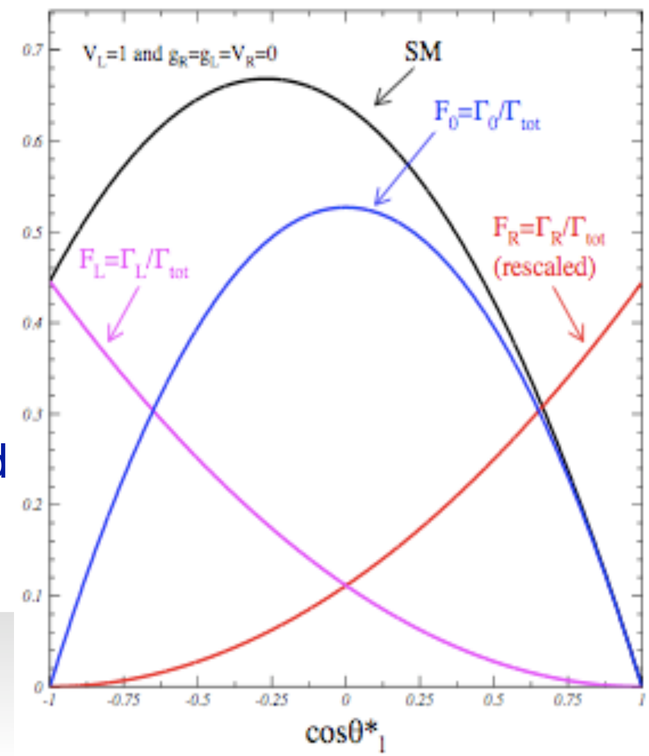
$$\frac{1}{N}\frac{\mathrm{d}N}{\mathrm{d}\cos\theta_\ell^*} = \frac{3}{2}\left[F_0\left(\frac{\sin\theta_\ell^*}{\sqrt{2}}\right)^2 + F_L\left(\frac{1-\cos\theta_\ell^*}{2}\right)^2 + F_R\left(\frac{1+\cos\theta_\ell^*}{2}\right)^2\right]$$





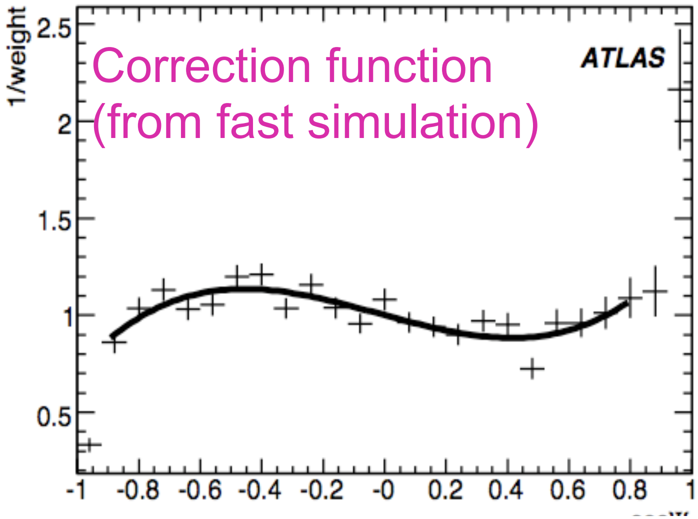
$F_R \neq 0$ only if $m_b > 0$

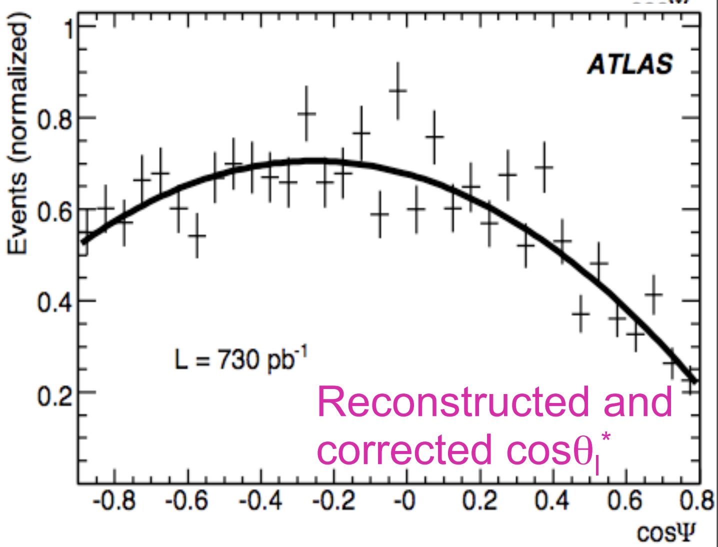
- In SM, $F_0 \approx 0.695$, $F_L \approx 0.304$, $F_R \approx 0.001$
  - Driven by m_t/m_W and V-A structure of weak int.
  - Extensions to SM can result in enhanced F_L and /or F_R
- Try reconstruct the $\cos\theta_l^*$ and fit the fractions of longitudinal, left and right polarised W



W polarisation studies at LHC

- Concentrate on the $\cos\theta_l^*$ method
  - Combined analysis with spin correlations
  - Select events with lepton + ≥4 jets and missing E_T, with two jets b-tagged
  - Expect around 10k events per fb^{-1}
    - Main background from t-tbar decays involving τ (around 10%); single top and W+jets < 5%
  - Reconstruct $\cos\theta_l^*$ distribution and go back to 'generator' level with correction weight function
    - Exclude extremes of distribution where correction is largest
    - Uncertainty / control of correction function is significant source of systematics
  - With enough statistics, can extract F_0 and F_R
    - And hence F_L via $F_0+F_L+F_R=1$





W polarisation results and prospects

- Some representative results and expectations
  - Using $\cos\theta_l^*$, other methods also used

Expt	fb^{-1}	F_0	F_L	F_R
CDF lj	1,9	±0.16		±0.07
D0 lj+ll	2,7	±0.11 ±0.09		±0.06±0.05
ATLAS lj	1	±0.04 ±0.02	0.02 ±0.03	±0.02 ±0.02
CMS lj	10	±0.02 ±0.02		

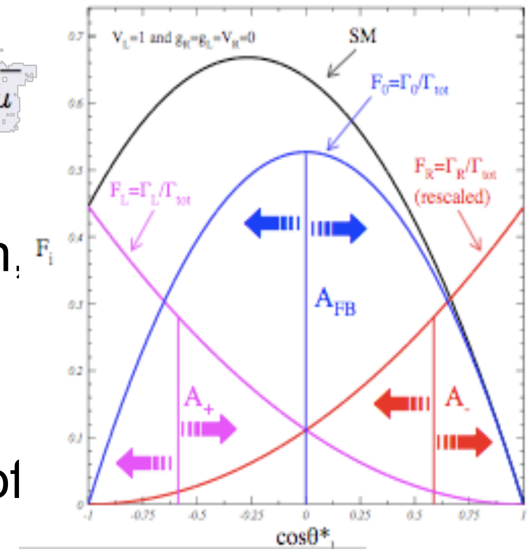
- Tevatron results already providing significant constraints … but statistics limited
  - LHC should give precision measurements (in particular for F_R)
  - Ultimate precision will depend on careful control of systematics

Wtb vertex anomalous couplings

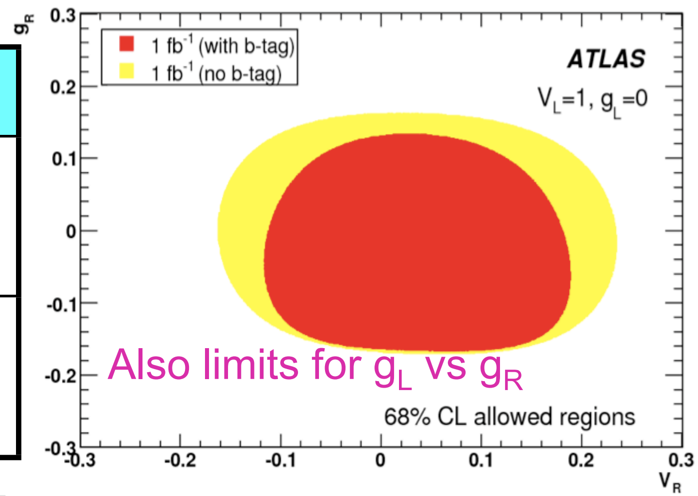
- More general parameterisation of Wtb vertex:

$$\mathcal{L} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}(V_L P_L + V_R P_R)\,t\,W^-_{\mu} - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}(g_L P_L + g_R P_R)\,t\,W^-_{\mu}$$

  - Anomalous couplings sensitive to ratios $\rho_{L,R}=F_{L,R}/F_0$
  - Can also study asymmetries in the $\cos\theta_l^*$ distribution, A_{FB}, A_+ and A_-
    - Each asymmetry insensitive to one parameter F_0,F_L,F_R
  - Measure using corrected $\cos\theta_l^*$ distribution in 1 fb^{-1} of +jet events; statistical and systematic errors:



	ρ_L	ρ_R	A_{FB}	A_+	A_-
No b-tag	±0.05 ±0.27	±0.008 ±0.017	±0.025 ±0.080	±0.024 ±0.074	±0.012 ±0.021
b-tag	±0.05 ±0.16	±0.007 ±0.012	±0.026 ±0.033	±0.028 ±0.052	±0.014 ±0.027



Also limits for g_L vs g_R

  - B-tagging helps reduce systematic errors
- Combined fit for couplings, may include s/t channel single top

Top quark rare decays and FCNC

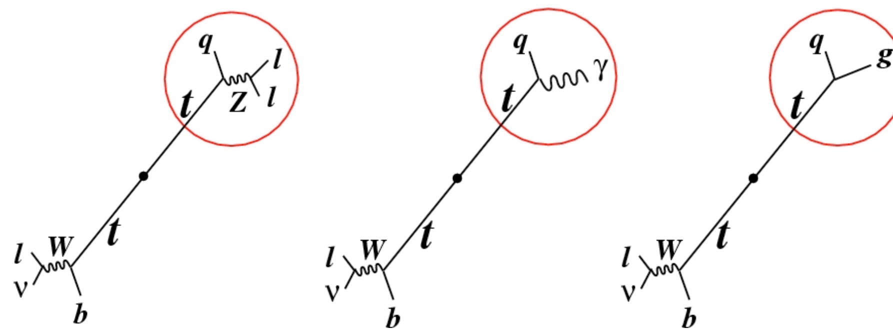
GIM suppressed in the SM

Higher BR in some SM extensions

	SM	2HDM	$\not{R}$ SUSY
$t \to qg$	4.6×10^{-12}	$\sim 10^{-4}$	2×10^{-4}
$t \to q\gamma$	4.6×10^{-14}	$\sim 10^{-6}$	10^{-6}
$t \to Zq$	10^{-14}	$\sim 10^{-7}$	3×10^{-5}

3 channels studied:

- Kinematics reconstruction (no b-tag)
- Minimize X^2 by looping on jet/leptons and scanning P_z(neutrino)



$$\chi^2 = \frac{\left(m_t^{FCNC} - m_t\right)^2}{\sigma_t^2} + \frac{\left(m_{\ell_a \nu j} - m_t\right)^2}{\sigma_t^2} + \frac{\left(m_{\ell_a \nu} - m_W\right)^2}{\sigma_W^2} + \frac{\left(m_{\ell_b \ell_c} - m_Z\right)^2}{\sigma_Z^2}$$

$m_t = 175$ GeV, $\sigma_t = 14$ GeV

$m_W = 80.42$ GeV, $\sigma_W = 10$ GeV

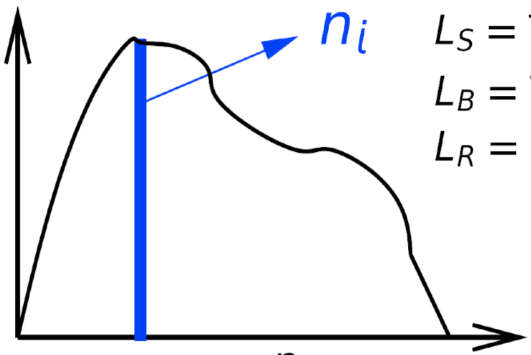
$m_Z = 91.19$ GeV, $\sigma_Z = 3$ GeV

Top quark rare decays and FCNC

after final selection:

$t\bar{t} \rightarrow bWq\gamma$:	
total bkg.	650 ± 66
signal %	7.6 ± 0.2
$t\bar{t} \rightarrow bWqZ$:	
total bkg.	125 ± 56
signal %	7.6 ± 0.2
$t\bar{t} \rightarrow bWqg$:	
total bkg.	19253 ± 359
signal %	2.9 ± 0.1

probabilistic analysis:

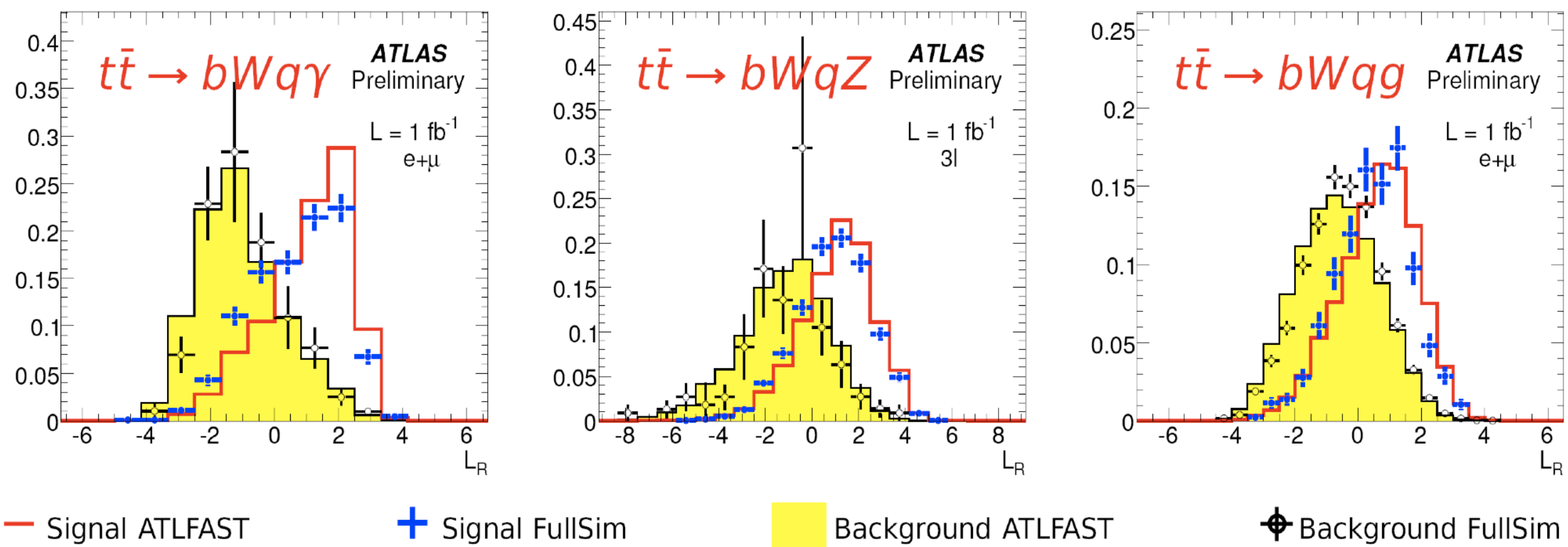


$$L_S = \Pi_{i=1}^{N} P_i^{signal}$$
$$L_B = \Pi_{i=1}^{N} P_i^{back.}$$
$$L_R = \ln(L_S/L_B)$$

no cut on L_R

$$P_i = \frac{n_i}{n_{total}}$$

normalised discriminant variables:



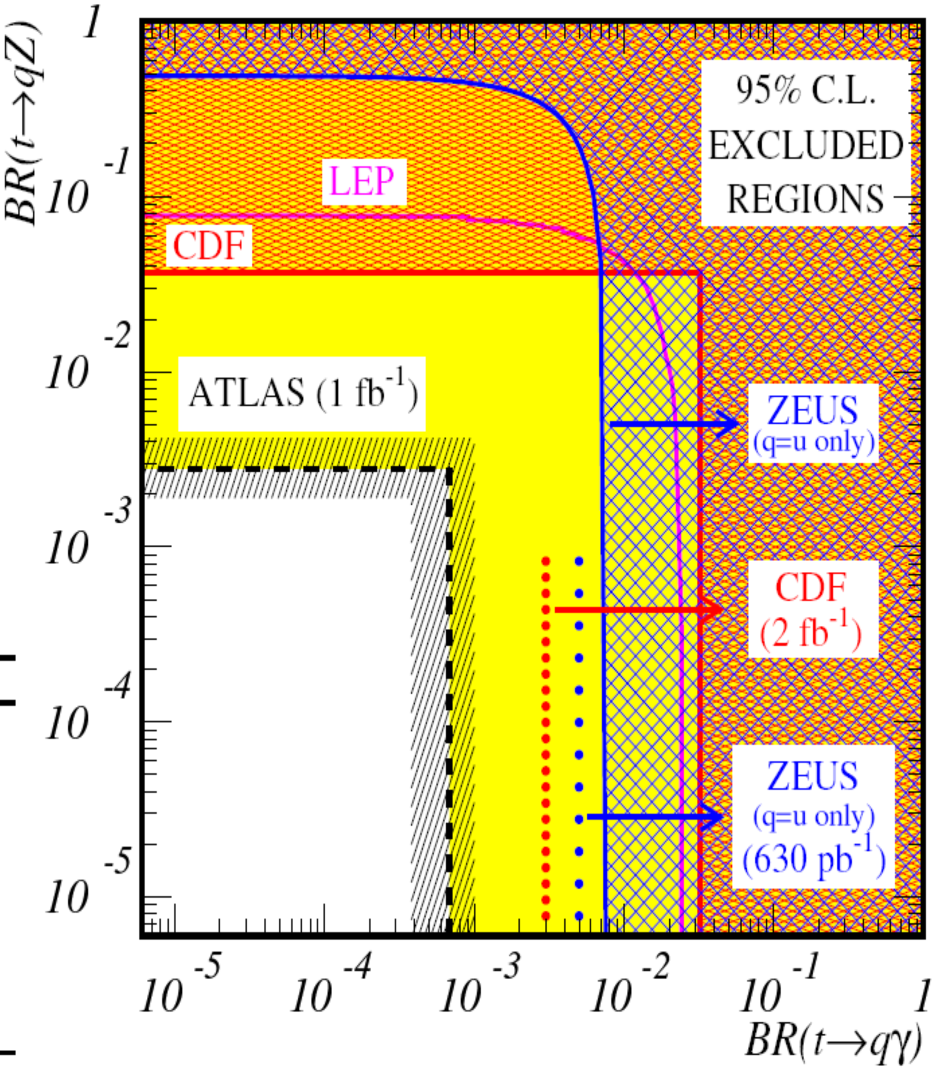
Top quark rare decays and FCNC

expected 95% CL limits:

-1σ	expected	$+1\sigma$
$t\bar{t} \rightarrow bWq\gamma$:		
3.8×10^{-4}	6.8×10^{-4}	1.0×10^{-3}
$t\bar{t} \rightarrow bWqZ$:		
1.9×10^{-3}	2.8×10^{-3}	4.2×10^{-3}
$t\bar{t} \rightarrow bWqg$:		
7.2×10^{-3}	1.2×10^{-2}	1.8×10^{-2}

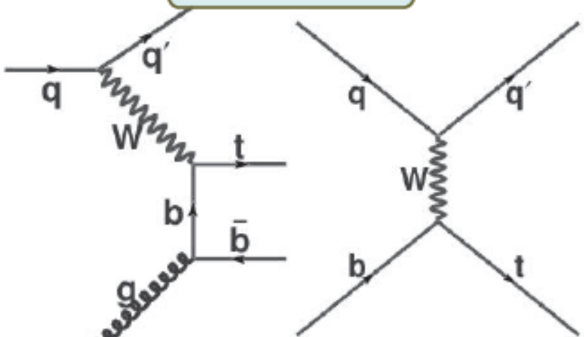
systematic uncertainties:

source	$t \rightarrow q\gamma$	$t \rightarrow qZ$	$t \rightarrow qg$
jet energy calibration	2%	5%	4%
luminosity	10%	6%	10%
top mass	6%	12%	5%
backgrounds σ	7%	12%	15%
ISR/FSR	17%	7%	9%
pile-up	22%	0%	13%
generator	4%	14%	4%
χ^2	4%	7%	9%
total	32%	25%	27%

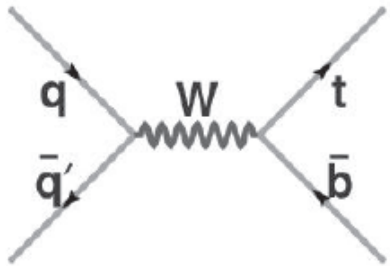


Single top

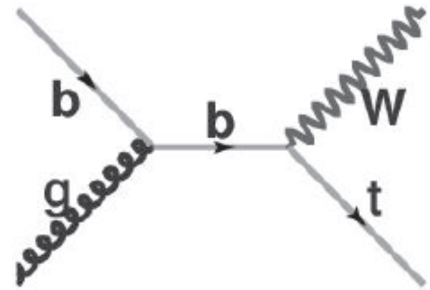
t-channel



s-channel



W+t channel



$$\sigma^{NLO} = 246.6^{+11.8}_{-12.2}\, pb$$

$$\sigma^{NLO} = 10.65^{+1.12}_{-1.02}\, pb$$

$$\sigma^{NLO} = 66 \pm 2\, pb$$

Pre-selection

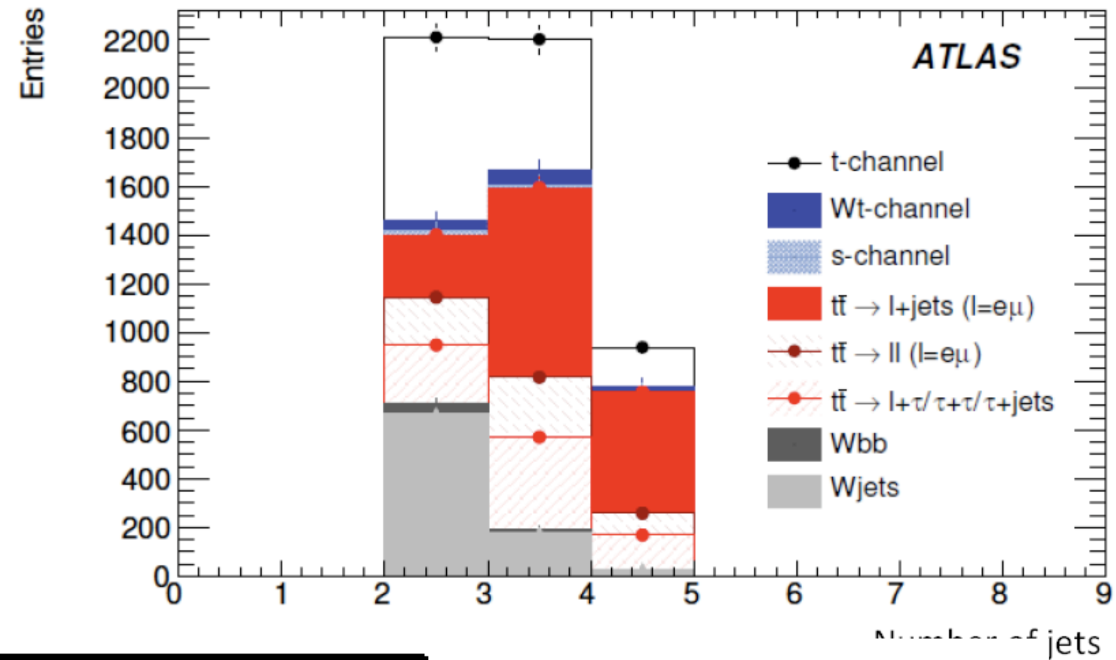
- 1 high P_T isolated lepton in the central region
- At least 2 jets with P_T > 30 GeV
- ≤ 4 jets with P_T > 15 GeV
- Among those jets, at least one has to be b-tagged
- Missing energy > 20 GeV

Measuring single top production

- Interesting SM measurement and BSM constraint

Affected by couplings to new particles like W’ and H-

- Background (mostly ttbar) brings large uncertainties



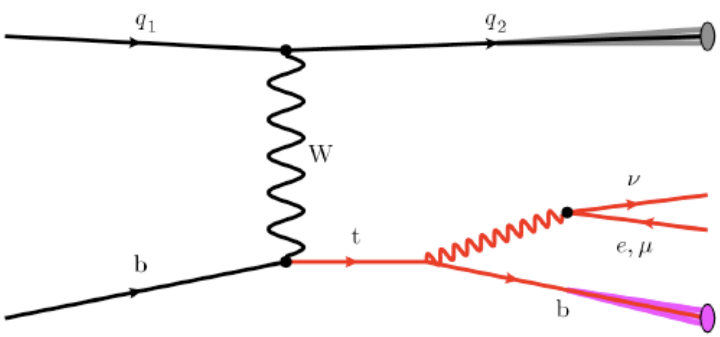
ATLAS projections (summary)		$\Delta\sigma/\sigma$ ($1 fb^{-1}$)		$\Delta\sigma/\sigma$ ($10 fb^{-1}$)	
		stat	*syst*	*stat*	*syst*
t-channel:	246 pb	6%	22%	2%	10%
W+top:	66 pb	21%	48%	7%	19%
s-channel:	11 pb	64%	94%	20%	48%

BDT (t-channel, s-channel)

Likelihood (W+top)

(CMS: similar 10 fb^{-1} results)

V_{tb} from single top (t-channel)



Cut based selection (1 fb^{-1})

- no additional lepton $P_T \geq 10$ GeV
- ≤ 4 jets with $P_T \geq 15$ GeV
- leading light jet |h|>2.5

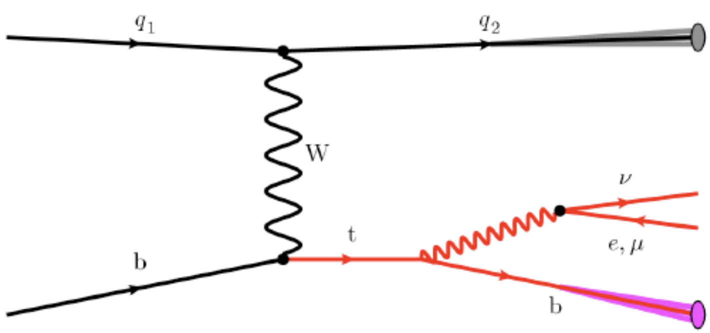
efficiency reduced (÷3) to improve tt rejection (x10)

- accepts 1.8% of signal, S/B=0.37

ATLAS: cut-based, 1 fb^{-1}

Statistics	*5.0%*
MC statistics	6.5%
Luminosity	18.3%
b-tagging	18.1%
Jet energy scale	21.6%
other experimental	2.3%
BG cross section	23%
PDF, ISR/FSR, signal model	16.3 %
Total	**45%**

Vtb from single top (t-channel)



jet $p_T > 30$

trigger lepton;
missing $E_T > 20$

b-tag; $|\eta| < 2.5$
$p_T > 50$

Cut- based selection (1 fb-1)

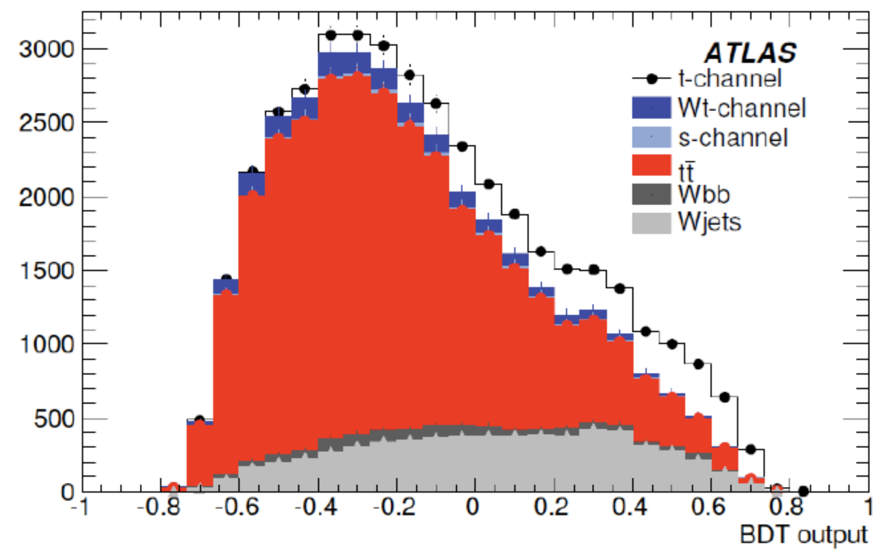
- no additional leptons: pT>10 GeV
- ≤ 4 jets with pT>15 geV

ATLAS: **Boosted Decision Trees**, 1 fb^{-1}

Relax untagged jet η cut

Add >15 variable chosen insensitive to JES

Statistics	*5.7%*
MC statistics	7.9%
Luminosity	8.8%
b-tagging	6.6%
Jet energy scale	9.9%
other experimental	1.8%
BG cross section	8.2%
PDF,ISR/FSR,signal model	9.8%
Total	**23%**



Measure $|V_{tb}|$ to 12% with 1 fb^{-1}

Summary

Observables	Expected Precision
Top quark charge (2/3 versus -4/3)	$\geq 5\sigma$
Spin Correlations:	
A	50%
A_{D}	34%
W-boson Polarisation:	
F_0	5%
F_{L}	12%
F_{R}	0.03
Angular Asymmetries:	
A_{FB}	19%
A_+	11%
A_-	4%
Anomalous Couplings:	
V_{R}	0.15
g_{L}	0.07
g_{R}	0.15
Top quark FCNC decays (95% C.L.):	
$Br(\mathrm{t} \rightarrow \mathrm{q}\gamma)$	10^{-3}
$Br(\mathrm{t} \rightarrow \mathrm{qZ})$	10^{-3}
$Br(\mathrm{t} \rightarrow \mathrm{qg})$	10^{-2}
$t\bar{t}$ Resonances (discovery):	
$\sigma \times Br$ ($m_{\mathrm{t\bar{t}}}$=700GeV)	$\geq$ 11 pb

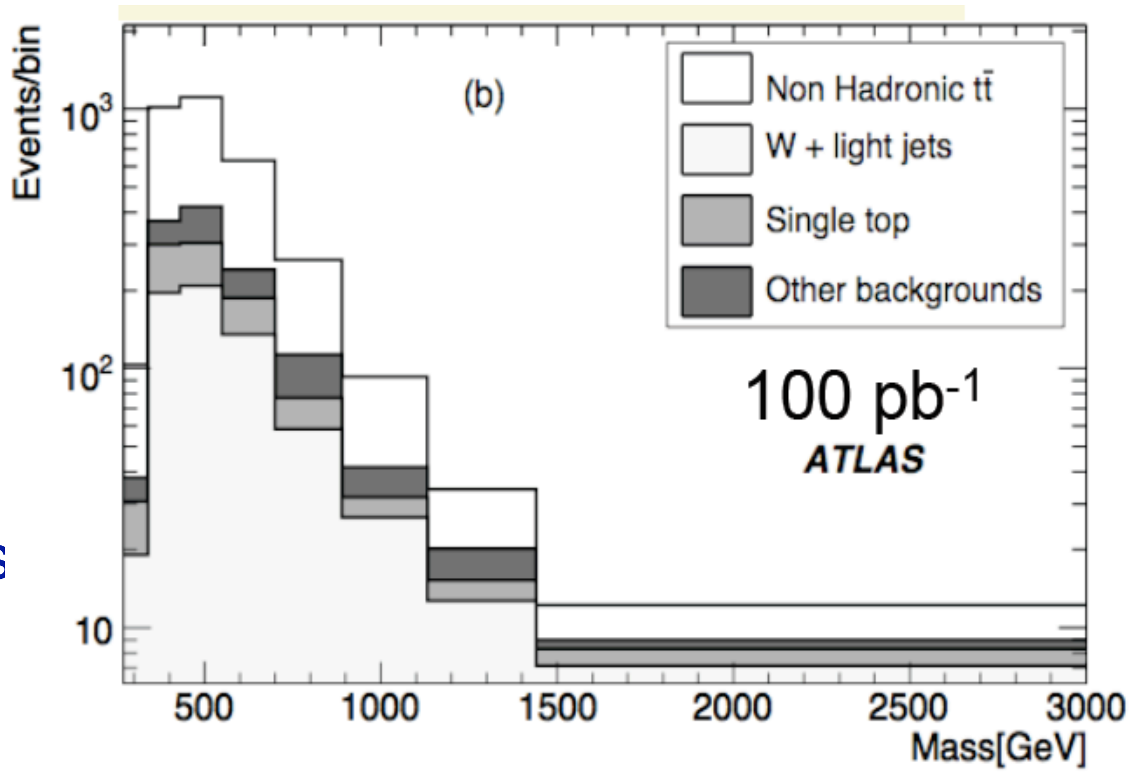
Summary and outlook

- The LHC 'top factory' offers an excellent opportunity for precision studies of top quark properties
  - Top signal can be identified after few tenths of pb-1
  - With 100 pb-1 cross section can be measured with < 20% precision
  - Studies of top spin correlations and the Wtb vertex require good detector understanding and 1-10 fb^{-1} to reach maturity
    - With O(1 fb^{-1}), can substantially improve on Tevatron constraints on W polarisation
    - Start to measure more parameters, add in constraints from single top
    - Will need > 1 fb^{-1} to make unambiguous observation of t-tbar spin correlations
- Most of these studies require full reconstruction of t-tbar
  - Can start to refine techniques, understand resolution and systematics as soon as a significant sample of t-tbar events is recorded and isolated
  - 100-200 pb^{-1} data is certainly enough to make good progress - first year of data will be very valuable

Differential cross section

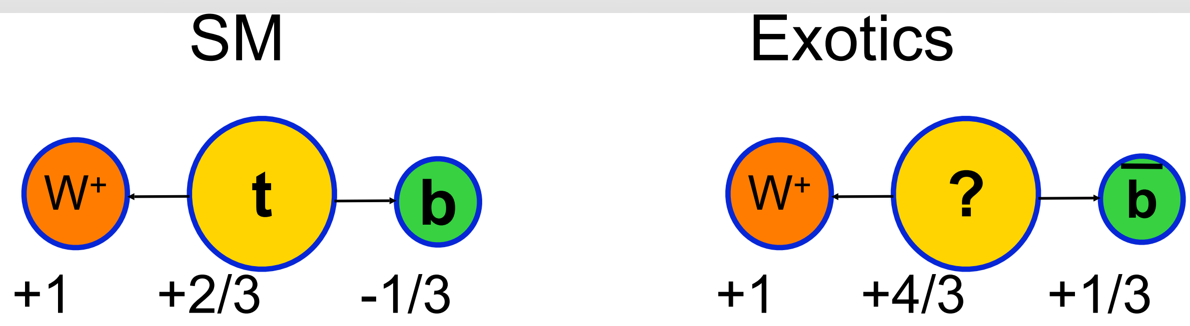
- Semileptonic decay channel (≥ 4 jets)

- Full least squares fit with MW and Mtop constraints OR simple reconstruction with leptonic W (by MW constraints) plus 4 jets

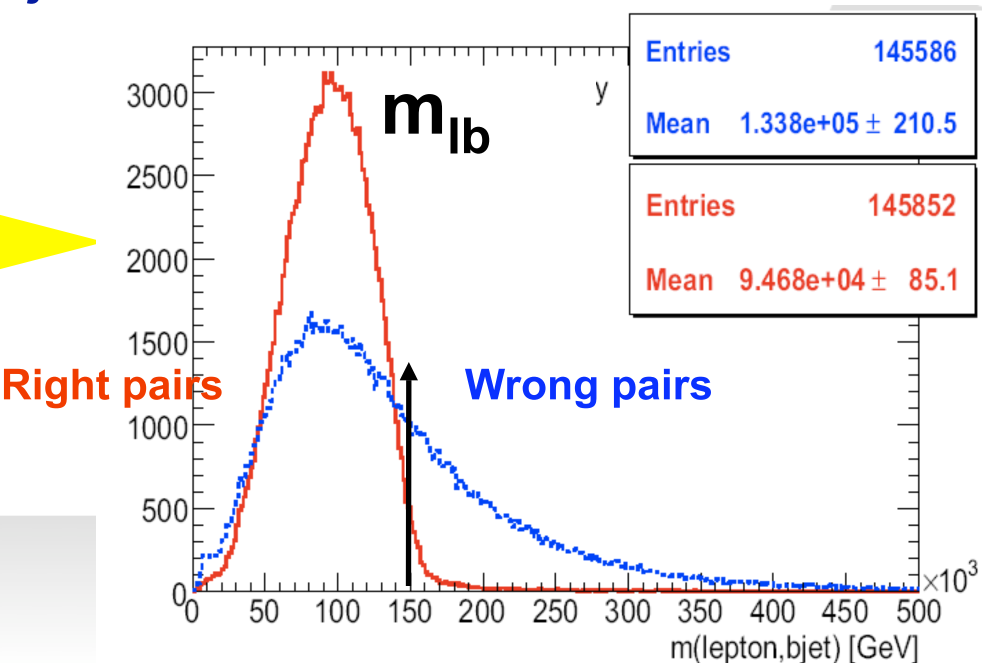


- Expected mass resolution 5-9% for 200-850 GeV,
- bin size twice the mass resolution

Top charge



- CDF: 4/3 excluded at 87% CL [CDF note 8967]
- DØ: 4/3 excluded at 92% CL [PRL 98, 041801 (2007)]
- Simple selection: require 2 b-jets
- Need to determine:
  - Lepton charge
  - Lepton-jet coupling
    ε = 31%, P = 86%
  - b-quark charge
- **Charge weighting**
- **Semileptonic b-decay**



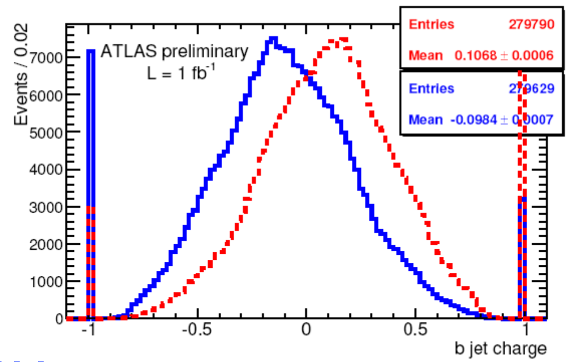
Charge weighting

1 fb^{-1}

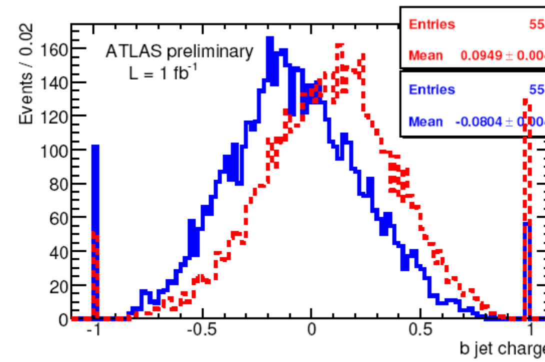
- b-quark charge:

$$Q_{b\,jet} = \frac{\sum_i q_i |\vec{j}_i \cdot \vec{p}_i|^\kappa}{\sum_i |\vec{j}_i \cdot \vec{p}_i|^\kappa}$$

MC truth

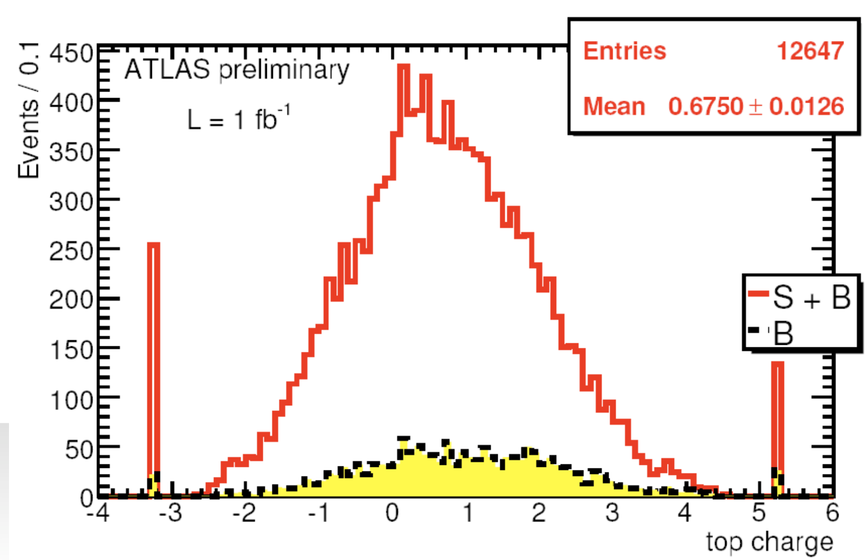


Full sim



- S/B (from W+jets) = 30
- $Q_{comb} = Q(l)+Q^{(l)}b\text{-jet} = -0.094 \pm 0.0042$ (stat)
- $Q_t = Q_l + Q_{b\text{-jet}} \times C_b = 0.67 \pm 0.06(\text{stat}) \pm 0.08$ (sys)

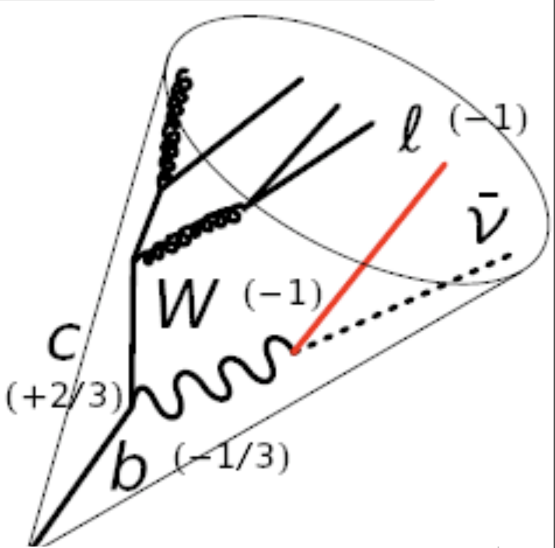
($C_b = Q_b^{SM}/Q_{comb} = 3.54 \pm 0.16$)

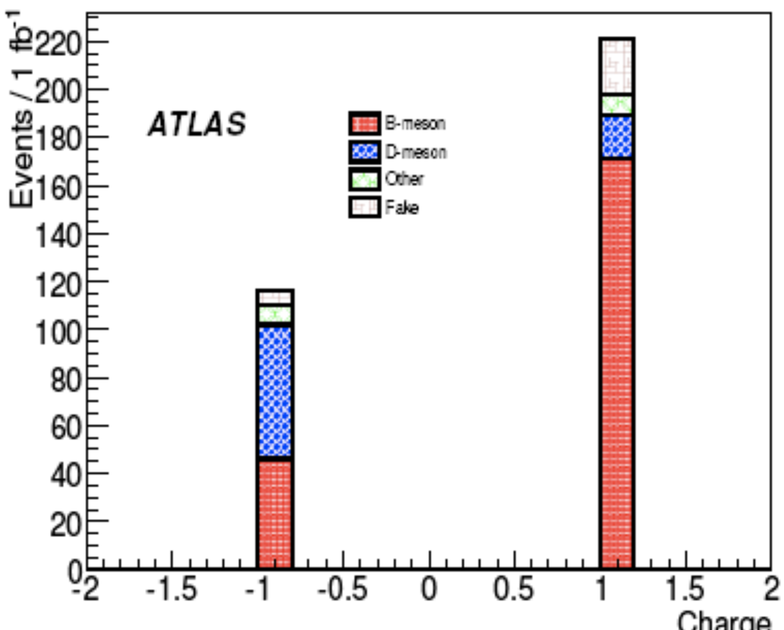


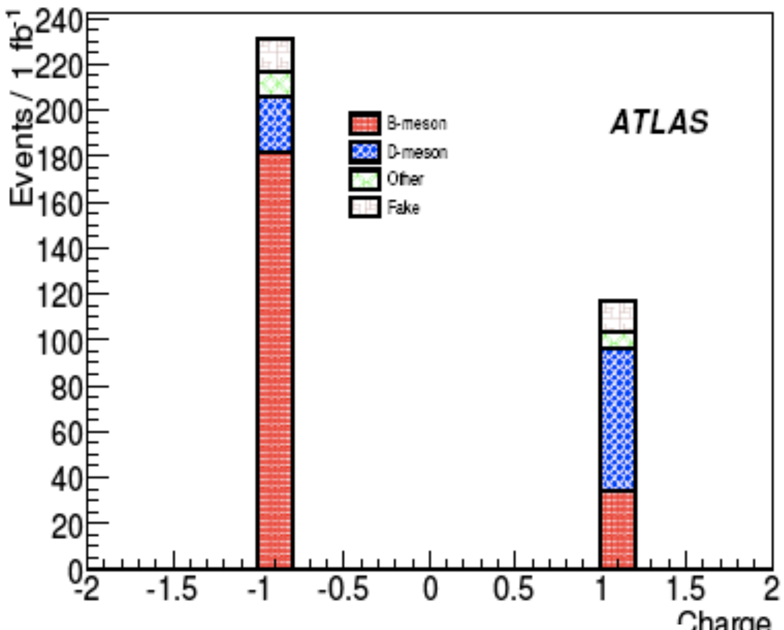
Semileptonic b-decay

$$b \to q l^- \bar{\nu},\ \bar{b} \to \bar{q} l^+ \nu,\ (q = u, c)$$

$$\bar{Q}_{nonIs} = \frac{N(l^+) - N(\ell^-)}{N(\ell^+) + N(\ell^-)}$$







$Q^{(-)}_{nonIs}$ = 0.30 ± 0.05

$Q^{(+)}_{nonIs}$ = - 0.32 ± 0.05

$$\bar{Q}^{(comb)}_{nonIs} = -0.31 \pm 0.04$$

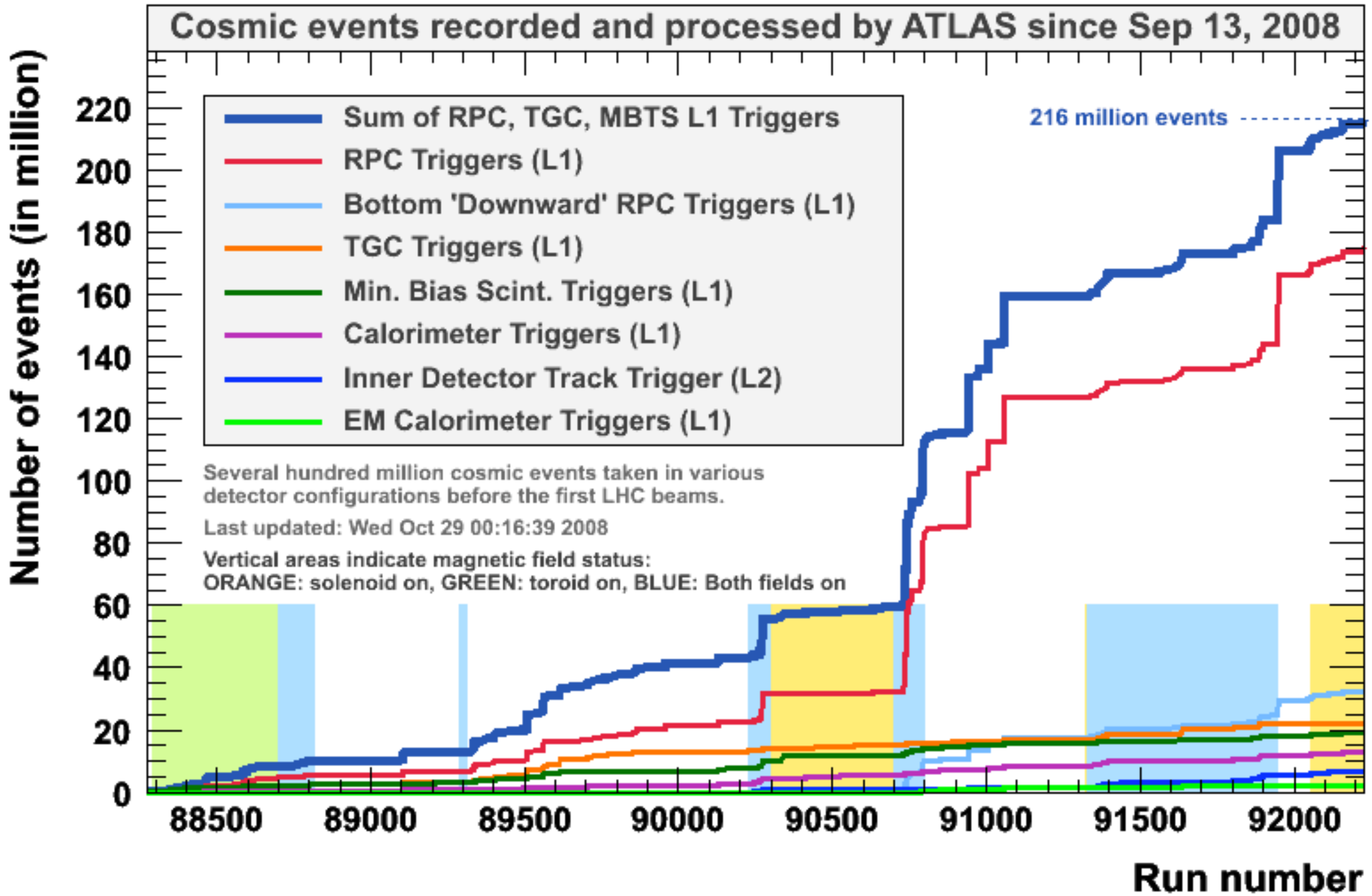
Charge systematics

Source	Weighting (%)	b-decay (%)
jet scale	0.7	0.3
b-jet scale	1.9	6
Δm_{t}	1.3	7
PDF	0.6	–
ISR	2.8	15
FSR	7.8	8
Pile-up	–	1.8
Background asymmetry	1	–
S/B ratio	9	–
total	12.5	19.3

ATLAS will be able to distinguish both charge hypotheses with a signicance above 5σ for 1 fb^{-1} of data

Data overview

ATLAS then went into a sustained cosmic-ray data taking campaign



Source	Likelihood fit Electron	Muon	Counting method (elec) Default	W const.
Statistical	10.5	8.0	2.7	3.5
Lepton ID efficiency	1.0	1.0	1.0	1.0
Lepton trigger efficiency	1.0	1.0	1.0	1.0
50% more W+jets	1.0	0.6	14.7	9.5
20% more W+jets	0.3	0.3	5.9	3.8
Jet Energy Scale (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 function	14.0	10.4	-	-

tt is fairly easy to trigger on

ATLAS

Sample of tt semileptonic with W→eν

Relative to offline analysis selection

Trigger	Compared to Monte Carlo Eff. [%]	Compared to offline selection Eff. [%]
e22i:		
L1 EM18I	74.7 ± 0.5	96.0 ± 0.6
L2 e22i	59.6 ± 0.6	92.7 ± 0.9
EF e22i	52.9 ± 0.6	89.8 ± 1.0
e12i:		
L1 EM7I	83.6 ± 0.4	98.6 ± 0.3
L2 e12i	66.7 ± 0.5	92.6 ± 0.8
EF e12i	63.5 ± 0.5	91.8 ± 0.8

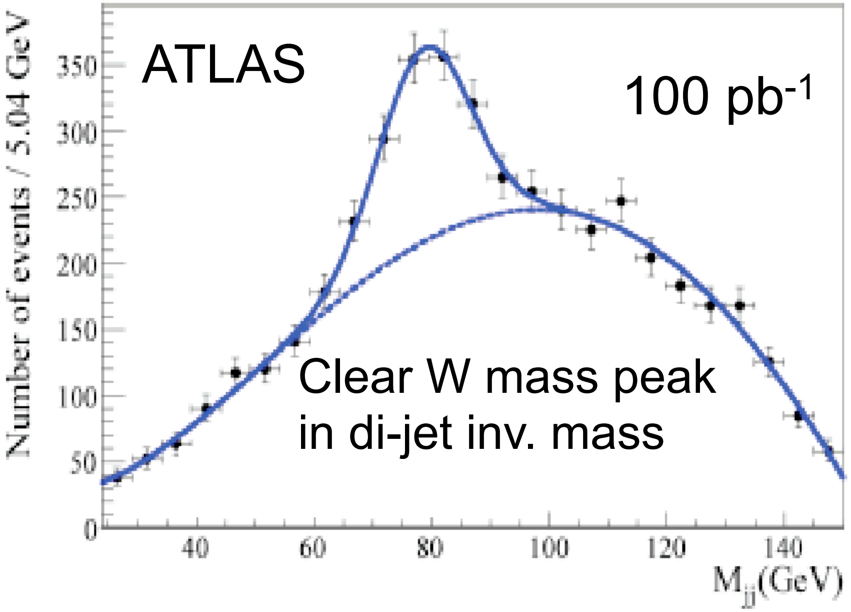
Selection cuts:

- > 1 electron, p_T> 20 GeV
- $E_{T,miss}$ > 20 GeV
- > 3 Jets w/ p_T>40 GeV

> 4 Jets w/ p_T>20 GeV

Main ref. here and below:
ATLAS: CERN-OPEN-2008-20

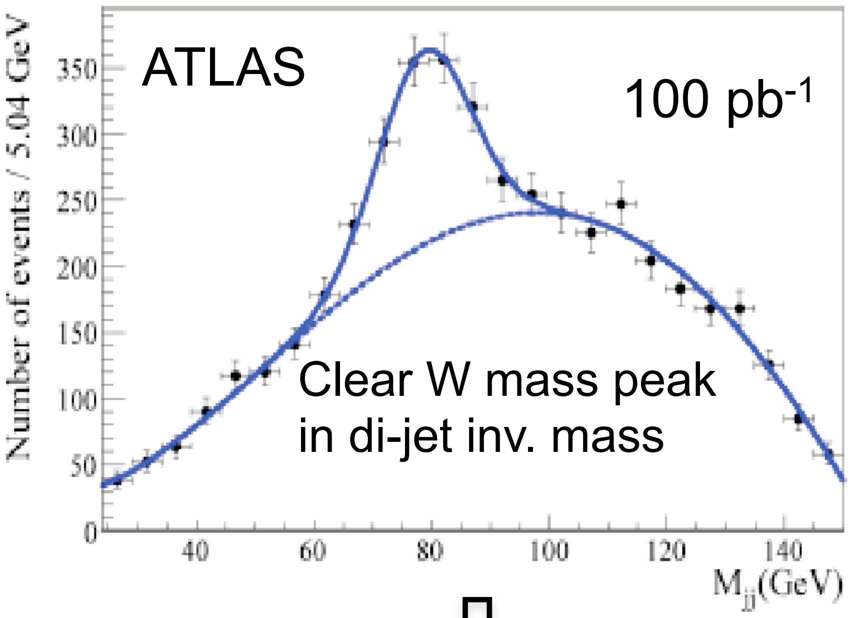
Light jet energy scale



Motivation

- tt → lepton + jets can be used to select an unbiased sample of W→ jet jet
- m_W constraint → light jet energy scale

Light jet energy scale



Motivation

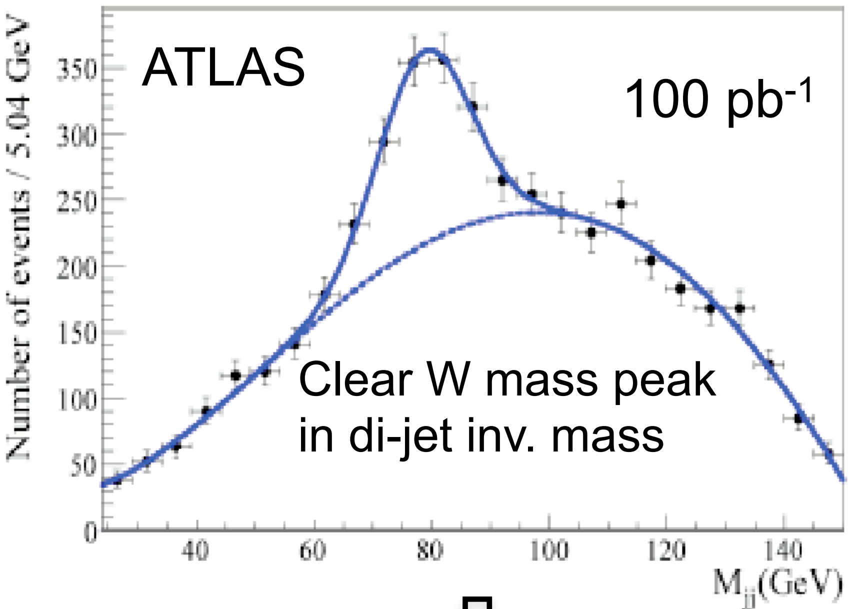
- tt → lepton + jets can be used to select an unbiased sample of W→ jet jet
- m_W constraint → light jet energy scale

Tight selection

- Exactly one isol. lepton, p_T > 20 GeV
- $E_{T,miss}$ > 20 GeV
- Exactly 4 jets, p_T > 40 GeV
- Exactly 2 jets tagged as b-jets

→ W purity ~ 80%

Light jet energy scale



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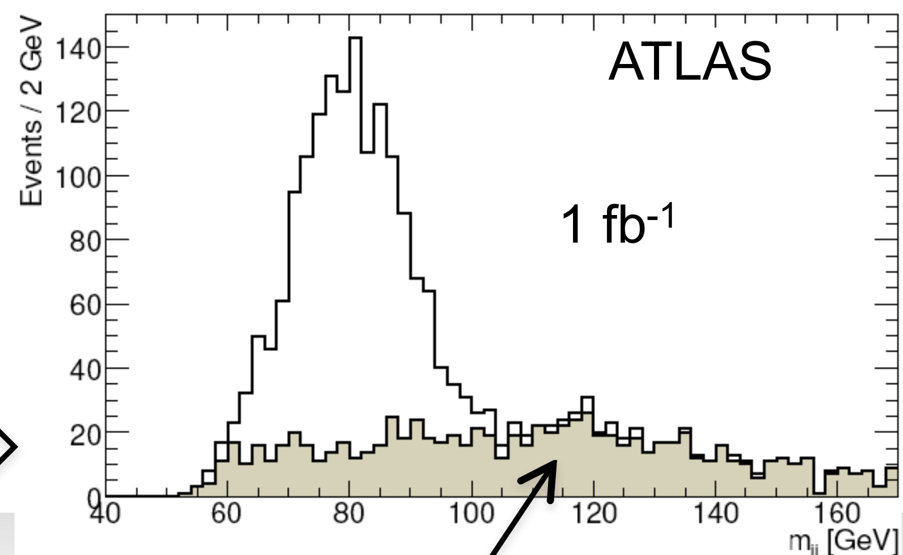

~ only combinatorial BKGS left

Light jet energy scale cont.

Light jet energy scale cont.

- Iterative re-scaling of E_{jet} in bins of E_{jet} and η to get $M_{W,PDG}$
  - Precision of ~ 2% for 1 fb^{-1}

Light jet energy scale cont.

- Iterative re-scaling of E_{jet} in bins of E_{jet} and η to get $M_{W,PDG}$
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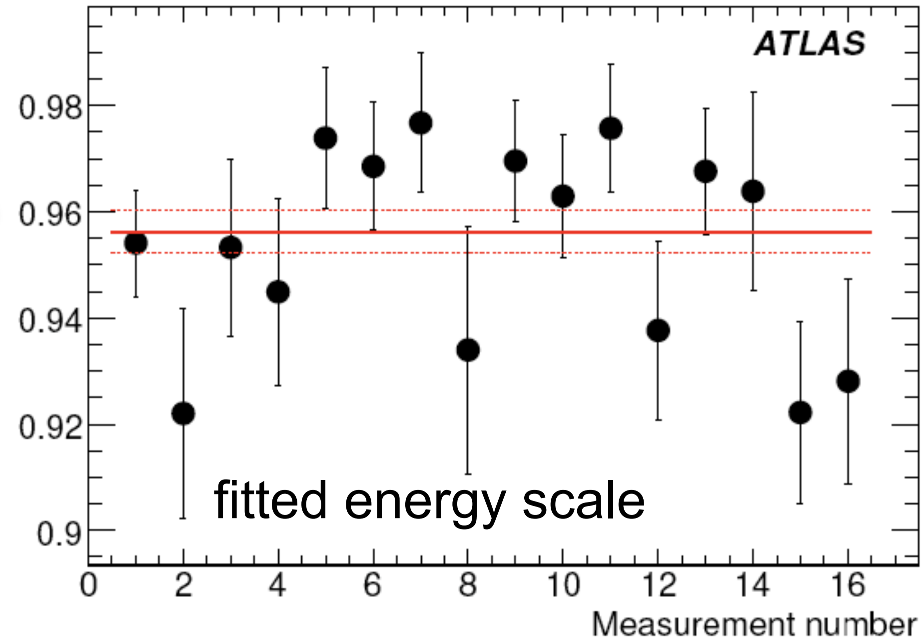
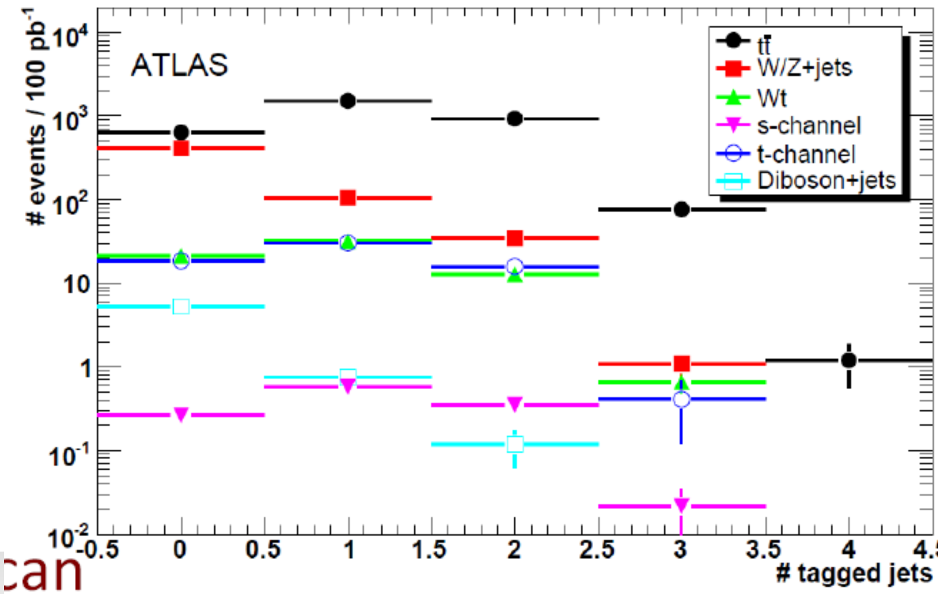
- Fit template distributions with energy scale α / resolution β
  - Precision of ~ 1% for 1 fb^{-1} for overall scale

Light jet energy scale cont.

- Iterative re-scaling of E_{jet} in bins of E_{jet} and η to get $M_{W,PDG}$
  - Precision of ~ 2% for 1 fb^{-1}
- Fit template distributions with energy scale α / resolution β
  - Precision of ~ 1% for 1 fb^{-1} for overall scale
- How about in the beginning?
  - Split up into samples of about 50 pb^{-1} each
  - Average, scatter and RMS behave as expected
  - Within 3-4% of the fitted best value at 1 fb^{-1}

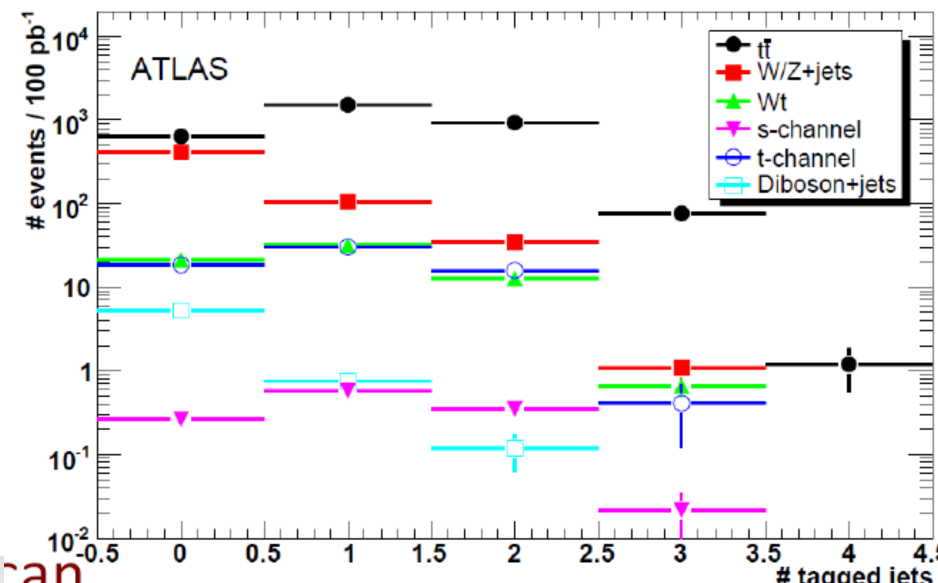


b-tag efficiency



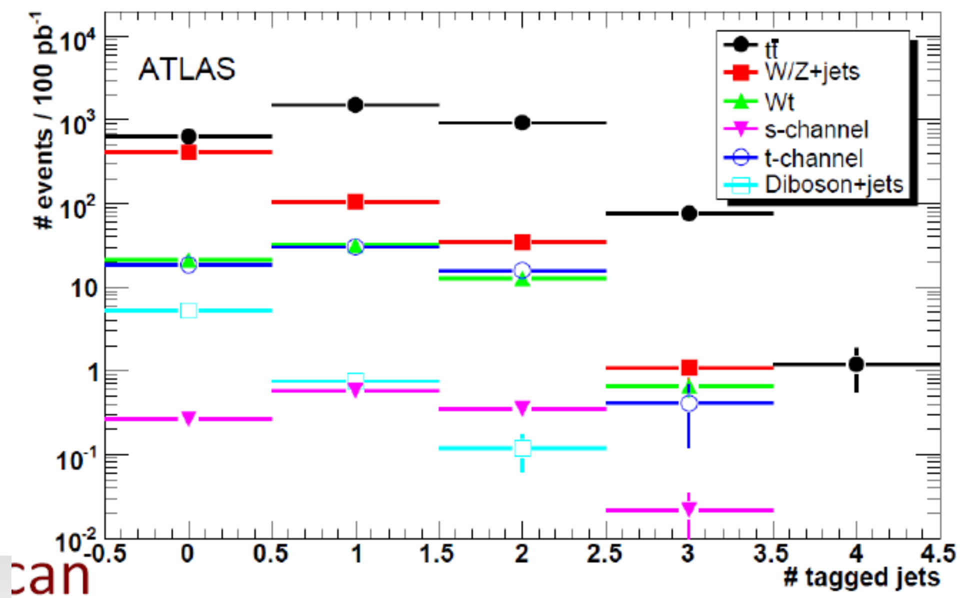
b-tag efficiency

- Select b-enriched samples using tt sample



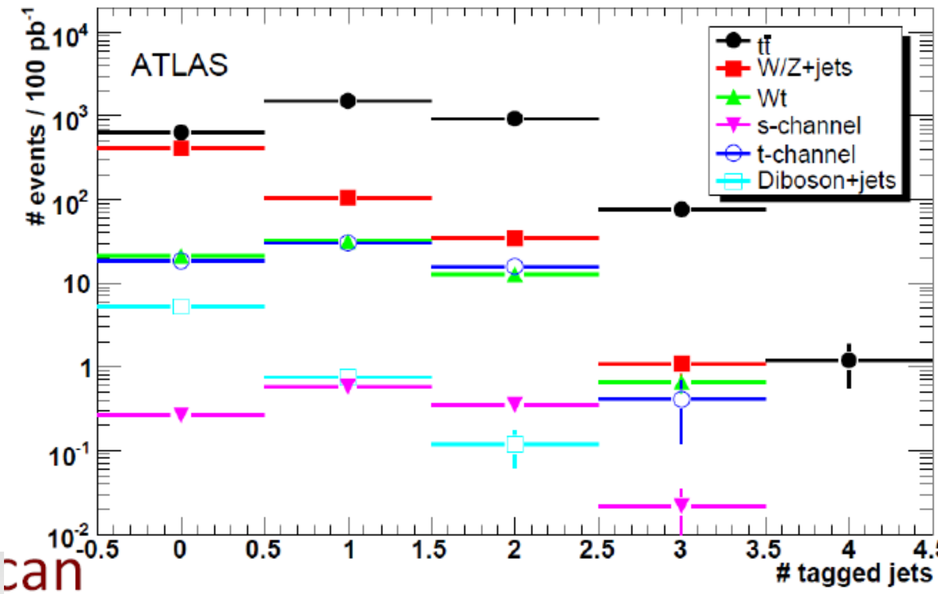
b-tag efficiency

- Select b-enriched samples using tt sample



b-tag efficiency

- Select b-enriched samples using tt sample
- Golden channel: 2 b-jets, 2 W daughters



b-tag efficiency

- Select b-enriched samples using tt sample
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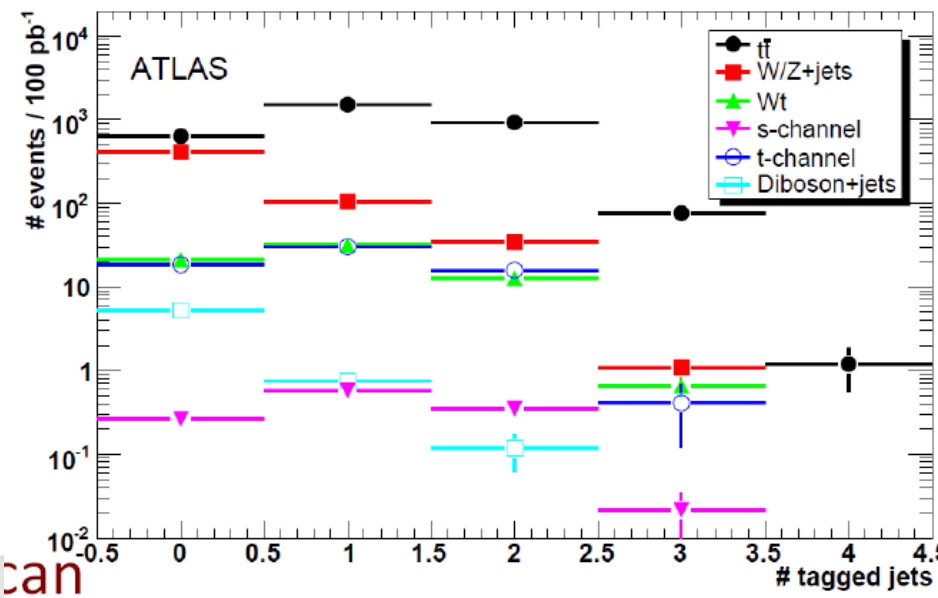
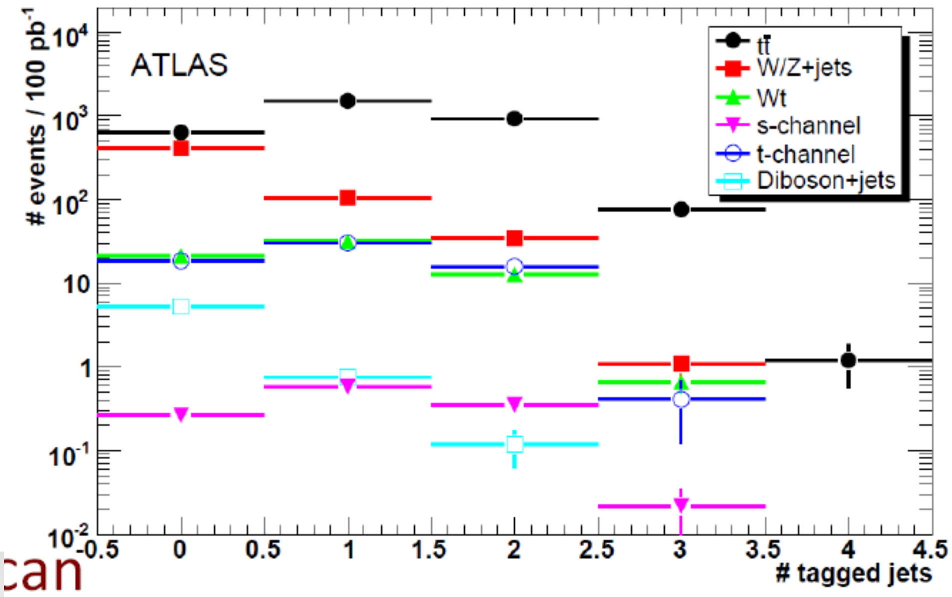


b-tag efficiency

- Select b-enriched samples using tt sample
- Golden channel: 2 b-jets, 2 W daughters
- b-jets determine b-tag efficiency $\varepsilon_{b:}$
  - Global $\varepsilon_{b:}$ from fit to Ntag distribution
  - Also determines ε_c and σtt
  - $\Delta\varepsilon_{b:/}\,\varepsilon_b$~ (2.7 (stat)+3.4 (syst))%



The 2009/10 LHC Run

Year	2009											2010														
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Baseline	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH		SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	SH	SH	SH	SH

Typical Run/Shutdown setup

Would leave little time for running in 2009

Delay may mean no running before autumn 2010!

The 2009/10 LHC Run

Year	2009											2010														
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Baseline	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH		SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	SH	SH	SH	SH

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Delay may mean no running before autumn 2010!

- Decisions taken
  - Physics run as soon as possible
  - Do not warm up all sectors
  - Top energy is 5 TeV (had been reached for all other sectors)
  - No winter shutdown 2009/10

The 2009/10 LHC Run

Year	2009											2010														
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Baseline	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH		SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	SH	SH	SH	SH

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- Decisions taken
  - Physics run as soon as possible
  - Do not warm up all sectors
  - Top energy is 5 TeV (had been reached for all other sectors)
  - No winter shutdown 2009/10
- Consequences

The 2009/10 LHC Run

Year	2009											2010														
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Baseline	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH		SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	SH	SH	SH	SH

Typical Run/Shutdown setup

Would leave little time for running in 2009

Delay may mean no running before autumn 2010!

- Decisions taken
  - Physics run as soon as possible
  - Do not warm up all sectors
  - Top energy is 5 TeV (had been reached for all other sectors)
  - No winter shutdown 2009/10

- Consequences
  - 8 M Euro additional electricity cost

The 2009/10 LHC Run

Year	2009											2010														
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Baseline	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH		SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	SH	SH	SH	SH

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Baseline	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH		SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	SH	SH	SH	SH

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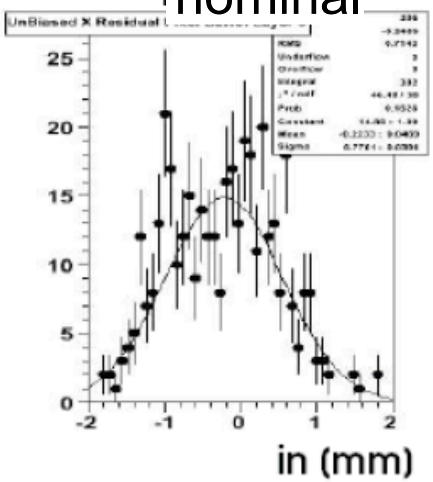
  - Enough data to compete with Tevatron in many areas by end of 2009/10 run

Good signs! Pixel alignment

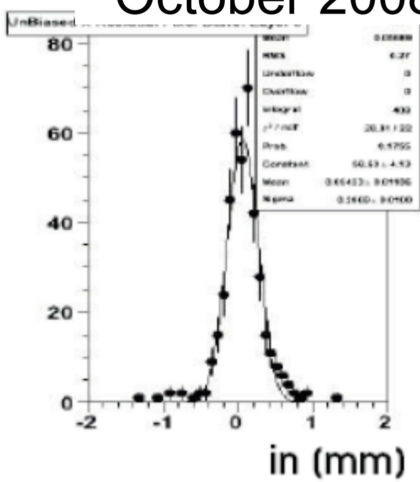
An example of using cosmic-ray data for detector alignment

nominal



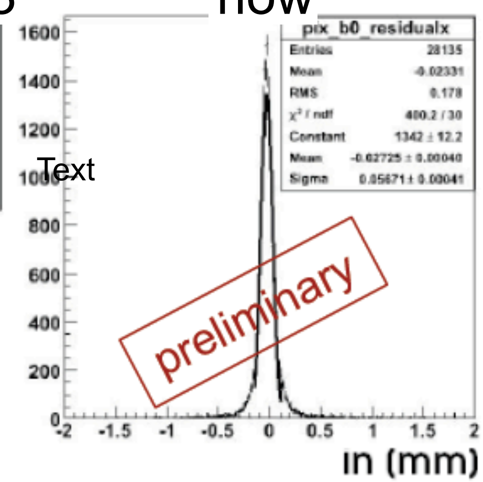
~1mm

~October 2008



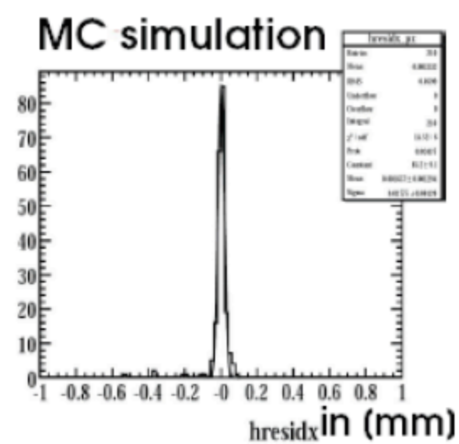
~250μm

now



~50μm

future



~15μm