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Twin Higgs from Left-Right Symmetry

Study of channel $W_H(1\,TeV/c^2) \rightarrow Tb$

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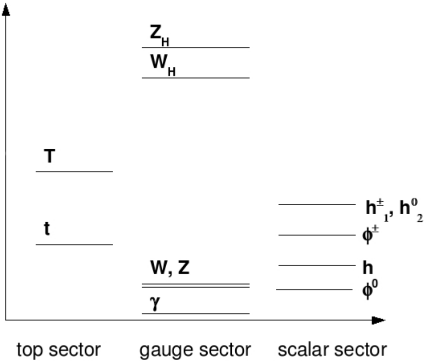
Talk Outline

- Twin Higgs Model from L-R symmetry
- $W_H(1\,TeV/c^2) \rightarrow Tb$
- W_H reconstruction
- B-tagging

Twin Higgs from Left-Right Symmetry

- The *Left-Right Twin Symmetry* when broken adds new terms to the Lagrangian.
- This eliminates cuadratic divergences (at NLO) from Higgs boson's mass.

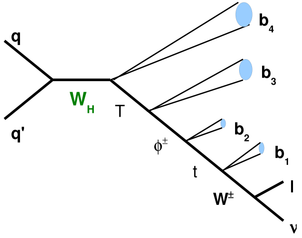


Mass is the only free parameter of the Twin Higgs model. Among its predictions, there are $SU(2)_R$ gauge bosons, vector-like quarks and a natural candidate to dark matter (h_2^0)

Z. Chacko, H.S. Goh, R. Harnik, A Twin Higgs model from left-right symmetry, JHEP 0601 (2006) 108, hep-ph/0512088

H.S. Goh, S. Su, Phenomenology of The Left-Right Twin Higgs Model, Phys. Rev. D 75 (2007) 075010

Study of channel $W_H(1\,TeV/c^2) \rightarrow Tb$



- $4b + l + E_T^{Miss}$ does not appear in *Little Higgs*
- Wide energy range b-jets (good test subject for b-tagging)
- Full and Fast simulation comparison

Particle	Mass (GeV)	Decay	BR
W_H	1000	$T_H b$	20%
T_H	500	$\phi^{\pm} b$	80%
$\phi^{\pm}$	200	tb	100%
t	175	$W^{\pm} b$	100%
$W^{\pm}$	80	$l\nu$	21%

"New Physics at the LHC: A Les Houches Report. Physics at Tev Colliders 2007" – New Physics Working Group. Gustaaf H. Brooijmans et al. Feb 2008 arXiv:0802.3715 [hep-ph]

Mass Template

- Data used
  - A sample of 20000 events of $W_H(1\,TeV/c^2) \rightarrow Tb$ was made with Athena v.12.0.6.1 using GRID and the Spanish Tier2 resources.
    - Generation with Pythia v.6.4
    - Simulation with GEANT4
    - Reconstruction made including IPatRec info.
  - Also 20000 events of background $t\bar{t}$ No Hadronic (Semileptonic + Dileptonic)
    - $p_T > 100\,GeV$
    - $\sqrt{s} > 500\,GeV$
    - Reconstruction made including IPatRec info.
- W_H Reconstruction Methode: Mass Template

Particle	Mass (GeV)	Decay	BR
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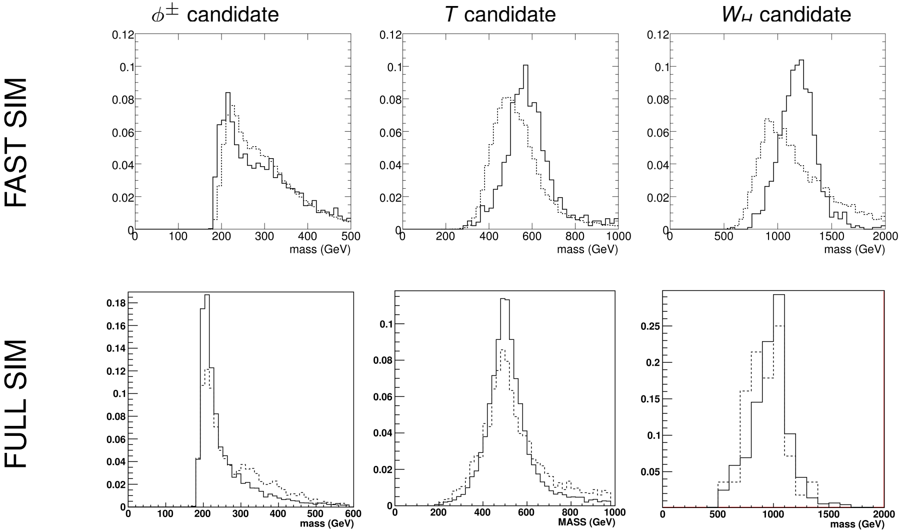
W_H invariant mass reconstruction.

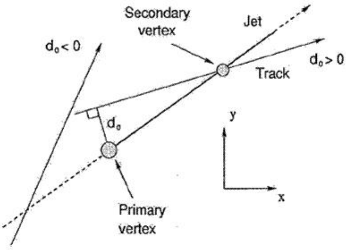


Mass distributions for different steps of the reconstruction of the decay chain for signal events (full line) and the dominant $t\bar{t}$ background (dashed histogram) both for Atlfast (up) and Full simulation (down)

B-tagging

IP3D and SV1

Both based on b's lifetime $c\tau = 450\mu m$

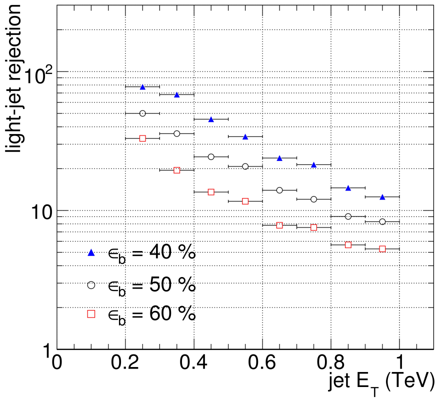


- Impact Parameter in 3D
  - Look at the impact parameter of tracks associated to the jet.
  - IP defined as the closest distance between the primary vertex and the track helix in the transverse plane (d_0) or in the longitudinal direction (z_0)

- Secondary Vertex Reconstruction
  - Reconstruct the secondary vertex associated to the jet.
    - Search all track pairs with $\chi^2 < 3.5$ with impact parameter significance > 2.
    - Fit track pairs into a common geometrical vertex.
    - Remove tracks with χ^2 is unacceptably large.
  - The probability to find a secondary vertex in a b-jet is high, and the same probability for u-jet is low.

B-tagging

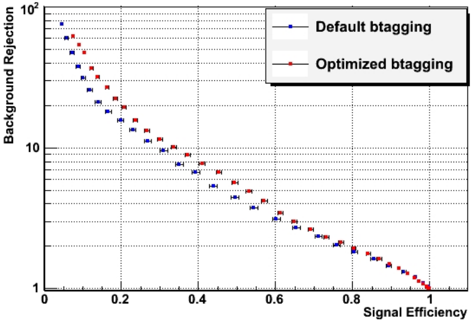
b-tagging performance greatly decreases as energy goes up.



u-jet rejection as a function of jet p_T for different values of b-tagging efficiency.

B-tagging

- Combination of IP3D and SV1 used.
- Started with b-tagging algorithms optimized for high p_T jets shown in the following plot as "default"
- $W_H \rightarrow Tb$ has a wider energy range b-jets so we had to change algorithms' parameters in order to improve background rejection.



- Sum weights of the four jets used on W_H reconstruction.
- Use events with sum > 34 (20% signal efficiency and 95% background rejection)

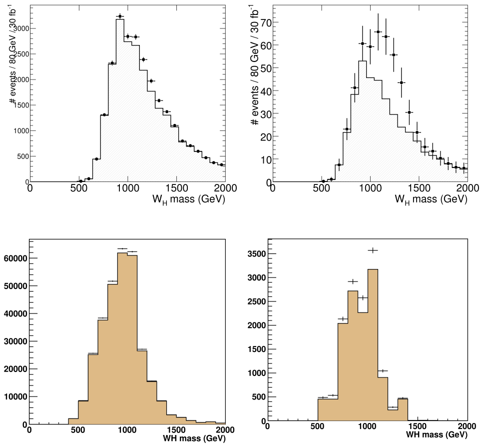
More on high p_T b-tagging:
CSC book: the ATLAS collaboration, Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics, arXiv:0901.0512

B-tagging effect on W_H invariant mass reconstruction.

Before b-tagging | After b-tagging

FAST SIM

FULL SIM



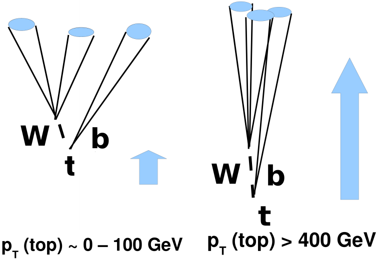
	Atlfast		Full	
selection	no b-tag	b-tag	no b-tag	b-tag
signal	1058	138	4414	917
$t\bar{t}$	23500	392	193537	7251
$S/\sqrt{B}$	6.90	7.00	10.00	10.80
S/B	0.05	0.40	0.02	0.13

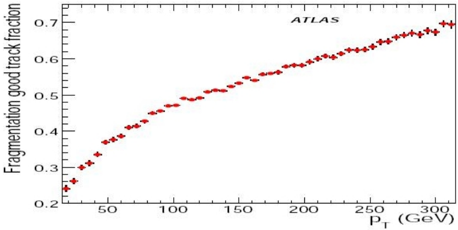
Even though both kinematic reconstruction and b-tagging work worse in FULL than in FAST we still get statistic significance for $W_H(1\,TeV)$

Reconstructed mass distribution of W_H candidates (data points). The contribution of the $t\bar{t}$ background is indicated by the colored region. Results shown both for Atlfast (up) and Full simulation (down)

Why are high p_T jets so hard?

Charged multiplicity in cone

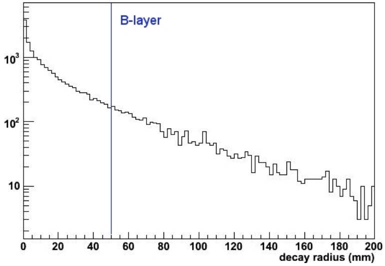


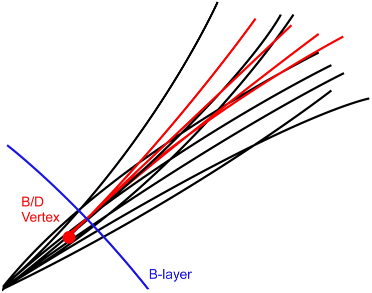


- Number of tracks in b-jet (core) increases with jet E_T
- As # tracks from B-decay is constant its relative weight decreases.

Why are high p_T jets so hard?

Displaced vertex





	$R_B R > 2.9(\%)$	$R_B R > 5.1(\%)$
$E_T > 100 GeV$	12.2	3.9
$E_T > 200 GeV$	21.1	7.9

- Average decay radius of B hadrons: $L = c\tau\gamma$
- For $Z_H(2TeV)$ L no longer $<<$ B-layer radius.
- B/D decays “right in front” of the B-layer: tracks from secondary/tertiary vertex have no “time” to separate.

Study's key points.

- Better understanding of the $t\bar{t}$ background will improve our results.
- Some expertisse on jet calibration and top reconstruction whould be very wellcome.
- Mid and high energy b jets identification (b-tagging) is crucial to study this channel. We are working on inproving high p_T b-tagging by using tracking on new versions of Athena.
- Data sample production is being done using ATLAS GRID.
- Analysis are also being used to test IFIC's Tier-2 and Tier-3 infraestructure.
  - ATLAS software installed at IFIC.
  - Data storaged at Tier-2 (Lustre+StoRM system)

Backup Slides

High p_T b-tagging

Efficiency definition

Sample:

- $Z_H(2TeV) \rightarrow b\bar{b}, u\bar{u}$

Particle selection:

- every charged particle that has no daughters
- must originate in a well-defined vertex (ie, the interaction point)
- we study only charged pions with $p_T > 1GeV$
- MC truth particle is considered efficiently reconstructed if a track is associated to the particle with a probability of at least 80%

Two classes of particles are distinguished:

- **Prompt tracks:** the origin vertex of the MC truth particle is required to be within 10mm of the interaction point
- **B-/D-decay tracks:** the origin vertex of the MC truth particle is required to be within 10mm of B-/D-decay vertex

Quality selection cuts applied:

- At least 1 hit on pixel b layer (b-hit)
- At least 2 hits on pixel.
- At least 7 hits on PIX+SCT.