

Galbraith W, Jenkins E W, Kycia T F, Leontic B A, Phillips R H, Read A L & Rubinstein R. Total cross sections of protons, antiprotons, and  $\pi$  and  $K$  mesons on hydrogen and deuterium in the momentum range 6-22 GeV/c. *Phys. Rev. B* 138:913-20, 1965.  
[Brookhaven Natl. Lab., Upton, and Lab. Nuclear Studies, \*Cornell Univ., Ithaca, NY]

Total hadronic cross sections were measured for  $\pi$  and  $K$  mesons and protons (of both charge signs) in hydrogen and deuterium over the momentum range 6-22 GeV/c. The  $\pi^+$  and  $\pi^-$  cross sections were equal at all momenta, verifying charge symmetry over this range; the pp and pn cross sections exhibited a small but significant and continuing decrease above 12 GeV/c. [The *SCI*® indicates that this paper has been cited in over 570 publications since 1965.]

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"In 1963, theory of the hadronic interaction was mainly concerned with the nature of exchanged particles, largely due to the theoretical predictions at that time concerning the high energy, or 'asymptotic,' behaviour of the total cross section ( $\sigma_T$ ) with increasing energy in the region beyond a few GeV. The experiment was devised initially by Ed Jenkins and Ted Kycia,<sup>1</sup> who had previously measured  $\sigma_T$ 's at Brookhaven National Laboratory (BNL), aided and abetted by Boran Leontic, Bob Phillips, Linc Read, and Roy Rubinstein. A new Cherenkov Counter, designed by Kycia, was central to the success of this work. I was on leave from AERE, Harwell, and joined this collaboration replacing the then group leader, Rod Cool, who was at CERN, Geneva, for the same period. Our group set out to do the most precise measurement of its type at the time. We had not one target, but three, all ten feet in length, where hydrogen, deuterium, and vacuum could be placed in turn into a beam of pions, kaons, and protons (of both charge signs). I recall the enormous enthusiasm of Al Schlafke and the cryogenics to get the targets operative in time and the detailed problems investigated to establish just how

much hydrogen and deuterium were present. Our electronic circuitry was all prototype nanosecond boxes made at BNL by the experts Higginbotham and Sugarman and housed in a small house trailer. It was just prior to the era of online data acquisition, so we recorded scalers by typewriter, cutting up and pasting lists into notebooks. We were kept on our toes by the nocturnal visits of Rudi Sternheimer, who would pass the time by discussing all manner of things besides the current state of the paper cutting exercise.

"The 1,000 hours of beam time (taken largely parasitically) proved a considerable strain upon the small team. The nonlinear extrapolation of the partial cross section to the forward scattering direction, and the role played by the 'Glauber connection' in establishing neutron total cross sections from the deuterium and proton data, were problems faced in data analysis. In the end, systematic errors, arising from the extrapolation procedures, prevented us from achieving very high precision of cross section in absolute terms, but the relative cross sections, as a function of energy, showed us clearly, for the first time, a cross section which continued to fall with increasing energy up to our highest limit (20 GeV).

"What does one recall of the fall and winter of 1963? For me, John Kennedy's death, the memories of being 'on campus' at BNL, a first experience of 'below zero' weather, flu on New Year's Eve, and a very happy collaboration, made all the more so by the friendship and enthusiasm of my colleagues at BNL. Why was this work so cited? The falling cross section indicated that more energy was needed to establish if 'asymptopia' was ever in sight and with the subsequent development of colliding pp and  $\bar{p}p$  beams at CERN, it is clear one always had to measure further  $\sigma_T$ 's as higher energies became available. Even now, these early cross section measurements still continue to appear on conference slides! It is surprising, but heart-warming to us all, that our early work has been so recognised.

"R. Battiston *et al.* recently published work in this field."<sup>2</sup>

1. Diddens A N, Jenkins E W, Kycia T F & Riley K F. Structure in the pion-proton total cross section between 2 and 3 BeV. *Phys. Rev. Lett.* 10:262-5, 1963. (Cited 115 times.)
2. Battiston R, Bozzo M, Braccini P L, Carbonara F, Carrara R, Castaldi R, Cervelli F, Chieffari G, Drago E, Haguenaier M, Koene B, Matthiae G, Merola L, Napolitano M, Palladino V, Sanguineti G, Sciacca G, Sette G, van Swol R, Timmermans J, Vannini C, Velasco J & Visco F. Measurement of the proton-antiproton elastic and total cross section at a centre-of-mass energy of 540 GeV. *Phys. Lett. B* 117:126-30, 1982.