# Search for Charged Higgs using Boosted Top Techniques

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# Motivation for a Charged Higgs

## Standard Model Higgs Sector

- Minimal Higgs model.
- One Higgs Doublet $\rightarrow$ One neutral Higgs Boson.
- Minimal choice is most economic, but arbitrary.

## Constraints on Higgs Sector

- Experimental: $\rho = m_W^2/(m_Z^2 \cos^2(\theta_W)) \simeq 1$
- Theoretical: (Non-)Existence of tree level FCNCs.

# Two Higgs Doublet Model

## Motivation

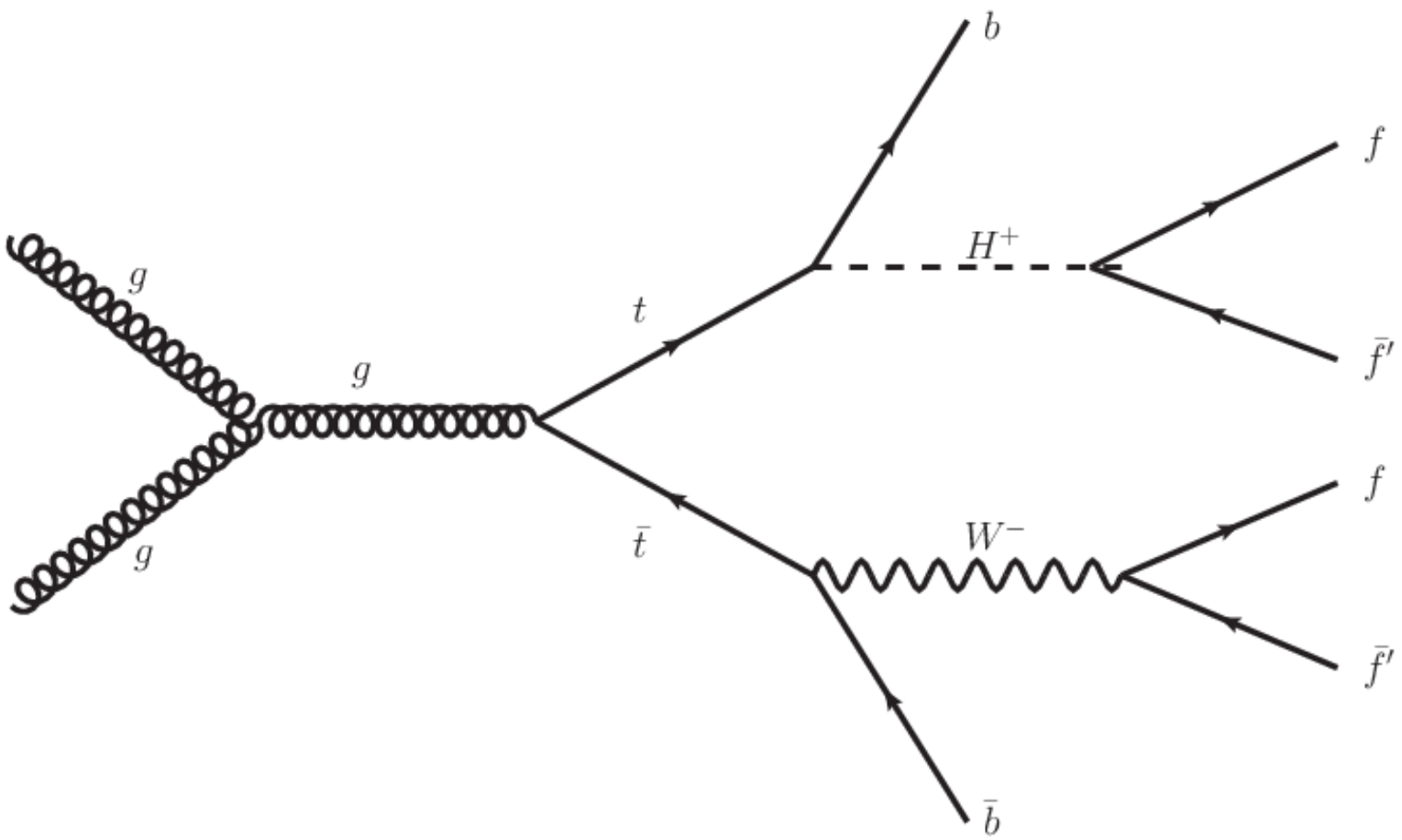
- Minimal Extentsion Higgs model.
- Fulfills Higgs Sector Constraints.
- Required in some SuperSymmetric Models.
- Keeps Fourth Generation hopes alive!

## Higgs Sector

- A Charged Higgs Pair $H^{\pm}$.
- Two Neutral CP-even Higgs $H^0$ and $h^0$.
- One Neutral CP-odd Higgs $A^0$.
- Six free parameters: Four Higgs Masses, $\tan\beta = v_2/v_1$ and a Higgs Mixing angle $\alpha$.

# Charged Higgs Production at the LHC

## Light Charged Higgs $M_{H^\pm} < m_t$



# Charged Higgs Production at the LHC

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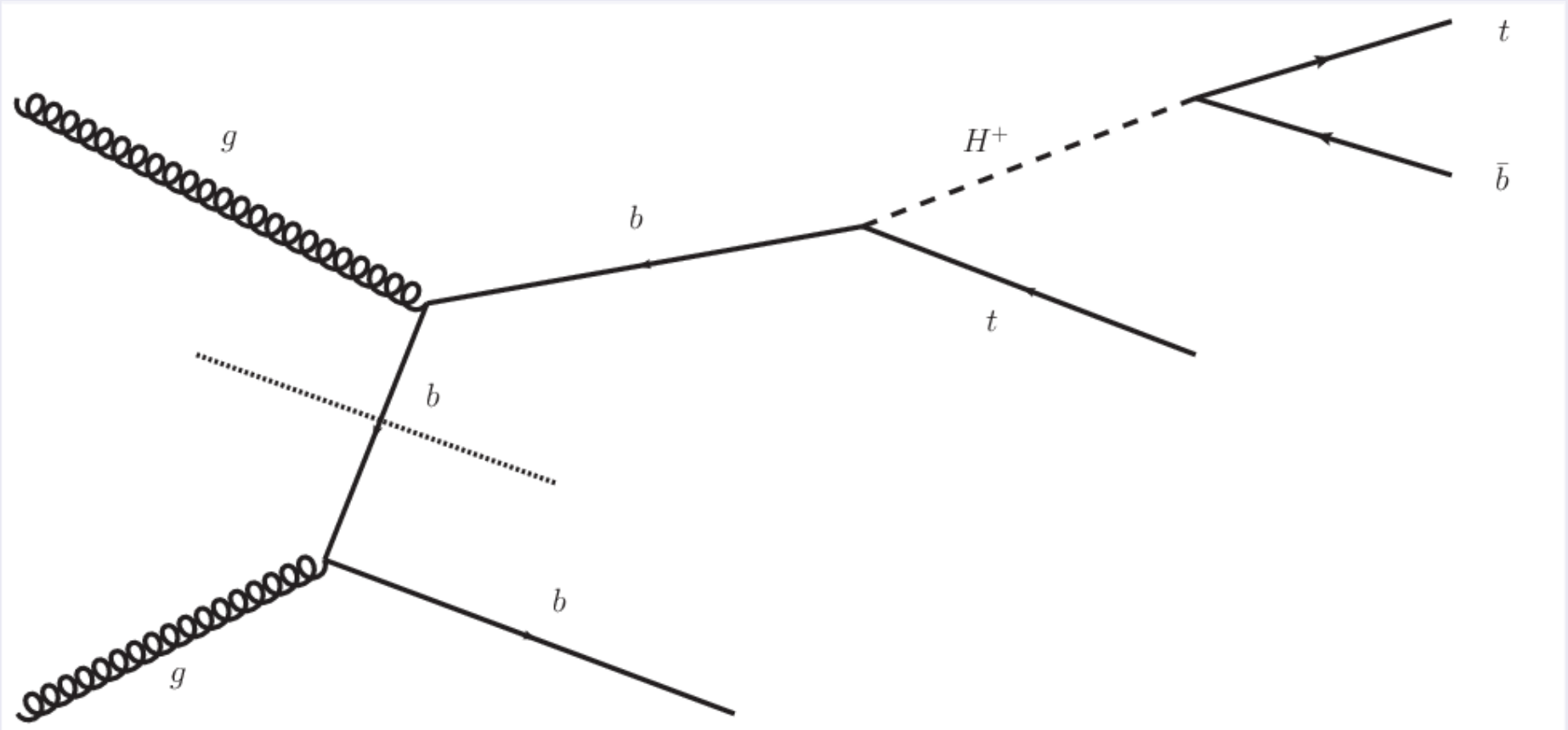
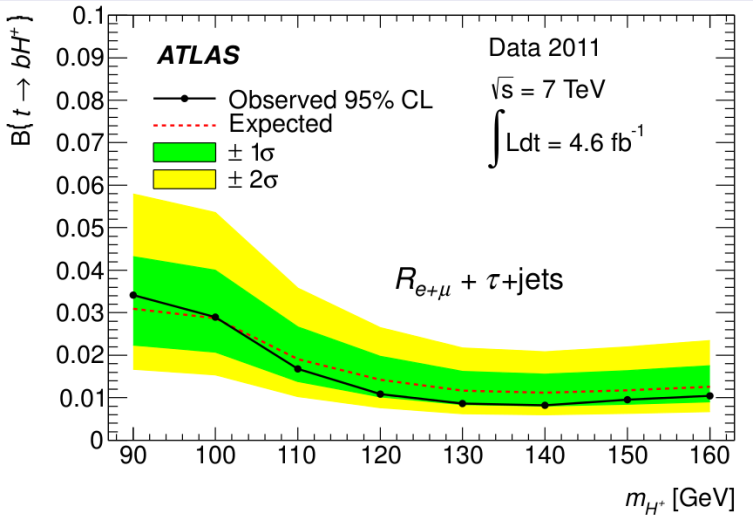


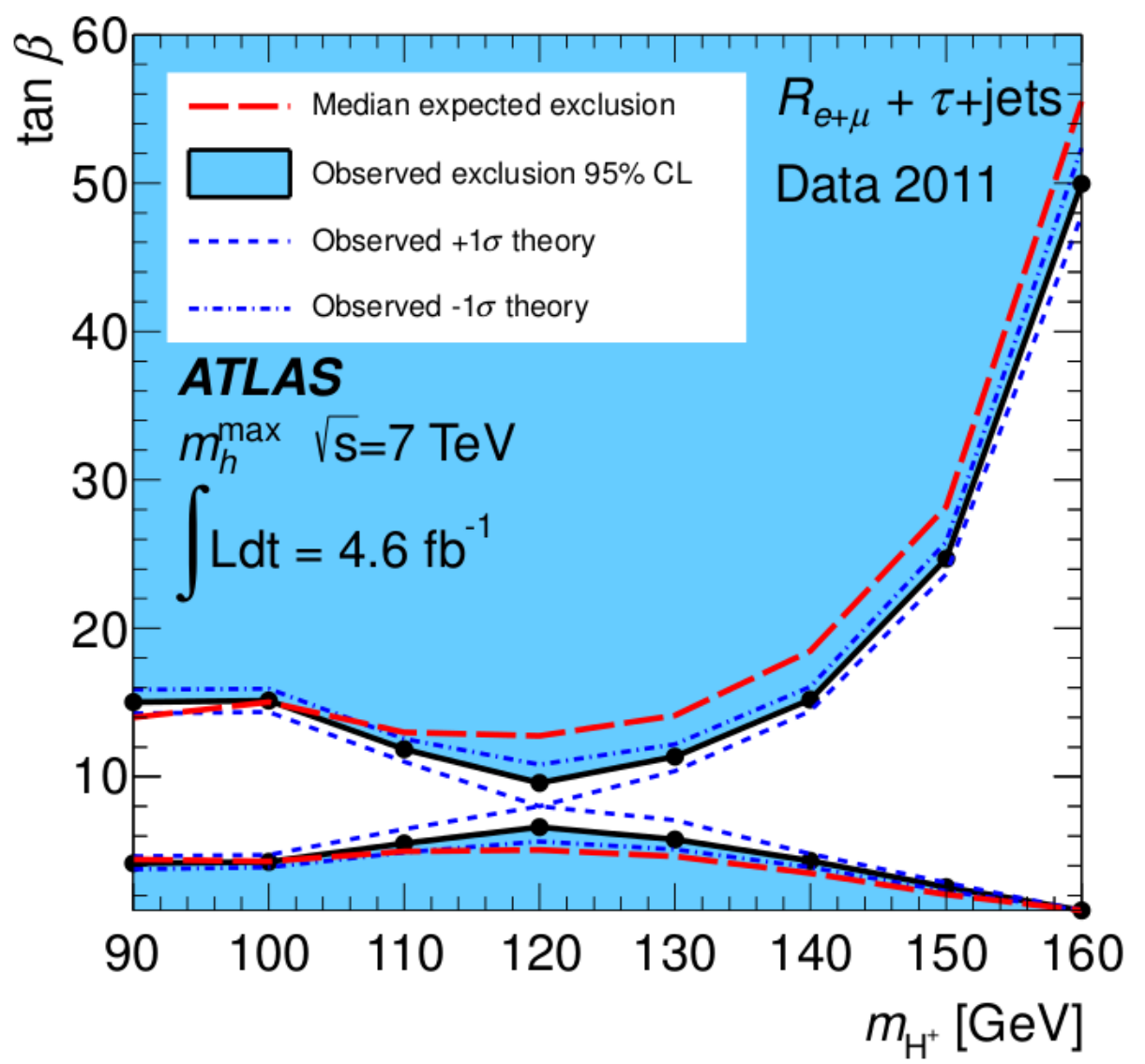
# Current Search Strategies and Limits

Search for charged Higgs bosons through the violation of lepton universality in $t\bar{t}$ events using $pp$ collision data at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS experiment.

- JHEP03(2013)076 arXiv:1212.3572
- Assume: $B(H^+ \to \tau\nu) = 100\%$
- Searches for $H^+$ in mass range $90 - 160\mathrm{GeV}$
- Measures the Ratio: $R_\ell = \dfrac{B(t\bar{t} \to b\bar{b} + \ell\tau_{had} + N\nu)}{B(t\bar{t} \to b\bar{b} + \ell\ell' + N\nu)}$



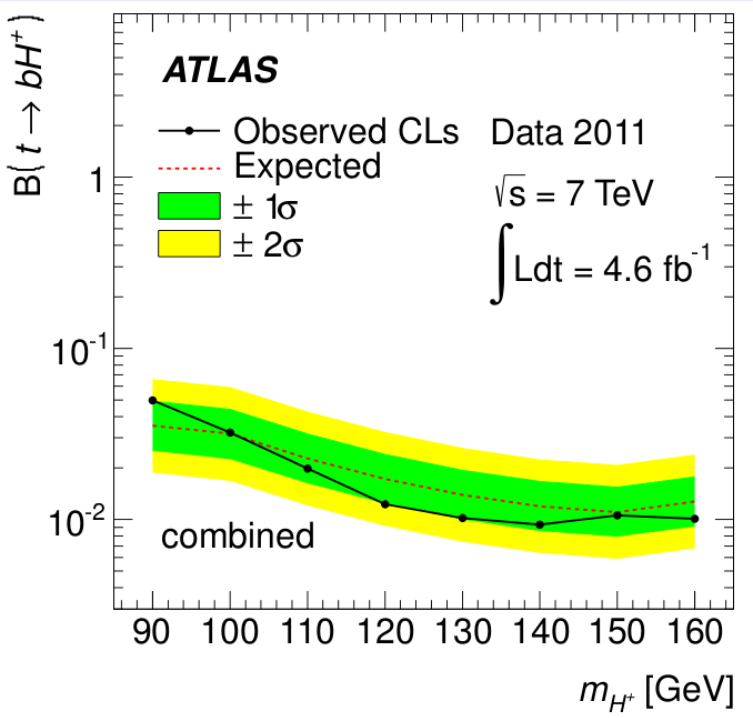
# Current Search Strategies and Limits



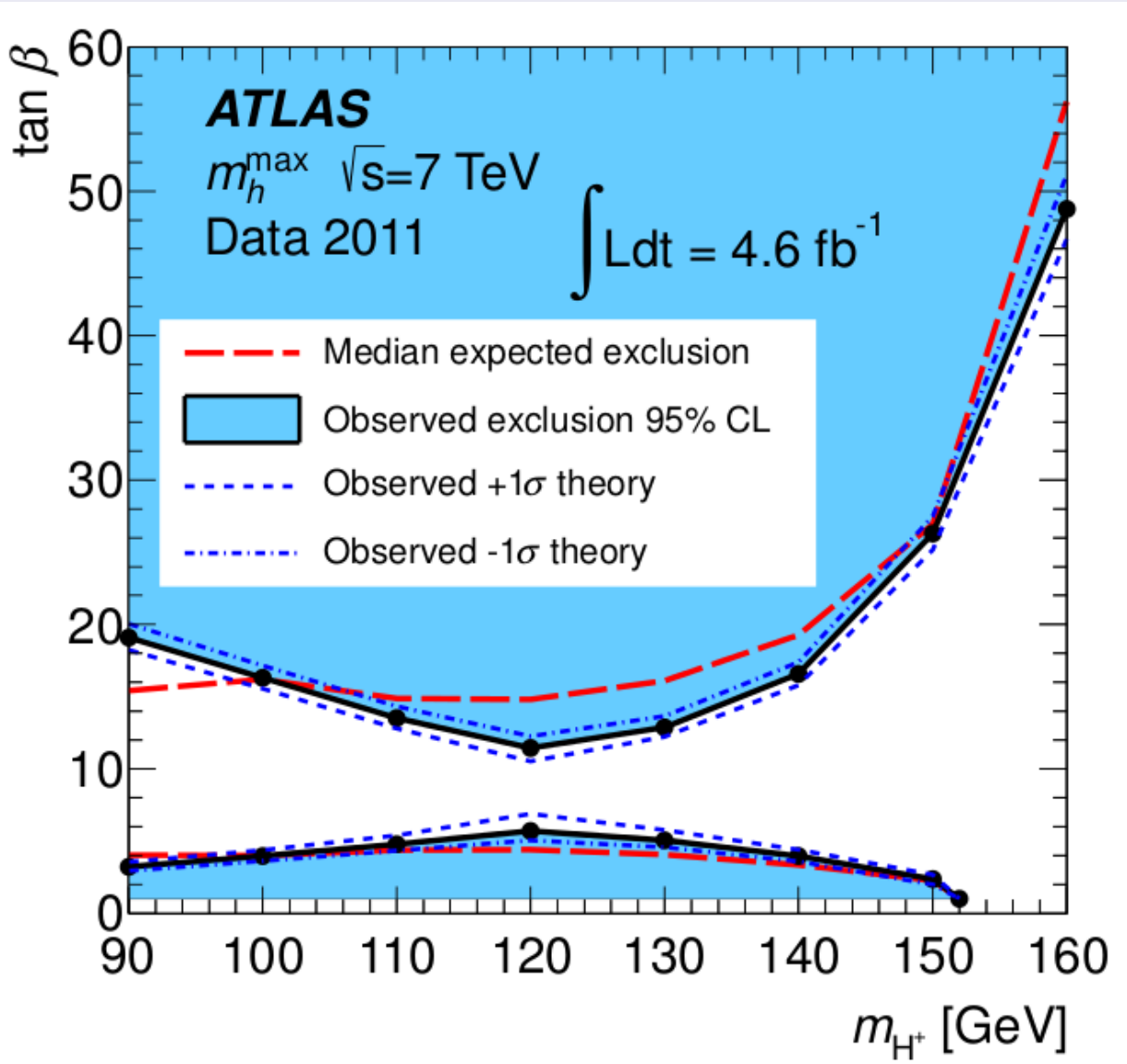
# Current Search Strategies and Limits

**Search for charged Higgs bosons decaying via $H^{\pm} \to \tau\nu$ in $t\bar{t}$ events using $pp$ collision data at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS detector.**

- JHEP1206(2012)039 arXiv:1204.2760
- Assume: $B(H^{+} \to \tau\nu) = 100\%$
- Searches for $H^{+}$ in mass range $90 - 160\mathrm{GeV}$



# Current Search Strategies and Limits



# Brief Aside: Jet Clustering Algorithms

## General Algorithm

Jet Algorithms run over lists of topological clusters. (Energy, Eta, Phi).

- For each cluster $(i)$ define the variable: $d_i = p_{T,i}^{2n}$
- For each pair of clusters $(i, j)$ define the variable: $d_{ij} = \frac{\Delta R_{ij}^2}{\Delta R^2} min(p_{T,i}^{2n}, p_{T,j}^{2n})$
- Find $min(d_i, d_{ij})$
- If the minimum is a $d_{ij}$: merge the entries $i$ and $j$
- If the minimum is a $d_i$: save the entry as a jet and remove it from the list.
- Repeat all steps until all entries are saved as jets and initial list is empty.

## Specific Algorithms

- $n = 1$: $k_T$ Algorithm - Clusters lowest $p_T$ entries first.
- $n = 0$: Cambridge/Aachen Algorithm - Purely geometric.
- $n = -1$: Anti-$k_T$ Algorithm - Clusters highest $p_T$ entries first.

# Planned Search Strategy for Heavy Charged Higgs

## Boosted Topologies

- Good Rule of Thumb for opening angle between constituents of two body decay: $Radius_{jet} < 2M_{(parent)}/p_{T,(parent)}$.
- Decay products coming from a Top quark with $P_T \approx 350\mathrm{GeV}$ potentially able to be reconstructed in a single Fat-jet with $\Delta R = 1.5$.
- Merging of Top quark decay products occurs with increasing Top quark Momentum.
- Jet algorithms using jets with small radii will become inefficient with increasing particle momentum.

# Planned Search Strategy for Heavy Charged Higgs

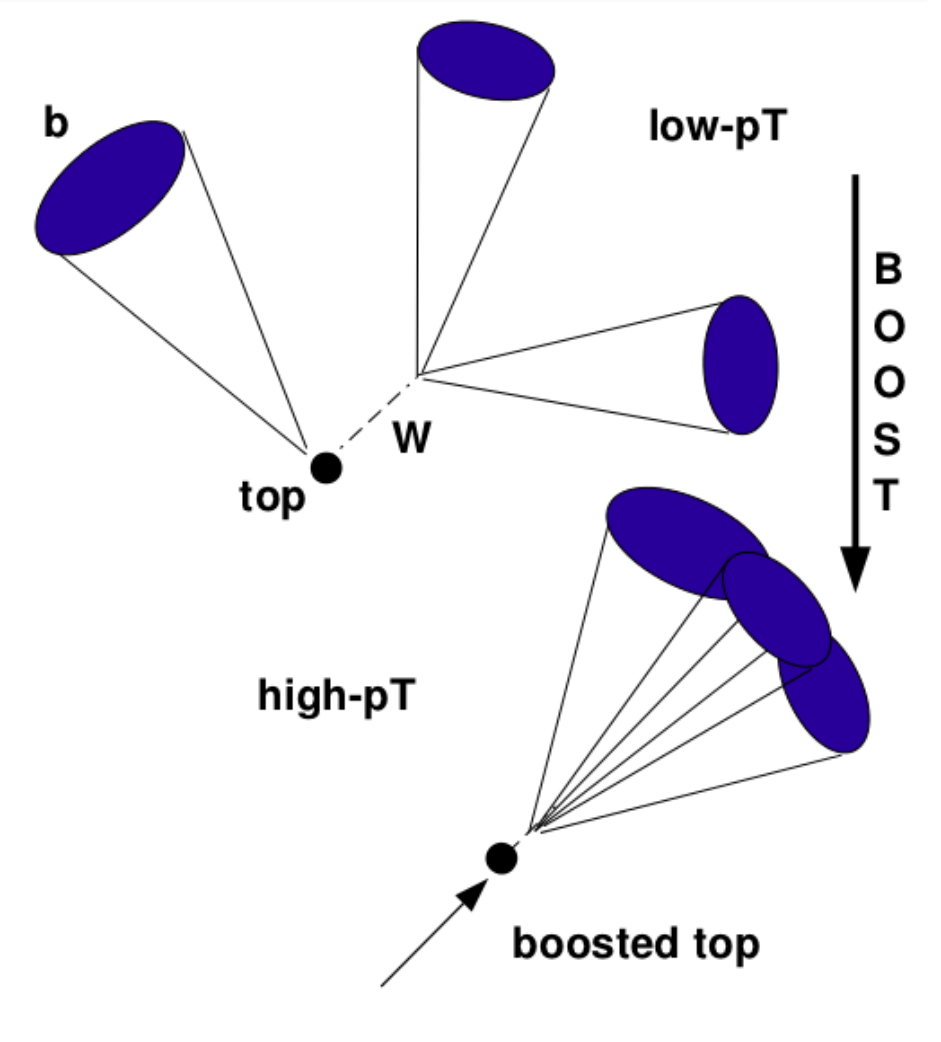
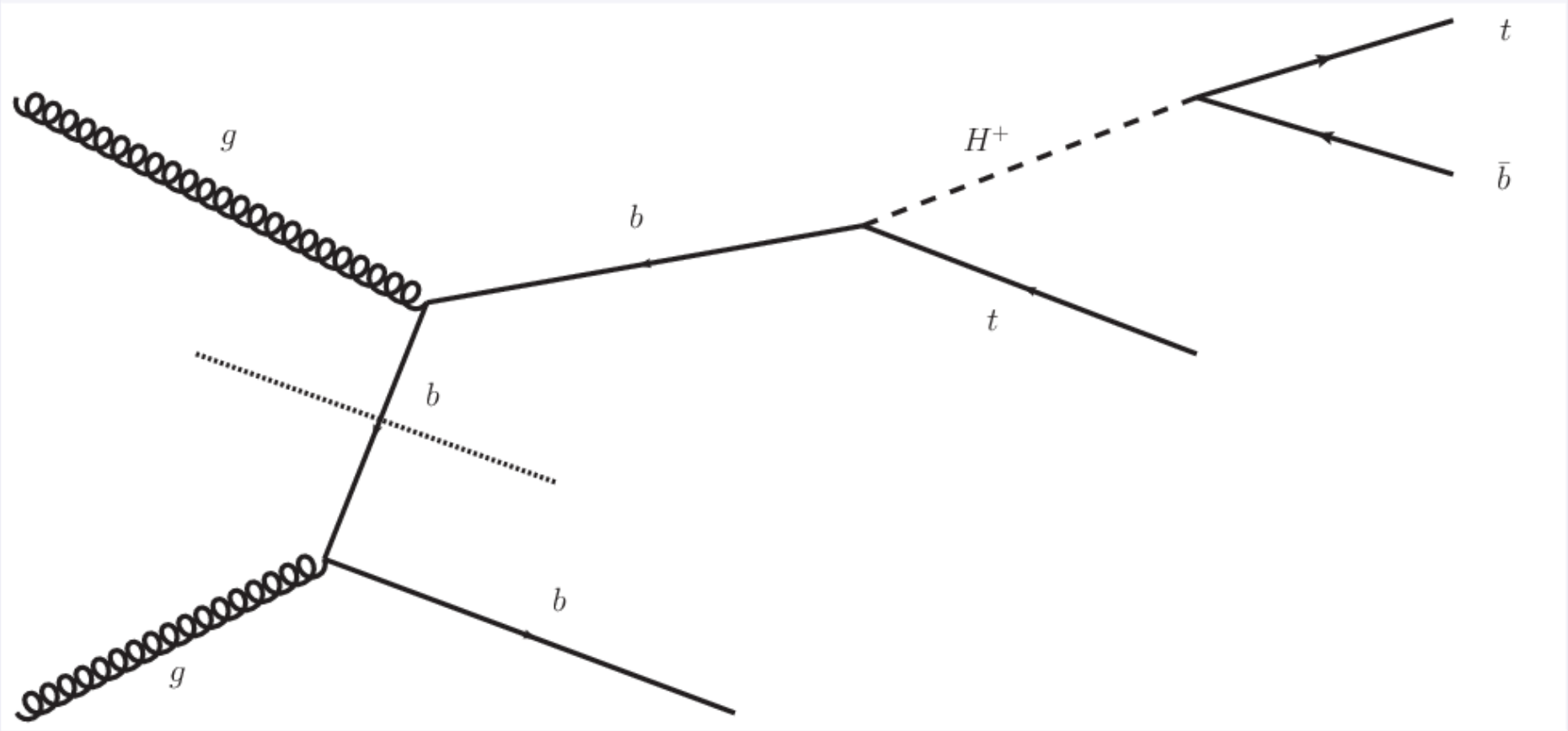



Figure taken from slides of C.Eckardt.

# Planned Search Strategy for Heavy Charged Higgs




- One Top-Tag.
- One Lepton plus Missing $E_T$ (MET).
- Up to 4 b-tags.

# Baseline Analysis

## Cuts

- Exactly One Lepton with $E_T > 25\mathrm{GeV}$.
- Five Jets with $P_T > 25\mathrm{GeV}, \eta < 2.5, |\mathrm{JVF}| > 0.5$.
- Three b-tags.
- MET $> 30\mathrm{GeV(el)}, > 20\mathrm{GeV(mu)}$
- MTW $> 30\mathrm{GeV(el)}$, MTW+MET$> 60\mathrm{GeV(el)}$

# ATLAS(/Another) Top Tagger (ATT) Analysis

## Cuts

- JHEP1209(2012)041. arXiv:1207.2409.
- Exactly One Lepton with $E_T > 25\mathrm{GeV}$
- MET $> 30\mathrm{GeV(el)}, > 20\mathrm{GeV(mu)}$
- MTW $> 30\mathrm{GeV(el)}$, MTW+MET$> 60\mathrm{GeV(el)}$
- Three b-tags.
- Anti-kT10 jet with $p_T > 300\mathrm{GeV}, m > 100\mathrm{GeV}$, $d_{12} > 40\mathrm{GeV}, \Delta\phi(\mathrm{jet}, \mathrm{lepton}) > 2.3, \Delta R(\mathrm{jet}, \mathrm{lepton}) > 1.5$
- Lepton Associated Anti-kT4 jet with $p_T > 25\mathrm{GeV}$ and $\Delta R(\mathrm{jet}, \mathrm{lepton}) < 1.5$.

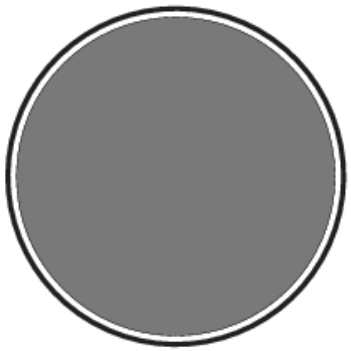
# HepTopTagger (HTT) Analysis

## Cuts

- ATLAS-CONF-2012-065
- Exactly One Lepton with $E_T > 25\mathrm{GeV}$
- MET $> 30\mathrm{GeV(el)}, > 20\mathrm{GeV(mu)}$
- MTW $> 30\mathrm{GeV(el)}$, MTW+MET$> 60\mathrm{GeV(el)}$
- Three b-tags.
- At Least one HepTopTag.
- Lepton Associated Anti-kT4 jet with $p_T > 25\mathrm{GeV}$ and $\Delta R(\mathrm{jet}, \mathrm{lepton}) < 1.5$.

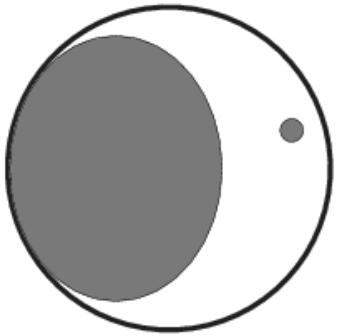
# HepTopTagger

## Theory Paper: Stop Reconstruction with Tagged Tops (arXiv:1006.2833)



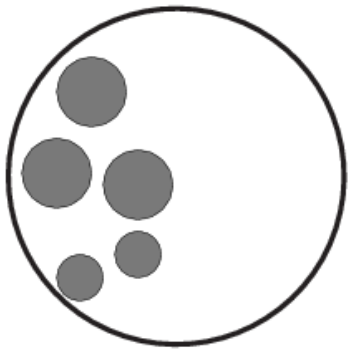
C/A Fatjet $\Delta R = 1.5$

$p_T > 200\text{GeV}$



$j_1, j_2$ with $m_1 > m_2$.

Require $m_1 < 0.8 m_{12}$ to keep $j_2$



$m_1 < 30GeV$

$\Delta R = min(0.3, \frac{\Delta R_{12}}{2}, \frac{\Delta R_{23}}{2}, \frac{\Delta R_{13}}{2})$

$150\text{GeV} < m_5 < 200\text{GeV}$

Recluster to form 3 jets.

Test these 3 subjets using invariant mass ratios

If more than one Top Candidate :

Take that with mass closest to Top quark mass

Future work to focus on how boosted search techniques can complement/improve upon resolved reconstruction search strategies.