1 Flavour separation

When both the electron and the positron beams are transversely polarized, a separation in space of quarks of different flavours f (u-type vs. d-type) is possible [1]. This effect comes about since the annihilation cross section has an azimuthal dependence (w.r.t. the beam polarization) which is flavour dependent.

Ignoring here the forward-backward asymmetry (since we shall integrate over a forward-backward symmetric interval in $\cos\theta$), the electroweak annihilation cross section takes the form

$$\frac{d^2\sigma_f}{d\cos\theta\, d\phi} = \frac{3}{4}\frac{\alpha^2}{s}\Big[h_f^{(1)}(s)(1+\cos^2\theta) + h_f^{(3)}(s) P_+^\perp P_-^\perp \sin^2\theta \cos(2\phi - \phi_+ - \phi_-)\Big], \tag{1}$$

with θ and ϕ polar and azimuthal angles of the quark momentum. The energy- and flavour-dependent functions $h_f^{(1)}(s)$ and $h_f^{(3)}(s)$ are given by

$$\begin{aligned} h_f^{(1)}(s) &= Q_f^2 - 2Q_f\, v\, v_f \mathrm{Re}\chi(s) + (v^2+a^2)(v_f^2+a_f^2)|\chi(s)|^2, \\ h_f^{(3)}(s) &= Q_f^2 - 2Q_f\, v\, v_f \mathrm{Re}\chi(s) + (v^2-a^2)(v_f^2+a_f^2)|\chi(s)|^2, \end{aligned} \tag{2}$$

with

$$\chi(s) = \frac{1}{4\sin^2 2\theta_{\mathrm{W}}}\frac{s}{s - M_Z^2 + iM_Z\Gamma_Z}, \tag{3}$$

and M_Z and Γ_Z the mass and width of the Z. Furthermore, Q_f is the quark charge, and the electroweak coupling constants are normalized as

$$\begin{array}{llll} e^-: & v = -1 + 4\sin^2 2\theta_{\mathrm{W}}, & a = 1, & \\ u: & v_u = 1 - \frac{8}{3}\sin^2 2\theta_{\mathrm{W}}, & a_u = 1, & Q_u = \frac{2}{3} \\ d: & v_d = -1 + \frac{4}{3}\sin^2 2\theta_{\mathrm{W}}, & a_d = -1, & Q_d = -\frac{1}{3}. \end{array} \tag{4}$$

The effect of flavour separation is thus related to the fact that the ratio $h_f^{(3)}(s)/h_f^{(1)}(s)$ depends on the flavour f. The effect is maximum for polar angle $\theta = \pi/2$. If one integrates over some range in polar angle, centered around $\theta = \pi/2$, one finds

$$\begin{aligned} \frac{d\sigma_f(\theta_0,\phi)}{d\phi} &= \int_{-\cos\theta_0}^{\cos\theta_0} \frac{d^2\sigma_f}{d\cos\theta\, d\phi}\, d\cos\theta \\ &= \frac{3\alpha^2}{2s}\cos\theta_0(1+\tfrac{1}{3}\cos^2\theta_0)\Big[h_f^{(1)}(s) + h_f^{(3)}(s)\xi\cos(2\phi-\phi_+-\phi_-)\Big], \end{aligned} \tag{5}$$

with

$$\xi = P_+^\perp P_-^\perp \frac{1-\frac{1}{3}\cos^2\theta_0}{1+\frac{1}{3}\cos^2\theta_0}. \tag{6}$$

Flavour separation is then achieved in the sense that the ratio

$$R_{u/d}(\phi) = \frac{d\sigma_u(\theta_0,\phi)}{d\sigma_d(\theta_0,\phi)} = \frac{h_u^{(1)}(s) + h_u^{(3)}(s)\xi\cos(2\phi-\phi_+-\phi_-)}{h_d^{(1)}(s) + h_d^{(3)}(s)\xi\cos(2\phi-\phi_+-\phi_-)} \tag{7}$$

becomes ϕ-dependent. This ratio is shown in Fig. 1, for $\cos\theta_0 = 0.5$ (integrated over $\pi/3 \leq \theta \leq 2\pi/3$) and for degrees of transverse polarization 1.0 and 0.8. Mass effects tend to make the distribution more isotropic, and thus reduce the degree of separation [1].

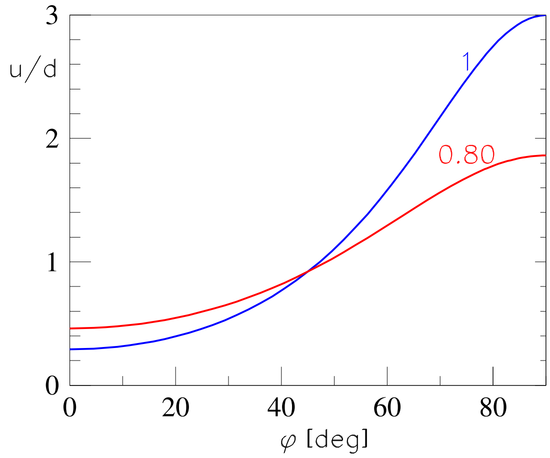

Figure 1: Flavour separation at $\sqrt{s} = 0.5$ TeV: u/d vs azimuthal angle, for the range $\pi/3 \leq \theta \leq 2\pi/3$, and for transverse degrees of polarization 1 and 0.80, as indicated.

References

[1] H. A. Olsen, P. Osland and I. Øverbø, Phys. Lett. B **97** (1980) 286.