# Search for new heavy bosons with b-tagged jets in the boosted regime with CMS


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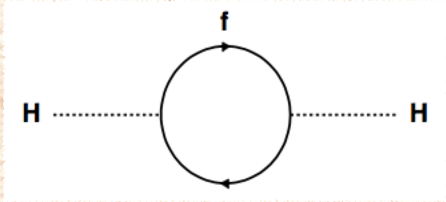
## The Higgs mass hierarchy problem

The Higgs mass gains quantum corrections from fermion loops

$M_H^2$ (125 GeV) = $M_0^2 + \delta M_H^2$



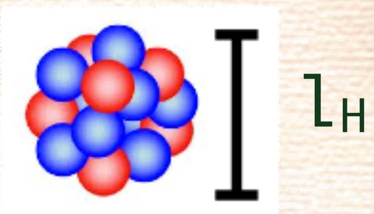
$$\delta M_H^2 = -2\frac{|\lambda_f|^2}{16\pi^2}\Lambda^2 + \ldots$$

**fine tuning:** $\Lambda$ ~ gravitational scale ~ $M_{Planck}$ ~ $10^{18}$ GeV

If new physics at the TeV scale exists the cut-off scale $\Lambda$ is set by the scale of the new dynamics ... $\Lambda$ ~ 1 TeV

## The composite Higgs model

- Higgs as a composite state of a new strong interaction

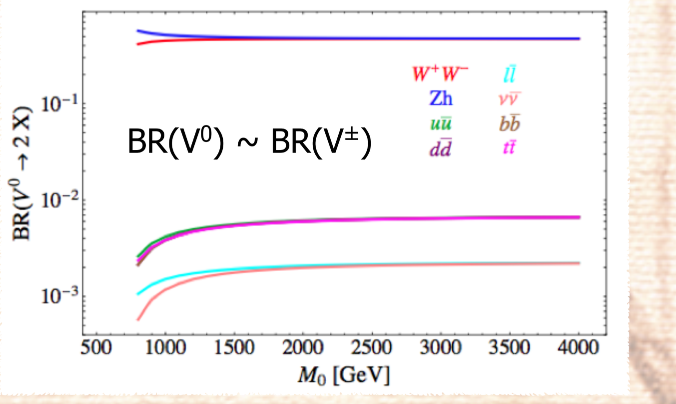


The hierarchy problem is solved:

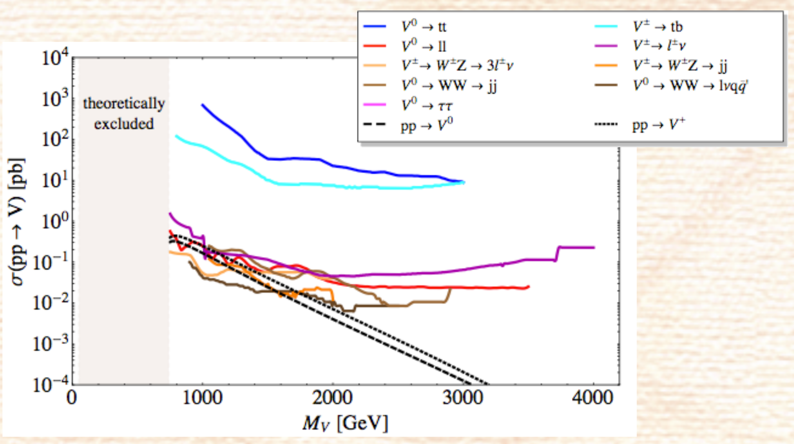
- corrections to $m_H$ screened at $1/l_H$

- The composite Higgs boson couples to the SM particles and to new heavier gauge bosons, such as **Z′** and **W′**, with masses in the TeV region
  - in this scenario the neutral ($V^0$) and the charged ($V^{\pm}$) heavy resonance decay primarly to SM vector bosons (W,Z,Higgs)

Branching Ratios for the two body decays of the neutral vector $V^0$ (Z′)

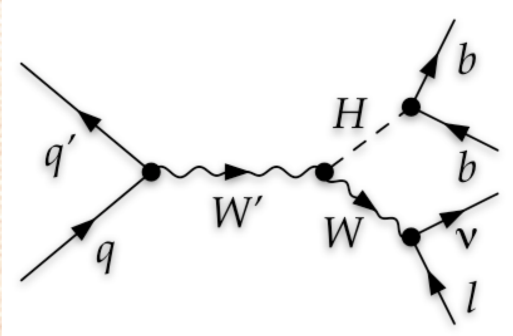



Bounds on the production cross sections




## W′ signal: **W′ ➜ WH ➜ $b\bar{b}\ell\nu$**

One of the first analyses attempting to look for exotic final states with a **Higgs boson**

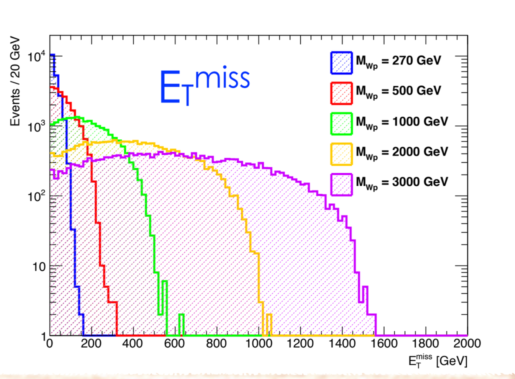


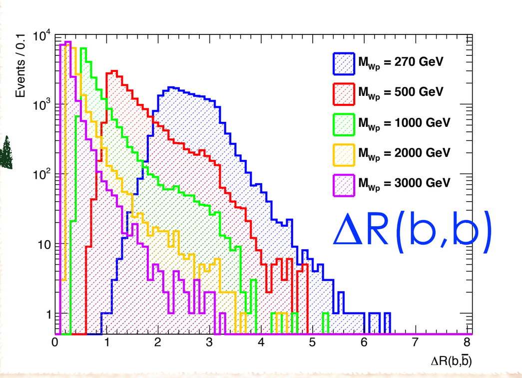
**H ➜ bb : dominant Higgs decay mode**

- overwhelmed by the large irreducible background from QCD production
- the presence of the vector boson in the final state highly suppresses the QCD background while also providing an efficient trigger path

### Signature:

- one high $p_T$ isolated lepton
- large missing transverse energy
- two high $p_T$ and collimated b-jets



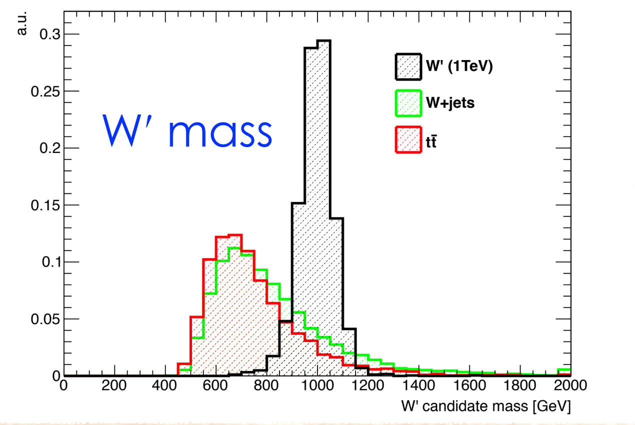




### W′ candidate mass reconstruction:

- start from the reconstructed W➜$\ell\nu$
- the W mass constraint is applied to extract the z component of the escaping neutrino

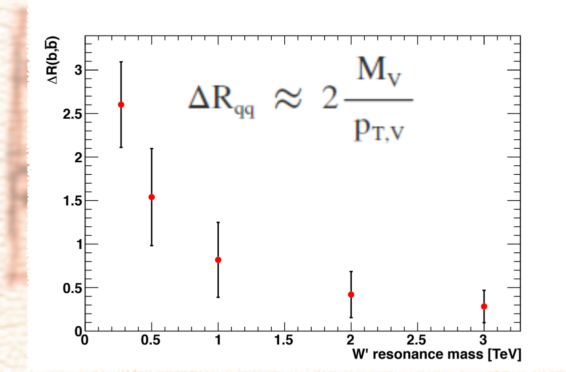
$$M_W^2 = (E_\mu + \sqrt{\mathbf{E}_T^{miss^2} + P_{z,\nu}^2})^2 - (\mathbf{P}_{T,\mu} + \mathbf{E}_T^{miss})^2 - (P_{z,\mu} + P_{z,\nu})^2$$

- the invariant mass of the lepton+neutrino+b-jets system is computed

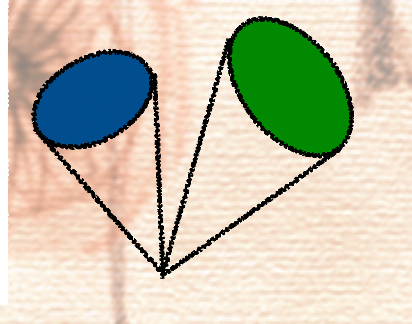



## Higgs-jet identification

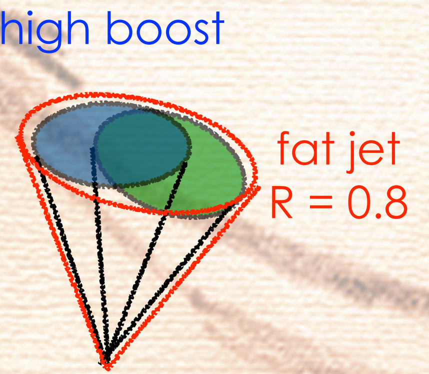
For large enough boost (depending on the resonance mass) )the b-jets from the Higgs are expected to merge into a single jet




low boost

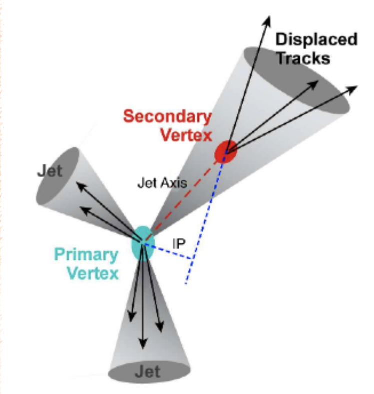


high boost




A large-radius jet (fat jet) is used to identify the Higgs-jet
**➜ Cambridge-Aachen algorithm with R=0.8**

## subjets b-tagging




The background associated with light quark jets is suppressed exploiting the b-jet special signature:

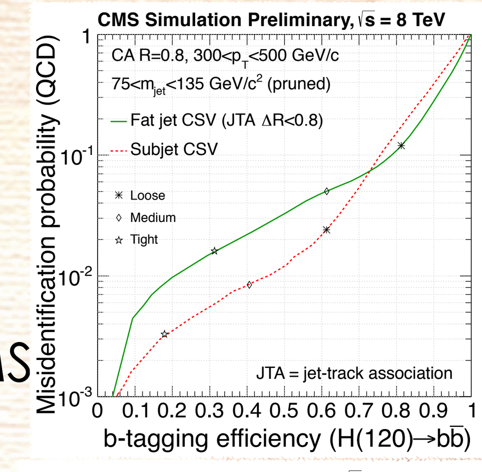
- secondary vertex displaced from the primary vertex
- large multiplicity of charged tracks with high impact parameter

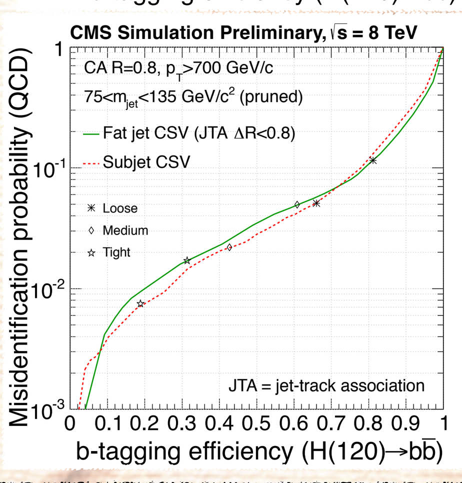
The **Combined Secondary Vertex** algorithm is used to combine all these information in one discriminator

Two b-tagging approaches currently used in CMS

- application of b-tagging to fat jet
- application of b-tagging to subjets reconstructed within the fat jet

**Subjets b-tagging** outperforms the fat jet tagging until the subjets get too close to each other (ΔR < 0.3)




## Jet substructures algorithms

The **jet pruning algorithm** is used to identify jets originating from heavy objects (W,Z or H) studying the substructures of the merged jet:

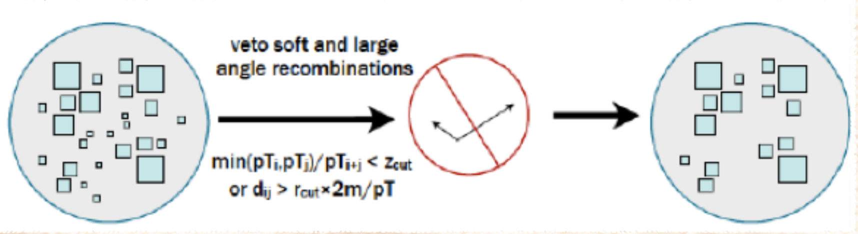
- start from a large-radius jet (CA with R=0.8)
- recluster the jet constituents and evaluate the hardness and angular separation of the last recombination
- remove the softest subjet if conditions not satisfied

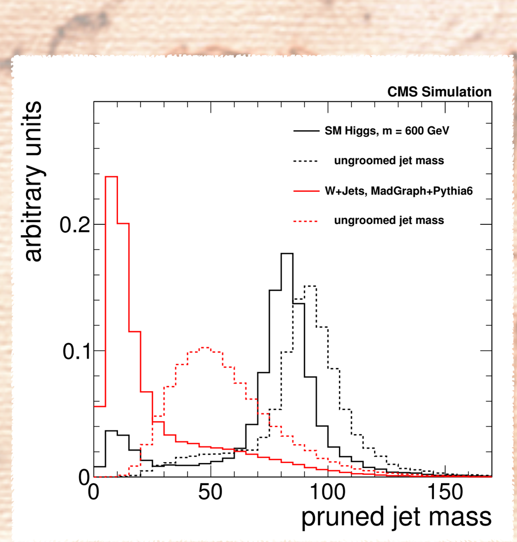
hardness

$$z = \frac{\min(p_{T,i}, p_{T,j})}{p_{T,JET}} > 0.1$$

angular separation

$$\Delta R < 0.5\frac{M_{JET}}{p_{T,JET}}$$

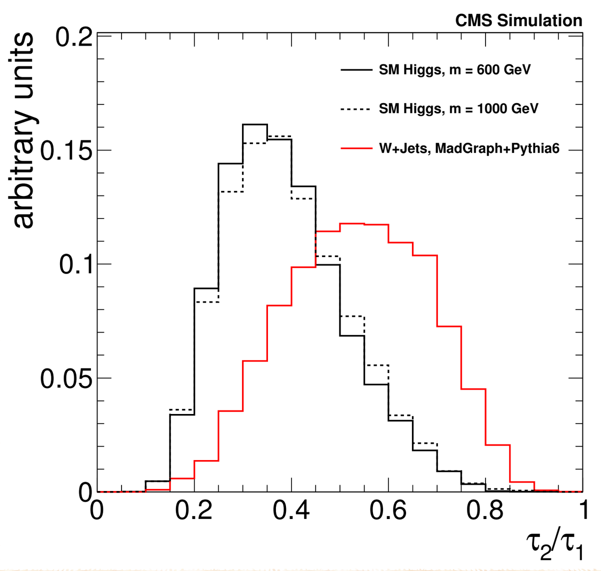



Pruning the jet mass gives improved discrimination power by suppressing background jet masses to zero while preserving the signal jet mass near the Higgs mass

Additional sensitivity is achieved by means of the **N-subjettiness algorithm:**

- start from unpruned jets
- check the topological compatibility between the jet and the hypothesis of N subjets
- compute $\tau_N$ and use the ratio $\tau_2/\tau_1$ to discriminate signal from background




$$\tau_N = \frac{1}{d_0}\sum_k p_{T,k}\min\{\Delta R_{1,k}, \Delta R_{2,k}, \ldots, \Delta R_{N,k}\}$$