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ESOTERIC PARTICLE PRODUCTION AT ISR

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Notions about scaling and recent measurements of lepton pairs emitted in proton-nuclear collisions permit estimates to be made of the production of a variety of interesting objects at the ISR. These are all states coupled to the hadrons via virtual photons or (through CVC) virtual weak bosons. The argument is:

1. The yield of lepton pairs in the reaction:

$$p + p \rightarrow \ell^+ + \ell^- + \text{anything} \tag{1}$$

can be written as:

$$\frac{d\sigma}{dm_{\ell\bar{\ell}}} = \frac{1}{m_{\ell\bar{\ell}}^3} F(m_{\ell\bar{\ell}}, s) \tag{2}$$

where $s = (\text{energy})^2$ available in the CM and obviously F is dimensionless.

$m_{\ell\bar{\ell}}$ = effective mass of dilepton .

2. In the limit that $m_{\ell\bar{\ell}} \rightarrow \infty$, $s \rightarrow \infty$, we may set the mass of muon, electron, proton = 0 in which case:

$$F = F(m_{\ell\bar{\ell}}^{\,2}/s) \tag{3}$$

in order for F to be dimensionless. Deviations from this simple, dimensional argument would either signify the existence of a new scale in nature or reveal deep generalizations about the hadronic electromagnetic interaction.

3. Although the $m_{\ell\bar{\ell}}$ and s values observed in the

Brookhaven experiment[1] hardly satisfy the requirements,

$1 \leqslant m_{\ell\bar{\ell}} \leqslant 6$ GeV $s \cong 55$ GeV^2 ,

we assume that $F(m^2/s)$ scales down to BNL energies. This assumption was encouraged by the observation of scaling at SLAC in a similar range of parameters.

4. Given the above, the BNL data is fairly well fitted by the equation

$$\frac{d\sigma}{dm_{\ell\bar{\ell}}} = \frac{\alpha^2}{m_{\ell\bar{\ell}}^3} e^{-10m_{\ell\bar{\ell}}^2/s} \qquad (4)$$

where $\alpha^2 = (1/137)^2 = 2 \times 10^{-32}$ cm^2/GeV.

Figure 1 shows the fit of (4) to the data. Alternative fits in the region of Q^2/s from 0.03 to 0.5 are also given. We have also calculated the cross section as predicted by the proton annihilation theory of Drell and Yan, where the structure function is directly related to νW_2 as observed at SLAC and the single adjustable parameter, which enters the theory as λ^{-2}, is set equal to 1.

By noting that $m_{\ell\bar{\ell}}^2 = Q^2$, the 4-momentum of the virtual photon, we can connect (1) to a variety of other processes and make these applicable to ISR by setting $s = (E_1+E_2)^2$ where E_1 and E_2 are the energies of the protons stored in ring 1 and ring 2:

A. Electron pair production via standard q.e.d.

$$\frac{d\sigma}{dm_{e\bar{e}}} = \frac{2\times10^{-32}}{m_{e\bar{e}}^3} e^{-10m_{e\bar{e}}^2/s} \qquad (5)$$

B. Production of Lee-Wick heavy photon pole at mass m_B.

$$\sigma_B = \frac{3\pi}{2\alpha} m_B \left(\frac{d\sigma}{dm_{e\bar{e}}}\right)_{m_B} \qquad (6)$$

$$\sigma_B = 1.3 \times 10^{-29}\left(\frac{1}{m_B}\right) e^{-10 m_B^2/s} \text{ cm}^2$$

C. Production of massive heavy lepton pairs L^+L^- with mass m_L

$$\sigma_{L^+L^-} = \int_{2m_L}^{\sqrt{s}-2m_L} \sqrt{1-\frac{4m_L^2}{m^2}} \left(1+\frac{2m_L^2}{m^2}\right) \left(\frac{d\sigma}{dm_{ee}}\right)_m dm \qquad (7)$$

D. Production of Quark pairs.

$$\sigma_{Q^+Q^-} = \left(\frac{e_Q}{e}\right)^2 \sigma_{L^+L^-} \quad (m_L = m_Q) \qquad (8)$$

Of course, other mechanisms may play a role in quark production but this one is calculable.

E. Production of Pairs of Magnetic Monopoles.

$$\sigma_{M\bar{M}} = \frac{eq}{\alpha^2} \sigma_{L^+L^-} \quad (m_M = M_L) \qquad (9)$$

$$\cong 10^4 \sigma_{L^+L^-}$$

(D & E yields may well be influenced by strong recombination effects and the produced particles may also not be coupled to photons in a pointlike manner.)

F. Weak Interactions: $p + p \rightarrow e^+ + \nu_e$ + anything

The similarity of this reaction to reaction (1) as embodied in the CVC hypothesis permits us to write:

$$\frac{d\sigma}{dm_{e\nu}} = \frac{d\sigma}{dm_{e\bar{e}}} \cdot \frac{G^2}{(4\pi\alpha)^2} m_{e\bar{e}}^4 K \qquad (10)$$

where MeV is the effective mass of the electron-neutrino pair and K is the ratio of the hadronic weak to the hadronic electromagnetic matrix elements. K is of the order unity especially if the weak axial form factor is neglected.

Thus:

$$\frac{d\sigma}{dm_{e\nu}} = K \cdot m_{ee} \left(\frac{G}{4\pi}\right)^2 F\left(\frac{m_{e\bar{e}}^2}{s}\right) \tag{11}$$

At the upper limit of ISR energies this combination is totally unobservable.

However, there are two, more encouraging possibilities:

1. First order interference between a virtual neutral W and the electromagnetic current (both couple to e^+e^- pairs):

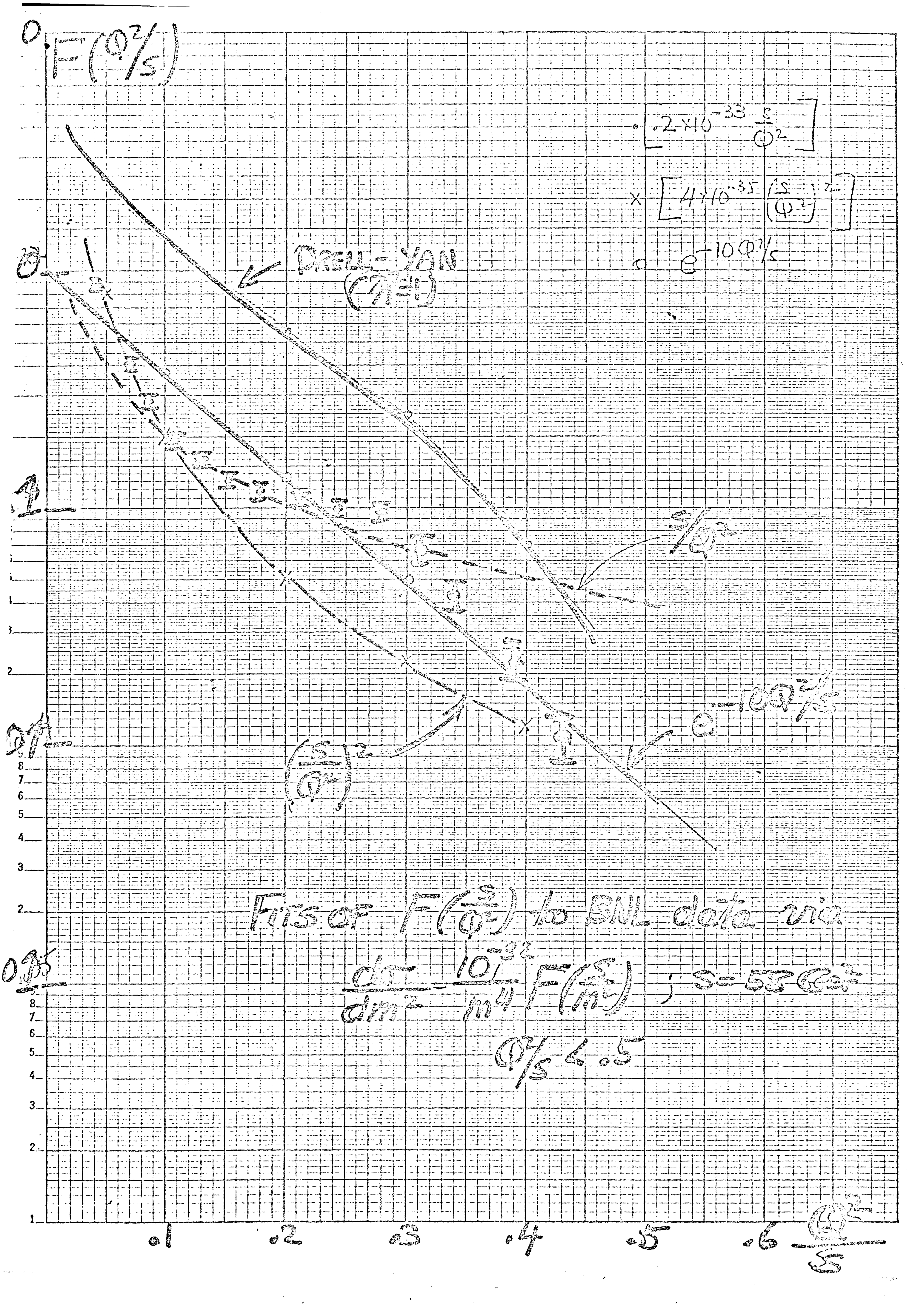
$$\frac{d\sigma}{dm_{e\bar{e}}} (obs) = \frac{d\sigma}{dm_{e\bar{e}}} (qed)\left[1 + \frac{G}{2\pi\alpha} m_{e\bar{e}}^2\right] \tag{12}$$

The weak cross term is of the order of 10% at $m_{e\bar{e}}$ = 22 GeV assuming this universal coupling. It could manifest itself via parity violation $(\vec{p}_{e^+} \times \vec{p}_{e^-} \cdot \vec{p}_{proton})$ or c-violating charge asymmetry.

2. A real $W^{\pm}$ exists within the mass domain of ISR. Then the cross section (12) must be integrated over the W width with a well known result:

$$\begin{aligned} \sigma_W &= \frac{3}{8\sqrt{2}} G\, F\left(\frac{M_W^2}{s}\right) K \\ &= 1.2 \times 10^{-33} K\, F\left(\frac{M_W^2}{s}\right) \\ &= 1.2 \times 10^{-33} K\, e^{-\frac{10 M_W^2}{s}} \end{aligned} \tag{13}$$

A neutral W of this magnitude would dominate the pairs at $M = M_W$ whereas a charged W gives more e^+ than e^- but, of course, requires successful "single particle" identification of beam-beam collisions.



F(Q²/s)
.2×10⁻³³ s/Q²
4×10⁻³⁵ (s/Q²)²
e^(−10Q²/s)
DRELL-YAN
s/Q²
(s/Q²)²
e^(−10Q²/s)
Fits of F(s/Q²) to BNL data via
dσ/dm² = 10⁻³²/m⁴ F(s/m²) ; s = 58 GeV²
Q²/s < .5
.1
.2
.3
.4
.5
.6
Q²/s

MODEL ISR : S = 2500 DATE Fig 2