MVA in ZH→ννbb

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Low mass Higgs meeting
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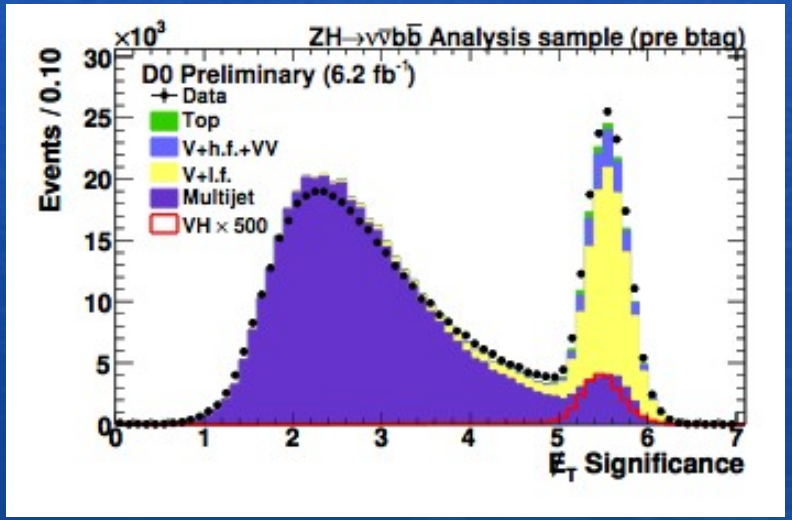
Overview

- Description of ZHνν̄bb̄ analysis
- Use of Decision Trees
- Decision tree studies
  - Input variables
  - Cuts and binning
- Plans

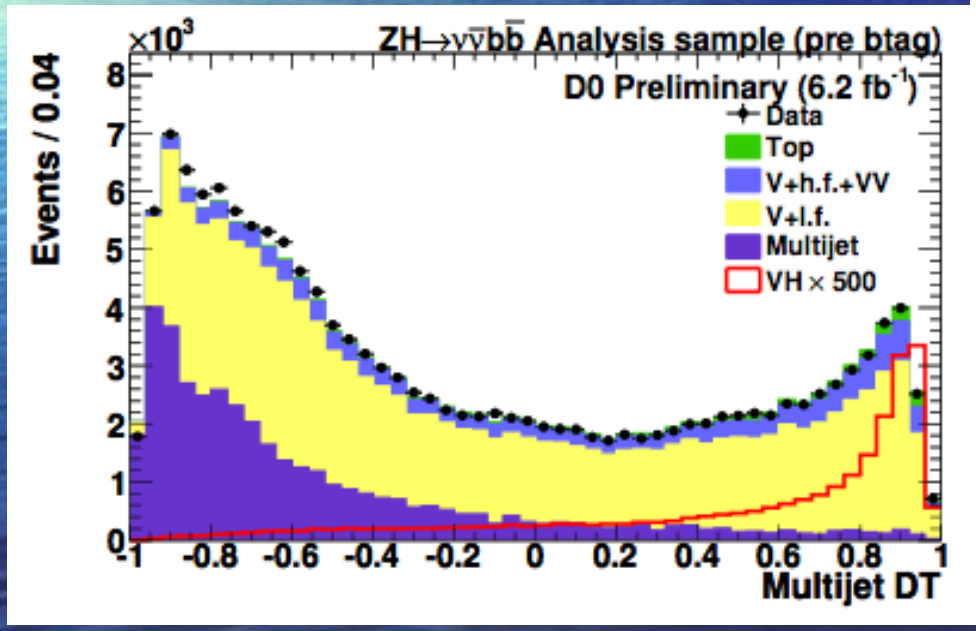
ZH νν̄bb̄ Analysis

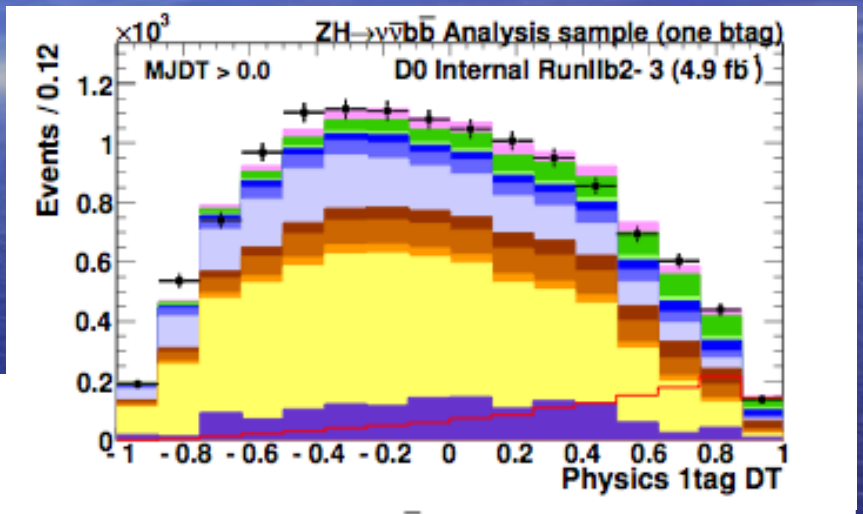
- Signal: 2 b-jets + MET
- Require:
  - 2 or 3 taggable jets
  - 1 or 2 tagged jets
  - MET > 40 GeV
  - MET Significance > 5
  - No isolated leptons
  - Multijet cut: $\Delta\phi$ (MET, MPT) < $\pi/2$

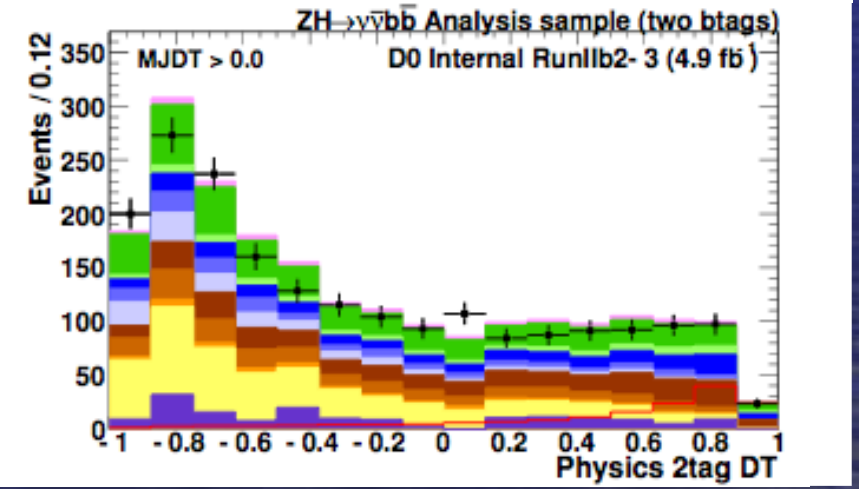


MVAs in ZHνν̄bb̄ Analysis

- Two tiers of DTs
- Separated by epoch



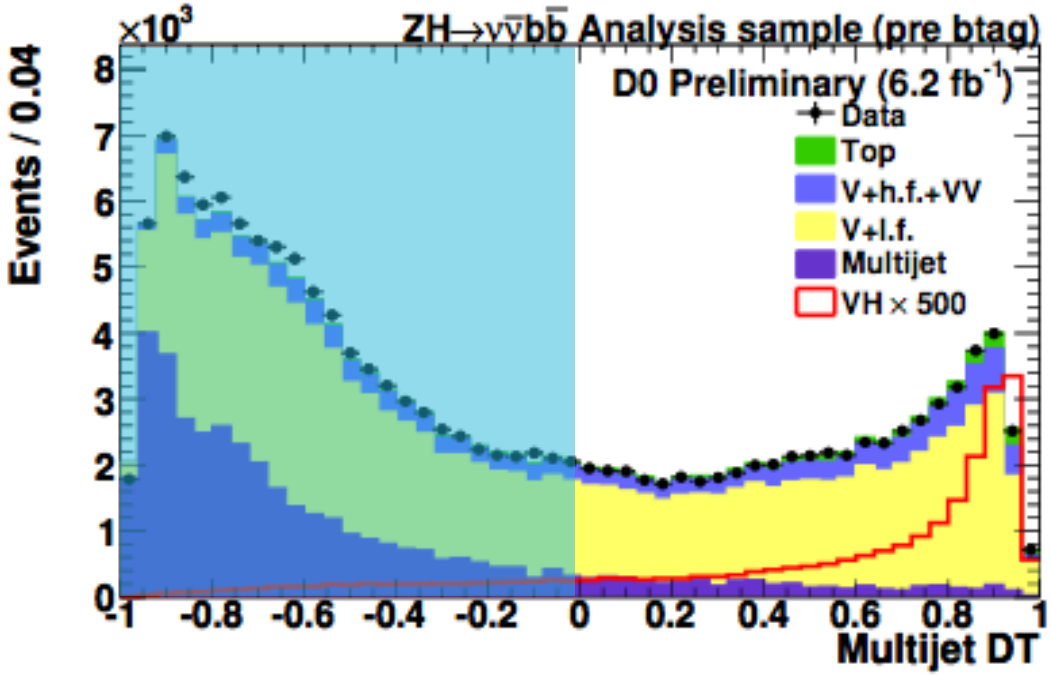


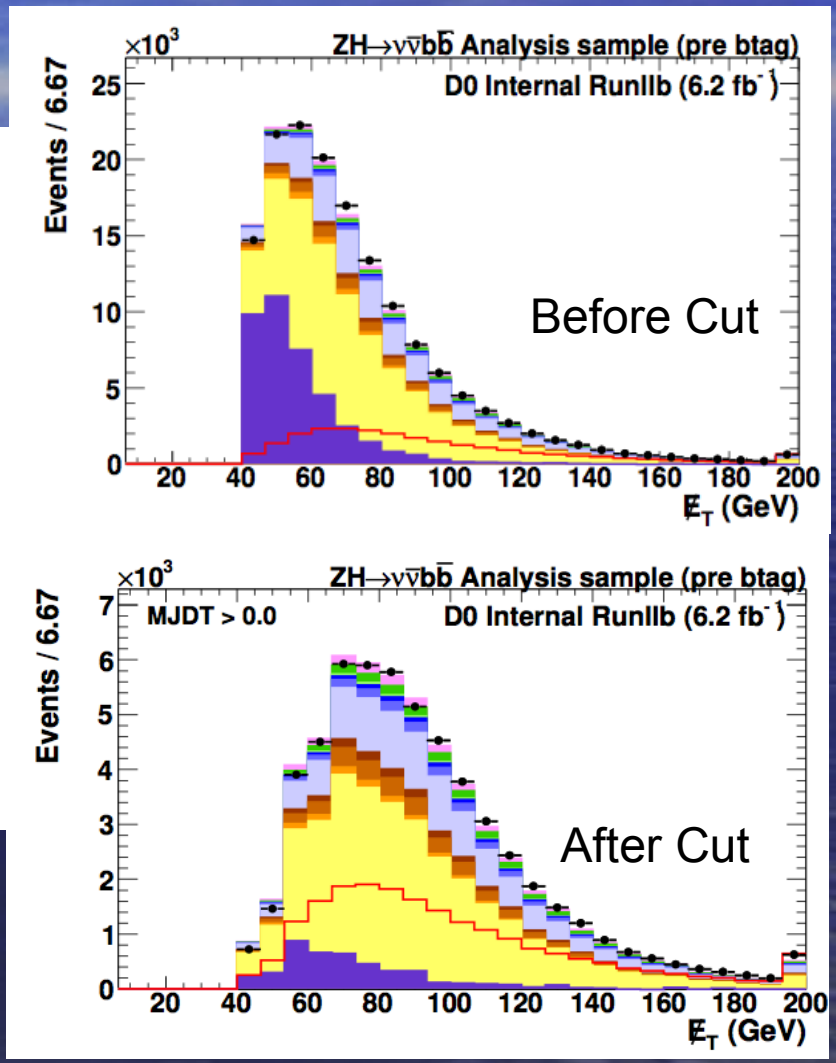


Motivation for Studies

- Studying MVAs
  - could gain sensitivity
  - helps to confirm current results
  - MVAs are quick to train and test
- Application to analysis is straightforward

Multijet DT





Signal: VH events
Background: Multijet events

MJ DT: Input Variables

- 20 Variables in MJDT
- Removed five variables at a time

1 – 5	6 – 10	11 – 15	16 – 20
MET	MHT/HT	$\Delta\varphi$(NLJ, MET)	L jet color φ
Di-jet M	Max$\Delta\varphi$+Min$\Delta\varphi$	η Higgs	Jet $\Delta\varphi$
MHT	L jet Pt	NL jet color φ	Σ
Transverse M	Max$\Delta\varphi$-Min$\Delta\varphi$	NL jet Pt	Jet ΔR
Di-jet Pt	Jet $\Delta\eta$	θ Higgs	N Jets

Max$\Delta\varphi$: Maximum $\Delta\varphi$(MET, jet_i)

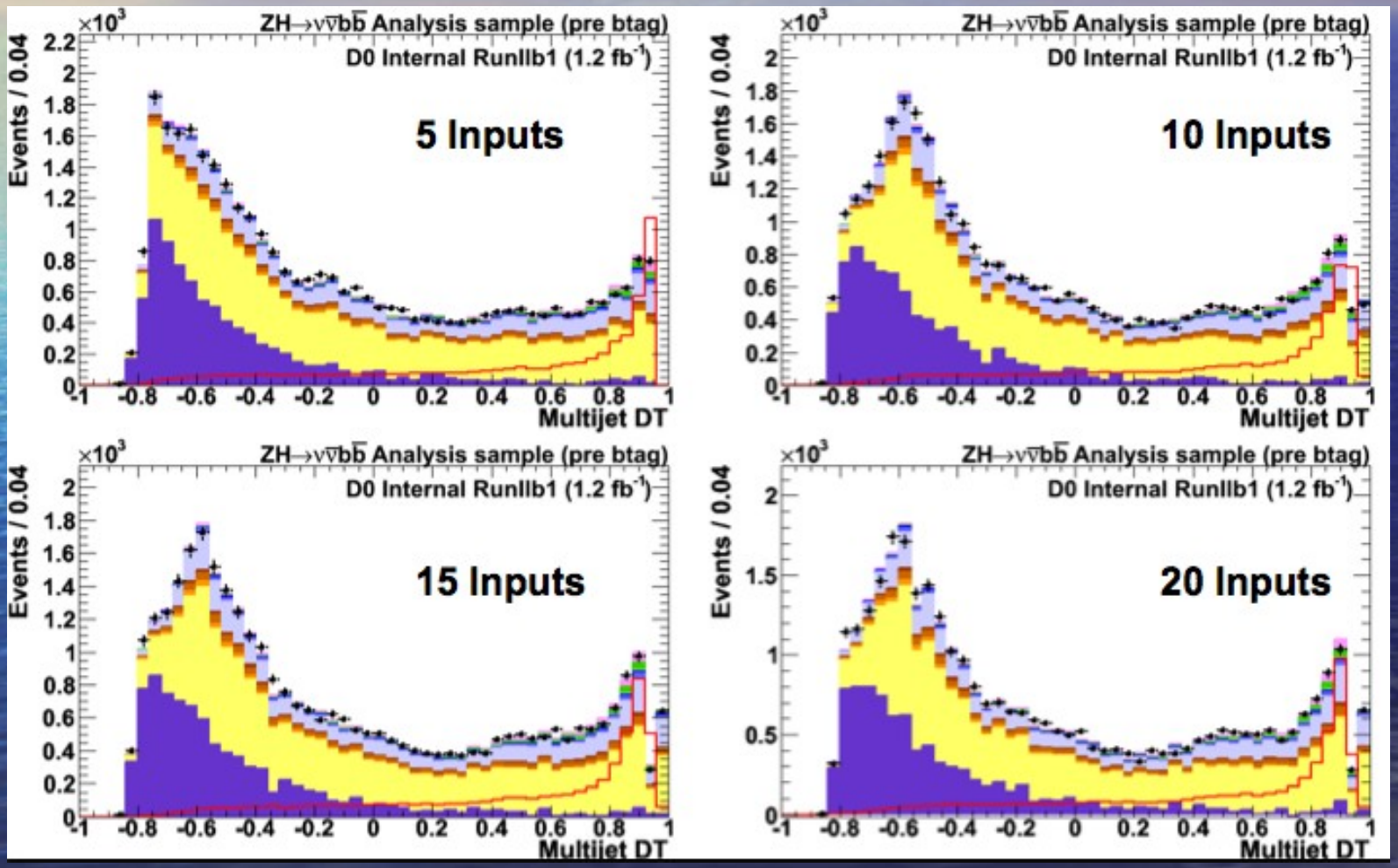
Min$\Delta\varphi$: Minimum $\Delta\varphi$(MET, jet_i)

Σ: P_T re-weighted ΔR

MJ DT: Input Variables

mH =100	110	115	120	130	140	150
MET	MET	MET	MET	MET	MET	MET
MHT	MHT	DIM	TM	TM	TM	TM
Dijetsubt	Dijetsubt	TM	MHT	MHT	MHT	L jet Pt
Jet dR	TM	Dijetsubt	Dijetsubt	L jet Pt	L jet Pt	MHT
DIM	DIM	- dPhi	DIM	DIM	DIM	DIM
TM	L jet Pt	dEta	L jet Pt	Dijetsubt	Dijetsubt	NL jet Pt
sigma	Jet dR	MHT	NL jet Pt	NL jet Pt	NL jet Pt	Dijetsubt
L jet Pt	NL jet Pt	+ dPhi	Jet dR	Jet dR	Jet dR	jet dR
dEta	sigma	NL jet Pt	sigma	dEta	dEta	dEta
MHT_HT	dEta	Jet dR	dEta	sigma	- dPhi	- dPhi

MJ DT: Input Variables



MJ DT: Input Variables

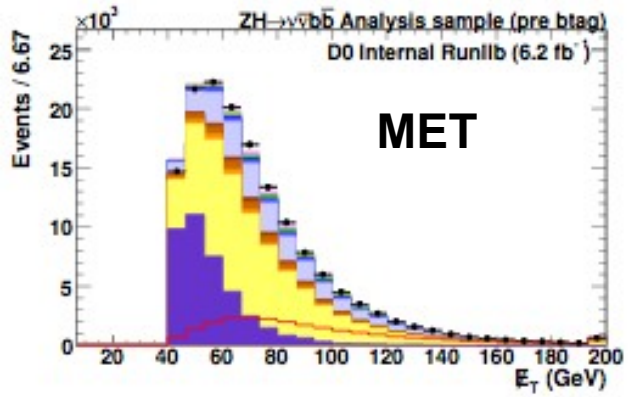
- Set expected limits with CLFit2
- Used di-jet invariant mass with MJ DT cut

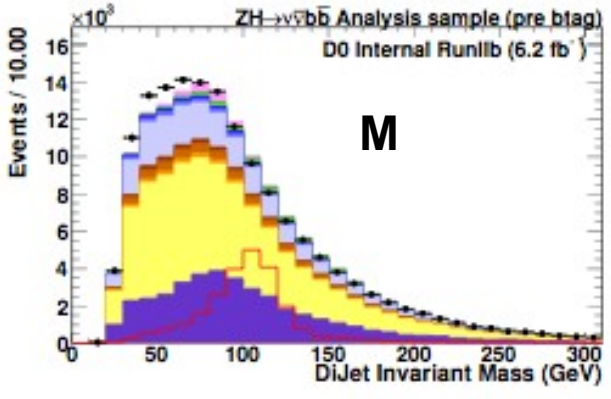
# Variables	5	10	15	20
RunIIb1	11.51	11.43	11.33	11.32
RunIIb23	6.33	6.33	6.34	6.43
Combined	5.55	5.57	5.51	5.63

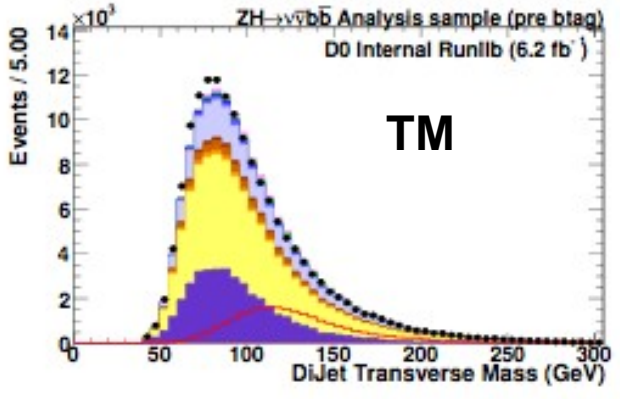
- Only 5 ("core") variables are needed:

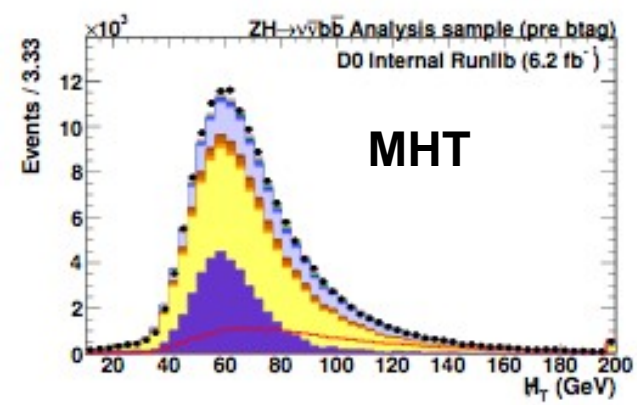
MET, MHT, M, MT, DiJetPt

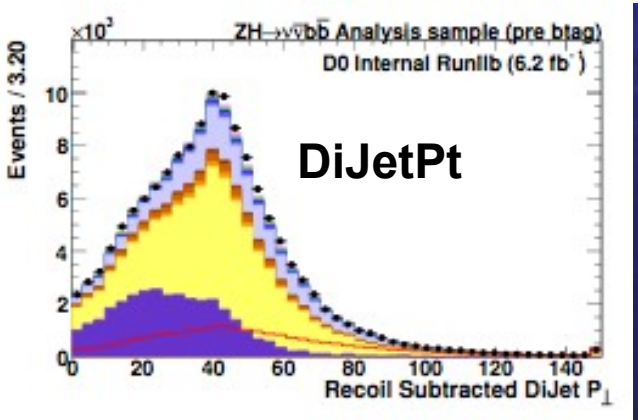
MJ DT: Input Variables









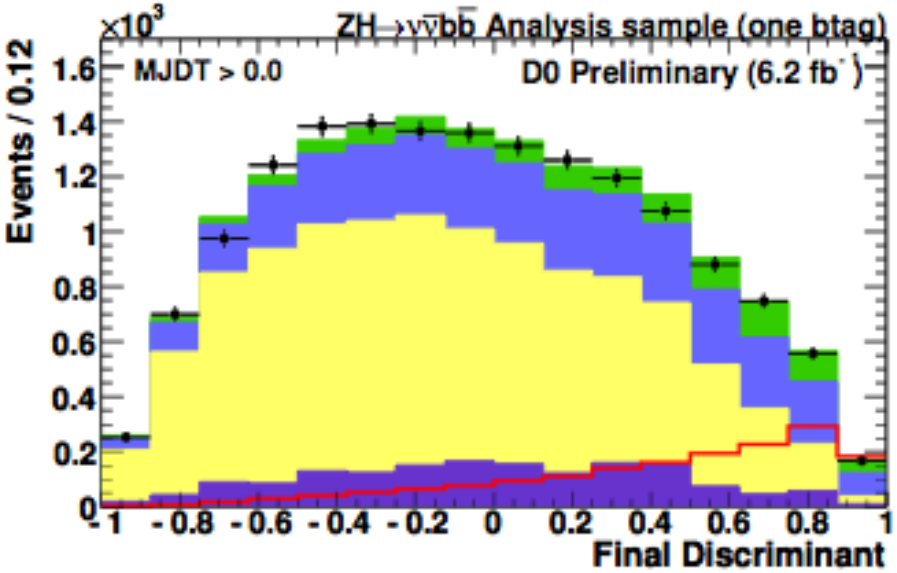


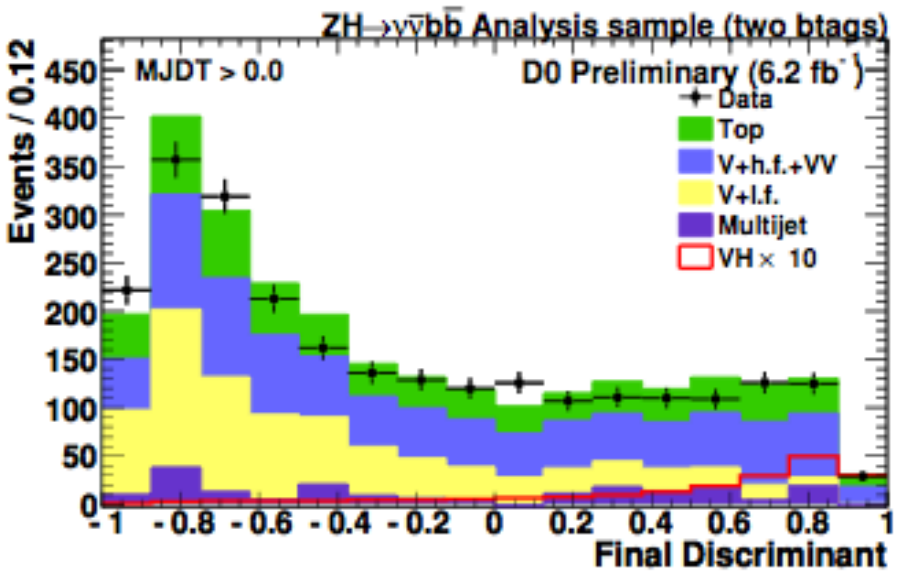
MJ DT Cut

- Cut on MJ DT to remove MJ background
- Tested several cuts by setting CLFast limits

# Variables	-0.1	0	0.1	0.2	0.3
RunIIb1	8.79	8.7	8.7	8.68	8.76
RunIIb23	4.44	4.36	4.38	4.27	4.28
Combined	3.92	3.88	3.88	3.85	3.87

Physics DTs





Signal: VH events
Background: MC Background
21/22 Input Variables

Physics DTs: Input Variables

- 21 (22) input variables
- Remove five variables at a time
- Set CLFit2 limits using physics DT as final variable

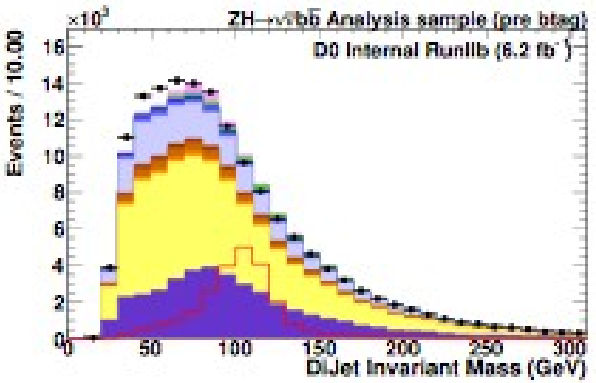
# Variables	6,7	11,12	16,17	21,22
RunIIb1	8.21	8.05	8.01	8.18
RunIIb23	4.54	4.13	4.16	4.18
Combined	3.98	3.66	3.65	3.74

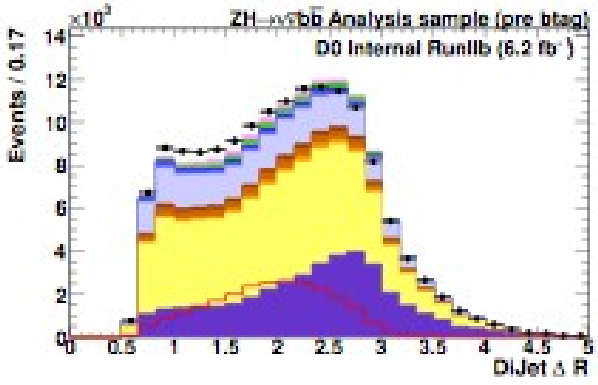
Physics DTs: Input Variables

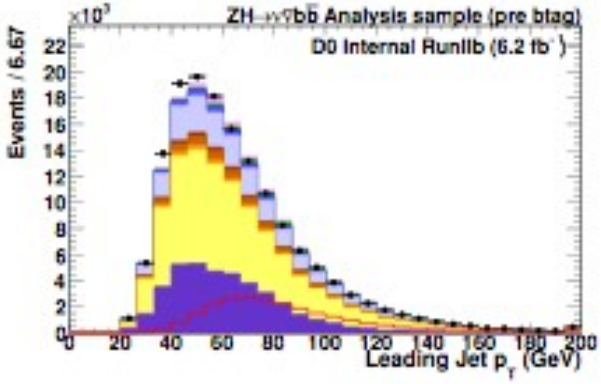
Higgs η

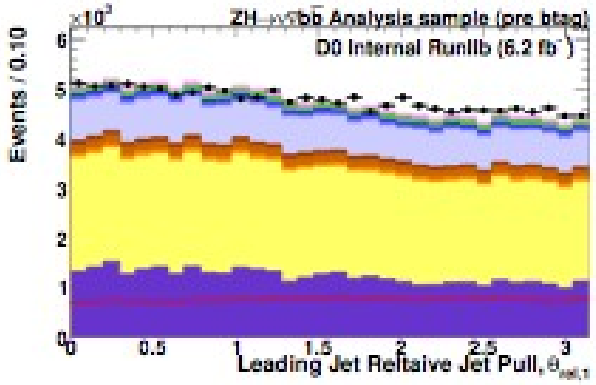
-ΔR

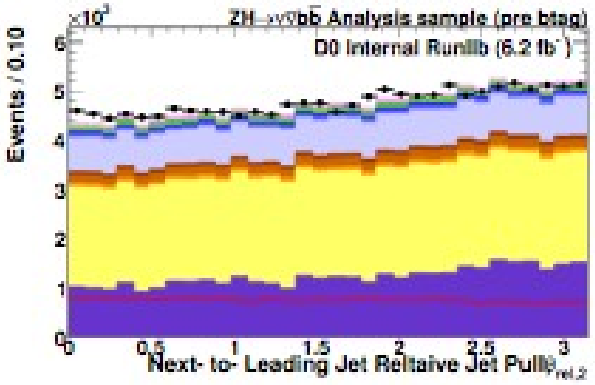
L Jet Pt

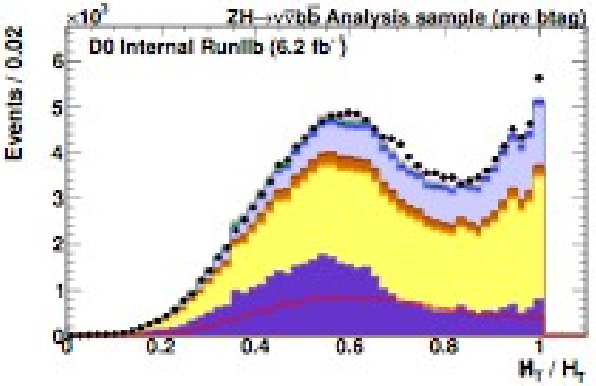












Jet Pull L Jet

Jet Pull NL Jet

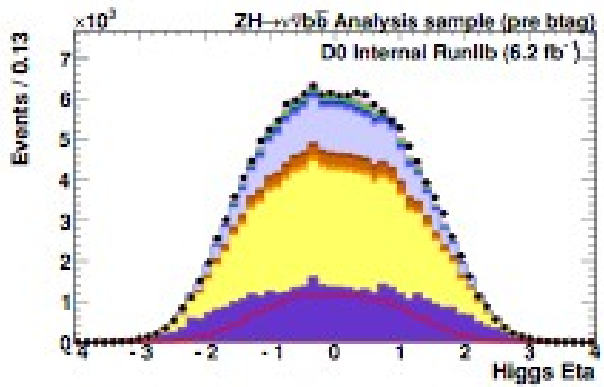
MHT/HT

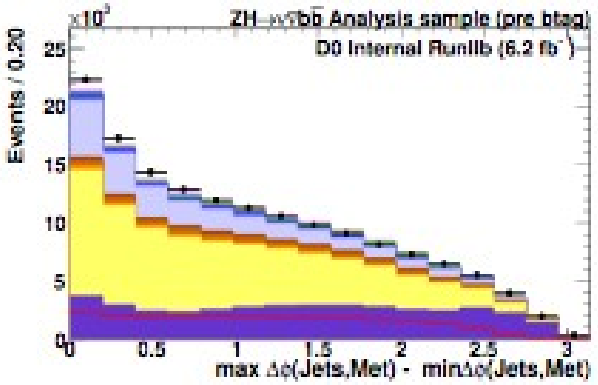
Physics DTs: Input Variables

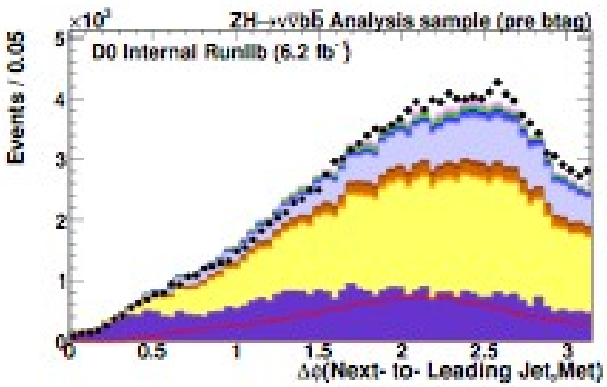
Higgs η

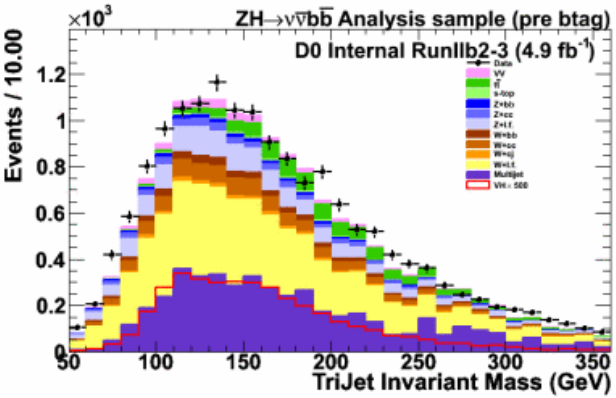
-Δφ

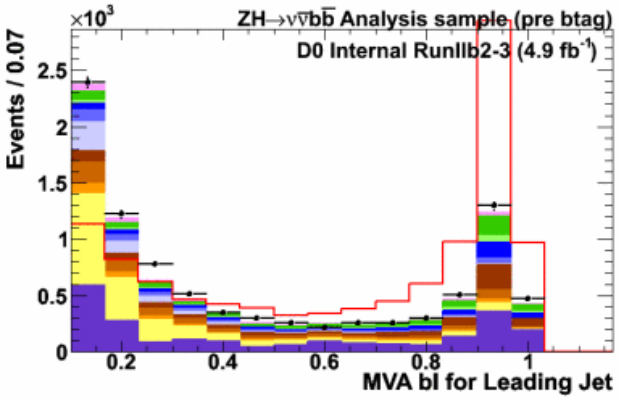
Δφ(MET, NLJet)

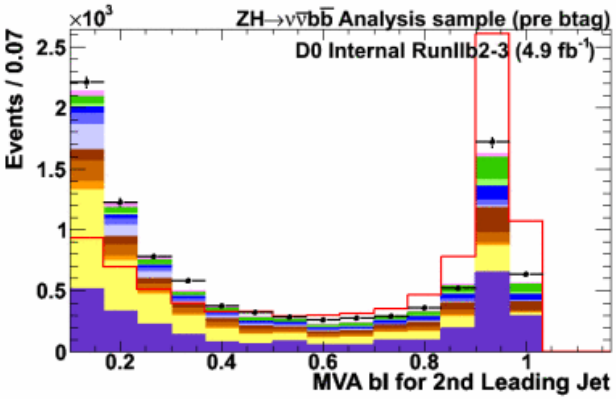










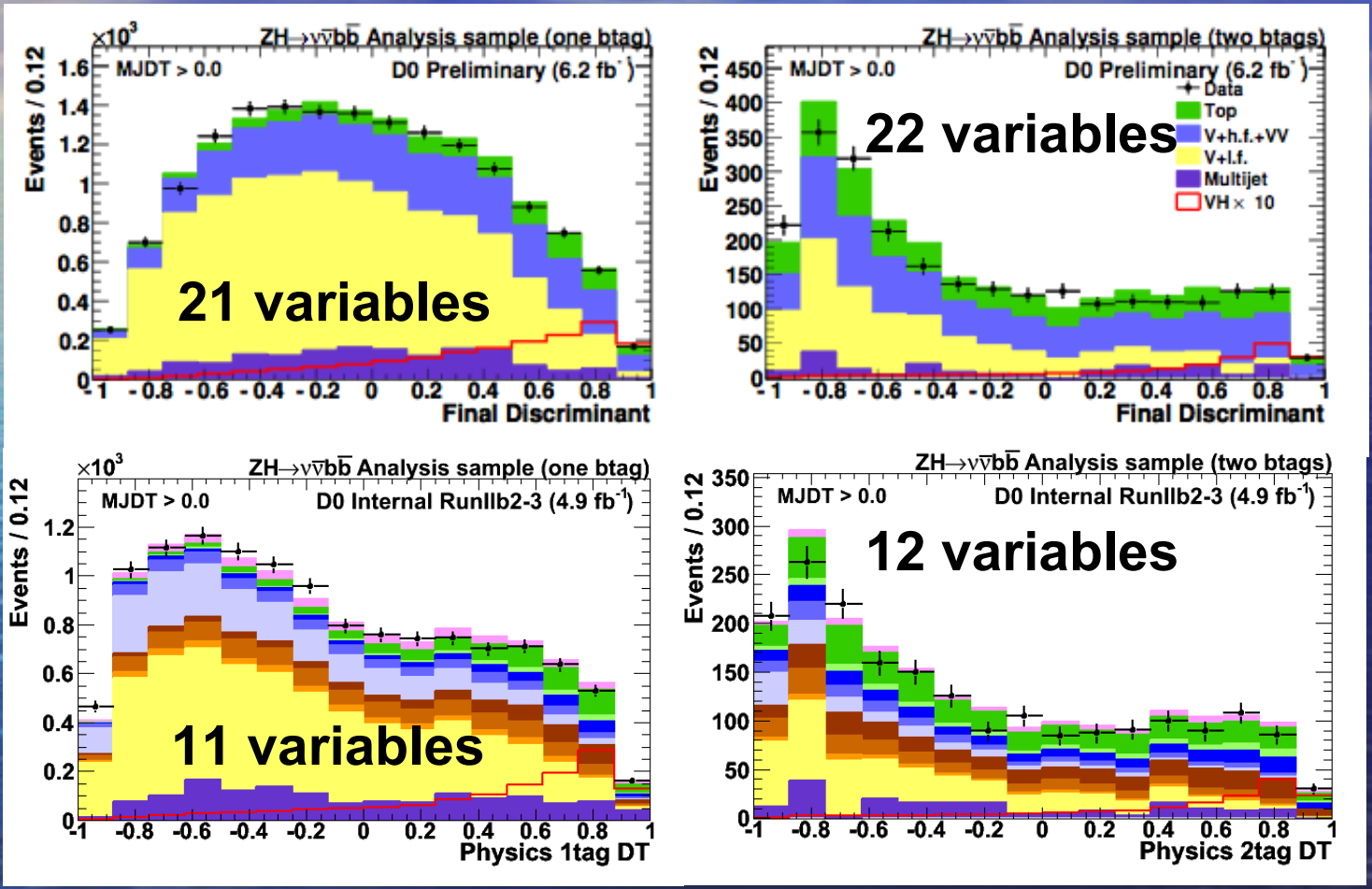


M (3Jet)

MVA bl (L Jet)

MVA bl (NL Jet)

Physics DTs



Reduced DTs: limits change from 3.6 to 3.6 (!)
1 tag channel: limits improve from 20.4 to 18.7

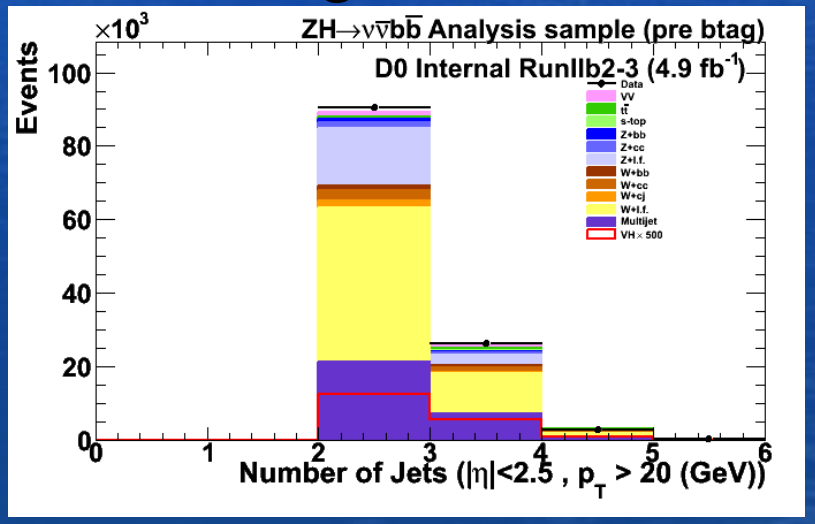
Final Variable Binning

- Tested binning of Physics DTs
- No visible improvement from increasing number of bins (originally used 16)

# Bins	2	8	*16*	25	40	50
RunIIb1	12.16	9.16	*8.23*	8.69	8.13	8.97
RunIIb23	7.04	4.48	*3.99*	4.24	4.04	4.52
RunIIb	6.2	3.98	*3.5*	3.75	3.59	4.03

Plans

- No further (major) updates to MVAs for EPS
- Investigating third jet tagging
  - Includes more signal and background events
- Possible to use 3-jet and 2-jet DTs
- Can also train separate DTs for $t\bar{t}$, WH



Summary

- Reviewed DTs used in ZH$\nu\nu$bb analysis
- No overall gains in sensitivity
  - ~8% gain in 1 tag channel
- Have identified “core” DTs
- Have confirmed previous findings

Additional Slides

Tests

- Merged DTs (complete for MJ)
- Input variables (complete)
- Training methods and final binning (complete)
- Separate DTs (to do)
  - By Jet multiplicity
  - By background and signal (ZH/WH)

Final DT Variables

- MJDT:
  - METMU, M, TM, MHT, Di-Jet Pt
- Physics:
  - M, M (3jet), LJetPt, leading jet colorPhi, second jet colorPhiNLJ, Jet ΔR, MHT/HT, -ΔPhi, ΔPhi(MET, NL Jet) Higgs η, MVA bl

1-tag Physics DT Variables

100	110	115	120	130	140	150
DIM	MVAblLJ	MVAblLJ	NLJ Δφ	DIM	DIM	DIM
MVAblLJ	DIM	DIM	MVAblLJ	MHT/HT	MVAblLJ	Δη
Higgs η	NLJ Δφ	colorφLJ	DIM	Higgs η	MHT/HT	MHT/HT
colorφNL	- Δφ	MHT/HT	Higgs η	TM	NLJ Δφ	MVAblLJ
colorφLJ	colorφNL	Higgs η	colorφNL	MVAblLJ	Higgs θ	TM
- Δφ	Higgs θ	NLJ Δφ	ΔR	colorφNL	colorφLJ	colorφNL
NLJ Δφ	colorφLJ	TM	MHT/HT	colorφLJ	TM	NLJ Δφ
MHT/HT	MHT/HT	Δη	Δη	METMU	LJ pt	Higgs η
TM	NLJ pt	colorφNL	DiJetSubt	Σ	Δη	colorφLJ
LJ pt	Δη	- Δφ	- Δφ	NLJ Δφ	colorφNL	Σ

Color Variables:

http://www-d0.hef.kun.nl//askArchive.php?base=agenda&categ=a10614&id=a10614s1t169/transparencies

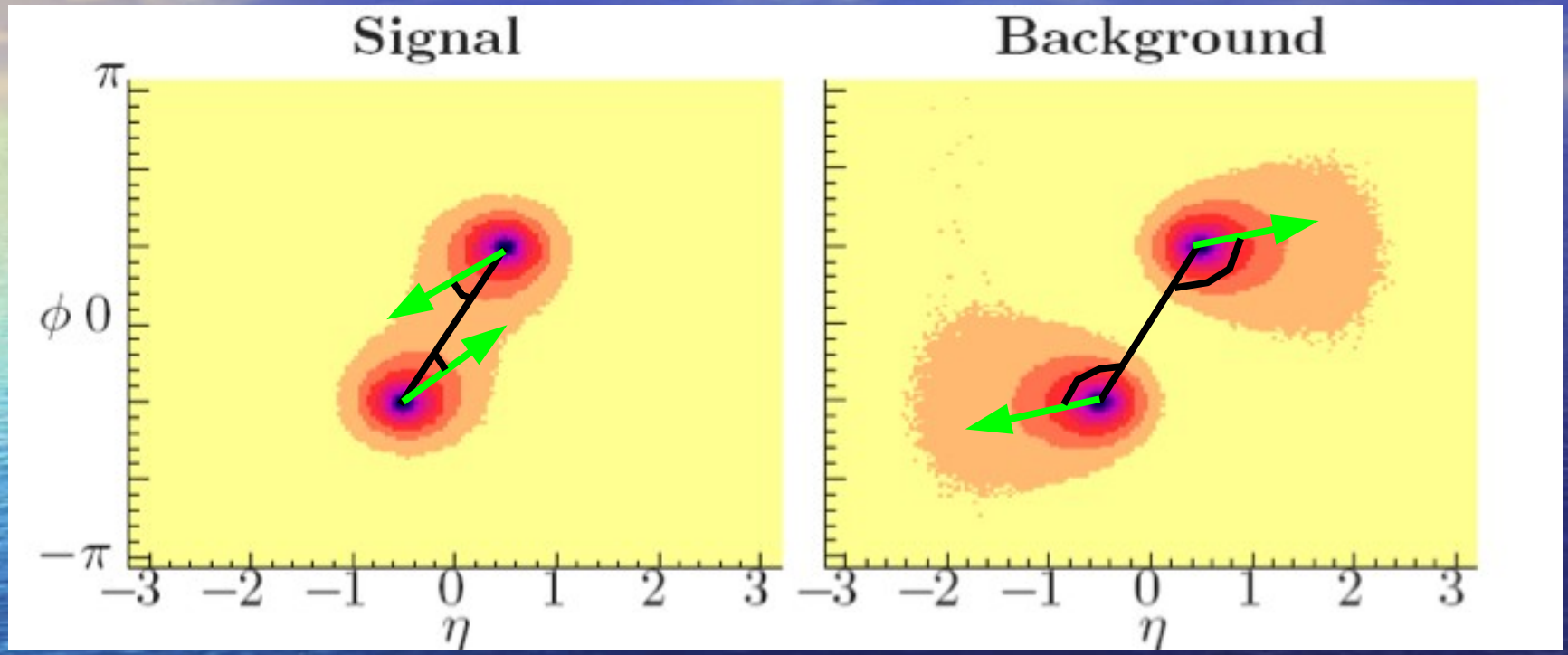
2-tag Physics DT Variables

100	110	115	120	130	140	150
MVAblNL	MVAblNL	MVAblLJ	MVAblLJ	MVAblLJ	MVAblLJ	MVAblLJ
MVAblLJ	MVAblLJ	MVAblNL	MVAblNL	MVAblNL	MVAblNL	TM
DIM	DIM	DIM	DIM	DIM	TM	DIM
Δη	colorφNL	Δη	TM	TM	DIM	MVAblNL
colorφLJ	Δη	ΔR	ΔR	ΔR	ΔR	ΔR
Higgs η	ΔR	Higgs θ	- Δφ	Δη	Δη	colorφNL
MHT/HT	- Δφ	TM	Δη	NLJ Δφ	METMU	NLJ Δφ
ΔR	TM	METMU	Higgs η	Higgs η	colorφNL	Δη
NLJ Δφ	Σ	- Δφ	colorφNL	colorφNL	NLJ pt	Higgs η
LJ pt	NLJ Δφ	NLJ Δφ	NLJ Δφ	METMU	LJ pt	METMU

Testing Methods

- Two desired properties:
  - Must show good signal/background separation
  - Must be modeled well in MC
- Testing Multijet DT:
  - Set limits using dijet inv. mass with MJ DT Cut
  - Compare number of data and background events after cut
- Physics DTs: set limits, check agreement

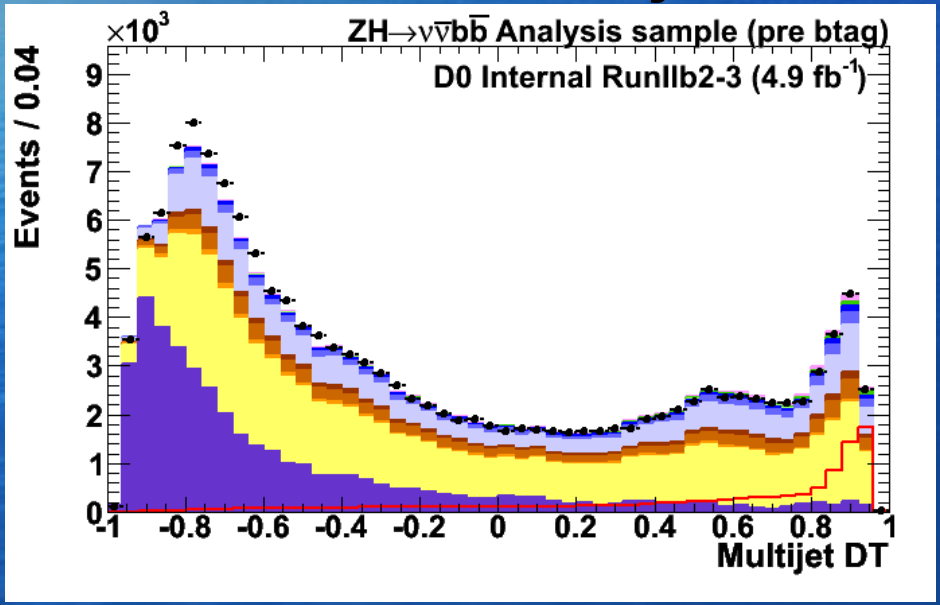
Colour Flow Angles



- Jet colour causes pull on jets
- E_T weighted average of calorimeter cells defines pull vector

MJ DT: Merging Epochs

- Trained a merged RunIIb DT
- Set limits on di-jet mass after MJ DT cut



- All systematics included
- No gain from merging