Flavour tagging studies with the LCFIVertex package

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Outline

- Brief introduction LCFIVertex package
- LCFIVertex parameters tuning
- Impact of backgrounds in flavour tagging
- Flavour tagging LDC x GLD → ILD_00
- Summary & Conclusions

LCFIVertex package

- The LCFIVertex package is a software package that uses the vertex-detector information for high-level event reconstruction at the ILC. It provides:
  - The ZVTOP vertex finder;
  - A flavour tagging algorithm based on neural networks approach;
    - Vertex charge determination for b- and c-jets.
- The code is based on Marlin and uses LCIO for input and output.
- The code and the networks are available from a CVS repository under *marlinreco* and *tagnet*, respectively: http://www-zeuthen.desy.de/lc-cgi-bin/cvsweb.cgi

LCFIVertex parameters tuning

- The aim of these studies is to extract an optimal set of the LCFIVertex parameters for flavour tagging considering more recent and more realistic detector model and reconstruction software:
  - Parameters for joint probability;
  - Neural networks;
  - Track selection for vertex reconstruction and flavour tag inputs.

Samples

- **Monte Carlo sample**:
  - $e^+e^- \rightarrow Z \rightarrow qq$, $\sqrt{s}$ = 91.2 GeV;
  - 10000 events;
  - Detector model: LDCPrime_02Sc.
- **Reconstruction**:
  - ilcsoft v01-03-06-p02; LCFIVertex HEAD;
  - tracking: FullLDCTracking;
  - clustering + particle flow: PandoraPFA;
  - jets: Satoru jet finder, durhamnjet, njet = 2;
  - realistic V0 + γ conversion, ConversionTagger processor

Parameters for joint probability

- Joint probability is the probability that a track in a jet comes from the primary vertex.
- The parameters used in the joint probability are obtained by fitting the negative impact parameters in RΦ and Z to a gaussian+exponential+exponential function. The SignificanceFit processor is used.
- The present default set of parameters for the joint probabilities in LCFIVertex were obtained with SGV.

Parameters for joint probability
SignificanceFit processor (requires JAIDA)

default - SGV

```
PARAMETERS FOR RPHI Joint Probability
 1.01313412
 0.0246350896
 0.102197811
 0.0411203019
 0.0157710761
PARAMETERS FOR Z Joint Probability
 1.01629865
 0.0271386635
 0.0948112309
 0.0410759225
 0.0148685882
```

LDCPrime_02Sc

```
PARAMETERS FOR RPHI Joint Probability
 0.843068
 0.364774
 0.619891
 0.150243
 0.0290308
PARAMETERS FOR Z Joint Probability
 0.910629
 0.305746
 0.422501
 0.139363
 0.028365
```

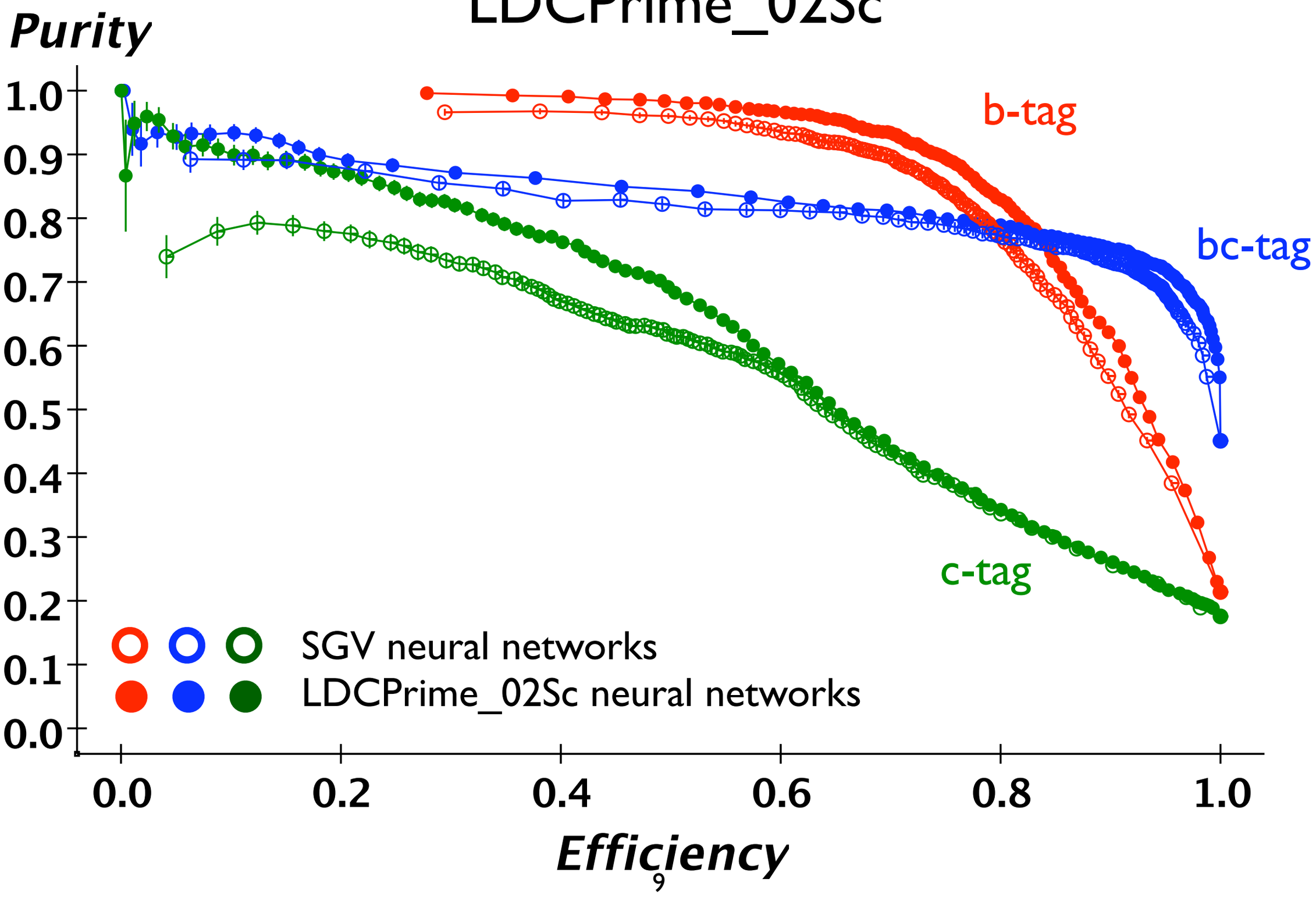
Marlin steering: FlavourTagInputsProcessor

```
<!--Standard deviations of the impact parameters in RPhi plane-->
<parameter name="JProbResolutionParameterRphi" type="FloatVec">
   0.843068 0.364774 0.619891 0.150243 0.0290308  </parameter>
<!--Standard deviations of the impact parameters in Z direction-->
<parameter name="JProbResolutionParameterZ"    type="FloatVec">
   0.910629 0.305746 0.422501 0.139363 0.028365   </parameter>
```

Neural networks training

- Flavour tagging uses 9 neural networks for the b-, c- and bc-tag each for the cases when 1 vertex, 2 vertices or more than 3 vertices are found.
- Samples (LDCPrime_02Sc, ilcsoft 01-03-06-p02):
  - 49000 events $Z \rightarrow bb$
  - 49000 events $Z \rightarrow cc$
  - 49000 events $Z \rightarrow uds$
- NeuralNetTrainer processor used.
- Durham_2Jets collection as input.
- Present LCFIVertex neural networks were trained using samples simulated with SGV.

Neural networks training



LCFIVertex parameters tuning

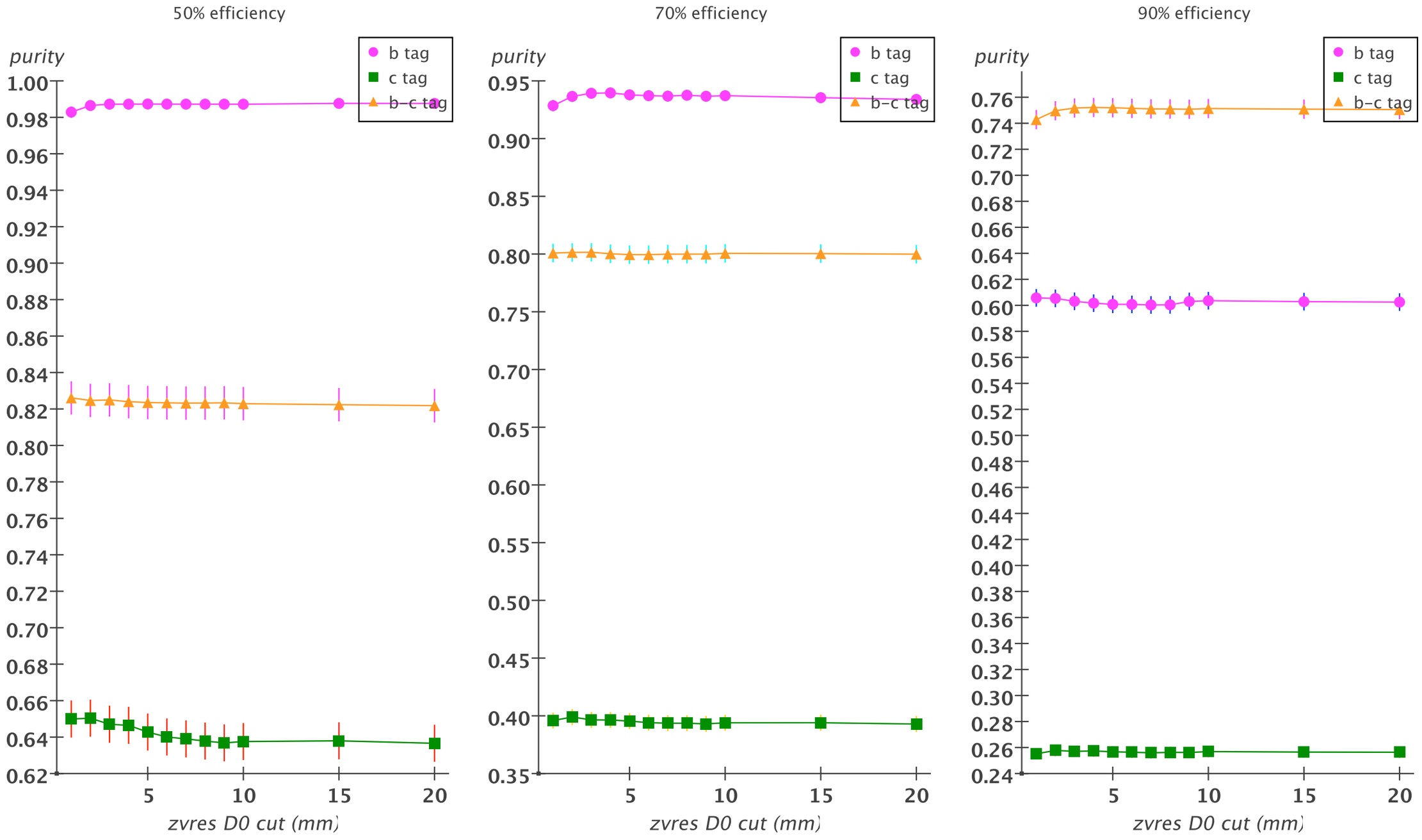
Track selection parameters

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	✓	✓

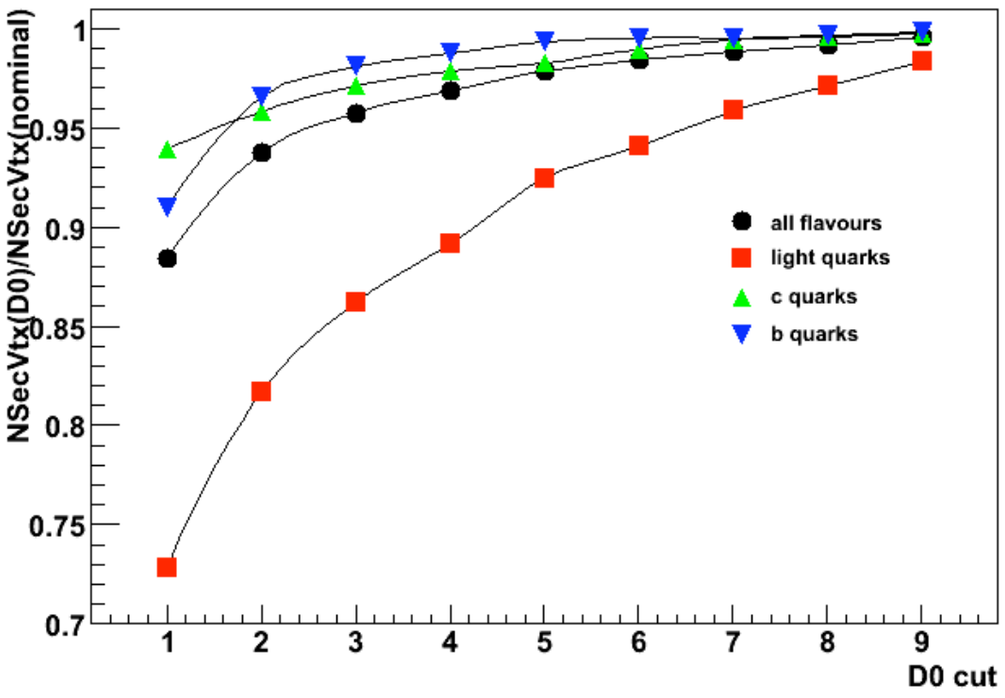
ConversionTagger is used

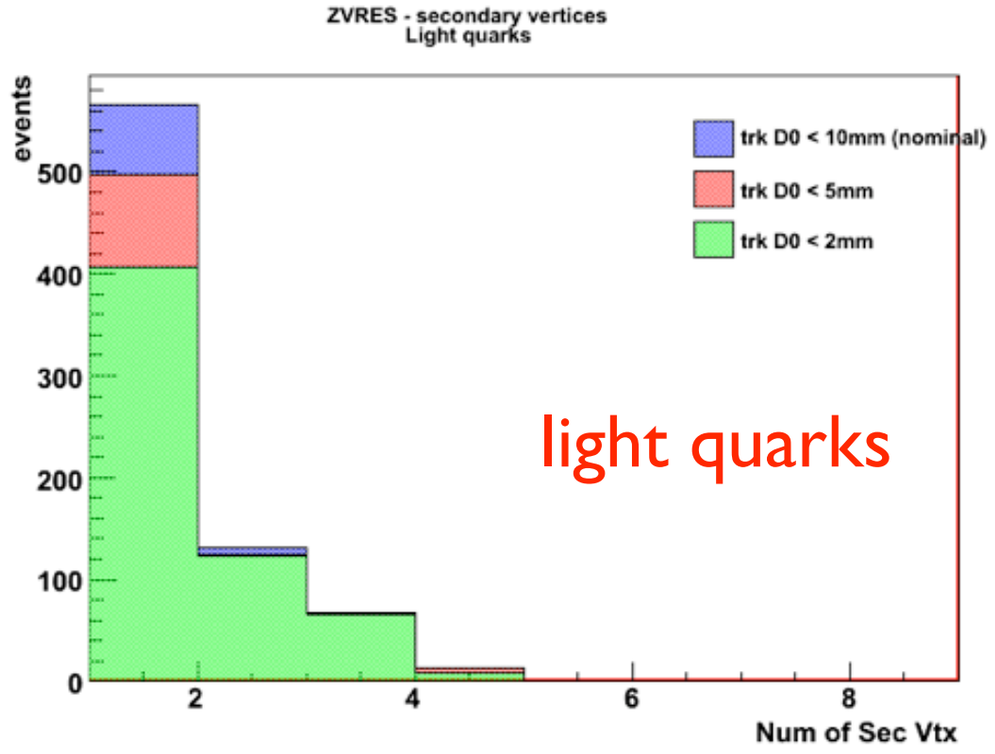
X: disabled; ✓: enabled

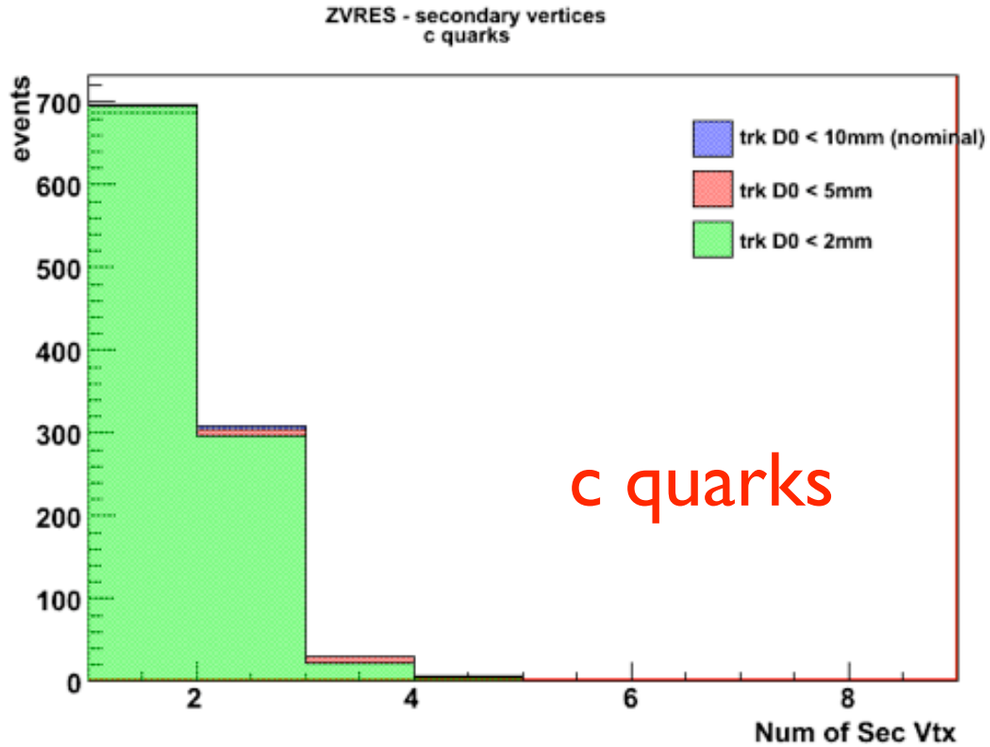
ZVRES: flavour tag purity as a function of the d0 of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: 10mm

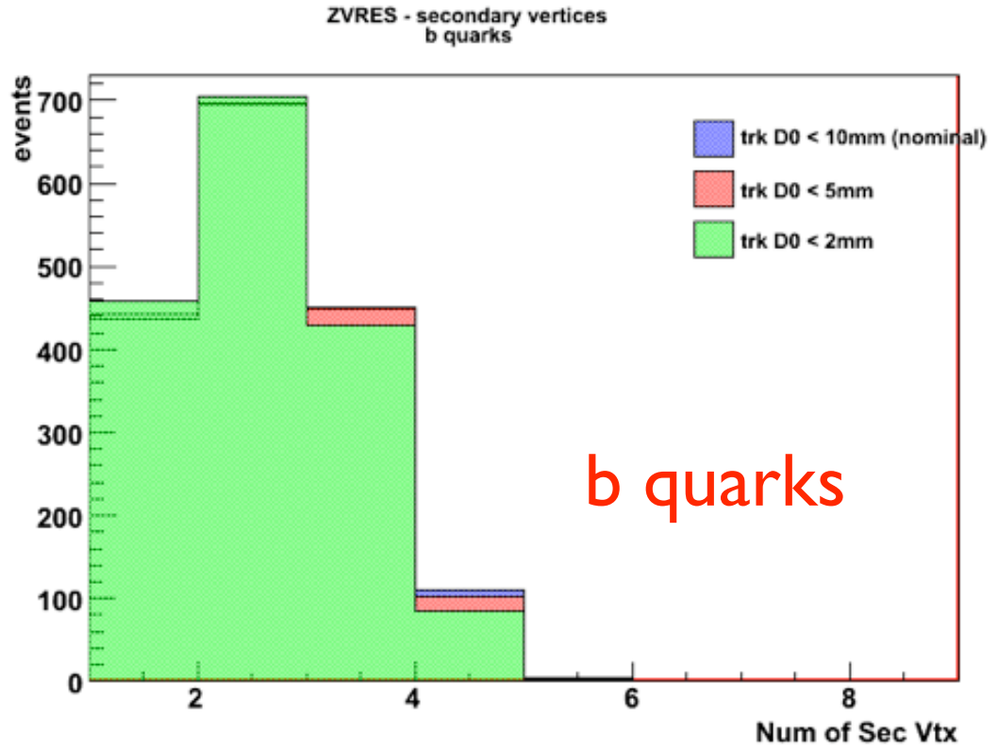


ZVRES secondary vertices (d0 cut)









LCFIVertex parameters tuning

Preliminary

IPFIT track selection:

- chi2/ndf < 5;
- d0 < 20mm;
- d0 error: no cut;
- z0 < 20mm;
- z0 error: nocut;
- p_T > 0.1 GeV;

ZVRES track selection:

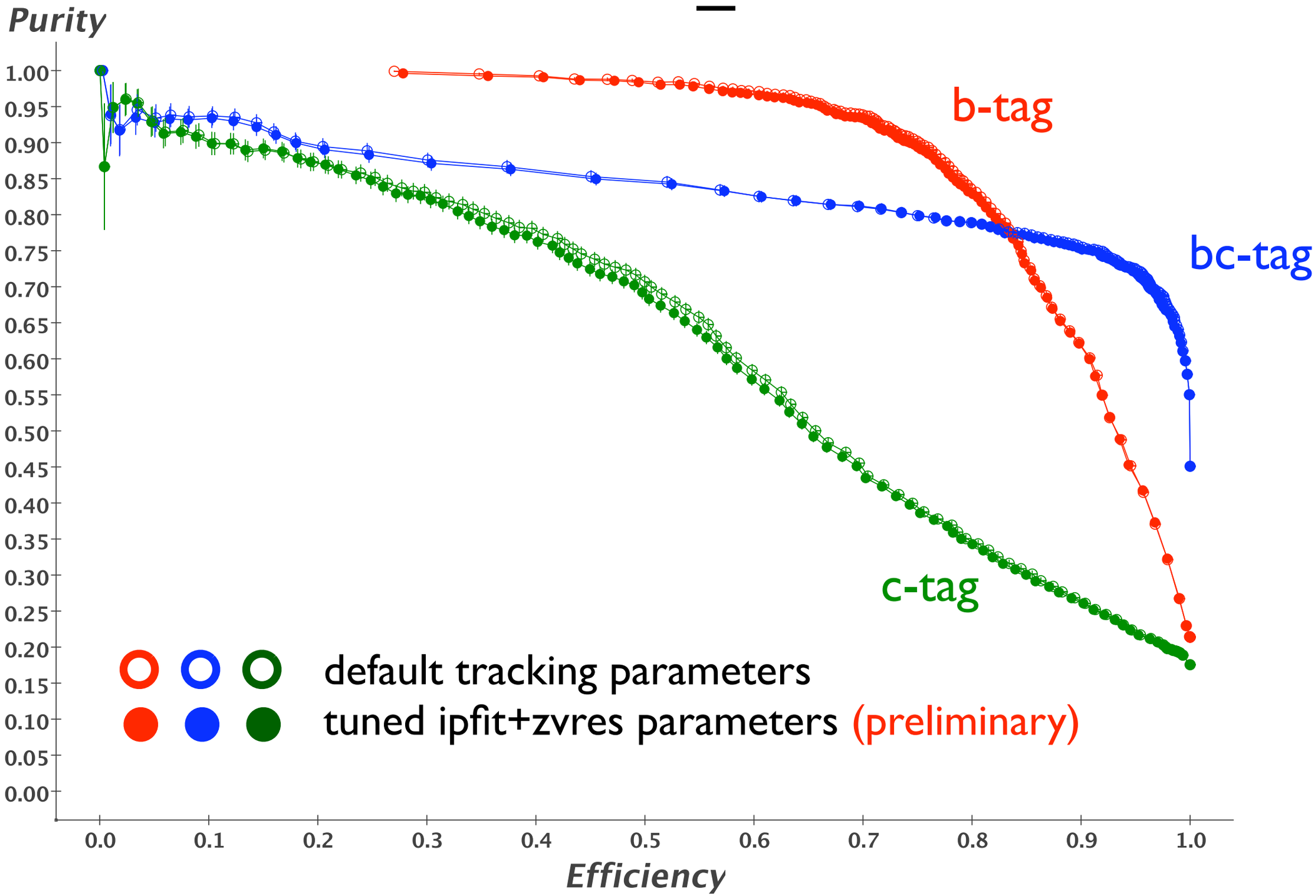
- chi2/ndf < 4;
- d0 < 2mm;
- d0 error < 0.007mm;
- z0 < 5mm;
- z0 error < 0.025mm;
- p_T > 0.2 GeV;

FTI track selection: ongoing!

Investigating correlations...

LCFIVertex parameters tuning

LDCPrime_02Sc



Background effects

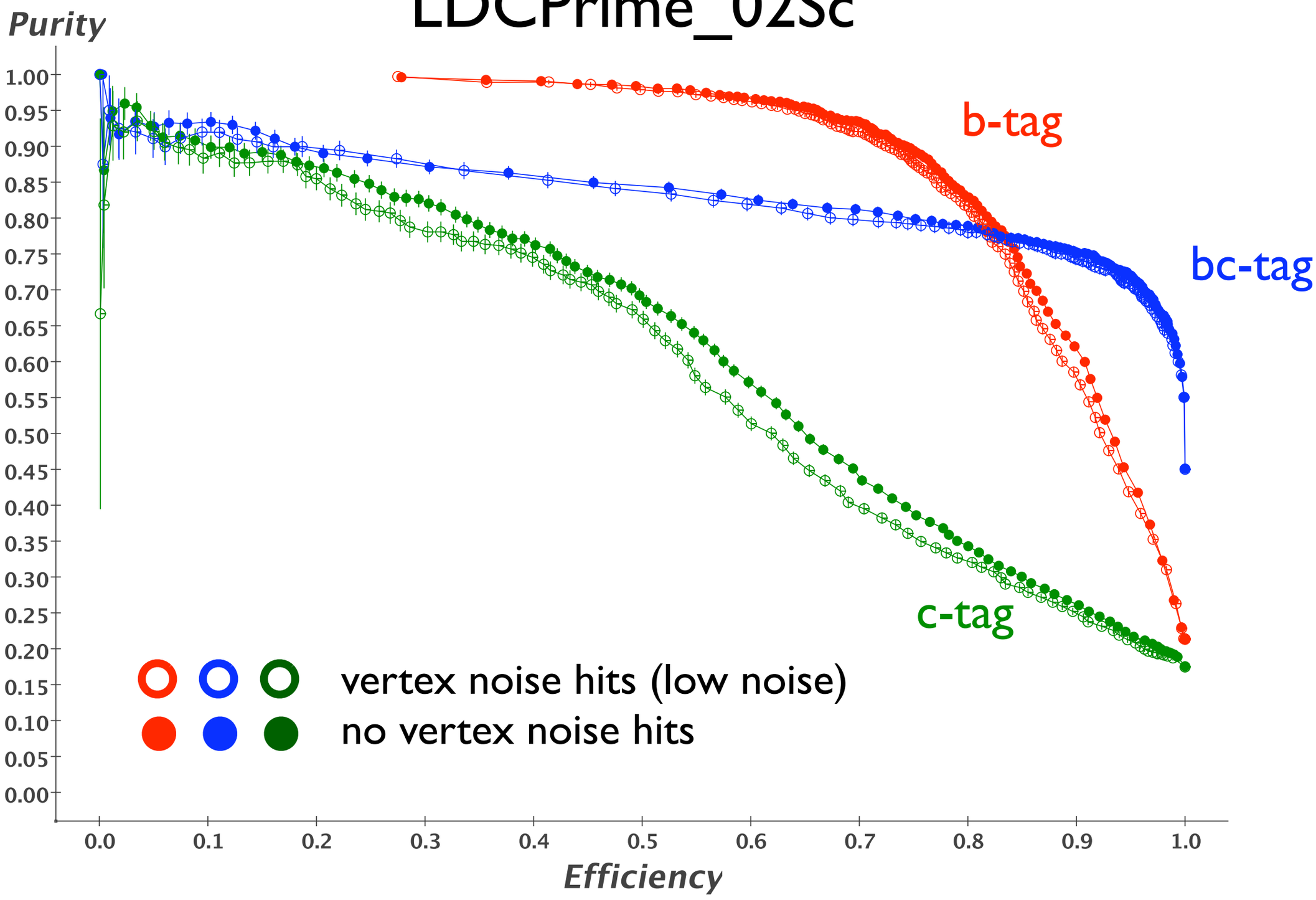
- Check the impact of backgrounds, also in the future with track selection tuning, in the flavour tagging performance.
- Using VTXNoiseHits to simulate backgrounds.
- Problems with Marlin jobs crashing.
- Parameters of VTXNoiseHits:
  - Using low hit densities (low noise):

```
<parameter name="HitDensityPerLayer_VTX"
type="FloatVec"> 100. 10. 4. 1. 1. </parameter>
```

  - Recommended hit densities (K.Wichmann):

```
<parameter name="HitDensityPerLayer_VTX"
type="FloatVec"> 400. 50. 15. 6. 3. </parameter>
```

Background effects

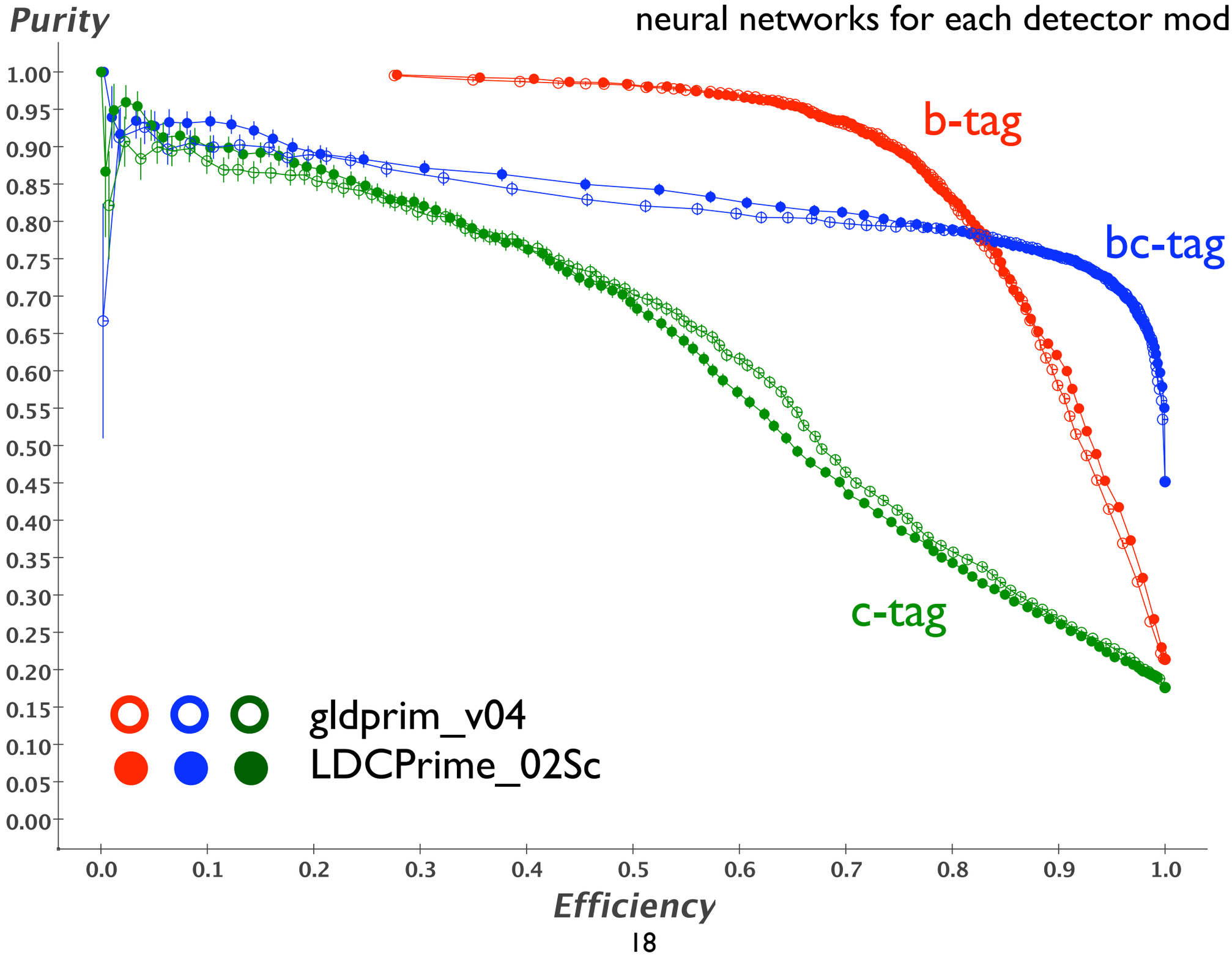


LDC x GLD → ILD_00

- Check stability of the flavour tagging performance for the GLD compared with LDC detector models towards the ILD detector model:

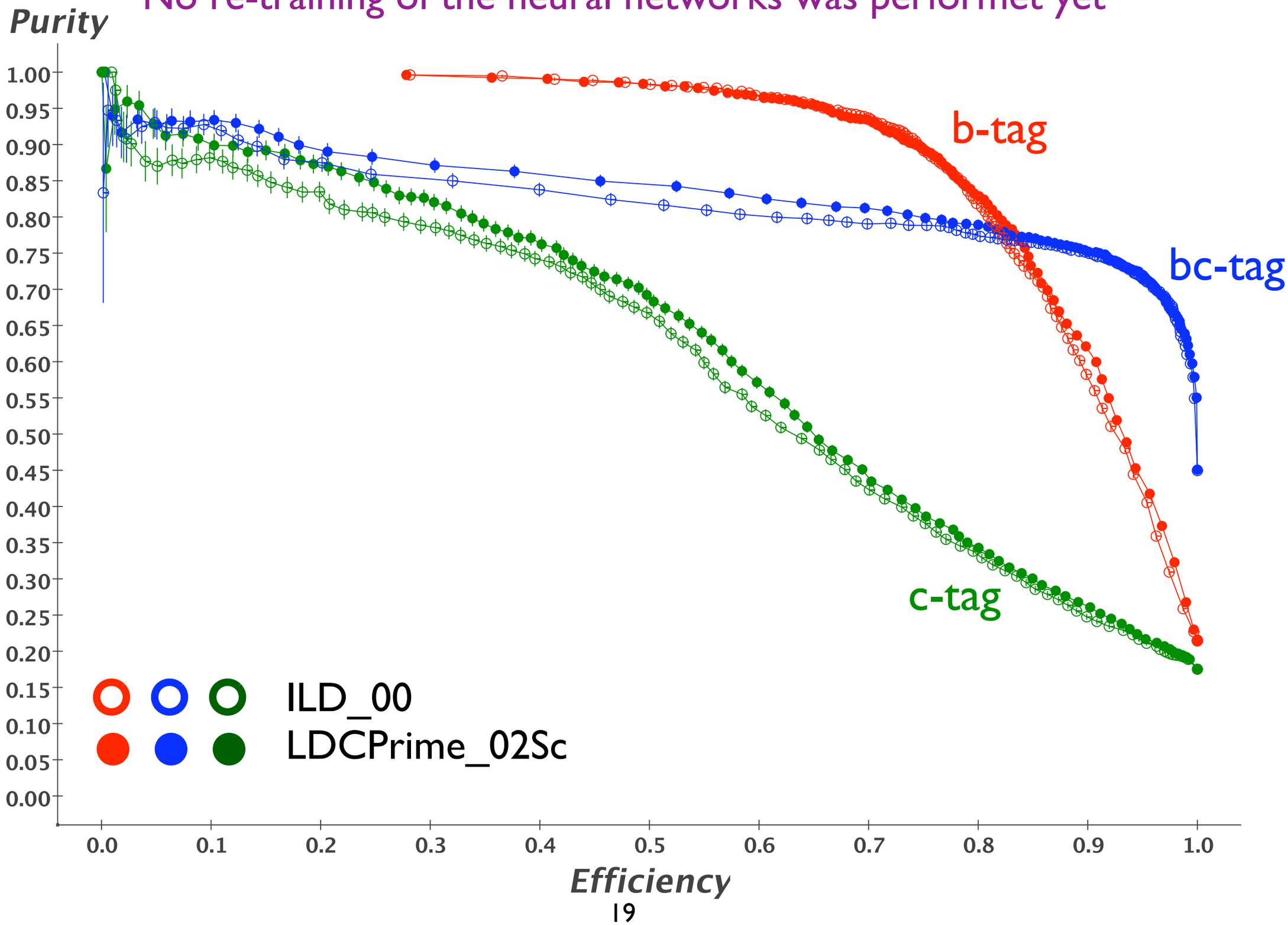
LDC x GLD

Parameters for the joint probability and re-training the neural networks for each detector model



LDC x GLD → ILD_00

No re-training of the neural networks was performet yet



Summary & Conclusions

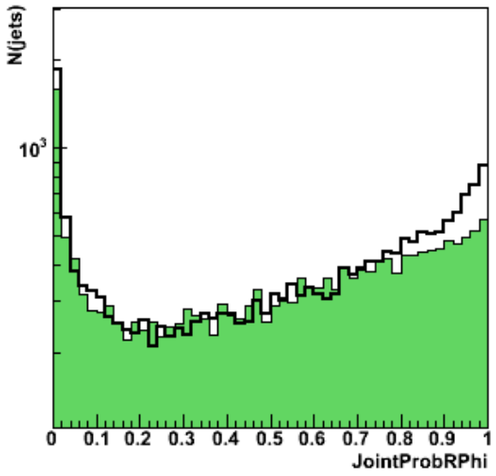
- Studies to obtain optimal sets of parameters of the LCFIVertex package for flavour tagging has been done.
- Proper set of parameters for the joint probability and neural networks play a major role in flavour tagging. Soon, available for ILD_00.
- Preliminary set of parameters of track selection for vertices reconstruction is proposed.
- Impact of backgrounds in flavour tagging being investigated.
- Flavour tagging performance very promising with ILD_00.

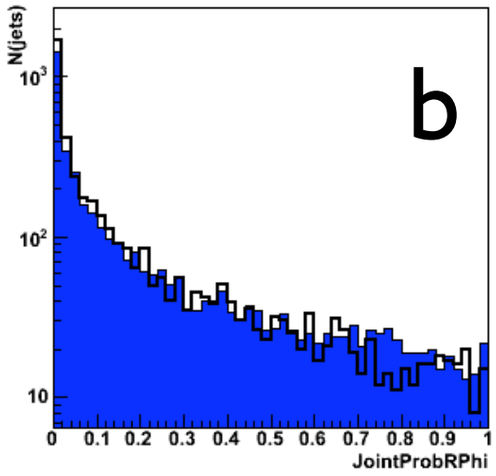
Extra slides

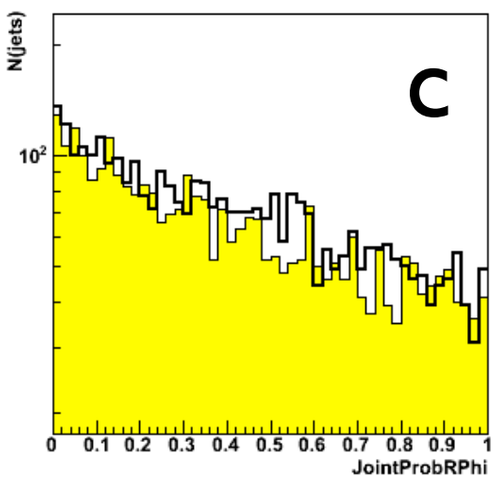
Joint probabilities
(with LDCPrime_02Sc parameters)

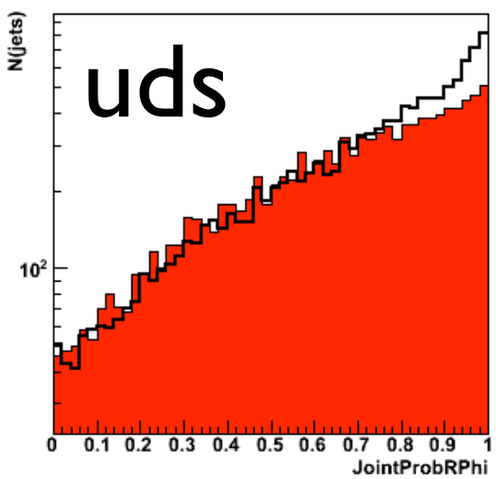
LDCPrime_02Sc - line; ILD_00 - histo

RPhi

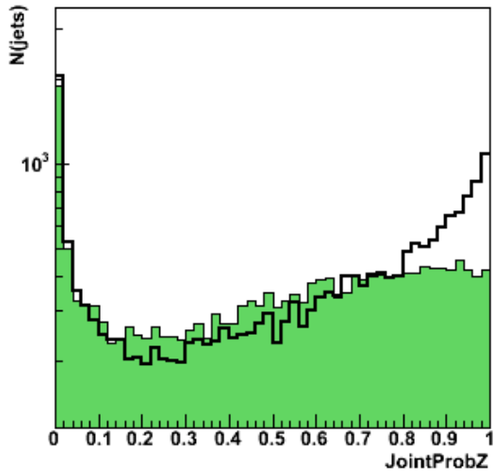


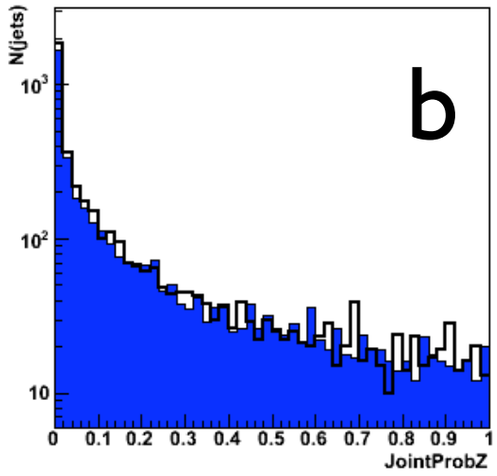


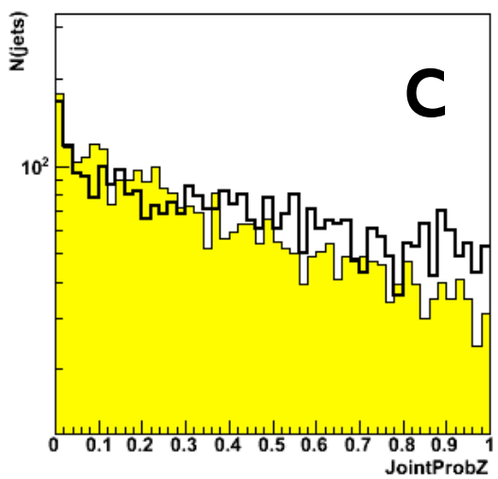


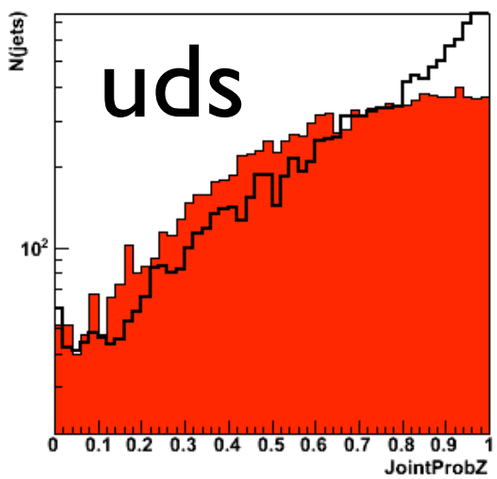


Z



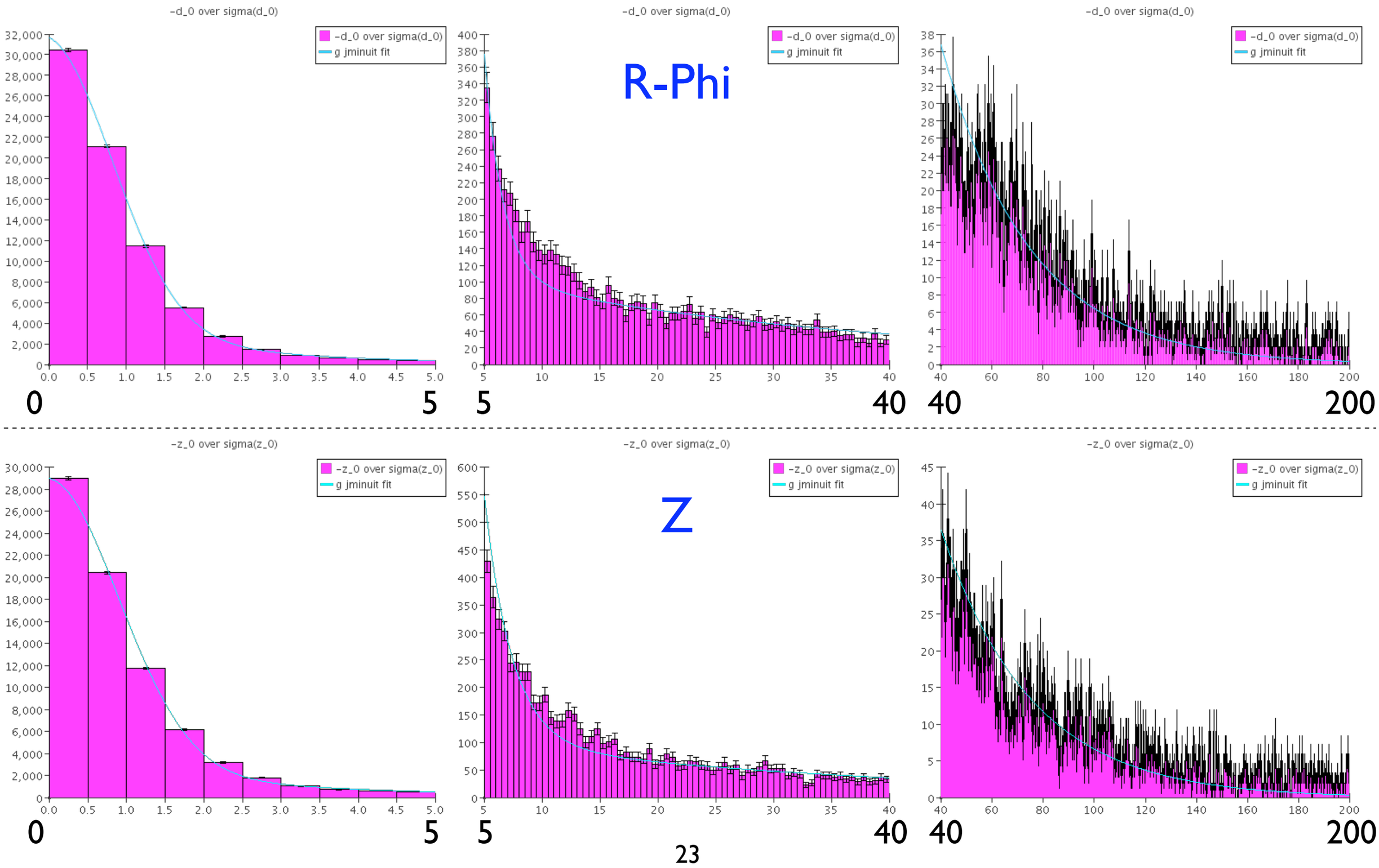






Joint probability parameters: SignificanceFit

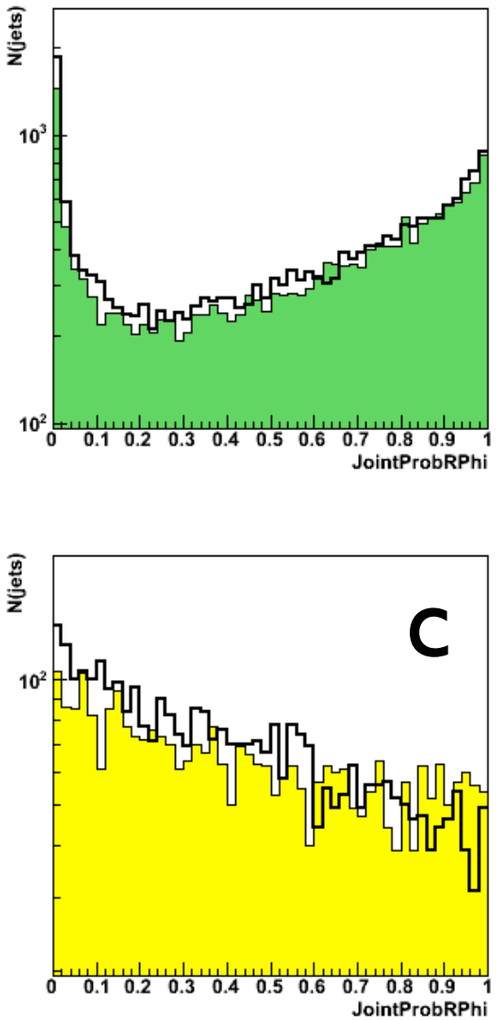
LDCPrime_02Sc: Zooming the global fit

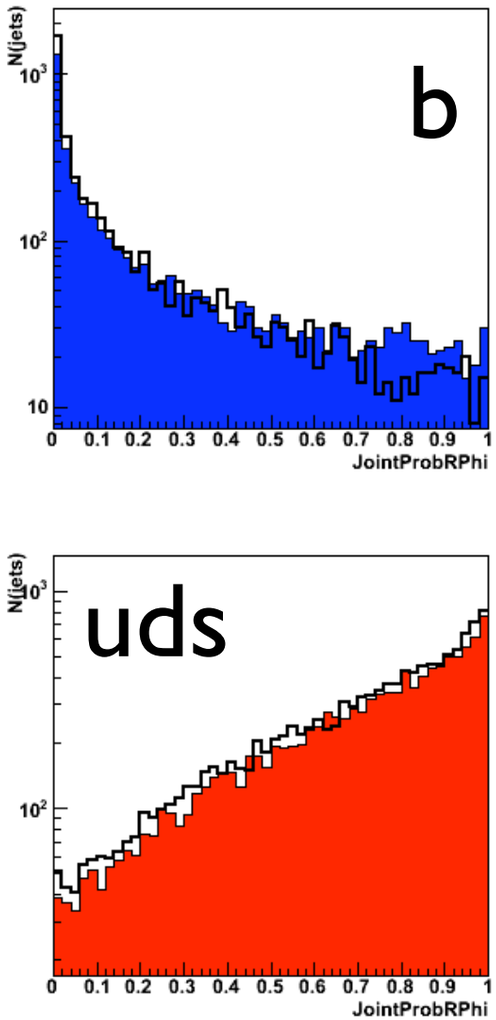


Joint probabilities
(with ILD_00 parameters)

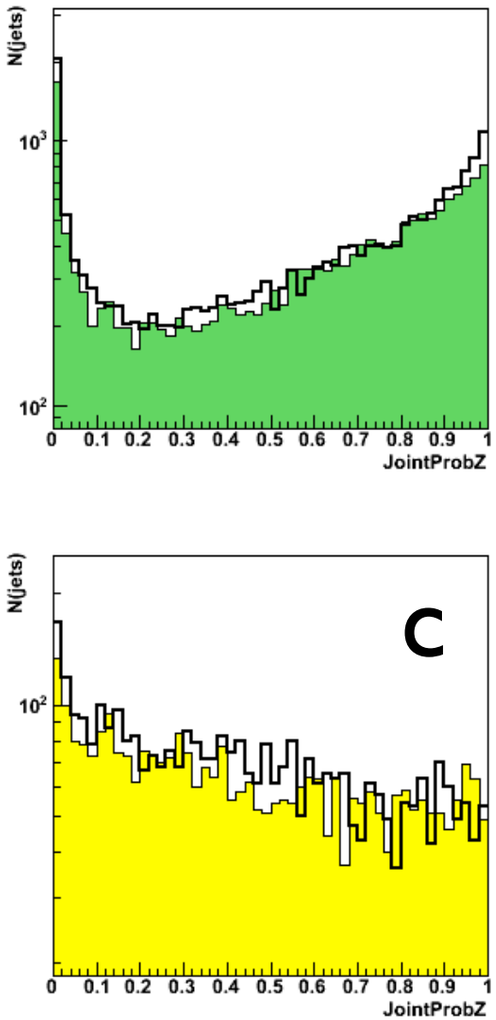
LDCPrime_02Sc - line; ILD_00 - histo

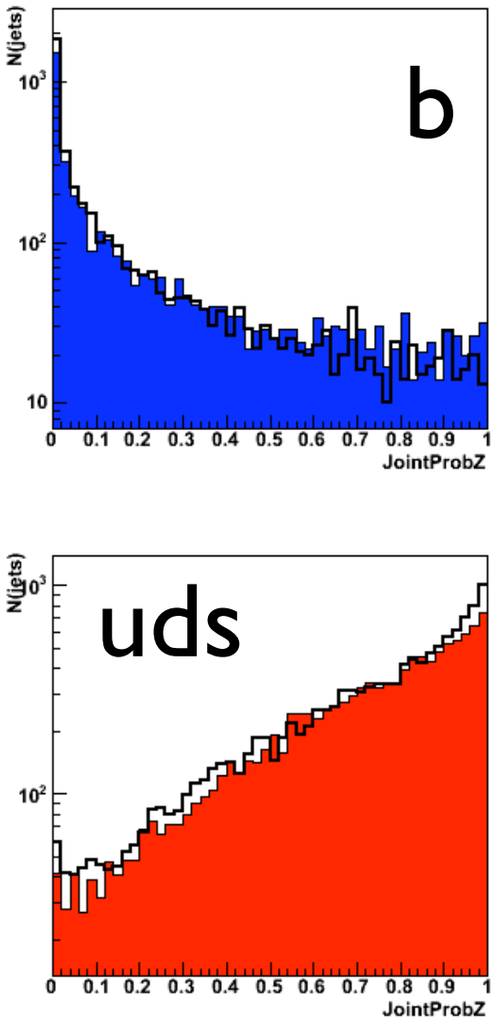
RPhi





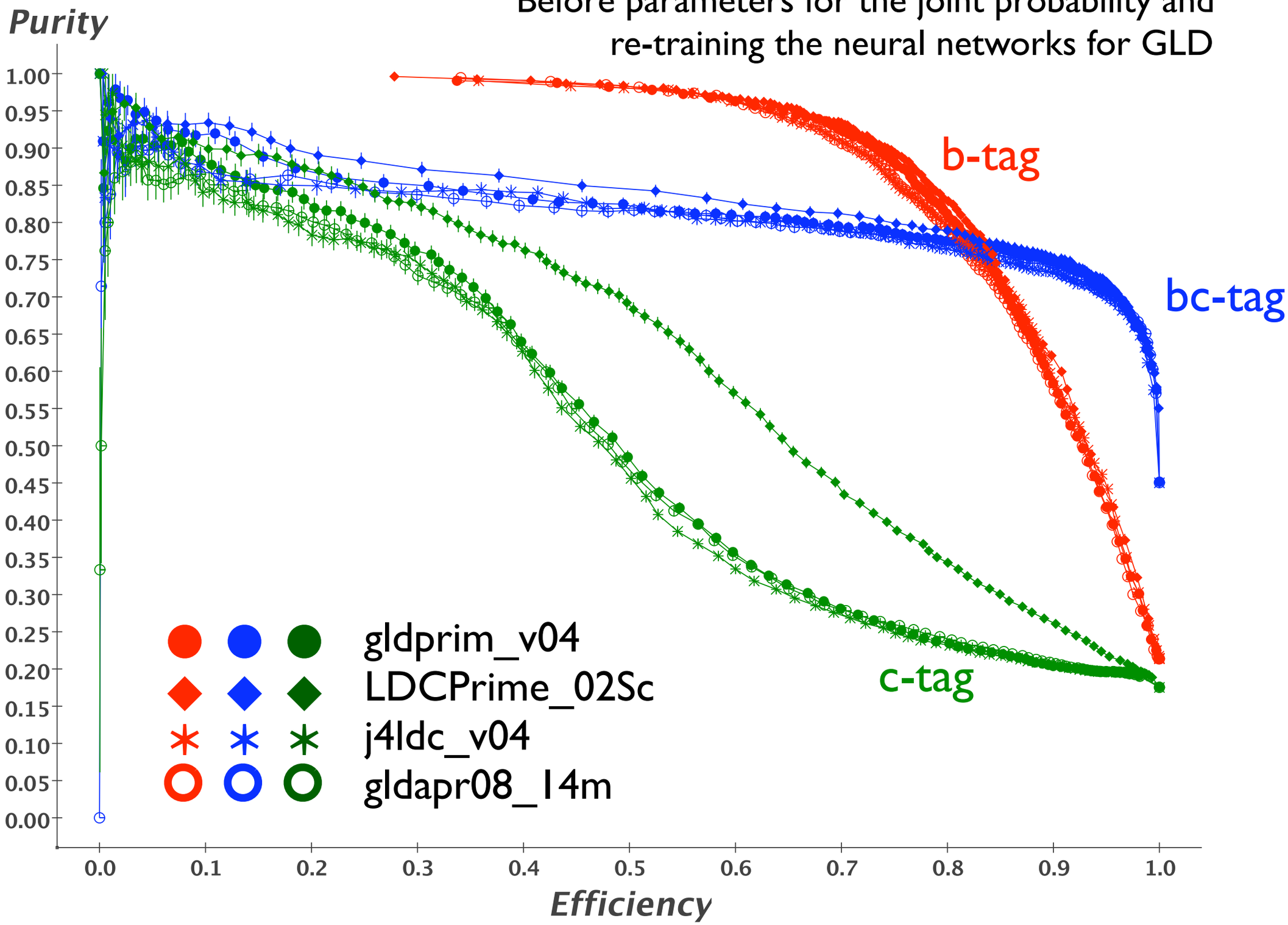
Z





LDC x GLD → ILD_00

Before parameters for the joint probability and
re-training the neural networks for GLD



FTI (z0err cut)