Top Quark Reconstruction at LHCb

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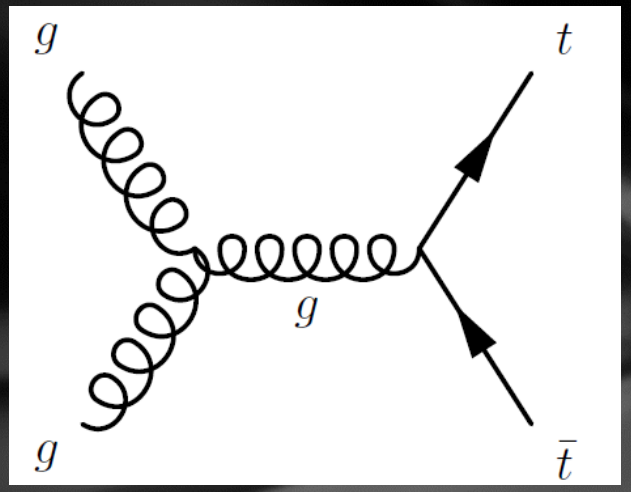
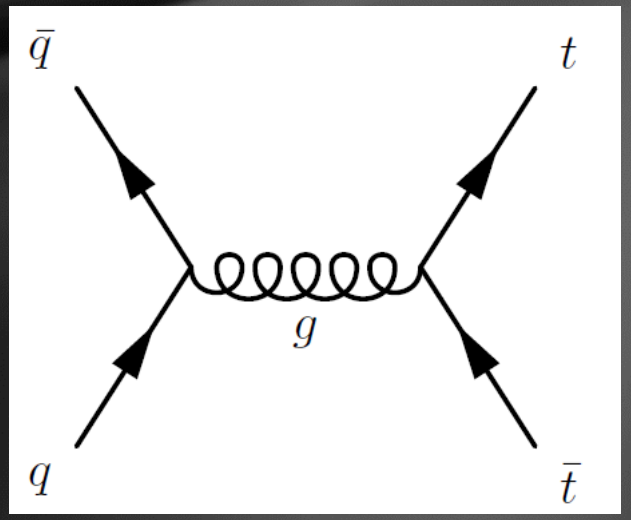
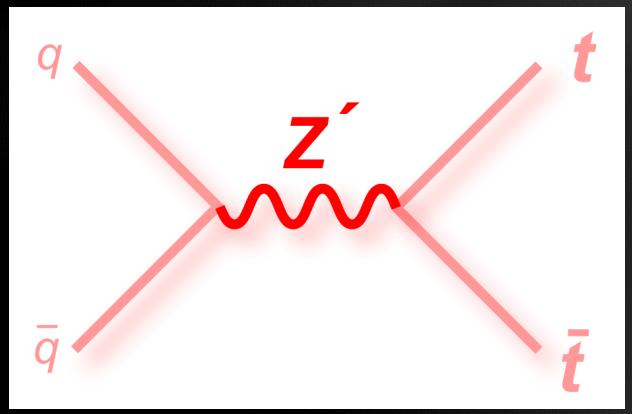
Introduction to Top

- Still the heaviest known fundamental particle
  - Decays before any hadronization
  - Best chance to see 'bare' quark
- Pair production (4π) at 7 TeV = $163\ ^{+7+9}_{-5-9}$ pb
- At 8 TeV, this increases to $234\ ^{+10}_{-7} \pm 12$ pb
- A forward region search has yet to be performed at the LHC
  - Sensitive to BSM physics





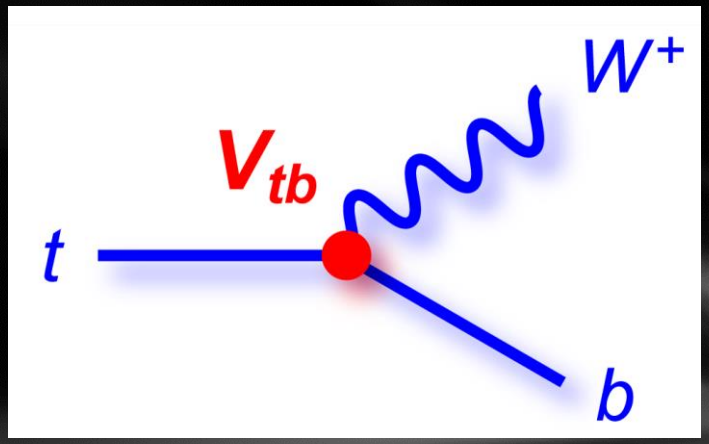
Top Asymmetry [R.Gauld's IOP talk of 9/4/13]

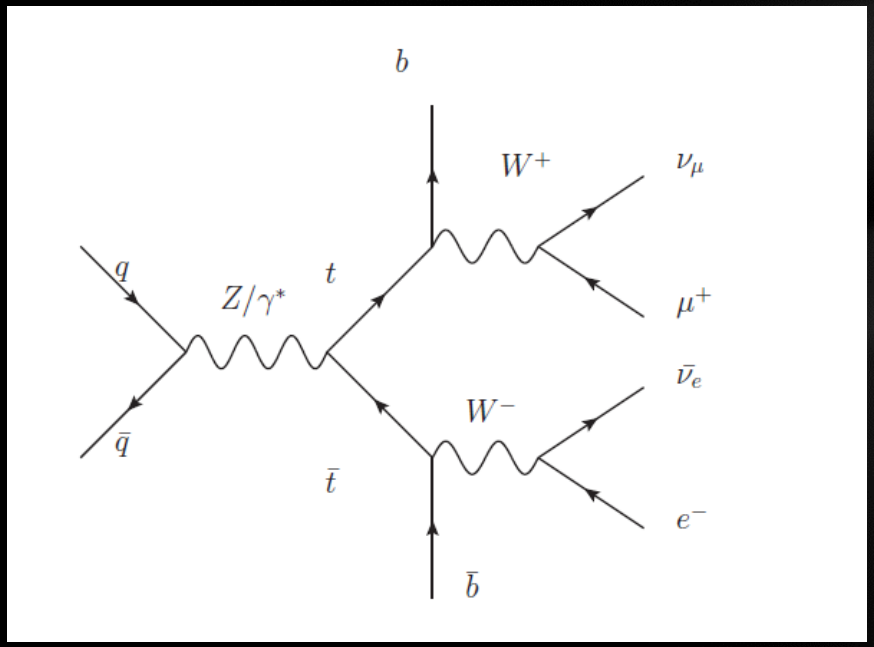


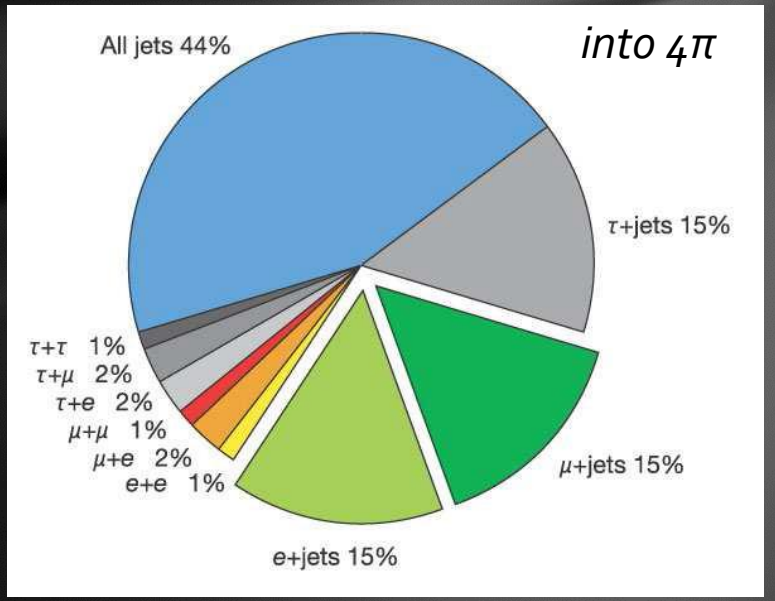
Top Decay Modes

$t \rightarrow b\ W^+$ is dominant because of the CKM term $|V_{tb}|^2$. This process occurs in approximately 99.8% of top decays

The decay modes refer to the decays of the W, e.g. all jets refers to $W \rightarrow qq'$, so 6-jet final state

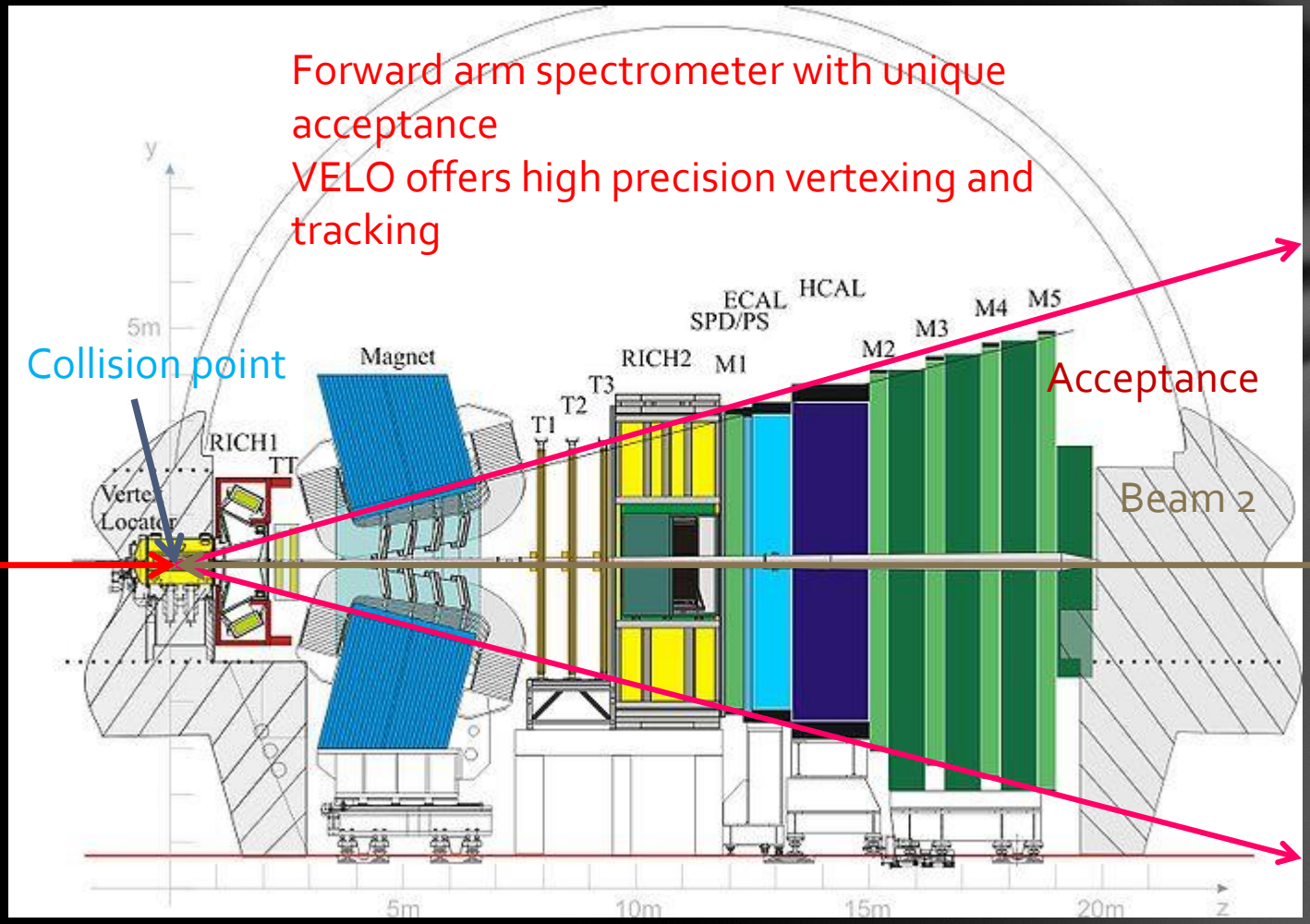






LHCb Detector

$2<\eta<5$ coverage

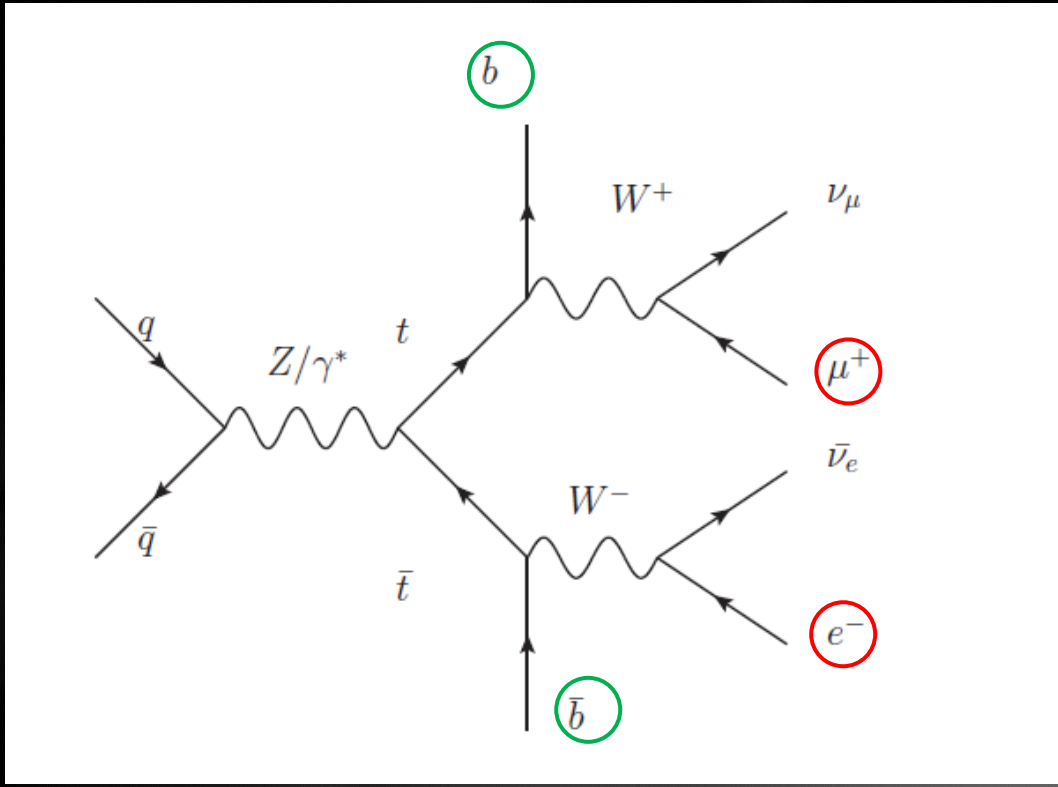


Top in LHCb

Di-lepton + b-jet search

1 fb^{-1} at C.M. = 7 TeV

2 fb^{-1} at C.M. = 8 TeV



7 TeV σ_{fid} = 9.5 ± 1.4(theory) ± 0.2(stat) fb

8 TeV σ_{fid} = 17.2 ± 2.9(theory) ± 0.2(stat) fb

LHCb Acceptance

(POWHEG+CT10NLO)

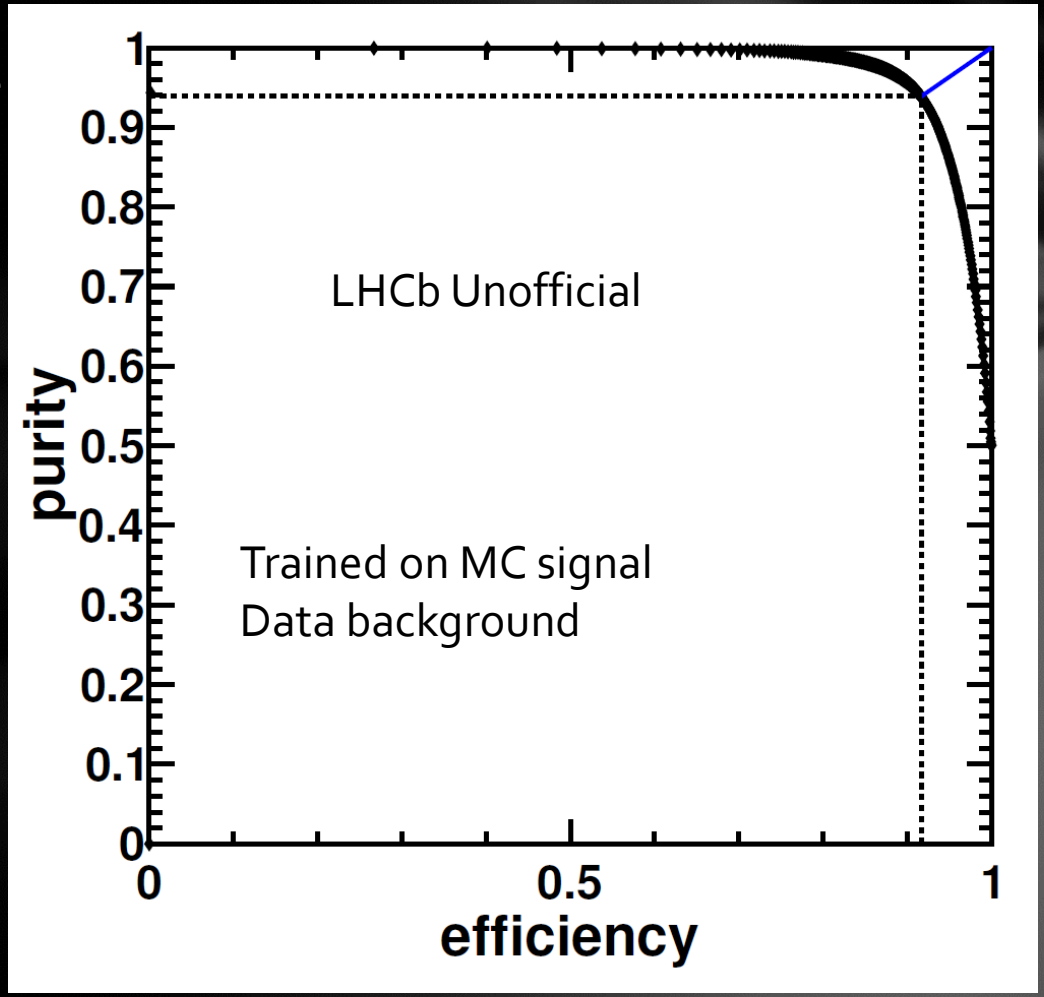
b-tagging Overview

Using neural network to analyze the correlation between variables to try and create discrimination between signal and background

- For example obvious correlated variables will be P_T, impact parameter

Two networks used

- Identifying tracks from *b*-hadron decays
- Cascade this information to another network using jetscope variables



b-tagging Results

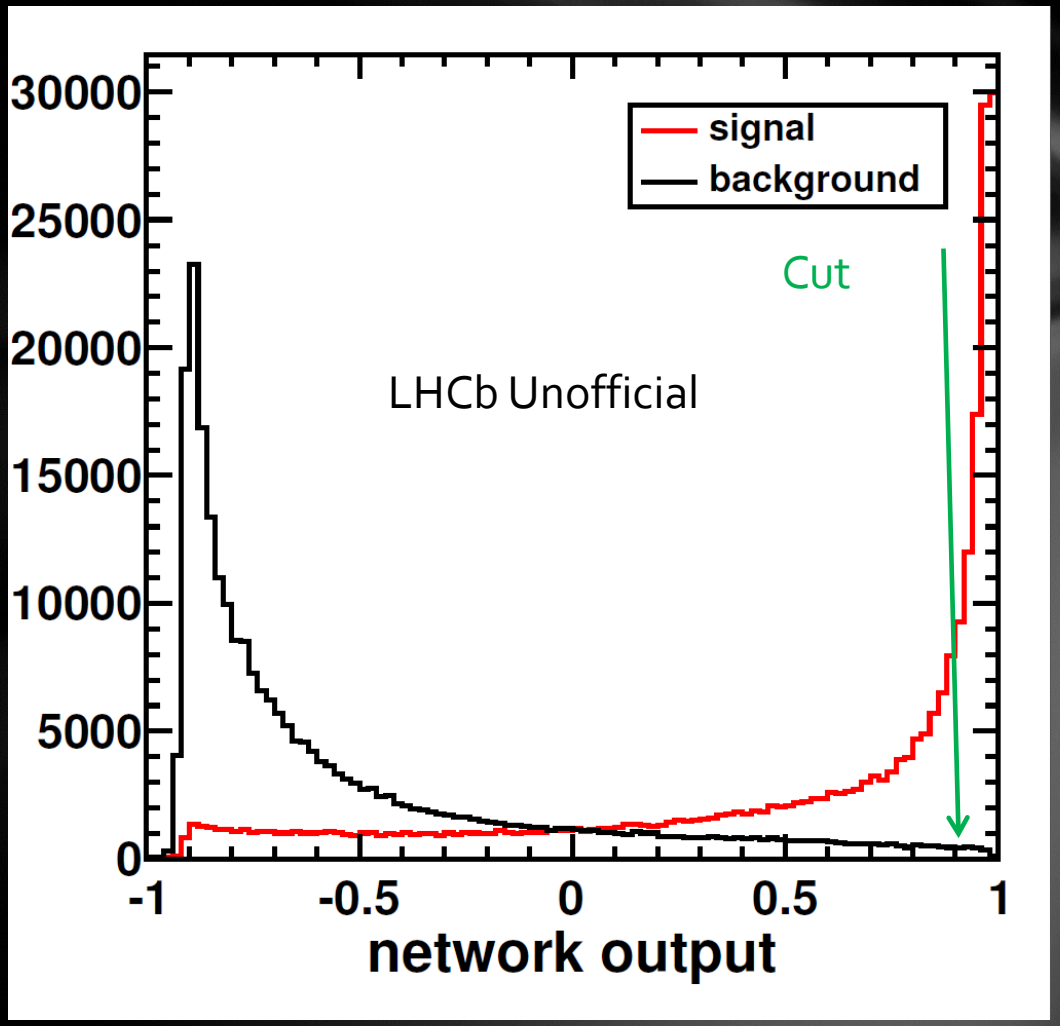
Output ranges from -1 to +1

TrackNet most significantly correlated parameters:

- Impact Parameter - 32σ
- IP Error - 34σ
- IP Significance - 59σ

JetNet:

- Maximum track net output - 120 σ
- Jet P_T - 191 σ
- Sum of track P_T – 59.6 σ



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Selection

- l P_T > 15 GeV/c
- l isolation > 90%
- $M_{inv(\mu e)}$ > 15 GeV/c^2
- l IP < 35 μm
- DOCA(ll) < 35 μm
- Neural Network b-tag ≥ 0.9

Trigger on single high P_T μ (>15 GeV/c)

Plots are for 8 TeV samples

Backgrounds

Normalized by NLO cross sections

Backgrounds considered:

$Z \rightarrow \tau\tau$

Z to $\mu\mu$ (μ faking e)

WW

$Z \rightarrow ee$ (e faking μ)

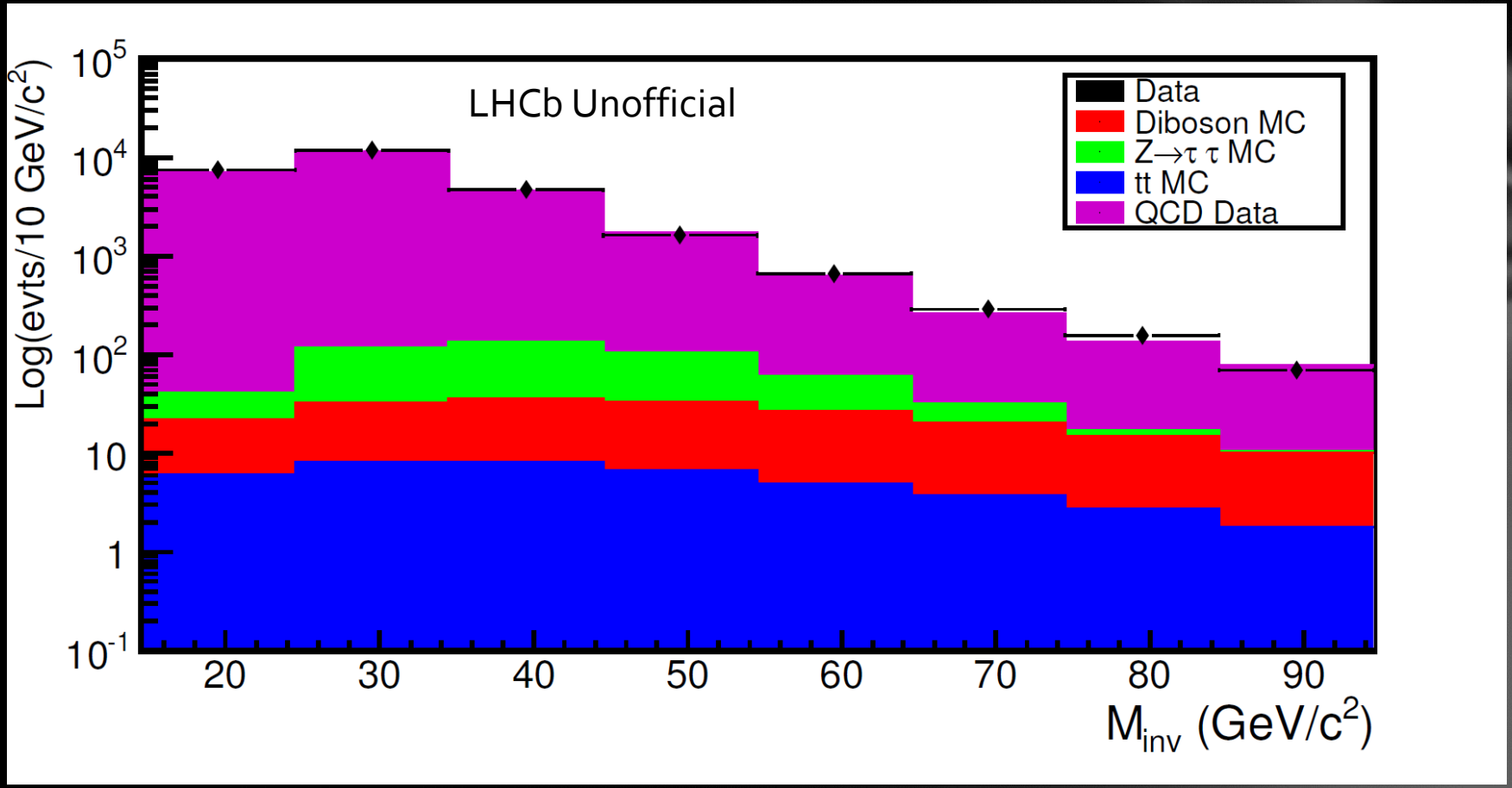
ZW

QCD

Jets are reconstructed using the Anti-K_T algorithm, P_T>5 GeV Tracks+neutrals

Preselection

e PT > 5 GeV/c
IP (l)< 35 μm
μ PT > 15 GeV/c
M_{inv} > 15 GeV/c^2

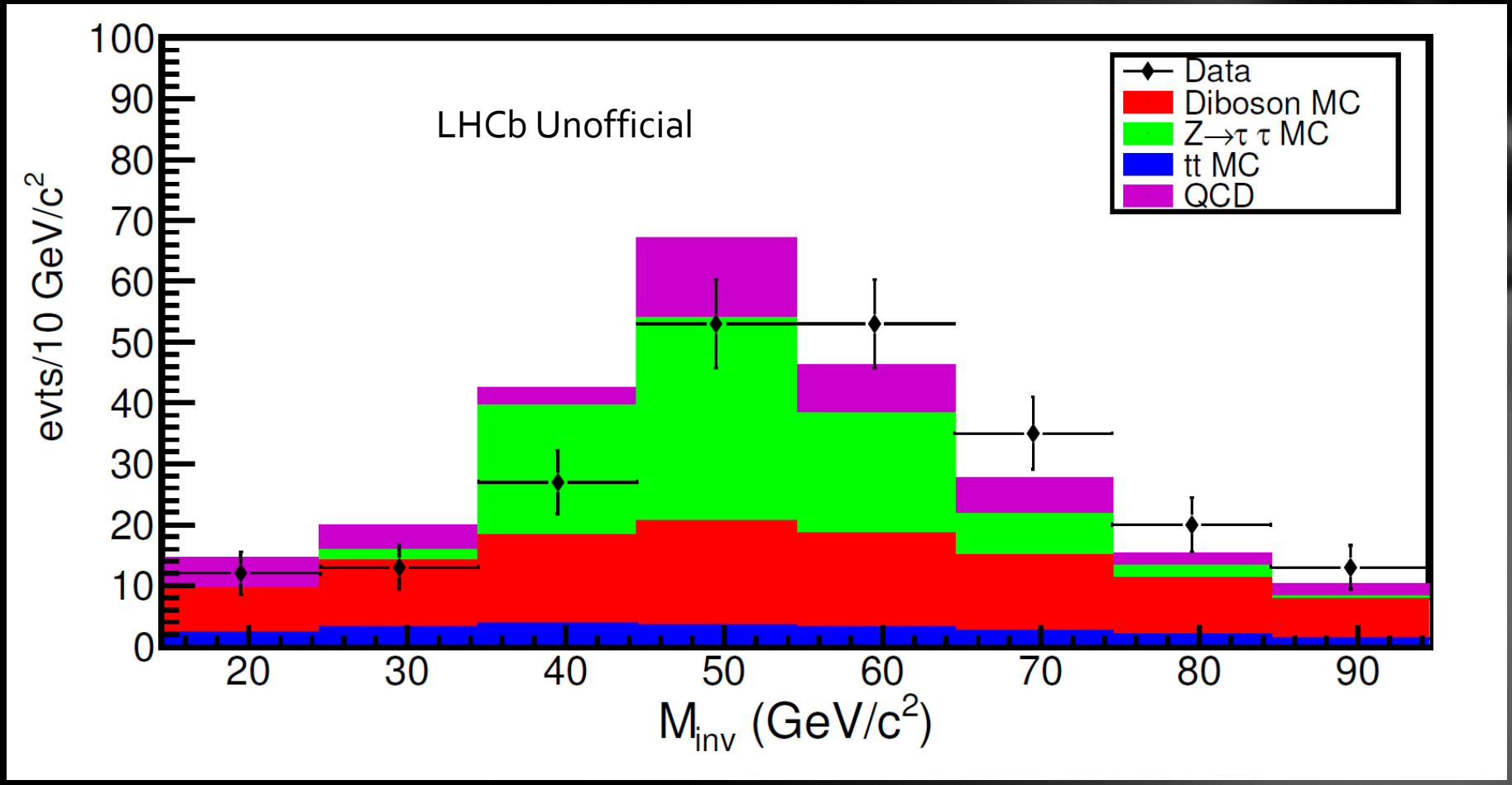


Signal Purity ≤ 0.2%

Lepton Cuts

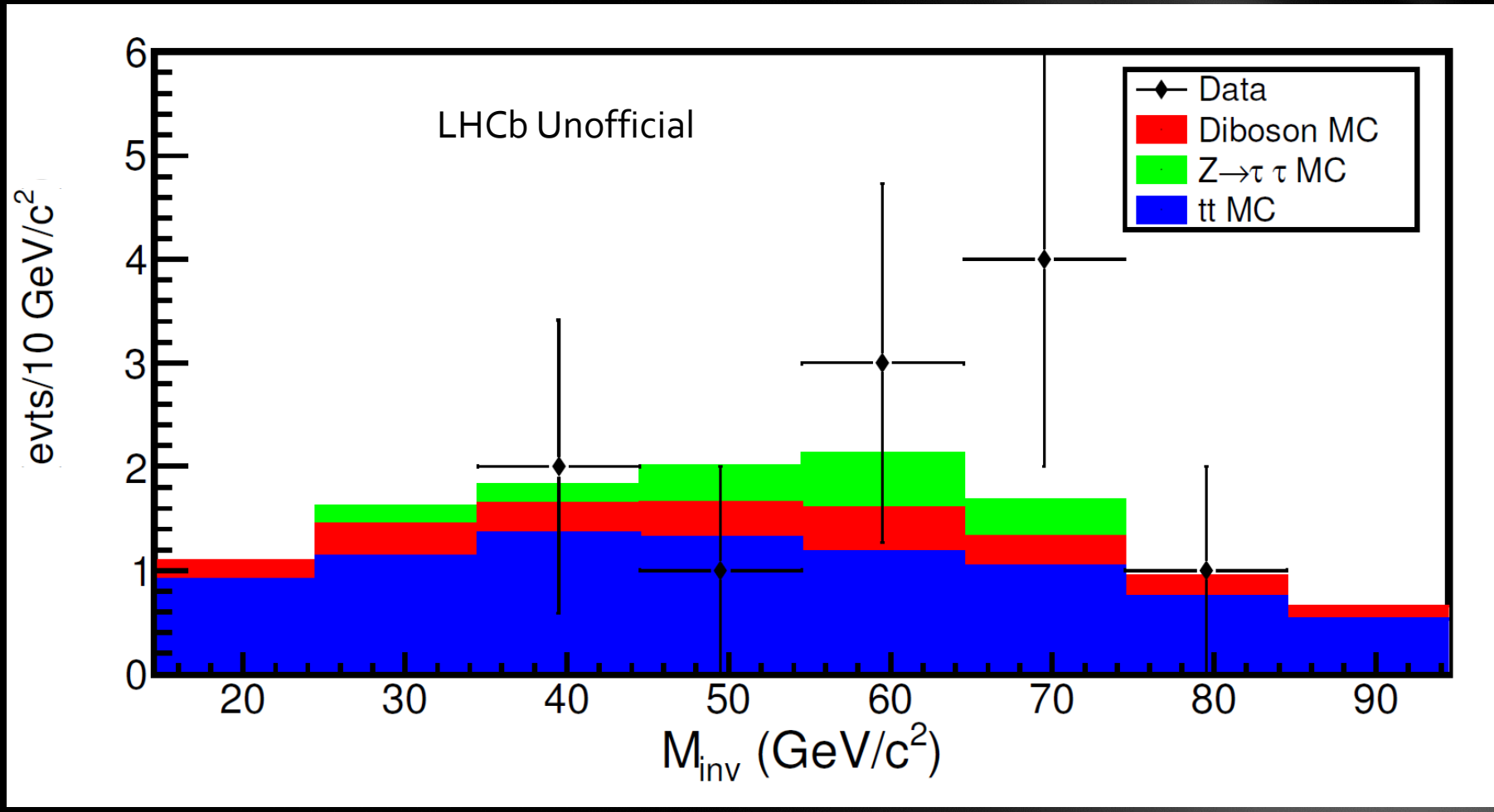
- l $P_T > 15$ GeV/c
- l isolation > 90%
- $M_{inv(\mu e)} > 15$ GeV/c^2
- l IP < 35 μm
- DOCA(ll) < 35 μm
- Neural Network b-tag ≥ 0.9

Lepton Cuts



Signal Purity ≈ 9%

b-tagged



Signal Purity ≈ 70%

b-tagged Expectation

Process	Events (in 2.01 fb^{-1})
Diboson	2.6 ± 0.1
$Z \rightarrow \tau\tau$	1.6 ± 0.5
Top pair	9.6 ± 0.1
Data ($2fb^{-1}$ 8 TeV sample)	12

Event Display

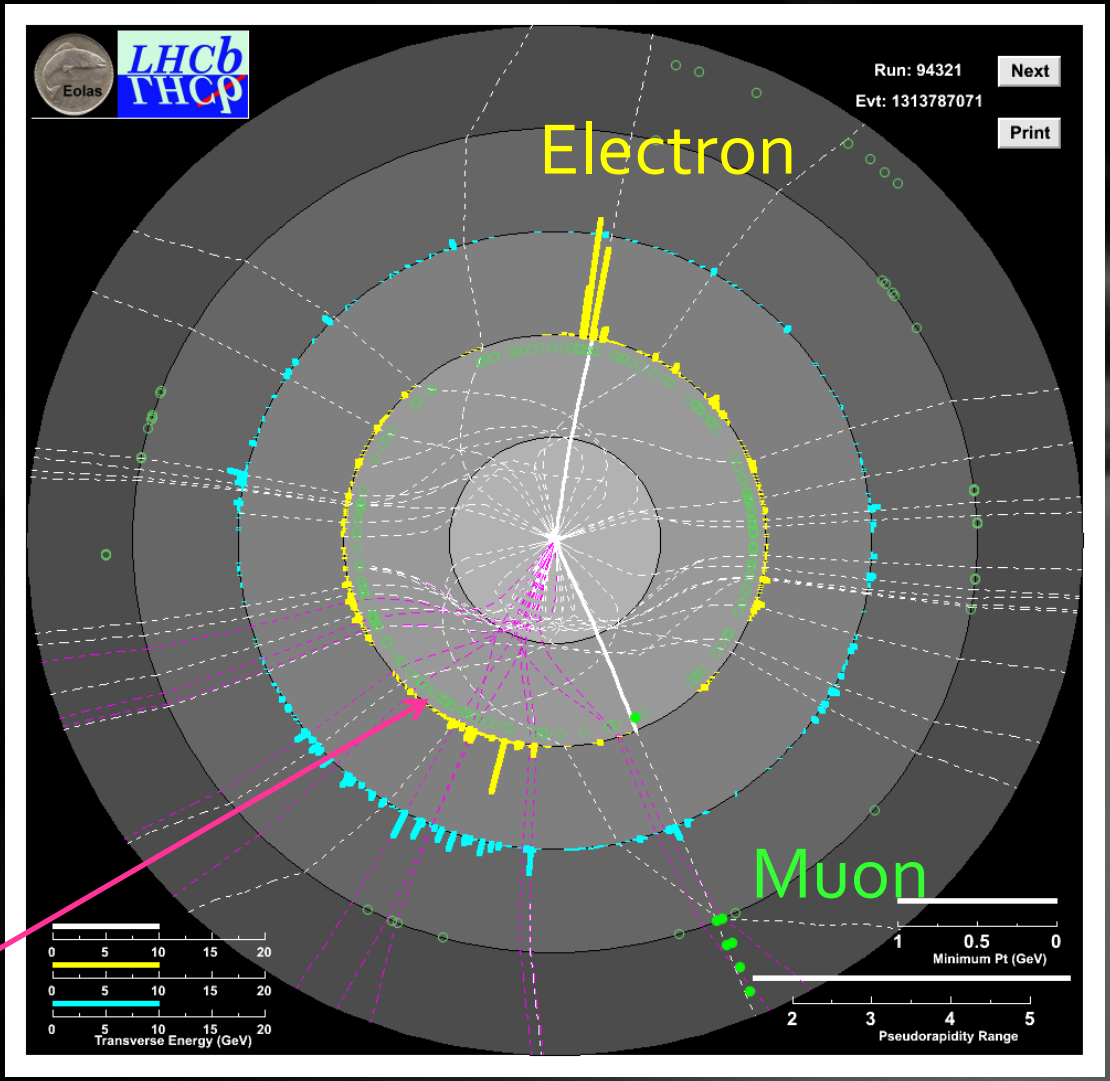
e P_T = 25 GeV/c

μ P_T = 25 GeV/c

M_{inv} = 48.5 GeV/c^2

b-jet P_T = 25 GeV/c

Tracks tagged to B-jet



Summary

- First measurements of top production in the forward region underway at LHCb
  - Current data samples at LHC phase 1 highly statistically limited
  - A top cross section in the forward region is interesting
  - At 14 TeV (LHCb Upgrade), 15fb^{-1} (approx) will have a statistical error comparable to theoretical cross section errors
  - 50fb^{-1} = ~10000 events
- 70% final state purity, 20% from diboson, 10% from $Z \rightarrow \tau\tau$
- 12 candidates found in 2012 data
- Cross section measurement being produced

Control regions

- Full selection before *b*-tag
  - Check data hypothesis is consistent with Z, diboson, and same sign contributions
- Same sign full selection
  - Check same sign after *b*-tag is consistent with just ZW hypothesis

Fiducial cross-sections (Backup)

Fiducial cross-section calculated by producing large MC sets

- Using POWHEG
- 16,000,000 evts for 7 TeV
- 24,000,000 evts for 8 TeV
- Use 3 different PDFs (NNPDF2.2, MSTW2008, CT10nlo)

Look at rate of μe +b quark in acceptance of LHCb

- Normalize to theoretical cross-sections
- b- quark acceptance systematic to be determined

Top Quark at LHCb

A summary of the possible final states in LHCb's acceptance per fb^{-1}

On going efforts in this channel too, early stages

Notes: l refers to μ or e, e.g. l^+l^- can be μμ, μe, ee

b_{any} refers to any b, rather than the b from the same top as the l

Channel	7TeV	8TeV	14TeV
lb	873±182	1566±245	11707±1649
lb_{any}	1398±277	2503±357	18643±2437
lbb	138±24	285±35	3139±377
lbj	182±41	385±53	4199±524
$lb_{any}j$	340±87	729±102	8092±1007
$lbbj$	44±13	111±13	1852±217
$lbjj$	24±14	59±11	975±118
$lb_{any}jj$	48±15	121±20	2036±249
$lbbjj$	7±3	20±3	515±65
l^+l^-	56±11	100±12	761±65
$l^+l^-b_{any}$	24±8	52±9	535±64

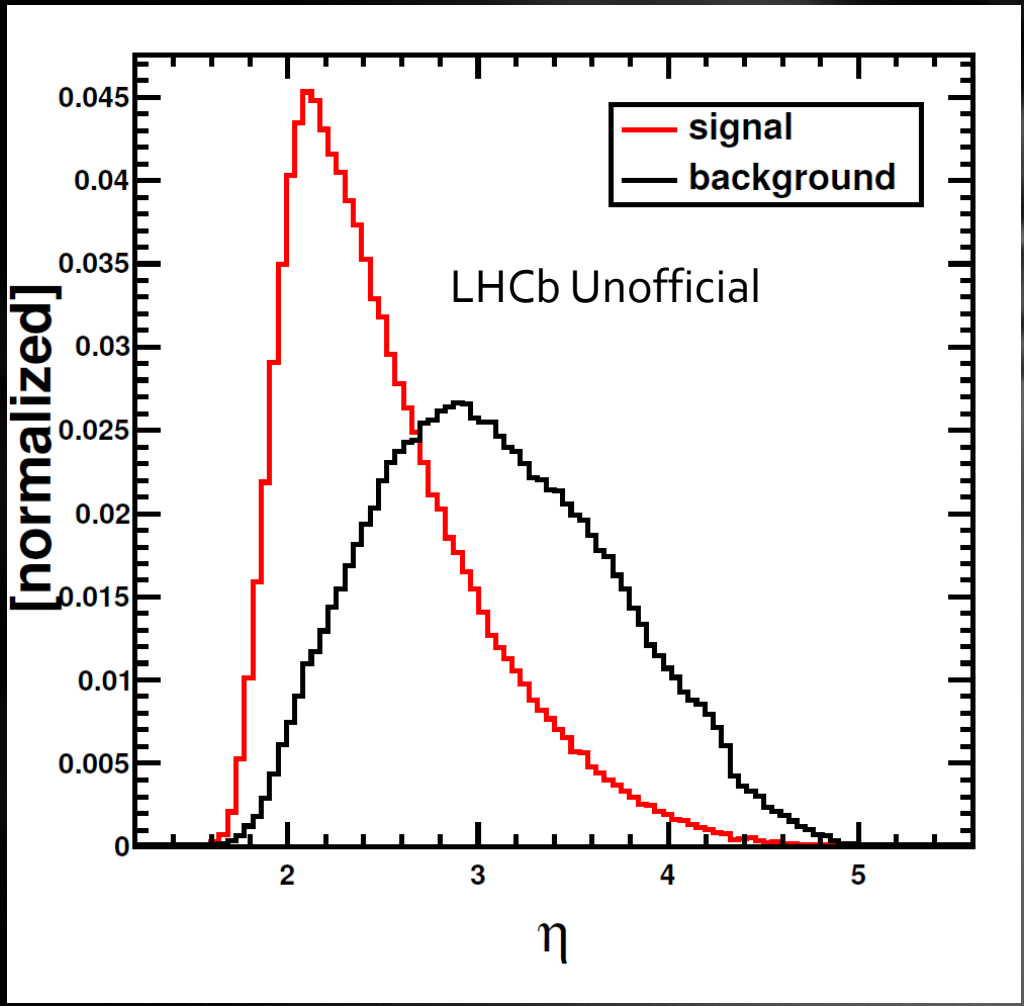
Track Net Variables

Variables:

- Impact Parameter - 32σ
- IP Error - 34σ
- IP Significance - 59σ
- P_T – 3.4 σ
- η - 11σ

Precuts:

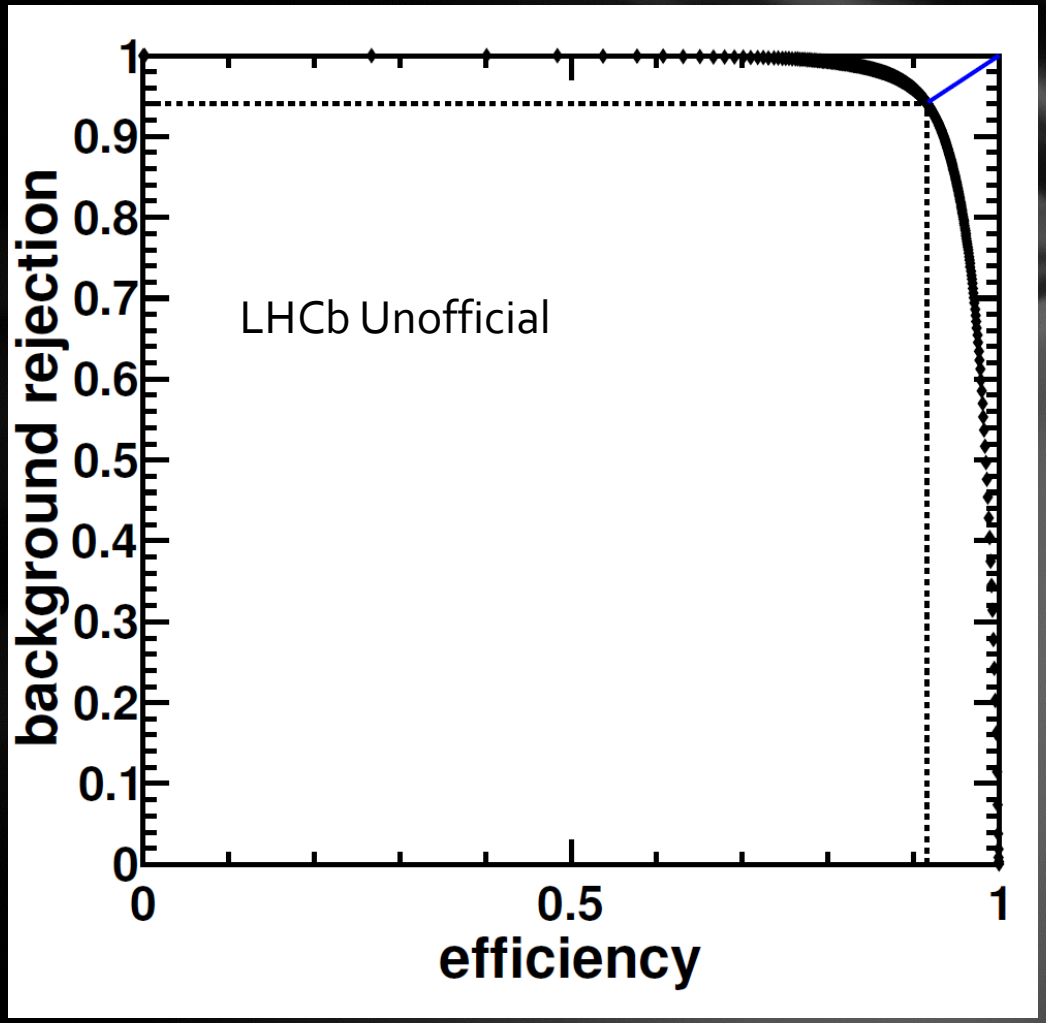
- P_T > 500 MeV
- 0.08 mm < IP < 3 mm
- IP Sig. > 0.5



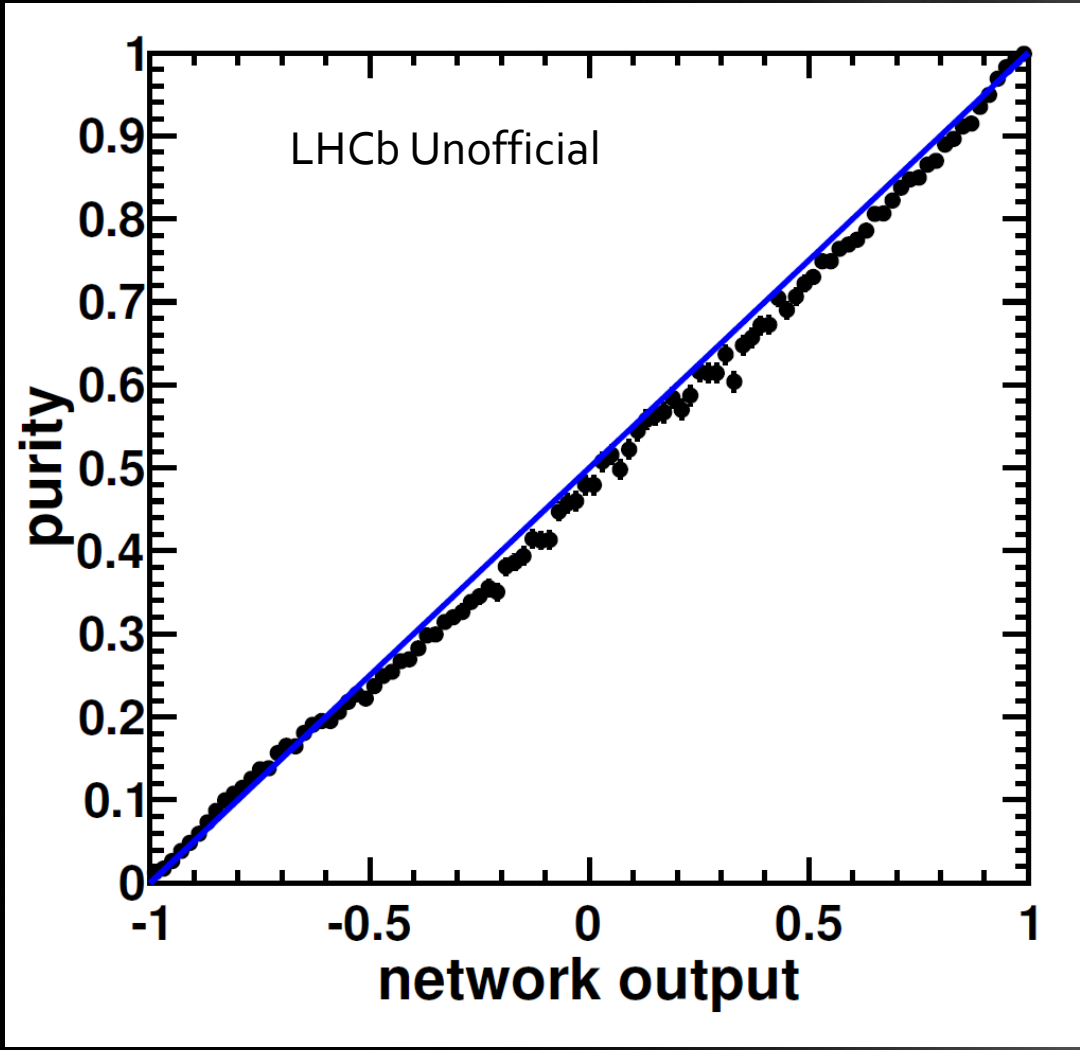
Jet Net Variables

Variables:

- Maximum track net output - 120 σ
- Jet P_T - 191 σ
- Maximum Track P_T – 10.8 σ
- Average track IP – 40.4 σ
- Sum of track P_T – 59.6 σ
- Signed IP Tag Sum – 34.5 σ
- Signed IP Tag 2nd track – 21.4 σ
- Signed IP Tag 3rd track – 12.6 σ



Purity vs Output (JetNet)

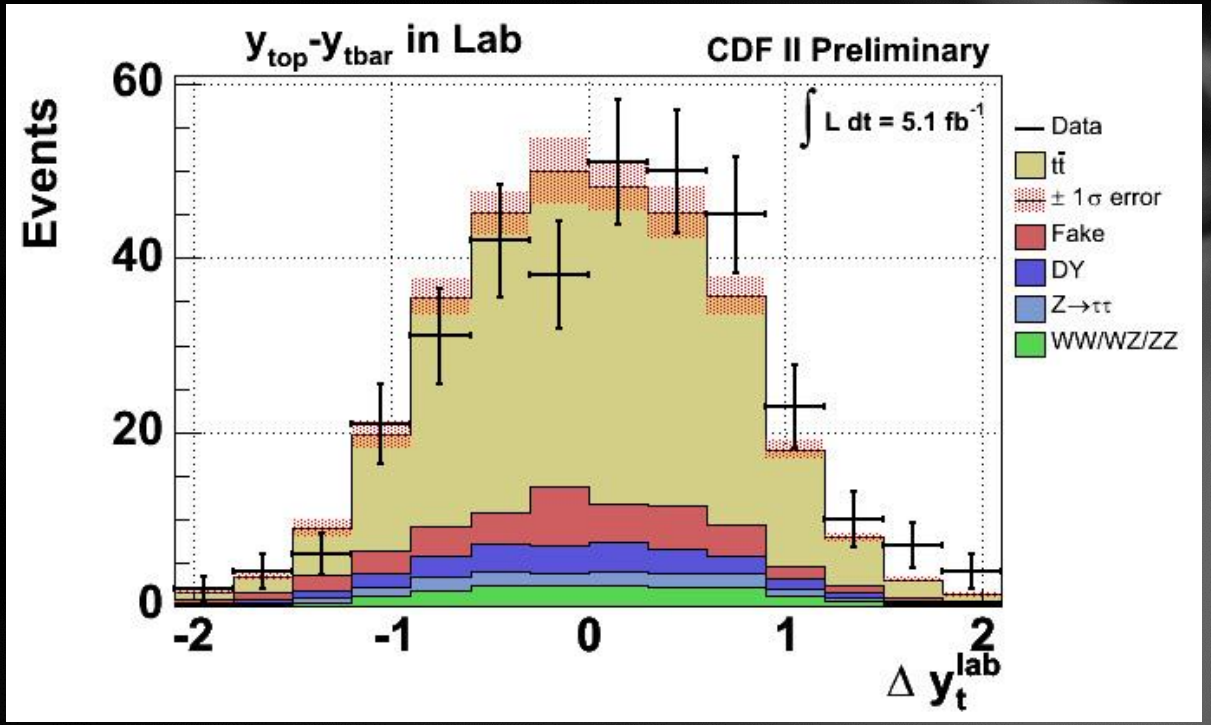


Top Asymmetry

Different preferential directions for top quark vs antitop

- Top quark is preferentially emitted in the direction of the incoming quark

Asymmetries have been observed in the top quark sector at CDF and D-o [arXiv:1211.6028]



Note: gluon fusion does not contribute to asymmetry