



Weekly meeting

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INSTITUTE FOR
COLLIDER
PARTICLE
PHYSICS

UNIVERSITY OF THE WITWATERSRAND



4 l -channel in Di-Higgs analysis

v9 and v10 mini-trees comparison

	Non-Res	qq \rightarrow ZZ	t \bar{t} Z	t \bar{t}	VVV	Significance
4 l	0.34 \pm 0.02	2770.42 \pm 5.53	163.75 \pm 1.00	2790.66 \pm 39.43	23.30 \pm 0.17	0.0045 \pm 0.0006
Total charge = 0	0.32 \pm 0.02	2696.51 \pm 5.45	144.69 \pm 0.94	2204.25 \pm 35.04	21.72 \pm 0.16	0.0045 \pm 0.0005
Trigger Match	0.32 \pm 0.02	2608.47 \pm 5.39	143.47 \pm 0.93	2018.67 \pm 33.43	21.64 \pm 0.16	0.0046 \pm 0.0005
Iso FixedCutLoose	0.25 \pm 0.02	2201.41 \pm 4.98	111.29 \pm 0.81	79.98 \pm 6.73	19.78 \pm 0.15	0.0051 \pm 0.0001
m_{VV} (SFOS) > 12 GeV	0.24 \pm 0.02	1958.99 \pm 4.79	108.25 \pm 0.79	54.35 \pm 5.69	19.63 \pm 0.15	0.0052 \pm 0.0000
0-SFOS	0.01 \pm 0.00	0.04 \pm 0.02	0.28 \pm 0.05	6.51 \pm 1.87	0.03 \pm 0.01	0.0051 \pm 0.0013
1-SFOS	0.10 \pm 0.00	29.91 \pm 0.58	54.29 \pm 0.56	263.02 \pm 4.04	8.77 \pm 0.11	0.0093 \pm 0.0006
2-SFOS	0.13 \pm 0.01	1929.04 \pm 4.76	53.69 \pm 0.56	21.82 \pm 3.54	10.83 \pm 0.11	0.0028 \pm 0.0000

	Non-Res	qq \rightarrow ZZ	t \bar{t} Z	t \bar{t}	VVV	Significance
4 l	0.39 \pm 0.02	3350.84 \pm 6.14	197.37 \pm 1.13	9316.14 \pm 136.85	25.34 \pm 0.18	0.0034 \pm 0.0029
Total charge = 0	0.37 \pm 0.02	3241.94 \pm 5.99	165.38 \pm 1.02	7465.08 \pm 121.76	23.59 \pm 0.17	0.0035 \pm 0.0024
Trigger Match	0.34 \pm 0.01	3067.67 \pm 5.83	163.70 \pm 1.01	6705.12 \pm 115.82	23.45 \pm 0.17	0.0035 \pm 0.0022
Iso FixedCutLoose	0.26 \pm 0.01	2521.02 \pm 5.25	117.04 \pm 0.83	217.40 \pm 18.32	21.22 \pm 0.16	0.0048 \pm 0.0003
m_{VV} (SFOS) > 12 GeV	0.25 \pm 0.01	2179.49 \pm 5.00	113.41 \pm 0.81	134.40 \pm 15.74	21.06 \pm 0.16	0.0050 \pm 0.0003
0-SFOS	0.02 \pm 0.00	0.05 \pm 0.02	0.43 \pm 0.06	14.76 \pm 2.29	0.04 \pm 0.01	0.0039 \pm 0.0007
1-SFOS	0.11 \pm 0.00	37.57 \pm 0.66	56.88 \pm 0.57	54.07 \pm 5.64	9.42 \pm 0.11	0.0085 \pm 0.0009
2-SFOS	0.13 \pm 0.00	2141.87 \pm 4.95	56.10 \pm 0.57	65.96 \pm 4.51	11.61 \pm 0.11	0.0026 \pm 0.0001

□ Looking at the optimisation

	Non-Res	qq \rightarrow ZZ	t \bar{t} Z	t \bar{t}	VVV	Significance
4 l	0.34 \pm 0.02	2770.42 \pm 5.53	163.75 \pm 1.00	2790.66 \pm 39.43	23.30 \pm 0.17	0.0045 \pm 0.0006
Total charge = 0	0.32 \pm 0.02	2696.51 \pm 5.45	144.69 \pm 0.94	2204.25 \pm 35.04	21.72 \pm 0.16	0.0045 \pm 0.0005
Trigger Match	0.32 \pm 0.02	2608.47 \pm 5.39	143.47 \pm 0.93	2018.67 \pm 33.43	21.64 \pm 0.16	0.0046 \pm 0.0005
Iso FixedCutLoose	0.25 \pm 0.02	2201.41 \pm 4.98	111.29 \pm 0.81	79.98 \pm 6.73	19.78 \pm 0.15	0.0051 \pm 0.0001
m_{VV} (SFOS) > 4 GeV	0.23 \pm 0.02	1822.18 \pm 4.50	102.29 \pm 0.77	75.72 \pm 4.66	19.63 \pm 0.15	0.0052 \pm 0.0001
0-1-SFOS	0.12 \pm 0.00	31.37 \pm 0.60	53.92 \pm 0.57	45.90 \pm 5.22	8.85 \pm 0.11	0.0099 \pm 0.0009
b-velo	0.11 \pm 0.00	29.34 \pm 0.58	6.76 \pm 0.20	29.32 \pm 4.15	8.18 \pm 0.10	0.0125 \pm 0.0015
$m_{b\bar{b}}$ > 10 GeV	0.11 \pm 0.00	29.13 \pm 0.58	6.74 \pm 0.20	28.86 \pm 4.14	8.16 \pm 0.10	0.0123 \pm 0.0015
$ m_{B_3} - m_{Z_3} < 25$ GeV	0.05 \pm 0.00	25.37 \pm 0.54	5.85 \pm 0.18	12.79 \pm 2.72	7.79 \pm 0.10	0.0066 \pm 0.0005
2-SFOS	0.06 \pm 0.00	3.76 \pm 0.20	0.89 \pm 0.07	16.07 \pm 3.12	0.37 \pm 0.02	0.0126 \pm 0.0029
$E_T^{\text{miss}} > 20$ GeV	0.06 \pm 0.00	2.60 \pm 0.18	0.82 \pm 0.07	15.29 \pm 3.04	0.35 \pm 0.02	0.0127 \pm 0.0031
2-SFOS	0.11 \pm 0.01	1790.81 \pm 4.56	46.37 \pm 0.52	30.82 \pm 4.14	9.18 \pm 0.10	0.0026 \pm 0.0000
b-velo	0.10 \pm 0.01	1793.46 \pm 4.51	5.40 \pm 0.18	17.72 \pm 3.19	8.48 \pm 0.09	0.0024 \pm 0.0000
$m_{b\bar{b}}$ > 10 GeV	0.10 \pm 0.01	1580.50 \pm 4.40	5.31 \pm 0.18	16.18 \pm 3.07	8.46 \pm 0.09	0.0024 \pm 0.0000
$ m_{B_3} - m_{Z_3} > 20$ GeV	0.09 \pm 0.01	368.81 \pm 2.08	3.72 \pm 0.15	11.54 \pm 2.56	4.75 \pm 0.08	0.0045 \pm 0.0000
$E_T^{\text{miss}} > 50$ GeV	0.06 \pm 0.01	21.30 \pm 0.50	3.21 \pm 0.13	10.07 \pm 2.44	3.64 \pm 0.07	0.0102 \pm 0.0008

	Non-Res	qq \rightarrow ZZ	t \bar{t} Z	t \bar{t}	VVV	Significance
4 l	0.34 \pm 0.02	2770.42 \pm 5.53	163.75 \pm 1.00	2790.66 \pm 39.43	23.30 \pm 0.17	0.0045 \pm 0.0006
Total charge = 0	0.32 \pm 0.02	2696.51 \pm 5.45	144.69 \pm 0.94	2204.25 \pm 35.04	21.72 \pm 0.16	0.0045 \pm 0.0005
Trigger Match	0.32 \pm 0.02	2608.47 \pm 5.39	143.47 \pm 0.93	2018.67 \pm 33.43	21.64 \pm 0.16	0.0046 \pm 0.0005
Iso FixedCutLoose	0.25 \pm 0.02	2201.41 \pm 4.98	111.29 \pm 0.81	79.98 \pm 6.73	19.78 \pm 0.15	0.0051 \pm 0.0001
m_{VV} (SFOS) > 12 GeV	0.24 \pm 0.02	1958.99 \pm 4.79	108.25 \pm 0.79	54.35 \pm 5.69	19.63 \pm 0.15	0.0052 \pm 0.0000
0-1-SFOS	0.11 \pm 0.00	29.95 \pm 0.58	54.87 \pm 0.56	32.83 \pm 4.48	8.80 \pm 0.11	0.0102 \pm 0.0008
b-velo	0.10 \pm 0.00	28.25 \pm 0.57	6.83 \pm 0.19	25.70 \pm 3.55	8.14 \pm 0.10	0.0126 \pm 0.0014
$m_{b\bar{b}}$ > 10 GeV	0.10 \pm 0.00	27.85 \pm 0.57	6.82 \pm 0.19	25.24 \pm 3.91	8.11 \pm 0.10	0.0124 \pm 0.0014
$ m_{B_3} - m_{Z_3} < 20$ GeV	0.05 \pm 0.00	24.93 \pm 0.54	5.79 \pm 0.18	12.54 \pm 2.71	7.75 \pm 0.10	0.0065 \pm 0.0005
$ m_{B_3} - m_{Z_3} > 20$ GeV	0.06 \pm 0.00	2.92 \pm 0.18	0.73 \pm 0.07	12.70 \pm 2.81	0.36 \pm 0.02	0.0137 \pm 0.0032
$E_T^{\text{miss}} > 20$ GeV	0.05 \pm 0.00	1.66 \pm 0.14	0.55 \pm 0.06	10.17 \pm 2.58	0.24 \pm 0.02	0.0133 \pm 0.0035
2-SFOS	0.13 \pm 0.01	1929.04 \pm 4.76	53.69 \pm 0.56	21.82 \pm 3.54	10.83 \pm 0.11	0.0028 \pm 0.0000
b-velo	0.11 \pm 0.01	1834.86 \pm 4.70	6.24 \pm 0.19	16.96 \pm 3.10	10.00 \pm 0.10	0.0026 \pm 0.0000
$m_{b\bar{b}}$ > 10 GeV	0.11 \pm 0.01	1634.86 \pm 4.70	6.24 \pm 0.19	16.95 \pm 3.10	10.00 \pm 0.10	0.0026 \pm 0.0000
$ m_{B_3} - m_{Z_3} > 25$ GeV	0.10 \pm 0.01	415.06 \pm 2.19	4.65 \pm 0.16	13.82 \pm 2.72	6.01 \pm 0.09	0.0050 \pm 0.0000
$E_T^{\text{miss}} > 50$ GeV	0.07 \pm 0.01	25.70 \pm 0.53	4.01 \pm 0.15	11.12 \pm 2.67	4.58 \pm 0.08	0.0105 \pm 0.0008

□ Combined significance is 0.0176 (0.181)

4 l -channel in Di-Higgs analysis

v9 and v10 mini-trees comparison

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	Non-Res	$qq \rightarrow ZZ$	$t\bar{t}Z$	$t\bar{t}$	VVV	Significance
4 l	0.39±0.02	3350.84±6.14	197.37±1.13	9316.14±136.85	25.34±0.18	0.0034±0.0025
Total charge = 0	0.37±0.02	3241.84±5.99	166.38±1.02	7463.08±121.46	23.59±0.17	0.0035±0.0024
Trigger Match	0.34±0.01	3067.18±5.87	163.70±1.01	6705.12±115.82	23.45±0.17	0.0035±0.0023
Iso FixedCutLoose	0.26±0.01	2521.02±5.25	117.04±0.83	217.40±18.32	21.22±0.16	0.0048±0.0003
$m_{\ell\ell} > 12$ GeV	0.25±0.01	2179.49±5.00	113.41±0.81	134.40±15.74	21.06±0.16	0.0050±0.0003
0/1-SFOS	0.12±0.00	37.62±0.66	57.31±0.58	68.83±6.09	9.45±0.11	0.0093±0.0010
b-veto	0.12±0.00	36.03±0.65	13.11±0.27	59.29±5.44	8.98±0.11	0.0106±0.0013
$m_{\ell_0\ell_1} > 10$ GeV	0.11±0.00	35.39±0.64	13.02±0.27	58.30±5.83	8.95±0.11	0.0105±0.0015
$ m_{Z_2} - m_Z < 20$ GeV	0.05±0.00	31.42±0.60	11.46±0.26	26.28±4.07	8.49±0.11	0.0059±0.0006
$ m_{Z_2} - m_Z > 20$ GeV	0.06±0.00	3.97±0.22	1.55±0.10	32.02±4.18	0.45±0.02	0.0099±0.0023
$E_T^{\text{miss}} > 20$ GeV	0.06±0.00	2.91±0.20	1.48±0.10	31.11±4.16	0.43±0.02	0.0098±0.0024
2-SFOS	0.13±0.00	2141.87±4.95	56.10±0.57	65.56±14.51	11.61±0.11	0.0026±0.0001
b-veto	0.11±0.00	2068.22±4.91	12.90±0.27	53.20±14.26	11.00±0.11	0.0024±0.0001
$m_{\ell_0\ell_1} > 10$ GeV	0.11±0.00	2068.22±4.91	12.90±0.27	53.20±14.26	11.00±0.11	0.0024±0.0001
$ m_{Z_1} - m_Z > 25$ GeV	0.10±0.00	513.93±2.36	9.49±0.24	43.81±13.33	6.70±0.09	0.0043±0.0007
$E_T^{\text{miss}} > 50$ GeV	0.07±0.00	47.79±0.59	8.02±0.22	22.18±3.45	5.14±0.08	0.0077±0.0005

- Combined significance is 0.0138
- The significance reduced by 25%

4 l -channel in Di-Higgs analysis

All background samples

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	Non-Res	$qq \rightarrow ZZ^*$	$gg \rightarrow ZZ^*$	$t\bar{t}Z$	$t\bar{t}$	VVV	Z+jets	WZ	Significance
4 l	0.65±0.02	5757.21±8.79	34.54±0.07	336.93±1.46	23066.40±186.37	43.79±0.25	3405.70±79.45	172.34±1.78	0.0036±0.0019
Total charge = 0	0.61±0.02	5569.18±8.60	34.05±0.07	284.19±1.32	18302.65±165.72	40.84±0.25	3055.61±74.35	105.00±1.39	0.0037±0.0019
Trigger Match	0.58±0.01	5271.19±8.43	31.74±0.06	279.83±1.31	16508.58±157.80	40.62±0.25	2676.03±68.79	98.05±1.35	0.0037±0.0019
Iso FixedCutLoose	0.44±0.01	4317.89±7.64	28.20±0.06	200.16±1.06	545.41±26.91	36.80±0.24	81.35±15.51	23.18±0.65	0.0061±0.0004
$m_{l^+l^-}$ (SFOS) > 12 GeV	0.42±0.01	3733.78±7.29	27.32±0.05	193.92±1.05	341.49±21.67	36.51±0.24	32.70±12.35	21.75±0.63	0.0063±0.0004
0-SFOS	0.03±0.00	0.09±0.02	0.00±0.00	0.70±0.08	36.23±6.26	0.08±0.01	0.00±0.00	0.04±0.02	0.0046±0.0024
1-SFOS	0.18±0.01	64.18±0.92	0.34±0.01	96.75±0.74	162.36±12.18	16.36±0.19	19.88±7.46	12.02±0.47	0.0093±0.0020
2-SFOS	0.21±0.01	3669.51±7.24	26.98±0.05	96.46±0.74	142.90±16.80	20.07±0.14	12.82±9.84	9.69±0.42	0.0034±0.0001
0/1-SFOS	0.21±0.01	64.27±0.92	0.34±0.01	97.45±0.74	198.59±13.69	16.44±0.19	19.88±7.46	12.06±0.47	0.0103±0.0025
b-velo	0.19±0.01	61.37±0.90	0.32±0.01	22.28±0.35	166.41±11.35	15.51±0.14	19.88±7.46	11.35±0.46	0.0113±0.0027
$m_{b\ell_1} > 10$ GeV	0.19±0.01	60.23±0.89	0.32±0.01	22.16±0.35	163.21±12.77	15.47±0.14	16.71±7.22	10.72±0.45	0.0113±0.0034
$ m_{Z_1} - m_{Z_2} < 20$ GeV	0.09±0.00	53.57±0.84	0.30±0.00	19.36±0.33	80.52±10.30	14.72±0.14	16.13±7.19	9.14±0.41	0.0063±0.0019
$ m_{Z_1} - m_{Z_2} > 20$ GeV	0.10±0.00	6.66±0.31	0.02±0.00	2.79±0.13	82.69±7.55	0.75±0.03	0.59±0.59	1.58±0.17	0.0107±0.0032
$E_{T}^{miss} > 20$ GeV	0.10±0.00	4.85±0.28	0.02±0.00	2.63±0.13	77.71±7.42	0.71±0.03	0.59±0.59	1.44±0.16	0.0106±0.0033
2-SFOS	0.21±0.01	3669.51±7.24	26.98±0.05	96.46±0.74	142.90±16.80	20.07±0.14	12.82±9.84	9.69±0.42	0.0034±0.0001
b-velo	0.19±0.01	3542.07±7.18	26.11±0.05	22.13±0.35	111.50±15.71	19.04±0.14	10.99±9.67	9.13±0.41	0.0031±0.0001
$m_{b\ell_1} > 10$ GeV	0.19±0.01	3542.07±7.18	26.11±0.05	22.13±0.35	111.50±15.71	19.04±0.14	10.99±9.67	9.13±0.41	0.0031±0.0001
$ m_{Z_1} - m_{Z_2} > 25$ GeV	0.17±0.01	878.26±3.39	5.18±0.03	16.29±0.30	95.46±14.78	11.52±0.12	11.14±9.57	7.05±0.36	0.0054±0.0006
$E_{T}^{miss} > 50$ GeV	0.12±0.00	86.20±0.89	0.55±0.01	13.77±0.28	57.36±6.55	8.92±0.10	6.99±6.49	3.65±0.26	0.0088±0.0015

□ Combined significance is 0.0151



Thank you!



Event Selection	
QUADRUPLET SELECTION	<ul style="list-style-type: none"> - Require at least one quadruplet of leptons consisting of two pairs of same-flavour opposite-charge leptons fulfilling the following requirements: - p_T thresholds for three leading leptons in the quadruplet: 20, 15 and 10 GeV - At most 1 calo-tagged, stand-alone or silicon-associated muon per quadruplet - Leading di-lepton mass requirement: $50 < m_{12} < 106$ GeV - Sub-leading di-lepton mass requirement: $m_{\text{threshold}} < m_{34} < 115$ GeV - $\Delta R(\ell, \ell') > 0.10$ for all lepton pairs in the quadruplet - Remove quadruplet if alternative same-flavour opposite-charge di-lepton gives $m_{\ell\ell} < 5$ GeV - Keep all quadruplets passing the above selection
ISOLATION NEEDS UPDATING	<ul style="list-style-type: none"> - Contribution from the other leptons of the quadruplet is subtracted - Muon track isolation ($\Delta R = 0.30$): $\Sigma p_T/p_T < 0.15$ - Muon calorimeter isolation ($\Delta R = 0.20$): $\Sigma E_T/p_T < 0.30$ - Electron track isolation ($\Delta R = 0.20$): $\Sigma E_T/E_T < 0.15$ - Electron calorimeter isolation ($\Delta R = 0.20$): $\Sigma E_T/E_T < 0.20$
IMPACT PARAMETER SIGNIFICANCE	<ul style="list-style-type: none"> - Apply impact parameter significance cut to all leptons of the quadruplet - For electrons: $d_0/\sigma_{d_0} < 5$ - For muons: $d_0/\sigma_{d_0} < 3$
BEST QUADRUPLET	<ul style="list-style-type: none"> - If more than one quadruplet has been selected, choose the quadruplet with highest Higgs decay ME according to channel: 4μ, $2e2\mu$, $2\mu2e$ and $4e$
VERTEX SELECTION	<ul style="list-style-type: none"> - Require a common vertex for the leptons: - $\chi^2/\text{ndof} < 5$ for 4μ and < 9 for others decay channels