ATLAS EXPERIMENT

IMPRS/GK YSW at Ringberg Castle
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Top Quark Mass Measurements at ATLAS

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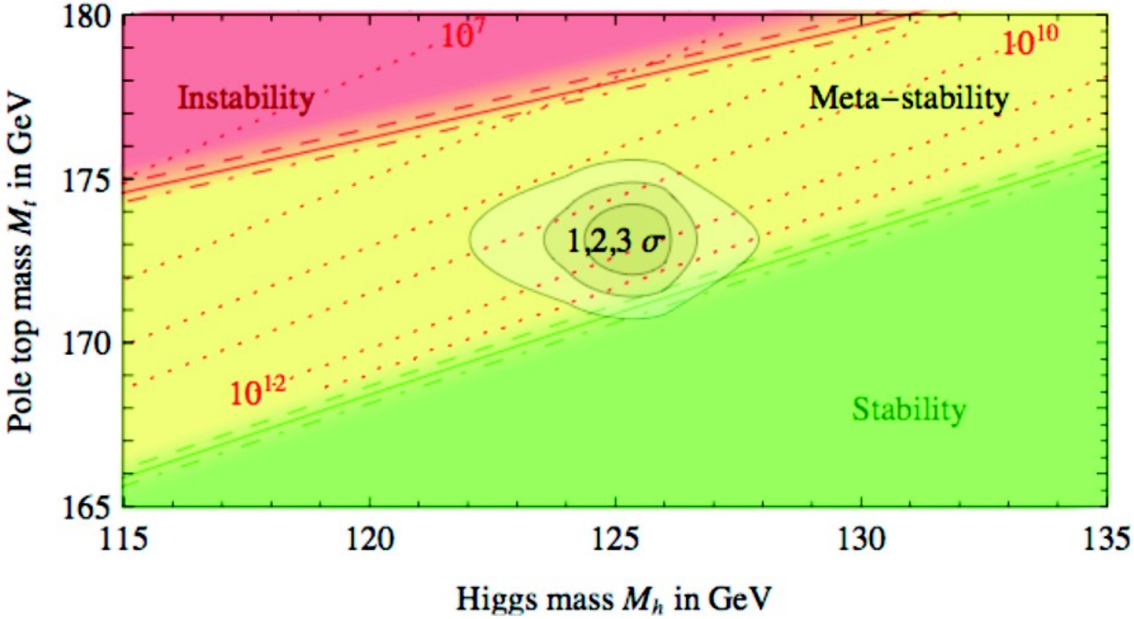
Motivation: why should we study top quarks?

- Top quark mass
  - relation to W boson mass for discrimination between SM and MSSM Higgs
  - determination of the Higgs quartic coupling and the vacuum stability



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  - polarisation, charge asymmetry, cross-section etc. as handle for physics beyond the SM (FCNC, MSSM etc.)

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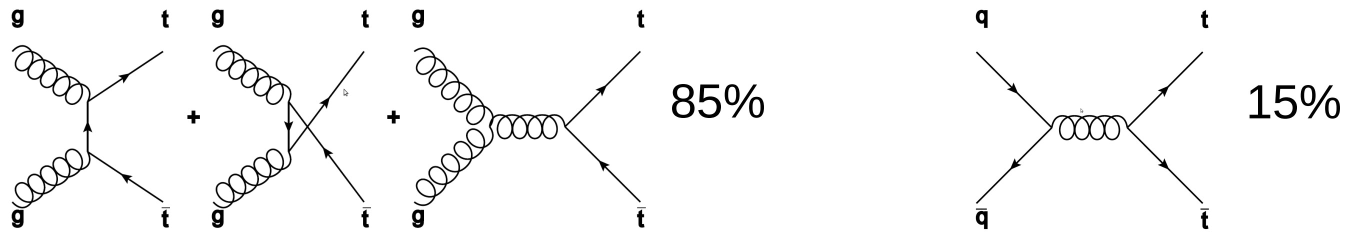
- Side effects
  - driver for developments in detector calibration and reconstruction performance
  - improvements in MC modelling
  - and much more

Top quarks pairs at LHC

- The LHC serves as a top quark factory
  - production cross-section: $\sigma_{t\bar{t}}(7TeV) = 177\,^{+10}_{-11}\,pb$
  - 2011 ATLAS dataset: ~0.8 M top pair events (4.7 fb^{-1})
  - production mechanism



- Decay channels for $t\bar{t} \to W^+ b W^- \bar{b}$:
  - "all jets" $WW \to qqqq$ 46 %
  - "lepton + jets" $WW \to l\nu qq$ 45 %
  - "dilepton" $WW \to l\nu l\nu$ 9 %

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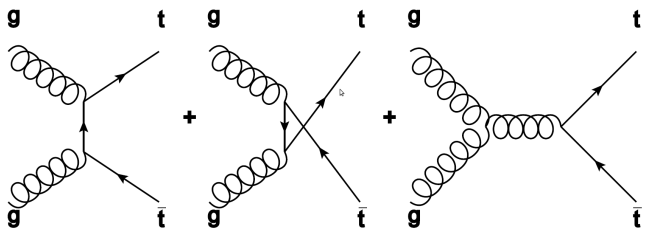
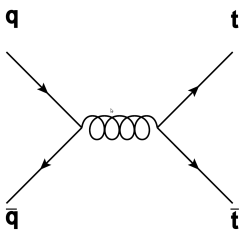


85%



15%

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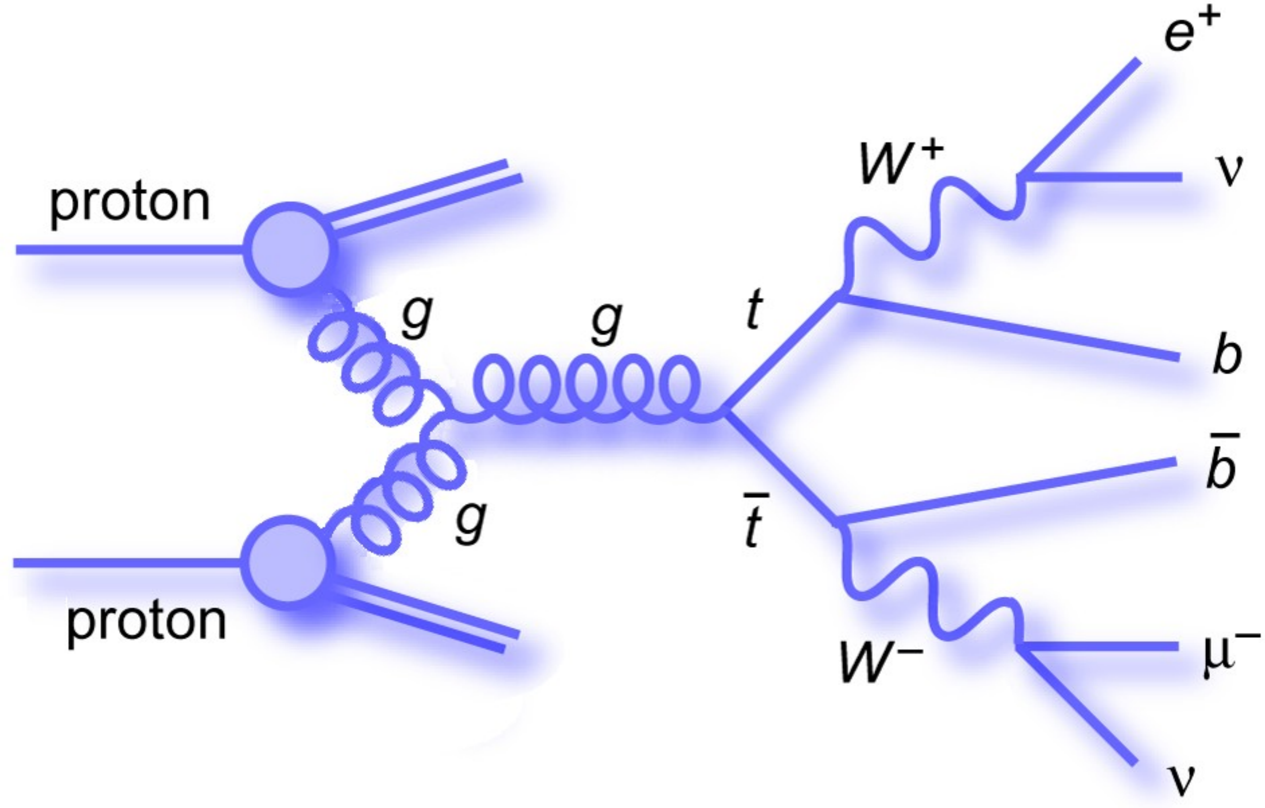
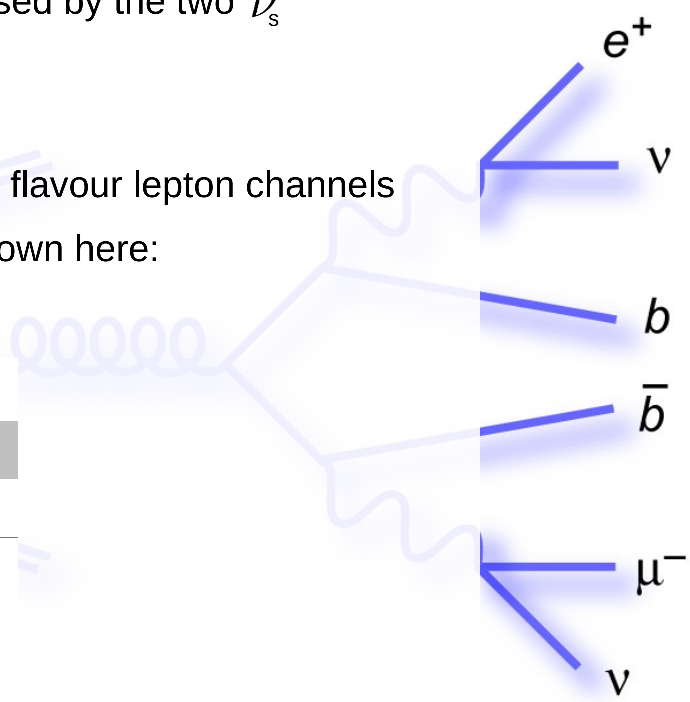
The dileptonic event hypothesis



The dilepton measurement

- Selection cuts:
  - 2 oppositely charged isolated leptons with high p_T
  - high missing transverse momentum E_T^{miss} caused by the two ν_s
  - 2 jets identified as originating from a b quark
  - additional cuts to reduce background
    - e.g. Z-boson mass exclusion for same flavour lepton channels
- The numbers of events after the final selection are shown here:



Contribution	Yield	Unc.
Data	2913	
top anti-top quark pairs	2400	400
Fake leptons	-4	7
Single top quarks	73	15
Z+jets	3.1	1.3
Dibosons	0.75	0.29
Total predicted	2500	400

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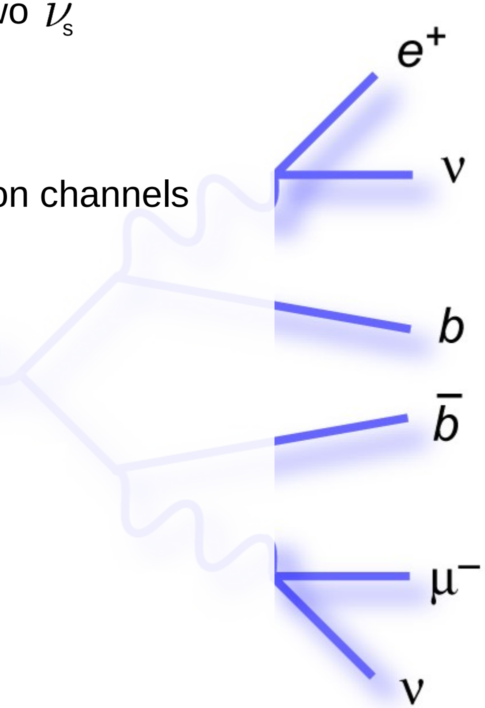
- Available information:

	2 x 4	(charged leptons)
	2 x 4	(b-quarks from b-jets)
	2	(E_T^{miss})
+	2	(neutrino masses)
+	2	(W masses)
+	1	(equality of t-quark masses)
=	23	Parameters

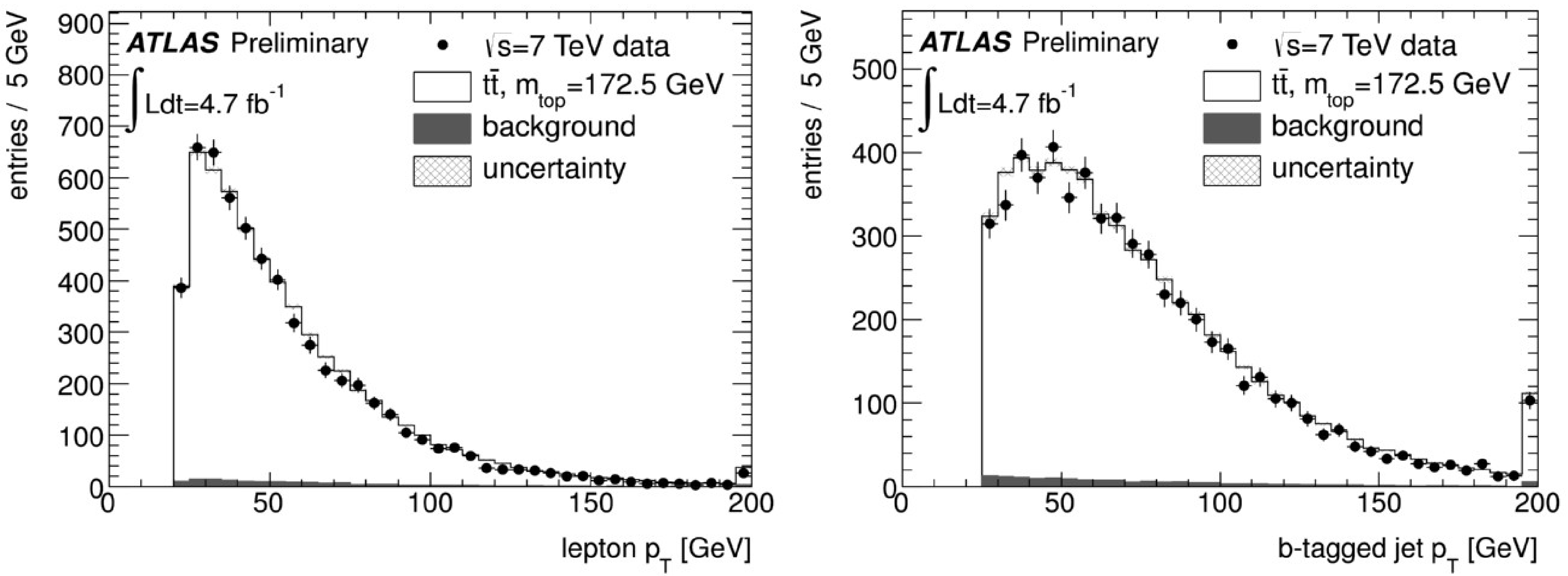


- Required information for full reconstruction:
  - 6 final four-vectors $(E, \vec{p}) \rightarrow$ 24 parameters
  - problem: underconstrained kinematics

Simple solution: the m_{lb} estimator

- Defined as the mean of invariant masses of lepton-b-jet systems

$$m^t_{\ell b} = \sqrt{E^2_{\ell b} - p^2_{\ell b}}, \quad m^{\bar{t}}_{\ell b} = \sqrt{E^2_{\ell b} - p^2_{\ell b}} \quad \rightarrow \quad m_{lb} = \frac{m^t_{\ell b} + m^{\bar{t}}_{\ell b}}{2}$$



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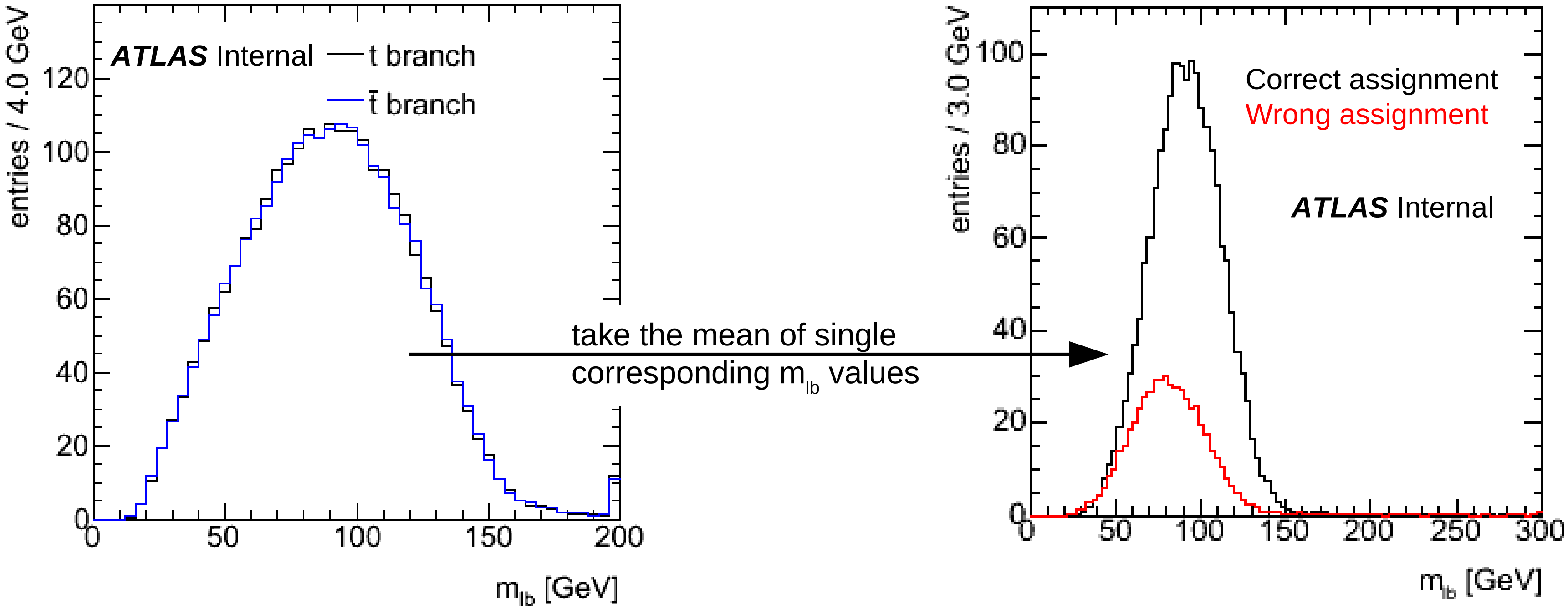
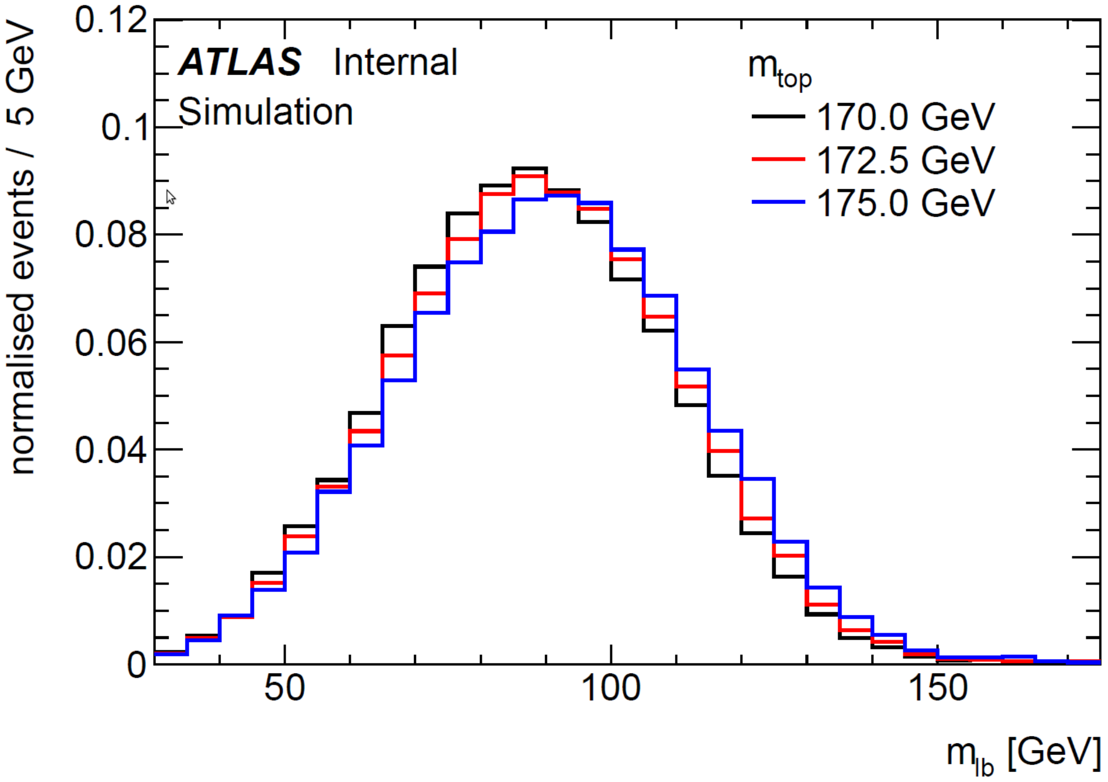
- b-jet to parton assignment: take pairing with minimum m_{lb}
- Correct choice in about 77% of the cases



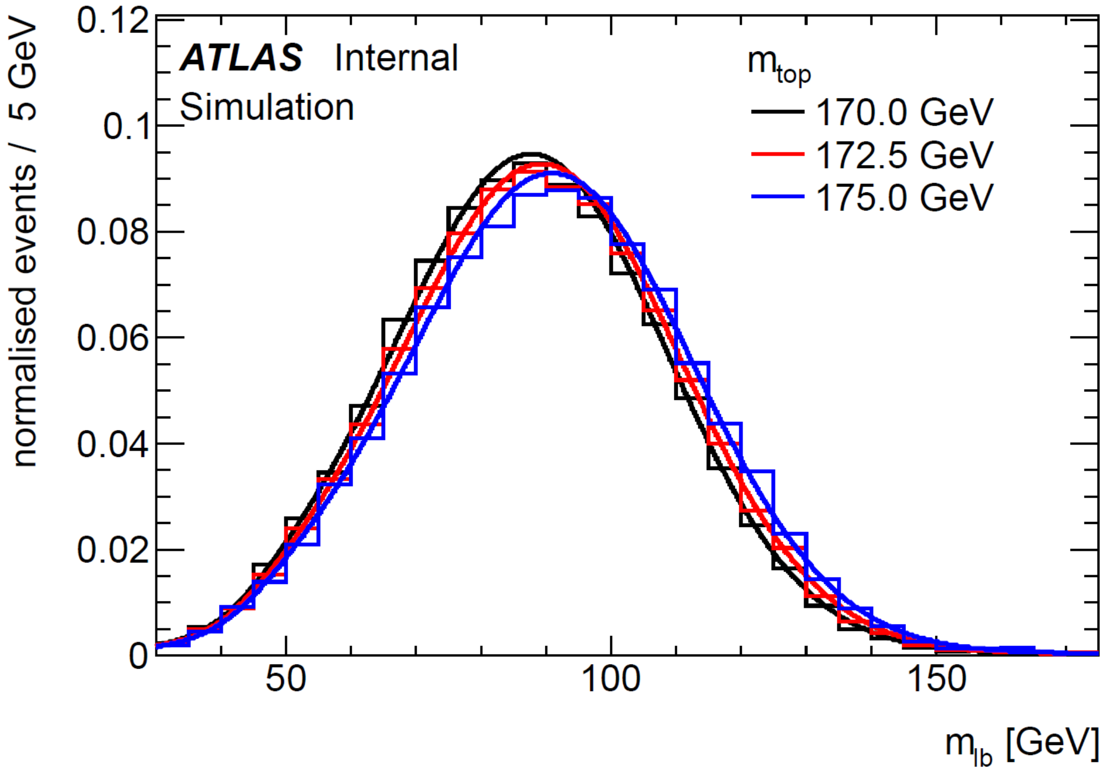
Extracting the mass information

- Evaluation of Monte Carlo simulation samples for different m_{top} hypotheses
- A clear sensitivity is observed and can be used for a measurement



Extracting the mass information

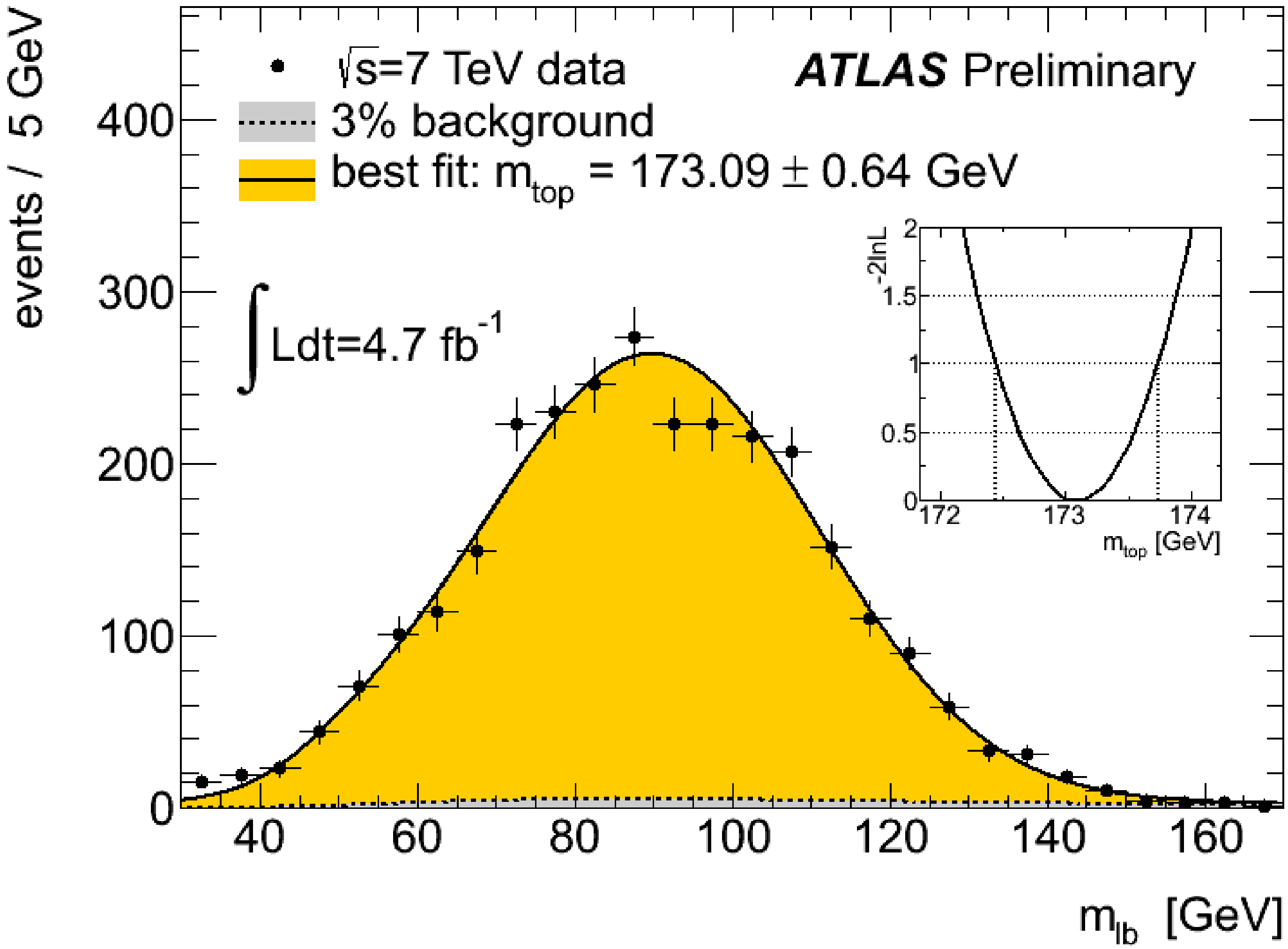
- Evaluation of Monte Carlo simulation samples for different m_{top} hypotheses
- A clear sensitivity is observed and can be used for a measurement
- Construction of “template fit functions” varying with m_{top} as the only parameter
- An unbinned likelihood fit of this function to data yields the most probable m_{top}



Central value in 2011 ATLAS data

ATLAS-CONF-2013-077, last Friday

- The template fit to data with the likelihood profile as inset



Uncertainties

- Evaluation of systematic uncertainties
  - analyse distributions varied by systematic effect
  - difference in m_{top}^{out} with respect to the standard sample as estimate of the impact on the measurement
- A selection including the most important contributions is shown here

Uncertainty source	Uncertainty [GeV]
Data statistics	0.64
Modelling uncertainties:	
Signal MC generator	0.20
Hadronisation	0.44
ISR and FSR	0.37
Detector uncertainties:	
Jet energy scale	0.89
b-jet energy scale	0.71
b-tagging efficiency and mistag rate	0.46
Total systematic uncertainty	1.50
Total uncertainty	1.63

Uncertainties

Difference in m_{top}^{out} using different MC generators

- MC@NLO vs. POWHEG both using HERWIG fragmentation
- renormalisation and factorisation scale variation

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Uncertainties

Difference in m_{top}^{out} using two different hadronisation programs

- Pythia P2011C (Lund-string model) vs. HERWIG (cluster fragmentation model) both using POWHEG event generator

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Uncertainties

Difference in m_{top}^{out} using different amount of QCD initial and final state radiation

- AcerMC with varied parton shower parameter using Pythia P2011C by 1σ

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Difference in m_{top}^{out} using different jet energy scales

- Variation of the scale up and down by 1 σ

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Difference in m_{top}^{out} using different b-jet energy scales

- Variation of the bJES up and down by 1 σ

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Modelling uncertainties:	
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Hadronisation	0.44
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Uncertainties

Difference in m_{top}^{out} using different b-tagging scale factors

- Variation the scale factors up and down by 1 σ

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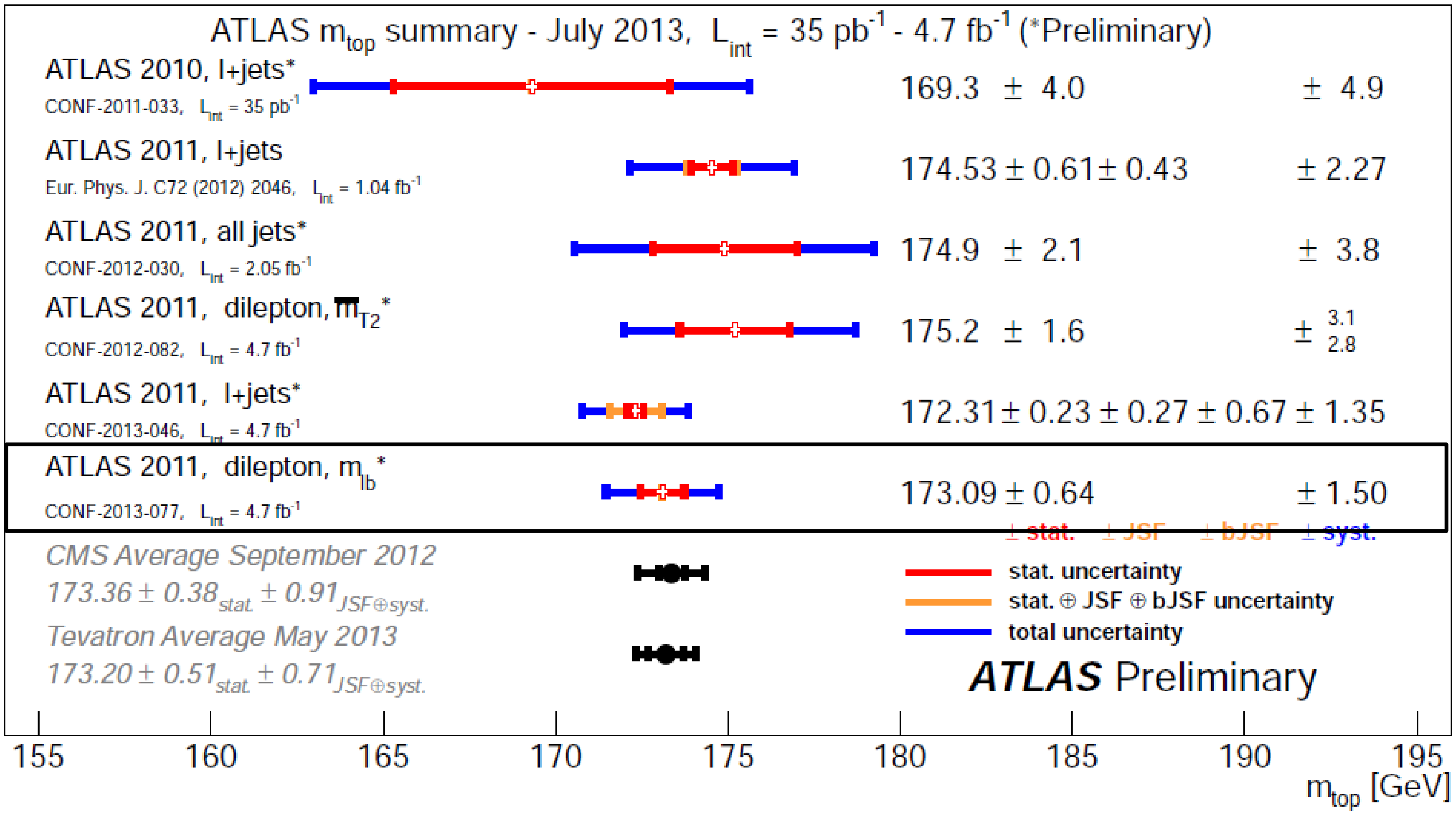
Current ATLAS results

ATLAS-CONF-2013-077, last Friday



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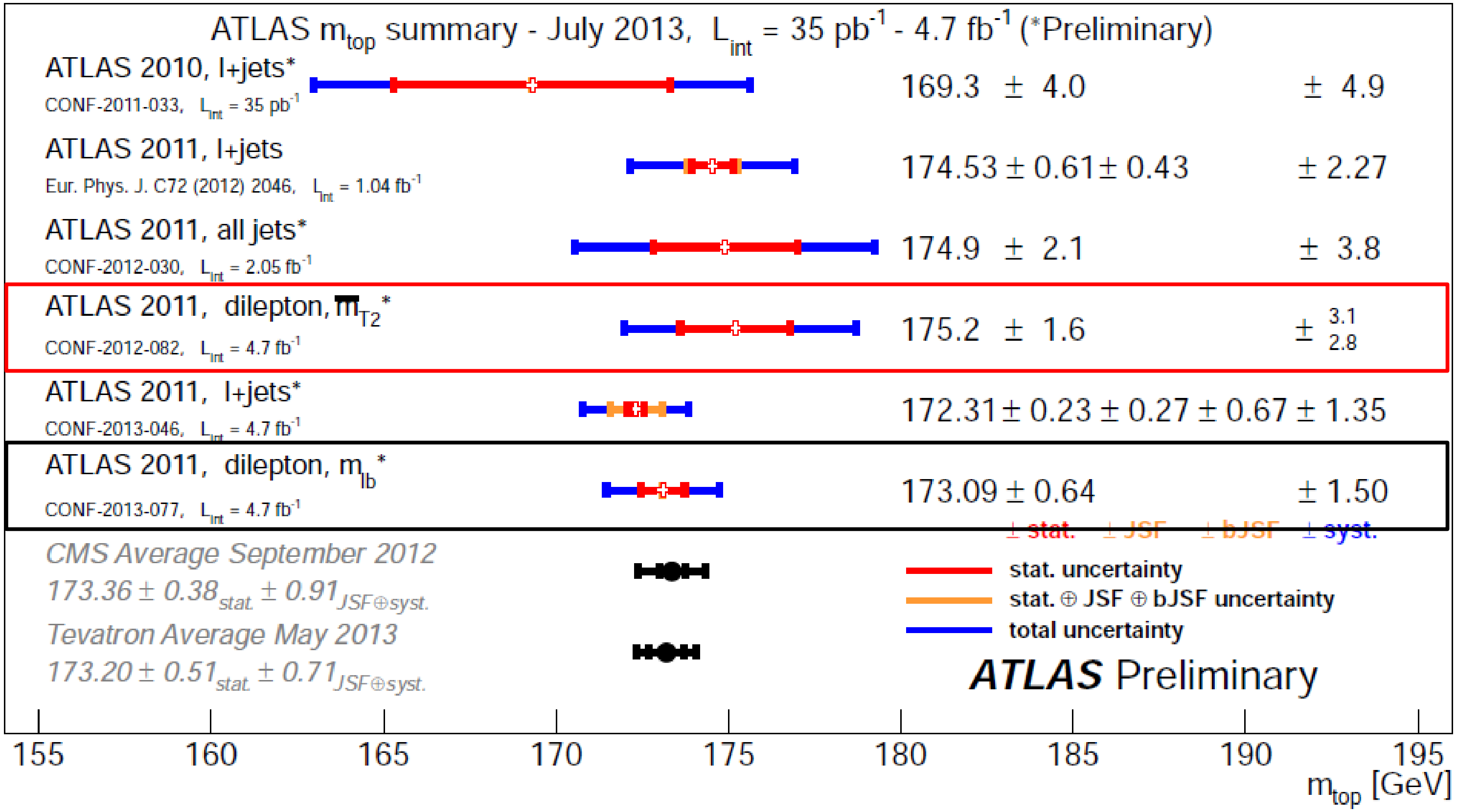
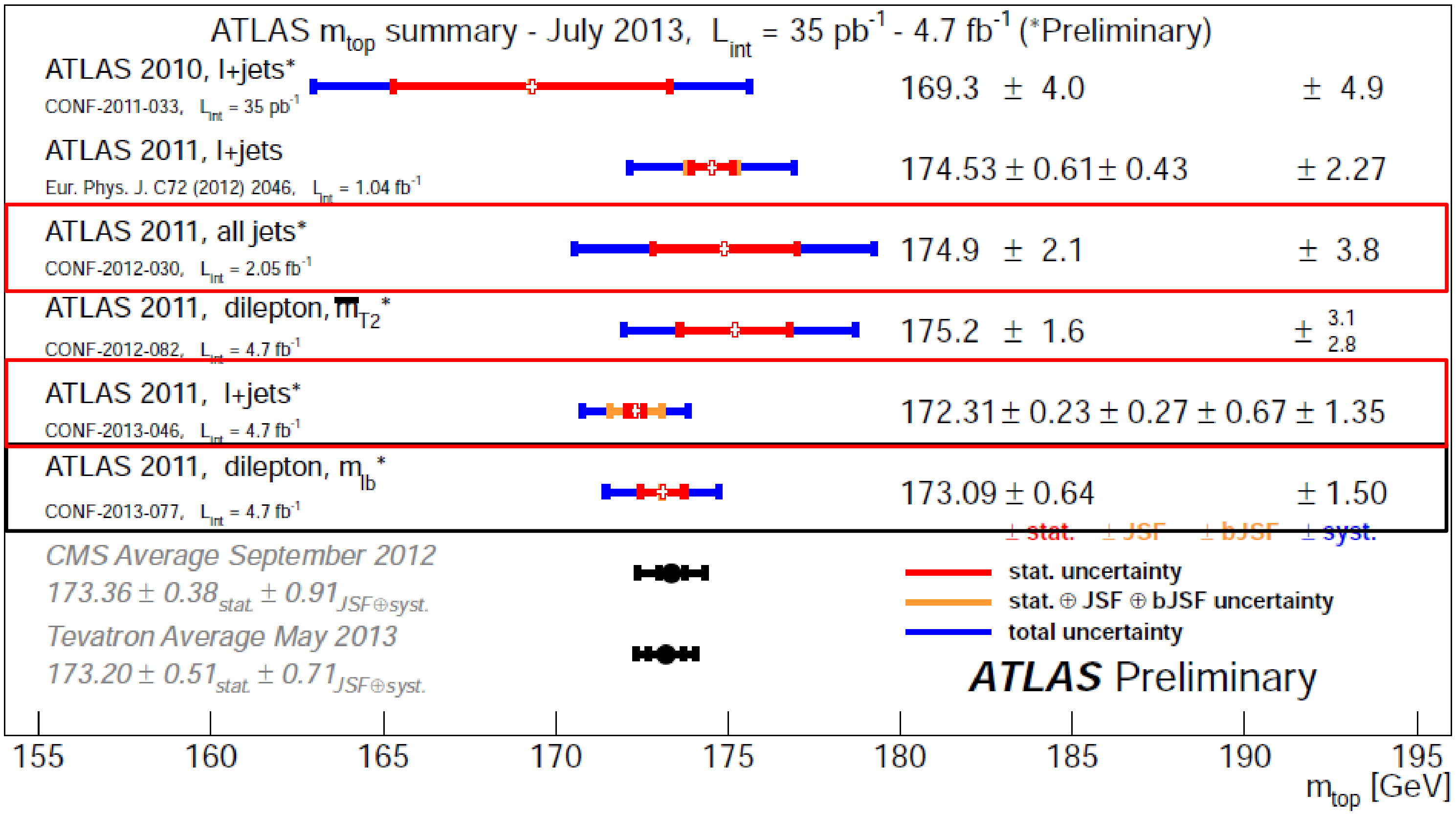


- Previous measurement with same statistics, but based on μμ channel only (67% of data)
- Main improvements: choice of estimator, JES and bJES calibrations, template method

Current ATLAS results



- The analyses from other channels
- Lets take a quick look at them to conclude the overview

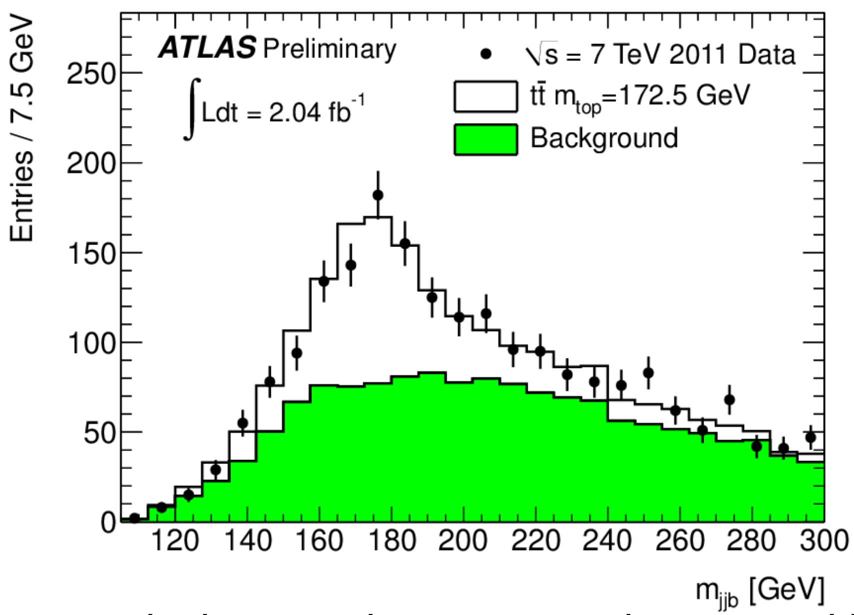
The all jets measurement

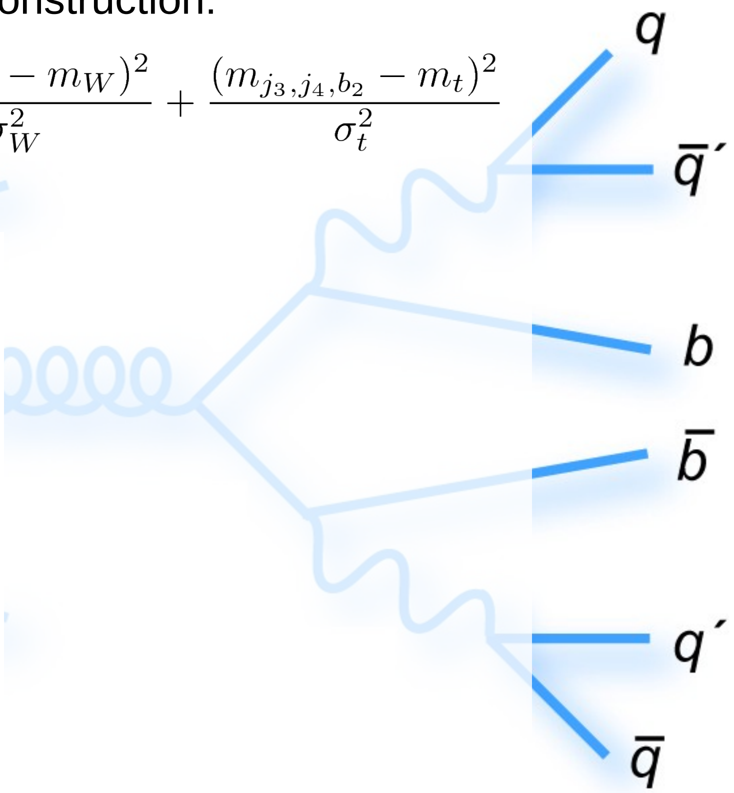
ATLAS-CONF-2012-030, March 2012

- Large statistics, large background
- Assignment of jets via minimal χ^2 based reconstruction:

$$\chi^2 = \frac{(m_{j_1,j_2} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_1,j_2,b_1} - m_t)^2}{\sigma_t^2} + \frac{(m_{j_3,j_4} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_3,j_4,b_2} - m_t)^2}{\sigma_t^2}$$

- data driven QCD multijet background





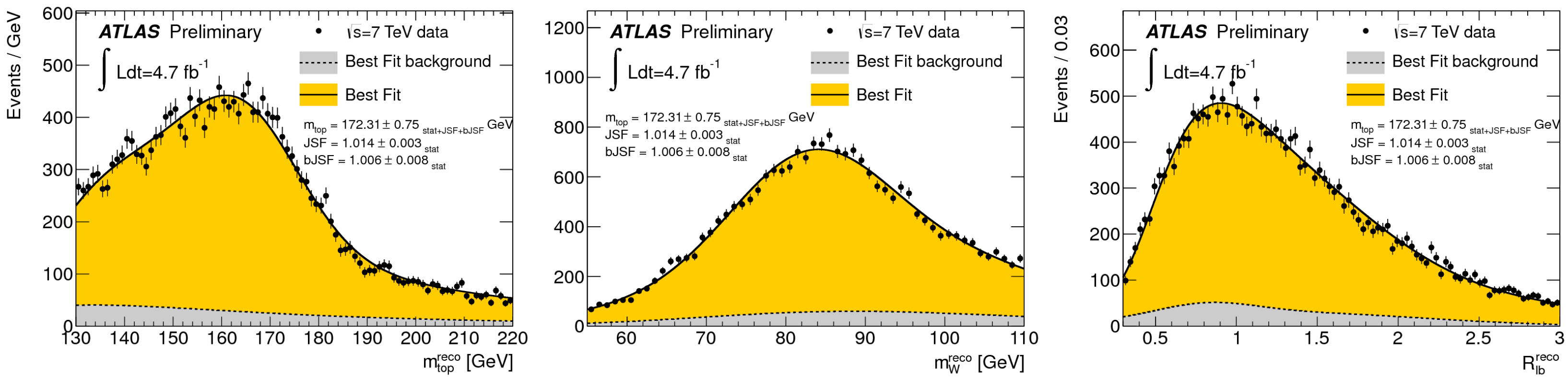
- $m_{j,j,b}$ is then used to measure the mass with the template method:

$$m_{top} = 174.9 \pm 2.1_{stat} \pm 3.8_{syst} GeV$$

The lepton + jets measurement

ATLAS-CONF-2013-046, May 2013

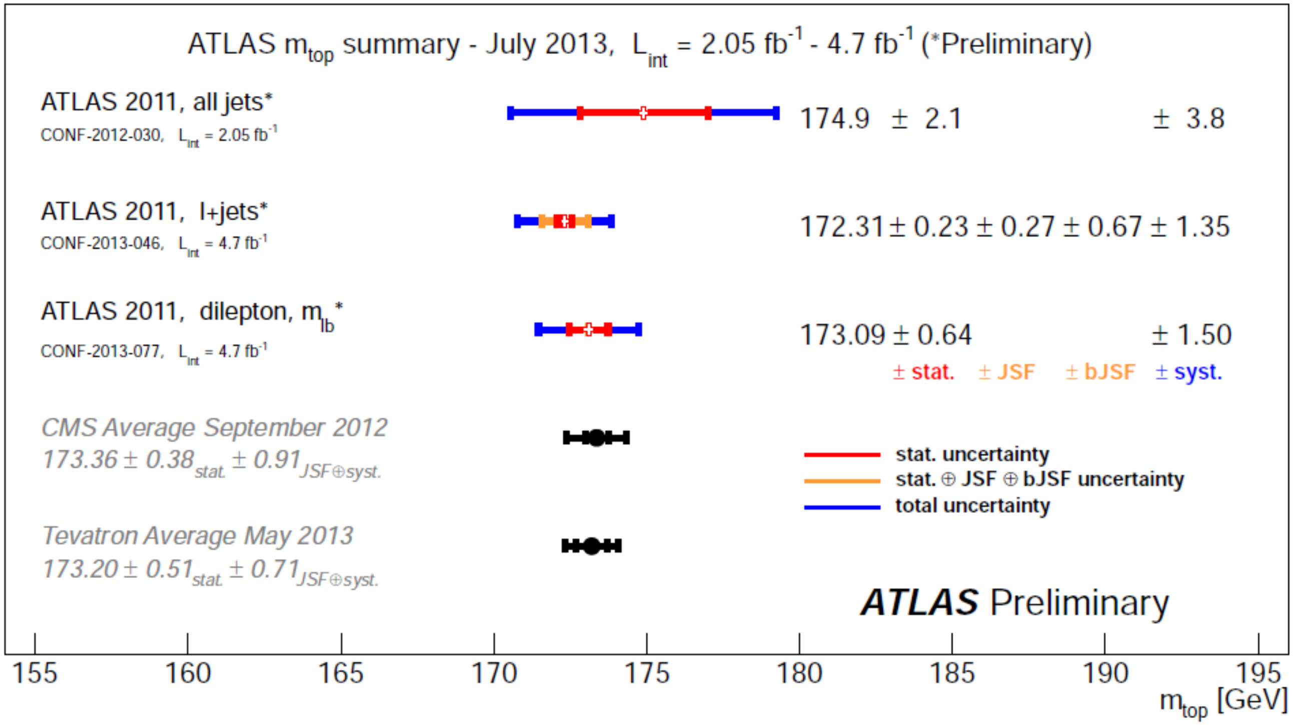
- Large statistics, moderate background (golden channel)
- Assignment of jets via maximal likelihood in Kinematical Likelihood Fitter relating jets to partons.
- Simultaneous fit of m_{top}, the jet scale factor (JSF) and the b-jet scale factor (bJSF) using a 3 dimensional template method.
- Leads to reduced systematic uncertainties at the cost of additional statistical components
- $m_{top}^{reco}, m_{W}^{reco}, R_{lb}^{reco} = \frac{\sum p_T^{b-tagjet}}{\sum p_T^{lightjet}}$ used as estimators for the measurement



$$m_{top} = 172.31 \pm 0.23_{stat} \pm 0.27_{JSF} \pm 0.67_{bJSF} \pm 1.35_{syst} GeV$$

Conclusion

- MPP and LMU provide significant contributions to the ATLAS m_{top} measurements
- A combination of channels is under investigation
- Full 2013 dataset awaits beeing analysed
- Stay tuned for the next developments



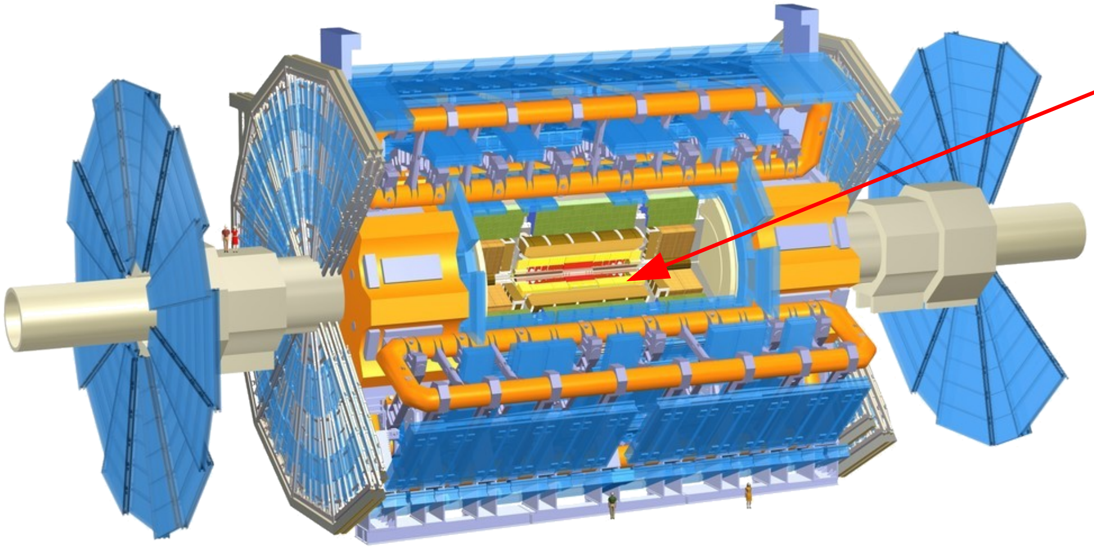
Thank you for your attention!

Backup

Andreas Alexander Maier

The ATLAS detector

- Multipurpose detector covering almost the full solid angle
- Analyzing pp collisions at LHC: 4.7 fb^{-1} in 2011



Inner detector

- b-quark identification
- charged lepton momenta

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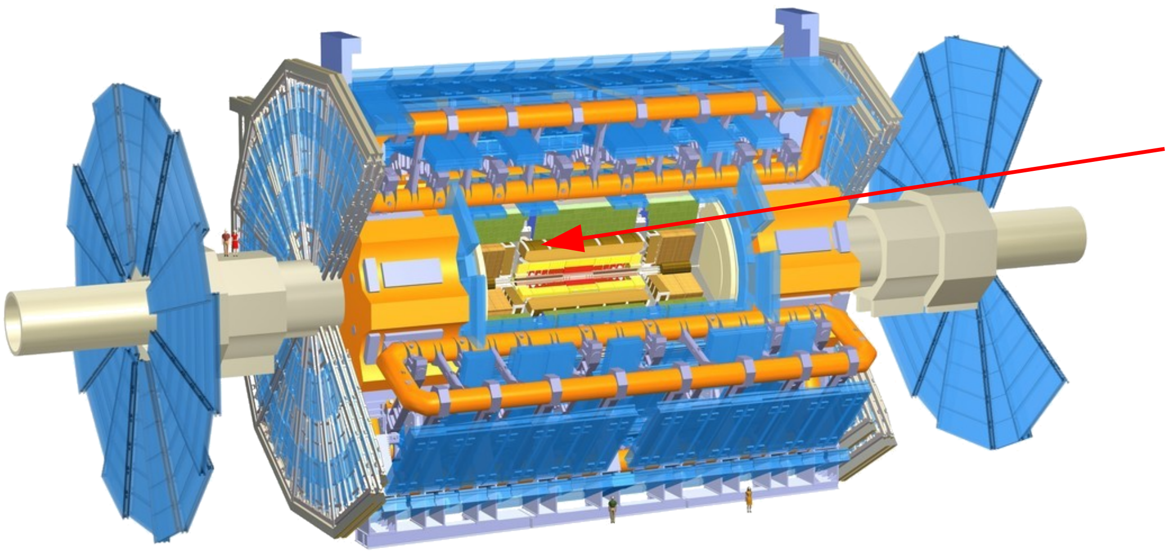

Inner detector

Calorimeters

- electron energy and direction
- jet energy and direction

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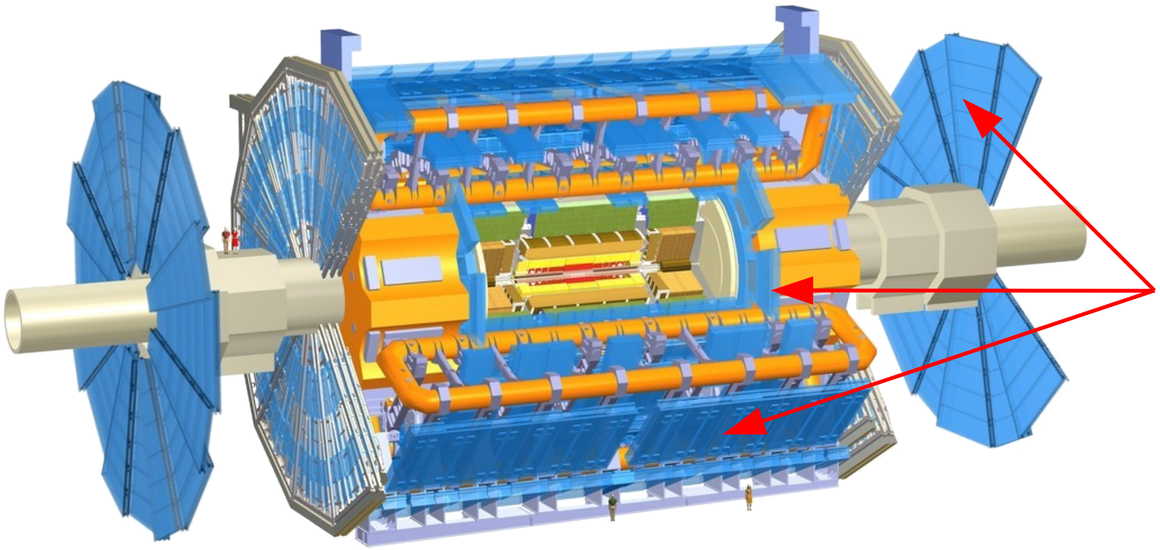

Inner detector

Calorimeters

Muon spectrometer

- muon momenta

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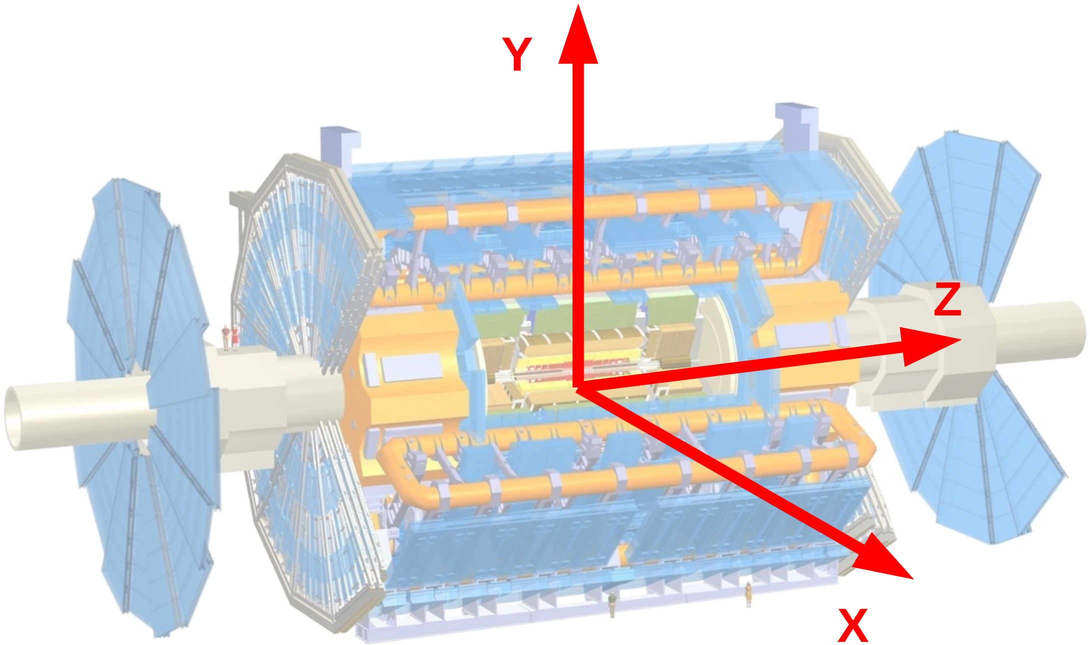

Inner detector

Calorimeters

Muon spectrometer

Magnet system

Measure for forward direction: pseudorapidity (a transformation of the polar angle)