Identification of Boosted $h \rightarrow bb$-Decays with the ATLAS-Detector

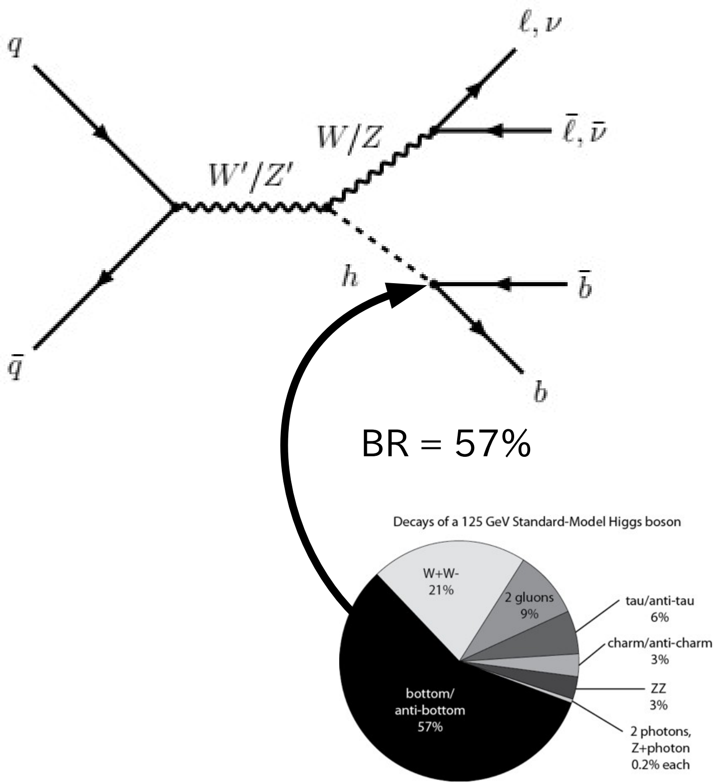
Stefan Raimund Maschek

Supervised by Dominik Duda

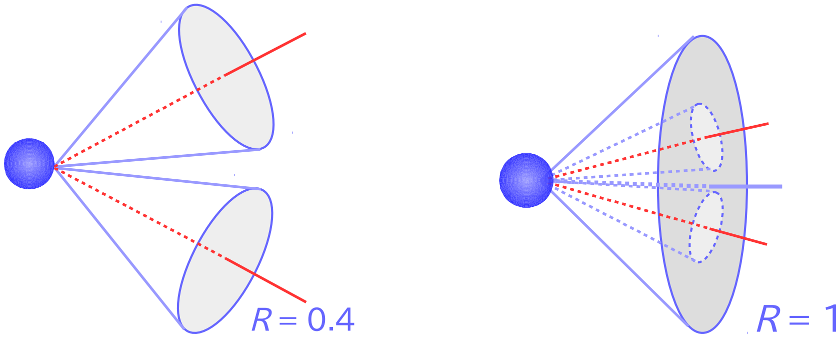
DPG spring meeting, March 27th 2019

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

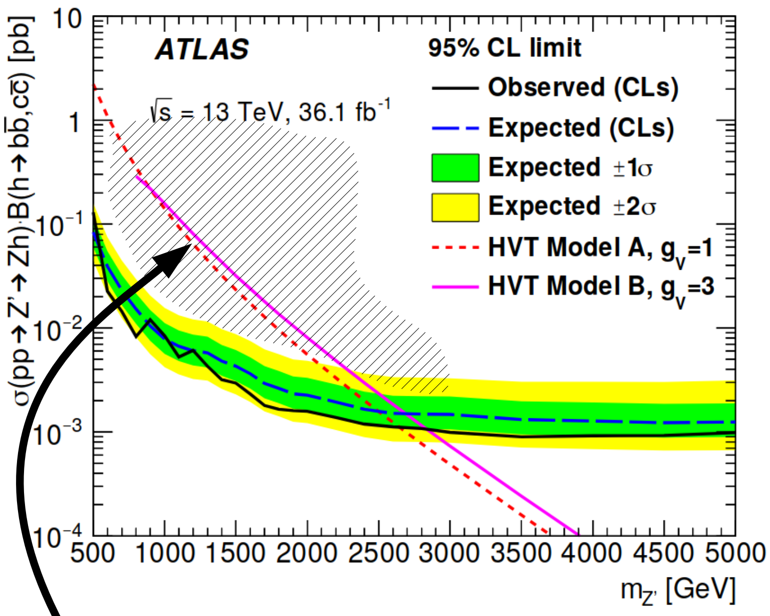
Introduction



- **Search for heavy diboson resonances decay into Zh or Wh (→ T.53.2, Andreas Hoenle)**
  - Predicted by several theoretical models
    - Minimal walking technicolor, composite Higgs, ...
  - Interpreted in a Phenomenological Lagrangian
    - Heavy vector triplet (HVT)
  - **Z and W**: leptonic decay into 0,1,2 charged leptons
    - **3 Channels** depending on lepton multiplicity
  - **h:** decay into bottom quarks
    Depending on the higgs momentum:
    - Lower Momentum ($p_T \lesssim 300$): Reconstruct two small (R=0.4) **resolved** b-jets
    - High Momentum ($p_T \gtrsim 300$): Reconstruct one **merged** jet (R=1)

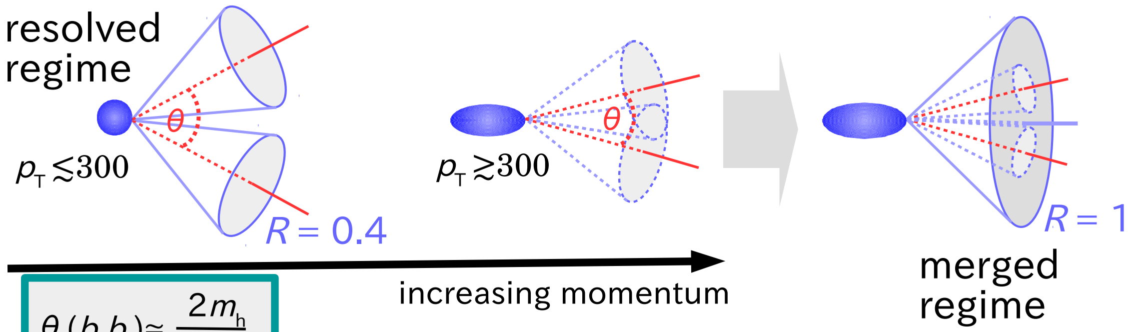


Last Public Results



Heavy vector triplet:
low masses are excluded

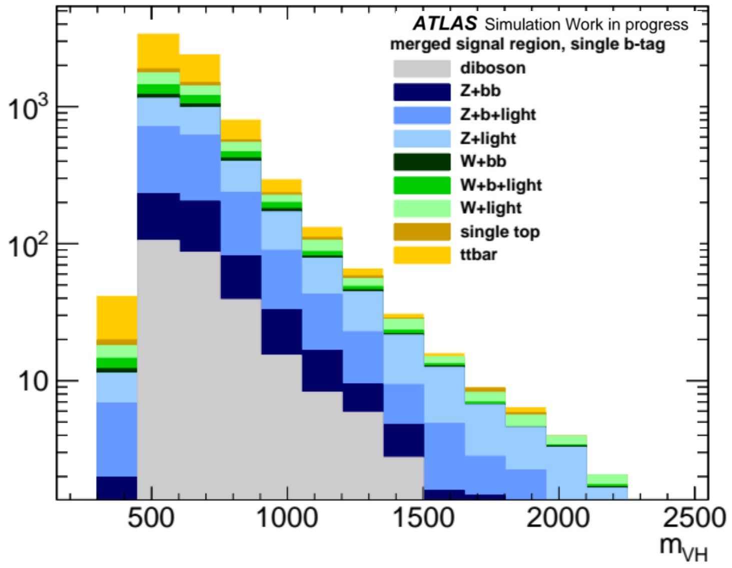
high Higgs momentum expected



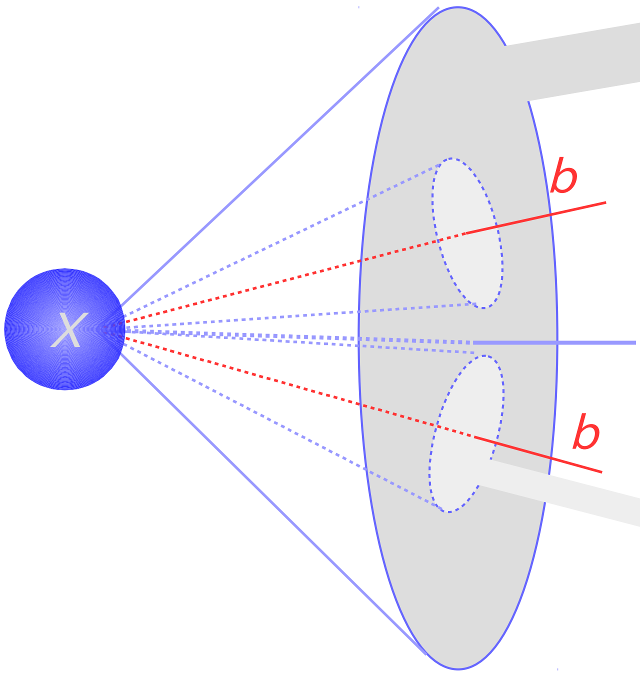
$$\theta(b,b) \simeq \frac{2m_h}{p_T}$$

Background composition in merged regime

- tt, single top
- Z+jets
- W+jets
- Diboson



Boosted Higgs→bb Tagging



Candidate jet
- Anti k_T R=1.0 Calorimeter
- Trimmed (pile-up mitigation)
- Muon-in-jet correction
- Combined mass

→ Measure mass of jet

↓

1st part of the talk

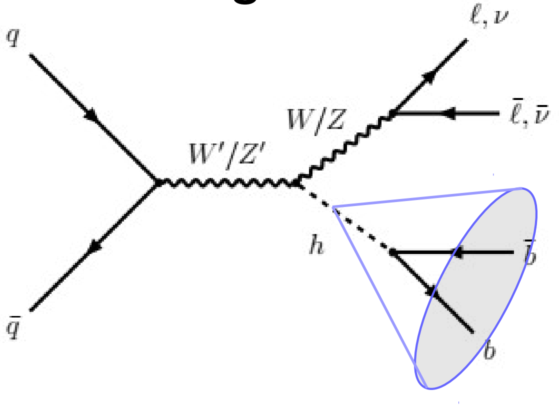
Track jets
- Matched to candidate jet
- Different jet definitions possible
- b-hadron identification using BDT/DNN

→ *b*-hadron identification

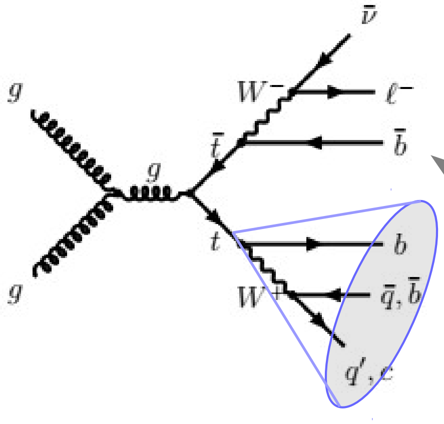
↓

2nd part of the talk

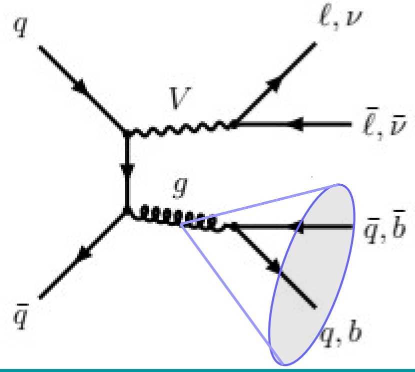
HVT signal



tt, single top

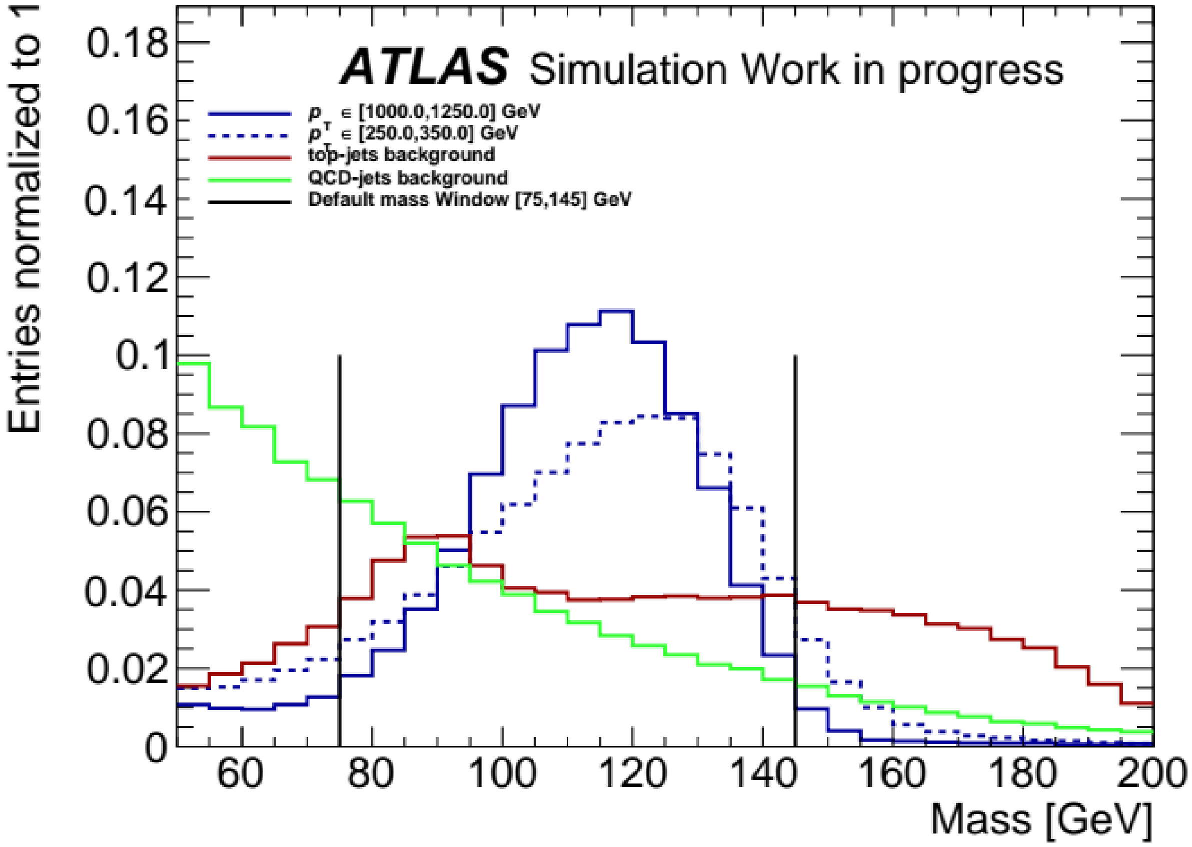


Z+jets, *W*+jets



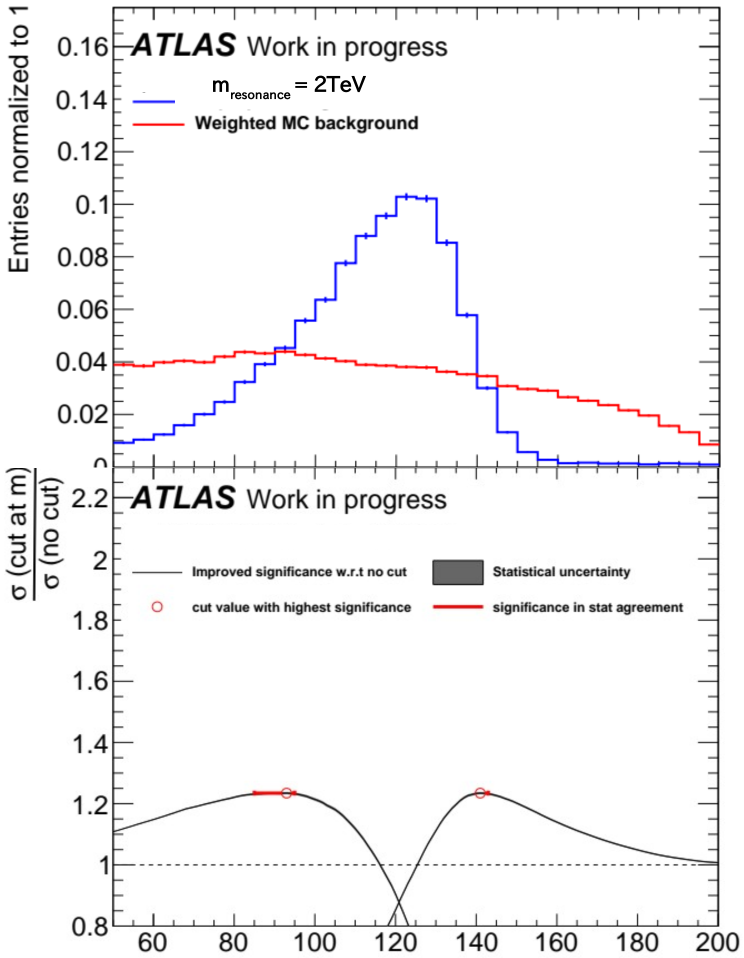
- **Top jet, (W-boson-jet)**
  - use mass and b-tagging to discriminate
  - Veto b-jets outside Candidate Jet
- **QCD jet**
  - Light-flavour QCD jets (u,d,s,c)
    - use mass and b-tagging to discriminate
  - Heavy-flavour QCD jets (e.g. g→bb)
    - suppressed by the mass cut

Mass Window Cut



- Default cut values on the $m_{bb/h}$ is at [75,145]
- Especially lower cut is not optimal
- Optimal cut seems to be resonance mass dependent

Mass Window Optimization



- Define reference significance without cut (normalized entries)

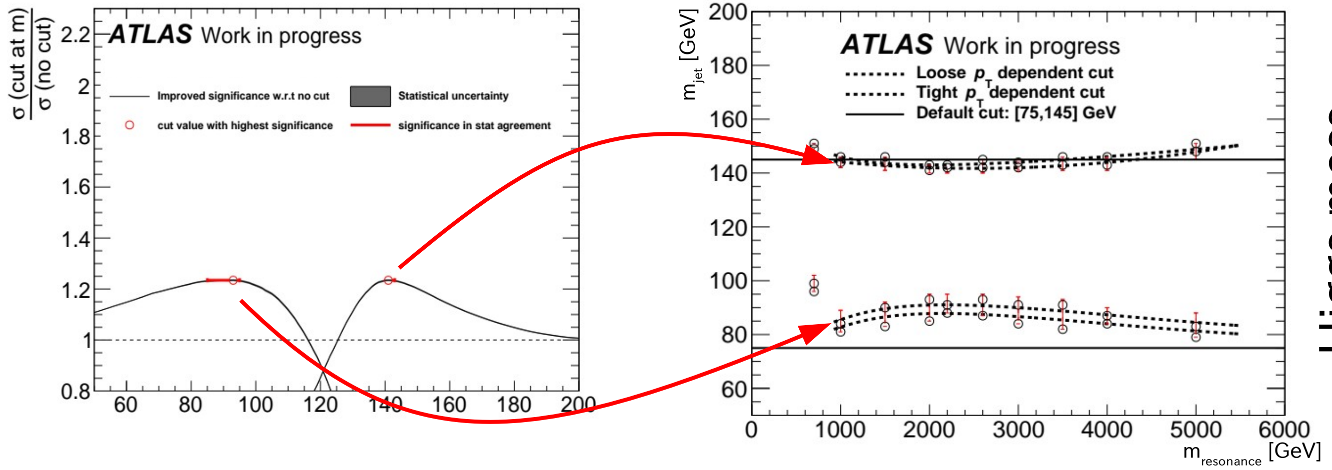
$$\sigma_0 = \frac{S}{\sqrt{B}} = 1$$

- Significance improvement

$$\Delta\,\sigma(m_{BB}^{low}, m_{BB}^{high}) = \frac{\sigma(m_{BB}^{low}, m_{BB}^{high})}{\sigma_0} = \frac{\varepsilon_S}{\sqrt{\varepsilon_B}}$$

- Take cut pair with highest Δσ as optimal cut values.
  - *For demonstration purpose (lower plot): Fix one of the cut values, vary the second*
- Cut pairs with $\Delta\sigma(m^{low}, m^{high})$ in statistical agreement with maximum: '*Uncertainty*' on the optimal cut value

Mass Window Optimization



Higgs mass

- Best choice of cut values is dependent on resonance mass
  - We do not want to repeat analysis for each mass point
  - Resonance mass is correlated to jet p_T

- Detector mass resolution depends on transverse momentum
  - Low momenta: Out of cone effects $\sim 1/p_T$

$$\delta m \propto \frac{1}{p_T}$$

  - High momenta: Mass resolution goes linear with p_T

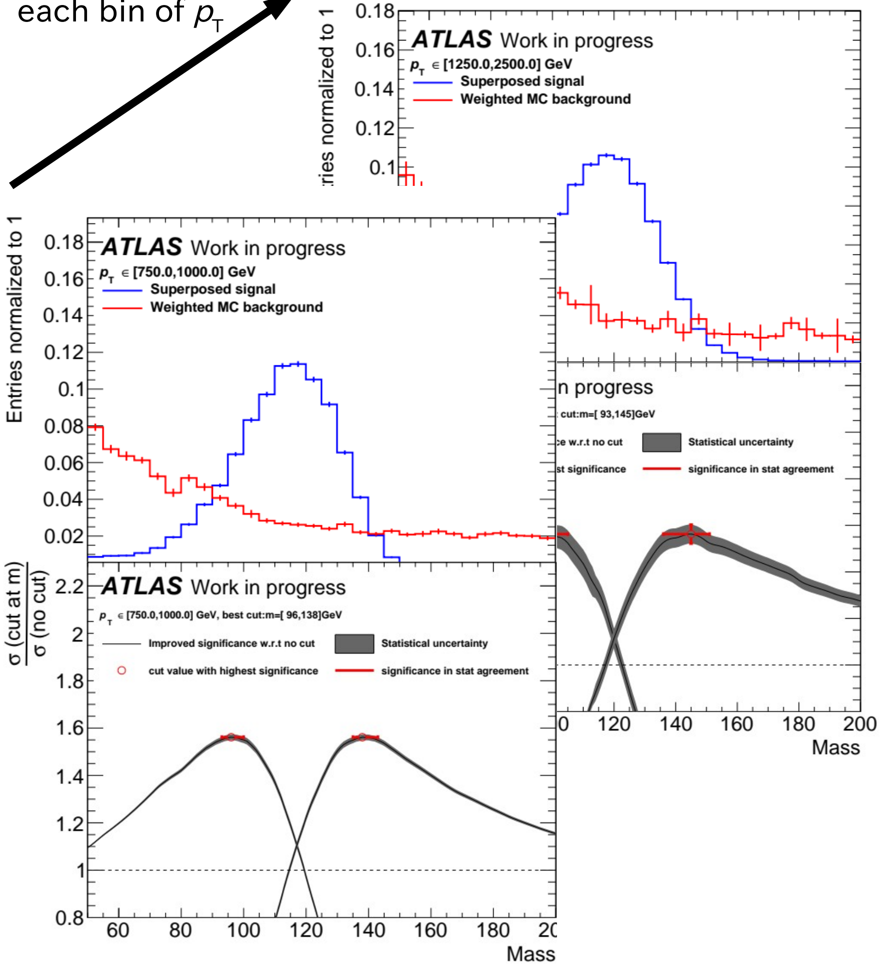
$$\delta m \propto a \cdot p_T + b$$

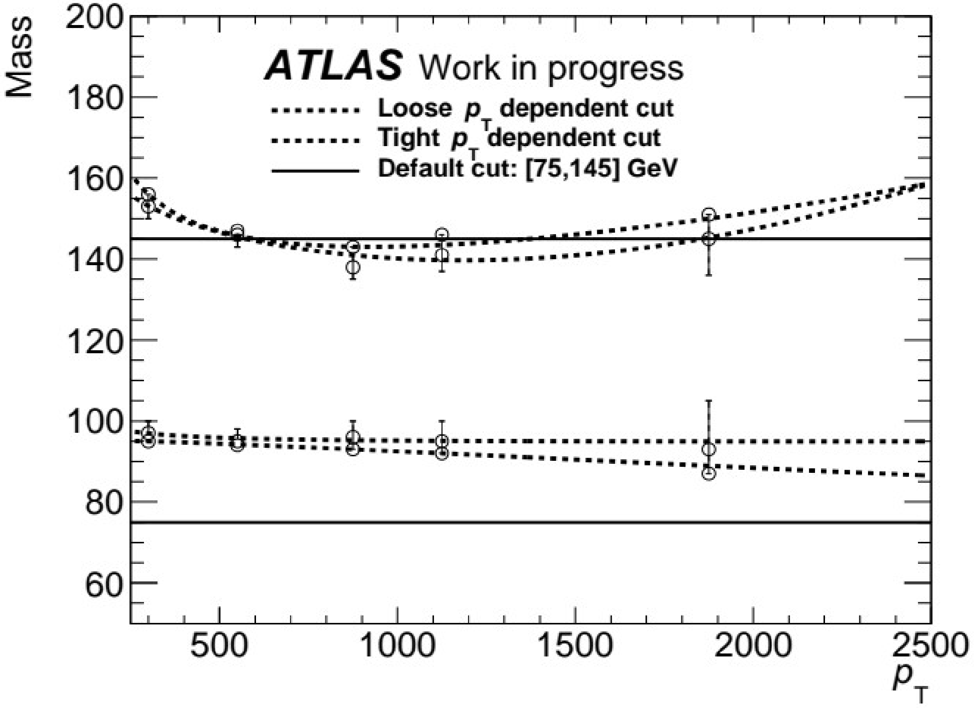
p_T dependent mass window

$$m_{cut} = \sqrt{\left(\frac{a}{p_T}\right)^2 + (b \cdot p_T + c)^2}$$

Mass window cut optimization with Background

separately in
each bin of p_T





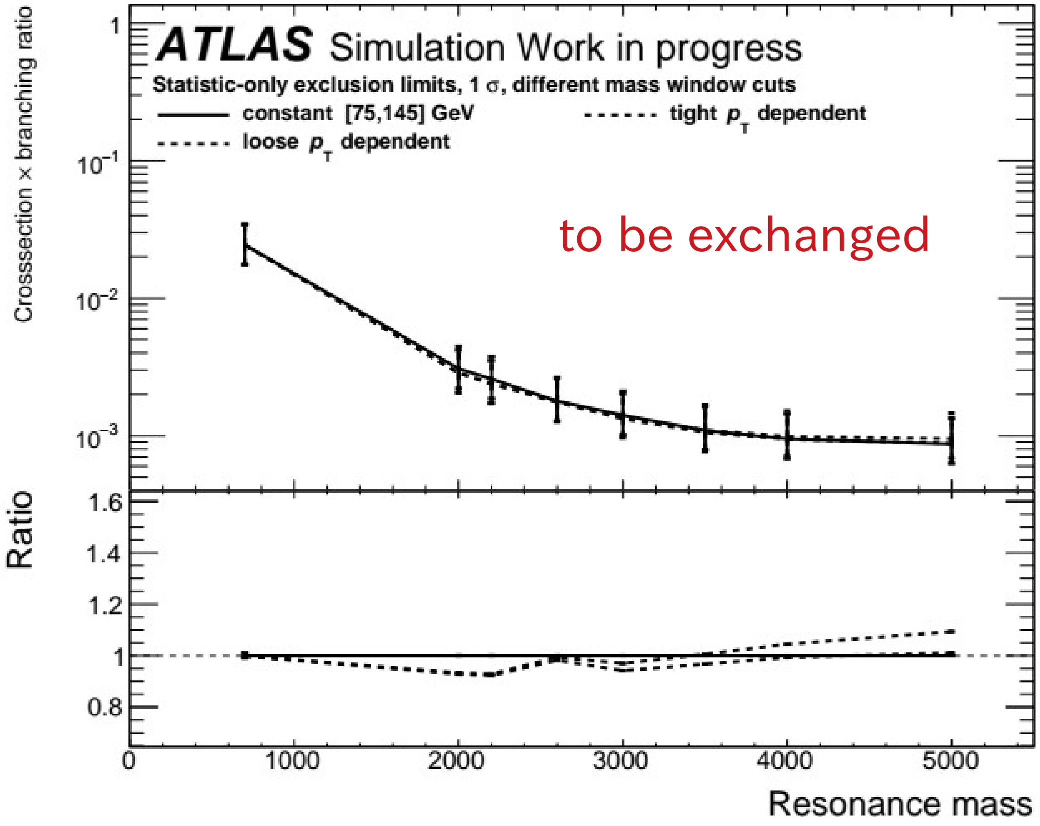
p_T dependent mass window

$$m_{cut} = \sqrt{\left(\frac{a}{p_T}\right)^2 + (b \cdot p_T + c)^2}$$

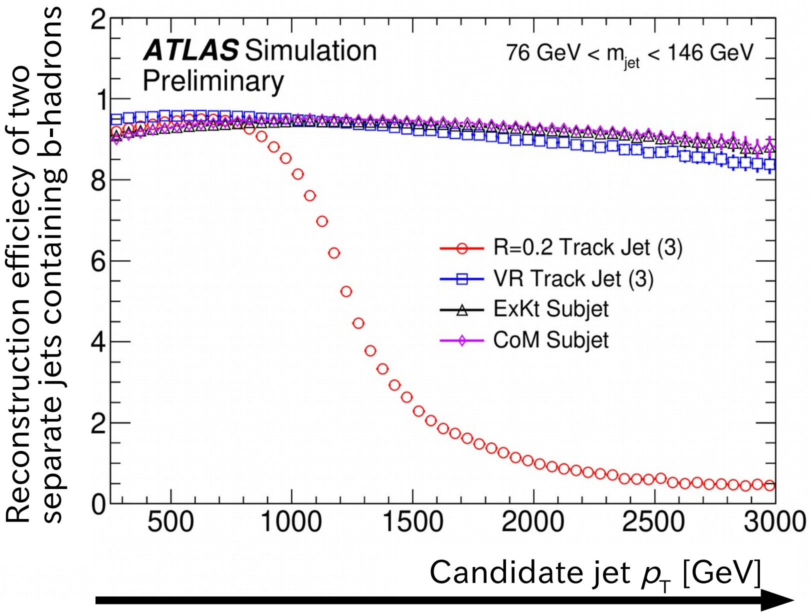
Background rejection

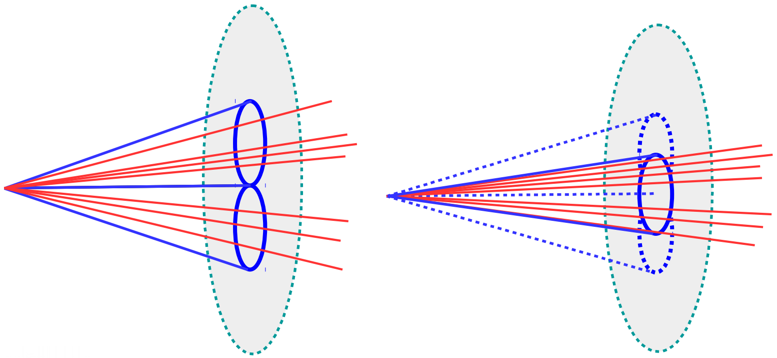
Selection reduction by new mass cut		
	1tag	2tag
signal	86%	90%
ttbar	83%	90%
W/Z+jets	55%	55%

- Statistic only likelyhood fit
- Expected limits with two different mass window approaches
  - Constant mass window
  - p_T dependent mass window
- Improved limits of up to 10% on cross section for most resonance masses

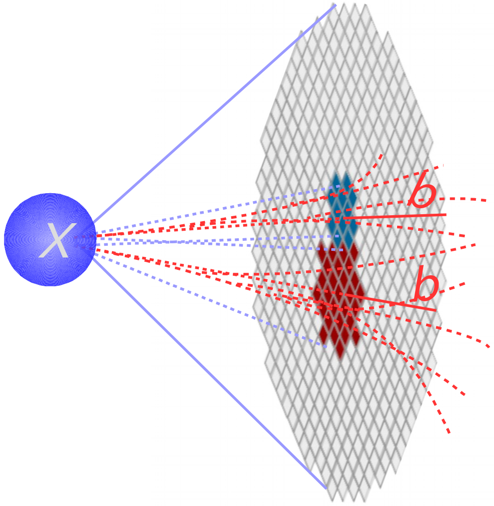


Merging Trackjets





- At some point (~1TeV) also R=0.2 subjets cannot be reconstructed separately
- Solutions:[ATL-PHYS-PUB-2017-010]
  - Variable radius trackjets (VR)

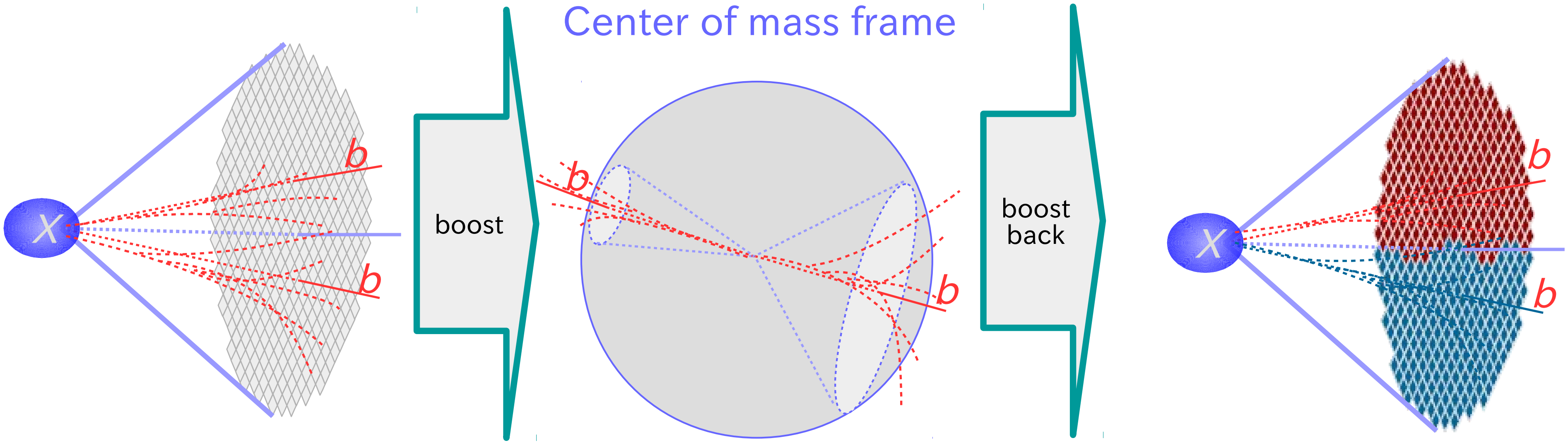


    - Current default
    - Idea: The higher the sub-jet momentum, the more collimated
    - While track jet clustering, decrease R parameter with increasing jet p_T

$$R = \frac{\Delta}{p_T}$$

  - Center of mass subjets (CoM)

The Center of Mass Reclustering



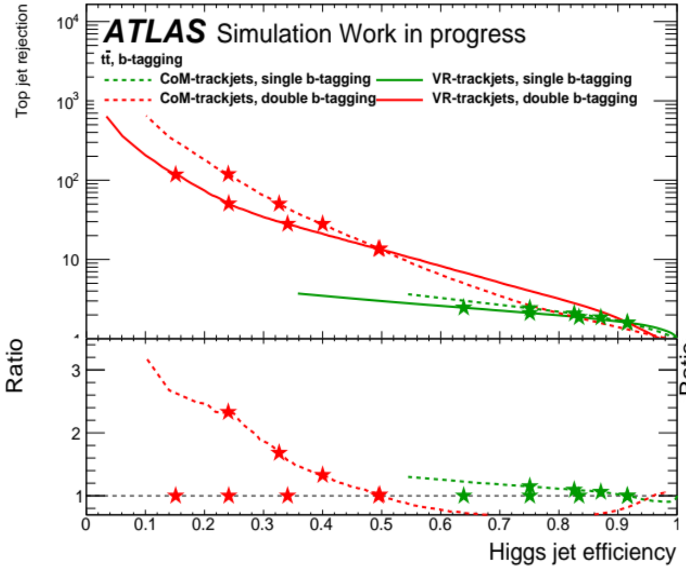
- Perform a boost into the large-R rest frame
- Back-to-back topology of the decay products
- Recluster the jet components with exclusive kt (demand exactly 2 jets with k_T algorithm)

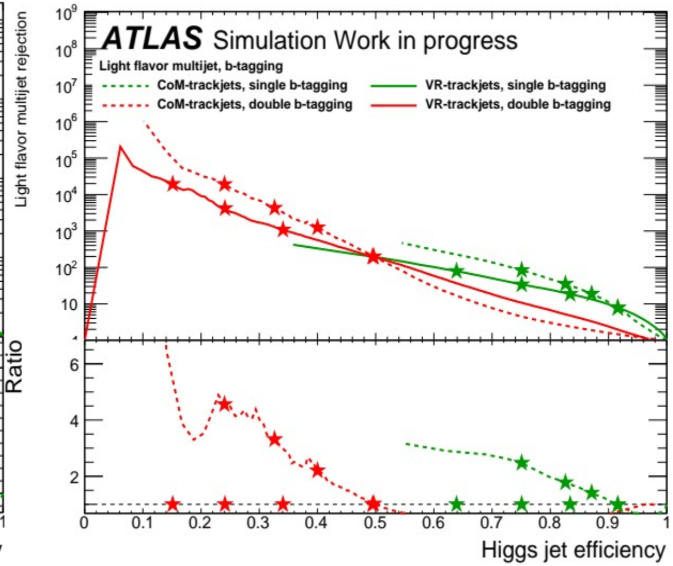
Background Rejection Improvement by CoM Subjets

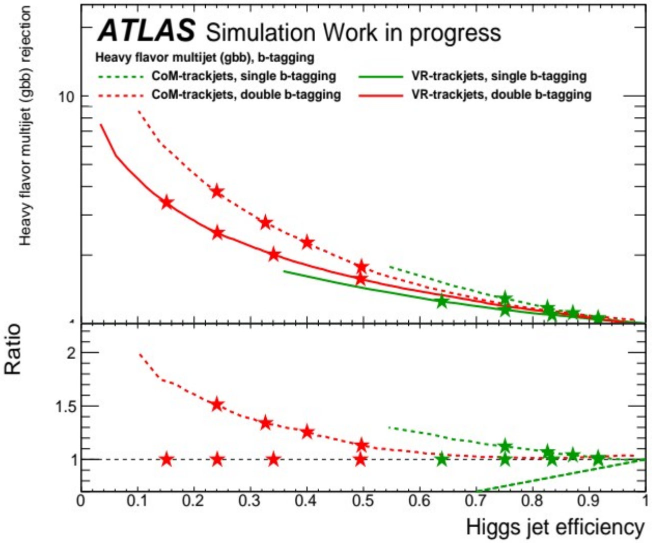
Top-jet rejection

Light flavour QCD-jet rejection

Heavy flavour QCD-jet rejection





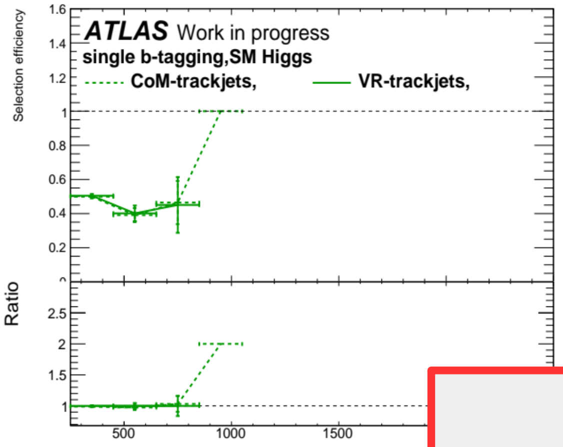


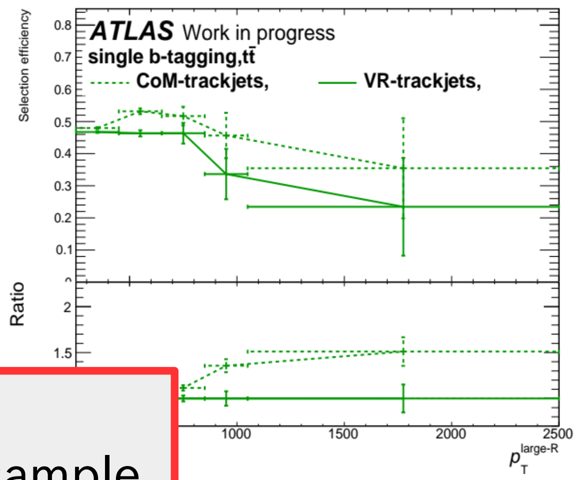
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

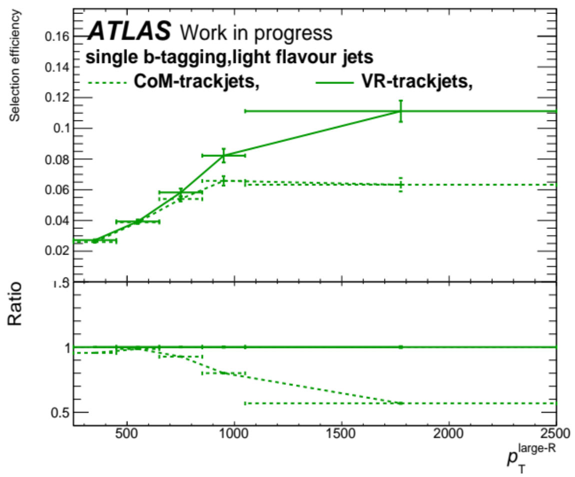
Summary

- Higgs jet ($h \rightarrow bb$) identification in the VH resonance channel
- Optimization studies
  - Variable mass window
    - Potential of lowering exclusion limits about 10%
  - b-tagging in Center-of-mass jets
    - Improvement of background rejection of 50% up to 400%
- Outlook:
  - <improve mass window optimization>
  - Calculate limits for Center-of-mass jets

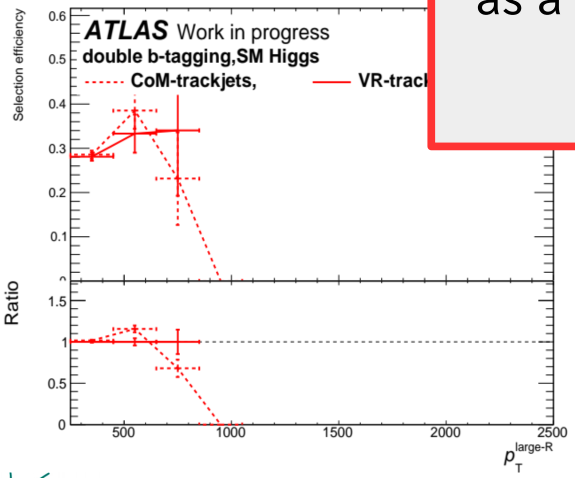
Efficiency improvements by CoM Subjets

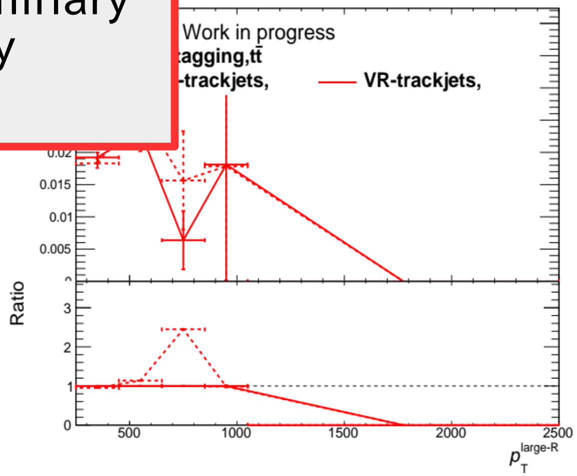


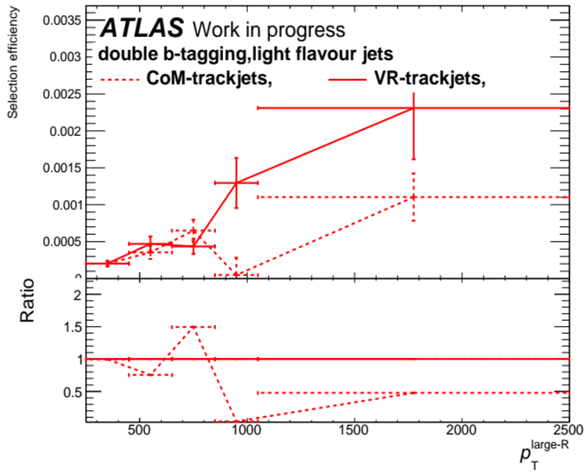




SM higgs sample as a preliminary proxy



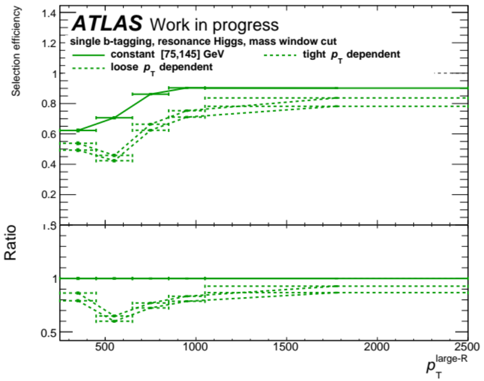


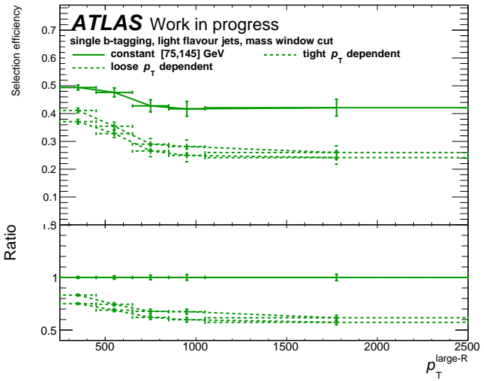


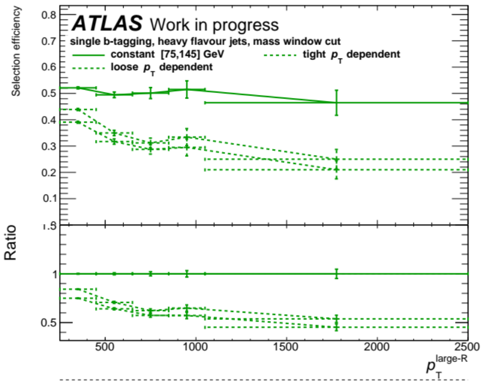
Mass Window Signal and Background Efficiencies

signal | light flavour | heavy flavour

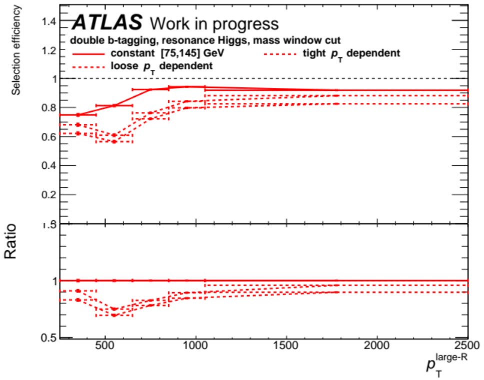
1tag

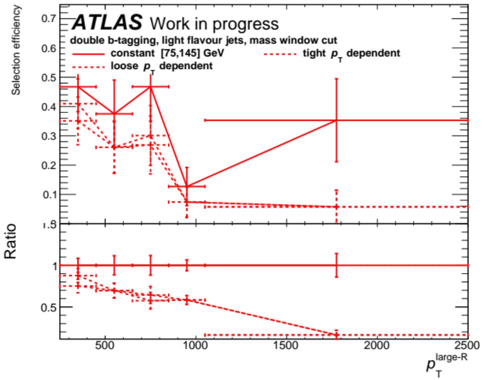


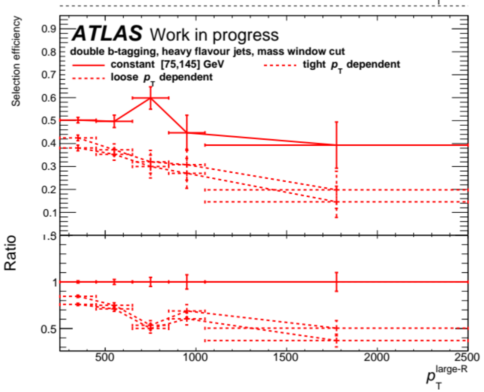




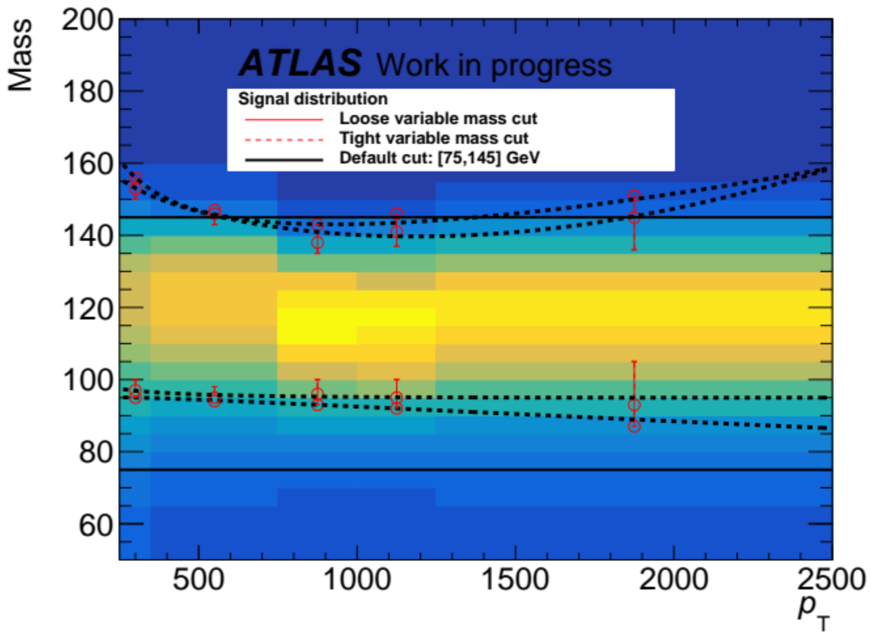
2 tag

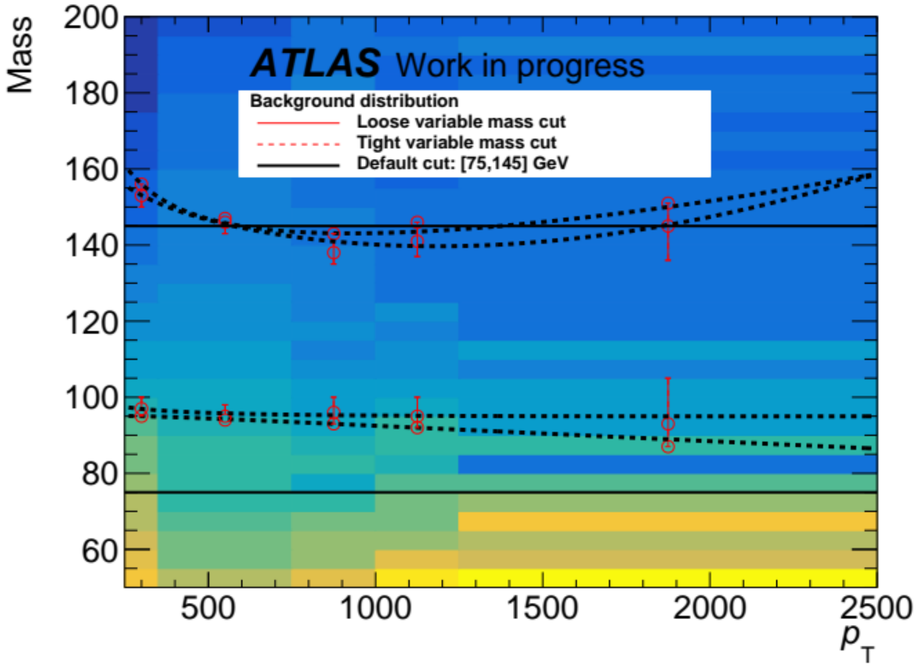






Result





$$m_{cut} = \sqrt{\left(\frac{a}{p_T}\right)^2 + \left(b \cdot p_T + c\right)^2}$$