

# Search for $ZH \rightarrow llbb$ with 1.1/fb using NN

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Higgs Results for  
Lepton Photon 2007

Special ADM

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# Data / MC samples

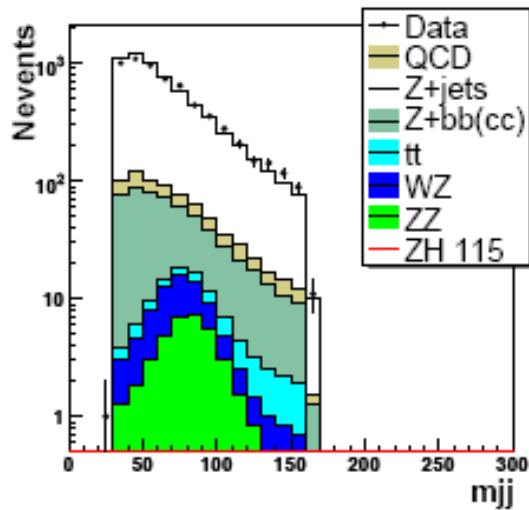
- All p17 pass3 data,  $L = 1.07 \text{ fb}^{-1}$ 
  - 2EMhighpt, 2MUhighpt skims
- MC
  - ZH  $\rightarrow$  eebb
    - Z+nlp ( $n = 0,1,2,3,4,5$ , HF skimmed) K-factor = 1.23
    - Z+bb, Z+cc K-factor = 1.35 (30% error for 2tag, 50% error for 1tag)
  - ZH  $\rightarrow$   $\mu\mu$ bb
    - Z+nlp: normalized to Z + 2jets data
    - Z+bb K-factor = 1.5 (this is higher than ee channel b/c lack of Z+cc)
  - Applied Z pT re-weighting, Z mass bug correction, and object ID corrections
  - Other MC: ttbar, WZ, ZZ

# Analysis

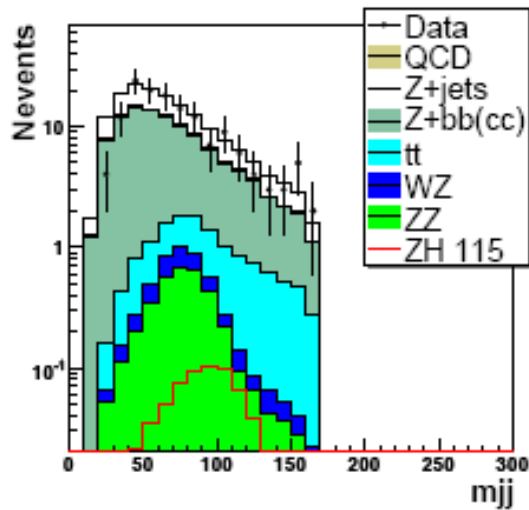
- Event selection
  - ZH  $\rightarrow$  eebb: 2 Loose\_trk electrons  $p_T > 15$  GeV at CC/EC
  - ZH  $\rightarrow$   $\mu\mu$ bb: 2 loose muons  $p_T > 10$  GeV
  - 2 jets  $p_T > 15$  GeV with  $|\eta| < 2.5$  ( $\Delta R_{ej} > 0.5$ )
  - $70 < M_{ee} < 110$  GeV, all triggers
  - QCD background: reversed EM likelihood or muon isolation data samples
- B-tagging
  - 1T sample: single VERYTIGHT tagged but *not* at least double L4 tagged
  - 2L sample: at least double L4 tagged

# NN selection

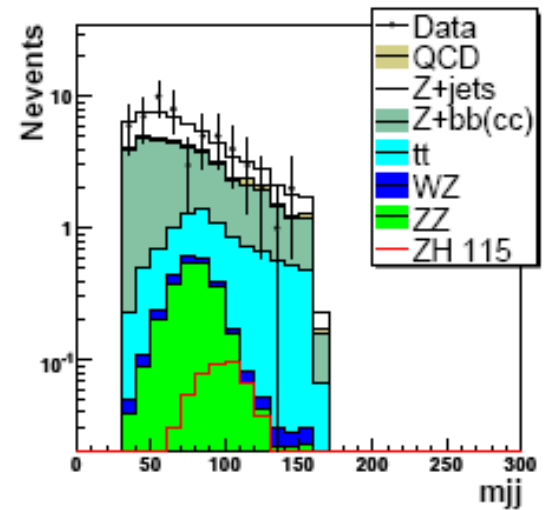
- Andy's NN scripts
  - ROOT TMultiLayerPerceptron
  - 6 (8) hidden neurons, 150 training epochs
  - 10 variables:  $M_{bb}$  ( $M_{jj}$ ),  $p_{T_{jet1}}$ ,  $p_{T_{jet2}}$ ,  $\Delta R(l1,l2)$ ,  $\Delta\eta(j1,j2)$ ,  $\Delta\phi(j1,j2)$ ,  $\Delta R(Z,j1)$ ,  $\eta_Z$ , MET, SET
  - $M_{jj}$  mass cut: within signal's mean  $\pm 3\sigma$
  - All backgrounds included (QCD from data)
  - Training weights:  $\#events \times b$ -tagging probabilities TRF
  - Train on ee and  $\mu\mu$  channels separately
  - Train on double-tagged and single-tagged samples separately

*Pre-tag**1T**2L*

(a)



(b)

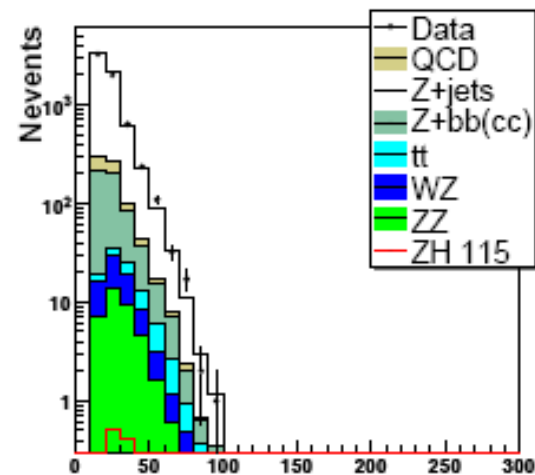
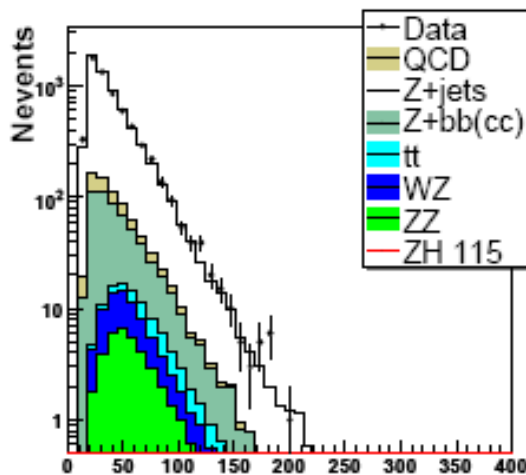
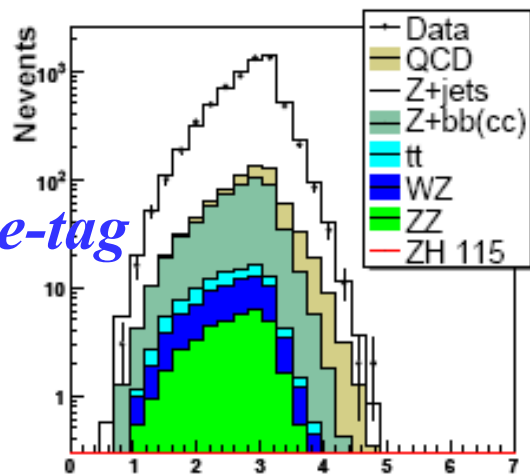


(c)

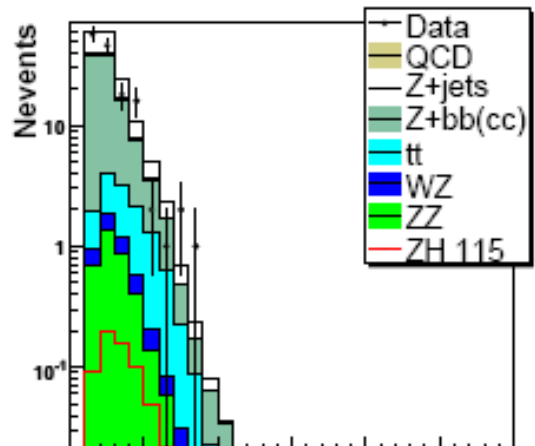
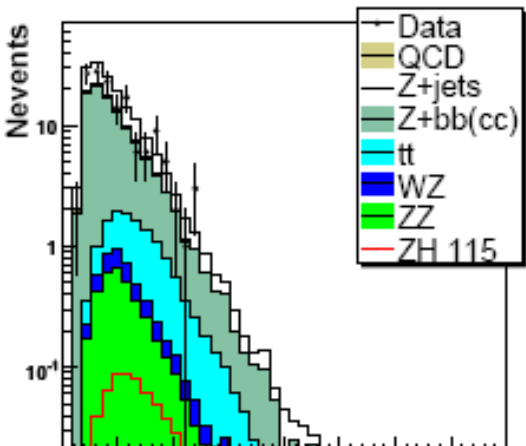
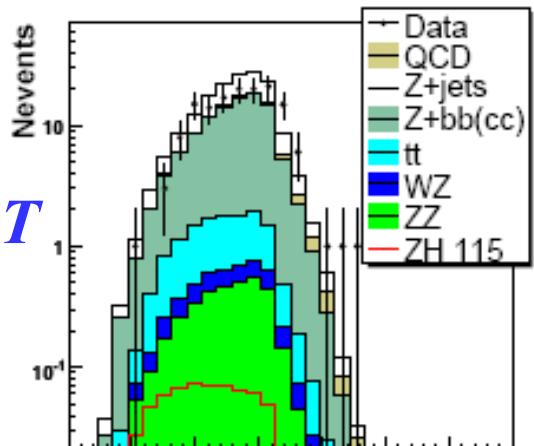
TABLE I: The number of data, background, and expected SM signal events (and systematic uncertainty) after 0, 1 tight (but not  $\geq 2$  loose), and  $\geq 2$  loose  $b$ -tagged jets are required, in the dielectron and dimuon channels.

Sample	dielectron channel			dimuon channel		
	Before $b$ -tagging	1T	2L	Before $b$ -tagging	1T	2L
Data	2985	73	24	4669	87	53
Total Bgnd.	$2961 \pm 533$	$57.4 \pm 21$	$27.9 \pm 7.8$	$4671 \pm 841$	$101.4 \pm 38$	$45.7 \pm 12.8$
$ZH$ 115 GeV	0.757	0.225	0.233	0.694	0.313	0.301
QCD	89.4	1.73	0.74	47.3	0.25	0.88
$Z + (udscg)$	$2451 + 252(c)$	$7.17 + 14.1(c)$	$5.12 + 5.53(c)$	4400.2	46.0	19.2
$Z + 2b$	120	29.6	12.0	167.7	47.6	18.5
$t\bar{t}$	9.61	2.84	3.09	10.64	4.84	5.34
$WZ$	20.3	0.60	0.17	24.2	0.82	0.24
$ZZ$	18.0	1.40	1.17	21.4	1.95	1.48

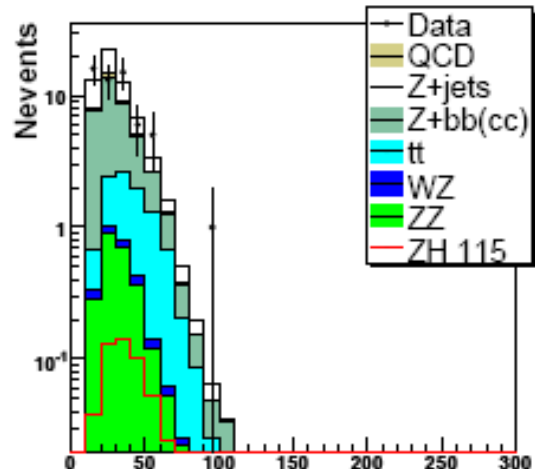
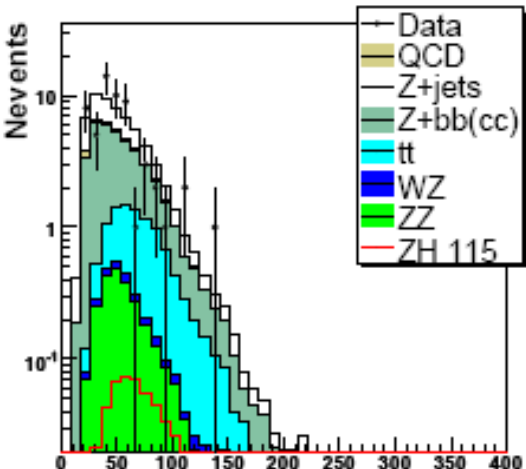
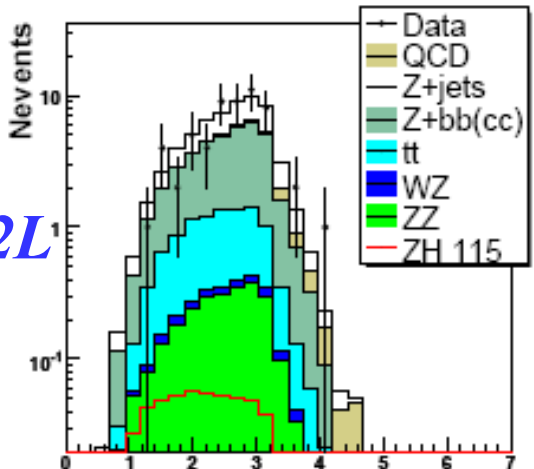
*Pre-tag*



*1T*

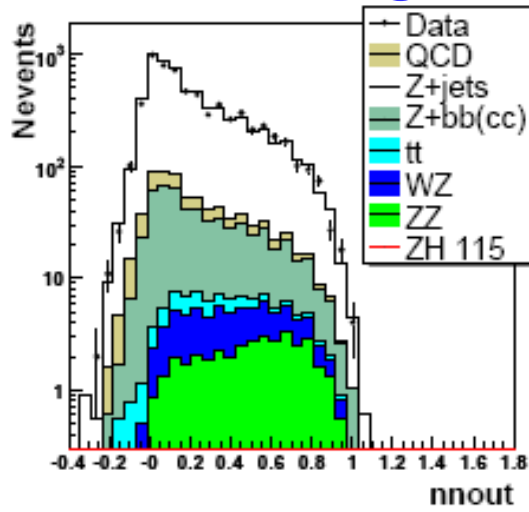


*2L*



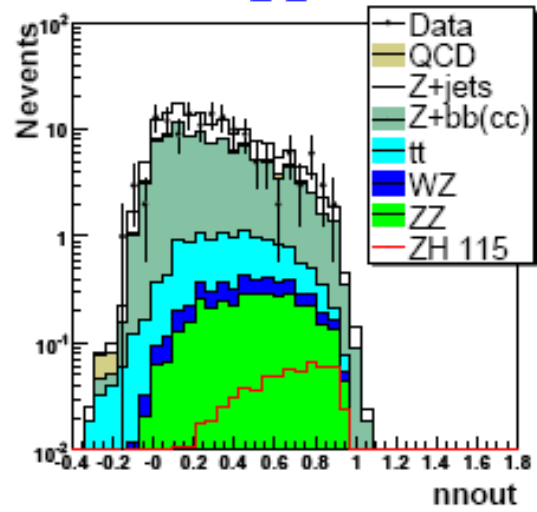
# NN output

*Pre-tag*



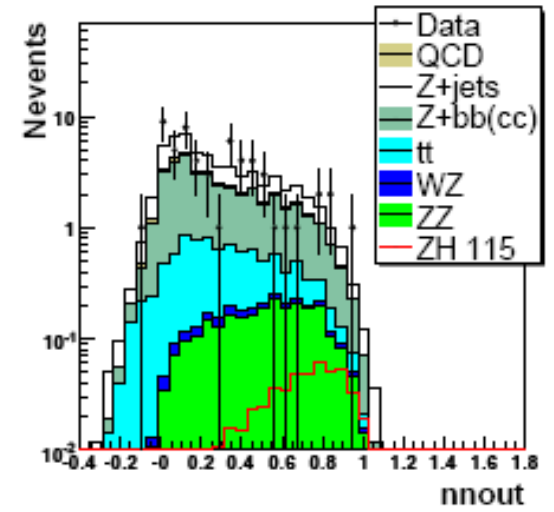
(a)

*1T*



(b)

*2L*



(c)

# Systematic uncertainties

- Luminosity: 6.5% uncertainty (or normalized to Z peak in mu)
- Lepton-ID: 4% uncertainty
- Other jet errors (resolution, jet ID): <1.5% and negligible
- Cross-section uncertainties (see below)
- QCD: 50% normalization error – very small contribution
- *NN output shape uncertainties – being added...*

TABLE IV: The systematic uncertainties for background and signal MC samples.

Sample	JES (%)	<i>b</i> -tagging & taggability (%)		cross section (%)	EM-ID (%)
		1T <i>b</i> -tag	2L <i>b</i> -tag		
<i>Z</i> +1p	+11/ – 11	+9.1/ – 9.1	+9.2/ – 8.8	15	4
<i>Z</i> +2 <i>b</i>	+7.5/ – 7.1	+4.9/ – 5.0	+7.3/ – 7.0	50(1T)/30(2L)	4
<i>Z</i> +2 <i>c</i>	+8.1/ – 7.7	+6.4/ – 6.5	+8.2/ – 7.9	50(1T)/30(2L)	4
<i>t</i> $\bar{t}$	+1.1/ – 1.8	+2.4/ – 2.9	+7.5/ – 7.3	8	4
<i>WZ</i>	+2.8/ – 3.7	+6.9/ – 6.9	+8.5/ – 8.2	7	4
<i>ZZ</i>	+4.0/ – 1.9	+3.8/ – 4.0	+7.2/ – 6.9	6	4
<i>ZH</i> 105	+2.8/ – 2.4	+2.8/ – 3.2	+7.3/ – 7.0		4
<i>ZH</i> 115	+1.5/ – 2.3	+2.7/ – 3.1	+7.3/ – 7.1		4
<i>ZH</i> 125	+1.3/ – 2.5	+2.6/ – 3.1	+7.4/ – 7.2		4
<i>ZH</i> 135	+1.4/ – 1.5	+2.5/ – 3.0	+7.5/ – 7.2		4
<i>ZH</i> 145	+1.6/ – 0.9	+2.4/ – 2.9	+7.6/ – 7.3		4

# Limits

- Combine 2L and 1T samples, combine ee and  $\mu\mu$  channels
- Calculate confidence levels using *profile likelihood fitting*
  - Provide a BEST GUESS for the central values of background expectations and uncertainties, then find the BEST FIT to data within the uncertainties
- Using Wade's limit codes (package collie, CLFit2)
  - SM factor limit goes from 13  $\rightarrow$  16 for ZH115 using CLFit $\rightarrow$ CLFit2

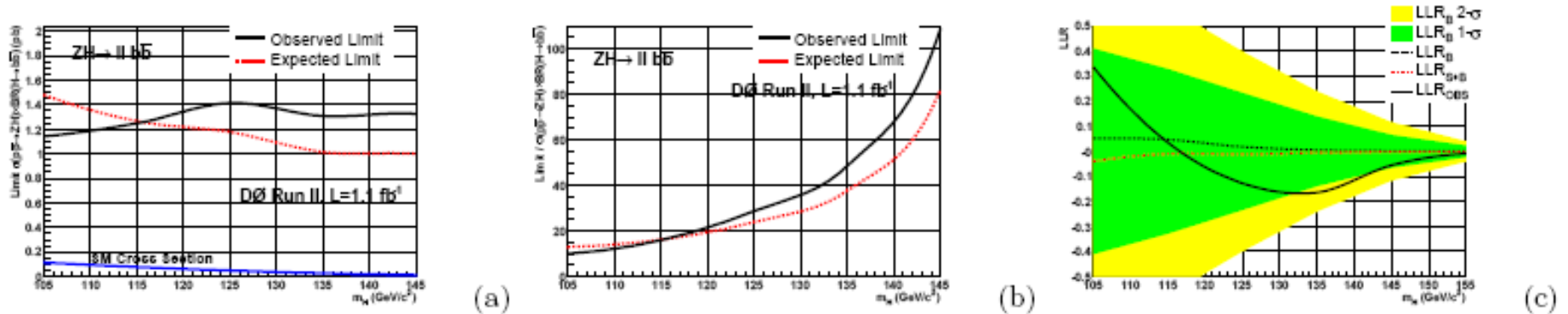


TABLE II: The expected and observed  $ZH$  cross section limits for each Higgs mass (and ratios to the SM cross section), derived from the combination of dielectron and dimuon samples.

$m_H$ (GeV)	ZZ	105	115	125	135	145
Observed limit (pb)	6.1 (4.30)	1.14 (10.0)	1.25 (16.0)	1.41 (28.8)	1.31 (48.7)	1.33 (108.8)
Expected limit (pb)	6.0 (4.26)	1.48 (13.0)	1.27 (16.2)	1.18 (24.0)	1.01 (37.8)	1.00 (82.0)

# Summary

- Combined limits:  
factor of 16 away from SM for  $ZH115$ ,  $\sim 4$  for  $ZZ$ 
  - CDF, also 16 (including MET corrected di-jet resolution!)
- Updated analysis notes for both  $ZH \rightarrow eebb$  and  $ZH \rightarrow \mu\mu bb$
- Wish to send combined  $ZH \rightarrow llbb$  conf. note to Lepton Photon
- Plans
  - Combine with Matrix Element method (which will include MET di-jet mass corrections) for  $2 \text{ fb}^{-1}$  analyses, publish!
  - Other missing pieces may go into  $2 \text{ fb}^{-1}$  analyses: di-jet mass resolution improvement, new JES, new Alpgen Z+HF MC, improved b-tagging, ...

# Back-up