

Flavor tagging performance in multi-jet environments (a part of LCFIVertex study)

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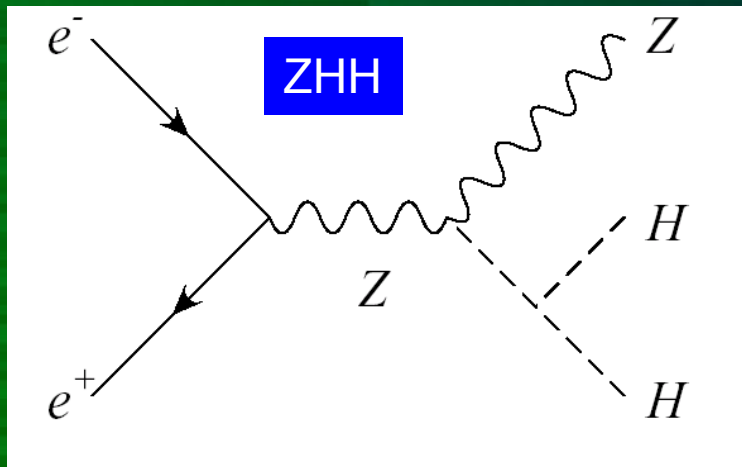
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Topics

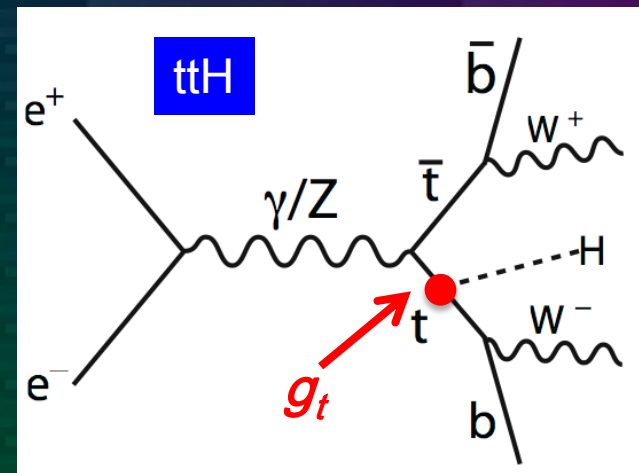
- Importance of flavor tagging in multi-jet environments
- Performance of 6-jet clustering in ZHH
- Modified jet clustering
 - Vertex finder without jet clustering
 - Jet clustering with vertex information
 - Preliminary performance

Multi-jet flavor analysis

- Many LC physics targets have
 - Many jets (4, 6, 8, ...)
 - Many b jets (from $H \rightarrow bb$, $t \rightarrow bW$ etc.)
- ➔ **b-tagging in multi-jet environment**



qqbbbb (32%) qqbbWW(14%)
 $\nu\nu$ bbbb (9%) etc. (120GeV Higgs)



bbbbqqqq(31%)
bbbbqq ν (31%) etc.

Current ILD reconstruction

Full-MC simulation (Mokka)



Event reconstruction

- Digitization
- Tracking
- Particle flow (PandoraPFA)

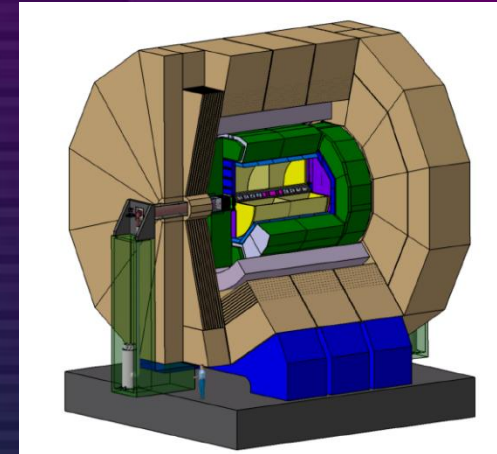


Jet clustering (Durham fixed # jets)



LCFIVertex

- ZVTOP vertex finder (for each jet)
- Neural-net based b-&c- tagging
- Quark charge identification



Jet clustering & vertex finder is independent



Mis-clustered jet gives wrong vertex/flavor result

B-tagging in ZHH (Z->qq)

Y. Takubo, ALCPG09

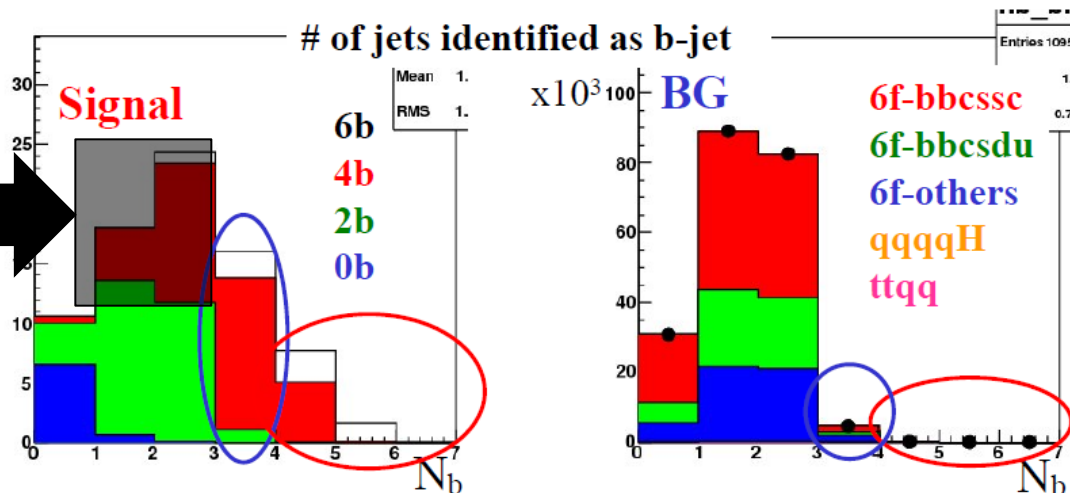
Selection of event samples

BG can be rejected effectively by using events with $N_b \geq 3$.

	No cut	$N_b = 3$	$N_b \geq 4$
Signal	79	15.9(0.20)	9.5(0.12)
BG	207,144	4663(0.02)	147(7×10^{-4})

$$\sigma = 0.16 \text{ fb}$$

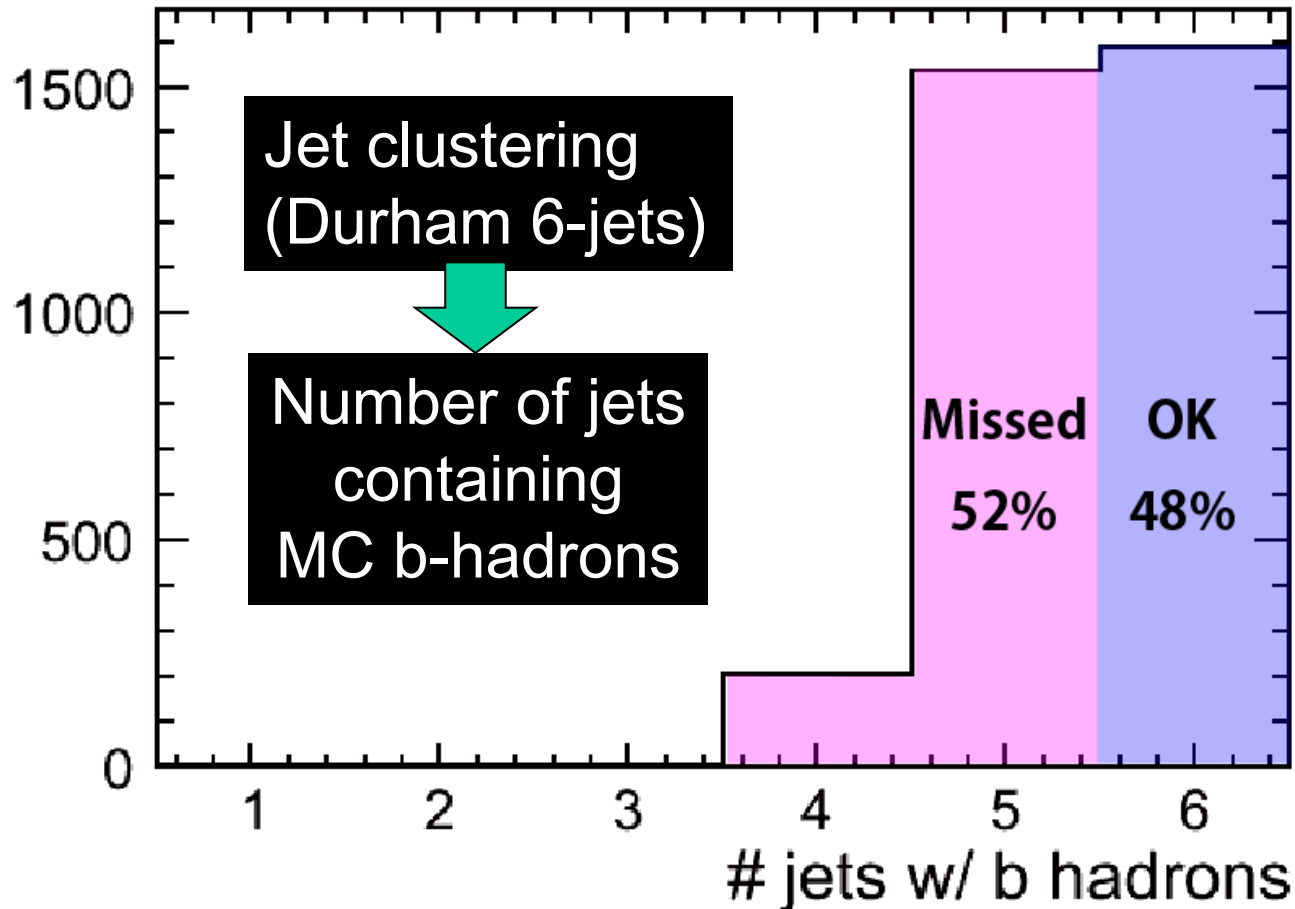
Events with $N_b = 3$ and $N_b \geq 4$ were selected as analysis samples.



b-tagging efficiency seems to be bad...

'# of b jets' in ZHH

ZHH \rightarrow bbbbbb events



of b-jets is reduced due to mis-jet-clustering.

Remedy: jet clustering with vtx. info

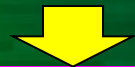
MC/digitization/tracking/PFA



Reconstructed particles

Vertex finder (w/o jet info)

ZVTOP ? -> Problem!



Reconstructed particles + vertices

Jet clustering (original)

Using vertex information (How?)



Jets (with tracks/vertices in each jet)

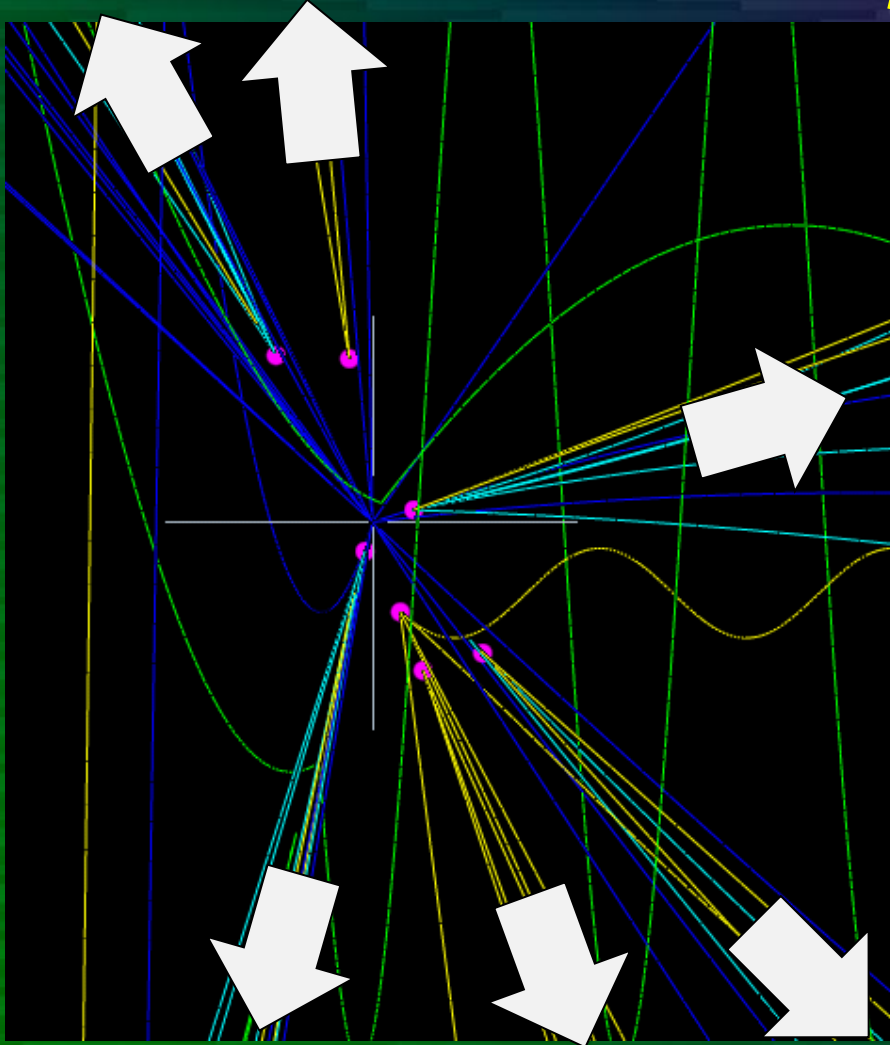
LCFIVertex

- Additional vertex finder?
- Neural-net based b-&c- tagging
- Quark charge identification

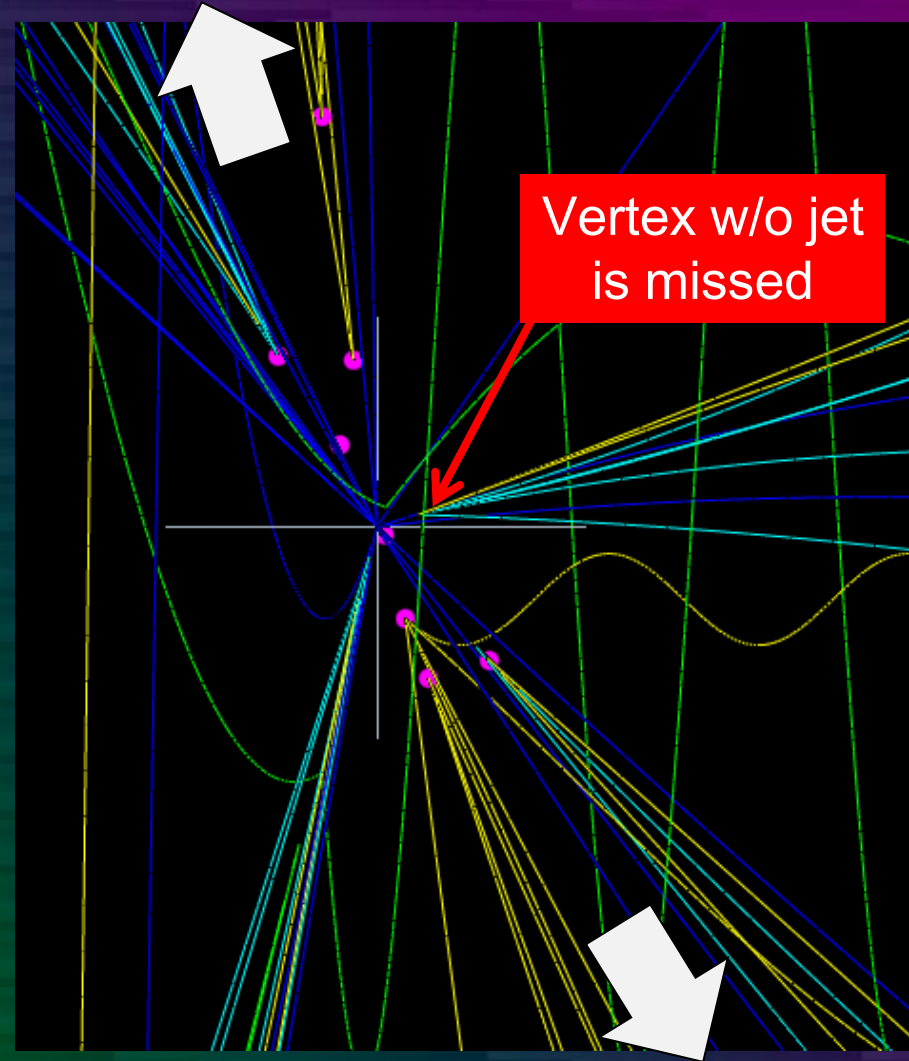
Today's talk: ideas and status in

- Vertex finder without jet information
- Jet clustering using vertex information

ZVTOP and jet direction



6-jet clustering



2-jet clustering

Need dedicated (or modified) vertex finder for jet clustering

Vertex finding methods

1. 'tear-down' method

- Fit a vertex with all tracks & eliminate the worst track – repeat until χ^2 becomes under threshold
- Used to obtain primary vertex

2. 'build-up' method

- Find a track pair which is crossed at certain point (vertex candidate) with low χ^2 – associate other tracks into the candidate to make a vertex
- Simple & good for secondary vertices

3. 'topological' method

- Modified build-up: use vertex function instead of track χ^2
- Adopted in ZVTOP

Easy-to-handle buildup vertex

- ZVTOP is packaged and completed – not easy to modify – then we are developing a simple vertex finder with build-up method for the jet clustering
- Basic procedure
 1. Obtain primary vertex and remove all primary tracks
 2. Find PCA (point of closest approach) for every track pair
 1. Helix crossing (or nearest) point P in x-y plane (analytical)
 2. Helix is parameterized in $x(t)$, $y(t)$, $z(t)$
error matrix is converted from $(d_0, z_0, \phi_0, \omega, \tan\lambda)$ to (x, y, z)
 3. Optimize t of each track with Minuit to minimize χ^2 at P
 3. Optimize P(x,y,z) with Minuit to minimize sum χ^2
 4. If sum χ^2 is over threshold, it is abandoned and try next

If sum χ^2 is under threshold, continue to next slide ...

Build-up vertex (cont.)

5. Combine other tracks
 1. Pick up a track with minimum χ^2 at P
 2. Refit P with sum χ^2 of all tracks
 6. Repeat 5. until all tracks have χ^2 over threshold
 7. Select a vertex with the maximum priority
 1. > 3 tracks, vertex point nearest to IP
 2. 2 tracks with $\chi^2 < 1$, vertex point nearest to IP
 3. 2 tracks with $\chi^2 < \text{threshold}$, minimum χ^2
 8. Repeat 2-7 until all vertices are selected
 9. Move primary tracks to secondary if χ^2 to secondary vertex is smaller than to primary
- selection criteria

Vertex selection

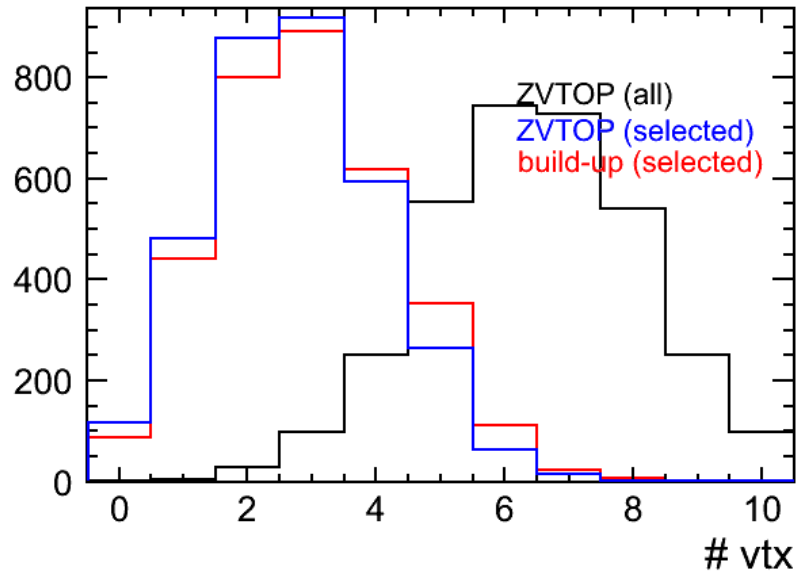
- Fake vertex significantly degrades performance of the jet clustering
 - ➔ Further vertex selection is necessary
- We currently select
 - Vertex with distance to IP 1-20 mm
 - Fake is concentrated around IP
 - χ^2 tends to be too low in far region (need study)
 - Far vertex is usually K_s^0 or V0/conversion
 - And vertex with ≥ 3 tracks
 - Lose efficiency, but to avoid fakes (safety)

Jet clustering with the vertices

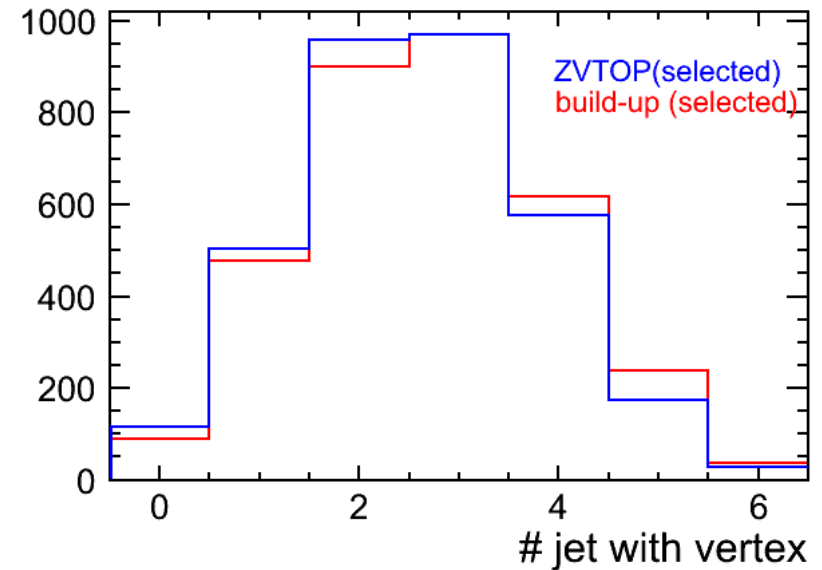
- Jet clustering with vertices
 - Combine all tracks in the vertex as a 'single particle' with summed 4-momentum
 - Avoid merging jets containing a vertex
 - all vertices should be separated to different jets (make y value infinite if both jets have vertices)
- Vertex combination
 - c- and b- vertex must be combined before the jet clustering to avoid forced separation
 - Currently 'CHEATED' – use MC to combine
 - Efficient vertex combination method is needed

Performance - # of vertices

ZHH \rightarrow bbbbbb



ZHH \rightarrow bbbbbb

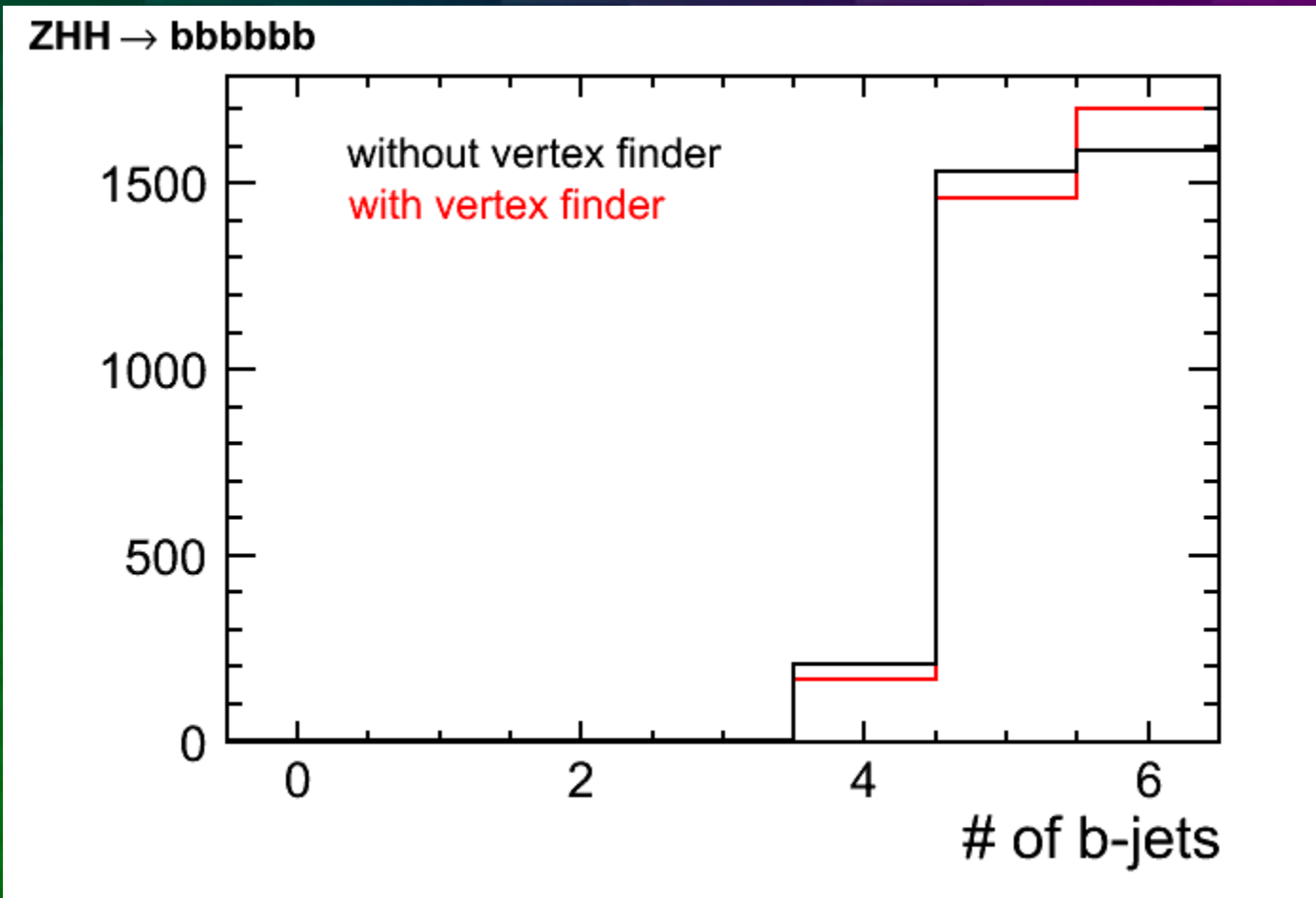


of reconstructed vertices
- comparable number in
ZVTOP and build-up

of jets containing vertices
- also comparable
~ half of jets have vertices

Vertex purity: 87% (ZVTOP-all),
99% (ZVTOP-selected), 98% (buildup-selected)

Performance - # of b-jets



Slight improvement can be seen!

Next steps

- Vertex combination – now developing
 - Use mass variables
 - Pt-corrected mass?
Need to include vertex position uncertainty
- Vertex selection
 - Current selection is too tight:
better efficiency is needed for jet clustering
 - Fake must be strongly suppressed
- Optimizing vertex finder
 - Treatment on 2-track vertices
- Speed – currently extremely slow (a few min./event)
- Apply b-tagging rather than counting MC b-hadrons

Summary & comment

- Flavor tagging in multi-jet environments is very important. – ex. ZHH, ttH...
- Some of b-hadrons are into the same jet – degrades analysis power significantly
- Jet clustering using vertex information can help to separate b-jets
Preliminary work indicates the improvement
- Another strategy: kinematic constraint jet clustering (ex. requiring W/Z/H/t with specific number of b-/c-/light jets)