Cross-sections of large-angle hadron production in proton– and pion–nucleus interactions II: beryllium nuclei and beam momenta from $\pm 3$ GeV/c to $\pm 15$ GeV/c

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Abstract We report on double-differential inclusive cross-sections of the production of secondary protons and charged pions, in the interactions with a 5% $\lambda_{abs}$ thick stationary beryllium target, of proton and pion beams with momentum from $\pm 3$ GeV/c to $\pm 15$ GeV/c. Results are given for secondary particles with production angles $20^\circ < \theta < 125^\circ$.

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1 Introduction

The HARP experiment arose from the realization that the inclusive differential cross-sections of hadron production in the interactions of few GeV/c protons with nuclei were known only within a factor of two to three, while more precise cross-sections are in demand for several reasons. Consequently, the HARP detector was designed to carry out a programme of systematic and precise measurements of hadron production by protons and pions with momenta from 1.5 to 15 GeV/c.

The detector combined a forward spectrometer with a large-angle spectrometer. The latter comprised a cylindrical Time Projection Chamber (TPC) around the target and an array of Resistive Plate Chambers (RPCs) that surrounded the TPC. The purpose of the TPC was track reconstruction and particle identification by dE/dx. The purpose of the RPCs was to complement the particle identification by time of flight.

The HARP experiment was performed at the CERN Proton Synchrotron in 2001 and 2002 with a set of stationary targets ranging from hydrogen to lead, including beryllium.

Here, we report on the large-angle production (polar angle $\theta$ in the range $20^\circ < \theta < 125^\circ$) of secondary protons and charged pions in the interactions with a 5% $\lambda_{abs}$ Be target of protons and pions with beam momenta of $\pm 3.0$, $\pm 5.0$, $\pm 12.0$, and $\pm 15.0$ GeV/c. We have reported earlier [1] on results from beam momenta of $+8.9$ and $-8.0$ GeV/c.

Our work involves only the HARP large-angle spectrometer. The detector characteristics and our analysis algorithms have been described in Ref. [1].

The data analysis presented in this paper rests exclusively on the calibrations of the TPC and the RPCs that we, the HARP–CDP group, published in Refs. [2] and [3]. As discussed in Refs. [4] and [5], and summarized succinctly in the appendix of Ref. [1], our calibrations disagree with those published by the ‘HARP Collaboration’ [6–9]. Conclusions of independent review bodies on the discrepancies between our results and those from the HARP Collaboration can be found in Refs. [10, 11].
2 The T9 proton and pion beams, and the target

The protons and pions were delivered by the T9 beam line in the East Hall of CERN’s Proton Synchrotron. This beam line supports beam momenta between 1.5 GeV/c and 15 GeV/c, with a momentum bite $\Delta p/p \sim 1\%$.

Beam particle identification was provided for by two threshold Cherenkov counters, BCA and BCB, filled with nitrogen, and by time of flight over a flight path of 24.3 m. Table 1 lists the beam instrumentation that was used at different beam momenta for $p/\pi^+$ and for $\pi/e$ separation.

The pion beam had a contamination by muons from pion decays. It also had a contamination by electrons from converted photons from $\pi^0$ decays. Only for the beam momenta of 3 and 5 GeV/c were electrons identified by a beam Cherenkov counter and rejected.

The fractions of muon and electron contaminations of the pion beam were experimentally determined [12, 13] and are listed in Table 2 for all beam momenta.\(^1\) For the determination of interaction cross-sections of pions, the muon and electron contaminations must be subtracted from the incoming flux of pion-like particles (except electrons at the beam momenta of 3 and 5 GeV/c).

The kaon contamination in the proton and pion beams is at the per-cent level. Beam kaons are rejected either by TOF or suppressed by the beam Cherenkov response; only at 5 GeV/c kaons are indistinguishable from pions. Because the kaon interaction cross-sections are close to the proton and pion interaction cross-sections, this contamination is ignored.

The beam trajectory was determined by a set of three multiwire proportional chambers (MWPCs), located upstream of the target, several meters apart. The transverse error of the impact point on the target was 0.5 mm from the resolution of the MWPCs, plus a contribution from multiple scattering of the beam particles in various materials in the beam line. Excluding the target itself, the latter contribution is 0.2 mm for a 8.9 GeV/c beam particle.

We select ‘good’ beam particles by requiring the unambiguous reconstruction of the particle trajectory with good $\chi^2$. In addition we require that the particle type is unambiguously identified. We select ‘good’ accelerator spills by requiring a minimal intensity and a ‘smooth’ variation of beam intensity across the 400 ms long spill.\(^2\)

The target was a cylinder made of high-purity (99.95%) beryllium, with a density of 1.85 g/cm\(^3\), a radius of 15 mm, and a thickness of 20.5 ± 0.1 mm (5% $\lambda_{abs}$).

The finite thickness of the target leads to a small attenuation of the number of incident beam particles. The attenuation factor is $f_{att} = 0.975$.

The size of the beam spot at the position of the target was several millimeters in diameter, determined by the setting of the beam optics and by multiple scattering. The nominal beam position\(^3\) was at $x_{beam} = y_{beam} = 0$, however, excursions by several millimeters could occur.\(^4\) A loose fiducial cut $\sqrt{x_{beam}^2 + y_{beam}^2} < 12$ mm ensured full beam acceptance. The muon and electron contaminations of the pion beam, stated above, refer to this acceptance cut.

3 The HARP large-angle detectors

Our calibration work on the HARP TPC and RPCs is described in detail in Refs. [2] and [3], and in references cited therein. In particular, we recall that static and dynamic TPC track distortions up to 10 mm have been corrected to better than 300 $\mu$m. Therefore, TPC track distortions do not affect the precision of our cross-section measurements.

\(^{2}\)A smooth variation of beam intensity eases corrections for dynamic TPC track distortions.

\(^{3}\)A right-handed Cartesian and/or spherical polar coordinate system is employed; the $z$ axis coincides with the beam line, with +$z$ pointing downstream; the coordinate origin is at the center of the beryllium target, 500 mm downstream of the TPC’s pad plane; looking downstream, the $+x$ coordinate points to the left and the $+y$ coordinate points up; the polar angle $\theta$ is the angle with respect to the $+z$ axis.

\(^{4}\)The only relevant issue is that the trajectory of each individual beam particle is known, whether shifted or not, and therefore the amount of matter to be traversed by the secondary hadrons.

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\(^{1}\)For the $-8.0$ GeV/c beam, the same electron contamination was taken as in the $+8.9$ GeV/c beam.

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Table 1  Beam instrumentation for $p/\pi^+$ and $\pi/e$ separation

| Beam momentum [GeV/c] | $p/\pi^+$ separation | $\pi/e$ separation |
|-----------------------|----------------------|--------------------|
| ±3.0                  | TOF                  | BCB (1.05 bar)    |
| ±5.0                  | TOF                  | BCB (2.05 bar)    |
| −8.0 and +8.9         | BCA (1.25 bar)       | BCB (1.50 bar)    |
| ±12.0 and ±15.0       | BCA (3.50 bar)       | BCB (3.50 bar)    |

Table 2  Contaminations of the pion beams by muons and electrons

| Beam momentum [GeV/c] | Muon fraction [%] | Electron fraction [%] |
|-----------------------|------------------|----------------------|
| ±3.0                  | 4.1 ± 0.4        | rejected             |
| ±5.0                  | 5.1 ± 0.4        | rejected             |
| −8.0                  | 1.9 ± 0.5        | 1.2 ± 0.5            |
| +8.9                  | 1.7 ± 0.5        | 1.2 ± 0.5            |
| ±12                   | 0.6 ± 0.6        | 0.5 ± 0.5            |
| ±15                   | 0.0 ± 0.5        | 0.0 ± 0.5            |
The resolution $\sigma(1/p_T)$ is typically 0.2 (GeV/c)$^{-1}$ and worsens towards small relative particle velocity $\beta$ and small polar angle $\theta$.

The absolute momentum scale is determined to be correct to better than 2%, both for positively and negatively charged particles.

The polar angle $\theta$ is measured in the TPC with a resolution of $\sim$9 mrad, for a representative angle of $\theta = 60^\circ$. To this a multiple scattering error has to be added which is $\sim$7 mrad for a proton with $p_T = 500$ MeV/c and $\theta = 60^\circ$, and $\sim$4 mrad for a pion with the same characteristics. The polar-angle scale is correct to better than 2 mrad.

The TPC measures $dE/dx$ with a resolution of 16% for a track length of 300 mm.

The intrinsic efficiency of the RPCs that surround the TPC is better than 98%.

The intrinsic time resolution of the RPCs is 127 ps and the system time-of-flight resolution (that includes the jitter of the arrival time of the beam particle at the target) is 175 ps.

To separate measured particles into species, we assign on the basis of $dE/dx$ and $\beta$ to each particle a probability of being a proton, a pion (muon), or an electron, respectively. The probabilities add up to unity, so that the number of particles is conserved. These probabilities are used for weighting when entering tracks into plots or tables.

4 Monte Carlo simulation

We used the Geant4 tool kit [14, 15] for the simulation of the HARP large-angle spectrometer.

We had expected that Geant4 would provide us with reasonably realistic spectra of secondary hadrons. We found this expectation met by Geant4's so-called QGSP_BIC physics list, but only for the secondaries from incoming beam protons with momentum less than 12 GeV/c. For the secondaries from beam protons at 12 and 15 GeV/c momentum, and from beam pions at all momenta, we found the standard physics lists of Geant4 unsuitable [16].

To overcome this problem, we built our own physics list (HARP_CDP) for the production of secondaries from incoming beam pions. It starts from Geant4’s standard QBBC physics list, but the Quark–Gluon String Model is replaced by the FRITIOF string fragmentation model for kinetic energy $E > 6$ GeV; for $E < 6$ GeV, the Bertini Cascade is used for pions, and the Binary Cascade for protons; elastic and quasi-elastic scattering is disabled. Examples of the good performance of the HARP_CDP physics list are given in Ref. [16].

5 Systematic errors

The systematic precision of our inclusive cross-sections is at the few-per-cent level, from errors in the normalization, in the momentum measurement, in particle identification, and in the corrections applied to the data.

The systematic error of the absolute flux normalization is taken as 2%. This error arises from uncertainties in the target thickness, in the contribution of large-angle scattering of beam particles, in the attenuation of beam particles in the target, and in the subtraction of the muon and electron contaminations of the beam. Another contribution comes from the removal of events with an abnormally large number of TPC hits above threshold.\footnote{Very rarely, because of apparatus malfunction, the number of TPC hits was much larger than possible for a physics event. Such events are considered unphysical and eliminated.}

The systematic error of the track finding efficiency is taken as 1% which reflects differences between results from different persons who conducted eyeball scans. We also take the statistical errors of the parameters of a fit to scan results as systematic error into account [1]. The systematic error of the correction for losses from the requirement of at least 10 TPC clusters per track is taken as 20% of the correction which itself is in the range of 5 to 30%. This estimate arose from differences between the four TPC sectors that were used in our analysis, and from the observed variations with time.

The systematic error of the $p_T$ scale is taken as 2% as discussed in Ref. [2].

The systematic errors of the proton, pion, and electron abundances are taken as 10%. We stress that errors on abundances only lead to cross-section errors in case of a strong overlap of the resolution functions of both identification variables, $dE/dx$ and $\beta$. The systematic error of the correction for migration, absorption of secondary protons and pions in materials, and for pion decay into muons, is taken as 20% of the correction, or 1% of the cross-section, whichever is larger. These estimates reflect our experience with rema

6 Cross-section results

In Tables A.1–A.36, collated in the Appendix, we give the double-differential inclusive cross-sections $d^2\sigma/dp\,d\Omega$ for all 36 combinations of incoming beam particle and secondary particle, including statistical and systematic errors. In each bin, the average momentum at the vertex and the average polar angle are also given.

The data of Tables A.1–A.36 are available in ASCII format in Ref. [17].
Cross-sections are only given if the total error is not larger than the cross-section itself. Since our track reconstruction algorithm is optimized for tracks with $p_T$ above $\sim 70$ MeV/c in the TPC volume, we do not give cross-sections from tracks with $p_T$ below this value. Because of the absorption of slow protons in the material between the vertex and the TPC gas, and with a view to keeping the correction for absorption losses below 30%, cross-sections from protons are limited to $p > 350$ MeV/c at the interaction vertex. Proton cross-sections are also not given if a 10% error on the proton energy loss in materials between the interaction vertex and the TPC volume leads to a momentum change larger than 2%. Pion cross-sections are not given if pions are separated from protons by less than twice the time-of-flight resolution.

The larger than usual error bars for the +15 GeV/c pion beam are caused by scarce statistics because the beam composition was dominated by protons.

We present in Figs. 1 to 7 what we consider salient features of our cross-sections. In these figures, we also show the data from the +8.9 GeV/c and −8.0 GeV/c beams that we published in Ref. [1].

Figure 1 shows the inclusive cross-sections of the production of protons, $\pi^+$'s, and $\pi^-$'s, from incoming protons between 3 GeV/c and 15 GeV/c momentum, as a function of their charge-signed $p_T$. The data refer to the polar-angle range $20^\circ < \theta < 30^\circ$. Figures 2 and 3 show the same for incoming $\pi^+$'s and $\pi^-$'s.

Figure 4 shows the inclusive cross-sections of the production of protons, $\pi^+$'s, and $\pi^-$'s, from incoming protons between 3 GeV/c and 15 GeV/c momentum, this time as a function of their charge-signed polar angle $\theta$. The data refer to the $p_T$ range $0.24 < p_T < 0.30$ GeV/c. In this $p_T$ range pions populate nearly all polar angles, whereas protons are absorbed at large polar angle and thus escape measurement. Figures 5 and 6 show the same for incoming $\pi^+$'s and $\pi^-$'s.

These figures highlight the rather strong differences in the production of proton, $\pi^+$ and $\pi^-$ secondaries for different beam particles and beam momenta.

In Fig. 7, we present the inclusive cross-sections of the production of secondary $\pi^+$'s and $\pi^-$'s, integrated over the momentum range $0.2 < p < 1.0$ GeV/c and the polar-angle range $30^\circ < \theta < 90^\circ$ in the forward hemisphere, as a function of the beam momentum.

7 Comparison of our results with results from other experiments

7.1 Comparison with E802 results

Experiment E802 [18] at Brookhaven National Laboratory measured secondary charged pions in the polar-angle range $5^\circ < \theta < 58^\circ$ from the interactions of +14.6 GeV/c protons with beryllium nuclei.

Figure 8 shows their published Lorentz-invariant cross-section of $\pi^+$ and $\pi^-$ production by +14.6 GeV/c protons, in the rapidity range $1.2 < y < 1.4$, as a function of $m_T - m_\pi$, where $m_T$ denotes the pion transverse mass. Their data are compared with our cross-sections from the interactions of $+15.0$ GeV/c protons with beryllium nuclei, expressed in the same unit as used by E802. Since E802 quoted only statistical errors, our data in Fig. 8 are also shown with their statistical errors.

The E802 $\pi^\pm$ cross-sections are in good agreement with our cross-sections measured nearly at the same proton beam momentum, taking into account the normalization uncertainty of (10–15)% quoted by E802. We draw attention to the good agreement of the slopes of the cross-sections over two orders of magnitude.

7.2 Comparison with E910 results

Experiment E910 [19] at Brookhaven National Laboratory measured secondary charged pions in the momentum range 0.1–6 GeV/c from the interactions of +12.3 GeV/c protons with beryllium nuclei. This experiment used a TPC for the measurement of secondaries, with a comfortably large track length of $\sim 1.5$ m. This feature, together with a magnetic field strength of 0.5 T, is of particular significance, since it permits considerably better charge identification and proton–pion separation by dE/dx than is possible in the HARP detector. Figure 9 shows their published cross-section $d^2\sigma / dp d\Omega$ of $\pi^\pm$ production by +12.3 GeV/c protons, in the polar-angle range $0.8 < \cos \theta < 0.9$. Since E910 quoted only statistical errors, our data in Fig. 9 from the interactions of $+12.0$ GeV/c protons are also shown with their statistical errors. The normalization uncertainty quoted by E910 is $\leq 5\%$.

Also here, the E910 data are shown as published, and our data are expressed in the same unit as used by E910. We draw attention to the good agreement in the $\pi^+/\pi^-$ ratio between the cross-sections from E910 and our cross-sections. See also Fig. 10(b) in Sect. 7.3.

7.3 Comparison with results from the HARP Collaboration

Figure 10(a) shows the comparison of our cross-sections of pion production by +12.0 GeV/c protons off beryllium nuclei with the ones published by the HARP Collaboration [20], in the polar-angle range $0.35 < \theta < 0.55$ rad. The latter cross-sections are plotted as published, while we expressed our cross-sections in the unit used by the HARP Collaboration. Figure 10(b) shows our ratio $\pi^+/\pi^-$ as a function of the polar angle $\theta$ in comparison with the ratios
Fig. 1 Inclusive cross-sections of the production of secondary protons, $\pi^+$'s, and $\pi^-$'s, by protons on beryllium nuclei, in the polar-angle range $20^\circ < \theta < 30^\circ$, for different proton beam momenta, as a function of the charge-signed $p_T$ of the secondaries; the shown errors are total errors.
Fig. 2 Inclusive cross-sections of the production of secondary protons, $\pi^+$'s, and $\pi^-$'s, by $\pi^+$'s on beryllium nuclei, in the polar-angle range $20^\circ < \theta < 30^\circ$, for different $\pi^+$ beam momenta, as a function of the charge-signed $p_T$ of the secondaries; the shown errors are total errors.
Fig. 3 Inclusive cross-sections of the production of secondary protons, π⁺'s, and π⁻'s, by π⁻'s on beryllium nuclei, in the polar-angle range $20^\circ < \theta < 30^\circ$, for different π⁻ beam momenta, as a function of the charge-signed $p_T$ of the secondaries; the shown errors are total errors.
Fig. 4 Inclusive cross-sections of the production of secondary protons, π⁺'s, and π⁻'s, with $p_T$ in the range $0.24-0.30$ GeV/c, by protons on beryllium nuclei, for different proton beam momenta, as a function of the charge-signed polar angle $\theta$ of the secondaries; the shown errors are total errors.
Fig. 5  Inclusive cross-sections of the production of secondary protons, $\pi^+$'s, and $\pi^-$'s, with $p_T$ in the range 0.24–0.30 GeV/c, by $\pi^+$'s on beryllium nuclei, for different $\pi^+$ beam momenta, as a function of the charge-signed polar angle $\theta$ of the secondaries; the shown errors are total errors.
Fig. 6 Inclusive cross-sections of the production of secondary protons, $\pi^+$'s, and $\pi^-$'s, with $p_T$ in the range $0.24-0.30$ GeV/c, by $\pi^-$'s on beryllium nuclei, for different $\pi^-$ beam momenta, as a function of the charge-signed polar angle $\theta$ of the secondaries; the shown errors are total errors.
Fig. 7 Inclusive cross-sections of the production of secondary $\pi^+$'s and $\pi^-$'s, integrated over the momentum range $0.2 < p < 1.0$ GeV/c and the polar-angle range $30^\circ < \theta < 90^\circ$, from the interactions on beryllium nuclei of protons (top row), $\pi^+$'s (middle row), and $\pi^-$'s (bottom row), as a function of the beam momentum; the shown errors are total errors and mostly smaller than the symbol size.
Fig. 8 Comparison of our cross-sections (black circles) of $\pi^\pm$ production by $+15.0\text{ GeV/c}$ protons off beryllium nuclei, with the cross-sections published by the E802 Collaboration for the proton beam momentum of $+14.6\text{ GeV/c}$ (open circles); all errors are statistical only.

Fig. 9 Comparison of our cross-sections of $\pi^\pm$ production by $+12.0\text{ GeV/c}$ protons off beryllium nuclei with the cross-sections published by the E910 Collaboration for the proton beam momentum of $+12.3\text{ GeV/c}$ (open circles); all errors are statistical only.

Published by the E910 Collaboration (at the slightly different proton beam momentum of $+12.3\text{ GeV/c}$) and by the HARP Collaboration.

The discrepancy between our results and those published by the HARP Collaboration is evident. We note the difference especially of the $\pi^+$ cross-section, and the difference in the reported momentum range. The discrepancy is even more serious as the same data set has been analysed by both groups.

We hold that the discrepancy is caused by problems in the HARP Collaboration’s data analysis. They result primarily, but not exclusively, from a lack of understanding TPC track distortions and RPC timing signals. These problems, together with others that affect the HARP Collaboration’s data analysis, are discussed in detail in Refs. [4, 5, 21–23] and in the Appendix of Ref. [1].

8 Summary

From the analysis of data from the HARP large-angle spectrometer (polar angle $\theta$ in the range $20^\circ < \theta < 125^\circ$), double-differential cross-sections $d^2\sigma/dp d\Omega$ of the production of secondary protons, $\pi^+$’s, and $\pi^-$’s, have been
obtained. The incoming beam particles were protons and pions with momenta from $\pm 3$ to $\pm 15 \text{ GeV}/c$, impinging on a 5\% $\lambda_{\text{abs}}$ thick stationary beryllium target. Our cross-sections for $\pi^+$ and $\pi^-$ production agree with results from the BNL experiments E802 and E910 but disagree with the results from the HARP Collaboration that were obtained from the same raw data.

Acknowledgements  We are greatly indebted to many technical collaborators whose diligent and hard work made the HARP detector a well-functioning instrument. We thank all HARP colleagues who devoted time and effort to the design and construction of the detector, to data taking, and to setting up the computing and software infrastructure. We express our sincere gratitude to HARP’s funding agencies for their support.

### Appendix: Cross-section tables

Table A.1 Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c str)] of the production of protons in $p + \text{Be} \rightarrow p + X$ interactions with $+3.0 \text{ GeV}/c$ beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/$c$, polar angle $\theta$ in degrees

| $p_T$ | 20 $\leq \theta < 30$ | 30 $\leq \theta < 40$ |
|-------|------------------|------------------|
| $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.20–0.24 | 0.221 | 24.7 | 58.52 $\pm$ 2.79 $\pm$ 3.92 | 0.271 | 34.9 | 54.76 $\pm$ 2.16 $\pm$ 2.96 |
| 0.24–0.30 | 0.269 | 25.1 | 64.24 $\pm$ 2.38 $\pm$ 3.63 | 0.330 | 35.1 | 51.23 $\pm$ 2.05 $\pm$ 2.50 |
| 0.30–0.36 | 0.329 | 24.9 | 58.05 $\pm$ 2.24 $\pm$ 2.98 | 0.390 | 34.9 | 52.43 $\pm$ 2.11 $\pm$ 2.44 |
| 0.36–0.42 | 0.390 | 24.9 | 57.81 $\pm$ 2.23 $\pm$ 2.75 | 0.460 | 34.9 | 43.86 $\pm$ 1.69 $\pm$ 1.83 |
| 0.42–0.50 | 0.459 | 24.8 | 54.37 $\pm$ 1.85 $\pm$ 2.27 | 0.549 | 34.8 | 35.55 $\pm$ 1.37 $\pm$ 1.47 |
| 0.50–0.60 | 0.548 | 24.8 | 43.78 $\pm$ 1.50 $\pm$ 1.80 | 0.654 | 34.9 | 24.47 $\pm$ 1.03 $\pm$ 1.26 |
| 0.60–0.72 | 0.656 | 24.8 | 35.71 $\pm$ 1.28 $\pm$ 1.73 | 0.800 | 35.0 | 16.01 $\pm$ 0.71 $\pm$ 1.08 |
| 0.72–0.90 | 0.800 | 35.0 | 16.01 $\pm$ 0.71 $\pm$ 1.08 |

| $p_T$ | 40 $\leq \theta < 50$ | 50 $\leq \theta < 60$ |
|-------|------------------|------------------|
| $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.30–0.36 | 0.332 | 45.0 | 45.49 $\pm$ 1.88 $\pm$ 2.08 | 0.390 | 55.1 | 41.48 $\pm$ 1.80 $\pm$ 1.82 |
| 0.36–0.42 | 0.391 | 45.0 | 46.83 $\pm$ 1.96 $\pm$ 2.13 | 0.461 | 55.3 | 35.87 $\pm$ 1.47 $\pm$ 1.49 |
| 0.42–0.50 | 0.461 | 45.1 | 37.82 $\pm$ 1.52 $\pm$ 1.55 | 0.551 | 55.0 | 32.08 $\pm$ 1.27 $\pm$ 1.42 |
| 0.50–0.60 | 0.551 | 45.0 | 33.10 $\pm$ 1.32 $\pm$ 1.44 | 0.663 | 55.2 | 24.47 $\pm$ 1.08 $\pm$ 1.41 |
| 0.60–0.72 | 0.659 | 44.9 | 27.41 $\pm$ 1.14 $\pm$ 1.42 | 0.803 | 54.7 | 12.21 $\pm$ 0.63 $\pm$ 1.00 |
| 0.72–0.90 | 0.806 | 44.9 | 13.53 $\pm$ 0.64 $\pm$ 0.96 | 1.030 | 54.7 | 16.9 $\pm$ 0.14 $\pm$ 0.32 |
| 0.90–1.25 | 1.037 | 44.8 | 2.97 $\pm$ 0.20 $\pm$ 0.46 | 0.389 | 113.6 | 6.77 $\pm$ 0.48 $\pm$ 0.51 |

| $p_T$ | 60 $\leq \theta < 75$ | 75 $\leq \theta < 90$ |
|-------|------------------|------------------|
| $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.36–0.42 | 0.391 | 67.3 | 40.49 $\pm$ 1.46 $\pm$ 1.60 | 0.459 | 81.5 | 20.38 $\pm$ 0.89 $\pm$ 0.97 |
| 0.42–0.50 | 0.460 | 67.2 | 35.62 $\pm$ 1.20 $\pm$ 1.31 | 0.547 | 81.4 | 13.19 $\pm$ 0.65 $\pm$ 0.81 |
| 0.50–0.60 | 0.549 | 67.1 | 30.01 $\pm$ 1.01 $\pm$ 1.33 | 0.660 | 81.3 | 6.31 $\pm$ 0.44 $\pm$ 0.69 |
| 0.60–0.72 | 0.660 | 66.9 | 14.59 $\pm$ 0.65 $\pm$ 0.94 | 0.791 | 81.1 | 1.68 $\pm$ 0.19 $\pm$ 0.26 |
| 0.72–0.90 | 0.803 | 66.4 | 5.20 $\pm$ 0.32 $\pm$ 0.57 | 1.031 | 81.5 | 0.17 $\pm$ 0.04 $\pm$ 0.09 |
| 0.90–1.25 | 1.027 | 66.1 | 0.67 $\pm$ 0.08 $\pm$ 0.17 | 0.389 | 113.6 | 6.77 $\pm$ 0.48 $\pm$ 0.51 |

| $p_T$ | 90 $\leq \theta < 105$ | 105 $\leq \theta < 125$ |
|-------|------------------|------------------|
| $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.36–0.42 | 0.458 | 96.5 | 10.78 $\pm$ 0.64 $\pm$ 0.79 | 0.456 | 113.0 | 4.70 $\pm$ 0.36 $\pm$ 0.40 |
| 0.42–0.50 | 0.549 | 96.0 | 5.78 $\pm$ 0.42 $\pm$ 0.52 | 0.539 | 111.7 | 1.45 $\pm$ 0.20 $\pm$ 0.21 |
| 0.50–0.60 | 0.659 | 95.5 | 1.58 $\pm$ 0.23 $\pm$ 0.23 | 0.659 | 112.3 | 0.23 $\pm$ 0.08 $\pm$ 0.08 |
| 0.60–0.72 | 0.785 | 94.8 | 0.38 $\pm$ 0.11 $\pm$ 0.12 |
Table A.2  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^+$’s in $p +$ Be → $\pi^+$ + X interactions with +3.0 GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|-------------------|-------------------|
|       | ($p_T$) | ($\theta$) | $d^2\sigma/dp\,d\Omega$ | ($p_T$) | ($\theta$) | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.116 | 24.5 | 26.72 | ± | 2.52 | ± | 2.91 | 0.113 | 35.8 | 25.91 | ± | 2.50 | ± | 3.03 |
| 0.13–0.16 | 0.146 | 24.6 | 38.71 | ± | 2.79 | ± | 3.07 | 0.146 | 34.7 | 34.51 | ± | 2.55 | ± | 2.95 |
| 0.16–0.20 | 0.180 | 25.0 | 54.17 | ± | 2.77 | ± | 3.39 | 0.179 | 34.5 | 36.55 | ± | 2.23 | ± | 2.41 |
| 0.20–0.24 | 0.220 | 24.9 | 59.69 | ± | 2.68 | ± | 3.04 | 0.220 | 34.8 | 39.25 | ± | 2.24 | ± | 2.35 |
| 0.24–0.30 | 0.269 | 25.0 | 34.60 | ± | 1.75 | ± | 1.83 | 0.268 | 34.6 | 33.40 | ± | 1.69 | ± | 1.72 |
| 0.30–0.36 | 0.328 | 25.3 | 27.87 | ± | 1.58 | ± | 1.53 | 0.329 | 35.2 | 24.06 | ± | 1.44 | ± | 1.35 |
| 0.36–0.42 | 0.388 | 25.0 | 16.61 | ± | 1.17 | ± | 1.18 | 0.386 | 35.1 | 16.13 | ± | 1.16 | ± | 1.04 |
| 0.42–0.50 | 0.458 | 25.1 | 11.44 | ± | 0.83 | ± | 0.77 | 0.458 | 34.8 | 9.70 | ± | 0.79 | ± | 0.65 |
| 0.50–0.60 | 0.548 | 25.0 | 4.88 | ± | 0.44 | ± | 0.45 | 0.549 | 34.9 | 5.58 | ± | 0.50 | ± | 0.46 |
| 0.60–0.72 | 0.656 | 24.9 | 3.72 | ± | 0.33 | ± | 0.58 | 0.654 | 35.3 | 3.21 | ± | 0.34 | ± | 0.40 |
| 0.72–0.90 | 0.798 | 34.7 | 1.73 | ± | 0.18 | ± | 0.59 |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|-------------------|-------------------|
|       | ($p_T$) | ($\theta$) | $d^2\sigma/dp\,d\Omega$ | ($p_T$) | ($\theta$) | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.116 | 45.4 | 20.82 | ± | 2.28 | ± | 2.40 |
| 0.13–0.16 | 0.146 | 45.0 | 27.15 | ± | 2.32 | ± | 2.26 |
| 0.16–0.20 | 0.180 | 45.0 | 35.34 | ± | 2.19 | ± | 2.32 |
| 0.20–0.24 | 0.219 | 44.4 | 32.30 | ± | 2.05 | ± | 2.01 |
| 0.24–0.30 | 0.271 | 44.6 | 25.09 | ± | 1.47 | ± | 1.44 |
| 0.30–0.36 | 0.329 | 44.6 | 18.15 | ± | 1.23 | ± | 1.10 |
| 0.36–0.42 | 0.391 | 44.7 | 12.60 | ± | 1.02 | ± | 0.86 |
| 0.42–0.50 | 0.457 | 44.9 | 8.79 | ± | 0.77 | ± | 0.63 |
| 0.50–0.60 | 0.544 | 45.1 | 3.35 | ± | 0.41 | ± | 0.29 |
| 0.60–0.72 | 0.649 | 44.4 | 2.43 | ± | 0.31 | ± | 0.33 |
| 0.72–0.90 | 0.806 | 44.0 | 1.24 | ± | 0.17 | ± | 0.33 |
| 0.90–1.25 | 1.048 | 54.2 | 0.14 | ± | 0.03 | ± | 0.04 |

| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|-------|-------------------|-------------------|
|       | ($p_T$) | ($\theta$) | $d^2\sigma/dp\,d\Omega$ | ($p_T$) | ($\theta$) | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.145 | 67.5 | 19.57 | ± | 1.66 | ± | 1.71 |
| 0.16–0.20 | 0.180 | 67.5 | 21.09 | ± | 1.41 | ± | 1.39 |
| 0.20–0.24 | 0.221 | 67.3 | 20.59 | ± | 1.36 | ± | 1.29 |
| 0.24–0.30 | 0.269 | 67.0 | 13.53 | ± | 0.88 | ± | 0.76 |
| 0.30–0.36 | 0.329 | 66.6 | 8.32 | ± | 0.69 | ± | 0.53 |
| 0.36–0.42 | 0.390 | 66.8 | 7.22 | ± | 0.65 | ± | 0.58 |
| 0.42–0.50 | 0.461 | 66.4 | 3.92 | ± | 0.41 | ± | 0.33 |
| 0.50–0.60 | 0.549 | 66.7 | 2.49 | ± | 0.29 | ± | 0.26 |
| 0.60–0.72 | 0.659 | 67.0 | 1.01 | ± | 0.17 | ± | 0.16 |
| 0.72–0.90 | 0.803 | 66.0 | 0.34 | ± | 0.08 | ± | 0.11 |

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|-------------------|-------------------|
|       | ($p_T$) | ($\theta$) | $d^2\sigma/dp\,d\Omega$ | ($p_T$) | ($\theta$) | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.145 | 97.6 | 14.79 | ± | 1.42 | ± | 1.45 |
| 0.16–0.20 | 0.183 | 97.8 | 15.13 | ± | 1.19 | ± | 1.14 |
| 0.20–0.24 | 0.218 | 97.3 | 11.01 | ± | 1.01 | ± | 0.87 |
| 0.24–0.30 | 0.264 | 96.7 | 6.15 | ± | 0.61 | ± | 0.49 |
| 0.30–0.36 | 0.330 | 96.6 | 3.62 | ± | 0.46 | ± | 0.39 |
| 0.36–0.42 | 0.386 | 96.2 | 2.62 | ± | 0.40 | ± | 0.36 |
| 0.42–0.50 | 0.457 | 95.5 | 0.87 | ± | 0.19 | ± | 0.15 |
| 0.50–0.60 | 0.548 | 96.3 | 0.40 | ± | 0.11 | ± | 0.11 |
| 0.60–0.72 | 0.662 | 92.0 | 0.11 | ± | 0.05 | ± | 0.06 |
Table A.3  Double-differential inclusive cross-section $d^2\sigma/dp
d\Omega$ [mb/(GeV/c ster)] of the production of $\pi^-$’s in $p + Be \rightarrow \pi^- + X$ interactions with $+3.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees.

| $p_T$ | $20 < \theta < 30$ | | $30 < \theta < 40$ | |
|------|-----------------|-----------------|-----------------|-----------------|
|      | (pt) (\theta)   | $d^2\sigma/dp
d\Omega$              | (pt) (\theta)   | $d^2\sigma/dp
d\Omega$              |
| 0.10-0.13 | 0.115 25.5 17.40 ± 2.00 ± 2.06 | 0.115 34.5 19.48 ± 2.02 ± 2.28 |
| 0.13-0.16 | 0.145 24.7 24.57 ± 2.20 ± 2.55 | 0.146 34.3 17.52 ± 1.79 ± 1.73 |
| 0.16-0.20 | 0.179 24.9 23.25 ± 1.76 ± 1.91 | 0.181 34.9 19.27 ± 1.55 ± 1.57 |
| 0.20-0.24 | 0.220 24.9 21.48 ± 1.70 ± 1.69 | 0.219 34.7 22.12 ± 1.69 ± 1.65 |
| 0.24-0.30 | 0.268 25.2 15.72 ± 1.18 ± 1.09 | 0.270 35.0 16.90 ± 1.19 ± 1.17 |
| 0.30-0.36 | 0.327 25.2 9.18 ± 0.90 ± 0.73 | 0.330 34.8 11.79 ± 0.99 ± 0.85 |
| 0.36-0.42 | 0.391 24.7 5.31 ± 0.68 ± 0.54 | 0.390 35.3 7.60 ± 0.81 ± 0.66 |
| 0.42-0.50 | 0.453 25.4 4.17 ± 0.53 ± 0.47 | 0.461 34.8 3.53 ± 0.48 ± 0.37 |
| 0.50-0.60 | 0.537 26.2 1.39 ± 0.27 ± 0.24 | 0.551 34.8 2.62 ± 0.37 ± 0.37 |
| 0.60-0.72 | 0.645 24.9 0.38 ± 0.13 ± 0.12 | 0.647 35.5 1.07 ± 0.22 ± 0.24 |
| 0.72-0.90 |                     | 0.767 36.4 0.25 ± 0.09 ± 0.13 |
Table A.4 Double-differential inclusive cross-section $d^2\sigma/dp\Omega$ [mb/(GeV/c sr)] of the production of protons in $\pi^+ + \text{Be} \rightarrow p + \text{X}$ interactions with +3.0 GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | | $30 < \theta < 40$ | |
|-------|-------------------|------------------|-------------------|------------------|
|       | $\langle p_T \rangle$ | $\langle\theta\rangle$ | $d^2\sigma/dp\Omega$ | $\langle p_T \rangle$ | $\langle\theta\rangle$ | $d^2\sigma/dp\Omega$ |
| 0.20–0.24 | 0.220 | 24.9 | 50.34 ± 1.88 ± 3.48 | 0.270 | 34.9 | 43.21 ± 1.37 ± 2.53 |
| 0.24–0.30 | 0.271 | 24.9 | 53.95 ± 1.58 ± 3.07 | 0.329 | 35.1 | 43.86 ± 1.37 ± 2.23 |
| 0.30–0.36 | 0.330 | 24.9 | 47.07 ± 1.46 ± 2.45 | 0.389 | 34.9 | 38.22 ± 1.30 ± 1.77 |
| 0.36–0.42 | 0.390 | 25.1 | 42.80 ± 1.37 ± 2.06 | 0.459 | 34.9 | 36.01 ± 1.10 ± 1.48 |
| 0.42–0.50 | 0.460 | 24.9 | 39.00 ± 1.11 ± 1.73 | 0.547 | 35.0 | 31.06 ± 0.91 ± 1.31 |
| 0.50–0.60 | 0.549 | 25.0 | 32.73 ± 0.91 ± 1.38 | 0.654 | 34.8 | 21.63 ± 0.68 ± 1.10 |
| 0.60–0.72 | 0.655 | 25.1 | 24.05 ± 0.73 ± 1.26 | 0.799 | 35.0 | 14.33 ± 0.47 ± 0.97 |

| $p_T$ | $40 < \theta < 50$ | | $50 < \theta < 60$ | |
|-------|-------------------|------------------|-------------------|------------------|
|       | $\langle p_T \rangle$ | $\langle\theta\rangle$ | $d^2\sigma/dp\Omega$ | $\langle p_T \rangle$ | $\langle\theta\rangle$ | $d^2\sigma/dp\Omega$ |
| 0.30–0.36 | 0.331 | 44.9 | 40.03 ± 1.27 ± 2.00 | 0.392 | 55.0 | 34.14 ± 1.18 ± 1.68 |
| 0.36–0.42 | 0.390 | 44.9 | 38.72 ± 1.29 ± 1.78 | 0.461 | 54.9 | 28.83 ± 0.95 ± 1.26 |
| 0.42–0.50 | 0.461 | 45.2 | 30.71 ± 1.00 ± 1.31 | 0.549 | 54.9 | 22.78 ± 0.78 ± 1.08 |
| 0.50–0.60 | 0.551 | 44.9 | 26.80 ± 0.86 ± 1.14 | 0.658 | 55.0 | 17.89 ± 0.67 ± 1.06 |
| 0.60–0.72 | 0.659 | 45.0 | 20.70 ± 0.71 ± 1.15 | 0.804 | 54.9 | 9.14 ± 0.39 ± 0.67 |
| 0.72–0.90 | 0.804 | 45.2 | 11.04 ± 0.41 ± 0.77 | 1.035 | 54.6 | 1.45 ± 0.09 ± 0.21 |
| 0.90–1.25 | 1.040 | 45.0 | 2.59 ± 0.13 ± 0.30 | |

| $p_T$ | $60 < \theta < 75$ | | $75 < \theta < 90$ | |
|-------|-------------------|------------------|-------------------|------------------|
|       | $\langle p_T \rangle$ | $\langle\theta\rangle$ | $d^2\sigma/dp\Omega$ | $\langle p_T \rangle$ | $\langle\theta\rangle$ | $d^2\sigma/dp\Omega$ |
| 0.36–0.42 | 0.391 | 67.4 | 32.41 ± 0.95 ± 1.35 | 0.460 | 81.9 | 19.96 ± 0.65 ± 1.00 |
| 0.42–0.50 | 0.461 | 67.3 | 28.38 ± 0.78 ± 1.06 | 0.548 | 82.0 | 12.18 ± 0.45 ± 0.77 |
| 0.50–0.60 | 0.549 | 67.0 | 22.20 ± 0.63 ± 1.01 | 0.655 | 81.4 | 5.92 ± 0.30 ± 0.52 |
| 0.60–0.72 | 0.658 | 67.0 | 11.22 ± 0.41 ± 0.73 | 0.804 | 82.2 | 2.17 ± 0.15 ± 0.29 |
| 0.72–0.90 | 0.803 | 66.7 | 4.69 ± 0.22 ± 0.46 | 1.035 | 81.3 | 0.24 ± 0.04 ± 0.06 |
| 0.90–1.25 | 1.041 | 66.8 | 0.71 ± 0.06 ± 0.14 | |

| $p_T$ | $90 < \theta < 105$ | | $105 < \theta < 125$ | |
|-------|-------------------|------------------|-------------------|------------------|
|       | $\langle p_T \rangle$ | $\langle\theta\rangle$ | $d^2\sigma/dp\Omega$ | $\langle p_T \rangle$ | $\langle\theta\rangle$ | $d^2\sigma/dp\Omega$ |
| 0.36–0.42 | 0.389 | 114.0 | 8.63 ± 0.40 ± 0.61 | 0.459 | 113.8 | 5.58 ± 0.29 ± 0.45 |
| 0.42–0.50 | 0.459 | 97.0 | 12.05 ± 0.50 ± 0.88 | 0.544 | 113.0 | 2.68 ± 0.19 ± 0.31 |
| 0.50–0.60 | 0.546 | 96.7 | 6.52 ± 0.32 ± 0.56 | 0.649 | 113.3 | 0.52 ± 0.08 ± 0.11 |
| 0.60–0.72 | 0.658 | 96.4 | 2.78 ± 0.20 ± 0.34 | 0.794 | 111.5 | 0.09 ± 0.03 ± 0.04 |
| 0.72–0.90 | 0.798 | 95.9 | 0.68 ± 0.09 ± 0.13 | 0.918 | 95.4 | 0.05 ± 0.02 ± 0.04 |
Table A.5  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^+$'s in $\pi^+ + Be \rightarrow \pi^+ + X$ interactions with $+3.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | 20 $< \theta < 30$ | 30 $< \theta < 40$ |
|-------|--------------------|--------------------|
|       | $(p_T)$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.115 | 24.8 | 43.47 ± 2.34 ± 4.31 | 0.115 | 34.9 | 33.36 ± 2.01 ± 3.40 |
| 0.13–0.16 | 0.145 | 24.8 | 50.46 ± 2.29 ± 3.82 | 0.146 | 34.5 | 36.70 ± 1.89 ± 2.97 |
| 0.16–0.20 | 0.181 | 24.7 | 64.45 ± 2.17 ± 3.95 | 0.181 | 34.9 | 47.62 ± 1.84 ± 3.14 |
| 0.20–0.24 | 0.220 | 24.8 | 67.24 ± 2.18 ± 3.57 | 0.220 | 34.7 | 55.06 ± 1.92 ± 3.08 |
| 0.24–0.30 | 0.270 | 24.9 | 66.04 ± 1.76 ± 2.86 | 0.270 | 34.8 | 53.58 ± 1.55 ± 2.50 |
| 0.30–0.36 | 0.329 | 24.9 | 59.60 ± 1.66 ± 2.52 | 0.329 | 34.8 | 47.63 ± 1.46 ± 2.11 |
| 0.36–0.42 | 0.389 | 24.9 | 47.34 ± 1.46 ± 1.99 | 0.389 | 34.7 | 36.43 ± 1.26 ± 1.64 |
| 0.42–0.50 | 0.460 | 25.0 | 35.97 ± 1.08 ± 1.66 | 0.458 | 34.9 | 32.72 ± 1.05 ± 1.51 |
| 0.50–0.60 | 0.548 | 24.9 | 24.39 ± 0.76 ± 1.47 | 0.547 | 35.0 | 20.98 ± 0.72 ± 1.21 |
| 0.60–0.72 | 0.657 | 25.0 | 17.10 ± 0.60 ± 1.49 | 0.654 | 34.9 | 13.91 ± 0.53 ± 1.12 |
| 0.72–0.90 | 0.798 | 34.7 | 9.18 ± 0.37 ± 1.12 |

| $p_T$ | 40 $< \theta < 50$ | 50 $< \theta < 60$ |
|-------|--------------------|--------------------|
|       | $(p_T)$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.116 | 45.0 | 32.76 ± 2.06 ± 3.31 | 0.145 | 54.9 | 32.66 ± 1.91 ± 2.70 |
| 0.13–0.16 | 0.146 | 44.7 | 38.57 ± 2.00 ± 3.15 | 0.180 | 54.8 | 35.10 ± 1.63 ± 2.29 |
| 0.16–0.20 | 0.181 | 44.7 | 38.32 ± 1.65 ± 2.58 | 0.220 | 54.5 | 33.05 ± 1.51 ± 2.00 |
| 0.20–0.24 | 0.220 | 44.8 | 40.72 ± 1.67 ± 2.39 | 0.270 | 54.7 | 32.36 ± 1.22 ± 1.57 |
| 0.24–0.30 | 0.271 | 44.8 | 42.43 ± 1.38 ± 2.01 | 0.331 | 54.7 | 27.80 ± 1.12 ± 1.28 |
| 0.30–0.36 | 0.331 | 44.6 | 33.97 ± 1.21 ± 1.55 | 0.390 | 54.9 | 24.49 ± 1.06 ± 1.18 |
| 0.36–0.42 | 0.391 | 44.7 | 29.63 ± 1.14 ± 1.41 | 0.461 | 54.9 | 18.68 ± 0.80 ± 1.00 |
| 0.42–0.50 | 0.460 | 44.7 | 24.72 ± 0.93 ± 1.18 | 0.550 | 54.7 | 13.98 ± 0.61 ± 0.90 |
| 0.50–0.60 | 0.551 | 44.7 | 17.94 ± 0.69 ± 1.06 | 0.660 | 54.6 | 8.57 ± 0.44 ± 0.72 |
| 0.60–0.72 | 0.662 | 44.6 | 12.72 ± 0.53 ± 0.97 | 0.800 | 54.7 | 4.44 ± 0.27 ± 0.50 |
| 0.72–0.90 | 0.802 | 44.5 | 6.08 ± 0.30 ± 0.67 | 1.026 | 54.3 | 0.69 ± 0.06 ± 0.14 |

| $p_T$ | 60 $< \theta < 75$ | 75 $< \theta < 90$ |
|-------|--------------------|--------------------|
|       | $(p_T)$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.146 | 67.2 | 27.36 ± 1.41 ± 2.13 | 0.145 | 82.3 | 23.85 ± 1.33 ± 1.95 |
| 0.16–0.20 | 0.180 | 67.4 | 32.26 ± 1.27 ± 1.96 | 0.181 | 82.2 | 27.84 ± 1.17 ± 1.73 |
| 0.20–0.24 | 0.220 | 67.5 | 28.37 ± 1.15 ± 1.62 | 0.219 | 82.1 | 22.35 ± 1.04 ± 1.36 |
| 0.24–0.30 | 0.270 | 67.3 | 23.71 ± 0.86 ± 1.13 | 0.269 | 82.1 | 17.37 ± 0.74 ± 0.91 |
| 0.30–0.36 | 0.331 | 67.2 | 20.19 ± 0.79 ± 0.93 | 0.331 | 81.5 | 12.76 ± 0.63 ± 0.71 |
| 0.36–0.42 | 0.392 | 67.1 | 16.77 ± 0.73 ± 0.82 | 0.389 | 81.1 | 10.39 ± 0.57 ± 0.68 |
| 0.42–0.50 | 0.461 | 66.9 | 12.41 ± 0.53 ± 0.71 | 0.460 | 82.3 | 6.55 ± 0.39 ± 0.51 |
| 0.50–0.60 | 0.550 | 66.4 | 8.58 ± 0.39 ± 0.63 | 0.552 | 82.0 | 4.47 ± 0.29 ± 0.44 |
| 0.60–0.72 | 0.659 | 66.6 | 4.59 ± 0.27 ± 0.47 | 0.658 | 81.5 | 2.01 ± 0.17 ± 0.27 |
| 0.72–0.90 | 0.793 | 66.1 | 1.75 ± 0.13 ± 0.24 | 0.809 | 81.6 | 0.56 ± 0.06 ± 0.12 |
| 0.90–1.25 | 1.029 | 66.0 | 0.20 ± 0.02 ± 0.05 | 1.035 | 82.4 | 0.05 ± 0.01 ± 0.03 |
Table A.5  (Continued)

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|---------------------|---------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ |
| 0.13–0.16 | 0.146 | 97.0 | 19.93 ± 1.20 ± 1.62 | 0.145 | 114.6 | 20.18 ± 1.07 ± 1.46 |
| 0.16–0.20 | 0.179 | 97.4 | 24.56 ± 1.12 ± 1.53 | 0.180 | 114.2 | 17.84 ± 0.83 ± 1.01 |
| 0.20–0.24 | 0.220 | 96.8 | 19.59 ± 0.98 ± 1.16 | 0.219 | 114.1 | 11.22 ± 0.64 ± 0.69 |
| 0.24–0.30 | 0.269 | 96.8 | 12.11 ± 0.62 ± 0.66 | 0.267 | 113.7 | 6.86 ± 0.41 ± 0.48 |
| 0.30–0.36 | 0.329 | 96.3 | 9.74 ± 0.55 ± 0.67 | 0.329 | 114.2 | 4.83 ± 0.34 ± 0.45 |
| 0.36–0.42 | 0.390 | 97.1 | 6.52 ± 0.46 ± 0.57 | 0.390 | 113.4 | 2.61 ± 0.24 ± 0.33 |
| 0.42–0.50 | 0.460 | 96.3 | 3.56 ± 0.29 ± 0.38 | 0.458 | 112.8 | 1.44 ± 0.15 ± 0.23 |
| 0.50–0.60 | 0.549 | 95.9 | 1.84 ± 0.18 ± 0.26 | 0.545 | 111.8 | 0.39 ± 0.06 ± 0.10 |
| 0.60–0.72 | 0.657 | 96.6 | 0.69 ± 0.09 ± 0.19 | 0.640 | 111.3 | 0.23 ± 0.05 ± 0.09 |
| 0.72–0.90 | 0.786 | 95.8 | 0.16 ± 0.03 ± 0.05 | 0.762 | 109.6 | 0.18 ± 0.04 ± 0.04 |

Table A.6  Double-differential inclusive cross-section $d^2\sigma/dp d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^-$'s in $p^+ + Be \rightarrow \pi^- + X$ interactions with $+3.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|---------------------|---------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ |
| 0.10–0.13 | 0.116 | 24.7 | 30.88 ± 1.92 ± 3.72 | 0.116 | 34.5 | 22.19 ± 1.56 ± 2.72 |
| 0.13–0.16 | 0.145 | 24.6 | 37.24 ± 1.96 ± 3.16 | 0.146 | 35.0 | 31.28 ± 1.75 ± 3.34 |
| 0.16–0.20 | 0.180 | 24.9 | 40.74 ± 1.69 ± 2.75 | 0.181 | 34.8 | 29.45 ± 1.39 ± 2.40 |
| 0.20–0.24 | 0.220 | 24.9 | 44.76 ± 1.77 ± 2.68 | 0.220 | 34.8 | 32.04 ± 1.46 ± 2.08 |
| 0.24–0.30 | 0.269 | 25.0 | 37.20 ± 1.30 ± 1.80 | 0.269 | 34.8 | 31.91 ± 1.17 ± 1.72 |
| 0.30–0.36 | 0.328 | 24.9 | 33.42 ± 1.24 ± 1.54 | 0.329 | 34.8 | 27.38 ± 1.09 ± 1.41 |
| 0.36–0.42 | 0.389 | 25.1 | 26.86 ± 1.12 ± 1.35 | 0.388 | 34.8 | 21.11 ± 0.96 ± 1.16 |
| 0.42–0.50 | 0.456 | 25.0 | 18.55 ± 0.80 ± 1.06 | 0.457 | 34.6 | 15.18 ± 0.71 ± 0.89 |
| 0.50–0.60 | 0.543 | 25.0 | 9.36 ± 0.50 ± 0.68 | 0.543 | 34.8 | 9.29 ± 0.50 ± 0.70 |
| 0.60–0.72 | 0.651 | 25.0 | 5.11 ± 0.35 ± 0.52 | 0.652 | 34.5 | 4.87 ± 0.34 ± 0.52 |
| 0.72–0.90 | 0.784 | 35.0 | 1.98 ± 0.19 ± 0.26 | 0.762 | 39.6 | 1.98 ± 0.19 ± 0.26 |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|---------------------|---------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ |
| 0.10–0.13 | 0.115 | 44.6 | 21.93 ± 1.62 ± 2.45 | 0.116 | 54.6 | 23.61 ± 1.58 ± 2.20 |
| 0.13–0.16 | 0.144 | 44.7 | 26.26 ± 1.62 ± 2.46 | 0.146 | 54.6 | 23.61 ± 1.58 ± 2.20 |
| 0.16–0.20 | 0.180 | 44.6 | 26.11 ± 1.34 ± 1.95 | 0.180 | 54.7 | 21.65 ± 1.22 ± 1.59 |
| 0.20–0.24 | 0.219 | 44.8 | 25.18 ± 1.30 ± 1.69 | 0.219 | 54.6 | 22.61 ± 1.26 ± 1.74 |
| 0.24–0.30 | 0.267 | 44.8 | 25.29 ± 1.05 ± 1.36 | 0.269 | 54.9 | 18.22 ± 0.90 ± 1.12 |
| 0.30–0.36 | 0.327 | 44.3 | 22.08 ± 1.00 ± 1.25 | 0.328 | 54.8 | 15.85 ± 0.84 ± 0.92 |
| 0.36–0.42 | 0.387 | 44.6 | 16.81 ± 0.85 ± 1.06 | 0.388 | 54.5 | 11.86 ± 0.73 ± 0.76 |
| 0.42–0.50 | 0.456 | 44.9 | 12.20 ± 0.65 ± 0.81 | 0.455 | 54.9 | 9.31 ± 0.57 ± 0.64 |
| 0.50–0.60 | 0.540 | 44.8 | 6.91 ± 0.43 ± 0.56 | 0.541 | 55.0 | 5.19 ± 0.38 ± 0.46 |
| 0.60–0.72 | 0.653 | 44.5 | 3.73 ± 0.29 ± 0.41 | 0.647 | 54.6 | 2.77 ± 0.25 ± 0.31 |
| 0.72–0.90 | 0.788 | 44.7 | 1.56 ± 0.16 ± 0.23 | 0.789 | 54.8 | 1.06 ± 0.13 ± 0.17 |
| 0.90–1.25 | 0.992 | 54.7 | 0.13 ± 0.02 ± 0.04 | 0.964 | 54.7 | 0.13 ± 0.02 ± 0.04 |
Table A.6  (Continued)

| $p_T$ | $60 < \theta < 75$ |   | $75 < \theta < 90$ |   |
|-------|------------------|---|------------------|---|
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.144 | 67.3 | 18.75 | ± | 1.16 | ± | 1.57 | 0.145 | 82.8 | 18.01 | ± | 1.14 | ± | 1.67 |
| 0.16–0.20 | 0.179 | 67.3 | 17.85 | ± | 0.93 | ± | 1.20 | 0.179 | 82.3 | 16.80 | ± | 0.91 | ± | 1.21 |
| 0.20–0.24 | 0.219 | 66.8 | 18.04 | ± | 0.91 | ± | 1.20 | 0.218 | 81.9 | 12.18 | ± | 0.75 | ± | 0.88 |
| 0.24–0.30 | 0.269 | 67.1 | 13.77 | ± | 0.64 | ± | 0.77 | 0.268 | 82.5 | 9.99 | ± | 0.56 | ± | 0.65 |
| 0.30–0.36 | 0.329 | 67.0 | 12.02 | ± | 0.61 | ± | 0.71 | 0.327 | 82.0 | 8.09 | ± | 0.50 | ± | 0.59 |
| 0.36–0.42 | 0.386 | 66.3 | 9.40 | ± | 0.53 | ± | 0.59 | 0.388 | 82.0 | 5.41 | ± | 0.41 | ± | 0.45 |
| 0.42–0.50 | 0.452 | 66.5 | 6.20 | ± | 0.37 | ± | 0.46 | 0.455 | 82.3 | 3.34 | ± | 0.28 | ± | 0.33 |
| 0.50–0.60 | 0.541 | 66.4 | 4.18 | ± | 0.28 | ± | 0.39 | 0.542 | 81.5 | 1.93 | ± | 0.19 | ± | 0.24 |
| 0.60–0.72 | 0.645 | 66.7 | 2.26 | ± | 0.18 | ± | 0.29 | 0.642 | 82.1 | 1.01 | ± | 0.12 | ± | 0.18 |
| 0.72–0.90 | 0.784 | 66.4 | 0.52 | ± | 0.07 | ± | 0.09 | 0.785 | 82.7 | 0.18 | ± | 0.04 | ± | 0.05 |
| 0.90–1.25 | 1.021 | 65.6 | 0.07 | ± | 0.02 | ± | 0.03 |   |   |   |   |   |   |   |

| $p_T$ | $90 < \theta < 105$ |   | $105 < \theta < 125$ |   |
|-------|------------------|---|------------------|---|
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.144 | 97.0 | 14.92 | ± | 1.04 | ± | 1.51 | 0.145 | 114.3 | 11.86 | ± | 0.81 | ± | 0.96 |
| 0.16–0.20 | 0.180 | 97.2 | 13.45 | ± | 0.81 | ± | 1.08 | 0.178 | 114.7 | 10.27 | ± | 0.63 | ± | 0.72 |
| 0.20–0.24 | 0.218 | 97.2 | 10.54 | ± | 0.72 | ± | 0.87 | 0.218 | 113.8 | 6.81 | ± | 0.50 | ± | 0.60 |
| 0.24–0.30 | 0.266 | 97.0 | 7.52 | ± | 0.49 | ± | 0.58 | 0.268 | 113.6 | 3.57 | ± | 0.29 | ± | 0.34 |
| 0.30–0.36 | 0.327 | 97.2 | 4.88 | ± | 0.39 | ± | 0.46 | 0.325 | 113.2 | 2.68 | ± | 0.25 | ± | 0.34 |
| 0.36–0.42 | 0.385 | 97.3 | 3.56 | ± | 0.33 | ± | 0.40 | 0.389 | 113.6 | 1.45 | ± | 0.18 | ± | 0.22 |
| 0.42–0.50 | 0.456 | 97.0 | 2.01 | ± | 0.22 | ± | 0.27 | 0.447 | 113.2 | 0.78 | ± | 0.11 | ± | 0.16 |
| 0.50–0.60 | 0.530 | 97.9 | 0.74 | ± | 0.11 | ± | 0.14 | 0.539 | 112.2 | 0.26 | ± | 0.05 | ± | 0.09 |
| 0.60–0.72 | 0.637 | 96.3 | 0.31 | ± | 0.06 | ± | 0.09 | 0.658 | 110.4 | 0.11 | ± | 0.03 | ± | 0.05 |
| 0.72–0.90 | 0.801 | 97.3 | 0.08 | ± | 0.02 | ± | 0.04 |   |   |   |   |   |   |   |
Table A.7  Double-differential inclusive cross-section $d^2\sigma/dp d\Omega$ [mb/(GeV/c sr)] of the production of protons in $\pi^- + {\text{Be}} \rightarrow p + X$ interactions with $-3.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | | $30 < \theta < 40$ | |
|-------|-------------------|---|-------------------|---|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ |
| 0.20–0.24 | 0.219 | 25.0 | 33.91 | ± | 1.47 | ± | 2.56 |
| 0.24–0.30 | 0.267 | 25.0 | 33.11 | ± | 1.17 | ± | 2.03 |
| 0.30–0.36 | 0.327 | 25.1 | 31.93 | ± | 1.16 | ± | 1.79 |
| 0.36–0.42 | 0.386 | 25.1 | 28.54 | ± | 1.07 | ± | 1.56 |
| 0.42–0.50 | 0.452 | 25.0 | 24.84 | ± | 0.87 | ± | 1.28 |
| 0.50–0.60 | 0.538 | 25.1 | 20.22 | ± | 0.71 | ± | 0.99 |
| 0.60–0.72 | 0.642 | 25.1 | 13.32 | ± | 0.51 | ± | 0.73 |
| 0.72–0.90 | 0.781 | 35.1 | 8.20 | ± | 0.35 | ± | 0.62 |

| $p_T$ | $40 < \theta < 50$ | | $50 < \theta < 60$ | |
|-------|-------------------|---|-------------------|---|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ |
| 0.30–0.36 | 0.330 | 45.0 | 25.49 | ± | 0.95 | ± | 1.51 |
| 0.36–0.42 | 0.389 | 45.1 | 22.78 | ± | 0.92 | ± | 1.17 |
| 0.42–0.50 | 0.458 | 45.0 | 19.31 | ± | 0.77 | ± | 1.01 |
| 0.50–0.60 | 0.547 | 45.1 | 15.77 | ± | 0.64 | ± | 0.86 |
| 0.60–0.72 | 0.656 | 45.0 | 11.75 | ± | 0.53 | ± | 0.81 |
| 0.72–0.90 | 0.801 | 44.9 | 6.18 | ± | 0.31 | ± | 0.50 |
| 0.90–1.25 | 1.034 | 44.7 | 1.94 | ± | 0.12 | ± | 0.25 |

| $p_T$ | $60 < \theta < 75$ | | $75 < \theta < 90$ | |
|-------|-------------------|---|-------------------|---|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ |
| 0.36–0.42 | 0.385 | 67.6 | 23.08 | ± | 0.74 | ± | 1.00 |
| 0.42–0.50 | 0.452 | 67.5 | 19.40 | ± | 0.60 | ± | 0.82 |
| 0.50–0.60 | 0.538 | 67.4 | 13.83 | ± | 0.47 | ± | 0.69 |
| 0.60–0.72 | 0.642 | 67.1 | 7.44 | ± | 0.33 | ± | 0.56 |
| 0.72–0.90 | 0.777 | 66.5 | 2.74 | ± | 0.17 | ± | 0.33 |
| 0.90–1.25 | 0.988 | 66.9 | 0.44 | ± | 0.05 | ± | 0.13 |

| $p_T$ | $90 < \theta < 105$ | | $105 < \theta < 125$ | |
|-------|-------------------|---|-------------------|---|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp d\Omega$ |
| 0.36–0.42 | 0.383 | 114.3 | 5.20 | ± | 0.29 | ± | 0.42 |
| 0.42–0.50 | 0.452 | 96.7 | 7.99 | ± | 0.37 | ± | 0.66 |
| 0.50–0.60 | 0.538 | 96.7 | 4.57 | ± | 0.26 | ± | 0.49 |
| 0.60–0.72 | 0.640 | 97.0 | 1.57 | ± | 0.16 | ± | 0.26 |
| 0.72–0.90 | 0.776 | 96.8 | 0.37 | ± | 0.07 | ± | 0.11 |
Table A.8  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^+$'s in $\pi^- + \text{Be} \rightarrow \pi^+ + X$ interactions with $-3.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees.

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.116 | 25.0 | 29.21 | ± | 1.74 | ± | 3.26 | 0.115 | 34.9 | 23.15 | ± | 1.54 | ± | 2.62 |
| 0.13–0.16 | 0.144 | 24.9 | 35.55 | ± | 1.85 | ± | 3.30 | 0.144 | 34.9 | 28.39 | ± | 1.54 | ± | 2.67 |
| 0.16–0.20 | 0.180 | 24.8 | 40.36 | ± | 1.62 | ± | 2.65 | 0.180 | 34.8 | 33.48 | ± | 1.44 | ± | 2.45 |
| 0.20–0.24 | 0.219 | 24.9 | 41.34 | ± | 1.60 | ± | 2.37 | 0.219 | 34.7 | 33.44 | ± | 1.43 | ± | 2.27 |
| 0.24–0.30 | 0.267 | 24.9 | 39.24 | ± | 1.28 | ± | 1.87 | 0.268 | 34.7 | 35.03 | ± | 1.20 | ± | 2.00 |
| 0.30–0.36 | 0.326 | 25.1 | 33.02 | ± | 1.16 | ± | 1.51 | 0.326 | 34.8 | 26.02 | ± | 1.01 | ± | 1.34 |
| 0.36–0.42 | 0.385 | 24.8 | 30.08 | ± | 1.14 | ± | 1.52 | 0.384 | 34.6 | 22.82 | ± | 0.95 | ± | 1.24 |
| 0.42–0.50 | 0.450 | 25.0 | 19.96 | ± | 0.77 | ± | 1.08 | 0.451 | 34.7 | 17.07 | ± | 0.73 | ± | 0.97 |
| 0.50–0.60 | 0.537 | 24.9 | 9.92 | ± | 0.44 | ± | 0.71 | 0.538 | 34.8 | 10.06 | ± | 0.48 | ± | 0.70 |
| 0.60–0.72 | 0.643 | 25.1 | 4.64 | ± | 0.26 | ± | 0.46 | 0.642 | 34.9 | 4.85 | ± | 0.29 | ± | 0.46 |
| 0.72–0.90 | 0.770 | 34.9 | 2.09 | ± | 0.14 | ± | 0.29 |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.117 | 44.9 | 21.69 | ± | 1.51 | ± | 2.58 |
| 0.13–0.16 | 0.145 | 44.8 | 25.29 | ± | 1.56 | ± | 2.28 |
| 0.16–0.20 | 0.180 | 45.0 | 25.92 | ± | 1.27 | ± | 1.97 |
| 0.20–0.24 | 0.219 | 44.4 | 29.52 | ± | 1.38 | ± | 2.04 |
| 0.24–0.30 | 0.269 | 44.7 | 24.30 | ± | 0.97 | ± | 1.35 |
| 0.30–0.36 | 0.330 | 44.8 | 19.35 | ± | 0.88 | ± | 1.01 |
| 0.36–0.42 | 0.389 | 45.0 | 15.92 | ± | 0.80 | ± | 0.92 |
| 0.42–0.50 | 0.457 | 44.7 | 12.48 | ± | 0.63 | ± | 0.77 |
| 0.50–0.60 | 0.547 | 44.8 | 7.93 | ± | 0.44 | ± | 0.58 |
| 0.60–0.72 | 0.654 | 44.7 | 4.22 | ± | 0.28 | ± | 0.43 |
| 0.72–0.90 | 0.793 | 45.2 | 1.63 | ± | 0.13 | ± | 0.22 |
| 0.90–1.25 | 1.014 | 54.2 | 0.16 | ± | 0.02 | ± | 0.05 |

| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.146 | 67.2 | 15.97 | ± | 1.01 | ± | 1.35 |
| 0.16–0.20 | 0.178 | 67.4 | 17.11 | ± | 0.86 | ± | 1.14 |
| 0.20–0.24 | 0.218 | 67.2 | 15.09 | ± | 0.79 | ± | 0.95 |
| 0.24–0.30 | 0.266 | 66.9 | 13.94 | ± | 0.62 | ± | 0.78 |
| 0.30–0.36 | 0.325 | 67.2 | 10.63 | ± | 0.55 | ± | 0.62 |
| 0.36–0.42 | 0.383 | 66.4 | 7.96 | ± | 0.47 | ± | 0.50 |
| 0.42–0.50 | 0.451 | 67.3 | 5.92 | ± | 0.35 | ± | 0.41 |
| 0.50–0.60 | 0.539 | 67.2 | 3.52 | ± | 0.23 | ± | 0.31 |
| 0.60–0.72 | 0.638 | 66.6 | 1.70 | ± | 0.14 | ± | 0.20 |
| 0.72–0.90 | 0.766 | 66.2 | 0.54 | ± | 0.06 | ± | 0.11 |
| 0.90–1.25 | 0.980 | 65.8 | 0.07 | ± | 0.02 | ± | 0.02 |
Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^-$ in $\pi^- +$ Be $\to \pi^- + X$ interactions with $-3.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|------|-----------------|-----------------|
|      | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| $0.10-0.13$ | $0.117$ | $24.8$ | $52.04$ | $2.38$ | $4.76$ | $0.116$ | $34.9$ | $41.17$ | $2.09$ | $3.81$ |
| $0.13-0.16$ | $0.146$ | $24.8$ | $63.35$ | $2.45$ | $4.58$ | $0.146$ | $35.0$ | $49.12$ | $2.09$ | $3.69$ |
| $0.16-0.20$ | $0.181$ | $24.7$ | $71.79$ | $2.15$ | $4.11$ | $0.181$ | $34.8$ | $55.30$ | $1.86$ | $3.42$ |
| $0.20-0.24$ | $0.221$ | $24.8$ | $69.90$ | $2.12$ | $3.49$ | $0.221$ | $34.8$ | $62.10$ | $1.95$ | $3.29$ |
| $0.24-0.30$ | $0.271$ | $24.7$ | $68.25$ | $1.67$ | $2.72$ | $0.272$ | $34.9$ | $57.09$ | $1.50$ | $2.48$ |
| $0.30-0.36$ | $0.333$ | $25.0$ | $59.39$ | $1.55$ | $2.20$ | $0.332$ | $34.8$ | $50.60$ | $1.41$ | $2.03$ |
| $0.36-0.42$ | $0.393$ | $25.1$ | $48.64$ | $1.42$ | $2.03$ | $0.394$ | $34.9$ | $41.06$ | $1.28$ | $1.75$ |
| $0.42-0.50$ | $0.464$ | $24.9$ | $37.94$ | $1.09$ | $1.71$ | $0.464$ | $35.1$ | $32.43$ | $1.00$ | $1.51$ |
| $0.50-0.60$ | $0.555$ | $25.1$ | $24.23$ | $0.77$ | $1.42$ | $0.554$ | $34.9$ | $20.71$ | $0.69$ | $1.21$ |
| $0.60-0.72$ | $0.669$ | $25.1$ | $14.21$ | $0.56$ | $1.12$ | $0.669$ | $34.8$ | $13.86$ | $0.55$ | $1.09$ |
| $0.72-0.90$ | $0.817$ | $34.8$ | $6.91$ | $0.33$ | $0.75$ | $0.817$ | $34.8$ | $6.91$ | $0.33$ | $0.75$ |
Table A.9 (Continued)

| \( \rho_T \) | \( 60 < \theta < 75 \) | \( 75 < \theta < 90 \) |
|--------------|----------------------|----------------------|
|              | \( \langle \rho_T \rangle \) | \( \langle \theta \rangle \) | \( d^2\sigma/d\rho d\Omega \) | \( \langle \rho_T \rangle \) | \( \langle \theta \rangle \) | \( d^2\sigma/d\rho d\Omega \) |
| 0.13–0.16    | 0.146                | 67.2                 | 33.59 ± 1.47 ± 2.45 | 0.147 | 82.6 | 26.96 ± 1.30 ± 2.10 |
| 0.16–0.20    | 0.181                | 67.1                 | 36.93 ± 1.28 ± 2.13 | 0.181 | 82.3 | 30.47 ± 1.17 ± 1.80 |
| 0.20–0.24    | 0.221                | 67.1                 | 31.13 ± 1.13 ± 1.64 | 0.220 | 82.0 | 26.87 ± 1.07 ± 1.47 |
| 0.24–0.30    | 0.271                | 67.0                 | 25.95 ± 0.84 ± 1.13 | 0.271 | 82.3 | 19.09 ± 0.73 ± 0.99 |
| 0.30–0.36    | 0.333                | 67.2                 | 22.56 ± 0.78 ± 1.00 | 0.330 | 81.9 | 13.08 ± 0.60 ± 0.72 |
| 0.36–0.42    | 0.393                | 66.8                 | 17.17 ± 0.69 ± 0.86 | 0.393 | 81.9 | 10.09 ± 0.52 ± 0.67 |
| 0.42–0.50    | 0.465                | 66.5                 | 13.19 ± 0.51 ± 0.76 | 0.462 | 81.7 | 8.45 ± 0.41 ± 0.65 |
| 0.50–0.60    | 0.557                | 66.9                 | 8.15 ± 0.36 ± 0.61 | 0.553 | 81.9 | 4.59 ± 0.28 ± 0.45 |
| 0.60–0.72    | 0.667                | 66.9                 | 4.73 ± 0.26 ± 0.47 | 0.664 | 81.5 | 2.18 ± 0.17 ± 0.28 |
| 0.72–0.90    | 0.805                | 66.8                 | 1.97 ± 0.13 ± 0.26 | 0.811 | 81.0 | 0.63 ± 0.06 ± 0.12 |
| 0.90–1.25    | 1.047                | 66.1                 | 0.17 ± 0.02 ± 0.04 | 1.049 | 80.5 | 0.05 ± 0.01 ± 0.02 |
|              |                      |                      |                     |       |     |                     |
| 0.13–0.16    | 0.146                | 97.1                 | 27.64 ± 1.33 ± 2.12 | 0.146 | 114.8 | 25.29 ± 1.11 ± 1.59 |
| 0.16–0.20    | 0.181                | 97.6                 | 24.44 ± 1.03 ± 1.44 | 0.180 | 113.9 | 20.30 ± 0.83 ± 1.03 |
| 0.20–0.24    | 0.221                | 97.0                 | 19.49 ± 0.91 ± 1.11 | 0.219 | 114.2 | 13.21 ± 0.67 ± 0.73 |
| 0.24–0.30    | 0.270                | 97.1                 | 15.05 ± 0.66 ± 0.87 | 0.270 | 114.1 | 8.17 ± 0.41 ± 0.54 |
| 0.30–0.36    | 0.331                | 97.0                 | 9.62 ± 0.51 ± 0.68 | 0.329 | 113.3 | 5.01 ± 0.32 ± 0.46 |
| 0.36–0.42    | 0.391                | 97.5                 | 6.99 ± 0.43 ± 0.63 | 0.393 | 112.4 | 2.66 ± 0.24 ± 0.32 |
| 0.42–0.50    | 0.466                | 96.4                 | 3.84 ± 0.28 ± 0.42 | 0.459 | 111.8 | 1.28 ± 0.14 ± 0.21 |
| 0.50–0.60    | 0.549                | 95.9                 | 1.71 ± 0.16 ± 0.26 | 0.551 | 110.0 | 0.40 ± 0.06 ± 0.10 |
| 0.60–0.72    | 0.672                | 95.8                 | 0.60 ± 0.08 ± 0.13 | 0.665 | 109.4 | 0.10 ± 0.03 ± 0.04 |
| 0.72–0.90    | 0.799                | 95.5                 | 0.09 ± 0.02 ± 0.04 |       |     |                     |
### Table A.10
Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of protons in $p + \text{Be} \rightarrow p + \text{X}$ interactions with $+5.0$ GeV/$c$ beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/$c$, polar angle $\theta$ in degrees.

| $p_T$  | $20 < \theta < 30$ | $30 < \theta < 40$ |
|--------|------------------|------------------|
|        | $(p_T)$          | $(\theta)$       | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.20–0.24 | 0.221 24.9 45.44 ± 1.74 ± 3.07 | 0.271 24.8 43.38 ± 1.46 ± 2.86 |
| 0.24–0.30 | 0.300 24.9 40.05 ± 1.45 ± 2.96 | 0.300 24.7 39.38 ± 1.34 ± 2.20 |
| 0.30–0.36 | 0.390 24.9 36.14 ± 1.33 ± 2.44 | 0.389 24.9 31.72 ± 1.28 ± 2.49 |
| 0.36–0.42 | 0.459 24.9 35.43 ± 1.13 ± 2.21 | 0.459 24.9 30.16 ± 1.13 ± 2.28 |
| 0.42–0.50 | 0.549 24.8 31.41 ± 0.97 ± 1.94 | 0.549 25.1 22.92 ± 0.85 ± 1.82 |
| 0.50–0.60 | 0.657 24.9 23.45 ± 0.73 ± 1.54 | 0.654 24.9 18.06 ± 0.72 ± 1.68 |
| 0.60–0.72 | 0.72–0.90 | 0.801 34.7 9.06 ± 0.40 ± 1.11 |
| 0.72–0.90 | 0.801 34.7 9.06 ± 0.40 ± 1.11 |
| 0.30–0.36 | 0.329 45.0 38.76 ± 1.27 ± 1.79 | 0.390 55.0 35.42 ± 1.19 ± 1.50 |
| 0.36–0.42 | 0.389 45.0 32.78 ± 1.18 ± 1.60 | 0.459 55.1 30.70 ± 1.02 ± 1.41 |
| 0.42–0.50 | 0.459 45.0 24.72 ± 0.98 ± 1.84 | 0.548 55.0 21.29 ± 0.86 ± 1.87 |
| 0.50–0.60 | 0.549 45.1 21.46 ± 0.85 ± 1.73 | 0.656 54.8 9.95 ± 0.54 ± 1.29 |
| 0.60–0.72 | 0.657 44.9 14.46 ± 0.66 ± 1.53 | 0.799 54.8 4.24 ± 0.32 ± 0.91 |
| 0.72–0.90 | 0.799 45.0 7.29 ± 0.41 ± 1.16 | 1.024 54.5 0.97 ± 0.09 ± 0.58 |
| 0.90–1.25 | 1.025 44.5 1.49 ± 0.12 ± 0.55 |
| 0.36–0.42 | 0.391 67.6 33.05 ± 0.92 ± 1.28 | 0.460 81.8 20.96 ± 0.64 ± 0.99 |
| 0.42–0.50 | 0.461 67.3 29.97 ± 0.78 ± 1.11 | 0.549 81.5 10.97 ± 0.44 ± 0.77 |
| 0.50–0.60 | 0.549 66.9 19.40 ± 0.62 ± 1.29 | 0.657 81.3 2.90 ± 0.26 ± 0.79 |
| 0.60–0.72 | 0.658 67.2 6.76 ± 0.37 ± 1.12 | 0.800 81.8 1.42 ± 0.15 ± 0.73 |
| 0.72–0.90 | 0.798 66.7 2.75 ± 0.20 ± 0.90 |
| 0.90–1.25 | 1.036 66.6 0.75 ± 0.08 ± 0.58 |
| 0.36–0.42 | 0.461 96.7 10.91 ± 0.45 ± 0.79 | 0.458 113.1 3.59 ± 0.25 ± 0.31 |
| 0.42–0.50 | 0.549 96.7 4.83 ± 0.32 ± 0.52 | 0.544 112.8 0.86 ± 0.13 ± 0.40 |
| 0.50–0.60 | 0.661 96.3 1.07 ± 0.14 ± 0.66 |
Table A.11 Double-differential inclusive cross-section \(d^2\sigma/dp d\Omega\) [mb/(GeV/c sr)] of the production of \(\pi^+\)'s in \(p + \text{Be} \to \pi^+ + X\) interactions with +5.0 GeV/c beam momentum; the first error is statistical, the second systematic; \(p_T\) in GeV/c, polar angle \(\theta\) in degrees

| \(p_T\) | \(20 < \theta < 30\) | \(30 < \theta < 40\) |
|-------|-----------------|-----------------|
| \(0.10 - 0.13\) | 0.115 25.1 51.01 ± 2.51 ± 4.66 | 0.115 34.8 36.25 ± 2.02 ± 3.39 |
| \(0.13 - 0.16\) | 0.146 25.0 58.36 ± 2.44 ± 4.22 | 0.146 34.7 40.18 ± 1.97 ± 3.02 |
| \(0.16 - 0.20\) | 0.180 24.7 67.65 ± 2.16 ± 3.93 | 0.180 34.6 49.15 ± 1.87 ± 3.07 |
| \(0.20 - 0.24\) | 0.220 24.6 70.51 ± 2.21 ± 3.90 | 0.220 34.5 44.32 ± 1.66 ± 2.50 |
| \(0.24 - 0.30\) | 0.269 24.7 59.93 ± 1.63 ± 2.68 | 0.269 34.6 42.81 ± 1.36 ± 2.00 |
| \(0.30 - 0.36\) | 0.328 24.9 44.50 ± 1.38 ± 1.93 | 0.328 34.6 32.99 ± 1.18 ± 1.51 |
| \(0.36 - 0.42\) | 0.389 24.8 33.20 ± 1.18 ± 1.56 | 0.389 34.6 28.65 ± 1.12 ± 1.47 |
| \(0.42 - 0.50\) | 0.459 24.8 22.23 ± 0.81 ± 1.14 | 0.456 34.8 21.63 ± 0.82 ± 1.13 |
| \(0.50 - 0.60\) | 0.546 24.6 15.78 ± 0.60 ± 1.02 | 0.545 34.6 12.17 ± 0.53 ± 0.77 |
| \(0.60 - 0.72\) | 0.657 24.9 8.99 ± 0.37 ± 0.81 | 0.655 34.6 6.93 ± 0.34 ± 0.61 |
| \(0.72 - 0.90\) | 0.799 34.7 3.92 ± 0.21 ± 0.51 |
### Table A.11 (Continued)

| $p_T$ (GeV/c) | 90 < $\theta$ < 105 | 105 < $\theta$ < 125 |
|---------------|---------------------|---------------------|
| $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma / dp d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma / dp d\Omega$ |
| 0.13–0.16 | 0.146 | 97.5 | 14.62 ± 0.95 ± 1.43 | 0.145 | 114.7 | 14.61 ± 0.82 ± 1.21 |
| 0.16–0.20 | 0.181 | 97.0 | 16.88 ± 0.91 ± 1.19 | 0.178 | 114.6 | 11.77 ± 0.65 ± 0.76 |
| 0.20–0.24 | 0.218 | 97.3 | 13.26 ± 0.77 ± 0.94 | 0.220 | 113.9 | 7.47 ± 0.50 ± 0.59 |
| 0.24–0.30 | 0.269 | 97.3 | 8.23 ± 0.50 ± 0.58 | 0.268 | 113.3 | 4.04 ± 0.31 ± 0.37 |
| 0.30–0.36 | 0.327 | 97.1 | 4.11 ± 0.33 ± 0.39 | 0.331 | 112.9 | 1.85 ± 0.19 ± 0.24 |
| 0.36–0.42 | 0.387 | 96.9 | 2.70 ± 0.27 ± 0.31 | 0.391 | 113.7 | 1.22 ± 0.17 ± 0.21 |
| 0.42–0.50 | 0.454 | 96.8 | 1.63 ± 0.17 ± 0.23 | 0.458 | 112.6 | 0.37 ± 0.07 ± 0.08 |
| 0.50–0.60 | 0.539 | 97.1 | 0.72 ± 0.12 ± 0.13 | 0.539 | 113.2 | 0.12 ± 0.03 ± 0.05 |
| 0.60–0.72 | 0.659 | 96.6 | 0.17 ± 0.04 ± 0.06 | &nbsp; | &nbsp; | &nbsp; |

### Table A.12

Double-differential inclusive cross-section $d^2\sigma / dp d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^-$'s in p + Be → $\pi^-$ + X interactions with +5.0 GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ (GeV/c) | 20 < $\theta$ < 30 | 30 < $\theta$ < 40 |
|---------------|---------------------|---------------------|
| $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma / dp d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma / dp d\Omega$ |
| 0.10–0.13 | 0.116 | 24.7 | 36.19 ± 2.03 ± 3.60 | 0.115 | 34.9 | 29.24 ± 1.80 ± 2.99 |
| 0.13–0.16 | 0.145 | 24.8 | 48.74 ± 2.25 ± 4.00 | 0.145 | 34.9 | 32.40 ± 1.69 ± 2.71 |
| 0.16–0.20 | 0.180 | 24.9 | 44.98 ± 1.71 ± 2.89 | 0.180 | 34.7 | 37.10 ± 1.63 ± 2.56 |
| 0.20–0.24 | 0.219 | 24.8 | 41.84 ± 1.69 ± 2.42 | 0.220 | 34.9 | 35.98 ± 1.54 ± 2.21 |
| 0.24–0.30 | 0.269 | 25.0 | 36.76 ± 1.27 ± 1.78 | 0.268 | 34.9 | 28.04 ± 1.08 ± 1.45 |
| 0.30–0.36 | 0.329 | 25.1 | 27.54 ± 1.11 ± 1.38 | 0.329 | 34.7 | 23.88 ± 1.01 ± 1.24 |
| 0.36–0.42 | 0.388 | 24.9 | 19.44 ± 0.91 ± 1.10 | 0.388 | 34.8 | 15.08 ± 0.75 ± 0.91 |
| 0.42–0.50 | 0.458 | 25.1 | 11.60 ± 0.62 ± 0.74 | 0.457 | 34.9 | 14.42 ± 0.72 ± 0.99 |
| 0.50–0.60 | 0.542 | 25.0 | 6.97 ± 0.43 ± 0.56 | 0.549 | 35.0 | 7.28 ± 0.43 ± 0.58 |
| 0.60–0.72 | 0.656 | 25.4 | 3.14 ± 0.25 ± 0.35 | 0.657 | 34.9 | 3.57 ± 0.28 ± 0.38 |
| 0.72–0.90 | 0.782 | 34.6 | 1.13 ± 0.12 ± 0.16 | &nbsp; | &nbsp; | &nbsp; |

| $p_T$ (GeV/c) | 40 < $\theta$ < 50 | 50 < $\theta$ < 60 |
|---------------|---------------------|---------------------|
| $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma / dp d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma / dp d\Omega$ |
| 0.10–0.13 | 0.115 | 44.8 | 23.15 ± 1.60 ± 2.53 | 0.146 | 54.8 | 21.23 ± 1.40 ± 1.93 |
| 0.13–0.16 | 0.146 | 44.9 | 31.22 ± 1.78 ± 2.67 | 0.179 | 54.9 | 23.44 ± 1.26 ± 1.68 |
| 0.16–0.20 | 0.180 | 45.1 | 28.87 ± 1.43 ± 2.02 | 0.220 | 54.7 | 23.77 ± 1.30 ± 1.67 |
| 0.20–0.24 | 0.219 | 44.9 | 27.86 ± 1.36 ± 1.88 | 0.270 | 54.9 | 17.08 ± 0.85 ± 1.08 |
| 0.24–0.30 | 0.269 | 44.8 | 25.22 ± 1.07 ± 1.40 | 0.330 | 54.7 | 12.20 ± 0.71 ± 0.79 |
| 0.30–0.36 | 0.330 | 44.9 | 16.84 ± 0.83 ± 0.94 | 0.388 | 54.8 | 12.25 ± 0.72 ± 0.88 |
| 0.36–0.42 | 0.388 | 44.7 | 16.05 ± 0.86 ± 1.05 | 0.456 | 54.7 | 7.76 ± 0.50 ± 0.57 |
| 0.42–0.50 | 0.459 | 44.8 | 8.95 ± 0.50 ± 0.63 | 0.546 | 54.7 | 4.02 ± 0.31 ± 0.36 |
| 0.50–0.60 | 0.544 | 44.9 | 6.37 ± 0.42 ± 0.54 | 0.649 | 54.8 | 2.20 ± 0.22 ± 0.27 |
| 0.60–0.72 | 0.653 | 44.6 | 2.79 ± 0.23 ± 0.31 | 0.797 | 54.9 | 0.63 ± 0.08 ± 0.13 |
| 0.72–0.90 | 0.790 | 44.1 | 1.05 ± 0.12 ± 0.16 | 1.015 | 54.9 | 0.15 ± 0.03 ± 0.05 |
Table A.12 (Continued)

| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|-------|---------------------|---------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.145 | 67.4 | 18.89 ± 1.11 ± 1.65 | 0.146 | 82.6 | 16.53 ± 1.03 ± 1.51 |
| 0.16–0.20 | 0.180 | 67.4 | 20.36 ± 0.97 ± 1.35 | 0.180 | 82.2 | 16.12 ± 0.84 ± 1.12 |
| 0.20–0.24 | 0.220 | 67.0 | 17.89 ± 0.91 ± 1.07 | 0.220 | 81.8 | 15.50 ± 0.84 ± 1.01 |
| 0.24–0.30 | 0.267 | 66.7 | 13.63 ± 0.64 ± 0.77 | 0.267 | 82.1 | 10.46 ± 0.55 ± 0.67 |
| 0.30–0.36 | 0.329 | 66.8 | 9.42 ± 0.51 ± 0.61 | 0.328 | 82.4 | 5.98 ± 0.41 ± 0.47 |
| 0.36–0.42 | 0.386 | 66.7 | 7.66 ± 0.48 ± 0.55 | 0.386 | 82.0 | 4.54 ± 0.37 ± 0.43 |
| 0.42–0.50 | 0.454 | 67.1 | 5.19 ± 0.33 ± 0.41 | 0.453 | 81.5 | 3.26 ± 0.26 ± 0.35 |
| 0.50–0.60 | 0.540 | 66.6 | 2.69 ± 0.22 ± 0.25 | 0.542 | 81.2 | 1.53 ± 0.16 ± 0.21 |
| 0.60–0.72 | 0.646 | 66.1 | 1.24 ± 0.13 ± 0.16 | 0.657 | 80.6 | 0.44 ± 0.07 ± 0.10 |
| 0.72–0.90 | 0.782 | 66.8 | 0.28 ± 0.05 ± 0.06 | 0.786 | 82.9 | 0.04 ± 0.02 ± 0.02 |
| 0.90–1.25 | 1.076 | 66.4 | 0.04 ± 0.01 ± 0.02 |            |            |              |

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|---------------------|---------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.145 | 97.5 | 15.36 ± 0.99 ± 1.44 | 0.144 | 114.8 | 15.54 ± 0.88 ± 1.21 |
| 0.16–0.20 | 0.179 | 97.6 | 14.54 ± 0.80 ± 1.03 | 0.179 | 114.0 | 12.75 ± 0.69 ± 0.86 |
| 0.20–0.24 | 0.219 | 97.2 | 12.63 ± 0.77 ± 0.89 | 0.218 | 114.1 | 6.18 ± 0.46 ± 0.49 |
| 0.24–0.30 | 0.268 | 96.7 | 7.83 ± 0.48 ± 0.58 | 0.266 | 113.6 | 3.39 ± 0.28 ± 0.33 |
| 0.30–0.36 | 0.326 | 96.7 | 4.32 ± 0.36 ± 0.46 | 0.323 | 112.7 | 2.20 ± 0.22 ± 0.30 |
| 0.36–0.42 | 0.386 | 96.8 | 2.26 ± 0.25 ± 0.29 | 0.385 | 113.2 | 1.22 ± 0.16 ± 0.22 |
| 0.42–0.50 | 0.448 | 96.1 | 1.37 ± 0.17 ± 0.20 | 0.444 | 111.8 | 0.53 ± 0.10 ± 0.12 |
| 0.50–0.60 | 0.538 | 96.8 | 0.49 ± 0.10 ± 0.10 | 0.538 | 111.8 | 0.13 ± 0.04 ± 0.05 |
| 0.60–0.72 | 0.635 | 96.9 | 0.13 ± 0.04 ± 0.05 |            |            |              |
Table A.13  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of protons in $\pi^+ + \text{Be} \rightarrow p + \text{X}$ interactions with $+5.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$  | $20 < \theta < 30$ | $30 < \theta < 40$ |
|--------|---------------------|---------------------|
|        | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.20–0.24 | 0.221 | 24.9 | 41.92 ± 1.44 ± 3.27 | 0.271 | 34.8 | 36.94 ± 1.07 ± 2.36 |
| 0.24–0.30 | 0.269 | 25.1 | 39.00 ± 1.13 ± 2.33 | 0.330 | 34.9 | 33.98 ± 1.03 ± 1.76 |
| 0.30–0.36 | 0.330 | 25.1 | 37.51 ± 1.10 ± 2.14 | 0.389 | 34.9 | 33.01 ± 1.02 ± 1.68 |
| 0.36–0.42 | 0.389 | 25.3 | 33.64 ± 1.04 ± 1.74 | 0.458 | 35.0 | 28.64 ± 0.83 ± 1.30 |
| 0.42–0.50 | 0.459 | 25.0 | 32.55 ± 0.87 ± 1.53 | 0.548 | 34.9 | 23.33 ± 0.66 ± 1.06 |
| 0.50–0.60 | 0.548 | 24.7 | 25.81 ± 0.67 ± 1.19 | 0.656 | 34.8 | 18.88 ± 0.54 ± 0.99 |
| 0.60–0.72 | 0.656 | 25.2 | 20.73 ± 0.54 ± 1.07 | 0.802 | 34.9 | 12.09 ± 0.36 ± 0.80 |
| 0.72–0.90 |        |       |                     |        |       |                     |

| $p_T$  | $40 < \theta < 50$ | $50 < \theta < 60$ |
|--------|---------------------|---------------------|
|        | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.30–0.36 | 0.329 | 45.0 | 32.30 ± 0.99 ± 1.69 | 0.389 | 55.0 | 29.76 ± 0.95 ± 1.61 |
| 0.36–0.42 | 0.389 | 45.1 | 31.21 ± 0.97 ± 1.65 | 0.459 | 54.9 | 24.78 ± 0.76 ± 1.30 |
| 0.42–0.50 | 0.458 | 44.9 | 26.21 ± 0.79 ± 1.22 | 0.545 | 55.0 | 18.18 ± 0.59 ± 0.94 |
| 0.50–0.60 | 0.547 | 44.9 | 19.55 ± 0.61 ± 0.98 | 0.654 | 55.0 | 13.12 ± 0.48 ± 0.83 |
| 0.60–0.72 | 0.656 | 44.8 | 14.89 ± 0.49 ± 0.87 | 0.796 | 54.7 | 6.78 ± 0.28 ± 0.55 |
| 0.72–0.90 | 0.799 | 44.8 | 9.60 ± 0.33 ± 0.68 | 1.025 | 54.6 | 1.72 ± 0.10 ± 0.22 |
| 0.90–1.25 | 1.028 | 44.7 | 3.10 ± 0.14 ± 0.33 |        |       |                     |

| $p_T$  | $60 < \theta < 75$ | $75 < \theta < 90$ |
|--------|---------------------|---------------------|
|        | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.36–0.42 | 0.391 | 67.2 | 28.20 ± 0.74 ± 1.21 | 0.459 | 81.9 | 16.51 ± 0.50 ± 0.85 |
| 0.42–0.50 | 0.461 | 67.3 | 24.13 ± 0.62 ± 1.06 | 0.548 | 81.9 | 10.75 ± 0.37 ± 0.72 |
| 0.50–0.60 | 0.549 | 67.2 | 17.32 ± 0.47 ± 0.83 | 0.659 | 81.9 | 4.87 ± 0.24 ± 0.48 |
| 0.60–0.72 | 0.657 | 67.2 | 10.56 ± 0.35 ± 0.70 | 0.803 | 81.3 | 1.78 ± 0.12 ± 0.24 |
| 0.72–0.90 | 0.801 | 66.8 | 3.97 ± 0.17 ± 0.40 | 1.031 | 81.4 | 0.33 ± 0.04 ± 0.07 |
| 0.90–1.25 | 1.039 | 66.9 | 0.80 ± 0.06 ± 0.14 |        |       |                     |

| $p_T$  | $90 < \theta < 105$ | $105 < \theta < 125$ |
|--------|---------------------|---------------------|
|        | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.36–0.42 |        |       |                     | 0.388 | 113.8 | 7.25 ± 0.32 ± 0.54 |
| 0.42–0.50 | 0.459 | 96.9 | 9.72 ± 0.37 ± 0.80 | 0.458 | 113.3 | 4.57 ± 0.22 ± 0.42 |
| 0.50–0.60 | 0.546 | 97.0 | 5.52 ± 0.26 ± 0.56 | 0.546 | 113.0 | 2.00 ± 0.14 ± 0.27 |
| 0.60–0.72 | 0.659 | 96.6 | 2.20 ± 0.16 ± 0.29 | 0.657 | 112.9 | 0.55 ± 0.07 ± 0.14 |
| 0.72–0.90 | 0.803 | 96.6 | 0.63 ± 0.08 ± 0.13 | 0.794 | 111.9 | 0.12 ± 0.03 ± 0.05 |
| 0.90–1.25 | 1.032 | 96.2 | 0.08 ± 0.02 ± 0.03 |        |       |                     |
Table A.14 Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^+$’s in $\pi^+ + \text{Be} \to \pi^+ + \text{X}$ interactions with $+5.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | 20 $< \theta < 30$ | | $30 < \theta < 40$ | |
|-------|-----------------|----------------|-----------------|----------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.115 | 25.0 | 42.31 ± 1.93 ± 4.05 | 0.115 | 34.8 | 36.97 ± 1.85 ± 3.45 |
| 0.13–0.16 | 0.146 | 24.9 | 58.31 ± 2.13 ± 4.42 | 0.145 | 35.0 | 48.46 ± 1.93 ± 3.70 |
| 0.16–0.20 | 0.181 | 24.8 | 68.61 ± 1.91 ± 4.17 | 0.180 | 34.7 | 52.84 ± 1.67 ± 3.25 |
| 0.20–0.24 | 0.220 | 24.7 | 73.75 ± 1.89 ± 3.96 | 0.221 | 34.8 | 55.36 ± 1.67 ± 3.06 |
| 0.24–0.30 | 0.269 | 24.7 | 77.78 ± 1.61 ± 3.42 | 0.270 | 34.7 | 56.69 ± 1.37 ± 2.60 |
| 0.30–0.36 | 0.329 | 24.9 | 66.69 ± 1.48 ± 2.70 | 0.329 | 34.8 | 49.78 ± 1.27 ± 2.19 |
| 0.36–0.42 | 0.389 | 24.7 | 59.86 ± 1.42 ± 2.49 | 0.389 | 34.8 | 46.53 ± 1.24 ± 2.06 |
| 0.42–0.50 | 0.458 | 24.8 | 48.91 ± 1.11 ± 2.14 | 0.459 | 34.8 | 35.48 ± 0.96 ± 1.59 |
| 0.50–0.60 | 0.547 | 24.8 | 31.94 ± 0.76 ± 1.90 | 0.546 | 34.6 | 23.41 ± 0.66 ± 1.40 |
| 0.60–0.72 | 0.655 | 24.9 | 17.89 ± 0.49 ± 1.53 | 0.655 | 34.4 | 12.85 ± 0.41 ± 1.09 |
| 0.72–0.90 | | | 0.798 | 34.7 | 6.48 ± 0.24 ± 0.79 |

| $p_T$ | 40 $< \theta < 50$ | | 50 $< \theta < 60$ | |
|-------|-----------------|----------------|-----------------|----------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.116 | 45.1 | 32.76 ± 1.81 ± 3.26 | 0.146 | 54.7 | 27.92 ± 1.52 ± 2.32 |
| 0.13–0.16 | 0.145 | 44.8 | 36.22 ± 1.69 ± 2.79 | 0.180 | 54.9 | 34.30 ± 1.37 ± 2.34 |
| 0.16–0.20 | 0.180 | 44.8 | 40.05 ± 1.49 ± 2.59 | 0.220 | 54.9 | 34.14 ± 1.35 ± 2.23 |
| 0.20–0.24 | 0.220 | 44.9 | 45.24 ± 1.54 ± 2.63 | 0.269 | 54.8 | 30.07 ± 1.02 ± 1.57 |
| 0.24–0.30 | 0.271 | 44.7 | 41.47 ± 1.19 ± 1.95 | 0.328 | 54.6 | 26.84 ± 0.96 ± 1.28 |
| 0.30–0.36 | 0.330 | 44.7 | 36.64 ± 1.12 ± 1.60 | 0.388 | 54.8 | 23.40 ± 0.92 ± 1.24 |
| 0.36–0.42 | 0.388 | 44.6 | 33.64 ± 1.08 ± 1.50 | 0.458 | 54.7 | 15.27 ± 0.61 ± 0.90 |
| 0.42–0.50 | 0.458 | 44.7 | 24.32 ± 0.79 ± 1.14 | 0.547 | 54.7 | 11.27 ± 0.46 ± 0.83 |
| 0.50–0.60 | 0.546 | 44.5 | 14.69 ± 0.52 ± 0.91 | 0.656 | 54.6 | 5.92 ± 0.30 ± 0.56 |
| 0.60–0.72 | 0.655 | 44.5 | 8.97 ± 0.37 ± 0.74 | 0.803 | 54.3 | 3.18 ± 0.19 ± 0.39 |
| 0.72–0.90 | 0.792 | 44.3 | 3.99 ± 0.19 ± 0.46 | 1.026 | 54.2 | 0.69 ± 0.06 ± 0.13 |

| $p_T$ | 60 $< \theta < 75$ | | 75 $< \theta < 90$ | |
|-------|-----------------|----------------|-----------------|----------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.146 | 67.1 | 23.55 ± 1.12 ± 1.93 | 0.146 | 82.6 | 20.77 ± 1.07 ± 1.80 |
| 0.16–0.20 | 0.181 | 67.2 | 28.89 ± 1.02 ± 1.94 | 0.181 | 82.4 | 20.75 ± 0.87 ± 1.35 |
| 0.20–0.24 | 0.221 | 67.1 | 29.33 ± 1.03 ± 1.87 | 0.220 | 82.4 | 18.97 ± 0.83 ± 1.17 |
| 0.24–0.30 | 0.269 | 67.0 | 21.83 ± 0.72 ± 1.11 | 0.269 | 82.5 | 14.12 ± 0.59 ± 0.78 |
| 0.30–0.36 | 0.330 | 66.9 | 17.07 ± 0.63 ± 0.83 | 0.330 | 82.1 | 11.05 ± 0.50 ± 0.71 |
| 0.36–0.42 | 0.391 | 66.6 | 14.13 ± 0.56 ± 0.81 | 0.391 | 82.1 | 7.59 ± 0.41 ± 0.58 |
| 0.42–0.50 | 0.458 | 66.8 | 10.28 ± 0.41 ± 0.69 | 0.460 | 81.9 | 5.40 ± 0.30 ± 0.46 |
| 0.50–0.60 | 0.549 | 66.4 | 6.46 ± 0.29 ± 0.53 | 0.549 | 81.7 | 3.37 ± 0.21 ± 0.35 |
| 0.60–0.72 | 0.658 | 66.5 | 3.71 ± 0.20 ± 0.40 | 0.657 | 81.2 | 1.88 ± 0.15 ± 0.25 |
| 0.72–0.90 | 0.799 | 66.1 | 1.54 ± 0.11 ± 0.21 | 0.791 | 81.8 | 0.50 ± 0.06 ± 0.10 |
| 0.90–1.25 | 1.040 | 66.3 | 0.23 ± 0.02 ± 0.05 | 1.008 | 80.8 | 0.06 ± 0.01 ± 0.02 |
Table A.14  (Continued)

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|-------------------|-------------------|
|       | $(p_T)$           | $d^2 \sigma/dp d\Omega$ | $(p_T)$           | $d^2 \sigma/dp d\Omega$ |
| 0.13–0.16 | 0.146 | 97.3 | 19.16 | ± 1.04 | ± 1.63 | 0.145 | 114.8 | 16.24 | ± 0.82 | ± 1.32 |
| 0.16–0.20 | 0.180 | 96.9 | 19.87 | ± 0.87 | ± 1.24 | 0.180 | 113.9 | 13.80 | ± 0.62 | ± 0.93 |
| 0.20–0.24 | 0.219 | 97.0 | 15.37 | ± 0.75 | ± 0.98 | 0.218 | 114.4 | 9.21 | ± 0.50 | ± 0.76 |
| 0.24–0.30 | 0.269 | 97.1 | 10.66 | ± 0.50 | ± 0.69 | 0.269 | 113.9 | 5.49 | ± 0.31 | ± 0.47 |
| 0.30–0.36 | 0.329 | 96.8 | 6.28 | ± 0.38 | ± 0.50 | 0.327 | 113.7 | 3.74 | ± 0.26 | ± 0.38 |
| 0.36–0.42 | 0.390 | 97.0 | 4.88 | ± 0.33 | ± 0.48 | 0.386 | 113.5 | 1.95 | ± 0.18 | ± 0.27 |
| 0.42–0.50 | 0.460 | 96.7 | 3.43 | ± 0.24 | ± 0.39 | 0.460 | 112.7 | 1.19 | ± 0.12 | ± 0.20 |
| 0.50–0.60 | 0.544 | 96.4 | 1.59 | ± 0.15 | ± 0.23 | 0.542 | 112.1 | 0.28 | ± 0.05 | ± 0.09 |
| 0.60–0.72 | 0.657 | 95.9 | 0.46 | ± 0.07 | ± 0.10 | 0.656 | 110.7 | 0.14 | ± 0.03 | ± 0.07 |
| 0.72–0.90 | 0.792 | 95.9 | 0.10 | ± 0.02 | ± 0.03 |          |          |          |          |          |

Table A.15  Double-differential inclusive cross-section $d^2\sigma/dp d\omega$ [mb/(GeV/c sr)] of the production of $\pi^-$'s in $\pi^+ + \text{Be} \rightarrow \pi^- + \text{X}$ interactions with +5.0 GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|-------------------|-------------------|
|       | $(p_T)$           | $d^2 \sigma/dp d\Omega$ | $(p_T)$           | $d^2 \sigma/dp d\Omega$ |
| 0.10–0.13 | 0.115 | 24.8 | 39.31 | ± 1.81 | ± 4.02 | 0.115 | 34.5 | 33.52 | ± 1.71 | ± 3.42 |
| 0.13–0.16 | 0.145 | 24.8 | 47.64 | ± 1.88 | ± 4.01 | 0.145 | 34.8 | 36.33 | ± 1.66 | ± 3.22 |
| 0.16–0.20 | 0.180 | 24.6 | 53.08 | ± 1.62 | ± 3.40 | 0.180 | 34.7 | 36.96 | ± 1.38 | ± 2.60 |
| 0.20–0.24 | 0.221 | 24.6 | 55.02 | ± 1.64 | ± 3.20 | 0.220 | 34.7 | 40.08 | ± 1.40 | ± 2.55 |
| 0.24–0.30 | 0.270 | 24.4 | 47.90 | ± 1.23 | ± 2.37 | 0.270 | 34.5 | 35.56 | ± 1.06 | ± 1.92 |
| 0.30–0.36 | 0.329 | 24.8 | 40.67 | ± 1.15 | ± 1.91 | 0.329 | 34.7 | 29.35 | ± 0.96 | ± 1.62 |
| 0.36–0.42 | 0.389 | 24.9 | 35.08 | ± 1.08 | ± 1.77 | 0.389 | 34.6 | 22.84 | ± 0.85 | ± 1.23 |
| 0.42–0.50 | 0.457 | 24.7 | 26.10 | ± 0.83 | ± 1.44 | 0.456 | 34.8 | 17.25 | ± 0.66 | ± 1.03 |
| 0.50–0.60 | 0.547 | 25.0 | 12.95 | ± 0.50 | ± 0.89 | 0.545 | 34.6 | 10.78 | ± 0.45 | ± 0.79 |
| 0.60–0.72 | 0.652 | 24.8 | 7.87 | ± 0.35 | ± 0.73 | 0.651 | 34.7 | 5.75 | ± 0.30 | ± 0.57 |
| 0.72–0.90 |          |          | 0.796 | 34.9 | 2.74 | ± 0.18 | ± 0.34 |          |          |          |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|-------------------|-------------------|
|       | $(p_T)$           | $d^2 \sigma/dp d\Omega$ | $(p_T)$           | $d^2 \sigma/dp d\Omega$ |
| 0.10–0.13 | 0.116 | 44.7 | 24.87 | ± 1.51 | ± 2.68 | 0.145 | 54.7 | 22.78 | ± 1.31 | ± 2.11 |
| 0.13–0.16 | 0.145 | 44.8 | 27.53 | ± 1.46 | ± 2.34 | 0.180 | 54.5 | 23.64 | ± 1.13 | ± 1.87 |
| 0.16–0.20 | 0.180 | 44.6 | 27.67 | ± 1.21 | ± 2.02 | 0.180 | 54.5 | 23.64 | ± 1.13 | ± 1.87 |
| 0.20–0.24 | 0.220 | 44.7 | 26.37 | ± 1.14 | ± 1.82 | 0.220 | 54.9 | 22.43 | ± 1.06 | ± 1.75 |
| 0.24–0.30 | 0.269 | 44.8 | 25.96 | ± 0.94 | ± 1.43 | 0.271 | 54.7 | 20.51 | ± 0.83 | ± 1.24 |
| 0.30–0.36 | 0.329 | 44.7 | 21.55 | ± 0.83 | ± 1.17 | 0.330 | 54.7 | 16.40 | ± 0.74 | ± 1.03 |
| 0.36–0.42 | 0.389 | 44.8 | 17.95 | ± 0.78 | ± 1.01 | 0.389 | 54.6 | 14.18 | ± 0.70 | ± 0.93 |
| 0.42–0.50 | 0.456 | 44.6 | 13.69 | ± 0.59 | ± 0.83 | 0.456 | 54.9 | 9.04 | ± 0.47 | ± 0.66 |
| 0.50–0.60 | 0.546 | 44.6 | 8.04 | ± 0.39 | ± 0.62 | 0.544 | 54.7 | 6.05 | ± 0.34 | ± 0.60 |
| 0.60–0.72 | 0.653 | 44.7 | 4.49 | ± 0.27 | ± 0.47 | 0.654 | 54.5 | 3.34 | ± 0.24 | ± 0.40 |
| 0.72–0.90 | 0.792 | 44.7 | 2.05 | ± 0.16 | ± 0.27 | 0.799 | 54.6 | 1.48 | ± 0.13 | ± 0.22 |
| 0.90–1.25 |          |          | 1.015 | 54.6 | 0.36 | ± 0.04 | ± 0.08 |          |          |          |
### Table A.15 (Continued)

| $p_T$     | 60 $< \theta < 75$ | 75 $< \theta < 90$ |
|-----------|------------------|------------------|
|           | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp d\Omega$ |
| 0.13–0.16 | 0.145 | 67.0 | 20.23 | ± 1.03 | ± 1.78 | 0.146 | 82.5 | 15.76 | ± 0.91 | ± 1.44 |
| 0.16–0.20 | 0.179 | 67.0 | 19.37 | ± 0.83 | ± 1.39 | 0.179 | 82.4 | 16.64 | ± 0.77 | ± 1.18 |
| 0.20–0.24 | 0.219 | 67.3 | 16.20 | ± 0.74 | ± 1.17 | 0.218 | 82.2 | 13.44 | ± 0.69 | ± 0.98 |
| 0.24–0.30 | 0.267 | 66.9 | 14.82 | ± 0.57 | ± 0.86 | 0.269 | 82.1 | 9.55 | ± 0.47 | ± 0.61 |
| 0.30–0.36 | 0.329 | 67.0 | 11.16 | ± 0.50 | ± 0.67 | 0.329 | 82.4 | 7.24 | ± 0.40 | ± 0.56 |
| 0.36–0.42 | 0.388 | 67.1 | 8.44  | ± 0.44 | ± 0.61 | 0.387 | 82.1 | 4.66 | ± 0.32 | ± 0.46 |
| 0.42–0.50 | 0.454 | 66.8 | 6.11  | ± 0.32 | ± 0.50 | 0.456 | 81.9 | 3.37 | ± 0.23 | ± 0.36 |
| 0.50–0.60 | 0.539 | 67.1 | 3.67  | ± 0.22 | ± 0.36 | 0.540 | 81.6 | 2.13 | ± 0.17 | ± 0.27 |
| 0.60–0.72 | 0.646 | 66.6 | 2.23  | ± 0.16 | ± 0.27 | 0.653 | 80.8 | 1.05 | ± 0.12 | ± 0.17 |
| 0.72–0.90 | 0.784 | 66.3 | 0.94  | ± 0.09 | ± 0.15 | 0.784 | 81.9 | 0.37 | ± 0.05 | ± 0.09 |
| 0.90–1.25 | 1.011 | 65.9 | 0.15  | ± 0.02 | ± 0.05 | 1.015 | 82.7 | 0.03 | ± 0.01 | ± 0.02 |

| $p_T$     | 90 $< \theta < 105$ | 105 $< \theta < 125$ |
|-----------|------------------|------------------|
|           | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp d\Omega$ |
| 0.13–0.16 | 0.145 | 96.7 | 15.55 | ± 0.92 | ± 1.48 | 0.145 | 114.5 | 12.24 | ± 0.70 | ± 1.11 |
| 0.16–0.20 | 0.179 | 97.3 | 13.18 | ± 0.70 | ± 0.96 | 0.178 | 114.0 | 9.88 | ± 0.52 | ± 0.77 |
| 0.20–0.24 | 0.217 | 97.2 | 9.96  | ± 0.60 | ± 0.80 | 0.218 | 114.1 | 7.30 | ± 0.44 | ± 0.70 |
| 0.24–0.30 | 0.268 | 96.6 | 7.43  | ± 0.41 | ± 0.57 | 0.267 | 114.2 | 4.38 | ± 0.28 | ± 0.44 |
| 0.30–0.36 | 0.328 | 96.2 | 4.13  | ± 0.30 | ± 0.42 | 0.326 | 113.5 | 2.46 | ± 0.21 | ± 0.30 |
| 0.36–0.42 | 0.387 | 97.2 | 2.84  | ± 0.25 | ± 0.35 | 0.381 | 112.6 | 1.57 | ± 0.17 | ± 0.24 |
| 0.42–0.50 | 0.456 | 96.9 | 2.18  | ± 0.19 | ± 0.30 | 0.453 | 113.1 | 0.87 | ± 0.10 | ± 0.18 |
| 0.50–0.60 | 0.539 | 97.4 | 1.08  | ± 0.12 | ± 0.18 | 0.538 | 112.2 | 0.40 | ± 0.06 | ± 0.14 |
| 0.60–0.72 | 0.653 | 94.8 | 0.37  | ± 0.06 | ± 0.10 | 0.658 | 111.9 | 0.06 | ± 0.02 | ± 0.04 |
| 0.72–0.90 | 0.791 | 95.7 | 0.04  | ± 0.02 | ± 0.03 |
Table A.16  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ (mb/(GeV/c sr)) of the production of protons in $\pi^- + \text{Be} \to p + X$ interactions with $-5.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|----------------|----------------|
|       | $\langle p_T \rangle$ | $\sigma$ | $\langle \theta \rangle$ | $\sigma$ | $\langle p_T \rangle$ | $\sigma$ |
| 0.20–0.24 | 0.217 | 25.0 | 33.01 | $\pm$ 1.18 | $\pm$ 2.52 |
| 0.24–0.30 | 0.265 | 24.9 | 30.80 | $\pm$ 0.92 | $\pm$ 1.93 |
| 0.30–0.36 | 0.323 | 25.1 | 28.41 | $\pm$ 0.89 | $\pm$ 1.65 |
| 0.36–0.42 | 0.381 | 25.1 | 25.33 | $\pm$ 0.83 | $\pm$ 1.39 |
| 0.42–0.50 | 0.445 | 24.9 | 24.57 | $\pm$ 0.70 | $\pm$ 1.20 |
| 0.50–0.60 | 0.530 | 24.9 | 18.14 | $\pm$ 0.53 | $\pm$ 0.90 |
| 0.60–0.72 | 0.630 | 25.0 | 14.01 | $\pm$ 0.42 | $\pm$ 0.80 |
| 0.72–0.90 | 0.764 | 35.0 | 7.80 | $\pm$ 0.27 | $\pm$ 0.61 |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|----------------|----------------|
|       | $\langle p_T \rangle$ | $\sigma$ | $\langle \theta \rangle$ | $\sigma$ | $\langle p_T \rangle$ | $\sigma$ |
| 0.30–0.36 | 0.330 | 45.1 | 22.87 | $\pm$ 0.75 | $\pm$ 1.28 |
| 0.36–0.42 | 0.388 | 45.2 | 22.59 | $\pm$ 0.76 | $\pm$ 1.28 |
| 0.42–0.50 | 0.458 | 45.2 | 18.42 | $\pm$ 0.61 | $\pm$ 0.97 |
| 0.50–0.60 | 0.548 | 44.9 | 14.52 | $\pm$ 0.50 | $\pm$ 0.79 |
| 0.60–0.72 | 0.655 | 45.0 | 10.32 | $\pm$ 0.39 | $\pm$ 0.66 |
| 0.72–0.90 | 0.800 | 45.0 | 5.60 | $\pm$ 0.24 | $\pm$ 0.47 |
| 0.90–1.25 | 1.029 | 44.9 | 1.92 | $\pm$ 0.10 | $\pm$ 0.23 |

| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|-------|----------------|----------------|
|       | $\langle p_T \rangle$ | $\sigma$ | $\langle \theta \rangle$ | $\sigma$ | $\langle p_T \rangle$ | $\sigma$ |
| 0.36–0.42 | 0.389 | 67.7 | 20.57 | $\pm$ 0.85 | $\pm$ 1.12 |
| 0.42–0.50 | 0.458 | 67.5 | 17.79 | $\pm$ 0.48 | $\pm$ 0.74 |
| 0.50–0.60 | 0.546 | 67.2 | 12.81 | $\pm$ 0.38 | $\pm$ 0.65 |
| 0.60–0.72 | 0.654 | 67.0 | 7.26 | $\pm$ 0.26 | $\pm$ 0.55 |
| 0.72–0.90 | 0.794 | 67.0 | 2.99 | $\pm$ 0.15 | $\pm$ 0.34 |
| 0.90–1.25 | 1.035 | 66.7 | 0.71 | $\pm$ 0.06 | $\pm$ 0.14 |

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|----------------|----------------|
|       | $\langle p_T \rangle$ | $\sigma$ | $\langle \theta \rangle$ | $\sigma$ | $\langle p_T \rangle$ | $\sigma$ |
| 0.36–0.42 | 0.388 | 96.9 | 7.12 | $\pm$ 0.29 | $\pm$ 0.55 |
| 0.42–0.50 | 0.456 | 96.1 | 3.69 | $\pm$ 0.19 | $\pm$ 0.38 |
| 0.50–0.60 | 0.547 | 95.8 | 1.24 | $\pm$ 0.12 | $\pm$ 0.21 |
| 0.60–0.72 | 0.652 | 95.5 | 0.39 | $\pm$ 0.06 | $\pm$ 0.12 |
| 0.72–0.90 | 0.790 | 94.2 | 0.07 | $\pm$ 0.02 | $\pm$ 0.06 |
Table A.17 Double-differential inclusive cross-section $d^2\sigma/d\rho d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^+$'s in $\pi^- + \text{Be} \rightarrow \pi^+ + X$ interactions with $-5.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | 20 $< \theta < 30$ | 30 $< \theta < 40$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/d\rho d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/d\rho d\Omega$ |
| 0.10–0.13 | 0.115 | 24.9 | 33.00 ± 1.51 ± 3.18 | 0.115 | 34.7 | 27.01 ± 1.43 ± 2.80 |
| 0.13–0.16 | 0.145 | 24.8 | 43.98 ± 1.64 ± 3.42 | 0.143 | 34.9 | 32.52 ± 1.40 ± 2.65 |
| 0.16–0.20 | 0.179 | 24.5 | 50.11 ± 1.43 ± 3.04 | 0.178 | 34.6 | 36.54 ± 1.26 ± 2.44 |
| 0.20–0.24 | 0.217 | 24.7 | 54.94 ± 1.48 ± 3.04 | 0.217 | 34.6 | 36.76 ± 1.19 ± 2.15 |
| 0.24–0.30 | 0.265 | 24.7 | 52.93 ± 1.20 ± 2.40 | 0.265 | 34.6 | 36.68 ± 0.93 ± 1.79 |
| 0.30–0.36 | 0.323 | 24.6 | 44.13 ± 1.07 ± 1.87 | 0.323 | 34.6 | 30.76 ± 0.83 ± 1.42 |
| 0.36–0.42 | 0.380 | 24.7 | 37.58 ± 0.99 ± 1.57 | 0.380 | 34.6 | 24.16 ± 0.78 ± 1.20 |
| 0.42–0.50 | 0.445 | 24.7 | 28.54 ± 0.76 ± 1.39 | 0.446 | 34.8 | 23.02 ± 0.71 ± 1.24 |
| 0.50–0.60 | 0.530 | 24.7 | 16.58 ± 0.49 ± 1.09 | 0.529 | 34.8 | 13.34 ± 0.45 ± 0.93 |
| 0.60–0.72 | 0.632 | 24.9 | 9.14 ± 0.31 ± 0.85 | 0.629 | 34.8 | 7.58 ± 0.29 ± 0.74 |
| 0.72–0.90 |  |  |  | 0.763 | 34.8 | 3.37 ± 0.16 ± 0.46 |

| $p_T$ | 40 $< \theta < 50$ | 50 $< \theta < 60$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/d\rho d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/d\rho d\Omega$ |
| 0.10–0.13 | 0.117 | 45.1 | 23.14 ± 1.34 ± 2.64 | 0.146 | 54.3 | 20.21 ± 1.12 ± 1.88 |
| 0.13–0.16 | 0.145 | 44.8 | 25.22 ± 1.27 ± 2.17 | 0.179 | 54.8 | 23.74 ± 1.04 ± 1.85 |
| 0.16–0.20 | 0.180 | 44.7 | 27.78 ± 1.09 ± 1.98 | 0.219 | 54.6 | 22.27 ± 0.97 ± 1.63 |
| 0.20–0.24 | 0.219 | 44.8 | 27.37 ± 1.05 ± 1.97 | 0.270 | 54.7 | 19.38 ± 0.72 ± 1.14 |
| 0.24–0.30 | 0.270 | 44.7 | 25.38 ± 0.83 ± 1.40 | 0.329 | 54.7 | 17.75 ± 0.70 ± 0.94 |
| 0.30–0.36 | 0.329 | 44.7 | 22.78 ± 0.77 ± 1.16 | 0.390 | 54.7 | 13.10 ± 0.61 ± 0.74 |
| 0.36–0.42 | 0.388 | 44.9 | 19.22 ± 0.73 ± 0.98 | 0.458 | 54.9 | 10.81 ± 0.47 ± 0.68 |
| 0.42–0.50 | 0.457 | 44.8 | 14.34 ± 0.55 ± 0.75 | 0.546 | 54.6 | 6.19 ± 0.31 ± 0.49 |
| 0.50–0.60 | 0.544 | 44.9 | 8.70 ± 0.37 ± 0.59 | 0.655 | 55.0 | 3.56 ± 0.22 ± 0.38 |
| 0.60–0.72 | 0.652 | 44.6 | 4.70 ± 0.24 ± 0.44 | 0.797 | 54.4 | 1.34 ± 0.10 ± 0.18 |
| 0.72–0.90 | 0.799 | 44.3 | 2.36 ± 0.13 ± 0.31 | 1.022 | 54.5 | 0.39 ± 0.03 ± 0.09 |

| $p_T$ | 60 $< \theta < 75$ | 75 $< \theta < 90$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/d\rho d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/d\rho d\Omega$ |
| 0.13–0.16 | 0.145 | 67.4 | 16.41 ± 0.84 ± 1.43 | 0.145 | 82.6 | 14.39 ± 0.78 ± 1.41 |
| 0.16–0.20 | 0.180 | 67.4 | 18.12 ± 0.72 ± 1.30 | 0.181 | 82.1 | 14.48 ± 0.65 ± 1.09 |
| 0.20–0.24 | 0.220 | 67.0 | 15.53 ± 0.65 ± 1.08 | 0.220 | 82.6 | 12.97 ± 0.61 ± 0.92 |
| 0.24–0.30 | 0.269 | 67.0 | 14.54 ± 0.53 ± 0.80 | 0.269 | 82.2 | 10.19 ± 0.45 ± 0.66 |
| 0.30–0.36 | 0.329 | 66.9 | 10.50 ± 0.45 ± 0.58 | 0.329 | 82.0 | 6.22 ± 0.34 ± 0.45 |
| 0.36–0.42 | 0.388 | 66.8 | 8.80 ± 0.40 ± 0.55 | 0.388 | 82.2 | 4.95 ± 0.30 ± 0.42 |
| 0.42–0.50 | 0.458 | 67.0 | 6.64 ± 0.30 ± 0.46 | 0.457 | 82.1 | 3.35 ± 0.21 ± 0.31 |
| 0.50–0.60 | 0.544 | 66.6 | 4.12 ± 0.21 ± 0.36 | 0.545 | 81.5 | 2.13 ± 0.15 ± 0.25 |
| 0.60–0.72 | 0.652 | 66.8 | 1.94 ± 0.13 ± 0.23 | 0.652 | 81.6 | 1.12 ± 0.10 ± 0.17 |
| 0.72–0.90 | 0.786 | 66.5 | 0.71 ± 0.06 ± 0.11 | 0.792 | 80.7 | 0.20 ± 0.03 ± 0.05 |
| 0.90–1.25 | 1.026 | 65.7 | 0.12 ± 0.02 ± 0.04 | 1.000 | 79.8 | 0.04 ± 0.01 ± 0.03 |
### Table A.17 (Continued)

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|---------------------|---------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.145 | 97.9 | 11.04 ± 0.69 ± 1.04 | 0.145 | 114.8 | 11.76 ± 0.62 ± 1.01 |
| 0.16–0.20 | 0.179 | 97.6 | 12.33 ± 0.62 ± 0.92 | 0.179 | 114.7 | 8.52 ± 0.43 ± 0.61 |
| 0.20–0.24 | 0.218 | 97.3 | 11.46 ± 0.58 ± 0.88 | 0.218 | 114.5 | 6.71 ± 0.38 ± 0.58 |
| 0.24–0.30 | 0.269 | 97.0 | 5.59 ± 0.32 ± 0.45 | 0.269 | 113.9 | 4.11 ± 0.25 ± 0.34 |
| 0.30–0.36 | 0.329 | 97.1 | 3.98 ± 0.28 ± 0.37 | 0.328 | 113.6 | 2.55 ± 0.19 ± 0.30 |
| 0.36–0.42 | 0.387 | 96.4 | 2.91 ± 0.22 ± 0.32 | 0.387 | 113.2 | 1.51 ± 0.15 ± 0.23 |
| 0.42–0.50 | 0.456 | 96.5 | 2.12 ± 0.18 ± 0.28 | 0.453 | 113.7 | 0.50 ± 0.07 ± 0.09 |
| 0.50–0.60 | 0.547 | 96.5 | 0.95 ± 0.10 ± 0.17 | 0.528 | 112.1 | 0.18 ± 0.04 ± 0.07 |
| 0.60–0.72 | 0.650 | 96.6 | 0.33 ± 0.05 ± 0.11 | 0.646 | 109.7 | 0.04 ± 0.02 ± 0.02 |
| 0.72–0.90 | 0.775 | 95.5 | 0.07 ± 0.02 ± 0.03 |

### Table A.18

Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^-$’s in $\pi^- + \text{Be} \rightarrow \pi^- + \text{X}$ interactions with $-5.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|---------------------|---------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.117 | 24.8 | 62.37 ± 2.16 ± 5.74 | 0.117 | 34.8 | 48.21 ± 1.91 ± 4.36 |
| 0.13–0.16 | 0.147 | 24.8 | 76.32 ± 2.20 ± 5.52 | 0.146 | 34.9 | 61.93 ± 1.99 ± 4.39 |
| 0.16–0.20 | 0.182 | 24.7 | 83.55 ± 1.87 ± 4.73 | 0.182 | 34.9 | 62.67 ± 1.65 ± 3.65 |
| 0.20–0.24 | 0.223 | 24.8 | 85.60 ± 1.86 ± 4.23 | 0.223 | 34.8 | 65.86 ± 1.66 ± 3.39 |
| 0.24–0.30 | 0.274 | 24.8 | 84.03 ± 1.51 ± 3.48 | 0.274 | 34.8 | 61.12 ± 1.25 ± 2.60 |
| 0.30–0.36 | 0.335 | 24.7 | 76.28 ± 1.44 ± 2.75 | 0.336 | 34.7 | 56.80 ± 1.22 ± 2.27 |
| 0.36–0.42 | 0.398 | 24.8 | 62.57 ± 1.32 ± 2.34 | 0.400 | 34.8 | 46.82 ± 1.12 ± 1.91 |
| 0.42–0.50 | 0.471 | 24.8 | 50.57 ± 1.04 ± 2.31 | 0.472 | 34.8 | 37.67 ± 0.88 ± 1.73 |
| 0.50–0.60 | 0.563 | 24.7 | 32.88 ± 0.72 ± 1.87 | 0.564 | 34.7 | 23.45 ± 0.61 ± 1.39 |
| 0.60–0.72 | 0.682 | 24.8 | 20.81 ± 0.52 ± 1.62 | 0.681 | 34.6 | 13.46 ± 0.41 ± 1.09 |
| 0.72–0.90 | 0.833 | 24.4 | 6.88 ± 0.25 ± 0.73 |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|---------------------|---------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.115 | 44.9 | 40.66 ± 1.85 ± 3.91 |
| 0.13–0.16 | 0.145 | 45.0 | 46.69 ± 1.72 ± 3.41 | 0.146 | 55.0 | 39.53 ± 1.61 ± 3.02 |
| 0.16–0.20 | 0.180 | 44.9 | 48.40 ± 1.47 ± 2.96 | 0.180 | 54.7 | 39.50 ± 1.32 ± 2.52 |
| 0.20–0.24 | 0.220 | 44.8 | 51.14 ± 1.49 ± 2.77 | 0.220 | 54.8 | 39.04 ± 1.29 ± 2.29 |
| 0.24–0.30 | 0.270 | 44.7 | 46.15 ± 1.14 ± 2.03 | 0.269 | 54.7 | 36.30 ± 1.01 ± 1.76 |
| 0.30–0.36 | 0.329 | 44.8 | 41.24 ± 1.06 ± 1.68 | 0.330 | 54.7 | 28.89 ± 0.89 ± 1.25 |
| 0.36–0.42 | 0.388 | 44.7 | 31.58 ± 0.92 ± 1.32 | 0.389 | 54.8 | 24.62 ± 0.84 ± 1.18 |
| 0.42–0.50 | 0.457 | 44.7 | 26.31 ± 0.74 ± 1.28 | 0.458 | 54.7 | 16.87 ± 0.58 ± 0.98 |
| 0.50–0.60 | 0.546 | 44.7 | 17.44 ± 0.53 ± 1.12 | 0.546 | 54.6 | 10.96 ± 0.41 ± 0.81 |
| 0.60–0.72 | 0.652 | 44.7 | 9.12 ± 0.34 ± 0.80 | 0.652 | 54.7 | 6.94 ± 0.31 ± 0.66 |
| 0.72–0.90 | 0.798 | 44.5 | 4.34 ± 0.20 ± 0.50 | 0.790 | 54.6 | 2.73 ± 0.16 ± 0.33 |
| 0.90–1.25 | 1.015 | 54.7 | 0.67 ± 0.06 ± 0.12 |
Table A.18  (Continued)

| $p_T$  | $60 < \theta < 75$ | $75 < \theta < 90$ |
|--------|---------------------|---------------------|
|        | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.146 | 67.2 | 30.13 | ± | 1.14 | ± | 2.19 | 0.145 | 82.5 | 26.15 | ± | 1.05 | ± | 2.03 |
| 0.16–0.20 | 0.180 | 67.4 | 32.26 | ± | 0.98 | ± | 1.86 | 0.179 | 82.4 | 28.40 | ± | 0.91 | ± | 1.66 |
| 0.20–0.24 | 0.220 | 67.1 | 30.28 | ± | 0.95 | ± | 1.67 | 0.220 | 82.2 | 24.92 | ± | 0.86 | ± | 1.34 |
| 0.24–0.30 | 0.268 | 67.0 | 23.68 | ± | 0.67 | ± | 1.02 | 0.269 | 82.1 | 16.88 | ± | 0.57 | ± | 0.81 |
| 0.30–0.36 | 0.329 | 66.8 | 19.13 | ± | 0.60 | ± | 0.84 | 0.328 | 81.8 | 12.14 | ± | 0.48 | ± | 0.70 |
| 0.36–0.42 | 0.389 | 67.1 | 15.73 | ± | 0.54 | ± | 0.84 | 0.389 | 81.7 | 8.58 | ± | 0.39 | ± | 0.64 |
| 0.42–0.50 | 0.459 | 66.9 | 10.41 | ± | 0.37 | ± | 0.67 | 0.458 | 81.6 | 6.55 | ± | 0.30 | ± | 0.56 |
| 0.50–0.60 | 0.544 | 66.5 | 7.04 | ± | 0.27 | ± | 0.58 | 0.547 | 81.5 | 3.33 | ± | 0.19 | ± | 0.35 |
| 0.60–0.72 | 0.652 | 66.8 | 3.77 | ± | 0.19 | ± | 0.40 | 0.650 | 80.8 | 1.82 | ± | 0.13 | ± | 0.25 |
| 0.72–0.90 | 0.790 | 66.4 | 1.60 | ± | 0.10 | ± | 0.22 | 0.787 | 81.2 | 0.39 | ± | 0.05 | ± | 0.08 |
| 0.90–1.25 | 1.032 | 67.0 | 0.18 | ± | 0.02 | ± | 0.04 | 0.992 | 79.4 | 0.03 | ± | 0.01 | ± | 0.02 |

| $p_T$  | $90 < \theta < 105$ | $105 < \theta < 125$ |
|--------|---------------------|---------------------|
|        | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.146 | 97.0 | 24.14 | ± | 1.05 | ± | 1.88 | 0.145 | 114.3 | 20.22 | ± | 0.81 | ± | 1.33 |
| 0.16–0.20 | 0.179 | 97.3 | 24.91 | ± | 0.89 | ± | 1.44 | 0.179 | 114.3 | 17.32 | ± | 0.63 | ± | 0.95 |
| 0.20–0.24 | 0.219 | 97.3 | 17.32 | ± | 0.71 | ± | 1.00 | 0.218 | 114.3 | 11.14 | ± | 0.49 | ± | 0.75 |
| 0.24–0.30 | 0.267 | 97.2 | 12.43 | ± | 0.48 | ± | 0.77 | 0.267 | 114.0 | 6.86 | ± | 0.31 | ± | 0.51 |
| 0.30–0.36 | 0.328 | 96.9 | 7.52 | ± | 0.37 | ± | 0.58 | 0.329 | 113.6 | 3.70 | ± | 0.23 | ± | 0.36 |
| 0.36–0.42 | 0.388 | 96.3 | 4.89 | ± | 0.30 | ± | 0.46 | 0.385 | 114.0 | 2.56 | ± | 0.19 | ± | 0.31 |
| 0.42–0.50 | 0.459 | 96.8 | 3.47 | ± | 0.22 | ± | 0.40 | 0.458 | 113.0 | 1.39 | ± | 0.12 | ± | 0.22 |
| 0.50–0.60 | 0.545 | 96.6 | 1.74 | ± | 0.14 | ± | 0.25 | 0.535 | 111.3 | 0.56 | ± | 0.06 | ± | 0.14 |
| 0.60–0.72 | 0.640 | 96.4 | 0.56 | ± | 0.07 | ± | 0.12 | 0.653 | 110.5 | 0.18 | ± | 0.03 | ± | 0.08 |
| 0.72–0.90 | 0.789 | 97.1 | 0.15 | ± | 0.03 | ± | 0.06 |
Table A.19  Double-differential inclusive cross-section $d^2\sigma/dp\Omega [\text{mb}/(\text{GeV}/c \, \text{sr})]$ of the production of protons in $p + \text{Be} \rightarrow p + X$ interactions with +12.0 GeV/$c$ beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/$c$, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ | $40 < \theta < 50$ | $50 < \theta < 60$ | $60 < \theta < 75$ | $75 < \theta < 90$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
|       | $(p_T)$            | $(\theta)$         | $d^2\sigma/dp\Omega$ | $(p_T)$            | $(\theta)$         | $d^2\sigma/dp\Omega$ | $(p_T)$            | $(\theta)$         | $d^2\sigma/dp\Omega$ |
| 0.20–0.24 | 0.220          | 24.8              | 42.26 ± 1.72 ± 2.32   | 0.270              | 34.9              | 40.58 ± 1.33 ± 1.92   | 0.796              | 34.8              | 14.17 ± 0.47 ± 0.82   |
| 0.24–0.30 | 0.269          | 25.0              | 47.06 ± 1.45 ± 2.34   | 0.328              | 35.1              | 39.35 ± 1.31 ± 1.55   | 0.387              | 35.0              | 37.43 ± 1.31 ± 1.27   |
| 0.30–0.36 | 0.329          | 25.2              | 44.12 ± 1.43 ± 1.87   | 0.387              | 35.0              | 37.43 ± 1.31 ± 1.27   | 0.544              | 34.8              | 28.13 ± 0.89 ± 0.90   |
| 0.36–0.42 | 0.388          | 25.2              | 40.91 ± 1.35 ± 1.53   | 0.457              | 34.9              | 30.10 ± 1.00 ± 1.02   | 0.652              | 34.8              | 20.54 ± 0.68 ± 0.85   |
| 0.42–0.50 | 0.456          | 24.8              | 37.62 ± 1.11 ± 1.23   | 0.548              | 55.0              | 18.48 ± 0.71 ± 0.70   | 0.796              | 54.9              | 8.30 ± 0.38 ± 0.56    |
| 0.50–0.60 | 0.545          | 24.9              | 32.32 ± 0.91 ± 1.06   | 0.658              | 55.0              | 14.18 ± 0.59 ± 0.70   | 1.031              | 54.9              | 2.21 ± 0.14 ± 0.24    |
| 0.60–0.72 | 0.651          | 24.9              | 27.50 ± 0.78 ± 1.08   | 0.798              | 54.8              | 8.30 ± 0.38 ± 0.56    | 1.052              | 81.0              | 0.62 ± 0.06 ± 0.10    |
| 0.72–0.90 | 1.040          | 44.7              | 4.00 ± 0.19 ± 0.38    | 1.031              | 54.9              | 2.21 ± 0.14 ± 0.24    | 1.052              | 81.0              | 0.62 ± 0.06 ± 0.10    |

Note: The table entries represent the double-differential inclusive cross-section for proton production in the specified kinematic ranges. The errors indicate the statistical and systematic uncertainties, respectively.
Table A20 Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ (mb/(GeV/c sr)) of the production of $\pi^+\pi^-$ in $p + \text{Be} \rightarrow \pi^+ + X$ interactions with $+12.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|--------------------|--------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.116 | 24.5 | 56.17 ± 2.74 ± 4.10 | 0.116 | 34.9 | 37.64 ± 2.12 ± 2.76 |
| 0.13–0.16 | 0.145 | 24.6 | 68.54 ± 2.74 ± 3.99 | 0.146 | 34.7 | 49.10 ± 2.30 ± 2.82 |
| 0.16–0.20 | 0.180 | 24.4 | 81.06 ± 2.45 ± 3.93 | 0.180 | 34.7 | 59.23 ± 2.18 ± 2.84 |
| 0.20–0.24 | 0.220 | 24.6 | 89.45 ± 2.60 ± 3.70 | 0.219 | 34.7 | 57.42 ± 2.05 ± 2.36 |
| 0.24–0.30 | 0.269 | 24.6 | 87.39 ± 2.08 ± 3.02 | 0.269 | 34.8 | 58.85 ± 1.70 ± 1.99 |
| 0.30–0.36 | 0.328 | 24.7 | 72.09 ± 1.84 ± 2.14 | 0.329 | 34.6 | 44.45 ± 1.44 ± 1.29 |
| 0.36–0.42 | 0.387 | 24.6 | 57.37 ± 1.63 ± 1.67 | 0.388 | 34.7 | 40.10 ± 1.39 ± 1.13 |
| 0.42–0.50 | 0.455 | 24.7 | 44.57 ± 1.24 ± 1.58 | 0.456 | 34.7 | 29.50 ± 0.99 ± 0.97 |
| 0.50–0.60 | 0.541 | 24.8 | 29.37 ± 0.88 ± 1.50 | 0.544 | 34.7 | 20.26 ± 0.74 ± 0.95 |
| 0.60–0.72 | 0.653 | 24.5 | 18.38 ± 0.62 ± 1.42 | 0.650 | 34.7 | 11.91 ± 0.48 ± 0.84 |
| 0.72–0.90 | 0.793 | 34.4 | 5.37 ± 0.24 ± 0.60 |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|--------------------|--------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.116 | 44.9 | 29.54 ± 1.89 ± 2.23 |
| 0.13–0.16 | 0.145 | 45.1 | 31.65 ± 1.79 ± 1.86 |
| 0.16–0.20 | 0.180 | 44.7 | 39.88 ± 1.74 ± 1.95 |
| 0.20–0.24 | 0.220 | 45.1 | 36.17 ± 1.59 ± 1.51 |
| 0.24–0.30 | 0.269 | 44.9 | 37.30 ± 1.34 ± 1.27 |
| 0.30–0.36 | 0.329 | 44.6 | 27.91 ± 1.13 ± 0.83 |
| 0.36–0.42 | 0.387 | 44.6 | 27.97 ± 1.17 ± 0.84 |
| 0.42–0.50 | 0.458 | 44.6 | 19.97 ± 0.85 ± 0.69 |
| 0.50–0.60 | 0.545 | 44.6 | 12.52 ± 0.56 ± 0.58 |
| 0.60–0.72 | 0.653 | 44.3 | 8.16 ± 0.42 ± 0.54 |
| 0.72–0.90 | 0.792 | 44.4 | 3.41 ± 0.21 ± 0.35 |
| 0.90–1.25 | 1.012 | 54.0 | 0.43 ± 0.04 ± 0.08 |

| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|-------|--------------------|--------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.146 | 67.2 | 18.07 ± 1.05 ± 1.18 |
| 0.16–0.20 | 0.181 | 67.2 | 23.29 ± 1.06 ± 1.14 |
| 0.20–0.24 | 0.221 | 67.2 | 22.23 ± 1.04 ± 0.89 |
| 0.24–0.30 | 0.272 | 67.3 | 20.62 ± 0.80 ± 0.67 |
| 0.30–0.36 | 0.333 | 66.7 | 15.24 ± 0.71 ± 0.47 |
| 0.36–0.42 | 0.396 | 66.5 | 10.73 ± 0.56 ± 0.37 |
| 0.42–0.50 | 0.464 | 67.0 | 7.43 ± 0.40 ± 0.33 |
| 0.50–0.60 | 0.555 | 66.3 | 4.91 ± 0.29 ± 0.30 |
| 0.60–0.72 | 0.666 | 66.4 | 3.29 ± 0.23 ± 0.28 |
| 0.72–0.90 | 0.806 | 66.1 | 0.96 ± 0.09 ± 0.12 |
| 0.90–1.25 | 1.043 | 65.3 | 0.17 ± 0.02 ± 0.04 |
Table A.20 (Continued)

| $p_T$ | $0^\circ < \theta < 105^\circ$ | $105^\circ < \theta < 125^\circ$ |
|-------|-------------------------------|-------------------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp_d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp_d\Omega$ |
| 0.13–0.16 | 0.147 | 97.4 | 12.17 ± 0.87 ± 0.80 | 0.146 | 115.1 | 11.86 ± 0.72 ± 0.76 |
| 0.16–0.20 | 0.181 | 97.4 | 13.20 ± 0.74 ± 0.71 | 0.181 | 113.9 | 10.37 ± 0.58 ± 0.55 |
| 0.20–0.24 | 0.220 | 97.3 | 11.44 ± 0.71 ± 0.45 | 0.219 | 114.0 | 8.53 ± 0.56 ± 0.36 |
| 0.24–0.30 | 0.270 | 97.6 | 9.23 ± 0.55 ± 0.34 | 0.269 | 113.7 | 3.86 ± 0.29 ± 0.17 |
| 0.30–0.36 | 0.331 | 97.2 | 4.67 ± 0.38 ± 0.21 | 0.330 | 113.6 | 2.57 ± 0.24 ± 0.13 |
| 0.36–0.42 | 0.393 | 97.5 | 5.31 ± 0.33 ± 0.22 | 0.393 | 113.6 | 1.53 ± 0.17 ± 0.08 |
| 0.42–0.50 | 0.466 | 96.3 | 2.68 ± 0.25 ± 0.22 | 0.459 | 113.7 | 1.67 ± 0.10 ± 0.08 |
| 0.50–0.60 | 0.550 | 96.1 | 0.95 ± 0.12 ± 0.11 | 0.563 | 112.5 | 0.26 ± 0.06 ± 0.04 |
| 0.60–0.72 | 0.662 | 96.1 | 0.30 ± 0.06 ± 0.05 | 0.669 | 108.6 | 0.08 ± 0.03 ± 0.02 |
| 0.72–0.90 | 0.812 | 97.0 | 0.11 ± 0.03 ± 0.02 |       |       | |

Table A.21 Double-differential inclusive cross-section $d^2\sigma/dp_d\Omega$ [nb/(GeV/c sr)] of the production of $\pi^-$'s in p + Be $\rightarrow \pi^- + X$ interactions with +12.0 GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20^\circ < \theta < 30^\circ$ | $30^\circ < \theta < 40^\circ$ |
|-------|-------------------------------|-------------------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp_d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp_d\Omega$ |
| 0.10–0.13 | 0.116 | 24.7 | 63.15 ± 2.80 ± 4.48 | 0.115 | 34.6 | 36.61 ± 1.99 ± 2.85 |
| 0.13–0.16 | 0.146 | 24.8 | 73.93 ± 2.87 ± 4.28 | 0.146 | 34.8 | 50.78 ± 2.28 ± 3.02 |
| 0.16–0.20 | 0.180 | 24.6 | 75.32 ± 2.35 ± 3.65 | 0.181 | 34.5 | 54.11 ± 1.94 ± 2.67 |
| 0.20–0.24 | 0.220 | 24.6 | 86.26 ± 2.56 ± 3.50 | 0.220 | 34.8 | 57.19 ± 2.04 ± 2.36 |
| 0.24–0.30 | 0.270 | 24.6 | 71.03 ± 1.84 ± 2.33 | 0.270 | 34.8 | 50.41 ± 1.55 ± 1.67 |
| 0.30–0.36 | 0.330 | 24.8 | 60.88 ± 1.71 ± 1.70 | 0.331 | 34.8 | 42.13 ± 1.42 ± 1.19 |
| 0.36–0.42 | 0.391 | 24.9 | 46.35 ± 1.50 ± 1.33 | 0.390 | 34.8 | 35.09 ± 1.30 ± 1.01 |
| 0.42–0.50 | 0.460 | 24.6 | 34.68 ± 1.11 ± 1.25 | 0.458 | 34.7 | 22.92 ± 0.86 ± 0.81 |
| 0.50–0.60 | 0.550 | 24.8 | 24.77 ± 0.85 ± 1.25 | 0.548 | 35.0 | 16.44 ± 0.70 ± 0.81 |
| 0.60–0.72 | 0.657 | 24.7 | 12.69 ± 0.54 ± 0.91 | 0.658 | 34.9 | 7.61 ± 0.39 ± 0.53 |
| 0.72–0.90 | 0.805 | 35.1 | 3.67 ± 0.23 ± 0.37 |       |       | |

| $p_T$ | $40^\circ < \theta < 50^\circ$ | $50^\circ < \theta < 60^\circ$ |
|-------|-------------------------------|-------------------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp_d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp_d\Omega$ |
| 0.10–0.13 | 0.116 | 44.8 | 26.29 ± 1.63 ± 2.21 |       |       | |
| 0.13–0.16 | 0.145 | 44.8 | 31.91 ± 1.69 ± 2.00 | 0.144 | 54.9 | 29.42 ± 1.74 ± 2.00 |
| 0.16–0.20 | 0.180 | 44.9 | 42.89 ± 1.85 ± 2.15 | 0.179 | 55.0 | 28.79 ± 1.41 ± 1.44 |
| 0.20–0.24 | 0.220 | 45.1 | 36.82 ± 1.59 ± 1.55 | 0.219 | 54.7 | 30.71 ± 1.48 ± 1.27 |
| 0.24–0.30 | 0.269 | 44.7 | 35.90 ± 1.32 ± 1.21 | 0.269 | 54.8 | 25.32 ± 1.10 ± 0.84 |
| 0.30–0.36 | 0.329 | 44.5 | 28.51 ± 1.12 ± 0.82 | 0.329 | 54.7 | 17.52 ± 0.84 ± 0.52 |
| 0.36–0.42 | 0.390 | 44.7 | 23.91 ± 1.06 ± 0.73 | 0.388 | 54.6 | 16.15 ± 0.86 ± 0.53 |
| 0.42–0.50 | 0.458 | 44.6 | 15.10 ± 0.67 ± 0.57 | 0.455 | 54.8 | 9.68 ± 0.55 ± 0.41 |
| 0.50–0.60 | 0.545 | 44.7 | 9.36 ± 0.47 ± 0.50 | 0.547 | 54.8 | 7.63 ± 0.46 ± 0.44 |
| 0.60–0.72 | 0.653 | 45.0 | 5.50 ± 0.36 ± 0.41 | 0.653 | 54.5 | 3.63 ± 0.27 ± 0.29 |
| 0.72–0.90 | 0.793 | 44.8 | 2.16 ± 0.17 ± 0.23 | 0.785 | 54.5 | 1.51 ± 0.14 ± 0.16 |
| 0.90–1.25 |       |       | 1.021 | 54.3 | 0.21 ± 0.03 ± 0.04 |
### Table A.21  (Continued)

| $p_T$  | $60 < \theta < 75$ | $75 < \theta < 90$ |
|--------|------------------|------------------|
|        | $\langle p_T \rangle$ | $\langle p_T \rangle$ | $d^2\sigma/dp d\Omega$ | $d^2\sigma/dp d\Omega$ |
|        | (\theta) | (\theta) |        |        |
| 0.13–0.16 | 0.145 | 67.4 | 19.97 | ± | 1.09 | ± | 1.39 | 0.145 | 82.4 | 16.93 | ± | 0.99 | ± | 1.21 |
| 0.16–0.20 | 0.180 | 67.5 | 22.77 | ± | 0.99 | ± | 1.15 | 0.178 | 82.3 | 18.92 | ± | 0.90 | ± | 1.00 |
| 0.20–0.24 | 0.218 | 67.2 | 21.03 | ± | 0.97 | ± | 0.81 | 0.217 | 82.3 | 16.53 | ± | 0.83 | ± | 0.63 |
| 0.24–0.30 | 0.267 | 66.9 | 16.28 | ± | 0.68 | ± | 0.51 | 0.265 | 81.9 | 13.64 | ± | 0.65 | ± | 0.43 |
| 0.30–0.36 | 0.327 | 66.8 | 13.78 | ± | 0.64 | ± | 0.42 | 0.324 | 81.8 | 7.88 | ± | 0.47 | ± | 0.30 |
| 0.36–0.42 | 0.384 | 66.7 | 9.72 | ± | 0.52 | ± | 0.35 | 0.383 | 82.0 | 5.92 | ± | 0.42 | ± | 0.30 |
| 0.42–0.50 | 0.452 | 66.2 | 5.78 | ± | 0.33 | ± | 0.29 | 0.451 | 81.4 | 3.52 | ± | 0.27 | ± | 0.22 |
| 0.50–0.60 | 0.535 | 66.4 | 4.40 | ± | 0.28 | ± | 0.29 | 0.534 | 82.4 | 2.34 | ± | 0.20 | ± | 0.20 |
| 0.60–0.72 | 0.638 | 66.3 | 1.97 | ± | 0.16 | ± | 0.17 | 0.636 | 81.4 | 0.74 | ± | 0.11 | ± | 0.09 |
| 0.72–0.90 | 0.773 | 66.4 | 0.76 | ± | 0.08 | ± | 0.10 | 0.752 | 83.0 | 0.18 | ± | 0.04 | ± | 0.03 |
| 0.90–1.25 | 0.988 | 66.5 | 0.11 | ± | 0.02 | ± | 0.02 | 1.041 | 78.8 | 0.02 | ± | 0.01 | ± | 0.01 |

| $p_T$  | $90 < \theta < 105$ | $105 < \theta < 125$ |
|--------|------------------|------------------|
|        | $\langle p_T \rangle$ | $\langle p_T \rangle$ | $d^2\sigma/dp d\Omega$ | $d^2\sigma/dp d\Omega$ |
|        | (\theta) | (\theta) |        |        |
| 0.13–0.16 | 0.144 | 97.3 | 15.64 | ± | 0.95 | ± | 1.21 | 0.145 | 114.2 | 13.59 | ± | 0.73 | ± | 1.01 |
| 0.16–0.20 | 0.179 | 96.9 | 13.02 | ± | 0.69 | ± | 0.78 | 0.178 | 114.4 | 8.83 | ± | 0.47 | ± | 0.53 |
| 0.20–0.24 | 0.218 | 96.6 | 10.87 | ± | 0.66 | ± | 0.47 | 0.218 | 113.7 | 6.54 | ± | 0.43 | ± | 0.35 |
| 0.24–0.30 | 0.265 | 97.7 | 6.63 | ± | 0.40 | ± | 0.27 | 0.265 | 113.4 | 5.25 | ± | 0.34 | ± | 0.28 |
| 0.30–0.36 | 0.324 | 97.2 | 5.36 | ± | 0.38 | ± | 0.27 | 0.325 | 113.5 | 2.20 | ± | 0.21 | ± | 0.16 |
| 0.36–0.42 | 0.387 | 96.6 | 2.69 | ± | 0.27 | ± | 0.18 | 0.380 | 112.3 | 1.38 | ± | 0.18 | ± | 0.14 |
| 0.42–0.50 | 0.453 | 96.4 | 1.47 | ± | 0.15 | ± | 0.13 | 0.444 | 111.2 | 0.91 | ± | 0.14 | ± | 0.12 |
| 0.50–0.60 | 0.529 | 96.6 | 0.95 | ± | 0.13 | ± | 0.12 | 0.526 | 111.0 | 0.25 | ± | 0.05 | ± | 0.04 |
| 0.60–0.72 | 0.643 | 97.4 | 0.20 | ± | 0.05 | ± | 0.03 | 0.623 | 115.0 | 0.04 | ± | 0.03 | ± | 0.02 |
| 0.72–0.90 | 0.762 | 94.4 | 0.11 | ± | 0.03 | ± | 0.02 |
Table A.22  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ (mb/(GeV/c sr)) of the production of protons in $\pi^+ + \text{Be} \to p + X$ interactions with +12.0 GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | 20 $< \theta < 30$ | 30 $< \theta < 40$ |
|-------|-----------------|-----------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.20–0.24 | 0.222 | 24.8 | 33.15 ± 5.14 ± 2.10 | 0.271 | 34.9 | 33.55 ± 4.04 ± 1.83 |
| 0.24–0.30 | 0.269 | 24.9 | 26.85 ± 3.64 ± 1.49 | 0.330 | 34.9 | 34.02 ± 4.00 ± 1.65 |
| 0.30–0.36 | 0.329 | 24.6 | 35.59 ± 4.18 ± 1.77 | 0.390 | 35.3 | 34.04 ± 4.12 ± 1.44 |
| 0.36–0.42 | 0.386 | 25.0 | 29.52 ± 3.74 ± 1.33 | 0.459 | 35.4 | 23.40 ± 2.93 ± 0.96 |
| 0.42–0.50 | 0.459 | 25.0 | 24.09 ± 2.90 ± 0.96 | 0.541 | 35.0 | 23.64 ± 2.72 ± 0.93 |
| 0.50–0.60 | 0.544 | 25.5 | 25.01 ± 2.66 ± 0.99 | 0.658 | 34.8 | 14.30 ± 1.84 ± 0.68 |
| 0.60–0.72 | 0.649 | 24.4 | 16.32 ± 1.87 ± 0.74 | 0.794 | 34.6 | 9.70 ± 1.25 ± 0.61 |
| 0.72–0.90 | 1.024 | 43.7 | 2.02 ± 0.41 ± 0.21 | 1.010 | 54.7 | 2.14 ± 0.45 ± 0.25 |

| $p_T$ | 40 $< \theta < 50$ | 50 $< \theta < 60$ |
|-------|-----------------|-----------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.30–0.36 | 0.327 | 45.1 | 24.69 ± 3.52 ± 1.03 | 0.387 | 55.8 | 20.10 ± 3.07 ± 0.88 |
| 0.36–0.42 | 0.393 | 45.2 | 27.74 ± 3.71 ± 1.10 | 0.458 | 55.1 | 18.02 ± 2.54 ± 0.74 |
| 0.42–0.50 | 0.456 | 45.1 | 23.65 ± 2.96 ± 0.93 | 0.550 | 55.2 | 13.05 ± 1.96 ± 0.63 |
| 0.50–0.60 | 0.545 | 45.0 | 17.32 ± 2.30 ± 0.72 | 0.663 | 54.5 | 9.40 ± 1.58 ± 0.54 |
| 0.60–0.72 | 0.657 | 44.7 | 10.89 ± 1.66 ± 0.56 | 0.786 | 54.3 | 5.25 ± 0.98 ± 0.39 |
| 0.72–0.90 | 0.805 | 44.8 | 9.28 ± 1.26 ± 0.62 | 1.010 | 54.7 | 2.14 ± 0.45 ± 0.25 |
| 0.90–1.25 | 1.024 | 43.7 | 2.02 ± 0.41 ± 0.21 | 1.010 | 54.7 | 2.14 ± 0.45 ± 0.25 |

| $p_T$ | 60 $< \theta < 75$ | 75 $< \theta < 90$ |
|-------|-----------------|-----------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.36–0.42 | 0.396 | 68.4 | 23.44 ± 2.62 ± 1.17 | 0.464 | 81.7 | 12.36 ± 1.67 ± 0.64 |
| 0.42–0.50 | 0.462 | 66.9 | 21.70 ± 2.25 ± 0.86 | 0.561 | 81.1 | 8.45 ± 1.30 ± 0.50 |
| 0.50–0.60 | 0.554 | 66.9 | 12.09 ± 1.55 ± 0.56 | 0.652 | 81.7 | 3.95 ± 0.83 ± 0.33 |
| 0.60–0.72 | 0.665 | 67.3 | 8.91 ± 1.28 ± 0.58 | 0.825 | 81.7 | 2.91 ± 0.62 ± 0.32 |
| 0.72–0.90 | 0.830 | 66.7 | 3.92 ± 0.70 ± 0.37 | 1.031 | 80.7 | 0.58 ± 0.20 ± 0.10 |
| 0.90–1.25 | 1.063 | 67.2 | 0.90 ± 0.24 ± 0.13 | 1.031 | 80.7 | 0.58 ± 0.20 ± 0.10 |

| $p_T$ | 90 $< \theta < 105$ | 105 $< \theta < 125$ |
|-------|-----------------|-----------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.36–0.42 | 0.393 | 112.5 | 7.10 ± 1.30 ± 0.38 | 0.462 | 114.0 | 3.66 ± 0.81 ± 0.26 |
| 0.42–0.50 | 0.468 | 96.4 | 6.41 ± 1.26 ± 0.43 | 0.562 | 112.9 | 2.41 ± 0.64 ± 0.26 |
| 0.50–0.60 | 0.552 | 96.5 | 4.78 ± 0.97 ± 0.39 | 0.689 | 109.0 | 0.88 ± 0.36 ± 0.14 |
| 0.60–0.72 | 0.679 | 96.1 | 2.80 ± 0.74 ± 0.29 | 0.803 | 109.4 | 0.29 ± 0.17 ± 0.07 |
| 0.72–0.90 | 0.846 | 97.0 | 0.59 ± 0.27 ± 0.08 | 0.803 | 109.4 | 0.29 ± 0.17 ± 0.07 |
| 0.90–1.25 | 1.063 | 98.3 | 0.20 ± 0.13 ± 0.04 | 0.803 | 109.4 | 0.29 ± 0.17 ± 0.07 |
### Table A.23
Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^+$’s in $\pi^+ + \text{Be} \to \pi^+ + \text{X}$ interactions with $+12.0 \text{ GeV/c}$ beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ (GeV/c) | $20 < \theta < 30$ | $30 < \theta < 40$ |
|--------------|------------------|------------------|
| $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.117 & 24.8 & 35.14 $\pm$ 7.12 $\pm$ 2.68 | 0.115 & 36.3 & 40.25 $\pm$ 7.54 $\pm$ 3.21 |
| 0.13–0.16 | 0.149 & 24.2 & 49.55 $\pm$ 7.52 $\pm$ 3.10 | 0.146 & 33.9 & 43.15 $\pm$ 7.16 $\pm$ 2.78 |
| 0.16–0.20 | 0.180 & 24.6 & 88.52 $\pm$ 8.54 $\pm$ 4.63 | 0.182 & 34.7 & 61.79 $\pm$ 7.47 $\pm$ 3.49 |
| 0.20–0.24 | 0.221 & 24.9 & 76.40 $\pm$ 8.04 $\pm$ 3.55 | 0.220 & 35.4 & 66.66 $\pm$ 7.43 $\pm$ 3.15 |
| 0.24–0.30 | 0.268 & 24.2 & 93.08 $\pm$ 7.11 $\pm$ 3.59 | 0.268 & 34.8 & 60.65 $\pm$ 5.76 $\pm$ 2.36 |
| 0.30–0.36 | 0.328 & 24.9 & 65.62 $\pm$ 5.87 $\pm$ 2.21 | 0.327 & 34.4 & 51.40 $\pm$ 5.12 $\pm$ 1.83 |
| 0.36–0.42 | 0.387 & 24.2 & 62.31 $\pm$ 5.97 $\pm$ 2.10 | 0.383 & 34.5 & 38.13 $\pm$ 4.49 $\pm$ 1.37 |
| 0.42–0.50 | 0.456 & 24.5 & 45.10 $\pm$ 4.14 $\pm$ 1.78 | 0.455 & 34.2 & 21.54 $\pm$ 2.80 $\pm$ 0.85 |
| 0.50–0.60 | 0.541 & 24.8 & 31.91 $\pm$ 3.08 $\pm$ 1.72 | 0.540 & 34.6 & 19.08 $\pm$ 2.42 $\pm$ 1.00 |
| 0.60–0.72 | 0.651 & 24.5 & 21.60 $\pm$ 2.28 $\pm$ 1.79 | 0.645 & 34.9 & 14.67 $\pm$ 1.84 $\pm$ 1.10 |
| 0.72–0.90 | 0.793 & 34.4 & 5.69 $\pm$ 0.84 $\pm$ 0.66 |

| $p_T$ (GeV/c) | $40 < \theta < 50$ | $50 < \theta < 60$ |
|--------------|------------------|------------------|
| $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.114 & 44.7 & 21.46 $\pm$ 5.40 $\pm$ 1.80 |
| 0.13–0.16 | 0.144 & 44.7 & 40.74 $\pm$ 6.75 $\pm$ 2.81 |
| 0.16–0.20 | 0.181 & 45.8 & 35.78 $\pm$ 5.57 $\pm$ 2.06 |
| 0.20–0.24 | 0.218 & 45.0 & 37.42 $\pm$ 5.36 $\pm$ 1.91 |
| 0.24–0.30 | 0.268 & 44.5 & 29.80 $\pm$ 3.99 $\pm$ 1.24 |
| 0.30–0.36 | 0.326 & 44.8 & 28.71 $\pm$ 3.82 $\pm$ 1.11 |
| 0.36–0.42 | 0.394 & 44.7 & 30.87 $\pm$ 4.08 $\pm$ 1.24 |
| 0.42–0.50 | 0.455 & 44.1 & 22.43 $\pm$ 2.98 $\pm$ 0.99 |
| 0.50–0.60 | 0.551 & 44.8 & 9.91 $\pm$ 1.69 $\pm$ 0.56 |
| 0.60–0.72 | 0.657 & 44.9 & 10.69 $\pm$ 1.64 $\pm$ 0.78 |
| 0.72–0.90 | 0.791 & 44.1 & 5.08 $\pm$ 0.87 $\pm$ 0.56 |
| 0.90–1.25 | 1.080 & 54.3 & 0.35 $\pm$ 0.14 $\pm$ 0.07 |

| $p_T$ (GeV/c) | $60 < \theta < 75$ | $75 < \theta < 90$ |
|--------------|------------------|------------------|
| $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.144 & 67.9 & 15.72 $\pm$ 3.32 $\pm$ 1.26 |
| 0.16–0.20 | 0.181 & 66.7 & 21.22 $\pm$ 3.35 $\pm$ 1.26 |
| 0.20–0.24 | 0.218 & 67.5 & 19.17 $\pm$ 3.19 $\pm$ 0.99 |
| 0.24–0.30 | 0.273 & 67.5 & 16.16 $\pm$ 2.36 $\pm$ 0.70 |
| 0.30–0.36 | 0.329 & 67.9 & 10.81 $\pm$ 1.99 $\pm$ 0.46 |
| 0.36–0.42 | 0.394 & 66.0 & 11.42 $\pm$ 1.95 $\pm$ 0.55 |
| 0.42–0.50 | 0.467 & 66.4 & 5.86 $\pm$ 1.17 $\pm$ 0.33 |
| 0.50–0.60 | 0.548 & 67.5 & 5.42 $\pm$ 1.02 $\pm$ 0.39 |
| 0.60–0.72 | 0.672 & 67.1 & 2.62 $\pm$ 0.68 $\pm$ 0.25 |
| 0.72–0.90 | 0.820 & 65.6 & 1.13 $\pm$ 0.32 $\pm$ 0.16 |
| 0.90–1.25 | 1.069 & 65.8 & 0.09 $\pm$ 0.06 $\pm$ 0.02 |
Table A.23 (Continued)

| $p_T$  | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|---------------------|---------------------|
| ($p_T$) | ($\theta$) | $d^2\sigma/dp_d\Omega$ | ($p_T$) | ($\theta$) | $d^2\sigma/dp_d\Omega$ |
| 0.13–0.16 | 0.146 96.5 | 12.51 ± 2.88 ± 1.07 | 0.143 114.9 | 9.25 ± 2.12 ± 0.76 |
| 0.16–0.20 | 0.179 96.9 | 10.03 ± 2.17 ± 0.74 | 0.177 116.0 | 9.61 ± 1.84 ± 0.62 |
| 0.20–0.24 | 0.218 96.1 | 10.93 ± 2.32 ± 0.70 | 0.221 112.4 | 4.74 ± 1.43 ± 0.31 |
| 0.24–0.30 | 0.268 96.6 | 9.37 ± 1.88 ± 0.53 | 0.265 113.9 | 3.88 ± 1.00 ± 0.27 |
| 0.30–0.36 | 0.329 97.1 | 3.40 ± 1.08 ± 0.23 | 0.319 113.5 | 2.03 ± 0.72 ± 0.18 |
| 0.36–0.42 | 0.398 98.5 | 2.04 ± 0.83 ± 0.18 | 0.391 113.8 | 1.59 ± 0.58 ± 0.20 |
| 0.42–0.50 | 0.475 96.8 | 1.64 ± 0.67 ± 0.18 | 0.472 110.7 | 0.37 ± 0.26 ± 0.05 |
| 0.50–0.60 | 0.542 95.5 | 1.48 ± 0.52 ± 0.21 | 0.675 112.8 | 0.52 ± 0.26 ± 0.12 |
| 0.60–0.72 | 0.766 93.0 | 0.22 ± 0.16 ± 0.06 | 0.76 ± 0.06 |

Table A.24 Double-differential inclusive cross-section $d^2\sigma/dp_d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^-$'s in $\pi^+ + \text{Be} \rightarrow \pi^- + X$ interactions with +12.0 GeV/c beam momentum; the first error is statistical, the second systematic: $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$  | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|---------------------|---------------------|
| ($p_T$) | ($\theta$) | $d^2\sigma/dp_d\Omega$ | ($p_T$) | ($\theta$) | $d^2\sigma/dp_d\Omega$ |
| 0.10–0.13 | 0.116 24.6 | 57.74 ± 8.98 ± 4.49 | 0.114 34.7 | 30.36 ± 5.92 ± 2.47 |
| 0.13–0.16 | 0.145 24.9 | 65.62 ± 9.02 ± 4.41 | 0.147 35.3 | 48.43 ± 7.48 ± 3.26 |
| 0.16–0.20 | 0.183 24.6 | 64.93 ± 7.34 ± 3.50 | 0.184 34.6 | 38.24 ± 5.44 ± 2.19 |
| 0.20–0.24 | 0.221 24.7 | 63.89 ± 7.29 ± 3.00 | 0.220 34.9 | 60.38 ± 6.97 ± 2.98 |
| 0.24–0.30 | 0.271 25.1 | 67.36 ± 5.97 ± 2.52 | 0.271 34.8 | 44.52 ± 4.82 ± 1.78 |
| 0.30–0.36 | 0.330 24.3 | 54.35 ± 5.29 ± 1.85 | 0.331 35.2 | 34.54 ± 4.30 ± 1.27 |
| 0.36–0.42 | 0.389 24.2 | 40.93 ± 4.61 ± 1.47 | 0.391 34.8 | 27.82 ± 3.80 ± 1.09 |
| 0.42–0.50 | 0.456 24.8 | 31.08 ± 3.50 ± 1.31 | 0.462 35.4 | 15.87 ± 2.38 ± 0.74 |
| 0.50–0.60 | 0.547 24.6 | 21.39 ± 2.62 ± 1.20 | 0.554 35.2 | 13.59 ± 2.12 ± 0.79 |
| 0.60–0.72 | 0.653 24.4 | 10.69 ± 1.65 ± 0.83 | 0.660 35.0 | 6.45 ± 1.20 ± 0.54 |
| 0.72–0.90 | 0.800 36.2 | 2.58 ± 0.65 ± 0.29 | 0.80 ± 0.29 |

| $p_T$  | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|---------------------|---------------------|
| ($p_T$) | ($\theta$) | $d^2\sigma/dp_d\Omega$ | ($p_T$) | ($\theta$) | $d^2\sigma/dp_d\Omega$ |
| 0.10–0.13 | 0.117 45.5 | 18.69 ± 4.70 ± 1.78 | 0.146 55.4 | 33.93 ± 6.29 ± 2.58 |
| 0.13–0.16 | 0.144 44.1 | 32.03 ± 5.60 ± 2.46 | 0.180 54.9 | 20.99 ± 4.06 ± 1.33 |
| 0.16–0.20 | 0.178 44.3 | 40.68 ± 5.98 ± 2.54 | 0.218 54.8 | 24.86 ± 4.42 ± 1.41 |
| 0.20–0.24 | 0.220 44.5 | 29.01 ± 4.59 ± 1.58 | 0.267 54.1 | 15.61 ± 2.86 ± 0.73 |
| 0.24–0.30 | 0.271 44.9 | 34.47 ± 4.28 ± 1.49 | 0.333 53.9 | 12.89 ± 2.40 ± 0.69 |
| 0.30–0.36 | 0.332 45.5 | 20.65 ± 3.19 ± 0.85 | 0.387 55.2 | 12.65 ± 2.53 ± 0.66 |
| 0.36–0.42 | 0.386 44.9 | 20.49 ± 3.25 ± 0.90 | 0.454 53.9 | 7.58 ± 1.62 ± 0.47 |
| 0.42–0.50 | 0.455 44.0 | 9.87 ± 1.79 ± 0.56 | 0.540 55.1 | 4.94 ± 1.24 ± 0.35 |
| 0.50–0.60 | 0.548 44.8 | 7.65 ± 1.42 ± 0.55 | 0.642 53.2 | 2.85 ± 0.79 ± 0.28 |
| 0.60–0.72 | 0.649 44.0 | 5.49 ± 1.17 ± 0.49 | 0.775 55.4 | 1.85 ± 0.53 ± 0.24 |
| 0.72–0.90 | 0.811 43.7 | 1.48 ± 0.47 ± 0.18 | 0.775 55.4 | 1.85 ± 0.53 ± 0.24 |
| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|------|----------------|-----------------|
|      | $\langle p_T \rangle$ | $\langle p_T \rangle$ | $d^2\sigma / dp d\Omega$ | $d^2\sigma / dp d\Omega$ |
| 0.13–0.16 | 0.146 | 66.3 | 11.91 | ± | 2.79 | ± | 1.00 | 0.144 | 83.5 | 12.66 | ± | 2.89 | ± | 1.02 |
| 0.16–0.20 | 0.175 | 66.3 | 16.88 | ± | 2.84 | ± | 1.09 | 0.177 | 83.2 | 14.35 | ± | 2.63 | ± | 1.01 |
| 0.20–0.24 | 0.216 | 68.0 | 13.44 | ± | 2.60 | ± | 0.75 | 0.214 | 83.0 | 11.01 | ± | 2.30 | ± | 0.72 |
| 0.24–0.30 | 0.266 | 66.8 | 8.88 | ± | 1.68 | ± | 0.43 | 0.261 | 81.9 | 10.46 | ± | 1.88 | ± | 0.55 |
| 0.30–0.36 | 0.323 | 67.3 | 11.35 | ± | 1.95 | ± | 0.55 | 0.328 | 82.3 | 4.73 | ± | 1.22 | ± | 0.31 |
| 0.36–0.42 | 0.377 | 64.5 | 7.16 | ± | 1.47 | ± | 0.44 | 0.385 | 81.0 | 4.66 | ± | 1.25 | ± | 0.35 |
| 0.42–0.50 | 0.456 | 65.8 | 5.81 | ± | 1.10 | ± | 0.44 | 0.448 | 81.3 | 4.22 | ± | 1.00 | ± | 0.38 |
| 0.50–0.60 | 0.535 | 66.1 | 3.97 | ± | 0.89 | ± | 0.32 | 0.534 | 81.3 | 2.47 | ± | 0.68 | ± | 0.30 |
| 0.60–0.72 | 0.629 | 67.1 | 1.17 | ± | 0.41 | ± | 0.13 | 0.647 | 81.0 | 1.00 | ± | 0.41 | ± | 0.15 |
| 0.72–0.90 | 0.811 | 65.2 | 0.85 | ± | 0.30 | ± | 0.12 | 0.773 | 88.4 | 0.21 | ± | 0.15 | ± | 0.05 |

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|------|----------------|----------------|
|      | $\langle p_T \rangle$ | $\langle p_T \rangle$ | $d^2\sigma / dp d\Omega$ | $d^2\sigma / dp d\Omega$ |
| 0.13–0.16 | 0.145 | 94.3 | 9.09 | ± | 2.43 | ± | 0.84 | 0.144 | 116.4 | 9.99 | ± | 2.08 | ± | 0.95 |
| 0.16–0.20 | 0.180 | 97.5 | 8.41 | ± | 1.84 | ± | 0.75 | 0.178 | 113.4 | 8.07 | ± | 1.51 | ± | 0.78 |
| 0.20–0.24 | 0.221 | 96.1 | 7.81 | ± | 1.85 | ± | 0.61 | 0.216 | 111.1 | 3.20 | ± | 1.01 | ± | 0.29 |
| 0.24–0.30 | 0.261 | 96.8 | 4.65 | ± | 1.13 | ± | 0.39 | 0.261 | 114.1 | 2.86 | ± | 0.83 | ± | 0.24 |
| 0.30–0.36 | 0.325 | 96.2 | 5.81 | ± | 1.33 | ± | 0.52 | 0.340 | 113.0 | 1.37 | ± | 0.56 | ± | 0.14 |
| 0.36–0.42 | 0.377 | 97.0 | 3.11 | ± | 0.94 | ± | 0.37 | 0.380 | 113.3 | 1.27 | ± | 0.57 | ± | 0.16 |
| 0.42–0.50 | 0.453 | 94.7 | 1.49 | ± | 0.53 | ± | 0.23 | 0.444 | 118.4 | 1.36 | ± | 0.56 | ± | 0.21 |
| 0.50–0.60 | 0.524 | 96.4 | 0.60 | ± | 0.35 | ± | 0.11 | 0.509 | 112.6 | 0.24 | ± | 0.17 | ± | 0.05 |
| 0.60–0.72 | 0.634 | 101.7 | 0.55 | ± | 0.27 | ± | 0.15 |
Table A.25 Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of protons in $\pi^- + \text{Be} \rightarrow p + X$ interactions with $-12.0 \text{ GeV/c}$ beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees.

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.20–0.24 | 0.219 | 24.7 | 24.37 | ± | 1.24 | ± | 1.58 |
| 0.24–0.30 | 0.270 | 25.2 | 27.58 | ± | 1.06 | ± | 1.57 |
| 0.30–0.36 | 0.330 | 24.9 | 25.60 | ± | 1.02 | ± | 1.26 |
| 0.36–0.42 | 0.390 | 25.1 | 23.23 | ± | 0.95 | ± | 1.07 |
| 0.42–0.50 | 0.460 | 24.9 | 20.04 | ± | 0.76 | ± | 0.81 |
| 0.50–0.60 | 0.548 | 24.9 | 17.86 | ± | 0.64 | ± | 0.71 |
| 0.60–0.72 | 0.656 | 25.0 | 14.16 | ± | 0.51 | ± | 0.66 |
| 0.72–0.90 | 0.802 | 34.8 | 7.41 | ± | 0.32 | ± | 0.47 |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.30–0.36 | 0.329 | 44.9 | 25.24 | ± | 0.99 | ± | 1.27 |
| 0.36–0.42 | 0.389 | 44.9 | 20.63 | ± | 0.89 | ± | 0.97 |
| 0.42–0.50 | 0.460 | 44.9 | 17.35 | ± | 0.72 | ± | 0.67 |
| 0.50–0.60 | 0.548 | 44.9 | 14.17 | ± | 0.60 | ± | 0.60 |
| 0.60–0.72 | 0.657 | 44.8 | 9.43 | ± | 0.44 | ± | 0.48 |
| 0.72–0.90 | 0.798 | 44.9 | 6.12 | ± | 0.31 | ± | 0.41 |
| 0.90–1.25 | 1.035 | 44.9 | 1.84 | ± | 0.12 | ± | 0.19 |

| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.36–0.42 | 0.390 | 67.3 | 17.90 | ± | 0.65 | ± | 0.85 |
| 0.42–0.50 | 0.459 | 67.4 | 14.10 | ± | 0.51 | ± | 0.56 |
| 0.50–0.60 | 0.549 | 67.3 | 10.83 | ± | 0.42 | ± | 0.50 |
| 0.60–0.72 | 0.658 | 67.3 | 6.07 | ± | 0.30 | ± | 0.40 |
| 0.72–0.90 | 0.795 | 66.7 | 3.21 | ± | 0.18 | ± | 0.30 |
| 0.90–1.25 | 1.033 | 66.7 | 0.76 | ± | 0.07 | ± | 0.12 |

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.36–0.42 | 0.389 | 114.0 | 5.02 | ± | 0.31 | ± | 0.28 |
| 0.42–0.50 | 0.457 | 96.5 | 6.38 | ± | 0.35 | ± | 0.43 |
| 0.50–0.60 | 0.547 | 97.0 | 3.60 | ± | 0.24 | ± | 0.29 |
| 0.60–0.72 | 0.655 | 96.8 | 1.95 | ± | 0.18 | ± | 0.21 |
| 0.72–0.90 | 0.788 | 96.4 | 0.65 | ± | 0.08 | ± | 0.09 |
| 0.90–1.25 | 1.040 | 95.5 | 0.17 | ± | 0.03 | ± | 0.03 |
Table A.26 Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^+$'s in $\pi^- + \text{Be} \rightarrow \pi^+ + X$ interactions with $-12.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.115 | 24.7 | 37.81 ± 2.11 ± 3.18 | 0.116 | 34.8 | 27.36 ± 1.72 ± 2.38 |
| 0.13–0.16 | 0.147 | 24.5 | 56.39 ± 2.36 ± 3.53 | 0.145 | 34.8 | 36.32 ± 1.89 ± 2.46 |
| 0.16–0.20 | 0.181 | 24.3 | 60.11 ± 2.04 ± 3.17 | 0.180 | 34.7 | 37.98 ± 1.59 ± 2.07 |
| 0.20–0.24 | 0.220 | 24.6 | 66.01 ± 2.09 ± 3.01 | 0.220 | 34.7 | 45.76 ± 1.75 ± 2.22 |
| 0.24–0.30 | 0.270 | 24.6 | 60.22 ± 1.60 ± 2.30 | 0.270 | 34.8 | 38.20 ± 1.27 ± 1.50 |
| 0.30–0.36 | 0.329 | 24.4 | 55.53 ± 1.53 ± 1.89 | 0.329 | 34.6 | 37.06 ± 1.26 ± 1.32 |
| 0.36–0.42 | 0.389 | 24.5 | 42.58 ± 1.34 ± 1.48 | 0.388 | 34.7 | 29.05 ± 1.12 ± 1.05 |
| 0.42–0.50 | 0.458 | 24.7 | 33.59 ± 1.01 ± 1.34 | 0.457 | 34.5 | 20.29 ± 0.78 ± 0.82 |
| 0.50–0.60 | 0.547 | 24.5 | 19.53 ± 0.67 ± 1.08 | 0.546 | 34.5 | 13.46 ± 0.55 ± 0.72 |
| 0.60–0.72 | 0.655 | 24.6 | 12.66 ± 0.48 ± 1.03 | 0.655 | 34.6 | 7.63 ± 0.37 ± 0.59 |
| 0.72–0.90 | 0.799 | 34.5 | 3.21 ± 0.17 ± 0.40 |          |       |         |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.115 | 44.8 | 20.24 ± 1.52 ± 1.83 | 0.146 | 55.2 | 18.96 ± 1.36 ± 1.44 |
| 0.13–0.16 | 0.145 | 44.8 | 22.63 ± 1.47 ± 1.59 | 0.180 | 54.8 | 20.77 ± 1.17 ± 1.23 |
| 0.16–0.20 | 0.180 | 44.9 | 27.72 ± 1.37 ± 1.61 | 0.219 | 54.8 | 17.76 ± 1.08 ± 0.94 |
| 0.20–0.24 | 0.220 | 44.9 | 27.68 ± 1.34 ± 1.41 | 0.270 | 54.4 | 18.53 ± 0.88 ± 0.81 |
| 0.24–0.30 | 0.270 | 44.8 | 28.76 ± 1.13 ± 1.19 | 0.330 | 54.7 | 14.68 ± 0.78 ± 0.60 |
| 0.30–0.36 | 0.330 | 44.6 | 22.58 ± 0.96 ± 0.87 | 0.391 | 54.5 | 10.85 ± 0.65 ± 0.53 |
| 0.36–0.42 | 0.388 | 44.6 | 18.41 ± 0.86 ± 0.80 | 0.458 | 54.4 | 8.72 ± 0.49 ± 0.44 |
| 0.42–0.50 | 0.458 | 44.5 | 13.56 ± 0.65 ± 0.60 | 0.547 | 54.5 | 6.43 ± 0.39 ± 0.40 |
| 0.50–0.60 | 0.545 | 44.8 | 7.94 ± 0.41 ± 0.54 | 0.650 | 54.4 | 3.19 ± 0.25 ± 0.28 |
| 0.60–0.72 | 0.650 | 44.1 | 4.72 ± 0.29 ± 0.39 | 0.792 | 54.7 | 1.55 ± 0.13 ± 0.18 |
| 0.72–0.90 | 0.790 | 43.9 | 2.51 ± 0.18 ± 0.28 | 1.020 | 55.1 | 0.29 ± 0.03 ± 0.06 |

| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|-------|------------------|------------------|
|       | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ | $(\theta)$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.146 | 66.6 | 15.03 ± 0.96 ± 1.15 | 0.146 | 81.6 | 10.31 ± 0.78 ± 0.83 |
| 0.16–0.20 | 0.180 | 67.0 | 15.09 ± 0.79 ± 0.90 | 0.180 | 82.5 | 11.99 ± 0.70 ± 0.79 |
| 0.20–0.24 | 0.220 | 67.3 | 14.63 ± 0.78 ± 0.75 | 0.218 | 81.8 | 9.59 ± 0.63 ± 0.56 |
| 0.24–0.30 | 0.269 | 66.7 | 12.15 ± 0.57 ± 0.56 | 0.271 | 81.3 | 7.54 ± 0.45 ± 0.38 |
| 0.30–0.36 | 0.329 | 66.9 | 9.86 ± 0.52 ± 0.42 | 0.327 | 81.7 | 5.51 ± 0.38 ± 0.29 |
| 0.36–0.42 | 0.389 | 67.3 | 7.28 ± 0.43 ± 0.39 | 0.387 | 82.1 | 4.04 ± 0.31 ± 0.30 |
| 0.42–0.50 | 0.456 | 66.9 | 5.77 ± 0.33 ± 0.36 | 0.456 | 81.1 | 3.10 ± 0.26 ± 0.22 |
| 0.50–0.60 | 0.548 | 67.1 | 3.53 ± 0.23 ± 0.27 | 0.544 | 81.6 | 1.74 ± 0.16 ± 0.17 |
| 0.60–0.72 | 0.656 | 66.2 | 1.91 ± 0.15 ± 0.20 | 0.647 | 81.5 | 0.89 ± 0.10 ± 0.12 |
| 0.72–0.90 | 0.787 | 66.3 | 0.59 ± 0.06 ± 0.09 | 0.776 | 80.3 | 0.22 ± 0.04 ± 0.04 |
| 0.90–1.25 | 1.016 | 66.1 | 0.09 ± 0.02 ± 0.02 | 1.021 | 80.9 | 0.06 ± 0.02 ± 0.02 |
### Table A.26 (Continued)

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|---------------------|----------------------|
|       | $(p_T)$ (\theta)    | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ (\theta)    | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.147 97.3 8.37 ± 0.68 ± 0.74 | 0.145 114.2 6.89 ± 0.51 ± 0.63 |
| 0.16–0.20 | 0.179 96.9 9.48 ± 0.59 ± 0.76 | 0.179 114.2 6.06 ± 0.39 ± 0.49 |
| 0.20–0.24 | 0.221 97.2 6.57 ± 0.48 ± 0.55 | 0.218 113.7 4.46 ± 0.35 ± 0.32 |
| 0.24–0.30 | 0.267 97.0 5.42 ± 0.38 ± 0.31 | 0.268 113.0 3.28 ± 0.25 ± 0.22 |
| 0.30–0.36 | 0.329 97.6 3.18 ± 0.28 ± 0.21 | 0.329 112.8 1.69 ± 0.18 ± 0.17 |
| 0.36–0.42 | 0.386 96.8 2.11 ± 0.22 ± 0.20 | 0.387 113.5 1.20 ± 0.16 ± 0.15 |
| 0.42–0.50 | 0.458 96.8 1.48 ± 0.17 ± 0.18 | 0.458 111.9 0.45 ± 0.08 ± 0.07 |
| 0.50–0.60 | 0.544 95.6 0.92 ± 0.12 ± 0.14 | 0.541 111.5 0.27 ± 0.06 ± 0.06 |
| 0.60–0.72 | 0.645 95.3 0.38 ± 0.07 ± 0.08 | 0.660 110.2 0.10 ± 0.03 ± 0.04 |
| 0.72–0.90 | 0.784 97.0 0.11 ± 0.03 ± 0.03 |                |

### Table A.27

Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^-$’s in $\pi^- + \text{Be} \rightarrow \pi^- + \text{X}$ interactions with $-12.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees.

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|---------------------|----------------------|
|       | $(p_T)$ (\theta)    | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ (\theta)    | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.115 24.7 61.40 ± 2.64 ± 4.67 | 0.116 34.9 37.58 ± 2.00 ± 3.13 |
| 0.13–0.16 | 0.146 24.6 74.65 ± 2.71 ± 4.59 | 0.145 34.8 51.55 ± 2.24 ± 3.35 |
| 0.16–0.20 | 0.181 24.6 89.44 ± 2.50 ± 4.58 | 0.179 34.6 56.00 ± 1.94 ± 2.98 |
| 0.20–0.24 | 0.220 24.7 93.92 ± 2.50 ± 4.10 | 0.220 34.8 55.62 ± 1.92 ± 2.54 |
| 0.24–0.30 | 0.269 24.7 89.26 ± 1.99 ± 3.18 | 0.270 34.5 56.17 ± 1.57 ± 2.08 |
| 0.30–0.36 | 0.329 24.6 80.56 ± 1.90 ± 2.52 | 0.329 34.4 48.82 ± 1.45 ± 1.61 |
| 0.36–0.42 | 0.389 24.8 61.66 ± 1.66 ± 1.99 | 0.388 34.7 40.31 ± 1.31 ± 1.37 |
| 0.42–0.50 | 0.457 24.6 49.30 ± 1.28 ± 1.96 | 0.457 34.6 31.63 ± 1.01 ± 1.25 |
| 0.50–0.60 | 0.546 24.6 35.99 ± 0.98 ± 1.90 | 0.545 34.7 19.87 ± 0.71 ± 1.05 |
| 0.60–0.72 | 0.654 24.7 20.76 ± 0.67 ± 1.53 | 0.655 34.9 12.42 ± 0.52 ± 0.90 |
| 0.72–0.90 | 0.798 34.5 6.06 ± 0.29 ± 0.62 |                |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|---------------------|----------------------|
|       | $(p_T)$ (\theta)    | $d^2\sigma/dp\,d\Omega$ | $(p_T)$ (\theta)    | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.115 44.6 26.91 ± 1.66 ± 2.31 | 0.146 54.9 26.40 ± 1.53 ± 1.92 |
| 0.13–0.16 | 0.146 44.9 32.36 ± 1.73 ± 2.29 | 0.180 54.8 28.89 ± 1.38 ± 1.71 |
| 0.16–0.20 | 0.181 45.0 39.25 ± 1.64 ± 2.18 | 0.180 54.8 28.89 ± 1.38 ± 1.71 |
| 0.20–0.24 | 0.220 44.9 40.39 ± 1.62 ± 1.94 | 0.220 54.9 34.31 ± 1.52 ± 1.68 |
| 0.24–0.30 | 0.269 44.6 35.17 ± 1.22 ± 1.36 | 0.269 54.9 25.48 ± 1.05 ± 1.01 |
| 0.30–0.36 | 0.329 44.7 30.35 ± 1.14 ± 1.07 | 0.330 54.6 22.27 ± 0.95 ± 0.88 |
| 0.36–0.42 | 0.389 44.9 25.10 ± 1.01 ± 1.00 | 0.389 54.4 18.13 ± 0.85 ± 0.84 |
| 0.42–0.50 | 0.458 44.7 19.57 ± 0.79 ± 0.86 | 0.458 54.8 12.33 ± 0.62 ± 0.60 |
| 0.50–0.60 | 0.548 44.6 12.89 ± 0.57 ± 0.77 | 0.545 54.7 8.63 ± 0.46 ± 0.56 |
| 0.60–0.72 | 0.655 44.7 7.61 ± 0.40 ± 0.60 | 0.650 55.0 5.04 ± 0.32 ± 0.42 |
| 0.72–0.90 | 0.796 44.8 4.16 ± 0.25 ± 0.46 | 0.796 54.7 2.06 ± 0.17 ± 0.24 |
| 0.90–1.25 |                    | 1.035 54.9 0.27 ± 0.03 ± 0.06 |
Table A.27 (Continued)

| $p_T$  | $60 < \theta < 75$ | $75 < \theta < 90$ |
|--------|-------------------|-------------------|
|        | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp d\Omega$ |
| 0.13–0.16 | 0.145 | 67.0 | 20.47 | ± | 1.10 | ± | 1.50 | 0.145 | 82.7 | 14.90 | ± | 0.88 | ± | 1.39 |
| 0.16–0.20 | 0.180 | 66.9 | 22.46 | ± | 0.96 | ± | 1.30 | 0.180 | 82.0 | 17.77 | ± | 0.85 | ± | 1.09 |
| 0.20–0.24 | 0.219 | 67.2 | 22.17 | ± | 0.98 | ± | 1.01 | 0.219 | 82.4 | 16.30 | ± | 0.82 | ± | 0.83 |
| 0.24–0.30 | 0.269 | 67.2 | 18.12 | ± | 0.70 | ± | 0.70 | 0.269 | 81.8 | 11.77 | ± | 0.57 | ± | 0.49 |
| 0.30–0.36 | 0.329 | 66.8 | 15.01 | ± | 0.66 | ± | 0.57 | 0.330 | 82.0 | 8.08 | ± | 0.47 | ± | 0.38 |
| 0.36–0.42 | 0.388 | 66.8 | 10.98 | ± | 0.54 | ± | 0.51 | 0.390 | 82.0 | 6.17 | ± | 0.41 | ± | 0.37 |
| 0.42–0.50 | 0.458 | 66.5 | 8.19 | ± | 0.40 | ± | 0.43 | 0.458 | 82.0 | 5.03 | ± | 0.33 | ± | 0.35 |
| 0.50–0.60 | 0.544 | 66.5 | 5.11 | ± | 0.29 | ± | 0.36 | 0.544 | 81.2 | 2.28 | ± | 0.19 | ± | 0.22 |
| 0.60–0.72 | 0.656 | 66.5 | 2.65 | ± | 0.19 | ± | 0.25 | 0.654 | 81.9 | 1.13 | ± | 0.12 | ± | 0.14 |
| 0.72–0.90 | 0.794 | 66.4 | 1.09 | ± | 0.10 | ± | 0.16 | 0.792 | 80.8 | 0.37 | ± | 0.05 | ± | 0.07 |
| 0.90–1.25 | 1.008 | 66.1 | 0.14 | ± | 0.02 | ± | 0.03 | 0.994 | 82.7 | 0.03 | ± | 0.02 | ± | 0.01 |
| $p_T$  | $90 < \theta < 105$ | $105 < \theta < 125$ |
|        | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp d\Omega$ |
| 0.13–0.16 | 0.144 | 97.5 | 14.53 | ± | 0.88 | ± | 1.45 | 0.145 | 114.6 | 11.01 | ± | 0.64 | ± | 0.85 |
| 0.16–0.20 | 0.180 | 97.0 | 13.24 | ± | 0.70 | ± | 0.89 | 0.178 | 114.6 | 10.36 | ± | 0.54 | ± | 0.71 |
| 0.20–0.24 | 0.219 | 96.3 | 12.73 | ± | 0.70 | ± | 0.72 | 0.219 | 114.3 | 7.09 | ± | 0.46 | ± | 0.43 |
| 0.24–0.30 | 0.268 | 96.9 | 7.41 | ± | 0.46 | ± | 0.36 | 0.266 | 113.9 | 5.35 | ± | 0.33 | ± | 0.32 |
| 0.30–0.36 | 0.329 | 96.7 | 6.16 | ± | 0.41 | ± | 0.38 | 0.329 | 113.2 | 2.96 | ± | 0.24 | ± | 0.26 |
| 0.36–0.42 | 0.387 | 97.3 | 4.18 | ± | 0.33 | ± | 0.35 | 0.385 | 112.0 | 1.76 | ± | 0.19 | ± | 0.21 |
| 0.42–0.50 | 0.457 | 97.0 | 2.70 | ± | 0.23 | ± | 0.26 | 0.458 | 112.4 | 0.92 | ± | 0.12 | ± | 0.14 |
| 0.50–0.60 | 0.545 | 96.1 | 1.22 | ± | 0.14 | ± | 0.17 | 0.554 | 111.6 | 0.23 | ± | 0.05 | ± | 0.04 |
| 0.60–0.72 | 0.662 | 97.0 | 0.44 | ± | 0.08 | ± | 0.08 | 0.633 | 109.6 | 0.09 | ± | 0.03 | ± | 0.02 |
| 0.72–0.90 | 0.769 | 96.3 | 0.08 | ± | 0.02 | ± | 0.02 |
Table A.28 Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of protons in $p + \text{Be} \to p + \text{X}$ interactions with $+15.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees.

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|---------------------|---------------------|
|       | $(p_T)$             | $(\theta)$          | $d^2\sigma/dp\,d\Omega$ | $(p_T)$             | $(\theta)$          | $d^2\sigma/dp\,d\Omega$ |
| 0.20–0.24 | 0.220 | 25.0 | 38.48 | ± | 1.80 | ± | 2.13 |
| 0.24–0.30 | 0.269 | 24.8 | 45.17 | ± | 1.57 | ± | 2.24 |
| 0.30–0.36 | 0.329 | 24.9 | 42.76 | ± | 1.52 | ± | 1.89 |
| 0.36–0.42 | 0.388 | 24.9 | 38.44 | ± | 1.41 | ± | 1.45 |
| 0.42–0.50 | 0.458 | 24.8 | 35.42 | ± | 1.17 | ± | 1.17 |
| 0.50–0.60 | 0.545 | 24.8 | 30.77 | ± | 0.97 | ± | 1.01 |
| 0.60–0.72 | 0.651 | 24.9 | 23.67 | ± | 0.77 | ± | 0.94 |
| 0.72–0.90 |       |       | 0.796 | 34.6 | 13.08 | ± | 0.49 | ± | 0.77 |
| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|---------------------|---------------------|
|       | $(p_T)$             | $(\theta)$          | $d^2\sigma/dp\,d\Omega$ | $(p_T)$             | $(\theta)$          | $d^2\sigma/dp\,d\Omega$ |
| 0.30–0.36 | 0.329 | 44.9 | 35.19 | ± | 1.34 | ± | 1.31 |
| 0.36–0.42 | 0.389 | 44.8 | 35.39 | ± | 1.38 | ± | 1.18 |
| 0.42–0.50 | 0.459 | 45.1 | 27.81 | ± | 1.06 | ± | 0.84 |
| 0.50–0.60 | 0.549 | 45.0 | 24.39 | ± | 0.93 | ± | 0.80 |
| 0.60–0.72 | 0.656 | 44.9 | 15.07 | ± | 0.65 | ± | 0.67 |
| 0.72–0.90 | 0.801 | 44.7 | 9.83 | ± | 0.44 | ± | 0.59 |
| 0.90–1.25 | 1.042 | 44.7 | 3.58 | ± | 0.19 | ± | 0.35 |
| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|-------|---------------------|---------------------|
|       | $(p_T)$             | $(\theta)$          | $d^2\sigma/dp\,d\Omega$ | $(p_T)$             | $(\theta)$          | $d^2\sigma/dp\,d\Omega$ |
| 0.36–0.42 | 0.391 | 67.4 | 30.19 | ± | 1.01 | ± | 1.17 |
| 0.42–0.50 | 0.459 | 67.5 | 22.43 | ± | 0.74 | ± | 0.70 |
| 0.50–0.60 | 0.547 | 67.2 | 17.44 | ± | 0.64 | ± | 0.72 |
| 0.60–0.72 | 0.656 | 67.2 | 9.77 | ± | 0.44 | ± | 0.59 |
| 0.72–0.90 | 0.796 | 66.4 | 5.08 | ± | 0.27 | ± | 0.45 |
| 0.90–1.25 | 1.027 | 66.5 | 1.30 | ± | 0.10 | ± | 0.19 |
| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|---------------------|---------------------|
|       | $(p_T)$             | $(\theta)$          | $d^2\sigma/dp\,d\Omega$ | $(p_T)$             | $(\theta)$          | $d^2\sigma/dp\,d\Omega$ |
| 0.36–0.42 |       |       | 0.389 | 113.1 | 6.78 | ± | 0.41 | ± | 0.27 |
| 0.42–0.50 | 0.457 | 96.6 | 11.28 | ± | 0.55 | ± | 0.66 |
| 0.50–0.60 | 0.545 | 96.7 | 6.14 | ± | 0.38 | ± | 0.44 |
| 0.60–0.72 | 0.650 | 96.3 | 2.59 | ± | 0.25 | ± | 0.26 |
| 0.72–0.90 | 0.786 | 96.2 | 1.08 | ± | 0.12 | ± | 0.13 |
| 0.90–1.25 | 1.028 | 97.3 | 0.23 | ± | 0.05 | ± | 0.04 |
Table A.29  Double-differential inclusive cross-section $d^2\sigma/dp\Omega$ [mb/(GeV/c sr)] of the production of $\pi^+$s in $p + B e \rightarrow \pi^+ + X$ interactions with +15.0 GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ (GeV/c) | $20 < \theta < 30$ (\theta) | $30 < \theta < 40$ (\theta) |
|---------------|-------------------------------|-------------------------------|
|               | $d^2\sigma/dp\Omega$          | $d^2\sigma/dp\Omega$          |
| 0.10–0.13     | 0.116 24.5 62.64 ± 3.15 ± 4.54 | 0.116 35.0 39.74 ± 2.47 ± 2.93 |
| 0.13–0.16     | 0.146 24.6 73.73 ± 3.14 ± 4.29 | 0.145 34.7 49.47 ± 2.56 ± 2.86 |
| 0.16–0.20     | 0.181 24.4 92.11 ± 2.93 ± 4.44 | 0.179 34.6 56.14 ± 2.30 ± 2.71 |
| 0.20–0.24     | 0.220 24.6 98.89 ± 2.98 ± 4.10 | 0.220 34.6 62.38 ± 2.36 ± 2.57 |
| 0.24–0.30     | 0.268 24.7 93.70 ± 2.34 ± 3.24 | 0.268 34.7 61.70 ± 1.93 ± 2.10 |
| 0.30–0.36     | 0.329 24.5 77.37 ± 2.10 ± 2.29 | 0.327 34.6 50.29 ± 1.70 ± 1.47 |
| 0.36–0.42     | 0.387 24.7 66.57 ± 1.99 ± 1.94 | 0.387 34.6 37.79 ± 1.44 ± 1.08 |
| 0.42–0.50     | 0.456 24.7 49.98 ± 1.45 ± 1.75 | 0.456 34.6 32.25 ± 1.16 ± 1.06 |
| 0.50–0.60     | 0.544 24.4 33.06 ± 1.01 ± 1.70 | 0.545 34.7 21.86 ± 0.84 ± 1.02 |
| 0.60–0.72     | 0.652 24.5 20.05 ± 0.70 ± 1.55 | 0.651 34.6 12.97 ± 0.58 ± 0.91 |
| 0.72–0.90     | 0.790 34.9 6.23 ± 0.30 ± 0.70 |

| $p_T$ (GeV/c) | $40 < \theta < 50$ (\theta) | $50 < \theta < 60$ (\theta) |
|---------------|-------------------------------|-------------------------------|
|               | $d^2\sigma/dp\Omega$          | $d^2\sigma/dp\Omega$          |
| 0.10–0.13     | 0.117 45.0 28.29 ± 2.11 ± 2.15 | 0.146 54.9 28.62 ± 1.83 ± 1.77 |
| 0.13–0.16     | 0.146 44.9 37.70 ± 2.25 ± 2.23 | 0.179 54.7 32.54 ± 1.70 ± 1.60 |
| 0.16–0.20     | 0.180 44.6 45.28 ± 2.08 ± 2.22 | 0.220 54.6 34.14 ± 1.78 ± 1.41 |
| 0.20–0.24     | 0.220 44.9 38.78 ± 1.80 ± 1.66 | 0.270 54.7 29.37 ± 1.31 ± 0.99 |
| 0.24–0.30     | 0.270 44.8 38.39 ± 1.49 ± 1.32 | 0.329 54.6 24.12 ± 1.18 ± 0.72 |
| 0.30–0.36     | 0.328 44.8 35.72 ± 1.43 ± 1.06 | 0.389 54.9 18.85 ± 1.03 ± 0.59 |
| 0.36–0.42     | 0.389 44.7 28.77 ± 1.27 ± 0.85 | 0.460 54.6 13.10 ± 0.73 ± 0.50 |
| 0.42–0.50     | 0.458 44.8 20.46 ± 0.93 ± 0.70 | 0.544 54.5 8.56 ± 0.52 ± 0.43 |
| 0.50–0.60     | 0.548 44.2 13.22 ± 0.65 ± 0.61 | 0.652 54.8 5.37 ± 0.39 ± 0.39 |
| 0.60–0.72     | 0.651 44.5 8.38 ± 0.46 ± 0.55 | 0.791 54.6 2.28 ± 0.18 ± 0.24 |
| 0.72–0.90     | 0.799 44.6 3.70 ± 0.24 ± 0.38 | 1.031 54.2 0.46 ± 0.05 ± 0.08 |
| 0.90–1.25     | 1.031 54.2 0.46 ± 0.05 ± 0.08 |

| $p_T$ (GeV/c) | $60 < \theta < 75$ (\theta) | $75 < \theta < 90$ (\theta) |
|---------------|-------------------------------|-------------------------------|
|               | $d^2\sigma/dp\Omega$          | $d^2\sigma/dp\Omega$          |
| 0.13–0.16     | 0.145 67.4 19.67 ± 1.23 ± 1.28 | 0.147 82.2 17.61 ± 1.17 ± 1.23 |
| 0.16–0.20     | 0.181 67.4 22.41 ± 1.15 ± 1.12 | 0.179 82.1 17.64 ± 0.98 ± 0.92 |
| 0.20–0.24     | 0.220 67.2 25.84 ± 1.21 ± 1.04 | 0.221 82.2 15.72 ± 0.92 ± 0.61 |
| 0.24–0.30     | 0.269 66.8 18.14 ± 0.83 ± 0.59 | 0.266 82.4 12.29 ± 0.69 ± 0.39 |
| 0.30–0.36     | 0.329 66.8 13.63 ± 0.70 ± 0.41 | 0.327 82.3 9.85 ± 0.63 ± 0.34 |
| 0.36–0.42     | 0.389 67.1 11.48 ± 0.65 ± 0.45 | 0.389 82.1 5.41 ± 0.44 ± 0.24 |
| 0.42–0.50     | 0.456 66.9 7.64 ± 0.44 ± 0.34 | 0.460 82.0 3.58 ± 0.30 ± 0.22 |
| 0.50–0.60     | 0.544 66.4 6.23 ± 0.38 ± 0.38 | 0.548 81.5 2.26 ± 0.21 ± 0.18 |
| 0.60–0.72     | 0.654 66.4 2.57 ± 0.20 ± 0.22 | 0.657 81.3 1.06 ± 0.13 ± 0.11 |
| 0.72–0.90     | 0.789 66.8 1.05 ± 0.11 ± 0.14 | 0.787 81.0 0.32 ± 0.06 ± 0.05 |
| 0.90–1.25     | 1.008 64.8 0.16 ± 0.02 ± 0.03 | 1.052 78.8 0.05 ± 0.02 ± 0.02 |
Table A.29  (Continued)

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|-----------------|-----------------|
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.146 | 96.9 | 14.04 ± 0.99 ± 0.96 | 0.144 | 114.7 | 12.91 ± 0.87 ± 0.85 |
| 0.16–0.20 | 0.179 | 97.0 | 15.15 ± 0.88 ± 0.80 | 0.180 | 113.8 | 10.22 ± 0.62 ± 0.56 |
| 0.20–0.24 | 0.219 | 97.2 | 10.26 ± 0.69 ± 0.41 | 0.221 | 112.7 | 7.81 ± 0.58 ± 0.36 |
| 0.24–0.30 | 0.269 | 96.7 | 8.02 ± 0.55 ± 0.28 | 0.270 | 113.8 | 5.14 ± 0.38 ± 0.25 |
| 0.30–0.36 | 0.327 | 97.4 | 4.92 ± 0.39 ± 0.24 | 0.329 | 113.7 | 2.55 ± 0.26 ± 0.17 |
| 0.36–0.42 | 0.387 | 96.8 | 3.39 ± 0.34 ± 0.22 | 0.385 | 111.7 | 1.55 ± 0.20 ± 0.15 |
| 0.42–0.50 | 0.458 | 96.4 | 2.08 ± 0.24 ± 0.18 | 0.455 | 113.3 | 0.72 ± 0.11 ± 0.08 |
| 0.50–0.60 | 0.545 | 97.0 | 1.09 ± 0.15 ± 0.13 | 0.539 | 111.1 | 0.26 ± 0.06 ± 0.04 |
| 0.60–0.70 | 0.646 | 96.2 | 0.25 ± 0.06 ± 0.04 | 0.657 | 111.5 | 0.08 ± 0.03 ± 0.02 |
| 0.72–0.90 | 0.808 | 94.3 | 0.10 ± 0.03 ± 0.02 | |

Table A.30  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^-$'s in $p + \text{Be} \rightarrow \pi^- + X$ interactions with +15.0 GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|-----------------|-----------------|
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.116 | 24.7 | 58.26 ± 3.00 ± 4.14 | 0.116 | 34.8 | 41.24 ± 2.36 ± 3.18 |
| 0.13–0.16 | 0.146 | 24.6 | 73.61 ± 3.09 ± 4.36 | 0.146 | 34.8 | 48.14 ± 2.37 ± 2.87 |
| 0.16–0.20 | 0.180 | 24.8 | 84.86 ± 2.76 ± 4.12 | 0.181 | 34.7 | 58.68 ± 2.32 ± 2.89 |
| 0.20–0.24 | 0.221 | 24.8 | 81.72 ± 2.66 ± 3.33 | 0.220 | 34.8 | 59.64 ± 2.32 ± 2.46 |
| 0.24–0.30 | 0.270 | 24.8 | 80.92 ± 2.18 ± 2.65 | 0.270 | 34.8 | 54.98 ± 1.79 ± 1.83 |
| 0.30–0.36 | 0.330 | 24.7 | 72.41 ± 2.10 ± 2.01 | 0.330 | 34.8 | 46.11 ± 1.61 ± 1.30 |
| 0.36–0.42 | 0.389 | 24.7 | 53.33 ± 1.74 ± 1.52 | 0.391 | 34.9 | 39.69 ± 1.56 ± 1.14 |
| 0.42–0.50 | 0.458 | 24.6 | 38.90 ± 1.28 ± 1.39 | 0.460 | 34.8 | 25.49 ± 1.00 ± 0.90 |
| 0.50–0.60 | 0.550 | 24.6 | 27.89 ± 1.00 ± 1.41 | 0.550 | 34.7 | 17.13 ± 0.75 ± 0.84 |
| 0.60–0.70 | 0.656 | 24.7 | 14.96 ± 0.64 ± 1.07 | 0.661 | 34.6 | 9.58 ± 0.50 ± 0.66 |
| 0.72–0.90 | 0.808 | 35.1 | 4.44 ± 0.28 ± 0.44 | |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|-----------------|-----------------|
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.117 | 44.8 | 29.37 ± 2.10 ± 2.53 | | 0.146 | 54.8 | 27.80 ± 1.76 ± 1.97 |
| 0.13–0.16 | 0.145 | 44.9 | 34.86 ± 2.07 ± 2.21 | 0.146 | 54.8 | 27.80 ± 1.76 ± 1.97 |
| 0.16–0.20 | 0.180 | 44.8 | 38.95 ± 1.87 ± 1.95 | 0.181 | 54.6 | 29.48 ± 1.56 ± 1.54 |
| 0.20–0.24 | 0.220 | 44.7 | 38.21 ± 1.77 ± 1.61 | 0.221 | 54.7 | 31.13 ± 1.65 ± 1.30 |
| 0.24–0.30 | 0.270 | 44.6 | 35.67 ± 1.42 ± 1.20 | 0.269 | 54.7 | 28.04 ± 1.30 ± 0.93 |
| 0.30–0.36 | 0.329 | 44.6 | 29.03 ± 1.26 ± 0.84 | 0.330 | 54.5 | 22.78 ± 1.09 ± 0.73 |
| 0.36–0.42 | 0.389 | 44.8 | 24.70 ± 1.19 ± 0.77 | 0.388 | 54.9 | 17.83 ± 0.93 ± 0.60 |
| 0.42–0.50 | 0.458 | 44.8 | 18.20 ± 0.85 ± 0.69 | 0.459 | 54.8 | 10.94 ± 0.64 ± 0.44 |
| 0.50–0.60 | 0.547 | 44.6 | 12.03 ± 0.61 ± 0.64 | 0.544 | 54.8 | 8.73 ± 0.54 ± 0.52 |
| 0.60–0.72 | 0.655 | 44.7 | 6.42 ± 0.39 ± 0.48 | 0.652 | 54.6 | 4.39 ± 0.35 ± 0.35 |
| 0.72–0.90 | 0.791 | 44.6 | 3.22 ± 0.26 ± 0.34 | 0.791 | 54.7 | 1.51 ± 0.14 ± 0.17 |
| 0.90–1.25 | | | 1.028 | 54.9 | 0.44 ± 0.06 ± 0.08 |
Table A.30 (Continued)

| $p_T$  | $60 < \theta < 75$ |  | $75 < \theta < 90$ |  |
|--------|------------------|---|------------------|---|
|        | $(p_T)$          | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$          | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.145 | 67.2 | 22.57 | ± | 1.34 | ± | 1.67 | 0.146 | 81.7 | 16.54 | ± | 1.11 | ± | 1.23 |
| 0.16–0.20 | 0.180 | 67.0 | 21.41 | ± | 1.03 | ± | 1.11 | 0.180 | 82.5 | 16.80 | ± | 0.89 | ± | 0.95 |
| 0.20–0.24 | 0.220 | 67.3 | 21.47 | ± | 1.05 | ± | 0.83 | 0.220 | 82.0 | 17.27 | ± | 0.98 | ± | 0.80 |
| 0.24–0.30 | 0.269 | 66.9 | 19.54 | ± | 0.87 | ± | 0.61 | 0.268 | 82.1 | 12.08 | ± | 0.65 | ± | 0.38 |
| 0.30–0.36 | 0.329 | 66.9 | 12.82 | ± | 0.66 | ± | 0.39 | 0.329 | 82.0 | 7.94 | ± | 0.50 | ± | 0.29 |
| 0.36–0.42 | 0.387 | 66.9 | 10.25 | ± | 0.56 | ± | 0.39 | 0.389 | 81.6 | 6.04 | ± | 0.46 | ± | 0.30 |
| 0.42–0.50 | 0.457 | 66.9 | 7.75 | ± | 0.45 | ± | 0.39 | 0.457 | 81.6 | 4.24 | ± | 0.34 | ± | 0.29 |
| 0.50–0.60 | 0.546 | 66.8 | 5.93 | ± | 0.37 | ± | 0.39 | 0.543 | 82.0 | 2.64 | ± | 0.23 | ± | 0.22 |
| 0.60–0.72 | 0.651 | 67.0 | 2.23 | ± | 0.17 | ± | 0.20 | 0.651 | 82.8 | 0.76 | ± | 0.11 | ± | 0.09 |
| 0.72–0.90 | 0.798 | 66.6 | 0.84 | ± | 0.09 | ± | 0.11 | 0.788 | 82.4 | 0.32 | ± | 0.06 | ± | 0.05 |
| 0.90–1.25 | 1.025 | 66.3 | 0.18 | ± | 0.03 | ± | 0.04 | 1.018 | 80.3 | 0.05 | ± | 0.02 | ± | 0.02 |

| $p_T$  | $90 < \theta < 105$ |  | $105 < \theta < 125$ |  |
|--------|------------------|---|------------------|---|
|        | $(p_T)$          | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $(p_T)$          | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.146 | 97.6 | 12.82 | ± | 0.90 | ± | 1.01 | 0.146 | 114.7 | 11.03 | ± | 0.68 | ± | 0.85 |
| 0.16–0.20 | 0.180 | 96.8 | 13.07 | ± | 0.75 | ± | 0.78 | 0.180 | 114.2 | 8.30 | ± | 0.49 | ± | 0.46 |
| 0.20–0.24 | 0.219 | 97.1 | 11.84 | ± | 0.76 | ± | 0.52 | 0.219 | 113.7 | 6.30 | ± | 0.45 | ± | 0.34 |
| 0.24–0.30 | 0.268 | 97.0 | 6.88 | ± | 0.45 | ± | 0.31 | 0.267 | 113.6 | 4.91 | ± | 0.36 | ± | 0.28 |
| 0.30–0.36 | 0.330 | 97.1 | 4.71 | ± | 0.40 | ± | 0.23 | 0.327 | 113.8 | 2.65 | ± | 0.24 | ± | 0.20 |
| 0.36–0.42 | 0.386 | 96.6 | 3.28 | ± | 0.33 | ± | 0.23 | 0.391 | 112.7 | 1.72 | ± | 0.22 | ± | 0.17 |
| 0.42–0.50 | 0.457 | 96.9 | 2.06 | ± | 0.22 | ± | 0.19 | 0.452 | 113.2 | 0.95 | ± | 0.15 | ± | 0.12 |
| 0.50–0.60 | 0.548 | 96.3 | 0.96 | ± | 0.14 | ± | 0.12 | 0.537 | 113.0 | 0.19 | ± | 0.05 | ± | 0.03 |
| 0.60–0.72 | 0.645 | 96.4 | 0.26 | ± | 0.06 | ± | 0.04 | 0.629 | 114.1 | 0.08 | ± | 0.04 | ± | 0.02 |
| 0.72–0.90 | 0.786 | 96.0 | 0.11 | ± | 0.03 | ± | 0.02 |  |  |  |  |  |  |  |
Table A.31  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of protons in $\pi^+ + \text{Be} \rightarrow p + X$ interactions with +15.0 GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees.

| $p_T$ | $20 < \theta < 30$ | | $30 < \theta < 40$ | |
|-------|------------------|---|------------------|---|
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.20–0.24 | 0.218 | 24.2 | 16.22 | $\pm$ | 9.16 | $\pm$ | 1.13 |
| 0.24–0.30 | 0.273 | 25.0 | 49.57 | $\pm$ | 14.27 | $\pm$ | 3.06 |
| 0.30–0.36 | 0.336 | 26.1 | 20.22 | $\pm$ | 9.42 | $\pm$ | 1.16 |
| 0.36–0.42 | 0.379 | 24.9 | 13.87 | $\pm$ | 7.05 | $\pm$ | 0.77 |
| 0.42–0.50 | 0.461 | 22.3 | 13.35 | $\pm$ | 5.87 | $\pm$ | 0.66 |
| 0.50–0.60 | 0.539 | 25.8 | 11.22 | $\pm$ | 5.00 | $\pm$ | 0.55 |
| 0.60–0.72 | 0.648 | 24.9 | 19.92 | $\pm$ | 5.83 | $\pm$ | 1.08 |
| 0.72–0.90 | | | | | | |
|       | | | | | | |
| 0.30–0.36 | 0.335 | 43.6 | 22.96 | $\pm$ | 9.40 | $\pm$ | 1.24 |
| 0.36–0.42 | 0.385 | 44.4 | 31.96 | $\pm$ | 11.47 | $\pm$ | 1.60 |
| 0.42–0.50 | 0.452 | 45.4 | 19.59 | $\pm$ | 7.77 | $\pm$ | 1.01 |
| 0.50–0.60 | 0.554 | 44.5 | 17.12 | $\pm$ | 6.80 | $\pm$ | 0.85 |
| 0.60–0.72 | 0.634 | 42.2 | 8.95 | $\pm$ | 4.29 | $\pm$ | 0.52 |
| 0.72–0.90 | 0.825 | 42.8 | 7.54 | $\pm$ | 3.24 | $\pm$ | 0.53 |
| 0.90–1.25 | 1.063 | 44.2 | 2.79 | $\pm$ | 1.41 | $\pm$ | 0.29 |
|       | | | | | | |
| 0.36–0.42 | 0.396 | 70.2 | 21.16 | $\pm$ | 7.49 | $\pm$ | 1.08 |
| 0.42–0.50 | 0.456 | 65.3 | 15.77 | $\pm$ | 5.34 | $\pm$ | 0.84 |
| 0.50–0.60 | 0.540 | 66.1 | 15.79 | $\pm$ | 5.21 | $\pm$ | 0.85 |
| 0.60–0.72 | 0.659 | 70.0 | 9.15 | $\pm$ | 3.68 | $\pm$ | 0.63 |
| 0.72–0.90 | 0.798 | 69.4 | 4.09 | $\pm$ | 2.09 | $\pm$ | 0.39 |
| 0.90–1.25 | 1.076 | 65.8 | 1.63 | $\pm$ | 1.00 | $\pm$ | 0.24 |
|       | | | | | | |
| 0.36–0.42 | 0.388 | 114.7 | 5.72 | $\pm$ | 3.31 | $\pm$ | 0.34 |
| 0.42–0.50 | 0.458 | 100.2 | 8.10 | $\pm$ | 4.07 | $\pm$ | 0.57 |
| 0.50–0.60 | 0.518 | 98.8 | 8.15 | $\pm$ | 3.74 | $\pm$ | 0.67 |
| 0.60–0.72 | 0.649 | 99.3 | 2.61 | $\pm$ | 2.07 | $\pm$ | 0.27 |
Table A.32  Double-differential inclusive cross-section $d^2\sigma/dp\Omega$ [mb/(GeV/c sr)] of the production of $\pi^+$'s in $\pi^+ + \text{Be} \to \pi^+ + \text{X}$ interactions with $+15.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|-------------------|-------------------|
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\Omega$ |
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\Omega$ |
| 0.13–0.16 | 0.141 | 33.9 | 42.30 | ± | 19.30 | ± | 3.17 |
| 0.16–0.20 | 0.180 | 35.1 | 33.27 | ± | 15.08 | ± | 2.11 |
| 0.24–0.30 | 0.264 | 24.6 | 44.67 | ± | 13.69 | ± | 2.14 |
| 0.30–0.36 | 0.326 | 33.71 | ± | 8.82 | ± | 2.12 |
| 0.36–0.42 | 0.378 | 24.5 | 69.69 | ± | 17.99 | ± | 3.31 |
| 0.42–0.50 | 0.461 | 24.6 | 48.52 | ± | 12.79 | ± | 2.45 |
| 0.50–0.60 | 0.555 | 23.4 | 33.71 | ± | 8.82 | ± | 2.12 |
| 0.60–0.72 | 0.656 | 25.5 | 24.11 | ± | 6.89 | ± | 2.08 |
| 0.72–0.90 | 0.809 | 32.7 | 4.61 | ± | 2.24 | ± | 0.57 |
|       |       |       |       |       |       |       |       |
| 0.10–0.13 | 0.120 | 47.2 | 25.06 | ± | 17.75 | ± | 2.46 |
| 0.13–0.16 | 0.150 | 54.4 | 24.24 | ± | 14.06 | ± | 2.18 |
| 0.16–0.20 | 0.185 | 44.4 | 26.34 | ± | 13.40 | ± | 1.79 |
| 0.20–0.24 | 0.223 | 45.8 | 38.82 | ± | 15.92 | ± | 2.42 |
| 0.24–0.30 | 0.275 | 44.3 | 36.38 | ± | 12.86 | ± | 1.95 |
| 0.30–0.36 | 0.332 | 45.0 | 37.02 | ± | 12.44 | ± | 1.93 |
| 0.36–0.42 | 0.397 | 45.5 | 21.52 | ± | 9.61 | ± | 1.17 |
| 0.42–0.50 | 0.458 | 43.4 | 15.84 | ± | 7.07 | ± | 0.91 |
| 0.50–0.60 | 0.545 | 43.7 | 7.56 | ± | 4.36 | ± | 0.50 |
| 0.60–0.72 | 0.628 | 45.0 | 6.45 | ± | 3.68 | ± | 0.55 |
| 0.72–0.90 | 0.777 | 43.9 | 6.20 | ± | 2.86 | ± | 0.73 |
|       |       |       |       |       |       |       |       |
| 0.13–0.16 | 0.148 | 66.1 | 28.94 | ± | 13.00 | ± | 2.70 |
| 0.16–0.20 | 0.182 | 66.1 | 16.43 | ± | 8.31 | ± | 1.18 |
| 0.20–0.24 | 0.236 | 63.6 | 8.08 | ± | 5.72 | ± | 0.52 |
| 0.24–0.30 | 0.263 | 67.1 | 13.13 | ± | 6.03 | ± | 0.73 |
| 0.30–0.36 | 0.332 | 67.4 | 17.84 | ± | 6.92 | ± | 1.01 |
| 0.42–0.50 | 0.449 | 71.0 | 5.54 | ± | 3.20 | ± | 0.40 |
| 0.50–0.60 | 0.807 | 63.9 | 0.15 | ± | 0.11 | ± | 0.02 |
|       |       |       |       |       |       |       |       |
| 0.13–0.16 | 0.141 | 98.0 | 28.25 | ± | 12.65 | ± | 3.10 |
| 0.16–0.20 | 0.184 | 113.0 | 19.87 | ± | 7.51 | ± | 1.78 |
| 0.20–0.24 | 0.215 | 95.3 | 7.34 | ± | 5.19 | ± | 0.70 |
| 0.24–0.30 | 0.274 | 100.2 | 5.74 | ± | 4.06 | ± | 0.41 |
| 0.30–0.36 | 0.321 | 91.0 | 7.52 | ± | 4.34 | ± | 0.69 |
| 0.36–0.42 | 0.405 | 94.9 | 5.56 | ± | 3.93 | ± | 0.57 |
| 0.42–0.50 | 0.469 | 94.2 | 4.32 | ± | 3.06 | ± | 0.53 |
| 0.50–0.60 | 0.539 | 112.7 | 2.46 | ± | 1.74 | ± | 0.52 |
### Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^-$’s in $\pi^+ + \text{Be} \to \pi^- + \text{X}$ interactions with $+15.0 \text{ GeV/c}$ beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ (GeV/c) | $20 < \theta < 30$ | $30 < \theta < 40$ | $40 < \theta < 50$ | $50 < \theta < 60$ | $60 < \theta < 75$ | $75 < \theta < 90$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|---------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.156 | 24.6 | 21.23 | ± 14.83 | ± 1.52 | 0.122 | 31.7 | 16.01 | ± 11.79 | ± 1.53 |
| 0.13–0.16 | 0.156 | 24.6 | 21.23 | ± 14.83 | ± 1.52 | 0.122 | 31.7 | 16.01 | ± 11.79 | ± 1.53 |
| 0.16–0.20 | 0.184 | 33.9 | 42.39 | ± 17.35 | ± 2.84 | 0.184 | 33.9 | 42.39 | ± 17.35 | ± 2.84 |
| 0.20–0.24 | 0.221 | 24.2 | 43.46 | ± 16.56 | ± 2.41 | 0.217 | 35.7 | 13.82 | ± 9.80 | ± 0.84 |
| 0.24–0.30 | 0.270 | 24.9 | 62.09 | ± 16.68 | ± 3.00 | 0.263 | 35.9 | 27.09 | ± 11.10 | ± 1.40 |
| 0.30–0.36 | 0.329 | 23.9 | 58.34 | ± 16.19 | ± 2.72 | 0.335 | 33.4 | 24.25 | ± 9.91 | ± 1.22 |
| 0.36–0.42 | 0.388 | 23.3 | 32.11 | ± 11.40 | ± 1.55 | 0.391 | 33.3 | 39.28 | ± 13.14 | ± 2.15 |
| 0.42–0.50 | 0.463 | 24.5 | 28.44 | ± 9.49 | ± 1.52 | 0.457 | 34.6 | 23.96 | ± 8.47 | ± 1.45 |
| 0.50–0.60 | 0.533 | 24.9 | 13.74 | ± 6.15 | ± 0.90 | 0.542 | 35.4 | 25.50 | ± 8.07 | ± 1.84 |
| 0.60–0.72 | 0.673 | 23.9 | 6.00 | ± 3.47 | ± 0.52 | 0.656 | 33.4 | 5.93 | ± 3.43 | ± 0.55 |
Table A.34  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of protons in $\pi^- +$ Be $\rightarrow p + X$ interactions with $-15.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$   | $20 < \theta < 30$ | $30 < \theta < 40$ | $40 < \theta < 50$ | $50 < \theta < 60$ | $60 < \theta < 75$ | $75 < \theta < 90$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|---------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
|         | $(p_T)$           | $(\theta)$        | $d^2\sigma/dp\,d\Omega$ | $(p_T)$           | $(\theta)$        | $d^2\sigma/dp\,d\Omega$ | $(p_T)$           | $(\theta)$        | $d^2\sigma/dp\,d\Omega$ |
| 0.20–0.24 | 0.219           | 24.9              | 25.27 ± 1.11 ± 1.86 | 0.267           | 34.8              | 24.14 ± 0.87 ± 1.47 | 0.778           | 35.0              | 6.81 ± 0.26 ± 0.47 |
| 0.24–0.30 | 0.268           | 24.7              | 27.07 ± 0.93 ± 1.66 | 0.327           | 25.8              | 29.05 ± 0.90 ± 1.51 | 0.385           | 25.3              | 16.63 ± 0.56 ± 0.76 |
| 0.30–0.36 | 0.327           | 24.8              | 25.87 ± 0.90 ± 1.51 | 0.451           | 24.7              | 21.24 ± 0.69 ± 1.03 | 0.538           | 25.0              | 17.99 ± 0.56 ± 0.86 |
| 0.36–0.42 | 0.385           | 25.0              | 23.79 ± 0.85 ± 1.25 | 0.42–0.50        | 0.545           | 24.9              | 19.11 ± 0.49 ± 0.60 | 0.622           | 24.9              | 9.01 ± 0.38 ± 0.52  |
| 0.42–0.50 | 0.451           | 24.7              | 21.24 ± 0.69 ± 1.03 | 0.50–0.60        | 0.538           | 25.0              | 17.99 ± 0.56 ± 0.86 | 0.622           | 24.9              | 9.01 ± 0.38 ± 0.52  |
| 0.50–0.60 | 0.538           | 25.0              | 17.99 ± 0.56 ± 0.86 | 0.60–0.72        | 0.642           | 24.9              | 12.92 ± 0.43 ± 0.70 | 0.642           | 24.9              | 12.92 ± 0.43 ± 0.70 |
| 0.60–0.72 | 0.642           | 24.9              | 12.92 ± 0.43 ± 0.70 | 0.72–0.90        | 0.799           | 45.0              | 5.25 ± 0.25 ± 0.37  | 0.797           | 55.0              | 4.33 ± 0.23 ± 0.34  |
| 0.72–0.90 | 0.799           | 45.0              | 5.25 ± 0.25 ± 0.37  | 0.90–1.25        | 1.029           | 45.3              | 1.61 ± 0.10 ± 0.17  | 1.029           | 54.8              | 1.17 ± 0.08 ± 0.14  |
| 0.90–1.25 | 1.029           | 45.3              | 1.61 ± 0.10 ± 0.17  | 0.30–0.36        | 0.331           | 45.1              | 23.42 ± 0.85 ± 1.19 | 0.389           | 54.9              | 19.23 ± 0.76 ± 1.04 |
| 0.36–0.42 | 0.389           | 45.0              | 20.03 ± 0.79 ± 1.06 | 0.42–0.50        | 0.458           | 44.9              | 17.40 ± 0.64 ± 0.85 | 0.458           | 54.9              | 15.32 ± 0.59 ± 0.81 |
| 0.42–0.50 | 0.458           | 44.9              | 17.40 ± 0.64 ± 0.85 | 0.50–0.60        | 0.545           | 44.9              | 11.91 ± 0.49 ± 0.60 | 0.548           | 54.9              | 12.11 ± 0.49 ± 0.65 |
| 0.50–0.60 | 0.545           | 44.9              | 11.91 ± 0.49 ± 0.60 | 0.60–0.72        | 0.653           | 44.8              | 9.01 ± 0.38 ± 0.52  | 0.654           | 55.0              | 7.68 ± 0.37 ± 0.48  |
| 0.60–0.72 | 0.653           | 44.8              | 9.01 ± 0.38 ± 0.52  | 0.72–0.90        | 0.799           | 45.0              | 5.25 ± 0.25 ± 0.37  | 0.797           | 55.0              | 4.33 ± 0.23 ± 0.34  |
| 0.72–0.90 | 0.799           | 45.0              | 5.25 ± 0.25 ± 0.37  | 0.90–1.25        | 1.029           | 45.3              | 1.61 ± 0.10 ± 0.17  | 1.029           | 54.8              | 1.17 ± 0.08 ± 0.14  |
| 0.90–1.25 | 1.029           | 45.3              | 1.61 ± 0.10 ± 0.17  | 0.30–0.36        | 0.331           | 45.1              | 23.42 ± 0.85 ± 1.19 | 0.389           | 54.9              | 19.23 ± 0.76 ± 1.04 |
| 0.36–0.42 | 0.389           | 45.0              | 20.03 ± 0.79 ± 1.06 | 0.42–0.50        | 0.458           | 44.9              | 17.40 ± 0.64 ± 0.85 | 0.458           | 54.9              | 15.32 ± 0.59 ± 0.81 |
| 0.42–0.50 | 0.458           | 44.9              | 17.40 ± 0.64 ± 0.85 | 0.50–0.60        | 0.545           | 44.9              | 11.91 ± 0.49 ± 0.60 | 0.548           | 54.9              | 12.11 ± 0.49 ± 0.65 |
| 0.50–0.60 | 0.545           | 44.9              | 11.91 ± 0.49 ± 0.60 | 0.60–0.72        | 0.653           | 44.8              | 9.01 ± 0.38 ± 0.52  | 0.654           | 55.0              | 7.68 ± 0.37 ± 0.48  |
| 0.60–0.72 | 0.653           | 44.8              | 9.01 ± 0.38 ± 0.52  | 0.72–0.90        | 0.797           | 46.7              | 2.96 ± 0.15 ± 0.29  | 0.790           | 81.9              | 1.48 ± 0.11 ± 0.18  |
| 0.72–0.90 | 0.797           | 46.7              | 2.96 ± 0.15 ± 0.29  | 0.90–1.25        | 1.029           | 66.6              | 0.86 ± 0.06 ± 0.13  | 1.029           | 81.0              | 0.38 ± 0.04 ± 0.07  |
| 0.90–1.25 | 1.029           | 66.6              | 0.86 ± 0.06 ± 0.13  |
Table A.35  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^+$'s in $\pi^- + \text{Be} \rightarrow \pi^+ + \text{X}$ interactions with $-15.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|-------------------|-------------------|
|       | $(p_T)$           | $(\theta)$        | $d^2\sigma/dp\,d\Omega$ | $(p_T)$           | $(\theta)$        | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.115 24.6 | 45.98 ± 2.08 ± 3.81 | 0.115 35.0 | 30.15 ± 1.63 ± 2.64 |
| 0.13–0.16 | 0.145 24.7 | 55.61 ± 2.07 ± 3.90 | 0.145 35.0 | 39.64 ± 1.77 ± 2.80 |
| 0.16–0.20 | 0.180 24.7 | 63.93 ± 1.87 ± 3.75 | 0.179 34.8 | 42.87 ± 1.54 ± 2.59 |
| 0.20–0.24 | 0.219 24.6 | 75.96 ± 2.01 ± 4.00 | 0.219 34.6 | 43.58 ± 1.50 ± 2.36 |
| 0.24–0.30 | 0.268 24.5 | 64.35 ± 1.48 ± 3.00 | 0.266 34.5 | 42.01 ± 1.19 ± 2.00 |
| 0.30–0.36 | 0.326 24.6 | 56.74 ± 1.38 ± 2.47 | 0.325 34.7 | 36.88 ± 1.13 ± 1.64 |
| 0.36–0.42 | 0.384 24.6 | 46.39 ± 1.24 ± 2.01 | 0.385 34.4 | 27.42 ± 0.94 ± 1.23 |
| 0.42–0.50 | 0.451 24.6 | 34.24 ± 0.91 ± 1.67 | 0.452 34.7 | 20.07 ± 0.69 ± 0.97 |
| 0.50–0.60 | 0.539 24.6 | 24.03 ± 0.66 ± 1.47 | 0.538 34.7 | 15.30 ± 0.54 ± 0.91 |
| 0.60–0.72 | 0.643 24.5 | 12.77 ± 0.42 ± 1.09 | 0.642 34.5 | 7.79 ± 0.32 ± 0.64 |
| 0.72–0.90 |         |             | 0.781 34.6 | 3.80 ± 0.17 ± 0.45 |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|-------------------|-------------------|
|       | $(p_T)$           | $(\theta)$        | $d^2\sigma/dp\,d\Omega$ | $(p_T)$           | $(\theta)$        | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.116 44.7 | 21.46 ± 1.42 ± 2.01 | 0.145 55.1 | 18.40 ± 1.14 ± 1.59 |
| 0.13–0.16 | 0.146 44.8 | 27.03 ± 1.44 ± 2.01 | 0.179 54.8 | 21.02 ± 1.04 ± 1.36 |
| 0.16–0.20 | 0.181 45.0 | 26.95 ± 1.21 ± 1.69 | 0.220 54.9 | 19.66 ± 0.99 ± 1.17 |
| 0.20–0.24 | 0.219 44.6 | 28.62 ± 1.23 ± 1.61 | 0.271 54.6 | 18.09 ± 0.78 ± 0.93 |
| 0.24–0.30 | 0.269 44.7 | 26.03 ± 0.93 ± 1.30 | 0.328 54.6 | 15.71 ± 0.71 ± 0.77 |
| 0.30–0.36 | 0.330 44.8 | 22.51 ± 0.87 ± 1.05 | 0.390 54.6 | 12.43 ± 0.63 ± 0.68 |
| 0.36–0.42 | 0.389 44.7 | 18.31 ± 0.77 ± 0.88 | 0.457 54.8 | 8.54 ± 0.44 ± 0.52 |
| 0.42–0.50 | 0.459 44.7 | 14.34 ± 0.59 ± 0.73 | 0.546 54.5 | 5.77 ± 0.32 ± 0.43 |
| 0.50–0.60 | 0.547 44.7 | 8.60 ± 0.39 ± 0.55 | 0.546 54.4 | 5.49 ± 0.37 ± 0.22 |
| 0.60–0.72 | 0.654 44.7 | 5.52 ± 0.29 ± 0.44 | 0.654 54.4 | 3.37 ± 0.22 ± 0.30 |
| 0.72–0.90 | 0.792 44.6 | 2.17 ± 0.14 ± 0.25 | 0.797 54.7 | 1.37 ± 0.11 ± 0.17 |
| 0.90–1.25 |         |             | 1.020 55.0 | 0.24 ± 0.03 ± 0.05 |

| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|-------|-------------------|-------------------|
|       | $(p_T)$           | $(\theta)$        | $d^2\sigma/dp\,d\Omega$ | $(p_T)$           | $(\theta)$        | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.146 67.0 | 13.85 ± 0.81 ± 1.11 | 0.146 82.4 | 10.71 ± 0.70 ± 0.95 |
| 0.16–0.20 | 0.180 67.1 | 14.41 ± 0.67 ± 0.98 | 0.180 82.3 | 11.12 ± 0.59 ± 0.88 |
| 0.20–0.24 | 0.220 67.2 | 15.85 ± 0.73 ± 0.90 | 0.219 82.1 | 11.09 ± 0.60 ± 0.67 |
| 0.24–0.30 | 0.268 67.0 | 12.71 ± 0.53 ± 0.63 | 0.268 82.2 | 7.35 ± 0.39 ± 0.42 |
| 0.30–0.36 | 0.328 66.9 | 9.96 ± 0.46 ± 0.51 | 0.330 81.4 | 5.88 ± 0.34 ± 0.39 |
| 0.36–0.42 | 0.389 67.0 | 7.93 ± 0.41 ± 0.45 | 0.389 82.0 | 3.82 ± 0.27 ± 0.30 |
| 0.42–0.50 | 0.460 67.2 | 5.04 ± 0.28 ± 0.36 | 0.457 82.0 | 2.84 ± 0.20 ± 0.29 |
| 0.50–0.60 | 0.544 66.3 | 3.80 ± 0.22 ± 0.31 | 0.546 81.6 | 1.67 ± 0.14 ± 0.17 |
| 0.60–0.72 | 0.654 66.4 | 1.72 ± 0.12 ± 0.21 | 0.652 81.9 | 0.81 ± 0.08 ± 0.12 |
| 0.72–0.90 | 0.791 65.9 | 0.66 ± 0.06 ± 0.10 | 0.813 81.1 | 0.17 ± 0.03 ± 0.04 |
| 0.90–1.25 | 1.030 67.1 | 0.11 ± 0.02 ± 0.03 | 1.016 81.0 | 0.04 ± 0.01 ± 0.02 |
Table A.35  (Continued)

| $p_T$ | $90 < \theta < 105$ | $105 < \theta < 125$ |
|-------|---------------------|---------------------|
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.13–0.16 | 0.145 | 97.7 | 7.88 ± 0.59 ± 0.79 | 0.145 | 114.0 | 7.20 ± 0.46 ± 0.75 |
| 0.16–0.20 | 0.181 | 96.9 | 8.14 ± 0.49 ± 0.61 | 0.179 | 114.3 | 6.60 ± 0.36 ± 0.58 |
| 0.20–0.24 | 0.219 | 97.3 | 7.33 ± 0.46 ± 0.57 | 0.217 | 114.6 | 3.84 ± 0.29 ± 0.33 |
| 0.24–0.30 | 0.268 | 97.4 | 5.37 ± 0.33 ± 0.33 | 0.268 | 113.2 | 3.15 ± 0.22 ± 0.25 |
| 0.30–0.36 | 0.328 | 97.2 | 3.68 ± 0.28 ± 0.26 | 0.327 | 112.5 | 1.85 ± 0.16 ± 0.19 |
| 0.36–0.42 | 0.387 | 96.5 | 2.27 ± 0.20 ± 0.24 | 0.386 | 111.8 | 1.03 ± 0.12 ± 0.14 |
| 0.42–0.50 | 0.458 | 95.7 | 1.66 ± 0.16 ± 0.19 | 0.460 | 112.3 | 0.46 ± 0.07 ± 0.09 |
| 0.50–0.60 | 0.549 | 95.4 | 0.61 ± 0.08 ± 0.10 | 0.545 | 113.3 | 0.21 ± 0.04 ± 0.05 |
| 0.60–0.72 | 0.647 | 96.9 | 0.26 ± 0.05 ± 0.05 | 0.646 | 110.9 | 0.07 ± 0.02 ± 0.02 |
| 0.72–0.90 | 0.763 | 95.3 | 0.08 ± 0.02 ± 0.04 |               |                |                  |

Table A.36  Double-differential inclusive cross-section $d^2\sigma/dp\,d\Omega$ [mb/(GeV/c sr)] of the production of $\pi^-$’s in $\pi^- + \text{Be} \rightarrow \pi^- + \text{X}$ interactions with $-15.0$ GeV/c beam momentum; the first error is statistical, the second systematic; $p_T$ in GeV/c, polar angle $\theta$ in degrees

| $p_T$ | $20 < \theta < 30$ | $30 < \theta < 40$ |
|-------|---------------------|---------------------|
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.115 | 24.6 | 57.96 ± 2.29 ± 4.67 | 0.116 | 34.8 | 36.13 ± 1.78 ± 3.15 |
| 0.13–0.16 | 0.146 | 24.7 | 74.78 ± 2.42 ± 5.04 | 0.146 | 34.6 | 44.08 ± 1.83 ± 3.12 |
| 0.16–0.20 | 0.182 | 24.5 | 83.43 ± 2.14 ± 4.84 | 0.181 | 34.6 | 49.76 ± 1.63 ± 2.99 |
| 0.20–0.24 | 0.221 | 24.6 | 90.28 ± 2.19 ± 4.63 | 0.222 | 34.7 | 55.36 ± 1.69 ± 2.95 |
| 0.24–0.30 | 0.272 | 24.5 | 84.12 ± 1.71 ± 3.75 | 0.271 | 34.6 | 52.07 ± 1.34 ± 2.40 |
| 0.30–0.36 | 0.332 | 24.6 | 74.96 ± 1.62 ± 3.10 | 0.333 | 34.7 | 42.92 ± 1.21 ± 1.85 |
| 0.36–0.42 | 0.394 | 24.6 | 62.60 ± 1.48 ± 2.64 | 0.394 | 34.6 | 37.25 ± 1.13 ± 1.63 |
| 0.42–0.50 | 0.464 | 24.6 | 46.78 ± 1.10 ± 2.21 | 0.464 | 34.6 | 28.82 ± 0.86 ± 1.39 |
| 0.50–0.60 | 0.555 | 24.6 | 30.44 ± 0.80 ± 1.80 | 0.555 | 34.8 | 21.50 ± 0.67 ± 1.30 |
| 0.60–0.72 | 0.667 | 24.6 | 19.92 ± 0.59 ± 1.62 | 0.667 | 34.6 | 11.61 ± 0.44 ± 0.92 |
| 0.72–0.90 | 0.763 | 24.6 | 1.02 ± 0.02 ± 0.04 |               |                |                  |

| $p_T$ | $40 < \theta < 50$ | $50 < \theta < 60$ |
|-------|---------------------|---------------------|
|       | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ | $\langle p_T \rangle$ | $\langle \theta \rangle$ | $d^2\sigma/dp\,d\Omega$ |
| 0.10–0.13 | 0.116 | 44.8 | 28.52 ± 1.55 ± 2.71 | 0.145 | 54.8 | 24.85 ± 1.34 ± 1.93 |
| 0.13–0.16 | 0.146 | 44.8 | 31.34 ± 1.50 ± 2.34 | 0.145 | 54.8 | 24.85 ± 1.34 ± 1.93 |
| 0.16–0.20 | 0.179 | 44.7 | 35.76 ± 1.39 ± 2.21 | 0.181 | 54.8 | 27.65 ± 1.19 ± 1.77 |
| 0.20–0.24 | 0.220 | 44.8 | 39.50 ± 1.44 ± 2.20 | 0.220 | 54.7 | 29.04 ± 1.23 ± 1.63 |
| 0.24–0.30 | 0.270 | 44.7 | 32.91 ± 1.04 ± 1.57 | 0.271 | 54.7 | 22.29 ± 0.86 ± 1.14 |
| 0.30–0.36 | 0.328 | 44.6 | 30.34 ± 1.02 ± 1.36 | 0.330 | 54.8 | 20.09 ± 0.82 ± 0.95 |
| 0.36–0.42 | 0.388 | 44.8 | 22.96 ± 0.87 ± 1.07 | 0.389 | 54.6 | 15.70 ± 0.71 ± 0.78 |
| 0.42–0.50 | 0.460 | 44.5 | 17.64 ± 0.66 ± 0.99 | 0.458 | 54.6 | 13.51 ± 0.58 ± 0.75 |
| 0.50–0.60 | 0.546 | 44.7 | 13.49 ± 0.53 ± 0.88 | 0.544 | 54.7 | 8.32 ± 0.41 ± 0.57 |
| 0.60–0.72 | 0.654 | 44.5 | 7.21 ± 0.35 ± 0.60 | 0.649 | 54.6 | 4.74 ± 0.28 ± 0.42 |
| 0.72–0.90 | 0.795 | 44.7 | 3.79 ± 0.21 ± 0.43 | 0.789 | 54.7 | 1.90 ± 0.14 ± 0.23 |
| 0.90–1.25 |               |                | 1.015 | 54.3 | 0.39 ± 0.04 ± 0.08 |
Table A.36 (Continued)

| $p_T$ | $60 < \theta < 75$ | $75 < \theta < 90$ |
|-------|---------------------|---------------------|
|       | \(<p_T\rangle\) (<$\theta$>) | $d^2\sigma/dp_d\Omega$ | \(<p_T\rangle\) (<$\theta$>) | $d^2\sigma/dp_d\Omega$ |
| 0.13–0.16 | 0.145 67.6 20.41 ± 0.97 ± 1.67 | 0.146 82.5 15.64 ± 0.82 ± 1.46 |
| 0.16–0.20 | 0.181 67.2 21.23 ± 0.82 ± 1.37 | 0.181 82.3 16.90 ± 0.72 ± 1.22 |
| 0.20–0.24 | 0.220 67.1 21.39 ± 0.85 ± 1.25 | 0.219 82.5 14.29 ± 0.67 ± 0.82 |
| 0.24–0.30 | 0.268 66.8 16.96 ± 0.61 ± 0.80 | 0.267 82.0 11.35 ± 0.49 ± 0.57 |
| 0.30–0.36 | 0.328 66.6 14.09 ± 0.56 ± 0.66 | 0.329 82.1 7.47 ± 0.40 ± 0.41 |
| 0.36–0.42 | 0.389 66.8 10.59 ± 0.47 ± 0.63 | 0.390 81.7 6.32 ± 0.37 ± 0.41 |
| 0.42–0.50 | 0.456 66.9 7.76 ± 0.35 ± 0.48 | 0.459 81.5 3.68 ± 0.24 ± 0.30 |
| 0.50–0.60 | 0.549 66.9 5.45 ± 0.27 ± 0.41 | 0.540 82.2 2.53 ± 0.18 ± 0.24 |
| 0.60–0.72 | 0.653 66.3 2.13 ± 0.14 ± 0.24 | 0.648 81.4 1.08 ± 0.10 ± 0.14 |
| 0.72–0.90 | 0.795 67.0 0.87 ± 0.08 ± 0.12 | 0.787 80.0 0.40 ± 0.05 ± 0.07 |
| 0.90–1.25 | 1.038 65.4 0.15 ± 0.02 ± 0.03 | 0.994 80.2 0.05 ± 0.02 ± 0.02 |

| $p_T$ | 90 < $\theta$ < 105 | 105 < $\theta$ < 125 |
|-------|---------------------|---------------------|
|       | \(<p_T\rangle\) (<$\theta$>) | $d^2\sigma/dp_d\Omega$ | \(<p_T\rangle\) (<$\theta$>) | $d^2\sigma/dp_d\Omega$ |
| 0.13–0.16 | 0.146 97.0 13.15 ± 0.74 ± 1.20 | 0.144 114.4 10.34 ± 0.55 ± 0.95 |
| 0.16–0.20 | 0.179 97.3 14.11 ± 0.63 ± 1.19 | 0.179 114.5 9.61 ± 0.45 ± 0.70 |
| 0.20–0.24 | 0.219 96.5 10.65 ± 0.58 ± 0.70 | 0.217 113.6 7.21 ± 0.40 ± 0.52 |
| 0.24–0.30 | 0.268 97.2 8.52 ± 0.43 ± 0.47 | 0.269 113.8 4.65 ± 0.27 ± 0.34 |
| 0.30–0.36 | 0.330 96.4 5.10 ± 0.33 ± 0.34 | 0.329 113.6 2.88 ± 0.21 ± 0.25 |
| 0.36–0.42 | 0.389 97.0 3.90 ± 0.28 ± 0.36 | 0.390 114.2 1.58 ± 0.15 ± 0.20 |
| 0.42–0.50 | 0.460 96.5 2.41 ± 0.19 ± 0.28 | 0.454 112.7 1.00 ± 0.10 ± 0.15 |
| 0.50–0.60 | 0.547 96.7 0.95 ± 0.11 ± 0.15 | 0.542 112.1 0.42 ± 0.06 ± 0.08 |
| 0.60–0.72 | 0.657 96.8 0.46 ± 0.07 ± 0.09 | 0.631 115.2 0.15 ± 0.04 ± 0.04 |
| 0.72–0.90 | 0.796 95.1 0.14 ± 0.03 ± 0.04 | | |

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