LH 2023: jet flavour

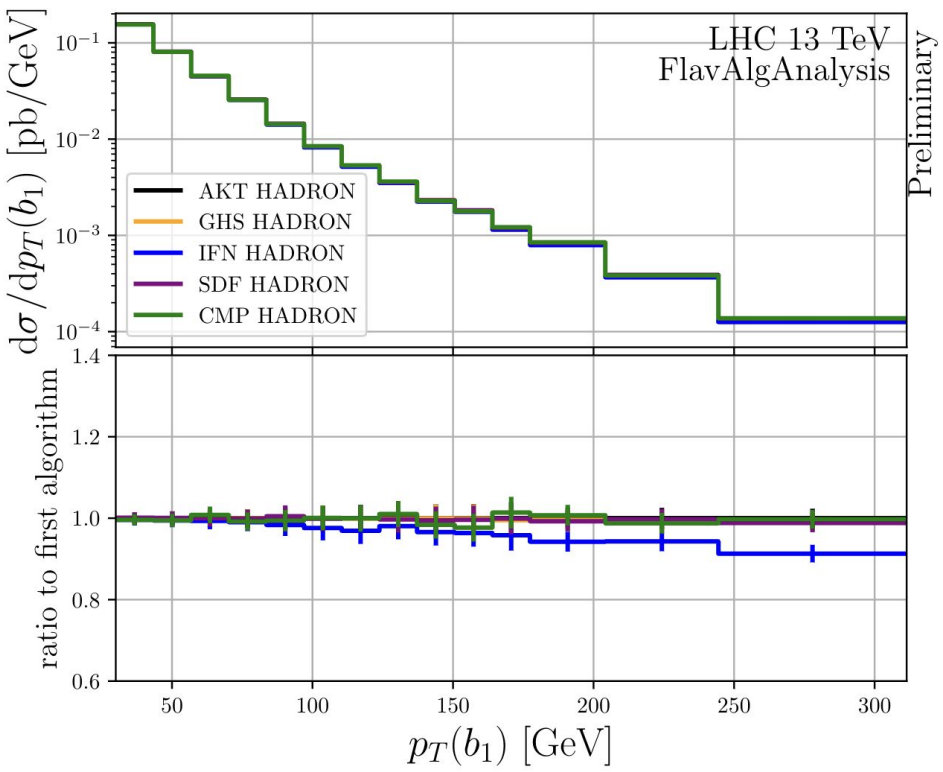
Study from the IFN collaboration

Sherpa Pythia Z+jet process (Rivet analysis)

Shows algorithms behaving similarly at low p_T of the leading b jet.

At higher p_T IFN algorithm seems to be systematically lower than the others.

Is IFN behaving sensibly?



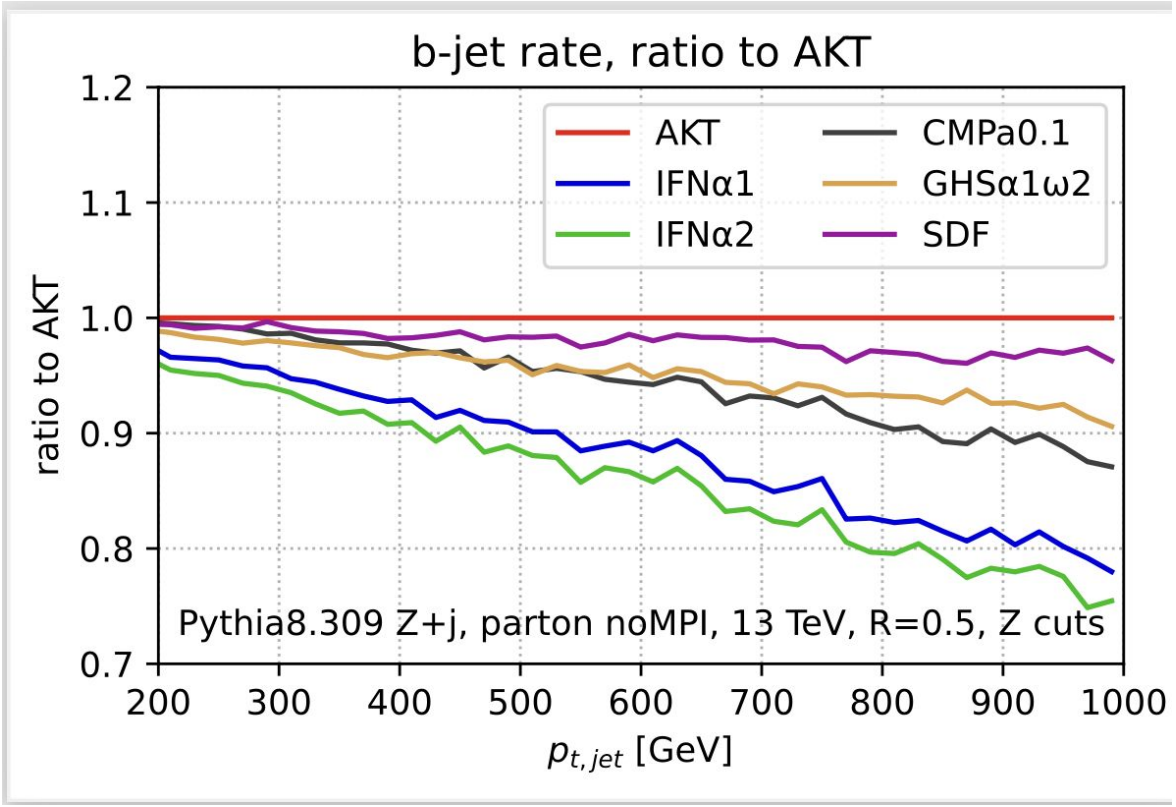
Simpler study: Pythia Z+jet process (partons, no MPI)

Easier to extend to high pt

Features at p_T~200 GeV are ~similar to full Sherpa sample

All flavour algorithms depart from AKT at high pt:

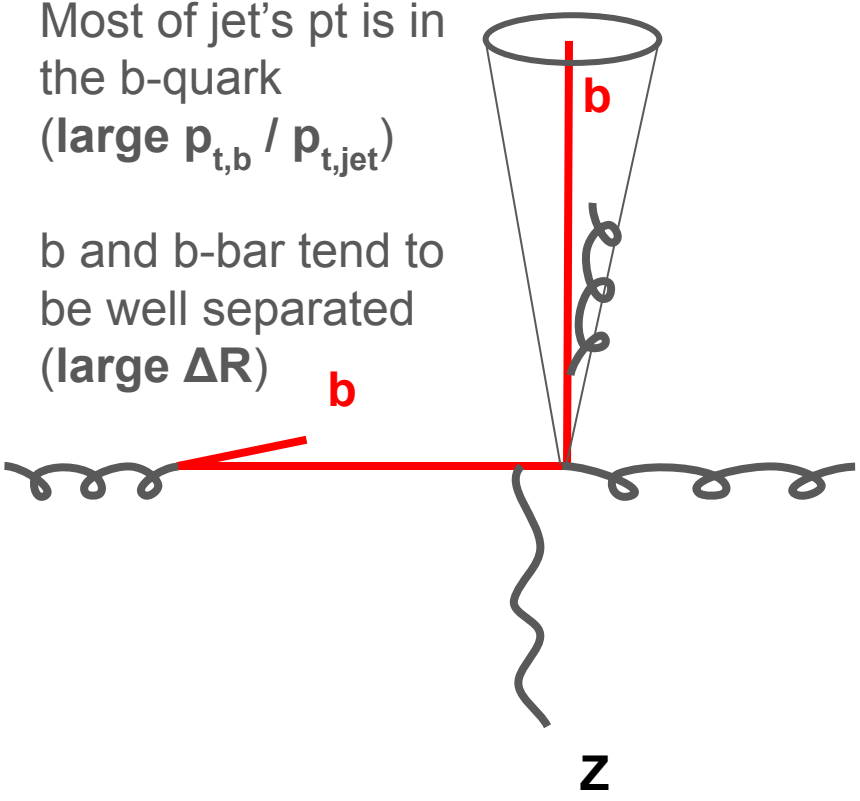
IFN < CMP < GHS < SDF



Genuine b-jet

Most of jet's pt is in the b-quark (**large $p_{t,b}$ / $p_{t,jet}$**)

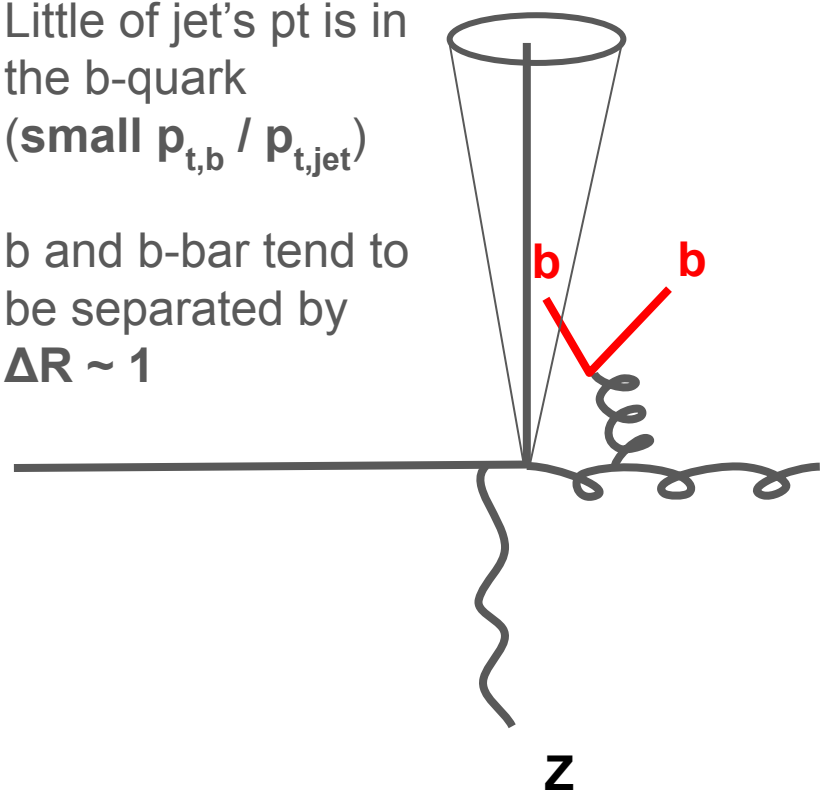
b and b-bar tend to be well separated (**large ΔR**)



Fake b-jet

Little of jet's pt is in the b-quark (**small $p_{t,b}$ / $p_{t,jet}$**)

b and b-bar tend to be separated by **ΔR ~ 1**



Examine an event where AKT & IFN differ

- Event 3736
- akt0.5 : pt=365.717, y=1.90836, phi=5.58856, m=44.1538, [b]
- akt0.5IFNa2 : pt=365.717, y=1.90836, phi=5.58856, m=44.1538, [g]
- akt0.5IFNa2mod2: pt=365.717, y=1.90836, phi=5.58856, m=44.1538, [g]
- akt0.5IFNa1 : pt=365.717, y=1.90836, phi=5.58856, m=44.1538, [g]
- CMP0.5-a0.10 : pt=365.717, y=1.90836, phi=5.58856, m=44.1538, [b]
- GHS : pt=365.717, y=1.90836, phi=5.58856, m=44.1538, [b]
- SDF : pt=365.717, y=1.90836, phi=5.58856, m=44.1538, [b]
- ih: 2 pt=10.9947, y=2.25043, phi=5.60292, m=4.8, [b]
- ih: 4 pt=6.62872, y=1.92128, phi=1.40879, m=4.8, [bbar]

JETS (7 agls)

b-quarks

Note the soft b-quarks

Examine an event where AKT & IFN differ

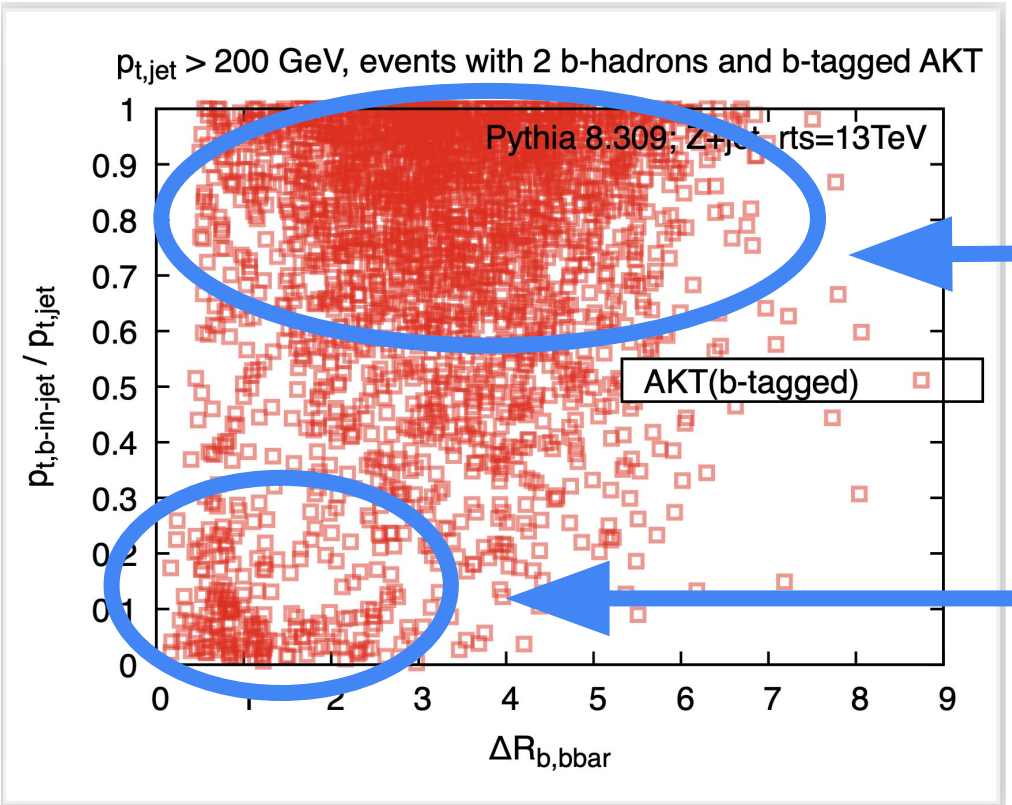
- Event 7300
- akt0.5 : pt=429.189, y=-0.0252231, phi=0.0539795, m=61.2719, [bbar]
- akt0.5IFNa2 : pt=429.189, y=-0.0252231, phi=0.0539795, m=61.2719, [g]
- akt0.5IFNa2mod2: pt=429.189, y=-0.0252231, phi=0.0539795, m=61.2719, [g]
- akt0.5IFNa1 : pt=429.189, y=-0.0252231, phi=0.0539795, m=61.2719, [g]
- CMP0.5-a0.10 : pt=436.371, y=-0.0322051, phi=0.0466832, m=77.6945, [g]
- GHS : pt=429.189, y=-0.0252231, phi=0.0539795, m=61.2719, [g]
- SDF : pt=429.189, y=-0.0252231, phi=0.0539795, m=61.2719, [bbar]
- ih: 7 pt=7.84606, y=-0.355632, phi=5.91932, m=4.8, [b]
- ih: 9 pt=34.2309, y=-0.160611, phi=6.11093, m=4.8, [bbar]

JETS (7 agls)

b-quarks

Note the soft b-quarks

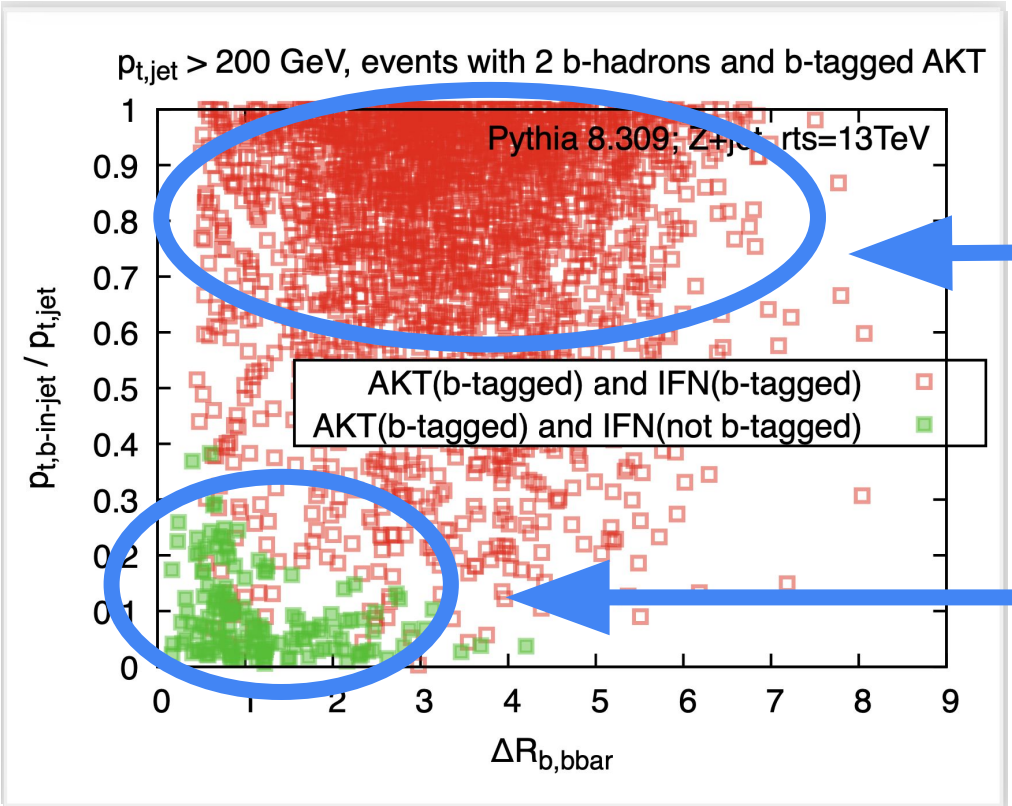
b-quark p_T fraction in jet vs. ΔR_{bb} (AKT jets)



Likely genuine b jets?

Fake b-jets?

b-quark p_T fraction in jet vs. ΔR_{bb} (AKT jets v. IFN)



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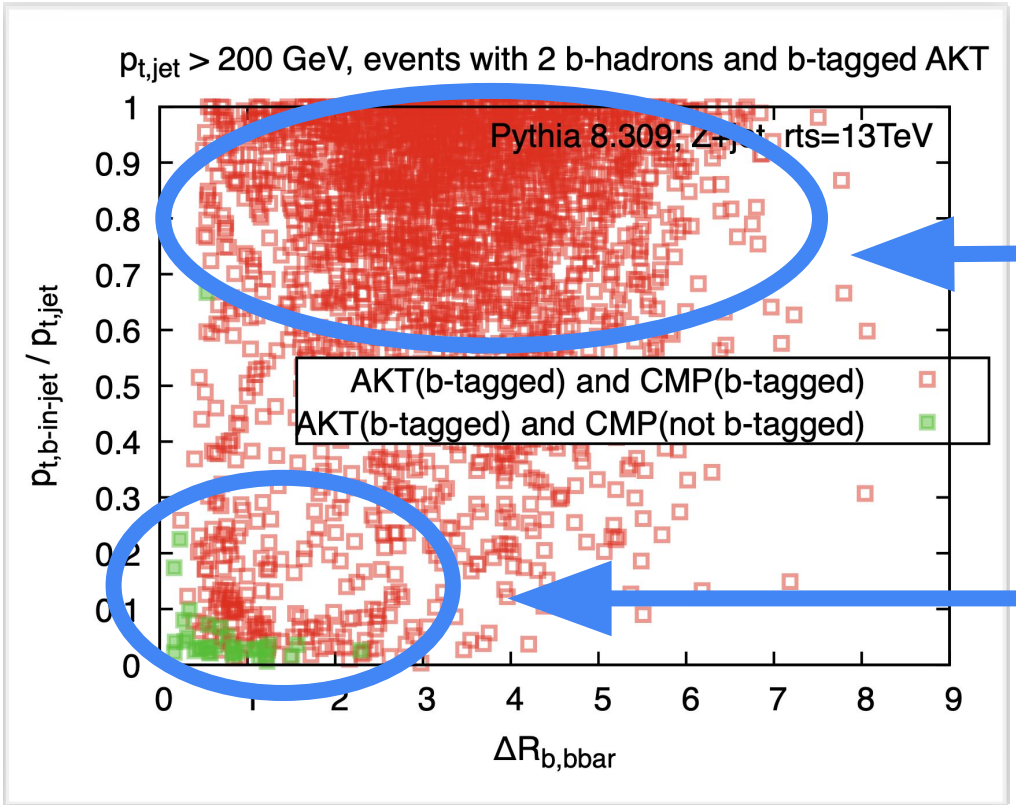
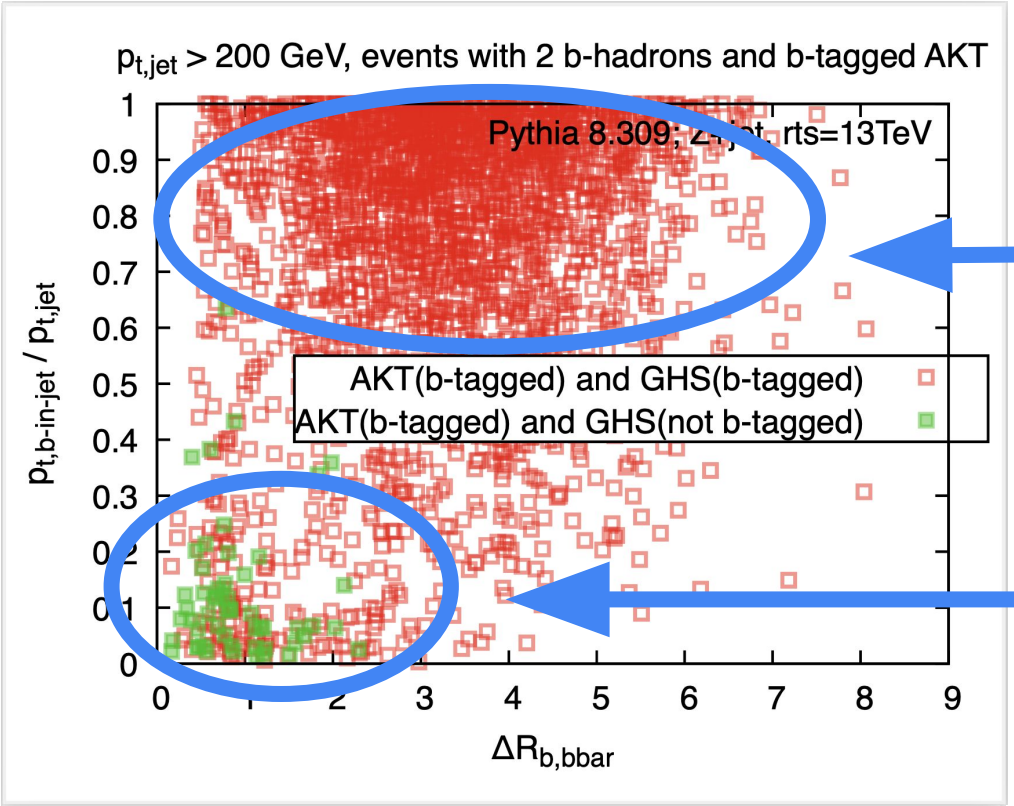
b-quark p_T fraction in jet vs. ΔR_{bb} (AKT jets v. CMP)



Likely genuine b jets?

Fake b-jets?

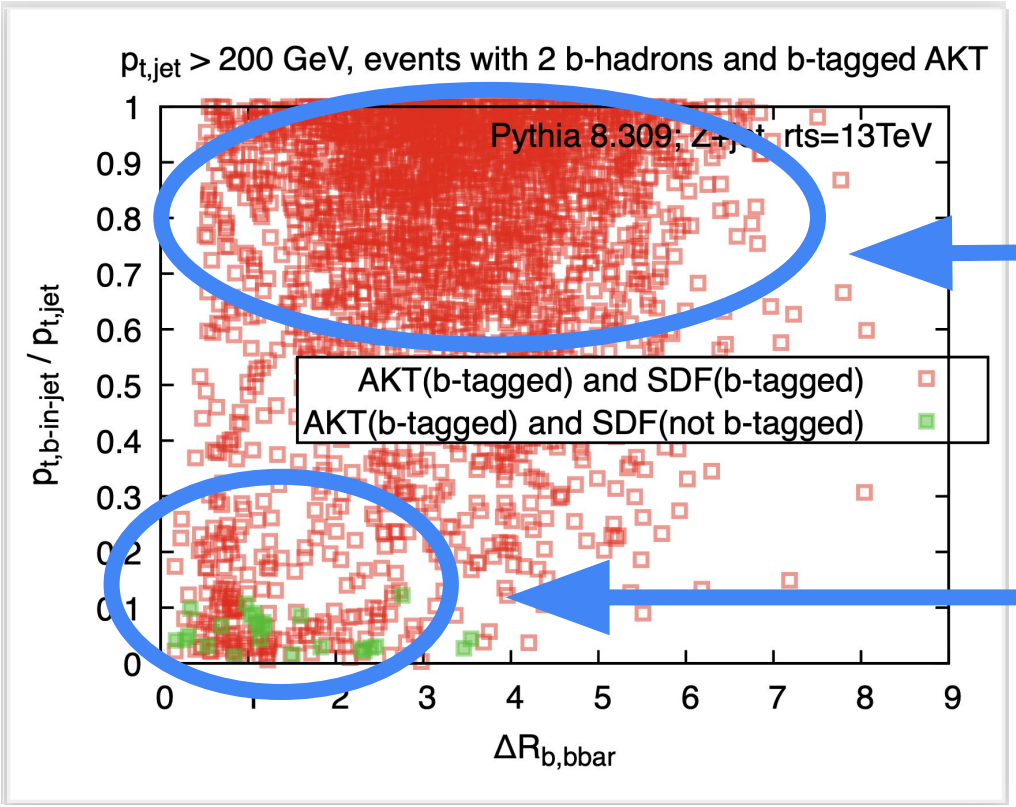
b-quark p_T fraction in jet vs. ΔR_{bb} (AKT jets v. GHS)



Likely genuine b jets?

Fake b-jets?

b-quark p_T fraction in jet vs. ΔR_{bb} (AKT jets v. SDF)



Likely genuine b jets?

Fake b-jets?

Thoughts (1)

- As long as different IRC safe algorithms give different results, there is freedom to choose which algorithm you think is more sensible.
- All IRC safe algorithms (IFN,CMP,GHS) differ from AKT to varying degrees
- Differences to AKT are largest at high p_T (because soft b-bbar gets a log enhancement)
- **Looking at the scatter plots and events, IFN seems to us to be behaving sensibly and the difference with respect to AKT is a sign that IFN is doing its job correctly.**

Thoughts (2)

Are other algorithms neutralising fewer b-bbar pairs because of “small” parameters? Specifically:

- CMP: a=0.1,
- GHS: jet p_T cut = 15-20 GeV
- SDF: soft-drop z_{cut}=0.1

We think each algorithm becomes IR unsafe as the small parameter “ε” → 0.
So maybe they are all effectively replacing

$$\alpha_s^2 \log(p_T/m_b) \rightarrow \alpha_s^2 \log(1/\varepsilon)$$

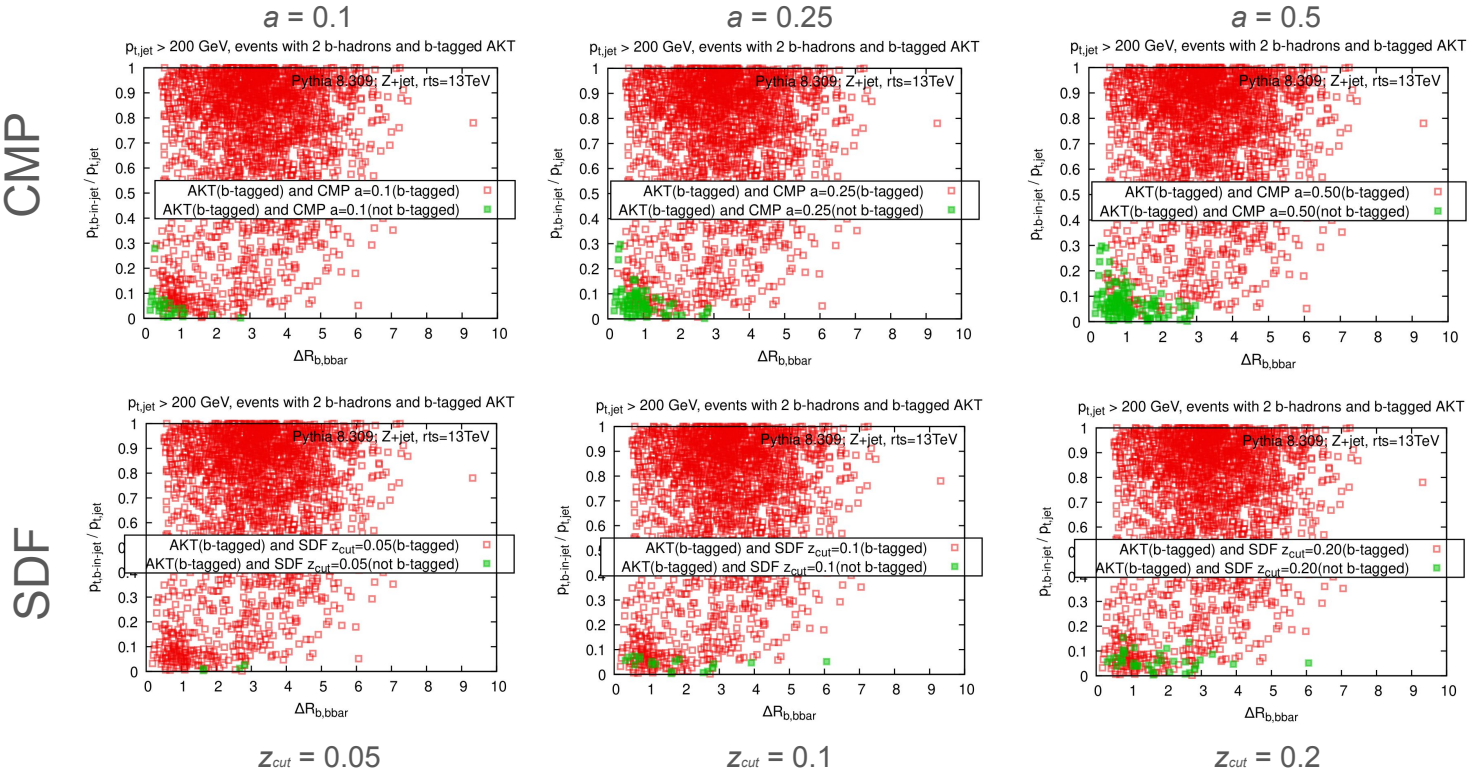
And since ε is not much smaller than m_b/p_T, they leave a significant fraction of the soft b contamination?

Single event: CMP *a*-parameter variation

```
Event 2042
 akt0.5       :  pt=238.502, y=1.8198, phi=3.85412, m=40.6667, [b ]
 akt0.5IFNa2  :  pt=238.502, y=1.8198, phi=3.85412, m=40.6667, [g]
 akt0.5IFNa2mod2:  pt=238.502, y=1.8198, phi=3.85412, m=40.6667, [g]
 akt0.5IFNa1  :  pt=238.502, y=1.8198, phi=3.85412, m=40.6667, [g]
 cmp0.5-a0.10   :  pt=238.502, y=1.8198, phi=3.85412, m=40.6667, [b ]
 cmp0.5-a0.25   :  pt=241.564, y=1.81583, phi=3.86672, m=58.1486, [g]
 cmp0.5-a0.50   :  pt=241.564, y=1.81583, phi=3.86672, m=58.1486, [g]
 GHS          :  pt=238.502, y=1.8198, phi=3.85412, m=40.6667, [g]
 SDF          :  pt=238.502, y=1.8198, phi=3.85412, m=40.6667, [b ]
   ih: 5 pt=25.2506, y=2.05541, phi=4.08007, m=4.8, [b ]
   ih: 9 pt=4.30449, y=1.66725, phi=4.63961, m=4.8, [bbar ]
```

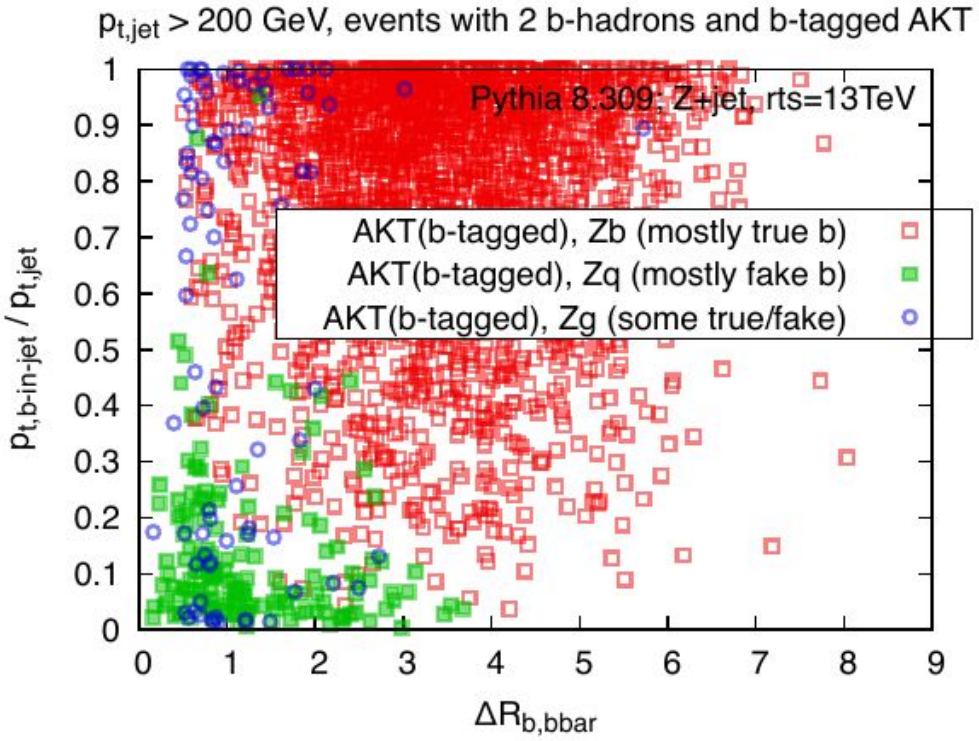
As *a* increases, flavour contamination decreases at similar values of ptb/pt

b-quark p_T fraction in jet vs. ΔR_{bb}

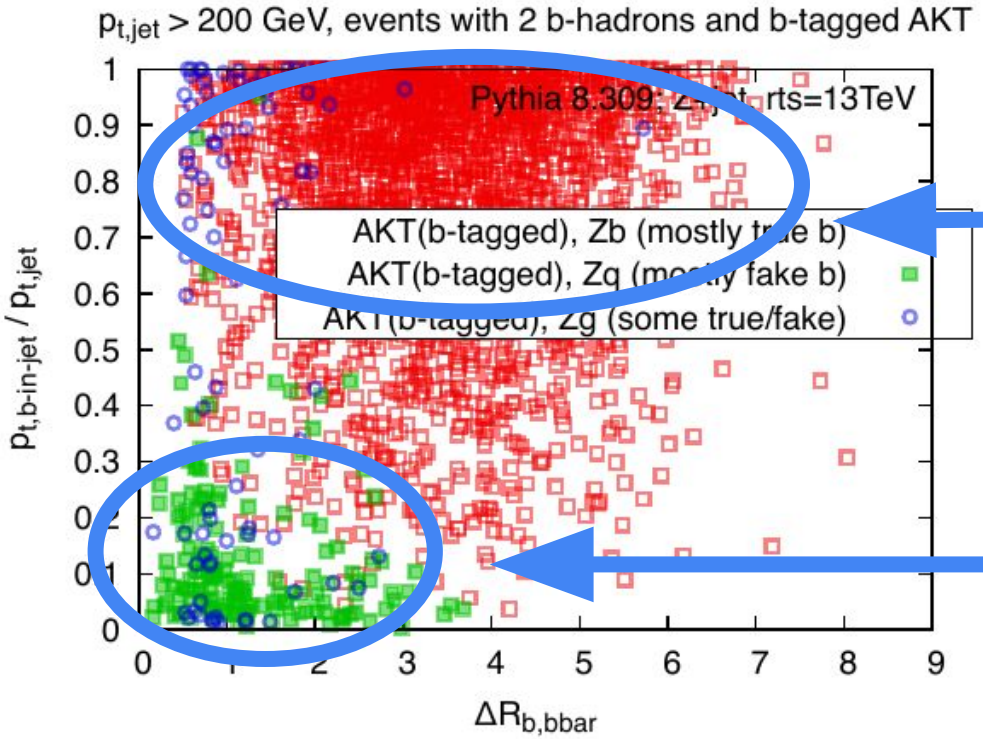


backup

Pythia Z+jet events, separated by (Pythia) channel



Pythia Z+jet events, separated by (Pythia) channel



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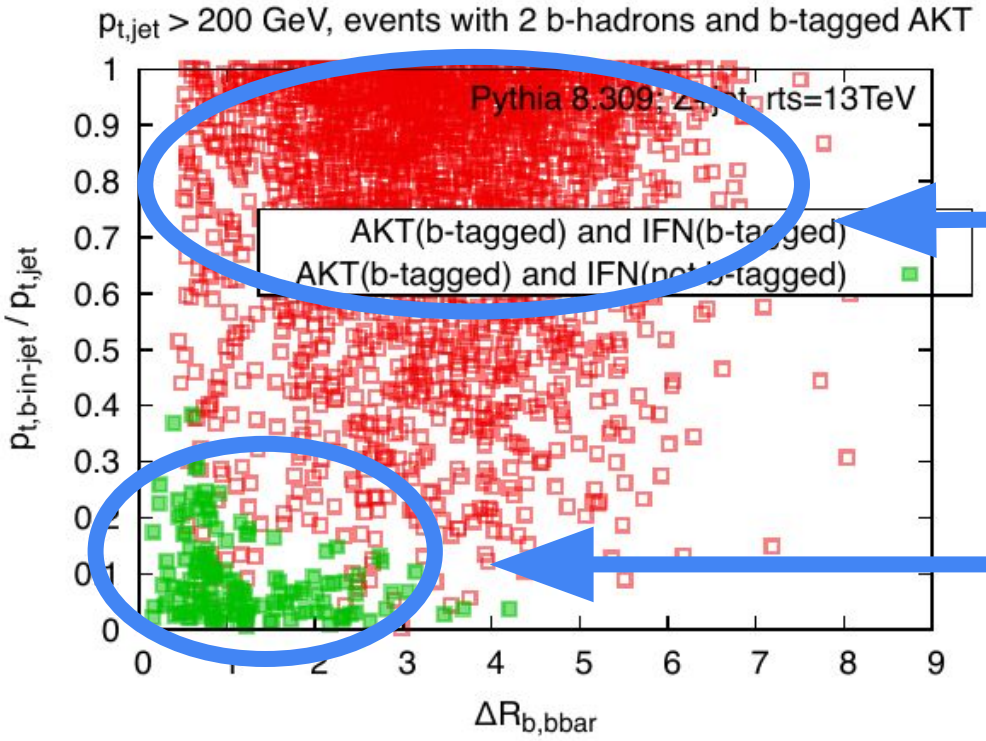
Fake b-jets?

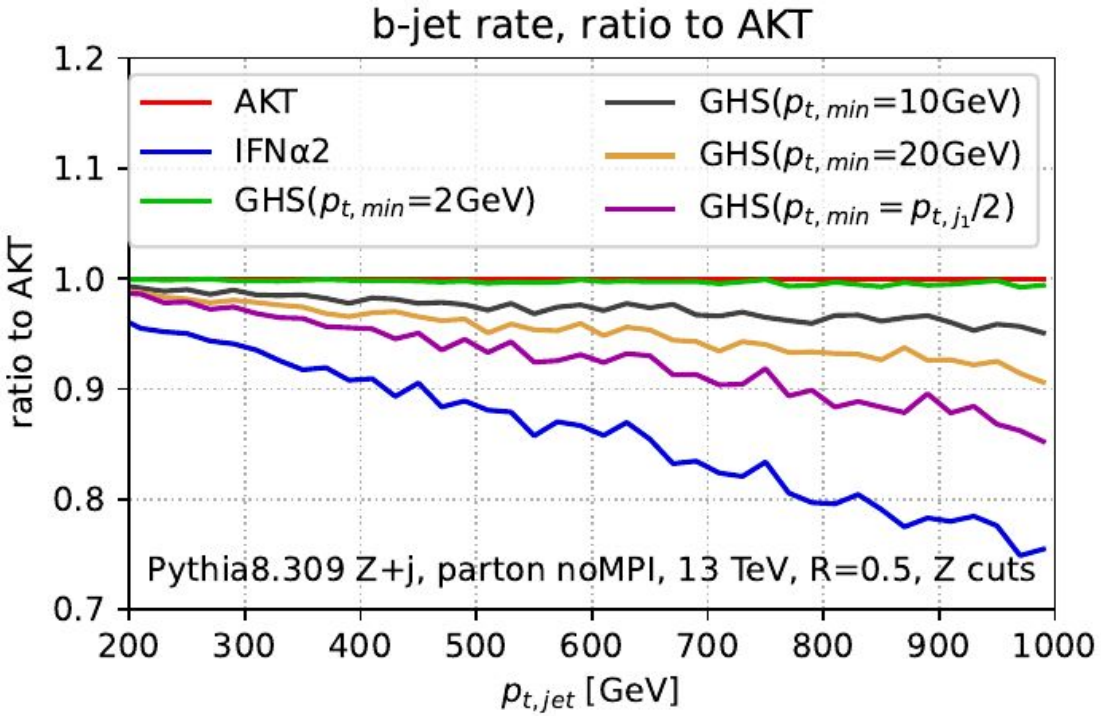
Pythia Z+jet events, classified by IFN



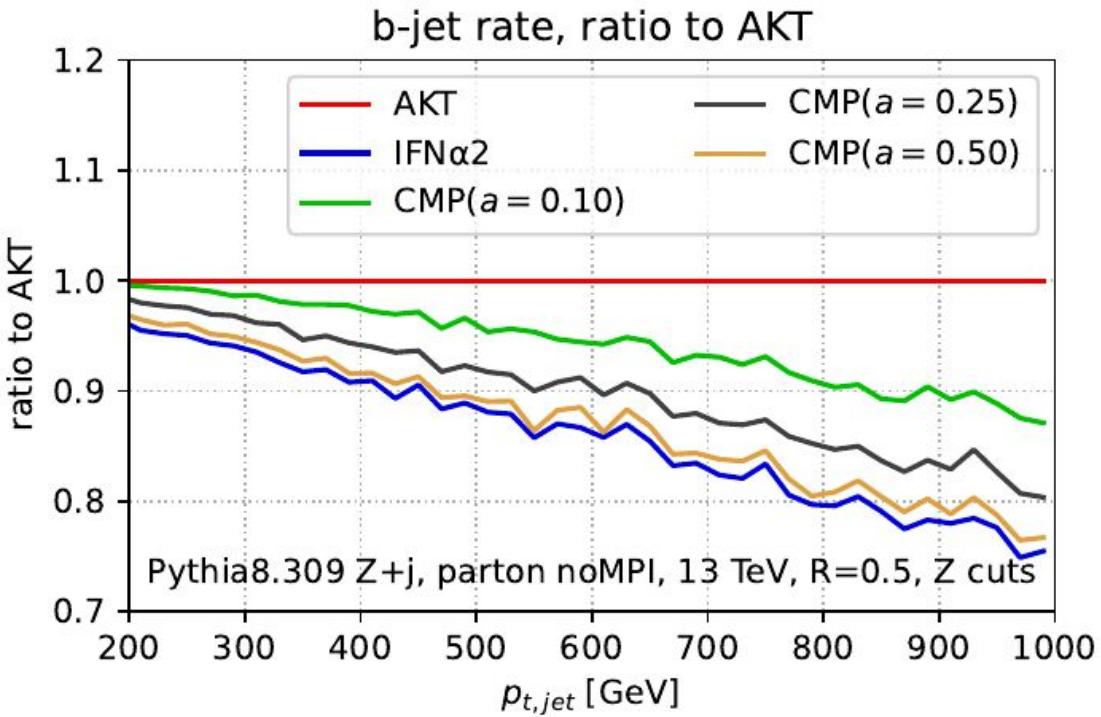
Likely genuine b jets?

Fake b-jets?

GHS spectrum v. pt cut



CMP spectrum v. pt cut



SDF spectrum v. pt cut