Single-Top Physics at ATLAS

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t-Channel Lepton + Jets Analysis with 2011-2012 Data Using a Kinematic Fit

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GEFÖRDERT VOM
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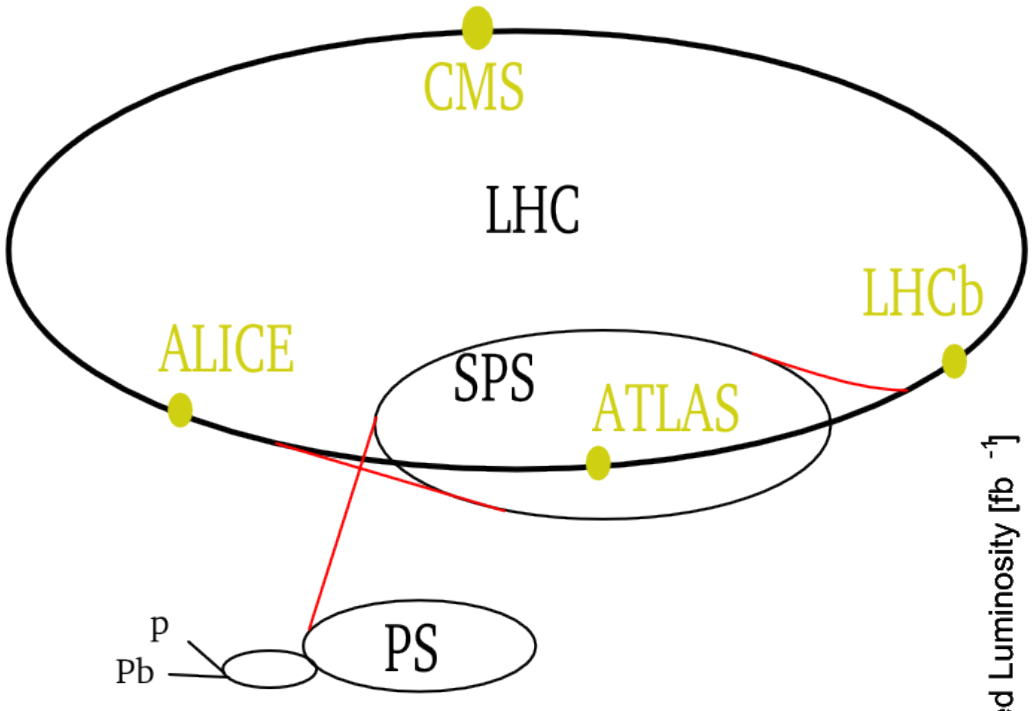
Contents

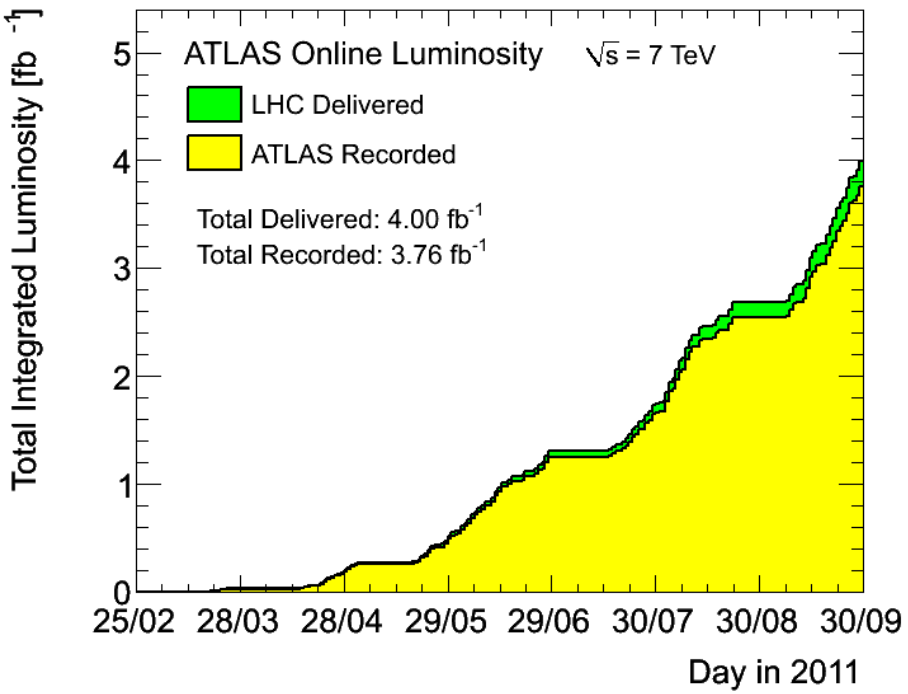
The Large Hadron Collider (LHC)



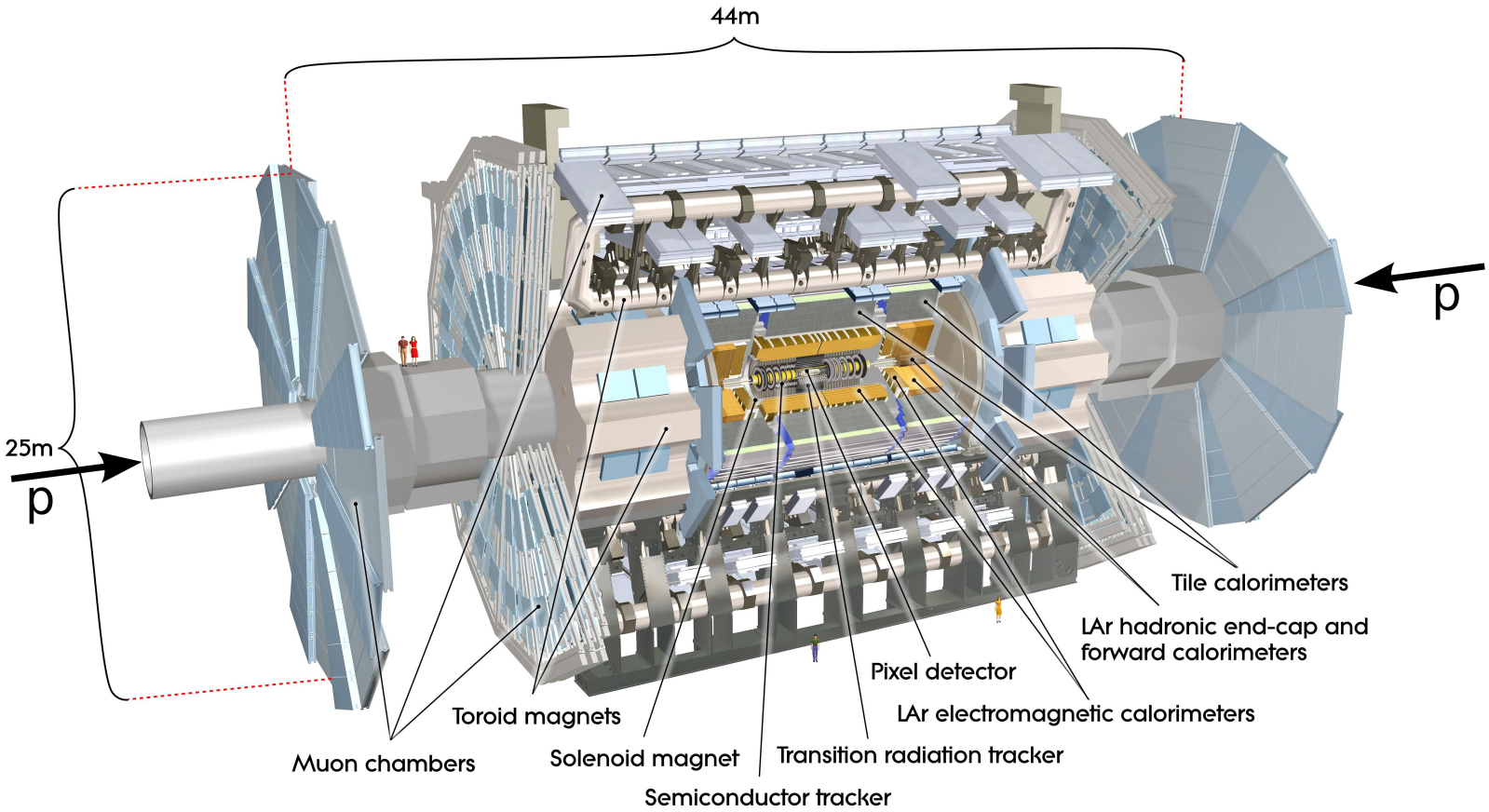
- Proton-proton collider at CERN
- Circumference: 27 km
- Currrent $\sqrt{s} = 7\,\mathrm{TeV}$

- Data taking since march 2010
- Current instantaneous luminosity $L = 3.2 \cdot 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Until now $\int L\,dt = 4\,\mathrm{fb}^{-1}$, till end of 2012 $\sim \int L\,dt = 10\,\mathrm{fb}^{-1}$

ATLAS data taking 2011

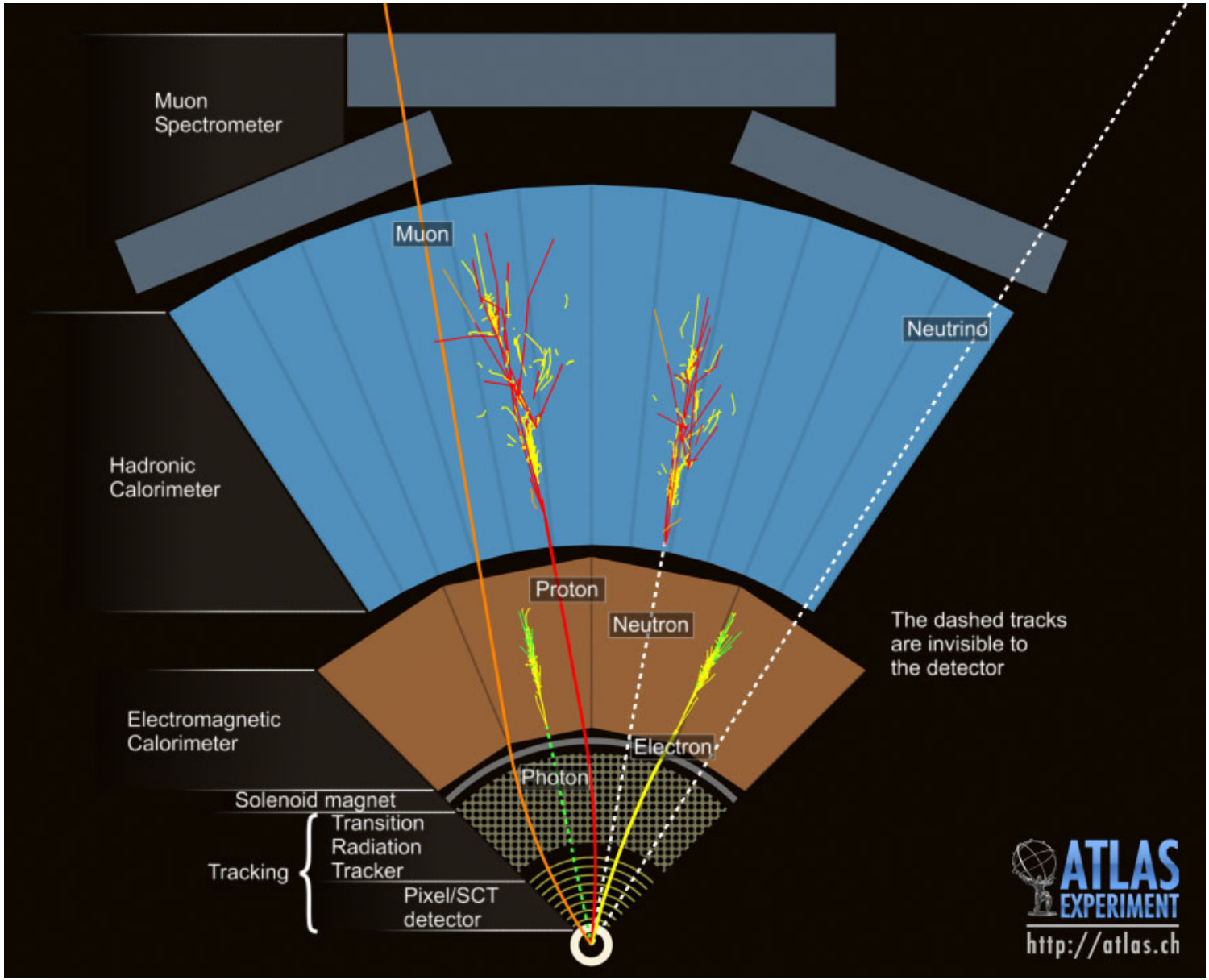


The ATLAS Detector

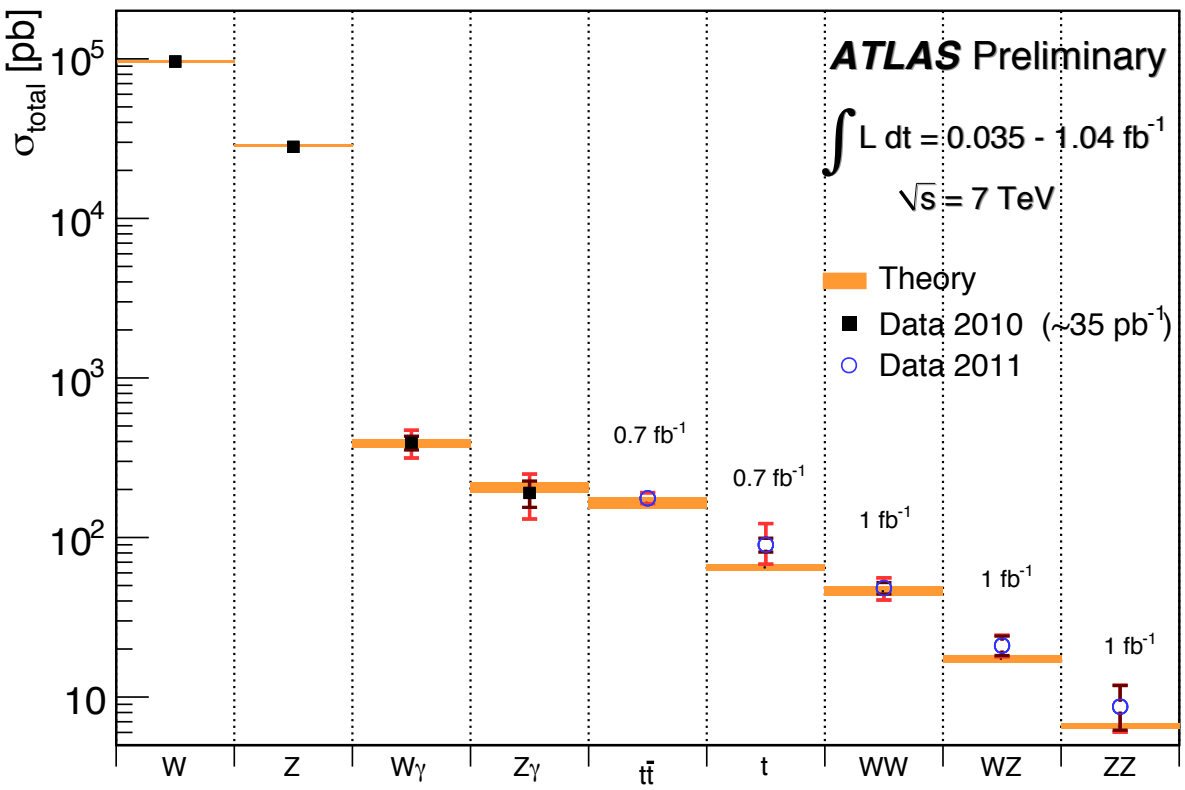


- Multipurpose detector at the LHC at interaction point P1
- Solenoid magnet ($2\,\mathrm{T}$), toroid magnet ($4\,\mathrm{T}$), $\sim$ 100 Mio readout channels
- Trigger: interaction rate $40\,\mathrm{MHz}$, recording $\sim 500\,\mathrm{Hz}$

Particle Detection and Identification

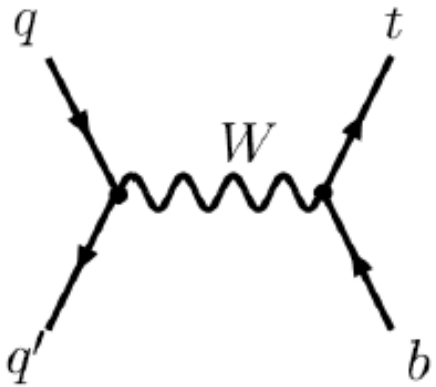


Cross Sections at Proton-Proton Scattering



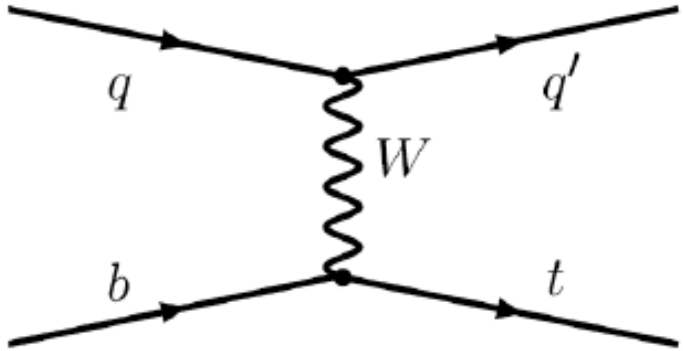
- Huge deviations in cross sections for different processes
  $\rightarrow$ much more background events (e.g. W+jets, $t\bar{t}$) than single-top
  $\rightarrow$ signal to background ratio $S/B < 1$
- Large uncertainties and deviations from theory for single-top
  $\sigma_{t,t\text{-channel}} = 90^{+9}_{-9}(\text{stat})^{+31}_{-20}(\text{syst})\,\text{pb}$

Single-Top Production Channels



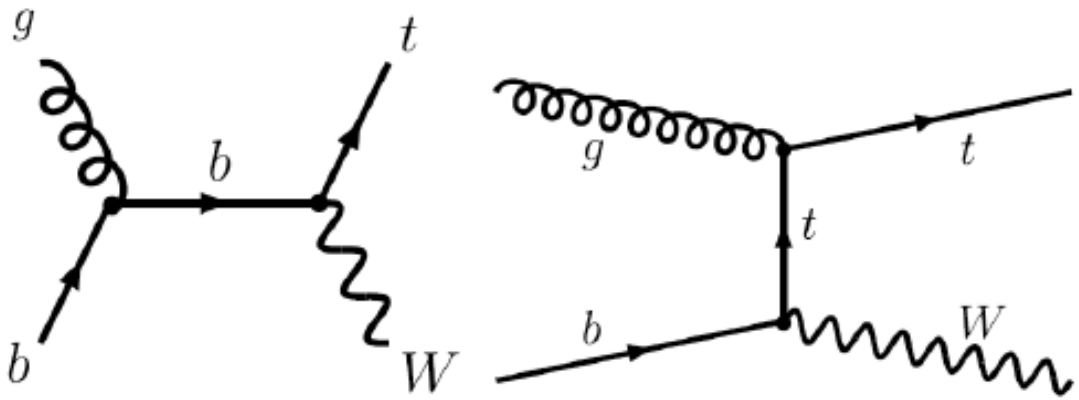
s-channel

$\sigma = 4.63^{+0.19}_{-0.17}\,\mathrm{pb}$



t-channel

$\sigma = 64.57^{+2.71}_{-2.01}\,\mathrm{pb}$



Wt-channel

$\sigma = 15.74^{+1.06}_{-1.08}\,\mathrm{pb}$

Cross sections: Approximate NNLO calculations, Kidonakis, Phys. Rev. D 83, 091503(R) (2011), Phys. Rev. D 81, 054028 (2010)

Why Is Single-Top of Interest?

- Single top quark production in electro-weak interaction

  $\rightarrow$ test EW interaction

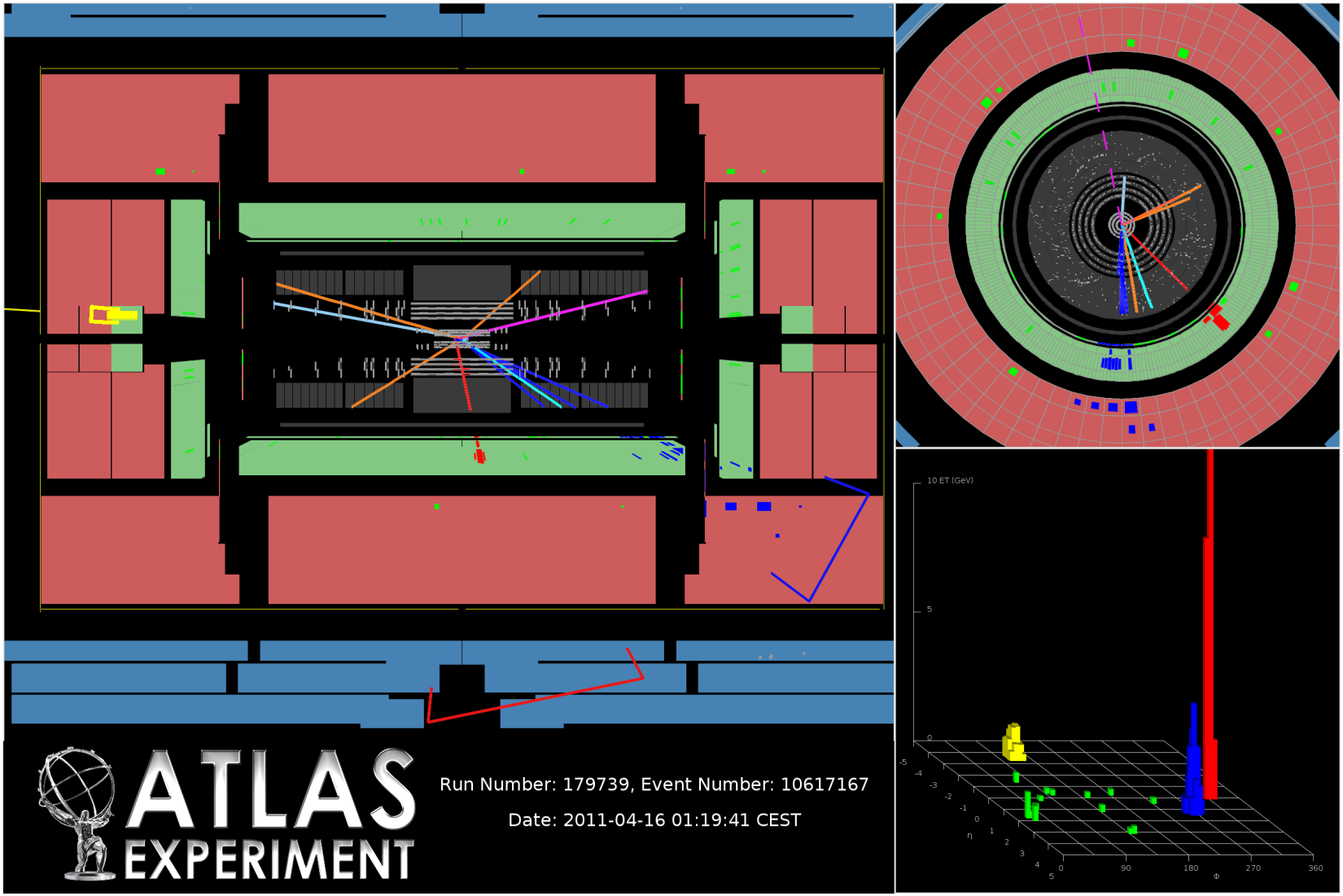
  - Direct measurement of CKM matrix element V_{tb}
    - CKM-matrix unitary? More than 3 quark generations?
  - $\tau_t < \tau_{had} \rightarrow$ spin information conserved in decay products:
    - Test $V - A$ structur of weak int. $\rightarrow$ anomalous couplings?
- Important background for charged Higgs and exotics analysis

Systematics for Single-Top Cross Section Measurement

Uncertainties already dominated by systematics

Source	$\Delta\sigma/\sigma$[%]	
DATA statistics	+13	-13
MC statistics	+6	-6
Object modeling	+23	-14
b-tagging scale factor	+18	- 13
Generators & PDF	+25	-22
Background normalization	+10	-10
Luminosity	+7	-6
All systematics	+41	-27
Total	+44	-30

Signature of the t-Channel eν



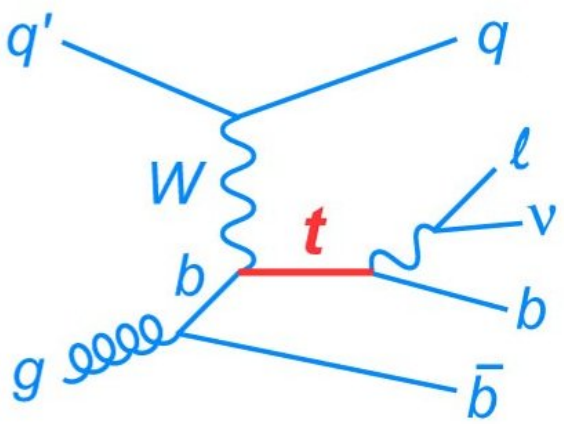
1 Electron, 1 b-jet, $\not{E}_T$, 1 „light flavour“ forward jet

Single-Top Production in the t-Channel

t-Channel

dominant at the LHC:

$\sigma^{\text{t-chan}}_{\text{single-top}} = 64.57^{+2.71}_{-0.17}\,\text{pb}$



Signature:

$t \to W\,b \to \ell\,\nu\,b$	(lepton, $\not{E}_T$, b-jet)
q′	(„Light-Flavour“ forward jet)

Main background:

QCD-multijet-processes	$\gg$	$\sigma^{\text{t-chan}}_{\text{single-top}}$
W + jets	$\approx 300\cdot$	$\sigma^{\text{t-chan}}_{\text{single-top}}$
Z + jets	$\approx 40\cdot$	$\sigma^{\text{t-chan}}_{\text{single-top}}$
$t\bar{t}$ - production	$\approx 3\cdot$	$\sigma^{\text{t-chan}}_{\text{single-top}}$

- Large background cross section compared to single-top $\rightarrow S/B < 1$
- Sophisticated reconstruction method needed to reduce background and extract the signal

Reconstruction Methods for Single-Top

Tevatron

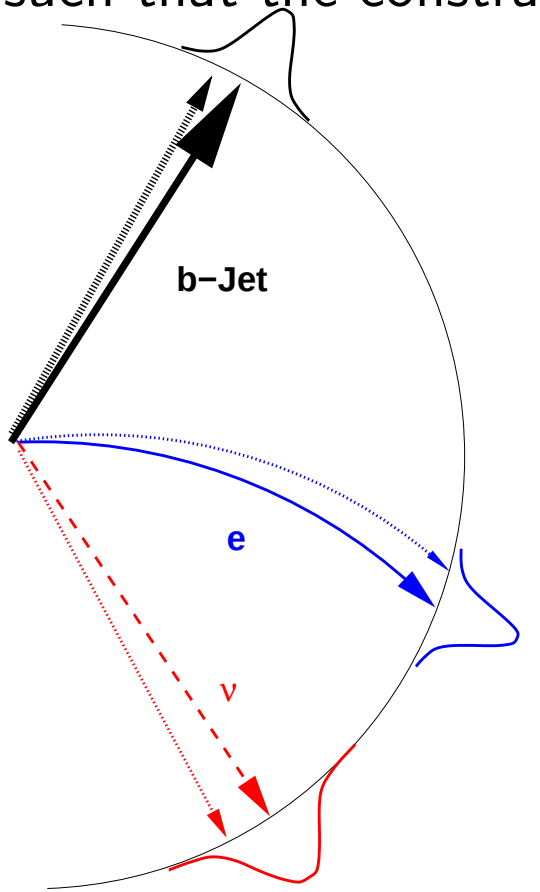
- Cut-based
- Kinematic fit
- Boosted decision tree
- Neuronal network
- Matrix element method (LO)

ATLAS

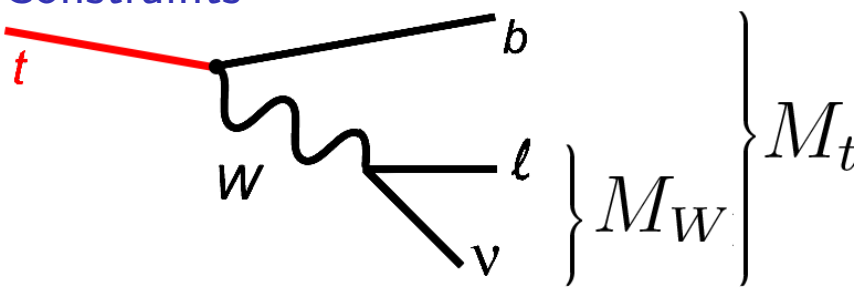
- Cut-based
- Kinematic fit – ongoing
- Boosted decision tree – planned
- Neuronal network
- Matrix element method (LO, NLO – P. Rieck) – planned

Kinematic Fit

- χ^2-based fit (KinFitter package, TU Dresden) with nonlinear constraints
- Use χ^2, provided by the fitter, to discriminate signal and background
- Corrects momenta of the final state objects, such that the constraints are fulfilled and χ^2 is minimized
- Tests for every event every possible combination of lepton, b-jet, $\not{E}_T$
- Best combination (smallest χ^2) is the top quark candidate



Constraints



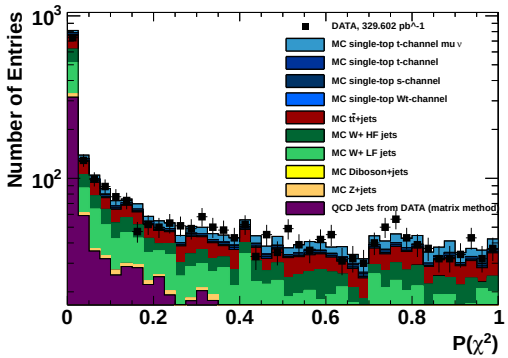
Kinematic Fit

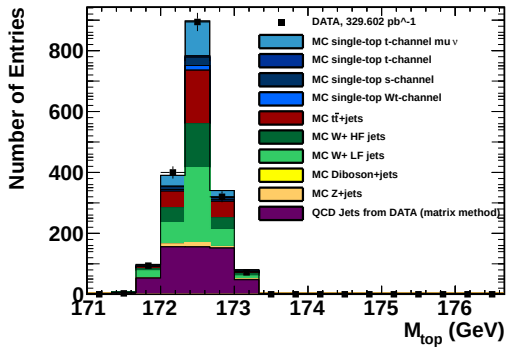
Advanteges:

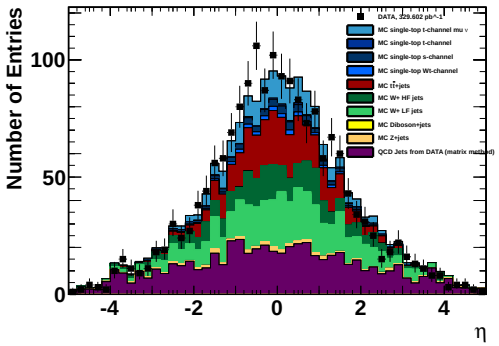
- Data-driven (i.e. no MC dependence)
- Corrected momenta of final state objects
  $\rightarrow$ less dependence from energy scale
- Neutrino Pz reconstructed
  $\rightarrow$ full 4-momenta of t and W
- Works even without b-tagging

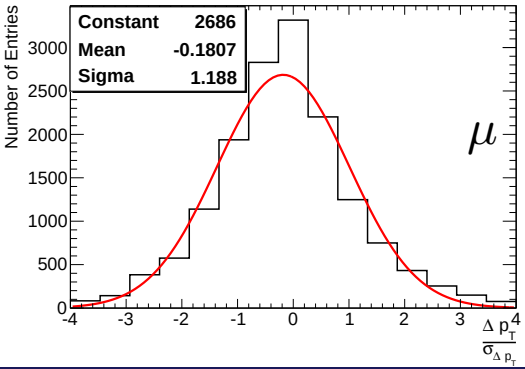
Results:

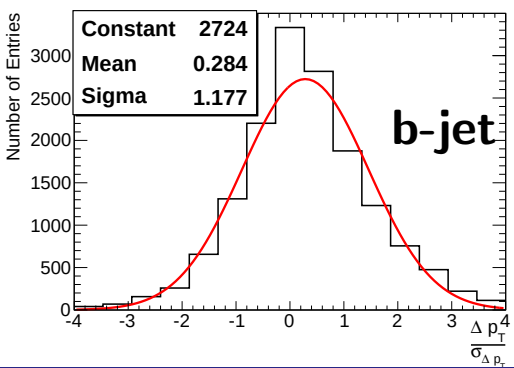
from MSc thesis by Patrick Rieck and PhD thesis (in progress) by Ruth Herrberg and Michelangelo Giorgi

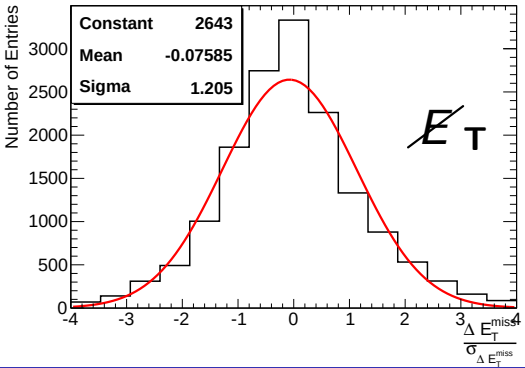












Project Discription

- Based on 2 PhD thesis for total cross section measurement

  (to be finalized in summer 2012):

  - Ruth Herrberg: t-channel
  - Michelangelo Girogi: Wt-channel
- Work on systematics of cross section measurement
- B-Tagging performance studies and systematics

  (highest contribution now)
- Measurement of differential cross sections

  $\rightarrow$ Interpretation of measurement, e.g. SM tests

  - $V_{tb} \rightarrow$ CKM-Fitter, Heiko Lacker
  - $V - A$ structure

Summary

- LHC provides unique production rates for single-top
- Single-top provides the possibility for testing the EW interaction
- First results published by ATLAS and CMS

  ATLAS: $\sigma_{\mathrm{t},t\text{-channel}} = 90^{+9}_{-9}(\mathrm{stat})^{+31}_{-20}(\mathrm{syst})\,\mathrm{pb}$

  theory: $\sigma_{\mathrm{t},t\text{-channel}} = 64.57^{+2.71}_{-2.01}\,\mathrm{pb}$
- Plan for my PhD:
  - Improving the signal extraction and background rejection of the analysis with a kinematic fit
  - Measure total and differential cross sections and improve systematics (esp. b-tagging) with 2011-2012 data

    $\rightarrow$ perform standard model tests (V_{tb}, $V-A$ structure)

Backup

B-Tagging

- Identification of jets originating from b-quarks
- Exploit longer lifetime of B-hadrons
  $\rightarrow$ secondary vertex and displaced tracks
- Taggers provide a b-tag probability weight W_{jet} for each jet
  $\rightarrow$ jet is tagged as b-jet if $W_{\text{jet}} > W_{\text{cut}}$