Trigger Scale Factors

for the $HH \to bb\tau\tau$ resonant analysis

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Overview

- The $HH \to bb\tau\tau$ analysis is targetting ICHEP 2022 (optimistic)
- This requires establishing a method for ***calculating and applying trigger scale factors***
- This presentation covers one MET trigger: `HLT_PFMETNoMu120_PFMHTNoMu120_IDTight_v`
- We considered **UL 2018 samples** (*MET* and *TT*)
- A standalone framework has been developped:
  - Starts from skimmed KLUB ntuples
  - Defines an equal-width binning, removing the top 5% quantile (outliers)
    - An optimal binning can be later defined manually
  - Calculates efficiencies and scale factors on HTCondor
  - Plots distributions, efficiencies and scale factors (results here)
  - Steps are chained with luigi, and should work with any trigger

The Orthogonal Dataset Method

- A Reference Trigger (**Ref**) is chosen:
  - *Orthogonal* to the trigger of interest X (**Trig$_X$**)
  - Its trigger scale factors are *already known*
- Data and MC efficiencies:

$$\epsilon_{\text{Data,MC}} = \frac{\text{pass(Ref) \&\& pass(Trig}_X\text{)}}{\text{pass(Ref)}}$$

- Scale factors:

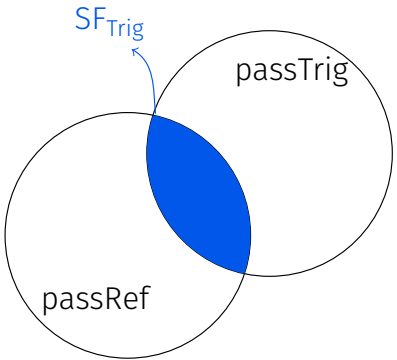
$$\text{SF} = \epsilon_{\text{Data}}/\epsilon_{\text{MC}}$$

- **Ref** takes precedence over **Trig** when applying the scale factors (next slides)
- It is important to carefuly define:
  - Which events are used to *calculate the scale factors*
  - To events are those same scale factors later *applied*

Calculate Scale Factors

- Use events that pass **both** the reference trigger and the trigger of interest
- Additionally apply cuts on trigger variables to avoid the turn-on curve
- Example: *HLT_PFMETNoMu120_PFMHTNoMu120_IDTight_v*
  - METNoMu > 200GeV && MHTNoMu > 200GeV
  - The values must be tuned

- Detail: cuts are not applied on variables as a function of which scale factors are calculated.
- Example
  SF as a function of *metnomu_et*: only *mhtnomu_et* > 200 GeV is applied

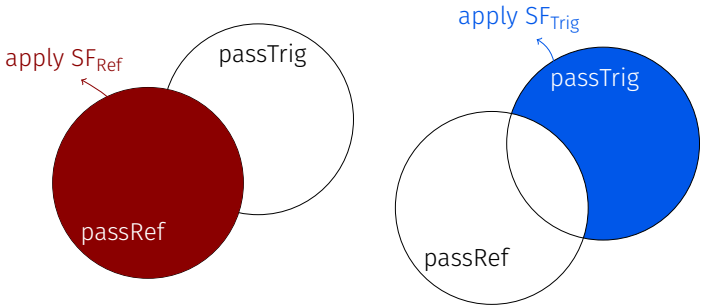


Apply Scale Factors

- If the events passes **Ref**, the reference scale factors are applied
- If the event does not pass **Ref** but passes the trigger of interest **Trig**, the new scale factors of interest are applied
- This assumes events captured by both triggers are uncorrelated (orthogonal)

Event loop

1: **if** passes(**Ref**) **then**
2: apply(SF_{Ref})
3: **else if** passes(**Trig**) **then**
4: apply(SF_{Trig})
5: ...
6: **end if**



Orthogonal Method: MET Example

- A lepton trigger (**Lep**) is chosen:
  - Orthogonal to the MET trigger
  - Lepton trigger scale factors are well known
- Data and MC MET efficiencies:

$$\epsilon_{\text{Data,MC(MET)}} = \frac{\text{pass(Lep) \&\& pass(MET)}}{\text{pass(Lep)}}$$

- Scale factors (intersection of triggers):

$$\text{SF}_{\text{MET}} = \epsilon_{\text{Data(MET)}} / \epsilon_{\text{MC(MET)}}$$

- **Lep** takes precedence over **MET** when applying the scale factors

Event loop

1: **if** passes(Lep) **then**
2: apply(SF_{Lep})
3: **else if** passes(MET) **then**
4: apply(SF_{MET})
5: **end if**

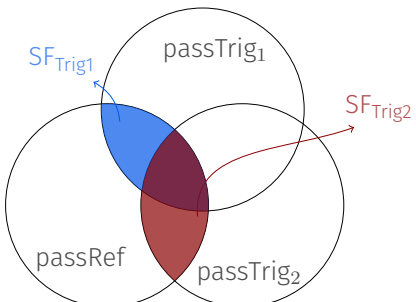
Generalization to multiple triggers: Calculating Scale Factors

- The method can be generalized to N triggers of interest

- Efficiencies only depend on **Ref** and on their own trigger of interest k:

$$\epsilon_{\text{Data,MC}(k)} = \frac{\text{pass(Ref) \&\& pass(Trig}_k\text{)}}{\text{pass(Ref)}}$$

- The picture shows 3 for convenience ($N = 2, k \in 1, 2$)



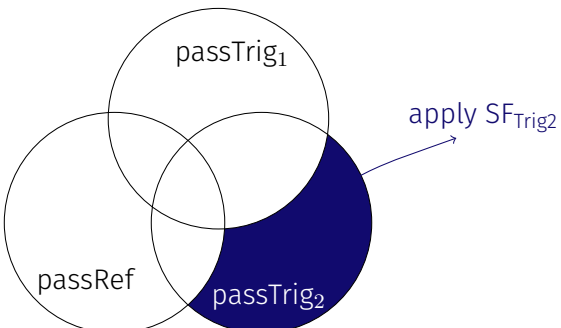
Generalization to multiple triggers: Applying Scale Factors

Scale factors are applied in order of trigger acceptance

- Each subsequent SF is applied to fewer and fewer events

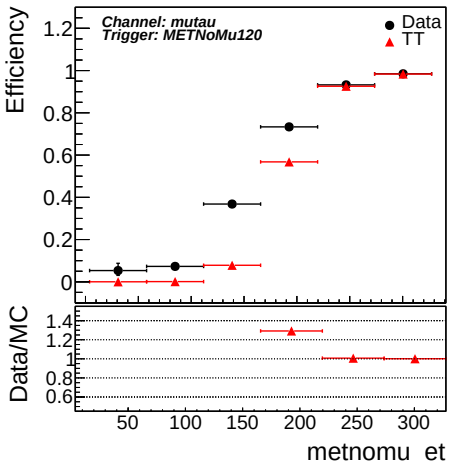
Event loop

1: **if** passes(**Ref**) **then**
2: apply(SF_{Ref})
3: **else if** passes(**$Trig_1$**) **then**
4: apply(SF_{Trig1})
5: **else if** passes(**$Trig_2$**) **then**
6: **apply(SF_{Trig2})**
7: ...
8: **end if**

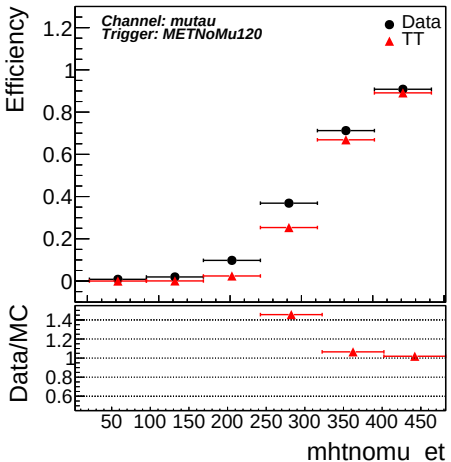


Preliminary `metnomu_et` and `mhtnomu_et` 1D Results: $\mu\tau_h$ channel

`mhtnomu_et` > 200 GeV

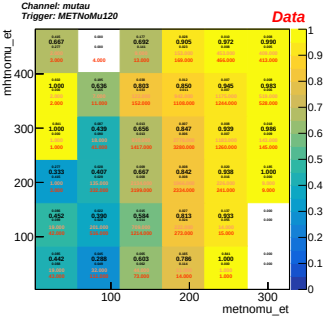


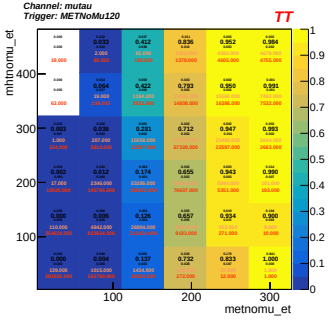
`metnomu_et` > 200 GeV

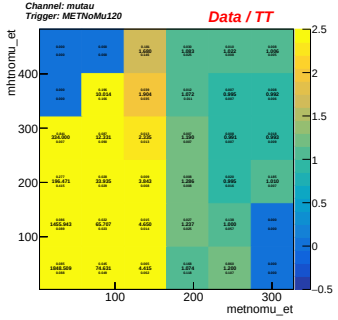


Preliminary `metnomu_et` vs `mhtnomu_et` 2D Results: $\mu\tau_h$ channel

- Orange shows how many events passed the trigger of interest (per bin)
- Red shows how many events there were in total (per bin)
- For the scale factors the color scale was capped





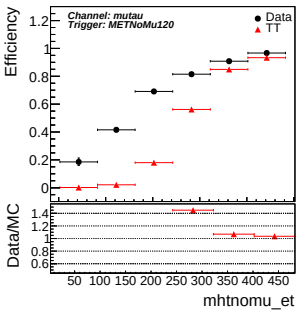


Study the impact of trigger variable cuts

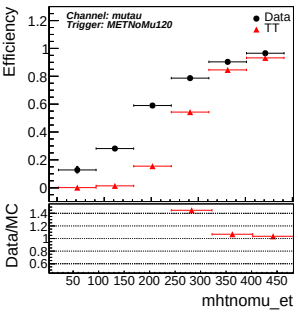
- Test several cuts on 1D efficiencies
- A strong dependence favours the 2D binning approach
- The framework allows a quick systematic study

Example: *mhtnou_et*
($\mu\tau_h$ channel)

met_et > 120GeV

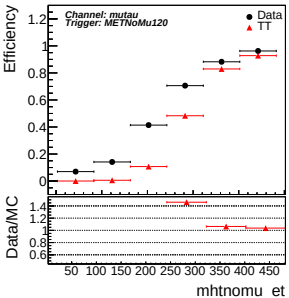


met_et > 140GeV

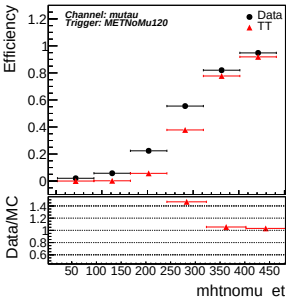


Study the impact of MET cuts

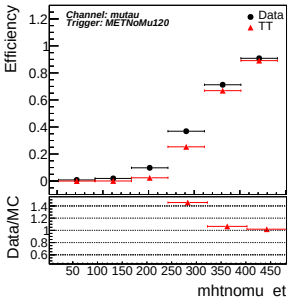
met_et > 160GeV



met_et > 180GeV



met_et > 200GeV



Conclusions & Next Steps

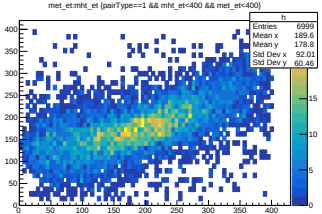
- We presented a ***flexible framework for trigger scale factors:*** testing triggers, cuts, variables, channels and datasets should be straightforward
- Decide whether to use 1D or 2D scale factors
  - 2D has less statistics per bin **but**
  - It does not get potentially biased by one additional cut
- Decide which ones should be used:
  - *met_et* vs *metnomu_et*
  - *mht_et* vs *mhtnomu_et*
- We used the *MET* dataset to study the MET trigger. A better approach might be to use a dataset orthogonal to the MET trigger: *SingleMuon*
- Should we fit the efficiencies to smoothen the scale factors out?

Backup

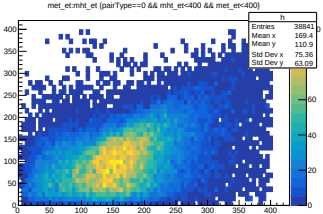
Differences for different channels

Skimmed KLUB ntuples: ***met_et*** vs ***mht_et***

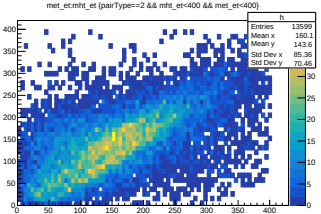
etau



mutau



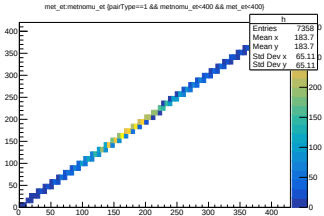
tautau



Differences for different channels

Skimmed KLUB ntuples: ***met_et*** vs ***metnomu_et***

etau



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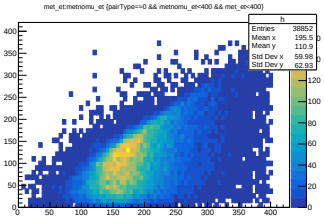

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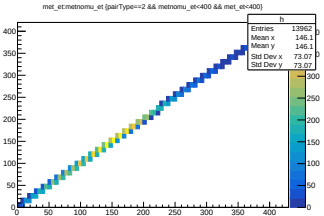

Lepton trigger:

- (one of the $e\tau_h / \mu\tau_h / \tau_h\tau_h$ OR single e/μ triggers is fired)
- AND the event contains reconstructed leptons matched to the trigger requirement

Different statistics after Ref trigger:

Channel	# pass(Ref)
$e\tau_h$	$\sim$5500
$\mu\tau_h$	$\sim$19000
$\tau_h\tau_h$	$\sim$400