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Top Physics at ATLAS

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Motivation for Top physics studies

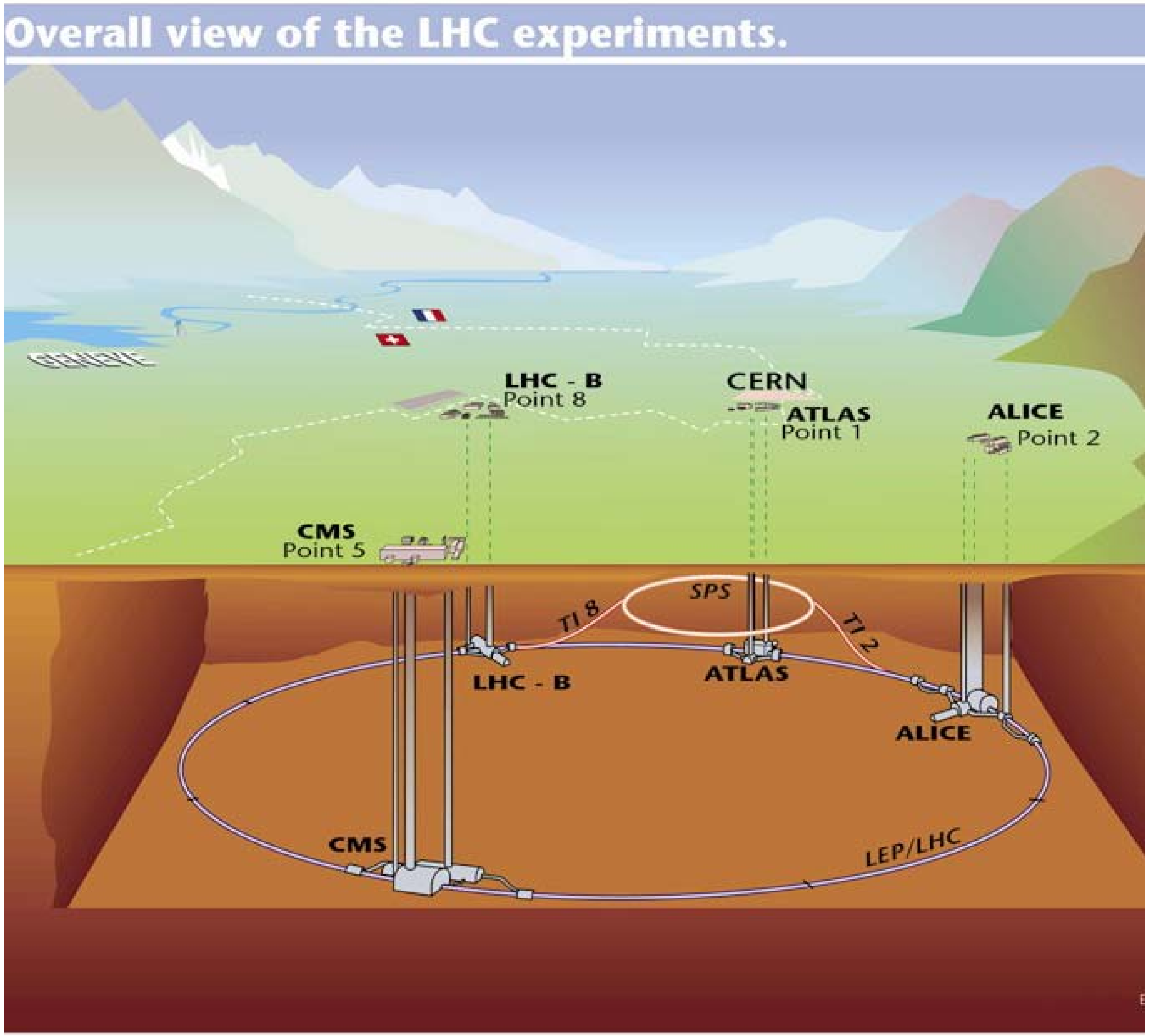
- Does the top behave as SM predicts?
  - Radiative corrections in the SM relate the top and the W masses to the mass of the SM Higgs.
  - The large value of the top mass implies that it can provide an excellent probe of the possible existence of other massive particles and of new physics by the detailed study of its properties.
- Other uses for top
  - Useful to calibrate the detector (e.g. $W \rightarrow jj$)
  - Top quarks will be a major source of background for almost every search for physics beyond the SM

Top production at LHC

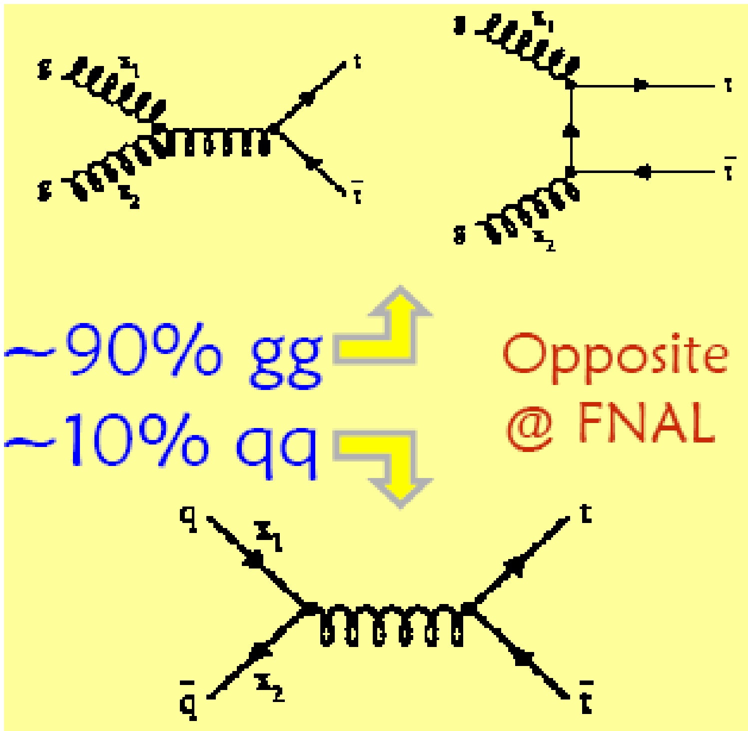
The Large Hadron Collider (LHC) is a proton-proton collider with 14 TeV centre of mass energy and design luminosity of 10^{34} cm^{-2}s^{-1}.

10 fb^{-1} of integrated luminosity are expected to be collected in one year of data taking at the initial low (10^{33}) luminosity and 100 fb^{-1} for one year of data taking at the nominal one.

Studies for the low luminosity period of LHC will be presented



Top production at LHC

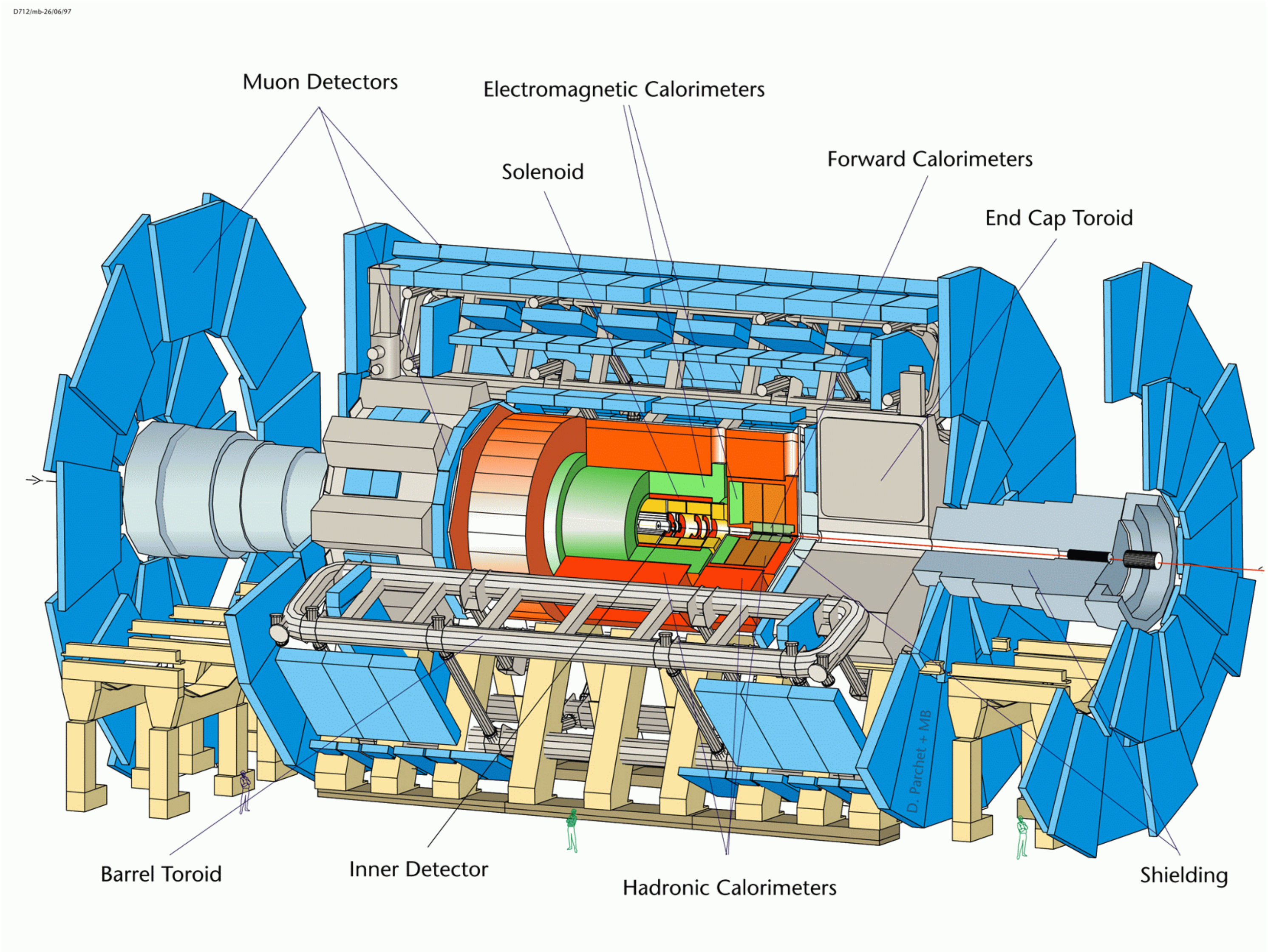


Top production cross-section ~100 x Tevatron

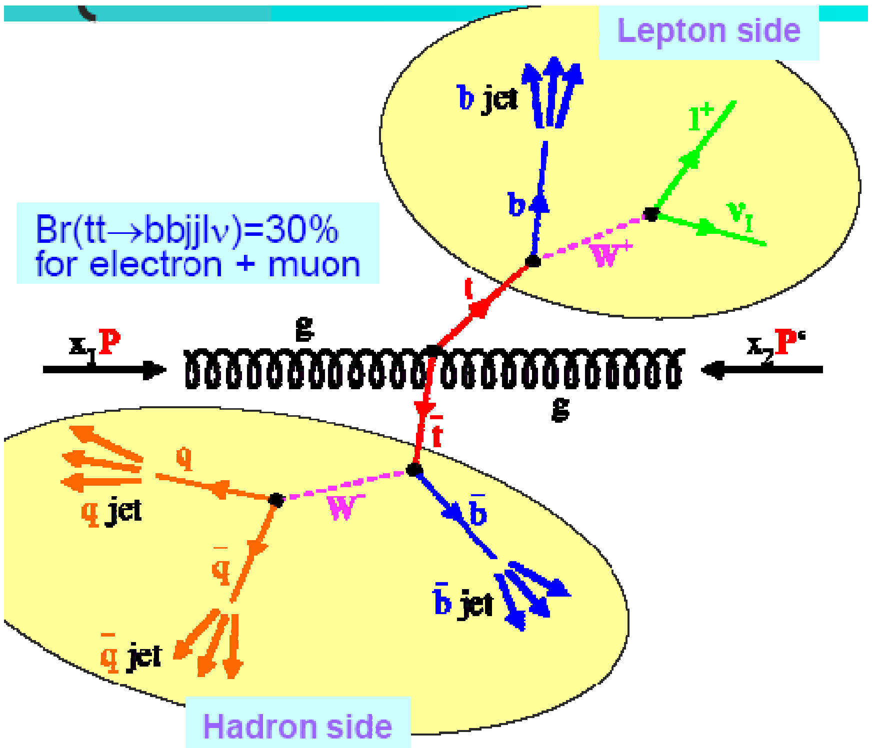
- **Cross Section determined to NLO precision**
  - **Total $\sigma_{NLO}(tt) = 834 \pm 100$ pb**
- **At Low luminosity we expect 10^7 events/year**

LHC is a top factory

The ATLAS Detector



Measurement of the top quark mass



Results obtained with a fast simulation program

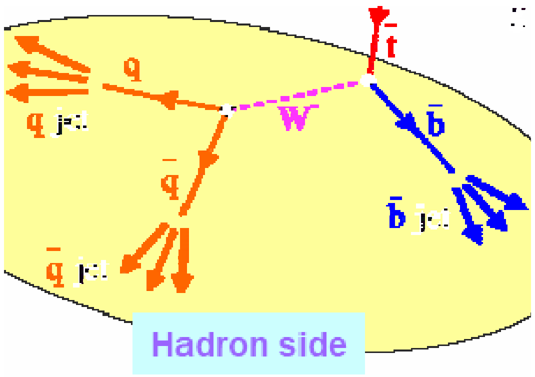
Single Lepton + Jet Selection Criteria

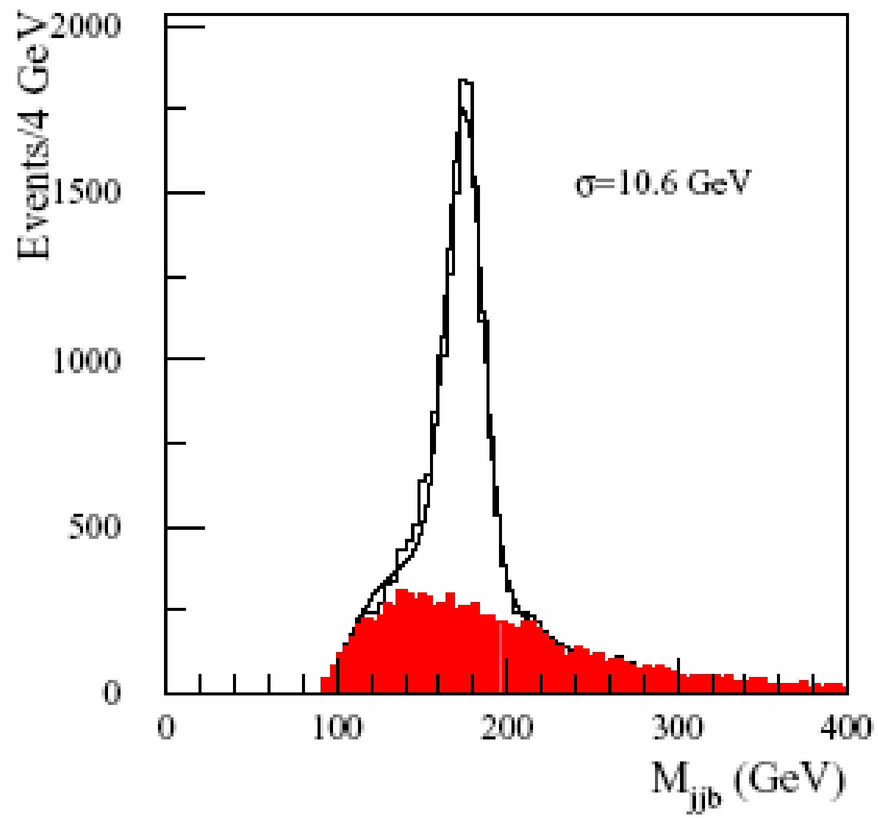
- Isolated lepton with p_T>20 GeV and $|\eta|$<2.5
- E_T^{miss} > 20 GeV
- ≥ 4 jets with E_T>40 GeV and $|\eta|$<2.5
- ≥ 2 jets tagged as b-jets

The above selection cuts result to

S/B ~ 65

Measurement of the top quark mass (cont.)





The $W \rightarrow jj$ was reconstructed from the non-b jets. The combination with closest invariant mass to m_W was selected. Events with $|m_{jj} - m_W| < 20$ GeV were kept. The W candidate was then combined with the b-jet which gives the highest p_T for the reconstructed top.

The determination of m_t by fitting the m_{jjb} resulted

δm_t(stat.) = ±0.070 GeV

Measurement of the top quark mass (cont.)

Summary of Systematic errors

Source of error in GeV	Lepton+jets inclusive sample	Lepton+jets large clusters sample	Dilepton	All jets high pT sample
Energy scale				
Light jet energy scale	0.2	-	-	0.8
b-jet energy scale	0.7	-	0.6	0.7
Mass scale calibration	-	0.9	-	-
UE estimate	-	1.3	-	-
Physics				
Background	0.1	0.1	0.2	0.4
b-quark fragmentation	0.1	0.3	0.7	0.3
Initial state radiation	0.1	0.1	0.1	0.4
Final state radiation	0.5	0.1	0.6	2.8
PDF	-	-	1.2	-

The Challenge: Determine m_t with ~1 GeV accuracy in one year of LHC (a Δm_W ~ 15 MeV would constrain m_h to within 30%)

Top quark decays and couplings

SM predicts : Br (t→Wb) ≈ 99.9%, Br (t→Ws) ≈ 0.1%, Br (t→Wd) ≈ 0.01%

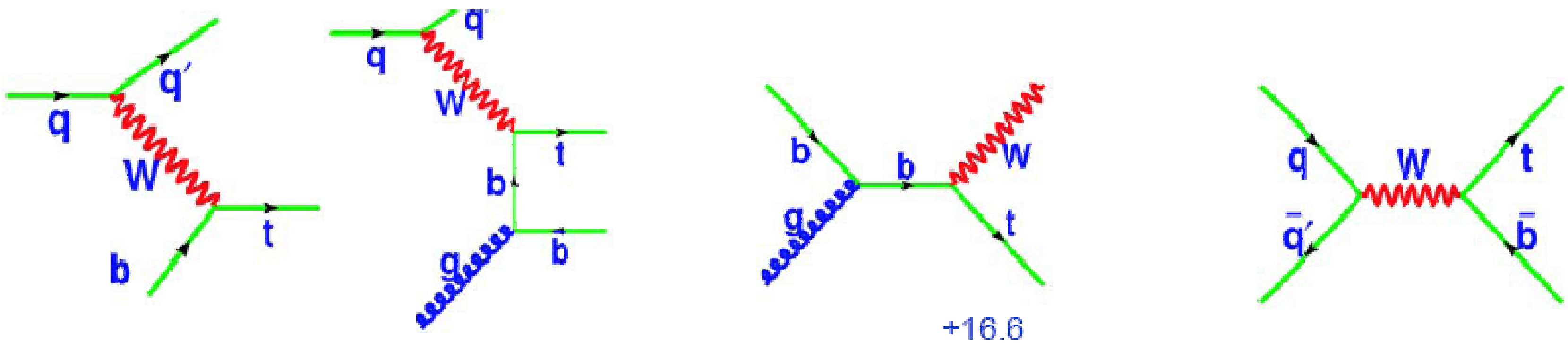
- This prediction can be checked by searching for t→WX (t→bX) decays.
  - Measure the ratio of ttbar events with a double b-tag (lepton-tag) to single b-tag (lepton-tag).
  - LHC will provide enough statistics for this measurement, but the systematic errors will be dominated by the uncertainties in the b-tagging (lepton) efficiency and fake rates.
- Can be checked also by measuring the top quark rare decays, especially the Flavor Changing Neutral Current (FCNC) ones.

FCNC rare decays

FCNC Decay	BR in SM	BR in MSSM	ATLAS Sensit. ($100\ fb^{-1}$)	Current limits
$t \rightarrow Zq$	$\approx 10^{-12}$	$\approx 10^{-8}$	$\approx 2 \times 10^{-4}$	< 0.137 (CDF)
$t \rightarrow \gamma q$	$\approx 10^{-12}$	$\approx 10^{-8}$	$\approx 1 \times 10^{-4}$	< 0.032 (CDF)
$t \rightarrow gq$	$\approx 10^{-10}$	$\approx 10^{-6}$	$\approx 7 \times 10^{-3}$	–

The branching ratios predicted by SM and MSSM are too small to be observable at LHC. However other theoretical models, including models with new interactions, with multiple Higgs doublets, and with new exotic fermions, allow branching ratios for FCNC top decays of $10^{-3} – 10^{-2}$.

Single Top Production



Wg fusion: 245±27 pb
S.Willenbrock *et al.*, Phys.Rev.D56, 5919

Wt: $62.2^{+16.6}_{-3.7}$ pb
A.Belyaev, E.Boos, Phys.Rev.D63, 034012

W* 10.2±0.7 pb
M.Smith *et al.*, Phys.Rev.D54, 6696

Provides the only means to directly measure the CKM matrix element V_{tb} at LHC and thereby explore the properties and nature of the Wtb vertex.

Provides an opportunity to study the polarization of top quarks (~100% polarized at LO) as well as of the W bosons produced in top decays (~70% longitudinally polarized).

Can provide an independent measurement of the top quark mass and may probe FCNC

Single Top Production (cont.)

In order to reduce the enormous QCD multi-jet backgrounds and to provide a high p_T lepton for trigger purposes, single top production with $t \rightarrow Wb$ followed by a leptonic decay $W \rightarrow l\nu$ ($l=e,\mu$) has been considered. In this decay topology main contributions to the background comes from ttbar and Wjj (specially Wbbbar) events.

Fake lepton rate, b-tag efficiency and purity, reconstruction of low energy jets, identification of forward jets are among the detector performance issues that have to be understood in detail.

Results with 30 fb^{-1} of data

Process	Signal	Bkg	S/B	δV_{tb} (stat)	δV_{tb} (th.)
Wg fusion	27k	8.5k	3.1	0.4%	6%
Wt	6.8k	30k	0.22	1.4%	6%
W*	1.1k	2.4k	0.46	2.7%	5%

Conclusions

The large production cross-sections at the LHC for ttbar pair production and electroweak single top production imply that over the lifetime of the ATLAS experiment, samples of many millions of top quarks events will be selected. These large data sets will allow very sensitive studies of the properties of the top quark.

The mass of the top quark will be measured with a precision of ~1 GeV, dominated entirely by systematic errors.

Rare decays of the top quark can be probed down to branching ratios as low as of order of 10^{-4}.

The detailed study of different mechanisms of electroweak single top production will yield a wealth of information including precision measurements of V_{tb}, measurement of the W and t polarizations, and searches for anomalous couplings.

And more … top quark Yukawa coupling, ttbar spin correlations and CP violation, heavy resonances decaying to ttbar.