Berlin 30.09.09

Top Quark Physics at ATLAS
from Cross-Section to New Physics

Valentina Ferrara

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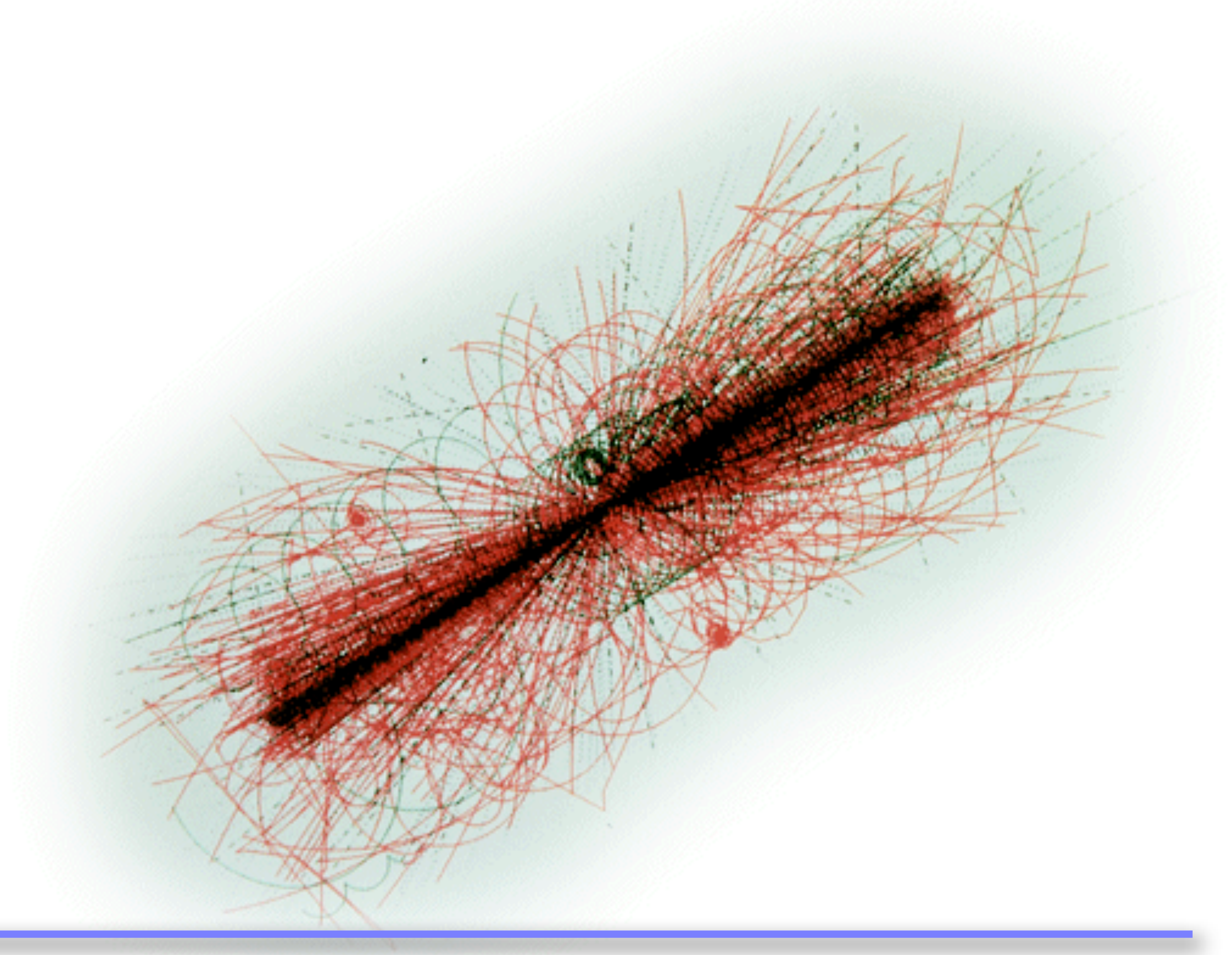
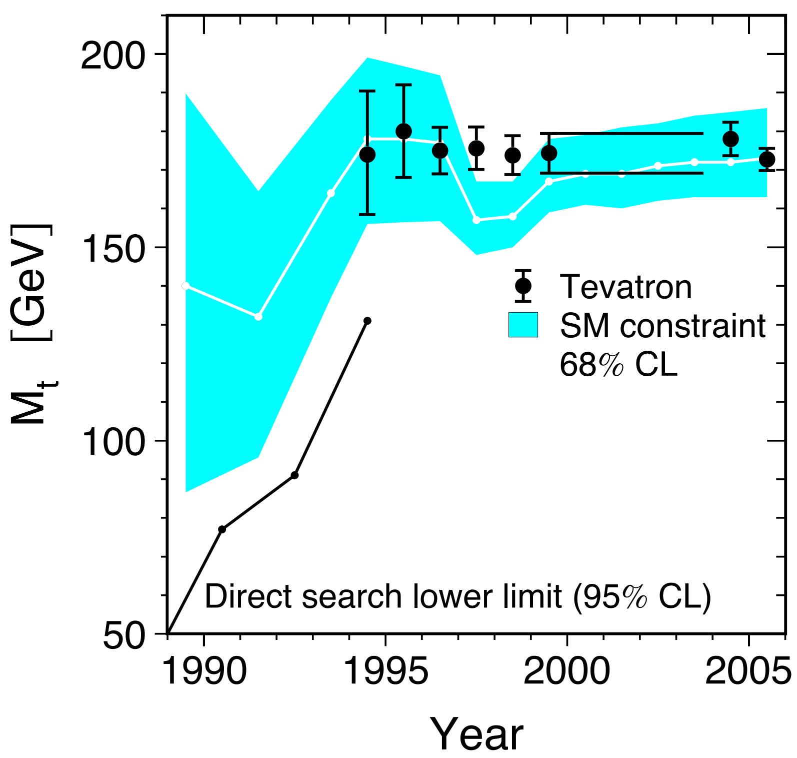


The discovery of the top quark

The discovery of the top quark completed the most massive generation of fermions

$$\ldots \begin{pmatrix} t \\ b \end{pmatrix}$$

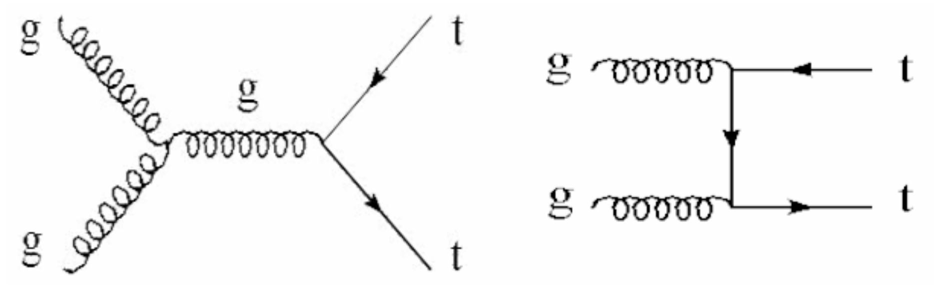
It demonstrated the enormous predictive power of the Standard Model

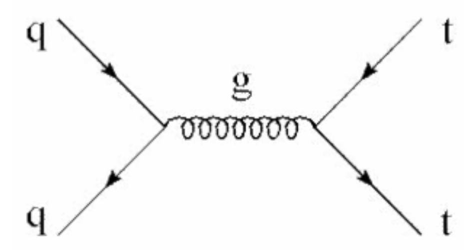


The Tevatron is the only place on Earth where top quarks can be produced and studied...until the LHC startup!

Standard Model Predictions

Production @ LHC

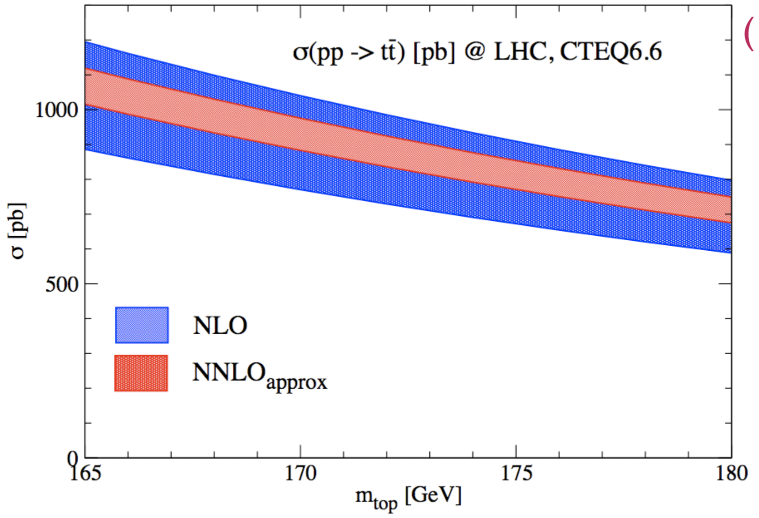




gluon-gluon fusion 90%

quark-antiquark annihilation 10%

Cross-Section



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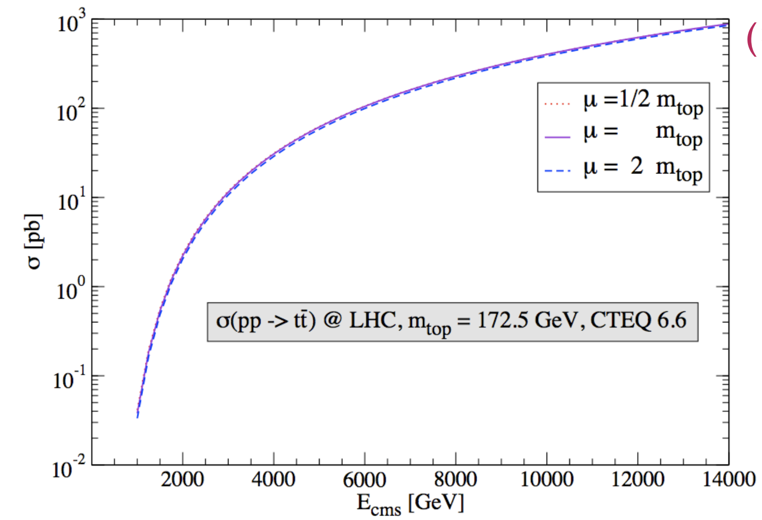


(*)

- σ_{tt} ($\sqrt{s}$ = 14 TeV) ≈ 886 pb
- σ_{tt} ($\sqrt{s}$ = 10 TeV) ≈ 403 pb
- σ_{tt} ($\sqrt{s}$ = 7 TeV) ≈161 pb

This translates into ($\sqrt{s}$ = 14 TeV):

~88.6 ×10^3 top pairs in 100 pb^{-1} of data

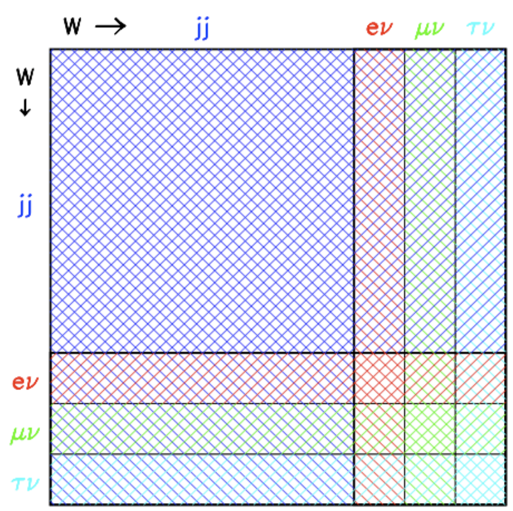
~10^7 top pairs per year before selection

A precision era will begin for top quark physics at the LHC!

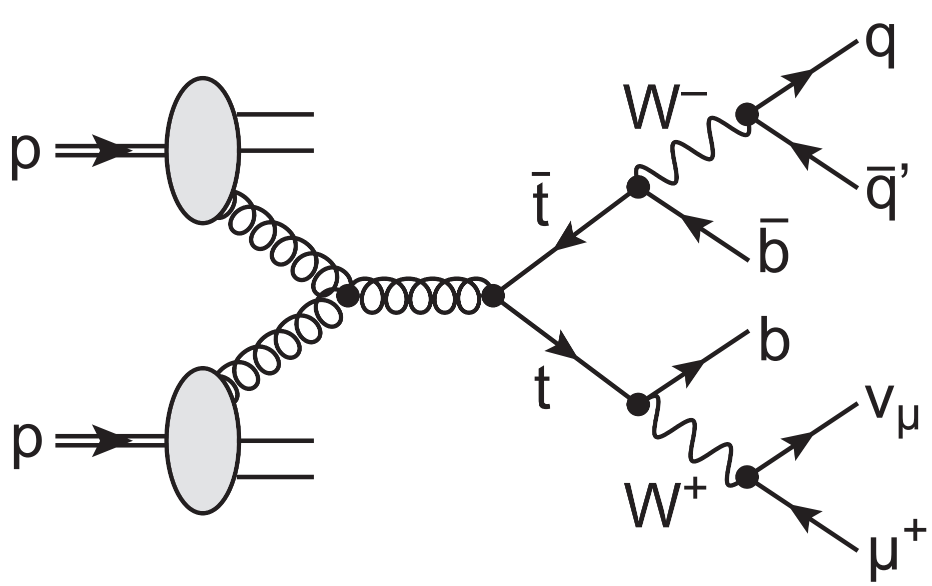
(*) arXiv:0907.2527

Top Quark Phenomenology

The top quark decays rapidly without forming hadrons, and almost exclusively through the single mode $t \rightarrow Wb$



Name	Signature	BR	xsec at 10 TeV
Fully Hadronic	jets	45.7%	191.5 pb
Lepton + Jets	e + jets	17.2%	71.9 pb
	μ + jets	17.2%	71.9 pb
Dilepton	$e\mu$ + jets	3.18%	13.3 pb
	$\mu\mu$ + jets	1.59%	6.67 pb
	ee + jets	1.59%	6.67 pb
Tau + Jets	τ + jets	9.49%	39.8 pb
Lepton + Tau	$\tau + e/\mu$ + jets	3.54%	14.8 pb
Tau + Tau	$\tau + \tau$ + jets	0.49%	2.06 pb
total	all	100%	419 pb



Semi-leptonic decay mode

Signature:
- one lepton
- missing energy from the neutrino
- two jets from the W boson
- two jets from the b quark

Determination of the Cross-Section

Given the high statistics which will be available even in the initial phase of the LHC, the top-pair cross section measurement can be performed relatively fast and with an imperfectly calibrated detector

Counting method:

number of observed events meeting the selection criteria of top-event signature

$$\sigma = \frac{N_{sig}}{L \times \epsilon} = \frac{N_{obs} - N_{bkg}}{L \times \epsilon}$$

number of background events estimated from Monte Carlo simulation and/or data samples

geometrical acceptance
trigger efficiency
event selection efficiency

- Trigger efficiencies determined from simulation represent a dangerous source of systematic uncertainty and should be determined directly from data $\longrightarrow$ **Tag&Probe technique**

Object and Event Selection

Firstly, we only want to use "good" particles. For example, good muons:

- STACO reconstruction algorithm
- transverse momentum > 10 GeV
- | pseudorapidity | < 2.5
- Isolation (energy deposit in cone 0.2 around object) < 6 GeV
- Inner Detector and Muon Spectrometer track match (preferably "best match")
- ...

Then, we apply the selection criteria for the semi-leptonic channel of top-pair events:

- (at least) one lepton
- missing transverse energy > 20 GeV
- (at least) 4 jets with transverse momentum >20 GeV
- of which (at least) 2 jets with transverse momentum >40 GeV

Trigger efficiency from Data

mu20 data sample

all events with mu20 trigger signature

i) first consider a sample of events that pass the three ATLAS trigger levels with at least a muon with transverse momentum higher than 20 GeV

selection

$Z \rightarrow \mu\,\mu$ events

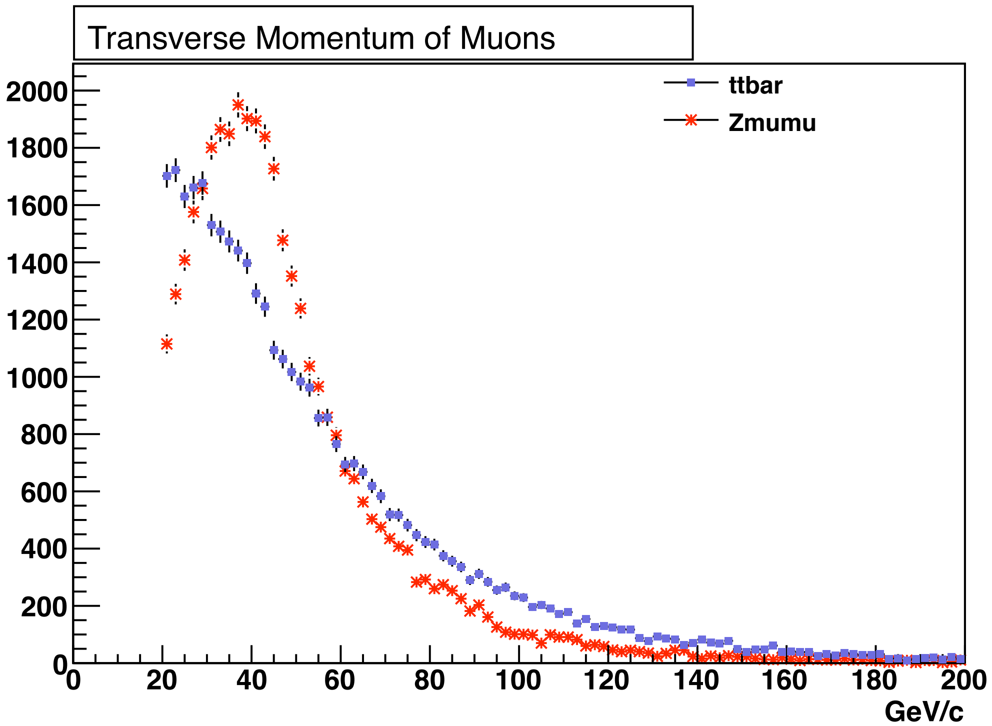
ii) for every muon that has fired the trigger ("Tag" muon) we require a second muon ("Probe") to be identified offline together with some identification conditions on the Z particle (e.g. the invariant mass of the pair must match the mass of the Z)

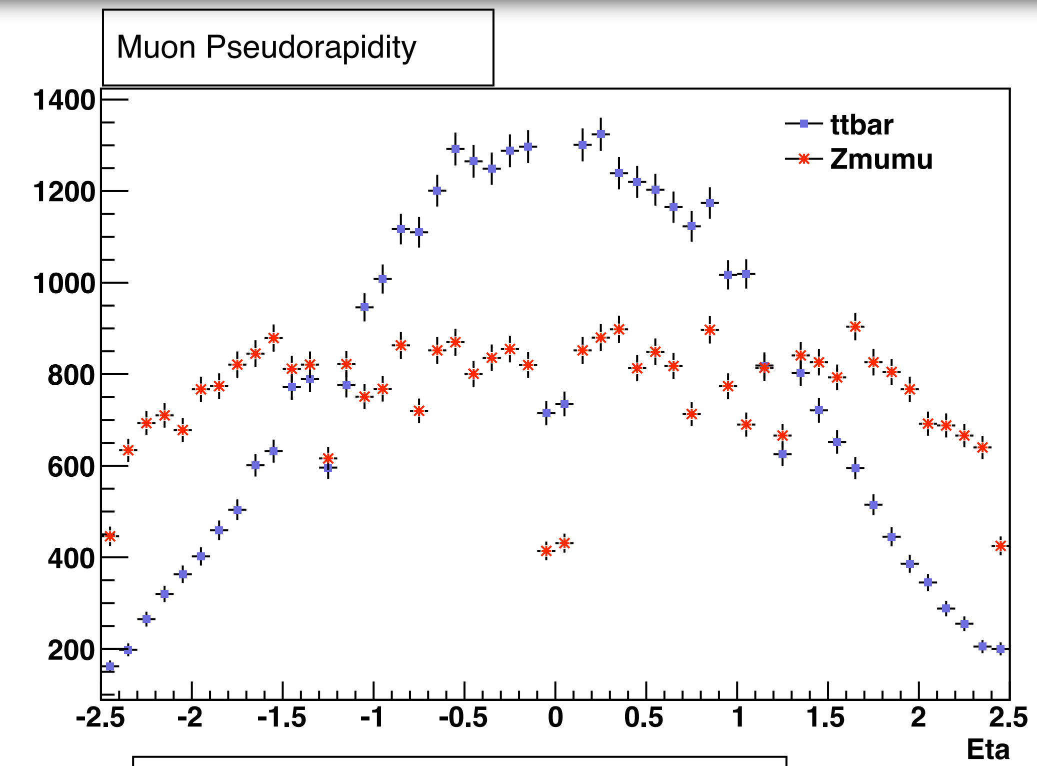
efficiency

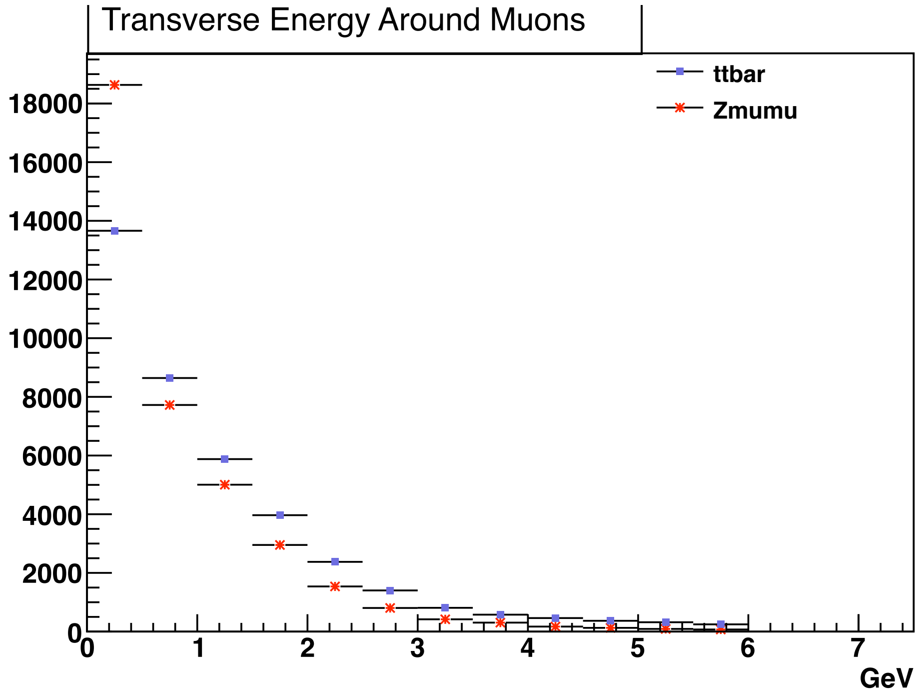
$$\frac{N_{(Tag\&Probe)}}{N_{(Tag)}}$$

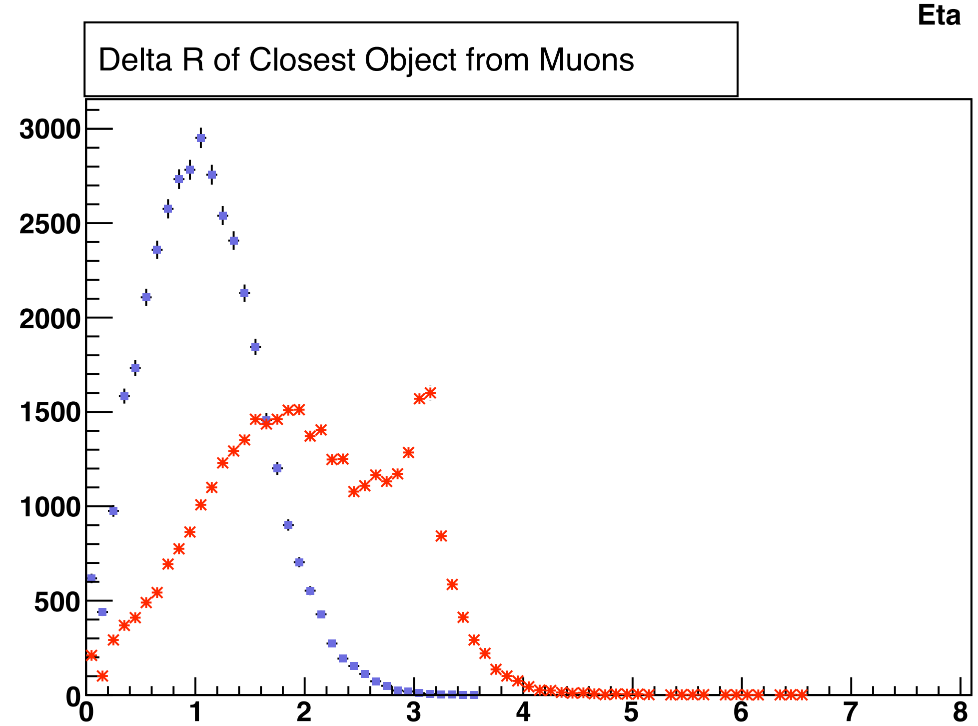
iii) The trigger efficiency is defined by the frequency with which the Probe muon in this sample <u>also</u> passed the trigger selection

Trigger efficiency from Data - Simulations





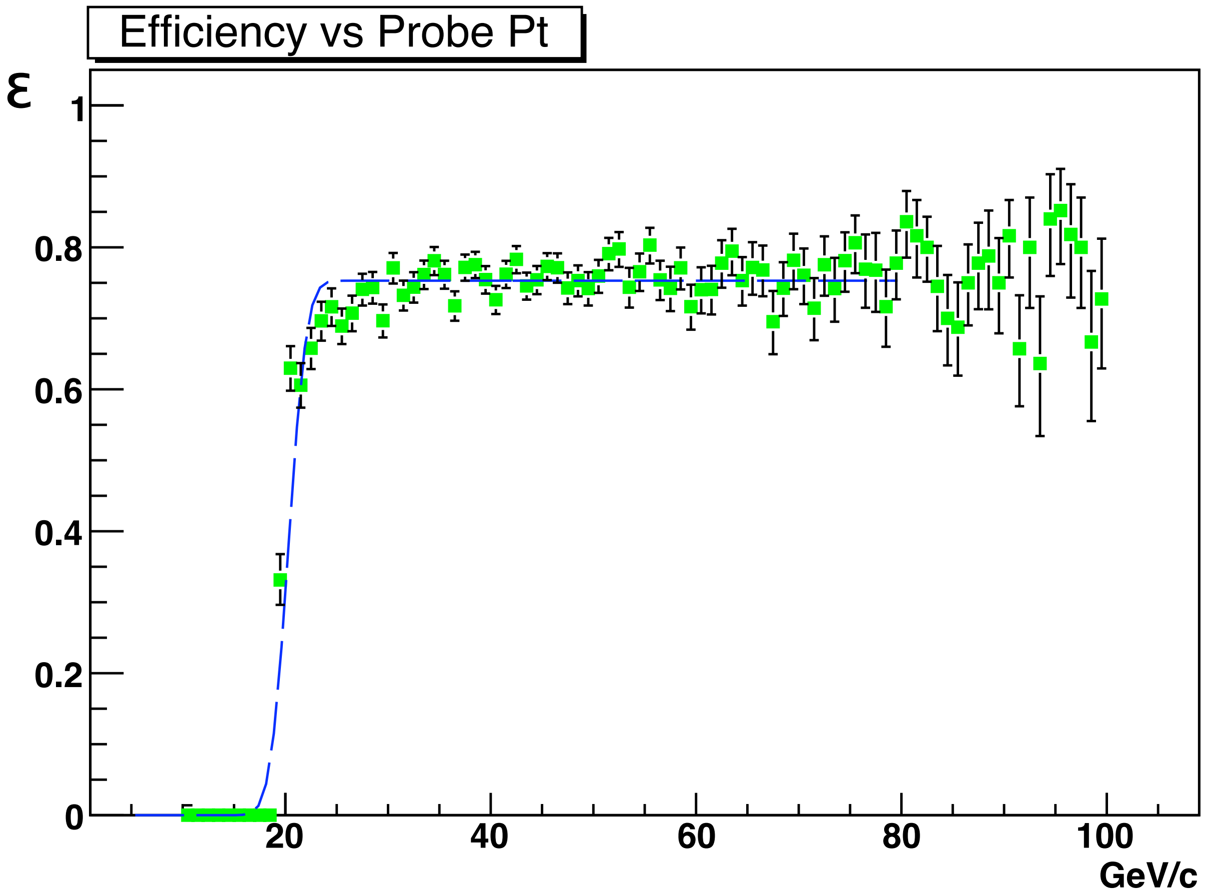


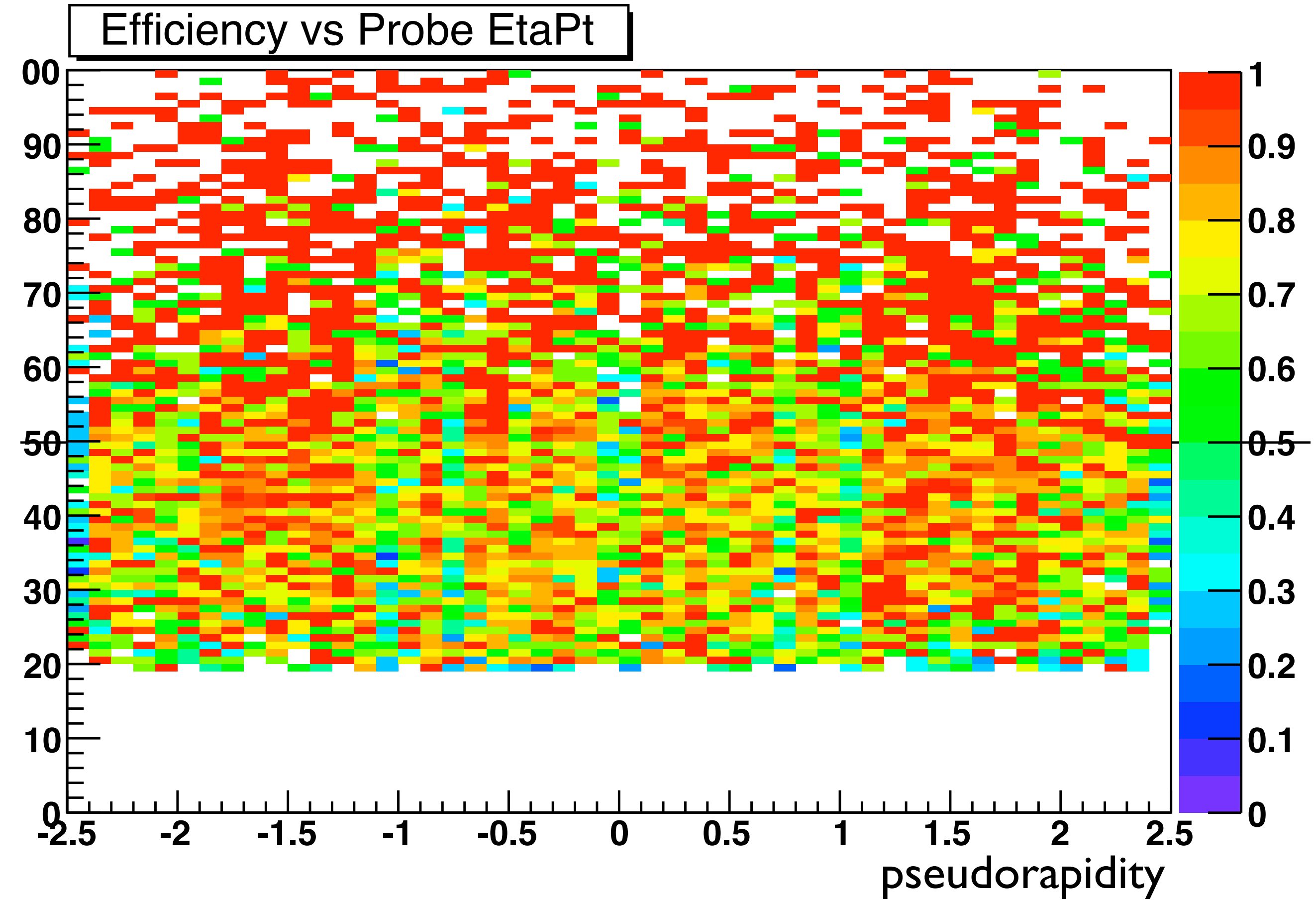


Z-boson decays and top-pair decays have different features...

can we apply efficiencies measured on Zμμ events to top-pair events?

Trigger efficiency from Data - Simulations





Parametrizing the efficiency with more than one variable allows to apply a weight on top-pair events according to the muon kinematic values and position in the detector

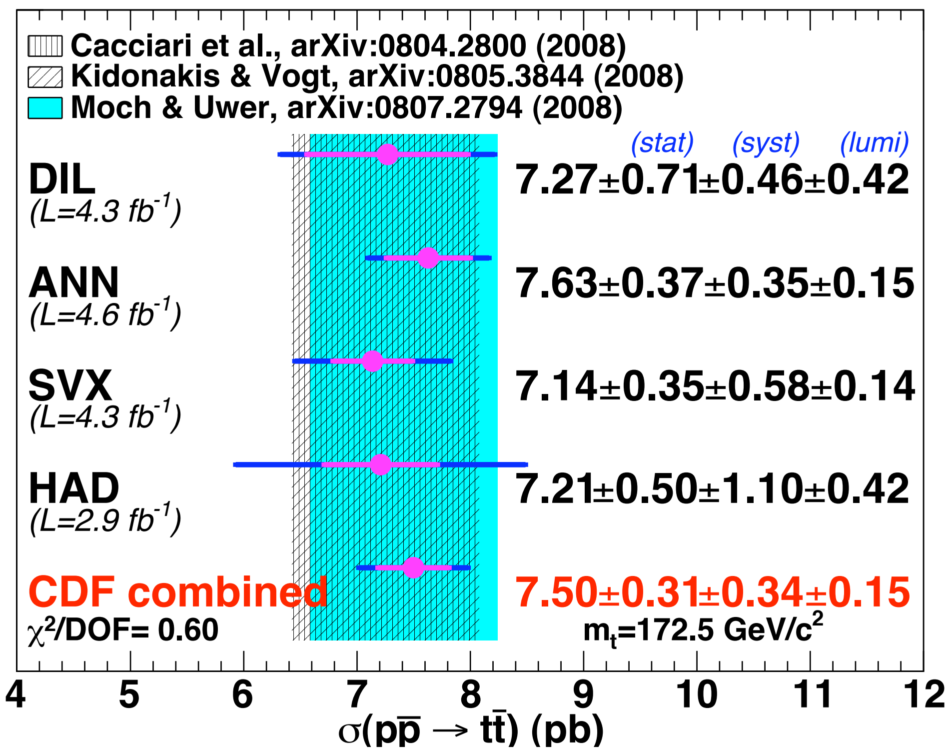
A Handle on New Physics

- Are the top pairs produced solely by gluon-gluon fusion and quark-antiquark annihilation? Is there some heavy object X which decays into top quarks, thus enhancing the observed rate over QCD predictions?

- Is the cross section in line with predictions regardless of the final state or is some non-standard decay of top somehow modifying the mix?

- Do the other properties of the top quark give preference to the Standard Model top quark hypothesis over more exotic scenarios?

- D0 and CDF have already initiated some of these studies but are limited by the statistics acquired



Summary

- The precise measurement of the top quark properties is an important task for the LHC

- Cross Section measurements are an important test of possible new production mechanisms (e.g. decay of heavier objects such as the top quark super-partner or Kaluza-Klein resonances)

- New physics may also modify the cross section times branching ratio differently in various decay channels (e.g. s̃upersymmetric channels with charged Higgs $t \rightarrow H^{+}b$ or with super-partner of the top quark $t \rightarrow t\ \chi^{0}$)