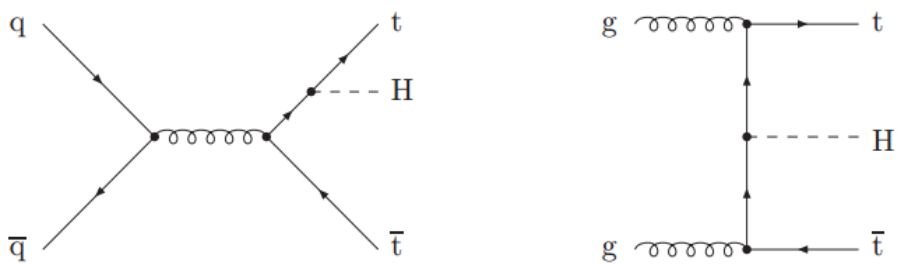
Higgs boson production in association with a top anti-top quark pair with $H \rightarrow b\bar{b}$ in $\sqrt{s}$ =13TeV

Sotiroulla Konstantinou
Supervisor: C. Diez Pardos

Thursday 8th September, 2016

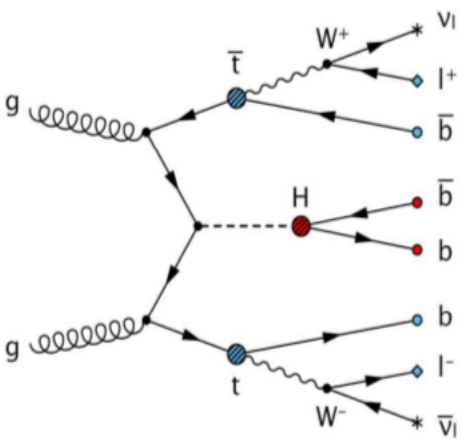
Introduction

- July 2012: Discovery of a new particle by the CMS and ATLAS Collaborations
  - Measured properties: Consistent with the Higgs Boson predicted by the SM
  - Important Discovery: Understanding of the Higgs mechanism
- Interesting measurement: Yukawa coupling of the Higgs Boson to the top quark
  - Top quark: Could play a special role in the context of the electroweak symmetry breaking due to its large mass
  - Higgs boson: Cannot decay to top quarks
  - Yukawa coupling: directly measured at the process of Higgs production in association with a top anti-top pair
  - $t\bar{t}H$ cross section ($\sqrt{s} = 13\,TeV$, $M_H = 125\,GeV$) $\sigma = 0.5pb$ (NLO) (Not observed yet)

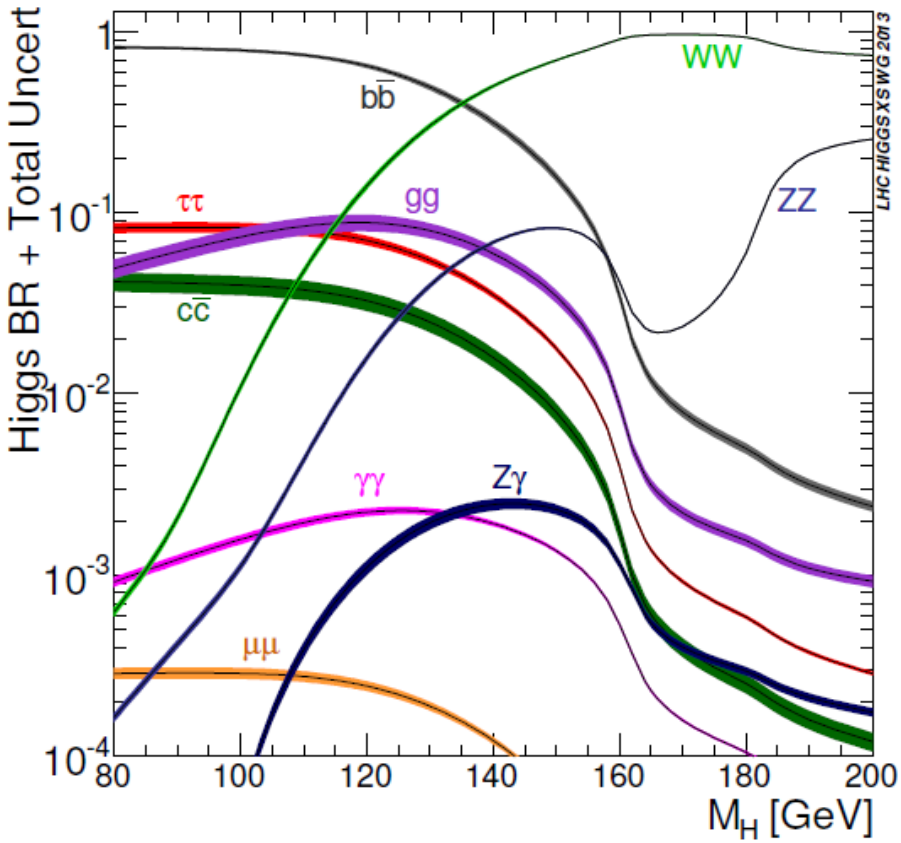


Final State

- Higgs Decay: Dominant channel
  $H \rightarrow b\bar{b}(\sim 58\%)$
- t-quark: $\sim 100\%$ to Wb
  - leptonic decay: low cross section
    $(\sim 6\%)$ but cleanest final state

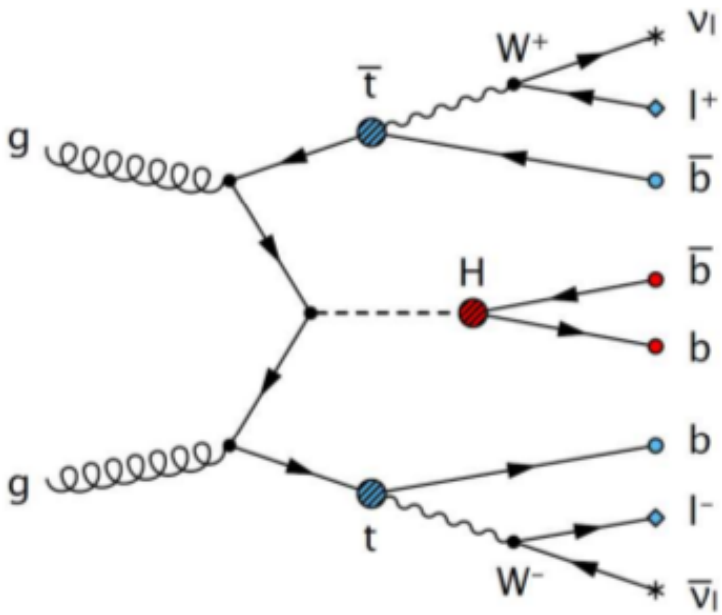


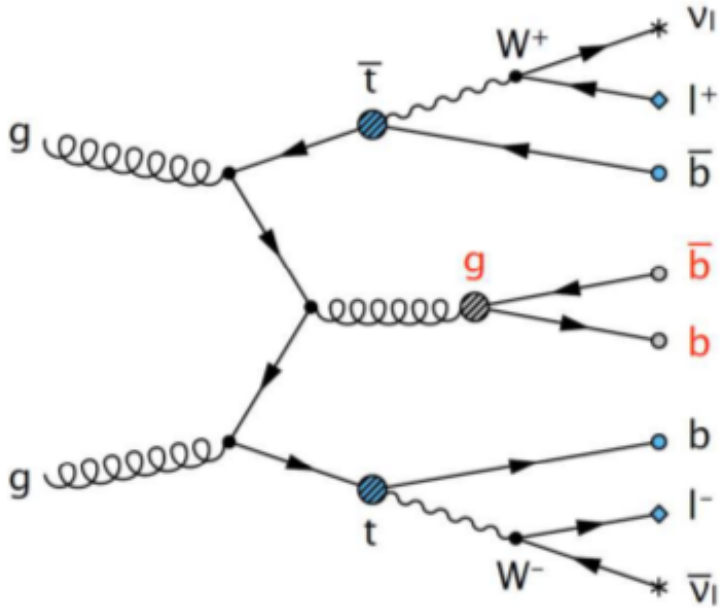
Higgs decay modes



- Four b-jets
- Two high p_T opposite signed isolated leptons

Most important background: $t\bar{t}$ +jets production



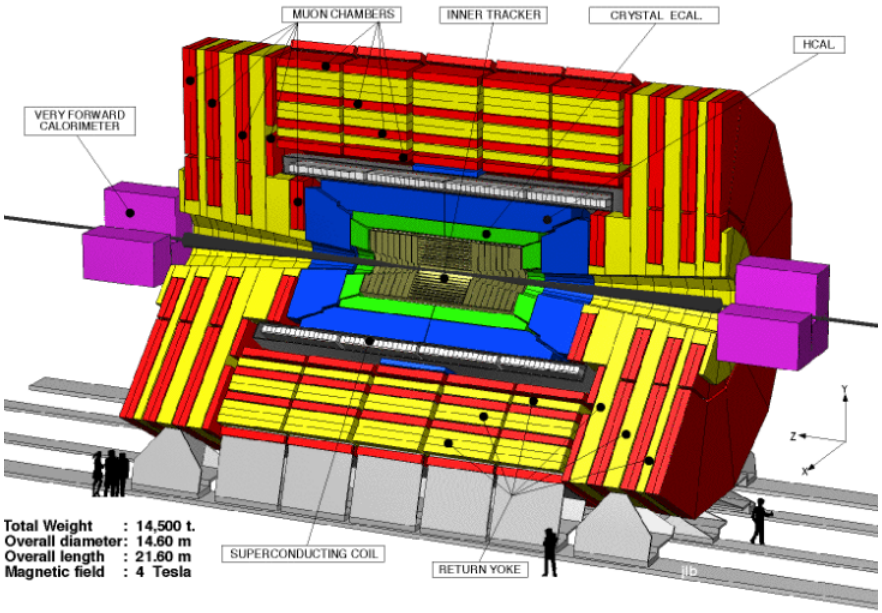


- Focus on Higgs boson with high p_T : Study improvement in sensitivity
- Study properties of merged jets

Compact Muon Solenoid - CMS

- Tracker Detector
- Electromagnetic Calorimeter
- Hadronic Calorimeter
- Muon Detector

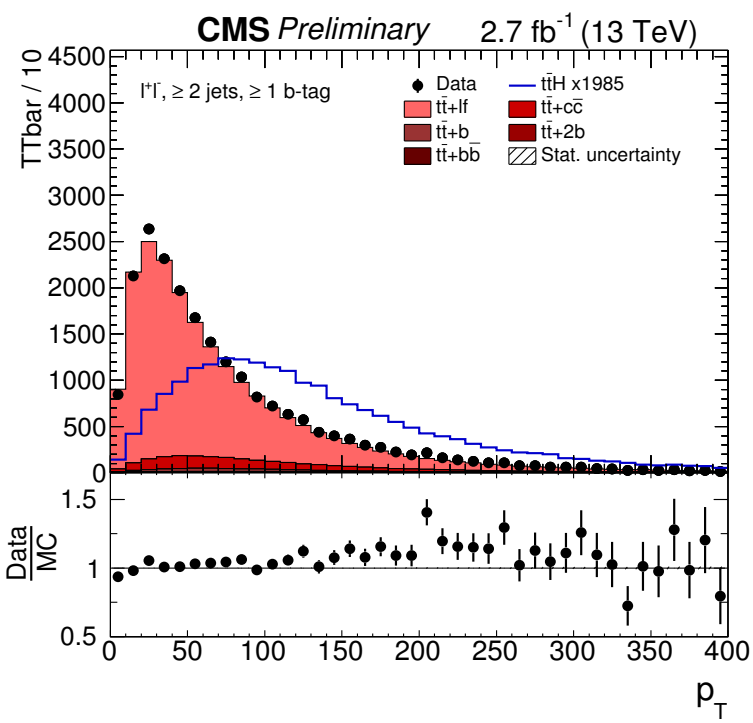
Neutrino detection: Missing transverse Energy

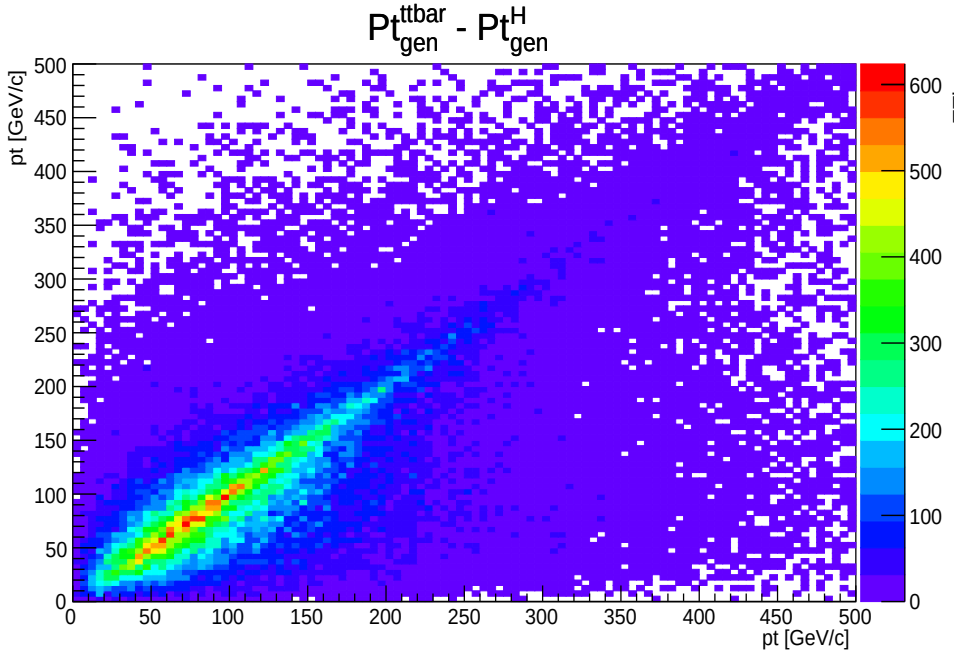


Data used in the analysis

- p-p collision data collected by the CMS detector
- $\sqrt{s} = 13$ TeV
- luminosity: 2.7 fb^{-1}

Characterizing the process





Selection:

- 2 leptons
- $\geq$ 2 jets, $\geq$ 1 b-jets

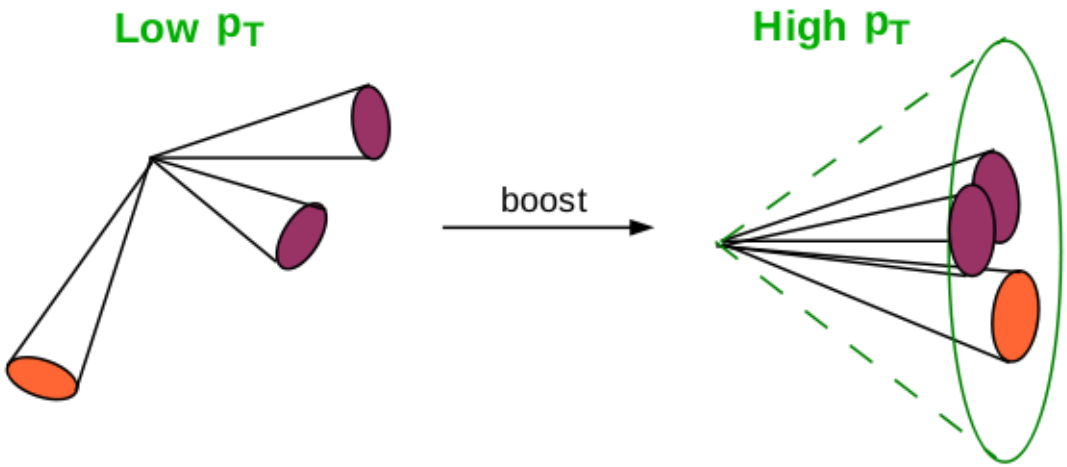
- *"Boosted regime"*: $p_T^{t\bar{t}} > 200\,GeV$

Expected and observed number of events

Sample	$2J, 1bTag$	$3J, 2bTags$	$3J, 3bTags$	$\geq 4J, 2bTags$	$\geq 4J, 3bTags$	$\geq 4J, 4bTags$	*Boosted*
Data	21768	3017	110	2852	308	27	1634
$t\bar{t}H$	26.1	1.3	0.4	8.8	4.0	1.2	5.7
Total Backgr	25374.0	3257.6	91.3	3647.9	310.2	26.3	1767.3
$signal/bckg (x10^{-2})$	0.10	0.04	0.44	0.24	1.29	4.10	0.32

Properties of boosted objects

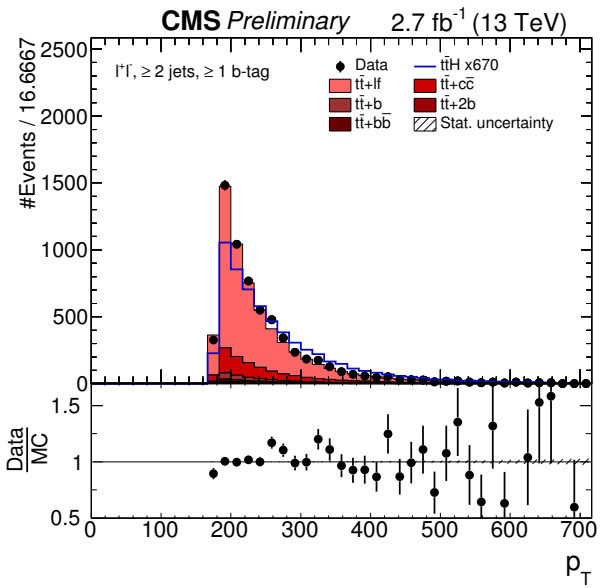
- Boosted Objects: Pass their momentum to the decay products
  - Jets: small ΔR distance
  - Products reconstructed to one big jet $\rightarrow$ Fat Jet
  - $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 1.5$



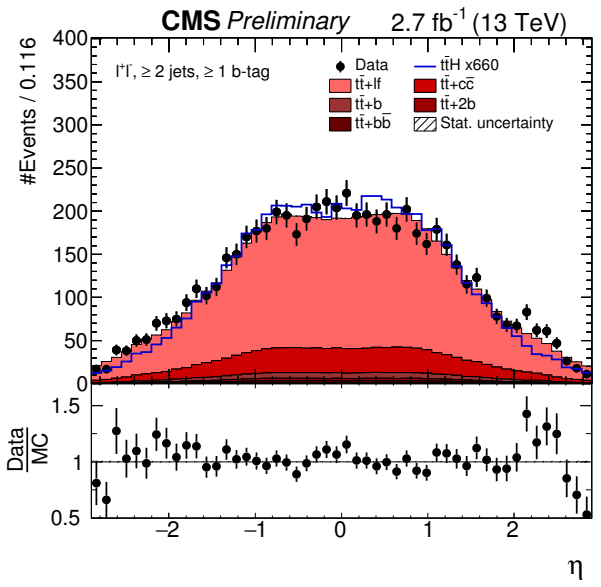
Properties of boosted objects

- Boosted Objects: Pass their momentum to the decay products
  - Jets: small ΔR distance
  - Products reconstructed to one big jet → Fat Jet
  - $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 1.5$

Fat jets P_T



Fat jets η



- Good description of the data

Fat jets - substructure

To identify if it's a Higgs boson or something else, we study the substructure of the fat jets

Algorithms: Look for the hard jets inside the fat jets and remove soft radiation

Filter Jets

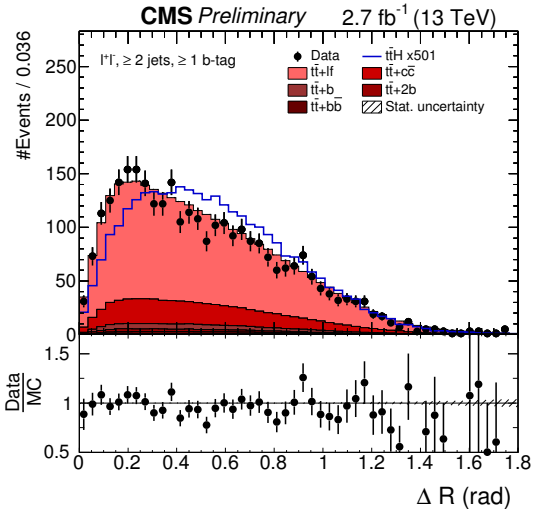
- Reconstruction of three subjets inside the main fat jet

Soft Drop Jets

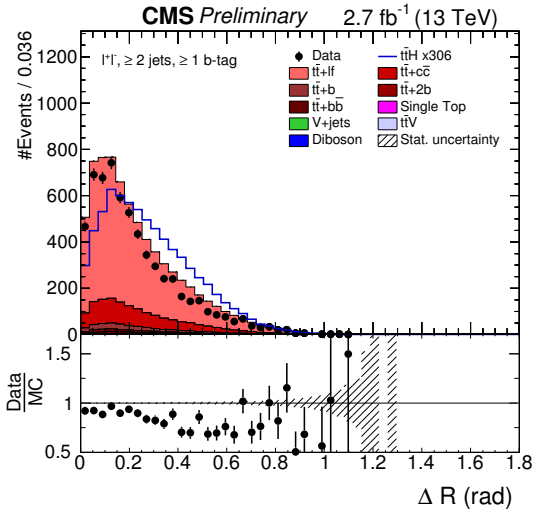
- Reconstruction of two subjets inside the main fat jet
- Removes soft wide-angle radiation from a jet

ΔR - FatJet

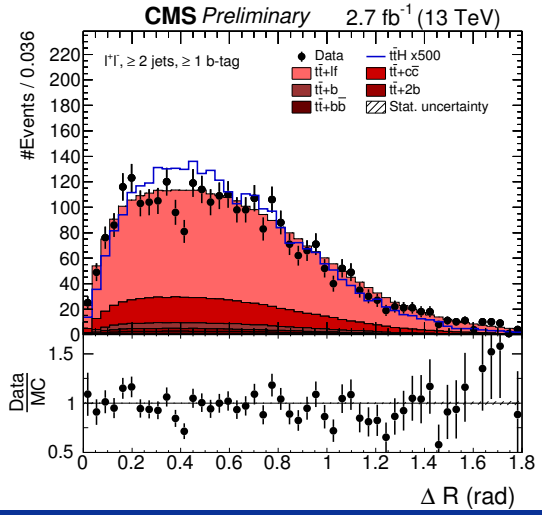
ΔR(filter1, fat)



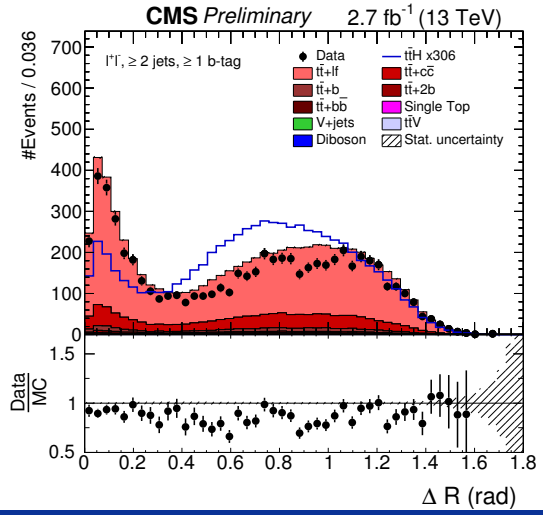
ΔR (SoftDrop1, fat)



ΔR (filter2, fat)

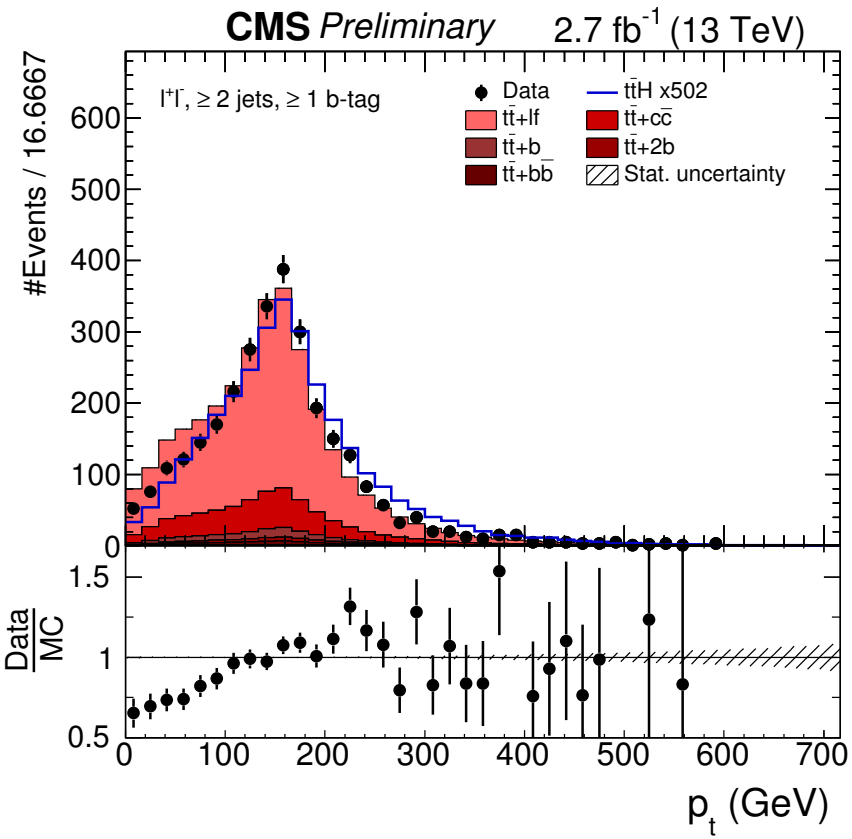


ΔR (SoftDrop2, fat)

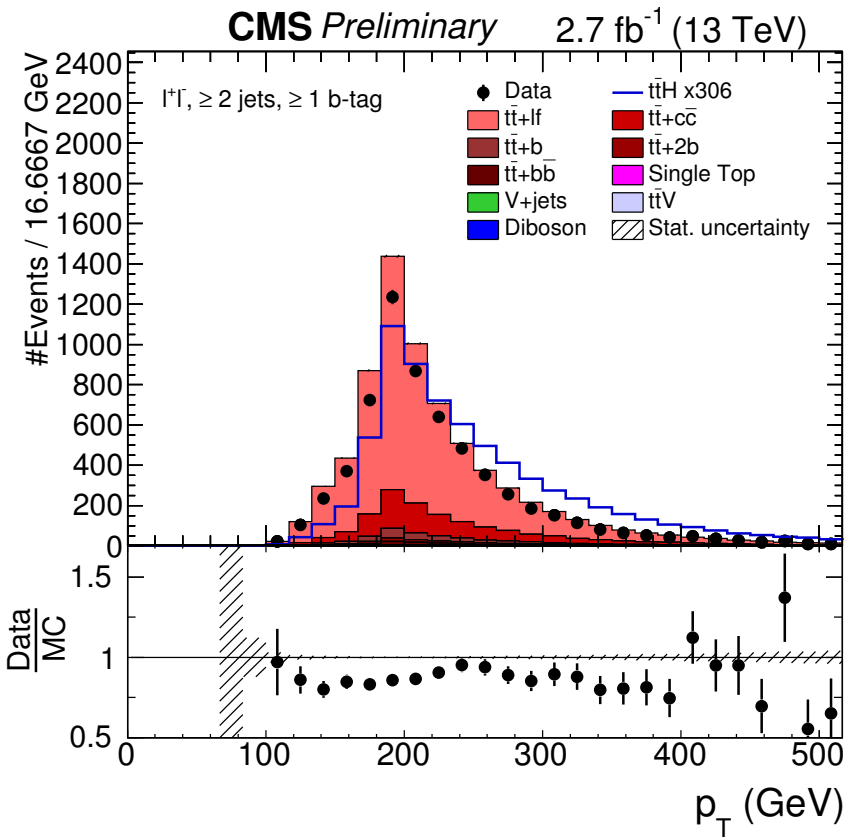


Jet1 - Jet2

filter Jets p_T^{12}

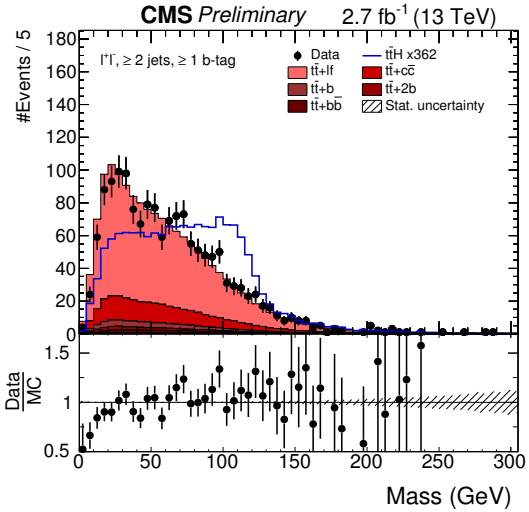


SoftDrop Jets p_T^{12}

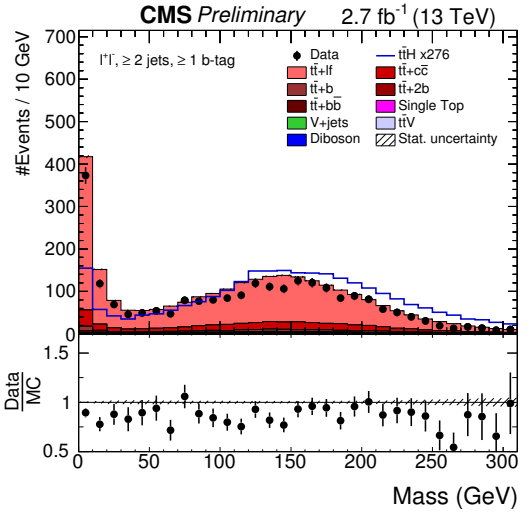


Mass (2Jets, 1 b-Tagged)

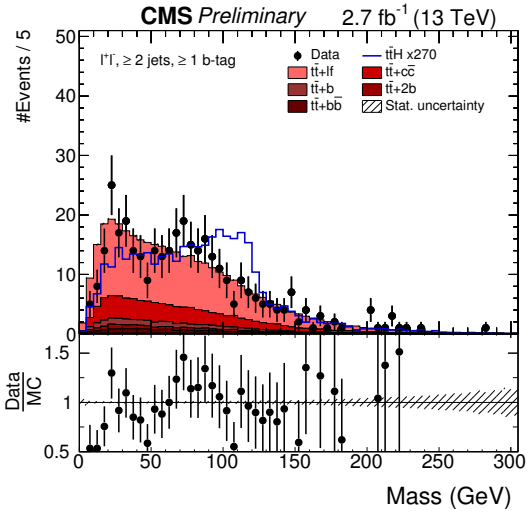
filter Jets



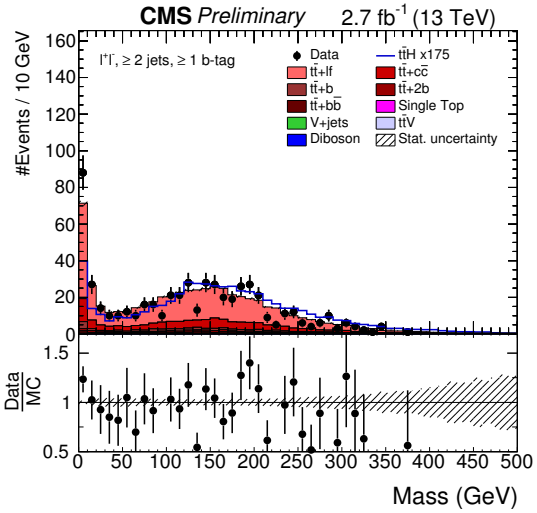
SoftDrop Jets



filter - boosted regime

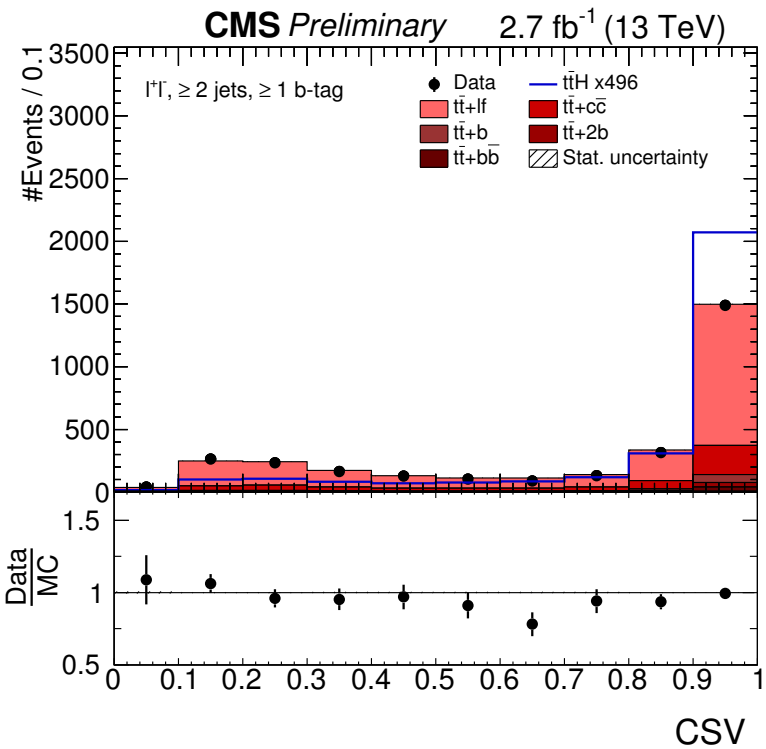


SoftDrop - boosted regime

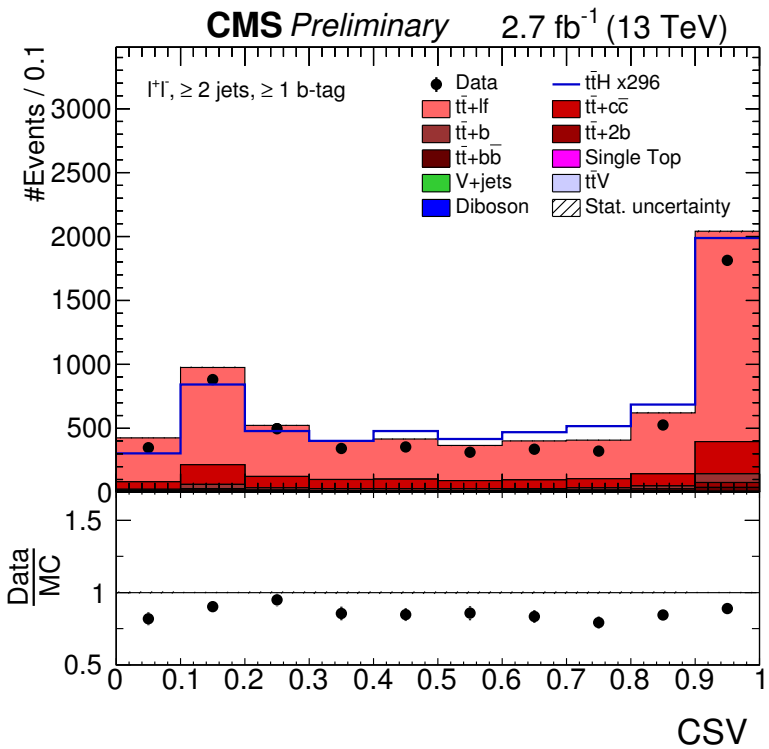


- Discriminate between b-jets from light jets
  - Output ranging from 0 to 1
    high discriminator value $\Rightarrow$ more likely it is to be a real b jet

filter hightest b-tagged jet

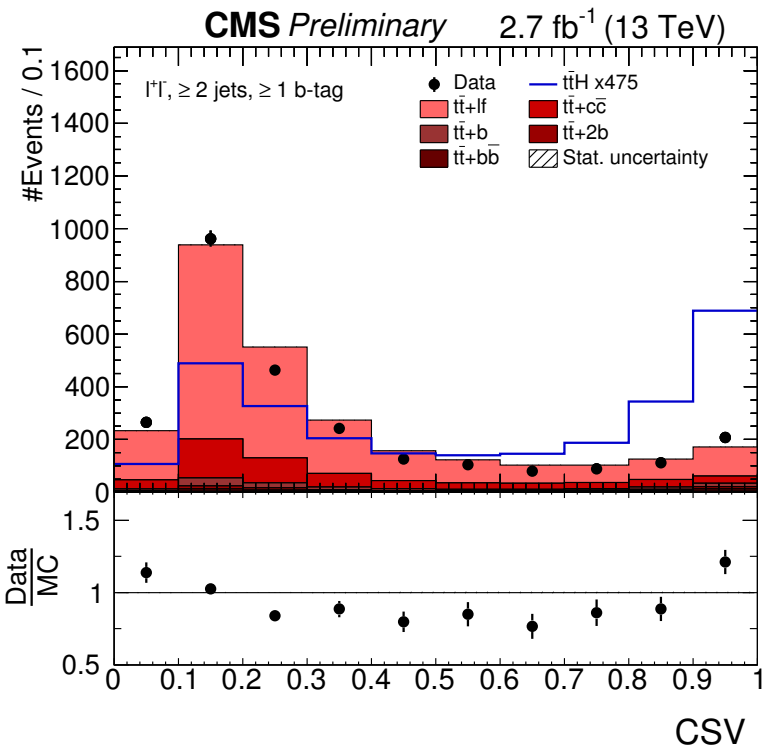


SoftDrop highest b-tagged jet

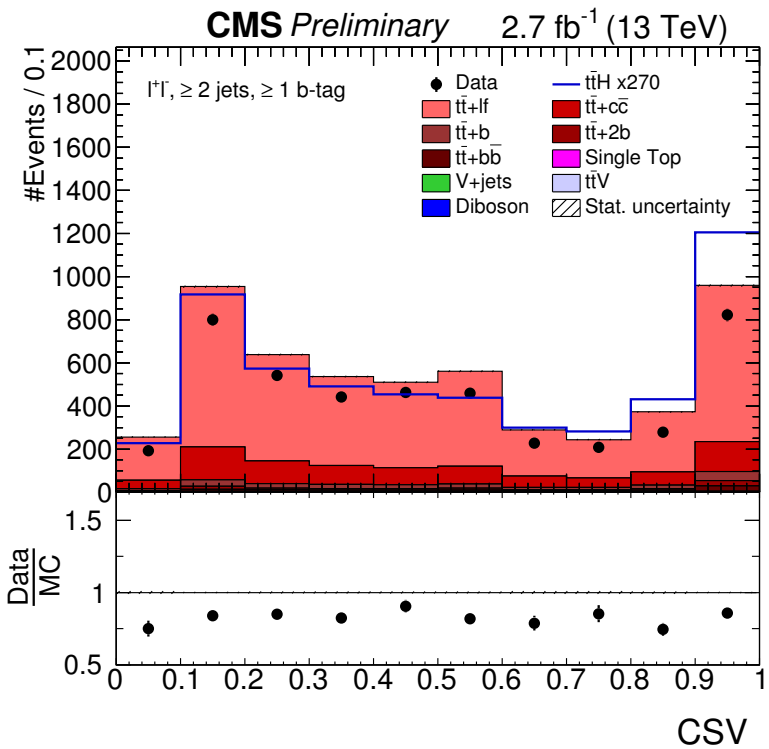


- Discriminate between b-jets from light jets
  - Output ranging from 0 to 1
    high discriminator value $\Rightarrow$ more likely it is to be a real b jet

filter 2^{nd} hightest b-tagged jet

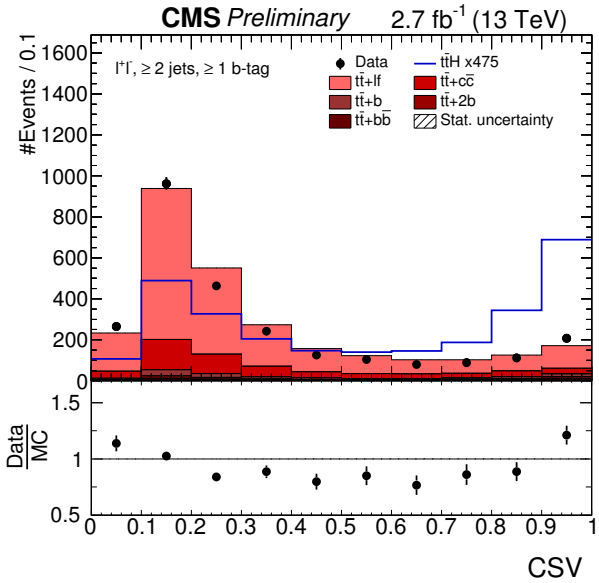


SoftDrop 2^{nd} highest b-tagged jet

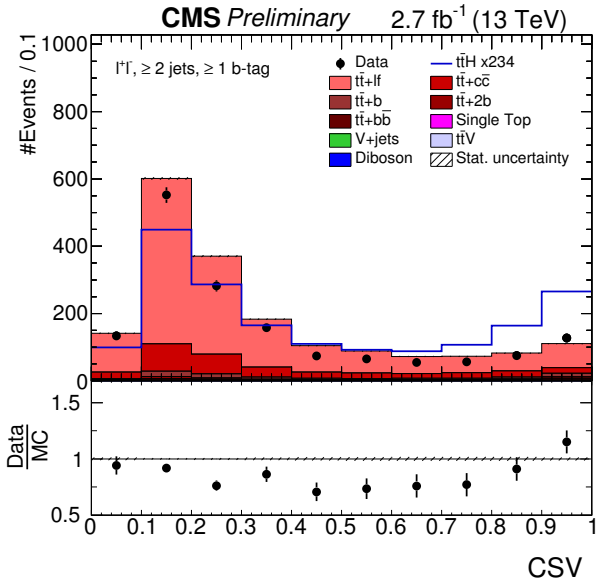


Results

filter 2^{nd} hightest b-tagged jet



filter 2^{nd} highest b-tagged jet - boosted



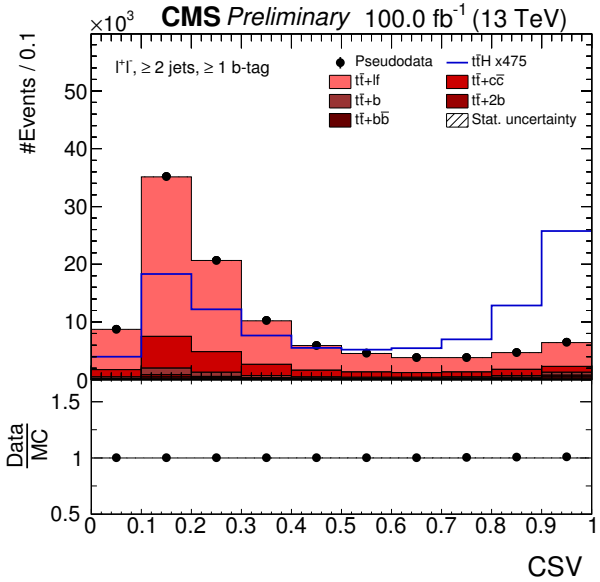
Observed and expected limit

No systematic uncertainties included

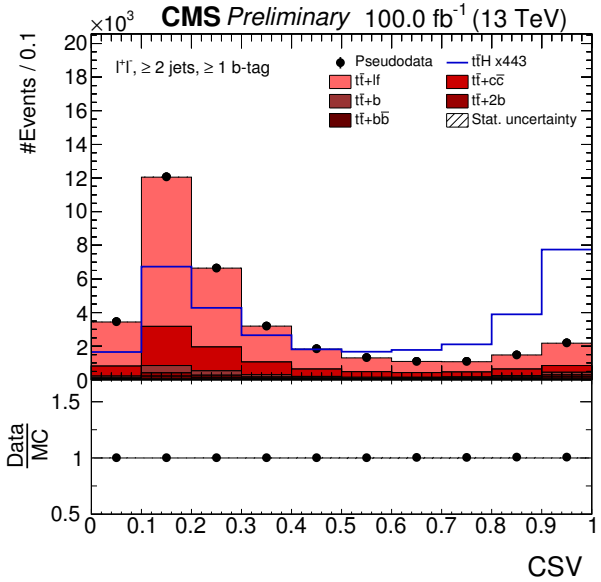
	Observed	Expected	1σ	2σ
	10.1	13.3	[9.5,18.6]	[7.1,25.0]
Boosted	13.1	23.0	[16.4,32.4]	[12.2,43.6]

Prospects with Luminosity 100 fb^{-1}

filter 2^{nd} hightest b-tagged jet



filter 2^{nd} highest b-tagged jet - boosted



Expected limit

No systematic uncertainties included

	Expected	1σ	2σ
	2.1	[1.5,3.0]	[1.1,3.9]
Boosted	3.6	[2.6,5.0]	[2.0,6.7]

Summary and Outlook

- I perform the first studies of the sensitivity of $t\bar{t}H$ in the boosted regime
- Comparison of two algorithms to identify decays of boosted Higgs to $b\bar{b}$
- Identify which variables have discriminant power
- First preliminary limits using boosted Higgs boson reconstruction
  - Next step: add systematic uncertainties
- This information can be included in the final analysis

Backup

Fat jets - substructure

To identify if it's a Higgs boson or something else, we study the substructure of the fat jets

Filter Jets

- Reconstruction of the subjets inside the main fat jet

Soft Drop Jets

- Removes soft wide-angle radiation from a jet
- Jet of radius R_o with two constituents ($p_T^1 > p_T^2$)

$$\frac{min(P_T^1, P_T^2)}{P_T^1 + P_T^2} > z_{cut}(\frac{\Delta R_{12}}{R_o})^{\beta} \quad (1)$$

  - True: j_{th} jet is the final soft drop jet
  - False: j=j1
- Parameters z, β:
  - $z_{cut} = 0.1, \beta = 0.0 \rightarrow$ *Default*
  - $z_{cut} = 0.2, \beta = 1.0 \rightarrow$ *Z2B1*