Hadronic signatures for New Physics?

Searches for new physics in early data using 3rd generation quarks

Marcel Vos, IFIC Valencia

A non-exhaustive, unordered list of hadronic signatures of New Physics that involve third generation quarks

Littlest Higgs model: $Z_H \rightarrow Zh \rightarrow l^+l^-$ bb, $W_H \rightarrow$ tb

(Eur.Phys.J.C39S2:13-24,2005)

Twin Higgs: $W_H \rightarrow$ tb

(ATL-COM-PHYS-2008-050)

SUSY cascade decays of squarks

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

ATL-PHYS-PUB-2006-002

Twin Higgs: cascade $W_H \rightarrow Tb \rightarrow bbbbl\nu$

(Les Houches 2007, arXiv:0802.3715)

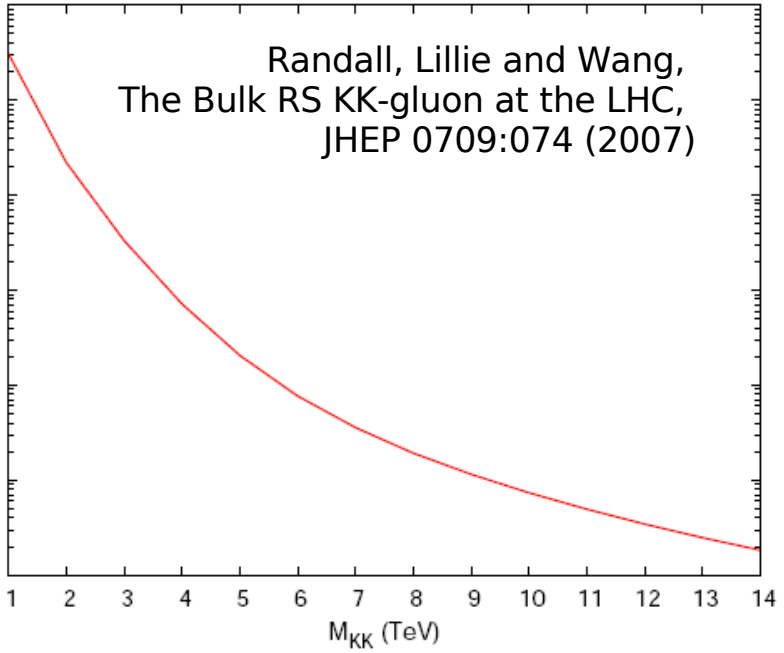
Some early physics

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 pair production, W+jets σ (pT (top) > 200 GeV) ~ 26 pb (LO, large K-factor)

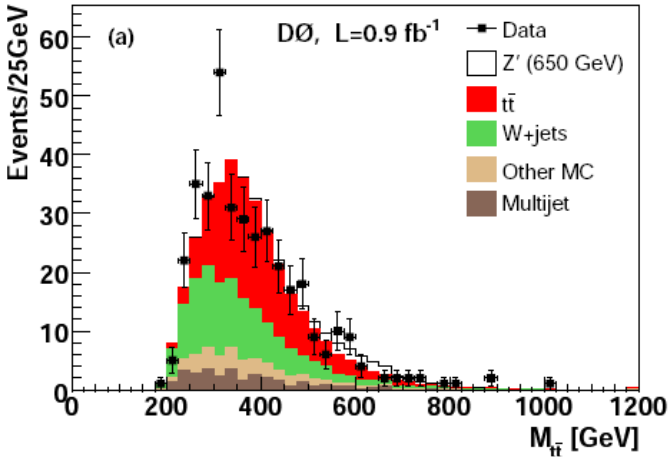


Taking 20 pb^{-1} :
10.000 signal events

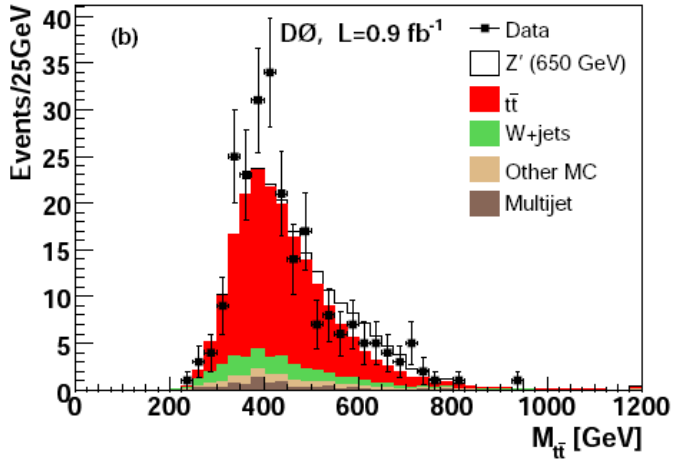
M g^* (GeV)	σ g^* (pb) @ 10 TeV	σ g^* (pb) @ 14 TeV
1 TeV	475	1109

Leading order cross-sections for ADD KK gluon

Tevatron



lν + 3 jets



lν + 4 jets

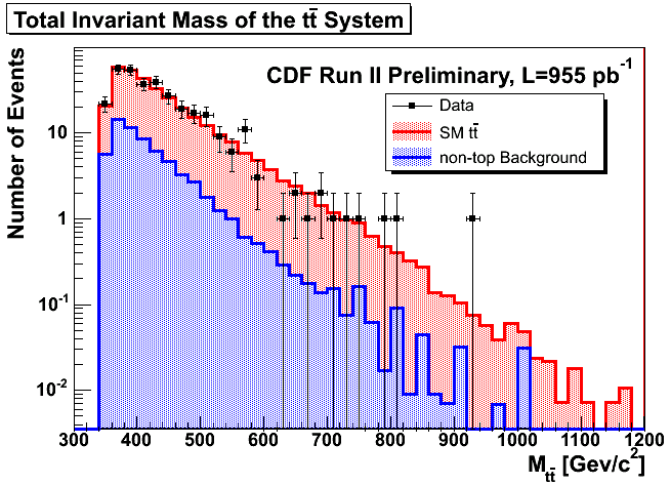
Intensive searches for tt resonances at the Tevatron. ~ 20 papers since 2000.

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

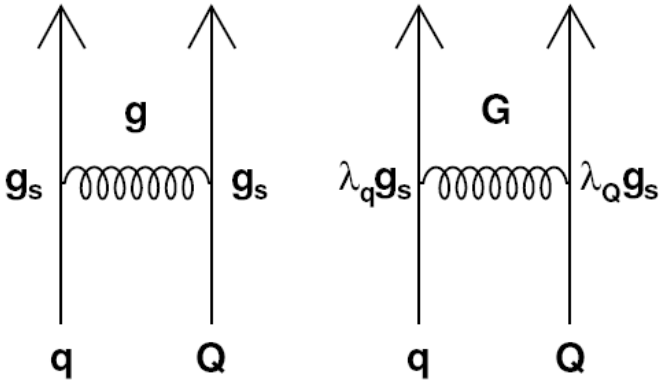
CDF, Phys.Rev.Lett.85 (2000) 2062-2067

CDF, arXiv:0710.5335v1

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

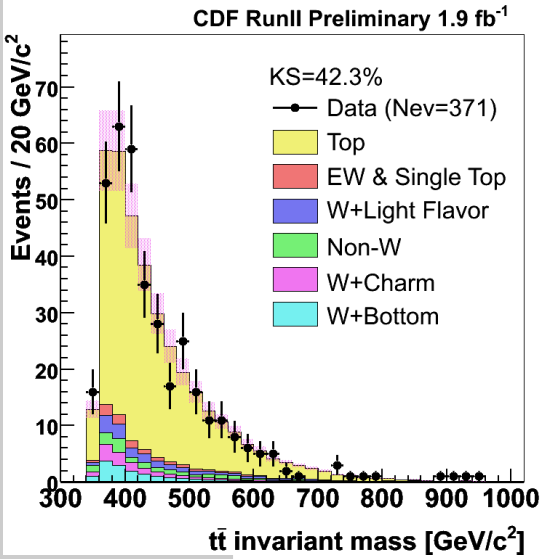


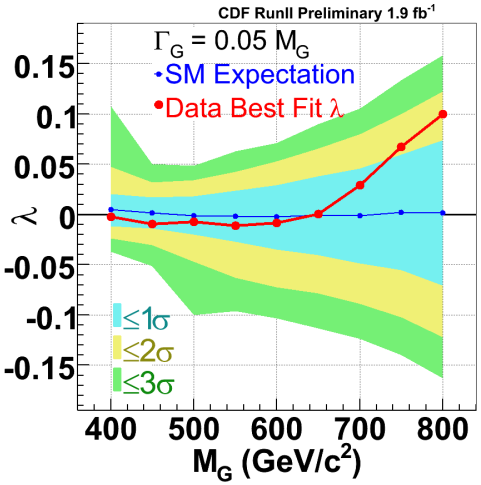
Tevatron - CDF

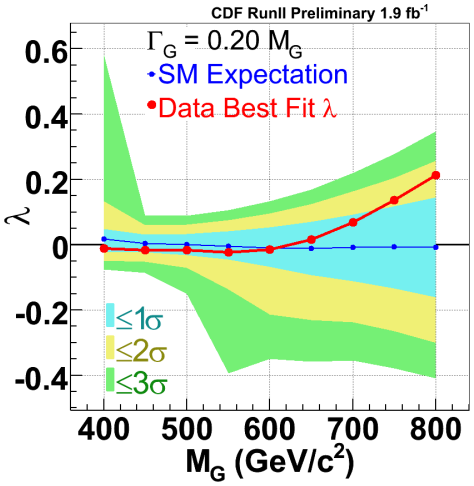


Preliminary results in CDF 9164 of a massive gluon search in 1.9 fb^{-1} finds data are compatible with SM within 1.7 σ

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



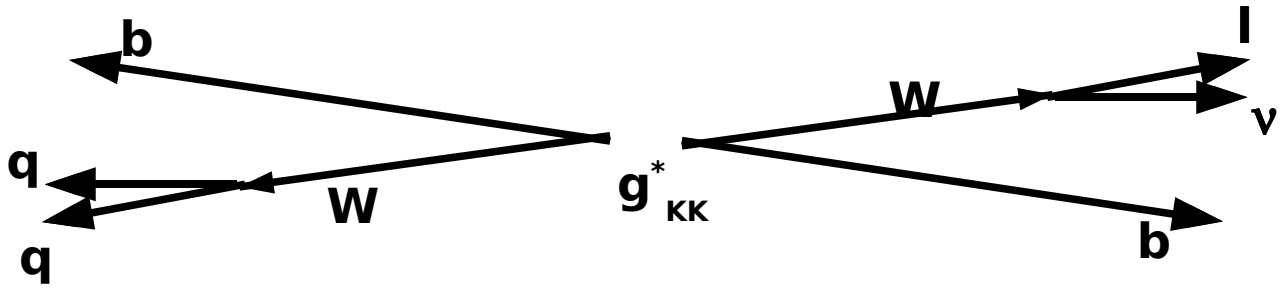




ATLAS g^*_{KK} reconstruction

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

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



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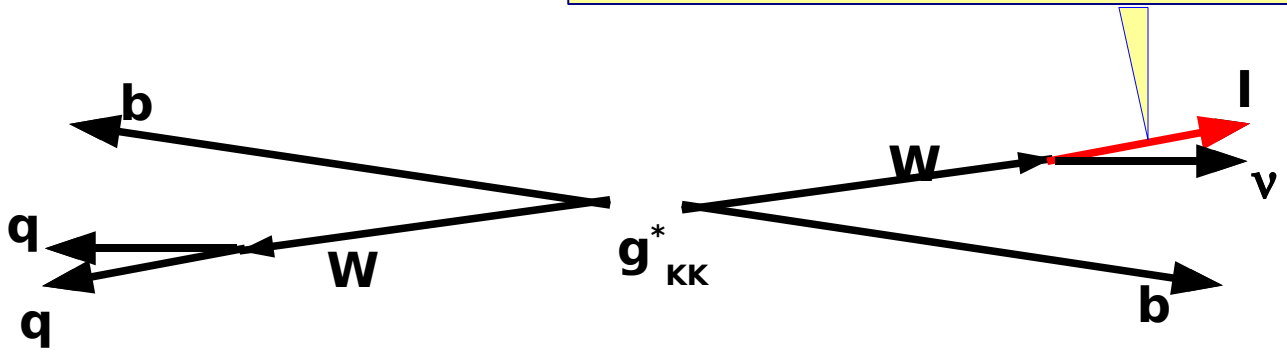
Isolated lepton (e,μ)

p_T > 25 GeV



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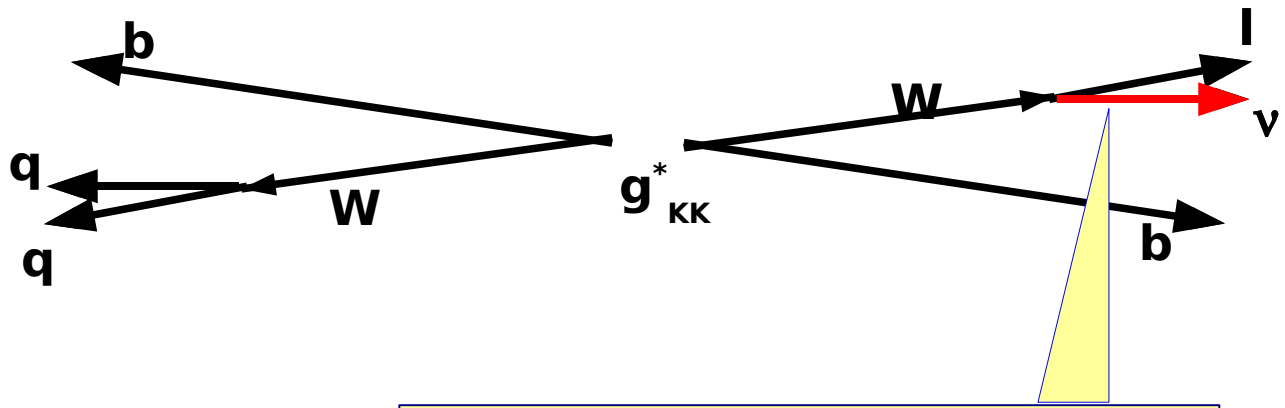

Missing transverse energy

$E^{miss}_T > 25$ GeV, $p_z^{\nu} // p_z^{l}$

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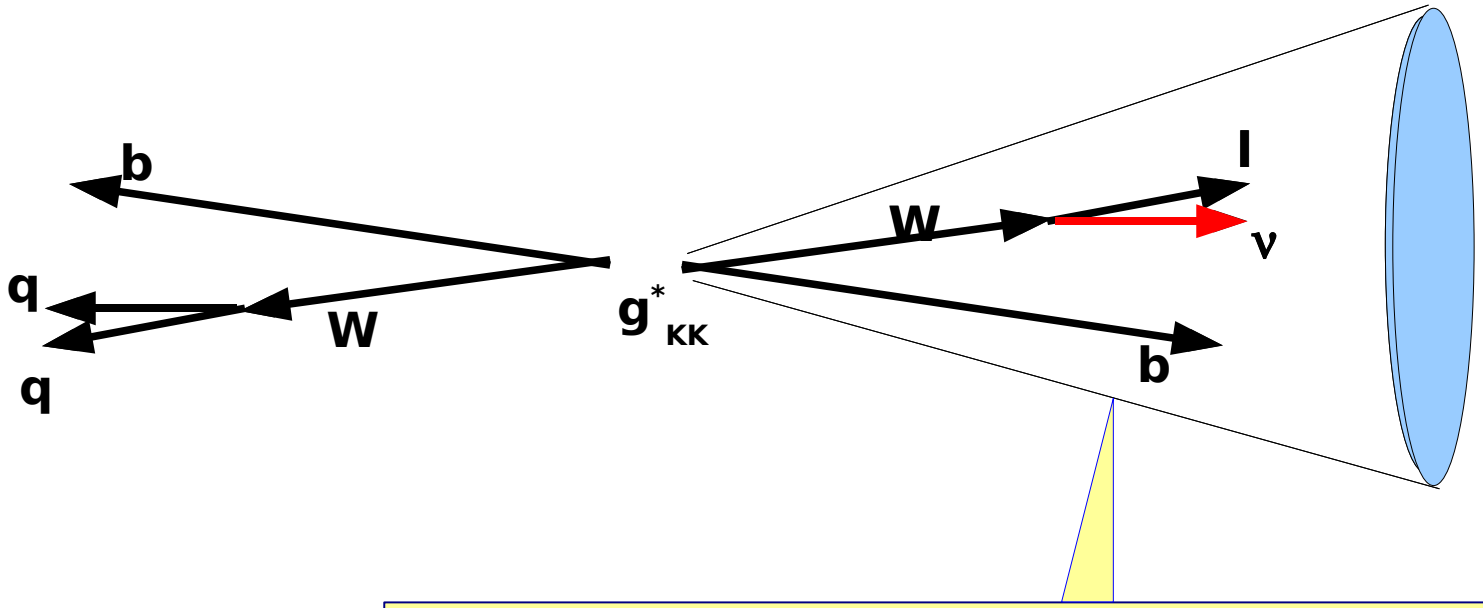
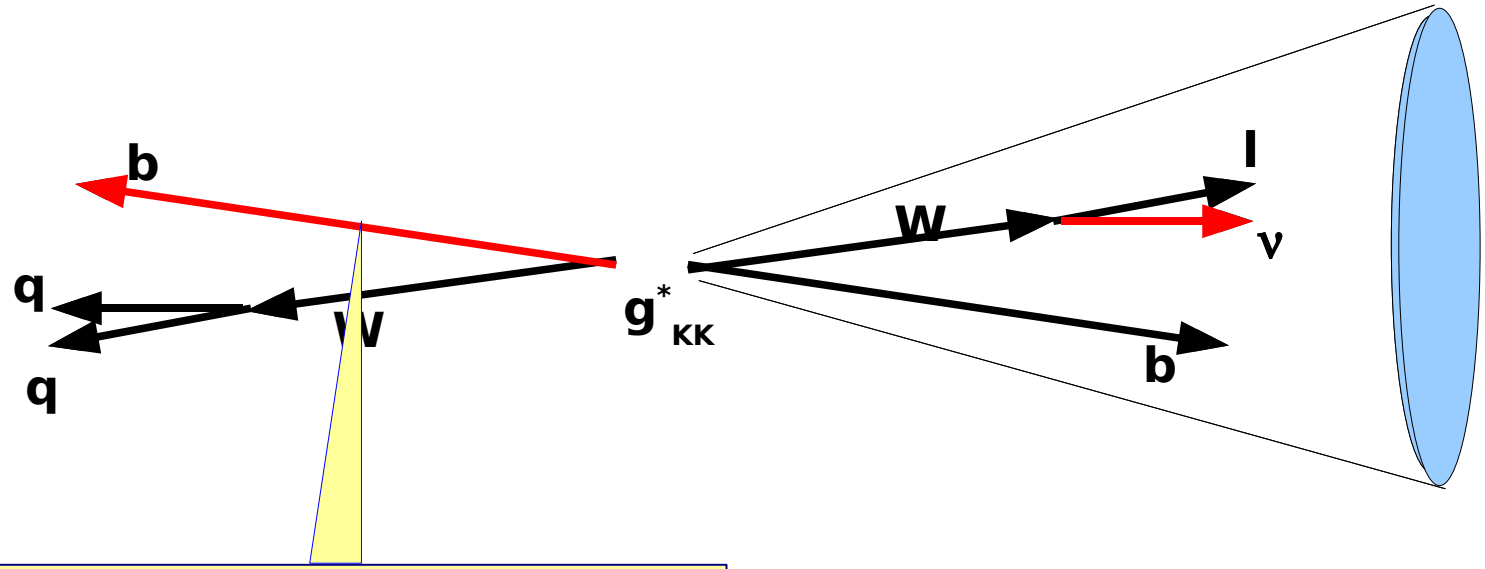


Leptonic top: add jet (E_T > 25 GeV) with smallest $\Delta r_{jet\text{-}lepton}$ p_T(top) > 200 GeV

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



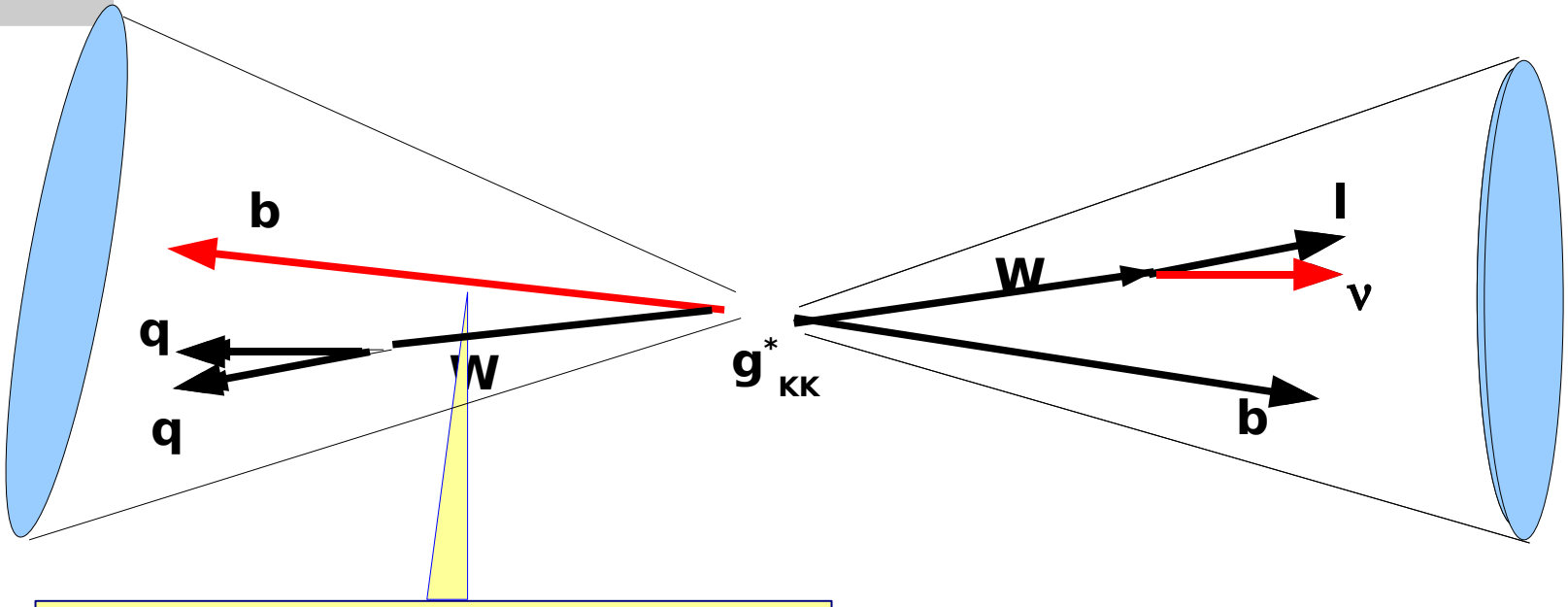
Look for highest E_T jet with

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

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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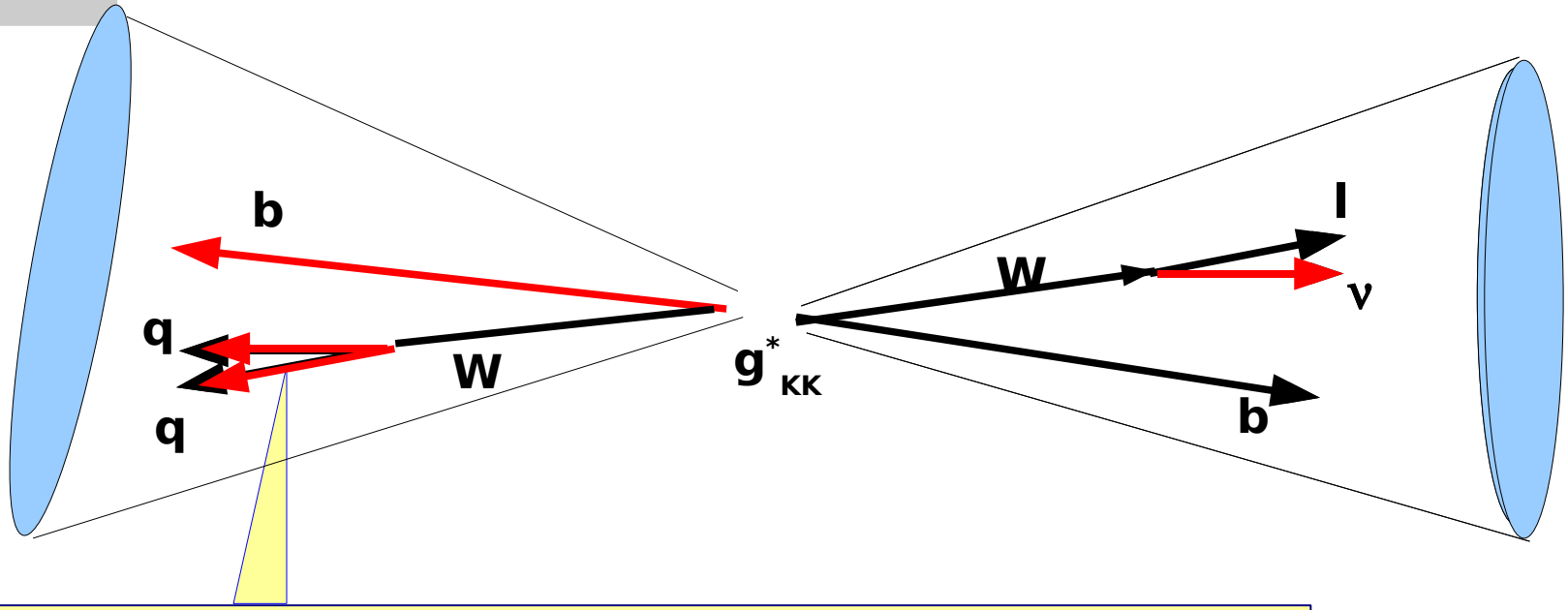


Hadronic top: sum all jets with $\Delta R_{jet\text{-}jet} < 1$

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

Early exotic physics

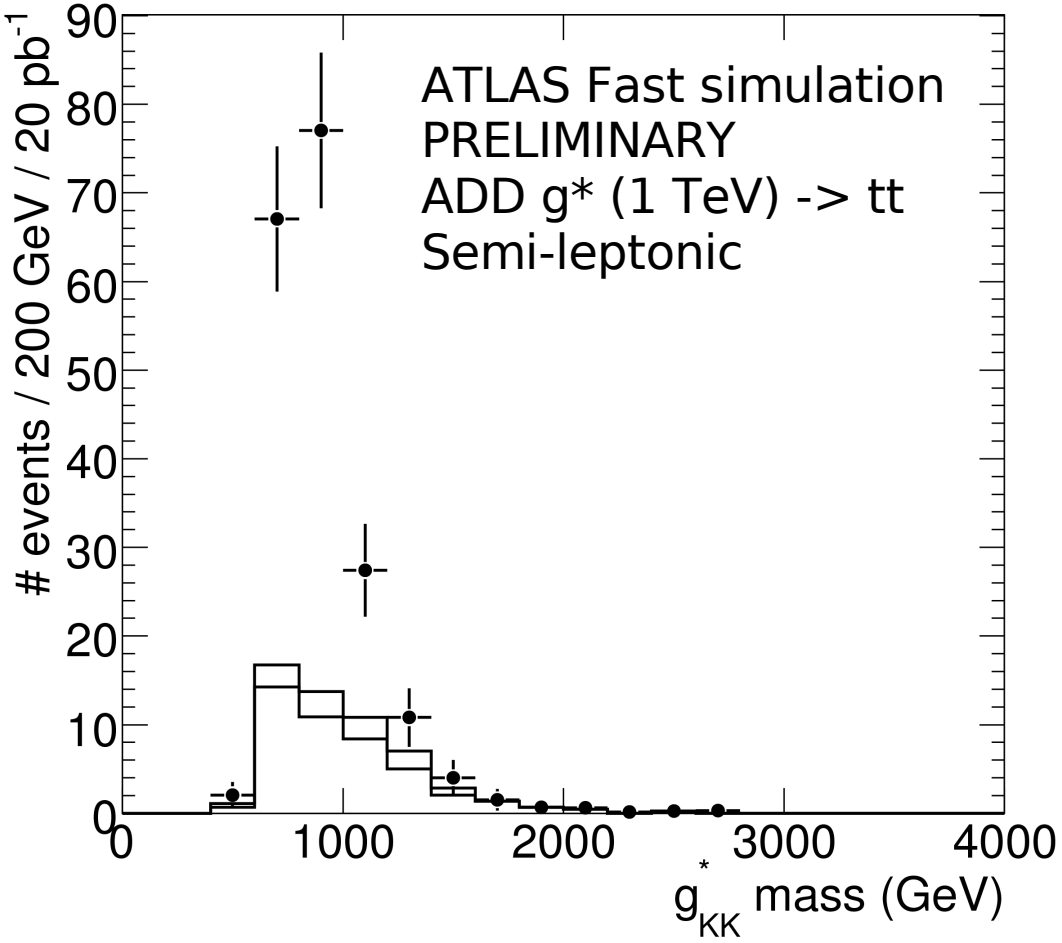
ATLAS 10 TeV, 20 pb^{-1}
preliminary

Fast simulation

Simplified early physics analysis: no b-tagging!

tt and W+jets backgrounds evaluated

(can we really ignore di-jets?)

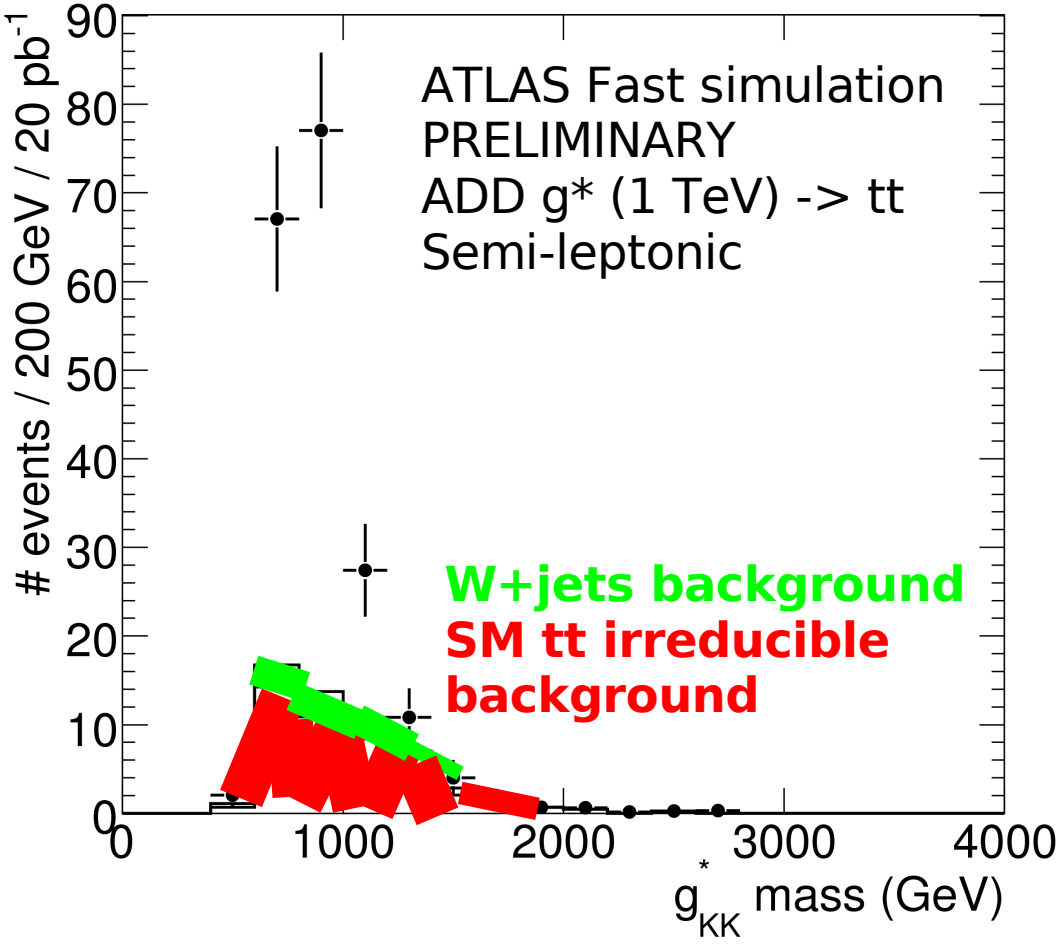


Early exotic physics

ATLAS 10 TeV, 20 pb^{-1}
preliminary

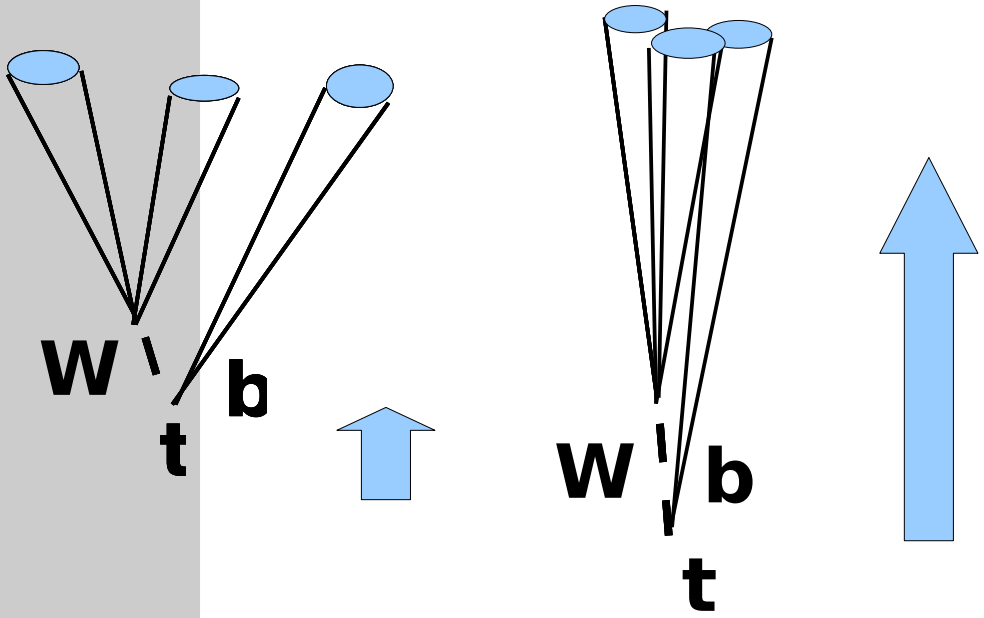
How can we be sure these are really tt events? flavour tagging, jet sub-structure

How do we estimate the background (normalization) from data? top p_T distribution



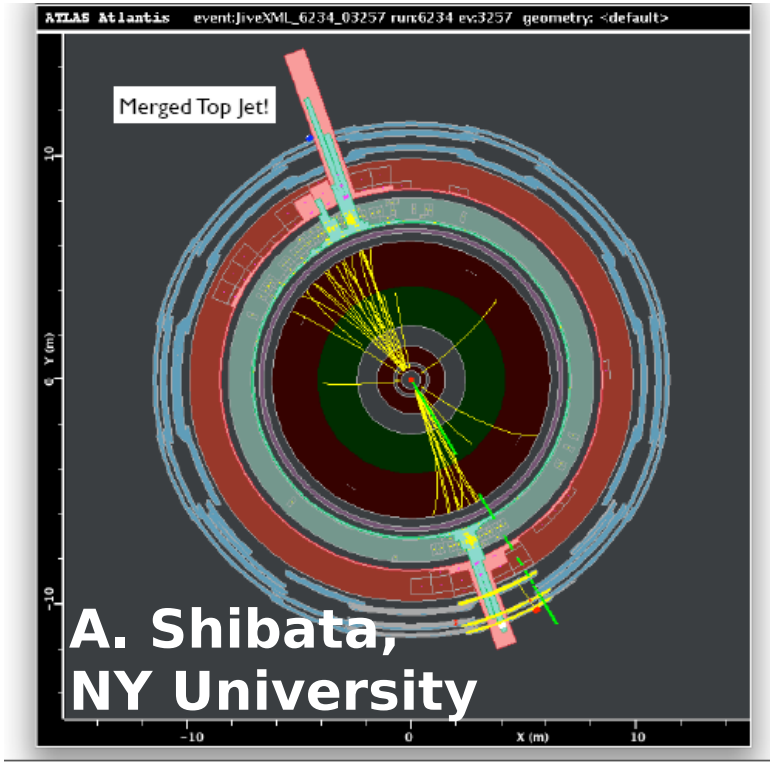
Reconstruction of hadronic top monojets

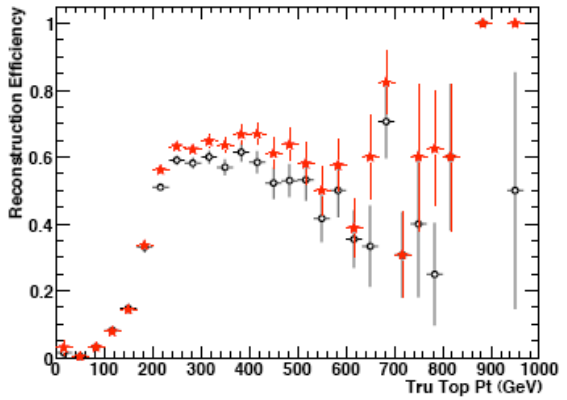
Top "monojet" tagging



p_T (top) ~ 0 – 100 GeV p_T (top) > 400 GeV

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



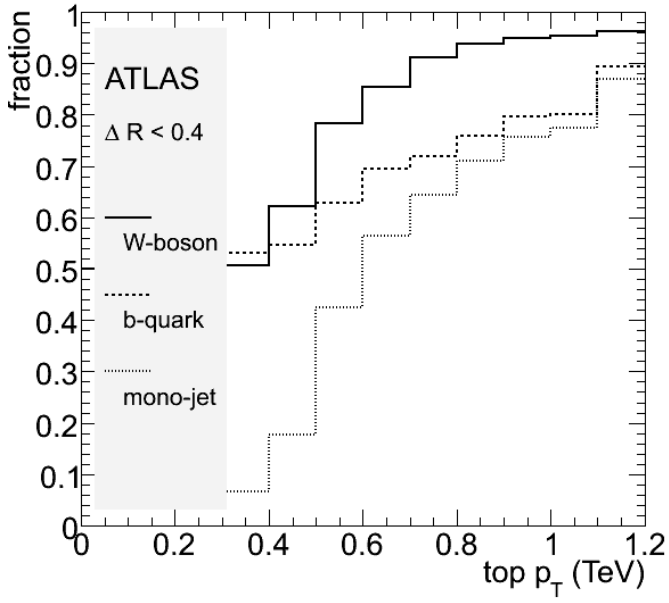


Reconstruction of top monojets

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

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**

For semi-leptonics events: reduce di-jet and W+jets background combining signatures from leptonic (lepton, missing E_T) and hadronic top (monojet)

Impact on mass resolution for tt resonance (fully hadronic or semi-leptonic). Preliminary: better than what one would expect from fast simulation

Putting it all together

To make real progress, full simulation is required
Should we try to request these samples once more?
Pull at least event generation through central production?

- signal (MadGraph)
- tt background (MC@NLO)
    unbiased and with pT (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

Manpower

People that are actively involved in high p_T top

NIKHEF: M Rijpstra, M. Vreeswijk
W'->tb, ATL-COM-PHYS-2008-050
U. Columbia: G. Brooijmans, F. Spano
Jet substructure (Les Houches report, ...)
Harvard: B. Smith
Splitting merged jets
IFIC Valencia: E. Ros, L. March, S. Gonzalez de la Hoz, M.Vos
Lifetime signature, ATL-COM-PHYS-2008-029

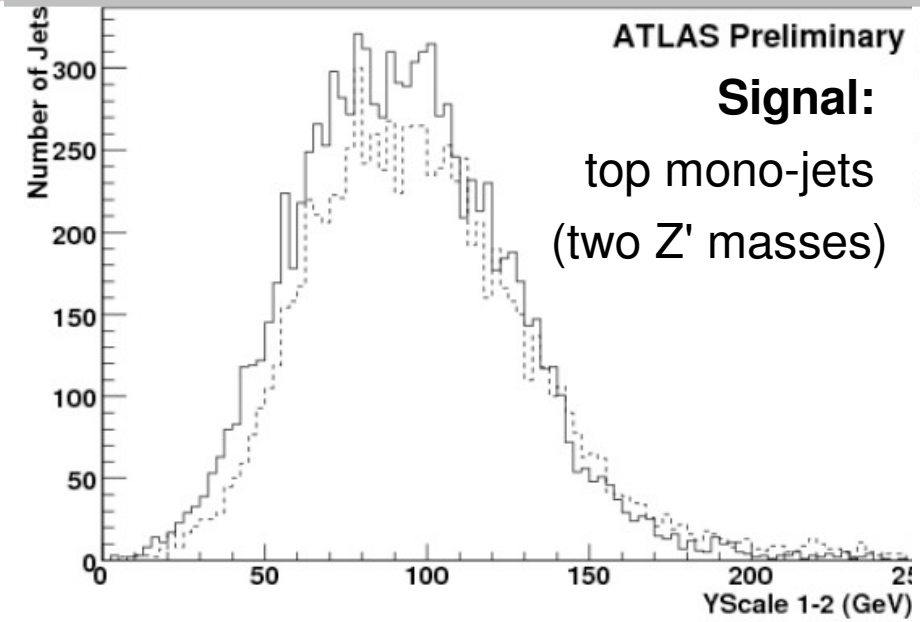
Top group: D. Pallin (Clermont Ferrand), A. Shibata (NY)

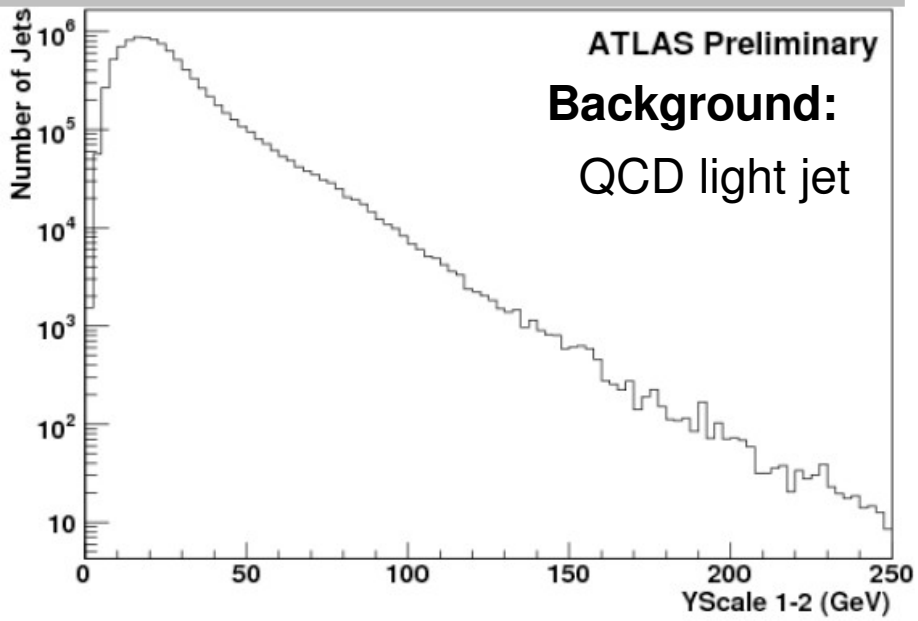
b-tagging: Vivek Jain (Indiana), G. Piacquadio (Freiburg)

Tracking: Michael Wilson (CERN)

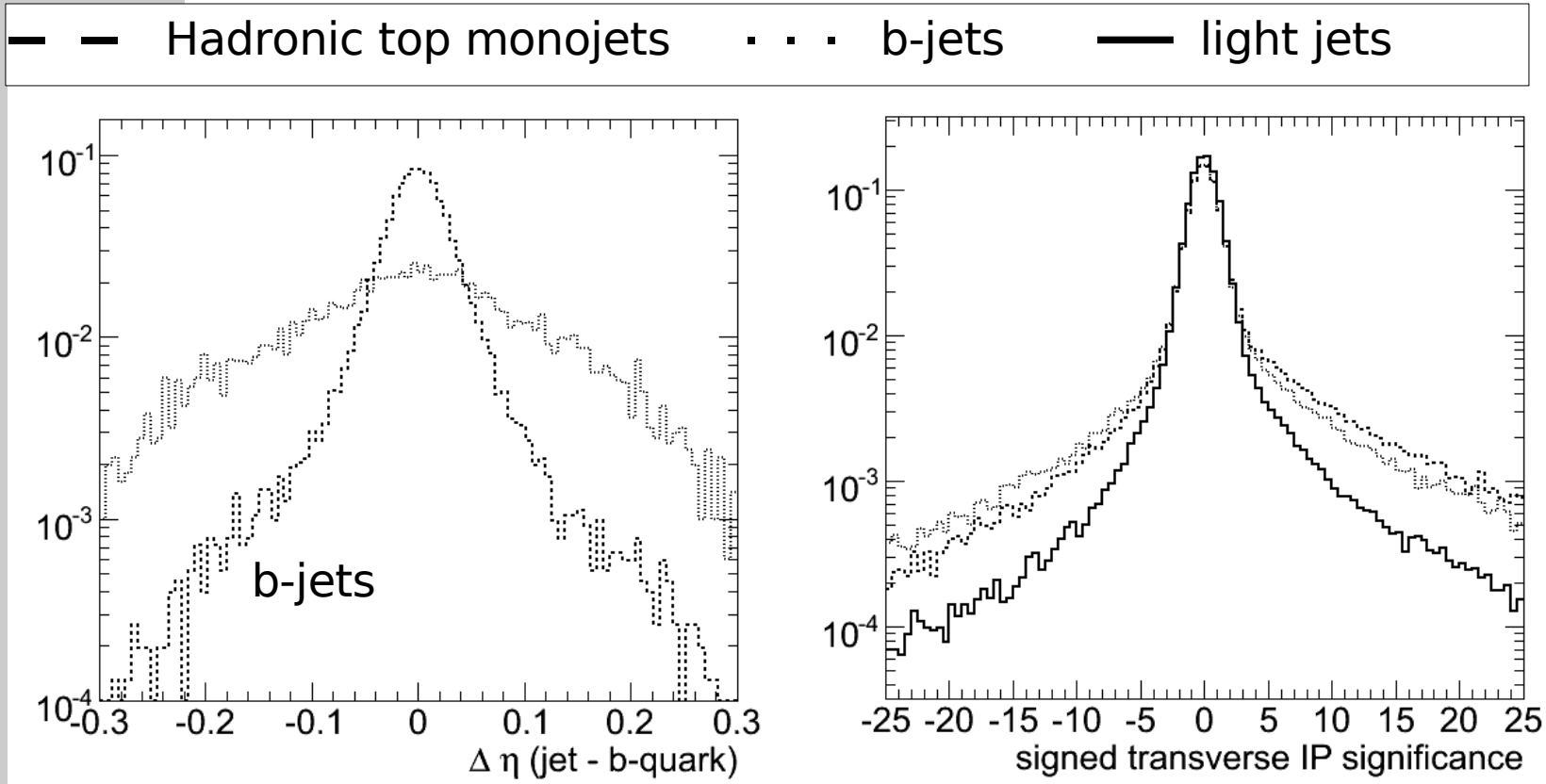
High p_T top: alternative approach

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





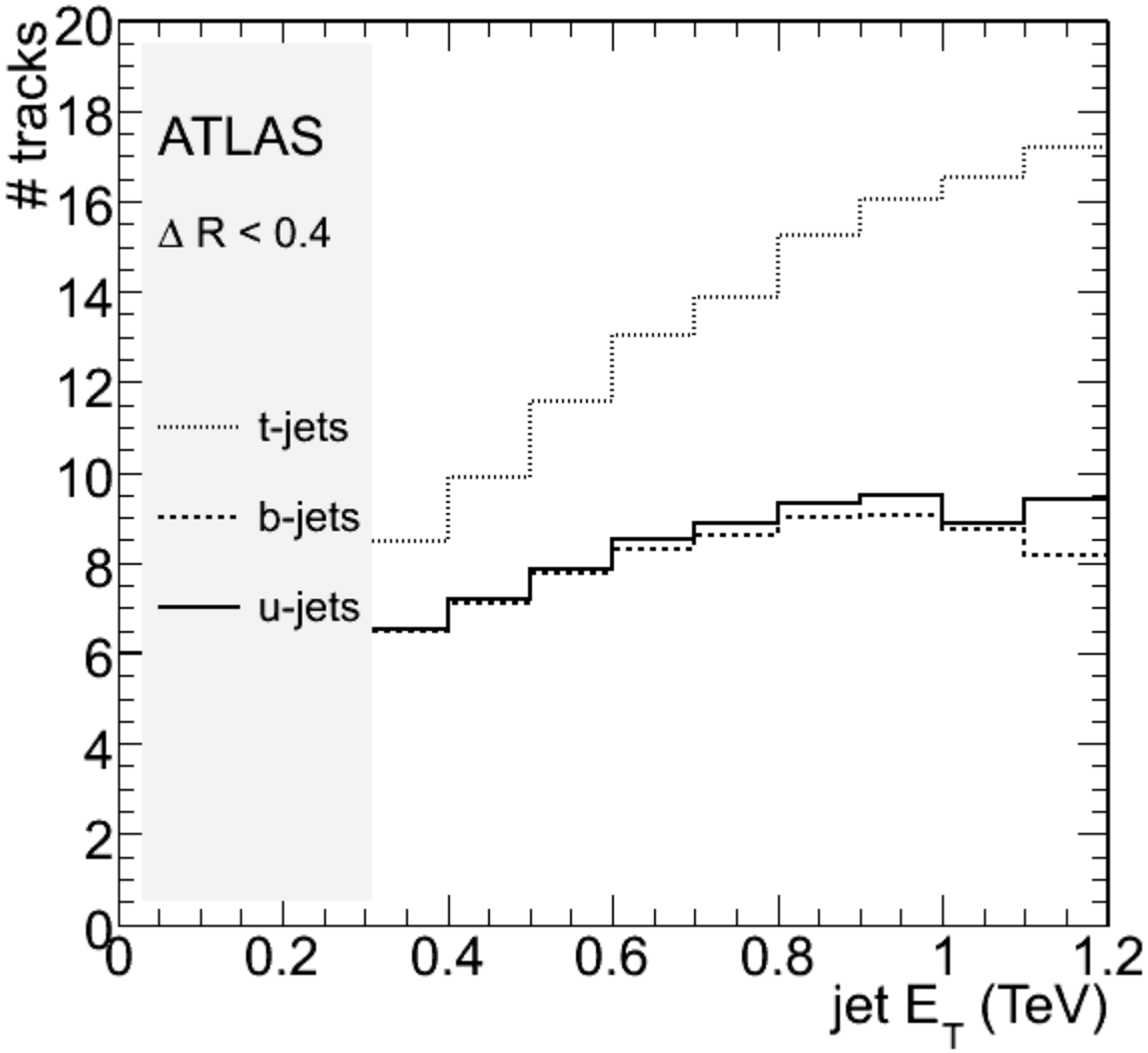
The lifetime signature



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

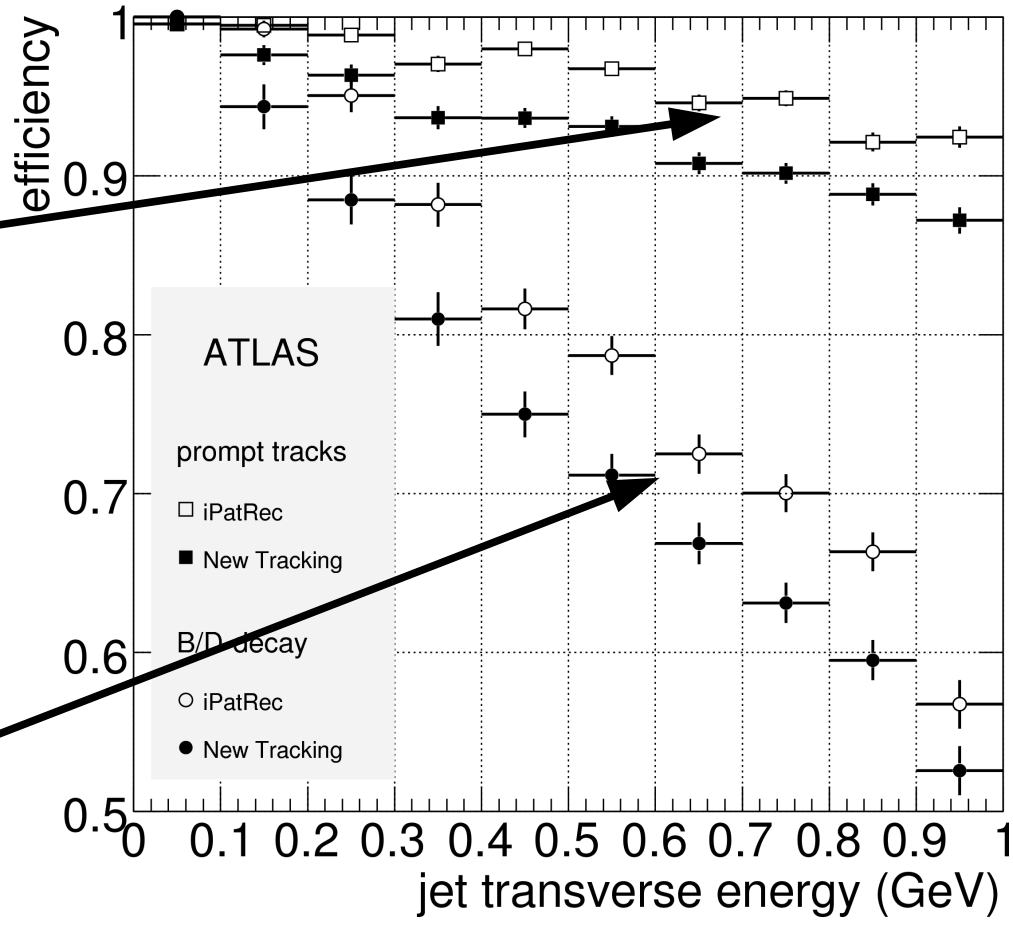


Great!!! even more tracks without lifetime...

Tracks from displaced vertices

Z' -> uu
tracks from interaction point

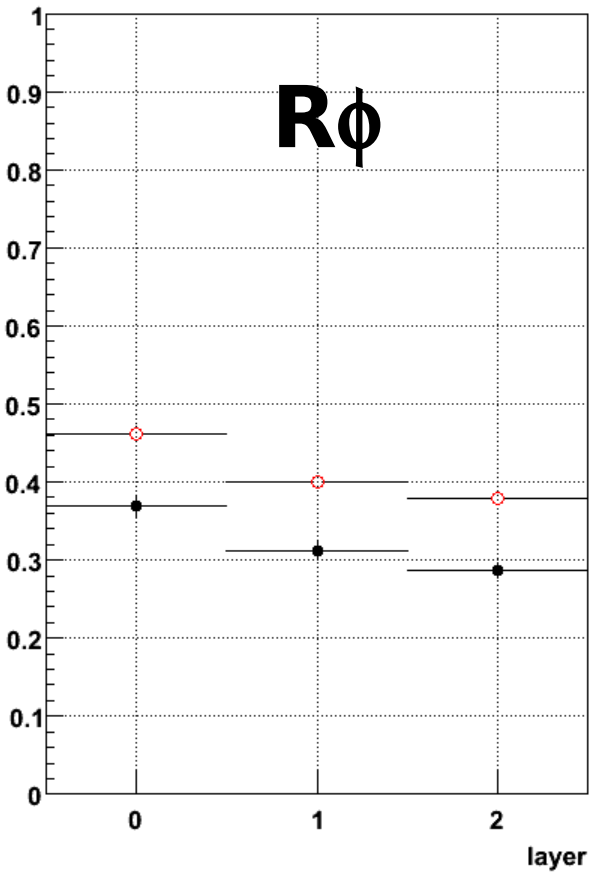
Z' -> bb
tracks from B/D vertex

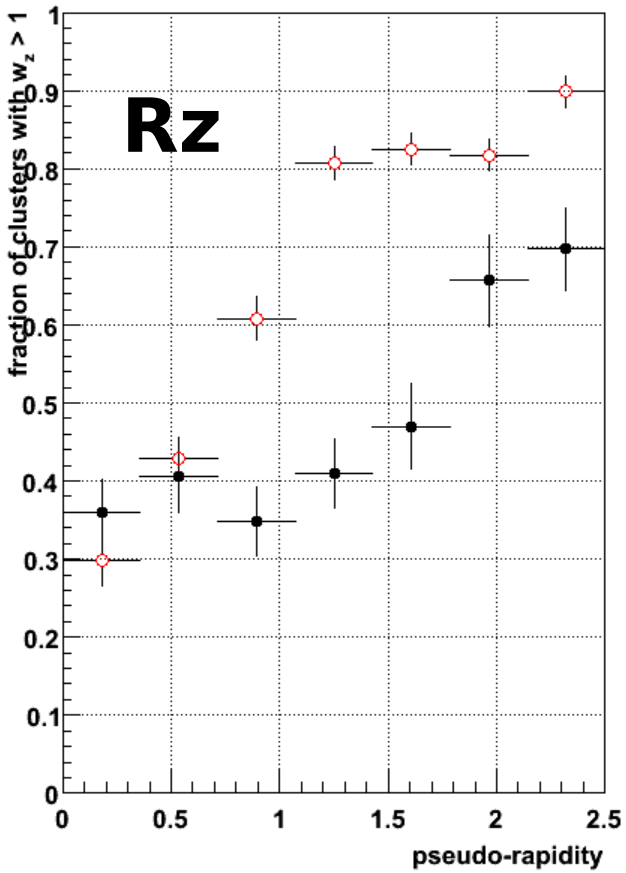


Pixel clustering

See the impact of different pixel clustering algorithms...

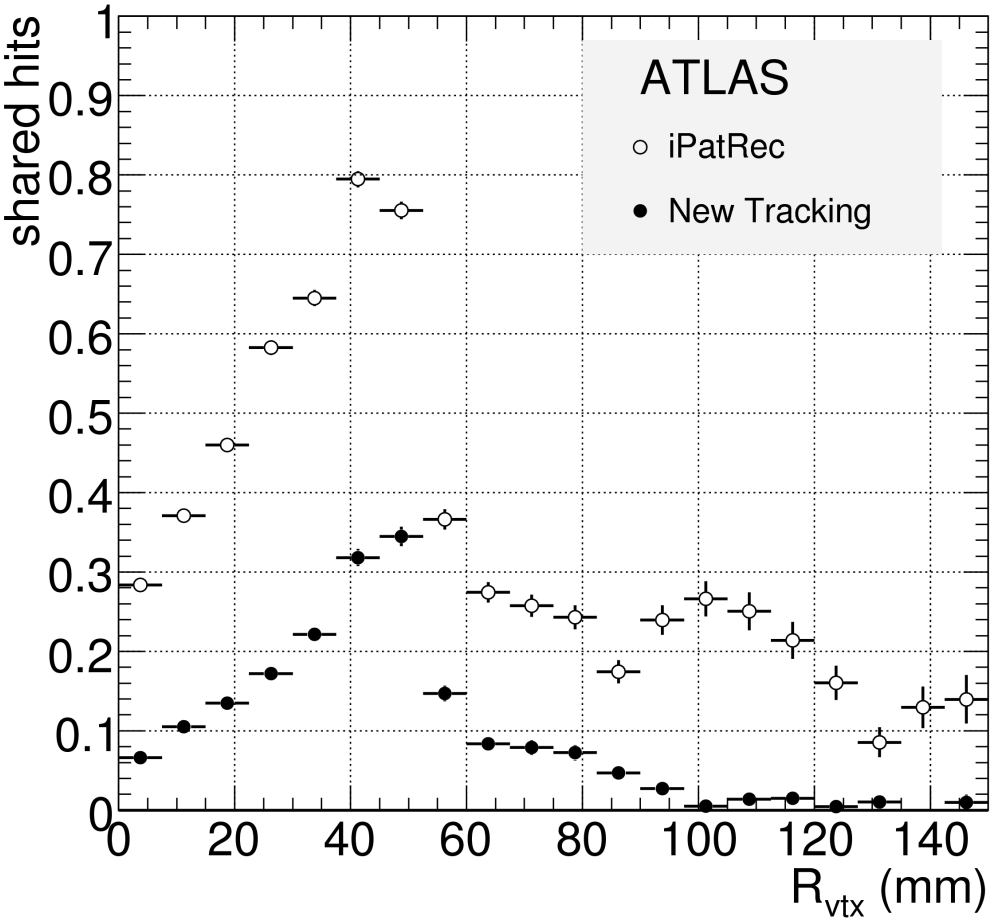
Fraction of pixels in B-layer with width > 1





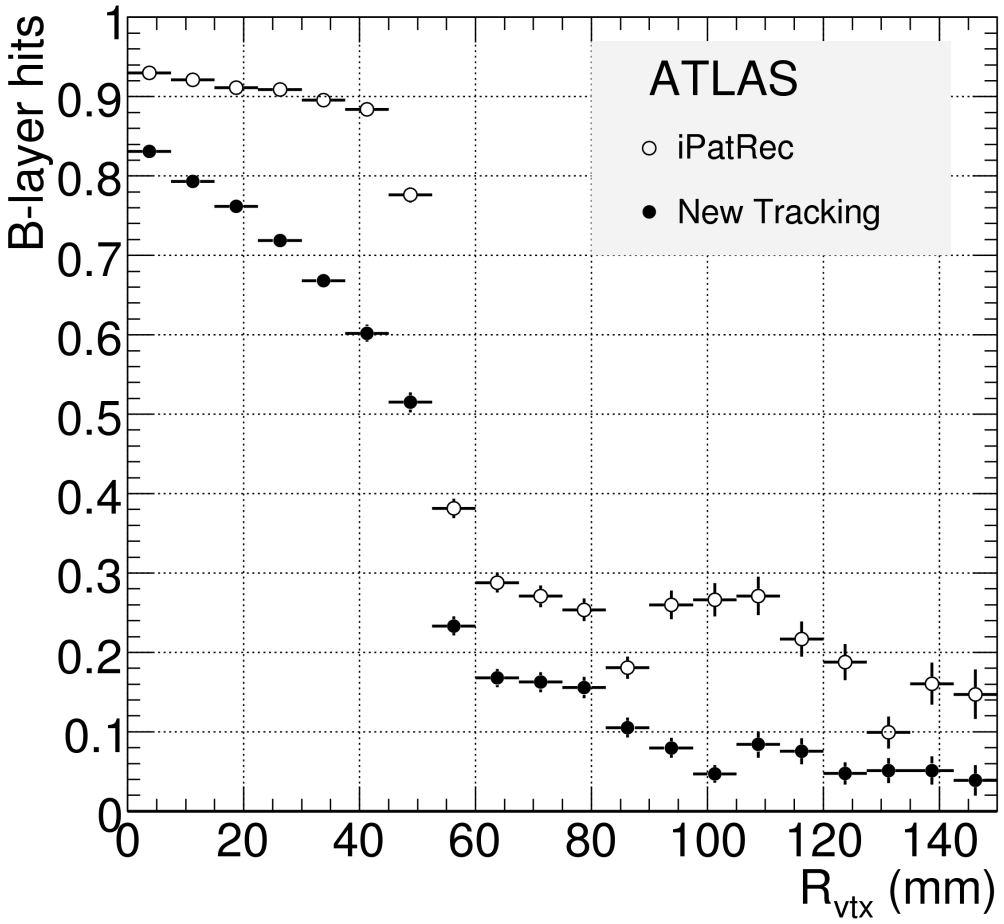
Treatment of ambiguities

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

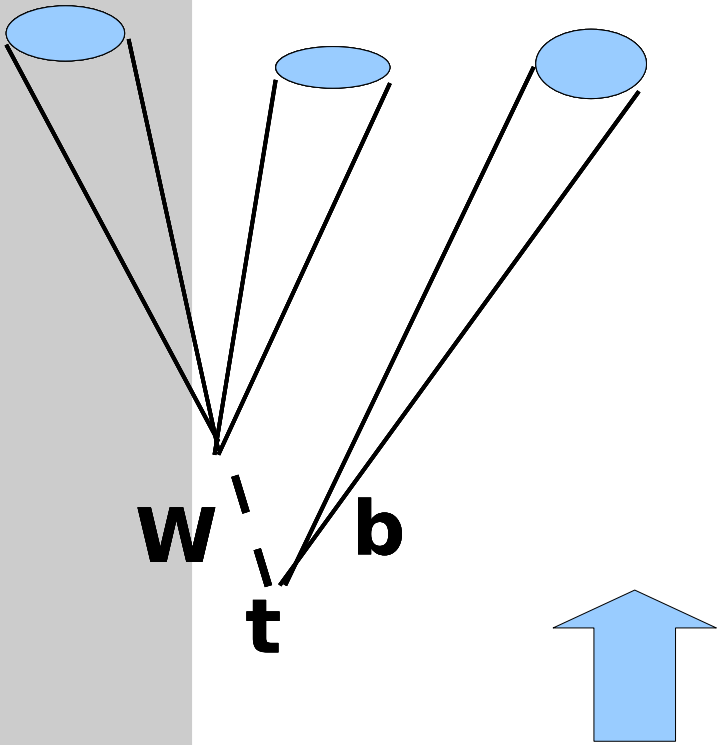


Tracks from displaced vertices

Even see hits that never existed!

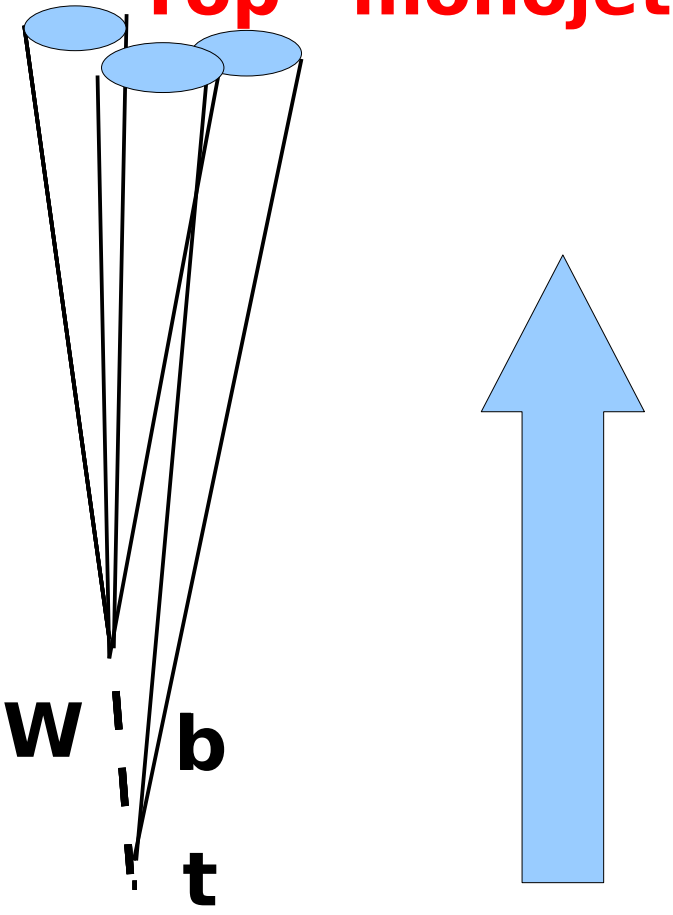


Reconstruction of hadronic top monojets



p_T (top) ~ 0 – 100 GeV

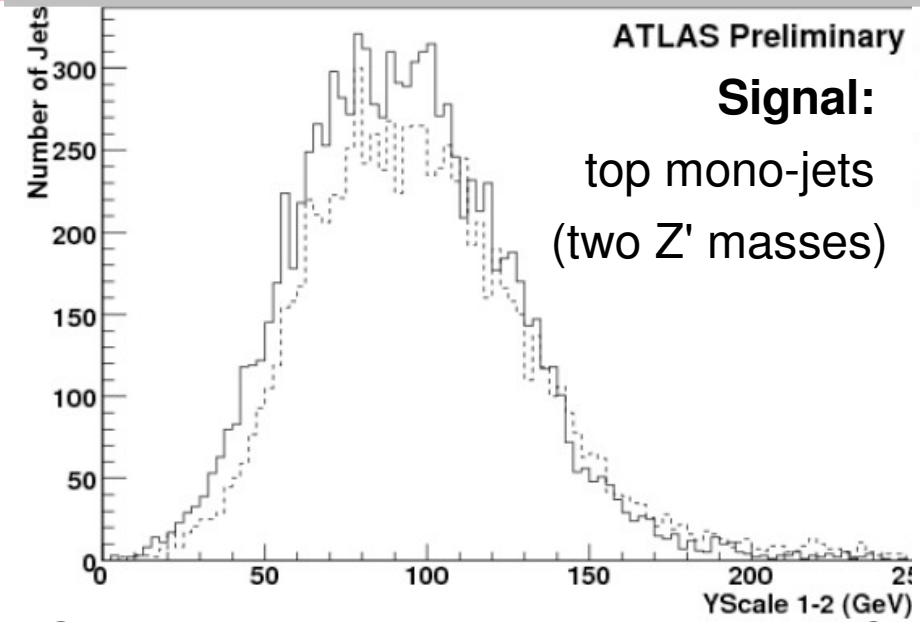
Top “monojet”

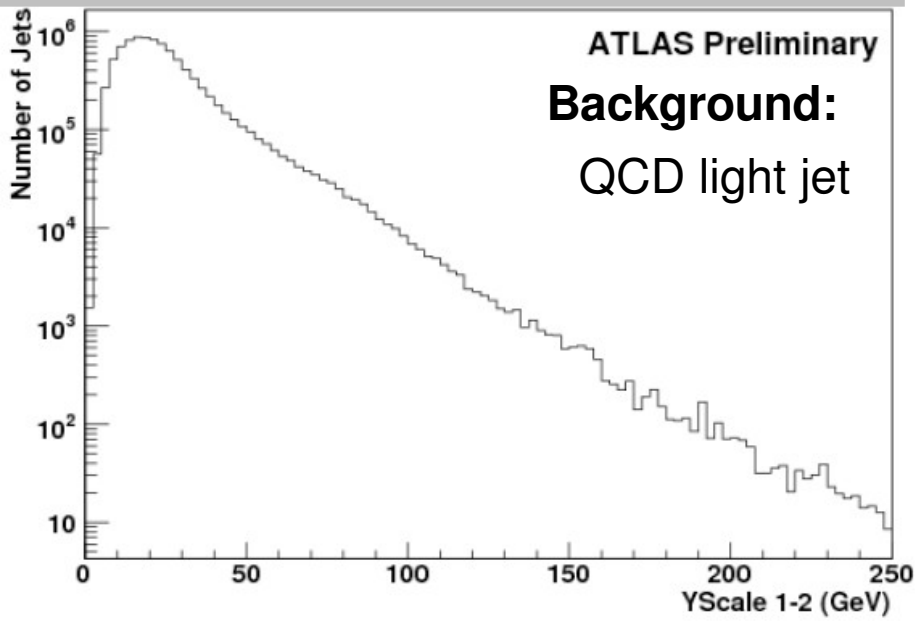


p_T (top) > 300 GeV

High p_T top: alternative approach

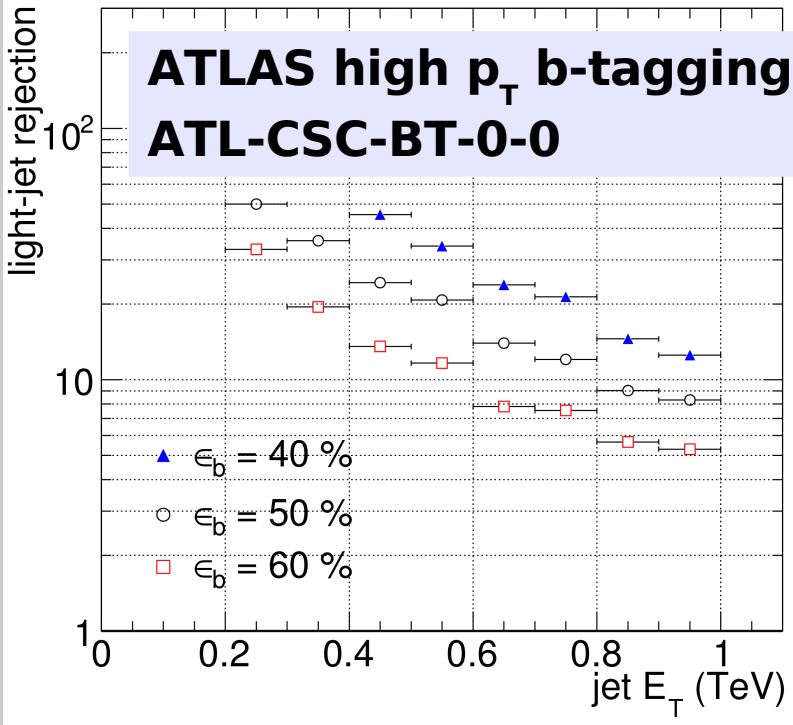
Distinguish top mono-jets from QCD (light) jet background using the jet structure

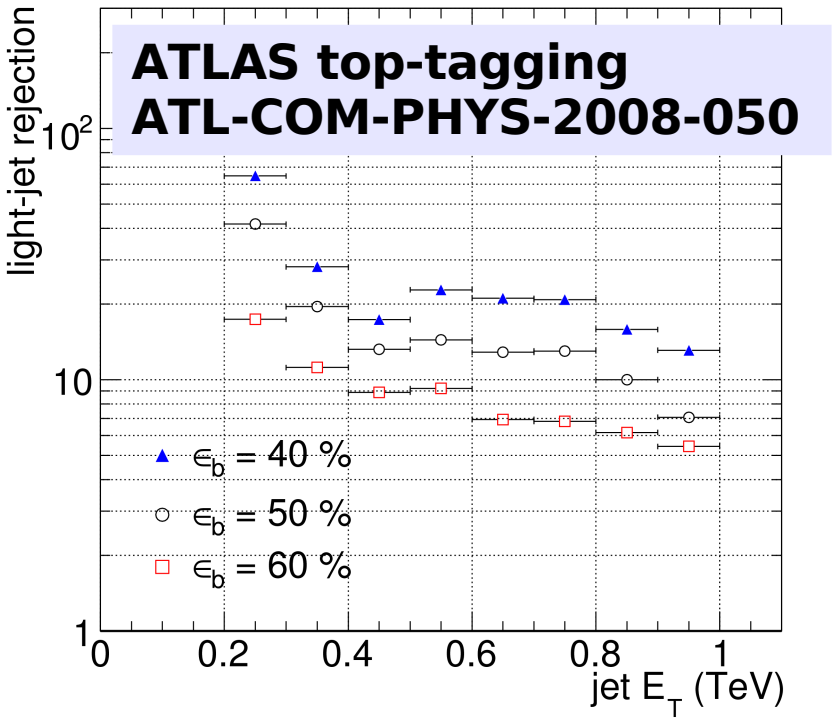




G. Brooijmans, High pT Hadronic Top Quark Identification Part 1 : Jet Mass and Ysplitter, ATL-PHYS-CONF-2008-008; ATL-COM-PHYS-2008-001

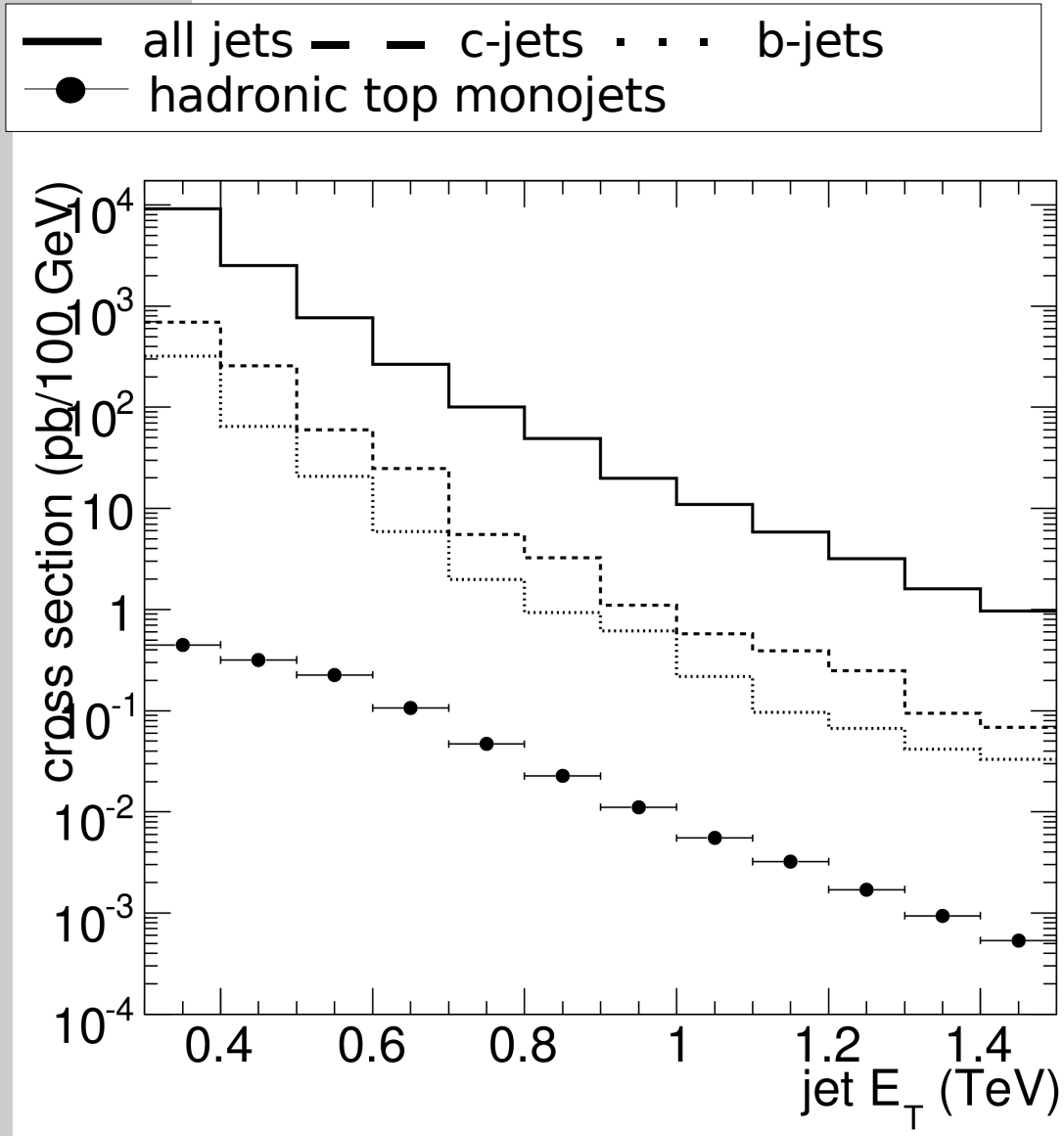
The lifetime signature





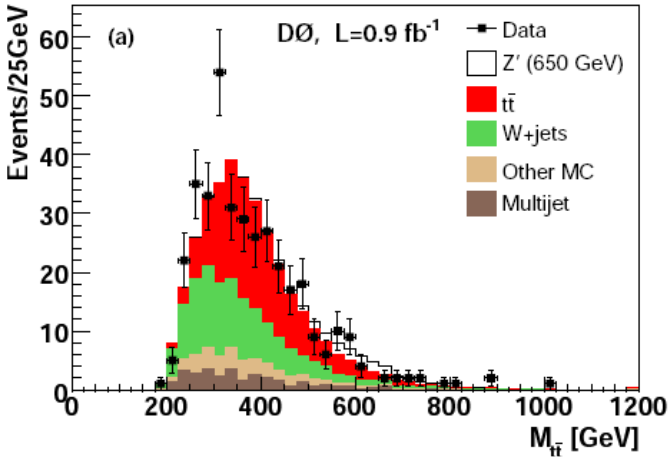
The b-tagging performance achieved with the SV1 + IP3D algorithm on iPatRec tracks after a rigorous paremeter retuning (association cone size, minimal track p_T) for high pT b-jets (leftmost figure) and hadronic top mono-jets (rightmost figure)

The lifetime signature

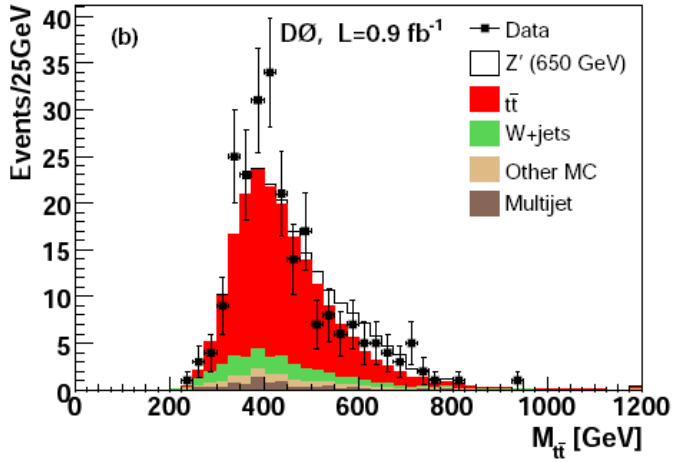


The abundance of heavy flavour in nature... (or at least in Pythia)

Tevatron - D0



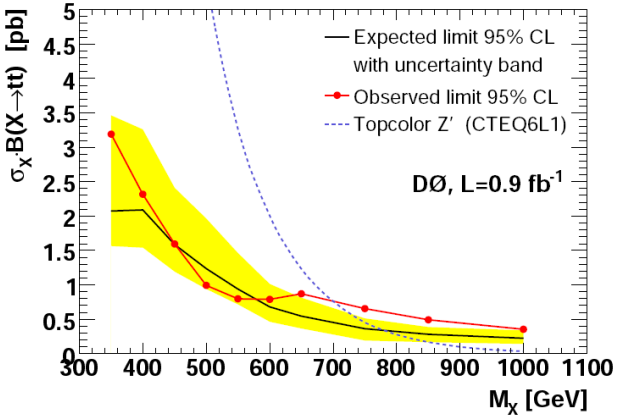
lν + 3 jets



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"