Feasibility Study of Measuring the Higgs Self-coupling Using the Muon Collider

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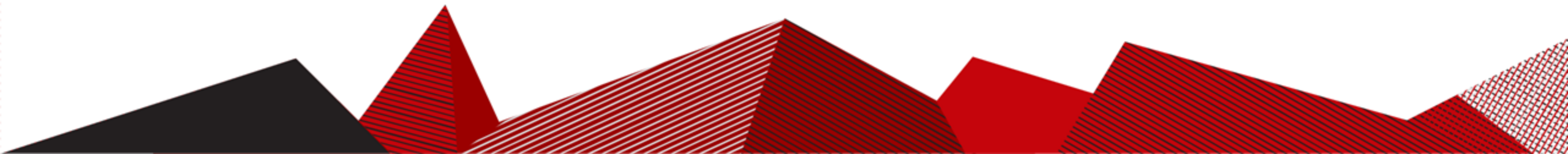
- Signal: $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + H + H$
- Background:
  - $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + b + \bar{b} + Z$
  - $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + b + \bar{b} + H$
  - $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + b + \bar{b} + b + \bar{b}$

Jets Calibration

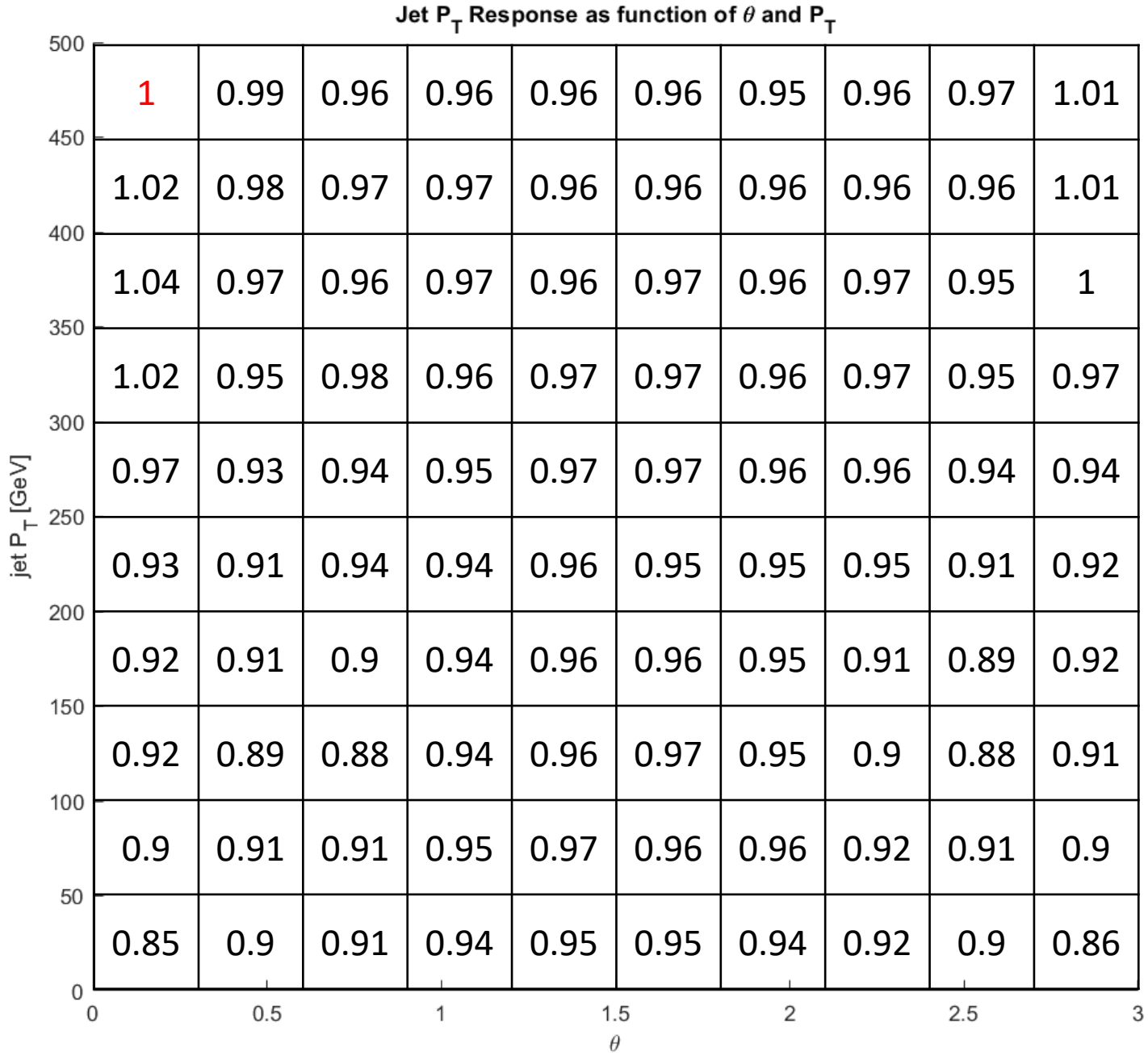


JES

- In order to have enough statistics, generate 100k events of
  - $\mu^- + \mu^+ \rightarrow t + \bar{t}$

Muon-in-jet situation

1. Create Muon-tagging:
   - For truth-matched jet, find gen level μ^- or μ^+ near the gen level jet center. If $\Delta R_{\mu\ jet} < 0.5$, add muon-tagging to jet.
2. Checked distributions of energy response for jets w/ and w/o muon-tagging in different regions.
3. Muon-in-jet correction:
   - Planning to add the matched muon's four-momentum to the jet.


Jet P_T Response as function of θ and P_T
jet P_T [GeV]
θ
500
450
400
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
1 0.99 0.96 0.96 0.96 0.96 0.95 0.96 0.97 1.01
1.02 0.98 0.97 0.97 0.96 0.96 0.96 0.96 0.96 1.01
1.04 0.97 0.96 0.97 0.96 0.97 0.96 0.97 0.95 1
1.02 0.95 0.98 0.96 0.97 0.97 0.96 0.97 0.95 0.97
0.97 0.93 0.94 0.95 0.97 0.97 0.96 0.96 0.94 0.94
0.93 0.91 0.94 0.94 0.96 0.95 0.95 0.95 0.91 0.92
0.92 0.91 0.9 0.94 0.96 0.96 0.95 0.91 0.89 0.92
0.92 0.89 0.88 0.94 0.96 0.97 0.95 0.9 0.88 0.91
0.9 0.91 0.91 0.95 0.97 0.96 0.96 0.92 0.91 0.9
0.85 0.9 0.91 0.94 0.95 0.95 0.94 0.92 0.9 0.86

Muon-tagging = true

Jet P_T Response as function of θ and P_T

jet P_T [GeV] \ θ	0	0.5	1	1.5	2	2.5	3
500	1	0.99	0.96	0.96	0.96	0.96	0.96	0.96	0.97	1.02
450	1	0.97	0.99	0.97	0.96	0.95	0.94	0.96	0.96	0.99
400	1.08	0.97	0.97	0.96	0.96	0.95	0.96	0.98	0.97	0.99
350	1.07	0.94	0.98	0.99	0.95	0.96	0.95	0.96	0.95	0.96
300	0.97	0.93	0.92	0.95	0.95	0.95	0.96	0.91	0.92	0.93
250	0.92	0.89	0.91	0.9	0.91	0.89	0.93	0.93	0.88	0.89
200	0.93	0.89	0.84	0.88	0.88	0.87	0.86	0.85	0.85	0.9
150	0.93	0.86	0.72	0.84	0.89	0.88	0.78	0.78	0.8	0.9
100	0.91	0.9	0.81	0.82	0.83	0.84	0.84	0.81	0.84	0.88
50	0.84	0.85	0.83	0.86	0.88	0.87	0.86	0.83	0.84	0.84
0										

θ

Muon-tagging = false

Jet P_T Response as function of θ and P_T

jet P_T [GeV]	θ = 0	0.5	1	1.5	2	2.5	3
500	1	0.99	0.96	0.96	0.95	0.95	0.95	0.96	0.97	1.01
450	1.02	0.98	0.97	0.97	0.96	0.96	0.97	0.95	0.96	1.01
400	1.03	0.97	0.96	0.97	0.96	0.97	0.97	0.97	0.95	1
350	1.01	0.95	0.98	0.96	0.97	0.98	0.97	0.97	0.96	0.98
300	0.97	0.93	0.94	0.95	0.98	0.98	0.96	0.97	0.94	0.94
250	0.93	0.92	0.94	0.95	0.97	0.96	0.95	0.95	0.91	0.93
200	0.92	0.91	0.91	0.95	0.97	0.97	0.96	0.92	0.89	0.92
150	0.91	0.9	0.9	0.95	0.96	0.98	0.96	0.92	0.9	0.91
100	0.9	0.91	0.92	0.96	0.98	0.97	0.97	0.94	0.92	0.9
50	0.85	0.91	0.92	0.94	0.96	0.95	0.95	0.93	0.91	0.86
0										

θ

Percent of jet's been tagged

Jet P_T Response as function of θ and P_T

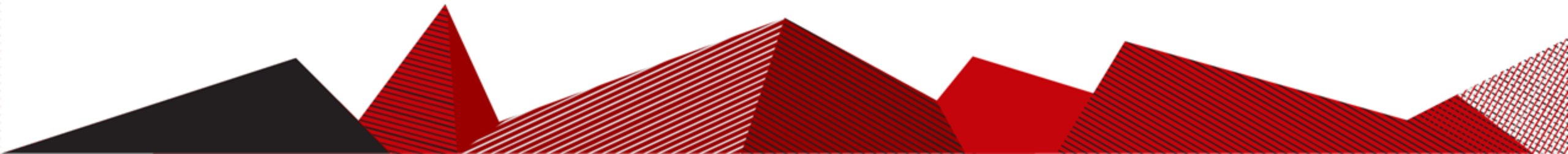
jet P_T [GeV] \ θ	0	0.5	1	1.5	2	2.5
500	N/A	22%	26%	29%	29%	29%
450	0%	21%	28%	27%	24%	24%
400	15%	22%	26%	23%	20%	17%
350	9%	21%	23%	17%	18%	15%
300	19%	22%	18%	16%	15%	13%
250	17%	20%	17%	11%	11%	10%
200	16%	18%	16%	10%	8%	9%
150	15%	16%	13%	9%	8%	7%
100	13%	12%	10%	7%	6%	6%
50	10%	9%	8%	6%	6%	5%

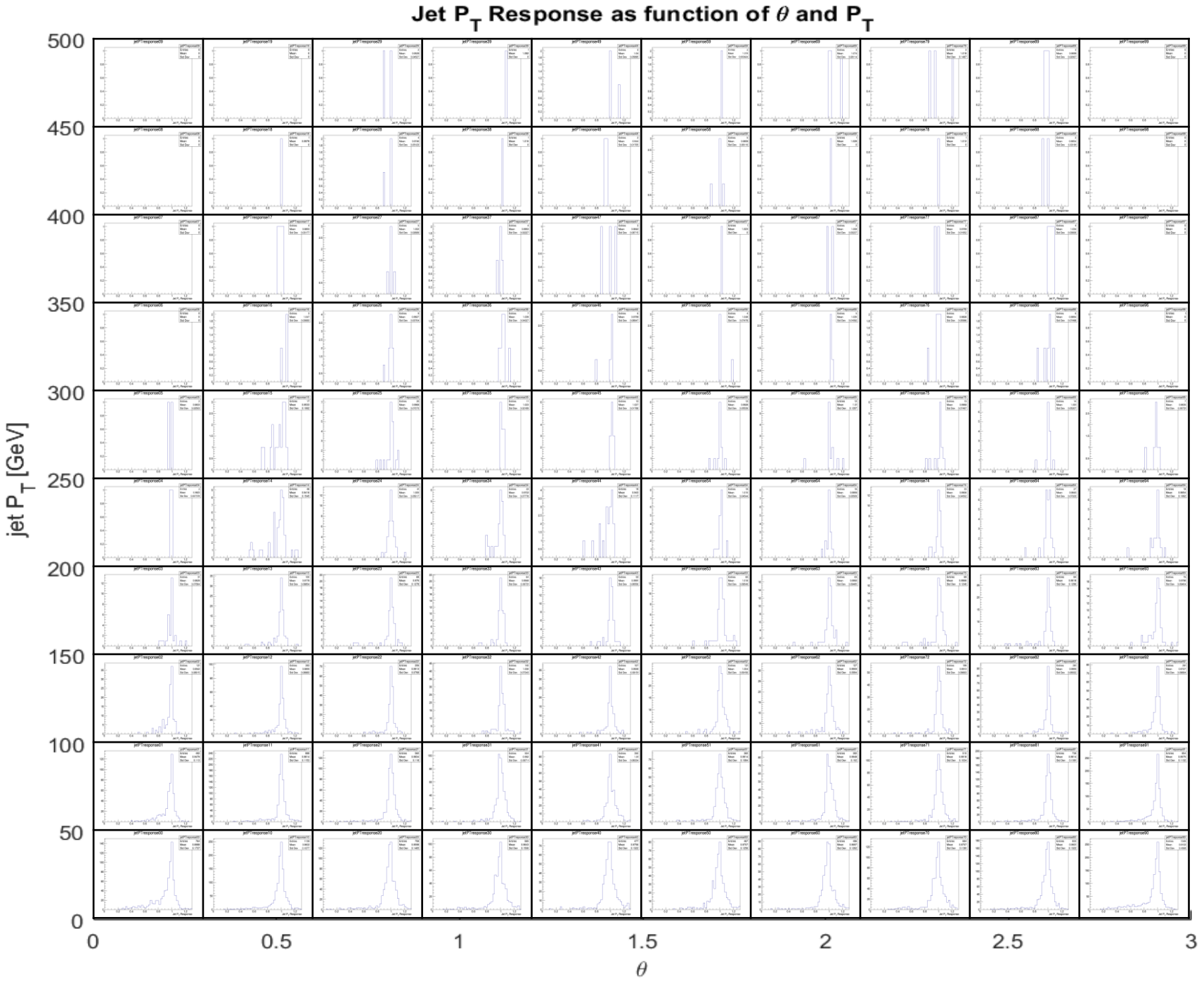
jet P_T [GeV] \ θ	2.5	3
500	28%	25%	19%
450	30%	28%	17%
400	26%	23%	17%
350	20%	24%	20%
300	18%	24%	19%
250	14%	17%	18%
200	13%	18%	17%
150	10%	16%	16%
100	9%	11%	13%
50	7%	8%	9%

Observations

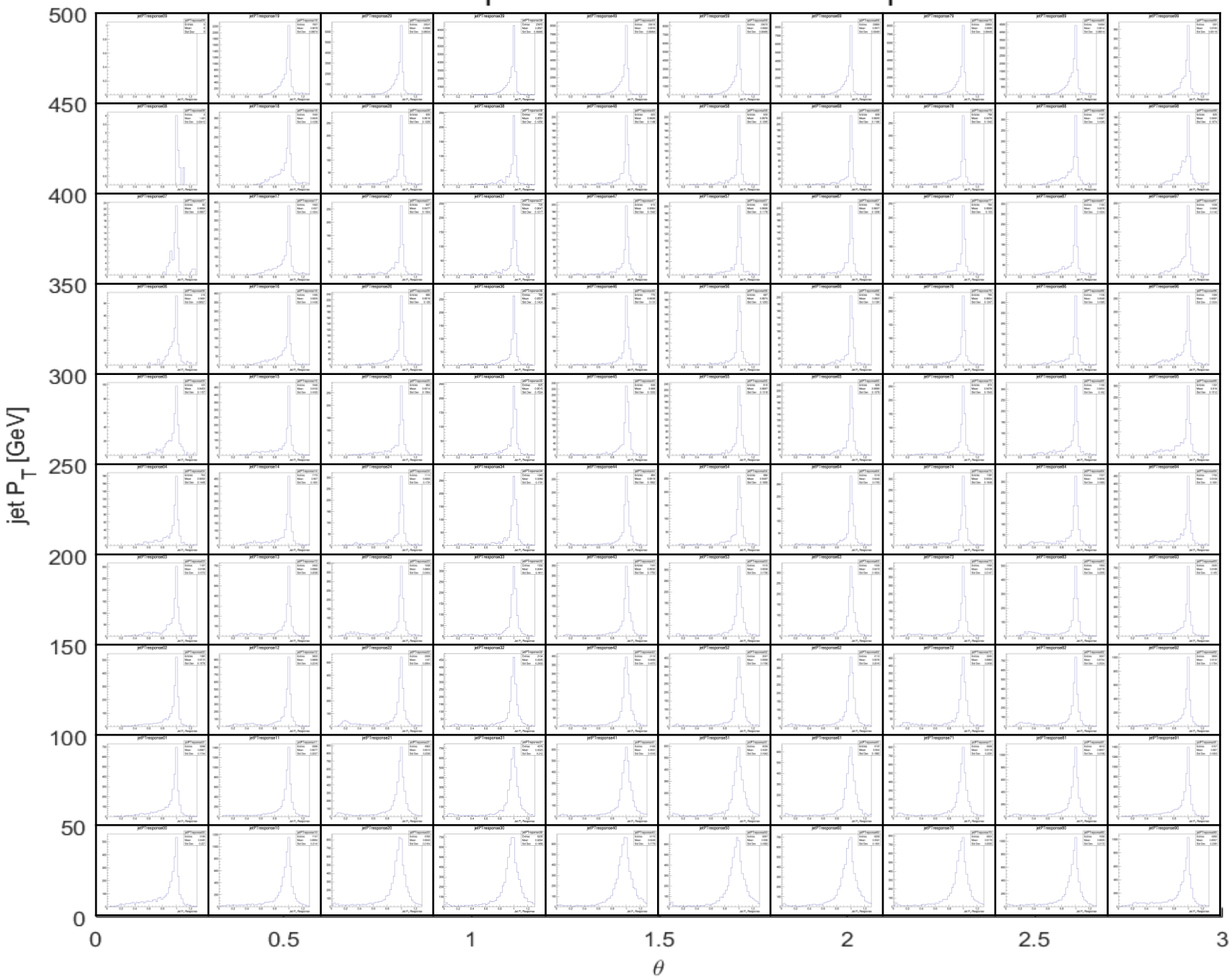
1. Is good to see that for $p_T < 400\ GeV$ the JES w/ muon-tagging is almost always smaller than JES w/o muon-tagging.
2. For $p_T > 400\ GeV$, JES are almost the same.
3. We could see a pattern that the muon-tagging jet are less for region with low p_T and θ close to the center of the detector.

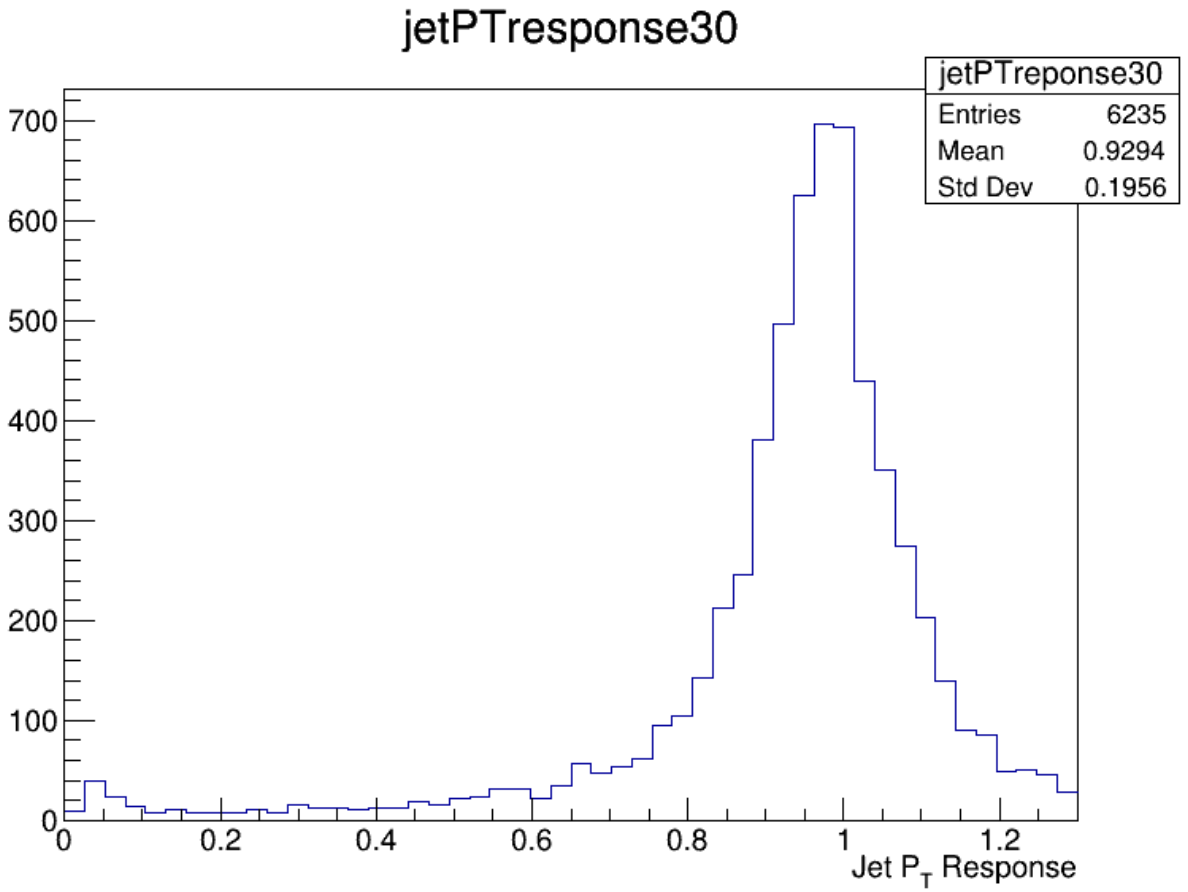
$\frac{P_{Treco}}{P_{Tgen}}$ distribution for each bins

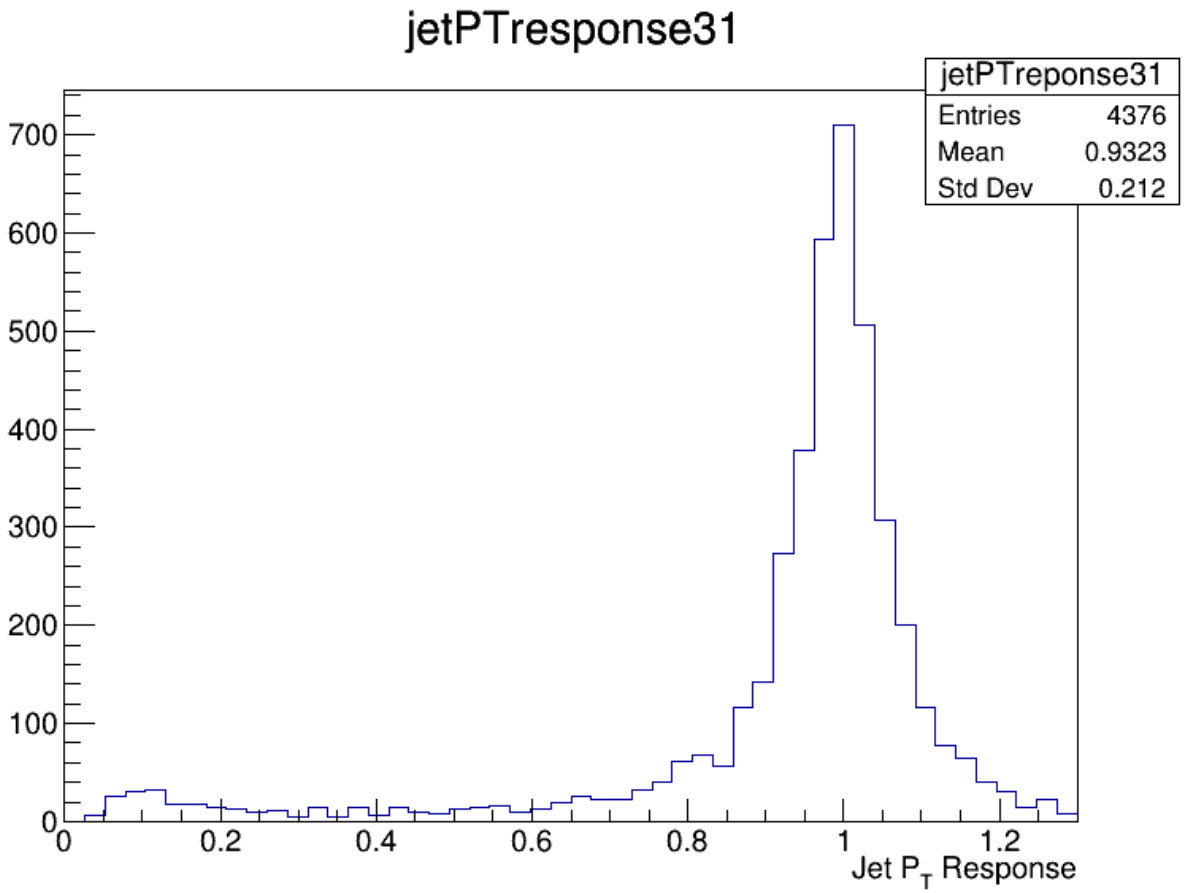


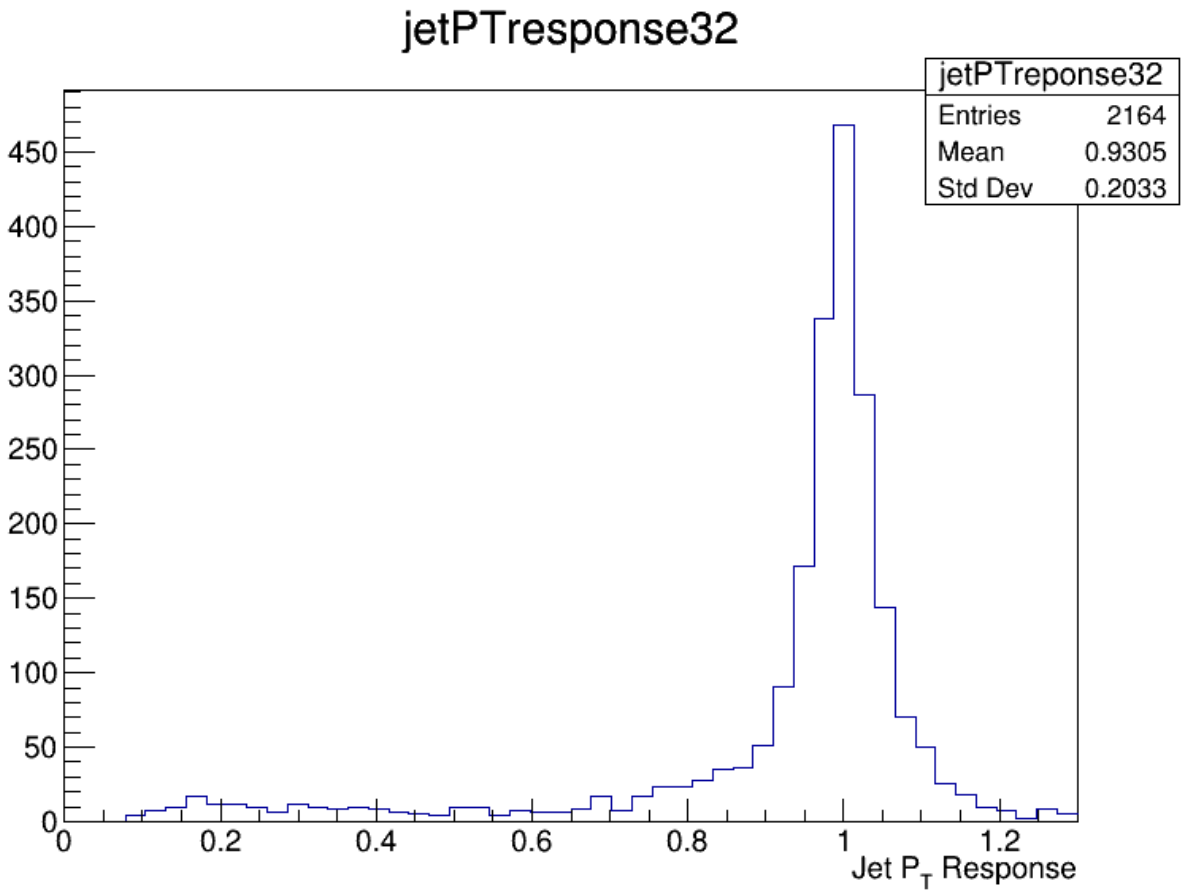


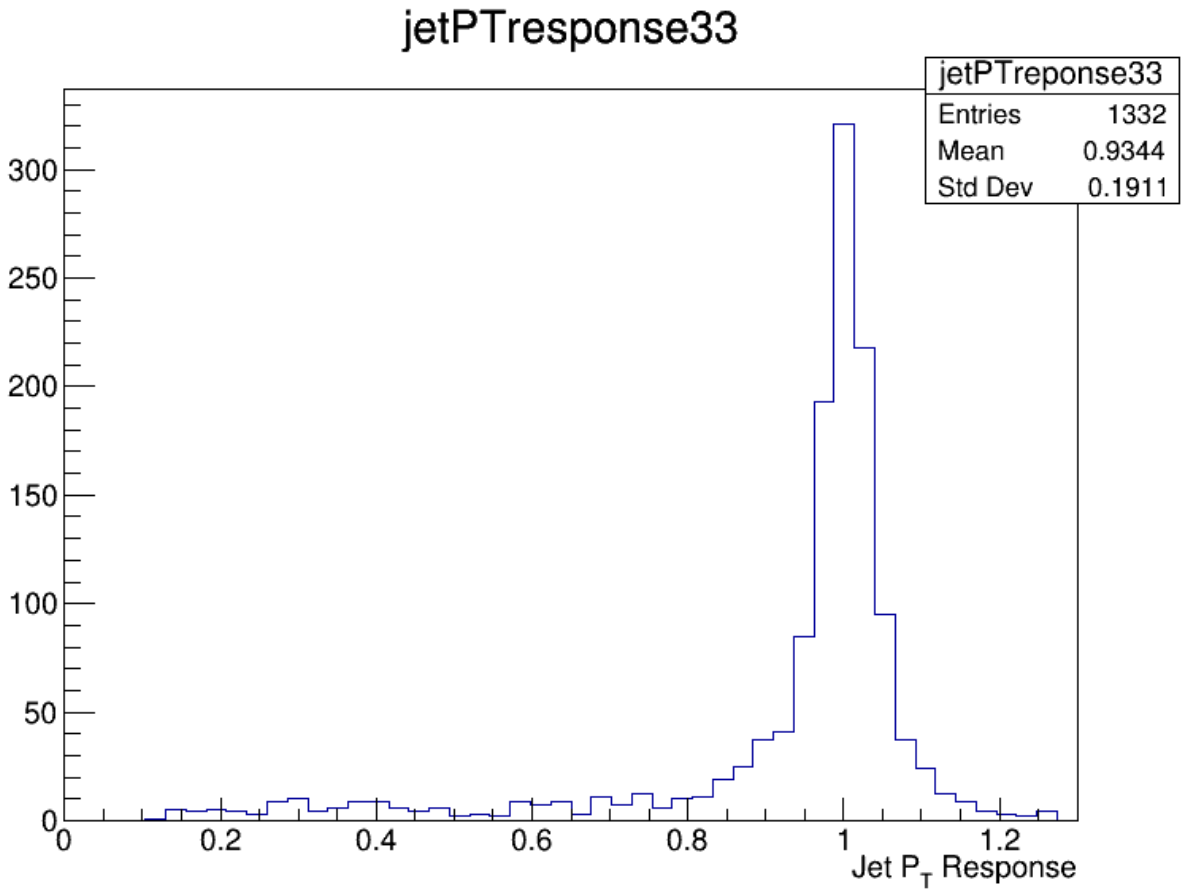
Old distribution without enough statistics

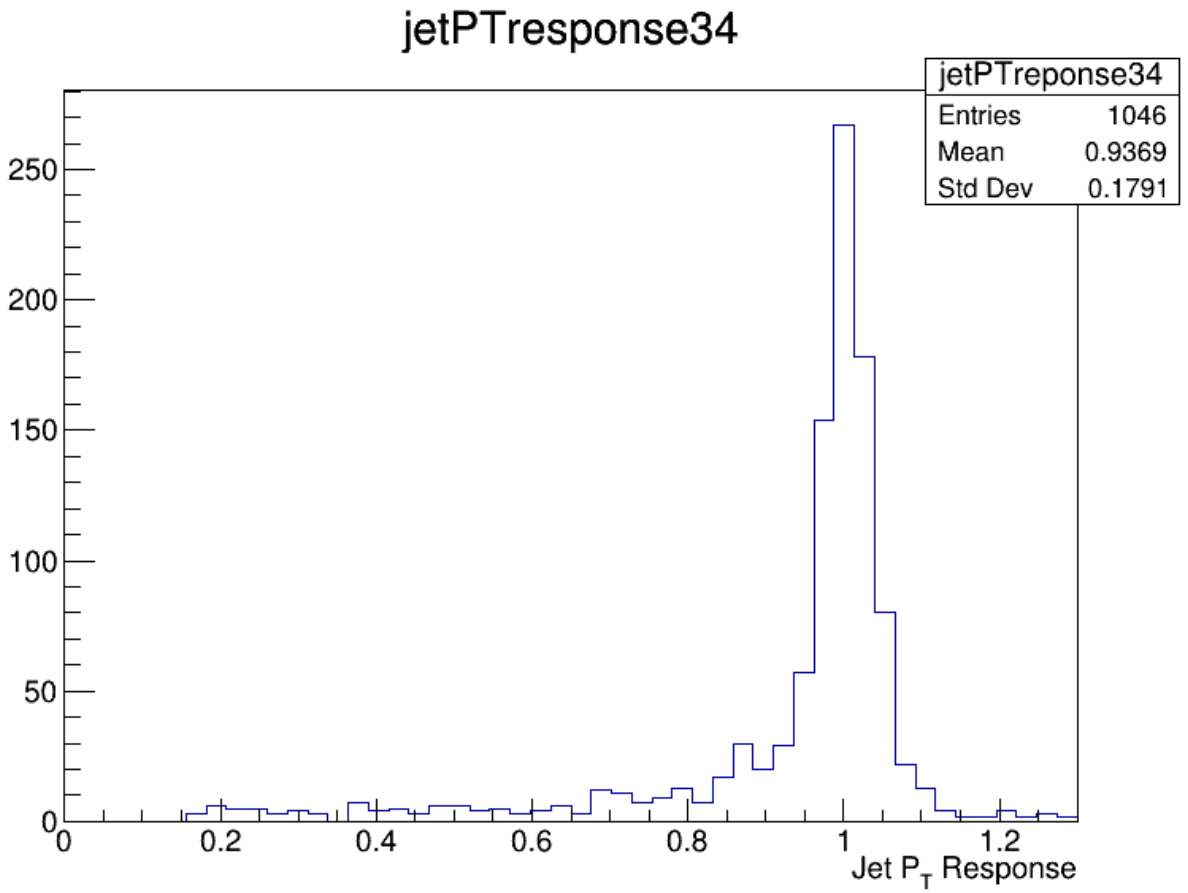

Jet P_T Response as function of θ and P_T
jet P_T [GeV]
0
50
100
150
200
250
300
350
400
450
500
0
0.5
1
1.5
2
2.5
3
θ

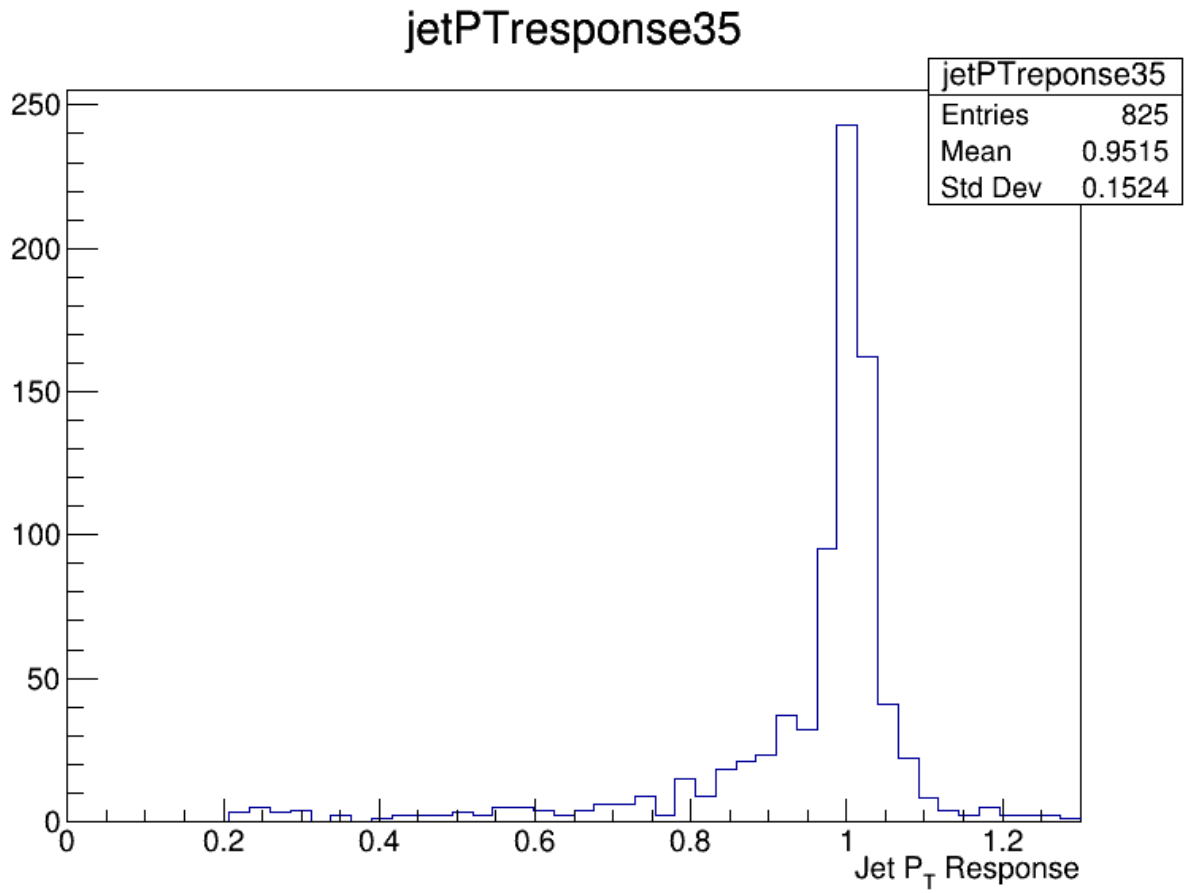

jetPTresponse30
jetPTreponse30
Entries 6235
Mean 0.9294
Std Dev 0.1956
700
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response

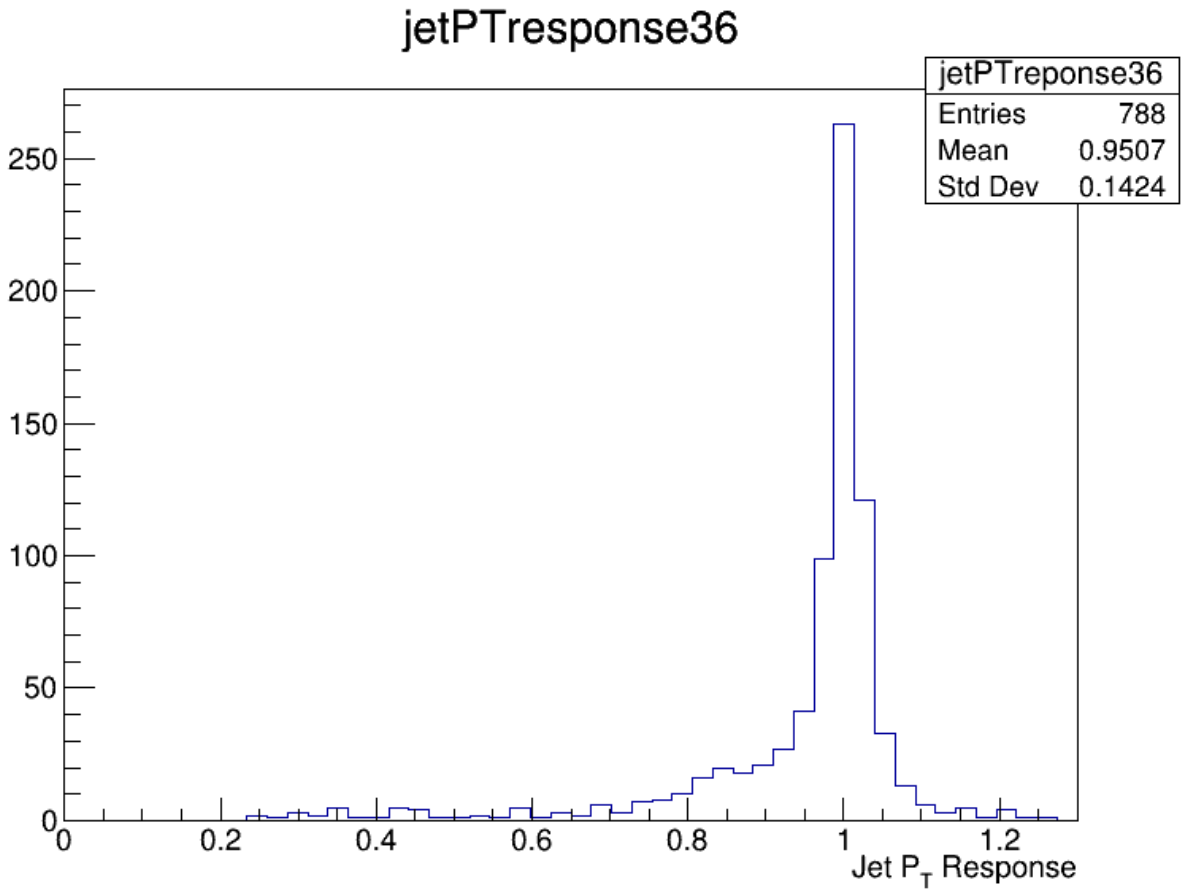

jetPTresponse31
jetPTreponse31
Entries 4376
Mean 0.9323
Std Dev 0.212
700
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response

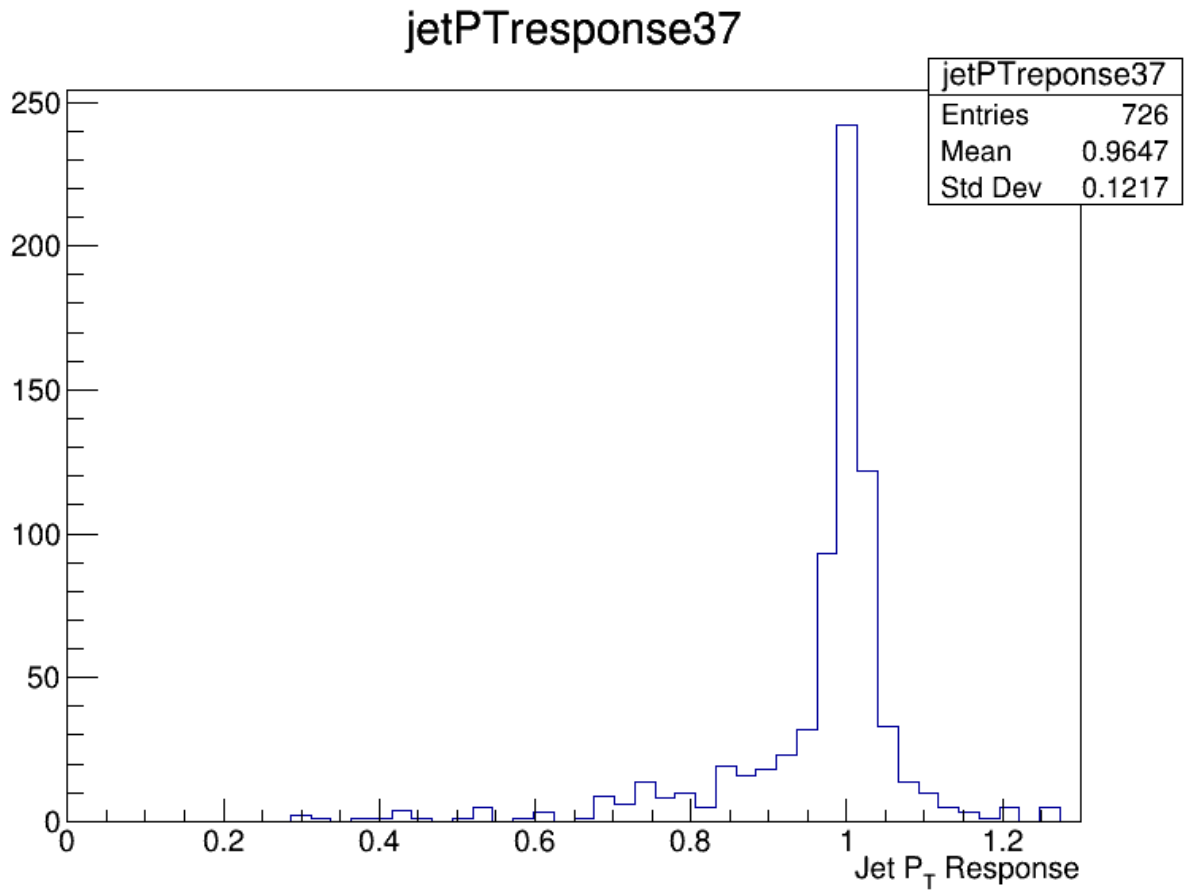

jetPTresponse32
jetPTreponse32
Entries 2164
Mean 0.9305
Std Dev 0.2033
450
400
350
300
250
200
150
100
50
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response

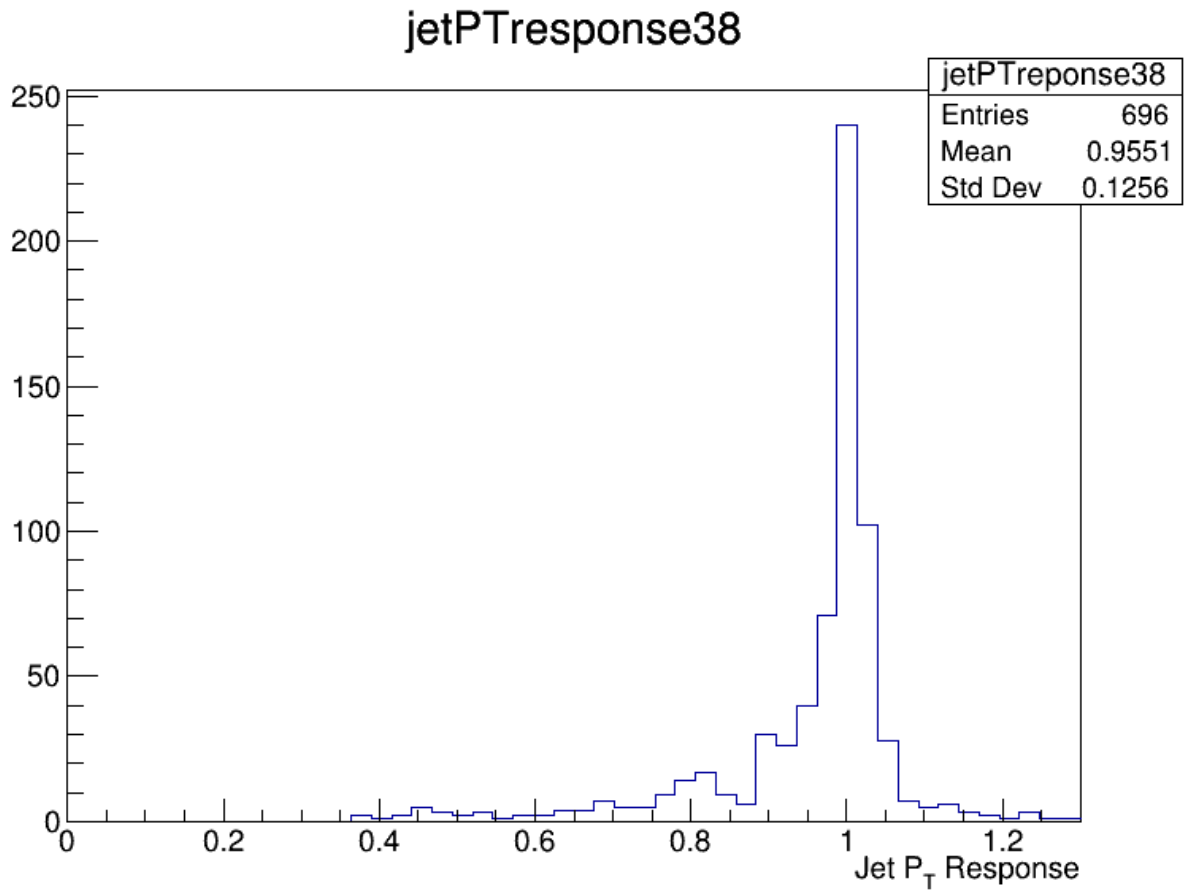

jetPTresponse33
jetPTreponse33
Entries 1332
Mean 0.9344
Std Dev 0.1911
300
250
200
150
100
50
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response

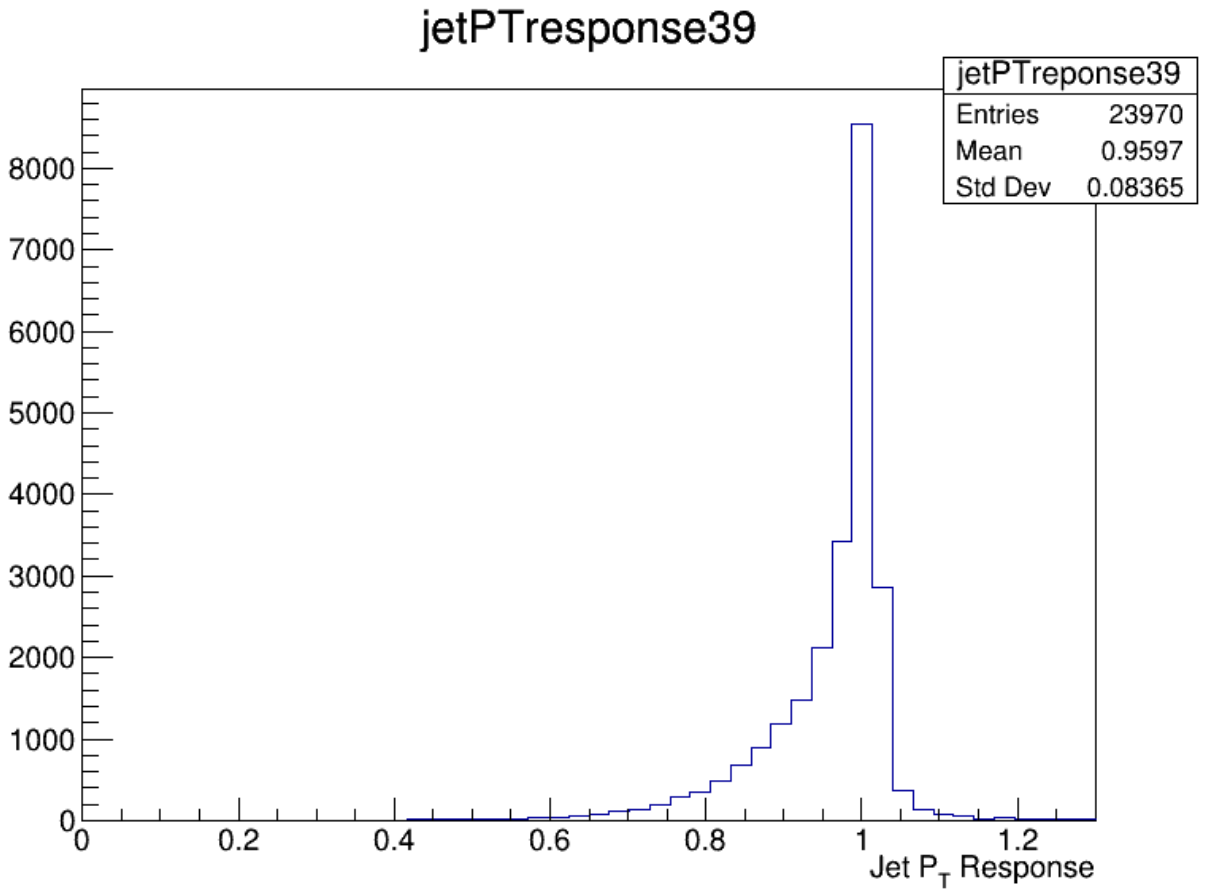

jetPTresponse34
jetPTreponse34
Entries 1046
Mean 0.9369
Std Dev 0.1791
250
200
150
100
50
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response

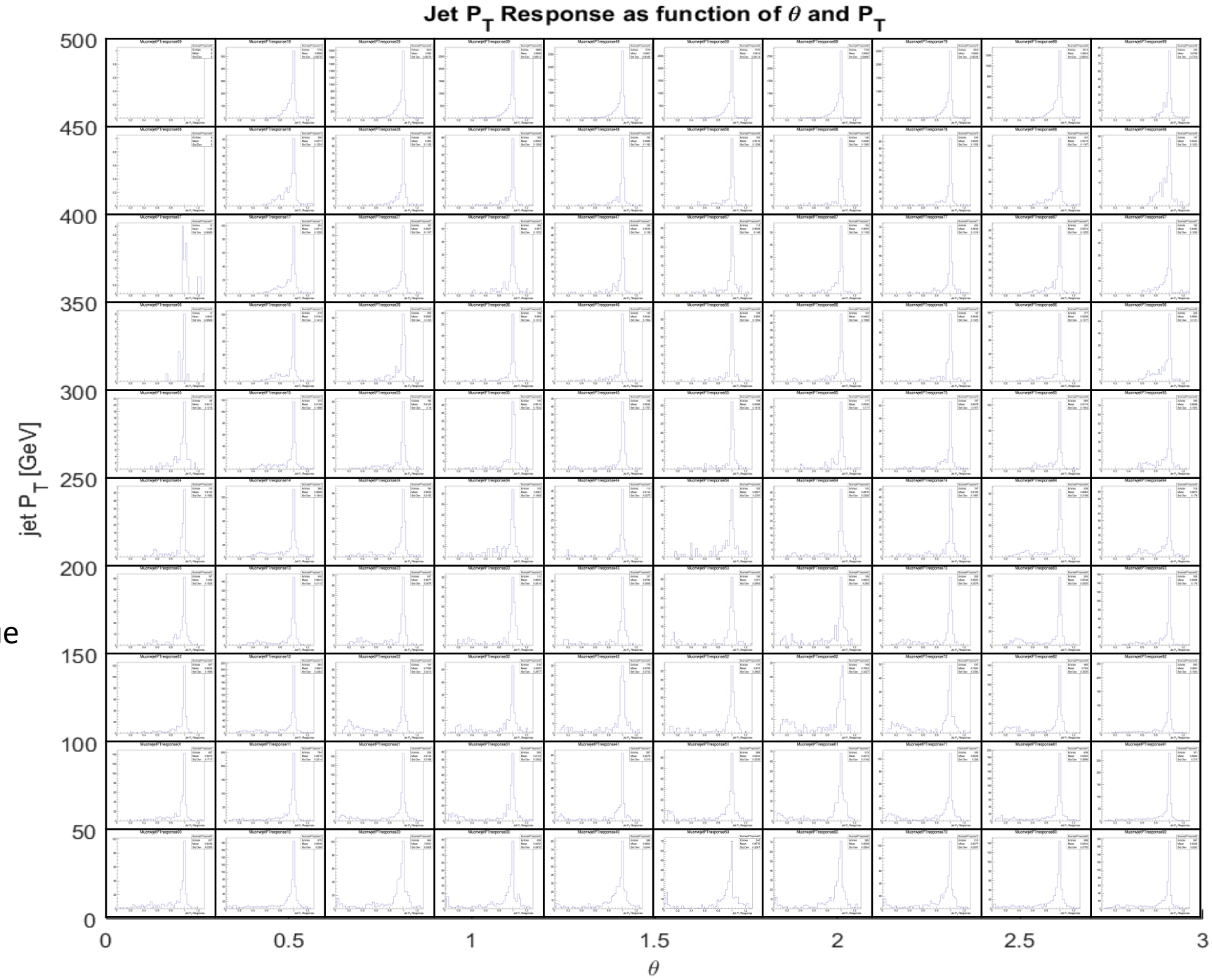

jetPTresponse35
jetPTreponse35
Entries 825
Mean 0.9515
Std Dev 0.1524
250
200
150
100
50
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response


jetPTresponse36
jetPTreponse36
Entries 788
Mean 0.9507
Std Dev 0.1424
250
200
150
100
50
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response

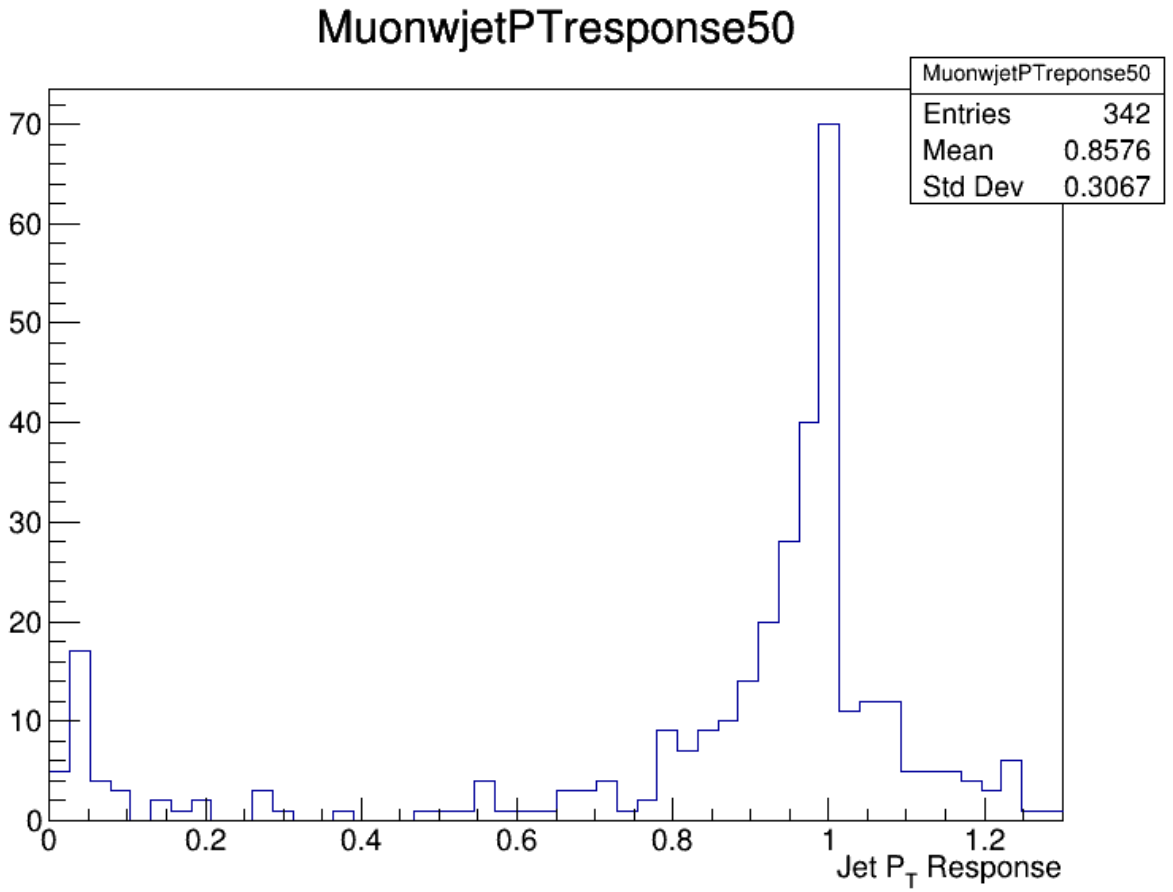

jetPTresponse37
jetPTreponse37
Entries 726
Mean 0.9647
Std Dev 0.1217
250
200
150
100
50
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response

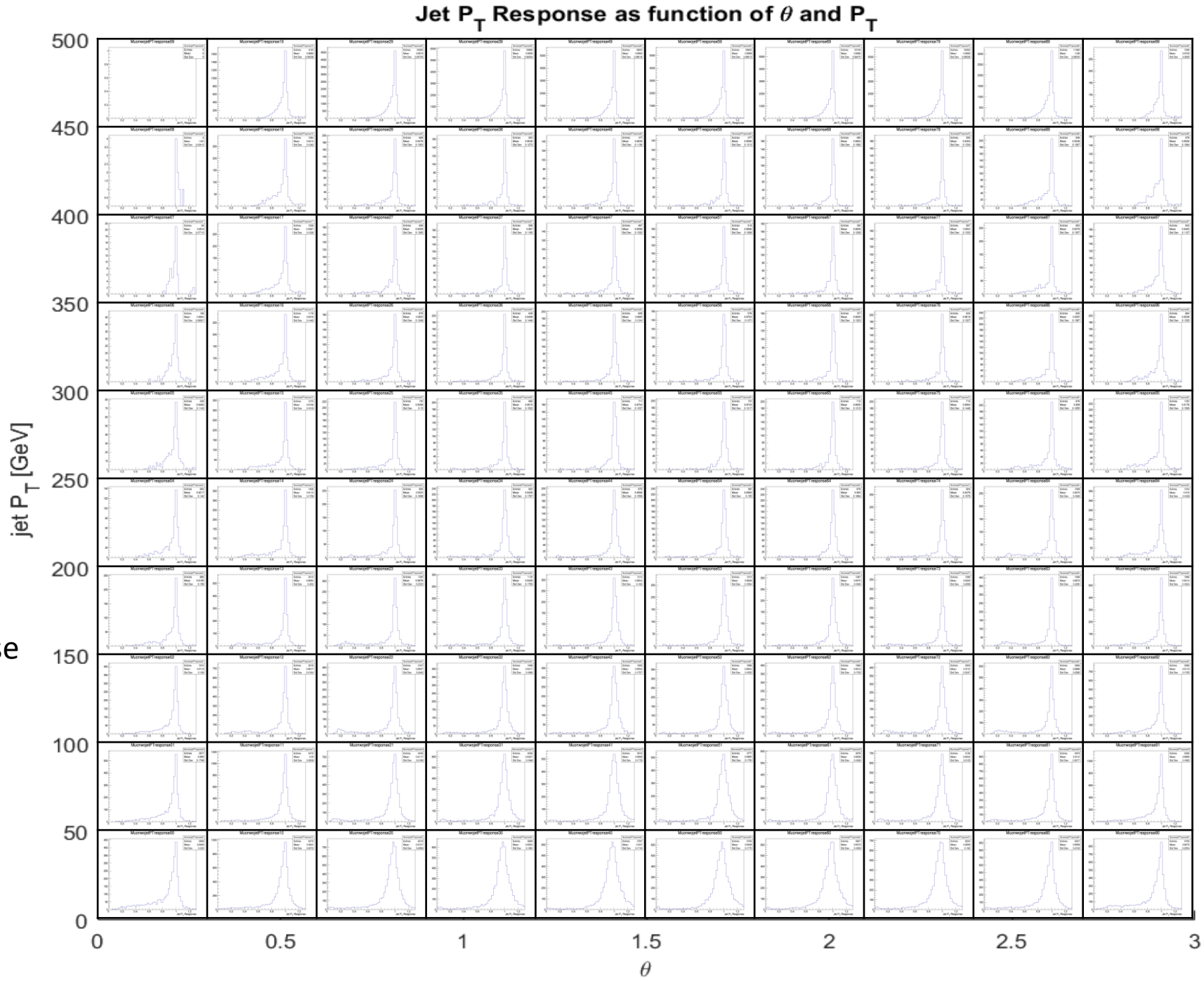

jetPTresponse38
jetPTreponse38
Entries 696
Mean 0.9551
Std Dev 0.1256
250
200
150
100
50
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response


jetPTresponse39
jetPTreponse39
Entries 23970
Mean 0.9597
Std Dev 0.08365
8000
7000
6000
5000
4000
3000
2000
1000
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response



Muon-tagging = true


MuonwjetPTresponse50
MuonwjetPTreponse50
Entries 342
Mean 0.8576
Std Dev 0.3067
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
Jet P_T Response



Muon-tagging = false

Next step:

1. Muon tagging:
   - Currently discriminant is whether a gen level muon near gen level jet, should I change to whether a reco muon near reco jet?
2. Adding muon-in-jet correction:
   - Adding gen level muon or reco level muon?
3. JES after muon-in-jet correction:
   - I am thinking about calculate the JES after adding a reco muon four-momentum to the reco jet then calculate the JES again, is this right?