Search for $ZH \rightarrow \mu\mu bb$ at DØ

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On Behalf of the DØ Collaboration

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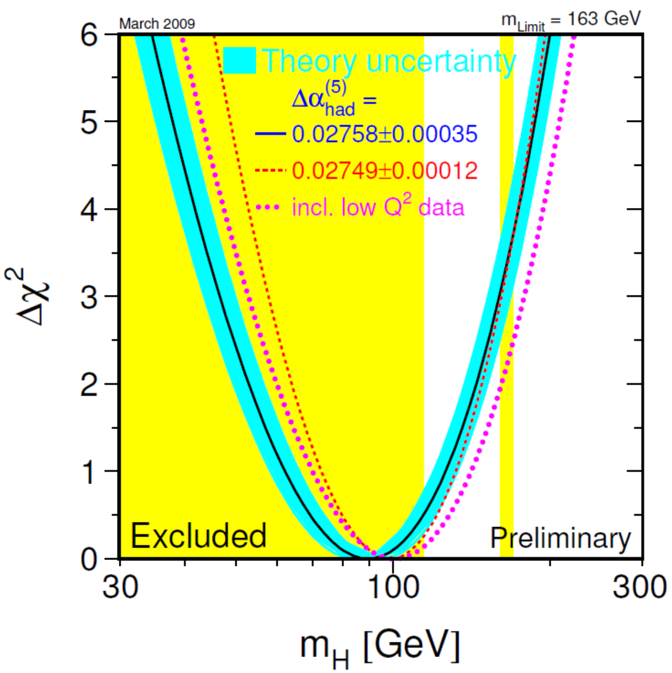
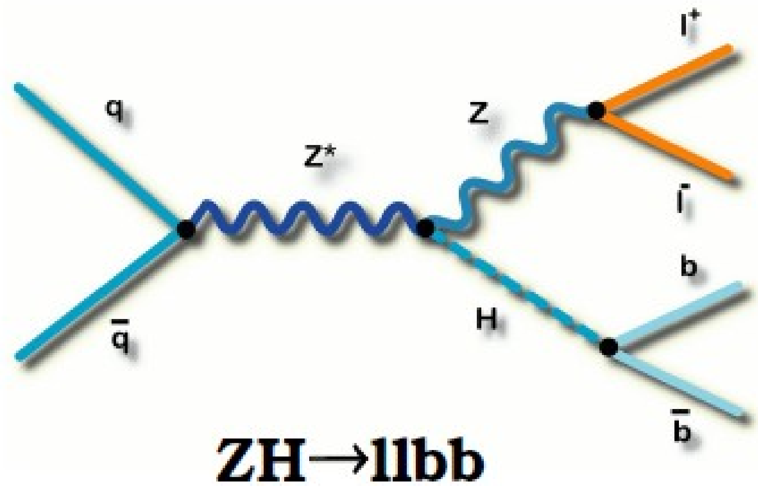
Introduction



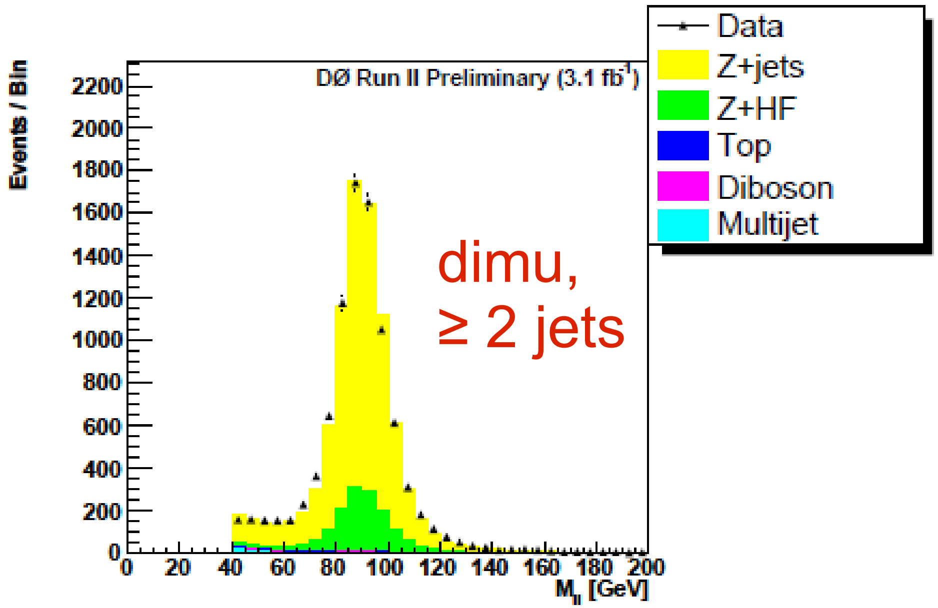
- LEP EWWG: $114 < m_H < 191$ GeV with low masses preferred
- SM Higgs below 135 GeV decays mostly to *bb*
- $\sigma(pp \rightarrow bb) \approx 10^6 * \sigma(pp \rightarrow H \rightarrow bb)$

- Reduce multijet background: look for associated *Z* production with decay to high-p_T lepton pair
- Backgrounds still present: *Z*+jets, diboson, top pair, multijet (small)

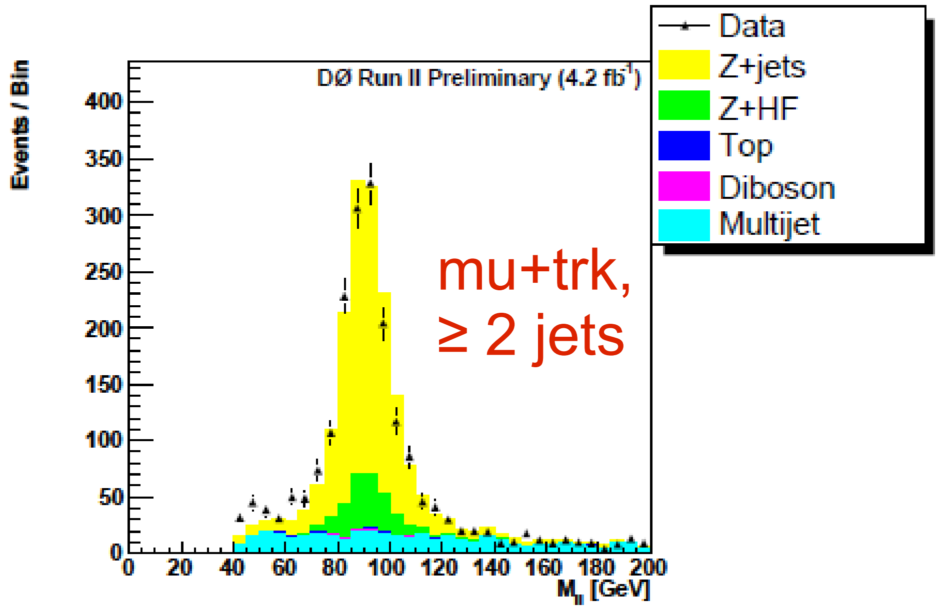


Z Selection

- Reconstruct *Z* boson with either 2 muons or 1 muon and 1 isolated track—mu+trk improves signal acceptance by 15%
  - dimu: muon p_T > 10 GeV
  - mu+trk: muon p_T > 10 GeV, track p_T > 20 GeV
- Lepton pairs have calorimeter, track isolation requirements
- Dilepton invariant mass cut: 70 < m_{ll} < 130 GeV



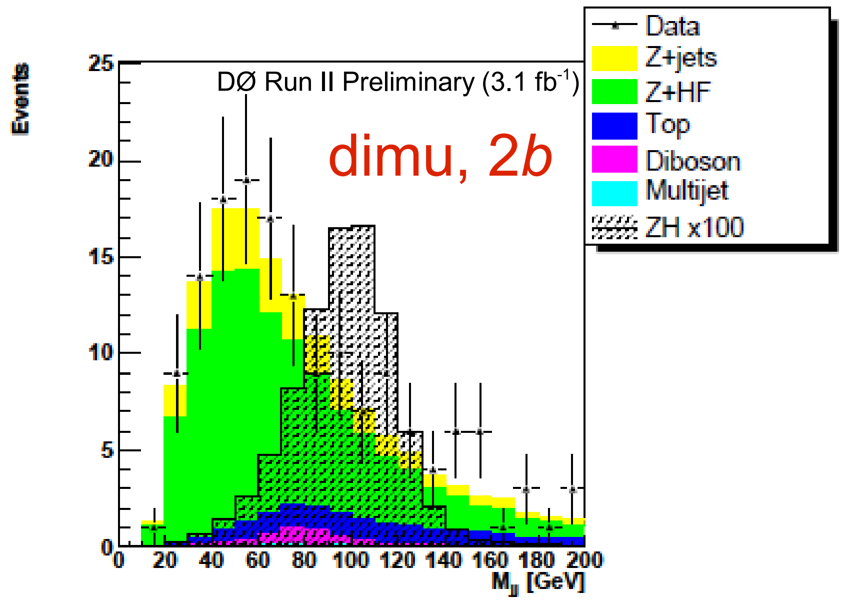
dimu, ≥ 2 jets

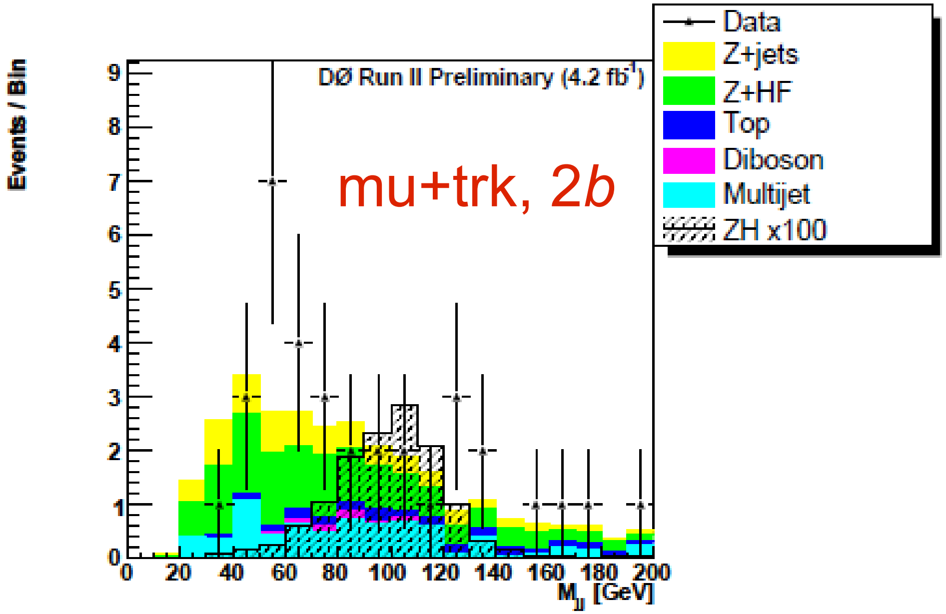


mu+trk, ≥ 2 jets

bb Selection

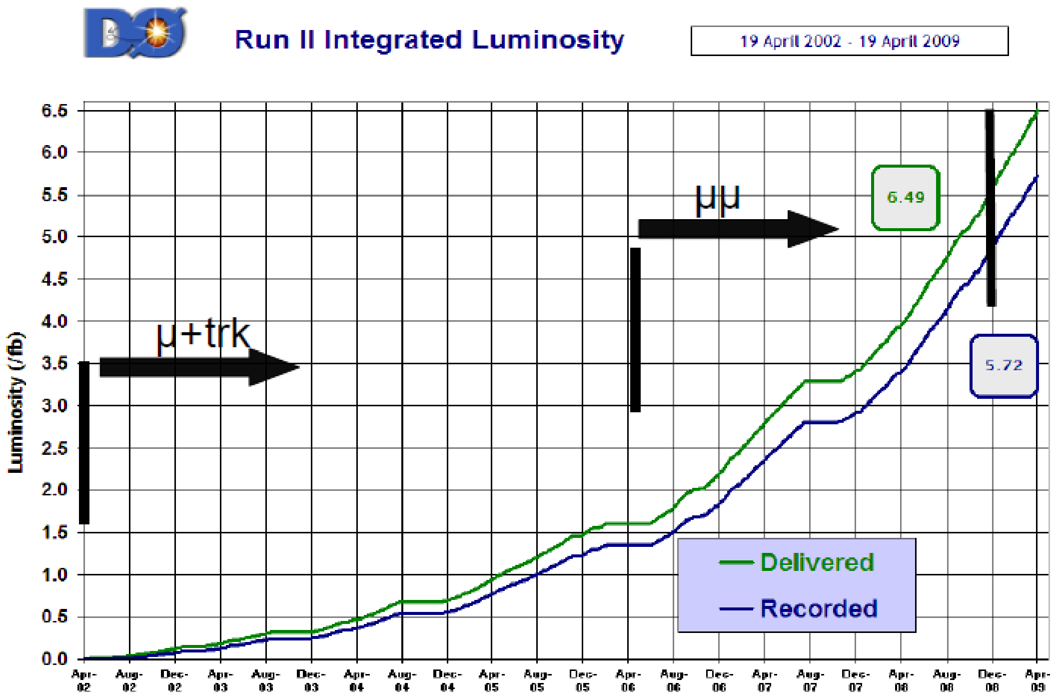
- At least 2 jets (dR = 0.5 cone) with tracks matched to the primary vertex
- Leading jet p_T > 20 GeV, other jets p_T > 15 GeV (S/B = 0.0003)
- Use neural network *b*-tagger to identify *b*-jets:
  - At least 2 loose *b*-tagged jets (S/B = 0.006)
  - Exactly 1 tight *b*-tagged jet (S/B = 0.003)





Data & MC

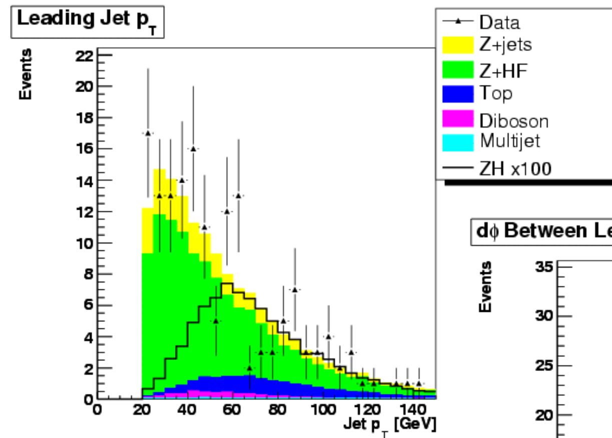
- Integrated Lumi: 4.2 fb^{-1} (4/02 – 12/08)
- Inclusive trigger approach: maximum signal acceptance!

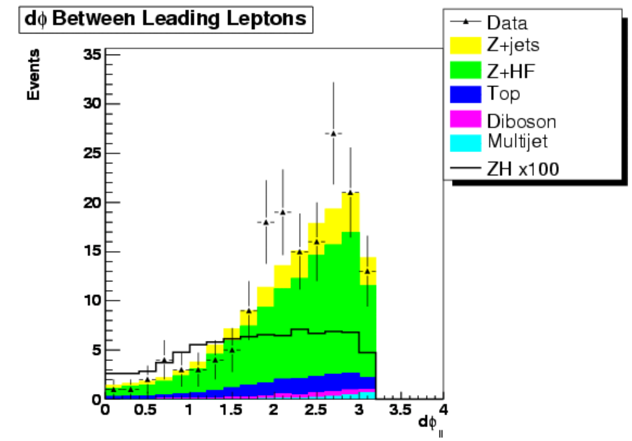


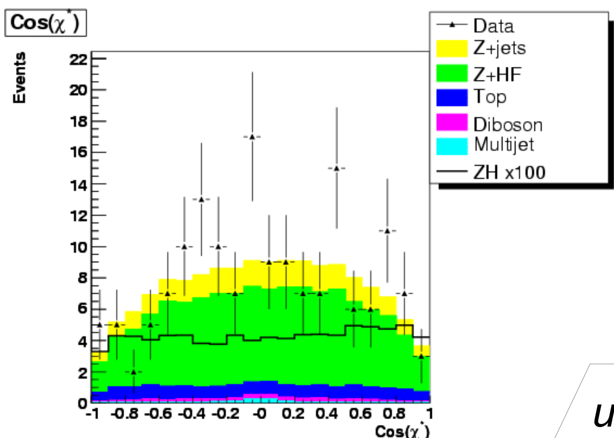
- Simulated backgrounds: *Z*+jets (Alpgen), top pair (Alpgen), diboson (Pythia)
- Multijet, *W*+jets, single top estimated using anti-isolated (dimu) or same-sign (mu+trk) data

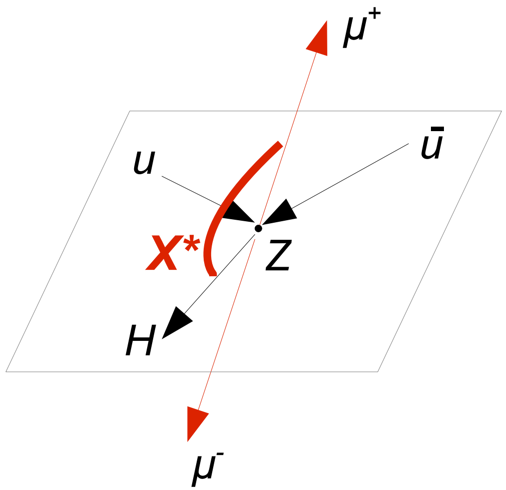
Discriminating Variables

- Dijet mass is most powerful single variable, but many other (*uncorrelated*) variables show significant separation power





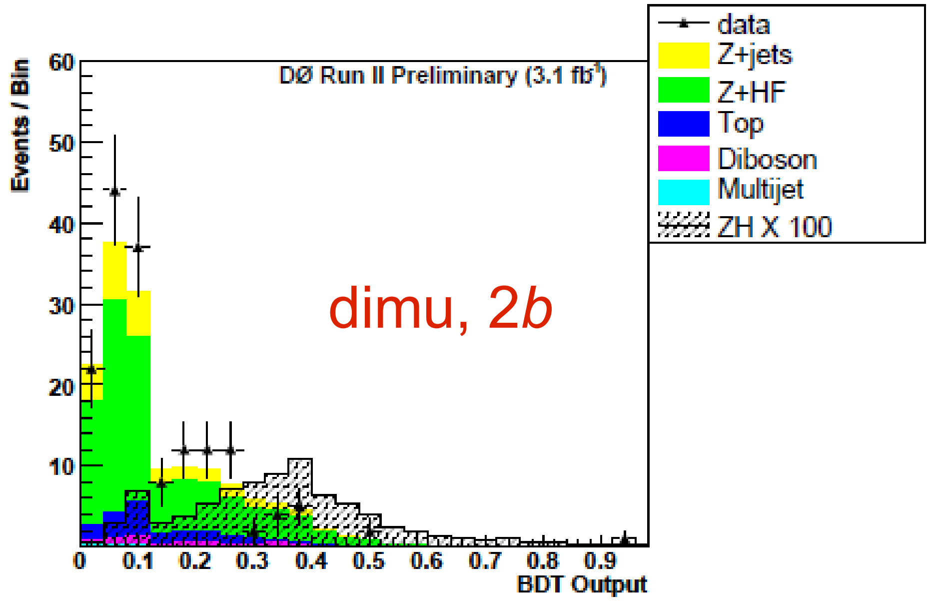


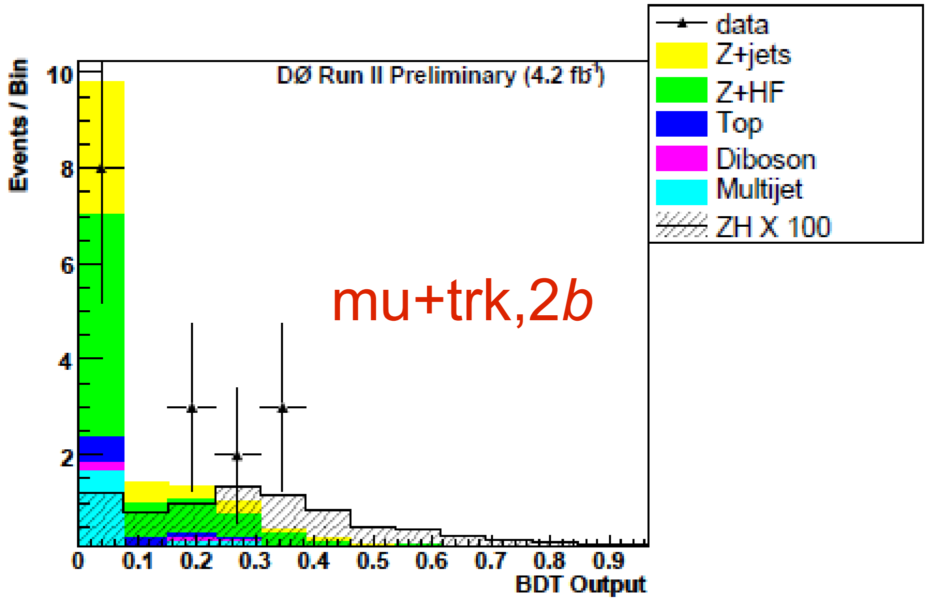


- Angle between *bb* system and lepton in *Z* rest frame exploits angular behavior:
  - scalar Higgs vs. vector gluon
  - s-channel *ZH* vs. t-channel *Z*+jets

Boosted Decision Trees

- Decision trees handle correlated input variables better that neural nets, but individual trees can be unstable
- Boosting: train a sequence of trees, each time giving more weight to events misclassified by previous tree—weighted average of boosted trees outperforms individual tree
- For each sub-channel (dimu & mu+trk, 1*b* and 2*b*), and each Higgs mass point, we trained 100 boosted trees





Systematic Uncertainties

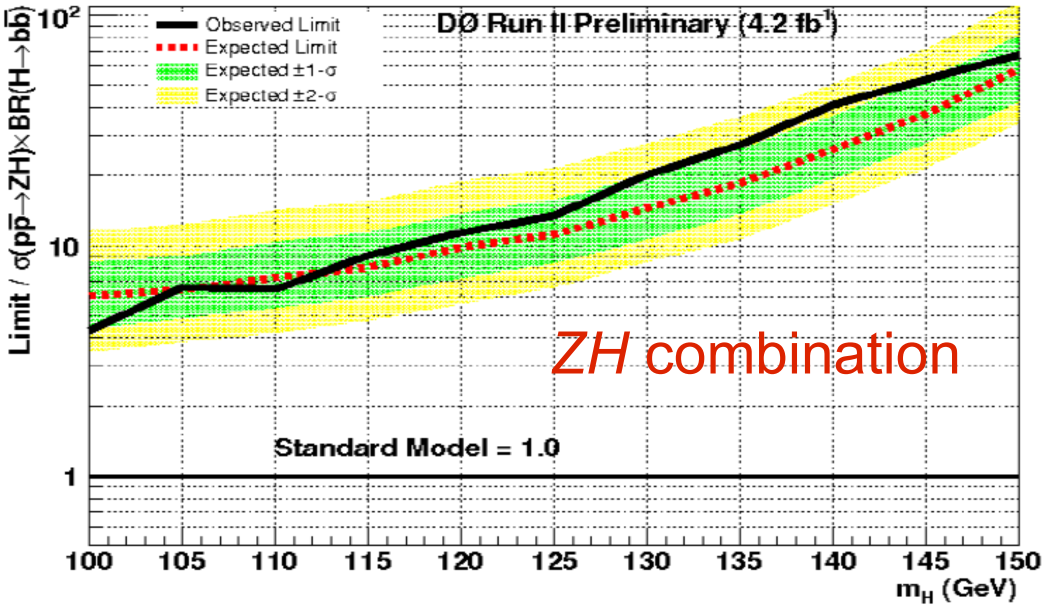
Systematic	Variable Uncertainty (%)	Tot Bkgd Uncertainty (%)
DØLumi	4.0	4.0
TeV Lumi	4.0	4.0
mu-id (each)	1.4	0.75
em-id (each)	2.8	2.0
ICR em-id	4.7	3.5
$Z + lp\ \sigma$	10	9
$Z + hf\ \sigma$	30	20
$Top\ \sigma$	10	0.5
$Diboson\sigma$	10	0.9
HF Scale	12	6
Jet ID	2.0	2.0
Jet Res	JSSR Default	2.5
Multijet $\mu\mu$	50	2
Multijet $\mu + trk$	25	2.5
Multijet $em + ICR$	20	2

Sample	JES	Jet ID	TRF b/c	TRF lp	B Frag	Zp_T	VCJ SF	$\Delta\phi(j,j)$	$\mu\mu$ Trig	μtrk Trig	m_{jj}
ZH (115)	11	1.4	1.0	0	1.0	0	3.0	0	0.1	15	0
Total	10	0.6	9.7	4.7	0.5	3.5	3.0	0.8	0.1	10	0.7
Z+lp	19.0	0.1	0	21	0	4.2	3.0	1.0	0.05	8.0	1.0
Z+bb	7.5	0.1	11	0	0.8	3.9	3.0	1.0	0.1	6.0	1.0
Z+cc	8.3	1.8	15	0	0.1	3.7	3.0	1.0	0.1	7.0	1.0
tt	0.0	1.4	4.9	0	0.8	0	3.0	0	0.1	11	0
WZ	6.7	1.0	0	11	0.4	0	3.0	0	0.1	12	0
ZZ	3.8	1.0	0	11	0.4	0	3.0	0	0.1	12	0

Results

	Run IIb $\mu\mu$		Run IIb ee		Full Run II μ+track		Run IIb e+ICR		Full Run II combination	
M_H (GeV)	Exp/SM	Obs/SM	Exp/SM	Obs/SM	Exp/SM	Obs/SM	Exp/SM	Obs/SM	Exp/SM	Obs/SM
100	9.29	7.7	11.4	18.5	38.6	43.4	42.3	38.0	6.0	4.3
105	11.1	9.0	12.6	19.2	43.2	45.3	45.6	53.8	6.4	6.6
110	12.8	10.9	14.6	17.0	46.7	69.7	50.2	56.3	7.3	6.5
115	14.7	13.3	15.3	18.7	50.4	78.0	57.0	68.2	8.0	9.1
120	17.7	14.2	19.2	23.9	63.4	75.2	68.8	87.7	9.9	11.4
125	20.7	19.5	20.9	27.0	74.1	86.7	85.5	91.2	11.2	13.5
130	26.2	25.6	27.4	42.4	90.4	120	102	130	14.5	20.3
135	34.2	44.1	34.9	43.6	126	142	146	159	18.7	27.5
140	47.9	62.0	50.3	73.2	167	188	198	232	26.2	40.8
145	64.9	91.5	69.2	85.5	250	252	269	243	37.5	52.7
150	104	129.3	114	123	428	331	457	380	58.3	67.6

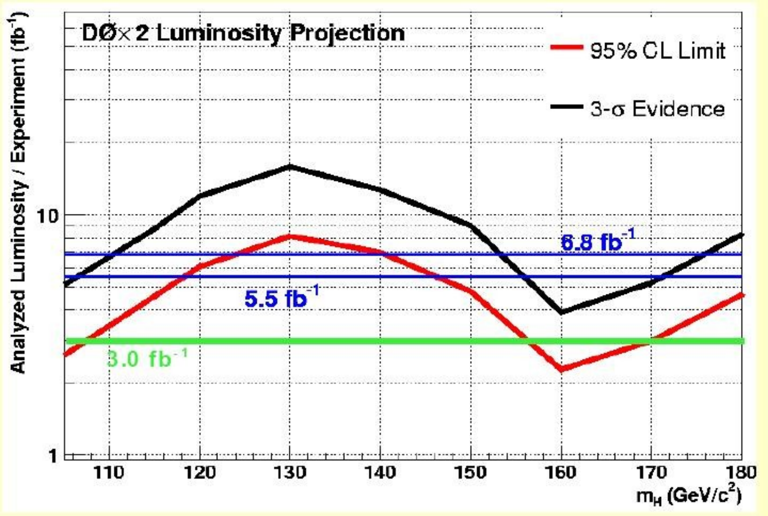
- dimu alone excludes *ZH* production above 13.3 (14.7) x SM at m_H=115 GeV
- mu+trk performs equally well despite track-only muon
- Combined *ZH* limit: 9.1 (8.0) x SM at m_H=115 GeV



Outlook

- More data is coming quickly:
  - Tevatron is performing better than ever! Already 6 fb^{-1} delivered to DØ and CDF—**expect at least 10 fb^{-1} by the end of Run II**
  - DØ running steadily at or above 90% data-taking efficiency

projection based on Sept. '08 results



- Many ways to improve the analysis:
  - Reduce systematic uncertainties
  - Loosen *b*-tagging requirements, explore asymmetric tagging
  - Further optimization of MVA: move to Random Forest, study other methods
  - Etc... (*see talk by S. Desai*)