Study of the mismatch between categories with 1 e/μ

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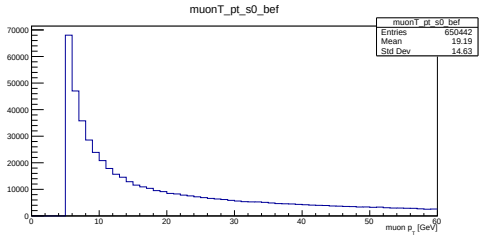
January 27, 2020

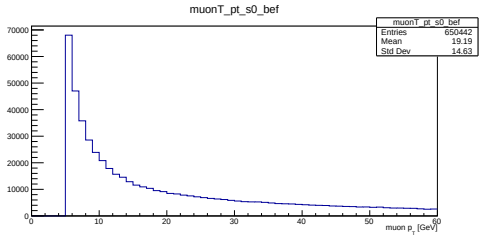
Lepton selection stages

- In order to understand what is introducing the mismatch in our selection, **split** the lepton **selections in stages**
  - **stage 0**: no requirements at all
  - **stage 1**: $|\eta| < 2.4$
  - **stage 2**: lepton ID
  - **stage 3**: ISO
  - **stage 4**: IP
- Stages are cumulative, so stage 4 corresponds to our "usual" leptons
- Preliminary study on **TTTT signal**

Tight muons


muonT_pt_s0_bef
muonT_pt_s0_bef
Entries 650442
Mean 19.19
Std Dev 14.63
70000
60000
50000
40000
30000
20000
10000
0
0
10
20
30
40
50
60
muon p_T [GeV]

Tight muons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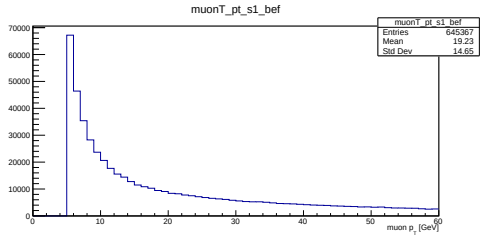
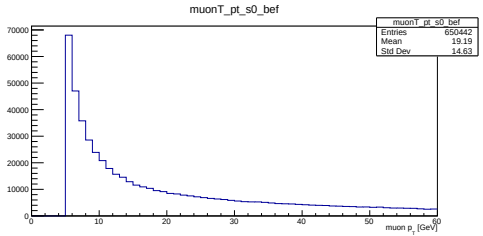

muonT_pt_s1_bef
muonT_pt_s1_bef
Entries 645367
Mean 19.23
Std Dev 14.65
70000
60000
50000
40000
30000
20000
10000
0
0
10
20
30
40
50
60
muon p_T [GeV]

Tight muons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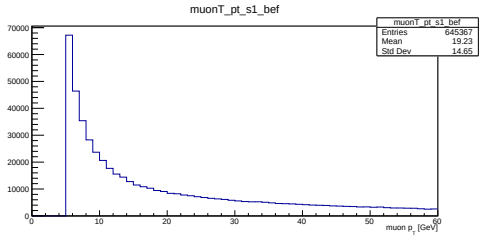
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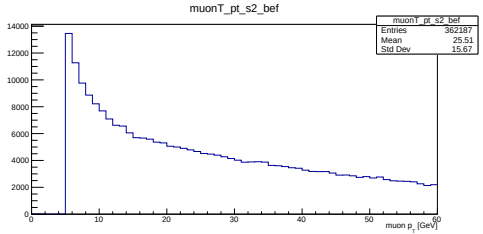
muonT_pt_s1_bef
Entries 645367
Mean 19.23
Std Dev 14.65
muon p_T [GeV]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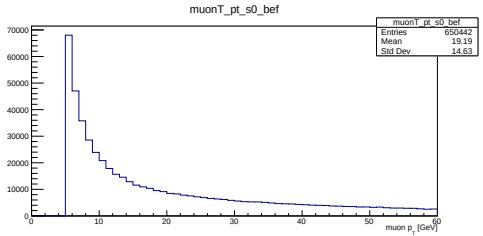
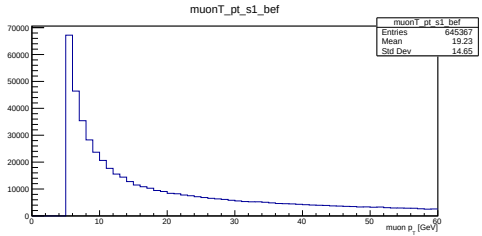
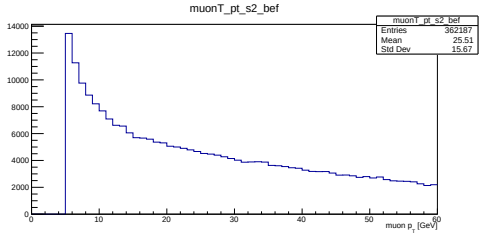
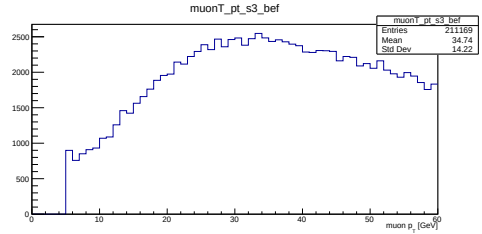
Mean 25.51
Std Dev 15.67
muon p_T [GeV]

Tight muons

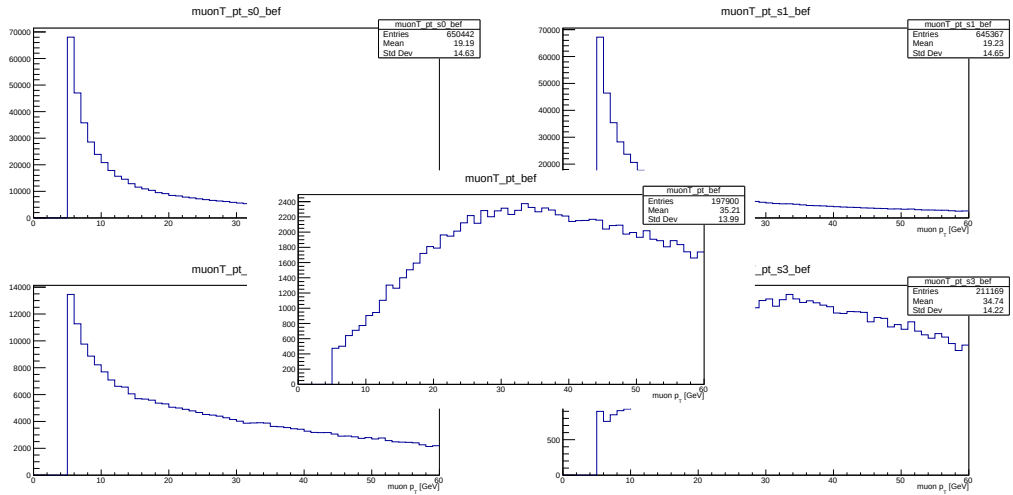








Tight muons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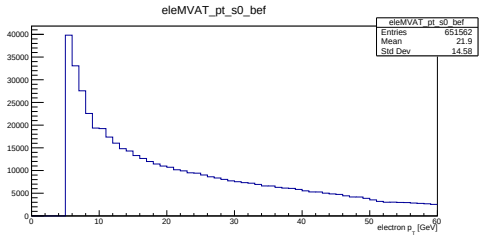
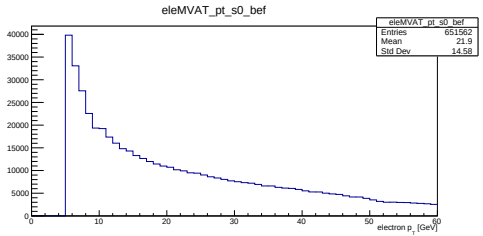
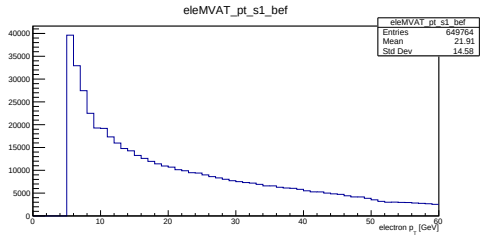
Entries 645367
Mean 19.23
Std Dev 14.65
muonT_pt_bef
muonT_pt_bef
Entries 197900
Mean 35.21
Std Dev 13.99
muonT_pt_
_pt_s3_bef
muonT_pt_s3_bef
Entries 211169
Mean 34.74
Std Dev 14.22
muon p_T [GeV]

Tight electrons

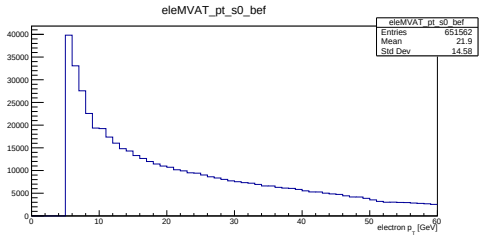


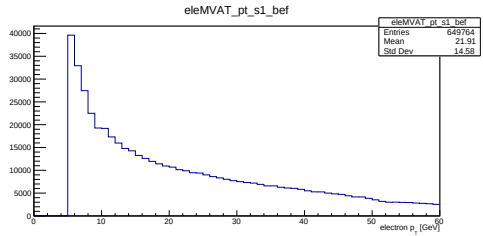
Tight electrons

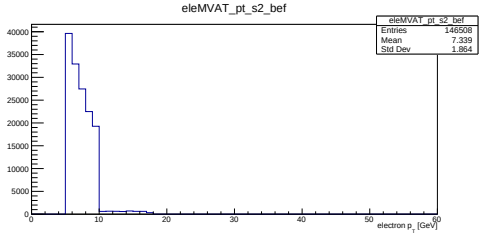




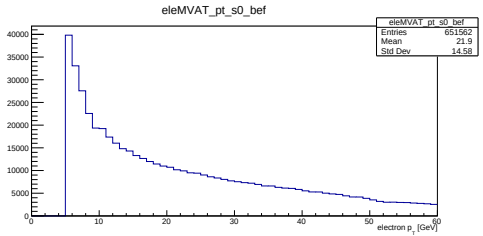
Tight electrons

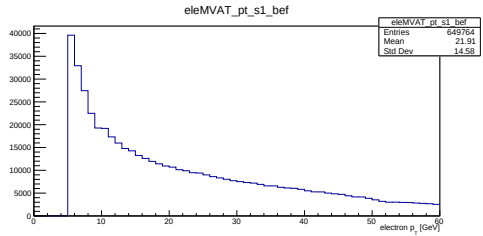


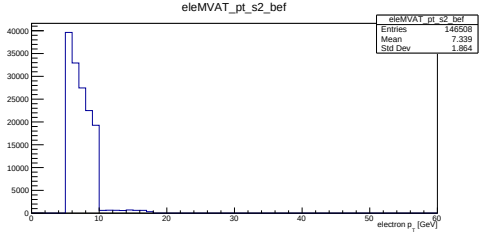


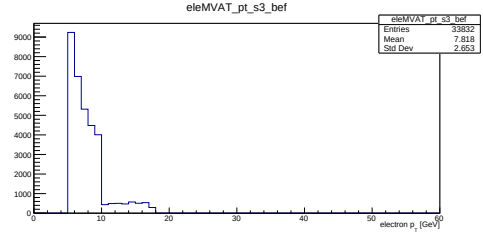


Tight electrons









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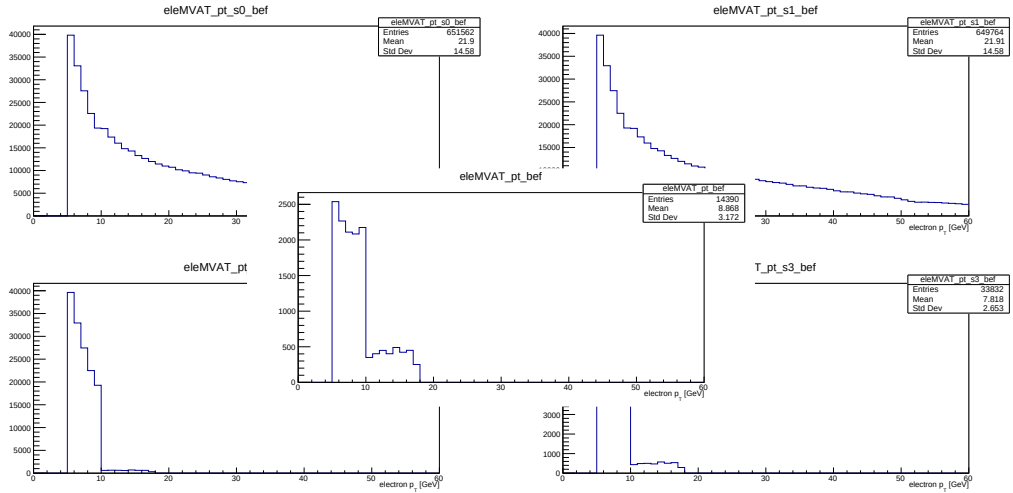


Electron issues

- Results on electrons look nonsense
- Seems 100% unreasonable to have this artificial cut at 18 GeV in p_T spectrum
- The code looks fine...
- **Check** the electron MVA ID **documentation** then

Electron issues

- From slides here:

Cuts/Equations for MVA (2016 - MVANoIso94XV2)

1

Different from 2017/2018

Tight

Region	MVA value, 10<ePt<40	MVA value ePt>=40
|η| < 0.8	> 3.447 + 0.063(pt - 25)	> 4.392
0.8 ≤ |η| < 1.479	> 2.522 + 0.058(pt - 25)	> 3.392
1.479 ≤ |η| < 2.5	> 1.555 + 0.075(pt - 25)	> 2.680

VLoose

Region	ePt: 5-10	10<ePt<25	ePt>=25
|η| < 0.8	> 1.309	> 0.887 + 0.088(pt - 25)	> 0.887
0.8 ≤ |η| < 1.479	> 0.373	> 0.112 + 0.099(pt - 25)	> 0.112
1.479 ≤ |η| < 2.5	> 0.071	> -0.017 + 0.137(pt - 25)	> -0.017

VLooseFO

Region	ePt: 5-10	10<ePt<25	ePt>=25
|η| < 0.8	> -0.259	> -0.388 + 0.109(pt - 25)	> -0.388
0.8 ≤ |η| < 1.479	> -0.256	> -0.696 + 0.106(pt - 25)	> -0.696
1.479 ≤ |η| < 2.5	> -1.630	> -1.219 + 0.148(pt - 25)	> -1.219

cms.InputTag("electronMVAValueMapProducer:ElectronMVAEstimatorRun2Fall17NoIsoV2RawValues")

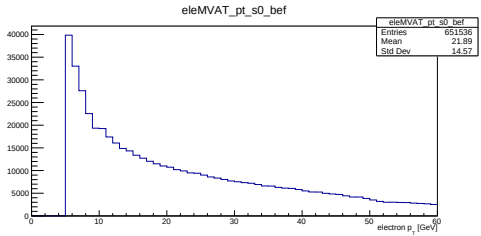
Electron issues

- To use the cuts in the table, the **raw values** of the electron MVA are needed
- We were using **squashed values** to the $[-1, 1]$ range!
- The SS AN says: *[...] Raw values can be obtained from squashed output via*

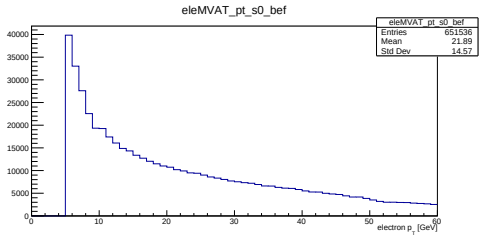
$$\text{raw} = \frac{1}{2} \log \left(\frac{1 + \text{squashed}}{1 - \text{squashed}} \right)$$

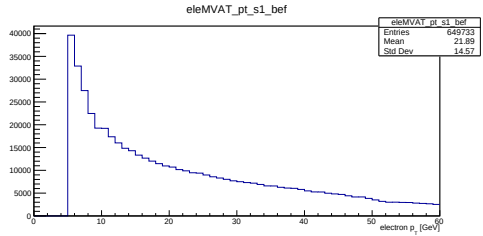
- Let's **try** these **raw values**

Tight electrons

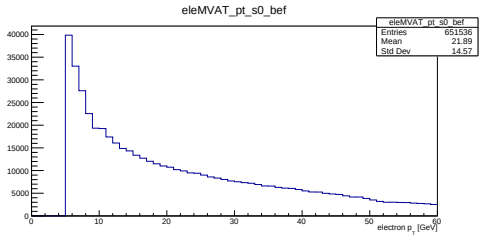


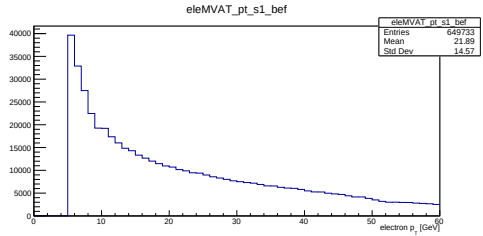
Tight electrons

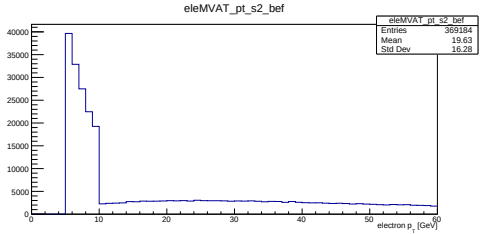




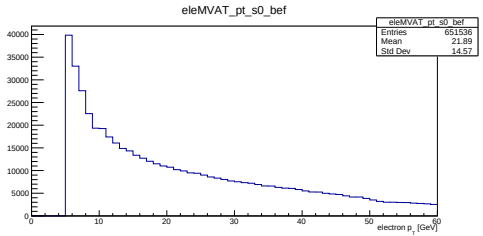
Tight electrons

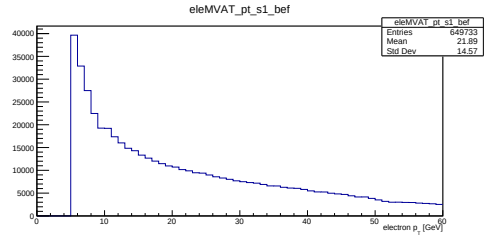


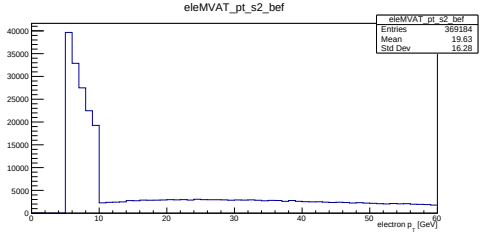


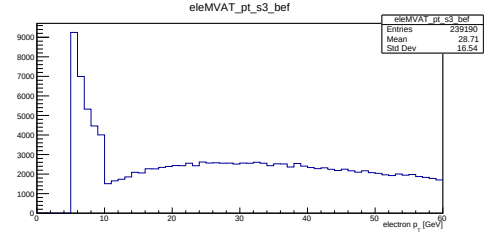


Tight electrons

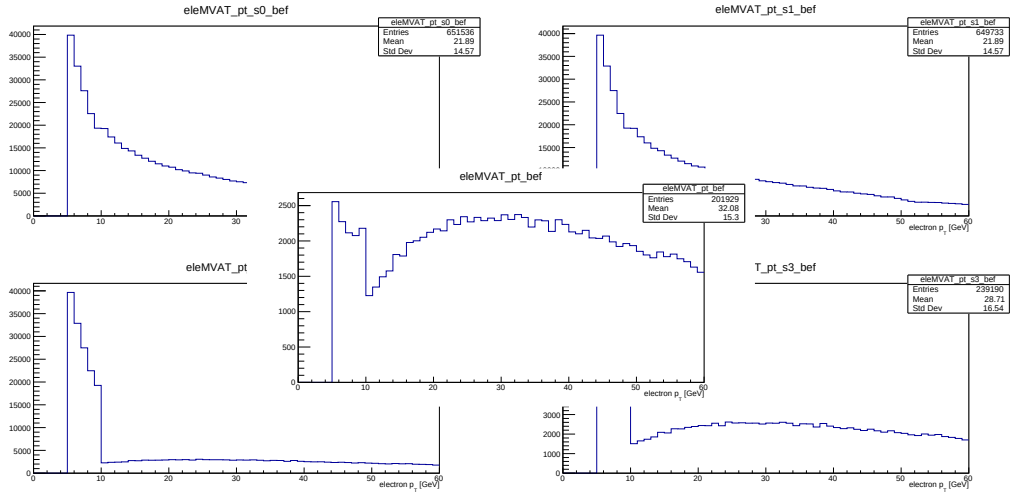








Tight electrons



Lepton loss at each stage

- Compute **number of leptons** at each stage, **normalized to** the number of **s0 leptons**

- **Left**: **pre bug fix**

	s0	s1	s2	s3	s4
e	1	0.99	0.22	0.05	0.02
μ	1	0.99	0.56	0.32	0.30

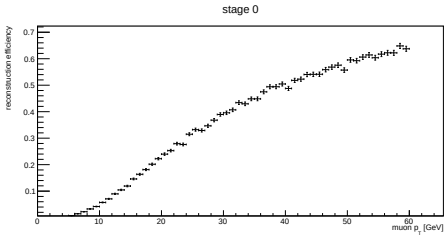
- **Right**: **post bug fix**

	s0	s1	s2	s3	s4
e	1	0.99	0.57	0.37	0.31
μ	1	0.99	0.56	0.32	0.30

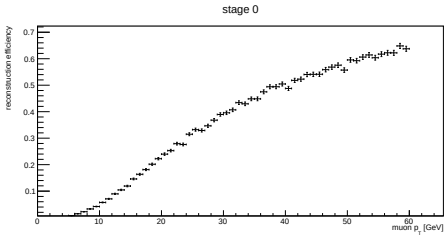
Lepton reconstruction efficiencies

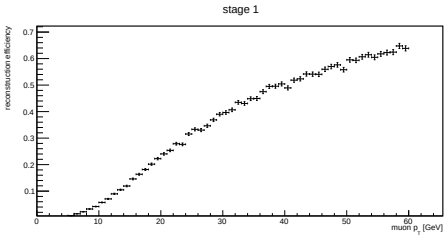
- Study **lepton reconstruction efficiencies** to see if everything looks normal
- Strategy:
  1. Loop over generated $\mathrm{e}\,(\mu)$ in the event
  2. See if a reconstructed $\mathrm{e}\,(\mu)$ matches
  3. Matching criterion: $\Delta \mathrm{R}_{\mathrm{gen-reco}} < 0.4$
  4. Study this as a function of the lepton p_{T}
  5. Do it for each lepton stage
  6. Use `TEfficiency` to properly treat errors

Tight muons

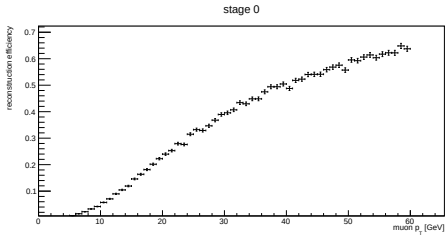

stage 0
reconstruction efficiency
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
muon p_T [GeV]

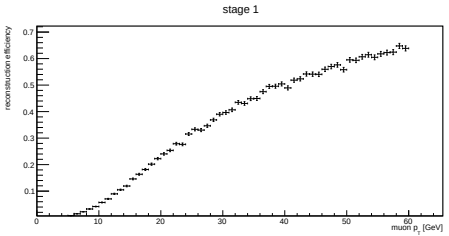
Tight muons

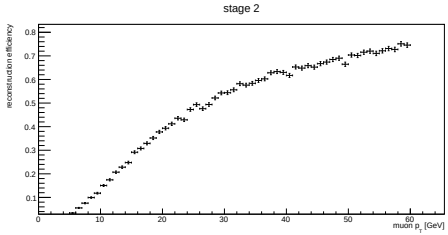

stage 0
reconstruction efficiency
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
muon p_T [GeV]


stage 1
reconstruction efficiency
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
muon p_T [GeV]

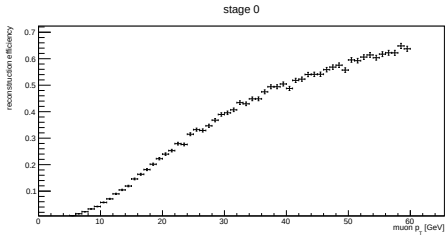
Tight muons

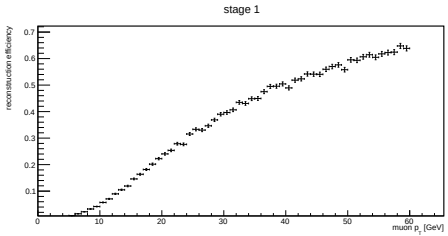

stage 0
reconstruction efficiency
muon p_T [GeV]

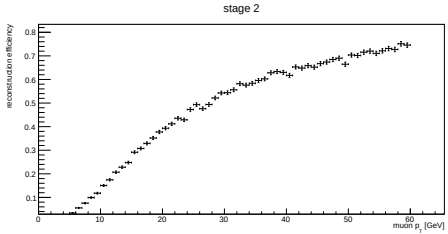

stage 1
reconstruction efficiency
muon p_T [GeV]

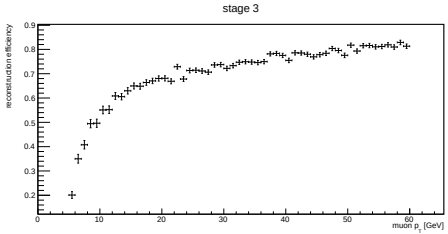

stage 2
reconstruction efficiency
muon p_T [GeV]

Tight muons

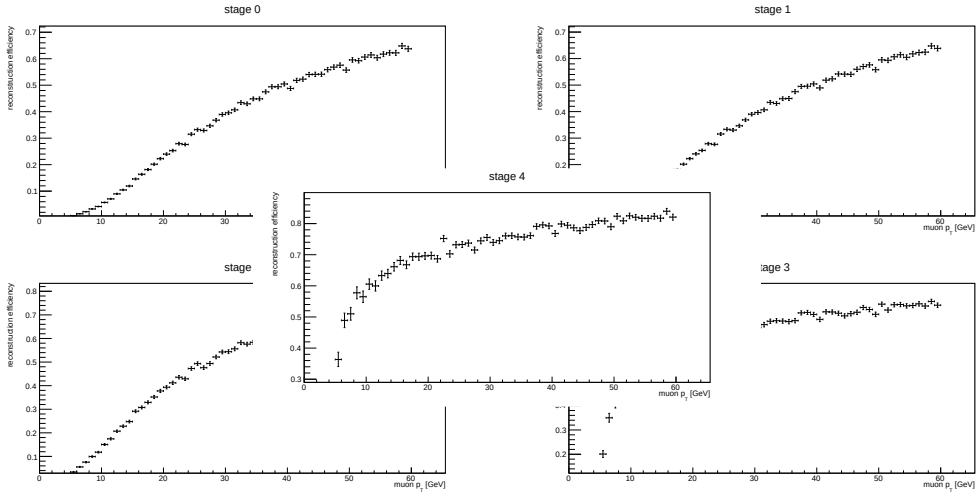

stage 0
reconstruction efficiency
muon p_T [GeV]


stage 1
reconstruction efficiency
muon p_T [GeV]

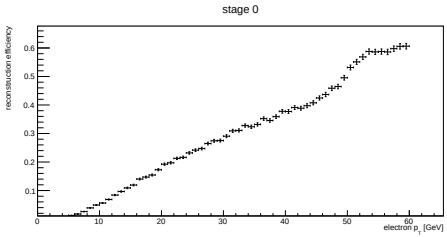

stage 2
reconstruction efficiency
muon p_T [GeV]


stage 3
reconstruction efficiency
muon p_T [GeV]

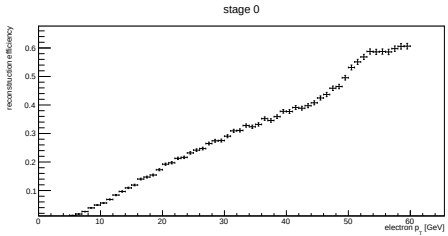
Tight muons

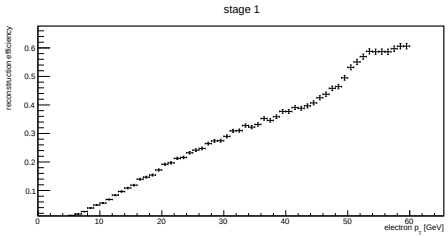

stage 0
stage 1
stage 4
stage
stage 3
reconstruction efficiency
muon p_T [GeV]

Tight electrons

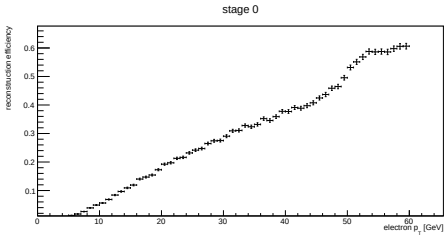


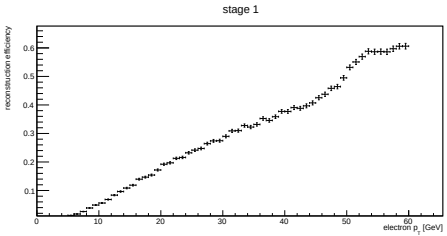
Tight electrons

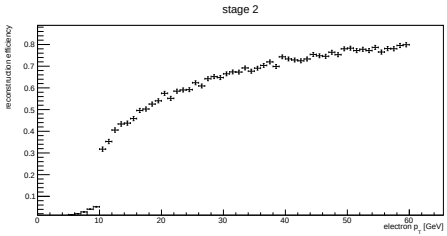




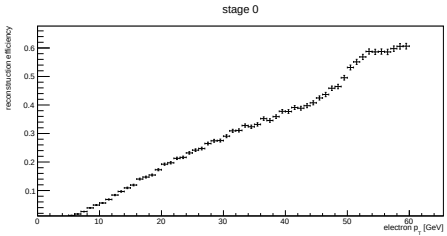
Tight electrons

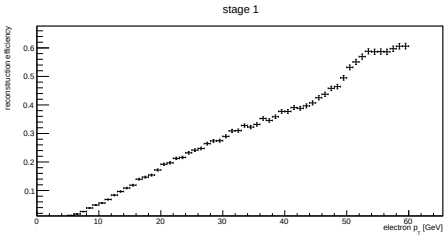


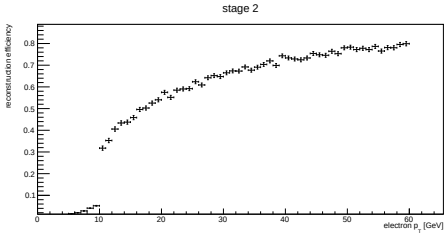


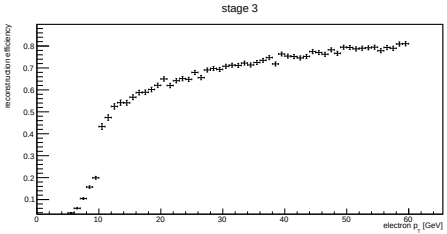


Tight electrons

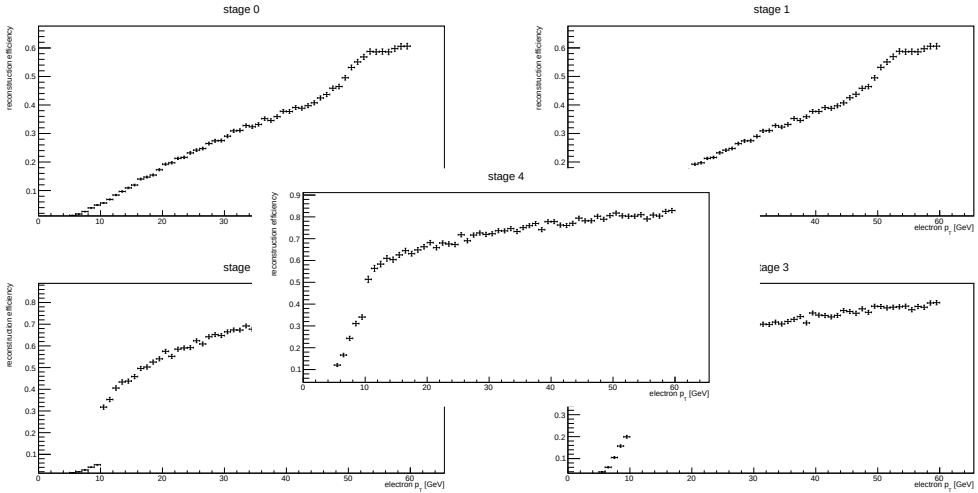








Tight electrons



Inclusive lepton efficiencies

- Also compute **inclusive** reconstruction **efficiencies**
- Simple ratio of numbers instead of histograms

$$\varepsilon^i = \frac{N^i_{\text{match}}}{N^i}, \qquad i \in \{\text{s0}, \text{s1}, \text{s2}, \text{s3}, \text{s4}\}$$

	s0	s1	s2	s3	s4
e	0.29	0.29	0.47	0.69	0.77
μ	0.30	0.30	0.53	0.80	0.82

Expected yields

- $1\tau\,1\mathrm{e}$

```
~~~ 2016 expected yields for category 1tau1e ~~~

tttt =      4.40892
tt =        2874.58
ttX =       115.16
VV =        0.181206
VVV =       0.402004
WJets =     0
DY =        0
ST =        79.378
H =         4.54063
total bkg = 3074.25
S/(S+B) =   0.00143209
```

- $1\tau\,1\mu$

```
~~~ 2016 expected yields for category 1tau1mu ~~~

tttt =      4.18067
tt =        1813.69
ttX =       78.6861
VV =        0.130724
VVV =       0.224811
WJets =     0
DY =        4.06545
ST =        44.7647
H =         1.78788
total bkg = 1943.35
S/(S+B) =   0.00214665
```

Expected yields

- $2\tau\,1\mathrm{e}$

```
~~~ 2016 expected yields for category 2tau1e ~~~

tttt =      0.163708
tt =        94.1001
ttX =       9.38053
VV =        0.0550114
VVV =       0.00706223
WJets =     0
DY =        4.06545
ST =        5.96161
H =         0.698973
total bkg = 114.269
S/(S+B) =   0.00143061
```

- $2\tau\,1\mu$

```
~~~ 2016 expected yields for category 2tau1mu ~~~

tttt =      0.122674
tt =        46.0045
ttX =       9.2377
VV =        0.00949311
VVV =       -0.0116671
WJets =     0
DY =        0
ST =        8.74382
H =         0.420428
total bkg = 64.4043
S/(S+B) =   0.00190113
```

- Expected yields for remaining categories in backup

Some considerations on expected yields

- The expected **yields seem** way **more reasonable** now that the bug in electron MVA ID is fixed
- There is still a **non negligible difference in ttbar** between $1e/1\mu$
  - Now we have more events in $1e$ than in 1μ
- I suspect this is **due to** all the electrons that fall in the **range [5, 10] GeV**
  - These are not subject to any electron ID requirement!
- And in fact, if I compute yields for $1e/1\mu$ when leptons have $p_T > 10$ GeV...

Expected yields: $p_T^\ell > 10$ GeV

- $1\tau\,1\mathrm{e}$

```
~~~ 2016 expected yields for category 1tau1e ~~~

tttt =      3.90842
tt =        1770.48
ttX =       84.3691
VV =        0.125187
VVV =       0.332103
WJets =     0
DY =        4.06545
ST =        64.7603
H =         3.58666
total bkg = 1927.72
S/(S+B) =   0.00202338
```

- $1\tau\,1\mu$

```
~~~ 2016 expected yields for category 1tau1mu ~~~

tttt =      4.08365
tt =        1738.76
ttX =       75.9781
VV =        0.084685
VVV =       0.222457
WJets =     0
DY =        4.06545
ST =        35.0809
H =         1.52776
total bkg = 1855.72
S/(S+B) =   0.00219574
```

Conclusions

- **Mismatch** in categories with $1e/1\mu$ seems to be **solved**
- Reconstruction efficiencies look reasonable
- **Remark**: lepton **selection** still needs **to be refined**
  1. Get rid of electrons out of the range in which the MVA ID acts?
  2. Put a lower bound on the lepton p_T?

Backup slides

Expected yields

- $1\tau 0L$

```
~~~ 2016 expected yields for category 1tau0L ~~~

tttt =      9.504
tt =        8029.88
ttX =       263.609
VV =        0.307525
VVV =       1.49717
WJets =     0
DY =        0
ST =        201.89
H =         3.54773
total bkg = 8500.73
S/(S+B) =   0.00111677
```

- $1\tau 1e$

```
~~~ 2016 expected yields for category 1tau1e ~~~

tttt =      4.40892
tt =        2874.58
ttX =       115.16
VV =        0.181206
VVV =       0.402004
WJets =     0
DY =        0
ST =        79.378
H =         4.54063
total bkg = 3074.25
S/(S+B) =   0.00143209
```

Expected yields

- $1\tau 1\mu$

```
~~~ 2016 expected yields for category 1tau1mu ~~~

tttt =      4.18067
tt =        1813.69
ttX =       78.6861
VV =        0.130724
VVV =       0.224811
WJets =     0
DY =        4.06545
ST =        44.7647
H =         1.78788
total bkg = 1943.35
S/(S+B) =   0.00214665
```

- $1\tau 2\text{OSL}$

```
~~~ 2016 expected yields for category 1tau2OSL ~~~

tttt =      1.71573
tt =        399.751
ttX =       41.6594
VV =        0.155906
VVV =       0.0967667
WJets =     0
DY =        4.06545
ST =        21.3706
H =         2.80154
total bkg = 469.901
S/(S+B) =   0.00363798
```

Expected yields

- 1τ2SSL

```
~~~ 2016 expected yields for category 1tau2SSL ~~~

tttt =      0.953608
tt =        216.082
ttX =       16.714
VV =        0.06846
VVV =       0.0640842
WJets =     0
DY =        0
ST =        15.0041
H =         0.425929
total bkg = 248.358
S/(S+B) =   0.00382496
```

- 1τ3L

```
~~~ 2016 expected yields for category 1tau3L ~~~

tttt =      0.233807
tt =        6.62186
ttX =       2.81792
VV =        0
VVV =       0.00235408
WJets =     0
DY =        4.06545
ST =        0.16477
H =         0.485961
total bkg = 14.1583
S/(S+B) =   0.0162455
```

Expected yields

- $2\tau 0L$

```
~~~ 2016 expected yields for category 2tau0L ~~~

tttt =      0.508648
tt =        907.543
ttX =       43.1935
VV =        0.220513
VVV =       0.136655
WJets =     0
DY =        0
ST =        48.0713
H =         5.31504
total bkg = 1004.48
S/(S+B) =   0.000506122
```

- $2\tau 1e$

```
~~~ 2016 expected yields for category 2tau1e ~~~

tttt =      0.163708
tt =        94.1001
ttX =       9.38053
VV =        0.0550114
VVV =       0.00706223
WJets =     0
DY =        4.06545
ST =        5.96161
H =         0.698973
total bkg = 114.269
S/(S+B) =   0.00143061
```

Expected yields

- $2\tau 1\mu$

```
~~~ 2016 expected yields for category 2tau1mu ~~~

tttt =      0.122674
tt =        46.0045
ttX =       9.2377
VV =        0.00949311
VVV =       -0.0116671
WJets =     0
DY =        0
ST =        8.74382
H =         0.420428
total bkg = 64.4043
S/(S+B) =   0.00190113
```

- $2\tau 2\text{OSL}$

```
~~~ 2016 expected yields for category 2tau2OSL ~~~

tttt =      0.036332
tt =        0.697038
ttX =       1.41173
VV =        0
VVV =       0.00470815
WJets =     0
DY =        0
ST =        3.38703
H =         0.155648
total bkg = 5.65615
S/(S+B) =   0.00638246
```

Expected yields

- 2τ2SSL

```
~~~ 2016 expected yields for category 2tau2SSL ~~~

tttt =      0.0162425
tt =        0.697038
ttX =       0.365499
VV =        0
VVV =       0
WJets =     0
DY =        0
ST =        0.0683976
H =         0.00145122
total bkg = 1.13239
S/(S+B) =   0.0141408
```