Study of Higgs Self-couplings at ILC

J. Tian (Tsinghua U.)

Y. Takubo (Tohuko U.)

K. Fujii (KEK)

Y. Gao (Tsinghua U.)

status of the full simulation
(preliminary)

$$e^+ + e^- \rightarrow ZHH \quad M(H) = 120 \text{GeV} \quad \int Ldt = 2\text{ab}^{-1}$$

Energy (GeV)	Modes	signal		background		significance	
						excess (I)	measurement (II)
500	$ZHH \rightarrow (l\bar{l})(b\bar{b})(b\bar{b})$	6.4		6.7		2.1σ	1.7σ
500	$ZHH \rightarrow (\nu\bar{\nu})(b\bar{b})(b\bar{b})$	5.2		7.0		1.7σ	1.4σ
500	$ZHH \rightarrow (q\bar{q})(b\bar{b})(b\bar{b})$	8.5	16.6	11.7	129	2.7σ	2.6σ

✳ cuts are re-optimized with higher statistics.

✳ llHH: eebb, mmbb, llqqh (done), evbbqq, mvbbqq (ongoing)

✳ vvHH: tauvbbqq, bbbb (done)

✳ qqHH: ttqq (donw), bbuddu, bbcsdu, bbcssc (ongoing)

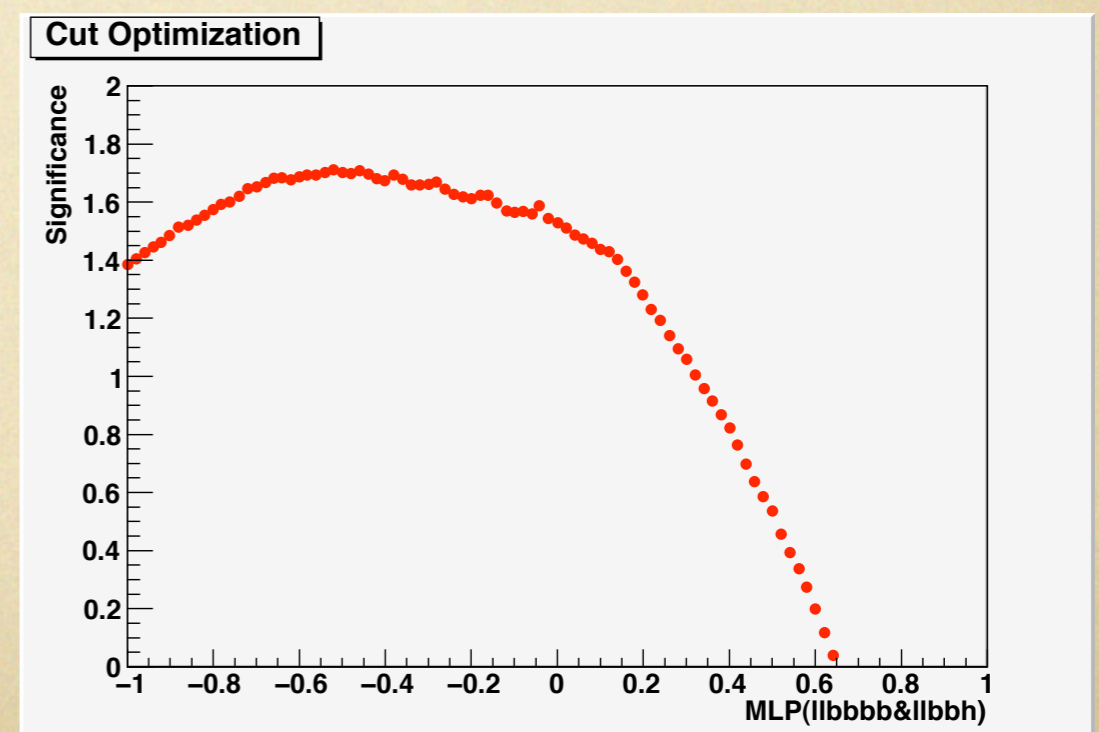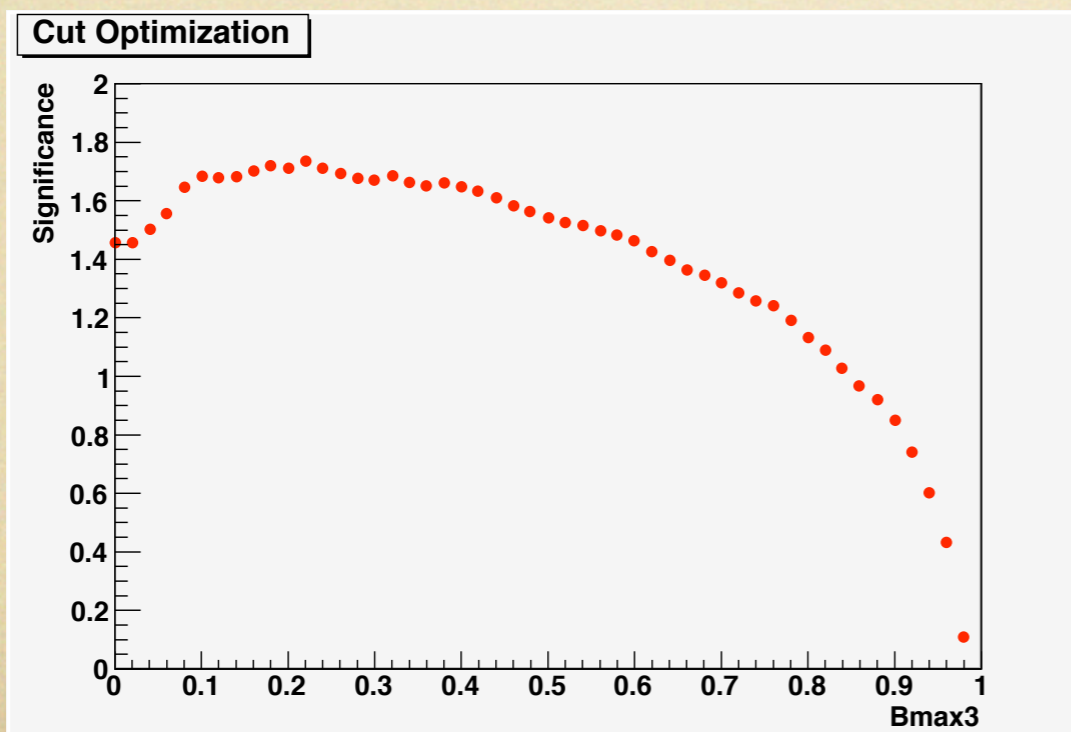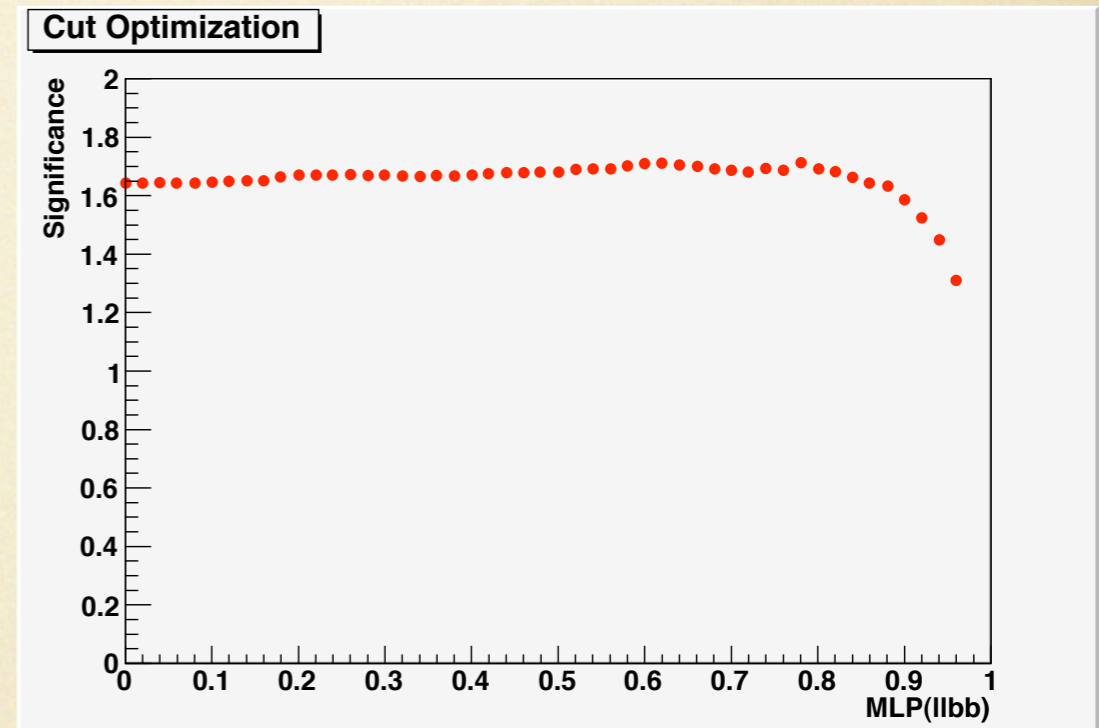# cut optimization (llHH)

Polarization: (e-,e+)=(-0.8,0.3) $\int L dt = 2\text{ab}^{-1}$

llhh	6.39±0.10
BG	6.74±0.35
llbbbb	1.23±0.10
llbbh	3.25±0.09
llqqh	1.07±0.04
llbb	1.22±0.32

$$\delta N = \frac{N_0}{M_0}\delta M = \frac{N_0}{M_0}\sqrt{M} = \sqrt{\frac{N_0}{M_0}}\sqrt{N}$$
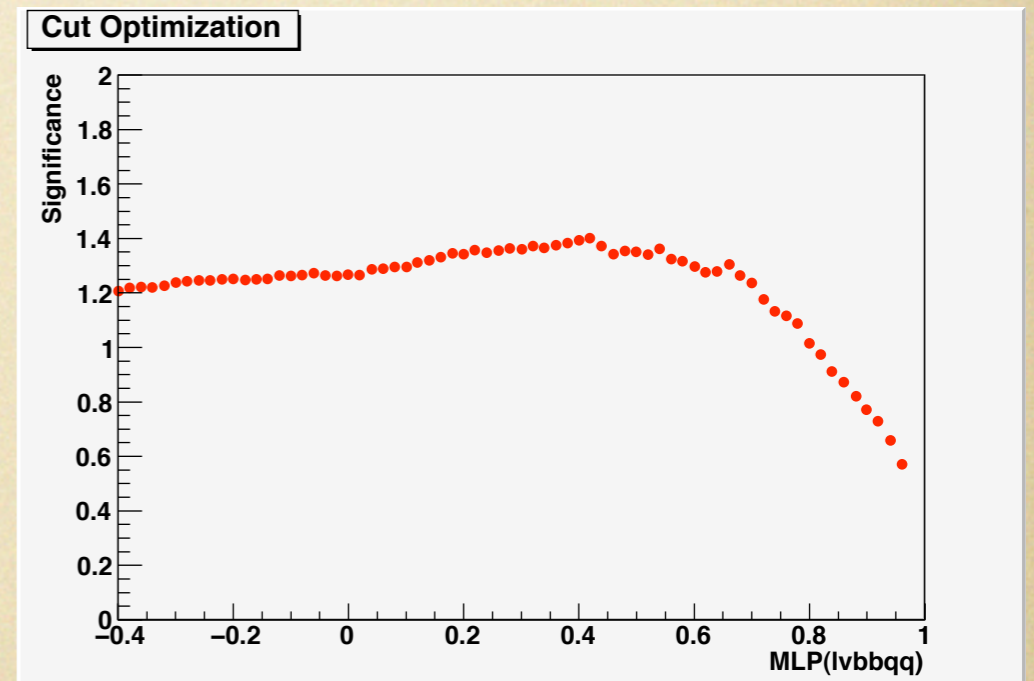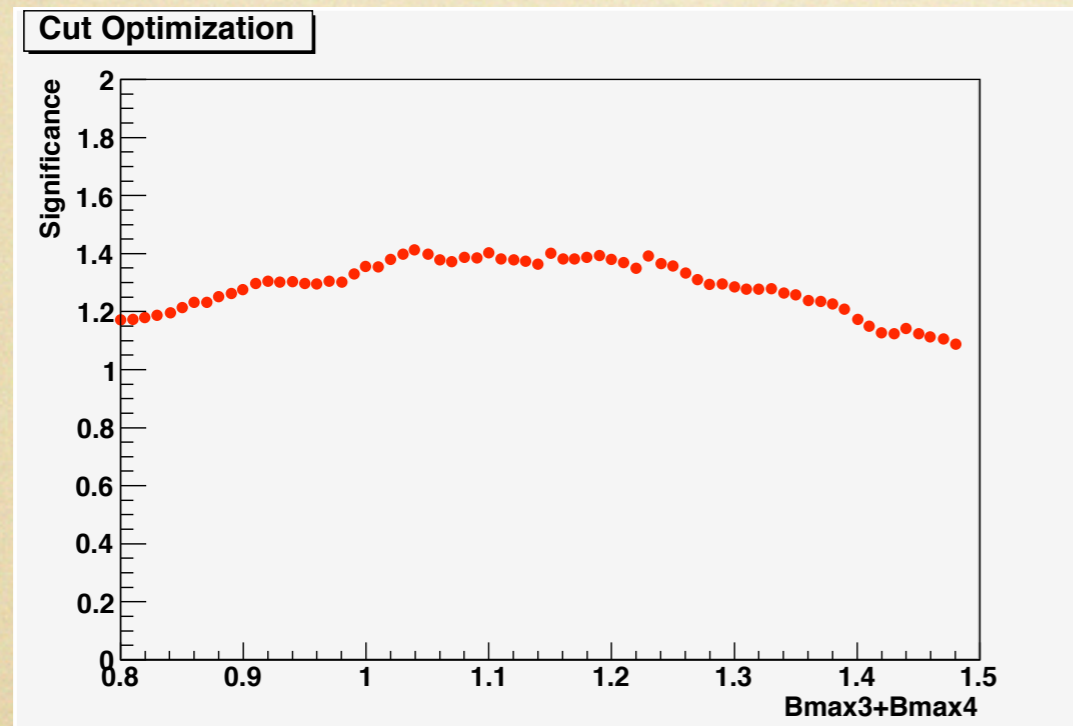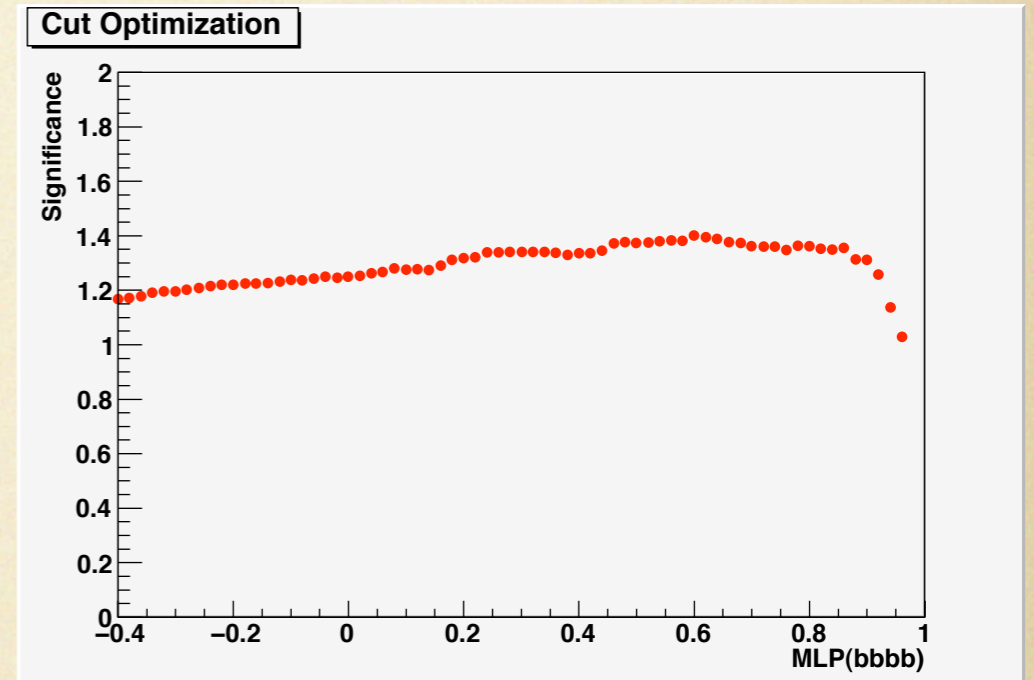

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cut optimization (vvHH)

Polarization: (e-,e+)=(-0.8,0.3) $\int Ldt = 2\text{ab}^{-1}$

full simulation @ 500GeV

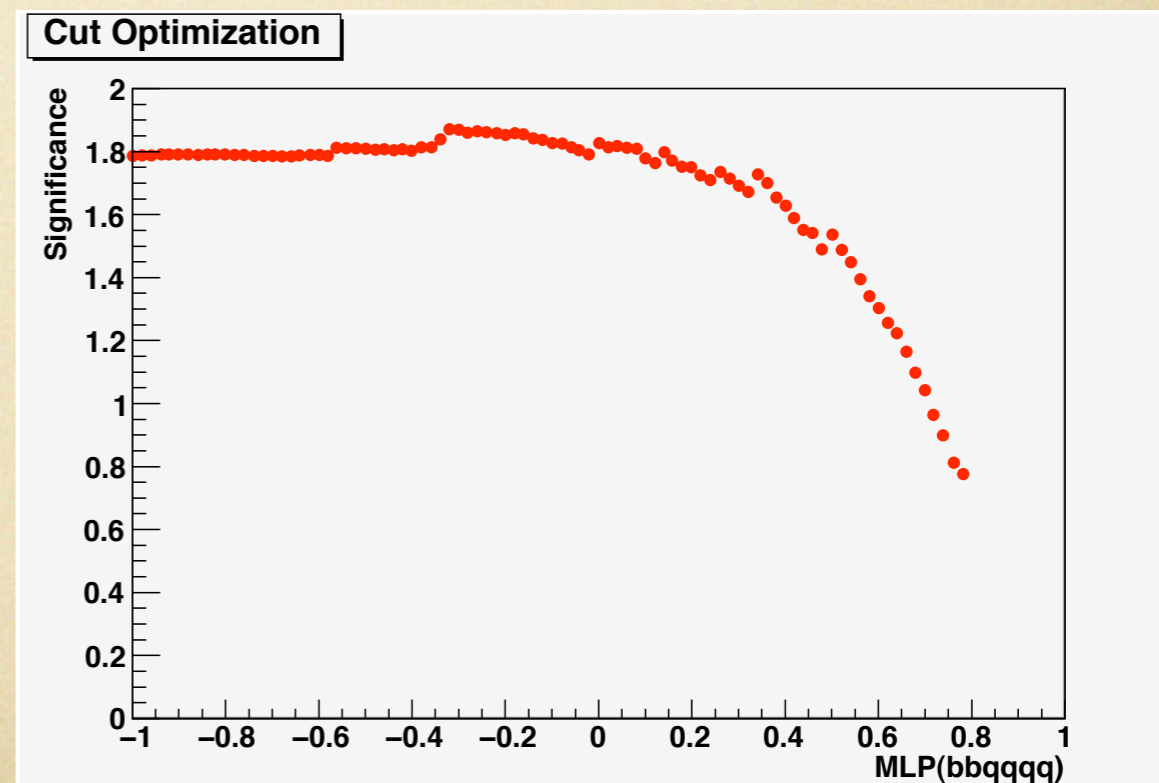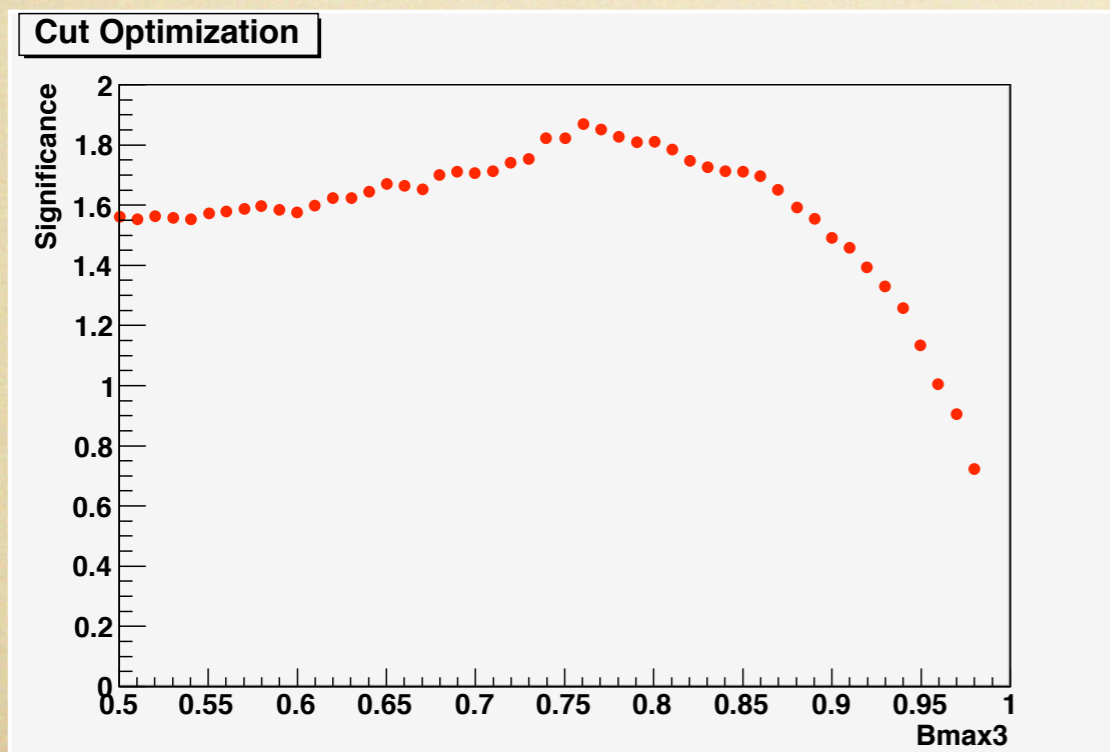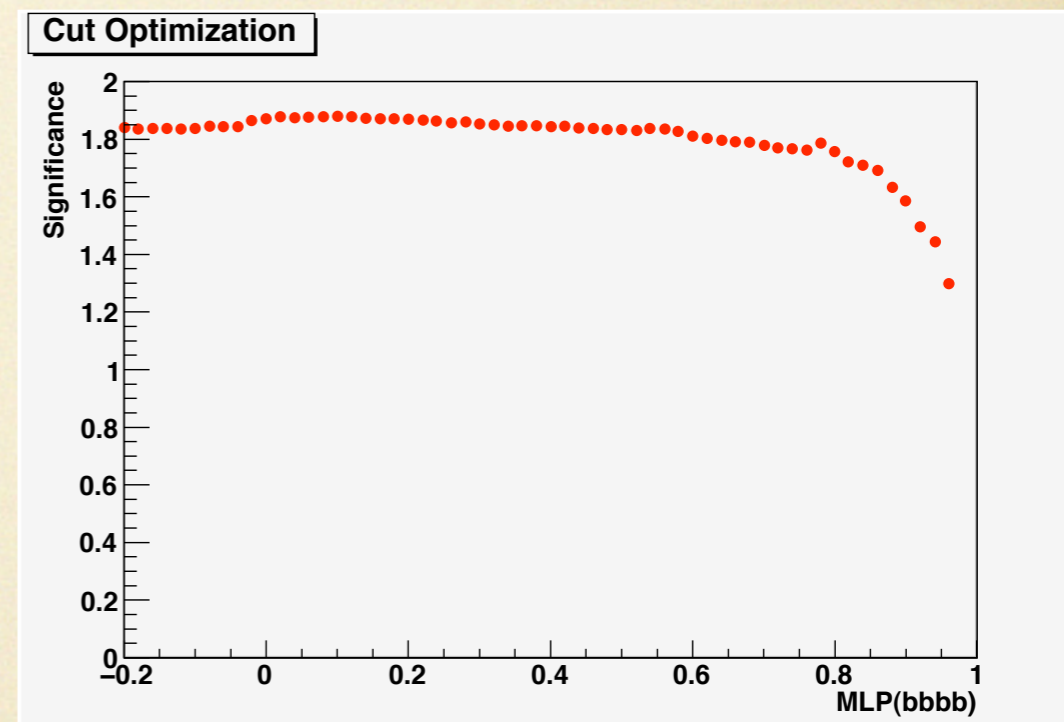|	
vvhh	6.21±0.15
BG	7.00±0.73
vvbbbb	0.63±0.10
vvbbh	1.50±0.08
bbbb	1.62±0.41
tauvbbqq	3.25±0.59

cut optimization (qqHH)

ProbZ1+ProbZ2>0.9

full simulation @ 500GeV

Polarization: (e-,e+)=(-0.8,0.3) $\int Ldt = 2\text{ab}^{-1}$

qqhh	8.5±0.2
BG	11.7±1.5
bbbb	1.27±0.35
ttqq	1.85±0.27
bbcsdu	1.38±0.92
bbcssc	2.01±1.12
qqbbbb	2.09±0.08
qqqqh	2.70±0.14

cut optimization (qqHH)

full simulation @ 500GeV

Polarization: (e-,e+)=(-0.8,0.3) $\int Ldt = 2\mathrm{ab}^{-1}$

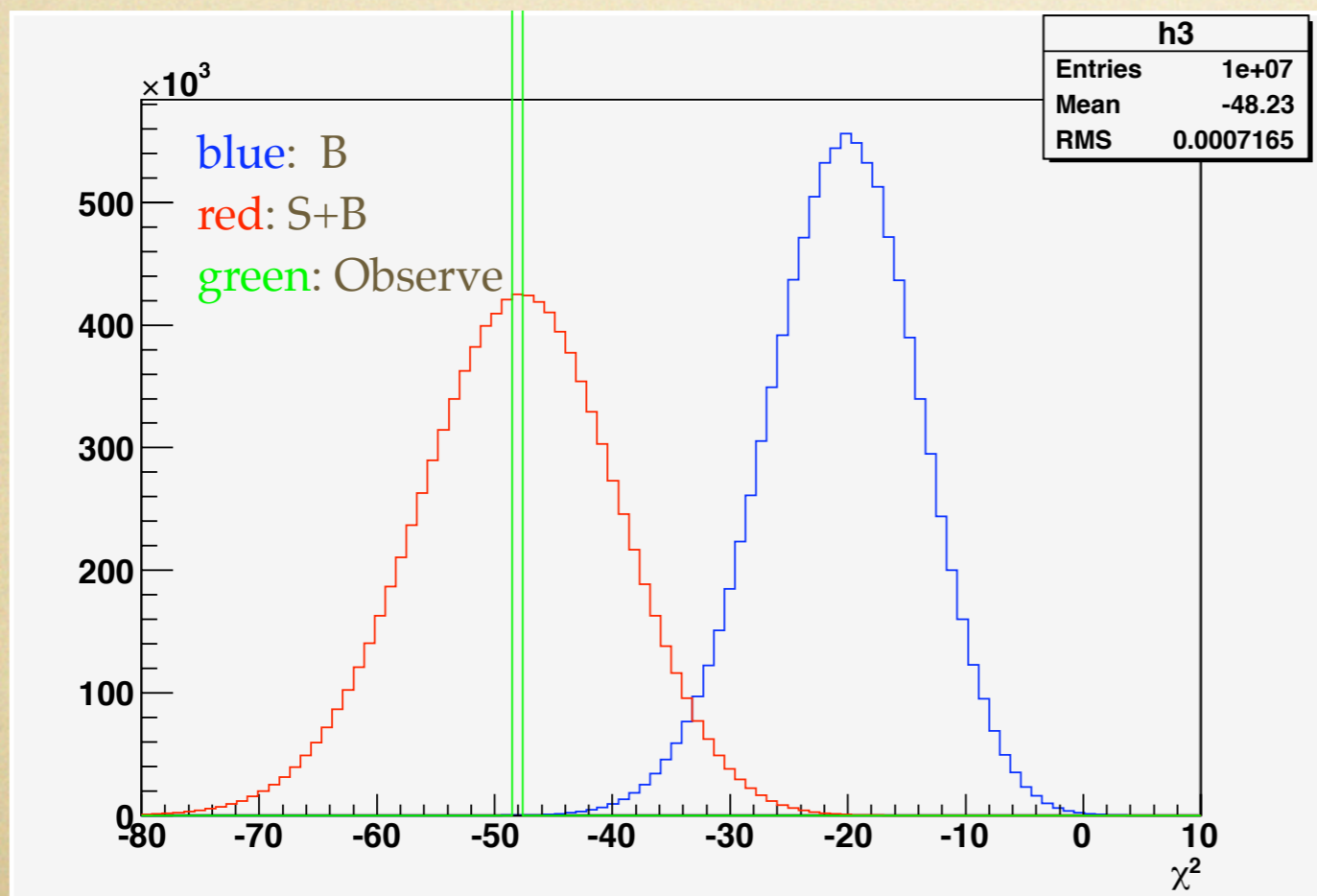|	
qqhh	16.6±0.3
BG	129±8
lvbbqq	4.3±1.2
bbbb	9.1±0.6
ttqq	13.7±0.7
bbuddu	5.4±3.6
bbcsdu	42.2±5.1
bbcssc	39.6±5.0
qqbbbb	6.7±0.4
qqqqh	7.6±0.2
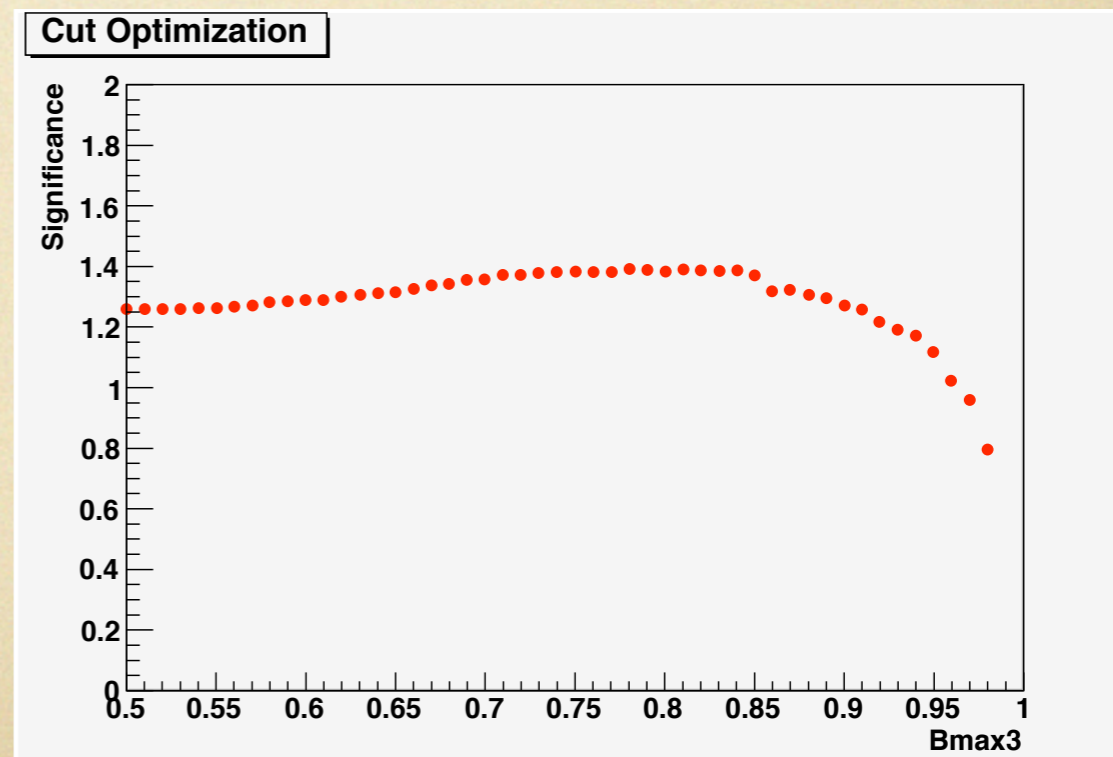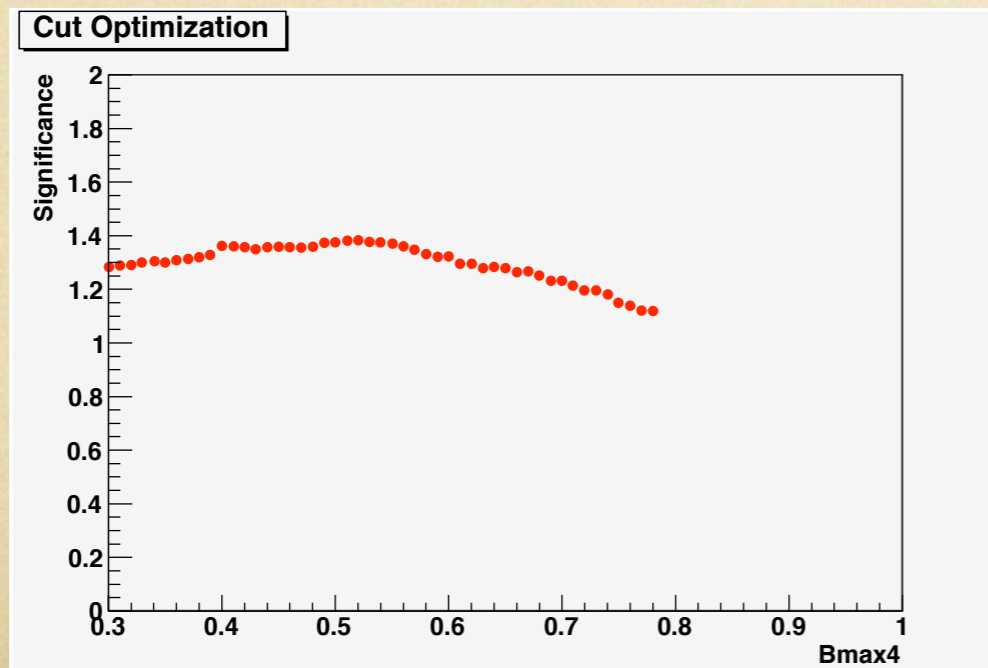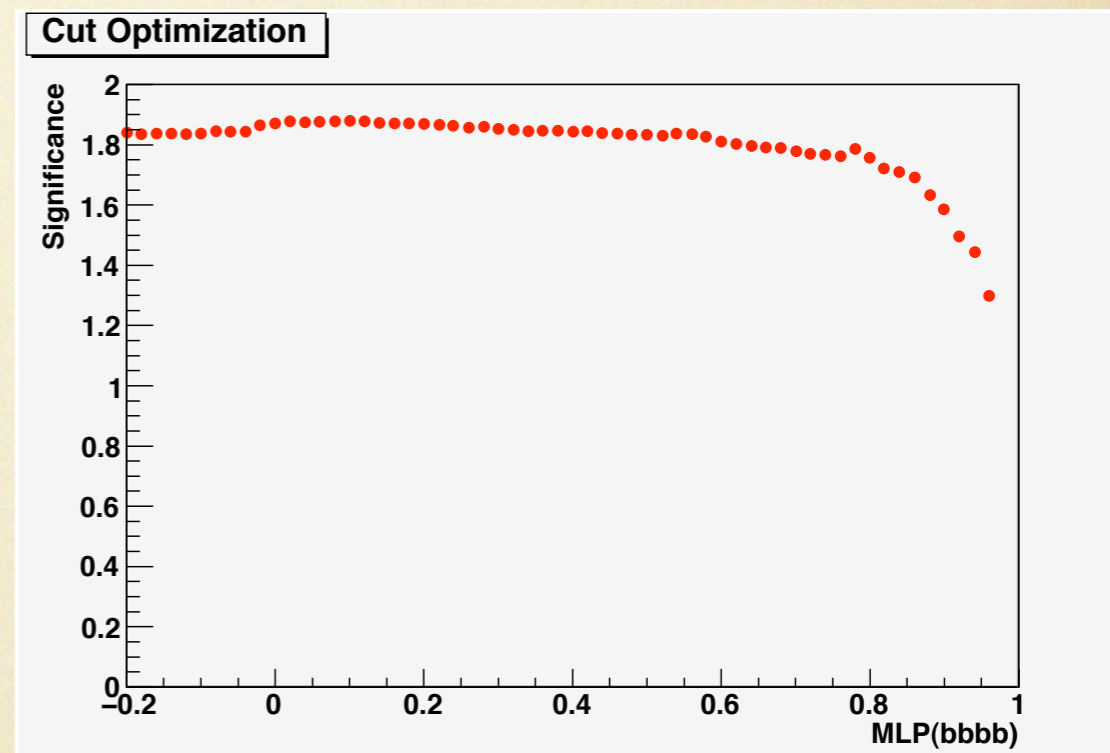
Hypothesis Test (Combined)

H0: background only   H1: ZHH events exist

test: $\chi^2 = -2\ln\dfrac{L_{s+b}}{L_b}$

$$L_{s+b} = \Pi_i \frac{e^{-(s_i+b_i)}(s_i + b_i)^{n_i}}{n_i!}$$

$$L_b = \Pi_i \frac{e^{-b_i}b_i^{n_i}}{n_i!}$$

blue: B
red: S+B
green: Observe

h3	
Entries	1e+07
Mean	-48.23
RMS	0.0007165

$$p = \int_{-\infty}^{\chi^2_{obv}} f_b(\chi^2)d\chi^2$$

= 4.6×10^{-5}

significance: 3.9σ

precision of cross section ~ 25%

precision of coupling ~ 45%

precision of cross section