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

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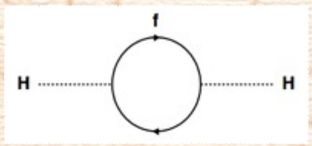
The Higgs mass hierarchy problem

The Higgs mass gains quantum corrections from fermion loops



M_H^2 (125 GeV) = M_0^2 + δM_H^2

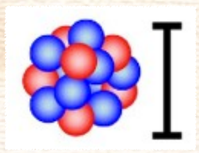
$$\delta M_H^2 = -2\frac{|\lambda_f|^2}{16\pi^2}\Lambda^2 + \dots$$

fine tuning: Λ ~ gravitational scale ~ M_{Planck} ~ 10^{18} GeV

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

The composite Higgs model

- Higgs as a composite state of a new strong interaction

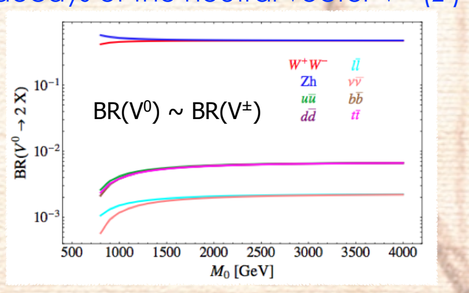


The hierarchy problem is solved:

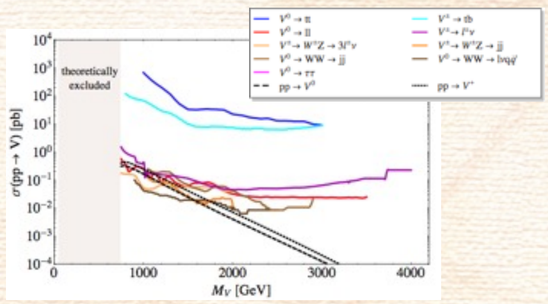
- corrections to m_H screened at $1/l_H$

- 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′)

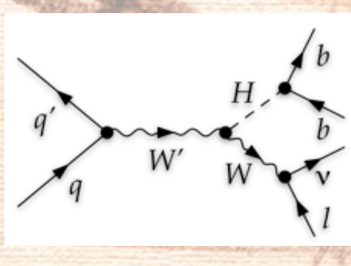


Bounds on the production cross sections



W′ signal: **W′ → WH → bb̄ℓν**

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

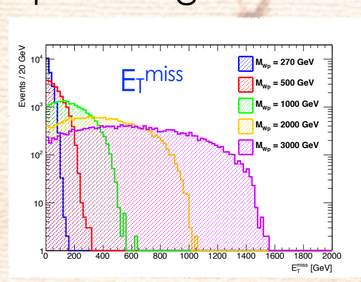


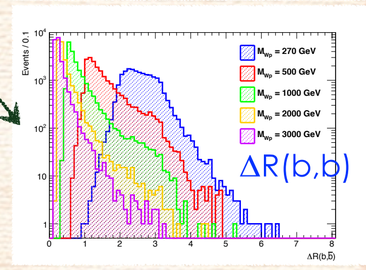
H → bb : dominant Higgs decay mode

- 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 <u>collimated</u> b-jets



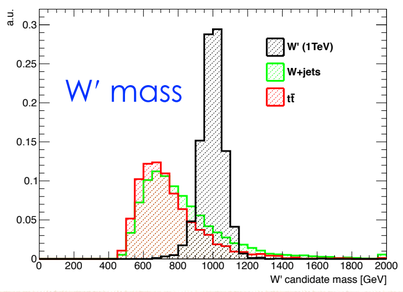


W′ candidate mass reconstruction:

- start from the reconstructed W→ℓν
- the W mass constraint is applied to extract the z component of the escaping neutrino

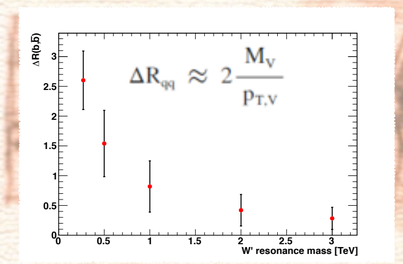
$$M_W^2 = (E_\mu + \sqrt{\mathbf{E}_T^{miss\,2} + P_{z,\nu}^2})^2 - (\mathbf{P}_{T,\mu} + \mathbf{E}_T^{miss})^2 - (P_{z,\mu} + P_{z,\nu})^2$$

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

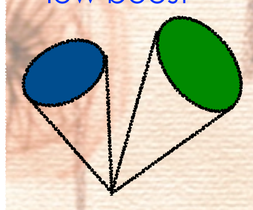


Higgs-jet identification

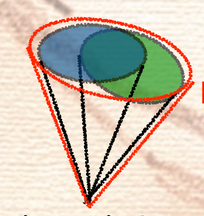
For large enough boost (depending on the resonance mass))the b-jets from the Higgs are expected to merge into a single jet



low boost



high boost



fat jet R = 0.8

A large-radius jet (fat jet) is used to identify the Higgs-jet

➜ **Cambridge-Aachen algorithm with R=0.8**

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:

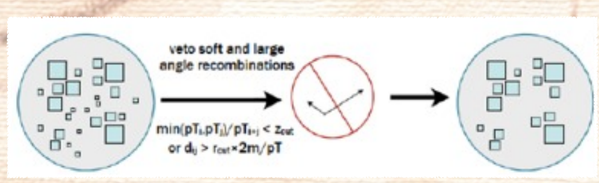
- start from a large-radius jet (CA with R=0.8)
- recluster the jet constituents and evaluate the hardness and angular separation of the last recombination
- remove the softest subjet if conditions not satisfied

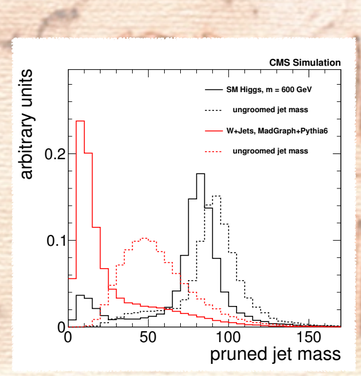
hardness

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

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

subjets b-tagging

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

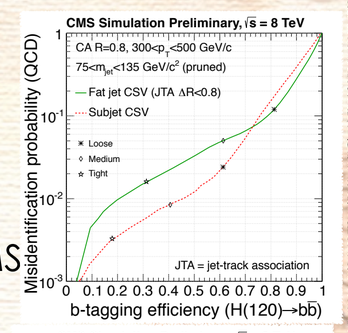
- secondary vertex displaced from the primary vertex
- large multiplicity of charged tracks with high impact parameter

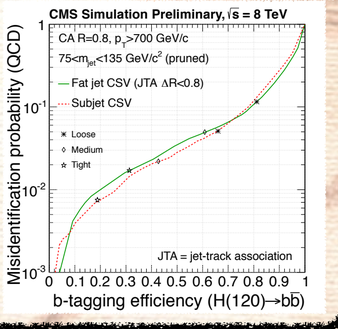
The **Combined Secondary Vertex** algorithm is used to combine all these information in one discriminator

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)





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 τ_N and use the ratio τ_2/τ_1 to discriminate signal from background

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