4ℓ+MET: Muon-jets overlap on EMPFlow

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EMPFlow bug fix checks

Introduction

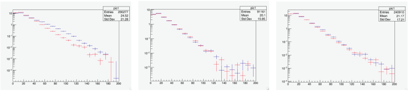
Following the bug on the Met calculation we observed, and the fix that implemented by the met experts on 21.2.124 release, we present a comparison between EMPFlow bug fix (On), EMPFlow bug fix (Off) and EMTopo.

- ☐ The fake MET has 50% difference between PFlow and Topo.
- ☐ The significance is 20% worse than Topo samples.

	$(m_R, m_H) = (390, 220)$	$qqZZ$	$qqZZ(EW)$	$ggZZ$	$t\bar{t}V$	$Z+jets$	$t\bar{t}$	VVV	WZ	$s/\sqrt{b}$
4ℓ	64.17±0.24	2523.28±4.48	40.67±0.15	350.23±0.72	35.56±0.45	12.95±10.85	2.78±0.22	4.73±0.37	19.18±0.12	2.605
B-veto	59.57±0.23	2376.47±4.39	32.55±0.13	330.65±0.69	5.92±0.18	12.94±10.85	1.68±0.14	4.36±0.35	17.51±0.11	2.507
$N_{jet}^{central} \geq 1$	31.66±0.17	759.81±2.13	28.35±0.12	118.04±0.41	4.63±0.16	0.38±0.42	0.88±0.10	1.81±0.22	8.14±0.08	2.314
$p_T^{4\ell} > 0.00$ GeV & Metsig > 0.00	31.66±0.17	759.81±2.13	28.35±0.12	118.04±0.41	4.63±0.16	0.38±0.42	0.88±0.10	1.81±0.22	8.14±0.08	2.314
$p_T^{4\ell} > 0.00$ GeV & Metsig > 0.50	31.11±0.17	633.26±1.89	23.38±0.11	102.33±0.38	4.54±0.16	0.38±0.42	0.86±0.10	1.75±0.22	8.00±0.08	2.481
$p_T^{4\ell} > 0.00$ GeV & Metsig > 1.00	29.40±0.16	404.21±1.47	14.54±0.09	70.16±0.32	4.34±0.16	0.56±0.34	0.83±0.10	1.60±0.21	7.60±0.07	2.907
$p_T^{4\ell} > 0.00$ GeV & Metsig > 1.50	26.75±0.16	226.10±1.10	7.64±0.06	41.73±0.24	4.05±0.15	0.24±0.20	0.81±0.10	1.46±0.20	7.03±0.07	3.491
$p_T^{4\ell} > 0.00$ GeV & Metsig > 2.00	23.39±0.15	120.95±0.82	3.79±0.04	23.01±0.18	3.69±0.15	0.01±0.01	0.73±0.10	1.30±0.19	6.37±0.07	4.105
$p_T^{4\ell} > 0.00$ GeV & Metsig > 2.50	19.57±0.13	63.66±0.63	1.83±0.03	12.05±0.13	3.30±0.14	0.01±0.01	0.62±0.09	0.97±0.16	5.67±0.07	4.628
$p_T^{4\ell} > 0.00$ GeV & Metsig > 3.00	15.81±0.12	33.75±0.44	0.88±0.02	6.37±0.10	2.89±0.13	0.00±0.00	0.56±0.08	0.68±0.13	5.01±0.06	4.954
$p_T^{4\ell} > 0.00$ GeV & Metsig > 3.50	12.32±0.11	17.98±0.33	0.46±0.02	3.36±0.07	2.50±0.12	0.00±0.00	0.46±0.06	0.59±0.12	4.33±0.06	5.017
$p_T^{4\ell} > 0.00$ GeV & Metsig > 4.00	9.32±0.09	9.63±0.24	0.23±0.01	1.71±0.05	2.22±0.12	0.00±0.00	0.38±0.06	0.54±0.12	3.73±0.05	4.813
$p_T^{4\ell} > 0.00$ GeV & Metsig > 4.50	6.85±0.08	4.99±0.17	0.13±0.01	0.92±0.04	1.89±0.11	0.00±0.00	0.29±0.05	0.49±0.11	3.22±0.05	4.402
$p_T^{4\ell} > 0.00$ GeV & Metsig > 5.00	4.97±0.07	2.61±0.12	0.07±0.01	0.47±0.03	1.55±0.10	0.00±0.00	0.23±0.04	0.38±0.10	2.75±0.05	3.888

	$(m_R, m_H) = (390, 220)$	$qqZZ$	$ggZZ$	$t\bar{t}Z$	$Z+jets$	$t\bar{t}$	VVV	$s/\sqrt{b}$
4ℓ	64.51±0.24	2510.45±5.75	349.64±0.71	8.94±0.05	3.87±0.84	3.55±0.23	19.08±0.11	2.661
B-veto	60.07±0.23	2394.48±5.70	334.96±0.69	1.72±0.02	3.63±0.84	2.27±0.16	17.79±0.11	2.540
$N_{jet}^{central} \geq 1$	32.05±0.17	787.13±2.63	123.31±0.42	1.30±0.02	1.53±0.83	1.27±0.13	8.49±0.08	2.341
$p_T^{4\ell} > 0.00$ GeV & Metsig > 0.00	32.05±0.17	787.13±2.63	123.31±0.42	1.30±0.02	1.53±0.83	1.27±0.13	8.49±0.08	2.341
$p_T^{4\ell} > 0.00$ GeV & Metsig > 0.50	31.46±0.17	657.01±2.45	106.88±0.39	1.28±0.02	1.49±0.83	1.27±0.13	8.32±0.08	2.506
$p_T^{4\ell} > 0.00$ GeV & Metsig > 1.00	29.70±0.16	409.28±1.53	72.34±0.32	1.23±0.02	1.43±0.83	1.21±0.12	7.89±0.08	2.968
$p_T^{4\ell} > 0.00$ GeV & Metsig > 1.50	26.92±0.16	217.56±1.12	41.32±0.25	1.15±0.02	1.29±0.82	1.15±0.12	7.29±0.08	3.638
$p_T^{4\ell} > 0.00$ GeV & Metsig > 2.00	23.40±0.15	104.71±0.82	21.23±0.18	1.04±0.02	0.25±0.05	1.04±0.12	6.55±0.07	4.473
$p_T^{4\ell} > 0.00$ GeV & Metsig > 2.50	19.58±0.13	48.63±0.61	10.13±0.12	0.93±0.02	0.18±0.04	0.95±0.11	5.79±0.07	5.324
$p_T^{4\ell} > 0.00$ GeV & Metsig > 3.00	15.63±0.12	22.57±0.33	4.78±0.08	0.81±0.01	0.09±0.03	0.86±0.11	5.06±0.06	5.932
$p_T^{4\ell} > 0.00$ GeV & Metsig > 3.50	11.99±0.10	10.40±0.23	2.21±0.06	0.69±0.01	0.05±0.03	0.67±0.09	4.40±0.06	6.198
$p_T^{4\ell} > 0.00$ GeV & Metsig > 4.00	8.99±0.09	4.83±0.15	0.98±0.04	0.58±0.01	0.03±0.02	0.55±0.08	3.78±0.05	6.079
$p_T^{4\ell} > 0.00$ GeV & Metsig > 4.50	6.61±0.08	2.36±0.10	0.45±0.03	0.49±0.01	0.01±0.02	0.43±0.07	3.25±0.05	5.553
$p_T^{4\ell} > 0.00$ GeV & Metsig > 5.00	4.74±0.07	1.14±0.07	0.18±0.02	0.40±0.01	-0.01±0.01	0.39±0.07	2.77±0.05	4.769

EMPFlow (top) and EMTopo (bottom)



(a) E_T^{miss} for 4μ (b) E_T^{miss} for $4e$ (c) E_T^{miss} for $2\mu 2e$

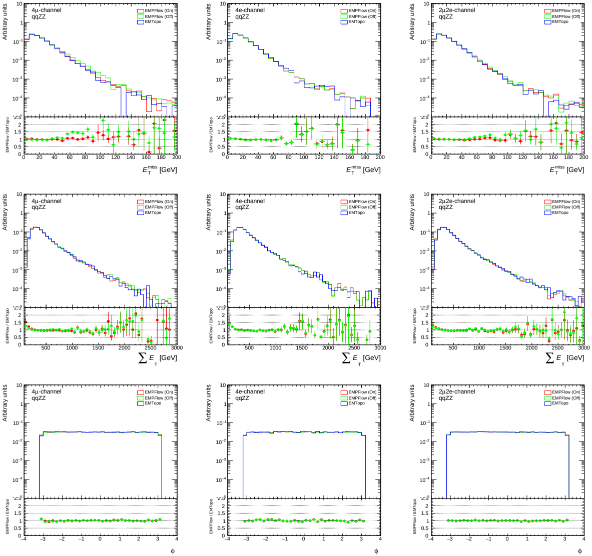
MET for *qqZZ*: PFlow (blue) & Topo (red)

EMPFlow bug fix checks

- The bug was on the METMaker and only affects the Met calculation.
- Next slide shows the Met distribution and it shows the effect after the bug fixed.
- *qqZZ* sample with 364252 DSID and p4191 p-tag (an official sample) is used to perform the check.
- This sample labelled as EMPFlow (On) with red colour after setting DoMuonPFlowBugfix to true on the HZZAnalRun2Code.
- The EMPFlow (Off), green colour, and EMTopo, blue colour, are qqZZ sample with p3872 p-tag generated by 21.2.91 release.
- The ratio is shown for EMPFlow (On) and EMPFlow (Off) to EMTopo for each distribution.

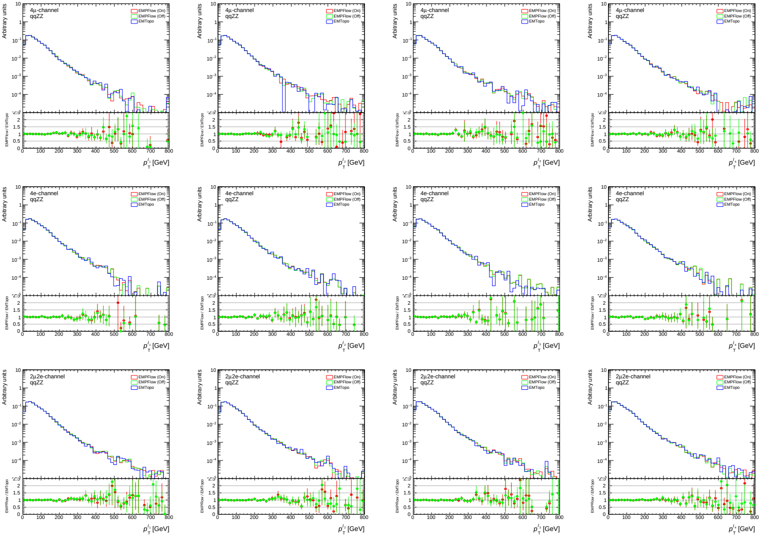
Kinematic distributions for Met

The $E_{\mathrm{T}}^{\mathrm{miss}}$, $\sum E_{\mathrm{T}}$ and ϕ



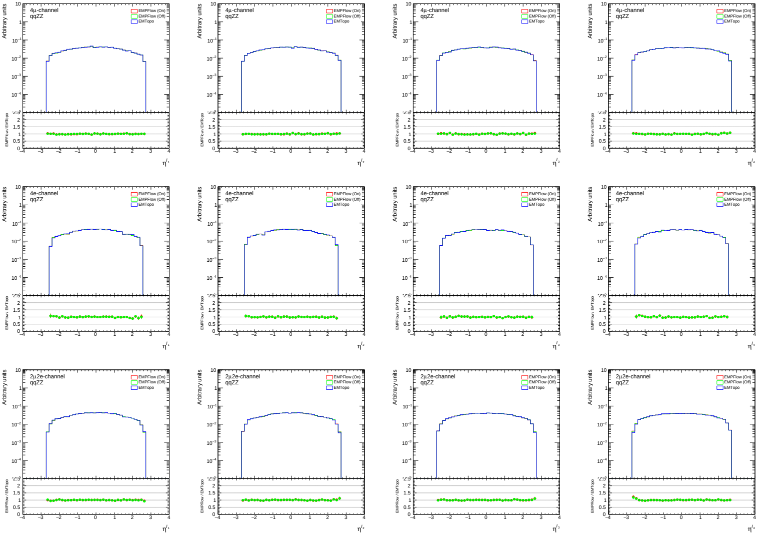
Kinematic distributions for the leptons

The transverse momentum of individual lepton



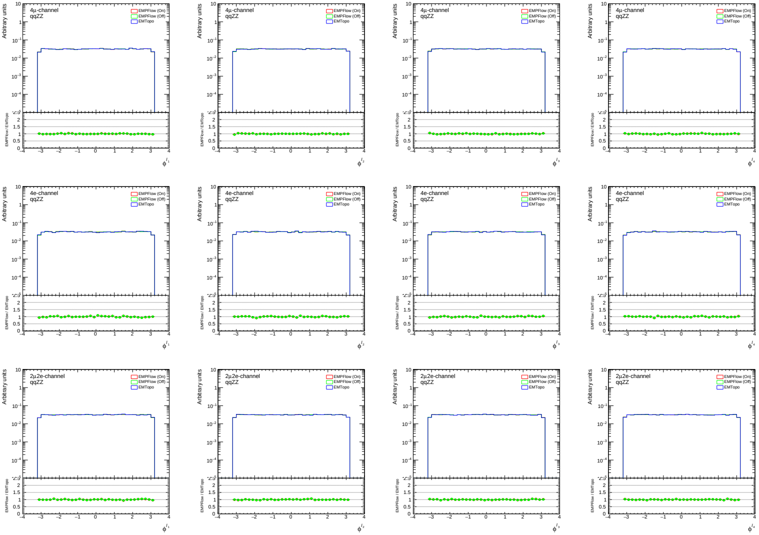
Kinematic distributions for the leptons

The η of individual lepton



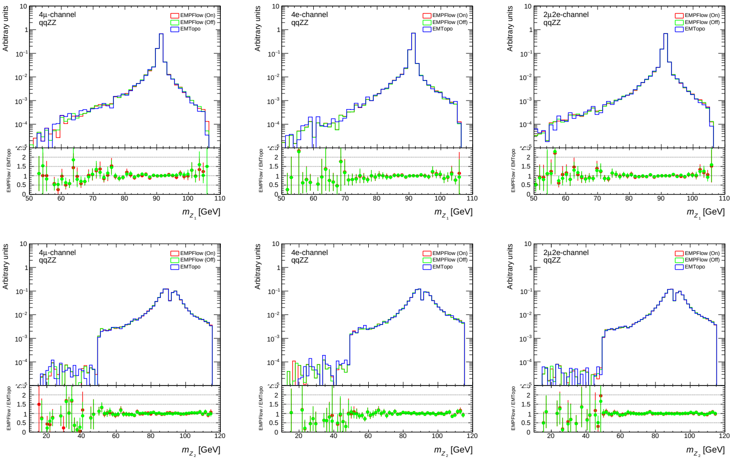
Kinematic distributions for the leptons

The ϕ of individual lepton



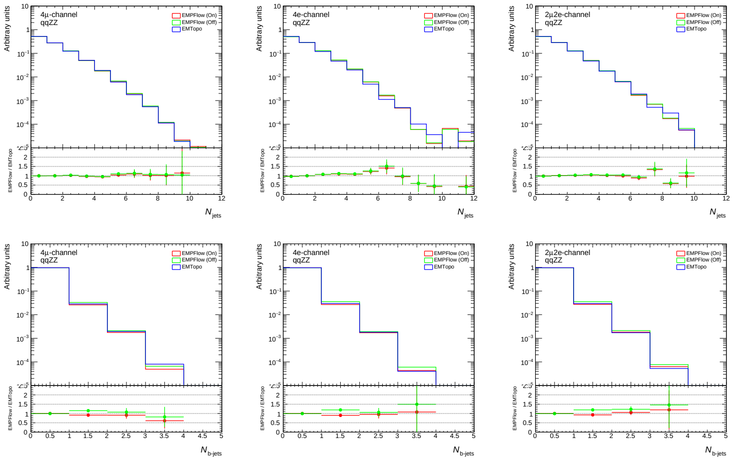
Kinematic distributions for the di-lepton

The m_{Z_1} and m_{Z_2} of di-lepton system



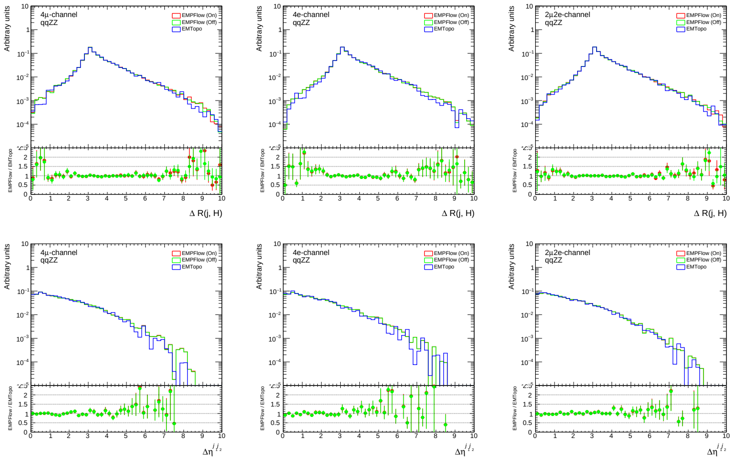
Kinematic distributions for the jets

The momentum, N_{jets}, and $N_{\mathrm{b-jets}}$ of leading jet



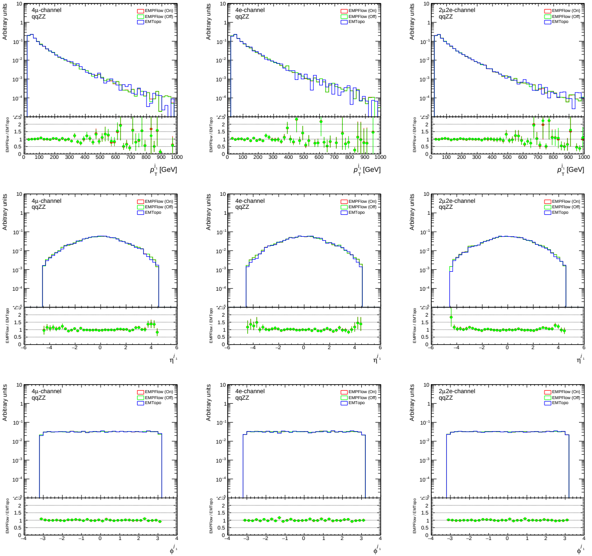
Kinematic distributions for the jets

The momentum, $\Delta R(j, H)$, and $\Delta\eta^{j_1 j_2}$



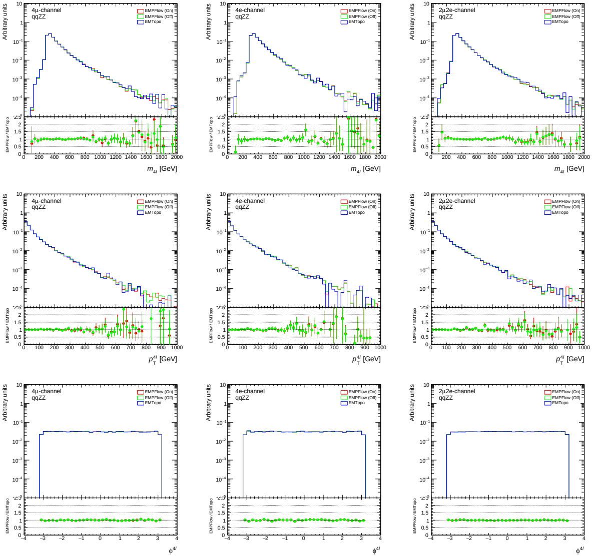
Kinematic distributions for the jets

The momentum, η, and ϕ of leading jet



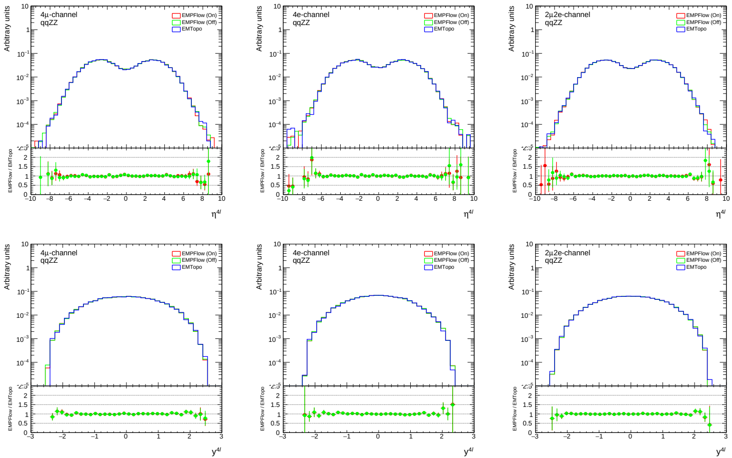
Kinematic distributions for the four leptons

The $m_{4\ell}$, $p_{\mathrm{T}}^{4\ell}$ and $\phi^{4\ell}$ of the 4-lepton system



Kinematic distributions for the four leptons

The momentum, $\eta^{4\ell}$, and $y^{4\ell}$ of the 4-lepton system



Summary

- A comparison between EMPFlow (21.2.124), EMPFlow (21.2.91) and EMTopo (21.2.91) is performed.
- Much improvement is seen from the Met distribution of 4μ and $2\mu2e$ channels, especially on the region between 40 < Met < 140 GeV.
- Also, the bug fix is a bit up on Met < 20 GeV on both 4μ and $2\mu2e$ channels.
- The $4e$-channel has stayed unchanged as expected after the bug fix.
- We showed kinematic distributions for the 4-lepton, di-lepton and jets.

Thank you!

Additional slides

Event Selection	
QUADRUPLET SELECTION	- Require at least one quadruplet of leptons consisting of two pairs of same-flavour opposite-charge leptons fulfilling the following requirements: - p_T thresholds for three leading leptons in the quadruplet: 20, 15 and 10 GeV - Maximum one calo-tagged or stand-alone muon or silicon-associated forward per quadruplet - Leading di-lepton mass requirement: $50 < m_{12} < 106$ GeV - Sub-leading di-lepton mass requirement: $m_{\text{threshold}} < m_{34} < 115$ GeV - $\Delta R(\ell, \ell') > 0.10$ for all leptons in the quadruplet - Remove quadruplet if alternative same-flavour opposite-charge di-lepton gives $m_{\ell\ell} < 5$ GeV - Keep all quadruplets passing the above selection
ISOLATION	- Contribution from the other leptons of the quadruplet is subtracted - FixedCutPFlowLoose WP for all leptons
IMPACT PARAMETER SIGNIFICANCE	- Apply impact parameter significance cut to all leptons of the quadruplet - For electrons: $d_0/\sigma_{d_0} < 5$ - For muons: $d_0/\sigma_{d_0} < 3$
BEST QUADRUPLET	- If more than one quadruplet has been selected, choose the quadruplet with highest Higgs decay ME according to channel: 4μ, $2e2\mu$, $2\mu 2e$ and $4e$
VERTEX SELECTION	- Require a common vertex for the leptons: - $\chi^2/\text{ndof} < 5$ for 4μ and < 9 for others decay channels