Empirically Reconstruct the Unbiased MET Distribution Using ZeroBias HLT noalg L1XE30 and HLT noalg L1XE50 Data

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Table of Contents

Objective

- Determine CELL MET Distribution as a function of μ
- Zerobias events run out of statistics above about 80 GeV
- Use `HLTnoalg_L1XExx` triggered events to extend to higher MET.
- Correct the HLTnoalg Data Using Efficiency determined from lower threshold triggers.
- Determine errors including statistical and those due to determination of efficiency.

Method

For each bin of actual number of interactions per bunch crossing (actint/InTimePileup):

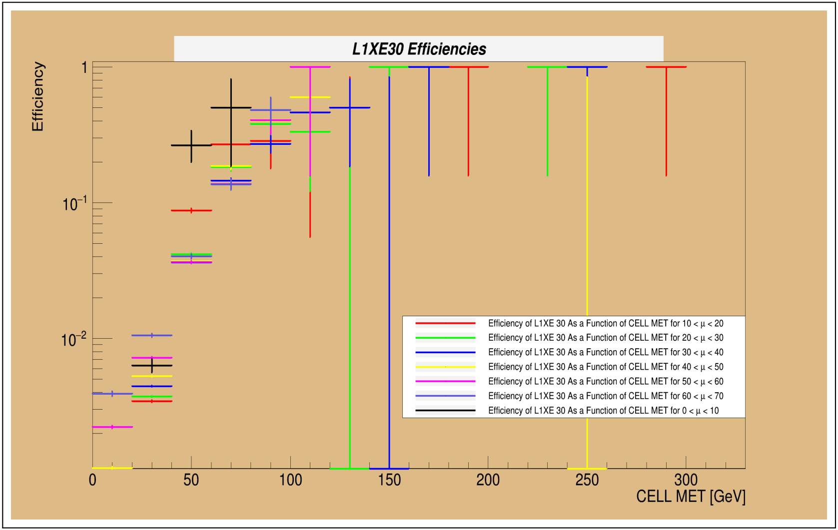
1. Compute the Efficiency of L1XE 30 for `HLTzb_L1ZB` events as a function of cell met
2. Obtain an unbiased (with respect to L1) CELL MET distribution from the `HLTnoalg_L1XE30` data by multiplying by the prescale and dividing by efficiency computed previously
3. Compute efficiency of L1XE50 for `HLTnoalg_L1XE30` data as a function of cell met
4. Obtain an unbiased (with respect to L1) CELL MET distribution from the `HLTnoalg_L1XE50` data by multiplying by the prescale and dividing by both of the previously computed efficiencies.

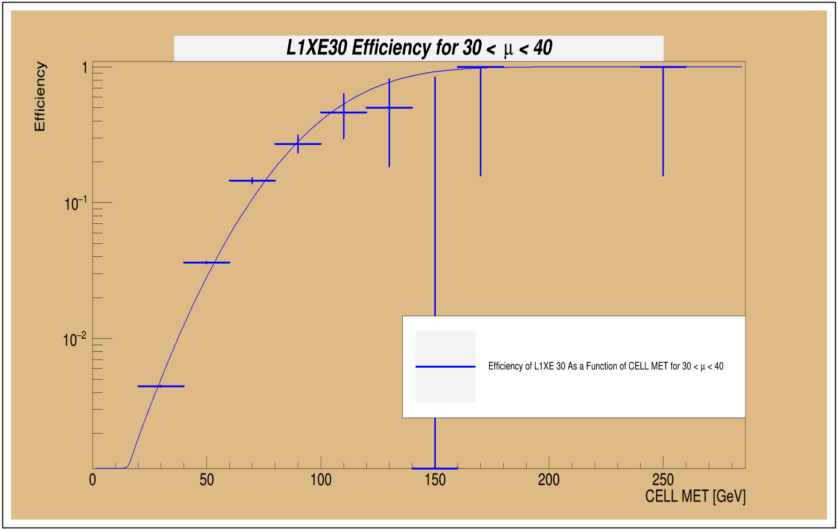
Data Used

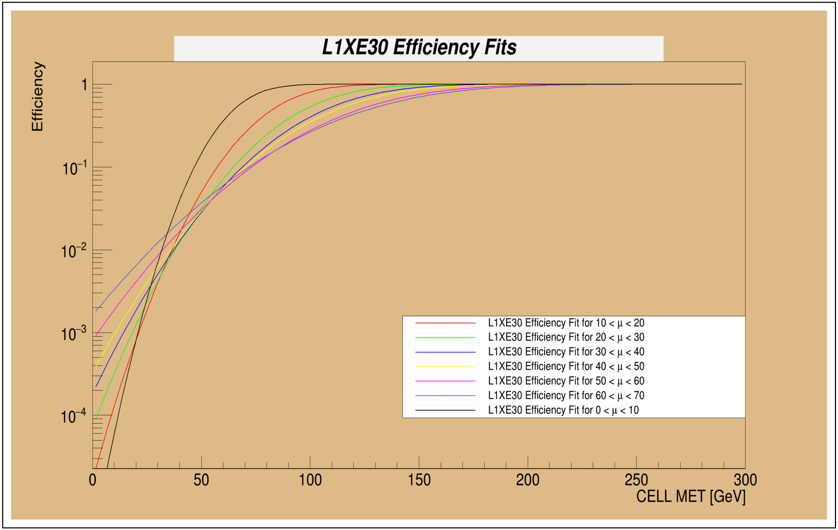
- Used 2015, 2016 and 2017 combined `HLTnoalg_L1ZB`, `HLTnoalg_L1XE30`, and `HLTnoalg_L1XE50` data produced by Jonathan Burr dated 2017-11-17 from ZB and JETM10 trees
- Removed events from Runs 330203, 331975 and 334487. These had large MET events without jets and logbook says there were calorimeter noise problems in these runs

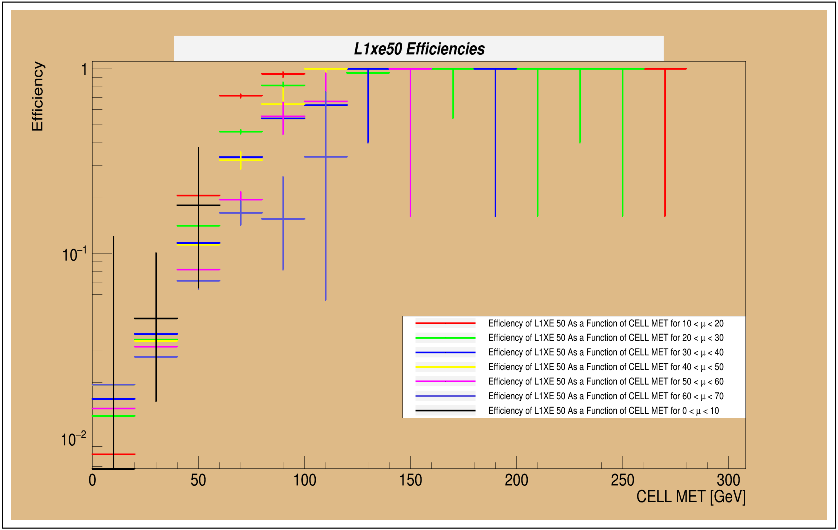
Efficiency Fits

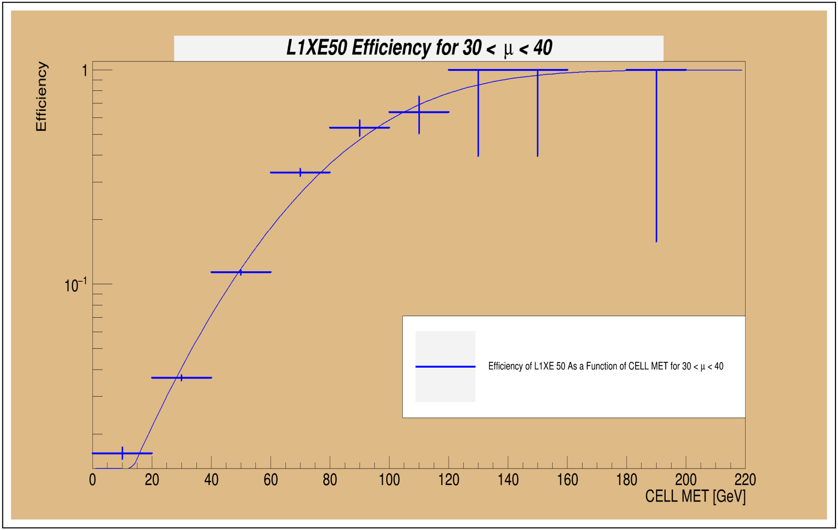
- Assume the distribution of L1 MET, given the value of CELL MET, is gaussian.
- Fitted an error function to the efficiency to evaluate a continuous function when correcting the distribution of `HLTnoalg` data.
- Fit function we used has 4 parameters: a, b, σ, and L1XE.
- $f(x) = \frac{1}{2}\left(1 + \mathrm{Erf}\left(\frac{ax+b-\mathrm{L1XE}}{\sigma\sqrt{2}}\right)\right)$.
- Fit in actint bins of $0-10, \ldots, 60-70$.

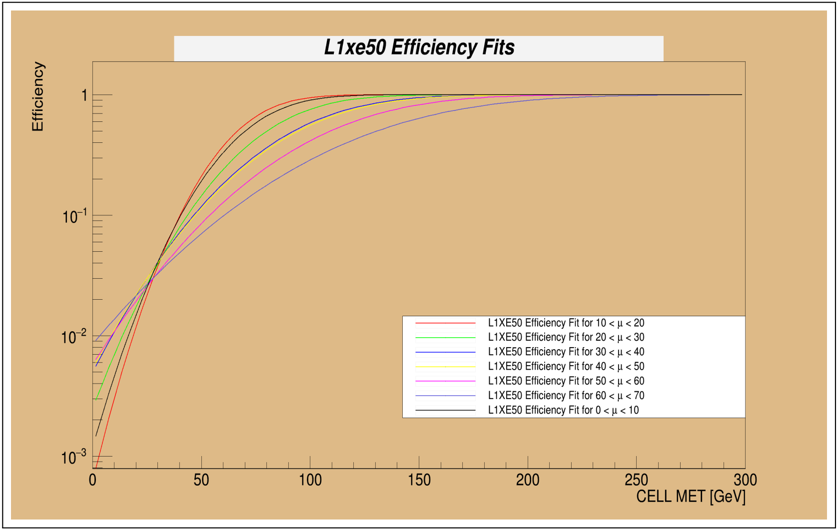

L1XE30 Efficiencies
Efficiency
1
10^{-1}
10^{-2}
0
50
100
150
200
250
300
CELL MET [GeV]
Efficiency of L1XE 30 As a Function of CELL MET for 10 < μ < 20
Efficiency of L1XE 30 As a Function of CELL MET for 20 < μ < 30
Efficiency of L1XE 30 As a Function of CELL MET for 30 < μ < 40
Efficiency of L1XE 30 As a Function of CELL MET for 40 < μ < 50
Efficiency of L1XE 30 As a Function of CELL MET for 50 < μ < 60
Efficiency of L1XE 30 As a Function of CELL MET for 60 < μ < 70
Efficiency of L1XE 30 As a Function of CELL MET for 0 < μ < 10


L1XE30 Efficiency for 30 < μ < 40
Efficiency
1
10^{-1}
10^{-2}
0
50
100
150
200
250
CELL MET [GeV]
Efficiency of L1XE 30 As a Function of CELL MET for 30 < μ < 40


L1XE30 Efficiency Fits
Efficiency
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
50
100
150
200
250
300
CELL MET [GeV]
L1XE30 Efficiency Fit for 10 < μ < 20
L1XE30 Efficiency Fit for 20 < μ < 30
L1XE30 Efficiency Fit for 30 < μ < 40
L1XE30 Efficiency Fit for 40 < μ < 50
L1XE30 Efficiency Fit for 50 < μ < 60
L1XE30 Efficiency Fit for 60 < μ < 70
L1XE30 Efficiency Fit for 0 < μ < 10


L1xe50 Efficiencies
Efficiency
1
10^{-1}
10^{-2}
0
50
100
150
200
250
300
CELL MET [GeV]
Efficiency of L1XE 50 As a Function of CELL MET for 10 < μ < 20
Efficiency of L1XE 50 As a Function of CELL MET for 20 < μ < 30
Efficiency of L1XE 50 As a Function of CELL MET for 30 < μ < 40
Efficiency of L1XE 50 As a Function of CELL MET for 40 < μ < 50
Efficiency of L1XE 50 As a Function of CELL MET for 50 < μ < 60
Efficiency of L1XE 50 As a Function of CELL MET for 60 < μ < 70
Efficiency of L1XE 50 As a Function of CELL MET for 0 < μ < 10


L1XE50 Efficiency for 30 < μ < 40
Efficiency
1
10^{-1}
0
20
40
60
80
100
120
140
160
180
200
220
CELL MET [GeV]
Efficiency of L1XE 50 As a Function of CELL MET for 30 < μ < 40

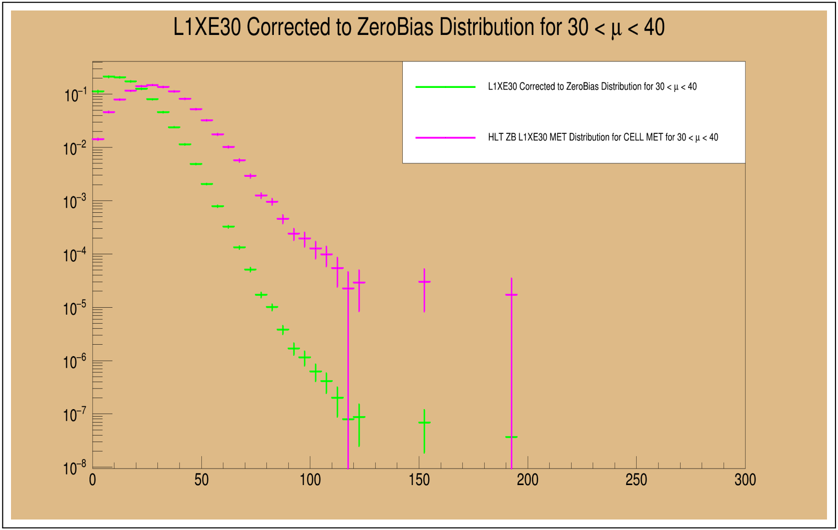

L1xe50 Efficiency Fits
Efficiency
1
10^{-1}
10^{-2}
10^{-3}
0
50
100
150
200
250
300
CELL MET [GeV]
L1XE50 Efficiency Fit for 10 < μ < 20
L1XE50 Efficiency Fit for 20 < μ < 30
L1XE50 Efficiency Fit for 30 < μ < 40
L1XE50 Efficiency Fit for 40 < μ < 50
L1XE50 Efficiency Fit for 50 < μ < 60
L1XE50 Efficiency Fit for 60 < μ < 70
L1XE50 Efficiency Fit for 0 < μ < 10

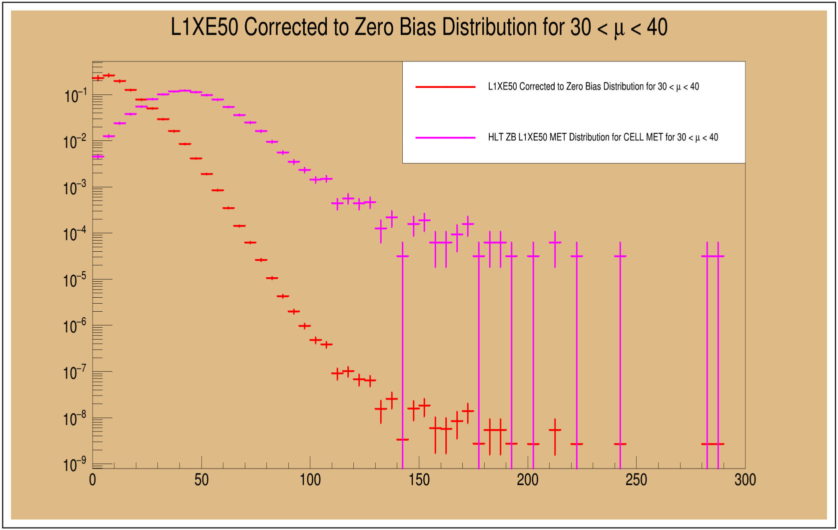
Correcting the HLTnoalg Distribution

- After computing the efficiency curves for the cuts on L1, the curves were used to correct the HLTnoalg distributions that are biased with respect to L1 so that they replicate the unbiased distribution
- In order to do this, it was necessary to multiply by the recorded prescale, and divide by the efficiency used to correct the data
  - For the HLTnoalg_L1XE30 data, we used the L1XE30 efficiency curve to correct the distribution
  - For the HLTnoalg_L1XE50 data we used the L1XE30 efficiency of the zerobias data, as well as the L1XE50 efficiency of HLTnoalg_L1XE30 data to correct the distribution

Error Propagation

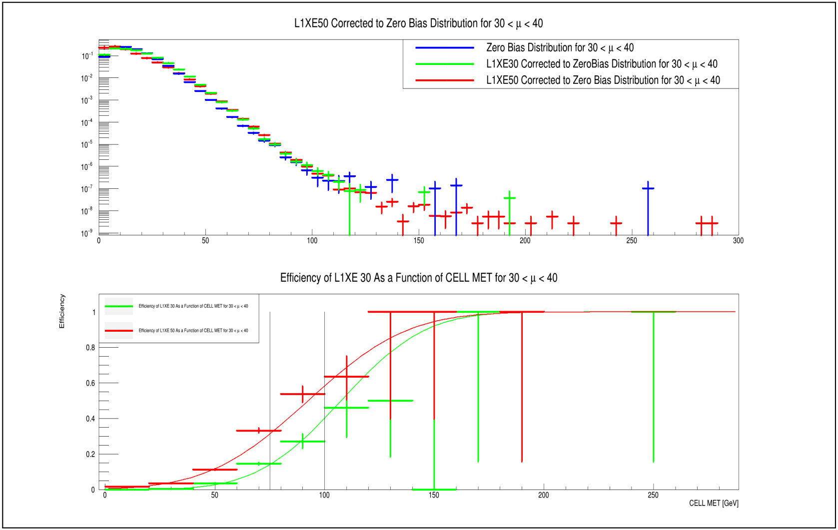
- The error in each efficiency value is determined by propagating the errors on the parameters of the respective fit function.
- The reconstructed MET distribution includes both the error determined above, and the statistical error.
- Since prescales vary for each bin, must keep track of errors event by event, rather than using ROOTs built-in errors.
- Kept track of the errors on the `L1XE30` corrected curves, as well as the `L1XE50` corrected curves, for each of the mu bins
- There is no error included to reflect the fact that the error function may not be a perfect model. Therefore, in final distribution, zerobias data is kept to as high an MET as possible and similarly for keeping `HLTnoalg_L1XE30` versus `L1XE50`


L1XE30 Corrected to ZeroBias Distribution for 30 < μ < 40
L1XE30 Corrected to ZeroBias Distribution for 30 < μ < 40
HLT ZB L1XE30 MET Distribution for CELL MET for 30 < μ < 40
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0
50
100
150
200
250
300

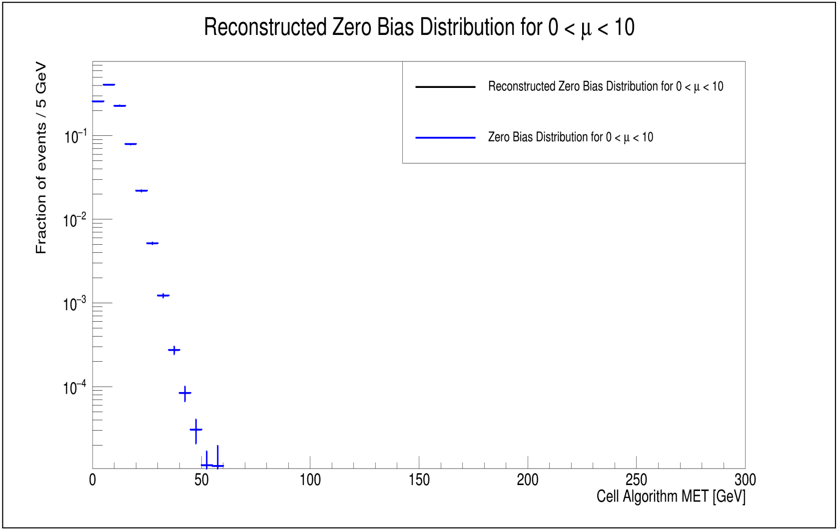

L1XE50 Corrected to Zero Bias Distribution for 30 < μ < 40
L1XE50 Corrected to Zero Bias Distribution for 30 < μ < 40
HLT ZB L1XE50 MET Distribution for CELL MET for 30 < μ < 40
0
50
100
150
200
250
300

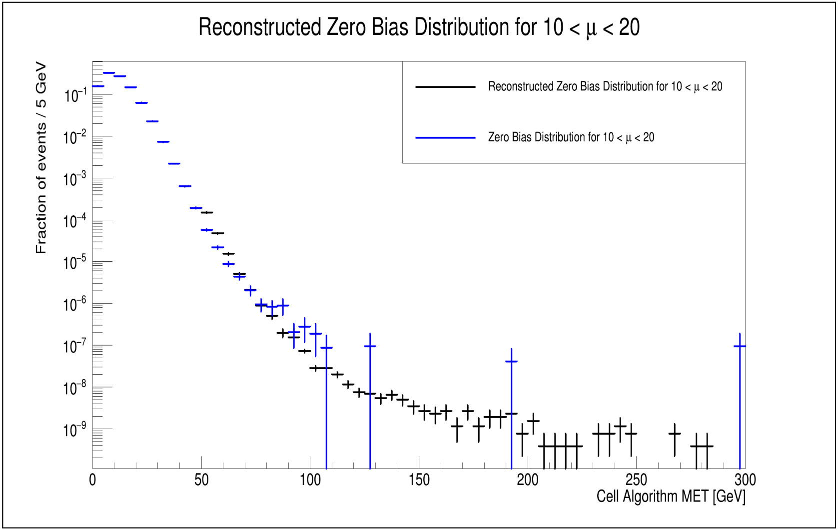
Relative Normalization

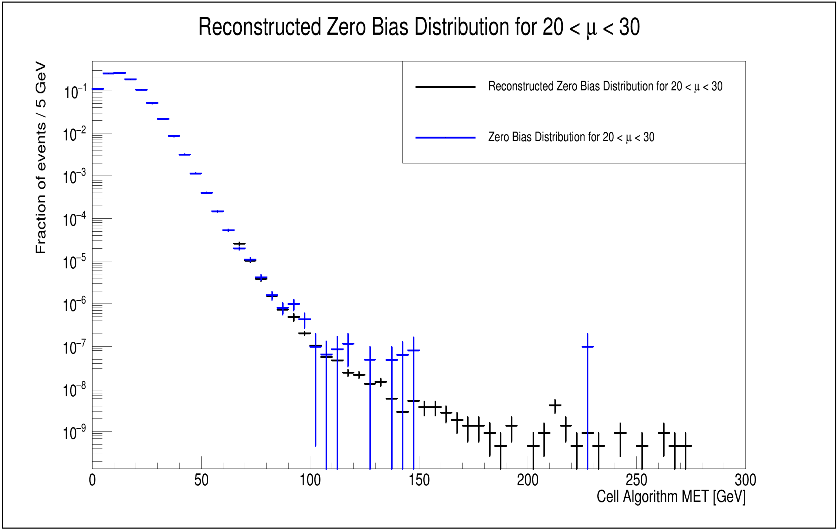
- Because the error bars are larger at low values of MET, it is not sufficient to normalize the entire curve to one. Instead, it was necessary to perform a relative overall normalization between the original zerobias distribution and the corrected curves in order to be able to compare the shapes more easily.
- The relative normalization factor was computed by taking a weighted average of ratios computed in the region where the slopes look most parallel.
- The following slides show all 3 sets of data points after all corrections and the relative normalization (from the corrected HLTnoalg data to the unbiased distribution) have been done.
- The vertical black lines on the following plots show where I've stopped using the zerobias data and started using the `HLTnoalg_L1XE30` and `HLTnoalg_L1XE50` data, respectively.

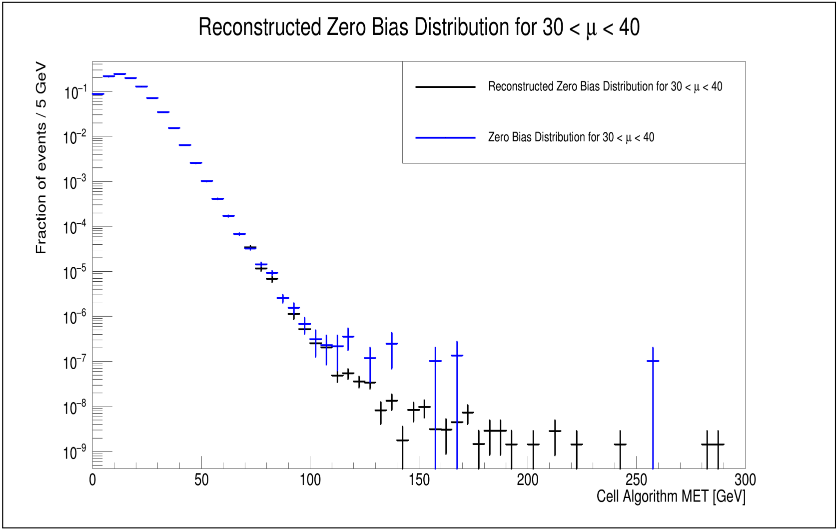


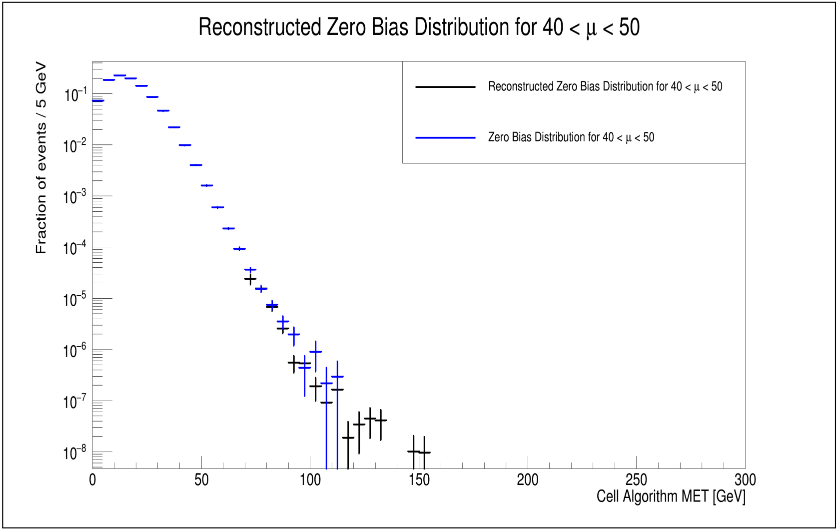
L1XE50 Corrected to Zero Bias Distribution for 30 < μ < 40
Zero Bias Distribution for 30 < μ < 40
L1XE30 Corrected to ZeroBias Distribution for 30 < μ < 40
L1XE50 Corrected to Zero Bias Distribution for 30 < μ < 40
Efficiency of L1XE 30 As a Function of CELL MET for 30 < μ < 40
Efficiency
Efficiency of L1XE 30 As a Function of CELL MET for 30 < μ < 40
Efficiency of L1XE 50 As a Function of CELL MET for 30 < μ < 40
CELL MET [GeV]


Reconstructed Zero Bias Distribution for 0 < μ < 10
Fraction of events / 5 GeV
10^-1
10^-2
10^-3
10^-4
0
50
100
150
200
250
300
Cell Algorithm MET [GeV]
Reconstructed Zero Bias Distribution for 0 < μ < 10
Zero Bias Distribution for 0 < μ < 10

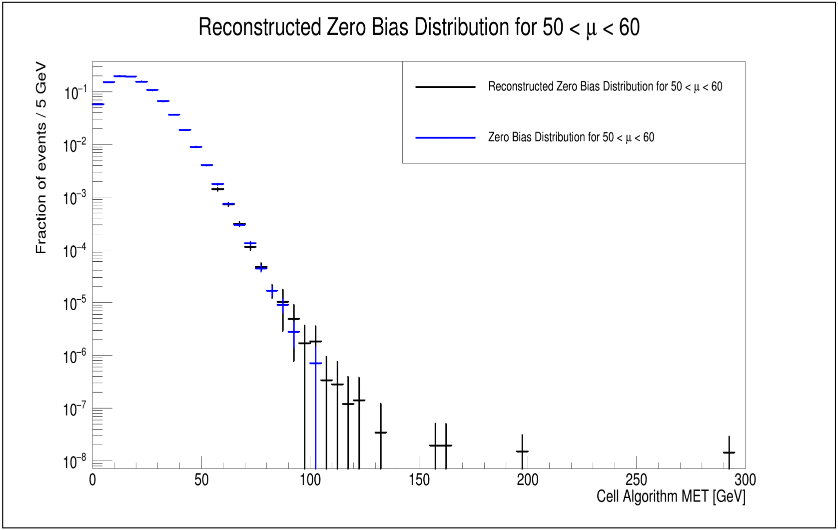

Reconstructed Zero Bias Distribution for 10 < μ < 20
Reconstructed Zero Bias Distribution for 10 < μ < 20
Zero Bias Distribution for 10 < μ < 20
Fraction of events / 5 GeV
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0
50
100
150
200
250
300
Cell Algorithm MET [GeV]


Reconstructed Zero Bias Distribution for 20 < μ < 30
Fraction of events / 5 GeV
Reconstructed Zero Bias Distribution for 20 < μ < 30
Zero Bias Distribution for 20 < μ < 30
Cell Algorithm MET [GeV]

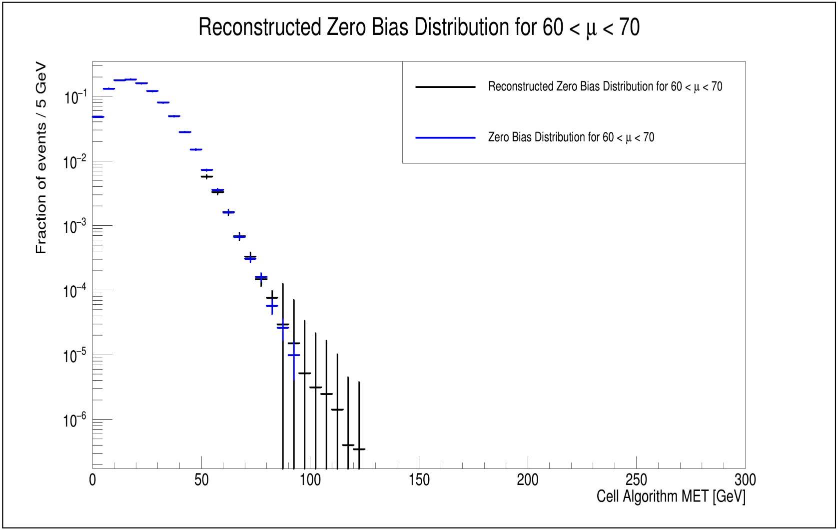

Reconstructed Zero Bias Distribution for 30 < μ < 40
Fraction of events / 5 GeV
Cell Algorithm MET [GeV]
Reconstructed Zero Bias Distribution for 30 < μ < 40
Zero Bias Distribution for 30 < μ < 40
0
50
100
150
200
250
300
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}



Reconstructed Zero Bias Distribution for 40 < μ < 50
Fraction of events / 5 GeV
Reconstructed Zero Bias Distribution for 40 < μ < 50
Zero Bias Distribution for 40 < μ < 50
Cell Algorithm MET [GeV]



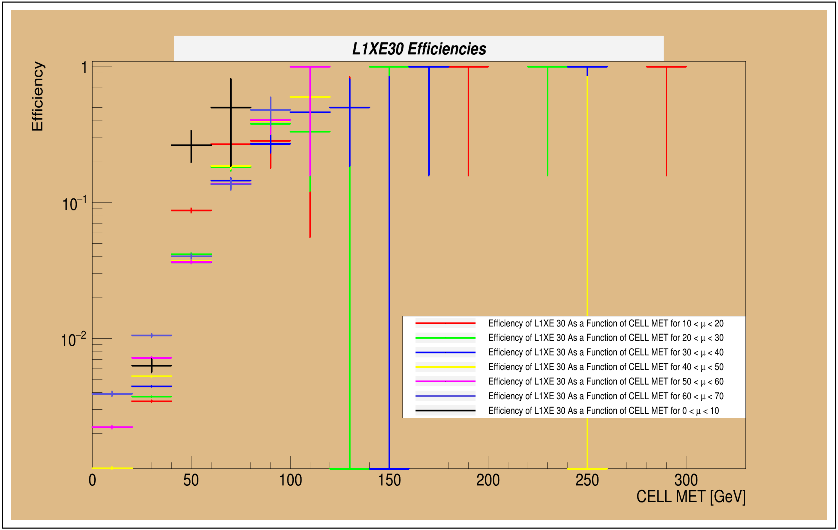
Reconstructed Zero Bias Distribution for 50 < μ < 60
Fraction of events / 5 GeV
Reconstructed Zero Bias Distribution for 50 < μ < 60
Zero Bias Distribution for 50 < μ < 60
Cell Algorithm MET [GeV]
0
50
100
150
200
250
300
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}



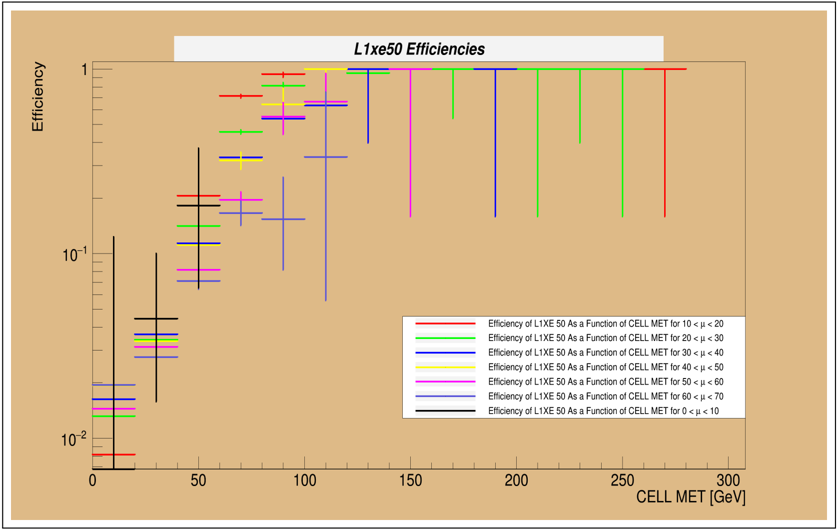
Reconstructed Zero Bias Distribution for 60 < μ < 70
Fraction of events / 5 GeV
Reconstructed Zero Bias Distribution for 60 < μ < 70
Zero Bias Distribution for 60 < μ < 70
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0
50
100
150
200
250
300
Cell Algorithm MET [GeV]

Appendix

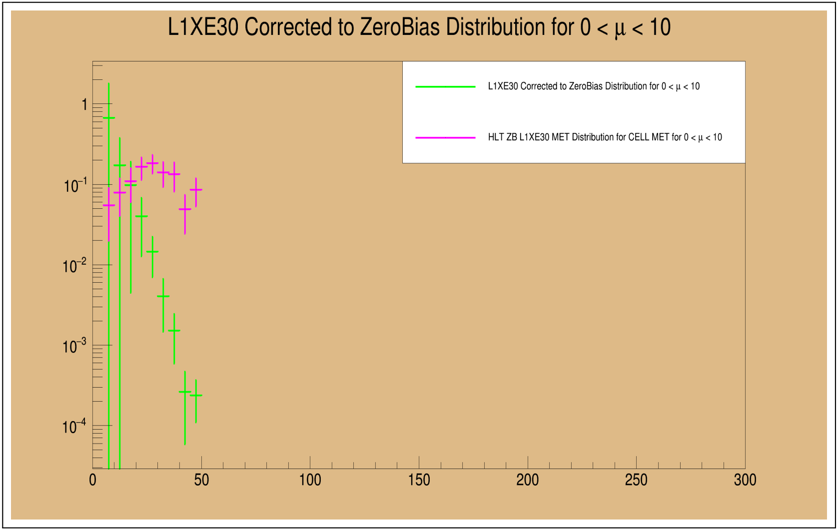
L1XE30 Efficiencies with respect to HLTnoalg_L1ZB Data



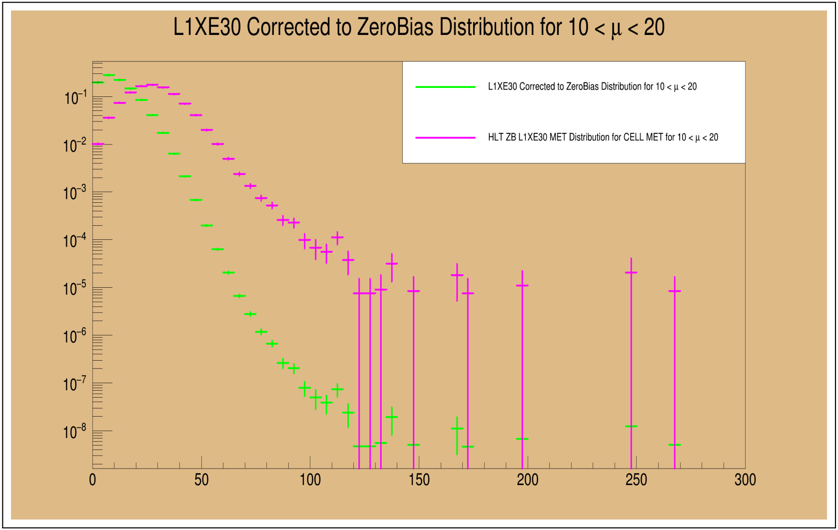
L1XE50 Efficiencies with respect to HLTnoalg_L1XE30 Data



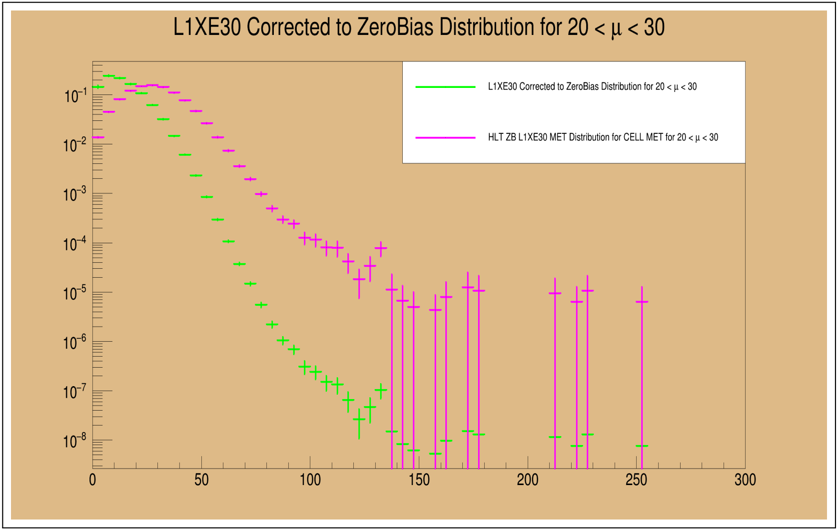
HLTnoalg_L1XE30 Plot for $0 < \mu < 10$



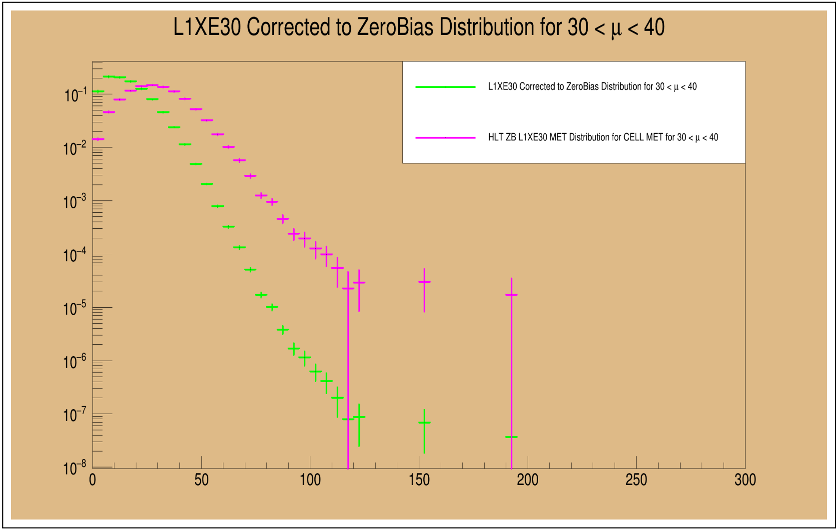
HLTnoalg_L1XE30 Plot for $10 < \mu < 20$



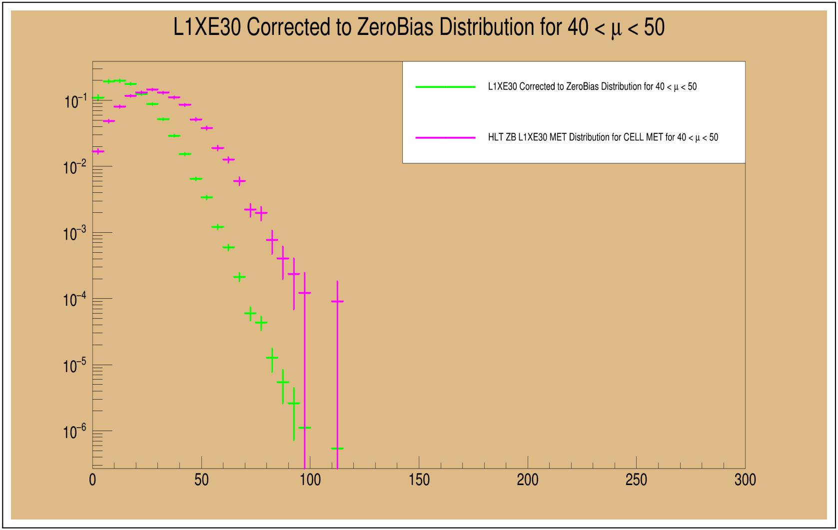
HLTnoalg_L1XE30 Plot for $20 < \mu < 30$



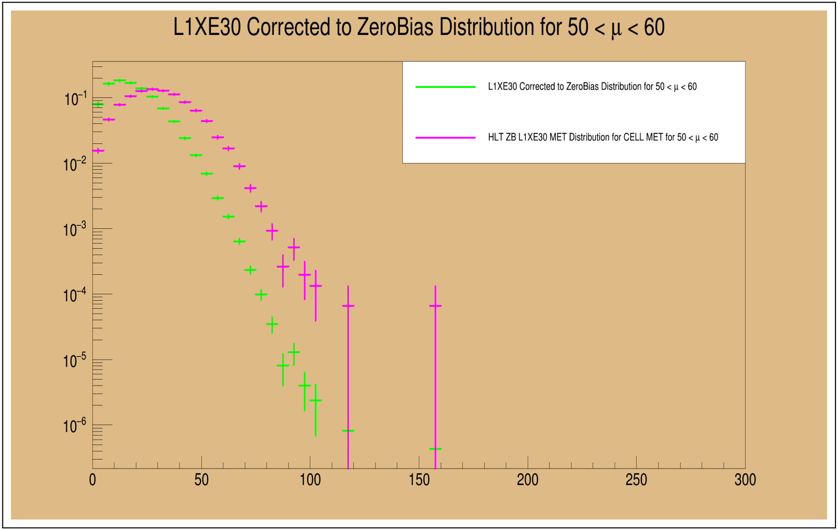
HLTnoalg_L1XE30 Plot for $30 < \mu < 40$



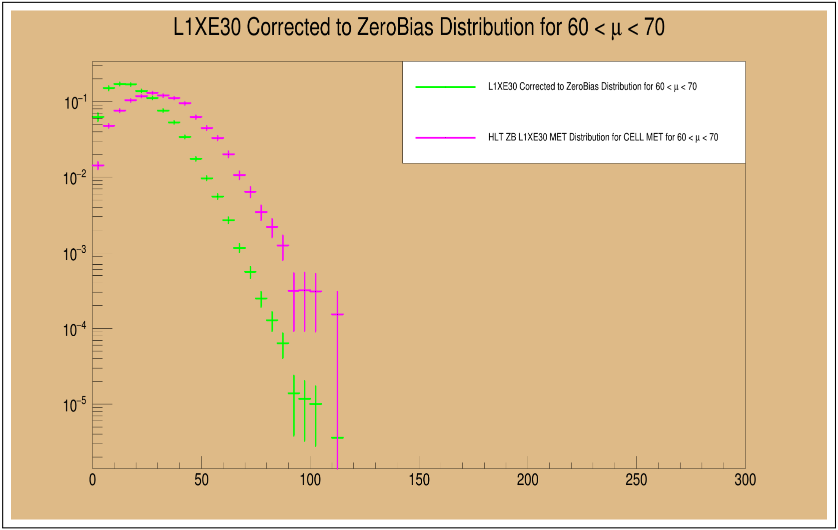
HLTnoalg_L1XE30 Plot for $40 < \mu < 50$



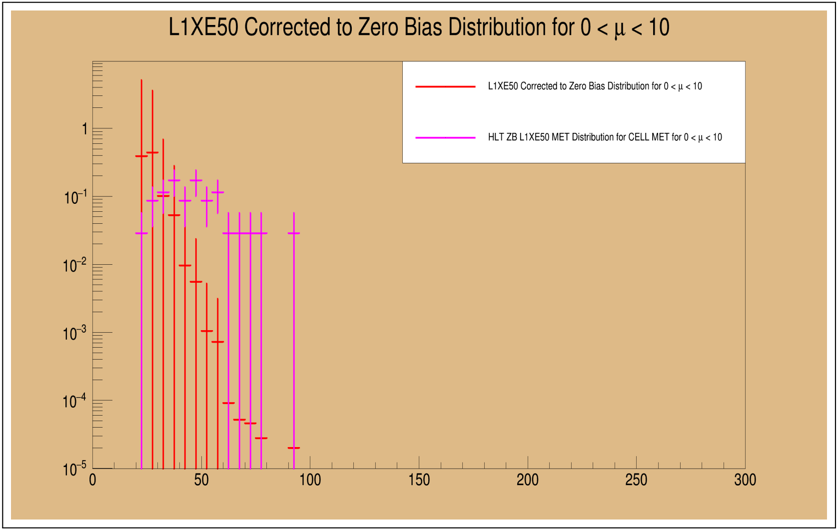
HLTnoalg_L1XE30 Plot for $50 < \mu < 60$



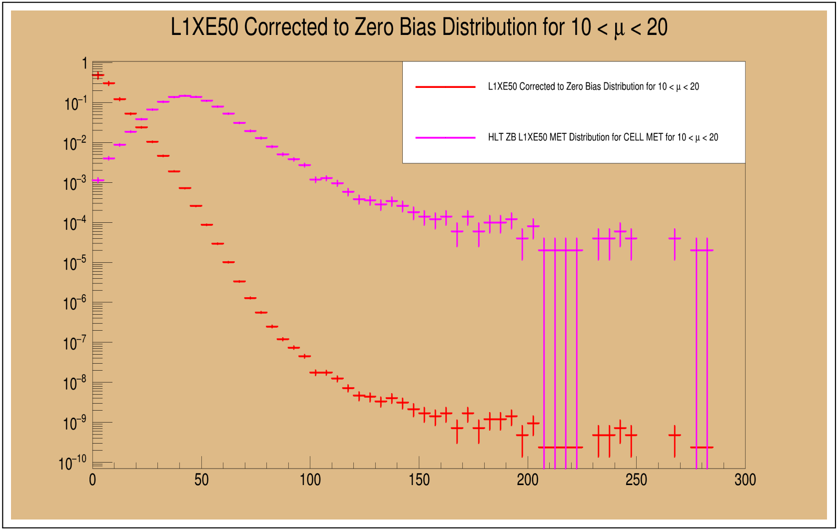
HLTnoalg_L1XE30 Plot for $60 < \mu < 70$



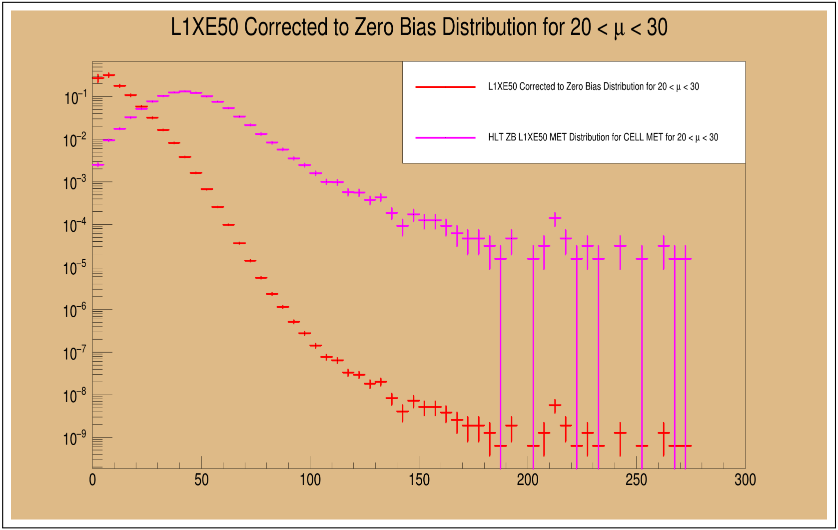
HLTnoalg_L1XE50 Plot for $0 < \mu < 10$



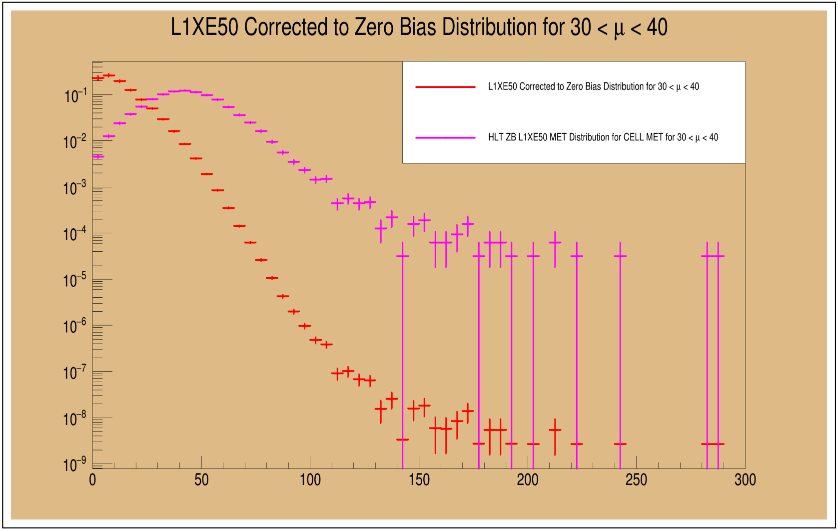
HLTnoalg_L1XE50 Plot for $10 < \mu < 20$



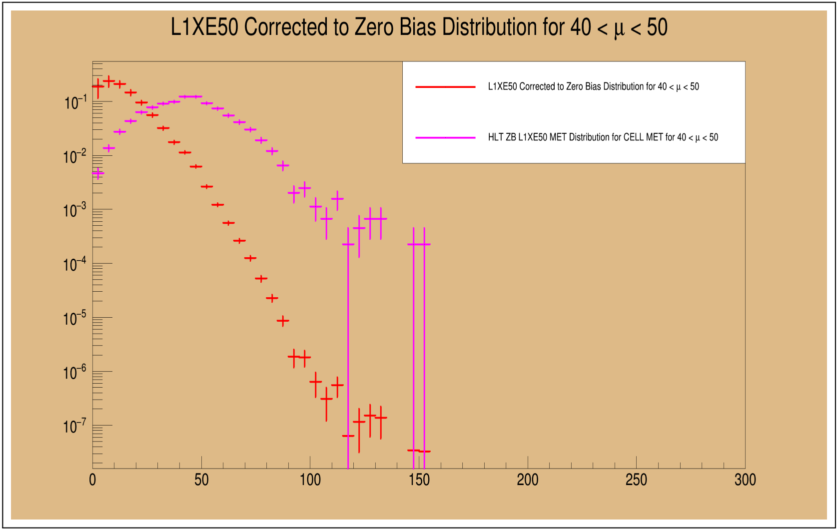
HLTnoalg_L1XE50 Plot for $20 < \mu < 30$



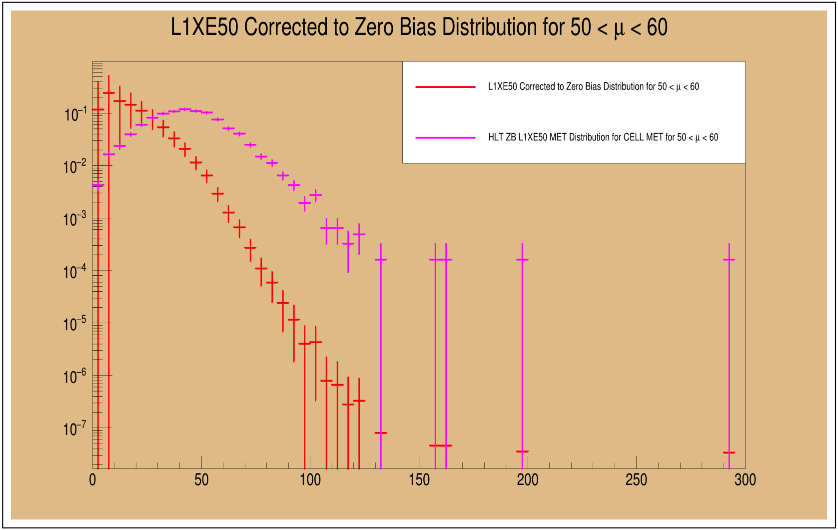
HLTnoalg_L1XE50 Plot for $30 < \mu < 40$



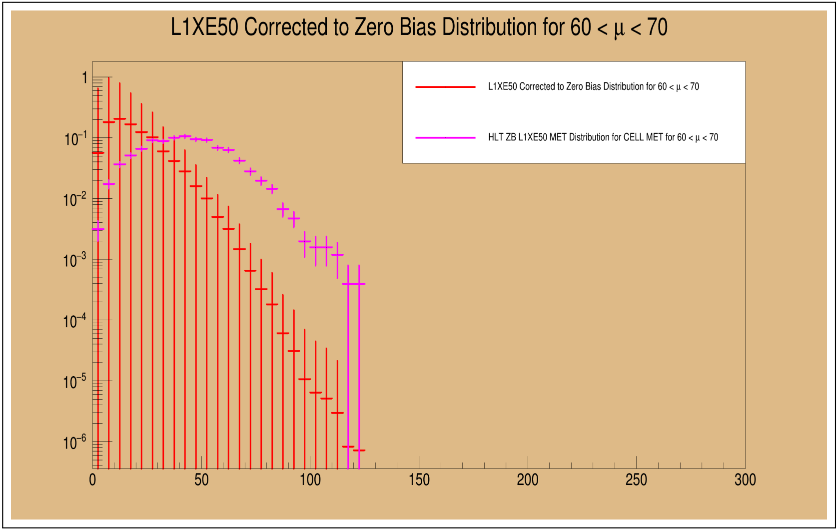
HLTnoalg_L1XE50 Plot for $40 < \mu < 50$



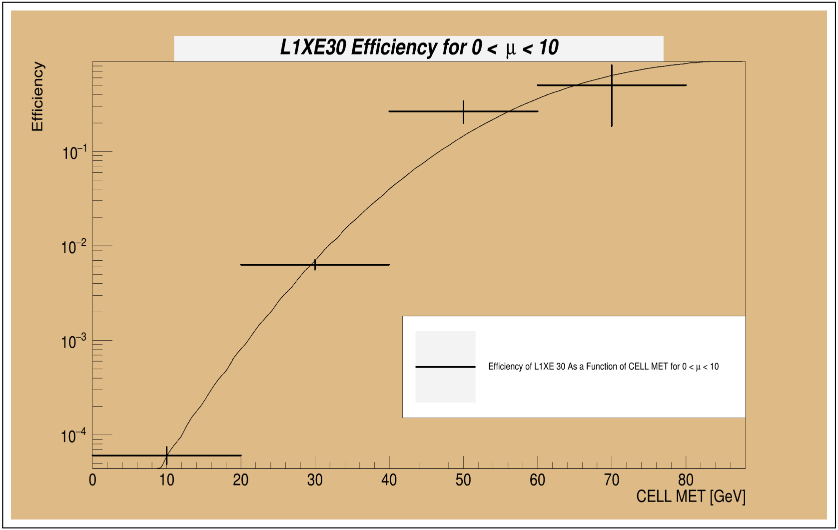
HLTnoalg_L1XE50 Plot for $50 < \mu < 60$



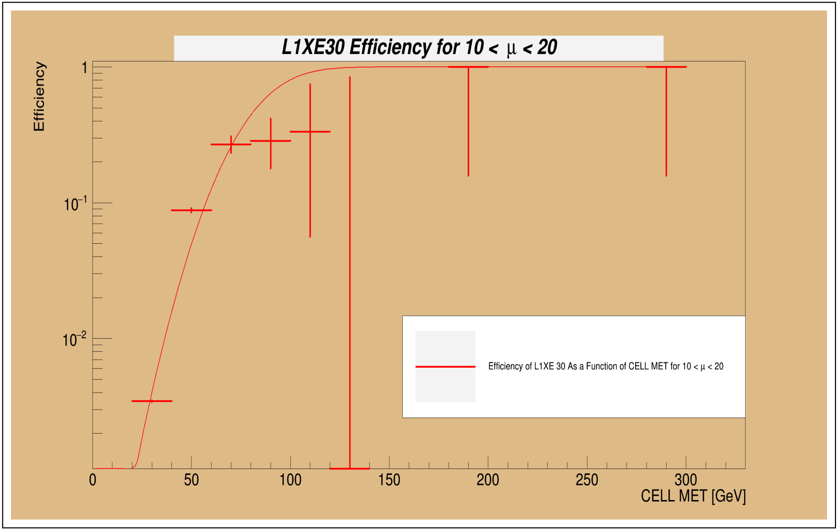
HLTnoalg_L1XE50 Plot for $60 < \mu < 70$



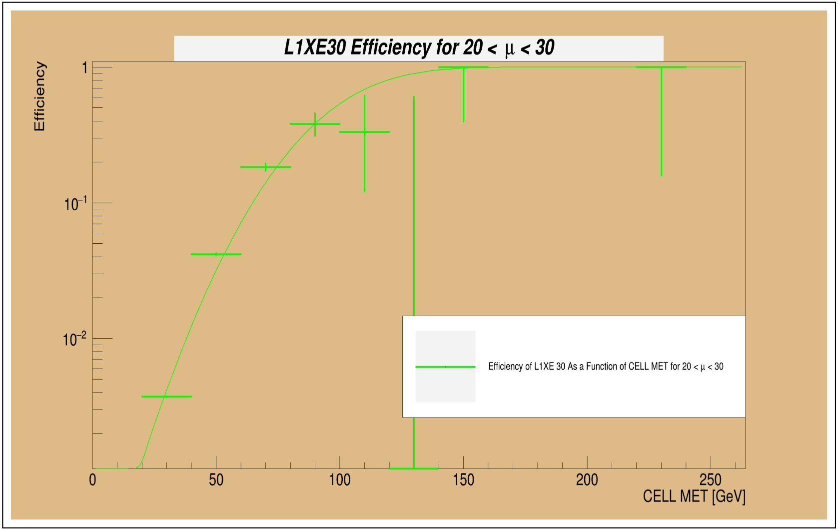
L1XE30 Efficiency Curve Plot for $0 < \mu < 10$



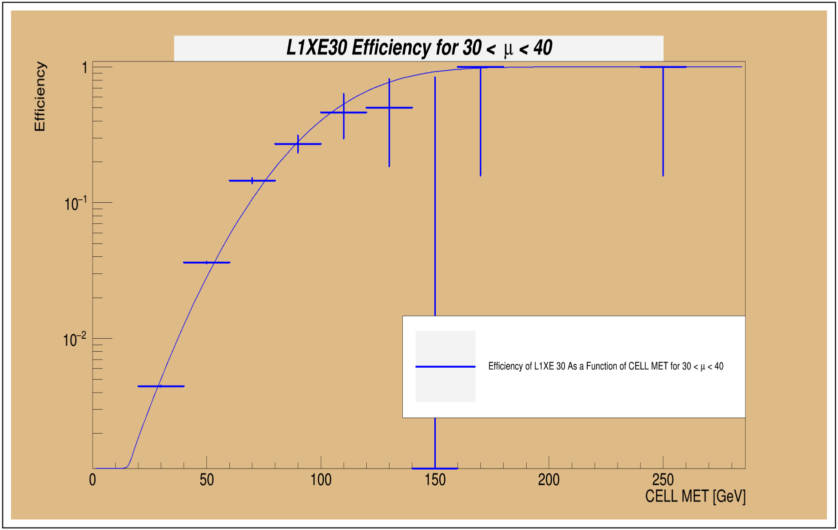
L1XE30 Efficiency Curve Plot for $10 < \mu < 20$



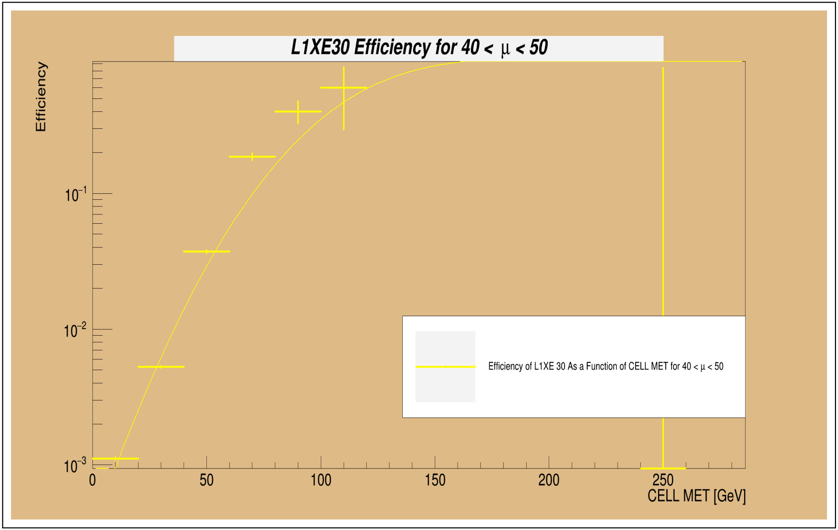
L1XE30 Efficiency Curve Plot for $20 < \mu < 30$



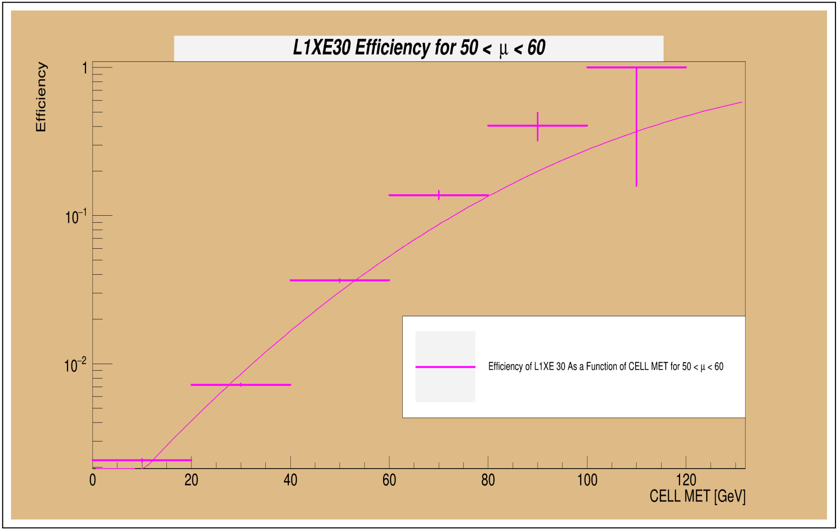
L1XE30 Efficiency Curve Plot for $30 < \mu < 40$



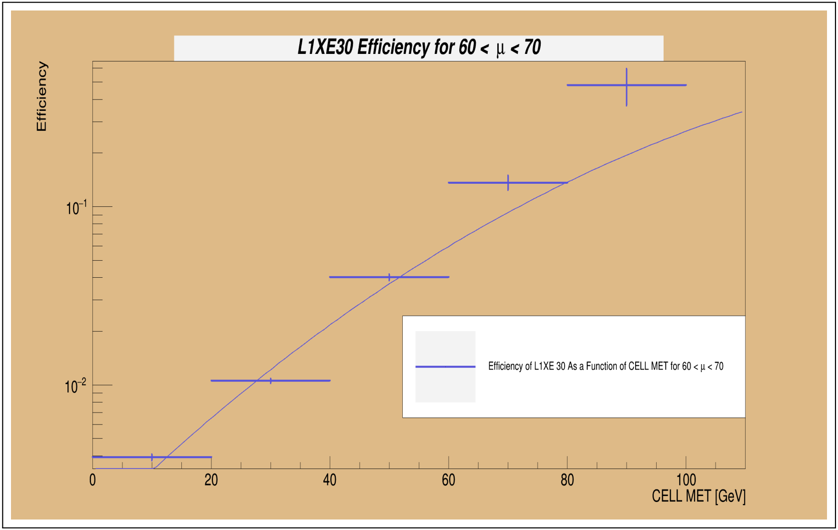
L1XE30 Efficiency Curve Plot for $40 < \mu < 50$



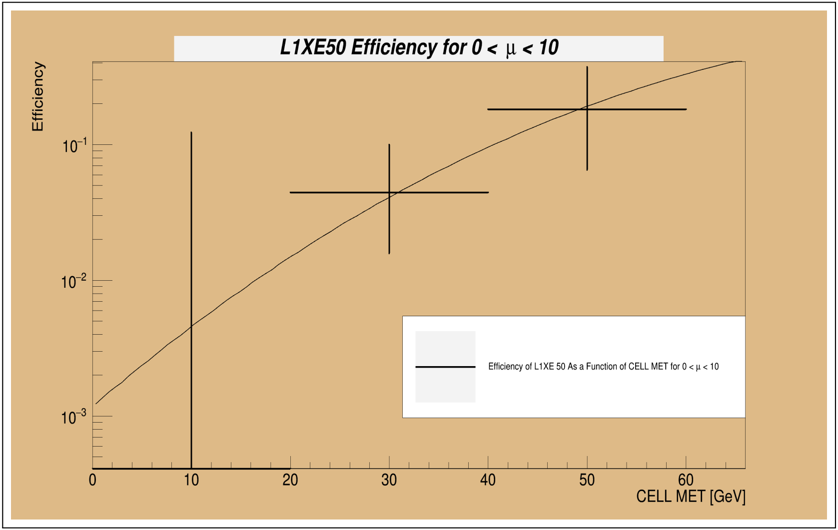
L1XE30 Efficiency Curve Plot for $50 < \mu < 60$



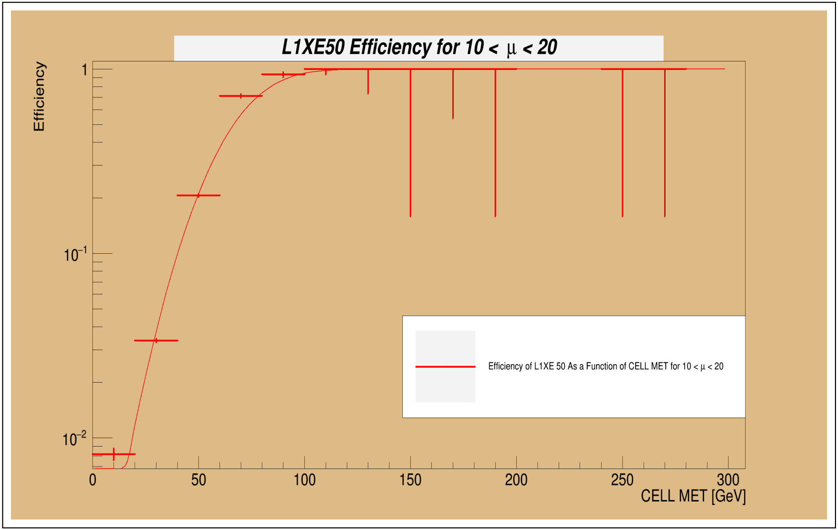
L1XE30 Efficiency Curve Plot for $60 < \mu < 70$



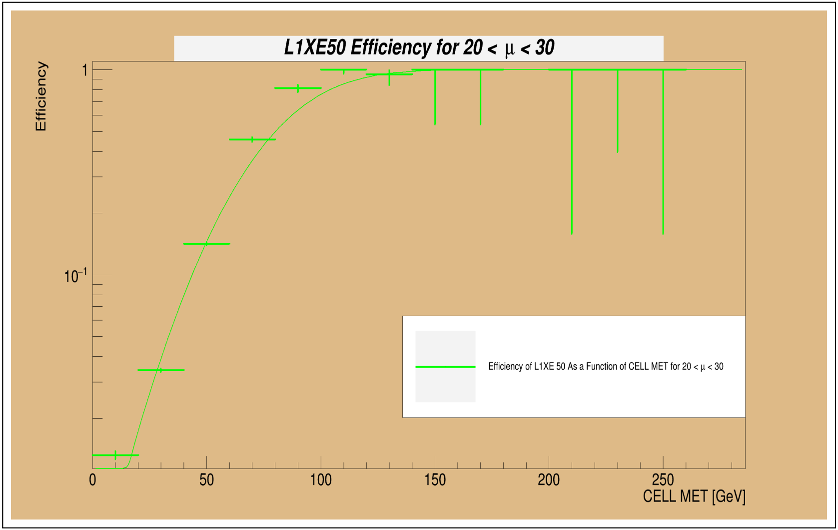
L1XE50 Efficiency Curve Plot for $0 < \mu < 10$



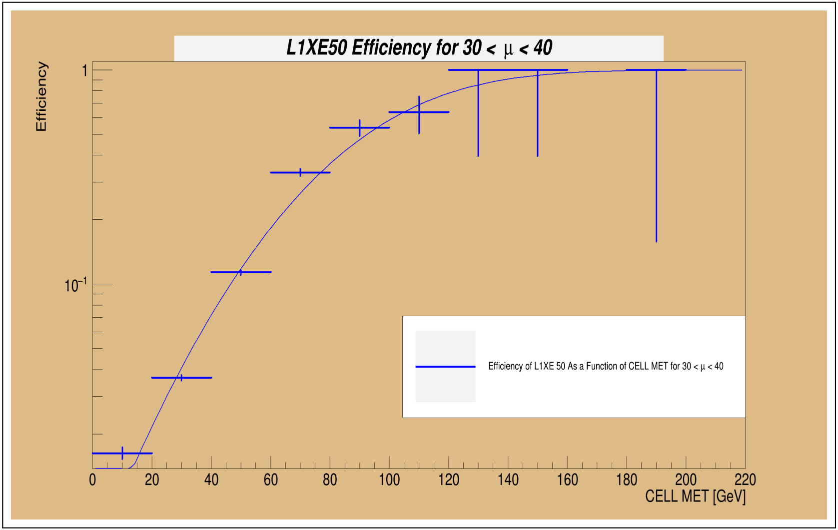
L1XE50 Efficiency Curve Plot for $10 < \mu < 20$



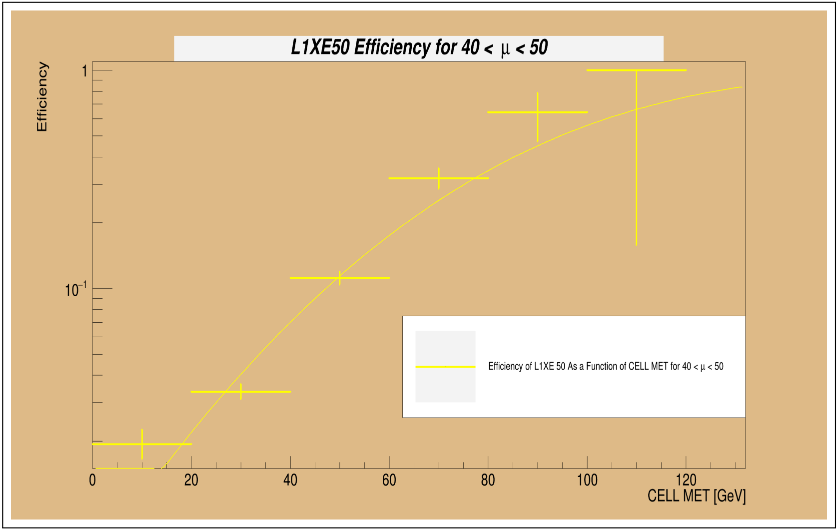
L1XE50 Efficiency Curve Plot for $20 < \mu < 30$



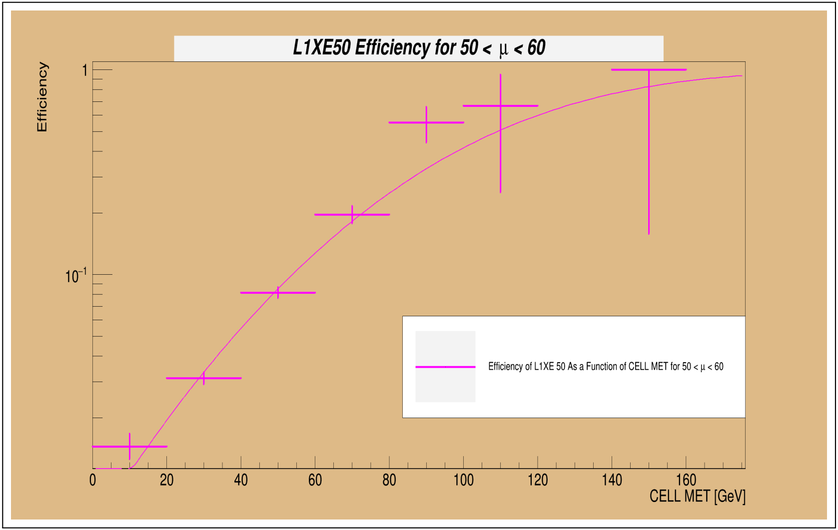
L1XE50 Efficiency Curve Plot for $30 < \mu < 40$



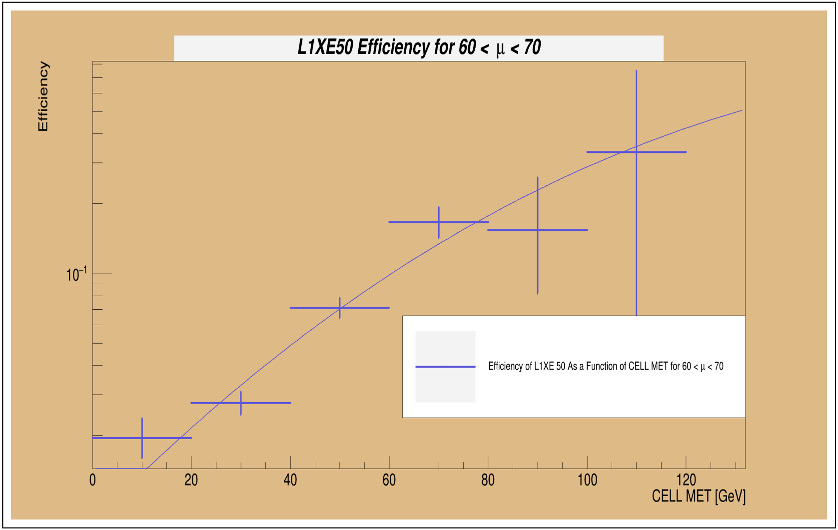
L1XE50 Efficiency Curve Plot for $40 < \mu < 50$



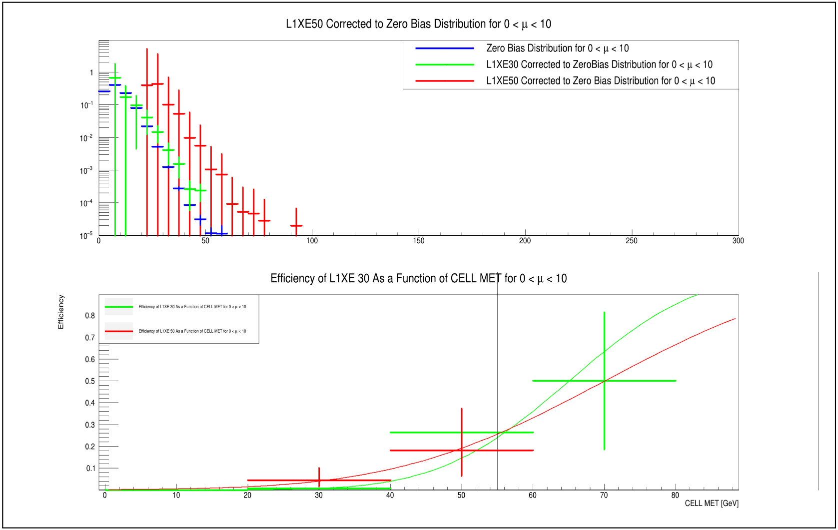
L1XE50 Efficiency Curve Plot for $50 < \mu < 60$



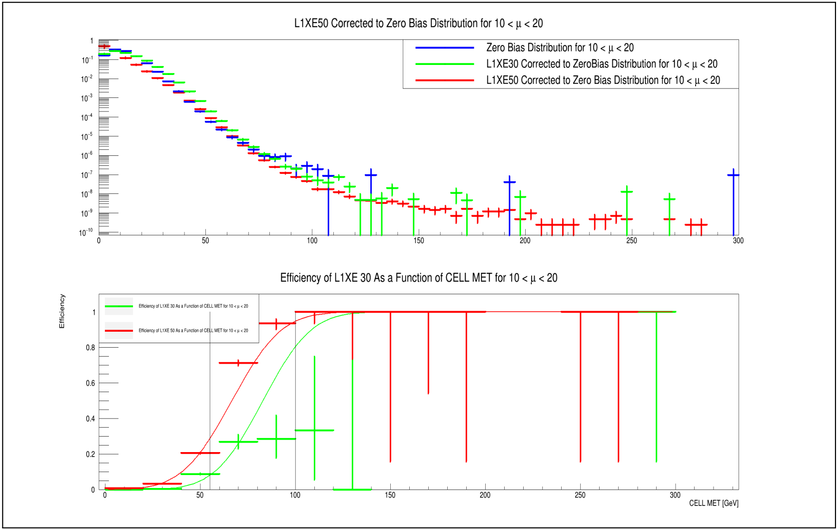
L1XE50 Efficiency Curve Plot for $60 < \mu < 70$



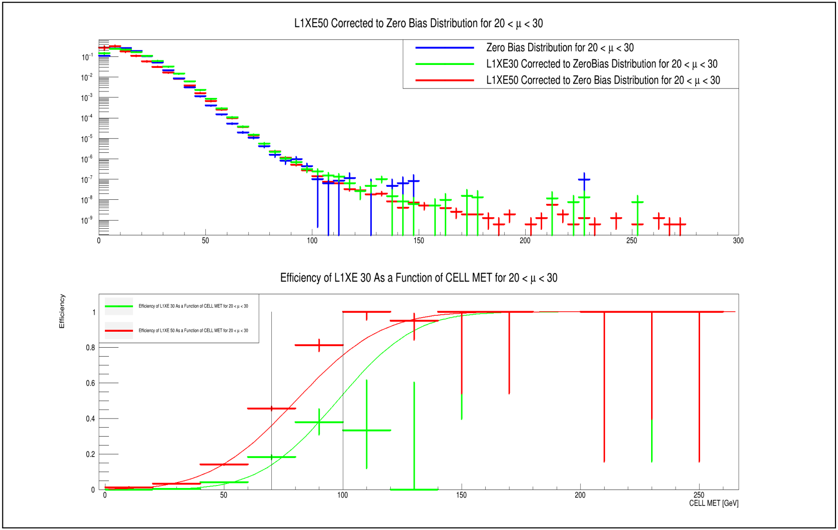
Unbiased Distributions for $0 < \mu < 10$



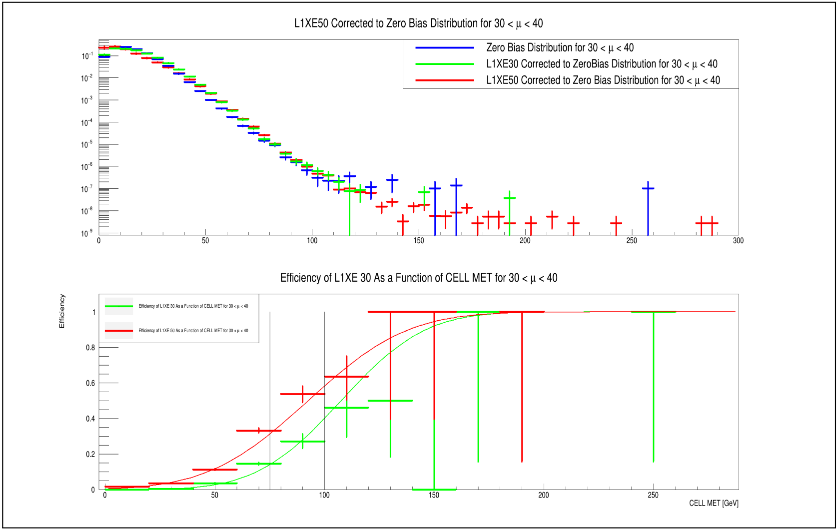
Unbiased Distributions for $10 < \mu < 20$



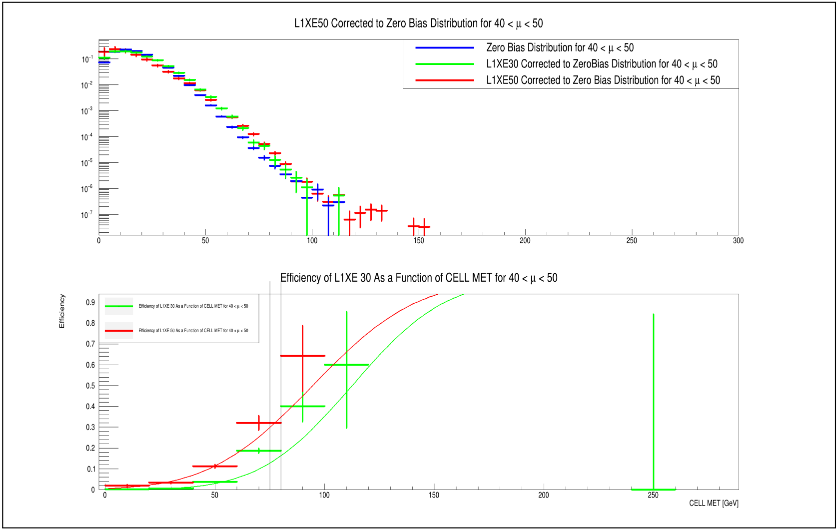
Unbiased Distributions for $20 < \mu < 30$



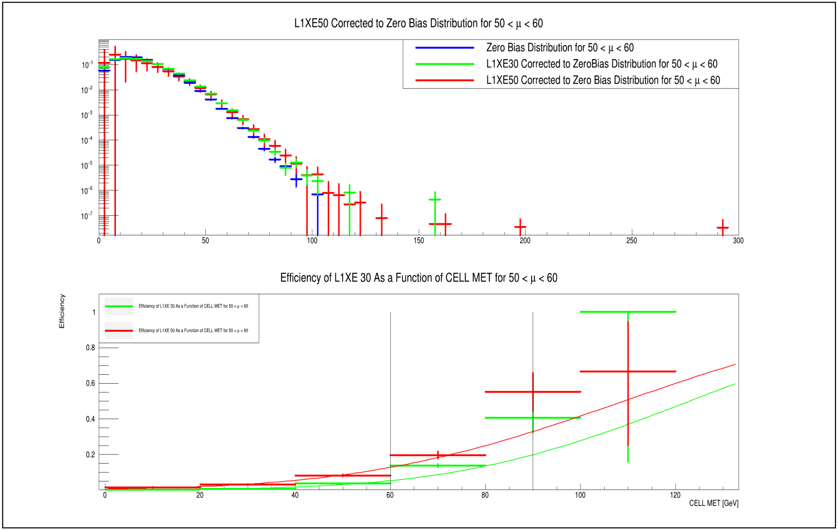
Unbiased Distributions for $30 < \mu < 40$



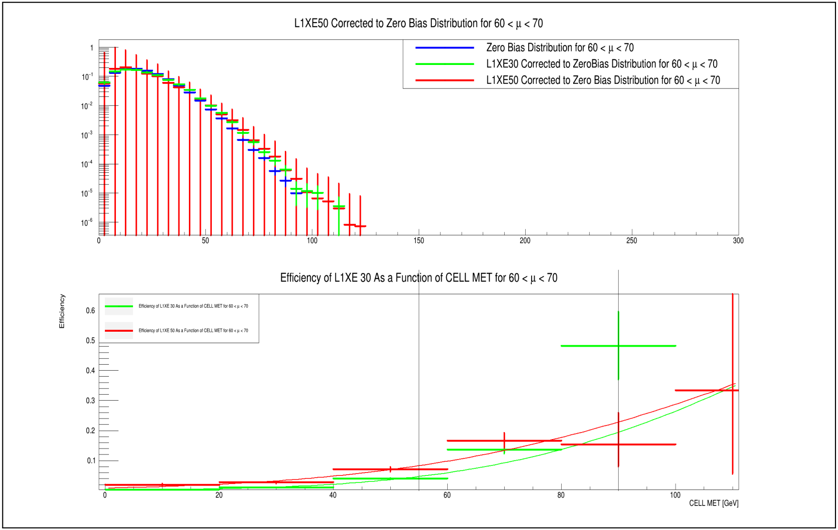
Unbiased Distributions for $40 < \mu < 50$



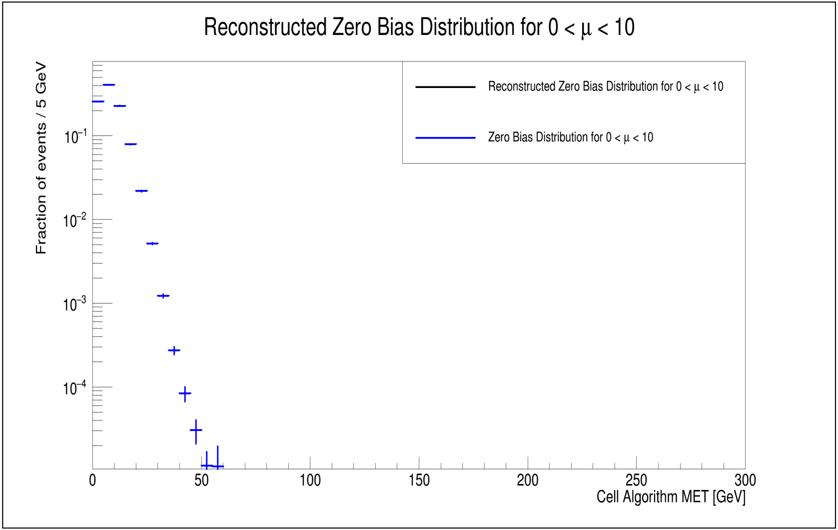
Unbiased Distributions for $50 < \mu < 60$



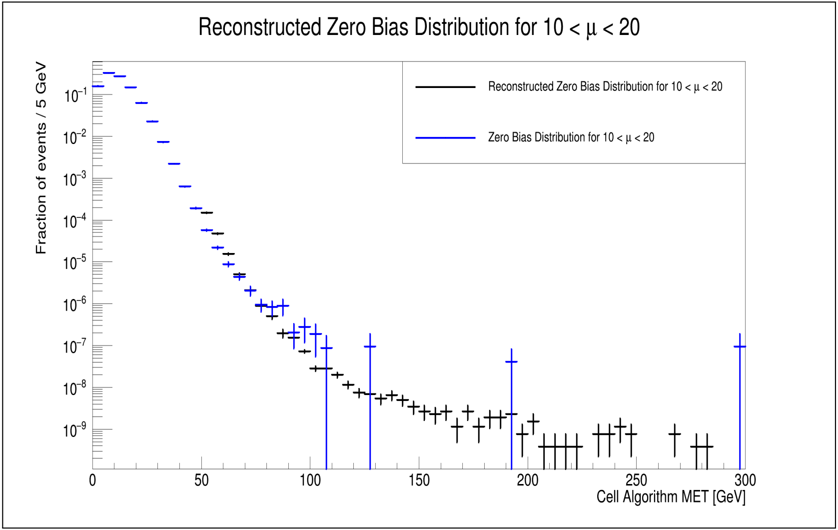
Unbiased Distributions for $60 < \mu < 70$



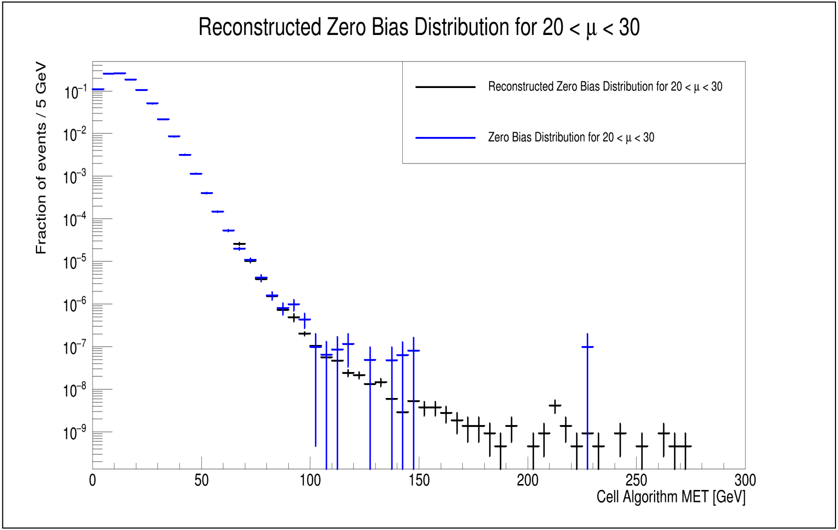
Reconstructed Unbiased CELL MET Distribution for $0 < \mu < 10$



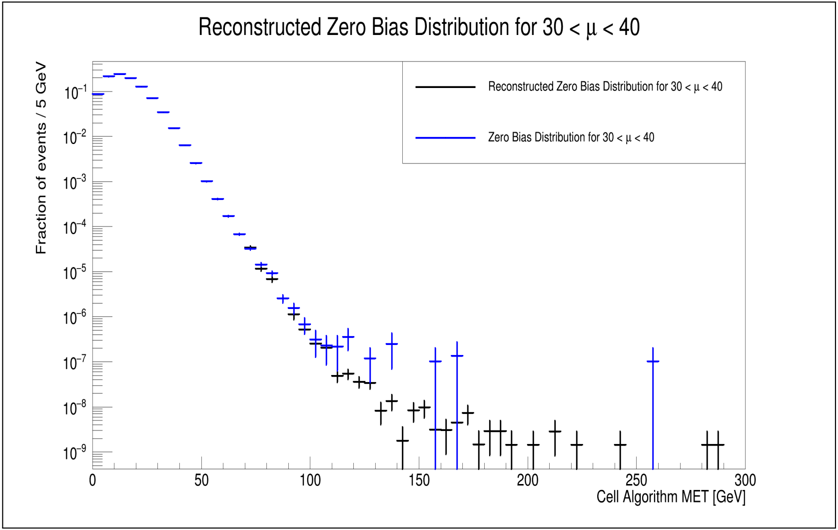
Reconstructed Unbiased CELL MET Distribution for $10 < \mu < 20$



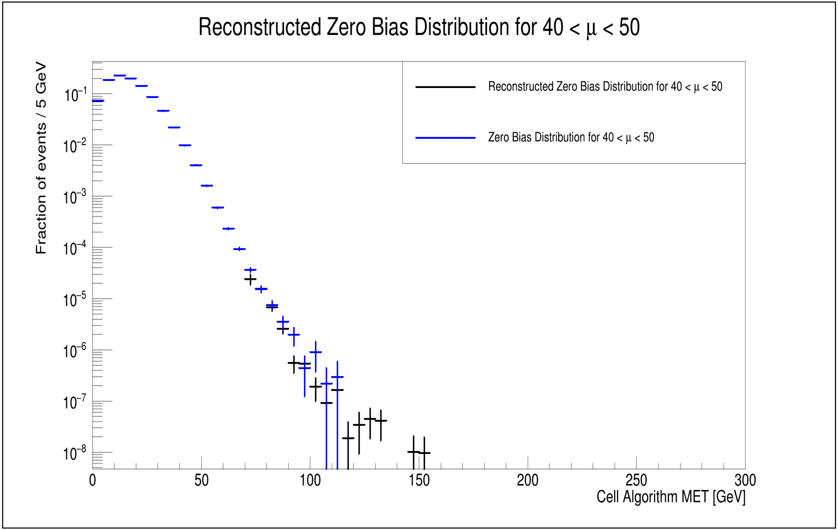
Reconstructed Unbiased CELL MET Distribution for $20 < \mu < 30$



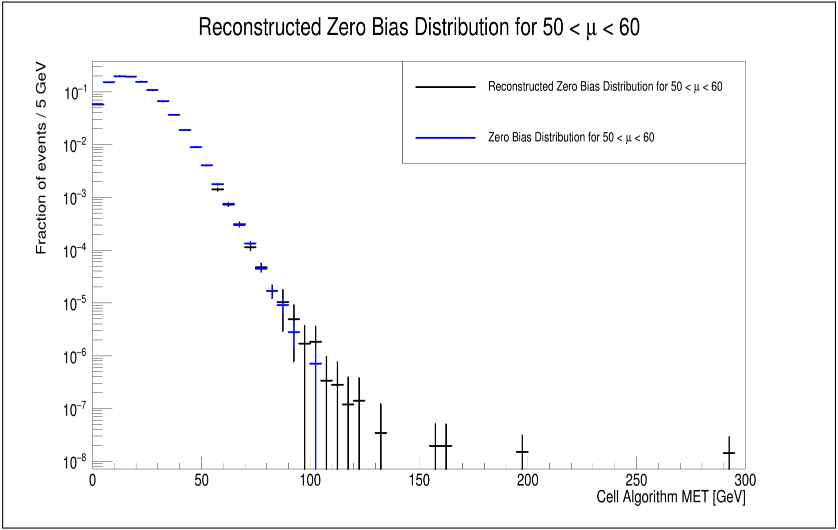
Reconstructed Unbiased CELL MET Distribution for $30 < \mu < 40$



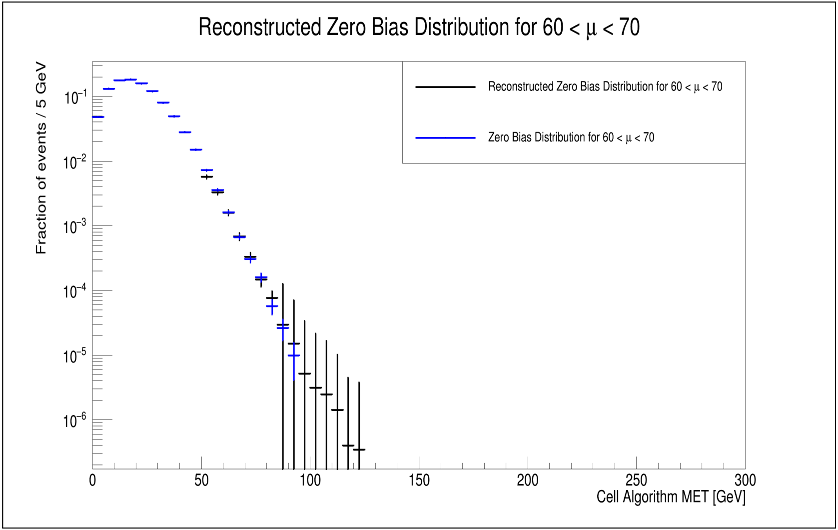
Reconstructed Unbiased CELL MET Distribution for $40 < \mu < 50$



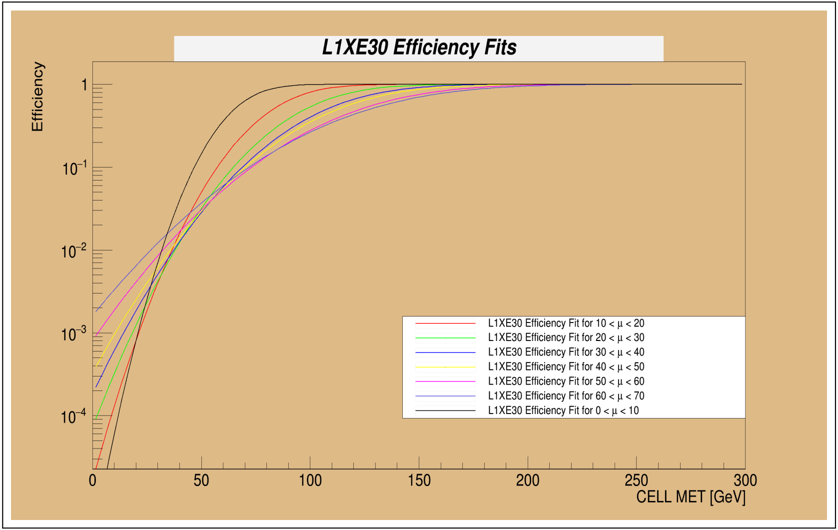
Reconstructed Unbiased CELL MET Distribution for $50 < \mu < 60$



Reconstructed Unbiased CELL MET Distribution for $60 < \mu < 70$



L1XE30 Efficiency Fits with respect to HLTnoalg_L1ZB Data



L1XE50 Efficiency Fits with respect to HLTnoalg_L1XE30 Data

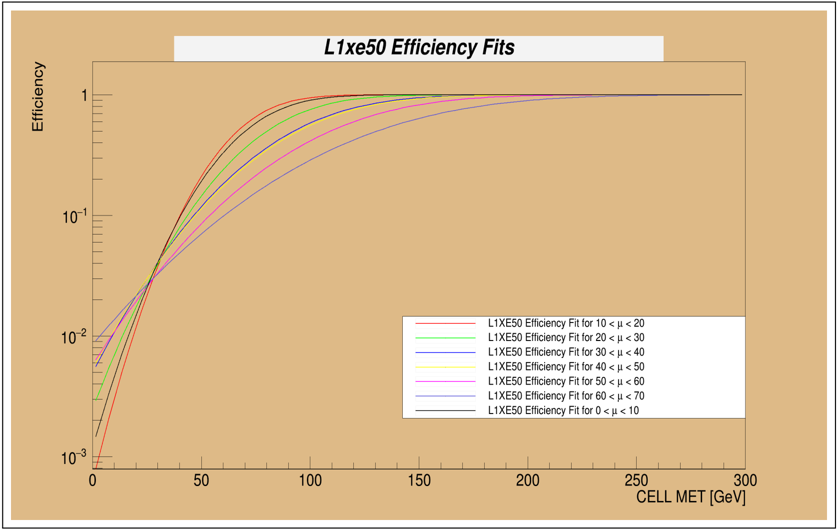


Table: Fit Parameter Table

a	b	σ	L1XE	μ bin
0.536043	-4.88401	7.63437	30	0
0.449818	18.4754	10.3507	50	0
0.40883	-3.87341	8.13195	30	1
0.505088	16.3944	10.3677	50	1
0.336915	-2.90115	8.63962	30	2
0.345437	22.3296	9.83129	50	2
0.29943	-2.17211	9.01473	30	3
0.277972	24.32	9.94887	50	3
0.281092	-1.63701	9.27598	30	4
0.289215	22.6488	10.6932	50	4
0.2487	-0.58147	9.68806	30	5
0.230607	24.8226	9.95501	50	5
0.231716	0.541431	9.99171	30	6
0.183126	26.0774	10.0148	50	6