EMTF BDT Training for Run-3

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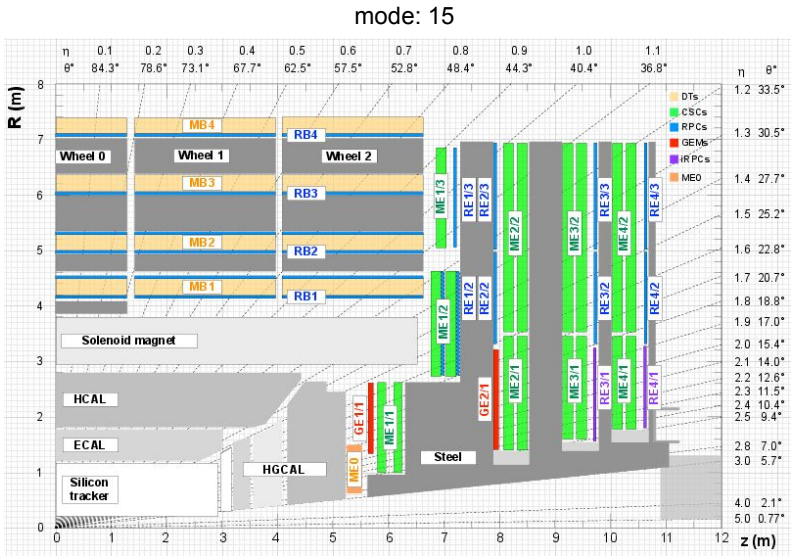
Detector and Trigger

- CMS is a particle detector whose job it is to identify particles and their characteristics such as momentum, charge, and position.
- Additionally, the Endcap Muon Track Finder (EMTF) is shown from Θ = 31° to 9.4°, which would be the bottom right of the detector, shown in the graph to the right.



Boosted Decision Trees

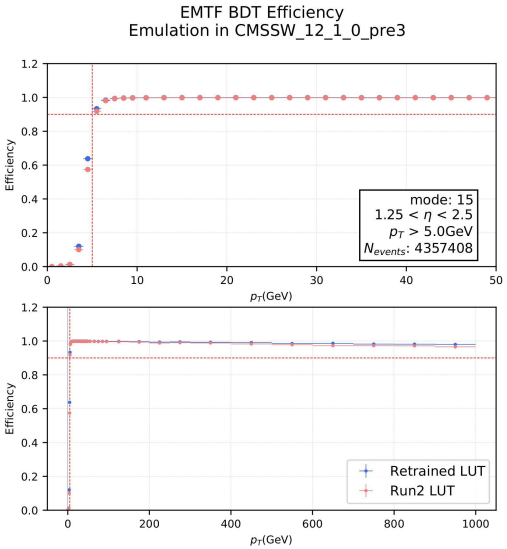
- Boosted Decision Trees (BDTs) are Machine Learning (ML) algorithms which can perform complex regressions through training on simulated events.
- In EMTF, a BDT is used for momentum assignment from from curved tracks in the muon detectors, which tells us about the mode and allows the BDT to assign pT.
- To pass the trigger, a particle in an event would need to be within a set pT threshold. If the particle is not within this pT threshold, it doesn't get past the trigger.
- This is related to rate, as it can be used to see how many events are passing that shouldn’t be.

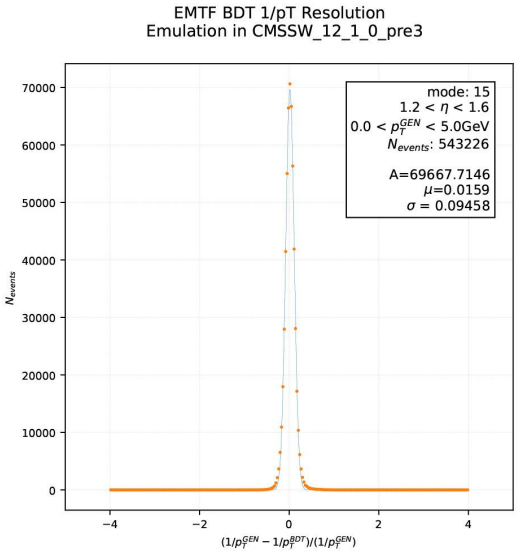
Evaluating the BDT

- To evaluate the BDT, we can look at three different aspects of the BDT; efficiency, resolution, and rate.
- The efficiency is the percentage of events that pass the trigger at a given pT threshold.
- The rate is the number of events that pass the trigger per second, and if it is high, it can waste storage and resources.
- The resolution is the accuracy of the trigger at certain pT, where it degrades at higher pT.
- With a higher efficiency, a higher rate usually follows, so the objective is to reach a higher efficiency while maintaining or lowering the rate and keeping a steady resolution at the same time for an optimal trigger.

Performance Plots

- The goal was to add a fit to unscaled efficiency plots, such as the plot to the left.
- To do this we first got efficiency from resolution, as each is connected the other, where it is expected that the resolution depends on the turn-off region of the efficiency plot.
- These can be compared through the resolution plot to the right.





Efficiency from Resolution

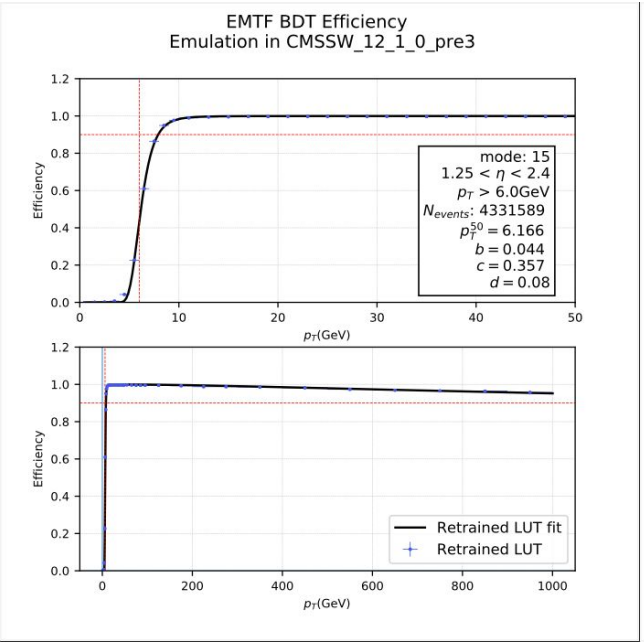
- Assuming $(p_T^{GEN} - p_T^{BDT})/(p_T^{GEN})$ is gaussian, then the probability of mismeasurement for muon of true momentum pT to be greater than the threshold, is the CDF with x=1-pT/pT_threshold
  - For a Gaussian, the CDF is a translated error function

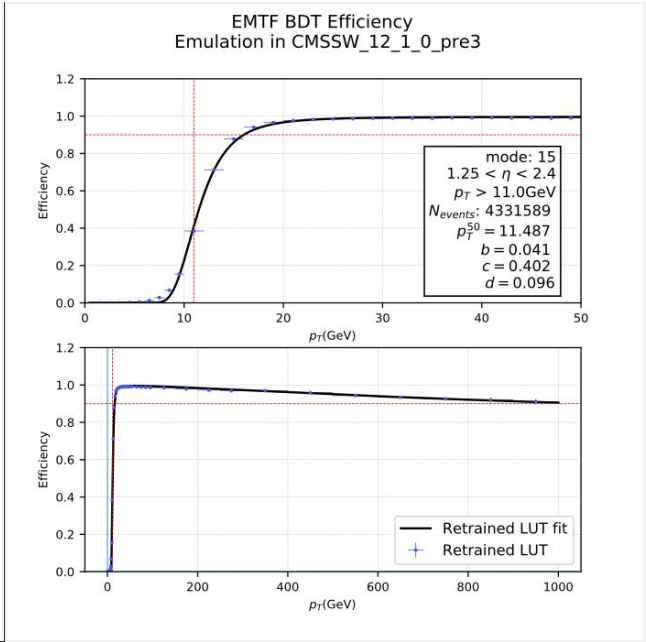
$$\frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)\right]$$

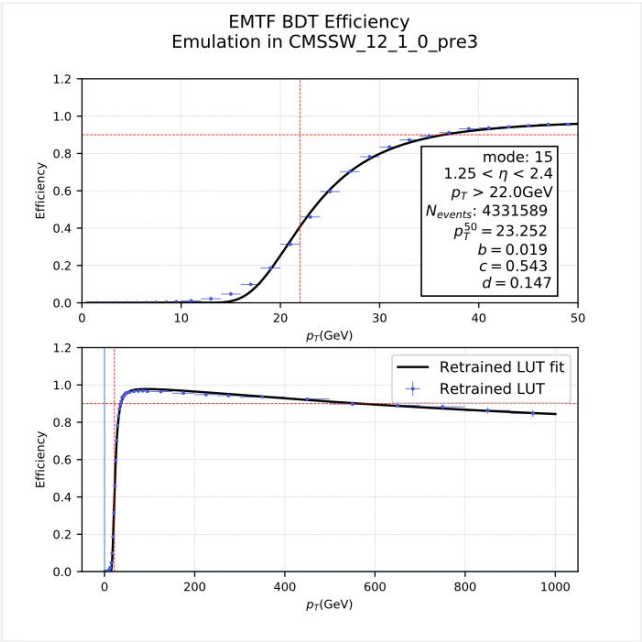
- Thus the equation for efficiency is related to the bias (μ) and resolution (σ) from $(p_T^{GEN} - p_T^{BDT})/(p_T^{GEN})$ distribution.
- Additionally, allowing the resolution to vary with pT like a power law allows for a fit to high pT

Unscaled Efficiency Fits

- We were able to create a fit for the efficiency plots for mode 15 of different pT thresholds.

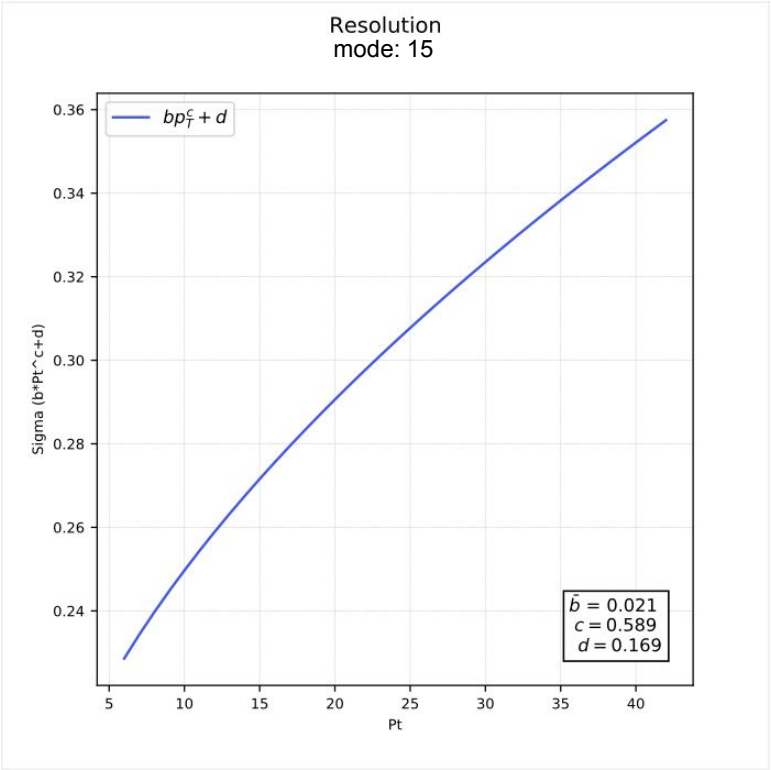






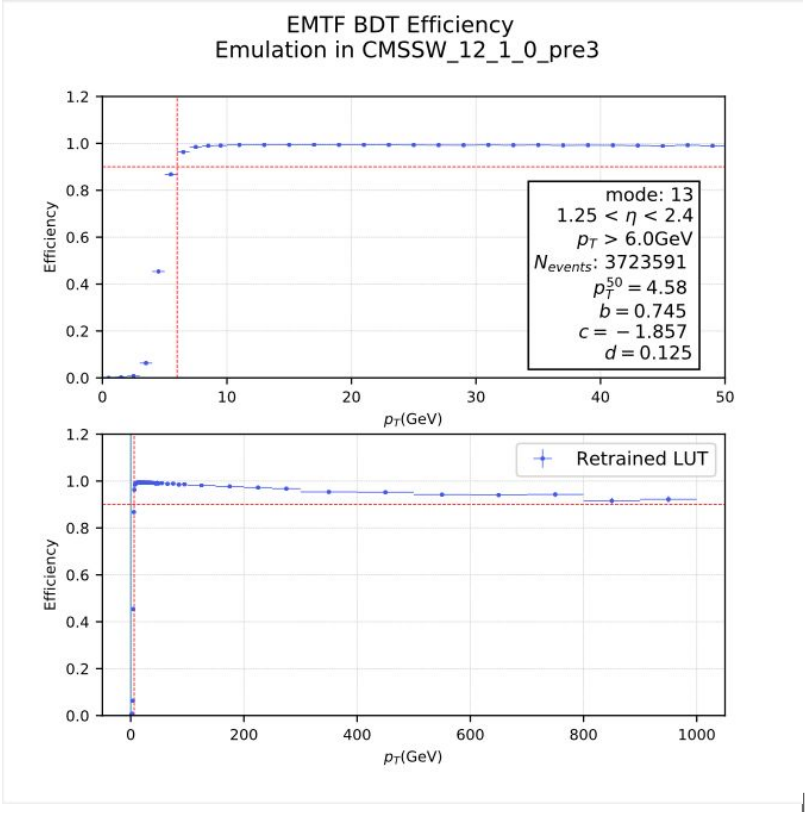
Extracting Resolution from Fits

- Using a power law fit, we were able to create a resolution plot.
- Resolution got worse when reaching high pT, as expected.



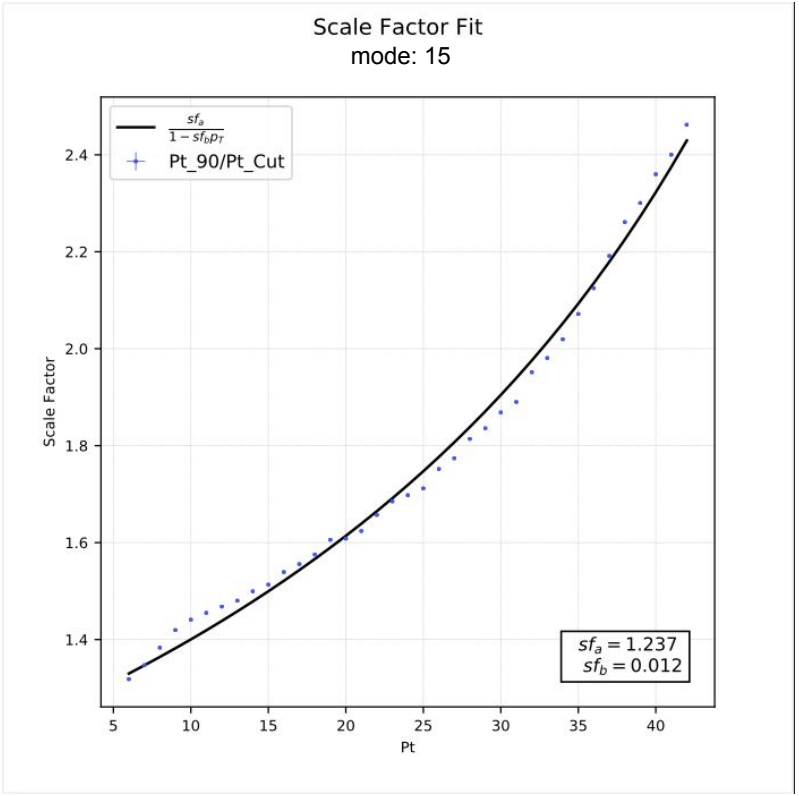
Scale Factor Extraction

- To scale these performance plots, we need to extract the scale factor.
- We have scale factors for convention sake, so it is clear where to find the plateau on an efficiency plot.
- This is an improvement because we have a way to extract the resolution from efficiency curves, and we can find the scale factor from the fit without guess-and-checking as before.
- With this we can also eventually use the efficiency to estimate the rate.



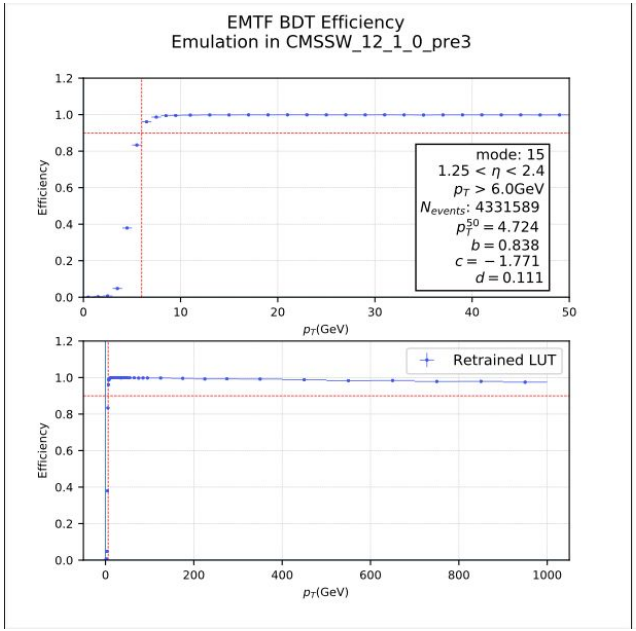
Solving for Scale Factor

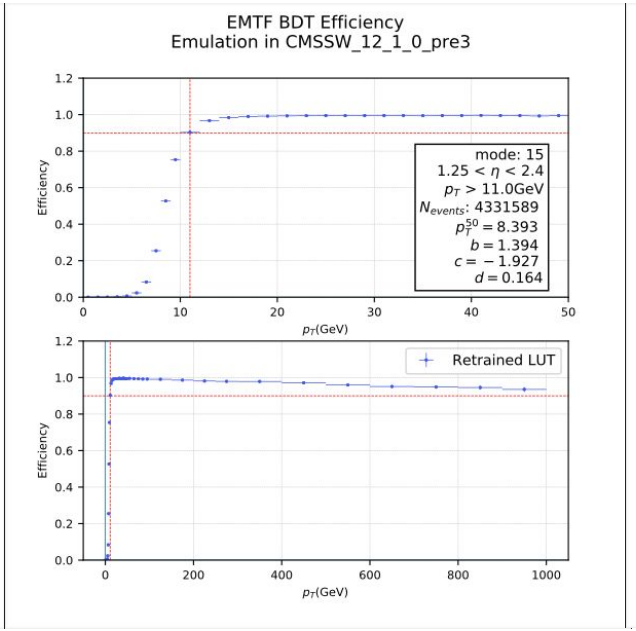
- Using the fit to efficiency, we can solve for the pT at 90% efficiency.
- We were able to find a scale factor for different values of pT.
- We applied a fit to the scale function used in Run2.

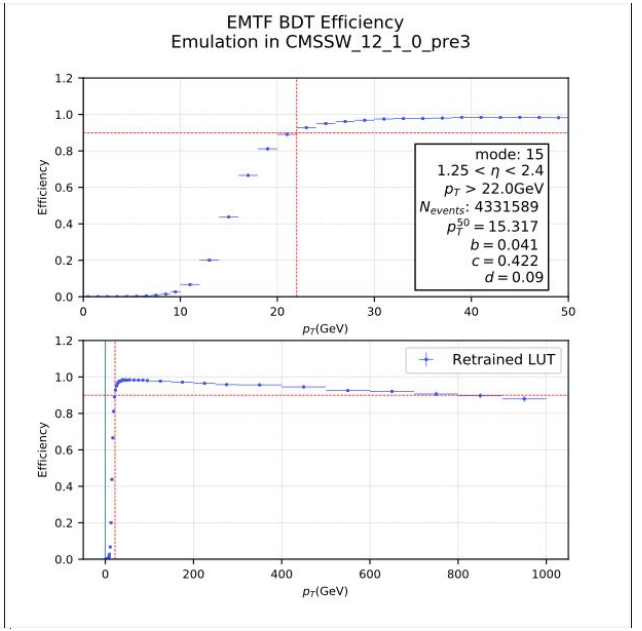


Applying New Scale Factor

Taking the sf_a and sf_b from the scale factor plots, we can use those values to create a scaled plot, which can be seen in these graphs for mode 15.

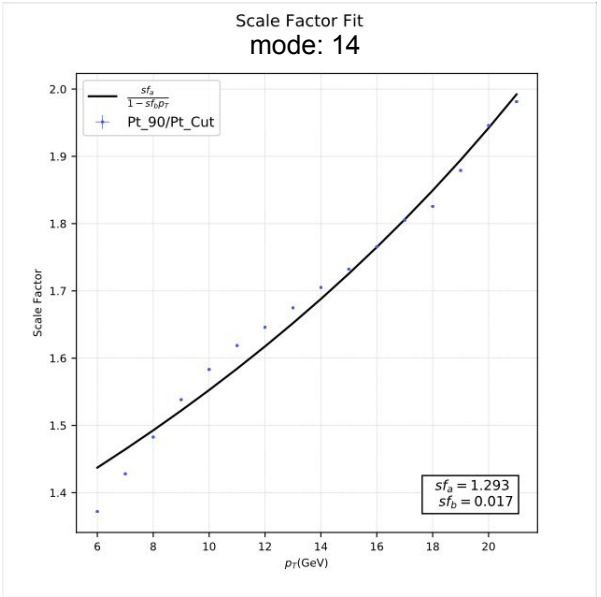


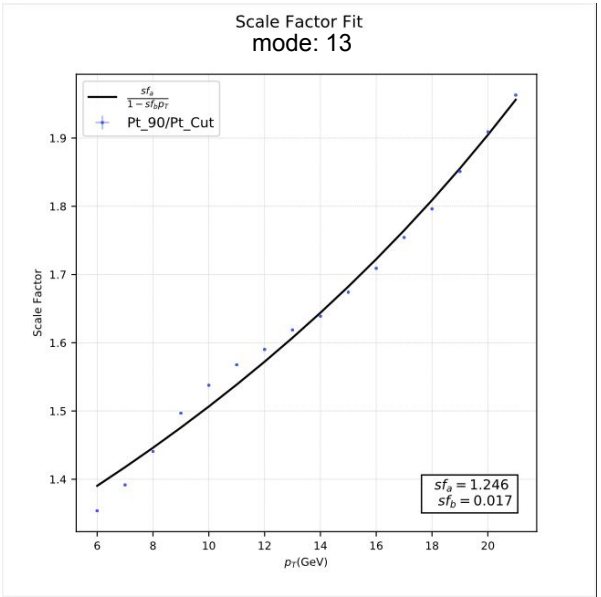


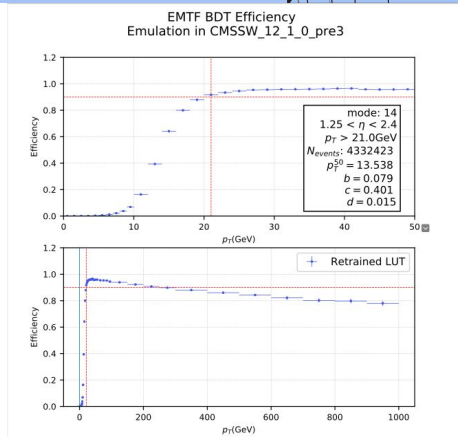


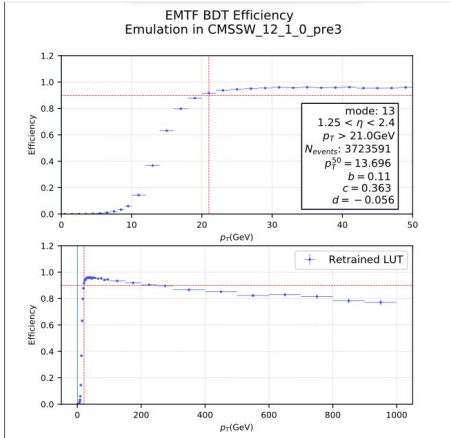
Scale Factor by Mode

These are different scale factor fits and scaled efficiency plots for different modes, specifically modes 13 and 14.









Future Work

- Using relative efficiency rather than absolute efficiency for scale factor studies
- Run2 comparison using our new scale factor
- Look at scale factor effects on the sharpness of the turn-on region
- Using unscaled fits, new scale factors, and convolution with ZB muons distribution to estimate single muon rates
- Knowing the rate would help us tune the scale factor as well