LCFIVertex Flavour Tagging Studies

Roberval Walsh
The University of Edinburgh

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Introduction

- The aim of these studies is to extract the optimal 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.

- Present LCFIVertex default parameters for flavour tagging are outdated (Tesla-SGV).

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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

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Parameters for Joint Probability

Thursday, 11 September 2008

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 $R\Phi$ and z to a gaussian+exponential+exponential function. The SignificanceFit processor is used.

Joint probability parameters: SignificanceFit

Zooming the global fit
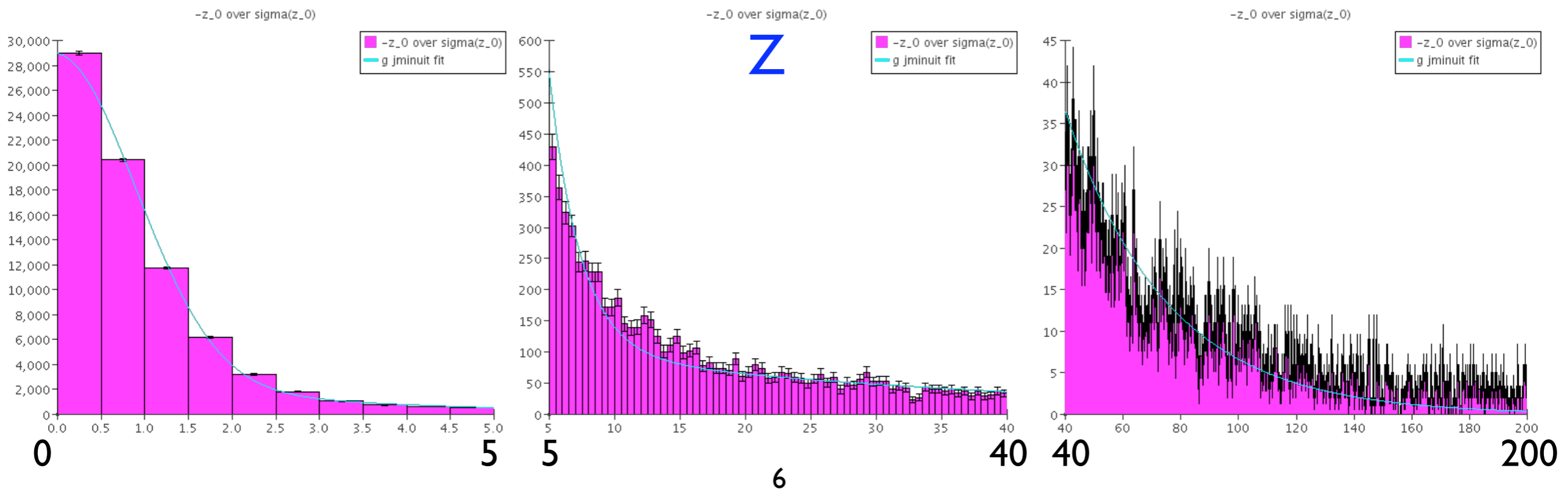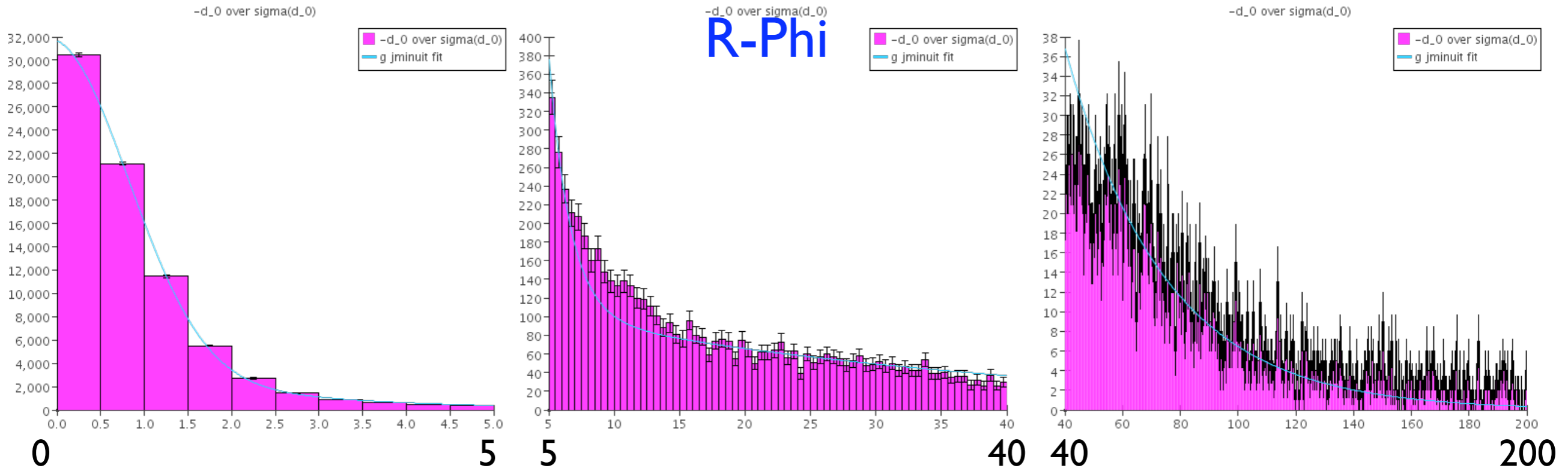
Joint probability parameters: SignificanceFit

default

```
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
```

new (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
```

LDC01_05Sc

```
PARAMETERS FOR RPHI Joint Probability
 1.01498
 0.27984
 0.561155
 0.00601934
 0.0476549
PARAMETERS FOR Z Joint Probability
 1.04273
 0.27057
 0.468457
 0.00631426
 0.0479484
```

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Flavour tag inputs

Flavour tag inputs

- **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;

  - vertexing and flavour tag inputs: ConversionTagger

Impact parameter significance Rφ

Most significant track

SGV - line; Mokka - histo
(S. Hillert)

LDCPrime_02Sc
cheat - line; conv. tag - histo
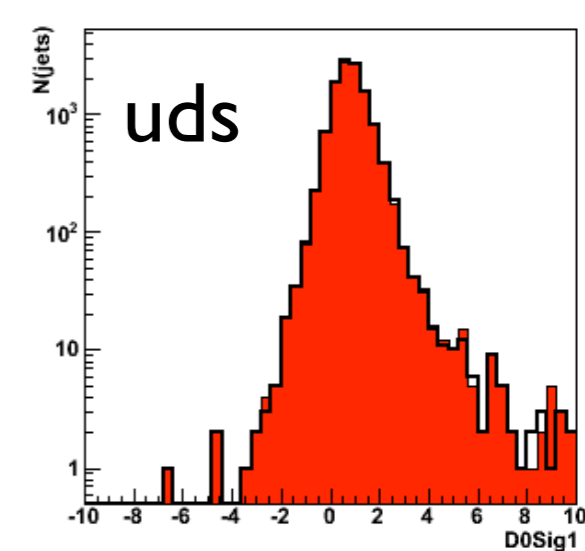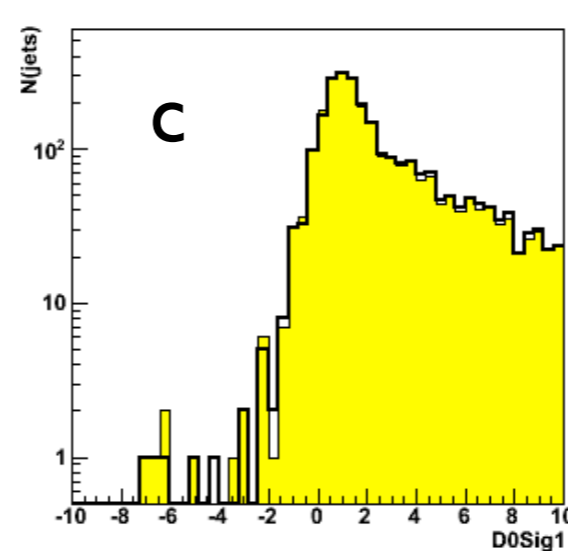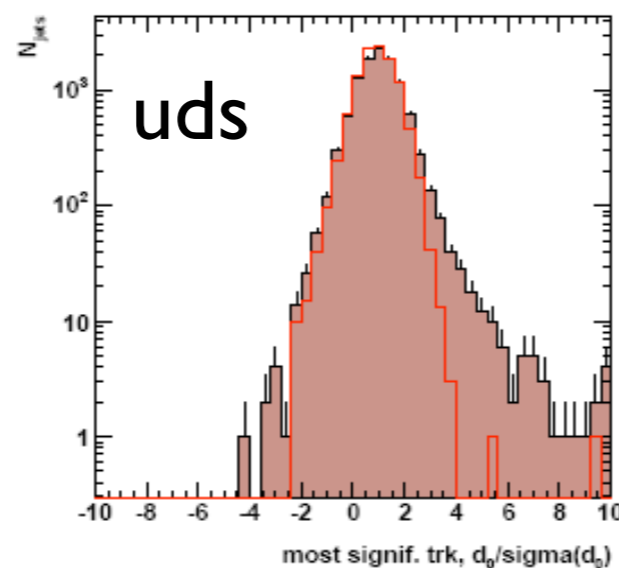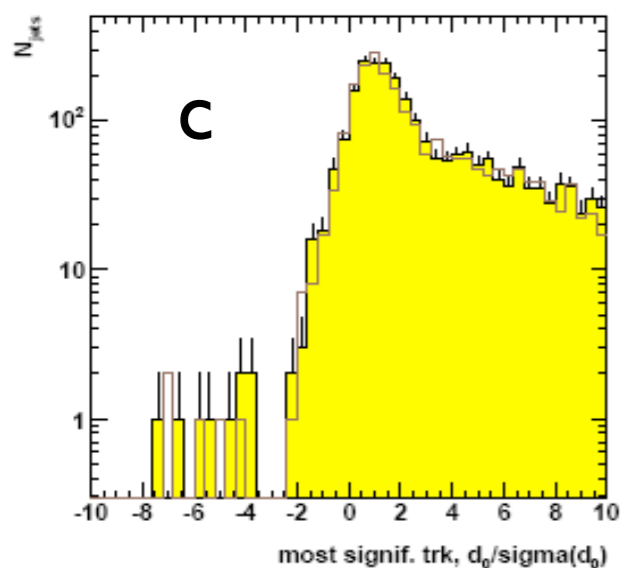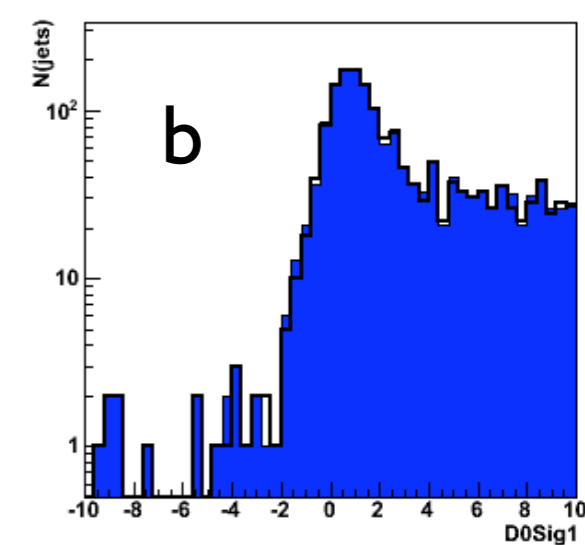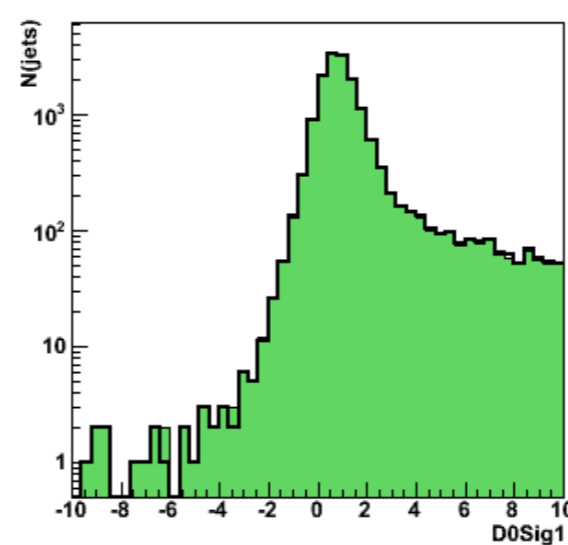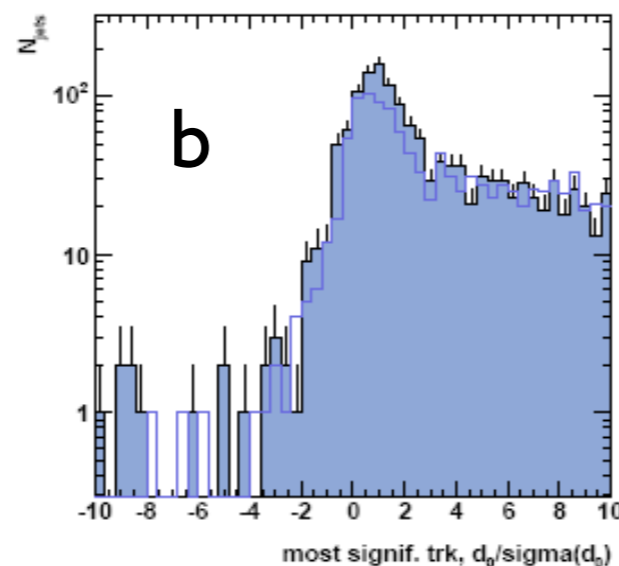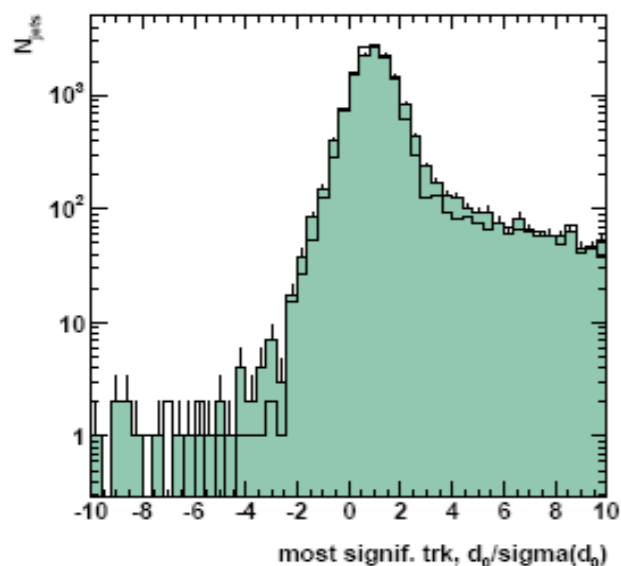
Notice the log scale!

Impact parameter significance Rφ

Second most significant track

SGV - line; Mokka - histo
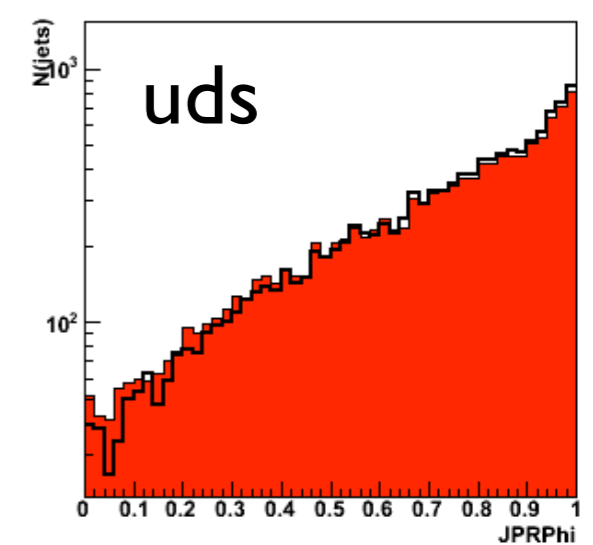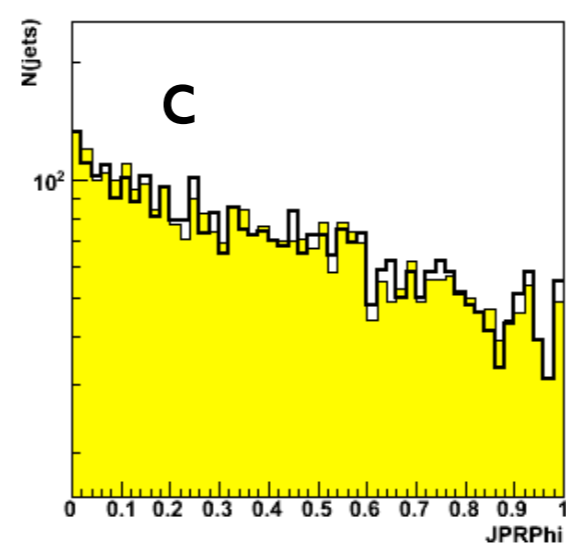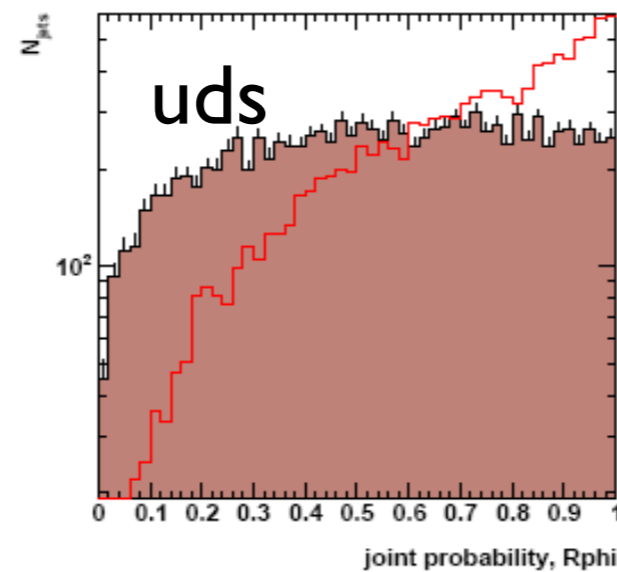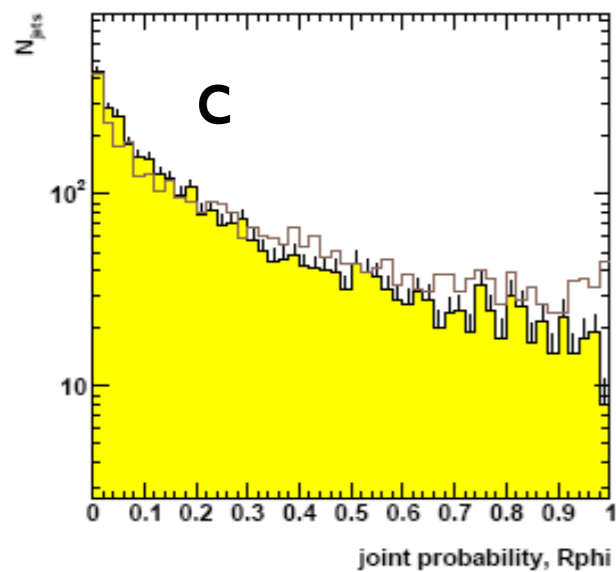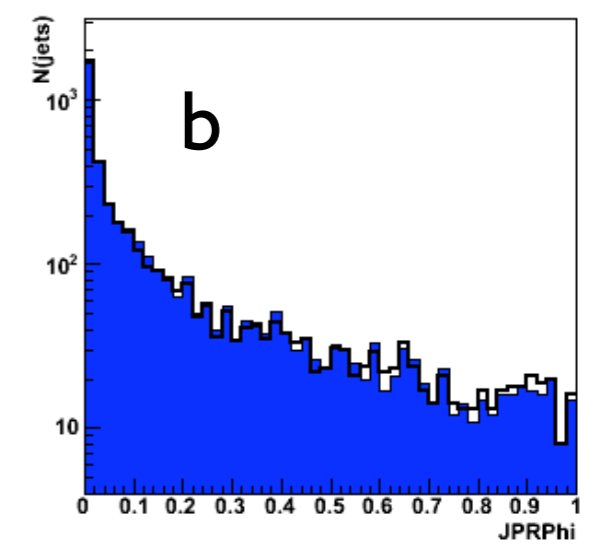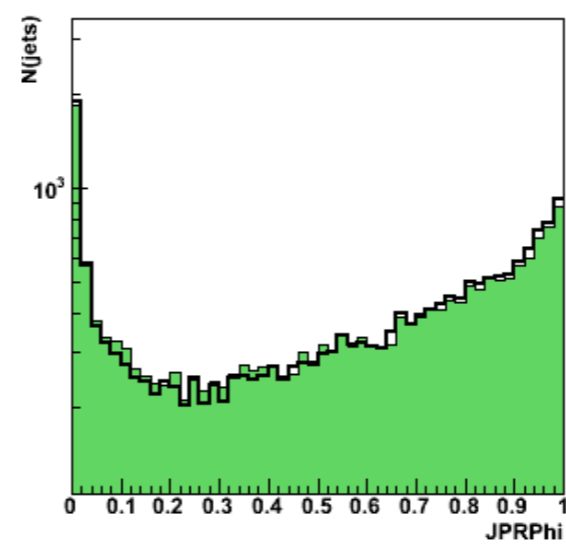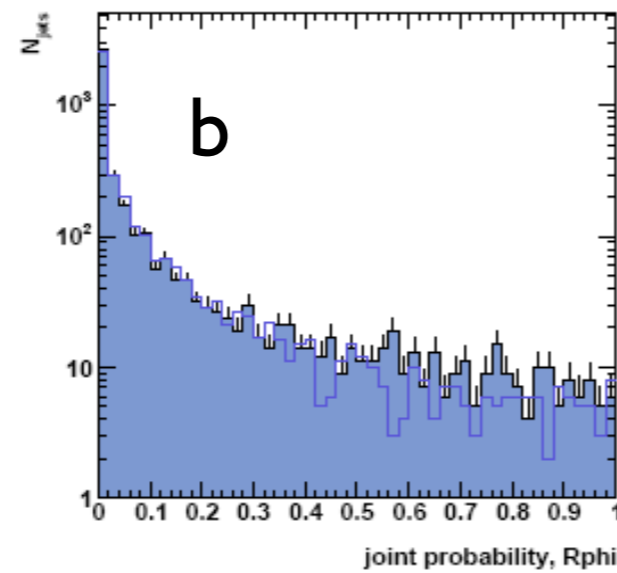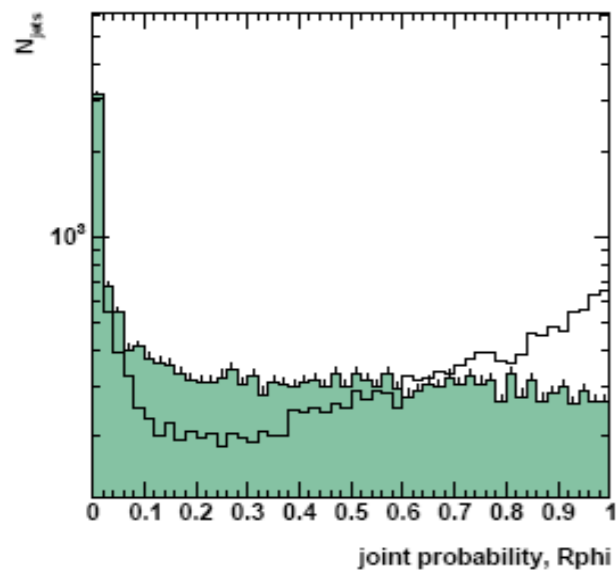(S. Hillert)

LDCPrime_02Sc
cheat - line; conv. tag - histo
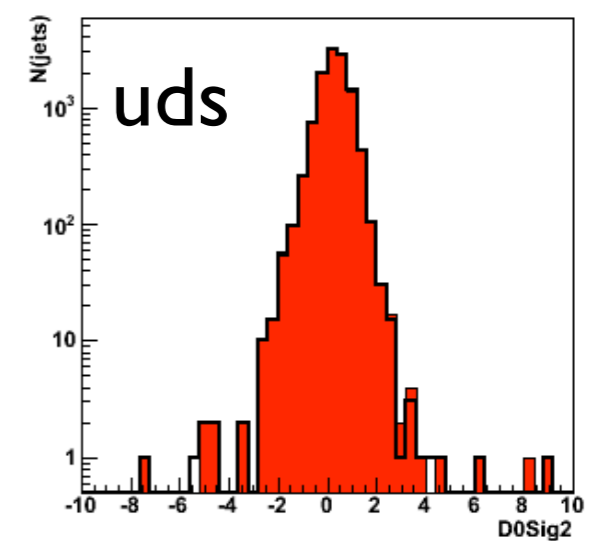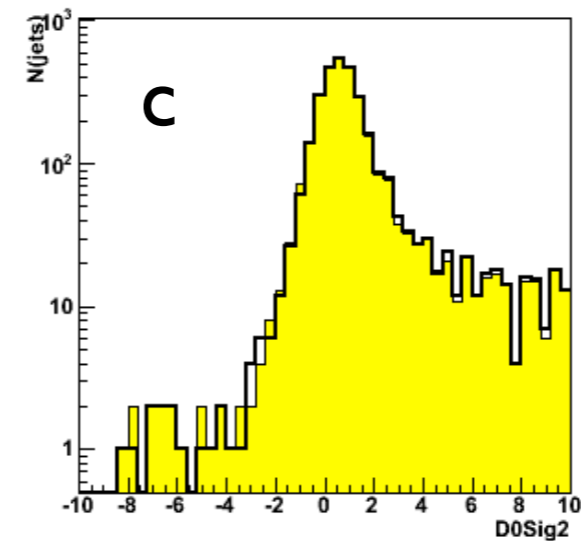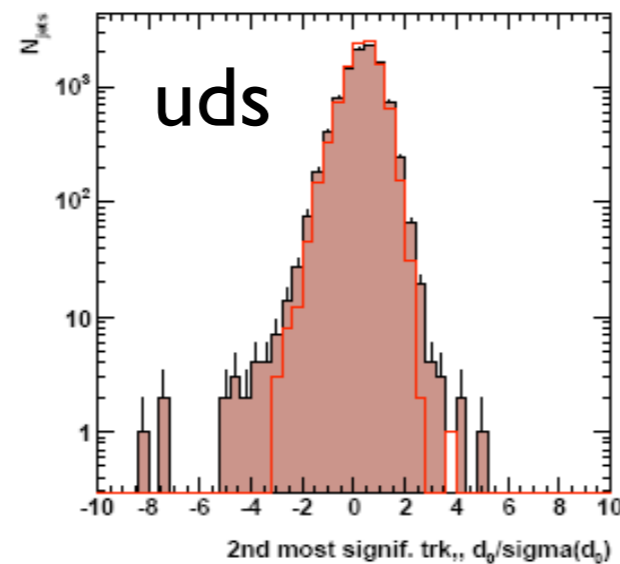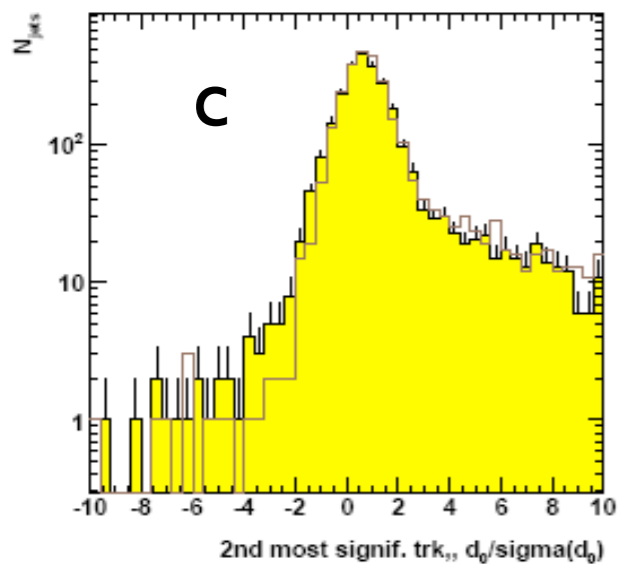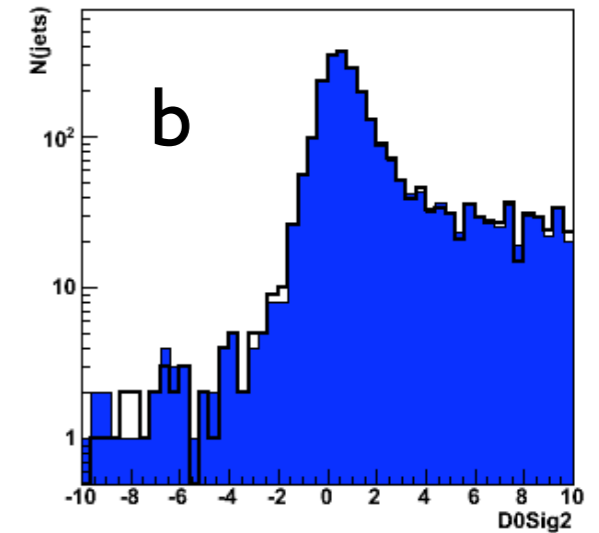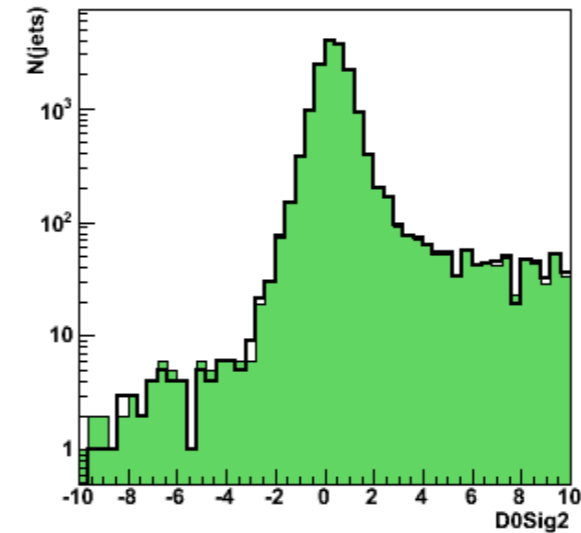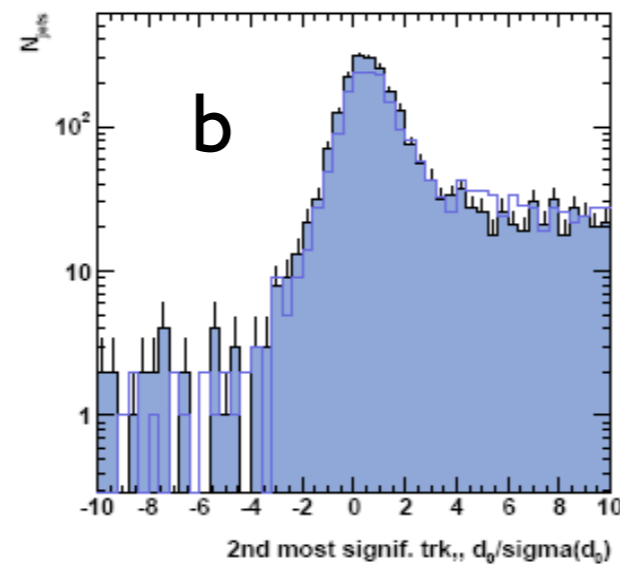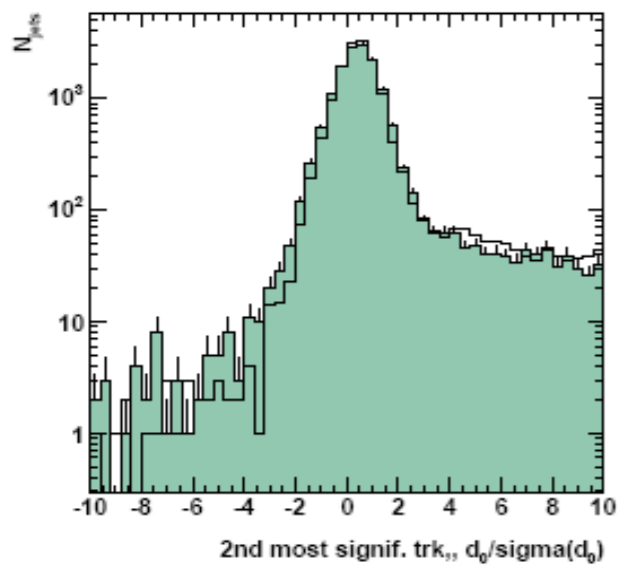
Notice the log scale!

Joint probability Rφ

SGV - line; Mokka - histo
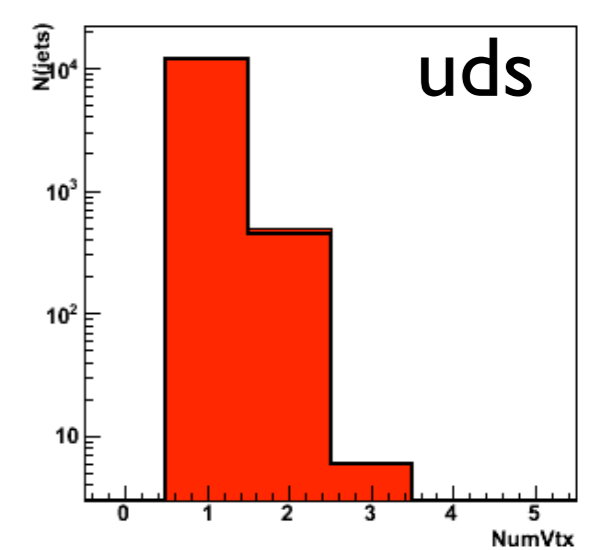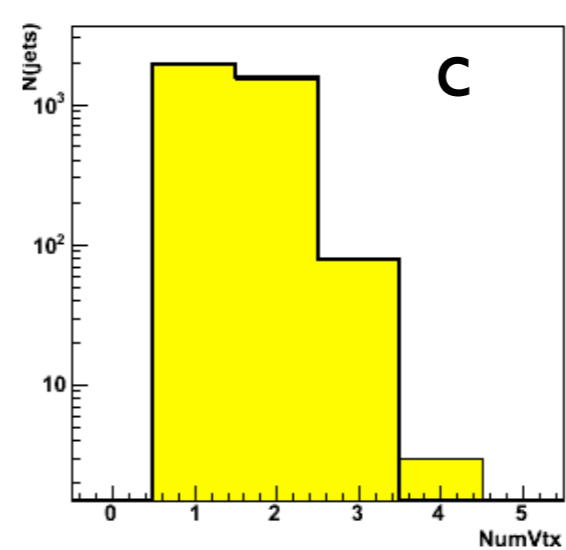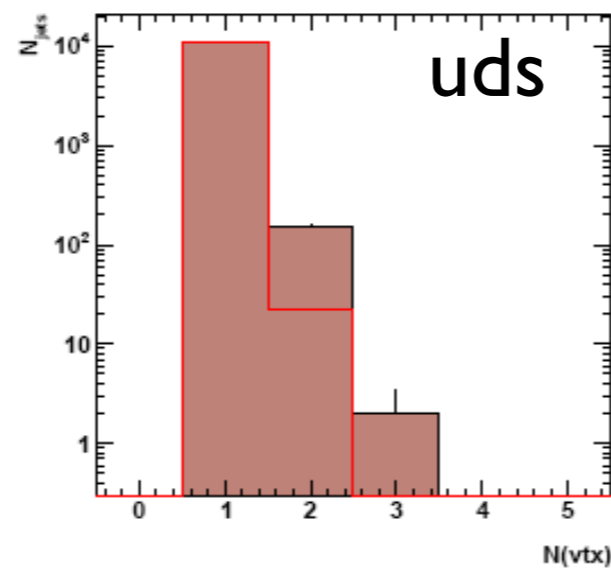(S. Hillert)

LDCPrime_02Sc
cheat - line; conv. tag - histo

Notice the log scale!

Vertex multiplicity

SGV - line; Mokka - histo
(S. Hillert)
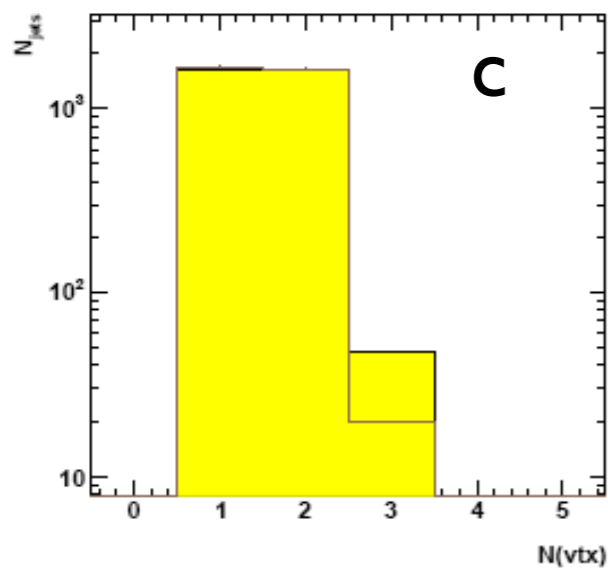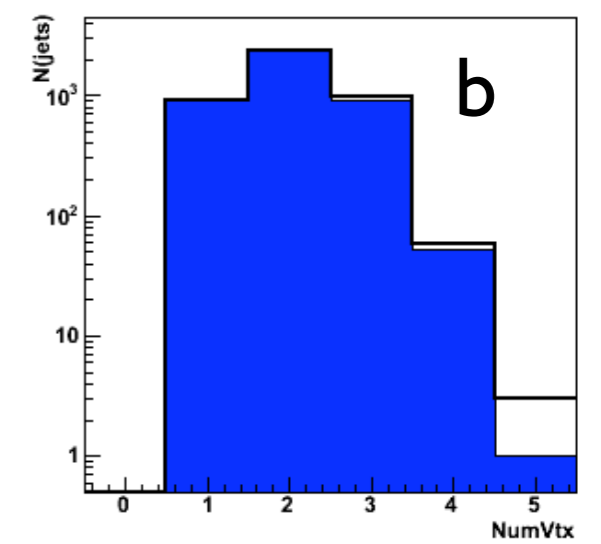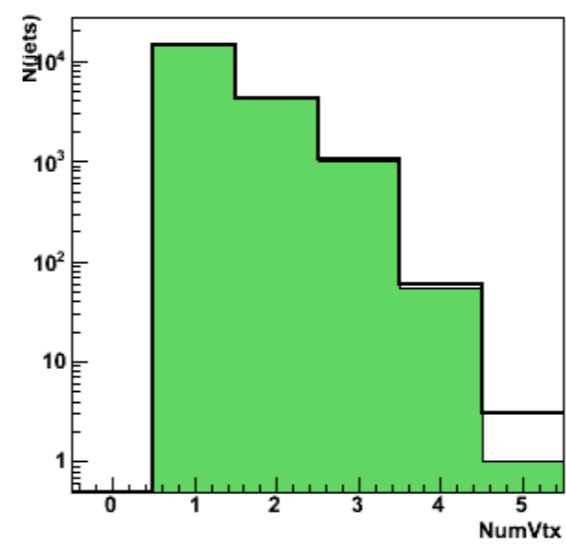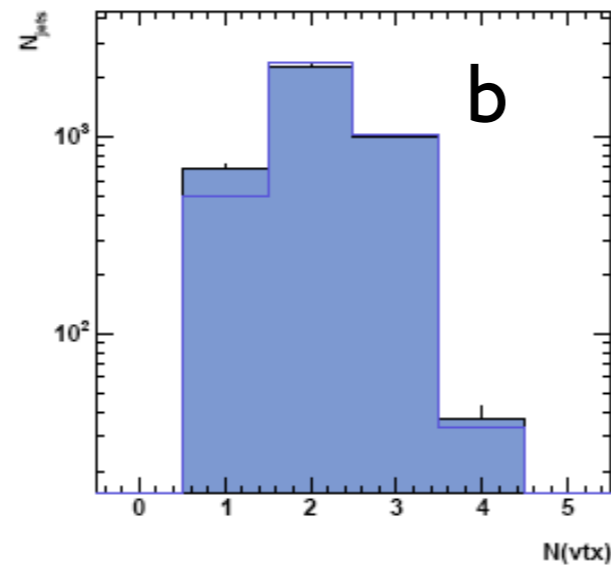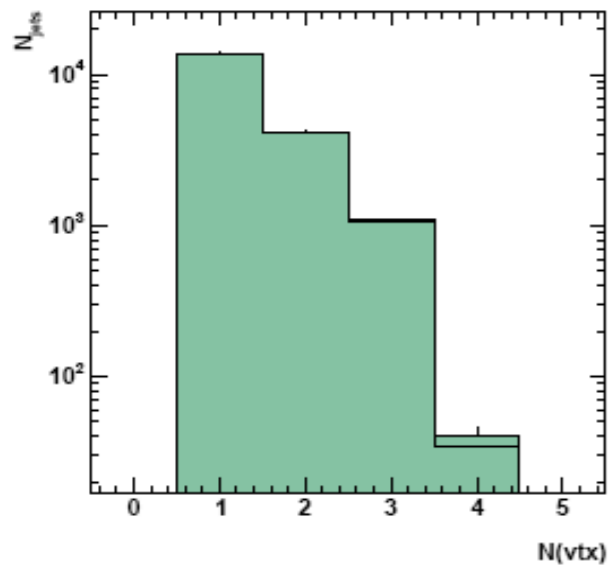
LDCPrime_02Sc
cheat - line; conv. tag - histo

Notice the log scale!
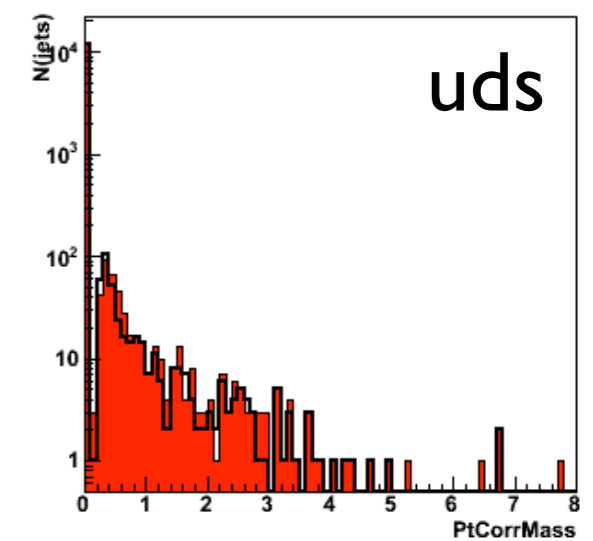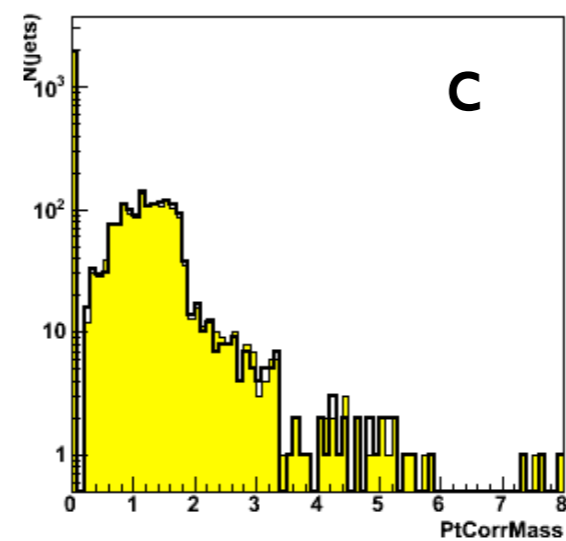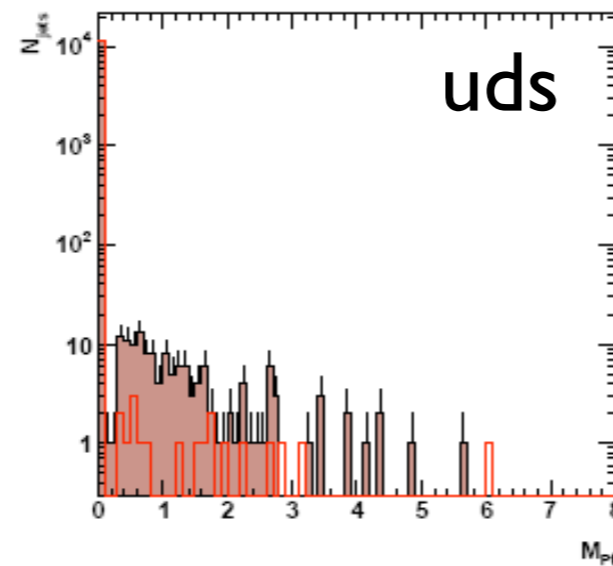
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Pt corrected mass

SGV - line; Mokka - histo
(S. Hillert)

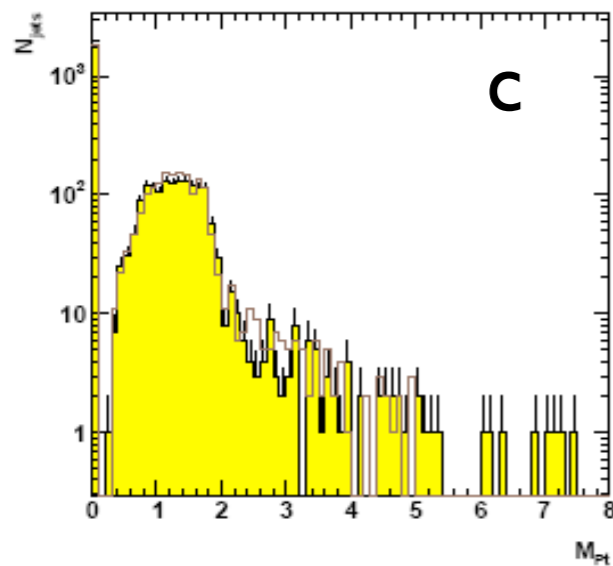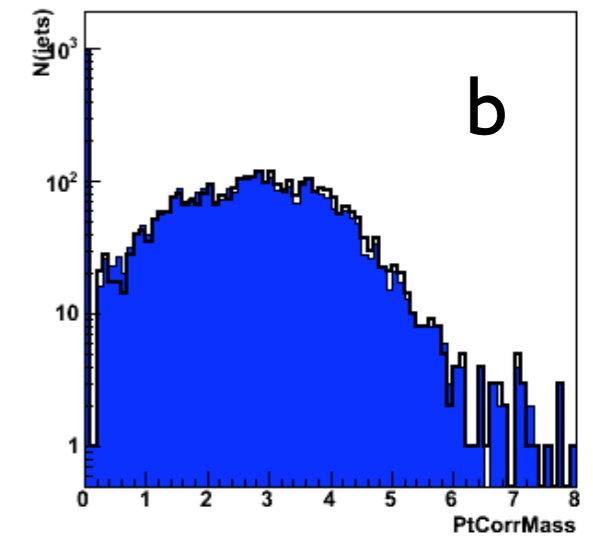LDCPrime_02Sc
cheat - line; conv. tag - histo
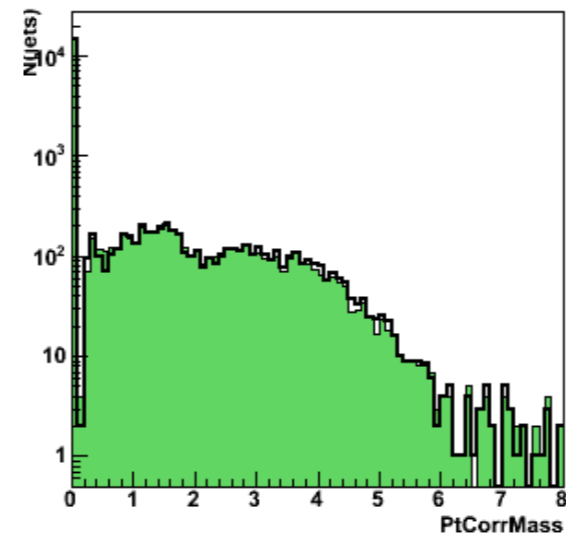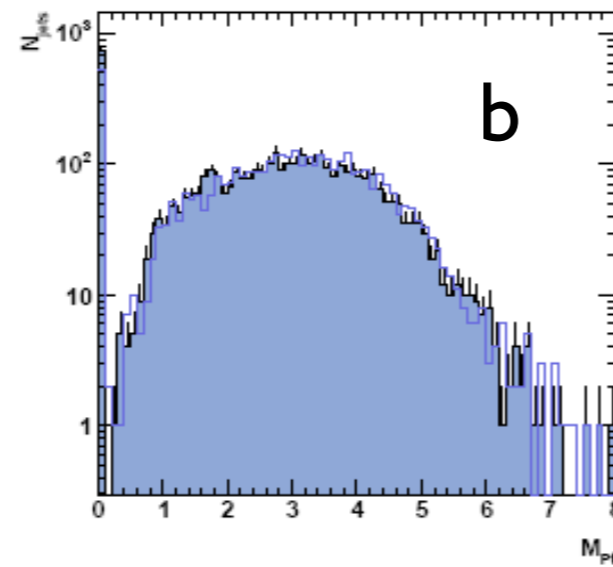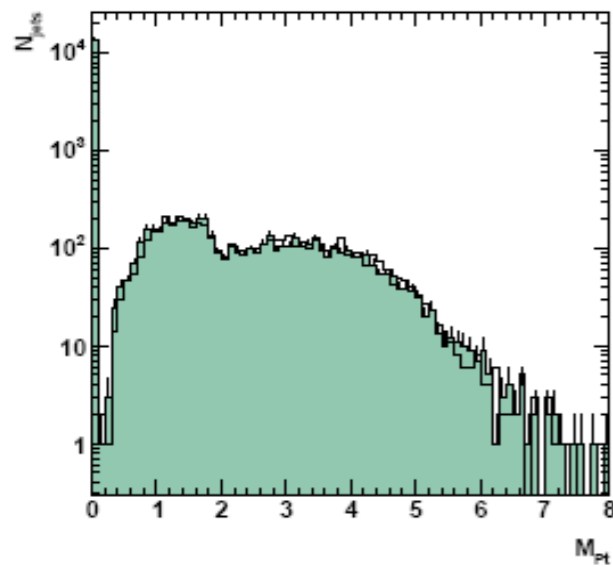
Notice the log scale!

Neural networks

Neural networks training

- Flavour tagging uses 9 neural networks for the b-, c- and bc-tag each for the cases where 1 vertex, 2 vertices or more than 3 vertices are found.

- Present LCFIVertex networks were trained using samples simulated with SGV.

- Samples (LDCPrime_02Sc, ilcsoft 01-03-06-p02):
  - 49000 events Z → bb
  - 49000 events Z → cc
  - 49000 events Z → uds

- NeuralNetTrainer processor used.

- Durham_2Jets collection as input.

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Neural networks training

Purity vs Efficiency plot with three tagging curves labeled b-tag (red), bc-tag (blue), and c-tag (green).

solid: lpcprime_02sc nets + V0,conversion tagger
open: lpcprime_02sc nets + cheating
star: sgv nets + cheating
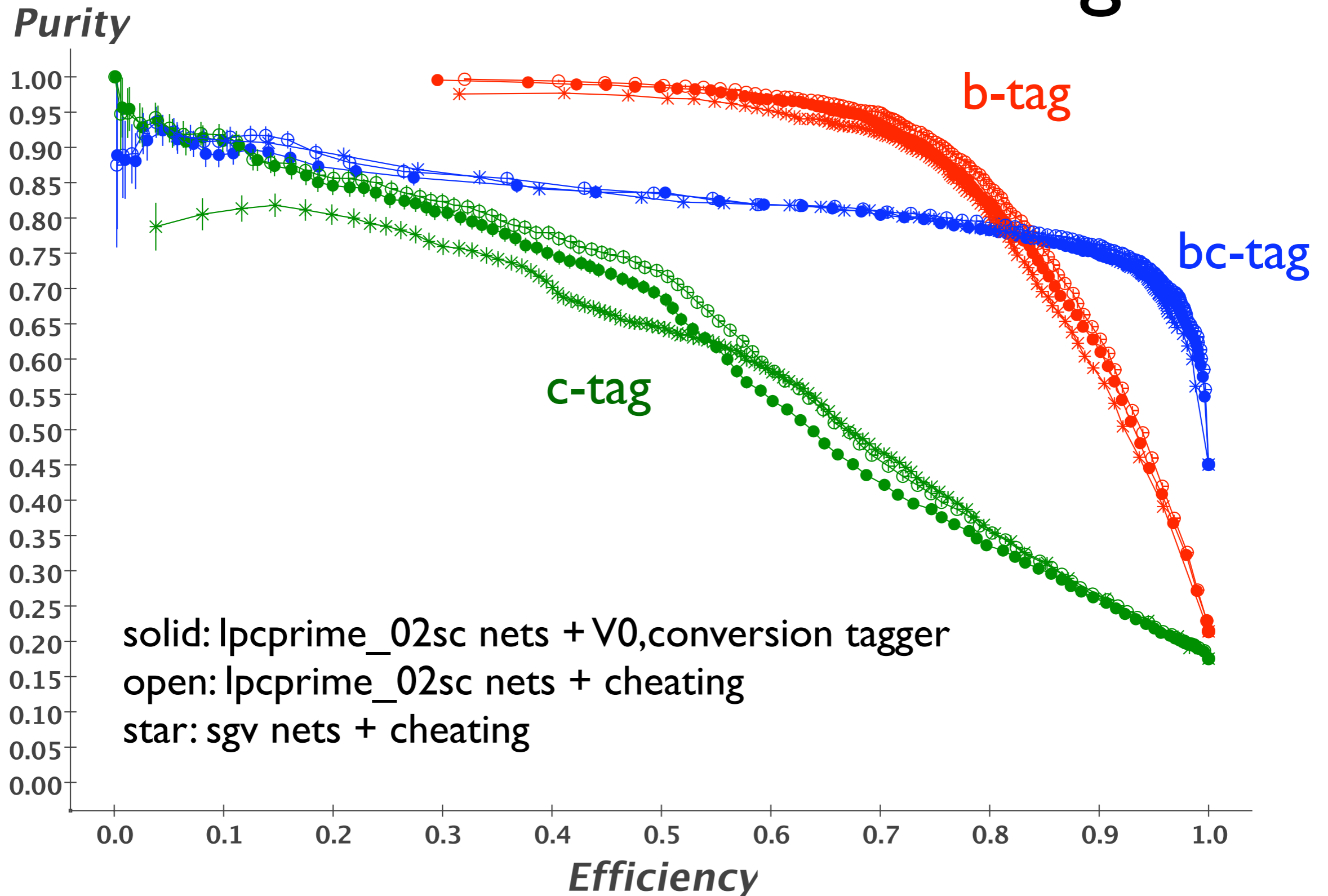
● ldcprime_02sc neural nets were trained with convertsion tagger!

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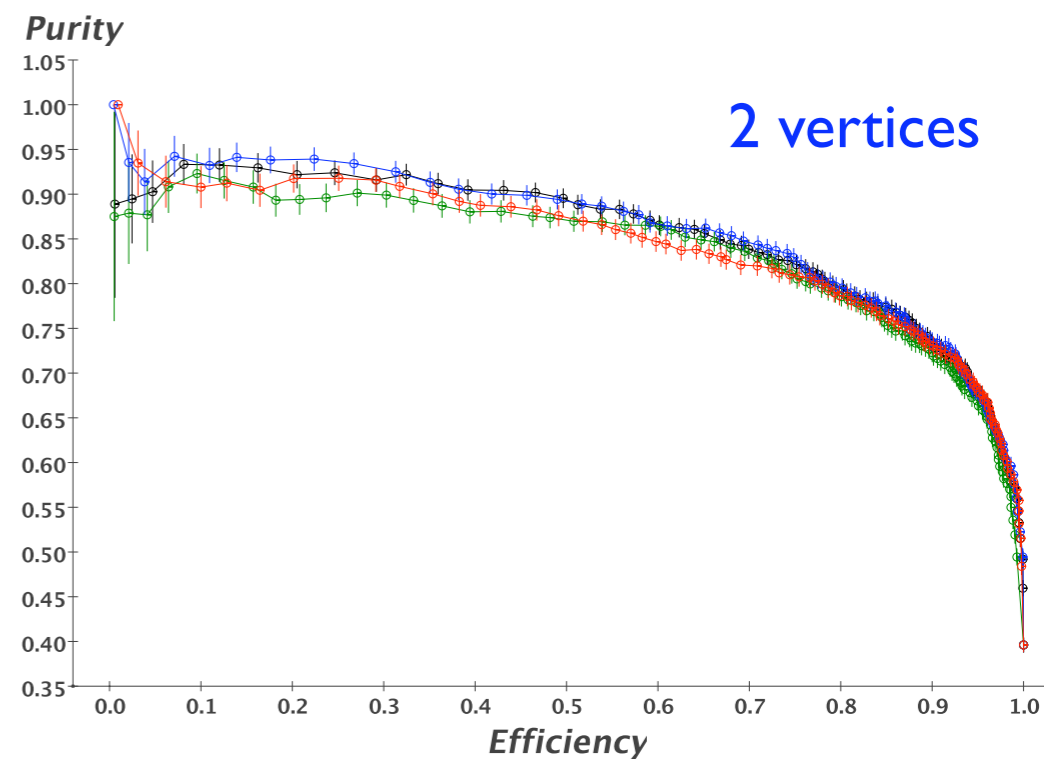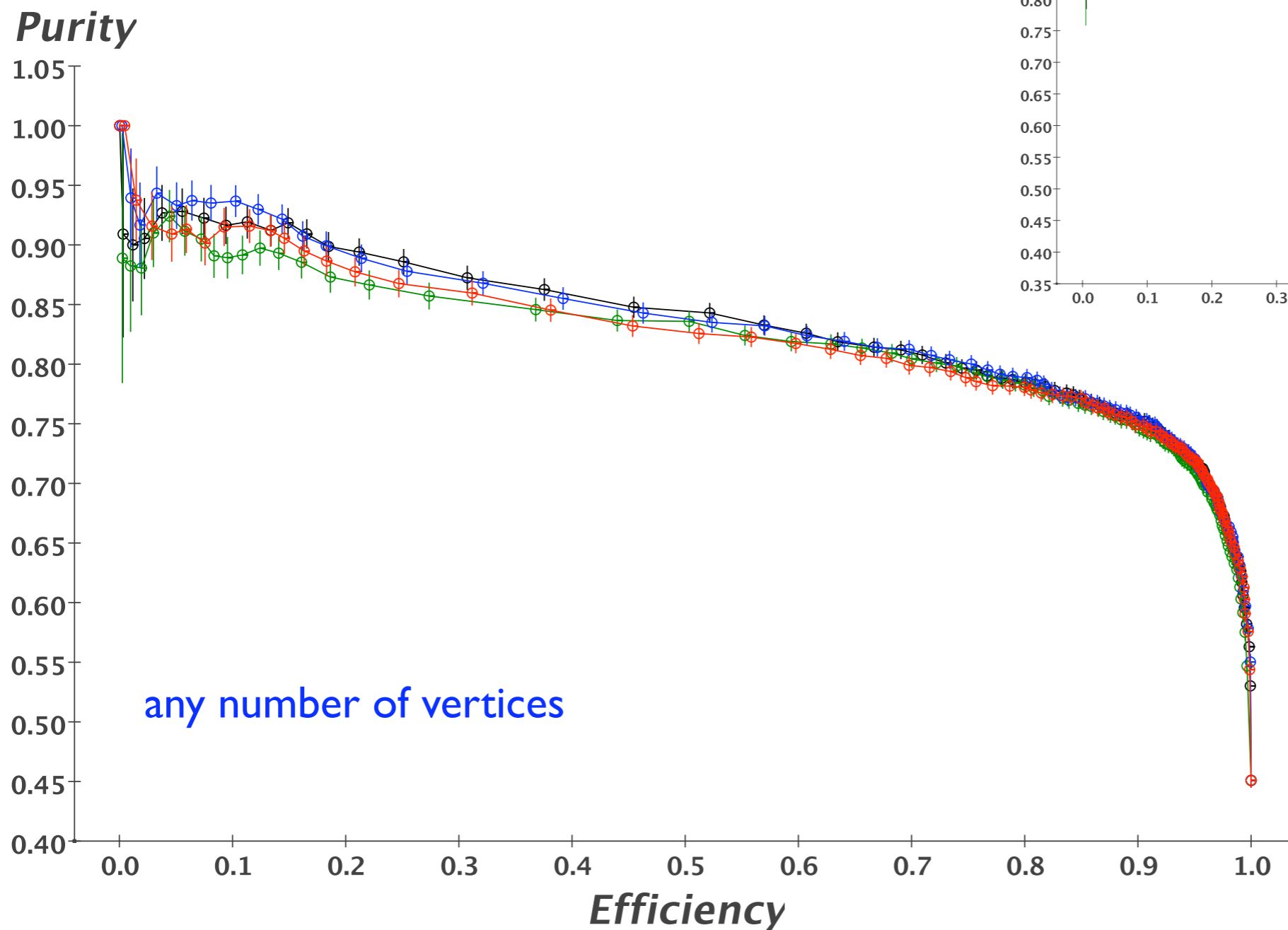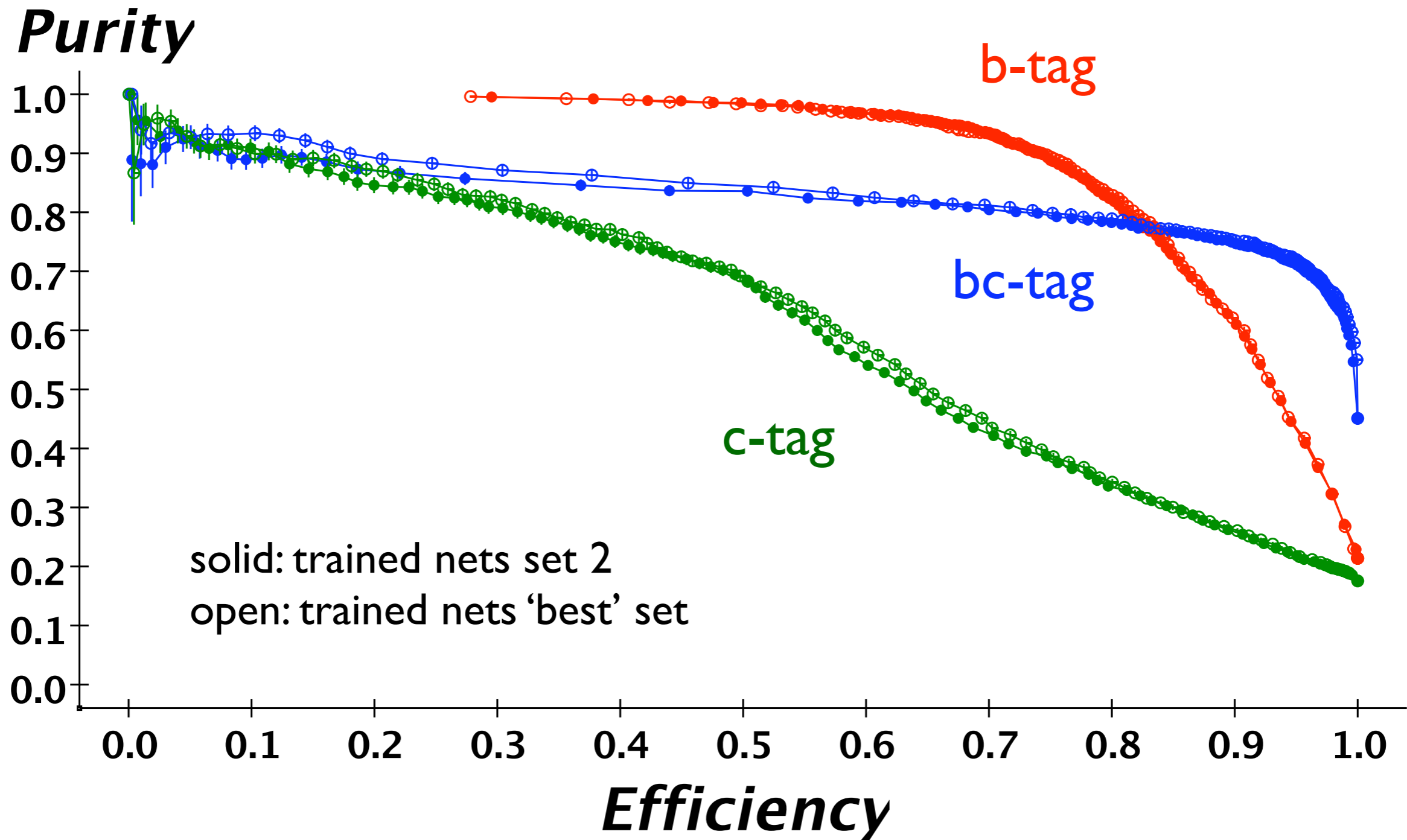# Neural networks training

- The random nature of the networks training produces fluctuations (up to ~2 sigma) in the efficiency x purity plots.

- Perform a certain number of training and pick the networks that give the best results.

- Four sets for each network were trained.

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Neural networks training

- BC-TAG

Purity

2 vertices

any number of vertices

Efficiency

Neural networks training

Purity vs Efficiency plot showing b-tag (red), bc-tag (blue), and c-tag (green) curves. solid: trained nets set 2; open: trained nets 'best' set

Track selection tuning

Track selection tuning

- Vary the parameters of track selection for the vertices reconstruction (IPFIT, ZVRES) and for the flavour tag inputs (FTI).

- Aim: Improve flavour tagging keeping the performance of vertex reconstruction and flavour tag inputs.
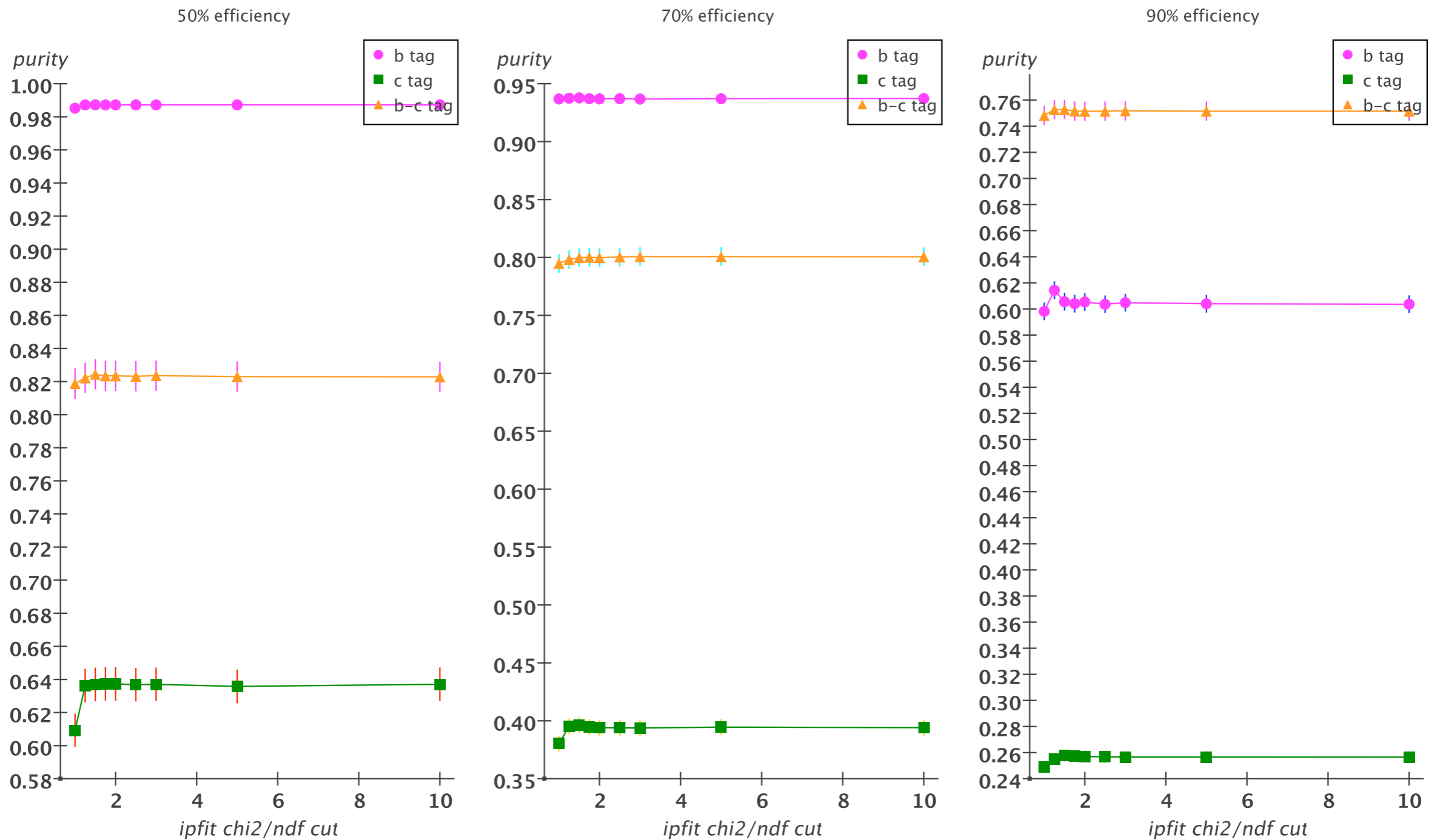
22

Track selection tuning

- **Monte Carlo sample**:

  - $e^+e^- \to Z \to qq$, $\sqrt{s} = 91.2$ 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;

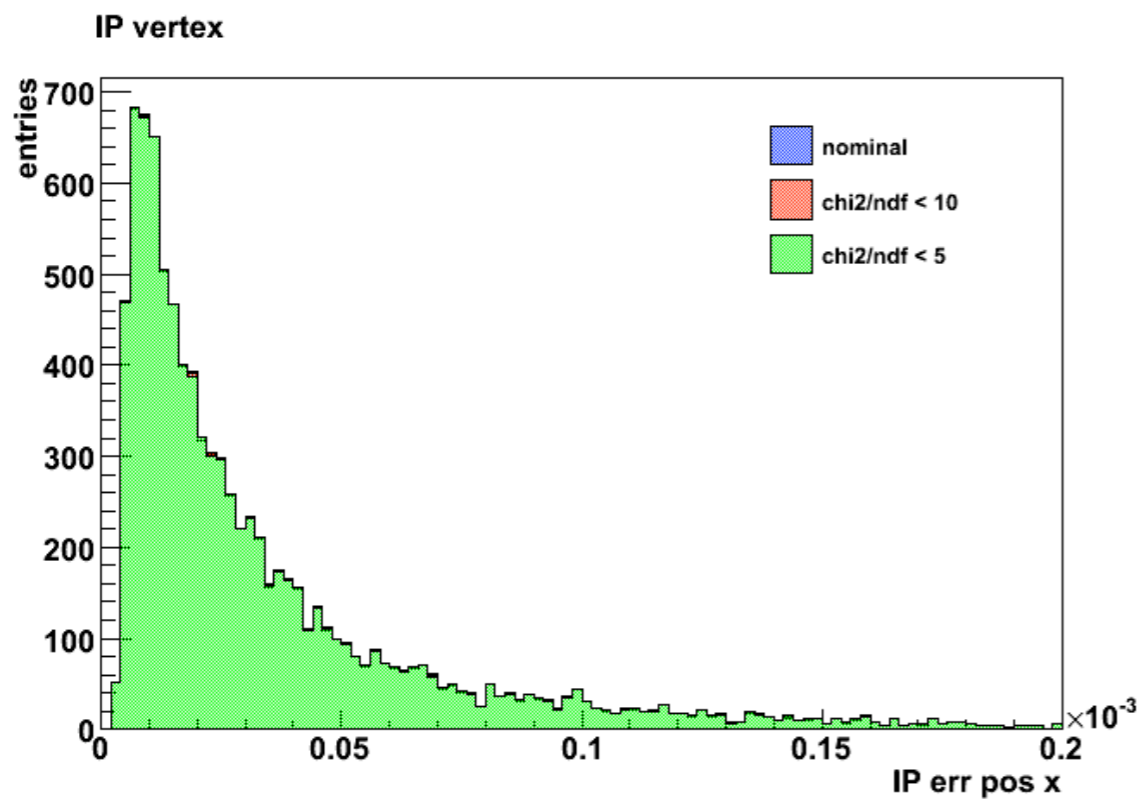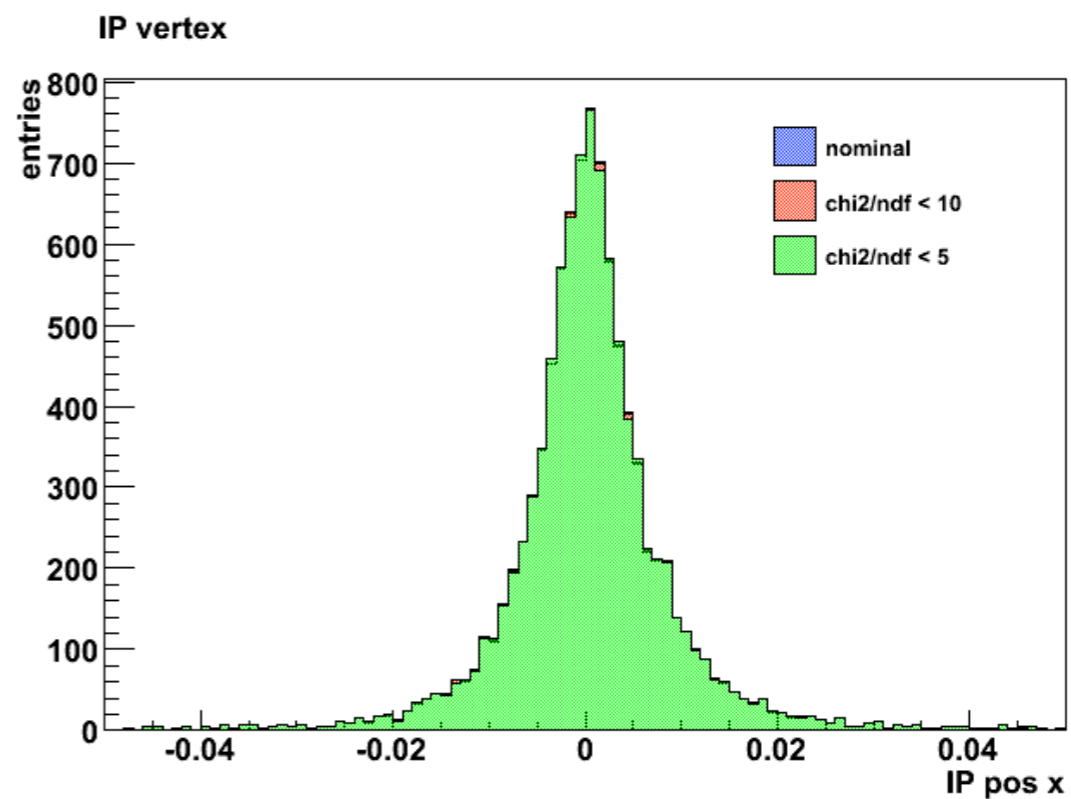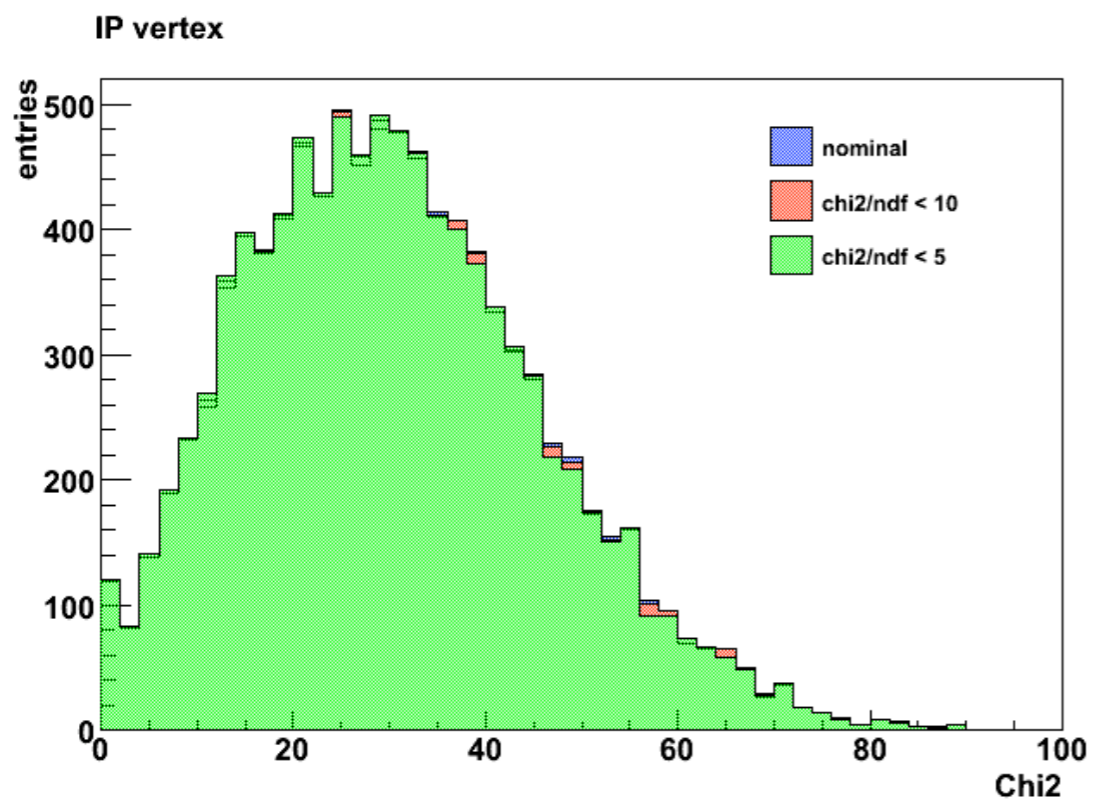 - vertexing and flavour tag inputs: ConversionTagger

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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
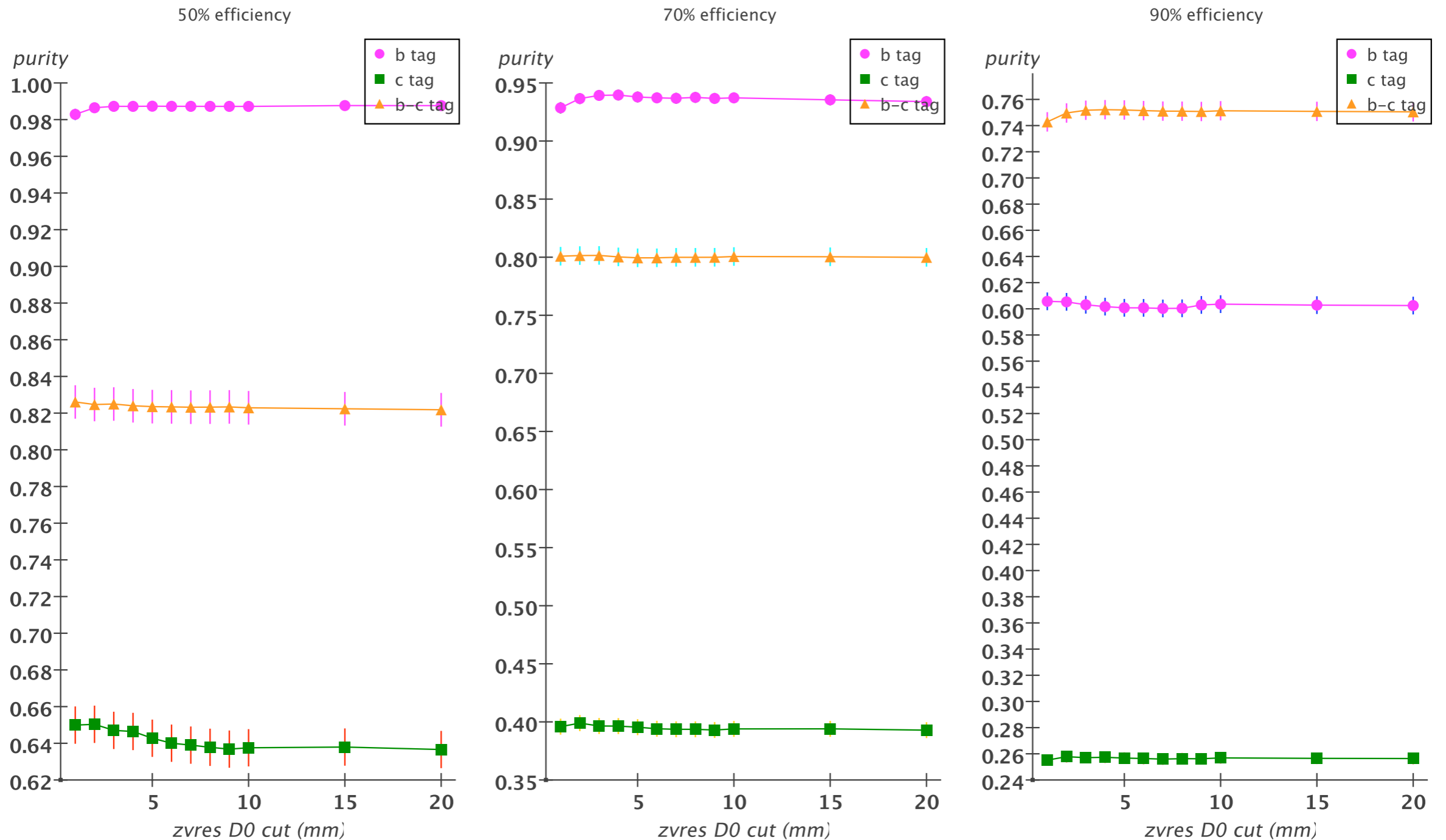
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IPFIT: flavour tag purity as a function of the chi2/ndf of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: no cut
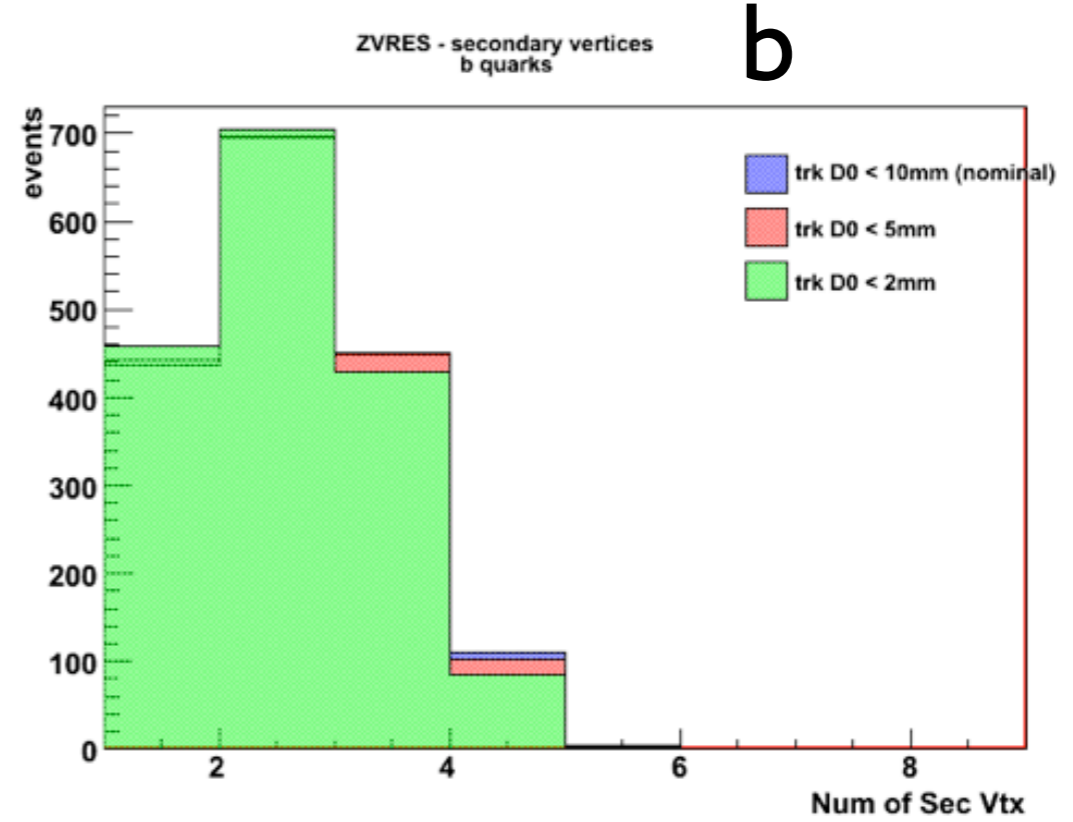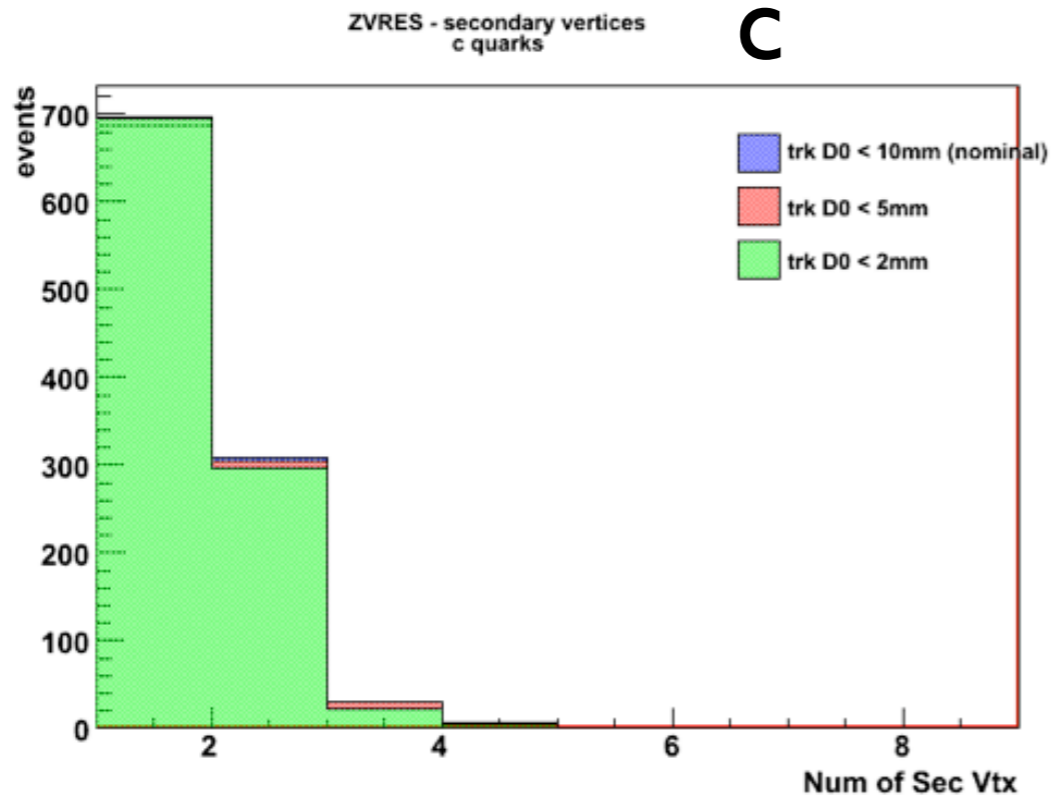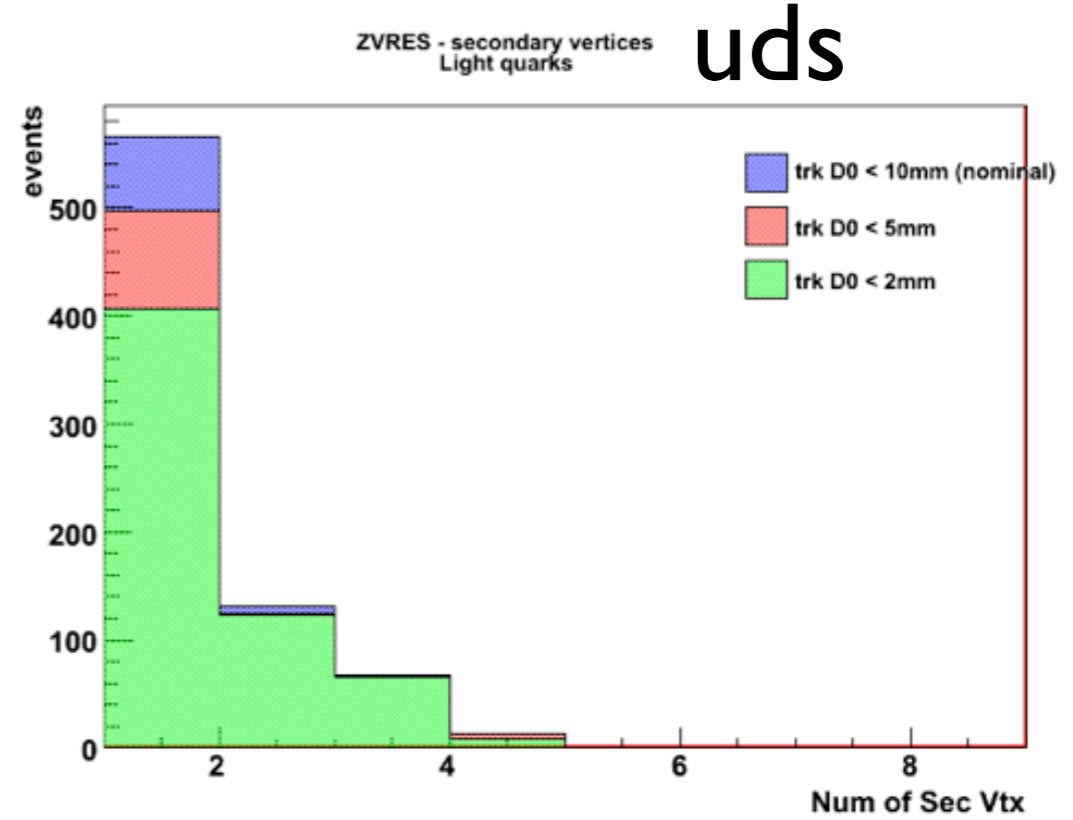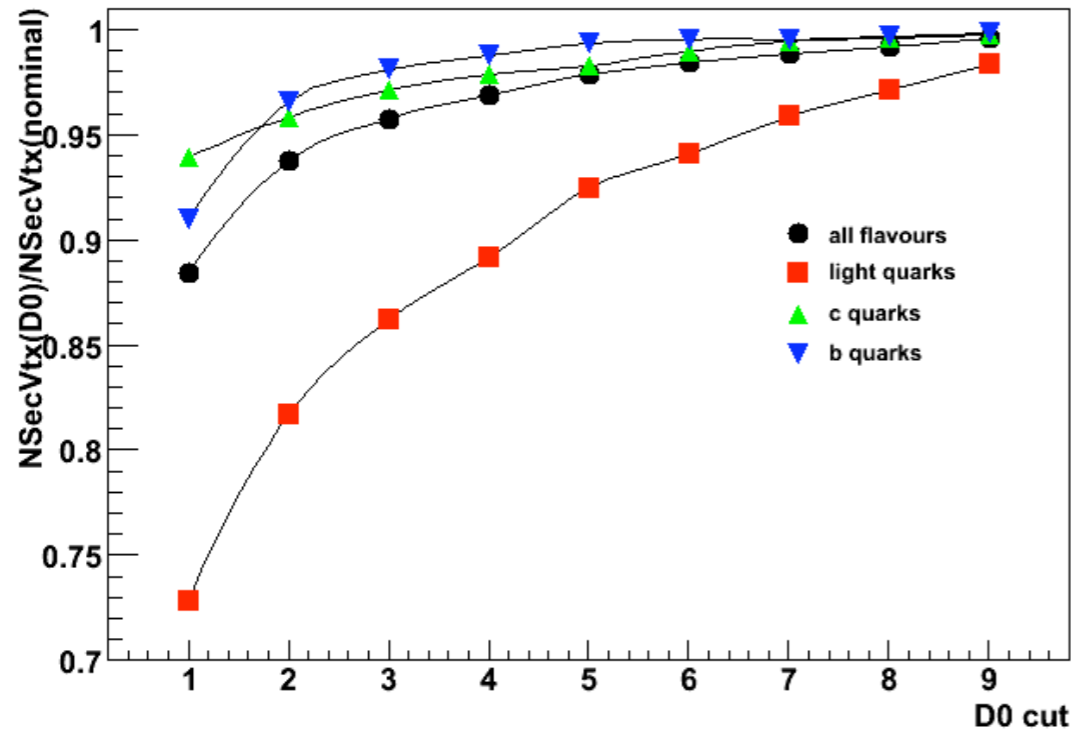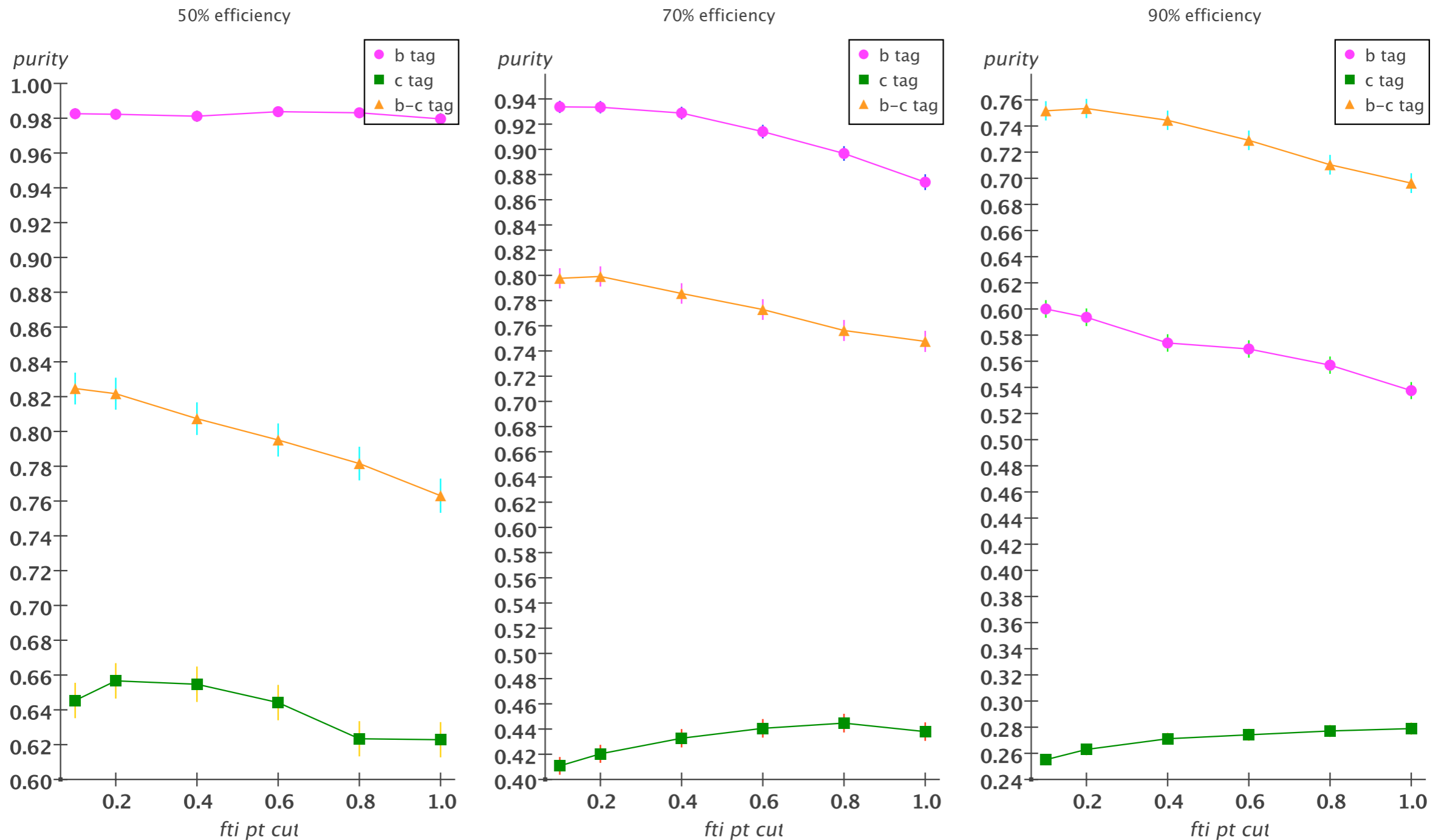
IP vertex (chi2/ndf cut)

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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

50% efficiency

70% efficiency

90% efficiency

ZVRES secondary vertices (d0 cut)

uds

c

b

FTI: flavour tag purity as a function of the pt of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: 0.1 GeV

Track selection tuning

One also has to be careful with correlations...

Considering...

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;

Track selection tuning

Purity (y-axis) vs Efficiency (x-axis) showing b-tag (red), bc-tag (blue), and c-tag (green) curves.

solid: default parameters
open: 'tuned' parameters
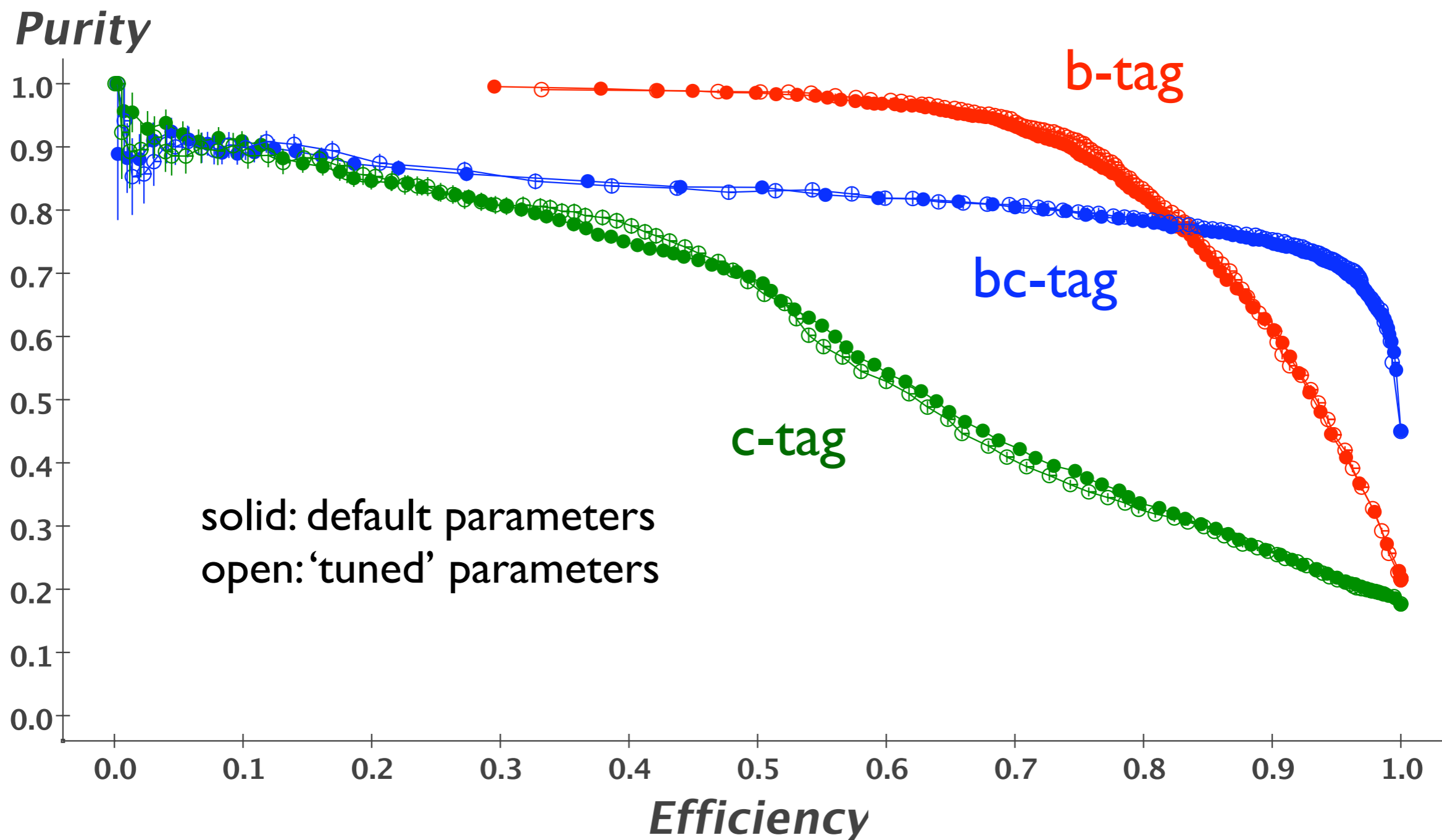
Note: Not using the 'best' set of neural nets.

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Summary & Conclusions

- Tuning of flavour tag is performed for detector model LDCPrime_02Sc:

  - Realistic V0 and photon conversion tagger is used;

  - Parameters for the joint probabilities were recalculated;

  - Neural networks for flavour tagging were trained;

  - Studies on track selection for vertex reconstruction on flavour tag inputs are performed.

Summary & Conclusions

- Realistic V0 and photon conversion tagger and re-trained neural networks give good performance for b- and bc-tag and c-tag at low efficiencies, but c-tag for high efficiencies is lightly degraded.

- Track selection tuning still ongoing. Need to be carefull with correlations. It may not improve the efficiency x purity performance, but tighter cuts should be needed when one considers beam backgrounds.

- More realistic status of the detector description and of the reconstruction software does not imply degradation in flavour tagging performances.

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Extra slides

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ZVTOP vertex finder: ZVRES

- ZVTOP (*D. Jackson, NIM A388, 247*) consists of two branches:
  - ZVRES: General algorithm that can handle arbitrary multi-prong topologies.
    - Each track is represented as a gaussian "probability tube" in 3D where the width of the tube is the error of the track.

    - The track "tubes" are combined into a "vertex probability function". A maximum of this function is searched in 3D-space and the χ^2 of the vertex fit is minimised iteratively.

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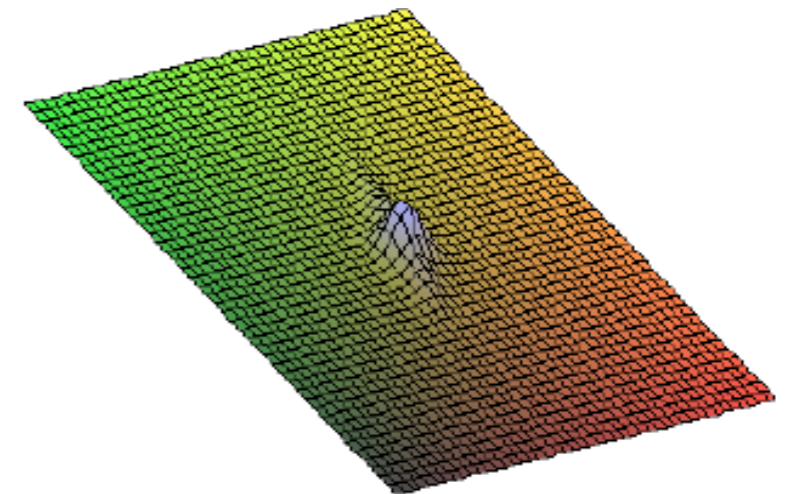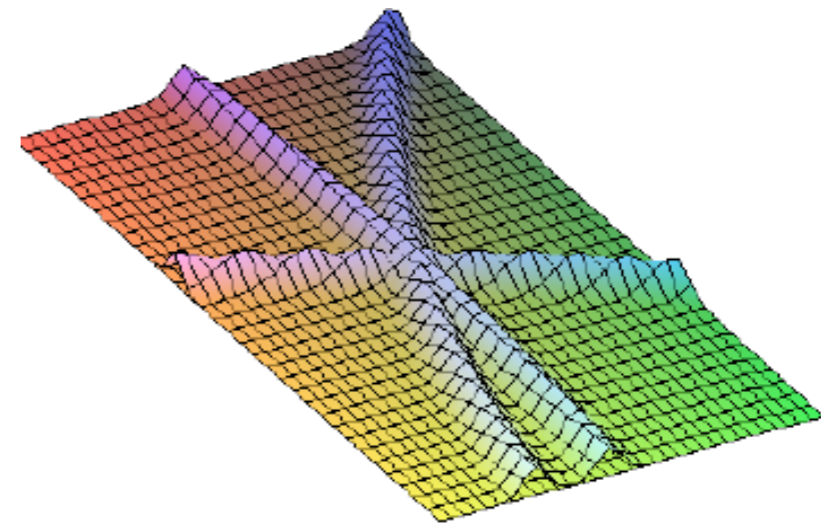
ZVTOP vertex finder: ZVKIN

- ZVKIN (ghost track): Specialised algorithm to reconstruct vertices in b-jets with two subsequent one-prong decays. e.g. in a IP → B → D decay chain.

  - Tracks not associated to any vertex but with small values (~50μm) of the 3D transverse impact parameter T are likely to come from a B decay chain.

  - The best estimate of the direction of flight of the B-hadron is found and a finite width is assigned → "ghost track".

  - The tracks in the jet are combined with the ghost track the IP to build up the decay chain along the ghost direction.

  - Should improve flavour tagging efficiency, as well as the vertex charge determination.

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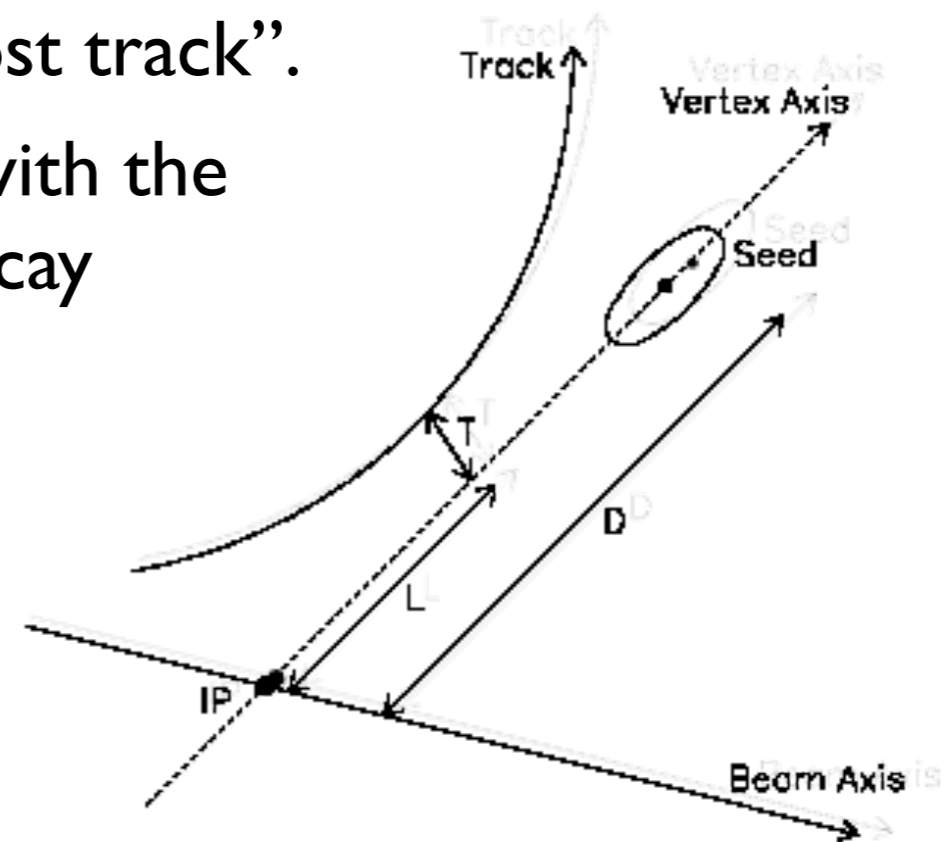
Flavour tagging

- The LCFIVertex package also incorporates a flavour tagging code (*R. Hawkings, LC-PHSM-2000-021*) using a neural network approach to discriminate between b-, c- and uds- or gluon-jets.

- Neural network input variables:

  - secondary vertex is found: p_T corrected mass, momentum, decay length and decay-length significance;

  - only IP is found: momentum and impact parameter significance in R-Φ of the two most significant tracks in the jet;

  - in all cases: joint probability in R-Φ and z (combined probability that each track of a jet comes from the primary vertex) .

39

Flavour tagging

Efficiency-purity for FlavourTag

ee → Z → qq @ 91GeV
Full Monte Carlo - LDC01_05Sc
Full reconstruction

40
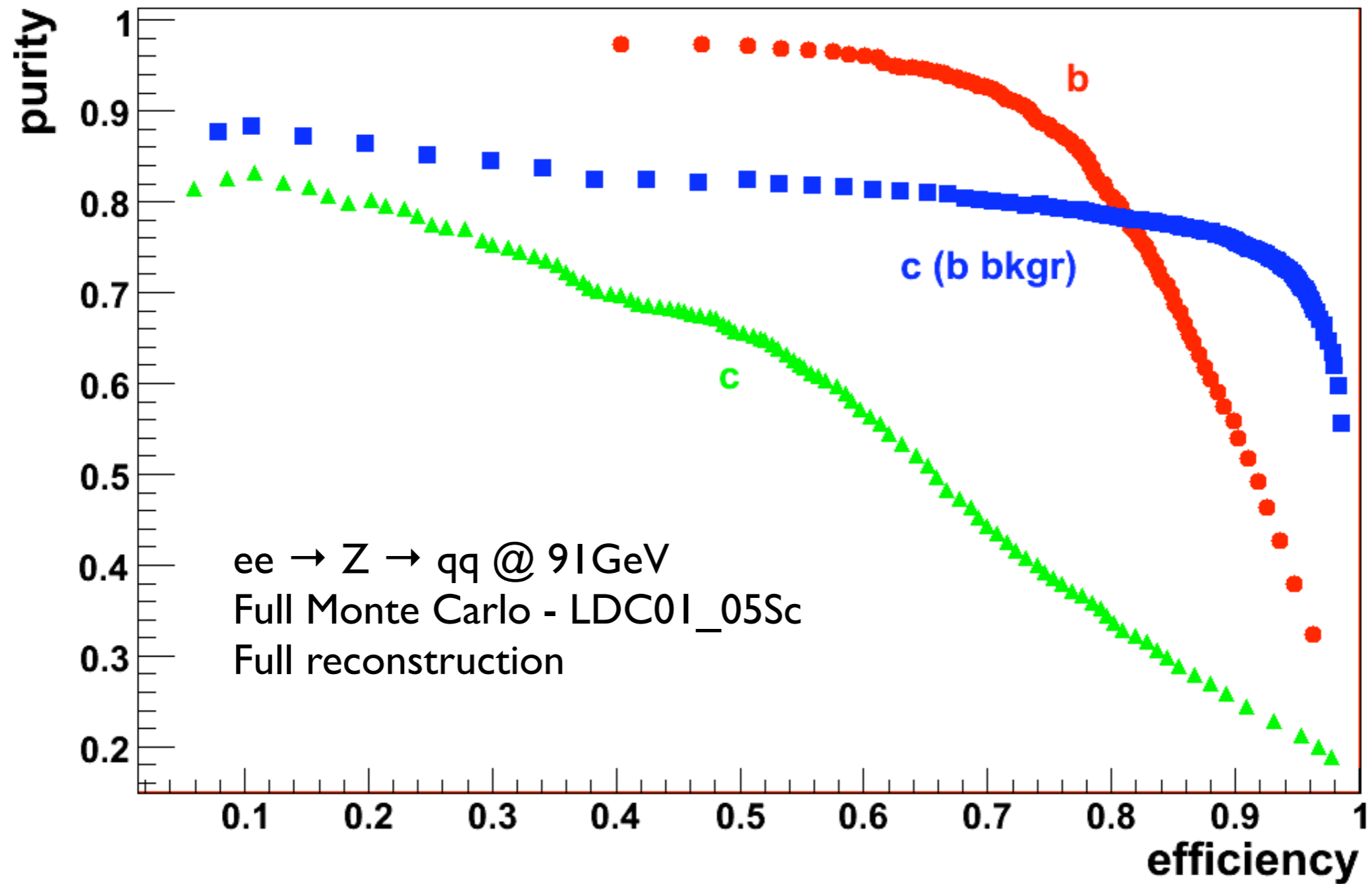
Vertex charge

- The vertex charge limited to charged B-hadrons (40% of the b-jets); to reconstruct the vertex charge it is necessary to find all stable tracks from the B-decay chain.

- Probability of mis-reconstruction of the vertex charge is small for both charged and neutral hadrons.

- To extend for neutral B-hadrons, a charge dipole technique is required (under development).
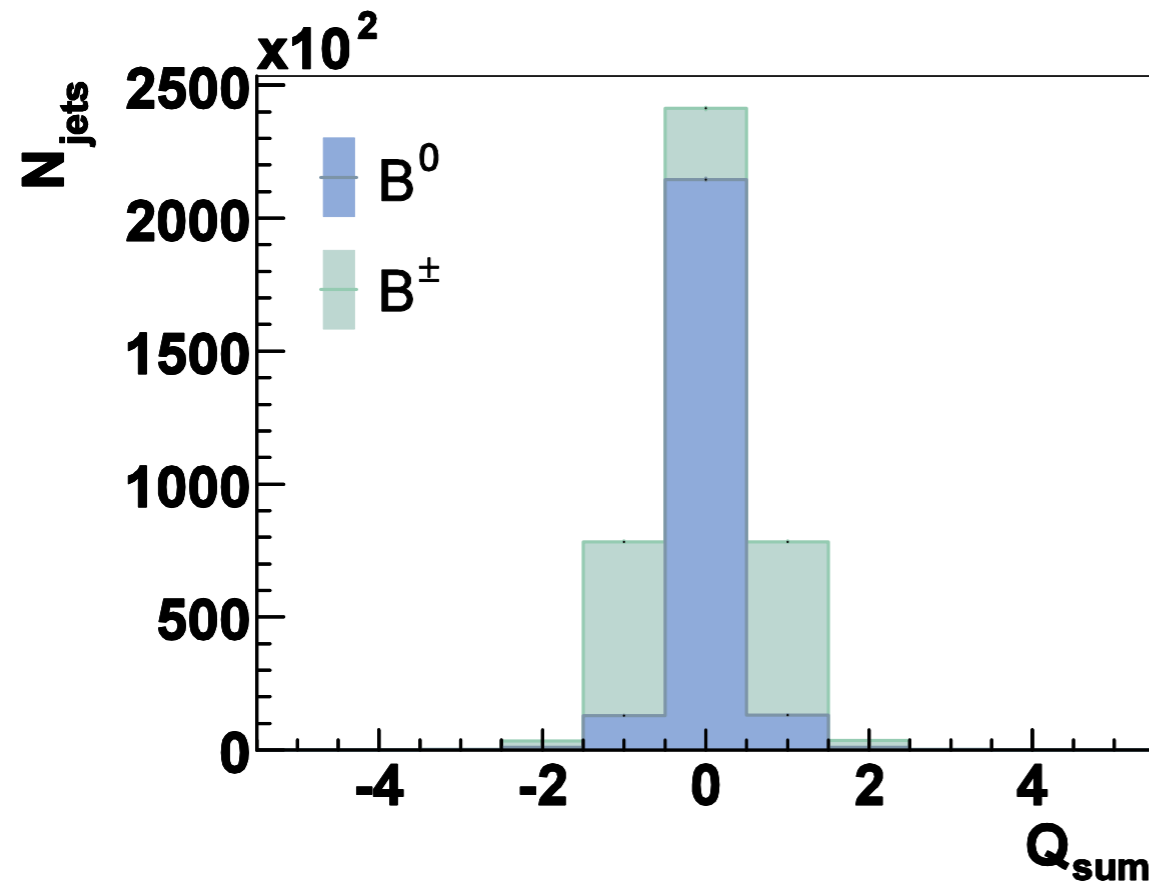
(SGV fast monte carlo sample
ee → Z → qq @ 91GeV)

41

Parameters for Joint Probability

SignificanceFit (Durham_2Jets)

Z->qq, 10000 events
LDCPrime_02Sc

ILC SOFT v01-03-06-p02, LCFIVertex HEAD,
V0+conversion tagger

r-phi: Chi2 = 1.97

43

SignificanceFit (Durham_2Jets)

Z->qq, 10000 events
LDCPrime_02Sc

ILC SOFT v01-03-06-p02, LCFIVertex HEAD,
V0+conversion tagger

z: Chi2 = 2.49

44
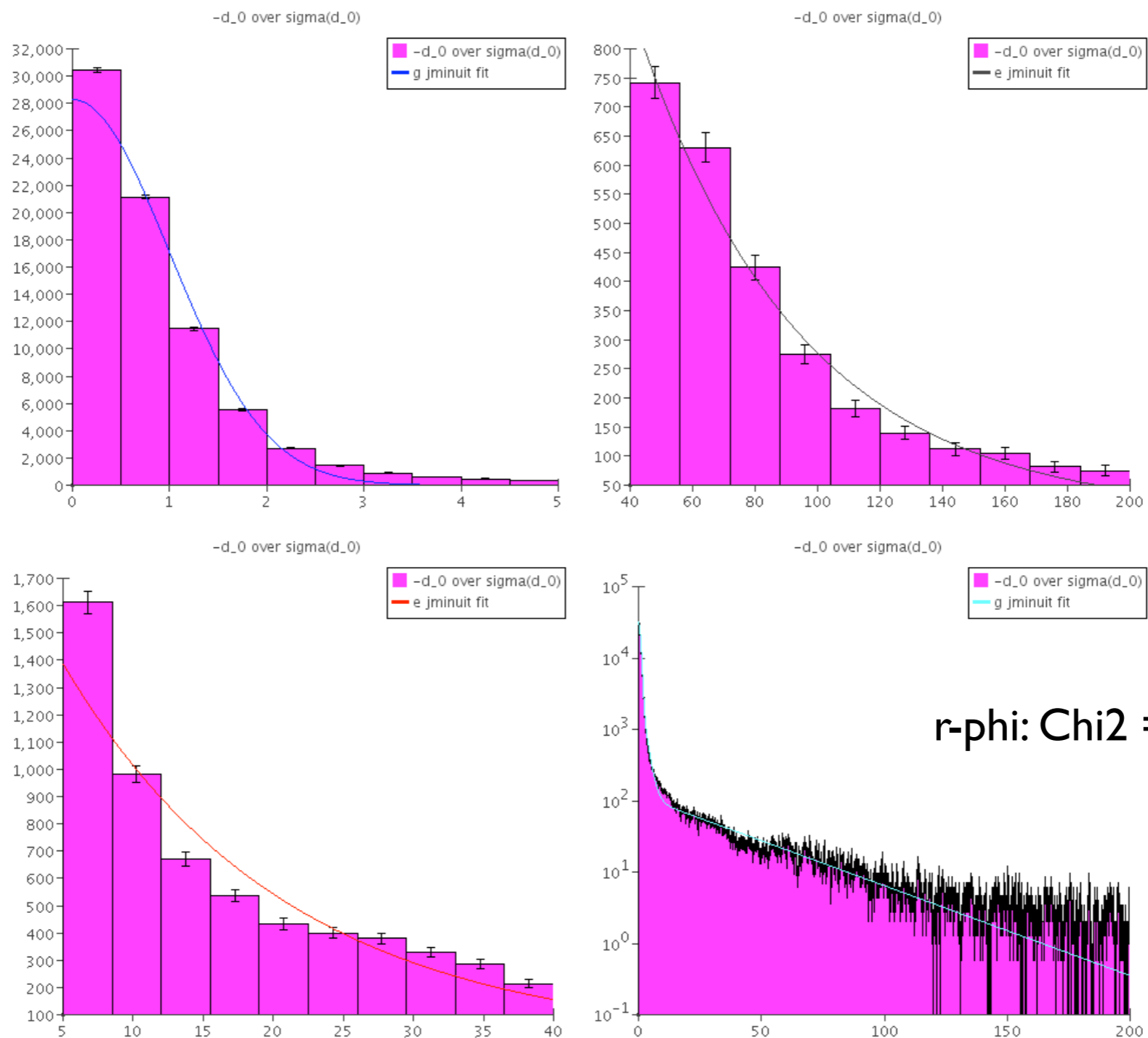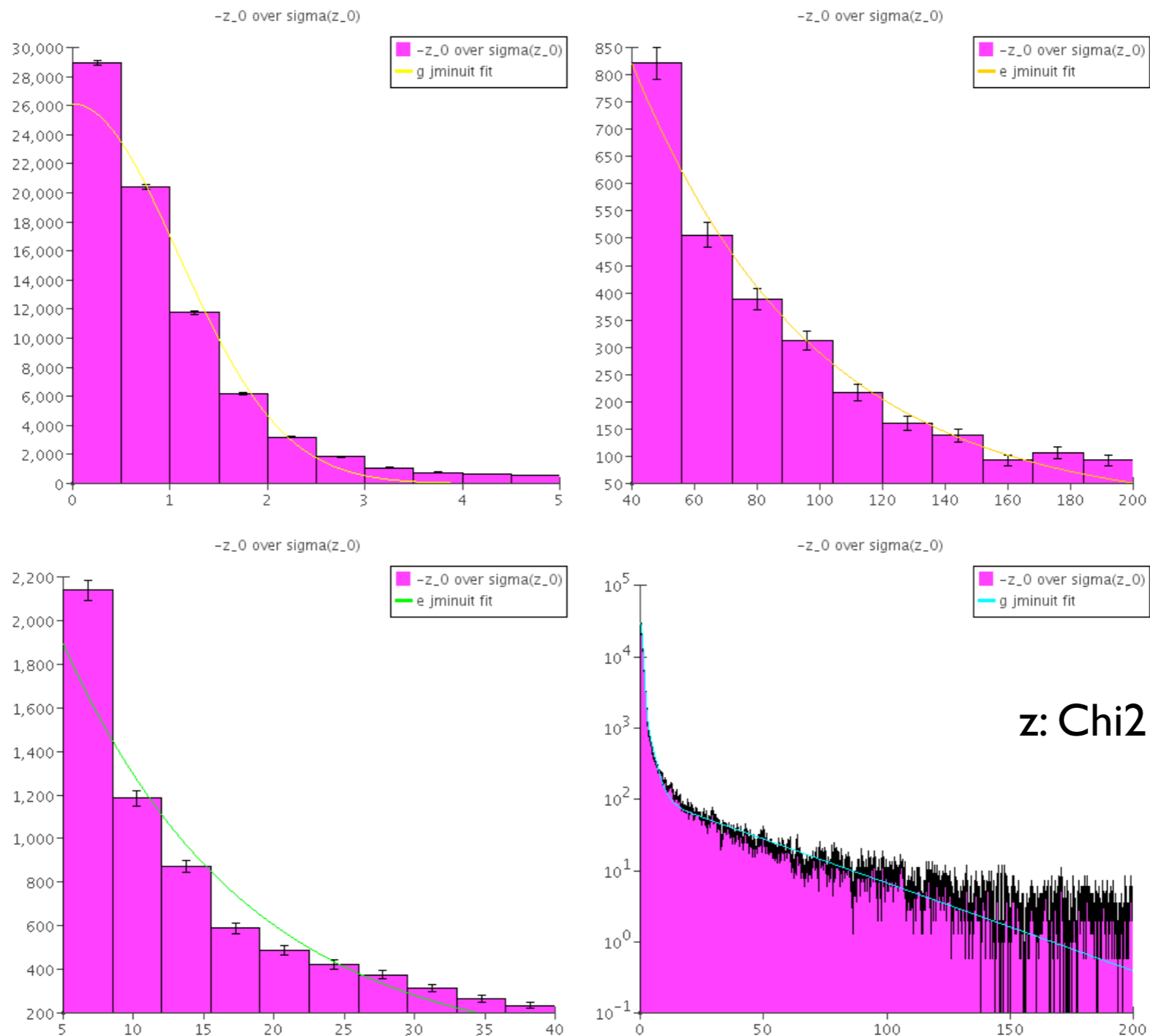
SignificanceFit (Durham_2Jets)

Zooming the global fit

d0

z0
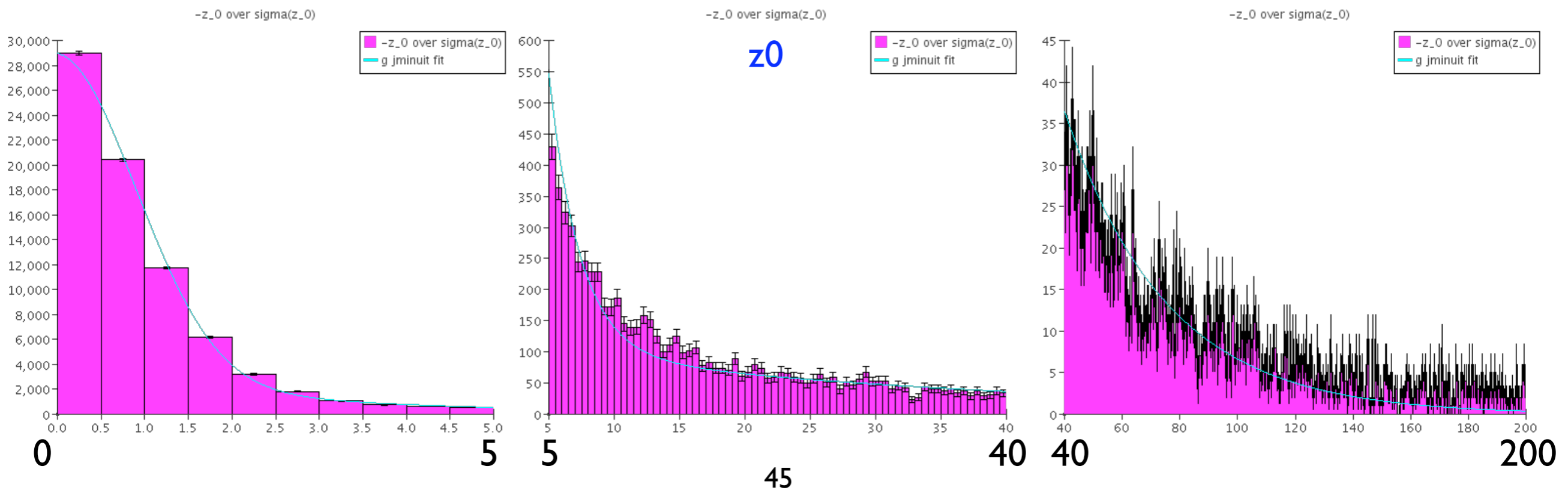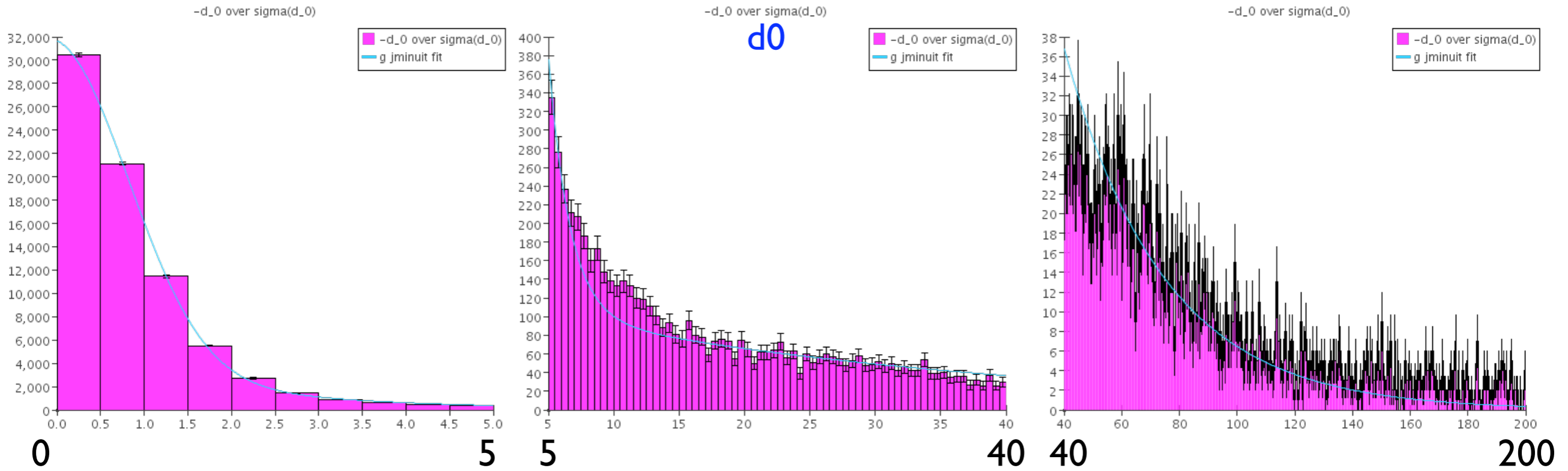
SignificanceFit (Durham_2Jets)

Fit results

```
  RPHI - Plane

Local Fit of Gaussian
Parameter    amplitude    28282.4
Parameter    mean      -9.27832e-11
Parameter    sigma      0.992607
Chi^2/ndf:    460.266
Local Fit of first Exponential
Parameter    amplitude    1893.54
Parameter    exponent    -0.0624859
Chi^2/ndf:    23.2849
Local Fit of second Exponential
Parameter    amplitude    1876.12
Parameter    exponent    -0.0191247
Chi^2/ndf:    5.02206

Global Fit
Parameter    amplitude    25456.5
Parameter    mean      -1.41158e-11
Parameter    sigma      0.843068
Parameter    amplitude_1    6082.21
Parameter    exponent    -0.619891
Parameter    amplitude_2    117.321
Parameter    exponent_2    -0.0290308
Chi^2/ndf:    1.97361
```

```
  Z - axis

Local Fit of Gaussian
Parameter    amplitude    26119.1
Parameter    mean      -8.87055e-11
Parameter    sigma      1.07717
Chi^2/ndf:    523.081
Local Fit of first Exponential
Parameter    amplitude    2767.23
Parameter    exponent    -0.0762036
Chi^2/ndf:    30.195
Local Fit of second Exponential
Parameter    amplitude    1642.4
Parameter    exponent    -0.0173515
Chi^2/ndf:    5.48903

Global Fit
Parameter    amplitude    25143.4
Parameter    mean      -6.88864e-11
Parameter    sigma      0.910629
Parameter    amplitude_1    3706.92
Parameter    exponent    -0.422501
Parameter    amplitude_2    113.437
Parameter    exponent_2    -0.028365
Chi^2/ndf:    2.49354
```

Parameters for Joint Probability

original ⟶ new (LDCPrime_02Sc, Durham_2Jets)

```
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
```

```
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
```

Talini's LDC01_05Sc

```
PARAMETERS FOR RPHI Joint Probability
 1.01498
 0.27984
 0.561155
 0.00601934
 0.0476549
PARAMETERS FOR Z Joint Probability
 1.04273
 0.27057
 0.468457
 0.00631426
 0.0479484
```

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Neural networks training

Neural nets training

- The random nature of the networks training produces fluctuations (up to ~2 sigma) in the efficiency x purity plots.

- Perform a certain number of training and pick the networks that give the best results.

- Four sets for each network of training are ready. Reconstruction ongoing.

Neural nets training

- C-TAG

any vtx

2 vtx

1 vtx

+3 vtx

50
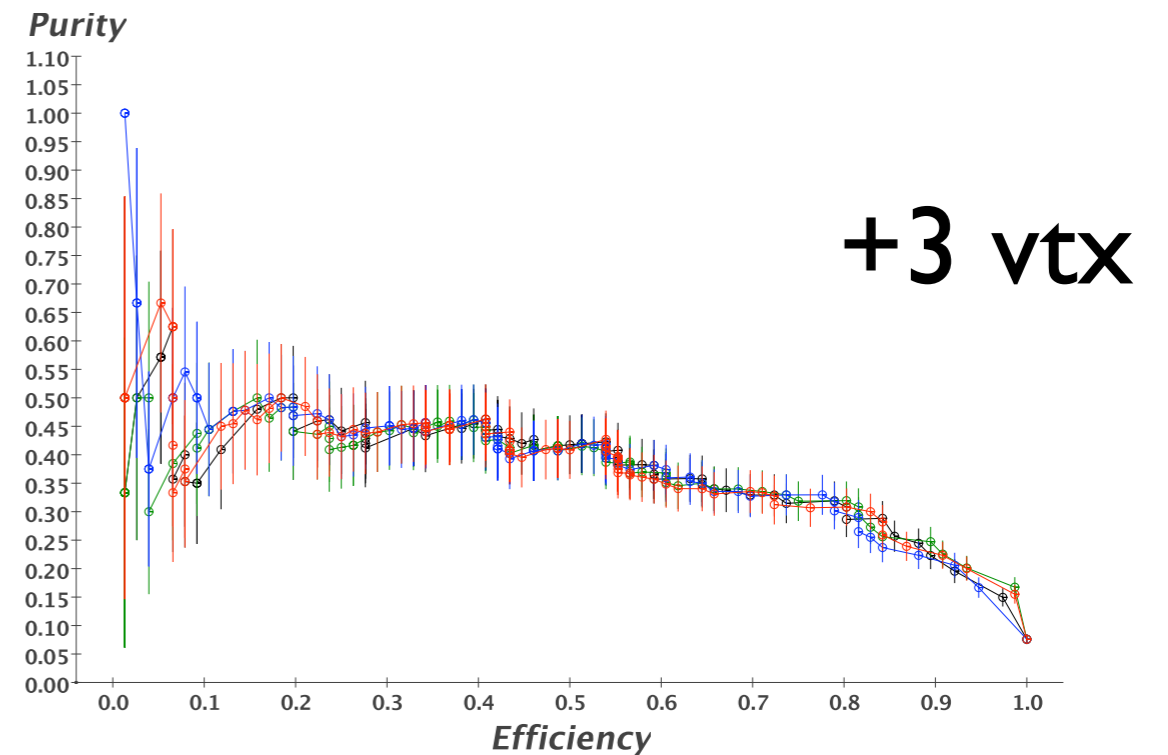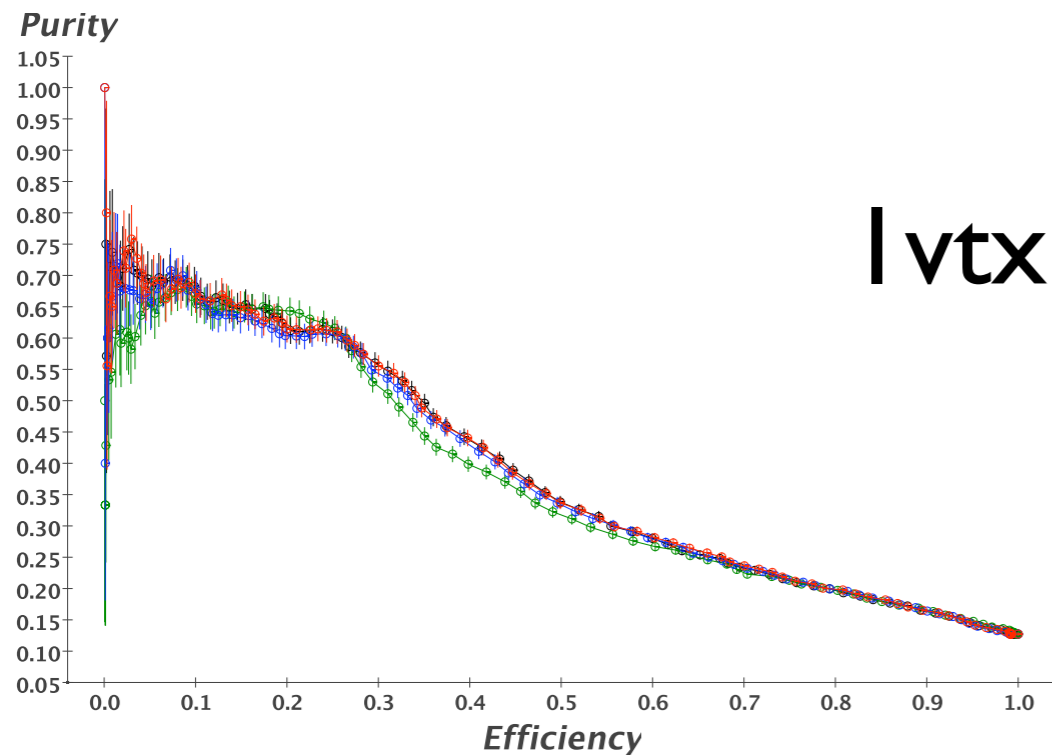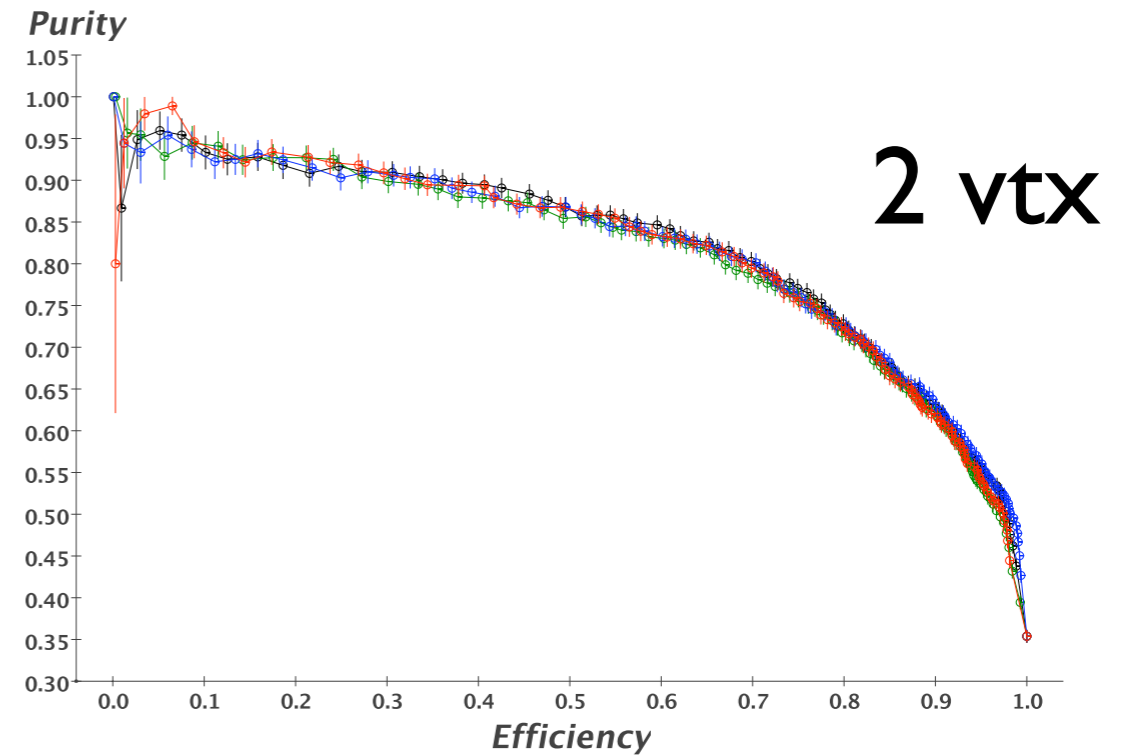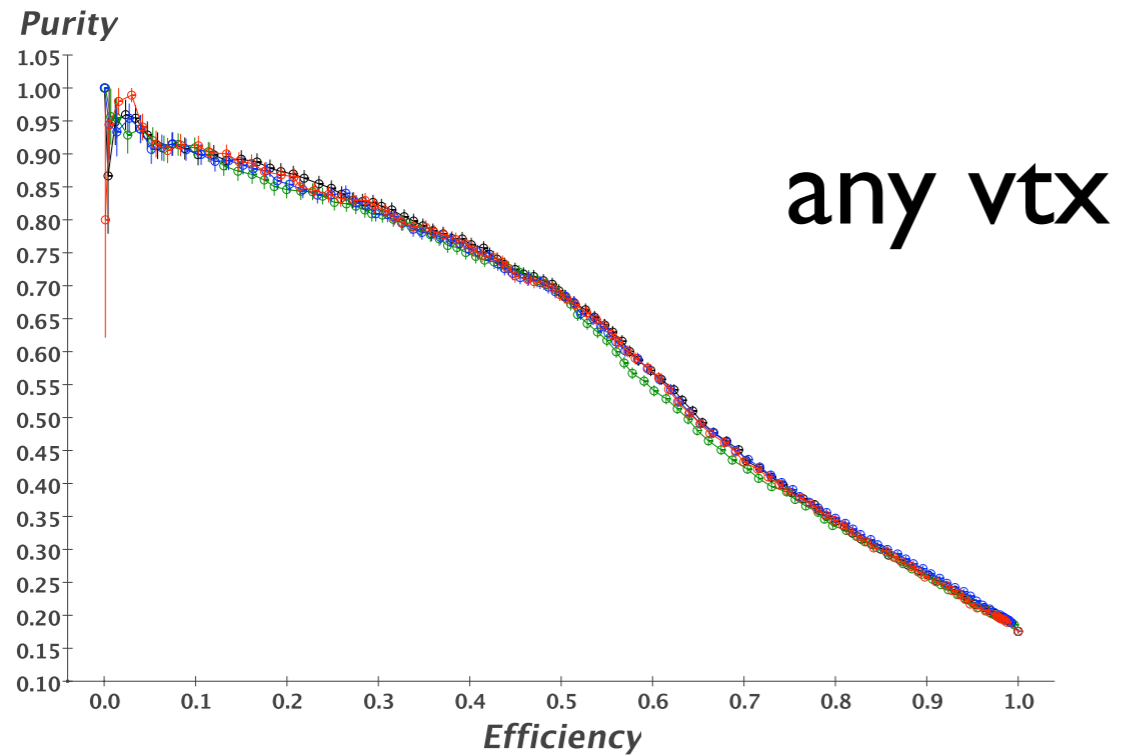
Neural nets training

- BC-TAG

any vtx

2 vtx

1 vtx

+3 vtx

51
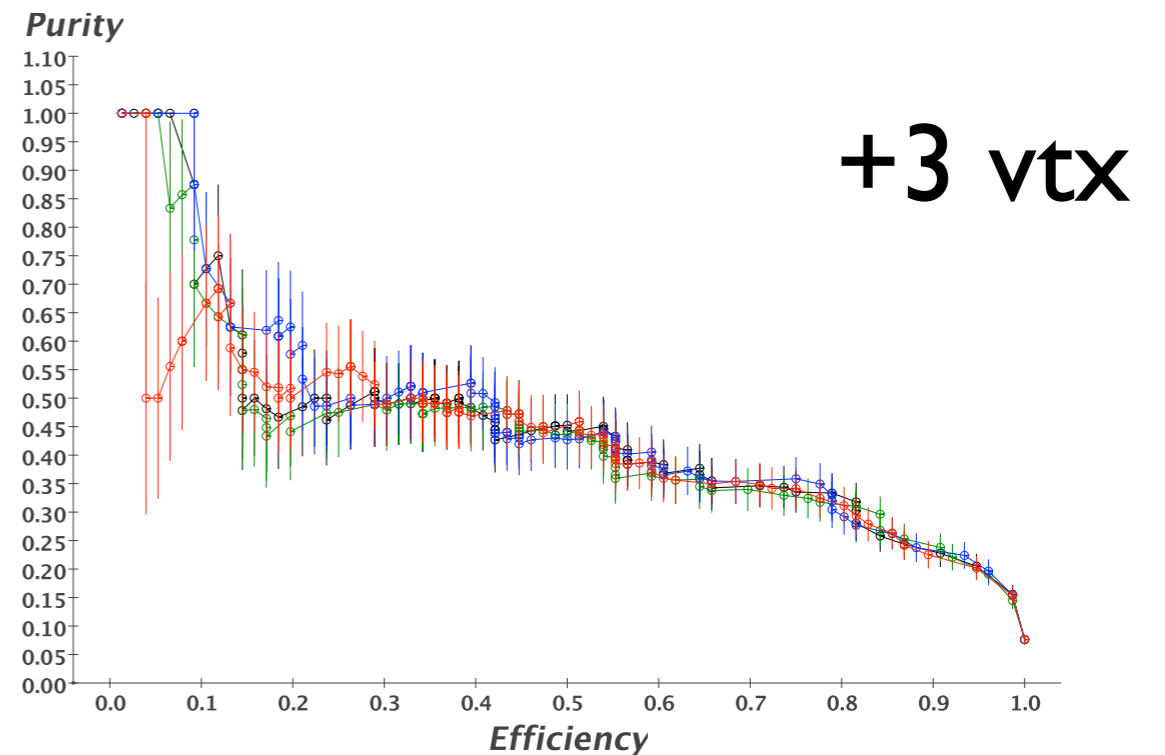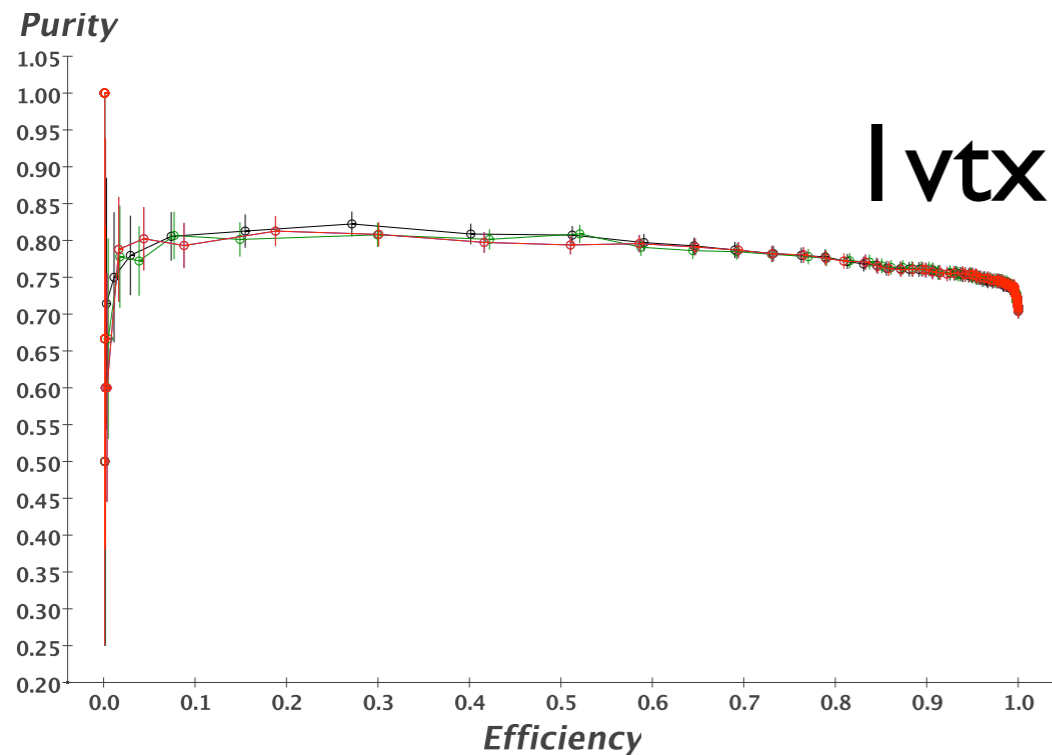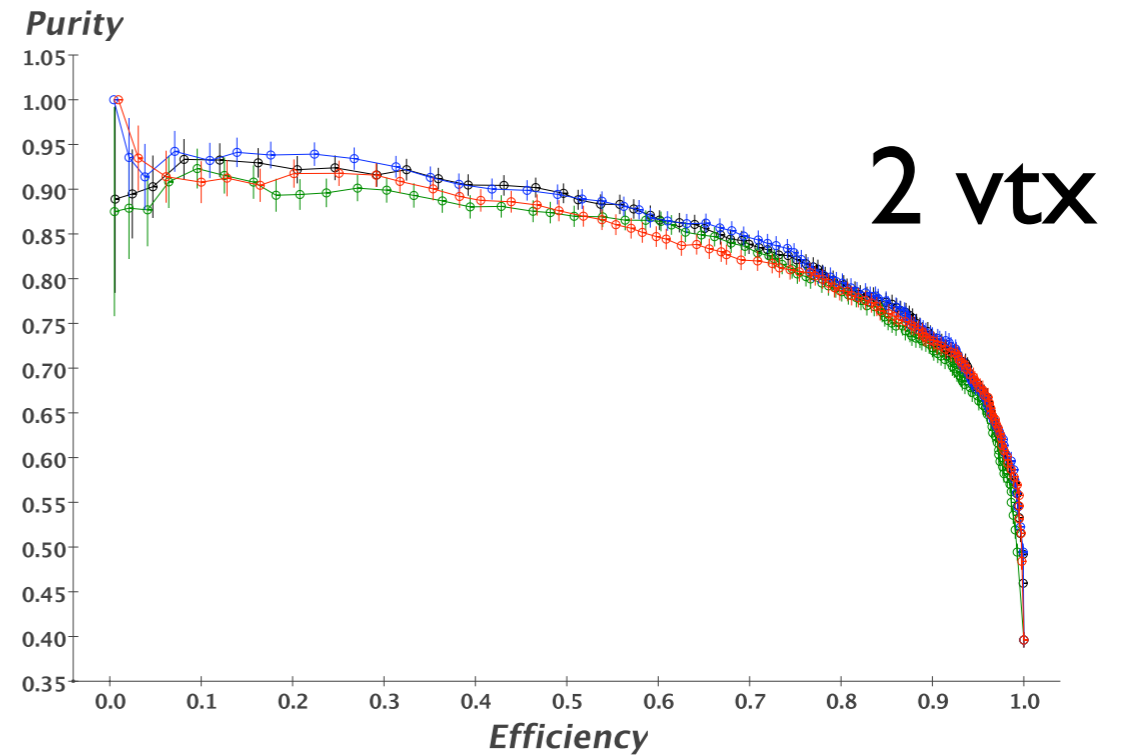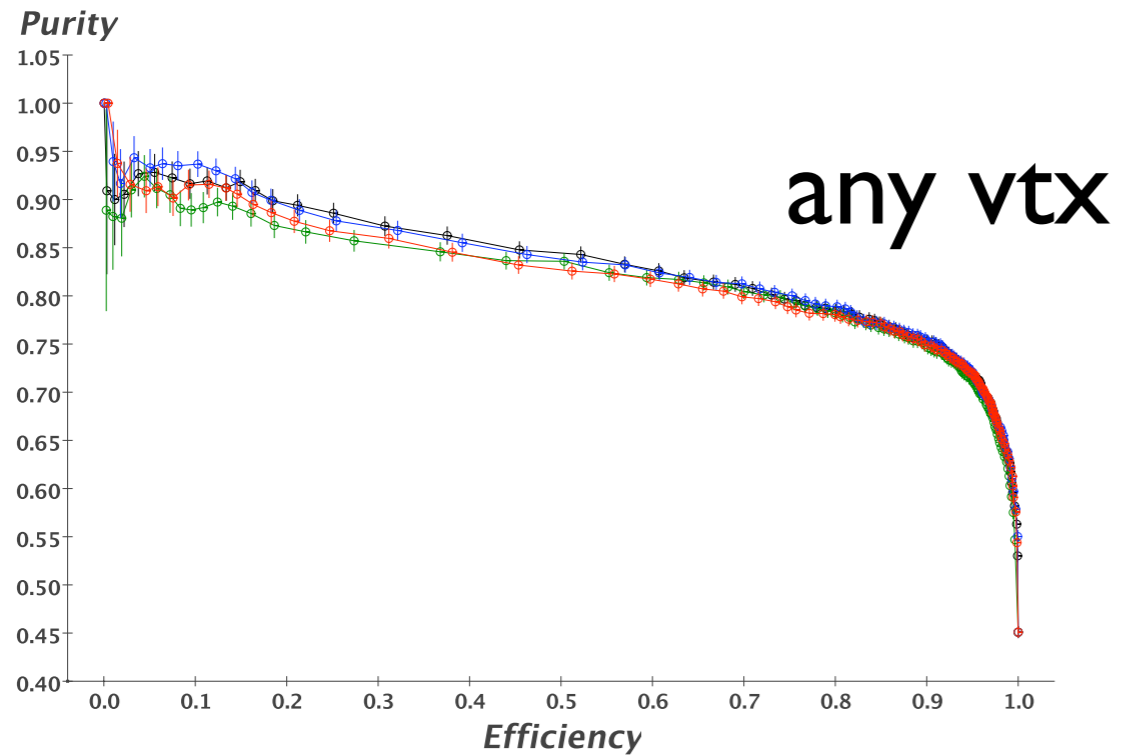
Neural nets training

- B-TAG

Neural Nets re-training

- Neural nets after retraining 1-vtx

MyLCFIAIDAPlotProcessor – FlavourTag_2Jets – OneVertex

Legend:
- LCFIPlots-old_JPP+old_NN-NoV0Veto.aida – Purity-Efficiency for B-Tag (OneVertex)
- LCFIPlots-old_JPP+old_NN-NoV0Veto.aida – Purity-Efficiency for BC-Tag (OneVertex)
- LCFIPlots-old_JPP+old_NN-NoV0Veto.aida – Purity-Efficiency for C-Tag (OneVertex)
- LCFIPlots-new_JPP_DU+new_NN_DU_nnets2.aida – Purity-Efficiency for B-Tag (OneVertex)
- LCFIPlots-new_JPP_DU+new_NN_DU_nnets2.aida – Purity-Efficiency for BC-Tag (OneVertex)
- LCFIPlots-new_JPP_DU+new_NN_DU_nnets2.aida – Purity-Efficiency for C-Tag (OneVertex)

solid: new NN
open: SGV

Neural Nets re-training

- Neural nets after retraining 2-vtx

solid: new NN
open: SGV

MyLCFIAIDAPlotProcessor – FlavourTag_2Jets – TwoVertices

- LCFIPlots–old_JPP+old_NN–NoV0Veto.aida – Purity–Efficiency for B–Tag (TwoVertices)
- LCFIPlots–old_JPP+old_NN–NoV0Veto.aida – Purity–Efficiency for BC–Tag (TwoVertices)
- LCFIPlots–old_JPP+old_NN–NoV0Veto.aida – Purity–Efficiency for C–Tag (TwoVertices)
- LCFIPlots–new_JPP_DU+new_NN_DU_nnets2.aida – Purity–Efficiency for B–Tag (TwoVertices)
- LCFIPlots–new_JPP_DU+new_NN_DU_nnets2.aida – Purity–Efficiency for BC–Tag (TwoVertices)
- LCFIPlots–new_JPP_DU+new_NN_DU_nnets2.aida – Purity–Efficiency for C–Tag (TwoVertices)

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Neural Nets re-training

- Neural nets after retraining +3-vtx

solid: new NN
open: SGV

Flavour tag inputs

Impact parameter significance

- Most significant track

SGV - line; Mokka - histo

LDCPrime_02Sc
cheat - line; ConvTag - histo
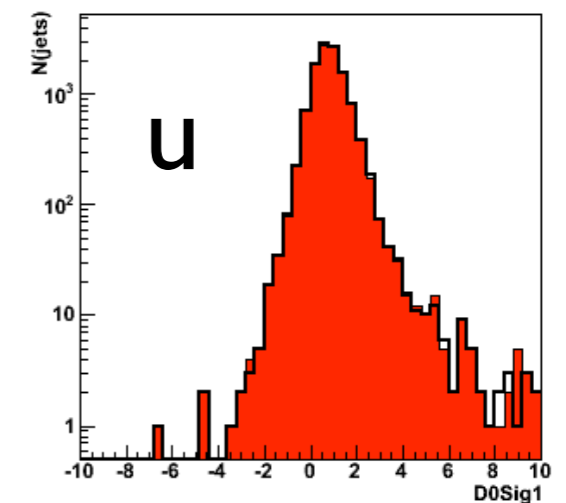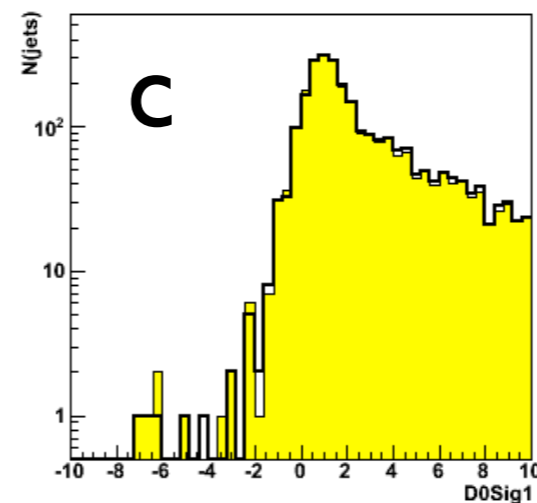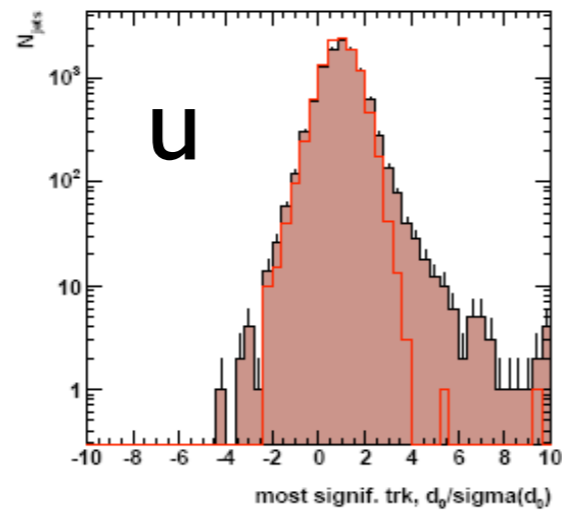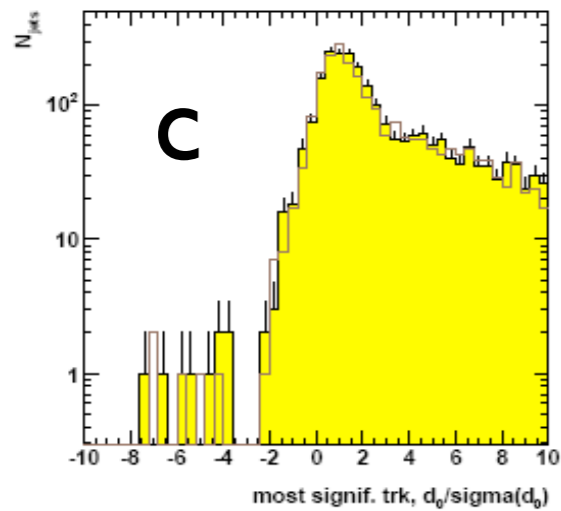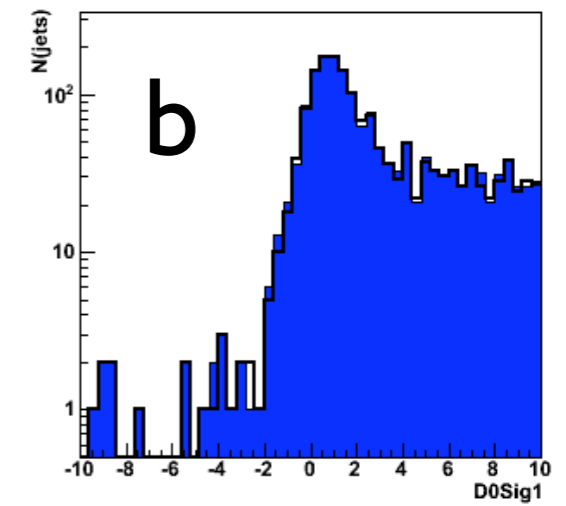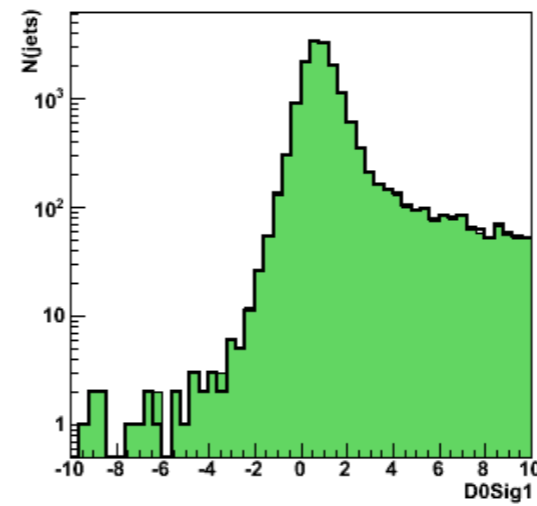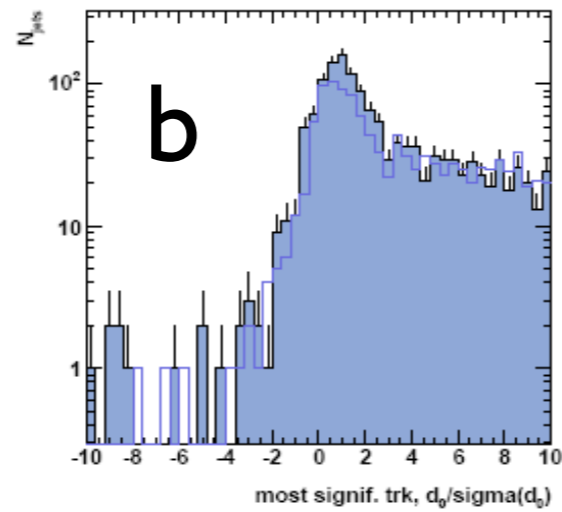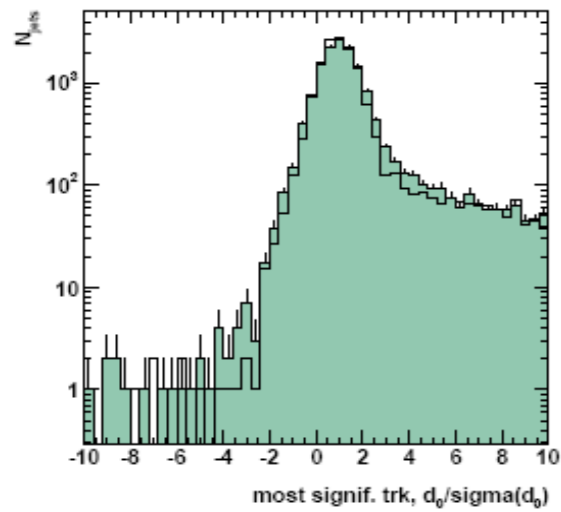
Impact parameter significance

- Second most significant track

SGV - line; Mokka - histo

LDCPrime_02Sc
cheat - line; ConvTag - histo
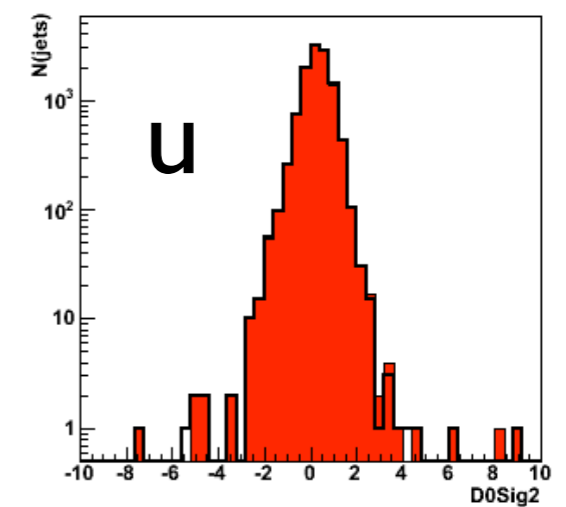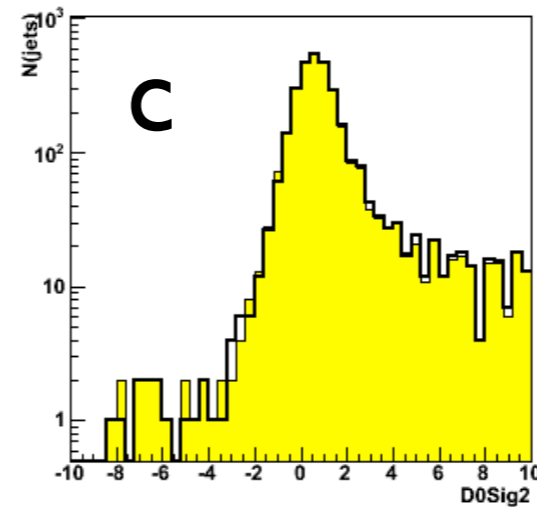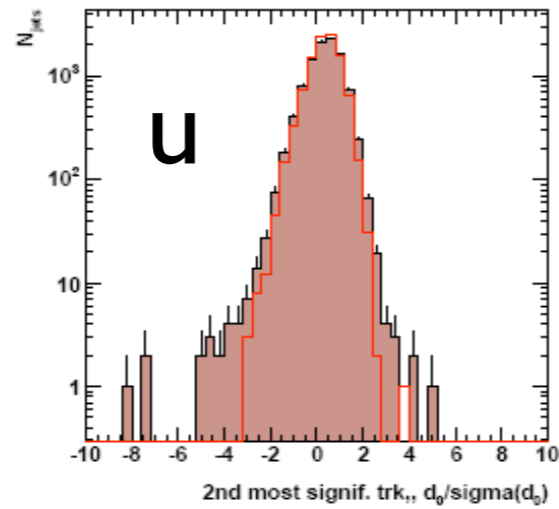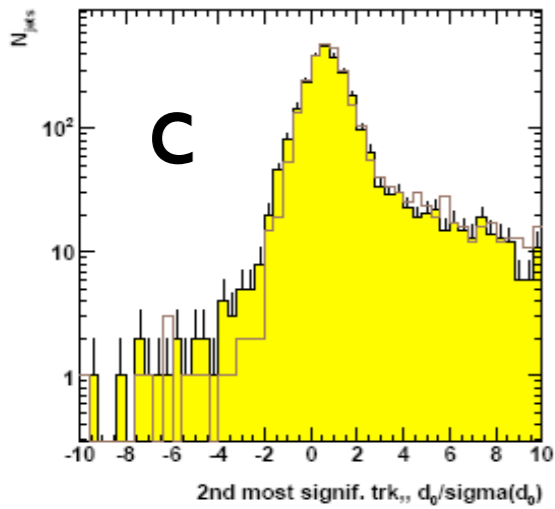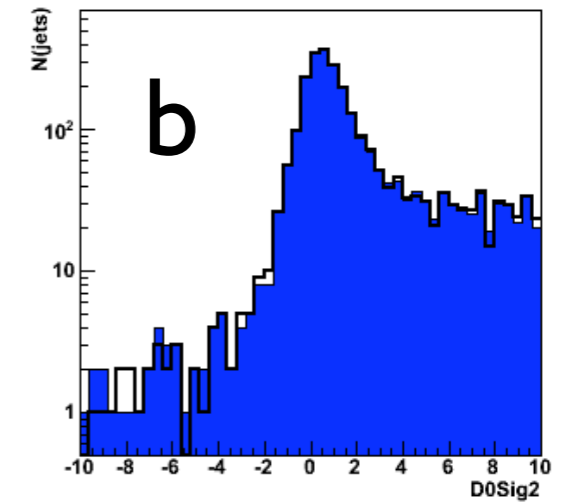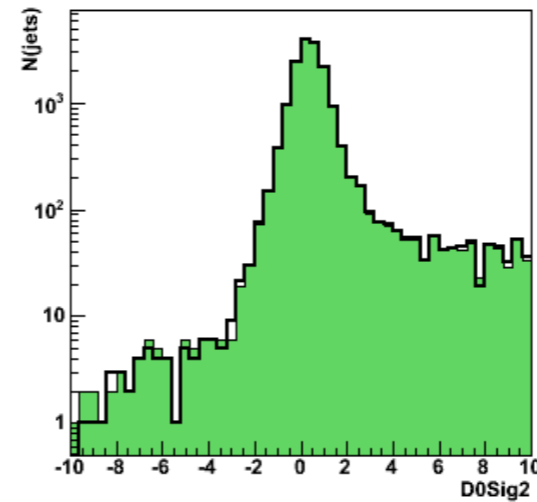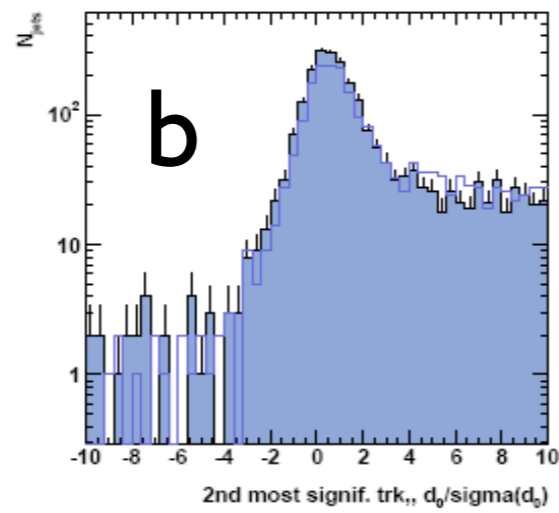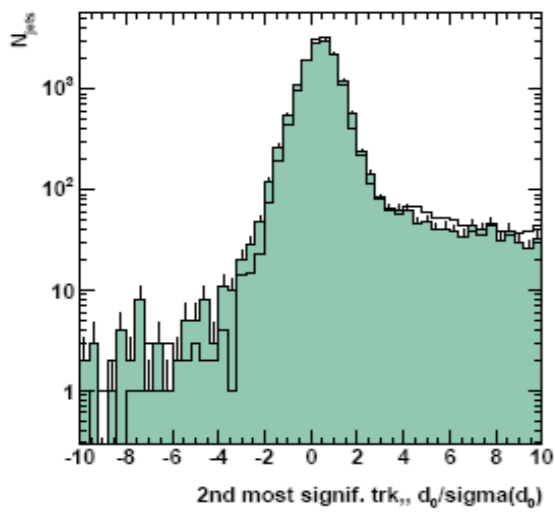
Joint probability

- R-Phi

SGV - line; Mokka - histo

LDCPrime_02Sc
cheat - line; ConvTag - histo
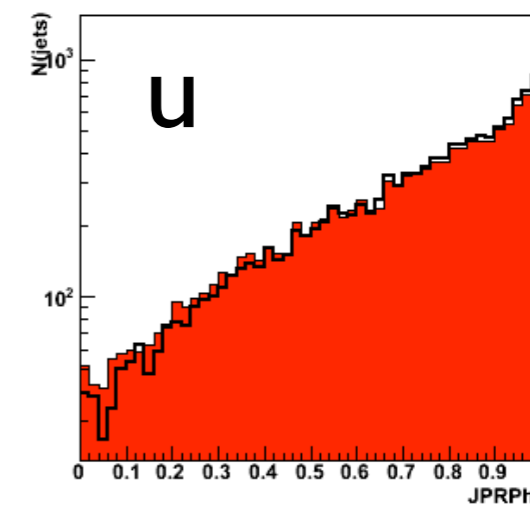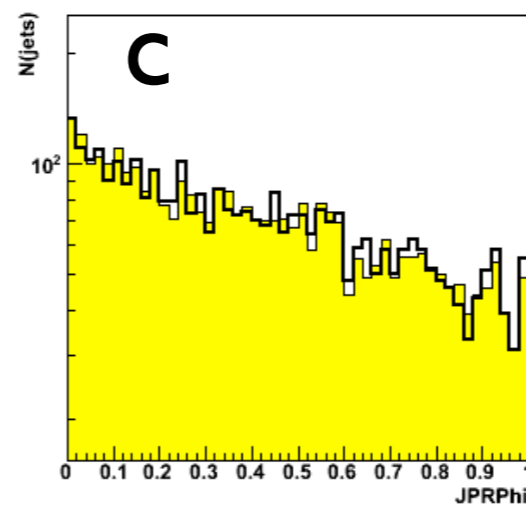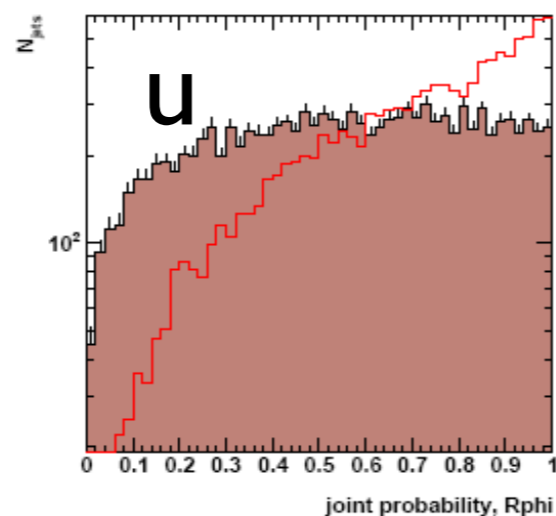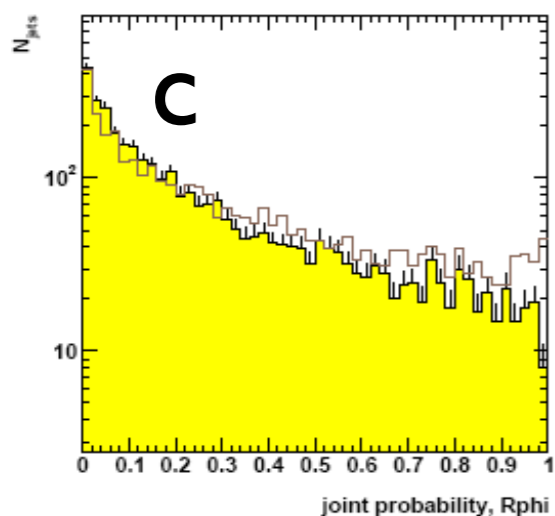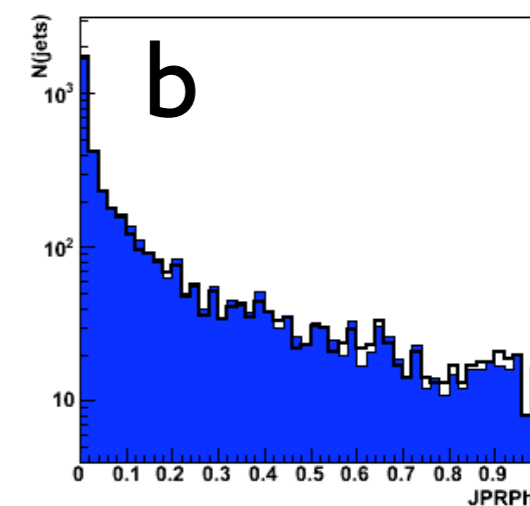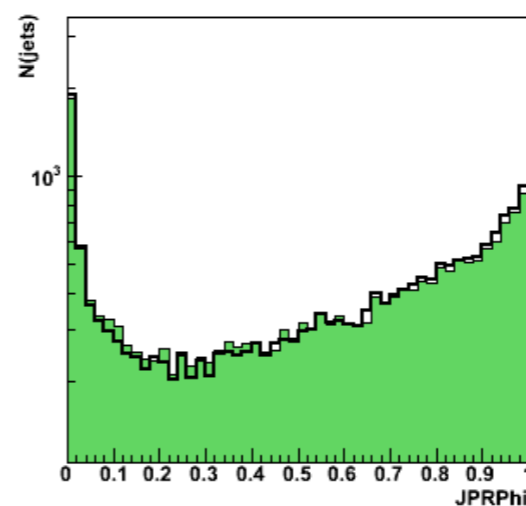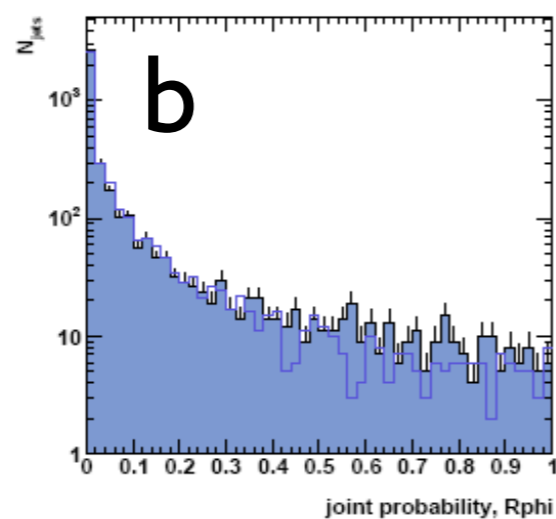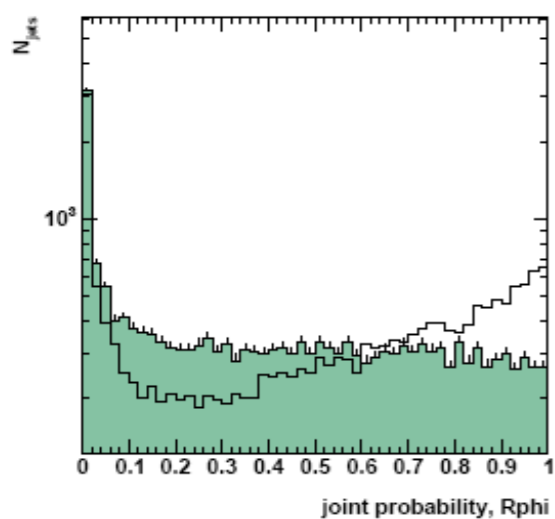
Vertex multiplicity

SGV - line; Mokka - histo

LDCPrime_02Sc
cheat - line; ConvTag - histo
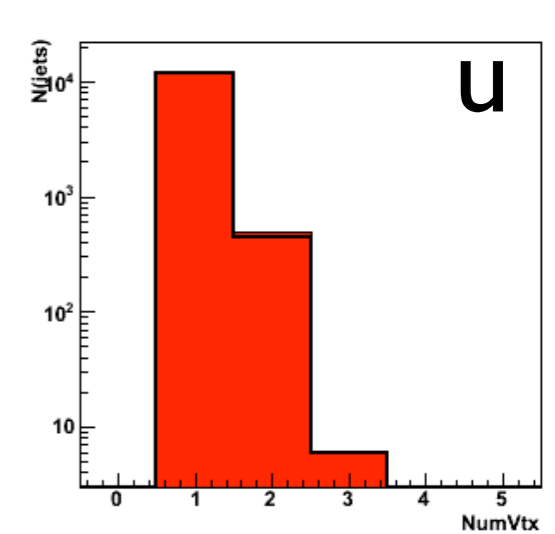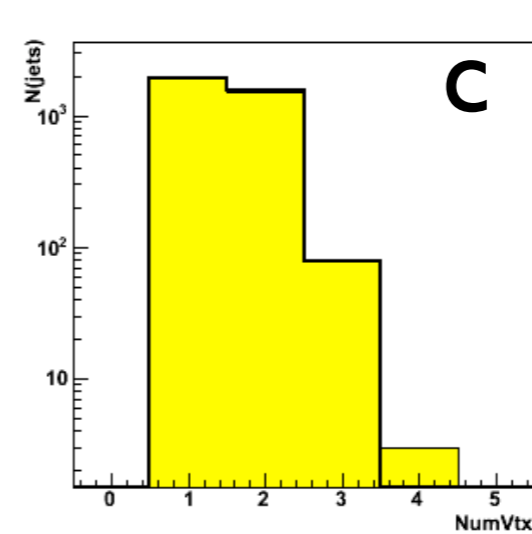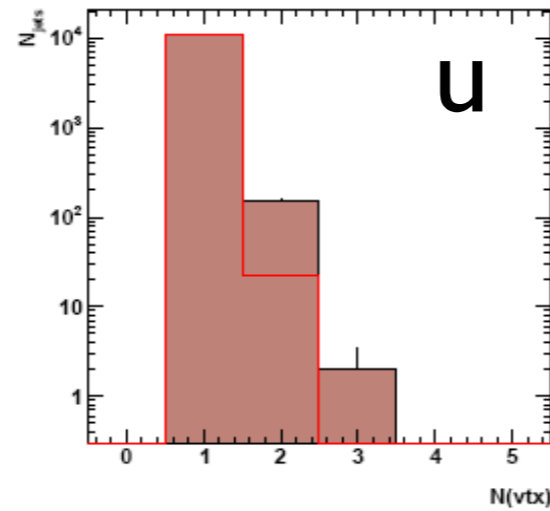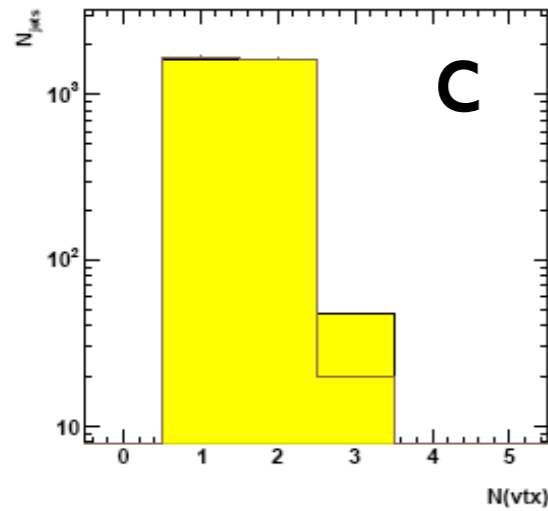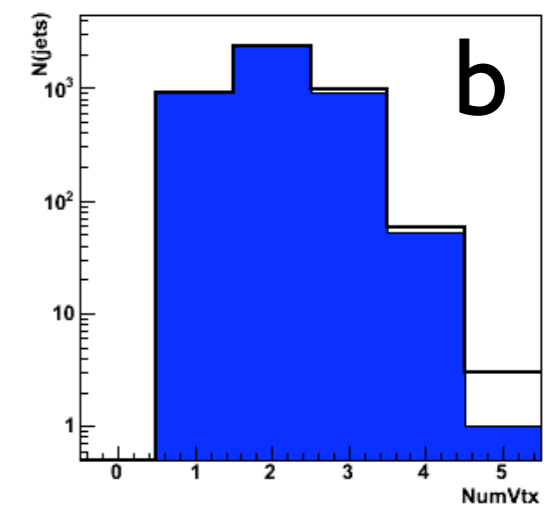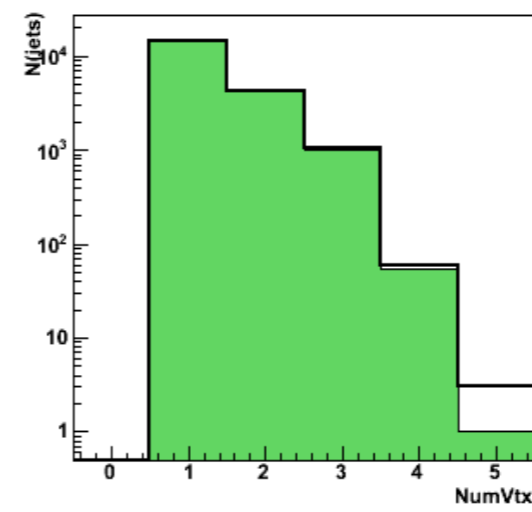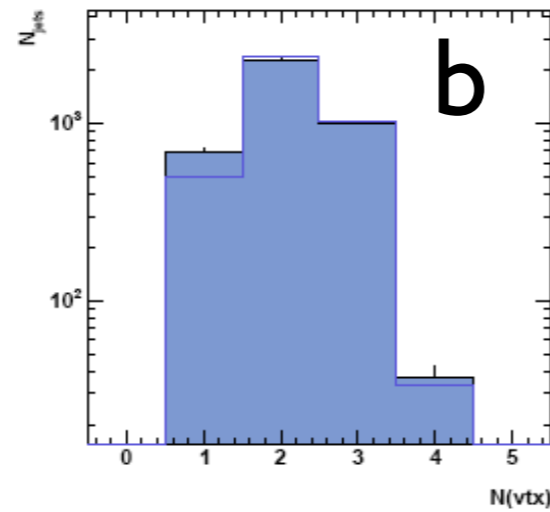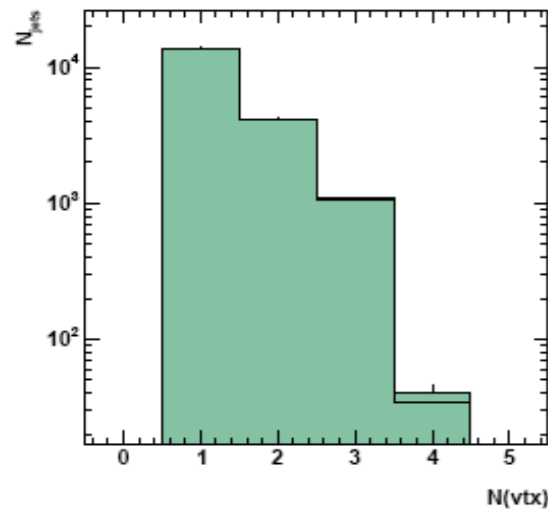
Pt corrected mass

SGV - line; Mokka - histo

LDCPrime_02Sc
cheat - line; ConvTag - histo
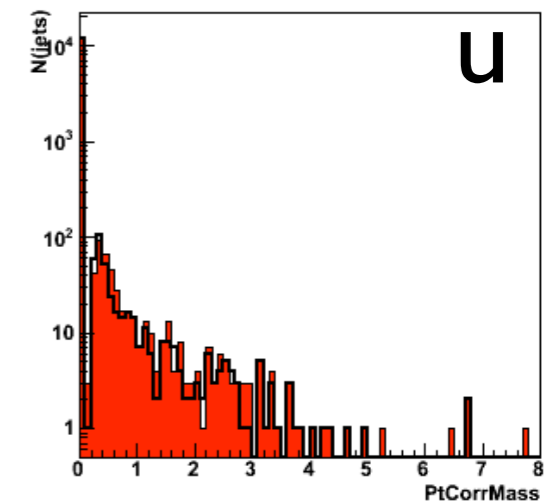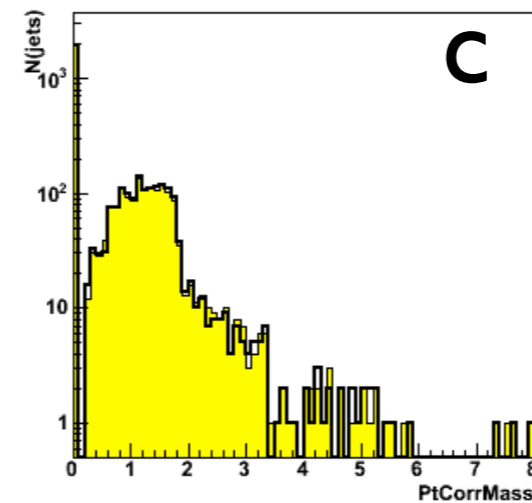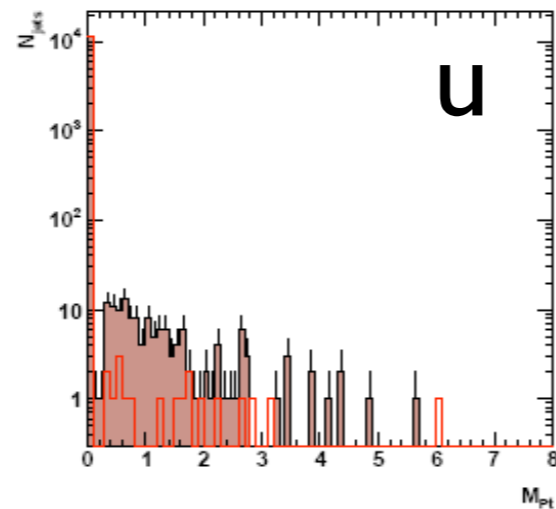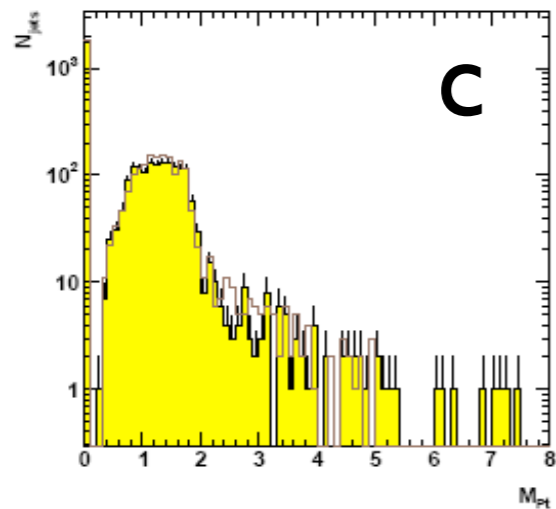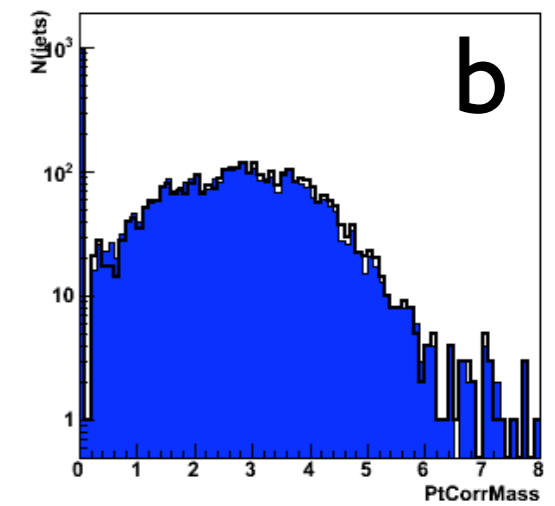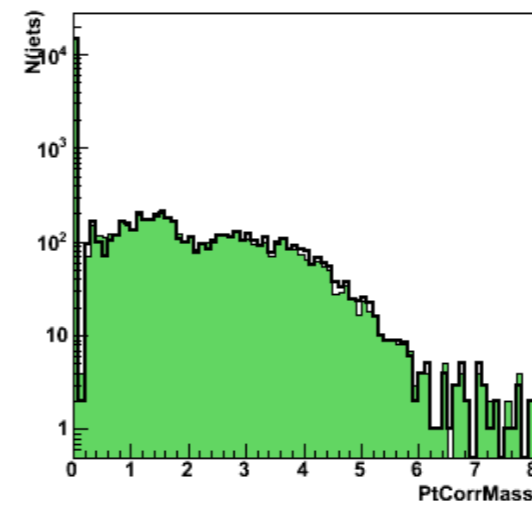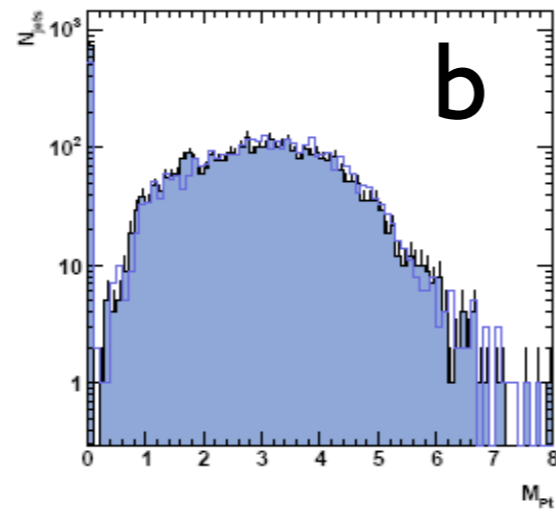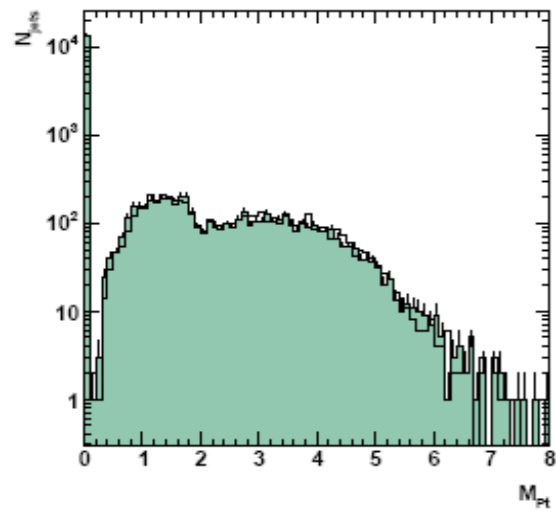
More flavour tag inputs...

LDCPrime_02Sc
cheat - line; ConvTag - histo

Decay length

Decay length significance
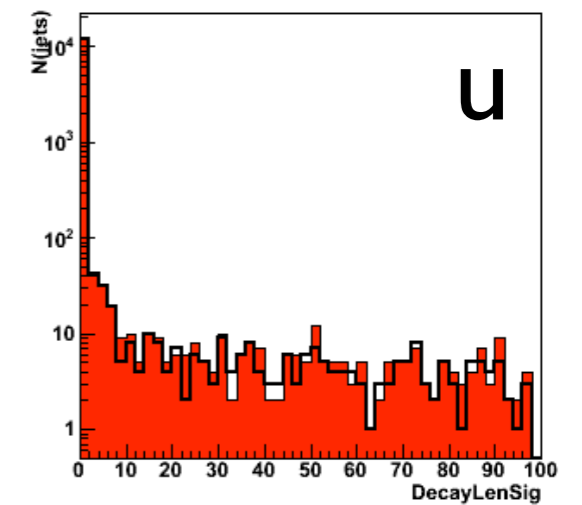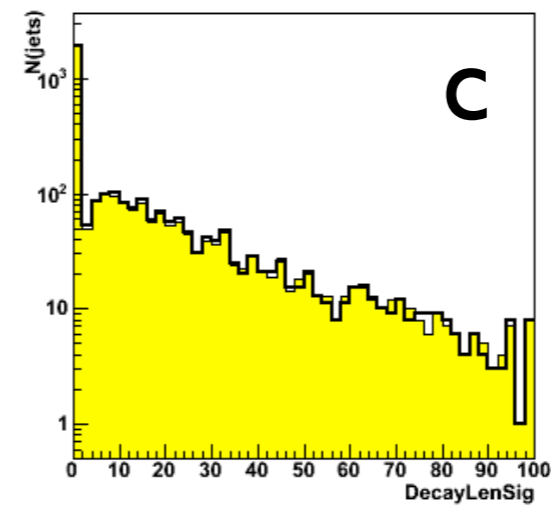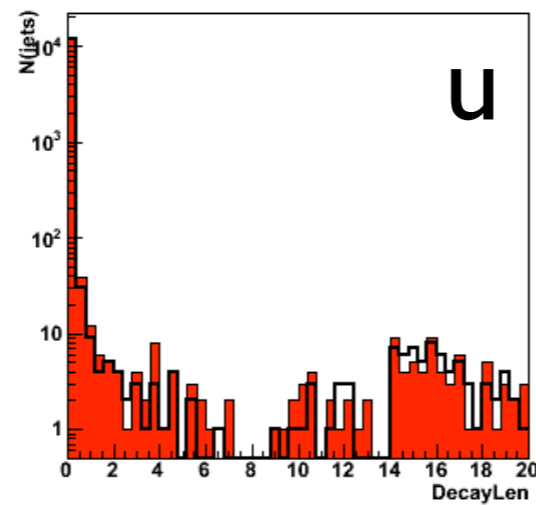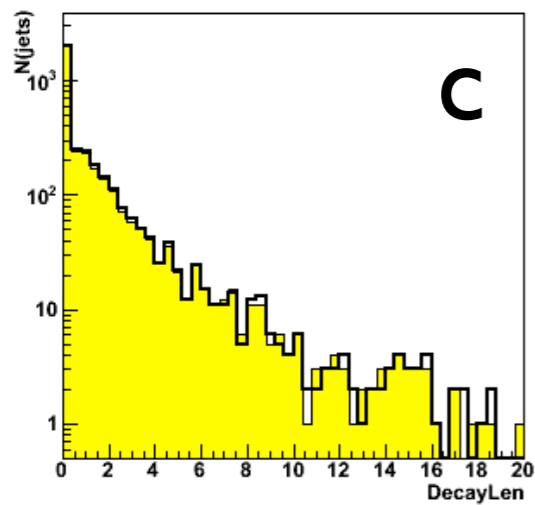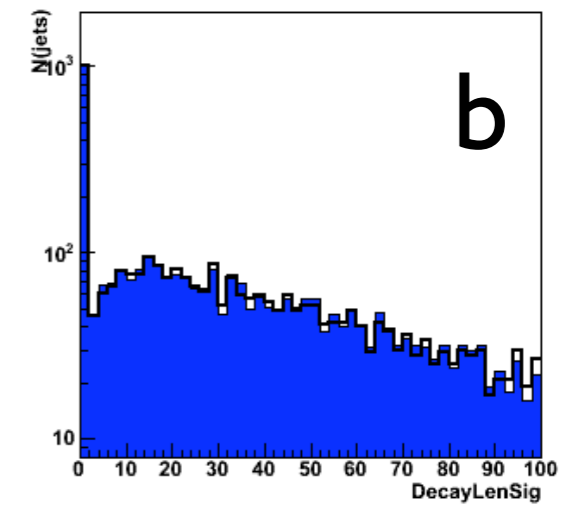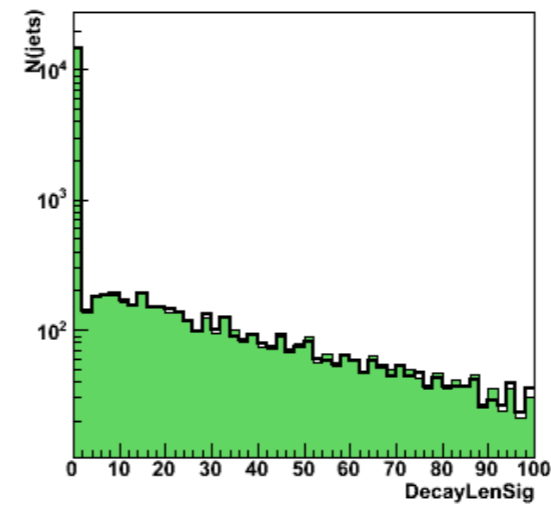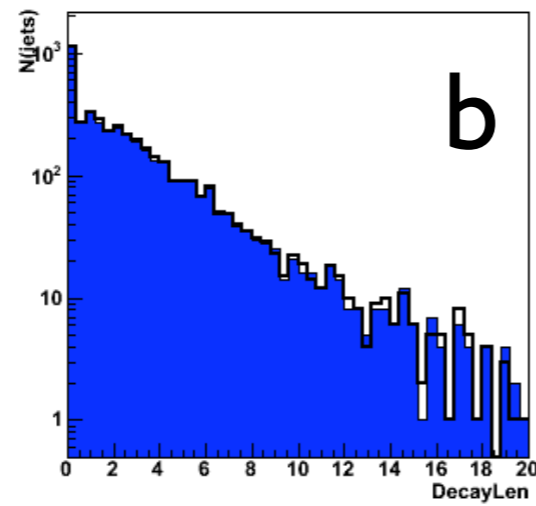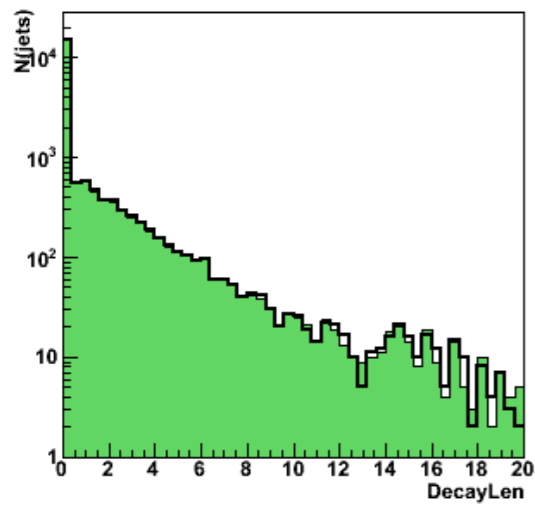
More flavour tag inputs...

LDCPrime_02Sc
cheat - line; ConvTag - histo

Momentum most significant track

Momentum second most significant track
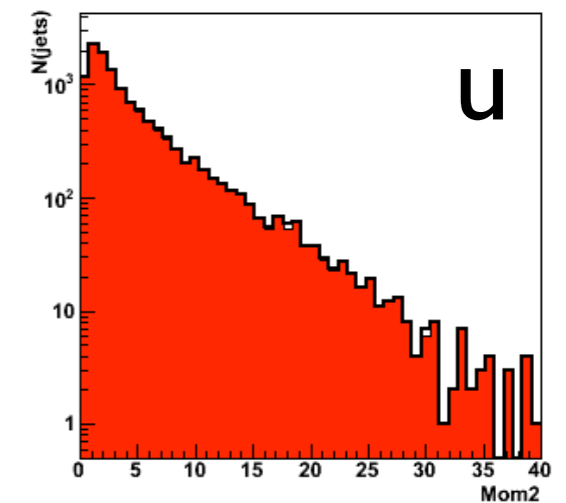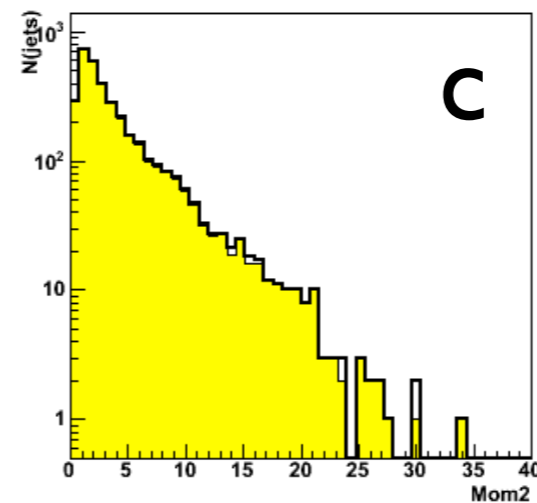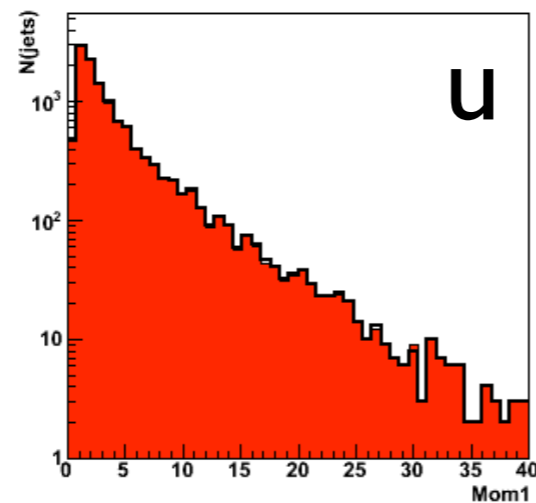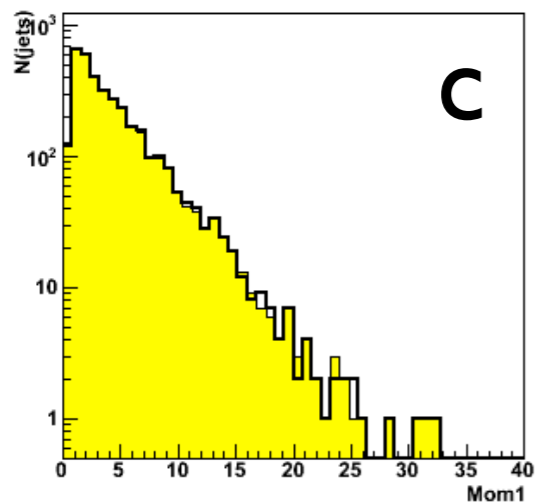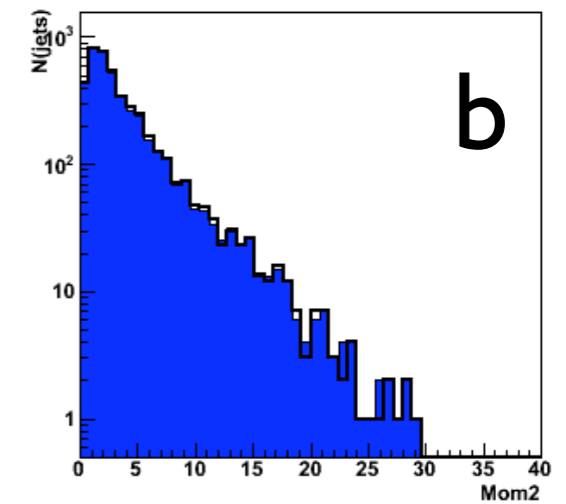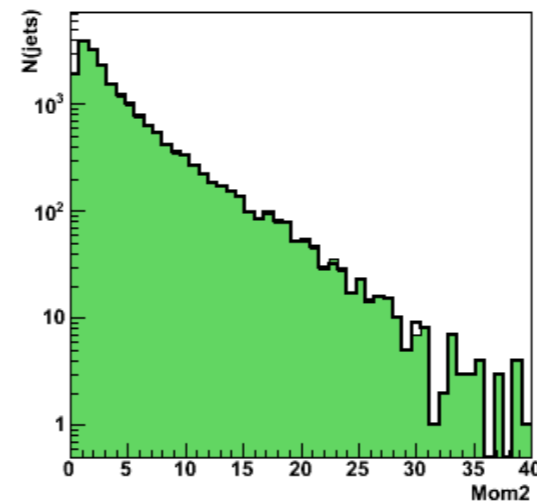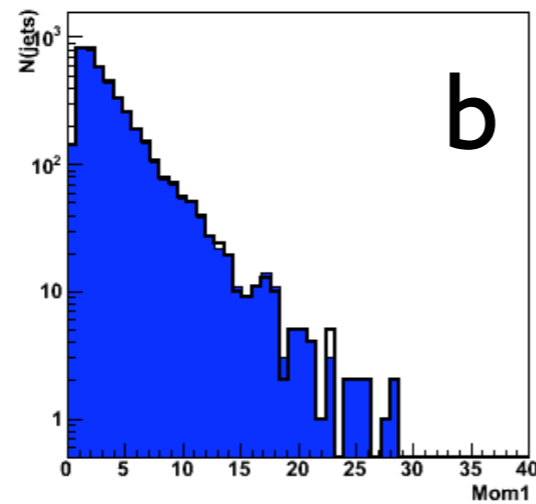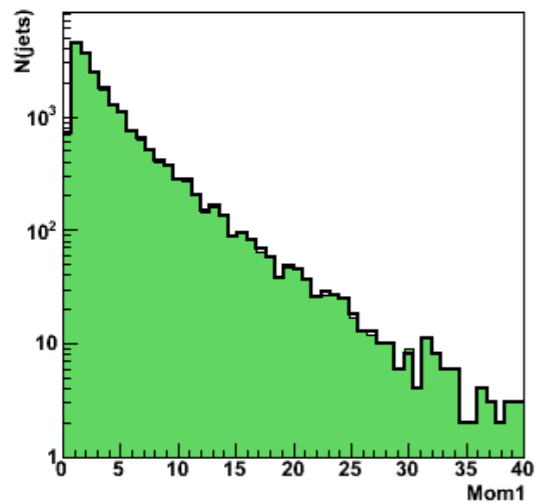
More flavour tag inputs...

LDCPrime_02Sc
cheat - line; ConvTag - histo

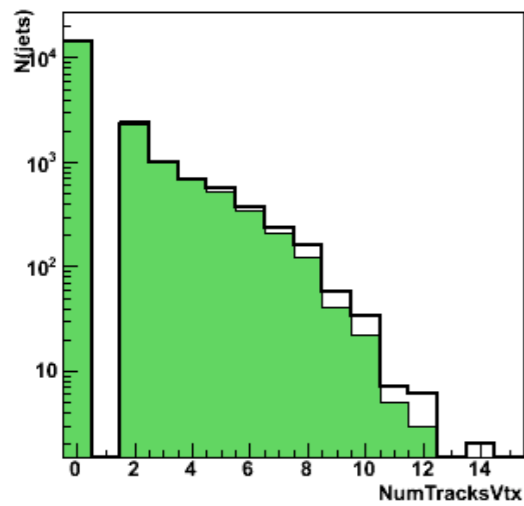Joint probablity Z   Raw momentum
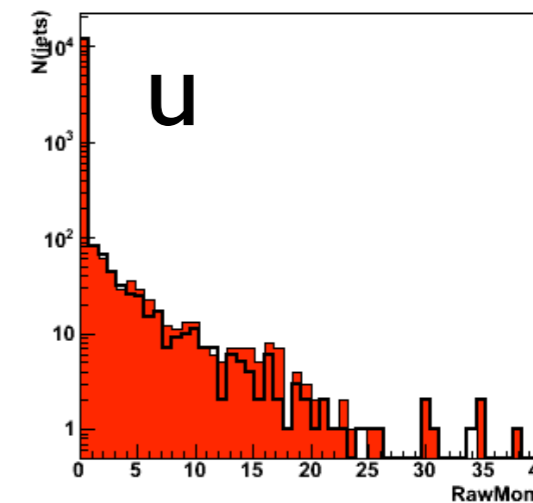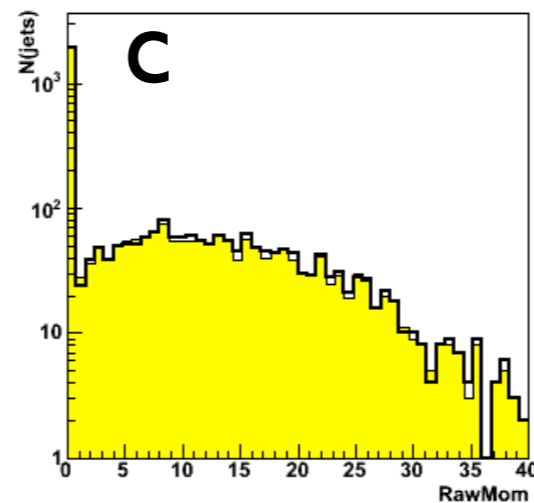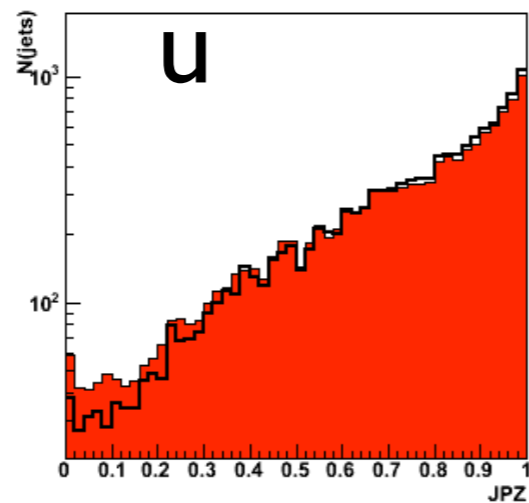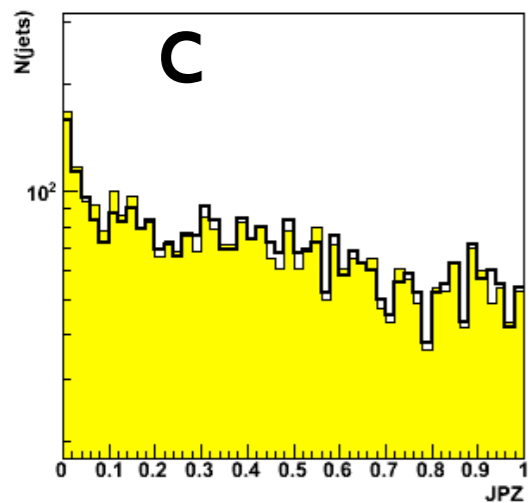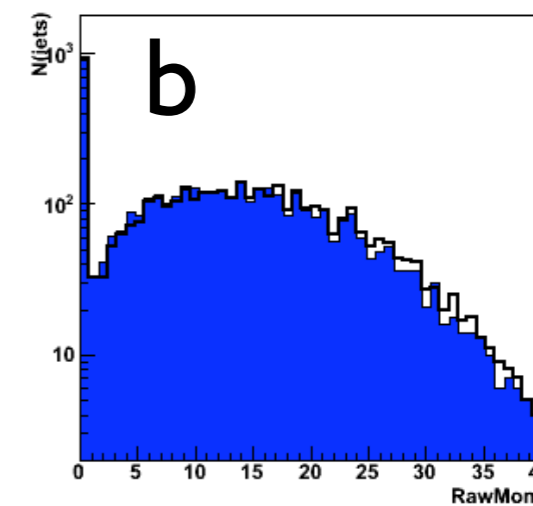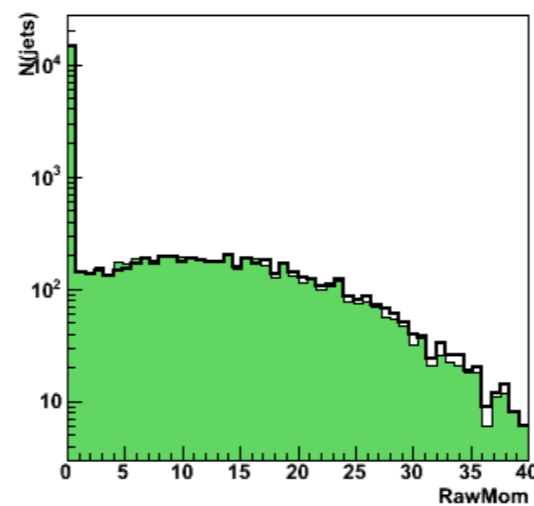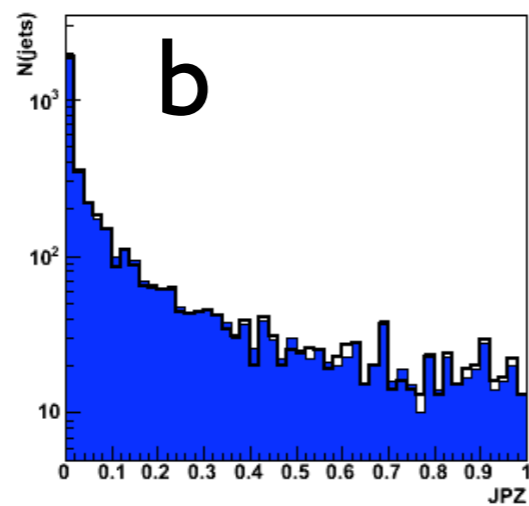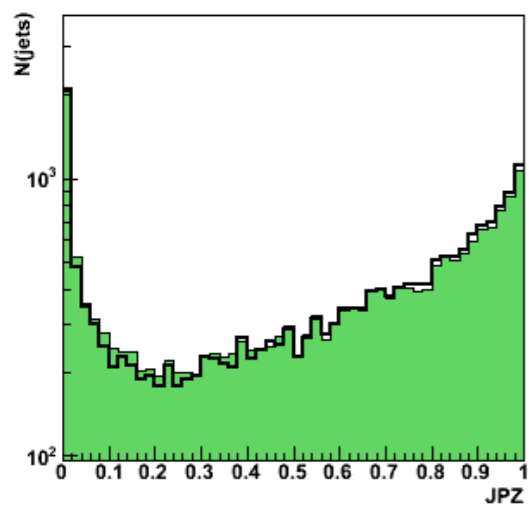
More flavour tag inputs...

LDCPrime_02Sc
cheat - line; ConvTag - histo

Num. of tracks vertex

Secondary vertex prob.
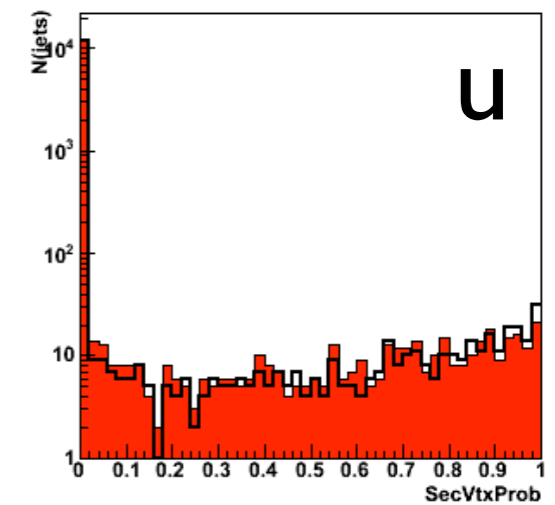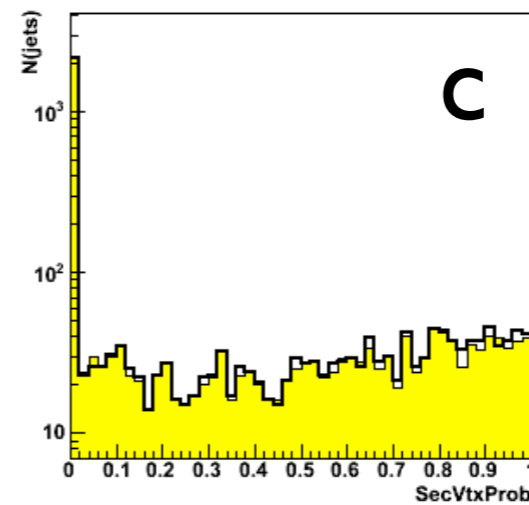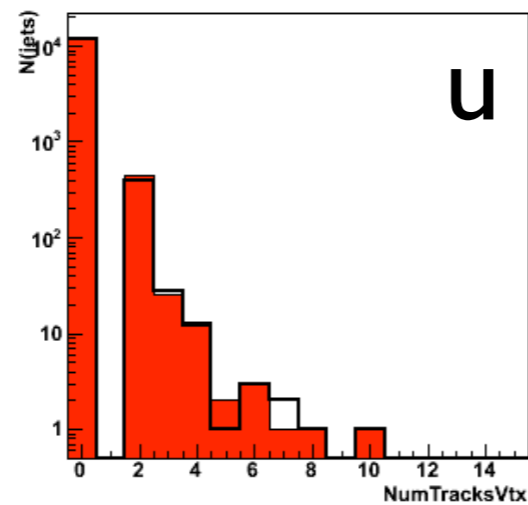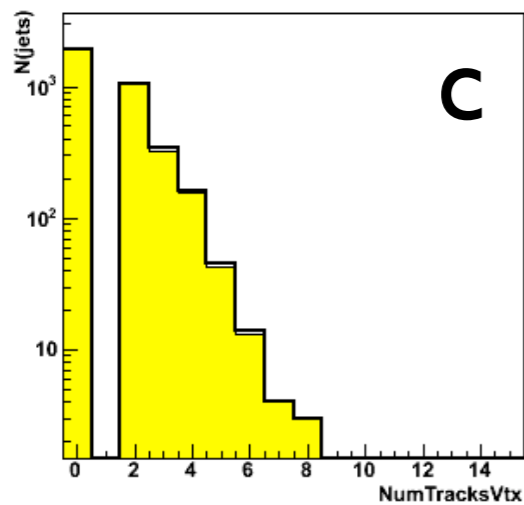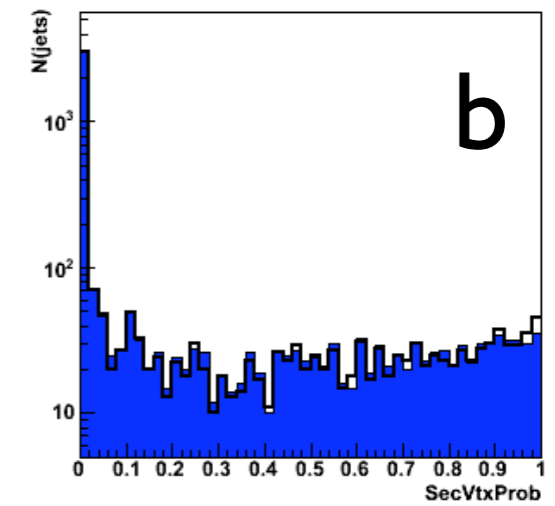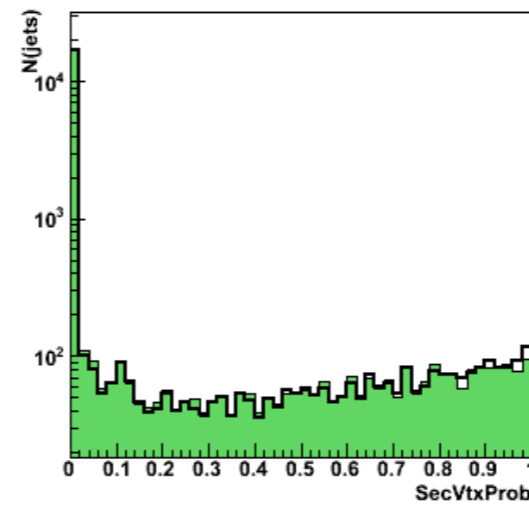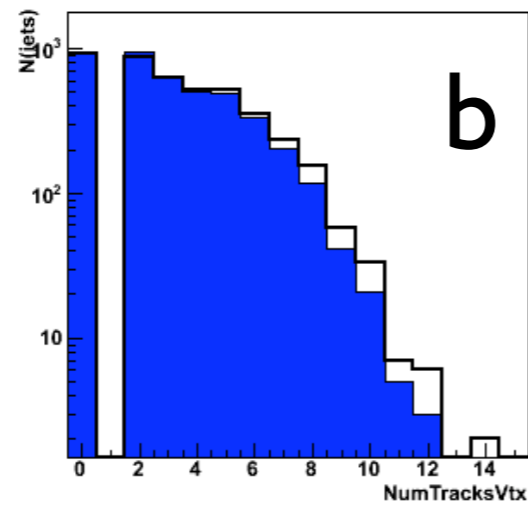
Track selection tuning

Track selection tuning

- Vary the parameters for track selection for the vertex reconstruction (IPFIT, ZVRES) and for the flavour tag inputs (FTI).

- Aim: Improve flavour tagging keeping the performance of vertex reconstruction and flavour tag inputs.

- **Monte Carlo sample** (Talini):
  - $e^+e^- \to Z \to qq$, $\sqrt{s} = 91.2$ 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;

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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

IPFIT: flavour tag purity as a function of the chi2/ndf of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: no cut
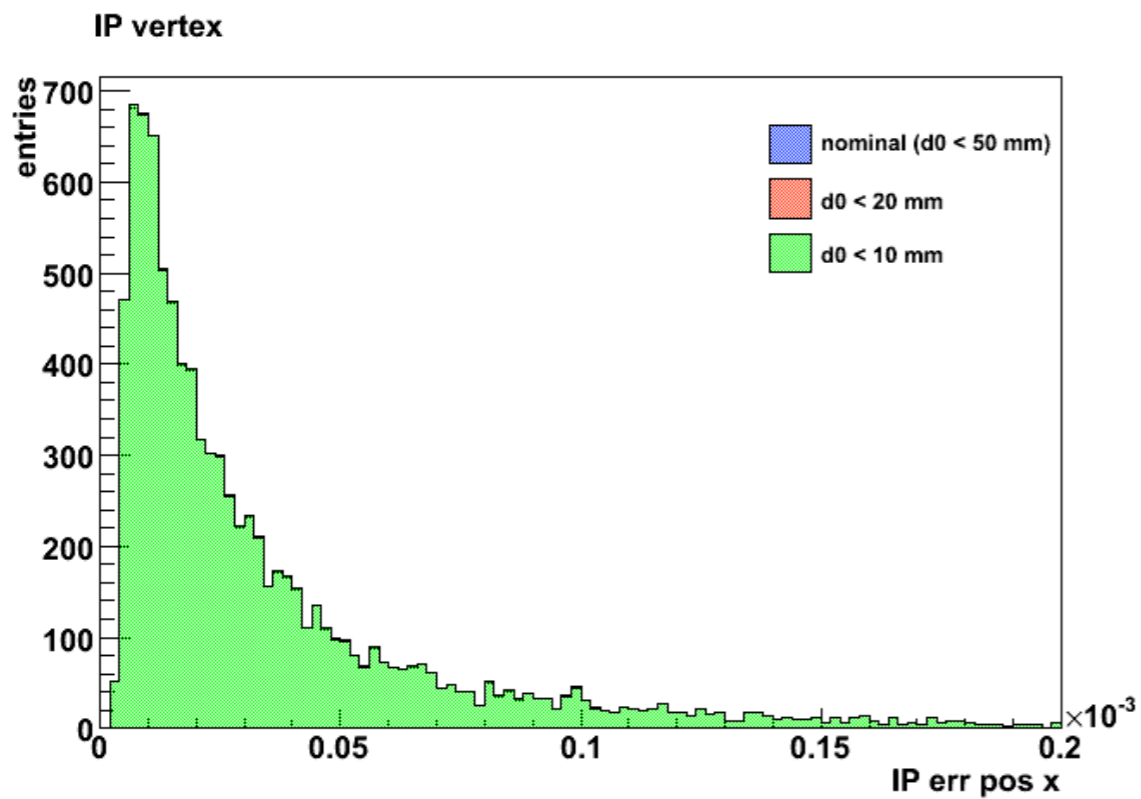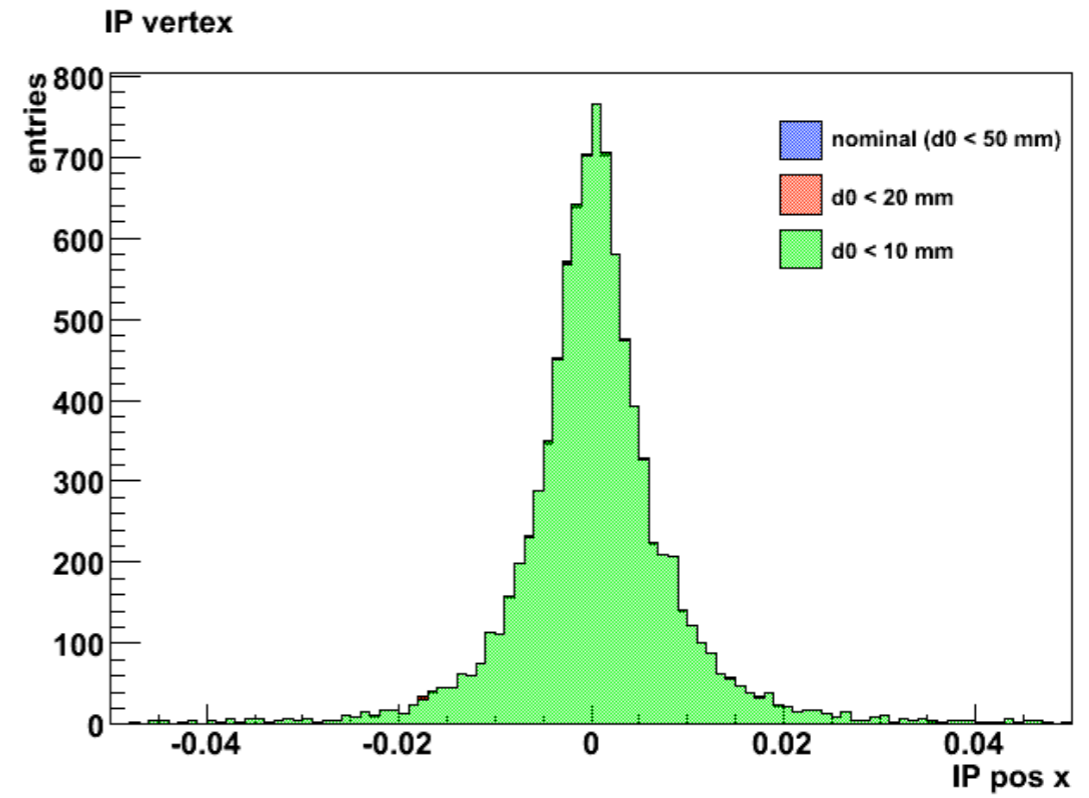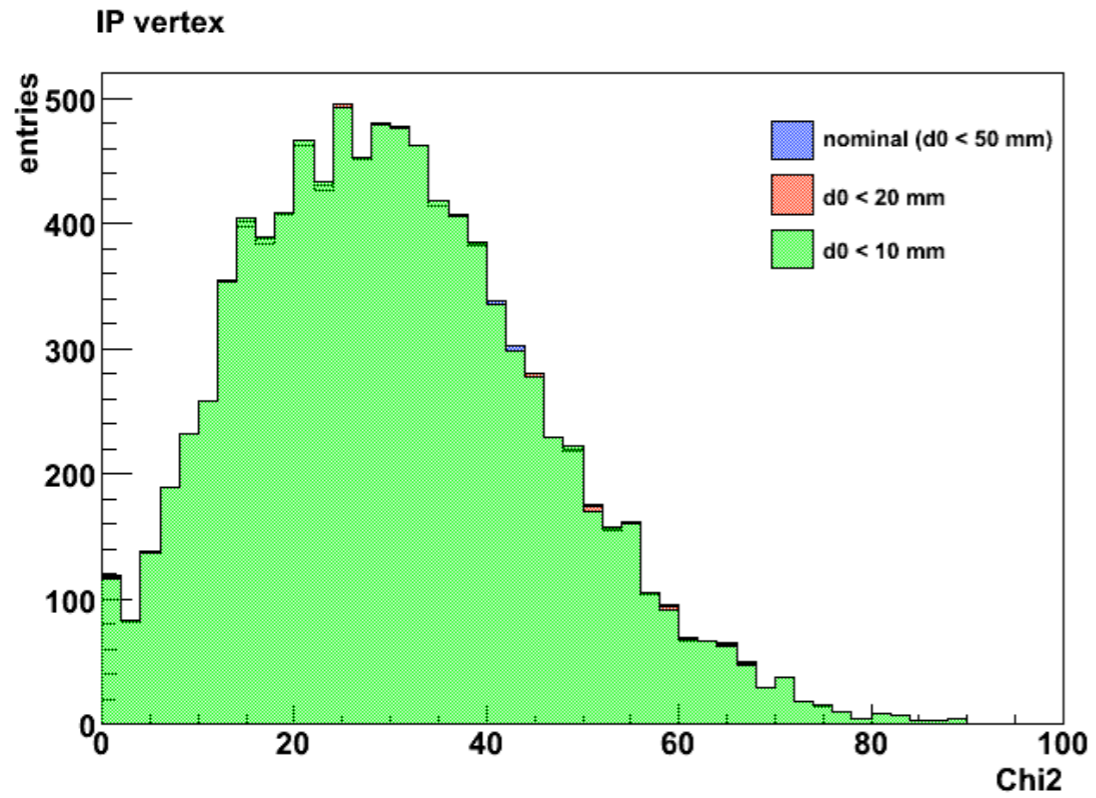

50% efficiency

70% efficiency
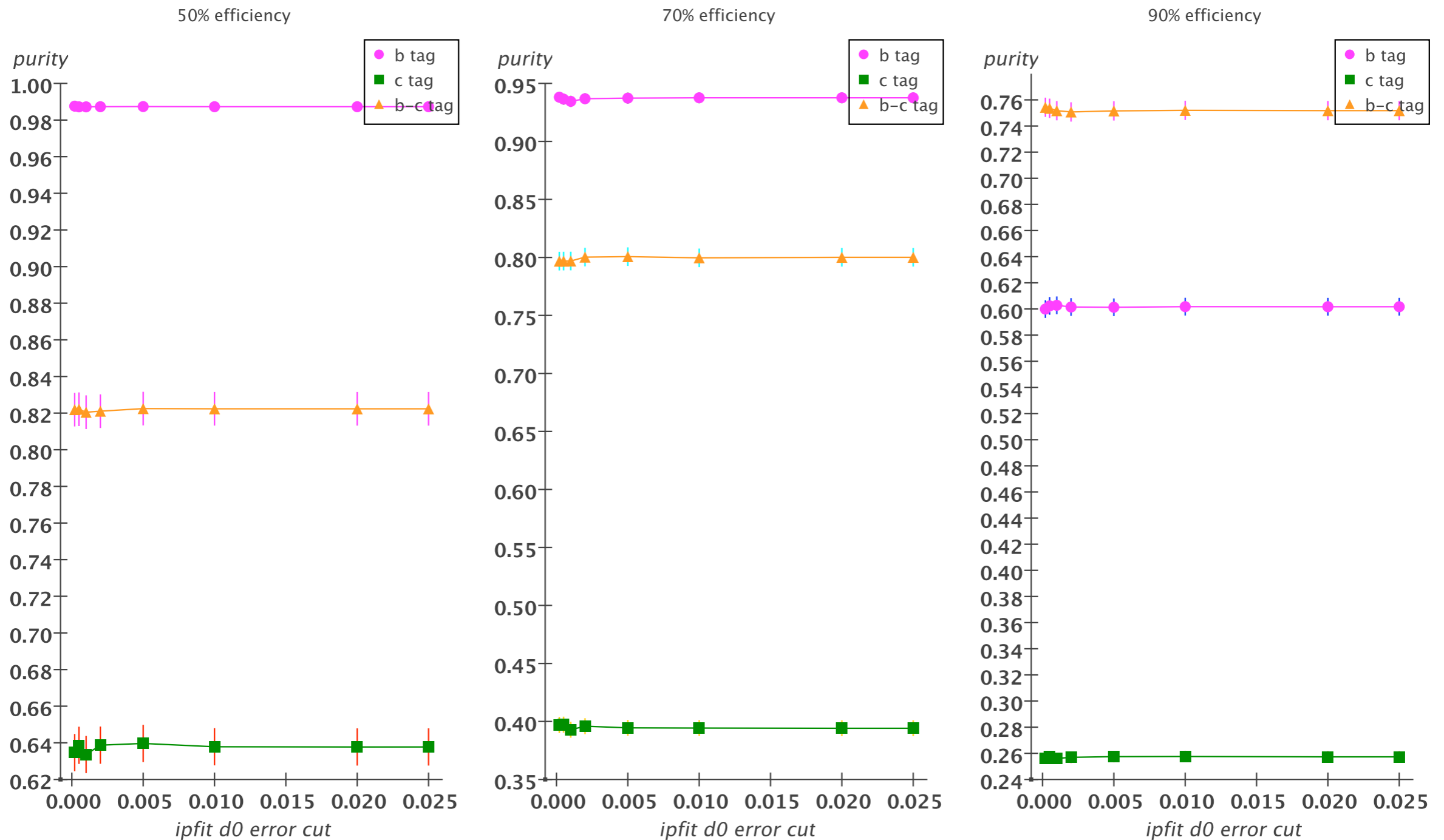
90% efficiency

70

IP vertex (chi2/ndf cut)

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IPFIT: 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: 50mm

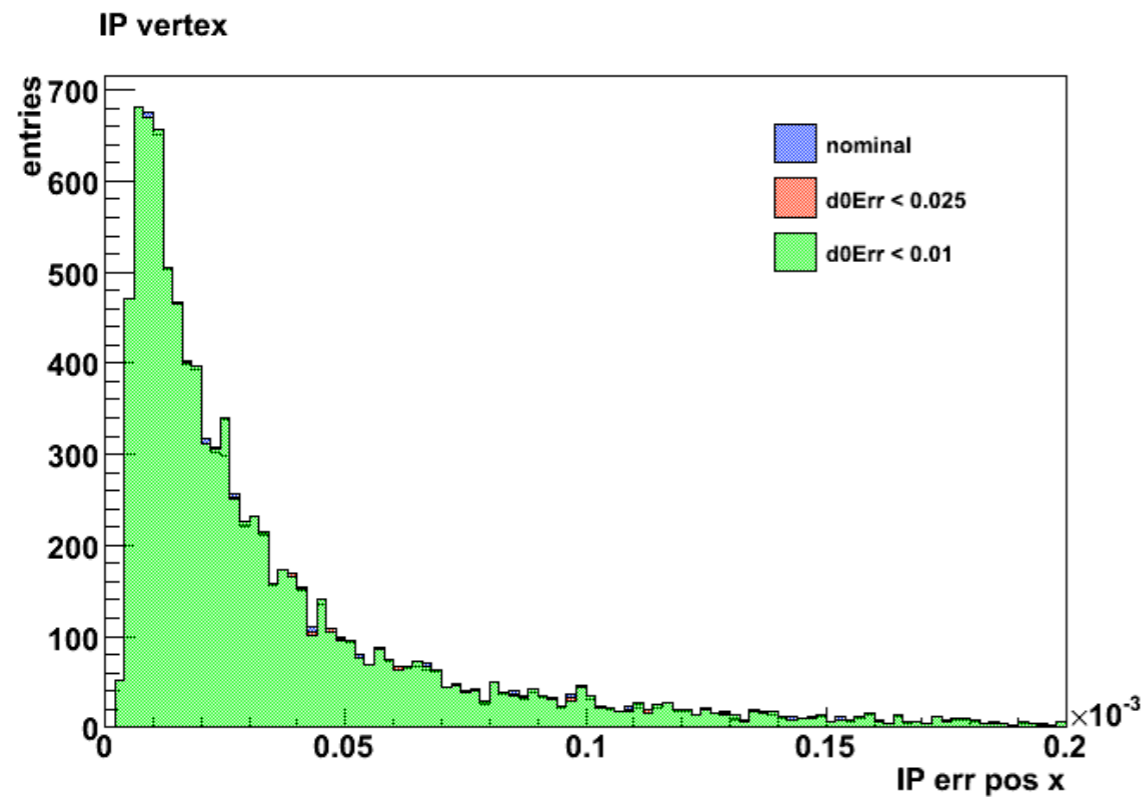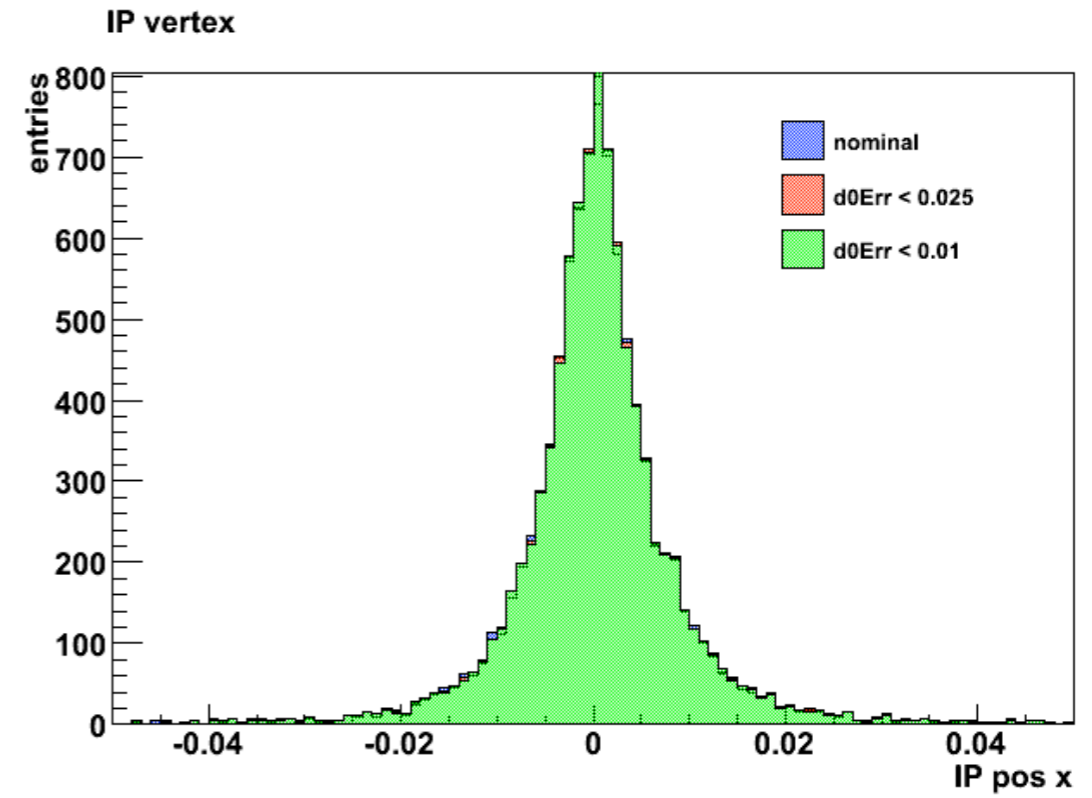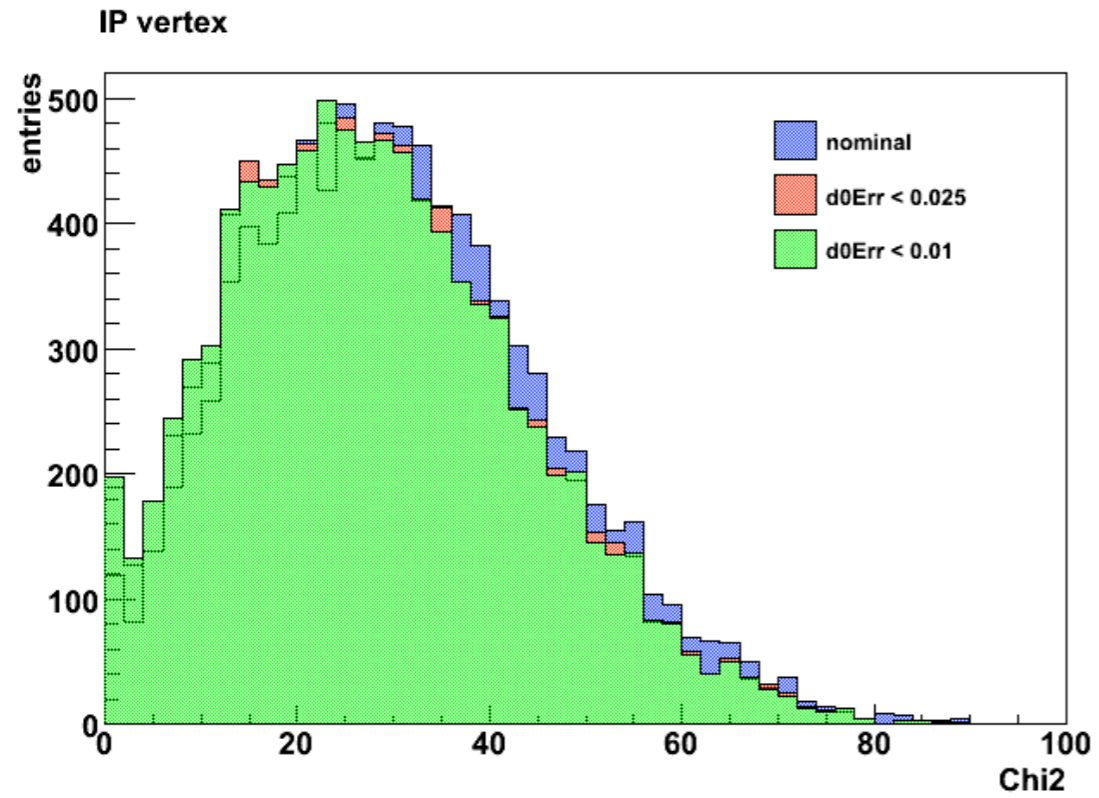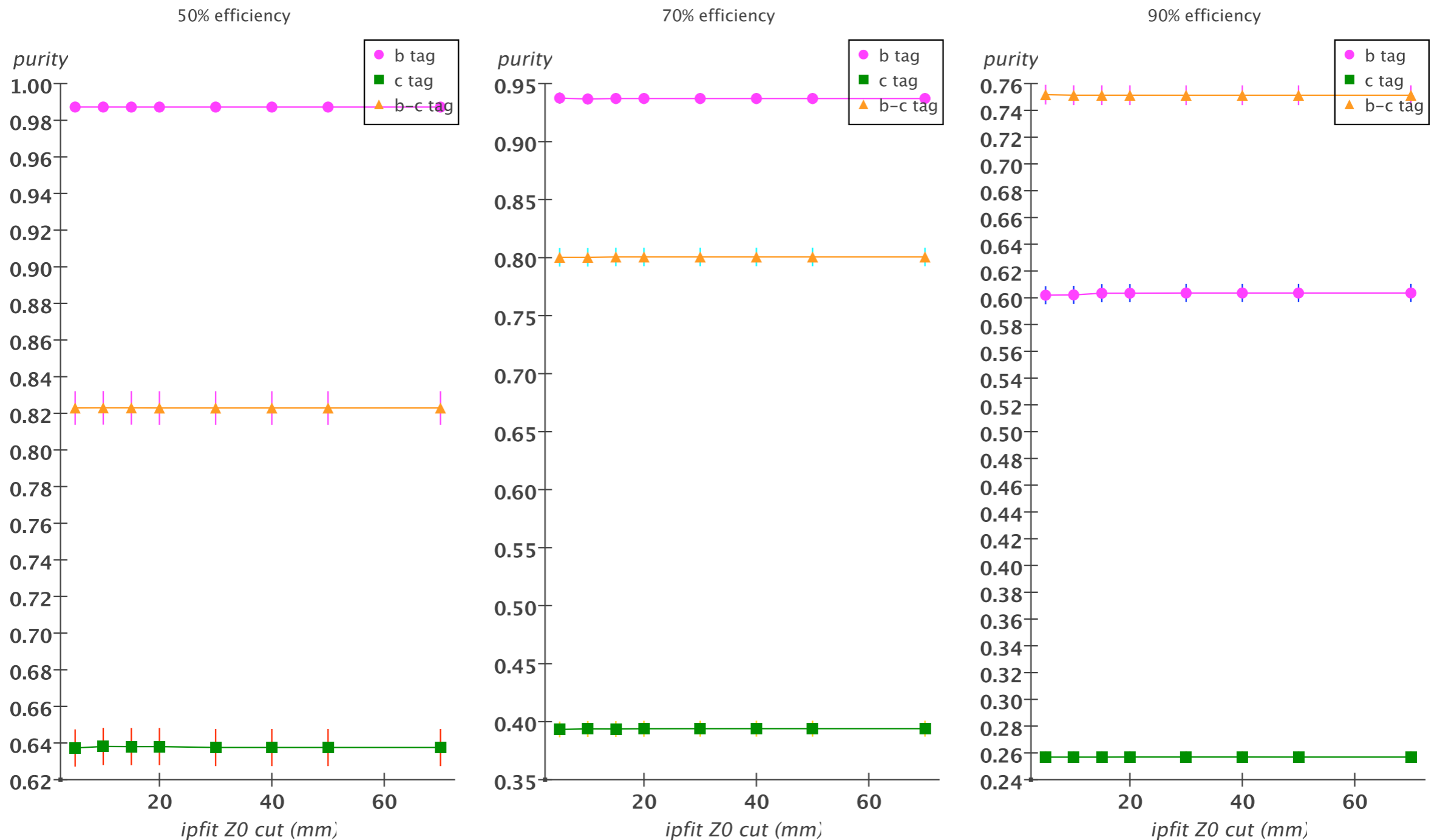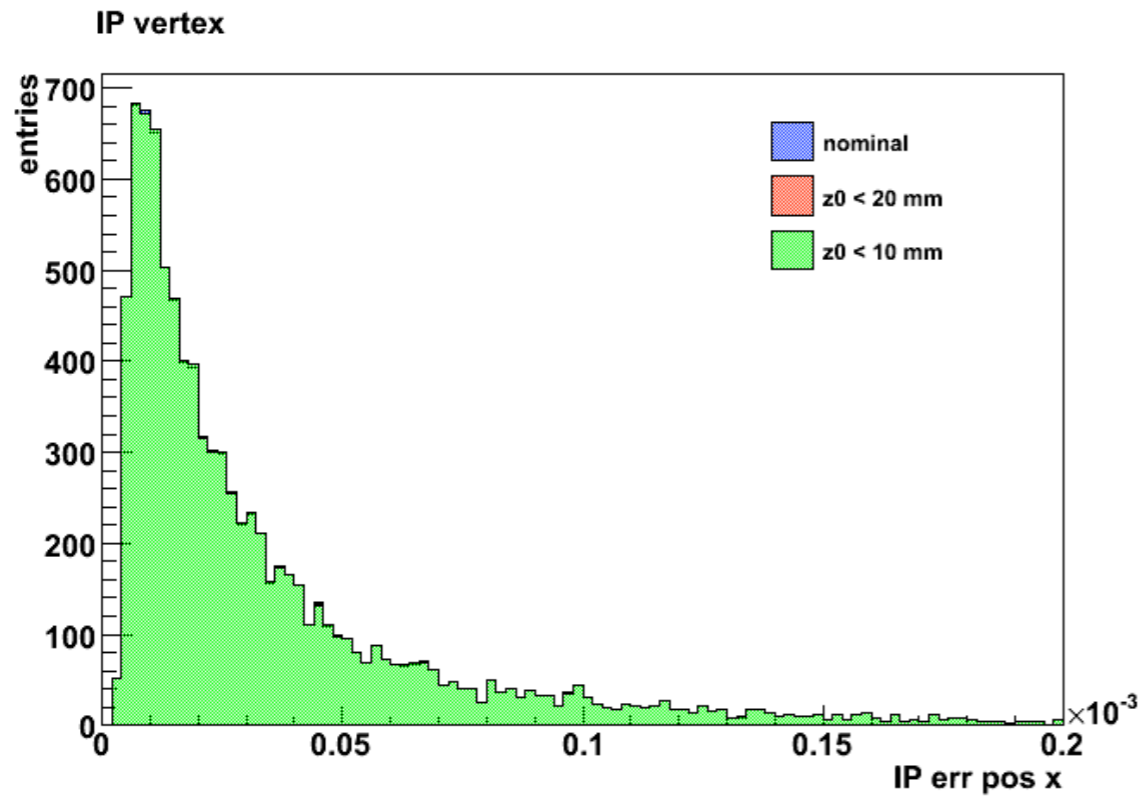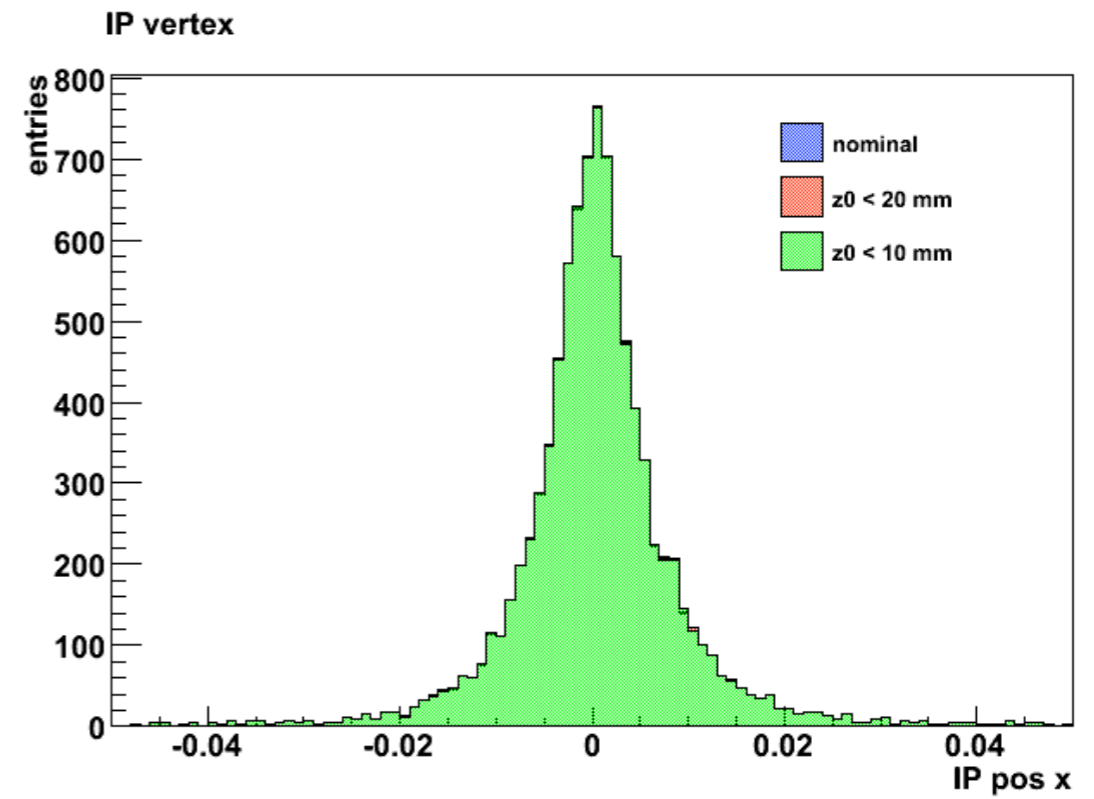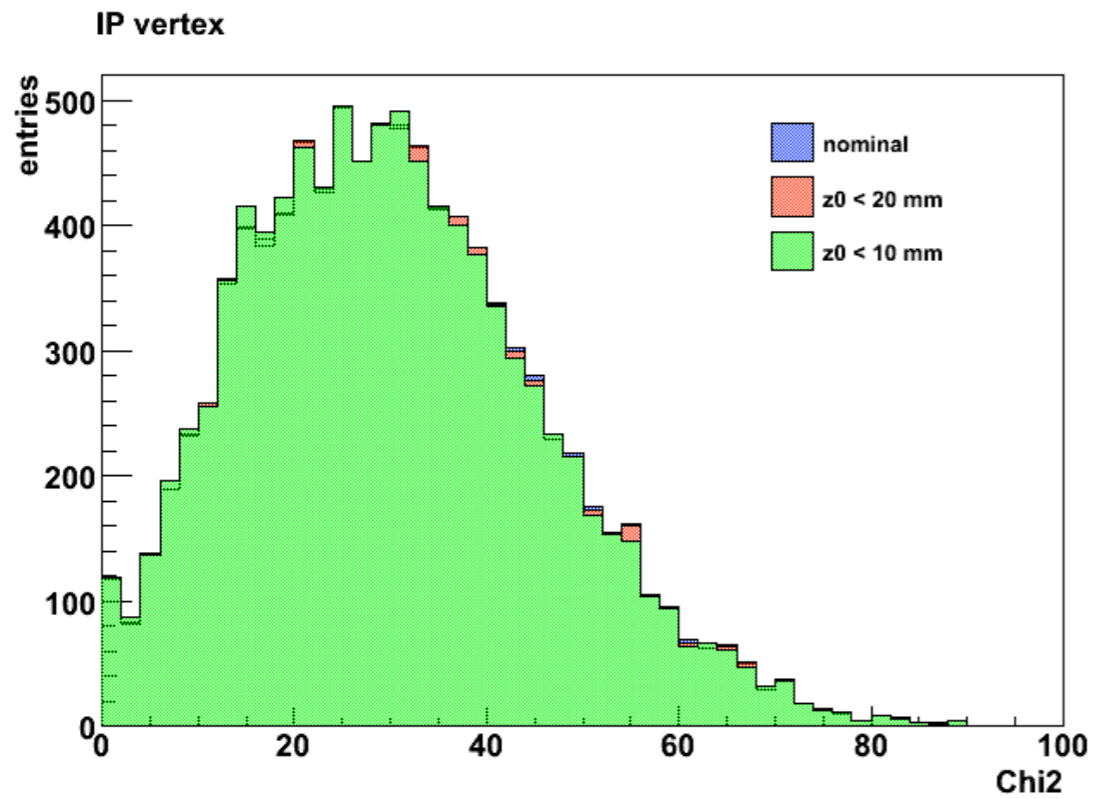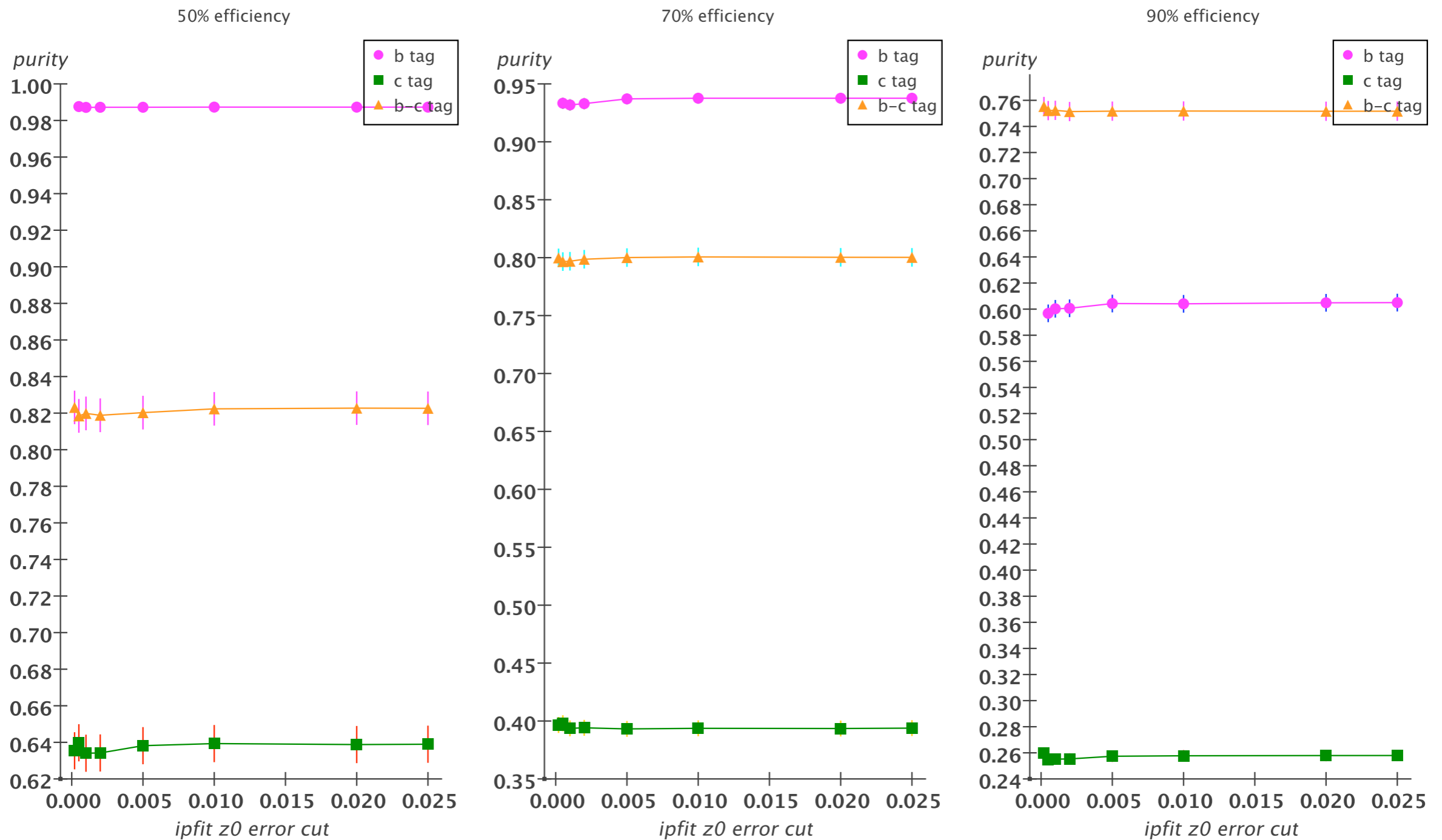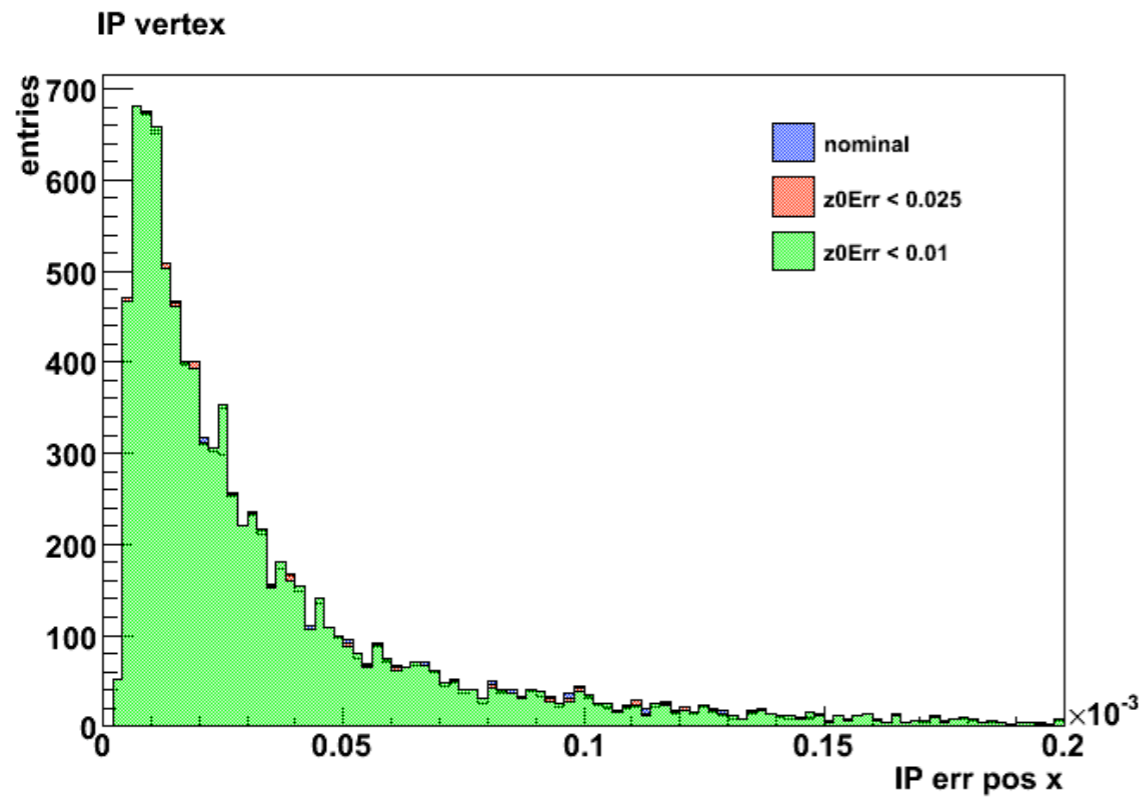
50% efficiency

70% efficiency

90% efficiency
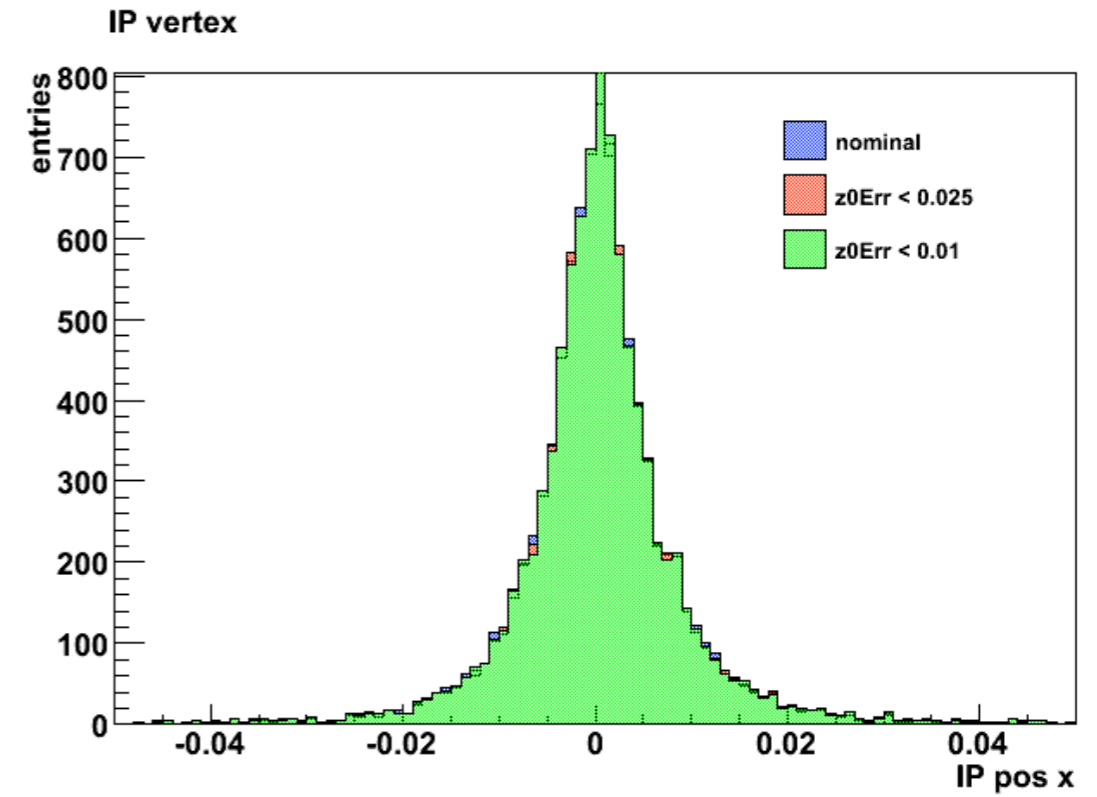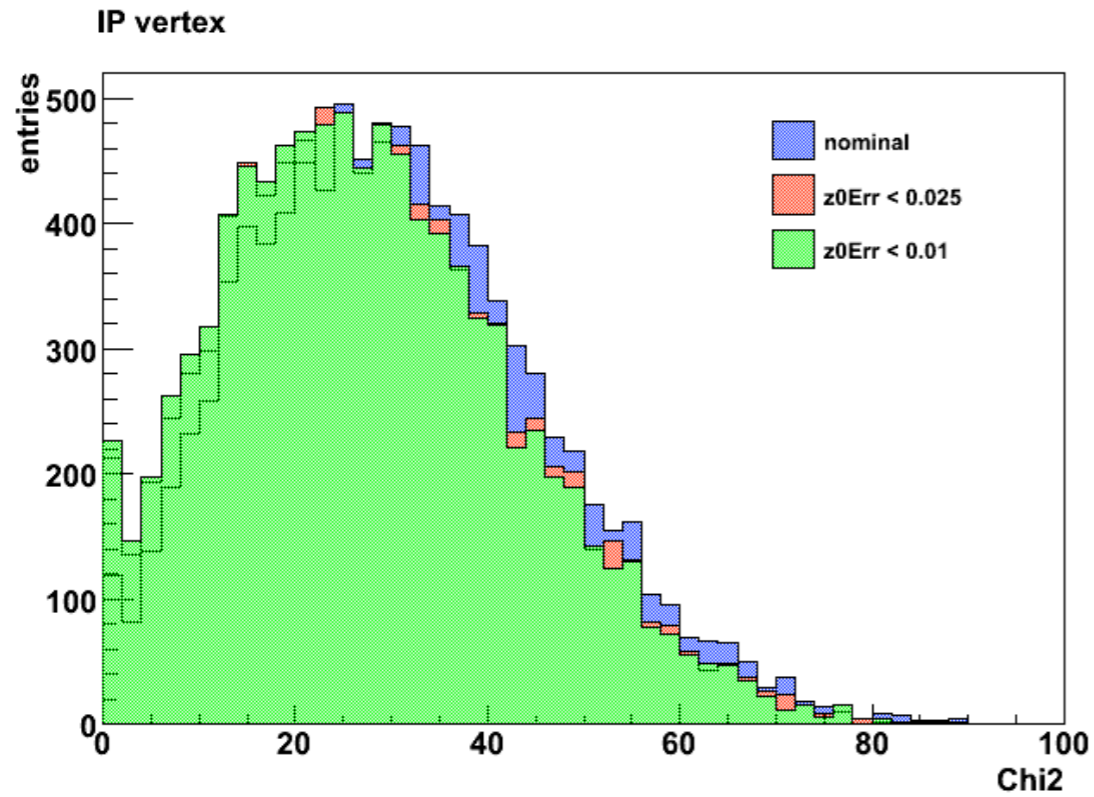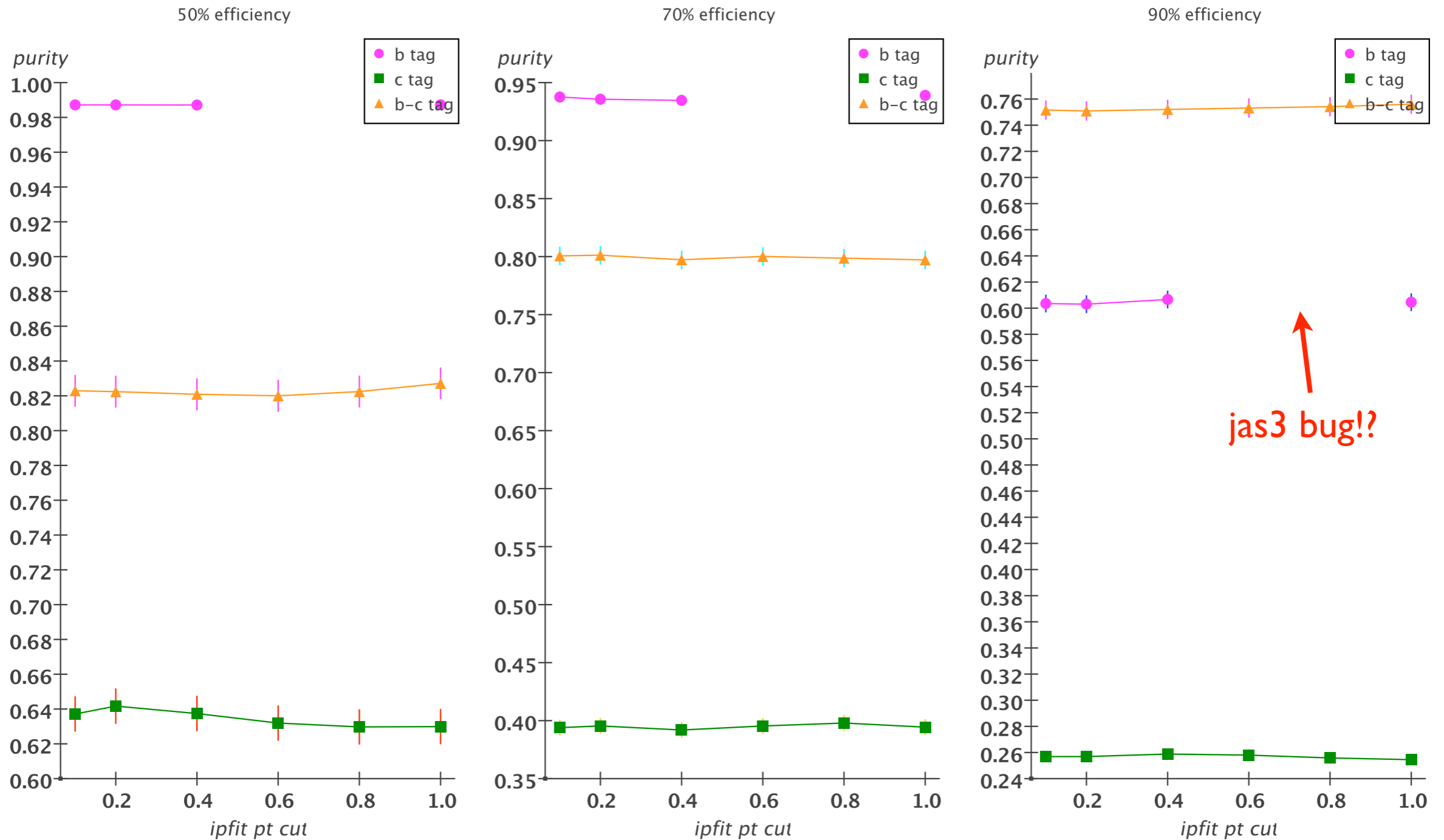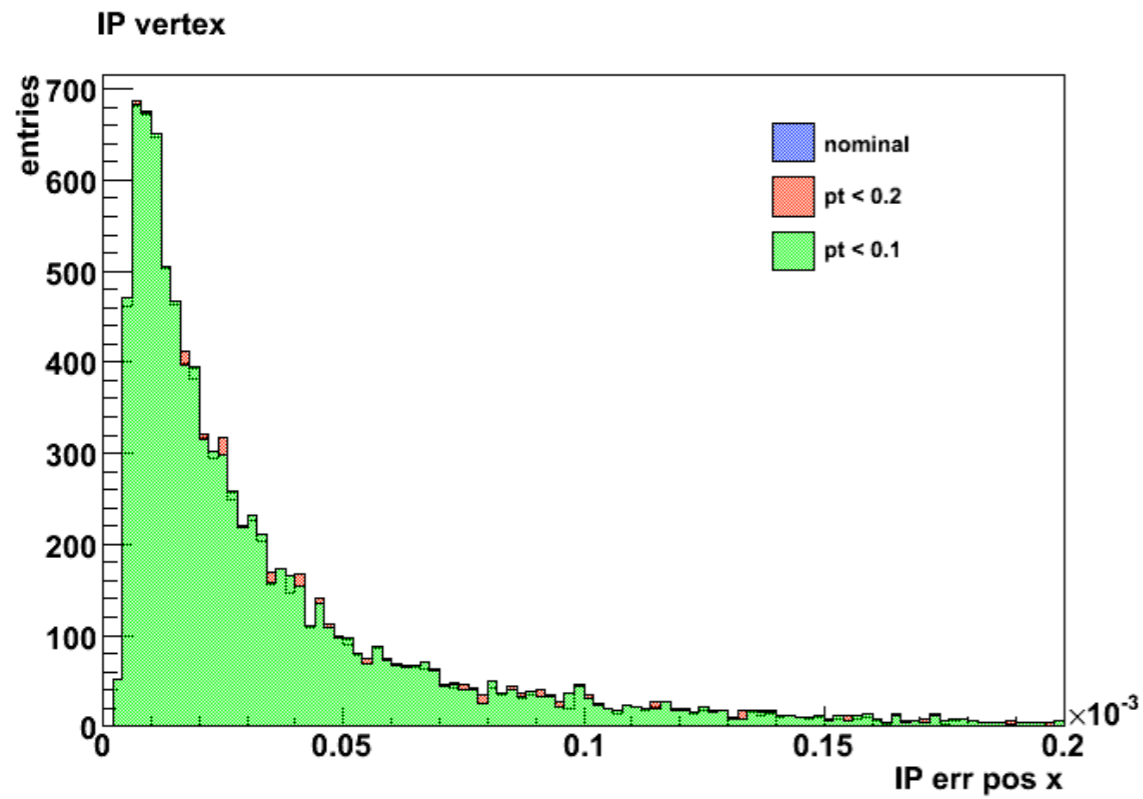
Thursday, 11 September 2008

IP vertex (d0 cut)

IPFIT: flavour tag purity as a function of the d0err of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: no cut
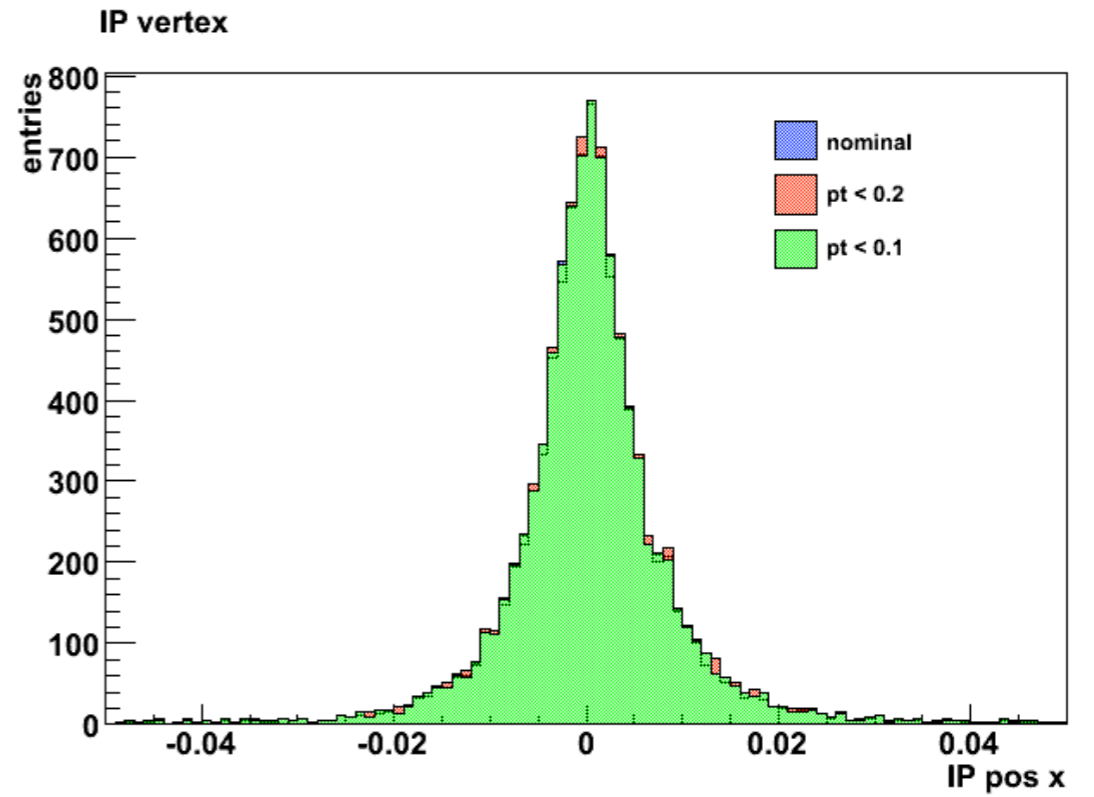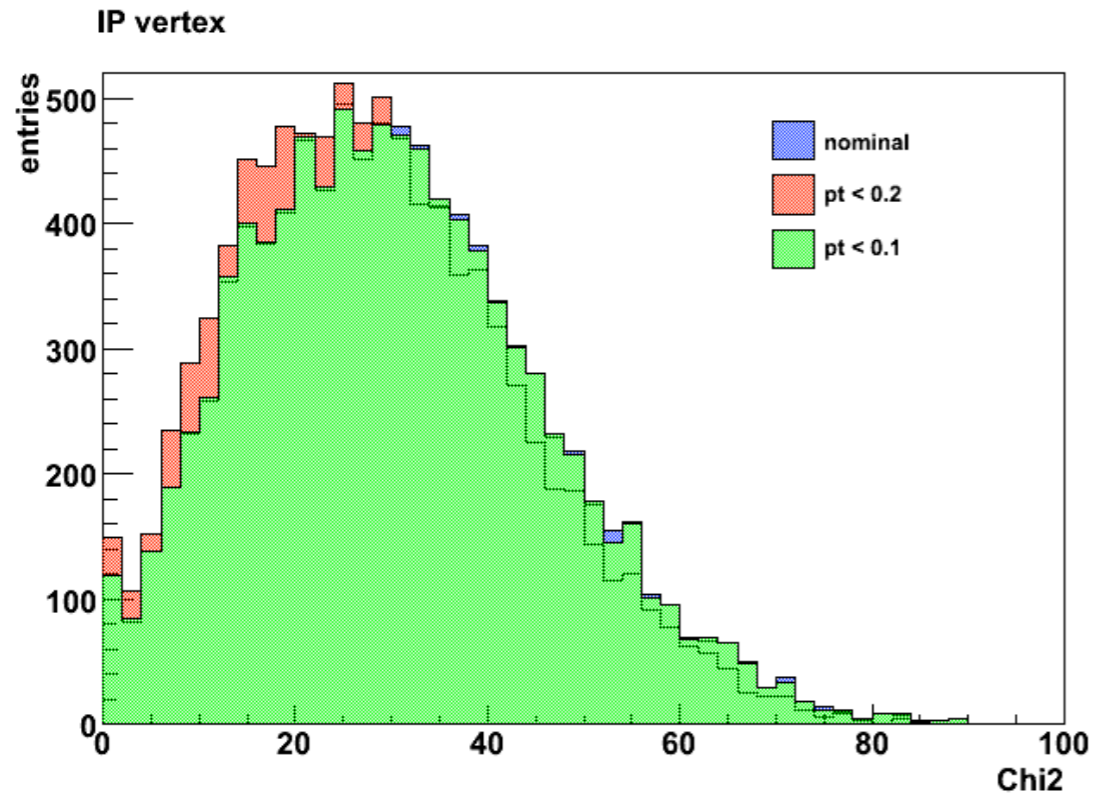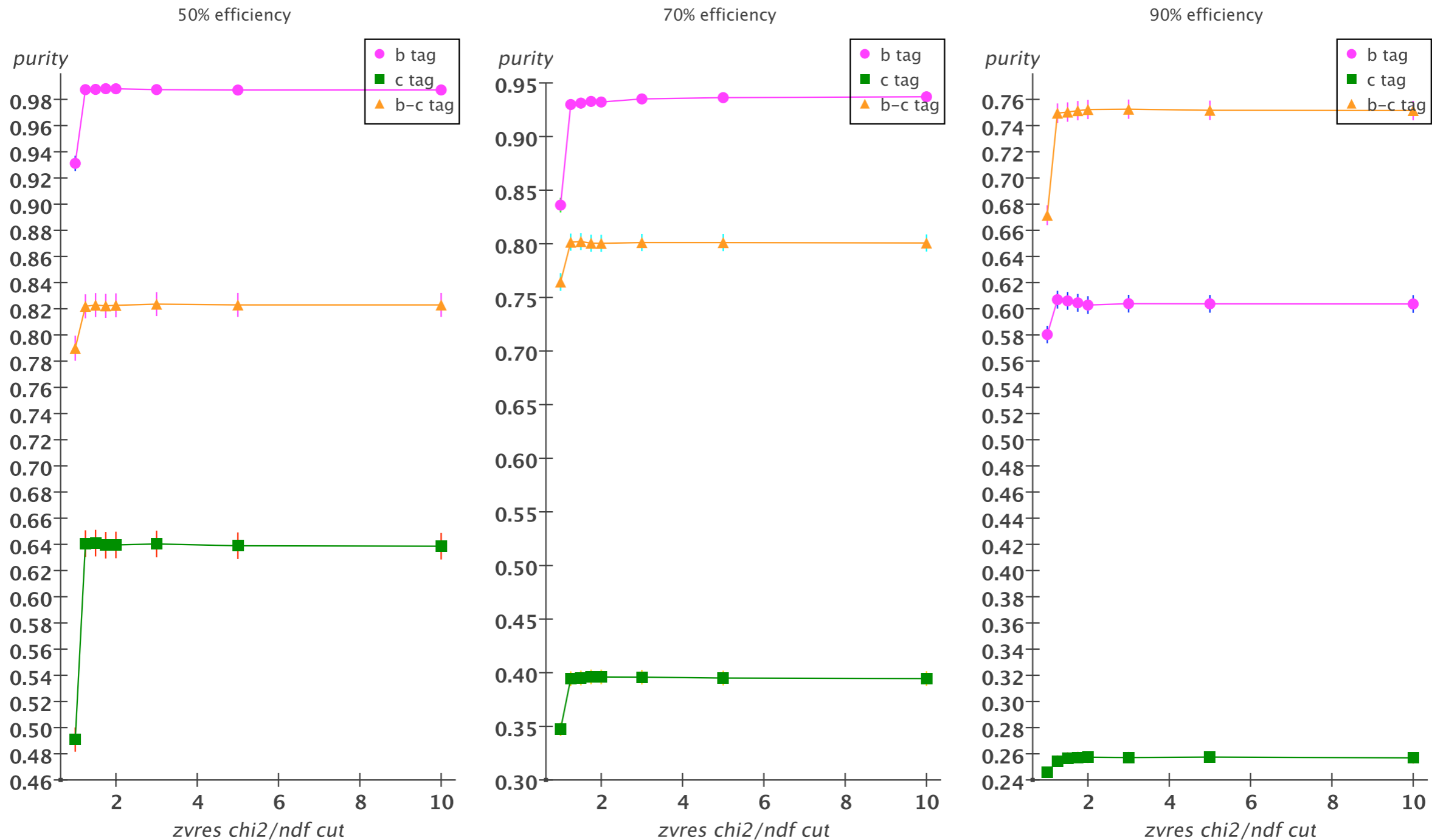

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IP vertex (d0err cut)

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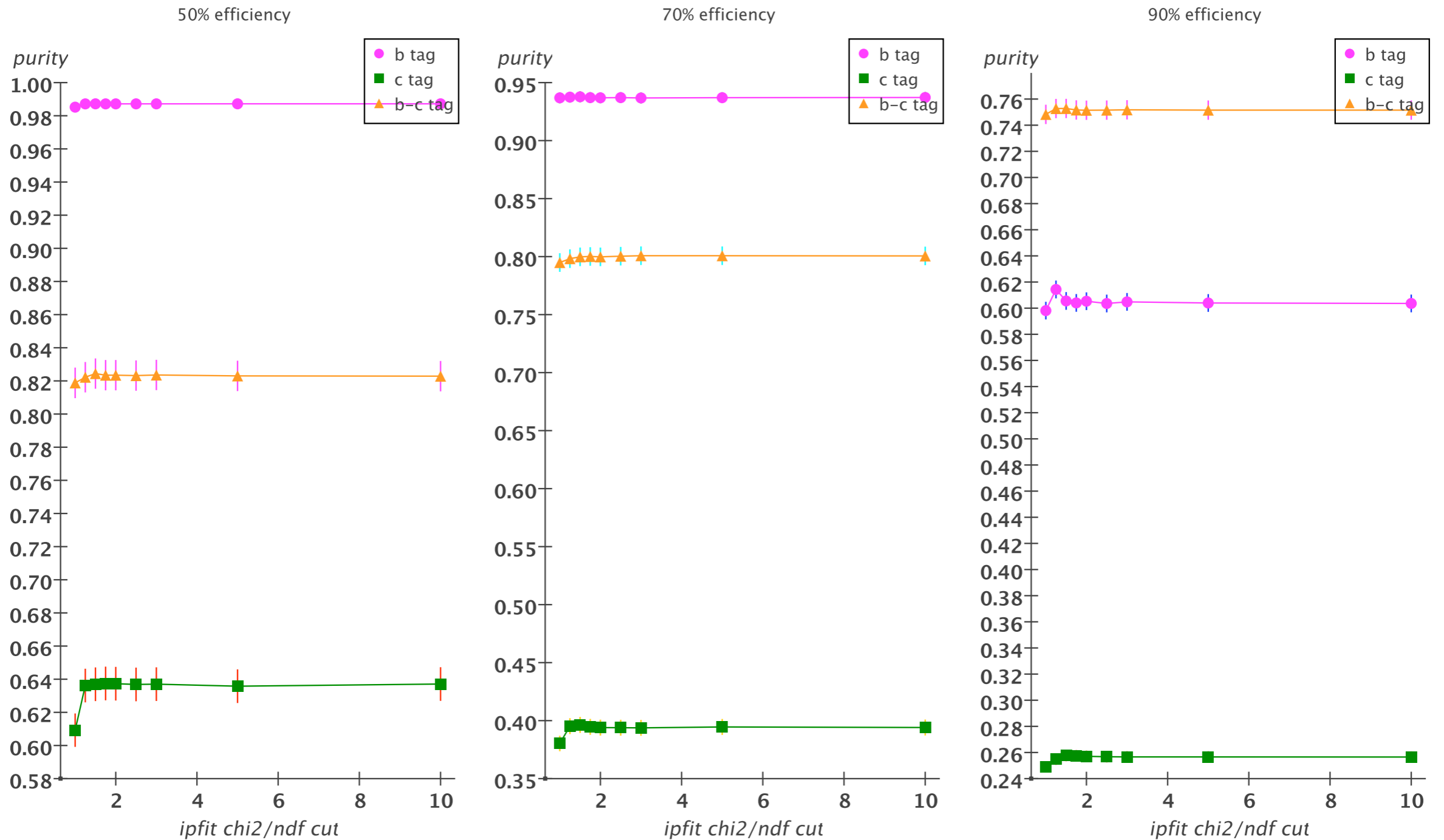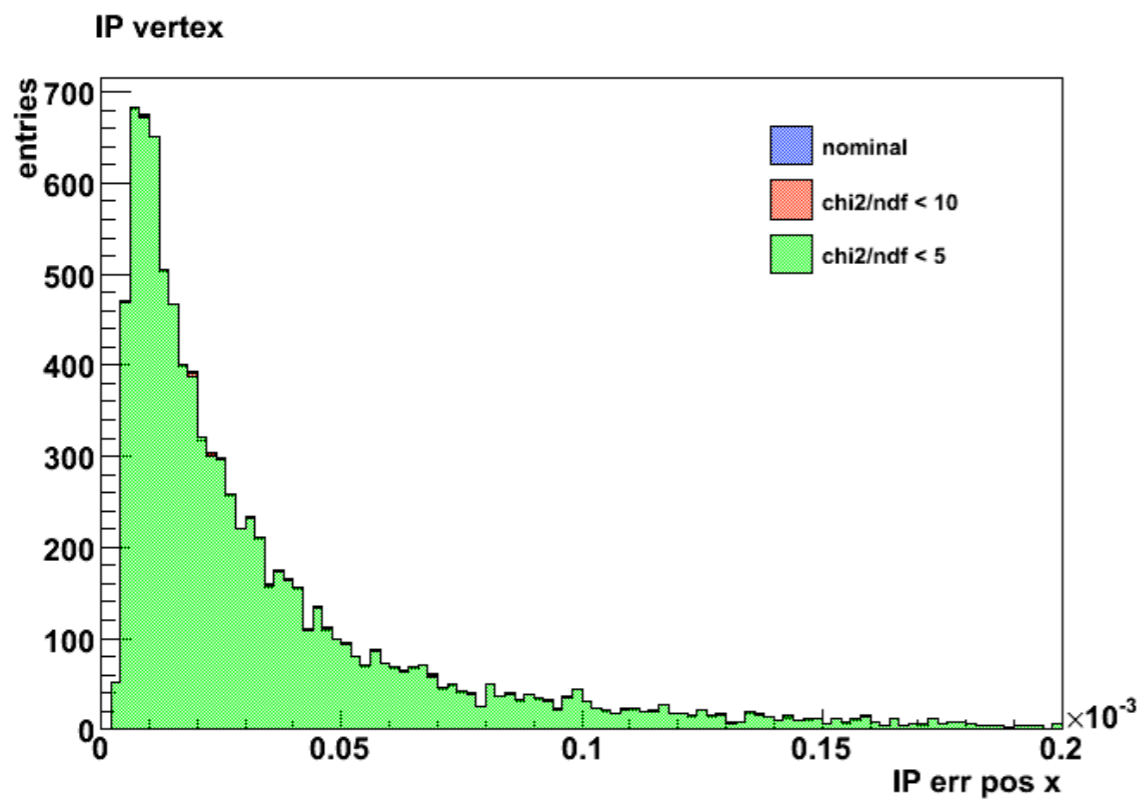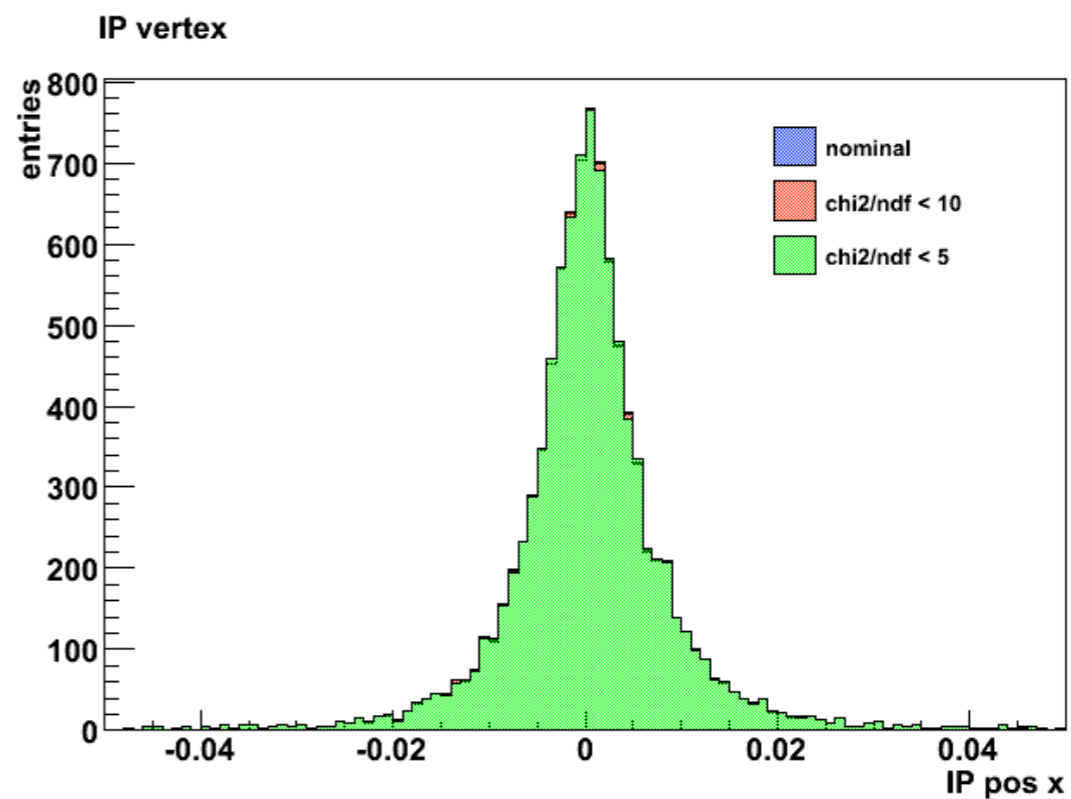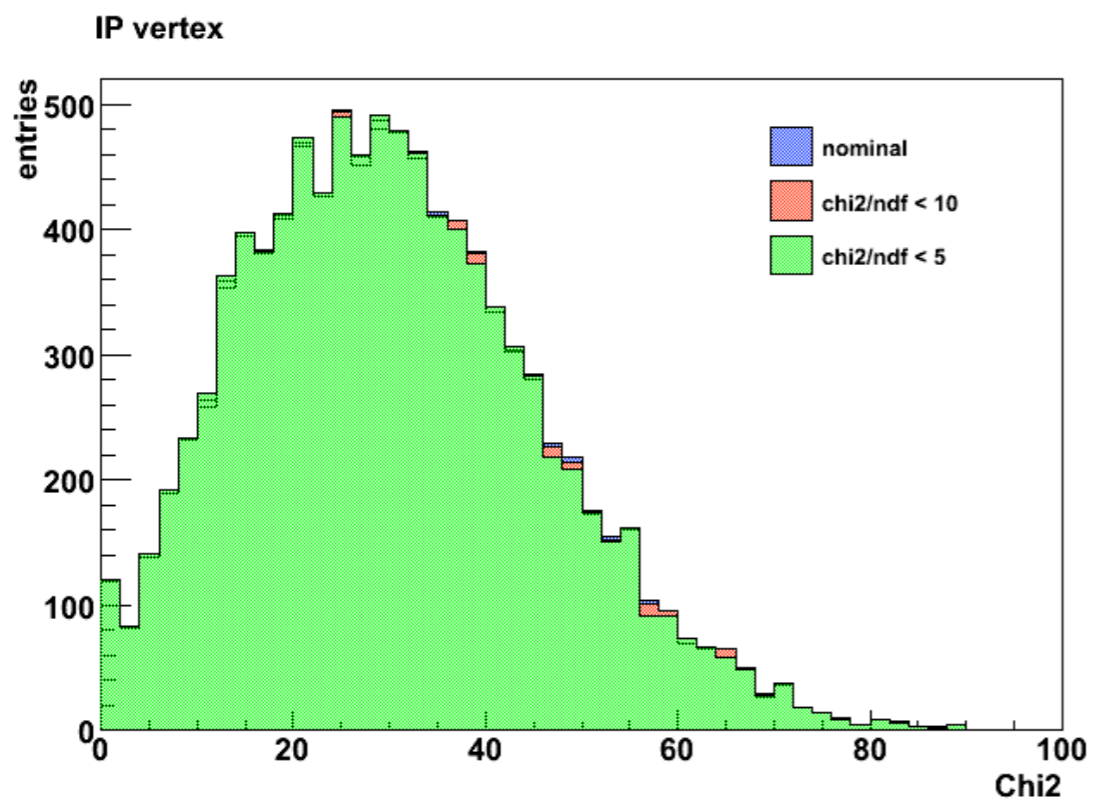
IPFIT: flavour tag purity as a function of the z0 of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: 50 mm

IP vertex (z0 cut)

IPFIT: flavour tag purity as a function of the z0err of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: no cut
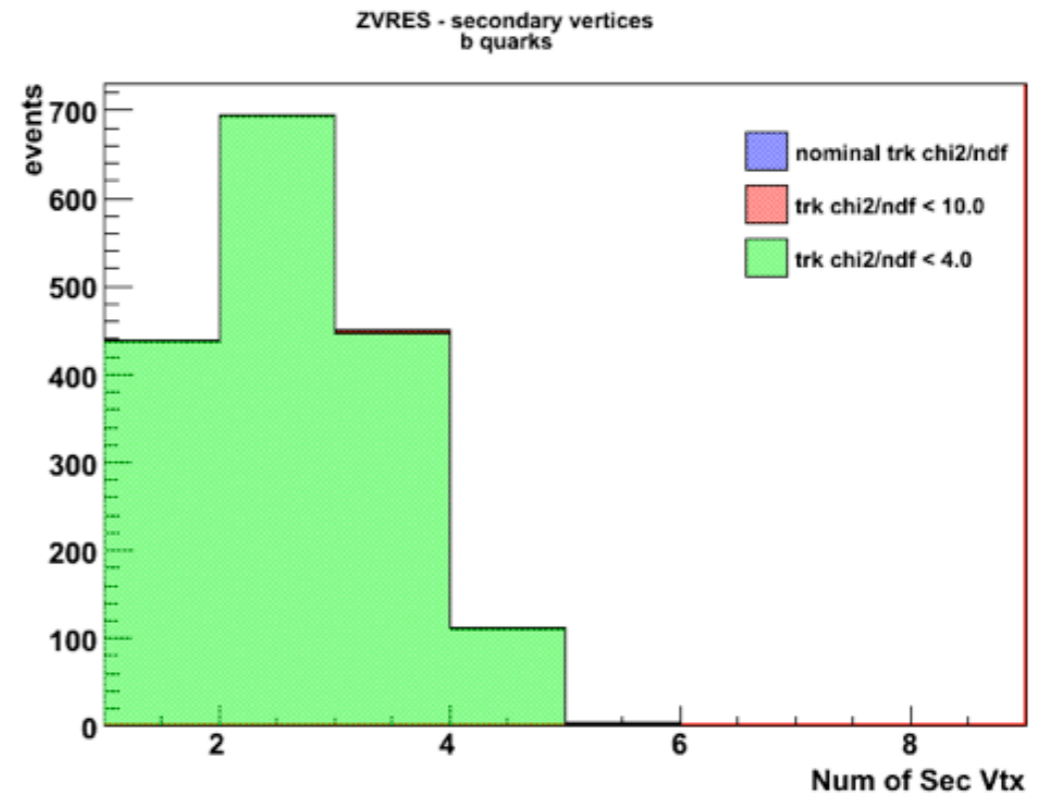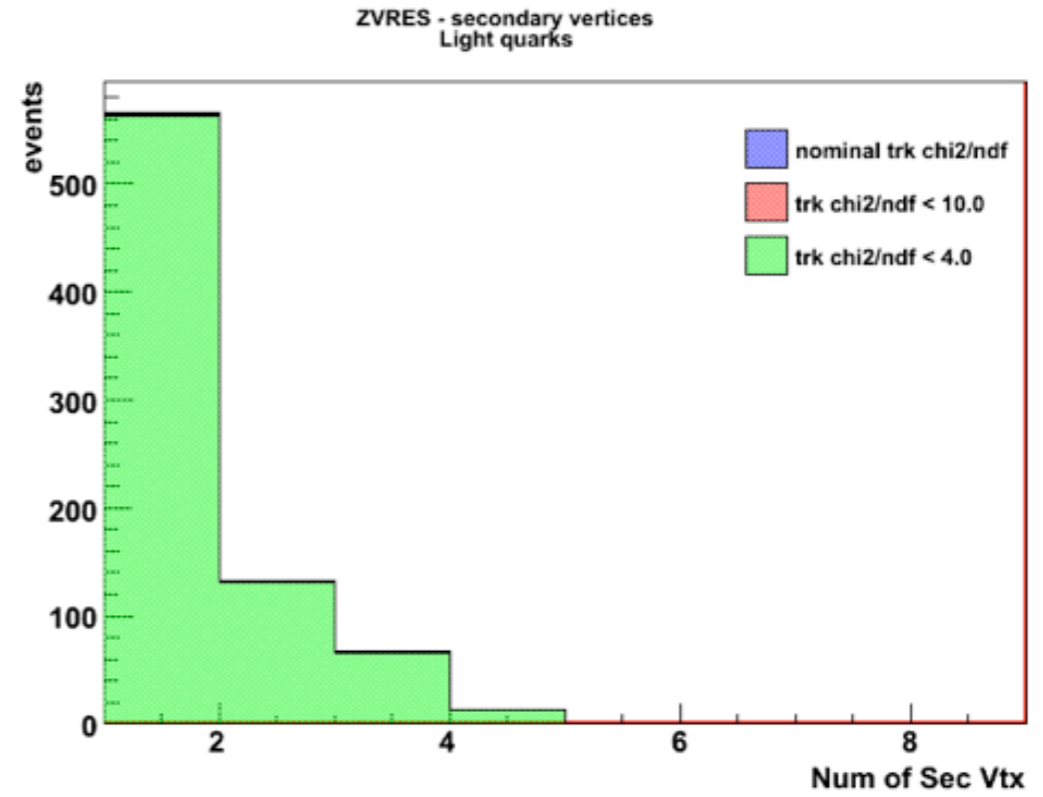
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IP vertex (z0err cut)

IPFIT: flavour tag purity as a function of the pt of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: no cut
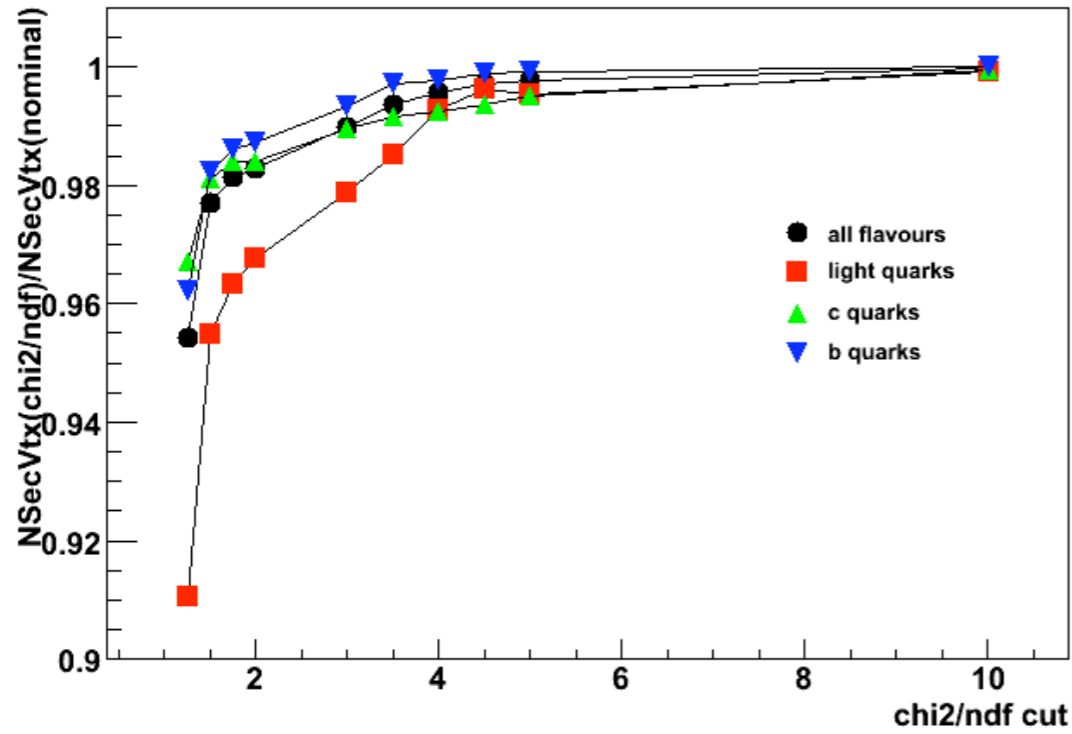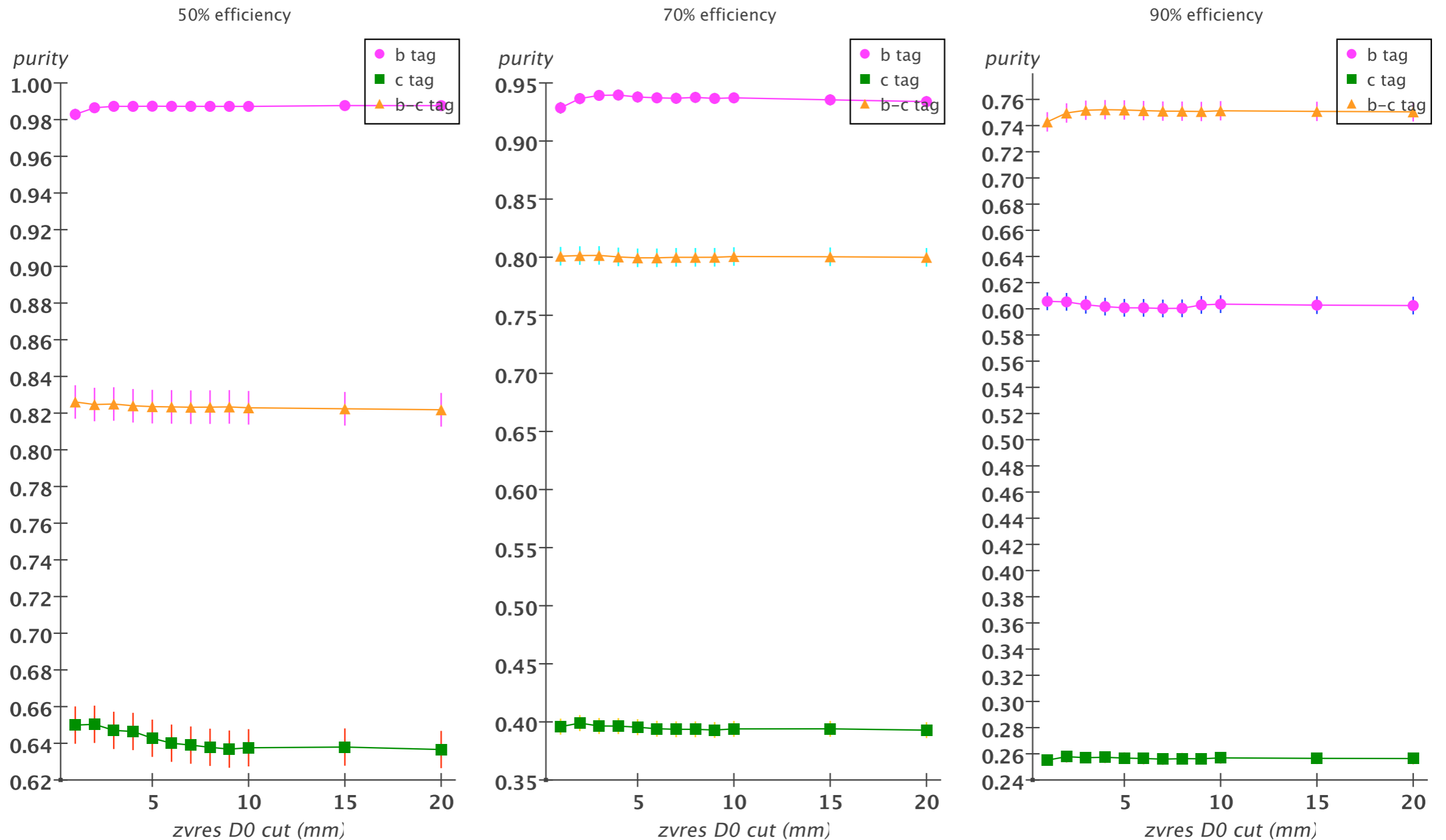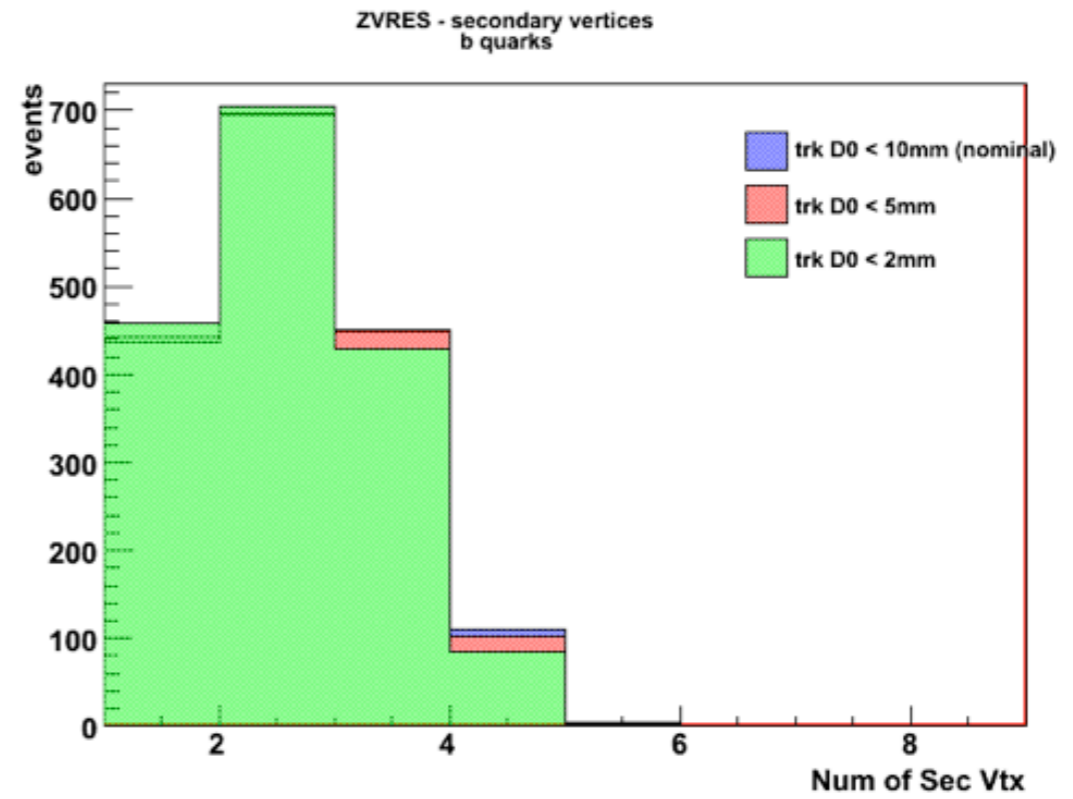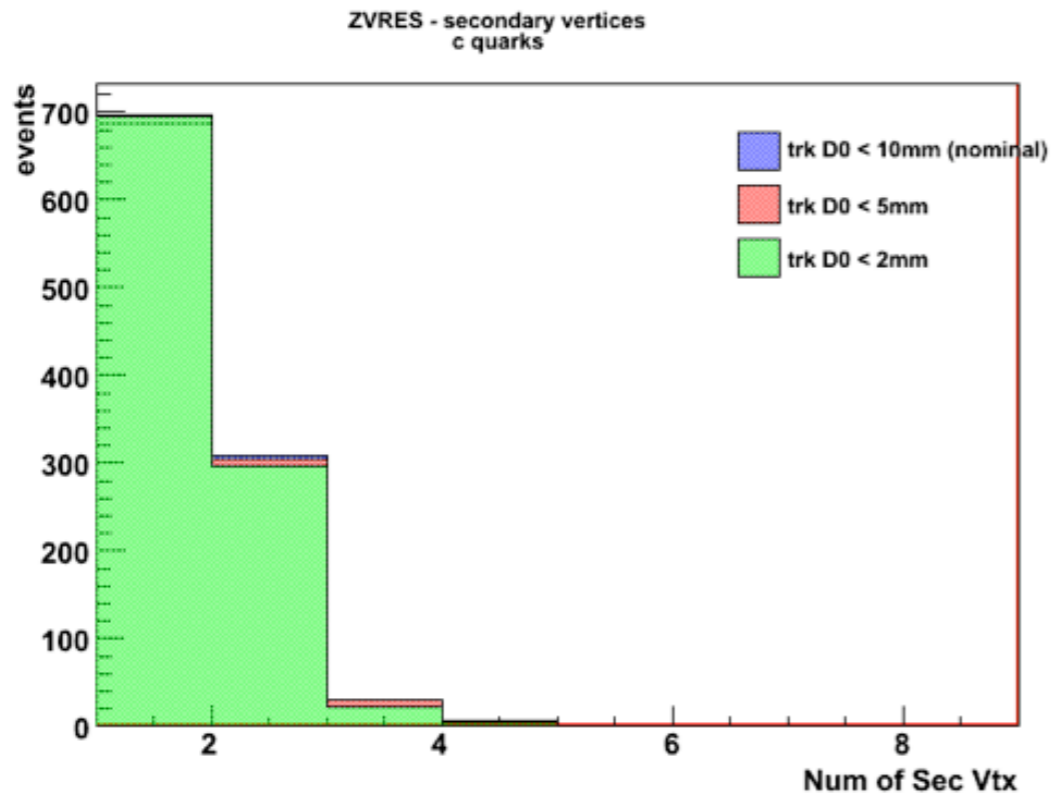

50% efficiency

70% efficiency

90% efficiency

jas3 bug!?

IP vertex (pt cut)

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ZVRES: flavour tag purity as a function of the chi2/ndf of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: no cut

50% efficiency

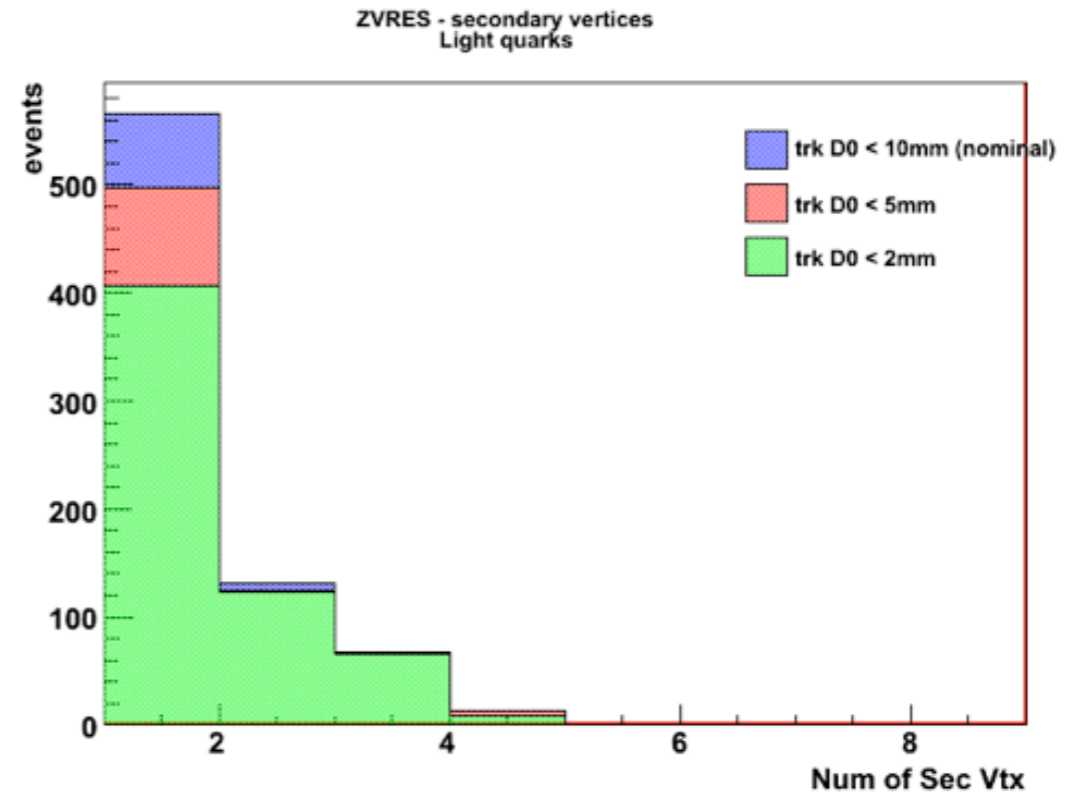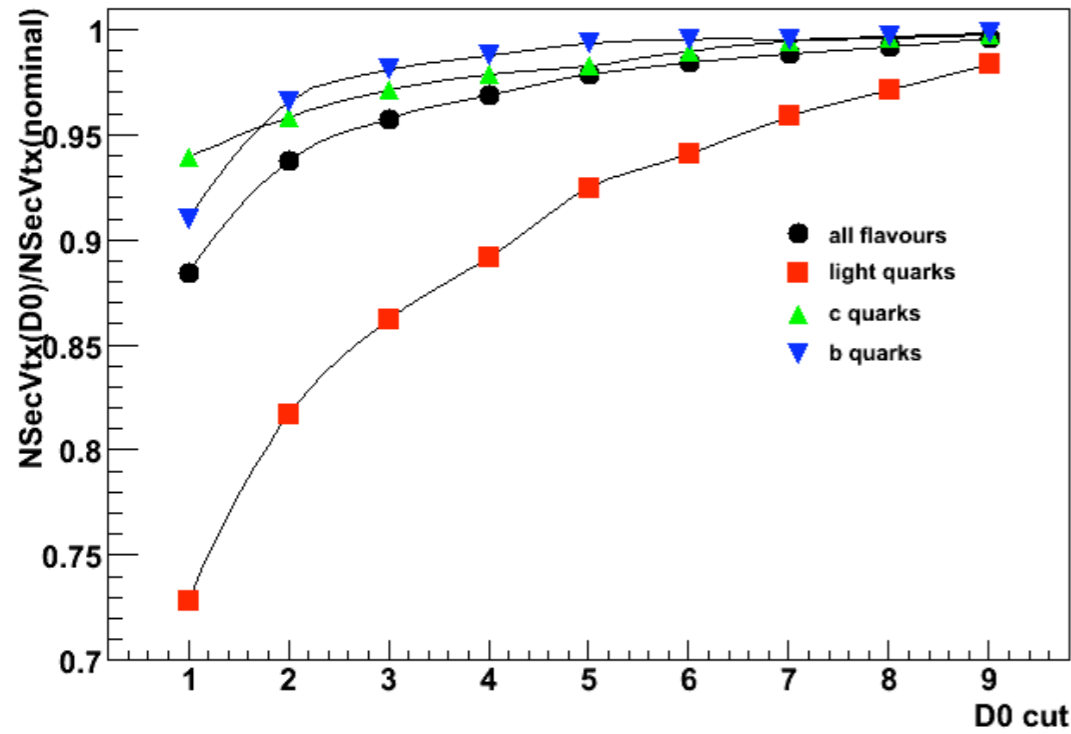70% efficiency

90% efficiency

Thursday, 11 September 2008
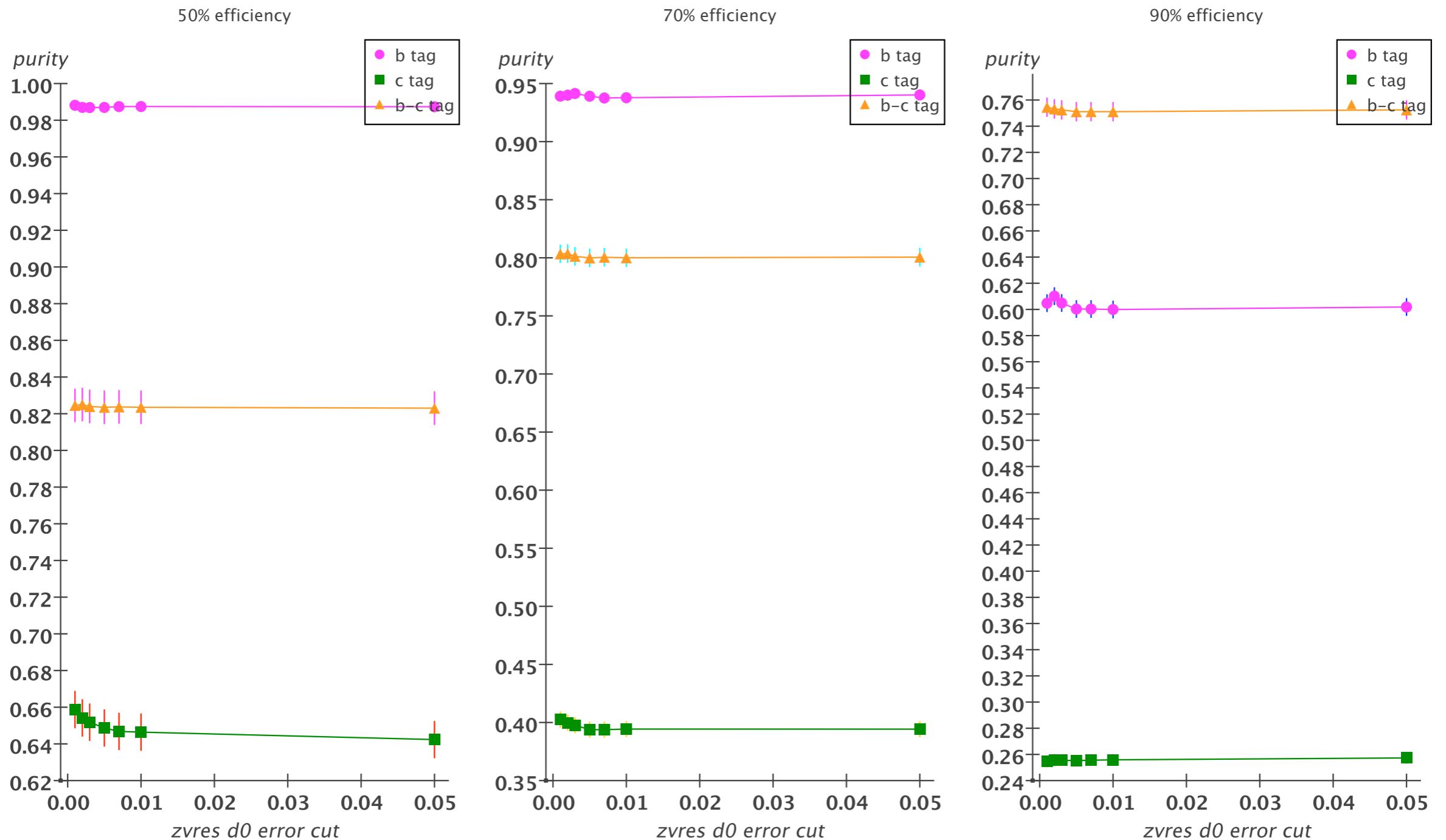
ZVRES secondary vertices (chi2/ndf cut)

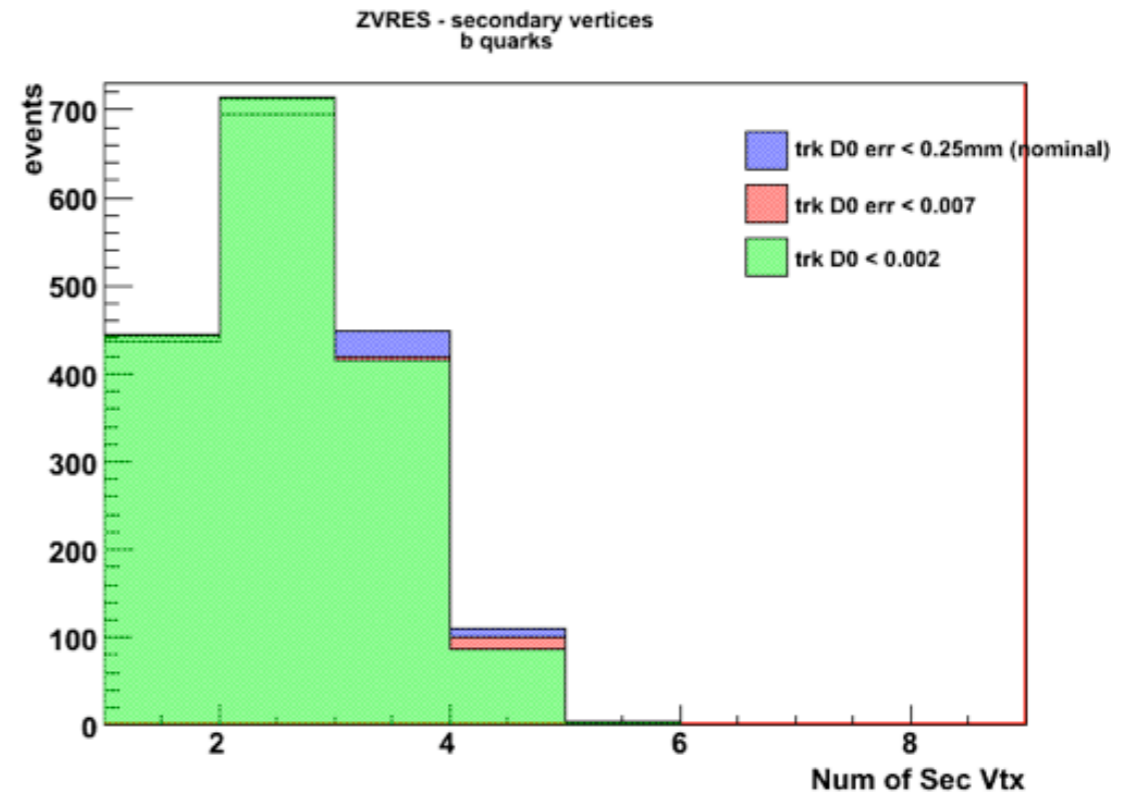# ZVRES: flavour tag purity as a function of the d0 of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: 10mm
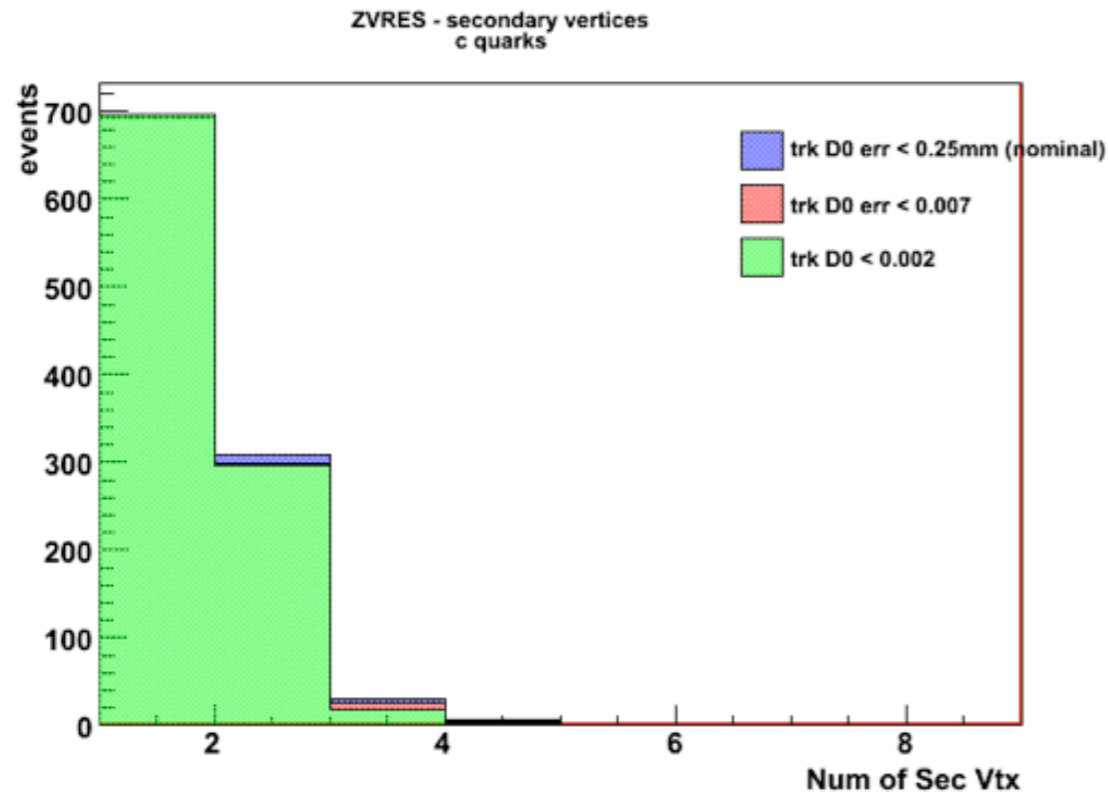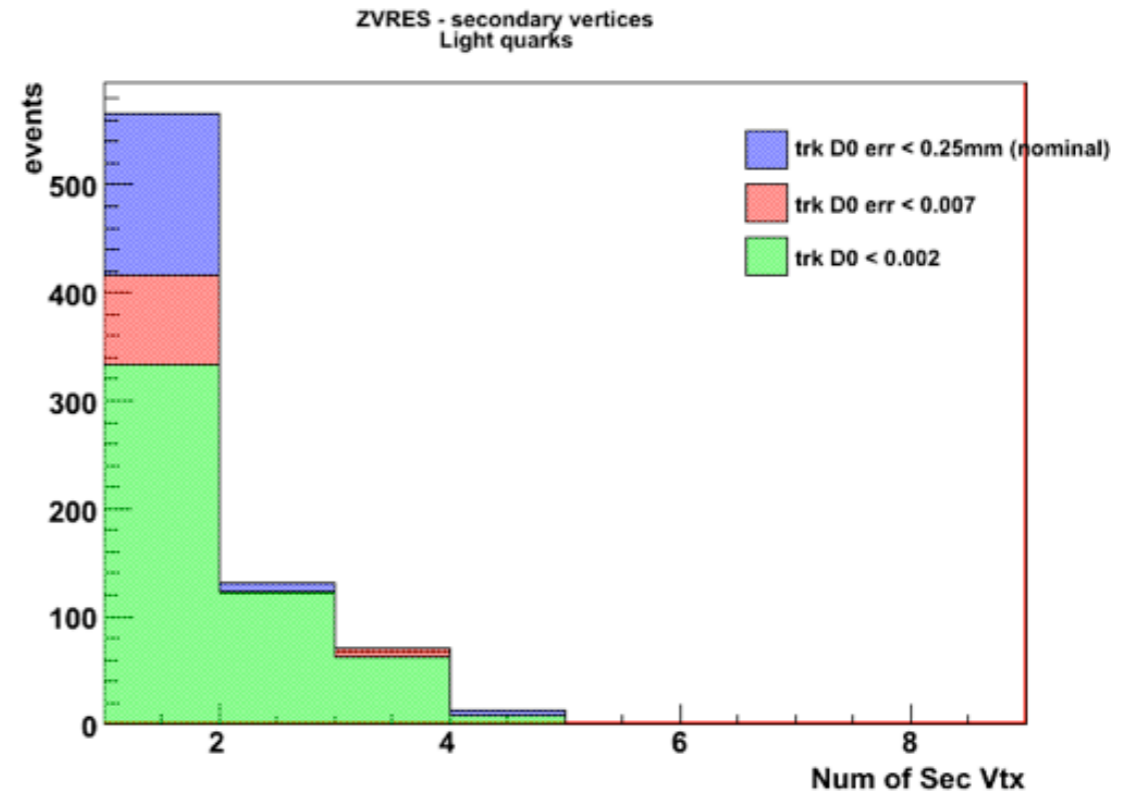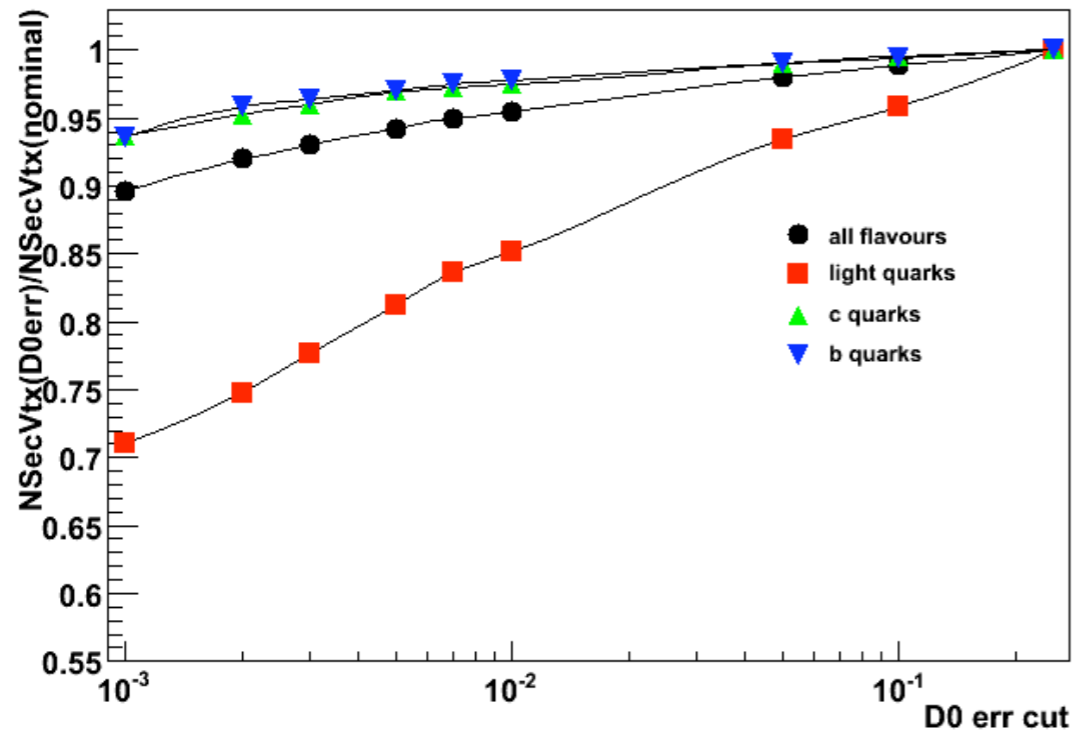
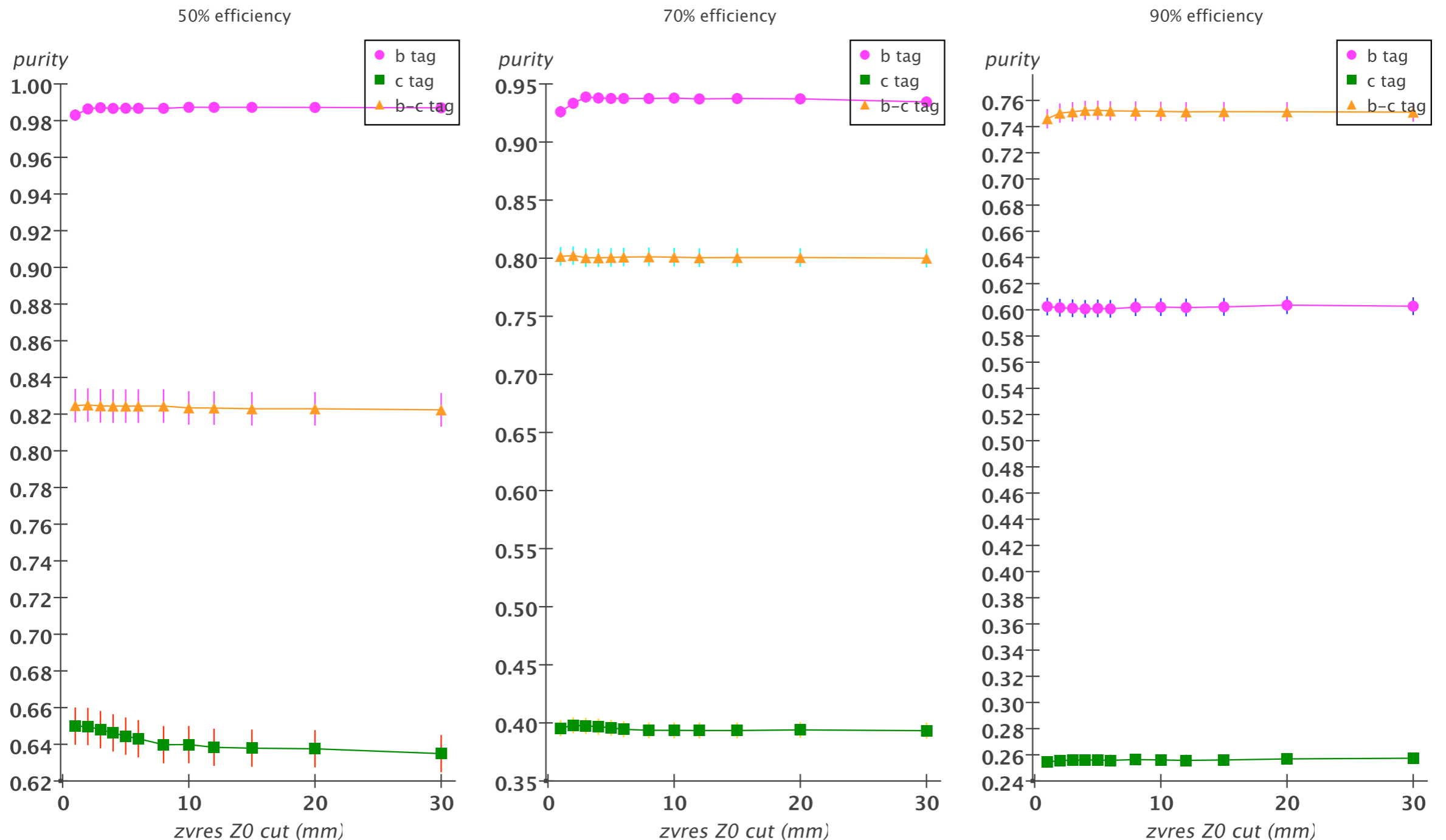# ZVRES secondary vertices (d0 cut)

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ZVRES: flavour tag purity as a function of the d0err of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: 0.25mm
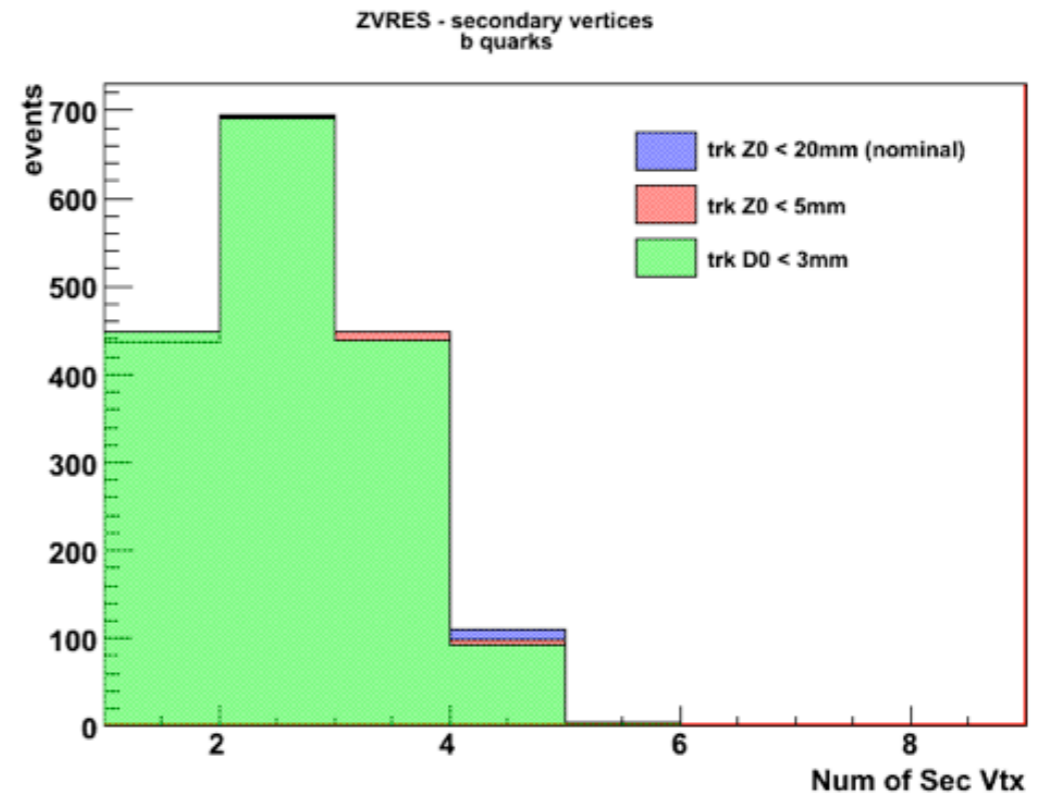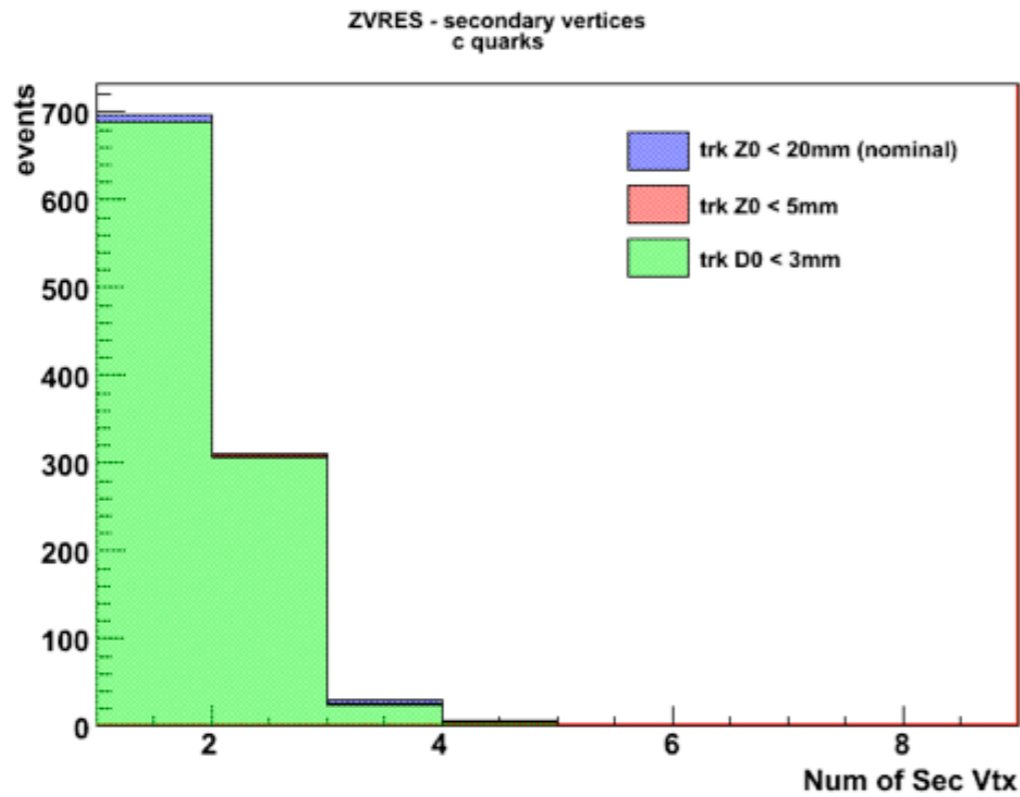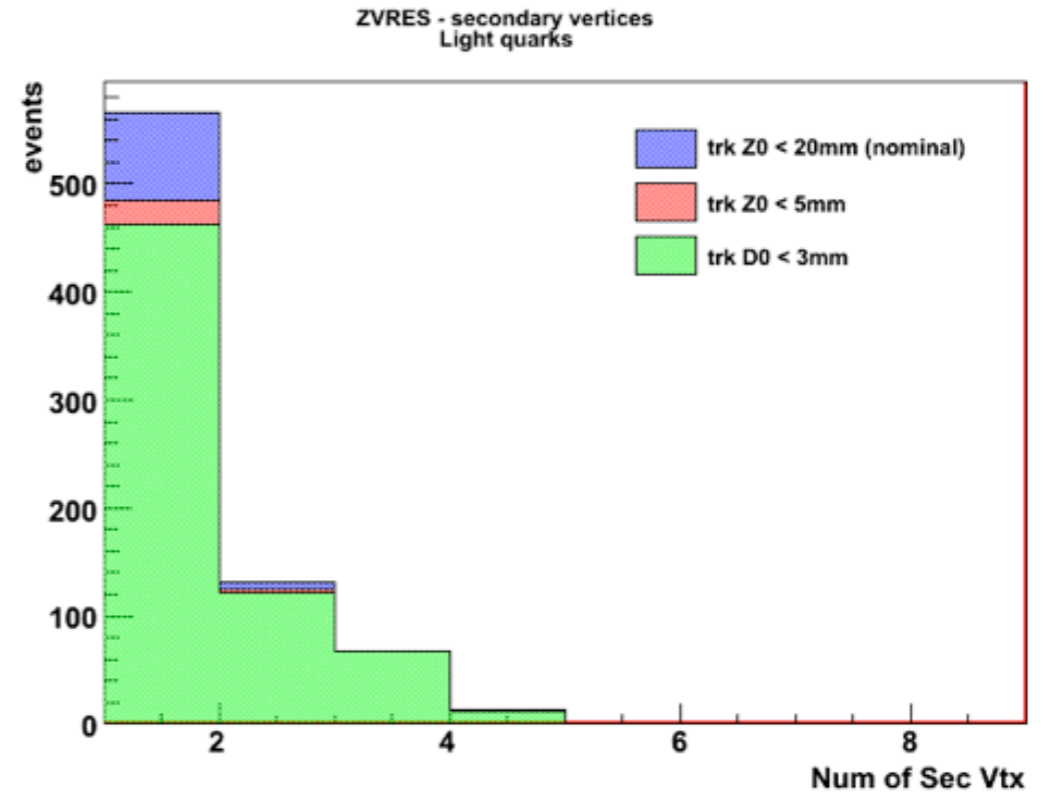

50% efficiency

70% efficiency

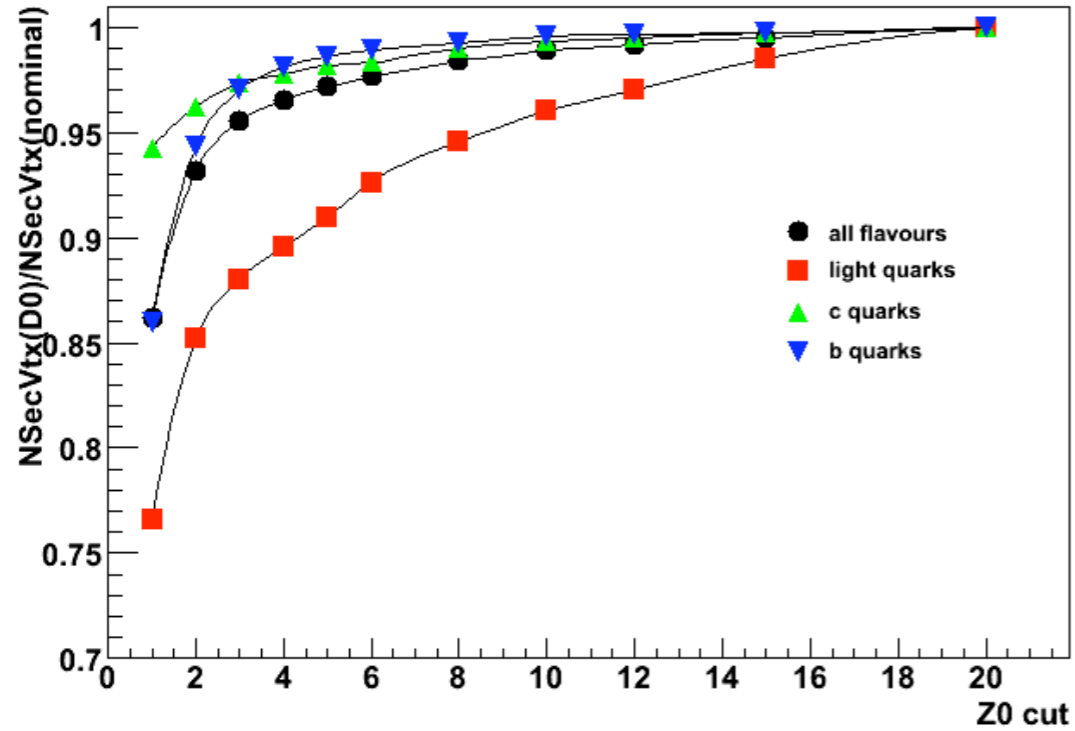90% efficiency

Thursday, 11 September 2008
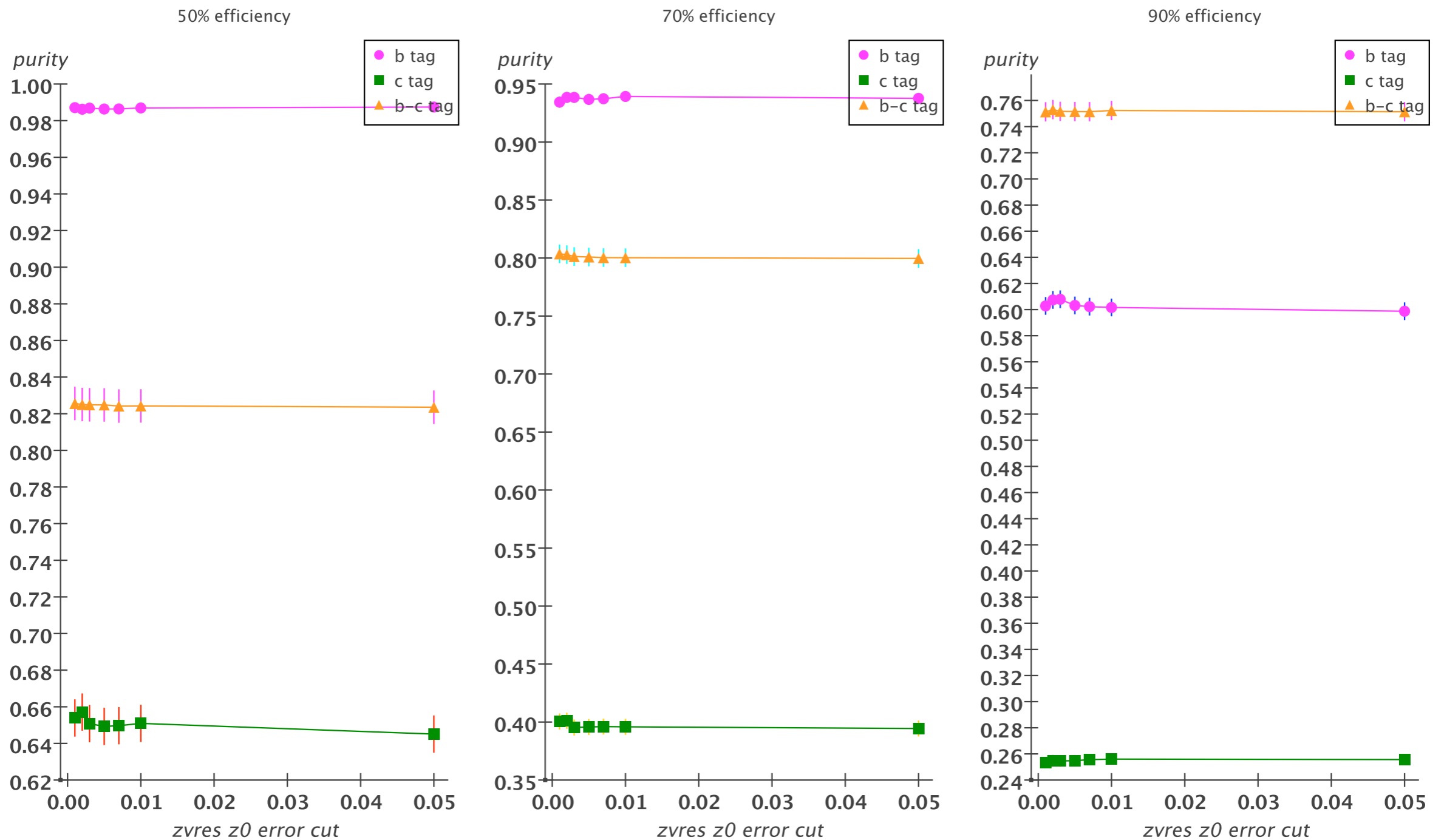
ZVRES secondary vertices (d0 error cut)

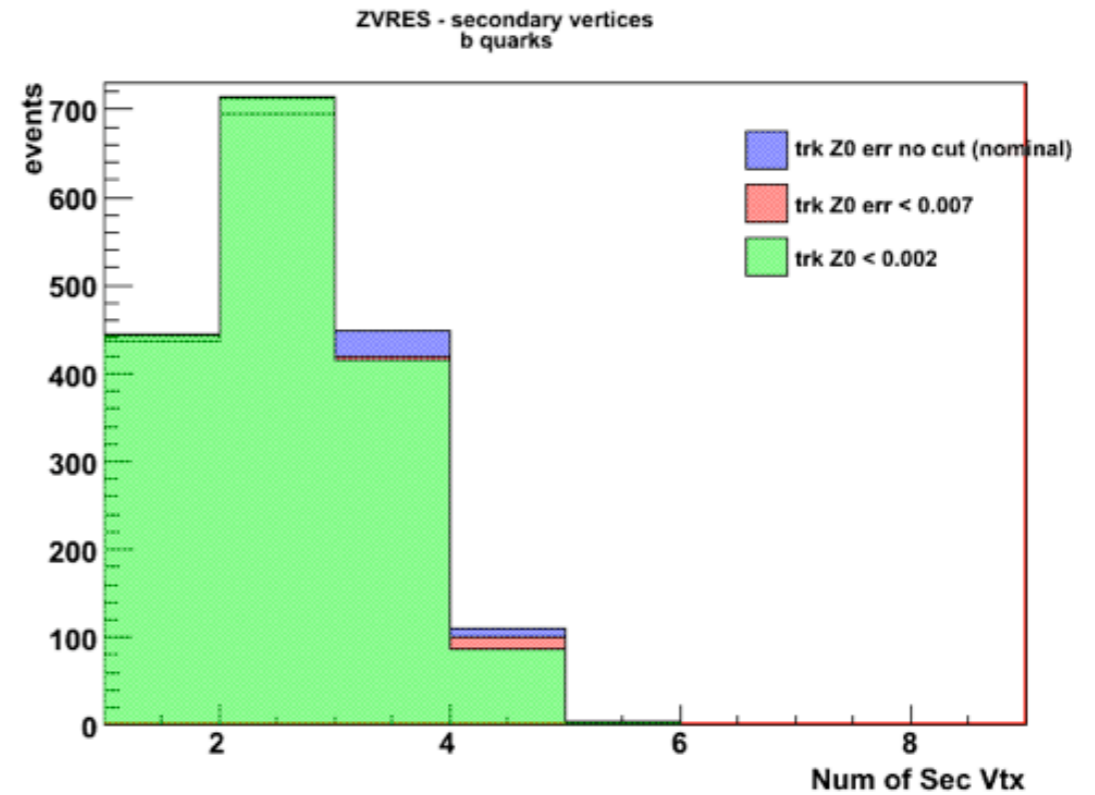# ZVRES: flavour tag purity as a function of the z0 of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: 20 mm
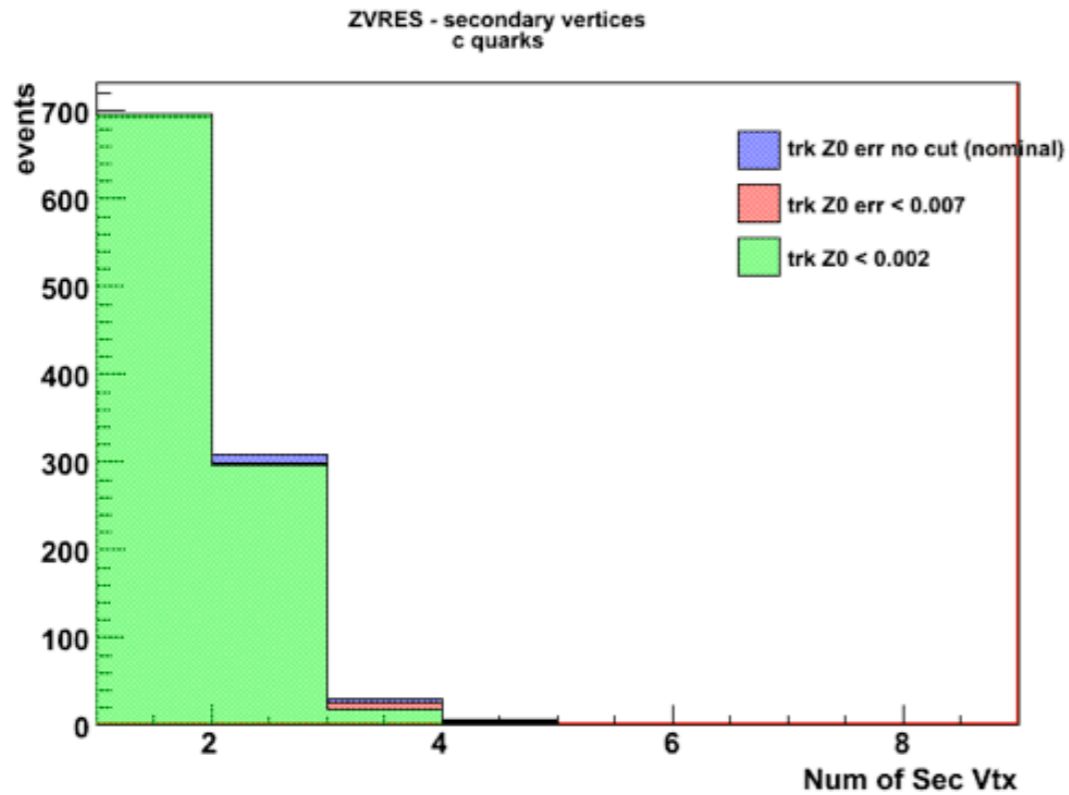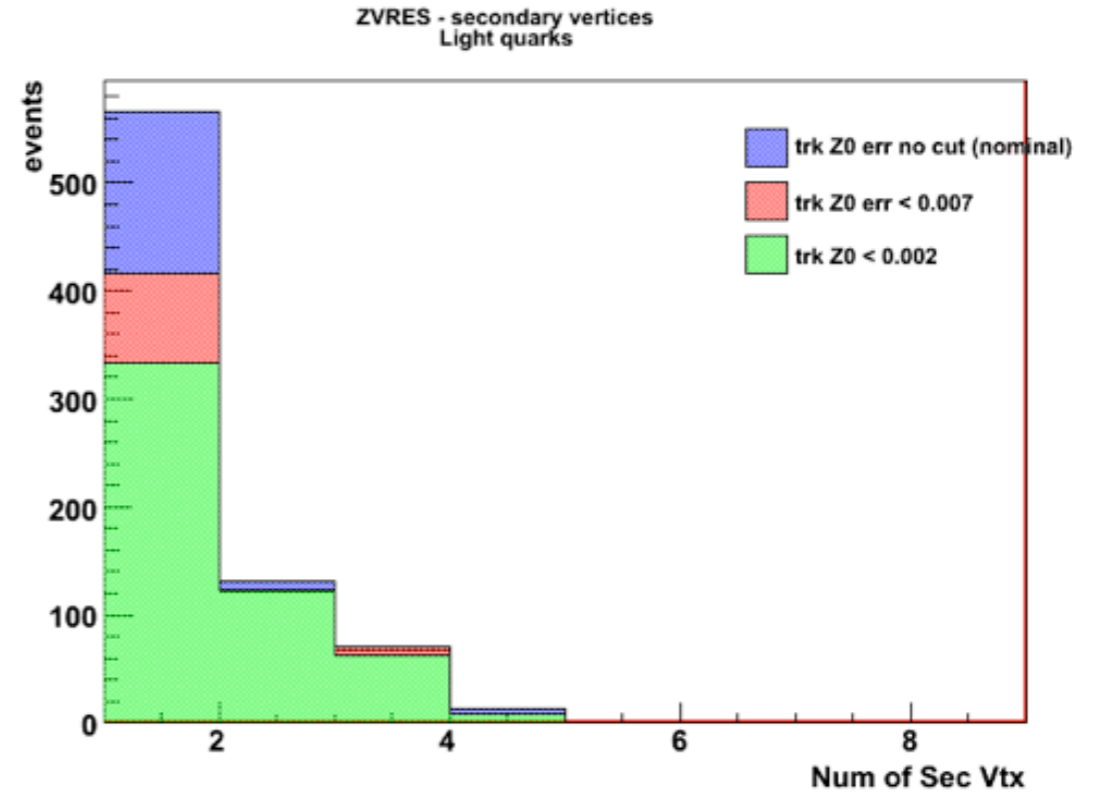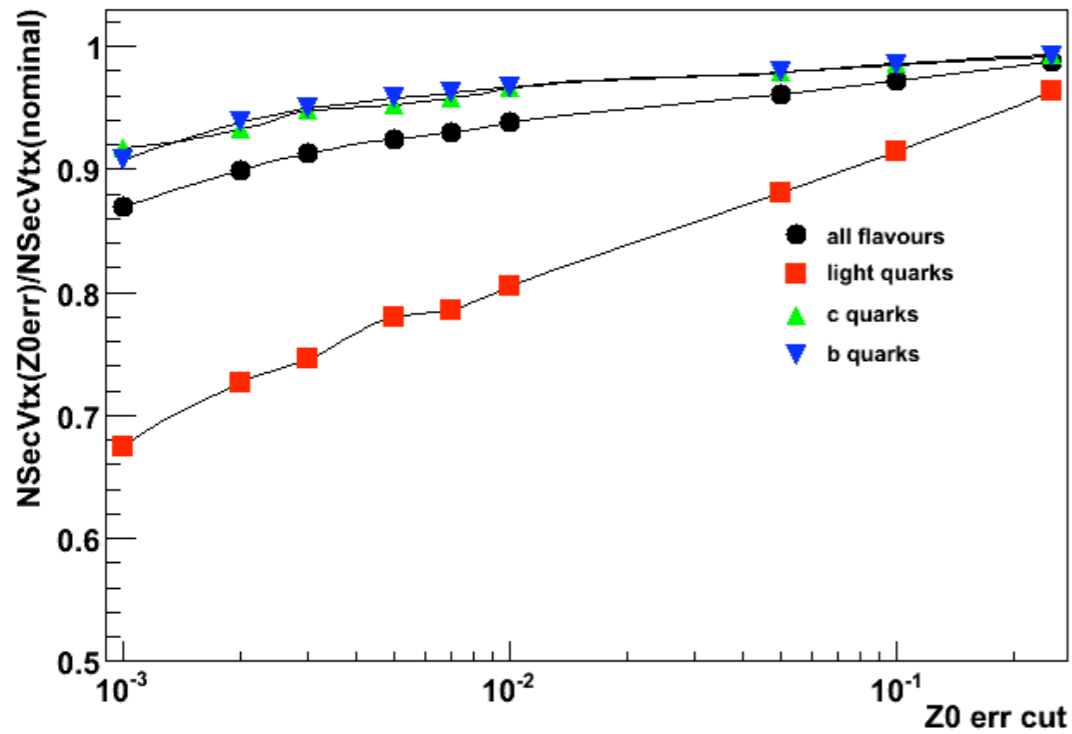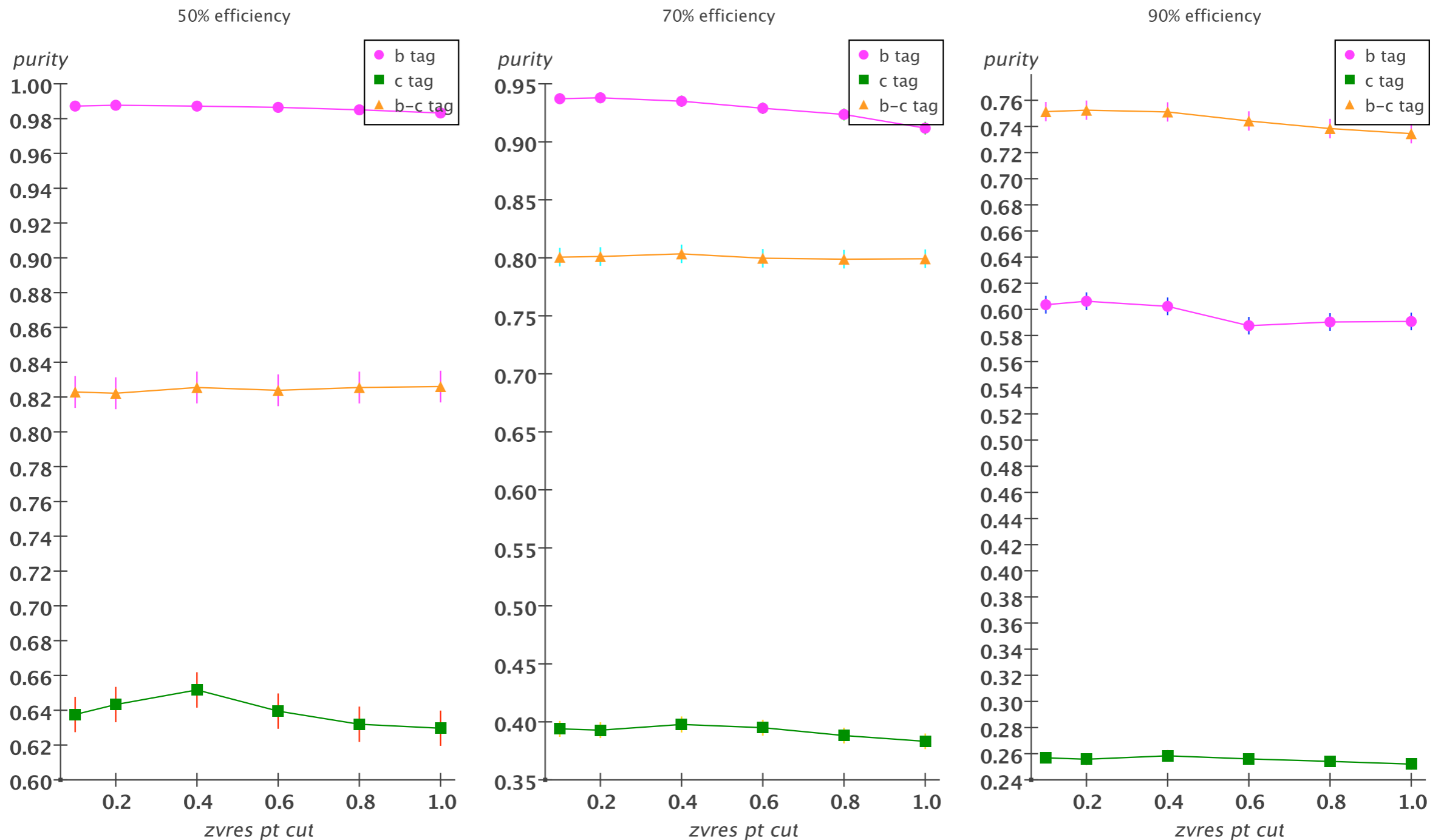
ZVRES secondary vertices (z0 cut)

ZVRES: flavour tag purity as a function of the z0err of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: no cut

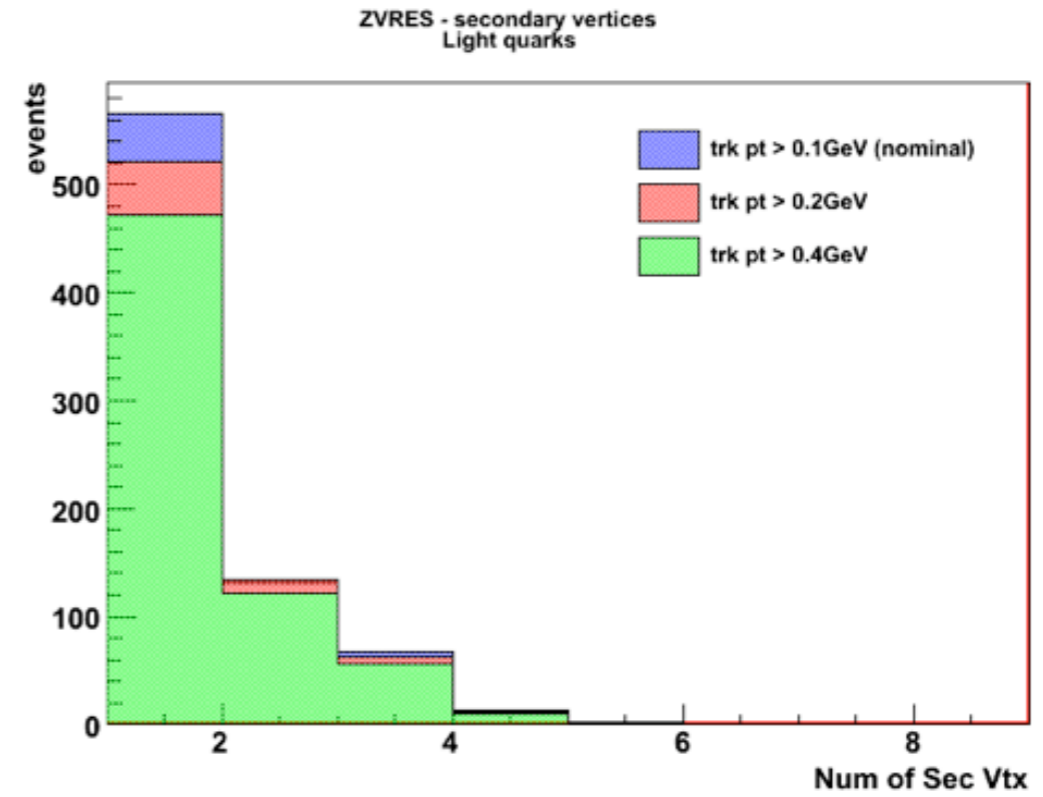
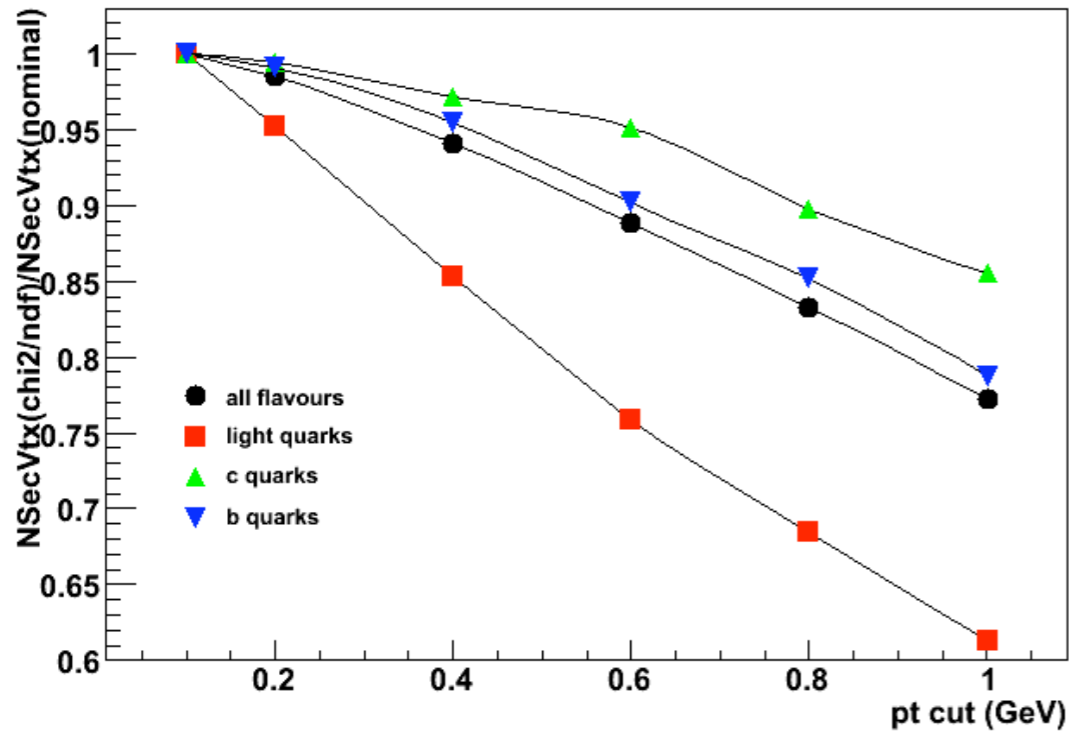50% efficiency

70% efficiency

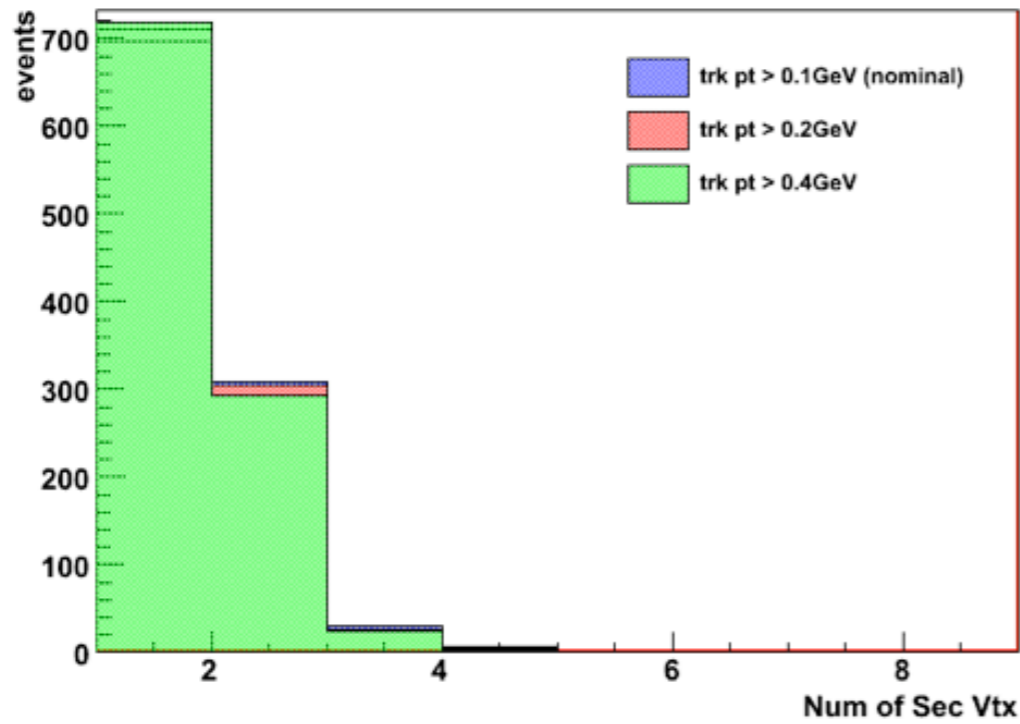90% efficiency

ZVRES secondary vertices (z0 error cut)

ZVRES: flavour tag purity as a function of the pt of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: 0.1 GeV
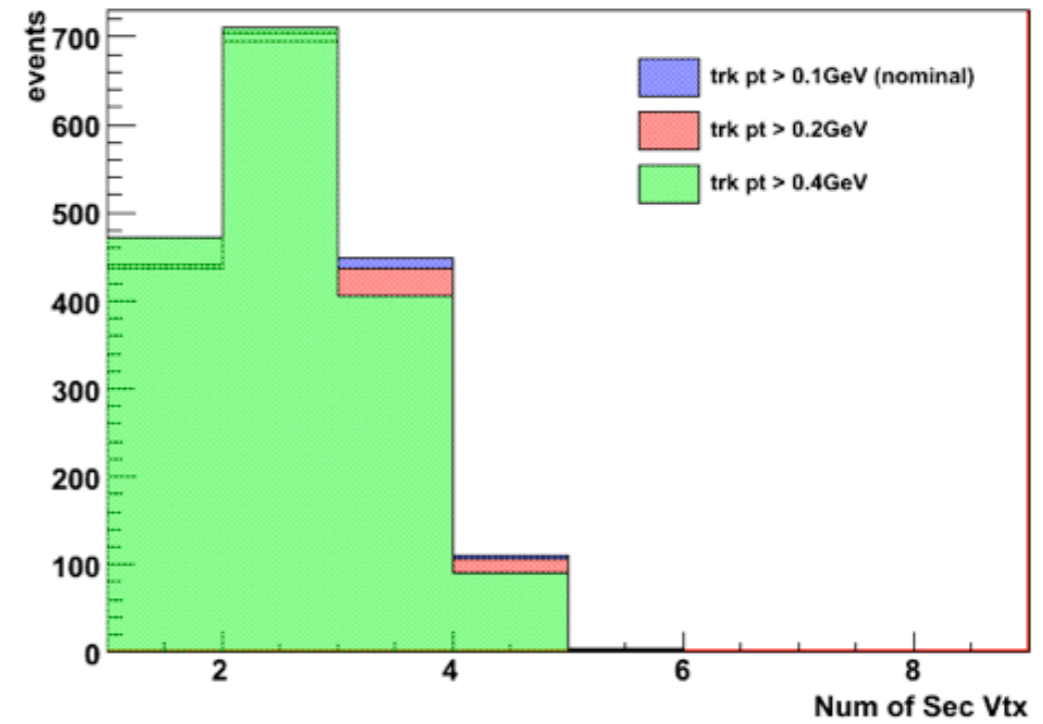
ZVRES secondary vertices (pt cut)

FTI: flavour tag purity as a function of the chi2/ndf of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: no cut

50% efficiency

70% efficiency
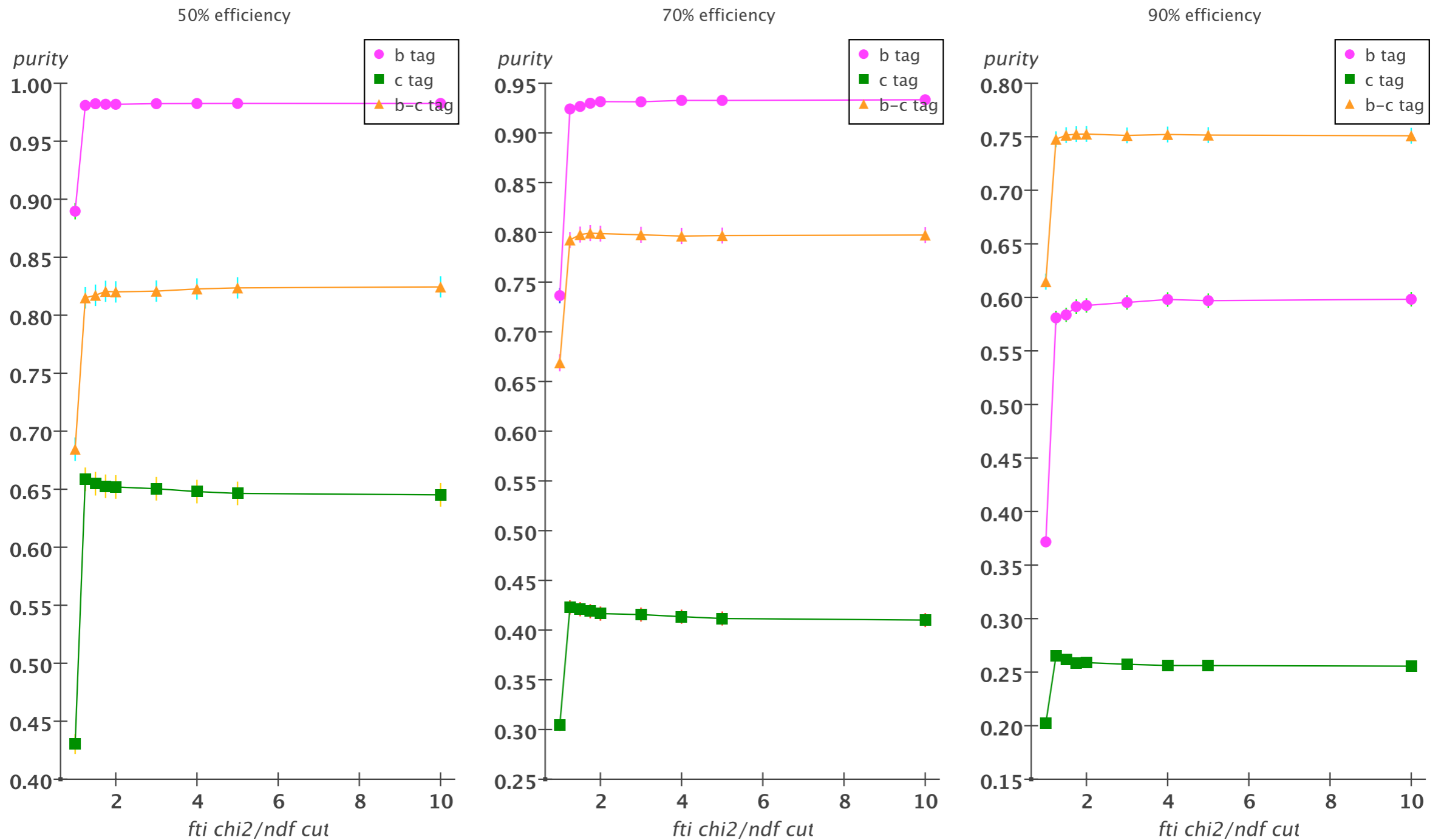
90% efficiency

FTI: 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
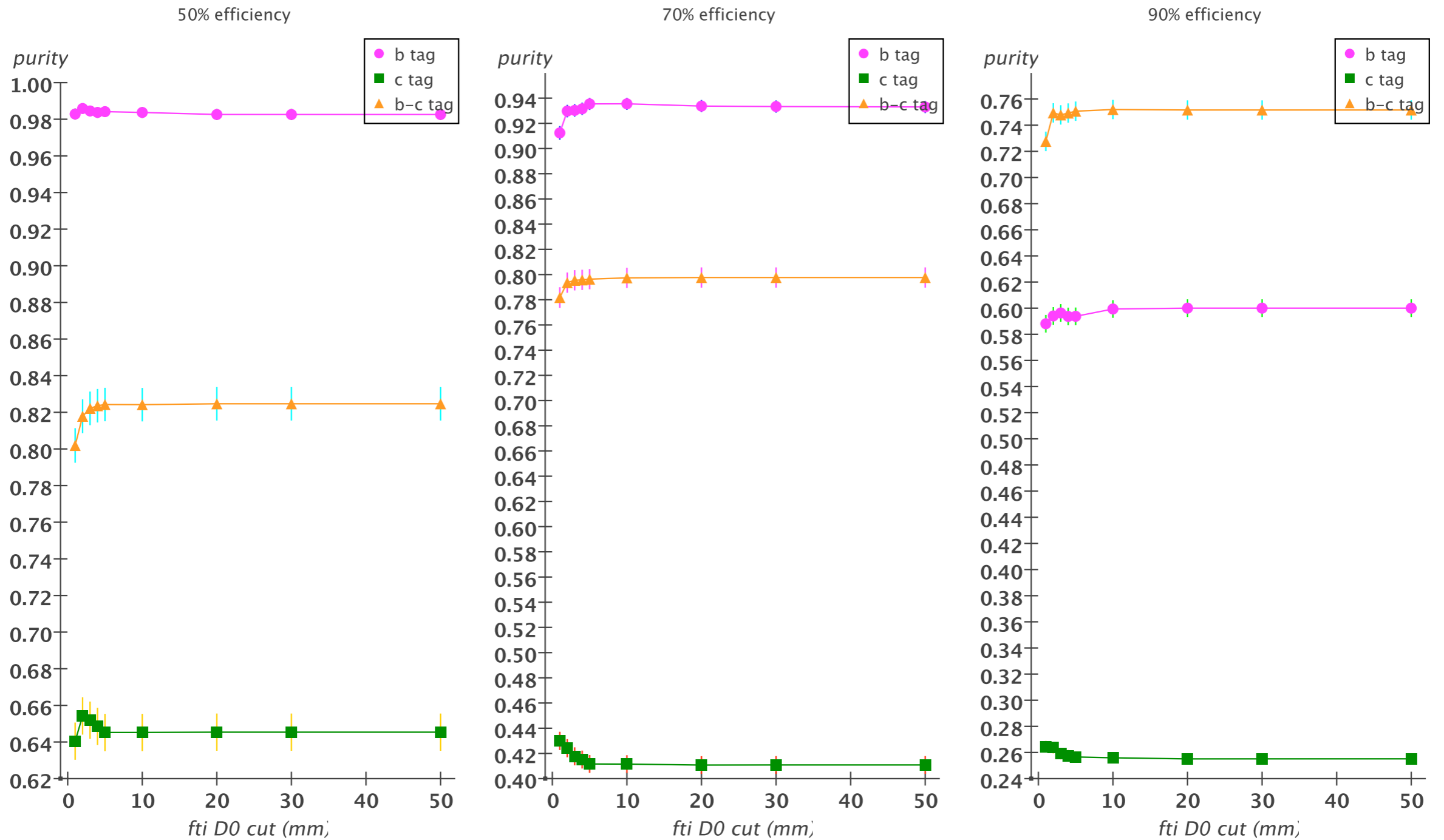
FTI: flavour tag purity as a function of the d0err of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: 0.25mm

50% efficiency

70% efficiency

90% efficiency

FTI: flavour tag purity as a function of the z0 of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: 20 mm
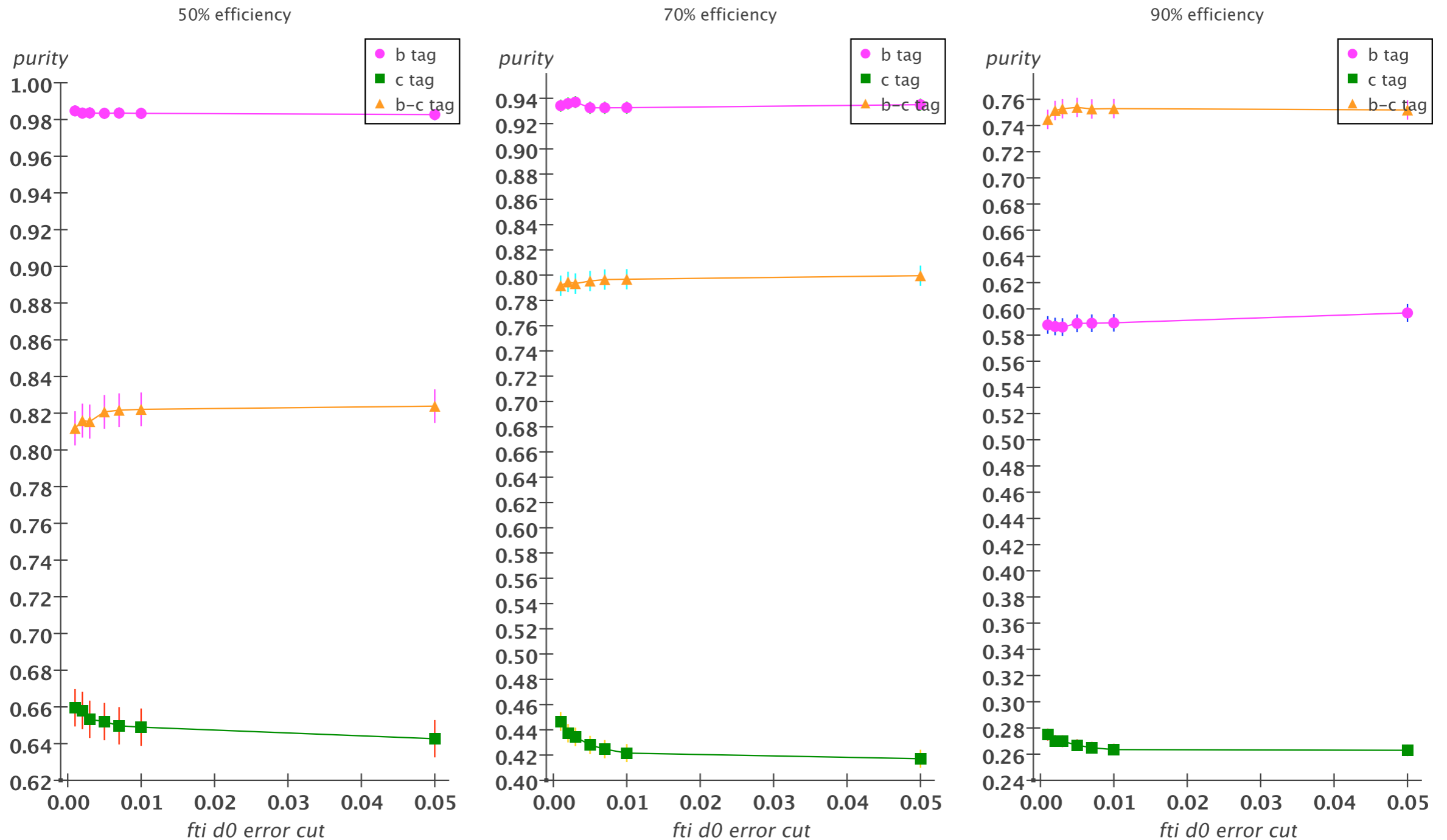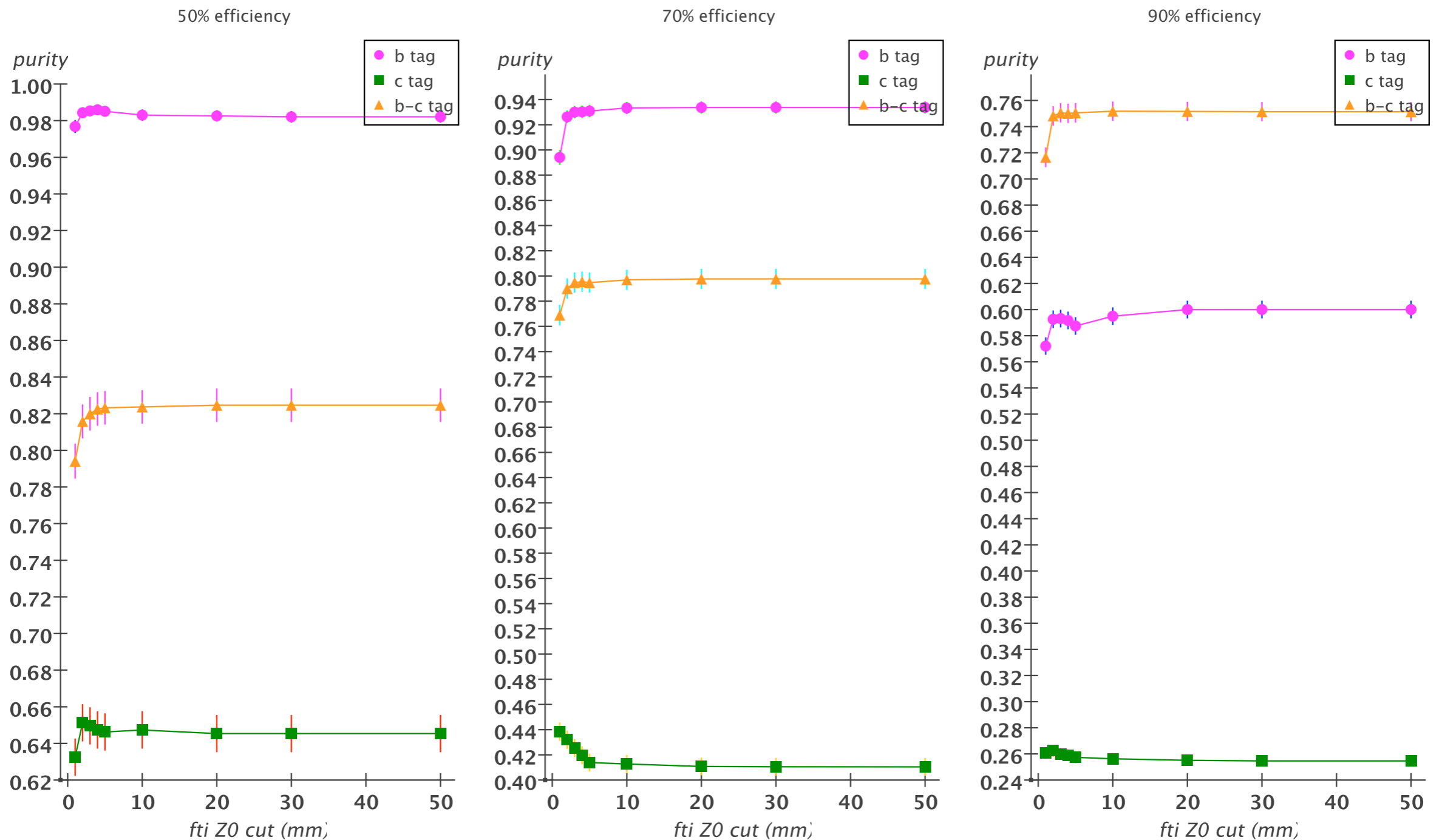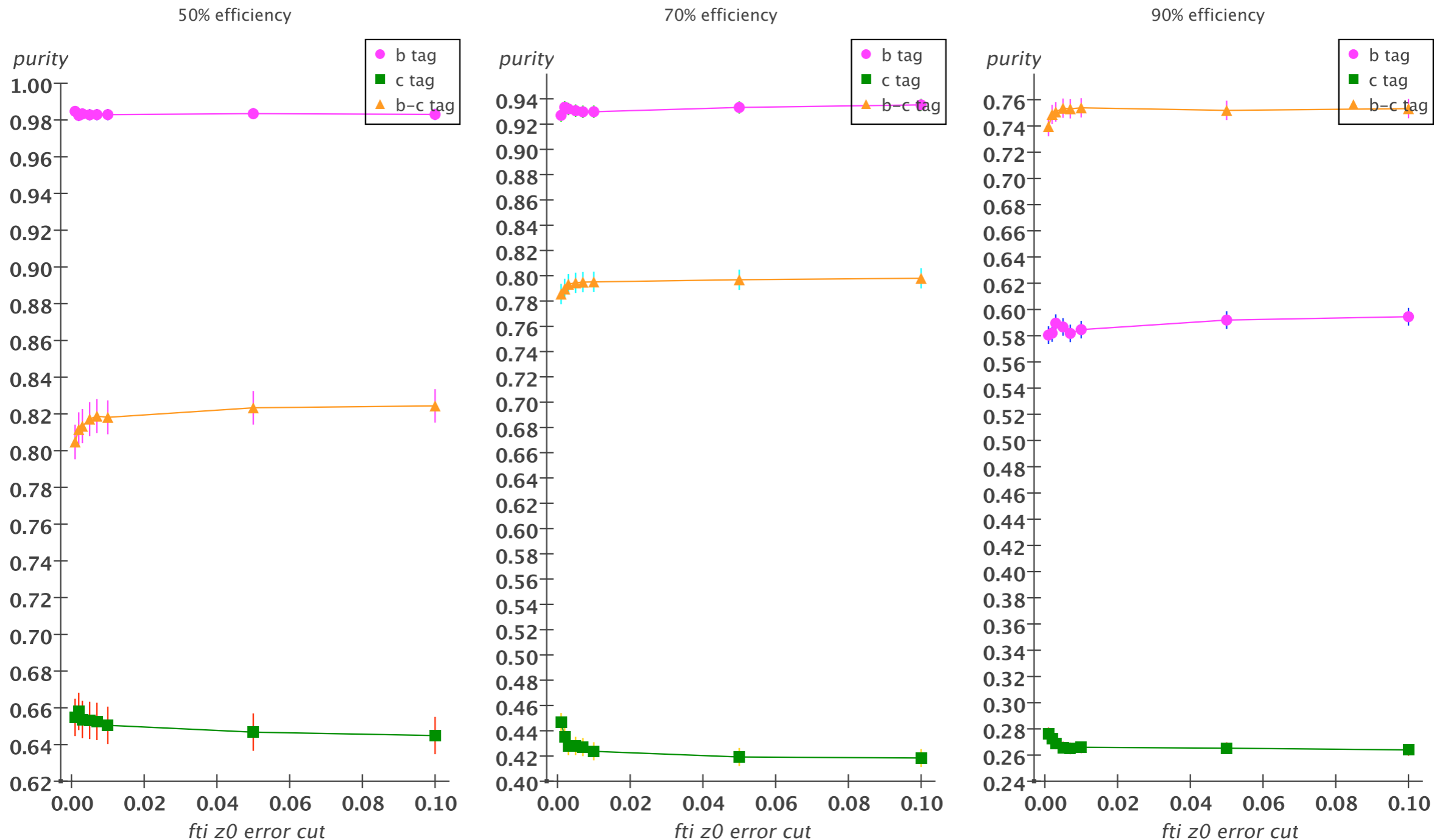
Thursday, 11 September 2008

FTI: flavour tag purity as a function of the z0err of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: no cut

50% efficiency

70% efficiency

90% efficiency

Thursday, 11 September 2008

FTI: flavour tag purity as a function of the pt of the tracks at efficiencies of 50%, 70% and 90% (any number of vertices) - nominal cut: 0.1 GeV