EVENT RATES TO BE EXPECTED AT PEP

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ABSTRACT: As a guide for planning experiments at PEP, some estimates are given of average luminosity, charged and neutral particle yields vs. momentum, QED test capabilities, and weak interaction effects.

I. Introduction

In this note I will summarize what might be expected for the yields in experiments at PEP based on the SPEAR results. In these estimates I will use an average luminosity for PEP of

$$\langle \mathcal{L} \rangle = \frac{\mathcal{L}_{pk}}{4} \quad . \qquad (1)$$

The derating factor of 4 is based on SPEAR experience and includes time lost for breakdowns of the ring, breakdowns of the linac injector, decay of the beams during a fill of the ring, and access time requested by the experimenters. In the last few running cycles of SPEAR, the derating factor has been about 3 rather than 4, but since the larger number of experiments to be run at PEP may require more experimenter access time, I will use the factor of 4.

The peak design luminosity of PEP is $10^{32} cm^{-2} sec^{-1}$. I think that this is a conservative number; for using the assumptions that have gone into the design of PEP, SPEAR and ACO are operating at their design luminosity and ADONE is operating above its design luminosity. I will therefore in what follows use an effective luminosity averaged over an experiment of

$$\langle \mathcal{L} \rangle = 2.5 \times 10^{31} cm^{-2} sec^{-1} \ .$$

II. Hadron Yields

a. Charged Particle Momentum Spectrum

Figure 1 shows the SPEAR charged particle data for $s \frac{d\sigma}{dx}$ vs. x at 3 values of $s^{1/2}$. In the long extrapolation required to get from $s^{1/2} = 4.8$ to $s^{1/2} = 30$, I have assumed that Bjorken scaling holds for $x \gtrsim 1/2$ and that below $x = 1/2$ the data will tend to the asyptotic limit shown on Figure 1. These assumptions lead to a cross section given by

$$s \frac{d\sigma}{dx} = \begin{cases} 30 \exp(-x/0.135), & x < 0.5 \\ 4.1 \, (1-x)^{2.5}, & x \geq 0.5 \end{cases} \quad (\mu b \; GeV^2). \qquad (2)$$

Equation 2 can be integrated to give

$$\int s \frac{d\sigma}{dx} dx = s \langle n \rangle_{ch} \sigma_{had} = 4.05 \ (x < 0.5) + 0.100 \ (x \geq 0.5) \ \mu b \ GeV^2. \quad (3)$$

Figure 2 shows the SPEAR invariant cross section vs. momentum. The assumption that the invariant cross section remains independent of energy, s, leads to a total cross section x multiplicity which remains constant with s and is very much larger than that given by equation 3 at PEP energies. In estimating hadron yields at PEP, I have taken the prudent course of using Equations (2) and (3).

The table below gives the expected total yield of charged hadrons as a function of x in an x bin 0.1 wide for a 30-day data run. The rates for low x are very large and should permit the use of relatively small solid angle detection (a few percent of 4π) up to hadron momenta of about 4 GeV/c. From 4 to about 12 GeV/c devices having solid angles of 10 to 20% of 4π will be required, while for momenta above 12 GeV/c very large detectors (1/2 of 4π) or more running time will be required.

x	p (GeV/c)	$s \frac{d\sigma}{dx}$ (μb GeV^2)	y/30 days ($\Delta x = \pm 0.05$)
0.1	1.5	14.3	1×10^5
0.2	3	6.8	4.9×10^4
0.3	4.5	3.3	2.3×10^4
0.4	6	1.6	1.1×10^4
0.5	7.5	0.72	5.2×10^3
0.6	9	0.41	3.0×10^3
0.7	10.5	0.20	1.4×10^2
0.8	12	0.073	5.3×10^2
0.9	13.5	0.013	9.4×10^1

b. Neutral Particle Momentum Spectrum

The yield of neutral particles is expected to be of the order of 1/2 to 1 times the charged particle yield. If all these particles were π^0, the ratio of γ yield to charged particle yield would be about

$$\frac{(d\sigma/dx)_\gamma}{(d\sigma/dx)_{chg}} \geq \frac{1-x}{2}, \qquad \text{for} \quad x > 1/2 \; . \tag{4}$$

Large solid angle devices will be needed above p_γ = 10 GeV/c.

c. Total Cross Section

Equation (3) can give the total cross section for events with any number of charged particles in them if we assume a mean charged multiplicity. If we assume $\langle n_{ch} \rangle$ varies as ln S (faster than is seen at SPEAR), the total yield of hadronic events is, assuming $\langle n_{ch} \rangle = 7.5$,

$$Y_{Had} \approx 1200/\text{day} \; . \tag{5}$$

This rate is roughly independent of machine energy since the assumed cross section is proportional to s^{-1} and the design luminosity is proportional to s.

d. Weak Interaction Effects.

Berman in his talk during the first week of this study estimated that weak interaction effects in hadronic final states might give rise to asymmetries of 5 to 20%. We have no way of guessing at what hadron momentum these asymmetries will show up, but if we assume they will not be washed out above p_{Had} = 2 GeV/c, an asymmetry of 5% would give a 15 standard deviation effect in a 30 day run using the cross section of Eq. (2). If the weak effects only show up at $x > 1/2$, we would get a 5 standard deviation effect in a 30 day run. Of course the electromagnetic contribution of σ_{TOT} may be very much larger than estimated in Eq. (2) (Eq. (2) together with a $\langle n \rangle_{ch} \propto \ln s$ implies $\sigma_{had}/\sigma_{\mu\mu} \approx 6$ at s = 900) in which case weak effects might be harder to see, but hadron physics will be more fun.

III. Leptonic Final States

a. QED Tests

The μ-pair rate into 4π sr at $s = 900$ with the assumed luminosity is about 200 per day. The limitation on the accuracy of an experiment to probe the limits of QED will probably be the accuracy of the radiative corrections and systematic errors in the apparatus and in normalization rather than statistics. For example, an apparatus which covers the polar angle range from 45° to 135° will get about 4000 μ-pairs in 30 days of data taking. While the statistical accuracy is better than 2%, the radiative correction calculation as presently done are probably only good to 1-2%.

If we assume that we can do no better than 4% accuracy, we could set a limit on a cutoff in the photon propagation of

$$\Lambda \gtrsim 150 \text{ GeV (95\% conf)} . \qquad (6)$$

b. Weak Effects in the Muon Final State

Here, I will only repeat the results of Strauch's analysis. He assumed 8000 total muons produced and analyzed the asymmetry expected in the Weinberg model. With the expected luminosity, it takes 40 days to accumulate 8000 produced muons. Comparing the polar angle interval from 20° - 70° with that from 110° to 160° yields a 5 standard deviation asymmetry from the interference of the weak axial vector with the electromagnetic interaction.

There is also an effect on the total μ-pair rate from the interference of the weak vector with the electromagnetic interaction. This is significant for $g_V \approx g_A$, but in the Weinberg model is much smaller (the effective value of $g_V = 0$ for $\sin^2\theta_W = 1/4$).

c. New Leptons

Sulak has reported on rates for new types of lepton production. With the exception of magnetic monopoles, the rates are all comparable to μ-pair production and the experiments are not rate limited. Magnetic monopole production has in first order, a cross section of

$$\sigma_{MM} = \frac{1}{4\alpha} \sigma_{\mu\mu} , \qquad (7)$$

a huge number.

IV. Conclusion

The rates for most experiments seem sufficiently large so that 30-60 days of data taking appears adequate. Thirty days seems to me to be an appropriate quantum of data time when one considers that "debugging" a large piece of experimental apparatus will itself usually require ≥ 30 days of beam time. If the experiments we now consider as being the most subtle require much more time than the minimum quantum, we should be neither surprised nor worried. If they are indeed the most important experiments, they deserve more time, and if experience is any guide, they will not turn out to be the most important after all.

With PEP's 5 interaction regions, assuming 8 months per year of operation (SLAC is now running 7 mo/yr), and assuming 1.5 experiments running simultaneously in each region, I calculate a total of 60 experimental quanta per year. If I stretched the average experiment to 4 quanta for debugging, data taking and incompatibilities with other experiments, I get an output of 15 experiments per year. The problem would seem to me to be finding the experimenters rather than the running time. There would seem to be plenty of opportunities for any group wanting to take part in PEP physics.

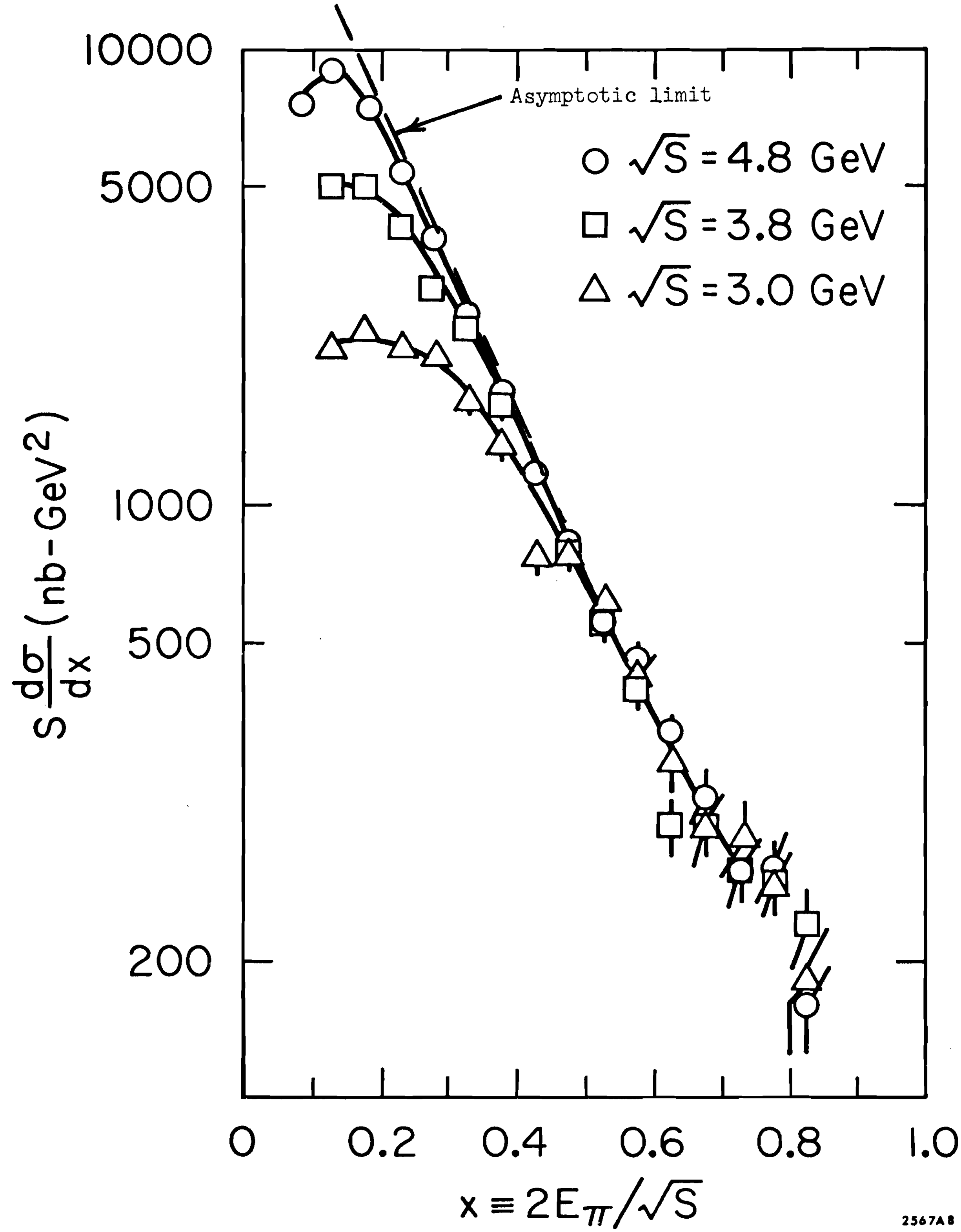
10000
5000
1000
500
200
Asymptotic limit
○ √S = 4.8 GeV
□ √S = 3.8 GeV
△ √S = 3.0 GeV
S dσ/dx (nb-GeV²)
0
0.2
0.4
0.6
0.8
1.0
x ≡ 2Eπ/√S
2567A8

Fig. 1

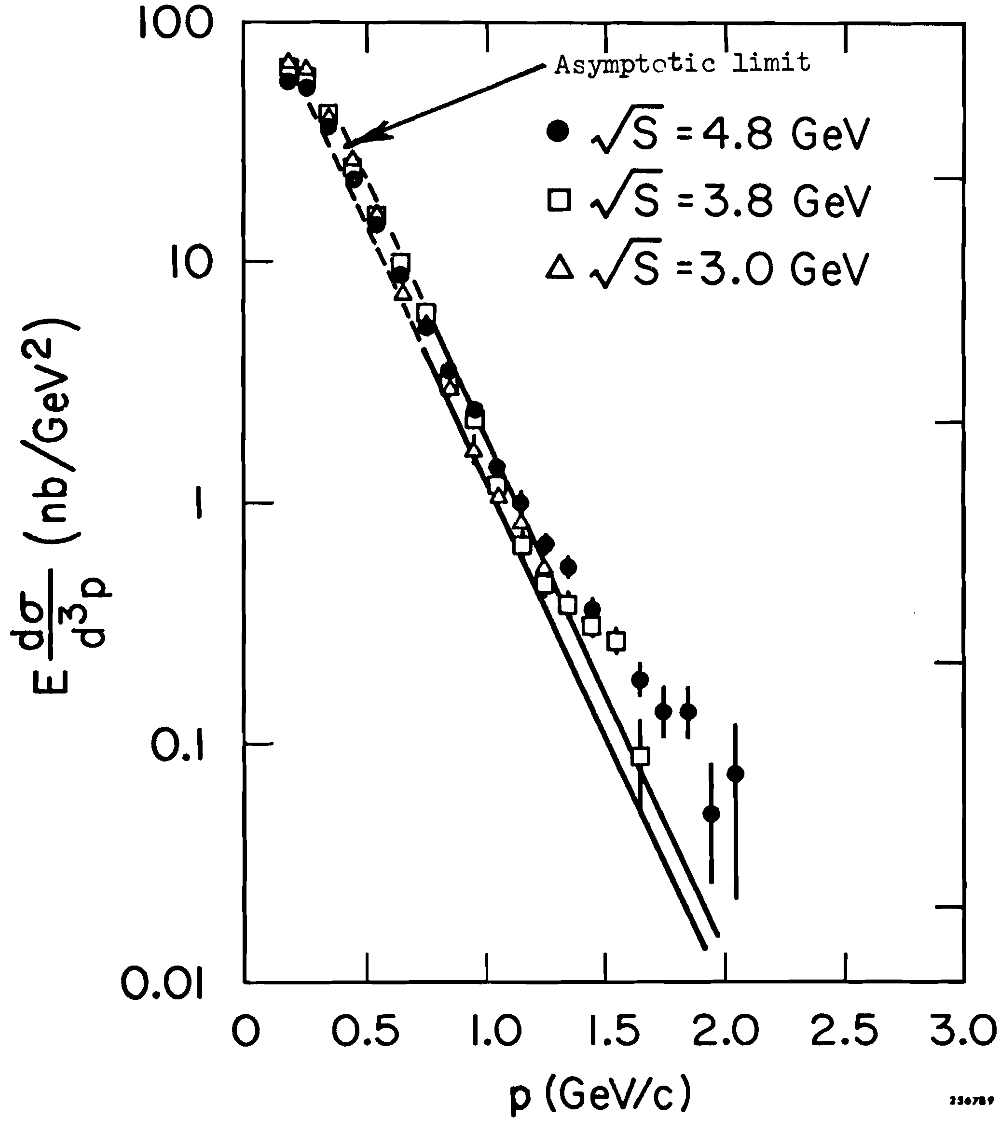
100
10
1
0.1
0.01
Asymptotic limit
● $\sqrt{S}$ = 4.8 GeV
□ $\sqrt{S}$ = 3.8 GeV
△ $\sqrt{S}$ = 3.0 GeV
$E\frac{d\sigma}{d^3p}$ (nb/GeV^2)
0
0.5
1.0
1.5
2.0
2.5
3.0
p (GeV/c)

Fig. 2