CDF/D0 Combined Upper Limit on Higgs Production

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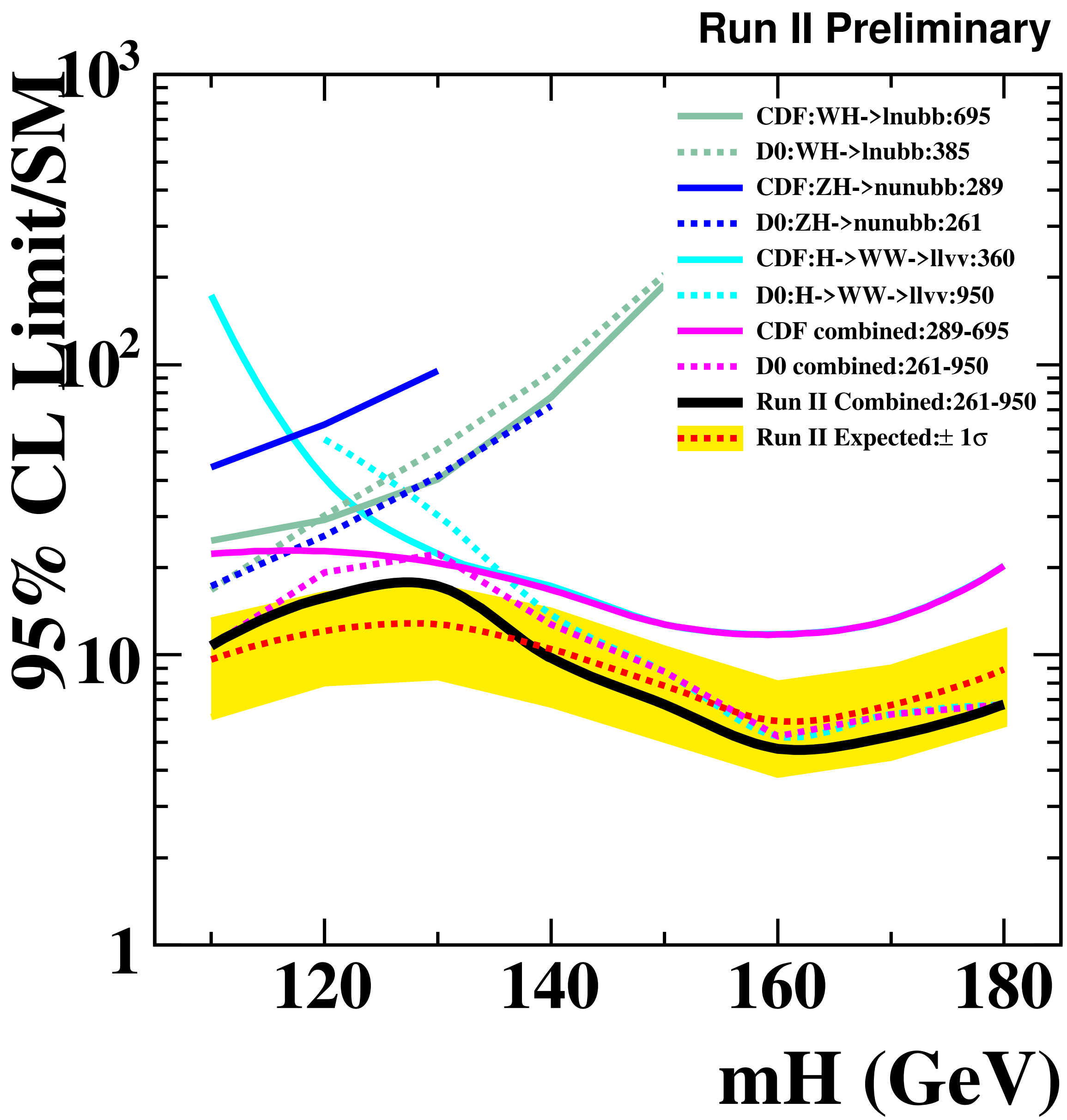
What's New

- Fix the data histogram in D0: $WW \to \mu\mu$ at mH=150 GeV/c^2 from Wade
- Rerun the observed and expected limited
- Impact of systematic on the limits
- Reminder: A Bayesian framework is used to compute the upper limit with all 13 channels combined.

Individual and Combined Limits



Observed and Expected Limits

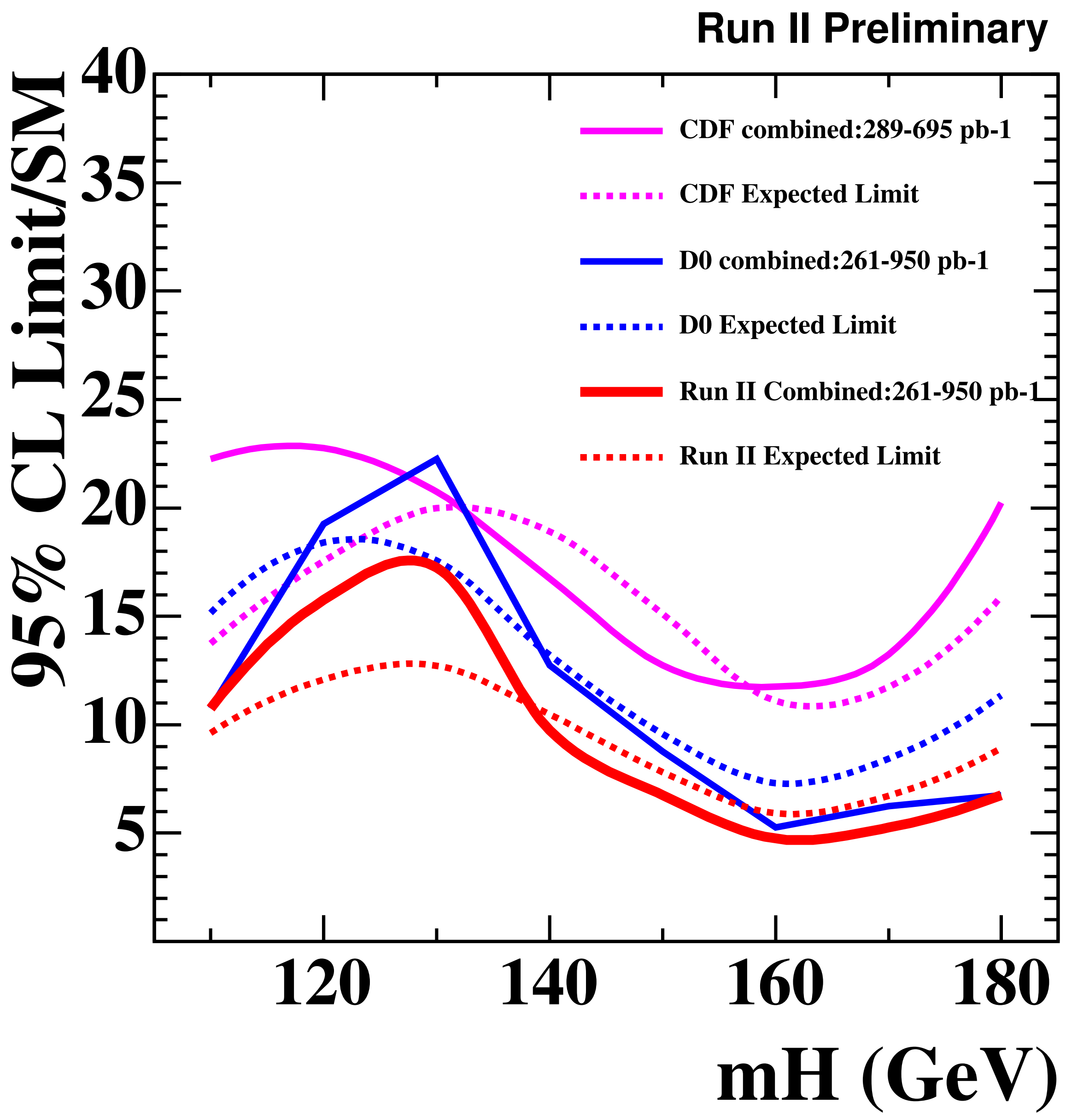


Table of Limits/NoSys

mh	110	120	130	140	150	160	170	180
CDF:WH Expected	24.8/20.2 16.4/15.5	29.2/25.8 22.6/21.6	40.2/36.2 35.2/33.2	77.2/69.8 64.4/63.8	189/173 155/140			
D0:WH Expected	16.8/13.8 25.1/21.5	30.2/24.8 36.1/31.0	51.2/41.8 57.4/50.7	93.8/76.2 106/90	205/176 214/196			
CDF:ZH Expected	44.2/43.2 33.0/31.4	62.2/60.8 40.9/38.8	95.2/92.8 63.4/60.8					
D0:ZH Expected	17.2/16.2 20.0/16.8	25.8/23.2 27.0/22.5	41.2/37.2 41.1/35.6	72.2/65.2 73.0/59.3				
CDF:WW Expected	174/165 186/184	40.8/38.2 65.2/62.1	22.2/20.8 32.0/29.6	17.2/16.2 20.3/19.1	12.8/12.2 15.1/14.4	11.8/11.2 11.2/10.4	13.2/12.8 12.0/11.3	20.2/19.2 16.0/15.3
D0:WW Expected		55.2/37.8 47.1/39.7	30.2/17.8 22.4/19.1	13.8/9.8 14.1/11.8	8.8/6.2 9.7/8.1	5.2/3.8 7.2/6.2	6.2/4.2 8.5/7.5	6.8/5.2 11.2/9.3
D0:ee Expected		114/106 82.5/75.2	51.2/46.8 41.6/38.2	30.2/27.2 27.5/24.9	16.8/15.2 18.7/17.6	13.2/12.2 14.2/13.1	16.8/15.8 16.5/15.6	19.2/17.8 20.9/19.5
D0:emu Expected		44.2/37.2 62.8/53.6	21.8/18.2 28.5/24.5	14.2/11.8 17.7/15.3	10.2/8.2 12.1/10.4	5.8/4.8 9.2/8.1	5.8/4.8 10.7/9.4	7.2/6.2 13.8/11.6
CDF:Comb Expected	22.2/19.2 13.8/13.3	22.8/21.2 17.5/17.4	20.8/20.2 20.0/19.6	16.8/16.8 18.9/17.9	12.8/12.2 15.1/14.5	11.8/11.2 11.1/10.5	13.2/12.8 11.7/11.1	20.2/19.2 15.9/14.9
D0:Comb Expected	10.8/9.8 15.2/12.9	19.2/14.8 18.4/16.3	22.2/14.8 17.6/15.0	12.8/9.8 13.2/11.6	8.8/6.2 9.6/8.4	5.2/3.8 7.3/6.1	6.2/4.2 8.4/7.4	6.8/5.2 8.9/9.5
Tev Comb Expected	10.8/10.2 9.6/9.0	15.8/13.2 12.1/11.1	17.2/12.2 12.7/11.8	9.8/7.8 10.5/9.5	6.8/5.2 7.8/6.7	4.8/3.2 5.9/5.1	5.2/3.8 6.7/5.9	6.8/5.2 8.9/7.5

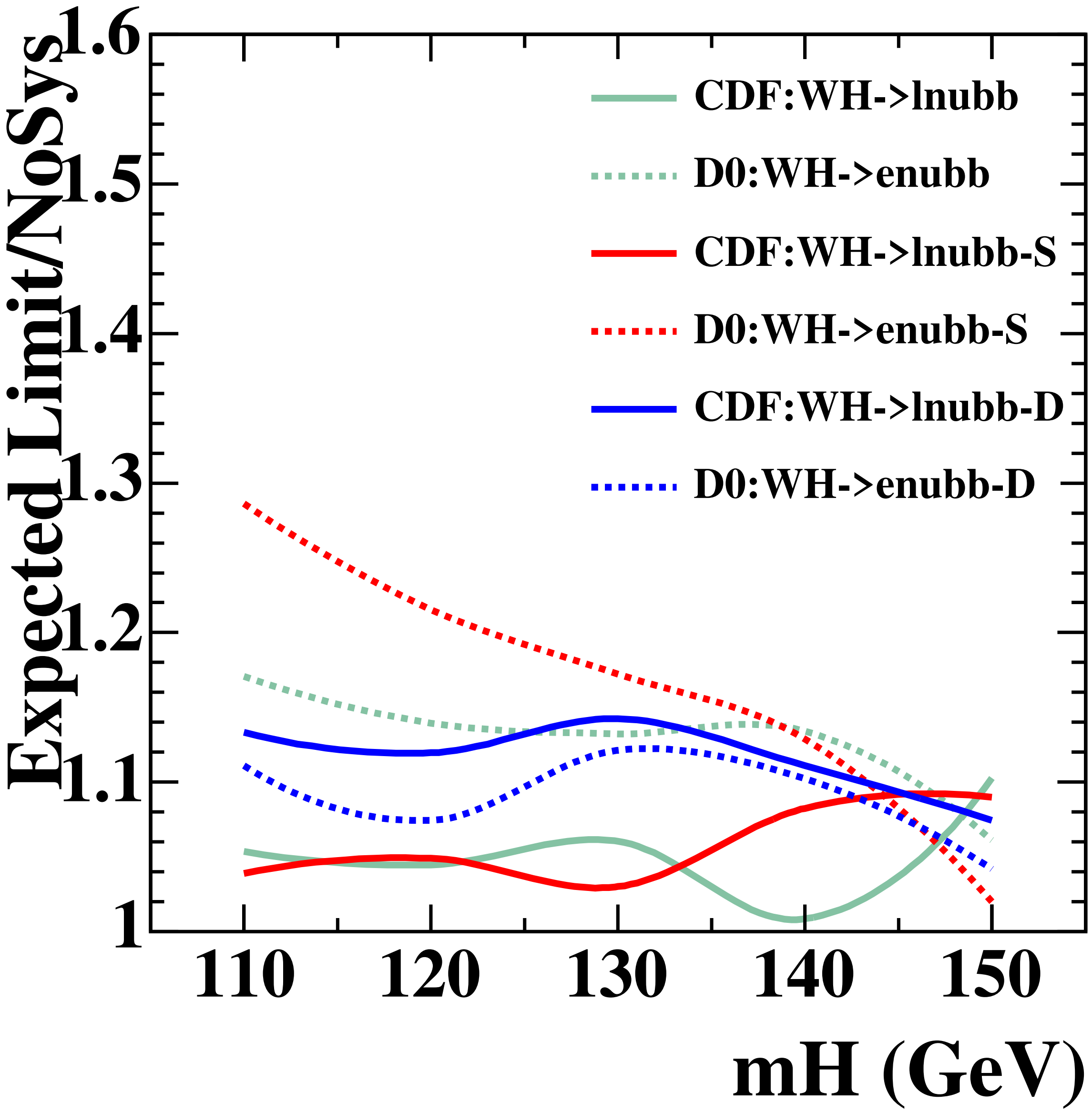
Comparison to Wade's Table

mh	110		130		160	
	Bayesian	CLs	Bayesian	CLs	Bayesian	CLs
CDF:WH Expect	24.8/20.2 16.4/15.5	34.8/19.7 27.1/12.3	40.2/36.2 35.2/33.2	64.2/35.0 55.3/26.4		
CDF:WHs Expect	37.8/32.2 24.2/23.3	55.1/30.9 42.2/18.3	60.8/57.8 48.4/47.0	99.2/54.8 82.7/38.3		
CDF:WHd Expect	25.2/20.8 23.3/20.6	24.4/20.5 21.0/17.7	50.8/42.8 53.2/46.6	48.9/41.5 46.9/39.9		
D0:evH Expect	25.8/21.2 31.1/26.5	1.30 1.23	75/60.8 70.4/62.2	1.21 1.22		
D0:evHs Expect	62.8/47.8 35.6/32.0	1.38 1.30	165/125.8 92.8/73.9	1.25 1.25		
D0:evHd Expect	30.2/27.2 35.6/32.0	1.07 1.07	78.2/70.8 82.8/73.9	1.06 1.07		
CDF:WW Expect	174/165 186/184	174.6/158.3 190.9/174.7	22.2/20.8 32.0/29.6	22.3/19.6 29.7/26.6	11.8/11.2 11.2/10.4	11.6/10.5 10.4/9.3
D0:WW Expect			30.2/17.8 22.4/19.1	20.4/17.2 20.3/17.2	5.2/3.8 7.2/6.2	4.6/3.7 6.6/5.7

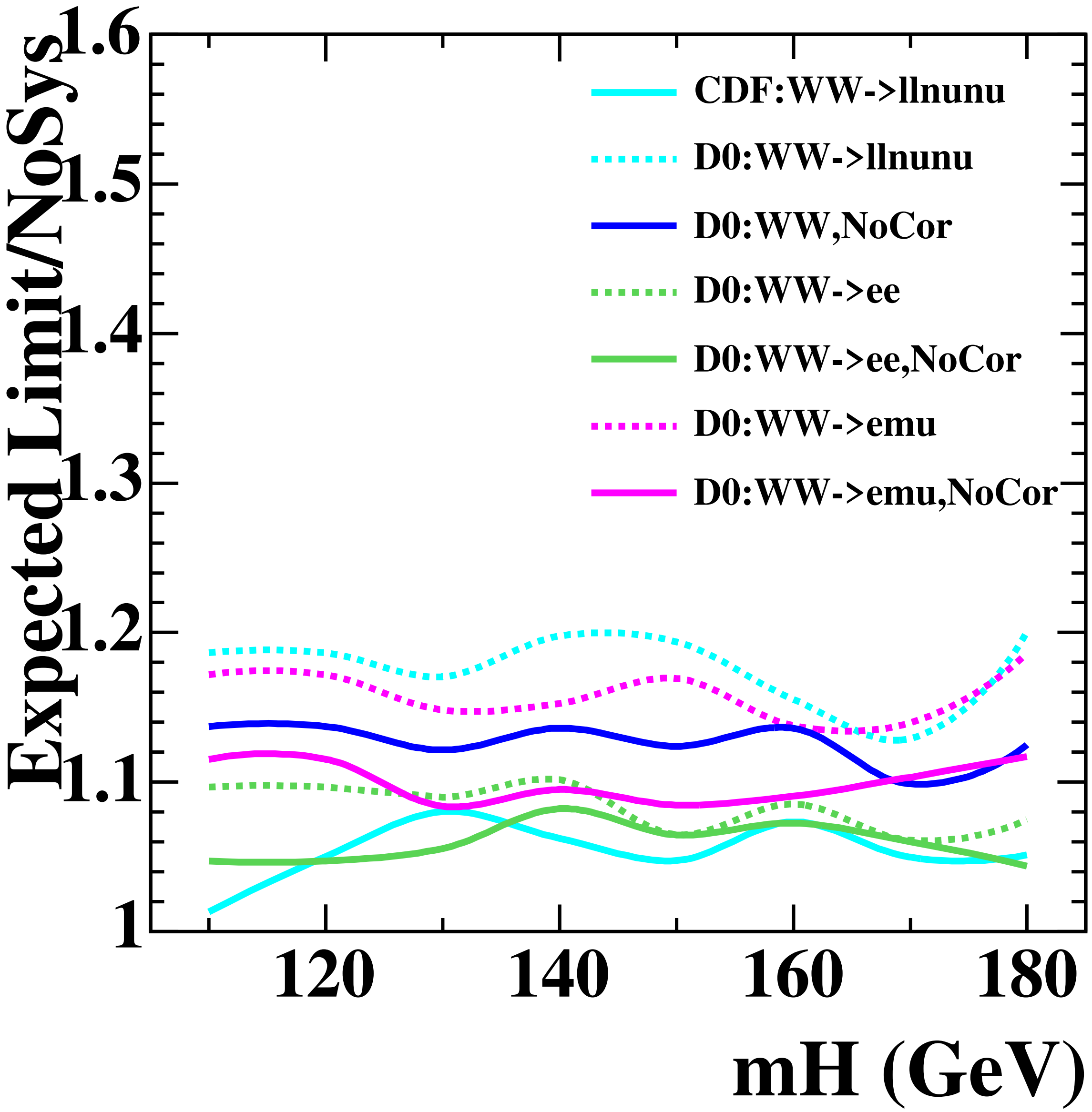
Table of Limits/NoSys, NoCor(S-B)

mh	110	120	130	140	150	160	170	180
CDF:WH	24.8/20.2	29.8/25.8	40.2/36.2	77.2/69.8	189/173			
Expect	16.4/15.5	22.6/21.6	35.2/33.2	64.4/63.8	155/140			
CDF:WHs	37.8/32.2	44.2/40.2	60.8/57.8	136/127	270/270			
Expect	24.2/23.3	33.5/31.9	48.4/47.0	97.4/89.9	204/187			
CDF:WHd	25.2/20.8	34.8/29.2	50.8/42.8	81.8/70.2	182/163			
Expect	23.3/20.6	33.0/29.5	53.2/46.6	94.2/84.8	207/192.7			
D0:evH	25.8/21.2	45.8/36.8	75/60.8	131/106	245/224			
Expect	31.1/26.5	43.4/38.1	70.4/62.2	124/109.2	226/213			
D0:evHs	62.8/47.8	102/77.2	165/125.8	262/234	286/284			
Expect	35.6/32.0	50.4/46.9	92.8/73.9	145/132	242/232			
D0:evHd	30.2/27.2	48.8/44.2	78.2/70.8	128/117	231/223			
Expect	35.6/32.0	50.4/46.9	82.8/73.9	145/132	242/232			
CDF:WW	174/165	40.8/38.2	22.2/20.8	17.2/16.2	12.8/12.2	11.8/11.2	13.2/12.8	20.2/19.2
Expect	186/184	65.2/62.1	32.0/29.6	20.3/19.1	15.1/14.4	11.2/10.4	12.0/11.3	16.0/15.3
D0:WW		55.2/37.8	30.2/17.8	13.8/9.8	8.8/6.2	5.2/3.8	6.2/4.2	6.8/5.2
Expect		47.1/39.7	22.4/19.1	14.1/11.8	9.7/8.1	7.2/6.2	8.5/7.5	11.2/9.3
NoCor		45.1	21.4	13.4	9.1	7.1	8.3	10.5
D0:ee		114/106	51.2/46.8	30.2/27.2	16.8/15.2	13.2/12.2	16.8/15.8	19.2/17.8
Expect		82.5/75.2	41.6/38.2	27.5/24.9	18.7/17.6	14.2/13.1	16.5/15.6	20.9/19.5
NoCor		78.8	40.3	27.0	18.7	14.1	16.5	20.3
D0:emu		44.2/37.2	21.8/18.2	14.2/11.8	10.2/8.2	5.8/4.8	5.8/4.8	7.2/6.2
Expect		62.8/53.6	28.5/24.5	17.7/15.3	12.1/10.4	9.2/8.1	10.7/9.4	13.8/11.6
NoCor		59.8	26.9	16.8	11.3	8.8	10.4	13.0

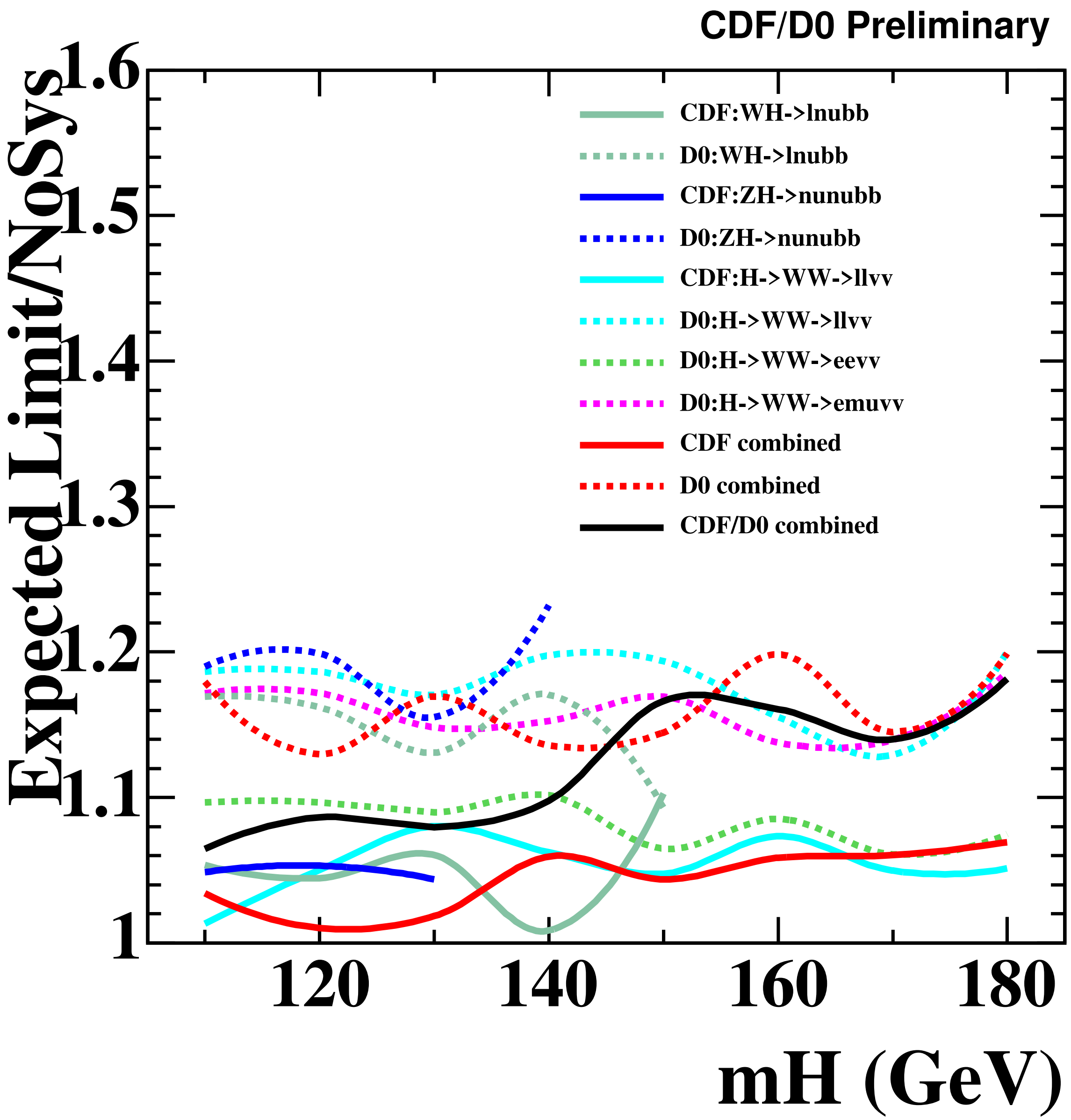
Single and Double tags in WH



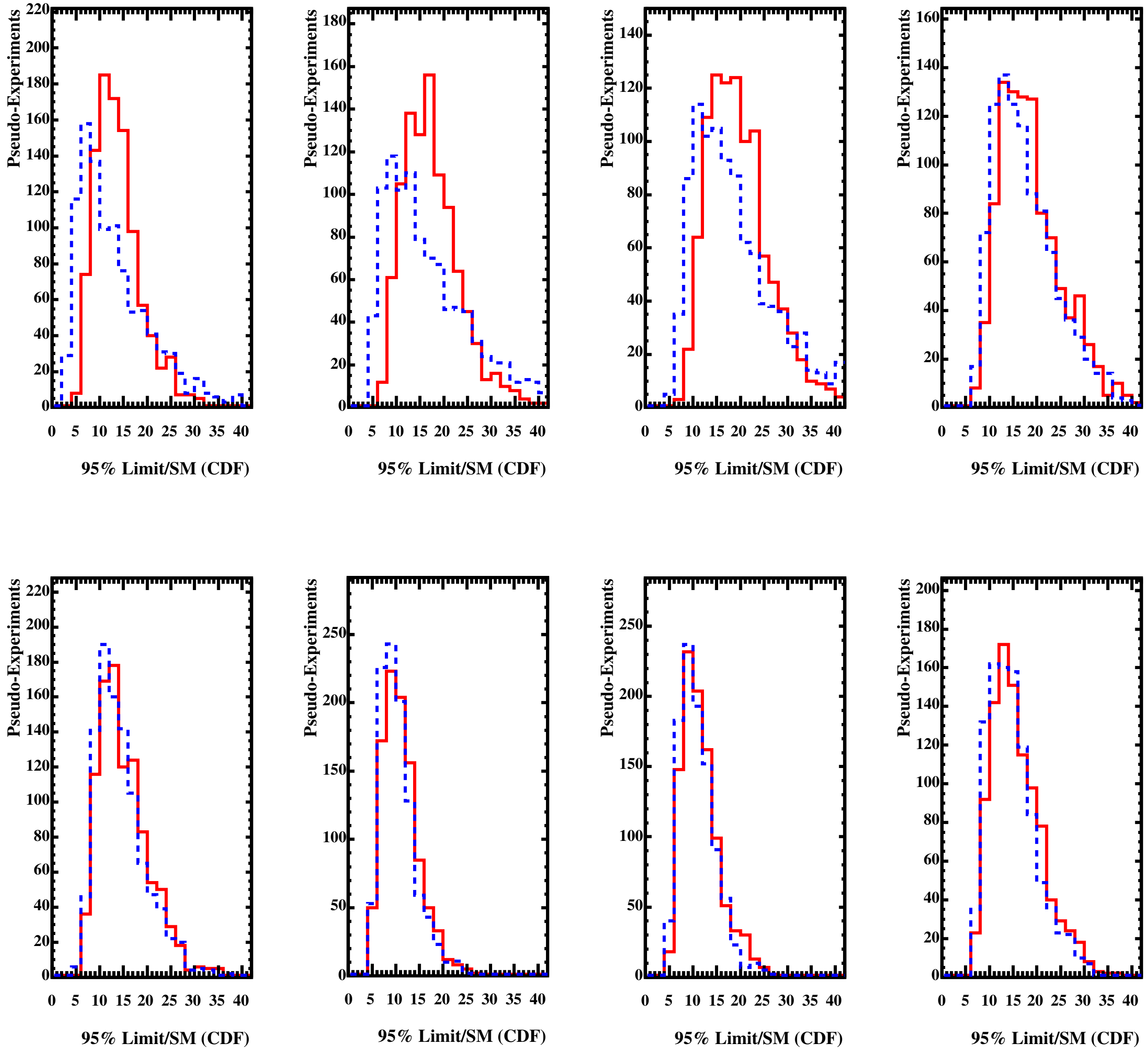
Correlations between Signal and Background



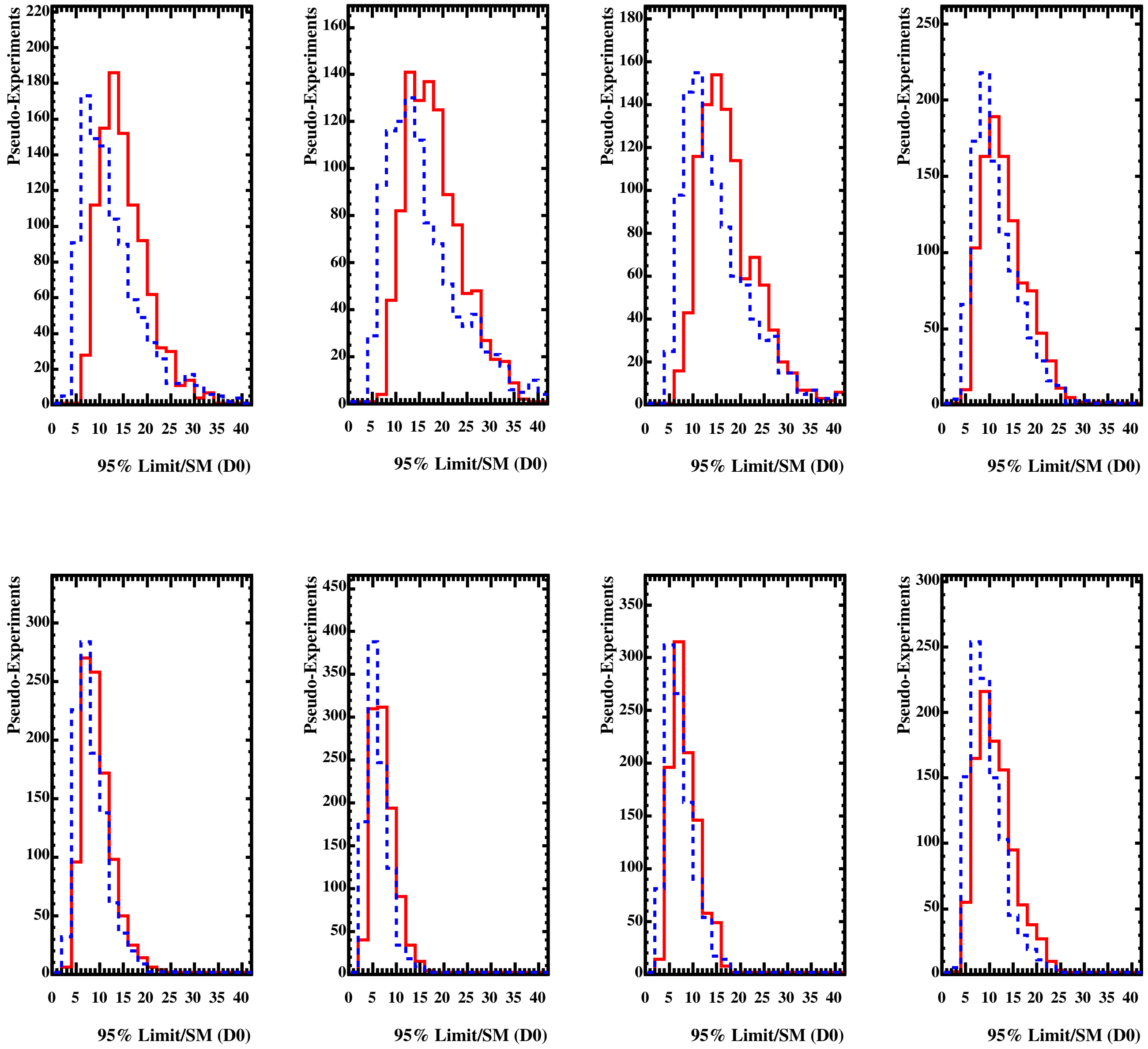
Impact of Systematic on Expected Limits



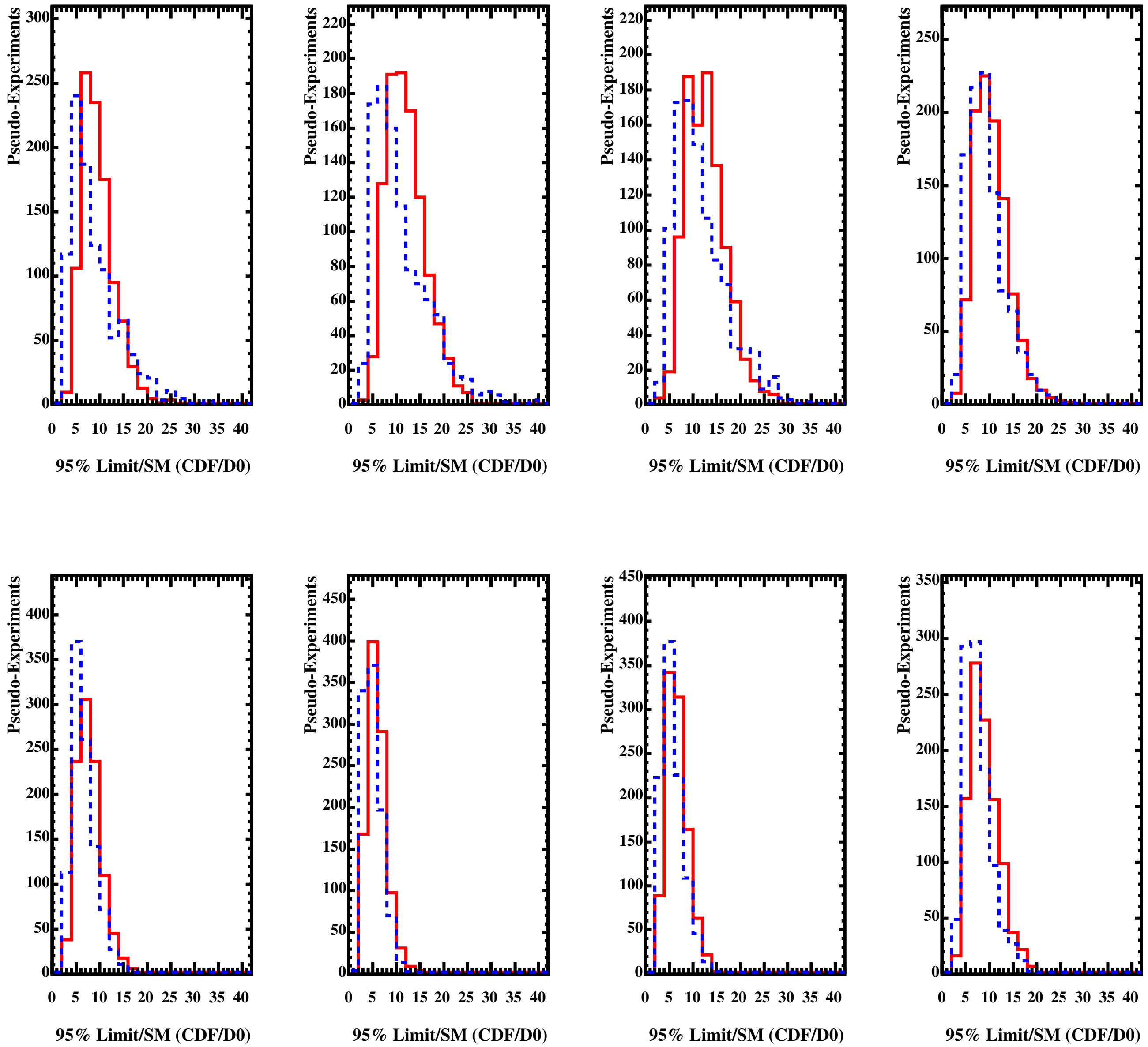
CDF Expected Limits from Pseudo-Experiments



D0 Expected Limits from Pseudo-Experiments



CDF/D0 Expected Limits from Pseudo-Experiments



Conclusion

- We obtain a combined Higgs limit from CDF/D0 using a Bayesian method.
- The returned limit for each individual channel seems reasonable after fixing D0:$WW \to \mu\mu$ problem.
- The combined limit and expectation of Pseudo-experiments are also consistent.
- The impact of systematic seems small in the CDF model because the correlations between signal and background are minimized.

BACKUP SLIDES

Likelihood Function

- $\mathcal{L}(R, \vec{s}, \vec{b}|\vec{n}) = \prod_{i=1}^{Nc} \prod_{j=1}^{Nbins} \frac{\mu_{ij}^{n_{ij}} \cdot e^{-\mu_{ij}}}{n_{ij}!}$
  - $R = \sigma \cdot B/SM$; s= $\sigma_i^{SM} \cdot B^{SM} \cdot \epsilon_{acc} \cdot L$.
  - $\vec{b}$: backgrounds
  - $\vec{n}$: data
  - N_C: channels
  - N_{bins}: histogram bins.
  - $\mu_{ij} = R \cdot s_{ij} + b_{ij}$.

- The expected signal event depends on:
  luminosity, btag sf, lepton id, jes, ISR/FSR+PDF, and the rest uncertainties

- The background consists of:
  HF, Mistag, top, non-W, diboson (WW), and other.

Priors, Posterior Densities and Upper Limit on R

- The priors for efficiencies and backgrounds are truncated Gaussian densities with its expected value within its uncertainty.

- Assign a flat prior to the number of Higgs events, instead of Higgs xsec.
  $\pi(R, \vec{s}, \vec{b}) = s_{tot} \cdot \theta(R \cdot s_{tot}) \cdot \pi(\vec{s}) \cdot \pi(\vec{b})$

- Posterior density:
  $p(R|\vec{n}) = \frac{\int d\vec{s} \int d\vec{b} \mathcal{L}(R,\vec{s},\vec{b}|\vec{n}) \cdot s_{tot}}{\int dR \int d\vec{s} \int d\vec{b} \mathcal{L}(R,\vec{s},\vec{b}|\vec{n}) \cdot s_{tot}}$

- 95% Upper Limit:
  $\int_0^{R_{0.95}} p(R|\vec{n}) dR = 0.95$

Source of Correlated Systematic (CDF)

Channels	$l\nu b\bar{b}_S$	$l\nu b\bar{b}_D$	$\nu\nu b\bar{b}$	W^+W^-
Luminosity (%)	6.0	6.0	6.0	6.0
btag SF(%)	5.3	16.0	6.3	0.
Lepton ID (%)	2.0	2.0	2.0	3.0
JES (%)	3.0	3.0	8.0	1.0
I(F)SR+PDF(%)	4.0	10.0	2.0	5.0
Trigger (%)	0.0	0.0	2.0	0.0
Backgrounds				
HF (%)	33.0	34.0	0.	0.
Mistag (%)	22.0	15.0	16.0	0.
Top (%)	13.5	20.0	18.0	0.0
QCD (%)	17.0	20.0	-34.0	0.
Diboson (%)	16	25	18	11
Others (%)	0.	0.	0.	-(12-18)

- The positive value means correlated, the negative value means uncorrelated
- The results seems insensitive to these correlations changing from 100% to 0%
- Common to D0: 4% on Luminosity; 8% on σ_t; 6% on σ_{EW}; 10% on $\sigma_{H\to WW}$

Source of Signal Systematic (D0)

0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 ! sig_Lumi_pos 0 and bkgd_Lumi_pos 0

0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 ! bkgd_Xsec_Top_pos 1

0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 ! bkgd_Xsec_EW_pos 2

0.025 0.025 0.025 0.025 0.025 0.025 0.025 0.025 0.025 ! DZero_sig_Lumi_pos 0

0.05 0.05 0.05 0.05 0.05 0.05 0 0 0 ! DZero_sig_JetID_pos 1

0.04 0.04 0.04 0.04 0.06 0.06 0.04 0.04 0.03 ! DZero_sig_JES_pos 2

0.03 0.03 0.03 0.03 0 0 0 0 0 ! DZero_sig_JetMult_pos 3

0.035 0.035 0.035 0.035 0 0 0 0 0 ! DZero_sig_JetMLM_pos 4

0.03 0.03 0.03 0.03 0.01 0.01 0 0 0 ! DZero_sig_Taggability_pos 5

0.055 0.055 0.04 0.055 0.03 0.07 0 0 0 ! DZero_sig_bTag_HF_pos 6

0.03 0.03 0 0 0 0 0 0 0 ! DZero_sig_EMTrigger_pos 7

0.03 0.03 0 0 0 0 0.03 0.02 0 ! DZero_sig_EMID_pos 8

0.04 0.04 0 0 0 0 0.02 0.02 0 ! DZero_sig_EMSmear_pos 9

0.03 0.03 0 0 0 0 0 0 0 ! DZero_sig_EMlike_pos 10

0 0 0.02 0.02 0 0 0 0 0 ! DZero_sig_MUTrigger_pos 11

0 0 0.02 0.02 0 0 0 0.022 0.03 ! DZero_sig_MUID_pos 12

0 0 0.041 0.041 0 0 0 0.024 0.01 ! DZero_sig_MUSmear_pos 13

0 0 0 0 0.05 0.05 0 0 0 ! DZero_sig_JetSmear_pos 14

0 0 0 0 0.05 0.05 0 0 0 ! DZero_sig_MJETTrigger_pos 15

0 0 0 0 0 0 0.01 0.01 0.01 ! DZero_sig_DiEMTrigger_pos 16, EMUTrigger_pos 17, DiMUTrigger_pos 18

Source of Background Systematic (D0)

0.025 0.025 0.025 0.025 0.025 0.025 0.025 0.025 0.025 ! DZero_bkgd_Lumi_pos 0
0.05 0.05 0.05 0.05 0.06 0.06 0 0 0 ! DZero_bkgd_JetID_pos 1
0.04 0.04 0.04 0.04 0.06 0.06 0.05 0.05 0.03 ! DZero_bkgd_JES_pos 2
0.03 0.03 0.03 0.03 0 0 0 0 0 ! DZero_bkgd_JetMult_pos 3
0.035 0.035 0.035 0.035 0 0 0 0 0 ! DZero_bkgd_JetMLM_pos 4
0.03 0.03 0.03 0.03 0.01 0.01 0 0 0 ! DZero_bkgd_Taggability_pos 5
0.055 0.055 0.04 0.055 0.04 0.07 0 0 0 ! DZero_bkgd_bTag_HF_pos 6
0.03 0.03 0 0 0 0 0 0 0 ! DZero_bkgd_EMTrigger_pos 7
0.03 0.03 0 0 0 0 0.04 0.03 0 ! DZero_bkgd_EMID_pos 8
0.01 0.01 0 0 0 0 0.03 0.02 0 ! DZero_bkgd_EMSmear_pos 9
0.03 0.03 0 0 0 0 0 0 0 ! DZero_bkgd_EMlike_pos 10
0 0 0.02 0.02 0 0 0 0 0 ! DZero_bkgd_MUTrigger_pos 11
0 0 0.02 0.02 0 0 0 0.029 0.031 ! DZero_bkgd_MUID_pos 12
0 0 0.041 0.041 0 0 0 0.024 0.01 ! DZero_bkgd_MUSmear_pos 13
0 0 0 0 0.02 0.02 0 0 0 ! DZero_bkgd_JetSmear_pos 14
0 0 0 0 0.04 0.04 0 0 0 ! DZero_bkgd_MJETTrigger_pos 15
0 0 0 0 0 0 0.02 0 0 ! DZero_bkgd_DiEMTrigger_pos 16
0 0 0 0 0 0 0 0.02 0 ! DZero_bkgd_EMUTrigger_pos 17
0 0 0 0 0 0 0 0 0.02 ! DZero_bkgd_DiMUTrigger_pos 18
0.08 0.08 0.06 0.08 0.07 0.1 0 0 0 ! DZero_bkgd_bTag_LF_pos 19
0.15 0.15 0.15 0.15 0.15 0.15 0 0 0 ! DZero_bkgd_Xsec_HF_pos 20
0.11 0.11 0.11 0.11 0.11 0.11 0.11 0.11 0.11 ! DZero_bkgd_Xsec_LF_pos 21
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 ! DZero_bkgd_Xsec_QCD_pos 22

- Generate a common Gaussian for each systematic source
- Multiply them to count for total systematic for each individual backgrounds