# b-tagging performance optimization for neutral MSSM Higgs bosons search with the ATLAS detector

A. Manfredini[1], J. Bronner[1], S. Kortner[1], R. Sandstroem[1], S. Stern[1], D. Zanzi[1]

[1]Max-Planck-Institute for Physics

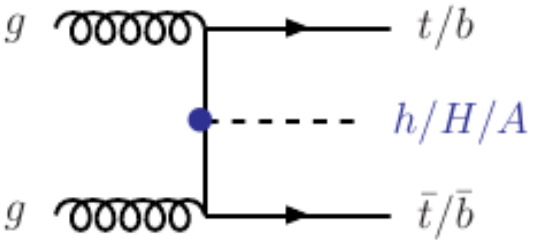
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

FSP 101 ATLAS

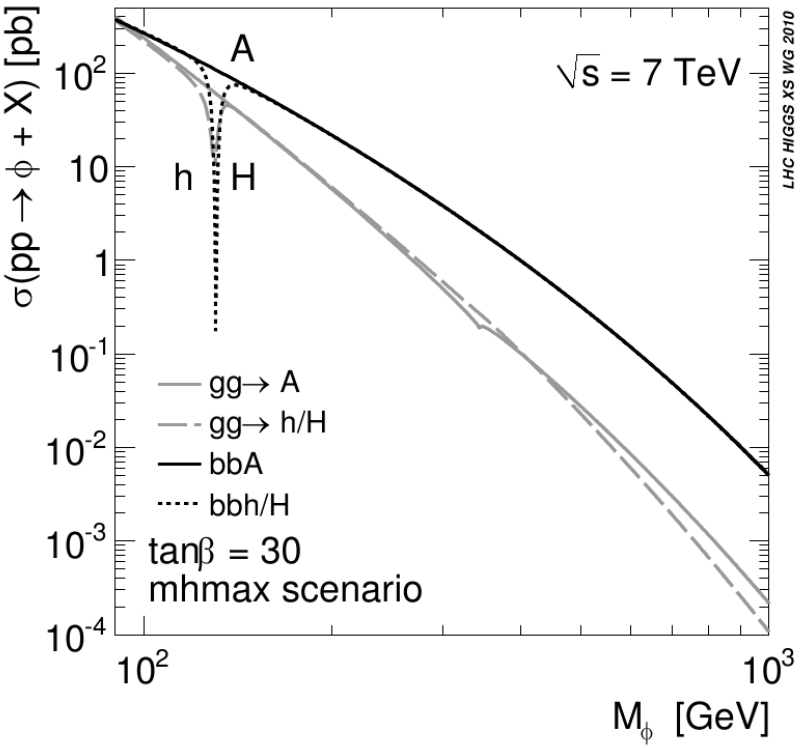
ATLAS EXPERIMENT

# Introduction

- Motivation of this study is optimization of the MSSM Higgs boson search




- One of the dominant production mode at LHC is "Associated b-quark production"



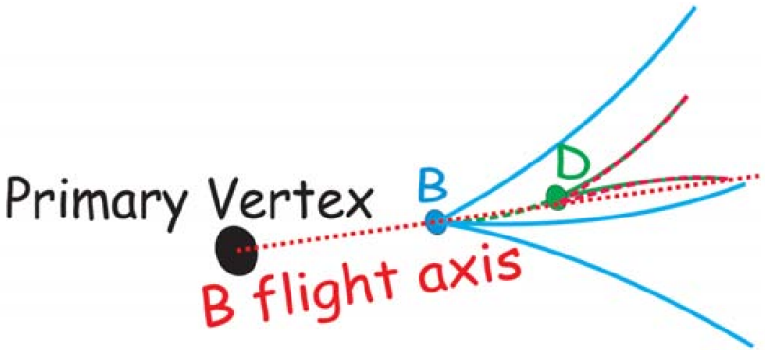

- We consider it's decay in τ pairs

# Introduction: Signature

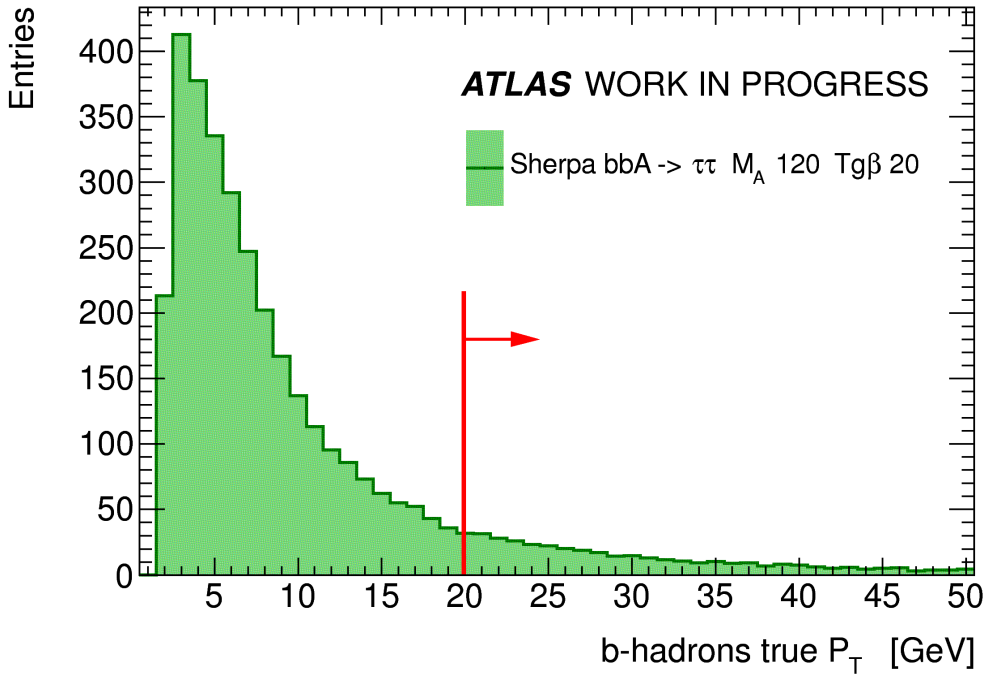
- 2 highly energetic and opposite charge $\tau$ that can undergo either lepton or hadron decays
- Missing Energy (neutrinos from $\tau$ decay)
- 2 b-jets: very specific! gives the opportunity to reduce backgrounds as $Z \rightarrow \tau\tau$ + jets
  - Needs b-tagging!

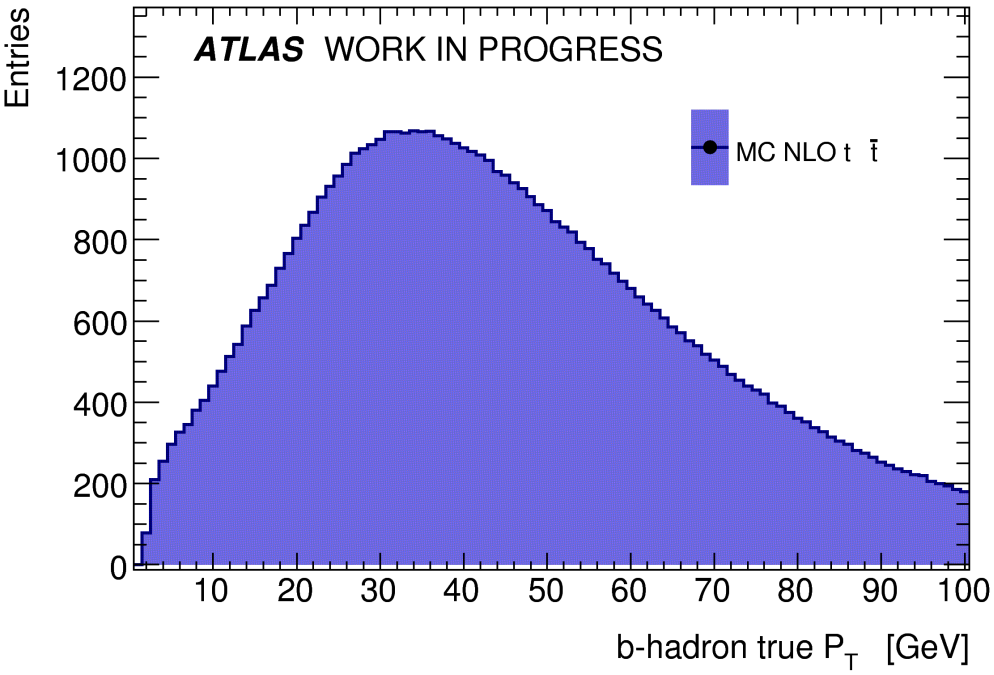
# Introduction: b-tagging

- Identification of b-hadron decay chain is possible due to their high mass
- In general two different approaches:
  - Impact parameter: measure of the deviation of the tracks from primary vertex
  - Secondary vertex finder



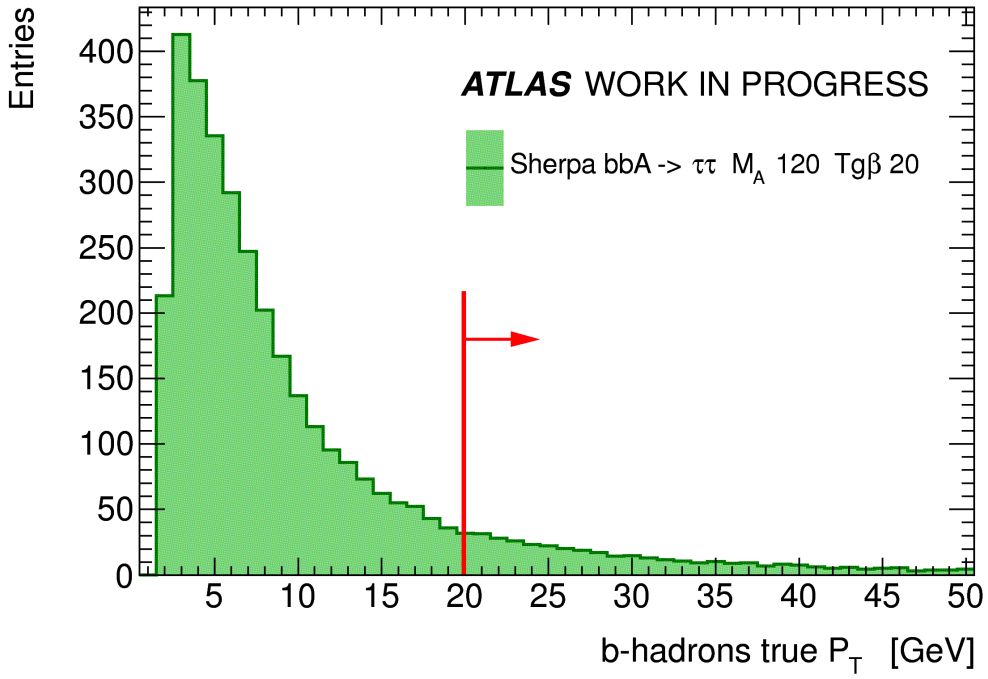
# Introduction: Task

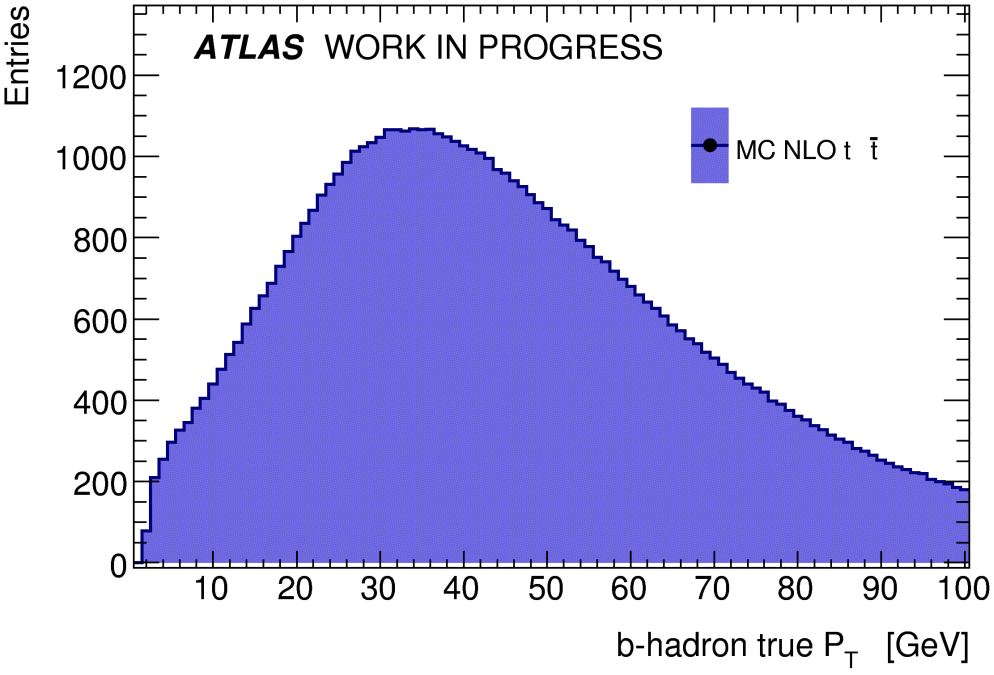



- B-hadron in signal has a low transverse momentum ($P_T$) distribution
- Be able to reconstruct jet object for low $P_T$
- Be able to b-tag this jets

# Introduction: Problems




- Technical problem with calorimeter jets calibration: due to ambient energy deposition (pileup) → Safe limit for usage @ 20 GeV $P_T$
- B-tagging algorithm present low performance @ low $P_T$ because of particle interaction with the material

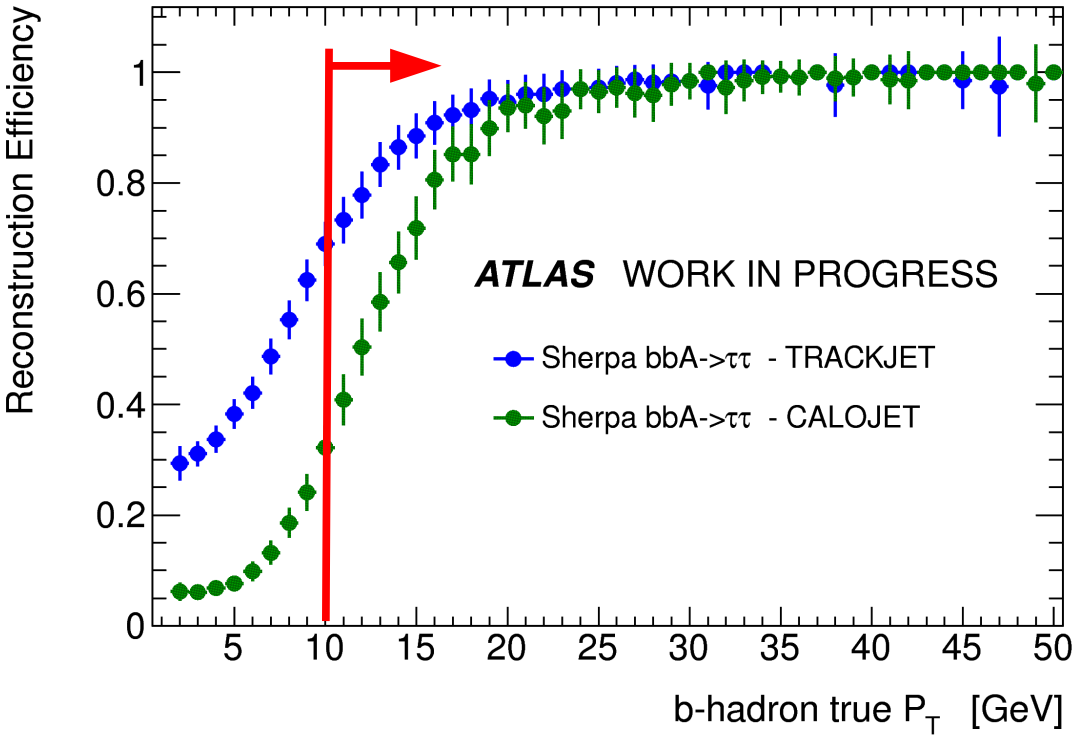
# Introduction: Alternative solution

- One can avoid calorimeter information using only tracking information for jets reconstruction
- Track-based jets:
  - Use only tracks from primary vertex → Safe against pileup
  - Possible to reconstruct jets up to very low $P_T$
  - Calibration problem due to loss of neutral particles (they present in mean ~ 2/3 of the total energy)

# Performance study

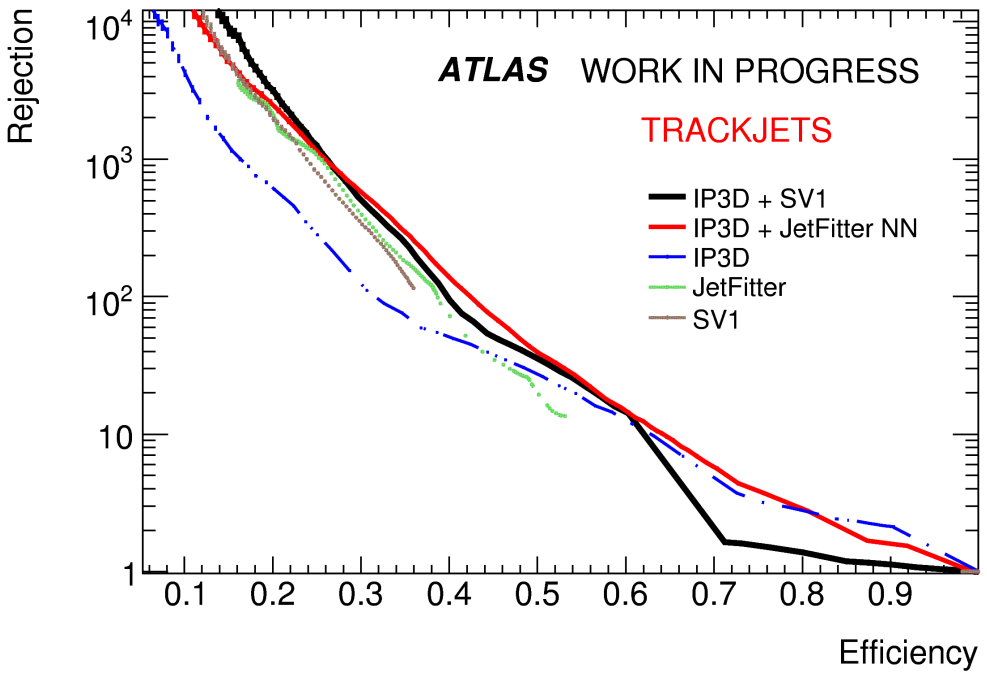
- Check performance of track-based jet for low $P_T$
- In the following:
  - Low $P_T$ B reconstruction efficiency
  - Performance of taggers on track-based jets
  - Comparison between track and calorimeter based jets
  - Preliminary result when track-based jets are applied to the MSSM bbA analysis

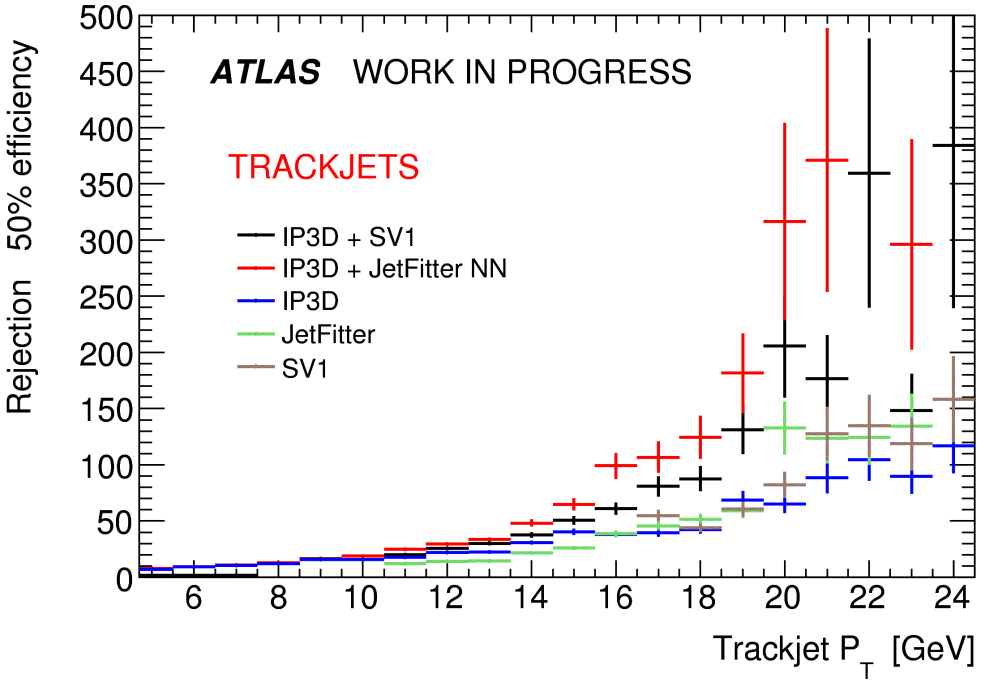
# Performance: reconstruction efficiency




- Efficiency of reconstructing a b-hadron
- For low $P_T$ track-based jet has better b-jet reconstruction efficiency

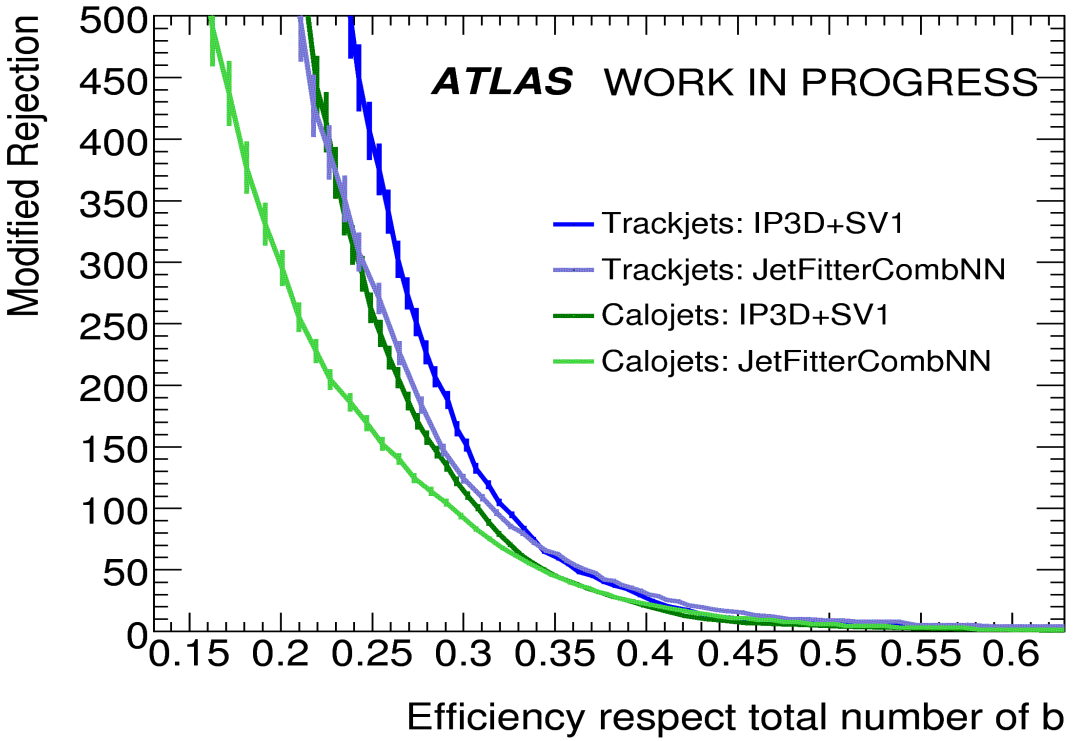
# Performance: Rejection VS Efficiecy and $P_T$




- Tagging efficiency: efficiency for a real b-jet to be tagged
- Rejection: inverse of the misidentification probability
- Low $P_T$ → low rejection power!

# Calorimeter and track based jet comparison




- Modified Efficiency: efficiency respect to the total number of b-hadron, before was respect the total number of jets
- Modified Rejection: inverse of the number of "light" jets that pas a tagger per event
- track-based jet presents slightly better tagging performance

# Standard analysis + track-based jet

- Samples:
  - Signal: MSSM bbA mass 120 GeV – tgβ 20
  - Considered backgrounds: Alpgen $Z \rightarrow \tau\tau$ ; MC@NLO top
- Selections Only "hadronic + μ" final state:
  - Only 1 μ $P_T > 20$ GeV
  - Only 1 τ $P_T > 20$ GeV
  - Electron veto
  - Transverse Mass < 30 GeV
  - Leading jet should be b-tagged
  - 20 < leading Jet $P_T$ <50 GeV

- The analysis is repeated Introducing track-based jets:
  - track-based jet: 5 < leading jet $P_T$ < 30 GeV → corresponding calorimeter jet range = [8,50] GeV

# Comparison with standard analysis

Normalized to 1 $fb^{-1}$ of integrated luminosity

| | bbA → ττ $M_A$ 120 tgβ 20 | | **Z → ττ** | | **top** | |
|---|---|---|---|---|---|---|
| | calo-jet | track-based jet | calo-jet | track-based jet | calo-jet | track-based jet |
| **b-Jet true matched** | 55 | 90 | 6 | 11 | 54 | 35 |
| **b-tag** | 34 | 47 | 24 | 38 | 43 | 30 |
| **Upper $P_T$ cut** | 23 | 37 | 14 | 27 | 5 | 2 |

- Number of event with a jet matched with b-hadron
- The jet should be b-tagged
- The jet should be within the specified range in $P_T$

# Comparison with standard analysis

Normalized to 1 $fb^{-1}$ of integrated luminosity

| | **bbA → ττ $M_A$ 120 tgβ 20** | | **Z → ττ** | | **top** | |
|---|---|---|---|---|---|---|
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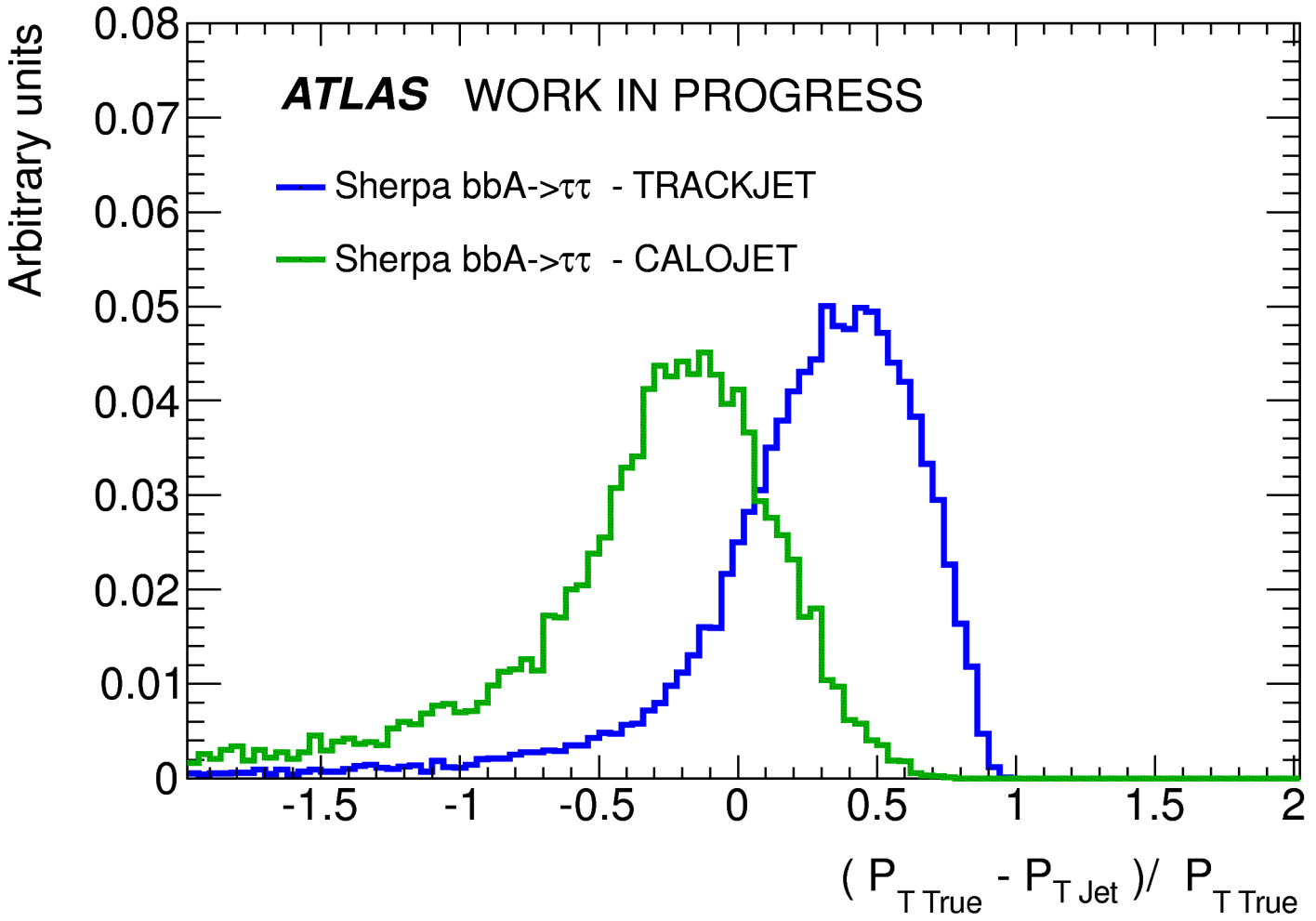
- One can gain using track-based jet
- But high b-tag fake rate leads to higher backgrounds
- Little gain in significance at the end (1.3 times more considering only those backgrounds)

# Summary & Conclusion

- MSSM Higgs heavy flavor associated production is characterized by very low $P_T$ b-jets
- Using track-based jets one can exploit such challenging $P_T$ region impossible for calorimeter jets
- track-based jets present good reconstruction efficiency of b-hadrons
- Taggers has to be optimize for track-based jets and low $P_T$

# Backup

# Residuals


ATLAS WORK IN PROGRESS
Sherpa bbA->ττ - TRACKJET
Sherpa bbA->ττ - CALOJET
Arbitrary units
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-1.5
-1
-0.5
0
0.5
1
1.5
2
( P T True - P T Jet )/ P T True

# Comparison with standard analysis

Normalized to 1 $fb^{-1}$ of integrated luminosity

| | **bbA → ττ $M_A$ 120 tgβ 20** | | **Z → ττ** | | **top** | |
|---|---|---|---|---|---|---|
| | calo-jet | track-based jet | calo-jet | track-based jet | calo-jet | track-based jet |
| **b-Jet true matched** | 55 | 53 | 6 | 6 | 54 | |
| **b-tag** | 34 | 35 | 24 | 27 | 43 | |
| **Upper $P_T$ cut** | 23 | 24 | 14 | 17 | 5 | |

- Applying same $P_T$ range to track-based jets [12,30]
- Very similar performance for calorimeter and track based jets

# Comparison with standard analysis

Normalized to 1 $fb^{-1}$ of integrated luminosity

| | **bbA → ττ** | | **Z → ττ** | | **top** | |
|---|---|---|---|---|---|---|
| | calo-jet | track-based jet | calo-jet | track-based jet | calo-jet | track-based jet |
| **b-Jet true matched** | 55 | 127 | 6 | 30 | 54 | 47 |
| **b-tag** | 34 | 54 | 24 | 66 | 43 | 33 |
| **Pt** | 23 | 50 | 14 | 55 | 5 | 3 |