Top Quark Physics With The ATLAS Detector

Young Scientist Workshop 2011

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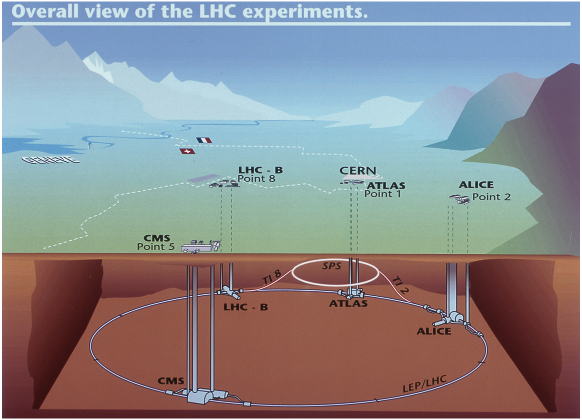
Outline

1. LHC and ATLAS
2. $t\bar{t}$ Production and Identification
3. Top Mass Measurement
4. Conclusions

The Large Hadron Collider



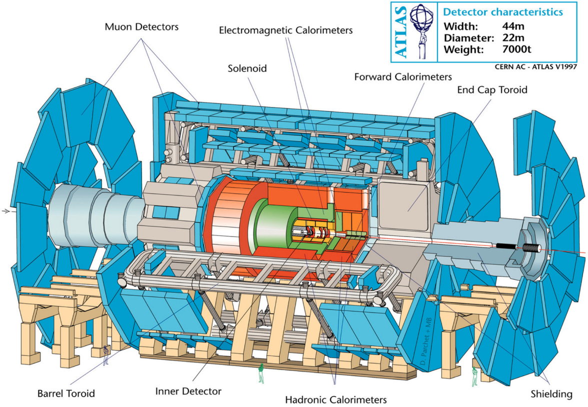
- proton-proton collider
- designed for center of mass energy of $\sqrt{s}$=14 TeV (currently $\sqrt{s}$=7 TeV)
- design luminosity of $10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- 4 main experiments at collision points: ATLAS, CMS (multipurpose detectors), LHCb and ALICE

The ATLAS Detector

inner detector:
track reconstruction

electromagnetic/hadronic calorimeter:
energy measurement of electrons, positrons, photons, hadrons

muon spectrometer:
precise standalone muon momentum measurement



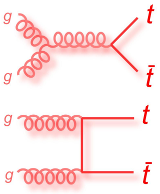
Top-Antitop Production at LHC

top pairs are produced via

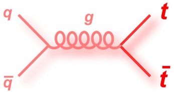
1. gluon-gluon fusion
2. quark-antiquark annihilation

due to the high center of mass energy (currently 7 TeV at LHC) the gluons (in the colliding protons) carry a large fraction of the momentum

→ gluon-gluon fusion main production process

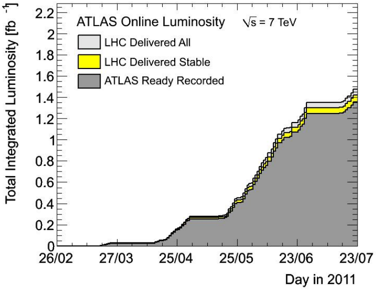


$t\bar{t}$ poduction via gluon fusion



$t\bar{t}$ poduction via quark-antiquark annihilation

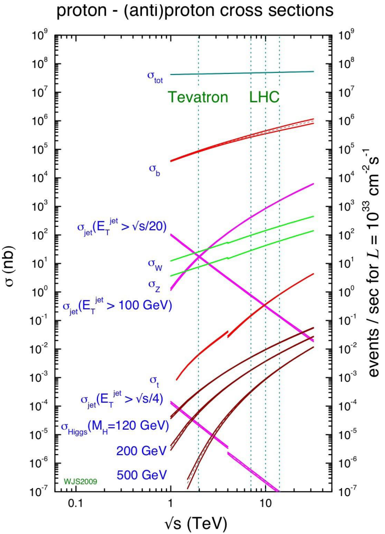
Top-Antitop Production at LHC



$t\bar{t}$ production cross section: $\approx$ 160 pb ($\sqrt{s}$=7 TeV)

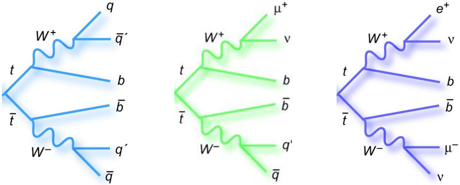
data recorded in 2011: $\int$L $\approx$ 1.4 fb^{-1}

top-antitop pairs in 2011 data: $\approx$ 200000

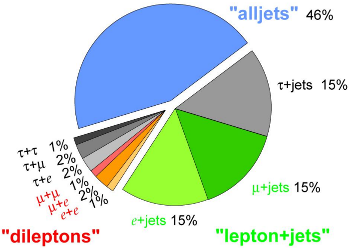


Top-Antitop Decay Channels

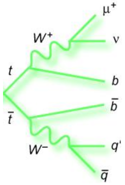
- top quark lifetime: $\approx 10^{-24}$s
  $\longrightarrow$ too short for hadronization
  $\longrightarrow$ need to identify top quarks via their decay products
- Standard Model prediction:
  t$\longrightarrow$ W + b ($\approx$ 100%)
  $\longrightarrow$ $t\bar{t}$ decay topology determined by W-decay
  - leptonic: W $\longrightarrow$ e, μ, τ + ν
  - hadronic: W $\longrightarrow$ $q\bar{q}$
- 3 $t\bar{t}$ decay channels:
  - all-hadronic: large BR but large QCD-background
  - semi-leptonic: still good statistics, moderate background
  - di-leptonic: small background, small BR
- will exclude τ decays



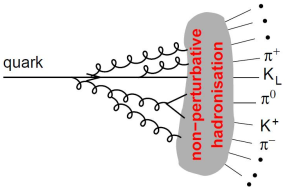
Top Pair Branching Fractions

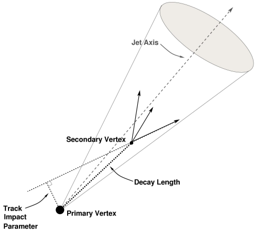


Semileptonic Top-Antitop Decays: Signal



- 1 lepton (e, μ)
- ν: cannot be detected $\longrightarrow$ missing transverse energy
- 4 quarks, thereof 2 b-quarks:

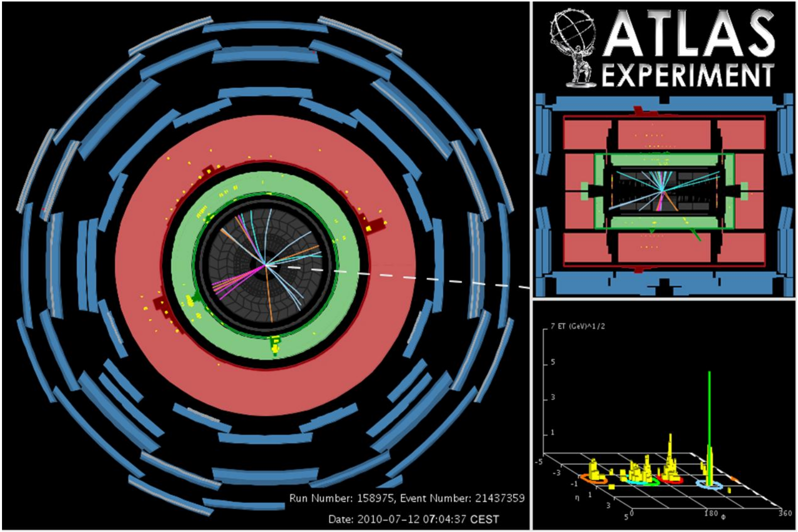




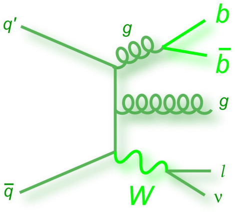
quarks/gluons produce bunches of collimated hadrons $\longrightarrow$ 4 jets

b-quarks/b-jets can be identified due to their specific properties (long b-hadron lifetime $\longrightarrow$ secondary vertex,...) $\longrightarrow$ 2 b-jets

Semileptonic Top-Antitop Decays: Signal

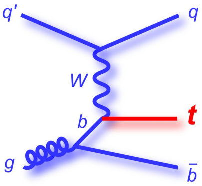


Semileptonic Top-Antitop Decays: Backgrounds



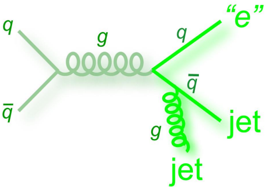
W+jets

- leptonically decaying W + jets from initial and final state radiation



single top

- singly produced top (together with a bottom quark) via weak, charged-current interactions
- additional I/FSR jets



QCD

- multijet events + fake leptons (e.g. leptons from weak decays in b-jets)
- not very likely to pass semi-leptonic event selection but high production cross section

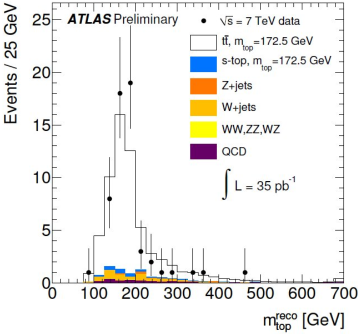
Top Mass Measurement Using Semileptonic $t\bar{t}$ Events

Selecting semileptonic $t\bar{t}$ events

1. rejection of non-collision background
2. rejection of non-$t\bar{t}$ events by requiring
    - exactly one isolated lepton
    - missing transverse energy
    - at least 4 jets, at least 1 b-tagged jet
    - transverse W-mass (reconstructed from lepton and E_T^{miss}) within predifined window

Reconstructing the Top Mass Peak

- jets from the top-decay are closer to each other (smaller $\Delta\phi$) w.r.t. the remaining jets
- the 3 jets stemming from the top-decay should therefore have the highest combined p_T (=p_T of vector sum)

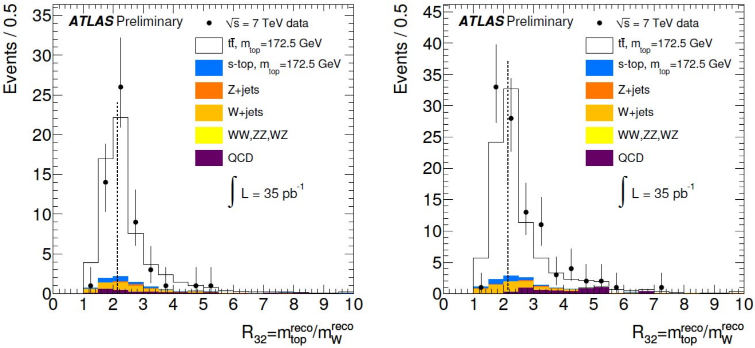


(a) Electron channel | (b) Muon channel

Calibrating The Top Mass

idea: use W-mass to calibrate the top mass peak:

$$m_{top} = \frac{m_{3-jet}}{m_{2-jet}} m_W \tag{1}$$



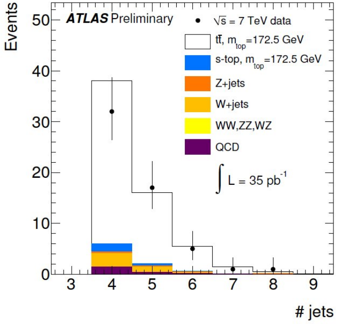
(a) Electron channel

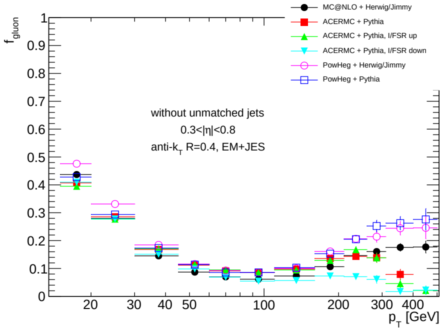
(b) Muon channel

Possible Improvement...

- in order to reconstruct the top mass peak we need to find the three jets coming from the hadronically decaying top
- in $t\bar{t}$ events we have
  - one additional b-jet from the second top-quark
  - additional (gluon) jets from initial and final state radiation

idea: try to identify gluon jets to improve the precission of the top mass measurement



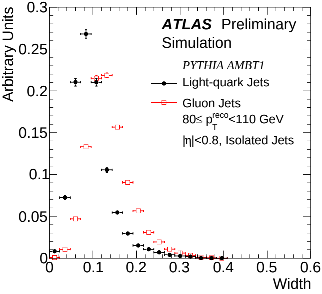


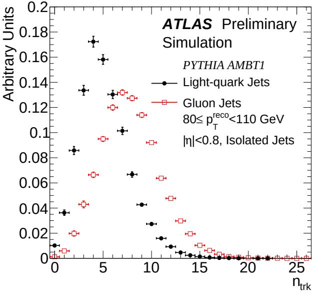
Differences Between (Light) Quark and Gluon Jets

gluon jets tend to...

- ...be wider, i.e. have larger values of $\sum_{constituents} \frac{p_{T,const} \times \Delta R_{const,jet}}{p_T^{jet}}$
- ...have more (softer) particles $\longrightarrow$ larger number of tracks associated with jet

than light quark jets (ATLAS-COM-CONF-2011-056)





Conclusions and Outlook

- LHC produces large number of top-antitop-pairs
- semi-leptonic channel = golden channel: moderate background, good statistics
- identifying gluon jets might be a useful tool when measuring the top mass