Status of the ZH→llbb search

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for the zhllbb Team

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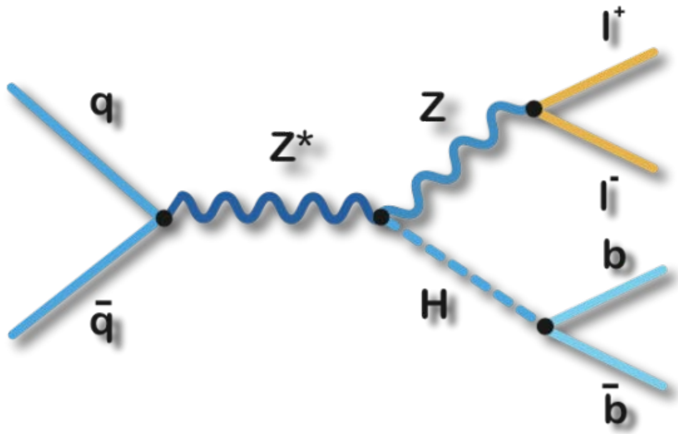


Channels
e^+e^-
ee_{ICR}
$\mu^+\mu^-$
$\mu\mu_{trk}$

Analysis history

Epoch	L_{int}	Exp.Lim/SM (115)	publication
Run2a+2b1+(2)	4.2 fb^{-1}	7.1	PRL **105**, 251801 (2010)
Run2a+2b12+(3)	6.2 fb^{-1}	5.7(5.8)	ICHEP'10 (preliminary)
Run2a+2b1+2b23+(4)	8.6 fb^{-1}	(5.0)	EPS'11 (preliminary)

Run2a data not reanalyzed – added to the limit from the publication

$ExpLim_{Run2a}/ExpLim_{All}$ ~3, sqrt(8/1) = 2.8

In the following we detail the analysis of the Run2b(1,2,3,4) data

Data selection (most salient features)*

Primary Vertex (PV) > 2 tracks $|z_{PV}| < 60$ cm

Leptons (2 isolated same flavor)

- e^+e^- CC(P0)+CC(P0)/EC(P0.5) $p_T>15$ GeV
- ee_{ICR} ICR(NNτ>0.7) + CC(P0)/EC_s(P0) $p_T>15$ GeV
- $\mu^+\mu^-$ LooseNCV w/ matched central track $p_T>15(10)$ GeV $|\eta_d| < 1.5(2.0)$
- $\mu\mu_{trk}$ 1μ ($|\eta_d| < 1.6$) + 1 isolated track $p_T>20$ GeV $|\eta_d| < 2.0$

Z

- $60 < M_{ll} < 150$ GeV $\Delta z(PV,l) < 1$cm
- Z→μμ: $I(\mu_1)I(\mu_{2,trk}) < 0.03$ (0.01) opposite charge

Jets

- > 1 JCCB (JESmuon) vertex confirmed (VC) $p_T>20(15)$ GeV $|\eta_d| < 2.0$

b-jets (MVA direct tagging)

- taggable jets
- DT: MegaTight+L3 ST: MegaTight+.not.L3

(*) vjets_cafe v05-06-07 as of May 24th 2011 used
new jet treatment of T. Guillemin used

Background

SM — Simulated by MC

$Z/\gamma^* \rightarrow ee/\mu\mu + n\,qq + (bb, cc)$	Alpgen + Pythia
WZ/ZZ/WW	Pythia
tt	Alpgen + Pythia

Instrumental (MultiJet) — Simulated by data

e^+e^-	Invert isolation+shower shape and reweight
ee_{ICR}	$NN\tau < 0.4$
$\mu^+\mu^-$	$I(\mu_1)I(\mu_2) > 0.03$
$\mu\mu_{trk}$	Select same charge pair

Size determined from the M_{ll} distribution ($40 < M_{ll} < 200$ GeV)

Signal

$Z(\rightarrow ee/\mu\mu/\tau\tau)H(\rightarrow bb/cc/\tau\tau)$ — Simulated by Pythia

Treatment of the MC samples

Overlayed zbias events

Epoch dependent simulation: Run2b1 p20.09.02(03), Run2b2(34) p20.15.04

Events reconstructed and selected as data

Applied efficiency corrections to simulation

Trigger (ee_{ICR},$\mu\mu$,μ_{trk})

Scale factors (object reconstruction, identification, VC, taggability, b-tag)

Reweighting/smearing (luminosity, PV, lepton/jets E/η, p_T^Z)

Cross sections normalized by *K*-factors to N(N)LO values

Background normalization

common fit of MJ, efficiencies to data including all channels at pretag

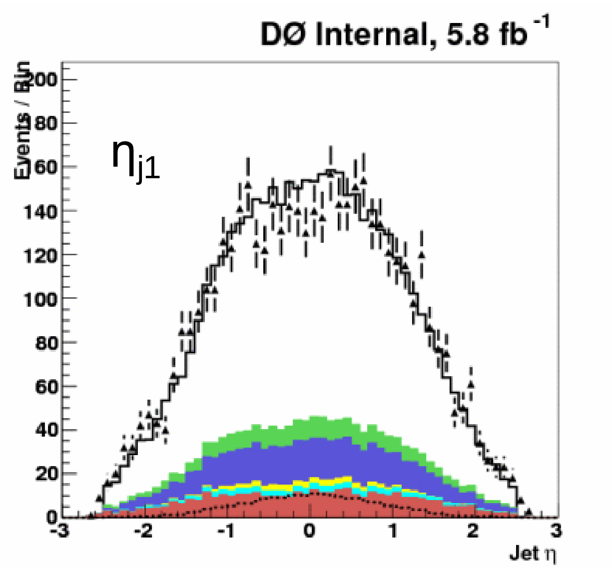
$$\chi^2 = \sum_i \sum_j \sum_m [D_m^{ij} - \alpha^{ij} Q_m^{ij} - k_L k_\varepsilon^i (k_Z^j Z_m^{ij} + O_m^{ij})]^2 / D_m^{ij} + \sum_c (k_X - 1)^2 / \sigma_X^2$$

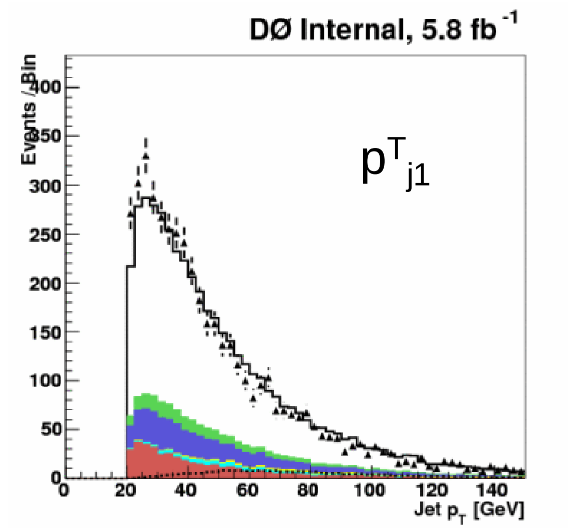
i: channels, *j*: jet multiplicity, *m*: M_{ll} bin

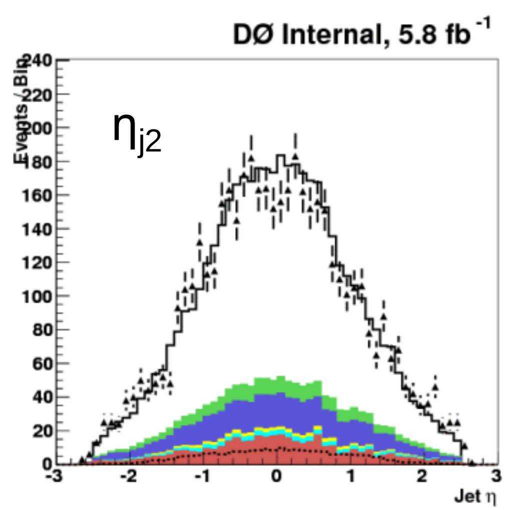
D: data, *Q/Z/O*: MJ/Z/Other backgrounds

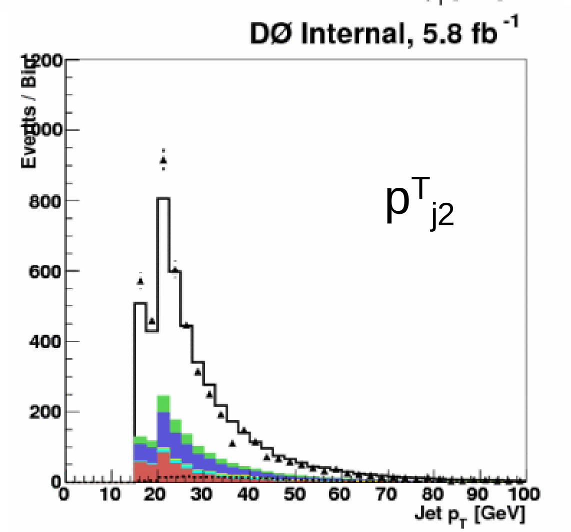
k: luminosity, efficiency and cross section scale factors

The departure of *k* from1 is a measure of systematic errors in the modeling http://www-d0.fnal.gov/Run2Physics/higgs/zh_llbb/d0_private/plots/archive/analysis_v3.2/preselection/zhccccbb_run2b234/2jet_masscut/





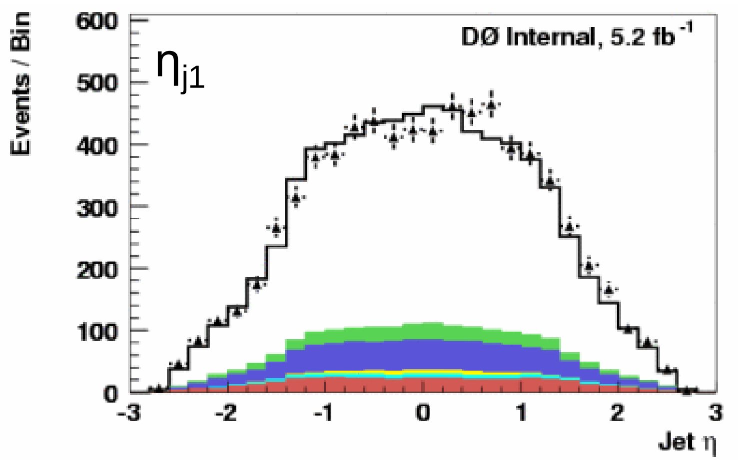


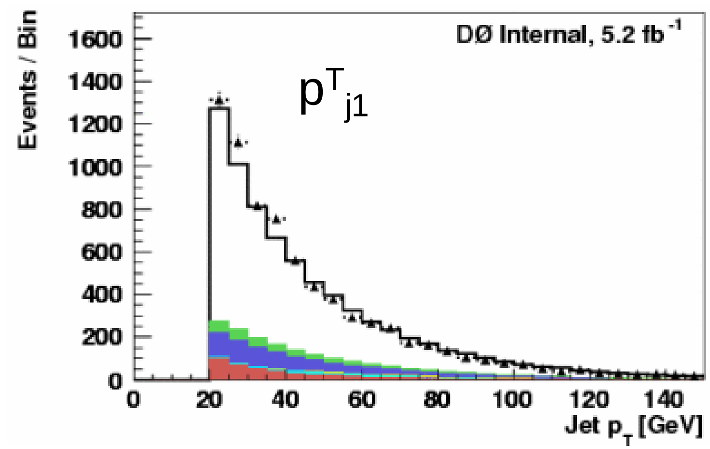


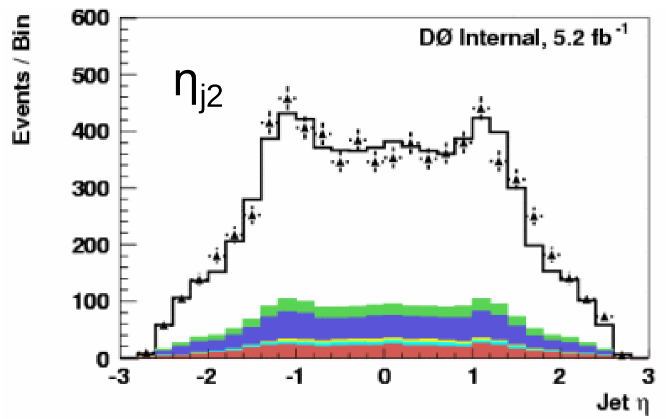
Mitigated by p^T>20 GeV in the EC

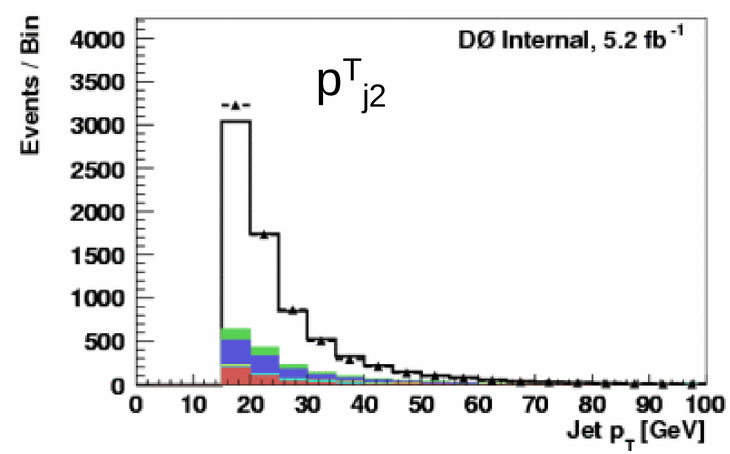
EPS'11 plots cccc run2b234

http://www-clued0.fnal.gov/~lwelty/d0_private/summer_2011/vjets_050607_p2122/summer_2011_results/nominal_newvjetrw_newicrrw/control_plots/run2b234/cccc/2jet_masscut/



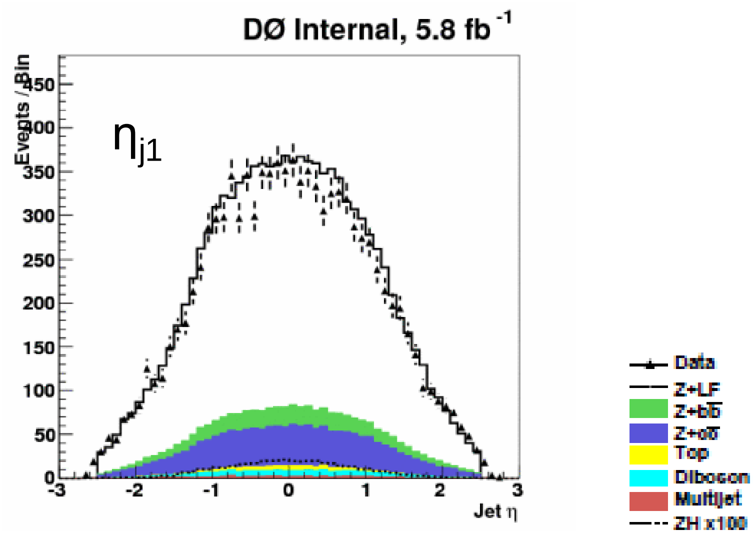


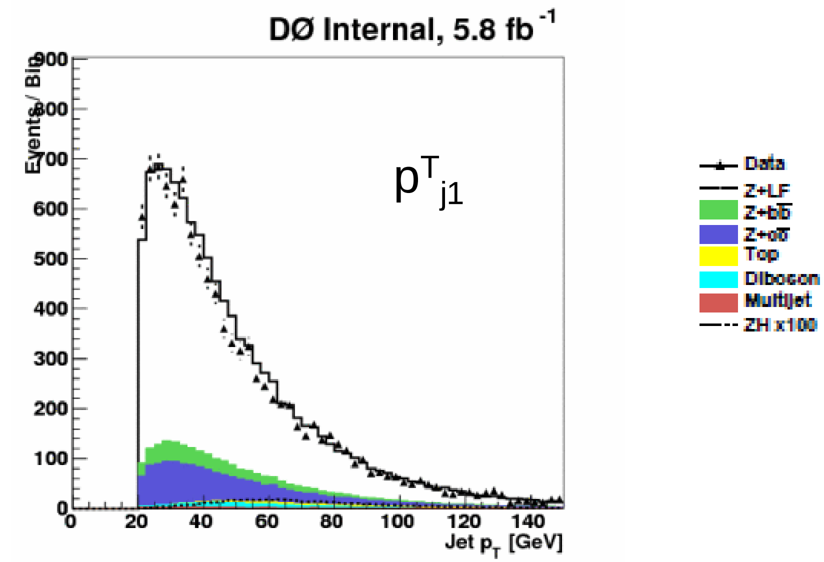


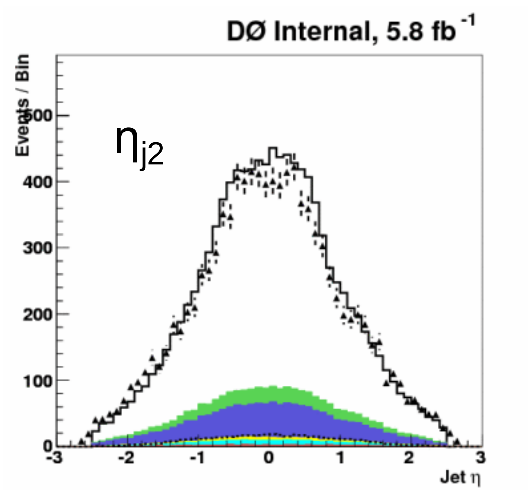


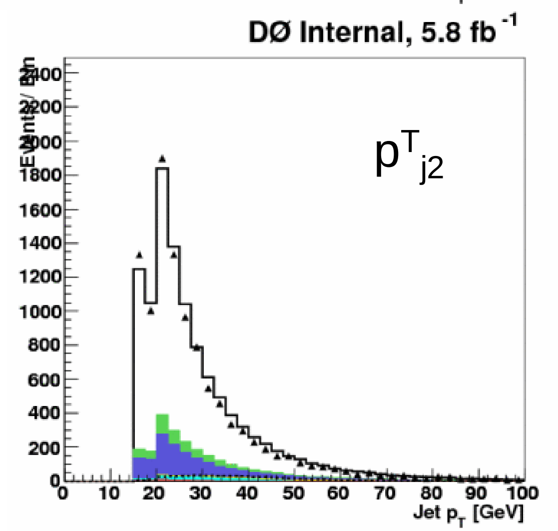
p^T>20 GeV
in the EC
no more needed

http://www-d0.fnal.gov/Run2Physics/higgs/zh_llbb/d0_private/plots/archive/analysis_v3.2/preselection/zhmumubb_run2b234/2jet_masscut/





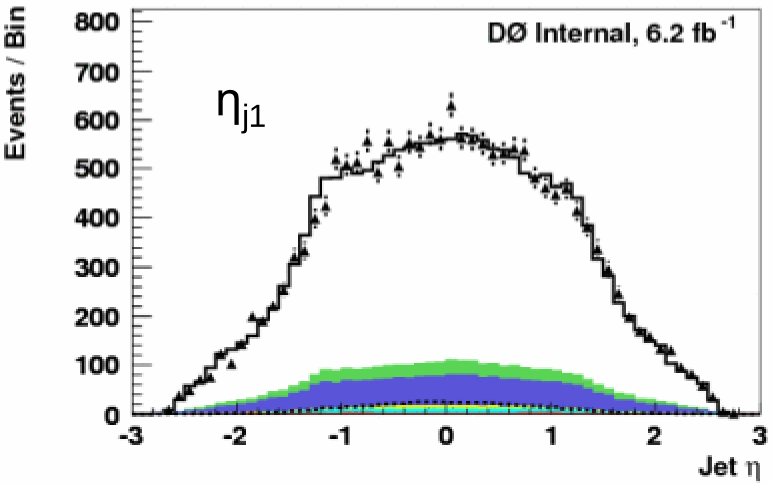


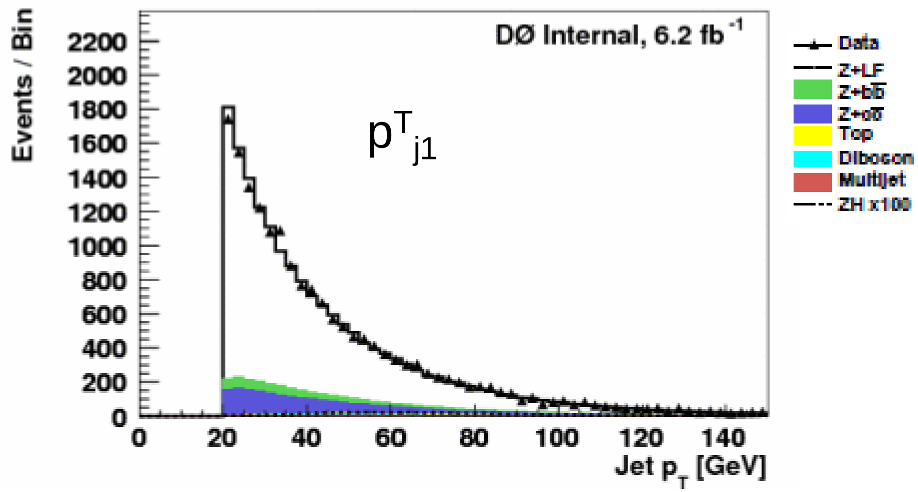


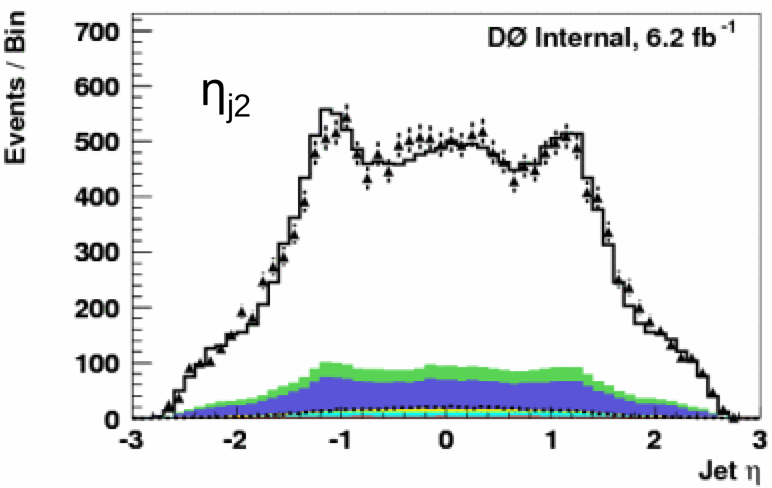
Mitigated by p^T>20 GeV in the EC

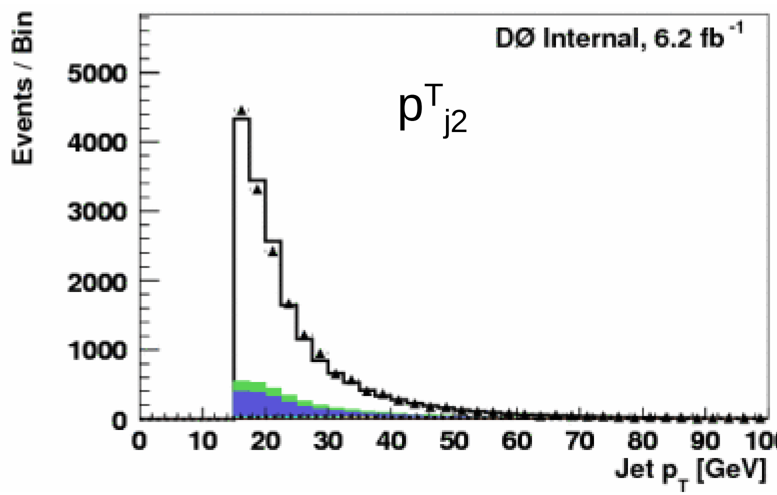
EPS'11 plots mumu run2b234

http://clued0.fnal.gov/~sun786/d0_private/run2b234_incl_newtrig_treatment/2jet_masscut/









p^T>20 GeV
in the EC
no more needed

Cut flow tables

Inclusive: 40 < M_{ll} < 200 GeV
2j pretag: 2j + 60 < M_{ll} < 150 GeV
ST, DT: taggability and direct b-tags

run2b234 eicr

	inclusive	0j	1j	2j-multijet	2j-pretag	ST	DT
data	133629	107943	12587	3947	3534	93	35
bkg	131497	107137	12392	3824.31	3441.25	95.3533	30.1701
Multijet	6928.65	5273.7	877.437	252.324	120.313	3.11076	0.576514
Zjj	121460	100353	10797.3	2926.2	2726.08	10.6169	0.621093
$Zb\bar{b}$	825.278	357.901	199.13	176.834	165.793	44.8949	16.9975
$Zc\bar{c}$	2251.36	1122.25	485.326	393.22	365.232	27.93	4.63486
ZZ	41.4038	11.9673	8.4564	19.4503	18.2897	1.61815	1.13408
WZ	58.1131	18.239	12.7474	24.4414	23.0389	1.01316	0.0877252
WW	59.0357	44.3807	8.15415	3.09917	2.0952	0.0395589	0.0190427
$t\bar{t}$	35.4079	0.511756	5.9724	28.7442	20.4231	6.13493	6.10282
$ZH(115)$	1.39202	0.109741	0.246742	1.01272	0.962371	0.267017	0.24536

run2b1 mumu

	inclusive	0j	1j	2j-multijet	2j-pretag	ST	DT
data	95394	73098	10914	4007	3682	84	36
all bkg	95351 ± 61	72764 ± 49	10759 ± 17	3891.1 ± 9.8	3594.0 ± 7.8	102.87 ± 0.91	39.26 ± 0.26
Multijet	1398 ± 32	1041 ± 32	222.7 ± 5.6	55.23 ± 0.65	15.04 ± 0.34	1.91 ± 0.12	1.33 ± 0.10
Zjj	90955 ± 52	70544 ± 38	9840 ± 15	3103.5 ± 9.6	2909.8 ± 7.6	8.76 ± 0.27	0.684 ± 0.098
$Zb\bar{b}$	772.0 ± 1.8	276.16 ± 0.63	193.42 ± 0.52	199.3 ± 1.4	187.13 ± 0.77	51.38 ± 0.45	20.41 ± 0.17
$Zc\bar{c}$	2012.4 ± 3.1	834.7 ± 1.7	465.3 ± 1.4	436.1 ± 1.4	404.5 ± 1.3	29.42 ± 0.49	4.909 ± 0.073
ZZ	44.04 ± 0.20	10.754 ± 0.096	8.612 ± 0.084	22.65 ± 0.15	21.50 ± 0.14	1.856 ± 0.043	1.455 ± 0.033
WZ	54.17 ± 0.43	14.64 ± 0.16	12.28 ± 0.14	24.27 ± 0.36	23.20 ± 0.36	1.042 ± 0.031	0.144 ± 0.013
WW	63.97 ± 0.58	41.75 ± 0.36	9.49 ± 0.17	7.28 ± 0.40	4.65 ± 0.39	0.161 ± 0.022	0.0272 ± 0.0079
$t\bar{t}$	51.78 ± 0.44	0.596 ± 0.045	7.92 ± 0.12	42.91 ± 0.41	28.19 ± 0.38	8.34 ± 0.54	10.31 ± 0.11
$ZH(115)$	1.640 ± 0.010	0.1362 ± 0.0033	0.2770 ± 0.0033	1.1938 ± 0.0090	1.1518 ± 0.0089	0.3214 ± 0.0047	0.3611 ± 0.0058

run2b2 mumu

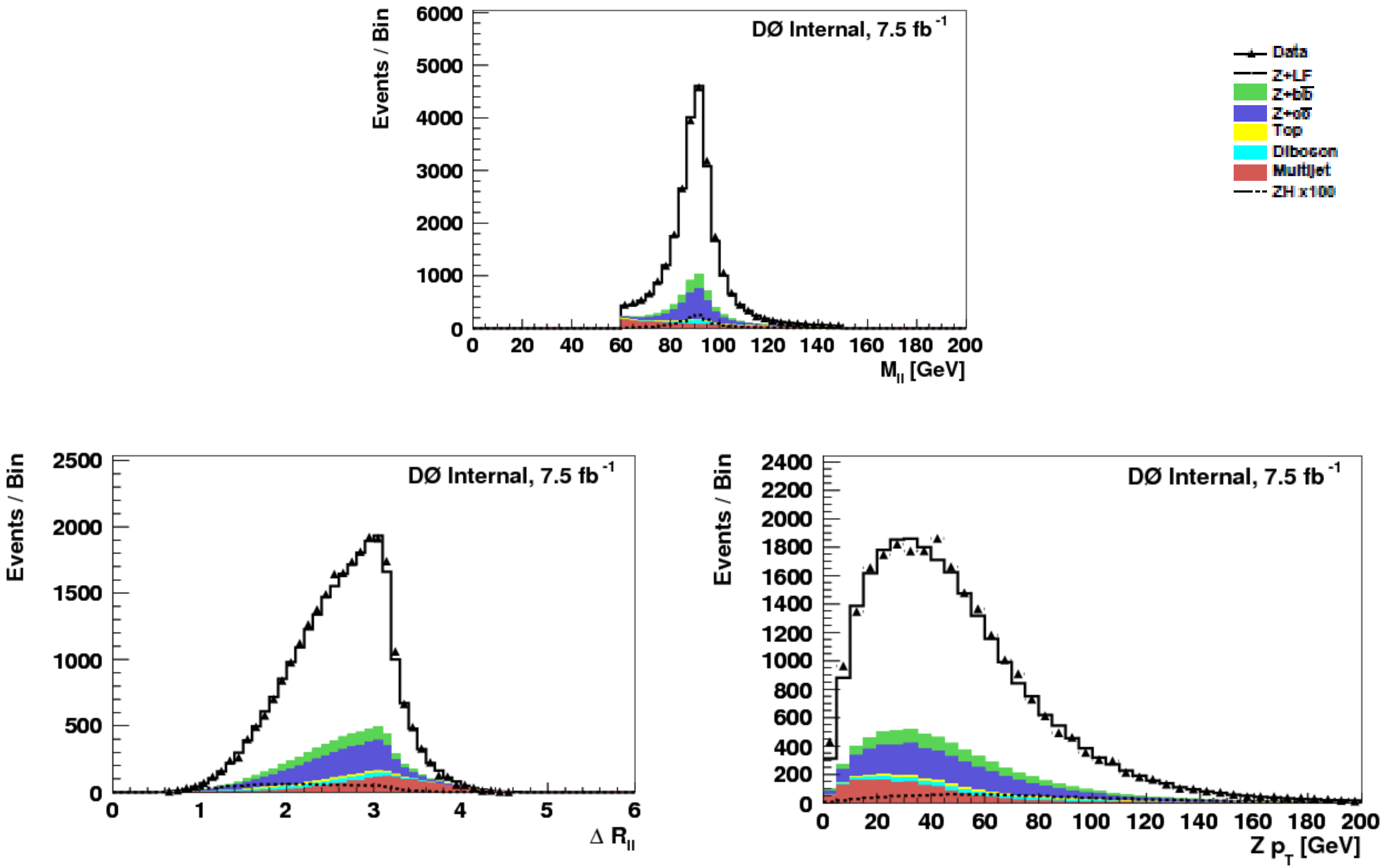
	inclusive	0j	1j	2j-multijet	2j-pretag	ST	DT
data	443411	334120	51282	19382	17856	458	173
all bkg	439490 ± 318	332956 ± 291	50988 ± 88	19196 ± 46	17760 ± 45	472.8 ± 3.7	180.0 ± 1.9
Multijet	9421 ± 90	7707 ± 89	1012 ± 11	301.9 ± 1.6	86.26 ± 0.85	9.69 ± 0.29	6.96 ± 0.24
Zjj	416432 ± 304	319947 ± 277	46832 ± 87	15385 ± 45	14455 ± 44	41.0 ± 1.3	2.19 ± 0.18
$Zb\bar{b}$	3525.3 ± 7.0	1244.0 ± 4.0	875.4 ± 3.3	958.1 ± 4.0	905.5 ± 3.9	235.5 ± 2.3	94.1 ± 1.2
$Zc\bar{c}$	9175 ± 16	3776.3 ± 9.9	2110.0 ± 7.2	2102.2 ± 8.4	1955.1 ± 7.9	135.5 ± 2.2	24.97 ± 0.79
ZZ	192.62 ± 0.74	42.62 ± 0.39	35.75 ± 0.29	105.69 ± 0.54	100.61 ± 0.53	8.54 ± 0.19	6.92 ± 0.16
WZ	230.4 ± 1.2	57.48 ± 0.56	48.54 ± 0.51	112.52 ± 0.84	107.56 ± 0.82	5.04 ± 0.19	0.731 ± 0.074
WW	283.0 ± 2.3	180.6 ± 1.8	43.81 ± 0.89	33.70 ± 0.86	20.38 ± 0.66	0.83 ± 0.15	0.164 ± 0.069
$t\bar{t}$	230.3 ± 2.7	2.17 ± 0.39	30.34 ± 0.94	196.6 ± 2.5	129.8 ± 2.0	36.7 ± 1.2	44.0 ± 1.2
$ZH(115)$	7.214 ± 0.042	0.3882 ± 0.0059	1.087 ± 0.015	5.633 ± 0.039	5.429 ± 0.038	1.471 ± 0.022	1.640 ± 0.022

k_Z^2 values

	standalone	err	discrepancy	pull
Combined	0.994	0.005	n/a	n/a
zhccccbb_run2b1	0.953	0.028	-4.1%	-1.48
zhccccbb_run2b234	0.990	0.013	-0.4%	-0.29
zhccecbb_run2b1	1.045	0.036	5.1%	1.42
zhccecbb_run2b234	0.978	0.016	-1.6%	-1.01
zheicrbb_run2b1	0.894	0.039	-10.0%	-2.55
zheicrbb_run2b234	0.993	0.018	-0.1%	-0.07
zhmumubb_run2b1	0.953	0.017	-4.2%	-2.46
zhmumubb_run2b234	1.008	0.008	1.4%	1.77
zhmutrkbb_run2b1	0.941	0.049	-5.3%	-1.08
zhmutrkbb_run2b234	1.059	0.023	6.6%	2.84

Combined all statistics (p^T_{j2} >20 GeV)

http://www-d0.fnal.gov/Run2Physics/higgs/zh_llbb/d0_private/plots/latest_spring2011/preselection/all/2jet_masscut/



Jets

EPS'11 plots

Combined all statistics (p^T_{j2} >20 GeV)

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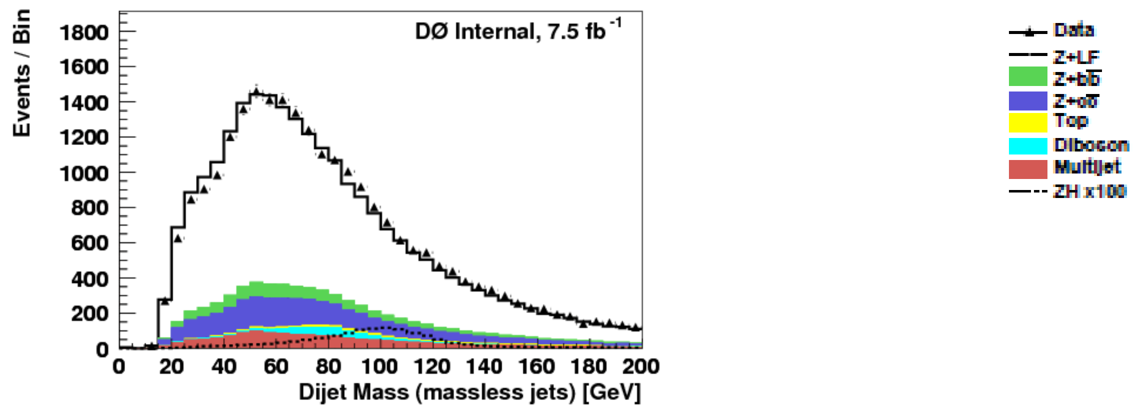
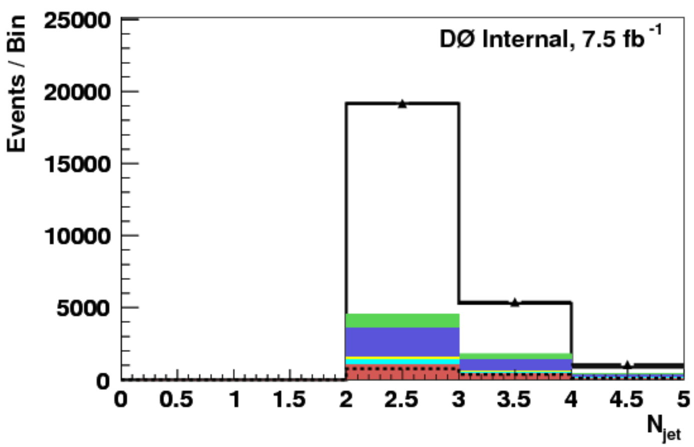
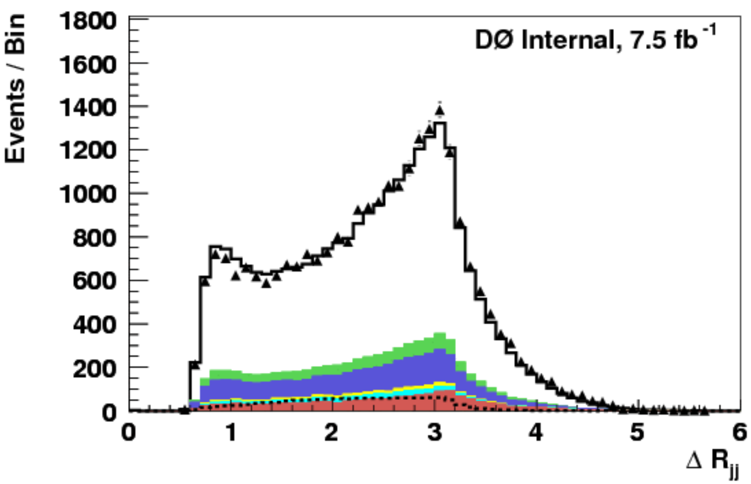


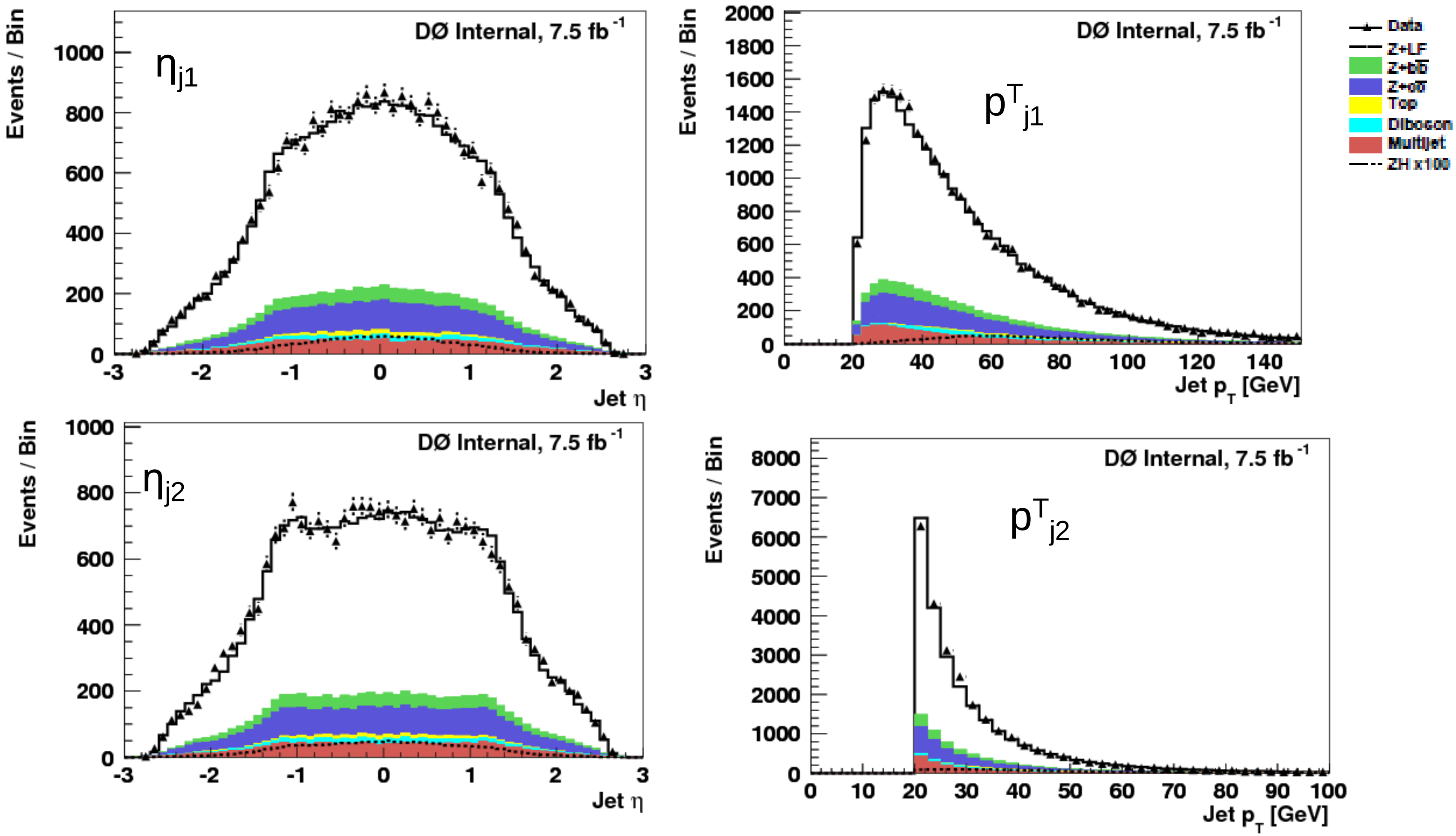




Jets EPS'11 plots

Combined all statistics (p^T_{j2} >20 GeV)

http://www-d0.fnal.gov/Run2Physics/higgs/zh_llbb/d0_private/plots/latest_spring2011/preselection/all/2jet_masscut/



Leptons+Jets EPS'11 plots

Combined all statistics (p^{T}_{j2} >20 GeV)

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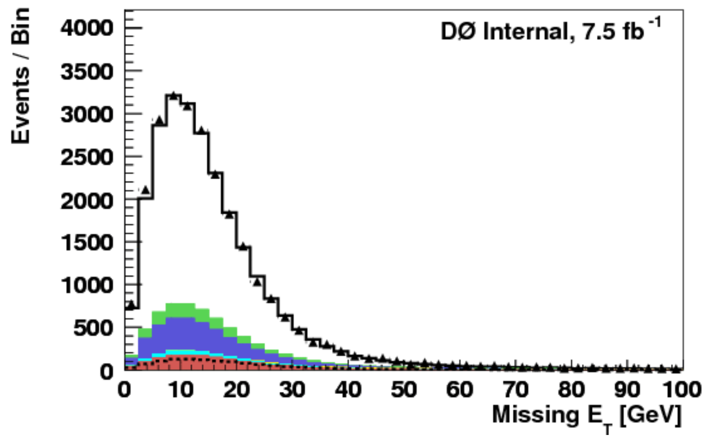
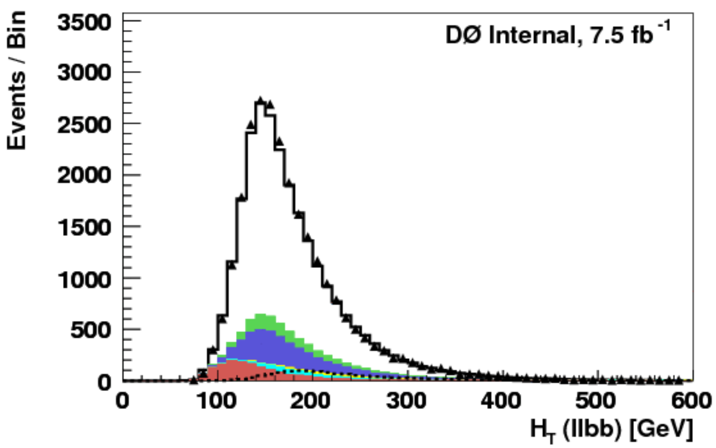
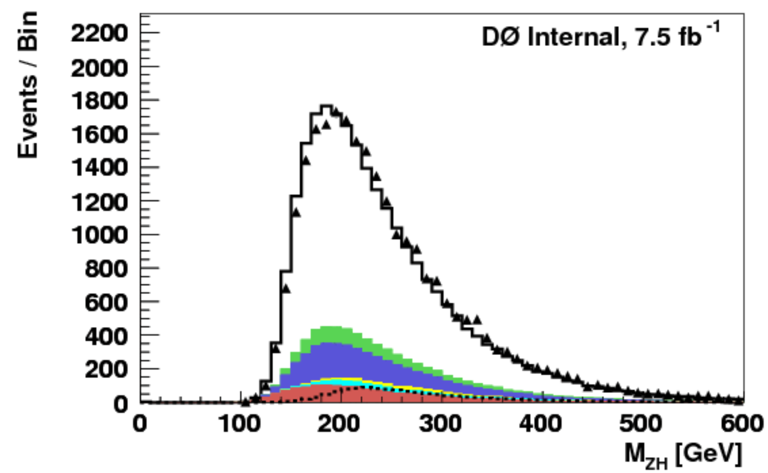






Kinematical fit

Recalculates the 2 lepton's and 2(3) jet's 3-momenta
in the Z(→ll)H(→bb)(+I/FSR) hypothesis

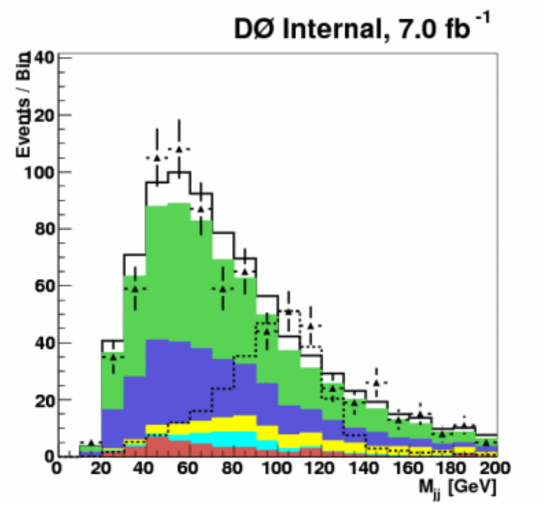
Constraints: measured angle and energy(momentum) errors
for jets transfer functions are used
di-lepton mass distribution (BW(Γ_Z)+Gaussian)
$\Sigma p_x \sim \Sigma p_y \sim 0 \pm 7$ GeV

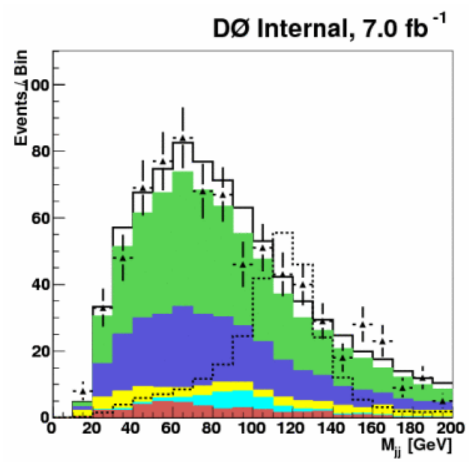
Fitted variables: improves bb mass resolution
discriminates background with large MET
used in final discrimination (RF)

M_{bb}

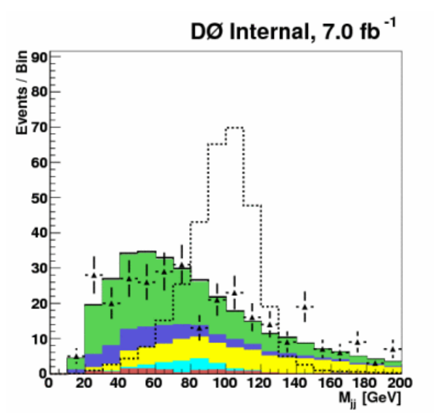
before kinematical fit after

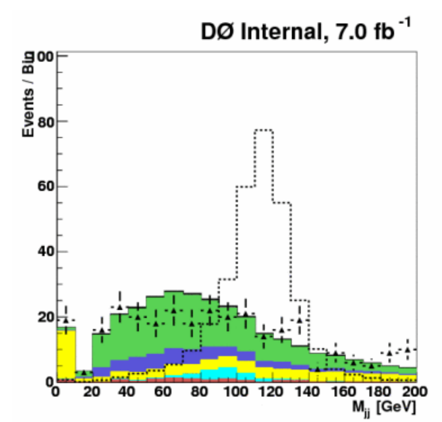
ST





DT





Final discriminant: MVA – Random Forest (200 decision trees)

Input variables: randomly chosen 10 out of the 19 variables

- Jets: M_{bb}, M_{bb}^{f}, p_T^{b1}, p_T^{b1f}, p_T^{b2}, p_T^{b2f}, p_T^{bb}, $\Delta\Phi(b_1,b_2)$, $\Delta\eta(b_1,b_2)$
- Z: p_T^{Z}, $\Delta\Phi(l_1,l_2)$, $\Delta\eta(l_1,l_2)$, $coll(l_1,l_2)$, $\Delta\Phi(Z,bb)$
- topological: $\cos\theta^*$, M(llbb), H_T(llbb), $M(\Sigma j_i)$, $pT(\Sigma j_i)$

Training: each mass point, ST, DT separately, all channels together, Run2b1

For now (group review), training for ICHEP'10 is used

For EB review, new training will be performed

Application: each mass points, each channels, each epoch, ST, DT

each shape dependent systematics

Systematic errors

Flat systematics

	signal	qcd	zjj	zbb	zcc	diB	ttbar
MJ norm		x					
k^2_Z(stat)			x	x	x		
Δ_{norm} (discrep)	x		x	x	x	x	x
k^0_Z fit	x					x	x
Run2a/Run2b	x					x	x
σ(Z+HF)				x	x		
σ(diB)						x	
σ(tt)							x
σ(VH)	x						
PDF	x		x	x	x	x	x

RF histograms scaled

Shape systematics

	signal	qcd	zjj	zbb	zcc	diB	ttbar
JES	x		x	x	x	x	x
JRES	x		x	x	x	x	x
JETID	x		x	x	x	x	x
VCJ	x		x	x	x	x	x
Taggab	x		x	x	x	x	x
Trigger	x		x	x	x	x	x
p_T^Z			x	x	x		
btagHF	x			x	x		x
btagLF			x			x	
vjrw			x	x	x		
icr_rw			x	x	x		
VH_pT	x						
AlpMLM			x				
AlpScale			x	x	x		
AlpUE			x	x	x		

Up/Down RF histograms by varying the nuisance parameters and/or event weight with ± 1 σ

Limit setting

Collie V00-04-09 is used

Channels: 5 x 2

CCCC CCEC eeICR µµ µµtrk

ST DT

Epochs: Run2a Run2b1 Run2b234

Limits w/o systematics (CLfast)

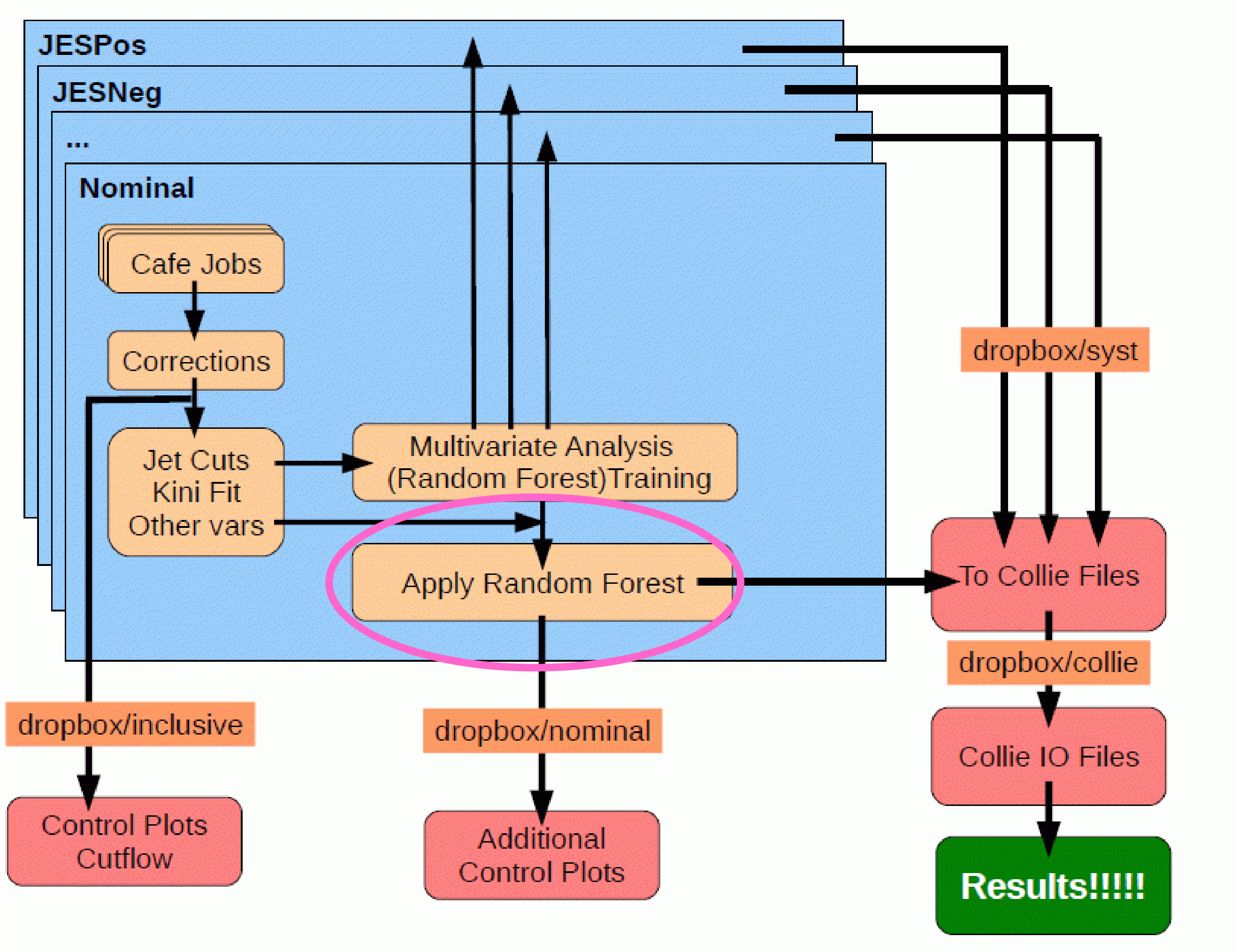
Limits w/ systematics (CLfit2)

nuisance parameters fitted to both bg and sg+bg hypotheses

on condensed files

channels epochs RF rebinned in similar s/sqrt(b) bins

Where are we today?



Summary

Since spring'11:
- new statistics
  - from Run2b4: now L_{int} = 8.6 fb^{-1}
  - mu+trk in Run2b included
- jet modeling improved → good Data/MC agreement
  - new jet treatment of T. Guillemin included
  - new jet eta reweighting
  - new parametrization of the QCD bg in di-e channel
- H→cc/ττ added to signal

As of today:
- Preselection completed
- To-Collie files (mainly systematic histograms) under preparation

Results (limits) and analysis note will be ready in the coming days

Backup slides

Comparison run2a vs total expected sqrt(8/1) = 2.8

-

(CLFit2 on condensed)

M_H	run2a ($1 fb^{-1}$)	all ($8 fb^{-1}$)	$R=L_{run2a}/L_{all}$	<R>
100	11.054	3.695	2.99	
105	12.128	4.053	3.00	
110	13.558	4.345	3.12	3.04
115	15.082	4.647	3.24	
120	17.747	5.233	3.33	
125	21.231	6.774	3.13	3.23
130	26.542	8.242	3.22	
135	35.470	11.366	3.12	
140	47.896	14.830	3.22	3.18
145	71.487	22.051	3.24	
150	111.280	34.764	3.20	3.22

In the first 3 masses the increase is ~3, for the others ~3.2

This doesn't point to a need for reanalyzing run2a
since expected improvement < 3%.

Epochs	L_{int} fb^{-1}
Run2a	1.1
Run2b1	1.2
Run2b23	5.0
Run2b4	1.3
Total	8.6

Backgrounds

Triggers

e^+e^-	Inclusive	~100%	No correction
ee_{ICR}	Ejets_OR		MC corrected
$\mu^+\mu^-$	Inclusive		MC corrected
$\mu\mu_{trk}$	Inclusive		MC corrected

EM-ID operating points

In CC Point0, in EC Point05 was used

Point0:

Isolation_CC: 0.09
Isolation_EC: 0.1
EMFraction_CC: 0.90
EMFraction_EC: 0.90
HMx8_EC: 40.
IsoHC4_CC: 4.0
IsoHC4_EC: 100.
TrkMatchChi2_CC: 0.0
EMHits_e_f_CC: 0.6
NNout7_CC: 0.4
NNout4_EC: 0.05
Sigphi_EC: 100.

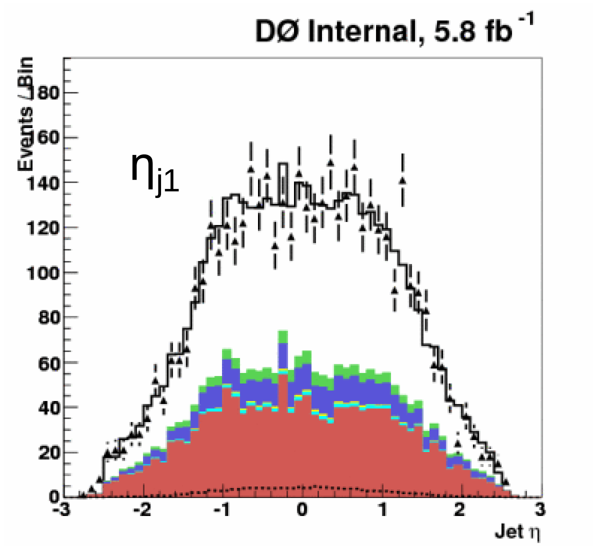
Point05:

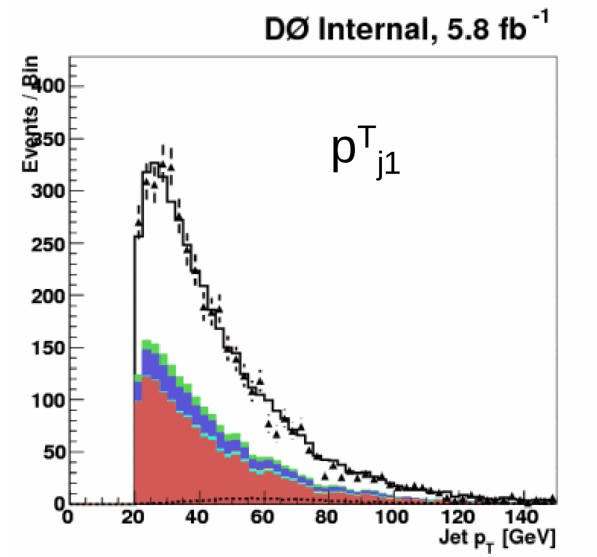
Isolation_CC: 0.15
Isolation_EC: 0.05
EMFraction_CC: 0.90
EMFraction_EC: 0.97
HMx8_EC: 10.
IsoHC4_CC: 3.5
IsoHC4_EC: 200.
TrkMatchChi2_CC: 0.0
NNout7_CC: 0.30
NNout4_EC: 0.20
Sigphi_EC: 100.
LHood_CC: 0.05
EOP_CC: 8.0

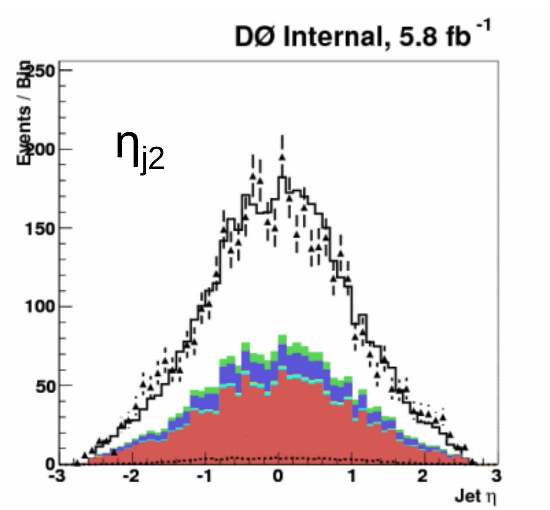
Modeling issues

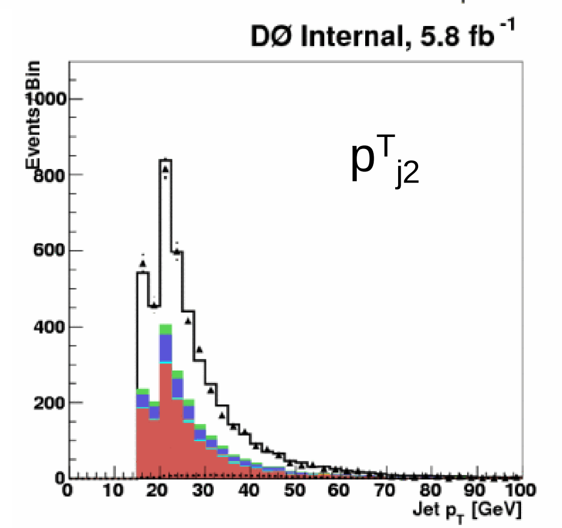
Spring'11 plots ccec run2b234

http://www-d0.fnal.gov/Run2Physics/higgs/zh_llbb/d0_private/plots/archive/analysis_v3.2/preselection/zhccecbb_run2b234/2jet_masscut/





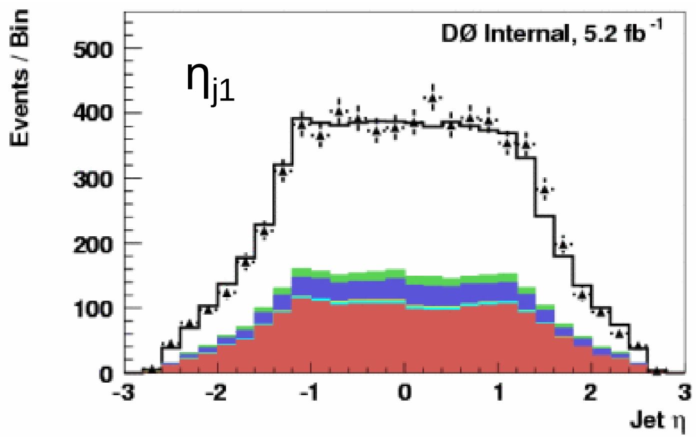


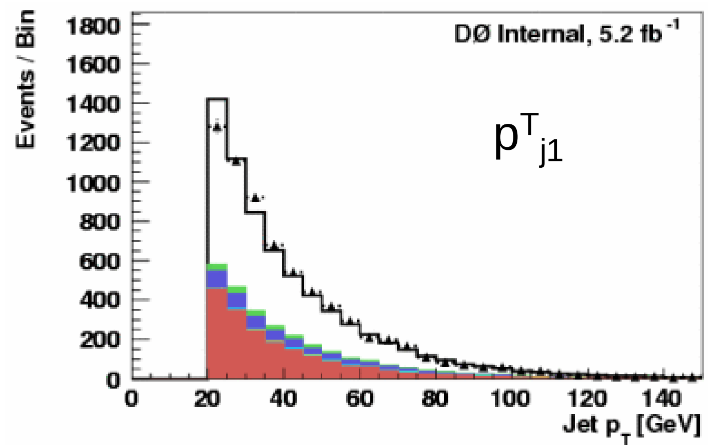


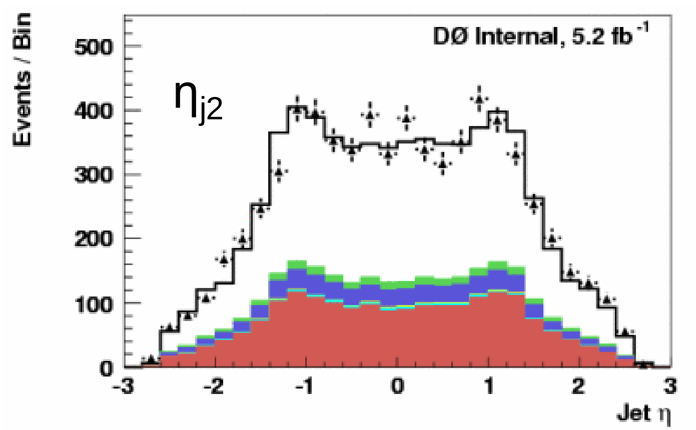
Mitigated by p^T>20 GeV in the EC

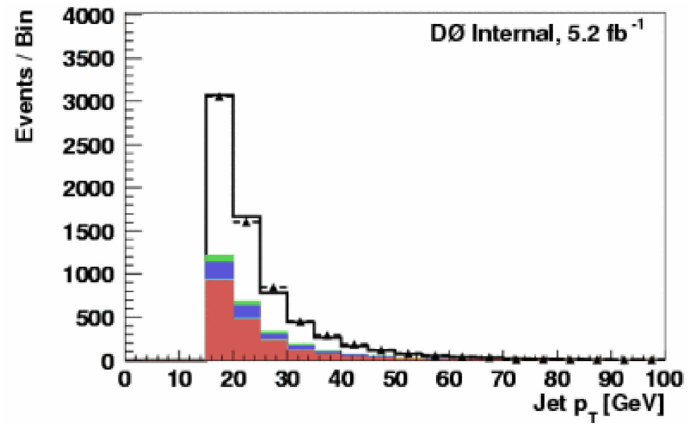
EPS’11 plots   ccec run2b234

http://www-clued0.fnal.gov/~lwelty/d0_private/summer_2011/vjets_050607_p2122/summer_2011_results/nominal_newvjetrw_newicrrw/control_plots/run2b234/ccec/2jet_masscut/



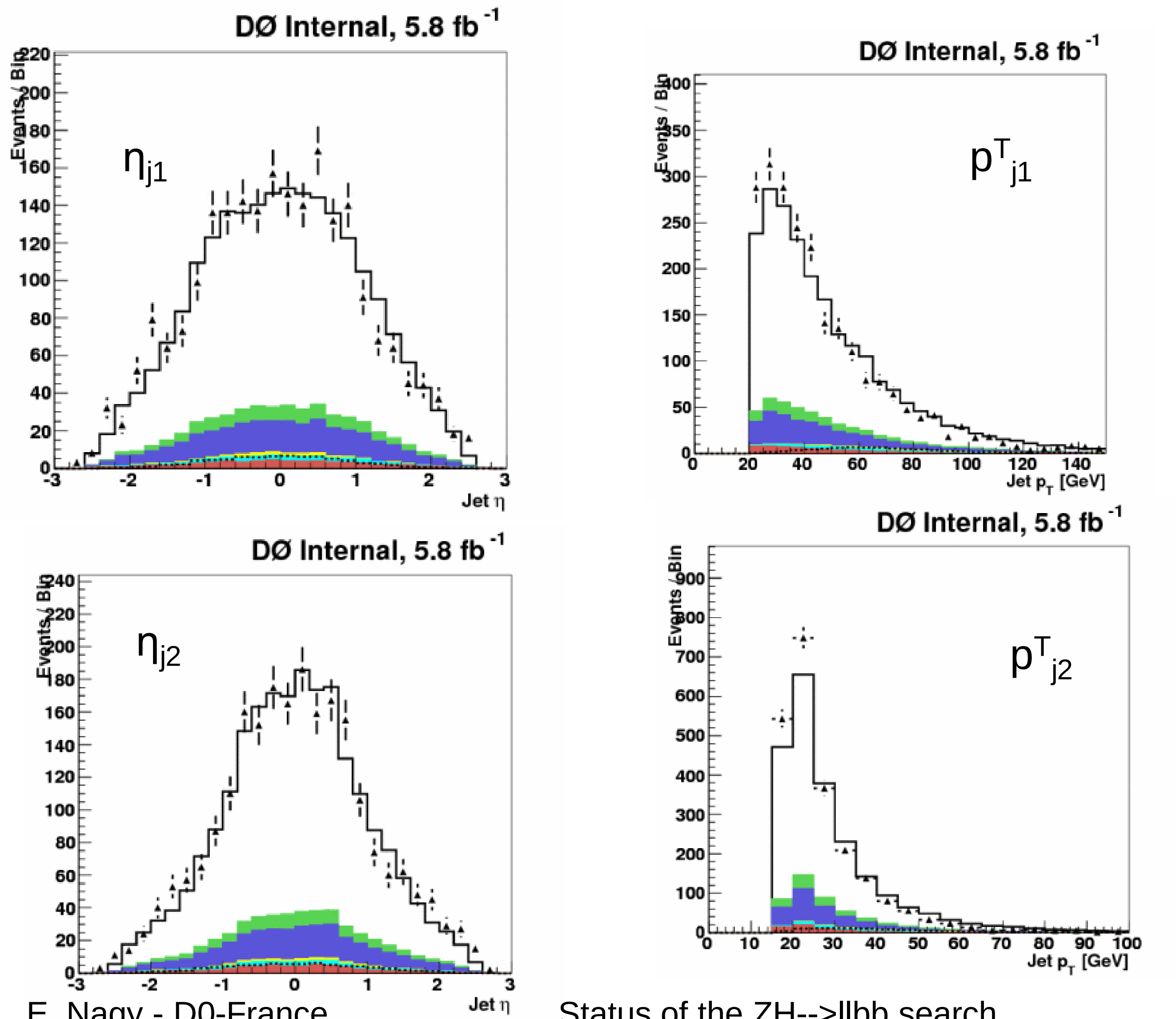






p^T>20 GeV
in the EC
no more needed

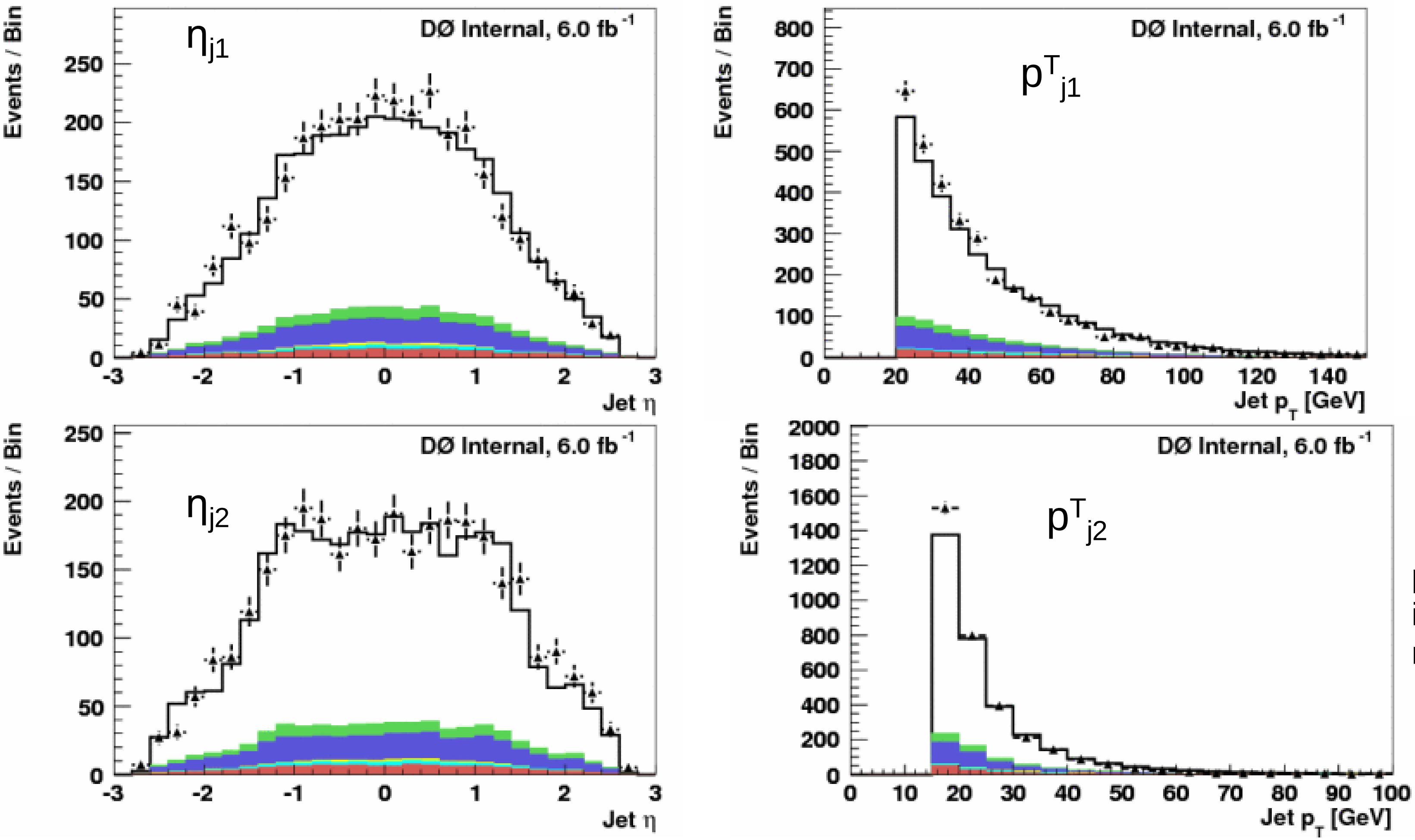
http://www-d0.fnal.gov/Run2Physics/higgs/zh_llbb/d0_private/plots/archive/analysis_v3.2/preselection/zheicrbb_run2b234/2jet_masscut/



Mitigated by p^T>20 GeV in the EC

EPS'11 plots eicr run2b234

http://www-clued0.fnal.gov/~cousinou/zheicr_run2b234-p201803_vj564_with-icrrw/2jet_masscut/



p^T>20 GeV
in the EC
no more needed

run2b1 cccc

	inclusive	0j	1j	$2j$-multijet	$2j$-pretag	ST	DT
data	57040	45457	6023	1888	1447	55	17
all bkg	55728 ± 47	44736 ± 42	5640 ± 11	1751.0 ± 6.6	1388.2 ± 5.1	44.10 ± 0.58	17.39 ± 0.15
Multijet	5138 ± 33	4200 ± 30	445.7 ± 9.5	192.3 ± 4.5	48.4 ± 2.0	0.90 ± 0.26	0.000000 ± 0.000000
Zjj	48867 ± 33	39766 ± 29	4779.7 ± 6.3	1214.3 ± 4.7	1056.5 ± 4.5	3.29 ± 0.14	0.347 ± 0.058
$Zb\bar{b}$	429.7 ± 1.2	177.37 ± 0.52	109.95 ± 0.39	90.46 ± 0.70	80.41 ± 0.68	22.61 ± 0.48	9.228 ± 0.093
$Zc\bar{c}$	1147.0 ± 2.3	539.6 ± 1.6	267.37 ± 0.86	204.0 ± 1.0	167.78 ± 0.85	12.09 ± 0.12	2.133 ± 0.038
ZZ	25.89 ± 0.15	7.826 ± 0.077	5.923 ± 0.067	10.99 ± 0.11	10.16 ± 0.11	0.845 ± 0.025	0.737 ± 0.069
WZ	30.34 ± 0.20	10.93 ± 0.13	7.322 ± 0.087	10.47 ± 0.10	10.00 ± 0.10	0.431 ± 0.019	0.0518 ± 0.0073
WW	55.64 ± 0.37	33.66 ± 0.30	16.41 ± 0.17	2.338 ± 0.081	1.084 ± 0.054	0.0259 ± 0.0096	0.0066 ± 0.0041
$t\bar{t}$	34.60 ± 0.23	0.894 ± 0.049	7.362 ± 0.099	26.07 ± 0.20	13.91 ± 0.12	3.903 ± 0.072	4.886 ± 0.068
$ZH(115)$	0.9303 ± 0.0067	0.1124 ± 0.0034	0.1996 ± 0.0026	0.5999 ± 0.0051	0.5820 ± 0.0050	0.1598 ± 0.0027	0.1799 ± 0.0024

run2b1 ccec

	inclusive	0j	1j	$2j$-multijet	$2j$-pretag	ST	DT
data	53344	42884	5202	1644	1299	31	15
all bkg	52982 ± 59	42878 ± 50	4966 ± 20	1562 ± 11	1271.7 ± 8.1	30.35 ± 0.70	9.57 ± 0.37
Multijet	10888 ± 52	8230 ± 44	1288 ± 20	463.7 ± 9.2	246.0 ± 6.0	4.20 ± 0.63	0.73 ± 0.24
Zjj	41033 ± 29	34144 ± 25	3447.2 ± 5.3	898.8 ± 5.2	841.2 ± 5.1	2.55 ± 0.15	0.174 ± 0.044
$Zb\bar{b}$	262.6 ± 1.1	114.63 ± 0.40	62.21 ± 0.27	52.87 ± 0.53	49.90 ± 0.51	13.19 ± 0.16	5.30 ± 0.27
$Zc\bar{c}$	739.3 ± 2.2	365.8 ± 1.0	157.39 ± 0.57	126.3 ± 1.8	117.2 ± 1.8	8.29 ± 0.21	1.259 ± 0.034
ZZ	11.582 ± 0.099	3.406 ± 0.054	2.597 ± 0.055	5.048 ± 0.058	4.848 ± 0.057	0.422 ± 0.019	0.314 ± 0.014
WZ	18.32 ± 0.16	6.079 ± 0.083	4.236 ± 0.066	7.10 ± 0.11	6.88 ± 0.11	0.313 ± 0.016	0.0335 ± 0.0064
WW	19.89 ± 0.24	14.26 ± 0.20	2.84 ± 0.10	1.436 ± 0.062	0.915 ± 0.049	0.0340 ± 0.0091	0.00091 ± 0.00091
$t\bar{t}$	9.02 ± 0.13	0.254 ± 0.057	1.696 ± 0.051	6.989 ± 0.099	4.732 ± 0.075	1.346 ± 0.046	1.765 ± 0.045
$ZH(115)$	0.3897 ± 0.0038	0.0408 ± 0.0010	0.0797 ± 0.0016	0.2599 ± 0.0033	0.2554 ± 0.0033	0.0712 ± 0.0017	0.0769 ± 0.0016

The D0 method

aka semi-frequentist or CLs method

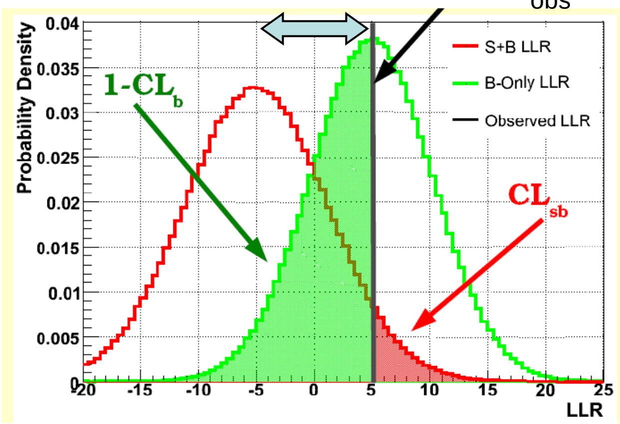
Log-Likelihood-Ratio (LLR) as test statistics: $LLR = -2\ln\frac{P(N|H_1)}{P(N|H_0)}$

H_0 and H_1 - test hypotheses of background w/o and w/ signal
N - ensemble of number of events
P - Poissonian pdf of N: $P = e^{-\mu}\mu^N/N!$
includes pdf of nuisance parameters θ: $\exp[-\frac{(\theta-\theta_0)^2}{2\sigma_\theta^2}]$

Profiling:
LLR is minimized wrt the nuisance parameters

LLR_{obs} = LLR(N=Data)
LLR_b = LLR(N=Background)
LLR_{sb} = LLR(N=Signal+Background)

signal—background separation



Confidence levels:
$1\text{-}CL_b = p(LLR_b < LLR_{obs}|H_0)$
$CL_{sb} = p(LLR_{sb} > LLR_{obs}|H_1)$
$CL_s = CL_{sb}/CL_b$

A signal $R=(\sigma xBR)/(\sigma xBR)_{SM}$ is excluded @ 95% CL if $CL_s(R)= 0.05$ i.e. $1\text{-}CL_s(R)= 0.95$

It has been checked that the Bayesian and CLs methods give comparable results (~10%)