# Studies of Heavy Flavour Jet Tagging with ZVTOP in JAS3

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Overview

- Jet flavour tagging in JAS3
- Cosθ dependence
- Primary vertex momentum
- Use of neutral energy
- Summary

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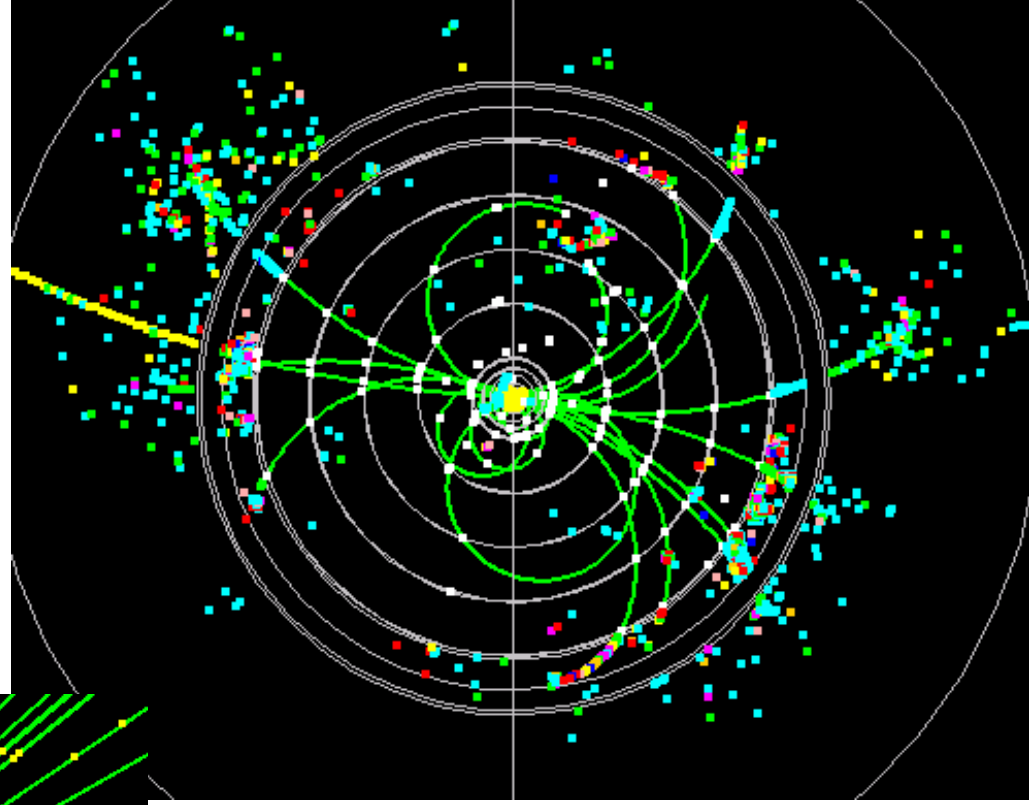
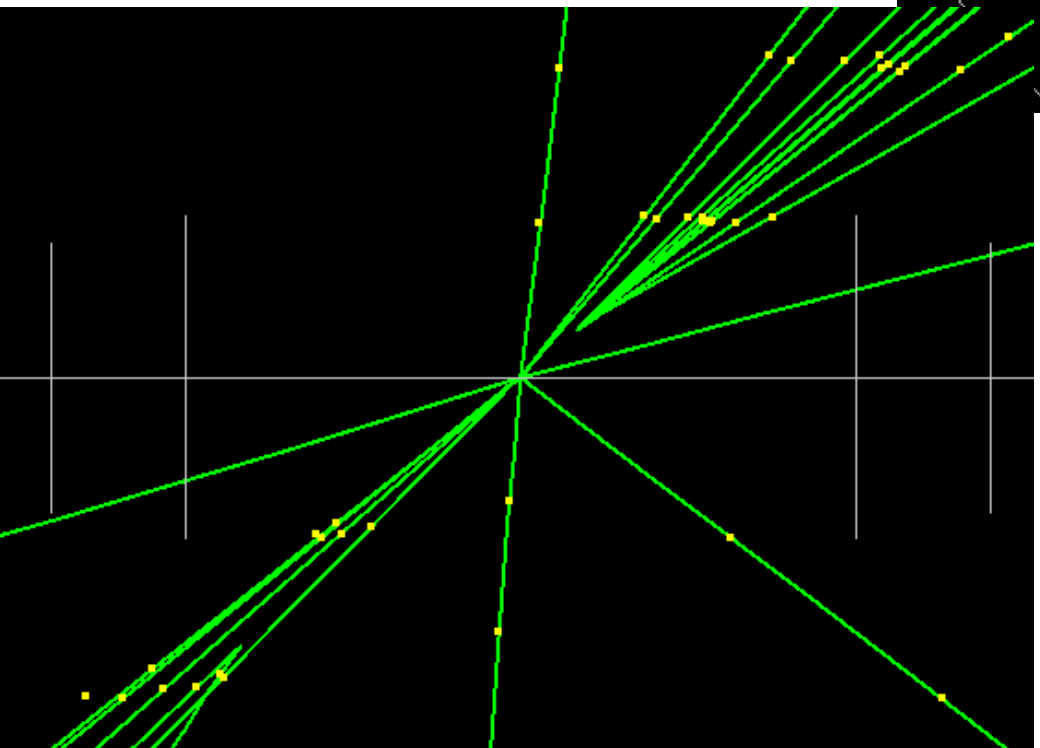
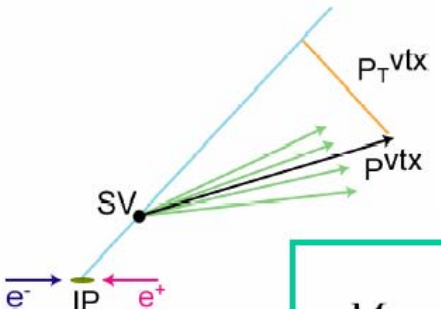
- $Z^0 \rightarrow b\bar{b}$ (pictured) and $c\bar{c}$ events; with 2-jet selection
- SiD detector simulation
- Analysed with JAS3





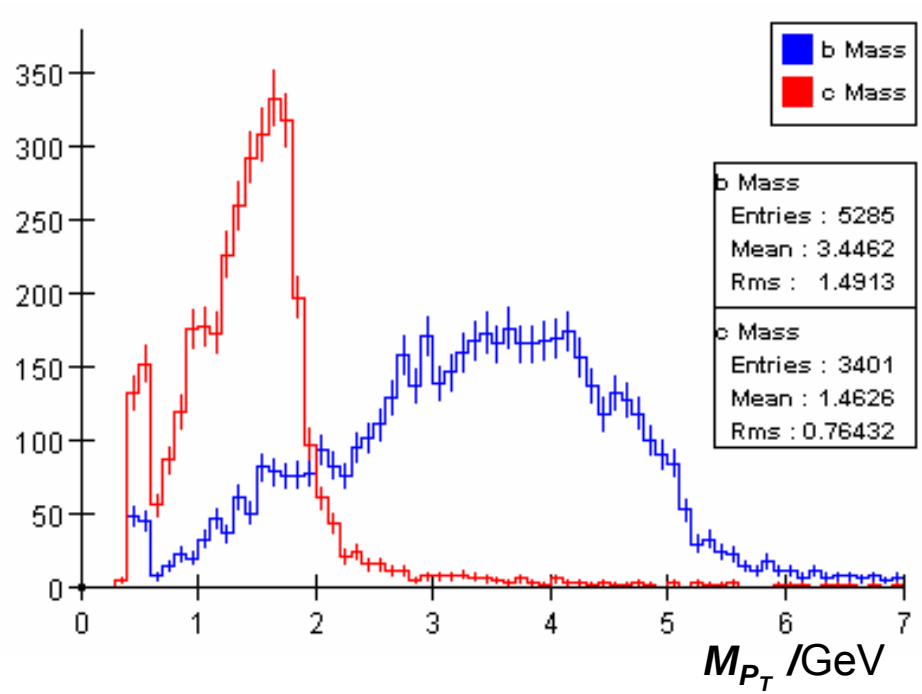
- **Vertex reconstruction using Java version of ZVTOP (by Wolfgang Walkowiak)**
- **Combine vertex and other inputs with a Neural Network (cjnn by Saurav Pathak) for jet flavour tagging.**

# Two input flavour tag (as seen at SLD)




**Apply a kinematic correction to $M_{VTX}$ to partially recover effect of missing neutral particles:**

$$M_{P_T} = \sqrt{M_{VTX}^2 + \left|P_T^{VTX}\right|^2} + \left|P_T^{VTX}\right|$$

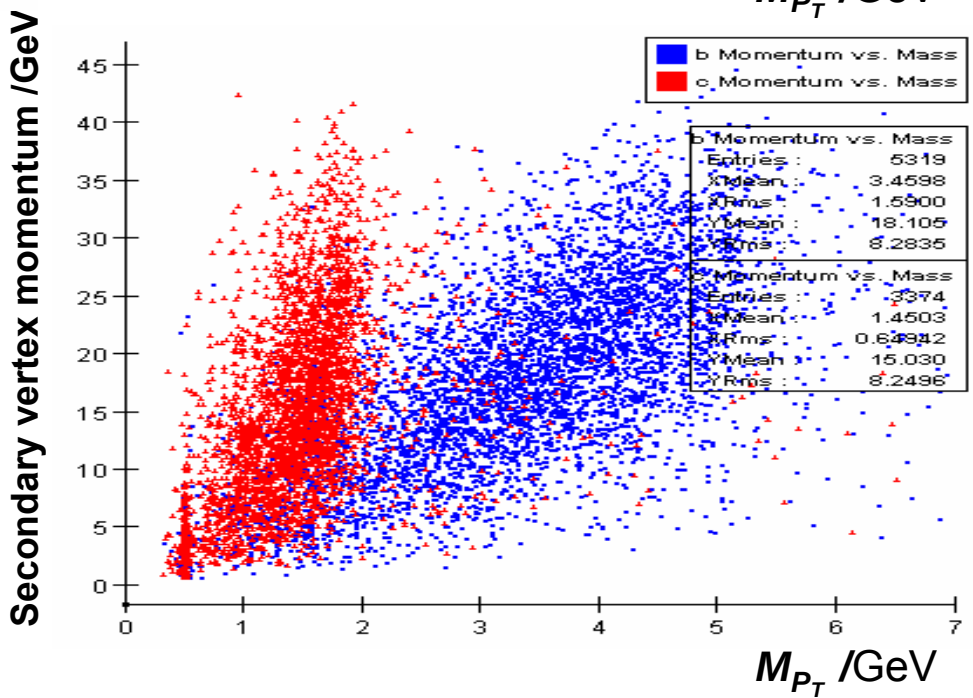



$M_{P_T}$ > 2 GeV gives a reasonably pure b-tag

Vertex momentum vrs mass gives better separation

b-jets

c-jets

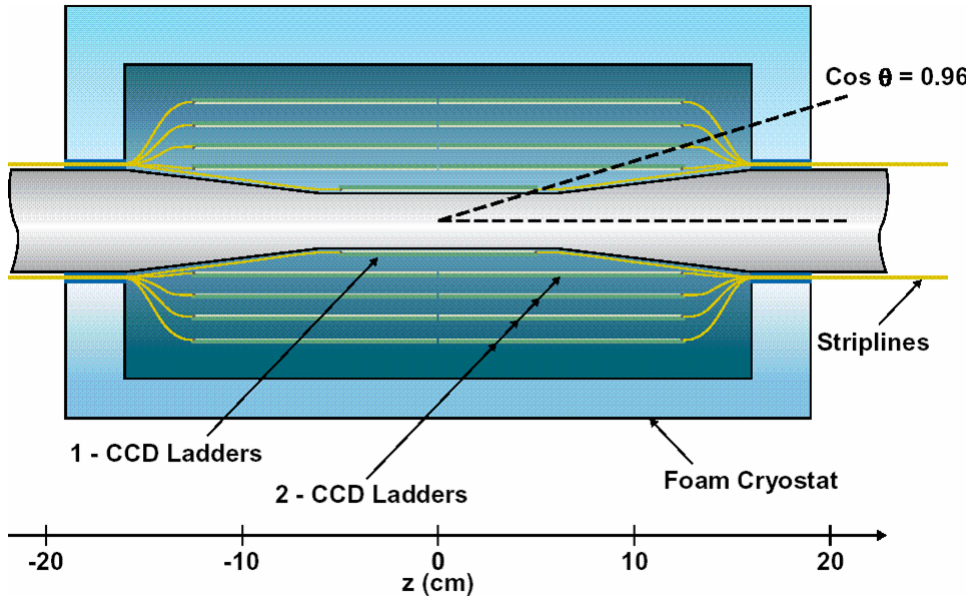


# Polar angle dependence of jet flavour tag

LCFI study with SGV for 5-layer ILC vertex detector; track resolution at interaction point:

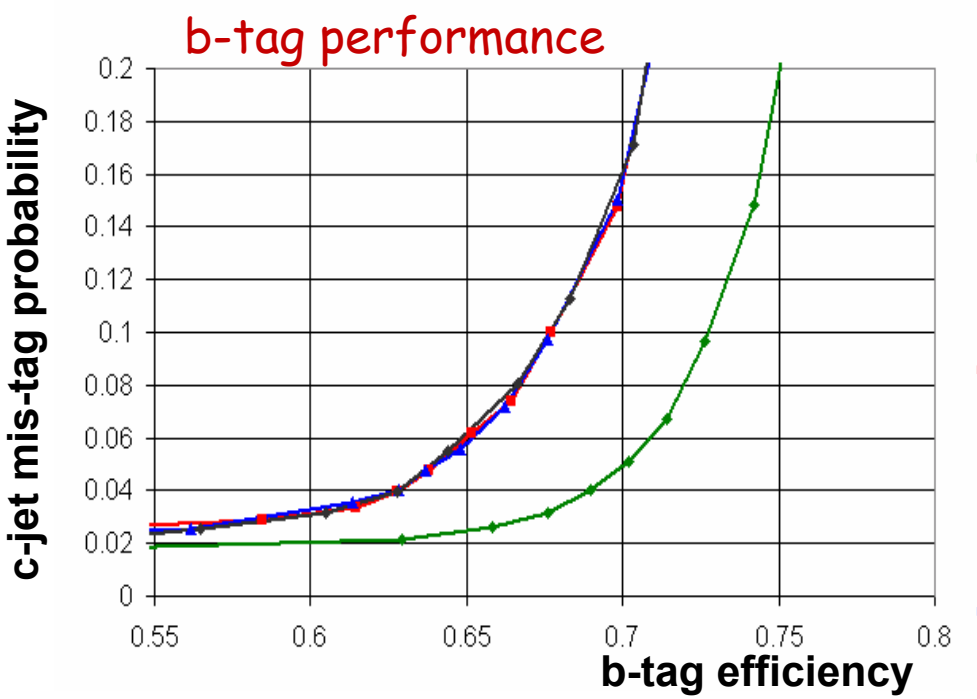
$$\sigma(z_0) = 4.1 \oplus 7.3/(p \sin^{3/2}\theta)\ \mu m$$

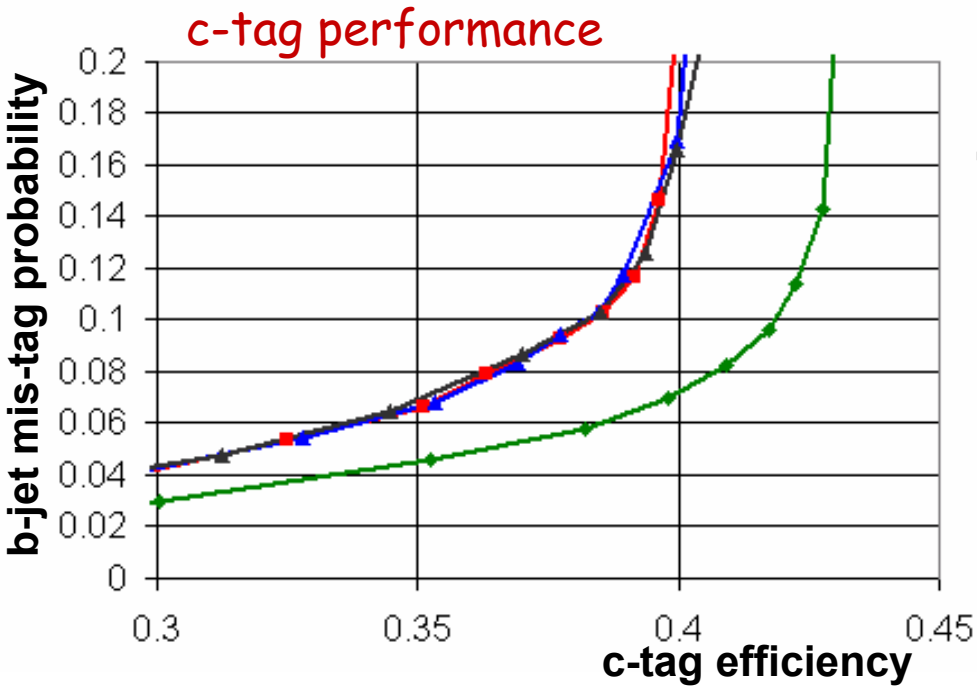
For a 1 GeV track at $\cos\theta \sim 0.9$ resolution is 3 times worse than at $\cos\theta \sim 0.0$.




Study:

- Consider 45 GeV jets from heavy quark Z decays, $|\cos\theta|<0.9$
- Set up 2-input NN b/c-jet flavour tag using vertex mass + momentum
- Look at tagging performance at large $|\cos\theta|$
- Can this be improved by tuning the tag in this region ?




Flavour tag performance for 2 input network (2-3-2 configuration)

Applied to region $|\cos\theta| > 0.8$ only

3-input network, with $|\cos\theta|$ as 3rd input (3-3-2 network configuration), applied to region $|\cos\theta| > 0.8$ only

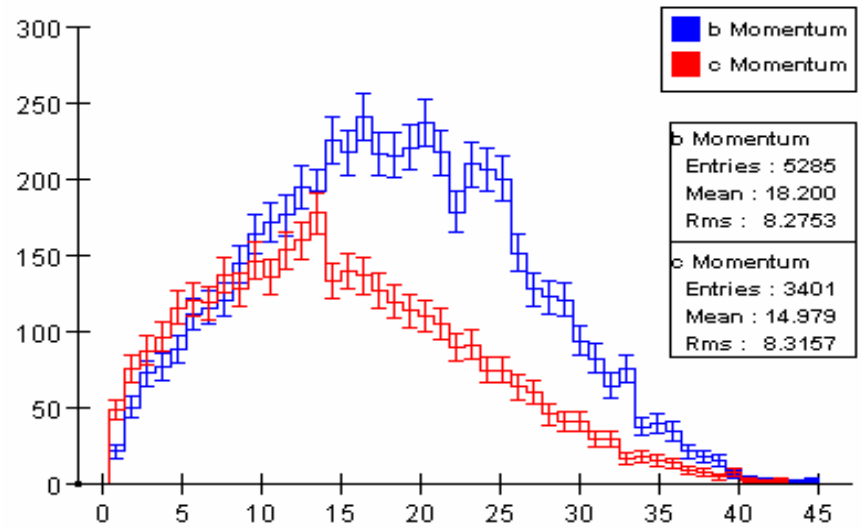
Original 2-input network trained and applied to $|\cos\theta| > 0.8$ region only

Conclusion:

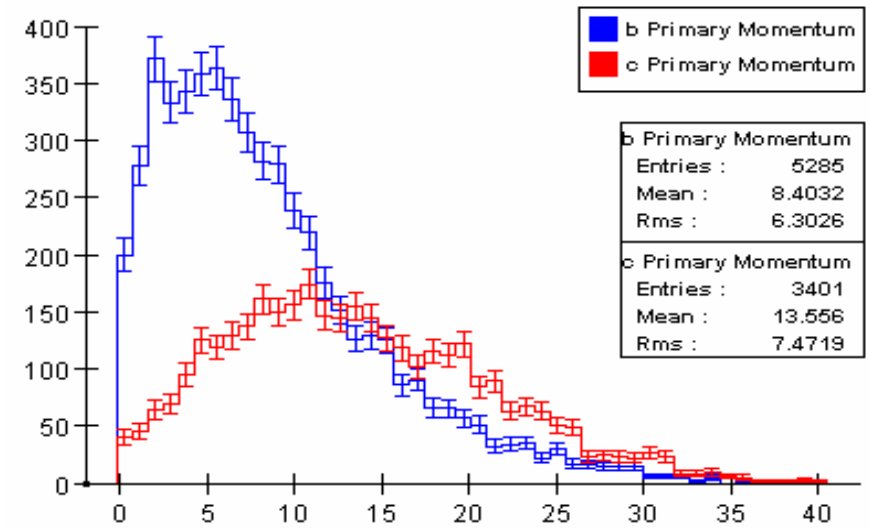
- Tagging performance degraded at large $|\cos\theta|$
- Not easily recoverable by retraining neural network

# ZVTOP flavour tagging generally based on properties of secondary vertex

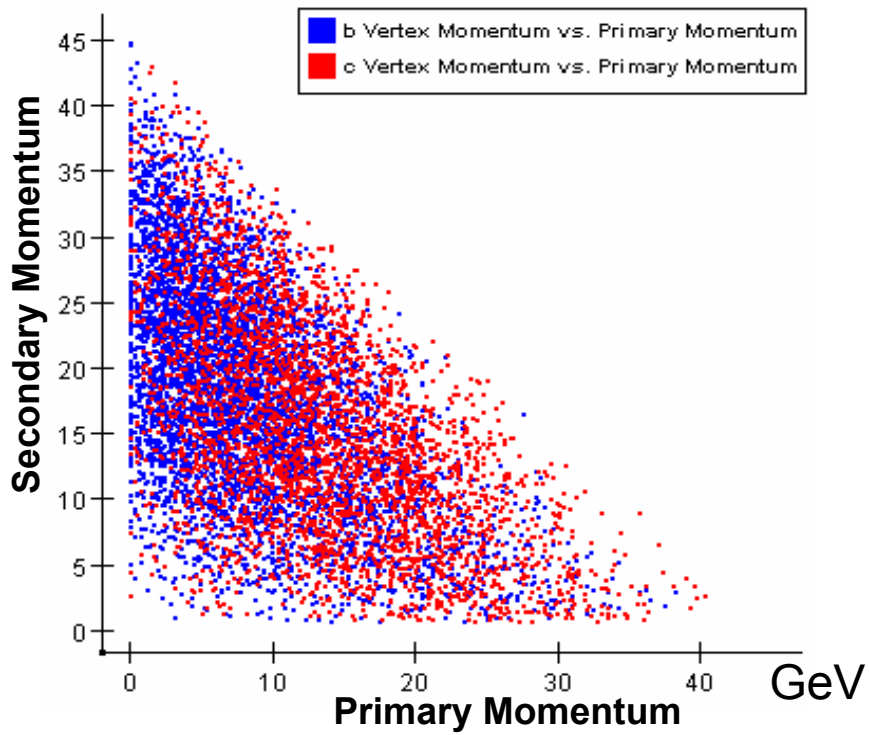
## Secondary vertex momentum

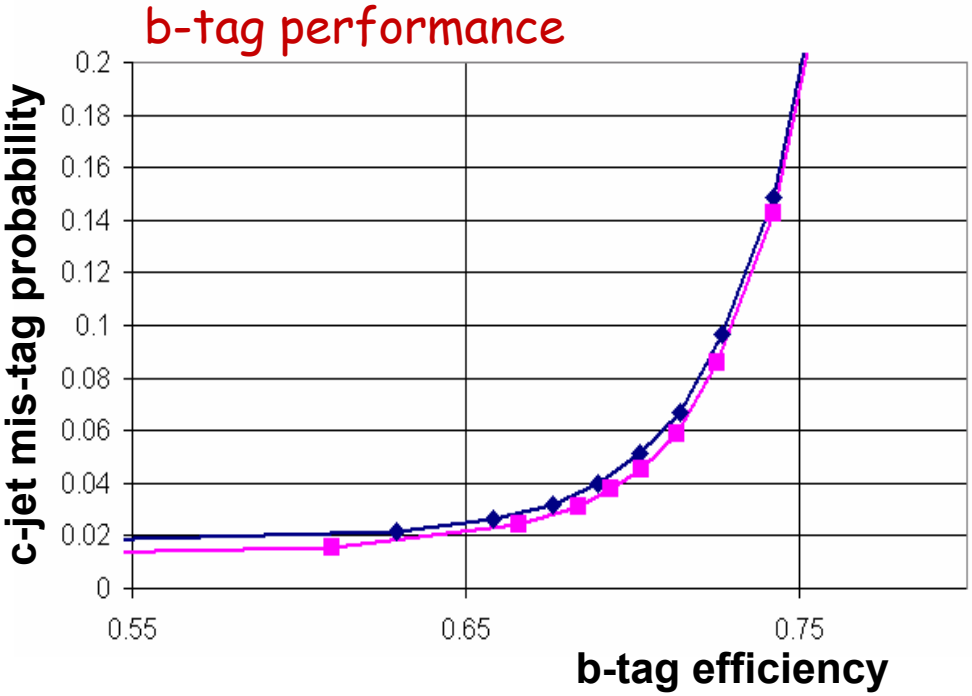



## Primary vertex momentum



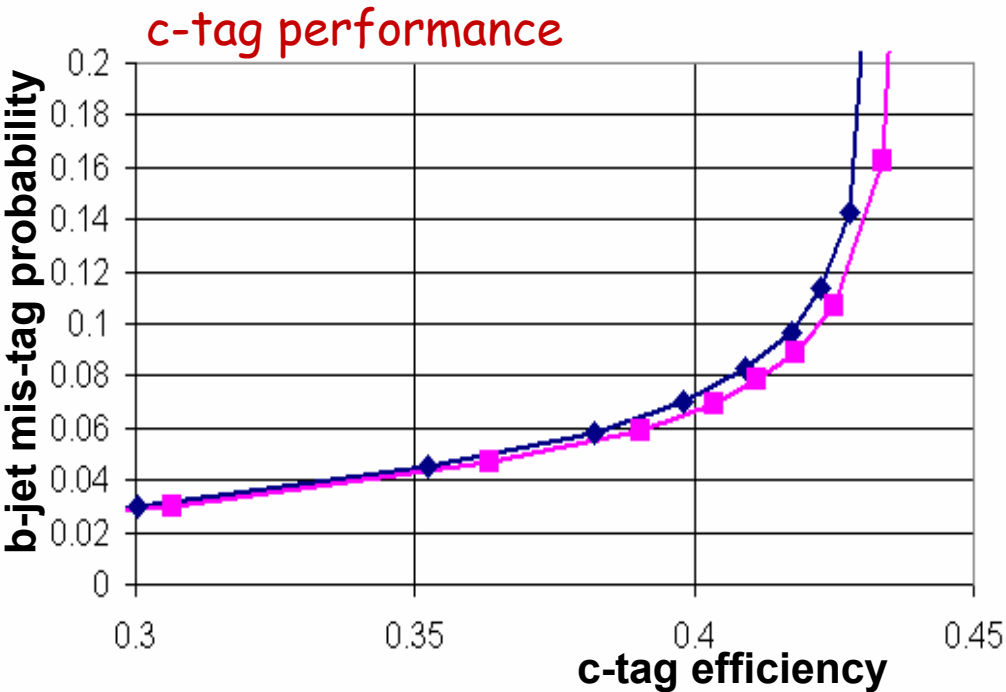

- The summed momentum of tracks in the primary vertex differs for b-jets and c-jets due to differing fragmentation functions.
- This information in the primary vertex is not 100% correlated with that in the secondary.
- Motivates study of this variable as an additional neural network input.






Flavour tag performance for 2 input network (2-3-2 configuration)

Flavour tag performance for 3 input network (3-3-2 configuration); with primary vertex momentum as 3rd input

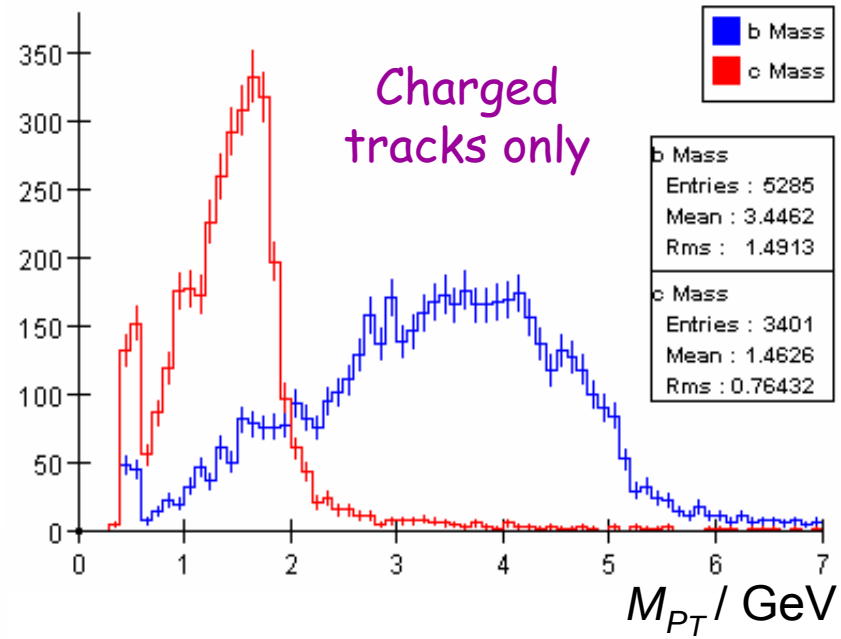


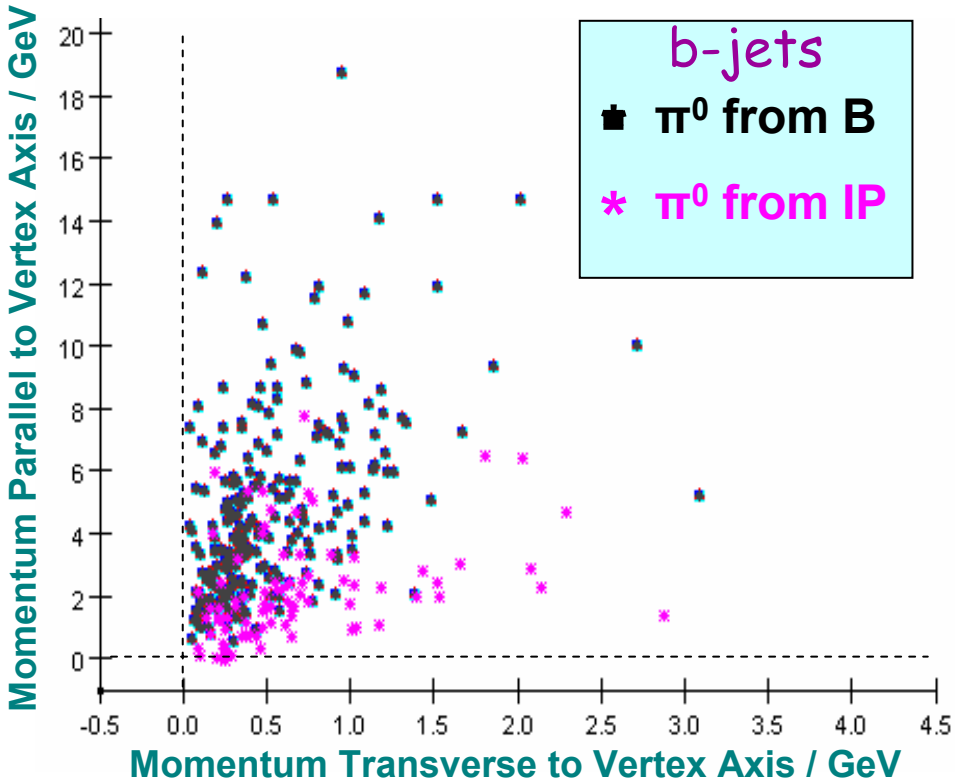

Conclusion:

- Including the primary vertex momentum improves the b/c separation by ~10% (a big gain for such a straight forward input)

# Use of Neutral Calorimeter Energy for Flavour Tag

- Main flavour tag variable is mass reconstruction of decay hadron
- Most of the missing energy is neutral $\pi^0/\gamma$ energy observable in calorimeter.
- Can this non-vertex information be kinematically associated with the hadron decay ? (cf B boost recon. at LEP)

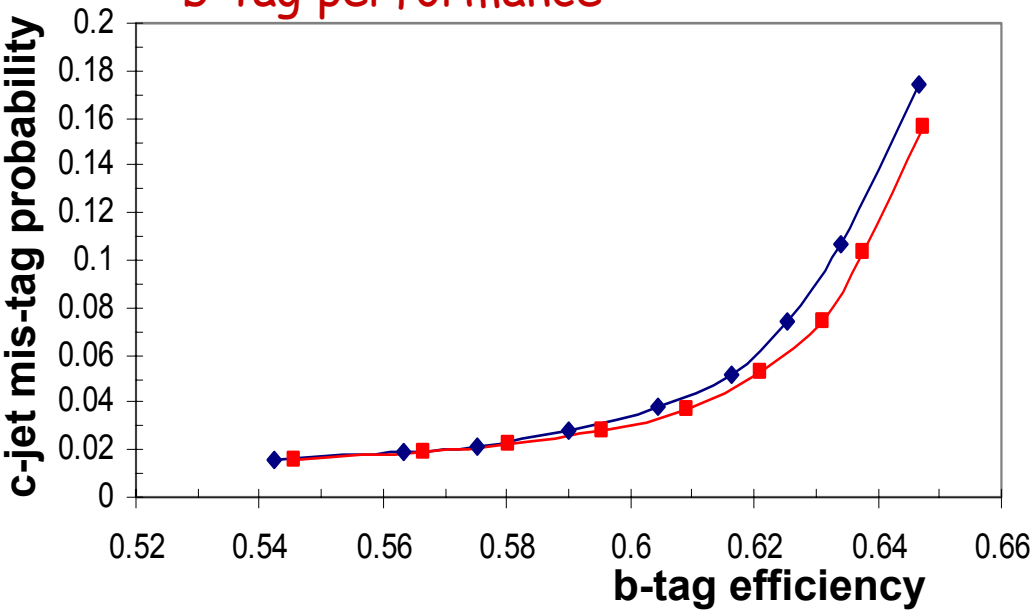



This Study:

- Select the highest energy MC $\pi^0$ in jet with a ZVTOP vertex (plot on left made with these $\pi^0$s)
- Recalculate $M_{PT}$ with the $\pi^0$ momentum 4-vector included
- Add the new information to the original 2-input neural network

## b-tag performance

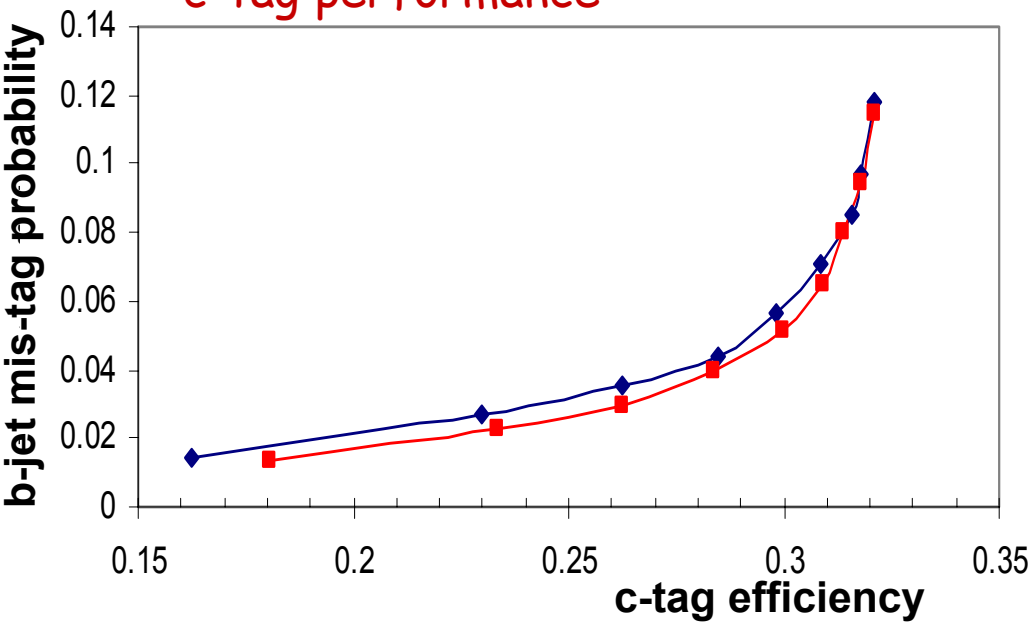



2 Inputs

4 Inputs

- $M_{PT}$ (Vertex)
- Momentum (Vertex)
- $M_{PT}$ (Vertex + $\pi^0$)
- Energy of $\pi^0$

## c-tag performance




Effect of adding highest energy $\pi^0$ information:

- Small increase in b-tag efficiency (~1%)
- Reduce b-jet background to c-tag by a relative 10-25%

# Summary

- Angular Dependence – performance degraded at large $|\cos\theta|$, as expected. Tuning the flavour tag should be considered for very small angles.
- Primary Vertex Momentum – still possible to identify straight forward tagging variables to aid tag (could have been used at SLD).
- Neutral Calorimeter Energy – briefly studied at SLD but not helpful due to poor resolution, but will assist flavour tag at the ILC.