

# FLAVOR-TAGGING TUTORIAL

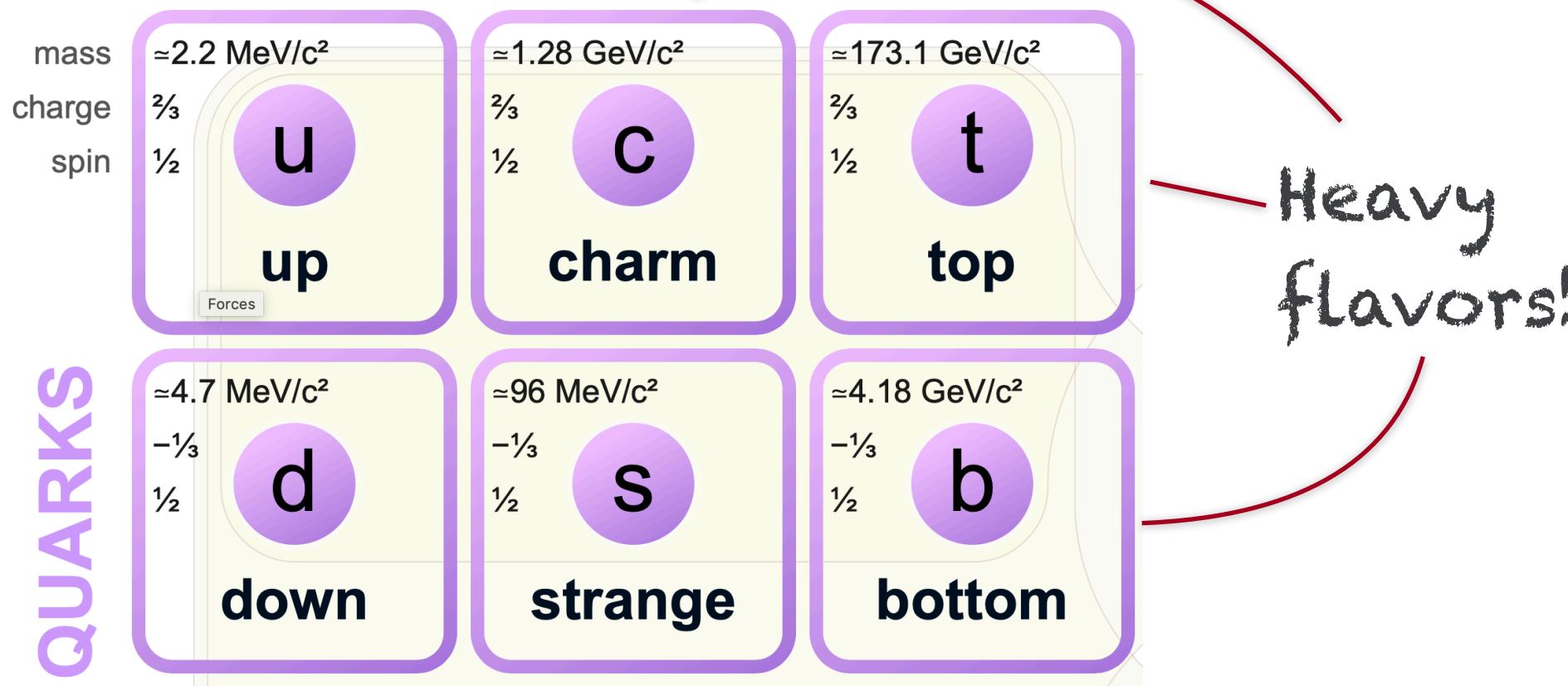
Rafael Teixeira de Lima  
[SLAC]

ATLAS  
Induction+Software  
Tutorial  
October 2019



# WHY TAG HEAVY FLAVOR?

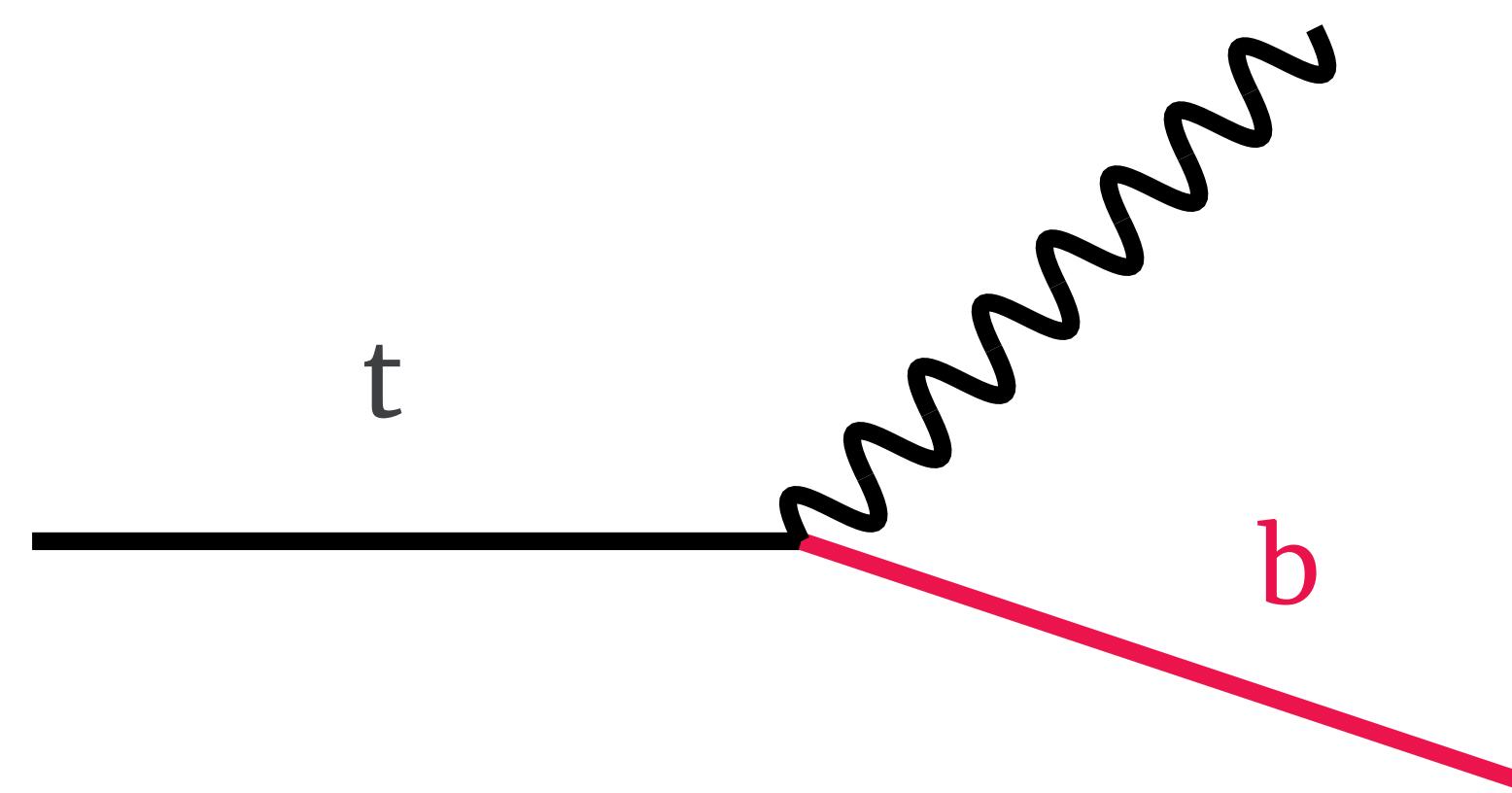
**Quark flavors:**



CKM Matrix:

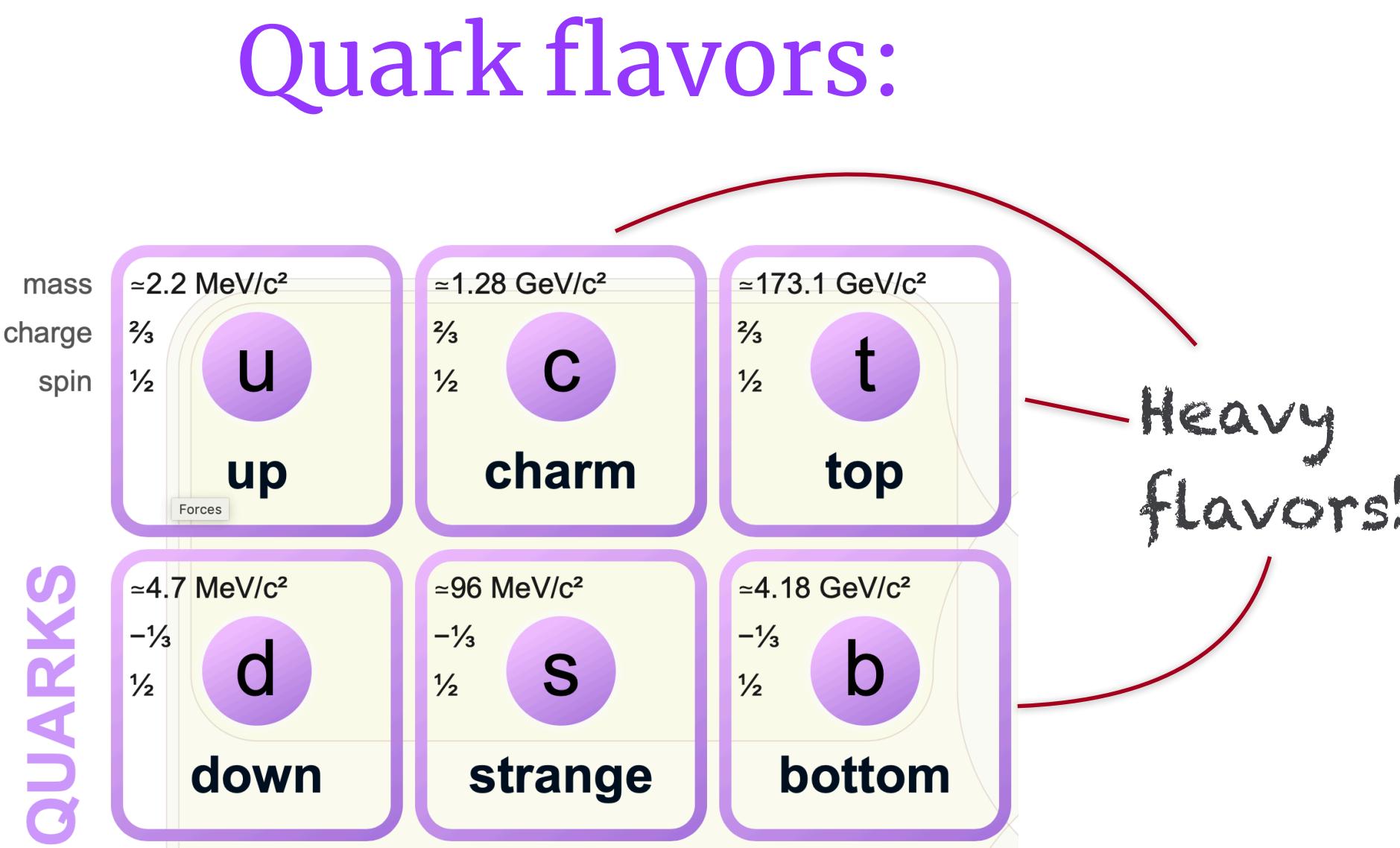
$$\begin{bmatrix} |V_{ud}| & |V_{us}| & |V_{ub}| \\ |V_{cd}| & |V_{cs}| & |V_{cb}| \\ |V_{td}| & |V_{ts}| & |V_{tb}| \end{bmatrix} \approx \begin{bmatrix} 0.974 & 0.225 & 0.003 \\ 0.225 & 0.973 & 0.041 \\ 0.009 & 0.040 & 0.999 \end{bmatrix}$$

Top quark decays through weak force before showering

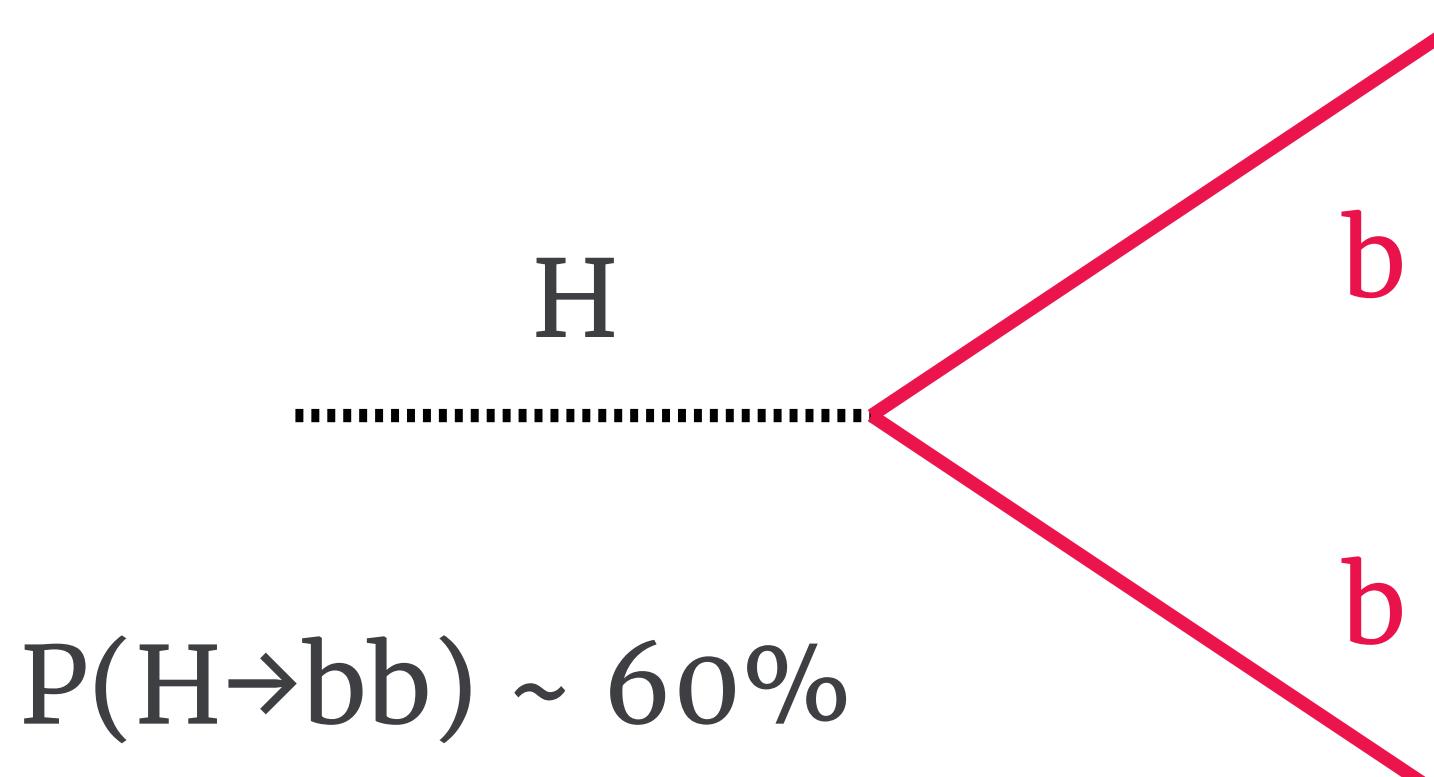
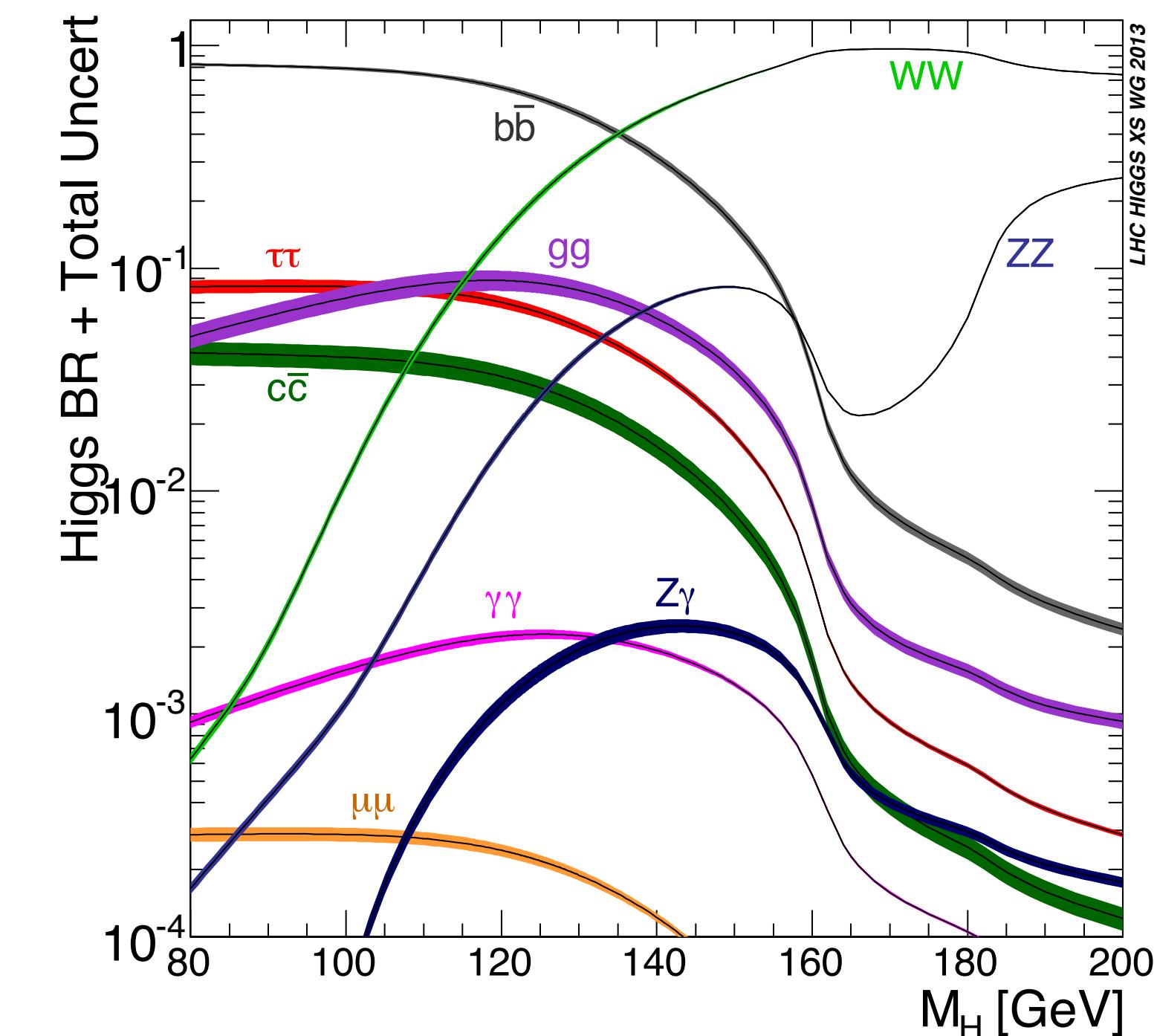


$P(t \rightarrow Wb) \sim 99.9\%$

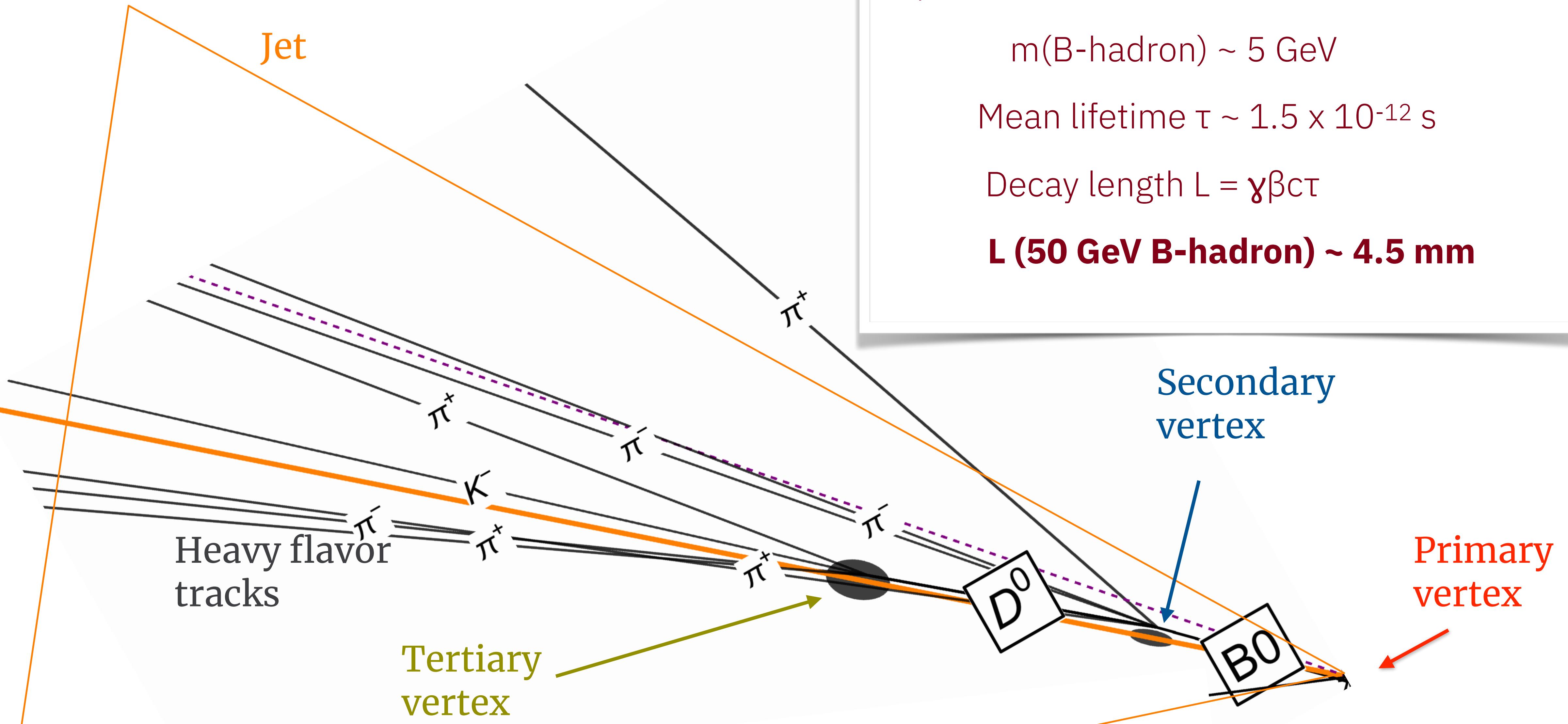
# WHY TAG HEAVY FLAVOR?



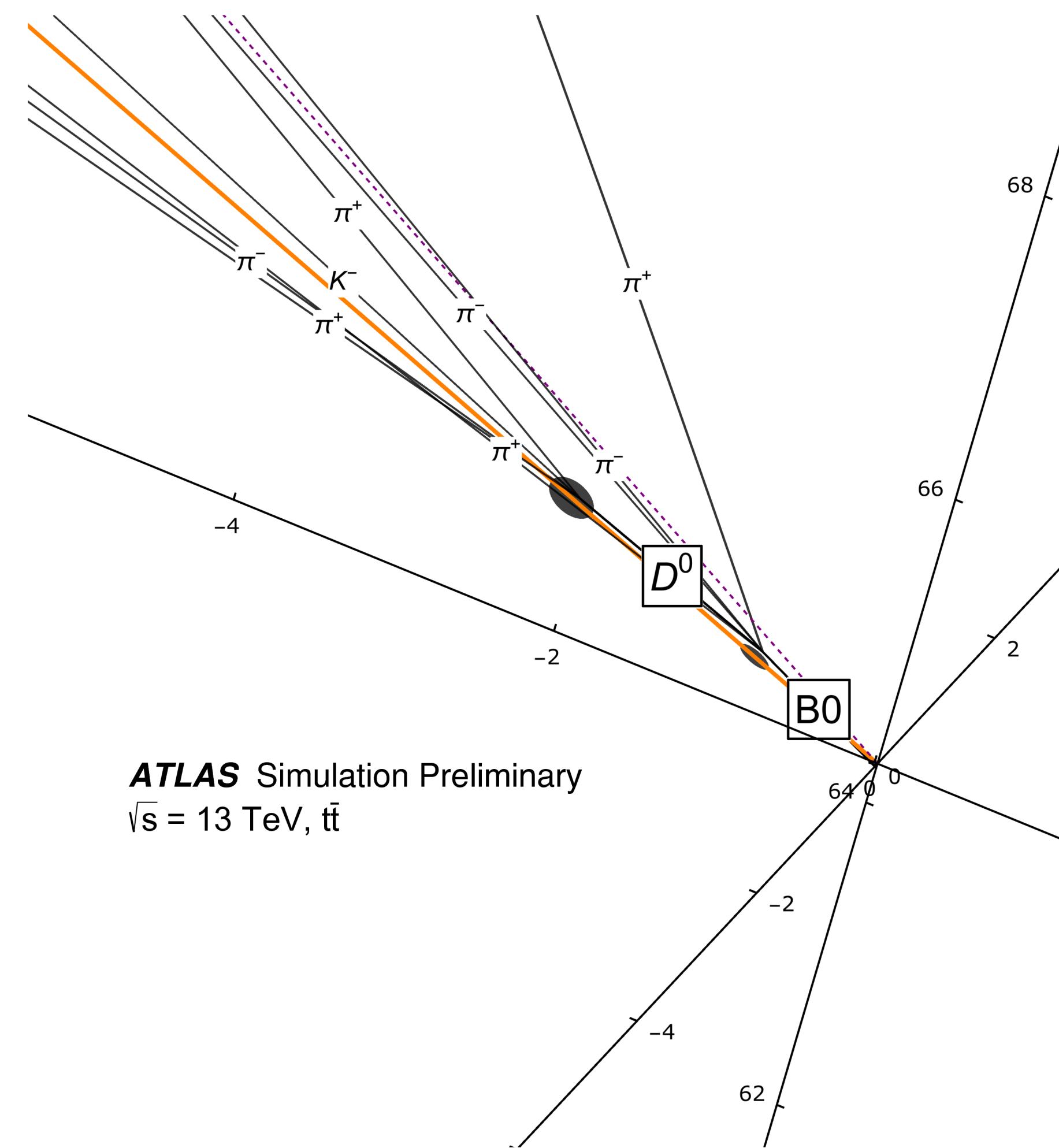
Higgs decay probabilities  
(branching ratios)



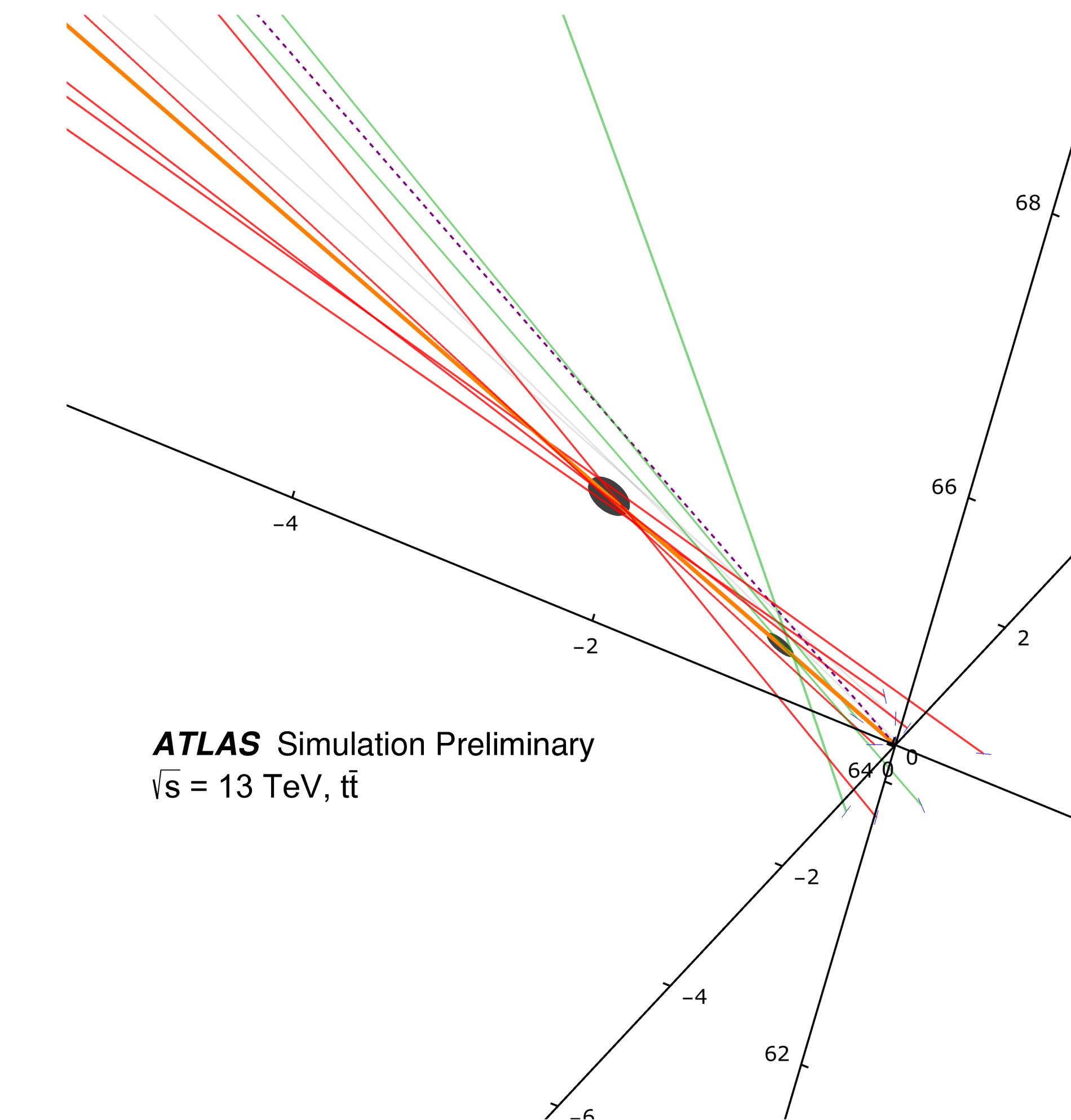
# ANATOMY OF A b - QUARK JET



## IN REAL LIFE

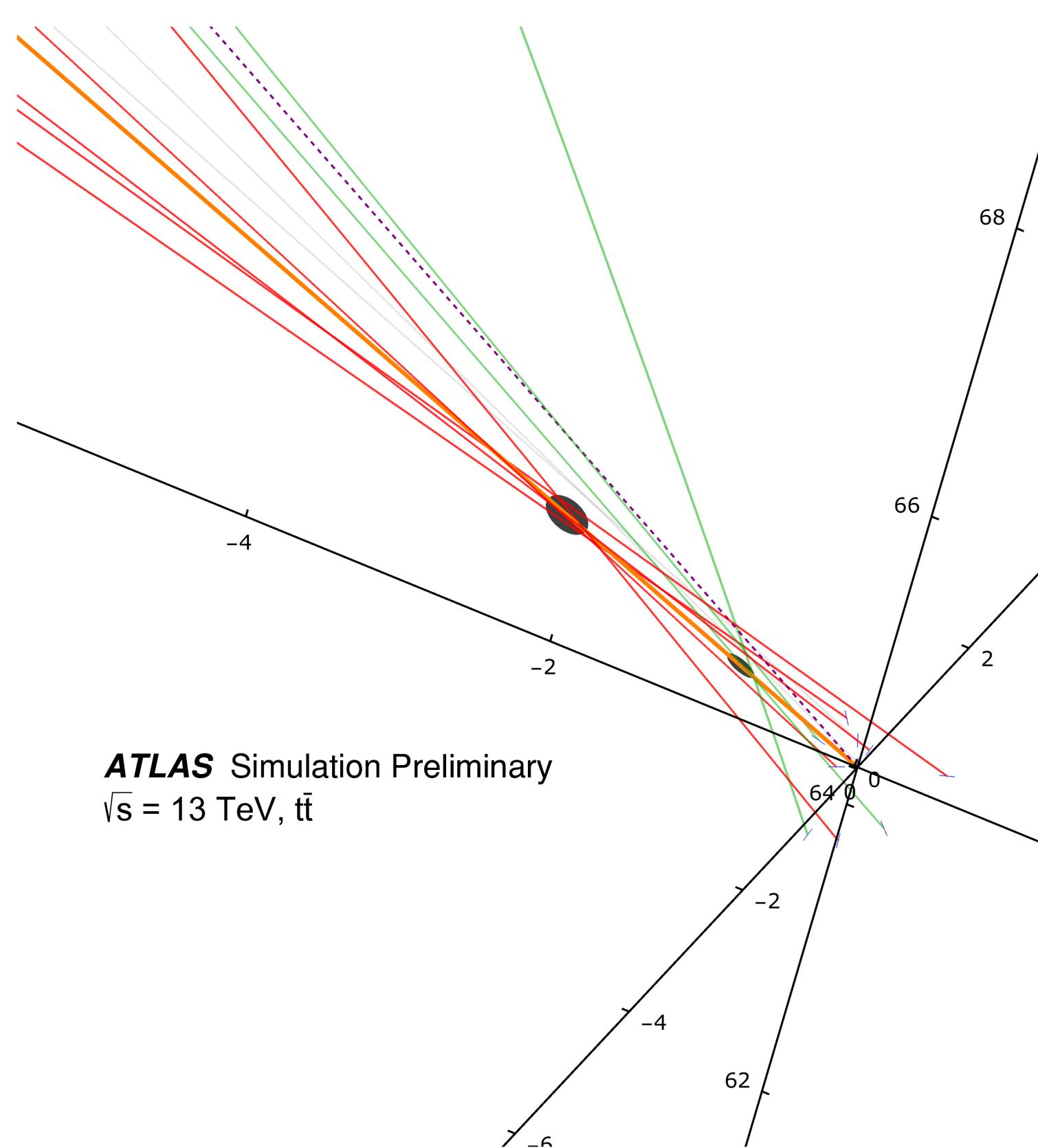


Underlying  
physics



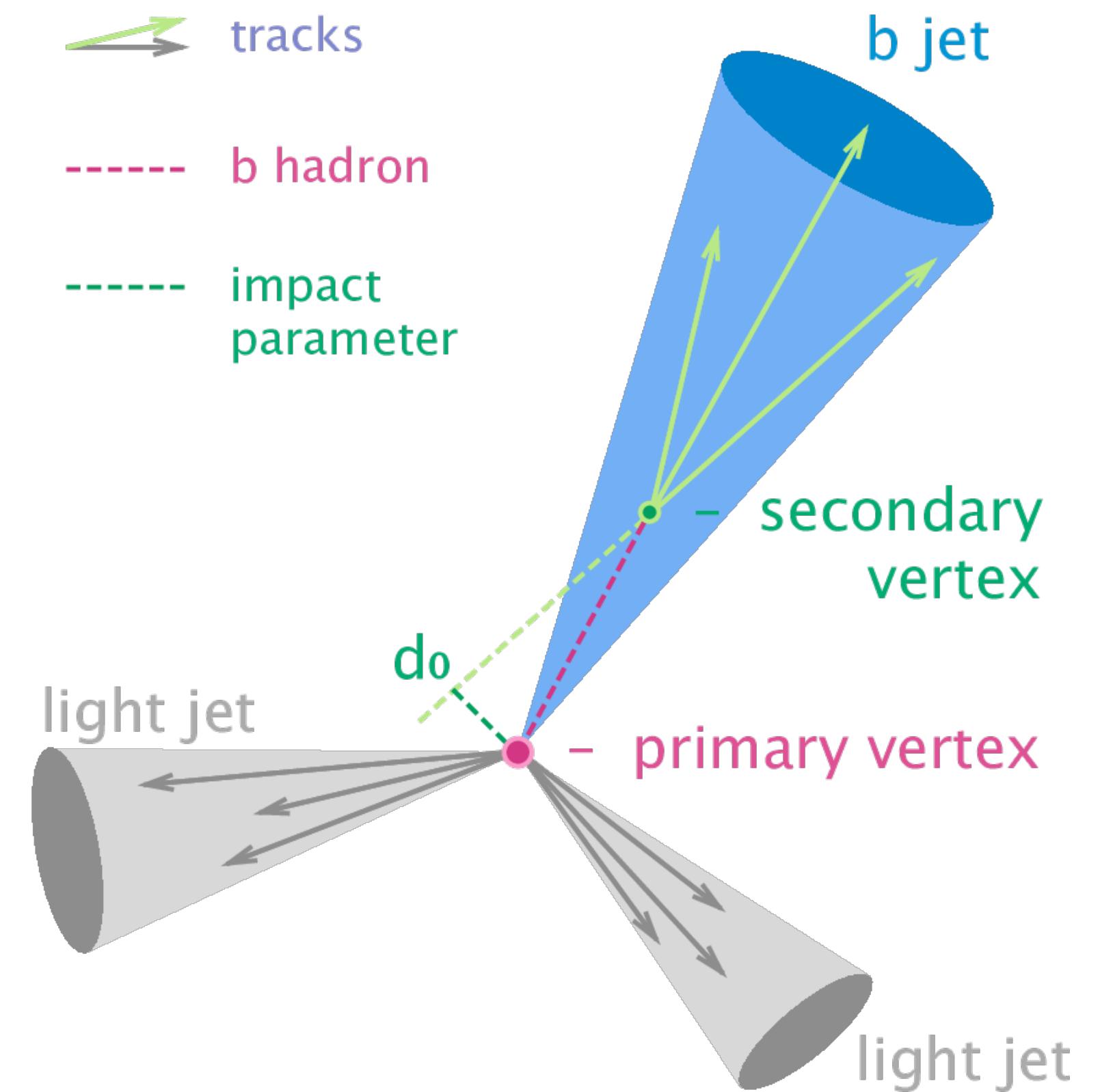
Detector view

# HOW TO IDENTIFY b - JETS?



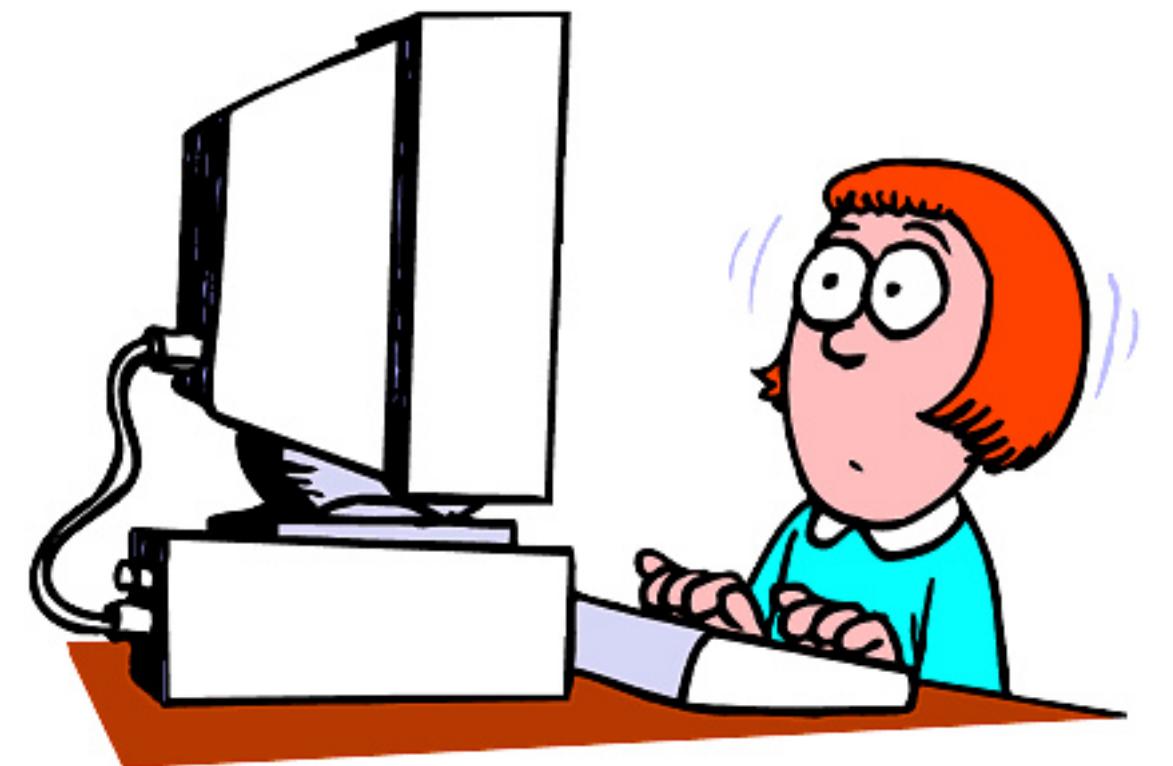
Detector view

calculating  
features  
that we  
expect to be  
different in  
heavy and  
light jets!



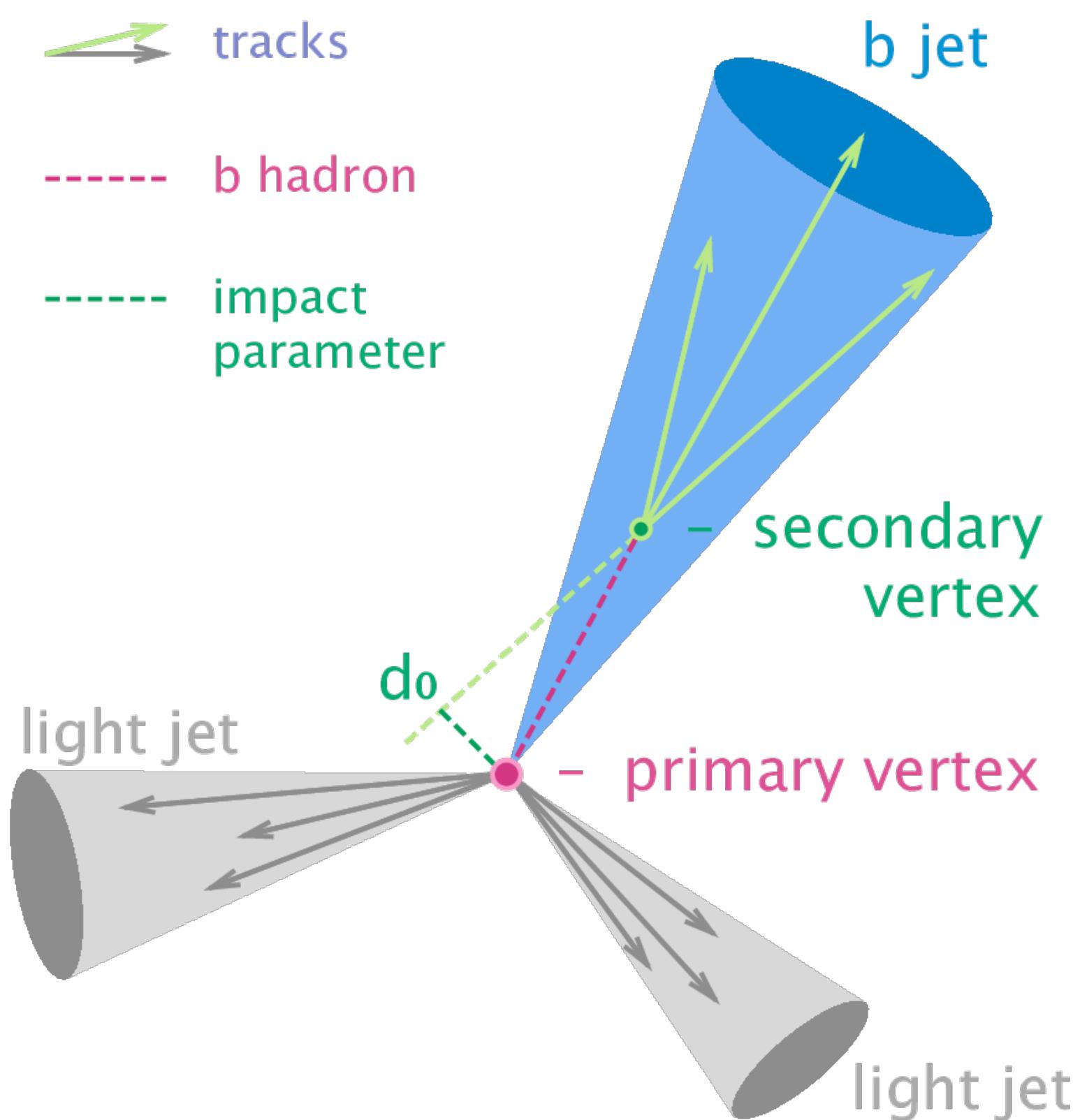
Calculated  
features

# IN REAL LIFE...



© Can Stock Photo - csp28269747

# b - J E T T A G G E R S

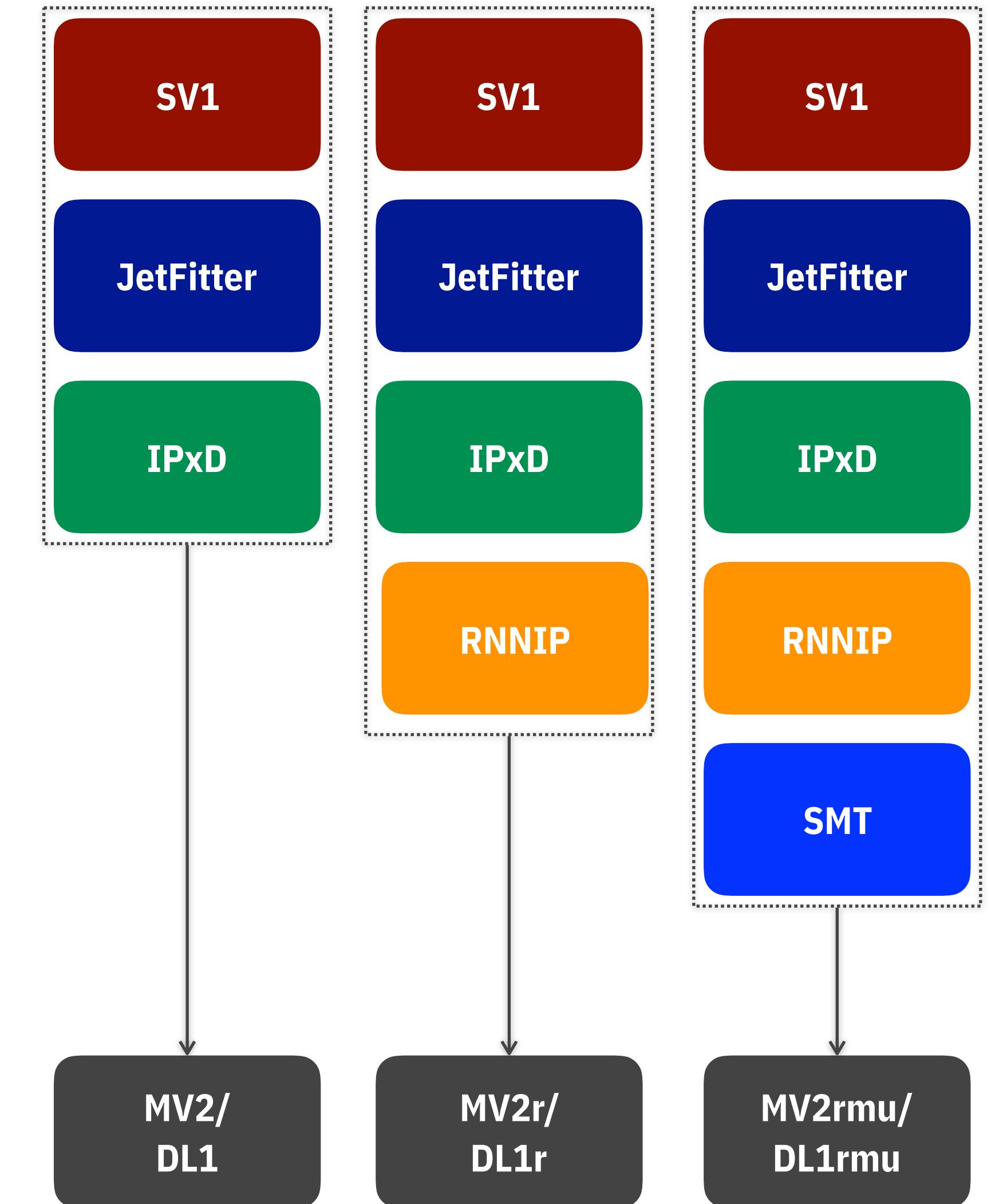


Calculated features

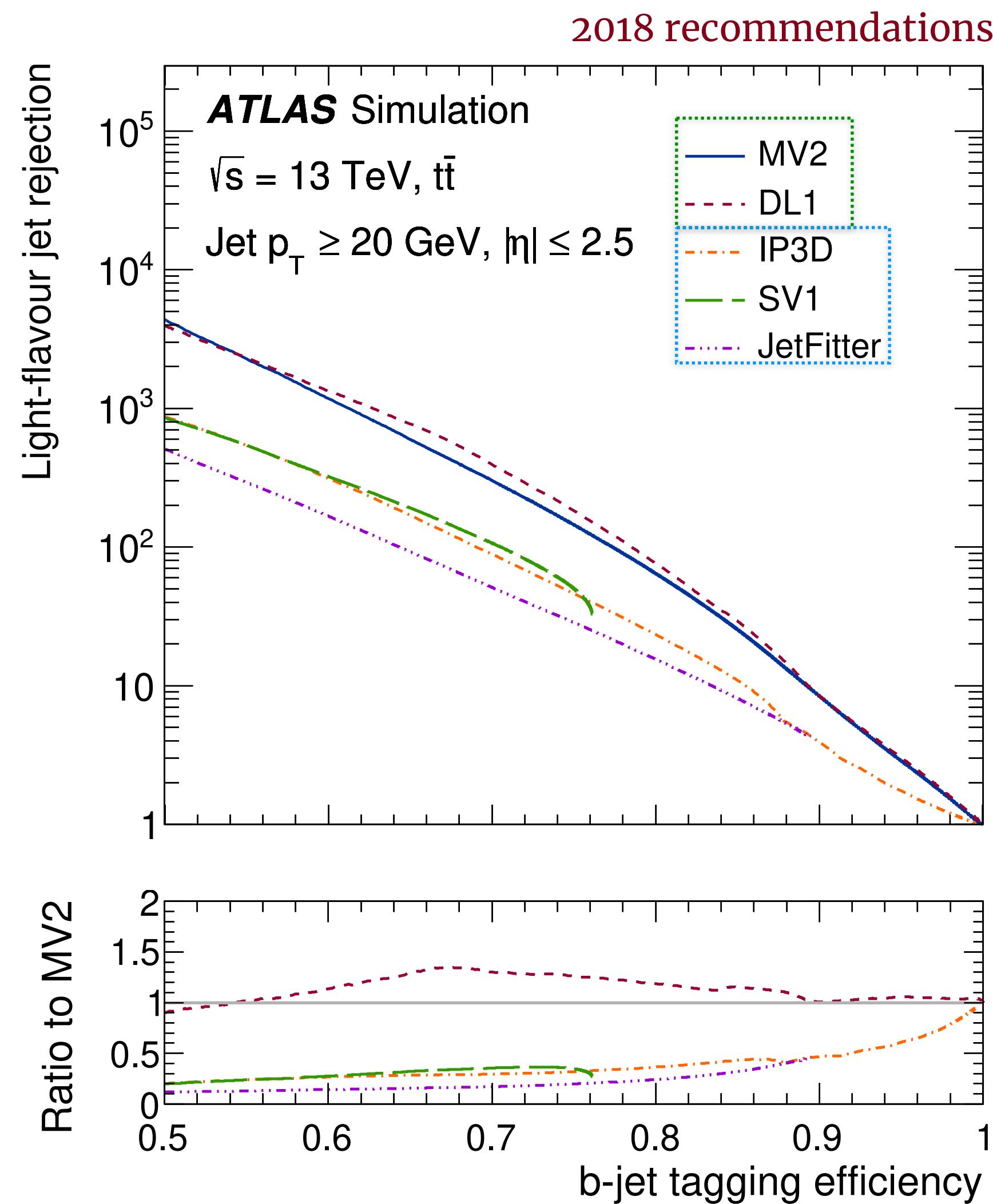
**Secondary Vertexing Algorithms:**  
SV1, JetFitter

**Impact Parameter Algorithms:**  
IP2d, IP3d,  
RNNIP

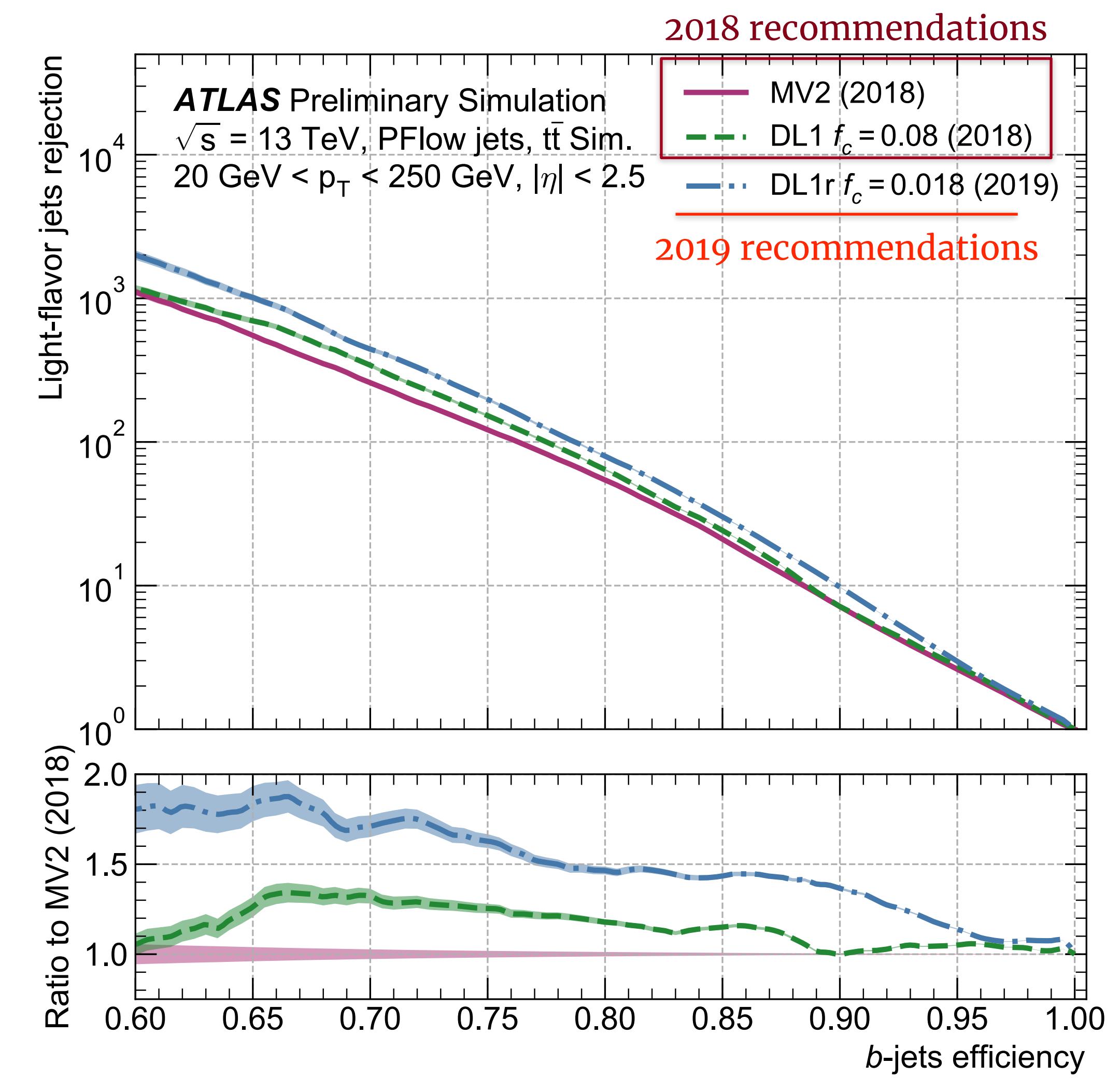
**Soft Lepton Algorithms:**  
SMT



# FLAVOR TAGGING PERFORMANCE IN ATLAS

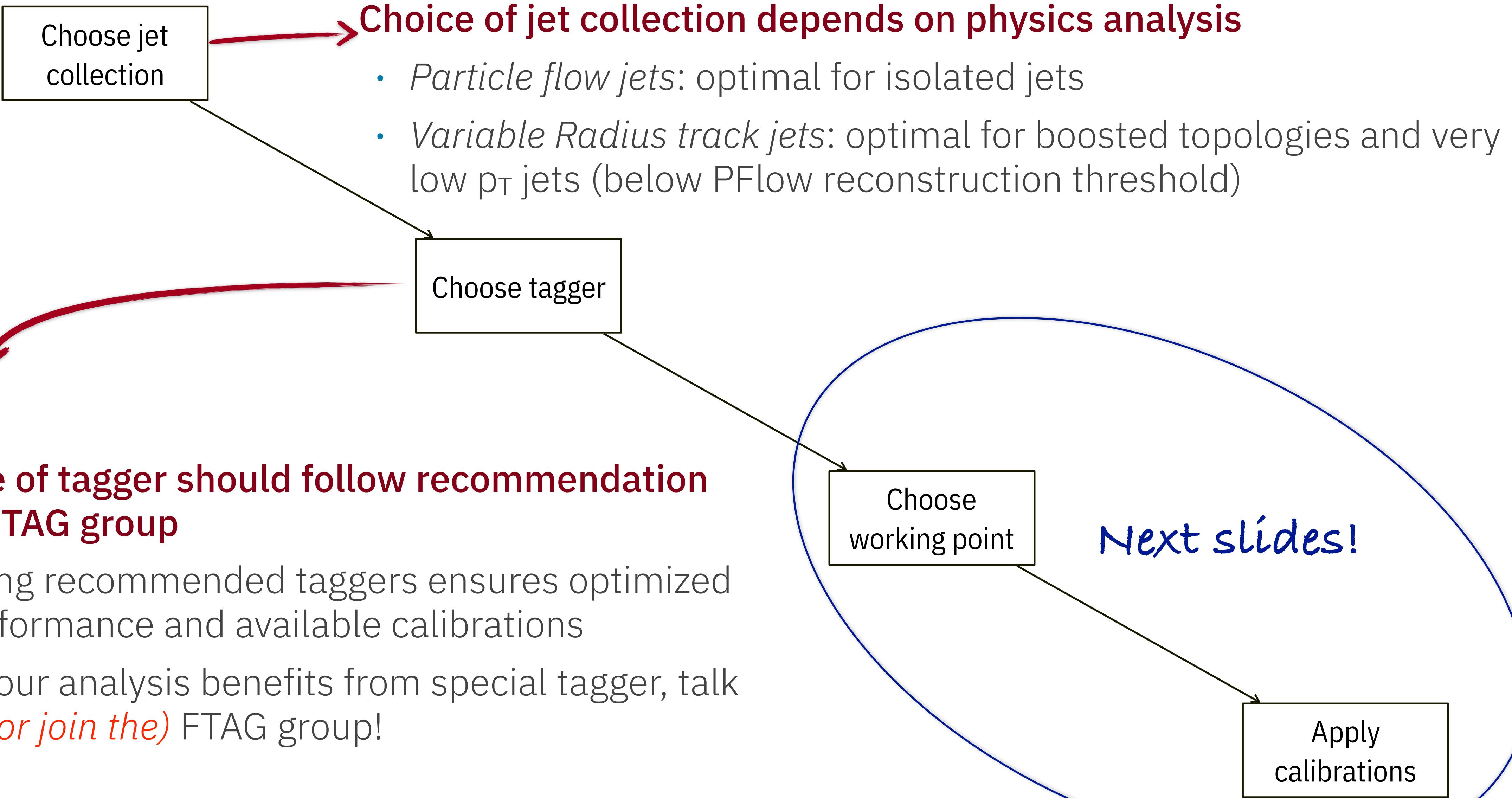


High-level  
taggers  
Low-level  
taggers

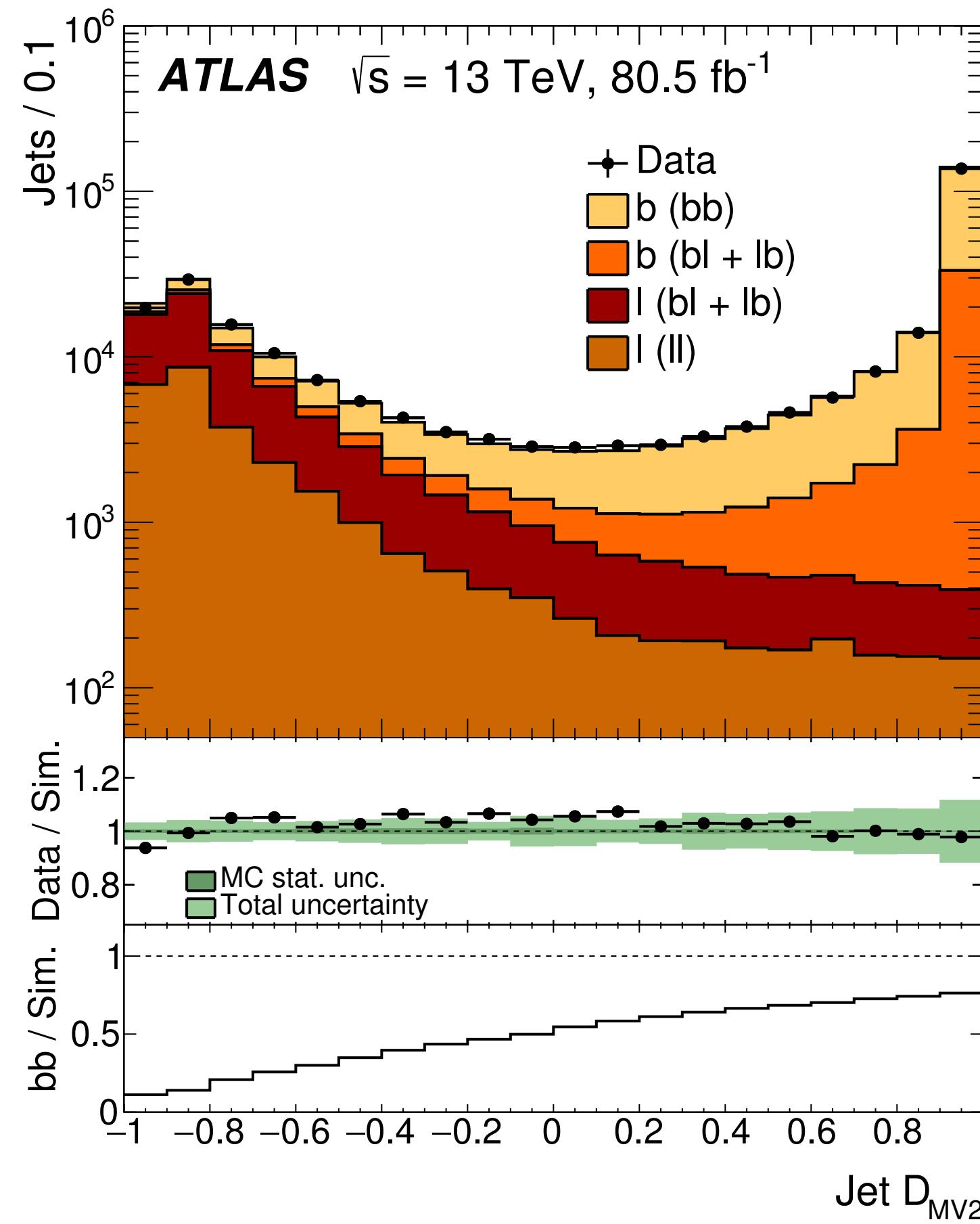


Taggers also optimized for Variable Radius track jets!

# HOW TO USE b-TAGGING?



# WORKING POINTS & CALIBRATIONS



Our simulation is not perfect!  
Need to correct MC with *scale factors*

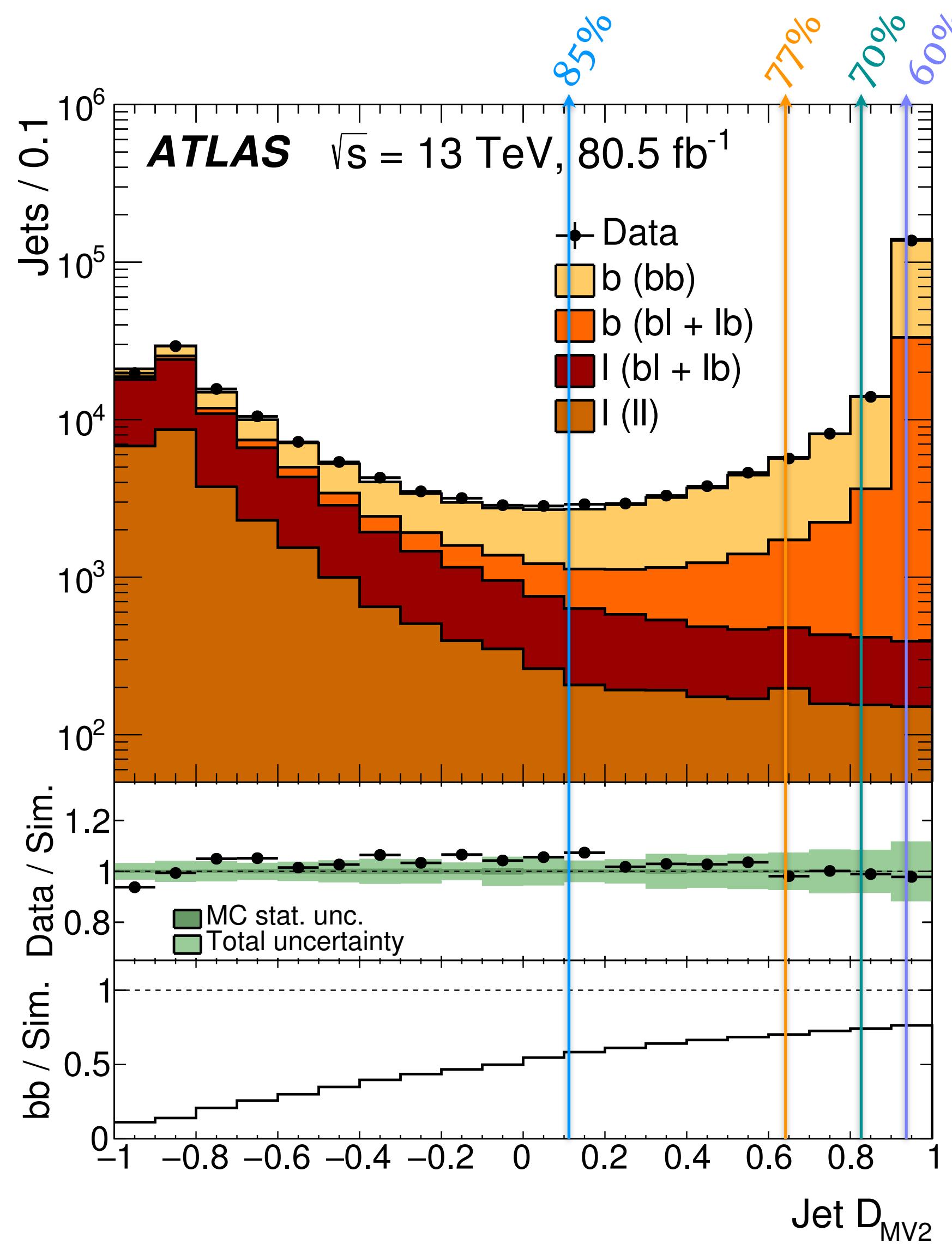
## Analysis cut efficiency (like b-tagging): $\epsilon^{\text{FTAG}}$

- Since data  $\neq$  MC,  $\epsilon^{\text{FTAG}}_{\text{data}} \neq \epsilon^{\text{FTAG}}_{\text{MC}}$
- Scale factor (SF) =  $\epsilon^{\text{FTAG}}_{\text{data}} / \epsilon^{\text{FTAG}}_{\text{MC}}$ 
  - SFs are measured with **data** in different  $p_T$  bins and for different jet flavors (b, c, light) individually

## Working points: calibrated cuts!

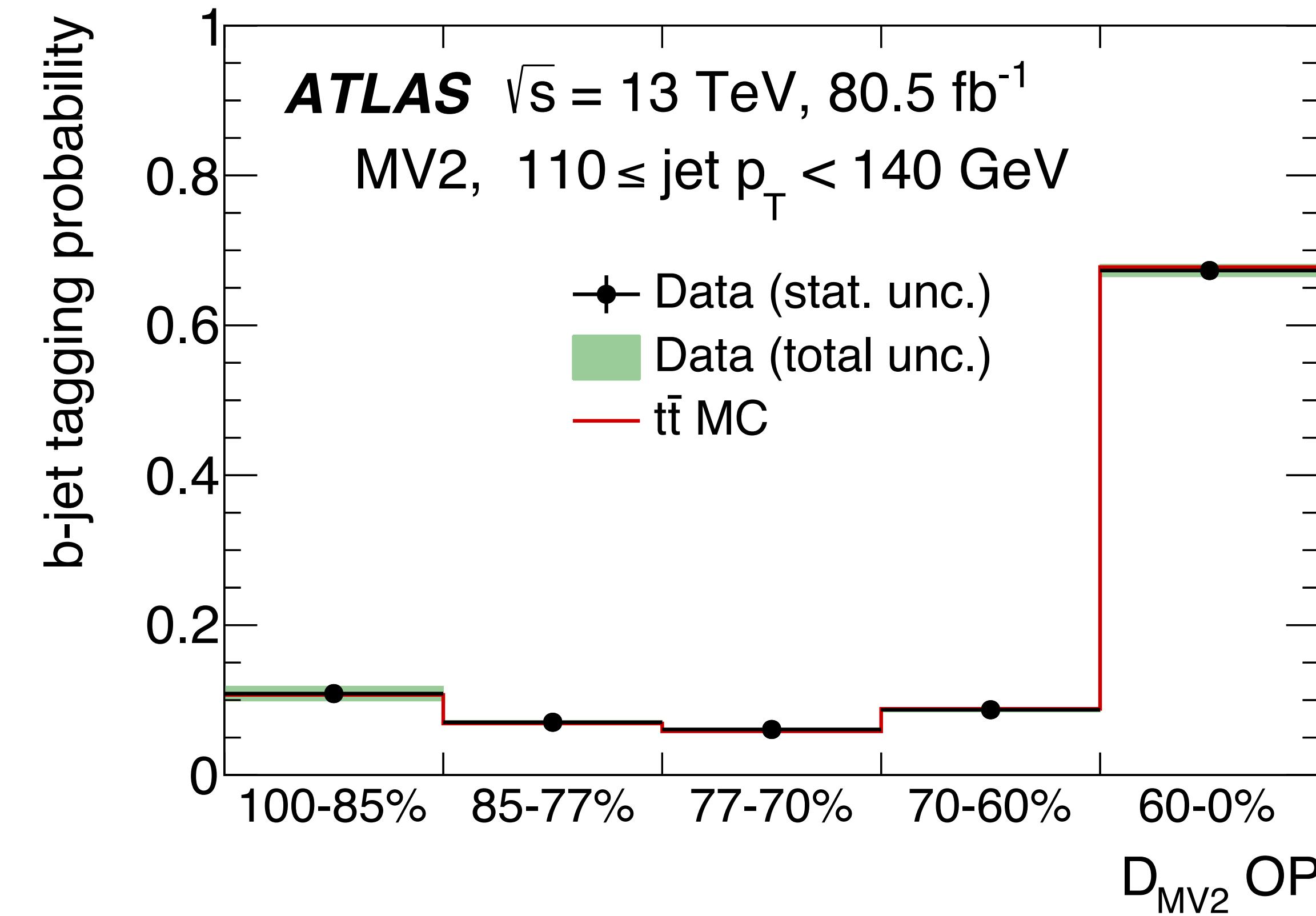
- WP x%  $\rightarrow$  efficiency of x% for b-jets (inclusive in  $p_T$ )
  - $x = \{60, 70, 77, 85\}$
  - WP choice based on your analysis performance!

# PSEUDO-CONTINUOUS CALIBRATION



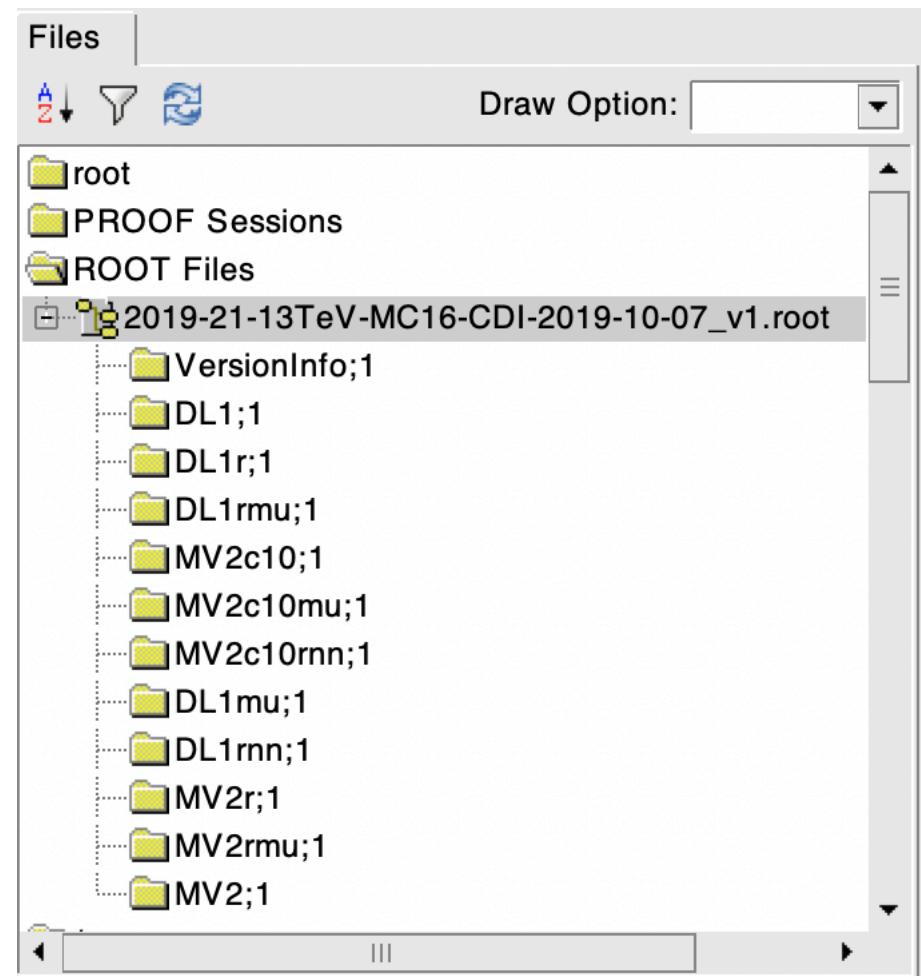
Calibration is either **inclusive** ( $\text{Jet } D_{\text{MV2}} > \text{WP}$ ) or **exclusive** ( $\text{WP}_1 < \text{Jet } D_{\text{MV2}} < \text{WP}_2$ )

- Exclusive calibration = “pseudo-continuous” working points

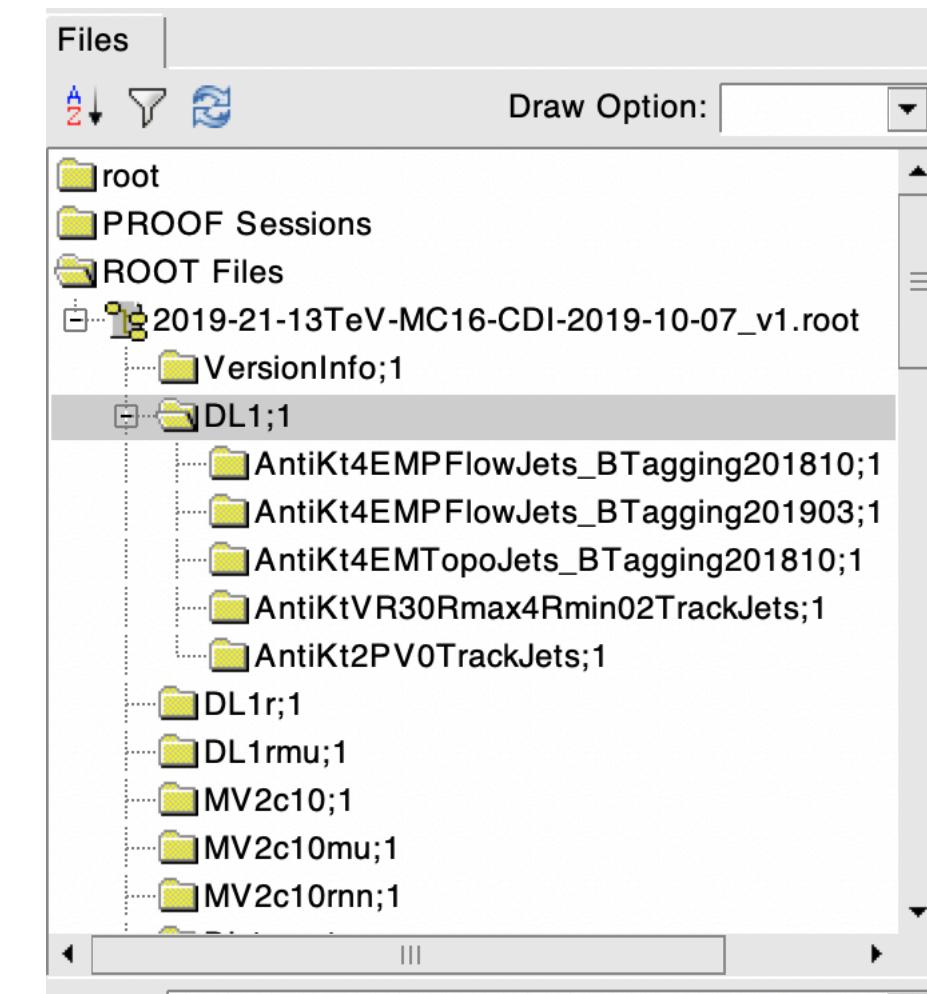


# THE CDI

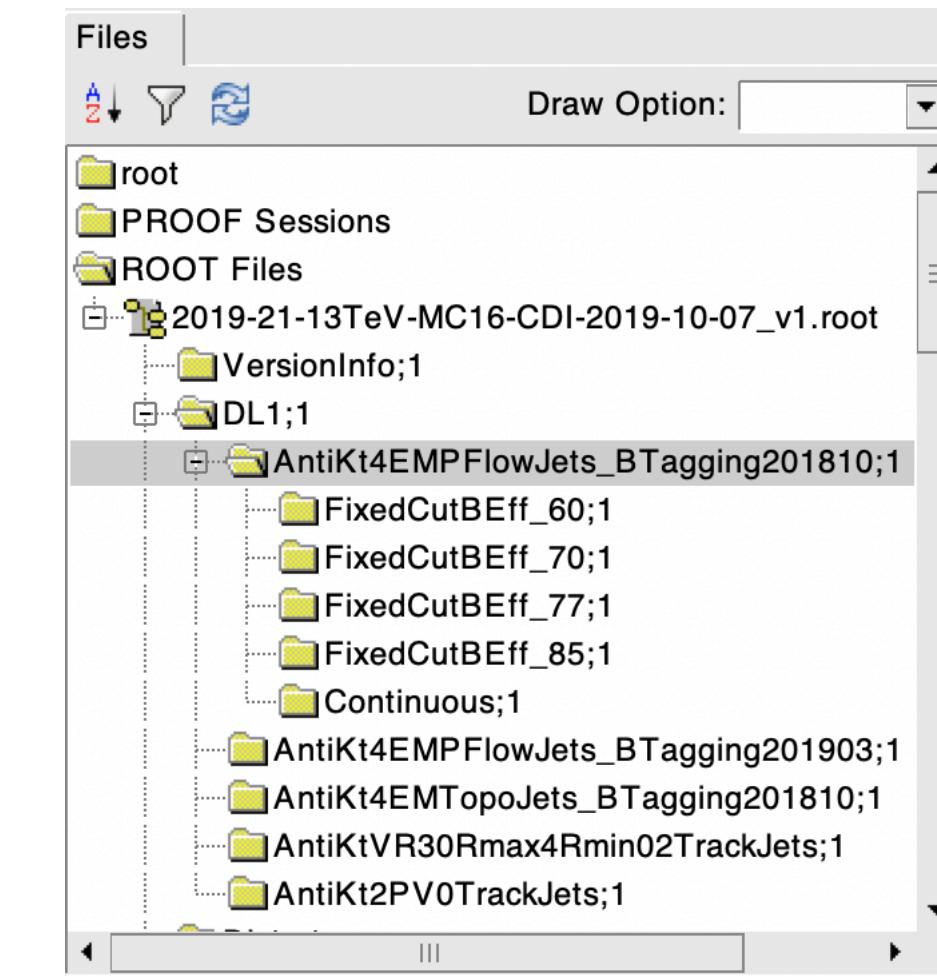
**Calibration Data Interface (CDI) file:** time stamped root file containing a complete snapshot of all the recommendations from the FTAG group



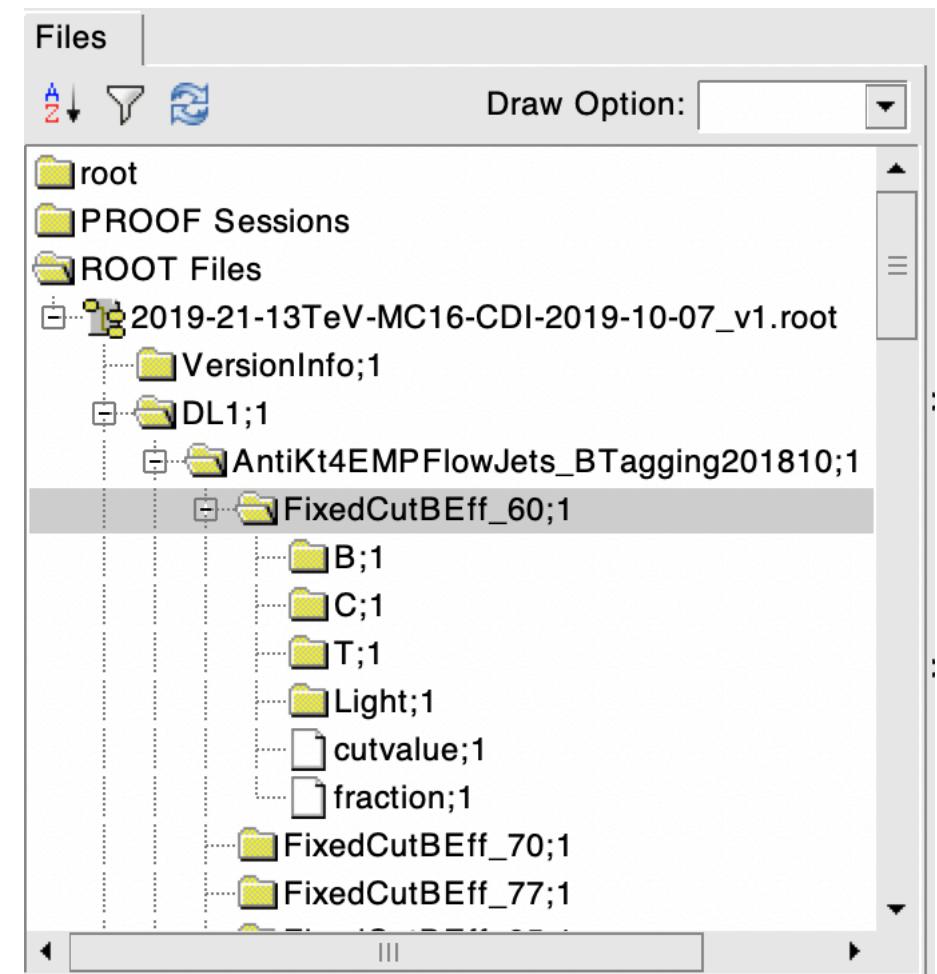
Supported taggers



Supported jet collections



Supported working points



Different flavors

**Latest CDI:** /eos/atlas/atlascerngroupdisk/asg-calib/xAODBTaggingEfficiency/13TeV/2019-21-13TeV-MC16-CDI-2019-10-07\_v1.root

- Browse it online! [https://gitlab.cern.ch/mstamenk/validation\\_cdi/tree/master/CDI-October2019](https://gitlab.cern.ch/mstamenk/validation_cdi/tree/master/CDI-October2019)

# IN PRACTICE

Example usage: [[BTaggingSelectionToolTester](#)]

## 1) Is my jet b-tagged?

- Choose tagger, choose WP
- Use **BTaggingSelectionTool** to get decision

## 2) Need to know jet flavor to obtain correct scale-factors

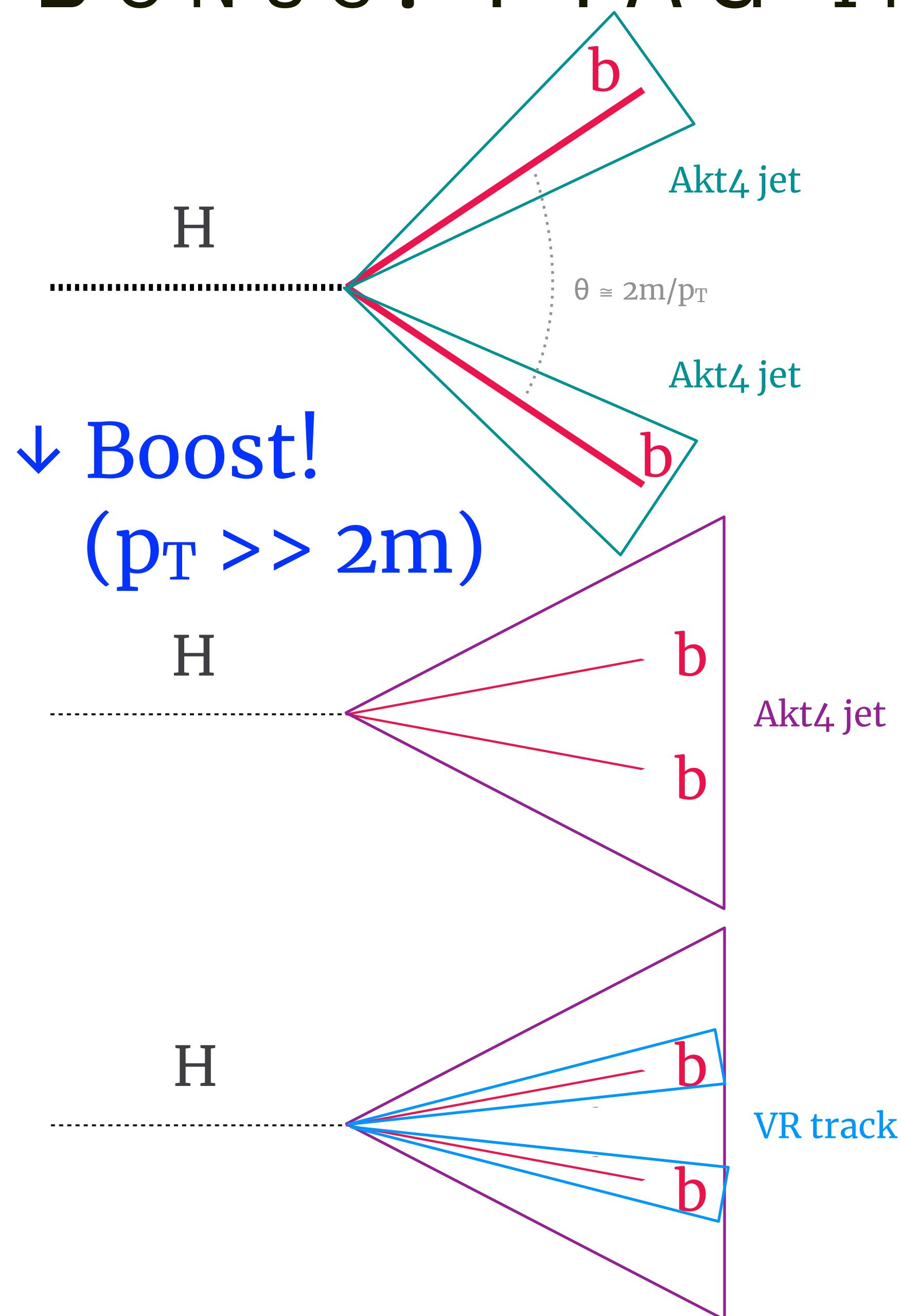
- ```
xAOD_Jet* myJet = myJetContainer[i];  
myJet->getAttribute<int>("HadronConeExclTruthLabelID");
```

## 3) What scale factors should I use for my selection?

- Choose which type of SFs to use (pseudo-continuous? Which scheme? MC-to-MC SFs?)
- Use **BTaggingEfficiencyTool** to get SFs

**BTaggingSelectionTool** and **BTaggingEfficiencyTool** are athena tools in [xAODBTaggingEfficiency](#)

# BONUS: FTAG IN BOOSTED ENVIRONMENTS



**Boosted objects (top, W, Z, Higgs, etc...):**

- Decay products collimated into single object
- How to identify a boosted  $H \rightarrow bb$  jet from a regular jet?

**We can resolve b-jets in boosted H with variable radius (VR) track jets!**

- Built only from tracks, using anti- $k_T$  with varying  $R$  (for us,  $R = 30 \text{ GeV}/p_T$  w/ $\max_R = 0.4$ ,  $\min_R = 0.02$ )
- Apply b-tagging requirements to VR jets just like regular (Akt4) jets\*\*!

*\*\*caveats apply, make sure to follow specific recommendations!*

# THE FTAG GROUP

**FTAG Conveners:** Carlo Schiavi, Chris Pollard

Meetings@Tuesdays 3:30pm, [hn-atlas-flavourtagperformance@cern.ch](mailto:hn-atlas-flavourtagperformance@cern.ch)

- **FTAG Algorithms:** Francesco di Bello, Rafael Teixeira de Lima
  - Meetings@Thursdays 1pm, [atlas-cp-flavtag-btagging-algorithms@cern.ch](mailto:atlas-cp-flavtag-btagging-algorithms@cern.ch)
- **FTAG Calibrations:** Bingxuan Liu, Dominik Duda, Reina Camacho Toro
  - Meetings@Mondays 1pm, [atlas-cp-flavtag-calibrations@cern.ch](mailto:atlas-cp-flavtag-calibrations@cern.ch)
- **FTAG Software:** Lidija Zivkovic, Sanmay Ganguly
  - Meetings@Tuesdays 1pm, [atlas-cp-flavtag-software@cern.ch](mailto:atlas-cp-flavtag-software@cern.ch)



**FTAG Twiki:** <https://twiki.cern.ch/twiki/bin/view/AtlasProtected/FlavourTagging>

# REFERENCES

Main FTAG twiki: [\*\*FlavourTagging\*\*](#)

FTAG release 21 algorithms recommendations: [\*\*BTagTaggerRecommendationsRelease21\*\*](#)

FTAG release 21 calibrations recommendations: [\*\*BTagCalib2017\*\*](#)

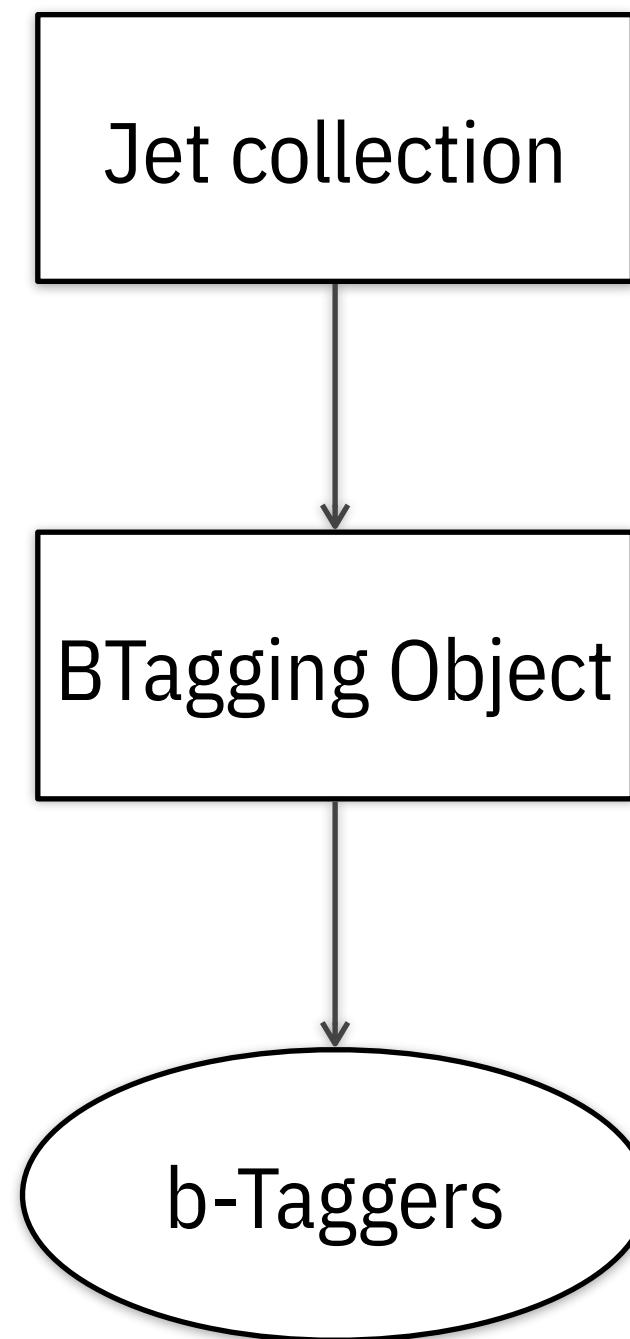
FTAG meetings indico: <https://indico.cern.ch/category/9120/>

FTAG public results: [\*\*FlavourTaggingPublicResultsCollisionData\*\*](#)

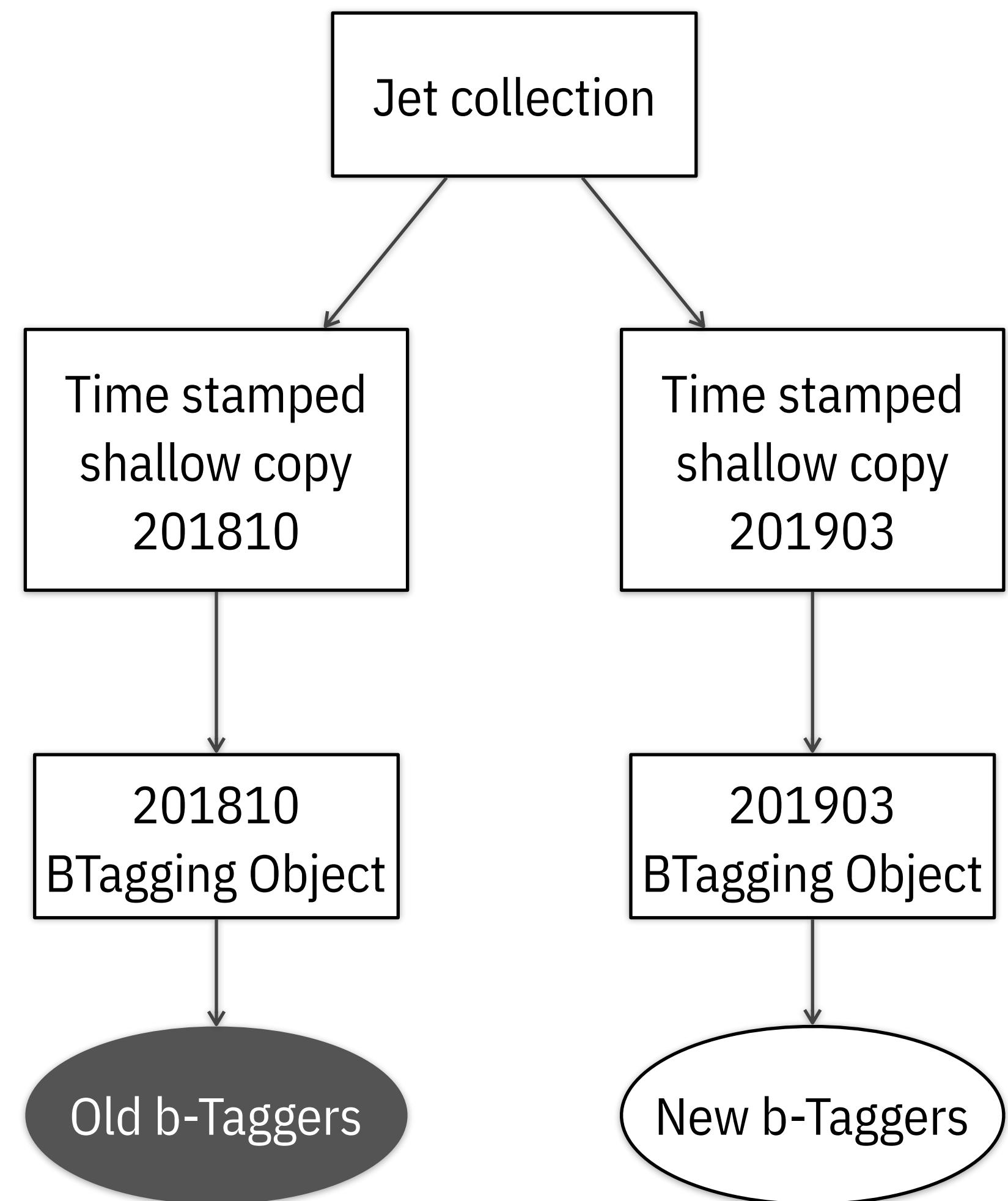
# BACKUP

# B T A G G I N G   O B J E C T

## Previous structure



## Current structure



## BTagging xAOD object contains taggers discriminants

- Object linked to jet collection (1 link per jet coll.)
- Need two BTagging objects for old (calibrated) and new taggers (not yet calibrated)

# SHALLOW COPIES

Jet shallow copies allow us to have two BTagging objects per jet collection without duplicating too much information

- A shallow copy points to the parent jet collection (no jet info duplication) and links to one BTagging object

To properly use b-tagging, you must specify the shallow copy name as your jet collection!

```
[rateixei@lxplus717 ~] $ checkxAOD ${MY_DAOD_FILE} | grep AntiKt4EMPFlowJets
 355.360 kb      92.511 kb      0.046 kb      3.841    2000  AntiKt4EMPFlowJets_BTagging201810 (DataVector<xAOD::Jet_v1>) [PFO]
 413.202 kb     114.681 kb      0.057 kb      3.603    2000  AntiKt4EMPFlowJets_BTagging201903 (DataVector<xAOD::Jet_v1>) [PFO]
 77313.018 kb   14204.385 kb     7.102 kb      5.443    2000  AntiKt4EMPFlowJets (DataVector<xAOD::Jet_v1>) [PFO]
```