Flavour tagging at the linear collider

Matthew Wing (University of Bristol, UK)

On behalf of the LCFI collaboration

- Introduction
- General performance and tagging
- Flavour tagging at low energies, E_{CM} = 91 GeV
- Performance at higher energies, E_{CM} = 500 GeV
- Vertex charge
- Summary and outlook

Introduction

- **Need to study basic performance of vertex detector design**
- **Performance at E_{CM} = 91.2 GeV for $ee \to q\bar{q}$ and comparison with SLD**
- **Have moved onto considering higher energies (E_{CM} = 500 GeV); difference in performance?**
- **Further optimisation of tagging possible?**
- **Vertex charge**
- **When all the above is optimised, need to apply to more interesting physics processes**

Details of studies

- Studies being performed by C. Damerell and S. Xella (RAL) and M. Wing (Bristol)

Documentation:

- S. M. Xella Hansen et al. "Flavour tagging studies for the TESLA linear collider", (LC-PHSM-2001-024), DESY preprint.
- R. Hawkings, "Vertex detector and flavour tagging studies for the TESLA linear collider", (LC-PHSM-2000-021), DESY preprint.

Software:

- use BRAHMS, where our R&D design for the CCD vertex detector is implemented, for event generation and track reconstruction
- use NN algorithm for flavour tagging, comprising of 3 methods:
  - "1-prong" tag (where no secondary vertices found)
  - joint impact probability tag
  - ZVTOP

Basic performance

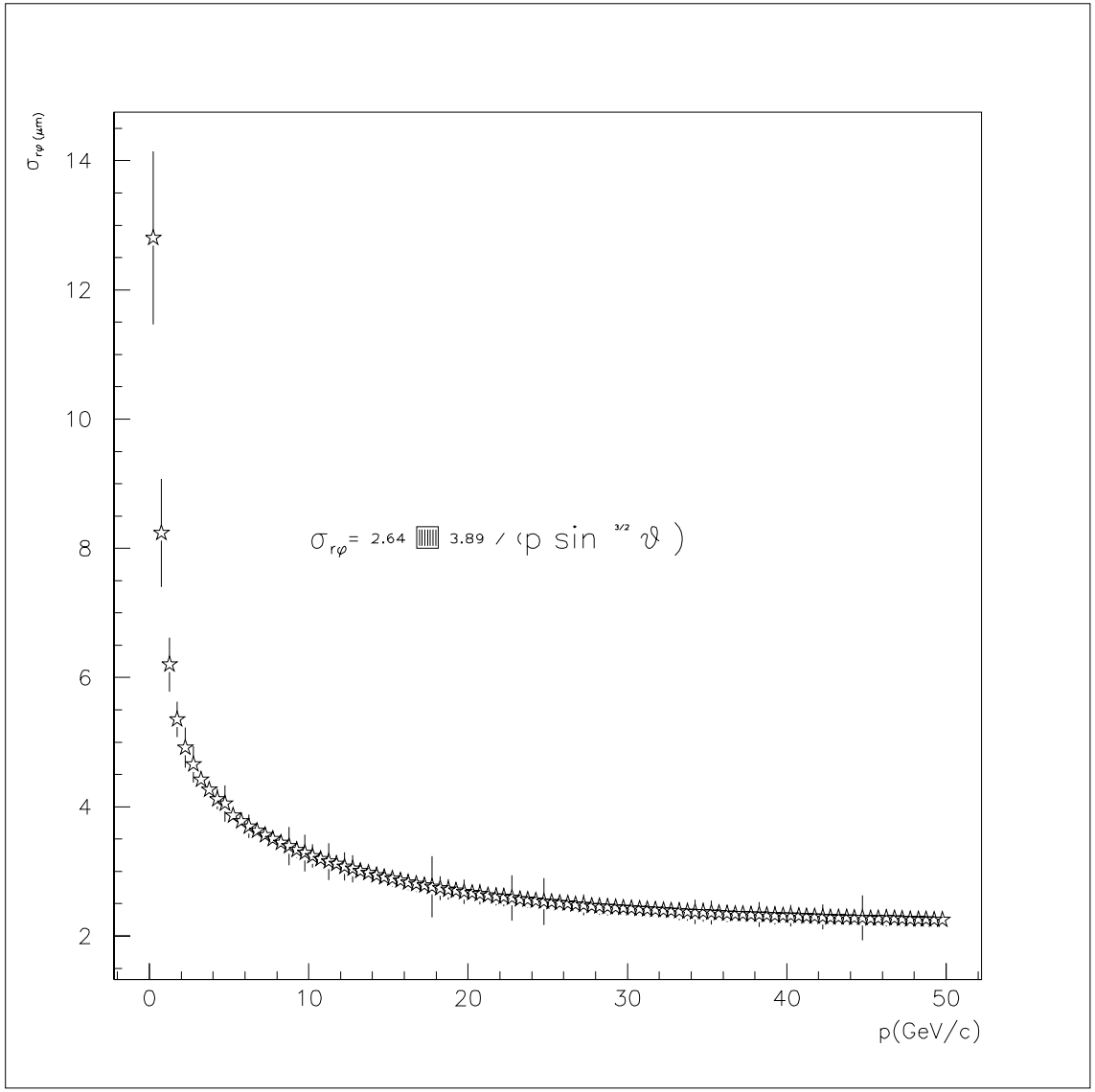
Linear collider:

$$\sigma_{r\phi} = 2.64 + 3.89/(p \sin^{3/2}\theta)$$

SLD:

$$\sigma_{r\phi} = 9 + 33/(p \sin^{3/2}\theta)$$

Improved performance of vertex detector with respect to SLD



"1-prong" tag

Use highest $d_0/\sigma(d_0)$,... in a jet when no secondary vertex found.

- **Problems occurred with tails in distribution for uds events**
- **Coming from physics process; b/c in gluon splitting and strange baryons**
- **Introduced new variables into NN; momentum and angle of highest IP track with respect to jet**
- **Improvement in NN figure of merit**

This tagging method is now in reasonable shape

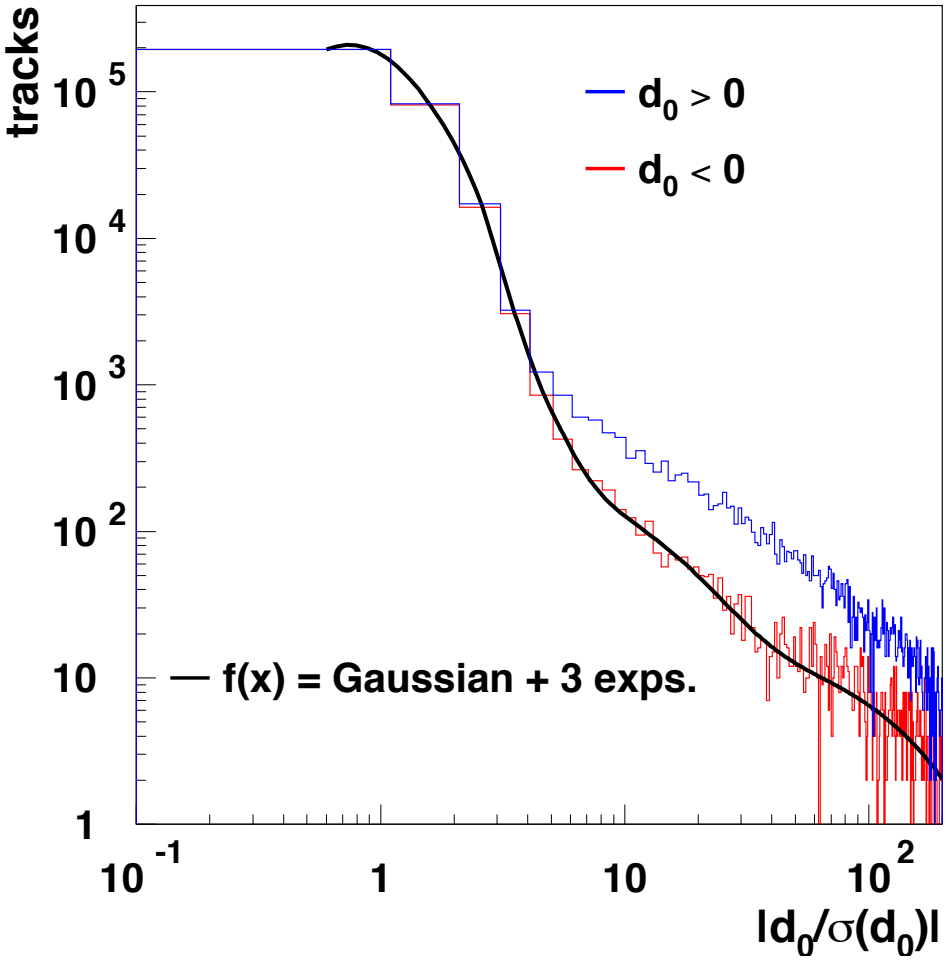
Impact parameter probability tag

Based on knowledge from LEP, redone for current setup

- **Fit negative side of impact parameter distribution →**
- **Probability estimator for each track found:**

$$P_i = \frac{\int_{b/\sigma_b}^{b_{\text{cut}}} f(x)dx}{\int_0^{b_{\text{cut}}} f(x)dx}$$

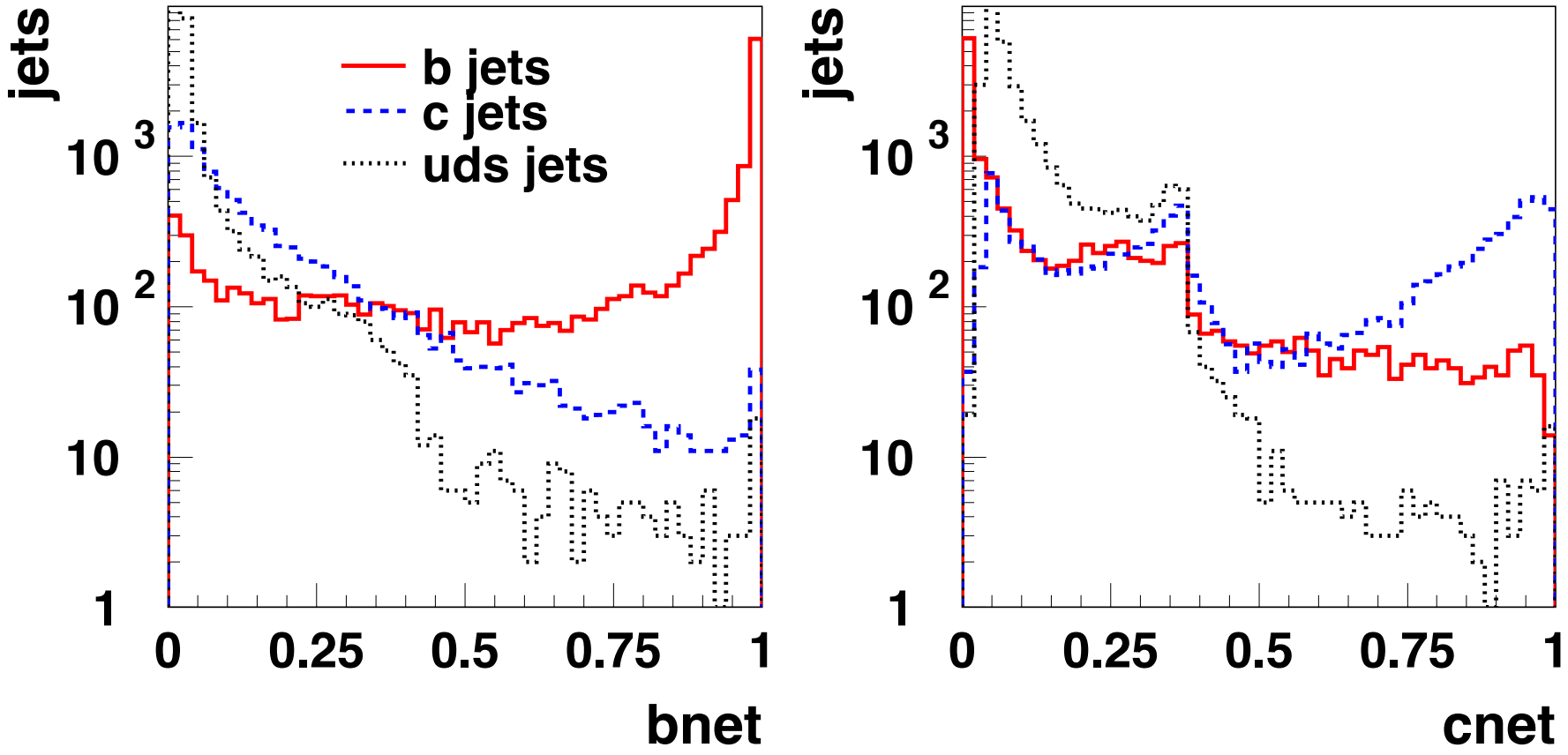
- P_i **tend to peak at 0 for** $b\bar{b}$ **events and 1 for** uds **events**
- **An input into NN tagging algorithm along with** `ZVTOP` **from SLD**



Done for 91.2 and 500 GeV. Look at performance for both energy regimes →

Performance at low energies, $E_{\mathrm{CM}} = 91.2$ GeV

After NN training, outputs $bnet$ and $cnet$ considered



Clear discrimination between different flavour of jets

Quantify this discrimination quality →

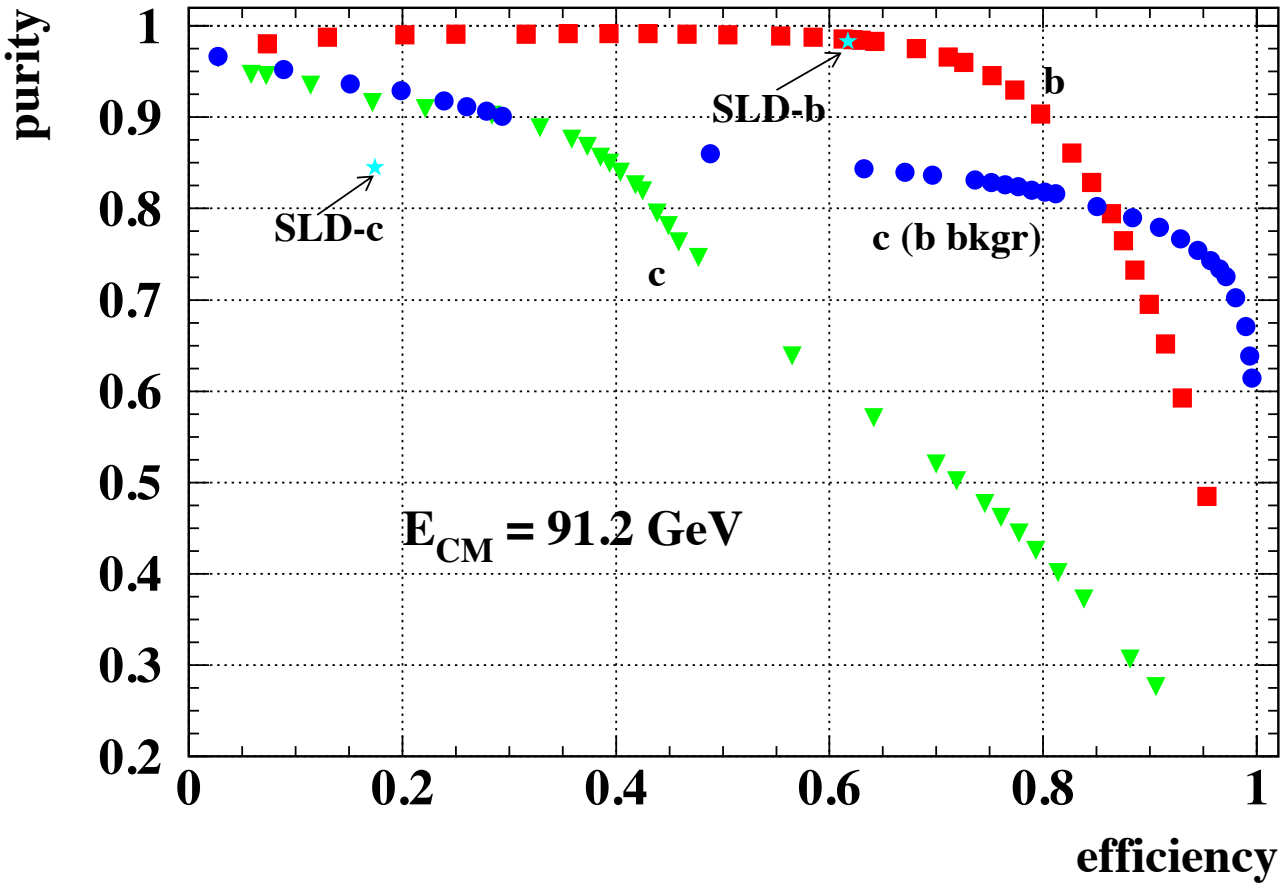
Purity vs efficiency at $E_{CM} = 91.2$ GeV

b jets:

- **Purity $> 90\%$ for efficiency up to 80%**
- **Performance very good and similar to SLD**

c jets:

- **Purity $> 80\%$ for efficiency up to 40%**
- **Factor 2-3 improvement over SLD performance**
- **Excellent c discrimination when b is only background**



SLD "benchmarks" met and surpassed.

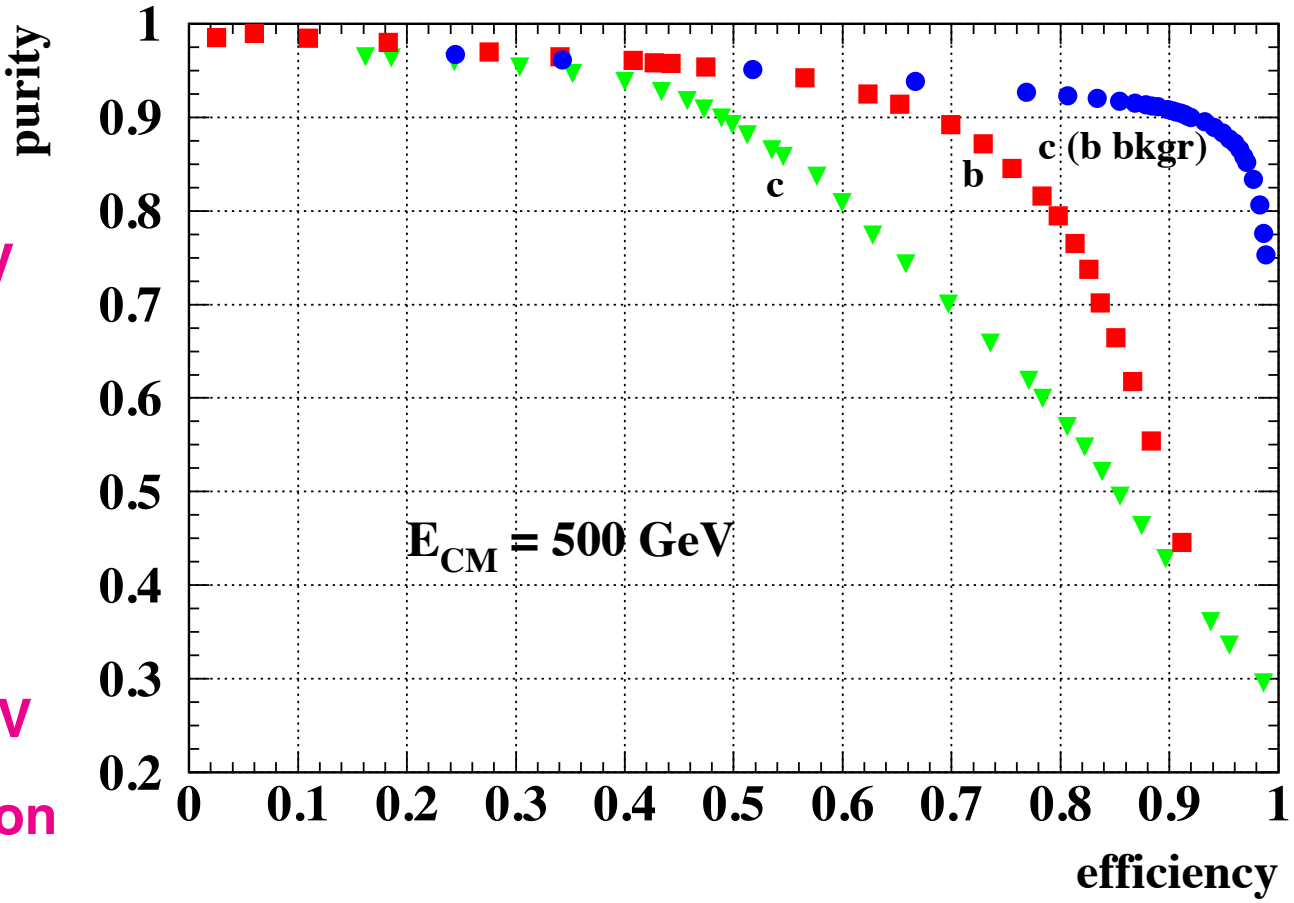
Purity vs efficiency at $E_{CM} = 500$ GeV

b jets:

- **Purity $> 90\%$ for efficiency up to 70%**
- **Reduced performance compared to $E_{CM} = 91$ GeV**

c jets:

- **Purity $> 80\%$ for efficiency up to 60%**
- **Performance significantly better than at $E_{CM} = 91$ GeV**
- **Outstanding c discrimination when b is only background**



Reasons for observed differences at low and higher energies?

High energy performance

Tagging of charm is very good at $E_{\mathrm{CM}} = 500$ GeV, but beauty tagging is poorer.

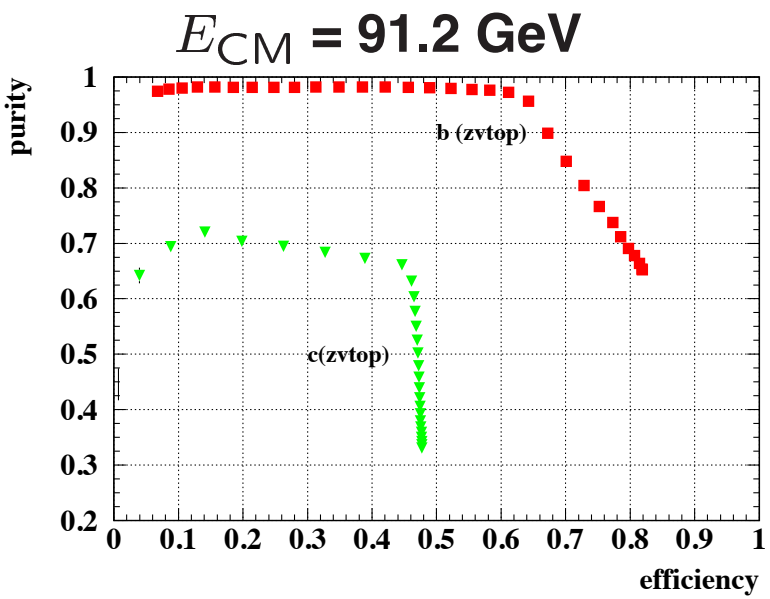
Why is b tagging reduced?

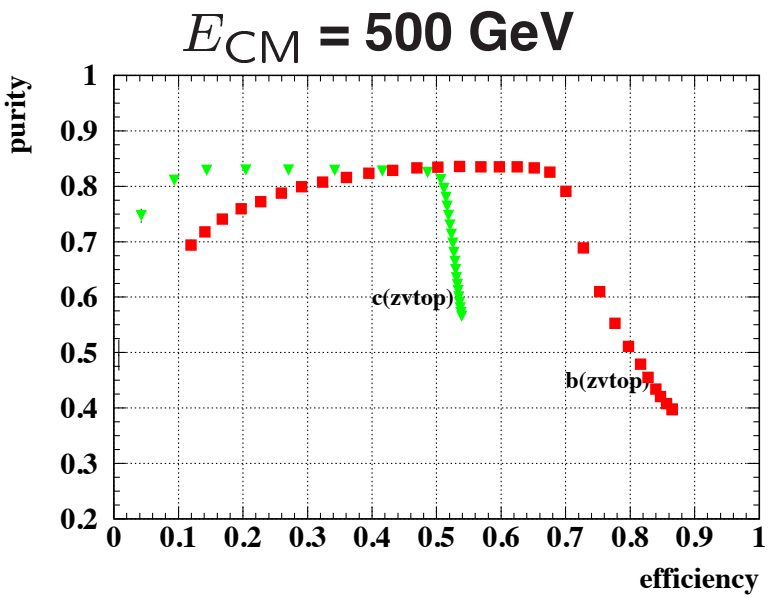
- **flavour composition changes with energy**
- **gluon splitting becomes more important at higher energy**
- **rejection of K_S^0**
- **distance of vertex form IP has energy dependence**

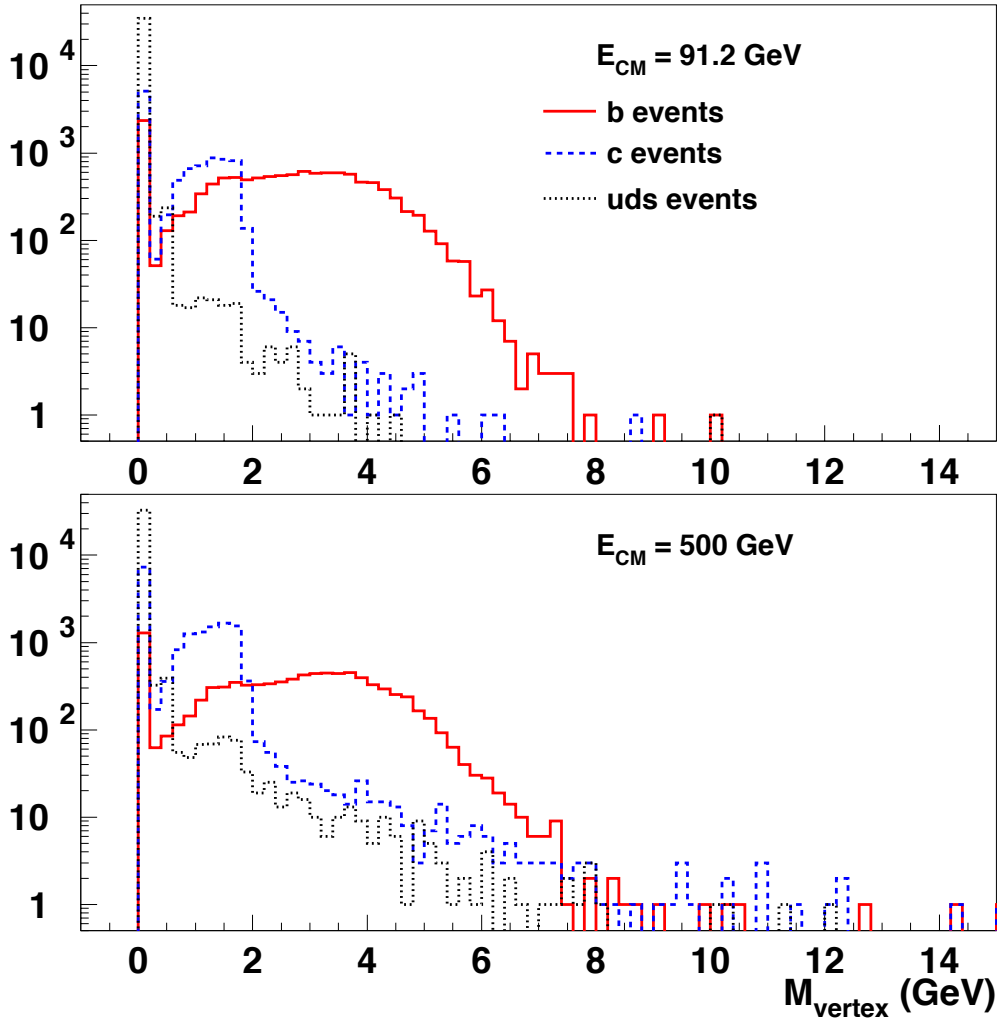
Above contribute to improving performance but not to values for E_{CM} = 91.2GeV

Effect coming from `ZVTOP` input variables

Effect of ZVTOP







Are the high-mass tails for c and uds events real?

Clear effect from ZVTOP variables

Further investigation needed...

Vertex charge

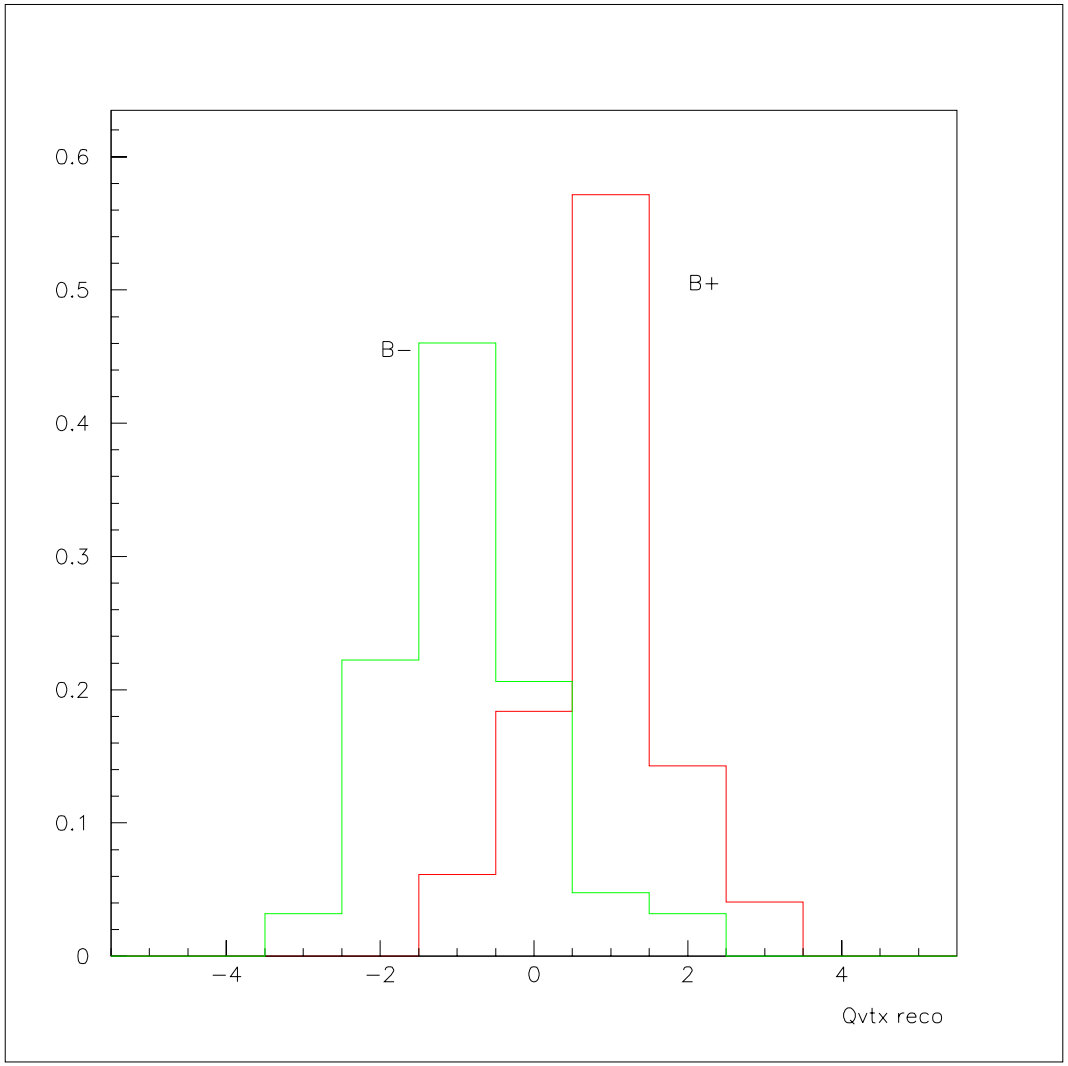
Can use vertex charge to distinguish b from $\overline{b}$ and c from $\overline{c}$

Vertex charge is sum of charges at all vertices in jet

Sign found for 75% of cases - comparable to SLD results

To understand asymmetry

Improvements to come...



Summary

At E_{CM} = 91.2 GeV, performance of new detector is excellent.

For b jets the performance is similar to and for c jets significantly exceeds SLD.

Tagging methods for NN have been thoroughly checked and improvements made and incorporated.

At E_{CM} = 500 GeV, c tagging further improved, but b tagging worsens.

A lot already understood, but work also ongoing to fully understand tagging at higher energies.

Promising results on tagging the charge of the vertex and distinguishing B and $\bar{B}$ mesons

Outlook

Immediate future

Complete understanding of performance at high energies.

Further tagging improvements (ghost algorithm, other variables,...)?

Write-up details in a note soon.

Near future

Need to apply to more interesting physics processes.

Will need to tune for each physics and background condition.