A MULITPLICITY JUMP B-TAGGER

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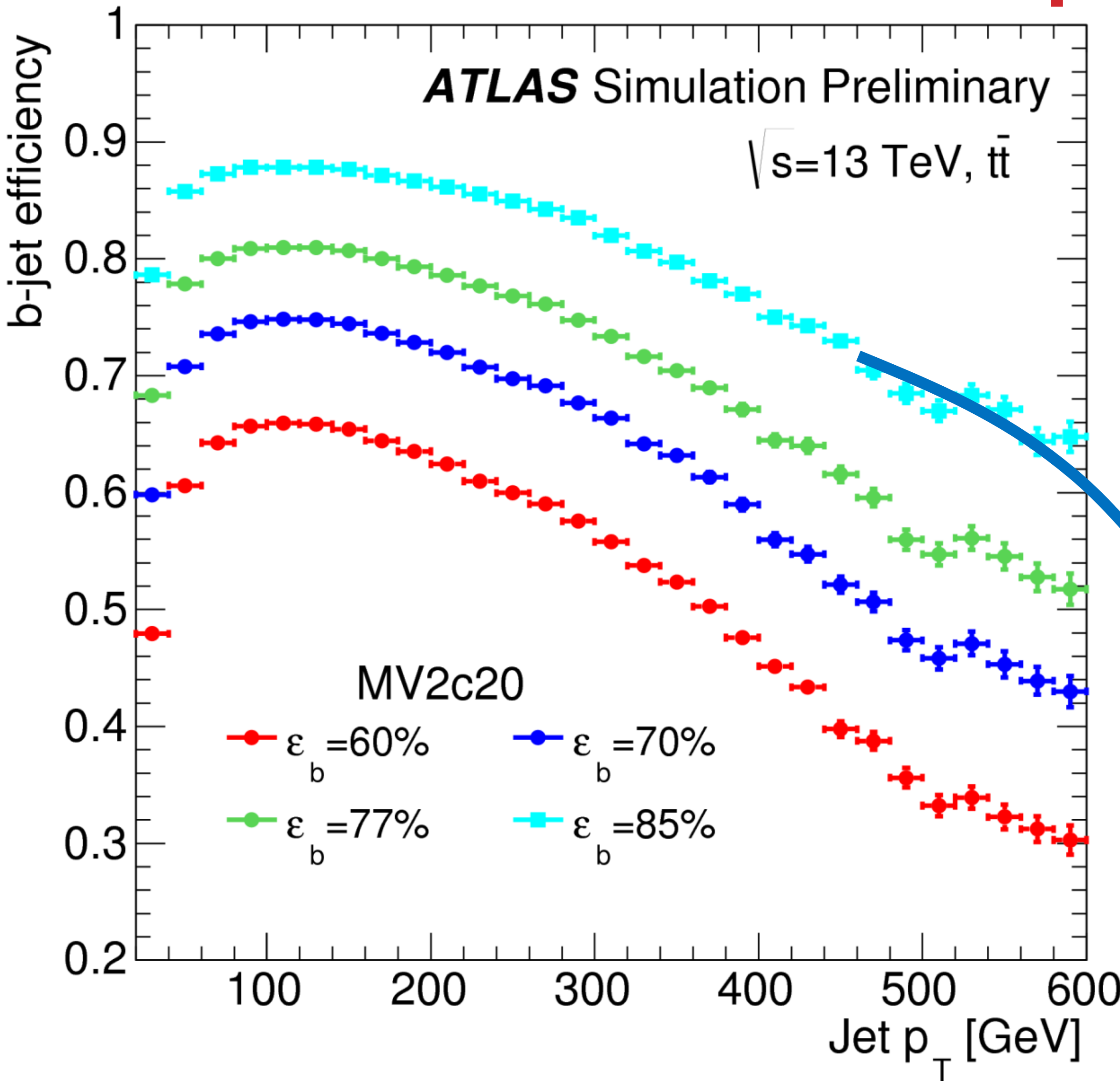
J. PHYS. G: NUCL. PART. PHYS 43 (2016) 085001

PROBLEM: TAG HIGH P_T B-JET

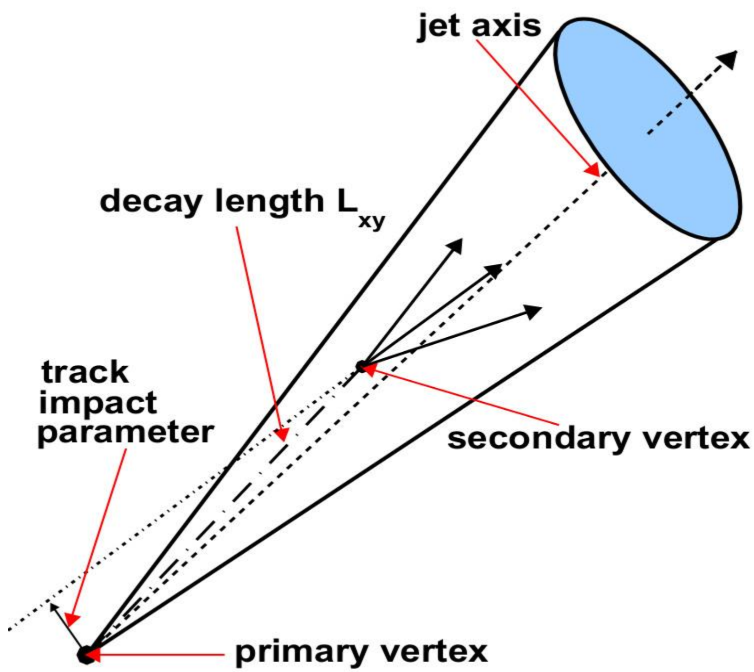


Aux. Fig. 4a → Pub. Note ATL-PHYS-PUB-2015-022

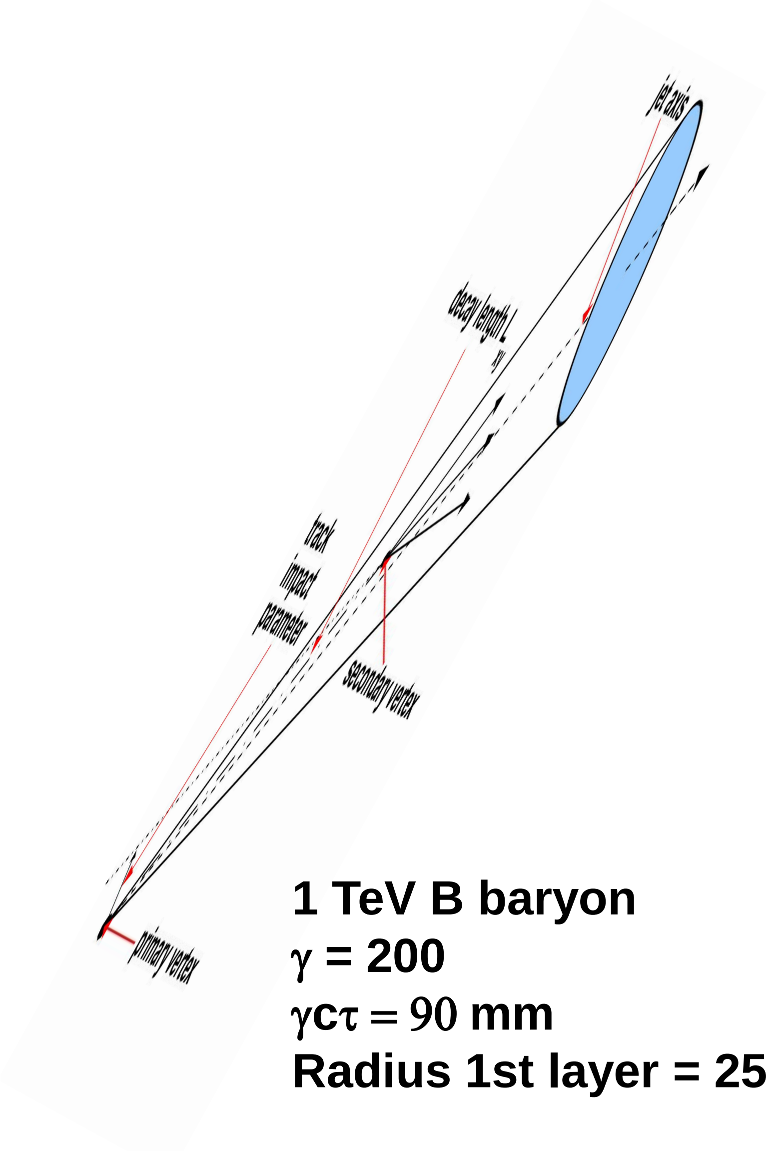
Next: Why it happens

B-TAGGERS FIGHT EINSTEIN

Small cone sizes are prevalent.
ΔR≈0.04 for a B in a 500+ GeV Jet.



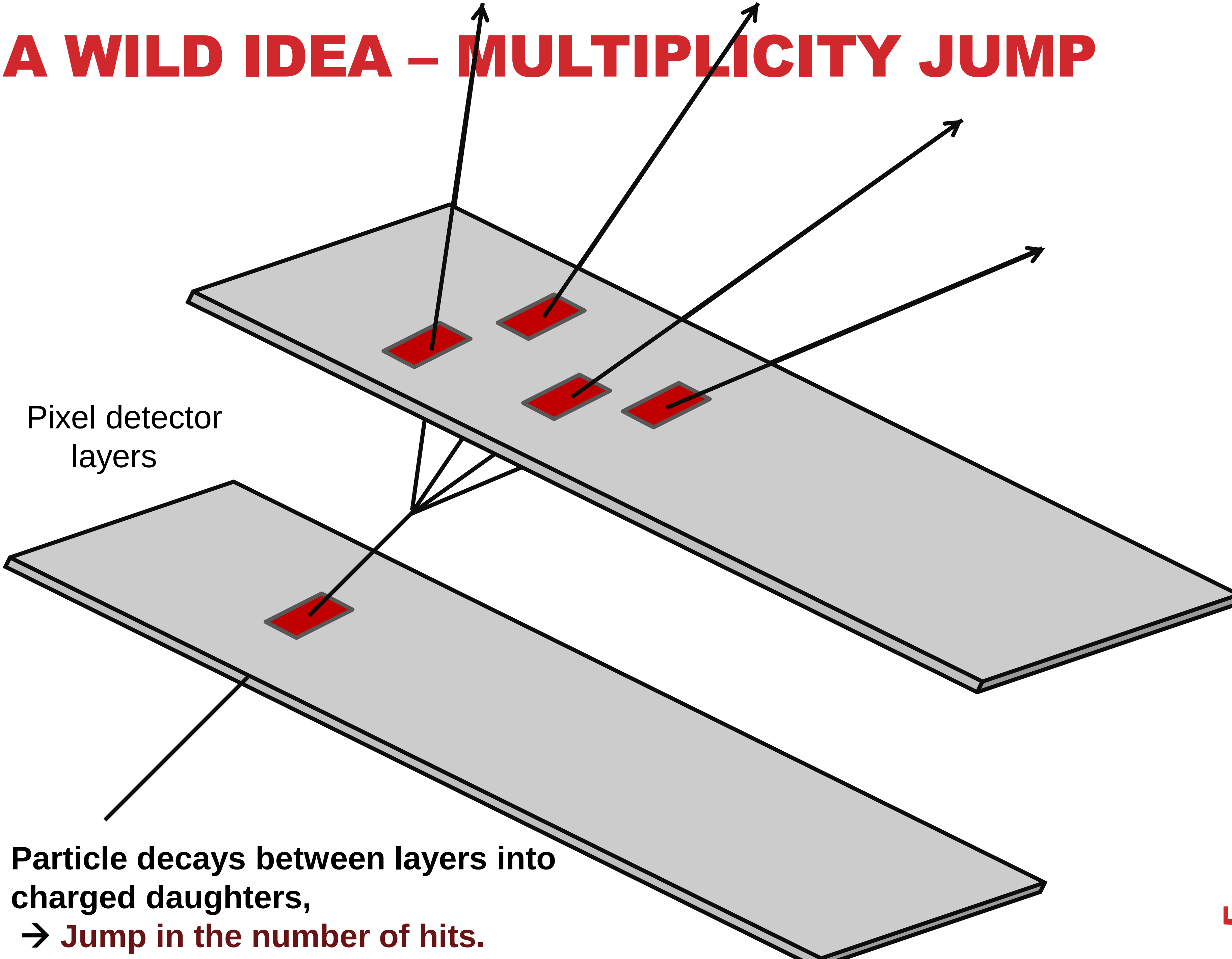
200 GeV B baryon
γ = 40
$\gamma c\tau$ = 18 mm



1 TeV B baryon
γ = 200
$\gamma c\tau$ = 90 mm
Radius 1st layer = 25 mm

AND NOW FOR SOMETHING COMPLETELY DIFFERENT

A WILD IDEA – MULTIPLICITY JUMP



Particle decays between layers into charged daughters,
→ Jump in the number of hits.

IDEA – NOT QUITE SO WILD

Had been tried in the 80's and early 90's in fixed target experiments at Hadron machines.

- ~400 GeV proton or pion beams
- Energy sufficient to make Bottom and Charm baryons

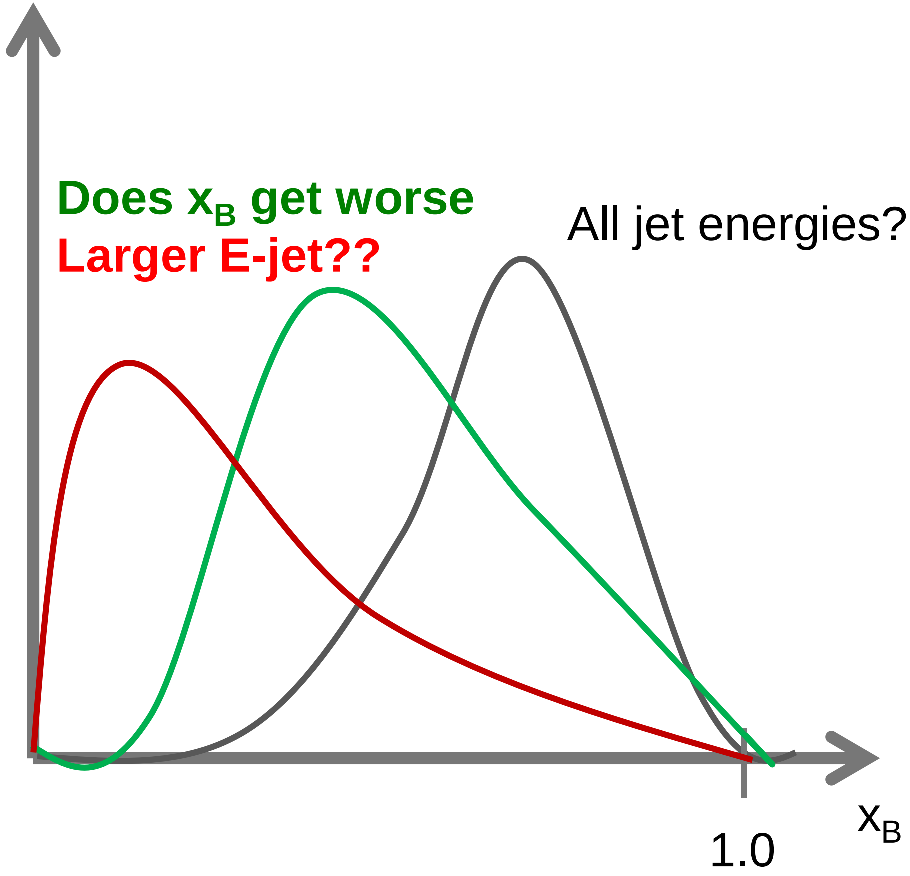
- Place detector "Downstream" of target; leave gap; second detector even further "downstream"
  - Detectors Scintillators or course resolution silicon detectors
  - Relied on integrating the ionization signal
  - Mica detector relied upon jump in amount of Cherenkov light
- Look for "Jump" in signal (details here)

- **Did not work very well → Tails in signals**
- **Modern Si pixel detectors have very high granularity. Do better?**

ENERGY-FRACTION OF B BARYONS? DOES IT DEPEND ON JET ENERGY?

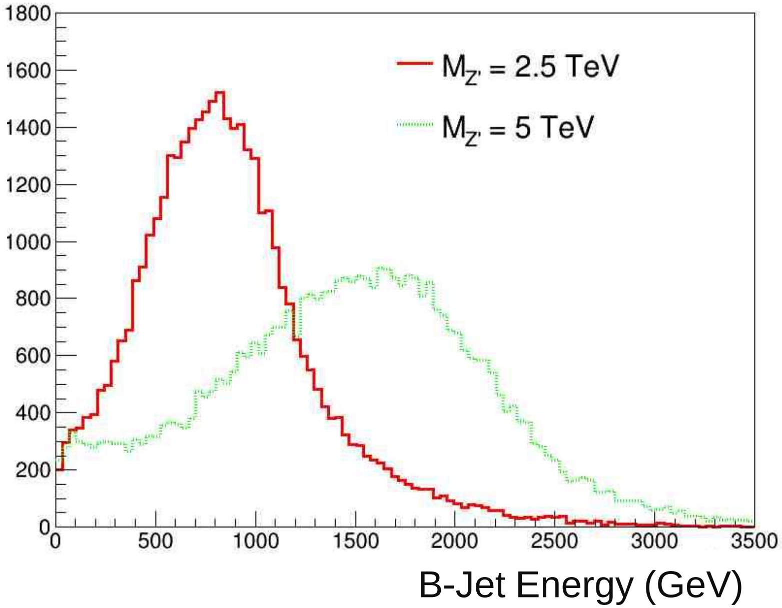
Energy fraction of B baryons as Jet energy increases

- x_B Logarithmic?
- x_B Non-linear?
- x_B Constant?
- If Jet energy → more tracks
    - Helps taggers



Let's at least find out what simulations say!

B BARYON ENERGY FRACTION (PYTHIA+FASTJET)

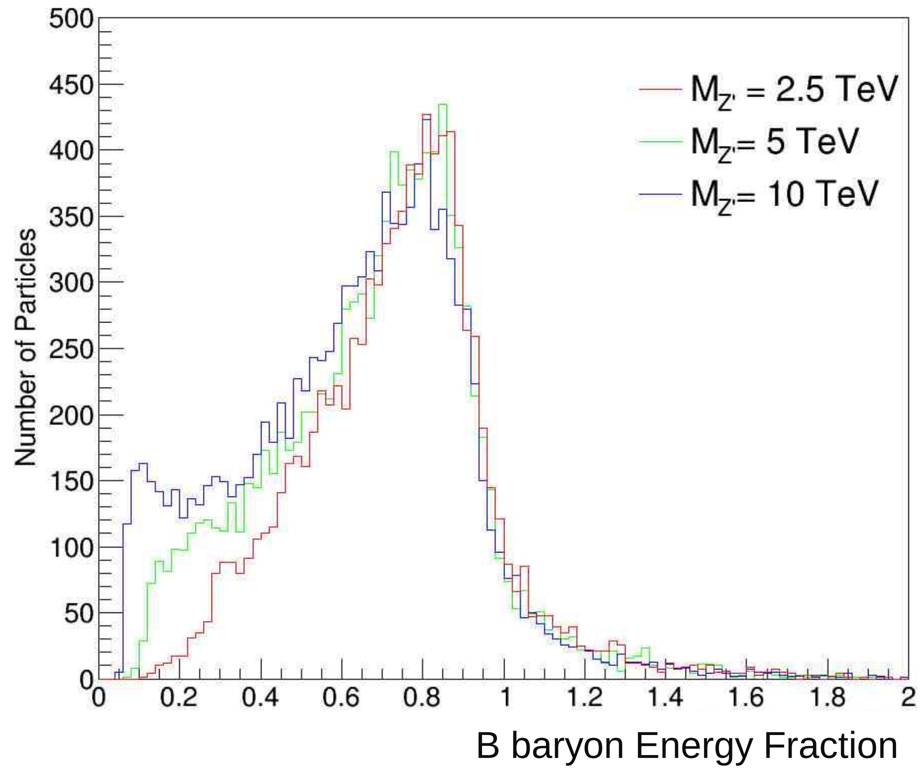


The energy of B hadrons in our simulation

As Jet energy increases, B-taggers less efficient.

And more B baryons will decay inside the detector volume.

However; Fraction of Jet energy each B baryon has does not strongly depend on energy of the jet.



SIMULATION DETAILS

Generator level simulation → Pythia 8

- pp collider with $\sqrt{s}$ = 13 TeV
- Generate Z' at 2.5 and 5 TeV
- Let the Z' decay only into u, d, s, c, and b quarks
- Use EvtGen to get B hadron decays correct

Jet simulation → FastJet 3

- Anti-Kt algorithm for forming jets
- Can set jet cone size
  - We've used R = 0.2

Detector simulation → GEANT4

- Volume → Cylinder 1.4 m radius filled with air, 2T mag. Field
- Silicon layers
  - Active at radii 25, 50, 88, and 122 mm
    - Small slabs 50 x 400 x 300 μm (φ x *z* x *r)*
    - ***inner layer 50 x 250 x 300 μm → IBL-like***
  - *Passive cylinders 2.5 mm thick to get to X_0=2.5% per layer*

ΔHIT FRACTION → F_I

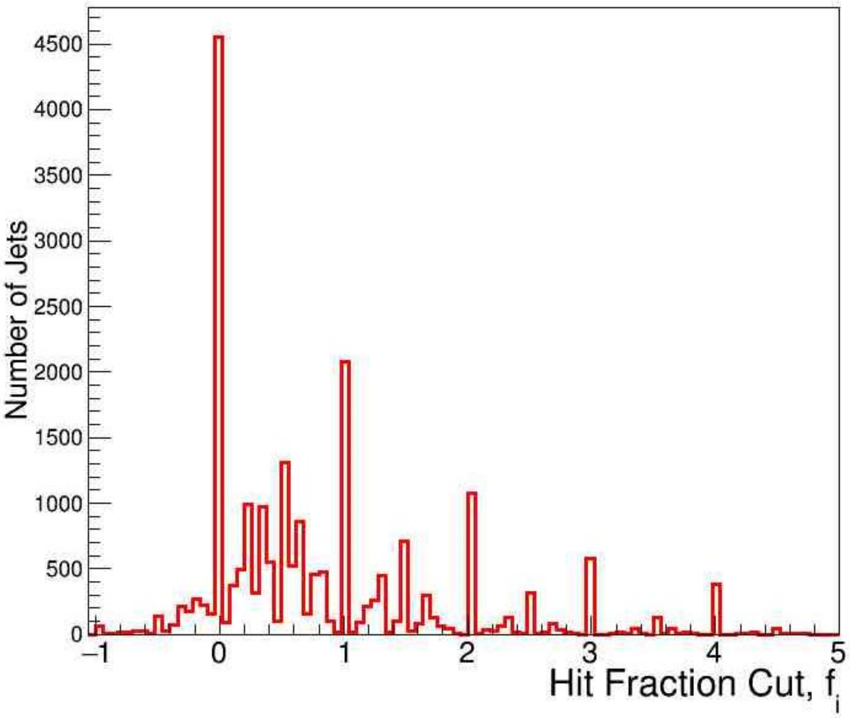
We *define* a quantity we call "Hit-difference Ratio" or "Hit-ratio" for short → "f_i".

- Use cone $\Delta R < 0.04$ around jet axis from Fastjet.
- **from i^{th} layer → f_i** $= (Nhits_{i+1} - Nhits_i)/Nhits_i$
  - **Can only have positive or zero hits, so:**
  - f_i is bounded from below by -1. & unbounded from above.

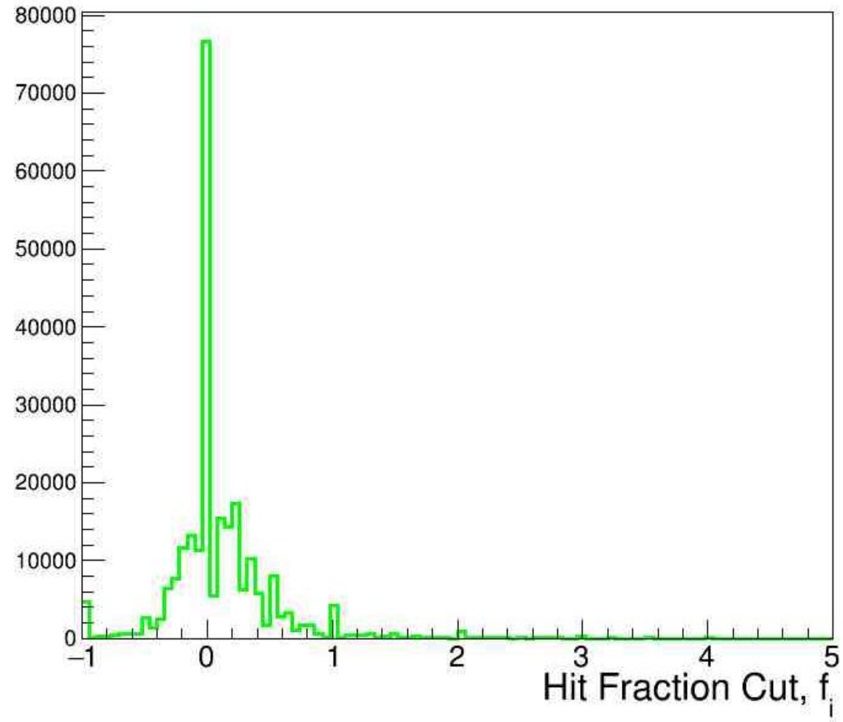
- Have a look at the f_i distribution.
  - Note: This sample → 0.5 to 2.5 TeV jets.

ΔHIT FRACTION = f_i – 2.5 TEV Z'

Jets with a B baryon
All gaps containing a decay



uds Jets



This looked promising → next use it as a cut variable

APPLYING ΔHIT$_F$ CUT

Start at f_i= -1.0 (i.e. no cut at all)

- And Start increasing the cut.

At each cut value, Plot (Number of Events passing cut)/(number of starting events)

NOTE! Only count B hadron jets where B decayed inside the layers!

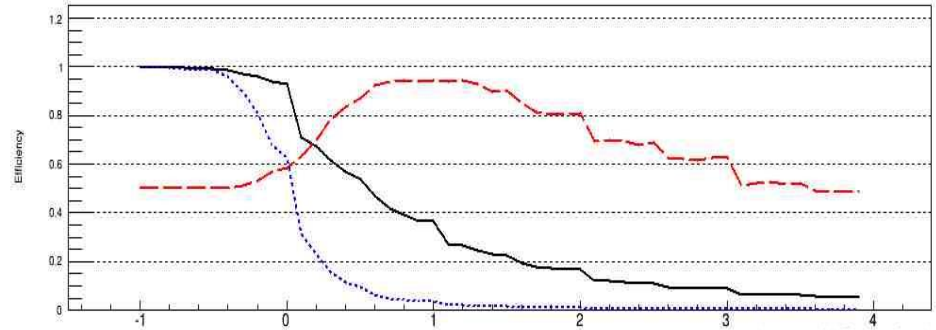
- Later: cut less effective with 5 TeV Z'. ΔR= 0.04 might be too big??

The "ALL Layers" plot is logical OR of individual layers, if any one of the ΔHit$_f$ between any pair of layers passes the cut, the event passes.

Charm not included.

EFF. OF F_I CUT SINGLE GAPS; $M_{Z'}$ = 2.5 TEV

$f_1 \rightarrow$ first gap



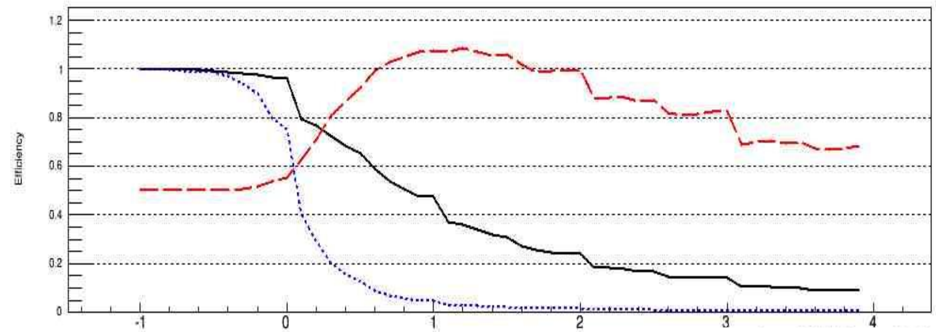
$\varepsilon \rightarrow$ B baryons

$\varepsilon \rightarrow$ uds jets

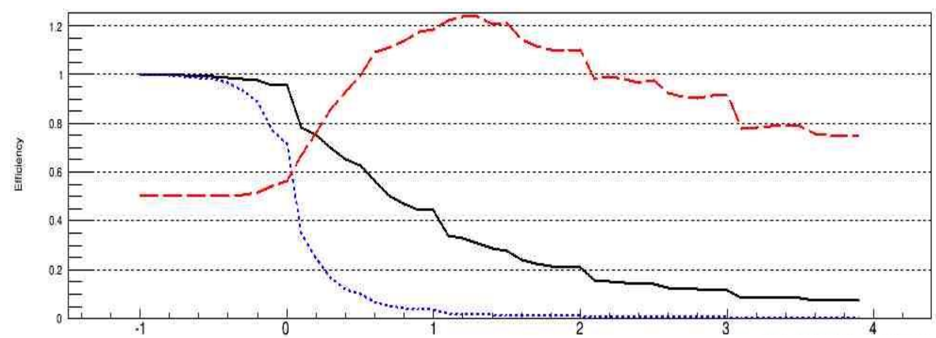
"Significance"

$S \equiv \varepsilon_b / \sqrt{\varepsilon_q}$ & scaled

$f_2 \rightarrow$ next gap



$f_3 \rightarrow$ last gap

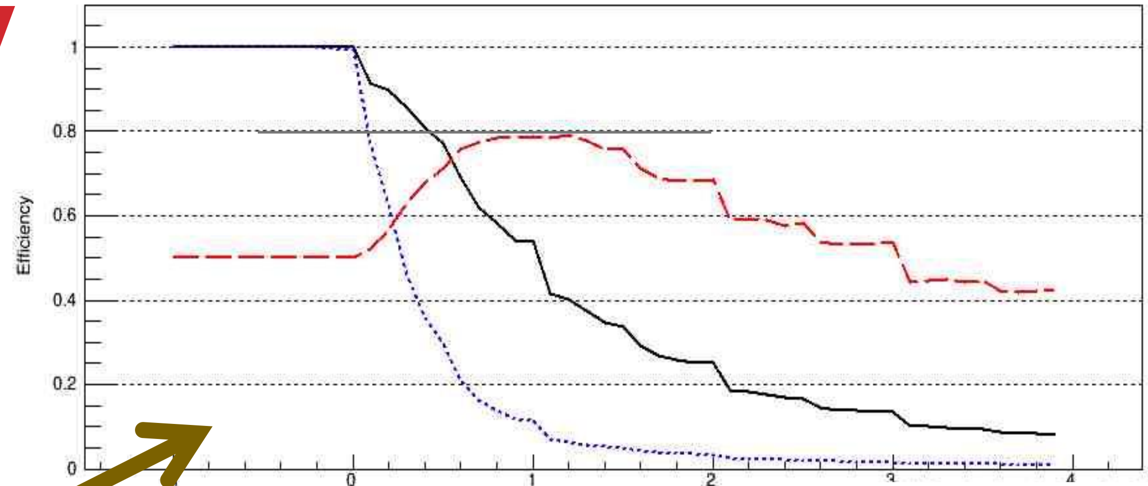


OK, try only the "OR" between all gaps

F_I EFFICIENCY AND PURITY - LAYERS 1234 $M_{Z'}$ = 2.5 TEV

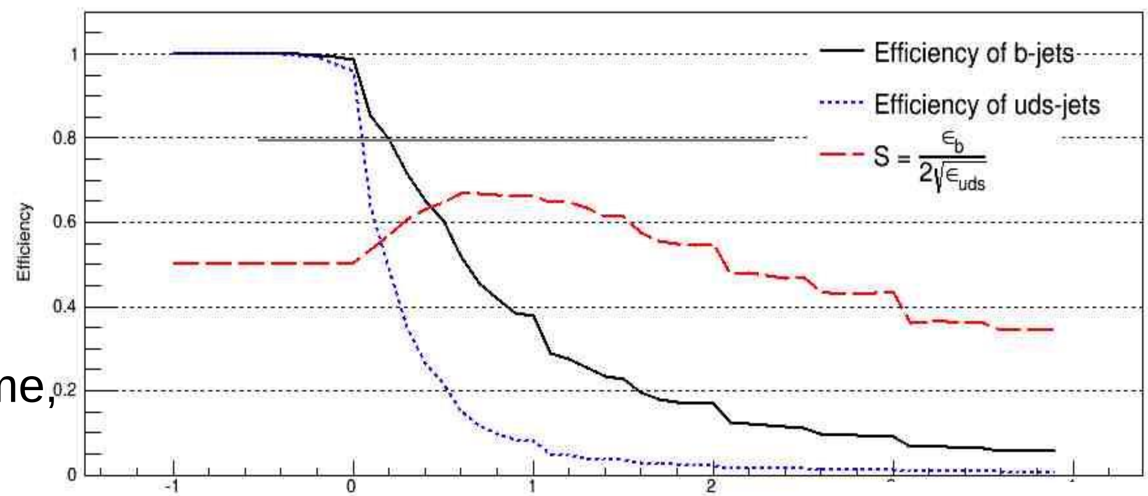
$f_i \geq F=1$

Layers:
1-2 or
2-3 or
3-4



Choose this one!!

Layers:
2-3 or
3-4

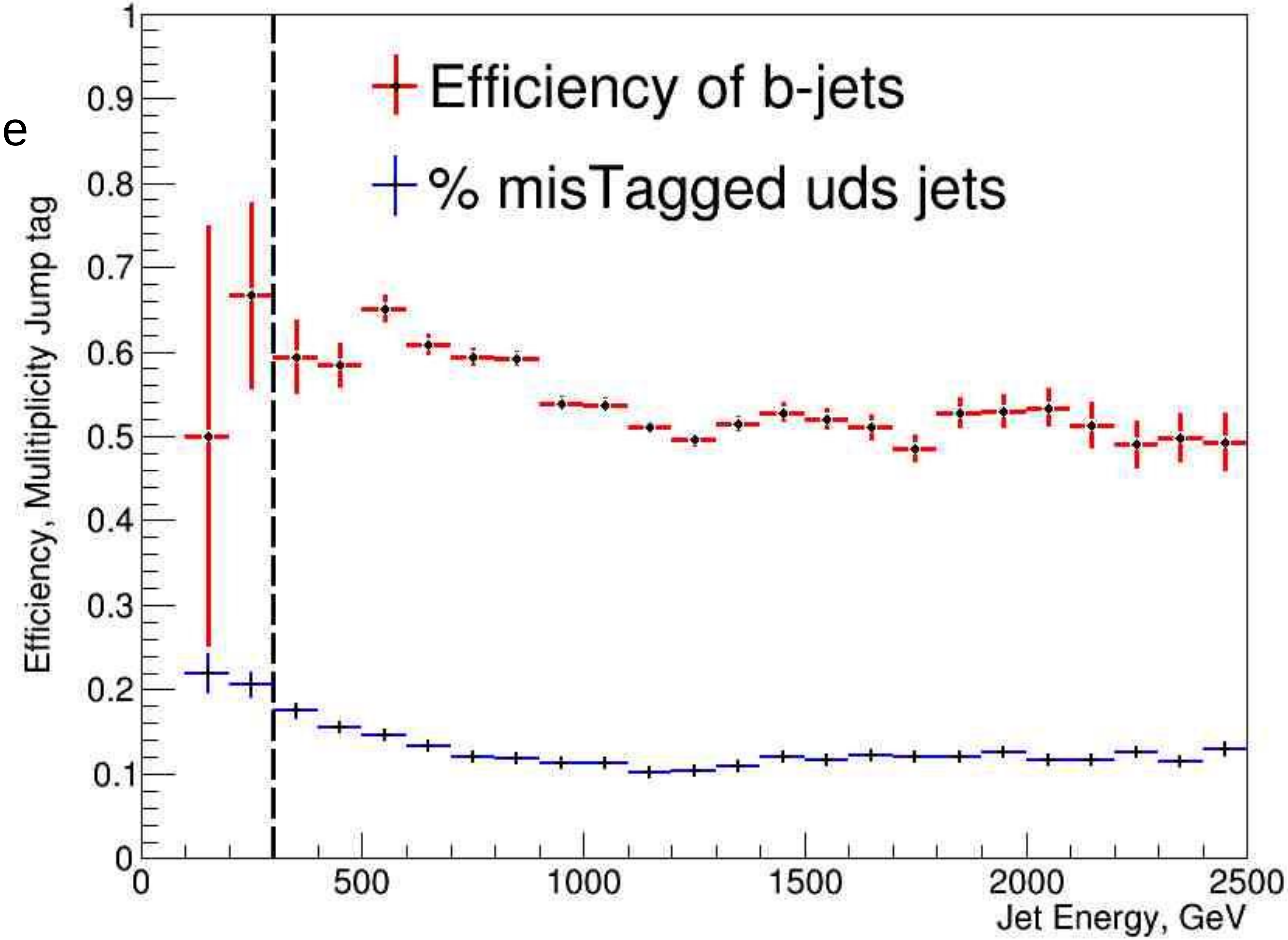


Fiducial region → Whole volume,
So can compare.

EFFICIENCY VS. JET ENERGY

By itself: Less than impressive tagger.

Propose to use alongside conventional taggers



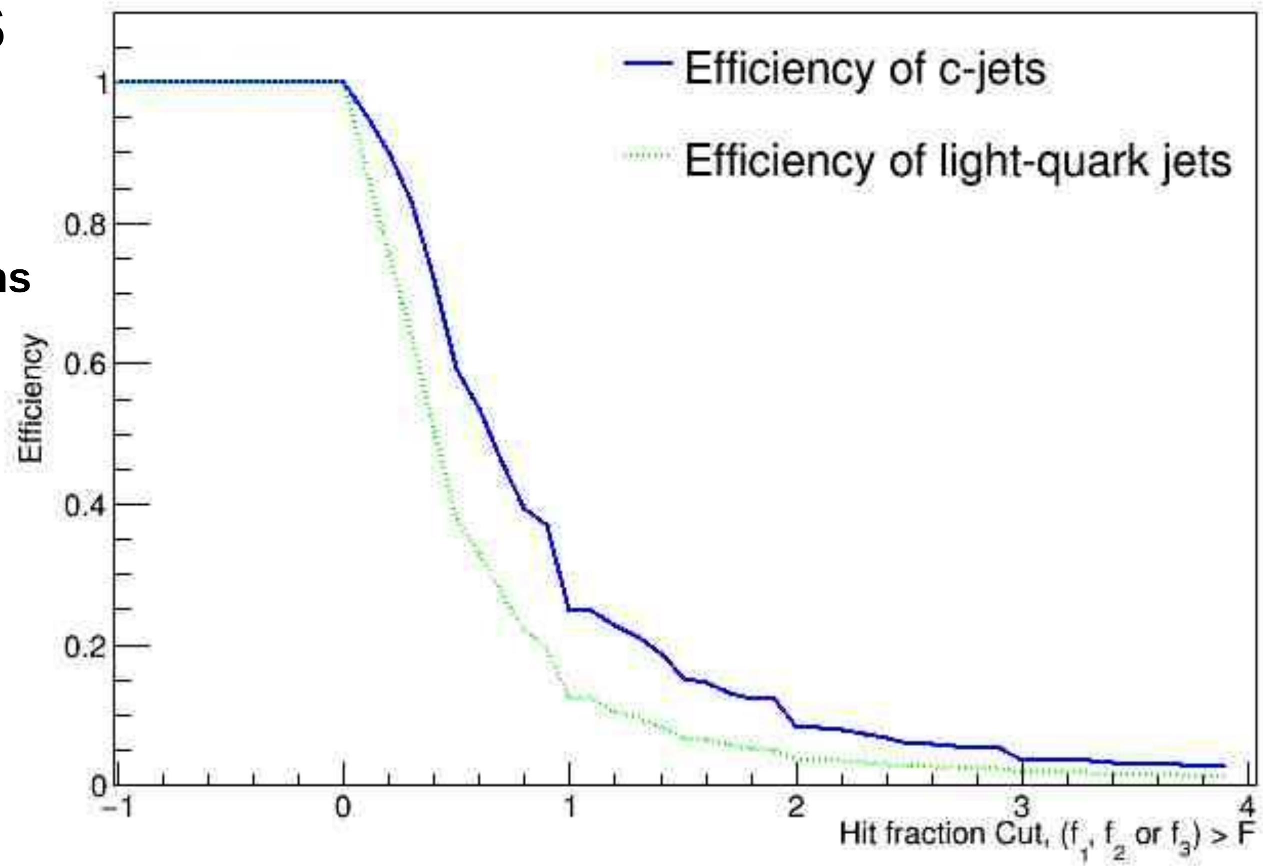
Might aid tagging of High P_T Jets

MAX(F_1,F_2,F_3) > ΔHIT

Completeness Charm jets

2.5 TeV

Same set of conditions



SUMMARY

Technique works!

- There are (many) caveats; clearly more work is needed.
  - For example….

More realistic detector simulation (wish list)

- Full Detector simulation
- Maybe include Si strip detectors as well
- Many Technical Difficulties to overcome
  - Detector overlaps
  - Getting raw hit information

Employ Neural net or other multi-variant techniques.

- Variable weights on layers
- Variable cone size, use fat-jets, include jumps that account for sequential charm decays??

Conclusion: Combine with conventional tagger

→ Looking for help!

THANK YOU!

BACKUP SLIDE

EFF. AND PURITY
$M_{Z'}$ = 10 TEV