Optimization of the Muon Tight WP for the ATLAS experiment

YONGWEN ZHENG

KEVIN NELSON

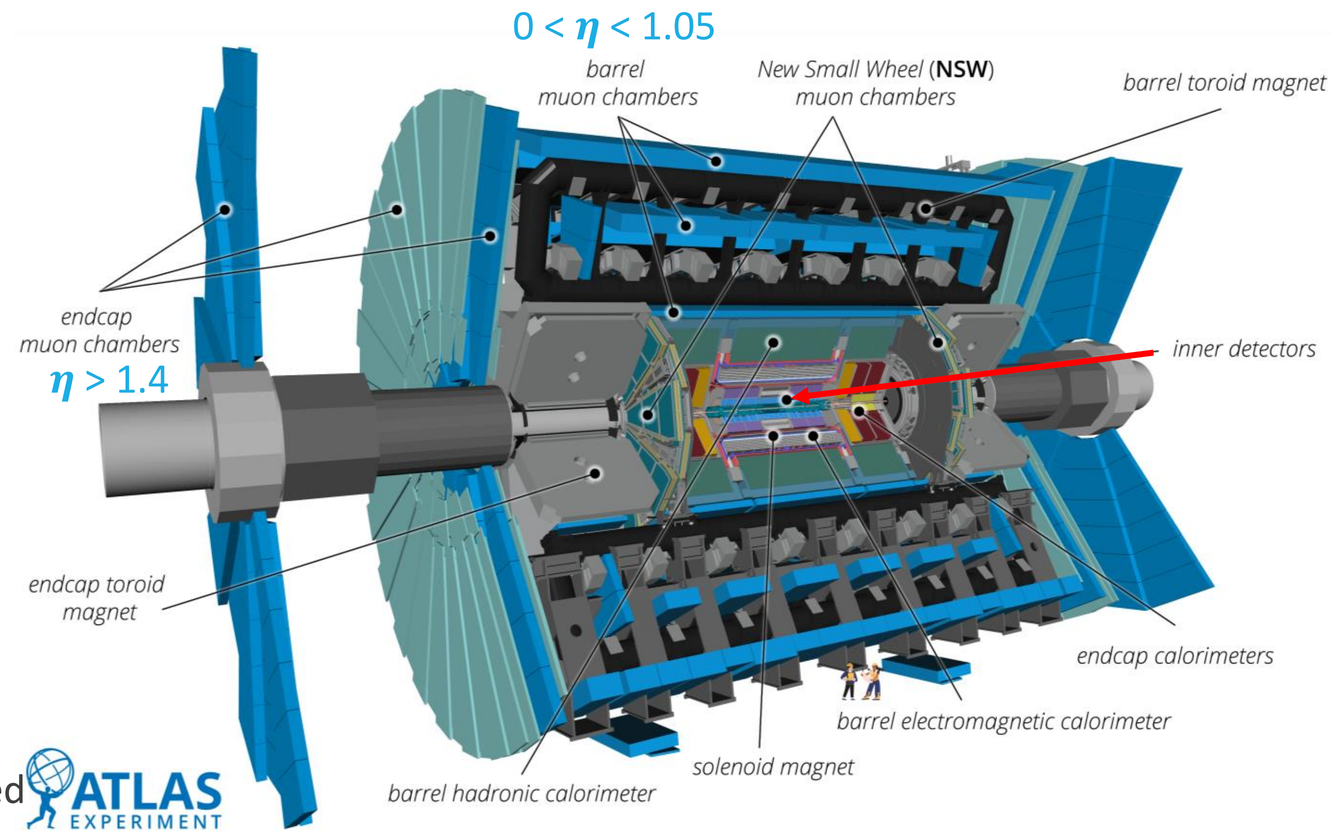
30 JULY 24

The ATLAS Detector in Run 3

Proton-proton collision with $\sqrt{s}$ = 13.6 TeV
- Generate lots of particles with muon final state

Tracking system:
- Inner detector (ID)
  - Pixel Detector
  - Semiconductor Tracker
  - Transition Radiation Tracker
- Muon spectrometer (MS)
  - Muon drift tubes

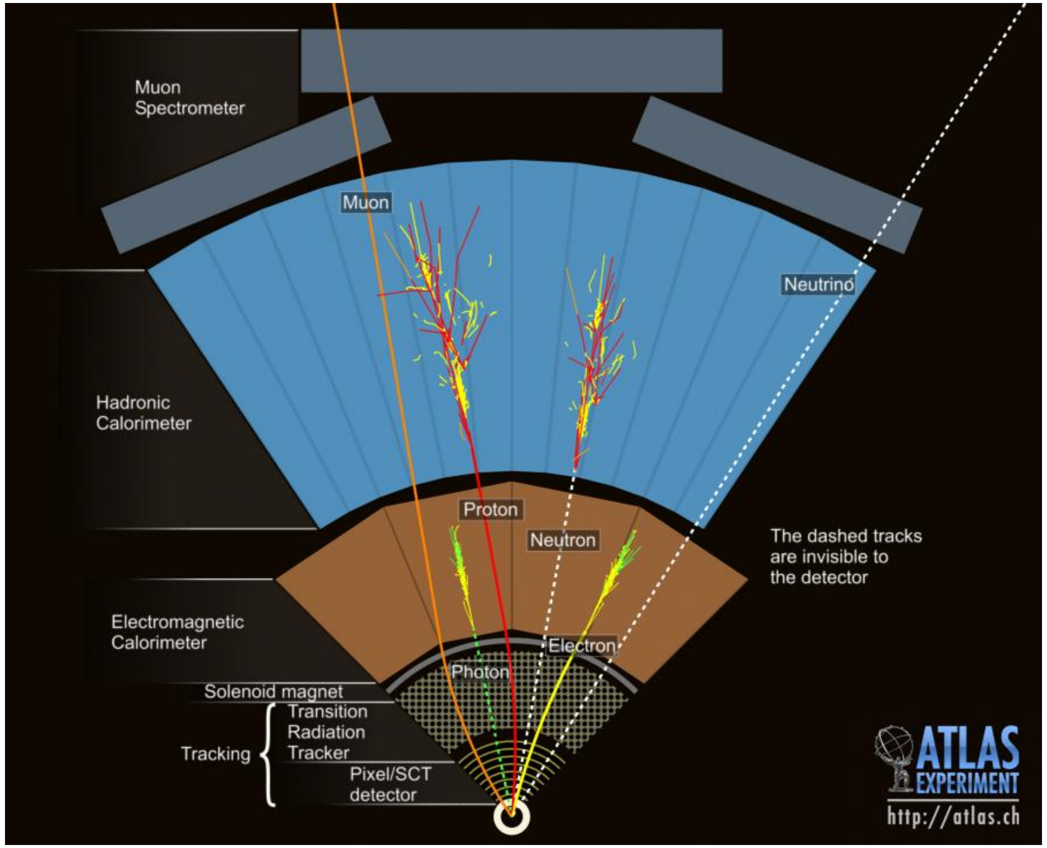
Types of muons:
- **ID**: reconstructed from inner detector alone
- **ME**: reconstructed from MS and track extrapolated to primary vertex
- **CB**: uses both ID and ME



Muon Identification Motivation

Type	Prompt	Non prompt	Light flavor
Main Decay Sources	t, H, W, Z	b, c jets, τ	π and K
Decay Time (s)	$< 10^{-22}$	$< 10^{-13}$	$< 10^{-8}$

- Want to study heavy particles (H, t) and increase pure sample of prompt muons
- **Increase prompt muon acceptance and light flavor rejection**
- Separating prompt and nonPrompt is work for isolation workgroup (not mine🙃)



Important Variables for Cuts

- Light flavor -> decay results in kink in track (distinguishable feature)
  - $\boldsymbol{q/p}$ **significance** : $\left|(q/p)_{ID} - (q/p)_{ME}\right| / \sqrt{\sigma_{ID}^2 + \sigma_{ME}^2}$ imbalance between ID and MS **on charge over momentum** (track curvature)
  - $\boldsymbol{\rho'}$: $\left|P_T^{ID} - P_T^{ME}\right| / P_T^{CB}$ imbalance between ID and MS **momentum**
  - **Reduced** $\boldsymbol{\mathcal{X}^2}$: goodness of track **fit**
- The distribution of $\boldsymbol{q/p}$ **significance and** $\boldsymbol{\rho'}$ changes in different $\boldsymbol{P_T}$ and $\boldsymbol{\eta}$ regions
- **Precision layers**: need to make enough hits in the detector for lower uncertainty

Working Point:

- Different strictness on the selection
  - Loose (efficiency) < medium (low systematics) < tight (purity)

Optimizing Tight WP - ρ and q/p signif

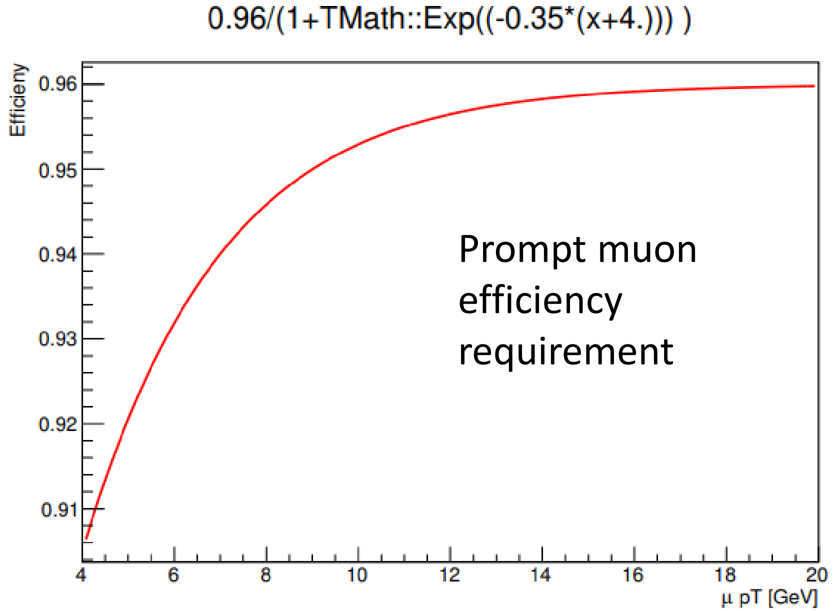
Medium ρ map, efficiency comparison

↓

New approach for L.F., efficiency

Tight WP definitions:

- **CB, precision layers > 1, medium WP, reduced χ^2 < 8**
- **Medium and high P_T**
  - 1D cut on ρ in discrete (η, P_T) bins satisfying prompt efficiency requirement (~96%)
- **Low P_T (4 - 20 GeV)**
  - 2D cut on ρ and q/p signif in discrete (η, P_T) bins satisfying prompt efficiency requirement (~96%) + maximizing light flavor decay rejection

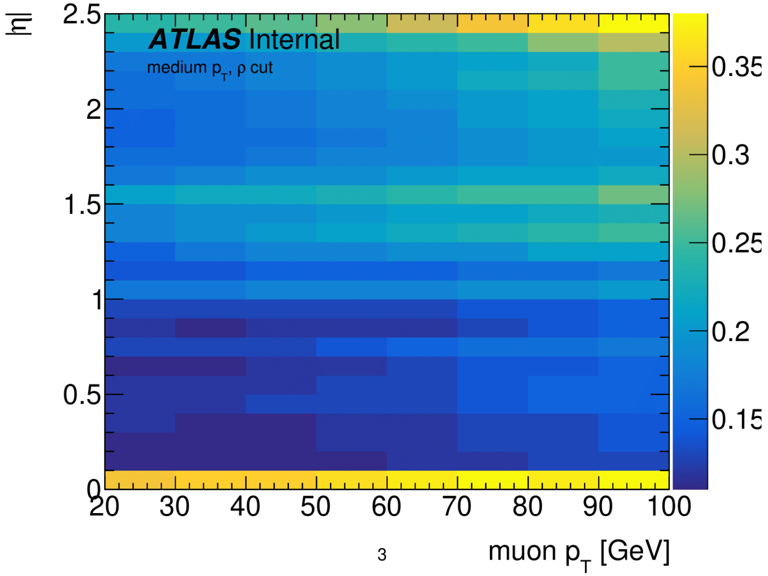


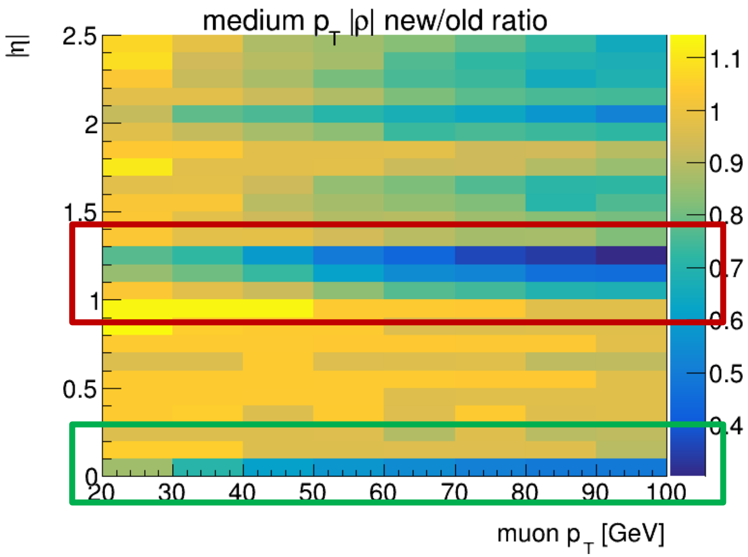
From WP internal note

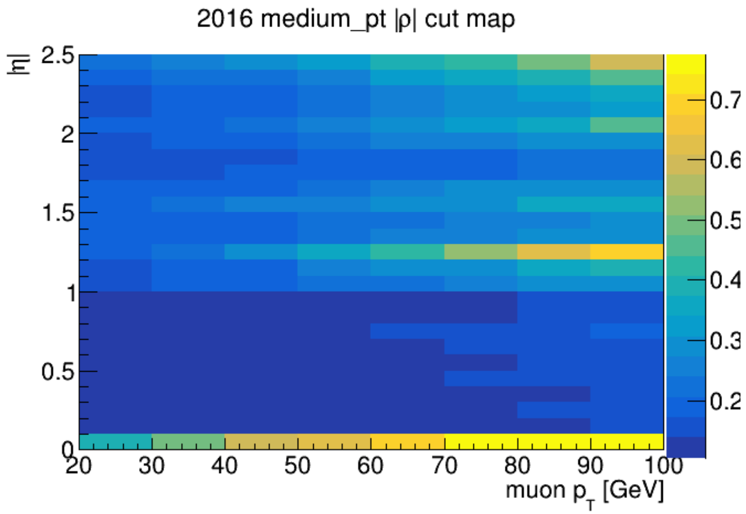
Focus on ρ and q/p signif cuts :

- Last done with Run2 data in 2016. Pileup and the detector has changed significantly since then.

Medium P_T - ρ Map



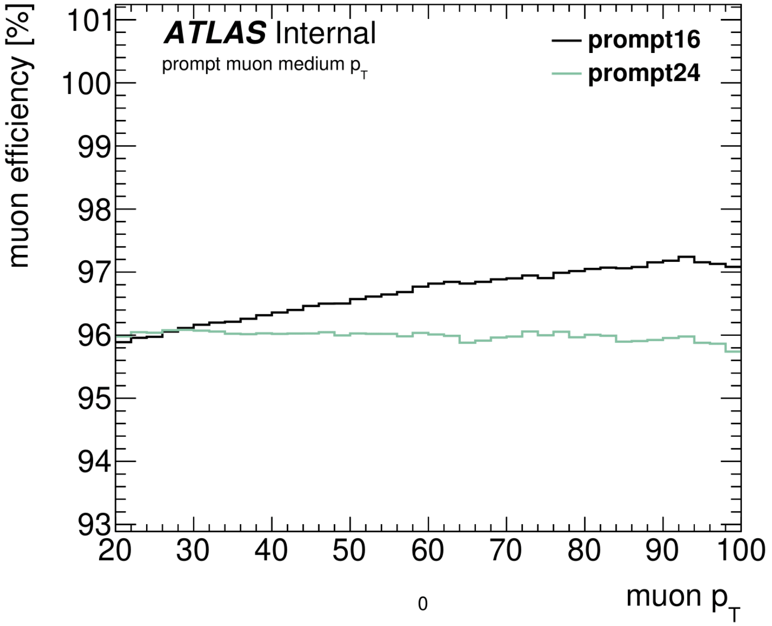


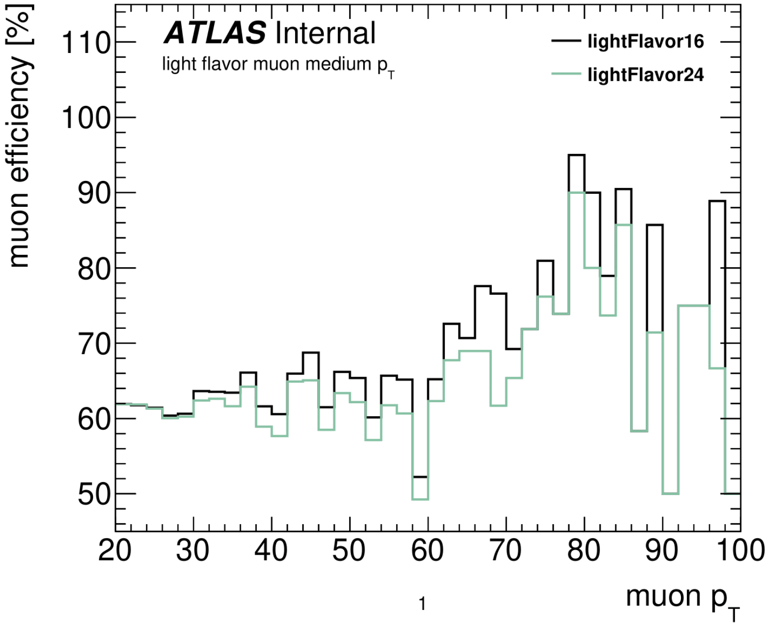


- The ρ cuts in the $1.1 < |\eta| < 1.3$ region are lower compared with the 2016 study due to a new chamber.
- The cuts at region $|\eta| < 0.1$ is also lower compared with the 2016 study. However, compared with $|\eta| > 0.1$ region, the ρ cut is significantly higher in both studies.

Medium P_T - efficiency by P_T

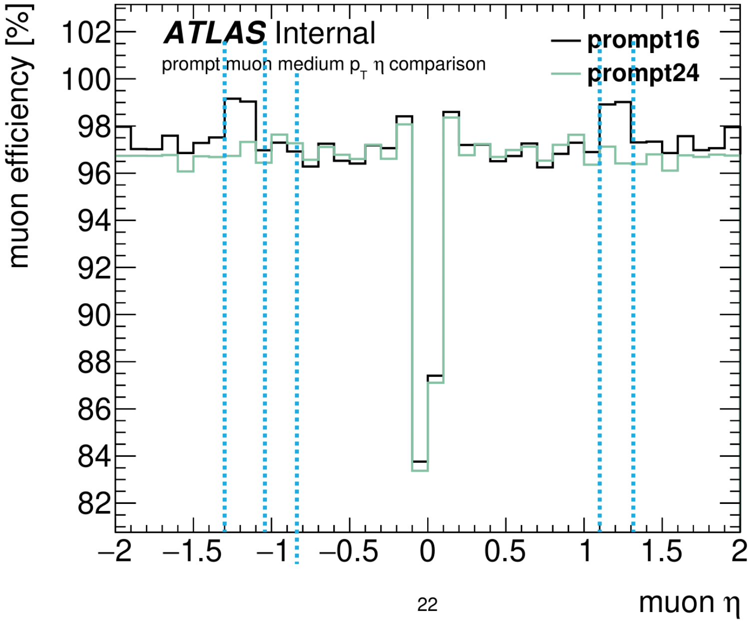
Efficiency := # of tight muons / # of medium muons

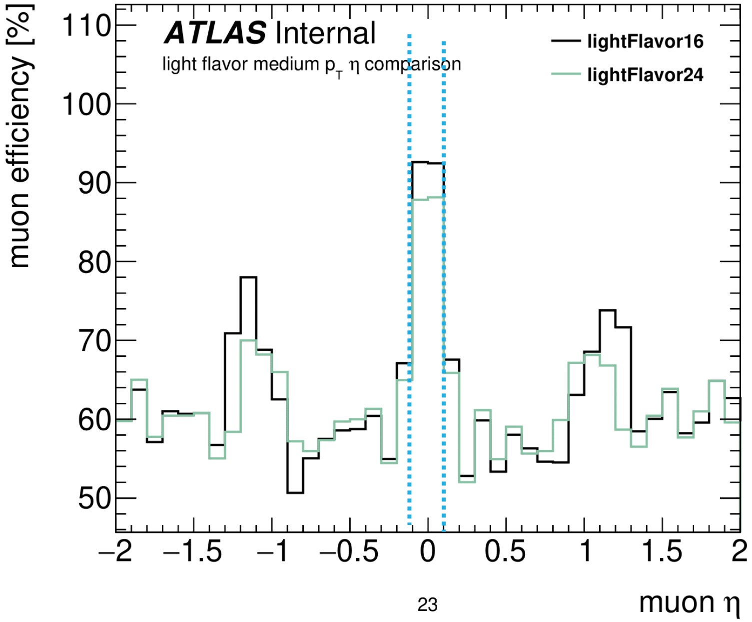




- ~1% loss of efficiency in prompt acceptance
- Significantly better in L.F. rejection

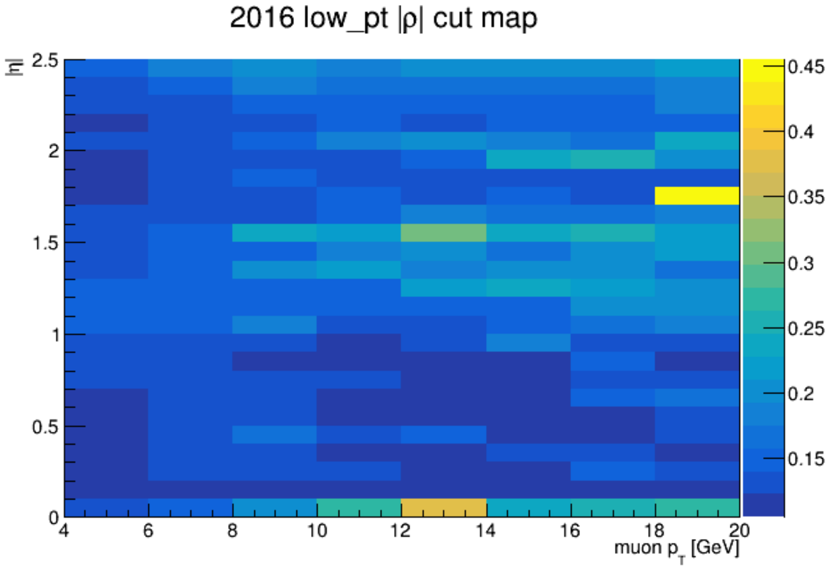
Medium P_T - efficiency by η



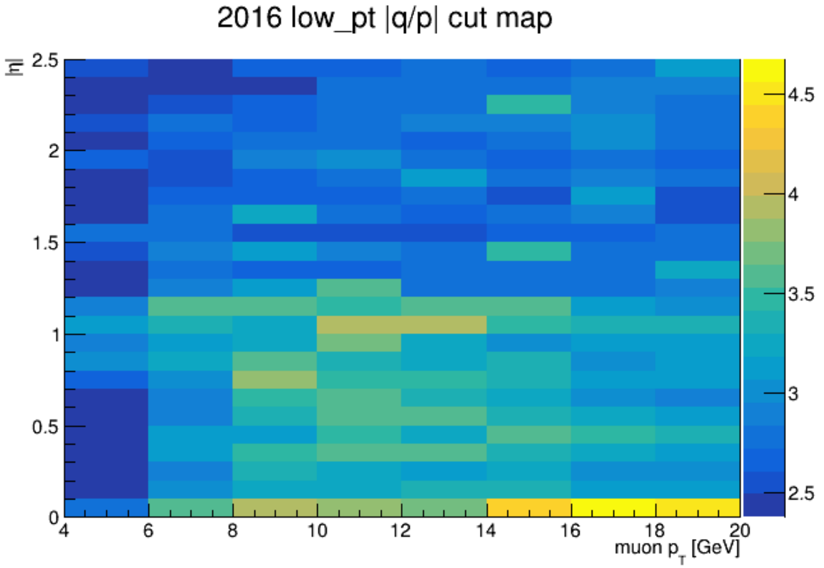


- Lower prompt efficiency in $1.1 < \eta < 1.3$ (new chamber region); comparable efficiency in other regions
- Lower light flavor efficiency in $1.1 < \eta < 1.3$ and $\eta < 0.1$; comparable efficiency in other regions

Low P_T - ρ and q/p Map



Average ~0.17



Average ~3.3

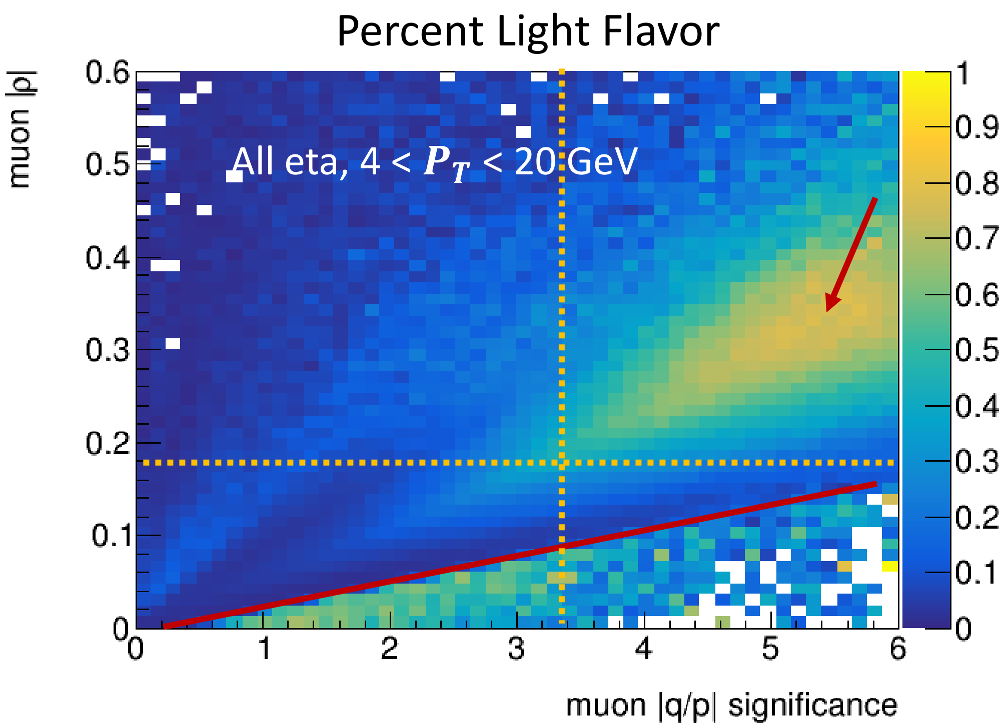
2016 studies

- 2D cut on ρ and q/p significance in discrete $(\boldsymbol{\eta}, \boldsymbol{P_T})$ bins satisfying prompt efficiency requirement (~96%) + maximizing light flavor decay rejection

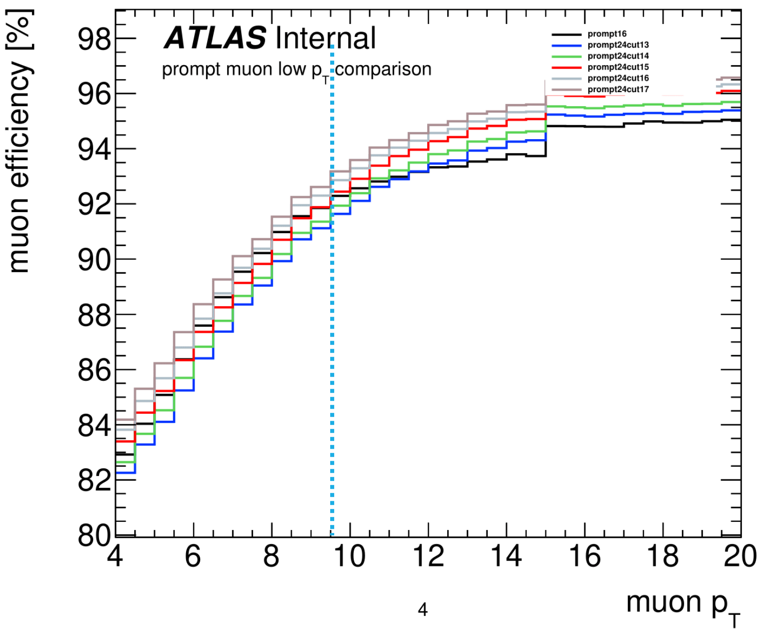
Low P_T - ρ and q/p Correlation

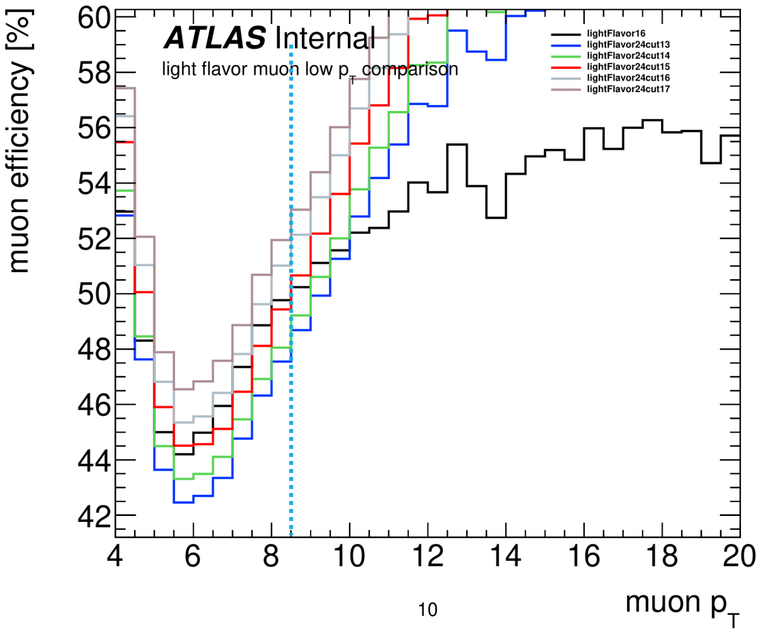
Examine ρ and q/p Correlation with L.F. :

- Certain phase spaces have higher L.F.%
  - Cone at high $|q/p|$ and medium $|\rho|$
  - Triangular area in the bottom
- Rectangular cut doesn't accurately reflect the correlation between ρ and q/p
- New approach
  - Places ρ and q/p cuts based on L.F. percent (e.g. < 20%)



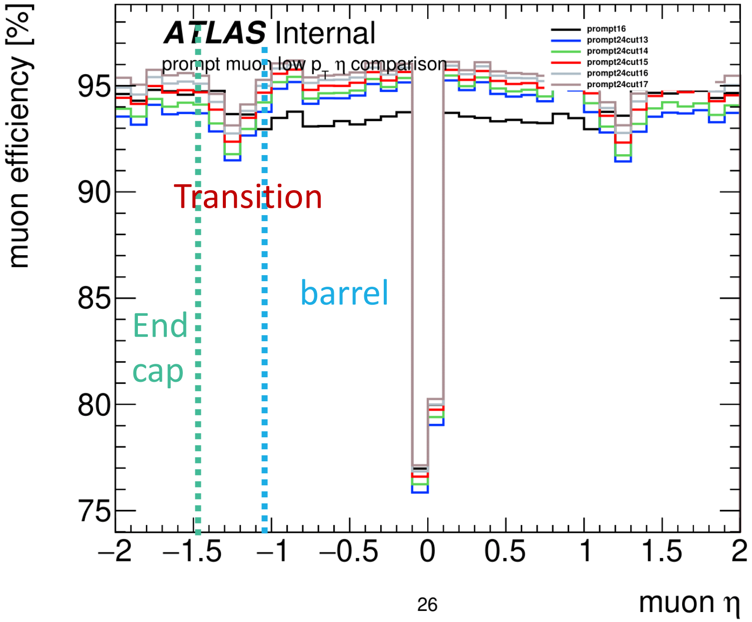
Low P_T - efficiency by P_T

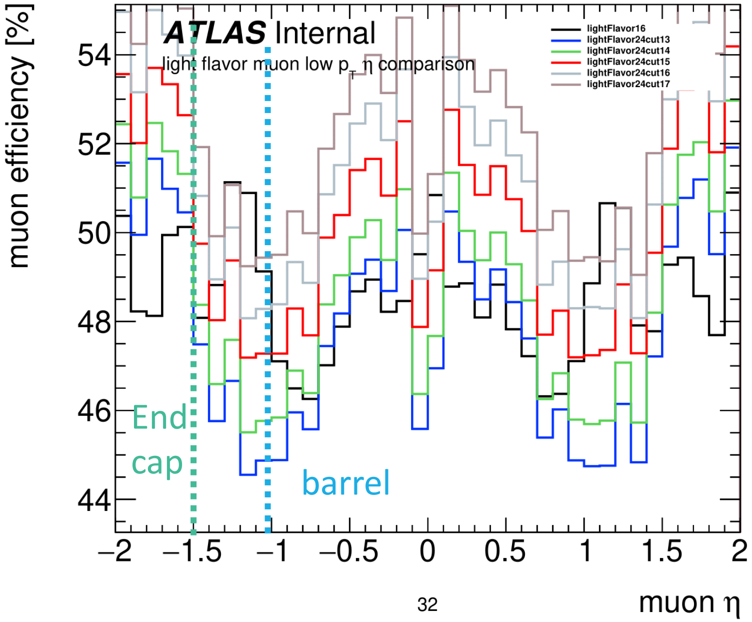




- Lower efficiency for both prompt and L.F. at lower P_T (< 8 – 10 GeV); higher efficiency at higher P_T
- The drop in L.F. efficiency is higher than prompt!
- Consider 1) different L.F. cut for different P_T or 2) generate ρ vs q/p L.F. for different P_T regions

Low P_T - efficiency by η



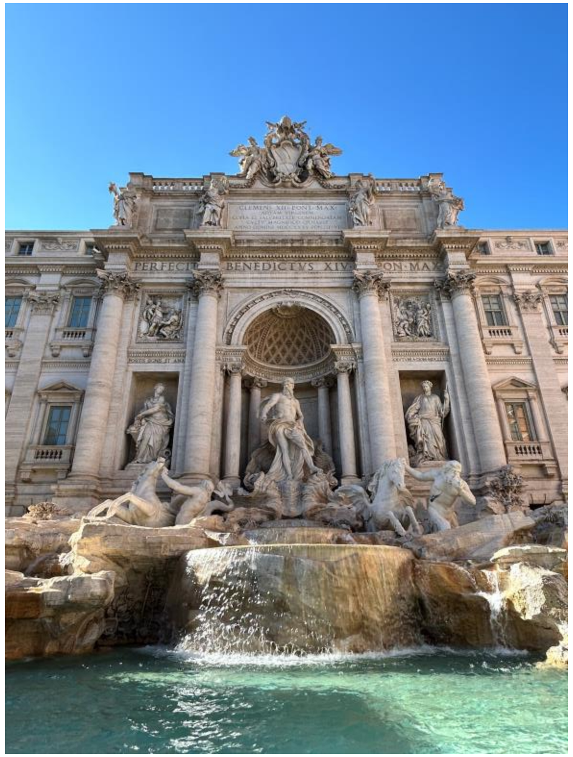


- Barrel: Better prompt efficiency and comparable L.F. rejection
- Transition: Comparable in L.F. rejection
- Further study in end cap -> Need binning in η

Next Steps

- Generate 2D ρ vs q/p light flavor percent maps changes for different $\boldsymbol{P_T}$ and $\boldsymbol{\eta}$ regions
- Uses different L.F. cuts for different region of the detector (barrel, transition, endcap)

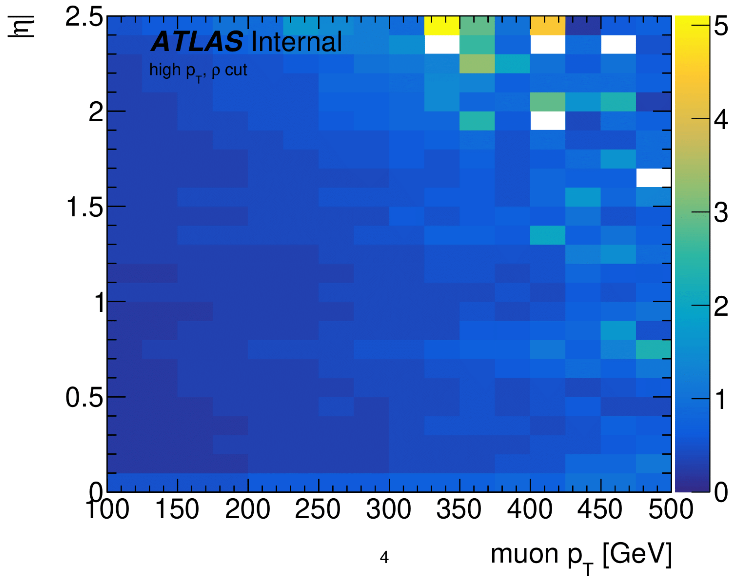
Fun Time

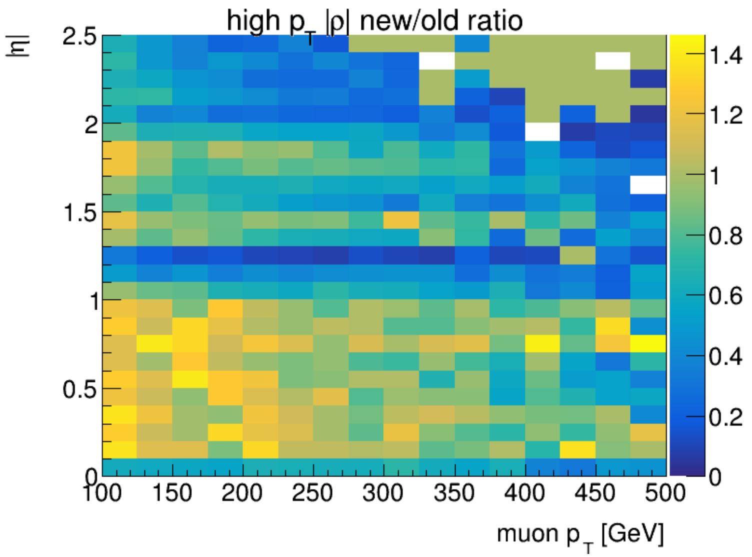


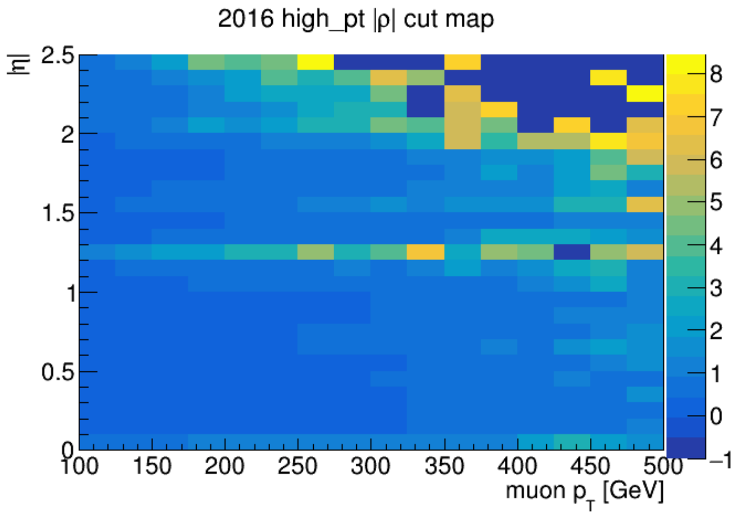
les tal	N files done	N files failed	%	Status (JEDI)	Duration, days	Task logge status
1666	0	40	0	broken	0.06	not enough
1666	0	40	0	broken	0.06	not enough
1666	0	0	0	aborted	0.04	kill by Yongwen
1666	0	0	0	aborted	0.04	kill by Yongwen
1666	0	0	0	aborted	0.01	kill by prodsy
1666	0	0	0	aborted	0.01	kill by prodsy
1666	0	0	0	aborted	0	kill by Yongwen
1666	0	0	0	aborted	0	kill by Yongwen
99	99	0	100	done	0.01	-
833	833	0	100	done	0.08	-
1666	1666	0	100	done	0.06	-
182	182	0	100	done	0.18	-

Back Up

High P_T - ρ Map

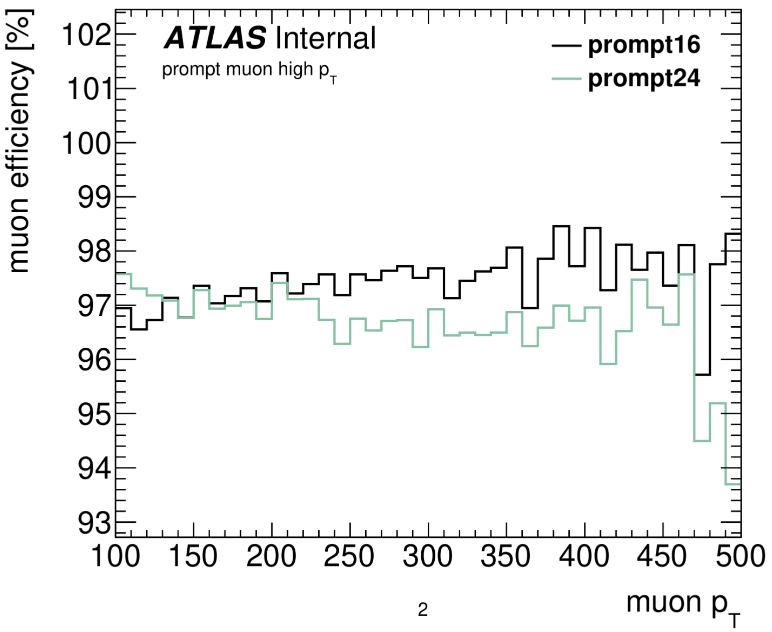


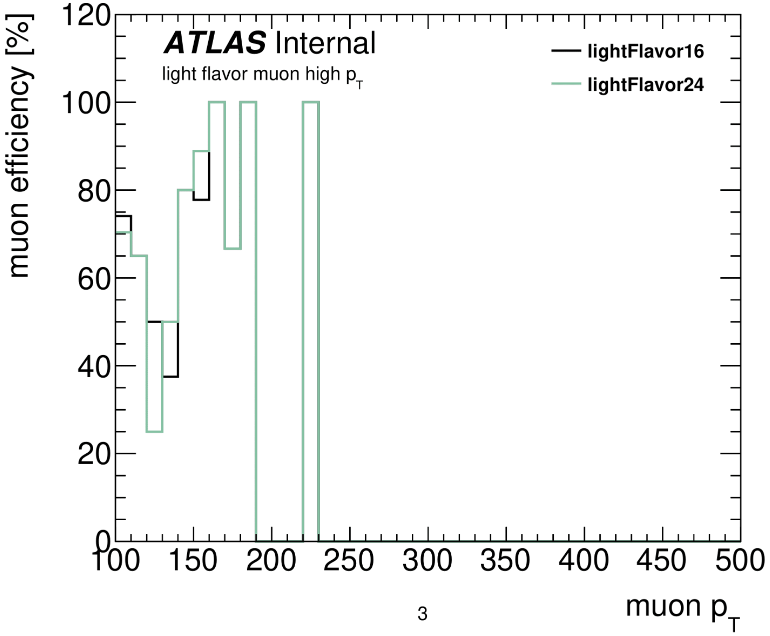




- Smaller P_T binning is used for high P_T.
- The old plots used -1 for underflowing bins. For these values in the ratio plot, $|\eta|$ is set to 1.
- In the region $1.1 < |\eta| < 1.3$, the ρ cuts are lower compared with the 2016 plot.

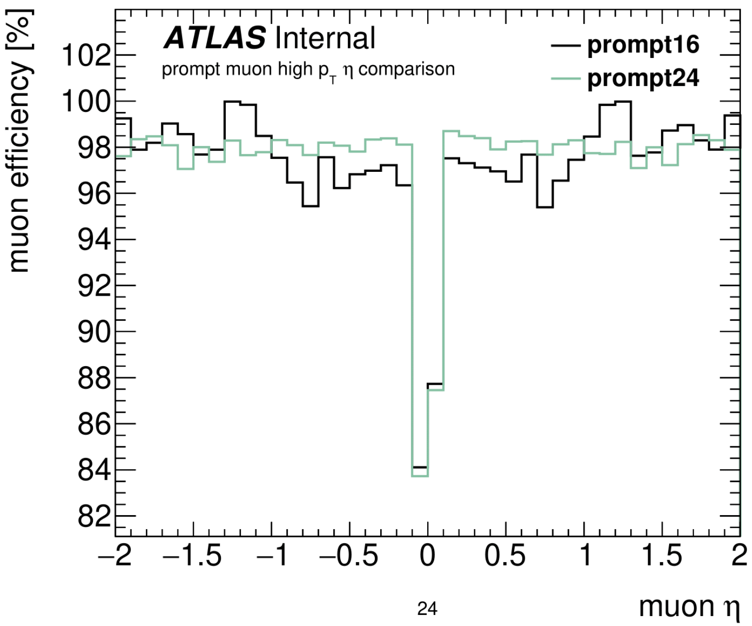
High P_T - efficiency by P_T

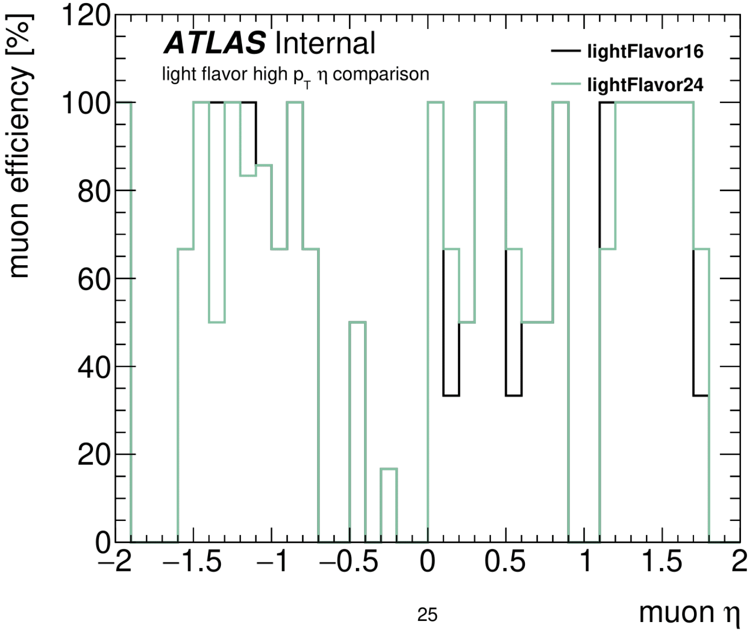




- Low statistics for high P_T region especially for light flavor

High P_T - efficiency by η





- Higher efficiency for prompt
- Low stats for light flavor