寻迹 (Tracking)

通过磁场测量 p_T

$$p_T = qB\rho \qquad \Rightarrow \qquad p_T\,[\mathrm{GeV}/c] = 0.3B\rho\,[\mathrm{T\,m}]$$

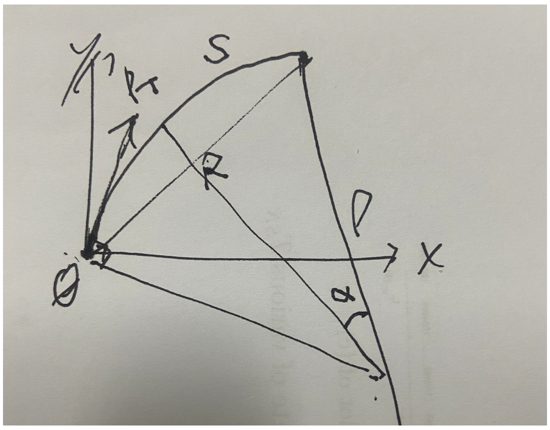
设圆筒外径 $R_m = 1.8\,\mathrm{m}$, 半长 $z_m = 2.9\,\mathrm{m}$, 磁场 $B = 3\,\mathrm{T}$, 则打到外筒的最小横动量 $p_{Tc} = 0.81\,\mathrm{GeV}/c$, 外筒边沿的极角 $\theta_m = \tan^{-1}(R_m/z_m) = 31.8°$

动量的测量精度 取决于 p_T 和极角 θ 的精度

$$p = \frac{p_T}{\sin\theta}$$

$$\left(\frac{\delta(p)}{p}\right)^2 = \left(\frac{\delta(p_T)}{p_T}\right)^2 + \left(\frac{\delta(\sin\theta)}{\sin\theta}\right)^2 = \left(\frac{\delta(p_T)}{p_T}\right)^2 + \left(\frac{\delta(\theta)}{\tan\theta}\right)^2$$

$$\frac{\delta(p)}{p} \approx \frac{\delta(p_T)}{p_T}, \qquad \text{when} \quad \frac{\delta(\theta)}{\tan\theta} \ll \frac{\delta(p_T)}{p_T}$$



带电粒子的轨迹 是螺旋线, 在 R-z 上的投影是**正弦曲线**

$$z = v_z t, \qquad s = v_T t = v_T z/v_z$$

$$\sin\alpha = \frac{R/2}{\rho}$$

$$R(z) = 2\rho\sin\frac{s}{2\rho} = 2\rho\sin\frac{zp_T}{2\rho p_z}$$

当 $p > p_{Tc}$ 时, 螺旋线可以与外筒相切 ($R_m = 2\rho$), 第一个切点条件为

$$\frac{\pi}{2} = \frac{zp_T}{R_m p_z} = \frac{z}{R_m}\tan\theta$$

若 $z = z_m$, 临界动量 p_c 和极角 θ_c 由确定

$$\tan\theta_c = \frac{\pi}{2}\frac{R_m}{z_m}, \qquad p_c = \frac{p_{Tc}}{\sin\theta_c}$$

$$\text{CEPC 3T} : p_{Tc} = 0.81\,\mathrm{GeV}, p_c = 1.16\,\mathrm{GeV}, \tan\theta_c = 0.975, \theta_c = 44.3°$$

给定 p, 可求 z ($p > p_c$ 时 $z > z_m$)

$$z = \frac{\pi}{2}R_m\frac{p_z}{p_{Tc}} = \frac{\pi}{2}R_m\sqrt{\frac{p^2}{p_{Tc}^2} - 1}, \qquad \sin\theta = \frac{p_{Tc}}{p}$$

给定 p 和 θ, 令 $C = \dfrac{0.3B}{2p}$

$$R(z_m) = \frac{\sin\theta}{C}\sin\frac{Cz_m}{\cos\theta}$$

$p > p_c$ 时, 可求经过 (R_m, z_m) 径迹的 θ_e

$$\frac{CR_m}{\sin\theta_e} = \sin\frac{Cz_m}{\cos\theta_e}$$

θ_e 难以解析求解, 范围是 $\theta_m(31.8°) < \theta_e < \theta_c(44.3°)$

打到外筒的径迹数比例 给定动量大小 p 时, 设 θ_0 为最小极角, 则比例 $f(p)$ 为

$$f(p) = \frac{\pi/2 - \theta_0}{\pi/2} = 1 - \frac{2\theta_0}{\pi}$$

$$\theta_0 = \begin{cases} \pi/2 & p \le p_{Tc} \\ \sin^{-1}(p_{Tc}/p) & p_{Tc} < p \le p_c \\ \theta_e & p > p_c \end{cases}$$

对于 $[p_1, p_2]$ 均匀分布的动量, 总比例 F 为

$$F = \frac{1}{p_2 - p_1}\int_{p_1}^{p_2} f(p)dp$$

$$F = \frac{1}{3 - 0.81}\int_{0.81}^{3} f(p)dp = 0.60$$