Flavour tagging performance studies at ILD

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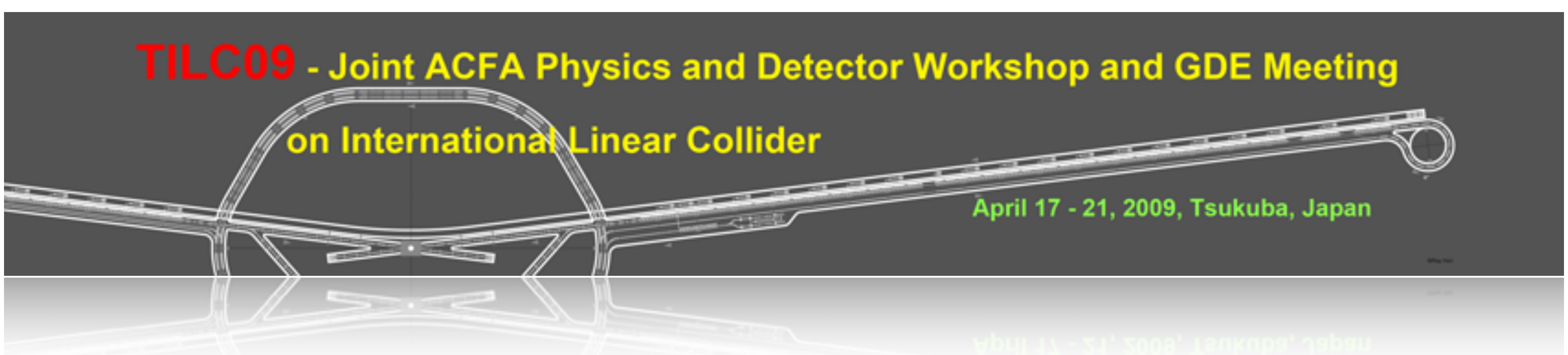

Outline

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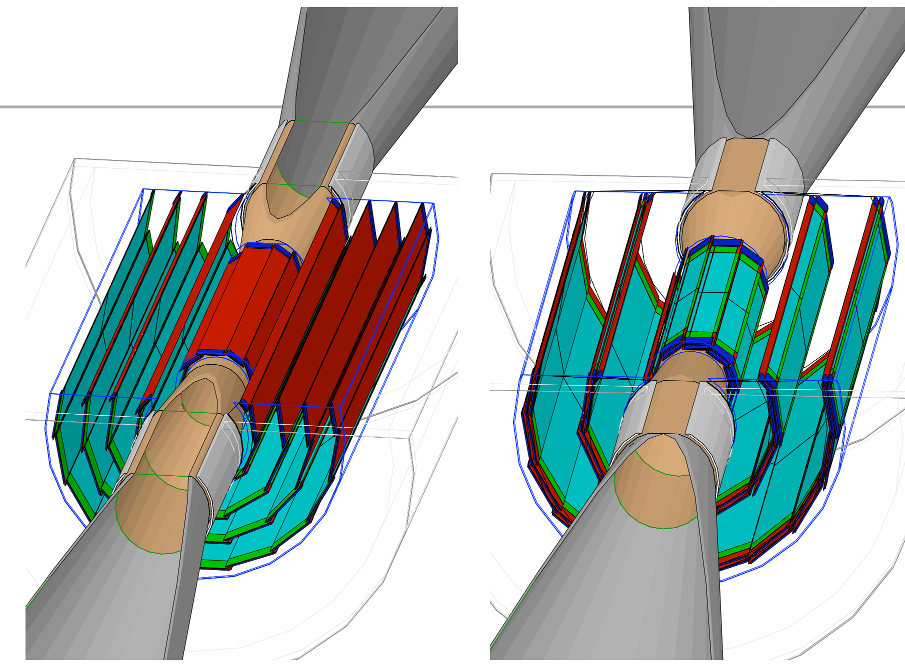
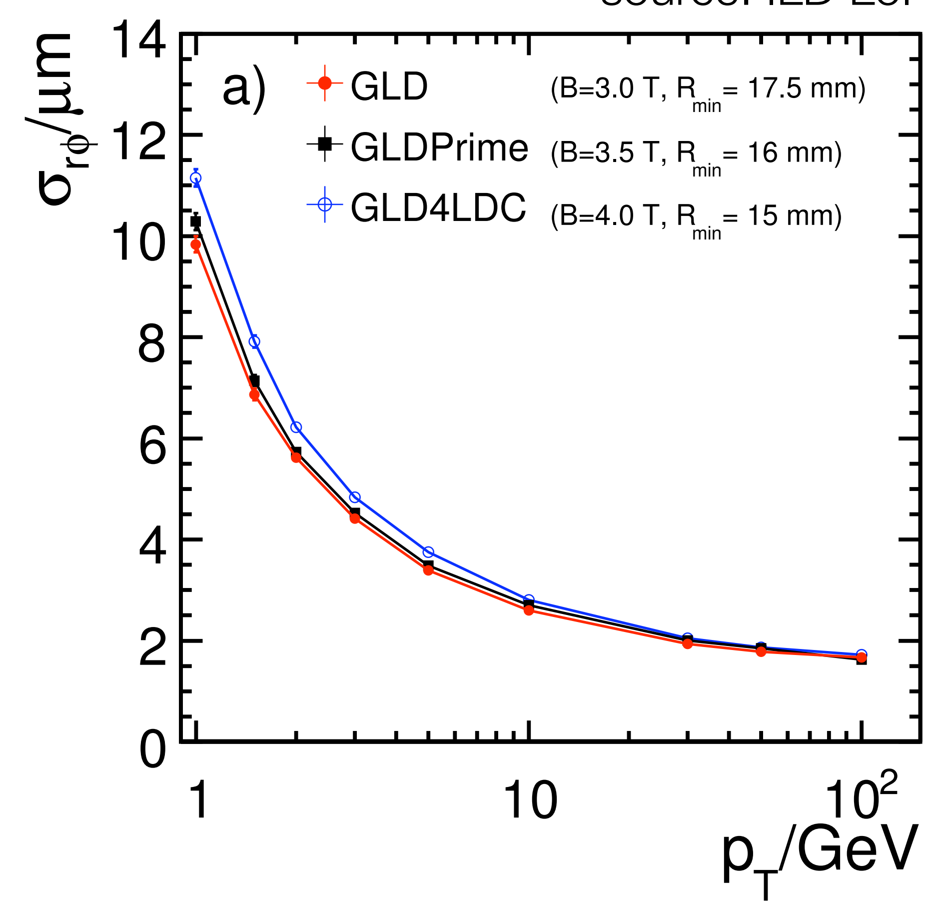
- Flavour tagging
- Ongoing studies
- To do's
- Summary

Introduction



- Flavour tagging is an important piece within the ILC physics programme.
- Flavour tagging primary dependencies: vertex geometry and impact parameter resolution.
- Studies were performed to optimise the LCFIVertex parameters more sensitive to global detector parameters.
- 8 different detector models within the GLD, LDC and ILD concepts were investigated.
- Z-pole was used as a benchmark process to evaluate the flavour tagging performance.

source: ILD LoI



LCFIVertex package

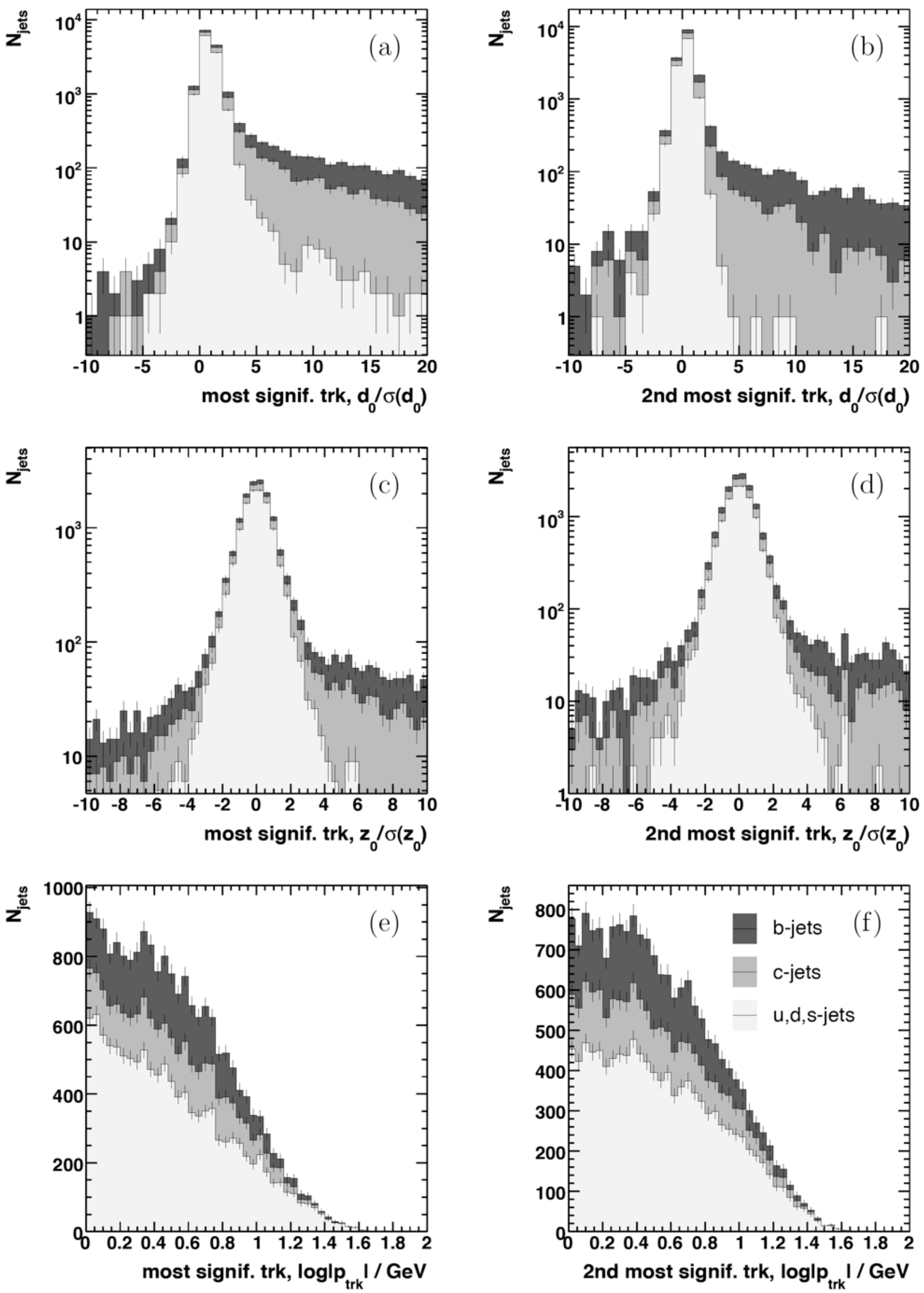
- The LCFIVertex package is a software package developed by the LCFI Collaboration that uses the vertex-detector information for high-level event reconstruction at the ILC:
  - The ZVTOP vertex finder (D. Jackson, NIM A388, 247);
  - A flavour tagging algorithm based on neural networks approach (R. Hawkings, LC-PHSM-2000-021);
  - Vertex charge determination for heavy flavour jets.
- The codes are based on Marlin and uses LCIO for input and output.
- Codes and neural networks are available from a CVS repository under marlinreco and tagnet, respectively: http://www-zeuthen.desy.de/lc-cgi-bin/cvsweb.cgi
- Paper recently submitted by the LCFI Collaboration to NIM.

Flavour tagging

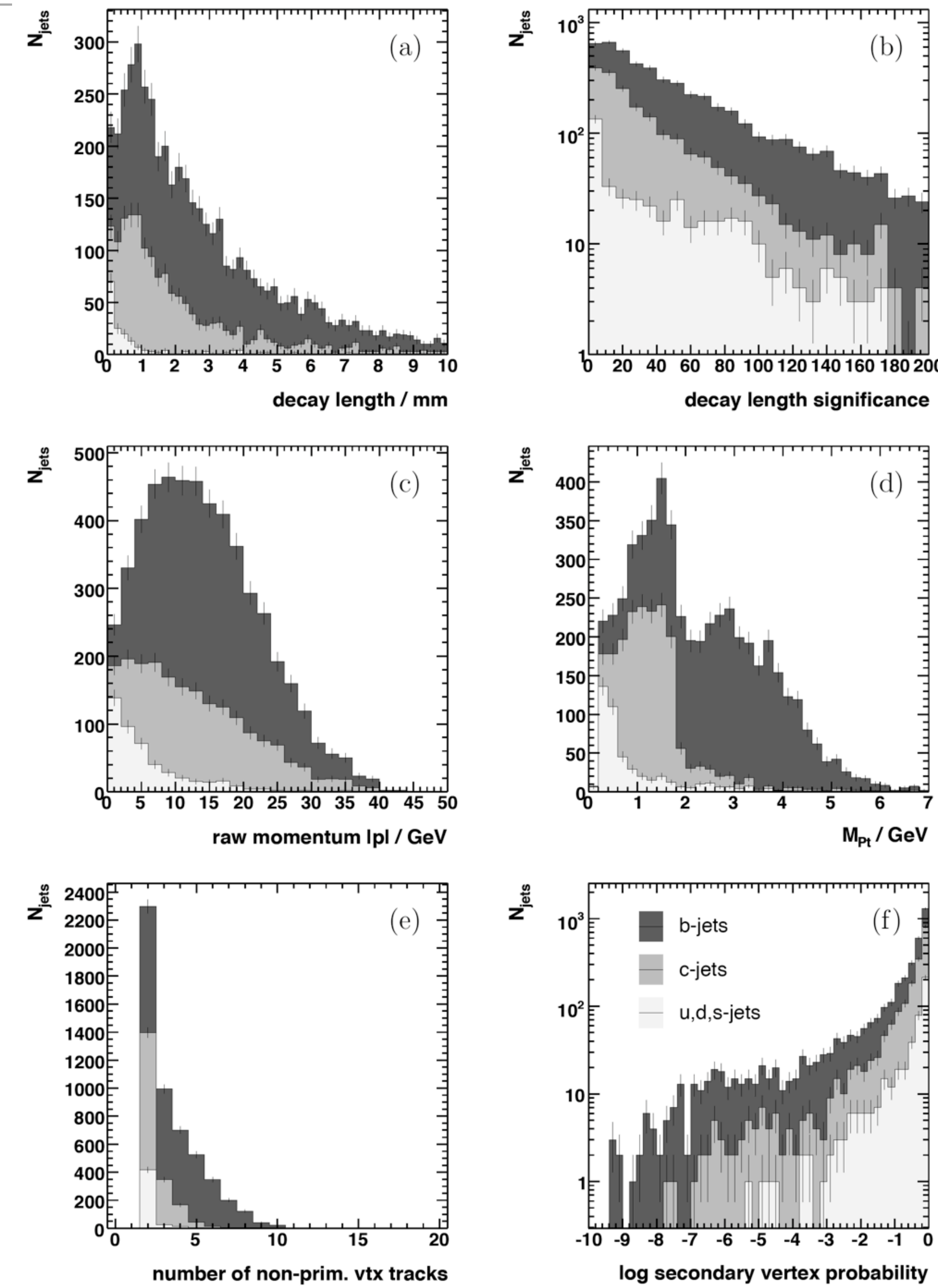
- The flavour tagging in the LCFIVertex package is based in a neural network approach to discriminate b-quark and c-quark jets from light-parton jets.
- 9 artificial neural networks (ANN) are used:
  - 3 **b-tag** ANNs: tag b-jets with 1, 2 or more than 2 vertices found in the jet;
  - 3 **c-tag** ANNs: tag c-jets with 1, 2 or more than 2 vertices found in the jet;
  - 3 **bc-tag** ANN: tag c-jets with 1, 2 or more than 2 vertices found in the jet with background composed of b-jets only.
- Neural network architecture:
  - Multilayer perceptron (NeuralNetTrainer processor);
  - N = 8 input discriminants;
  - 1 hidden layer with 2N-2 nodes;
  - Weights calculated with back propagation conjugate gradient algorithm.

Flavour tagging - neural network inputs

jets with 1 vertex

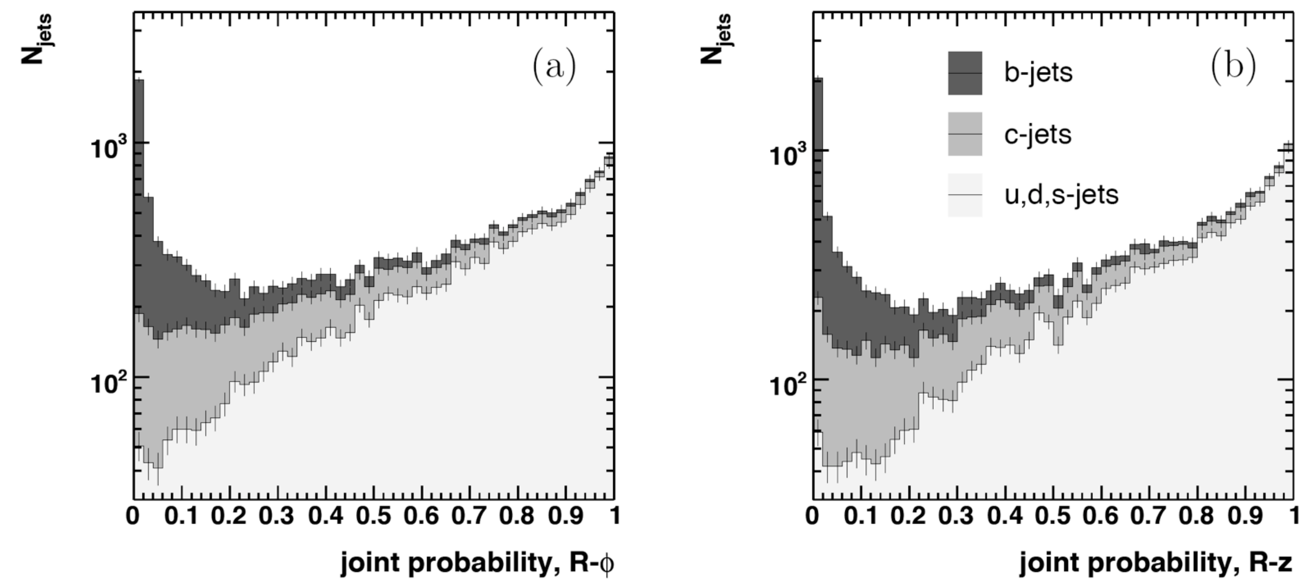


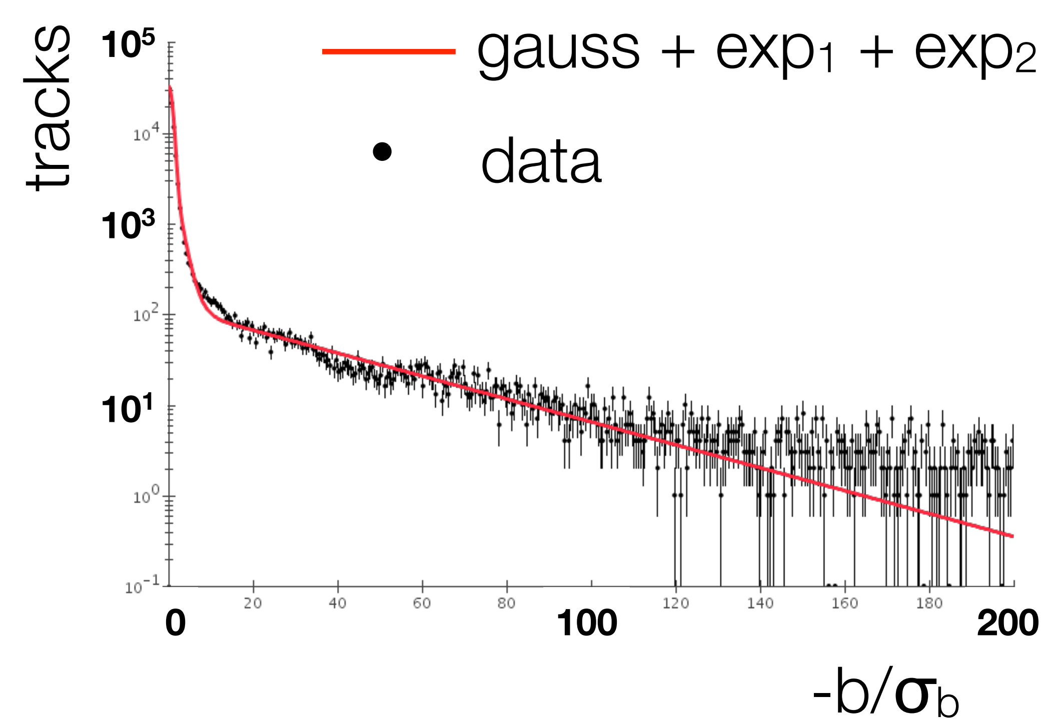
jets with >1 vertex



Flavour tagging - neural network inputs joint probabilities

- In any case there are 2 more inputs:
  - The joint probabilities in R-φ and R-z that all tracks in a jet come from the primary vertex.
  - The joint probabilities depend on parameters obtained by fitting the impact parameter significances.
  - Flavour tagging is very sensitive to the joint probabilities!
  - The parameters for the joint probabilities were obtained for the detector models in these studies using SignificanceFit in LCFIVertex.

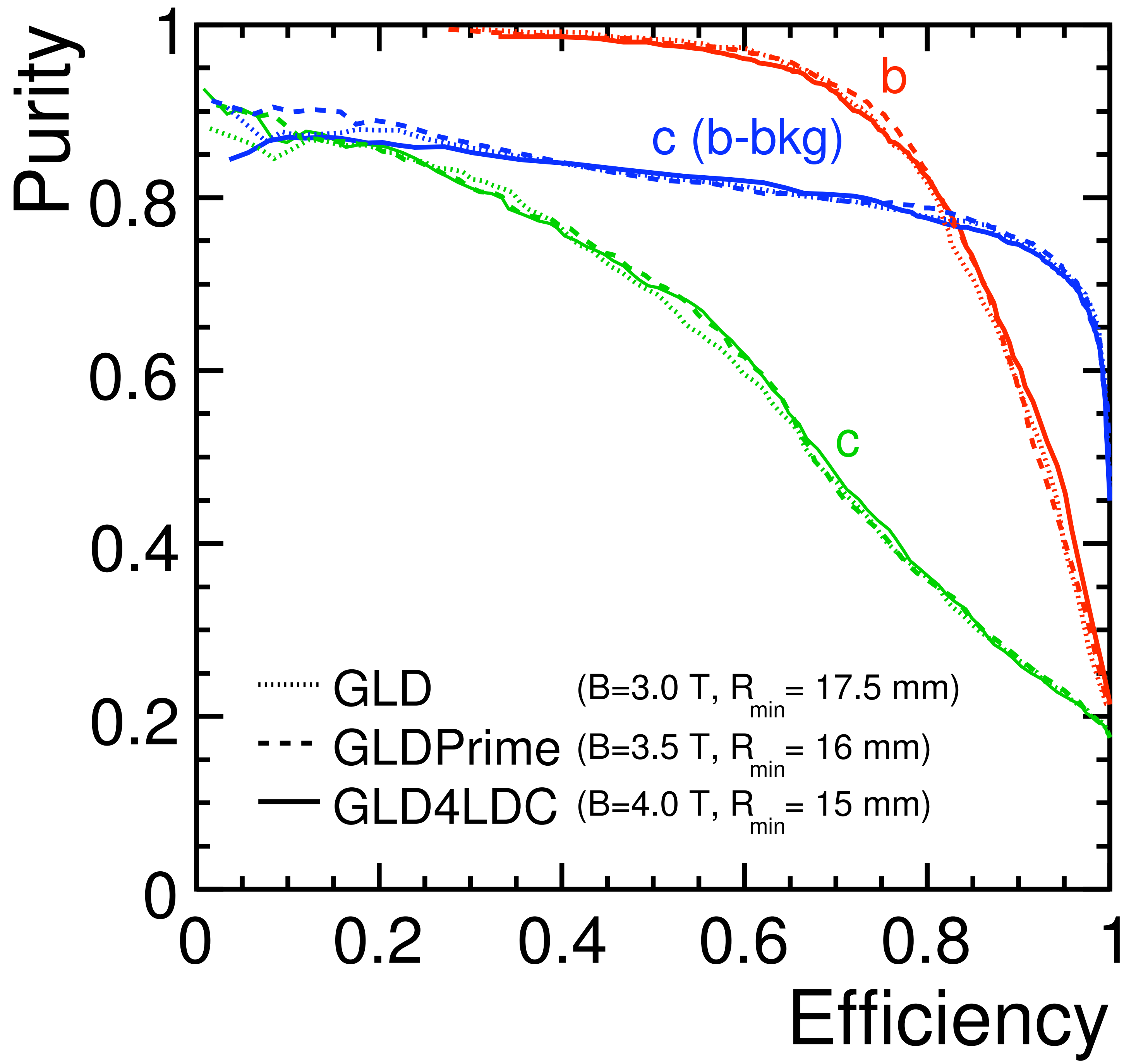




Flavour tagging - training neural networks

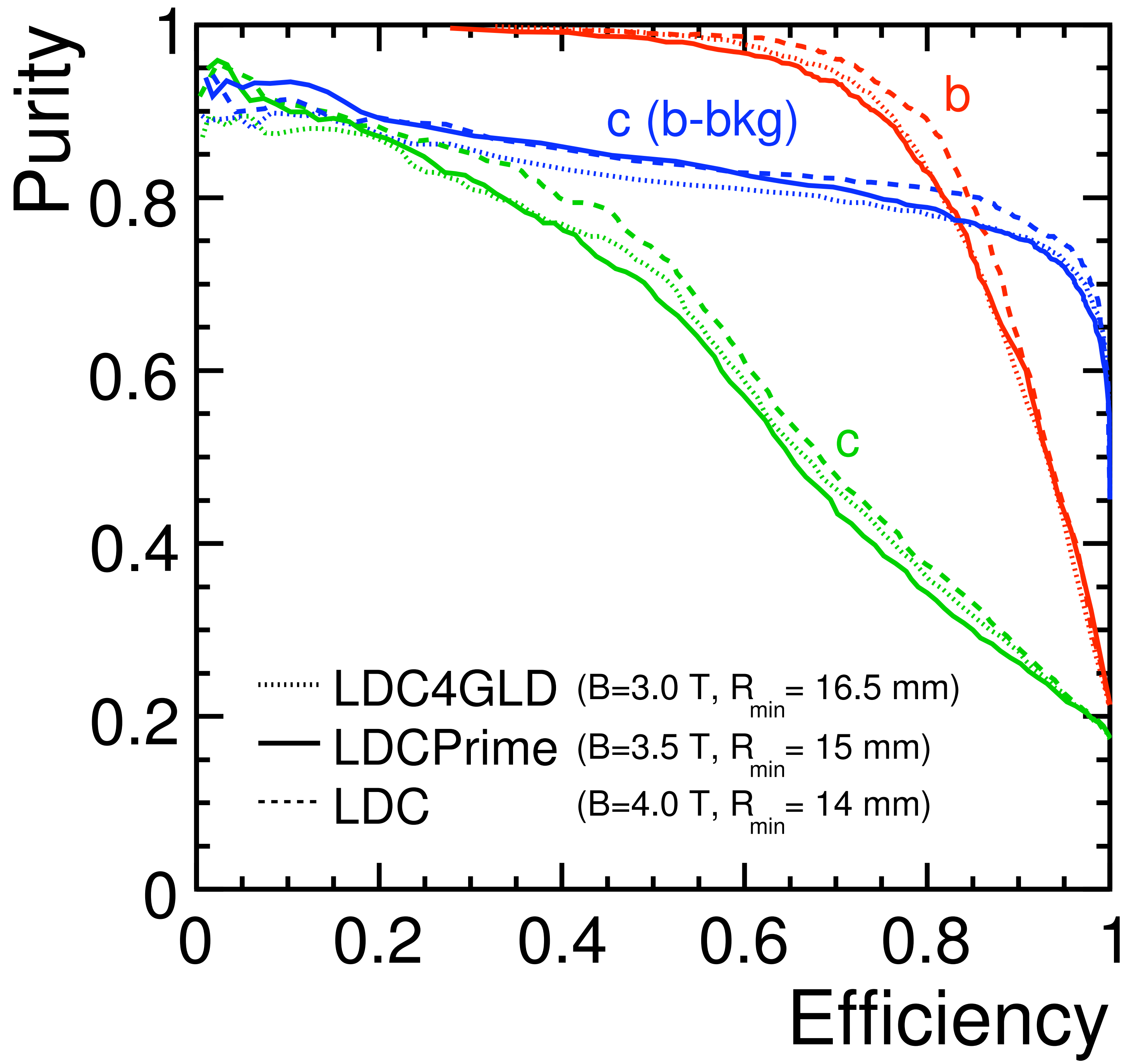
- Dedicated neural networks training for the detector models in these studies.
- Training samples (Pythia): $e^+e^- \rightarrow Z$ @ $\sqrt{s} = 91$ GeV
  - ~ 50k generated events $Z \rightarrow bb$
  - ~ 50k generated events $Z \rightarrow cc$
  - ~ 50k generated events $Z \rightarrow uu,dd,ss$
- Test samples (Pythia): $e^+e^- \rightarrow Z$ @ $\sqrt{s} = 91$ GeV:
  - ~ 10k generated events $Z \rightarrow qq$, follows Z branching ratios.
- Events were simulated with Mokka (at DESY) or Jupiter (at KEK) and fully reconstructed with MarlinReco, PandoraPFA and LCFIVertex.
  Final states were forced into 2 jets.
- NeuralNetTrainer processor of LCFIVertex package used.

Flavour tagging performance - GLD



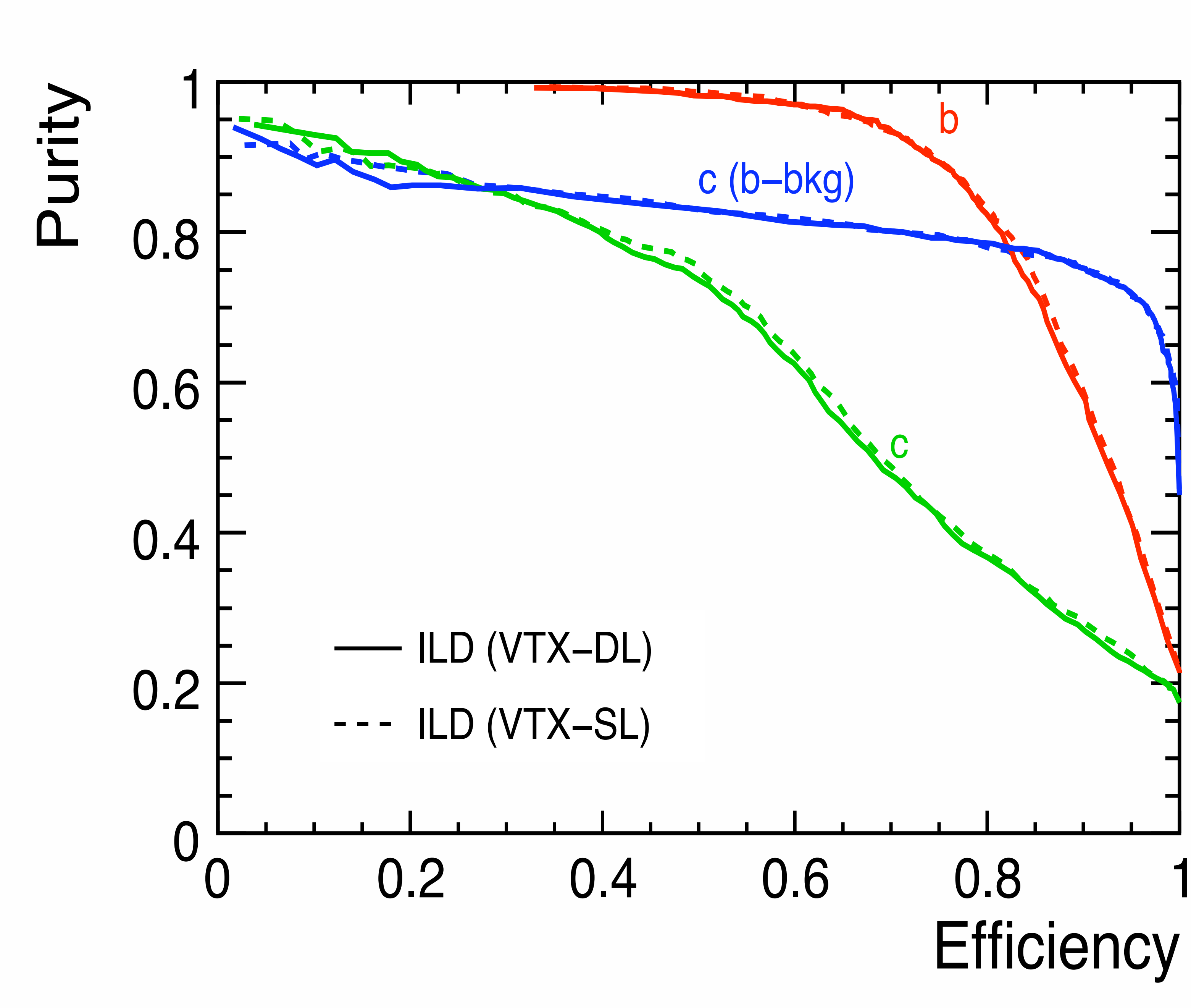
- All three GLD detector models show similar performances for flavour tagging, as expected since the differences in the impact parameter resolutions are not large.
- A slight preference for larger fields is observed.
- Estimated uncertainties ≤ 2%.

Flavour tagging performance - LDC



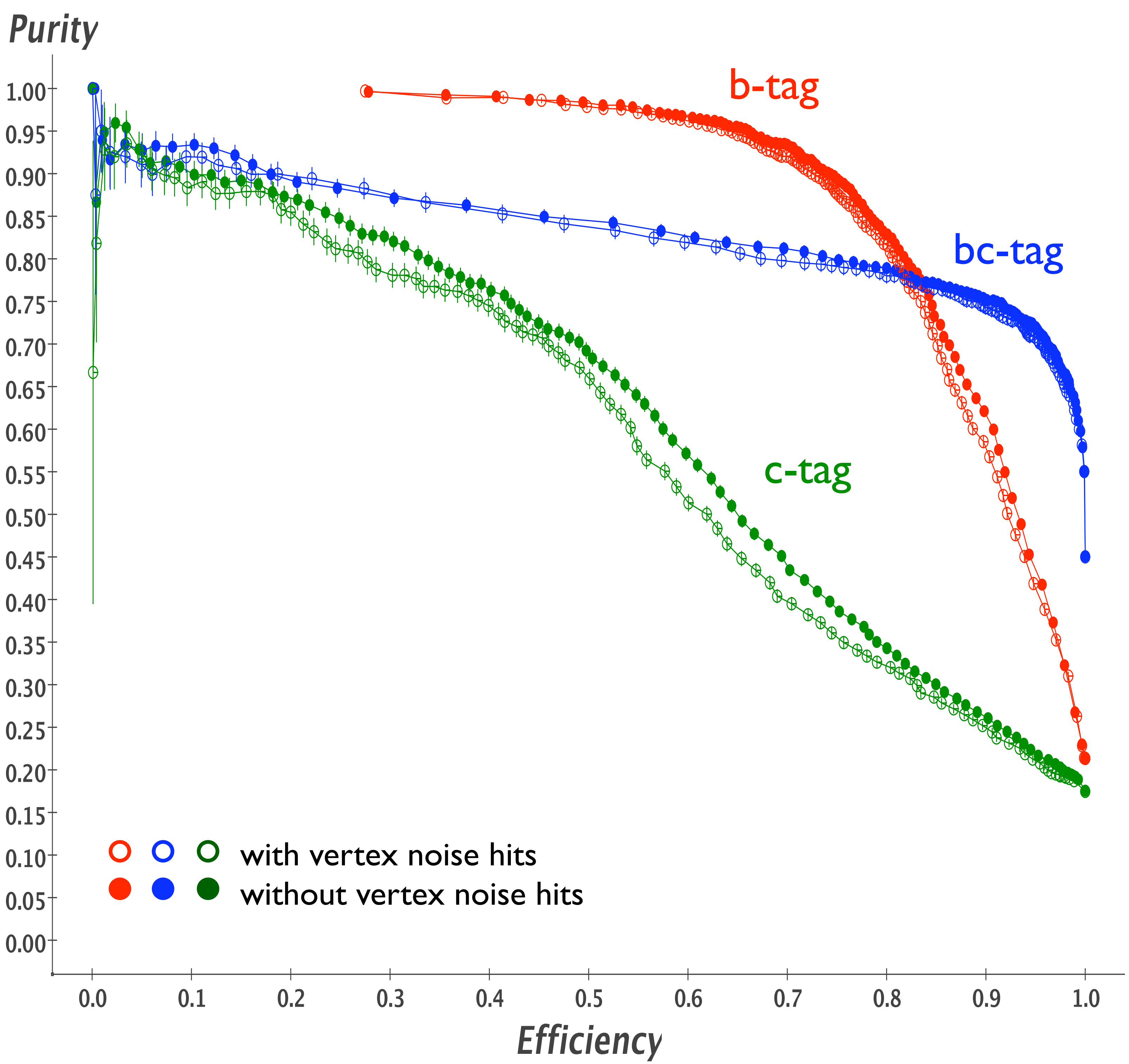
- All three LDC detector models show similar ≤4% performances for flavour tagging, with a preference for LDC (4T field).
- LDCPrime slightly worse than LDC4GLD but differences within errors.
- Estimated uncertainties ≤ 2%.

Flavour tagging performance - ILD



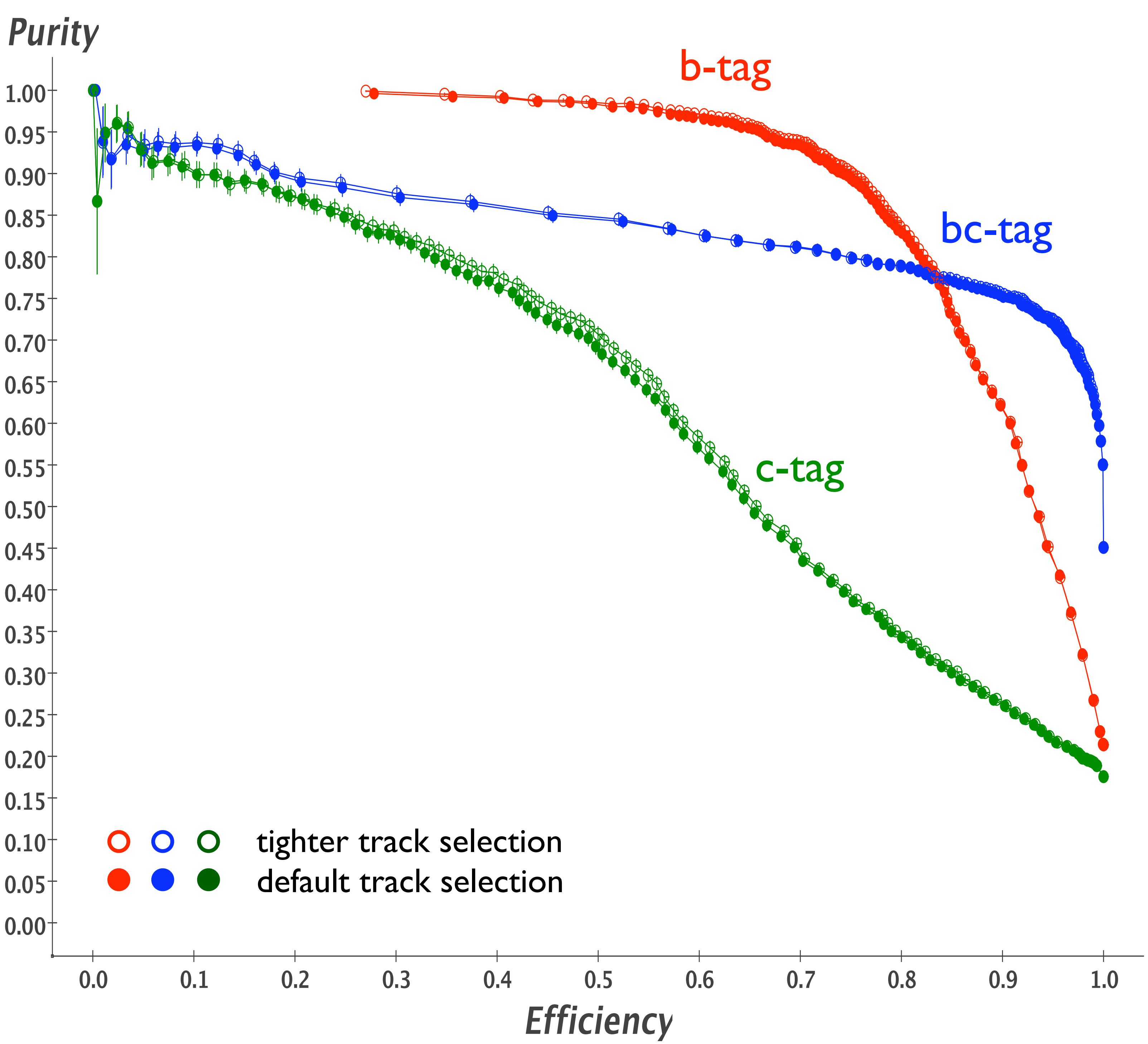
- Performance for ILD with a 3 double-layer vertex detector and with the optional vertex detector with 5 layers.
- Same neural networks of the baseline detector was used in the modified one. Input distributions were very similar.
- More studies needed for VTX-DL optimisation.
- Estimated uncertainties ≤ 2%.

Ongoing studies - backgrounds



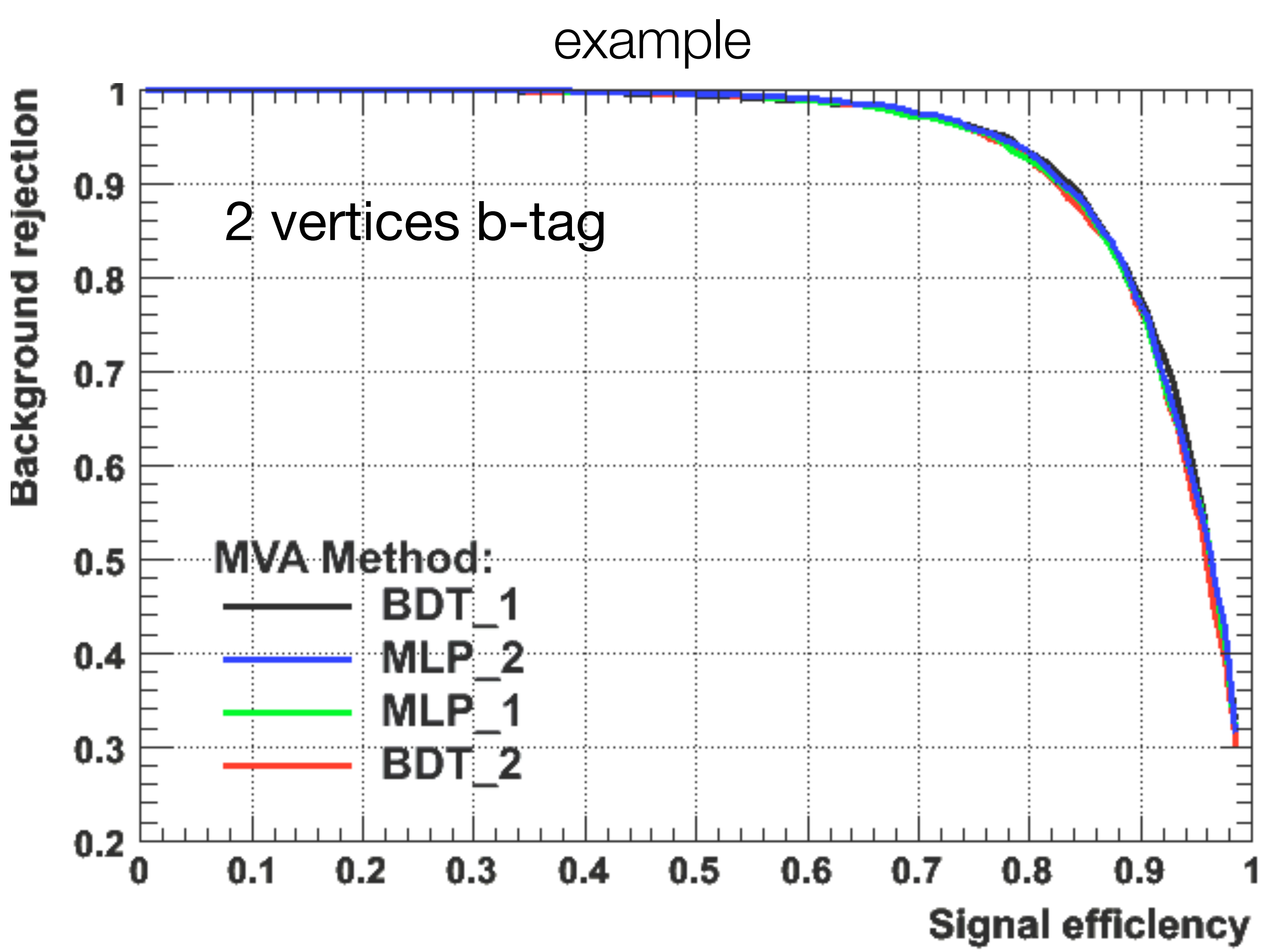
- LDCPrime_02Sc (VTX-SL)
- 'Salt & Pepper' hits.
- Low noise mode (~4x less than realistic background):
  - Hit densities (100 BX) from inner to outer layer: 100. 10. 4. 1. 1.
- No track pre-selection before PandoraPFA so far!
- Further studies needed!

Ongoing studies - LCFIVertex track selection



- LCFIVertex provides parameters for track selection in vertex reconstruction and flavour tag inputs.
- Studies to check flavour tagging performance with tighter tacks selection.
- Aim for suppression of background effects and improve performance.

Ongoing studies - other multivariate methods



- Other multivariate methods such as Boosted Decision Trees, etc could help improve the performance, also in the presence of background or higher energy jets.
- Linking the LCFIVertex to TMVA package* available in ROOT.
- To be available soon on CVS!

* http://tmva.sourceforge.net

To do’s

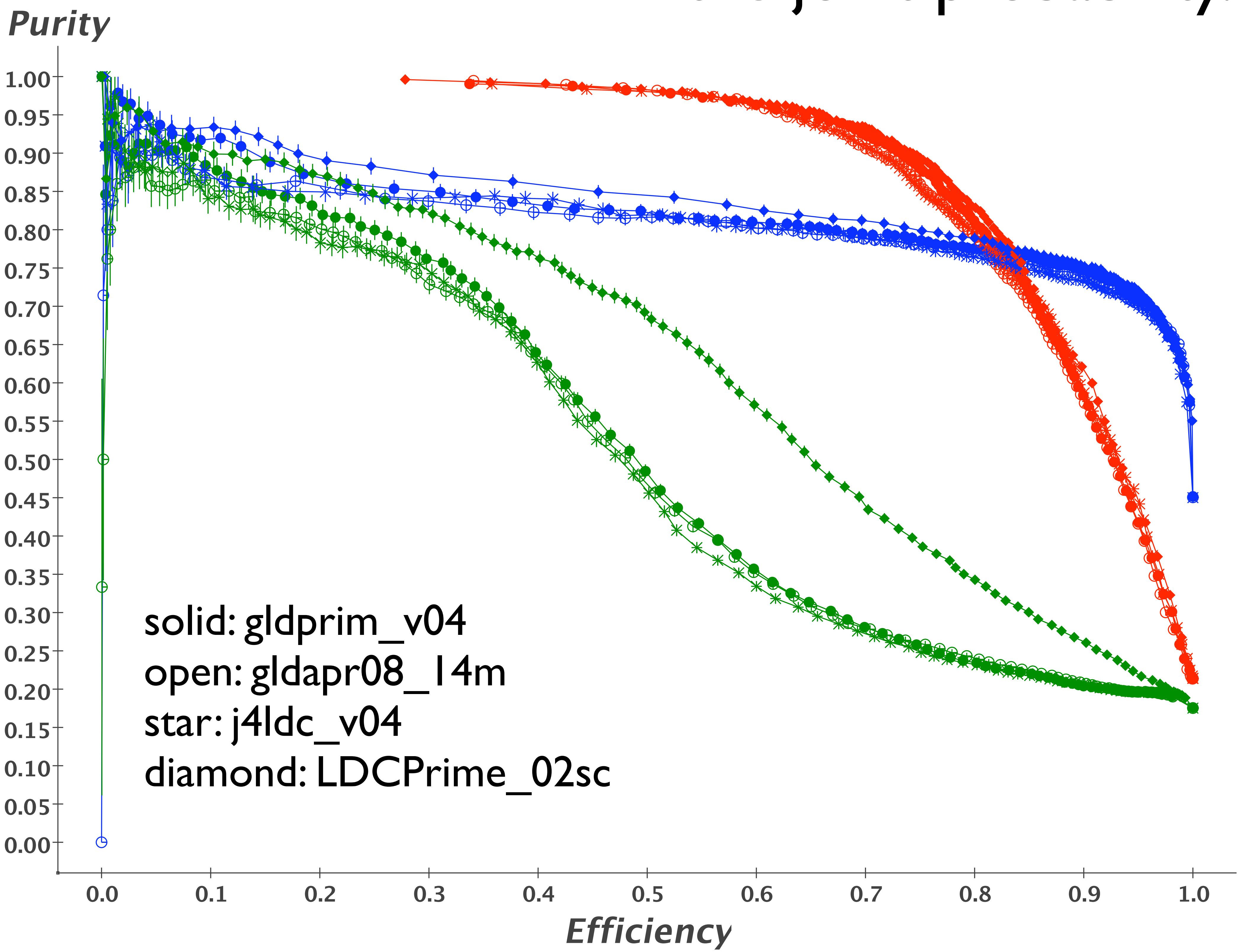
- More studies to be done:
    - **Impact of beam backgrounds in the flavour tagging performance;**
    - Optimisation of track selection and parameters for vertex reconstruction and for neural network input variables;
    - Further investigation double-layer *vs* single-layer geometries, in particular in the presence of backgrounds;
    - Other techniques for flavour tagging: Boosted Decision Trees etc. Processor linked to TMVA to be available soon in LCFIVertex;
    - Lepton identification (PFOID) from leptonic decays in heavy flavour jets;
    - Optimise flavour tagging of high-energy jets;

Summary

- The performance of the flavour tagging and its dependence on global parameters for different detector models within the GLD, LDC and ILD detector concepts were investigated.
- Parameters of the flavour tagging procedure in LCFIVertex optimised for each detector model.
- Similar flavour tagging performance obtained for all detector models.
- Slight preference for large B-fields is observed.
- Many studies still need to be done, most important...
- **A complete investigation of background effects in flavour tagging performance must be the priority!**

extra slides

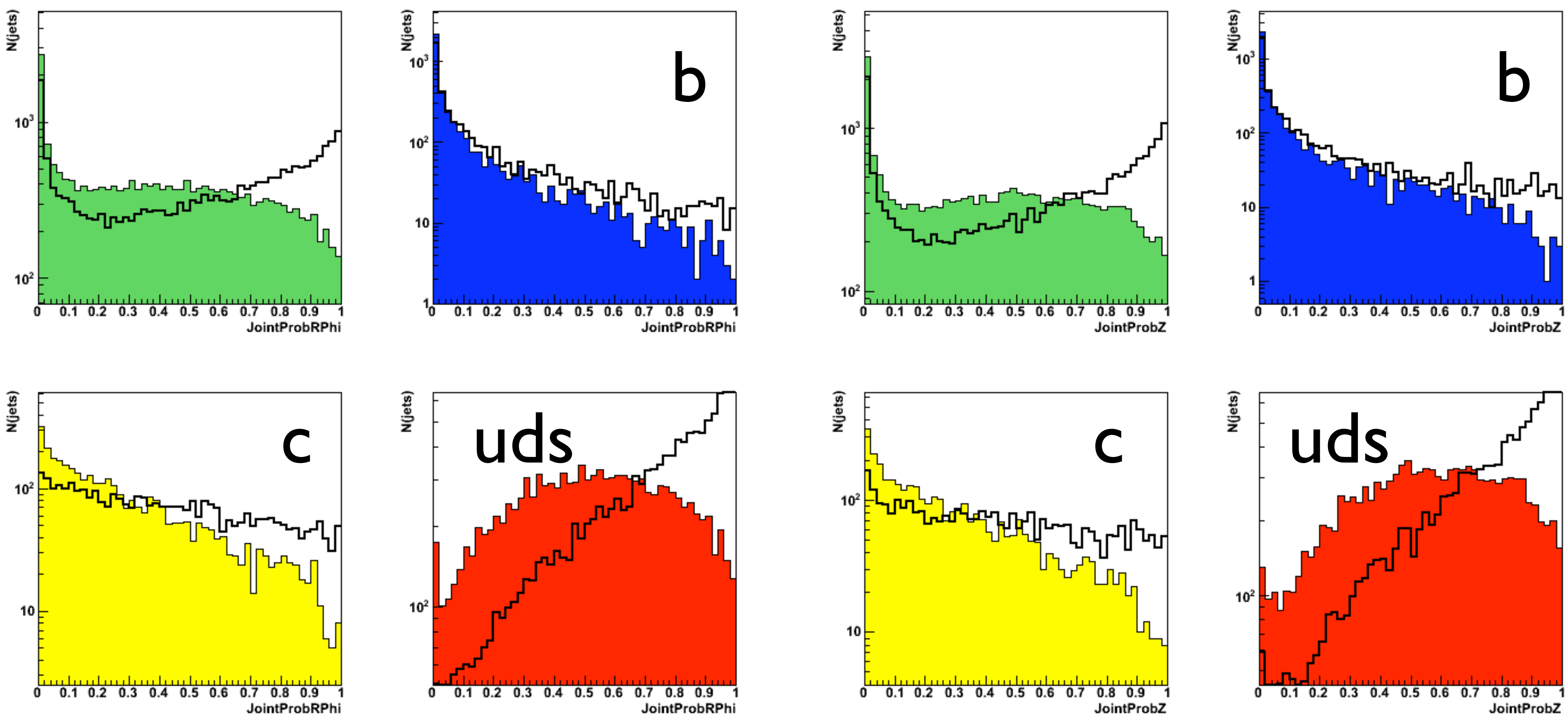
Using LDC' neural nets and parameters for the joint probability...



Flavour tag inputs

LDCPrime_02Sc (line) x gldprim_v04 (histogram)

JointProbRPhi JointProbZ

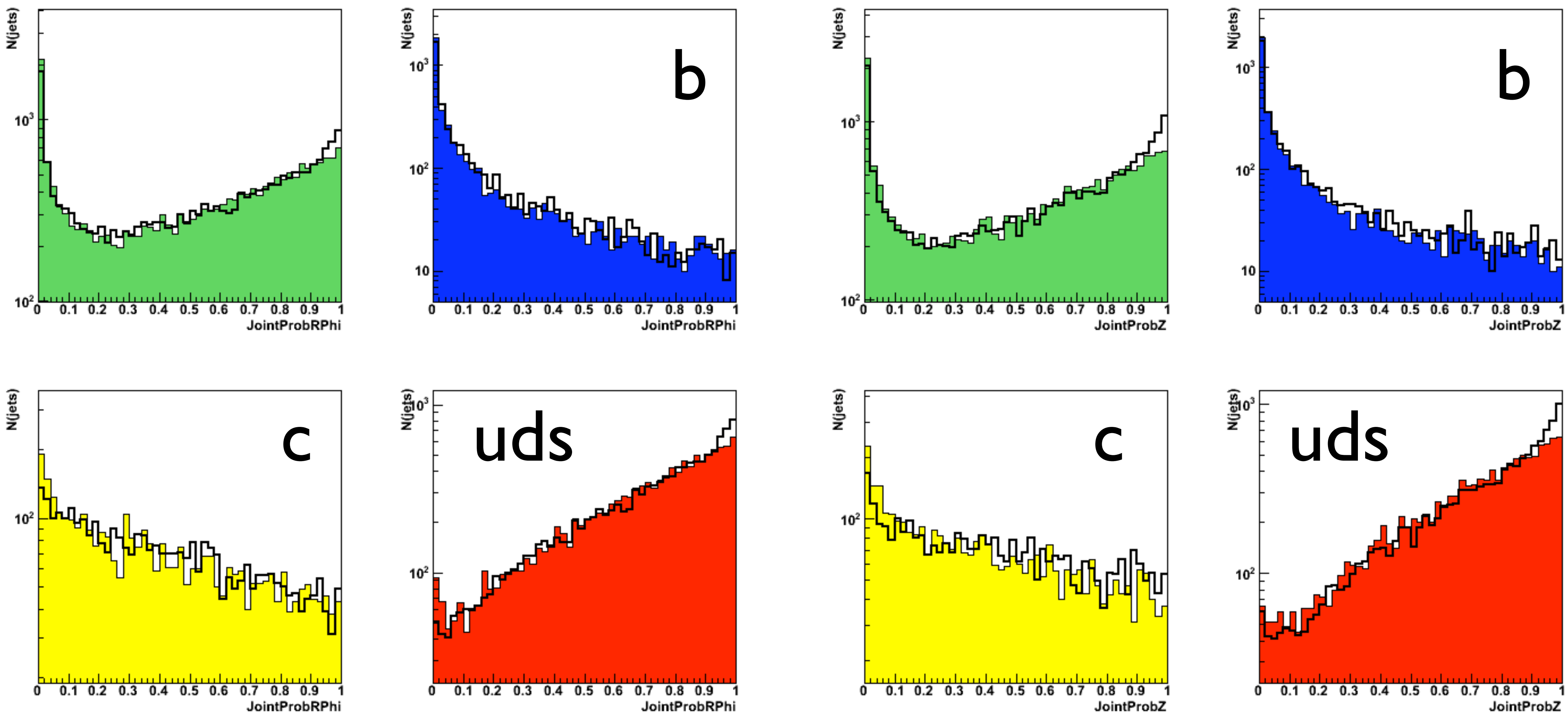


Flavour tag inputs
(gldprim_v04 w/ GLD JointProb parameters)

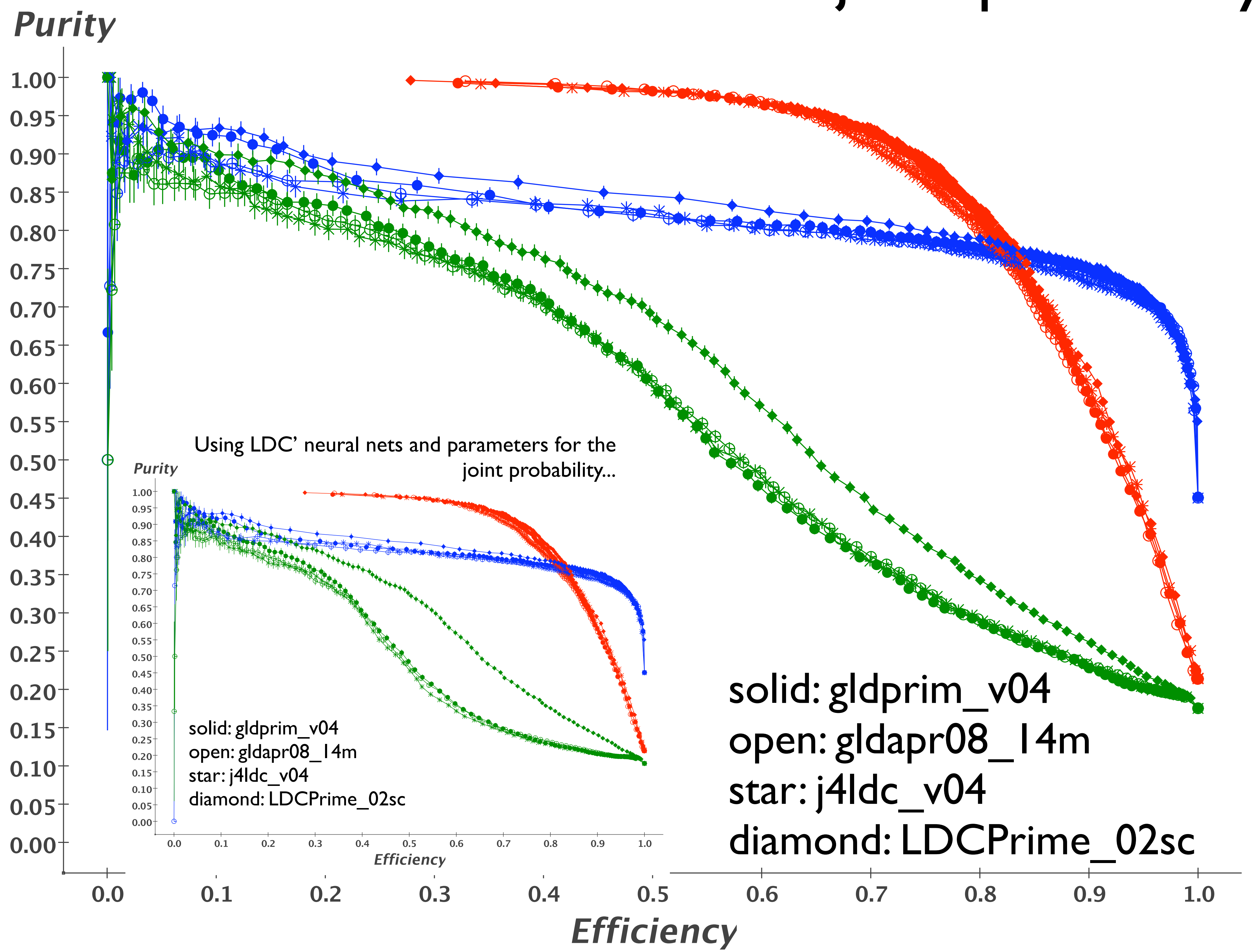
LDCPrime_02Sc (line) x gldprim_v04 (histogram)

JointProbRPhi

JointProbZ



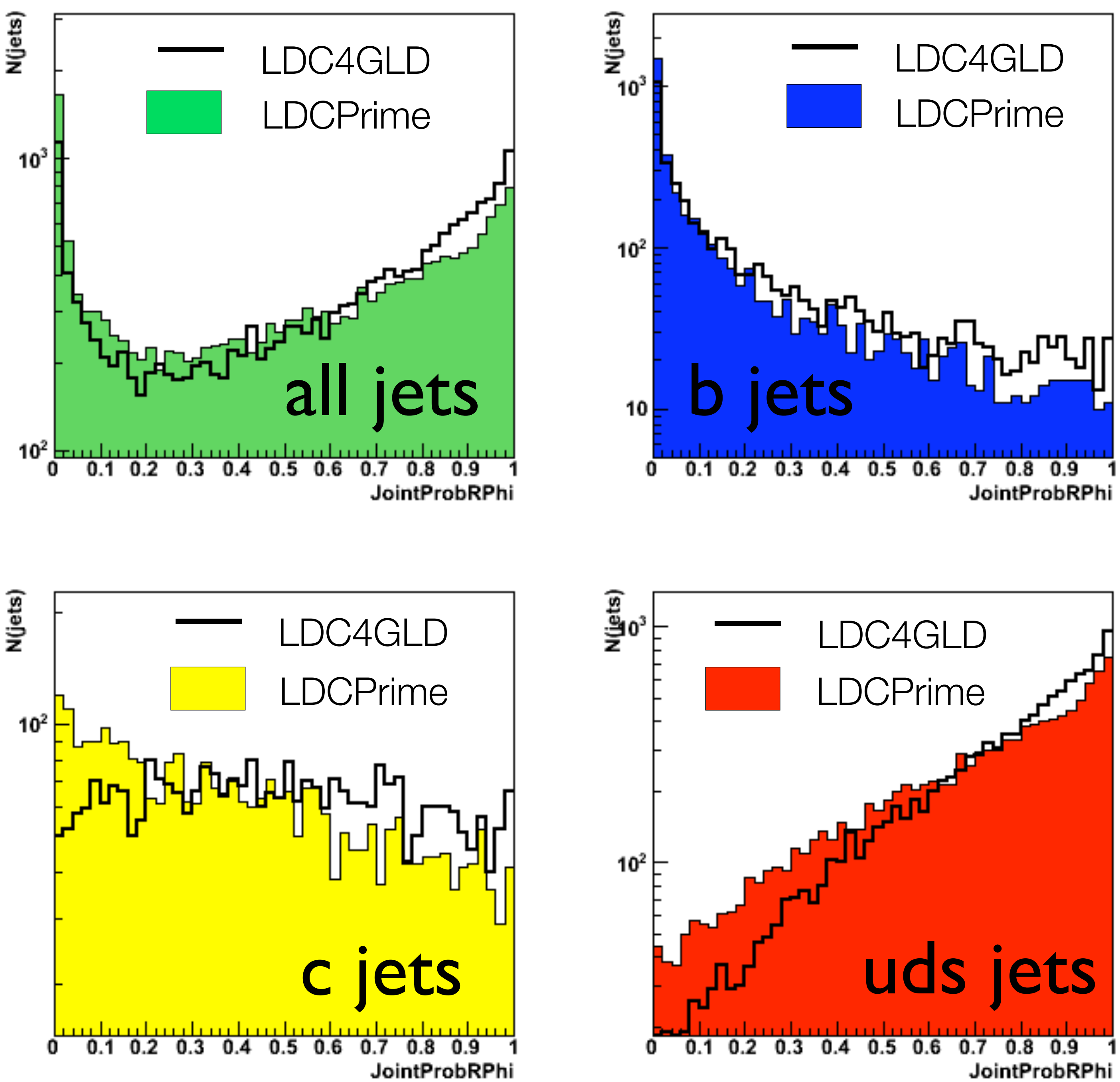
Using LDC' neural nets and GLD parameters for the joint probability...



solid: gldprim_v04
open: gldapr08_14m
star: j4ldc_v04
diamond: LDCPrime_02sc

Flavour tagging performance - LDC

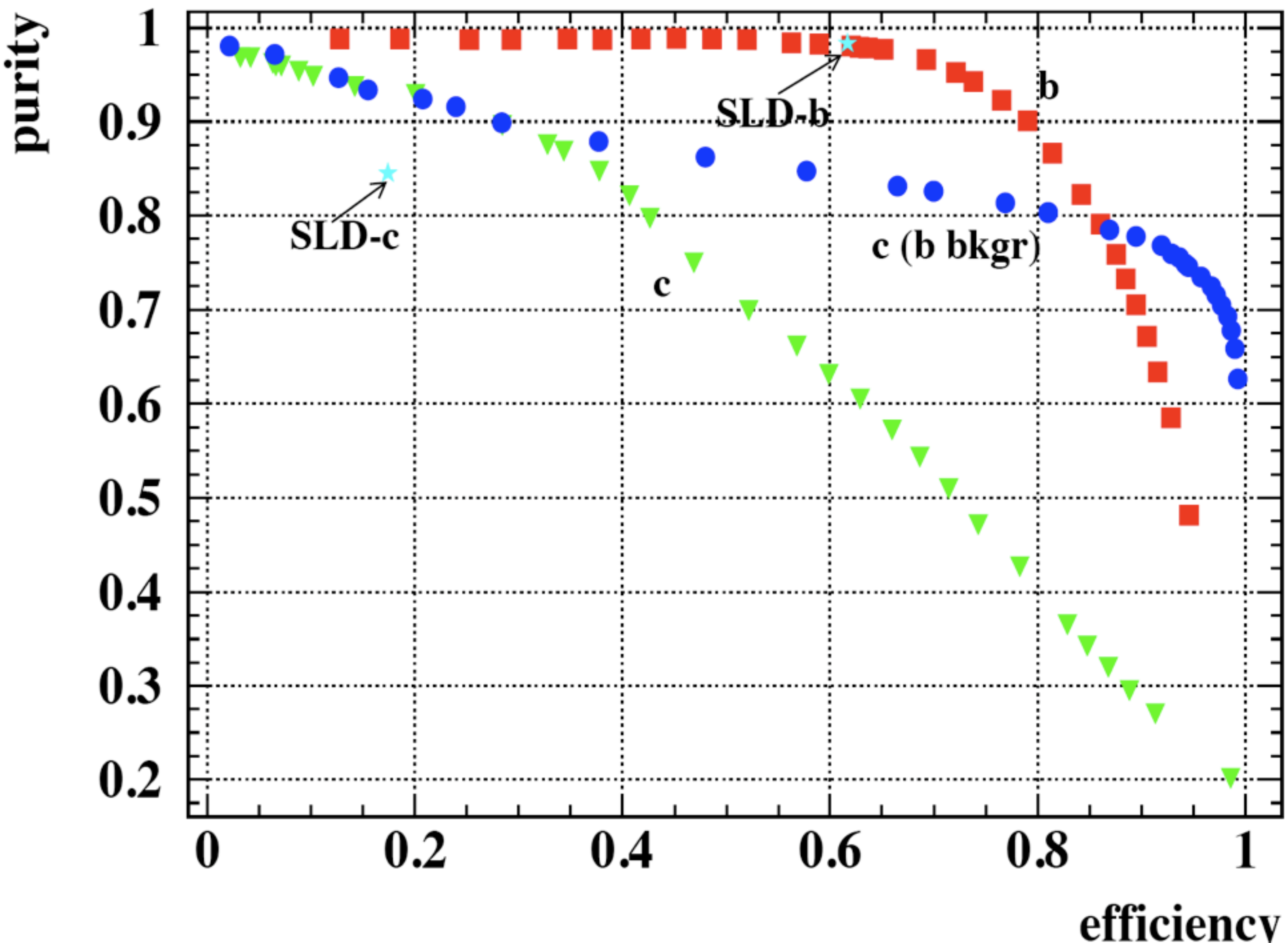
joint probability R-φ



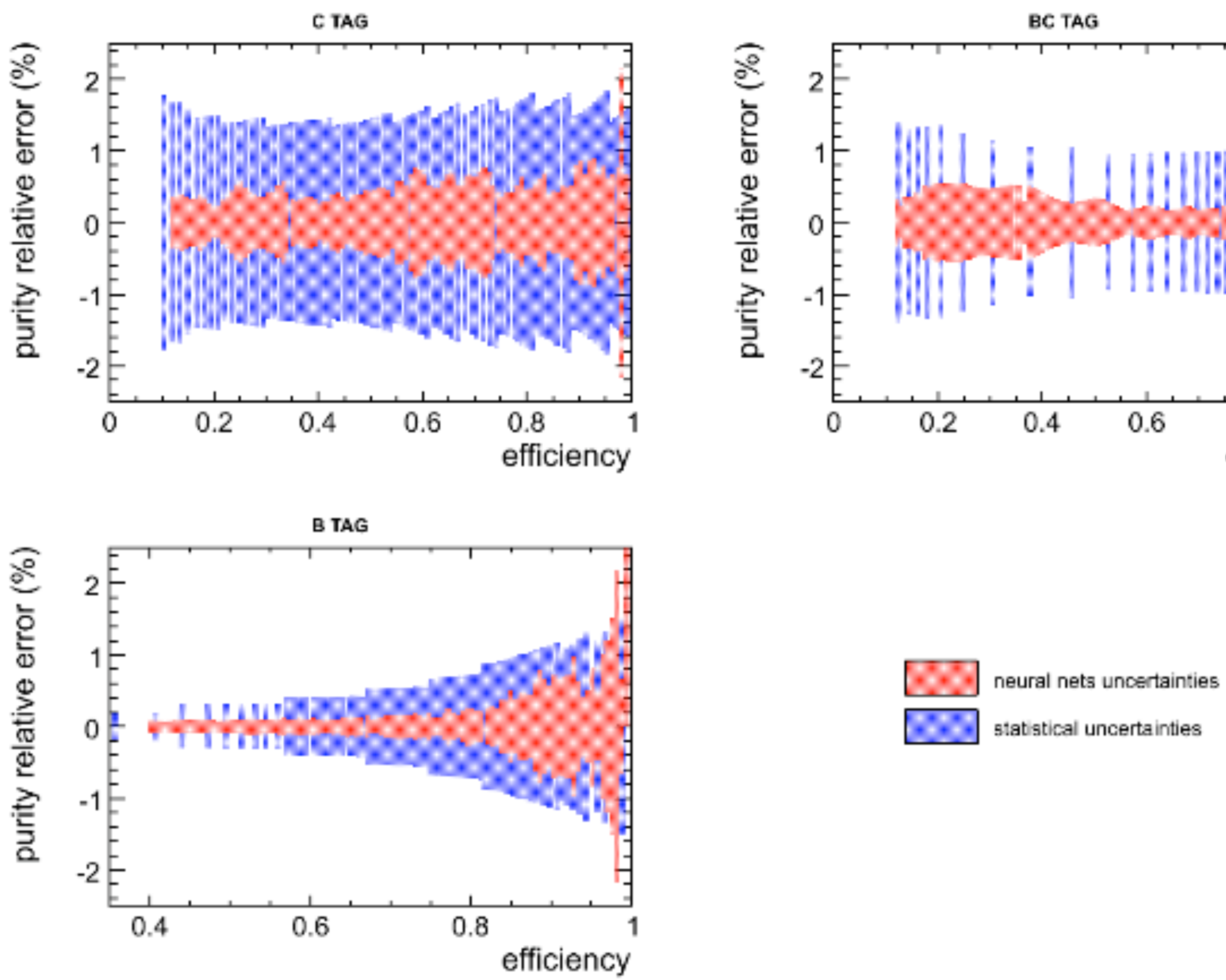
- Besides the uncertainties other factors may contribute to unexpected differences.
- In the LDC case, as expected the joint probabilities distributions are slightly better for LDCPrime compared to The joint probabilities

Other old detectors - Tesla & SLD

source: LCFI proposal



Estimative of uncertainties

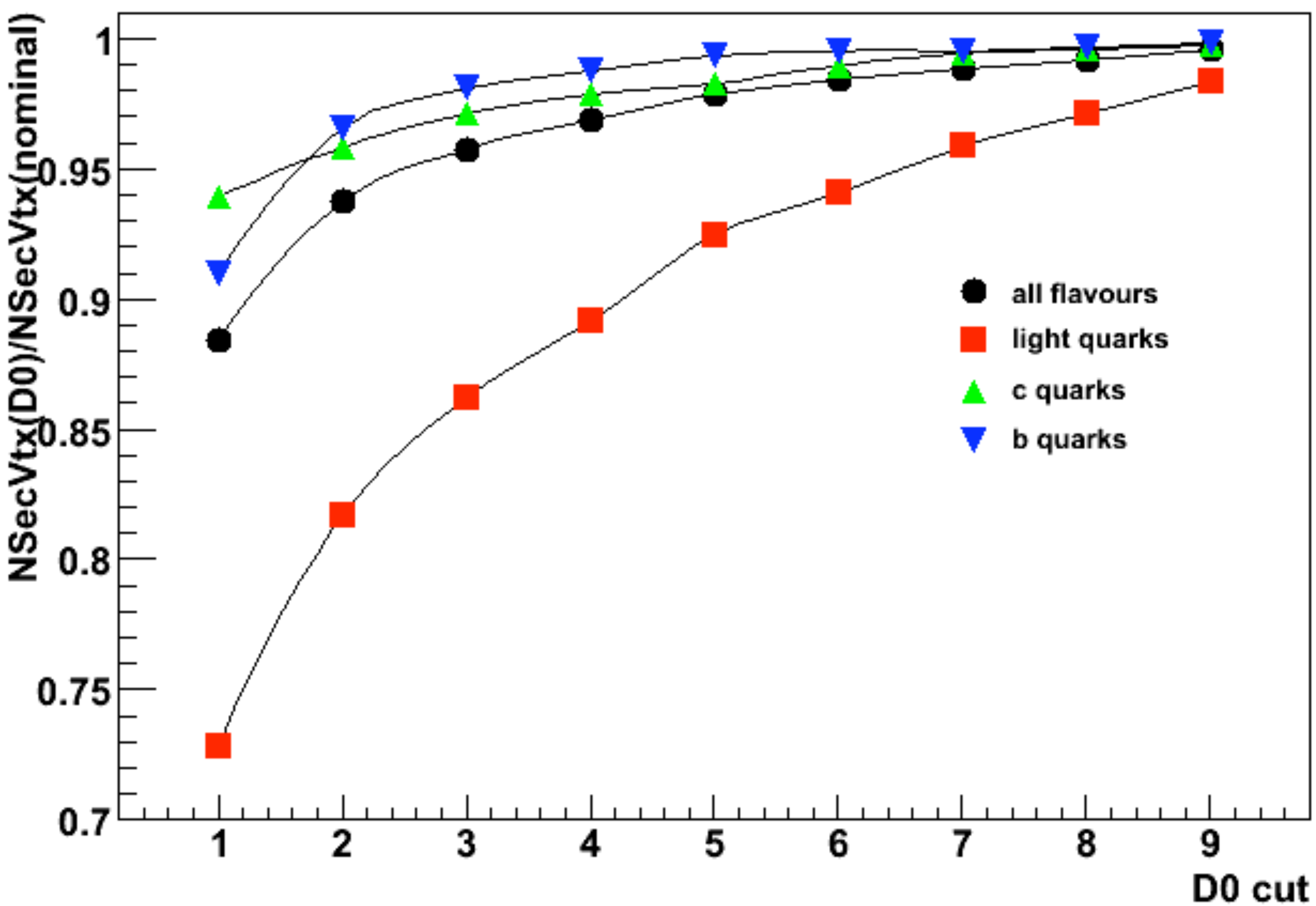


LCFVIVertex: Default track selection parameters

Description	xml parameter names	Code default	ipfit.xml	zvres.xml	fti.xml
Cut on χ^2/ndf of track fit	a1_Chi2OverDOFEnable a2_Chi2OverDOFCutLowerThan a3_Chi2OverDOFCutValue	10	10 X	10 X	10 X
Cut on d0 (Rϕ impact parameter)	b1_D0Enable b2_D0CutLowerThan b3_D0CutValue	20	50 ✓ (mm)	10 ✓ (mm)	20 ✓ (mm)
Cut on d0 error	c1_D0ErrEnable c2_D0ErrCutLowerThan c3_D0ErrCutValue	0.25	0.025 X (mm)	0.25 ✓ (mm)	0.025 X (mm)
Cut on z impact parameter	d1_Z0Enable d2_Z0CutLowerThan d3_Z0CutValue	20	50 ✓ (mm)	20 ✓ (mm)	20 ✓ (mm)
Cut on error on z imp param	e1_Z0ErrEnable e2_Z0ErrCutLowerThan e3_Z0ErrCutValue	0.25	0.025 X (mm)	0.025 X (mm)	0.025 X (mm)
Cut on pT of track	f1_PTEnable f2_PTCutLowerThan f3_PTCutValue	0.1	0.1 X (GeV/c)	0.1 ✓ (GeV/c)	0.1 ✓ (GeV/c)
cut on Ks, Λ decay tracks	h1_MCPIDEnable h2_CutPIDS h3_MonteCarloLCRelationCollection	0	X	✓ +- 310 +- 3122	✓ +- 310 +- 3122

X: disabled; ✓: enabled

Track selection - remove fake vertices



Using GLD neural nets and GLD parameters for the joint probability...