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The Impact of New Collider Data on Fits and Extrapolations of Cross Sections and Slopes[*]

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Abstract

The latest Collider data are compared with our earlier extrapolations. Fits that include the new data are made. Those for which σ_{tot} grows as $\log^2(s/s_0)$ indefinitely give a significantly poorer χ^2 than those for which σ_{tot} eventually levels out. For the proposed SSC energy the former fits predict $\sigma_{tot}(\sqrt{s} = 40 \text{ TeV}) \approx 200$ mb while the latter give $\sigma_{tot}(\sqrt{s} = 40 \text{ TeV}) \approx 100$ mb.

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Several years ago[1,2] we undertook a careful fitting of the pp and $p\bar{p}$ data for σ_{tot} and $\rho = Ref(t=0)/Imf(t=0)$ for energies 5 GeV $\leq \sqrt{s} \leq$ 62 GeV. Among the conclusions of that study were:

1. The data were fitted quite well by simple functional forms incorporating the proper analyticity.
2. The data were consistent with a $\log^2(s/s_0)$ growth of σ_{tot} at high energy.
3. The data were also consistent with a form that grew as $\log^2(s/s_0)$ in the ISR energy region, but asymptotically became constant. This form introduced an extra parameter, but did not give a significantly better χ^2.
4. The data were consistent with the hypothesis that $\sigma_{p\bar{p}} - \sigma_{pp} \propto s^{-\frac{1}{2}}$. Thus impressive limits could be placed on "odderons", odd amplitudes corresponding to Regge trajectories with intercept $\alpha_{odderon} = 1$.

About 90 pieces of data, including σ_{tot} and ρ for both pp and $p\bar{p}$ were used in the fits. No attempts were made to smooth the data. The values and experimental errors were taken directly from the publications.

The even and odd amplitudes used were for $E_{lab} \gg m_p$ (with $f_{pp} = \frac{1}{2}(f_+ - f_-), f_{p\bar{p}} = \frac{1}{2}(f_+ + f_-)$)

$$\frac{4\pi}{p} f_+ = i\left[A + \frac{\beta[\ln s/s_0 - i\pi/2]^2}{1 + a[\ln s/s_0 - i\pi/2]^2} + cs^{\mu-1}e^{i\pi(1-\mu)/2}\right], \tag{1a}$$

$$\frac{4\pi}{p} f_- = -Ds^{\alpha-1}e^{i\pi(1-\alpha)/2}. \tag{1b}$$

where p is the lab momentum and by the optical theorem, $\sigma = (4\pi/p)Imf(t=0)$. The simple fits set $a = 0$, so $\sigma \sim \log^2(s/s_0)$. In conformity with the standard picture of the ρ, ω, f, and A_2 trajectories, μ was set equal to 0.5 when this term was included. The value of α was fitted, with the result $\alpha \approx 0.50$, as expected from the standard picture.

Our original fits were done before the earliest measurements of σ_{tot} at the SPS collider. Those data were not included in the later fits because they had large uncertainties and would not have had any statistical significance in our fits.

We have recalculated our fits using the recently published UA-1[3] and UA-4[4] data. The inputs for our fits were the experimentally measured quantites. For

UA-4 it was $\sigma_{tot}(1+\rho^2) = 63.3 \pm 1.5$ mb.[4] For UA-1 it was $\sigma_{tot}(1+\rho^2)^{1/2} = 67.6 \pm 6.5$ mb.[5] Although the two measurements are consistent, the much smaller error reported by UA-4 makes it dominate the fitting procedure at high energies. The conclusions we draw from our new analysis are[6]

1. For fits with $\sigma_{tot} \propto \log^2(s/s_0)$, adding the UA1 and UA4 points changes the $\chi^2/d.f.$ from about 1.20 to 1.66 if data down to $\sqrt{s} = 5$ GeV are used. The UA-1 point contributes negligibly to χ^2 while the UA-4 point contributes about 20 to χ^2. There is a clear contradiction between the hypothesized form and the UA-4 data point. Similar results are obtained if just the data for $\sqrt{s} > 10$ GeV or $\sqrt{s} > 15$ GeV are used.

2. For fits with σ_{tot} eventually constant ($a \neq 0$), including the UA1 and UA4 data, the $\chi^2/d.f.$ is 1.19, a completely satisfactory agreement between the data and the assumed form. The UA-4 point essentially detemines a and the present value 0.007 ± 0.0015 is completely compatible with our earlier fit value $a = 0.0066 \pm 0.0030$.

In Table 1 are displayed the predictions of two fits, one with $\sigma \sim \log^2(s/s_0)$ ($a = 0$) and the other with $\sigma \sim const.$($a = 0.0072$).

$\sqrt{s}$ (GeV)	540	540	2000	2000
	σ_{tot} (mb)	ρ	σ_{tot} (mb)	ρ
$a = 0$	67.2 ± 0.7	0.134 ± 0.004	91.5 ± 1.5	0.135 ± 0.003
$a = 0.0072$	63.5 ± 1.1	0.116 ± 0.011	74.2 ± 2.8	0.068 ± 0.012

Table 1

Clearly, forthcoming measurements should be able to clarify which fit is better.

Two questions that are often posed when fits to σ_{tot} and ρ are presented are

1. Can't you accommodate the UA4 point just by using $[\log(s/s_0)]^\gamma$ and fitting γ?

2. Doesn't the Amaldi fit still work fine?

We have investigated these two points. The first is easily answered. Withou the UA-4 point we find a good fit (χ^2/d.f. = 1.15) with $\gamma = 2.015 \pm 0.007$. With the UA-4 point the best fit gives $\gamma = 1.999 \pm 0.008$ and χ^2/d.f. = 1.50 which is no satisfactory. The UA-4 point clearly contributes ≈ 17 to the χ^2 for this fit. Clearly just allowing γ to vary is not an adequate remedy.

The refrain "Doesn't the Amaldi fit work?" cannot be discussed without first recalling some details of that fit.[6] The forms used were

$$\sigma = B_1 + B_2(\log s)^\gamma + C_1 E^{-\nu_1} \mp C_1 E^{-\nu_2}$$

where the upper sign is for pp and the lower for $p\bar{p}$. In the second term s is measured in GeV^2, *i.e.* the scale is arbitrarily set as $s_0 = 1$ GeV^2. Since the fit was made in 1976, the ISR data were limited and, in particular, included no $p\bar{p}$ experiments. Indeed no values of $\rho(p\bar{p})$ were used in the fit at any energy. No χ^2 is quoted for the fit.

We have tried a fit of this sort ourselves, using our standard forms, except adopting Amaldi's $(\log s)^\gamma$ (with $s_0 = 1$ GeV^2) term. We have used all our usual data in the fit including the UA1 and UA4 points. The even Regge intercept, μ, is expected to be near 0.5. If we fix it to the 0.5, the resulting fit has χ^2/d.f. = 4.5 which is completely unsatisfactory. If we allow μ to vary, the best fit occurs for μ = 0.81 and $\gamma = 1.999$. The χ^2/d.f. is then 1.26. Although the χ^2/d.f. is reasonable, we reject this fit since the value of μ is far from the 0.5 expected from Regge analysis.

We see that the $pp/p\bar{p}$ total cross sections and ρ value remain interesting topics for investigation and may still hold some surprises.

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