Recent developments: theorists writing papers

CP3-07-29
March 27, 2008

Top pair invariant mass distribution: a window on new physics

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Abstract

We explore in detail the physics potential of a measurement of the $t\bar{t}$ invariant mass distribution. First, we assess the accuracy of the best available predictions for this observable and find that in the low invariant mass region, the shape is very well predicted and could be used to perform a top mass measurement. Second, we study the effects of a heavy s-channel resonance on the $t\bar{t}$ invariant mass distribution, in a model independent way. We provide the necessary Monte Carlo tools to perform the search and outline a simple three-step analysis.

UB-HET-08-01
March 2008

Searching for $t\bar{t}$ Resonances at the Large Hadron Collider

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Dept. of Physics and Astronomy, University of Rochester, Rochester, NY 14627, USA

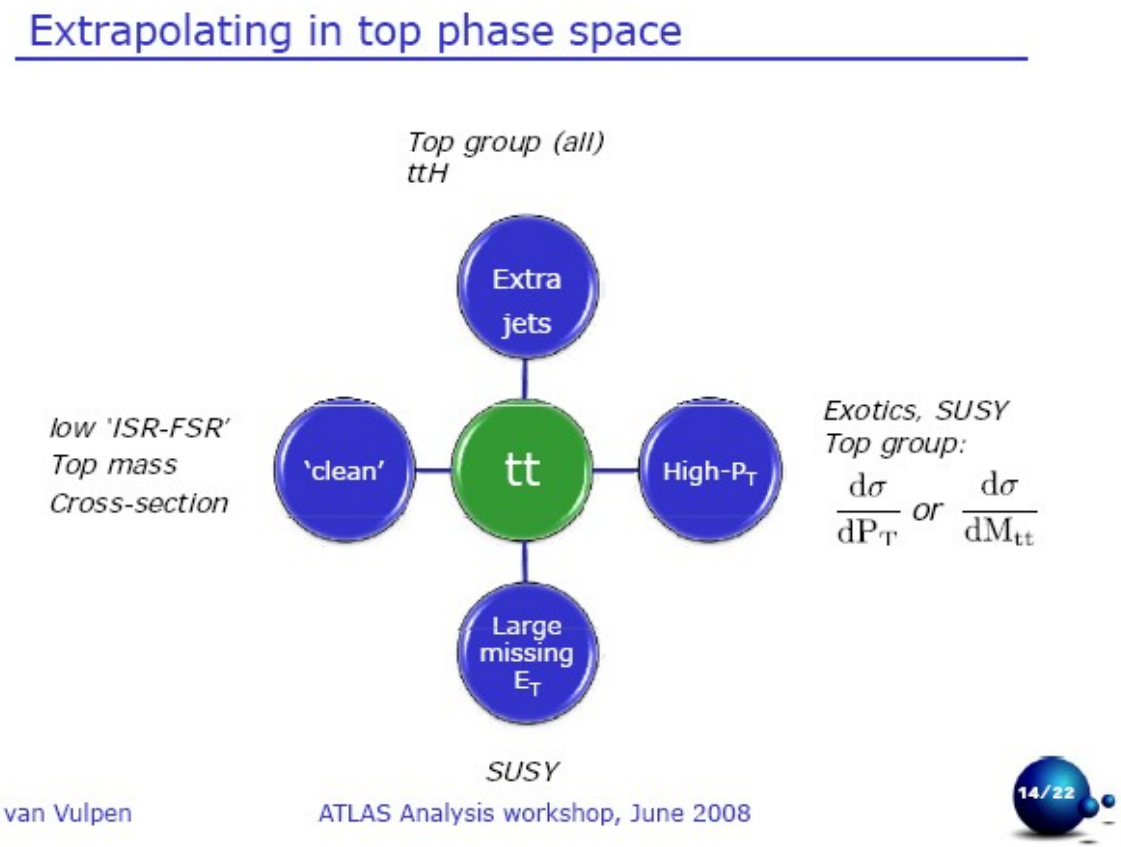
Abstract

Many new physics models predict resonances with masses in the TeV range which decay into a pair of top quarks. With its large cross section, $t\bar{t}$ production at the Large Hadron Collider (LHC) offers an excellent opportunity to search for such particles. We present a detailed study of the discovery potential of the CERN Large Hadron Collider for Kaluza-Klein (KK) excitations of the gluon in bulk Randall-Sundrum (RS) models in the $t\bar{t} \to \ell^{\pm}\nu b\bar{b}q\bar{q}'$ ($\ell = e, \mu$) final state. We utilize final states with one or two tagged b-quarks, and two, three or four jets (including b-jets). Our calculations take into account the finite resolution of detectors, the energy loss due to b-quark decays, the expected reduced b-tagging efficiency at large $t\bar{t}$ invariant masses, and include the background originating from $Wb\bar{b}$+ jets, $(Wb+W\bar{b})$+ jets, W+jets,

Some of these actually tell us things we didn't know yet.
Regular communication?

Recent developments: the new organization

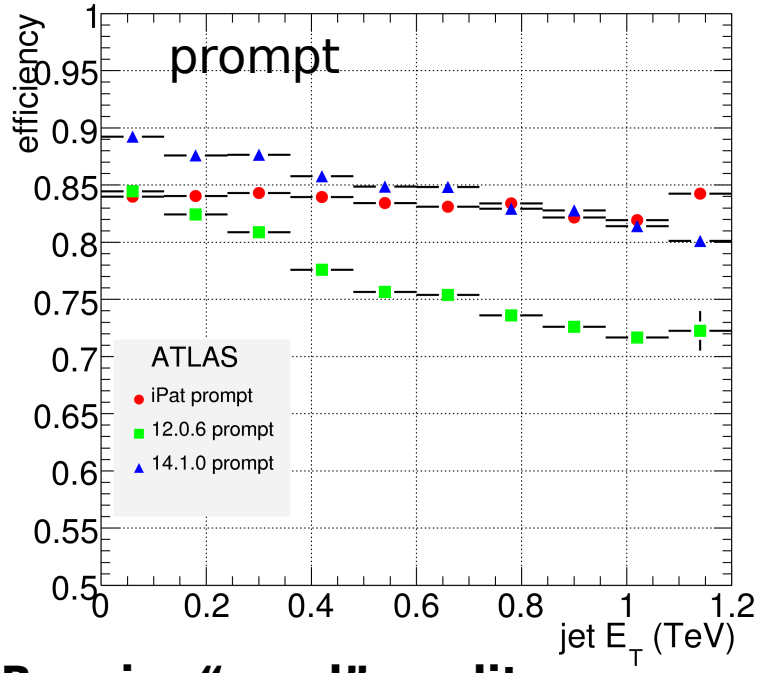
Several groups/individuals have been working on tt-resonances. Plenty of top-specific expertise in the top reconstruction group. Hopefully, the new organization will allow to connect to low-p_T activity

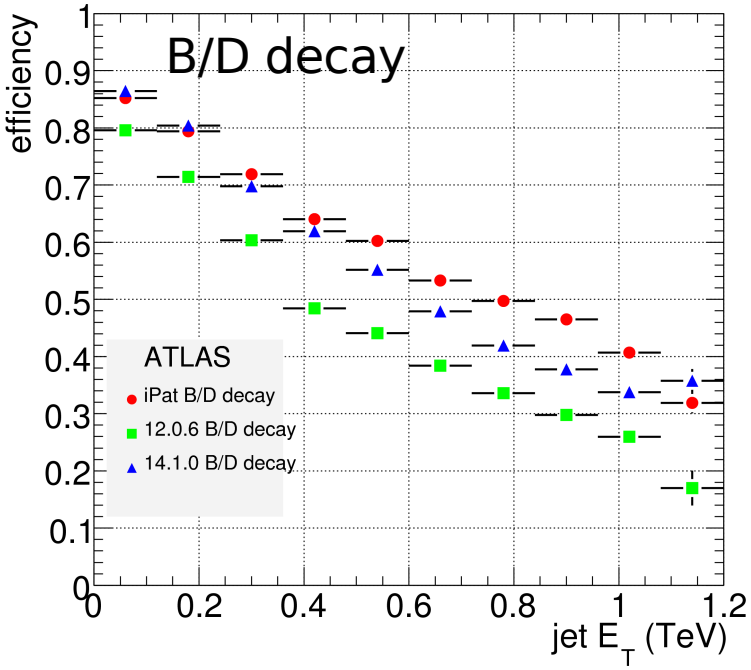


Recent developments: release 14

Some good news: release 14 New Tracking performs very well in high p_T jets, for prompt and B-decay tracks

Opens the door to standard AOD-based analysis





Require "good" quality:

7 silicon hits
2 pixel hits
1 B-layer hit

qualitatively confirmed by Michael Wilson (CERN)

iPatRec on 12.0.6
New Tracking on 12
New Tracking 14.1.0

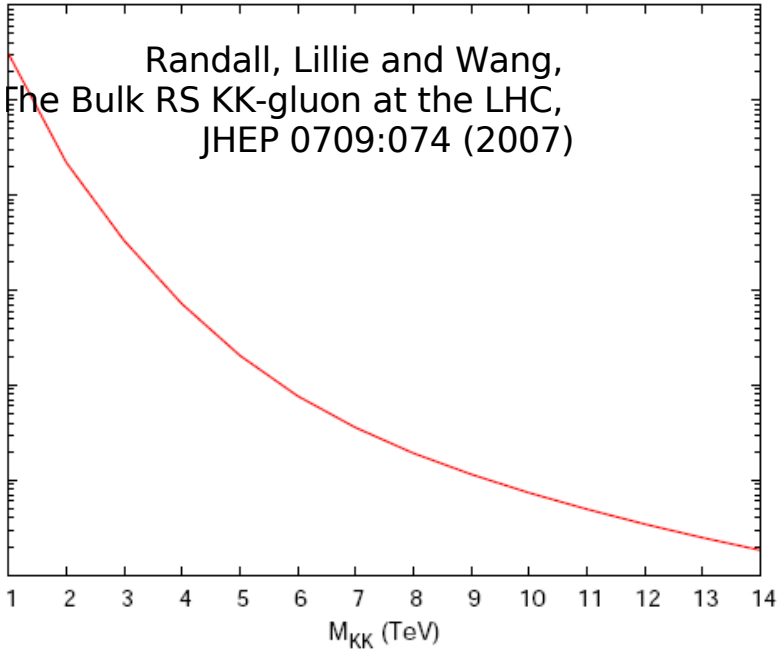
Some early physics

Kaluza Klein excited state of the gluon

Present in models with Large Extra Dimesions where gauge bosons propagate in the bulk.

Strong coupling, large cross-section
Broad resonance into tt: $\Gamma/M \sim 0.2$

Backgrounds: SM top pairs, W+jets
σ (pT (top) > 200 GeV) ~ 26 pb
(LO, large K-factor)

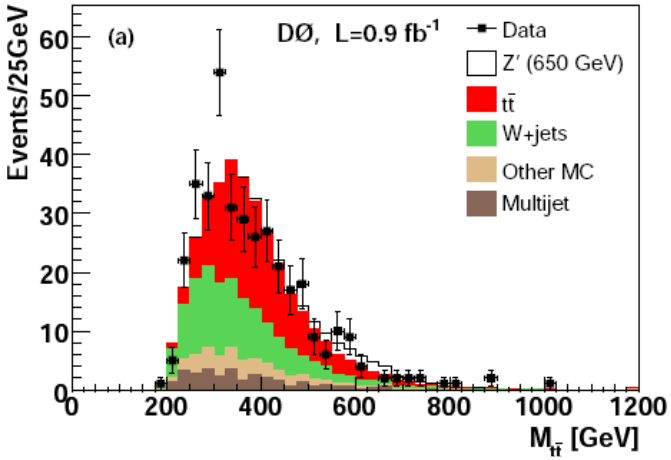


Taking 20 pb^{-1} :
10.000 signal events

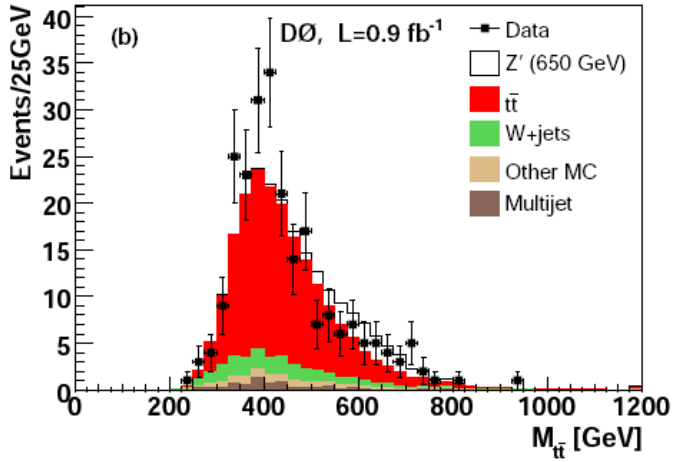
M g^* (GeV)	σ g^* (pb) @ 10 TeV	σ g^* (pb) @ 14 TeV
1 TeV	475	1109

Leading order cross-sections for ADD KK gluon

Tevatron



lν + 3 jets



lν + 4 jets

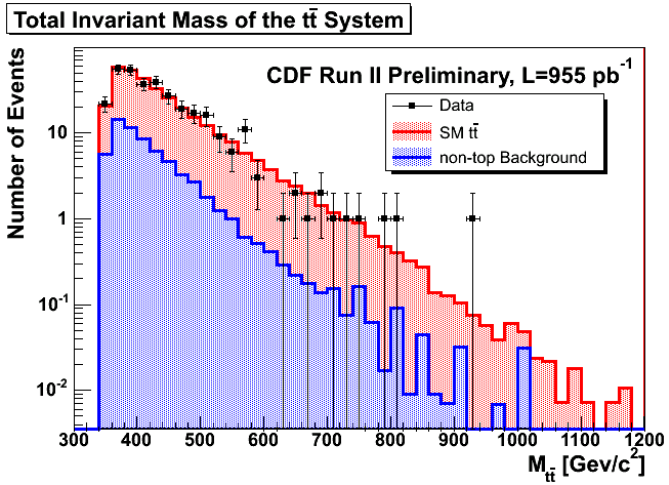
Intensive searches for tt resonances at the Tevatron. ~ 20 papers since 2000.

D0, FERMILAB-PUB-08-097E, arXiv:0804.3664

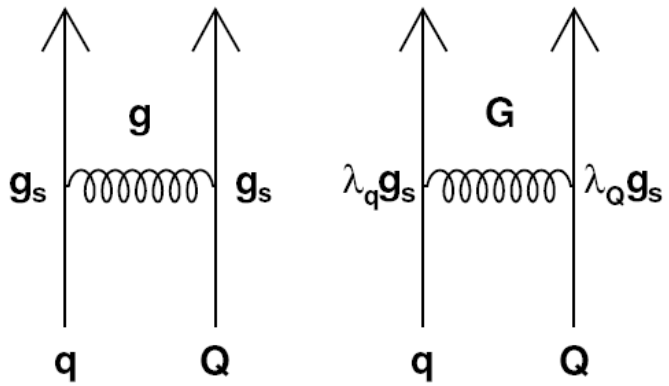
CDF, Phys.Rev.Lett.85 (2000) 2062-2067

CDF, arXiv:0710.5335v1

Few events at large mass (CDF totals 347 evts. In 1 fb^{-1})

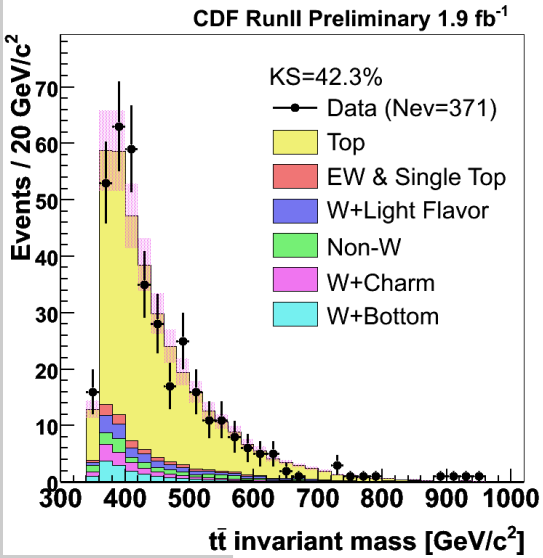


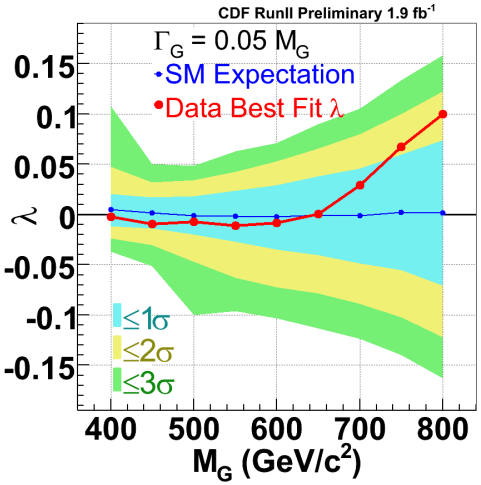
Tevatron - CDF

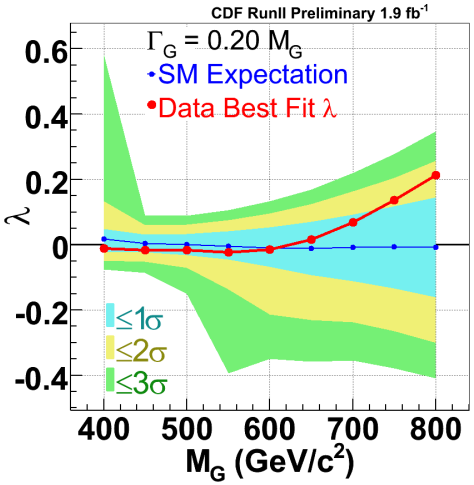


Preliminary results in CDF 9164 of a massive gluon search in 1.9 fb^{-1} finds data are compatible with SM within 1.7 σ

Exclusion limits are modest due to the lower Tevatron center-of-mass energy



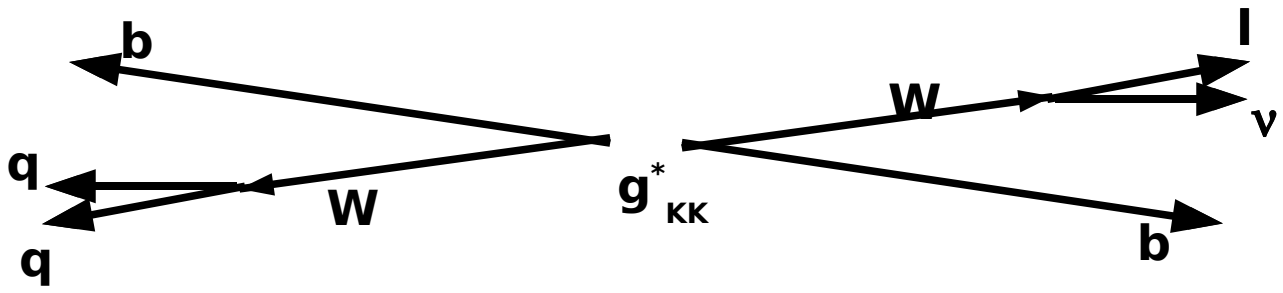




ATLAS g^*_{KK} reconstruction

KK excitations in models with Extra Dimensions $g^* \rightarrow tt$

reconstruction strategy for semi-leptonic events - ATL-PHYS-PUB-2006-002



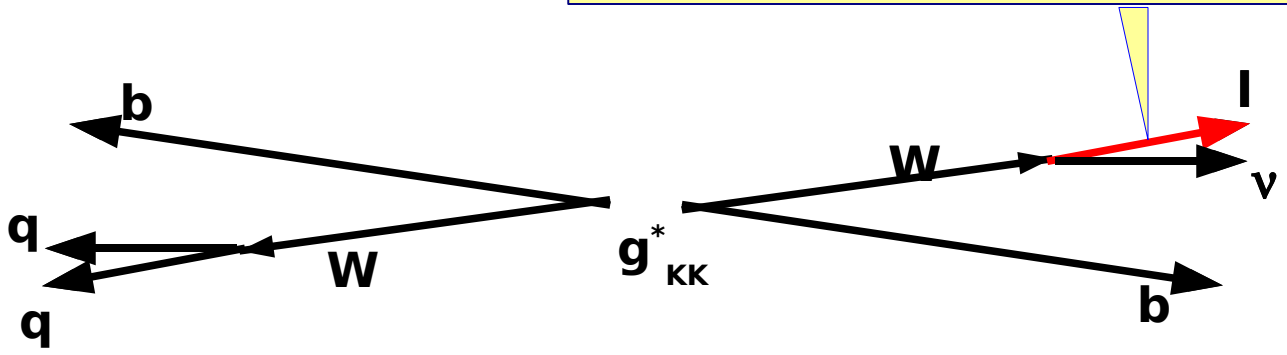
ATLAS g^*_{KK} reconstruction

KK excitations in models with Extra Dimensions $g^* \rightarrow tt$

reconstruction strategy for semi-leptonic events - ATL-PHYS-PUB-2006-002

Isolated lepton (e,μ)

p_T > 25 GeV



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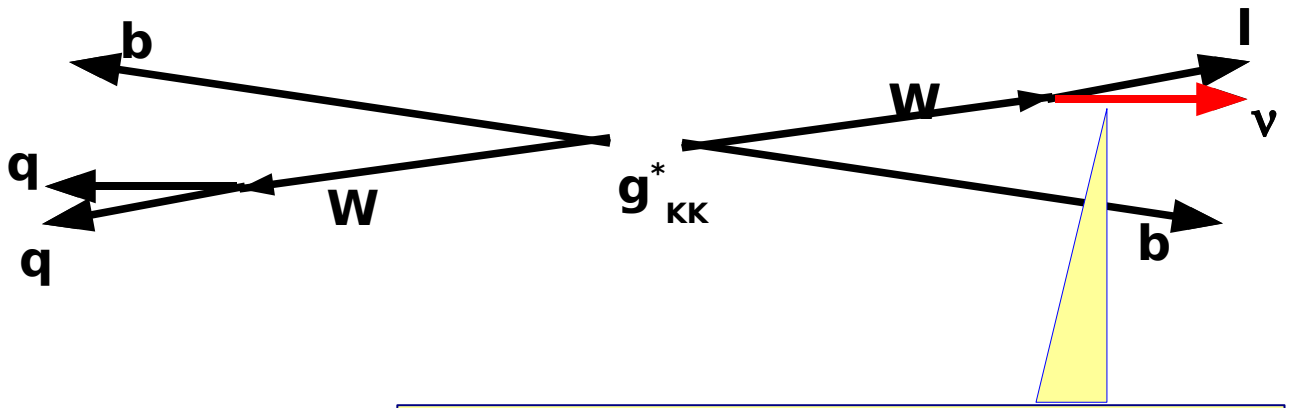


Missing transverse energy

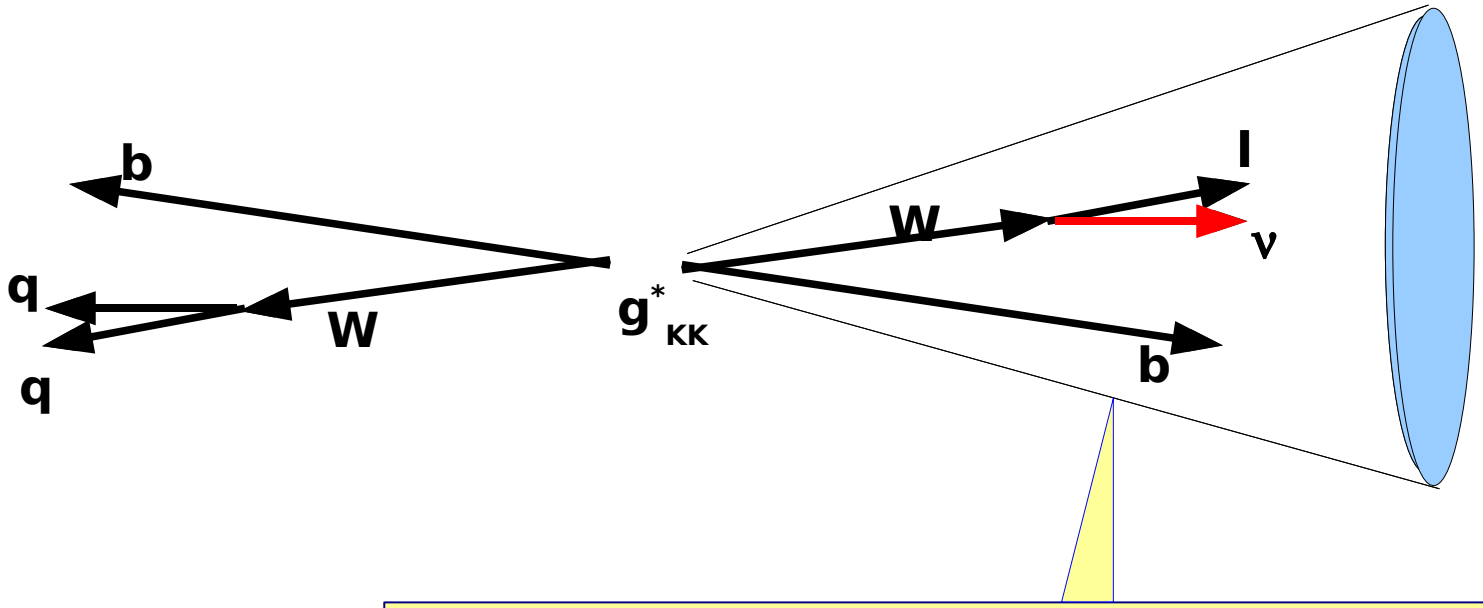
E^{miss}_T > 25 GeV, p_z^ν // p_z^l

can we avoid using it altogether?

ATLAS g^*_{KK} reconstruction

KK excitations in models with Extra Dimensions $g^* \rightarrow tt$

reconstruction strategy for semi-leptonic events - ATL-PHYS-PUB-2006-002

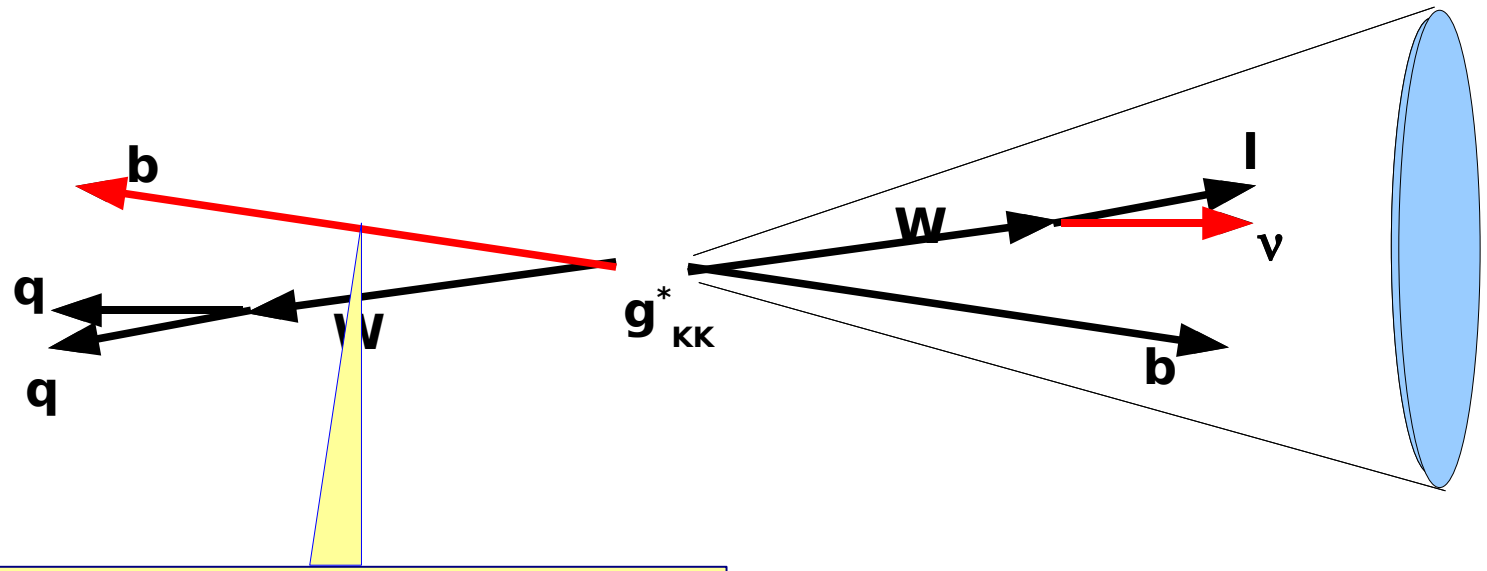


Leptonic top: add jet (E_T > 25 GeV) with smallest $\Delta r_{jet\text{-}lepton}$ p_T(top) > 200 GeV

ATLAS g^*_{KK} reconstruction

KK excitations in models with Extra Dimensions $g^* \rightarrow tt$

reconstruction strategy for semi-leptonic events - ATL-PHYS-PUB-2006-002



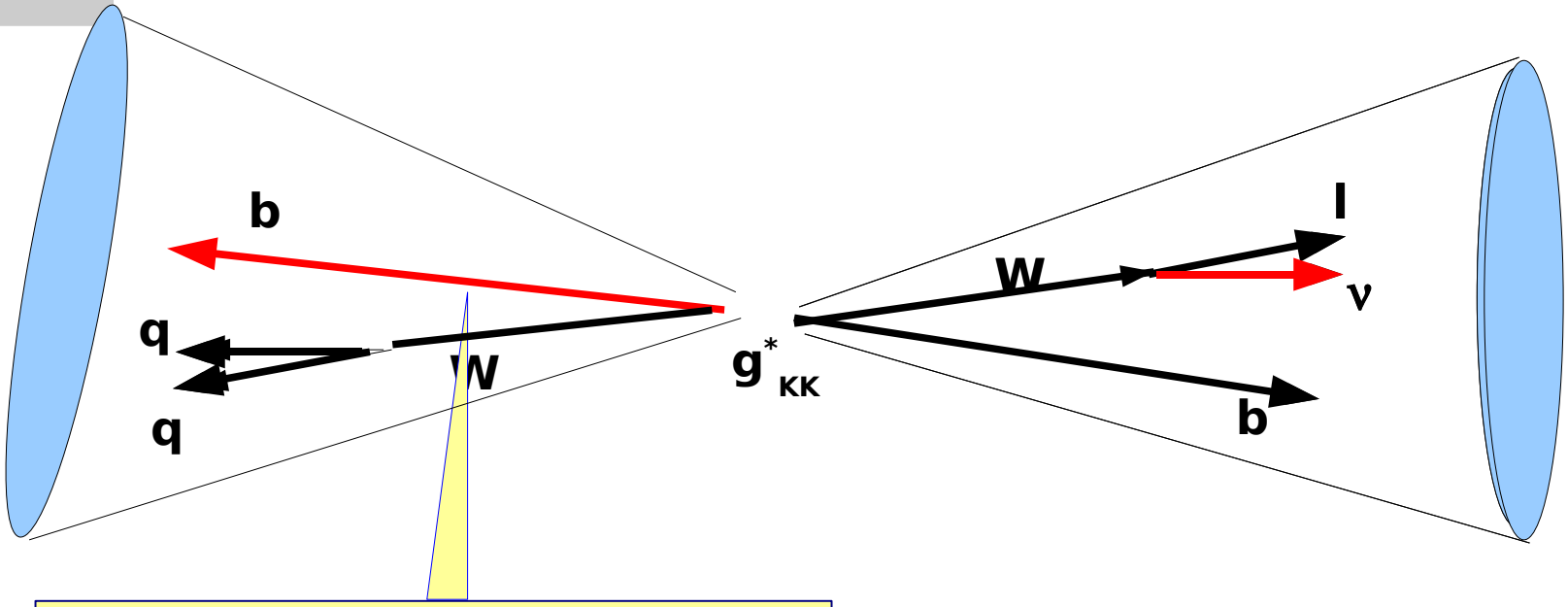
Look for highest E_T jet with

$\Delta R_{jet\text{-}lepton} > 2$

ATLAS g^*_{KK} reconstruction

KK excitations in models with Extra Dimensions $g^* \rightarrow tt$

reconstruction strategy for semi-leptonic events - ATL-PHYS-PUB-2006-002



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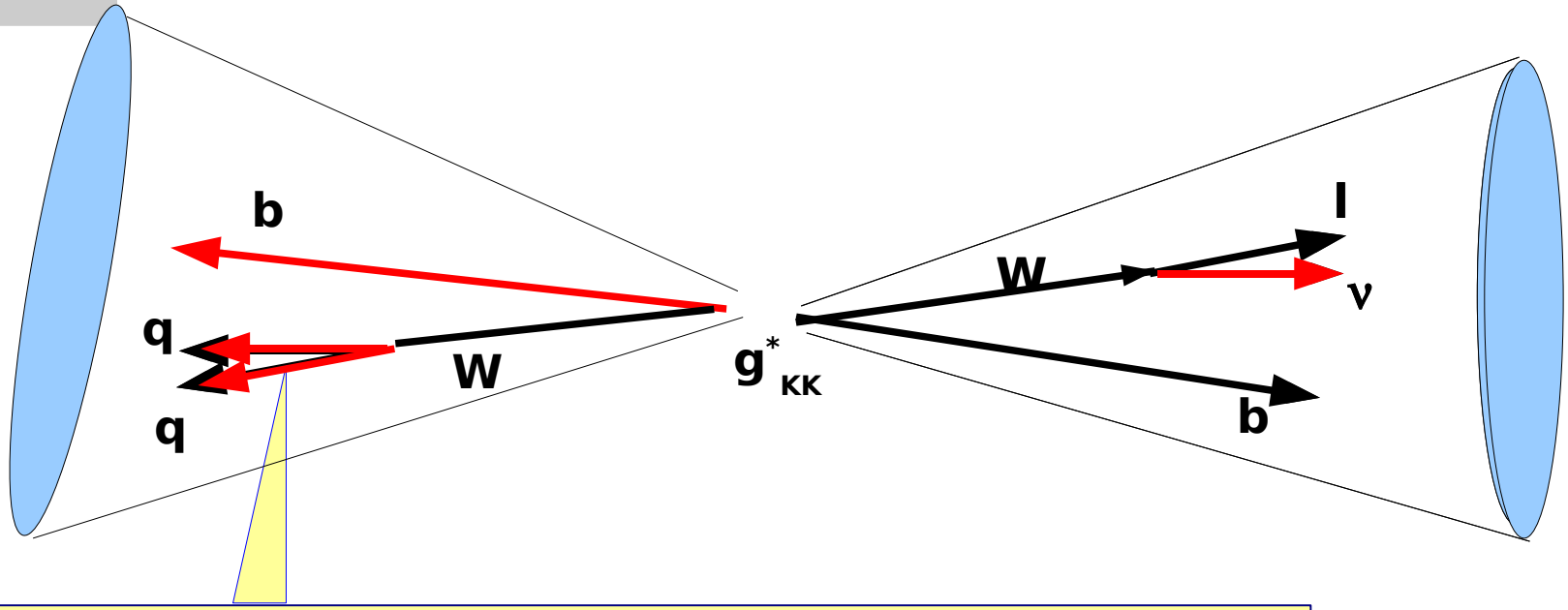


Hadronic top: sum all jets with $\Delta R_{jet\text{-}jet} < 1$

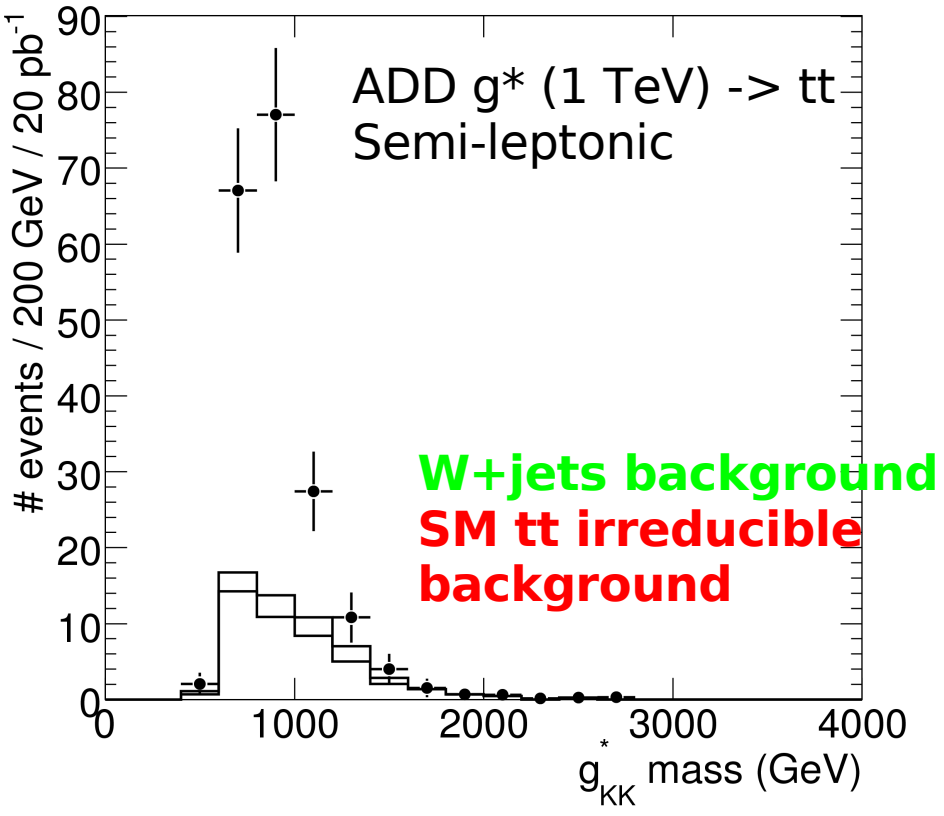
(i.e. reonstruct top mono-jet), p_T(top) > 200 GeV

Early exotic physics

ATLFAST 10 TeV, 20 pb^{-1}
preliminary
Simplified early physics analysis: no b-tagging! Only tt and W+jets backgrounds evaluated

can we really ignore di-jets?

How can we be sure these are really tt events?
flavour tagging, jet sub-structure



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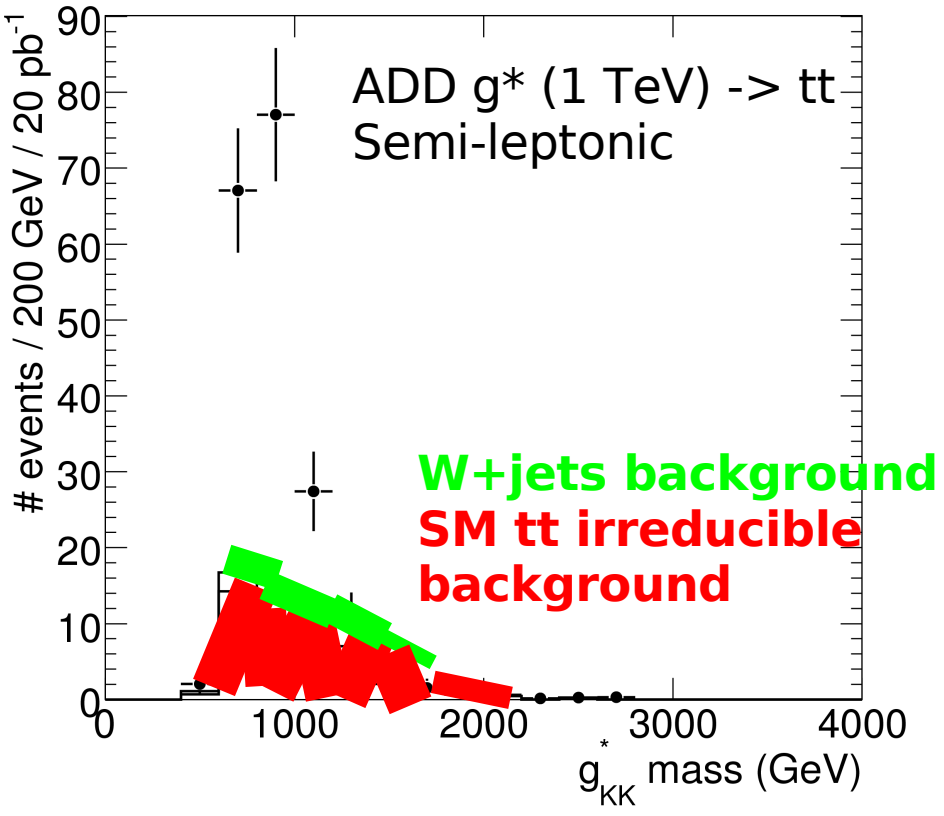


Top mono-jets

Demonstrated that very significant **rejection of udscgb jets** can be achieved using a combination of jet substructure and lifetime signatures of hadronic top mono-jets. **Understand in detail how top monojets fit in a real analysis**

ATLAS NOTE

ATL-COM-PHYS-2008-001

February 4, 2008

ATL-PHYS-CONF-2008-008

05 February 2008

High p^T Hadronic Top Quark Identification
Part I: Jet Mass and YSplitter

Gustaaf Brooijmans
Columbia University

Abstract

At the LHC objects with masses at the electroweak scale will for the first time be produced with very large transverse momenta. In many cases, these objects decay hadronically, producing a set of collimated jets. This interesting new experimental phenomenology requires the development and tuning of new tools, since the usual reconstruction methods would simply reconstruct a single jet. This note describes the application of the YSplitter algorithm in conjunction with the jet mass to identify high transverse momentum top quarks decaying hadronically.

ATLAS NOTE

ATL-PHYS-PUB-2008-000

June 6, 2008

High p_T Hadronic Top Quark Identification
Part II: the lifetime signature

M. Vos
IFIC (U. Valencia/CSIC), Valencia, Spain

Abstract

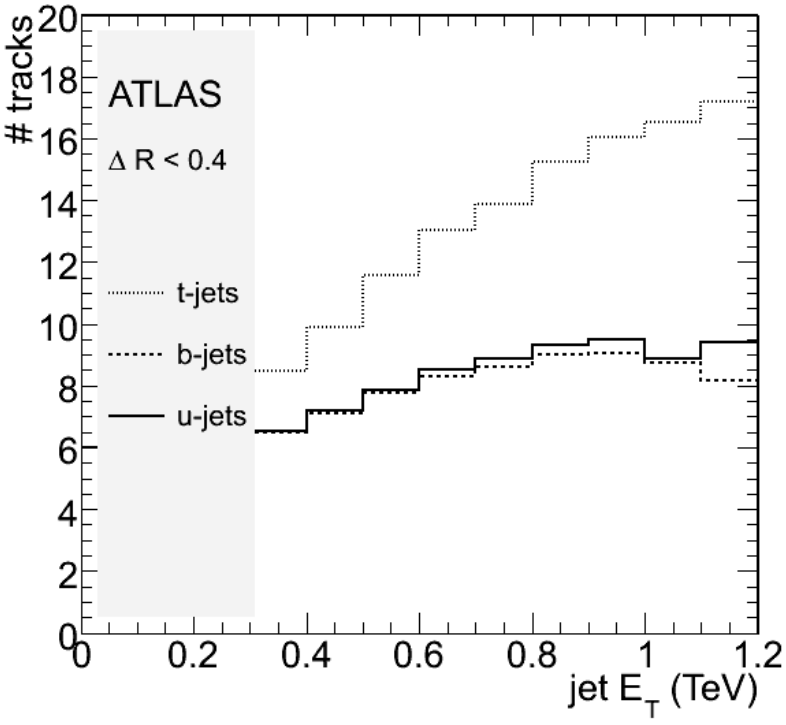
At the LHC top quarks will for the first time be produced abundantly and with very large transverse momenta. For hadronic decays of top quarks at large p_T the three jets merge into a single jet: a top *monojet*. Identification of these objects among the overwhelming QCD di-jet background requires the development of specific experimental techniques. In this note the use of flavour tagging algorithms based on the B-hadron lifetime for the identification of top *monojets* will be explored.

What's left for part III, IV, V....

Tracker information on sub-jets, before:
- the magnetic fields washes out structure
- showers develop

no neutrals... but plenty of charged tracks (of decent quality) around

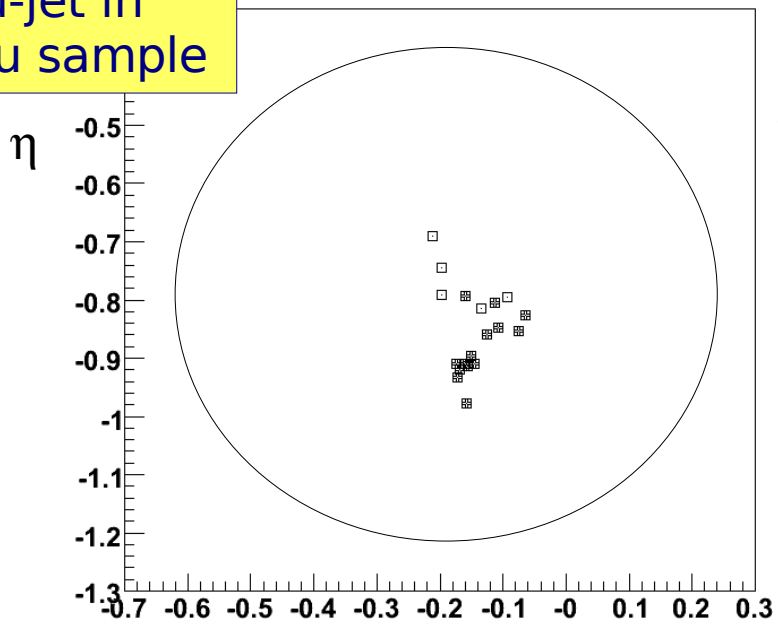
Could even use just the hit distribution (doesn't require pattern recognition to work)



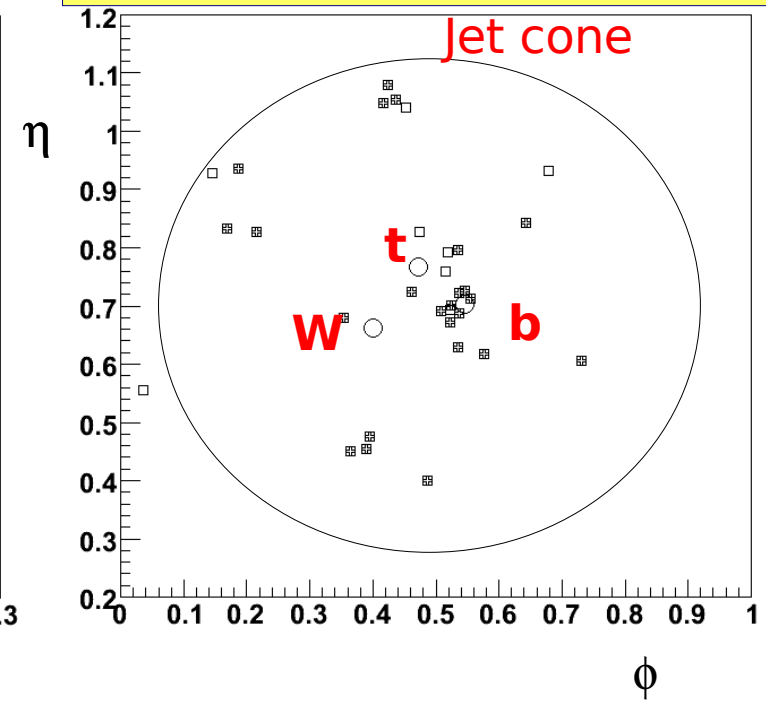
What's left for part III, IV, V....

Tracker information: measure sub-jets before:
- the magnetic fields washes out structure
- showers develop

The first u-jet in the Z'->uu sample



The first hadronic top mono-jet in the Z'->tt sample



charged particle (MC truth)

Reconstructed track (good quality)

Very very early data

σ (p_T (top) > 200 GeV) ~ 26 pb,
falling rapidly for higher threshold

Even before getting interesting statistics of high p_T tops we will get:

a wealth of di-jet events (several nb) that allow to study many of the failures of high p_T performance aspects:

- structure of light jets
- missing E_T in events with high p_T jets (leakage)
- lepton reconstruction in close proximity jets
- flavour tagging

low p_T tops

- missing transverse energy (real neutrinos)
- flavour tagging (real b, +/- under control)

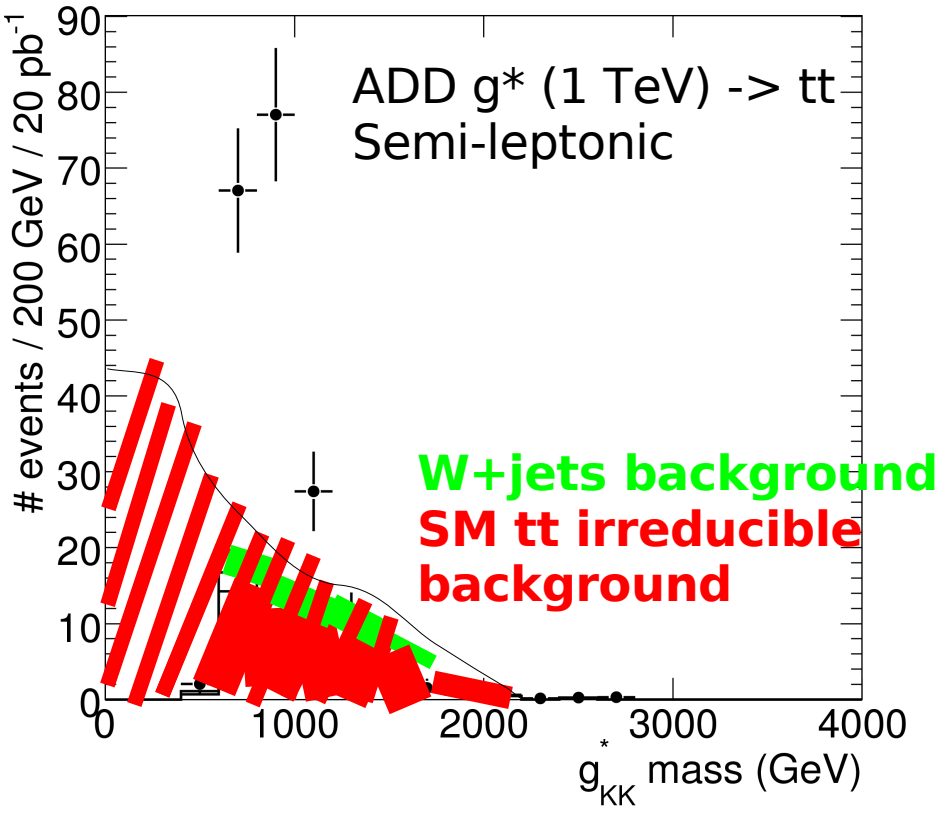
Early exotic physics

ATLFAST 10 TeV, 20 pb^{-1}
preliminary
Simplified early physics analysis: no b-tagging! Only tt and W+jets backgrounds evaluated

can we estimate the background level from data?

Connect to moderate pT analysis

Transition to resolved approach?



Putting it all together
a mini-CSC analysis for g*->tt, semi-leptonic

A lot to do: trigger, Lepton reconstruction/isolation, missing E_T (or work-around), jet energy calibration (b? t?), Hadronic top mono-jet reconstruction/identification, mass resolution (versus efficiency?), background estimates from data, determine limits

To make real progress, full simulation is required
Pull at least event generation through central production?

STATUS: sample numbers requested, job options being validated
high priority exotics samples

- **signal: MadGraph g* (1000) → tt, W' (750) → tb**
- **tt background (MC@NLO)** p_T (t or t-bar) > 200 GeV), top group?
- **W+jets background (ALPGEN?)** SM group?
- **di-jet background,** jet combined performance group?

@ $\sqrt{s}$ = 10 TeV

Summary

g* in Extra Dim models is our most promising candidate for early exotic physics with high p_T b- and top quarks: discovery or improved limits with only 20 pb^{-1} of understood data

Much work required to establish a complete analyis

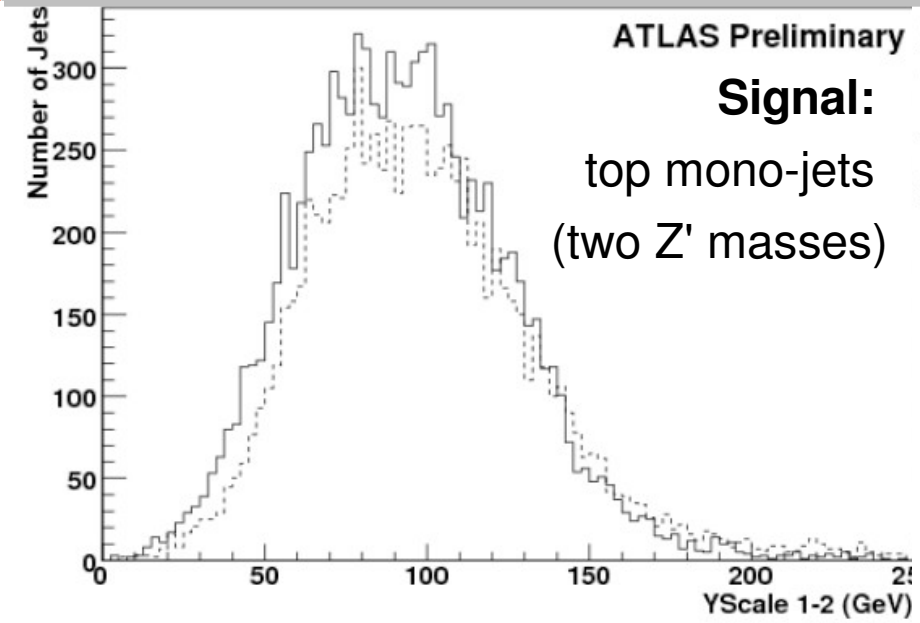
- reconstruction high p_T top
- reduction of non tt backgrounds
- determine irreducible background using data

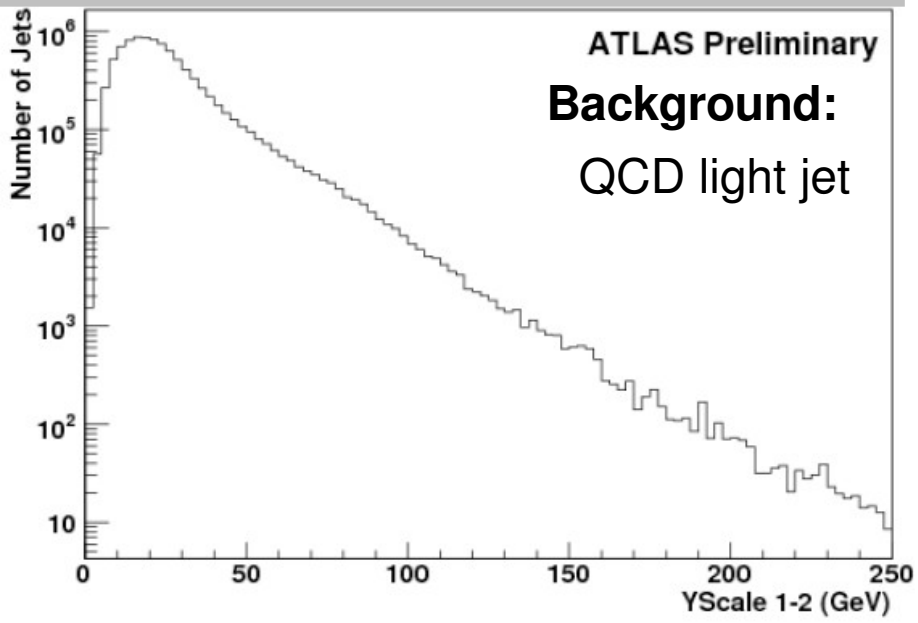
Need full MC to make progress

BACKUP SLIDES

High p_T top: alternative approach

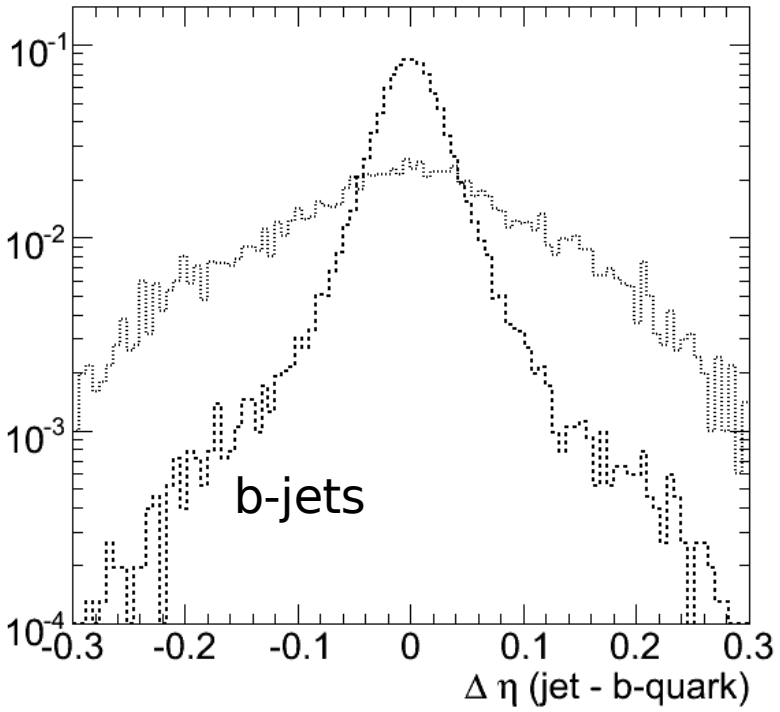
Distinguish top mono-jets from QCD (light) jet background using the jet structure

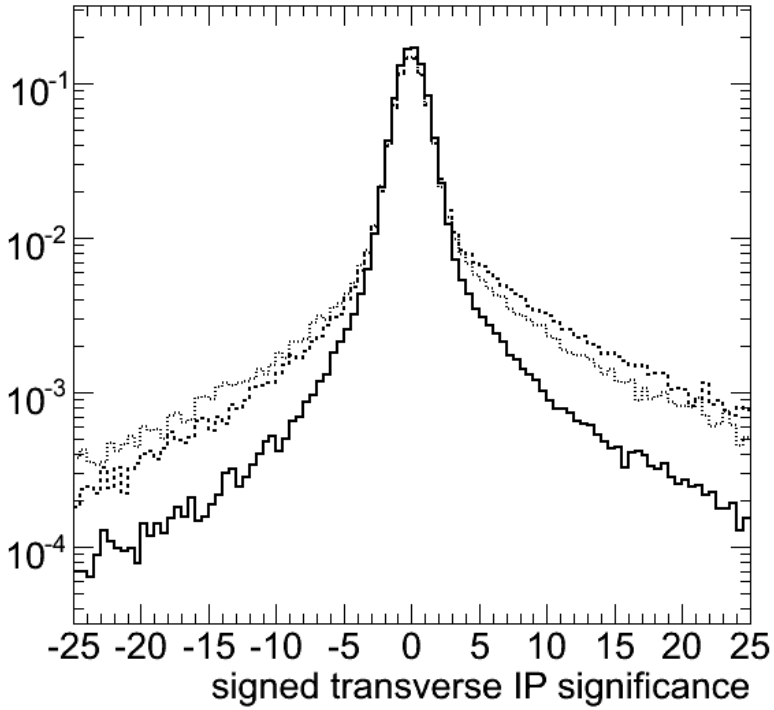




The lifetime signature

Hadronic top monojets · · · b-jets —— light jets

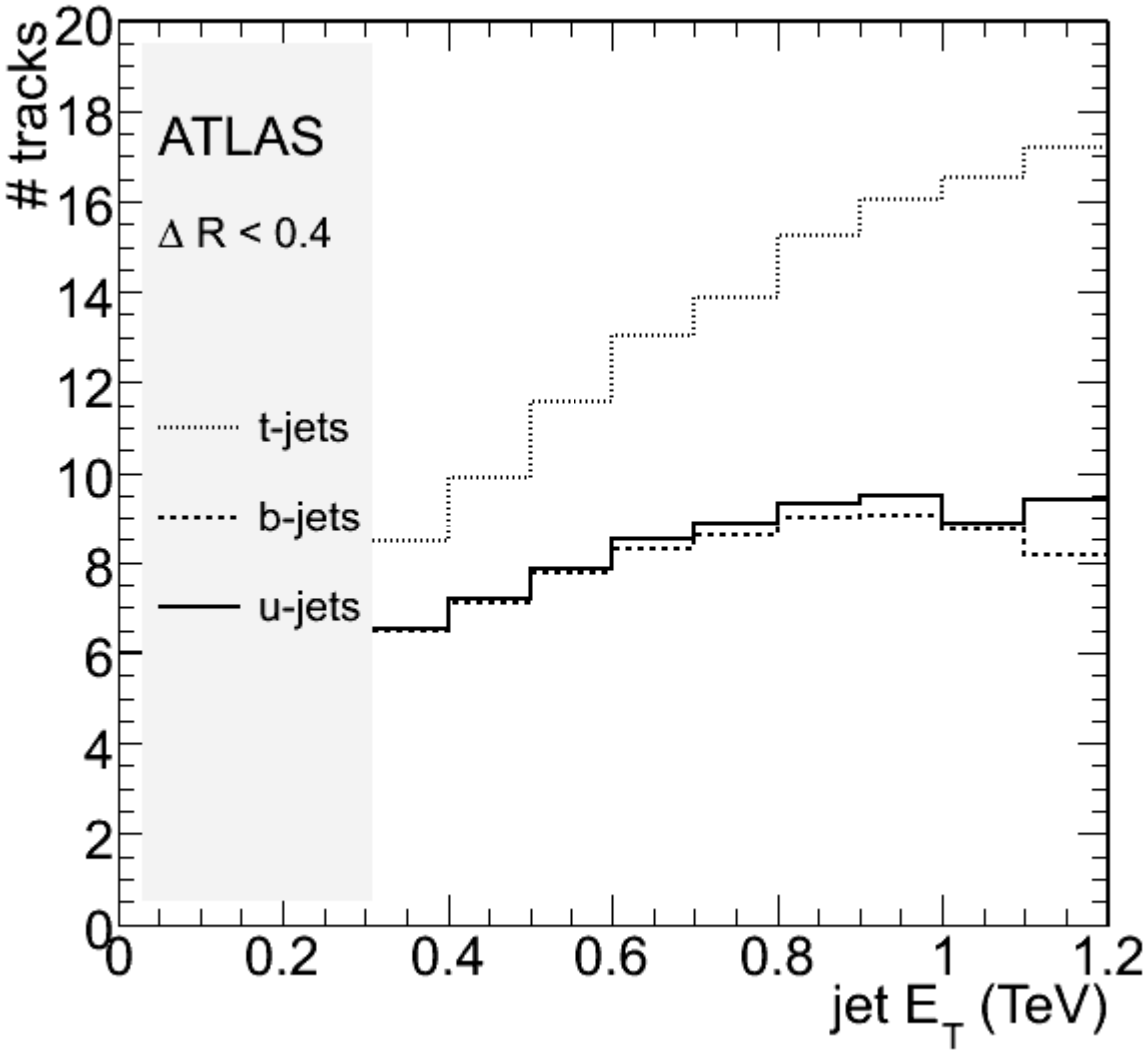




The "noise" from close-by W-decay:

- jet direction no longer as readily identified with B-hadron flight path
- impact parameter sign more often incorrect

The lifetime signature

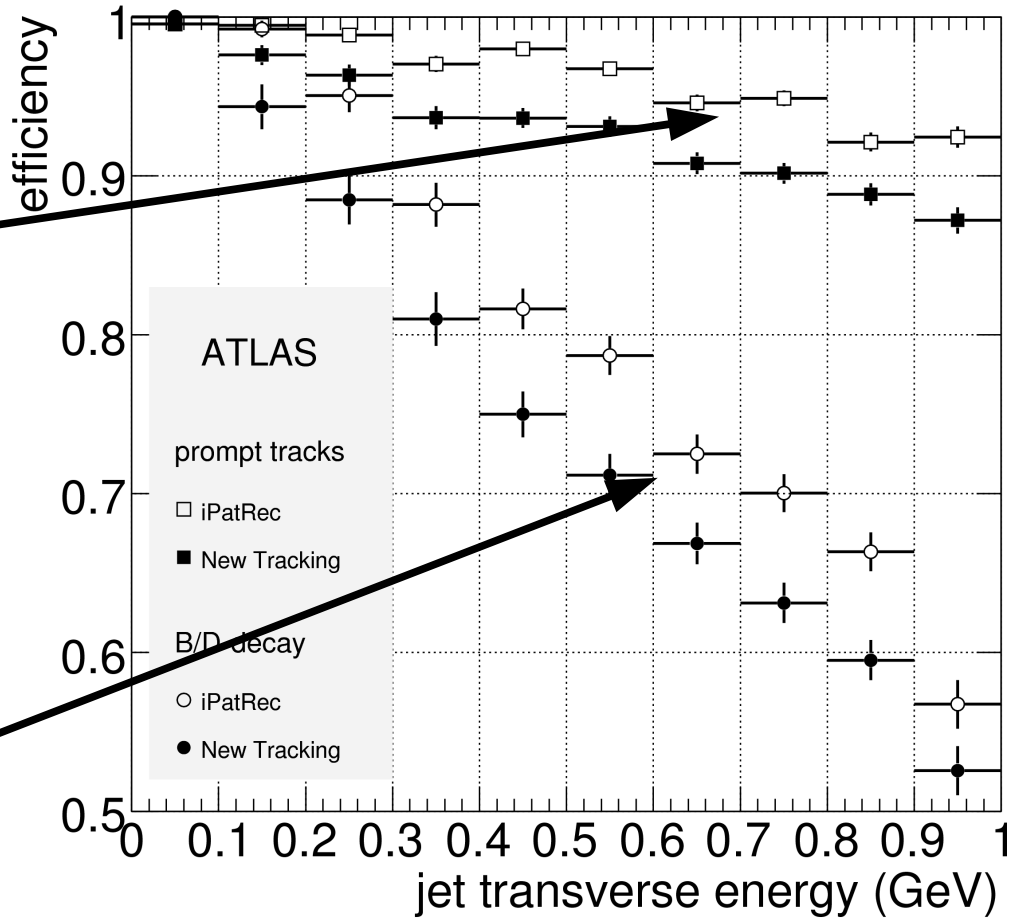


Great!!! even more tracks without lifetime...

Tracks from displaced vertices

Z' -> uu
tracks from interaction point

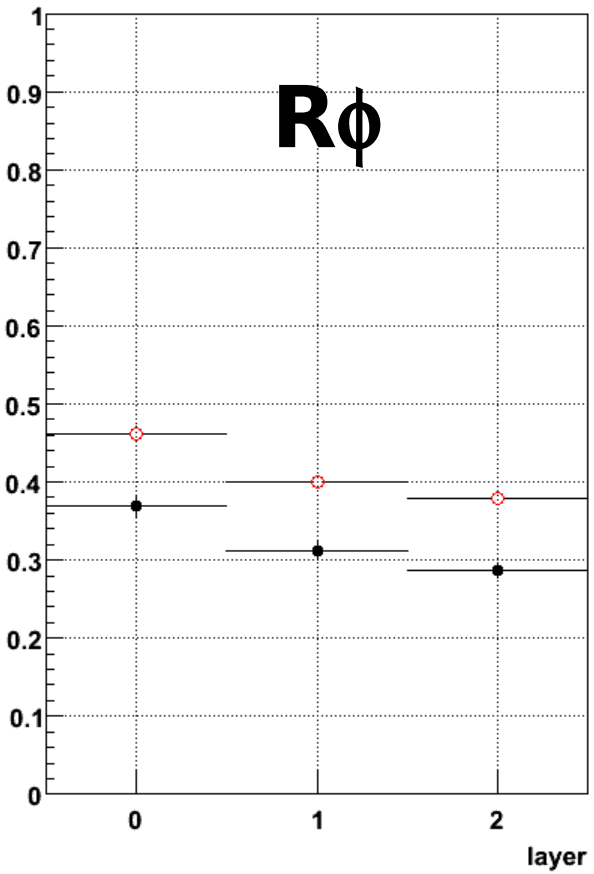
Z' -> bb
tracks from B/D vertex

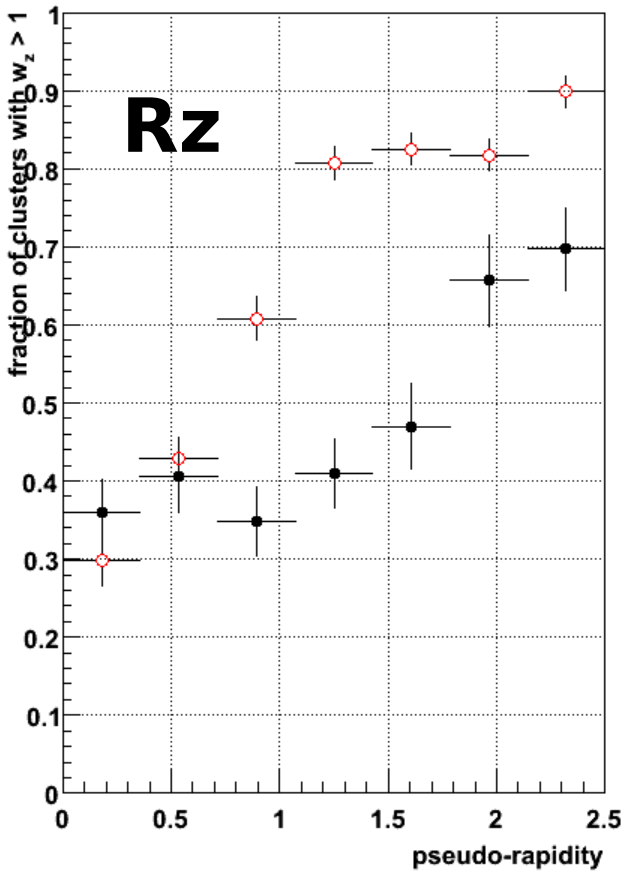


Pixel clustering

Fraction of pixels in B-layer with width > 1

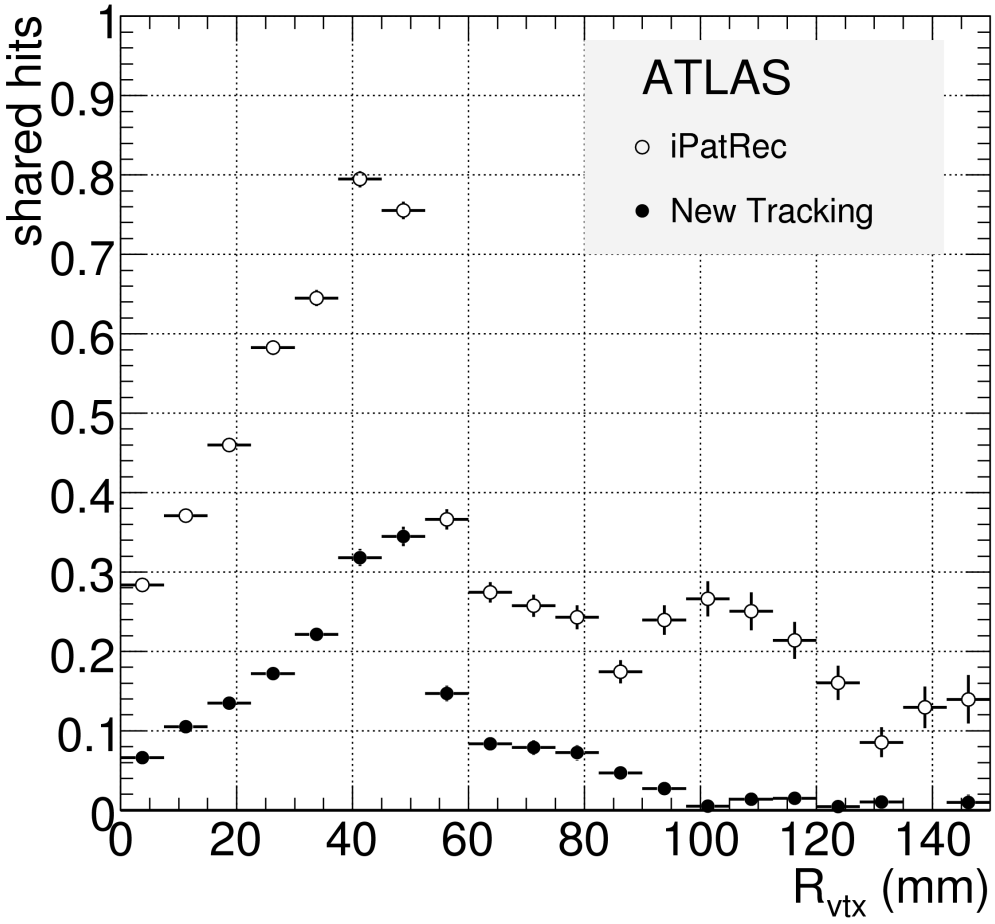
See the impact of different pixel clustering algorithms...





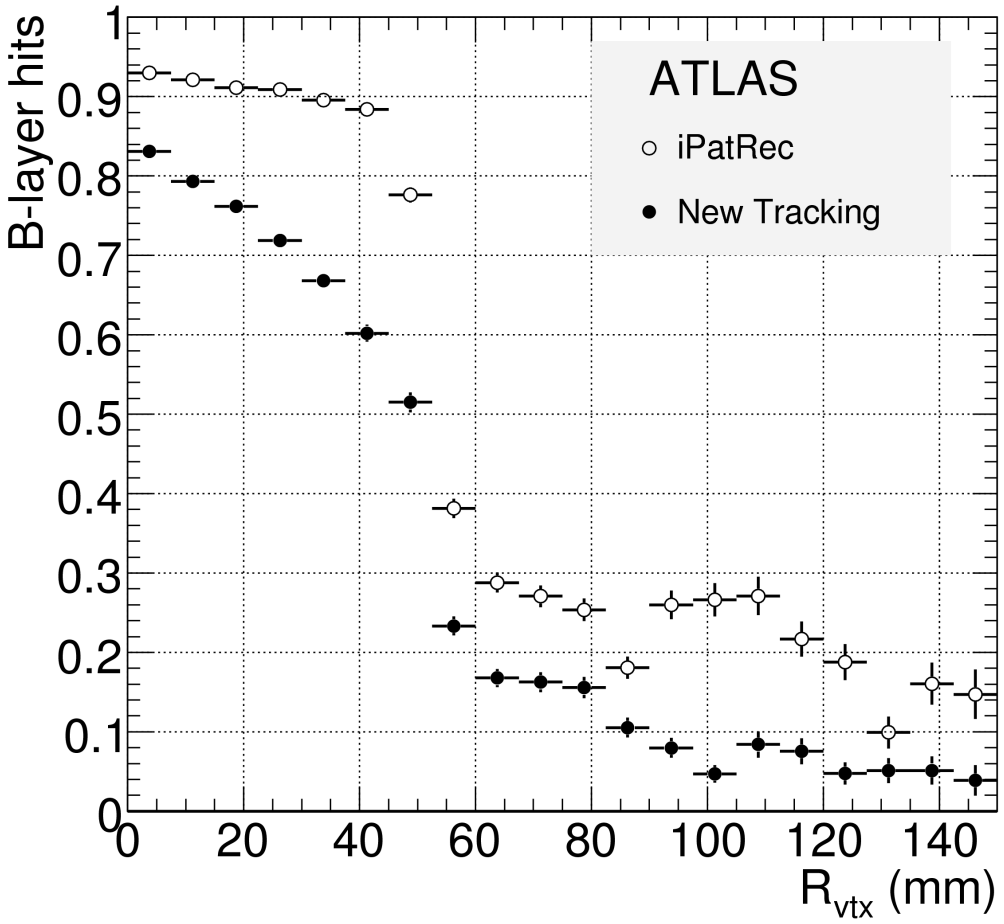
Treatment of ambiguities

See the impact of different ways to treat ambiguities...

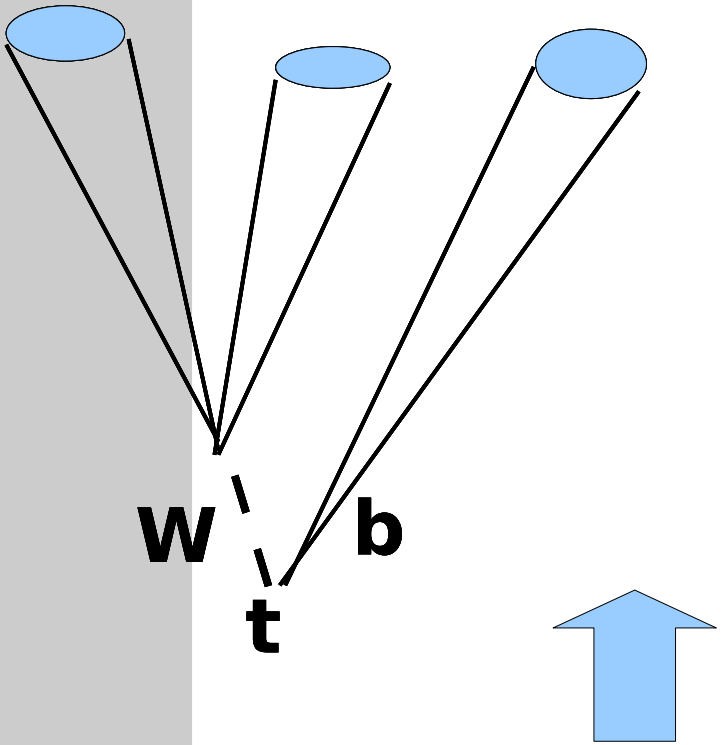


Tracks from displaced vertices

Even see hits that never existed!

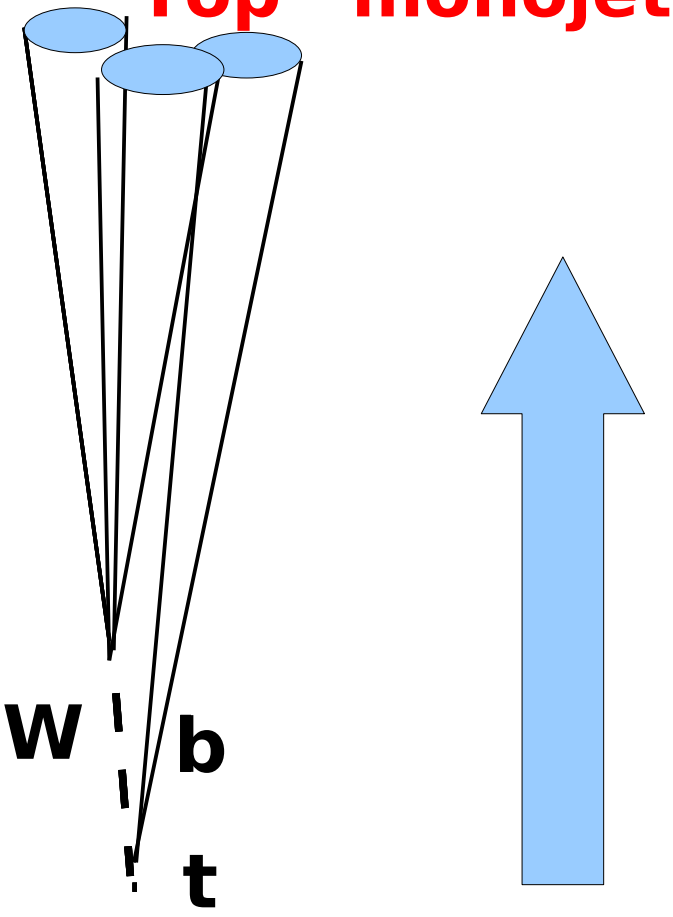


Reconstruction of hadronic top monojets



p_T (top) ~ 0 – 100 GeV

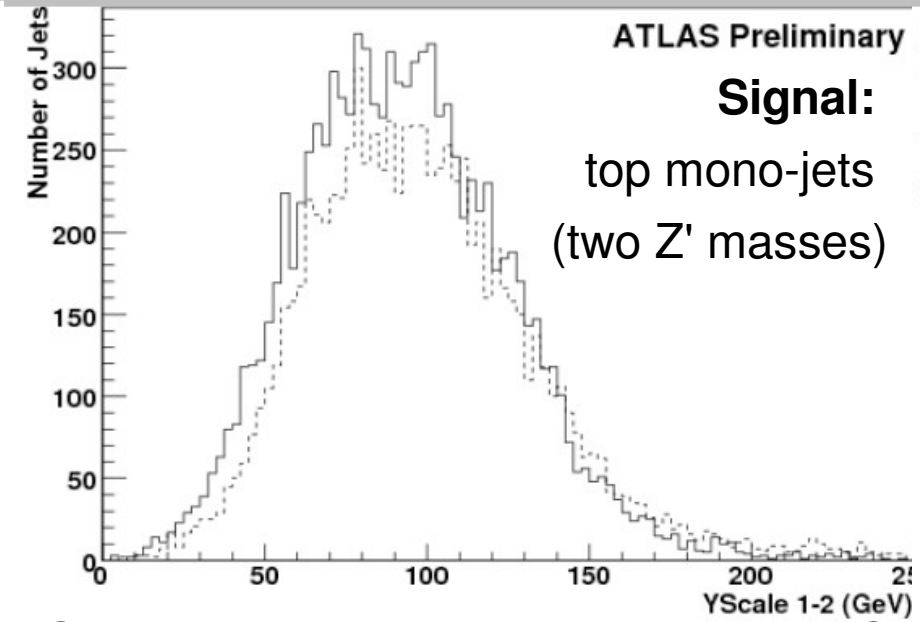
Top "monojet"

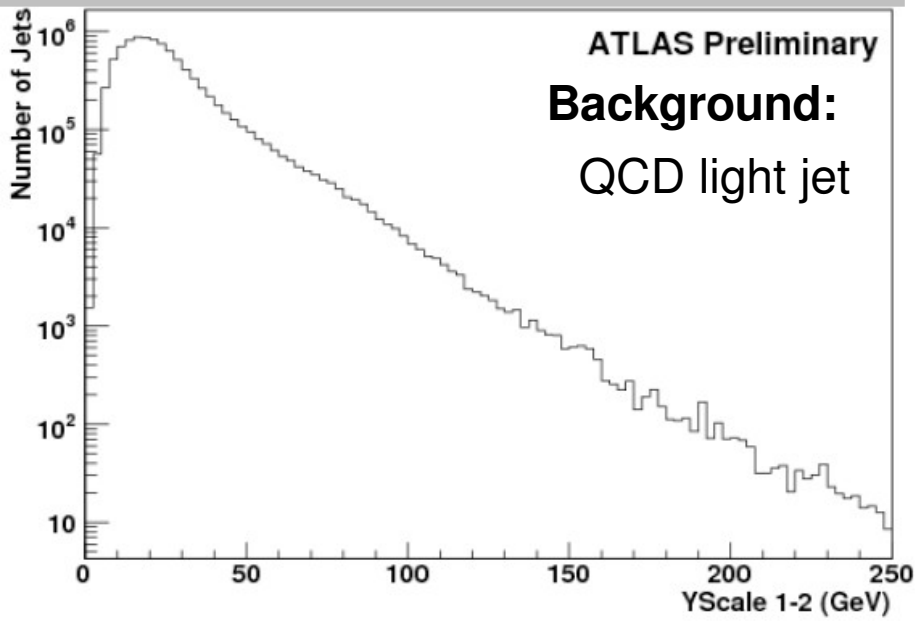


p_T (top) > 300 GeV

High p_T top: alternative approach

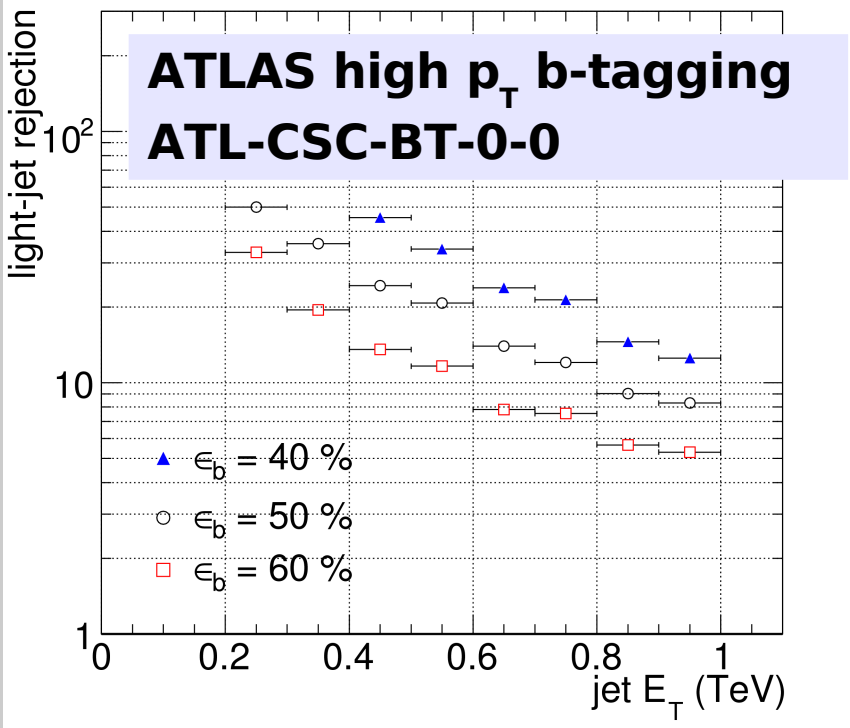
Distinguish top mono-jets from QCD (light) jet background using the jet structure

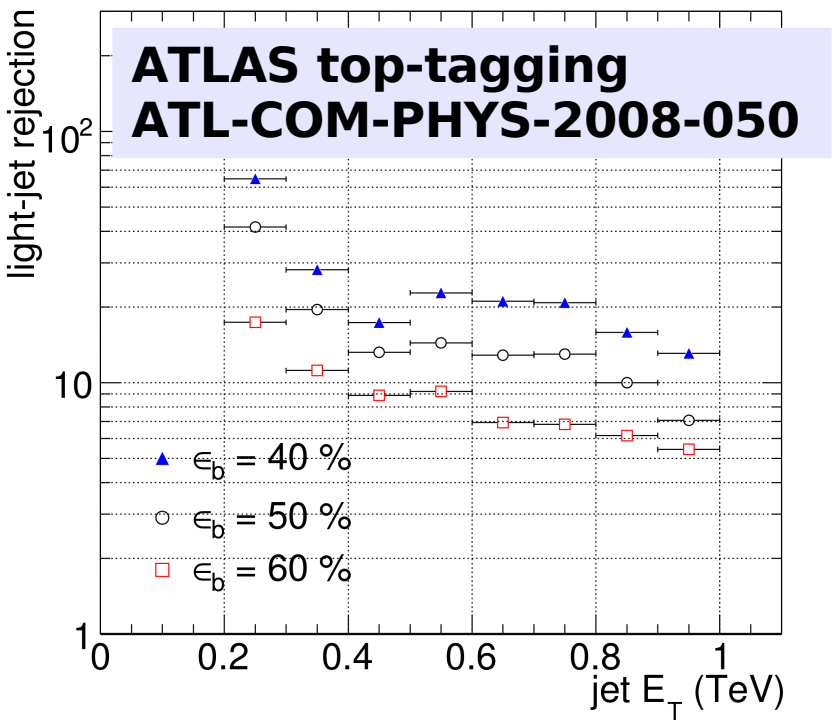




G. Brooijmans, High pT Hadronic Top Quark Identification Part 1 : Jet Mass and Ysplitter, ATL-PHYS-CONF-2008-008; ATL-COM-PHYS-2008-001

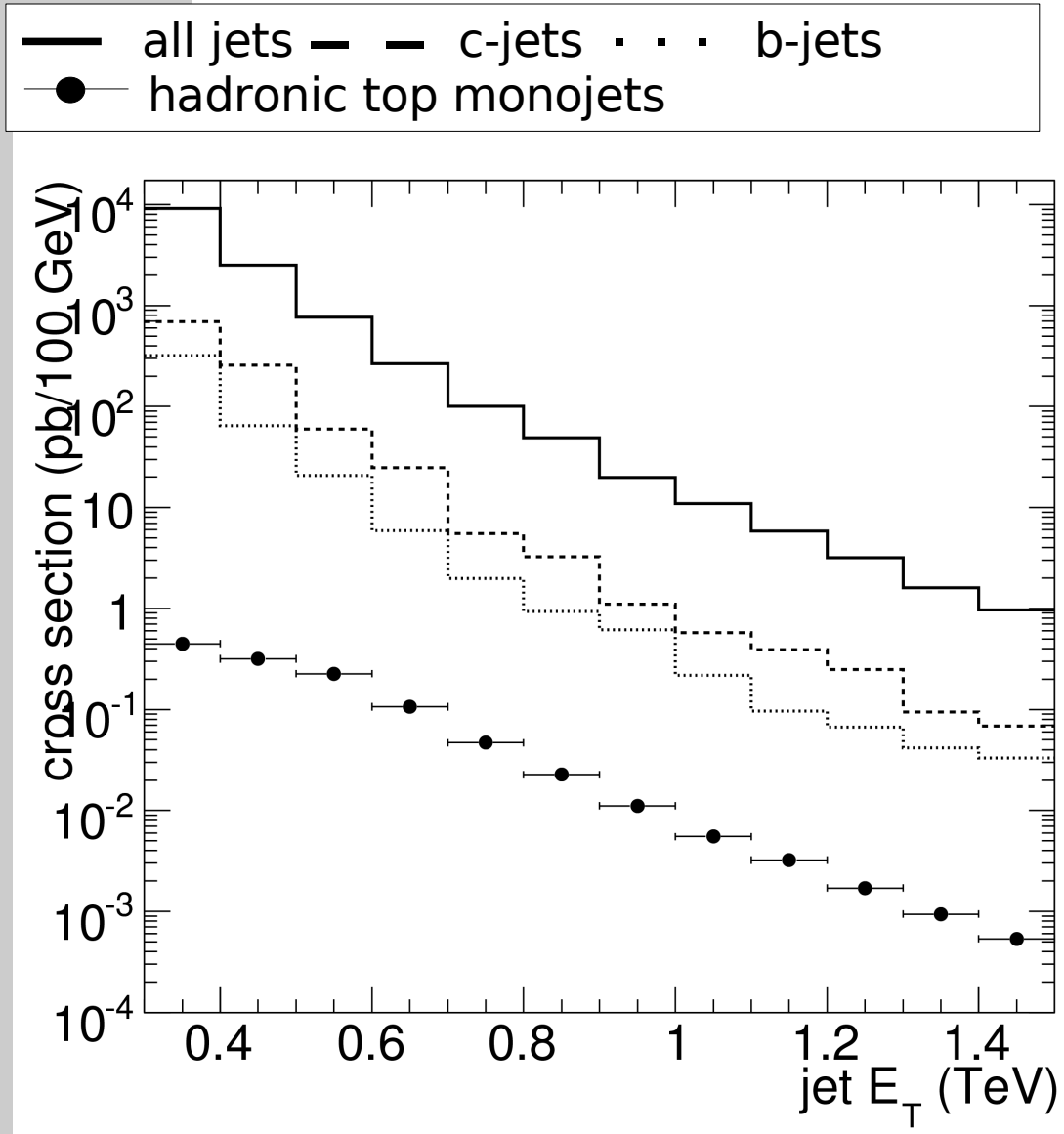
The lifetime signature





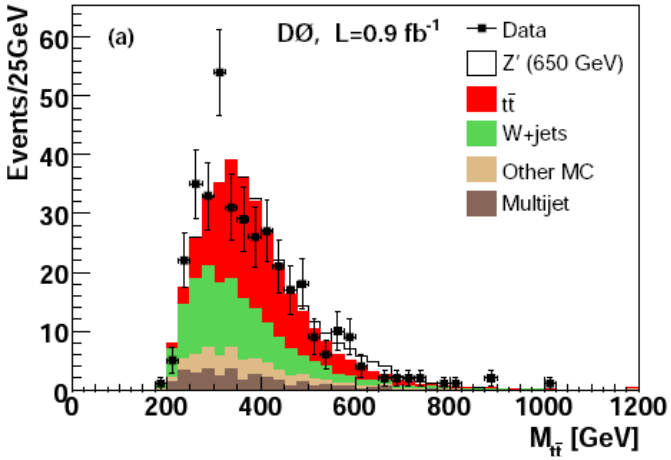
The b-tagging performance achieved with the SV1 + IP3D algorithm on iPatRec tracks after a rigorous paremeter retuning (association cone size, minimal track p_T) for high pT b-jets (leftmost figure) and hadronic top mono-jets (rightmost figure)

The lifetime signature

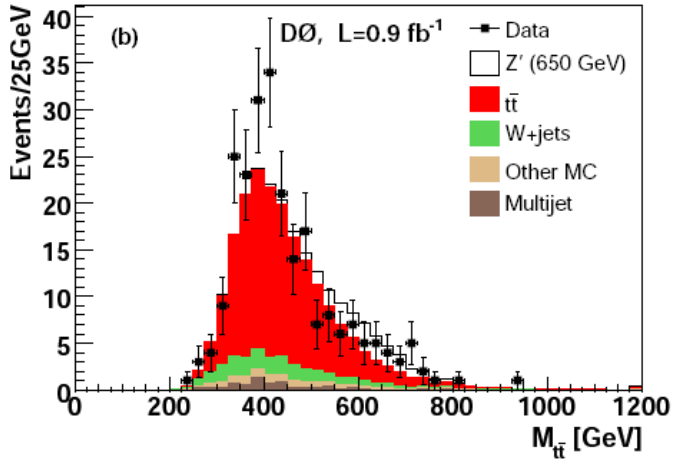


The abundance of heavy flavour in nature... (or at least in Pythia)

Tevatron - D0



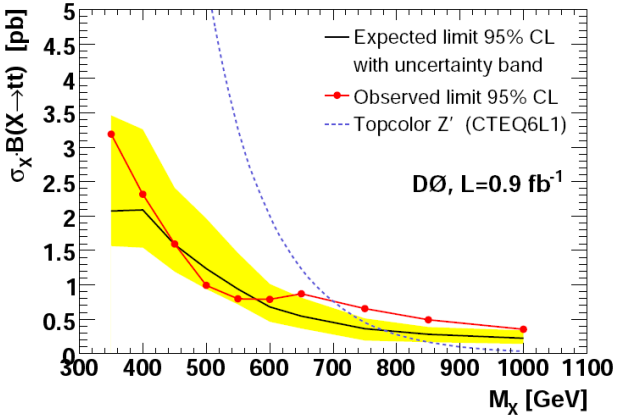
lν + 3 jets



lν + 4 jets

D0, *Search for tt resonances in the lepton plus jets final state in p¯p collisions at √s = 1.96TeV*, FERMILAB-PUB-08-097E, arXiv [hep-ex] 0804.3664

Within a Topcolor-assisted technicolor model the existence of a leptophobic Z' boson, with $M_{Z'} < 700$ GeV and $\Gamma_{Z'} = 0.012$ $M_{Z'}$, is excluded at 95 % C.L.



Tevatron - CDF

Tevatron: long series of papers to report on searches for tt resonances

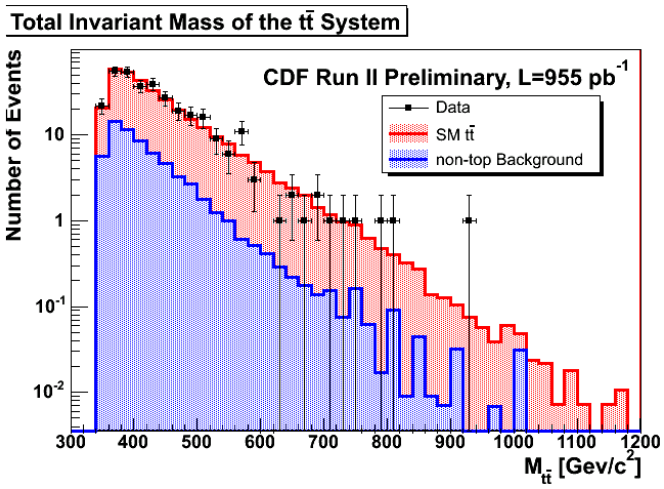
CDF, *Search for New Particles Decaying to tt in pp Collisions at √s = 1.8 TeV,* Phys.Rev.Lett.85 (2000) 2062-2067

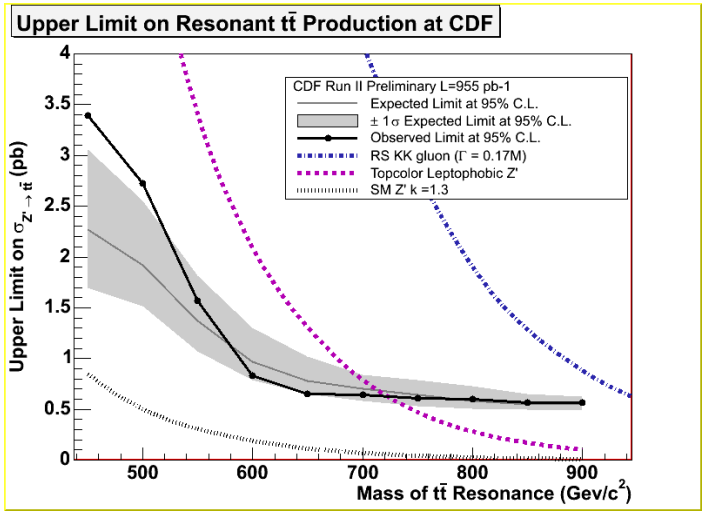
CDF, *Limits on the Production of Narrow t-tbar Resonances in p-pbar Collisions at sqrt(s)=1.96 TeV,* arXiv:0710.5335v1

Using 347 event in 1 fb-1: No evidence of Beyond the SM physics

95 % exclusion limit for (narrow) leptophobic technicolor Z' (> 720 GeV)

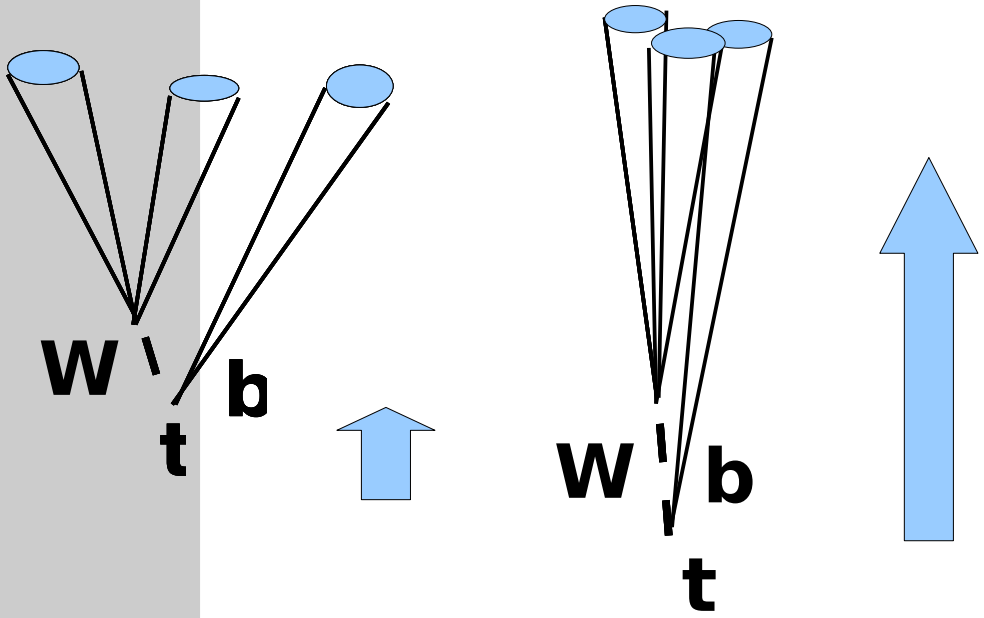
curve for broad RS KK gluon drawn in "for comparison"

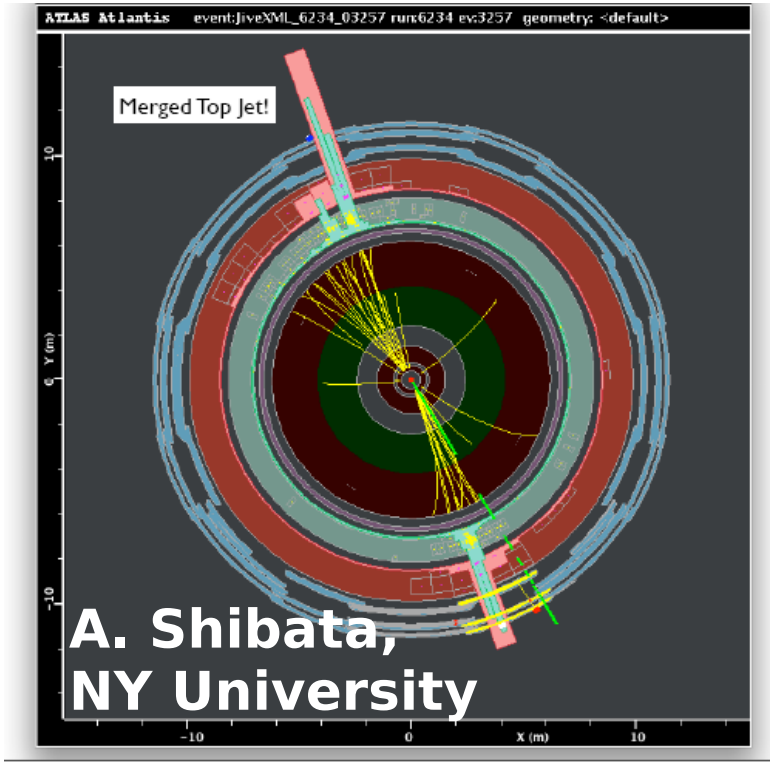




Reconstruction of hadronic top monojets

Top "monojet" tagging

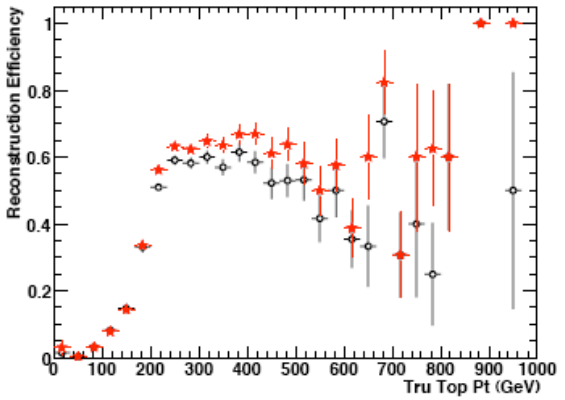




p_T (top) ~ 0 – 100 GeV

p_T (top) > 400 GeV

Standard resolved "commissioning style" top reconstruction. Beyond 400 GeV strongly reduced

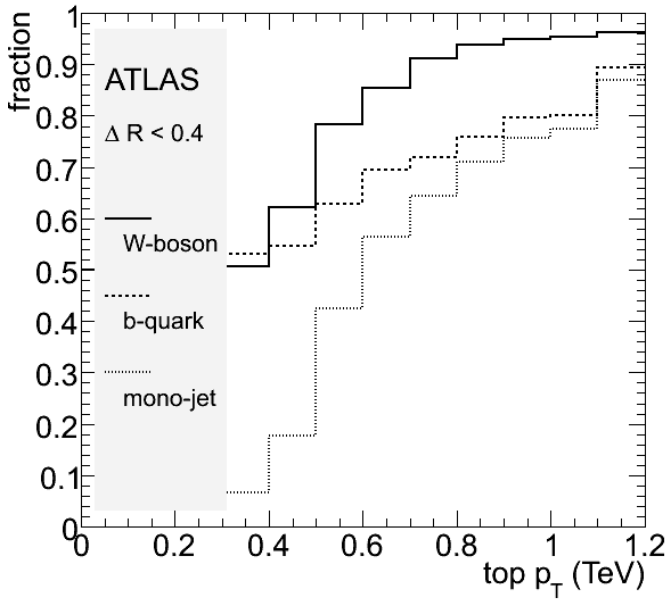


Reconstruction of top monojets

Top mono-jet reconstruction

A mono-jet: reconstructed jet contains both W and b-quark (within $\Delta R < 0.4$)

Probability to find top decay products in a small cone around the reconstructed jet-->



Top mono-jet identification

G. Brooijmans, High p_T Hadronic Top Quark Identification Part 1 : **Jet Mass and Ysplitter**,

ATL-PHYS-CONF-2008-008; ATL-COM-PHYS-2008-001

M. Vos, High p_T Hadronic Top Quark Identification Part 1 : **the life-time signature**,

ATL-COM-PHYS-2008-050

Some news

Top quarks, axigluons and charge asymmetries at Hadron Colliders

O. Antuñano, J.H. Kuhn, G. Rodrigo, arXiv:0709.1652

D.E. Kaplan, K. Rehermann, M.D. Schwartz, B. Tweedie, Top-tagging: a method for identifying boosted hadronic tops

arXiv:0806.0848