D0 Note 5824

# Muon ID Certification for p20 data

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This note reviews muon identication in p20 data. The changes in the definitions of basic objects related to muons between p17 and p20 are given plus p20 measured efficiencies. The efficiencies discussed here are released for cafe users in muid_eff v04-03-00.

## 1. Introduction

There have been only minor changes in muon ID from p17 to p20 and only the changes are described in detail in this note. Greater details on the definitions of muon quality, track quality, muon isolation, and trigger objects are found in D0 Note 5157 [1]. Efficiencies for muon quality categories loose and medium are determined. The tight category is now longer supported. Also in that note are discussions of backgrounds and fake rates which are not repeated here.

The muon certification program muo_cert uses dimuons (mostly from Z decays) to estimate the efficiencies. For muon categories, a tag&probe technique is used where the tag muon is selected by requiring that it satisfy a muon trigger, muon loose quality, and is matched to a central track. The probe muon is selected using only central tracking criteria and angular relationships with the probe track. The $|\eta|$ of the probe track extends to 2. Results from muo_cert are obtained after the elimination of events which fail data quality criteria (bad runs and LBN flags), and uses the appropriate beam positions. Version V07-01-01 of wzreco and muo_cert were used for the results in this note. An updated description of how to run muo_cert is found on the muon Wki page:

https://plone4.fnal.gov/P1/D0Wiki/object-id/mu_id/MuonCertification.

Three samples are presented in this note. The first are the efficiencies from the Summer 2008 dataset which are Run2b runs taken from the beginning, run 220000 to about run 242000 and are shown with their original muon certification efficiencies. Their average luminosity is 86e30 with an integrated luminosity of 1.9 fb$^{-1}$. The second sample is the data certified for Wniter 2009 and includes all Run2b data from run 220000 to about run 246000. Its average luminosity is 85e30 and it has a total integrated luminosity of about 2.6 fb$^{-1}$. The third sample is a subset of Winter 2009 and is all runs greater than 24200, just before making the PDT firmware in August 2008, and has an average luminosity of 118e30 and an integrated luminosity of 0.7 fb$^{1}$. The sum of the first and third samples equals the second sample while the second and third samples are shown with the new certification results There are 159,425 probe muons which pass the muonid flag in the second sample and 43,800 in the third sample. Black, red, and green dots are used for the Summer 12008, Winter 2009, and >242000 samples respectively. The data from spring and summer 2008 often had missing A-layer PDTs. This will be seen in a reduction of the efficiency for medium muons in the central region which, for nseg=1 and nseg=3, require both A-layer scintillator and PDT hits.

## 2. Muon quality categories

There has been one minor change to the definition of muon quality. For nseg=3 (A+BC muon layers), if a muon in the central region has a hit in the A-scint, >1 A-wire, and >1 BC-wire then it is labeled as medium whether or not there is a BC-scint. Previously, if there were >3 BCwires then a BC-scint was required. The requirements for nseg3medium in the forward region, which require a BC-scint plus >1 BC-wire, were unchanged. This change is implemented in caf_util/src/MuonSelector.cpp and also in muonid/src/MuoCandidate.cpp, which is used by d0correct. It is not in the version of the reconstruction used to process events. It is currently implemented only for Run2b samples (p20) which for MuoSelector means caf_util versions greater than or equal to p21-br-8. It is intended to also be added for Run2a (p17) once its impact on the efficiency is measured and a new set of spc files are available. For muons wich statisfied a tight scintillator trigger, there will not be a change in the nseg3medium efficiency. For the dimuon sample used by muo_cert (which is a mix of triggers) the increase in the number of nseg3medium is about 3-4%.

## 3. Muon Reconstruction Efficiencies

The efficiencies for different muon ID categories are determined using the probe tracks. These efficiencies apply to untriggered muons, and since they are mostly determined by geometry are correlated with muon trigger efficiencies. The efficiency for loose muon quality (for nseg=1,2 or 3) is given in Fig. 1. All three samples are in agreement with an overall efficiency of (92.1+-0.2)% for the Winter 2009 sample.

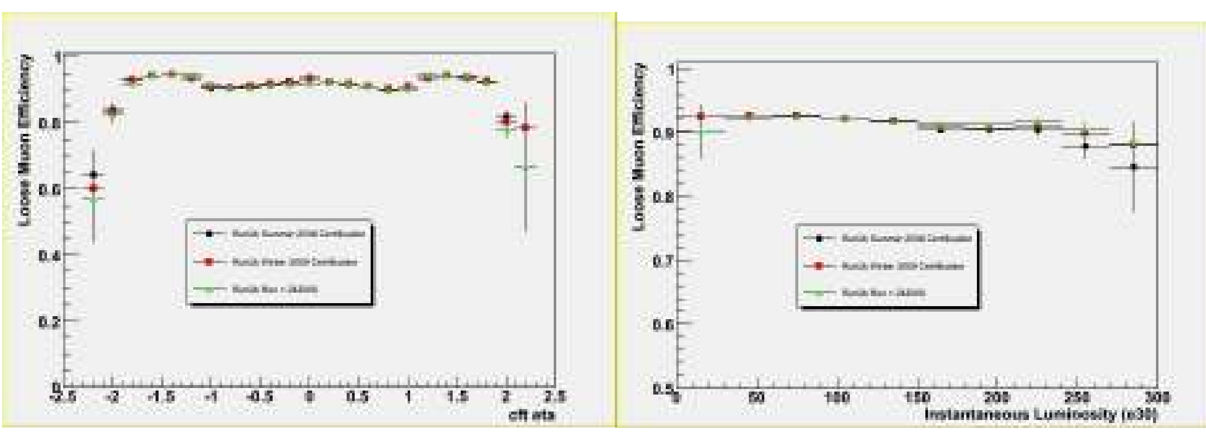

Fig. 1. The efficiency for the loose muon quality category for the three samples as a function of η and instantaneous luminosity.

The efficiency for medium quality muons (nseg=1,2 or 3) is given in Fig. 2. The efficiency for the complete Winter 2009 sample is (83.1+-0.2)% compared to the Summer 2008 certification value of (82.1+-0.3)%. This increase is due to the change in the nseg3medium definition. However, the subsample after run 242000 has a lower efficiency of (81.3+-0.4)% due to failures of A-layer PDTs (25, 31, 32, 23, and 21 were out during part of the period from run 242000-245100). This can be seen in Fig. 3 where the drop in efficiency is mostly in the central region octants 3 and 4 and also in Fig. 4 which show the efficiency of all runs > 242000 and all runs > 245100. Removing the run>242000 sample gives an efficiency of 83.8% for the Winter2009 sample and so an increase in efficiency due to the nseg3medium change of about 1.7% integrated over all η.

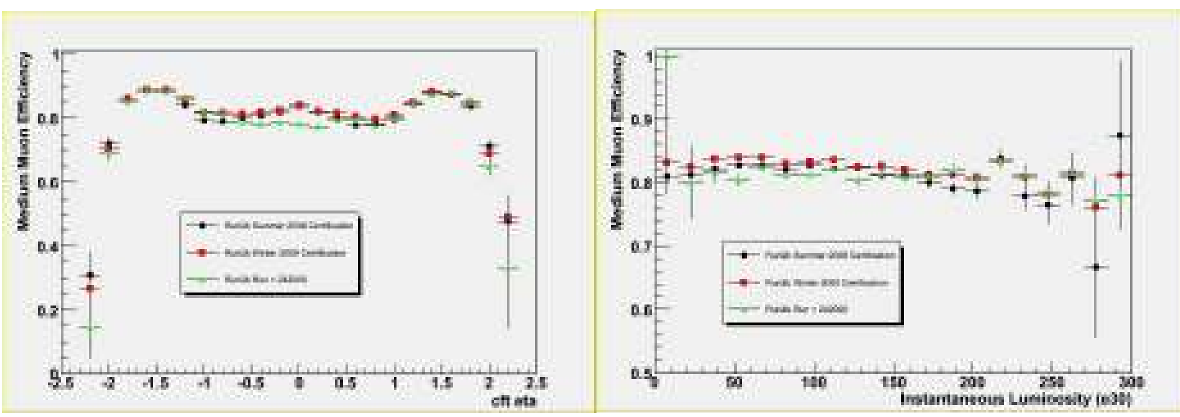


Fig. 2. The efficiency for medium muon category for the three samples as a function of η and instantaneous luminosity.

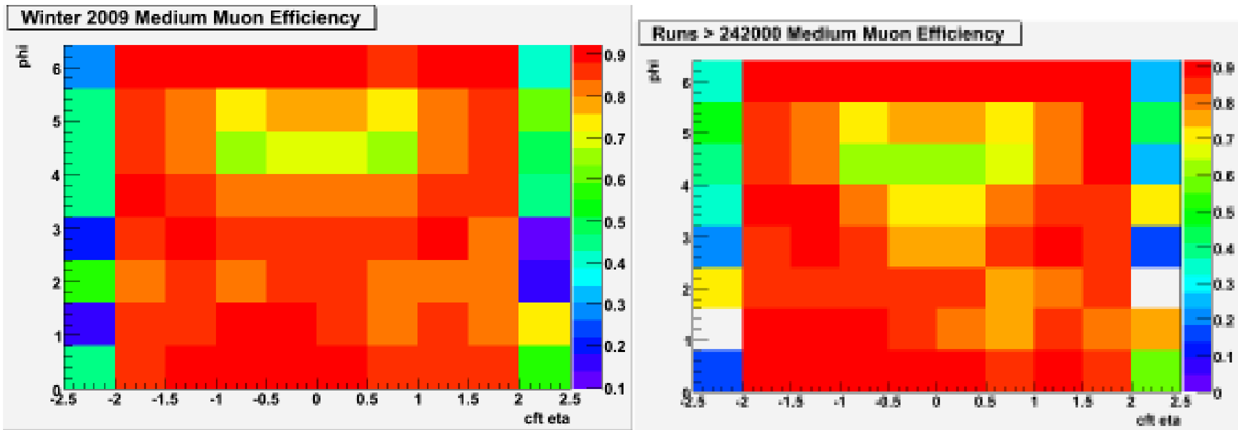


Fig. 3. The medium quality efficiency in (η,ϕ) bins for the entire sample and the run > 242000 sub-sample.

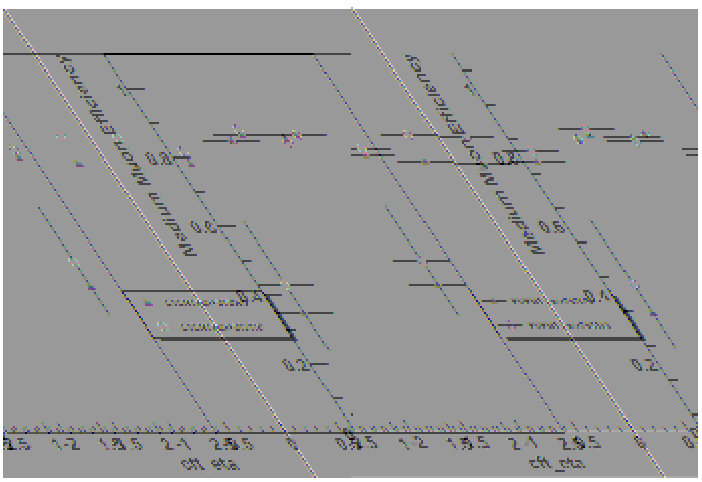

Fig. 4. The loose reconstruction efficiency versus η for all runs > 242000 (blue) and for the subset of runs > 245100 (yellow).

The efficiency for nseg3medium is given in Fig. 5 and as this category dominates medium muons, the conclusions are identical as those discussed in the preceding paragraph. The efficiency is (72.6+-0.3)% for the Summer 2008 sample, (73.9+-0.2)% for the Winter 2009, and

(72.7+-0.4)% for the >242000 sample with the newest data showing little change as a function of instantaneous luminosity.

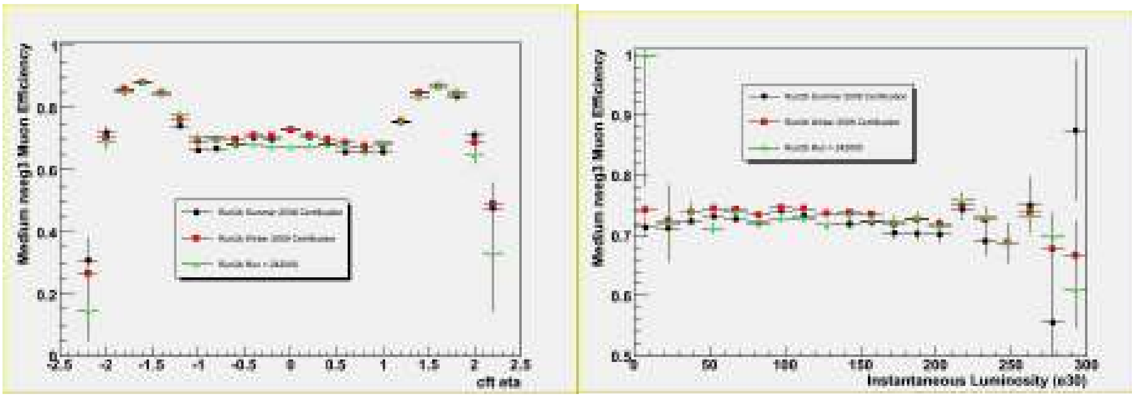


Fig. 5. The efficiency of nseg3medium versus η and instantaneous luminosity.

As the previous figures have shown, there is little dependence of the efficiency on instantaneous luminosity. Compared to the overall values of 92.1% and 83.1% for loose and medium categories in the full winter 2009 sample, values of 90.7% and 81.2% are obtained for runs with Inst. Lum. >180e30. But as the data collected in summer 2008 had both high luminosity and some inefficiencies due to missing A-layer PDTs, if we remove runs between 242000 and 245100, we obtain loose and medium efficiencies of 92.2% and 83.8% for all events and 90.6% and 81.8% for lumi>180. A difference of (1-2)% persists. However, for the latest sample with runs > 245100, values of 93.2% and 84.6% for all data and 93.1% and 85.2% are found, indicating no dependence on instantaneous luminosity in that subsample.

The efficiencies also do not have any strong dependence on momentum. The WZ selection requires $p_T$ > 20 GeV/c and the efficiencies as a function of $p_T$ are given in Fig. 6 for loose, medium and nseg3medium. The values for 20<$p_T$< 30 GeV are 91.4% and 82.4% for loose and medium compared to 92.1% and 83.1% for all events. We have attempted to use the muo_cert procedure to extend the transverse momentum range below 20 GeV. There exist two problems. The requirement that the invariant mass of the tag&probe pair is near the Z mass forces the low

$p_T$ track to be in the forward region. Also, there is a large increase in the fraction of probe tracks which are not themselves muons. As such different methods will be needed to provide efficiencies for lower $p_T$ muons.

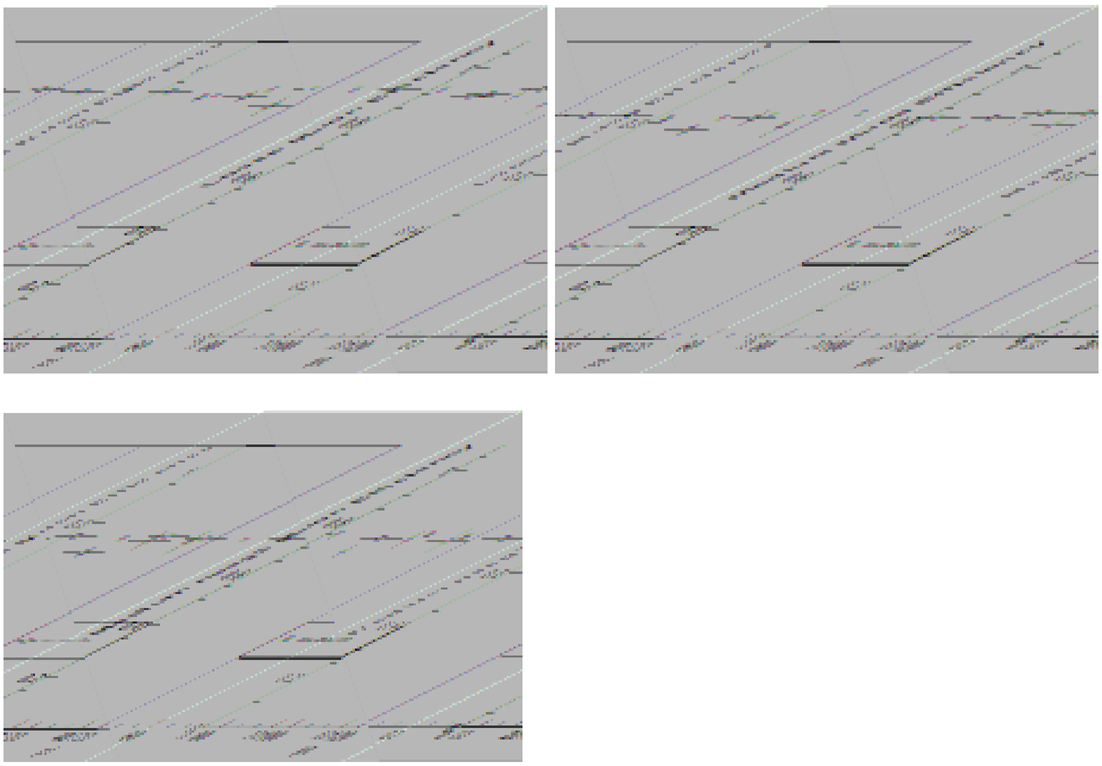

Fig. 6. The reconstruction efficiency versus $p_T$ for loose, medium, and mediumnseg3 categories.

The reconstruction efficiency does depend slightly on the tracking category of the probe track. The efficiencies given above require a medium track which has DCA cuts of 0.2 cm (no SMT hits) or 0.02 cm (with SMT hits) and a $\chi^2$/dof < 4. A loose track has the same dca requirement but without $\chi^2$/dof cut while a tight track requires at least one smt hit. About 95% of loose probes pass the medium cut and 86% of loose pass the tight cut. The muon reconstrc\uction efficiency for medium and tight tracks are almost identical: loose/medium/mediumnseg3 = (.921,.831,.728) for medium and (.922,.832,.730) for tight. However the efficiency is lower for loose tracks (.910,.821,.720) or for those loose&&!medium

(.689,.618,.557). Part of this is due to rejecting fake or poorly reconstructed tracks with the $\chi^2$/dof but if we assume that the good muon fraction is independent of the tracking quality, there is a 1% difference in the muon reconstruction efficiencies due to tracking criteria.

## 4. Comparison to Monte Carlo

A sample of Z's decaying to muons was run through the identical muo_cert procedures. The reconstruction efficiencies versus $\eta$ for loose, medium, and mediumnseg3 are given in Fig. 7 and summarized in Table 1. The efficiency for loose in the MC is almost identical to data as is the efficiency for medium and mediumnseg3 for the forward region. The central region has slightly lower efficiency for medium muons in the central region. There are at least two reasons for this. As seen above, the data collected from runs 242000 – 245100 had lower efficiencies for the medium category due to the A-layer PDT requirement. Removing those runs reduces the difference seen between data and MC. There are still PDT inefficiencies in the data which cause part of the remaining difference. Also, in tuning the muon tracking code, it was seen that one could increase slightly, by 1-2%, the number of nseg3 tracks but at the expense of missing some found nseg1 or nseg2 muons (loose and tight). This indicated that there is a small migration between categories in the data which may not be reproduced by MC (the impact on muon pattern recognition tuning may have last been studied in 2000-01).

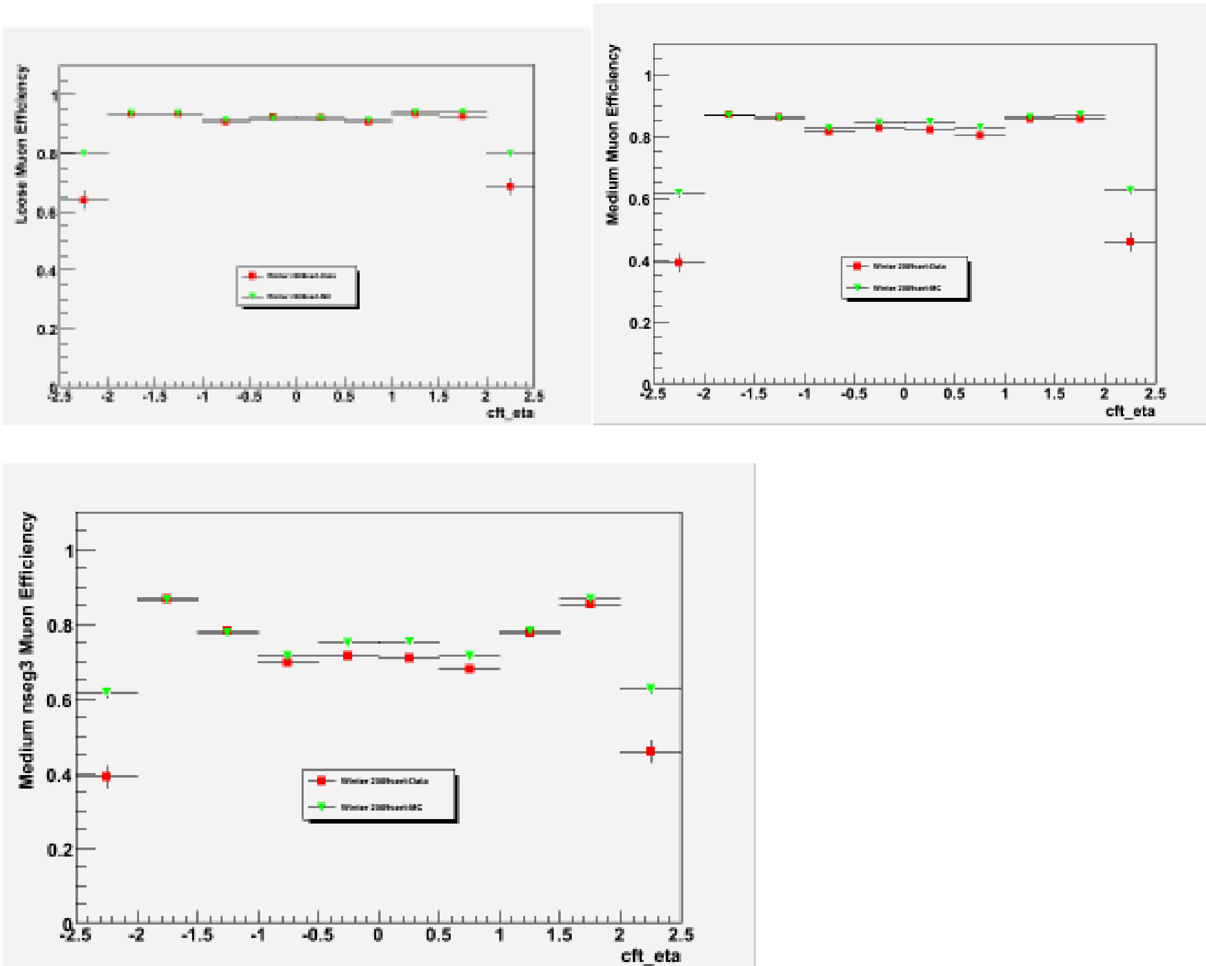


Fig. 7. Comparisons between data and Monte Carlo for loose, medium, and mediumnseg3 efficiencies.

There is a difference between the number of data and MC passing the track quality cuts used to define the probe track. That is more a "tracking" efficiency then a "muon reconstruction" efficiency and so somewhat irrelevant for the results presented here. It has yet to be studied completely with the p20 muon certification sample. For now we just note that the ratio of medium/loose track (that is adding the $\chi^2$ cut) is about .951 for data and .989 for MC while tight (requiring smt)/medium are .901 for data and .913 for MC.

Table 1. Muon reconstruction efficiencies for data and MC.

| Data Sample | Monte Carlo | Winter2009 | skip 242000-245100 |
|---|---|---|---|
| Loose all eta | .922 | .921 | |
| Medium all eta | .846 | .831 | |
| Mediumnseg=3 all eta | .758 | .728 | |
| Loose $\|\eta\|<1$ | .911 | .912 | .913 |
| Medium $\|\eta\|<1$ | .830 | .809 | .820 |
| Mediumnseg=3 $\|\eta\|<1$ | .723 | .678 | .686 |
| Loose $1<\|\eta\|<1.5$ | .954 | .946 | |
| Medium $1<\|\eta\|<1.5$ | .885 | .879 | |
| Mednseg=3 $1<\|\eta\|<1.1$ | .799 | .799 | |

## 5. Systematic Error Summary

We can use the results shown in the previous sections to estimate the systematic uncertainty on muon ID selection. This does not include the efficiency (and its systematic error) on reconstructing the central track. It is an estimate on how the muon reconstruction efficiency would change if it is being applied to different data sets then what was used to generate the values; for example different momentum distribution, different run ranges, or a different instantaneous luminosity profile. The largest error is due to using loose versus medium central tracking. Removing the $\chi^2$/dof requirement increases the number of non-muon tracks selected as probes but also the number of muons which might fail the matching criteria. For the systematic error estimate we assume that all the probe tracks are good muons. A summary of systematic errors is given in Table II.

Table II. Systematic errors on muon ID selection.

| | | Estimated Systematic |
|---|---|---|
| statistics | | 0.007 |
| eta variation -- included in spc files | | < 0.005 |
| $p_T$ | for high $p_T$ (t/W/Z) | 0 |
| | for $p_T < 20$ | 0.020 |
| if different average inst luminosity | | < 0.003 |
| if different run period | loose muon quality | 0 |
| | medium muon quality | 0.020 |
| muon category type (loose vs medium vs mediumnseg3) | | < 0.004 |
| central tracking category | | 0.011 |

## 6. Muon Trigger Efficiencies

Some trigger efficiencies are also studied in muo_cert. The official muon trigger efficiencies for physics analysis are provided by the trigger group. The efficiencies presented here are for monitoring the stability of the muon system. The L1 tight scint efficiency requires scintillator in both the A and BC-layers to be used in the trigger. Its efficiency relative to those probe tracks which passed the loose muon criteria is given in Fig. 8. The efficiencies for the three samples are consistent: Summer 2008 (81.4+-0.3)%, Winter 2009 (81.7+-0.2)%, and >242000 (82.2+-0.4)%

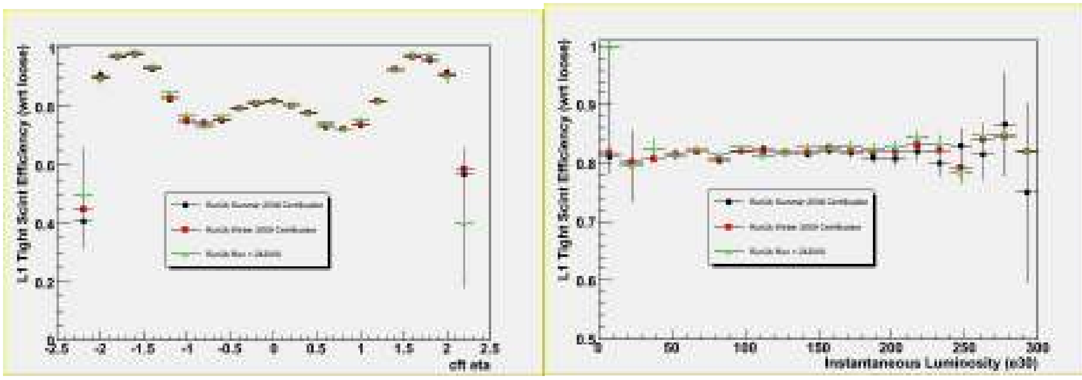


Fig. 8. The efficiency of the L1 tight scintillator trigger relative for events passing loose muon quality criteria versus η and instantaneous luminosity.

The L1 loose wire efficiency for those probe tracks which satisfied loose muon quality is shown in Fig. 9. The loose trigger requires a A-layer wire as a trigger element. The three samples are in agreement with efficiencies of 92.8%, 92.6% and 92.4%. The small dip near η=0 for the latest sample is within statistics but is also the region that had some PDTs inoperational for part of the period.

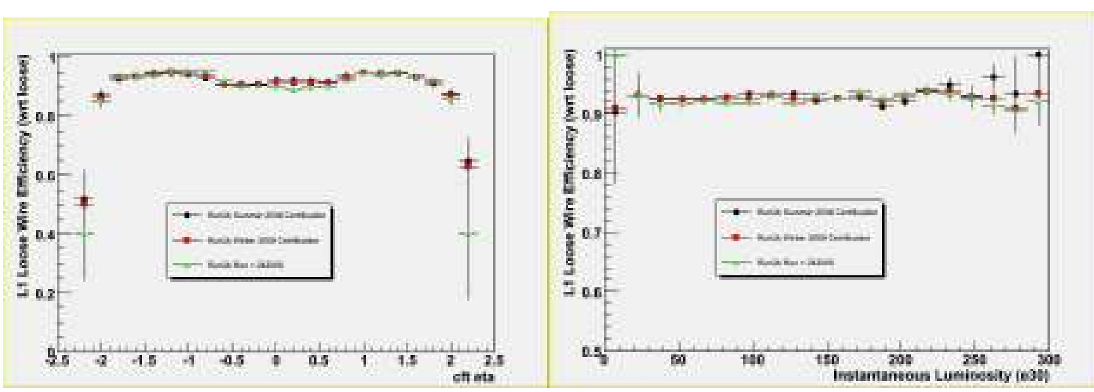


Fig. 9. The efficiency of the L1 loose wire trigger relative for events passing loose muon quality criteria versus η and instantaneous luminosity.

References

[1] Muon Identification Certification for P17, P. Calfayan et al., D0 Note 5157, February, 2007.