Topological flavour tagging at TESLA

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- Experimental environment
- Tool for vertexing : ZVTOP
- Studies at ECM=91.2 GeV (benchmark)
- Neural Net: b and c selection
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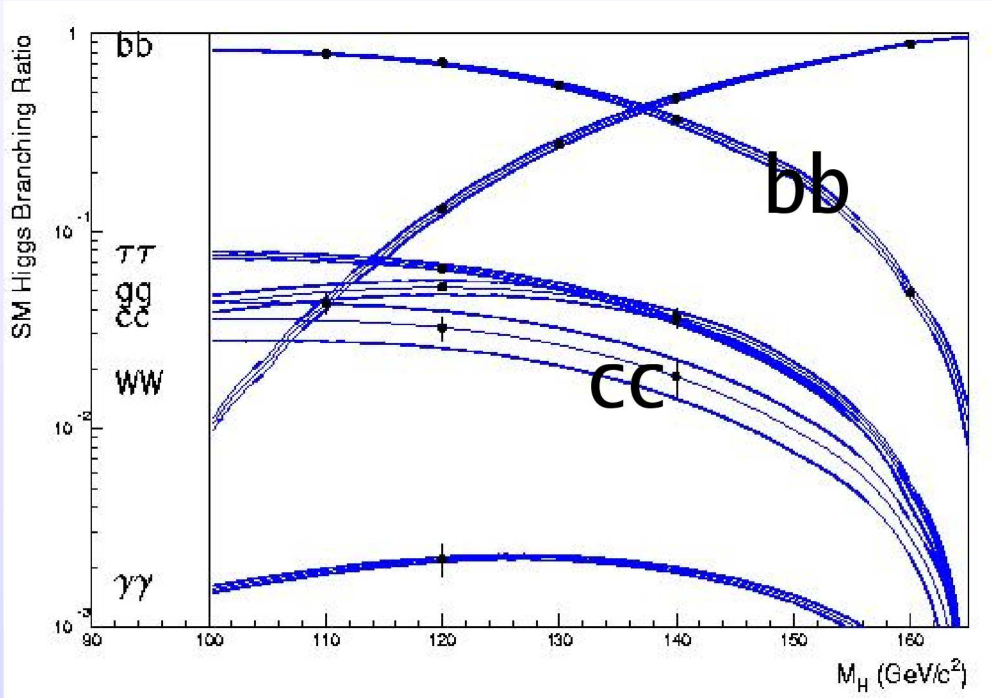
Physics motivation

Discovery and high precision physics:

- Higgs boson sector
- SUSY
- Top physiscs
- Gauge boson couplings
- Giga-Z
- ...

Detector requirements:

- 10 times better than LEP and LHC
- Example: charm tagging

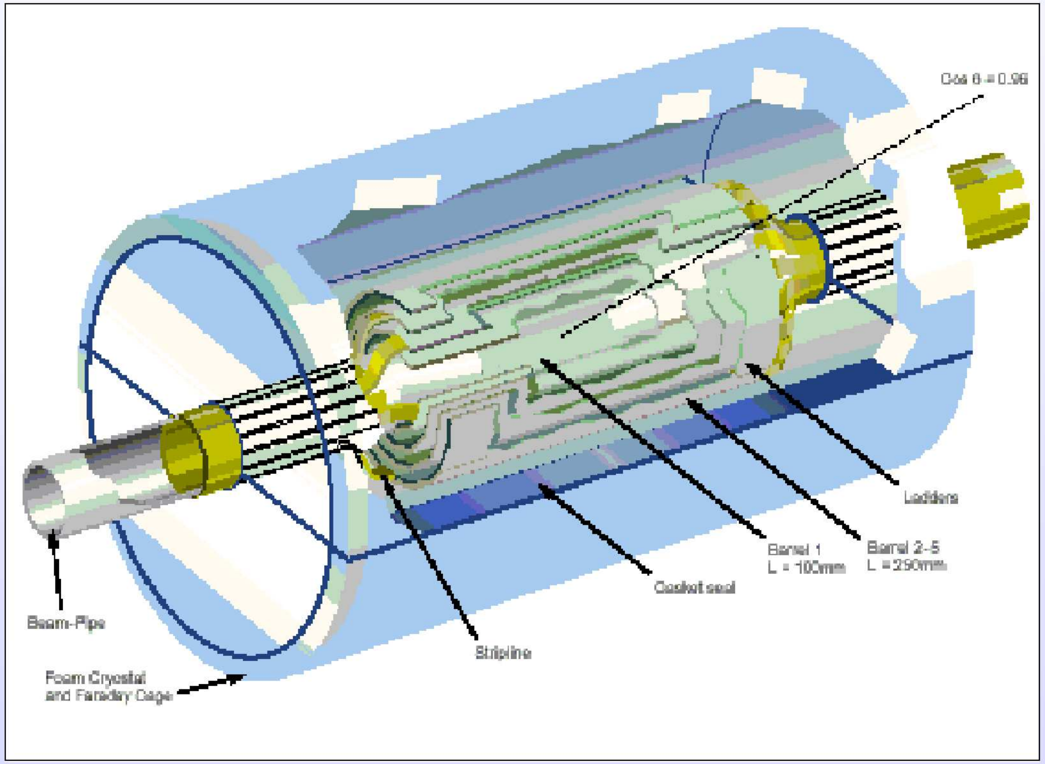


CCD Vertex Detector

- Four different concepts
  - CCD
  - Depfet
  - Hybrid-APS
  - Monolit-APS (CMOS)
- 5 layer vertex detector
- Size: 20x20 μm^2
- Innermost layer: R=1.5 cm
- 900 Megapixel
- Bunch train structure:

Continuous readout

- Resolution:

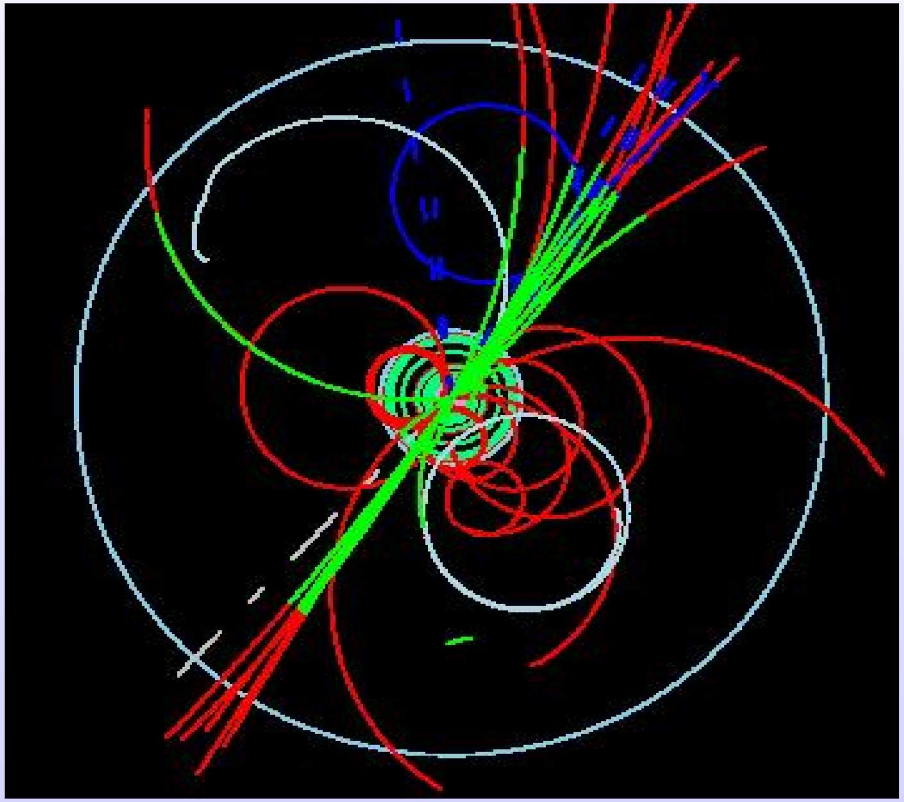


$$\sigma_{IPr-\phi} = \left(4.20 \oplus \frac{4.00}{(p/GeV)\sin^{3/2}(\theta)}\right)_{\mu}\ \mathrm{m}$$

Detector Simulation

- Full Simulation:
  - → Brahms
  - → Based on Geant 3

- Fast Simulation:
  - → Simdet
  - → Smearing based on Brahms parametrisation

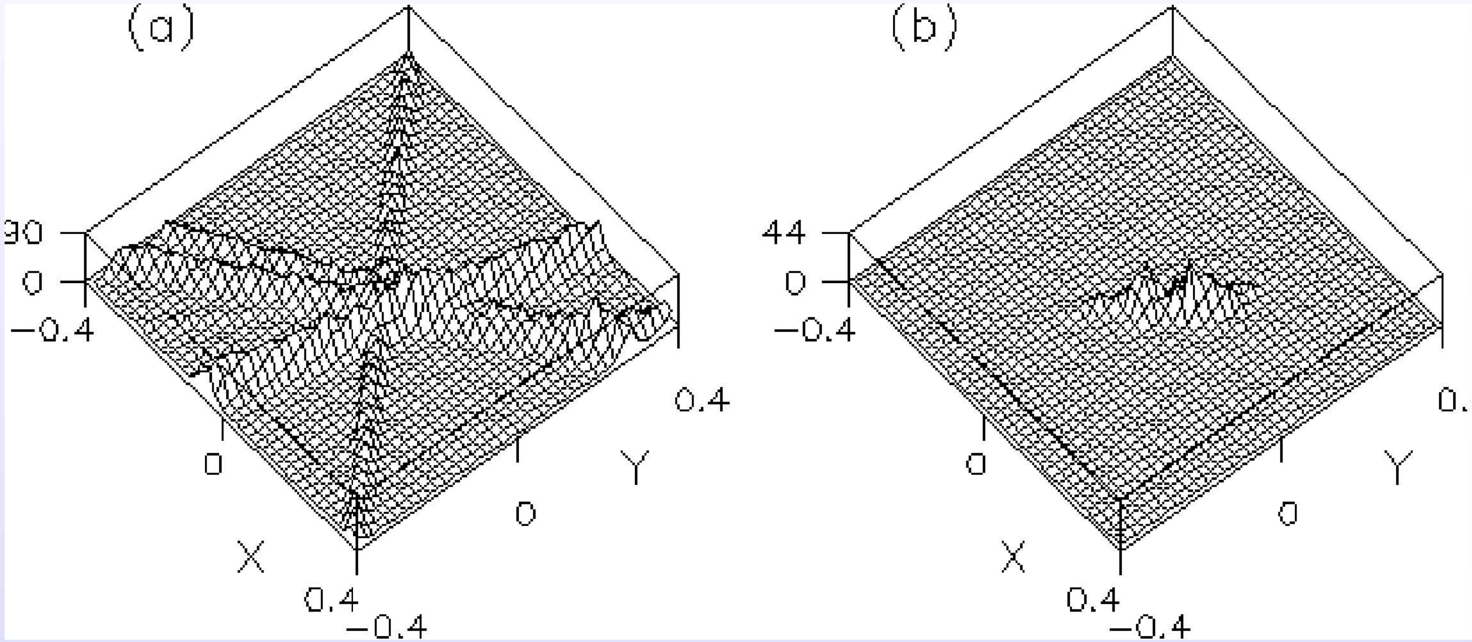


Vertex reconstruction tool:

ZVTOP

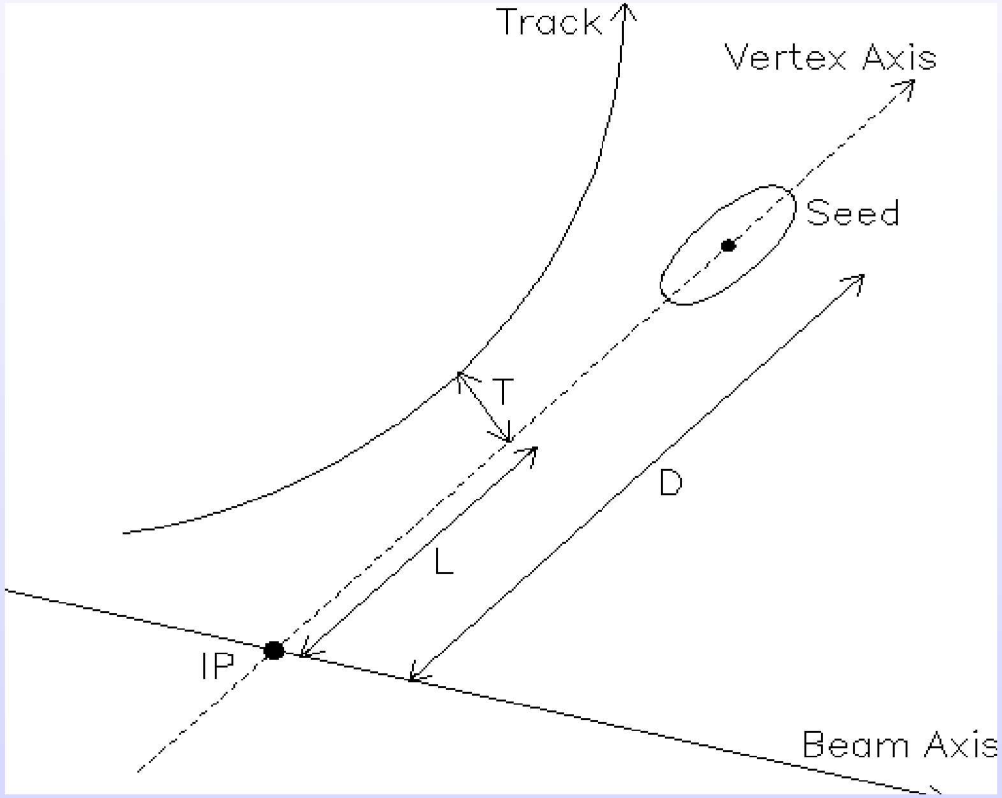
http://www-flc.desy.de/flc/science/analysis_ntuple/index.html

Vertexing:ZVTOP



- SLD Vertex finder (Nucl.Instrum.Meth.A388:247-253,1997)
- Tracks are described as Gaussian probability tubes
- Look for overlapping regions
- These are seed vertices (including primary vertex)

Track Attachment



- Cascade decays b->c->s: several seed vertices
- Start: Vertex with biggest D
- Attach reasonably close tracks

Most important variable:Vertex Mass

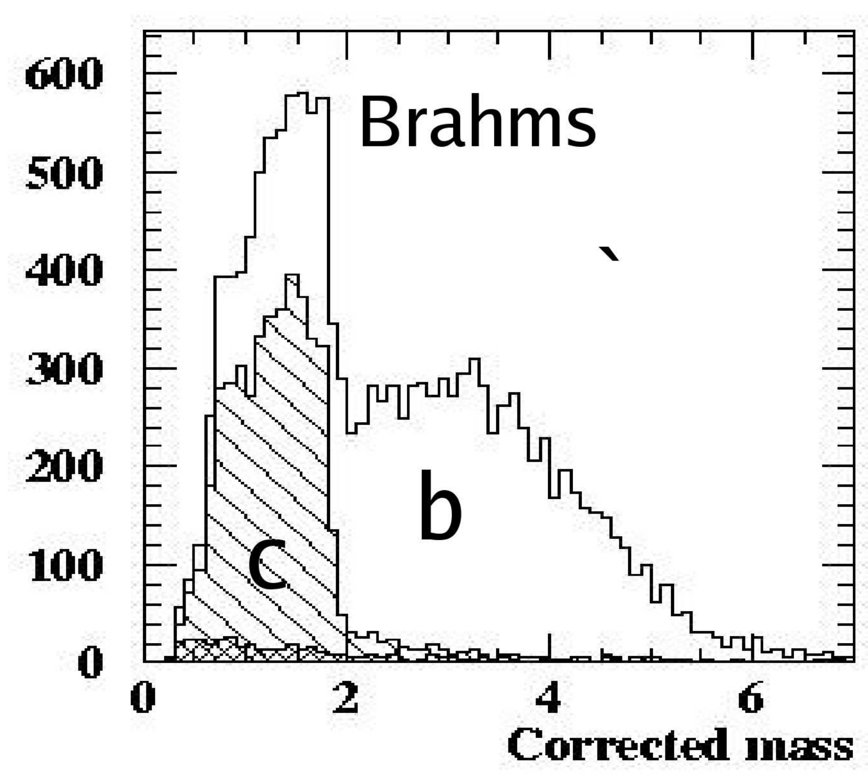
- Use all tracks from secondary vertex
- Calculate invariant mass
- correct for missing p_t

$$M_{pt} = \sqrt{M_{VTX}^2 + P_t^2} + |P_t|$$

Cut at M_{pt} = 2 GeV:

- b-Efficiency: 55%
- b-Purity : 97%

LC-PHSM-2000-021



SLD (barrel only): Efficiency: 52%

Purity : 98%

High efficiency:

Neural Net selection

Neural Net

Introduction: LC-PHSM-2001-024

- Based on topological vertexing (ZVTOP):
  - ➔ Corrected vertex mass
  - ➔ Decay length / decay length significance
  - ➔ Vertex momentum
  - ➔ Vertex probability
- Additional trackwise information
  - ➔ IP joint probability (Aleph)
  - ➔ IP significance
- 3 different classes
  - ➔ Only primary vertex found
  - ➔ Also one secondary vertex found
  - ➔ Three or more vertices found

NN: Benchmarking at 91.2 GeV

b-Net:

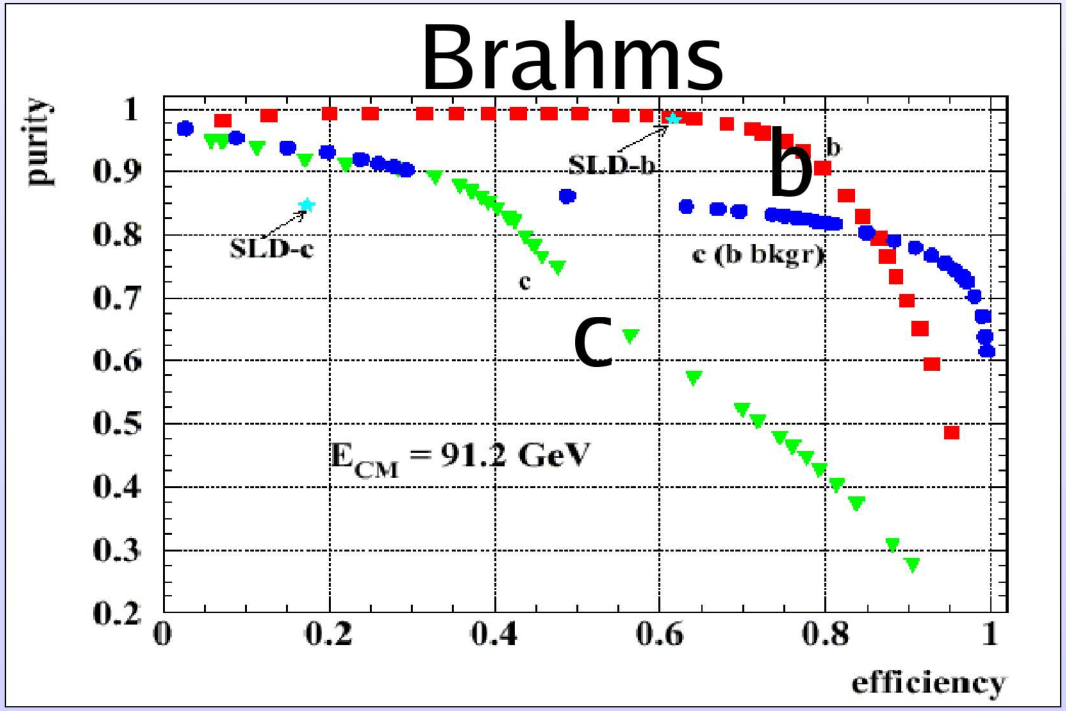
- Efficiency: 80%
- Purity : 90%
- Comparable to SLD central detector

c-Net:

- Efficiency: 40%
- Purity : 80%
- 2-3 times better than SLD

Why 91.2 GeV ?

- Benchmark
- Comparison TESLA to LEP/SLD
- Giga-Z option (+ calibration)



Summary:Vertexing at the Z-Peak

- ZVTOP: Very efficient vertex finder
- N-Net selection: Very good flavor separation
- B-Tagging:
  - Efficiency 60(90)%, 98(80)% Purity
  - As good as SLD for a much bigger theta range; important for searches in multi jet final states
- C-Tagging:
  - Efficiency 40%, 80% Purity
  - Much better than SLD
- Excellent tool for vertexing which a very good angular coverage

Optimize Detector configurations

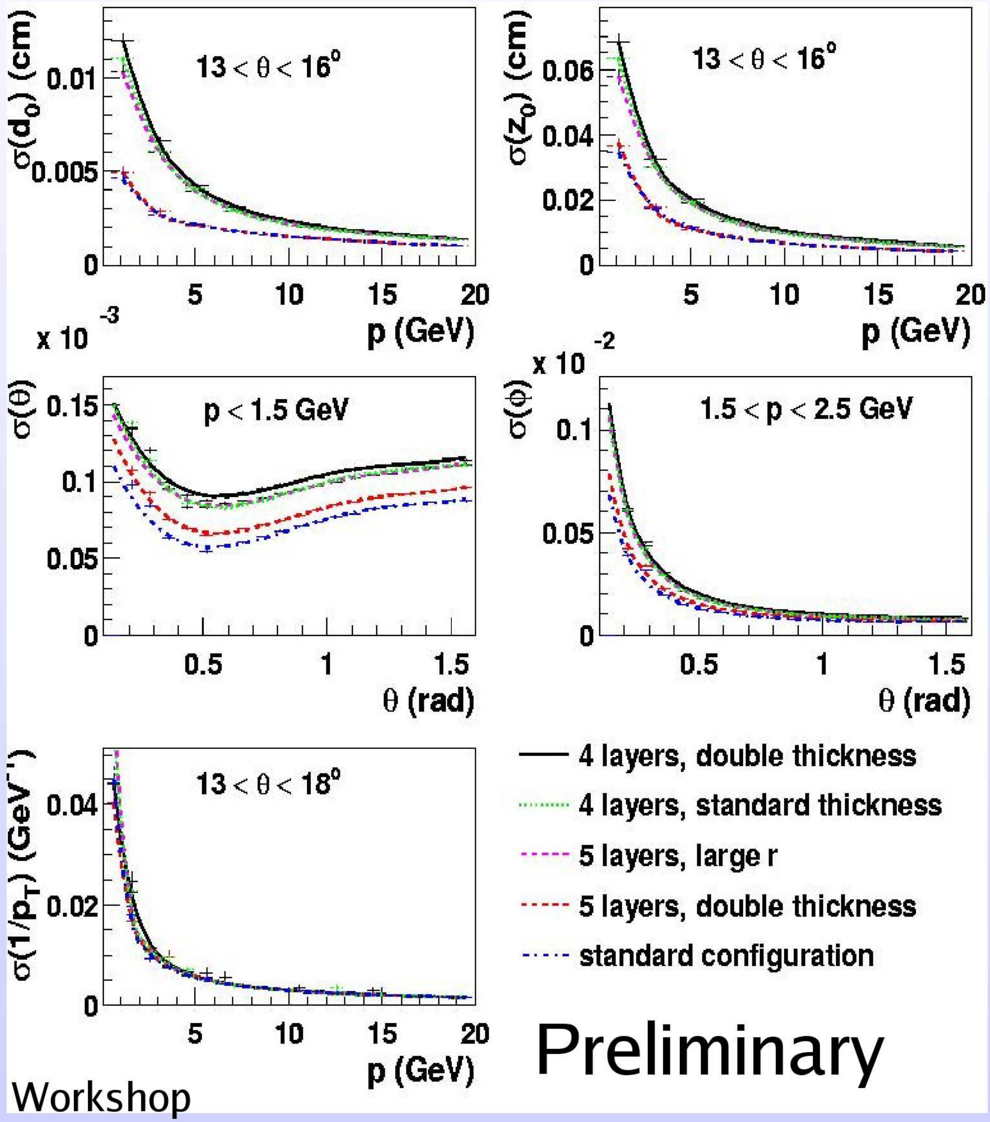
Detector dependence

Comparison:
CCD
"Standard"
Configuration:

- 5 Layers

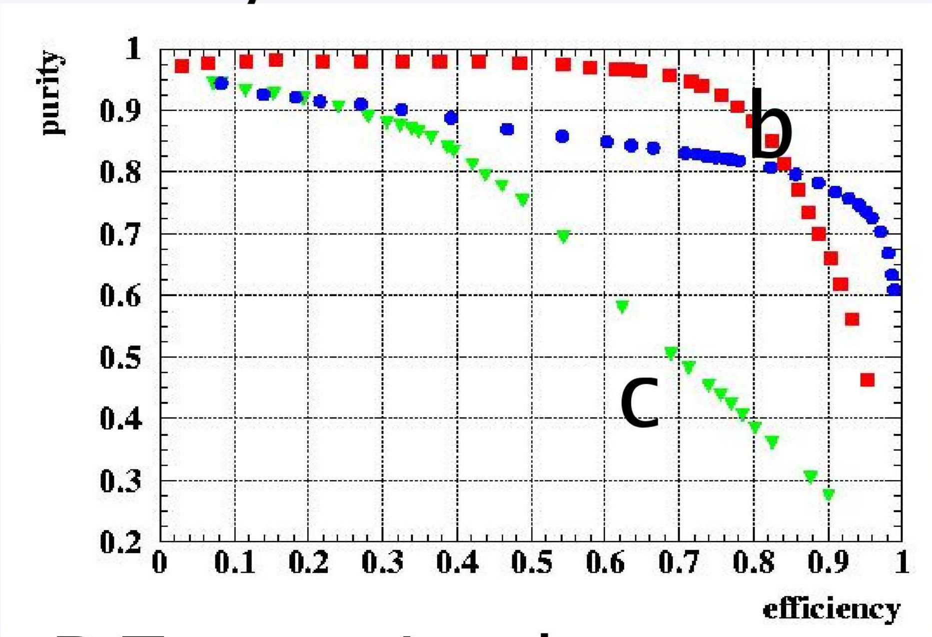
Worst case configurations:

- Remove inner layer
- Double sensor thickness
- Move inner layer to 2 cm

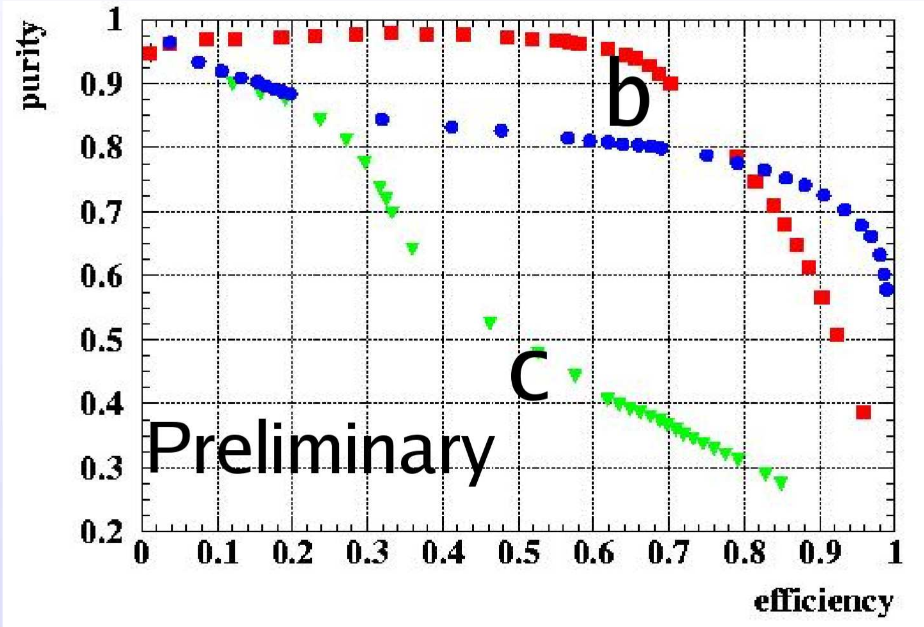


Neural Net Comparison

- 5 Layer



- 4 layer/ double thickness

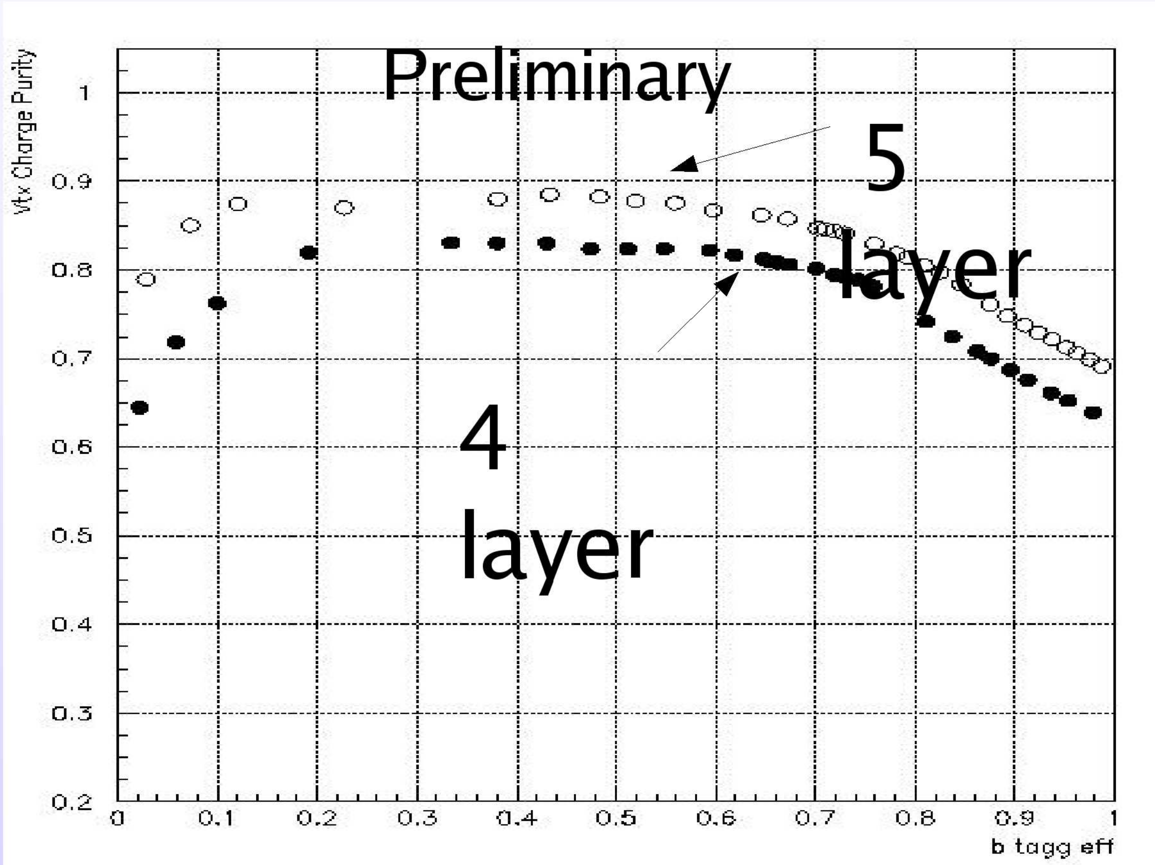


- B-Tag: again robust
- C-tag really suffers

mainly because of the 2/3 of c-quark events with no vertex found;short lived D^0's which are very sensitive to impact parameter resolution

Vertex charge for B's

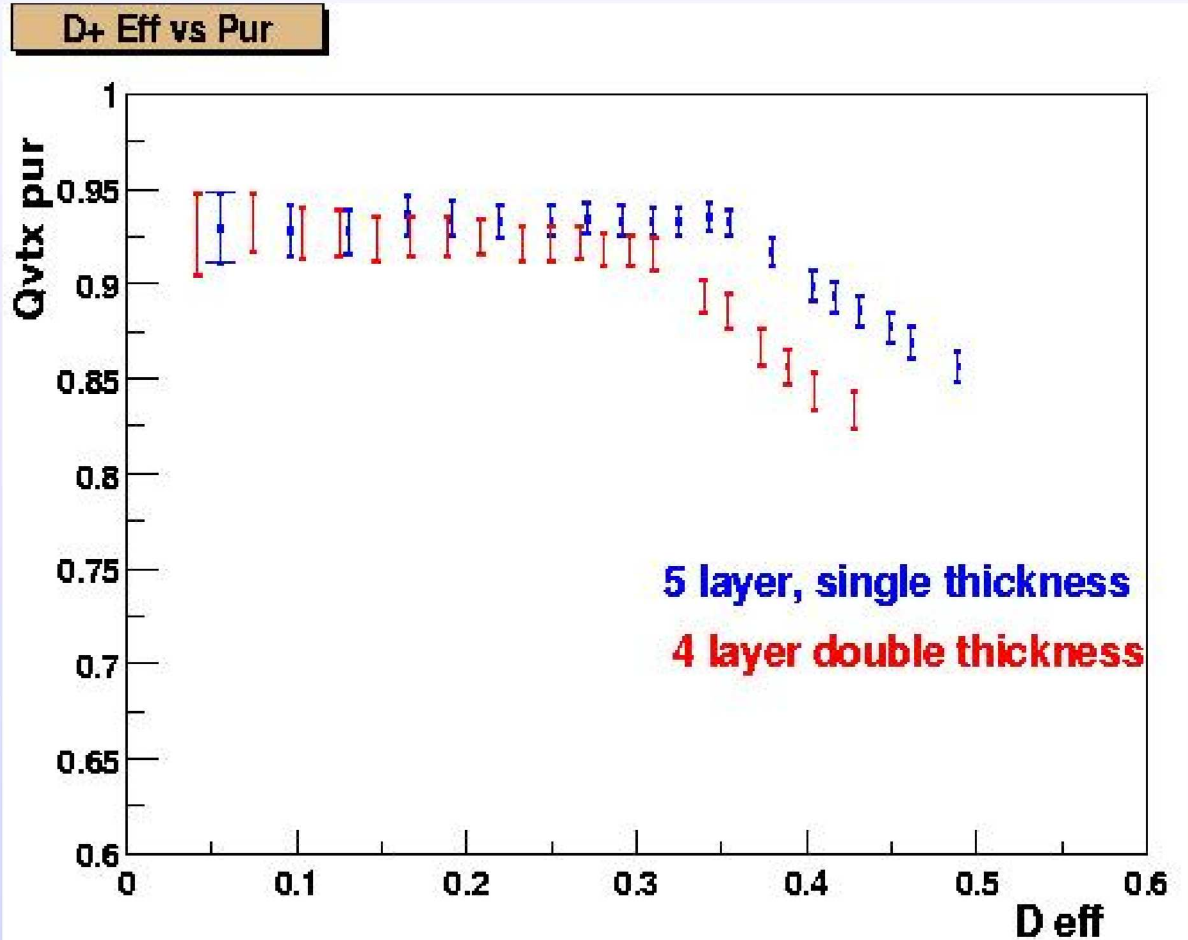
- Fraction of correctly reconstructed charge Vs b-net output
- 4-Layer: ~6% less efficient



Huge factor in multijet final states!

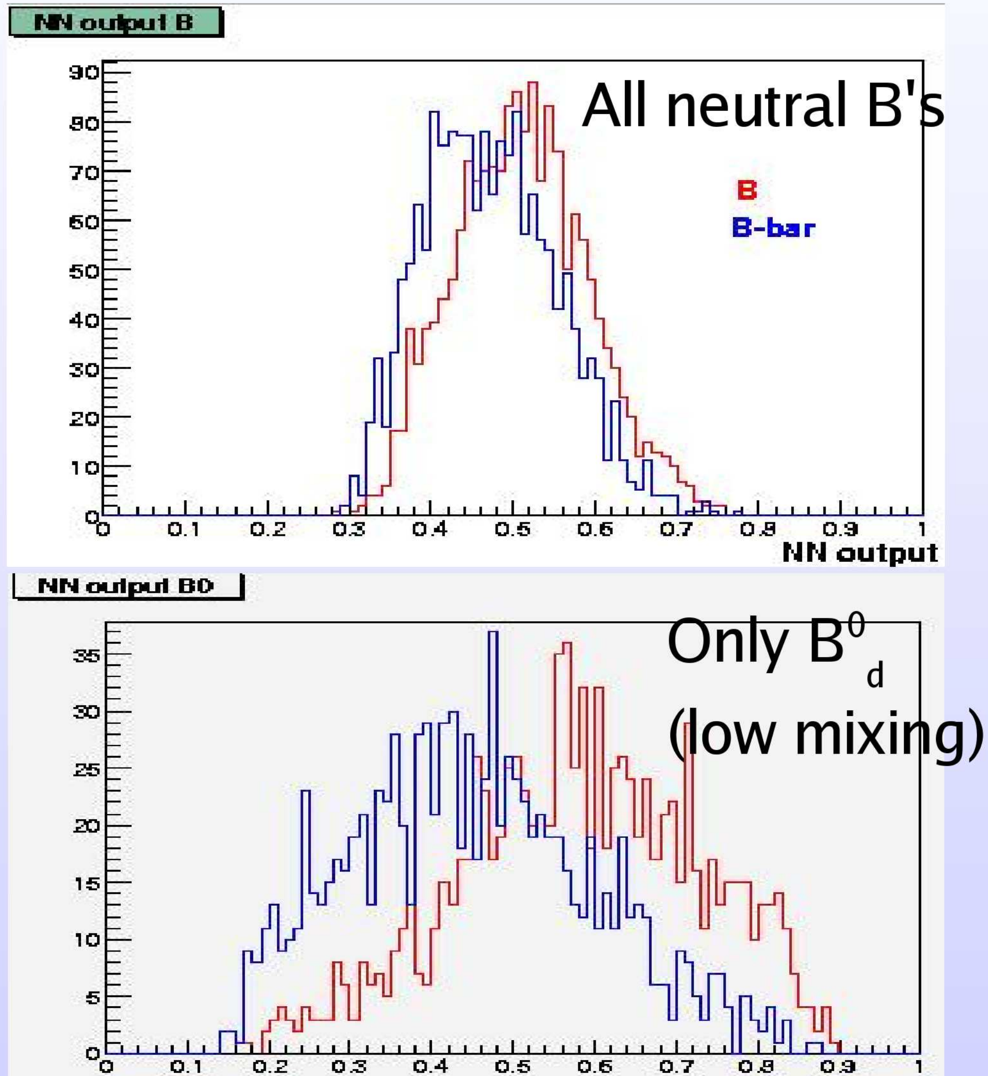
Vertex charge for c's

- Fraction of correctly reconstructed charge vs D+ efficiency of NN
- Drop because of poorly reconstructed D's



b/bbar separation for neutral B's

- Neural net based on jet-charge
- Heavily affected by bbar-mixing



Summary:Detector Configurations

Comparison of 4 thick vs 5 thin layers:

Flavor tagging:

- b-tagging efficiency very robust
- c-tagging performance drops rapidly
- b-charge reconstruction efficiency drops by ~5 %

Other issues:

- Standalone pattern recognition much more difficult
- Material: more multiple scattering and more photon conversion background in outer detectors; important for main tracker (TPC) ?

And we can separate b and bbar even in jets with neutral B^0

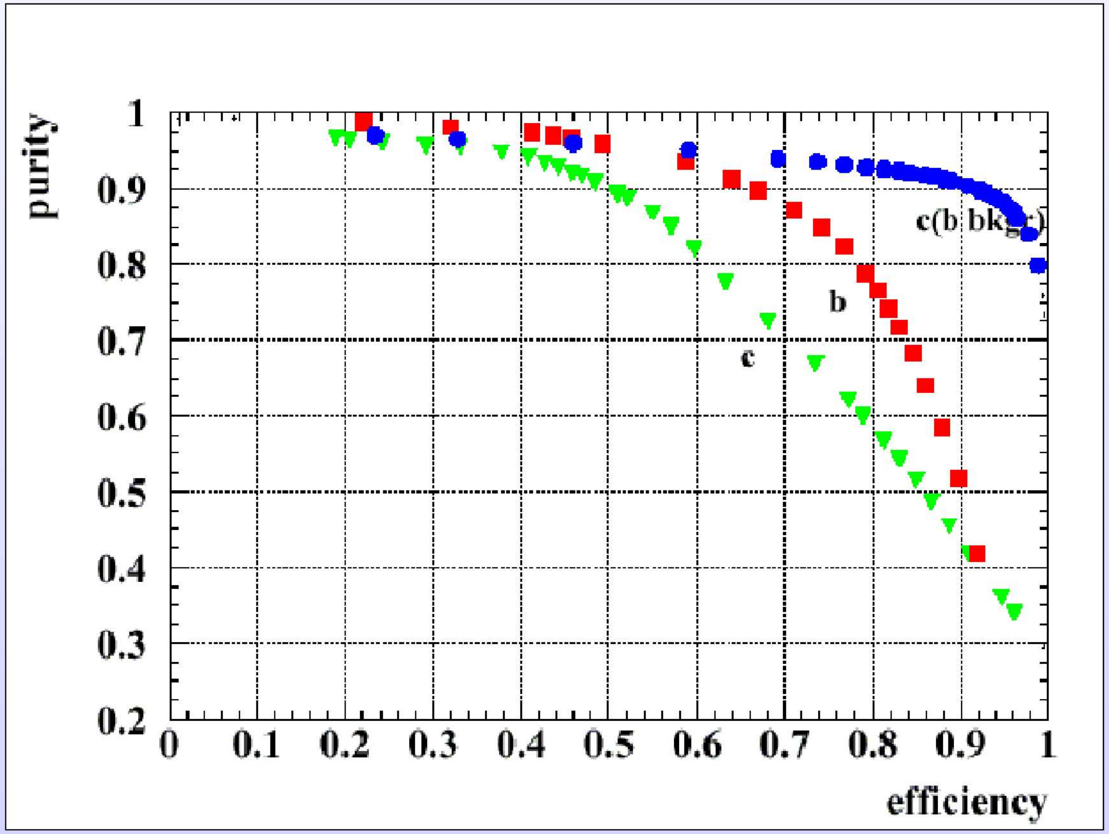
Flavor tagging
at
high energy

Neural Net for 500 GeV

c-Net:

- Efficiency (fixed): 40%
- Purity :80%->95%
- Purity(fixed) :60%
- Efficiency :60%->80%

Much improved
w.r.t 91.2 GeV!



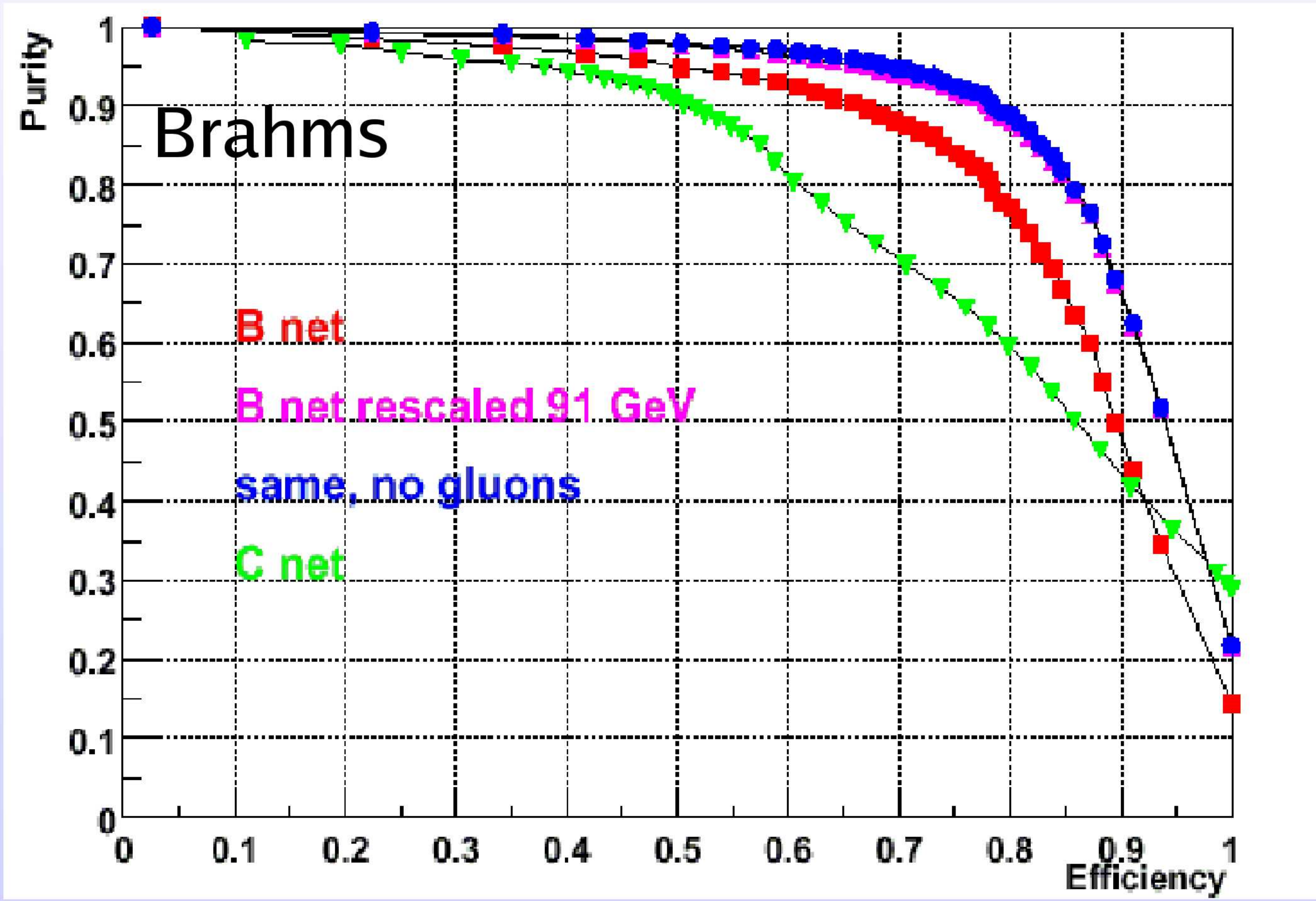
B/c separation excellent!

b-Net:

- Purity (fixed) :90%
- Efficiency : 80->65%

NN 500 GeV cont.

Why this poor b-Net performance at 500 GeV ???



Different flavor composition

- Gluon splitting to b and c is enhanced

Performance equal to 91.2 GeV !!!

Tagging in multi jet final states at 500 GeV

Jetwise flavor tagging

Why ???

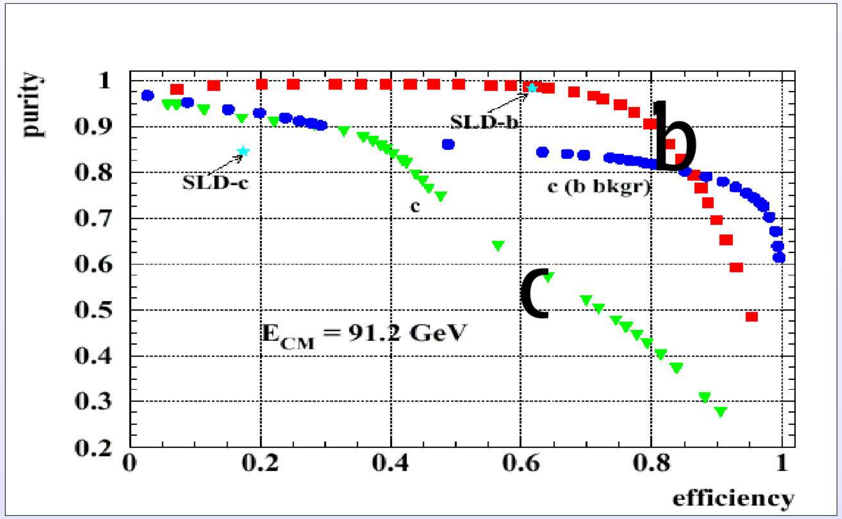
Multi jet final states:

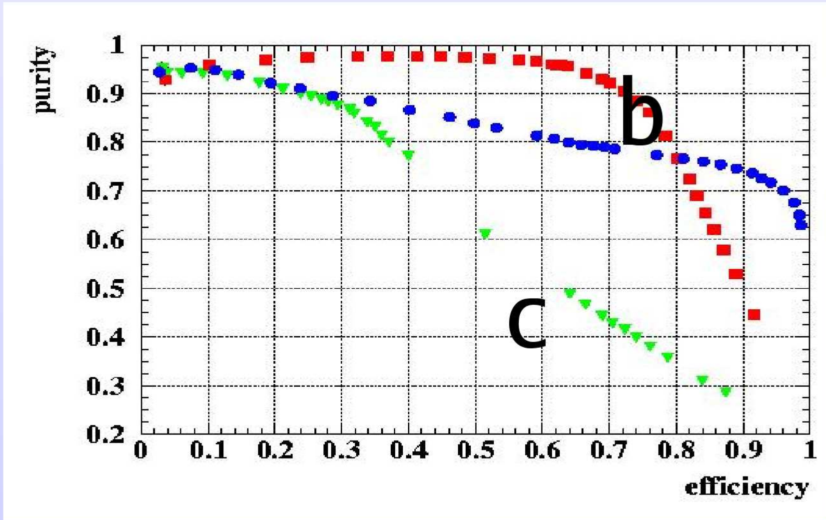
- Z-Pairs
- Top-Pairs
- Higgs searches
- SUSY-searches

Problems:

- Jet-track assignment

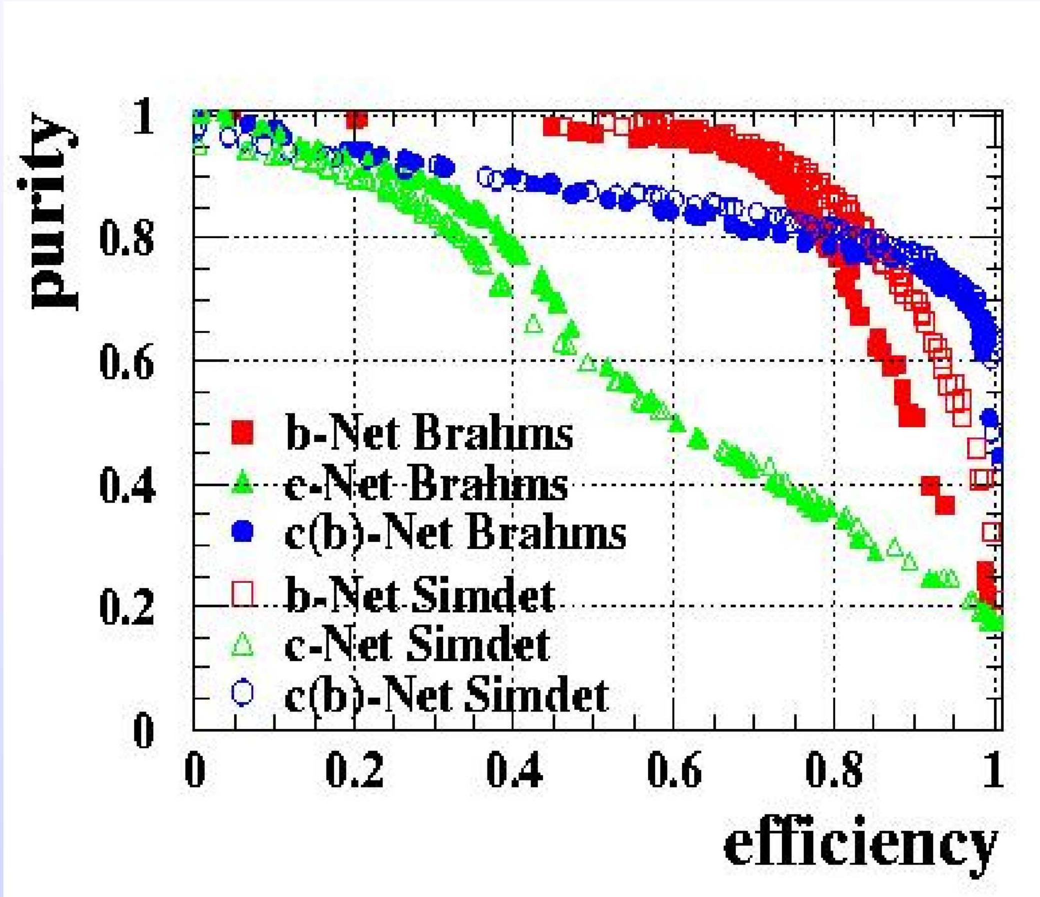
Performance drops by ~5-10%



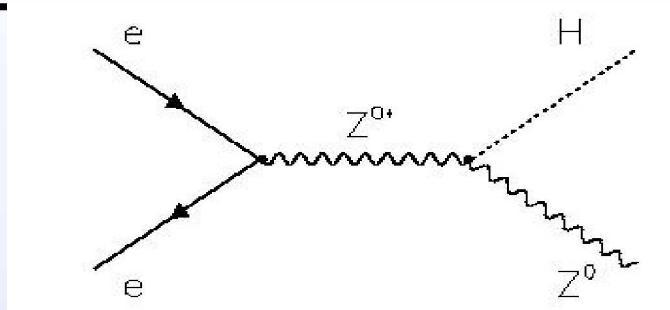


Verify fast simulation

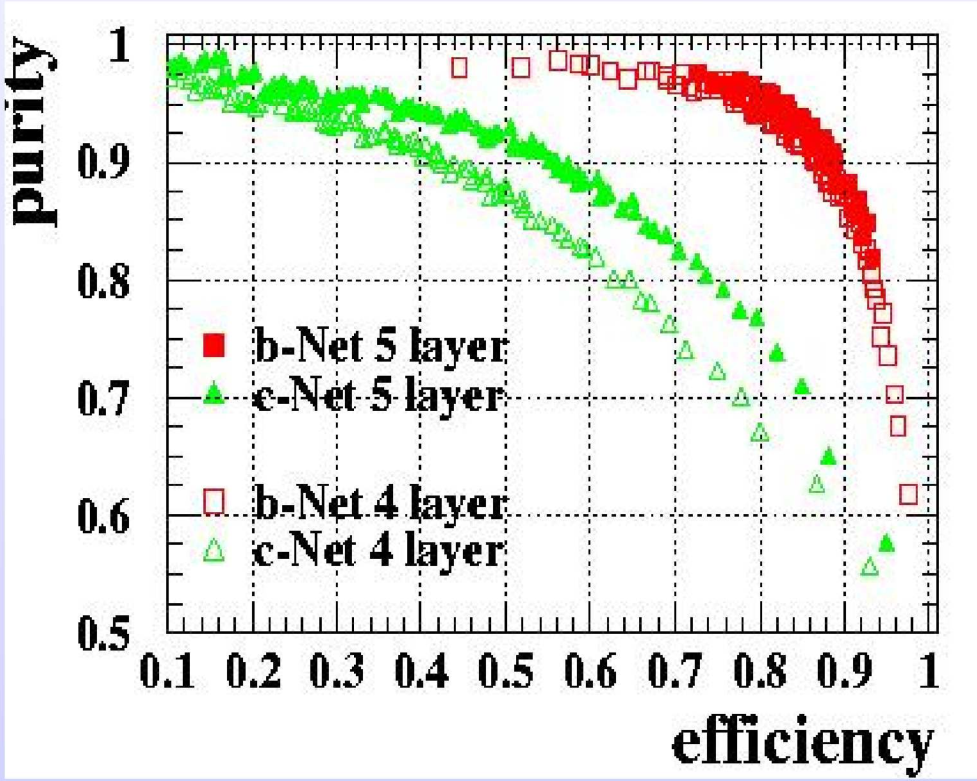
- Simdet: high statistics analysis (~1000 times faster)
- Compare with full simulation Brahms
- General agreement better that 10 %
- Simdet a bit optimistic for high Btag efficiency -->missing tails in d0/z0 distributions
- Surprisingly good



NN as tool: HZ branching ratio analysis



- Higgs-Strahlung
- HZ --> bbqq, ccqq, ggqq
- Results including full hadronic final states:
  - (BR(H-->bb))=1.1%
  - (BR(H-->cc))=12.8%
  - (BR(H-->gg))=11.3%
- Results close to TDR (Parametrisation)
- Still a lot of improvement possible for kinematic setection

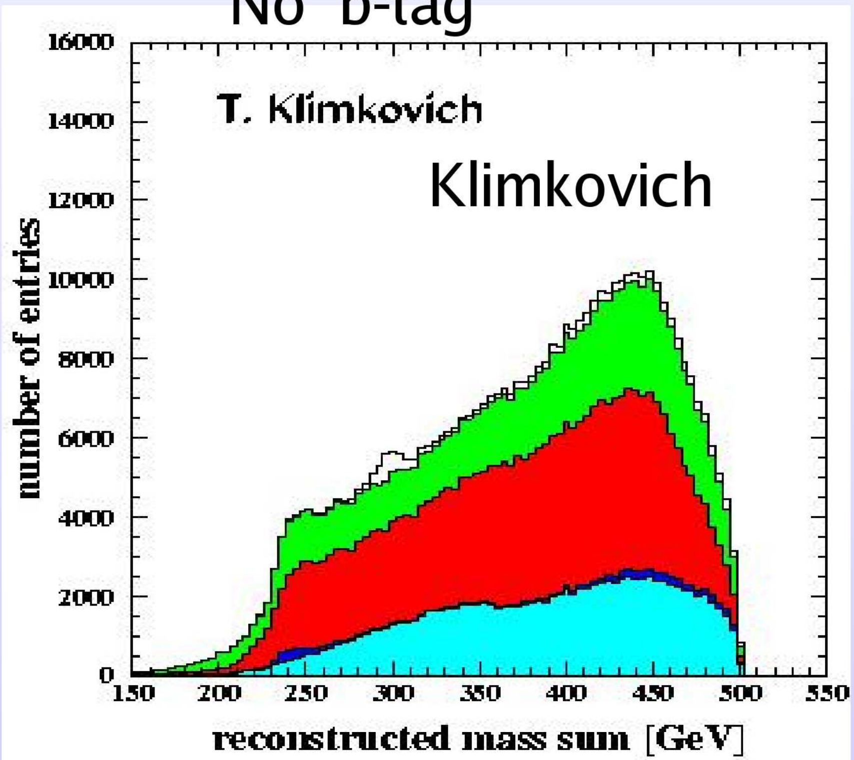


NN as tool: 4 jet 4-b final states

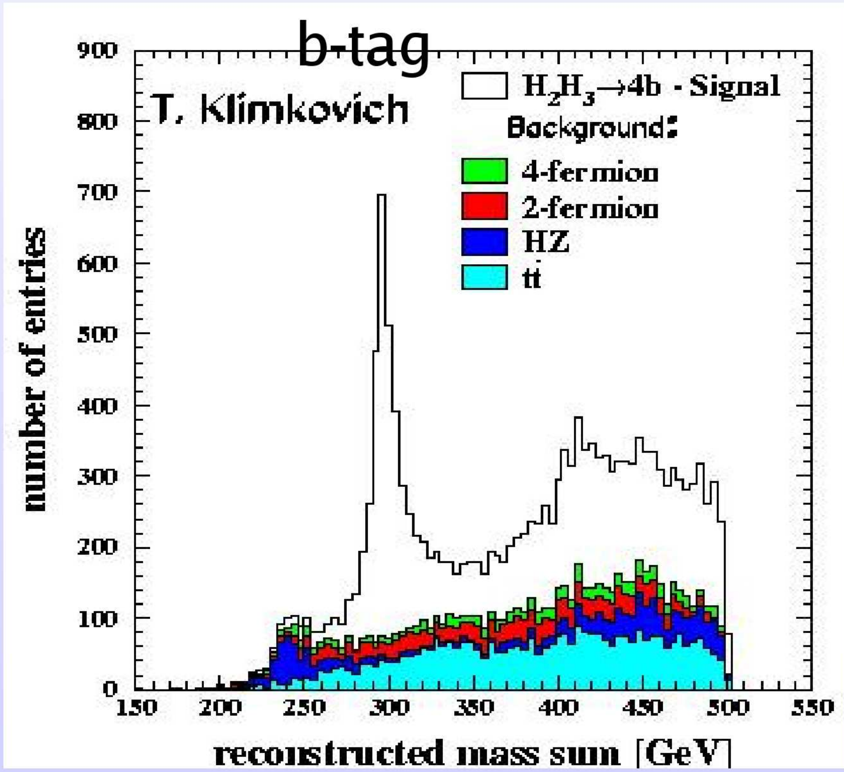
- SUSY searches AH
- Sum of the two 2-jet masses before/after B-Tag

- 4-b Efficiency: ~60 %
- 2-b Efficiency: ~ 4 %
- 0-b Efficiency: ~ 0.1 %

No b-tag



b-tag



Summary: Tagging at 500 GeV

b-Tagging:

- As good as for 91.2 GeV

c-Tagging:

- Much improved because of boost

Multi jet final state:

- Jetwise tag ~5-10% less efficient than hemisphere tag
- Fast simulation verified
- Excellent tool for searches

Summary

- Topological flavour tagging study
- Combination of exellent TESLA vertex detector and suffisticated analysis tools
- Excellent tagging performance for b and especially for c at low and high energy e.g. Precision Higgs physics
- Comparison 5 to 4 layer: Importance of fifth layer shown for c-tag and vertex charge
- Use this tool (and no parametrisation):

  http://www-flc.desy.de/flc/science/analysis_ntuple/index.html