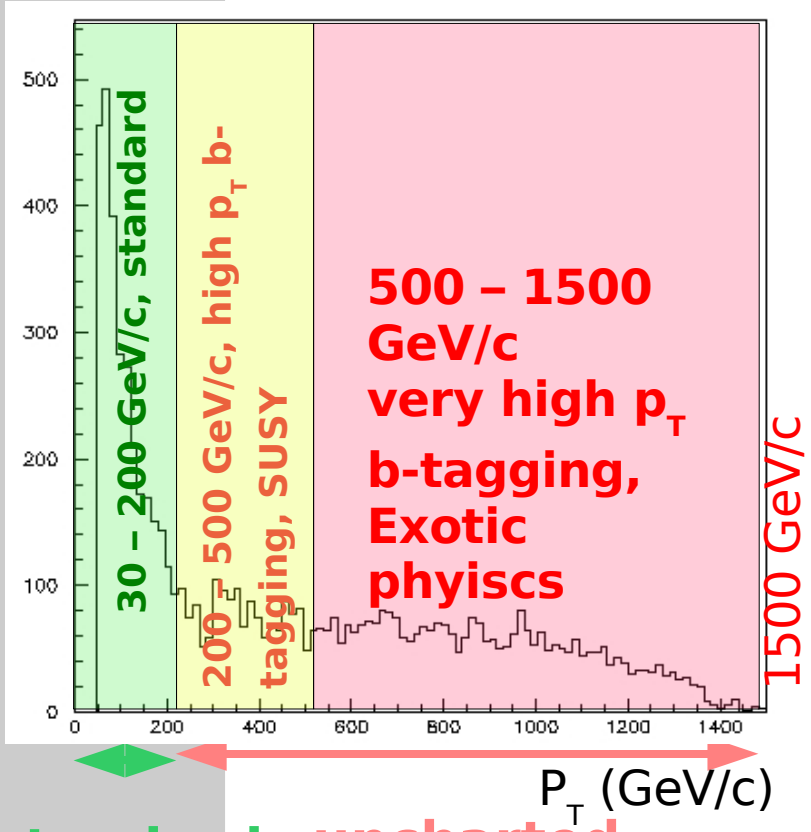
Tagging high p_T jets

Marcel Vos – IFIC Valencia

Physics case for high p_T b-tagging

P_T spectrum for b-jets in

W_H (3 TeV/c^2) → Tb → 4 b + l + E_t^{miss}



standard studies

uncharted territory

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

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

Twin Higgs: $W_H \rightarrow$ tb

(ATL-COM-PHYS-2008-050)

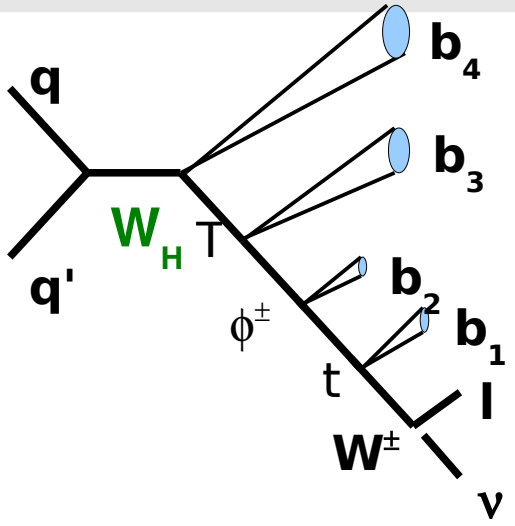
SUSY cascade decays of squarks

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

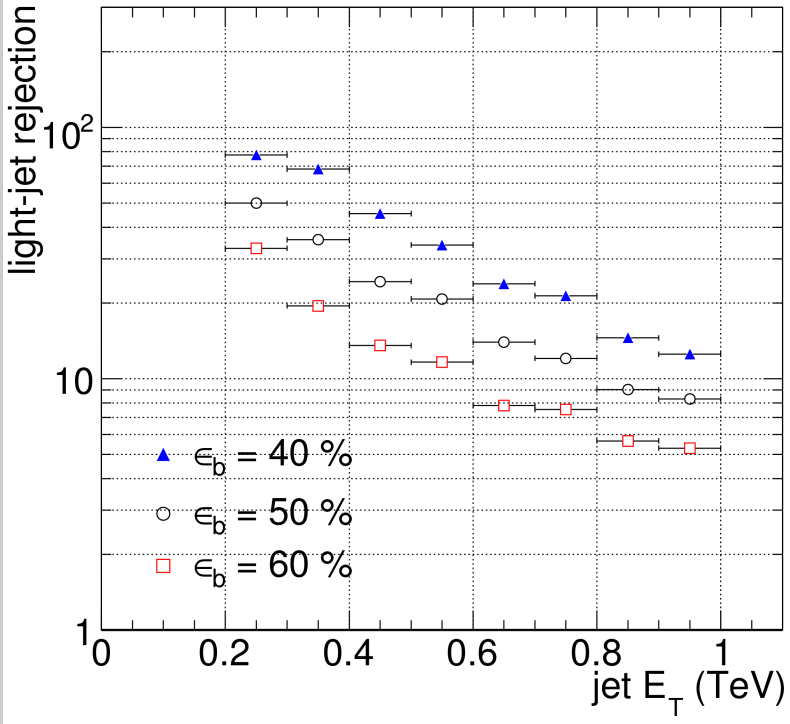
ATL-PHYS-PUB-2006-002

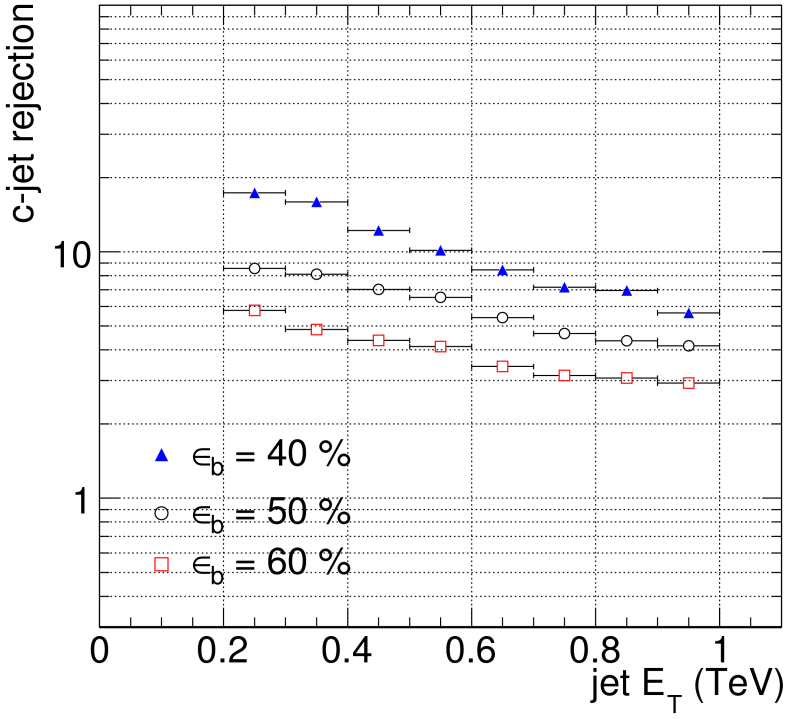
Twin Higgs: cascade $W_H \rightarrow$ Tb

(Les Houches 2007, arXiv:0802.3715)



The lifetime signature





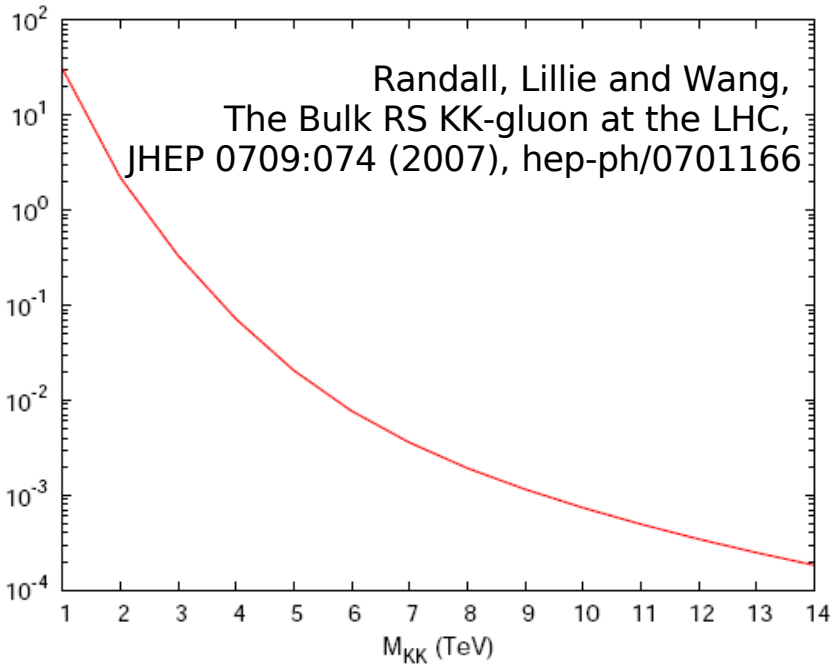
The b-tagging performance achieved with the SV1 + IP3D algorithm on iPatRec tracks after a rigorous parameter retuning (association cone size, minimal track p_T, see ATL-CSC-BT-0)

Not the factor 1000 rejection you are used to! Will go into the “why” and the “what can we do about it” later in this talk.

Some early physics

Kaluza Klein excitated 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: $\Gamma/M \sim 0.2$
RS KK gluons like the top quark: over 90 % decay into tt



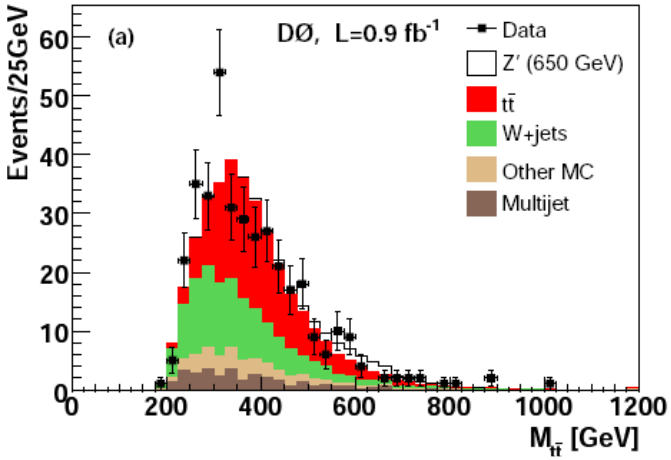
Backgrounds: SM top pair production, W+jets σ (pT (top) > 200 GeV) ~ 26 pb (LO, large K-factor)

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

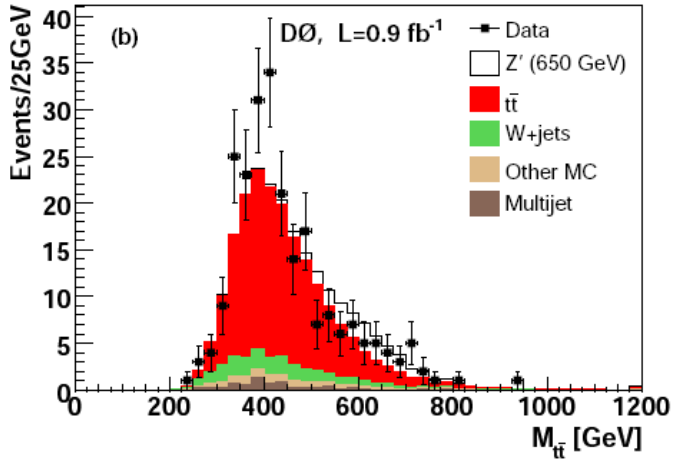
M g* (GeV)	σ g* (pb) @ 10 TeV	σ g* (pb) @ 14 TeV
1 TeV	475	1109

Leading order cross-sections for ADD KK gluon

Tevatron - D0



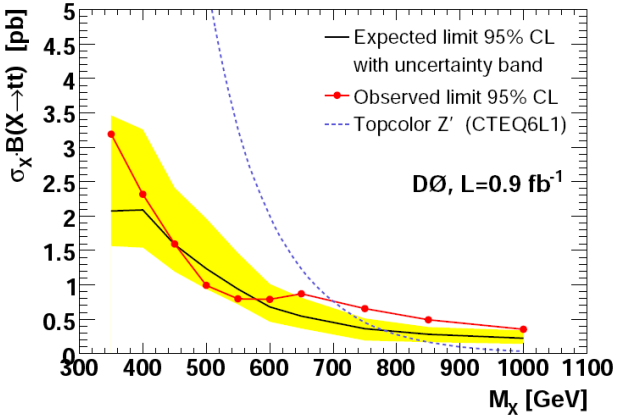
lν + 3 jets



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

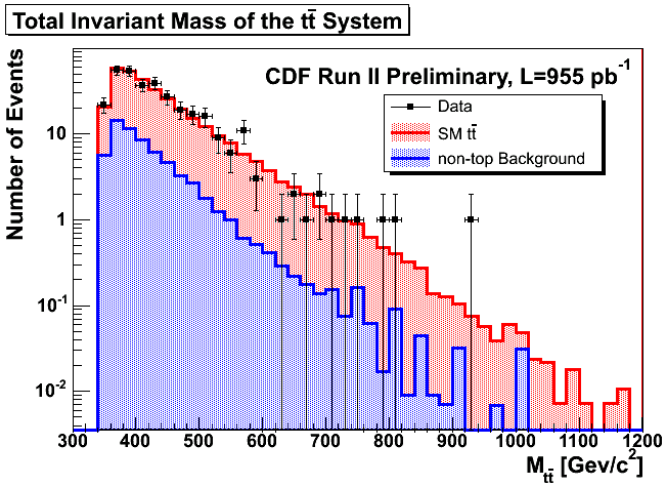
CDF, *Search for New Particles Decaying to tt in pp Collisions at √s = 1.8 TeV,* Phys.Rev.Lett.85 (2000) 2062-2067

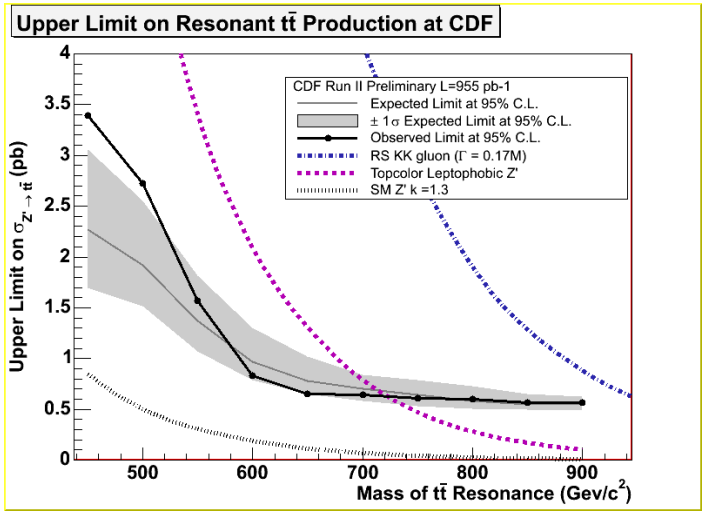
CDF, *Limits on the Production of Narrow t-tbar Resonances in p-pbar Collisions at sqrt(s)=1.96 TeV,* arXiv:0710.5335v1

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

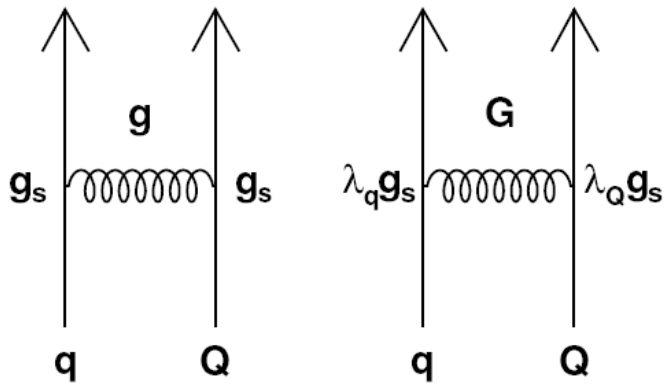
95 % exclusion limits assuming narrow width for:

leptophobic technicolor Z' (> 720 GeV) curve for broad RS KK gluon drawn in for comparison

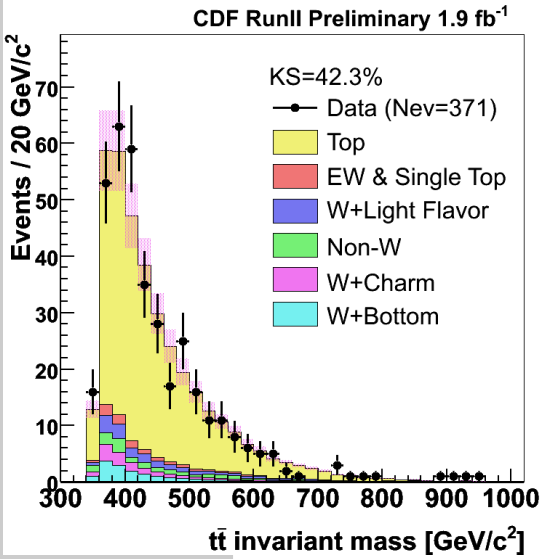


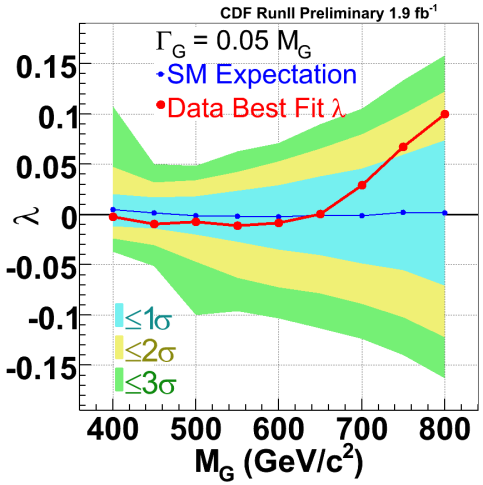


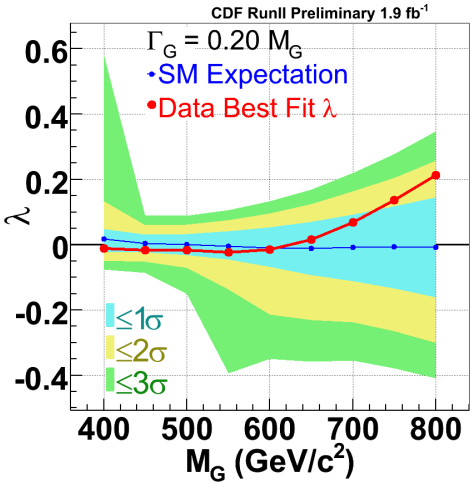
Tevatron - CDF



Preliminary results in CDF 9164 of an analysis of 1.9 fb-1, explicitly taking into account the width and interference of a massive gluon. Finds CDF data are compatible with SM within 1.7 σ





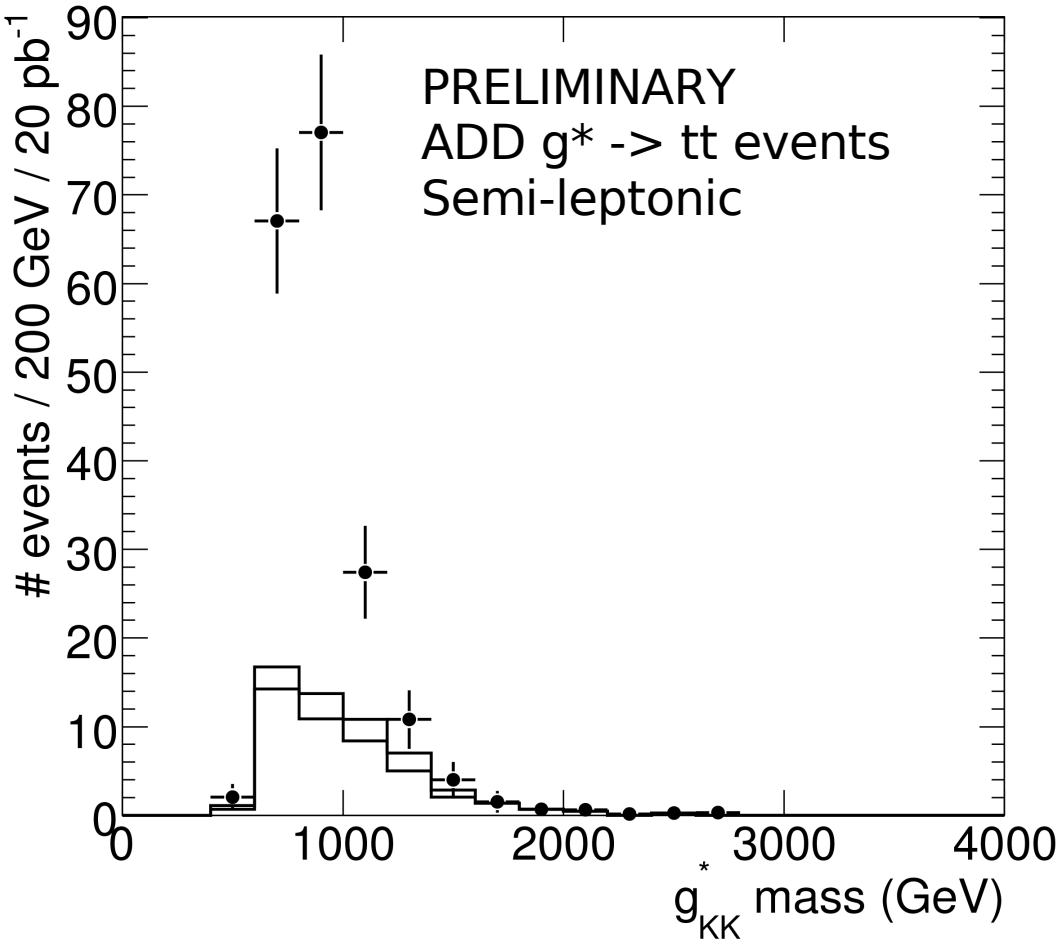


ATLAS preliminary
10 TeV, 20 pb-1
Simplified early physics analysis:
e/μ + E_T^{miss} + closest jet, opposite-side "mono-jet"
no b-tagging!

Background dominated by SM tt continuum

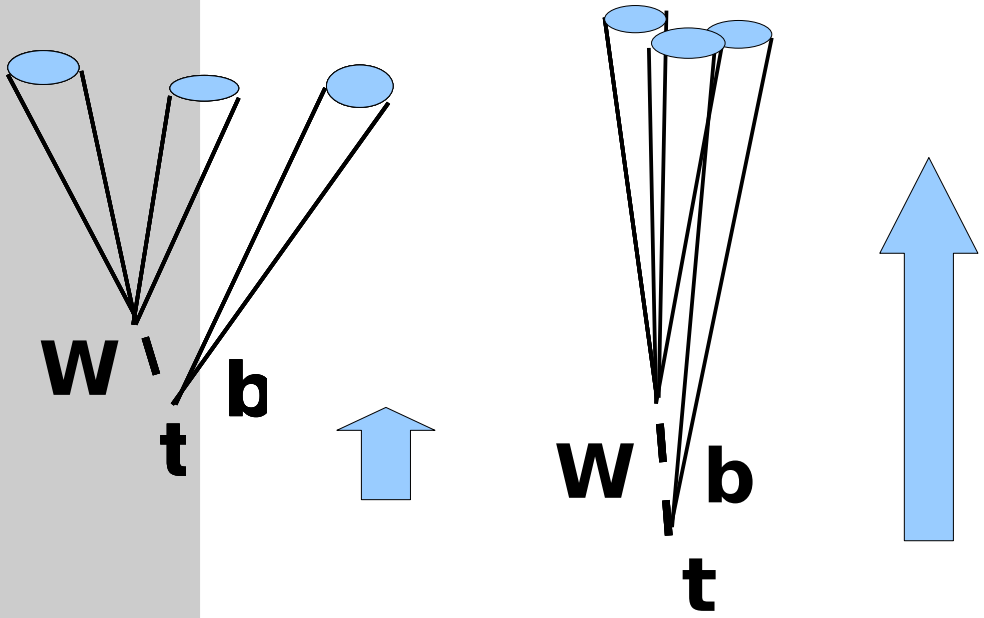
How can we be sure it's really tt?
(this is where the flavour tagging comes in)

How do we estimate the background normalization from data?



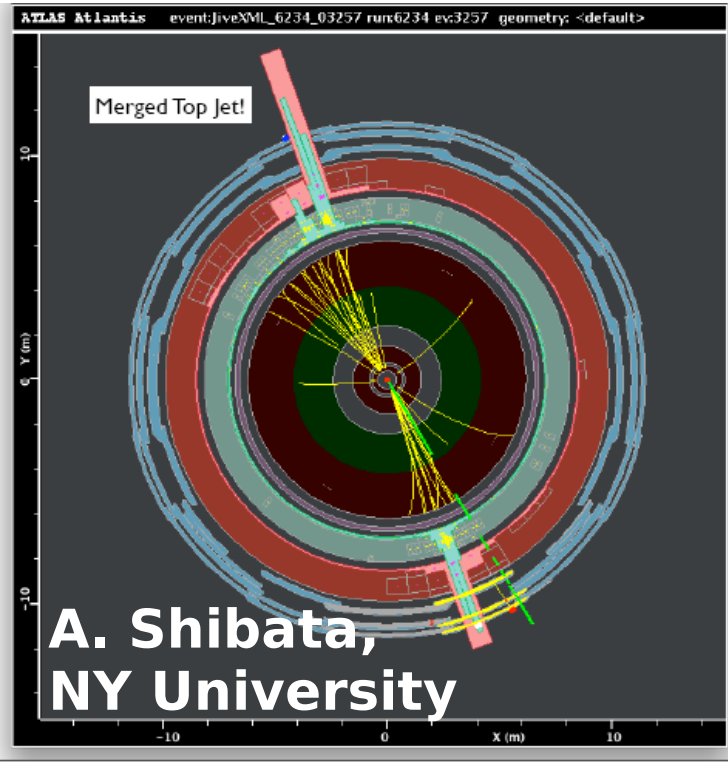
Reconstruction of hadronic top monojets

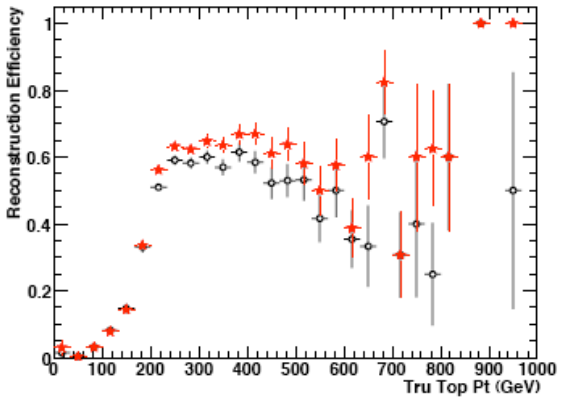
Top “monojet” tagging



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

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

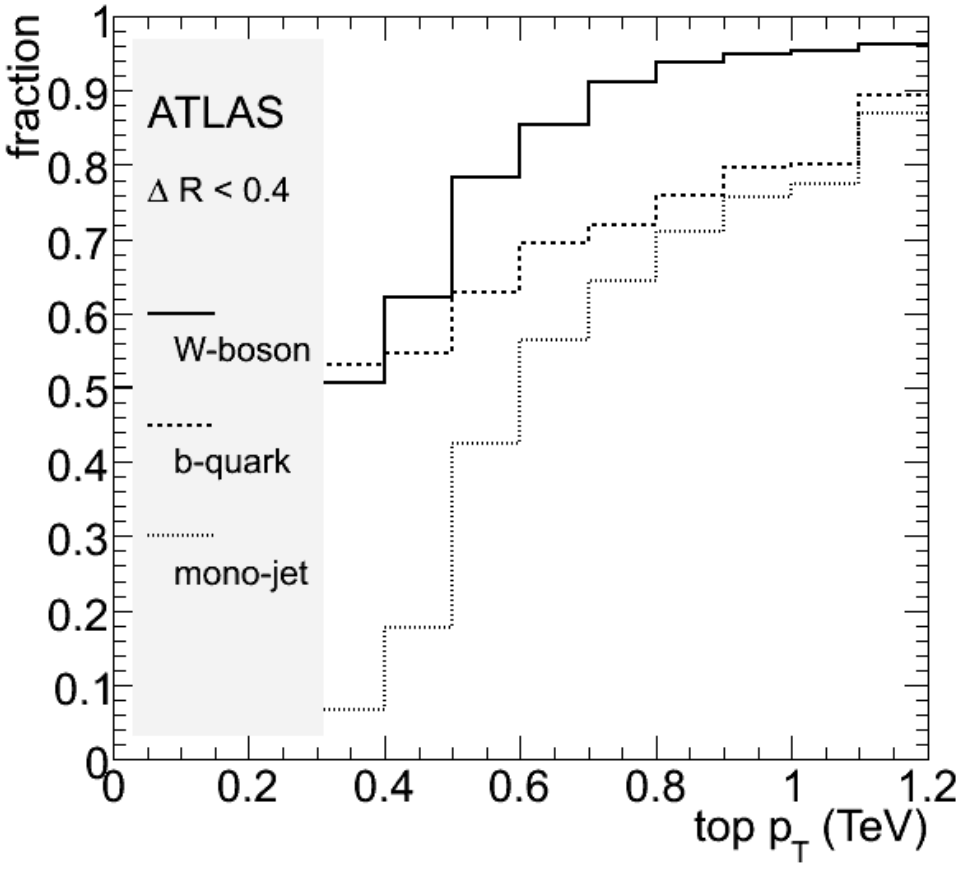




Reconstruction of top monojets

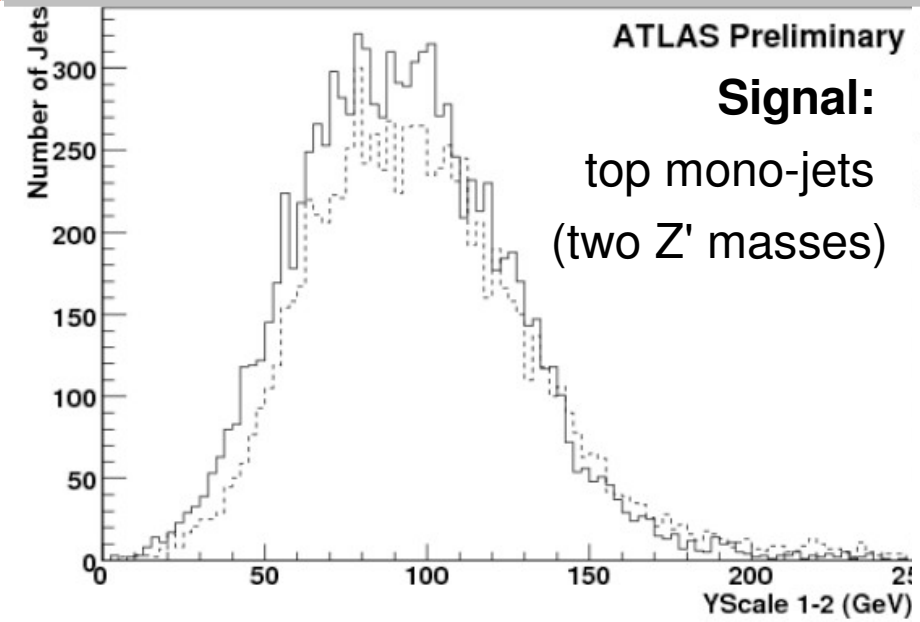
Probability to find top decay products in a small cone around the reconstructed jet

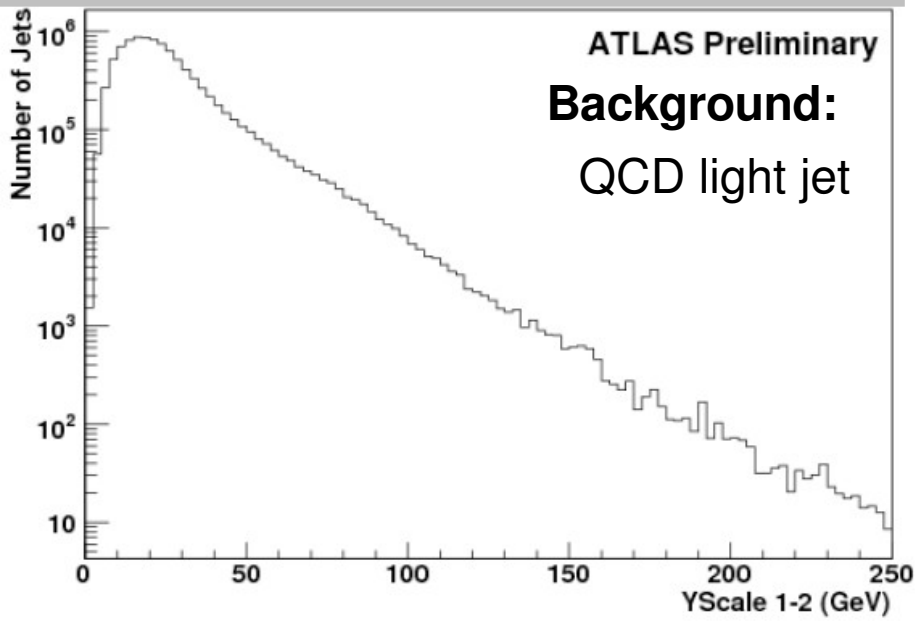
A mono-jet: reconstructed jet contains both W and b-quark (within $\Delta R < 0.4$)



High p_T top: alternative approach

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

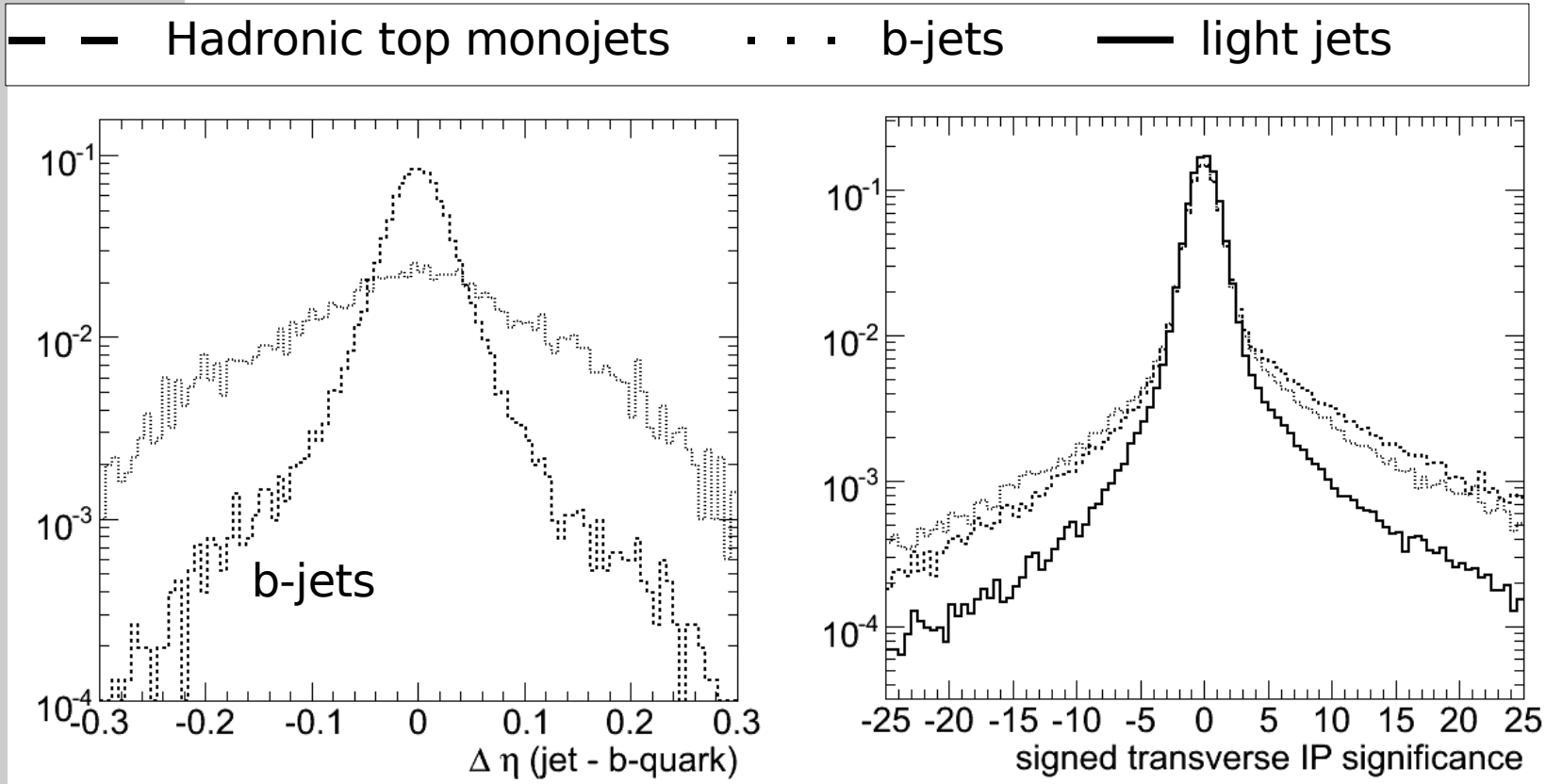




G. Brooijmans, High pT Hadronic Top Quark Identification Part 1 : Jet Mass and Ysplitter, ATL-PHYS-CONF-2008-008; ATL-COM-PHYS-2008-001

To be complemented by the lifetime signature (part II)

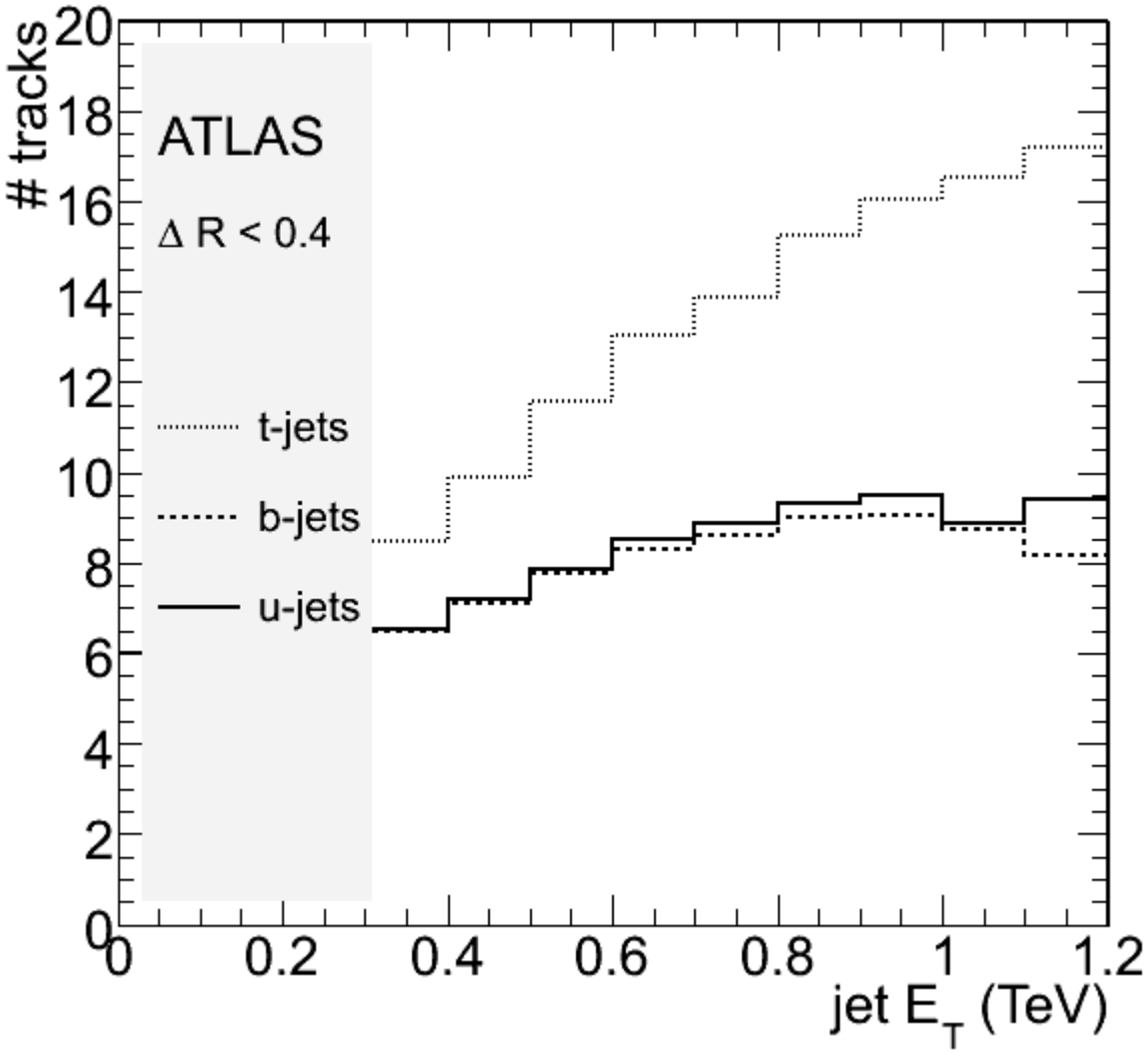
The lifetime signature



The “noise” from close-by W-decay:

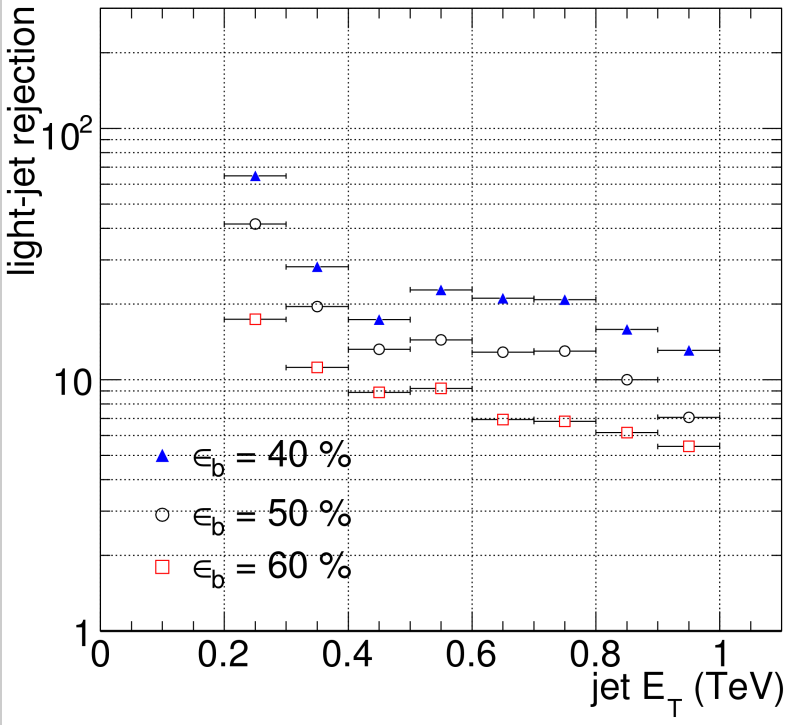
- jet direction no longer as readily identified with B-hadron flight path
- impact parameter sign more often incorrect

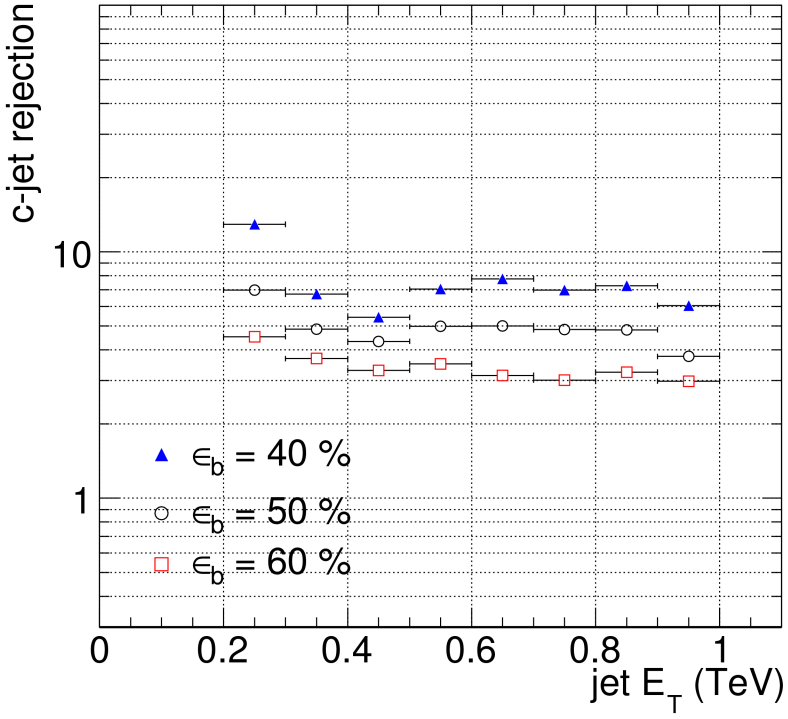
The lifetime signature



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

The lifetime signature

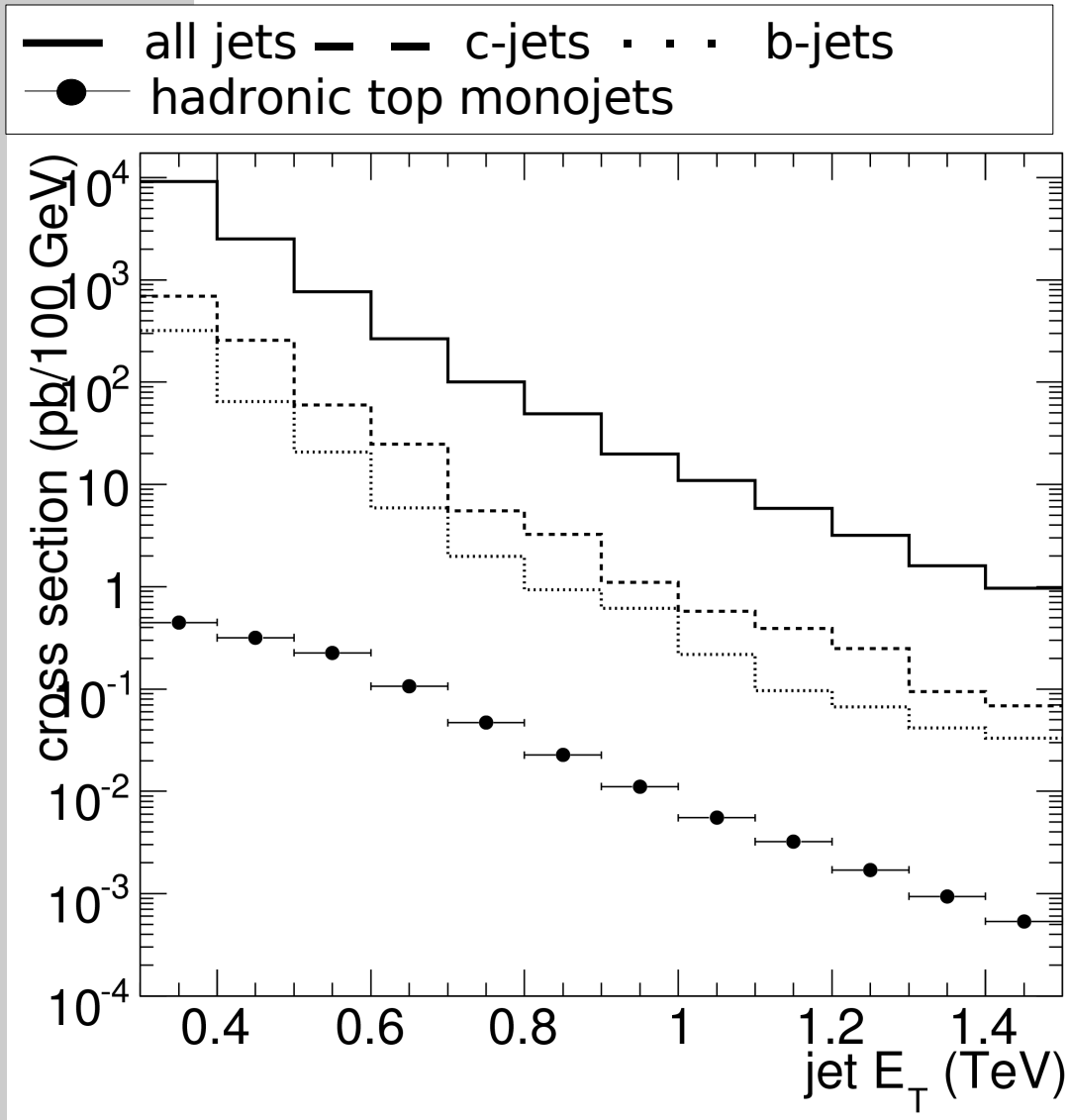




the hadronic top monojet tagging performance achieved with the retuned SV1 + IP3D algorithm on iPatRec tracks (release 12.0.6)

Top-tagging performance worse than b-tag at same E_T due to "noise from W-decay"

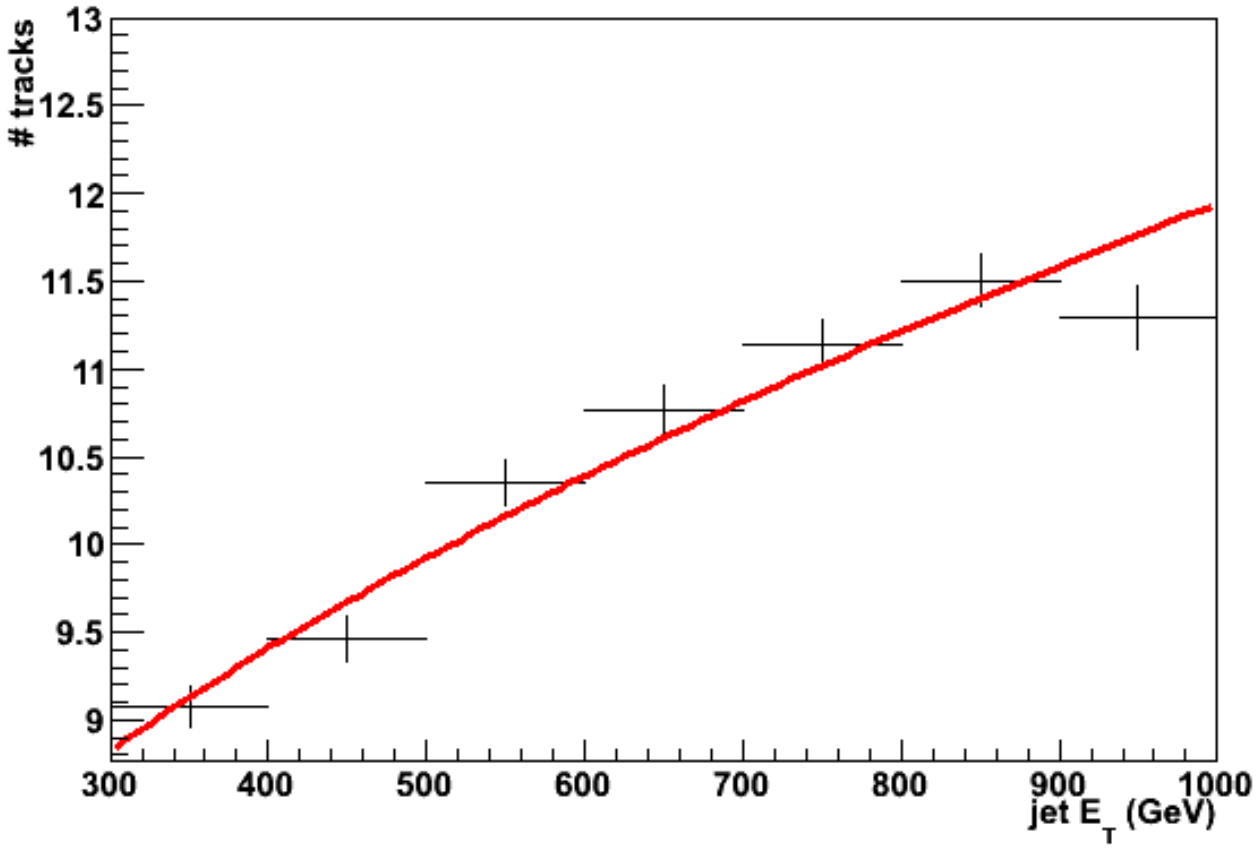
The lifetime signature



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

Why are high pT jets so hard?

High p_T jets: charged multiplicity in cone

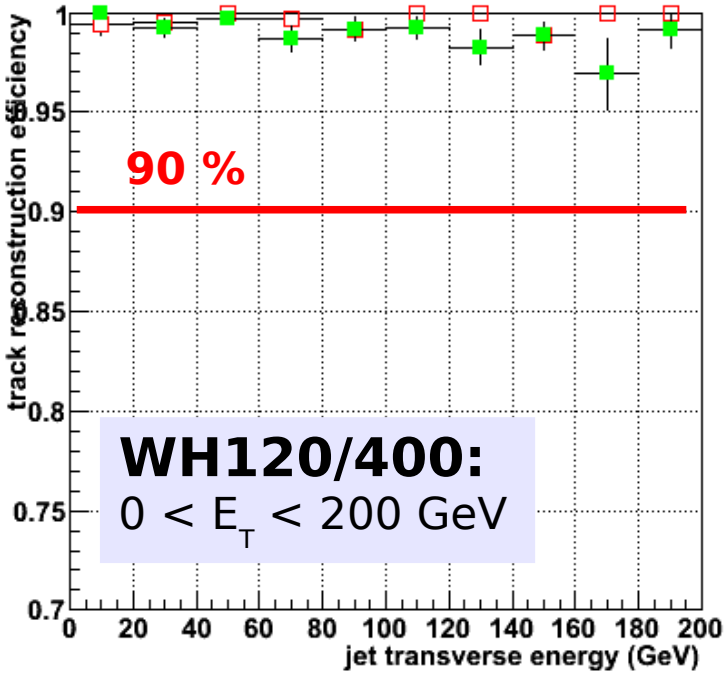


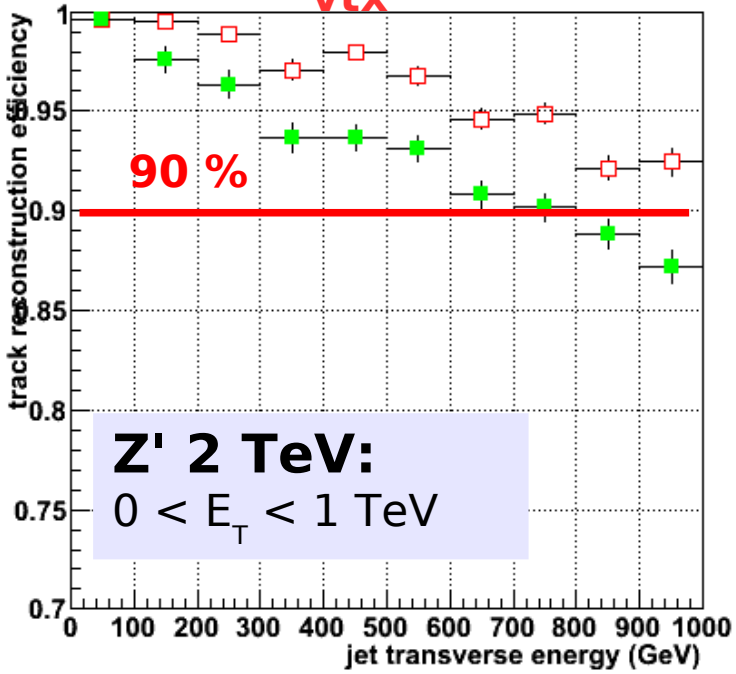
Number of tracks in b-jet (core) increases with jet E_T

 # tracks from B-decay = constant: relative weight tracks from B-decay decreases

prompt tracks

$\pi^{\pm}$ that do not decay, and R_{vtx} < 10 mm





Reconstruction efficiency for "good tracks" from InvertedTruthMap

Efficiency >90% inside highest p_T jets!

IpatRec (red) performs slightly better than New Tracking (green)

Tracks from displaced vertices

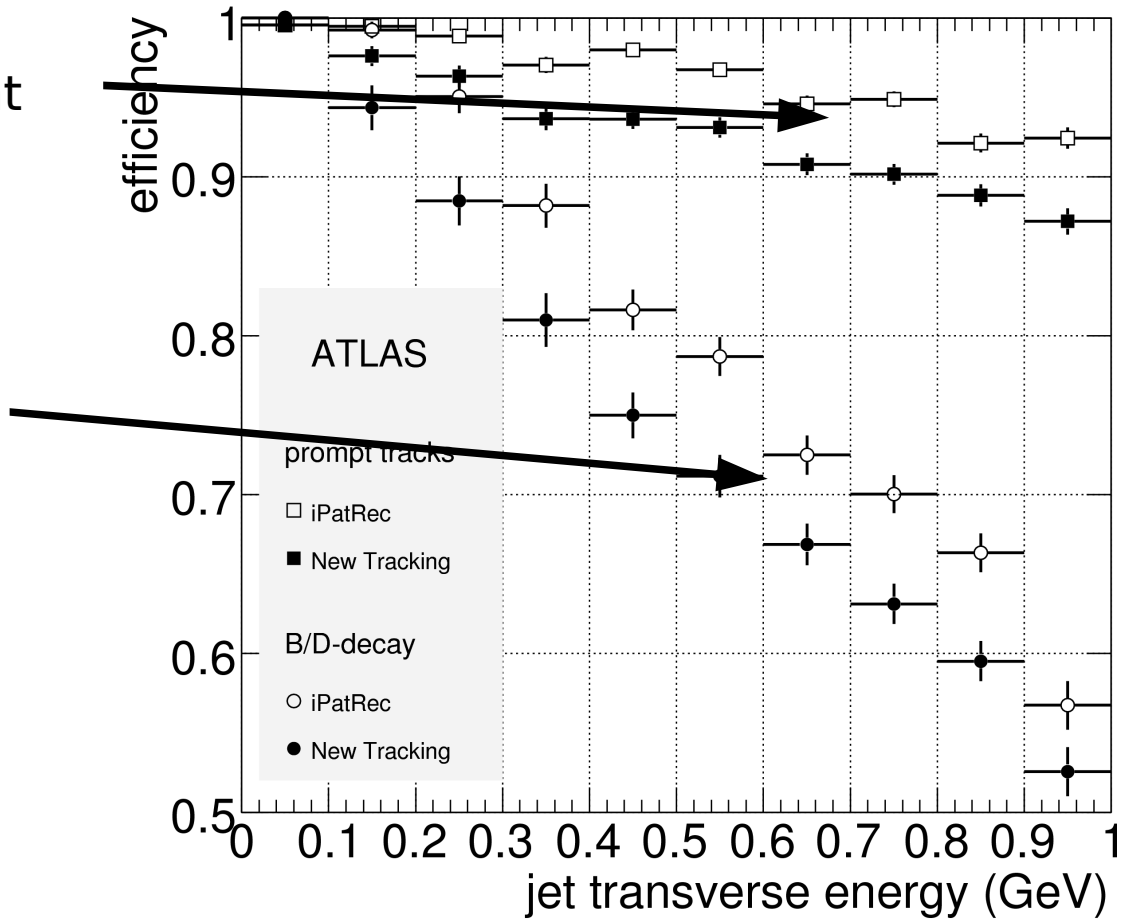
Z' → uu

tracks from interaction point
90 % efficient up to 1 TeV

Z' → bb

tracks from B/D vertex
steadily degrading
efficiency with jet energy

It's not (only) about the dense environment



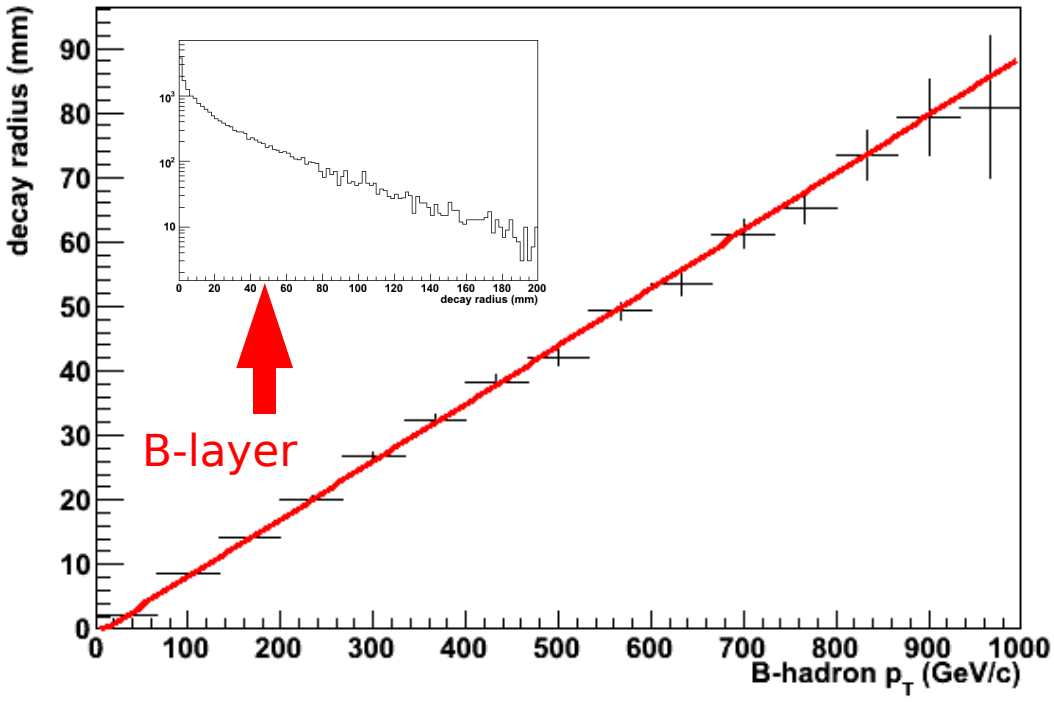
High p_T b-jets: displaced vertex

$L = c \tau \gamma$

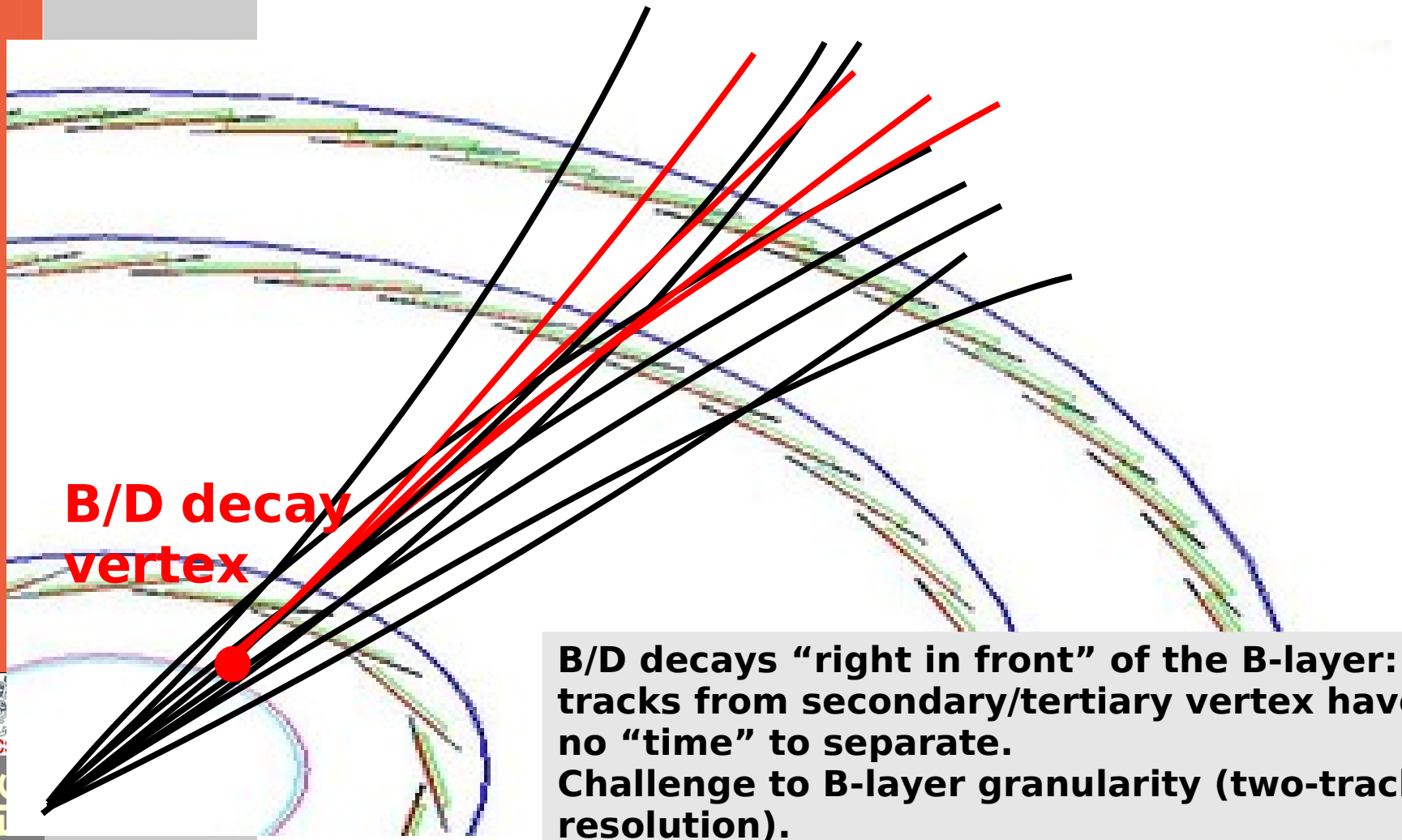
Average decay radius of B hadrons versus B-hadron transverse momentum

Insert plot: decay radius distribution for B-hadrons in Z'->bb events ($m_{Z'}$ = 2 TeV)

L no longer << B-layer radius



high p_T b-jet: zoom on innermost layers



B/D decays “right in front” of the B-layer: tracks from secondary/tertiary vertex have no “time” to separate.
Challenge to B-layer granularity (two-track resolution).

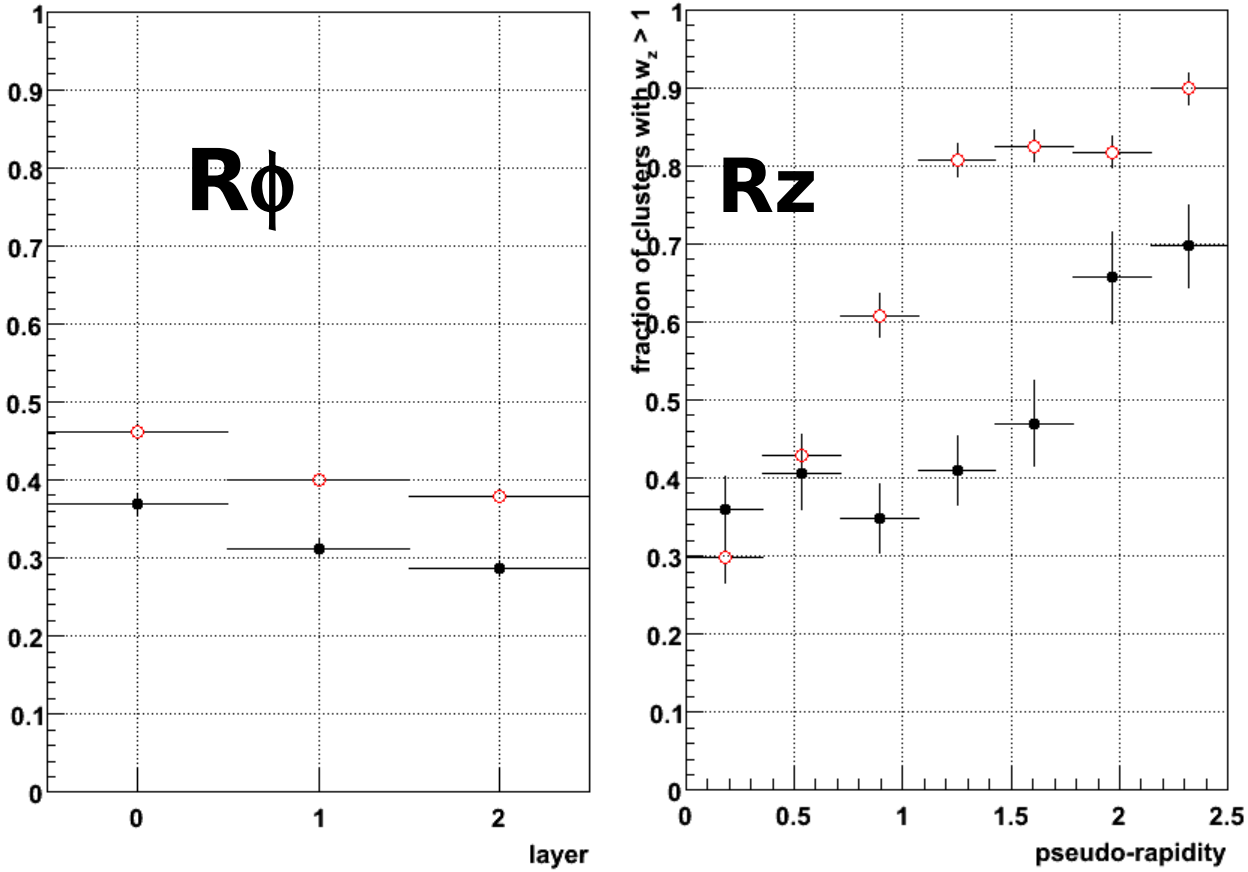
Pixel clustering

Fraction of clusters in the B-layer with size > 1

See the impact of pixel clustering (12.0.6)

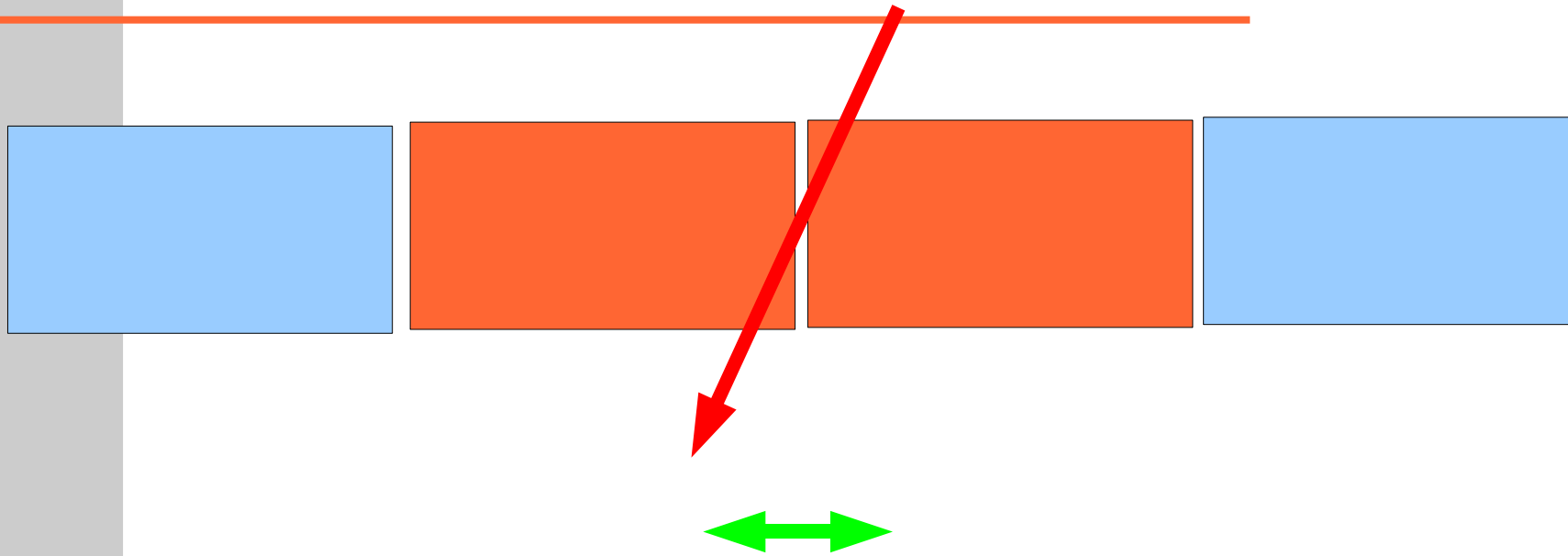
Red markers:
clusters in the core of high p_T b-jets ($\Delta R < 0.15$).

Black markers
less dense outer region of the jet



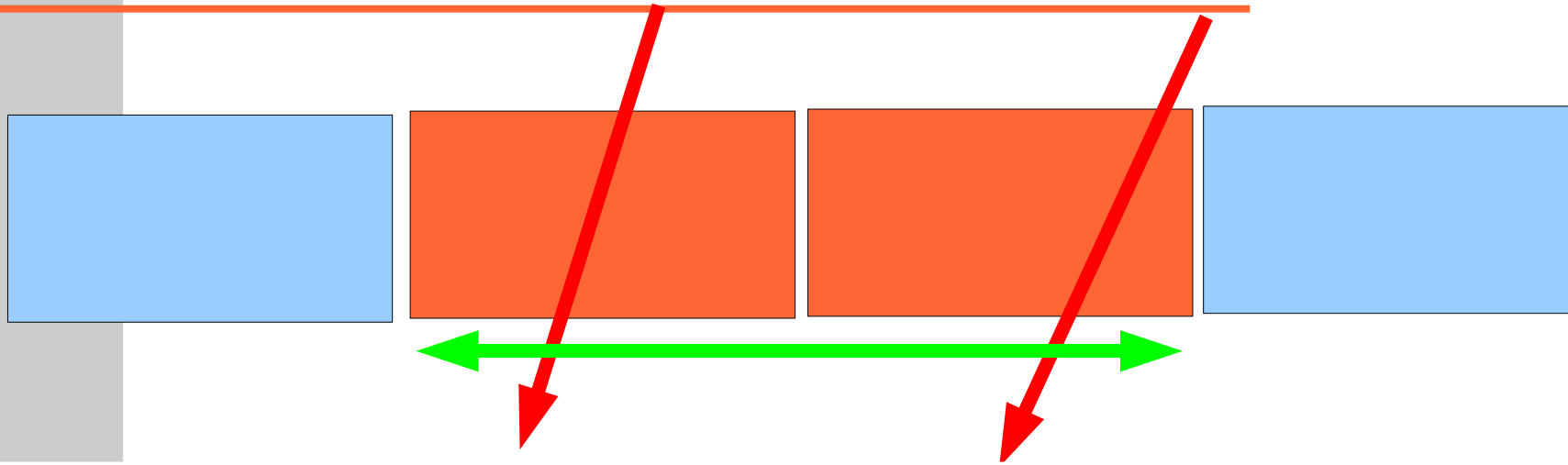
Pixel detector two-track resolution starts to play a role in these extreme topologies (and maybe also in 3-prong taus)

Pixel clustering



Large cluster due to single charged particle: small error on position (use ToT to improve cluster position estimate)

Pixel clustering



Large cluster due to more than one charged particle:

large error on position (taken into account by new outlier treatment in track fitter)

hit will be shared between two tracks (there is a risk that one track will not make it, b-layer has large weight in scoring function, b-tagging cuts typically do not accept tracks without b-layer hit)

If two tracks survive, their parameters will be biased

Some good news

Attilio Andreazza, this workshop:

Options (*Some of these may be useful for high-pt jets*):

- acceptDiagonalClusters = 0
  - pixel cells must have a side in common to be added to the cluster, a corner is not enough
- splitCluster = 1
  - Prevents formation of clusters larger than expected (in $R\phi$ and/or in z)
  - Current limits are no more than 2 rows (in $R\phi$) and 2 or 3 columns (depending on η).
- splitCluster = 2
  - As above, but maximum z size is always 2

Proposed a new generic interface during the Ringberg workshop:

- **broad errors**:

```
ROT* broad(TrkPrepRawData&, TrakParameters&, bool broad)
```

- **splitting**:

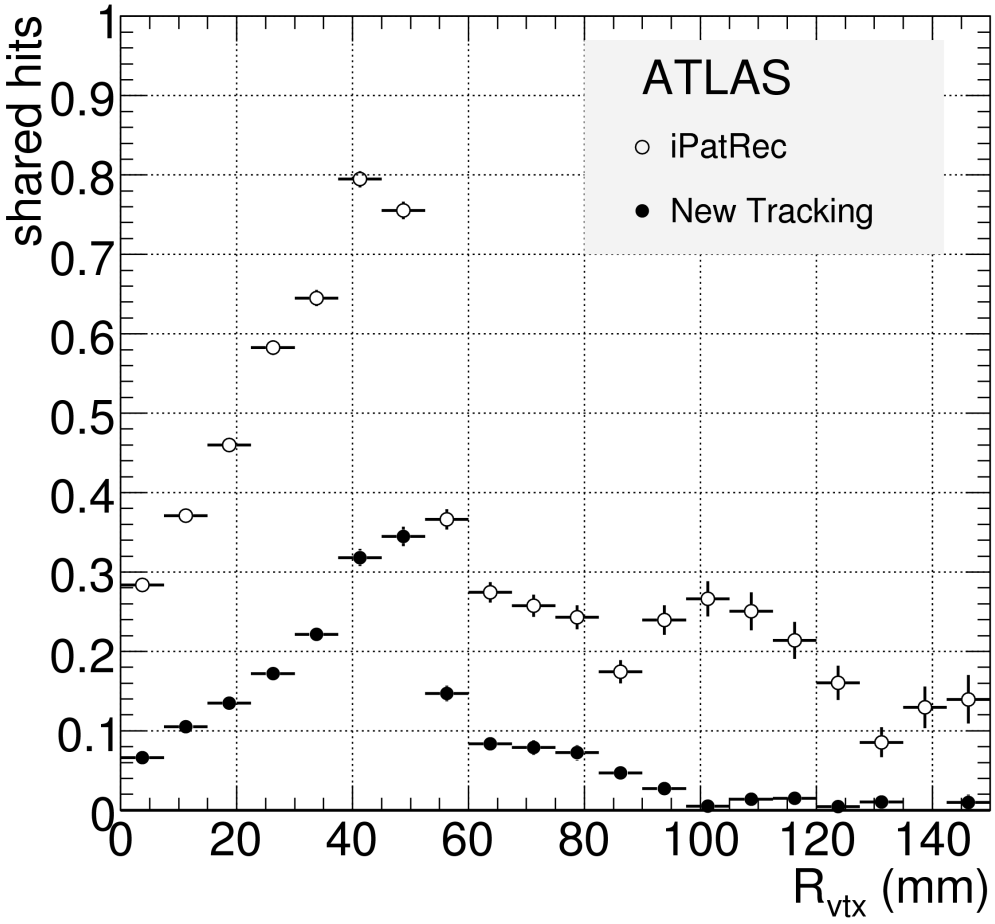
```
vector<ROT*>* split(PRD&, vector<Tpar*>)
```

Hope to have an implementation in 14.2.0
(since general tracking need to be approved by ID and MUON)

What about using ToT information in first clustering?

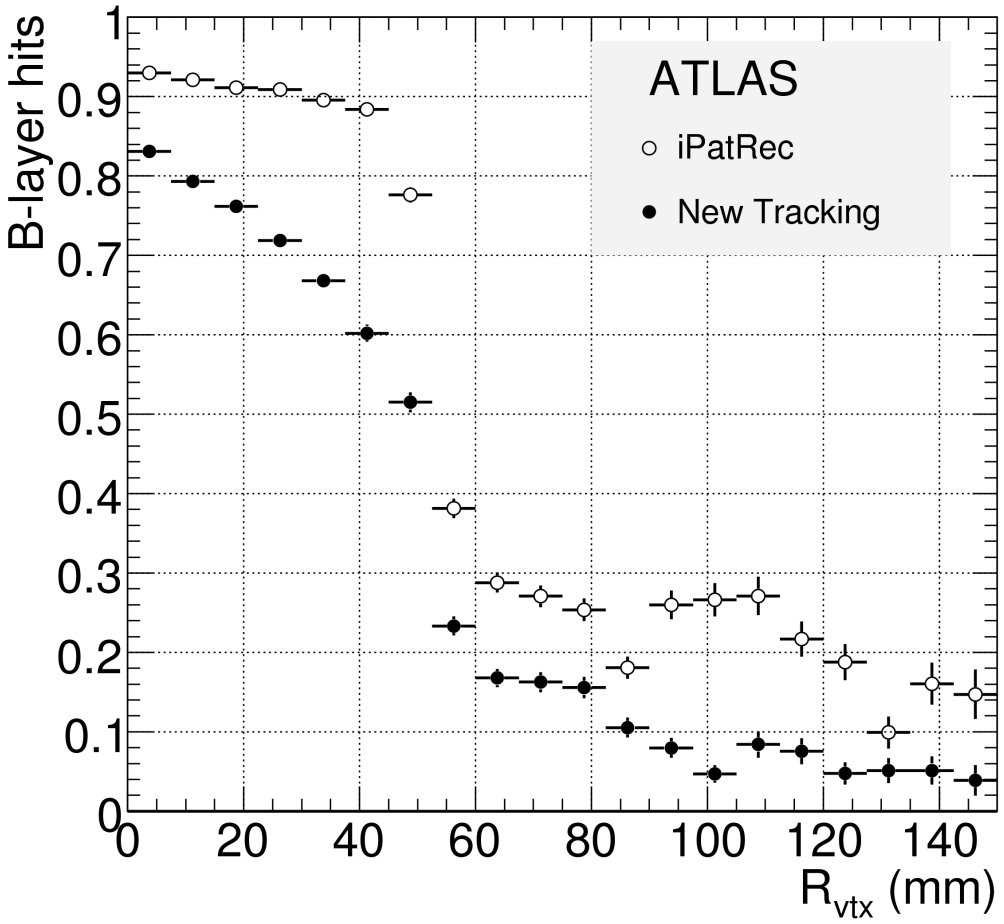
Treatment of ambiguities

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



Tracks from displaced vertices

Even see hits that never existed!



Validation, frequent production of samples

Want to monitor the impact on high p_T tracking of ongoing software development. Not many samples are sensitive to pattern recognition.

Need Z' bb,uu samples to be produced on a regular basis. Over that last half year have tried (desperately) to produce private samples soon enough after a new release to provide useful feedback. An utter failure!

New approach: validation sample “A” extended with a few thousands of these events (thanks to Iacopo Vivarelli, Wouter Verkerke and especially to Stephen Haywood)

Centralized, large statistics “flavour tagging” group production whenever the alarm bells ring?

Conclusions

Physics case for high pT b-tagging has been made since long.

Very relevant early discovery physics to be done with high p_T tops.

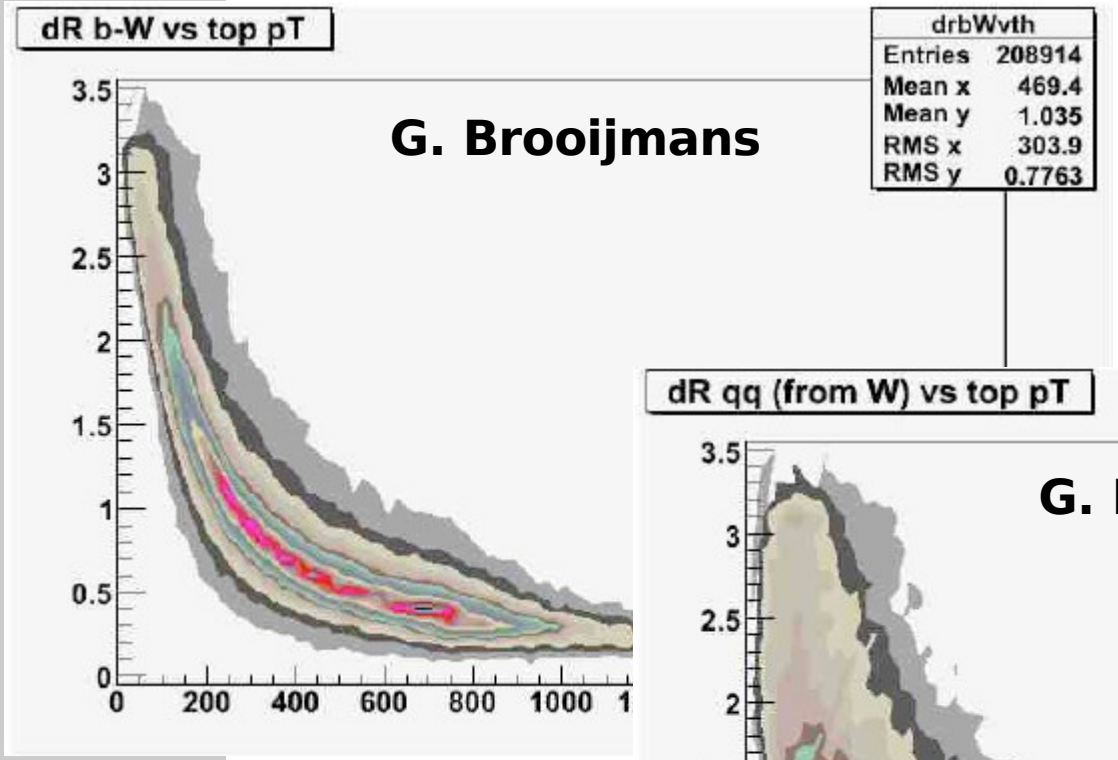
High p_T b- and top-tagging required (not today, but pretty soon).

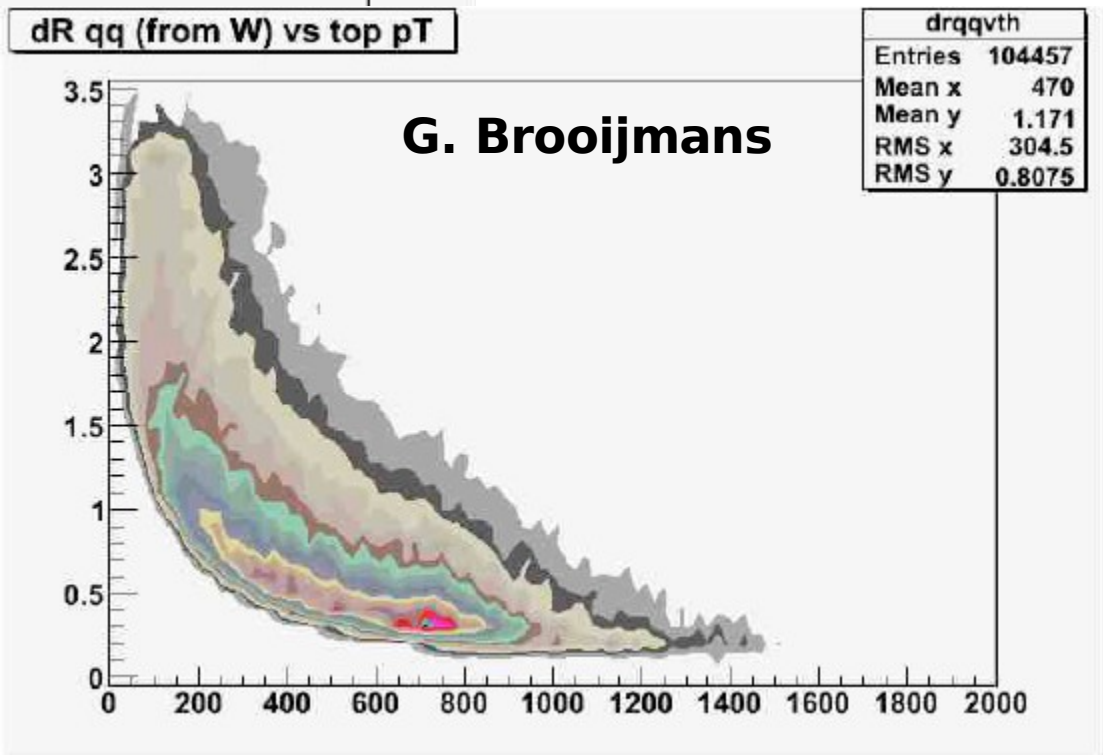
We are not ready: basic tools are still being developed, work on realistic strategies to be started.

The most urgent challenge remains in tracking in very high p_T jets.

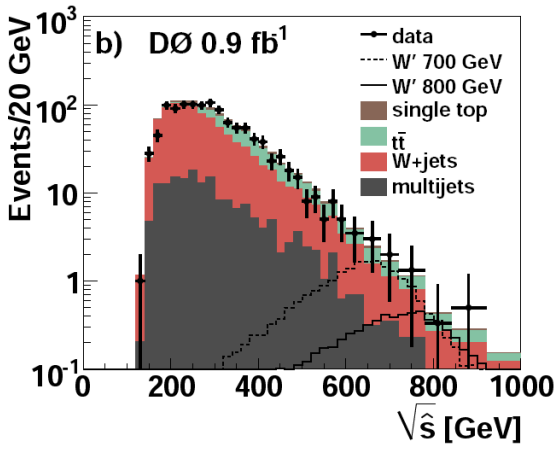
BACKUP SLIDES

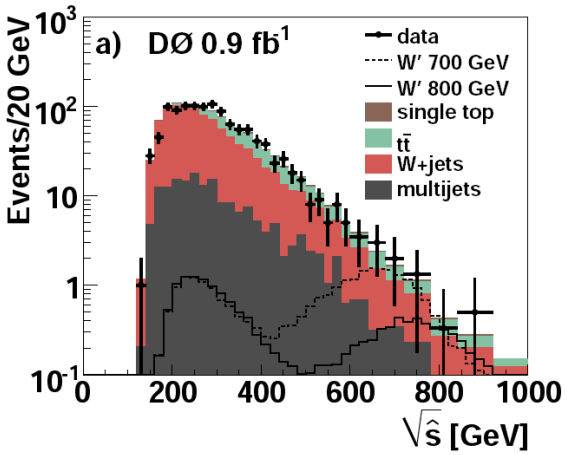
Reconstruction of top monojets





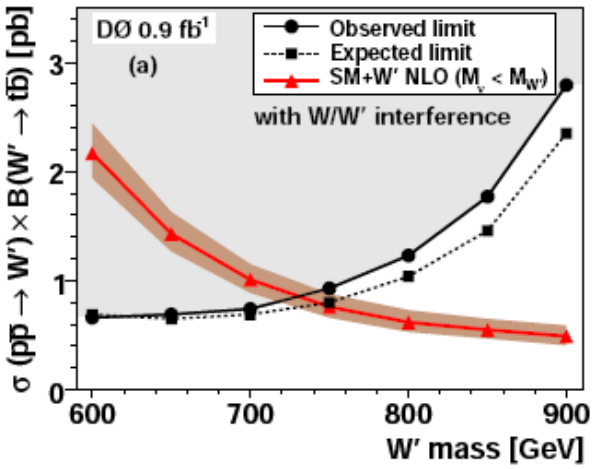
Tevatron - D

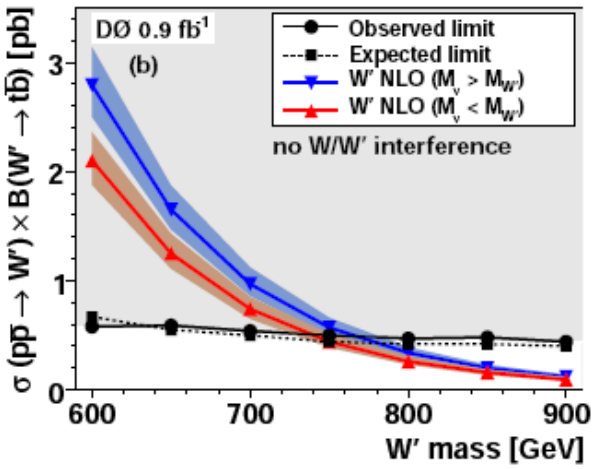


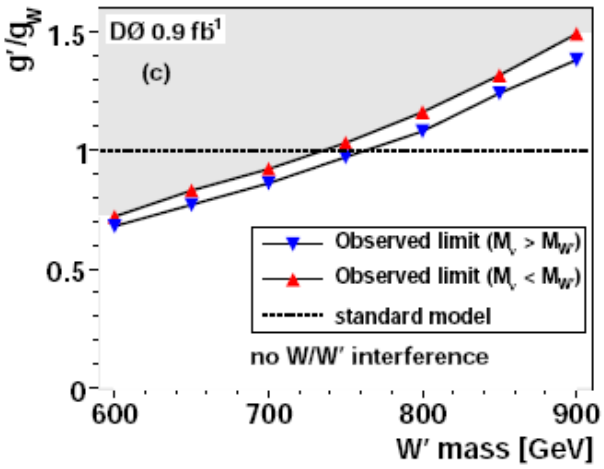


The D0 collaboration, *Search for W′ boson resonances decaying to a top quark and a bottom quark*, arXiv:0803.3256 [hep-ex]
W'->tb : M > 731 GeV (739 / 768 GeV for W_R)

W' searches in other final states: ln (SM couplings): M(W') > 1 TeV
qq (couples to right-handed leptons): M(W') > 800 GeV







1. A. Leike, Phys. Rep. 317, 143, 1999. arXiv:hep-ph/9805494

2. J. Rosner, CERN-TH/96-169, 1996.

3. B. Lillie, L. Randall, L.T.Wang, the bulk RS gluon. arXiv:hep-ph/0701166

4. T. Rizzo, Testing the nature of Kaluza Klein excitations at future lepton colliders, Phys.Rev D61 (2000) 055005, arXiv:hep/ph/9909232

5. L. Sehgal, M. Wanninger, Forward - Backward Asymmetry In Two Jet Events: Signature Of Axigluons In Proton - Anti-Proton Collisions, Phys. Lett B200, 211, 1988.

6. C. Hill, S. Park, PRD49, 4454, 1994.