Search for the Higgs boson in the ATLAS Experiment: Optimization of the H-WW 0-jet cuts for 2011 and 2012 data

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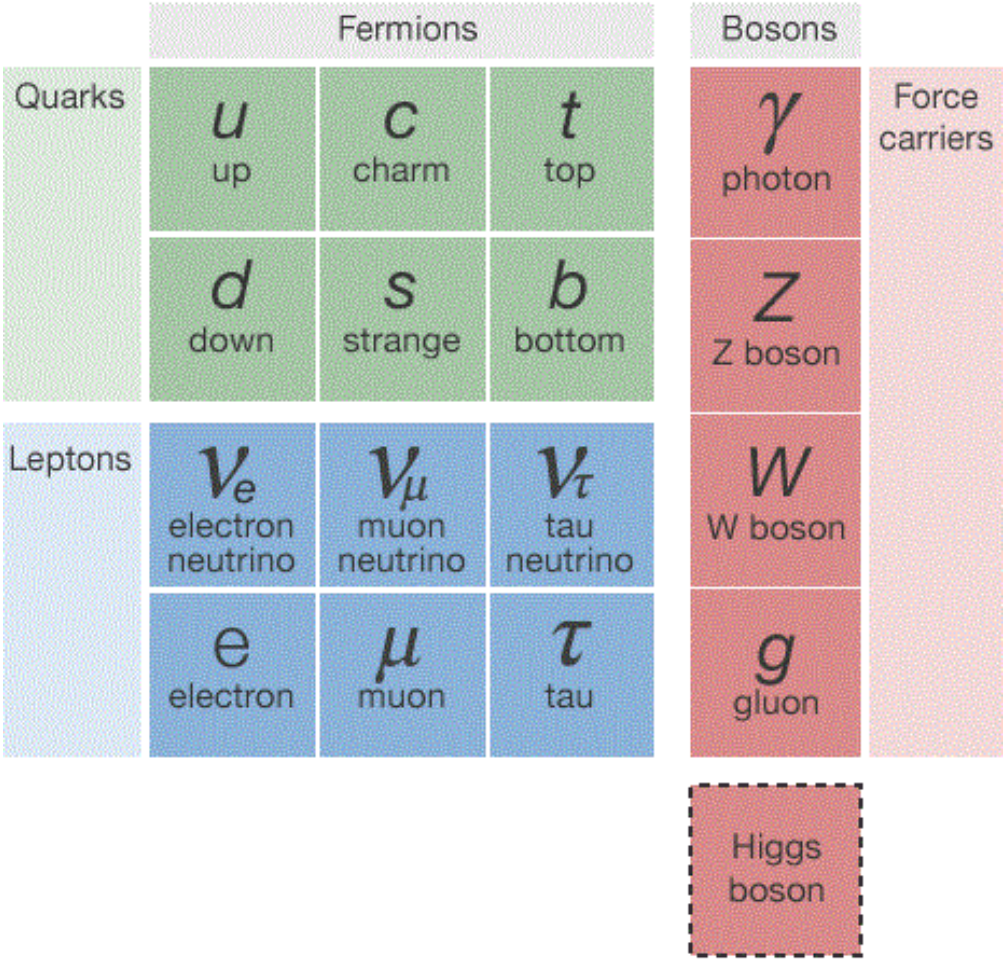
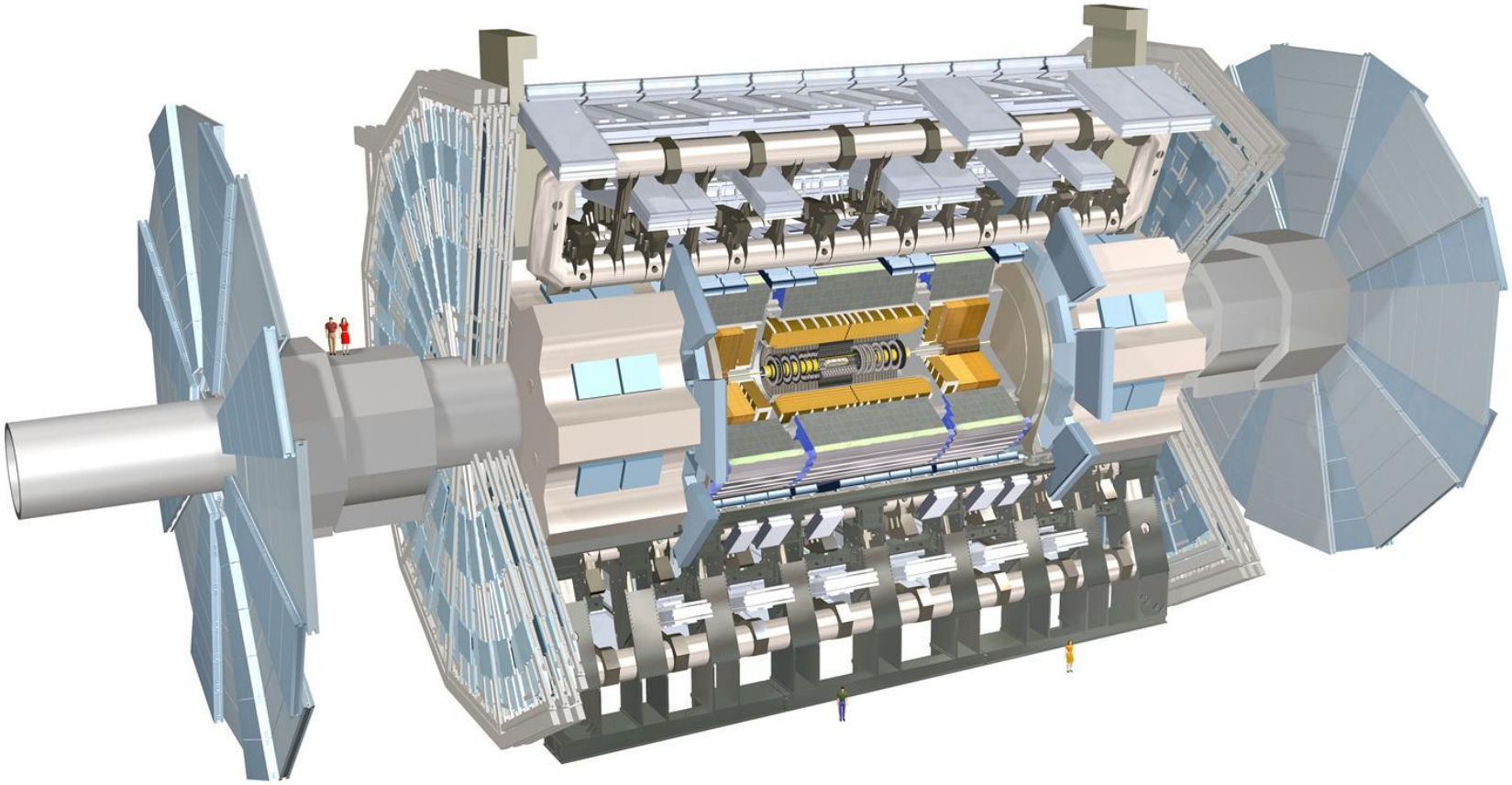
Outline

- Background
- Motivation of my project
- Description of the process
- Optimization with 2011 data
- Optimization with 2012 data (all channels)
- Optimization with 2012 data (em,me)

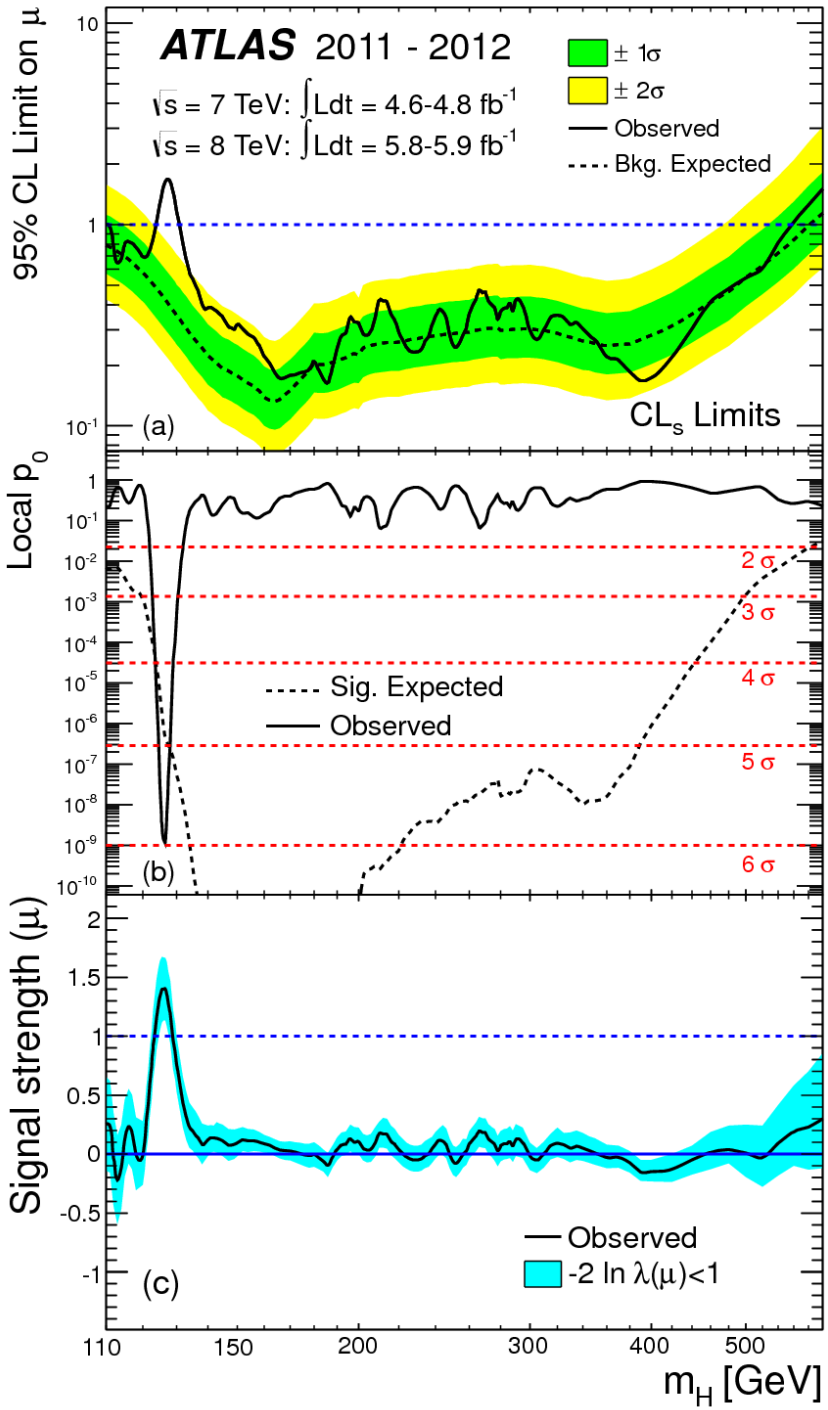
The Standard Model



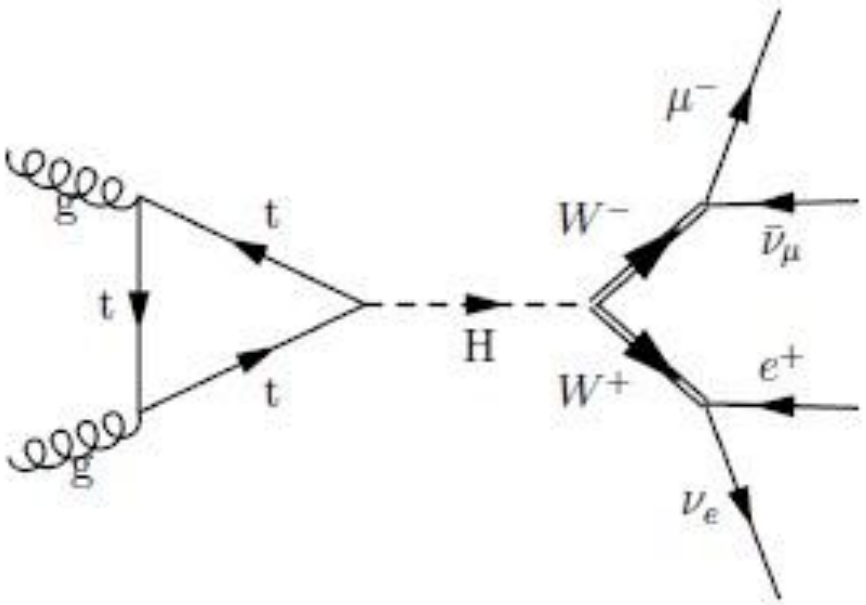
The ATLAS Detector



The ATLAS Higgs Results



$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ decay channel



Project and Motivation

Project: Optimization of the H-WW 0-jet cuts for 2011 and 2012 data

- With the available data, try to maximize the signal significance by choosing the 'best' cut values
- Cross-check on the nominal cuts used
- Possibility of analysis improvement

H + 0-jet Cuts

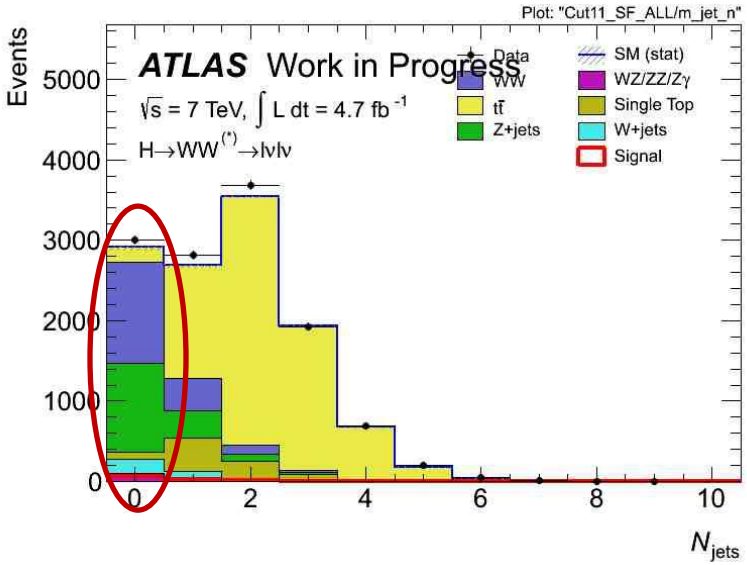
- Dilepton invariant mass
  - $m_{ll} < 50\ GeV$
- Transverse momentum of the dilepton system (suppress Drell-Yan background)
  - $\boldsymbol{p}_T{}^{ll} > 45\ GeV\ (ee, \mu\mu)$
  - $\boldsymbol{p}_T{}^{ll} > 30\ GeV\ (e\mu, \mu e)$
- Dilepton opening angle in transverse plane (spin correlations in the H->WW system, spin-0 Higgs)
  - $\Delta\phi_{ll} < 1.8\ rads$

Strategy

- Optimize the 0-jet Cuts
- Optimization was done by maximizing:

$$R = \frac{signal\ count}{\sqrt{background\ count}}$$

(scaled event yield after each cut)



Optimize cuts *simultaneously*

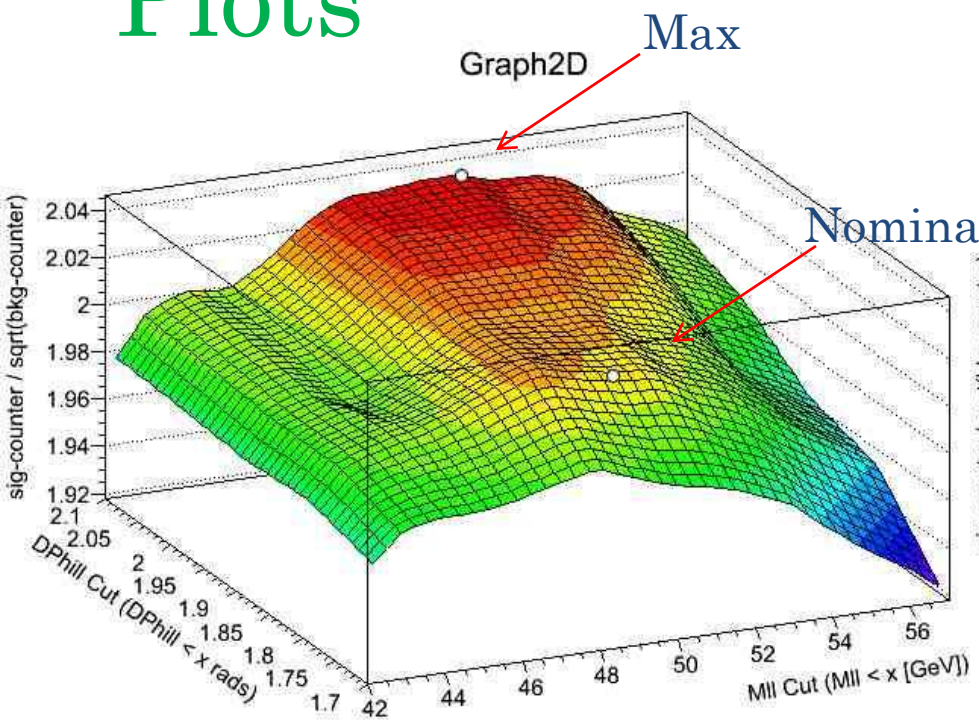
- Turns out that the cuts are slightly *correlated* and hence to truly maximize our ratio R, we need to optimize *all 4 cuts simultaneously*
- Harder to visualize (5-D plot!)
  My code prints a table of the run, plots different variables, and outputs the best cut values for each optimization run

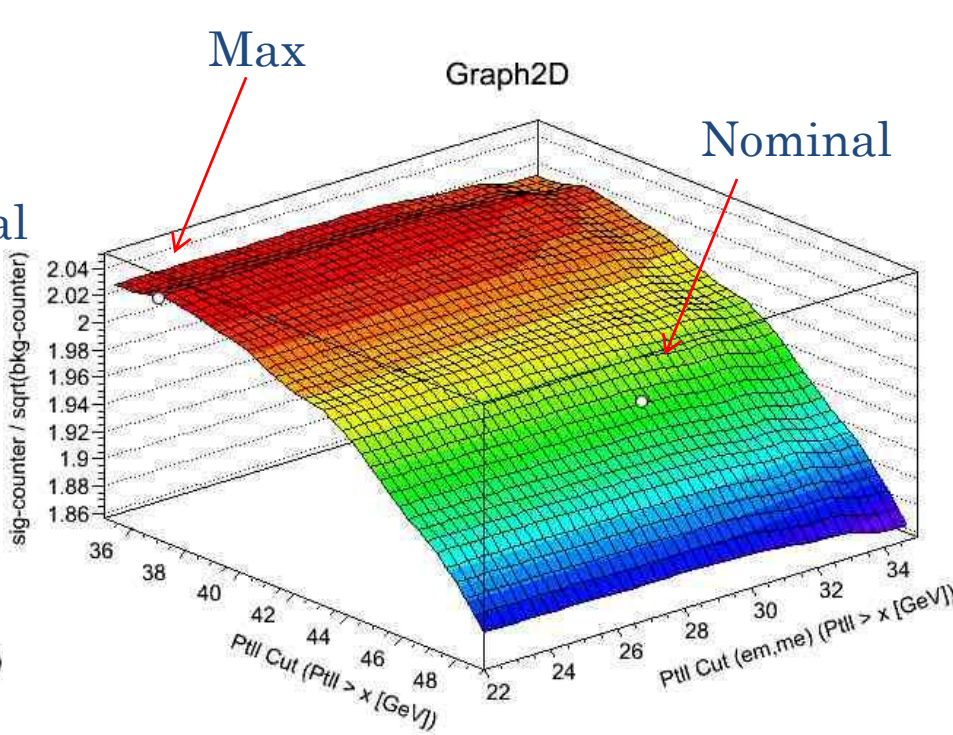
Optimization with 2011 data

(*all* subchannels: ee,mm,em)

- Optimization Sweep:
  - Ptll cut (ee,mm) — 35→49 GeV (1GeV steps)
  - Ptll cut (em) — 22→35 GeV (1GeV steps)
  - Mll cut — 42→57 GeV (1GeV steps)
  - Δφll cut — 1.7→2.1 rads (0.1 steps)
- Results: (max R)
  - Ptll cut (ee,mm) — ***37 GeV***
  - Ptll cut (em) — ***22 GeV***
  - Mll cut — ***51 GeV***
  - Δφll cut — ***2.1 rads***

Plots





set Ptll cut ≡ 37 GeV (ee,mm)
≡ 22 GeV (em,me)
→Plot R in *Mll vs Δφll* cuts space

set Mll cut ≡ 51 GeV
Δφll cut ≡ 2.1 rads
→Plot R in *Ptll vs Ptll(em,me)* cuts space

Results with 'best cuts'

Nominal Cuts

	Signal [125 GeV]	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	Single Top	Z+jets	W+jets	Total Bkg.	Observed	Data/MC	Data/(MC+sig[125])
0j: jet veto	57.10 ± 0.23	1246.35 ± 5.45	99.49 ± 5.07	174.21 ± 2.85	93.99 ± 2.63	1027.61 ± 22.88	174.07 ± 20.94	2815.72 ± 32.13	3005	1.07 ± 0.02	1.05 ± 0.02
0j: $p_{T,\ell\ell}$ >45.30 GeV	48.04 ± 0.21	1018.43 ± 4.92	80.37 ± 4.47	150.96 ± 2.65	83.04 ± 2.47	45.49 ± 4.24	123.05 ± 17.48	1501.34 ± 19.52	1637	1.09 ± 0.03	1.06 ± 0.03
0j: $m_{\ell\ell} < 50$ GeV	40.42 ± 0.19	275.87 ± 2.59	38.16 ± 3.68	27.42 ± 1.21	17.55 ± 1.13	21.47 ± 2.54	43.11 ± 10.58	423.58 ± 11.89	457	1.08 ± 0.06	0.98 ± 0.05
0j: $\Delta\phi_{\ell\ell} < 1.8$	**39.30 ± 0.19**	269.38 ± 2.56	36.35 ± 3.54	27.04 ± 1.20	17.41 ± 1.13	20.59 ± 2.49	38.94 ± 10.12	**409.71 ± 11.42**	**443**	1.08 ± 0.06	**0.99 ± 0.05**
0j: $0.75 \cdot m_H \leq m_T \leq m_H$	26.01 ± 0.16	105.10 ± 1.61	12.27 ± 1.78	6.47 ± 0.60	4.37 ± 0.56	11.32 ± 1.76	25.87 ± 8.45	165.40 ± 8.99	177	1.07 ± 0.10	0.92 ± 0.08

$$\mathbf{R} = \frac{signal\ count}{\sqrt{background\ count}} = \mathbf{1.94}$$ 2011 data (all ch)

'Best Cuts'

	Signal [125 GeV]	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	Single Top	Z+jets	W+jets	Total Bkg.	Observed	Data/MC
0j: jet veto	57.10 ± 0.23	1246.35 ± 5.45	99.49 ± 5.07	174.21 ± 2.85	93.99 ± 2.63	1027.61 ± 22.88	174.07 ± 20.94	2815.72 ± 32.13	3005	1.07 ± 0.02
0j: $p_{T,\ell\ell}$ >37.22 GeV	53.94 ± 0.23	1138.90 ± 5.21	91.90 ± 4.94	160.68 ± 2.74	88.52 ± 2.55	100.15 ± 6.39	139.12 ± 18.50	1719.27 ± 21.18	1879	1.09 ± 0.03
0j: $m_{\ell\ell} < 51$ GeV	44.97 ± 0.20	306.81 ± 2.73	44.57 ± 4.09	29.36 ± 1.25	18.84 ± 1.18	37.05 ± 3.34	47.03 ± 10.97	483.67 ± 12.60	531	1.10 ± 0.06
0j: $\Delta\phi_{\ell\ell} < 2.1$	**44.38 ± 0.20**	302.66 ± 2.71	44.08 ± 4.09	29.26 ± 1.25	18.67 ± 1.17	34.06 ± 3.21	47.03 ± 10.97	**475.76 ± 12.56**	**519**	1.09 ± 0.06
0j: $0.75 \cdot m_H \leq m_T \leq m_H$	29.85 ± 0.17	124.74 ± 1.76	15.25 ± 2.05	7.36 ± 0.63	5.22 ± 0.62	18.67 ± 2.37	29.79 ± 8.93	201.02 ± 9.67	214	1.06 ± 0.09

$$\mathbf{R} = \frac{signal\ count}{\sqrt{background\ count}} = \mathbf{2.03}$$ 2011 data (all ch)

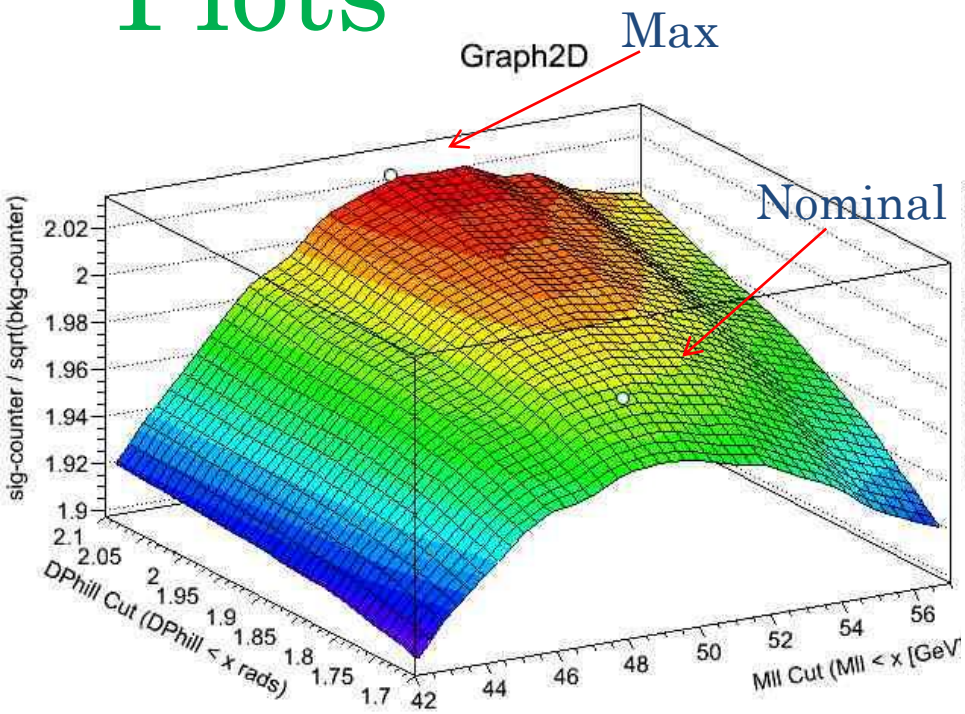
✓ There is a significant gain in signal/sqrt-background ratio.

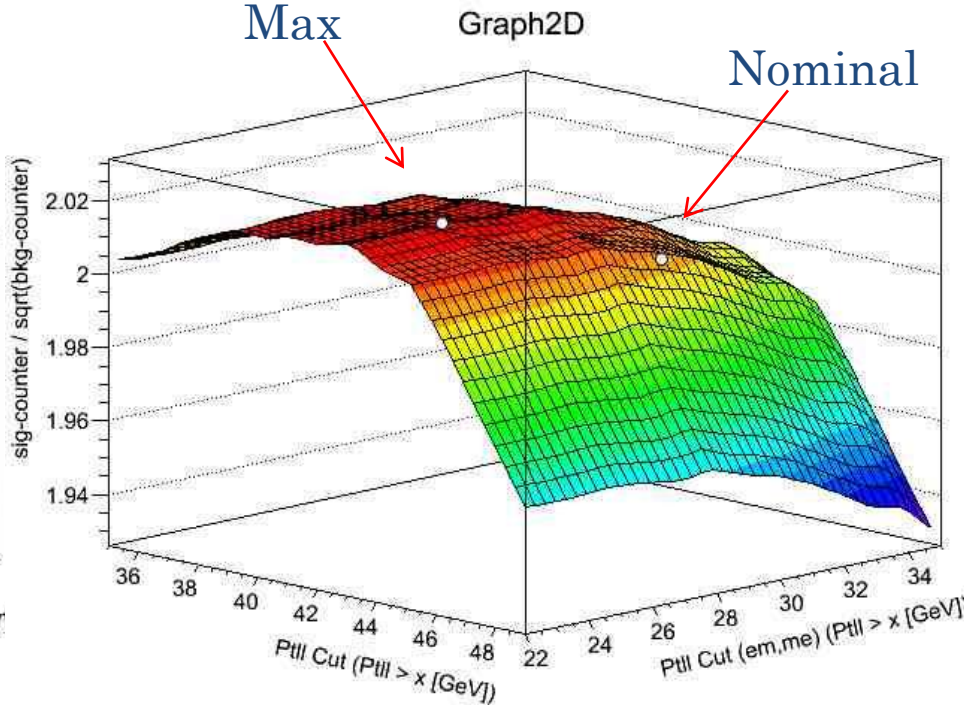
Optimization with 2012 data

(*all* subchannels: ee,mm,em,me)

- Optimization Sweep: (same)
  - Ptll cut (ee,mm) — 35→49 GeV (1GeV steps)
  - Ptll cut (em) — 22→35 GeV (1GeV steps)
  - Mll cut — 42→57 GeV (1GeV steps)
  - Δφll cut — 1.7→2.1 rads (0.1 steps)
- Results: (max R)
  - Ptll cut (ee,mm) — ***43 GeV***
  - Ptll cut (em,me) — ***25 GeV***
  - Mll cut — ***50 GeV***
  - Δφll cut — ***2.1 rads***

Plots





set Ptll cut ≡ 43 GeV (ee,mm)
≡ 25 GeV (em,me)
→Plot R in *Mll vs Δφll* cuts space

set Mll cut ≡ 50 GeV
Δφll cut ≡ 2.1 rads
→Plot R in *Ptll vs Ptll(em,me)* cuts space

Results with 'best cuts'

Nominal Cuts

	Signal [125 GeV]	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	Single Top	Z+jets	W+jets	Total Bkg.	Observed	Data/MC	Data/(MC+sig[125])
0j: jet veto	73.74 ± 0.54	1951.67 ± 11.07	189.54 ± 4.52	246.20 ± 4.25	143.25 ± 5.94	5049.62 ± 67.75	180.00 ± 4.97	7760.30 ± 69.37	6536	0.84 ± 0.01	0.83 ± 0.01
0j: $p_{T,ll}$ >45.30 GeV	61.59 ± 0.50	1564.56 ± 9.90	143.57 ± 3.95	212.07 ± 3.95	126.98 ± 5.62	293.14 ± 14.70	117.98 ± 2.54	2458.30 ± 19.58	2296	0.93 ± 0.02	0.91 ± 0.02
0j: m_{ll} < 50 GeV	51.76 ± 0.46	401.01 ± 5.14	45.98 ± 2.25	38.75 ± 1.79	26.62 ± 2.68	138.57 ± 5.20	36.37 ± 1.35	687.31 ± 8.41	526	0.77 ± 0.03	0.71 ± 0.03
0j: $\Delta\phi_{ll}$ < 1.8	**50.42 ± 0.45**	390.73 ± 5.07	44.99 ± 2.22	38.27 ± 1.77	26.46 ± 2.68	137.26 ± 5.04	32.33 ± 1.28	**670.03 ± 8.25**	**511**	0.76 ± 0.04	**0.71 ± 0.03**
0j: $0.75 \cdot m_H \leq m_T \leq m_H$	30.58 ± 0.35	155.96 ± 3.22	16.77 ± 1.36	10.06 ± 0.86	5.19 ± 1.02	78.20 ± 3.79	20.10 ± 0.98	286.29 ± 5.41	185	0.65 ± 0.05	0.58 ± 0.04

$$\mathbf{R} = \frac{signal\ count}{\sqrt{background\ count}} = \mathbf{1.98}$$ 2012 data (all ch)

'Best Cuts'

	Signal [125 GeV]	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	Single Top	Z+jets	W+jets	Total Bkg.	Observed	Data/MC
0j: jet veto	73.74 ± 0.54	1965.11 ± 11.15	189.54 ± 4.52	246.20 ± 4.25	143.25 ± 5.94	5049.62 ± 67.75	180.00 ± 4.97	7773.73 ± 69.38	6536	0.84 ± 0.01
0j: $p_{T,ll}$ >43.25 GeV	64.70 ± 0.51	1678.41 ± 10.29	154.34 ± 4.10	219.01 ± 4.02	131.00 ± 5.71	369.15 ± 17.00	134.67 ± 2.77	2686.58 ± 21.64	2469	0.92 ± 0.02
0j: m_{ll} < 50 GeV	53.68 ± 0.47	417.35 ± 5.25	48.60 ± 2.31	39.62 ± 1.81	27.02 ± 2.70	155.82 ± 5.64	41.67 ± 1.46	730.08 ± 8.80	539	0.74 ± 0.03
0j: $\Delta\phi_{ll}$ < 2.1	**53.29 ± 0.46**	414.46 ± 5.23	48.03 ± 2.29	39.41 ± 1.81	27.02 ± 2.70	153.59 ± 5.41	39.78 ± 1.43	**722.29 ± 8.63**	**534**	0.74 ± 0.03
0j: $0.75 \cdot m_H \leq m_T \leq m_H$	32.54 ± 0.36	169.63 ± 3.36	17.75 ± 1.39	10.61 ± 0.89	5.59 ± 1.06	89.15 ± 4.00	24.89 ± 1.10	317.62 ± 5.69	196	0.62 ± 0.05

$$\mathbf{R} = \frac{signal\ count}{\sqrt{background\ count}} = \mathbf{2.02}$$ 2012 data (all ch)

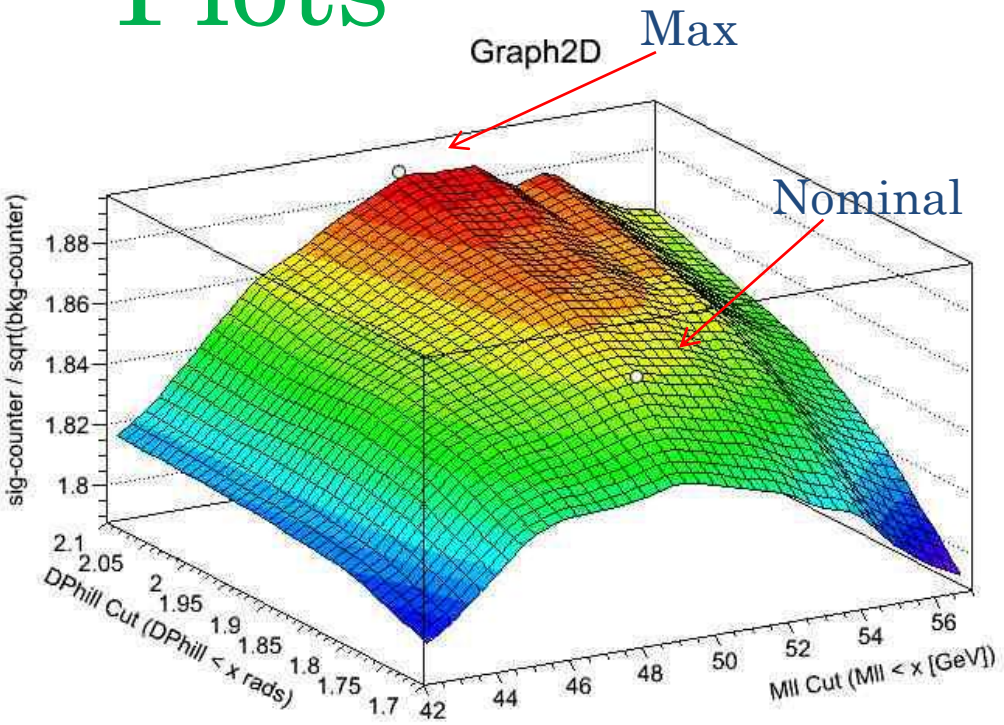
✓ There is a small gain in signal/sqrt-background ratio; nominal cuts are close to optimum.

Optimization with 2012 data

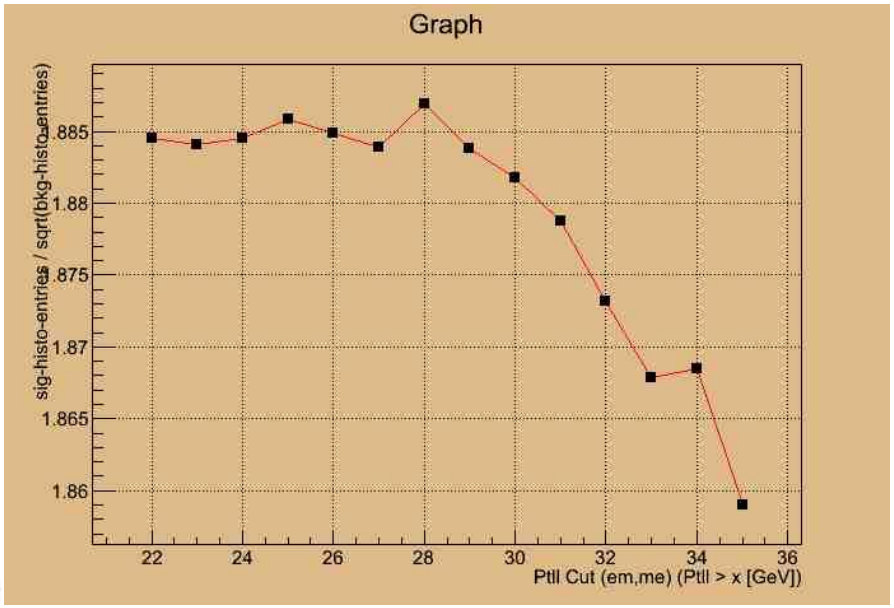
(*only* subchannels: em,me)

- Optimization Sweep: (same)
  - Ptll cut (ee,mm) — set ≡ 45 GeV
  - Ptll cut (em,me) — 22→35 GeV (1GeV steps)
  - Mll cut — 42→57 GeV (1GeV steps)
  - Δφll cut — 1.7→2.1 rads (0.1 steps)
- Results: (max R)
  - Ptll cut (ee,mm) — ***45 GeV*** (set)
  - Ptll cut (em) — ***28 GeV***
  - Mll cut — ***50 GeV***
  - Δφll cut — ***2.1 rads***

Plots



set Ptll cut ≡ 45 GeV (ee,mm)
≡ 28 GeV (em,me)
→Plot R in *Mll vs Δφll* cuts space



set Mll cut ≡ 50 GeV
Δφll cut ≡ 2.1 rads
→Plot R in *Ptll(em,me)* cut space

Results with 'best cuts'

Nominal Cuts

	Signal [125 GeV]	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	Single Top	Z+jets	W+jets	Total Bkg.	Observed	Data/MC	Data/(MC+sig[125])
0j: jet veto	46.84 ± 0.43	1307.82 ± 8.98	125.15 ± 3.94	184.44 ± 3.95	108.72 ± 5.60	850.07 ± 31.97	138.23 ± 4.00	2714.43 ± 34.37	2691	0.99 ± 0.02	0.97 ± 0.02
0j: $p_{T,\ell\ell}$ >45,30 GeV	42.75 ± 0.42	1077.47 ± 8.14	99.20 ± 3.53	165.35 ± 3.74	98.36 ± 5.34	46.94 ± 7.69	101.77 ± 2.29	1589.10 ± 13.62	1664	1.05 ± 0.03	1.02 ± 0.03
0j: $m_{\ell\ell} < 50$ GeV	34.60 ± 0.37	243.86 ± 3.96	32.59 ± 2.05	27.71 ± 1.60	17.38 ± 2.34	5.29 ± 2.27	28.99 ± 1.13	355.82 ± 5.86	421	1.18 ± 0.06	1.08 ± 0.05
0j: $\Delta\phi_{\ell\ell} < 1.8$	**33.31 ± 0.37**	233.85 ± 3.87	31.61 ± 2.02	27.14 ± 1.58	17.19 ± 2.33	3.99 ± 1.87	25.03 ± 1.05	**338.80 ± 5.62**	**407**	1.20 ± 0.06	**1.09 ± 0.06**
0j: $0.75 \cdot m_H \leq m_T \leq m_H$	20.09 ± 0.29	101.29 ± 2.56	11.49 ± 1.19	8.05 ± 0.82	3.36 ± 0.85	1.90 ± 1.31	15.42 ± 0.80	141.51 ± 3.42	185	1.31 ± 0.10	1.14 ± 0.09

$$\mathbf{R} = \frac{signal\ count}{\sqrt{background\ count}} = \mathbf{1.86}$$ 2012 data (em,me)

'Best Cuts'

	Signal [125 GeV]	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	Single Top	Z+jets	W+jets	Total Bkg.	Observed	Data/MC
0j: jet veto	46.84 ± 0.43	1329.55 ± 9.13	125.15 ± 3.94	184.44 ± 3.95	108.72 ± 5.60	850.07 ± 31.97	138.23 ± 4.00	2736.16 ± 34.41	2691	0.98 ± 0.02
0j: $p_{T,\ell\ell}$ >45.28 GeV	43.51 ± 0.42	1130.55 ± 8.41	103.27 ± 3.60	167.86 ± 3.77	99.56 ± 5.37	61.94 ± 8.63	106.66 ± 2.37	1669.83 ± 14.38	1729	1.04 ± 0.03
0j: $m_{\ell\ell} < 50$ GeV	34.96 ± 0.38	250.80 ± 4.04	33.27 ± 2.06	27.76 ± 1.60	17.38 ± 2.34	6.31 ± 2.46	29.96 ± 1.16	365.49 ± 6.01	428	1.17 ± 0.06
0j: $\Delta\phi_{\ell\ell} < 2.1$	**34.75 ± 0.37**	249.32 ± 4.03	32.93 ± 2.05	27.67 ± 1.60	17.38 ± 2.34	5.37 ± 2.27	28.78 ± 1.13	**361.46 ± 5.92**	**426**	1.18 ± 0.06
0j: $0.75 \cdot m_H \leq m_T \leq m_H$	20.96 ± 0.29	109.58 ± 2.69	12.00 ± 1.21	8.36 ± 0.84	3.36 ± 0.85	1.90 ± 1.31	17.76 ± 0.86	152.95 ± 3.55	194	1.27 ± 0.10

$$\mathbf{R} = \frac{signal\ count}{\sqrt{background\ count}} = \mathbf{1.89}$$ 2012 data (em,me)

✓ There is a small gain in signal/sqrt-background ratio; nominal cuts are close to optimum.

Summary

- There is a higher gain from the optimization with the 2011 data (all subchannels)
- Nominal cuts for 2012 data (all 4 subch, and also em/me) are close to optimum

- My plan is to send this study around to the HSG3 group for feedback and record purposes

Thanks!

University of Michigan REU

CERN

UoT