



# Lepton isolation studies

Abdualazem Fadol and Fang Yi

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中国科学院高能物理研究所  
*Institute of High Energy Physics*  
*Chinese Academy of Sciences*



UNIVERSITY OF THE  
WITWATERSRAND,  
JOHANNESBURG

- Preliminary cuts:
  - pass vtx4lCut;
  - invariant mass of the 4 leptons lies in [115, 130];
  - pass  $d_0$  significance cut; and
  - boosted Decision Tree (BDT > 0).
- Significant formulas:

$$Z_A^{\textcircled{1}} = \sqrt{2 \left( (s+b) \ln \left[ \frac{(s+b)(b+\sigma_b^2)}{(b^2+(s+b)\sigma_b^2)} \right] - \frac{b^2}{\sigma_b^2} \ln \left[ 1 + \frac{\sigma_b^2 s}{(b(b+\sigma_b^2))} \right] \right)}$$

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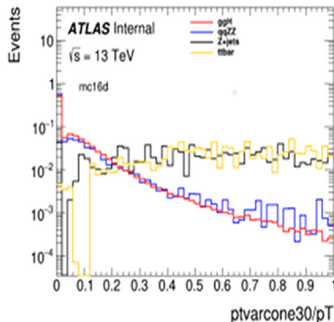
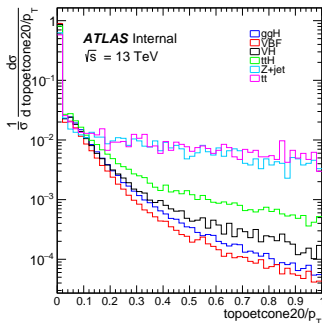
<sup>①</sup>You can check it out here: [Expected discovery significance for counting.](#)

## □ Leptons PU-robust

Working point	Objects	Calo isolation	Track isolation	Combined isolation
FixedCutHighMuTight	electrons, muons	Cut: topoetcone20/pT < 0.15	Cut: ptvarcone30_TightTTVA_pt1000/pT < 0.04 below 50 GeV, ptcone20_TightTTVA_pt1000/pT < 0.04	-
FixedCutHighMuLoose	electrons, muons	Cut: topoetcone20/pT < 0.30	Cut: ptvarcone30_TightTTVA_pt1000/pT < 0.15 below 50 GeV, ptcone20_TightTTVA_pt1000/pT < 0.15	-
FixedCutHighMuTrackOnly	electrons, muons	-	Cut: ptvarcone30_TightTTVA_pt1000/pT < 0.06 below 50 GeV, ptcone20_TightTTVA_pt1000/pT < 0.06	-
FixedCutPflowTight	electrons, muons	-	-	(max(ptcone20_TightTTVA_pt500, ptvarcone30_TightTTVA_pt500)+0.4neflowisol20)/pT < 0.045
FixedCutPflowLoose	electrons, muons	-	-	Cut: (max(ptcone20_TightTTVA_pt500, ptvarcone30_TightTTVA_pt500)+0.4neflowisol20)/pT < 0.16

Note the change in the isolation variable above 50 GeV! This change was not previously mentioned on the IFF twiki page (corrected on September 1st)

# ptvarcone30 plot for all the samples



I applied several pile-up cuts but it didn't change the curves. The Z+jet and tt samples behave like the qqZZ curve in  $\text{topetcone20}/p_T < 0.2$ .

# Efficiencies and significance

mc16a samples

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FixedCutHighMuLoose							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	78.77 %	78.68 %	71.77 %	53.72 %	1.33 %	0.52 %	4.02
$4e$	81.95 %	82.47 %	76.73 %	62.51 %	2.36 %	2.33 %	3.62
$2\mu 2e$	81.91 %	83.09 %	77.30 %	61.51 %	3.69 %	1.48 %	3.23
$2e 2\mu$	80.33 %	81.82 %	75.39 %	56.79 %	2.34 %	0.62 %	3.03
mc16a							

FixedCutPflowLoose							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	80.33 %	80.71 %	73.12 %	54.41 %	1.35 %	0.50 %	4.04
$4e$	80.62 %	81.33 %	74.63 %	59.46 %	2.48 %	1.96 %	3.59
$2\mu 2e$	81.28 %	83.21 %	76.38 %	60.16 %	3.30 %	1.00 %	3.47
$2e 2\mu$	80.49 %	82.52 %	75.34 %	56.61 %	2.17 %	0.43 %	3.20
mc16a							

# Efficiencies and significance

mc16d samples

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FixedCutHighMuLoose							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	75.87 %	76.11 %	69.83 %	51.81 %	1.59 %	0.23 %	4.39
$4e$	80.19 %	80.49 %	74.80 %	61.43 %	3.63 %	4.61 %	3.21
$2\mu 2e$	79.53 %	81.32 %	74.96 %	60.30 %	3.96 %	1.03 %	3.46
$2e 2\mu$	77.12 %	78.92 %	73.19 %	55.28 %	1.47 %	0.73 %	3.45
mc16d							

FixedCutPflowLoose							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	78.88 %	79.16 %	72.30 %	53.10 %	1.85 %	0.37 %	4.17
$4e$	78.68 %	79.45 %	72.44 %	58.05 %	3.10 %	2.75 %	3.51
$2\mu 2e$	78.81 %	81.37 %	73.98 %	59.02 %	3.07 %	1.10 %	3.67
$2e 2\mu$	78.30 %	80.45 %	73.68 %	55.57 %	1.31 %	0.79 %	3.57
mc16d							

# Efficiencies and significance

mc16a and mc16d combined

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FixedCutHighMuLoose							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	77.20 %	77.29 %	70.72 %	52.68 %	1.45 %	0.36 %	4.54
$4e$	81.03 %	81.42 %	75.71 %	61.94 %	2.97 %	3.42 %	3.72
$2\mu 2e$	80.65 %	82.15 %	76.06 %	60.87 %	3.82 %	1.25 %	3.65
$2e 2\mu$	78.61 %	80.26 %	74.20 %	55.98 %	1.87 %	0.68 %	3.46
mc16a and mc16d combined							

FixedCutPflowLoose							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	79.55 %	79.88 %	72.68 %	53.70 %	1.58 %	0.43 %	4.41
$4e$	79.60 %	80.33 %	73.48 %	58.72 %	2.78 %	2.34 %	3.94
$2\mu 2e$	79.98 %	82.23 %	75.11 %	59.55 %	3.19 %	1.05 %	3.93
$2e 2\mu$	79.32 %	81.41 %	74.44 %	56.05 %	1.70 %	0.63 %	3.63
mc16 and mc16d combined							

# Comparing with Heling and Rongkun

For  $4\mu$  category

$4\mu$ category	ggH	VBF	VH	ttH	Z+jets	tt	Significance
FixedCutLoose	-	-	-	-	-	-	-
Heling	-	-	-	-	-	-	-
FixedCutHighMuLoose	75.87 %	76.11 %	69.83 %	51.81 %	1.59 %	0.23 %	4.39
FixedCutPflowLoose	78.88 %	79.16 %	72.30 %	53.10 %	1.85 %	0.37 %	4.17
FixedCutHighMuLoose500Customize	-	-	-	-	-	-	-
FixedCutHighMuLoose1000Customize	-	-	-	-	-	-	-
FixedCutPflowLoose500Customize	-	-	-	-	-	-	-
FixedCutPflowLoose1000Customize	-	-	-	-	-	-	-

4mu	ggH	VBF	VH	ttH	Zjets	tt	signf	signfcmp
<b>FixedCutLoose</b>	0.7801	0.8160	0.746	0.5701	0.0171	0.0052	14.70	4.84
<b>Heling</b>	0.8239	0.85	0.7873	0.612	0.0227	0.0055	14.56	4.96
<b>FixedCutHighMuLoose</b>	0.7626	0.7640	0.6974	0.5174	0.0179	0.0041	14	4.78
<b>FixedCutPflowLoose</b>	0.7903	0.7920	0.719	0.5292	0.0185	0.0056	14.57	5
<b>FixedCutHighMuLoose500Customize</b>	0.720	0.738	0.658	0.4734	0.0108	0.0020	15.07	4.63
<b>FixedCutHighMuLoose1000Customize</b>	0.7891	0.7899	0.7176	0.5263	0.0197	0.0028	14.54	4.8
<b>FixedCutPflowLoose500Customize</b>	0.7575	0.7659	0.6898	0.5034	0.0151	0.0042	14.69	4.8
<b>FixedCutPflowLoose1000Customize</b>	0.7838	0.7843	0.7115	0.5226	0.0198	0.0044	14.39	4.82



# Comparing with Heling and Rongkun

For 4e category

4e category	ggH	VBF	VH	ttH	Z+jets	tt	Significance
FixedCutLoose	-	-	-	-	-	-	-
Heling	-	-	-	-	-	-	-
FixedCutHighMuLoose	80.19 %	80.49 %	74.80 %	61.43 %	3.63%	4.61 %	3.21
FixedCutPflowLoose	78.68 %	79.45 %	72.44 %	58.05 %	3.10 %	2.75 %	3.51
FixedCutHighMuLoose500Customize	-	-	-	-	-	-	-
FixedCutHighMuLoose1000Customize	-	-	-	-	-	-	-
FixedCutPflowLoose500Customize	-	-	-	-	-	-	-
FixedCutPflowLoose1000Customize	-	-	-	-	-	-	-

4e	ggH	VBF	VH	ttH	Zjets	tt	signf	signfcmp
<b>FixedCutLoose</b>	0.8224	0.8507	0.816	0.7427	0.0708	0.0607	8.67	3.35
<b>Heling</b>	0.8971	0.91	0.8800	0.802	0.1014	0.0892	8.52	3.46
<b>FixedCutHighMuLoose</b>	0.8494	0.8810	0.8169	0.6736	0.0400	0.0327	10	3.43
<b>FixedCutPflowLoose</b>	0.8377	0.8760	0.800	0.6558	0.0381	0.0236	9.98	3
<b>FixedCutHighMuLoose500Customize</b>	0.781	0.833	0.751	0.6058	0.0294	0.0173	9.98	3.29
<b>FixedCutHighMuLoose1000Customize</b>	0.8551	0.8885	0.8201	0.6714	0.0452	0.0225	9.88	3.4
<b>FixedCutPflowLoose500Customize</b>	0.8001	0.8441	0.7646	0.6233	0.0338	0.0187	9.92	3.3
<b>FixedCutPflowLoose1000Customize</b>	0.8290	0.8644	0.7936	0.6469	0.0400	0.0222	9.86	3.38

# 2D plots for topetcone20 vs ptcone30\_pt500

$4\mu$  and  $4e$  category

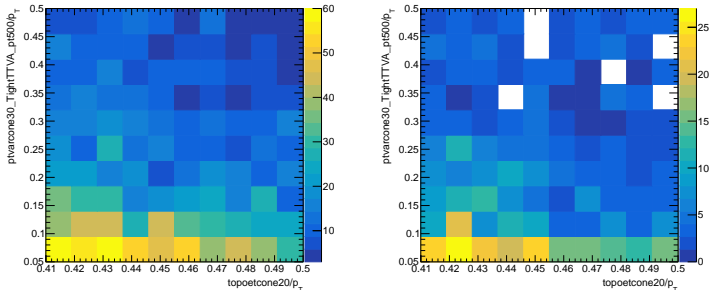


Figure:  $4\mu$  (left) and  $4e$  (right).

Still need to fill in the z-axes with the significance as Heling and Rongkun in their slides. This is, however, may gives us the customized variables. Do I need to get these customized ones?

- The efficiency for the  $4\mu$  category is fairly matched with Runkun numbers;
- But in case of the  $4e$  there's 4% difference for the ggH and VBF;
- Not all the significances are calculated using the formula;
- I have to do a 2D scan to find out how the optimisation of the variables is done;
- There's new update on this study by Heling, and he's now using Pro\_v19 samples; and
- I've no idea if you still need to study Pro\_v18. I've looked at the samples but the iso variables have been changed!



**Thank you!**



# Additional slides

mc16a samples

13

FixedCutHighMuTight							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	51.12 %	55.35 %	47.76 %	33.14 %	0.54 %	0.12 %	4.54
$4e$	52.72 %	57.93 %	51.12 %	39.10 %	0.97 %	0.65 %	3.89
$2\mu 2e$	52.25 %	58.16 %	50.76 %	37.50 %	1.38 %	0.26 %	3.79
$2e 2\mu$	52.48 %	57.74 %	51.02 %	35.49 %	0.80 %	0.23 %	3.63
mc16a							
FixedCutHighMuTrackOnly							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	69.17 %	72.27 %	63.13 %	44.69 %	1.24 %	0.19 %	4.00
$4e$	69.56 %	73.16 %	65.66 %	51.17 %	3.04 %	1.03 %	3.25
$2\mu 2e$	69.63 %	74.39 %	65.69 %	50.14 %	2.71 %	0.64 %	3.51
$2e 2\mu$	70.35 %	74.83 %	66.19 %	48.17 %	1.73 %	0.55 %	3.16
mc16a							
FixedCutPflowTight							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	44.88 %	50.88 %	42.46 %	29.03 %	0.25 %	0.00 %	5.37
$4e$	40.87 %	46.61 %	39.83 %	30.38 %	1.15 %	0.41 %	3.34
$2\mu 2e$	42.11 %	49.23 %	41.54 %	30.63 %	0.77 %	0.13 %	3.96
$2e 2\mu$	41.12 %	47.62 %	39.97 %	28.35 %	0.46 %	0.07 %	3.88
mc16a							

# Additional slides

mc16d samples

14

FixedCutHighMuTight							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	45.70 %	50.00 %	43.49 %	29.78 %	0.73 %	0.00 %	4.59
$4e$	48.01 %	53.04 %	46.55 %	36.72 %	1.57 %	0.99 %	3.49
$2\mu 2e$	47.10 %	52.99 %	46.29 %	34.94 %	0.76 %	0.43 %	4.11
$2e 2\mu$	46.74 %	52.17 %	46.22 %	32.50 %	0.48 %	0.07 %	4.25
mc16d							
FixedCutHighMuTrackOnly							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	67.19 %	70.26 %	62.16 %	43.26 %	1.63 %	0.15 %	4.14
$4e$	67.24 %	70.75 %	62.93 %	49.34 %	3.16 %	1.40 %	3.38
$2\mu 2e$	67.39 %	72.18 %	63.44 %	48.62 %	1.93 %	0.59 %	4.04
$2e 2\mu$	67.82 %	72.51 %	64.26 %	46.28 %	1.25 %	0.72 %	3.39
mc16d							
FixedCutPflowTight							
	Signal				Background		Significance
	ggH	VBF	VH	ttH	Z+jet	ttbar	$Z_A$
$4\mu$	41.25 %	46.73 %	39.41 %	26.77 %	0.40 %	0.00 %	5.19
$4e$	36.12 %	41.68 %	34.61 %	26.85 %	1.18 %	0.00 %	3.46
$2\mu 2e$	37.10 %	43.92 %	37.30 %	27.69 %	0.49 %	0.17 %	4.23
$2e 2\mu$	36.56 %	42.90 %	36.20 %	26.06 %	0.28 %	0.11 %	4.15
mc16d							