Measurement of charged pion cross section in proton carbon interaction at 30 GeV with the NA61/SHINE apparatus

Sebastien Murphy
on behalf of the NA61/SHINE collaboration

University of Geneva, DPNC, 24 Quai E. Ansermet, 1201 Geneva, Switzerland

Abstract. Among other goals, the NA61/SHINE (SHINE $\equiv$ SPS Heavy Ion and Neutrino Experiment) detector at CERN SPS aims at precision hadro-production measurements to characterise the neutrino beam of the T2K experiment at J-PARC. These measurements are performed using a 30 GeV proton beam produced at the SPS with a thin carbon target and a full T2K replica target. Preliminary spectra of π^- and π^+ inclusive inelastic cross section were obtained from pilot data collected in 2007 with a 2 cm thick target (4% of the interaction length). After a description of the SHINE detector and its particle identification capabilities, results from three different analysis are presented.

Keywords: hadroproduction measurements, neutrino physics, T2K, SPS
PACS: 13.85.Hd,13.85.Ni,13.85.Lg

PHYSICS MOTIVATION

In T2K, neutrinos are produced by a high intensity proton beam of 30 GeV impinging on a carbon target and producing mesons (π and K) from the decay of which the neutrinos are produced. There exist so far no measurements of hadron inclusive spectra from p+C at 30 GeV. Thus the NA61/SHINE experiment will provide a precise measurement of meson yield production in carbon at the proton beam energy (30 GeV/c) of interest for T2K. These measurements will be used for the T2K neutrino beam simulation and consequently reduce the systematic uncertainties of the neutrino energy distribution at the needed level for the physics goals of T2K [1].

THE SHINE DETECTOR AND COMBINED PARTICLE IDENTIFICATION

The set-up of the NA61/SHINE is shown in Fig. 1. The main components of the NA61 detector were constructed and used by the NA49 experiment [2]. The tracking apparatus consists in four large volume Time Projection Chambers (TPCs). Two of them, the vertex TPCs (VTPC-1 and VTPC-2), are located in the magnetic field of two super-conducting dipole magnets and, two TPCs (MTPC-L and MTCP-R) are positioned downstream of the magnets, symmetrically on the left and right of the beam line. The TPCs provide a measurement of charged particle momenta p with a high resolution. For the 2007 run a new forward time of flight detector (ToF-F) was constructed in order to extend the acceptance of the NA61/SHINE set-up for pion and kaon identification as required for the T2K measurements [3]. The ToF-F detector consists of 64 scintillator bars, vertically orientated, and read out on both sides with Hamamatsu R1828 photo-multipliers. The resolution of the ToF-F wall is $<$ 120 ps [3] which provides a 5 σ π/K separation at 3 GeV/c. It is installed downstream of the MTPC-L and MTPC-R, closing the gap between the ToF-R and ToF-L walls. The ToF-F provides full acceptance coverage of the T2K phase-space (parent particles generating a neutrino which hit the far detector).

As demonstrated in Fig. 2, high purity particle identification can be performed by combining the tof and dE/dx information over the whole momentum range needed for T2K. Moreover, in the momentum range 1–4 GeV/c, where dE/dx bands for different particle species overlap, particle identification is in general only possible using the tof method. In each (p, θ) bin the bin-by-bin maximum likelihood method was applied to fit yields of π^+ and π^- mesons. The pion yields were calculated summing all particles within 2σ around the fitted pion peak.

PRELIMINARY π^+, π^- CROSS SECTIONS

The differential inclusive inelastic cross section $\frac{d\sigma_{inel}}{dp}$ are extracted using three independent analysis:

- π^+ and π^- spectra identified with dE/dx below 800 MeV/c [5].
- π^- spectra from a so called h-minus analysis in which all negative tracks were selected and yields

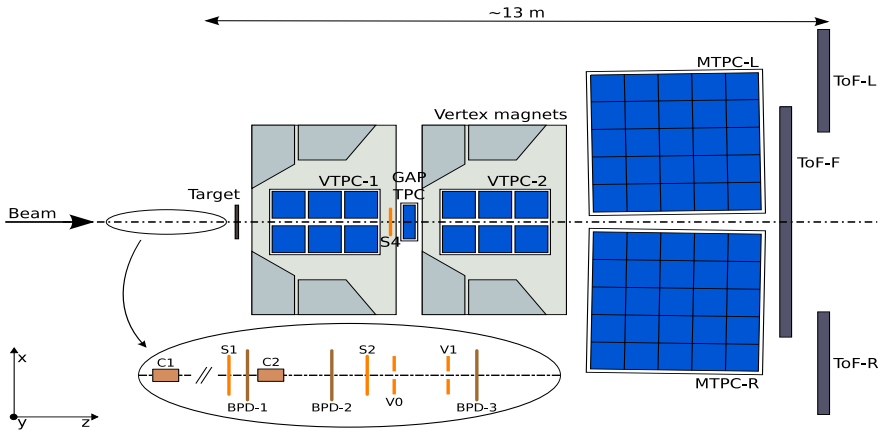

FIGURE 1. The layout of the NA61/SHINE set-up in the 2007 data taking.

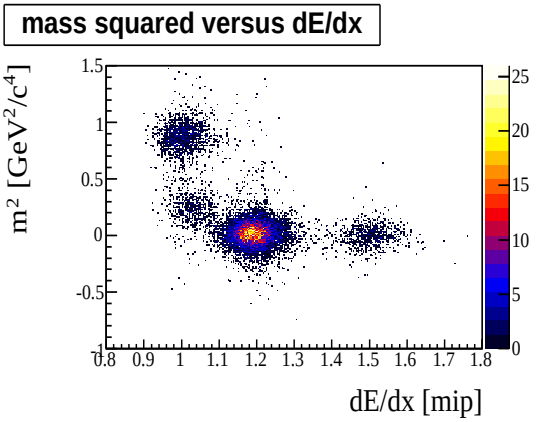

FIGURE 2. Examples of a bidimentional m^2-dE/dx plot in the momentum range 3-4 GeV/c. 4 islands corresponding to pions, electrons, kaons and protons are clearly defined. A high purity samples of pions can be extracted with this method.

were extracted from a global Monte Carlo factor [4].

- π^+ and π^- yields identified with the combined tof+dE/dx method [6].

All pion yields were corrected with the help of the NA61 Geant3 based Monte-Carlo. The following effects have been accounted for: geometrical acceptance of the detector; efficiency of the reconstruction chain; decays and secondary interactions; ToF detection efficiency; pions coming from Lambda and K0s decays (called feed-down correction). The corrections applied to the spectra for one angular bin in the tof+dE/dx analysis are shown in Fig. 3 as an example. In addition to several track quality cuts, maximum acceptance regions were selected by applying a cut on the azimuthal angle, thereby assuring tracks have a large number of measured points, and a very high reconstruction efficiency. The results from all three analysis are presented in Fig. 4 and Fig. 5 in four polar angle bins. Only statistical errors are shown and for these preliminary results systematical uncertainties are estimated to be 20% or below.

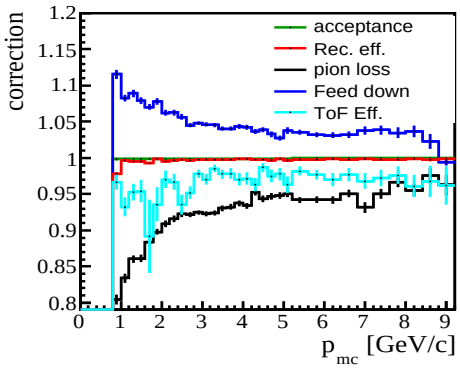

FIGURE 3. Corrections applied to the π^+ spectra in the 180-240 mrad angular bin for the tof+dE/dx analysis.

CONCLUSION

Preliminary results of pion inclusive cross-section from proton carbon interactions at 30 GeV are now available and used for the T2K flux prediction. Final results with reduced systematics will soon be published. Another much larger set of data has been collected at the end of 2009, after a major readout upgrade, an extension of the ToF-F and a new trigger system. The calibration of this data is currently being finalized. With this larger set of statistics the goal, amongst others, is to produce kaon cross-sections results which is crucial for T2K to predict the intrinsic ν_e contamination of the neutrino beam. Such results would greatly improve the T2K sensitivity in its search for the last unknown neutrino mixing angle θ_{13}.

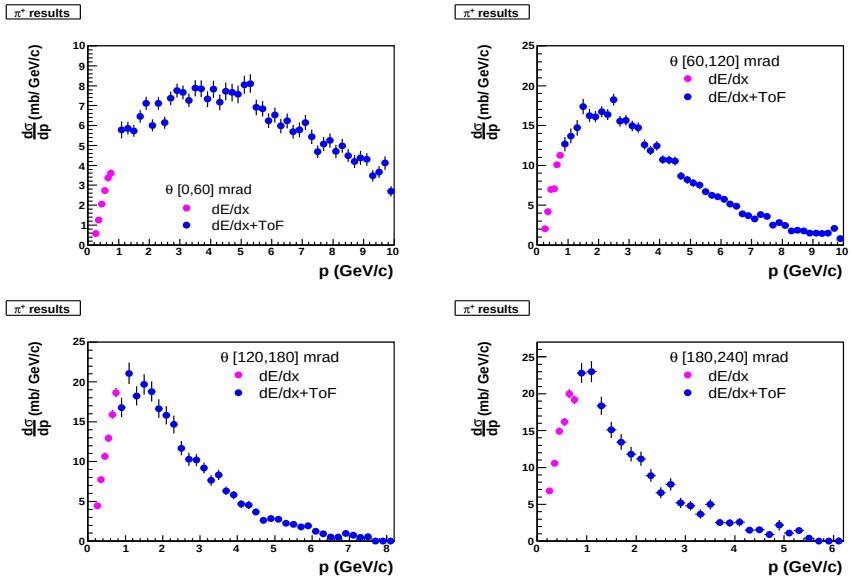

FIGURE 4. Double differential inclusive inelastic cross section for π^+ from collisions of 30 GeV protons on the thin carbon target. Results are shown in 4 bins of polar angle θ between 0 and 240 mrad with statistical errors only. The results from ToF + dE/dx in blue are compare with the "dE/dx only" analysis in pink.

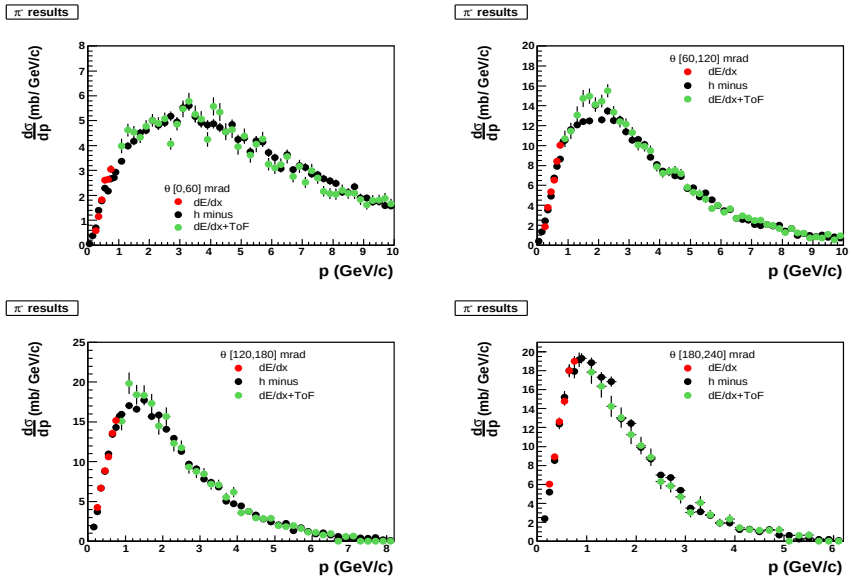

FIGURE 5. Double differential inclusive inelastic cross section for π^-. Results from 3 analysis are shown with statistical errors only.

REFERENCES

1. N. Abgrall [NA61 Collaboration], XLVth Rencontres de Moriond, Electroweak interactions and unified theories, La Thuile (March 2010).
2. S. Afanasev *et al.* [NA49 Collaboration], Nucl. Instrum. Meth. A 430, 210 (1999).
3. N. Abgrall *et al.* [NA61 Collaboration], CERN-SPSC-2008-018.
4. T. Palczewski, Ph.D. Thesis in preparation, Soltan Institute for Nuclear Studies, 2011, Warsaw Poland.
5. M. Posiadala, Ph.D. Thesis in preparation, University of Warsaw, 2011, Warsaw Poland.
6. S. Murphy, Ph.D. Thesis in preparation, University of Geneva, 2011, Geneva Switzerland.