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GAS SCATTERING EFFECTS FOR THE SPS

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Two estimates show the influence of multi-Coulomb scattering on the beam. The first is based on the assumption that the beam never touches the wall but the normalized emittance grows, the second assumes no acceleration and gives the asymptotic life time for a beam when injected into the DC driven main ring at 10 GeV/c.

1. Growth of normalized emittance

For nitrogen we find

$$\Delta\left(\frac{E}{\pi}\,\beta\gamma\right) = \frac{0.32\ \lambda\!\!\!^{-} P}{\mathrm{Torr\cdot s}}\ \left|\log(1-\eta)\right| \cdot \int_{t_1}^{t_2} \frac{dt}{\beta^2\gamma}$$

During the first period of debunching we may take

$\lambda\!\!\!^{-}$ = average β-value $\simeq$ 54 m

$P = 3 \cdot 10^{-7}$ Torr

$|\log(1-\eta)| \simeq 3$; $\eta = 95\%$ = percentage of the beam contained in the emittance.

$\beta^2\gamma = 10.61$

$t_2 - t_1 \simeq 0.2$ s

and find $\Delta\left(\frac{E}{\pi}\,\beta\gamma\right) \simeq 0.3$ µrad m which is negligible.

For acceleration we assume $(\dot{\beta\gamma}) = 175/s$ and evaluate for stage C (400 GeV/c)

$$\int_{t_{inj}}^{t_{top}} \frac{dt}{\beta\gamma^2} = \frac{1}{(\dot{\beta\gamma})} \left(\frac{1}{\beta_{inj}} - \frac{1}{\beta_{top}} + \ln \frac{\gamma_{top}(1+\beta_{top})}{\gamma_{inj}(1+\beta_{inj})} \right) \simeq 2.1 \cdot 10^{-2}$$

yielding $$\Delta \left(\frac{E\beta\gamma}{\pi} \right) = 0.33 \ \mu \text{ rad m.}$$

2. The relevant formula for the natural life time of the beam for a rectangular vacuum chamber of horizontal acceptance A_H and vertical acceptance A_V is

$$t_\square = 2.16 \frac{\beta^3\gamma^2 \text{ Torrs}}{\pi P \left(\frac{1}{A_H/\pi} + \frac{1}{A_V/\pi} \right)}$$

or $$\frac{t_\square}{A_V/\pi} = \frac{2.16\ \beta^3\gamma^2}{\pi P} \ \frac{r}{1+r} \simeq 15 \frac{r}{1+r} \ \frac{\text{Torr} \cdot \text{s}}{\mu \text{ rad m}}$$

r means A_H/A_V.

The life time for an elliptic vacuum chamber can be written

$$t_0 = t_\square \left(0.58 + 0.42 \frac{1+r}{(1+\sqrt{r})^2} \right)$$

yielding $$\frac{t}{A_V/\pi} \simeq 15\ r \left(\frac{0.58}{1+r} + \frac{0.42}{(1+\sqrt{r})^2} \right) \frac{\text{Torrs}}{\mu \text{ rad m}}$$

for our parameters.

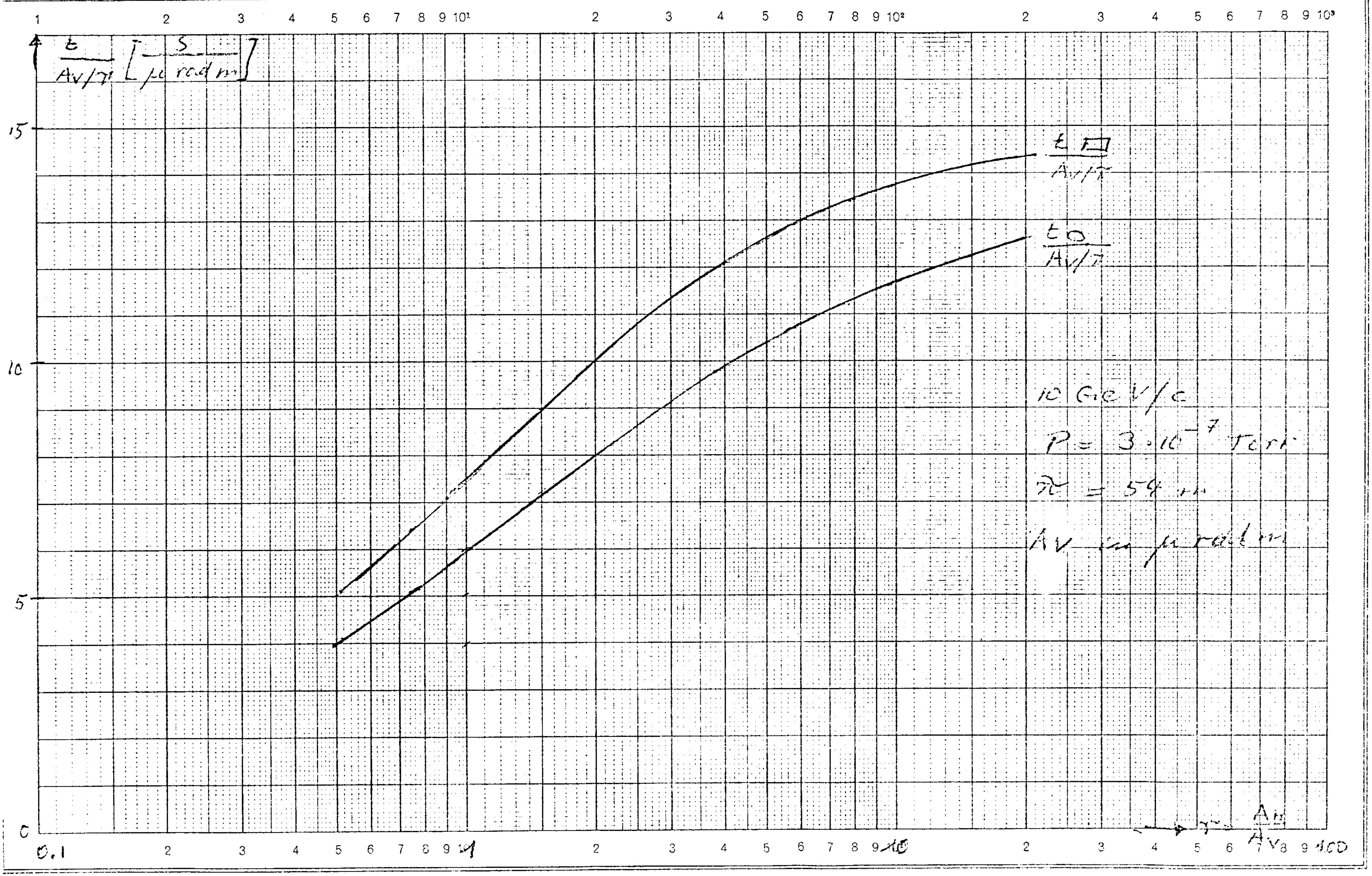
These two curves can be seen in the attached graph. As an example we may take the case of no corrections when still a pencil beam should be injected. Comparing to the staircase diagram in Figure 2.6 of the green book (CERN/1050) we find $A_V/\pi \sim 0.3\ \mu$ rad m, $A_H/\pi \simeq 3.5\ \mu$ rad m; thus $r = 10$.

From the graph one finds

$$\tau_\square \simeq 4 \text{ s} \quad \text{and} \quad t_0 \simeq 3.5 \text{ s.}$$

<u>Reference</u>

- W. Hardt, A few simple expressions for checking vacuum requirements in a proton synchrotron, ISR-300/GS/68-11 (1968.



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