

ZHH Analysis.

WBF observables

Julie Munch Torndal
Analysis meeting
May 11, 2026

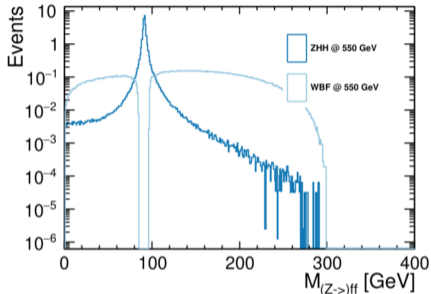
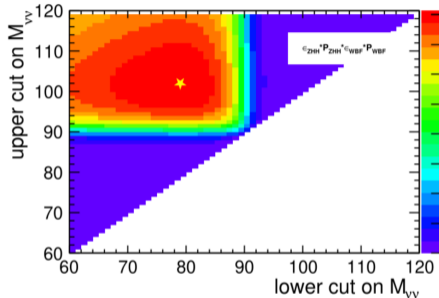


HELMHOLTZ



Slide from Jan 2, 2025

Separating WBF and ZHH with cut on $M_{\nu\nu}$



Max $\epsilon_{ZHH} * p_{ZHH} * \epsilon_{WBF} * p_{WBF}$ with cut window at **79 GeV to 102 GeV** (after setting negative bin content to zero...)

$$\epsilon_{ZHH} = 0.9177 \quad , \quad p_{ZHH} = 0.9860$$

$$\epsilon_{WBF} = 0.9913 \quad , \quad p_{WBF} = 0.9009$$

- prioritises purity for ZHH and efficiency for WBF → keep more WBF events for BDT training

Cross sections

E_{CM} 550 GeV	$eeHH$	$\mu\mu HH$	$\tau\tau HH$	$\nu_e\nu_e HH$	$\nu_{\mu,\tau}\nu_{\mu,\tau} HH$	$qqHH$
σ_{LR} [fb]	0.0132	0.0127	0.0126	0.0407	0.0501	0.256
σ_{RL} [fb]	0.00832	0.00811	0.00809	0.0160	0.0320	0.164
σ_{LL} [fb]	0.000512					
σ_{RR} [fb]	0.000512					
$\sigma_{(-0.8,0.3)}$ [fb]	0.00820	0.00769	0.00767	0.0244	0.0304	0.155
N_{exp}	16.4	15.4	15.3	48.8	60.8	311
	$\ell\ell HH$		$\nu_\ell\nu_\ell HH$		$qqHH$	
$\sigma_{(-0.8,0.3)}$ [fb]	0.024		0.055		0.16	
N_{exp}	47		110		310	

In cross sections, 17% of events from WBF+interference:

$$(48, 8-30, 4)/(48, 8 + 60, 8) = 0.17$$

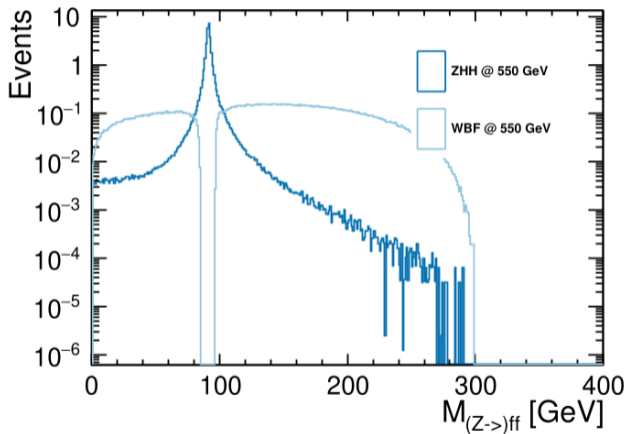
In training, 28% of events assigned as WBF events:

$$10, 5/(16, 5 + 20, 6) = 0.28$$

→ cross check bias between wbf from cut on $M_{\nu\nu}$ and subtracting histograms

	σ [fb]	expected events
$e\nu bbqq$	113	$2.27 \cdot 10^5$
$\mu\nu bbqq$	112	$2.25 \cdot 10^5$
$\tau\nu bbqq$	113	$2.26 \cdot 10^5$
$\nu\nu bbbb$	0.0662	132
$bbqqqq$	326	$6.52 \cdot 10^5$
$\nu\nu bb$	168	$3.35 \cdot 10^5$
$\tau\tau bb$	13.9	$2.79 \cdot 10^4$
$bbbb$	12.2	$2.44 \cdot 10^4$
$qqbb$	147	$2.94 \cdot 10^5$
ttH	1.32	$2.64 \cdot 10^3$
ttZ	3.38	$6.75 \cdot 10^3$
$\nu\nu qqH$	0.418	837
Other bkg	$3.08 \cdot 10^4$	$6.15 \cdot 10^7$
Total bkg	$3.18 \cdot 10^4$	$6.36 \cdot 10^7$
$\nu\nu HH$	0.0548	110
($\nu 23\nu 23 bbbb$)	0.0103	20.6
($\nu 1\nu 1 bbbb$)	0.00827	16.5
(WBF)	0.00524	10.5

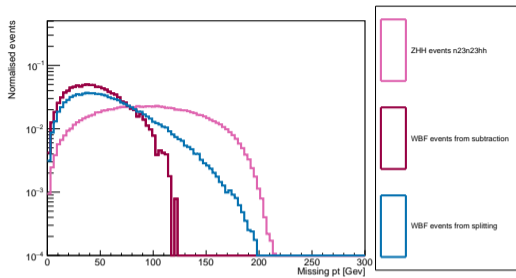
ZHH/WBF splitting



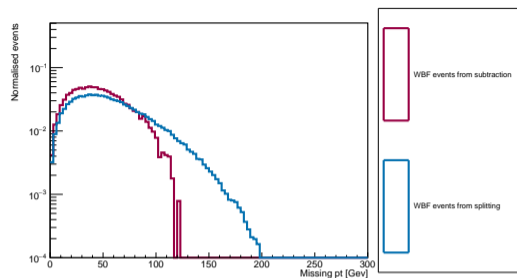
Expected $\nu\nu bbb$ events from wbf: 6.0
cut windows:

- $79 \text{ GeV} < M_{\nu\nu} < 102 \text{ GeV}$: 8.7 events
- $|M_{\nu\nu} - M_Z| < 20 \text{ GeV}$: 7.8 events
- $|M_{\nu\nu} - M_Z| < 30 \text{ GeV}$: 6.8 events
- $|M_{\nu\nu} - M_Z| < 40 \text{ GeV}$: 5.9 events

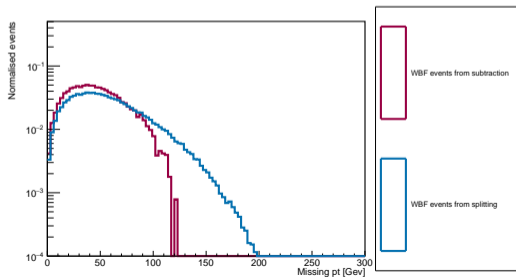
$79 \text{ GeV} < M_{\nu\nu} < 102 \text{ GeV}$:



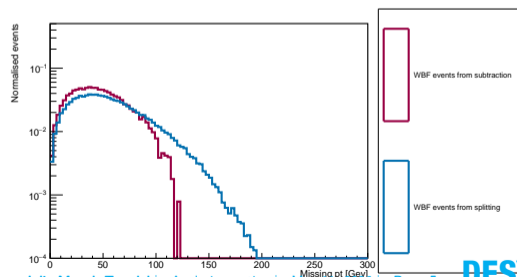
$|M_{\nu\nu} - M_Z| < 20 \text{ GeV}$:



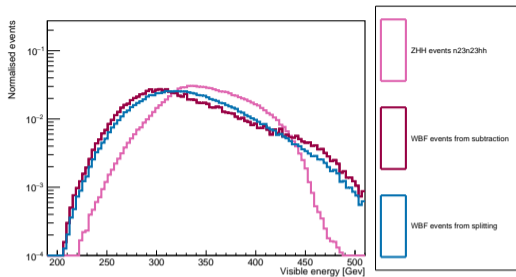
$|M_{\nu\nu} - M_Z| < 30 \text{ GeV}$:



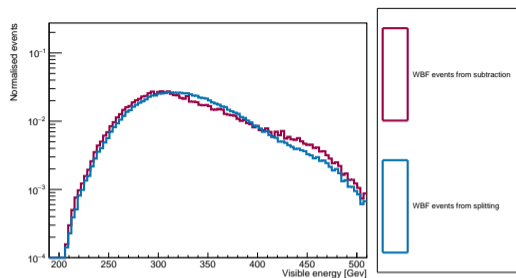
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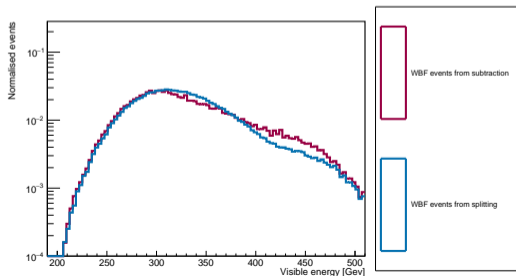
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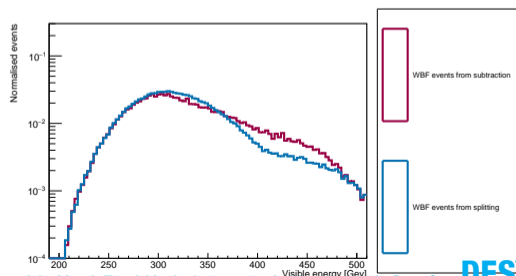
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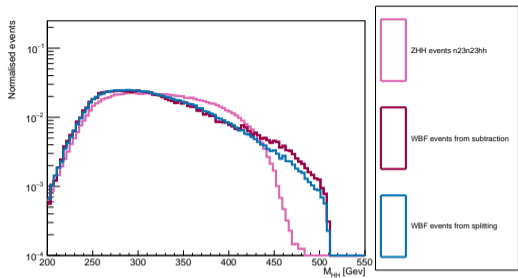
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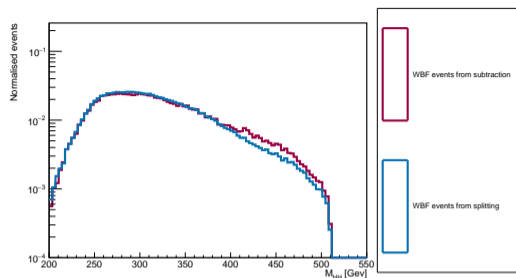
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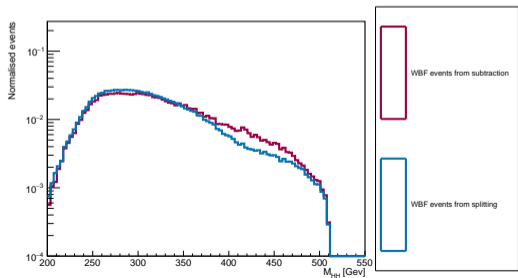
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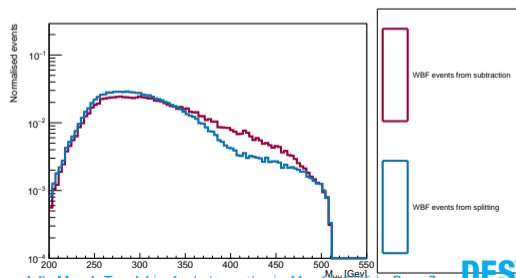
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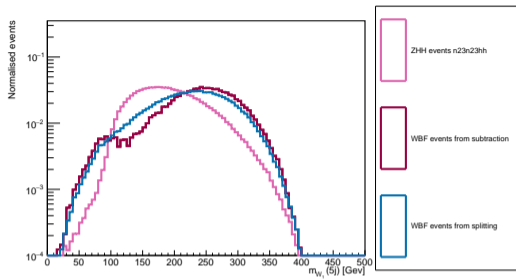
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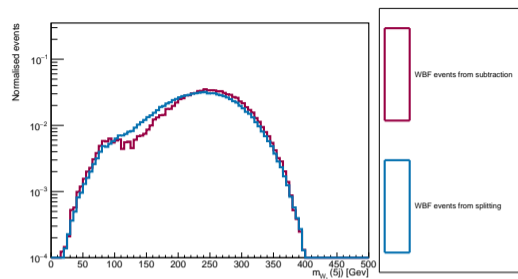
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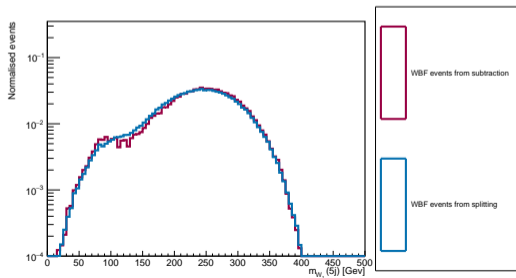
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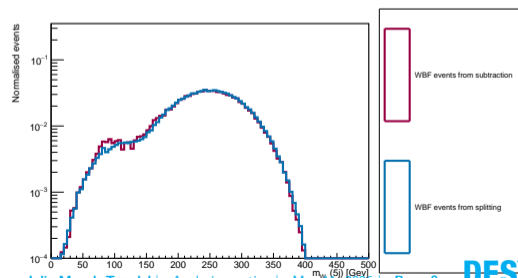
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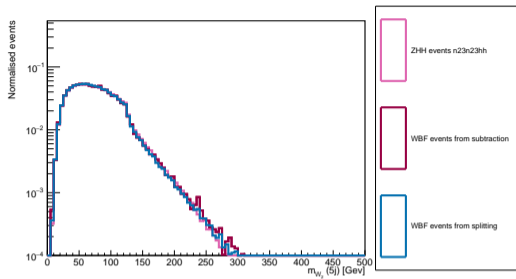
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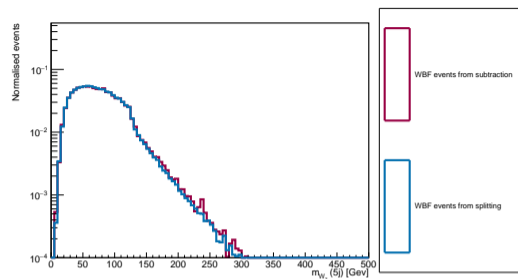
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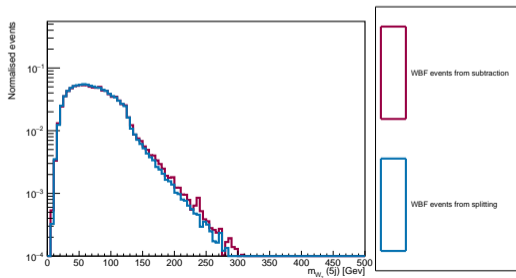
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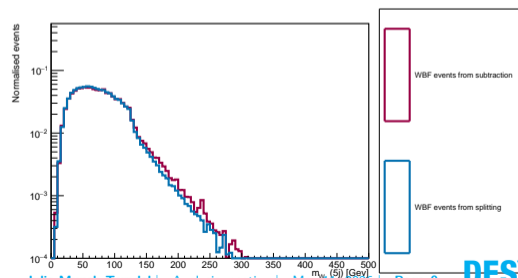
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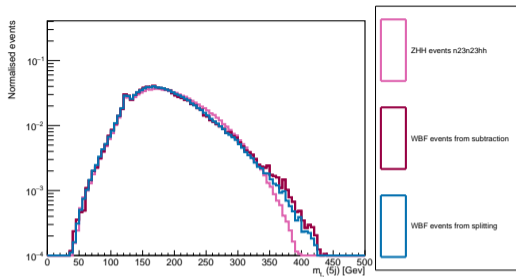
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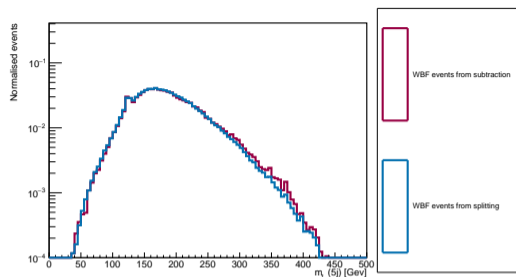
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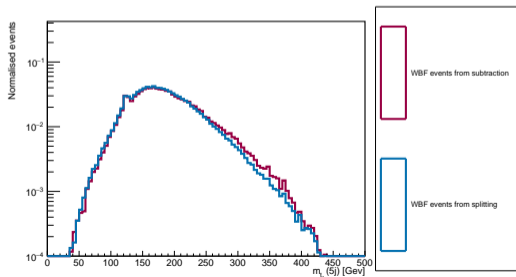
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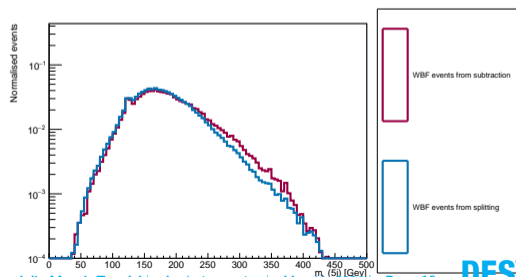
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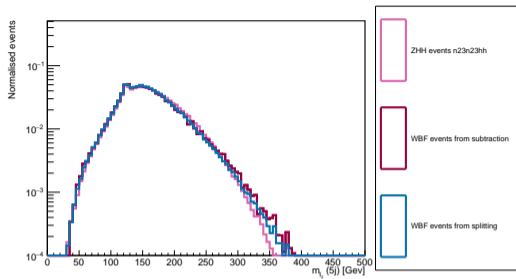
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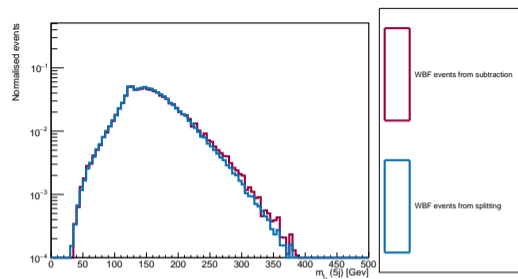
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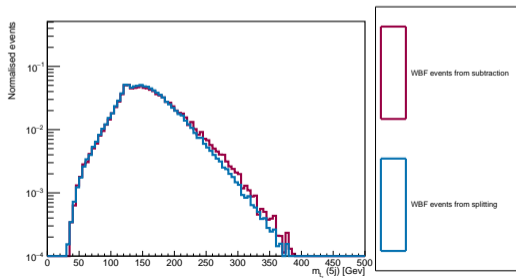
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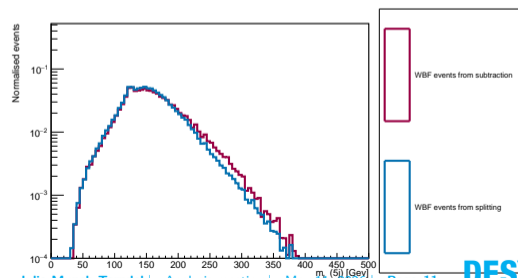
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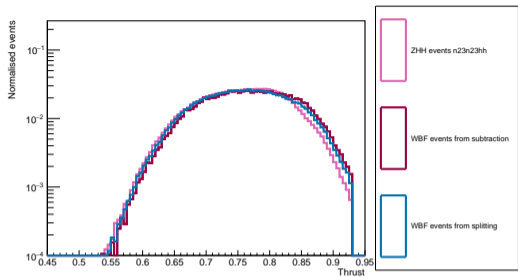
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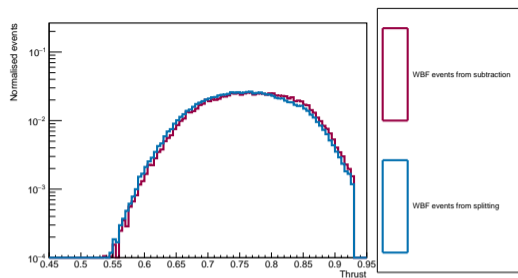
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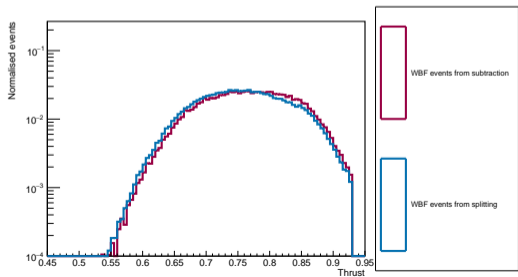
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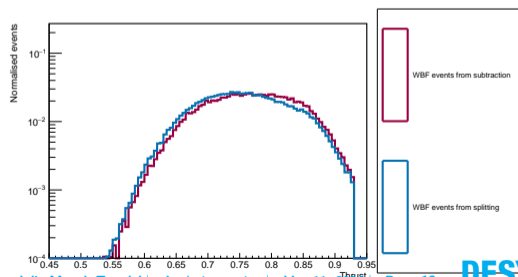
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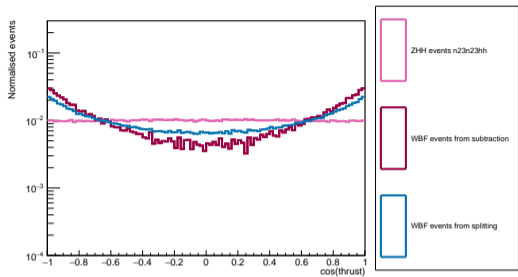
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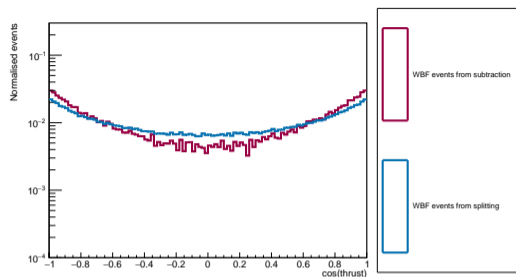
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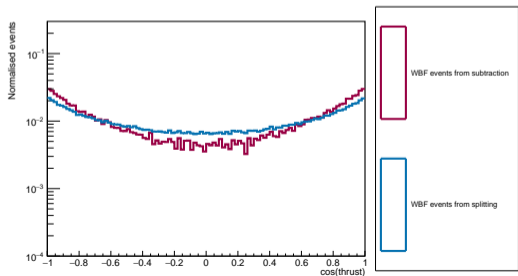
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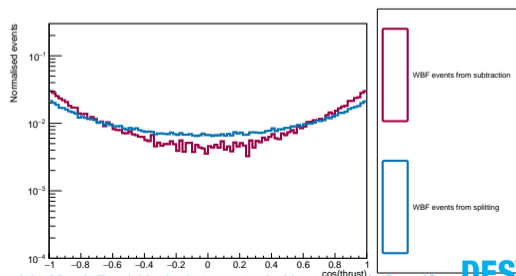
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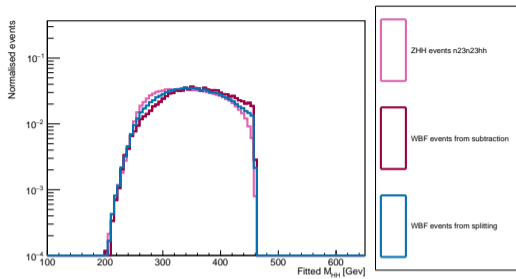
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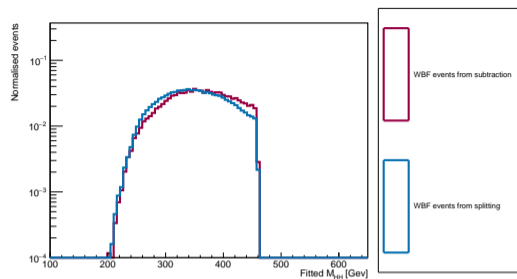
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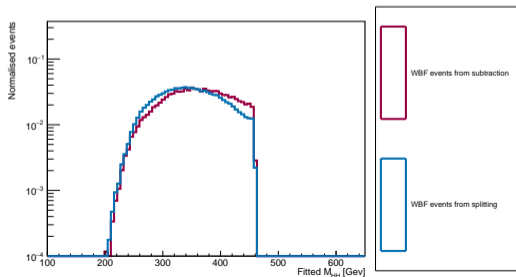
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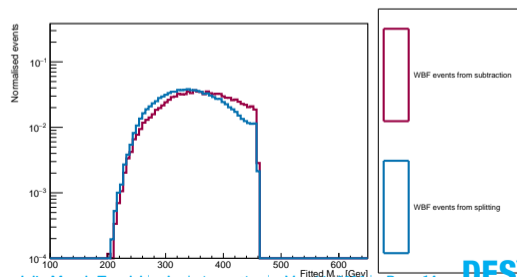
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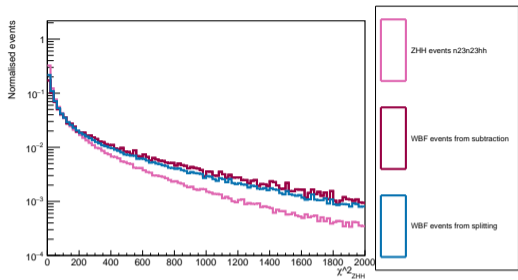
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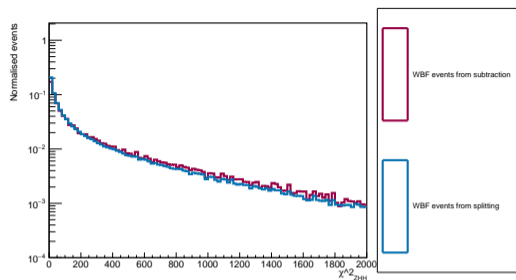
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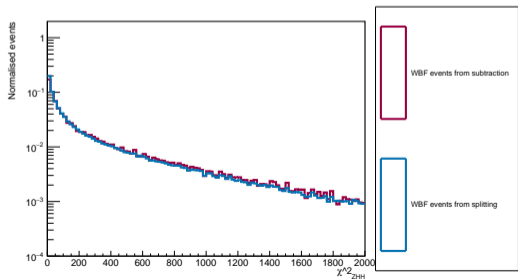
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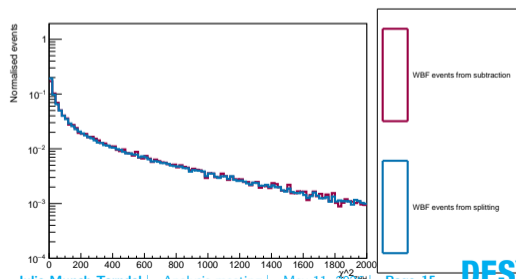
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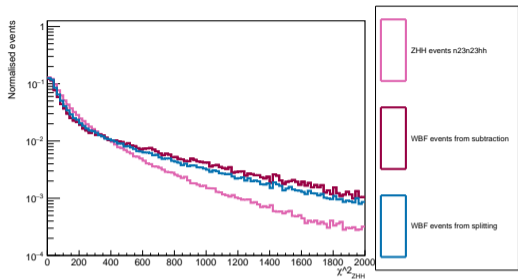
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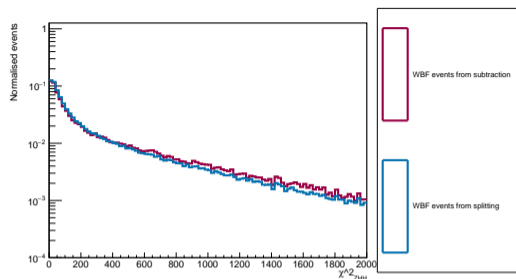
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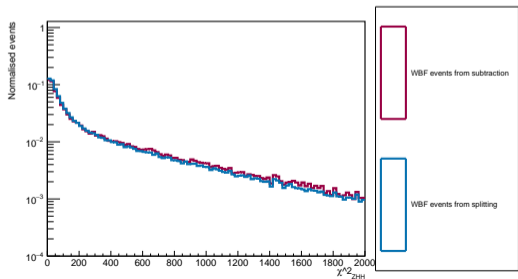
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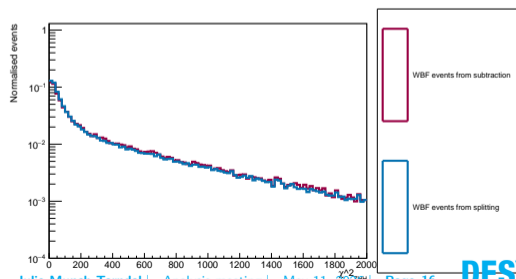
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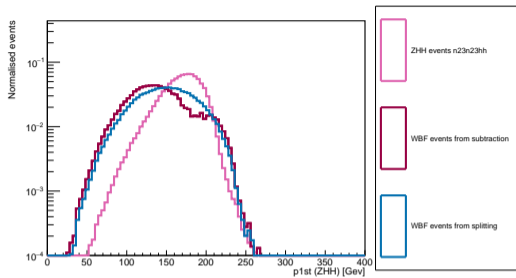
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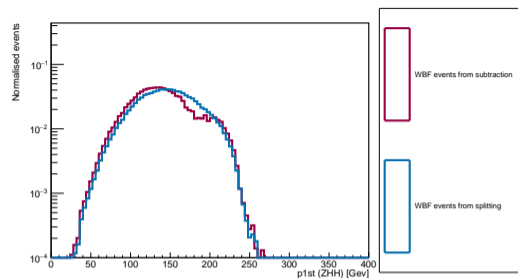
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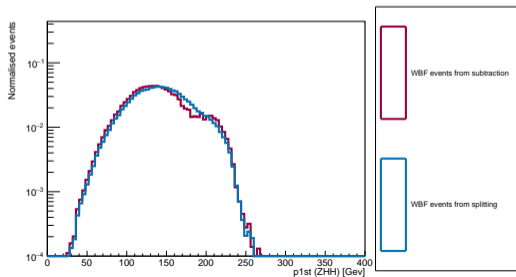
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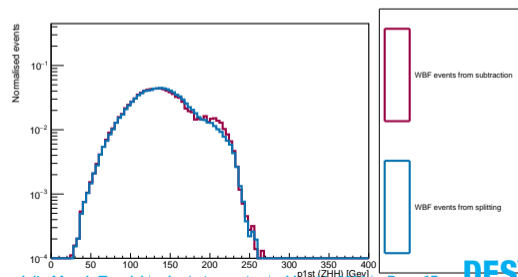
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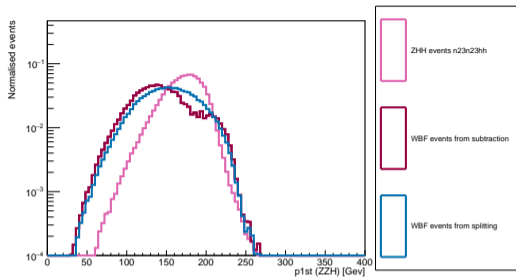
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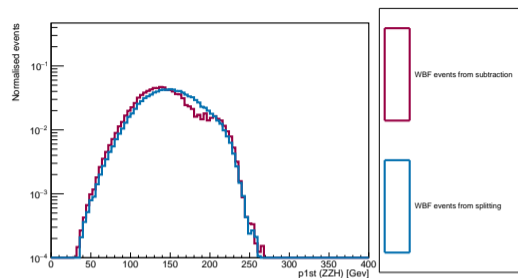
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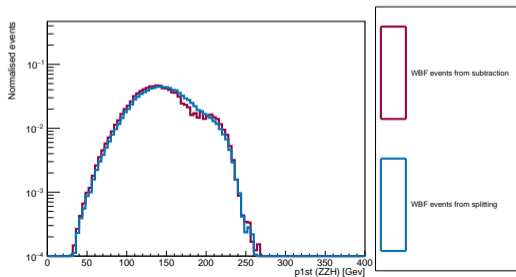
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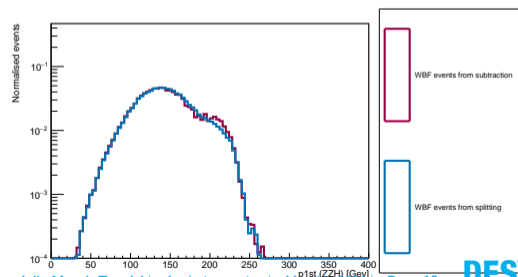
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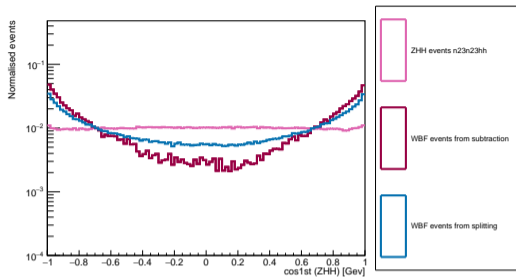
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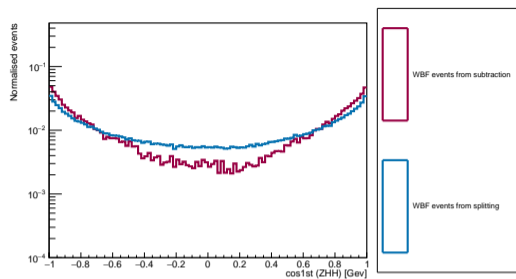
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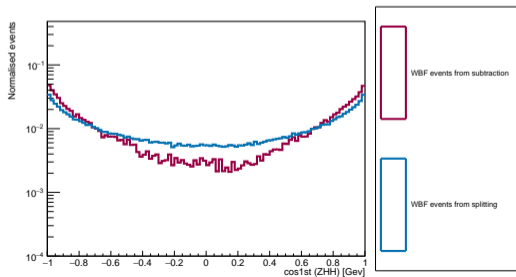
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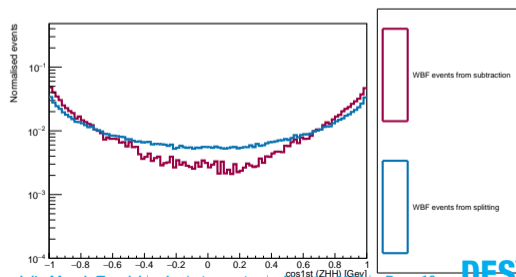
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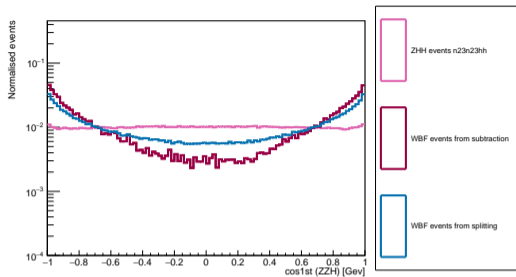
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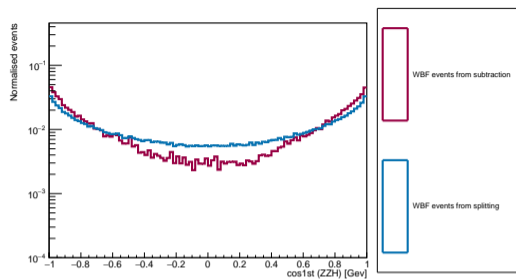
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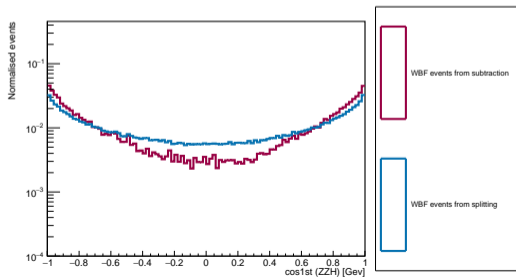
$79 \text{ GeV} < M_{\nu\nu} < 102 \text{ GeV}$:



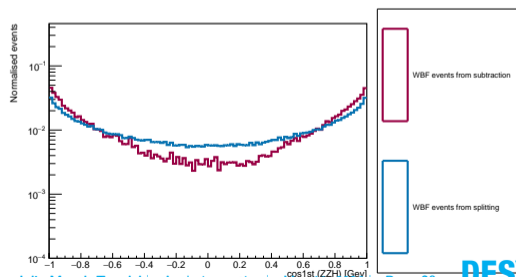
$|M_{\nu\nu} - M_Z| < 20 \text{ GeV}$:



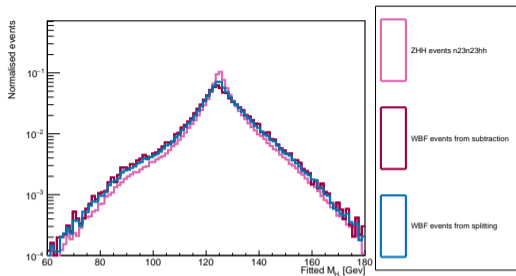
$|M_{\nu\nu} - M_Z| < 30 \text{ GeV}$:



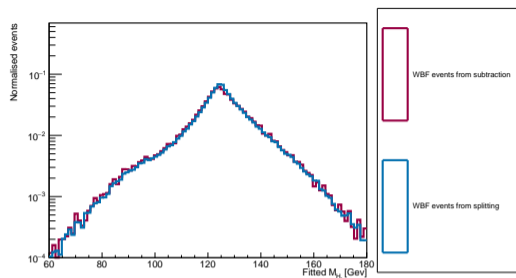
$|M_{\nu\nu} - M_Z| < 40 \text{ GeV}$:



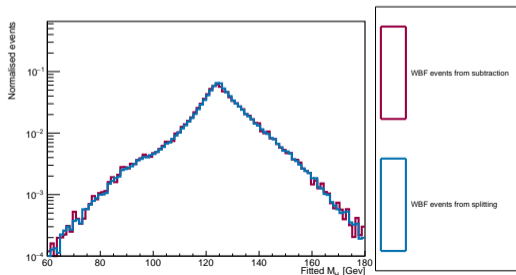
$79 \text{ GeV} < M_{\nu\nu} < 102 \text{ GeV}$:



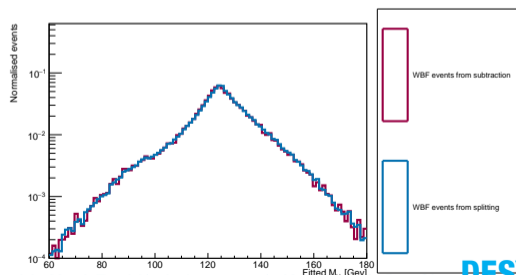
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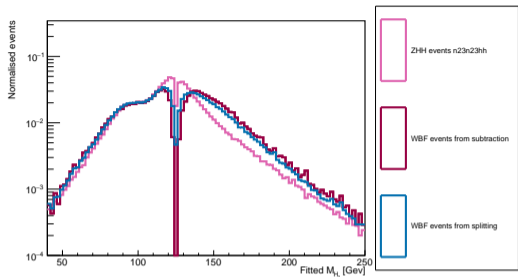
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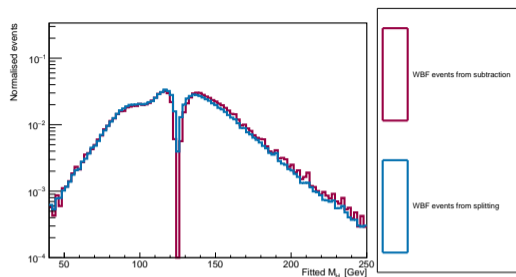
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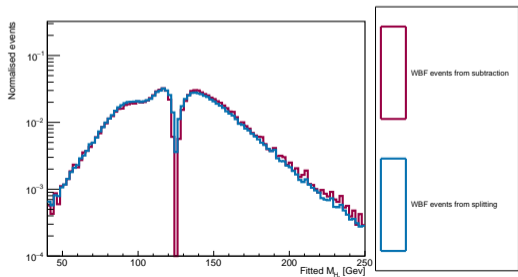
$79 \text{ GeV} < M_{\nu\nu} < 102 \text{ GeV}$:



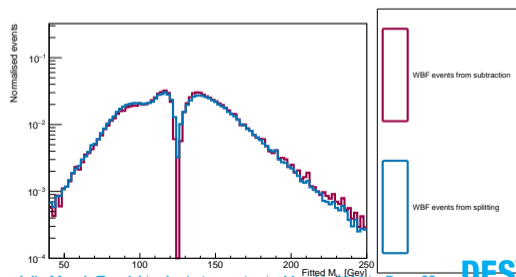
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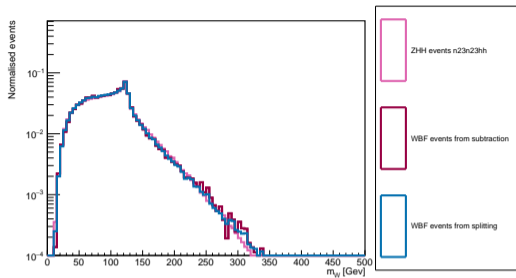
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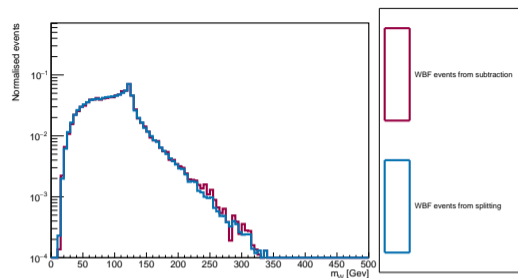
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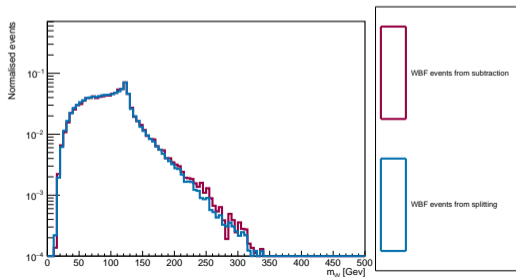
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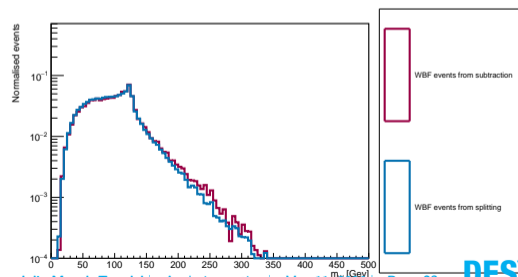
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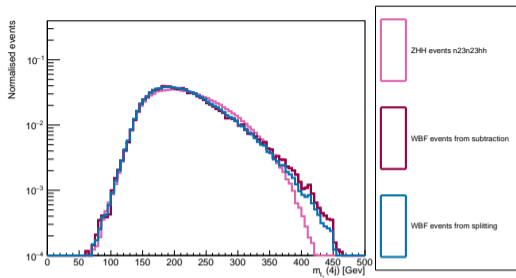
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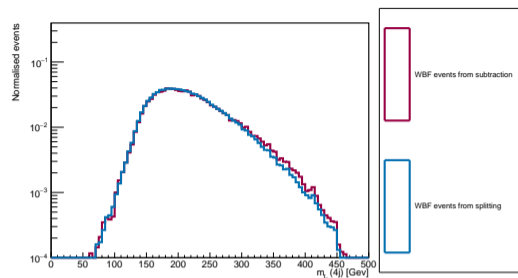
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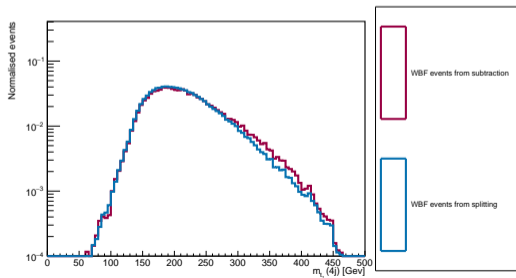
$79 \text{ GeV} < M_{\nu\nu} < 102 \text{ GeV}$:



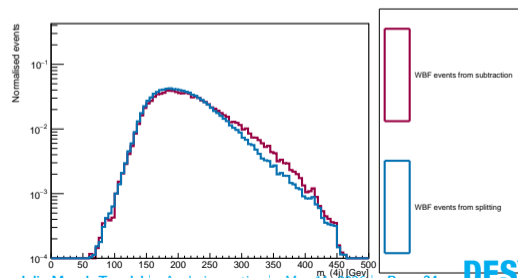
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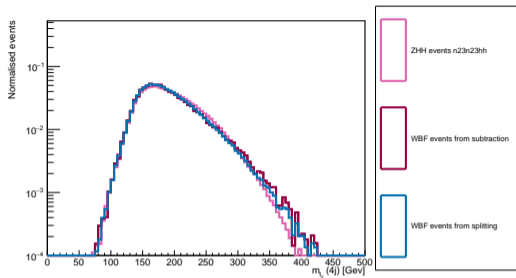
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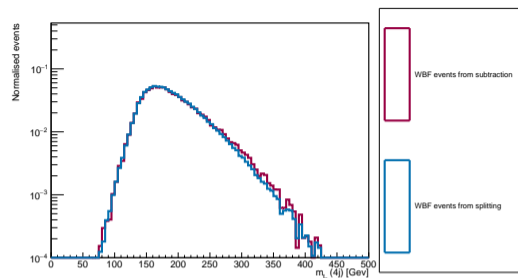
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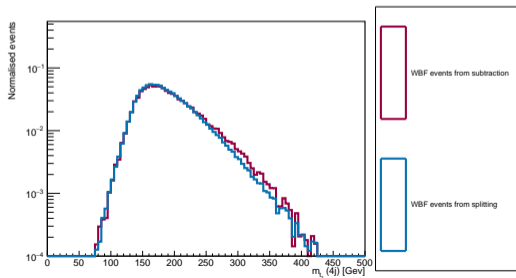
$79 \text{ GeV} < M_{\nu\nu} < 102 \text{ GeV}$:



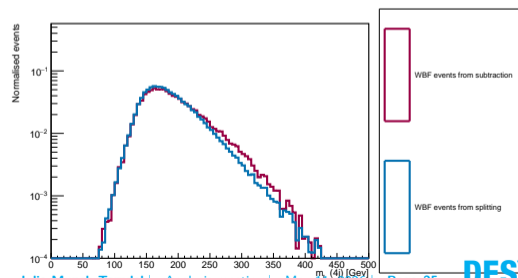
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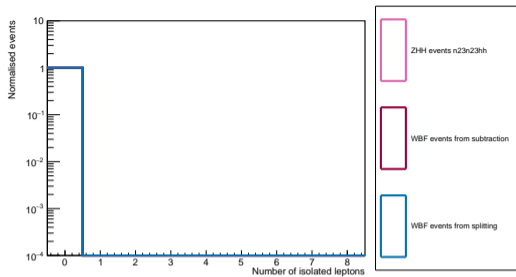
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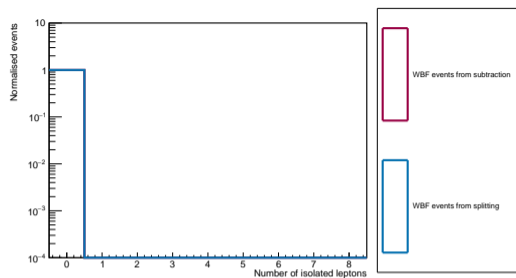
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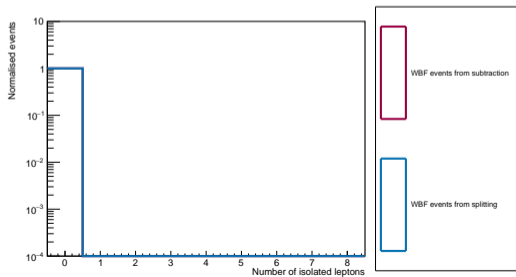
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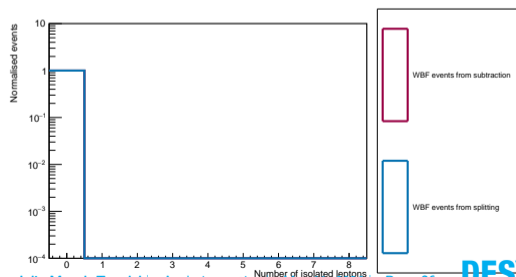
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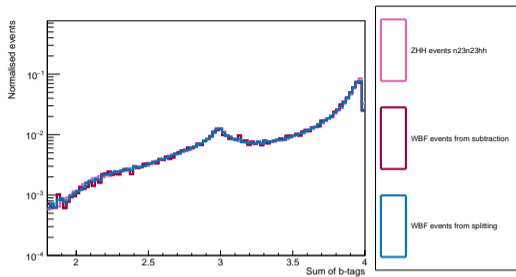
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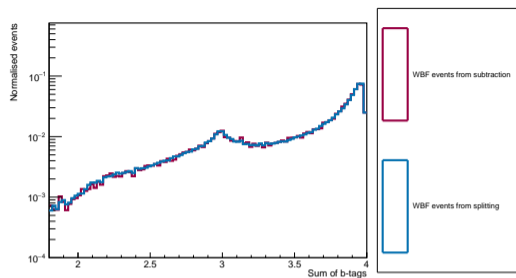
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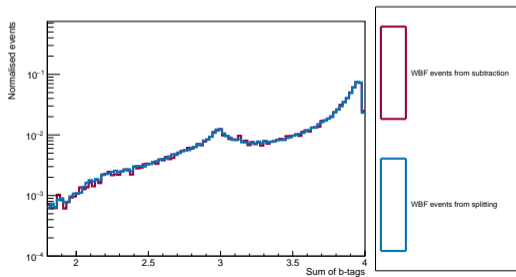
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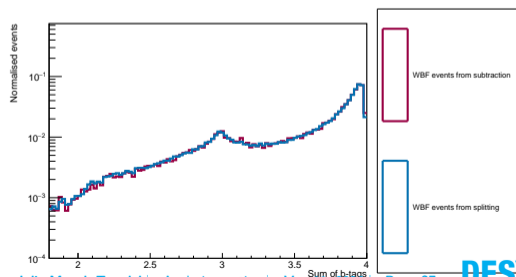
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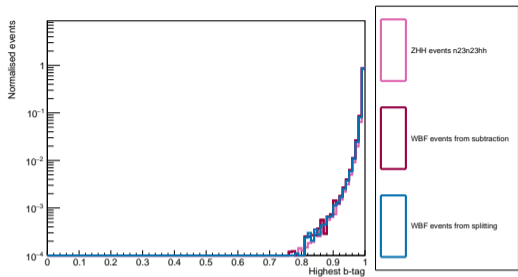
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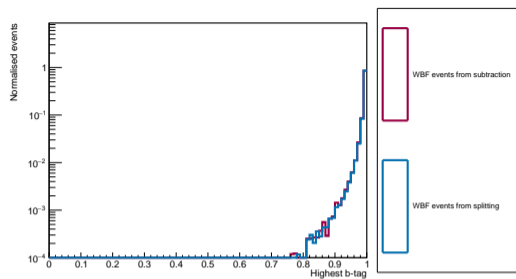
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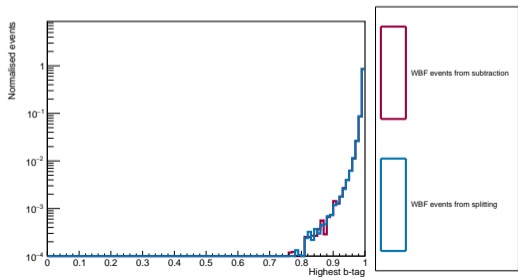
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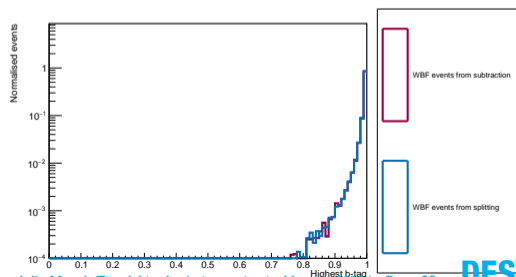
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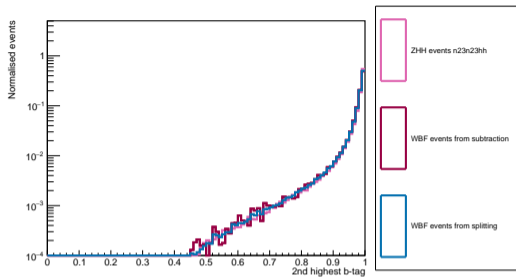
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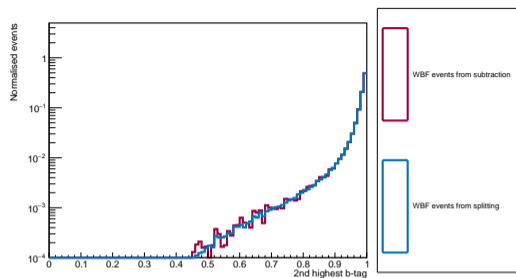
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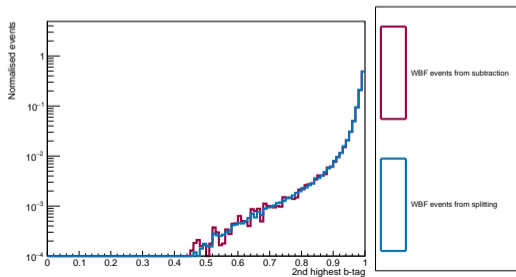
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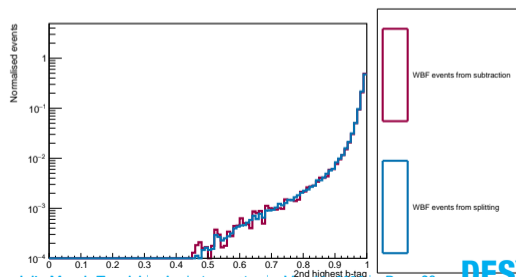
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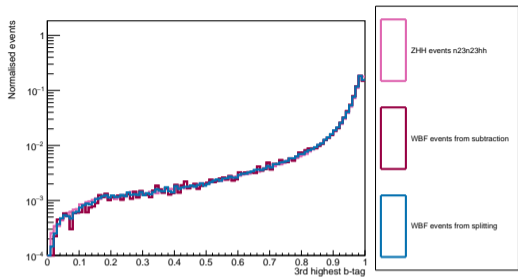
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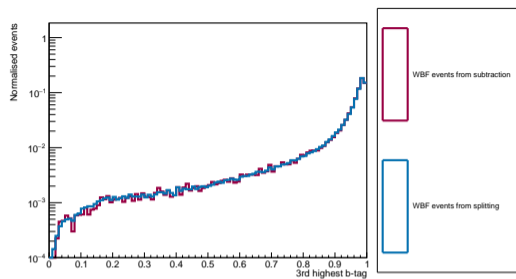
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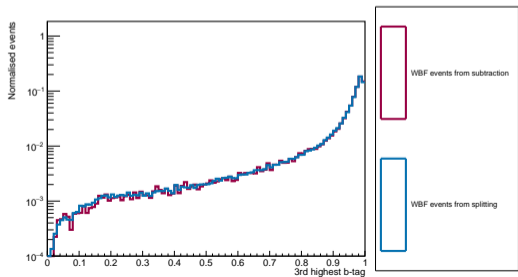
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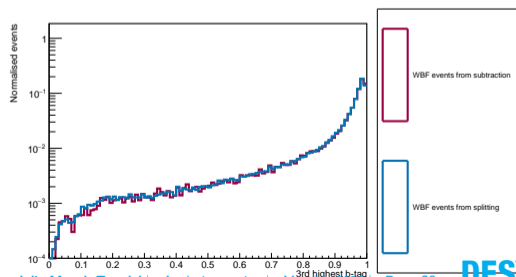
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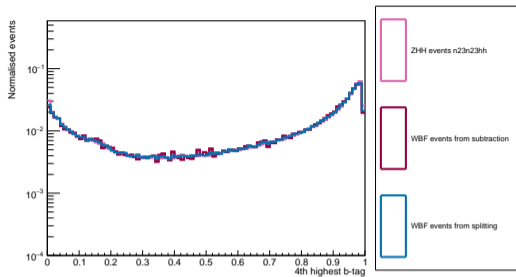
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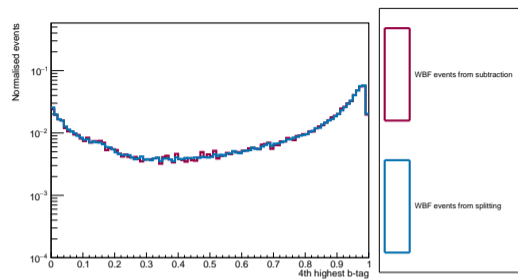
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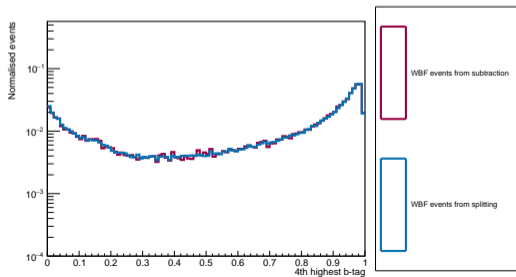
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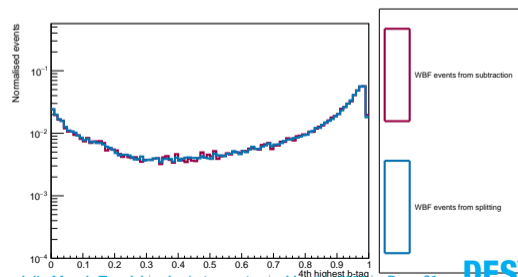
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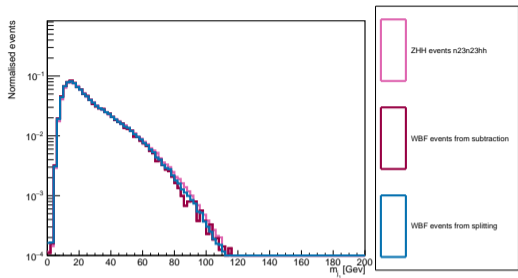
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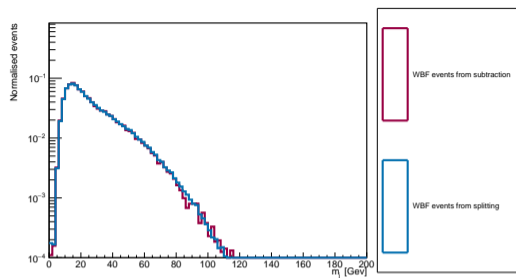
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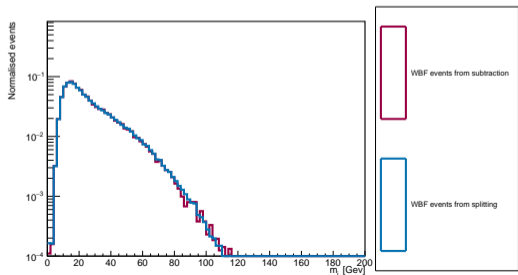
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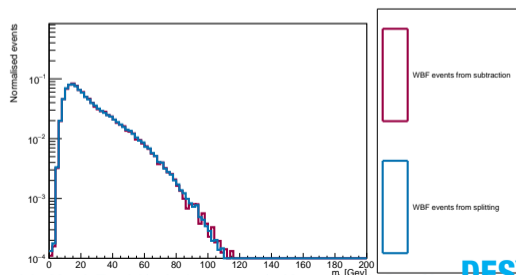
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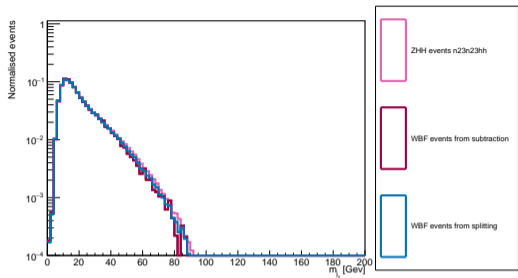
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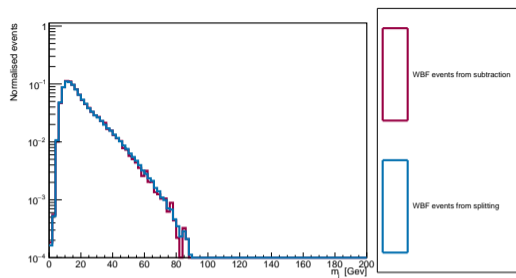
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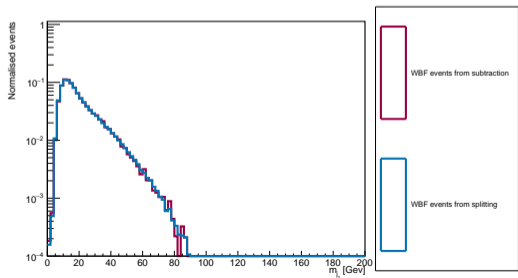
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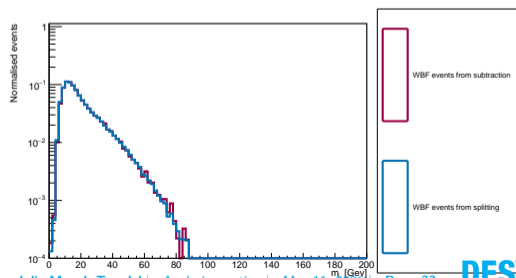
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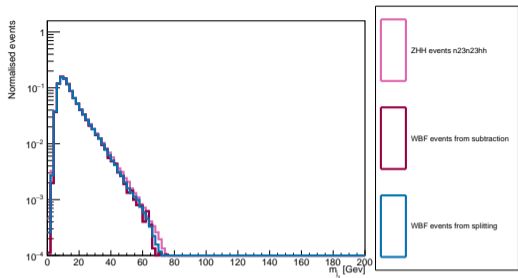
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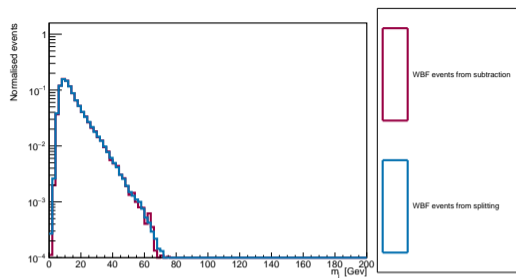
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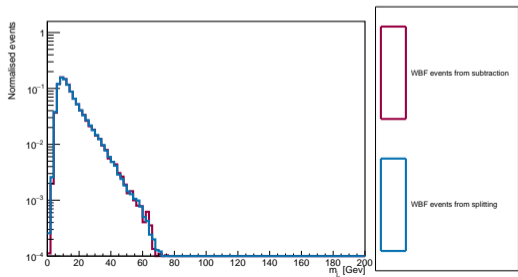
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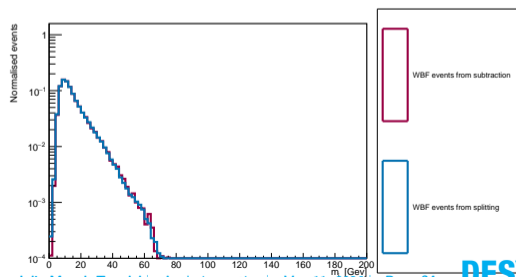
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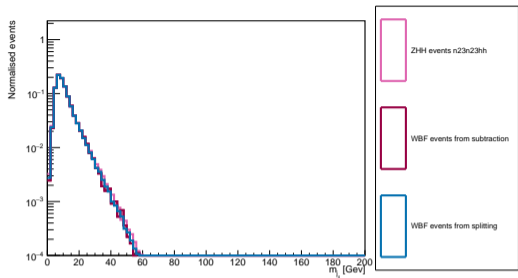
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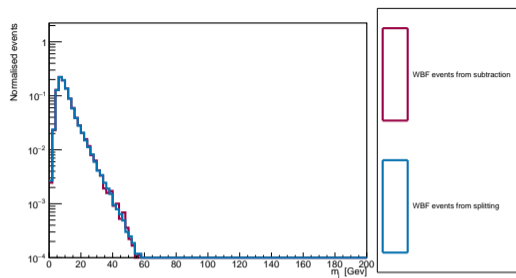
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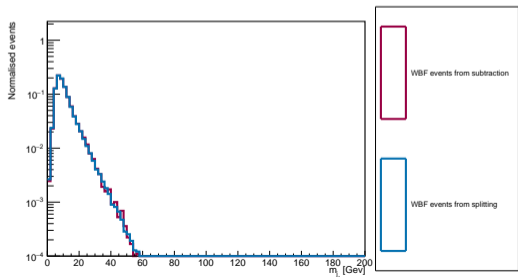
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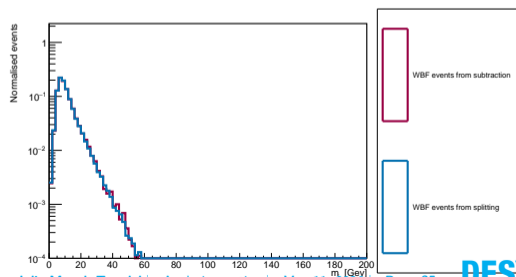
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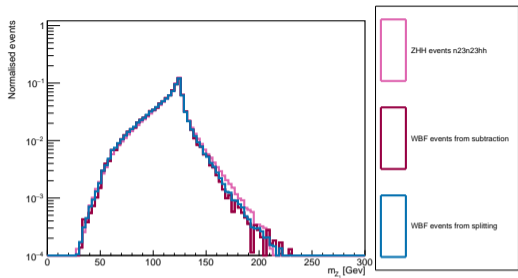
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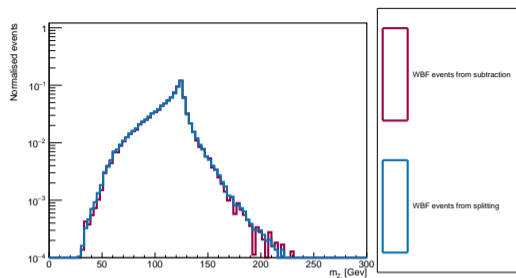
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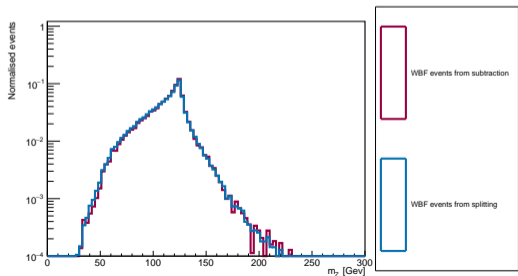
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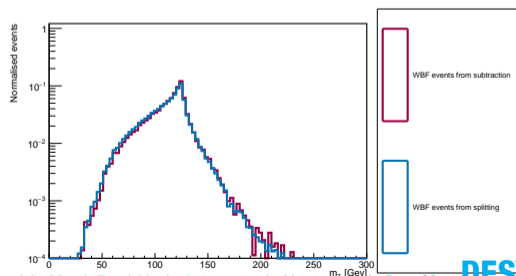
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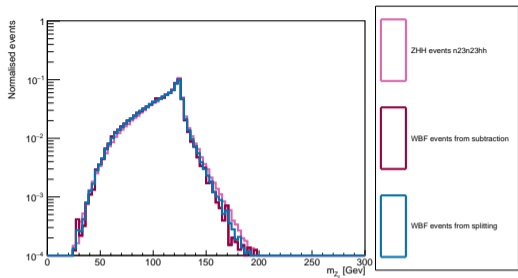
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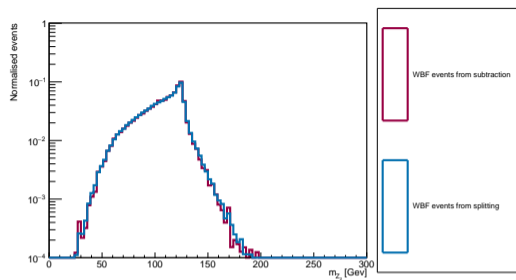
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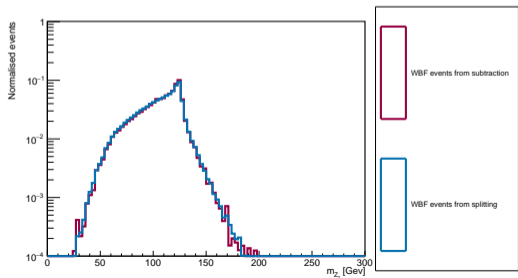
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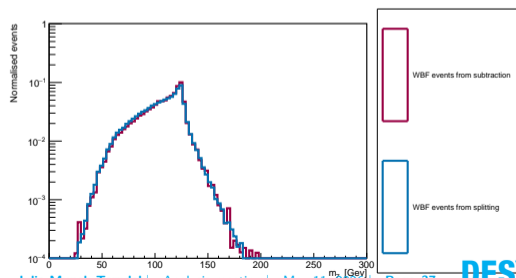
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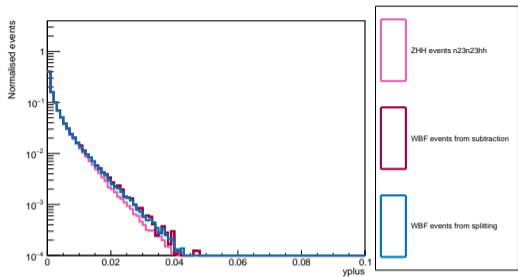
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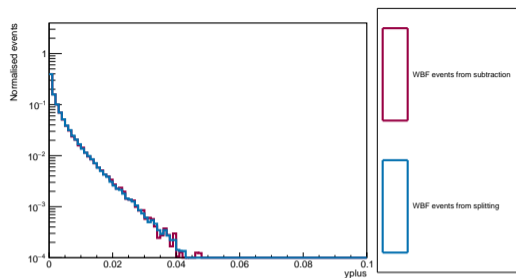
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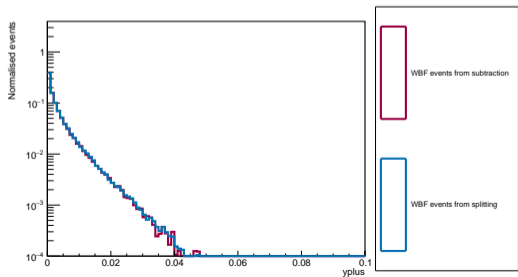
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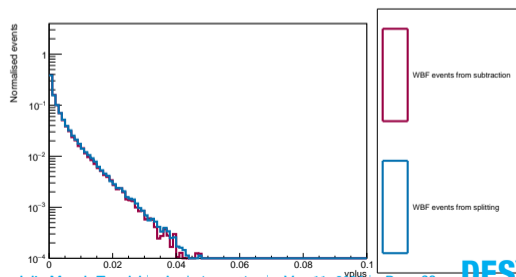
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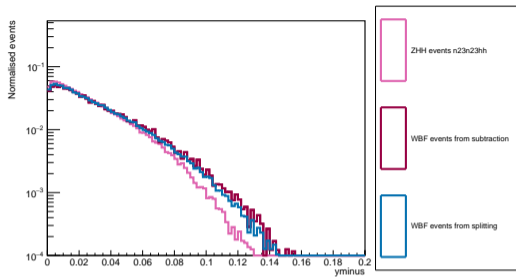
$|M_{\nu\nu} - M_Z| < 30 \text{ GeV}$:



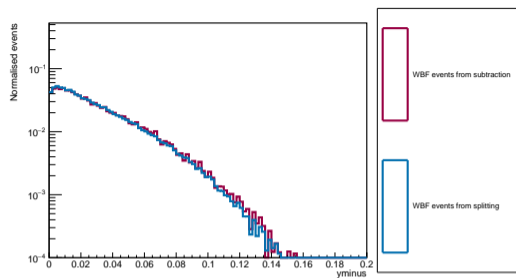
$|M_{\nu\nu} - M_Z| < 40 \text{ GeV}$:



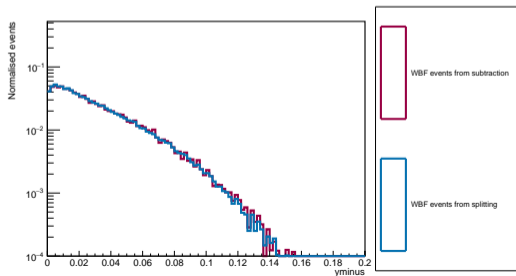
$79 \text{ GeV} < M_{\nu\nu} < 102 \text{ GeV}$:



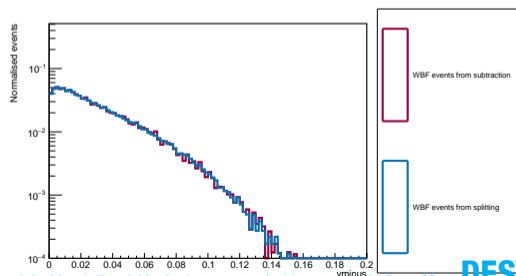
$|M_{\nu\nu} - M_Z| < 20 \text{ GeV}$:



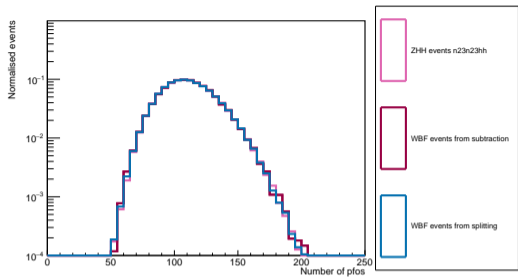
$|M_{\nu\nu} - M_Z| < 30 \text{ GeV}$:



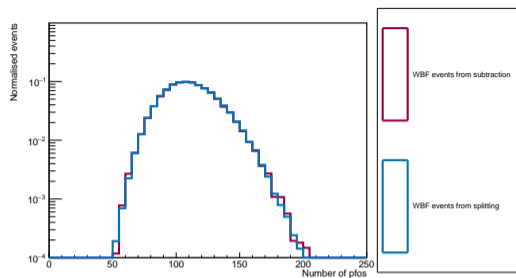
$|M_{\nu\nu} - M_Z| < 40 \text{ GeV}$:



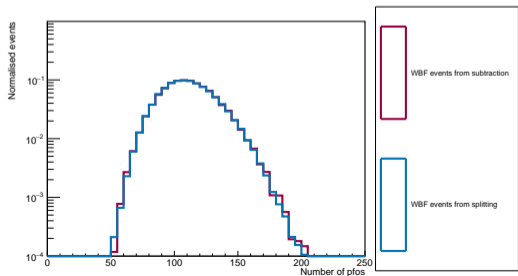
$79 \text{ GeV} < M_{\nu\nu} < 102 \text{ GeV}$:



$|M_{\nu\nu} - M_Z| < 20 \text{ GeV}$:



$|M_{\nu\nu} - M_Z| < 30 \text{ GeV}$:



$|M_{\nu\nu} - M_Z| < 40 \text{ GeV}$:

