Flavour ID simulations for future LC

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Our friends theoreticians tell us that at a 500 GeV e^+e^- linear collider (LC) very interesting studies can be done, but to be most usefull we need to be able to distinguish heavy flavor jets very well.

SLC and the LEP experiments tell us that heavy flavor tagging, to be higly efficient and pure, needs to use informations about the topological vertex structure of the jets in the event.

$\rightarrow$ a very high precision vertex detector is clearly needed to reach this goal.

Richard Hawkings study

Richard's study (see note LC-PHSM-2000-021-TESLA) has helped a lot quantifying the requirements for the LC vertex detector and stressing the points to work on further, to get high heavy flavor jet tagging efficiency and separation.

Some points worth stating:

- Resolution on track parameters depends on multiple scattering.
  Eg. for impact parameter (cylindrical detector),
  $\sigma_{r\phi} = a \oplus b/(p\ sin\theta^{3/2})$

  Tracks in jets at LC will have momentum around 1 GeV (low p), so the multiple scattering term is important. How should we improve track parameters precision?

  – vtx detector mass should be as low as possible

  – vtx detector should be placed as close as possible to the beam pipe (to reduce extrapolation error to IP).

  A solution for a vertex detector, with 5 layers, and placed 1.0 cm from the beampipe, with a inner layer length as long as possible, should be favored.

Richard Hawkings study (II)

- high purity and efficiency are obtained by:
  - having good sensitivity at short decay times. Most of the statistics is in this region, so here is most important to reduce as much as possible misassignement of tracks from SV to PV.
  - reconstructing as many of the vertices in the jet as possible , since the number of vertices is a good separator
  - reconstructing well the vertex mass (from 2nd plus eventual 3rd vertex), since this is also a good separator
  - combining in a NN approach vertex informations (decay length/error, numb. of vertices, mass,...) and non vertex informations (usefull when a secondary vertex cannot be found).
  - including in tagging sample also jets with 1 prong decays (i.e. B or D decaying into only 1 charged track). This especially gives boost to charm efficiency. (Even better would be to reconstruct the vertex of the 1 prong decay)

The ZVTOP algorithm from SLD does an excellent job, but needs some additional tagging info to maximize performance, especially for charm tagging.

Further study needed

An improved geometry for the CCD detector option has been considered this year by C.Damerell and the LCFI collaboration (see also Chris talk in this session), and therefore an update of CCD detector performances was needed. Further, some points were not completely clear from the previous study and needed to be investigated further.

In the following you will see:

- new numbers for impact parameter resolution for tracks
- new efficiency/purity numbers for b/c jet tagging
- a brief summary of what we think needs to be investigated further (before the TDR)

All this will be documented in the Tesla TDR and as a separate note, within the end of this year.

Tools used

To do this study, BRAHMS software for Tesla detector together with Pythia 6.1 were used for generating events, and for track fitting (DELPHI routines).
Then ZVTOP code from SLD and other algorithms from OPAL are combined and interfaced to BRAHMS (work done by R.Hawkings).
This allows to study heavy flavor tagging.

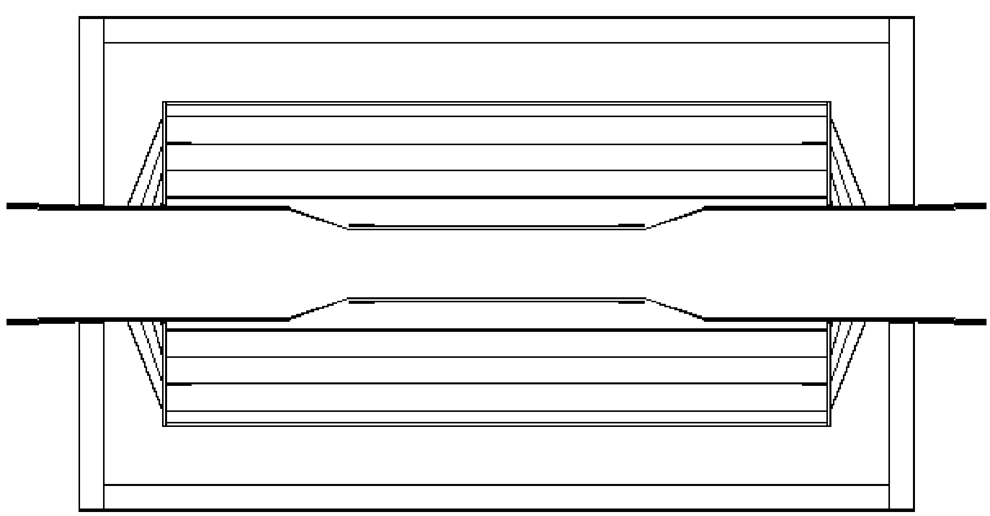
ZVTOP code is used to find vertices, and then for tagging one can use either mass reconstructed from ZVTOP alone, or one of the 3 neural network outputs (with input from ZVTOP and other algorithms from OPAL). The 3 outputs of the neural network are for distinguishing b jets from other jets in Z0 decays, c jets from other jets in Z0 decays, c jets from b jets.

New geometry

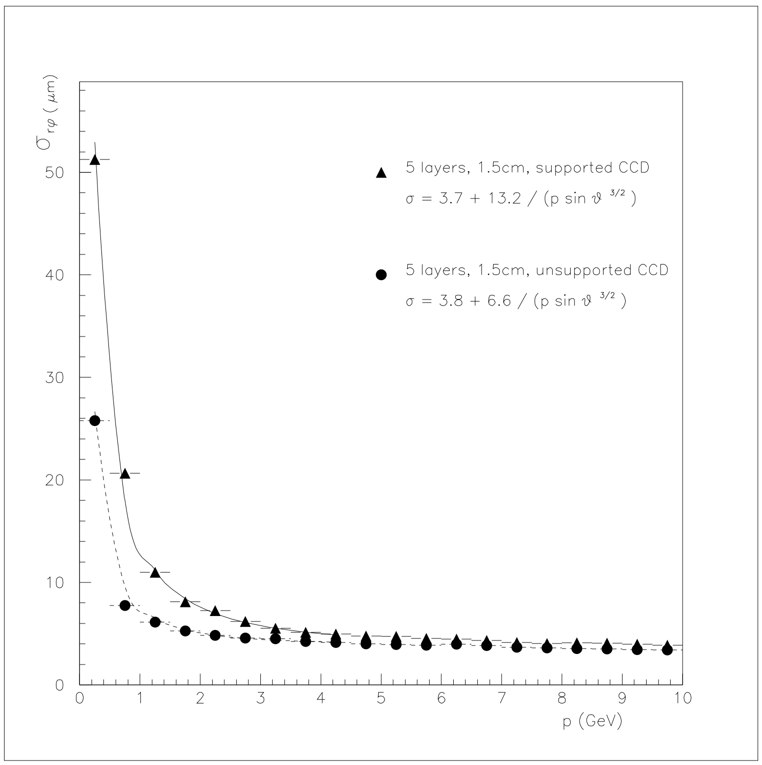
changes wrt previous study:

- longer layer 1
- thinner layers
- thinner beampipe

for more details, please see Chris talk in this session



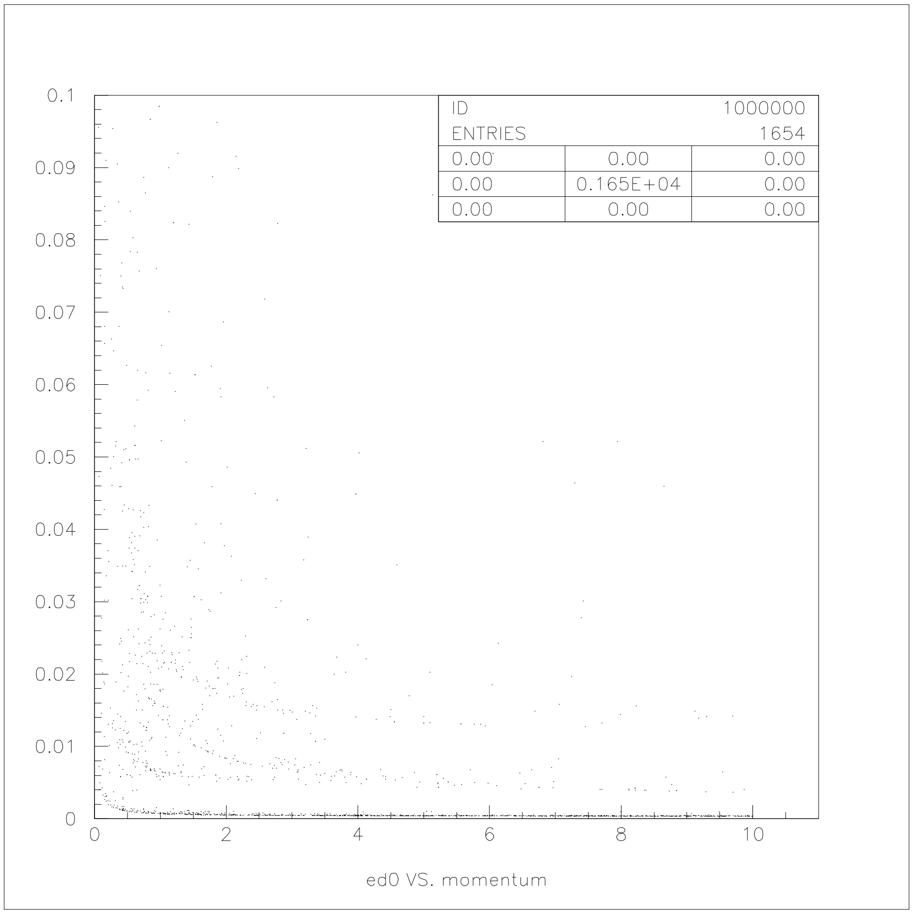
Impact parameter resolution



Plot obtained generating pions with random p and direction (cos(theta)<0.9).
$\rightarrow$ Resolution at low momenta with unsupported ladders improved by factor 2 ! Important since in multi jets events many tracks will be in the range 1-2 GeV.

LC : $\sigma_{r\phi} = 3.8 \oplus 6.6/(p\ sin\theta^{3/2})$
SLD : $\sigma_{r\phi} = 7.8 \oplus 33/(p\ sin\theta^{3/2})$

Impact parameter resolution (II)

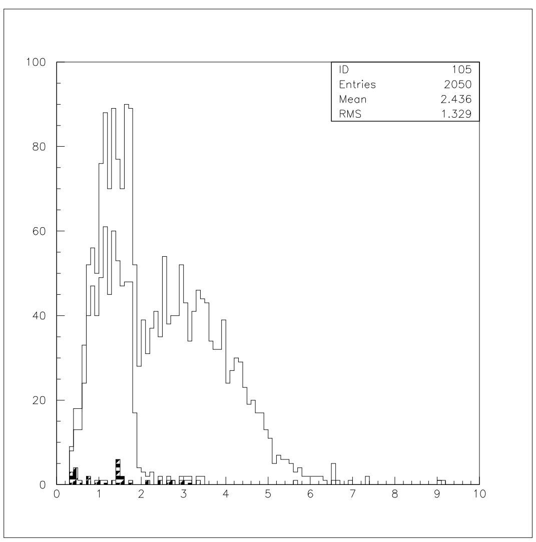


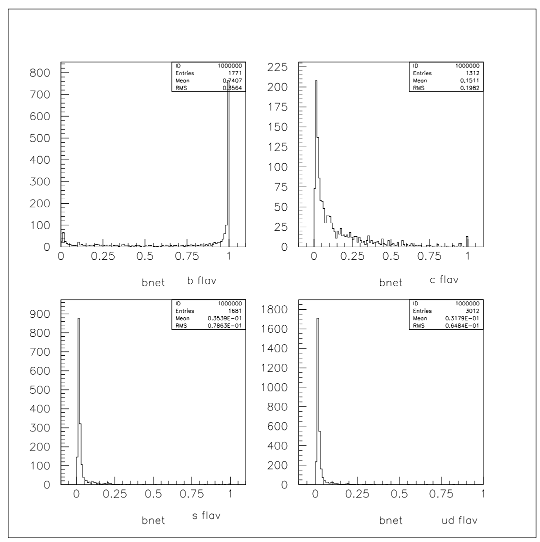
All tracks found in event are shown here. Problem at all p, not yet clear origin, needs to be studied further. Effect of more than 10%. "Bad tracks" removed by asking to be a pion(truth MC) and having 5 hits in vtx detector (remaining shown in previous slide for two different detector geometries). But tracks are generated all with cos(theta) less than 0.9, so within full acceptance of CCD detector. ??

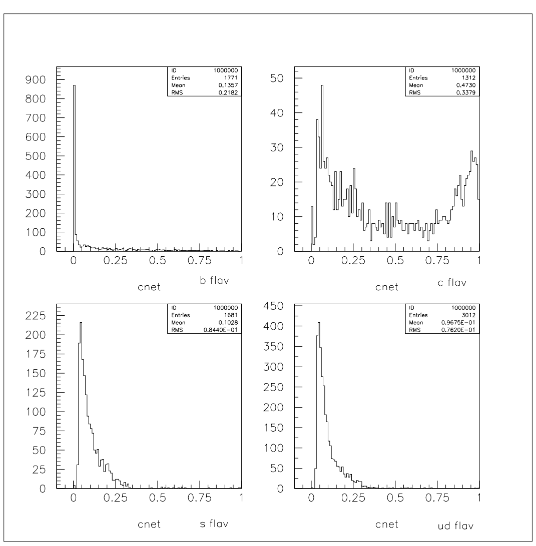
Study needs also to be repeated in newer version of brahms.

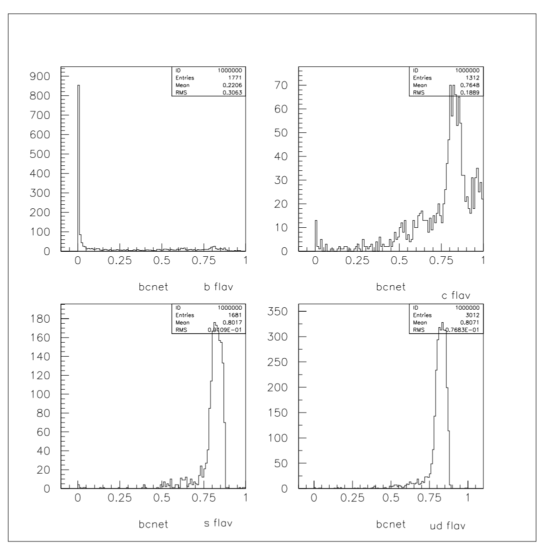
Tagging variables

Corrected mass from ZVTOP (left,top), and neural network output for b and c against background (bnet,cnet), and b against c (bcnet) separation. This and the following plots, unless specified differently, refer to Z0 events at 45 GeV.

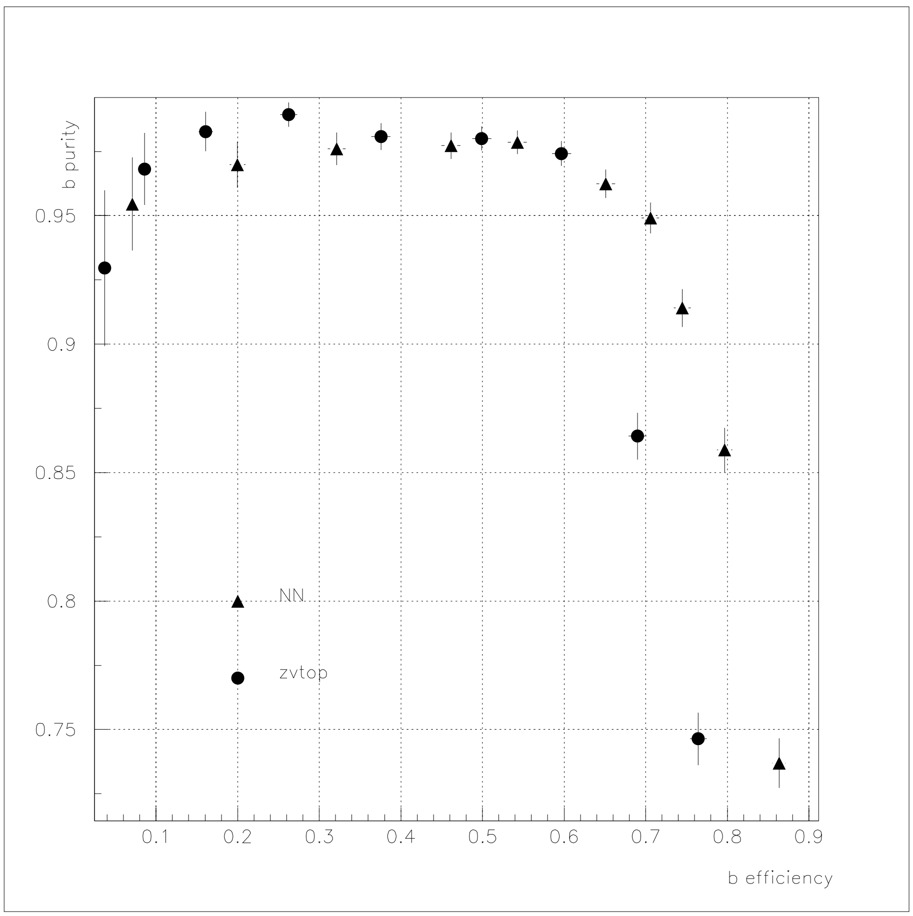








efficiency vs purity for b jet tag

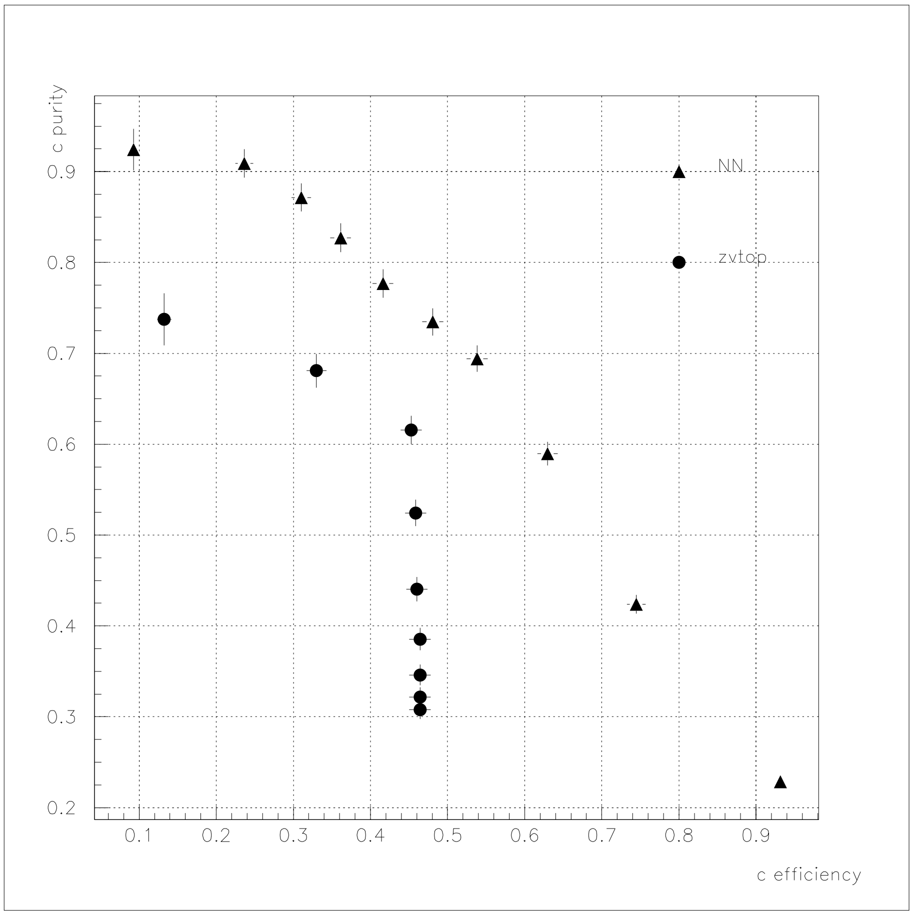


Neural network allows higher performances.

NN: 70% efficiency and 95 % purity

zvtop mass only: 70 % efficiency and 86% purity

efficiency vs purity for c jet tag

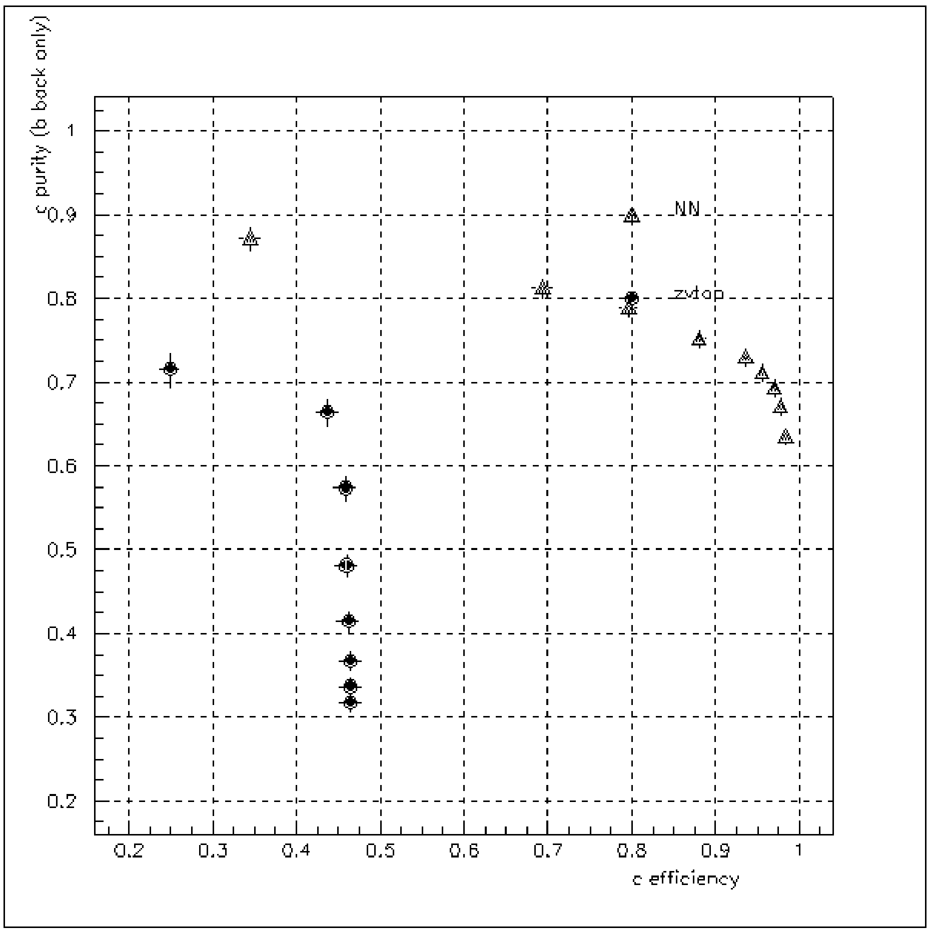


Neural network allows higher performances. It is clearly shown how the 1-prong variables of NN boost efficiency beyond the knee of ZVTOP only tag.

NN: 40% efficiency and 65 % purity

zvtop mass only: 40 % efficiency and 80% purity

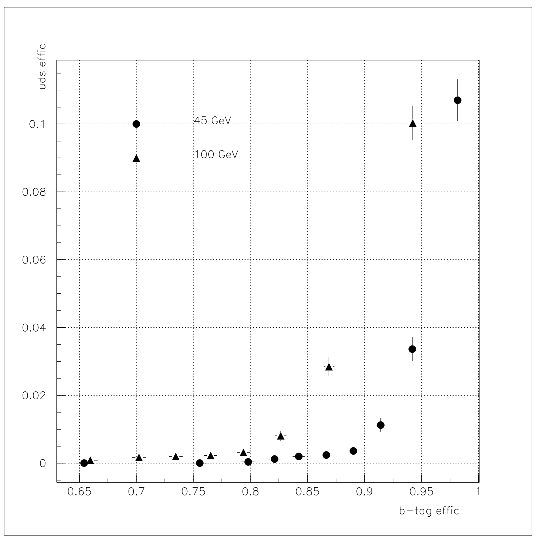
efficiency vs purity for c jet tag (b bkg only)

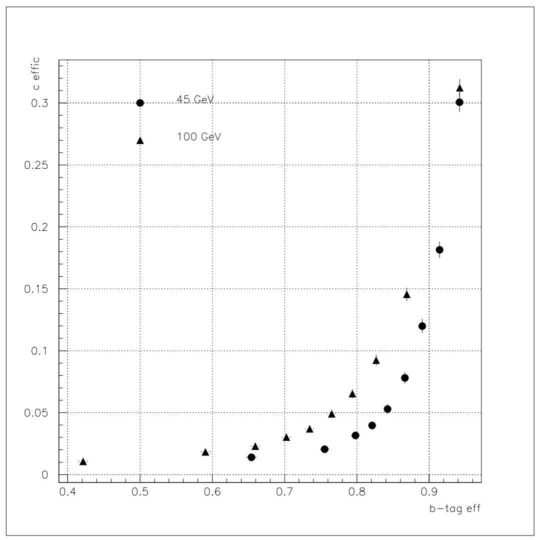


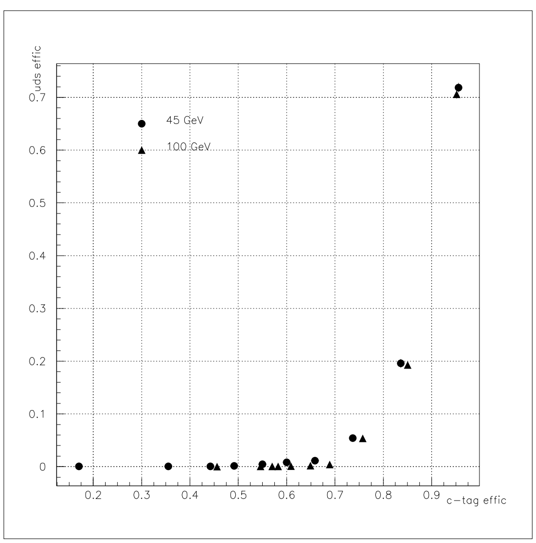
The initial purity of the sample is 42 %.
NN: 70% efficiency and 80 % purity

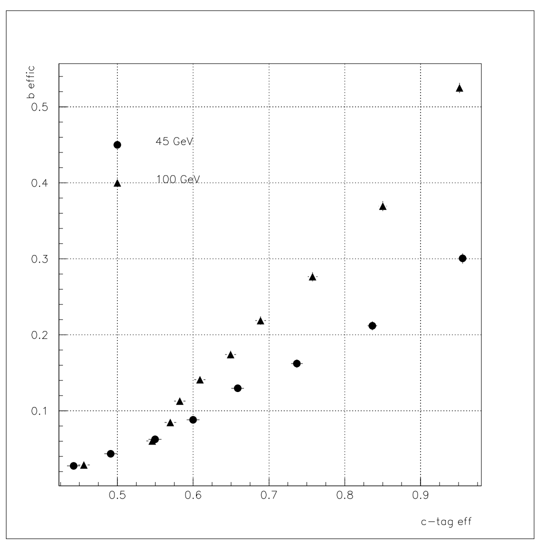
efficiency for b/c tagg., for different energies

For this study we use monojets of different flavors generated with JETSET, for energy 45 GeV and 100 GeV. We show efficiency for b (or c) tag, compared with the efficiency (with the same cut) to select background, uds and c (or b).









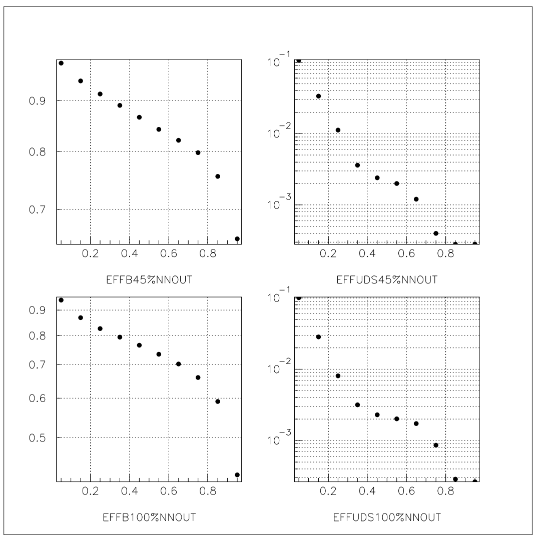
efficiency for b/c tagg., for different energies (II)

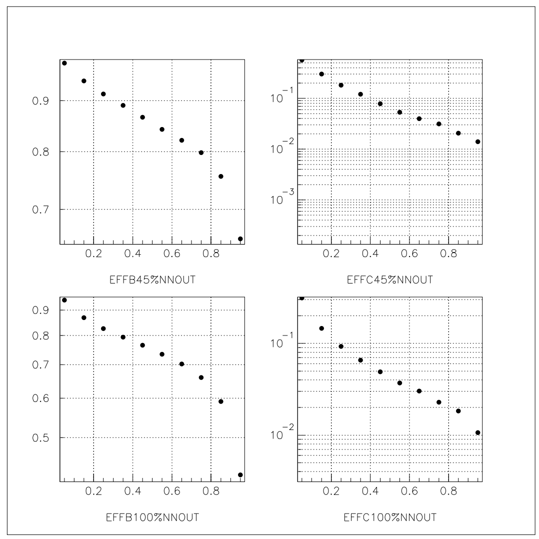
previous figures should be read in the following way: efficiency for b is dropping when energy is increasing (rather than uds efficiency increasing). See also following plots.

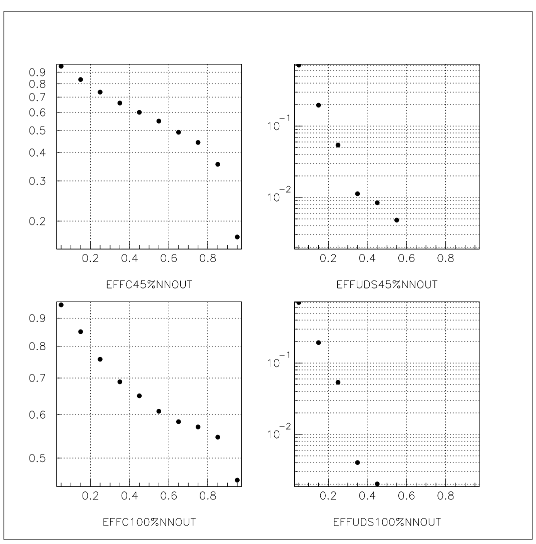
We believe reason for this is not fundamental, but might be due simply to wrong initialization of vertex fitting routine from OPAL. There is additonal observation that b tag efficiency drops when decay length is increasing, which can be explained by the previous statement, and has caused same type of problems at SLD in the beginning. Then, overall decrease in eff with energy might be simply due to more b jets having long decay length at higher energies.

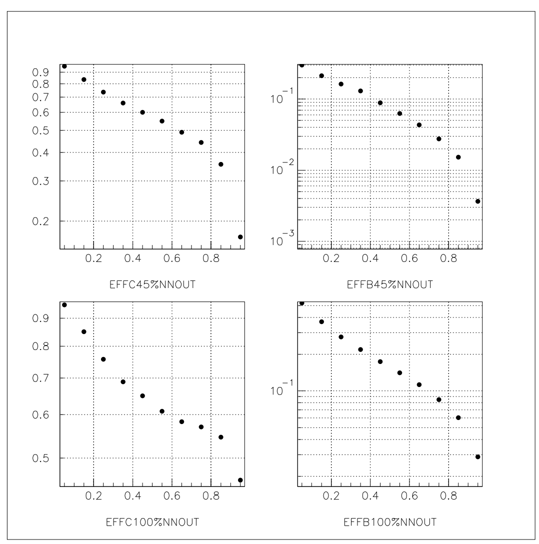
Update on this soon.

efficiency for b/c tagg., for different energies (III)









Conclusion - Outlook

- update of Richard's study for newer geometry is done. Slight increase in eff/purity performances reviewed in his note, and better resolution at low momenta for track parameters. Puzzle of "bad tracks" might be limiting the improvement, and also we did not yet look at all the performances (e.g. vertex charge separation).

- when studying performances with higher energy jets, we did not retrain the NN. This might give important improvement, and anyway should be done for correctness.

- We still need to update ZVTOP to ZVTOP3. Why? ZVTOP3 has a new important algorithm, which
  - increases overall efficiency and purity (especially at low decay lengths, where most of the statistics is)
  - allows to reconstruct vertices for 1-prong decays.

  Work for this is on-going, expected to be done within next month. after this all plots should be reupdated.

- We should look at vertex charge and dipole charge performances for b/bbar and c/cbar separation (see SLD, in Chris talk in this session). This might be feasible within TDR deadline.

- Study of a detailed physics case?

$\rightarrow$ lots of place for improvement still, stay tuned.