Fermi National Accelerator Laboratory

FERMILAB-TM-1949

Present Status of $\bar{p}p$ Elastic and Total Cross Section Data

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October 1995

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

PRESENT STATUS OF PP ELASTIC AND TOTAL CROSS SECTION DATA

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Abstract: A review of the recent published (and some unpublished) measurements with recollections of how they have evolved. A talk given at the VIth Blois Workshop on Frontiers in Strong Interactions, June 20-24, 1995.

I begin by giving credit to the thesis of Sasan Sadr[33]. It was the first paper I reread in the process of preparing this talk and served to remind me of many of the measurements that have been made over the last several decades. The reference list at the end of this paper is divided into several sections according to how and where the data were produced. Nearly 30 years ago asymptopia was first approached as the total cross section measurements in fixed target experiments [1],[2],[3] stopped falling with increasing energy and became flat. Then the ISR pp experiments and the Fermilab fixed target experiments[4],[5],[6],[7],[8],[9] showed the total cross sections starting to rise. After CERN developed the $\bar{p}$ accumulator, both the ISR and the S$\bar{p}$pS measured the $\bar{p}$p total and elastic cross sections[11]-[19]. The detailed comparison between the pp and the $\bar{p}$p data from the ISR showed that the differences between them were disappearing with increasing energy and that they were identical to within measurement errors at the maximum ISR energy of $\sqrt{s} = 62$ GeV. This was true not only for σ_{tot} but also for the ratio of elastic to total cross section (σ_{el}/σ_{tot}), the logarithmic slope of the elastic cross section (B), and the ratio of the real to the imaginary part of the forward nuclear scattering amplitude (ρ). The S$\bar{p}$pS data showed a dramatic 50% increase in σ_{tot} from 43.5 mb at the highest ISR energy[7] to 61.9 mb $\pm$ 1.5 mb at $\sqrt{s}$ =546 GeV[18]. All the other parameters also increased significantly - σ_{el}/σ_{tot} from 0.17 at the ISR to 0.22 at the S$\bar{p}$pS, B from 12 $(GeV/c)^{-2}$ at the ISR to 15.2 $(GeV/c)^{-2}$ at the S$\bar{p}$pS and ρ from 0.1 at the ISR to the UA4 value of $\rho = 0.24 \pm 0.04$[20]. Various models[15],[22] fit all of this data very well except for the ρ value.

This set the stage for the Fermilab Collider experiments, CDF and E710. In 1989 E710 published[24] the first Fermi Collider σ_{tot} result, $\sigma_{tot} = 78.3 \pm 5.9$ mb and B $= 16.3 \pm 0.5$ $(GeV/c)^{-2}$. This was normalized using the accelerator measured luminosity, which had an uncertainty of 15%. A year later E710 published[24] $\sigma_{tot} = 72.1 \pm 3.3$ mb , $\sigma_{el} = 16.6 \pm 1.6$ mb. This was normalized using the "luminosity independent" method utilizing the optical theorem. Shortly after this the CDF collaboration began presenting[27] the preliminary result from their small angle data, $\sigma_{tot} = 72.0 \pm 3.6$ mb. This was again normalized using their best estimate of the accelerator luminosity. A year after this, in 1992, E710 was able to reanalysize their data to improve the background subtraction at low t and published [29] $\rho = 0.14 \pm 0.069$, $\sigma_{tot} = 72.8 \pm 3.1$ mb, B = $16.99 \pm 0.47 (GeV/c)^{-2}$, $\sigma_{el} = 16.6 \pm 1.6$ mb, $\sigma_{el}/\sigma_{tot} = 0.23 \pm 0.024$ and $2\sigma_{sd} = 8.1 \pm 1.7$ mb.

The difficulties models were having fitting the UA4 $\sqrt{s}$ =546 GeV ρ value and all of this new Fermilab $\sqrt{s}$ = 1800 GeV data motivated the formation of the UA4/2 collaboration to remeasure ρ with greater precision. In 1993 the UA4/2 collaboration published [21] their new value of $\rho = 0.135 \pm 0.015$ which "superseded" the old UA4 value. All the other values measured in the new experiment were consistent with the UA4 results enumerated above. General satisfaction with the consistentcy of all the data was cut short by the publication of the CDF results [32] which now used the luminosity independent method to normalize. Their results are σ_{tot} = 80.03 $\pm$ 2.24 mb, B = 16.98 $\pm$ 0.25 $(GeV/c)^{-2}$, σ_{el} = 19.70 $\pm$ 0.85 mb, σ_{el}/σ_{tot} = 0.246 $\pm$ 0.004 at $\sqrt{s}$ =1800. This significant disagreement with E710 remains unexplained. Table I summarizes all the recent data. The figures display the same data.

All of these figures illustrate the rise of all these parameters with s with the possible exception of ρ, which is not well measured at the highest energy. One can only hope that by the next Blois Workshop, E811 at Fermilab, (which is the successor to E710), will be able to improve the measurement of ρ and remove the uncertainty in σ_{tot} due to the difference between E710 and CDF. In preparing this talk, I found one other interesting indication of the "progress" in the last decade. Using dispersion relations, one can parameterize the pp and $\bar{p}p$ total cross sections as[10]

$$\sigma_{+-} = C_0 + A_1(E)^{-N1} \mp A_2 (E)^{-N2} + C2 (\ln s)^{\gamma}$$

A decade ago this procedure was applied to all the data up through the UA4 result[15]. Recently the UA4/2 Collaboration updated this to include all the recent data[22]. The only changes are that the errors are larger.

fit constant	Amos et al[15]	Augier et al (UA4/2)[22]
C_0	28.3+-0.2	30+3-4
A_1	43+-0.6	42.5+2-1.6
N1	0.41 +-.01	0.45 +.08-.06
A_2	24.8+-0.9	25.5 +.5-.4
N2	0.56+-.01	0.565+.005-.004
C2	0.19+-.01	0.10+0.15-0.06
γ	2.02+-.01	2.25+0.35_0.31

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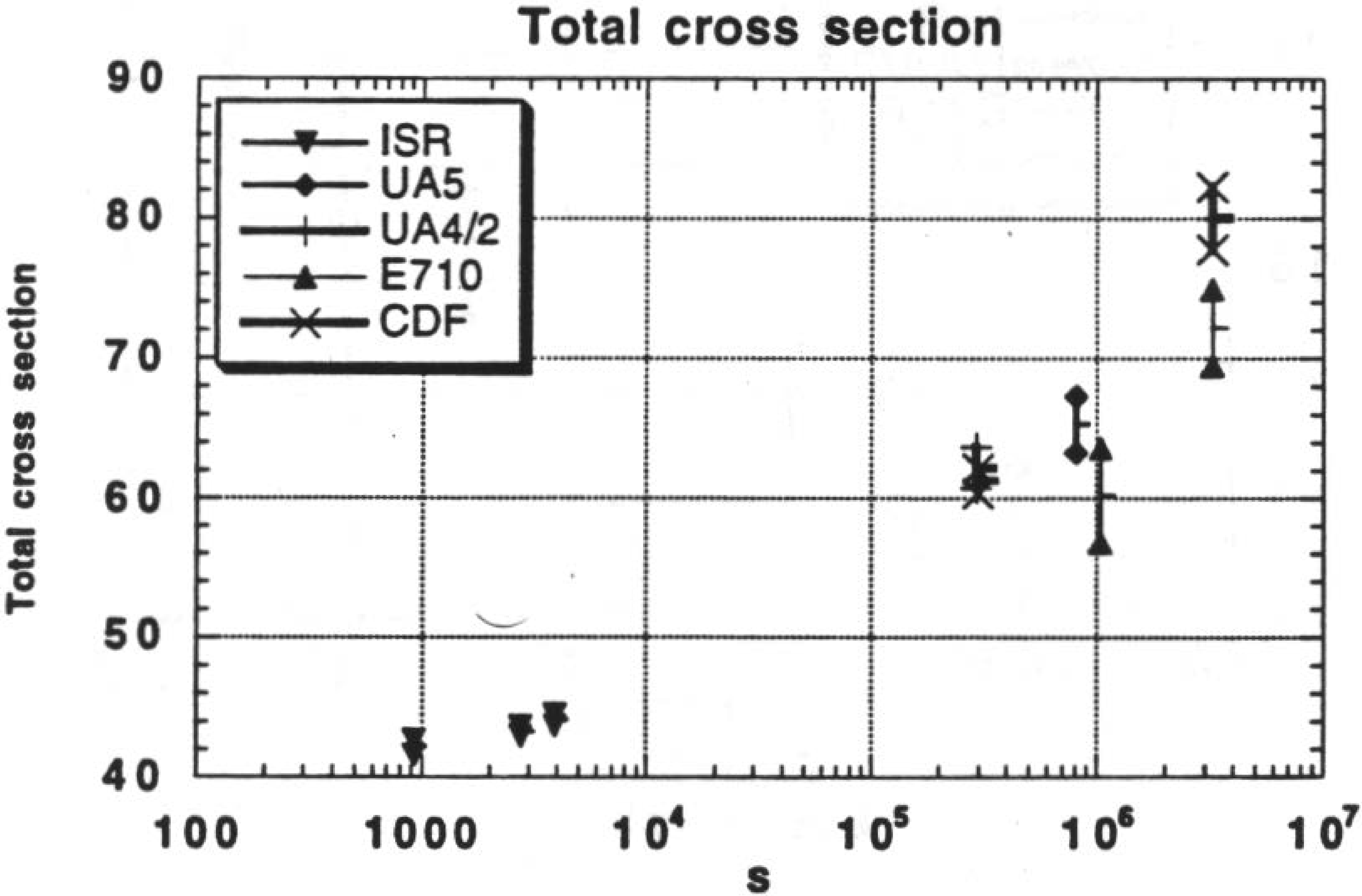

Figure 1

σ_{tot} (mb) vs s (GeV^2)

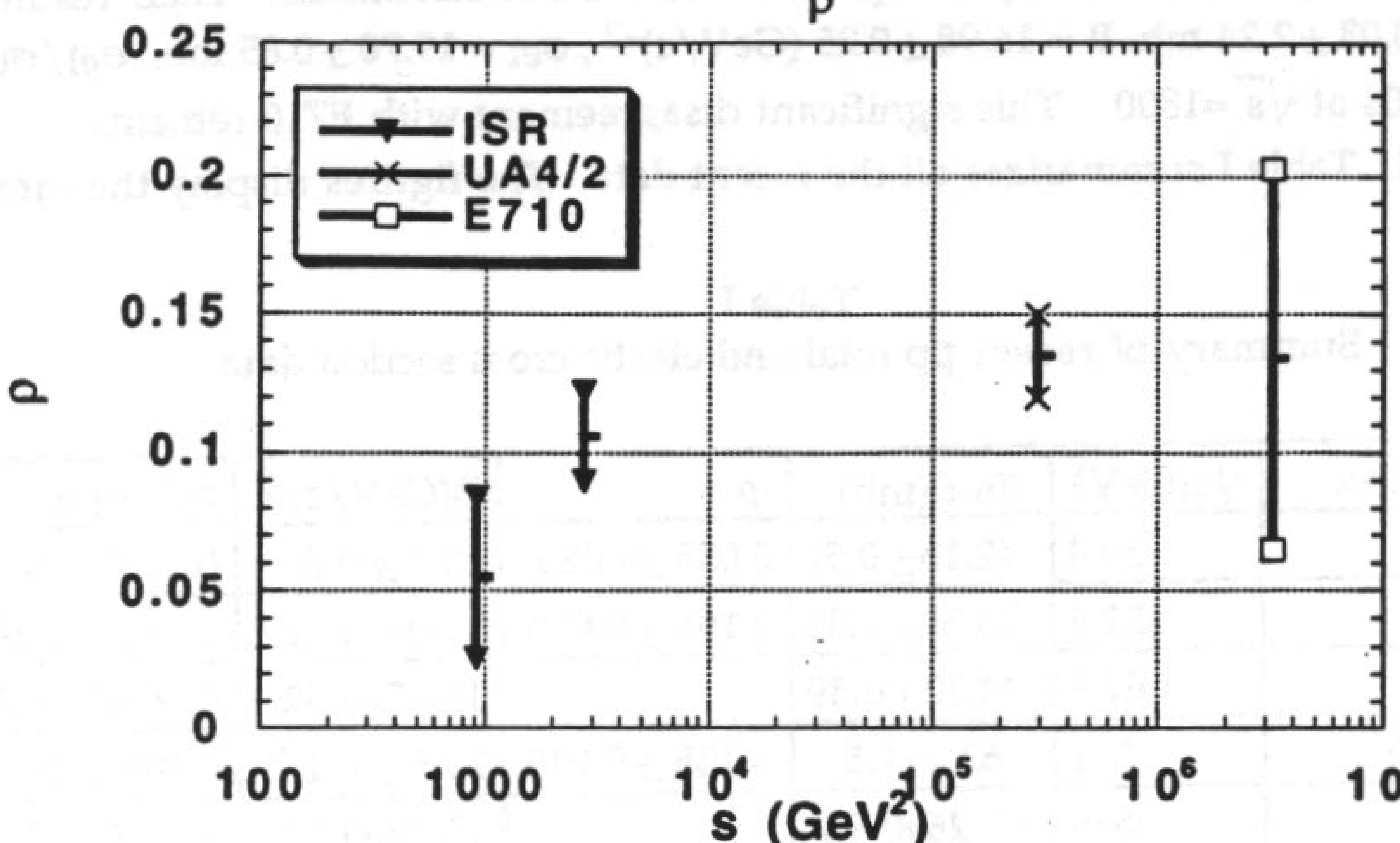

Figure 2

ρ vs s (GeV^2)

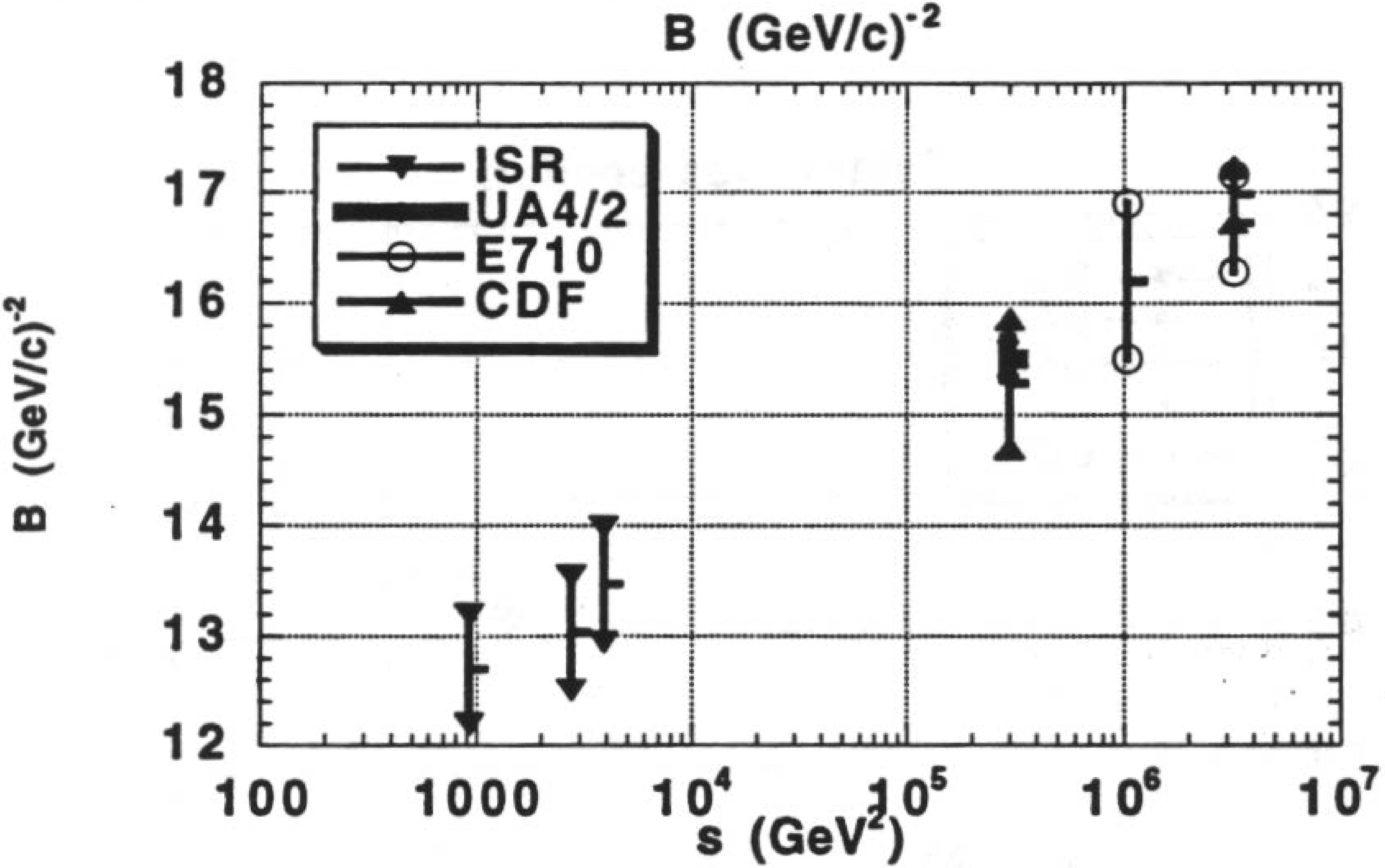

Figure 3
B vs s (GeV^2)

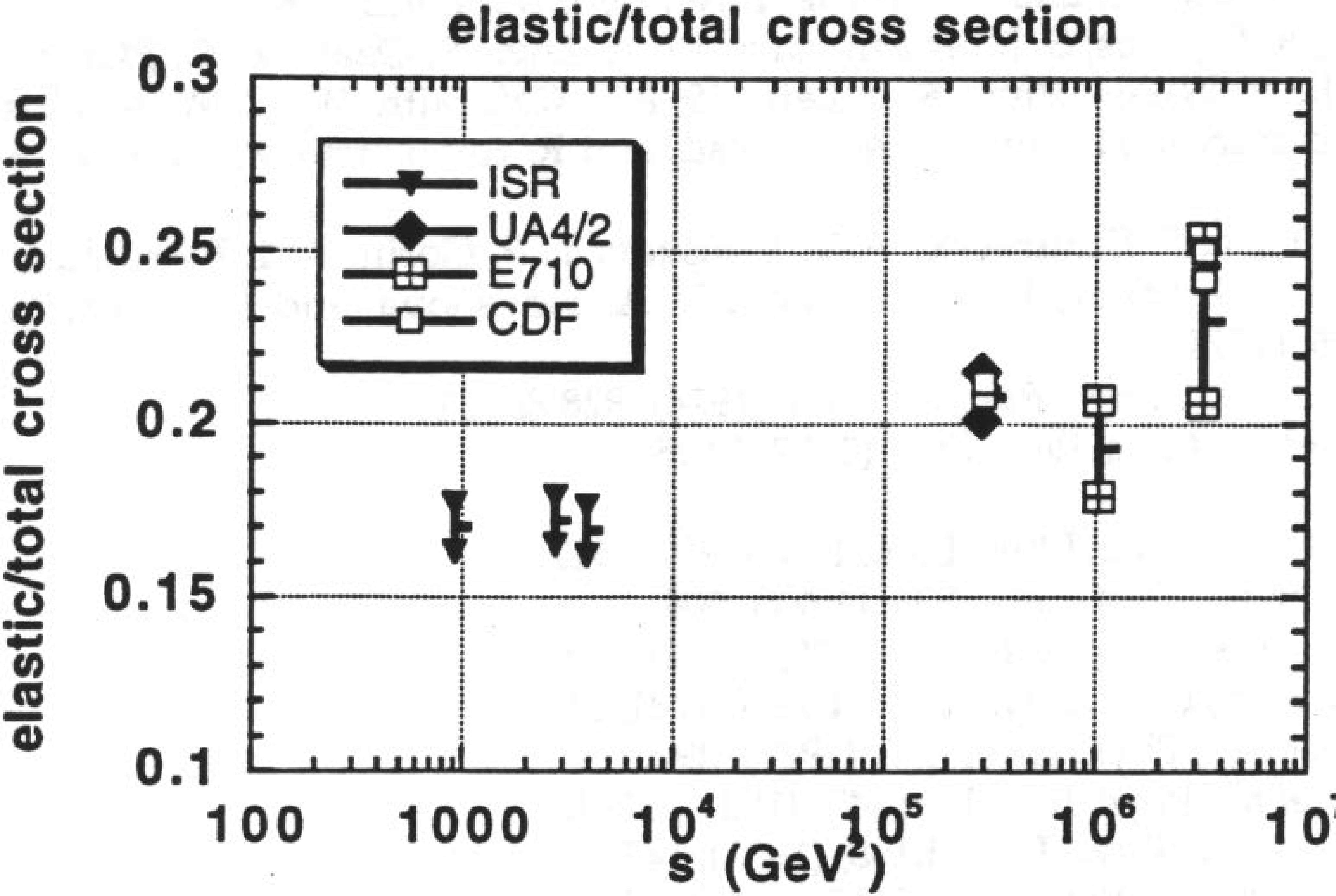

Figure 4

Ratio of elastic to total cross sections vs s (GeV^2)

Table I

Summary of recent $\bar{p}p$ total and elastic cross section data

Collaboration	$\sqrt{s}$(GeV)	σ_{tot} (mb)	ρ	$B(GeV/c)^{-2}$	σ_{el}/σ_{tot}
ISR[15)]	30.4	42.13 ± 0.57	0.055 ±0.029	12.7 ± 0.5	0.17±0.007
	52.6	43.32 ± 0.34	0.106 ± 0.016	13.03±0.52	0.172±0.007
	62.3	44.12 ± 0.39		13.47±0.52	0.169±0.007
UA4[18,21,23)]	541	62.2±1.5	0.135 ±0.015	15.5 ± 0.1	0.208±0.007
CDF[32)]	546	61.26±0.93		15.28±0.58	0.21±0.002
UA5[19)]	900	65.3 ±2.			
E710[31)]	1020	60.2 ±3.4		16.2 ± 0.7	0.193±0.014
CDF[32)]	1800	80.03±2.24		16.98 ± 0.25	0.246±0.004
E710[28,33)]	1800	72.2±2.7	0.14 ± 0.07	16.99 ± 0.47	0.23±0.024