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CROSS SECTION ESTIMATES FOR MULTI-TEV PHYSICS

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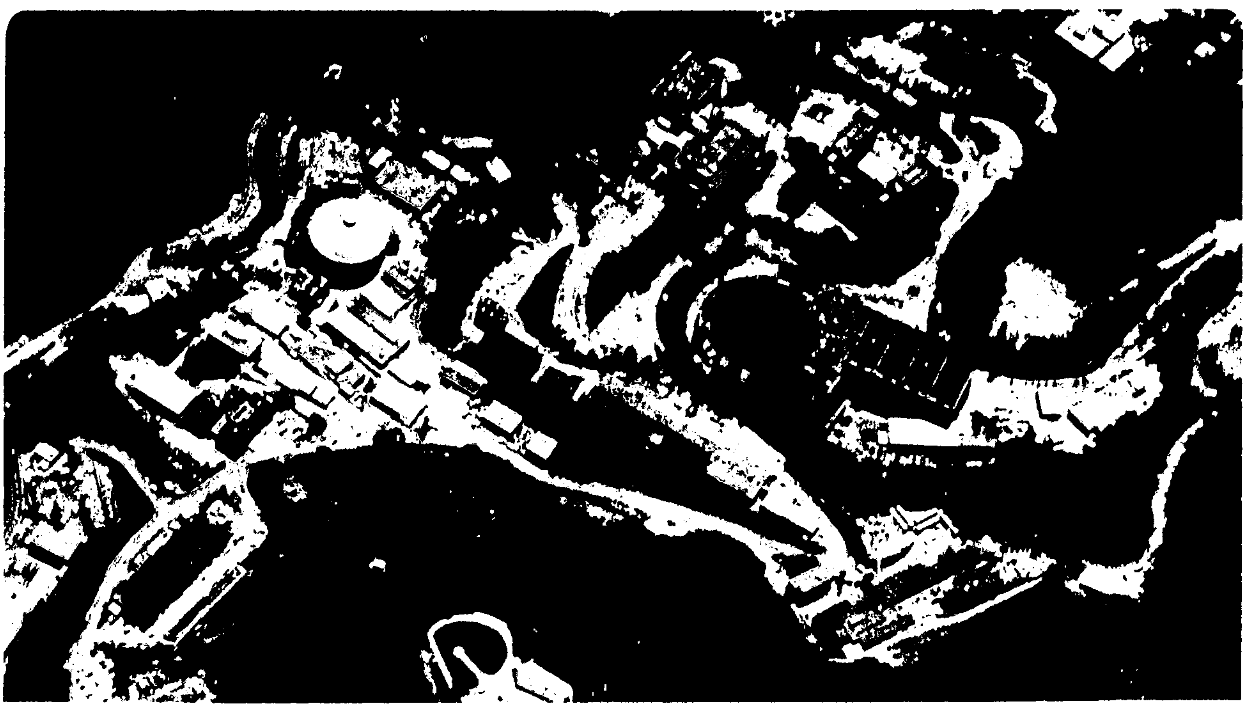

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Summary

This note provides rough estimates for cross sections of interest in the multi-TeV regime.

Introduction

In designing detectors for the multi-TeV region, it is worthwhile to consider what cross sections might be anticipated on the basis of present experience and theoretical prejudice. Such projections must be treated with a good deal of skepticism since they require very large extrapolations from the ISR-FNAL energy range or slightly lesser extrapolations from the fragmentary SPS Collider data. Even worse, some predictions are founded nearly entirely on theoretical pictures which have not been extensively tested. Nevertheless, this is the best we can do. Depending on the process, the uncertainties may be as little as a factor of two, or as much as an order of magnitude or two.

It should be emphasized that the projections given here are not only very approximate, but furthermore do not represent what is most likely to be interesting at these very high energies. After all, we want to look for new phenomena, not just the standard catalogue of jets, dileptons, and the like. Nevertheless, these mundane items do furnish us with benchmarks, standards for the cross sections which are potentially interesting and perhaps examples of signatures which could help identify truly new physics.

These estimates are based on my SLAC Summer School Lectures of 1982 to which the reader is directed for more complete discussion and references.[1]

Total Cross Section

Ever since the rise the in pp cross section was first discovered at the ISR, it has been popular to interpret the data as saturating the Froissart bound form, $\ln^2 s$. Such a fit is indeed possible and is not inconsistent with the measurement at the SPS Collider of about 65 mb.[2] Still, it is possible to produce a fit with all the required analyticity which while giving a $\ln^2 s$ behavior at present energies, eventually becomes constant.[3] These two kinds of fits give very different predictions at $\sqrt{s} = 20-40\,\text{TeV}$. Calling the pure $\ln^2 s$ fit #1 and the one which becomes constant asymptotically #2, we have

$\sqrt{s}$	Fit #1	Fit #2
0.54 TeV	71 mb	66 mb
2 TeV	100 mb	82 mb
20 TeV	173 mb	107 mb
40 TeV	200 mb	114 mb

It is worth noting that even for the total cross section where we have excellent low energy data and the theoretical constraints of analyticity, when we extrapolate to the 40 TeV region, there are uncertainties of 100%. Similar extrapolations [4] for the slope parameter of elastic scattering, B, suggest that its value which is about 13 GeV^{-2} at the ISR will be about twice that at $\sqrt{s} = 20\,\text{TeV}$.

Lepton Pair Production

Lepton pair production has been a tremendously important process because it has led to the discovery of the J/ψ and the Υ and because the continuum production is an especially important process theoretically. Using a crude model for the quark distributions, it is possible to obtain a simple estimate[1] for the cross section to produce a dilepton pair with an invariant mass $m_{\mu\bar{\mu}} = \sqrt{\tau s}$:

$$\sigma(m_{\mu\bar{\mu}} > \sqrt{\tau_0 s}) \approx 10^{-37}\text{cm}^2\left(\frac{540\text{GeV}}{m_{\mu\bar{\mu}}}\right)^2 2^{-20\sqrt{\tau_0}}.$$

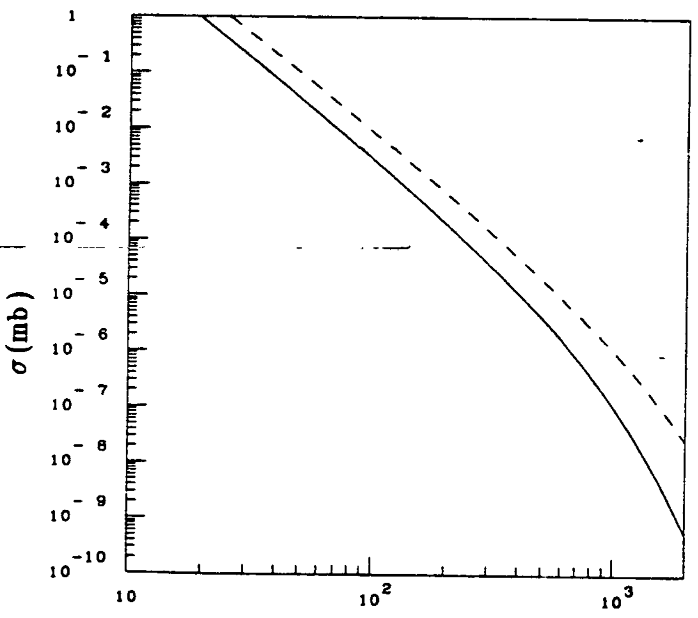
We see that the last factor is nearly unity at 20 TeV for reasonable cross sections, so the behavior is nearly as $m_{\mu\bar{\mu}}^{-2}$. The cross section to produce a pair with mass greater than 180 GeV is about 10^{-36}cm^2.

W and Z Production

If past history is a guide, W and Z production will be an important background for something interesting. Their masses are small enough compared to the available energy at multi-TeV machines that there is little energy dependence in their production cross sections. Using quark distributions appropriate to the SPS Collider without modifications for possible non-scaling effects, we find that the cross sections should be roughly $5 \cdot 10^{-33}\mathrm{cm}^2$ for each species in either pp or $p\bar{p}$ machines.

High Transverse Momentum Jets

The early data from the SPS Collider indicate that high transverse momentum jets do become prominent, well-defined features at such energies in contradistinction to the situation at ISR energies where jets are often obscured by fluctuations in the non-jet events. QCD predicts cross sections for these processes but with great uncertainties. The uncertainties arise from two sources: the quark distributions and radiative QCD corrections to the basic partonic cross sections. To get a crude idea of the cross sections, we finesse these problems by ignoring them: we use scaling distributions for the quarks and lowest order calculations for the cross sections.



Typical results are shown in the Figure. The curves show the cross section to produce a jet with transverse momentum greater than a given amount, considering only the subprocess gluon + gluon → gluon + gluon. The solid curve is for $\sqrt{s} = 20\mathrm{TeV}$ and the dashed curve is for $\sqrt{s} = 40$ TeV.

Heavy Flavor Production

Heavy flavor production has been considered by Combridge in a QCD model.[5] If we restrict ourselves to the two mechanisms gluon+gluon → $Q\,\overline{Q}$ and $q\bar{q} \rightarrow Q\overline{Q}$, it is clear on dimensional grounds that the production cross section must go as α_s^2/M^2 where M is the heavy quark mass. There may in addition be a factor representing the suppression for making the quarks at finite s. At the multi-Tev machines, this suppression is not important for $M < \sqrt{s}/100$, so we expect a cross section nearly equal to the naive estimate above. At more detailed analysis suggests that the numerical factor which multiplies the dimensional quantity is about 5. For $M = 40\,\mathrm{GeV}$, this gives a cross section of about $5 \cdot 10^{-32}\mathrm{cm}^2$.

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