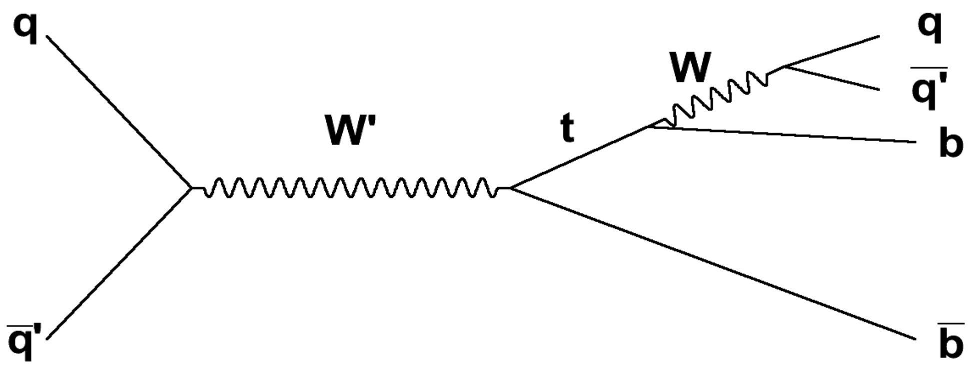
Search for W' → tb in the hadronic final state



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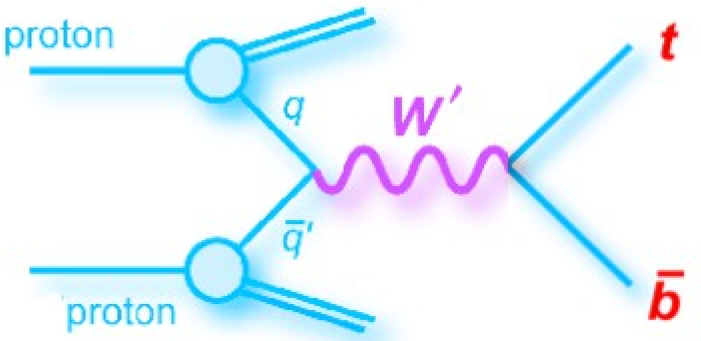
Introduction

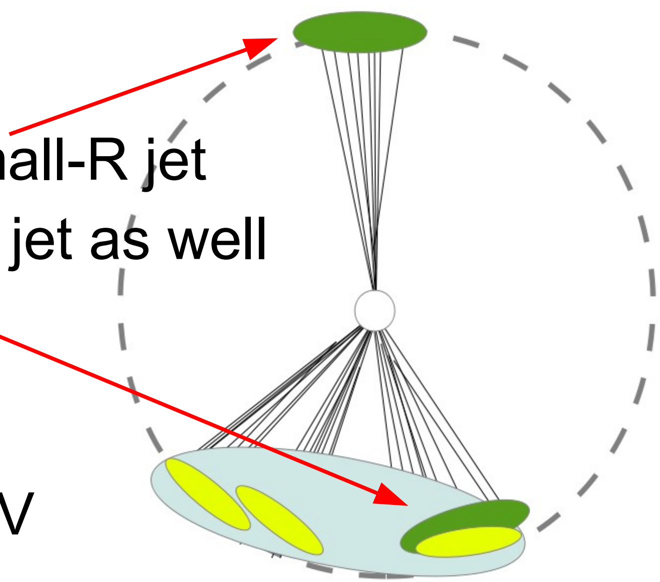
- What is W'?
  - A new, heavy, Standard-Model-like gauge boson
  - Same charge, and spin as Standard Model W gauge boson
- W' boson is consequence of physics beyond the Standard Model
  - e.g. Extra Dimension model, Little Higgs models, technicolor
- Search channels
  - $W' \rightarrow l\nu$, $l = e, \mu$
  - $W' \rightarrow tb$
  - $W' \rightarrow WZ$



- $W' \rightarrow tb$ channel
  - Only experimental results on $W' \rightarrow tb \rightarrow l\nu bb$, $l = e, \mu$
    - ATLAS limits (14.3 fb^{-1}): 1.74 TeV (W'_L) and 1.84 TeV (W'_R)
    - Stay tuned for the coming CMS talk
  - No result on $W' \rightarrow tb \rightarrow qqbb$ yet
    - Advantages: $t \rightarrow Wb \rightarrow qqb$ has three times higher branching ratio than $t \rightarrow Wb \rightarrow l\nu b$. Hadronic channel has better mass resolution
    - Disadvantage: enormous QCD background

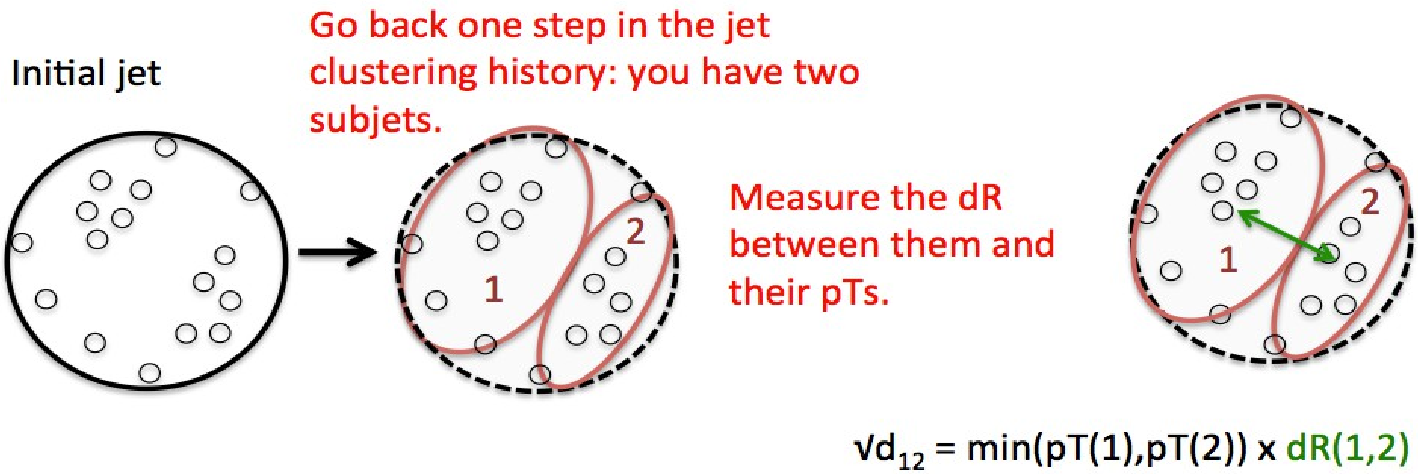
W' → tb in hadronic final state search strategy

- Given the current high W' → tb mass limit, W' has high mass if exists
  - Top is boosted, decay products of top merged
  - Reconstruct top decay products by large-R jets
  - Use jet substructure information to distinguish top jets from light jets
- Tagged dijet events
  - One top-tagged large-R (R=1.0) jet with P_T > 350 GeV and $|\eta| < 2.0$
  - One b-tagged small-R (R=0.4) jet with P_T > 350 GeV and $|\eta| < 2.5$
- Two channels
  - 1 btag channel: only b-tag high P_T recoiling small-R jet
  - 2 btag channel: b-tag an small-R jet inside top jet as well
- Search for a bump in the M_{tb} spectrum
  - Start the search at W' mass > 1.5 TeV
  - Analysis currently blinded at W' mass < 1.3 TeV
- Main background is QCD dijets. ttbar is less than 2% in 1 btag channel and about 10% for 2 btag channel.



Jet substructure variables for top-tagging

- Splitting scale $\sqrt{d_{12}}$, n-subjettiness τ_{21} and τ_{32} are used to distinguish top jets and light jets
  - Splitting scale $\sqrt{d_{12}}$

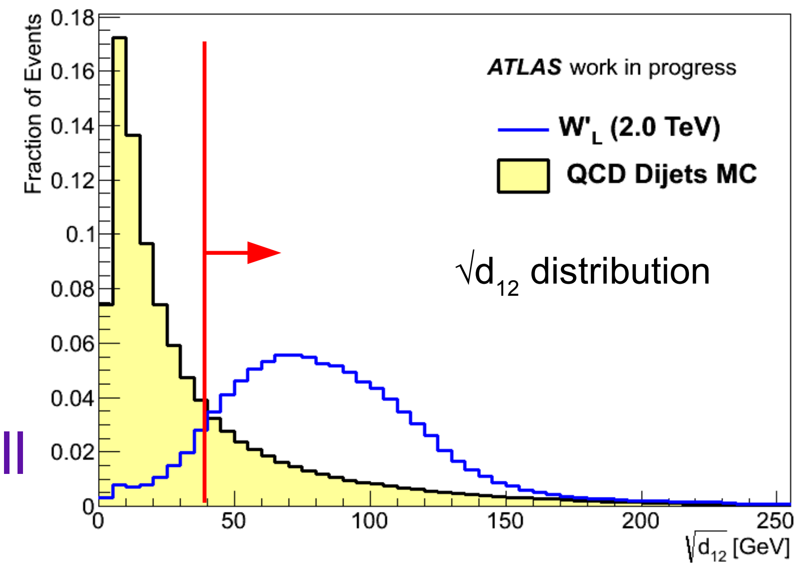


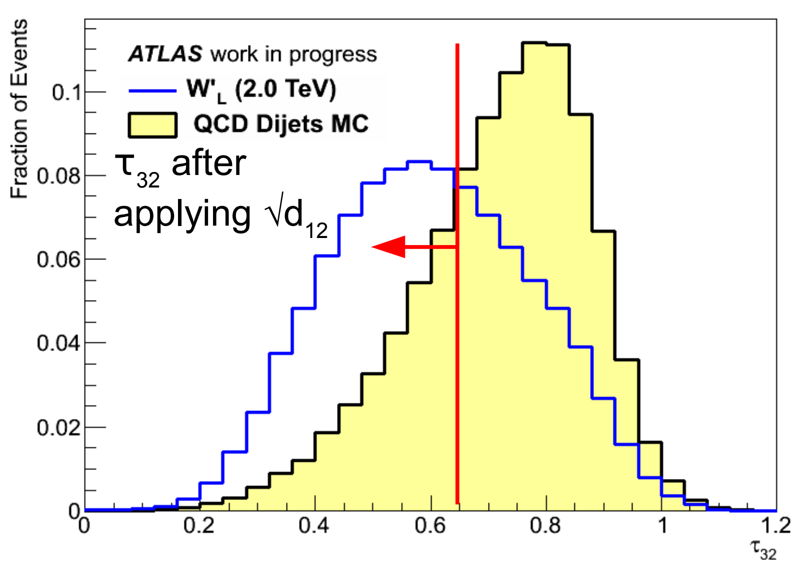
  - Expected value ~$M_{jet}/2$ for jets that consist of massive particles from 2-body decay, and a steeply falling spectrum for light jets

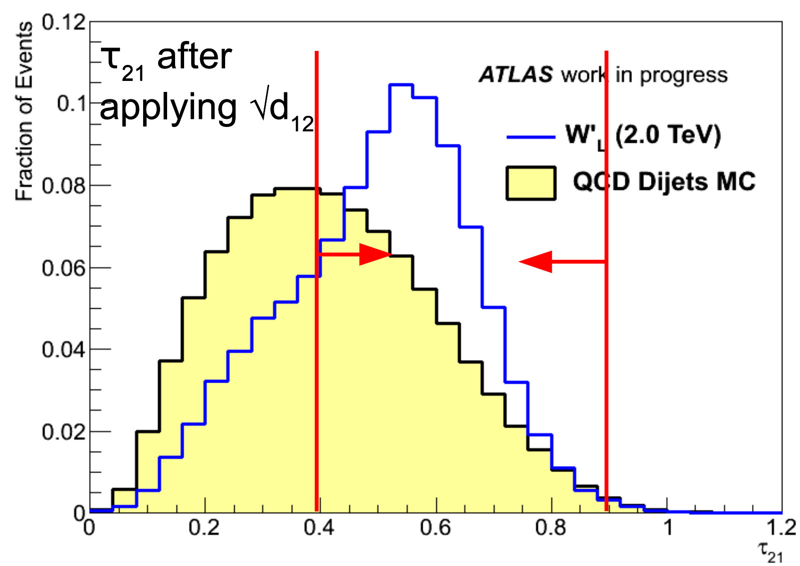
  - n-subjettiness τ_{mn}
    - Ratio related to subjet multiplicity
    - Peak at 0 when more likely to have m subjets; peak at 1 when more likely to have n subjets

Cut-based top tagger for boosted hadronic top

- Optimize splitting scale $\sqrt{d_{12}}$, n-subjettiness τ_{21} and τ_{32}
  - Use $eff_{signal}/\sqrt{eff_{background}}$ for optimization
    - Signal: 2 TeV W'_L MC
    - Background: PYTHIA QCD dijets with jet P_T between 0.5-1.0 TeV
  - Optimize n-subjettiness after applying $\sqrt{d_{12}}$ to improve performance over the full jet mass range
  - $\sqrt{d_{12}} > 40$ GeV, $\tau_{32} < 0.65$, $\tau_{21} > 0.4$, $\tau_{21} < 0.9$

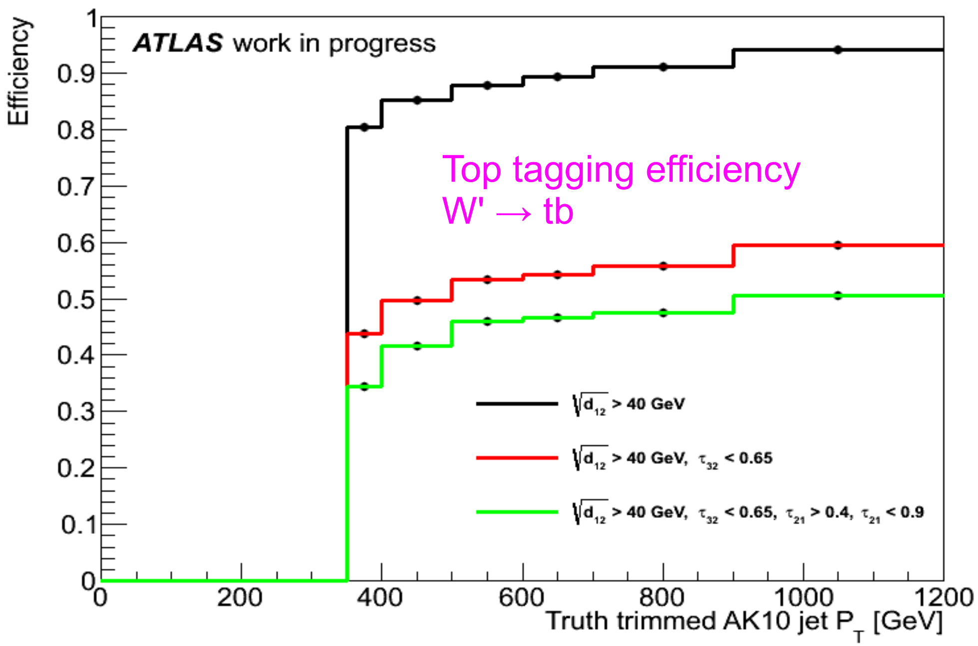


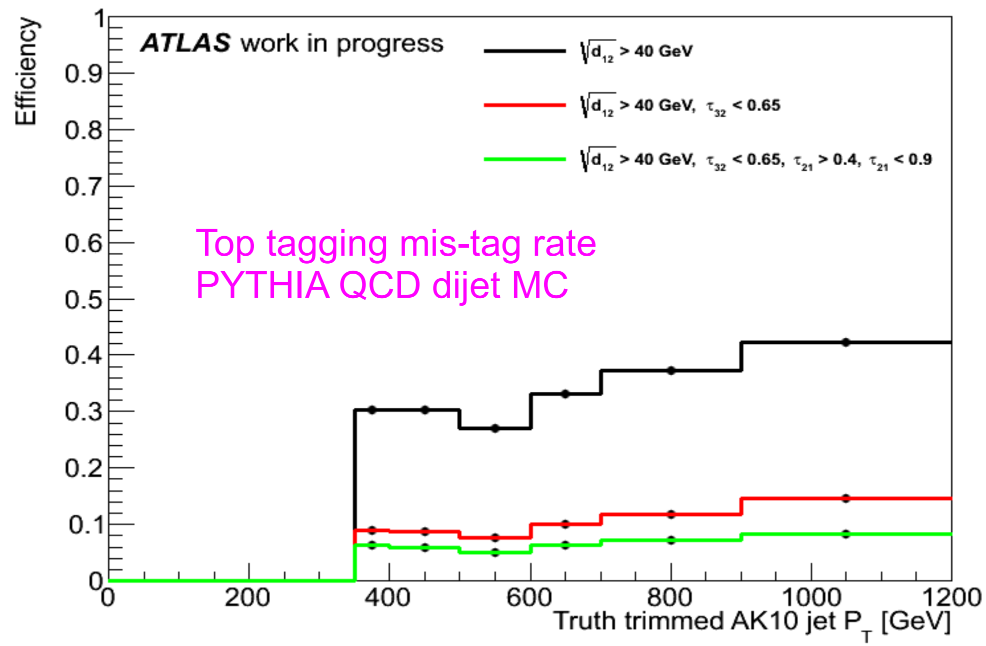




Cut-based top tagger: efficiencies

- Top tagging efficiency as a function of truth jet P_T
  - Use large-R jets that satisfy $\Delta R < 0.4$ with top quarks from W' sample to obtain top tagging efficiency
  - Top jet with P_T of 750 GeV has an efficiency of 47.5% in 2 TeV $W'_L \rightarrow tb$ MC
- Top tagging mis-tag rate for light jets as a function of truth jet P_T
  - Use PYTHIA QCD dijet MC
  - 7.2% mis-tag rate for 750 GeV light jets





Background estimation

- Estimations of ttbar
  - Hadronic: MC@NLO+Herwig
  - Semileptonic: Powheg+PYTHIA

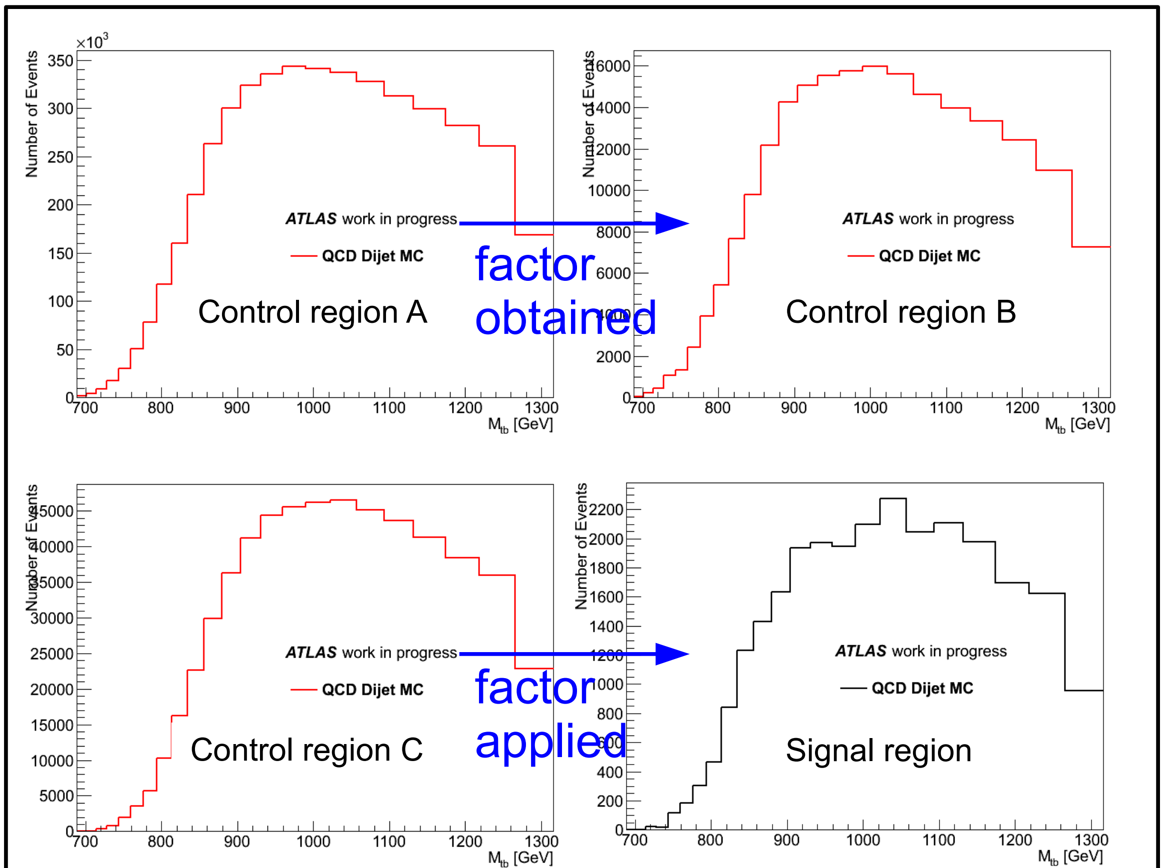
- Data-driven ABCD method for QCD dijet background in 1 btag channel
  - Use top tagging criterion on large-R jet and b-tagging criterion on small-R jet (ΔR(two jets) > 2.0) to set control regions
    - Correlation is the only systematics, 1.1%±0.7% at M_{tb} < 1.3 TeV by using PYTHIA QCD dijet MC
    - Since the same object is reconstructed as both large-R and small-R jets, defining control region A and B is ambiguous
      - Select large-R jet with lower jet mass to be the large-R jet, and the higher jet mass one to be small-R jet
  - Work in progress for 2 btag channel

	not b-tagged	b-tagged
not top-tagged	N_A	N_B
top-tagged	N_C	N_{Signal}

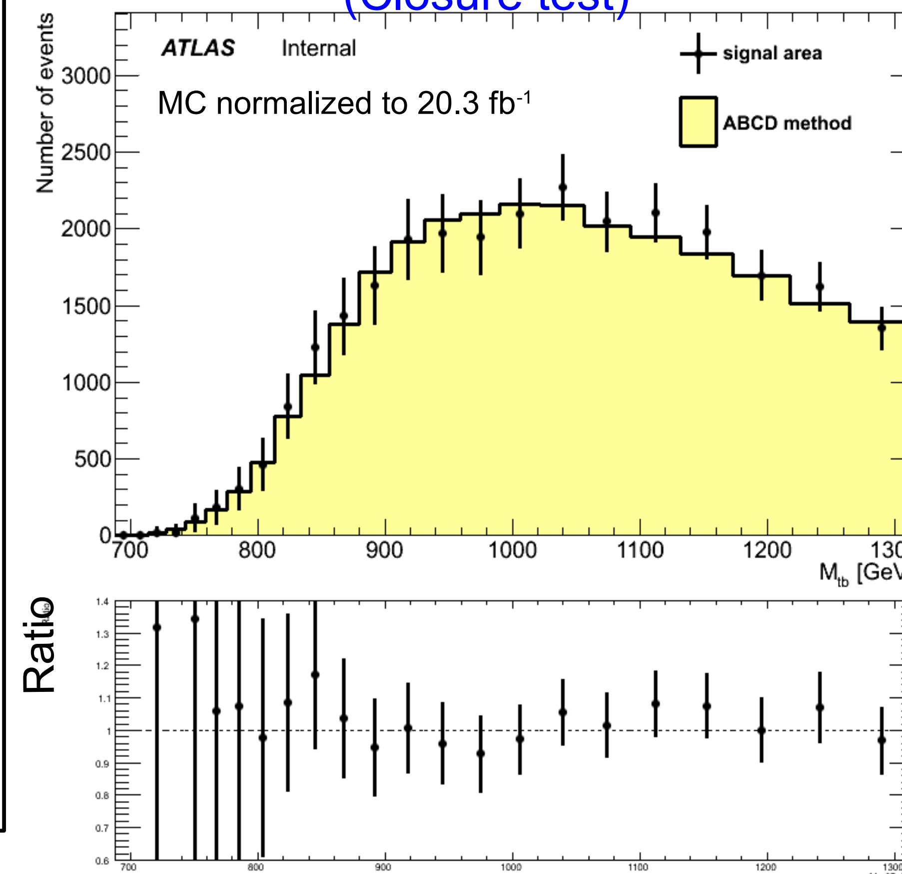
Background estimation: ABCD method for 1btag channel

- ABCD method
  - Scale N_C by factor obtained from comparing N_A and N_B, and extrapolate into signal region
    - ABCD extrapolation = $N_C(N_B/N_A)$
    - Bin-by-bin scaling
  - Here shows example by using MC

	not b-tagged	b-tagged
not top-tagged	N_A	N_B
top-tagged	N_C	N_{Signal}



ABCD extrapolation VS. signal in MC (Closure test)

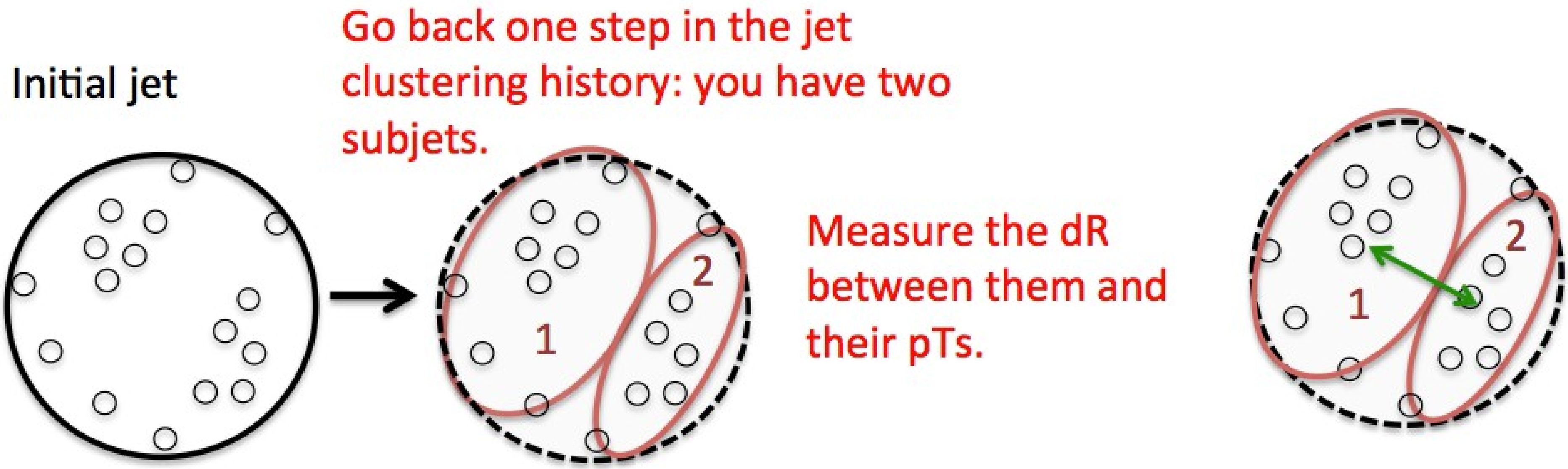


Summary

- W' → tb is a well-motivated, interesting, and unique search channel for many theories beyond the Standard Model
- Top from W' is boosted given the current high W' mass limit
  - Reconstruct top decay products as one large-R jet
  - Use jet substructure information to distinguish top from light jets
- Looking for dijets events with one jet top-tagged and the other one b-tagged
  - 2 btag channel: additional b-tagged small-R jet inside top
- QCD dijets is the main background and is estimated by data-driven ABCD method in 1 btag channel
- Work on-going, hopefully result will come out soon :)
- Thank you!

backup

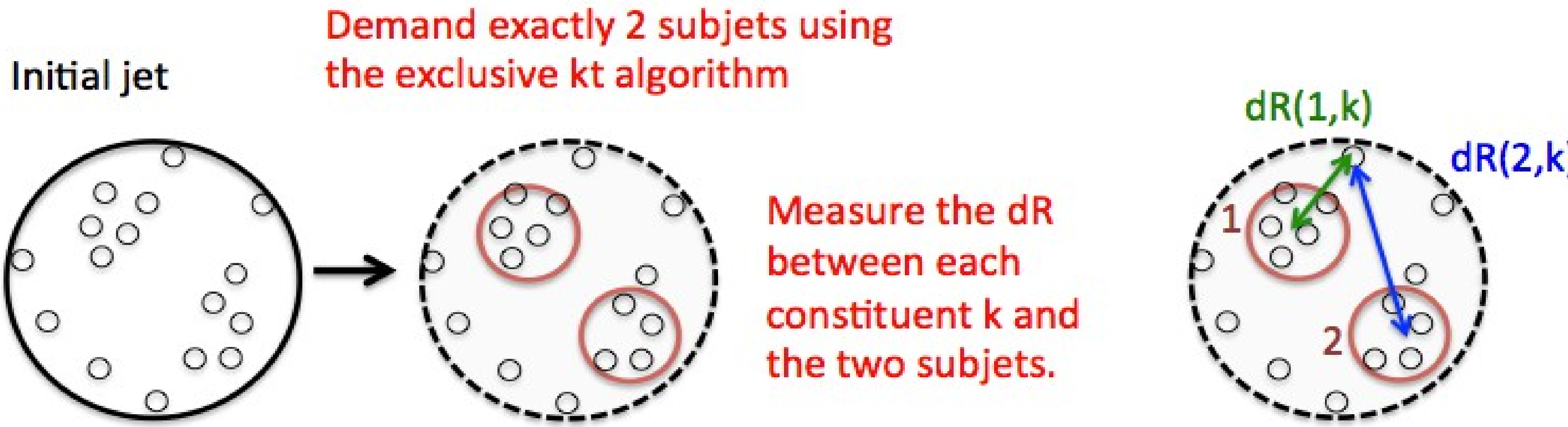
Splitting scale



$\sqrt{d_{12}}$ = min(pT(1),pT(2)) x dR(1,2)

- If the distance between the subjets is large, $\sqrt{d_{12}}$ is large.
- If the softer of the two subjets in the last clustering has high pT, then $\sqrt{d_{12}}$ is large.
- Both these things indicate large $\sqrt{d_{12}}$ in symmetric two body decays.

N-subjettiness



d_k = pT(k) x min(dR(1,k),dR(2,k))

- If constituent k is within, or close to, a subjet, the d_k will be small.
- Sum over all the d_k, and divide by $d_0 = \Sigma(p_T(k) \times R)$, where R is the initial jet radius.
- Now $\Sigma d_k / d_0$ is the two-subjettiness, τ_2. If this is small, the jet is very two-subjetty. If it is close to 1 (or above- see note * below) then it is not.
- To get τ_1, demand a single subjet. To get τ_3, demand exactly three, and take the minimum of the three dR(i,k) values.

* Note: the min(dR(1,k),dR(2,k) *can* be larger than R. If the *average* min is larger than R (unlikely but possible), we get a value for τ_2 that is larger than 1.