# Collection of plots showing interesting effects of pT-dependent behavior of the VXDTF

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# 1 Useful information

**Situation:** For a long time now there is an interesting effect causing drops in efficiency for certain phi and theta ranges. The efficiency drops in $\phi$ strongly correlate with the geometrical overlapping region of the ladders in layer 3 (some minor effects could maybe caused by other layers, but this was not studied in detail yet). This effect will from now on called in this document the "$\phi$-issue". The second effect discussed in this document is the $\theta\,90^\circ$ -issue, which is known much longer than the $\phi$-issue. This document shall provide a collection of plots which help analyzing these issues.

**Summary for the anxious ones:** Effect of the $\phi$-issue and the $\theta\,90^\circ$ -issue are strongly correlating. They are very likely symptoms of the same issue (from now on, the combined effect will be titled as the $\theta\,90^\circ$ -issue only, since this effect was known for longer than the $\phi$-issue). The effect can not be seen at low momenta but only emerges at higher momenta. There seems to be no charge dependency. Single tracks reveal the same issue and therefore excludes high occupancy issues. Removing K-shorts from the decay list increases the TF-efficiency, but has no visible impact on the $\theta\,90^\circ$ -issue. This issue is decoupled from the position of the primary vertex, which means that particles lying far away from the assumed IP at (0,0,0) can not be the cause of this effect in a disproportionate way. Additional studies of heavier particles like charged Kaons and Protons show that the effect is actually not momentum dependent as assumed before but in reality is coupled to $\beta\gamma$ . For values of $\beta\gamma$ of 1 and less the efficiency is best (down to about 0.4 $\beta\gamma$ , where energy loss becomes to severe to get useful tracks at all). For higher values of $\beta\gamma$ , the effect starts to emerge slowly when moving from $\beta\gamma$ 1 to $\beta\gamma$ 2 and reaches a plateau in its severity. This dependency of $\beta\gamma$ decouples the issue from single sectorMaps too.

**Setup:** A note beforehand, this document contains plots with VXD (6 layer) only, but the effects are the same for SVD-only. The revision used for the runs was r15345 with some minor modifications in the analysis tools used. The sectorMaps used were:
$secMapEvtGenAndPGunWithSVDGeo2p2OnR13760Nov2014VXDStd{-}moreThan500MeV_PXDSVD$,
$secMapEvtGenAndPGunWithSVDGeo2p2OnR13760Nov2014VXDStd{-}125to500MeV_PXDSVD$,
$secMapEvtGenAndPGunWithSVDGeo2p2OnR13760Nov2014VXDStd{-}30to125MeV_PXDSVD$
(in order of application).

A 5000 events used with the standard settings of evtGenInputModule. This run was mainly used to illustrate the problems.

B 5000 events used with evtGenInputModule again, but this time all decays containing K-shorts were suppressed.

C A particle gun was used with 10 muons (PDG ±13) at the same transverse momentum for 5000 events. Transverse momenta of 35, 50, 62, 75, 85, 100, 125, 150, 175, 200, 225 250, 500, 1000, 2000, 3000 and 4000 MeV/c were made. The primary vertex varied uniformly distributed within the range of (cm) X: [±0.01], Y: [±0.01], Z: [±0.5]. The transverse momenta mentioned by the plots are not taken from the primary vertex but from the innermost hit (mostly at layer 1), therefore the values in the plots are slightly less than mentioned above.

D A similar setup was used as above with one difference: instead of 10 tracks, this setup used single tracks to exclude occupancy-dependent effects

E Again similar to Setup C, but this time only one charge was used (separated runs for positive and for negative charges only)

F Another setup similar to Setup C, but this time with fixed vertex at (0,0,0)

G Run like Setup F, but with (anti-)Protons (PDG ±2212).

H Run like Setup F but with charged (anti-)Kaons (PDG ±321).

**How to watch the plots:** To provide better comparability, on each page a plot with efficiency (theta, upper one) and efficiency (phi, lower one) is positioned in a way that if one displays the document on screen pagewise (or ideally as presentation), one can easily see the changes between the momentum steps. For cases of distance to IP plots and for others like p-pT-dependent plots a similar approach was chosen.

# 2 Setup A - evtGen normal

A typical run, the plots for p and pT do reach a plateau at small momenta and stay there. The effect of the $\theta\, 90^\circ$ -issue can clearly be seen in the plots for $\phi$ and $\theta$. New are the plots of the efficiency in dependency of the distance of the vertex to the assumed IP (0,0,0). The number of tracks vastly decreases with increasing distance to the IP and therefore the results are not completely reliable. But a clear tendency can be seen, that the TF strongly depends on tracks near the assumed origin. But Since this should actually be covered by a solid training of the sectormap, this point is a bit surprising and does state that there is room for improvement.

Still interesting is the diverging behavior of the efficiency between p and pT for high momenta.

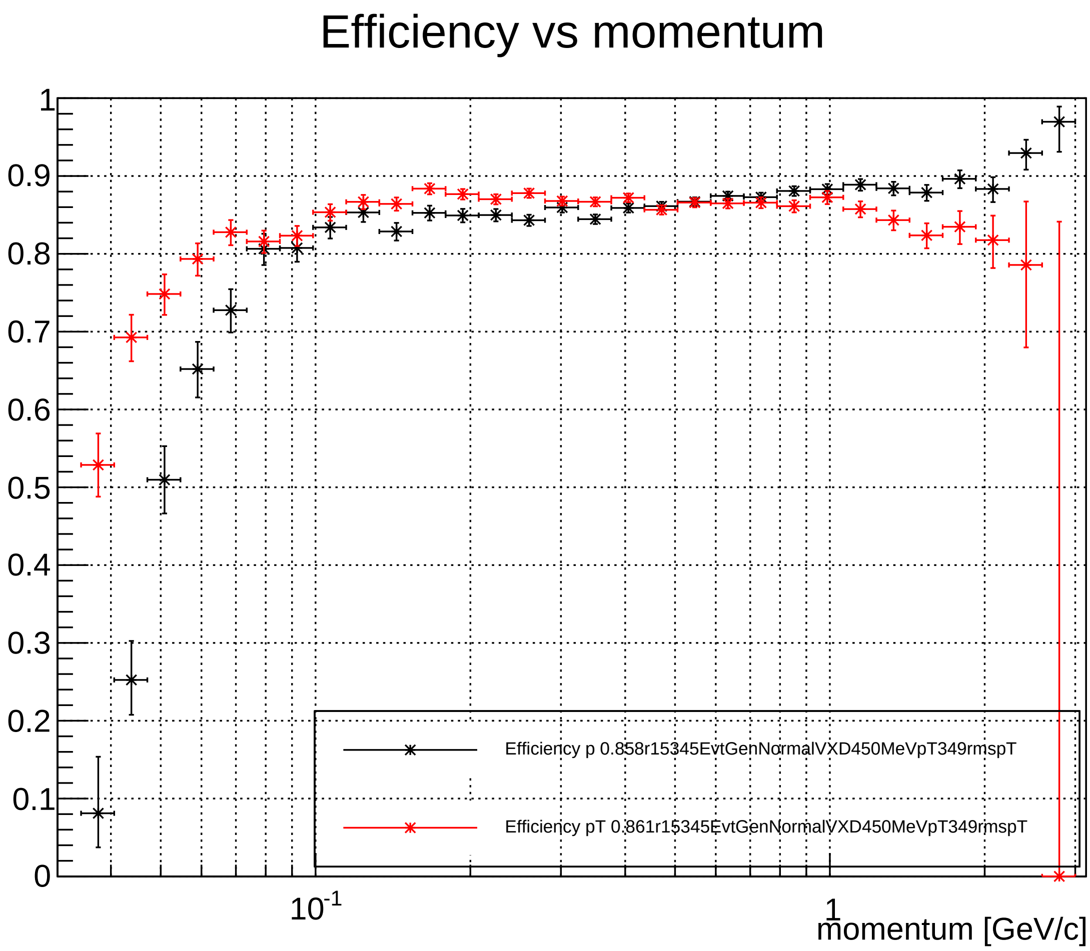



Figure 2.1: evtGen normal

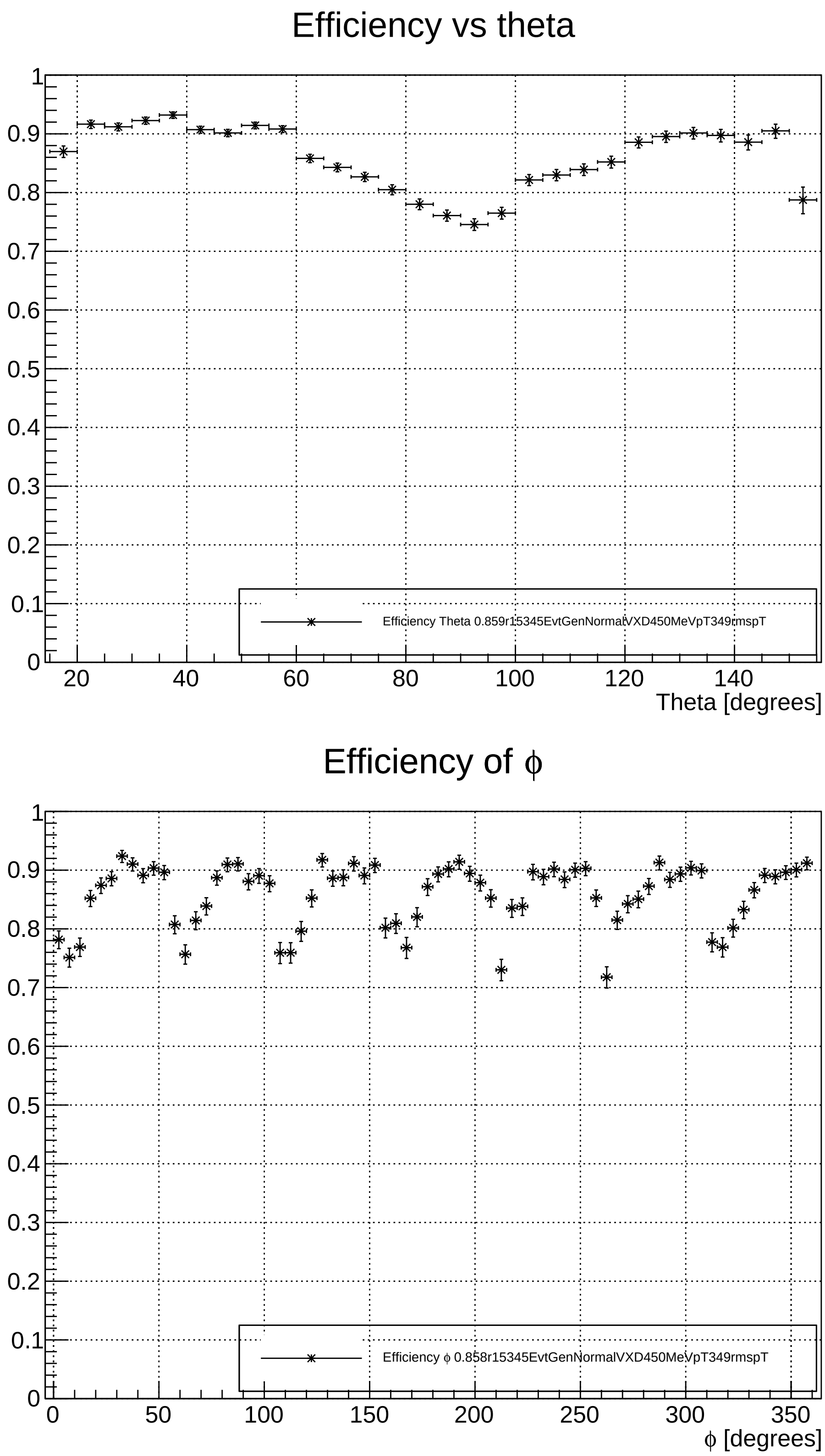



Figure 2.2: evtGen normal

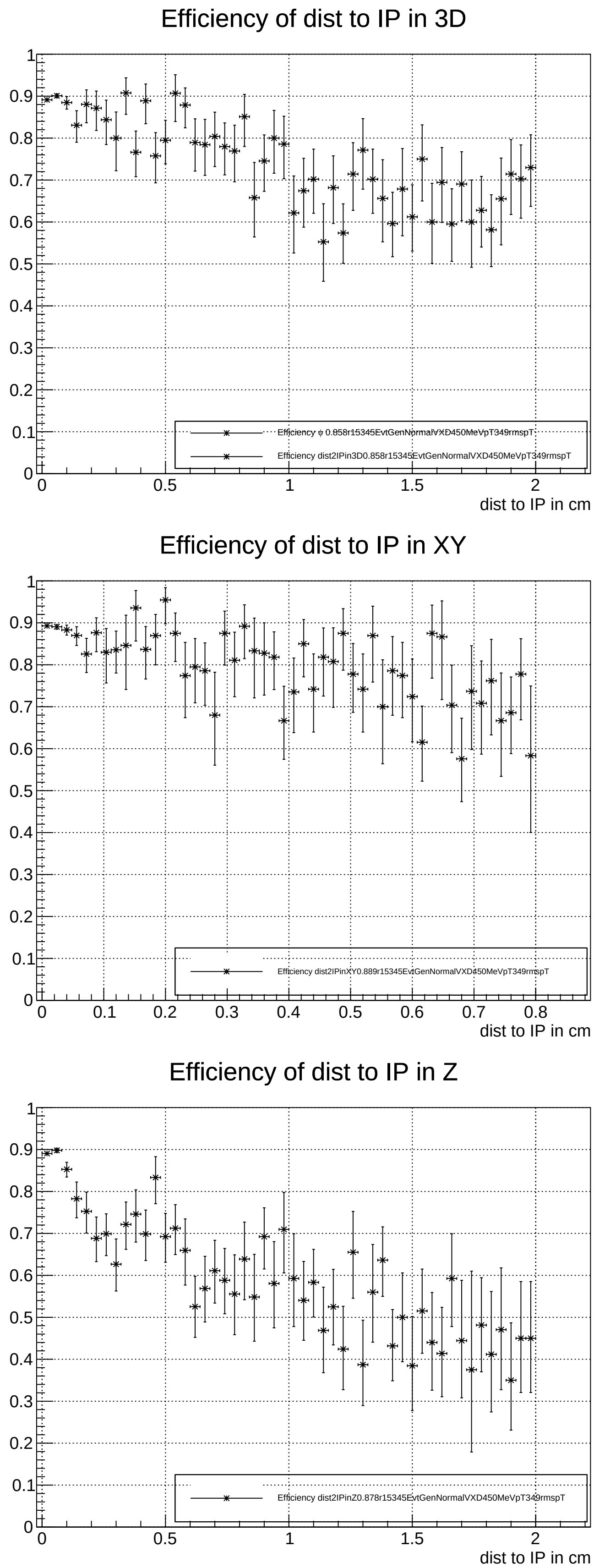



Figure 2.3: evtGen normal

# 3 Setup B - evtGen no K-shorts

The overall efficiency is a bit better for this case compared to the “full” range of decays shown in the last chapter, but all the other effects are practically identical with the normal run. The only relevant difference is now that the number of particles not coming from near the ideal IP is much smaller than for the normal case.

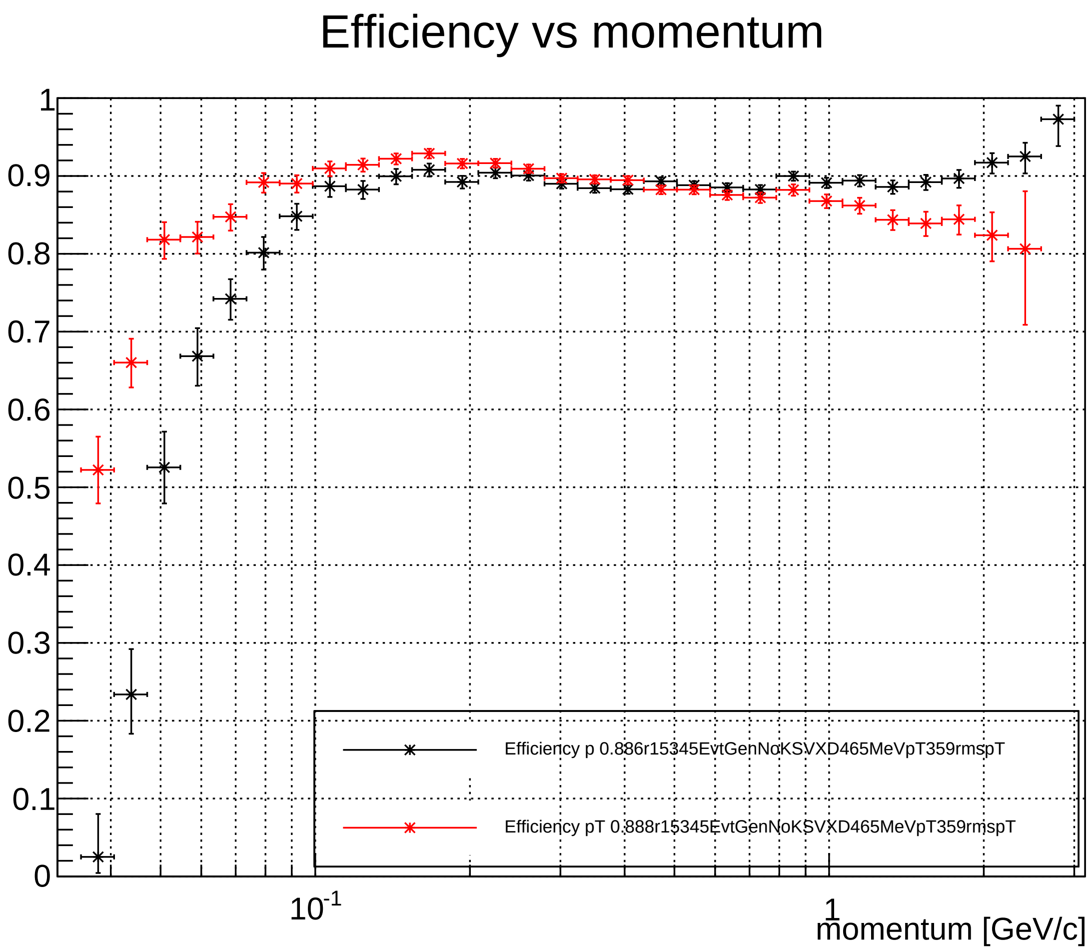
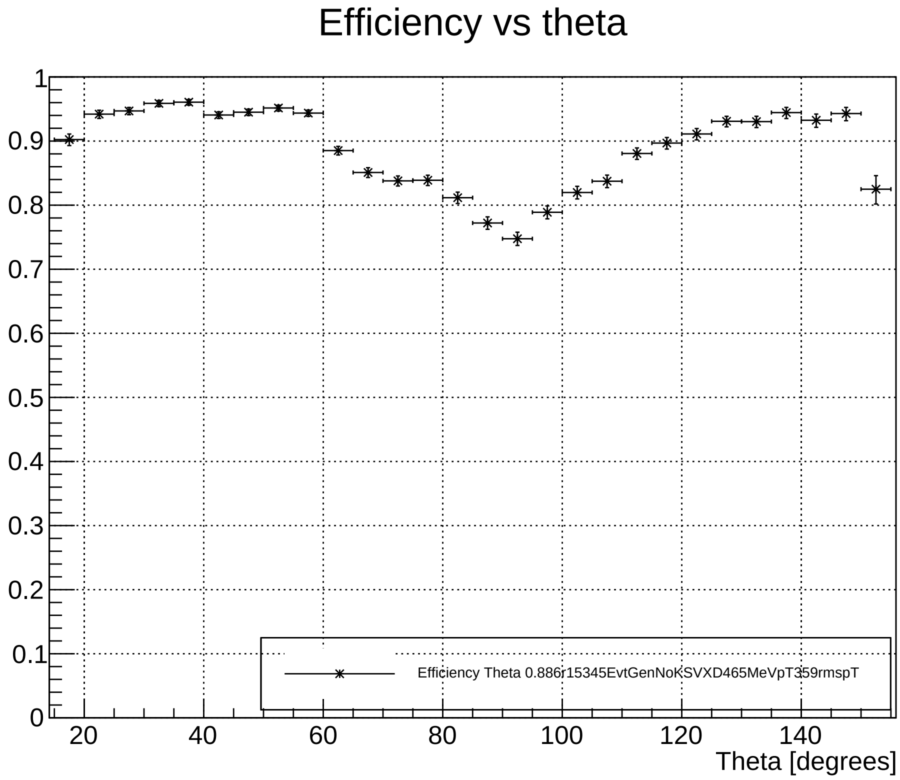



Figure 3.1: evtGen no K-shorts



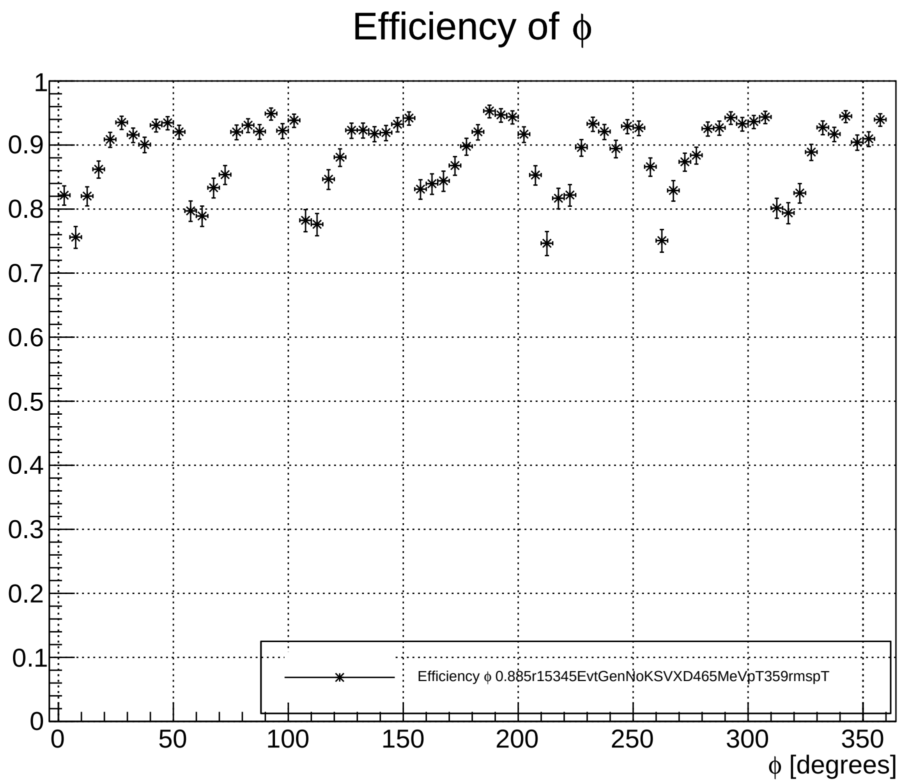




Figure 3.2: evtGen no K-shorts

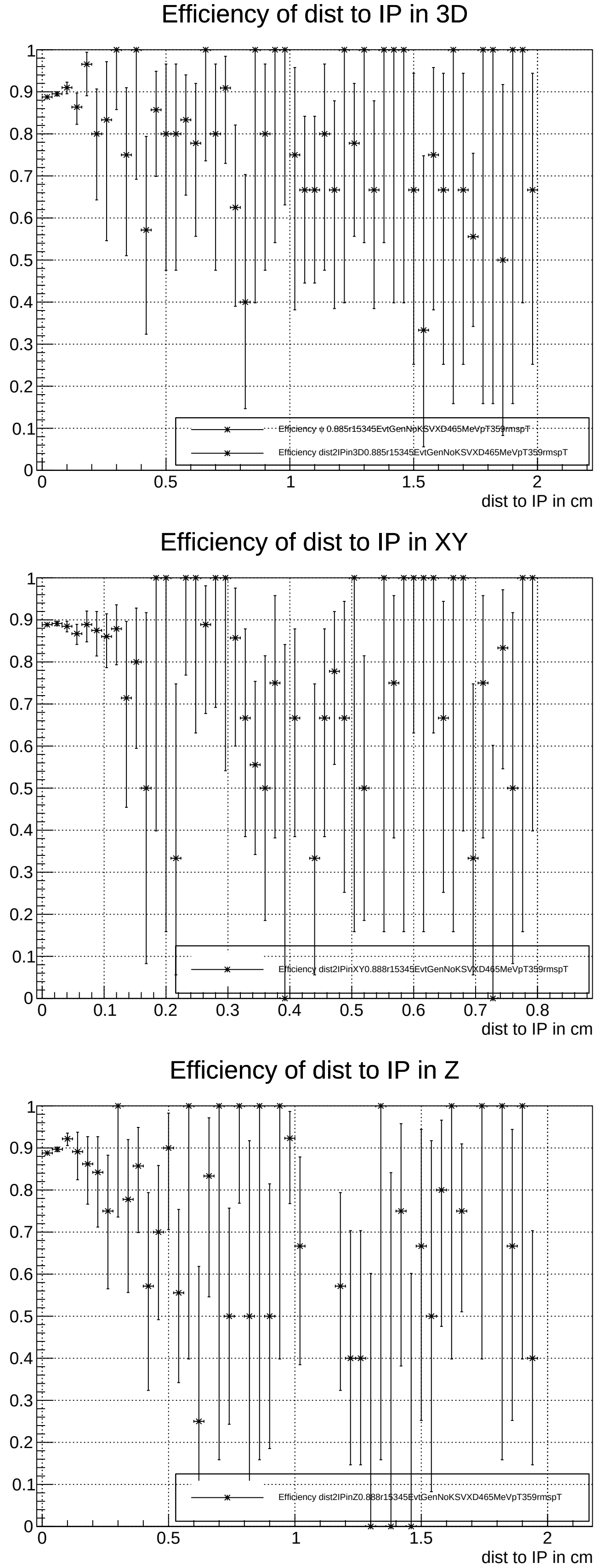
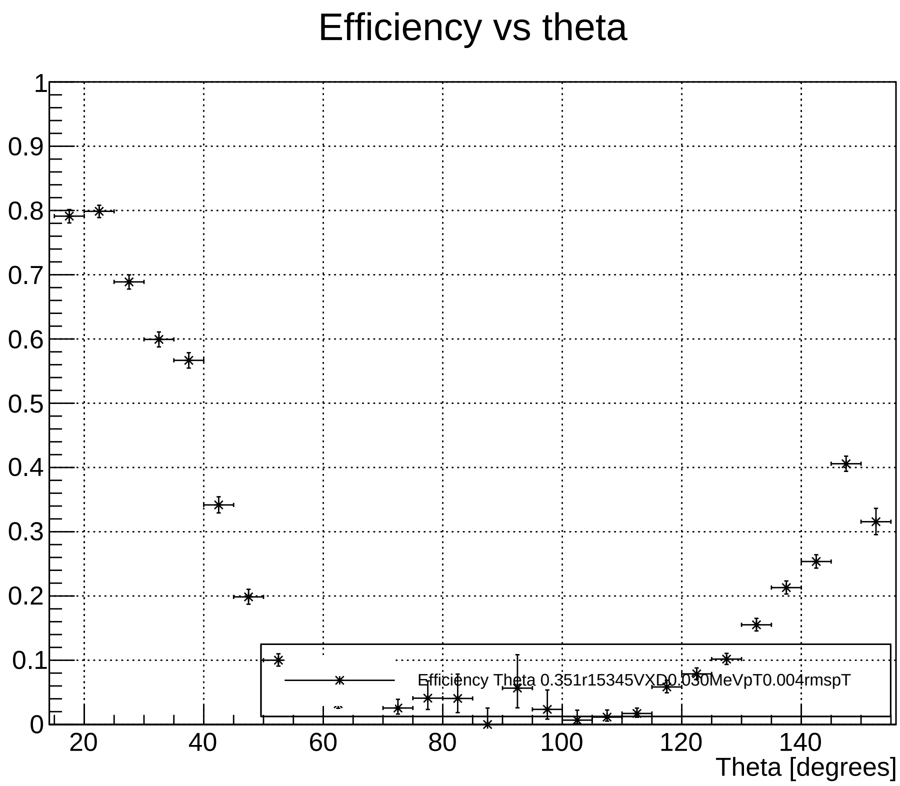



Figure 3.3: evtGen no K-shorts

# 4 Setup C - pGun 10T muons



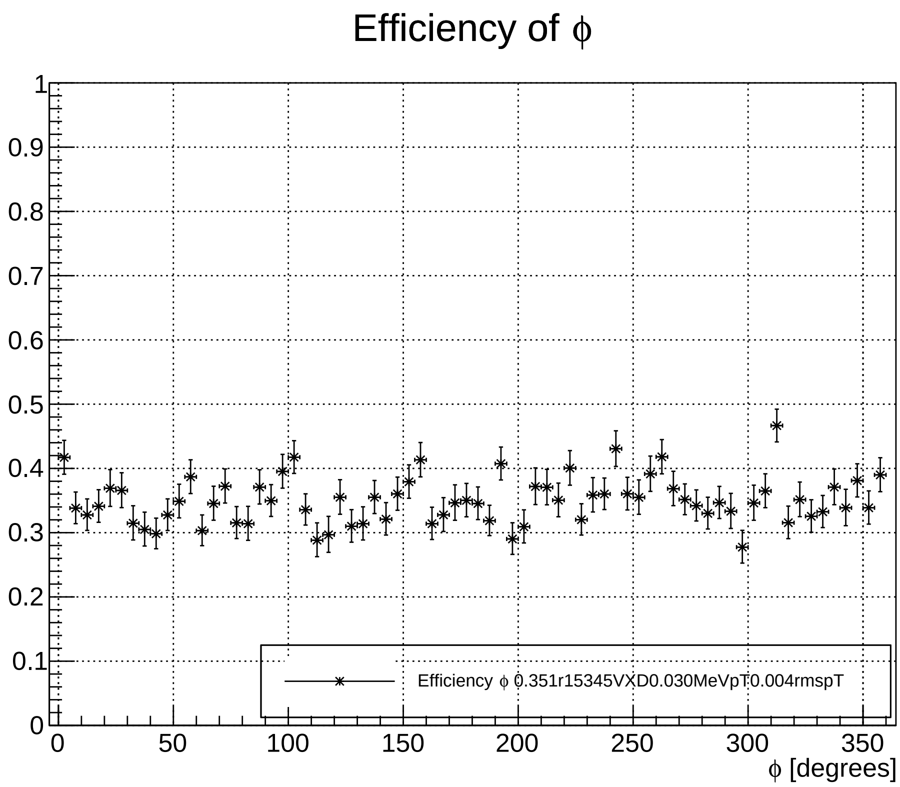




Figure 4.1: 35 MeV/c pT

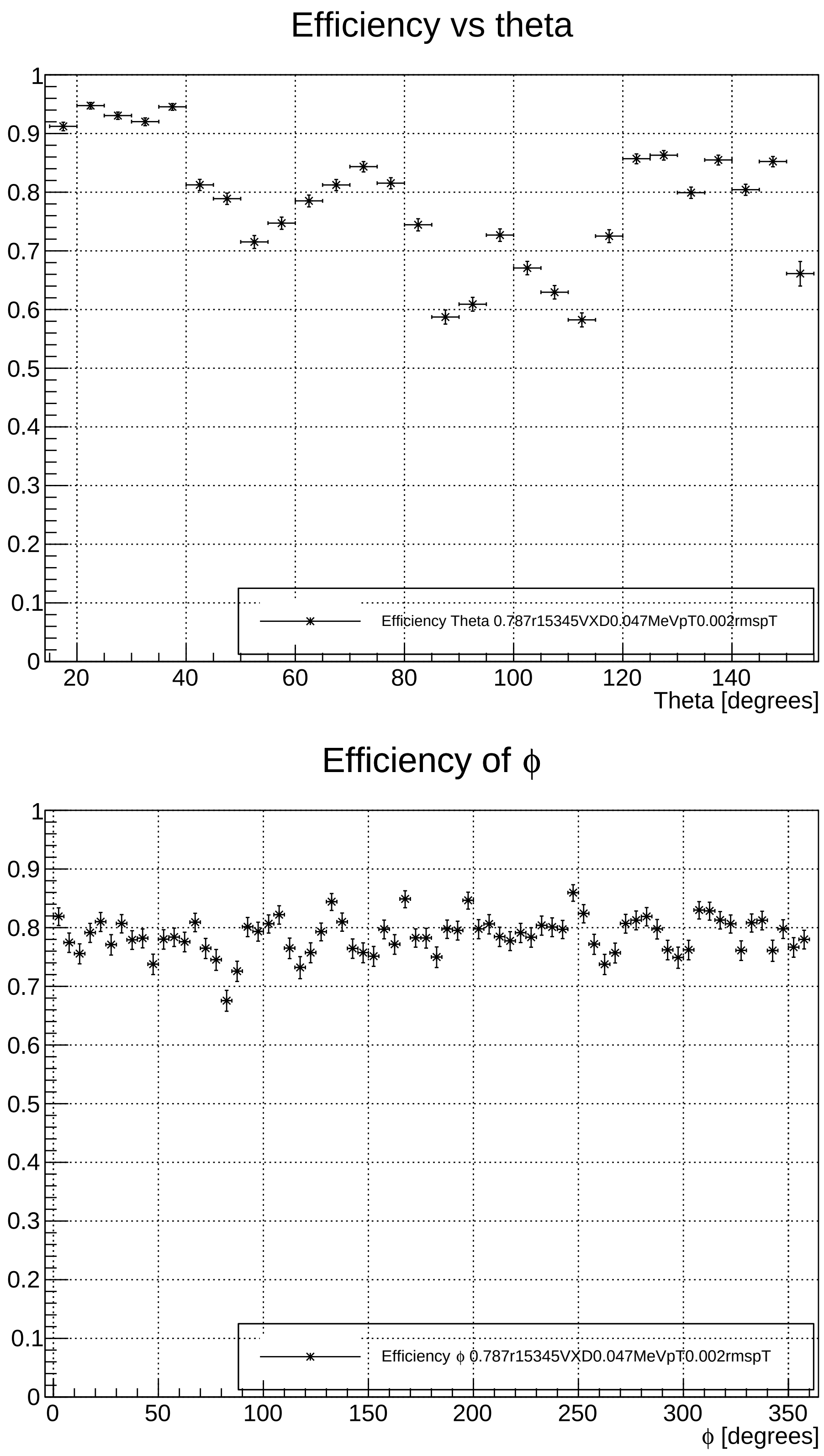
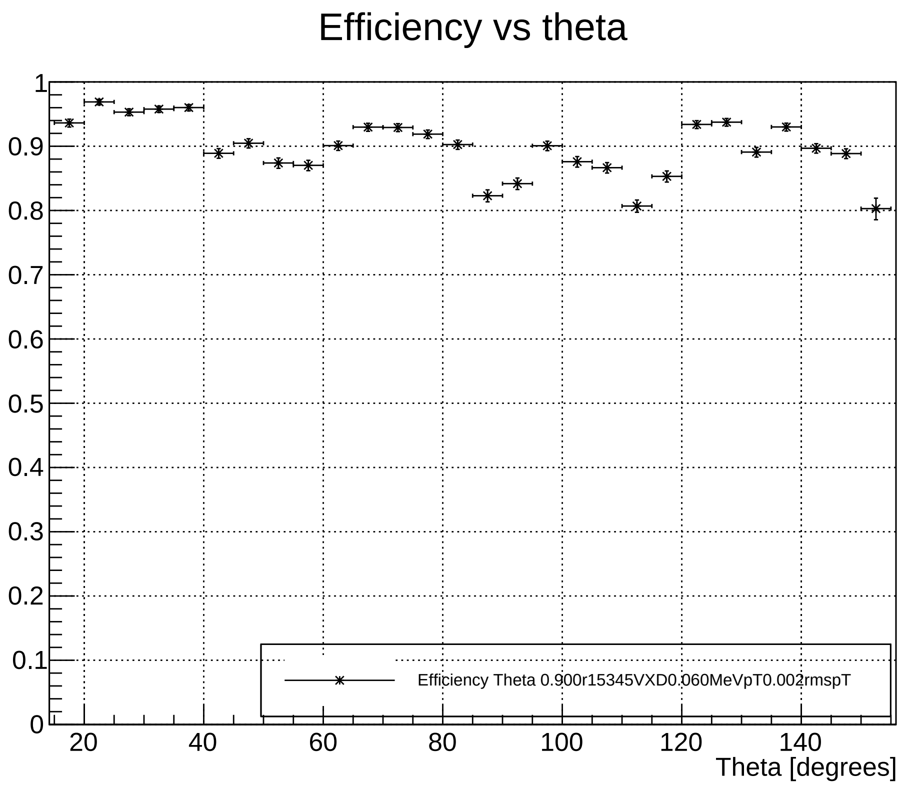



Figure 4.2: 50 MeV/c pT



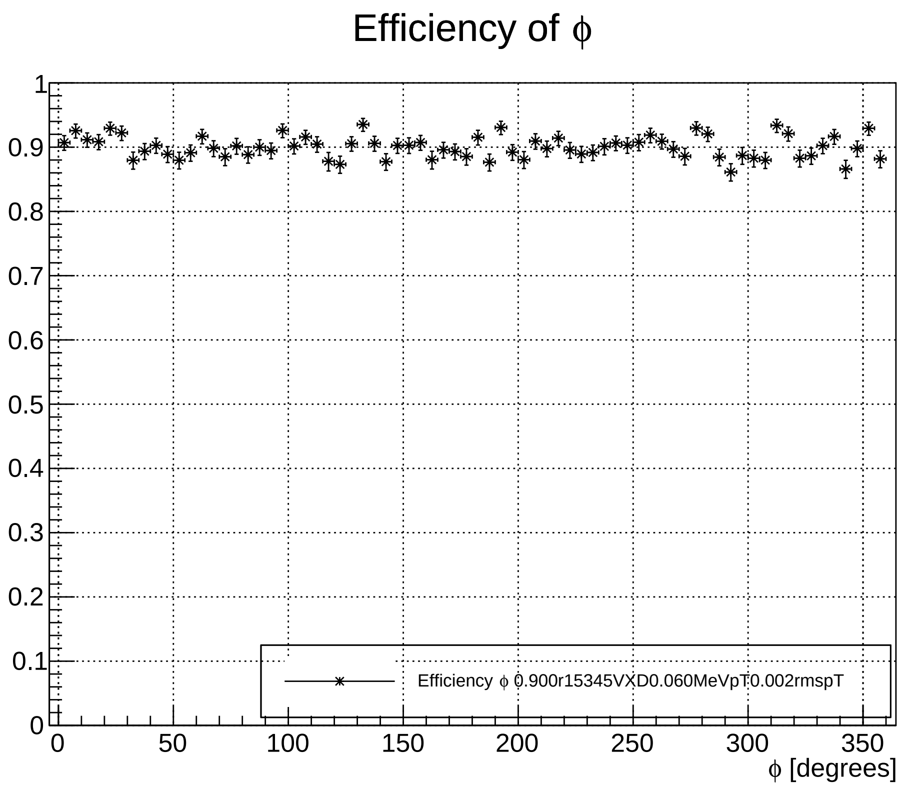




Figure 4.3: 62 MeV/c pT

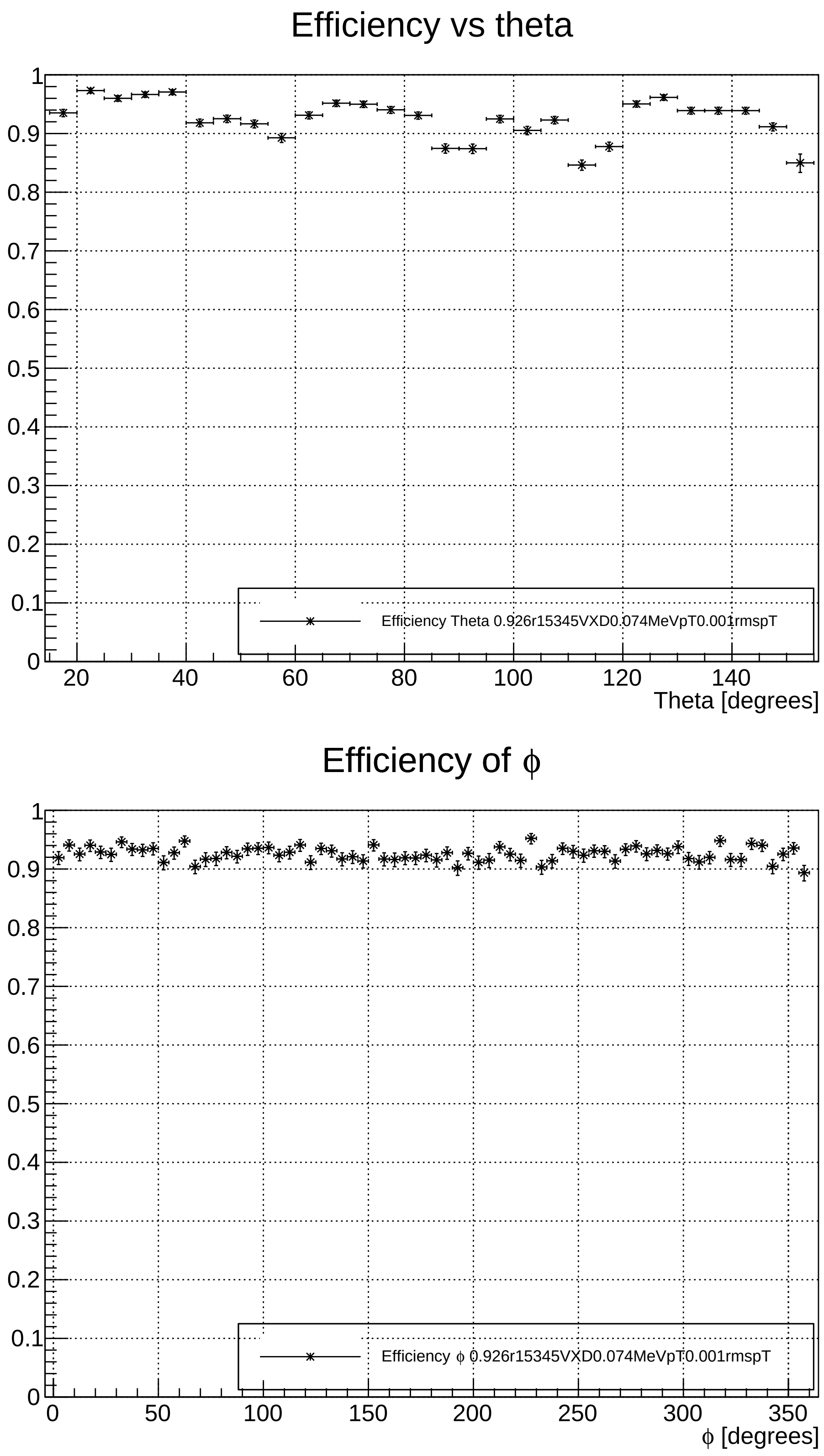



Figure 4.4: 75 MeV/c pT

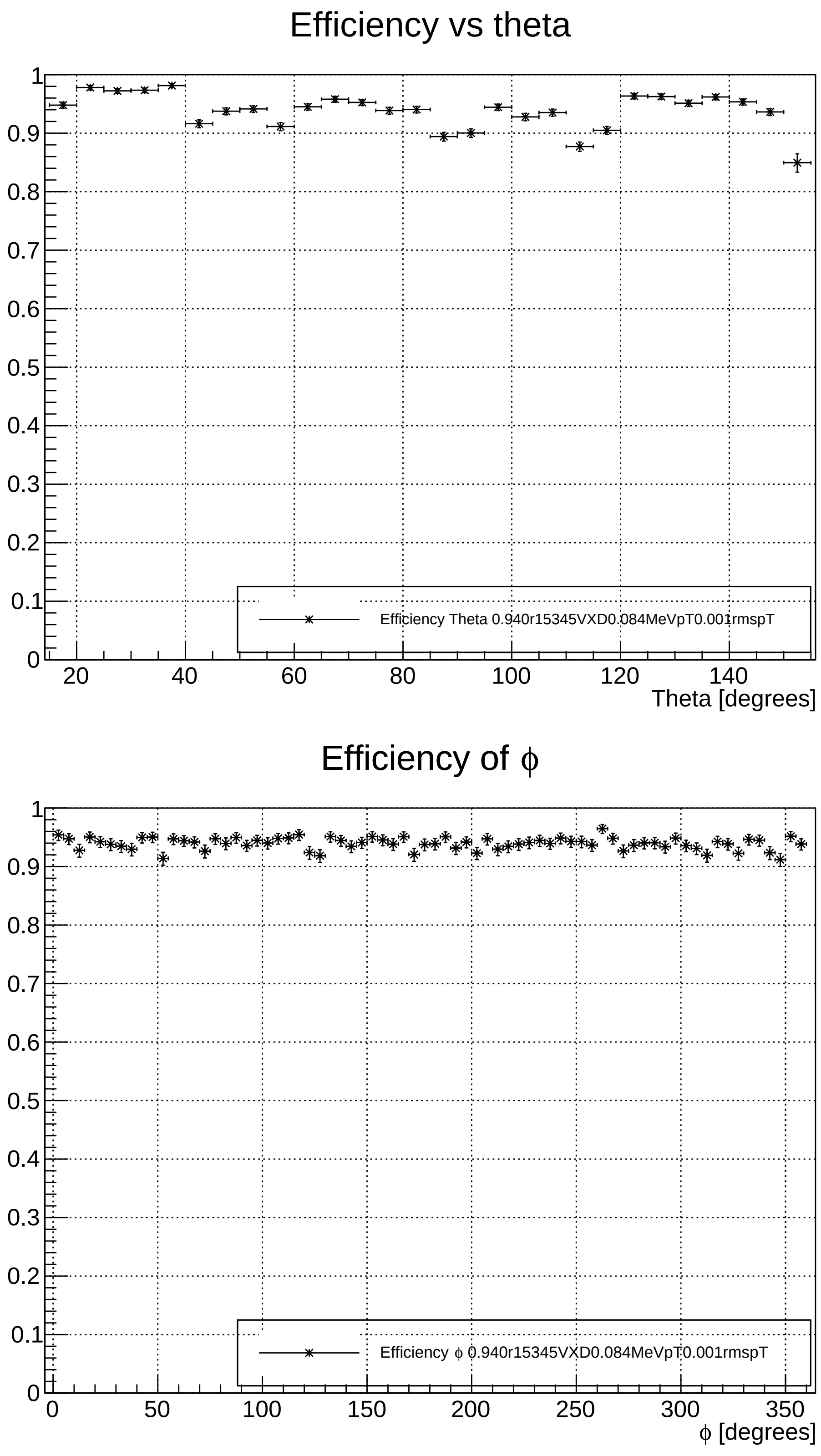
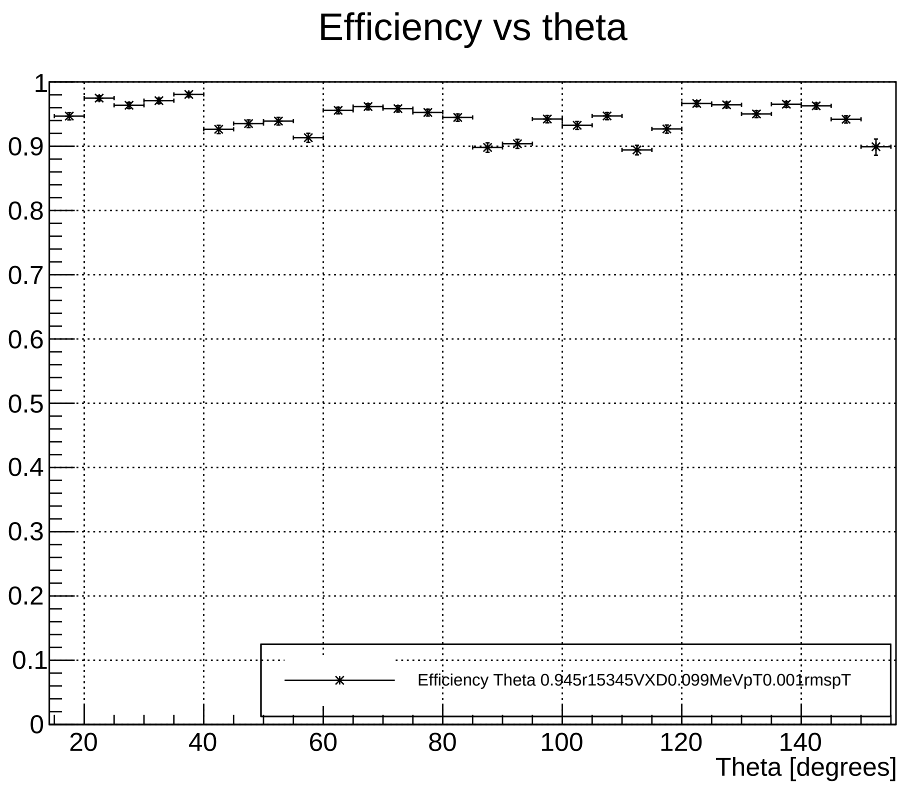



Figure 4.5: 85 MeV/c pT



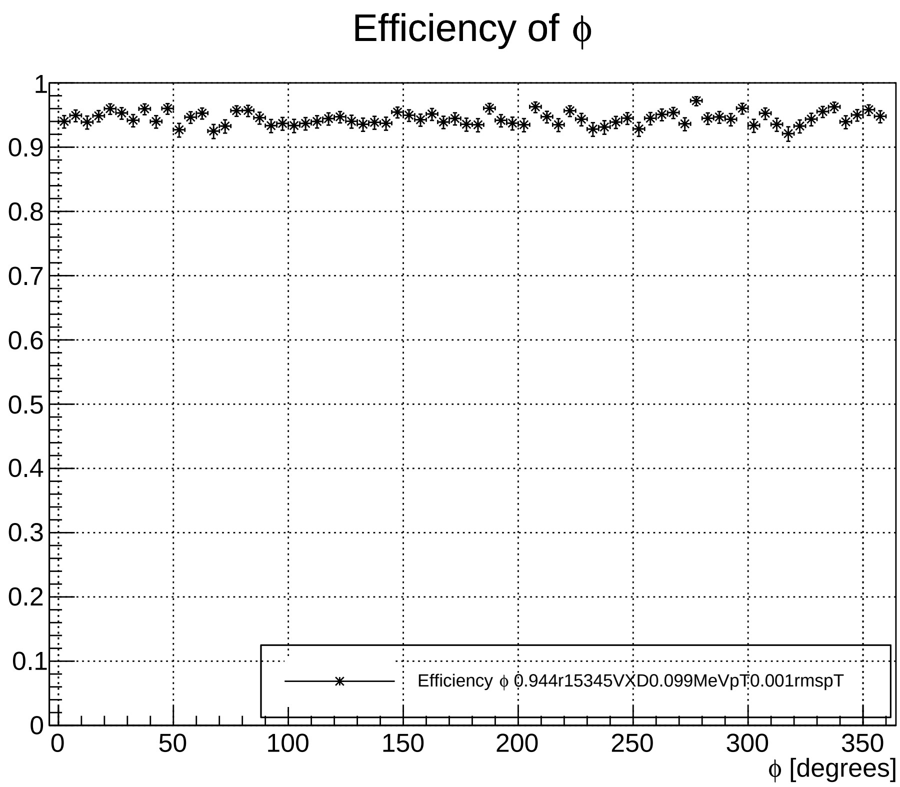




Figure 4.6: 100 MeV/c pT

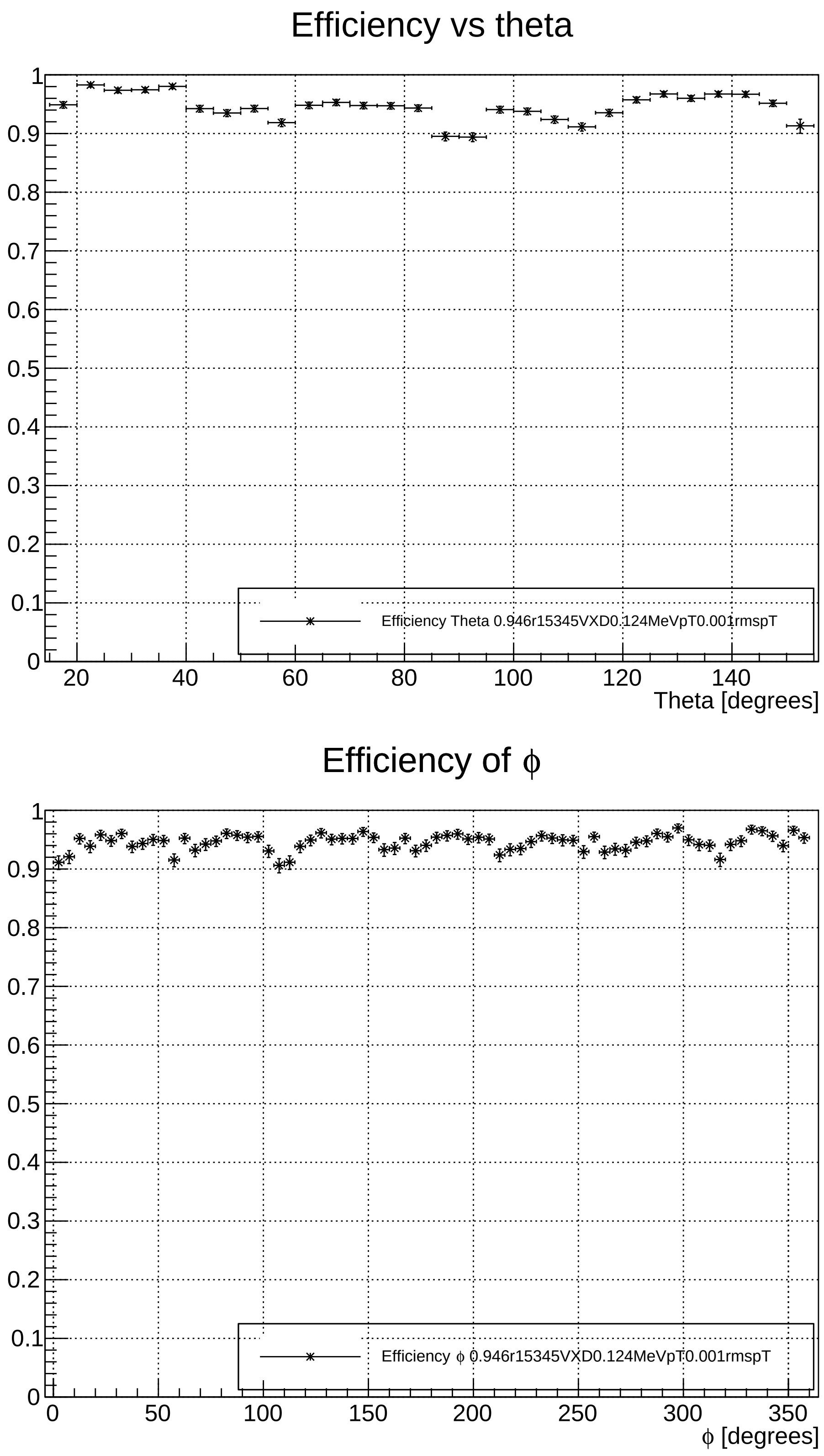
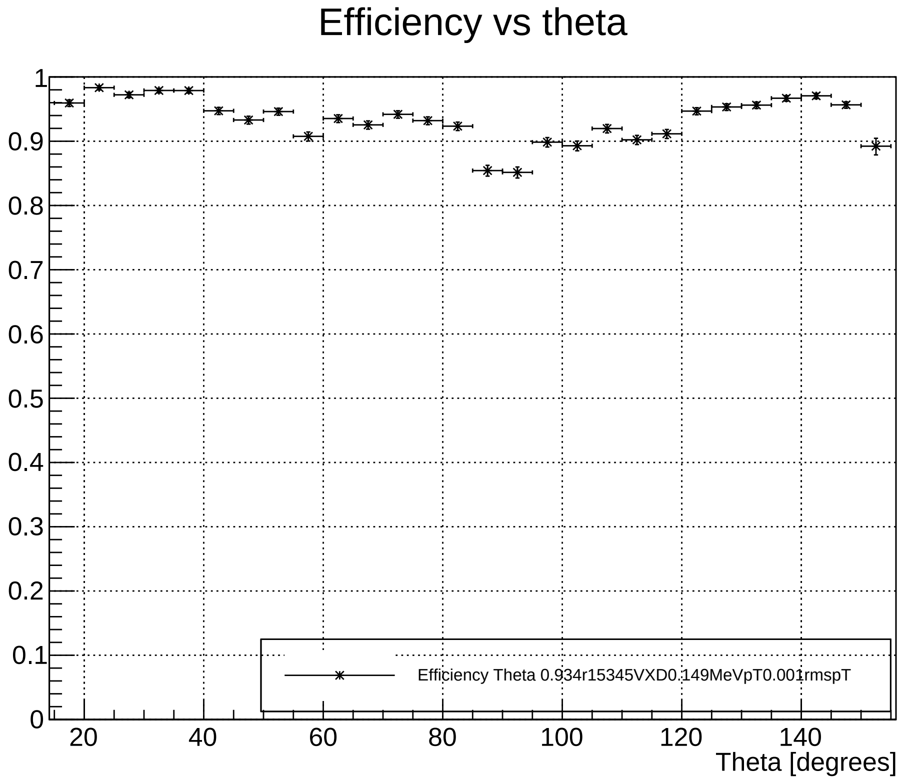



Figure 4.7: 125 MeV/c pT



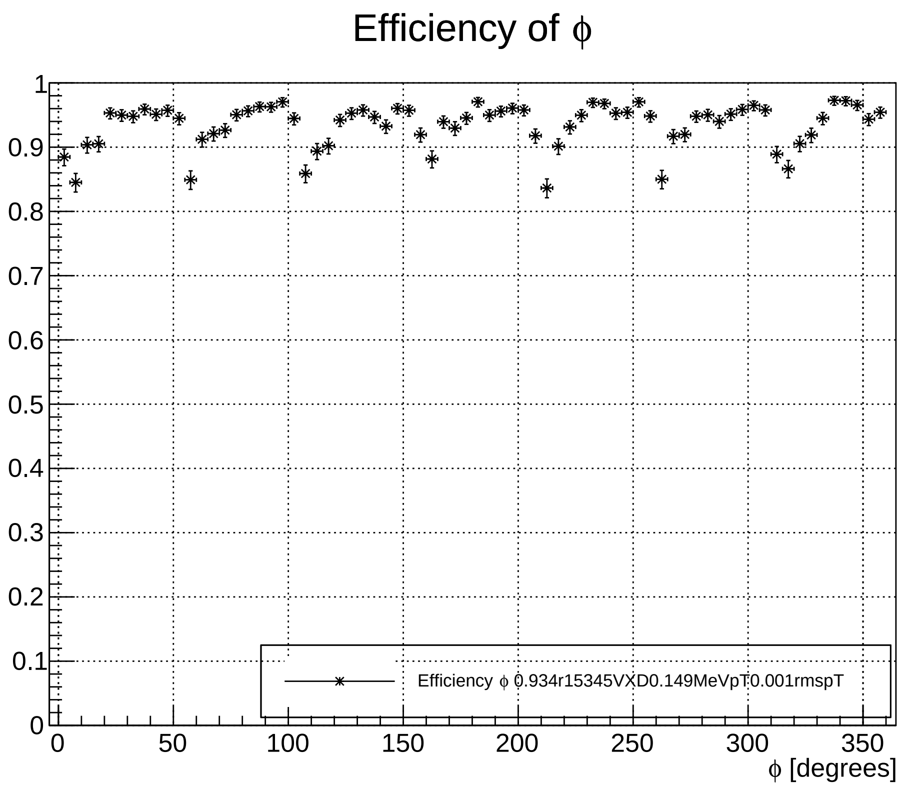
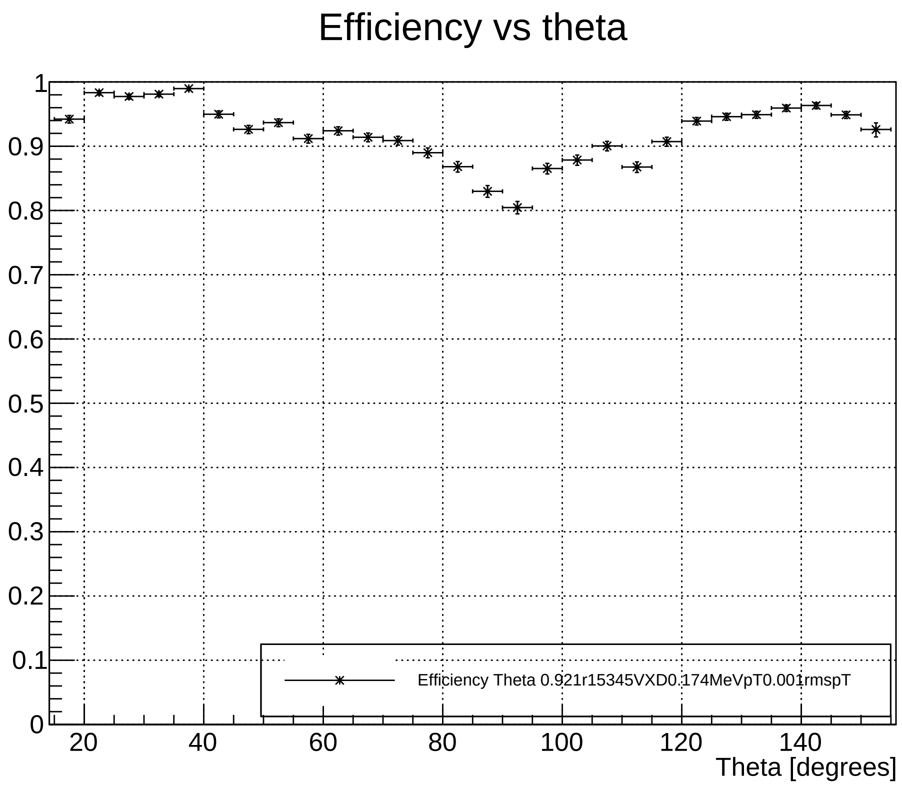




Figure 4.8: 150 MeV/c pT



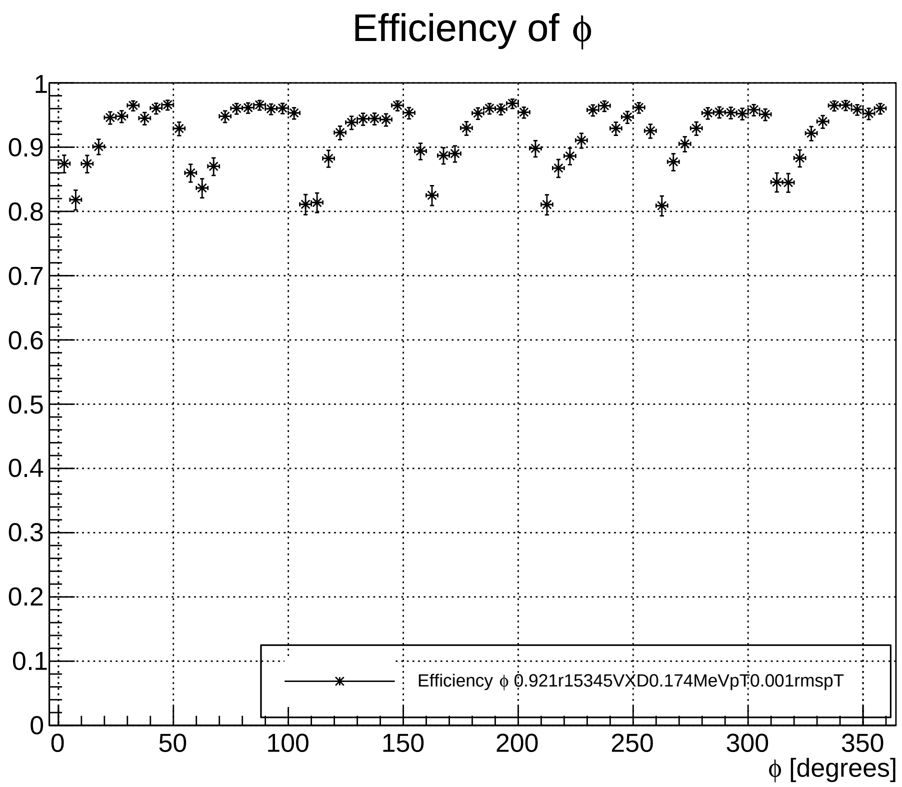
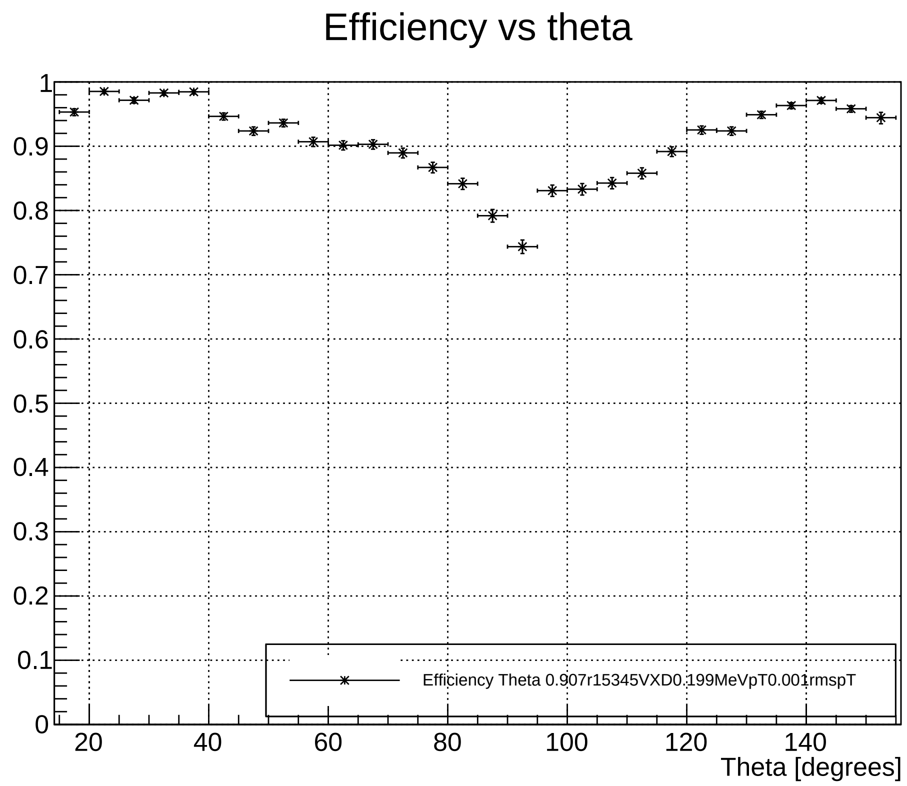




Figure 4.9: 175 MeV/c pT



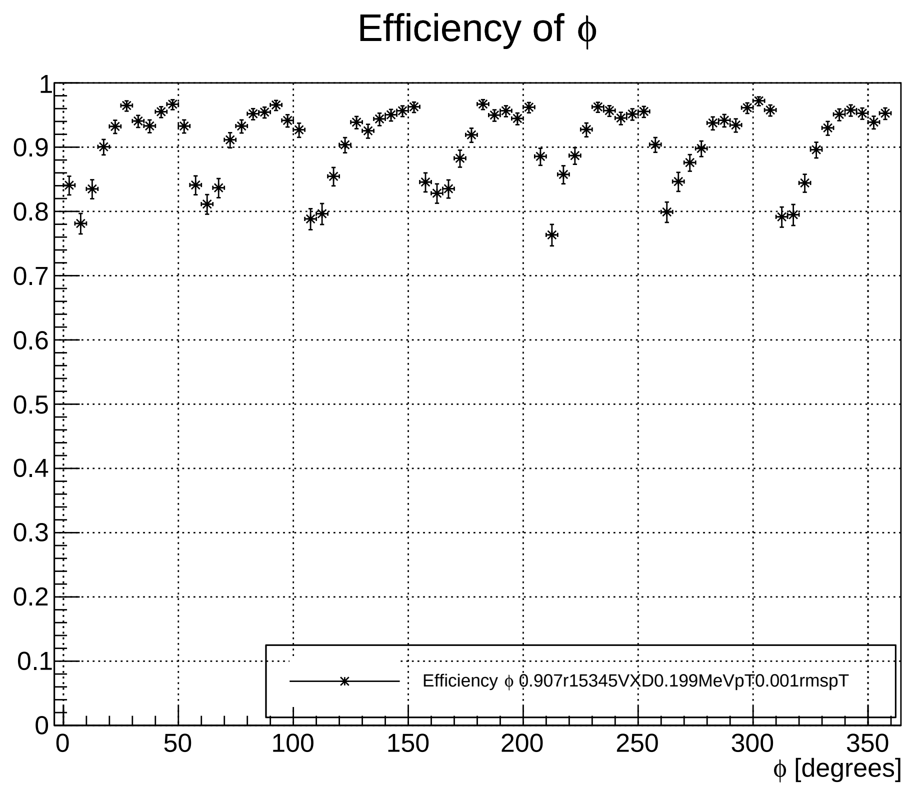
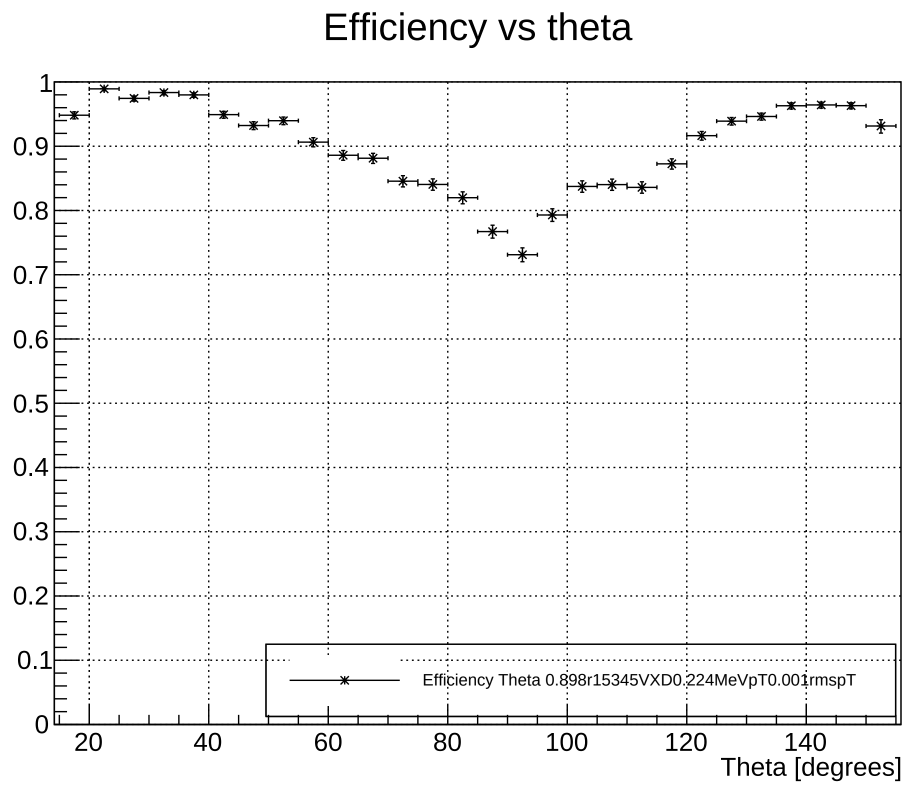




Figure 4.10: 200 MeV/c pT



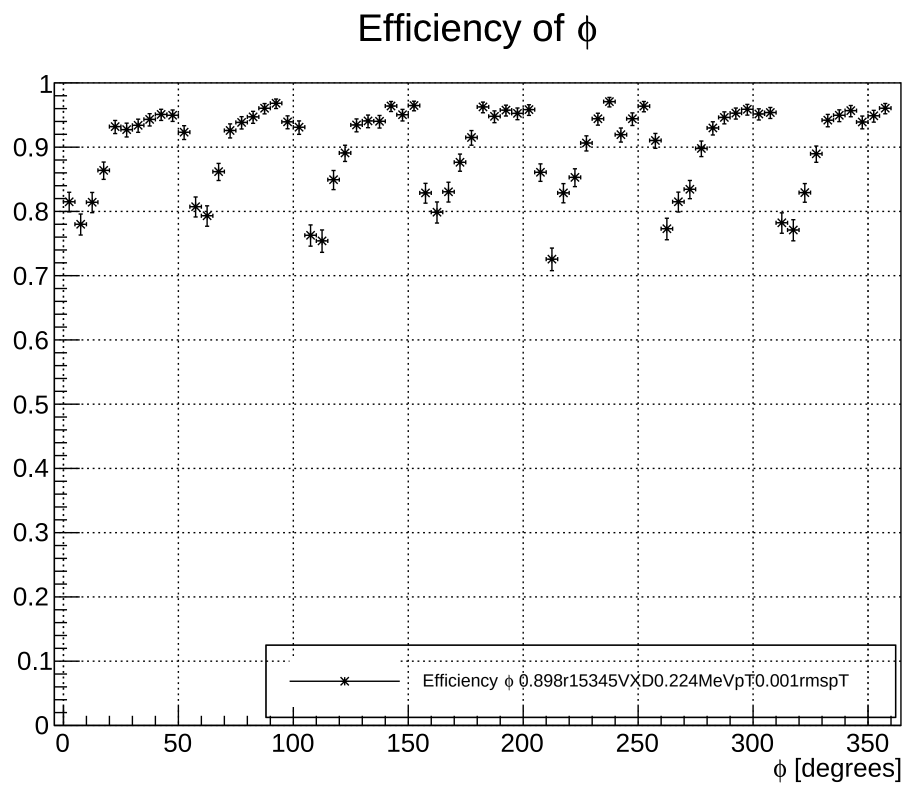
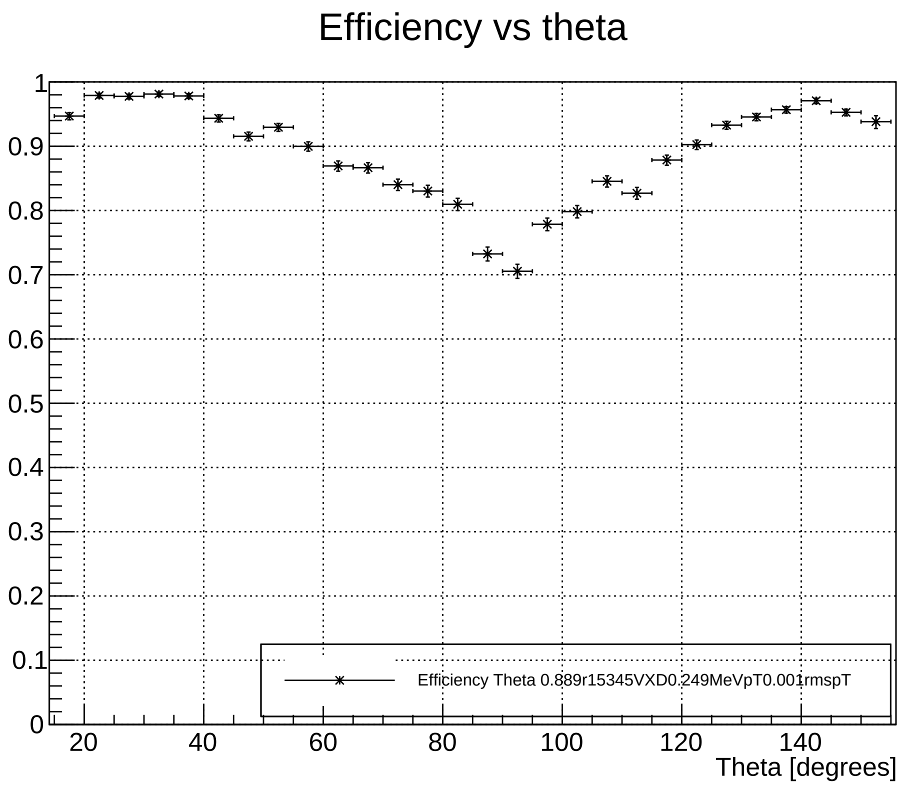




Figure 4.11: 225 MeV/c pT



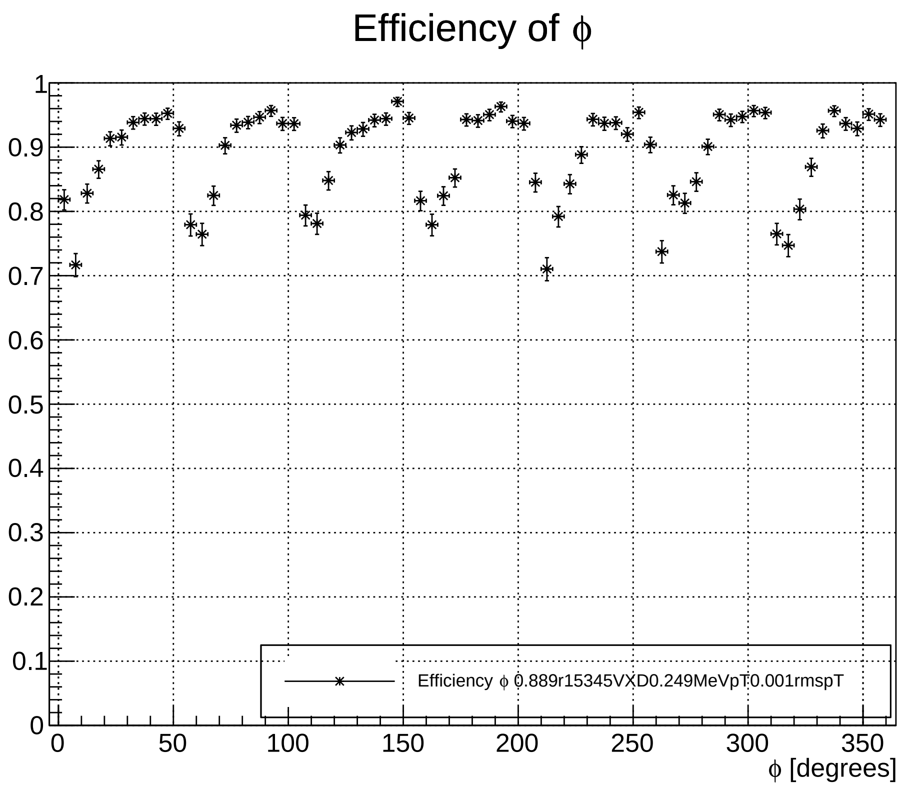
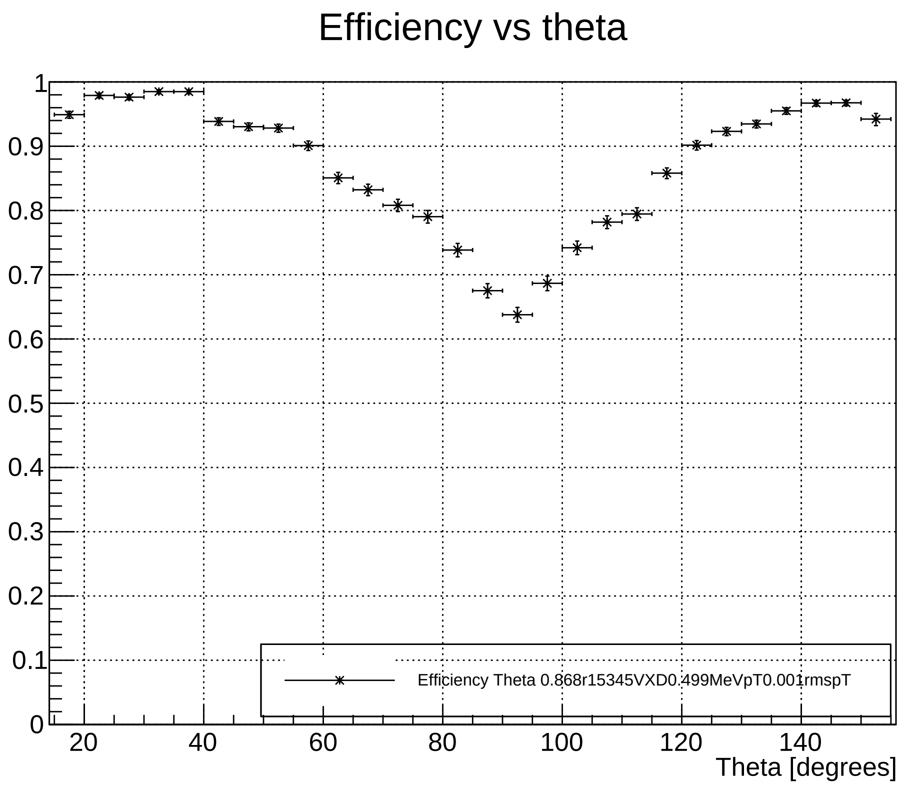




Figure 4.12: 250 MeV/c pT



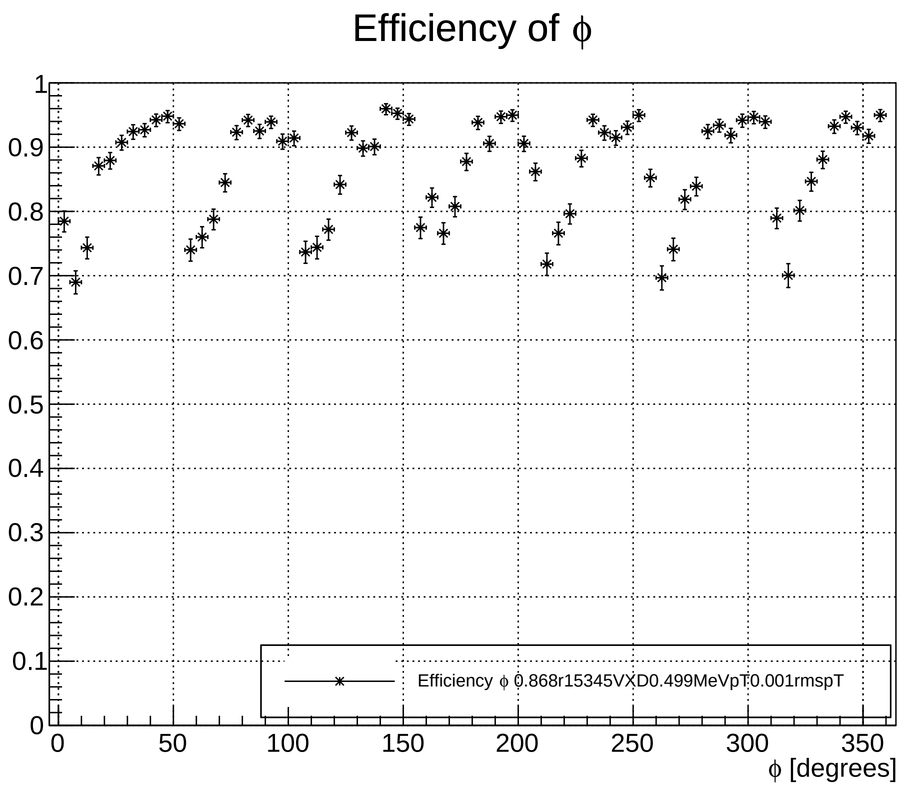




Figure 4.13: 500 MeV/c pT

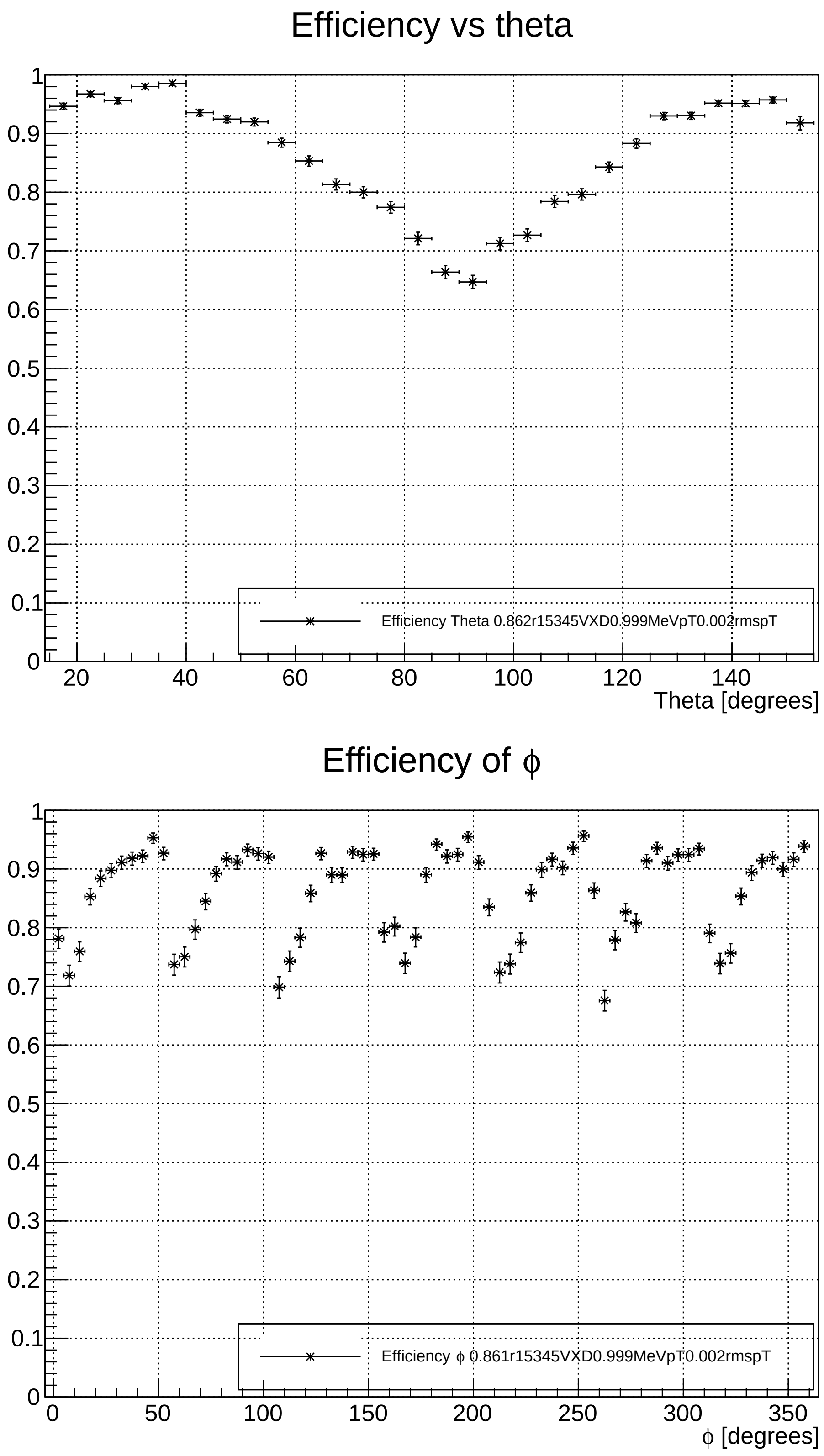



Figure 4.14: 1000 MeV/c pT

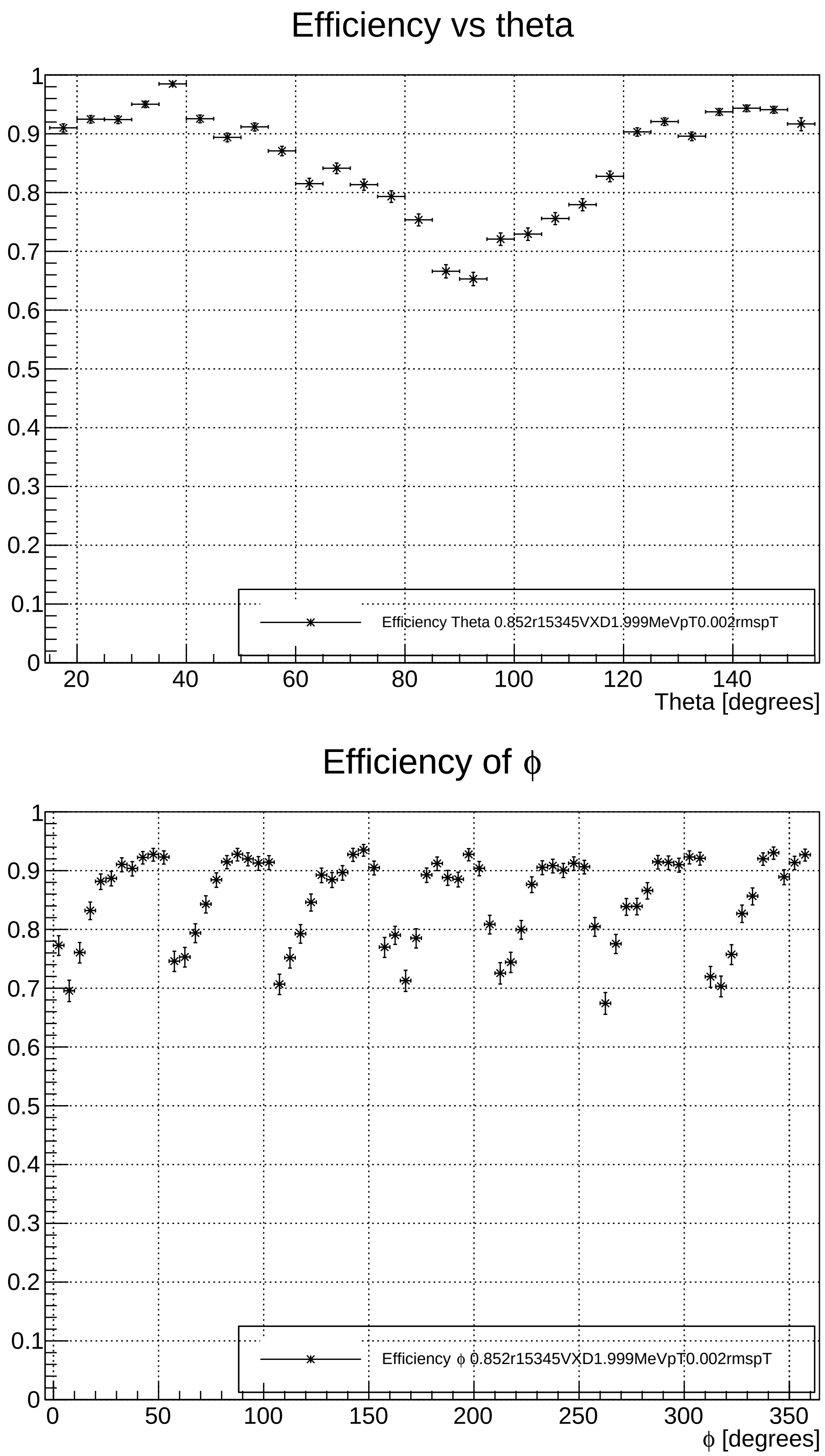



Figure 4.15: 2000 MeV/c pT

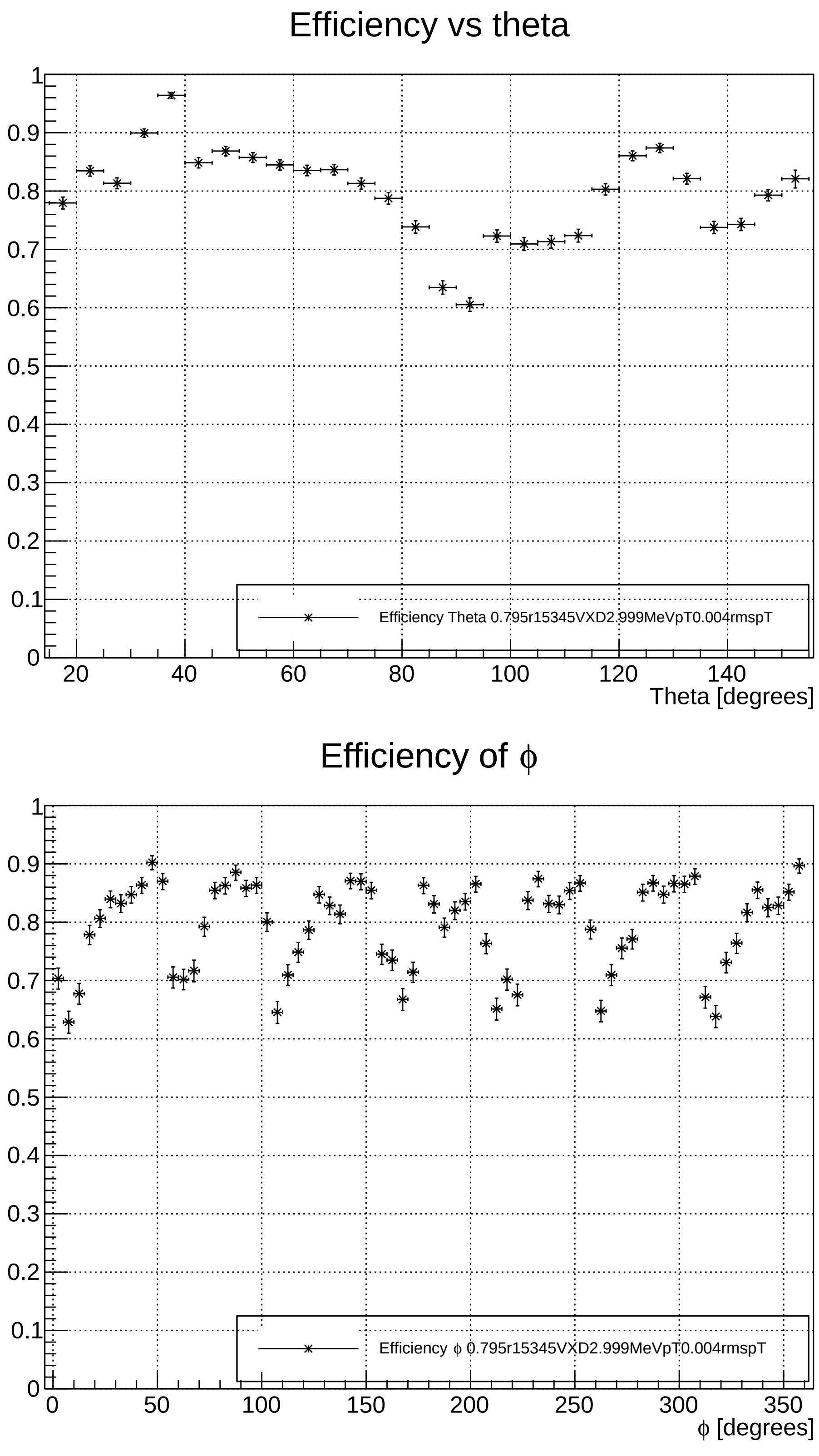
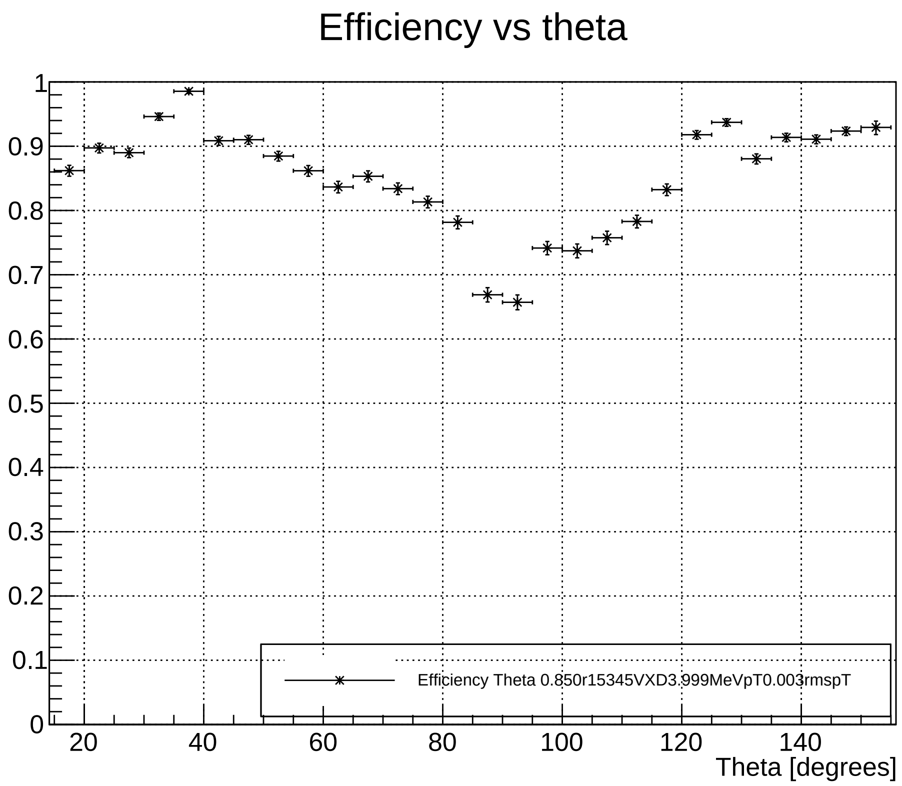



Figure 4.16: 3000 MeV/c pT



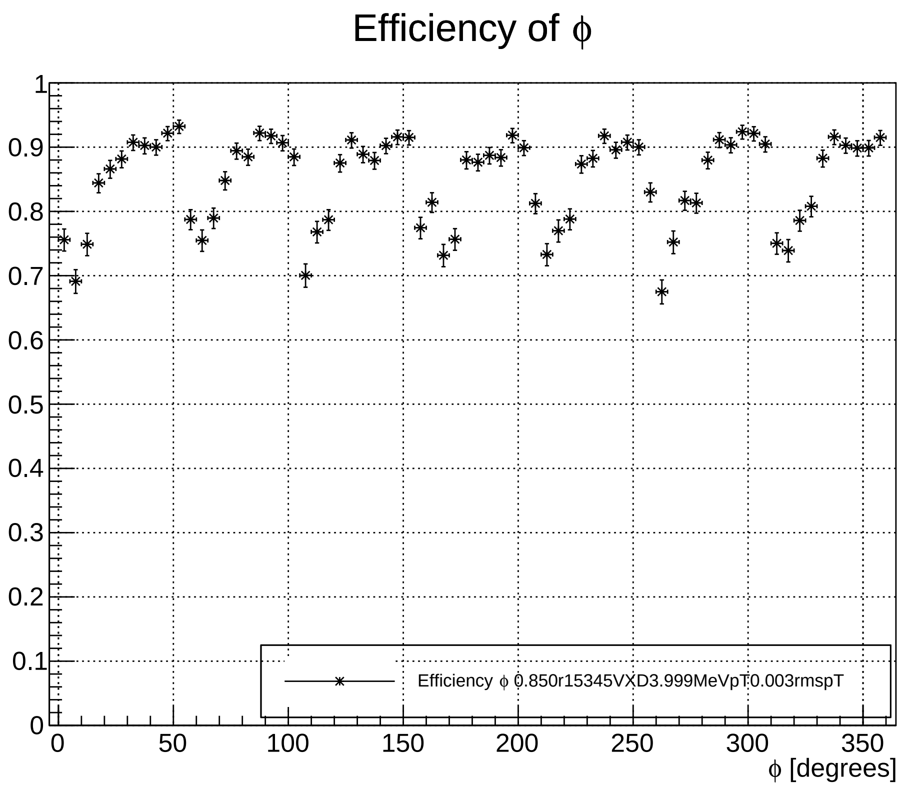
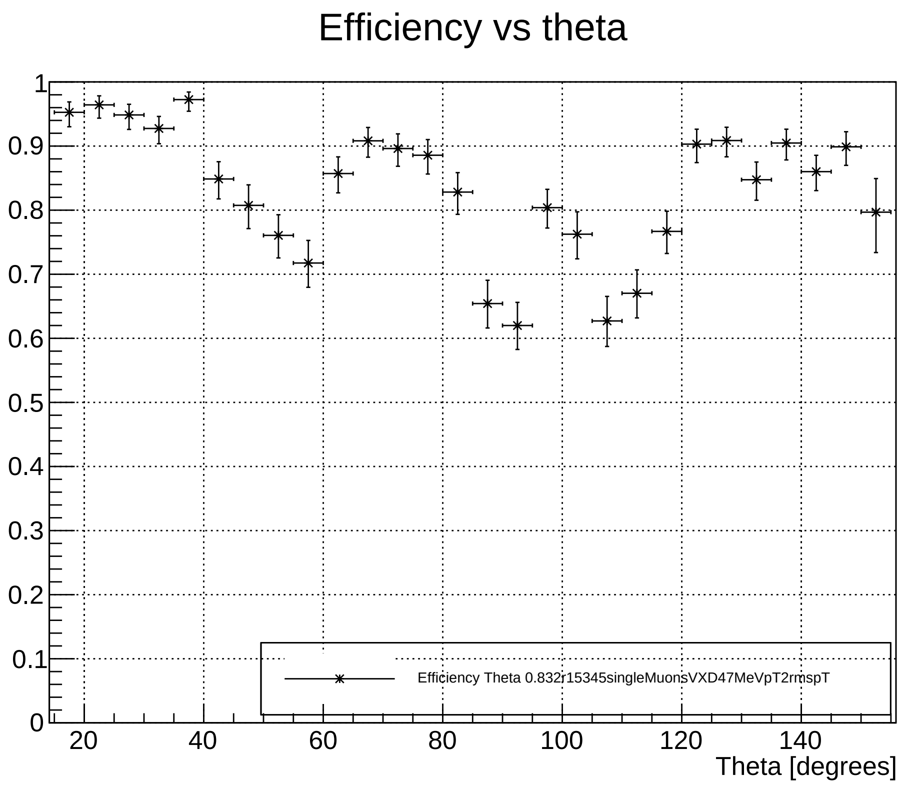




Figure 4.17: 4000 MeV/c pT

# 5 Setup D - pGun single muons

Efficiency is better than for 10T of course, but the $\theta\, 90^\circ$ -issue is still here.



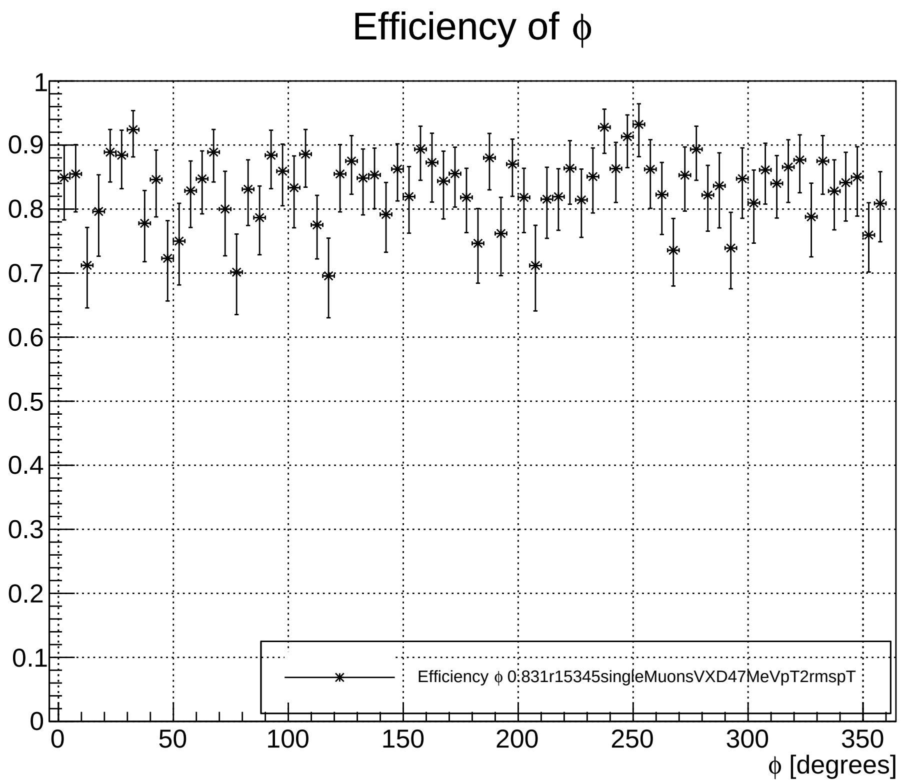




Figure 5.1: 50 MeV/c pT

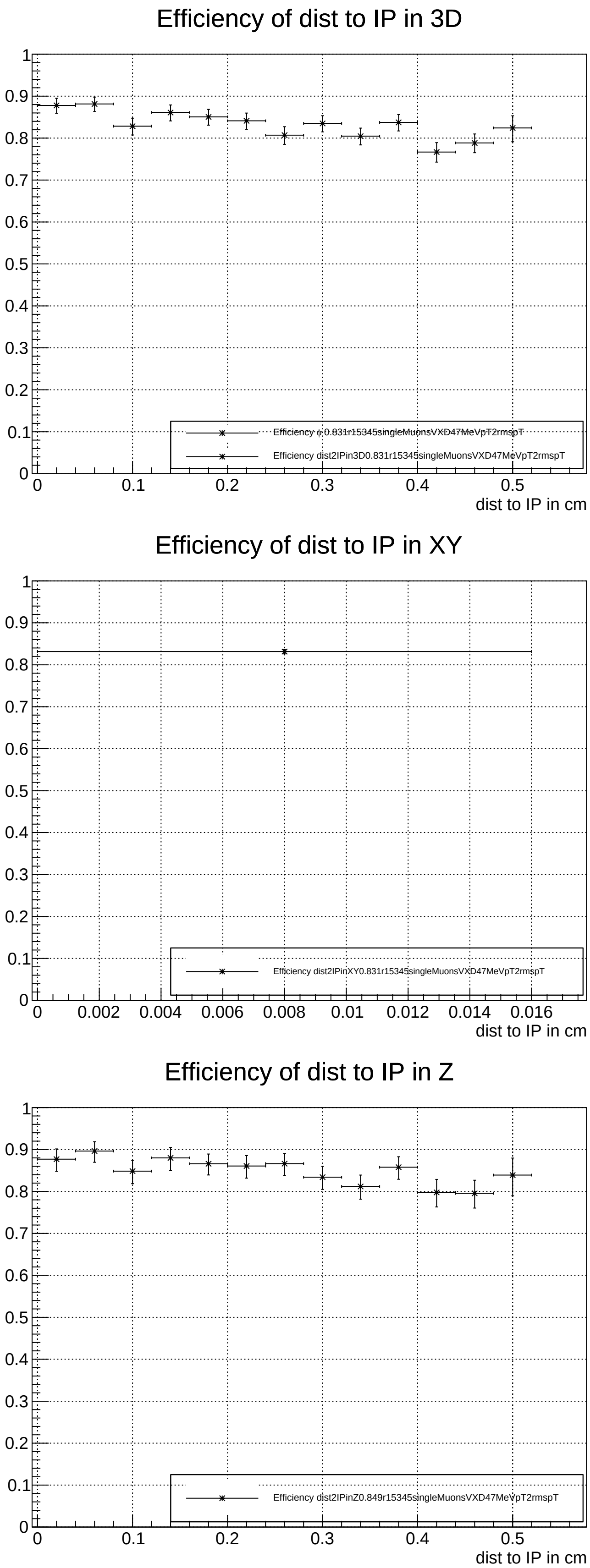
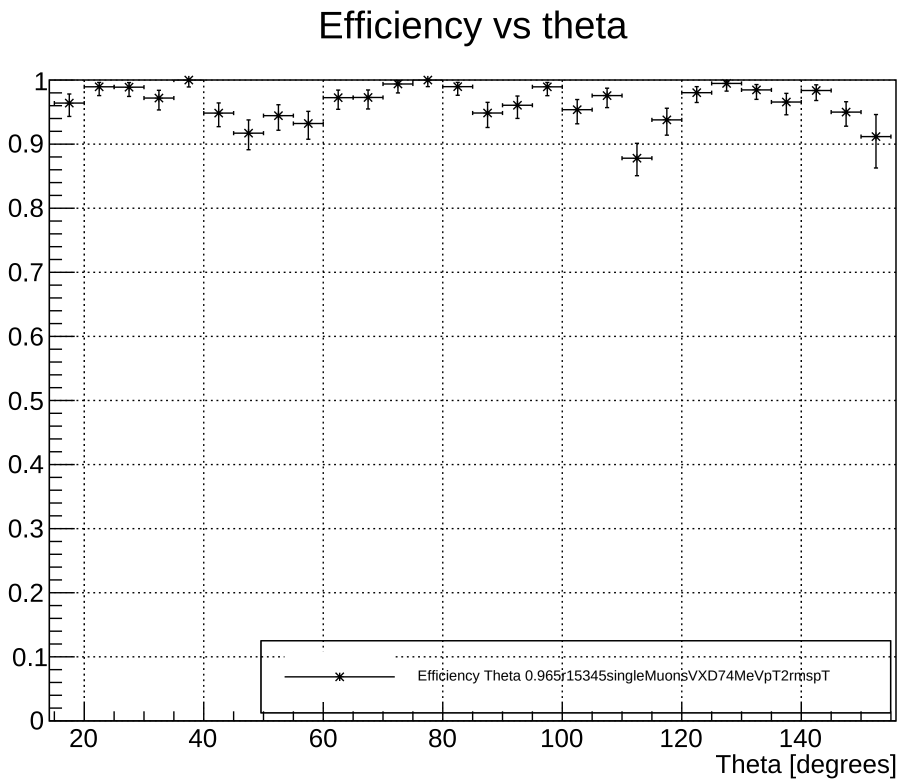



Figure 5.2: 50 MeV/c pT



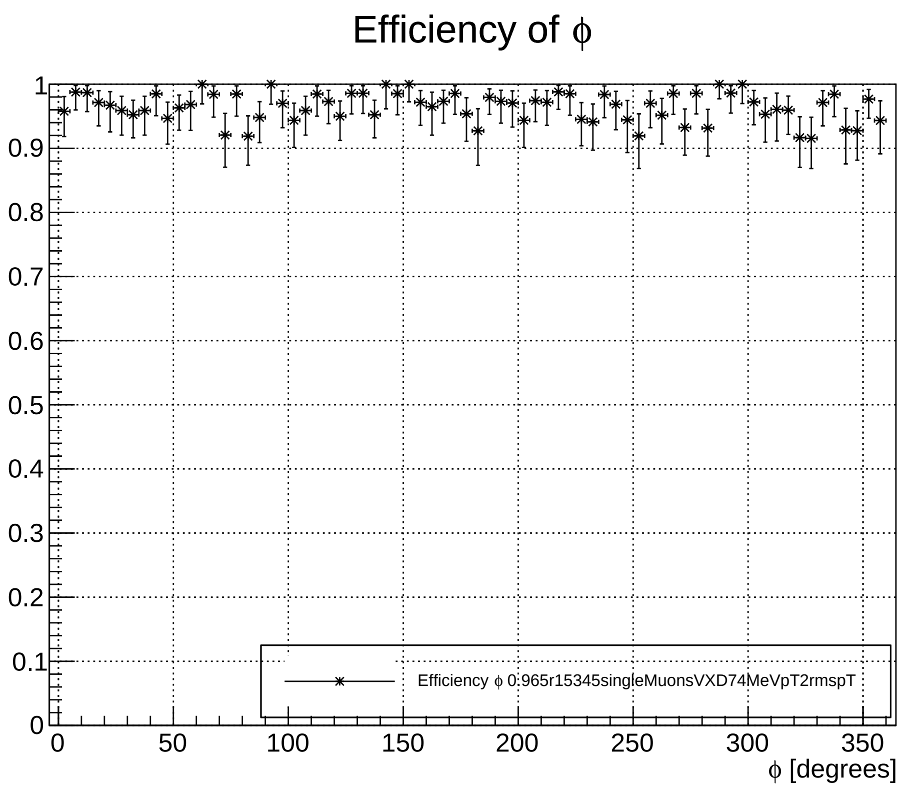




Figure 5.3: 75 MeV/c pT

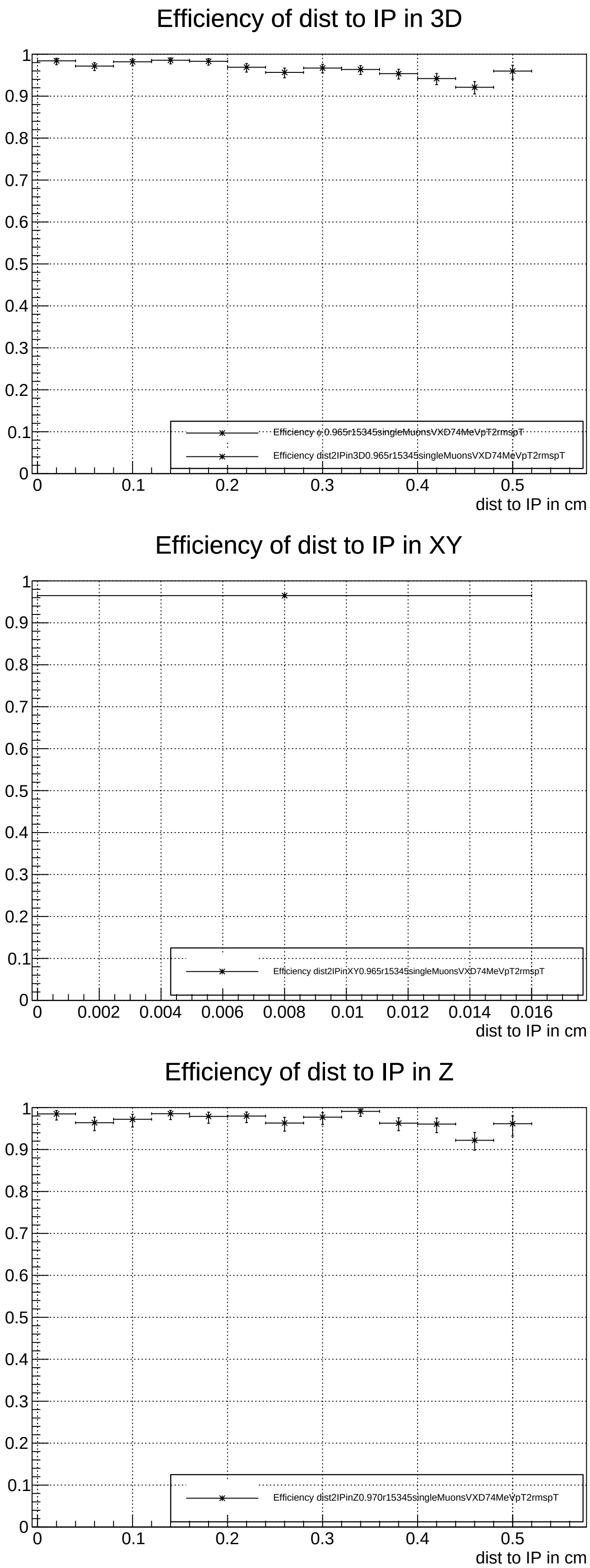



Figure 5.4: 75 MeV/c pT

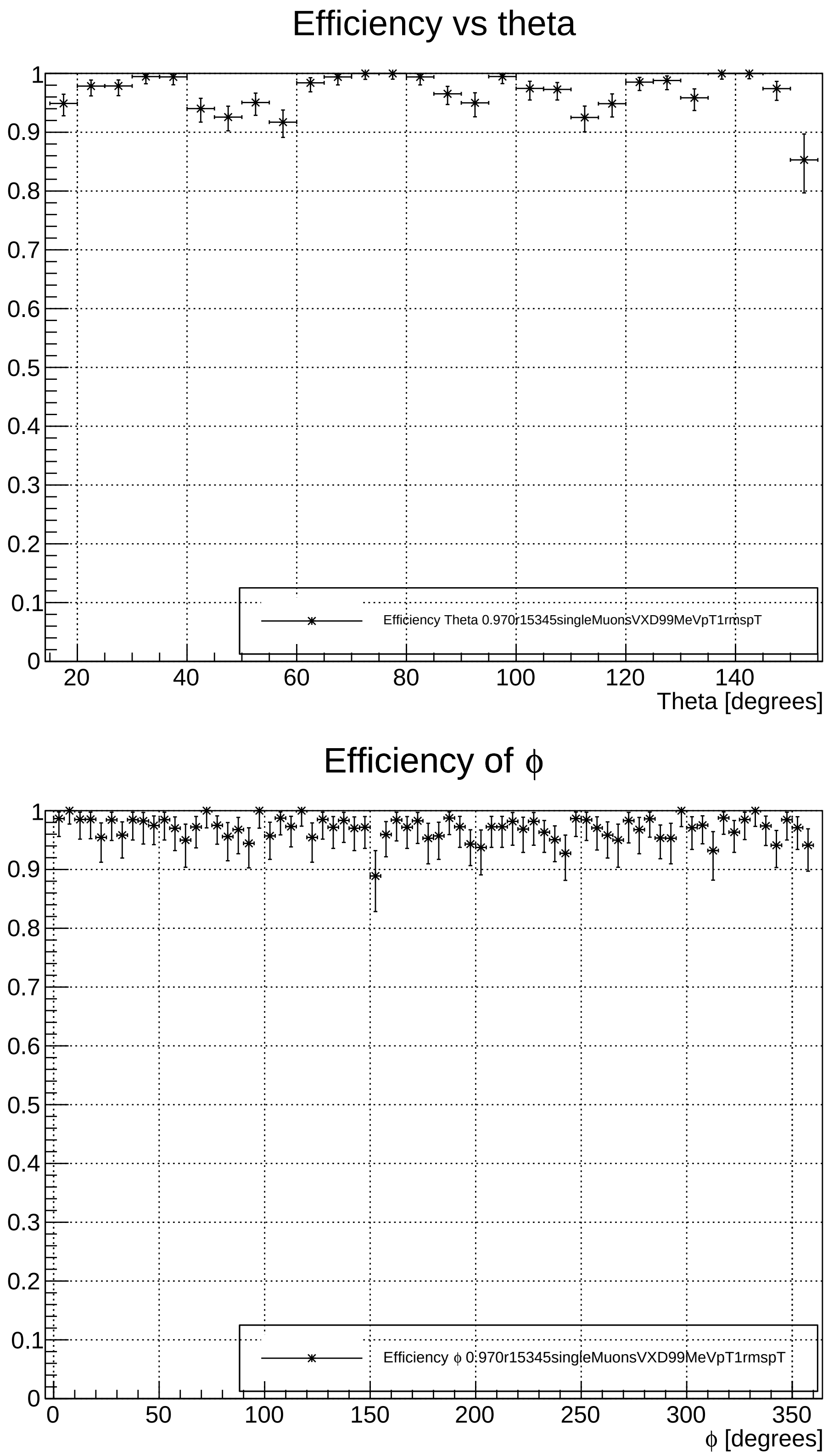



Figure 5.5: 100 MeV/c pT

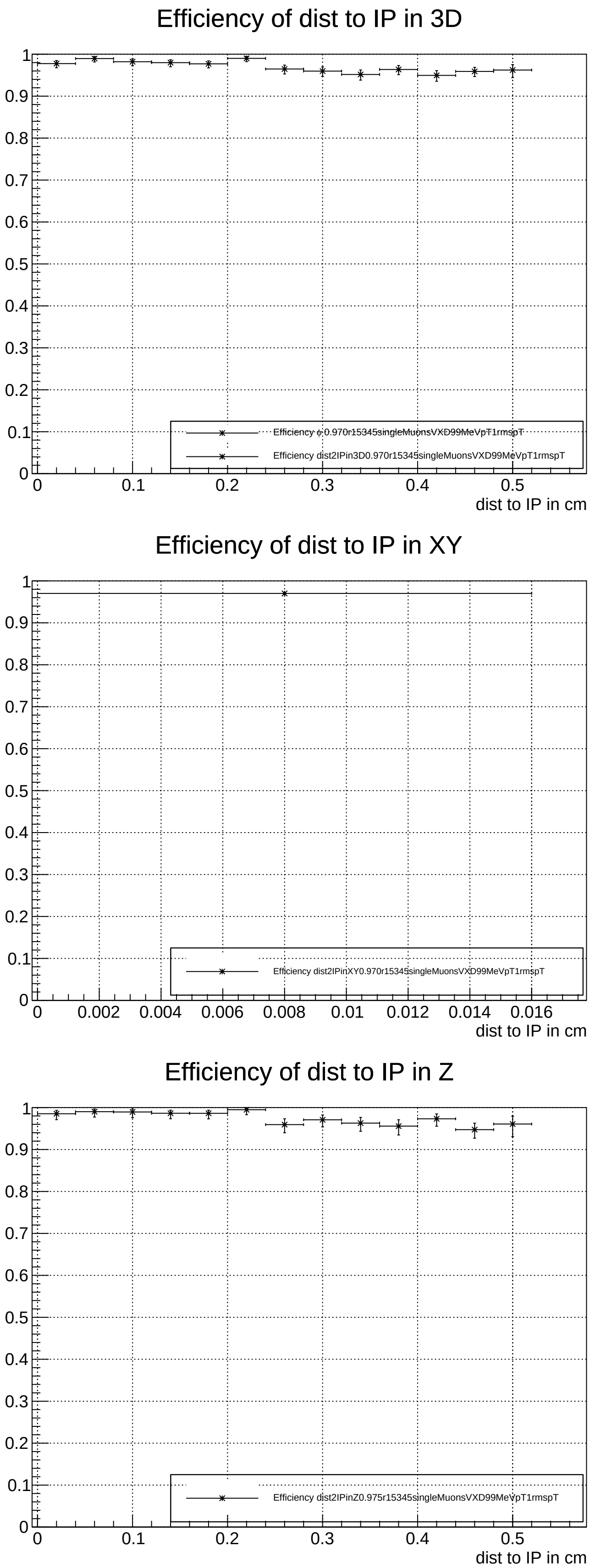



Figure 5.6: 100 MeV/c pT

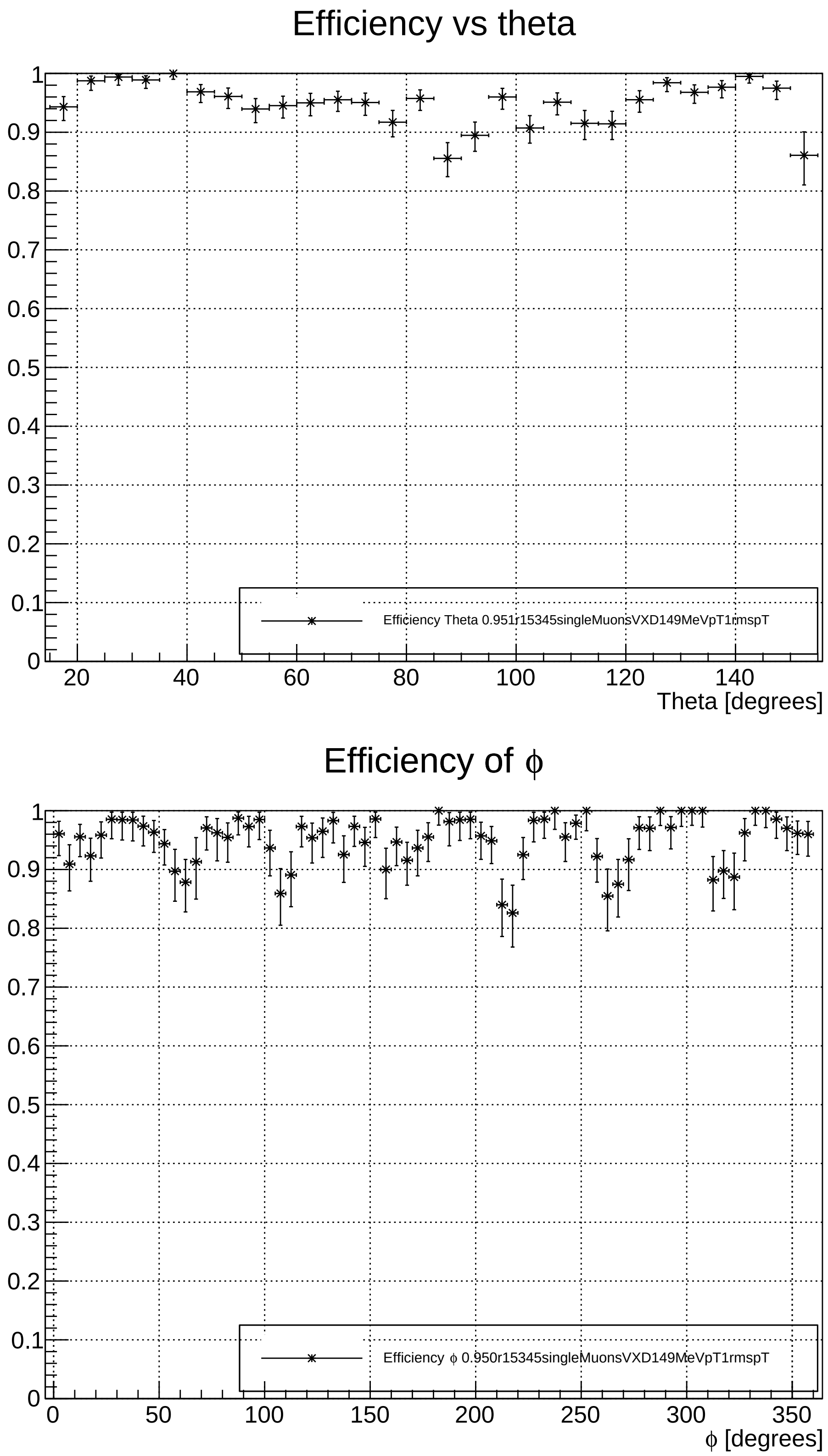



Figure 5.7: 150 MeV/c pT

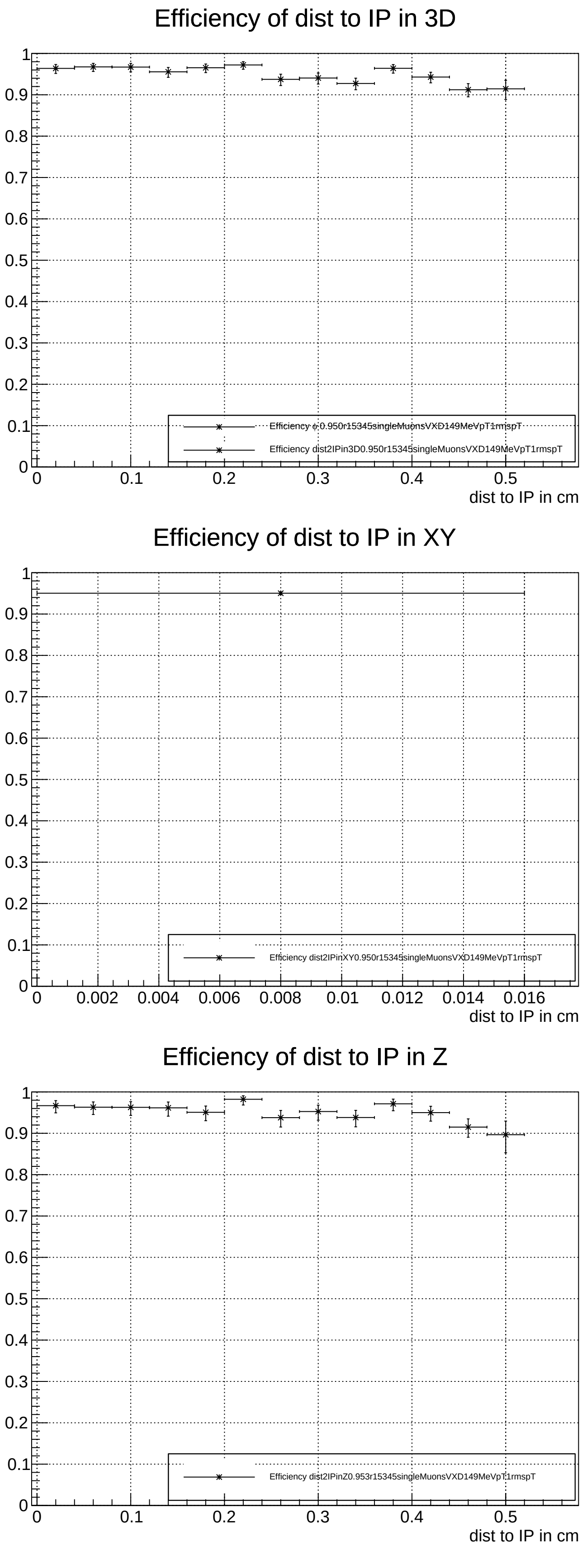
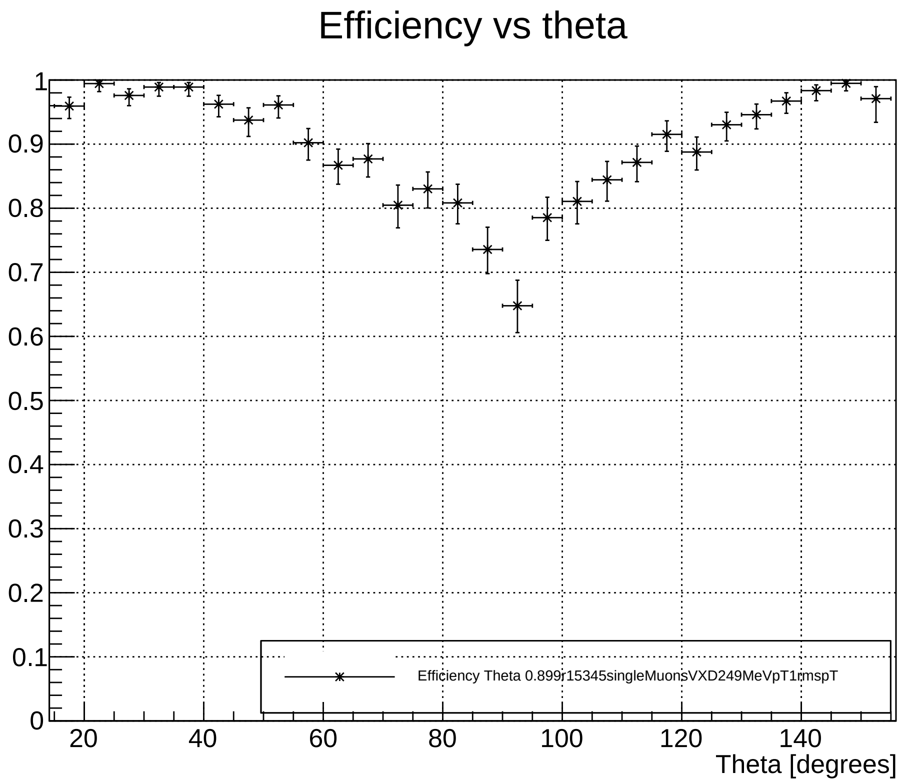



Figure 5.8: 150 MeV/c pT



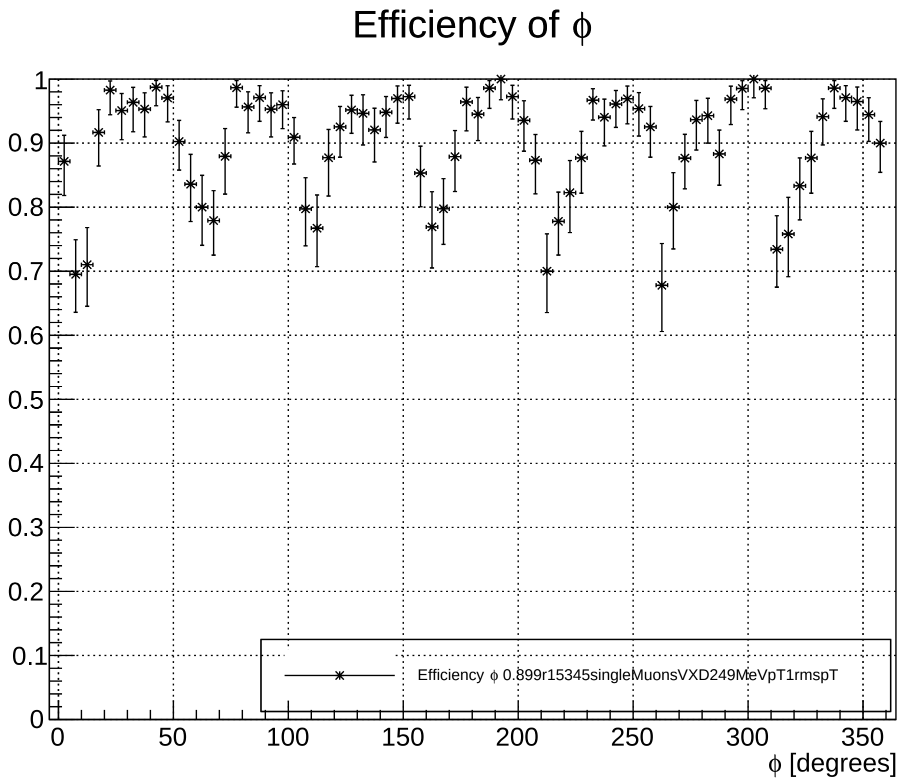




Figure 5.9: 250 MeV/c pT

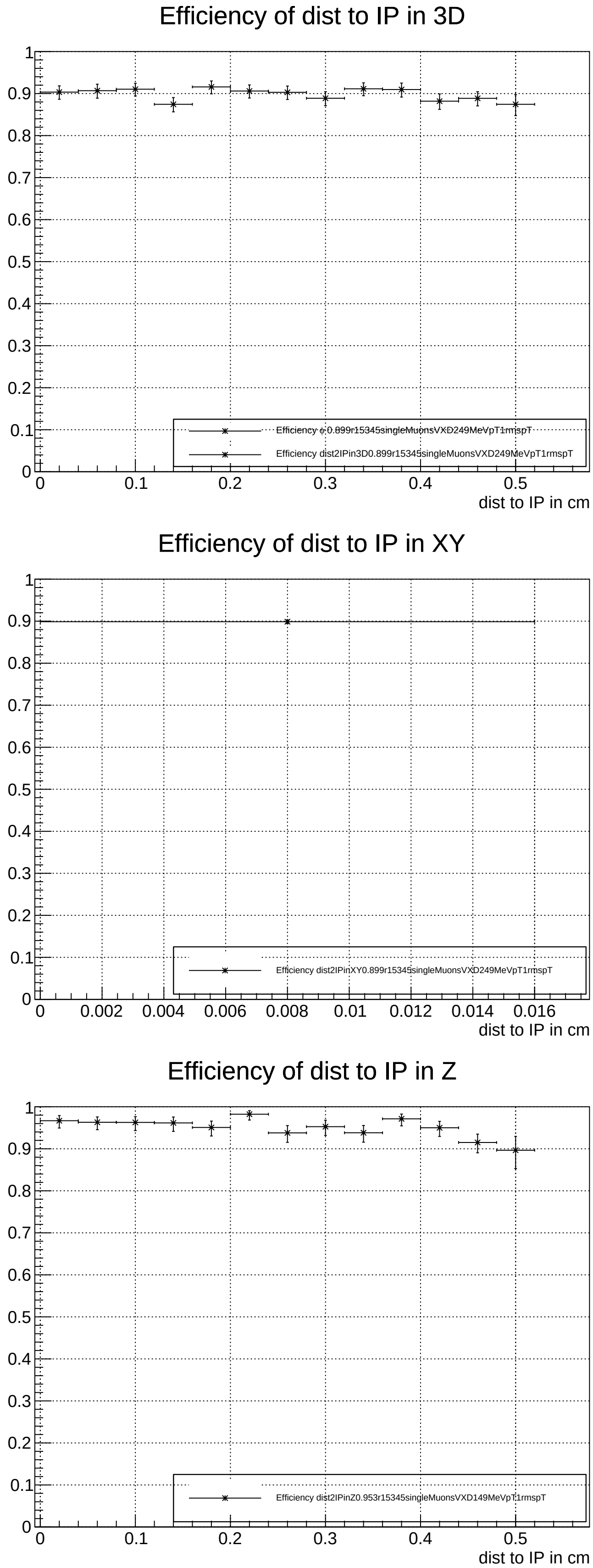



Figure 5.10: 250 MeV/c pT

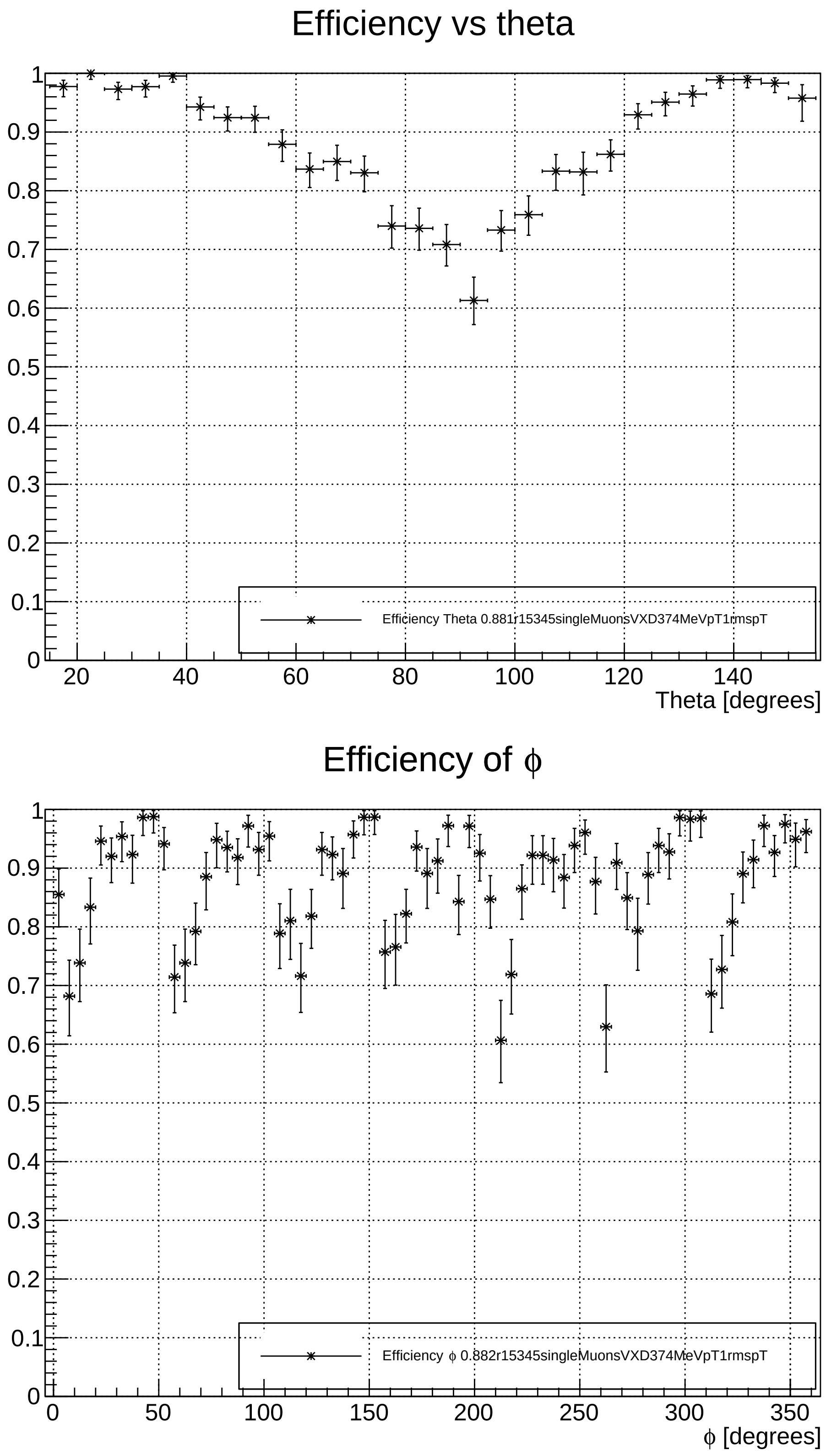



Figure 5.11: 375 MeV/c pT

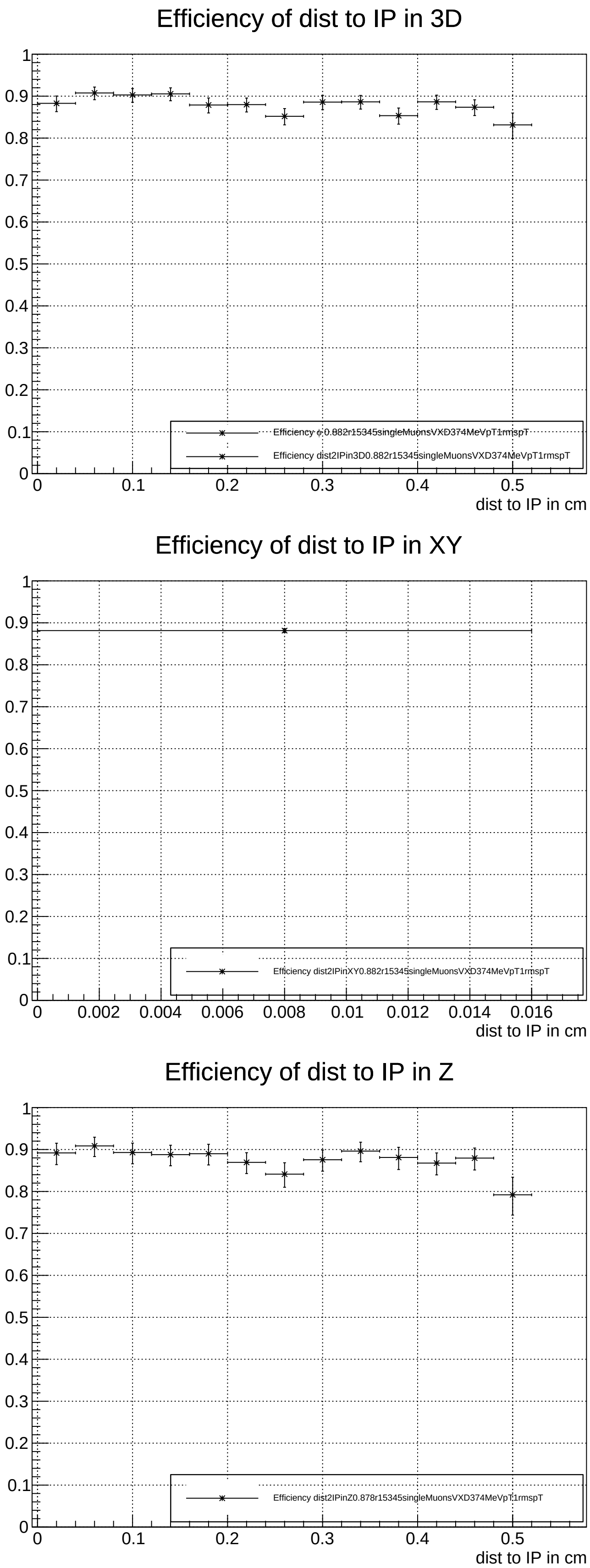



Figure 5.12: 375 MeV/c pT

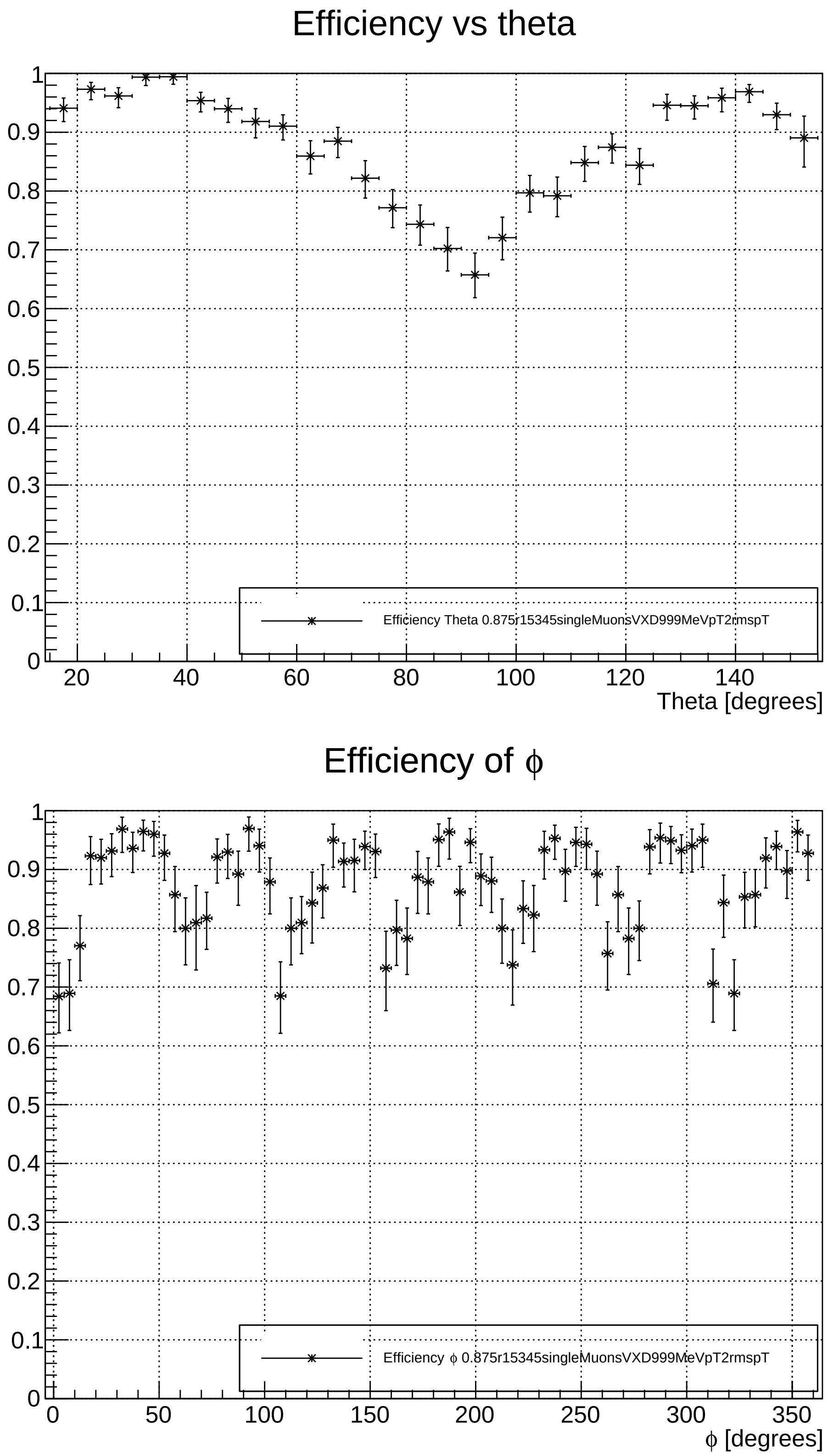



Figure 5.13: 1000 MeV/c pT

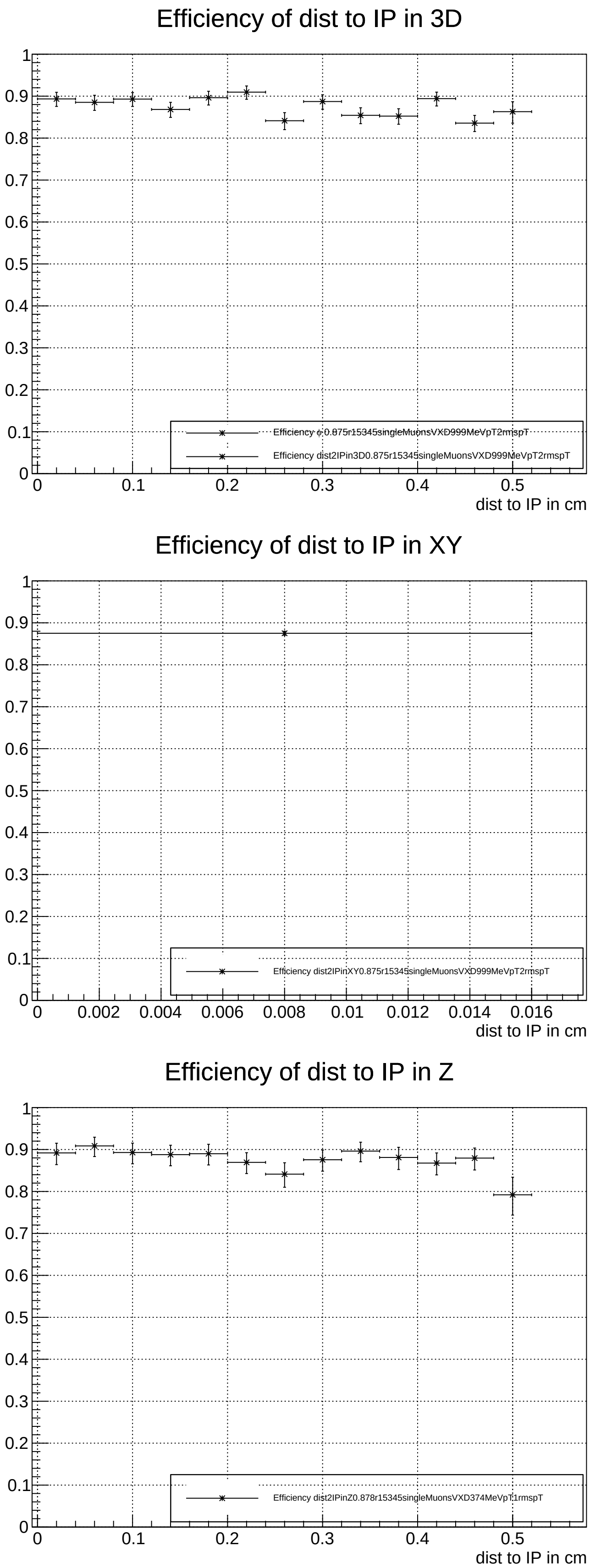



Figure 5.14: 1000 MeV/c pT

# 6 Setup E - pGun 10T muons, single charge

The results of muons and antimuons are practically identical.

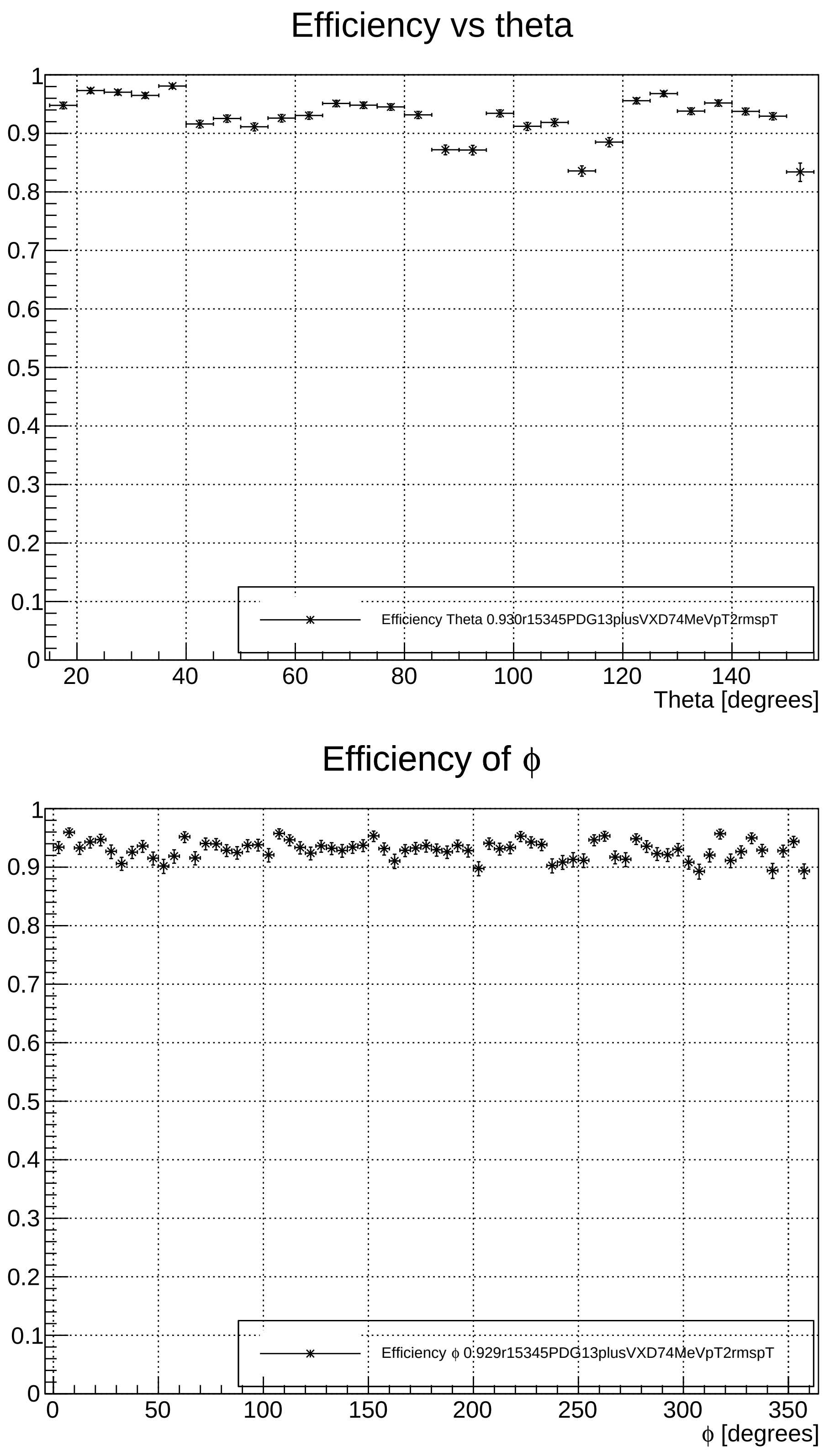



Figure 6.1: PDG +13 - 75 MeV/c pT

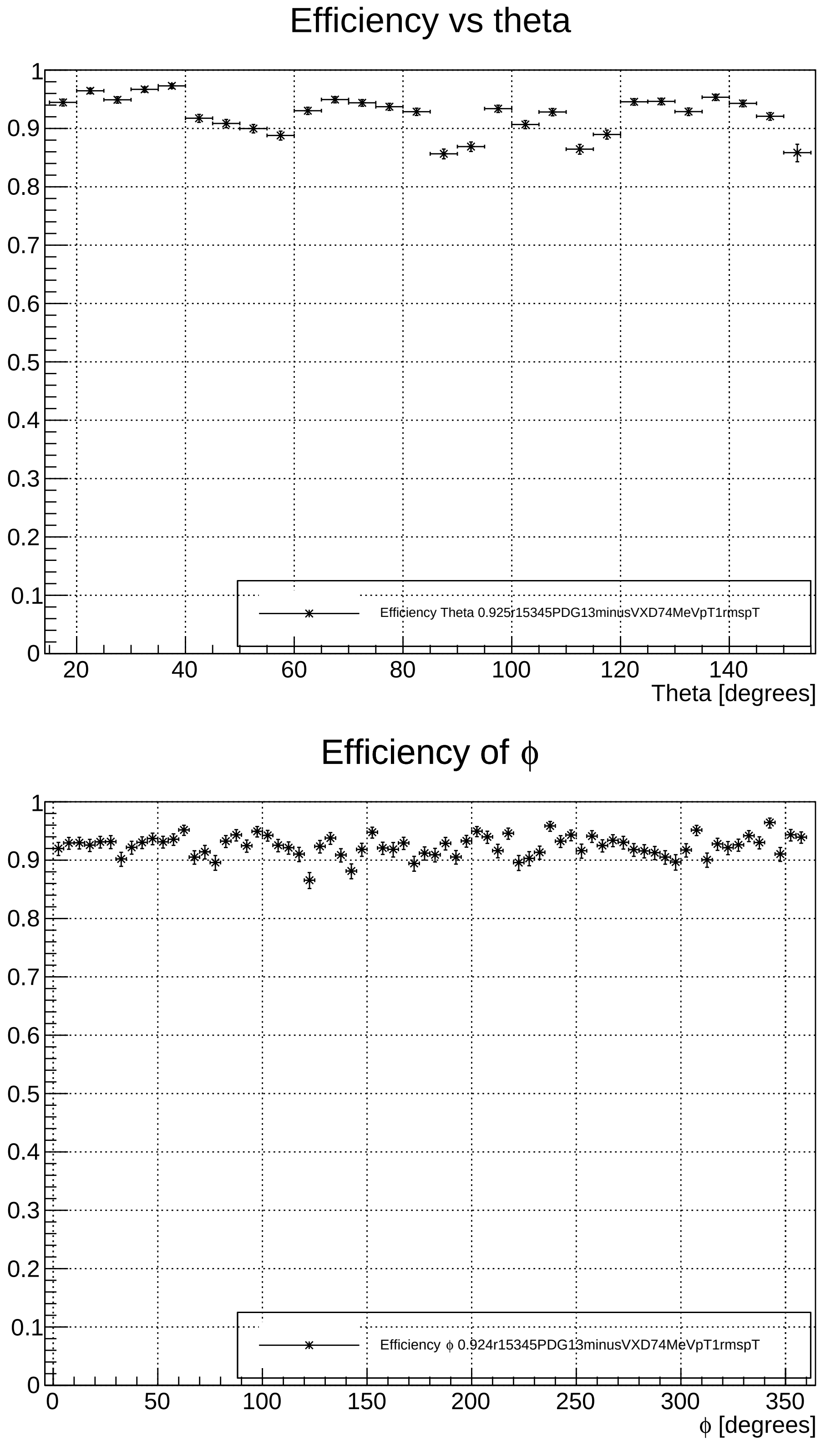



Figure 6.2: PDG -13 - 75 MeV/c pT

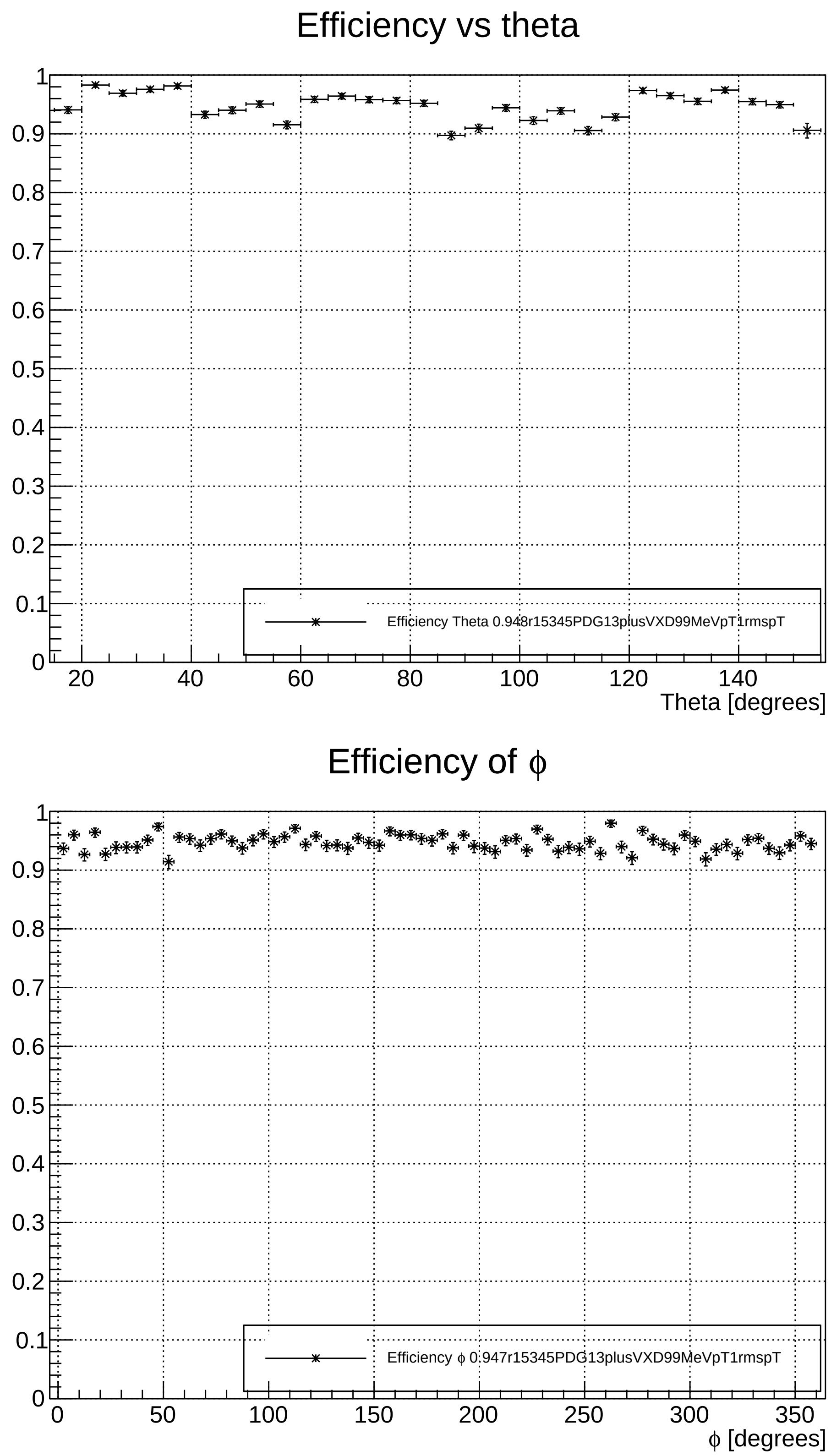
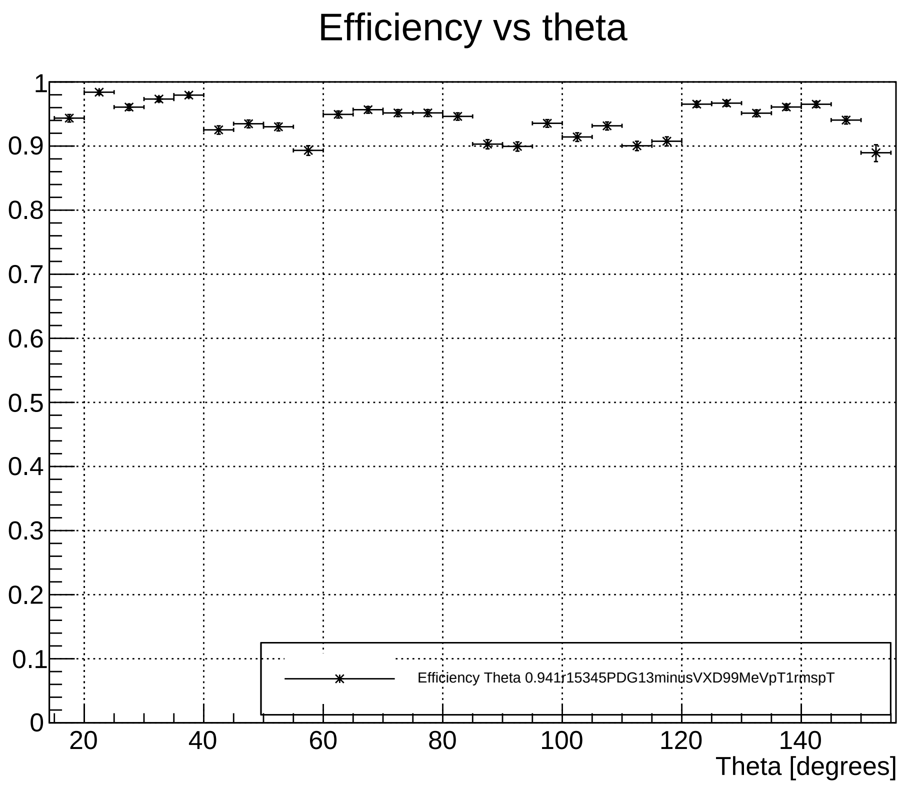



Figure 6.3: PDG +13 - 100 MeV/c pT



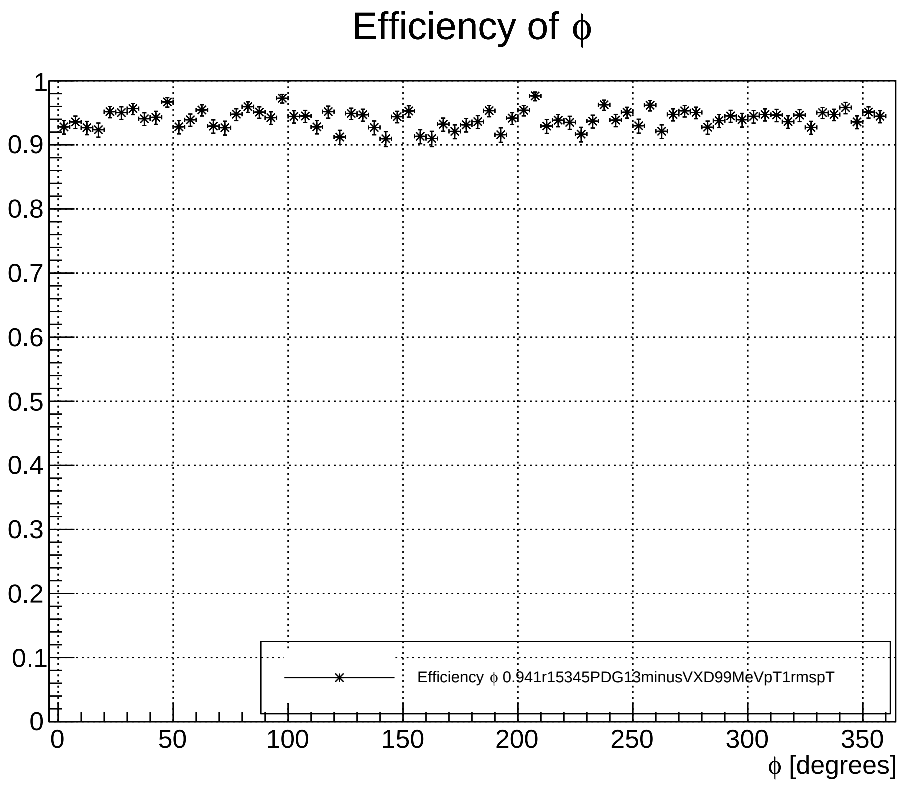
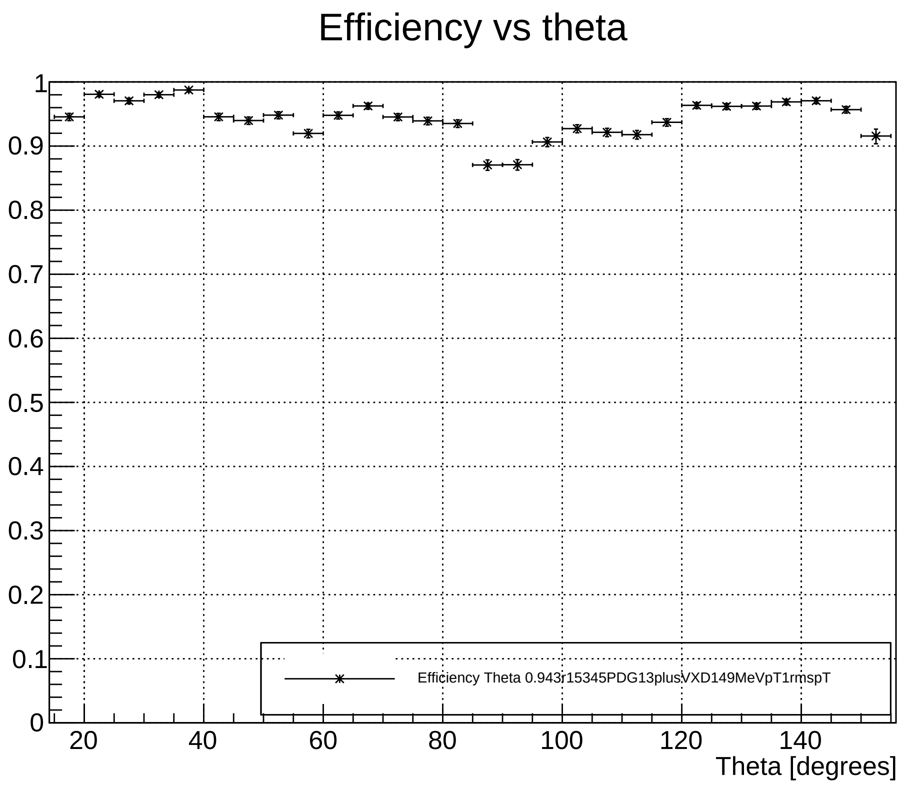




Figure 6.4: PDG -13 - 100 MeV/c pT



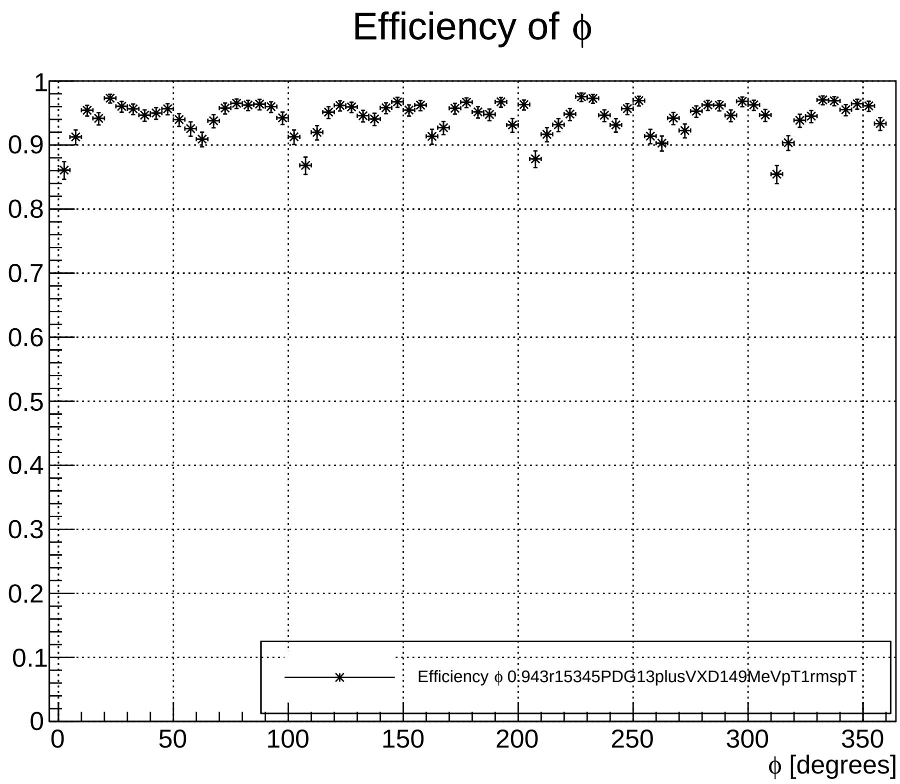
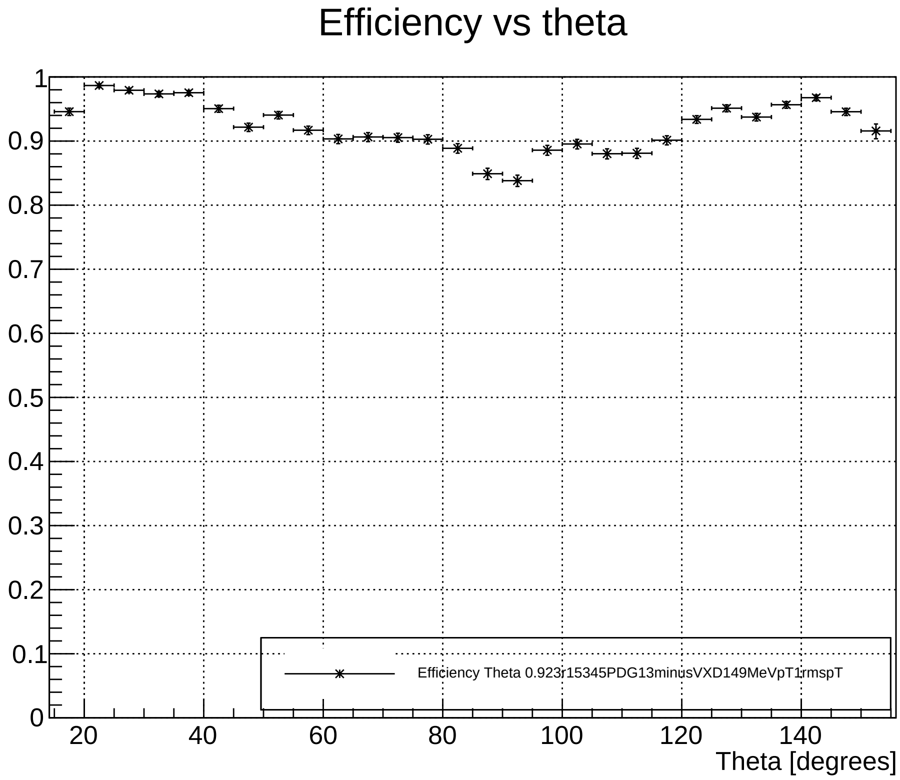




Figure 6.5: PDG +13 - 150 MeV/c pT



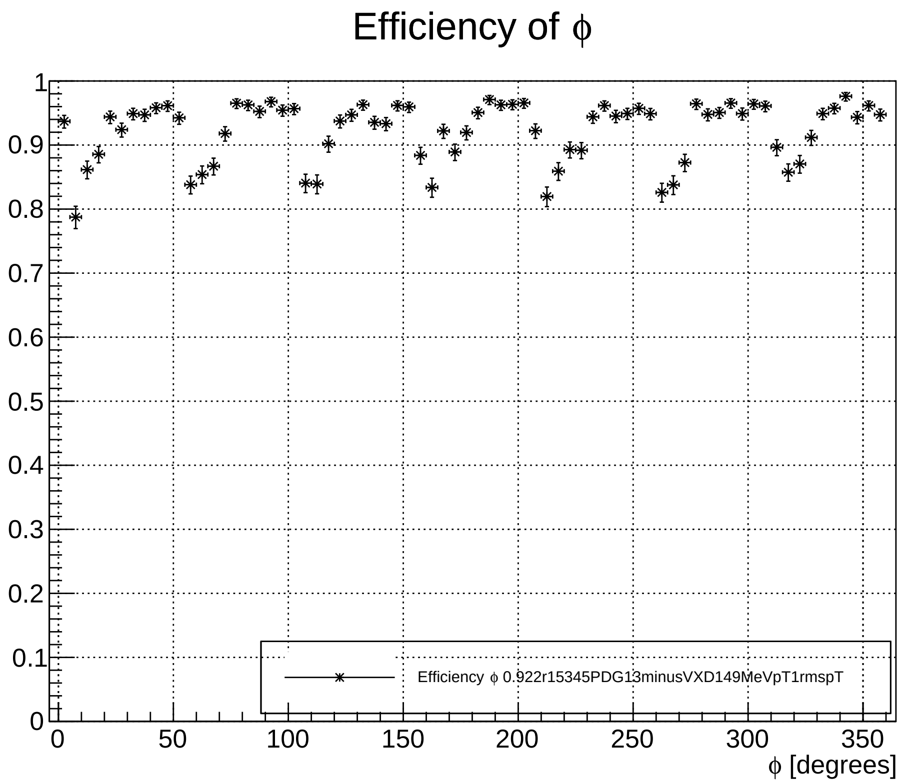
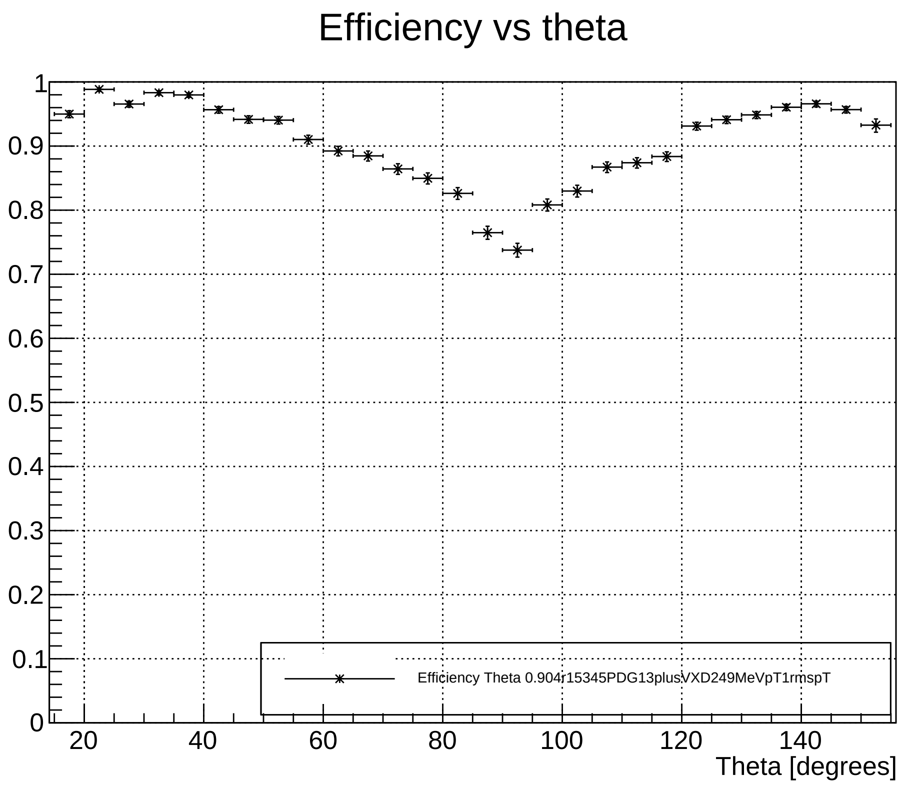




Figure 6.6: PDG -13 - 150 MeV/c pT



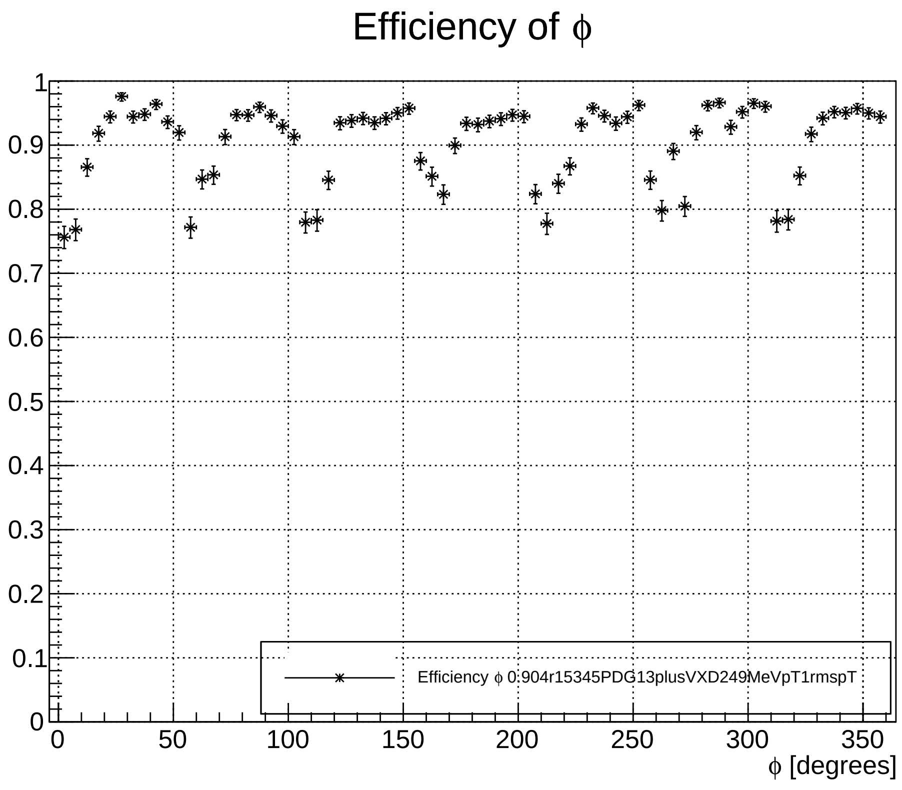




Figure 6.7: PDG +13 - 250 MeV/c pT

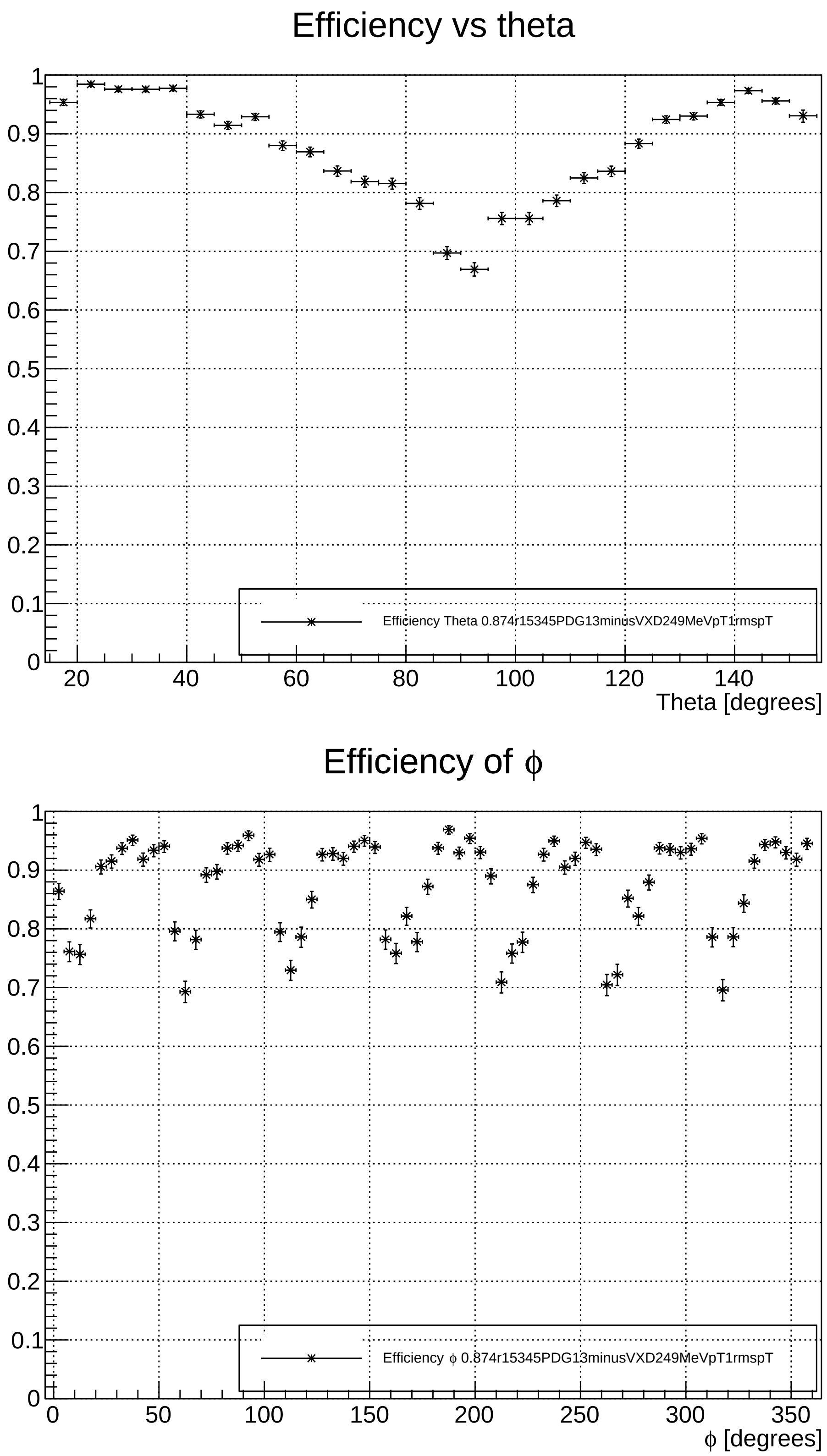
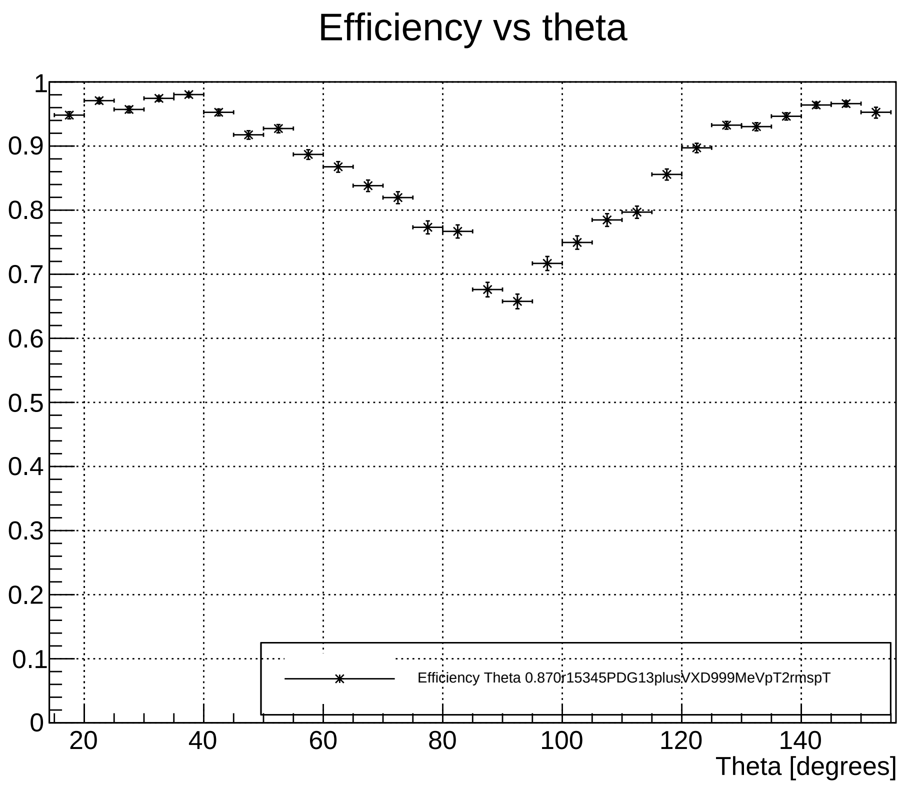



Figure 6.8: PDG -13 - 250 MeV/c pT



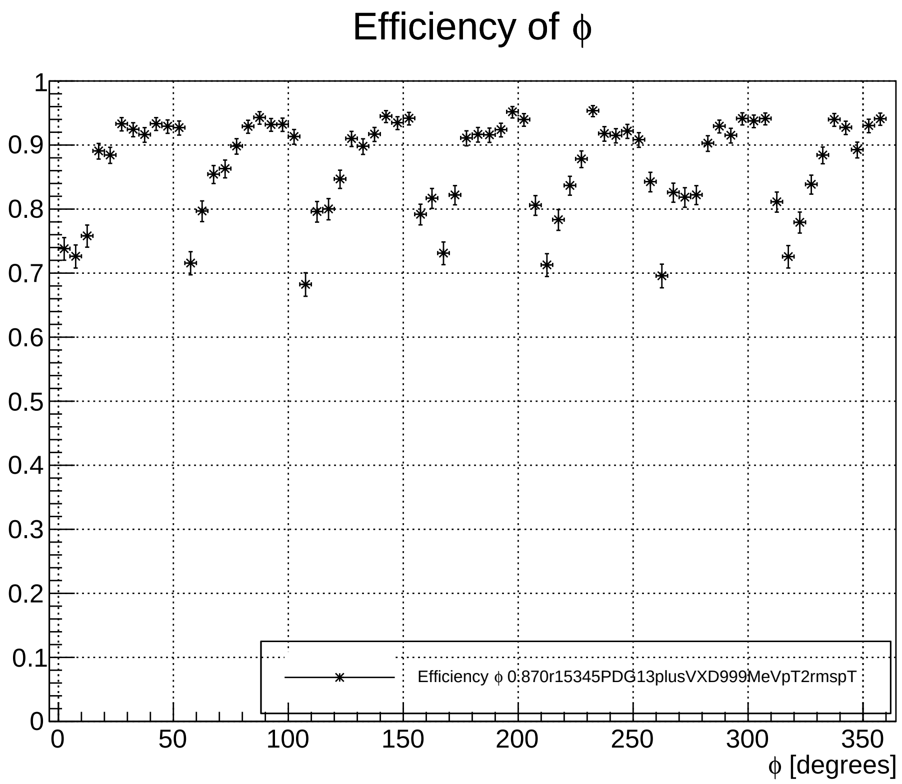




Figure 6.9: PDG +13 - 1000 MeV/c pT

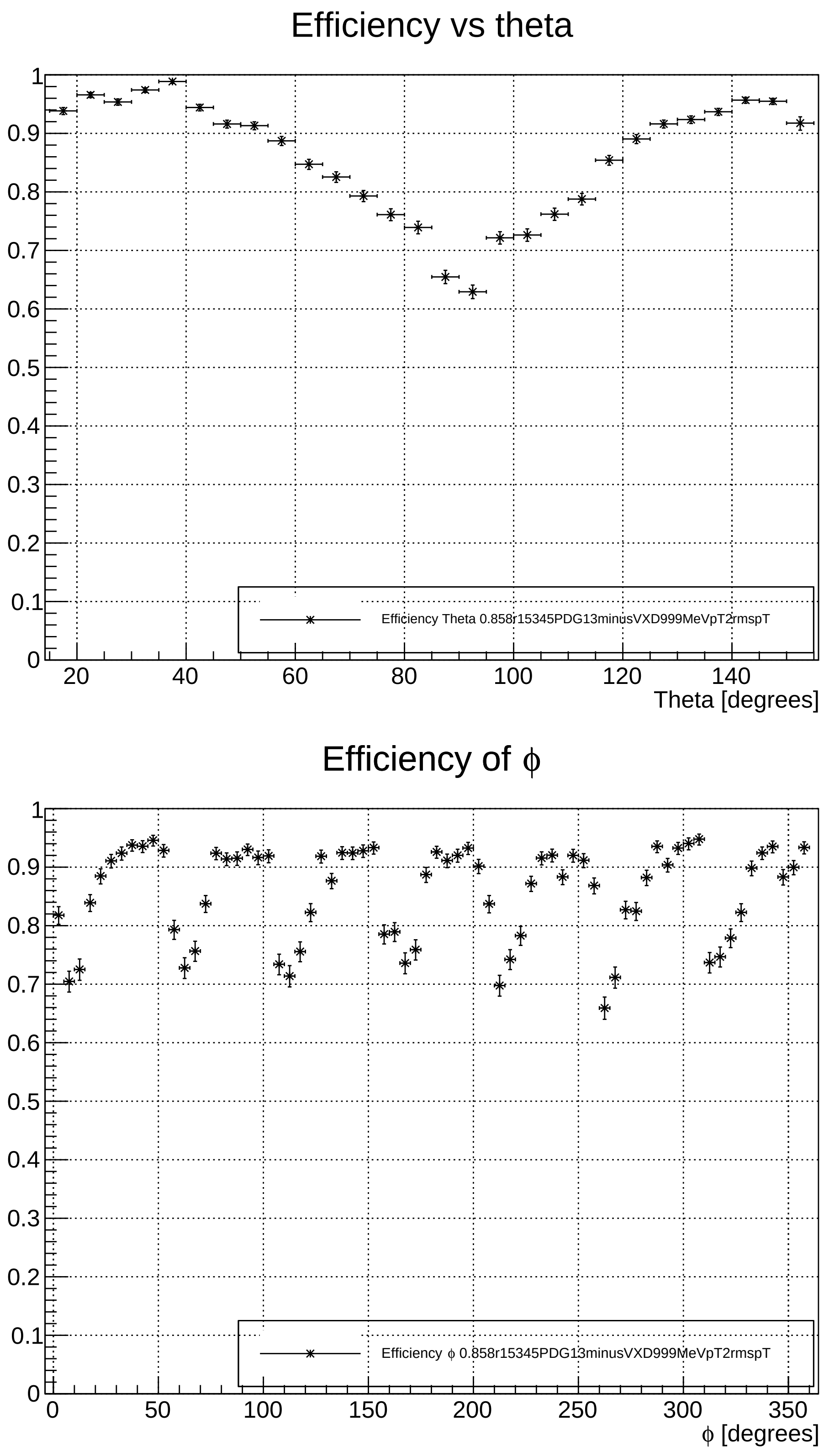



Figure 6.10: PDG -13 - 1000 MeV/c pT

# 7 Setup F - pGun fixed IP

Because of the simplified conditions the efficiency rises a bit, but the $\theta\,90^\circ$ -issue is still there.

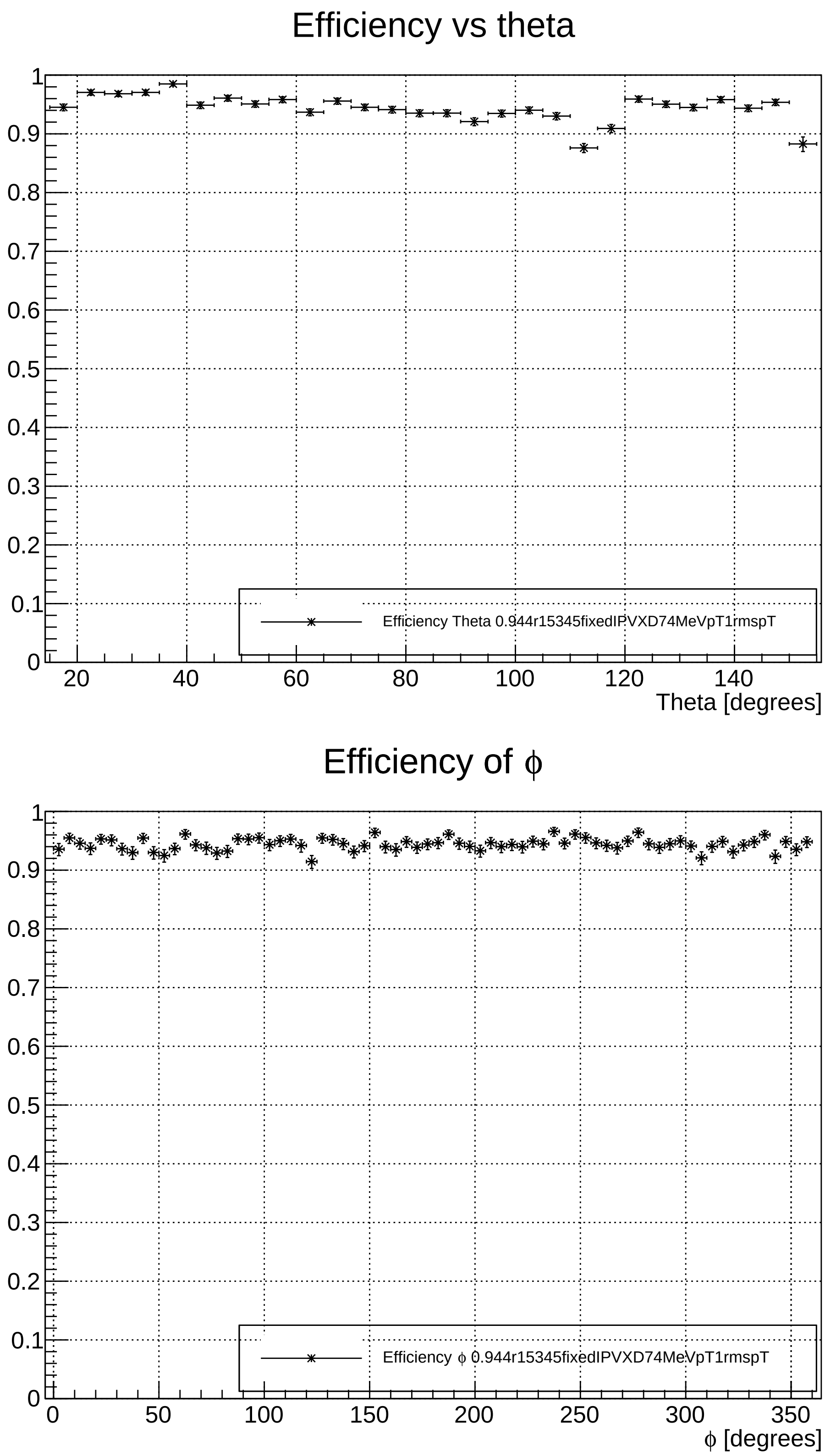



Figure 7.1: pGun fixed IP - 75 MeV/c pT

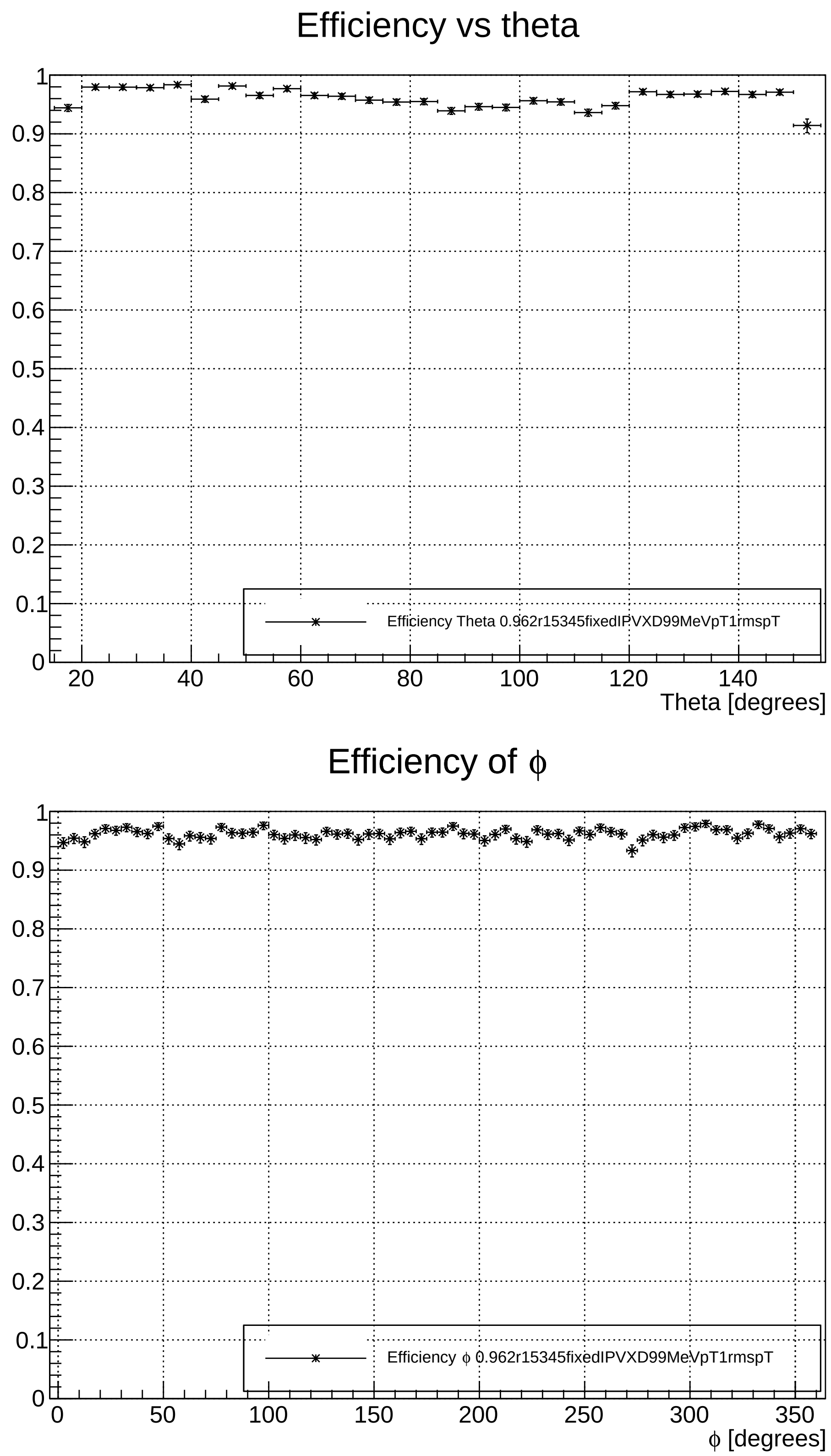



Figure 7.2: pGun fixed IP - 100 MeV/c pT

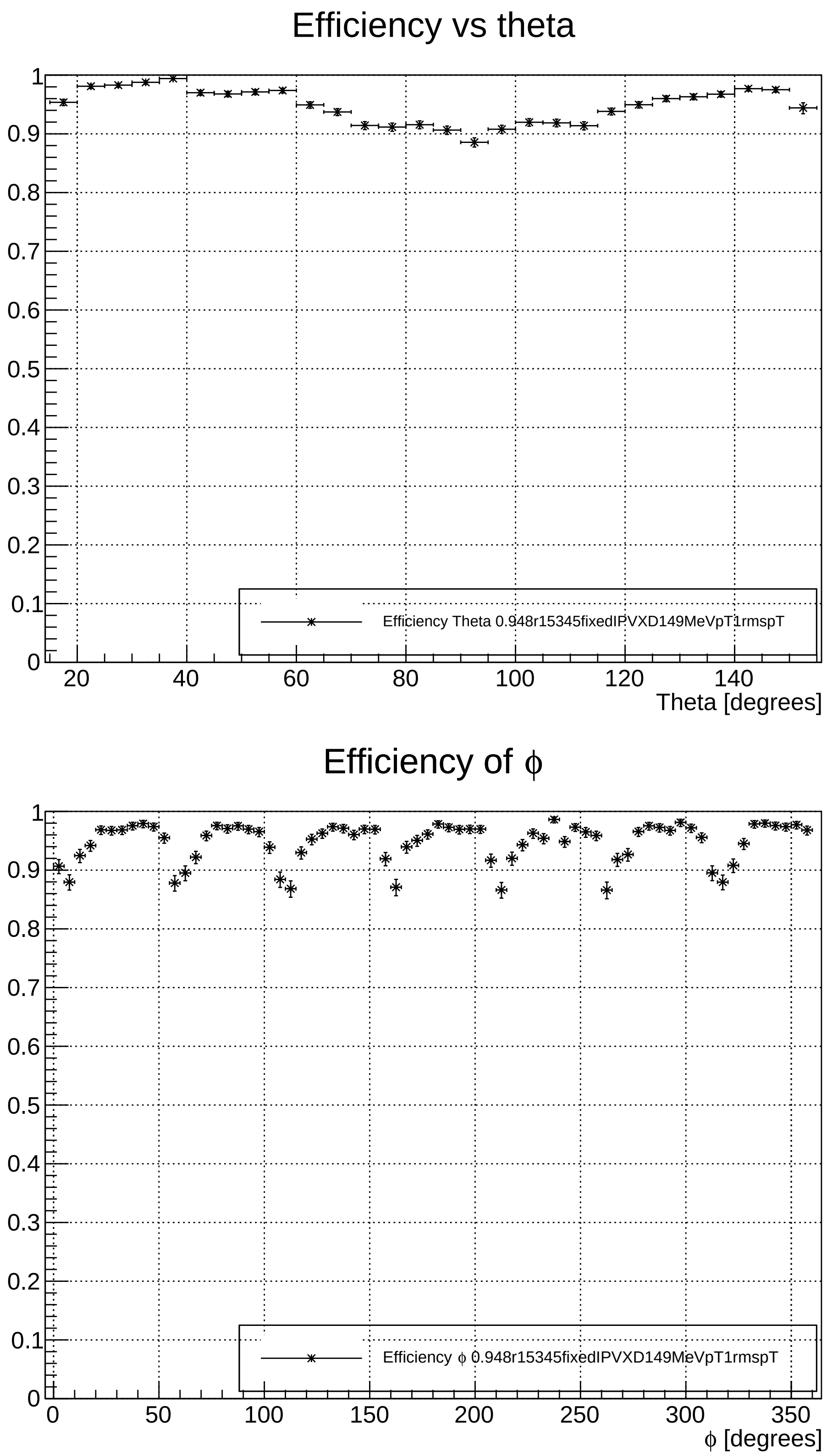



Figure 7.3: pGun fixed IP - 150 MeV/c pT

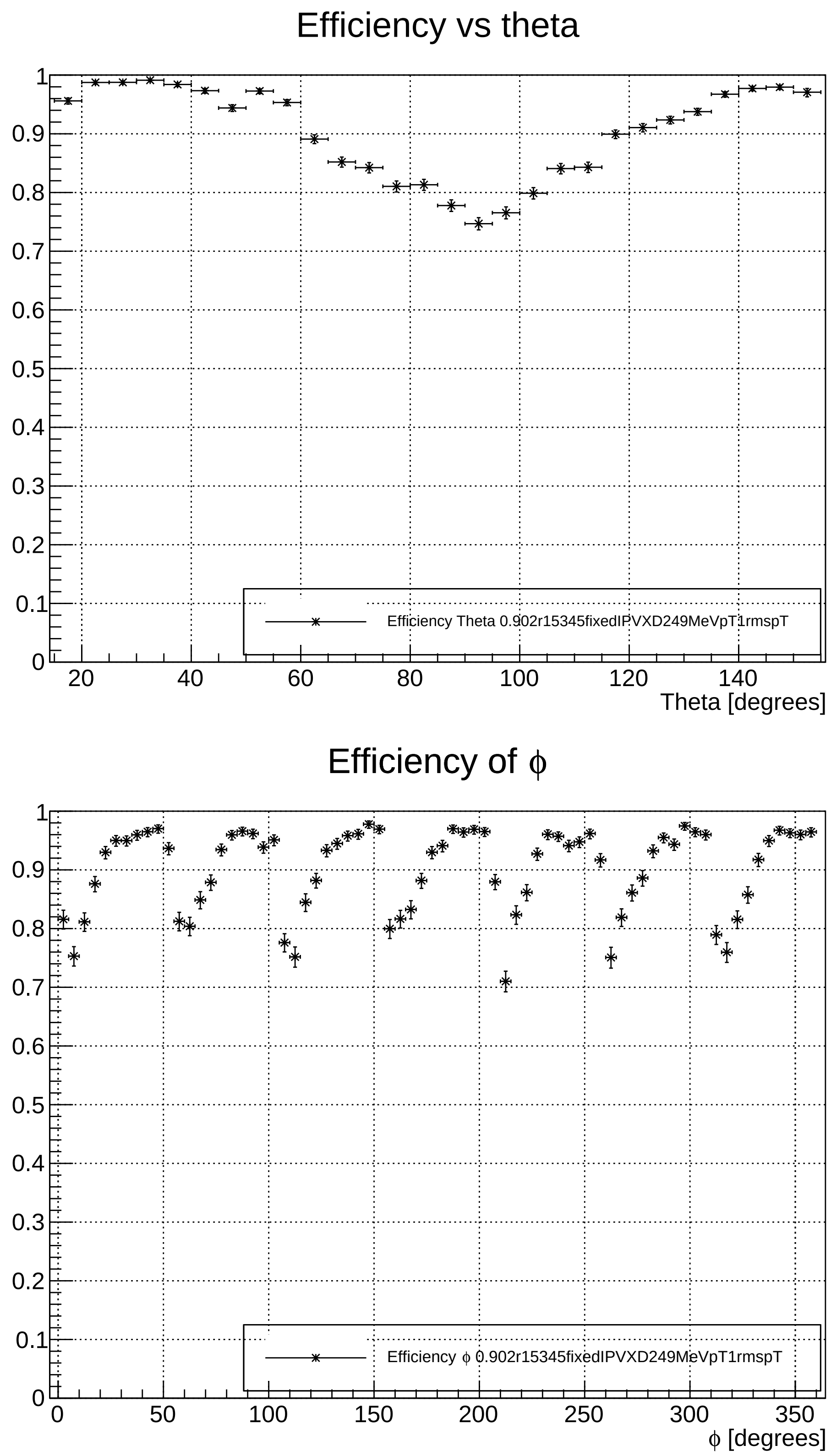



Figure 7.4: pGun fixed IP - 250 MeV/c pT

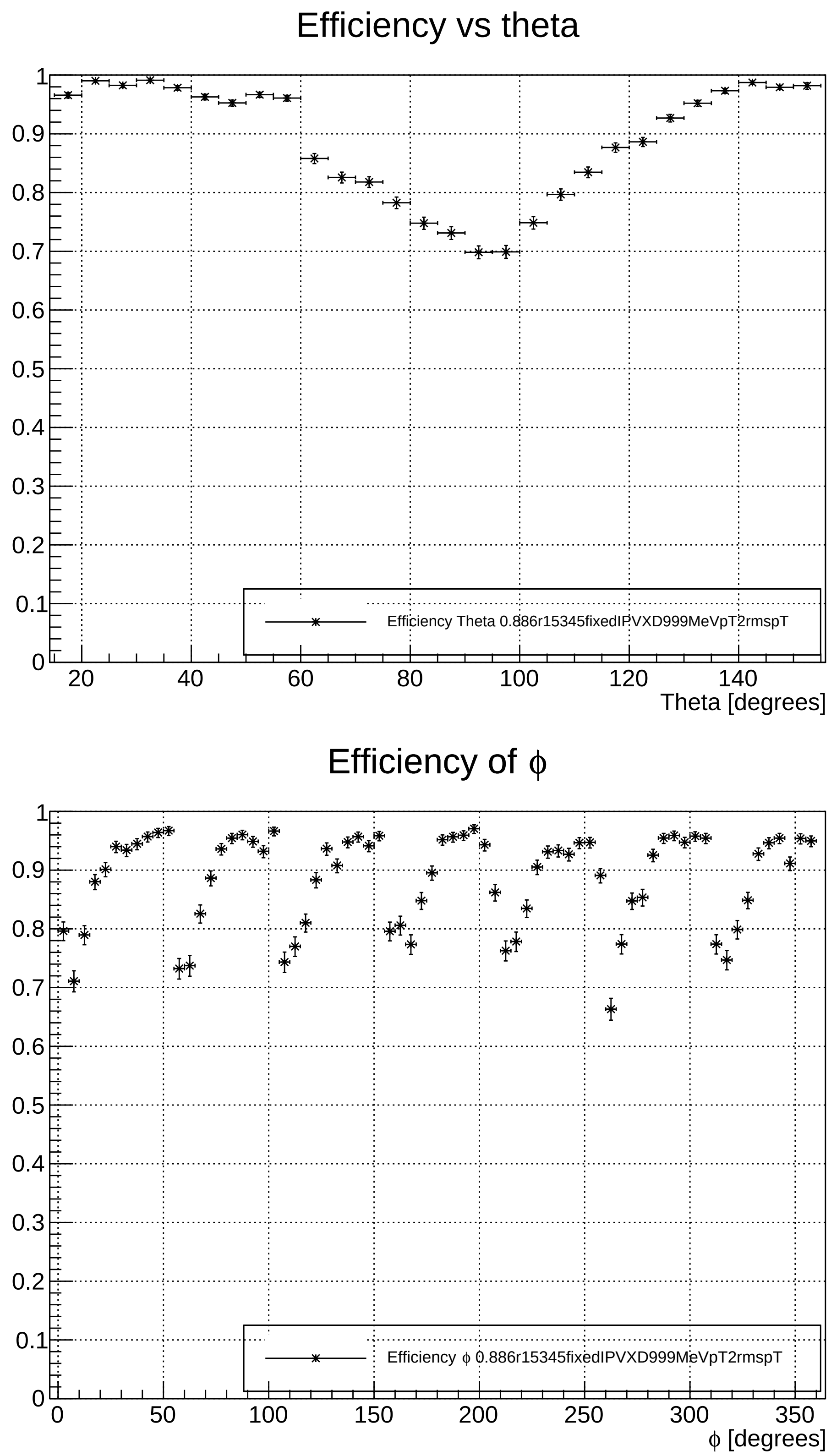



Figure 7.5: pGun fixed IP - 1000 MeV/c pT

# 8 Setup G - pGun 10T Protons

Fixed IP, since for low momenta protons suffer from extensive energy loss, these plots start at 150 MeV/c. At these momenta, muons already start to form the typical structure of the $\theta\,90^\circ$ -issue. Interestingly Protons do have a similar picture - but with much higher momenta. At 1 GeV the efficiency looks pretty good, at 2 GeV the results resembles the 250 MeV-plot when using muons.

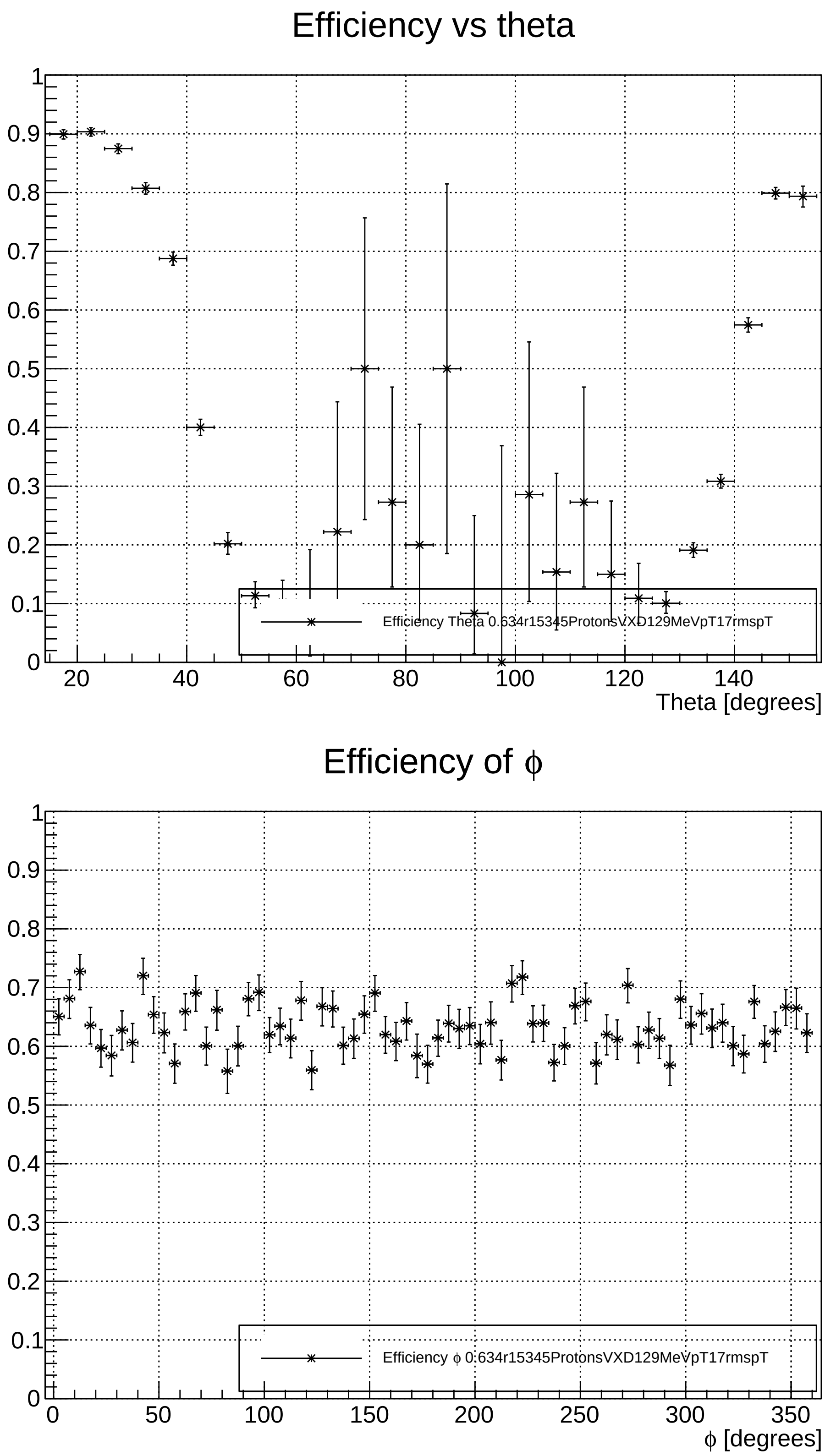



Figure 8.1: pGun protons - 150 MeV/c pT

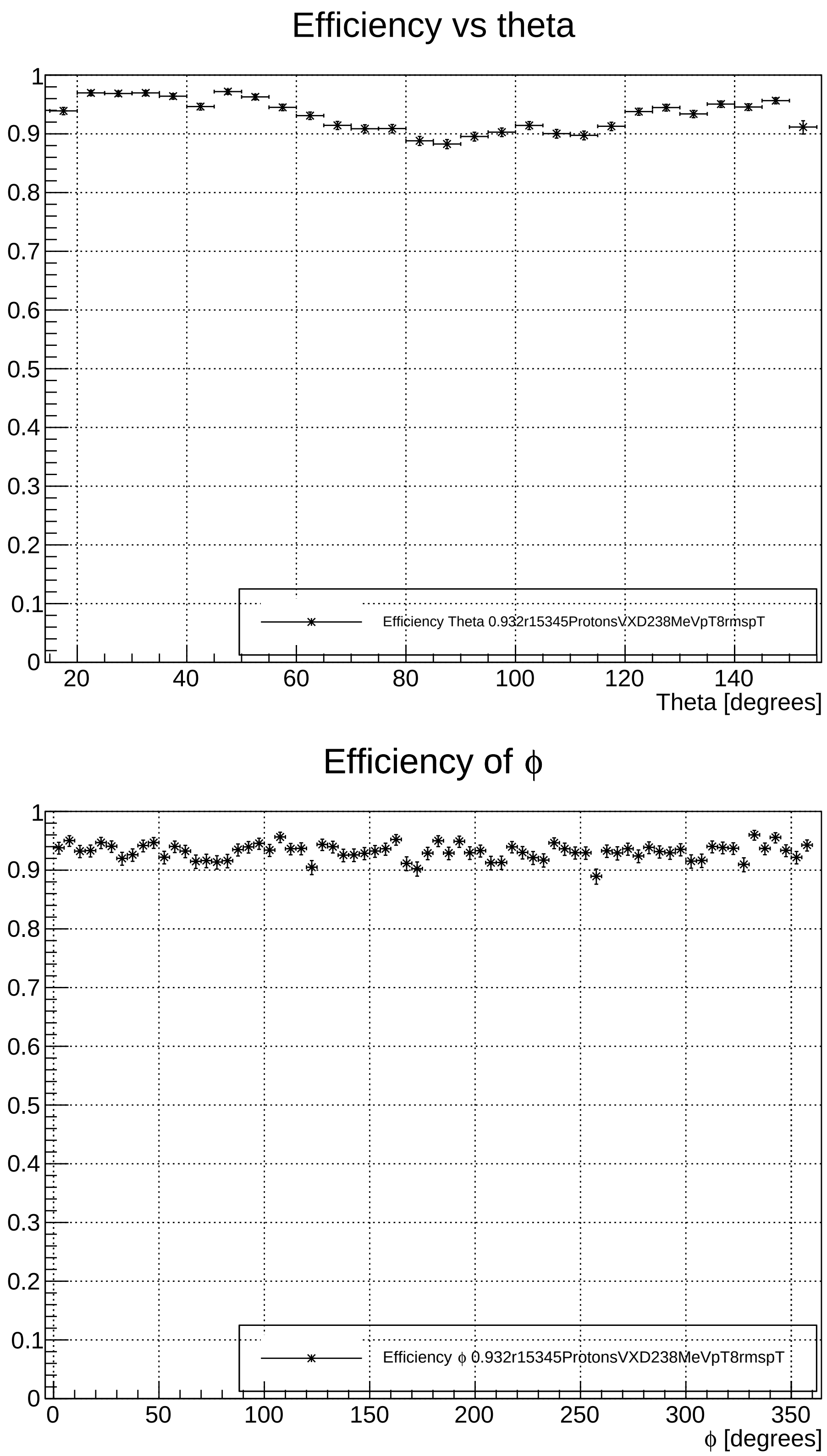
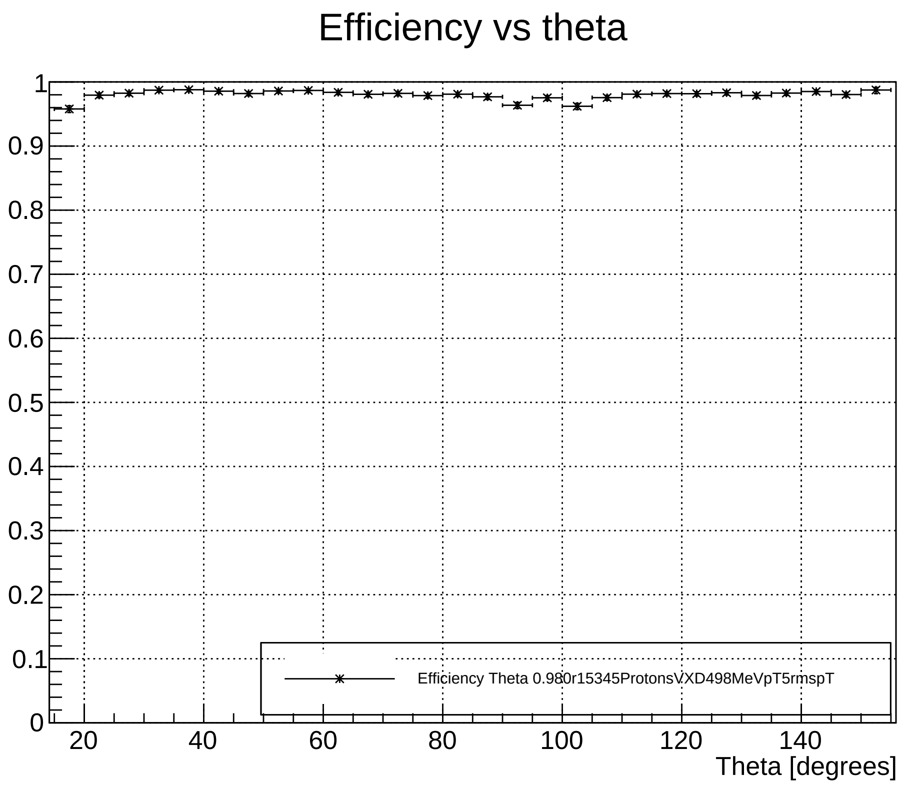



Figure 8.2: pGun protons - 250 MeV/c pT



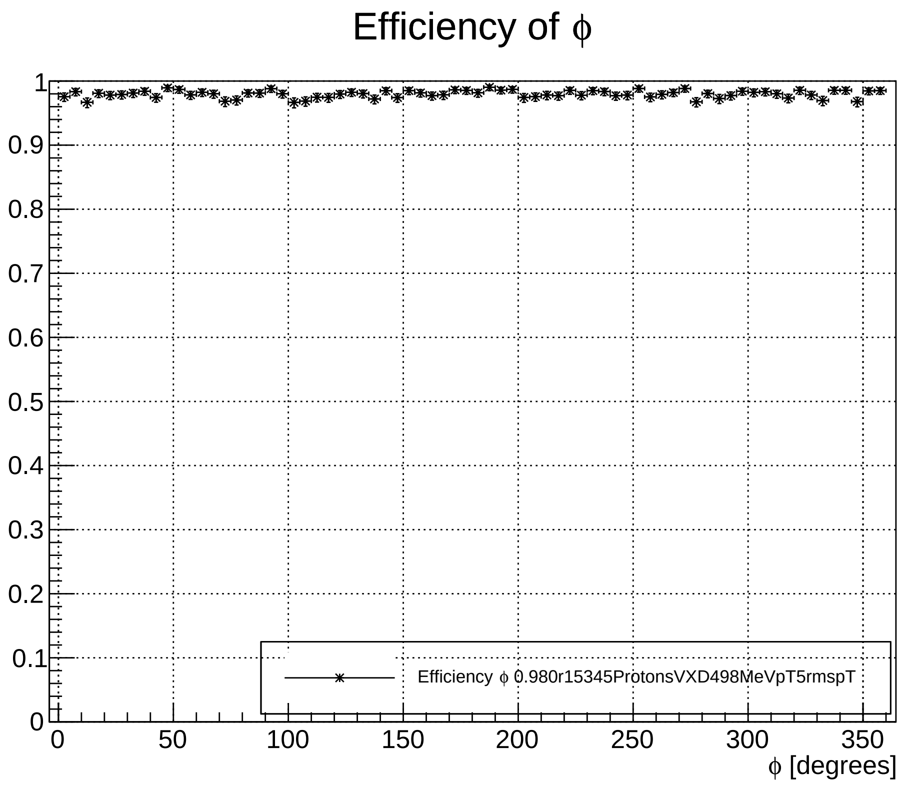




Figure 8.3: pGun protons - 500 MeV/c pT

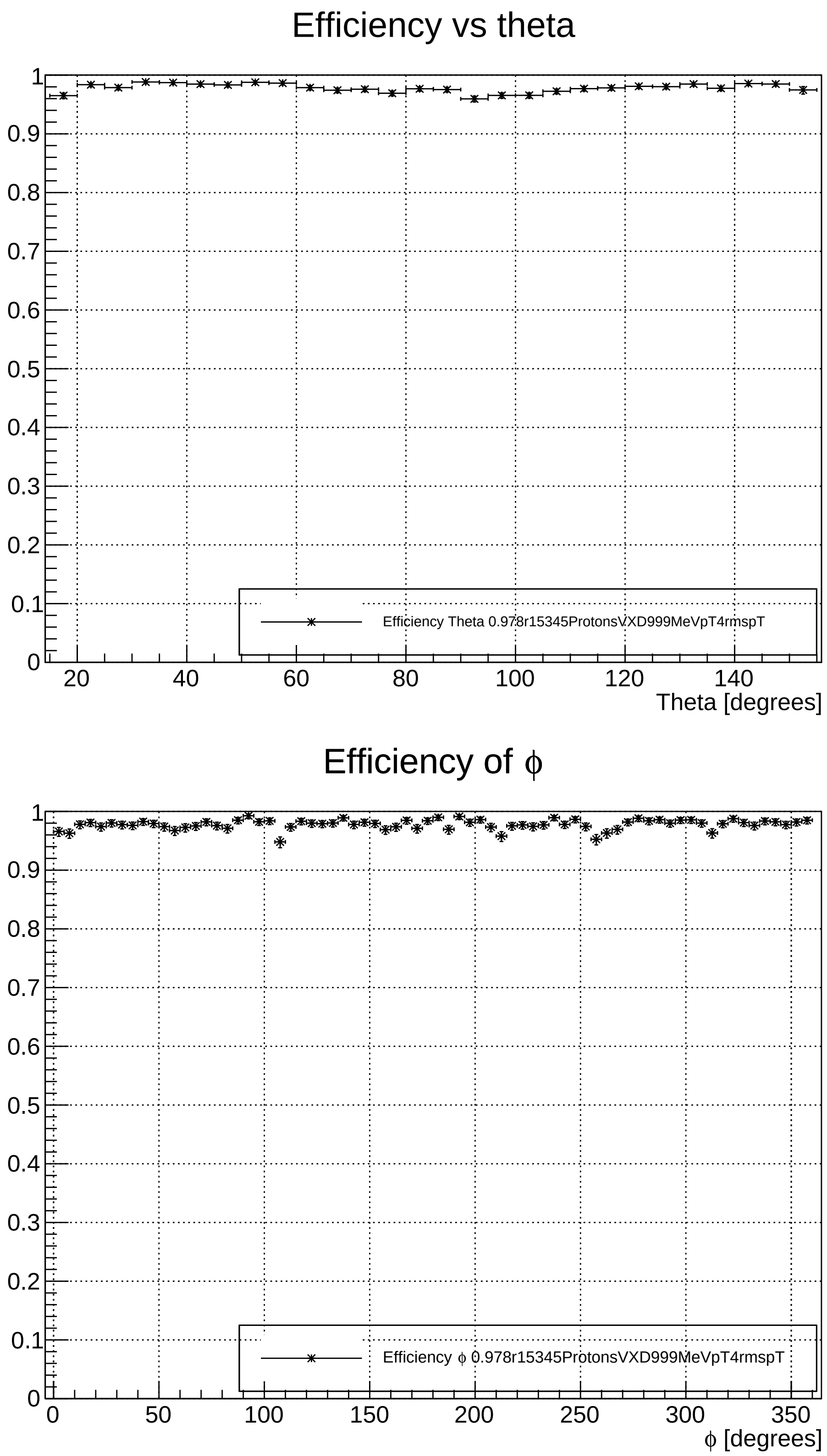
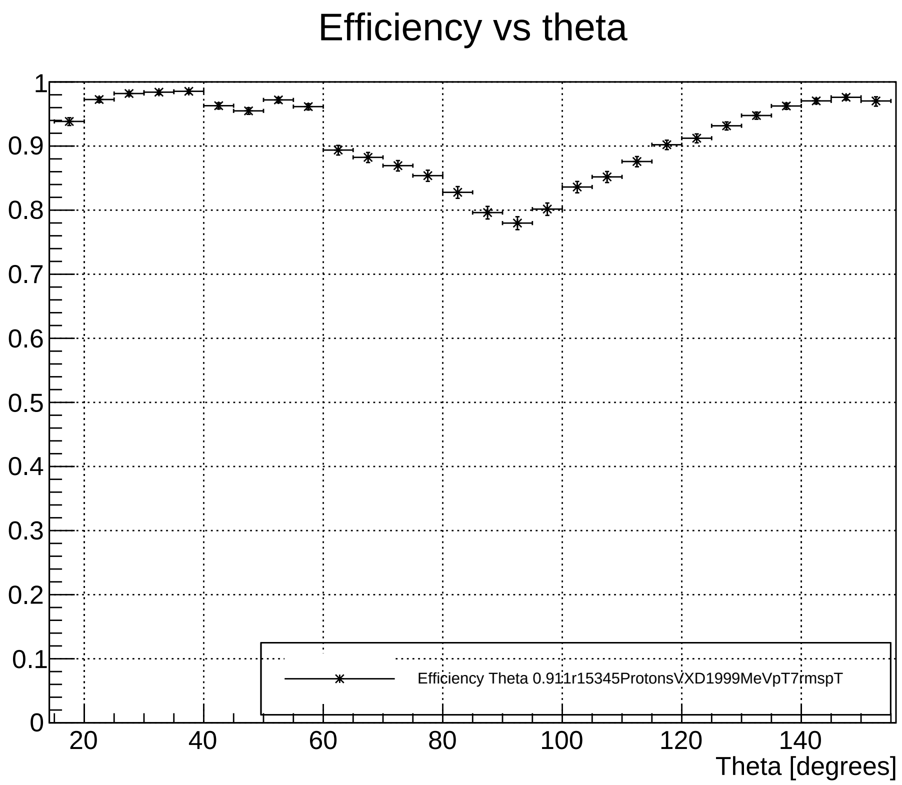



Figure 8.4: pGun protons - 1000 MeV/c pT



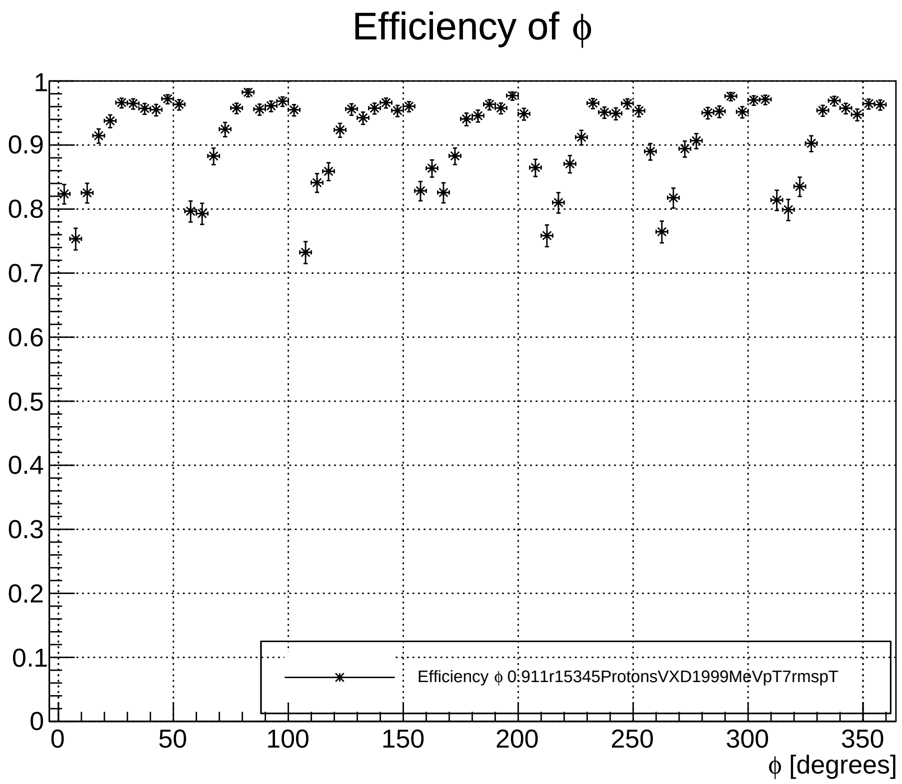
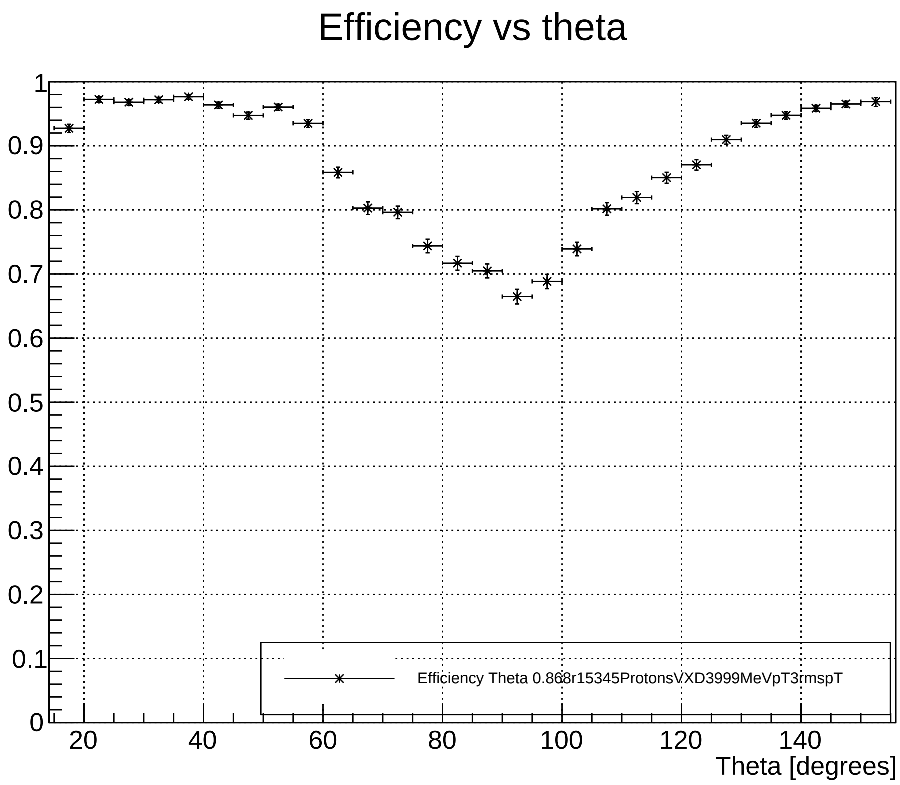




Figure 8.5: pGun protons - 2000 MeV/c pT



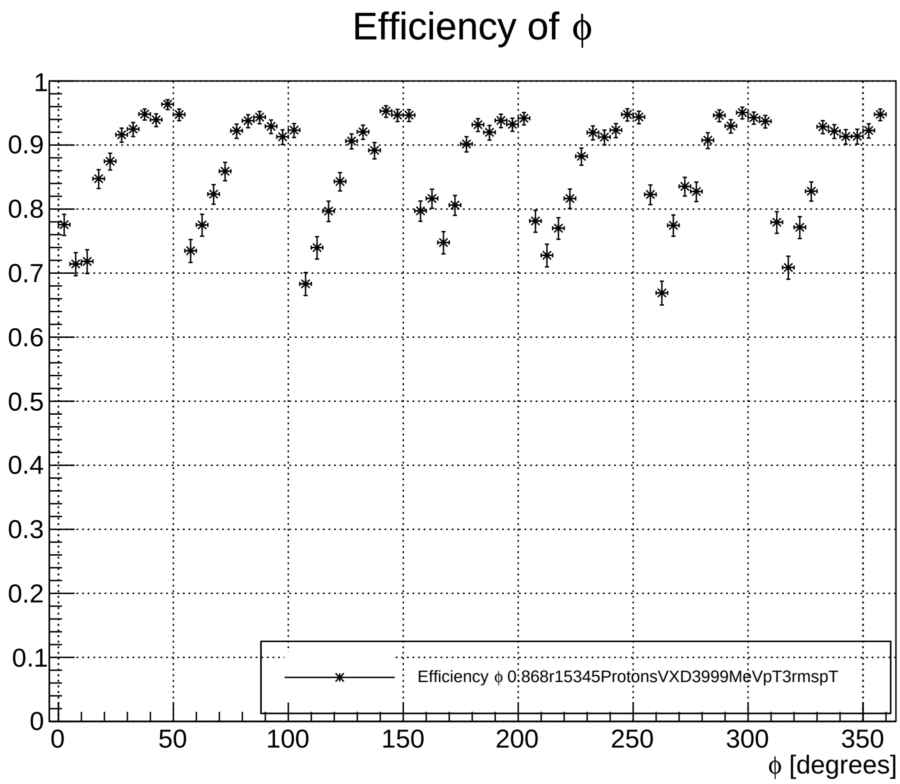




Figure 8.6: pGun protons - 4000 MeV/c pT

# 9 Setup H - pGun 10T Kaons

Muons start with about 125 MeV/c to form the $\theta\,90^\circ$ -structure, protons do the same above 1000 MeV/c . Are these correlations with the particle masses happenstance? The counter-test is using a third particle, here charged Kaons are used, their mass at rest is a bit less than 500 MeV/c , therefore their results at 500 MeV/c should be good and momenta above that start forming again the typical $\theta\,90^\circ$ -structure. And the plots support that idea $\rightarrow$ the $\theta\,90^\circ$ -structure is strongly coupled with $\beta\gamma$ . The only effect I know of which is basically coupled to $\beta\gamma$ is the energy loss. But exactly at those regions where track reconstruction in terms of energy loss is the easiest, the efficiency drops most. Therefore the $\theta\,90^\circ$ -effect should be indirect proportional to the actual energy loss of the particle. This consequently leads us to another suspect: particles with low energy loss leave the least amount of charges in the detector. Since one of the sides of the SVD has got a worse S:N-ratio, the signal quality could cause the clusterizer to throw away single clusters. These clusters are then missing for the reconstruciton of the track. Since the CA is currently not supporting any single cluster hits, this could be a possible reason. This is definitively a hint worth for further investigations.

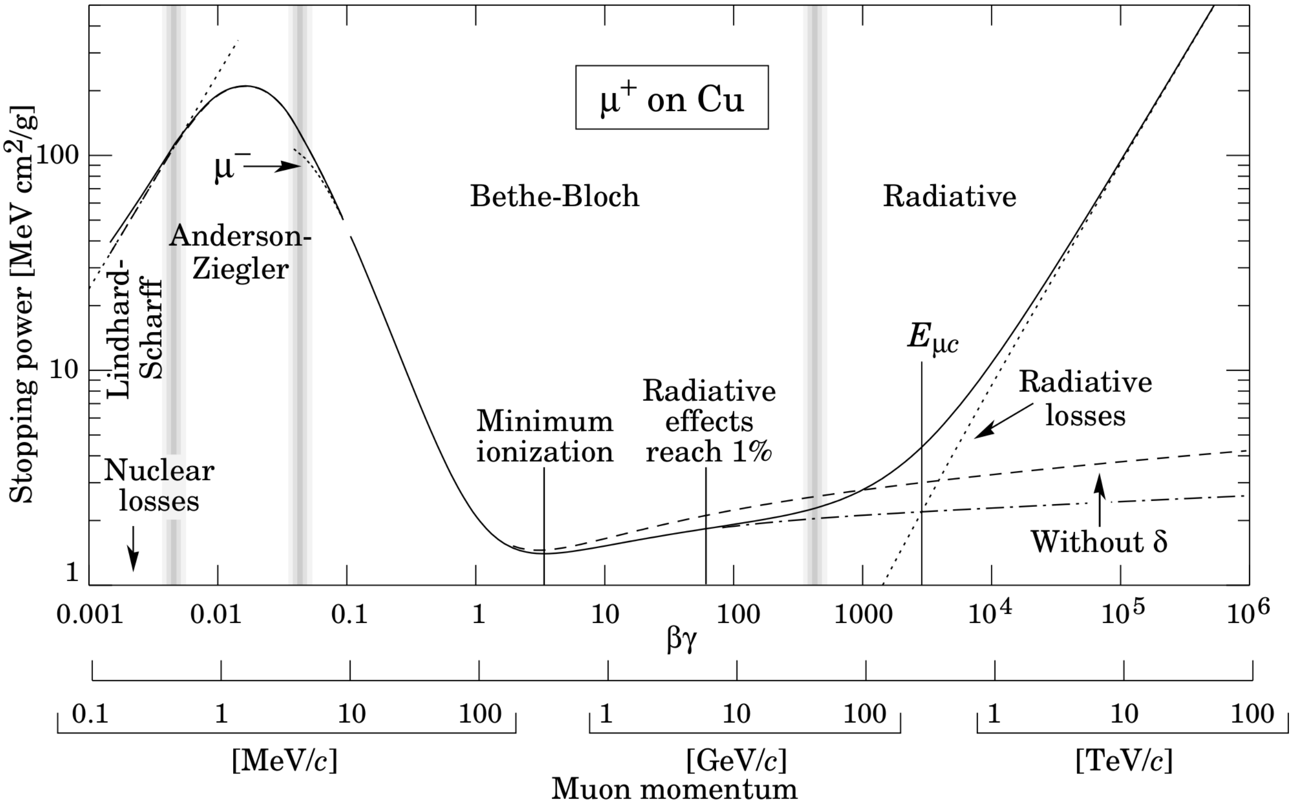



Figure 9.1: the energy loss of muons in dependency on $\beta\gamma$

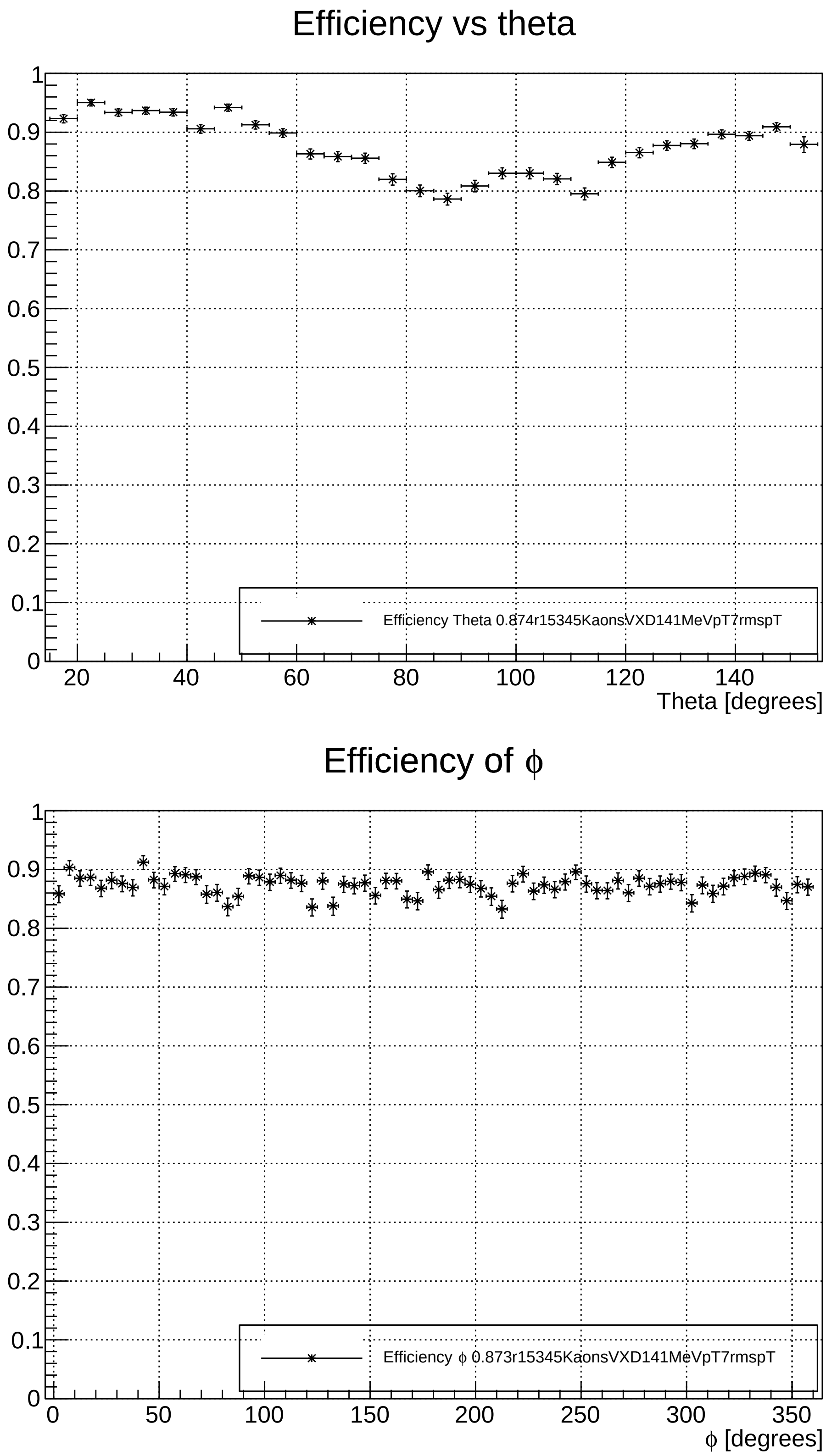



Figure 9.2: pGun protons - 150 MeV/c pT

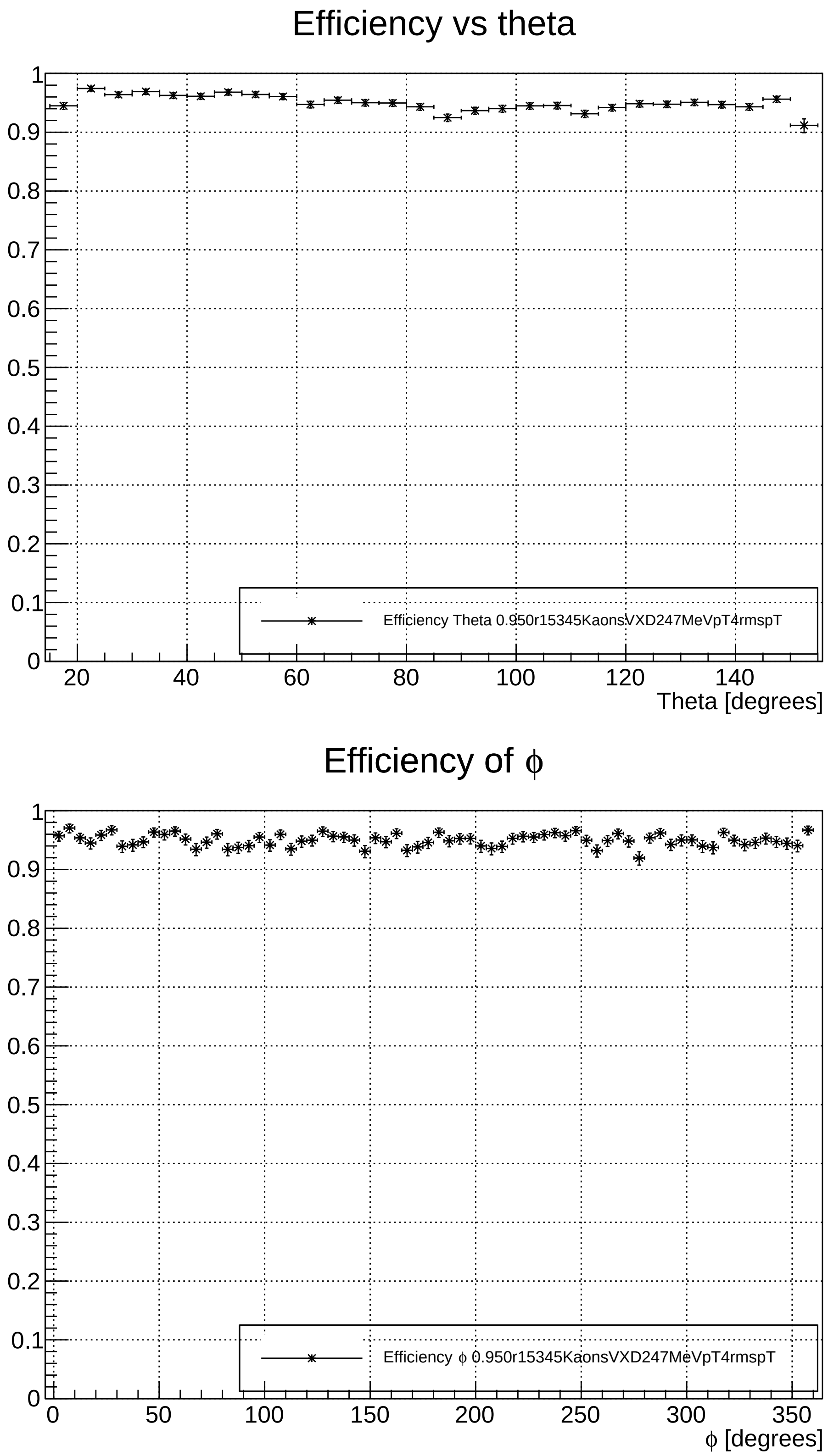



Figure 9.3: pGun protons - 250 MeV/c pT

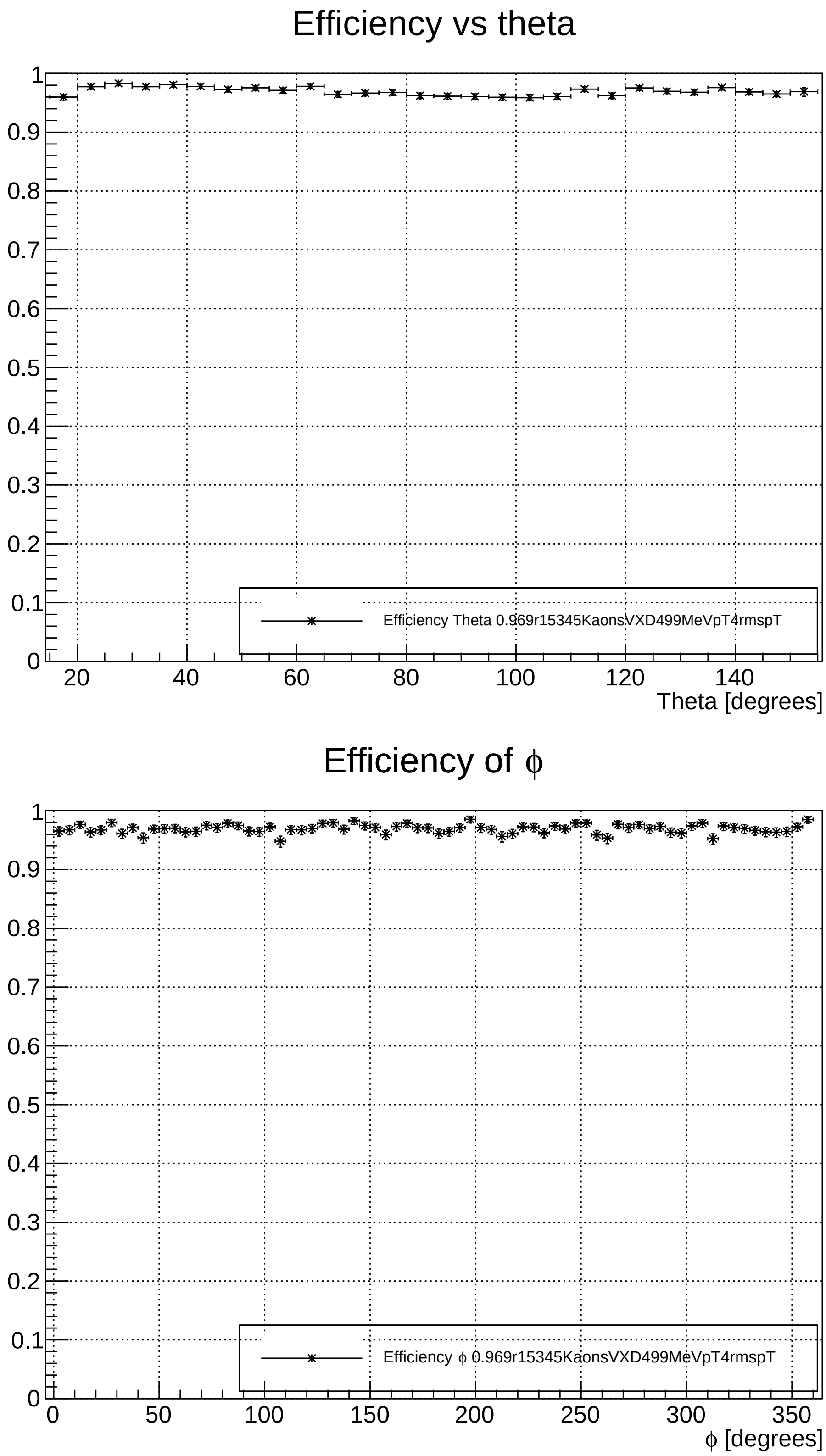



Figure 9.4: pGun protons - 500 MeV/c pT

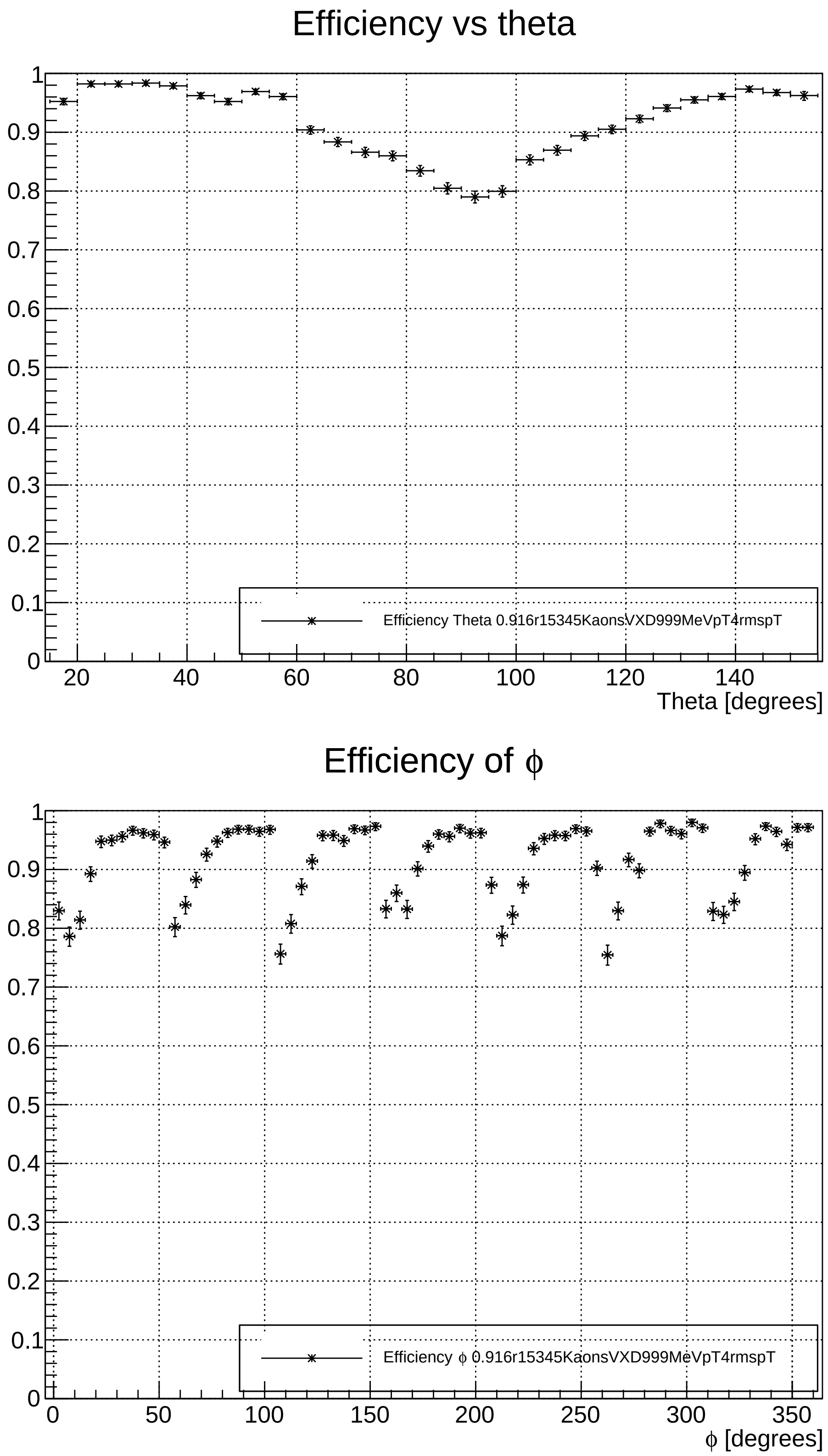
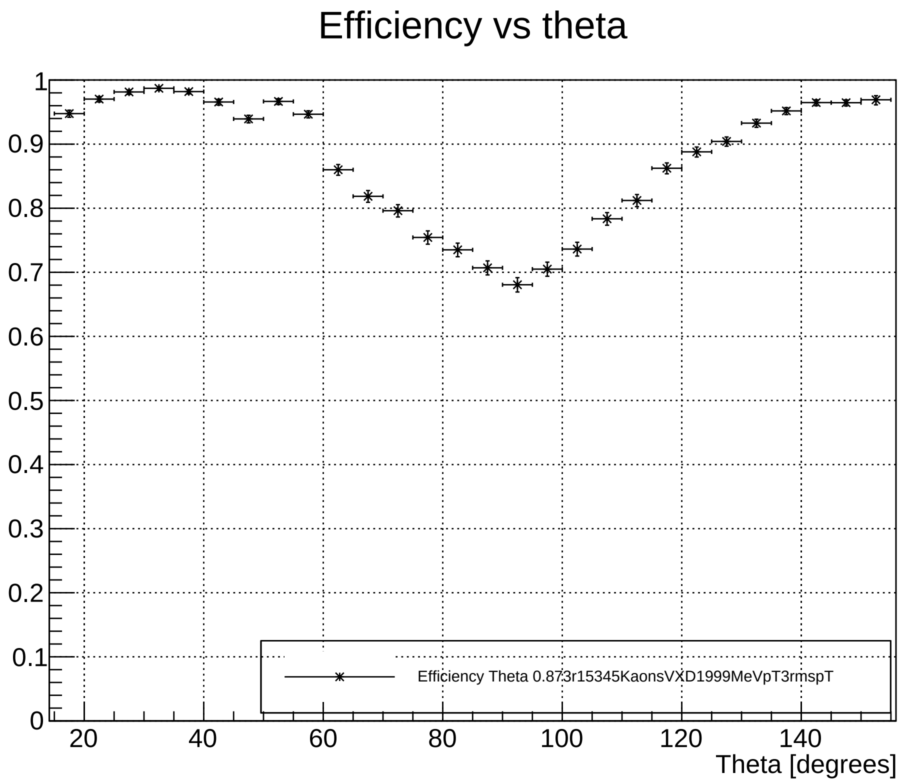



Figure 9.5: pGun protons - 1000 MeV/c pT



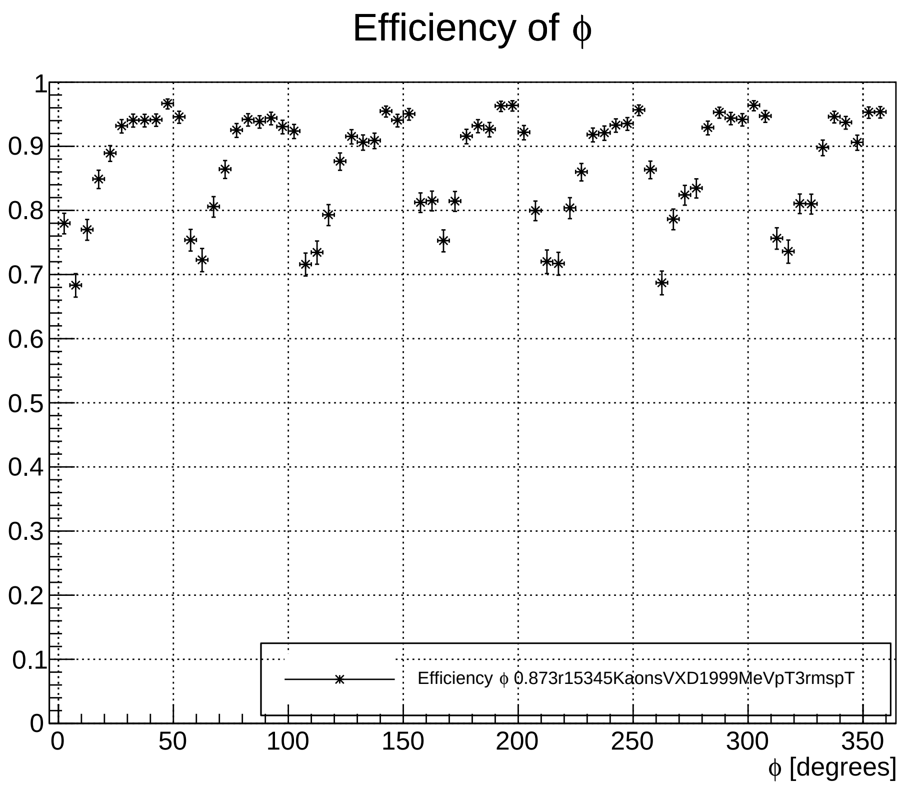




Figure 9.6: pGun protons - 2000 MeV/c pT

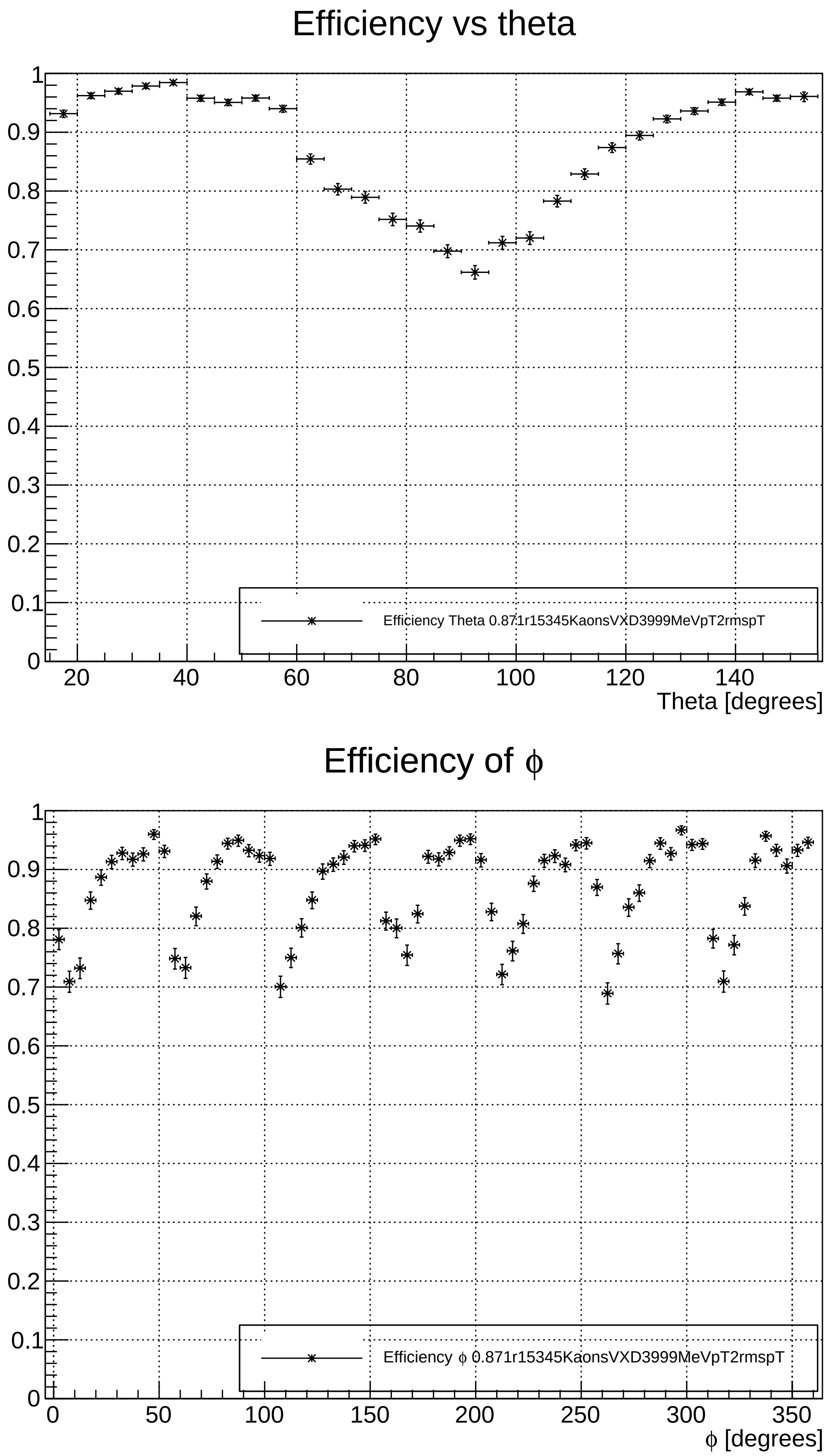



Figure 9.7: pGun protons - 4000 MeV/c pT